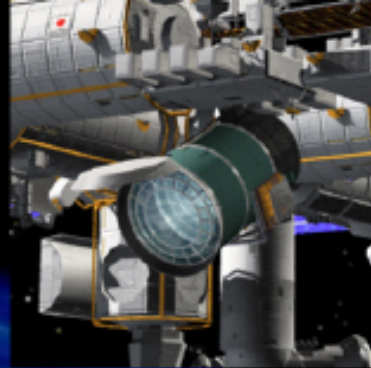


Extreme Universe Space Observatory



JEM-EUSO mission

戎崎俊一
理化学研究所


for the JEM-EUSO Collaboration



北海道大学 2008年9月10日

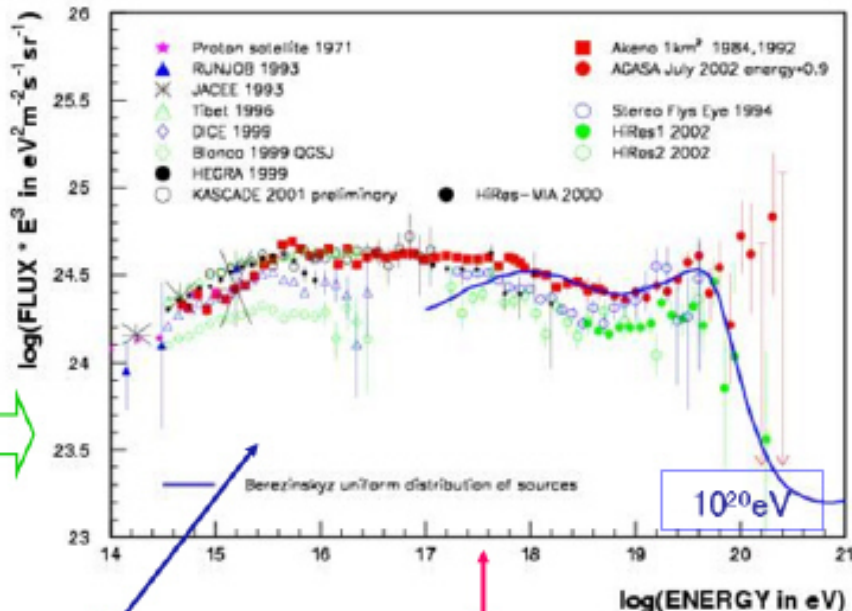
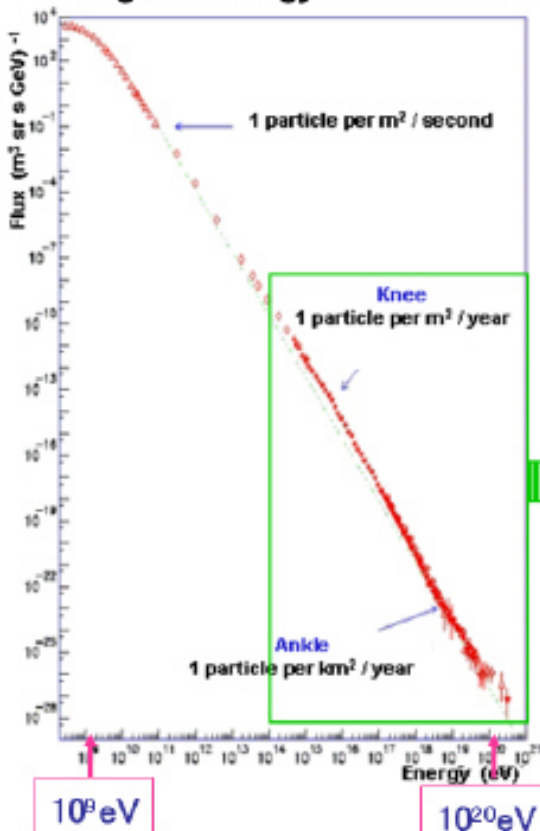
JEM-EUSO Collaboration

10 countries, 56 institutions, 149 members

- 
- ▶ **Japan** : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin Univ.*), N. Inoue (*Saitama Univ.*), Y. Uchihori (*NIRS*), K. Nomoto (*Univ. of Tokyo*), Y. Takahashi (*Tohoku Univ.*), M. Takeda (*ICRR, Univ. Tokyo*), Y. Arai, Y. Kurihara, H.M. Shimizu, J. Fujimoto (*KEK*), S. Yoshida, K. Mase (*Chiba Univ.*), K. Asano, S. Inoue, Y. Mizumoto, J. Watanabe, T. Kajino (*NAOJ*), H. Ikeda, M. Suzuki, T. Yano (*ISAS, JAXA*), T. Murakami, D. Yonetoku (*Kenazawa Univ.*), T. Sugiyama (*Nagoya*), Y. Ito (*STEL, Nagoya Univ.*), S. Nagataki (*YITP, Kyoto Univ.*), A. Saito (*Kyoto Univ.*), S. Abe, M. Nagata (*Kobe Univ.*), T. Tajima (*KPSI, JAEA*), M. Chikawa (*Kinki Univ.*), and M. Tajima (*Hiroshima Univ.*)
 - ▶ **USA** : J. H. Adams Jr., S. Mitchell, M.J. Christl, J. Watts Jr., A. English, R. Young (*NASA/MSFC*), Y. Takahashi, D. Gregory, M. Bonamente, P. Readon, V. Connaughton, K. Pittalo, J. Hadaway, J. Geary, R. Lindquist, P. Readon (*Univ. Alabama in Huntsville*), H. Crawford, C. Pennypacker (*LBL, UC Berkeley*), K. Arisaka, D. Cline, J. Kolonko, V. Andreev (*UCLA*), T. Weiler, S. Csorna (*Vanderbilt Univ.*),
 - ▶ **France** : J-N. Capdevielle, P. Gorodetzky, P. Salin, J. Dolbeau, T. Patzak, F. Vanucci (*APC,CNRS*), J. Weisbard (*IN2P3*)
 - ▶ **Germany**: M. Teshima, T. Schweizer (*MPI, Munich*), A. Santangelo, E. Kendziorra, F. Fenu (*Univ. Tuebingen*), P. Biermann (*MPI Bonn*), K. Mannheim (*Wuerzburg*), J. Wilms (*Univ. Erlangen*)
 - ▶ **Italy** : E. Pace, M. Focardi, P. Spillantini (*U. Firenze*) V.Bratina, A. Zuccaro, L. Gambicorti (*CNR-INOA Firenze*), A. Anzalone, O. Catalano, M.C. Maccarone, P. Scarsi, B. Sacco, G. La Rosa (*IAS-PA/INAF*), G. D'All Staiti, D. Tegolo (*U. Palermo*), M. Casolino, M.P. De Pascale, A. Morselli, P. Picozza, R. Sparvoli (*INFN and Univ. Rome "Tor Vergata"*), P. Vallania (*IFSI-INAF Torino*), P. Galeotti, C. Vigorito, M. Bertaina (*U. Torino*), A. Gregorio (*Trieste*), F. Isgro, F. Guarino, D. D'urso (*U. "Federico II" di Napoli*), G. Osteria, D. Campana, M. Ambrosio, C. Aramo (*INFN-Napoli*)
 - ▶ **Mexico**: G. Medina-Tanco, J.C. D'Olivo, J.F.Valdes (*Mexico UNAM*), H. Salazar, O. Martinez (*BUAP*), L. Villasenor (*UMSNH*)
 - ▶ **Republic of Korea** : S. Nam, I. H. Park, J. Yang (*Ehwa W. Univ.*)
 - ▶ **Russia**: Garipov G.K., Khrenov, B.A., Klimov P.A. Panasyuk M.L, Yashin I.V. (*SINP MSU*), D. Naumov, Tkachev. L (*Dubna JINR*)
 - ▶ **Switzerland** : A. Maurissen, V. Mitev (*Neuchatel, Switzerland*) :
 - ▶ **Spain**: D.Rodriguez-Frias, L.Peral, J.Gutierrez, R.Gomez-Herrero (*Univ. Alcala*)

Status and the challenges of the highest-energy Universe by observing cosmic rays

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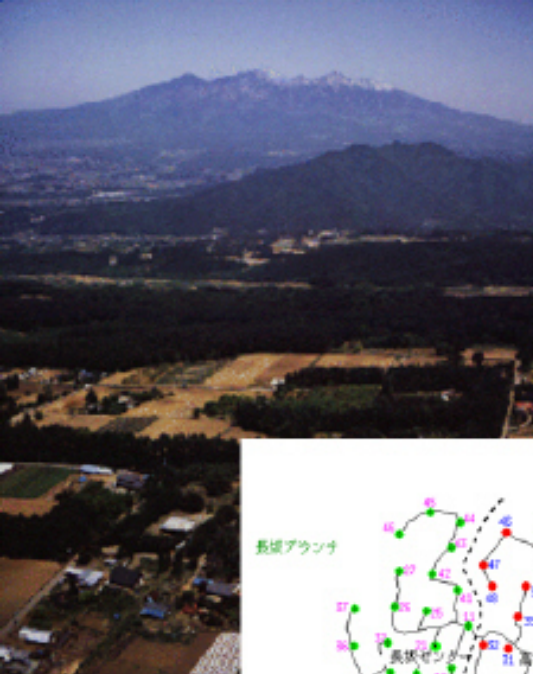
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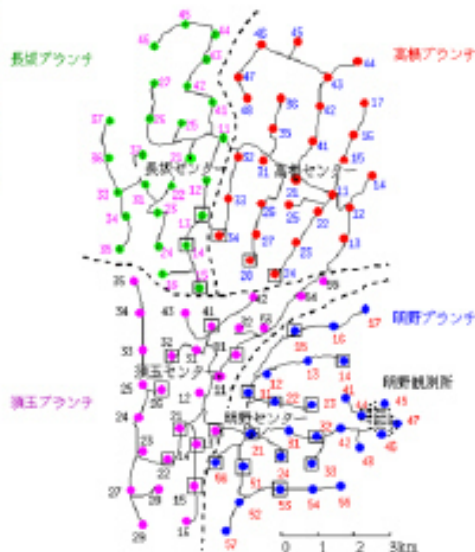
AGASA

- 地域全体を検出器とした。
- 全体で約100km²
- 13年で11個の超10²⁰eV事象



AGASA

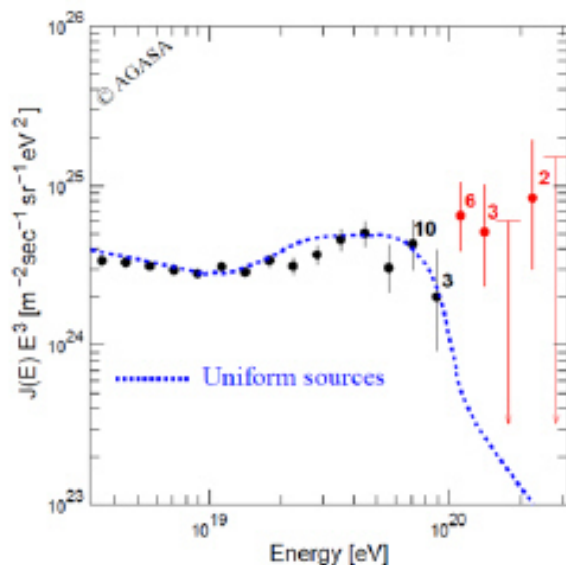
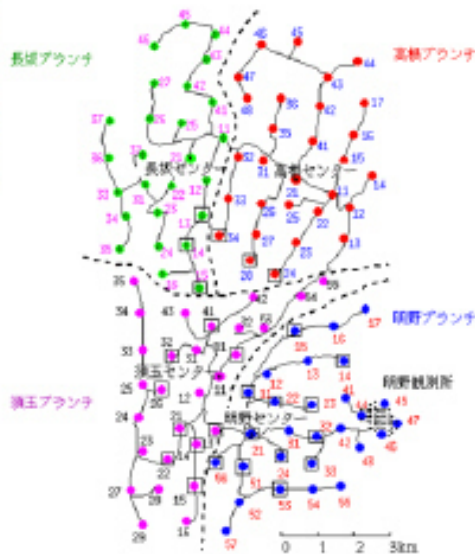
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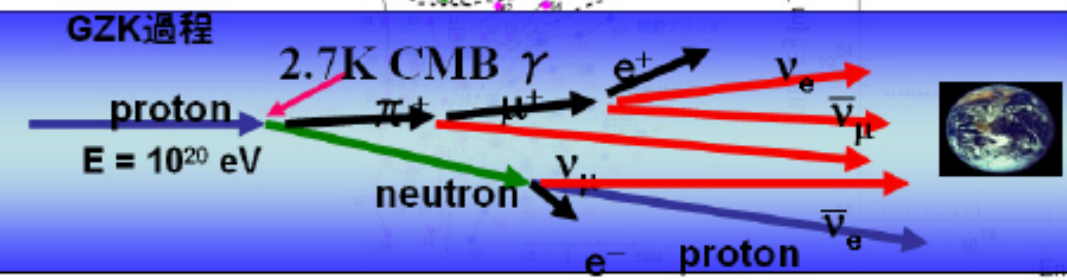
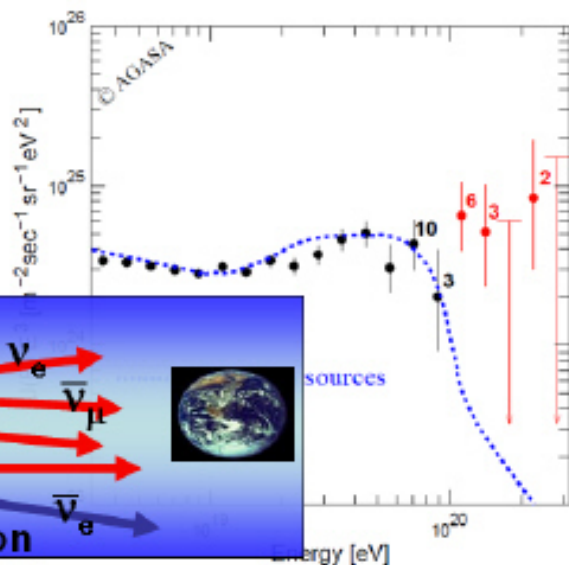
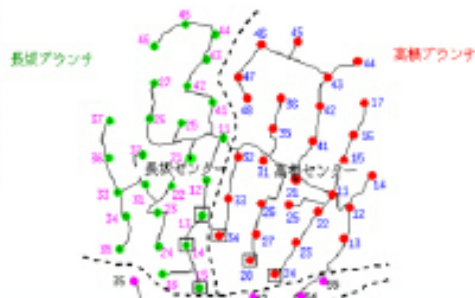
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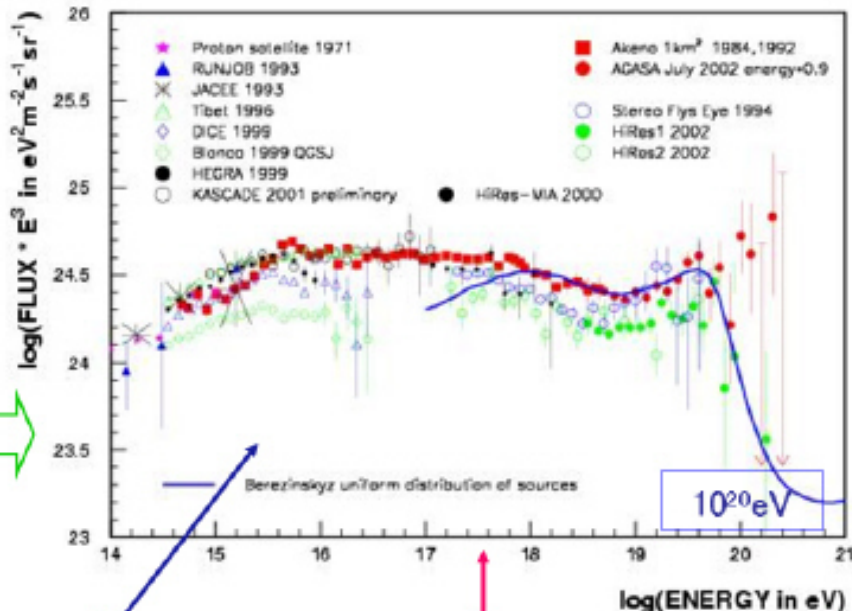
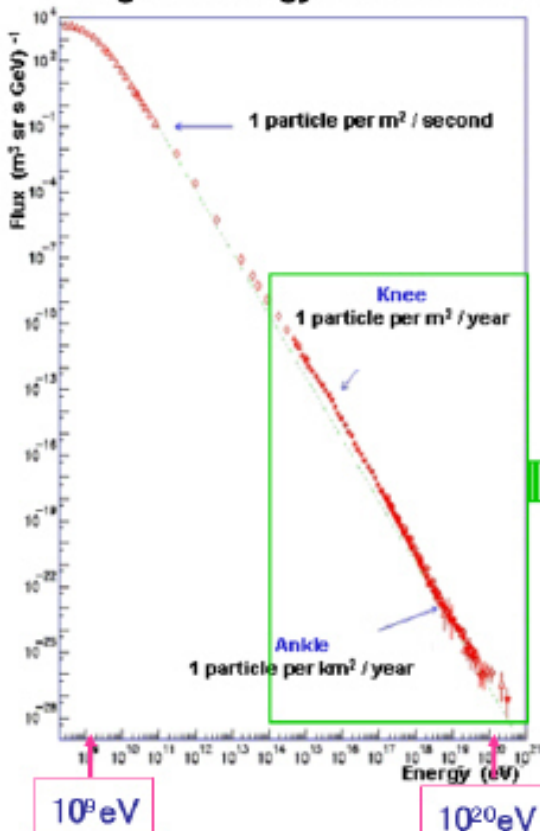
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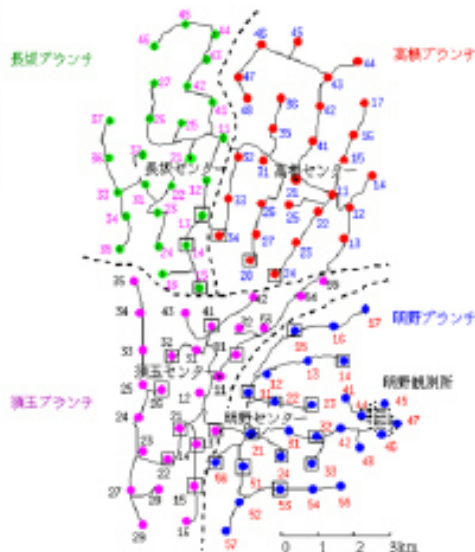
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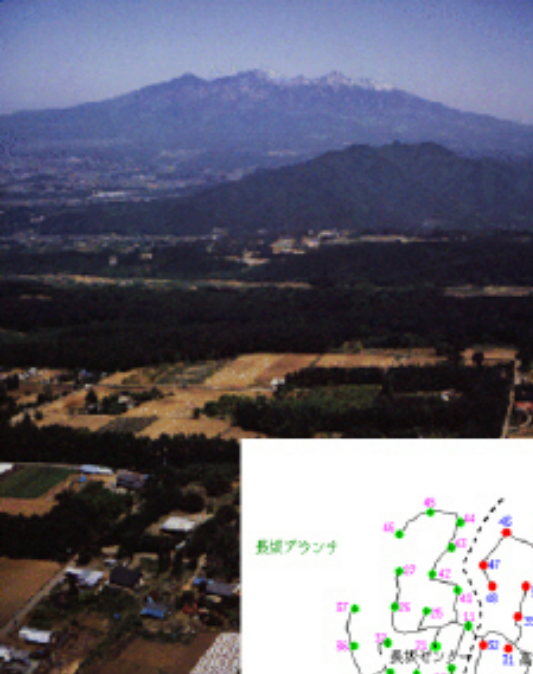
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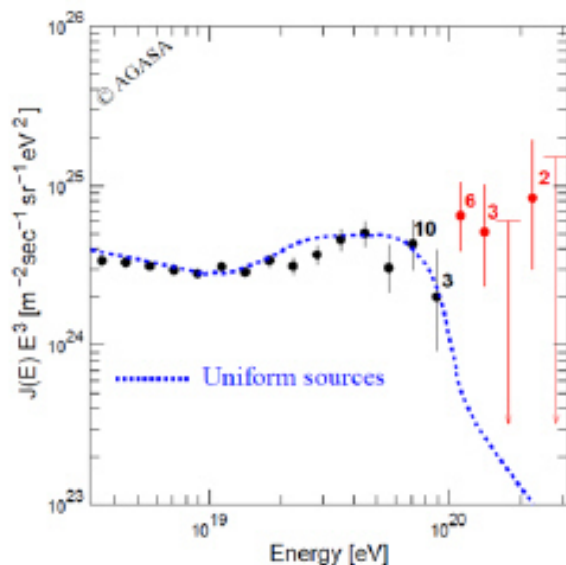
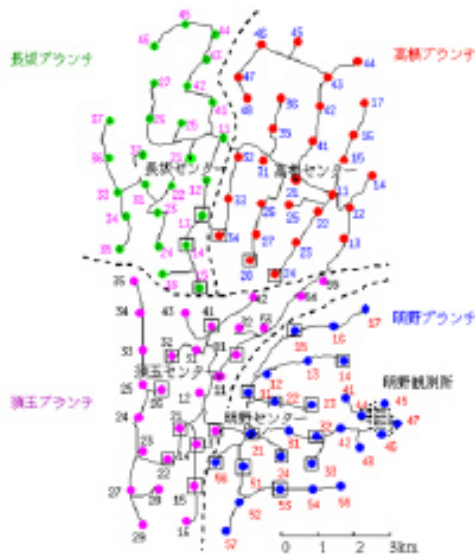
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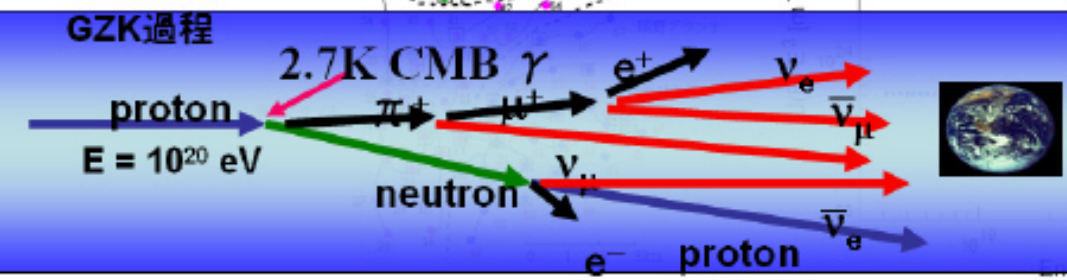
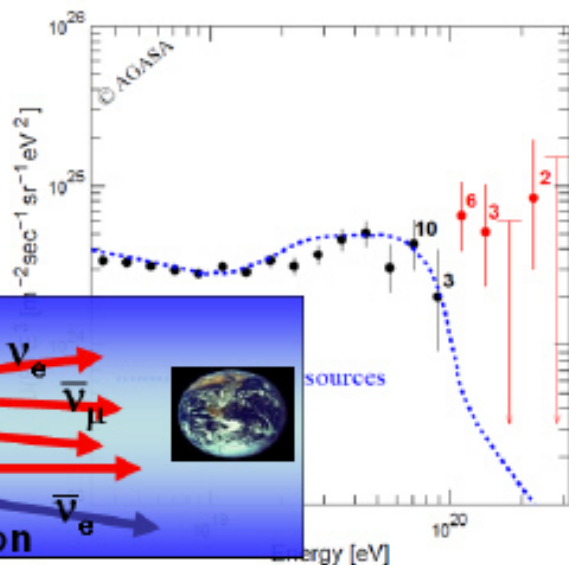
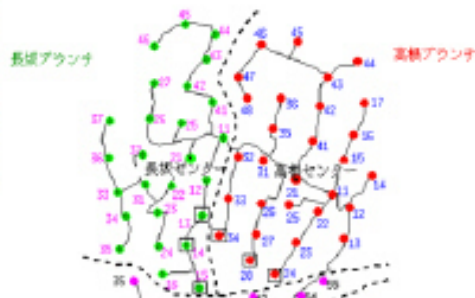
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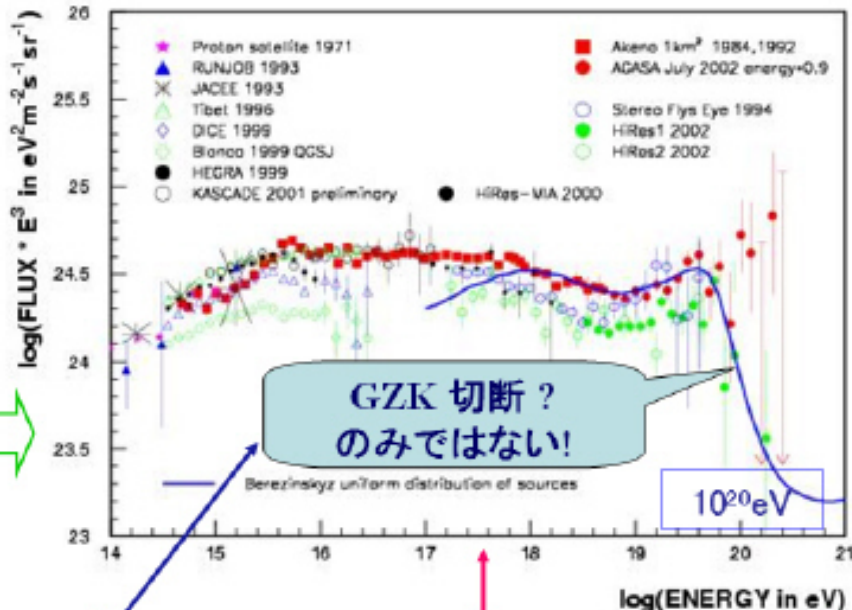
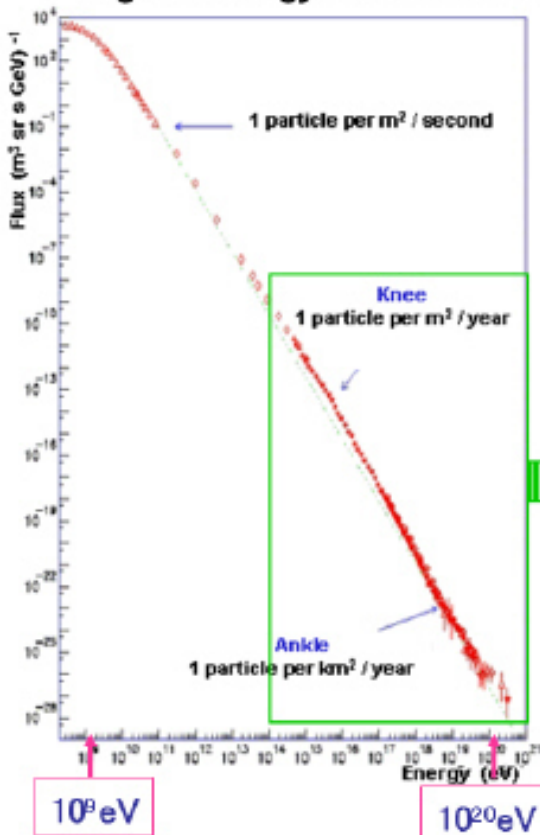
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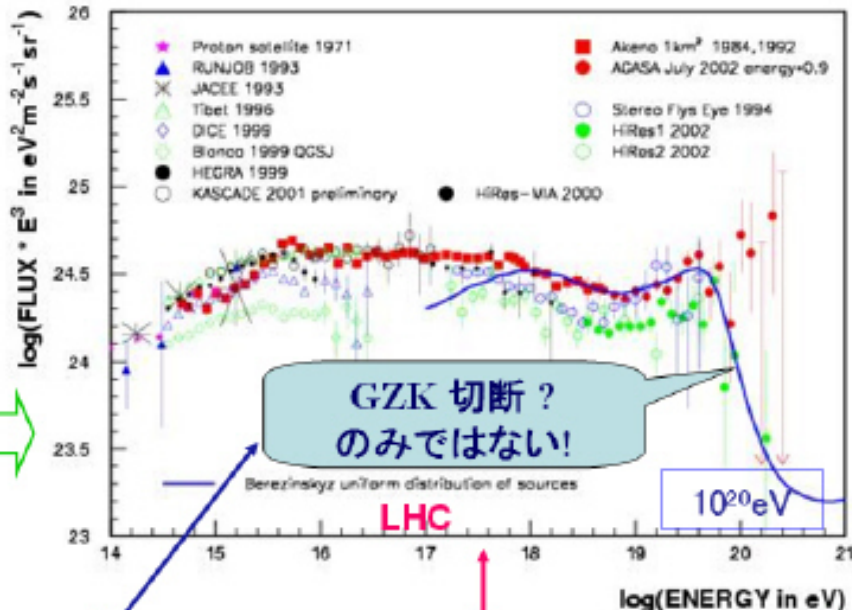
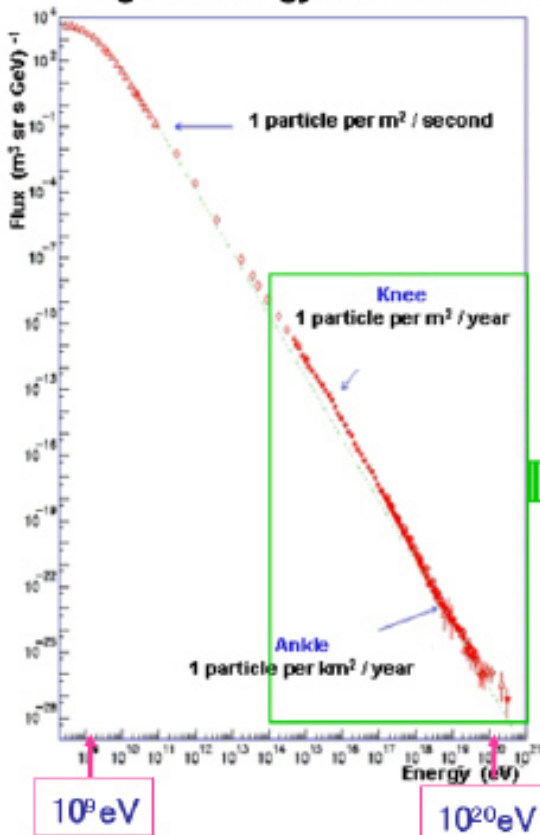


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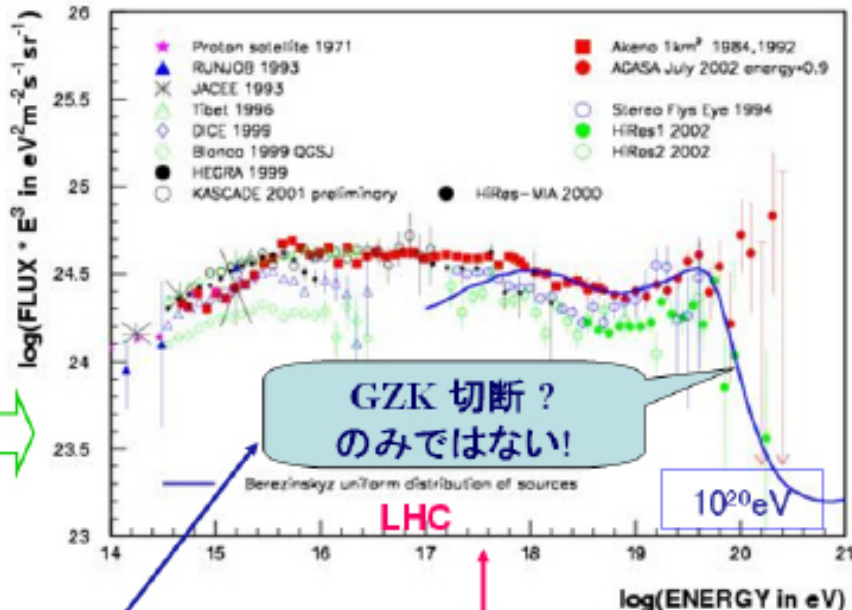
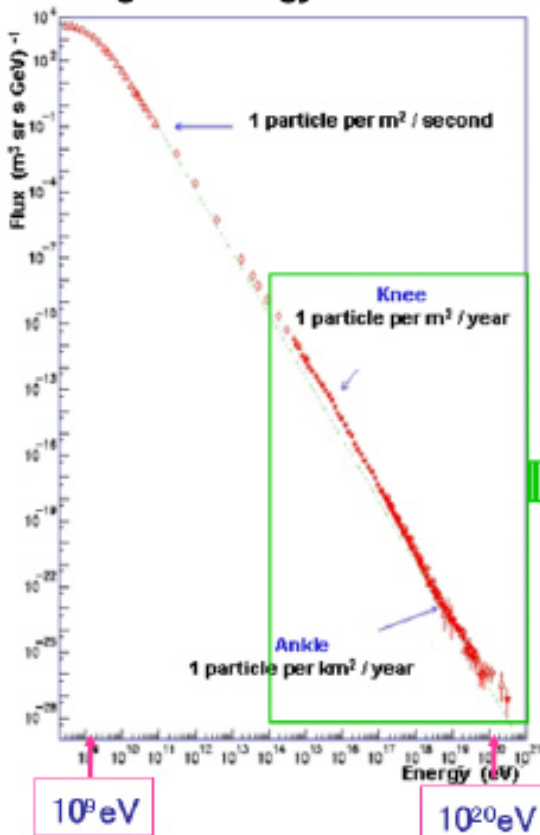


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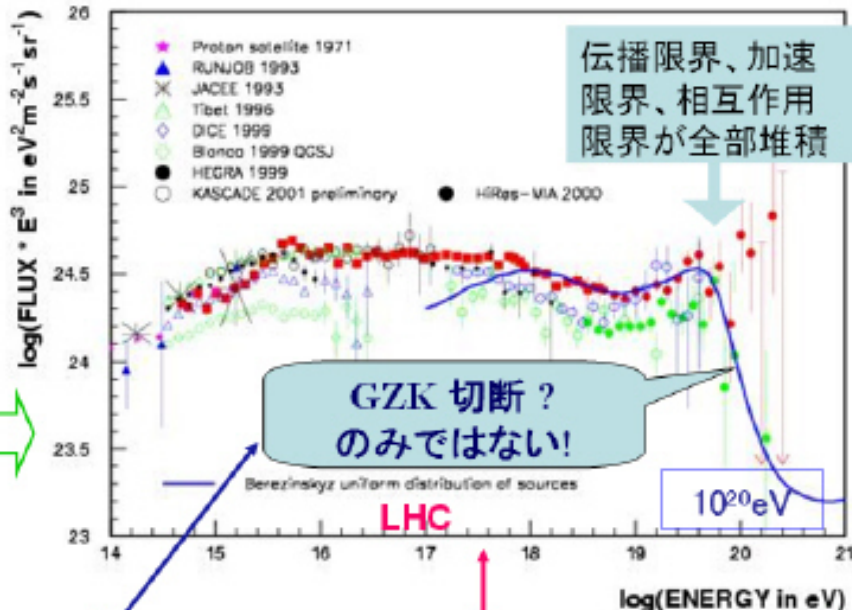
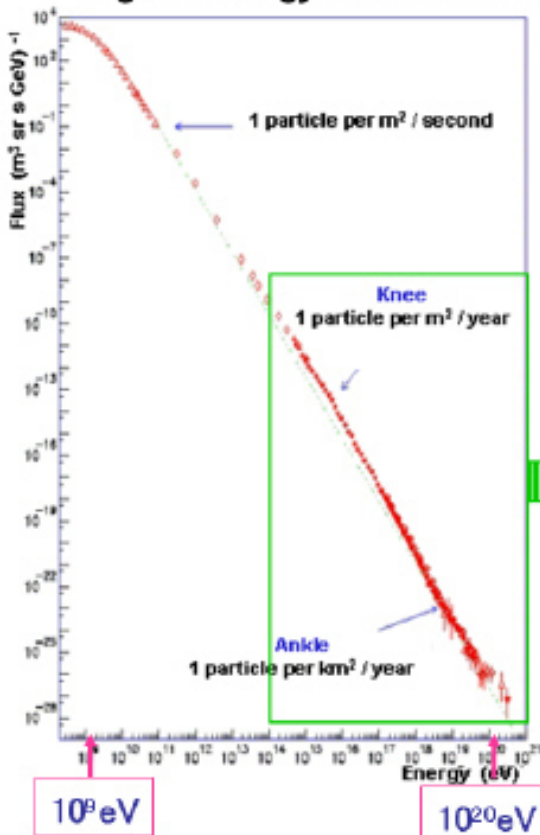


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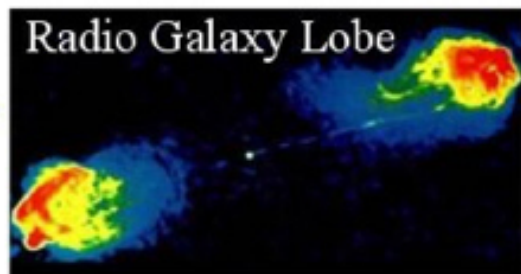
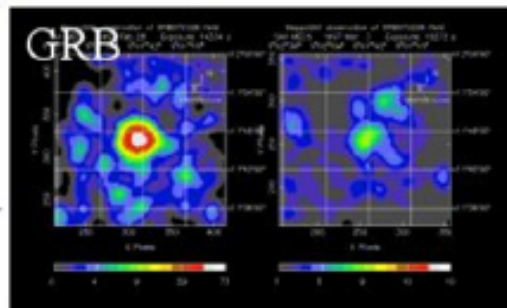
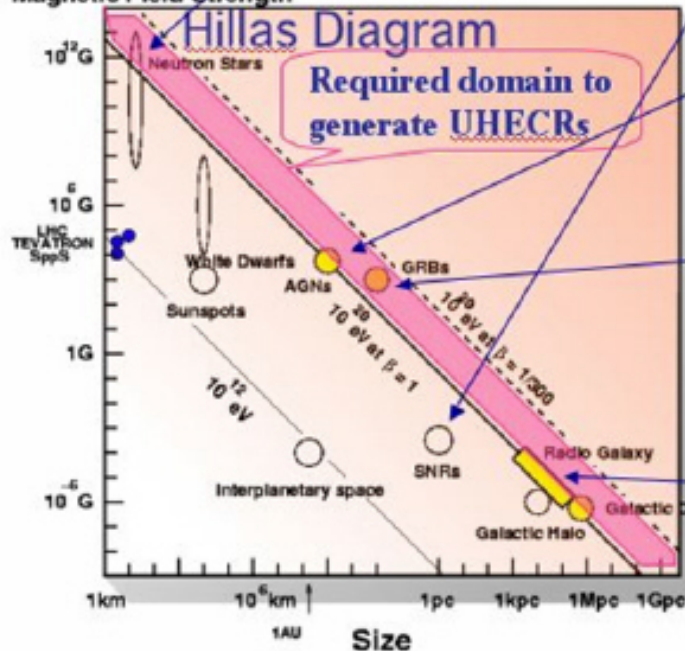
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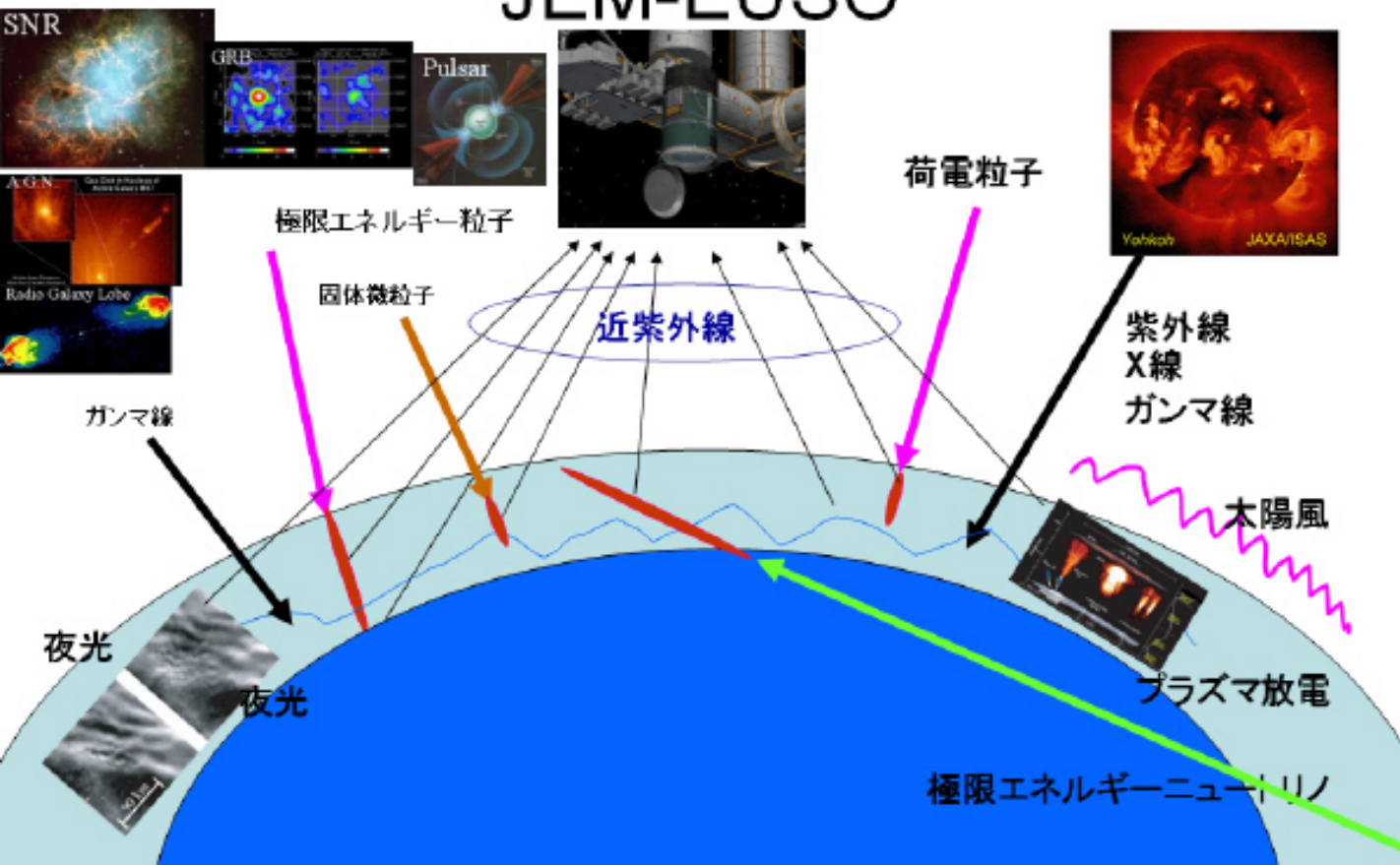
ヒラス 理論的加速限界 $< 10^{20}$ eV



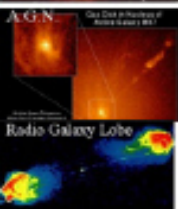
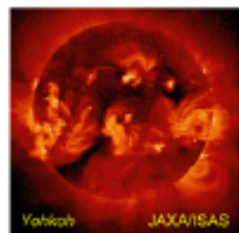
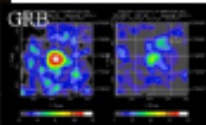
Magnetic Field Strength



地を見て天を知る天文台=地文台 JEM-EUSO



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極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

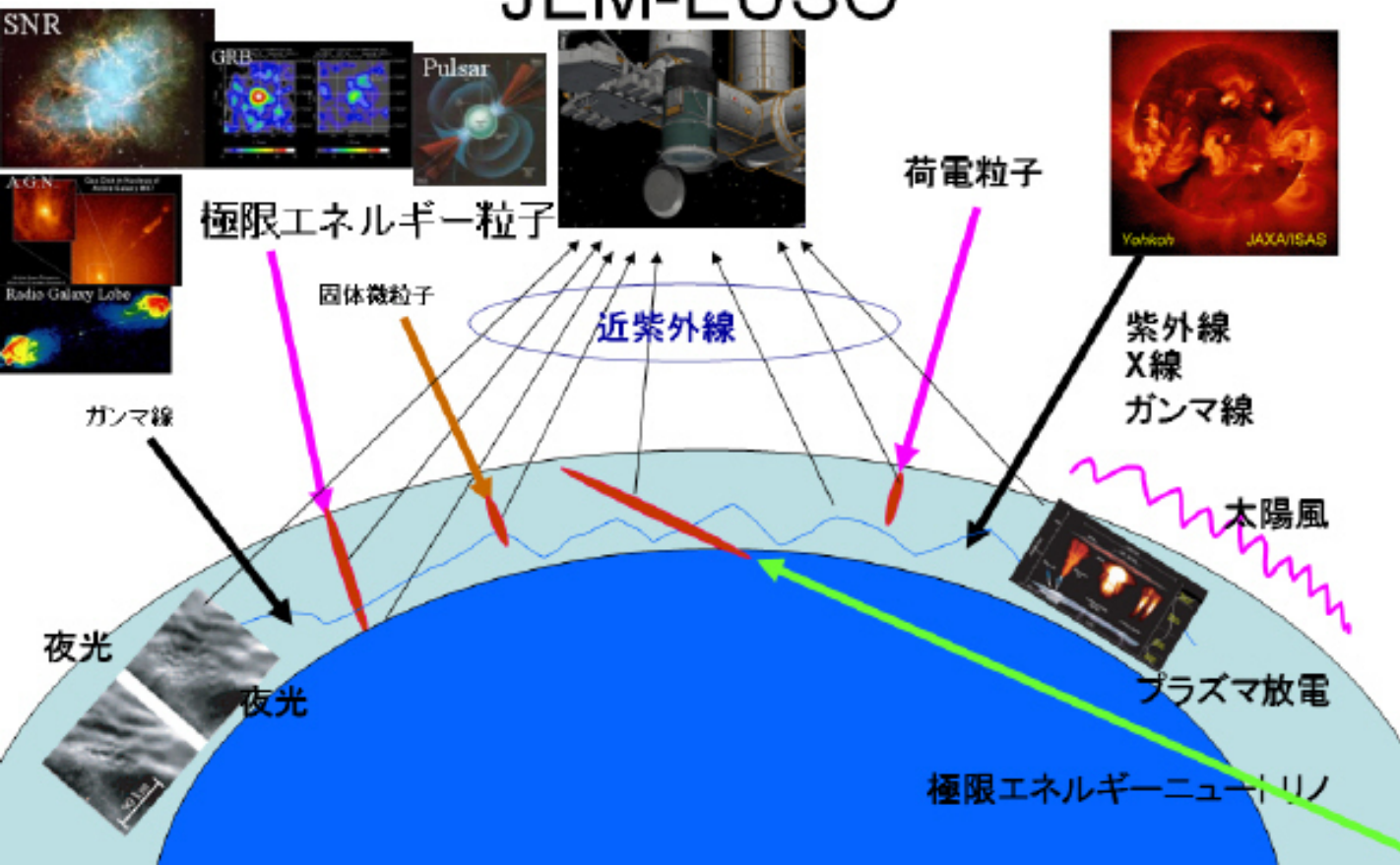
太陽風

夜光

夜光

プラズマ放電

極限エネルギーニュートリノ



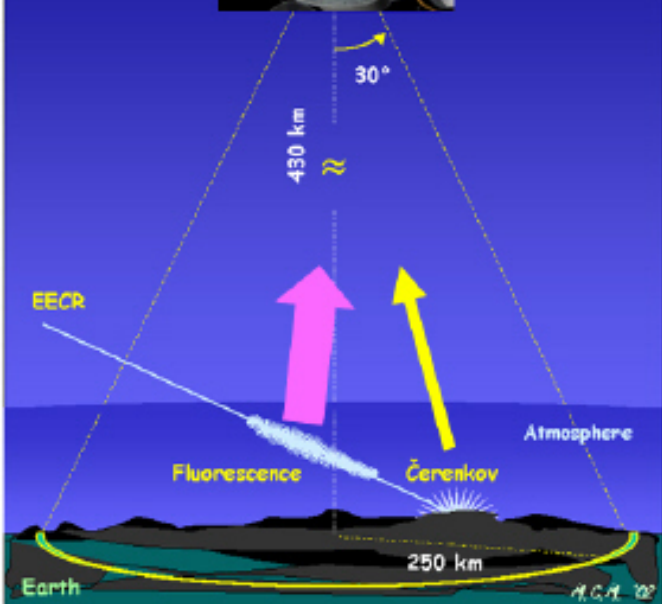
EUSOの観測方法



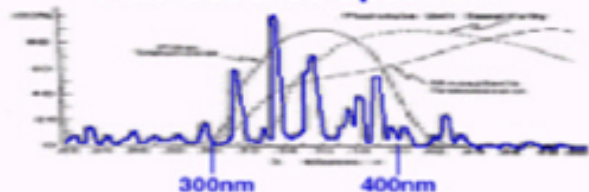
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

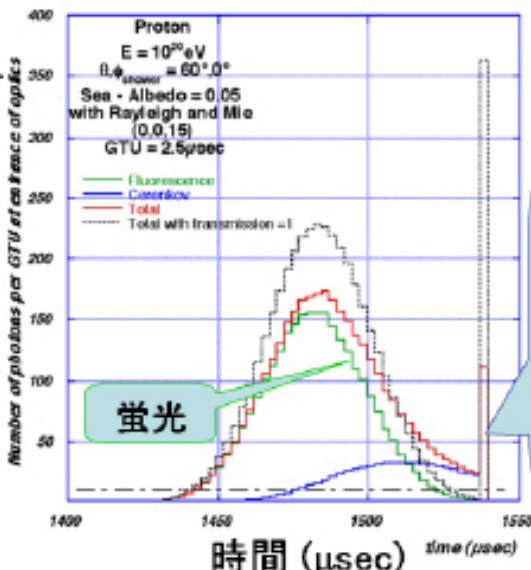
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



光学系入口径での光子数 (/2.5μsec)

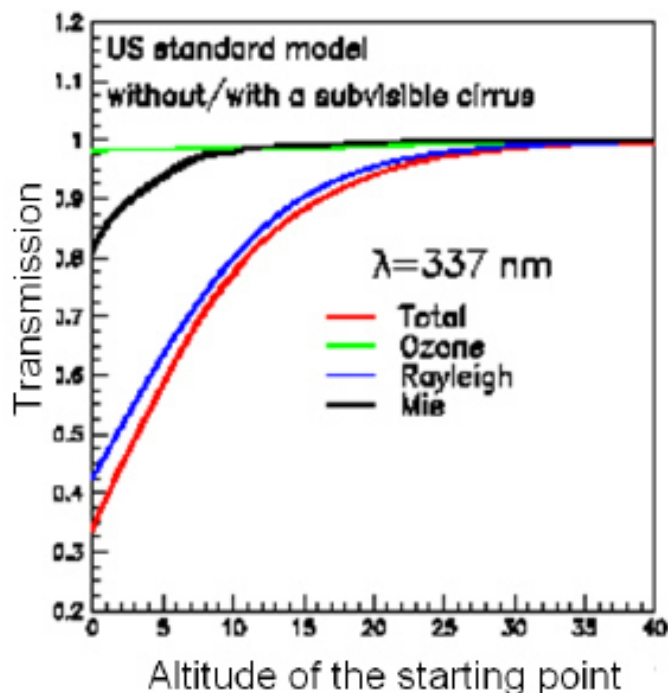


蛍光

チェレンコフ光

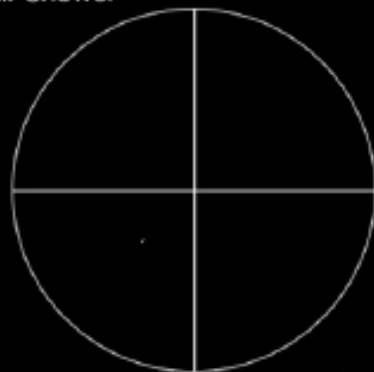
宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)

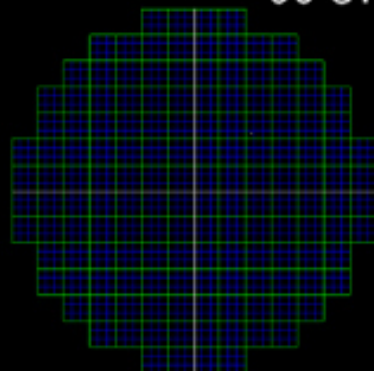


JEM-EUSOで見る空気シャワー

Air Shower

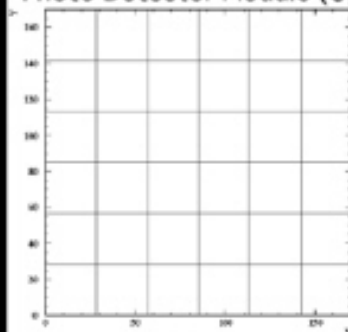


00 GTU

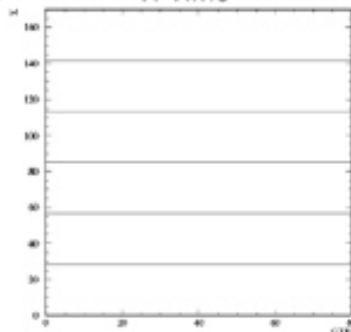


EUSO Focal Surface

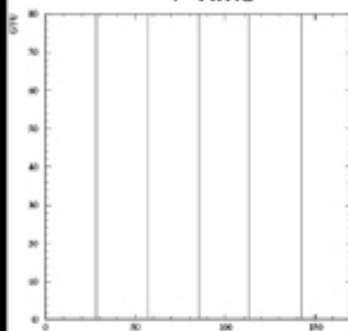
Photo Detector Module (3,3)



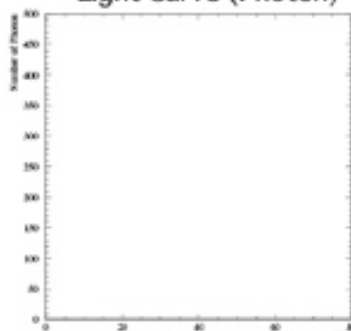
X-Time



Y-Time

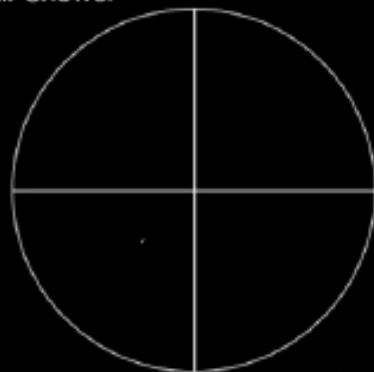


Light Curve (Photon)

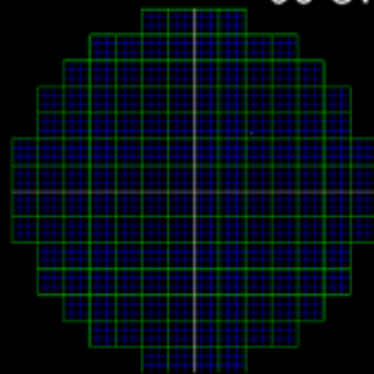


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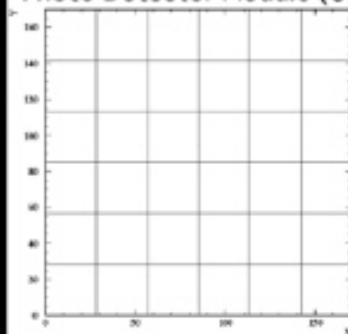


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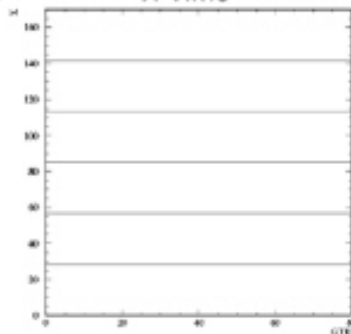


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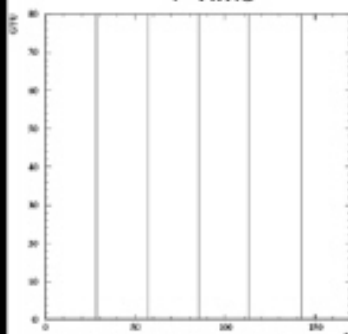
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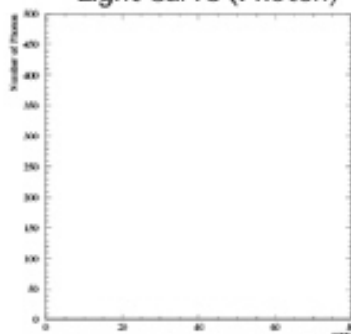
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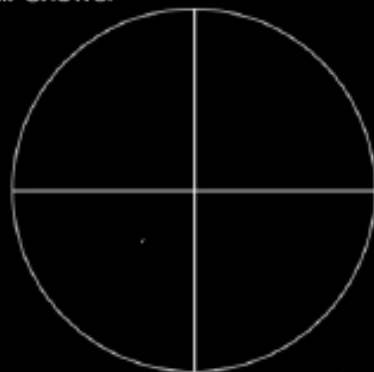
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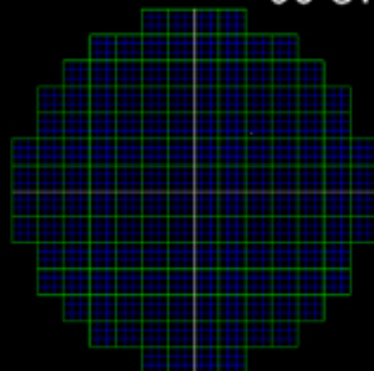


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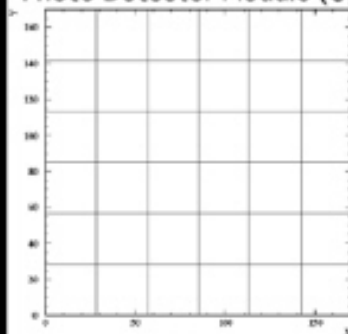


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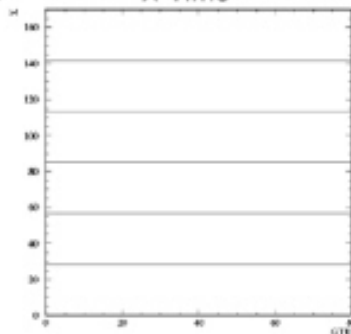


EUSO Focal Surface

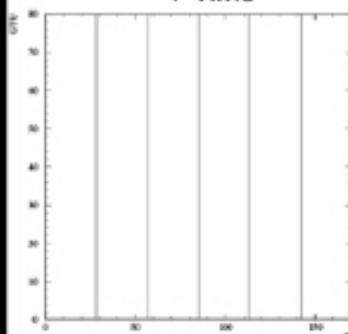
Photo Detector Module (3,3)



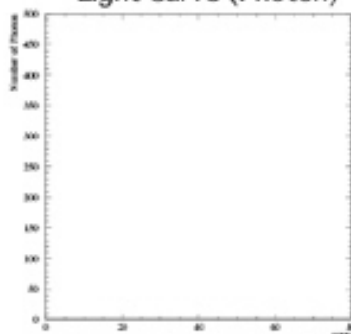
X-Time



Y-Time



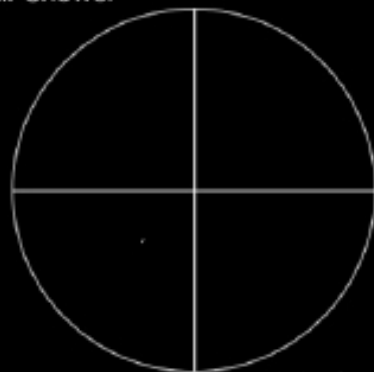
Light Curve (Photon)



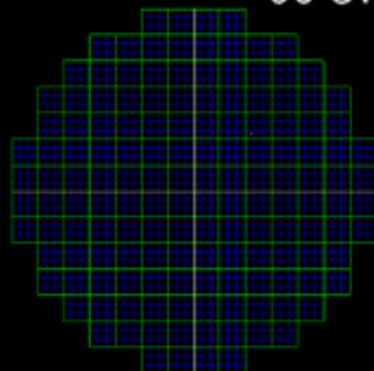


JEM-EUSOで見る空気シャワー

Air Shower

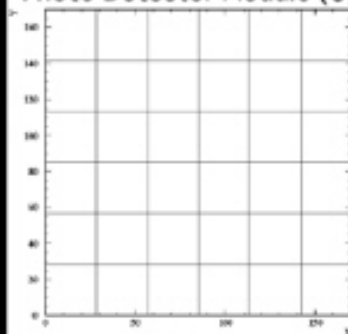


00 GTU

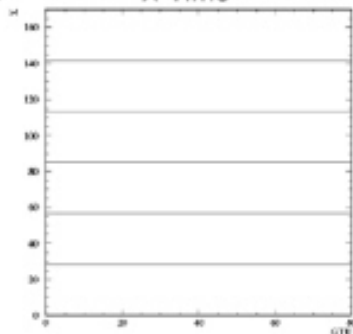


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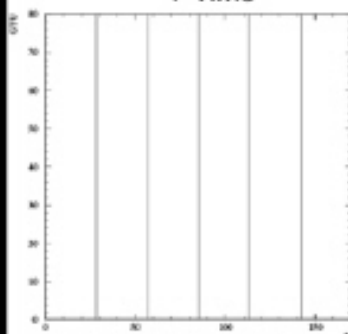
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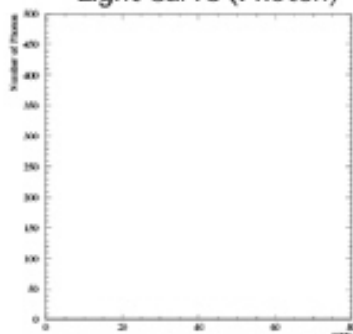
X-Time



Y-Time



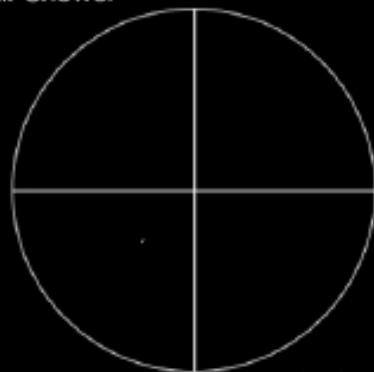
Light Curve (Photon)



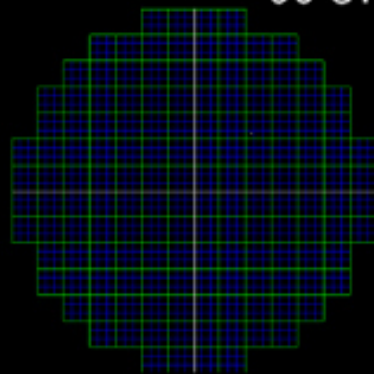


JEM-EUSOで見る空気シャワー

Air Shower

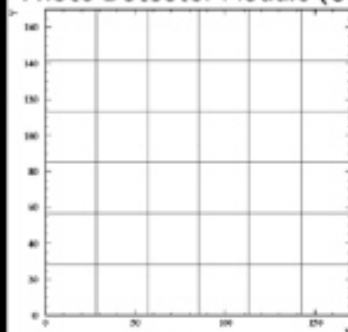


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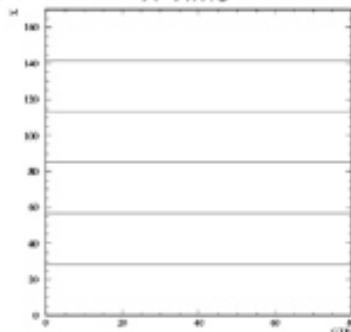


EUSO Focal Surface

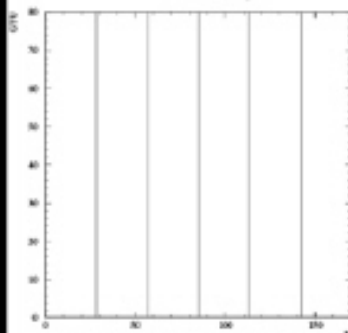
Photo Detector Module (3,3)



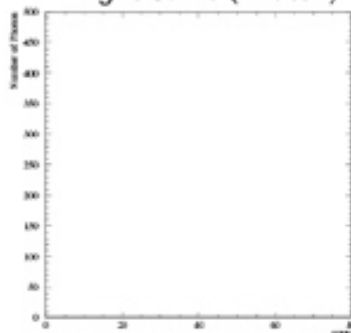
X-Time



Y-Time



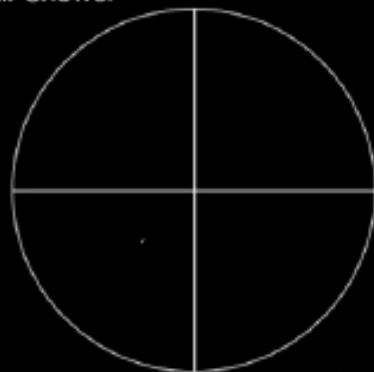
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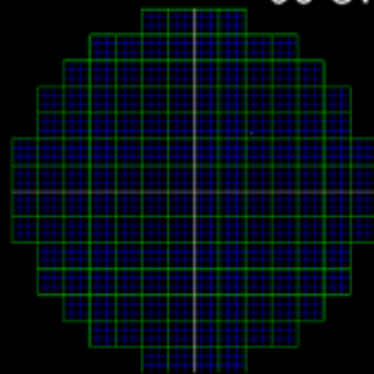


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Air Shower

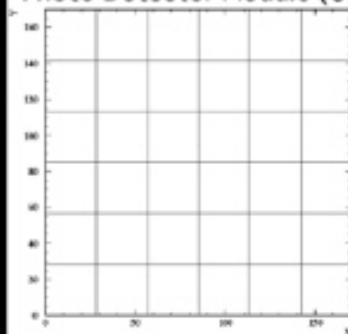


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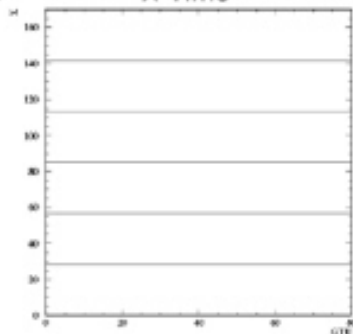


EUSO Focal Surface

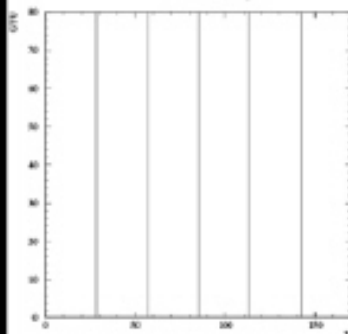
Photo Detector Module (3,3)



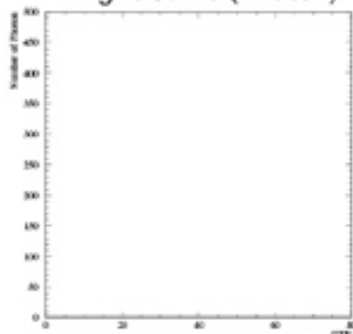
X-Time



Y-Time

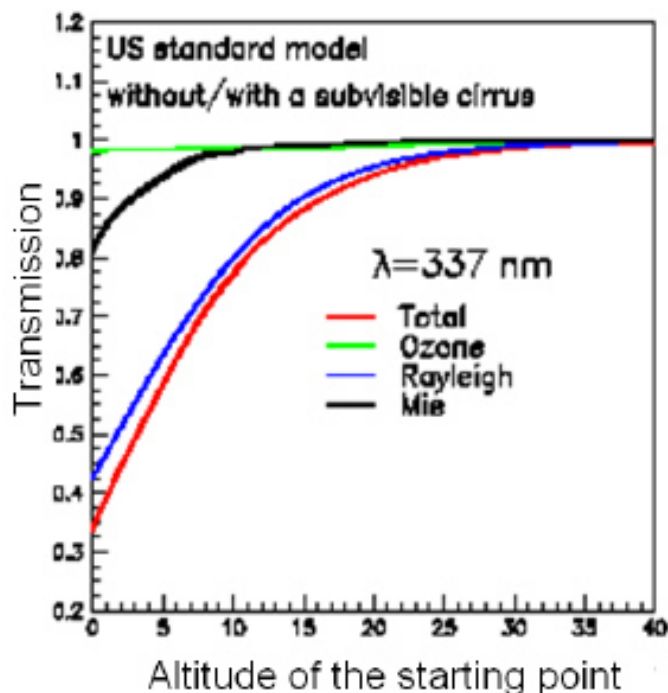


Light Curve (Photon)



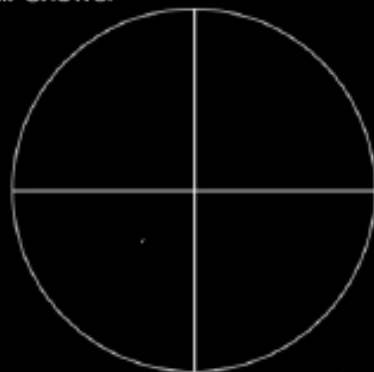
宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)

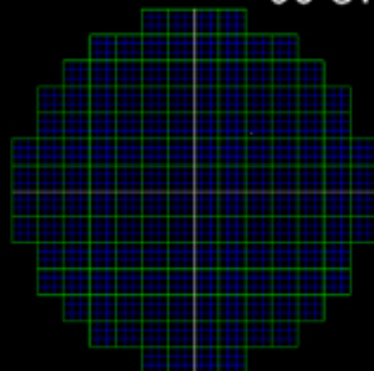


JEM-EUSOで見る空気シャワー

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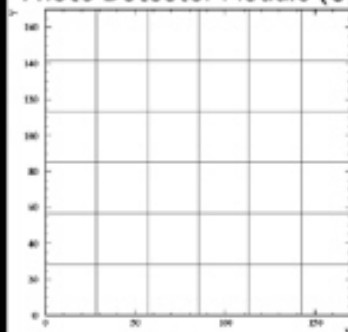


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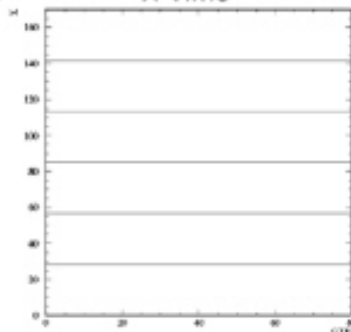


EUSO Focal Surface

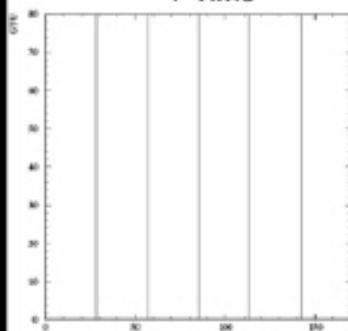
Photo Detector Module (3,3)



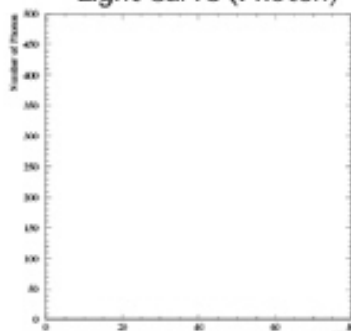
X-Time



Y-Time

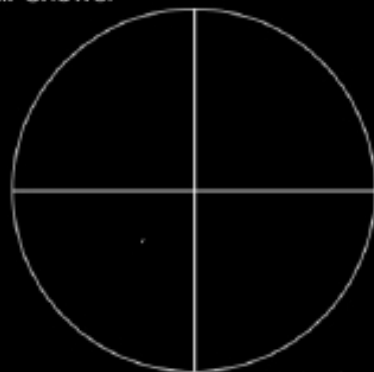


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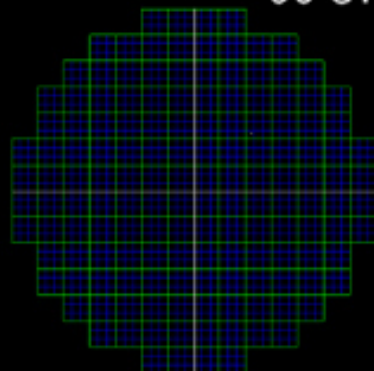


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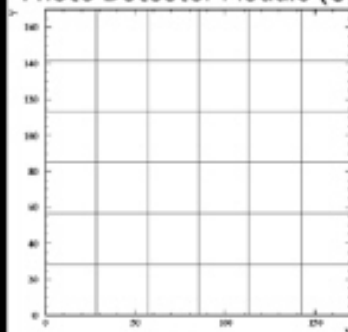


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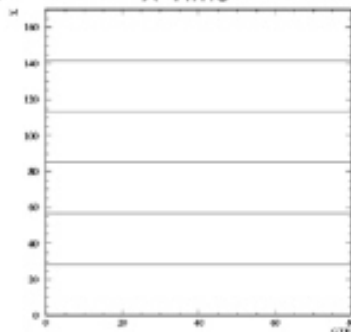


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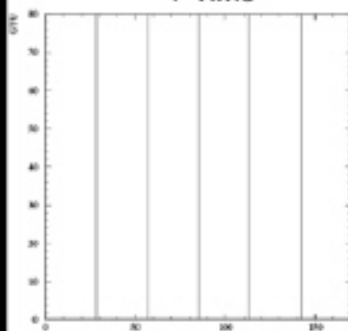
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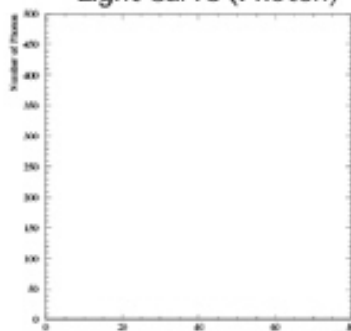
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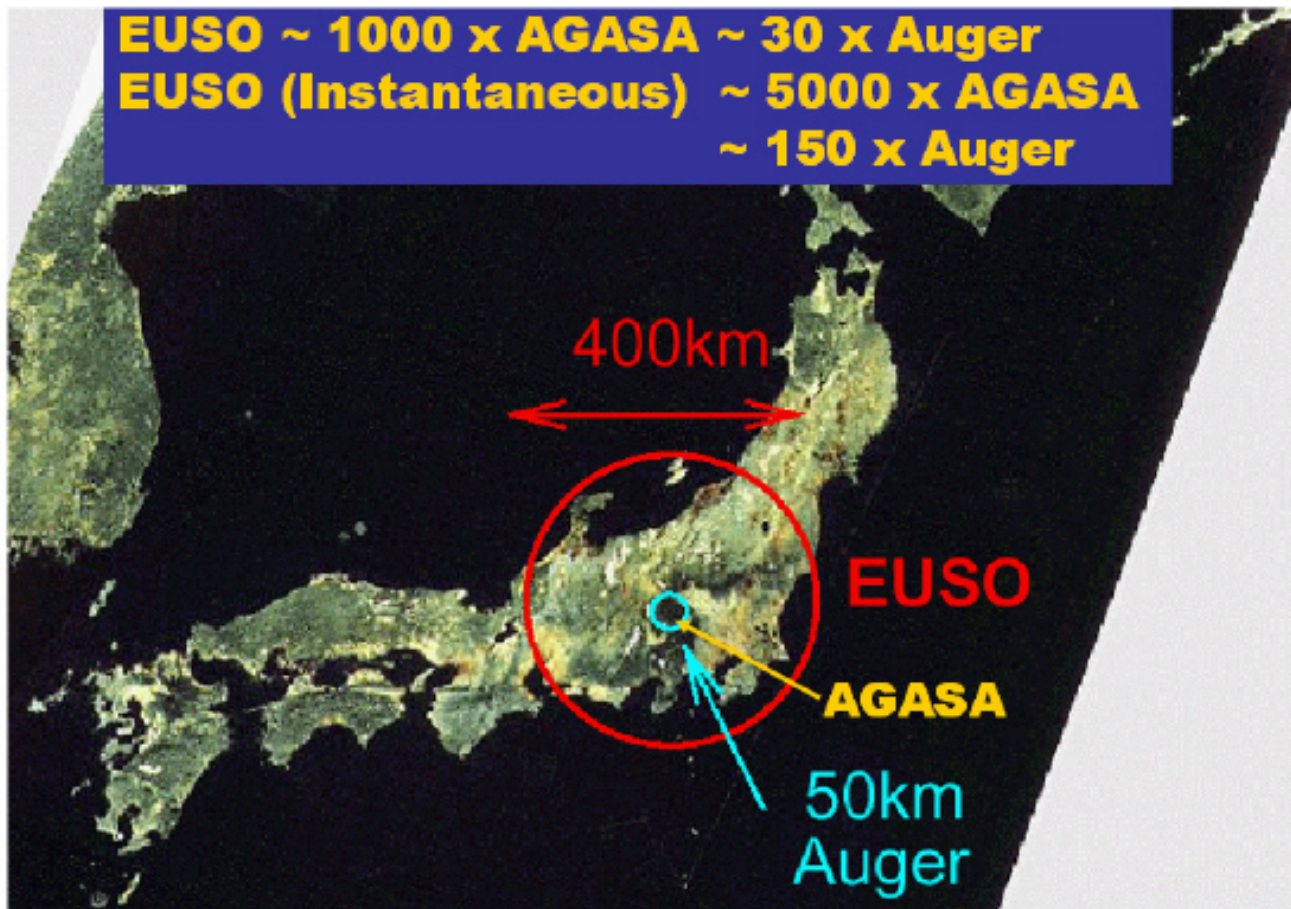






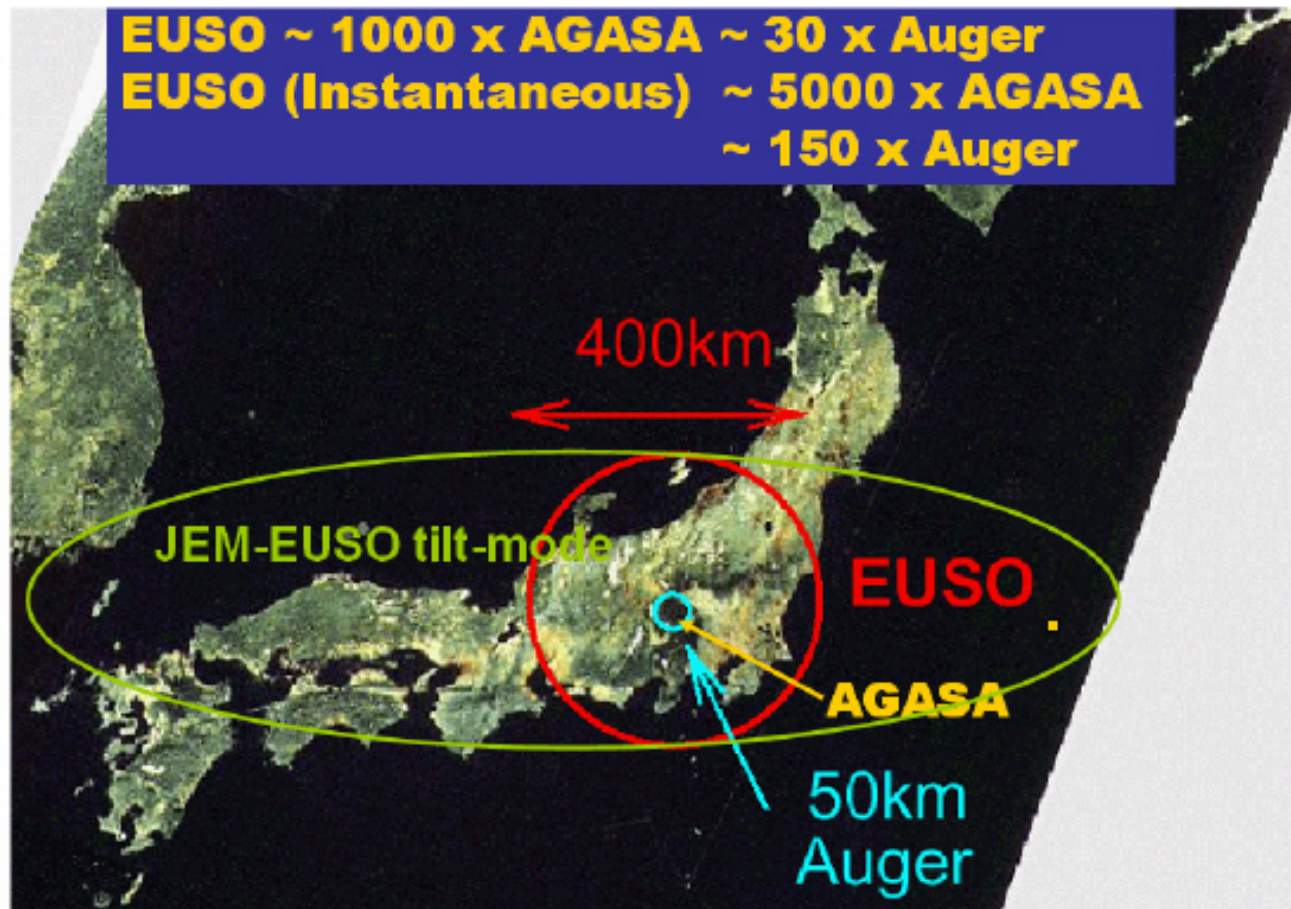
EUSOの巨大な視野

EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



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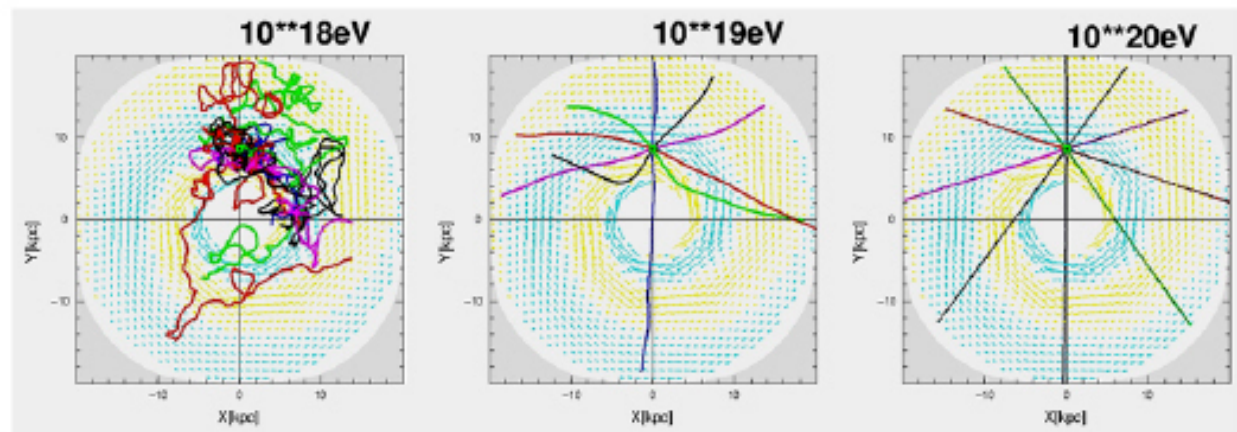
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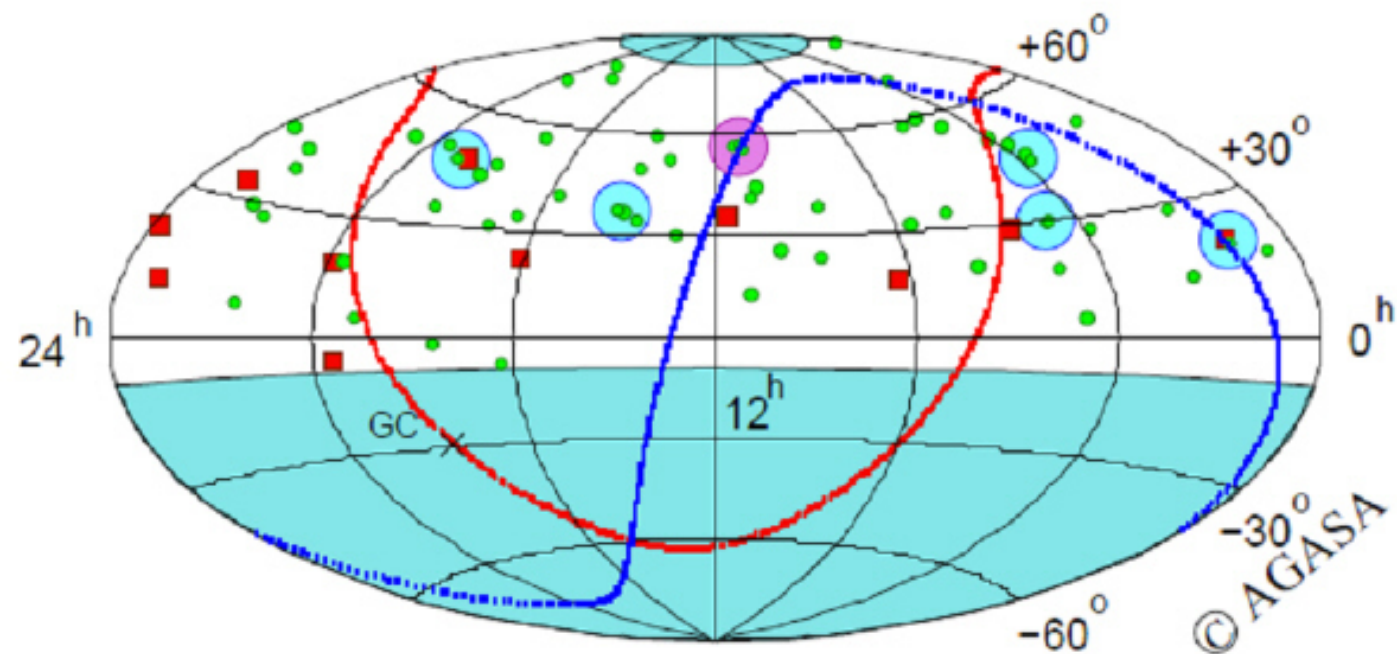
$E > 10^{20}$ eV 粒子は曲がらない



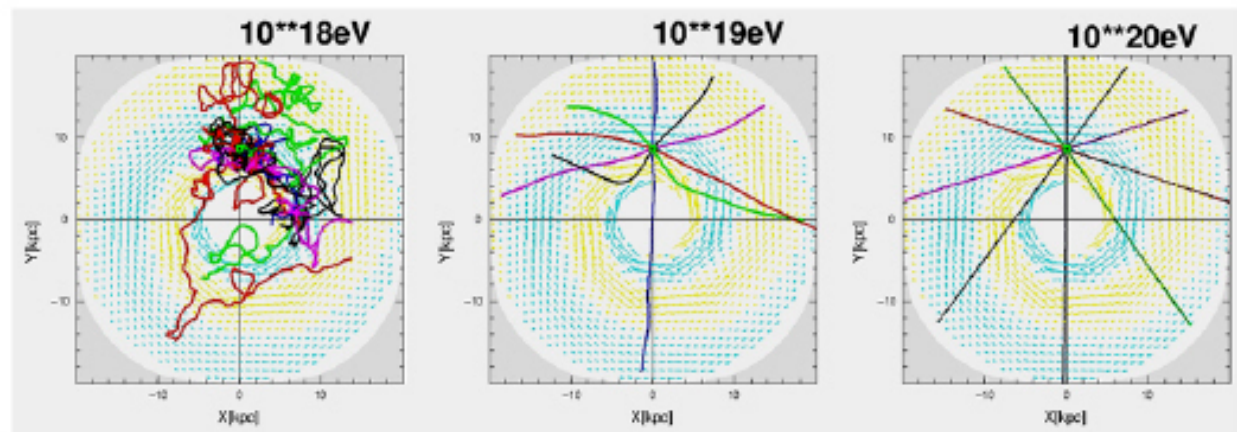
銀河内の伝播シミュレーション

到来方向解析により起源天体を特定: 粒子天文学

Arrival Directions (AGASA)



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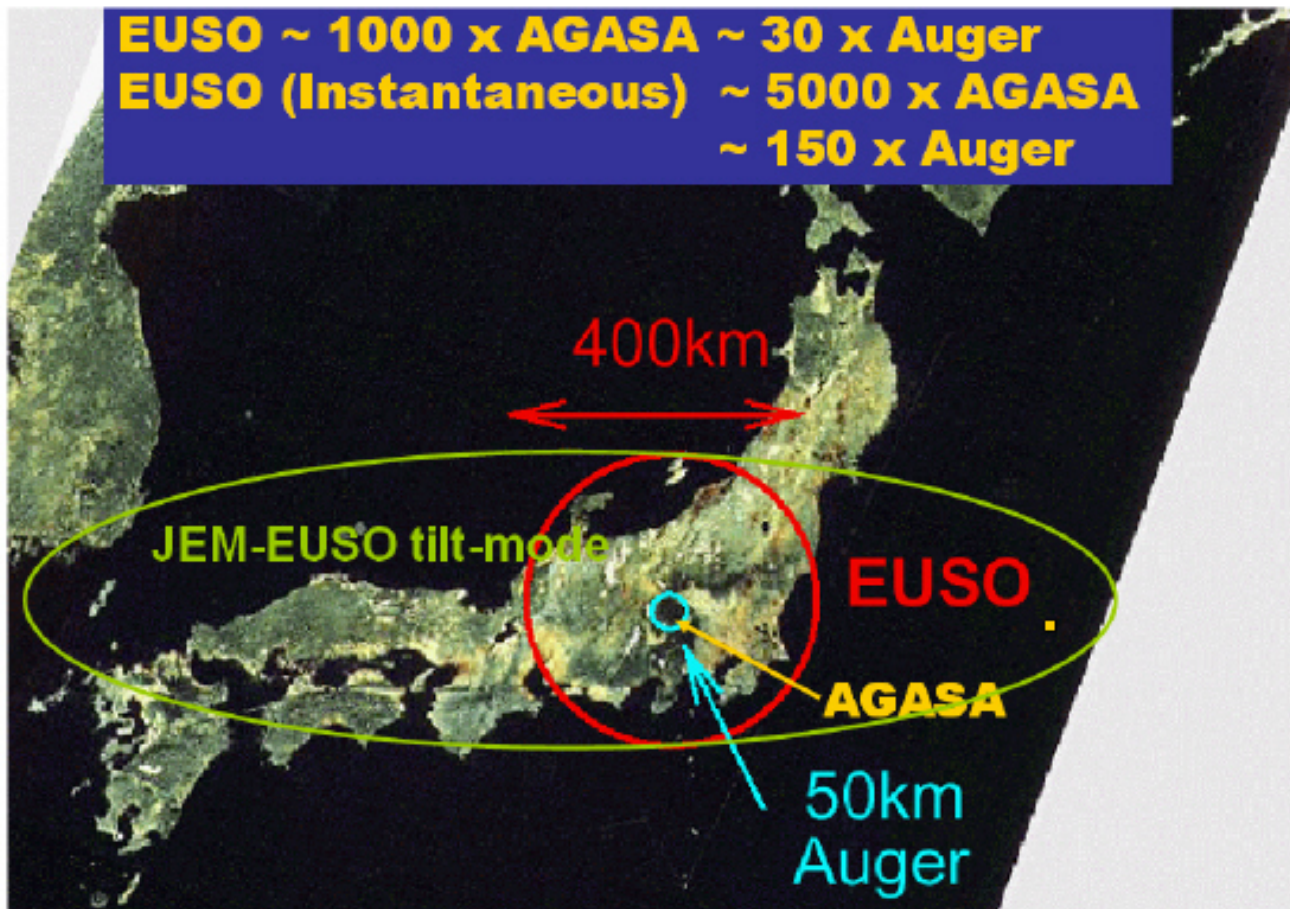
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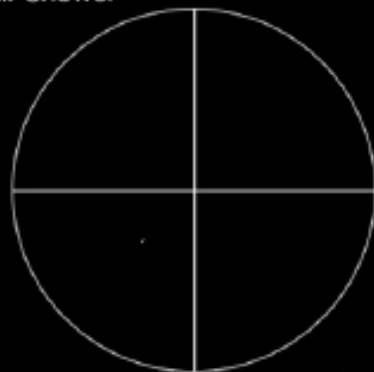
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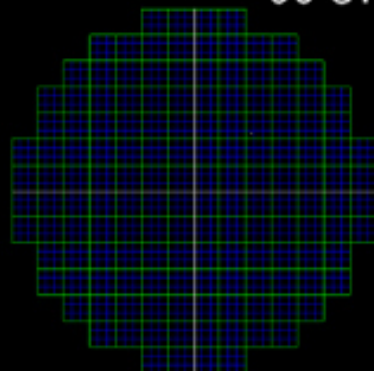


JEM-EUSOで見る空気シャワー

Air Shower

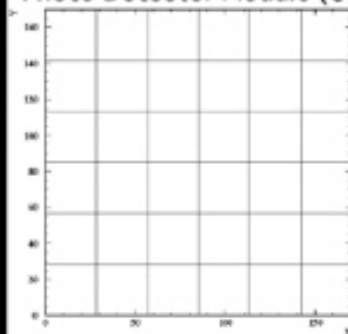


00 GTU

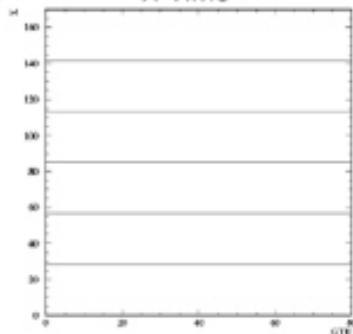


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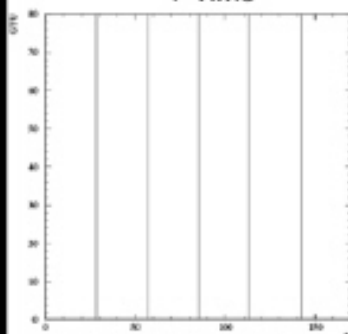
Photo Detector Module (3,3)



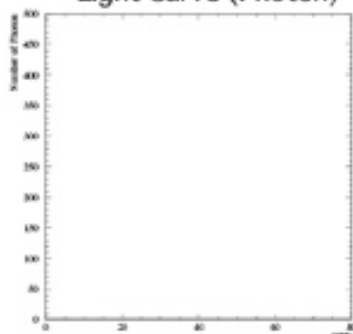
X-Time



Y-Time



Light Curve (Photon)

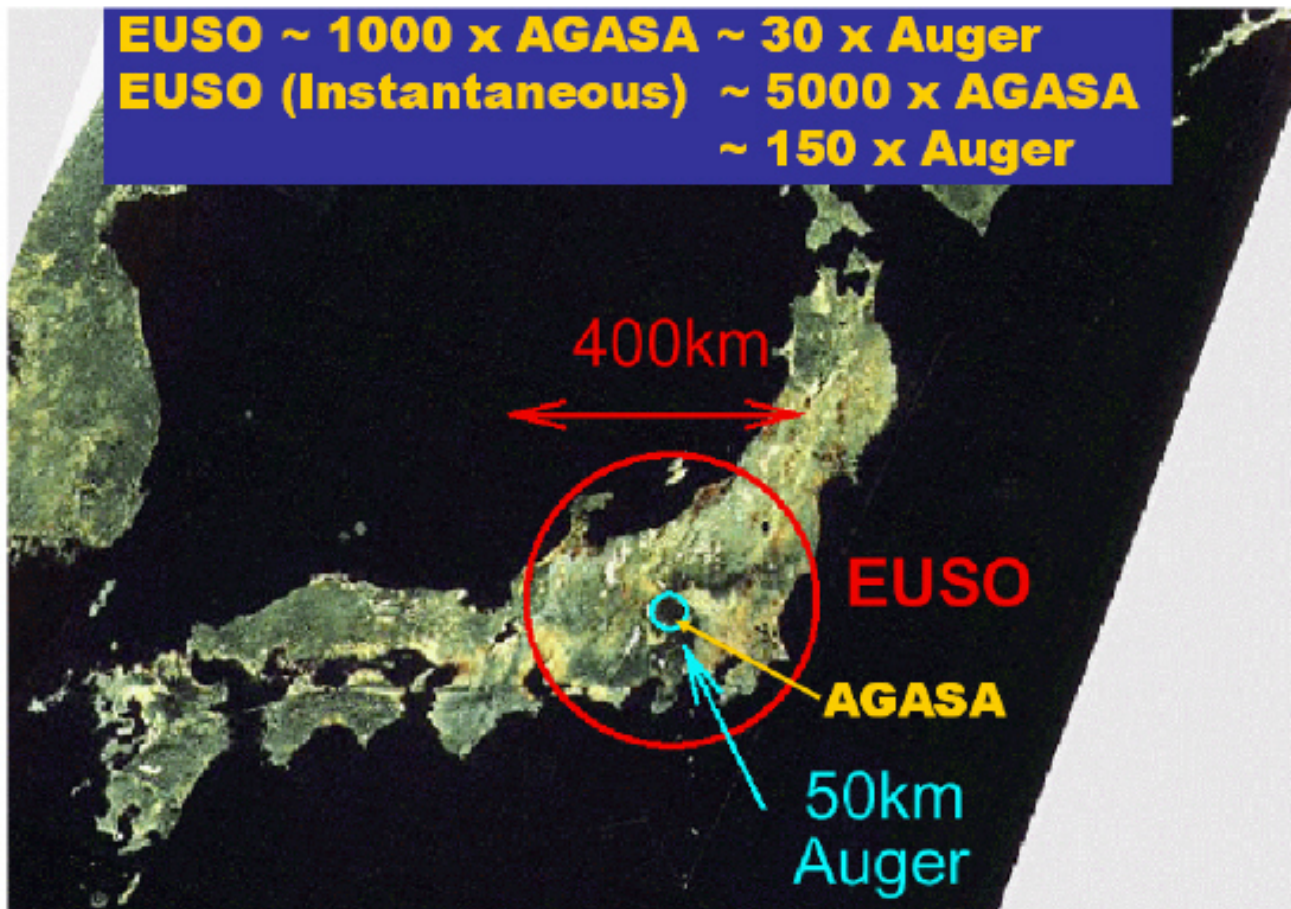






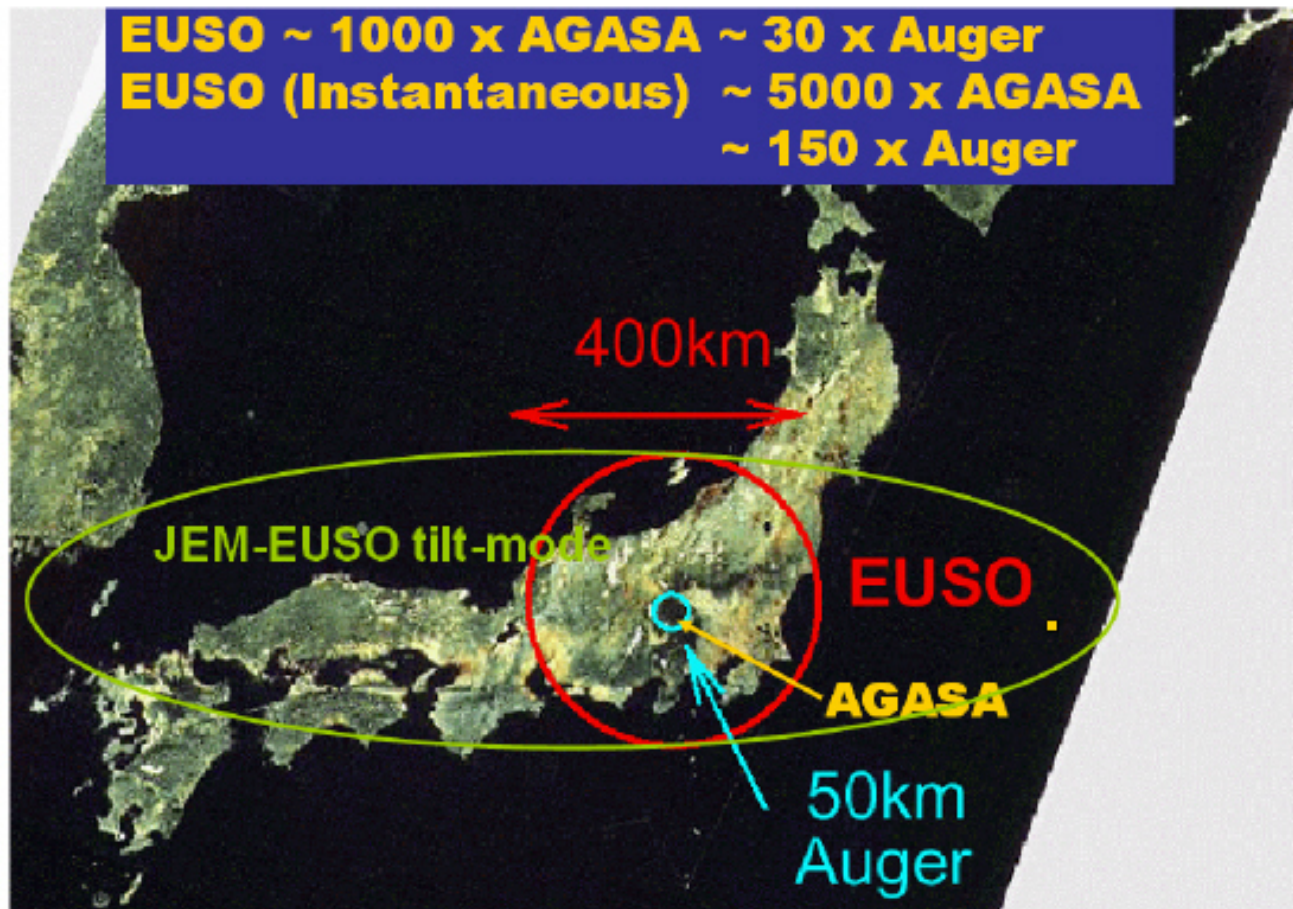
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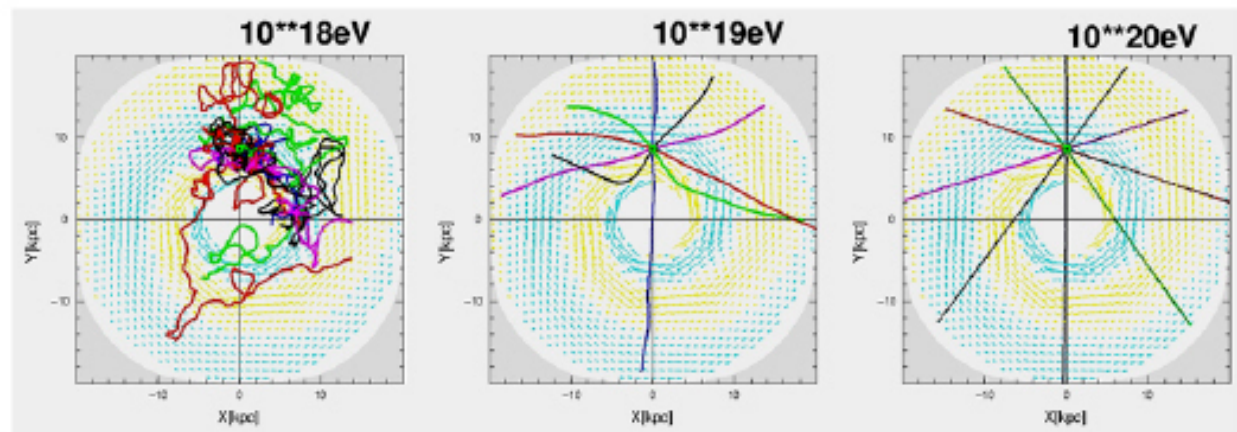
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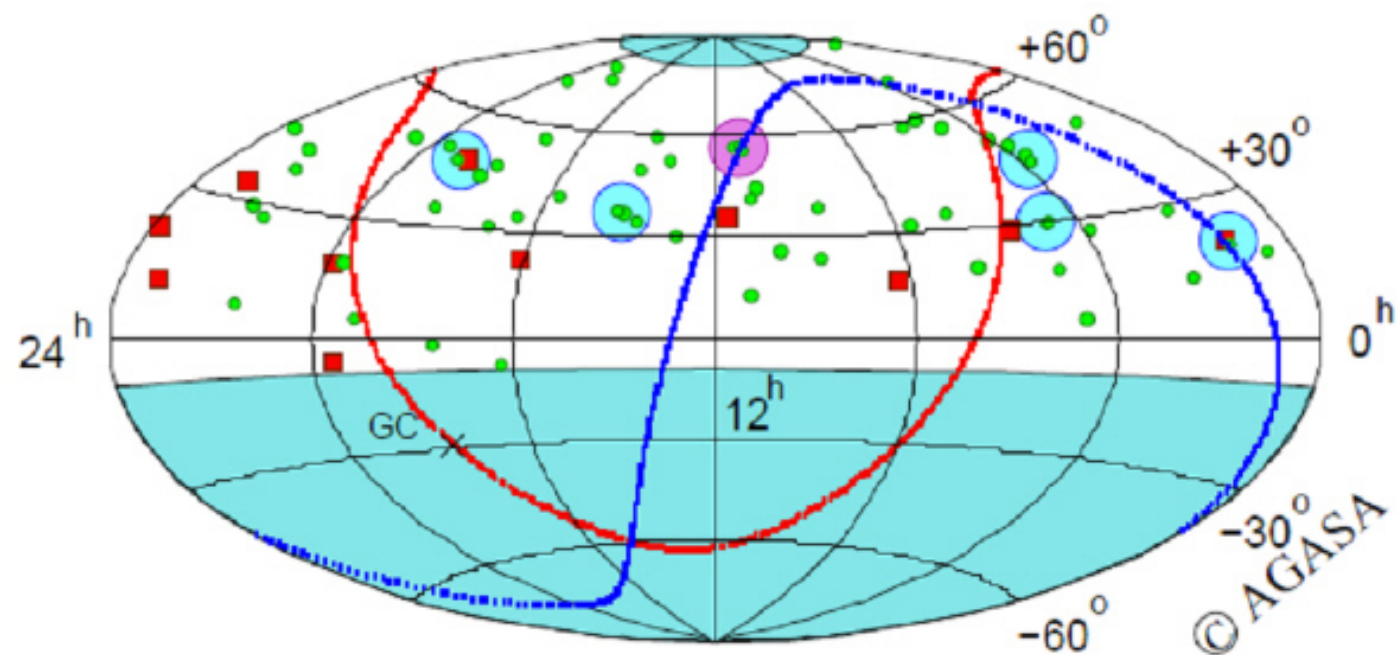
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Arrival Directions (AGASA)



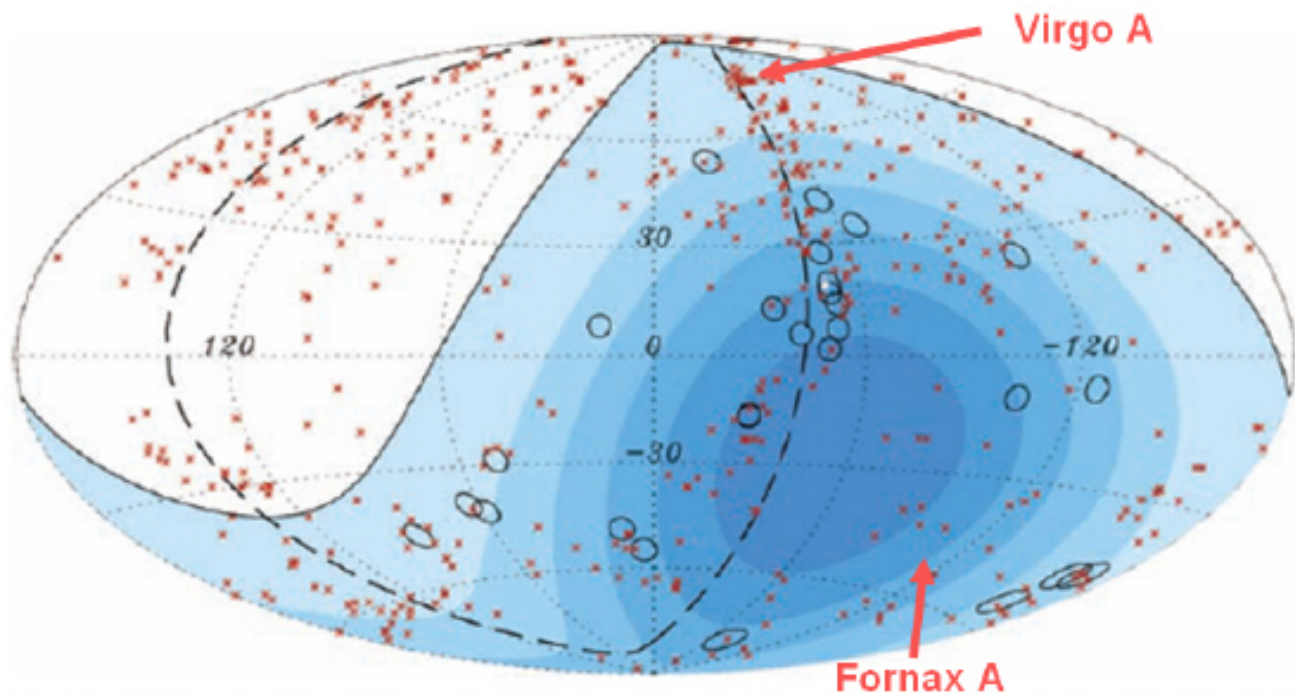


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

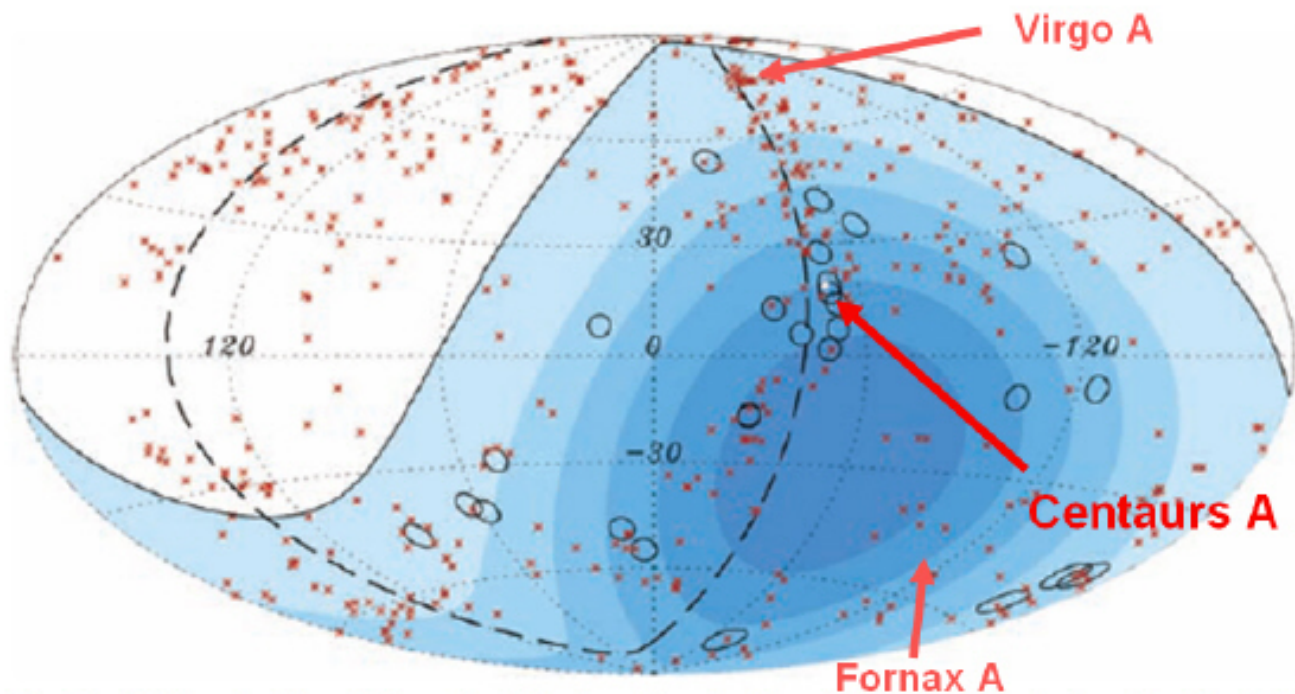


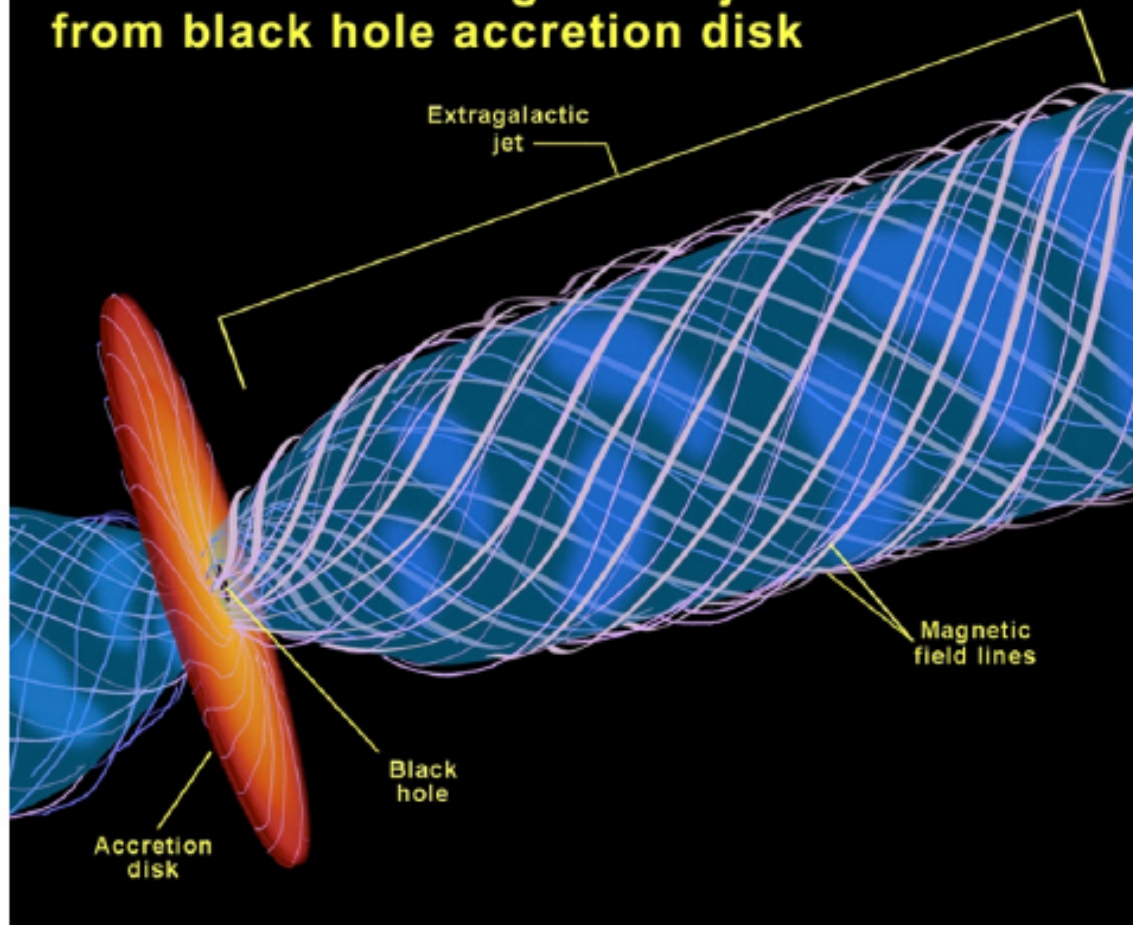
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ケンタウルス座 A

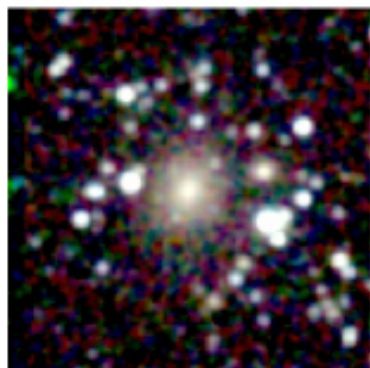
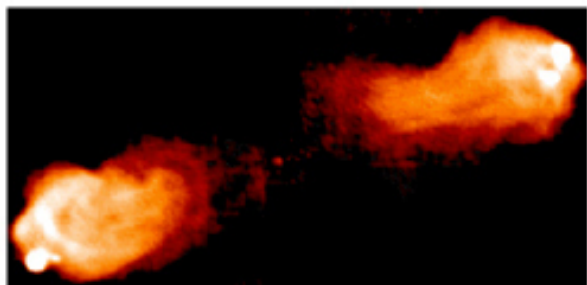
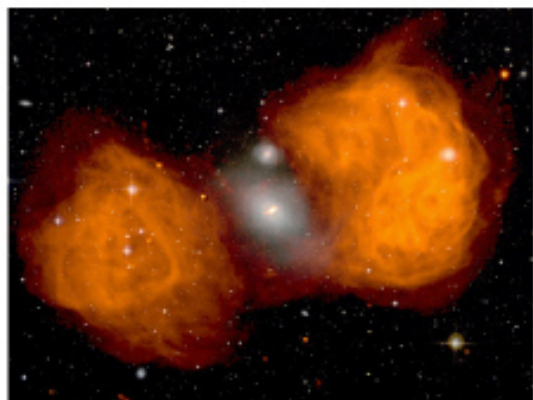


- 距離: 3.4Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度～電波光度
～ 2×10^{41} W

Formation of extragalactic jets from black hole accretion disk



他の電波銀河

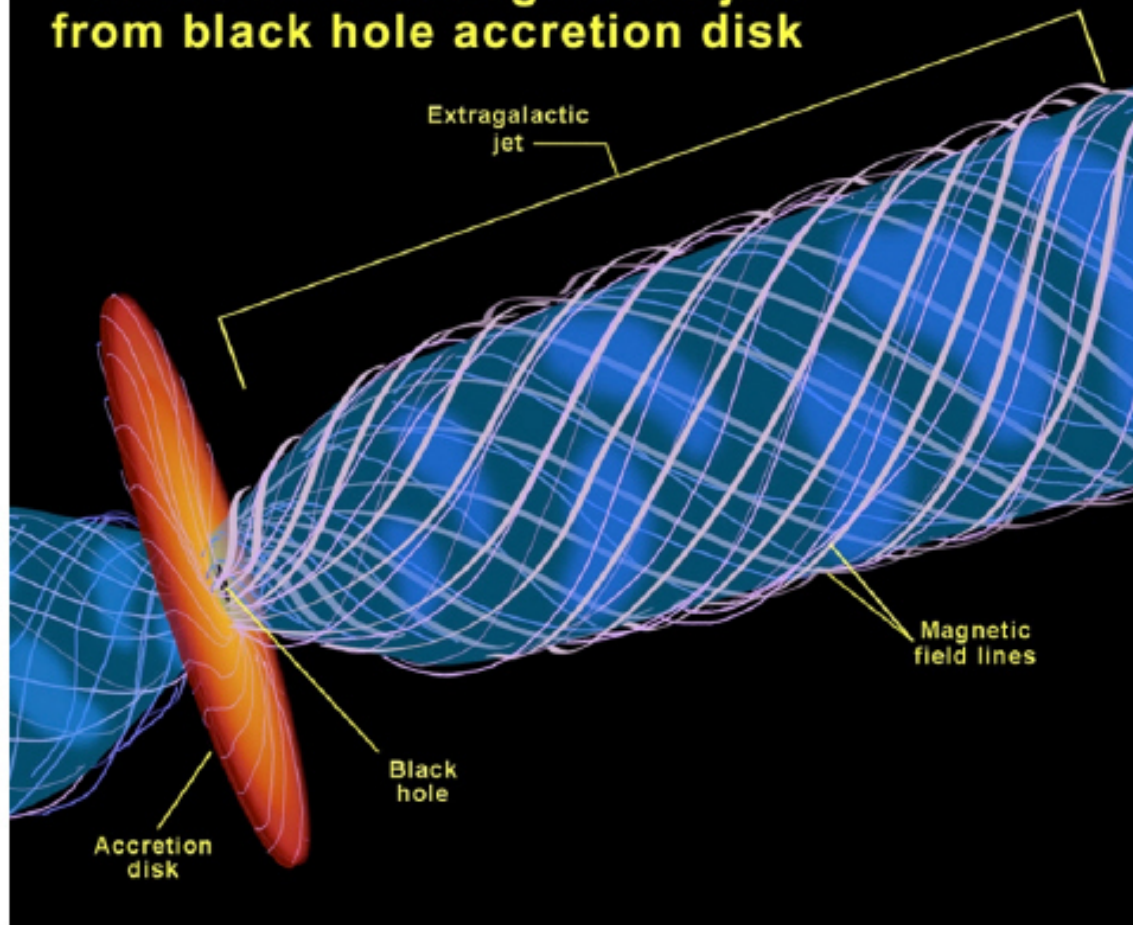


Fornax A

Cygnus A



Formation of extragalactic jets from black hole accretion disk

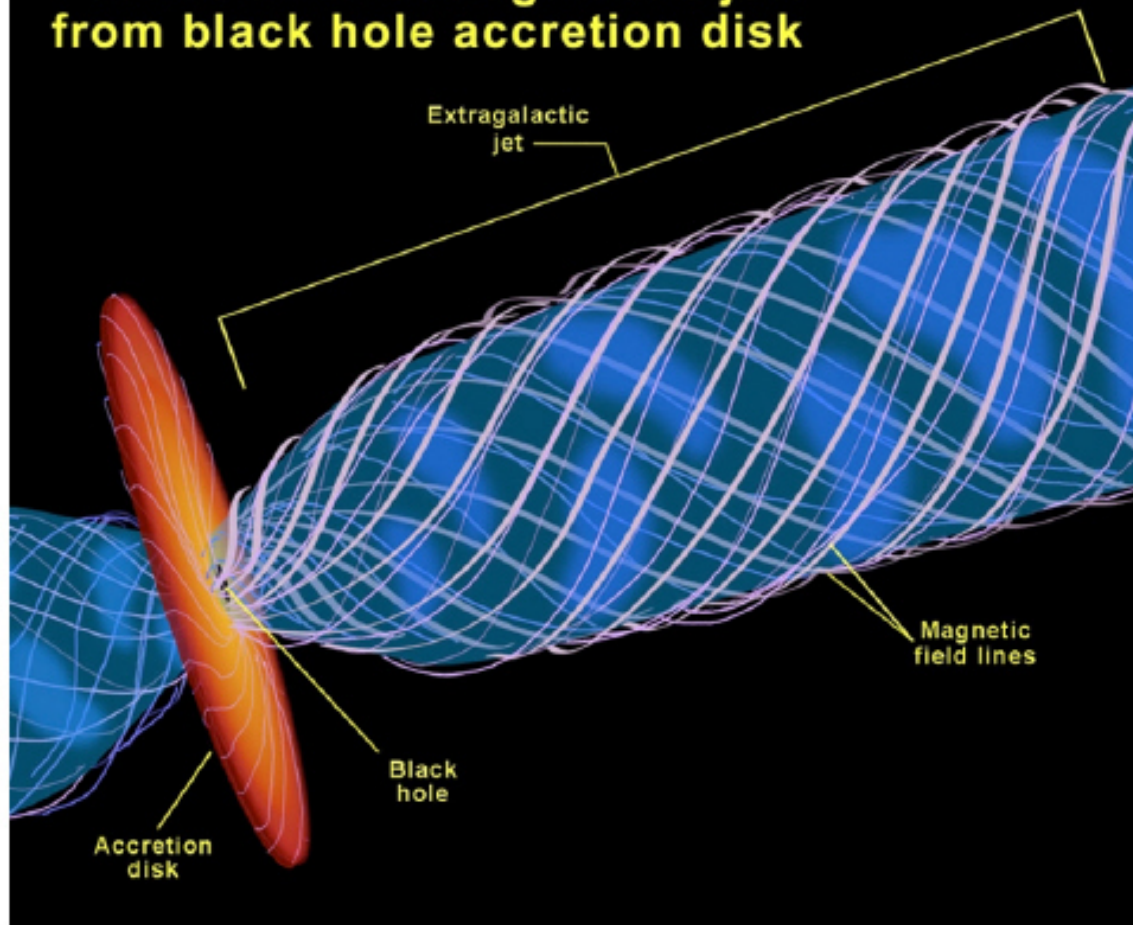


ケンタウルス座 A



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Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



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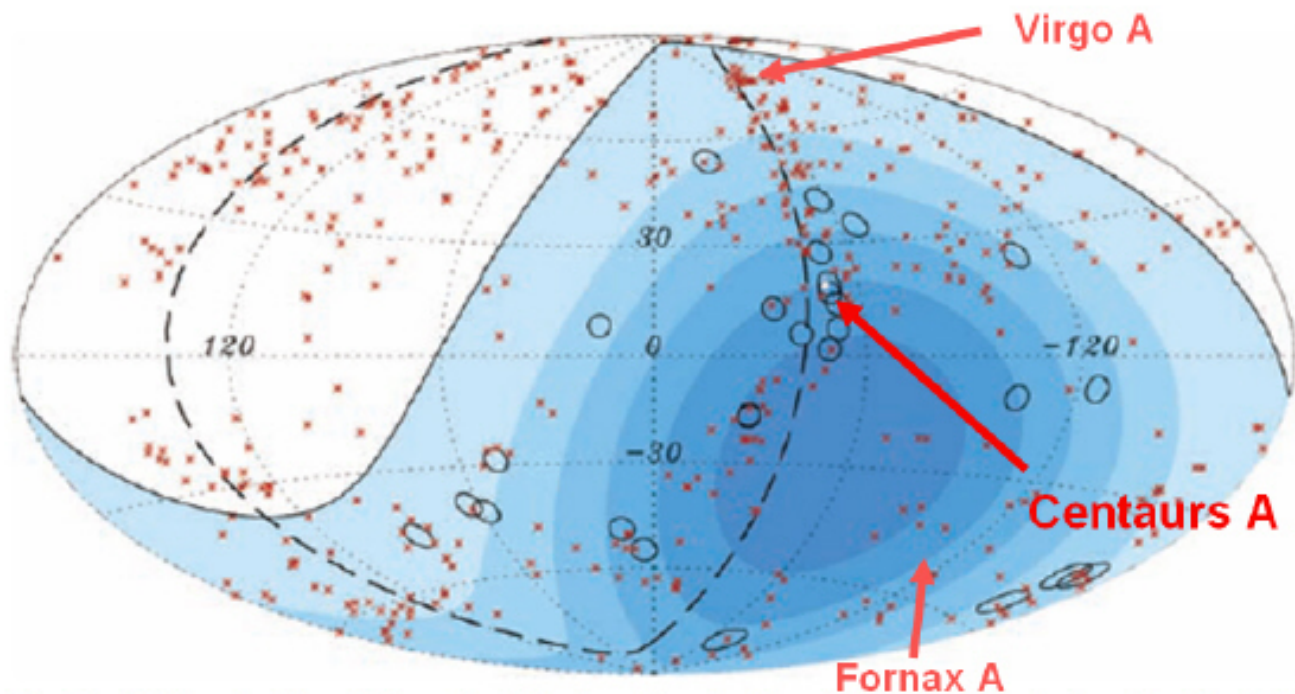


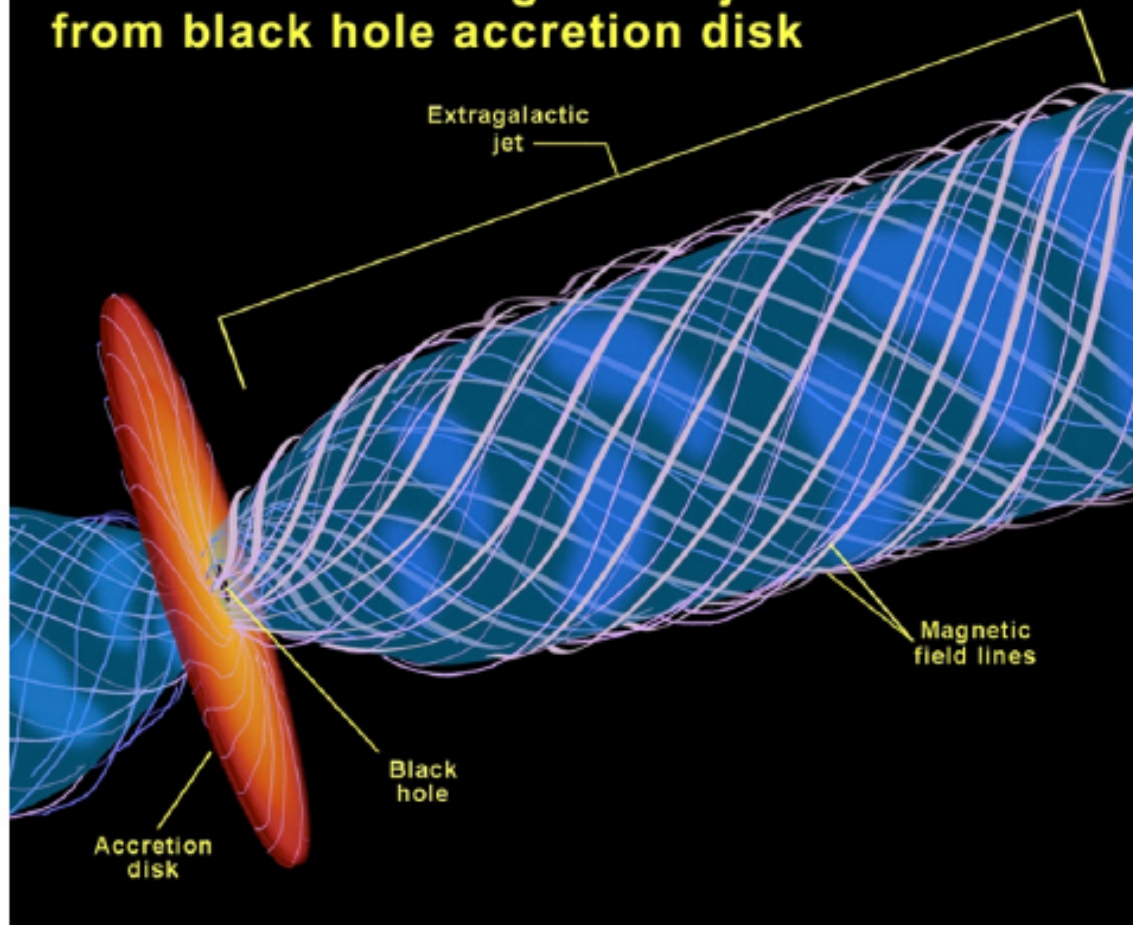
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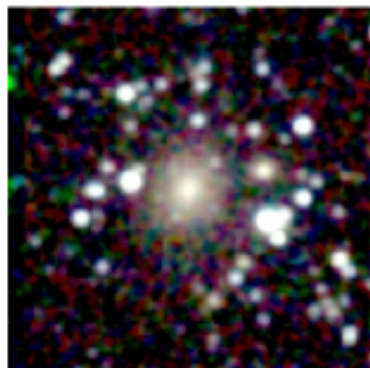
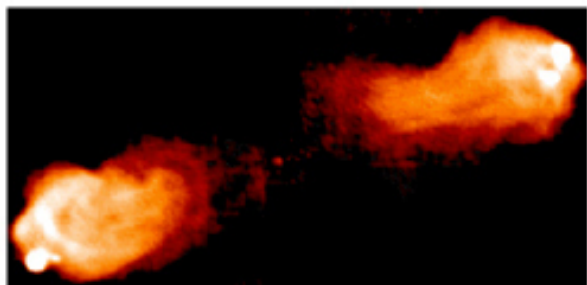
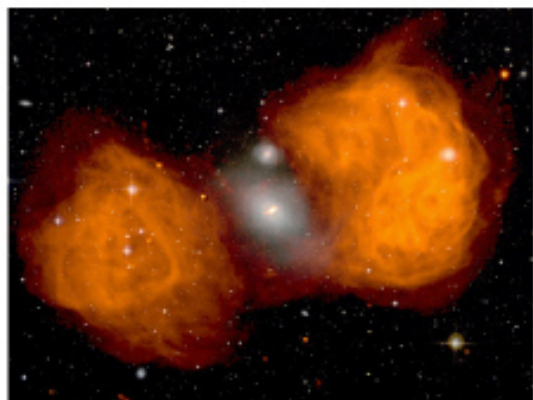


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- 荷電粒子光度 ~ 電波光度
~ 2×10^{41} W

Formation of extragalactic jets from black hole accretion disk



他の電波銀河

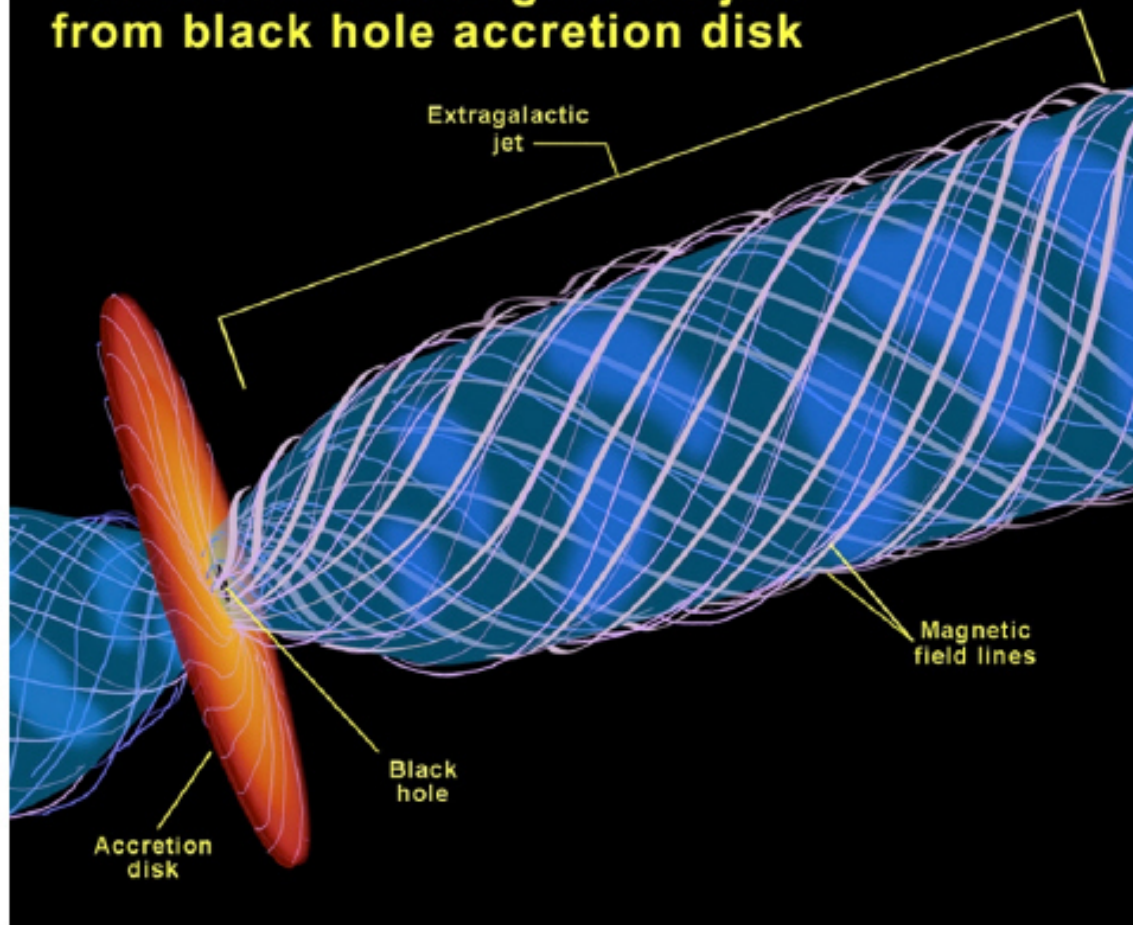


Fornax A

Cygnus A



Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



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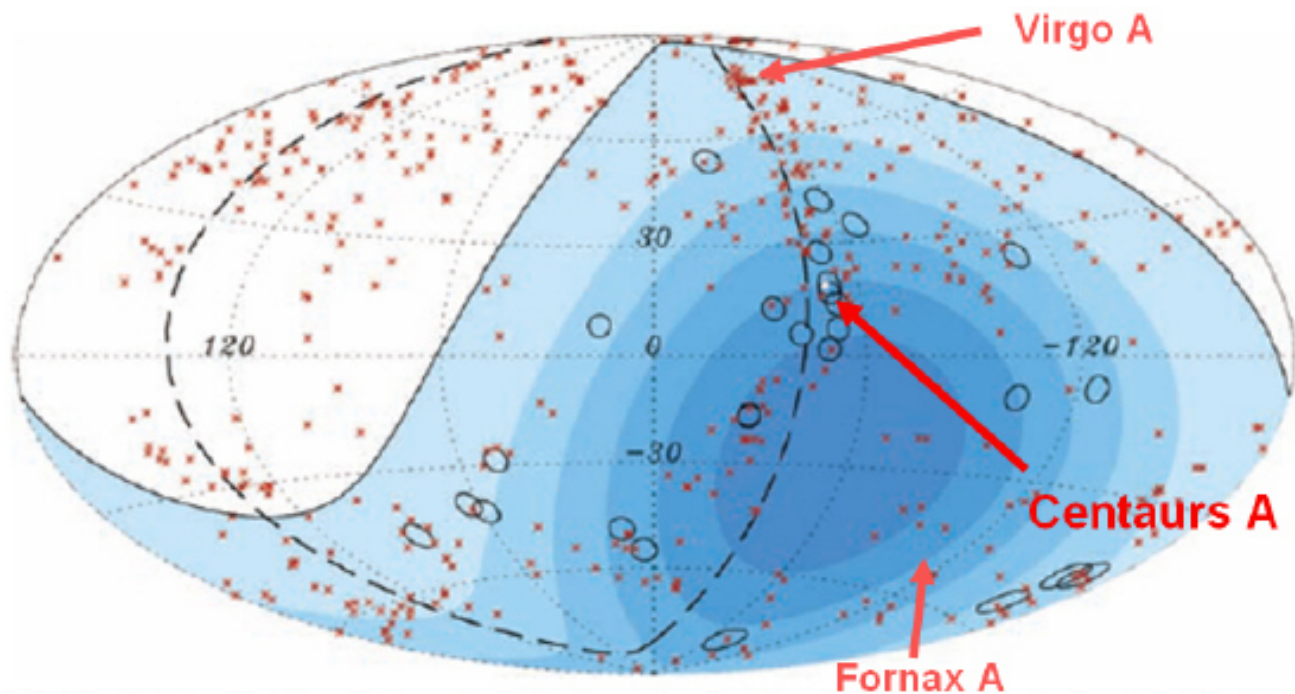


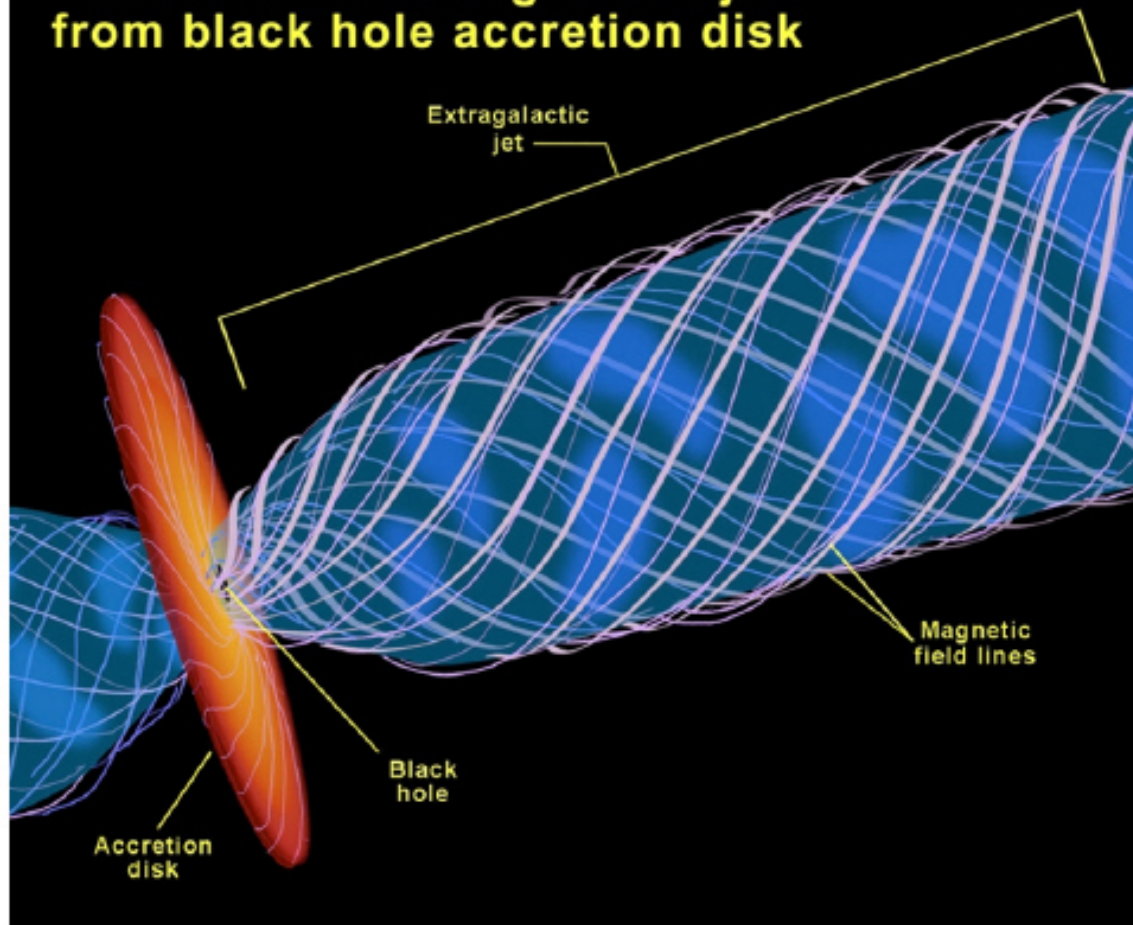
Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

ケンタウルス座 A



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Formation of extragalactic jets from black hole accretion disk

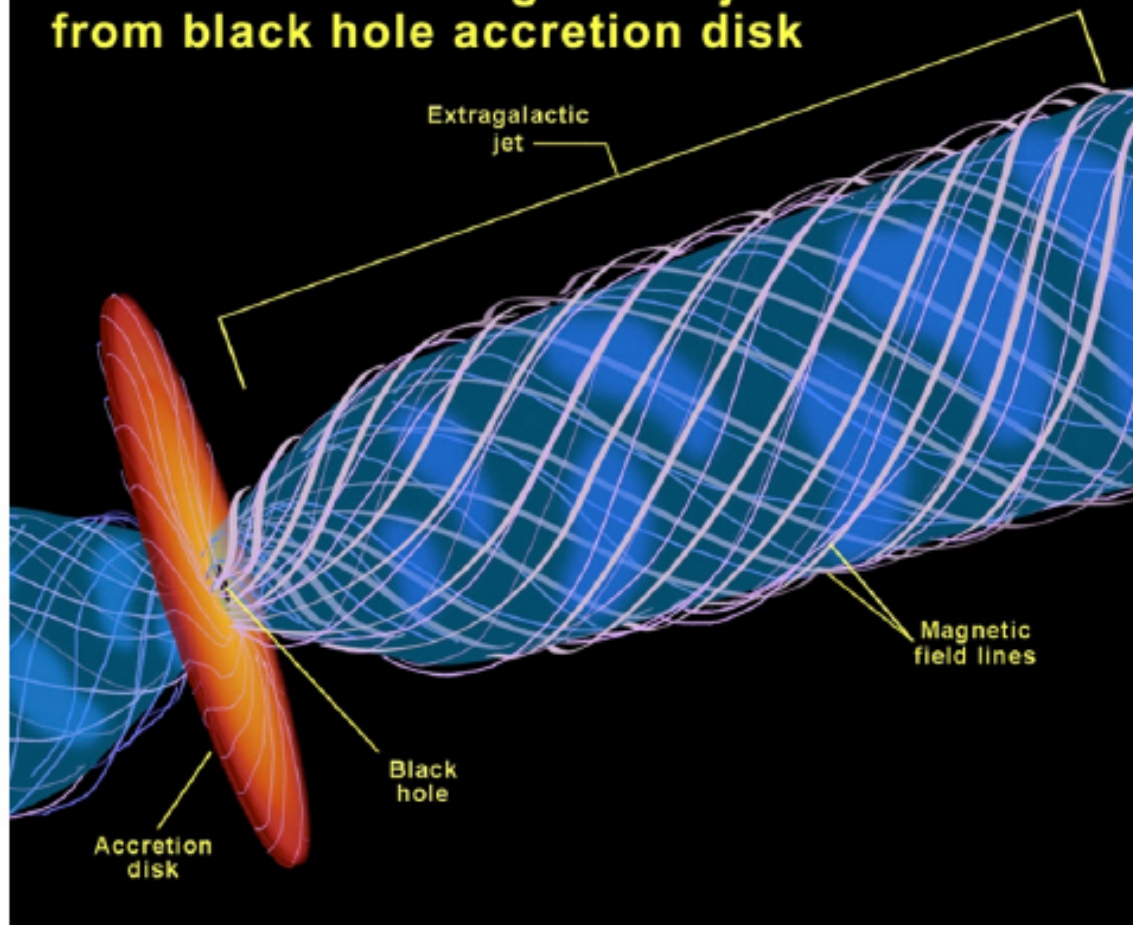


ケンタウルス座 A

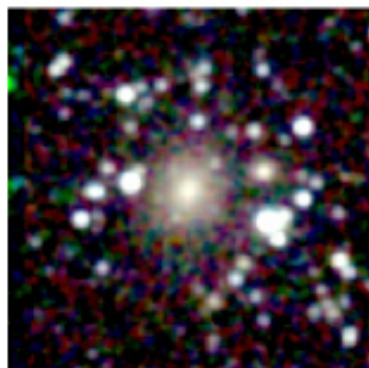
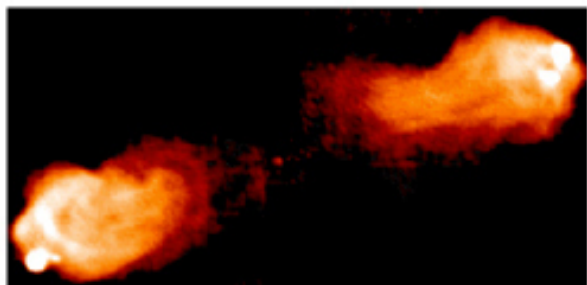
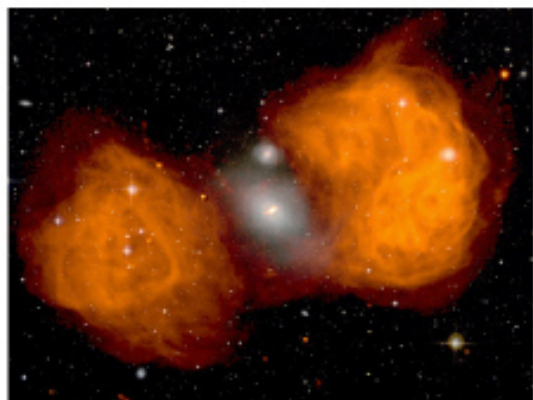


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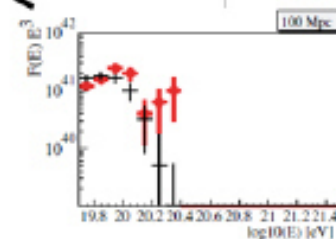
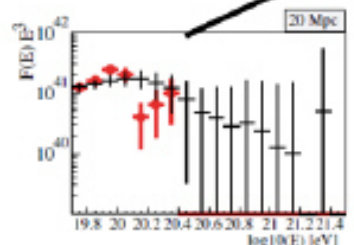
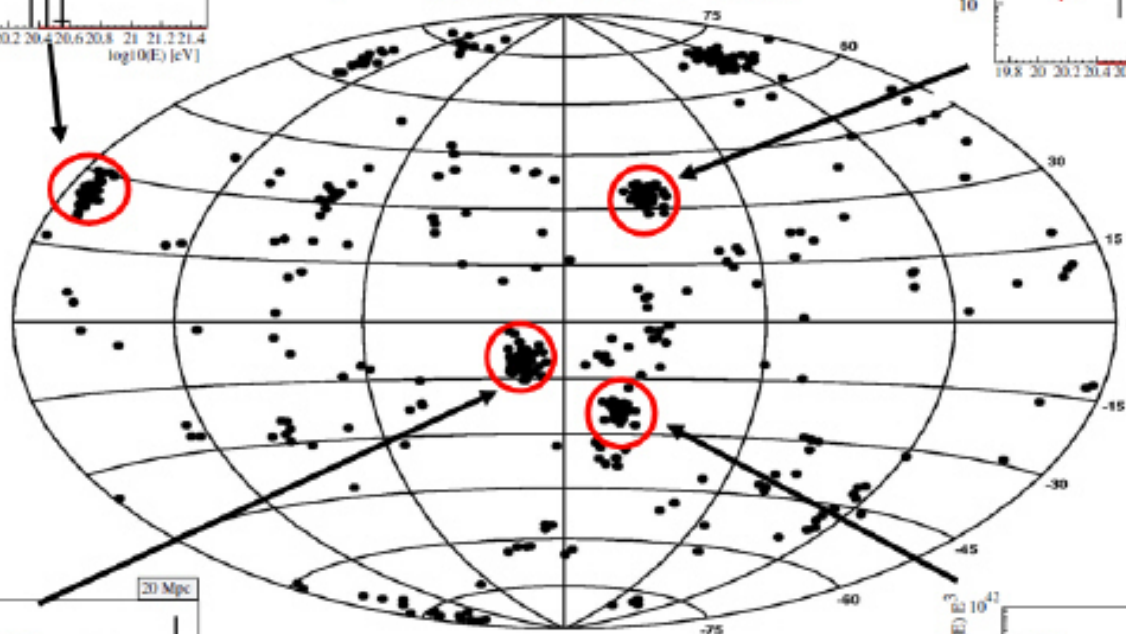
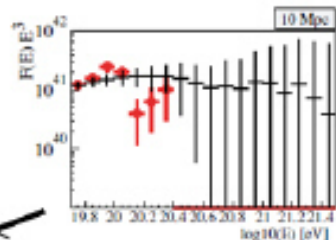
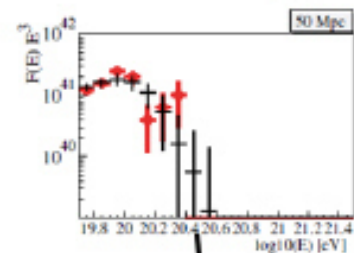
Fornax A

Cygnus A



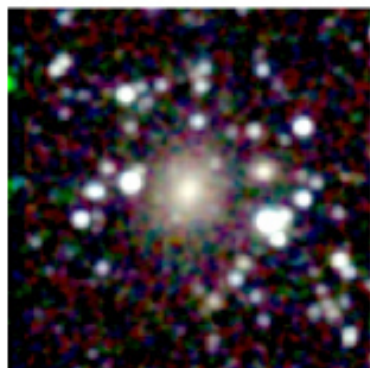
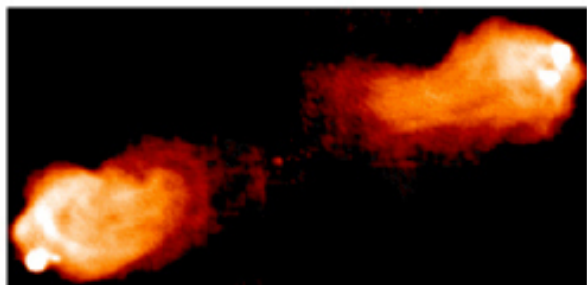
極限粒子天文学

1,000事象の場合の予測



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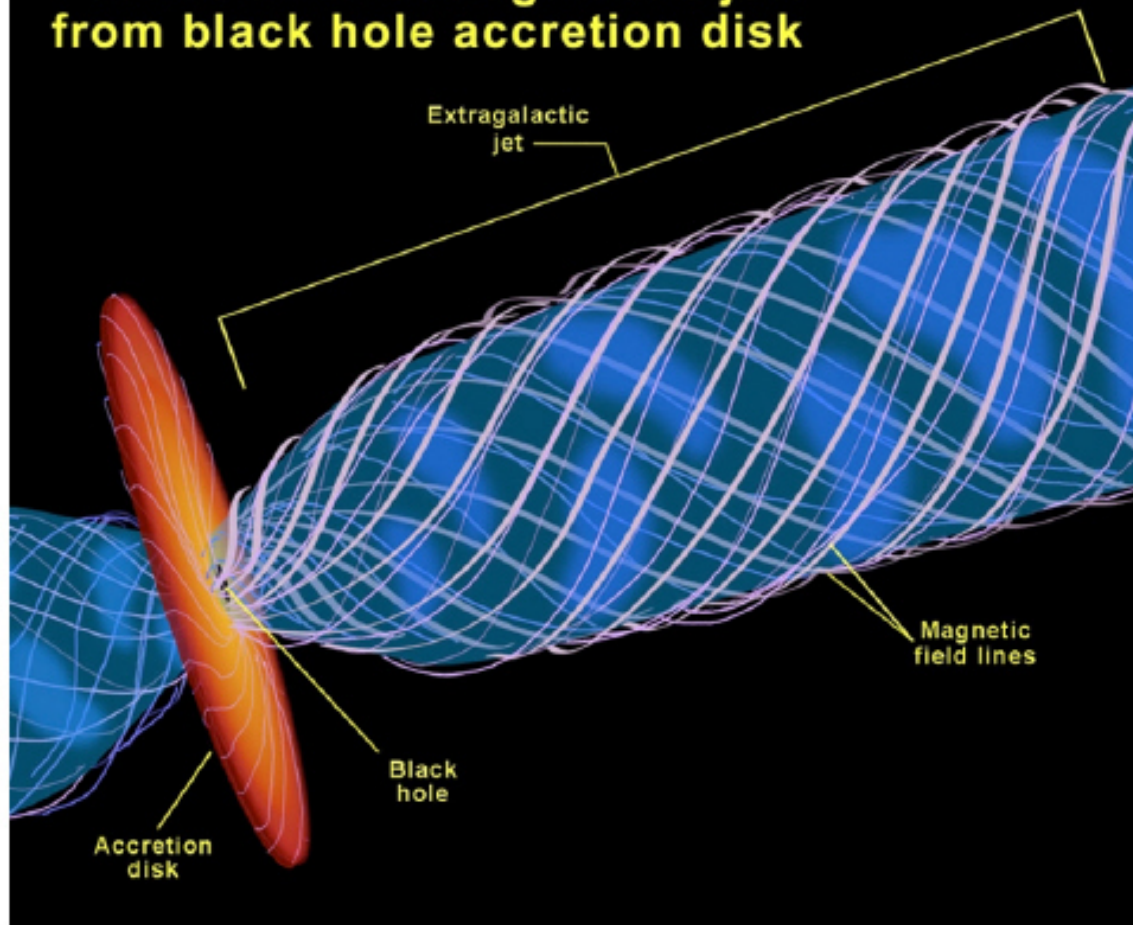


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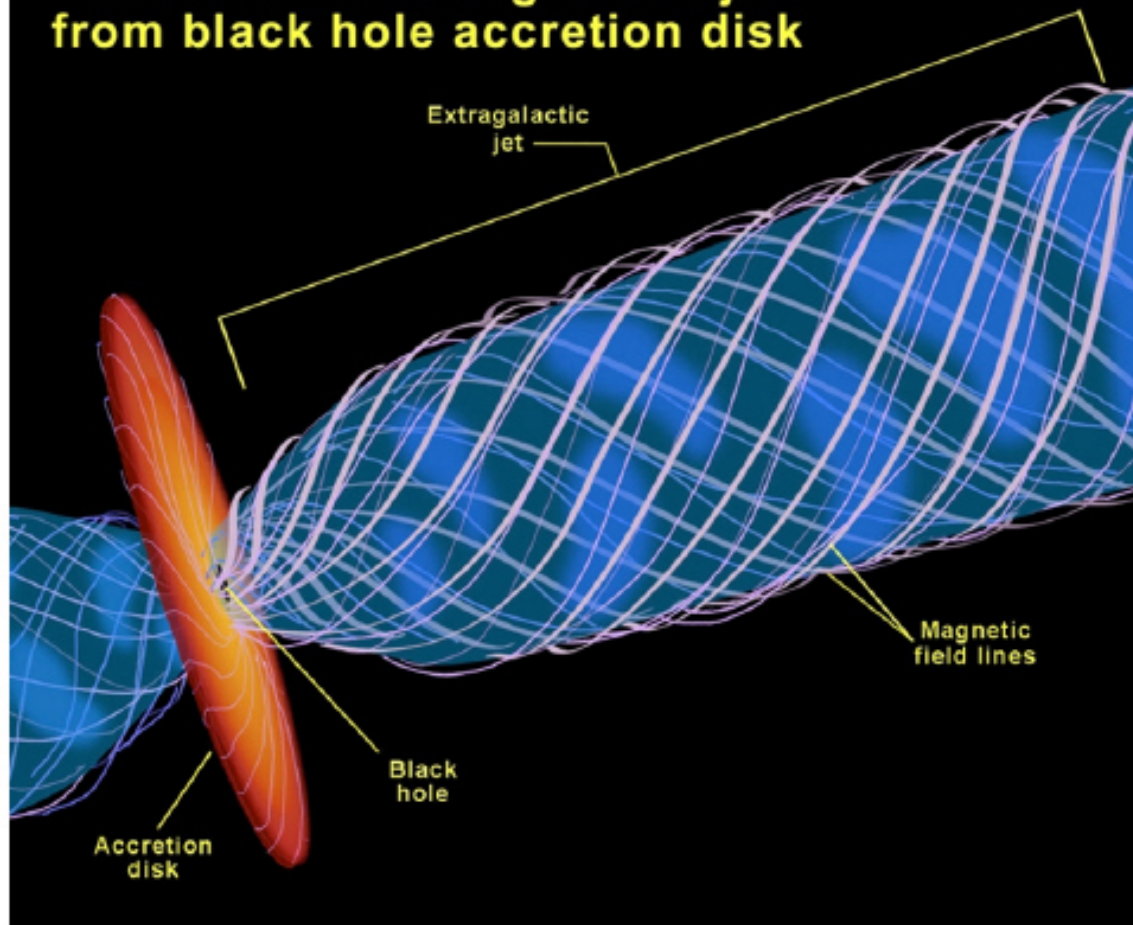


ケンタウルス座 A

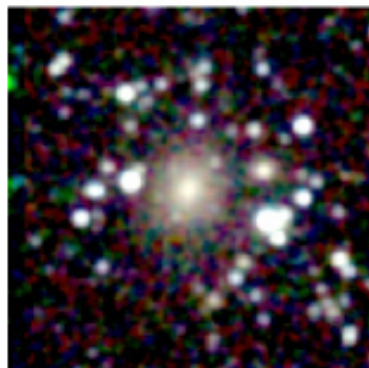
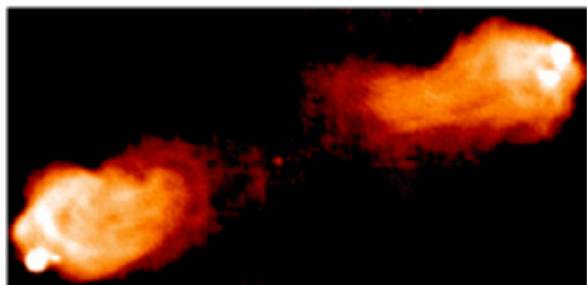
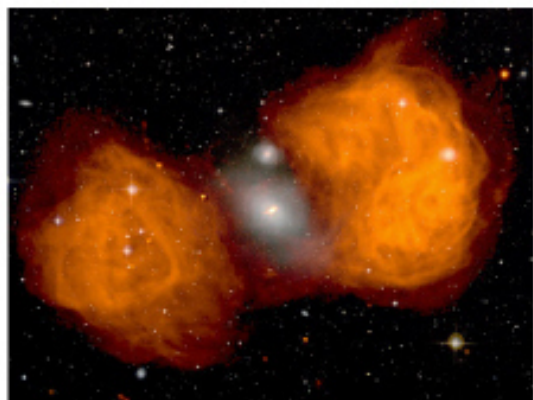


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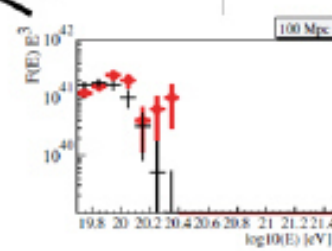
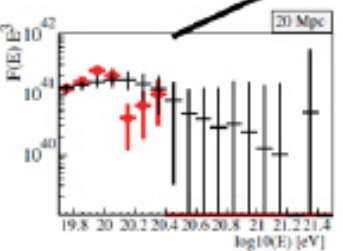
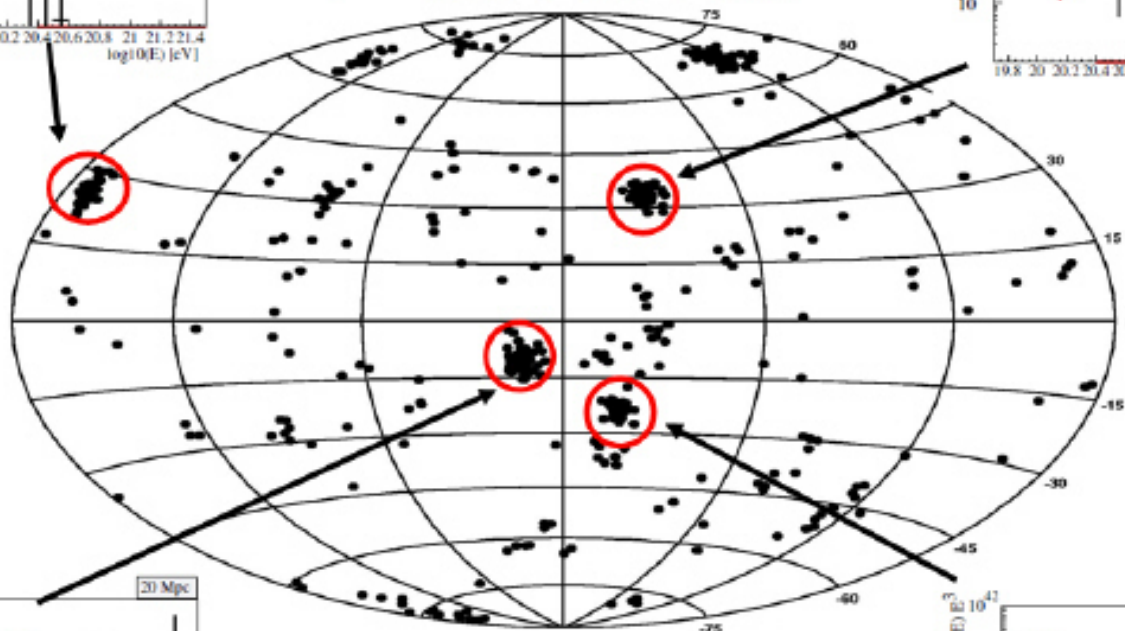
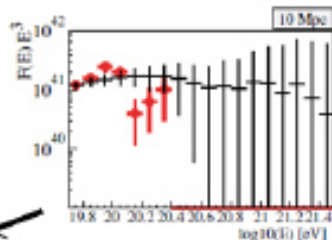
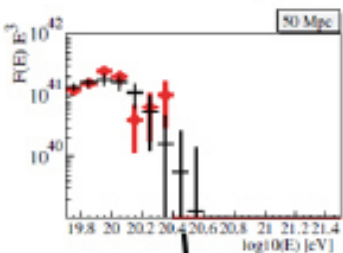


Fornax A

Cygnus A

極限粒子天文学

1,000事象の場合の予測



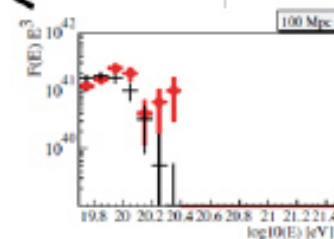
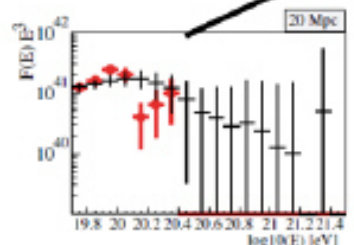
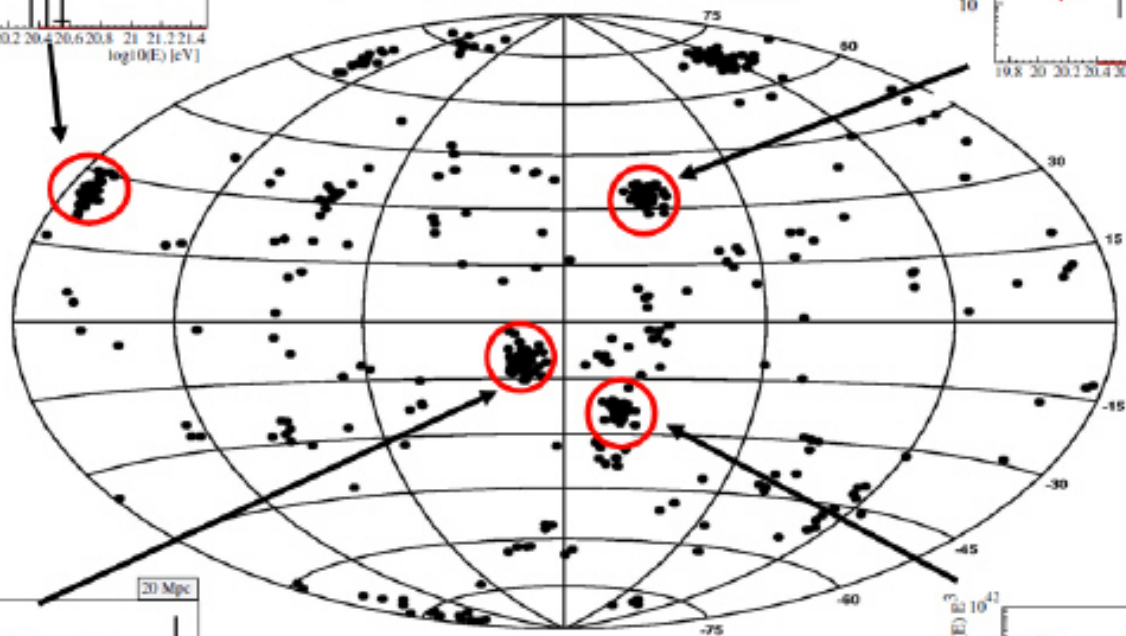
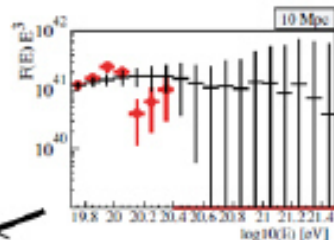
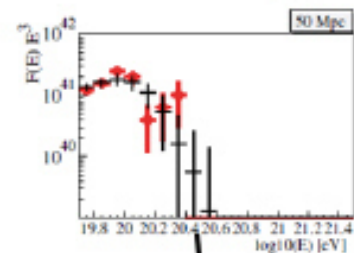
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事例数：5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

極限粒子天文学

1,000事象の場合の予測



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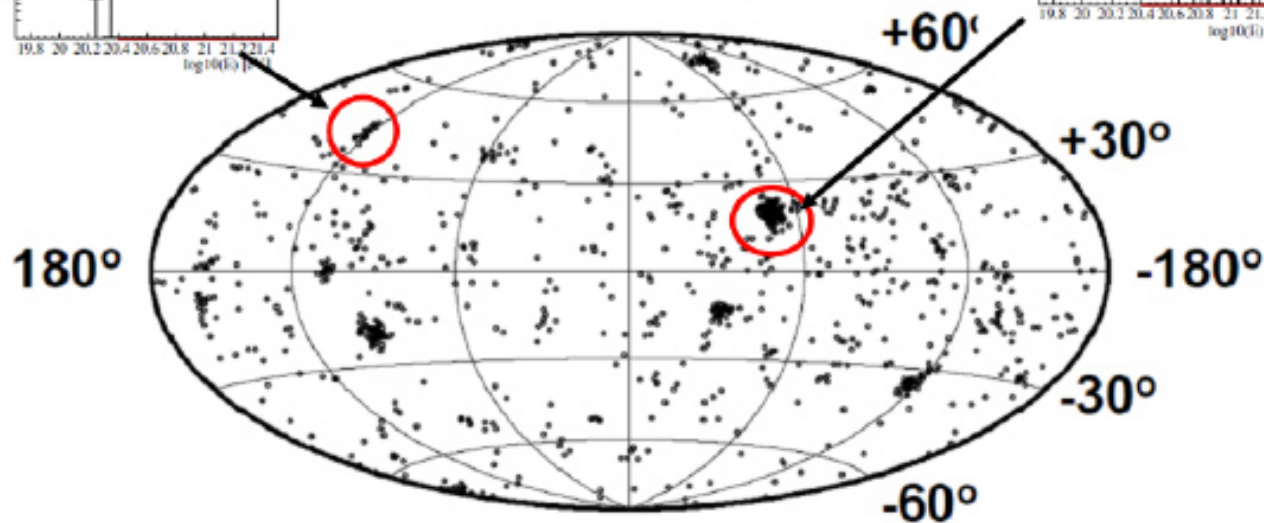
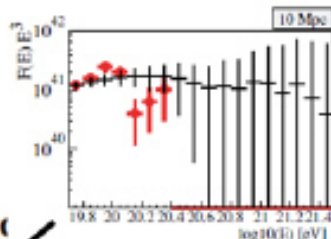
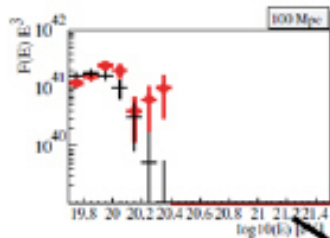
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極限粒子天文学

1,000事象の場合の予測

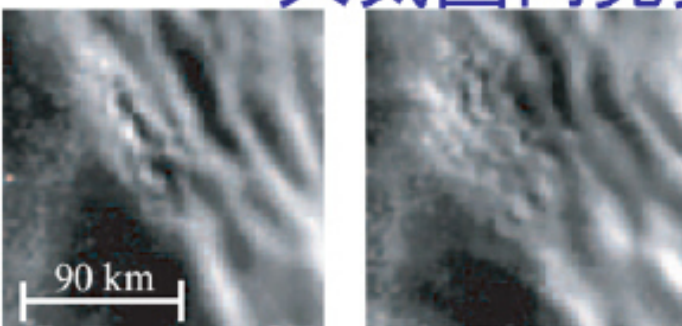
粒子光度 \propto X線光度 (AGN)



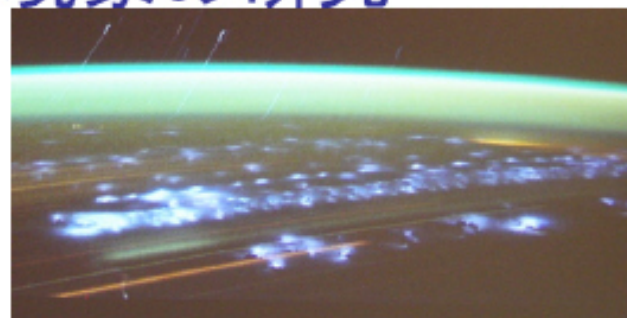
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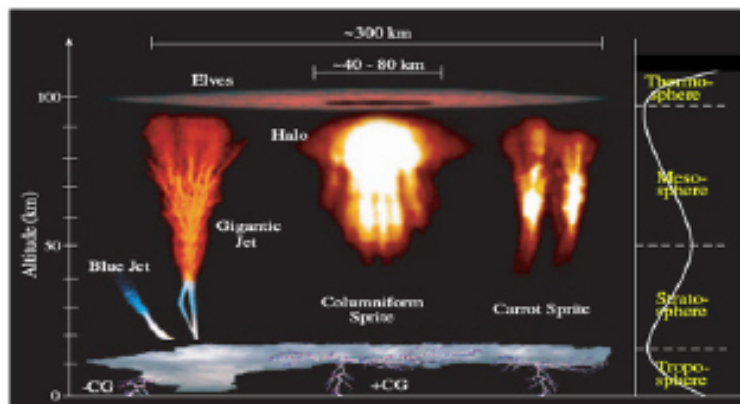
探求的試験研究3: 大気圏内発光現象の研究



地上から観測したOH 大気光の変化



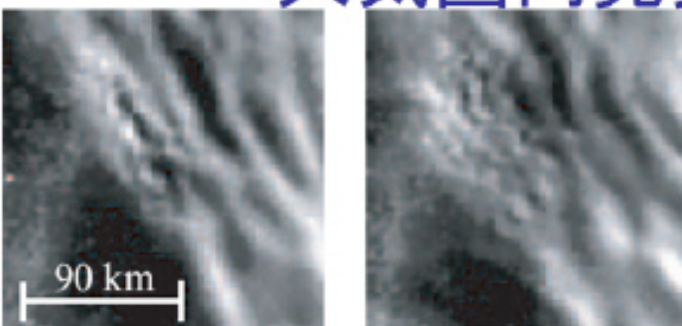
国際宇宙ステーションから連続撮影した雷光

ハイビジョンカメラによる
2001年のしし座流星群雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

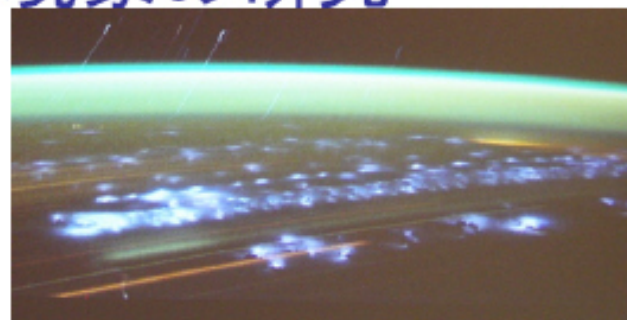
JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星

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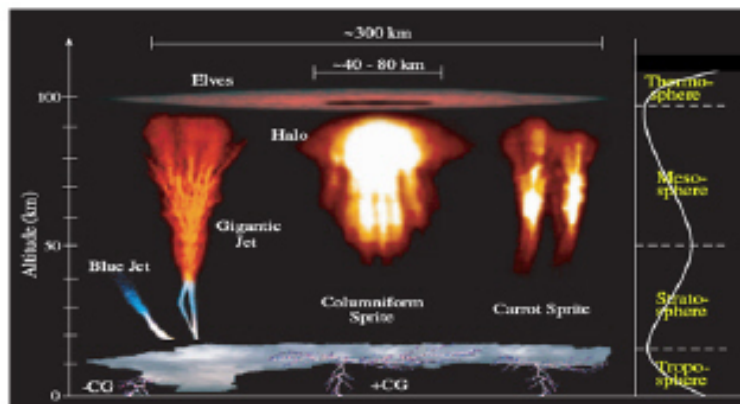
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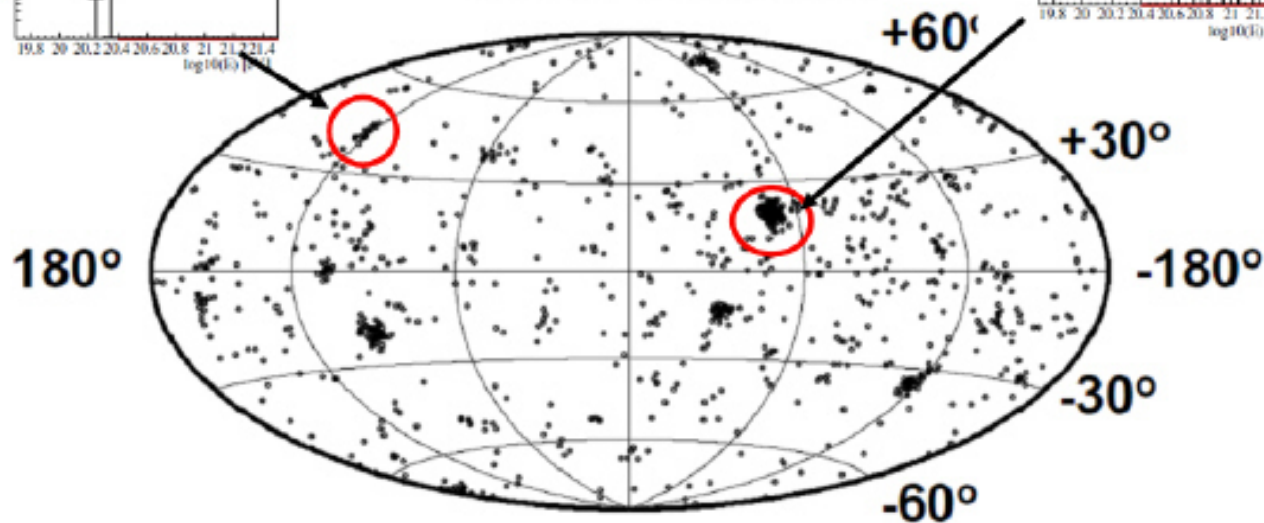
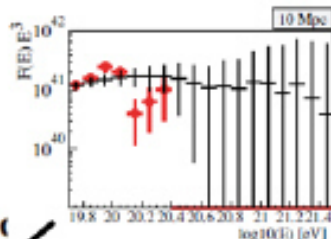
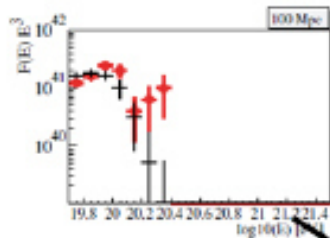


雷放電に伴う成層圏・中間圏・下部
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極限粒子天文学

1,000事象の場合の予測

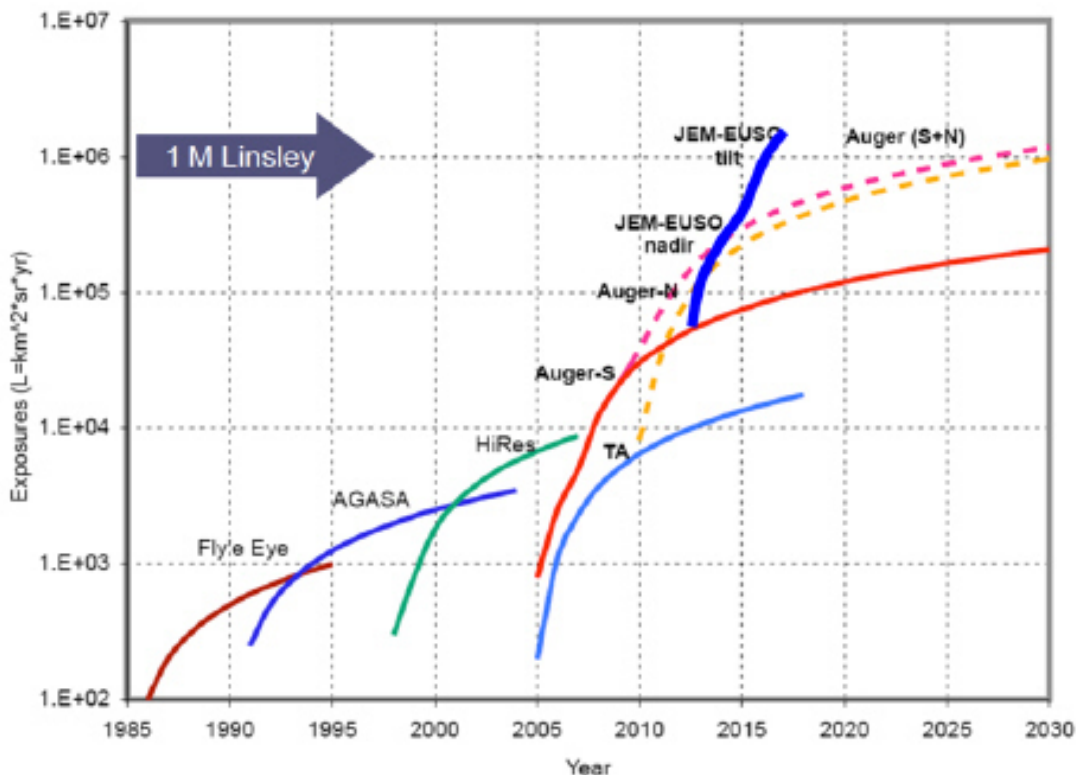
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有効露出の増加期待値



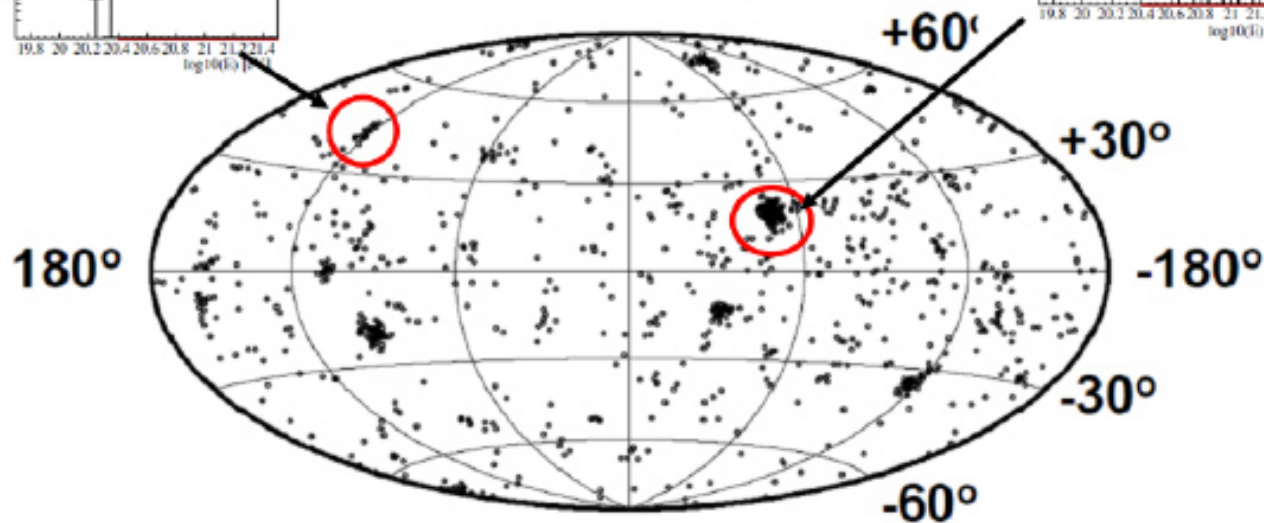
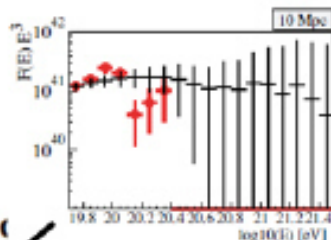
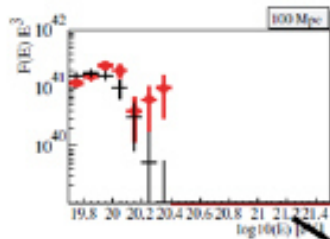
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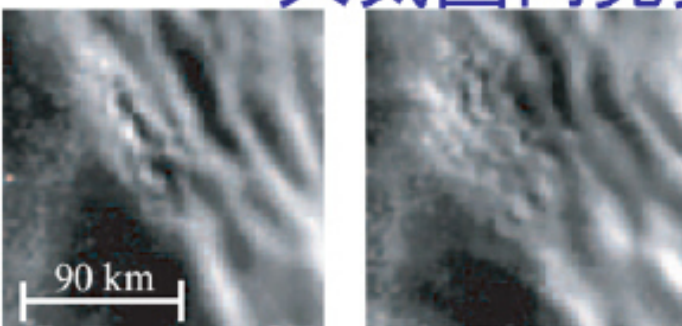
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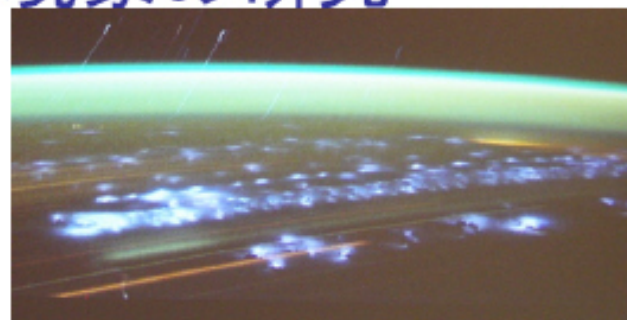
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探求的試験研究3: 大気圏内発光現象の研究



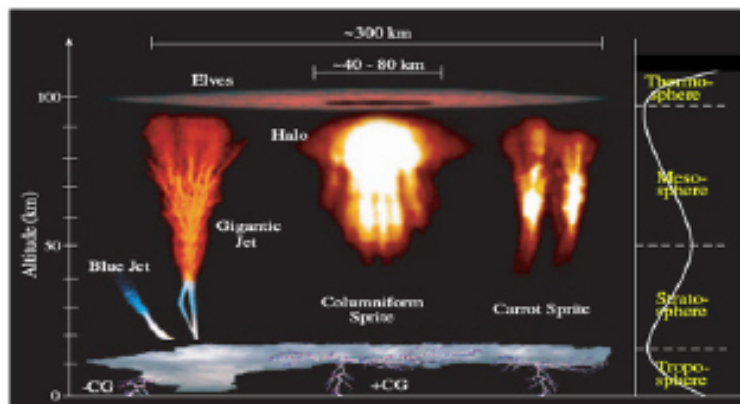
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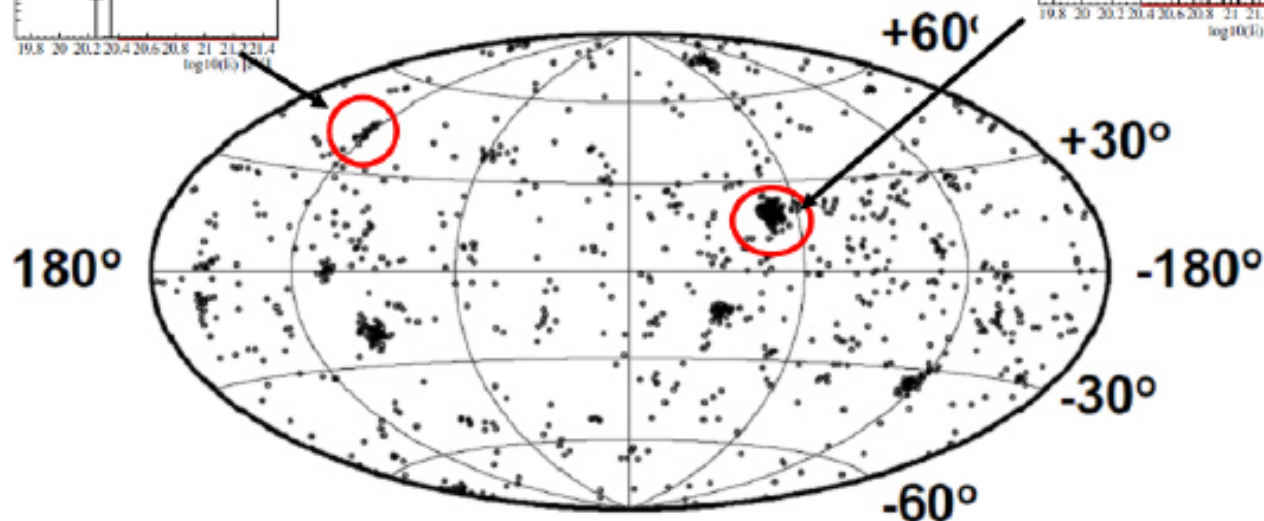
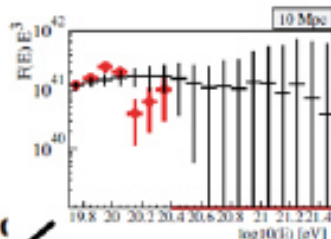
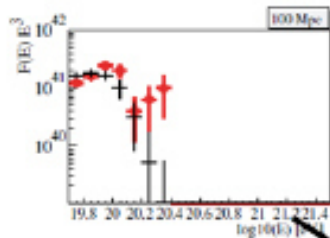


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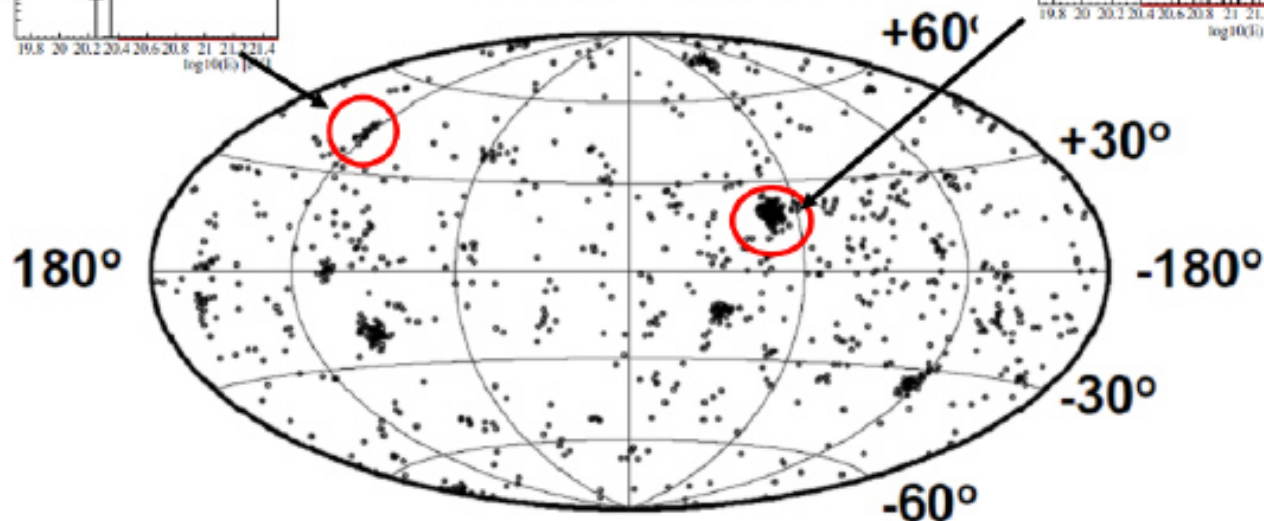
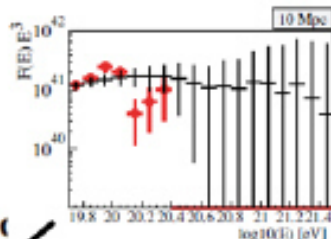
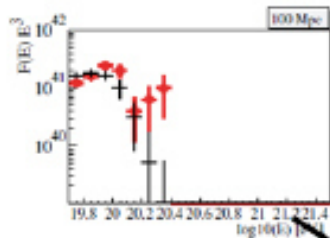
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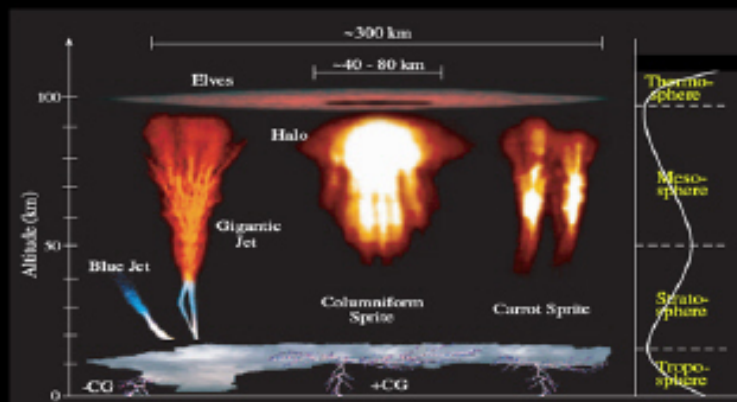
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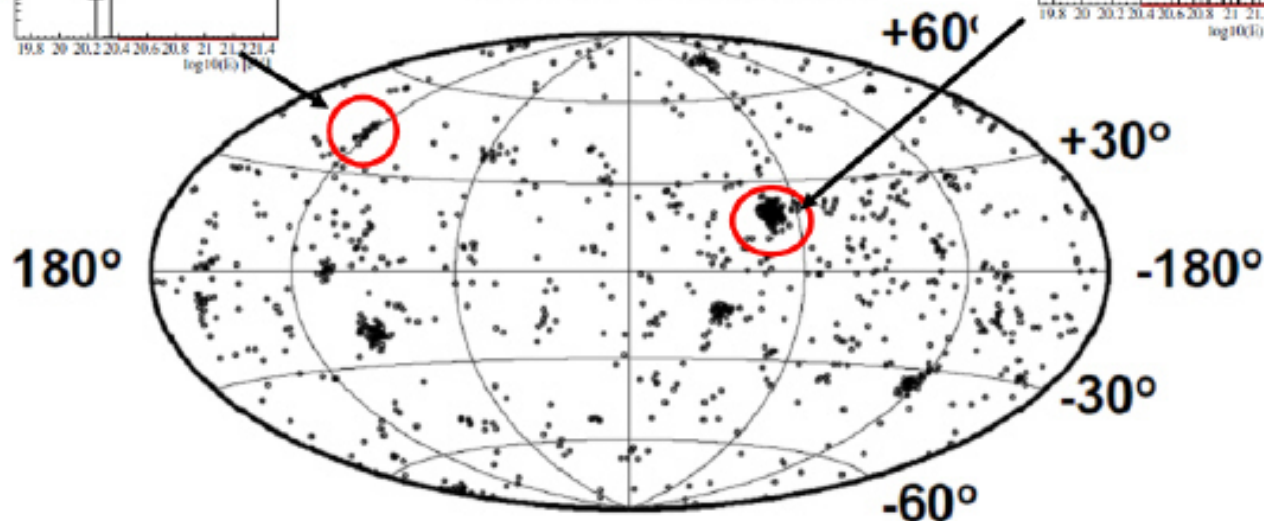
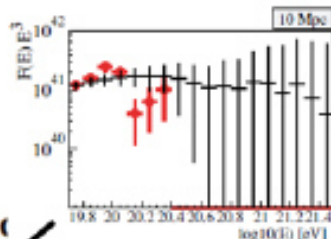
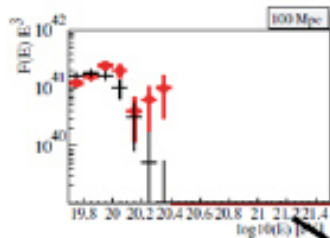


雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

極限粒子天文学

1,000事象の場合の予測

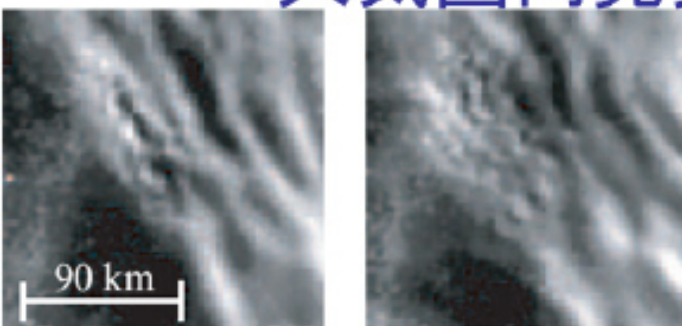
粒子光度 \propto X線光度 (AGN)



- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

Takami 2008

探求的試験研究3: 大気圏内発光現象の研究



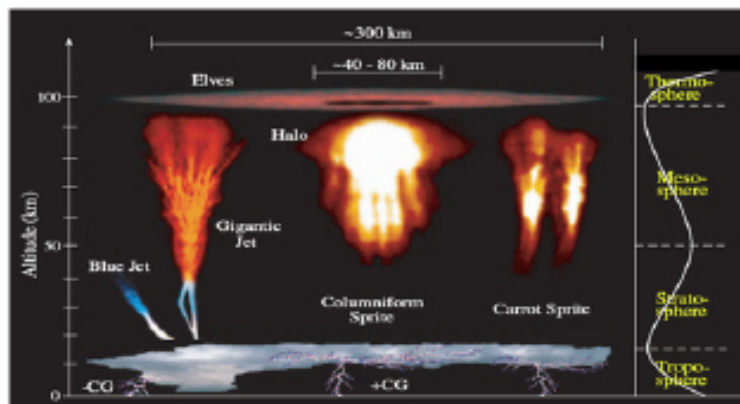
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



ハイビジョンカメラによる
2001年のしし座流星群

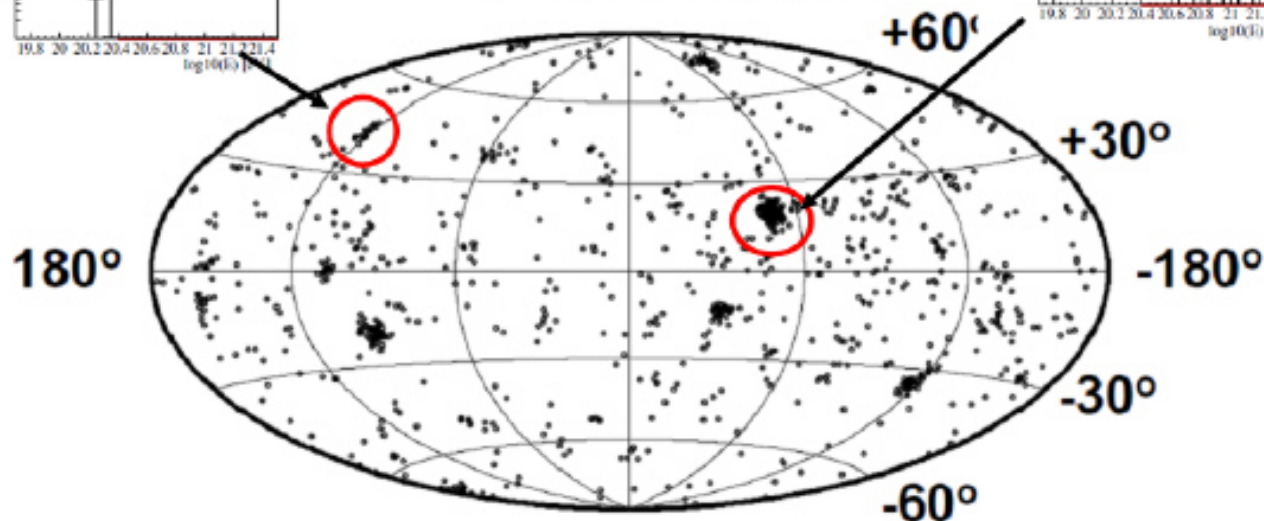
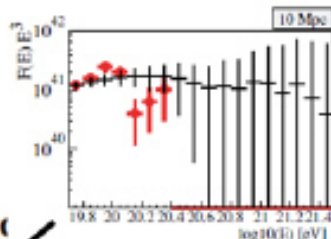
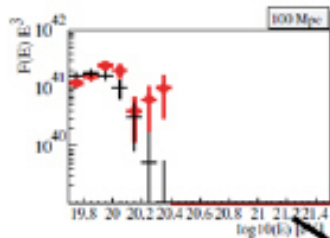


雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

極限粒子天文学

1,000事象の場合の予測

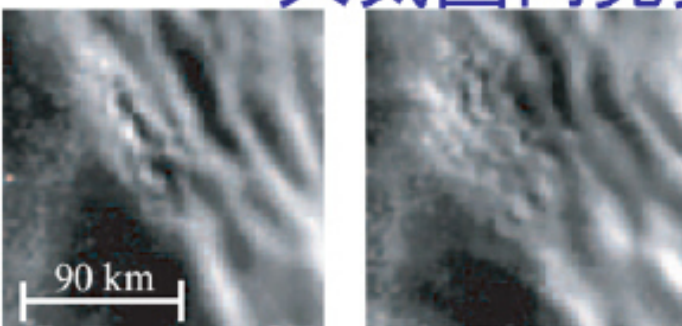
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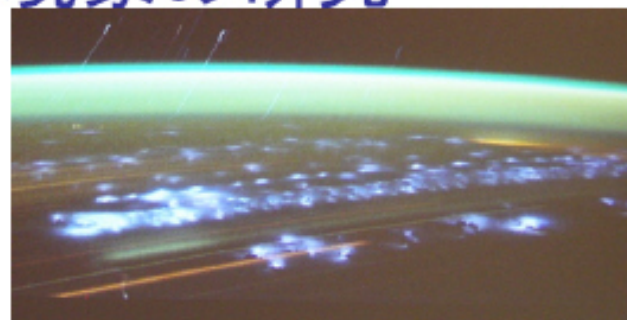
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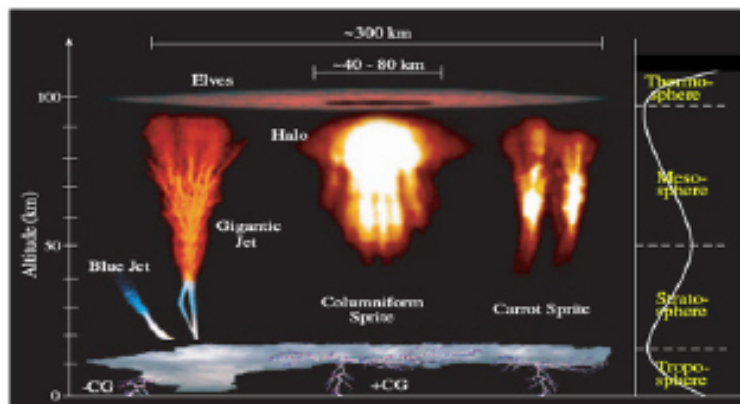
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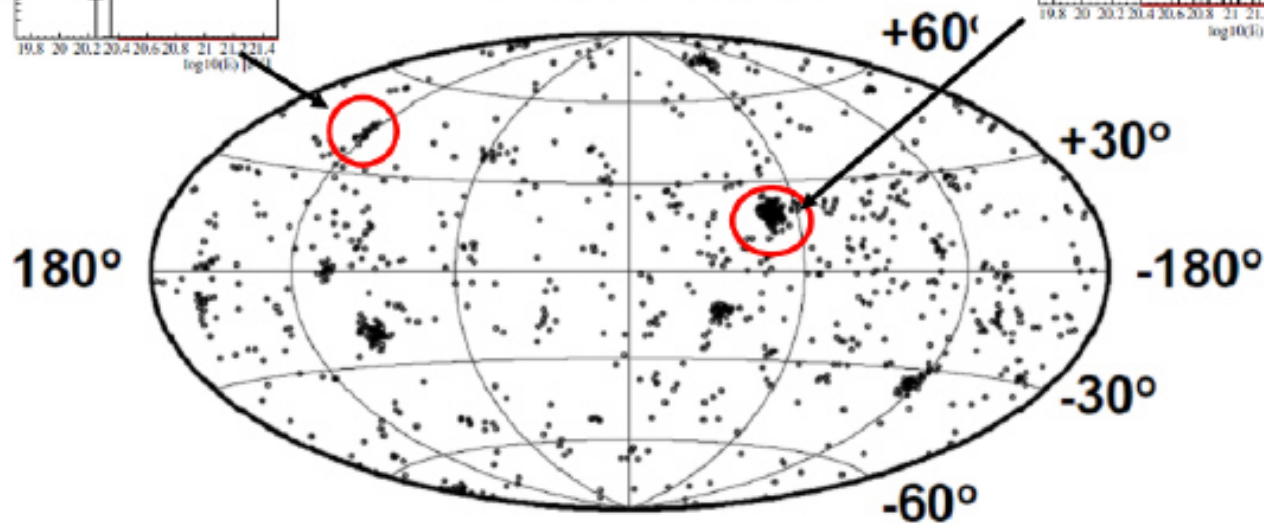
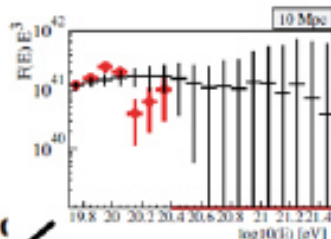
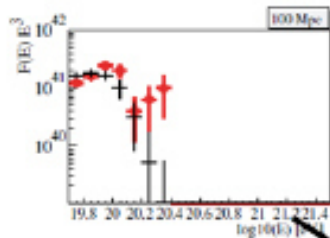


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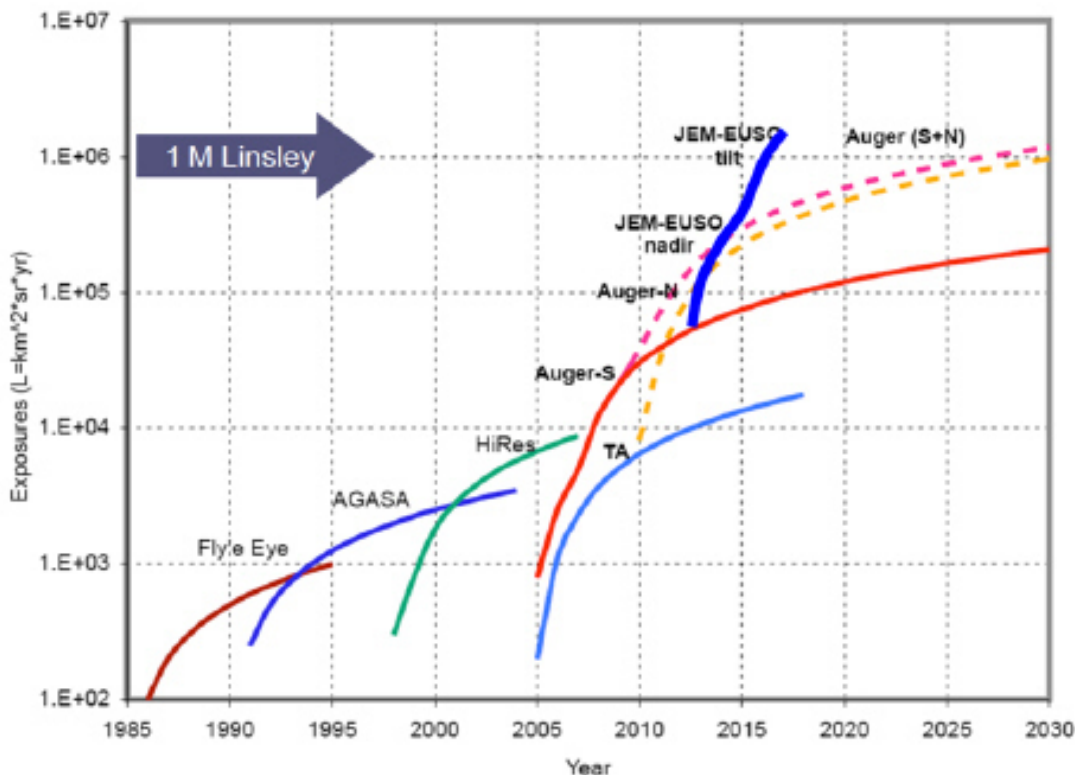
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Takami 2008

有効露出の増加期待値

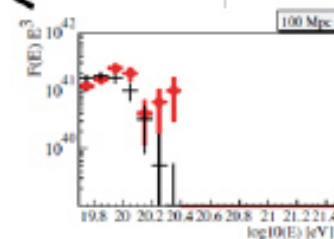
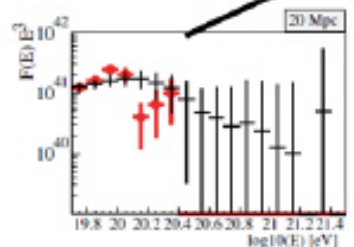
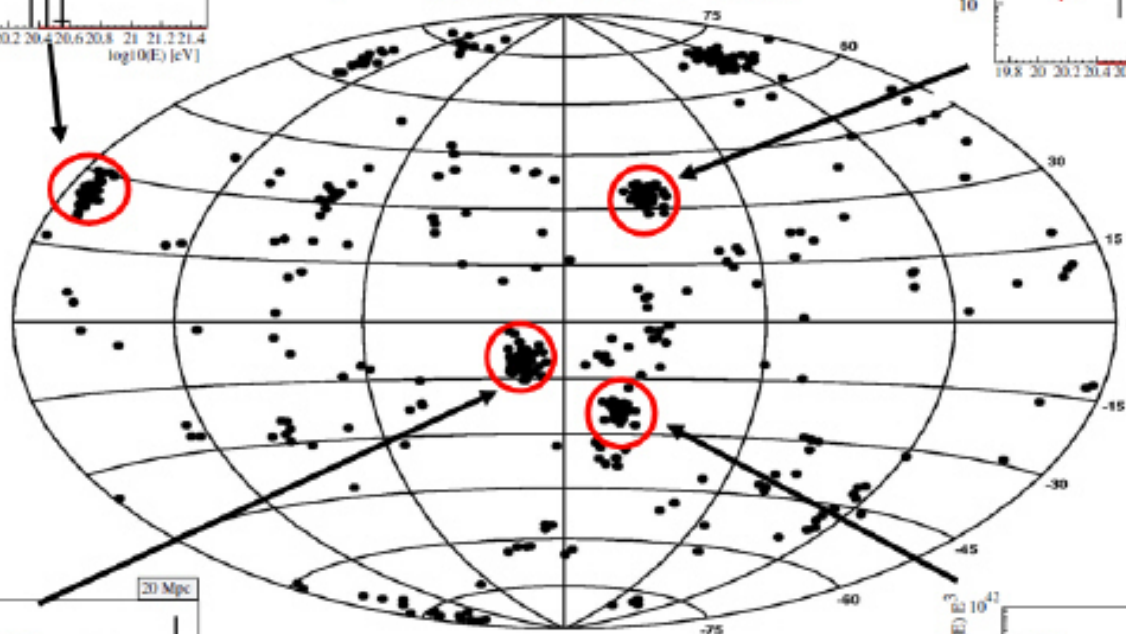
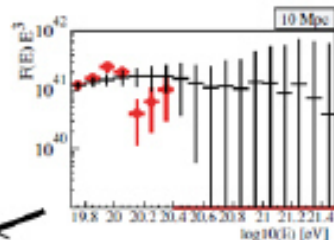
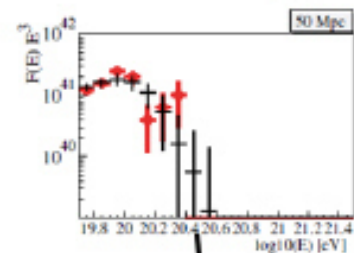


事例数：5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

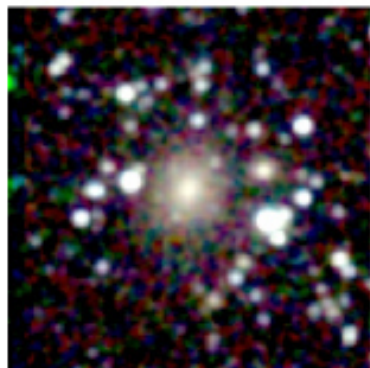
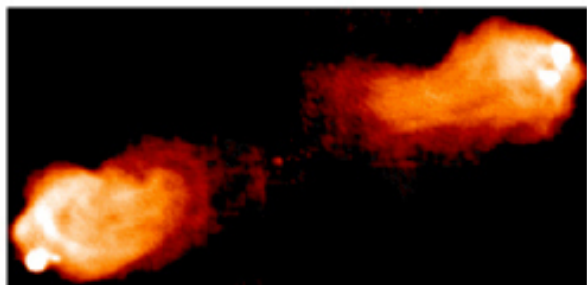
極限粒子天文学

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他の電波銀河

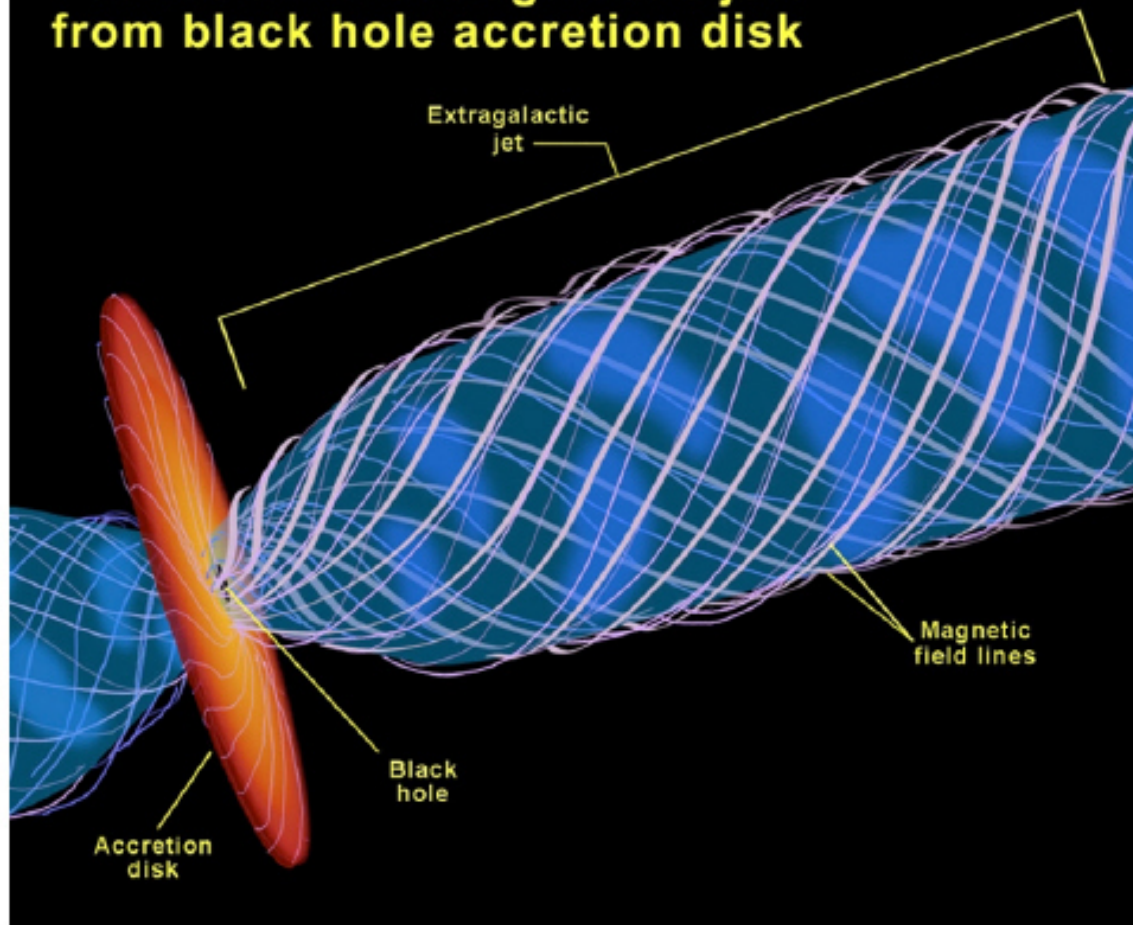


Fornax A

Cygnus A



Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



- 距離: 3.4Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度～電波光度
～ 2×10^{41} W

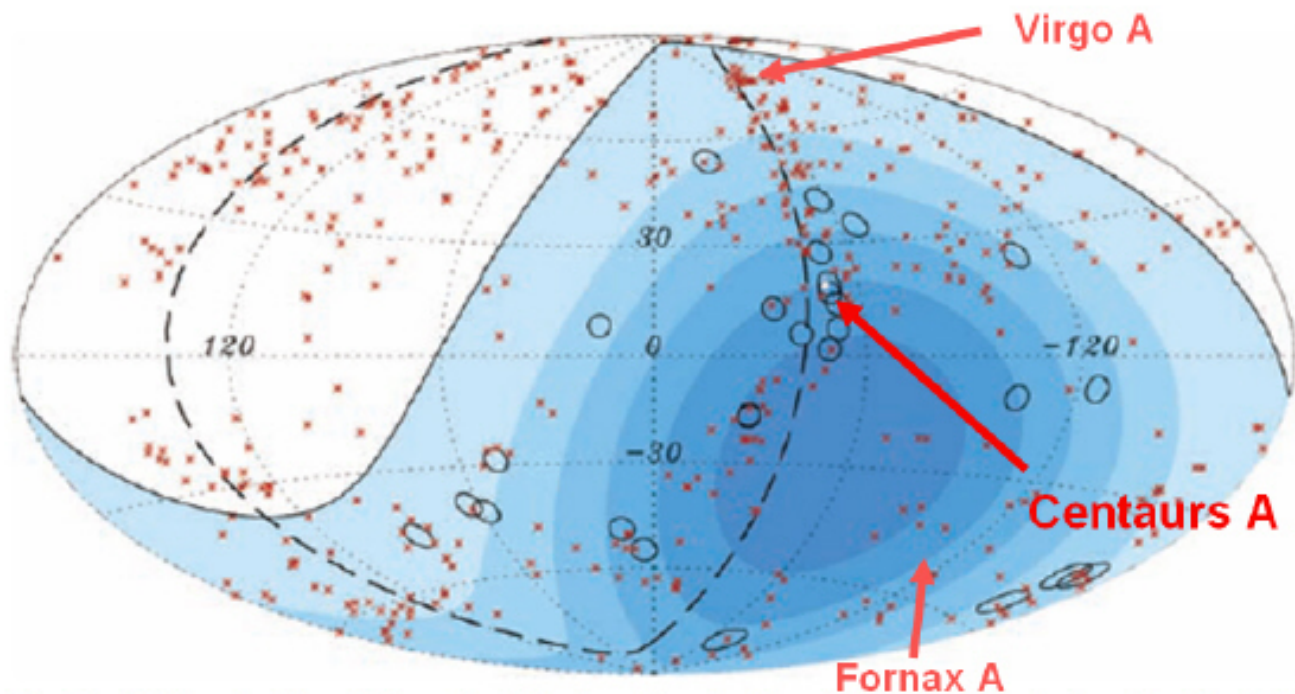
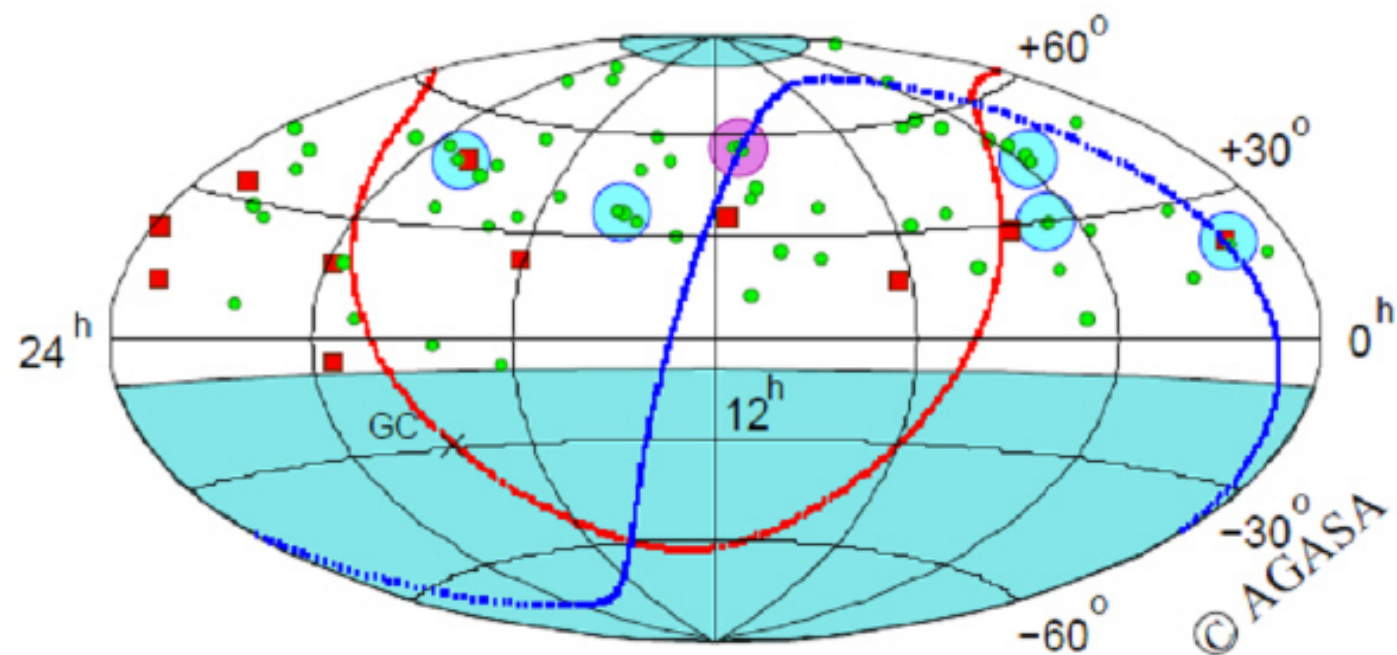
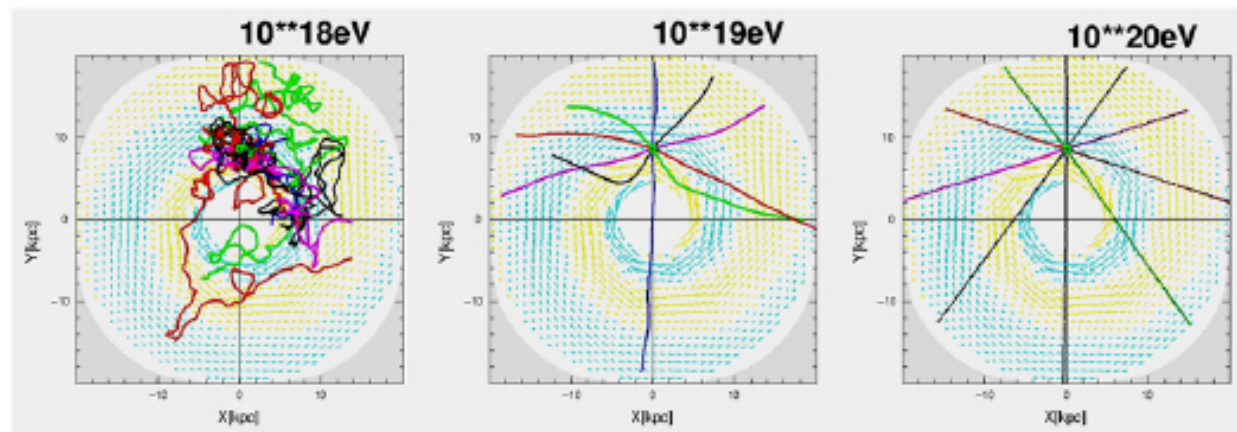


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

Arrival Directions (AGASA)



$E > 10^{20}$ eV 粒子は曲がらない



銀河内の伝播シミュレーション

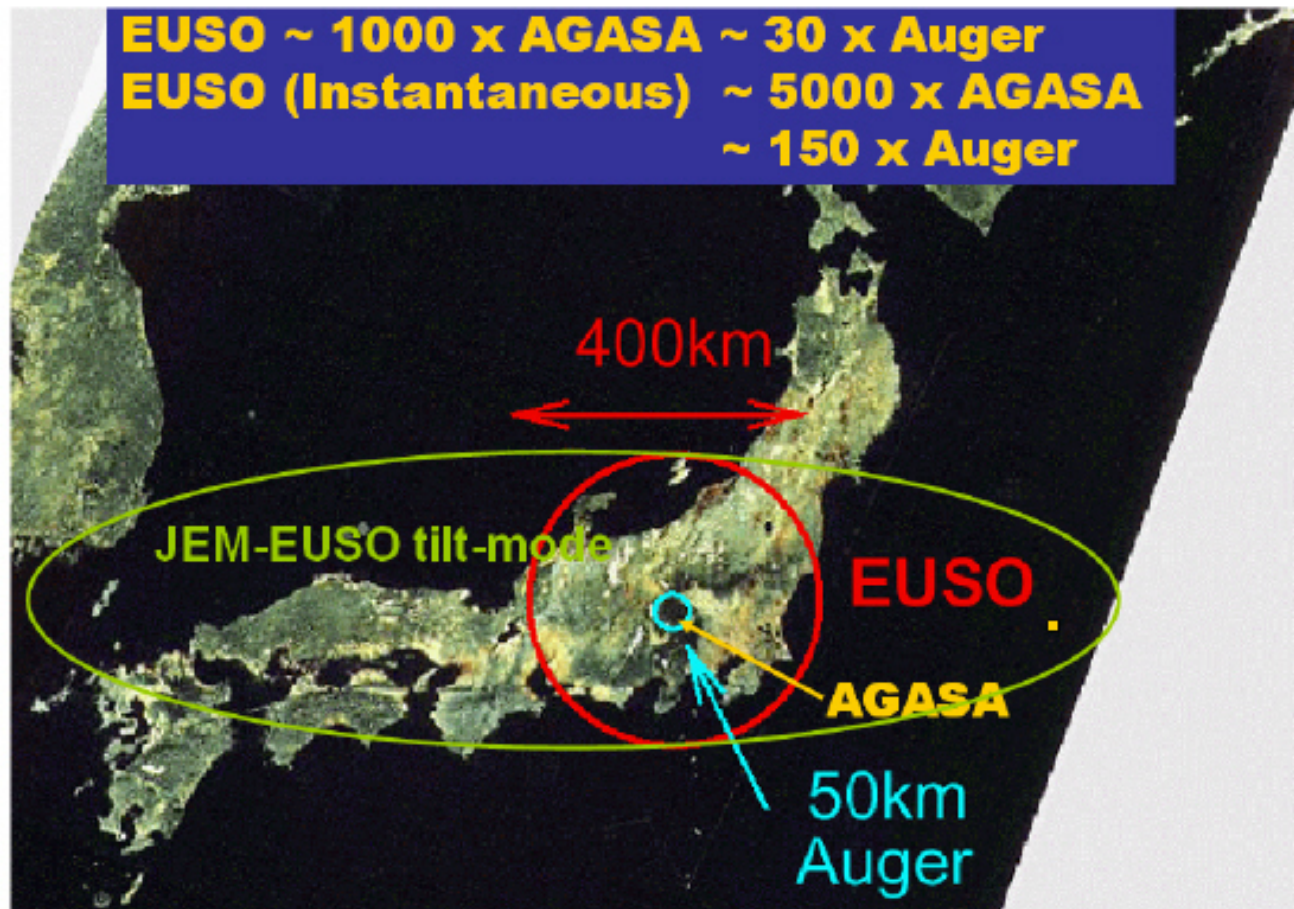
到来方向解析により起源天体を特定: 粒子天文学

科学目的

- 基本研究: 極限エネルギー—**粒子による新天文学**
 - 高統計到来方向解析による**起源天体**の同定
 - 個別天体からのエネルギースペクトル測定による**加速・放射機構**の検証
- 探求的試験研究
 - 極限エネルギー—**宇宙ガンマ線**の測定
 - 極限エネルギー—**宇宙ニュートリノ**の検出
 - **銀河磁場**の構造と強度の推定
 - **相対論、量子重力**効果の検証
 - **大気圏**発光現象の研究

EUSOの巨大な視野

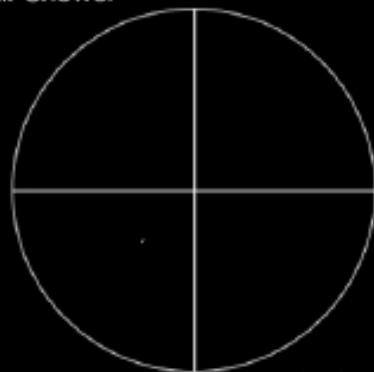
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



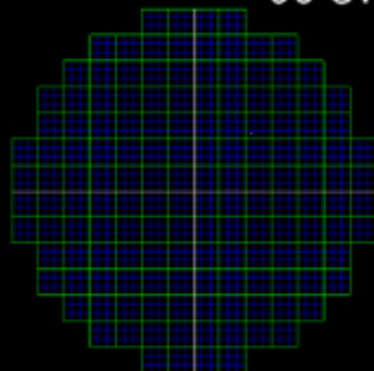


JEM-EUSOで見る空気シャワー

Air Shower

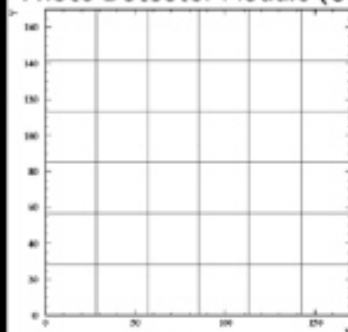


00 GTU

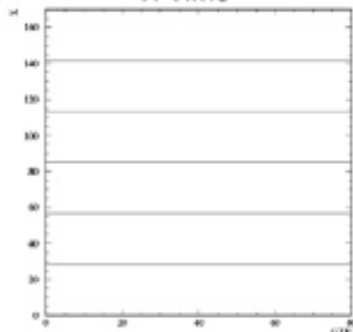


EUSO Focal Surface

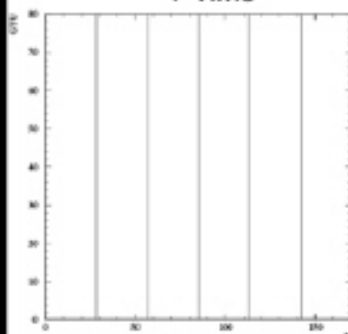
Photo Detector Module (3,3)



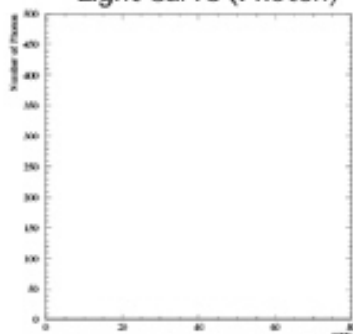
X-Time



Y-Time

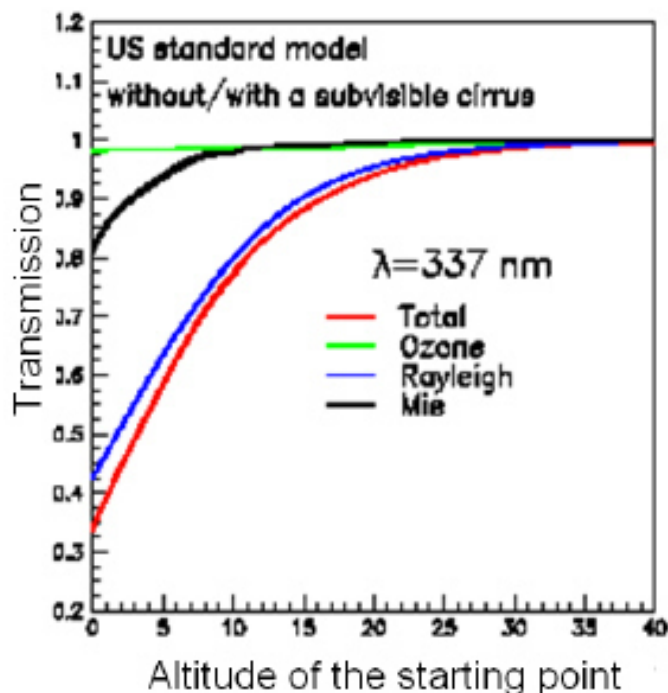


Light Curve (Photon)



宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)



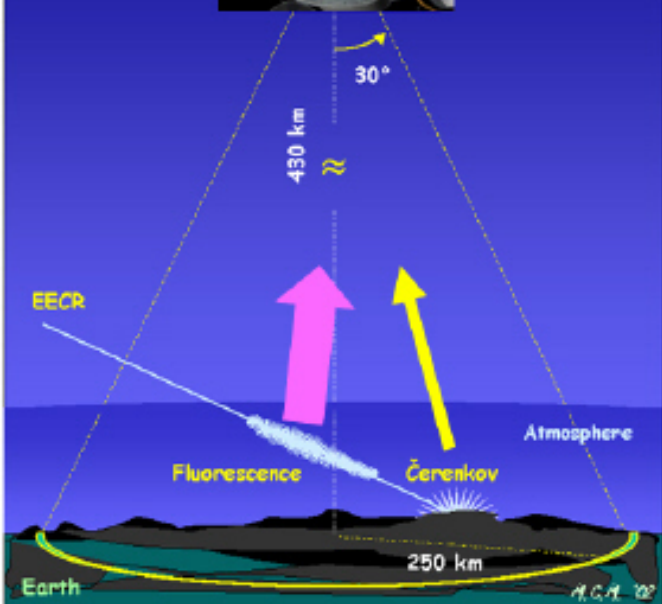
EUSOの観測方法



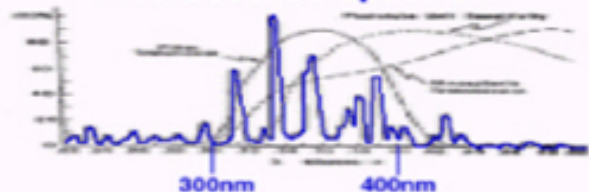
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

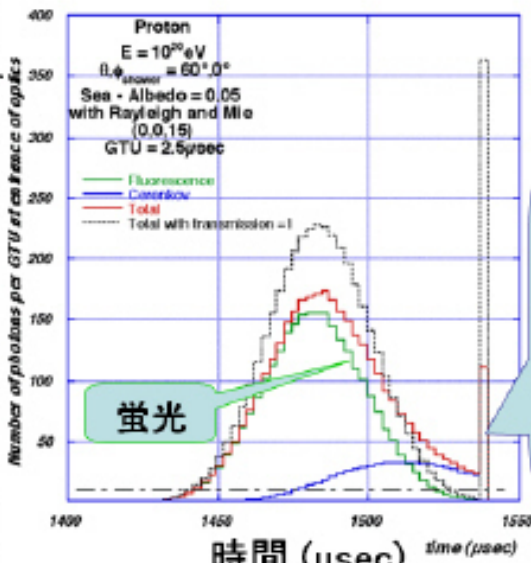
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



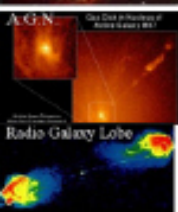
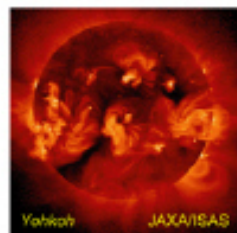
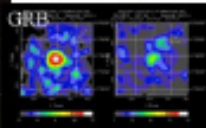
光学系入口径での光子数 (/2.5μsec)



チェレンコフ光

蛍光

地を見て天を知る天文台=地文台 JEM-EUSO



極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

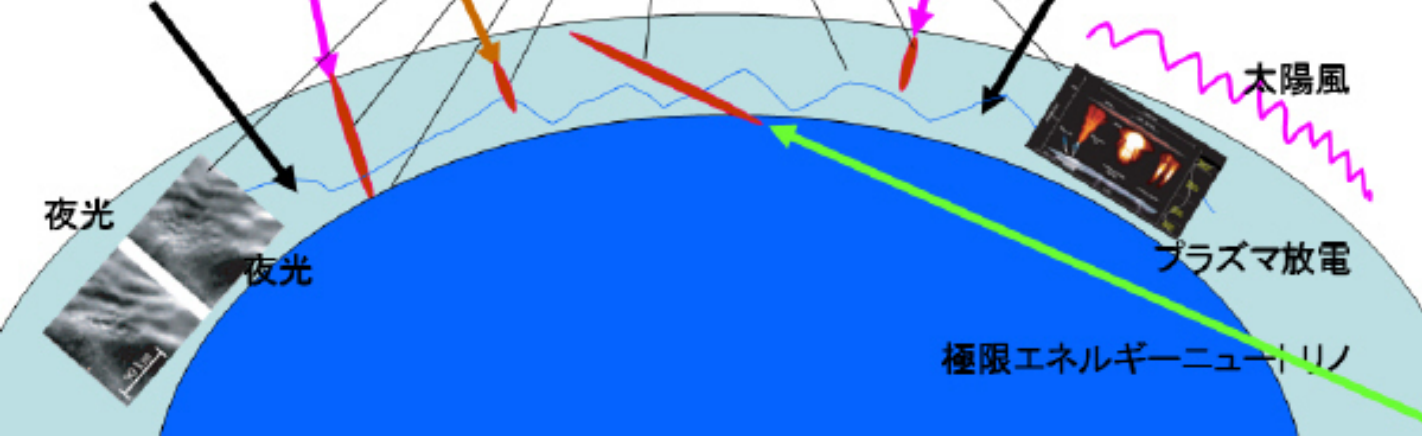
太陽風

夜光

夜光

プラズマ放電

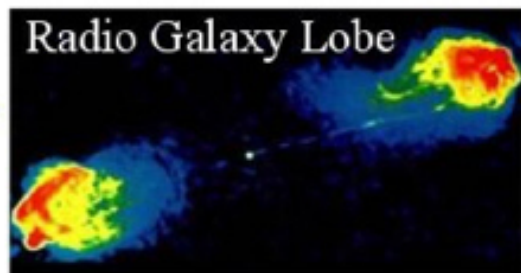
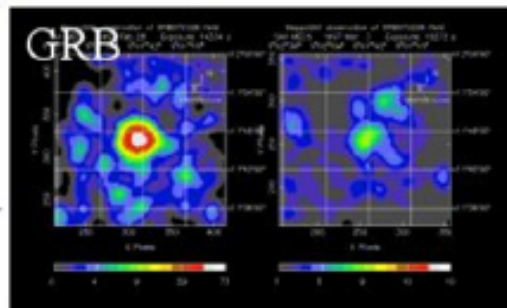
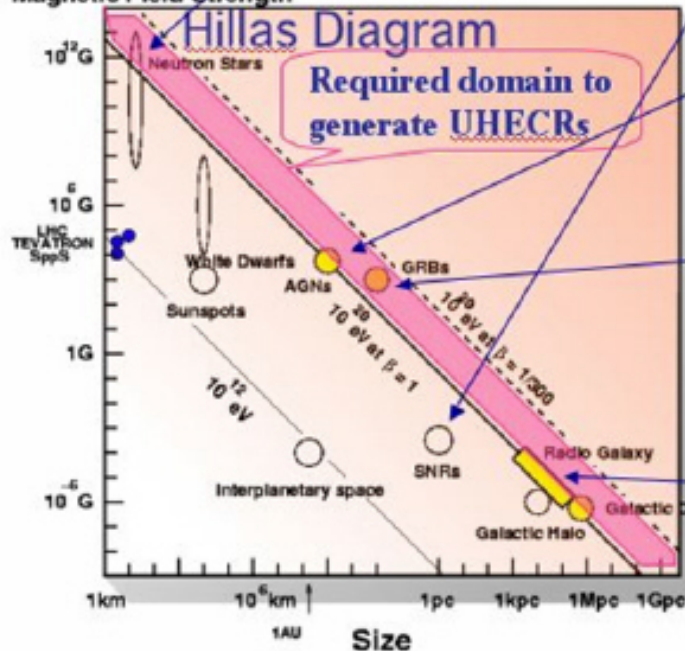
極限エネルギーニュートリノ



ヒラス 理論的加速限界 $< 10^{20}$ eV

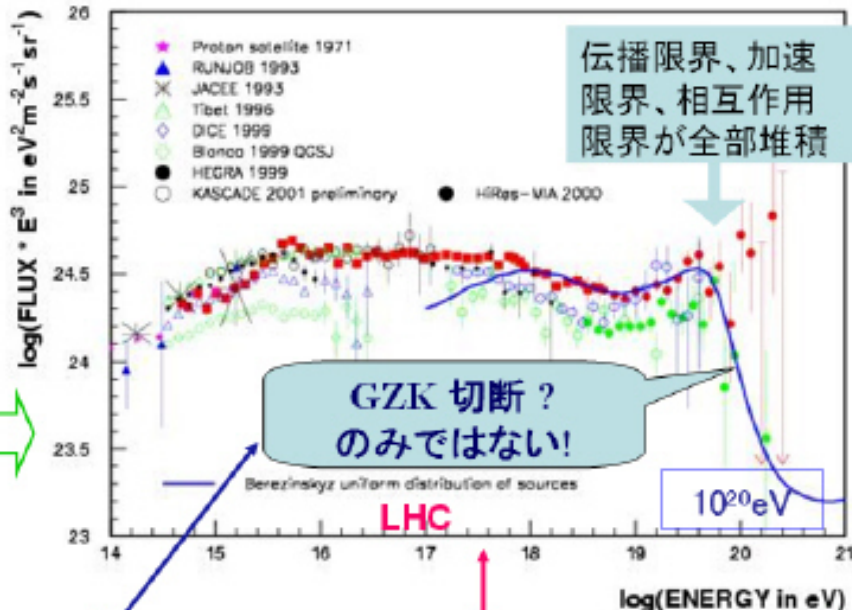
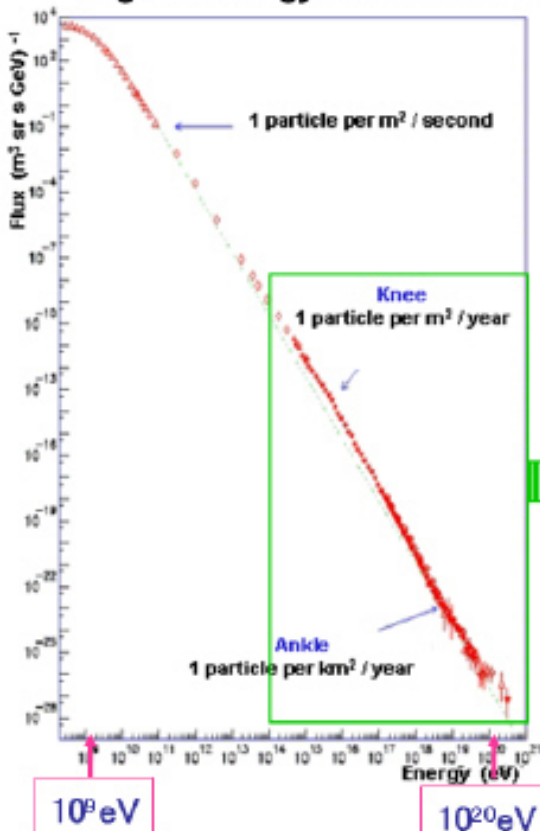


Magnetic Field Strength



Status and the challenges of the highest-energy Universe by observing cosmic rays

- LHC explores HIGGS, SUSY DM $< 7 \text{ TeV}/c^2 (\leq 10^{17} \text{ eV})$ from Dec 2007
- Highest energy CR: Unknown for origin, acceleration; physics unknown at $> 300 \text{ TeV}/c^2$



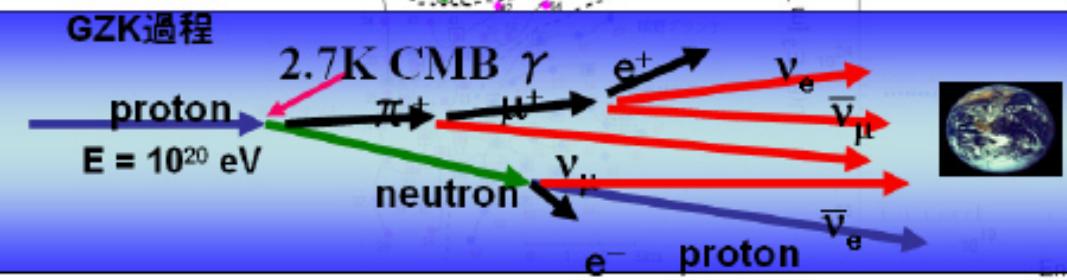
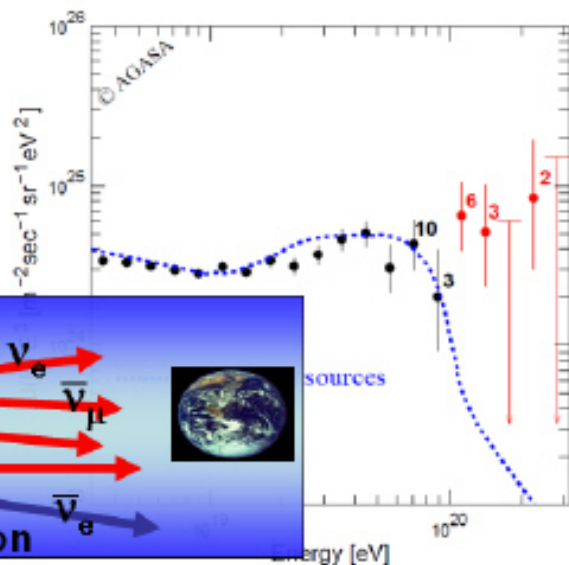
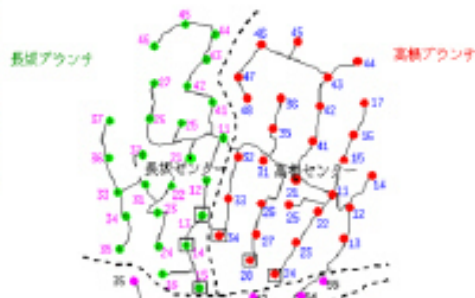
$$p + \gamma_{2.7\text{K}} \rightarrow e^+ e^- + p \text{ above LHC } 5 \cdot 10^{17} \text{ eV}$$

$$p + \gamma_{2.7\text{K}} \rightarrow \Delta^+ \rightarrow n + \pi^+, p + \pi^0$$



AGASA

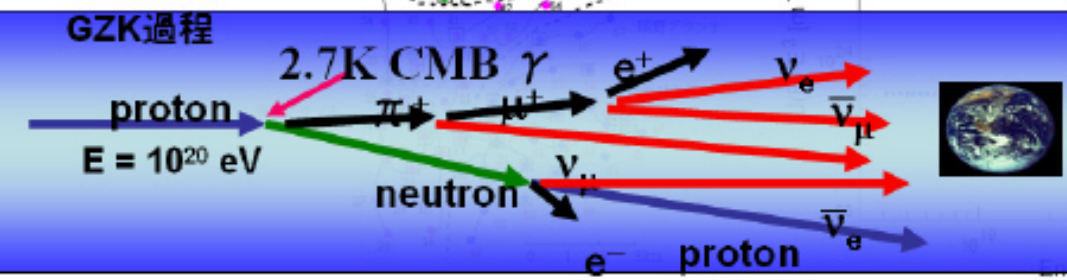
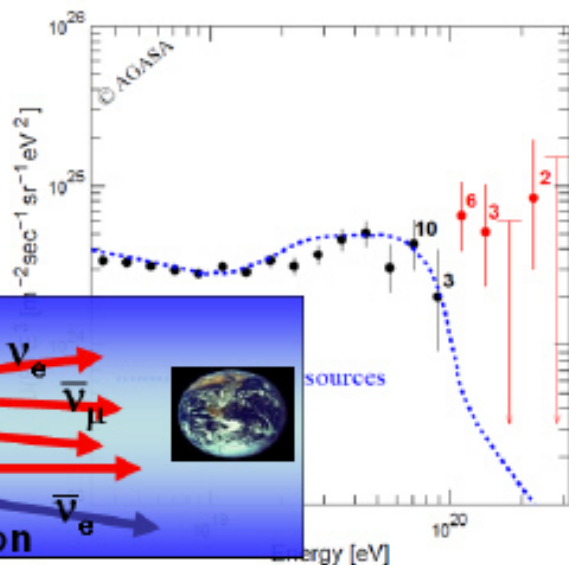
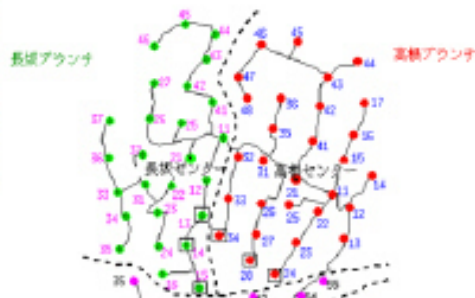
- 地域全体を検出器とした。
- 全体で約100km²
- 13年で11個の超10²⁰eV事象





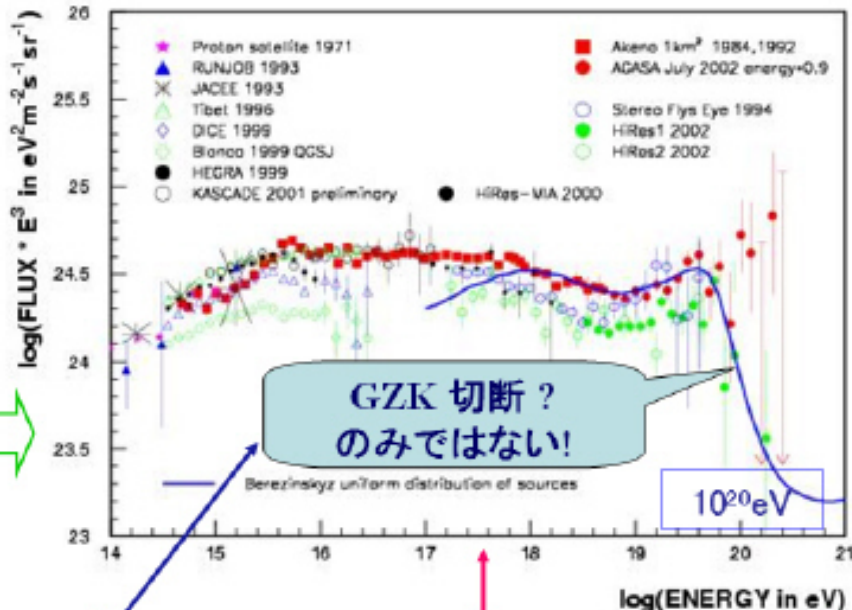
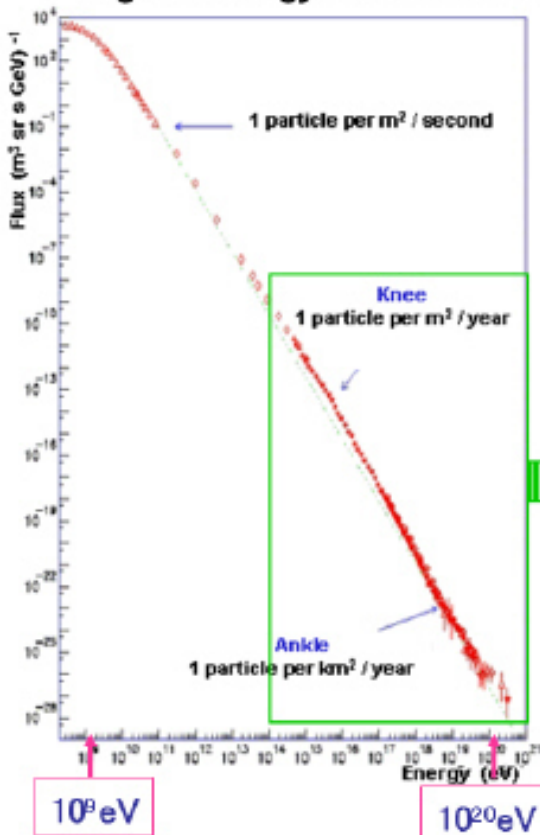
AGASA

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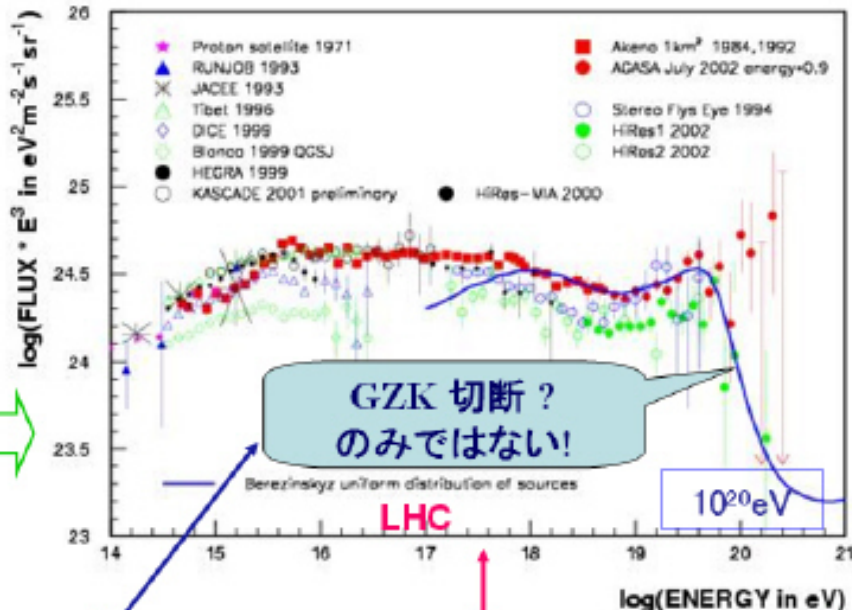
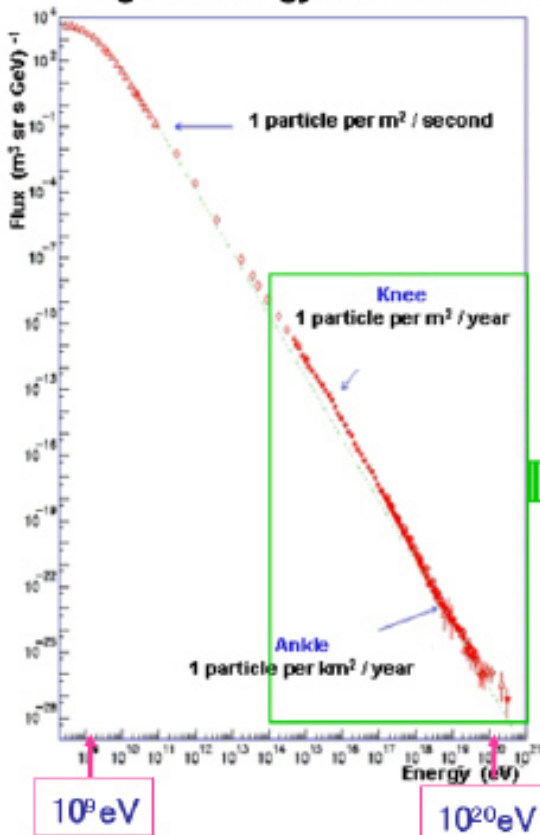


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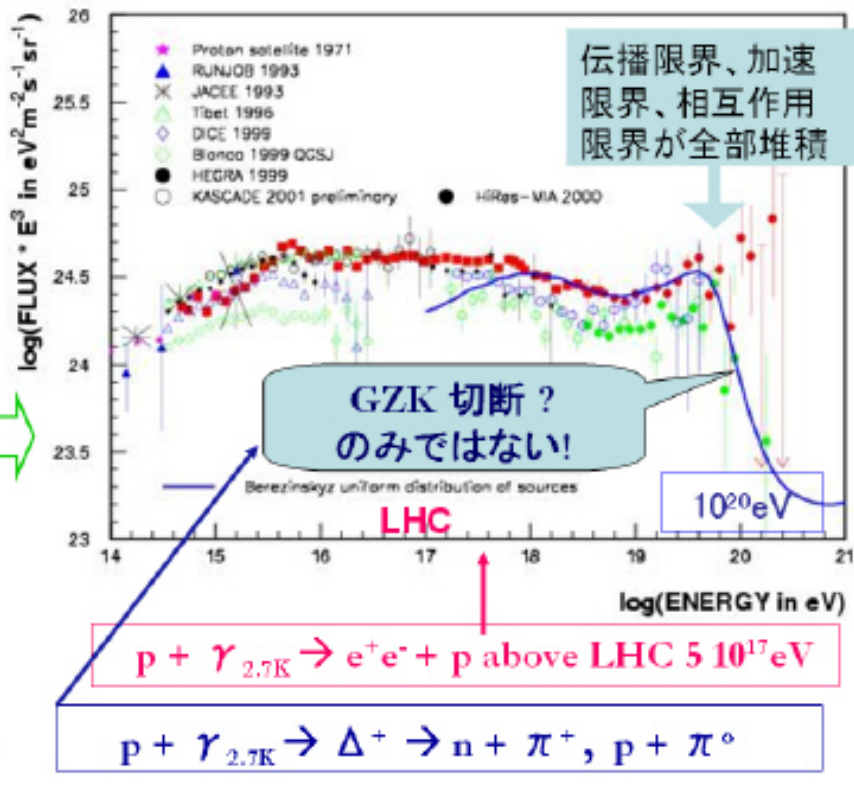
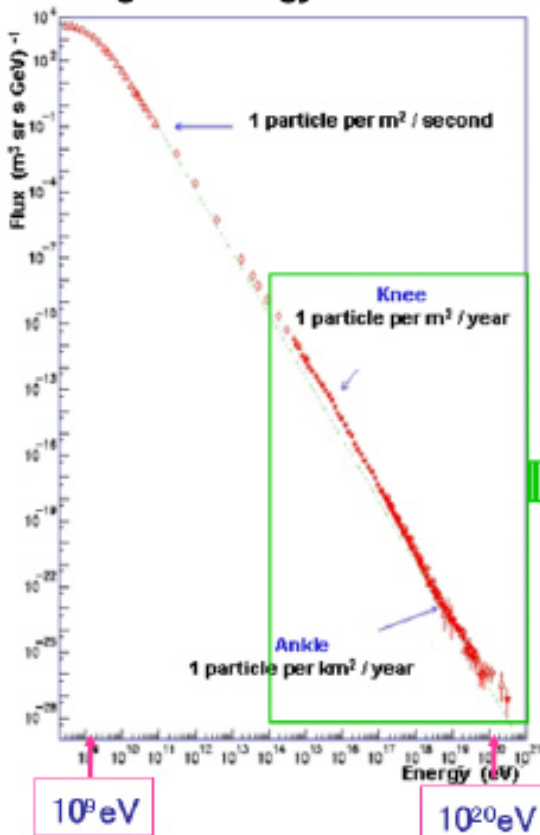


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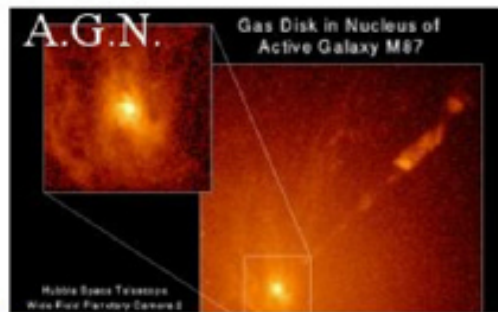
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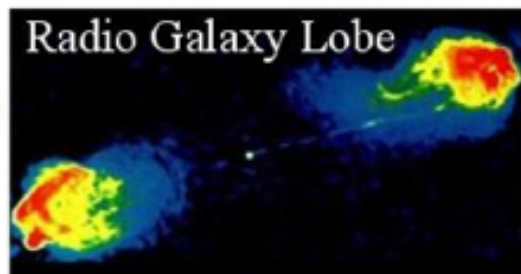
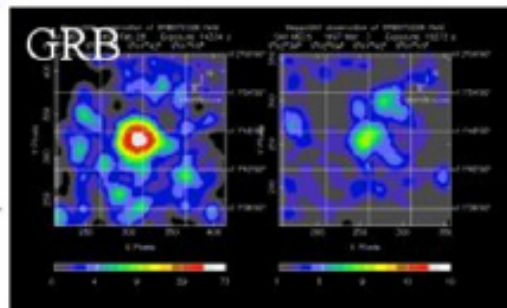
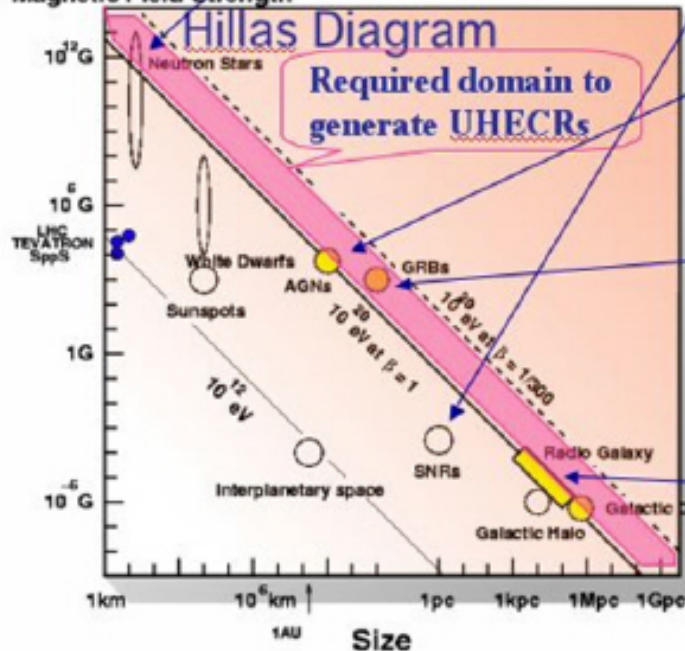
- LHC explores HIGGS, SUSY DM $< 7 \text{ TeV}/c^2 (\leq 10^{17} \text{ eV})$ from Dec 2007
- Highest energy CR: Unknown for origin, acceleration; physics unknown at $> 300 \text{ TeV}/c^2$



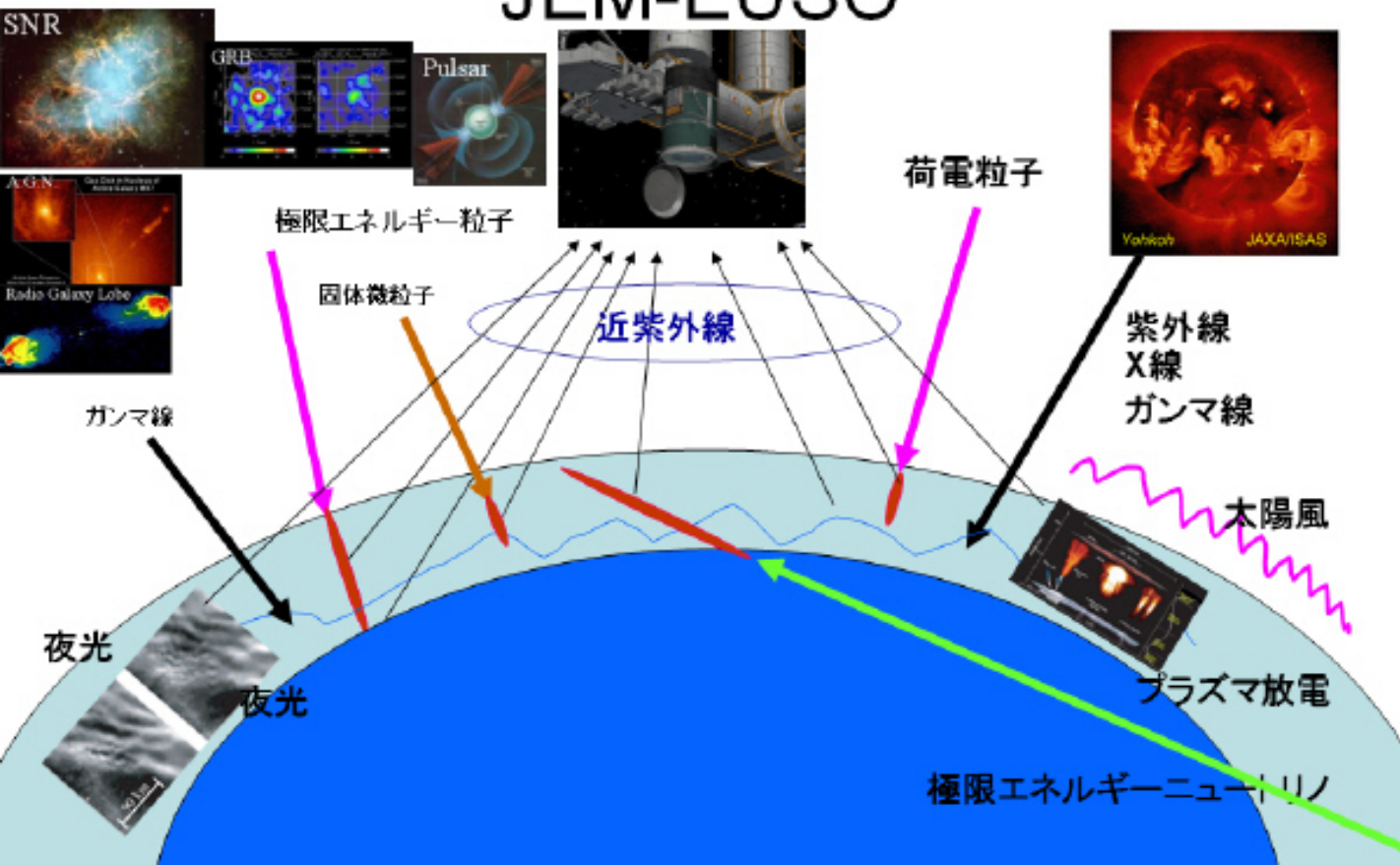
ヒラス 理論的加速限界 10^{20} eV



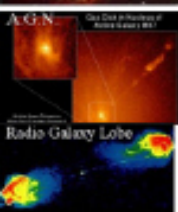
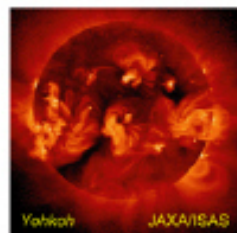
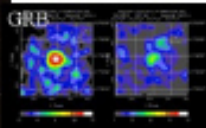
Magnetic Field Strength



地を見て天を知る天文台=地文台 JEM-EUSO



地を見て天を知る天文台=地文台 JEM-EUSO



極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

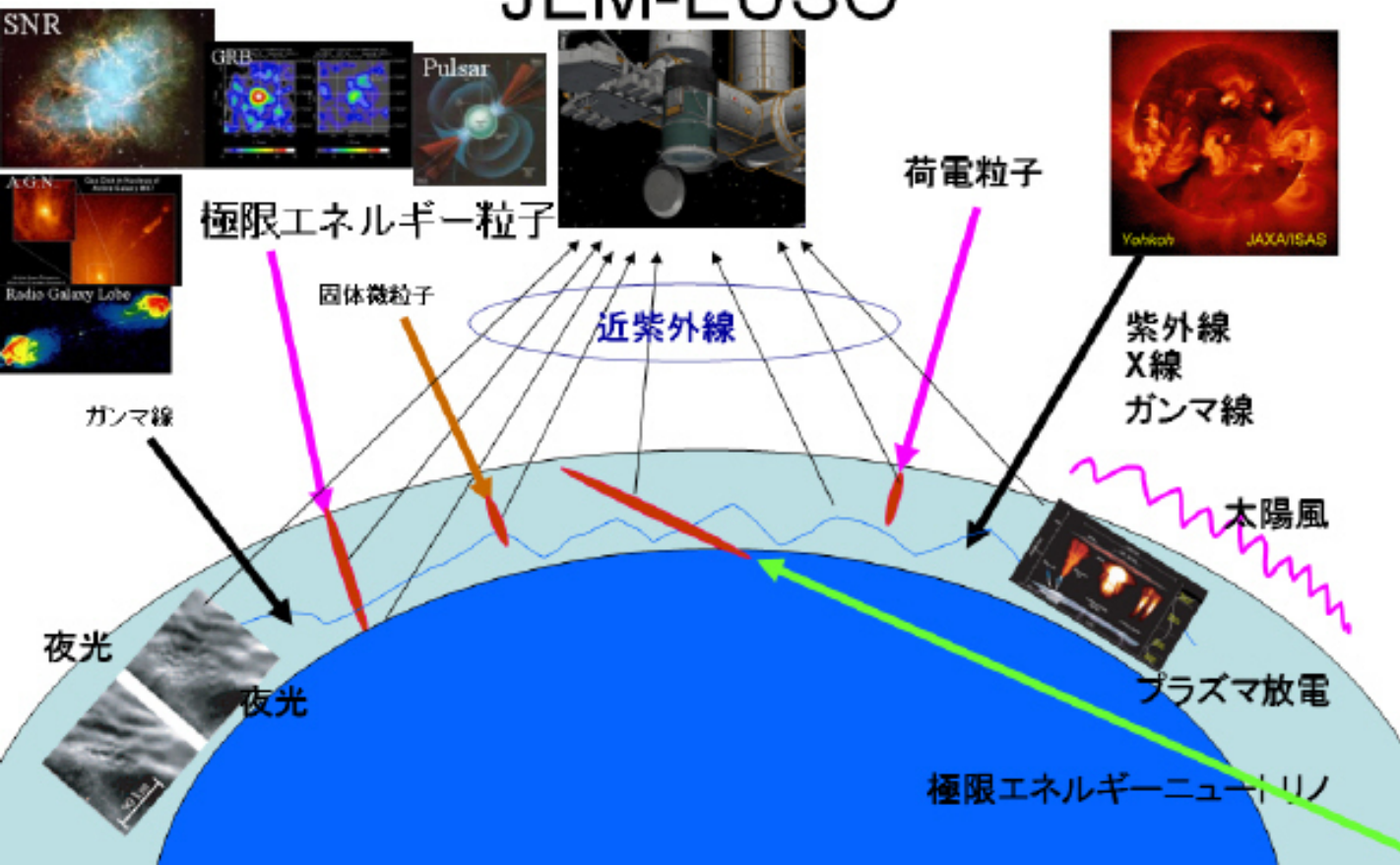
太陽風

夜光

夜光

プラズマ放電

極限エネルギーニュートリノ



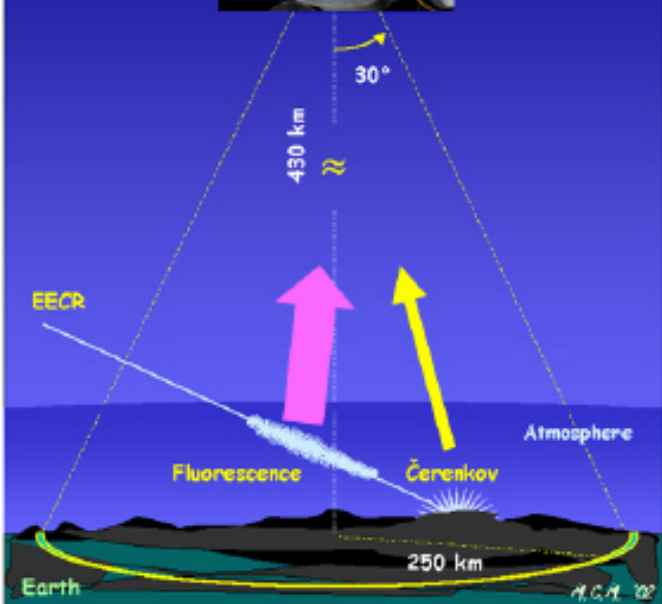
EUSOの観測方法



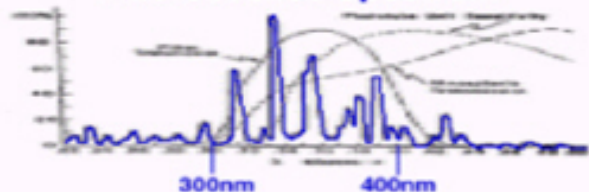
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

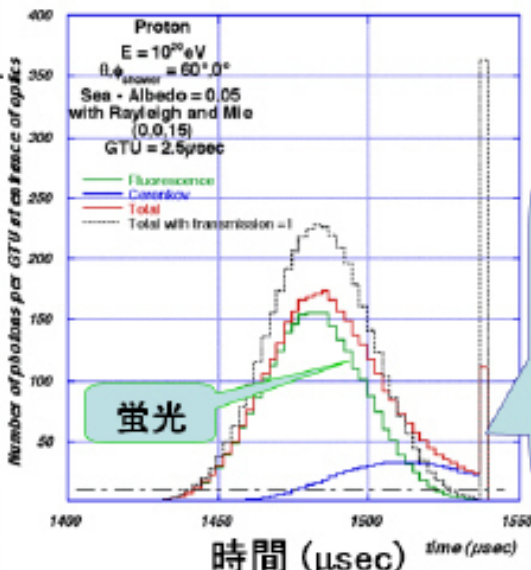
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



光学系入口径での光子数 (/2.5μsec)

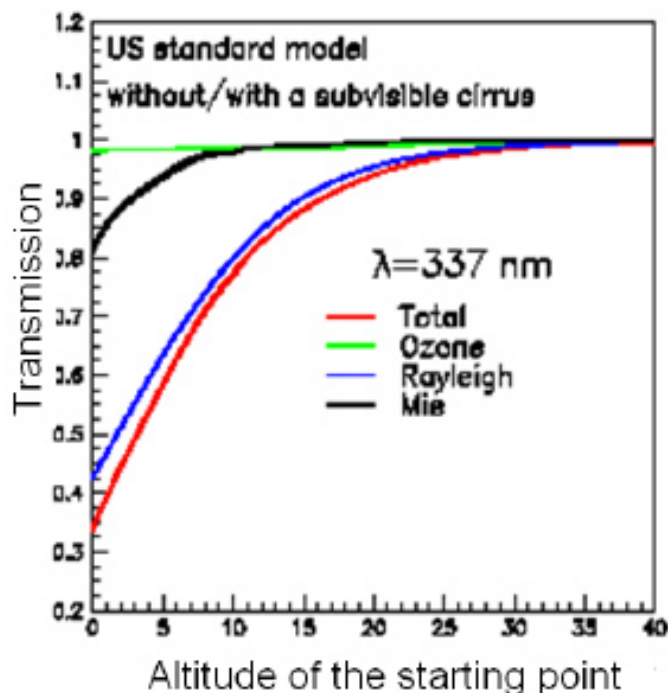


蛍光

チェレンコフ光

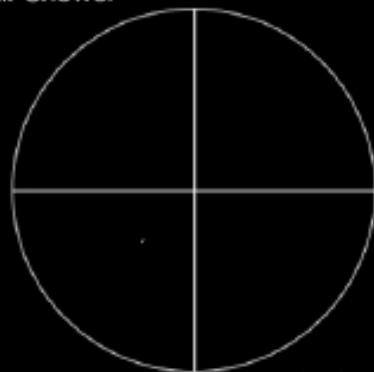
宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)

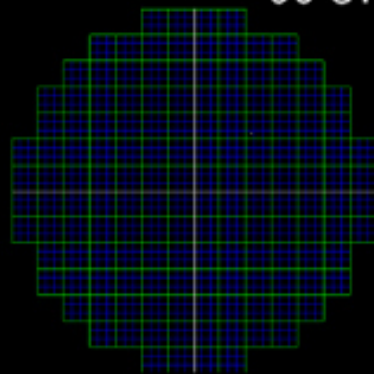


JEM-EUSOで見る空気シャワー

Air Shower

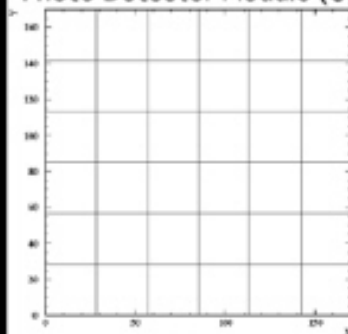


00 GTU

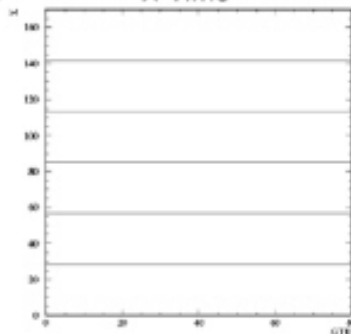


EUSO Focal Surface

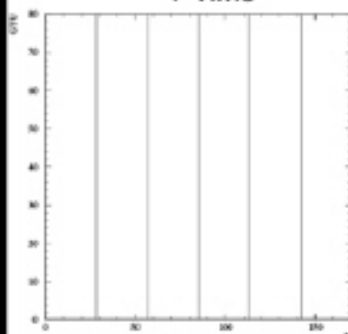
Photo Detector Module (3,3)



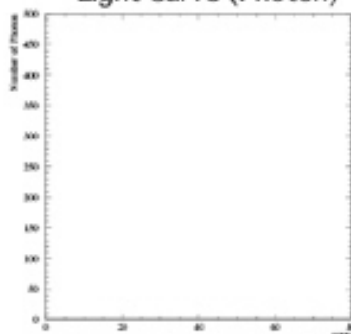
X-Time



Y-Time

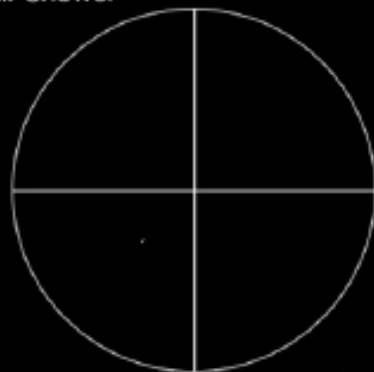


Light Curve (Photon)

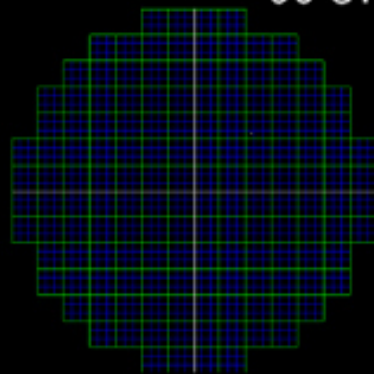


JEM-EUSOで見る空気シャワー

Air Shower

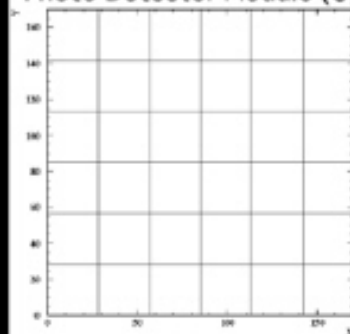


00 GTU

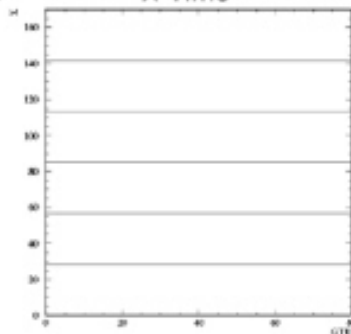


EUSO Focal Surface

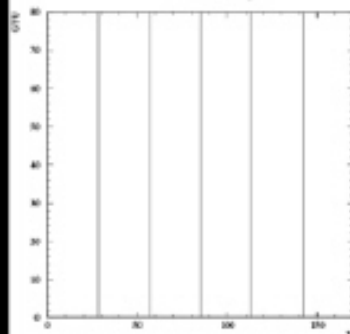
Photo Detector Module (3,3)



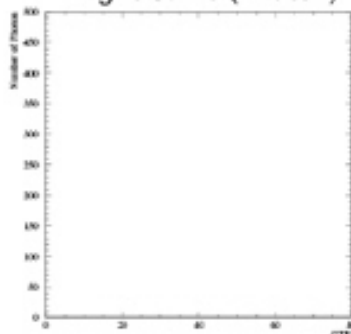
X-Time



Y-Time



Light Curve (Photon)

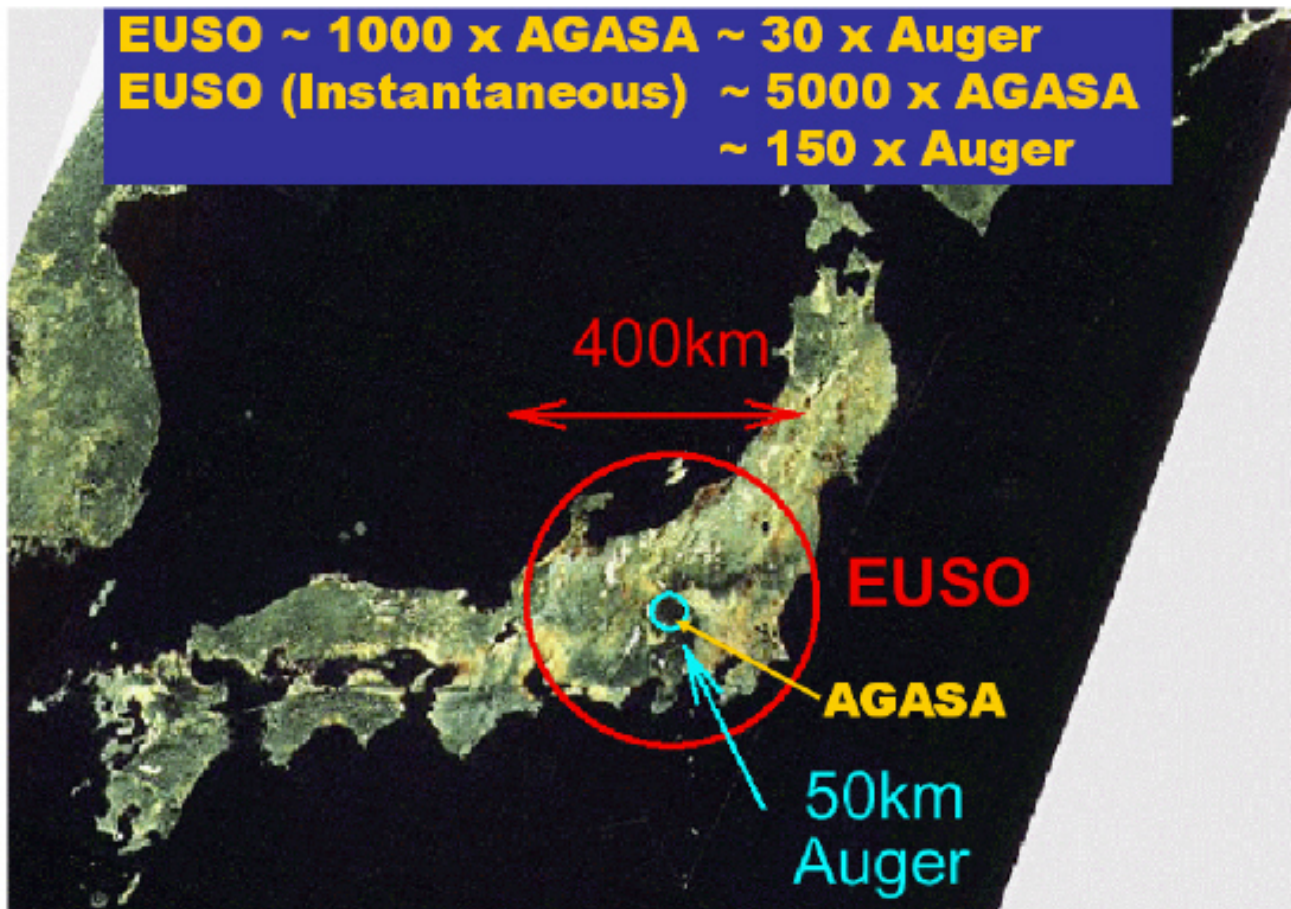






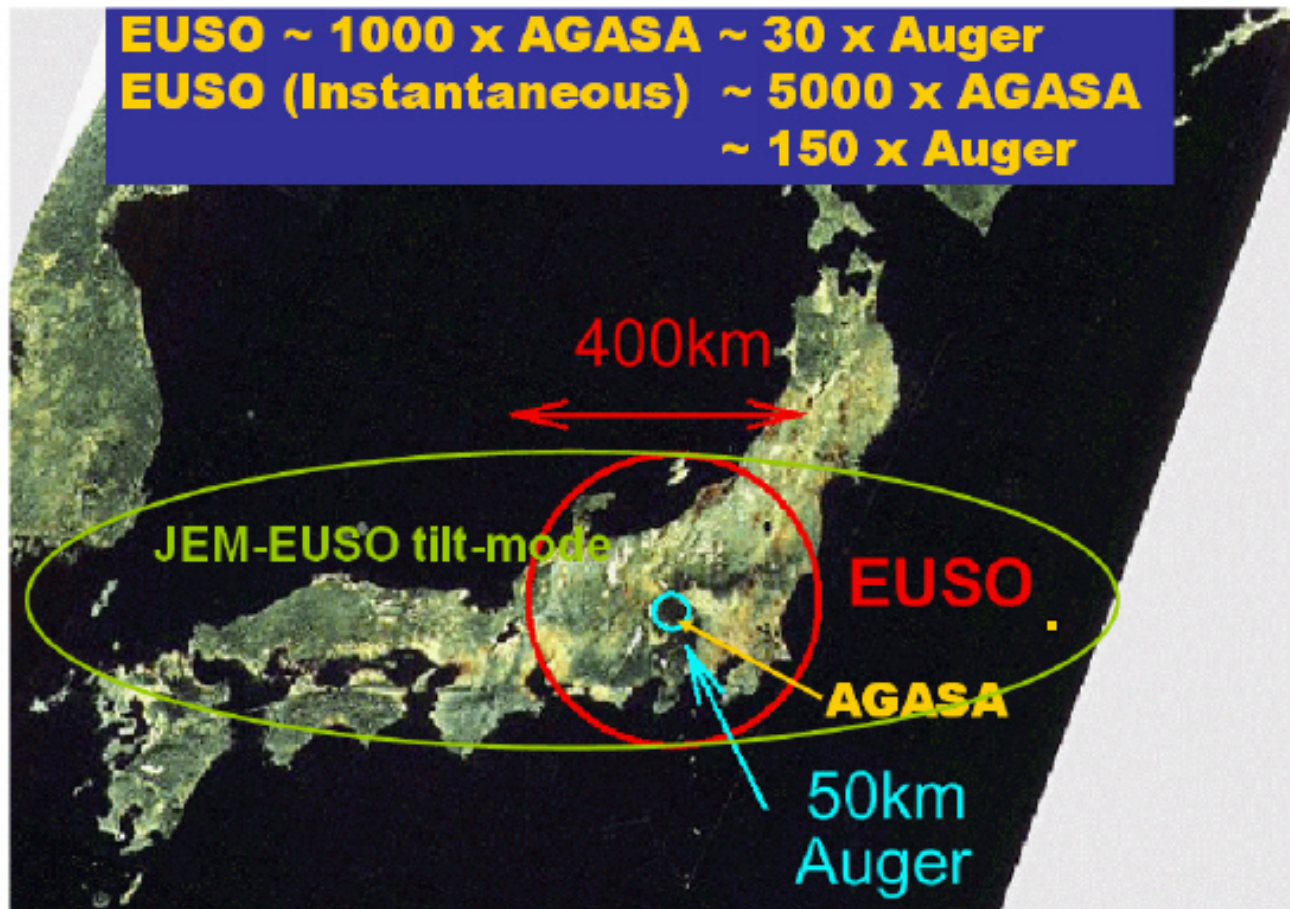
EUSOの巨大な視野

EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



EUSOの巨大な視野

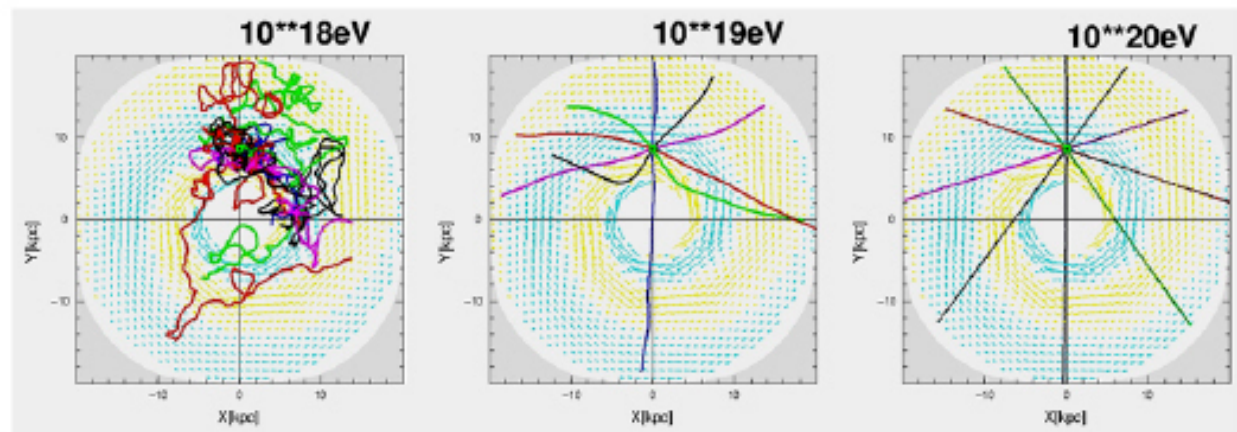
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



科学目的

- 基本研究: 極限エネルギー—**粒子による新天文学**
 - 高統計到来方向解析による**起源天体**の同定
 - 個別天体からのエネルギースペクトル測定による**加速・放射機構**の検証
- 探求的試験研究
 - 極限エネルギー—**宇宙ガンマ線**の測定
 - 極限エネルギー—**宇宙ニュートリノ**の検出
 - **銀河磁場**の構造と強度の推定
 - **相対論、量子重力**効果の検証
 - **大気圏**発光現象の研究

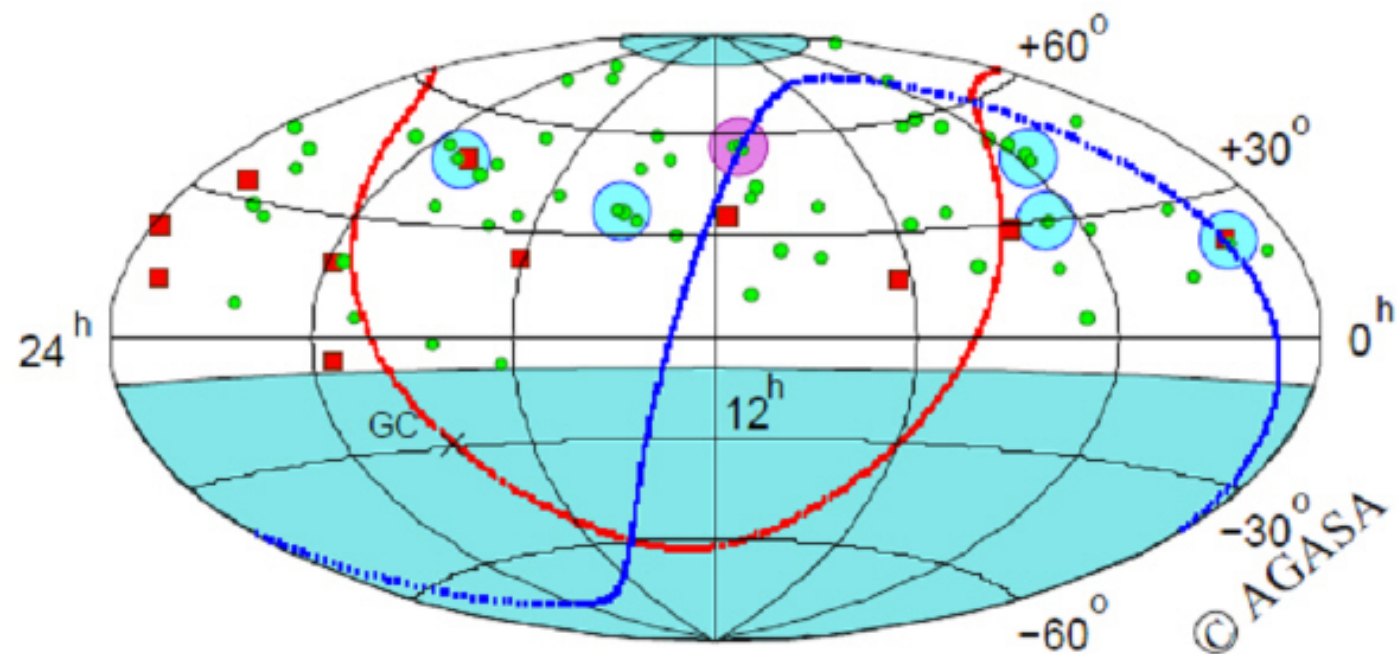
$E > 10^{20}$ eV 粒子は曲がらない



銀河内の伝播シミュレーション

到来方向解析により起源天体を特定: 粒子天文学

Arrival Directions (AGASA)



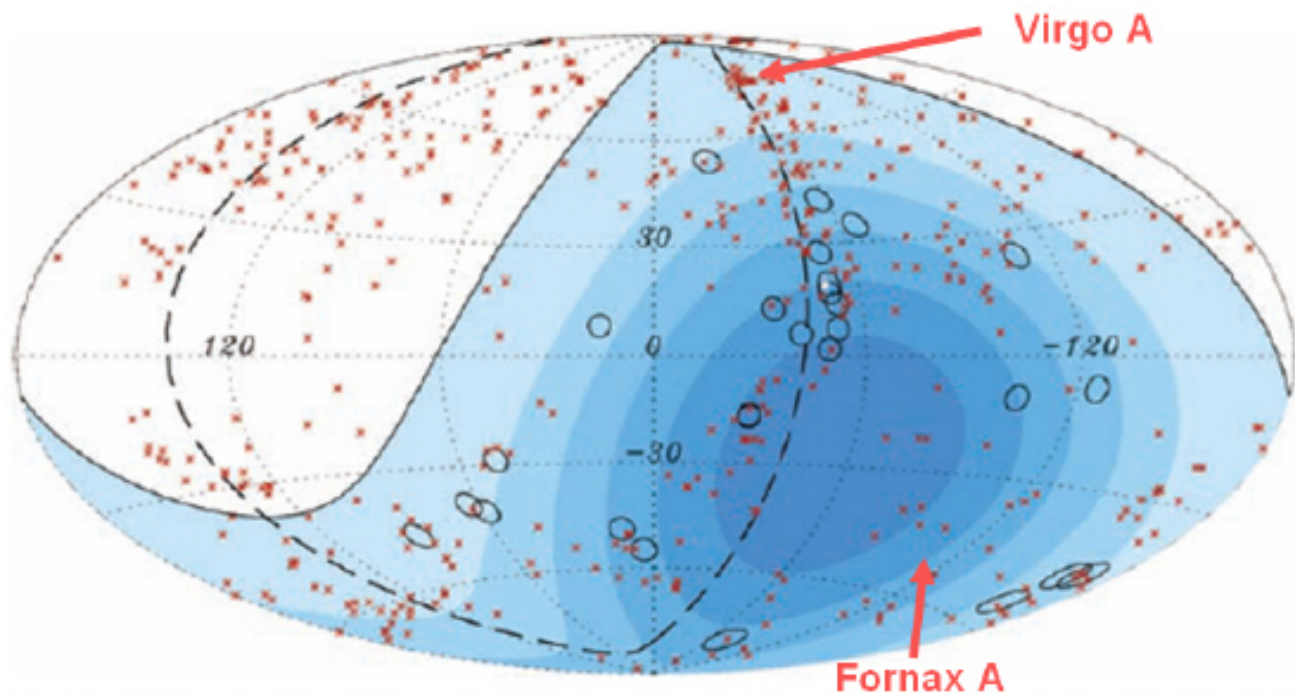


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

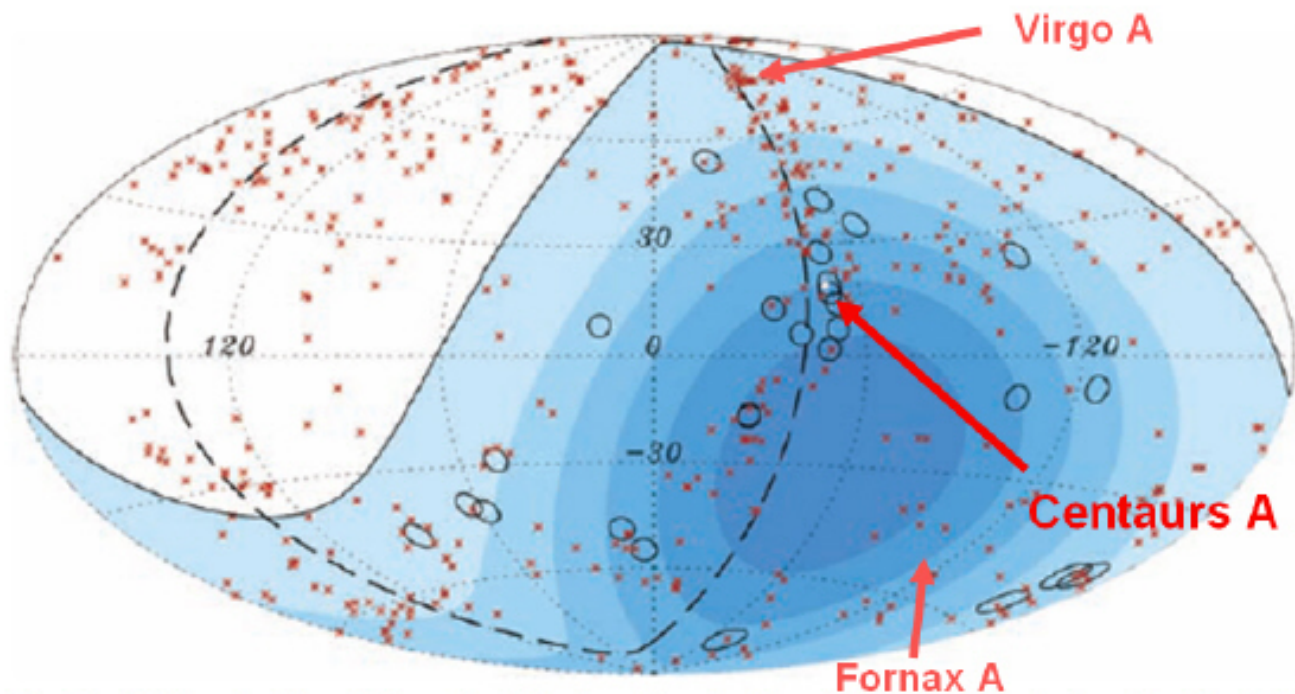


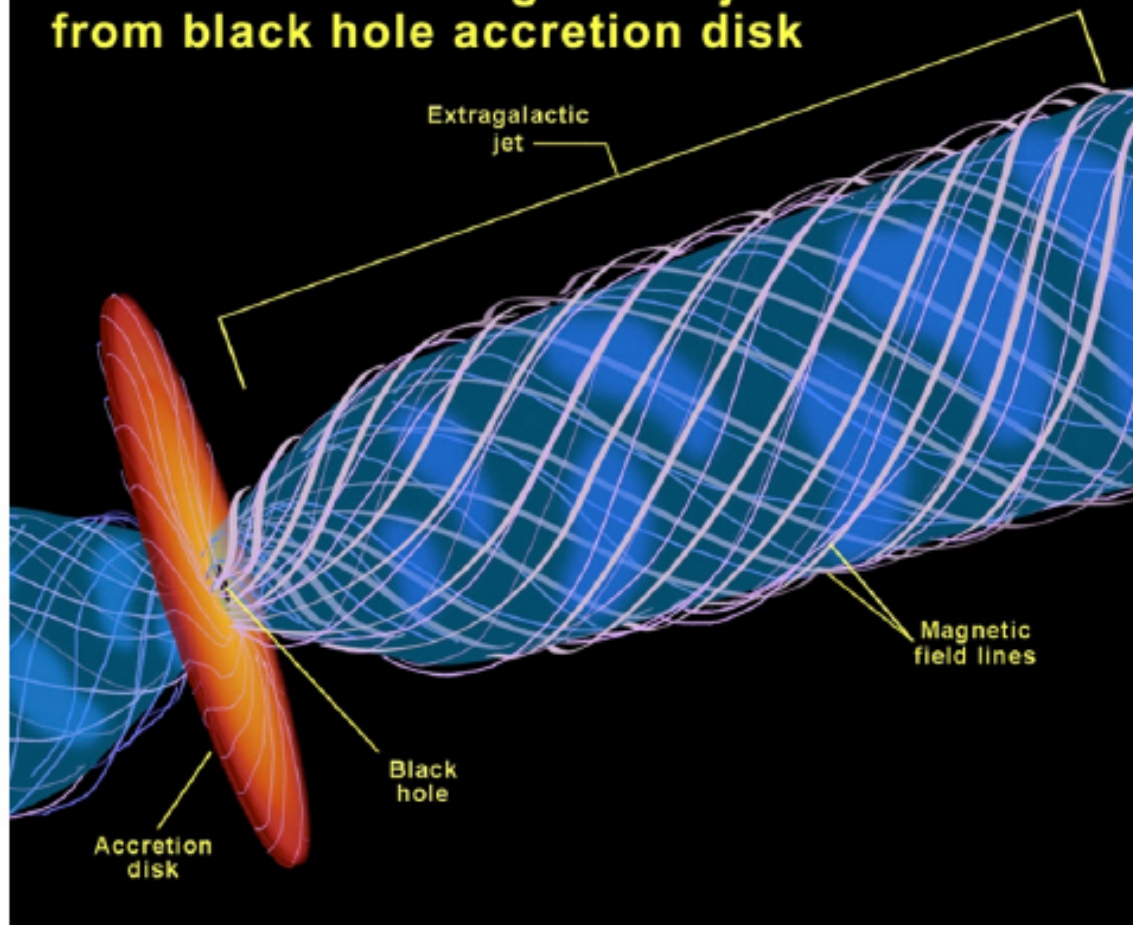
Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

ケンタウルス座 A

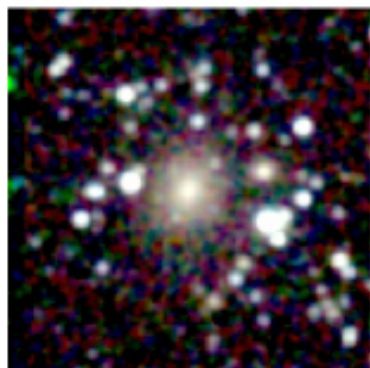
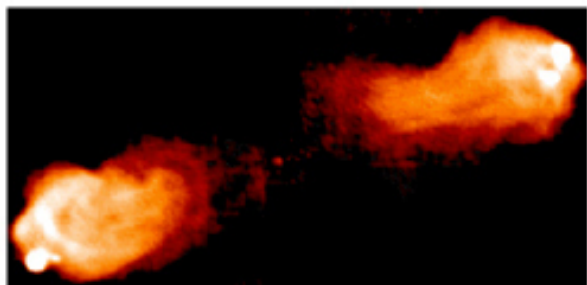
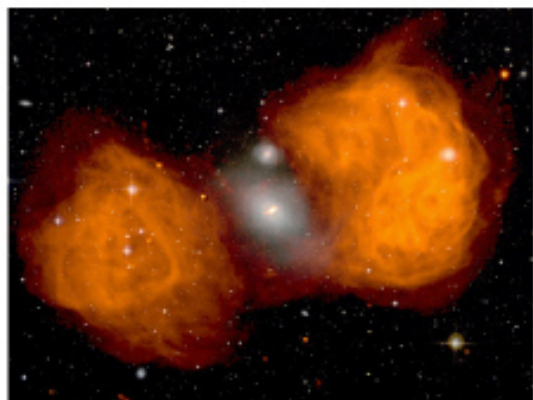


- 距離: 3.4Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度～電波光度
～ 2×10^{41} W

Formation of extragalactic jets from black hole accretion disk



他の電波銀河



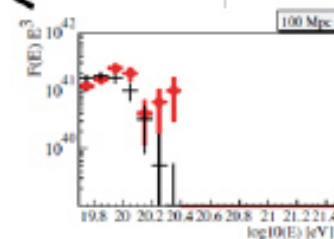
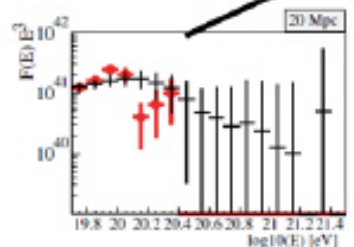
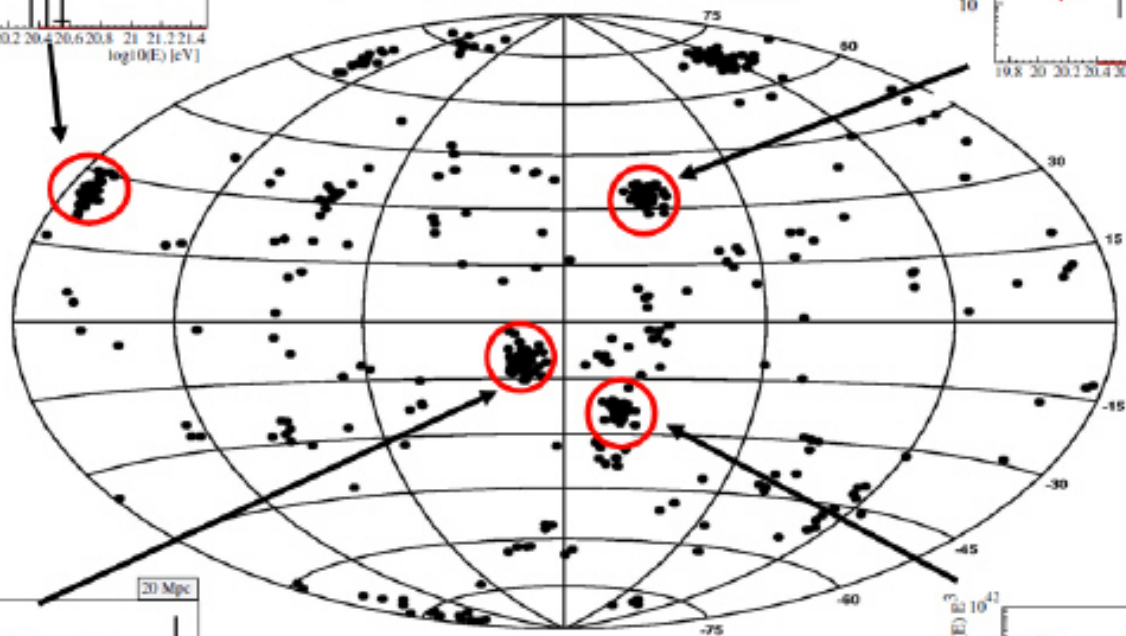
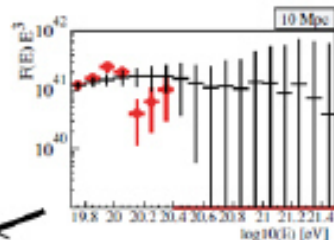
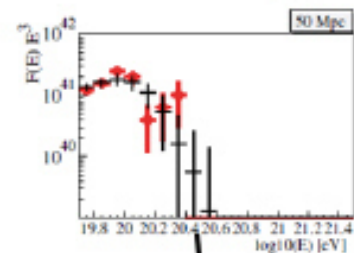
Fornax A

Cygnus A



極限粒子天文学

1,000事象の場合の予測

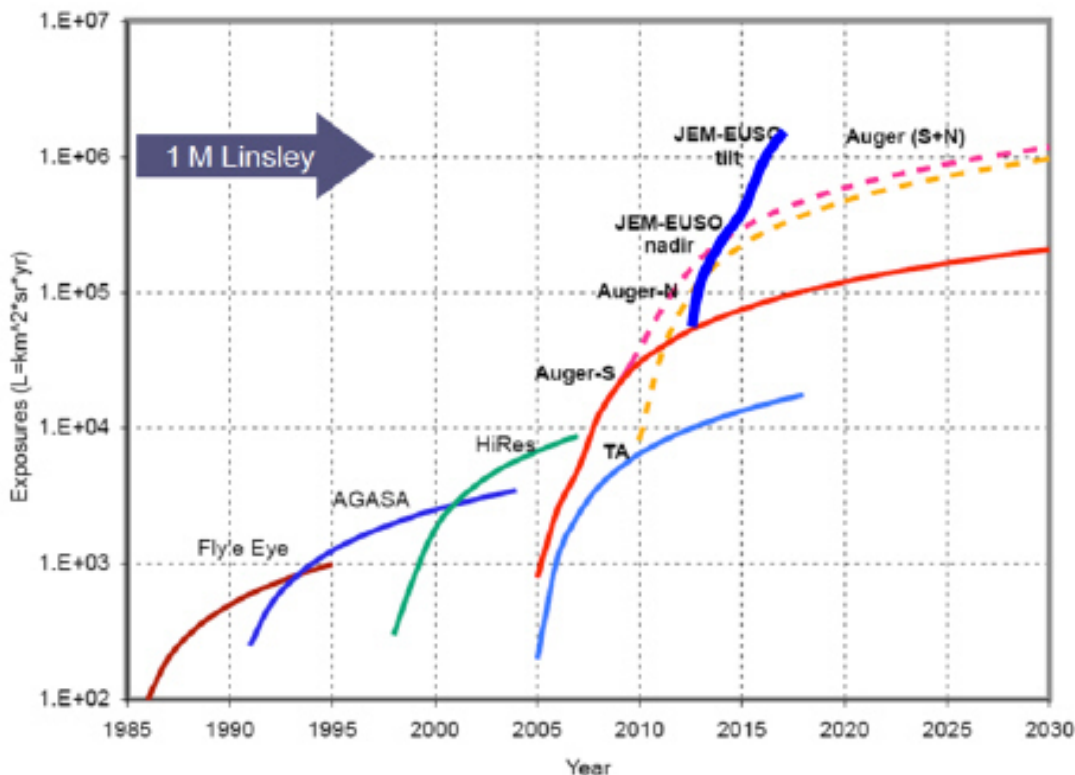


- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

事例数：5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

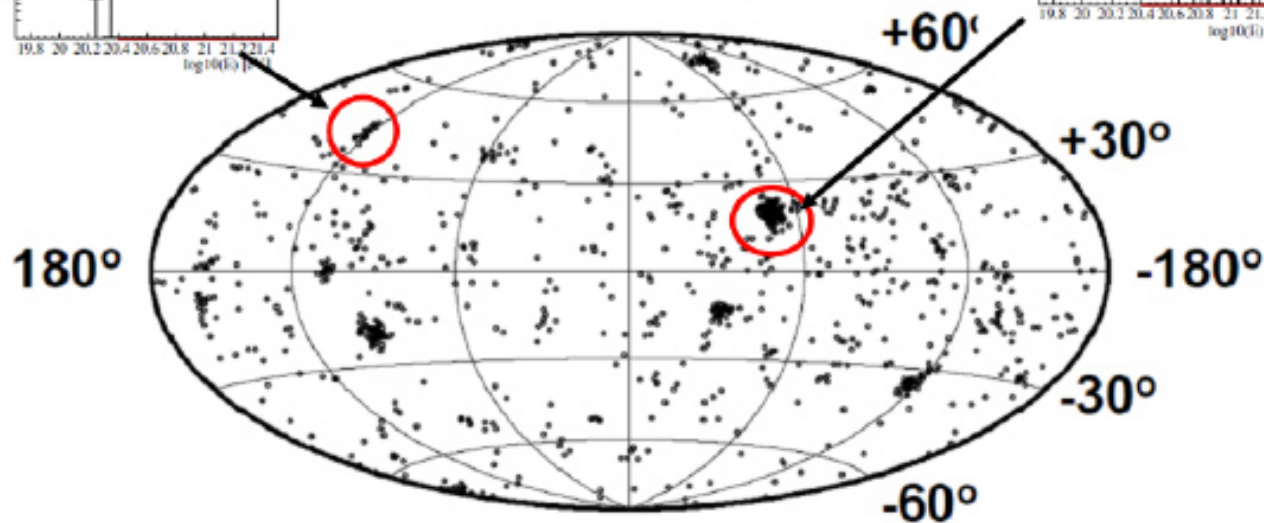
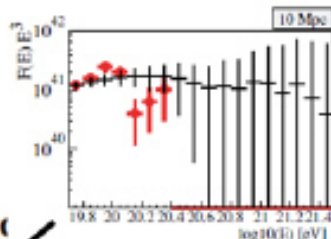
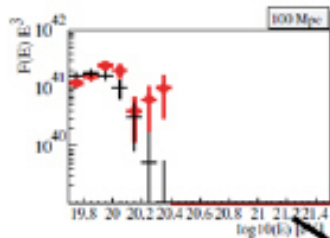
有効露出の増加期待値



極限粒子天文学

1,000事象の場合の予測

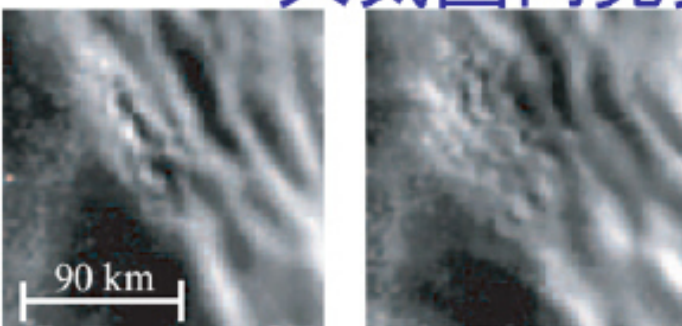
粒子光度 \propto X線光度 (AGN)



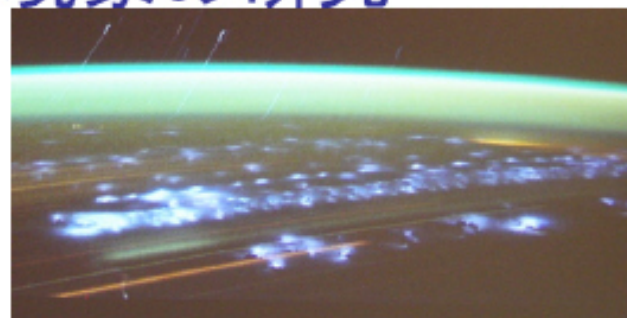
- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

Takami 2008

探求的試験研究3: 大気圏内発光現象の研究



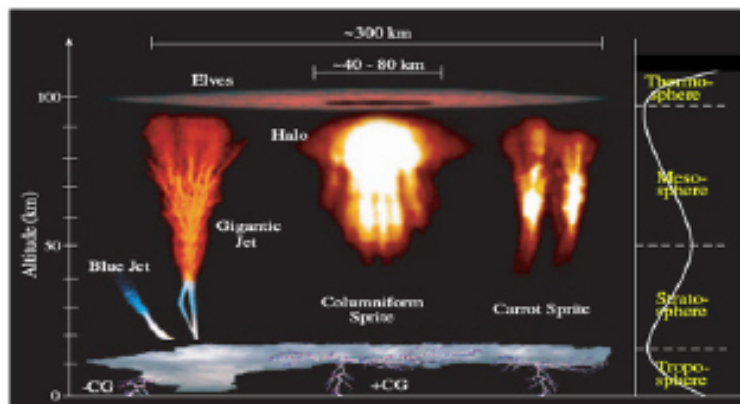
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



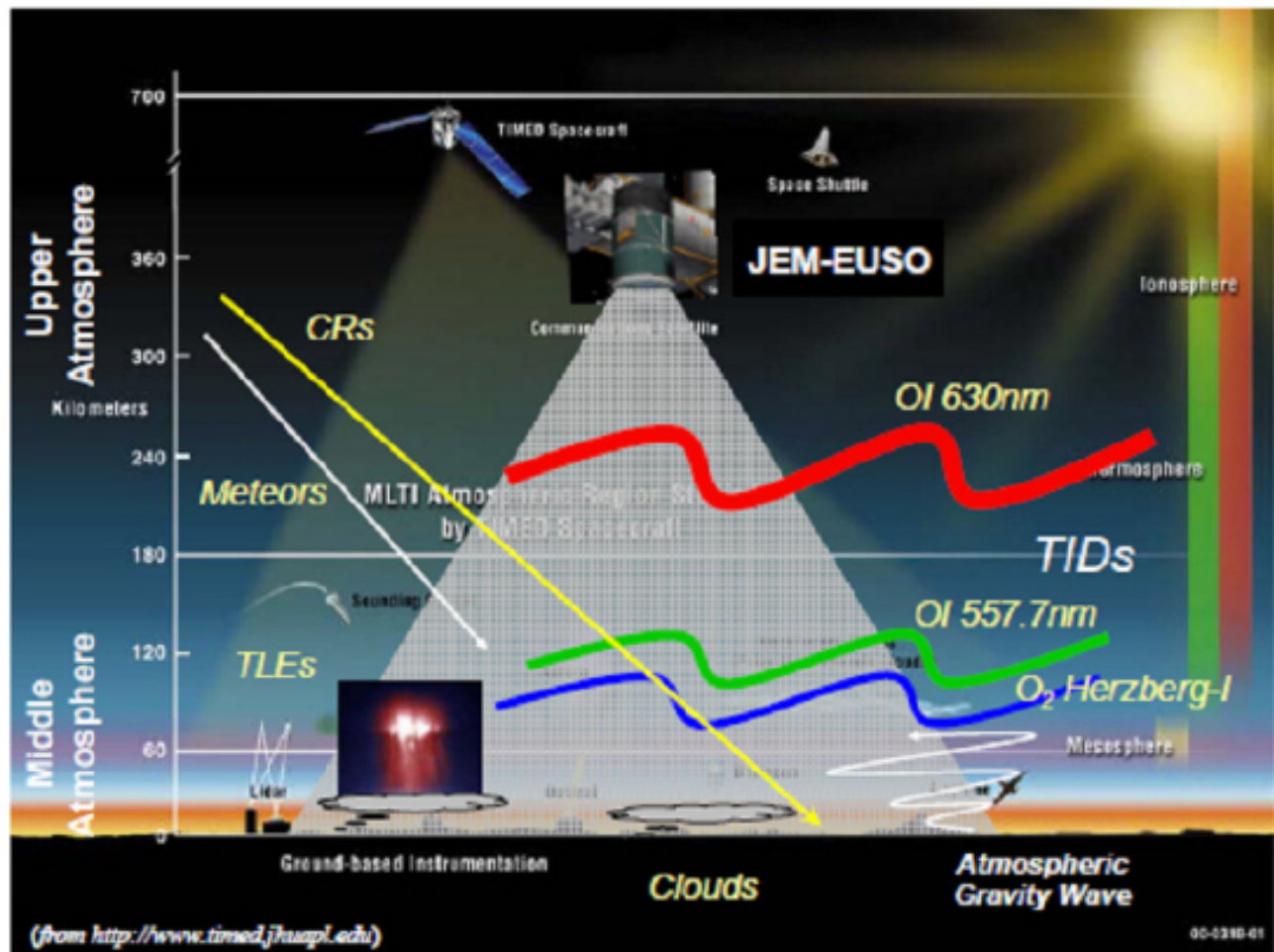
ハイビジョンカメラによる
2001年のしし座流星群



雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星

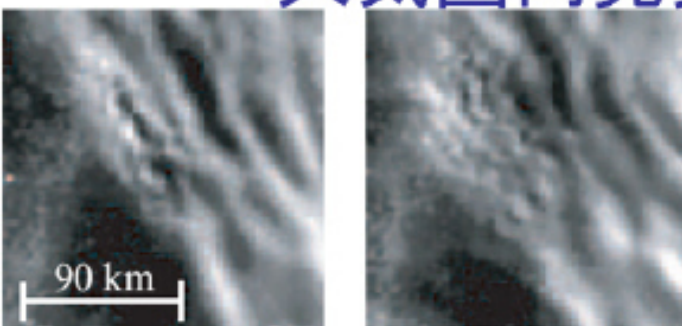


(from <http://www.timed.jhuapl.edu>)

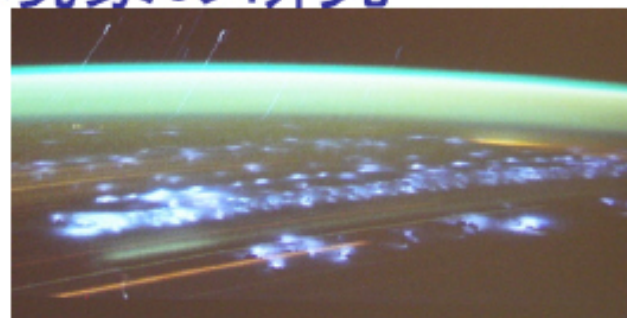
JEM-EUSOによる大気圏科学

- 雷放電とTLE
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- 流星

探求的試験研究3: 大気圏内発光現象の研究



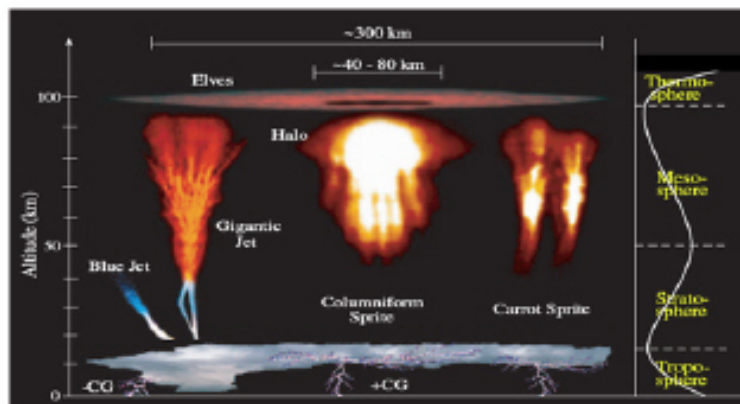
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



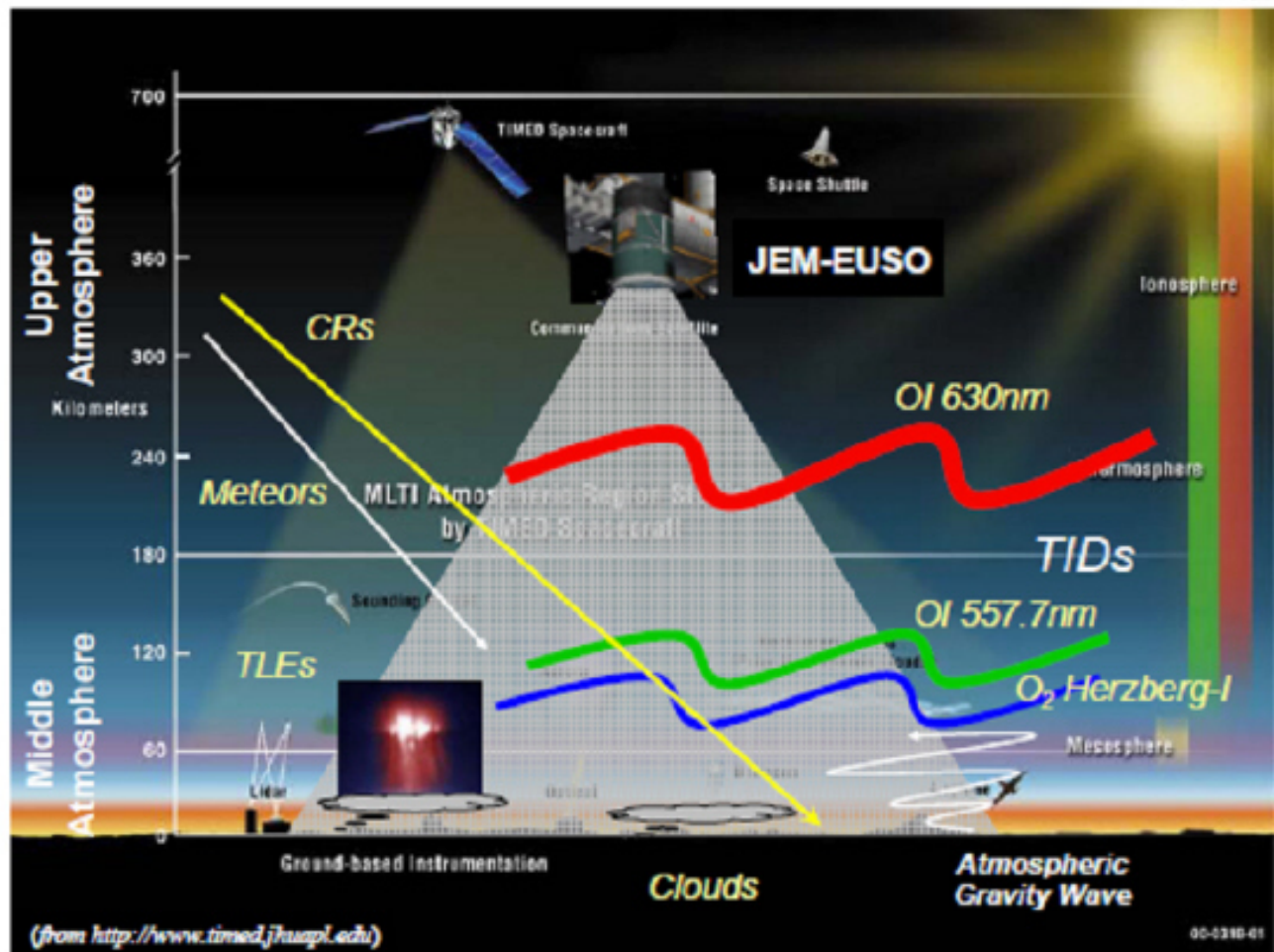
ハイビジョンカメラによる
2001年のしし座流星群



雷放電に伴う成層圏・中間圏・下部
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- 雲
 - 雲頂高度の全球観測
- 流星



サクセスクライテリア

フルサクセス:

極限エネルギー事例: 1000個以上
(7×10^{19} eV 以上)

ミニマムサクセス:

フルサクセスの半分の事例数を得る: 500個

分布から起源を議論の余地なく特定できる臨界量

- 粒子到来方向解析
 - 到来方向決定精度: 2.5度以下
- スペクトル解析
 - エネルギー決定精度: 30%以下
- ハドロン／光子／ニュートリノの識別:
 - シャワー最大深さ決定精度: 120 g/cm^2 以下

ミッション諸元

- 打ち上げ時期: year 2013
- 運用期間: 3 years (+ 2 years)
- 打ち上げロケット: H2B
- ISSへの運搬: HTV非与圧キャリア
- 装着場所: JEM EFU#2
- 軌道高度: ~430km
- 軌道傾斜角: 51.6°
- 質量: 1896 kg
- 使用電力: 998 W (operative),
344 W (non-operative)
- データ転送量: 297 kpbs

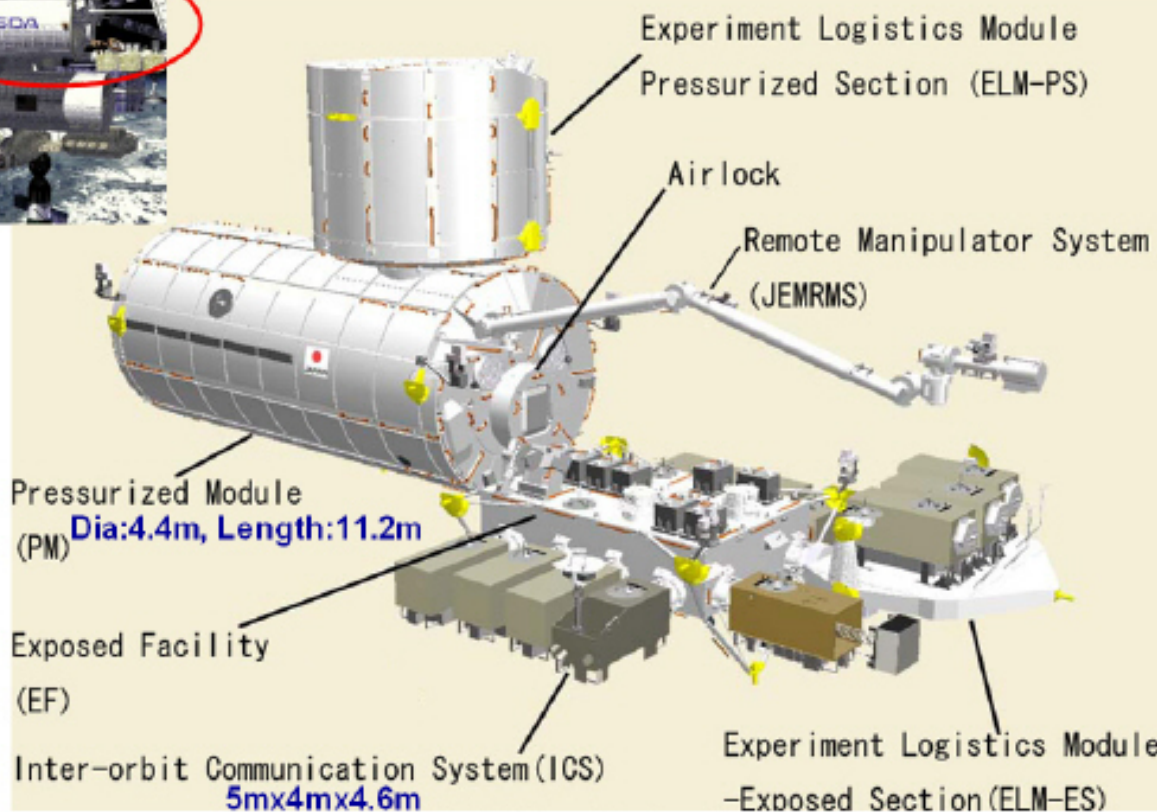
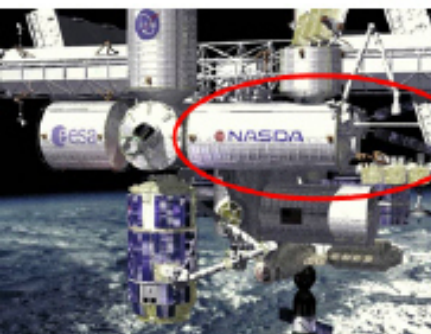
これまでの経緯

- ESA—EUSO
 - ESA 採択 2000;
 - NASA 採択 2003;
 - Phase-A 完了 2004
 - 地上公募研究: 1998 - 2001 2002 - 2004
- 2006年6月:
 - JEM-EUSO WGが宇宙理学委員会において承認ISAS/JAXA
- 2006年8月:
 - JEM-EUSO計画化委員会が理研中央研究所に設置
- 2006年11月:
 - 第二期利用ミッション候補公募開始
- 2007年2月:
 - 理研から提案書提出
- 2007年5月:
 - 採択の正式通知
- 2007年6月
 - Kick-Off会合
 - 国際アドバイザーボード会合
- 2007年7月
 - 第一回国際JEM-EUSO会合(国際宇宙線会議@メキシコ)

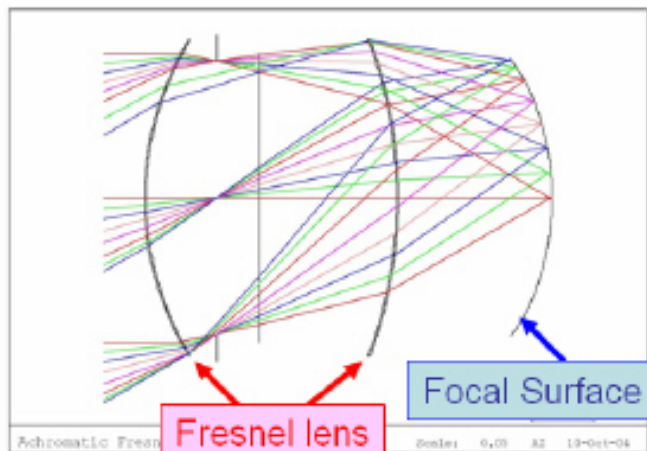
これからの予定

- 2007年度－2008年度(準備研究・概念設計)
 - 2007年10月 曝露部分科会へ報告
 - 2007年11月 国際JEM-EUSO会合
 - 2008年1月 国際アドバイザーボード会合
 - 2008年3月 国際シンポジウム開催
 - 2008年4月 中間評価
 - 2009年3月 最終評価
- 2009年度－2012年度
 - 製作段階
- 2013年 打ち上げ

日本実験棟「きぼう」

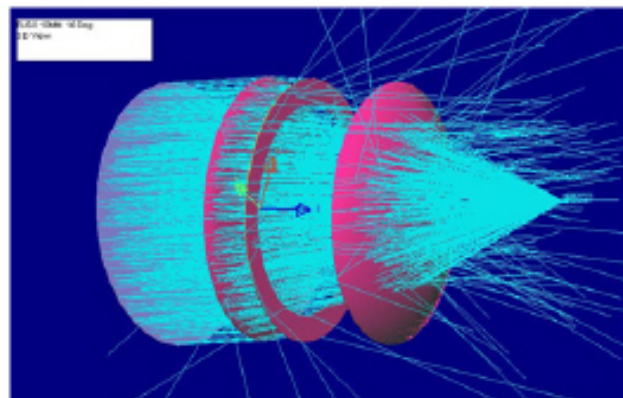


CYTOPを用いた新光学系



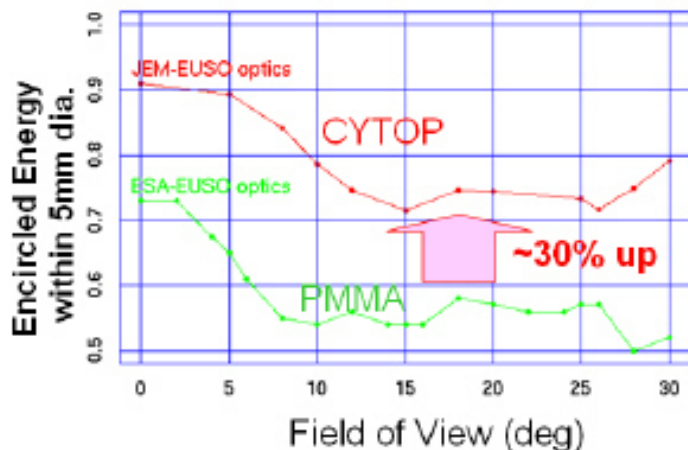
Optics Requirements

- FoV $\pm 30^\circ$
- Pupil entrance pupil ≥ 2 m
- $F/\# \leq 1.0$
- Spot dimension $\sim 0.1^\circ$ (5mm Φ)
- Spectral range 330-400 nm

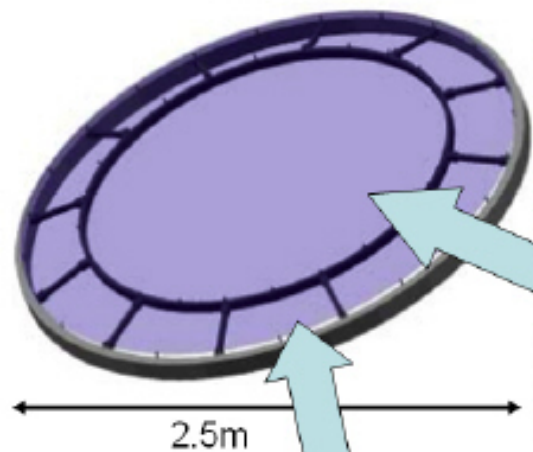


Ray trace

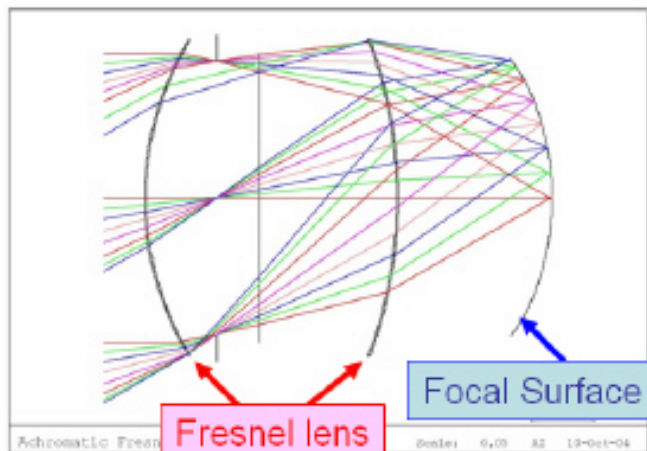
JEM-EUSO vs ESA-EUSO optics



フレネルレンズ製作

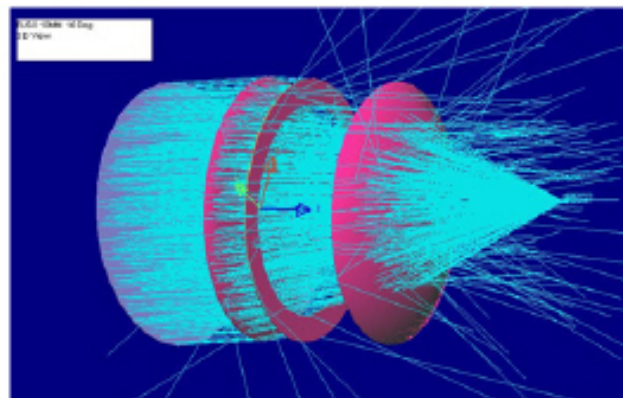


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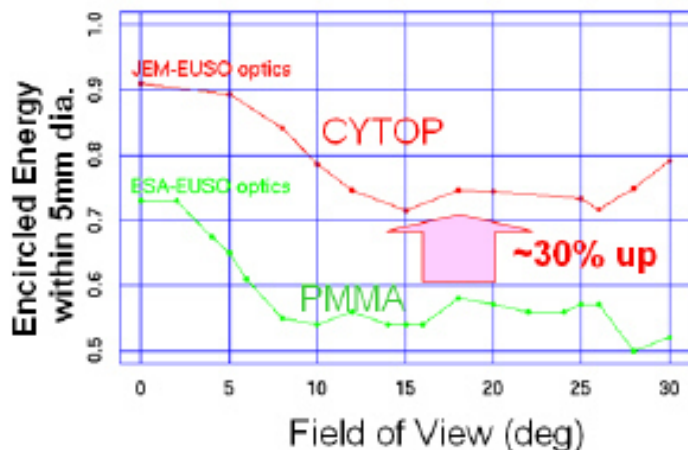
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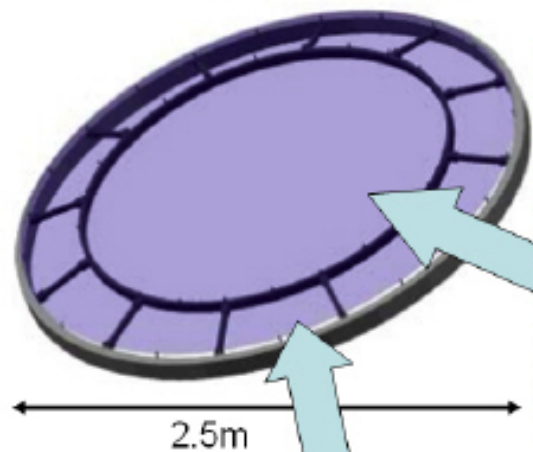


Ray trace

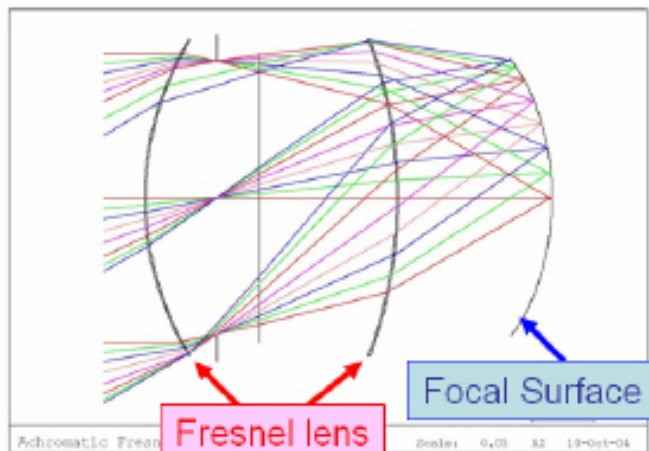
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フレネルレンズ製作

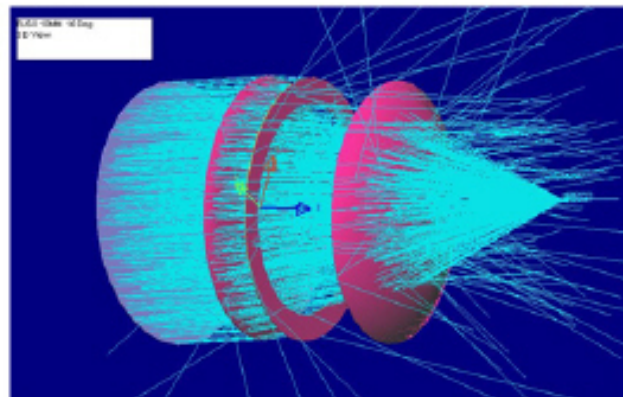


CYTOPを用いた新光学系



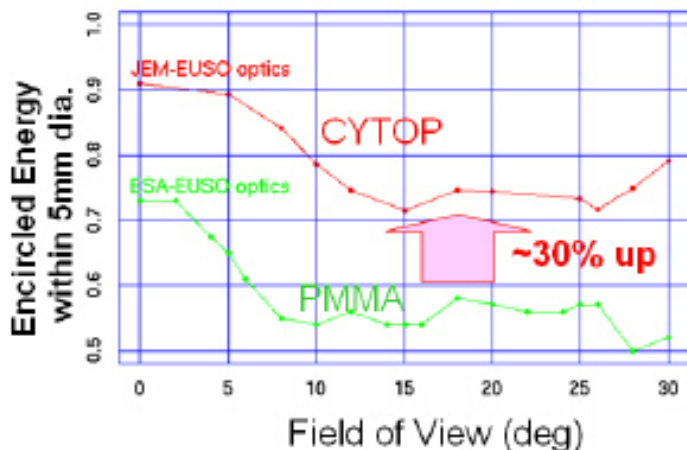
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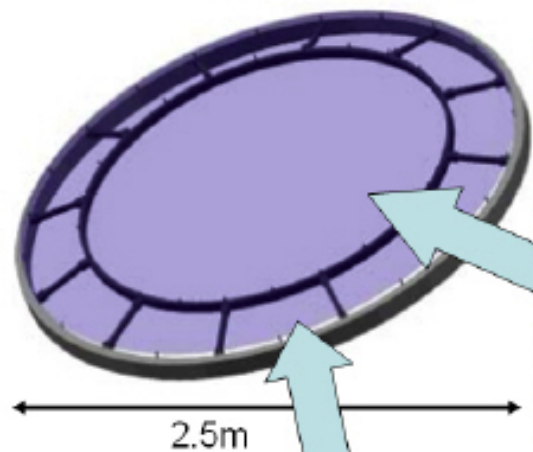


Ray trace

JEM-EUSO vs ESA-EUSO optics



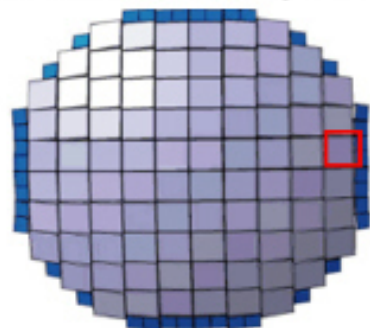
フレネルレンズ製作



JEM-EUSO 焦点面の構造

Focal Surface detector

(164PDMs = 0.2M pixels)



2.26 m max

Elementary Cell

(2x2 PMTs = 144 pixels)

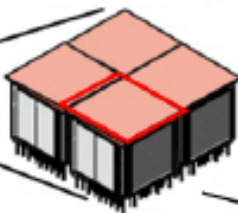
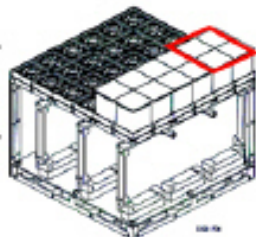


Photo-Detector Module

(3x3 ECs = 1296 pixels)



MAPMT
(6x6 pixels)

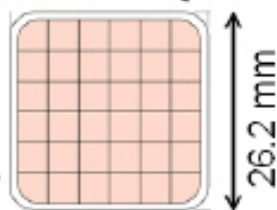


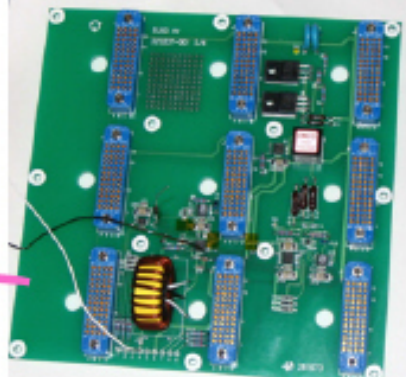
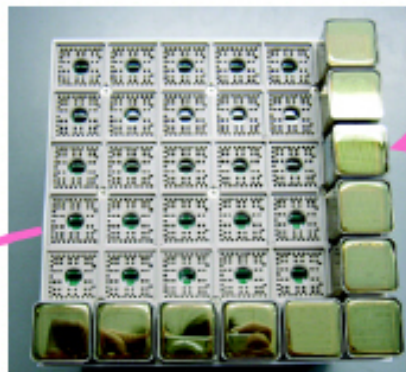
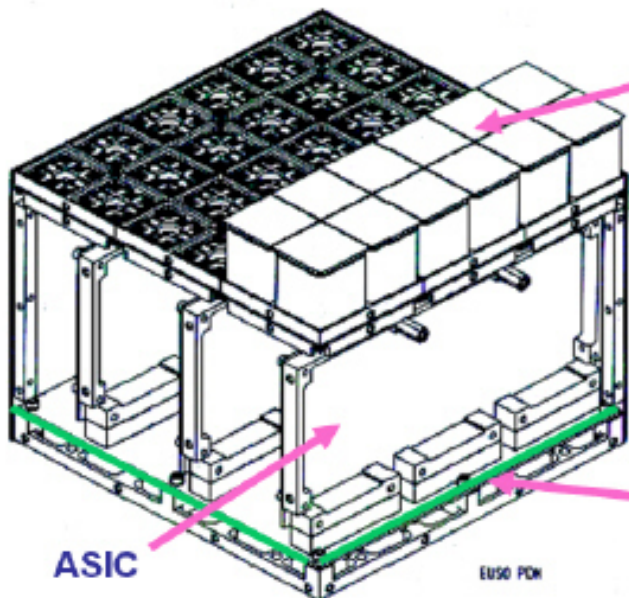
Photo Detector Module (PDM)

- 9 Elementary Cell (EC), 1 HV module, 9 HV divider

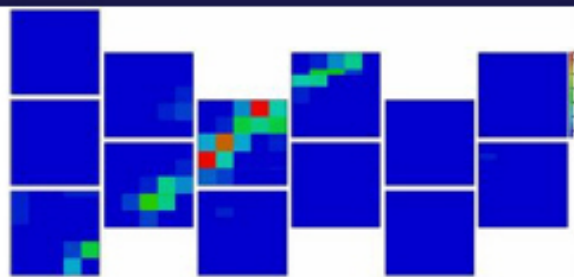
✓ 構造解析と振動試験 (済)

✓ 放射線試験 (済)

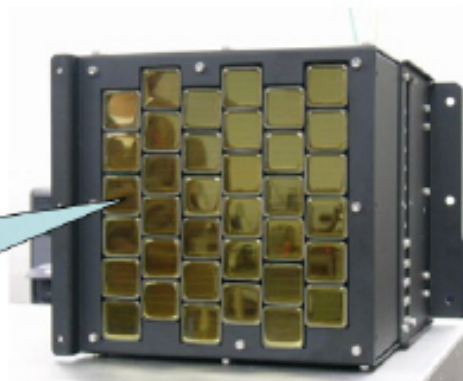
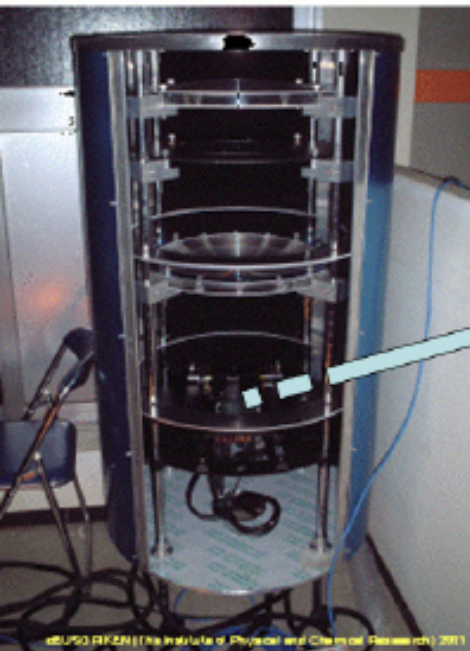
✓ 大光量保護回路 (済)



Progress: 小さなEUSOを製作

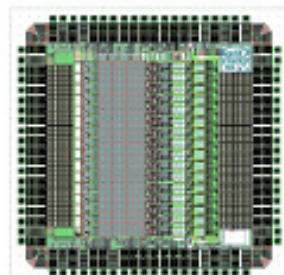


40cm Diameter



**ASIC
by Ikeda**

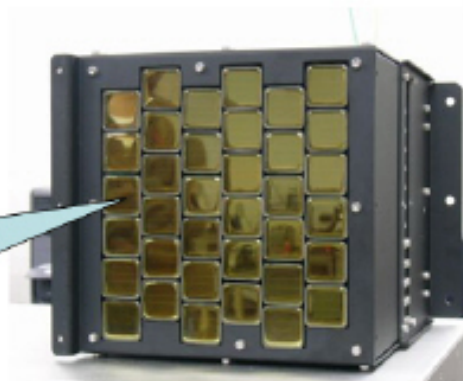
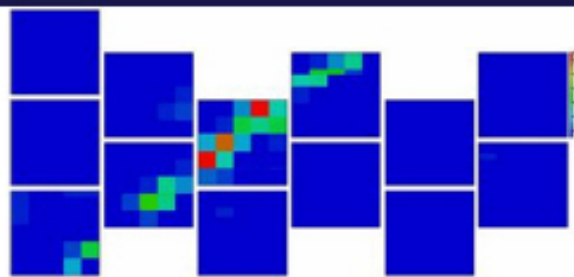
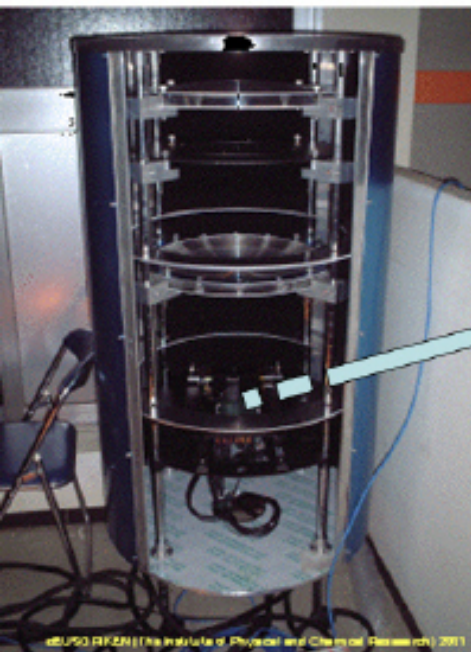
Prototype PDM



Progress: 小さなEUSOを製作

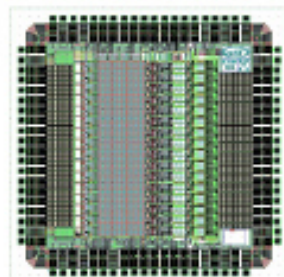
UV Laser

40cm Diameter

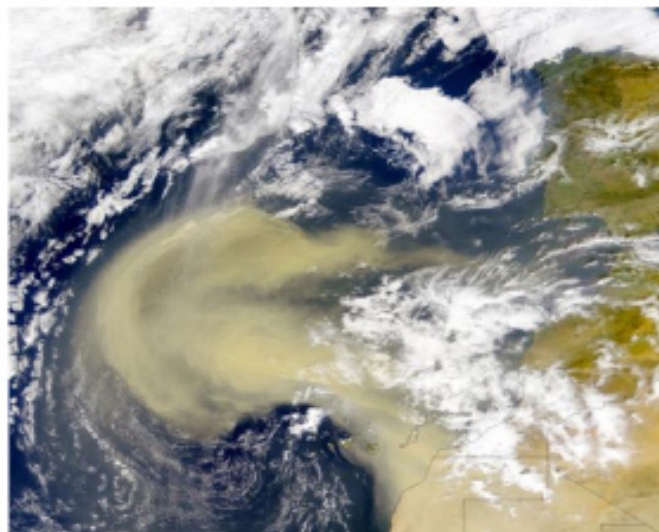


Prototype PDM

**ASIC
by Ikeda**



■ *The real atmosphere – clouds and desert dust*



Sahara dust over the Atlantic on 26.2.2000

Atmospheric Monitoring System

- **IR Camera**

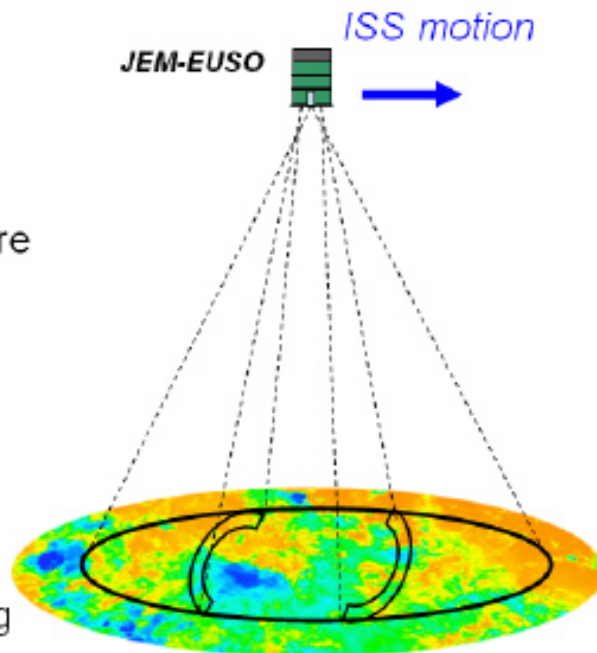
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

Ranging observation using UV laser

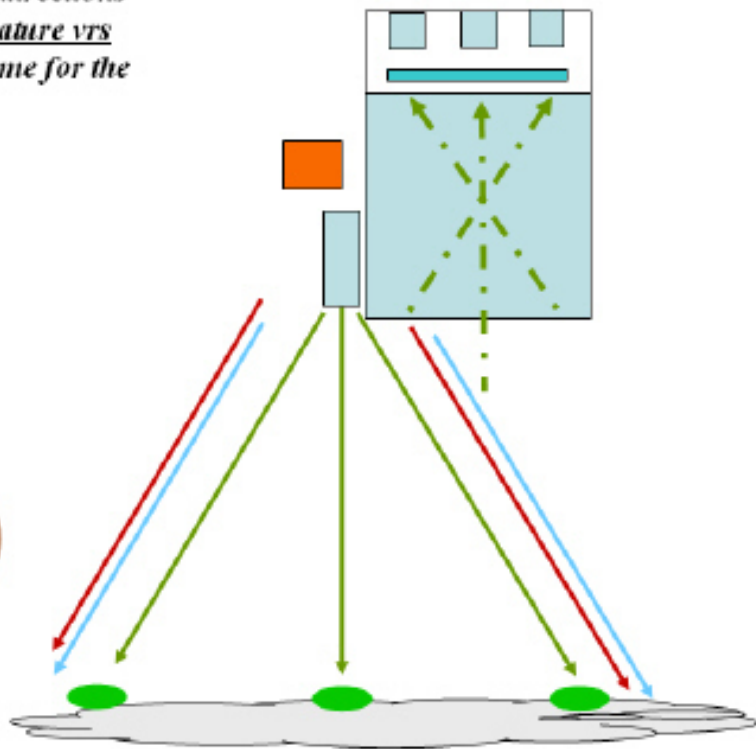
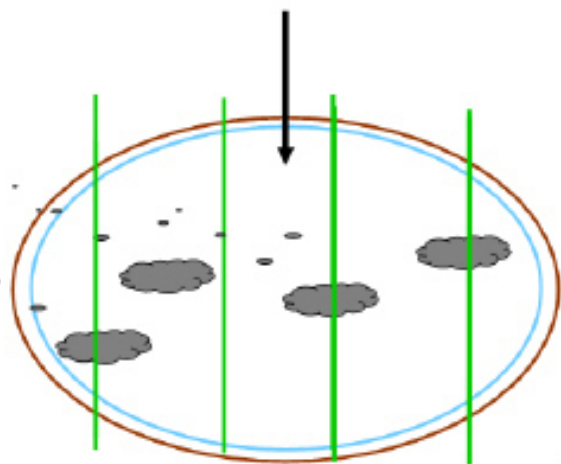
- **JEM-EUSO “slow-data”**

Continuous background photon counting



- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
- *Calibration of telescope:* (Lidar)

*Using the measurements in these three-four directions
for calibration of the IR radiometer temperature vrs
cloud top altitude – Reference lines ; the same for the
UV « slow mode »*



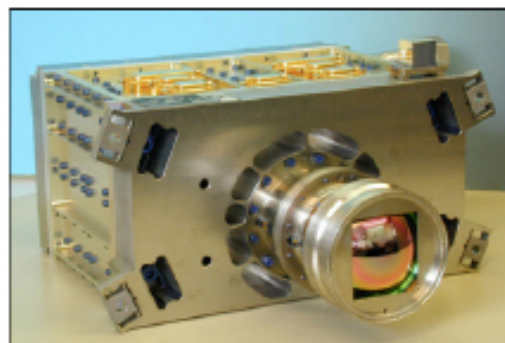
IR Camera

Requirement

Item	Value	Reason
Wavelength	10 – 13 μ m	Atmospheric transmission, S/N
FOV	> 60°	Same FOV as JEM-EUSO
Spatial Resolution	0.25°	1.8 km/pix @ nadir
Observation Temperature Range	200 – 320 K	Cloutop temperature in troposphere
Absolute Temperature Resolution	< 3 K	Altitude resolution < 500m
IR Sensor	Uncooled Microbolometer Array	Mass, Power
Exposure Time	133 msec	ISS motion within $\frac{1}{2}$ - pix of IR camera
Observation Interval	30 sec (5 sec TBC)	ISS motion of JEM-EUSO $\frac{1}{2}$ FOV

IR Camera Development with EADS/SODERN

CIM01 (or IASI) onboard METOP1 satellite



IASA Specification

- Scanning Mirror
- Sensor (CIM01)

λ : 10.3 - 12.5

μm

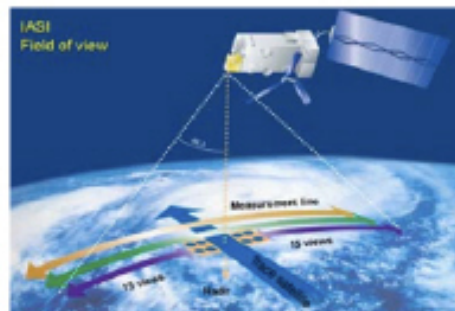
sensor: bolometer array

pix. size: 64×64

res.: 12 bit

FOV: 60×60 mrad

NETD : <80 mK



IR Camera Development with EADS/SODERN

Major Change from CIM01 to JEM-EUSO IR Camera

(1) Pixel size of detector

"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

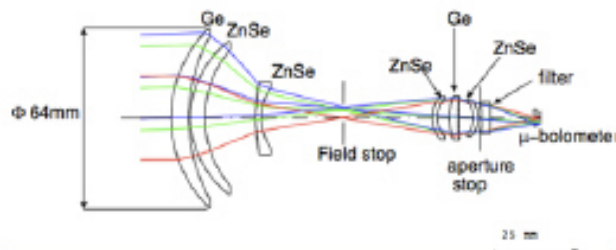
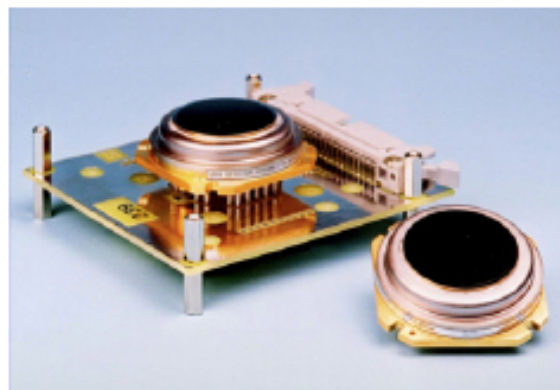
(2) FOV

Line scanning → >60°

Based on CIM01 design, they can produce FM of JEM-EUSO IR camera with 5.5MEuro within 5 years.

Specification of IR Camera

Should be determined before 12E, 2007



Lidar

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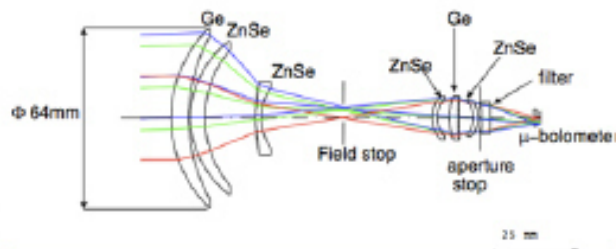
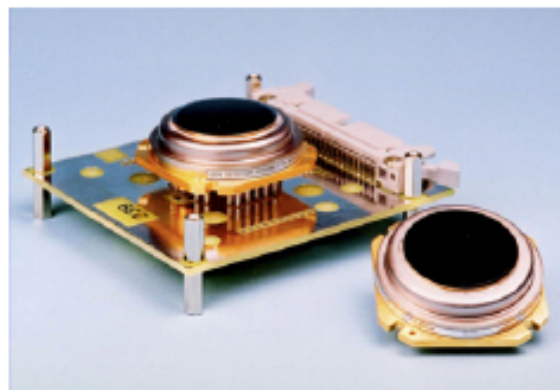
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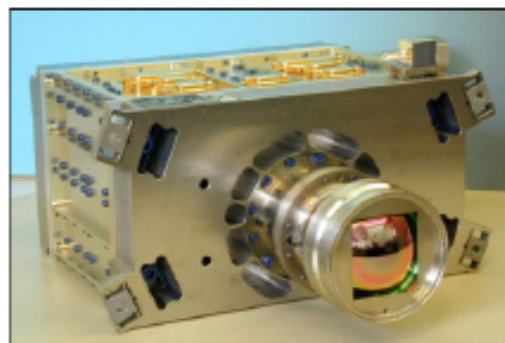
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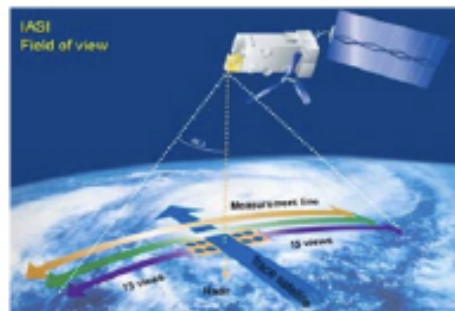
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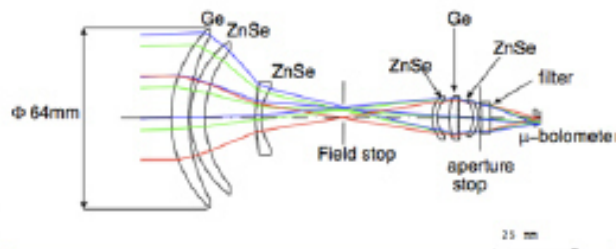
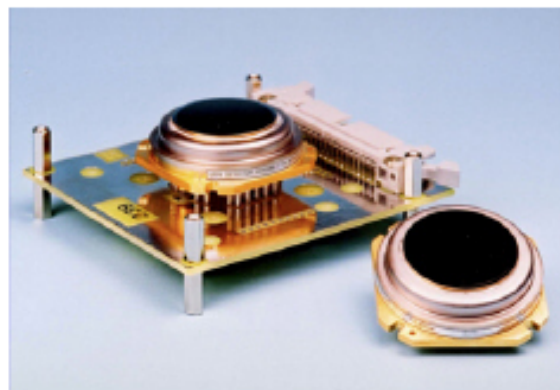
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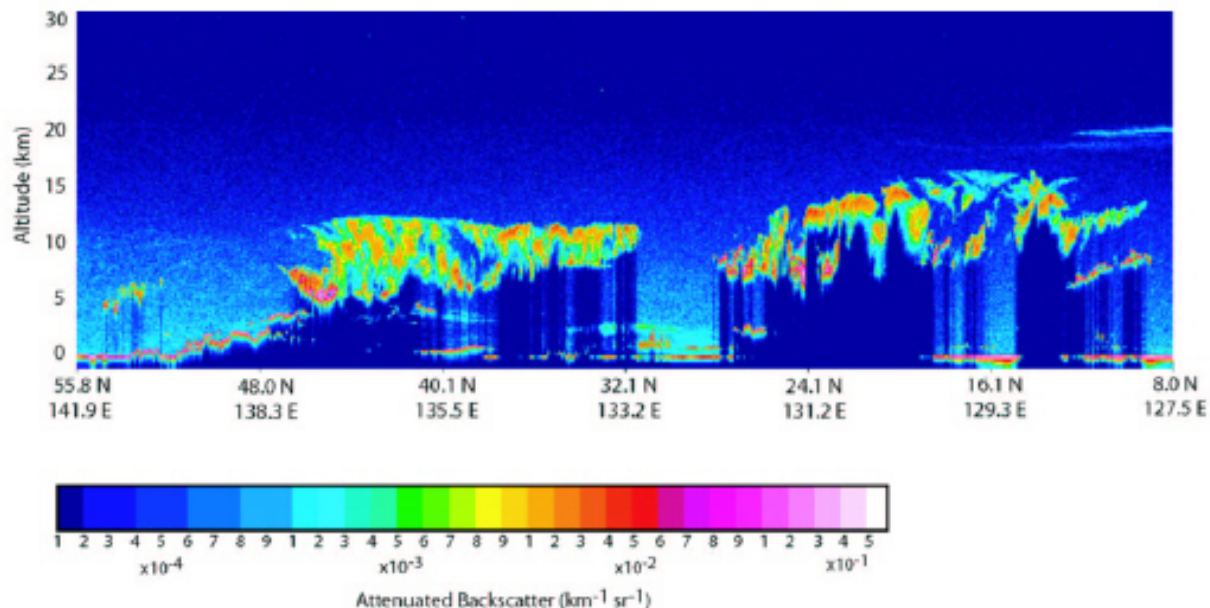
Specification of IR Camera

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Lidar

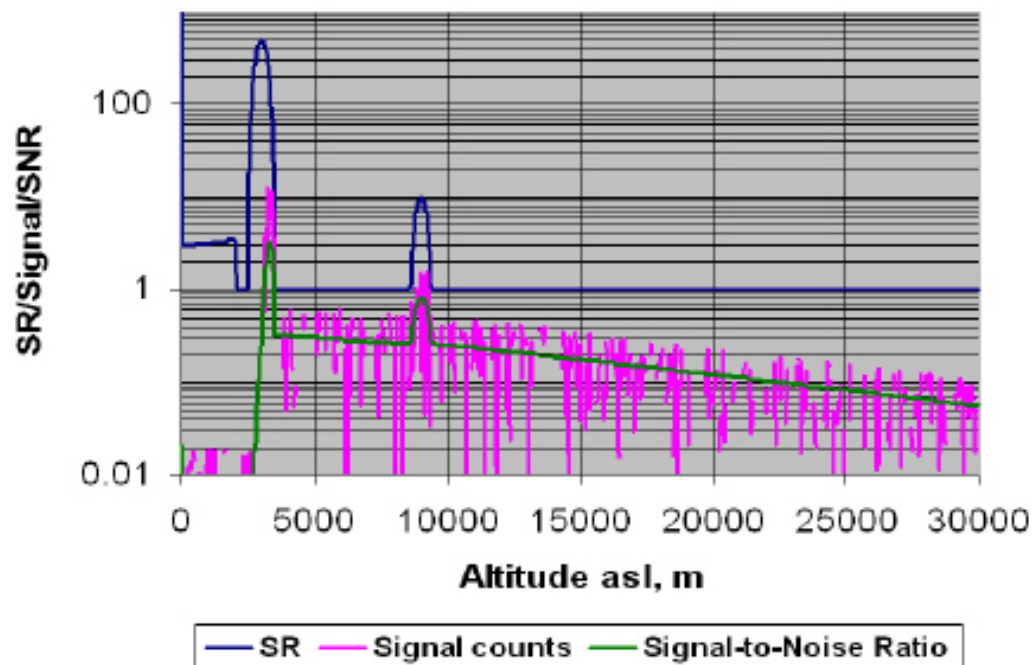
Another spaceborne lidar– first CALIPSO results (#2)



Performance simulations, #1: Subsystems

Subsystem		Lidar 1	Lidar 2
Transmitter	Wavelength, nm	355	532
	Pulse repetition rate, pps	100	100
	Averaged transmitted power, W	1	1
	Divergence full angle, mrad	0.08	0.08
	Optical efficiency	80	80
Receiver	Primary receiver aperture diam, cm	250	250
	Secondary mirror aperture, cm	0	0
	Field of View full angle, mrad	0.2	0.2
	Interference filter, FWHM	0.25	0.25
	Interference filter, transmission %	50	50
	Optical efficiency (without filter)	25	25
Detector	Quantum efficiency, %	25	25
	Dark noise, counts per second	500	500
Acquisition (ph. counting)	Range resolution, bin meters	30	30
	Integration time, sec	0.01/1	0.01/1
Satellite	Altitude, km	500	500

Performance simulations, #3:



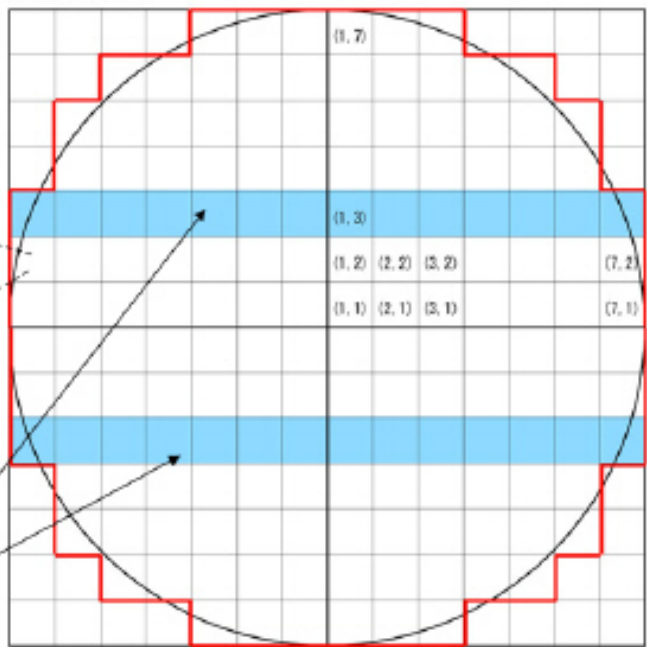
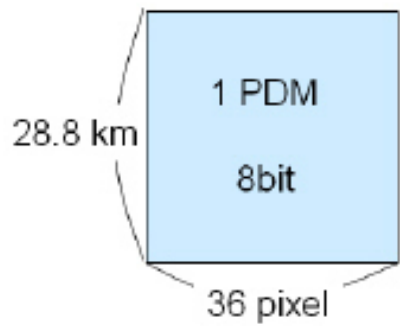
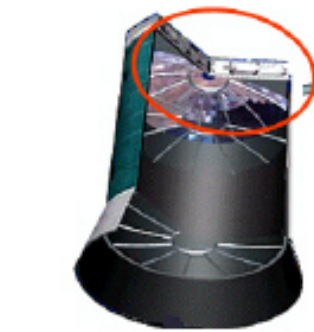
results for
355nm, 0.01sec
integration time,
30m range
resolution

Slow-Data

- All of PDMs equip "slow-data" DAQ
- Continuous BG photon counting

V_{ISS}
↑

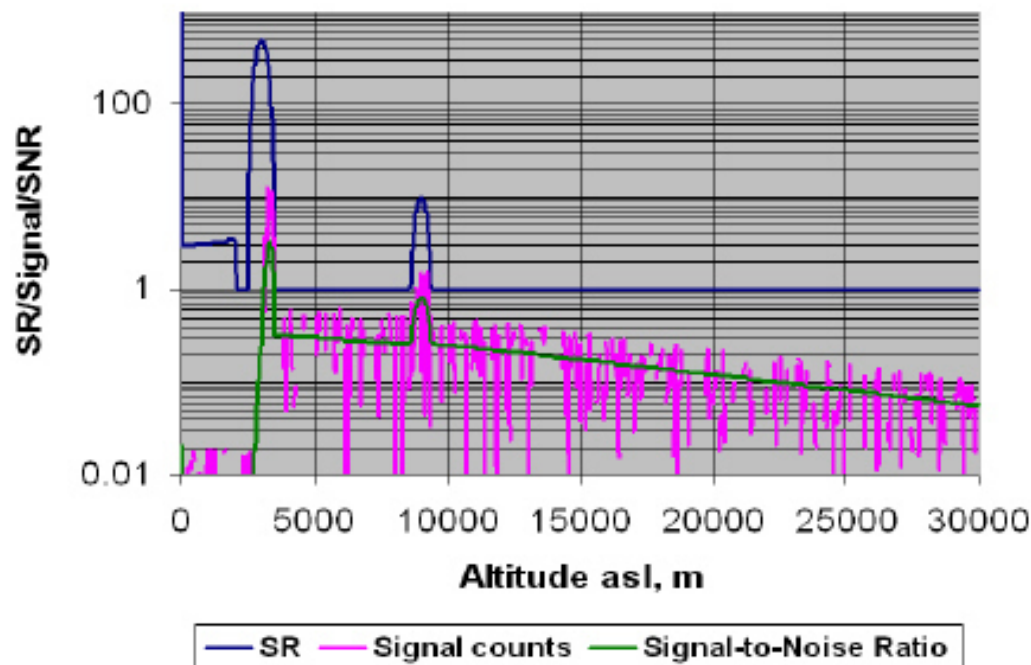
JEM-EUSO FS



Slow-data obtained at only 2 PDM lines will be stored!

Slow-Data

Performance simulations, #3:

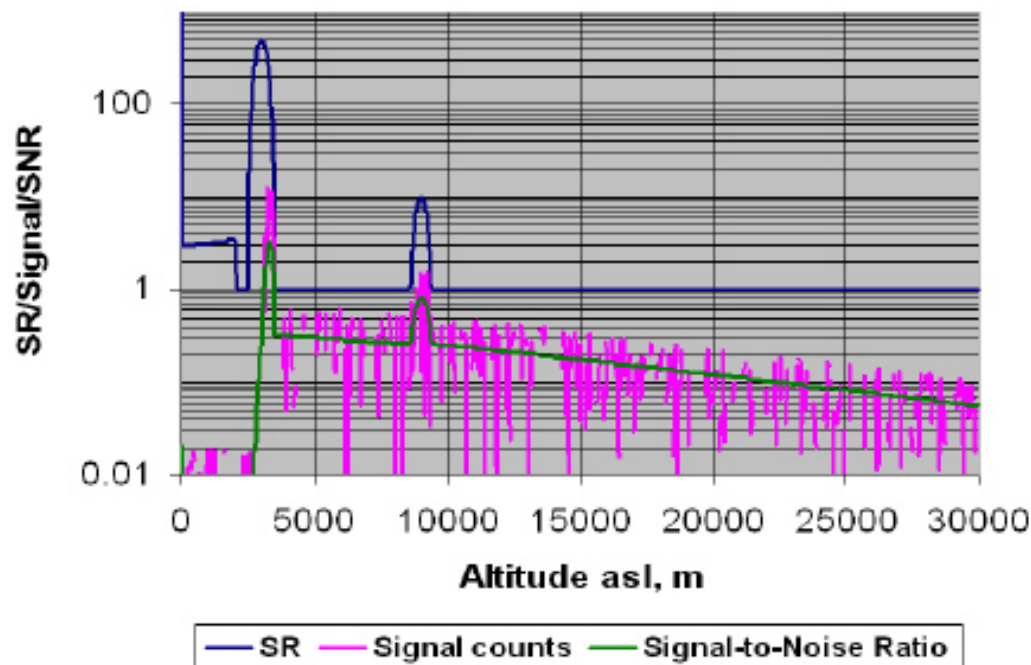


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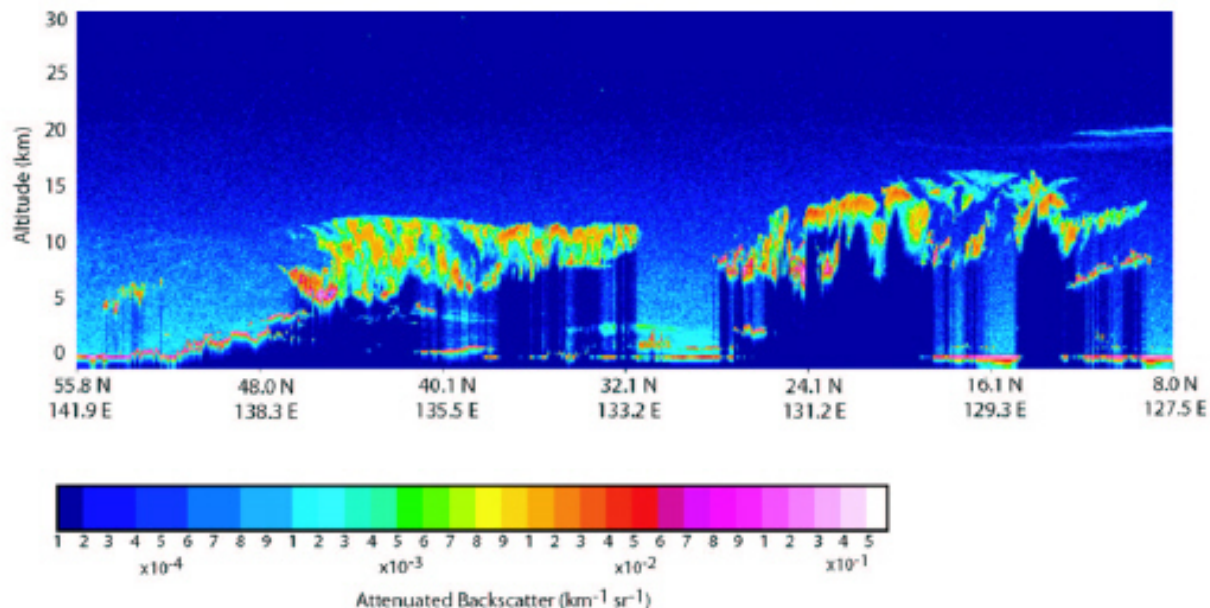


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Another spaceborne lidar– first CALIPSO results (#2)



Lidar

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Major Change from CIM01 to JEM-EUSO IR Camera

(1) Pixel size of detector

"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

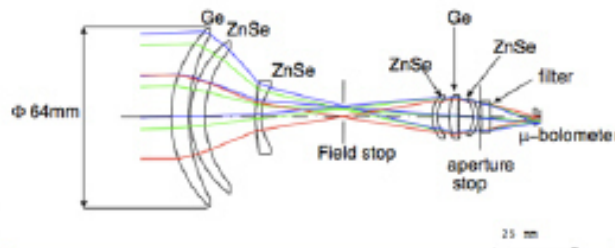
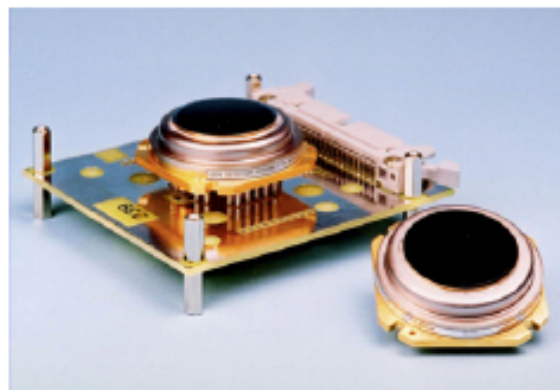
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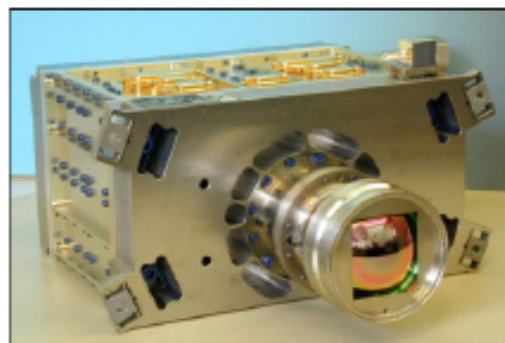
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Should be determined before 12E, 2007



IR Camera Development with EADS/SODERN

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λ : 10.3 - 12.5

μm

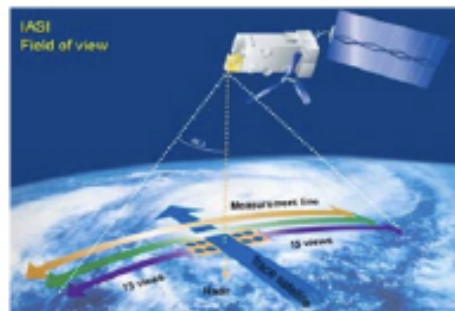
sensor: bolometer array

pix. size: 64×64

res.: 12 bit

FOV: 60×60 mrad

NETD : <80 mK

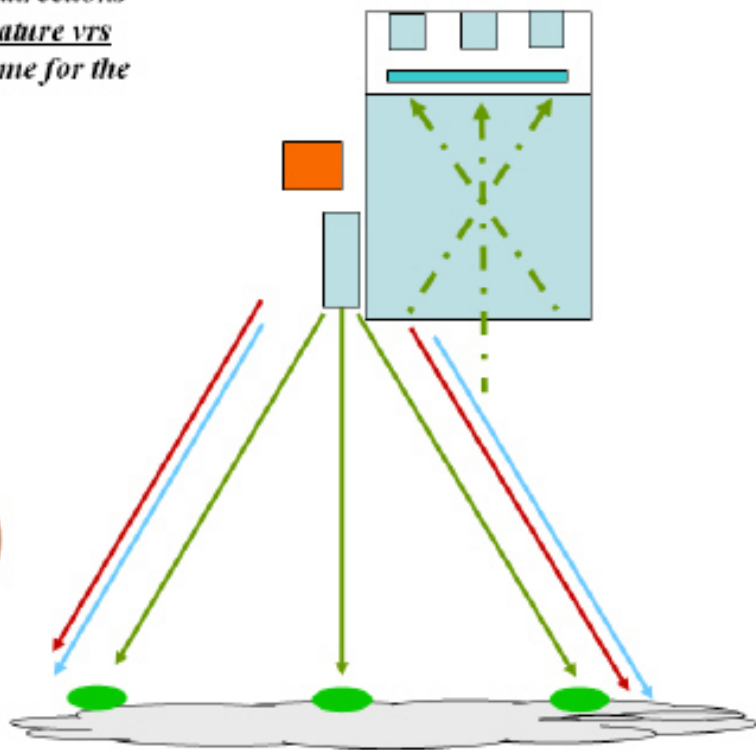
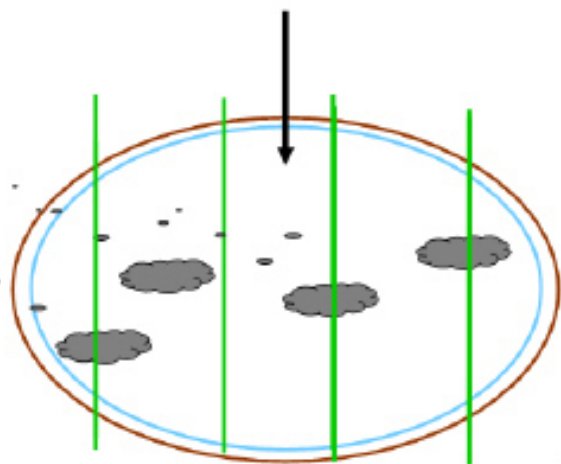


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IR Camera

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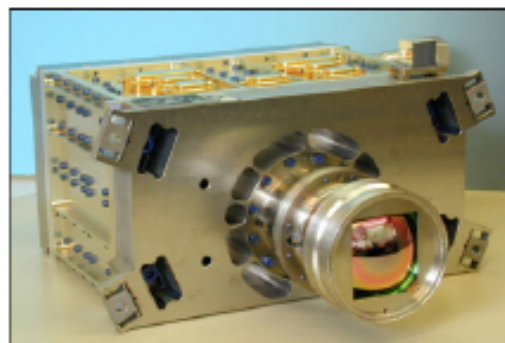
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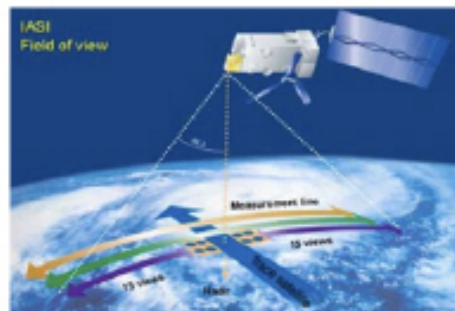
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"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

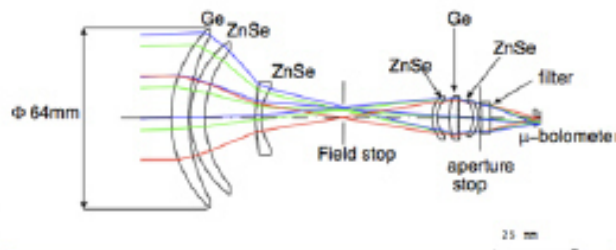
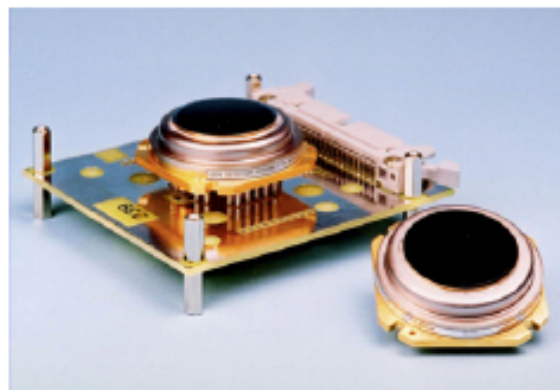
(2) FOV

Line scanning → >60°

Based on CIM01 design, they can produce FM of JEM-EUSO IR camera with 5.5MEuro within 5 years.

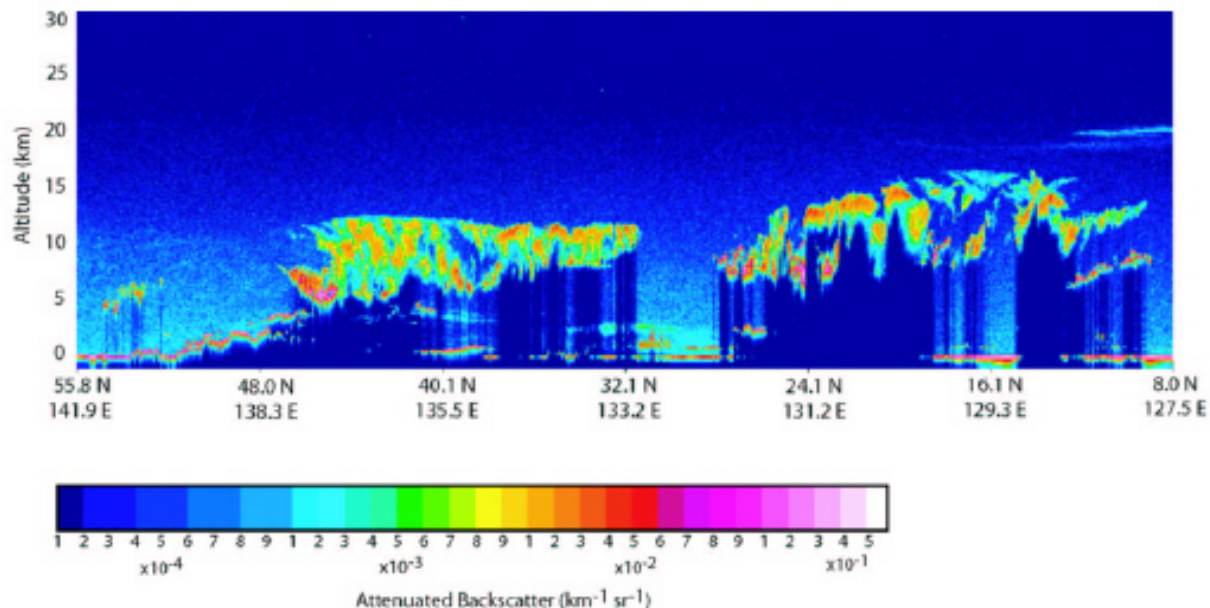
Specification of IR Camera

Should be determined before 12E, 2007



Lidar

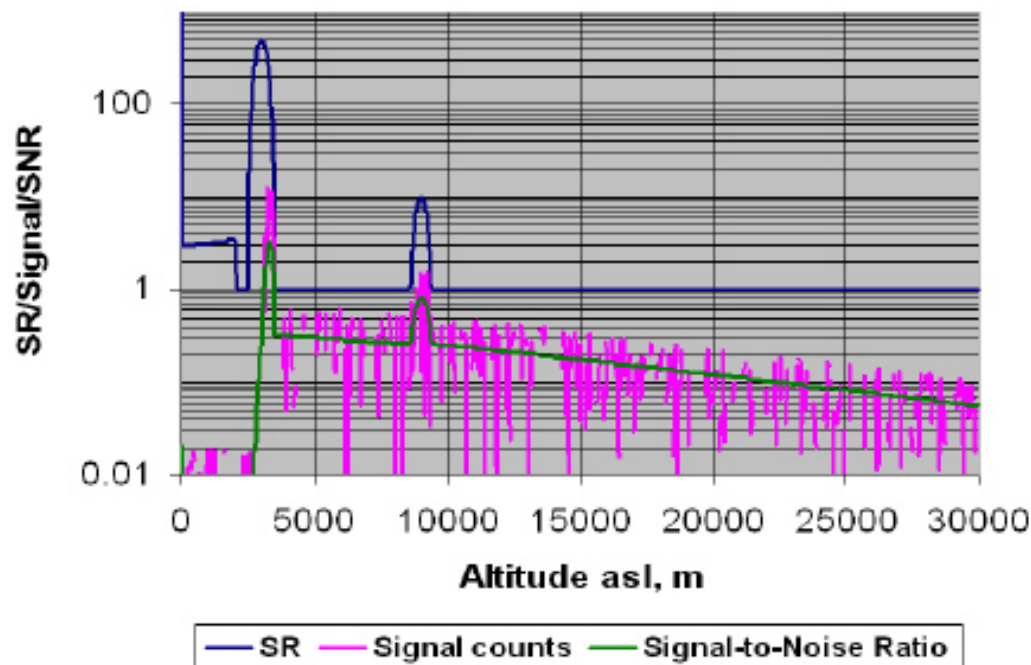
Another spaceborne lidar– first CALIPSO results (#2)



Performance simulations, #1: Subsystems

Subsystem		Lidar 1	Lidar 2
Transmitter	Wavelength, nm	355	532
	Pulse repetition rate, pps	100	100
	Averaged transmitted power, W	1	1
	Divergence full angle, mrad	0.08	0.08
	Optical efficiency	80	80
Receiver	Primary receiver aperture diam, cm	250	250
	Secondary mirror aperture, cm	0	0
	Field of View full angle, mrad	0.2	0.2
	Interference filter, FWHM	0.25	0.25
	Interference filter, transmission %	50	50
	Optical efficiency (without filter)	25	25
Detector	Quantum efficiency, %	25	25
	Dark noise, counts per second	500	500
Acquisition (ph. counting)	Range resolution, bin meters	30	30
	Integration time, sec	0.01/1	0.01/1
Satellite	Altitude, km	500	500

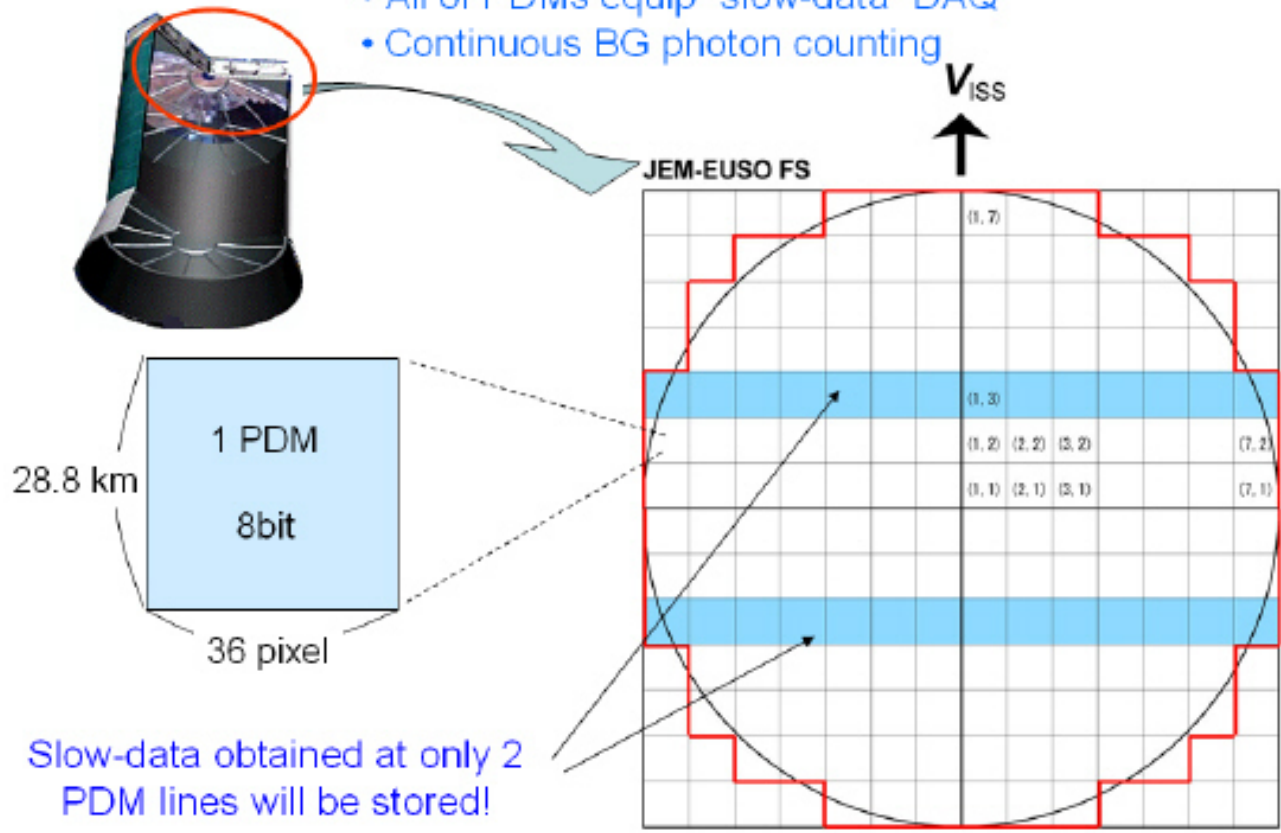
Performance simulations, #3:



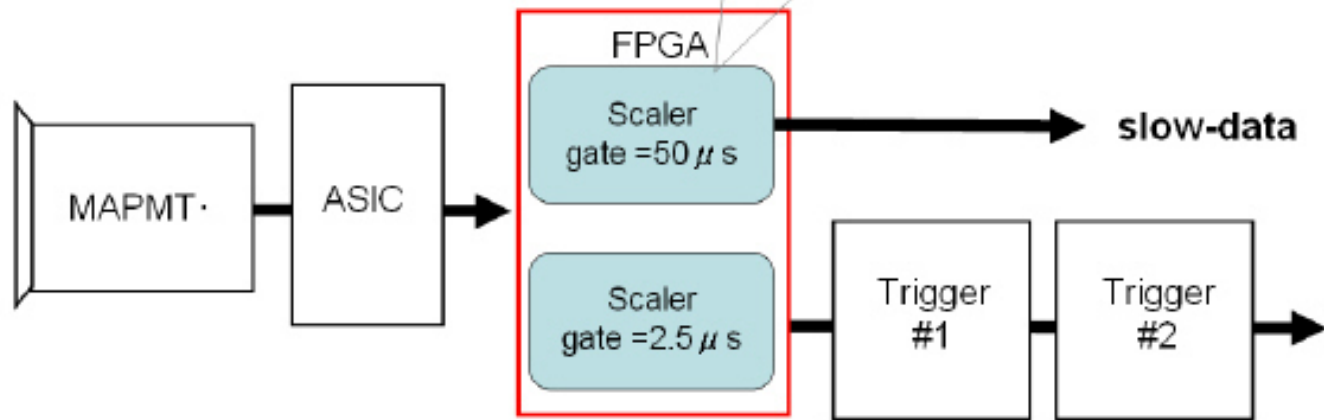
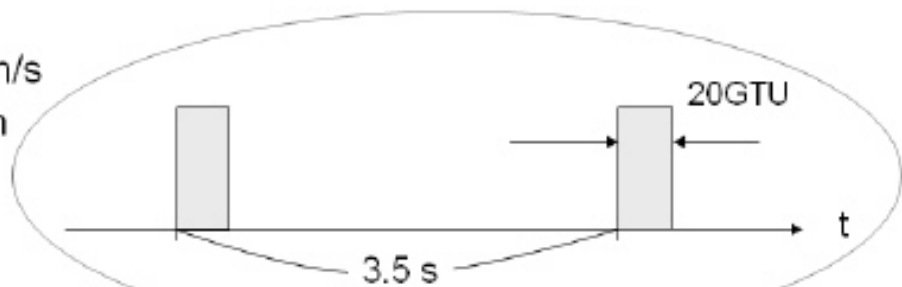
results for
355nm, 0.01sec
integration time,
30m range
resolution

Slow-Data

- All of PDMs equip "slow-data" DAQ
- Continuous BG photon counting



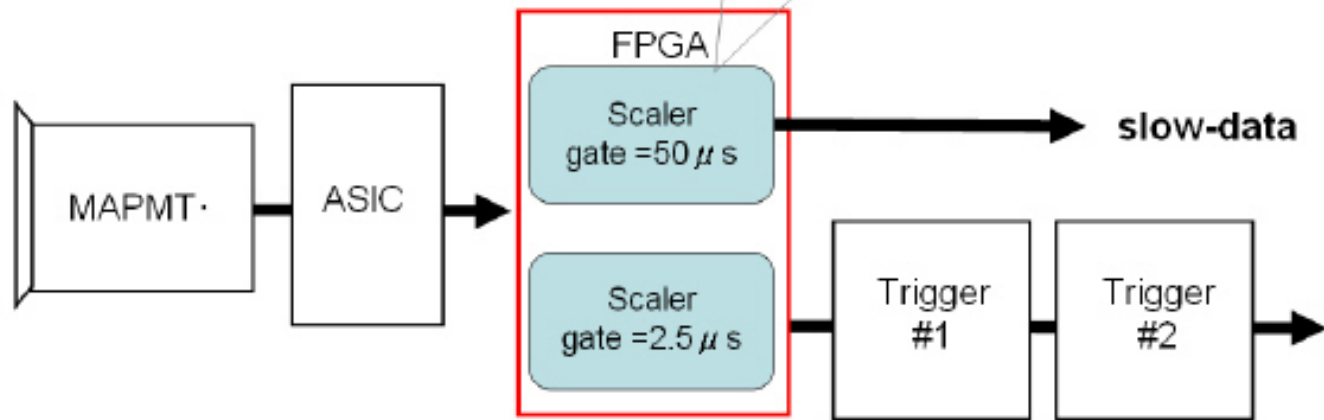
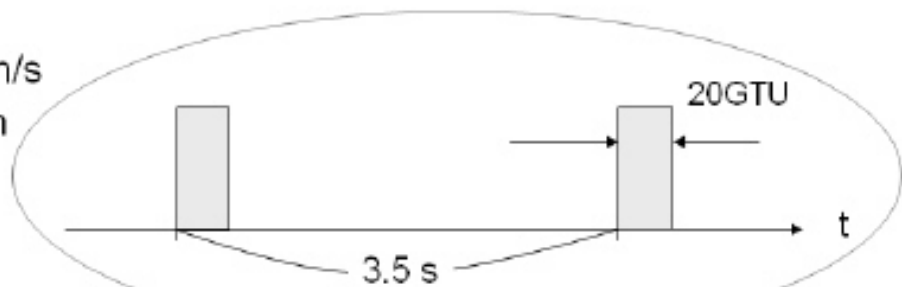
- Velocity of ISS: 7.9 km/s
- FOV of 1PDM: 28.8 km



Slow Data

- 雲頂高度
 - ステレオ測定
- 流星
 - 10等～13等(トリガによる)
 - $1 \sim 10^5$ /day
 - 散在流星数の季節変化
 - 流星群観測(入射角、速度が一定)
- 夜光
- Tatiana UV Flash

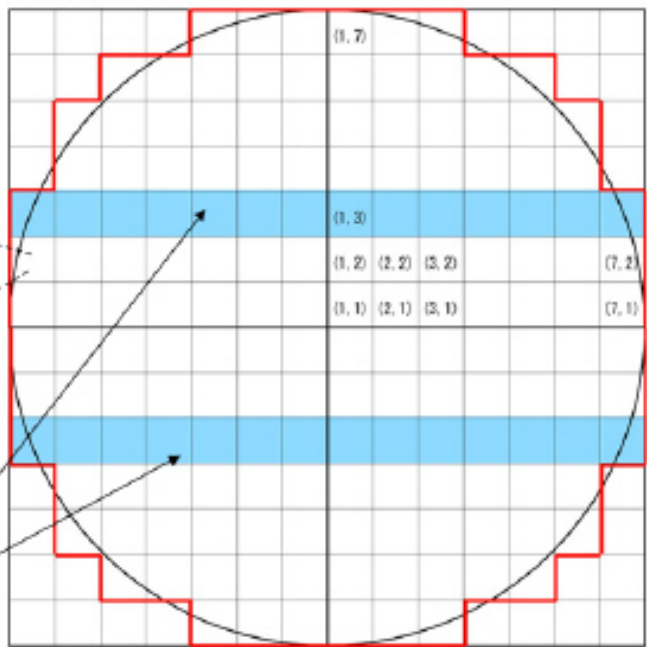
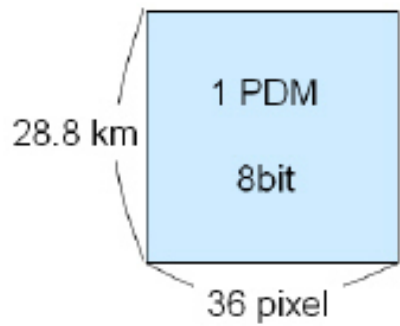
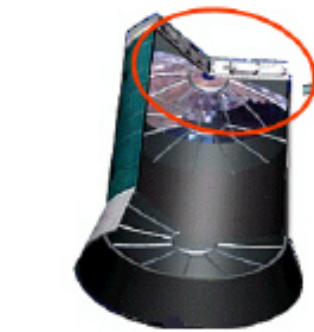
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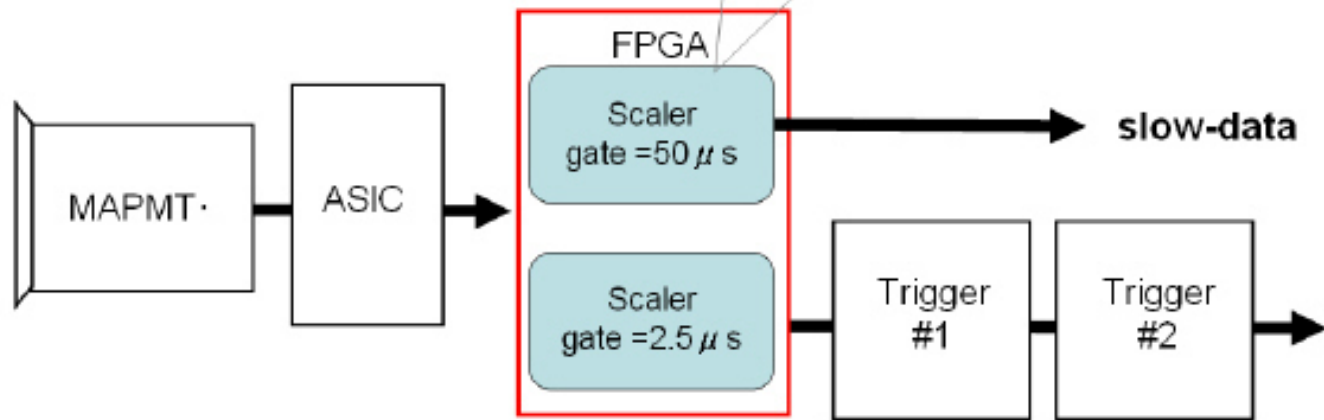
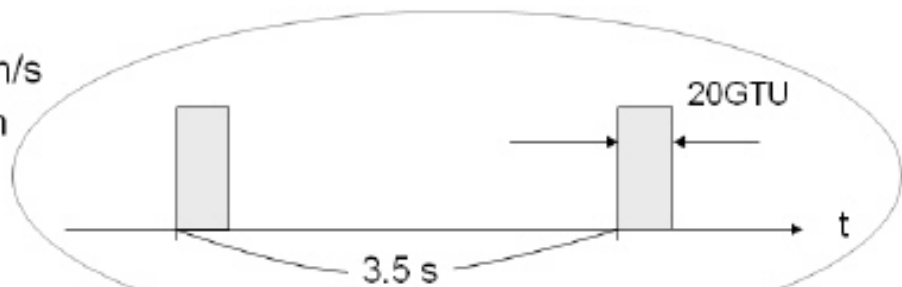
V_{ISS}
↑

JEM-EUSO FS



Slow-data obtained at only 2 PDM lines will be stored!

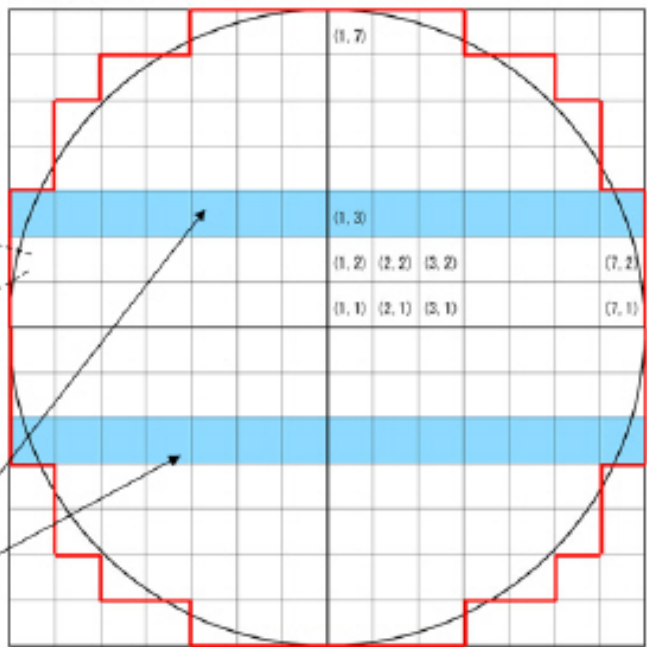
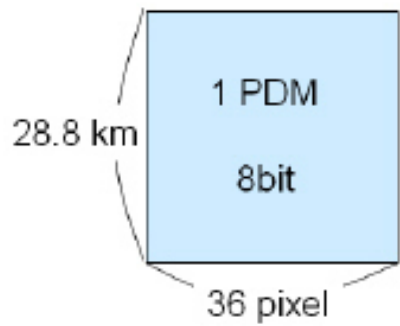
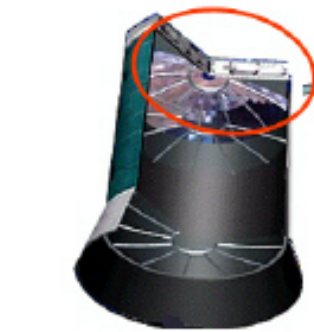
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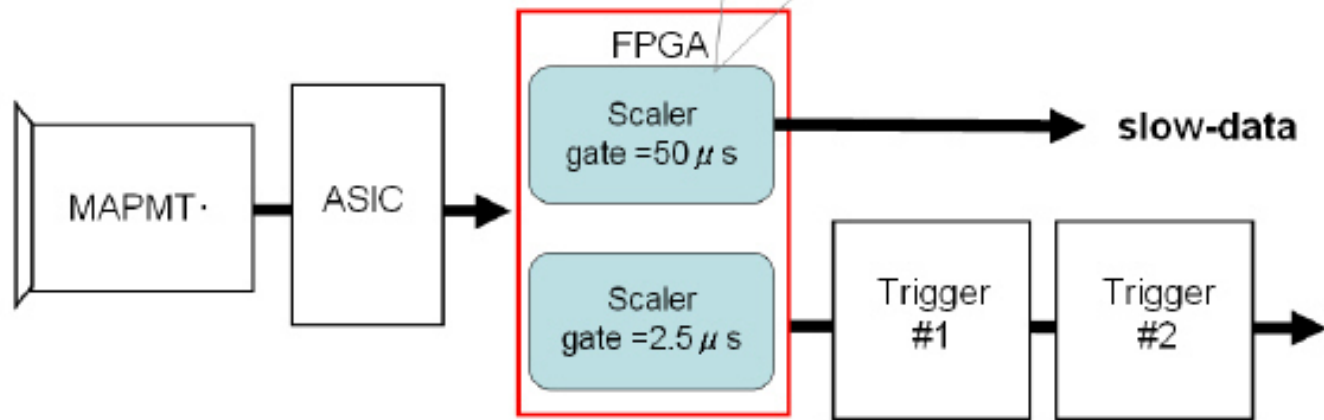
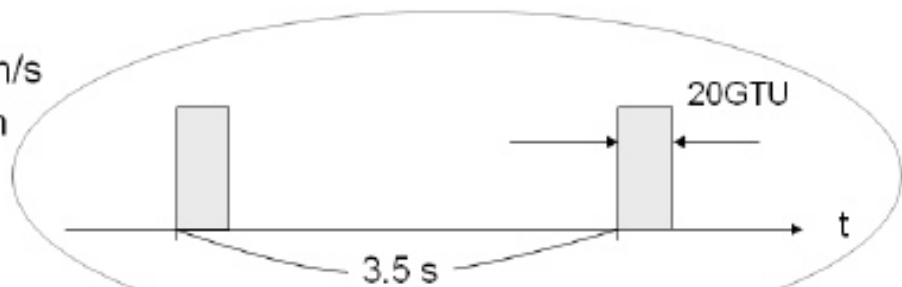
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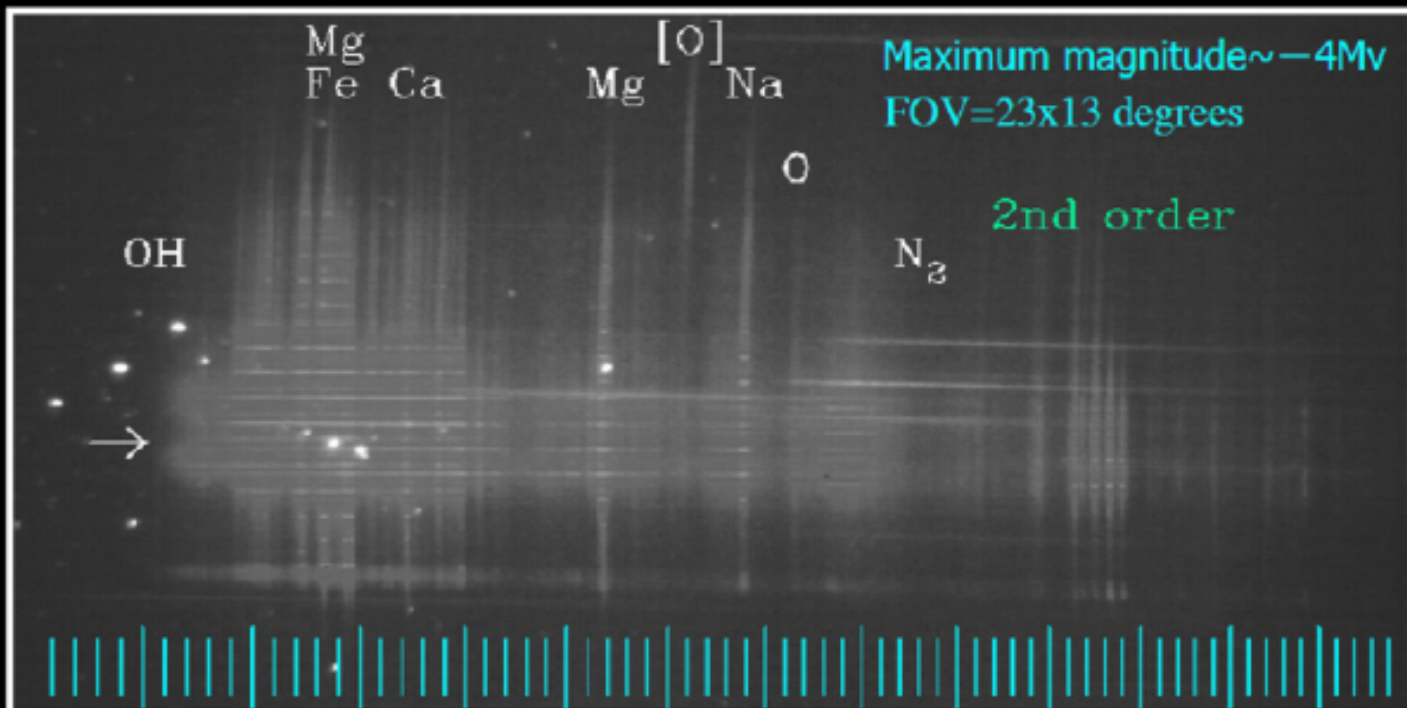
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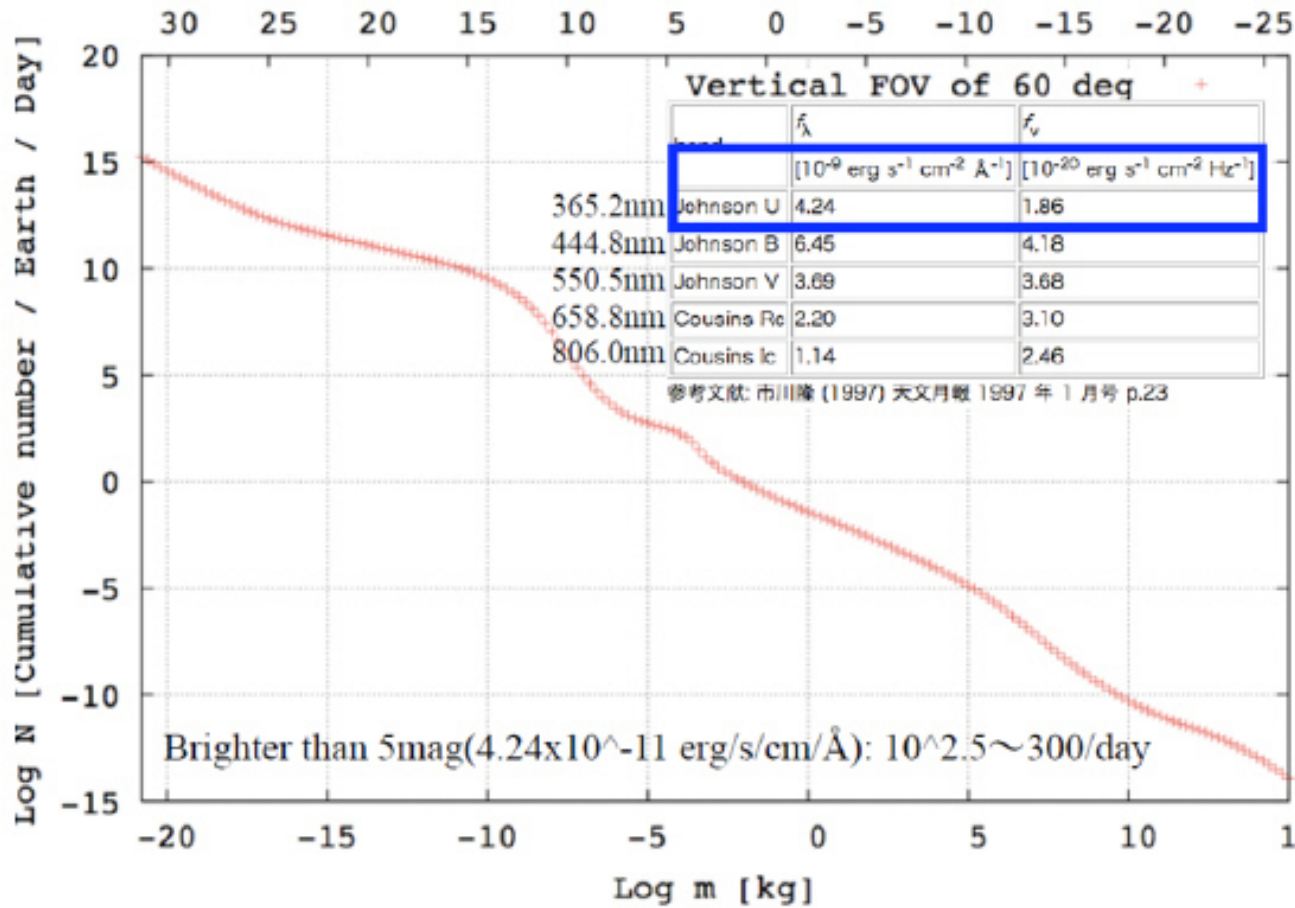
HDTV Spectrum of 2001 Leonid Meteor



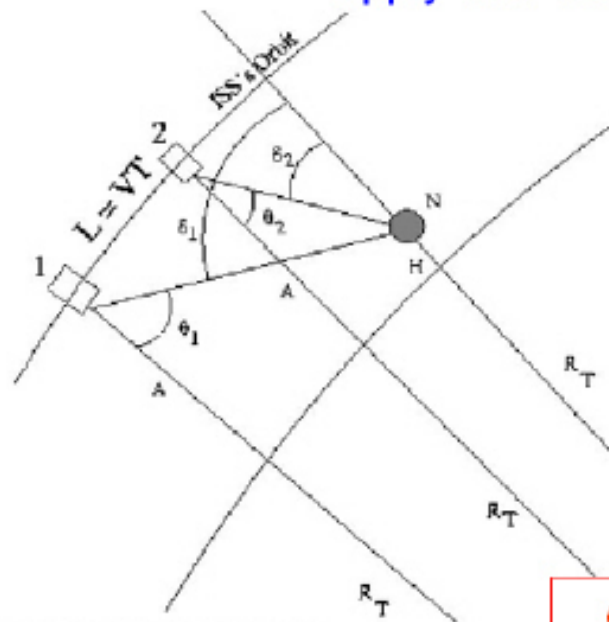
300 350 400 450 500 550 600 650 700 750 800 850 900

wavelength (nm)

Magnitude from ISS



- Photon counting of background photons
 - Continuous measurements with the ISS motion
- Apply the “stereoscopic vision” method



Background photons

$$I = 500 \text{ (ph/m}^2\text{/str/ns)}$$

Detected photoelectrons

$$N_{p.e.} = 1 \text{ (p.e./pix/GTU)}$$

Expected slow-data counts

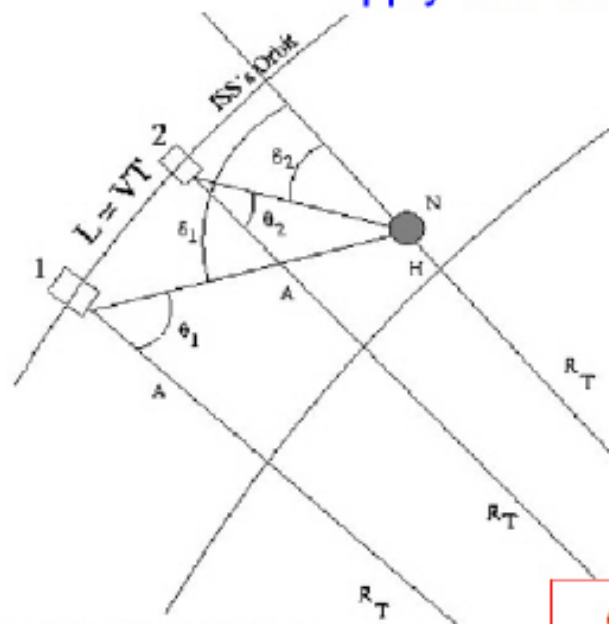
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Cloud top altitude: $\Delta h \approx 1 \text{ km}$

Specification

Item	Value	Reference
Wavelength	330 – 400 nm	Same as JEM-EUSO detector
Spatial res.	800m x 800m	
Detector	MAPMTs	
Resolution	8 bit	
Cloud top altitude determination res.	~ 1 km	IFOV of 1-pixel
Exposure gate time	50 μ sec	= 20GTU
Time interval	3.5 sec	ISS travel time of 1-PDM FOV
Data rate	35 kbps	

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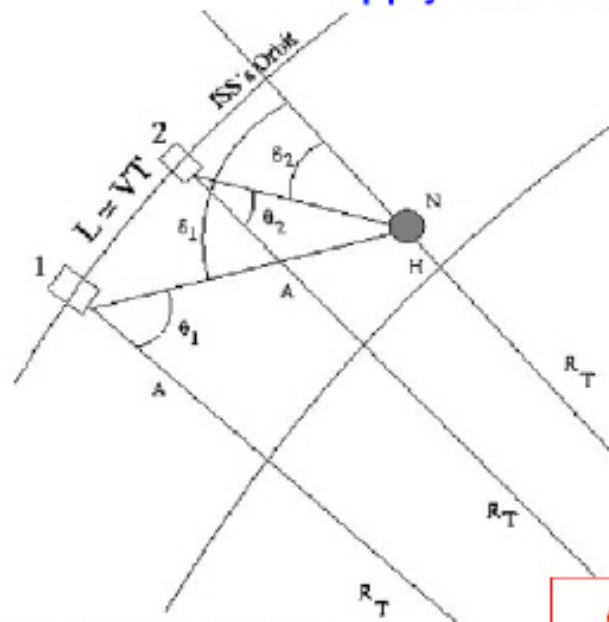
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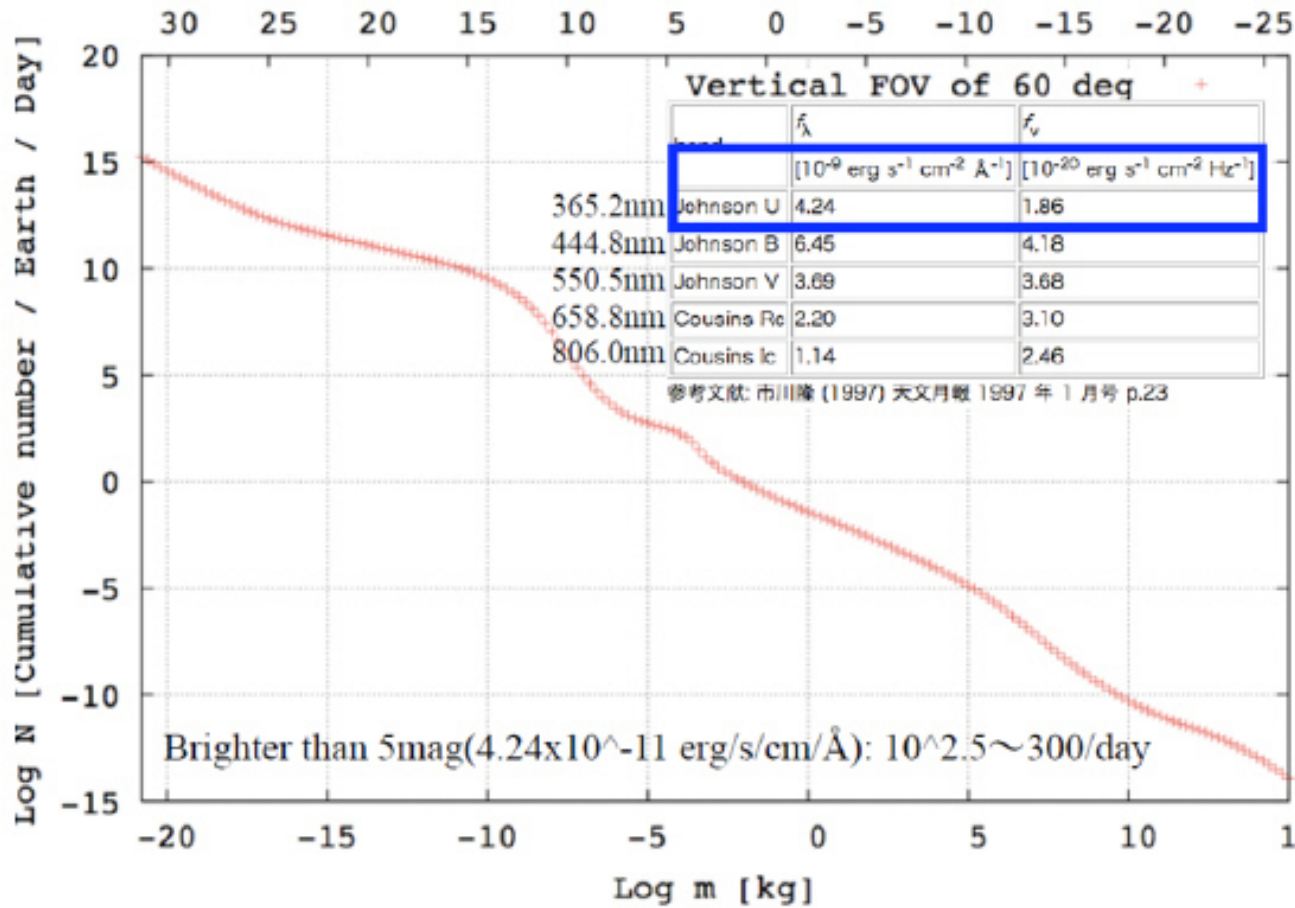
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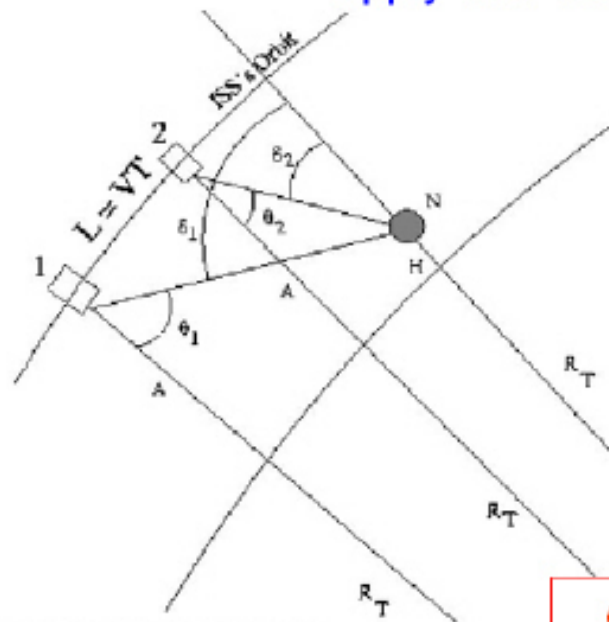
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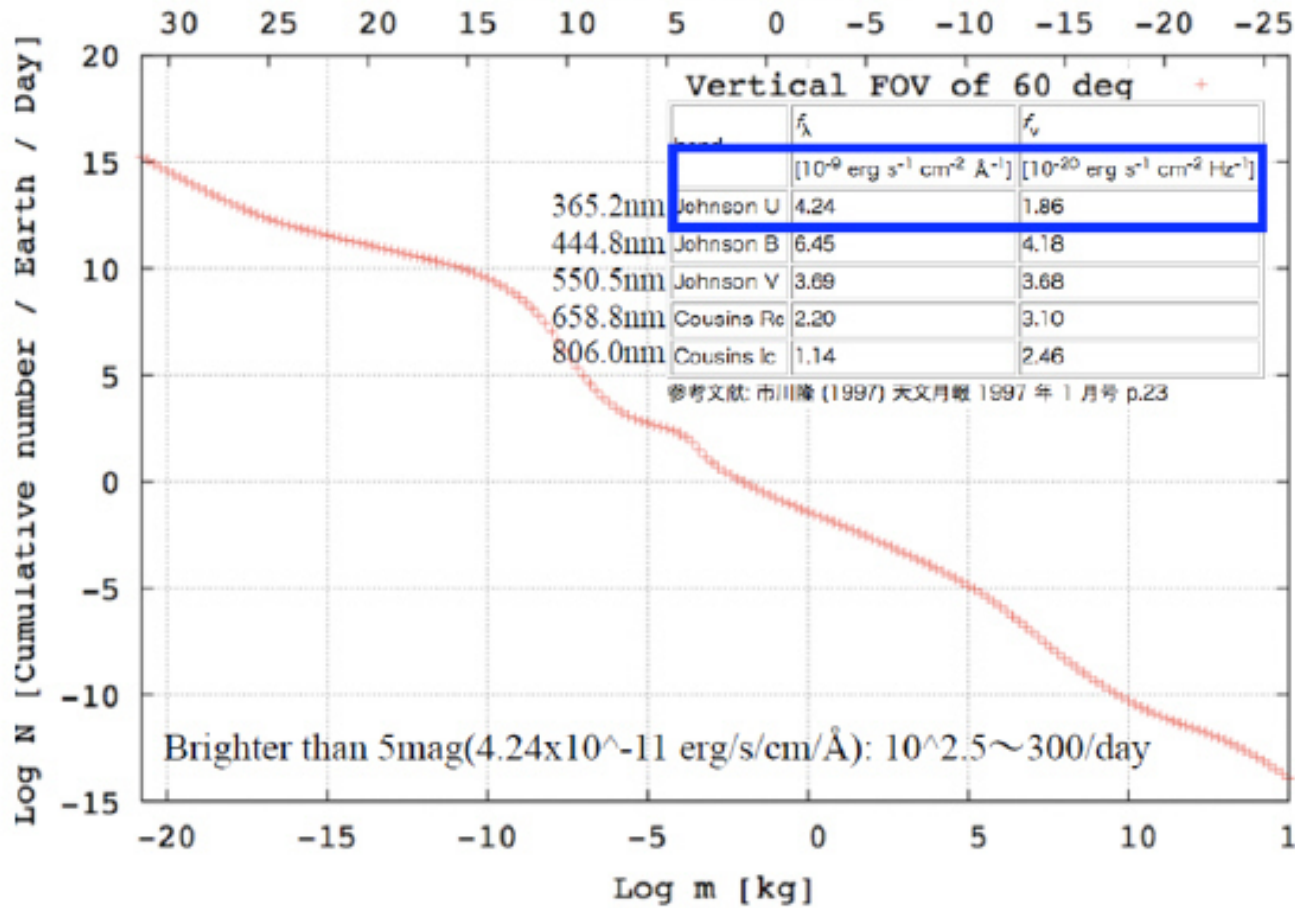
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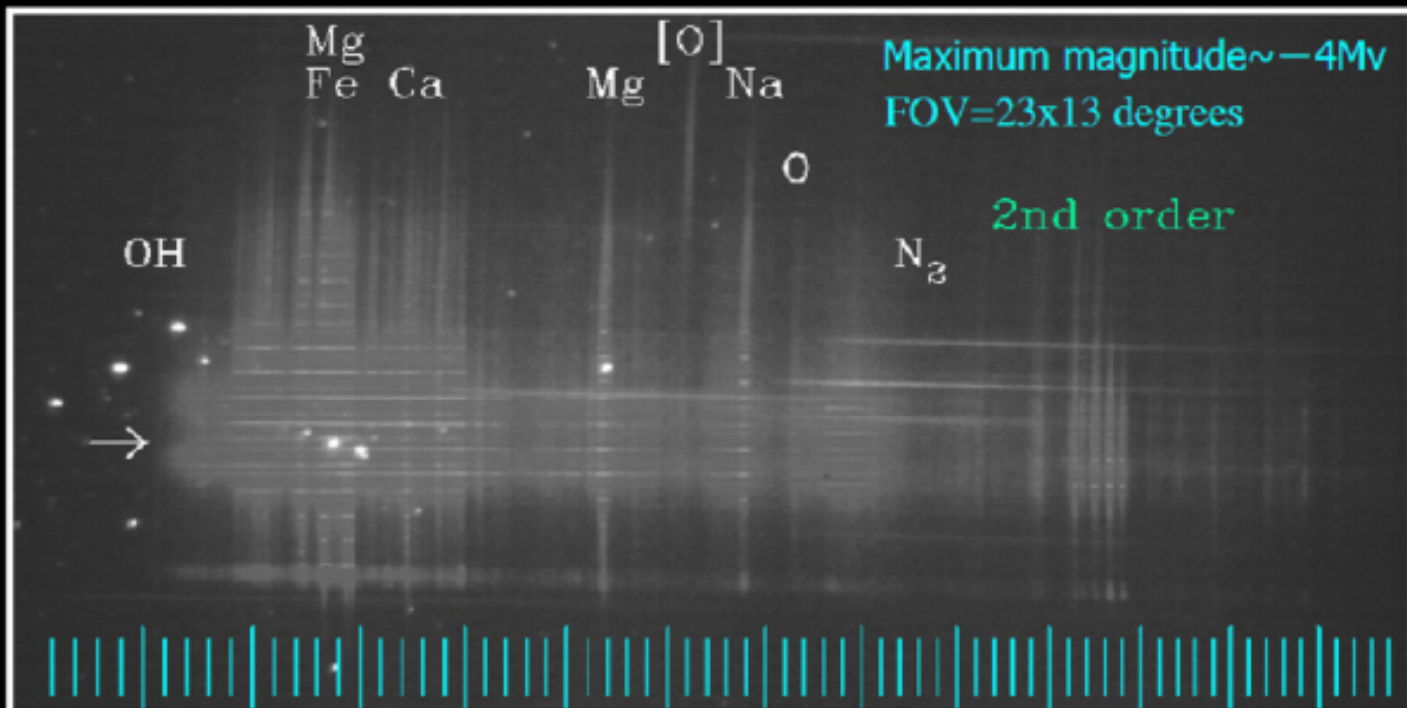
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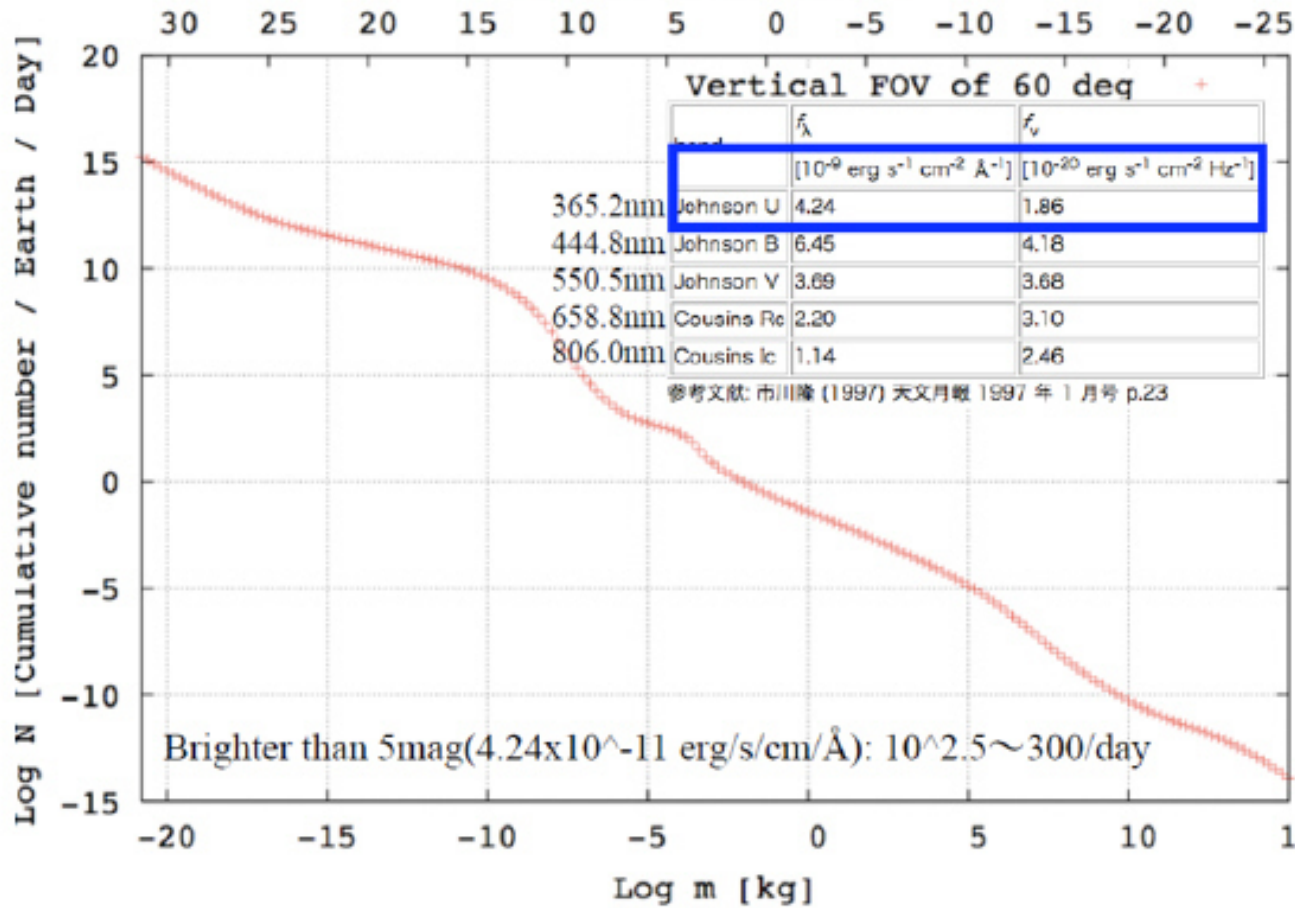
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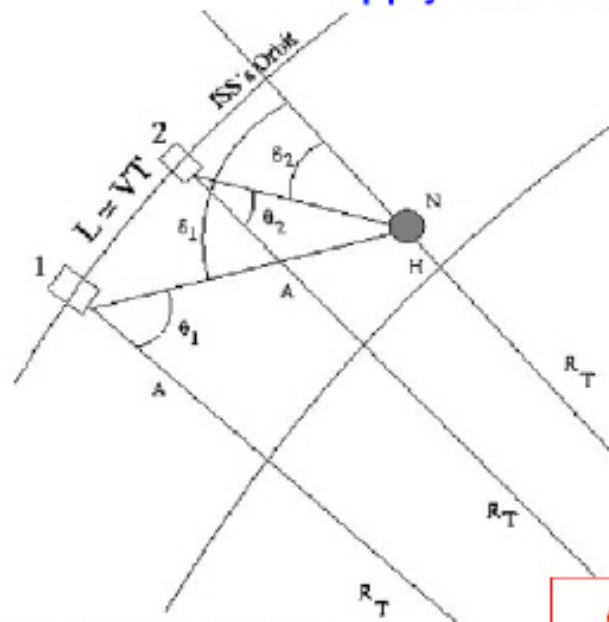
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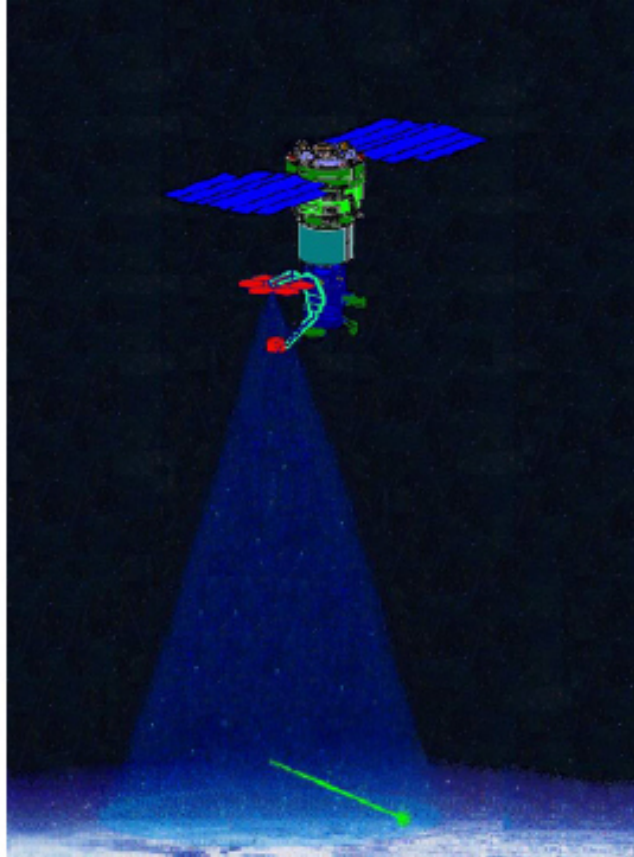
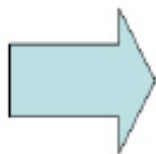
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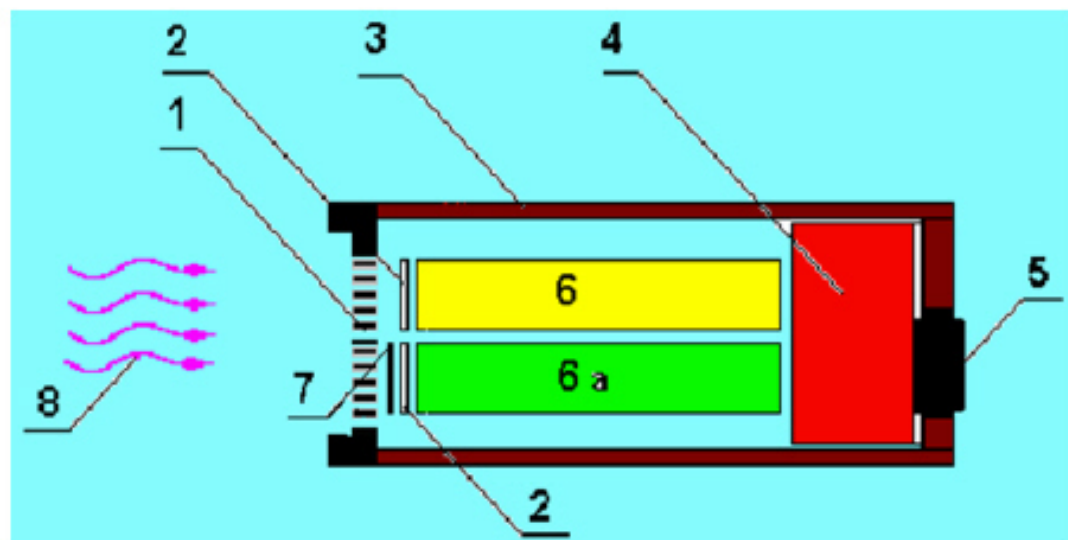
Tatiana UV Flash

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The results of satellite
"Tatiana" launched in
January 2005 are
important for planning
TUS.



The detector of UV radiation



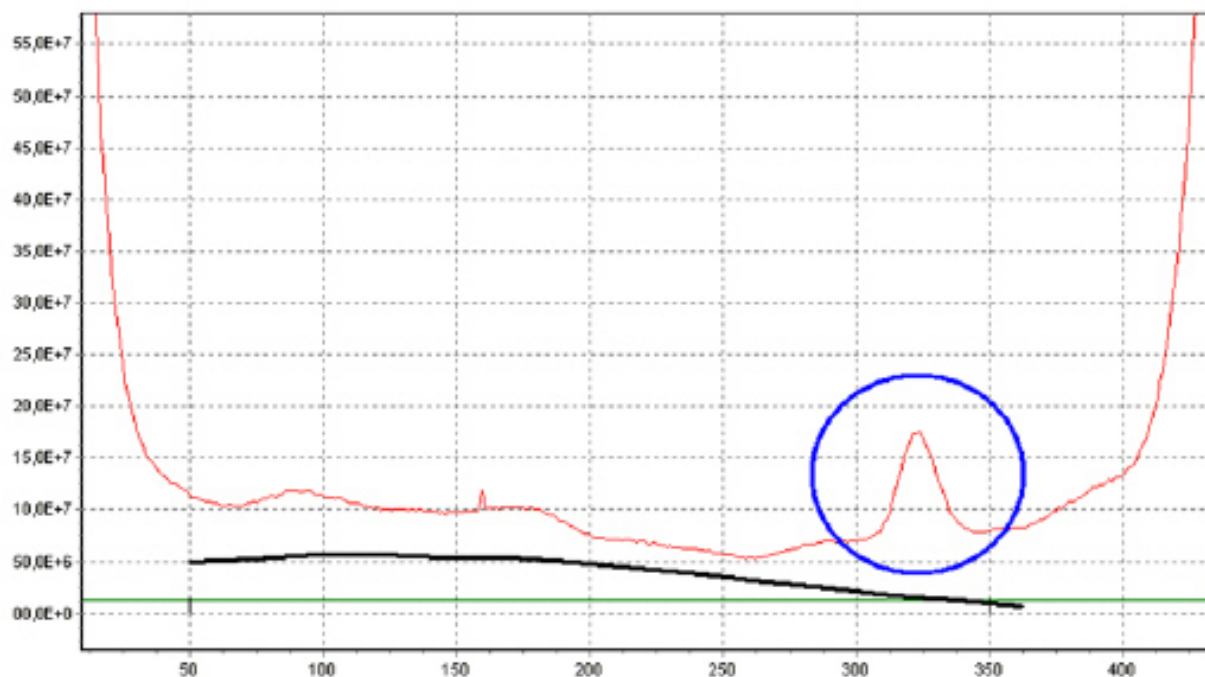
Some detector parameters:

FOV: 15°

$S = 0,4 \text{ c m}^2$.

UV filter: 200 – 400 nm

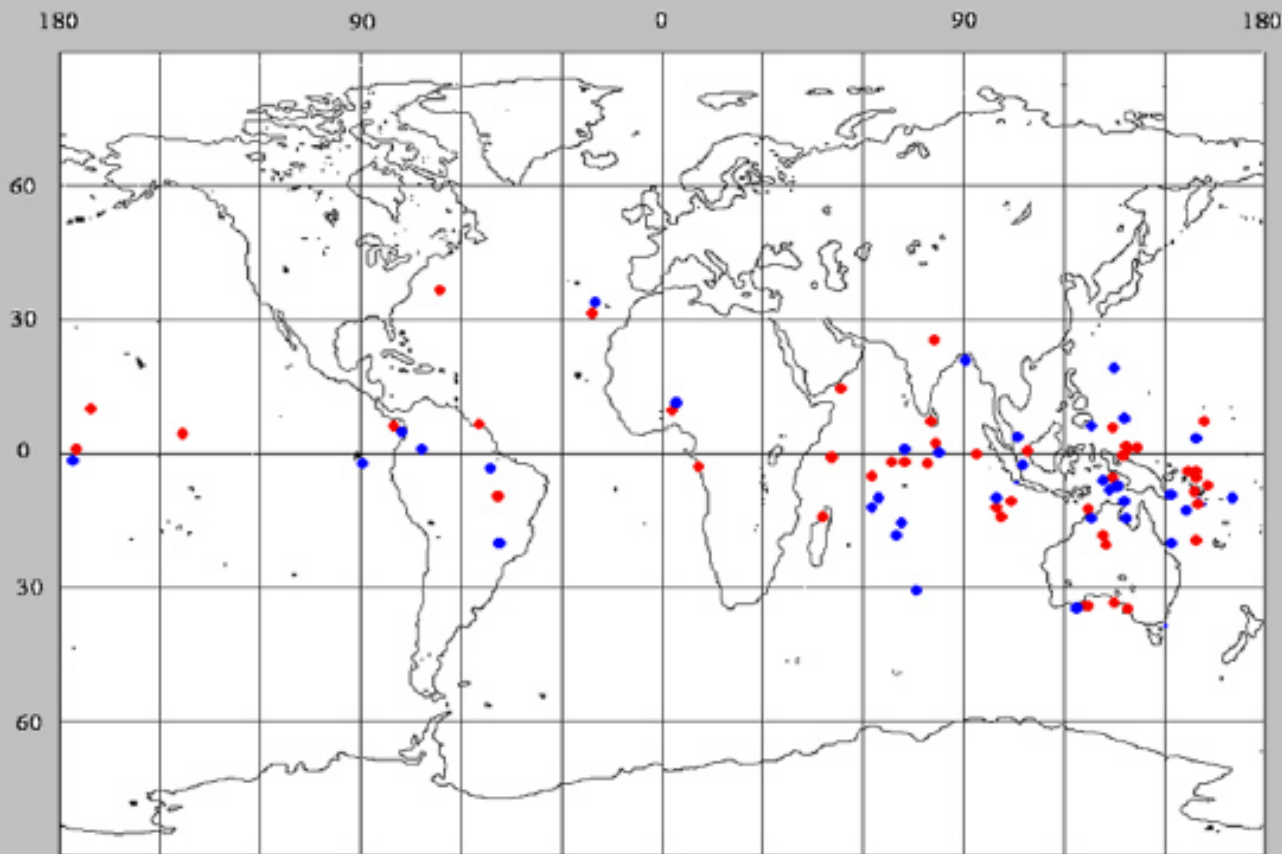
Examples of satellite "Tatiana" data



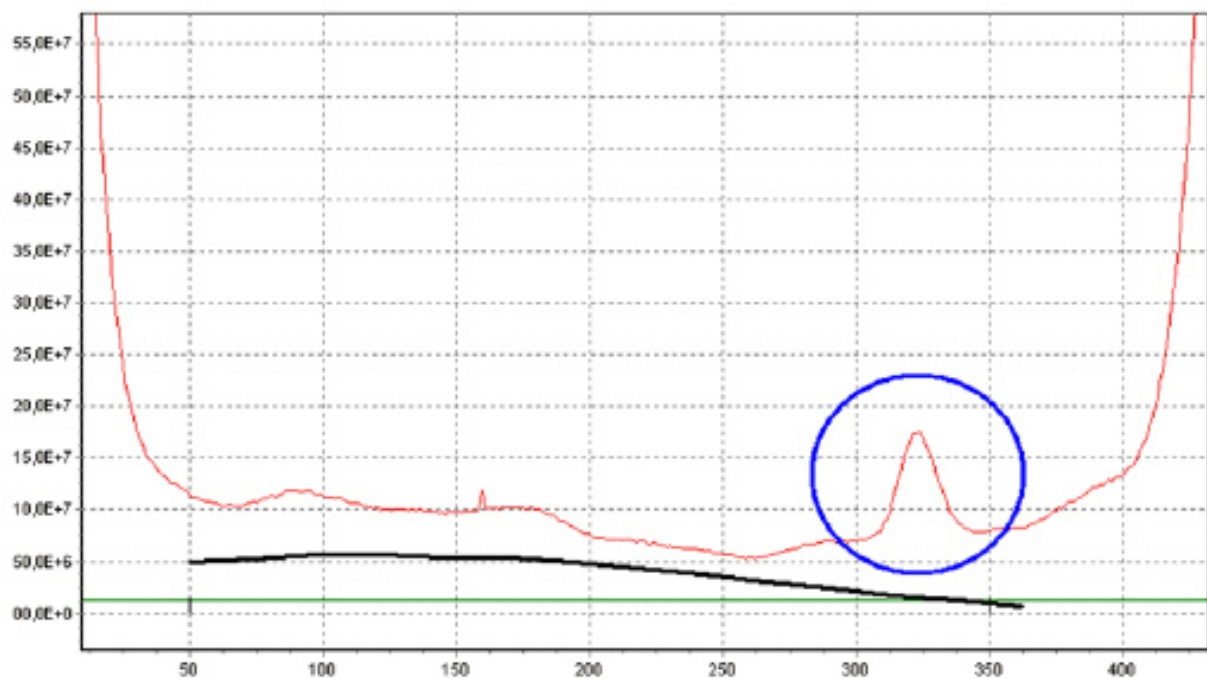
13.02.2005

Moon phase 25 %, Blue oval – the satellite is above Japan.

The geographical distribution of UV flashes



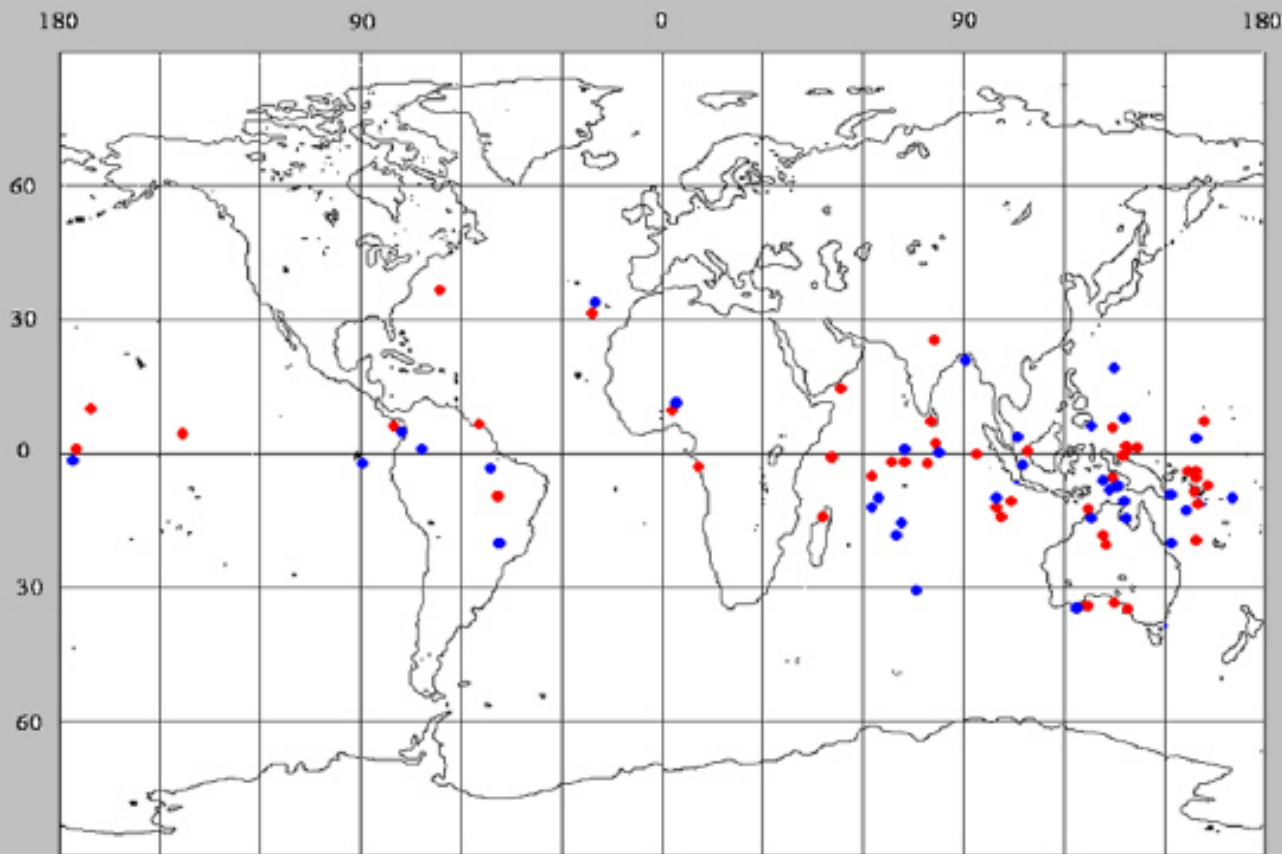
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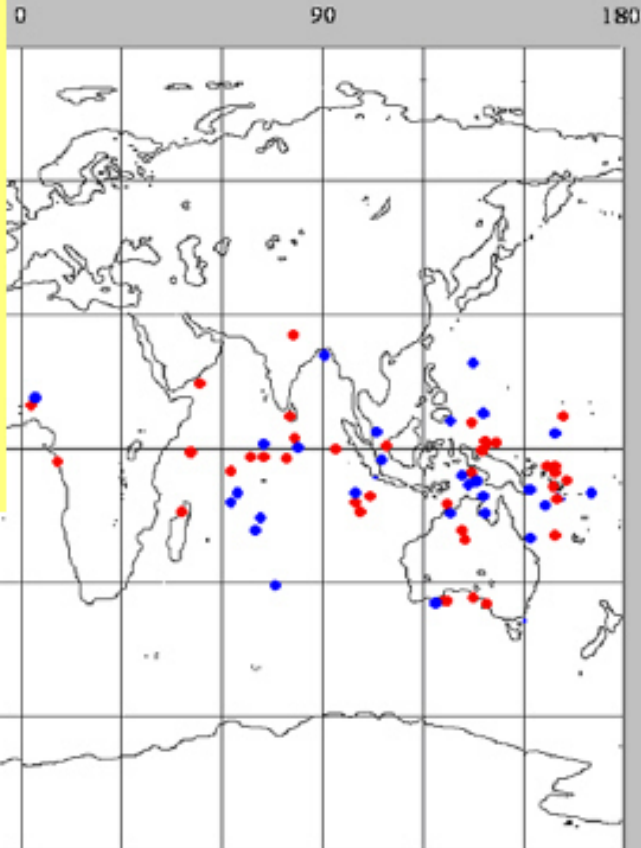
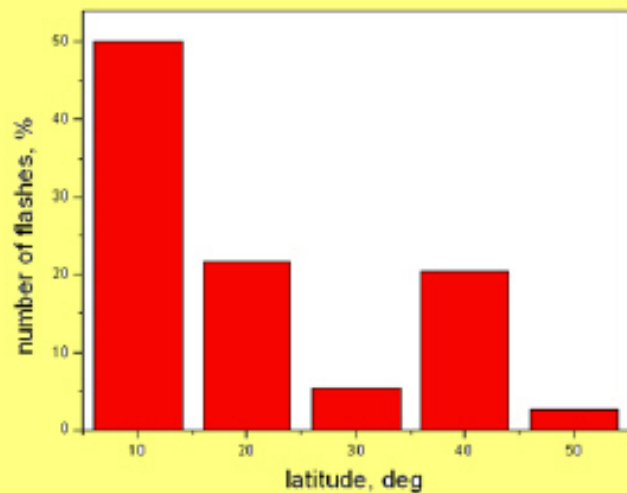
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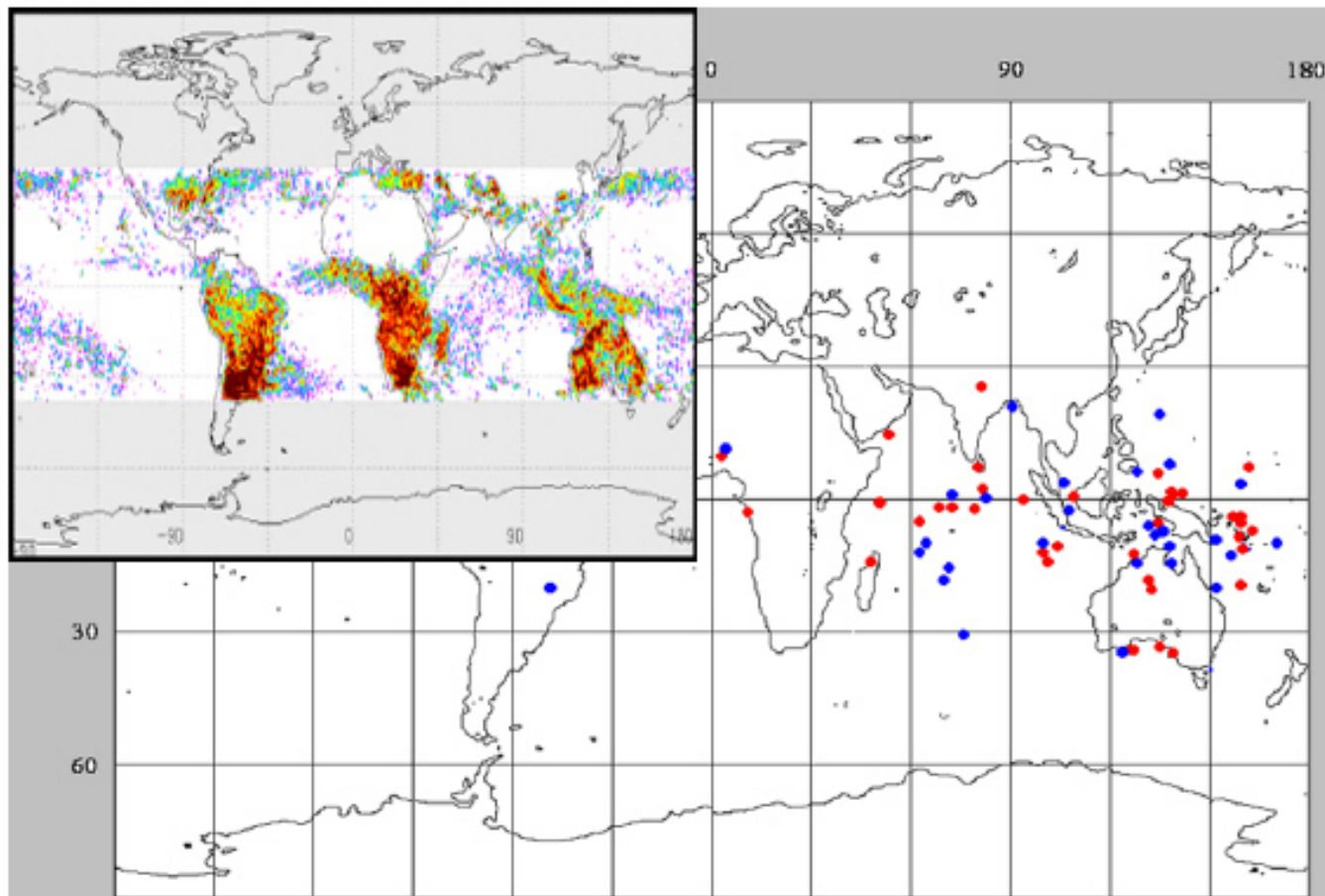
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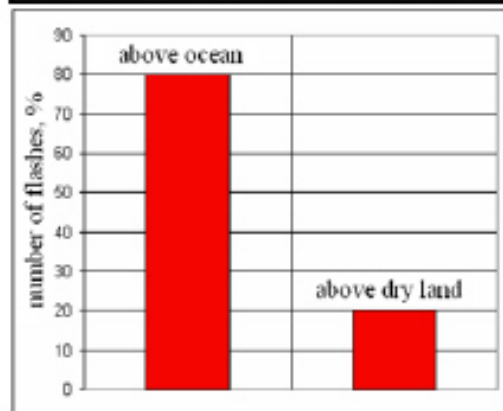
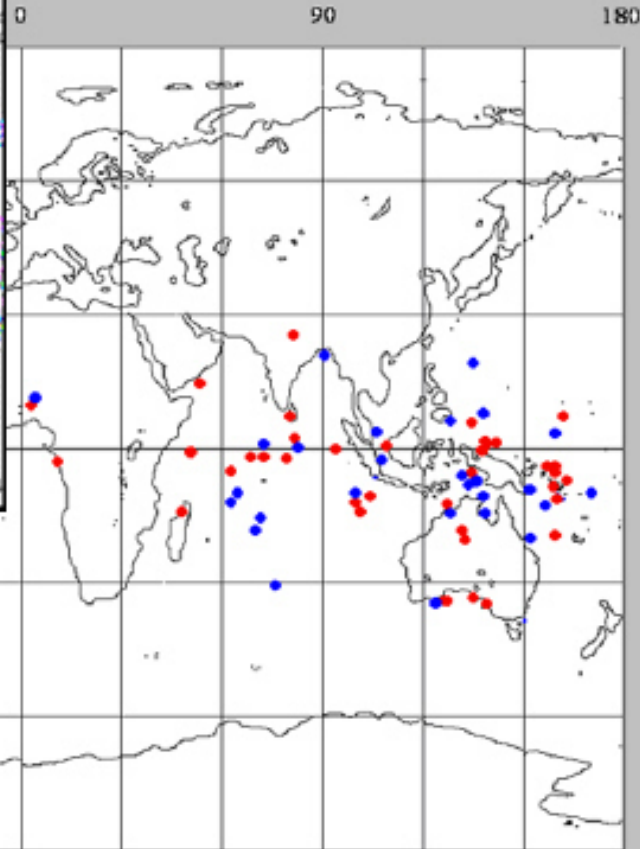
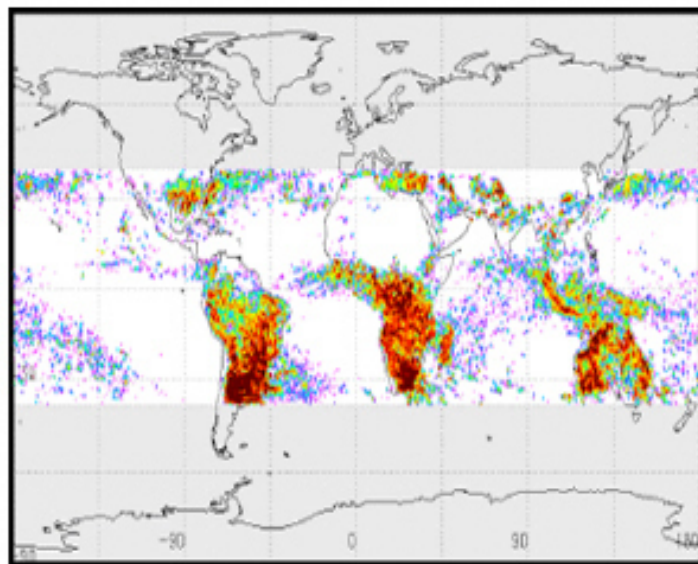
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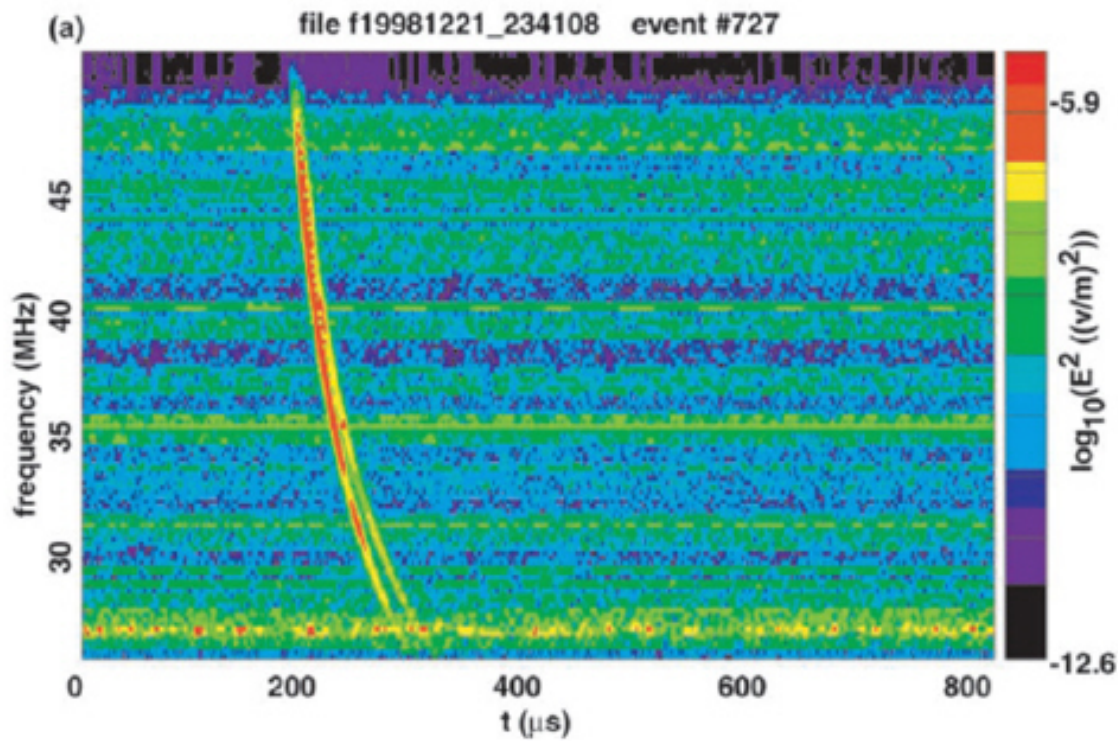
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Narrow Bipolar Event

- FORTE衛星によるVHF観測
- 孤立した電波パルスイベント
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 - $T < 1 \mu s$
 - 10J-100J
- 可視光に対応する閃光パルスなし
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NBEの伝播効果



NBEの空間分布

海上に多い？！

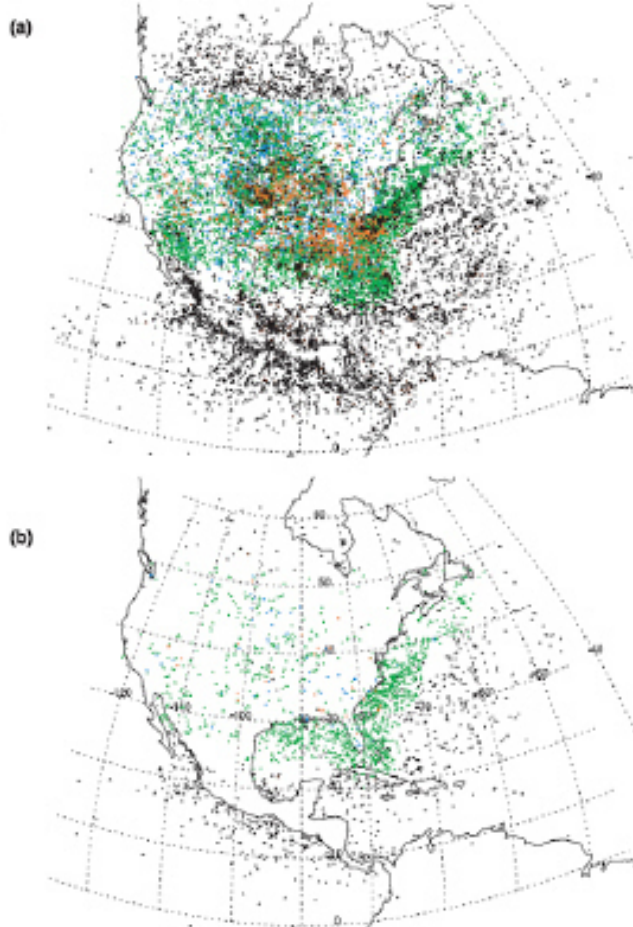
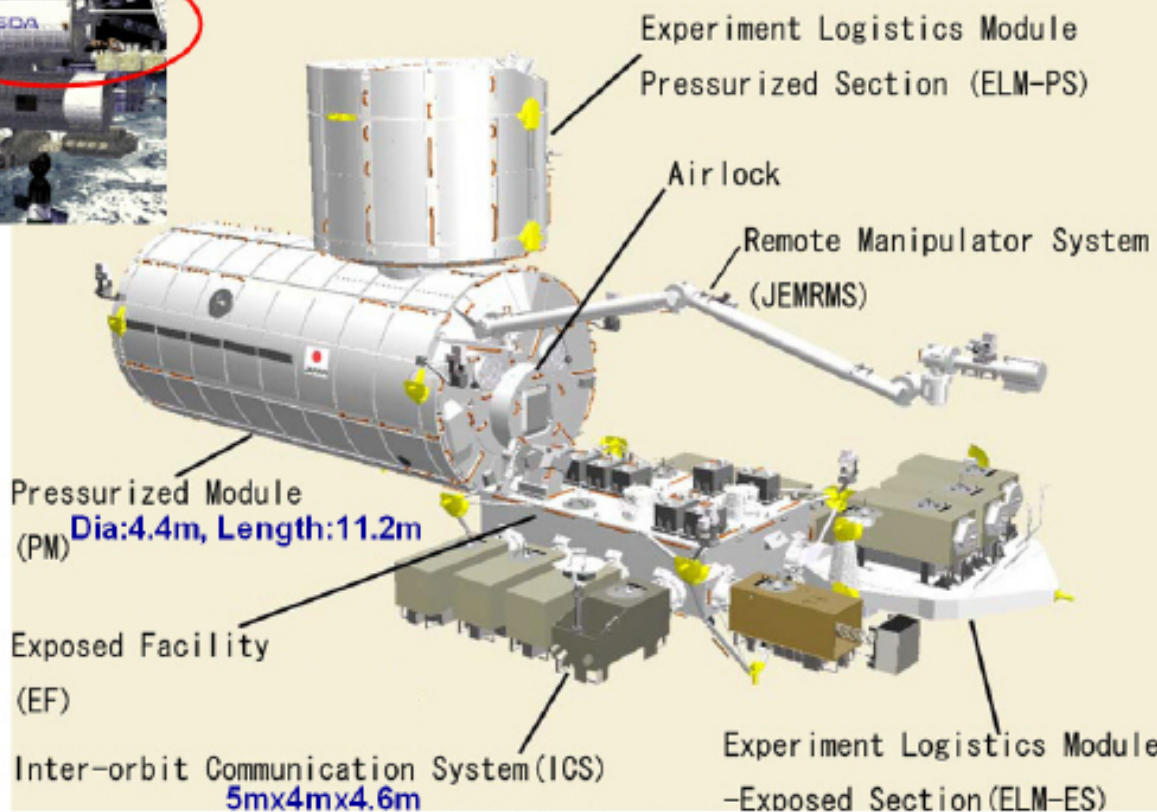
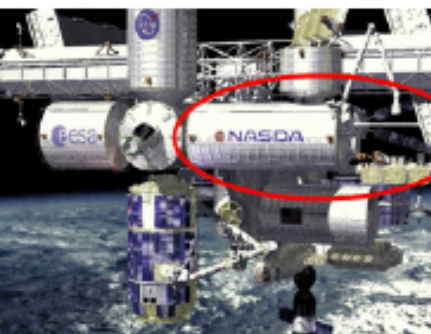


Figure 1. (a) Map of ~25,000 NLDN stroke locations that are accompanied by closely coincident FORTE VHF events. The stroke type is marked in color: green is -CG, blue is +CG, red is IC, and black is uncharacterized type (due to the nearest participating NLDN station being >625 km from the stroke). (b) Similar, but for the ~2,400 FORTE VHF events meeting the automatic selection criteria to qualify as extremely narrow pulses.

日本実験棟「きぼう」



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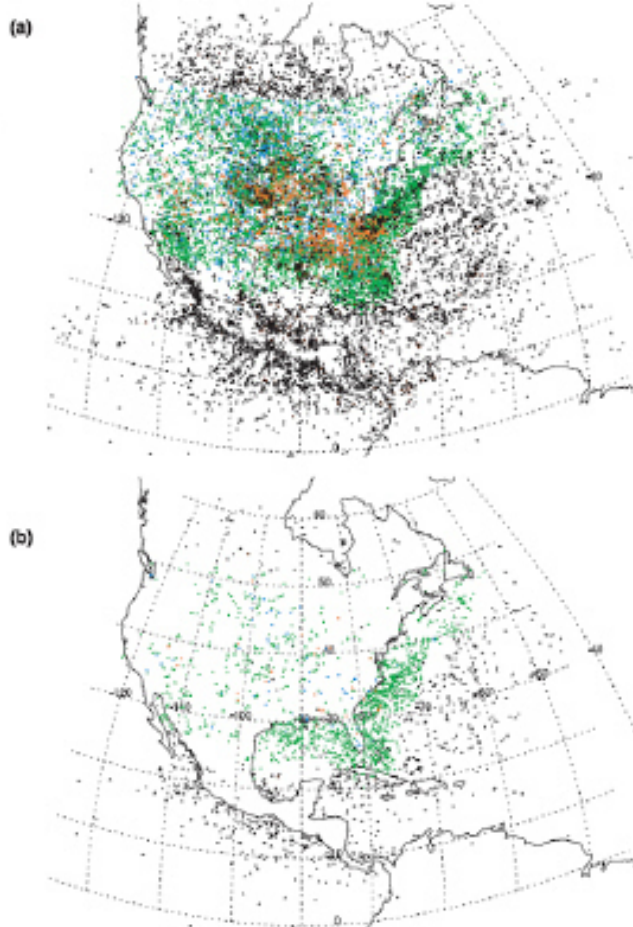
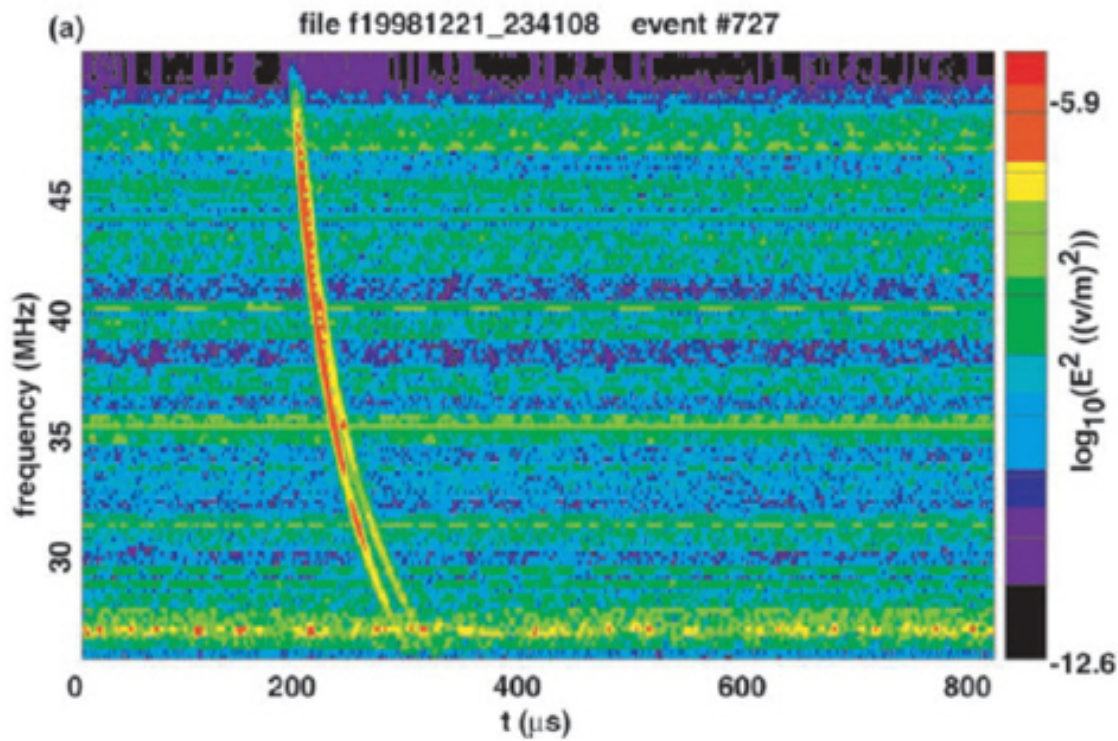


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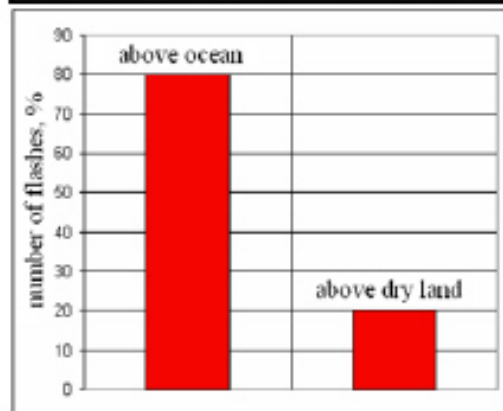
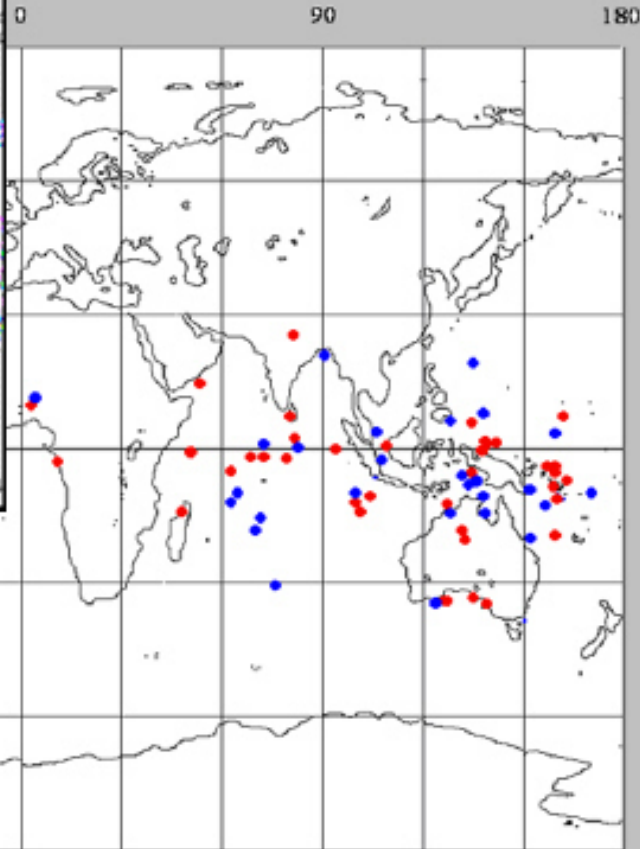
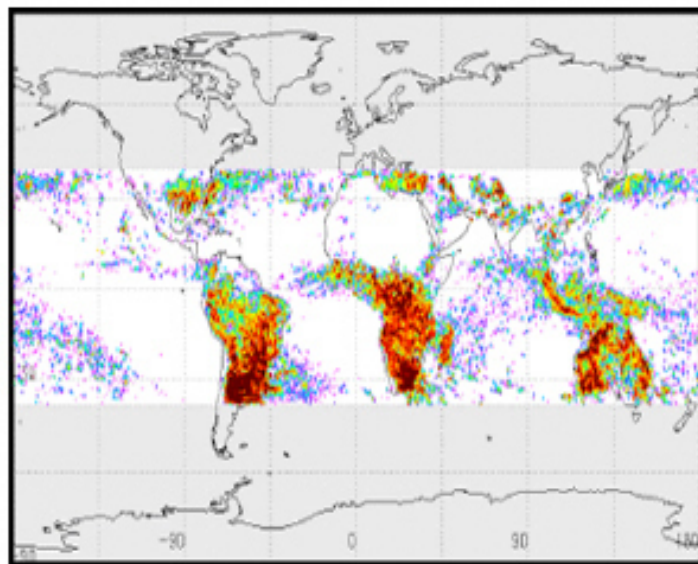
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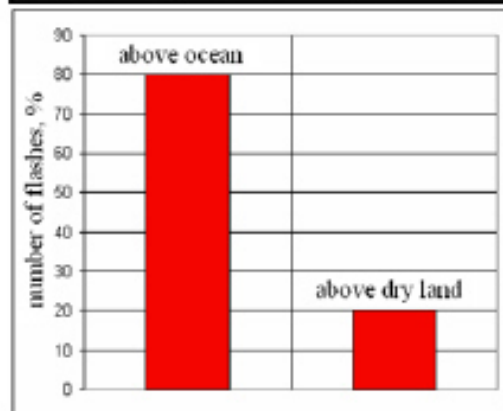
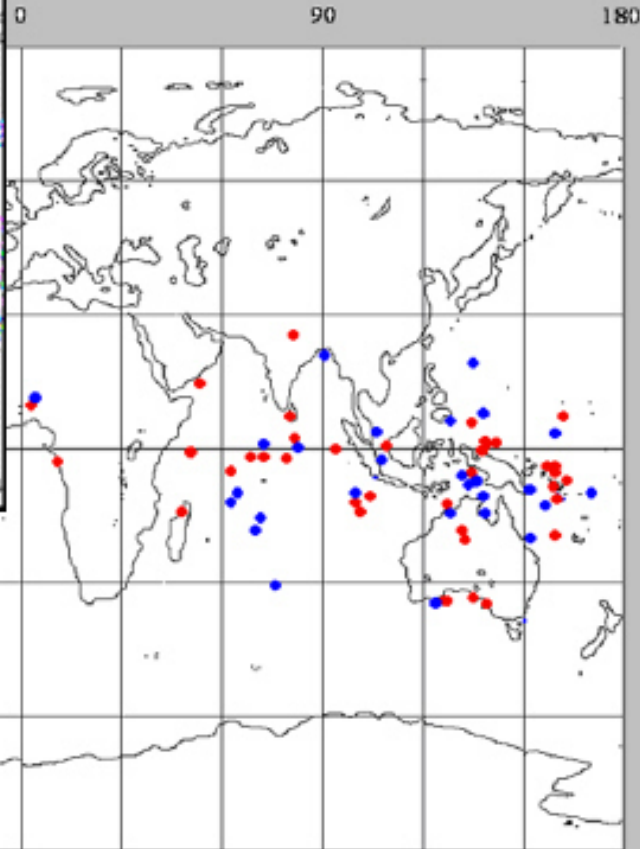
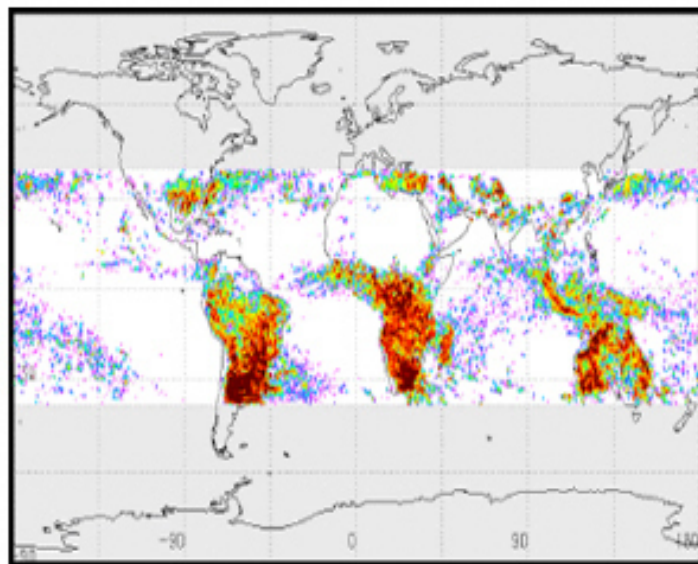
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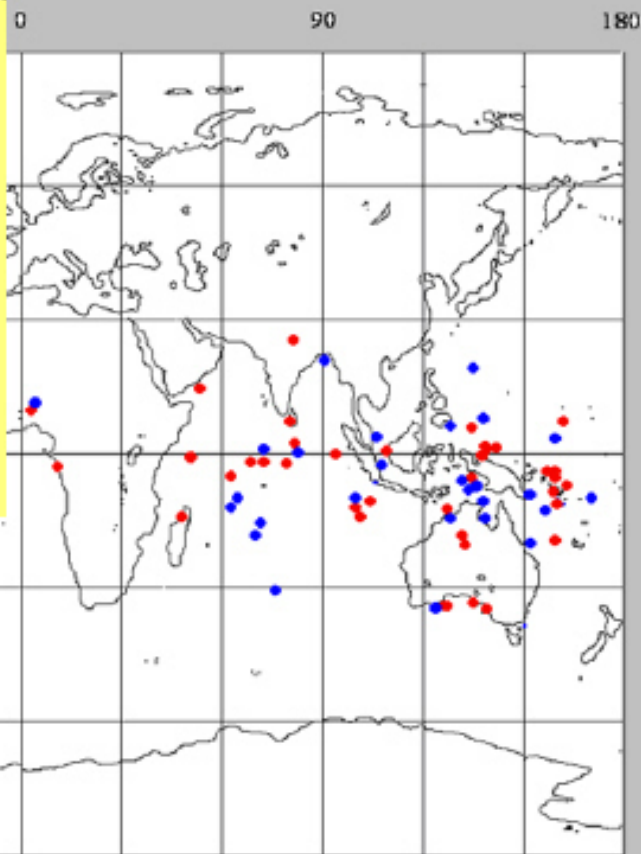
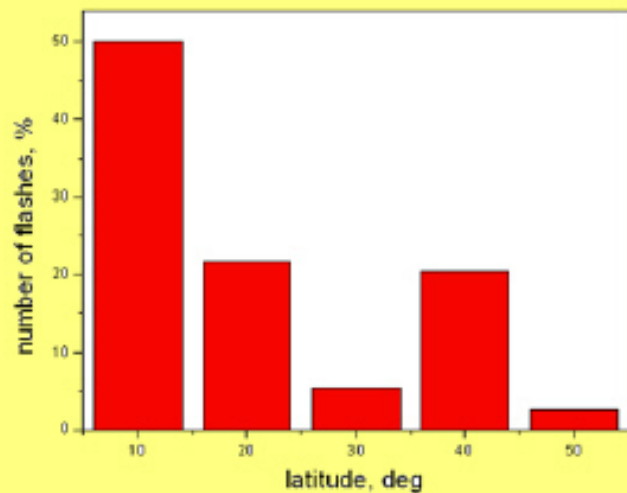
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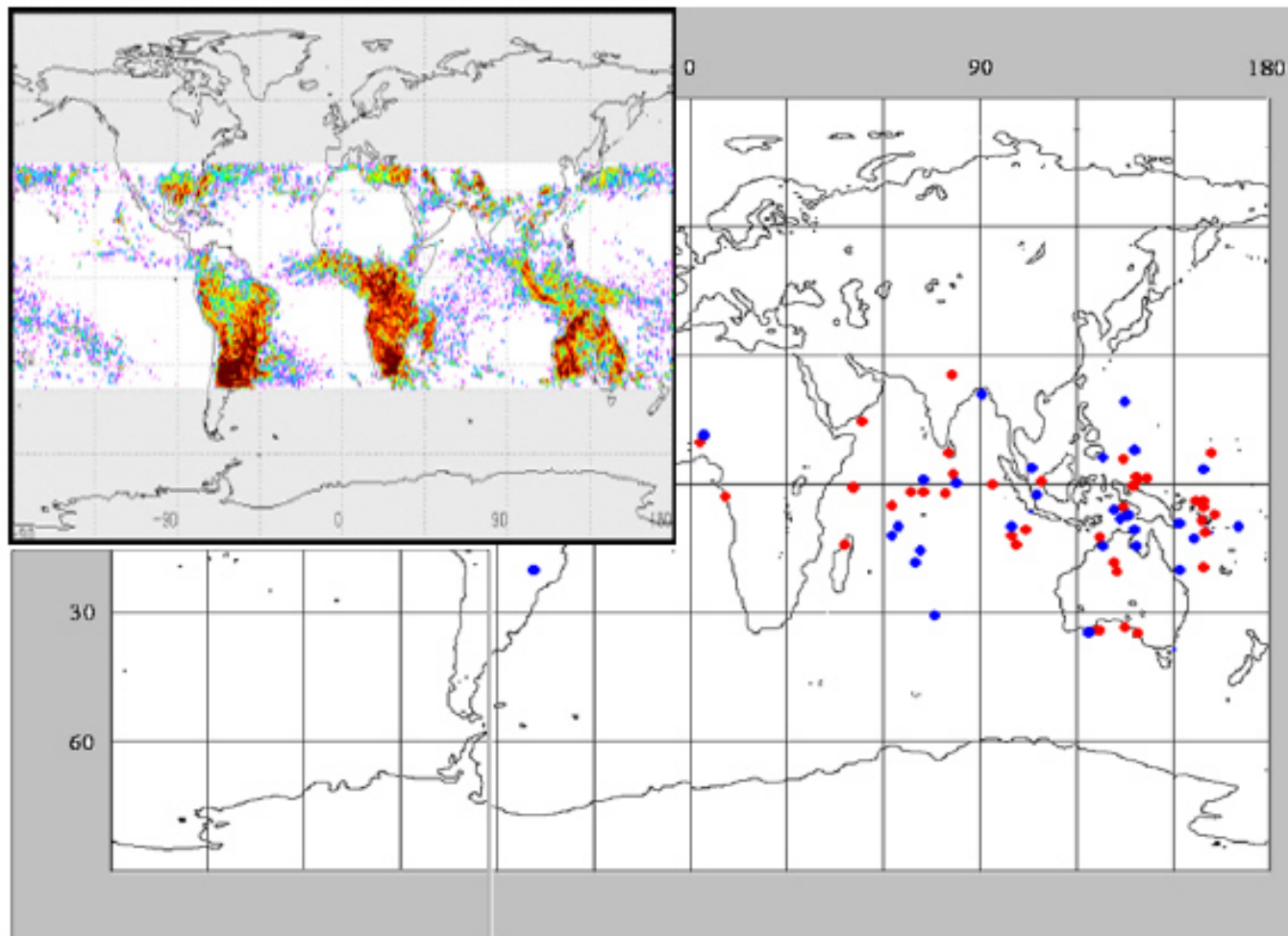
The geographical distribution of UV flashes



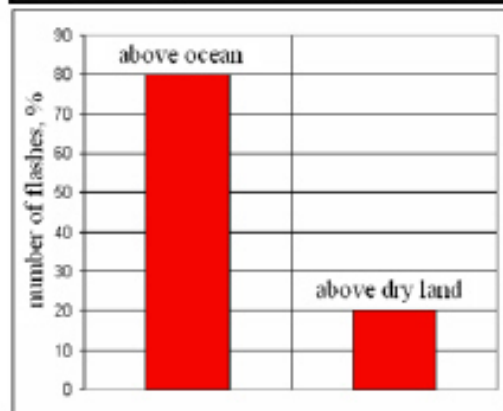
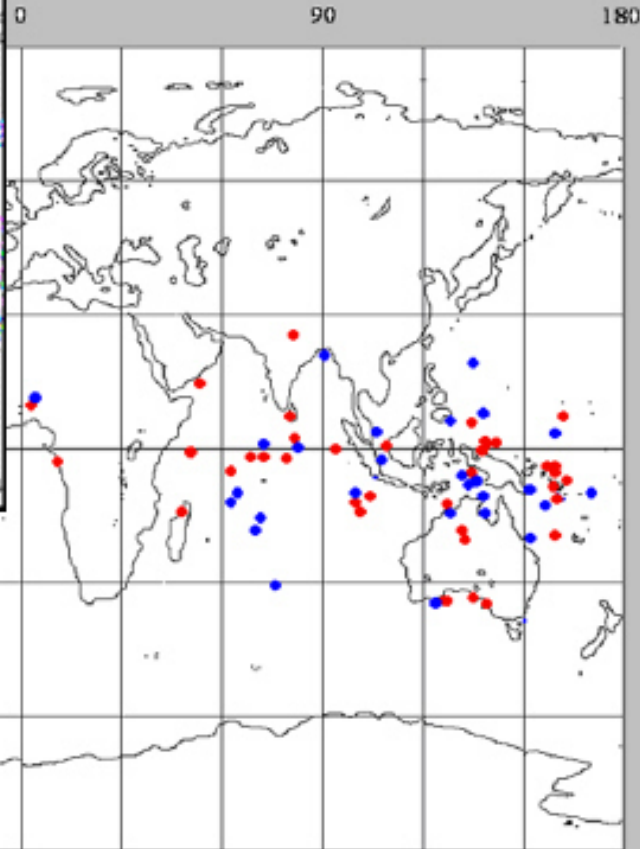
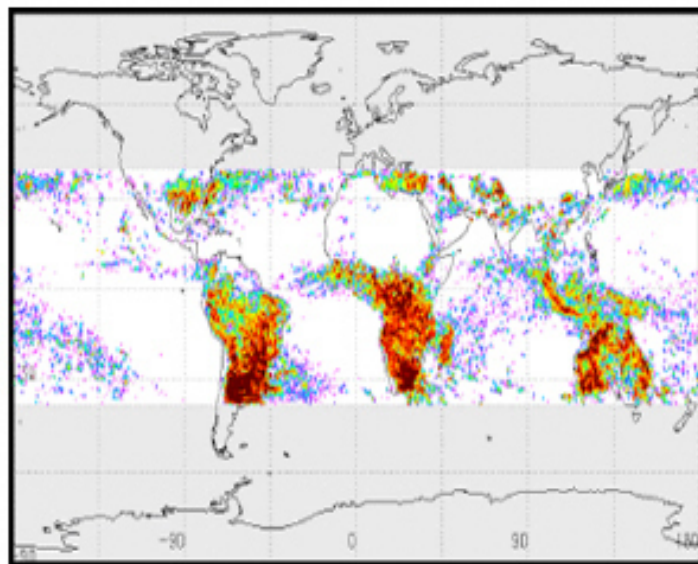
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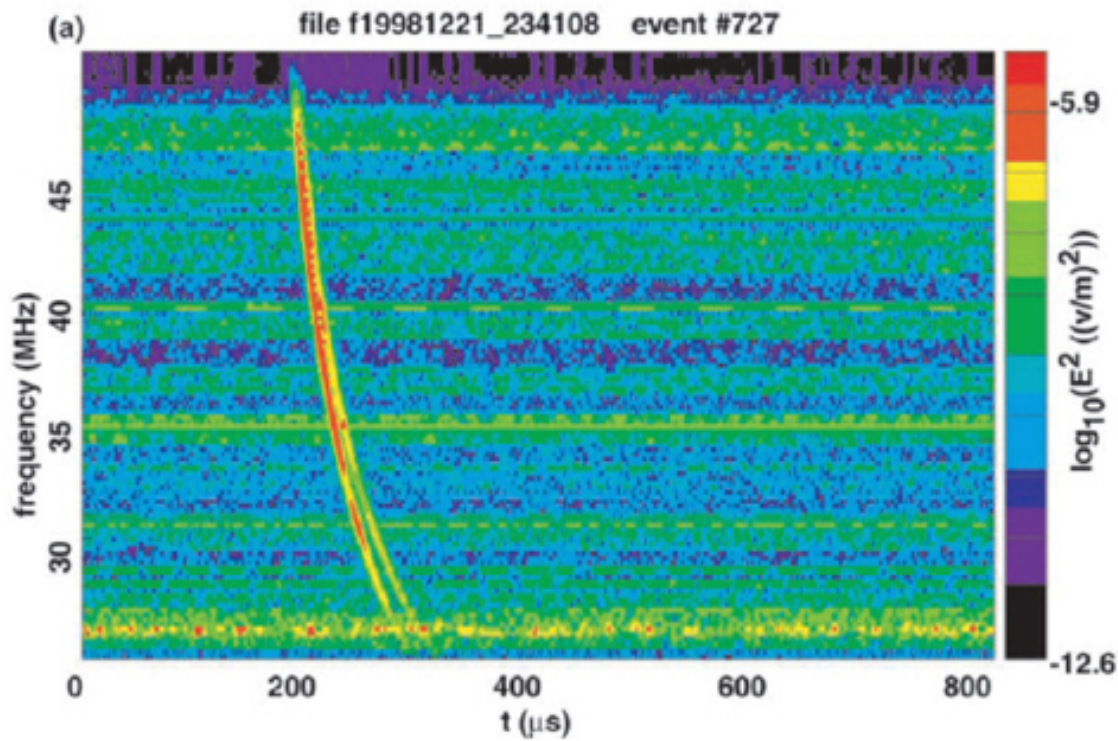
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NBEの伝播効果



NBEの空間分布

海上に多い？！

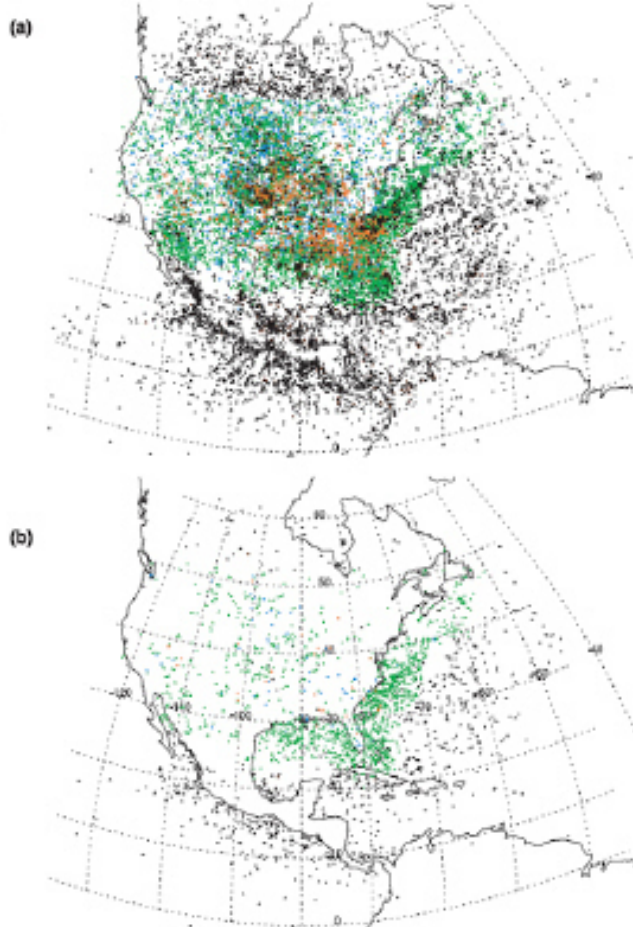
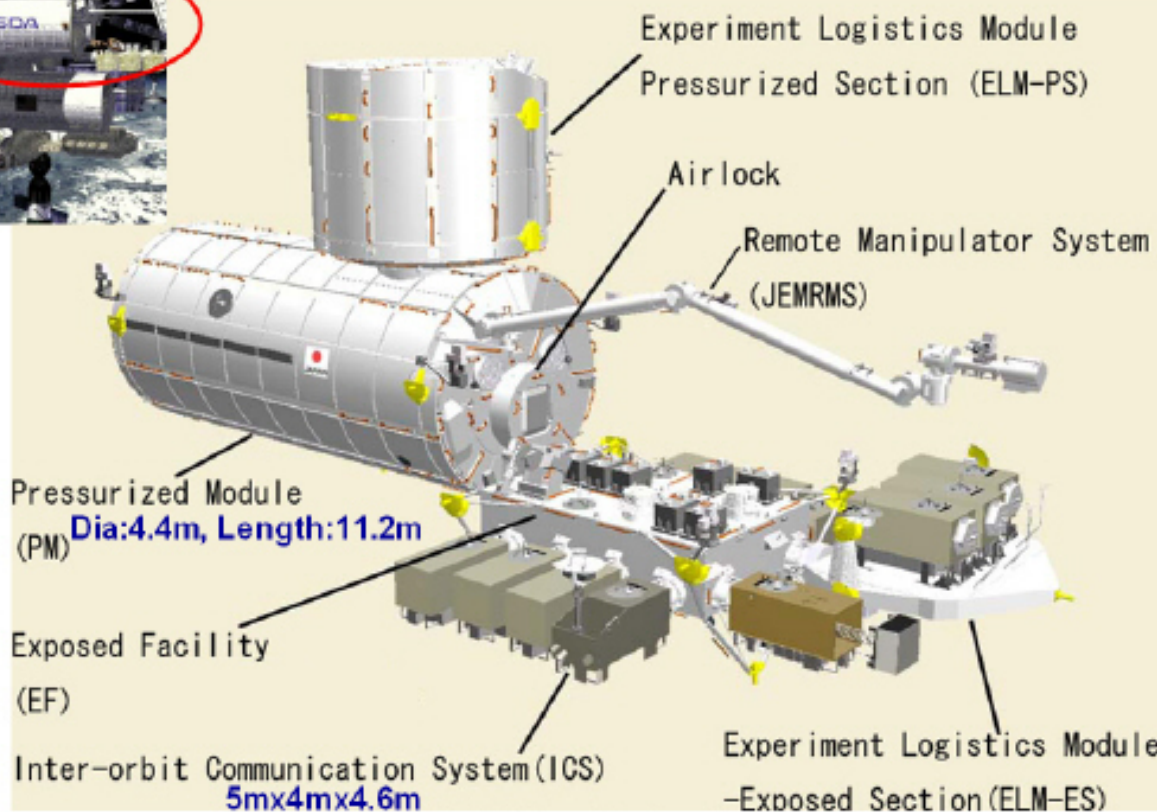
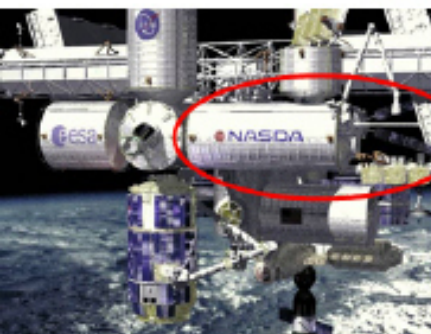


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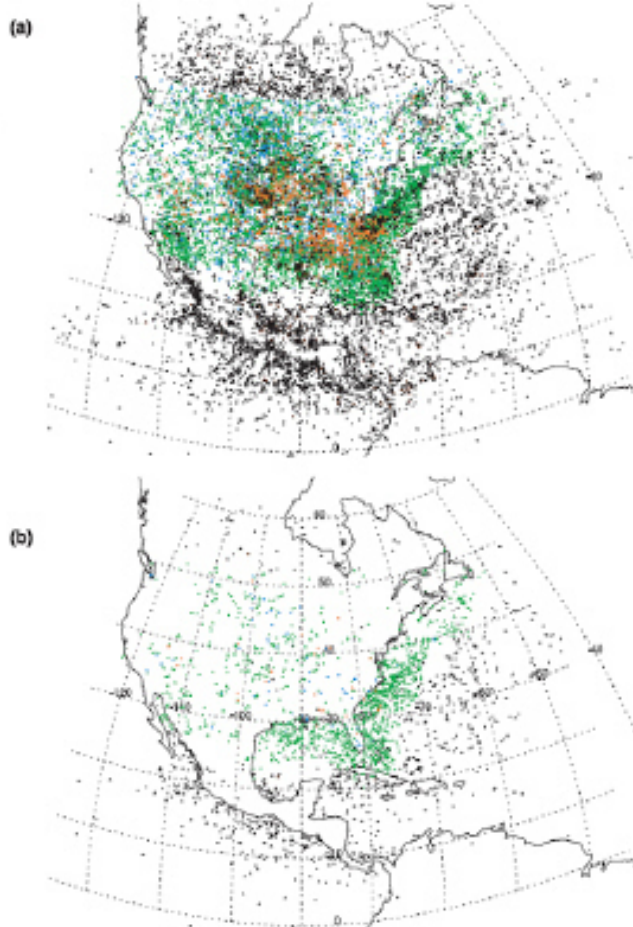
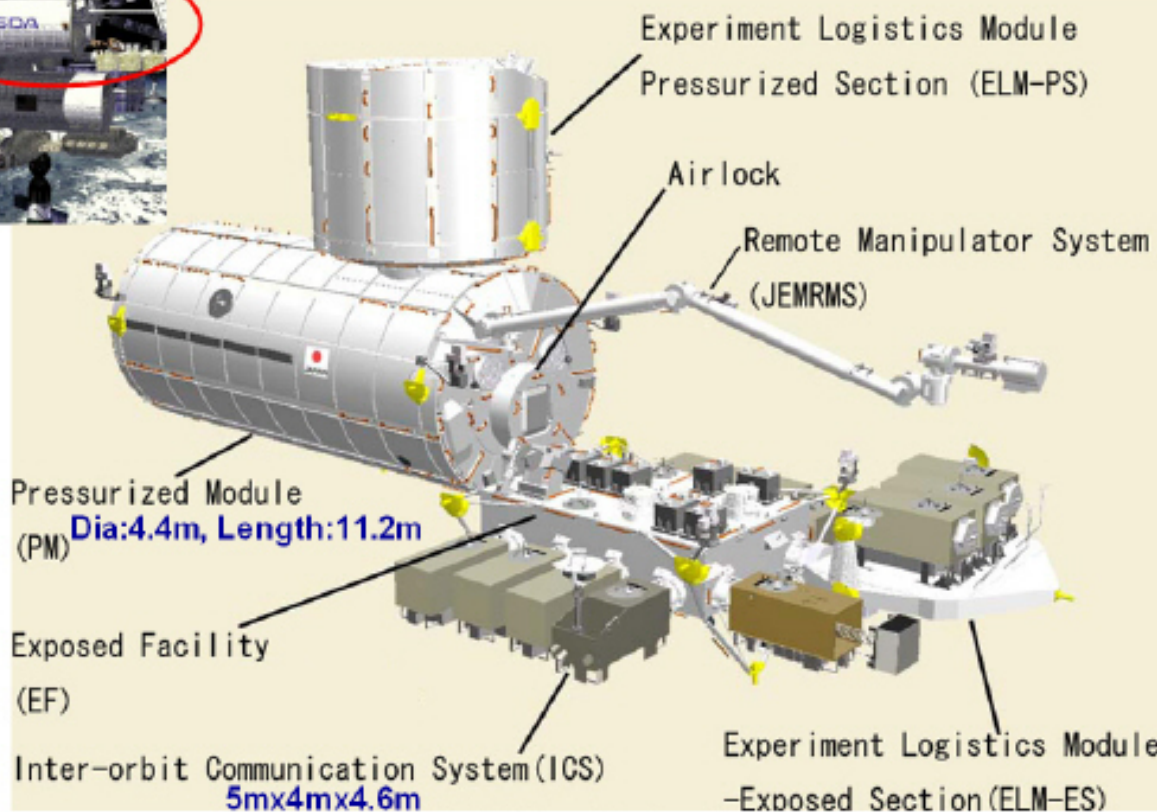
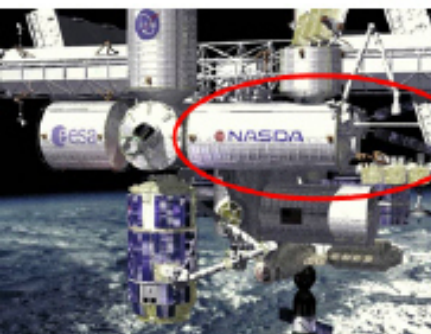


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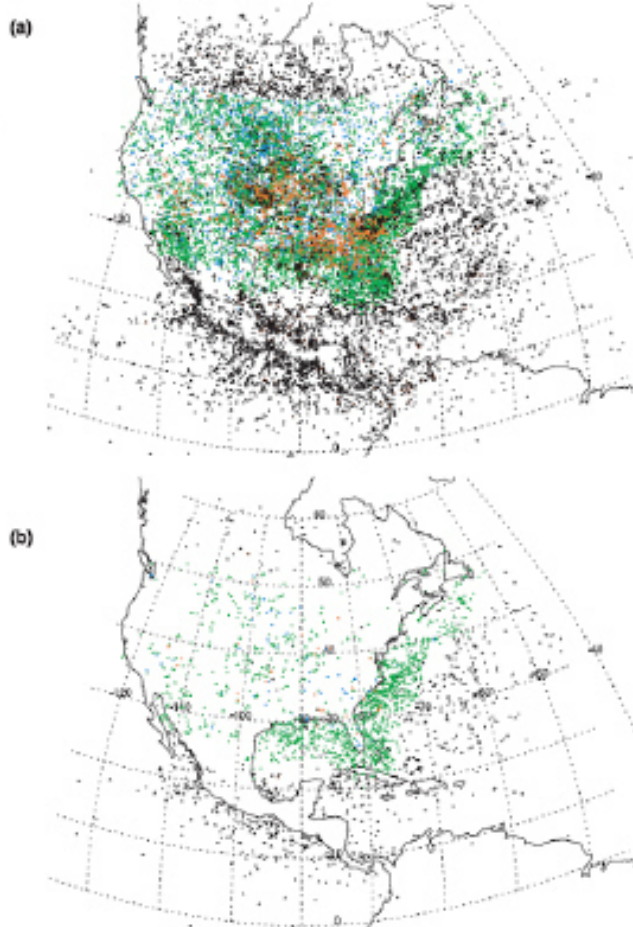
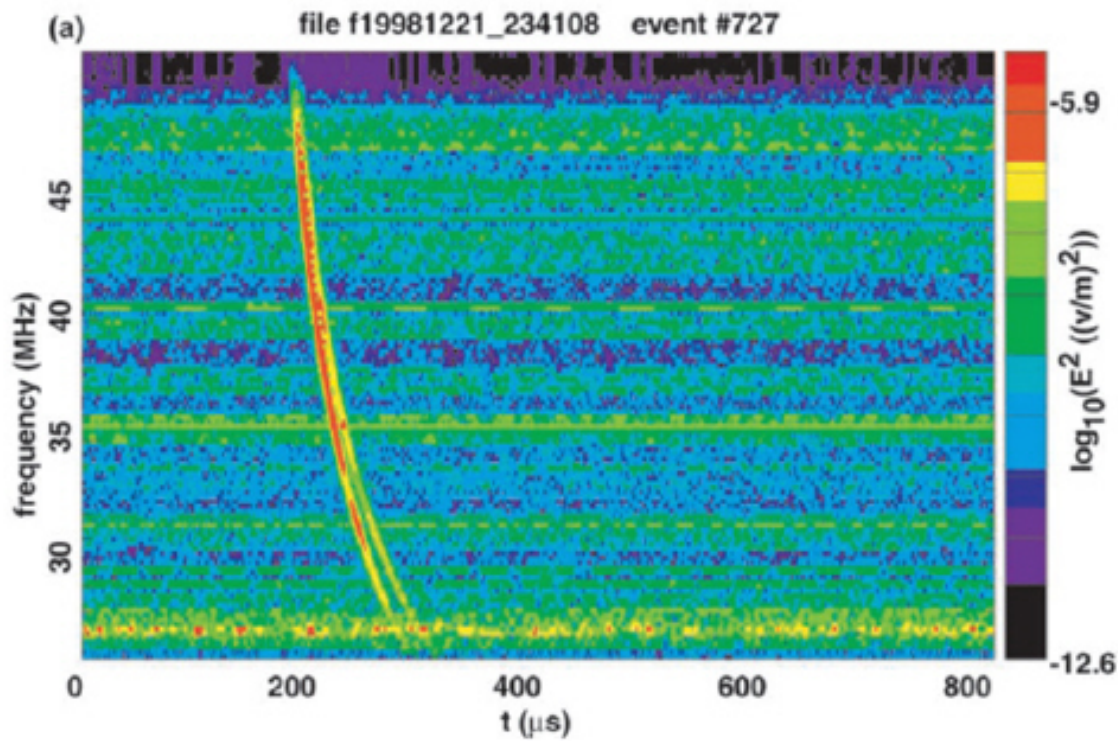


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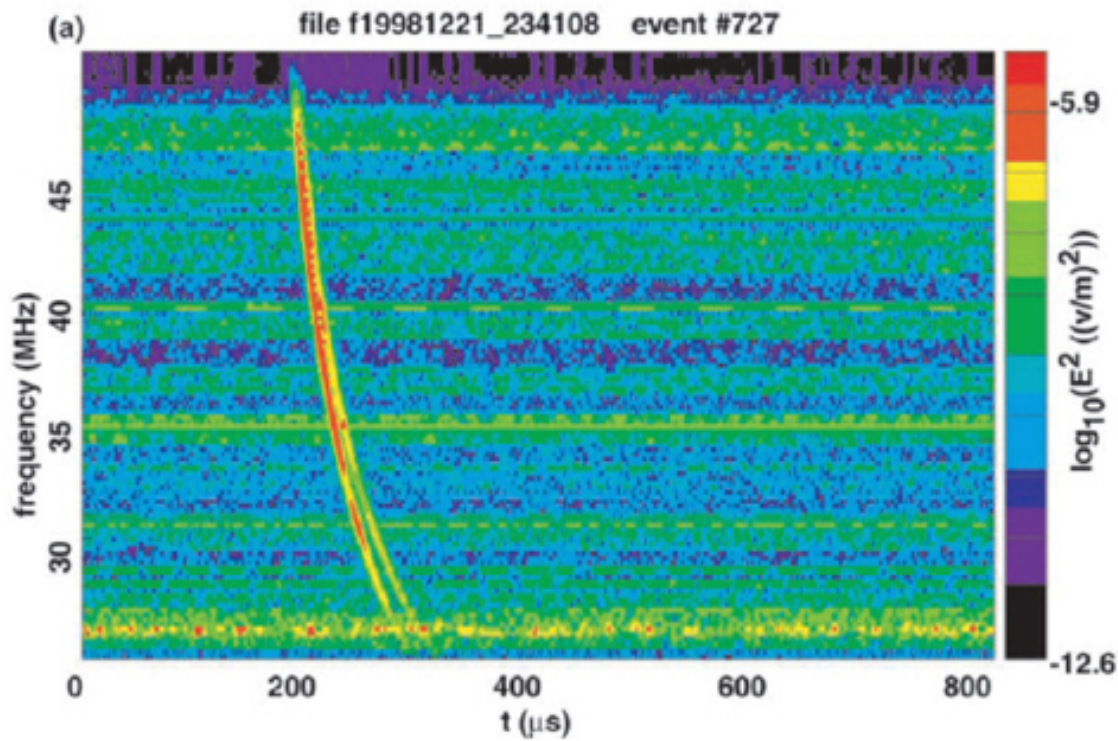
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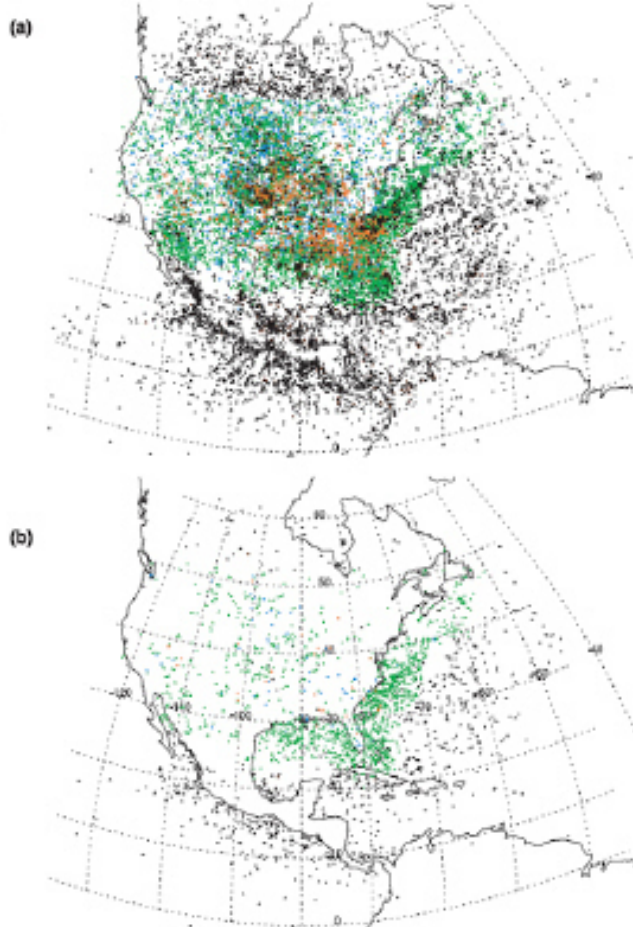
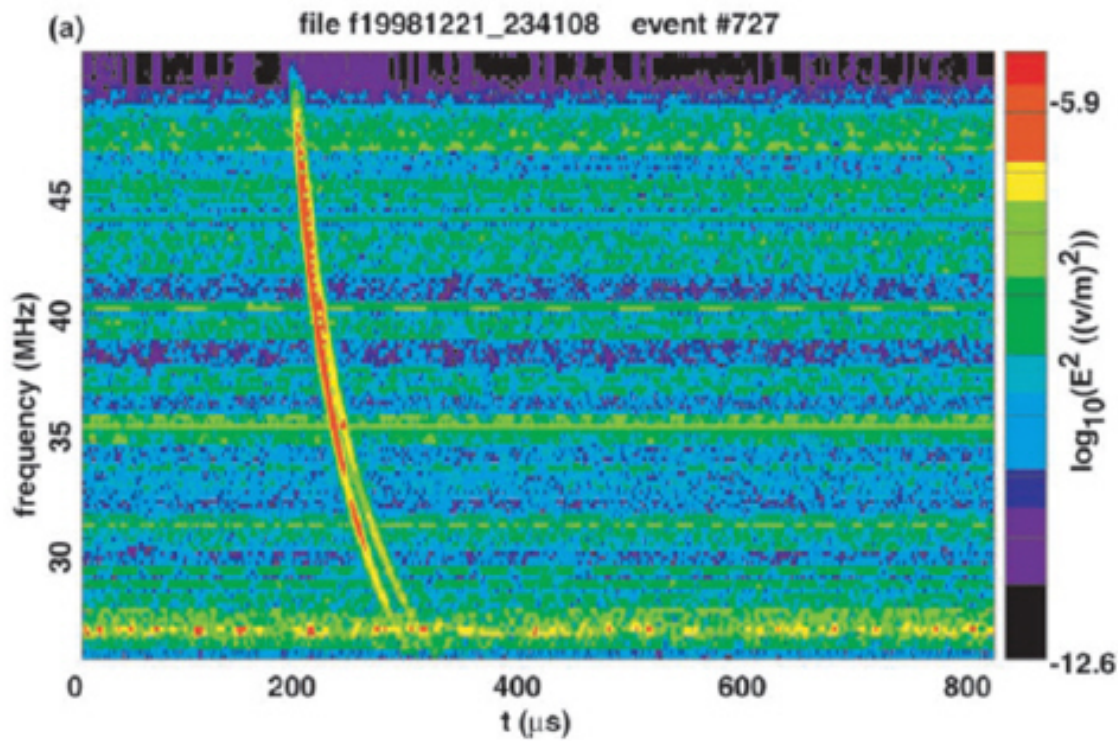


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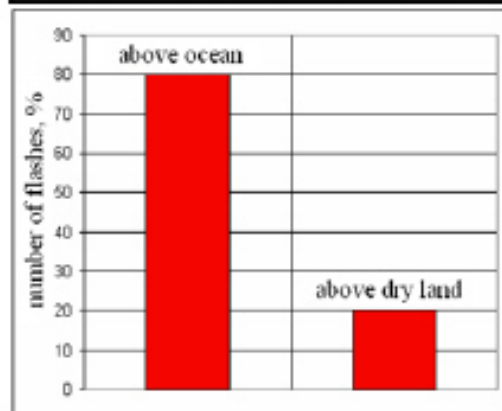
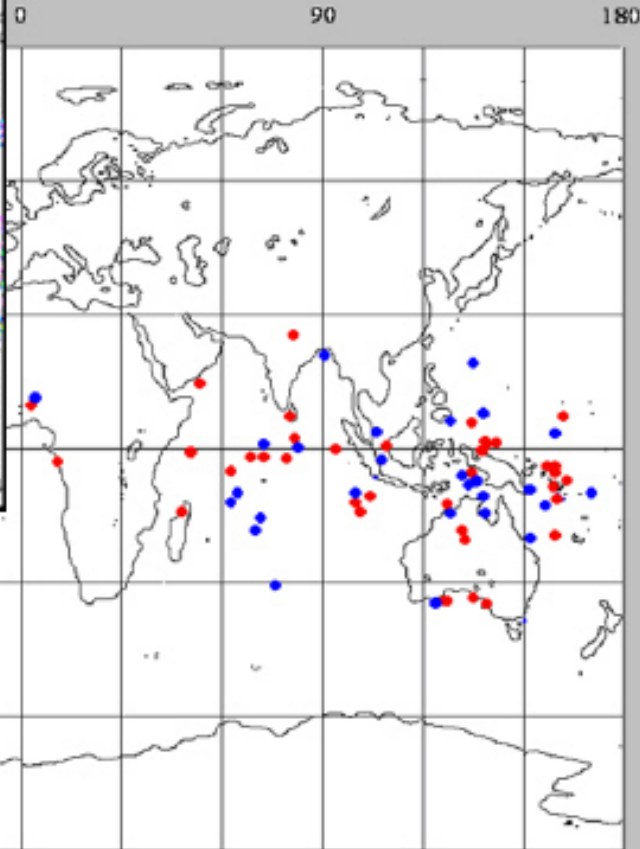
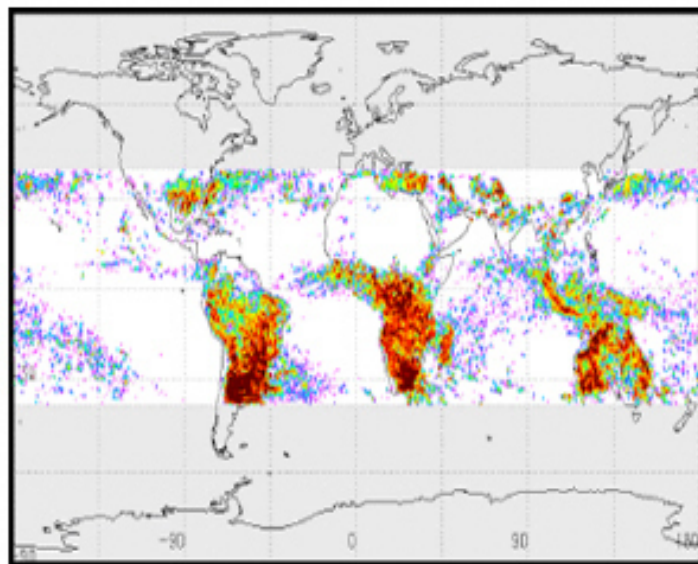
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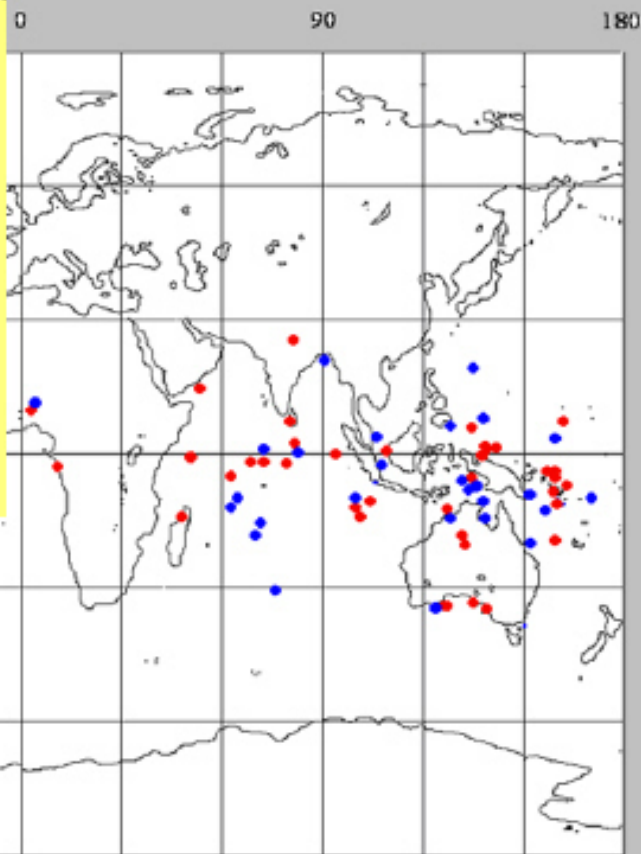
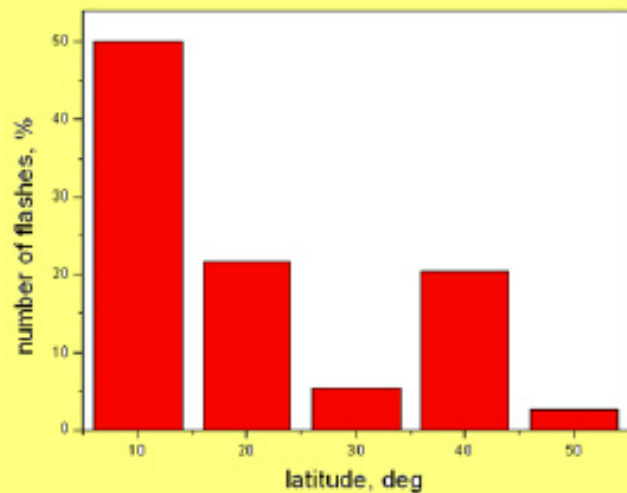
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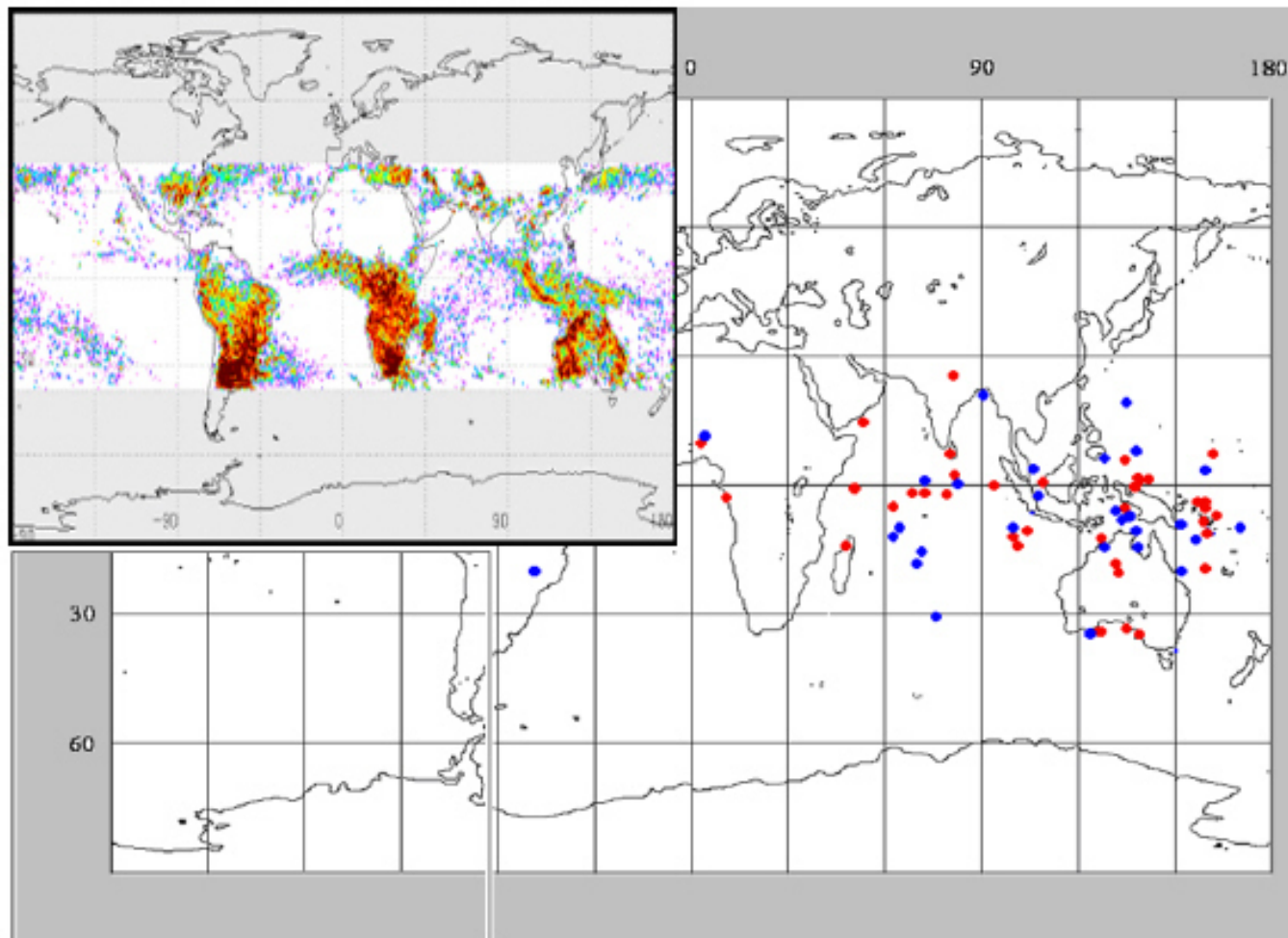
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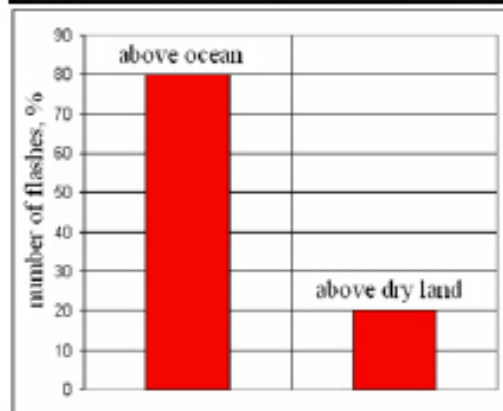
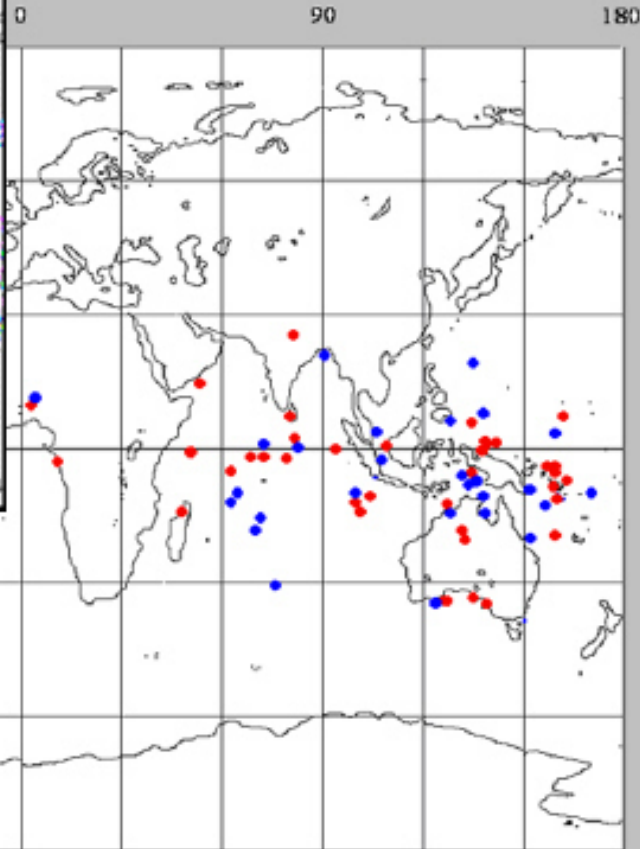
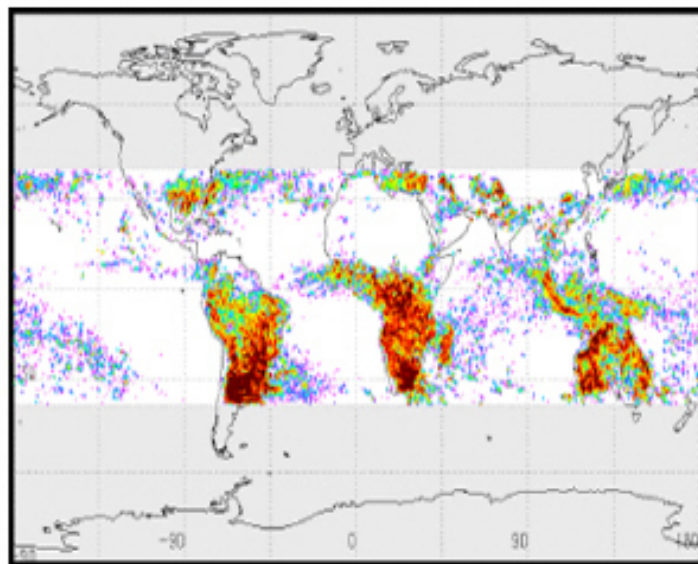
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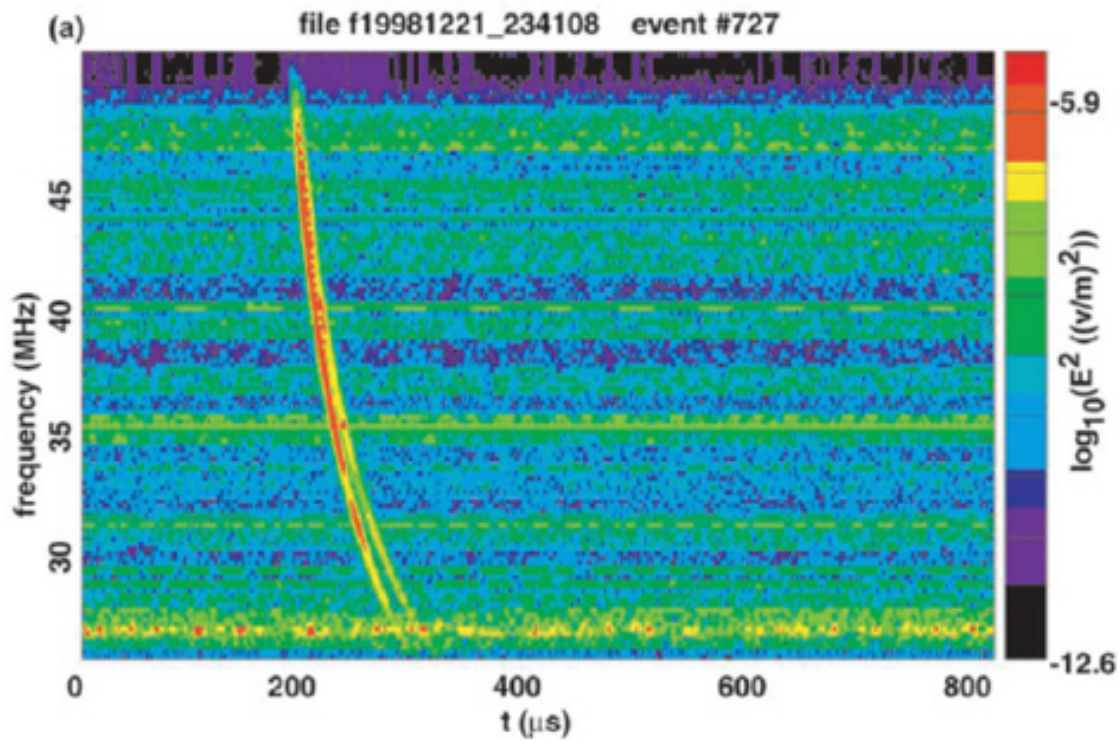
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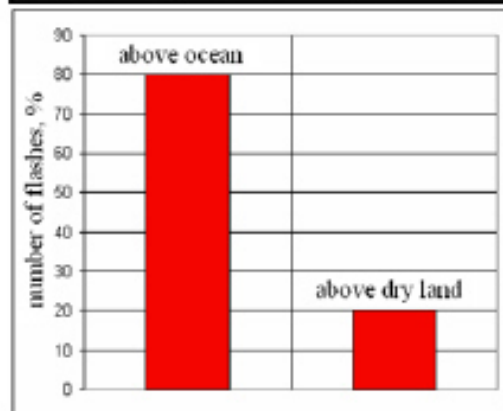
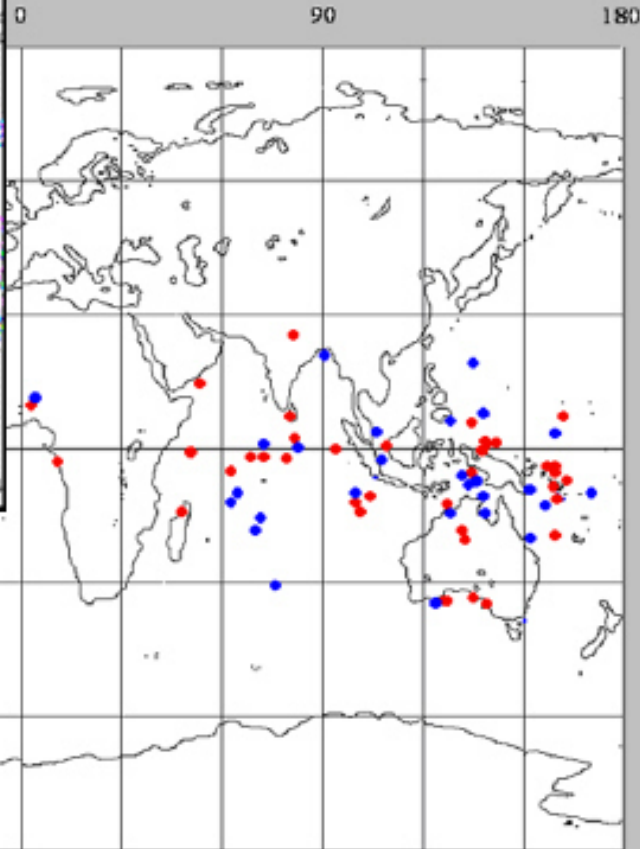
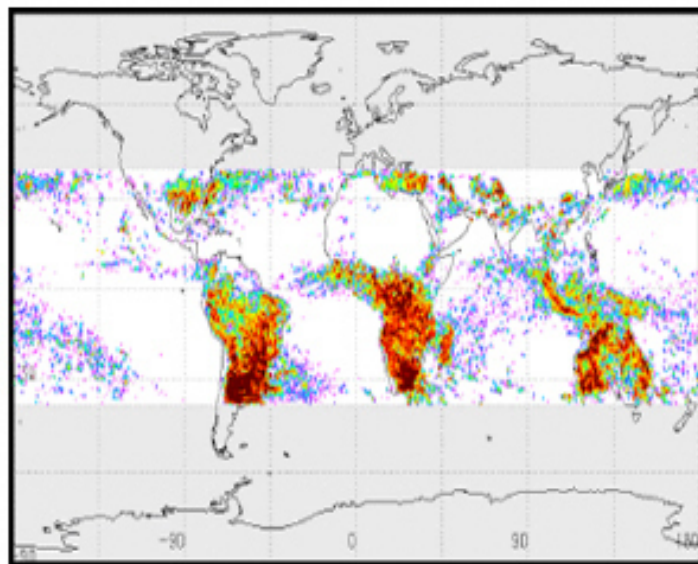
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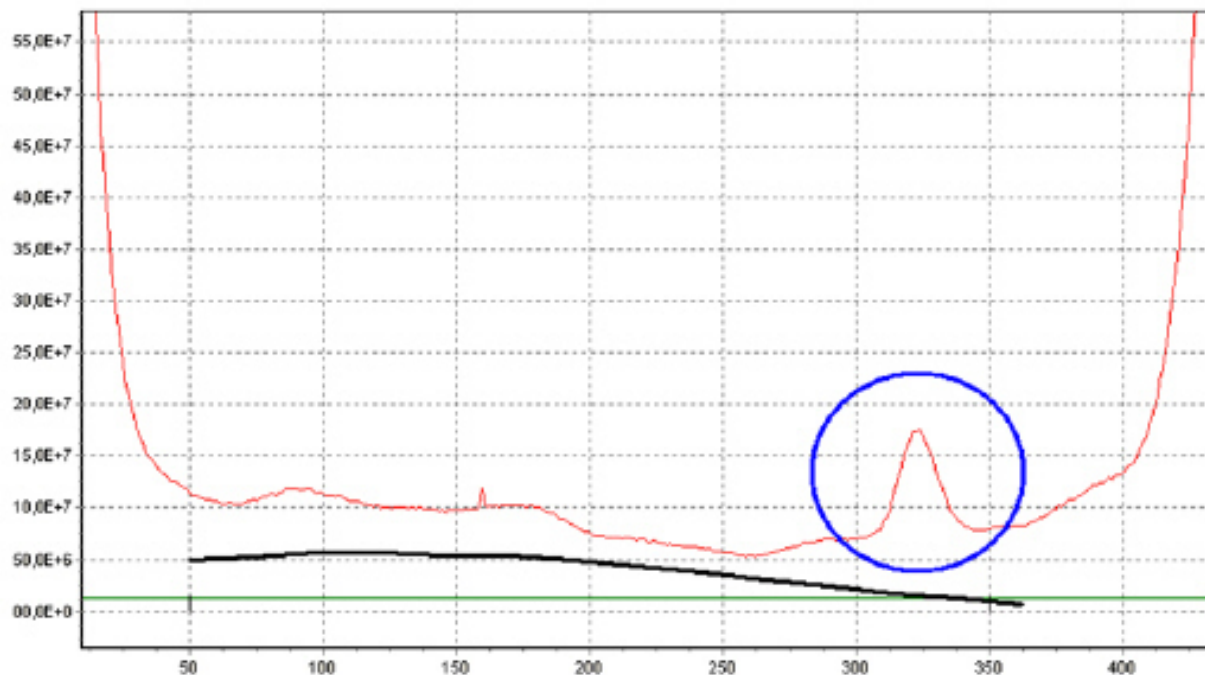
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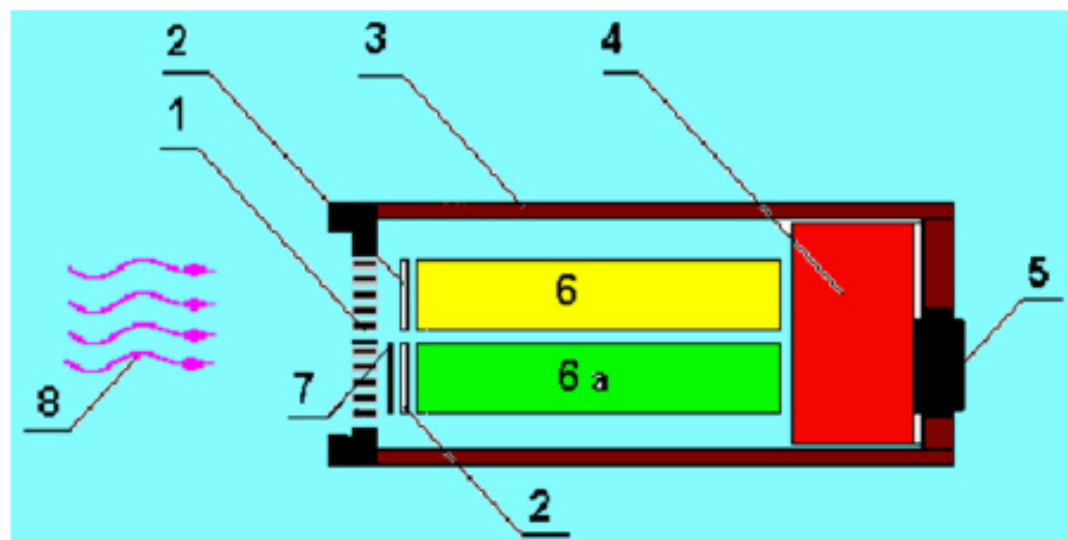
Examples of satellite "Tatiana" data



13.02.2005

Moon phase 25 %, Blue oval – the satellite is above Japan.

The detector of UV radiation



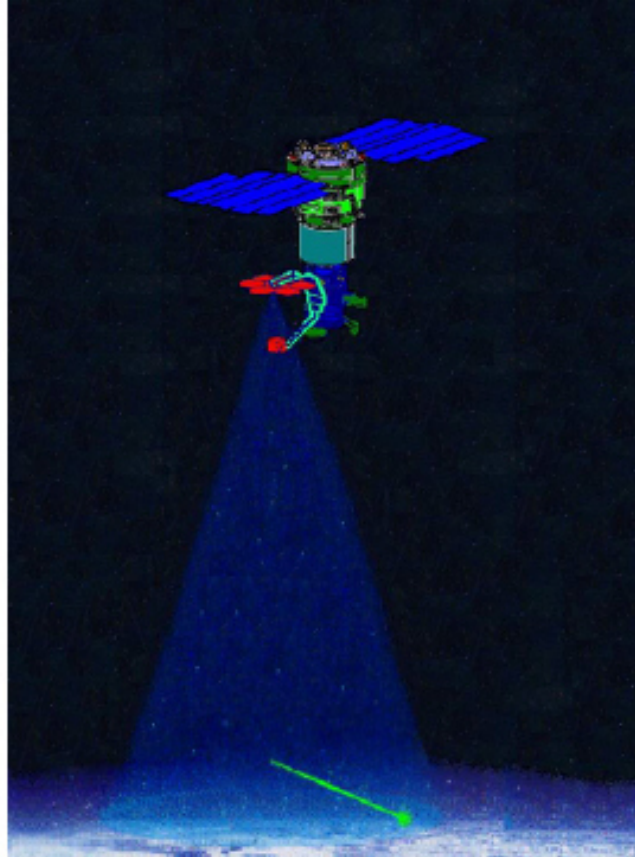
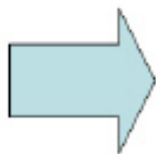
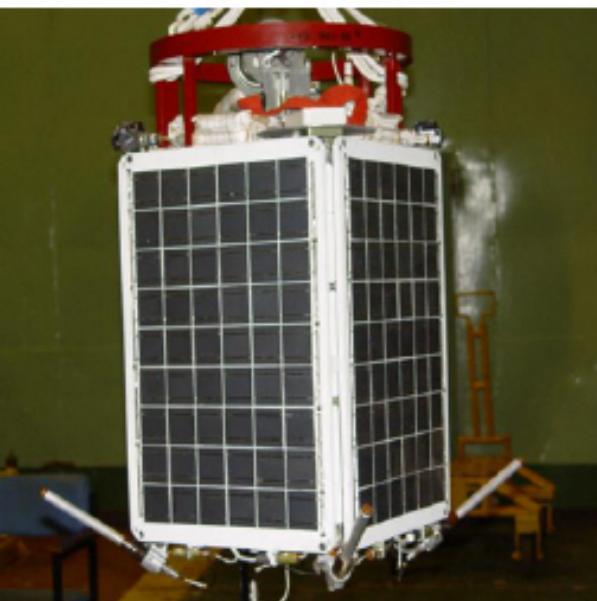
Some detector parameters:

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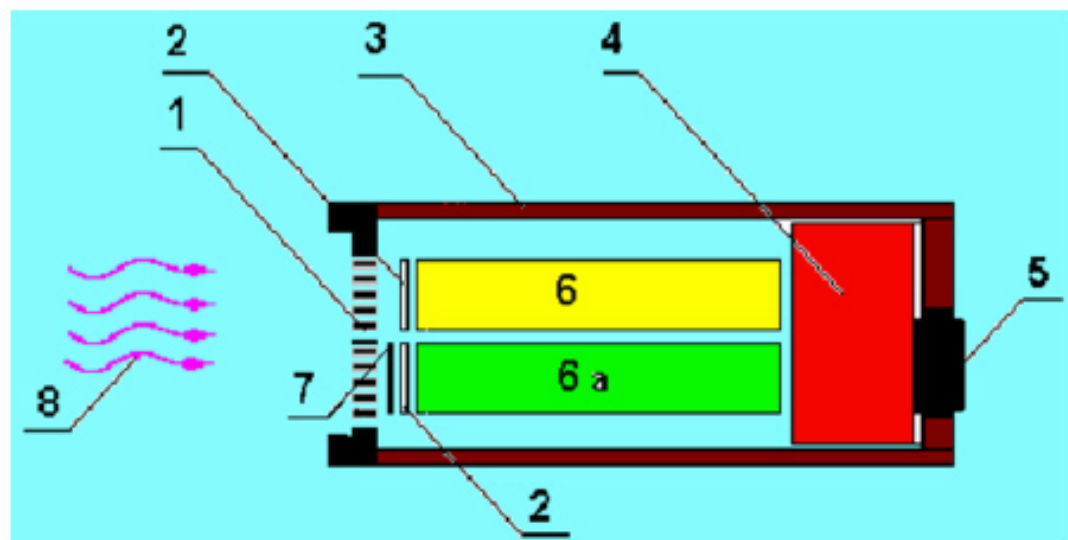
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UV filter: 200 – 400 nm

The results of satellite
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TUS.



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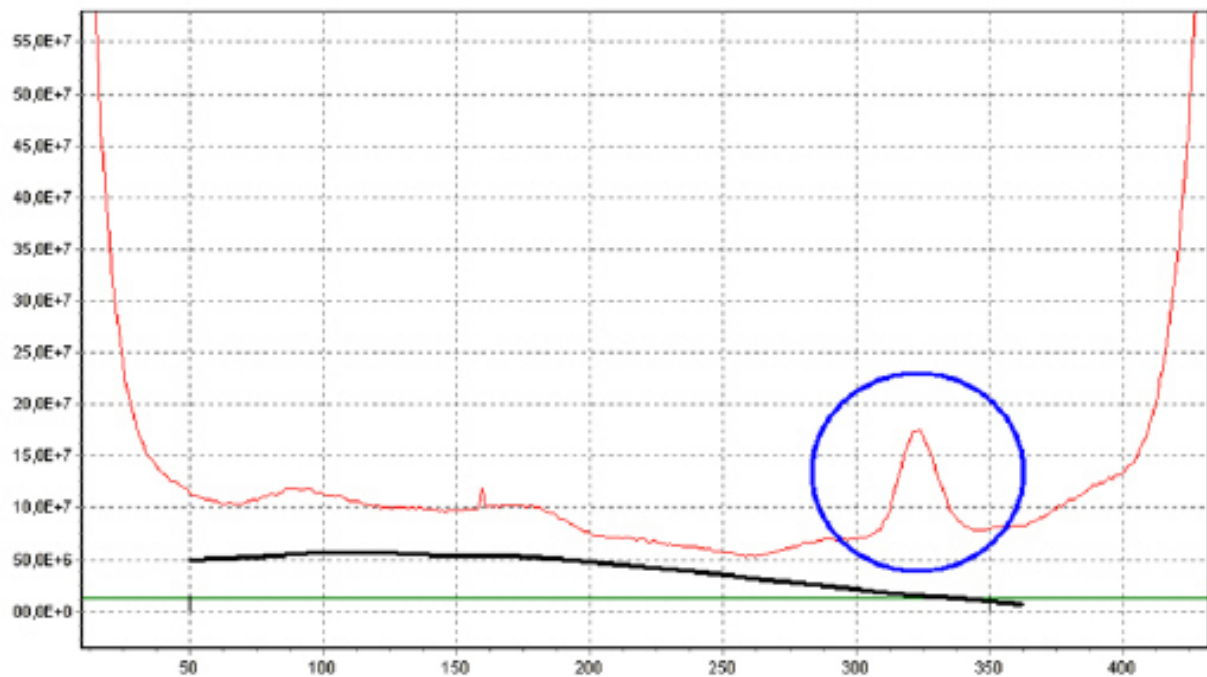
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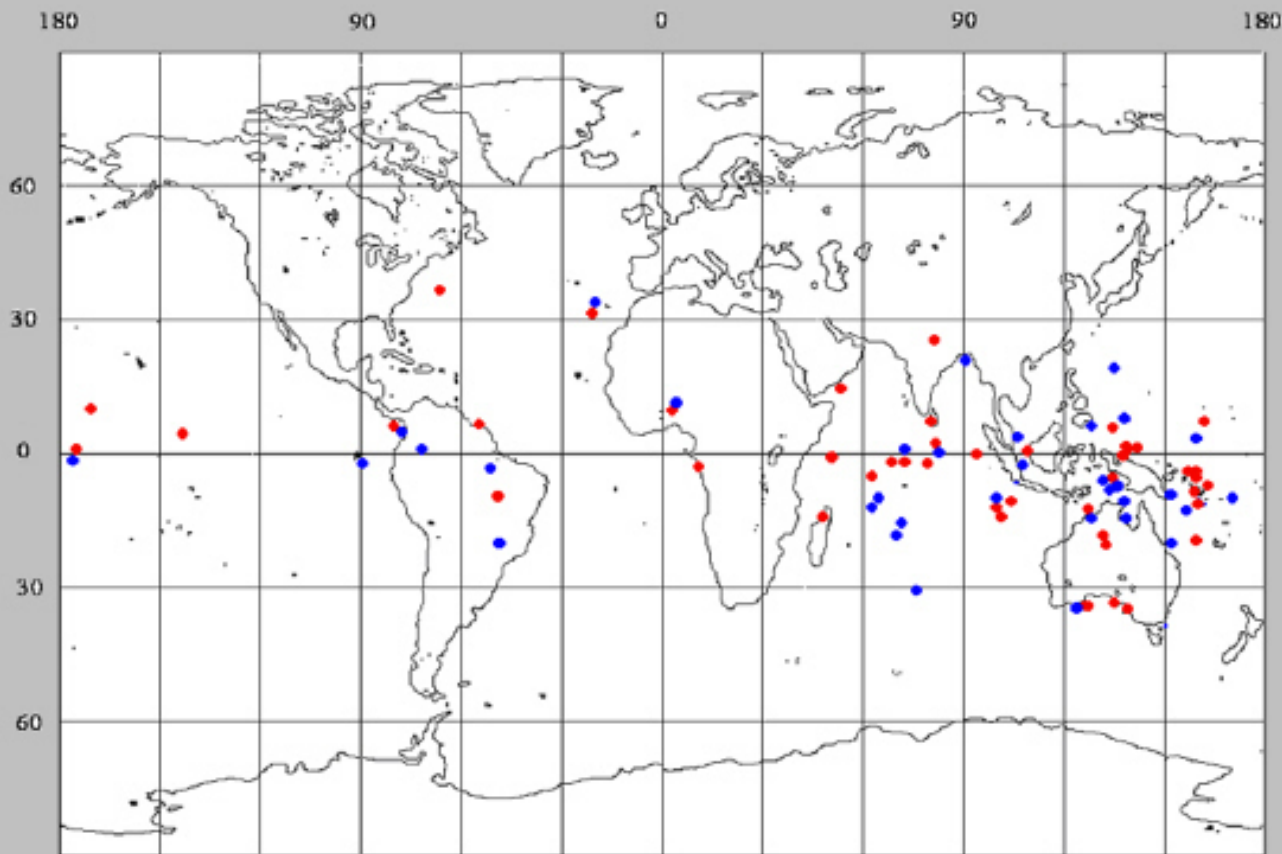
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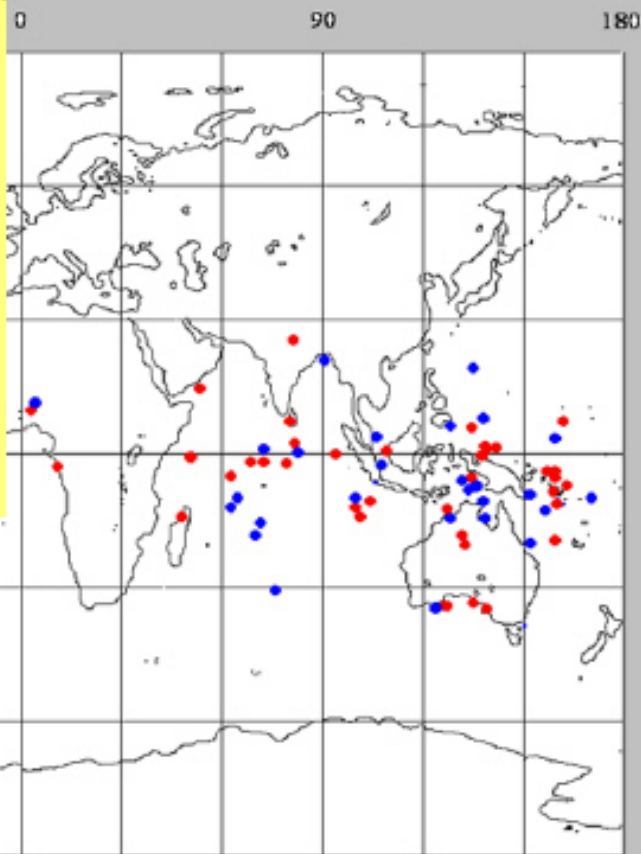
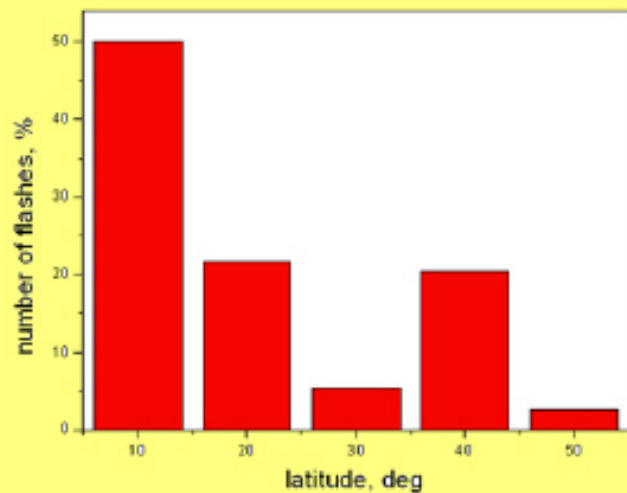
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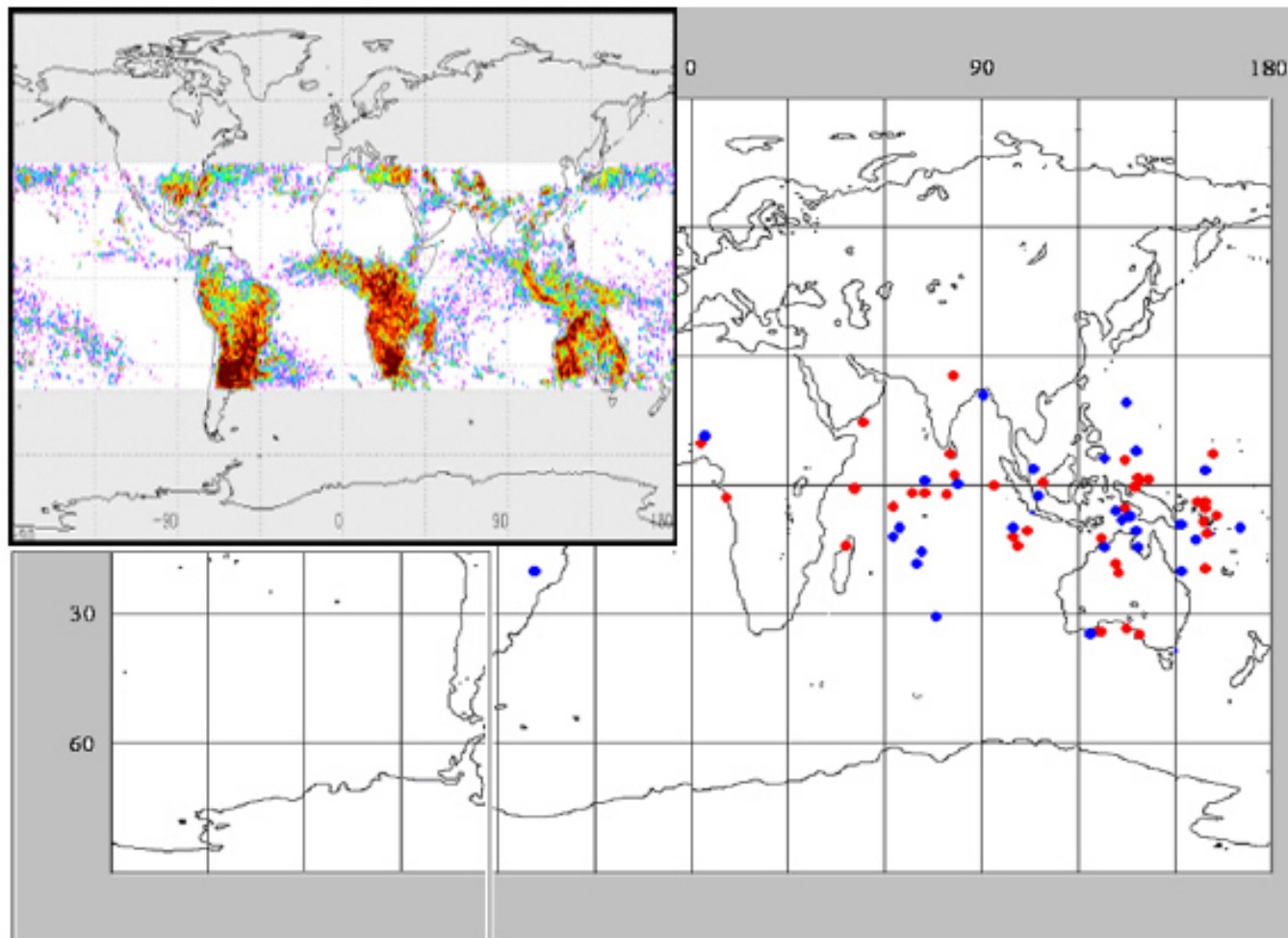
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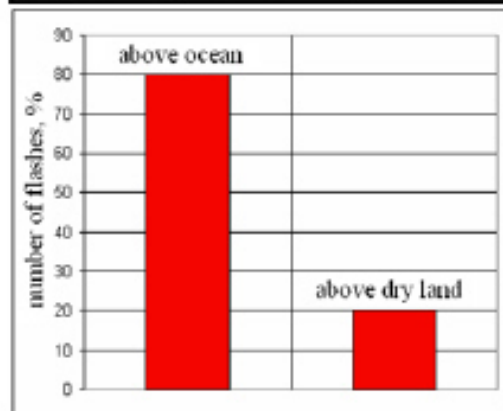
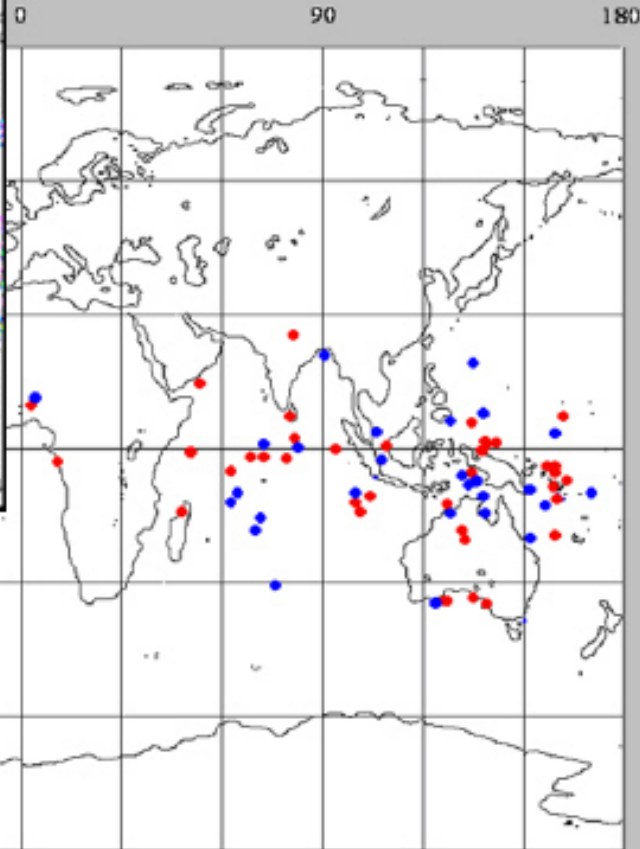
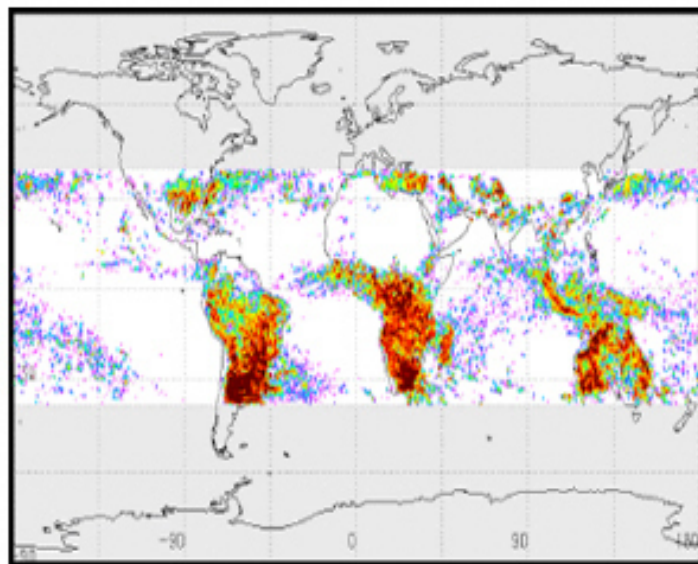
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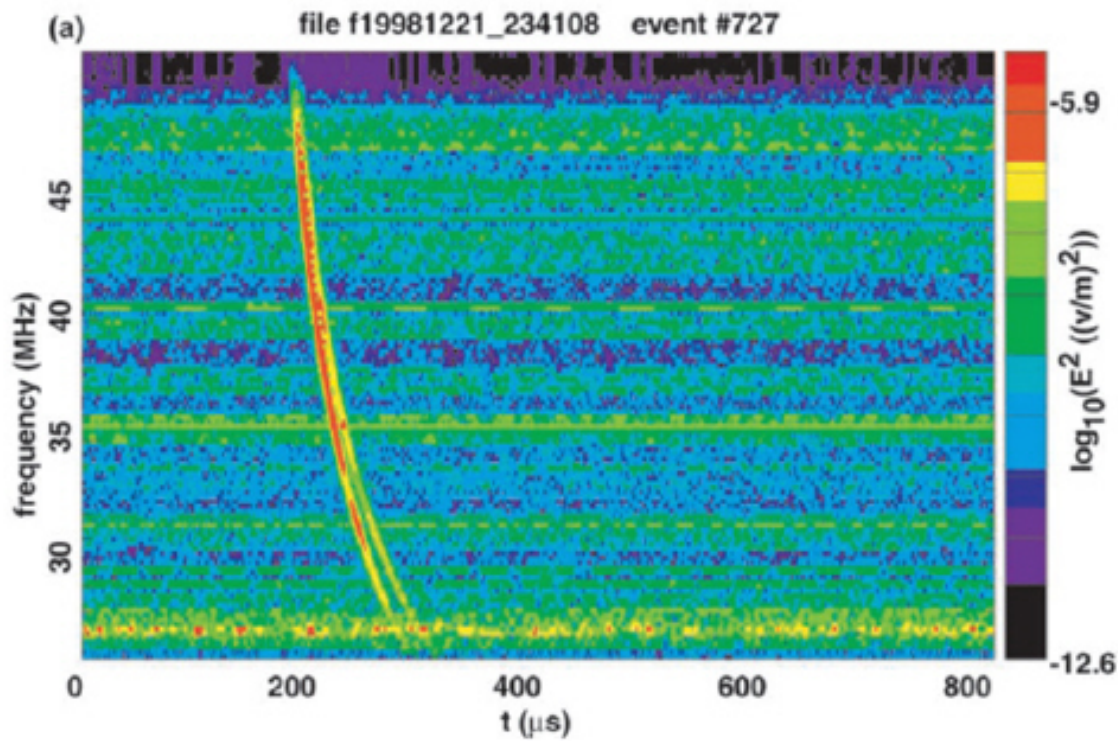
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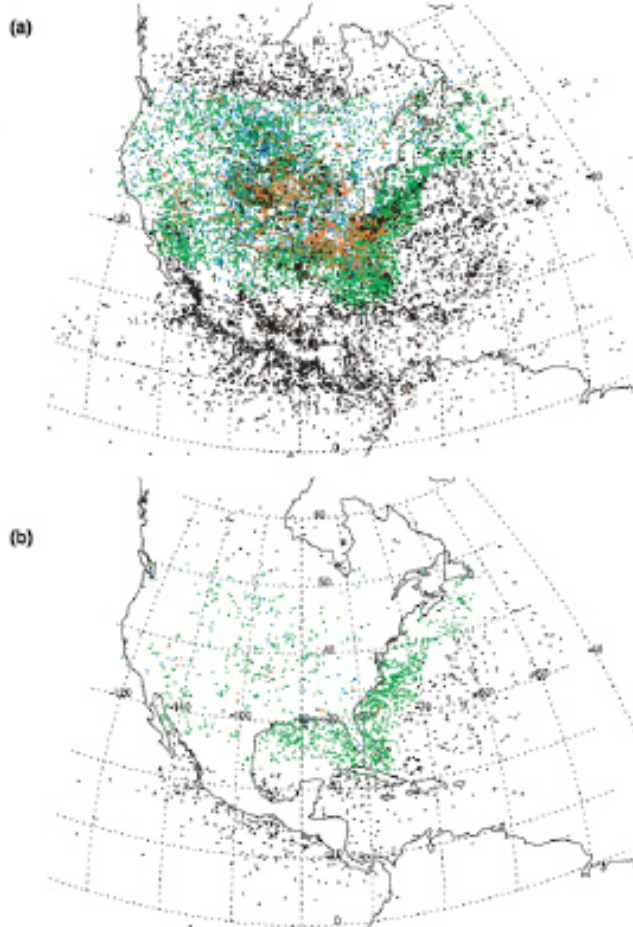
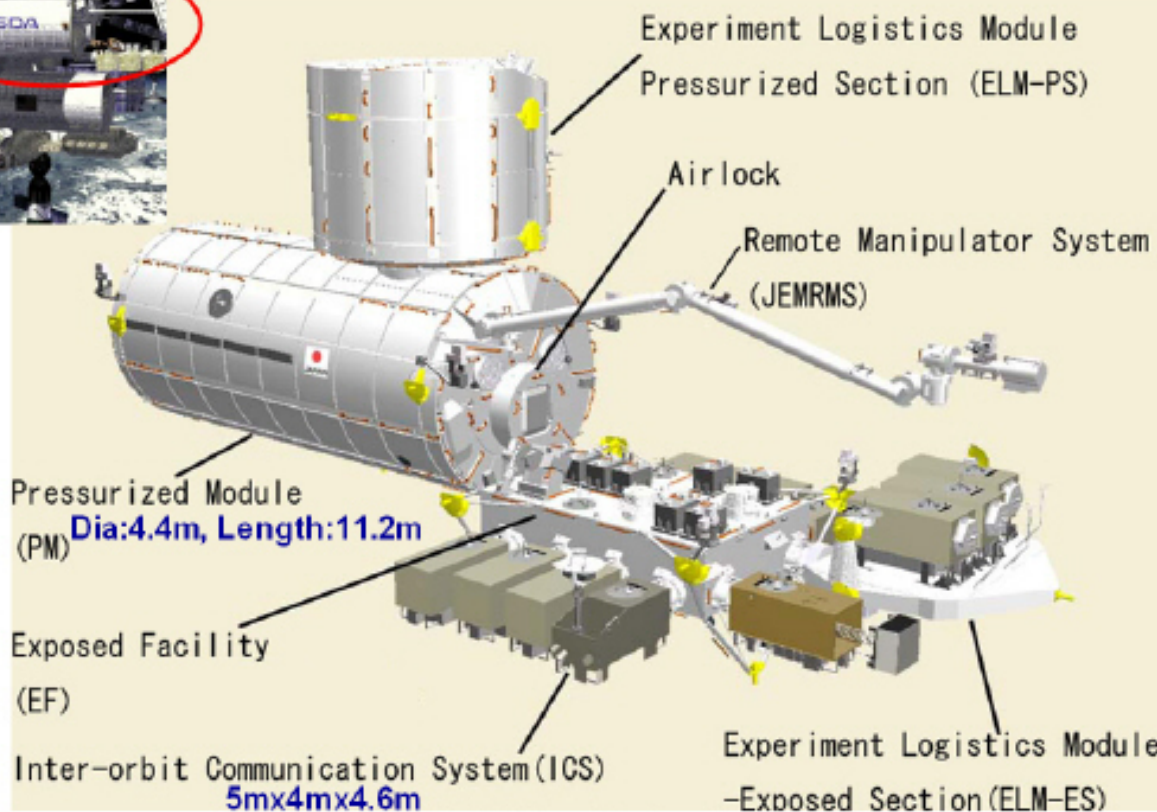
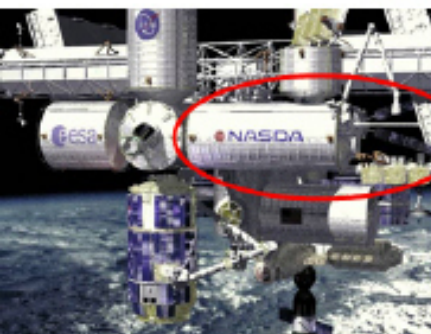


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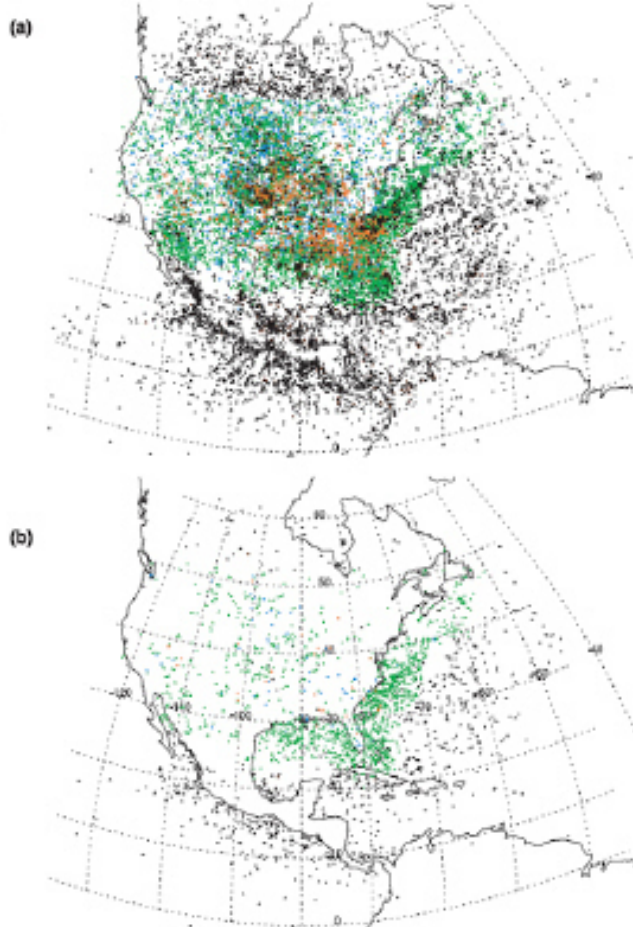
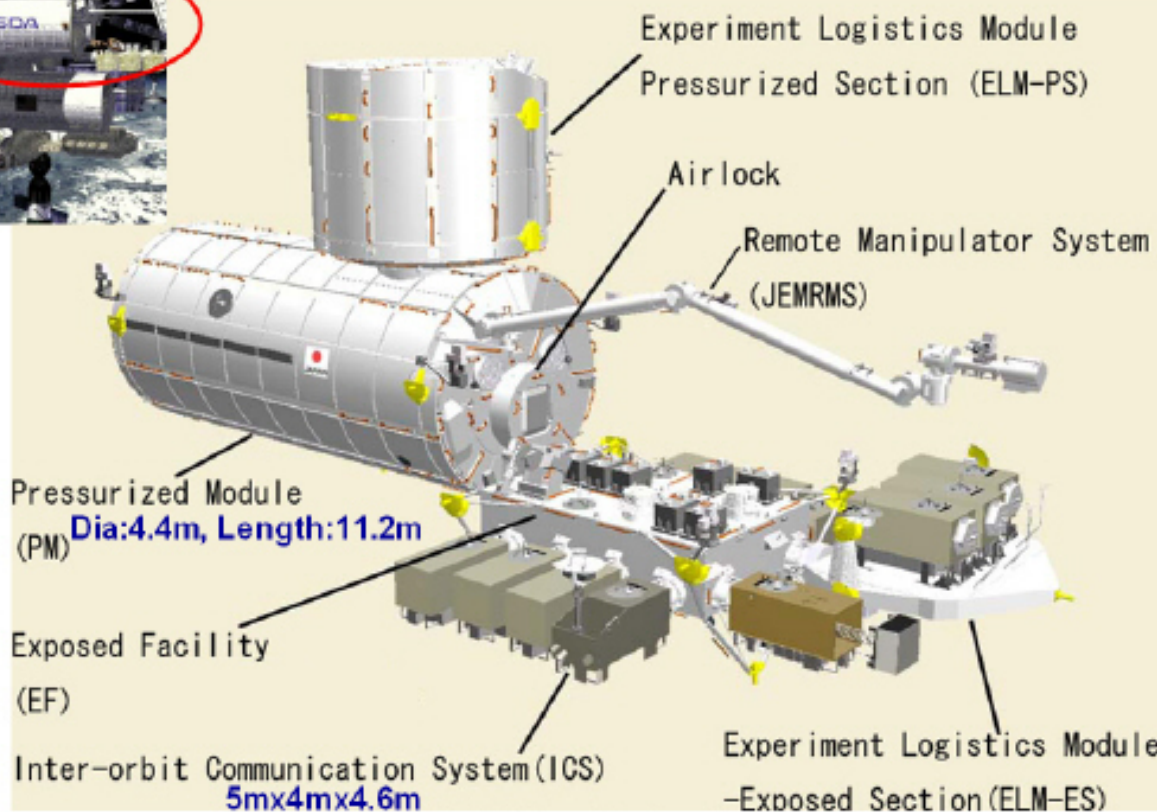
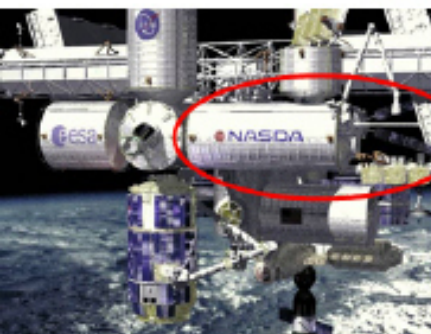


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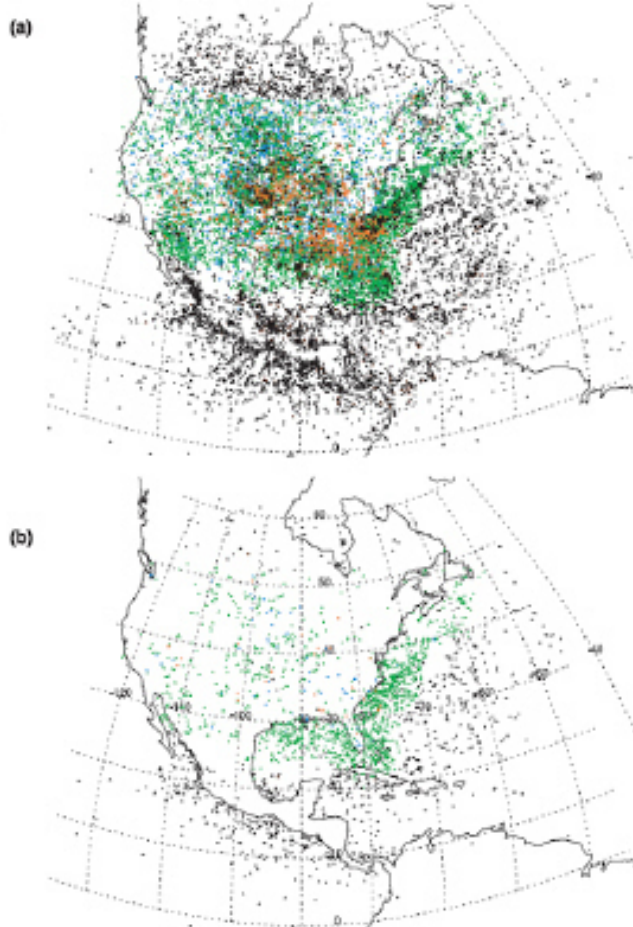
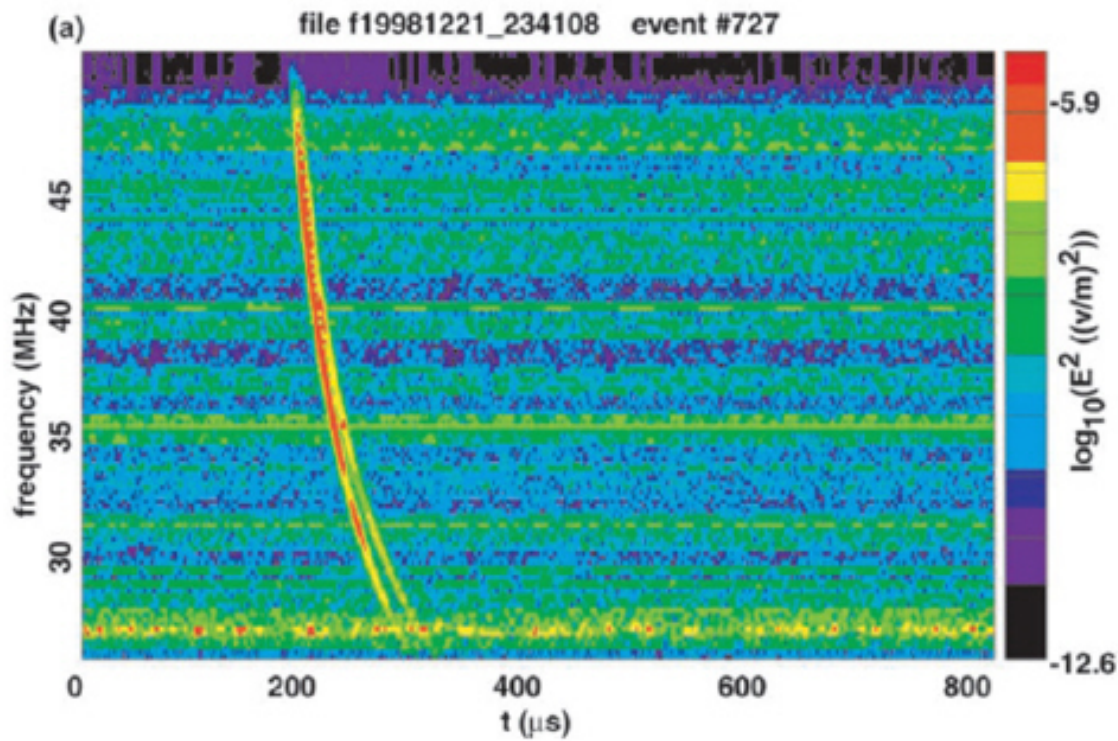


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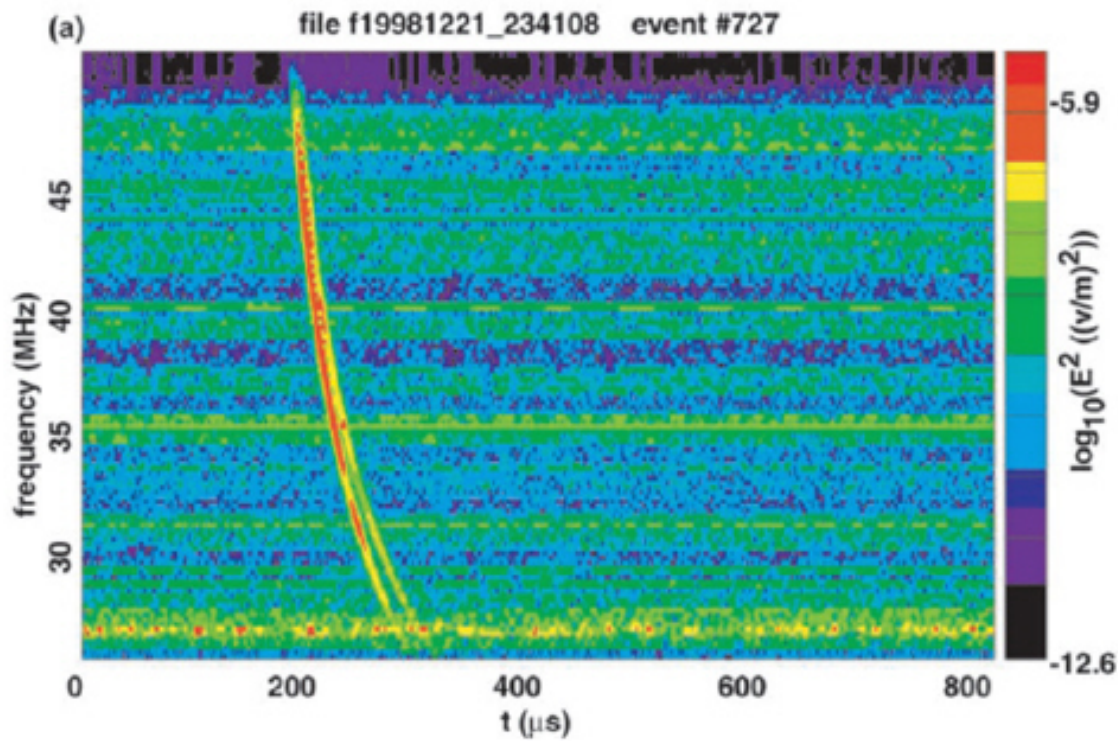
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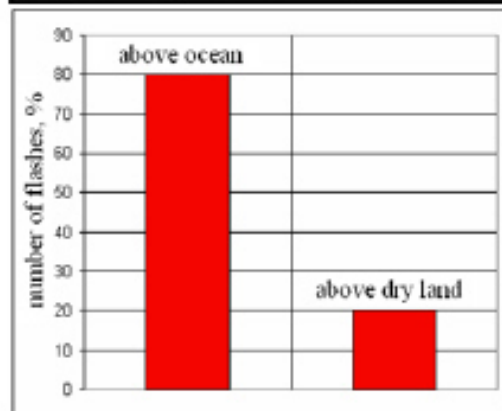
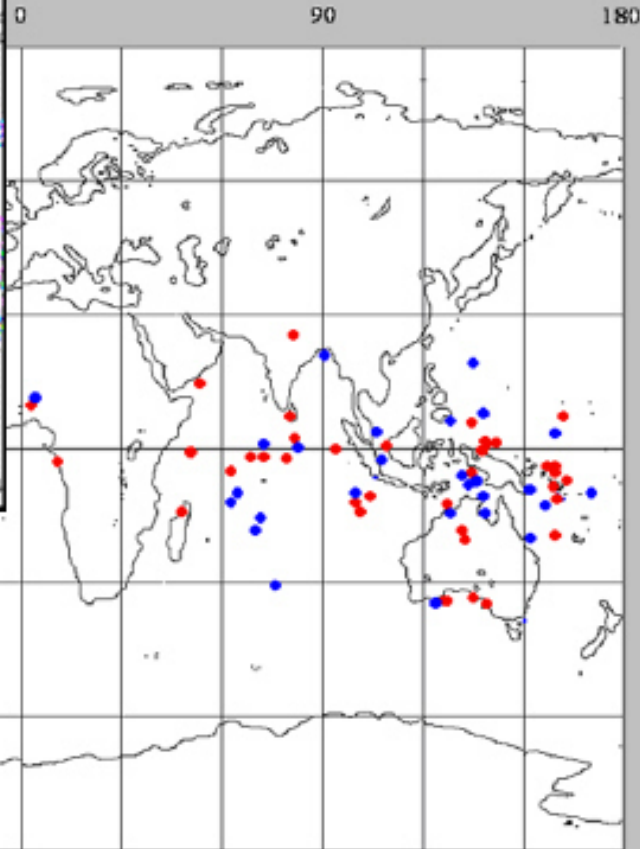
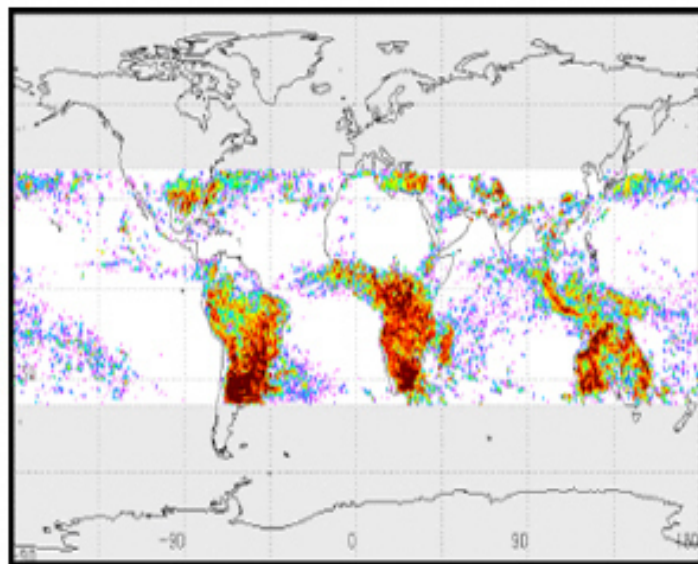
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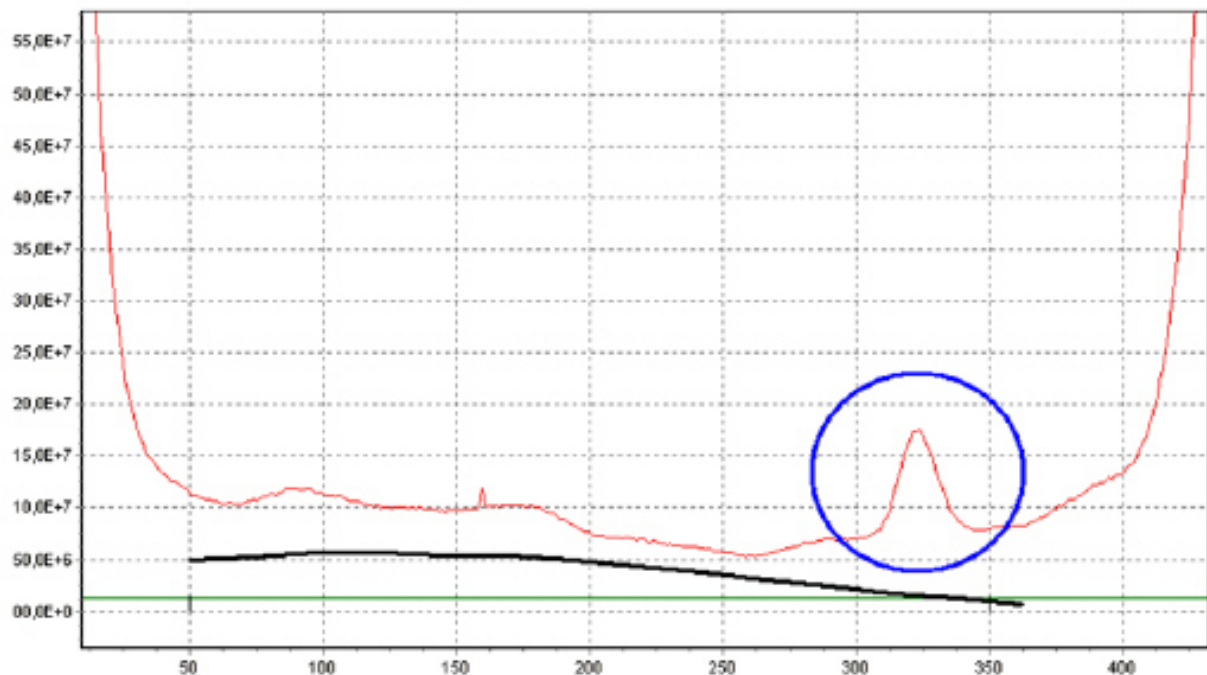
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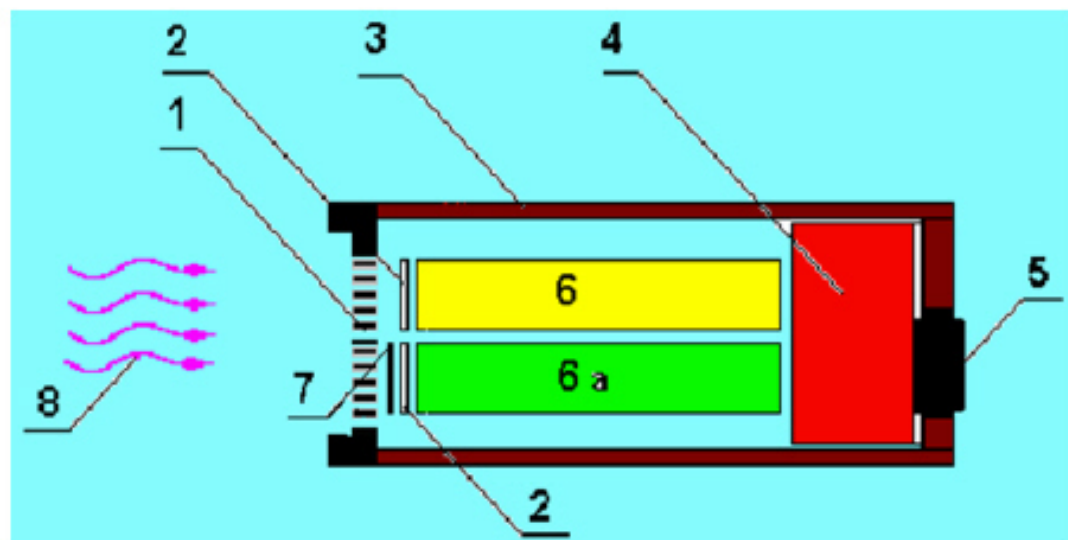
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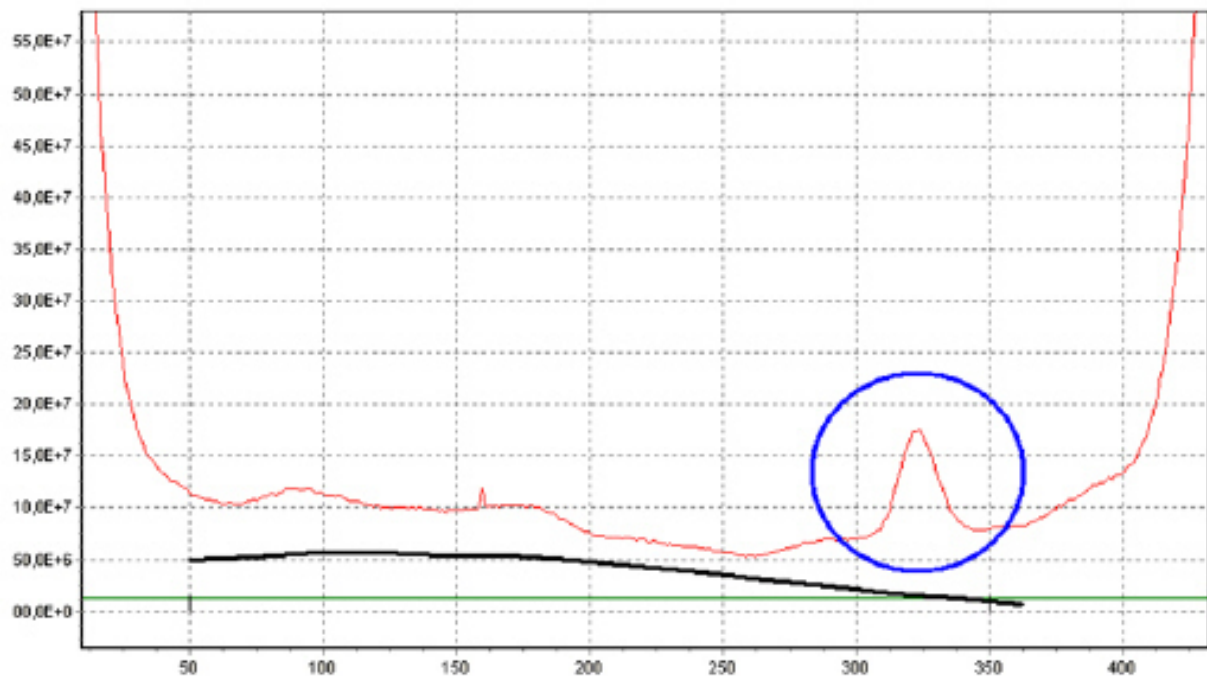
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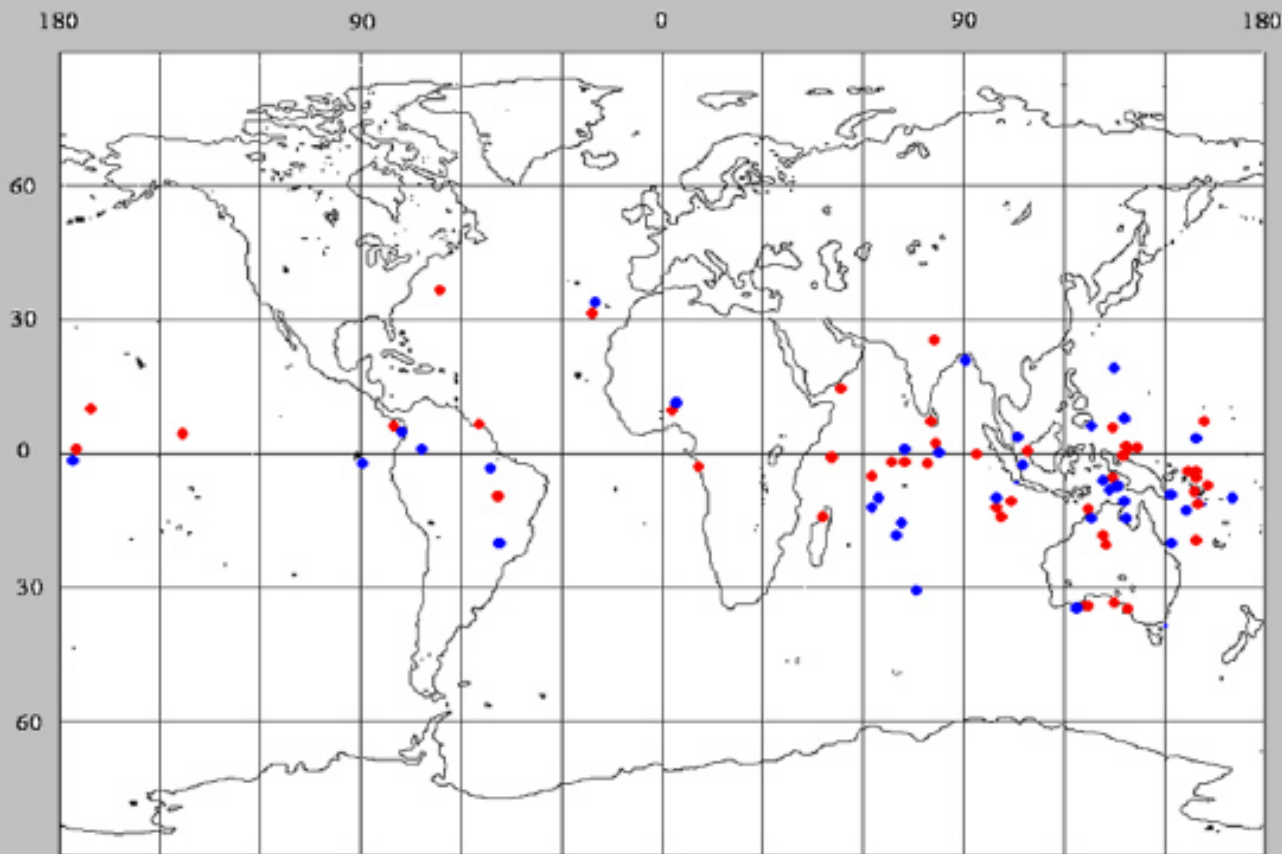
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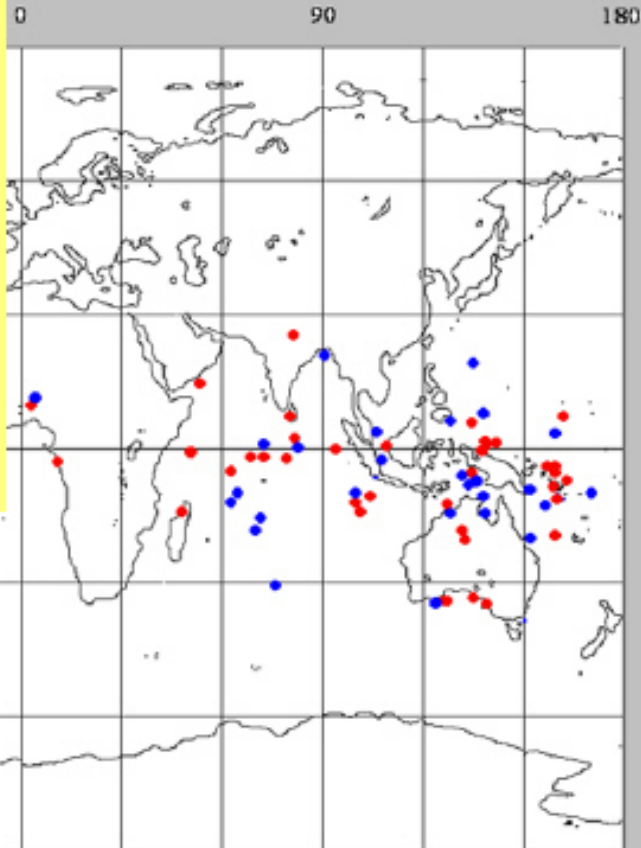
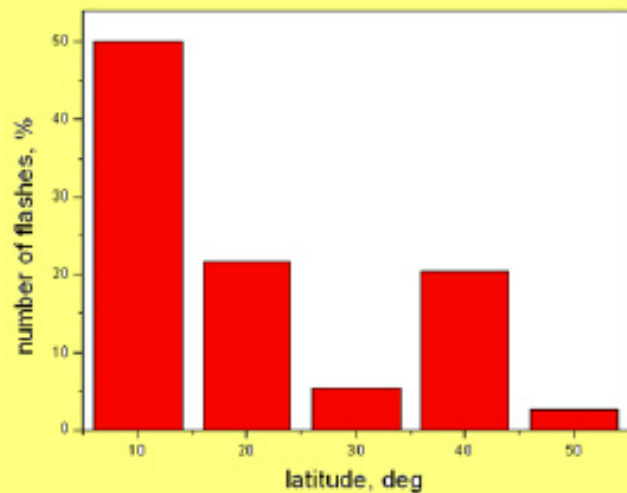
13.02.2005

Moon phase 25 %, Blue oval – the satellite is above Japan.

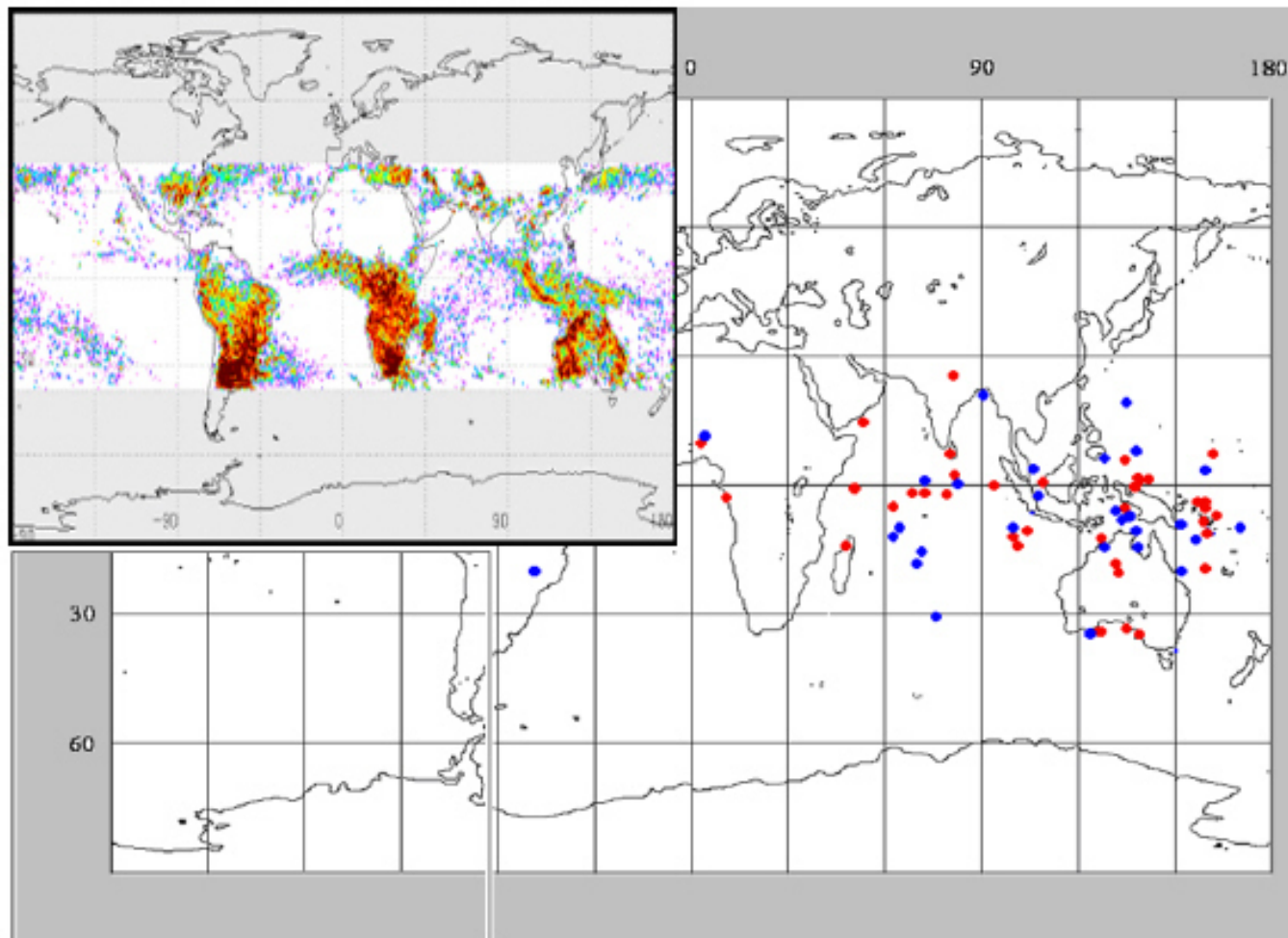
The geographical distribution of UV flashes



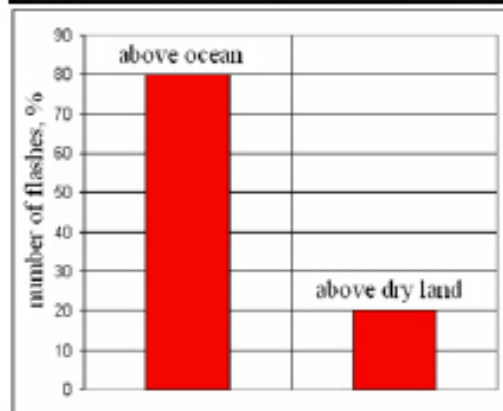
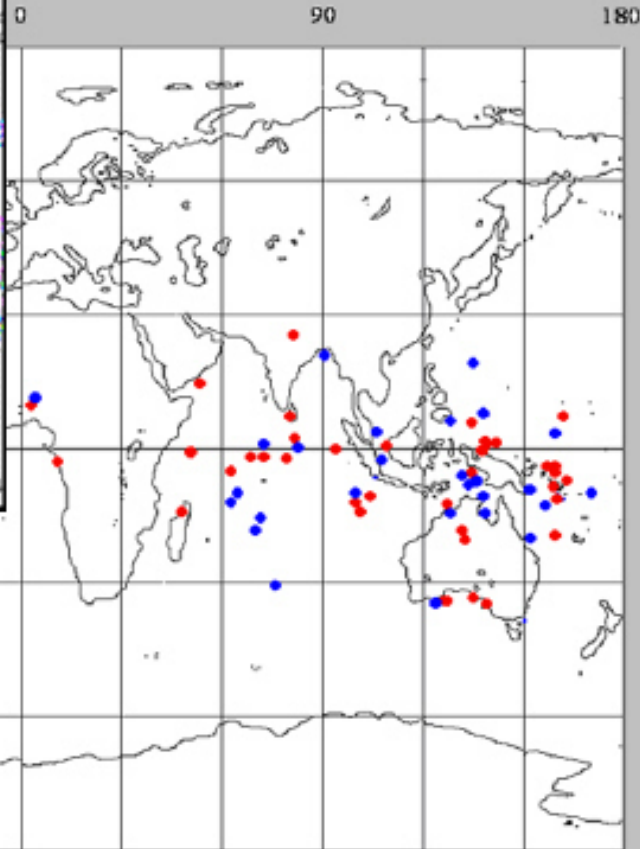
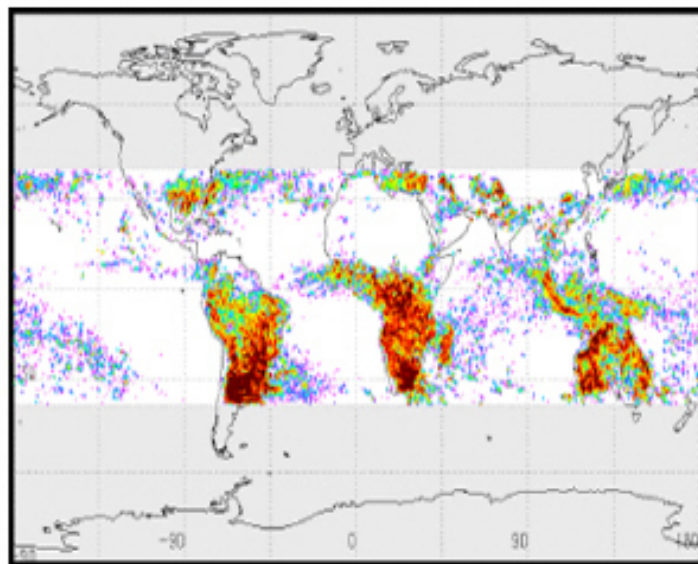
The geographical distribution of UV flashes



The geographical distribution of UV flashes



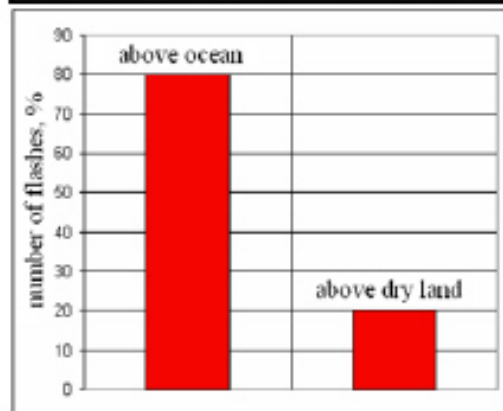
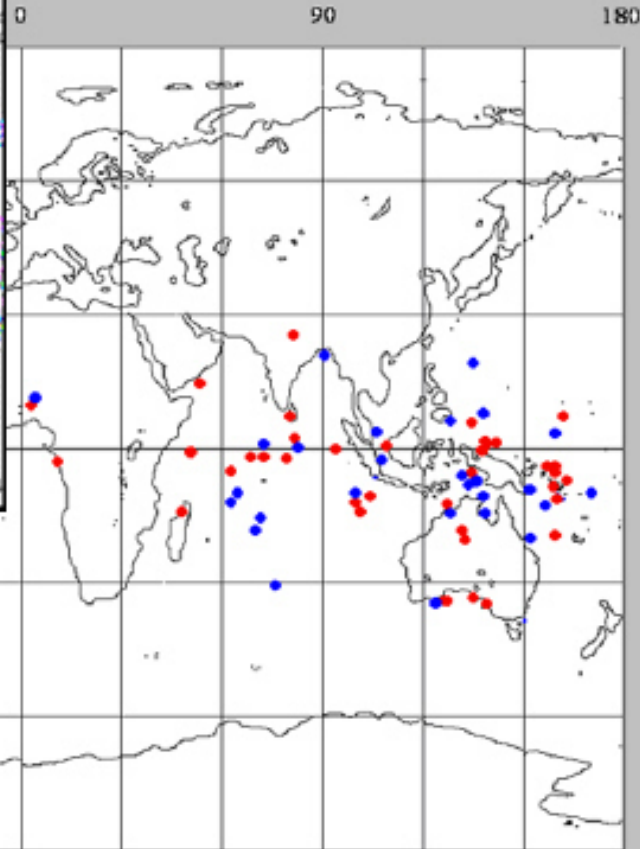
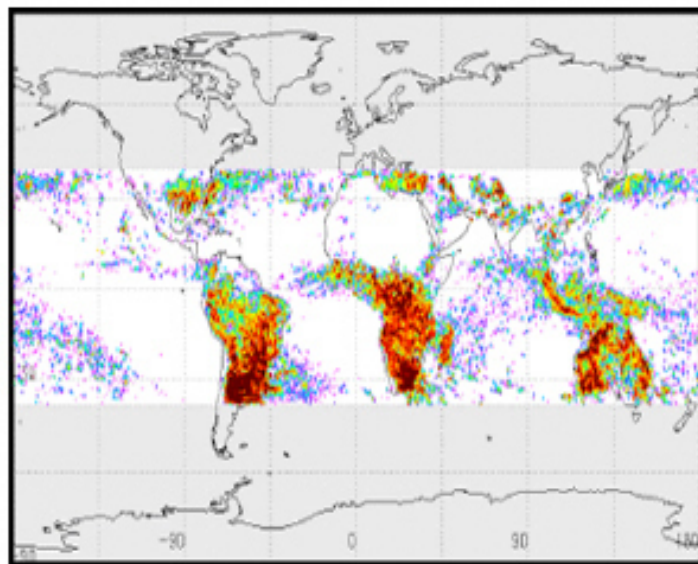
The geographical distribution of UV flashes



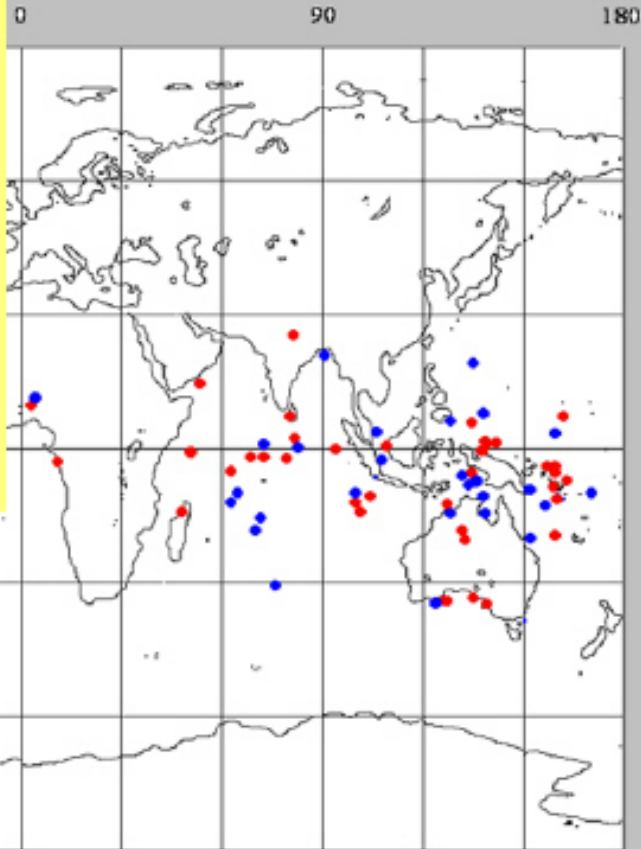
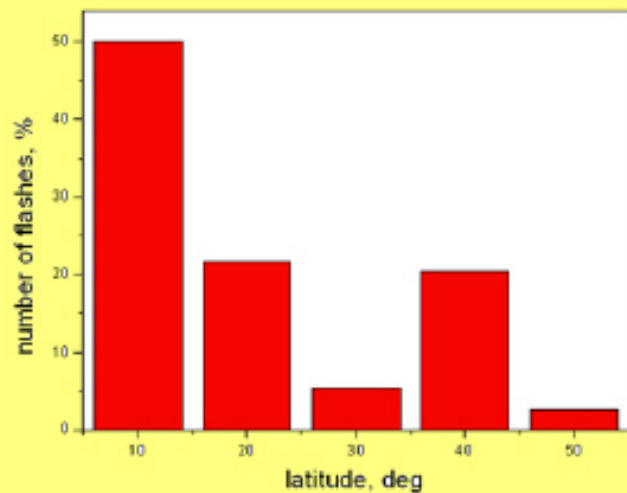
Narrow Bipolar Event

- FORTE衛星によるVHF観測
- 孤立した電波パルスイベント
 - 一般の雷のパルス列に先行
 - $T < 1 \mu s$
 - 10J-100J
- 可視光に対応する閃光パルスなし
- Runaway Electron Breakdown
 - Gurevich and Zybin 2004
 - 宇宙線空気シャワーがトリガ？
 - 電子が100-1000倍に増大
 - 近紫外で蛍光

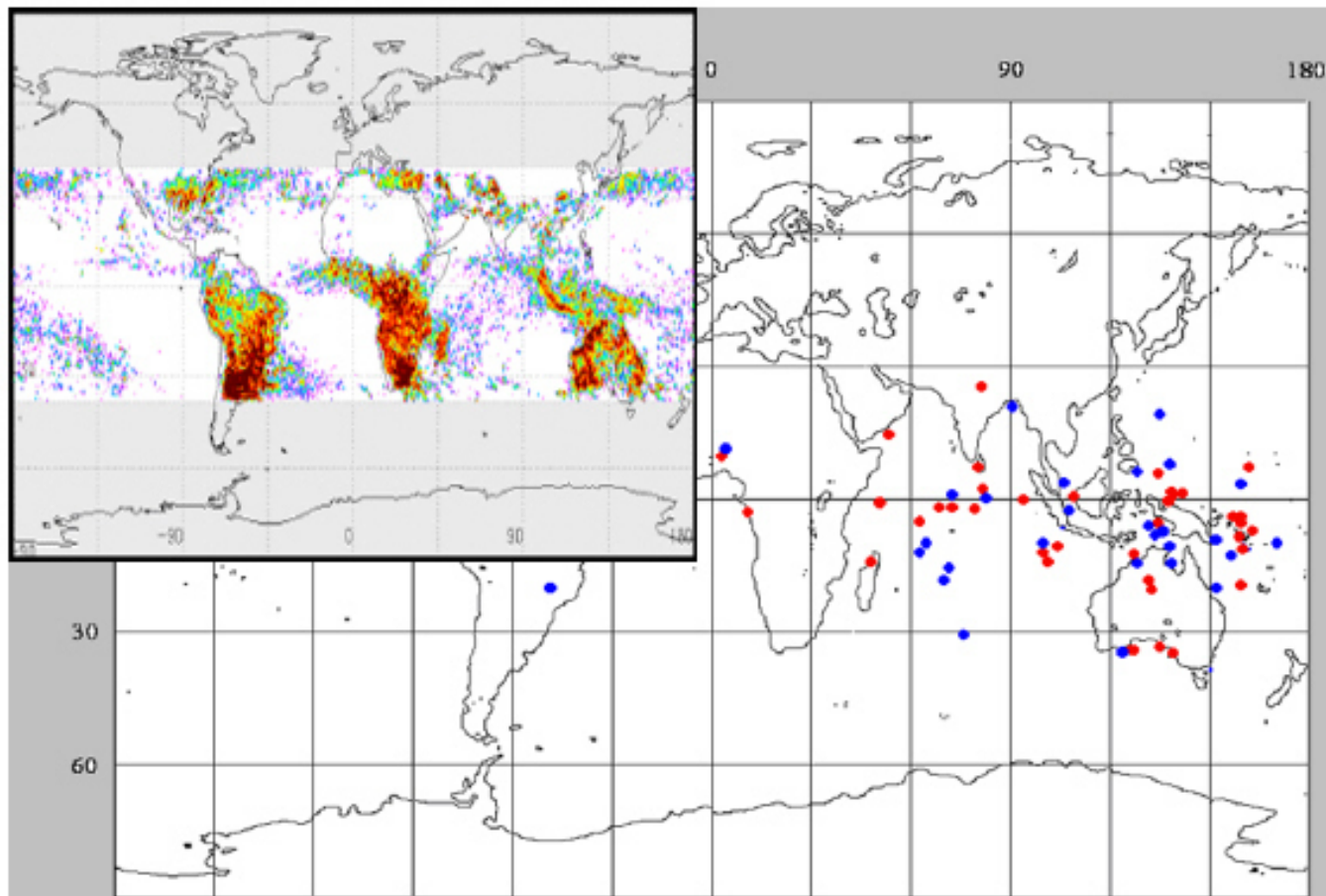
The geographical distribution of UV flashes



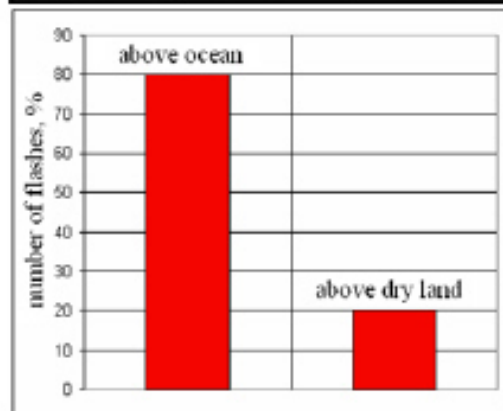
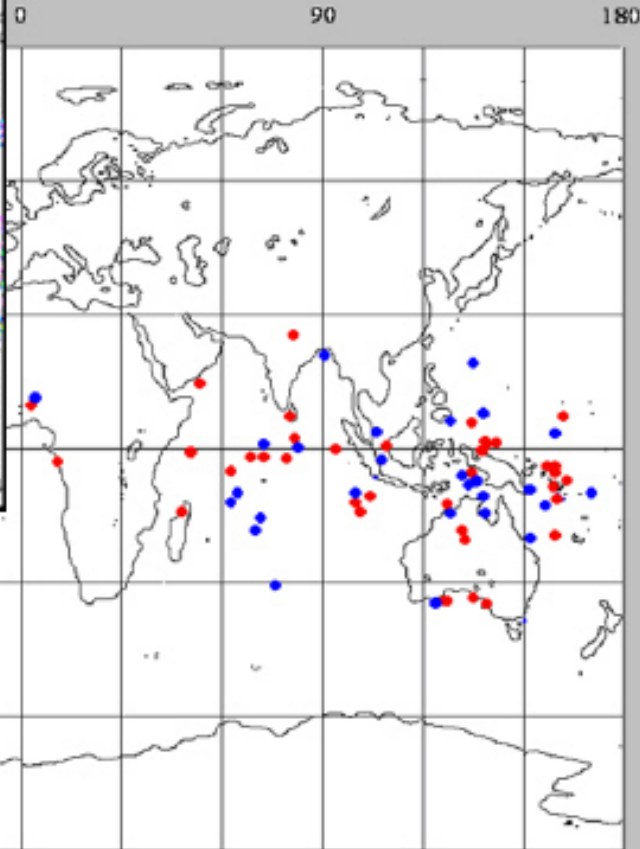
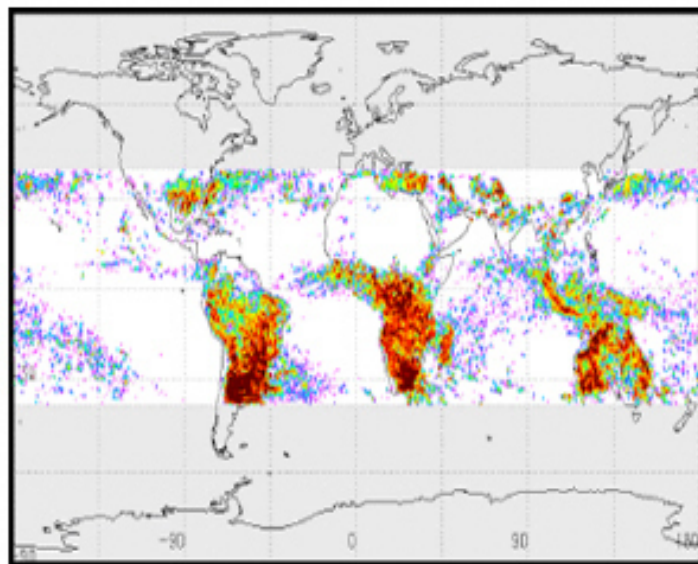
The geographical distribution of UV flashes



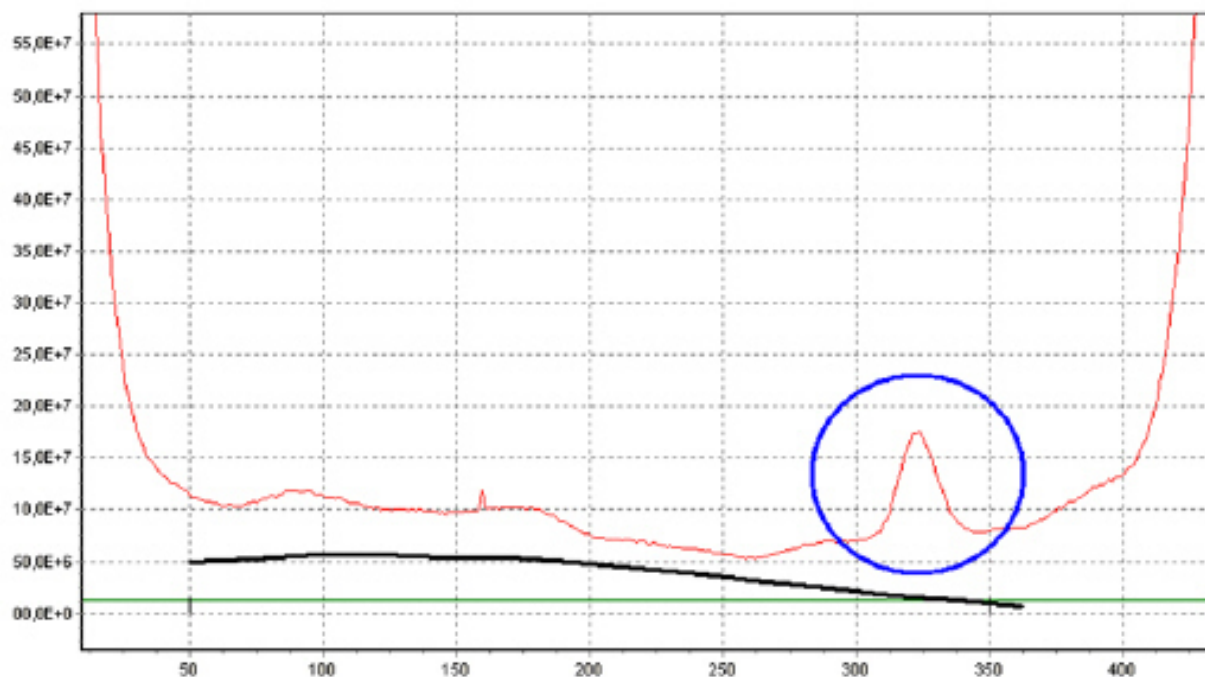
The geographical distribution of UV flashes



The geographical distribution of UV flashes



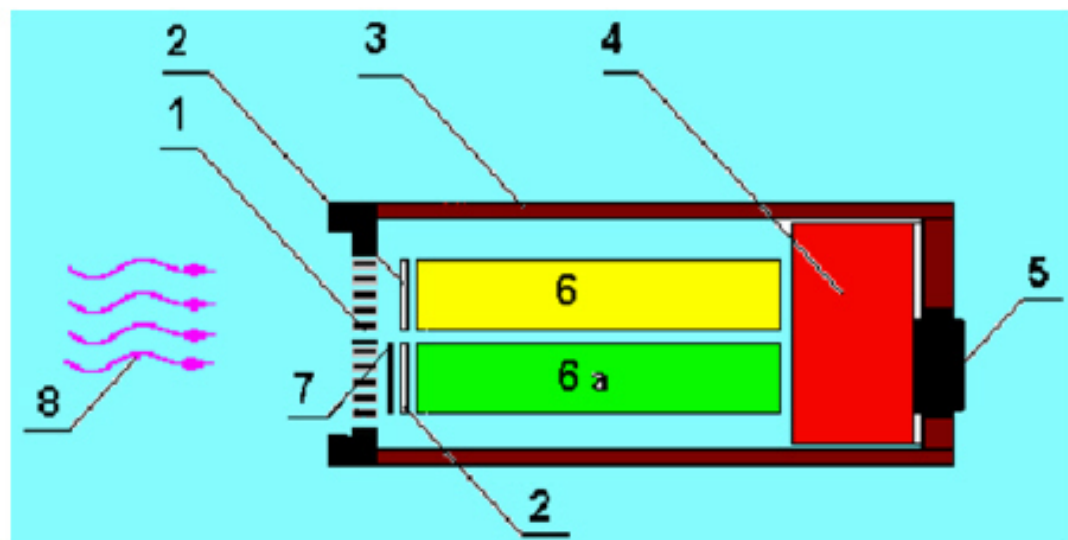
Examples of satellite "Tatiana" data



13.02.2005

Moon phase 25 %, Blue oval – the satellite is above Japan.

The detector of UV radiation



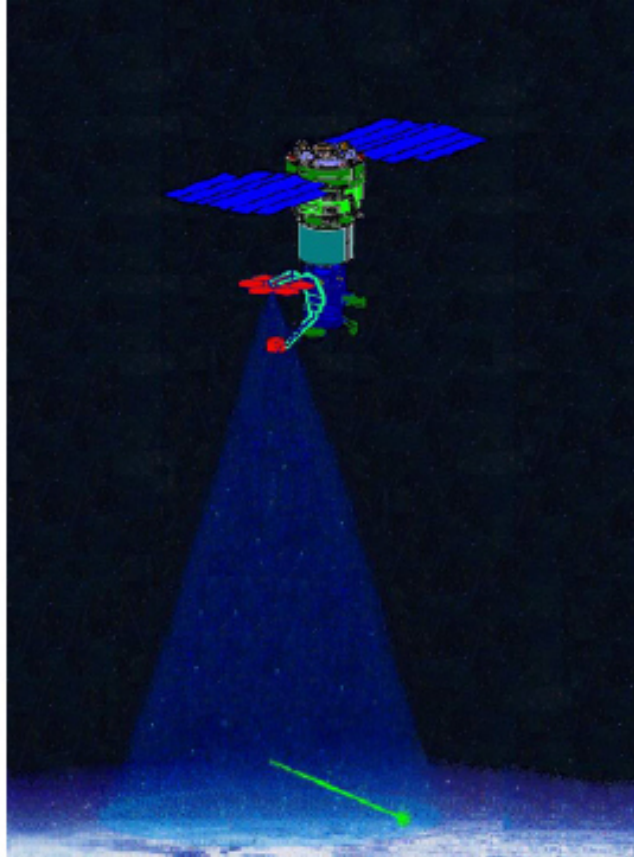
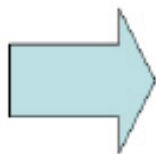
Some detector parameters:

FOV: 15°

$S = 0,4 \text{ c m}^2$.

UV filter: 200 – 400 nm

The results of satellite
"Tatiana" launched in
January 2005 are
important for planning
TUS.



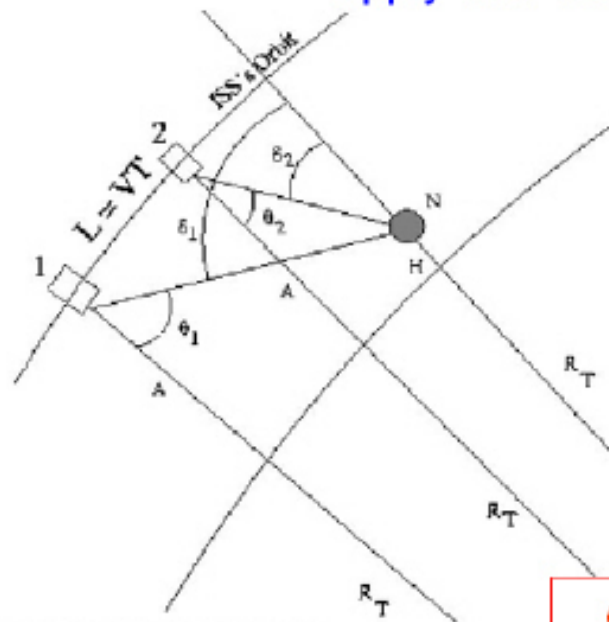
Tatiana UV Flash

- 雷雲と関係あると考えるのがもっともらしい
- 落雷との時間相関なし
- 雲-雲放電？
 - たくさんの小さな放電の寄与か

Specification

Item	Value	Reference
Wavelength	330 – 400 nm	Same as JEM-EUSO detector
Spatial res.	800m x 800m	
Detector	MAPMTs	
Resolution	8 bit	
Cloud top altitude determination res.	~ 1 km	IFOV of 1-pixel
Exposure gate time	50 μ sec	= 20GTU
Time interval	3.5 sec	ISS travel time of 1-PDM FOV
Data rate	35 kbps	

- Photon counting of background photons
 - Continuous measurements with the ISS motion
- Apply the “stereoscopic vision” method



Background photons

$$I = 500 \text{ (ph/m}^2\text{/str/ns)}$$

Detected photoelectrons

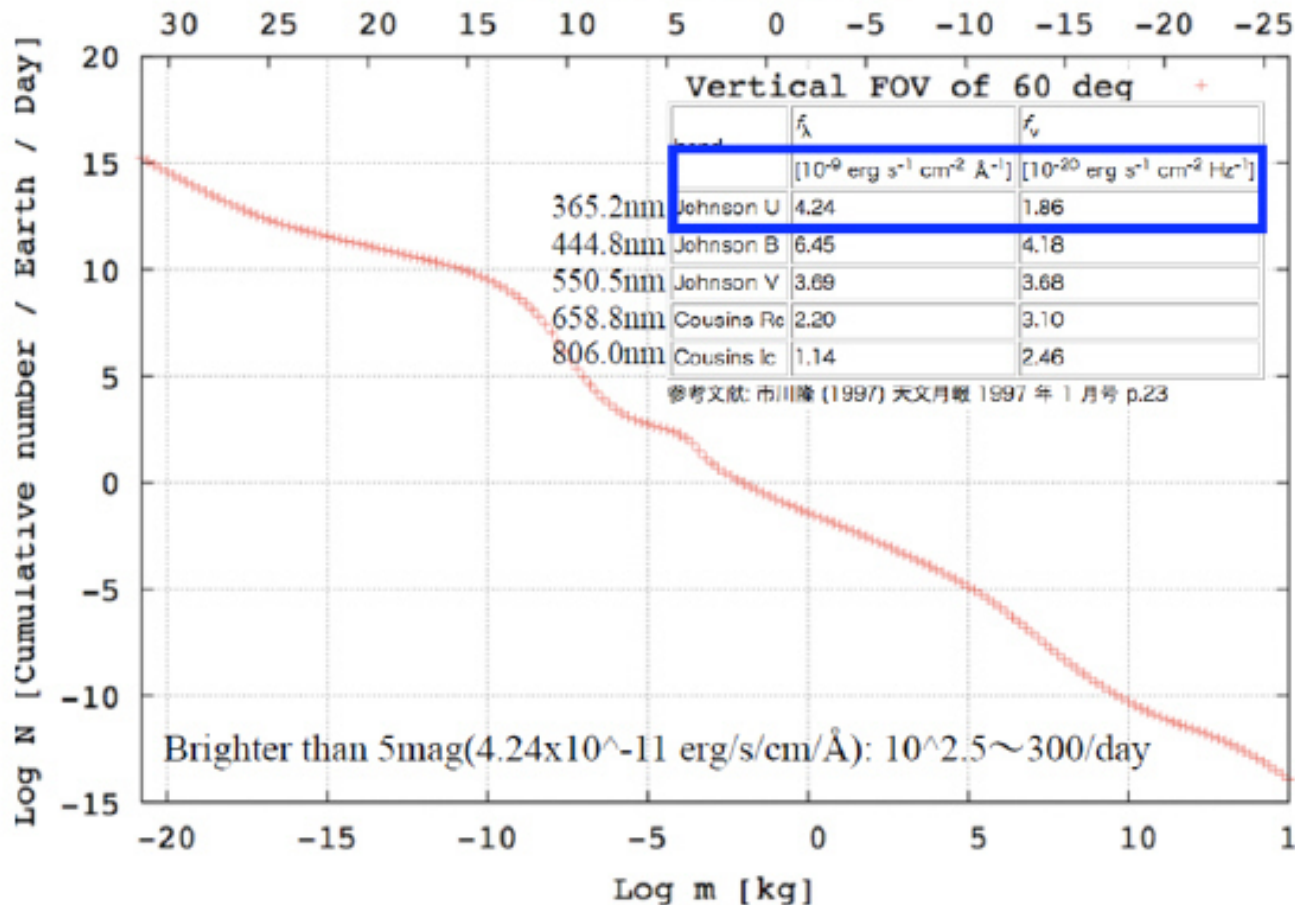
$$N_{p.e.} = 1 \text{ (p.e./pix/GTU)}$$

Expected slow-data counts

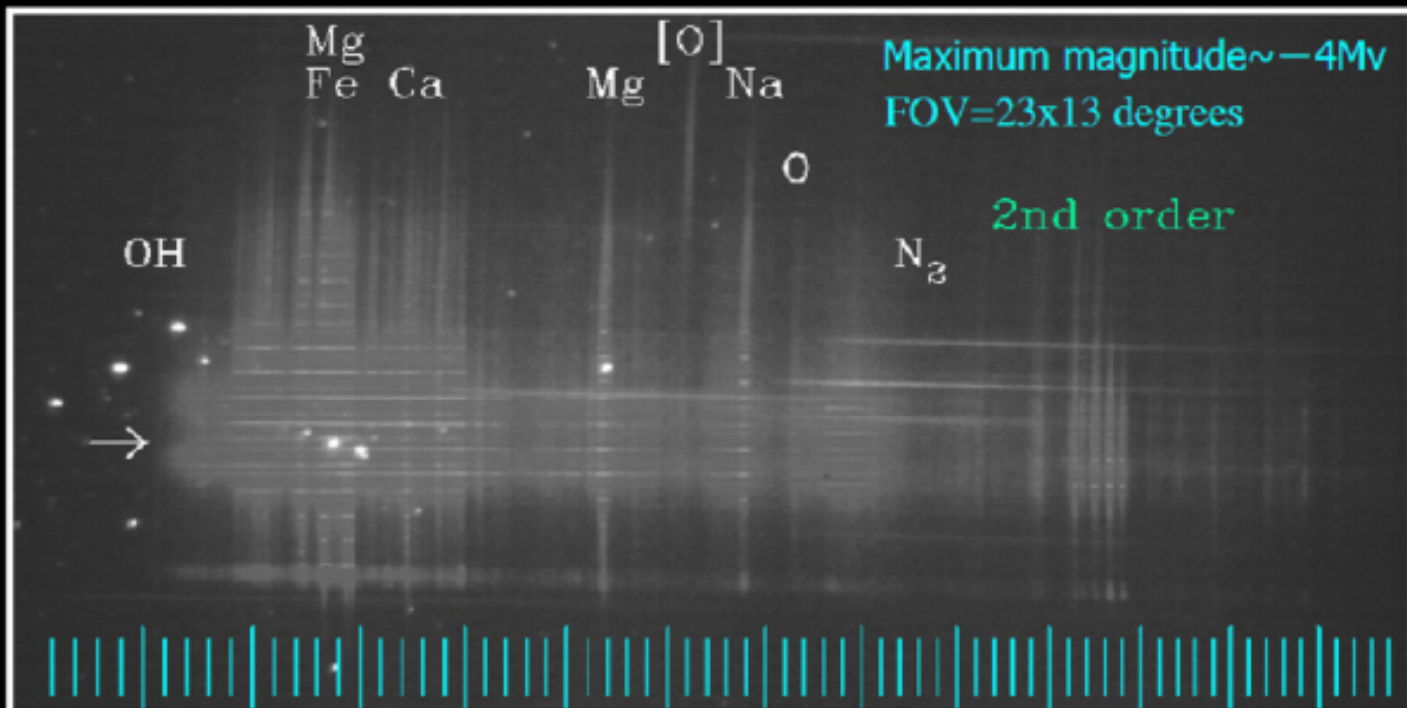
$$N_{p.e.} = 50 \text{ (p.e./pix/50 } \mu\text{s)}$$

Cloud top altitude: $\Delta h \approx 1 \text{ km}$

Magnitude from ISS



HDTV Spectrum of 2001 Leonid Meteor



Maximum magnitude ~ -4Mv
FOV=23x13 degrees

2nd order

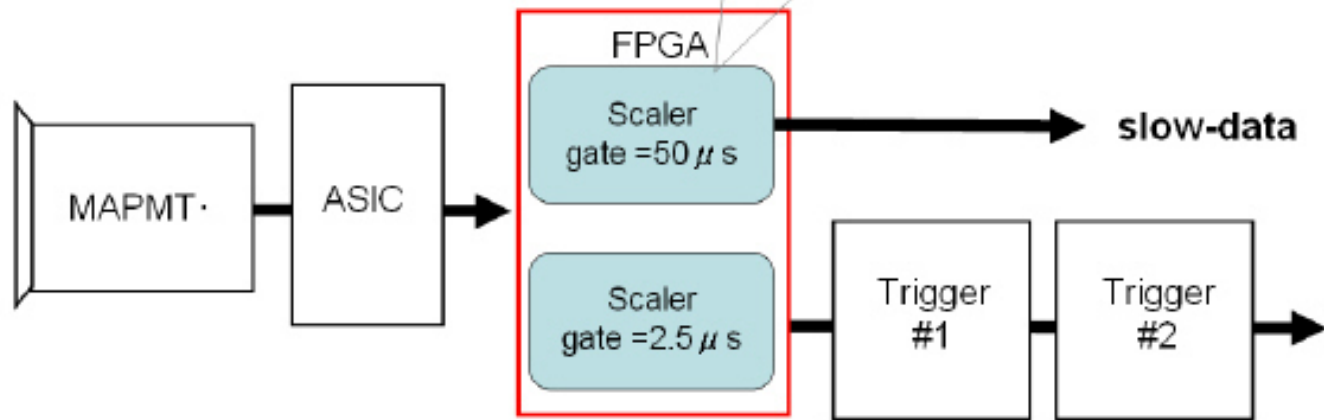
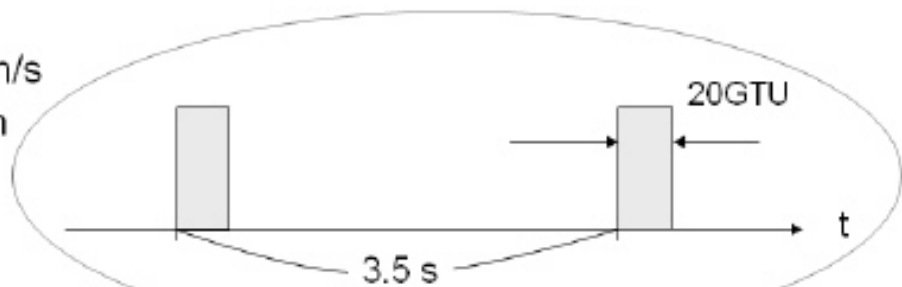
300 350 400 450 500 550 600 650 700 750 800 850 900

wavelength (nm)

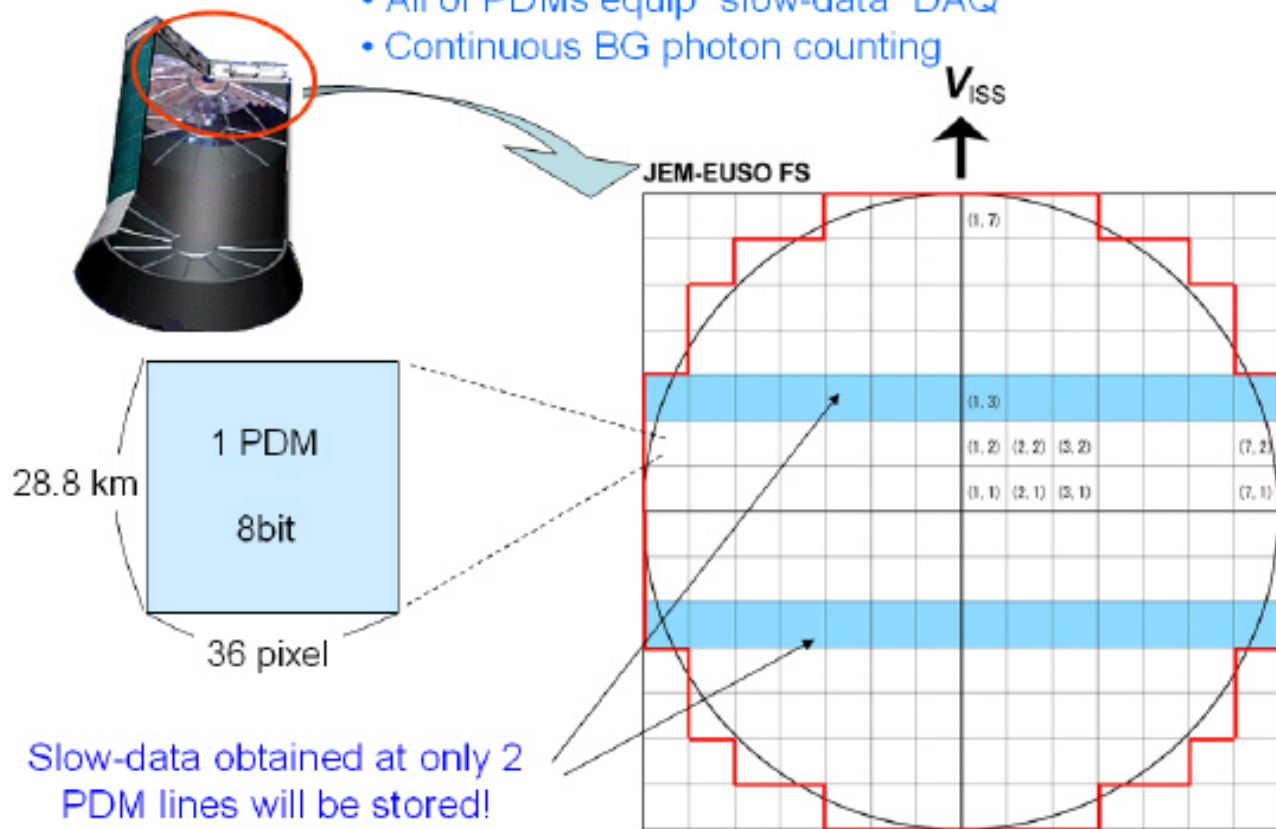
Slow Data

- 雲頂高度
 - ステレオ測定
- 流星
 - 10等～13等(トリガによる)
 - $1 \sim 10^5$ /day
 - 散在流星数の季節変化
 - 流星群観測(入射角、速度が一定)
- 夜光
- Tatiana UV Flash

- Velocity of ISS: 7.9 km/s
- FOV of 1PDM: 28.8 km

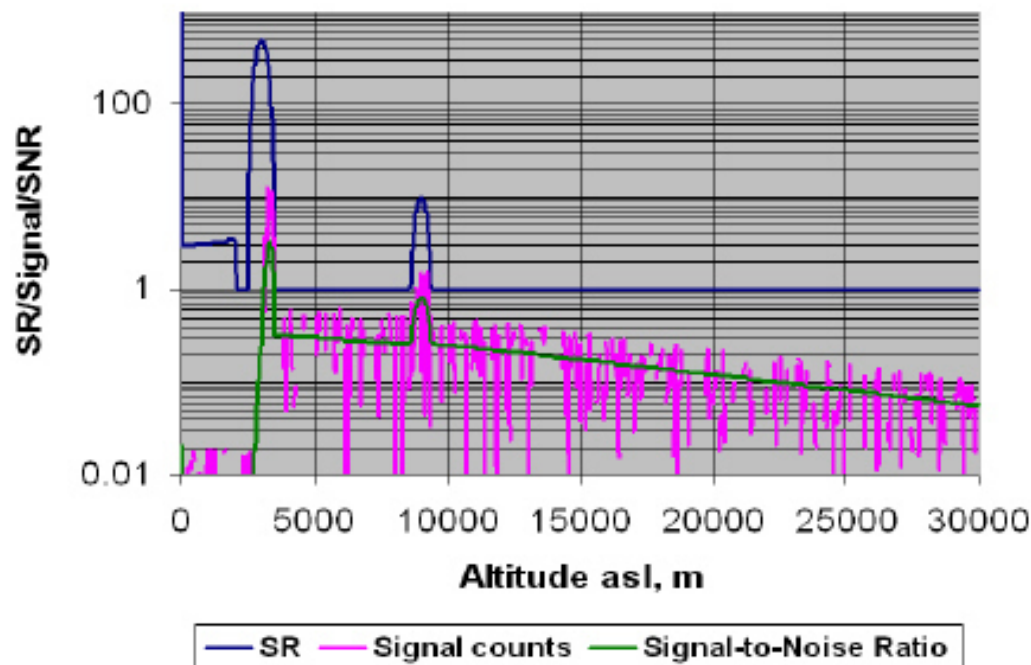


- All of PDMs equip "slow-data" DAQ
- Continuous BG photon counting



Slow-Data

Performance simulations, #3:

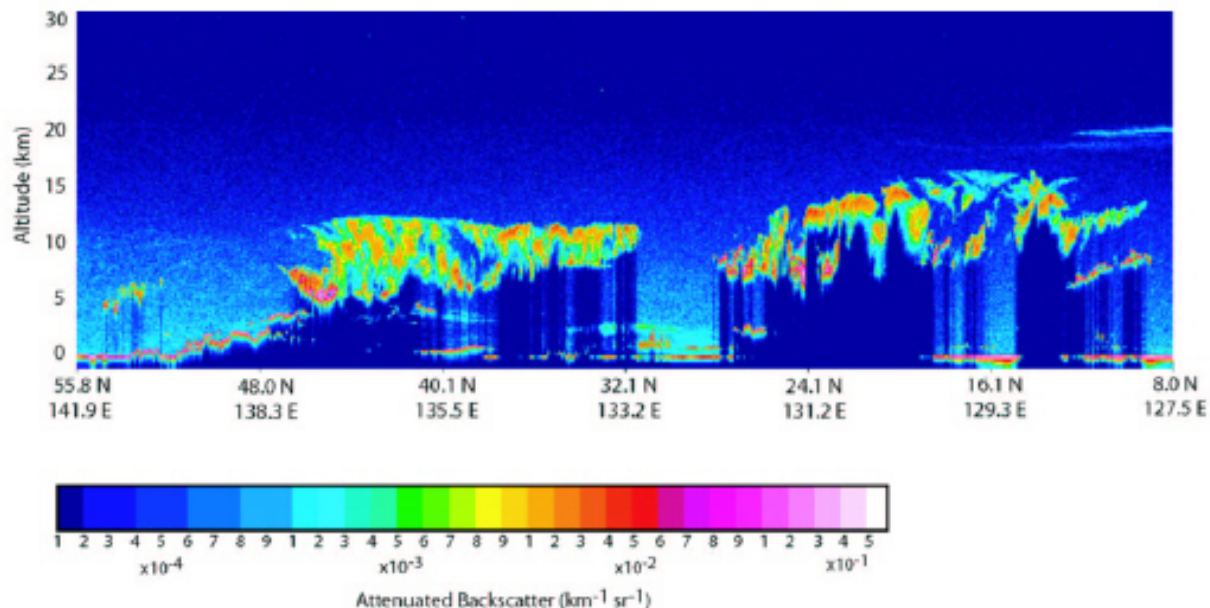


results for
355nm, 0.01sec
integration time,
30m range
resolution

Performance simulations, #1: Subsystems

Subsystem		Lidar 1	Lidar 2
Transmitter	Wavelength, nm	355	532
	Pulse repetition rate, pps	100	100
	Averaged transmitted power, W	1	1
	Divergence full angle, mrad	0.08	0.08
	Optical efficiency	80	80
Receiver	Primary receiver aperture diam, cm	250	250
	Secondary mirror aperture, cm	0	0
	Field of View full angle, mrad	0.2	0.2
	Interference filter, FWHM	0.25	0.25
	Interference filter, transmission %	50	50
	Optical efficiency (without filter)	25	25
Detector	Quantum efficiency, %	25	25
	Dark noise, counts per second	500	500
Acquisition (ph. counting)	Range resolution, bin meters	30	30
	Integration time, sec	0.01/1	0.01/1
Satellite	Altitude, km	500	500

Another spaceborne lidar– first CALIPSO results (#2)



Lidar

IR Camera Development with EADS/SODERN

Major Change from CIM01 to JEM-EUSO IR Camera

(1) Pixel size of detector

"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

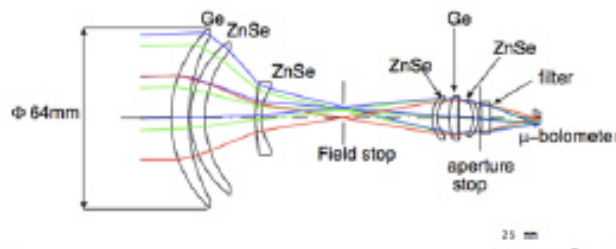
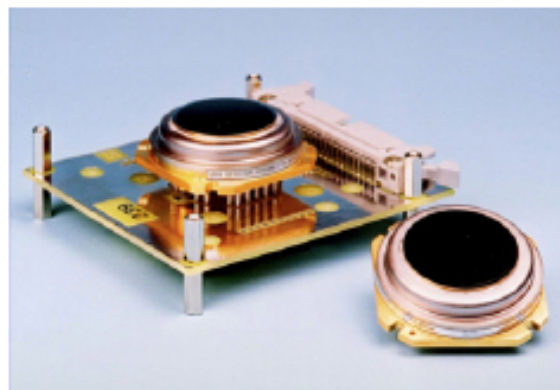
(2) FOV

Line scanning → >60°

Based on CIM01 design, they can produce FM of JEM-EUSO IR camera with 5.5MEuro within 5 years.

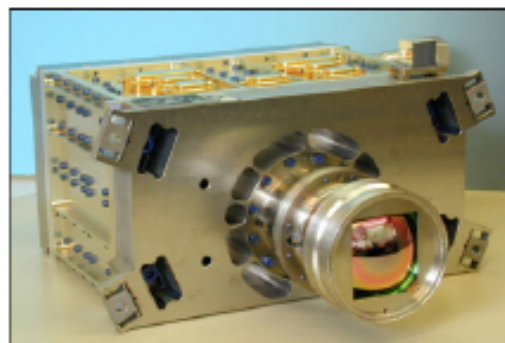
Specification of IR Camera

Should be determined before 12E, 2007



IR Camera Development with EADS/SODERN

CIM01 (or IASI) onboard METOP1 satellite



IASA Specification

- Scanning Mirror
- Sensor (CIM01)

λ : 10.3 - 12.5

μm

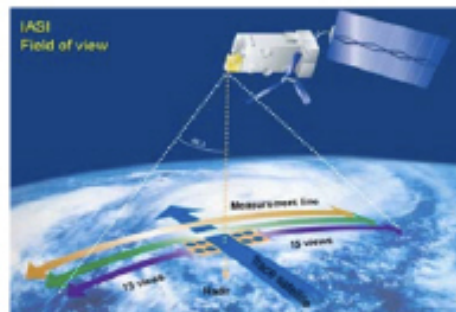
sensor: bolometer array

pix. size: 64×64

res.: 12 bit

FOV: 60×60 mrad

NETD : <80 mK

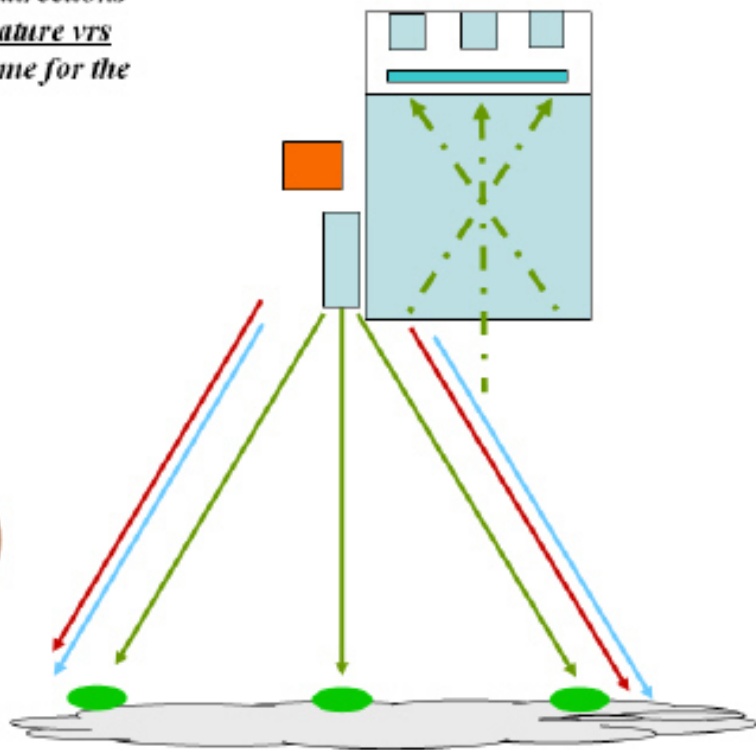
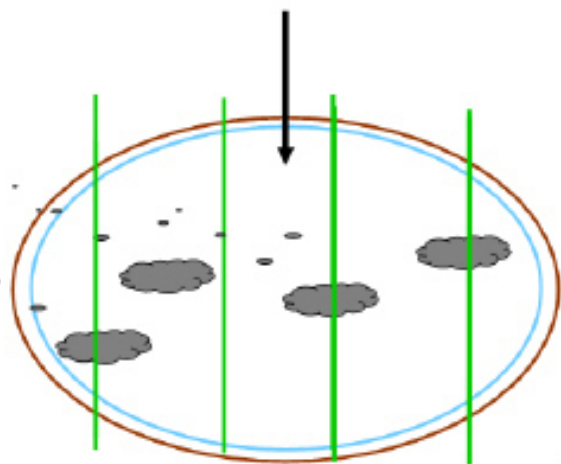


Requirement

Item	Value	Reason
Wavelength	10 – 13 μ m	Atmospheric transmission, S/N
FOV	> 60°	Same FOV as JEM-EUSO
Spatial Resolution	0.25°	1.8 km/pix @ nadir
Observation Temperature Range	200 – 320 K	Cloutop temperature in troposphere
Absolute Temperature Resolution	< 3 K	Altitude resolution < 500m
IR Sensor	Uncooled Microbolometer Array	Mass, Power
Exposure Time	133 msec	ISS motion within $\frac{1}{2}$ - pix of IR camera
Observation Interval	30 sec (5 sec TBC)	ISS motion of JEM-EUSO $\frac{1}{2}$ FOV

IR Camera

*Using the measurements in these three-four directions
for calibration of the IR radiometer temperature vrs
cloud top altitude – Reference lines ; the same for the
UV « slow mode »*



Atmospheric Monitoring System

- **IR Camera**

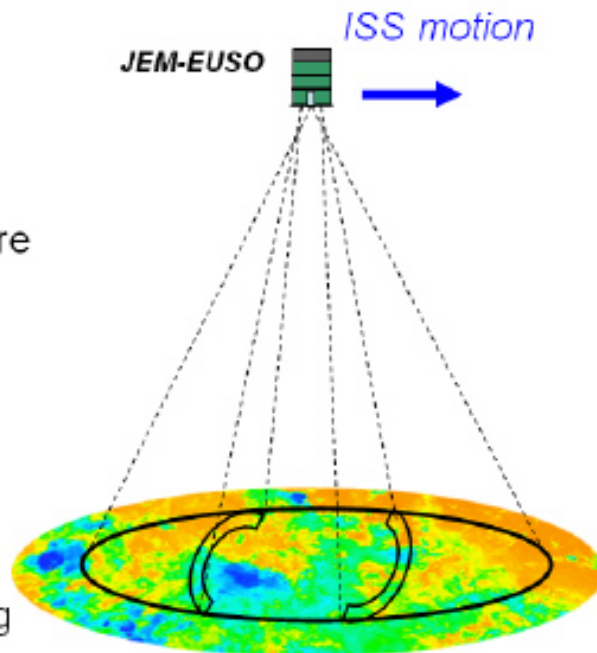
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

Ranging observation using UV laser

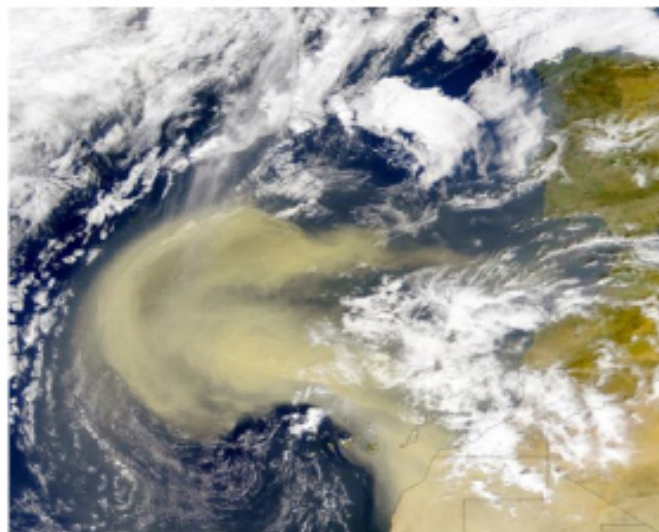
- **JEM-EUSO “slow-data”**

Continuous background photon counting



- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
- *Calibration of telescope:* (Lidar)

■ *The real atmosphere – clouds and desert dust*



Sahara dust over the Atlantic on 26.2.2000

Atmospheric Monitoring System

- **IR Camera**

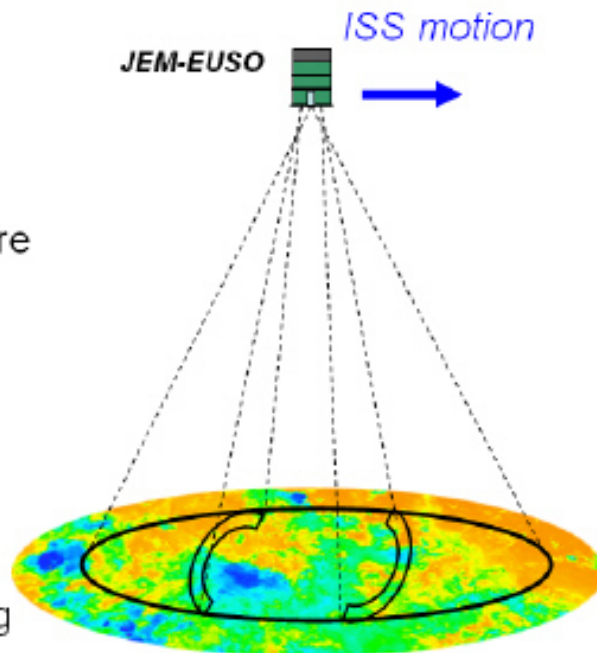
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

Ranging observation using UV laser

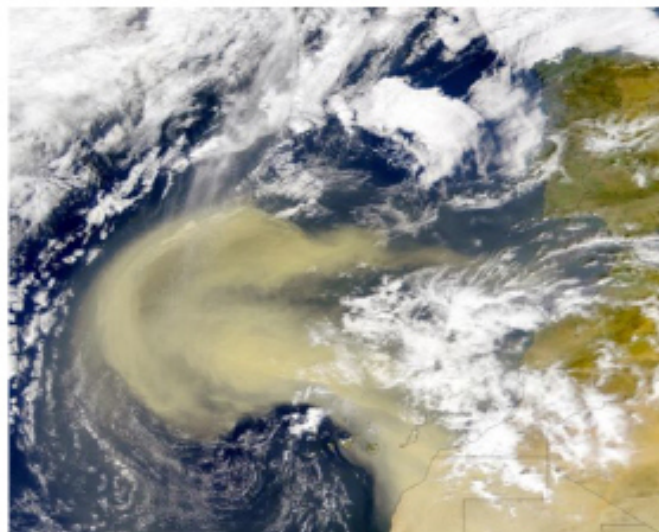
- **JEM-EUSO "slow-data"**

Continuous background photon counting



- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
- *Calibration of telescope:* (Lidar)

■ *The real atmosphere – clouds and desert dust*

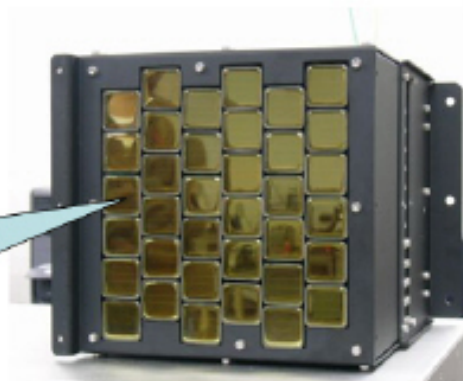
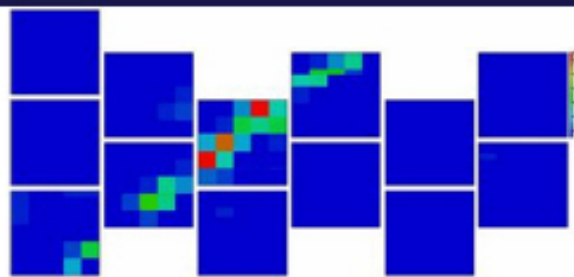


Sahara dust over the Atlantic on 26.2.2000

Progress: 小さなEUSOを製作

UV Laser

40cm Diameter



Prototype PDM

**ASIC
by Ikeda**

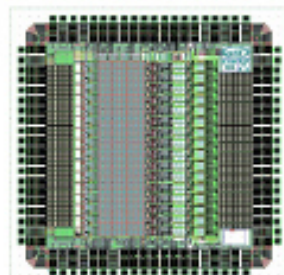


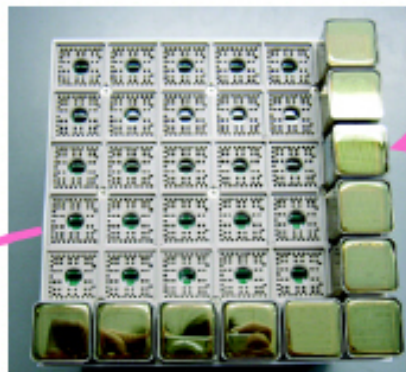
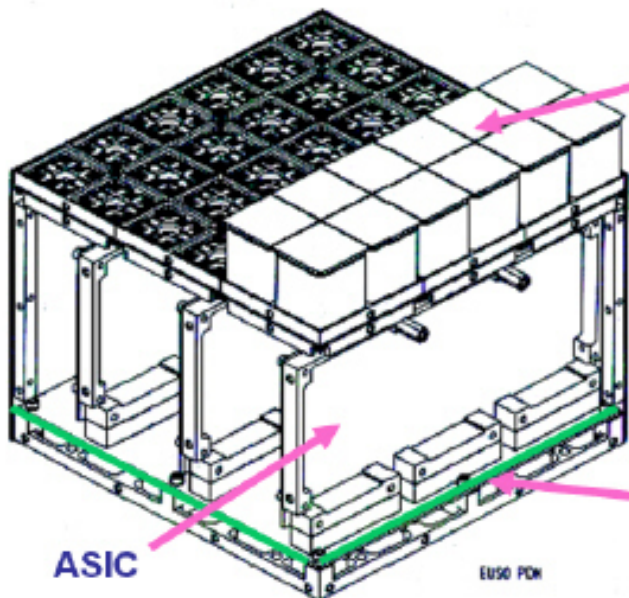
Photo Detector Module (PDM)

- 9 Elementary Cell (EC), 1 HV module, 9 HV divider

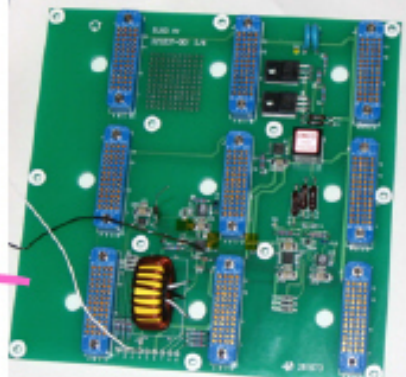
✓ 構造解析と振動試験 (済)

✓ 放射線試験 (済)

✓ 大光量保護回路 (済)



MAPMT
36PMTx36ch

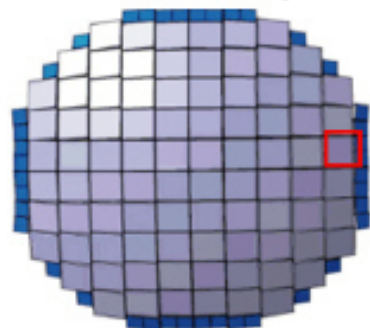


HV board

JEM-EUSO 焦点面の構造

Focal Surface detector

(164PDMs = 0.2M pixels)



2.26 m max

Elementary Cell

(2x2 PMTs = 144 pixels)

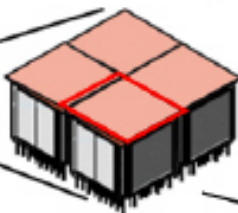
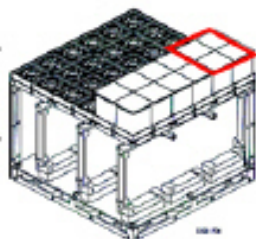
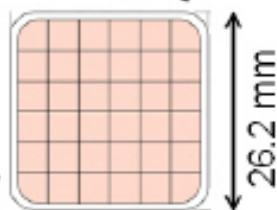


Photo-Detector Module

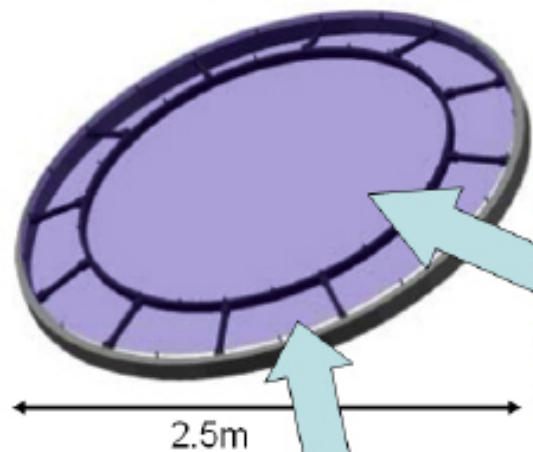
(3x3 ECs = 1296 pixels)



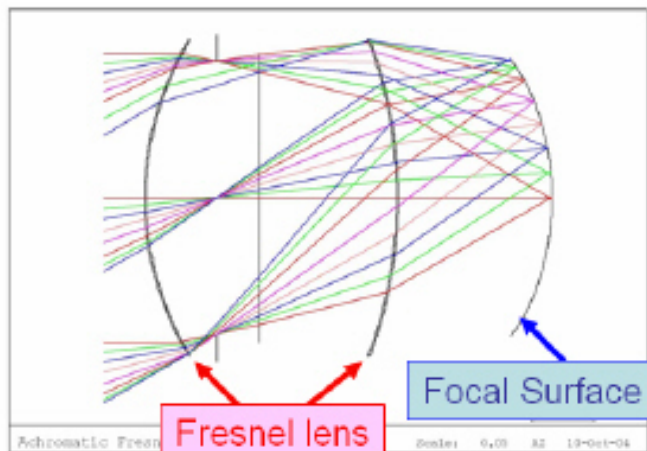
MAPMT
(6x6 pixels)



フレネルレンズ製作

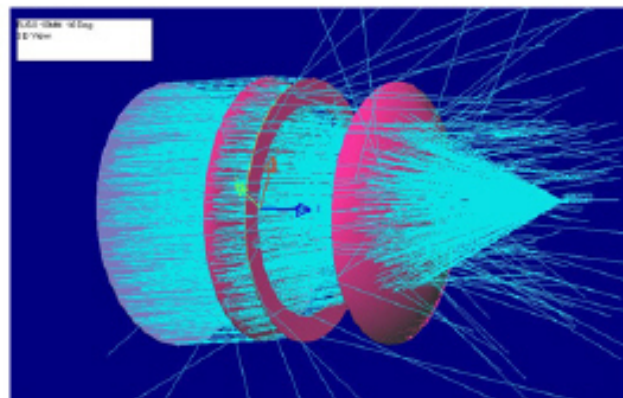


CYTOPを用いた新光学系



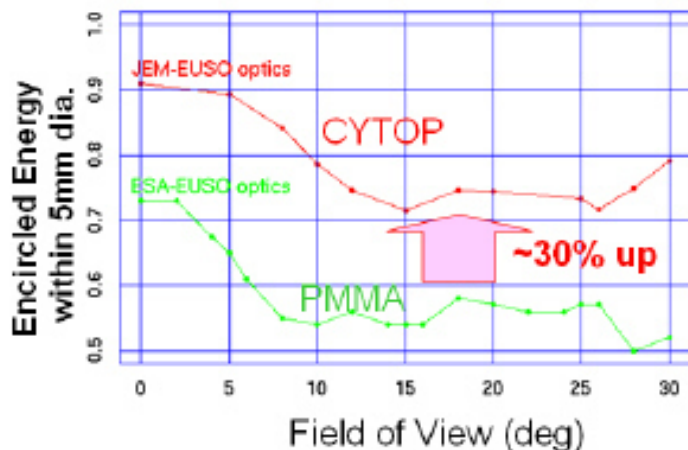
Optics Requirements

- FoV $\pm 30^\circ$
- Pupil entrance pupil ≥ 2 m
- $F/\# \leq 1.0$
- Spot dimension $\sim 0.1^\circ$ (5mm Φ)
- Spectral range 330-400 nm

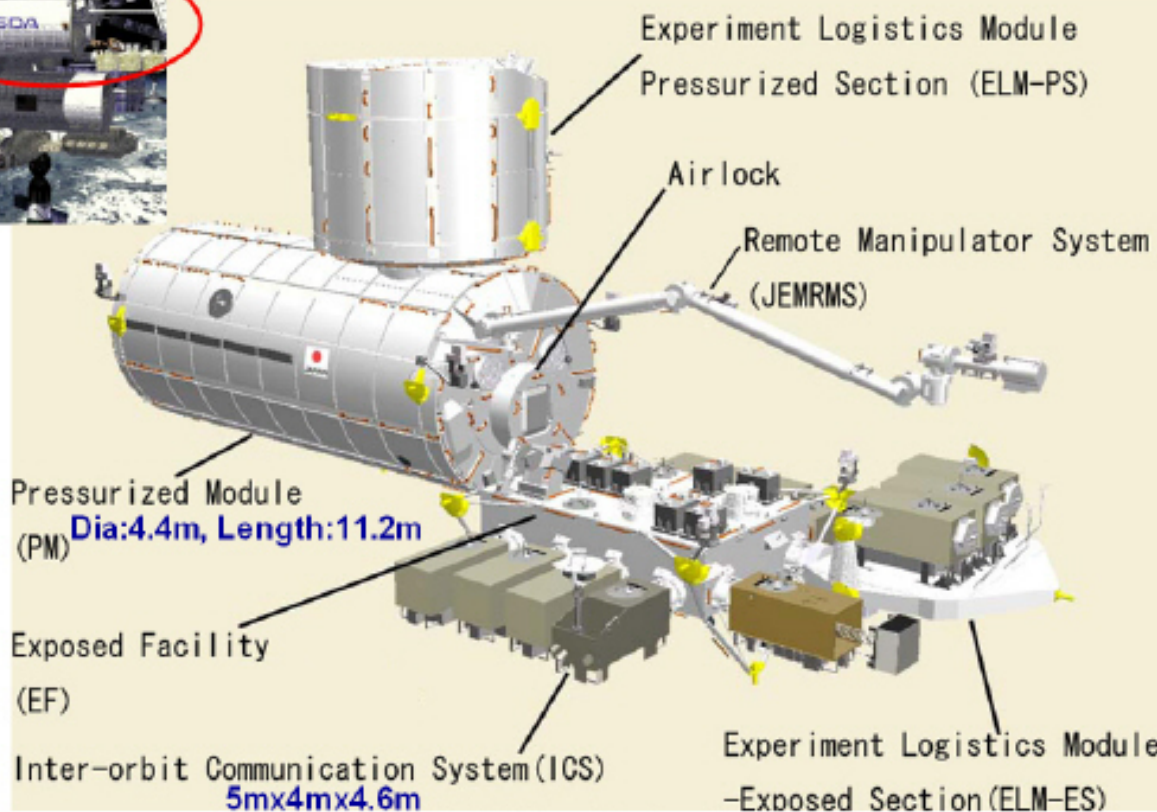
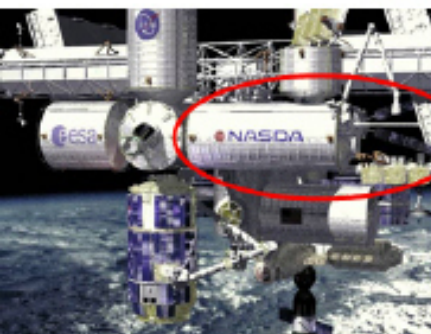


Ray trace

JEM-EUSO vs ESA-EUSO optics



日本実験棟「きぼう」



これからの予定

- 2007年度－2008年度(準備研究・概念設計)
 - 2007年10月 曝露部分科会へ報告
 - 2007年11月 国際JEM-EUSO会合
 - 2008年1月 国際アドバイザーボード会合
 - 2008年3月 国際シンポジウム開催
 - 2008年4月 中間評価
 - 2009年3月 最終評価
- 2009年度－2012年度
 - 製作段階
- 2013年 打ち上げ

これまでの経緯

- ESA—EUSO
 - ESA 採択 2000;
 - NASA 採択 2003;
 - Phase-A 完了 2004
 - 地上公募研究: 1998 - 2001 2002 - 2004
- 2006年6月:
 - JEM-EUSO WGが宇宙理学委員会において承認ISAS/JAXA
- 2006年8月:
 - JEM-EUSO計画化委員会が理研中央研究所に設置
- 2006年11月:
 - 第二期利用ミッション候補公募開始
- 2007年2月:
 - 理研から提案書提出
- 2007年5月:
 - 採択の正式通知
- 2007年6月
 - Kick-Off会合
 - 国際アドバイザーボード会合
- 2007年7月
 - 第一回国際JEM-EUSO会合(国際宇宙線会議@メキシコ)

ミッション諸元

- 打ち上げ時期: year 2013
- 運用期間: 3 years (+ 2 years)
- 打ち上げロケット: H2B
- ISSへの運搬: HTV非与圧キャリア
- 装着場所: JEM EFU#2
- 軌道高度: ~430km
- 軌道傾斜角: 51.6°
- 質量: 1896 kg
- 使用電力: 998 W (operative),
344 W (non-operative)
- データ転送量: 297 kpbs

サクセスクライテリア

フルサクセス:

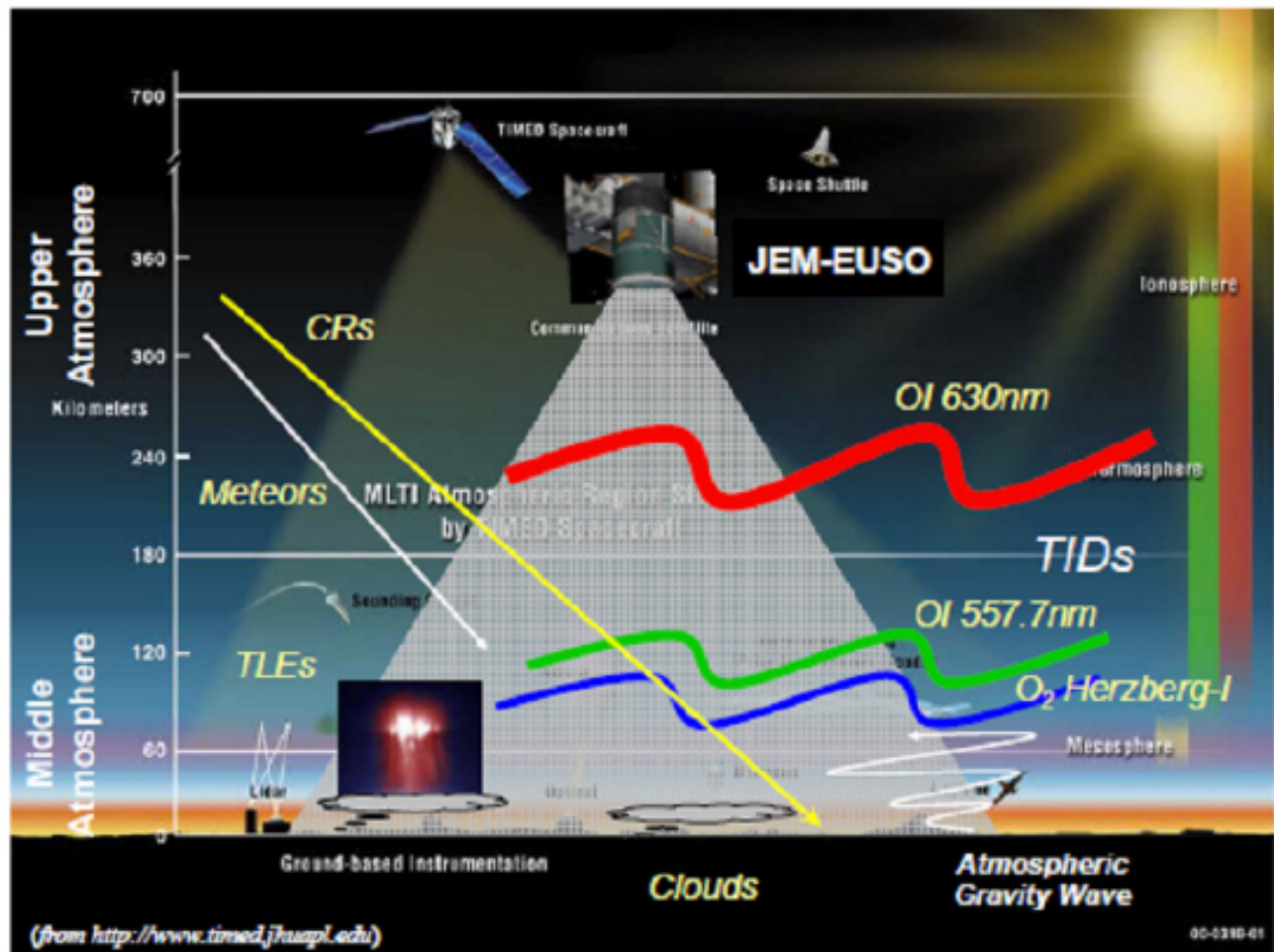
極限エネルギー事例: 1000個以上
(7×10^{19} eV 以上)

ミニマムサクセス:

フルサクセスの半分の事例数を得る: 500個

分布から起源を議論の余地なく特定できる臨界量

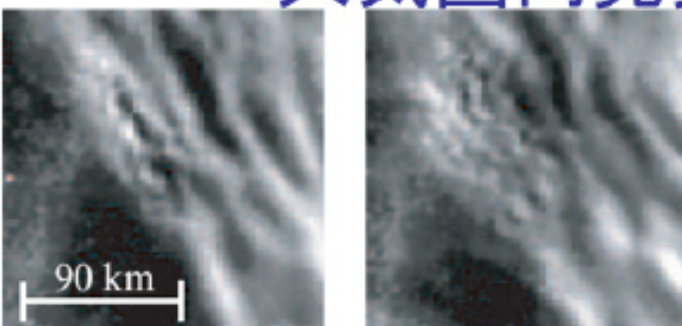
- 粒子到来方向解析
 - 到来方向決定精度: 2.5度以下
- スペクトル解析
 - エネルギー決定精度: 30%以下
- ハドロン／光子／ニュートリノの識別:
 - シャワー最大深さ決定精度: 120 g/cm^2 以下



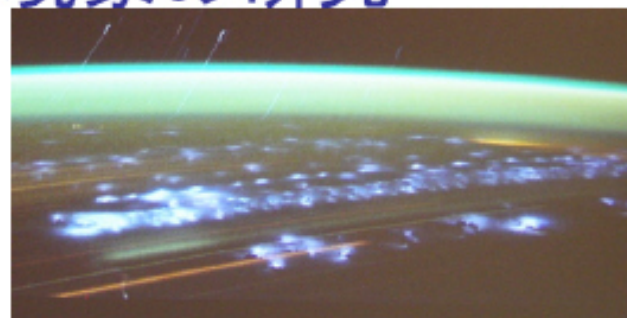
JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星

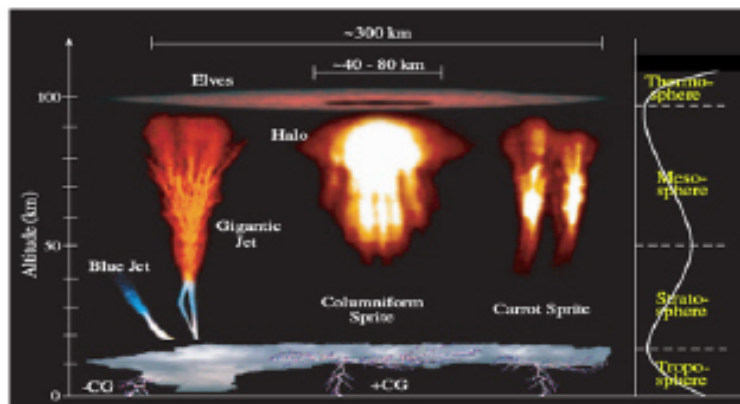
探求的試験研究3: 大気圏内発光現象の研究



地上から観測したOH 大気光の変化

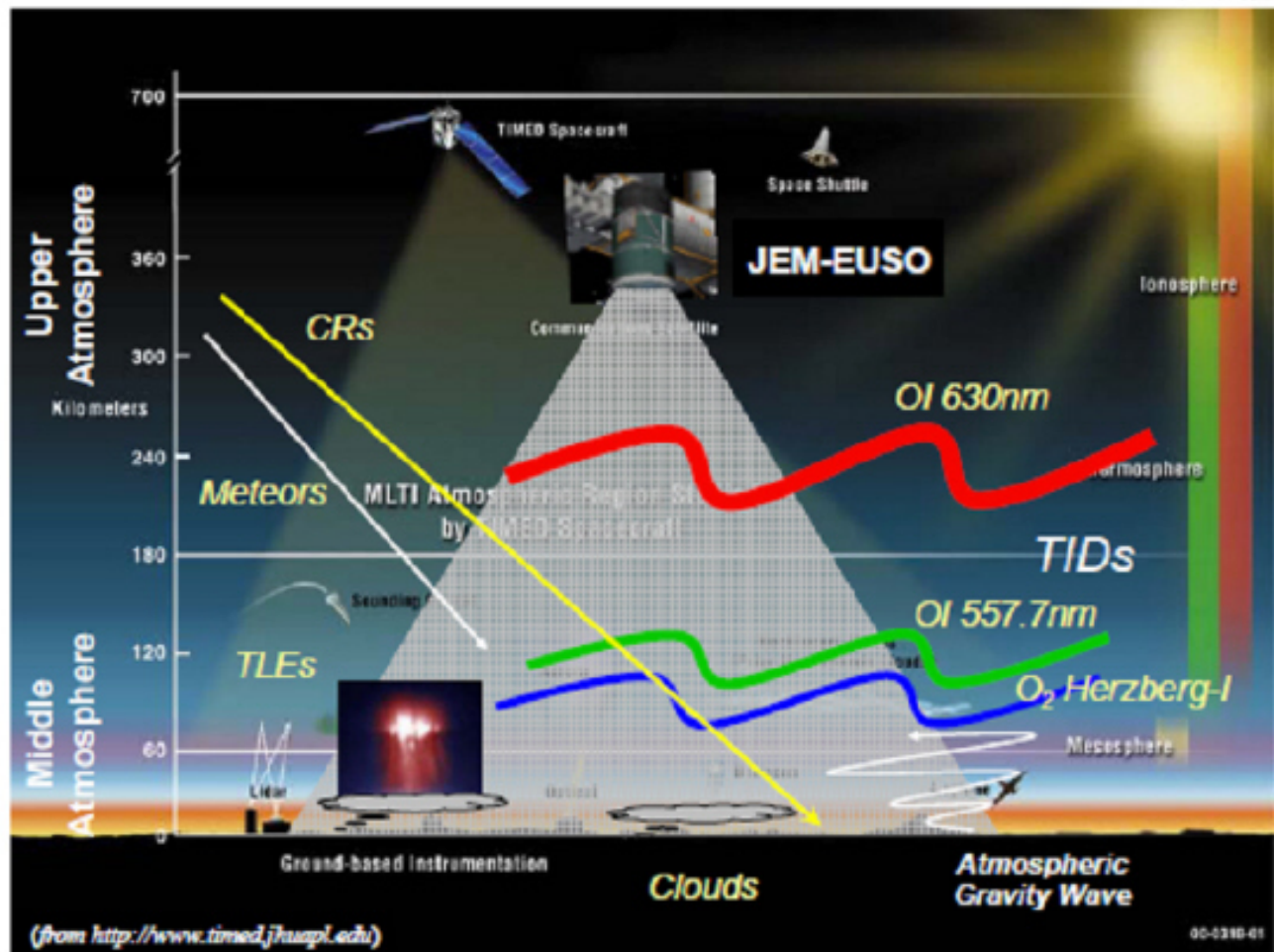


国際宇宙ステーションから連続撮影した雷光

ハイビジョンカメラによる
2001年のしし座流星群雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星



サクセスクライテリア

フルサクセス:

極限エネルギー事例: 1000個以上
(7×10^{19} eV 以上)

ミニマムサクセス:

フルサクセスの半分の事例数を得る: 500個

分布から起源を議論の余地なく特定できる臨界量

- 粒子到来方向解析
 - 到来方向決定精度: 2.5度以下
- スペクトル解析
 - エネルギー決定精度: 30%以下
- ハドロン／光子／ニュートリノの識別:
 - シャワー最大深さ決定精度: 120 g/cm^2 以下

ミッション諸元

- 打ち上げ時期: year 2013
- 運用期間: 3 years (+ 2 years)
- 打ち上げロケット: H2B
- ISSへの運搬: HTV非与圧キャリア
- 装着場所: JEM EFU#2
- 軌道高度: ~430km
- 軌道傾斜角: 51.6°
- 質量: 1896 kg
- 使用電力: 998 W (operative),
344 W (non-operative)
- データ転送量: 297 kpbs

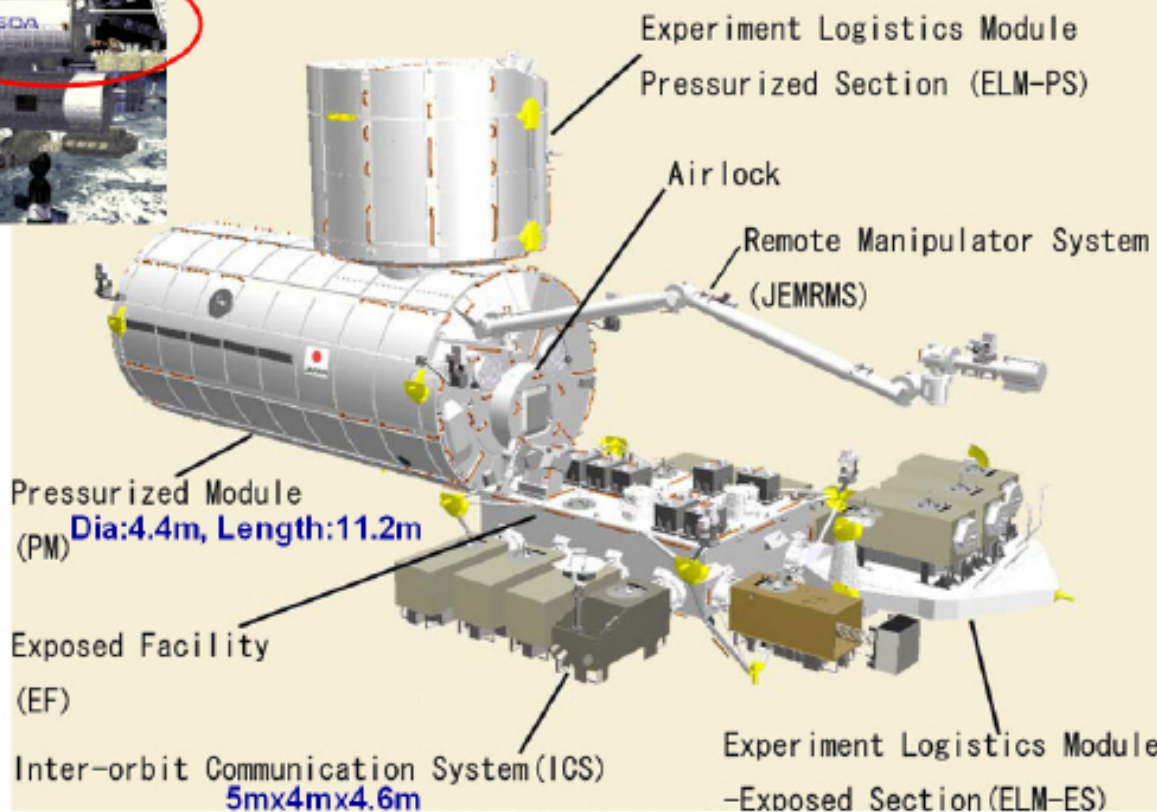
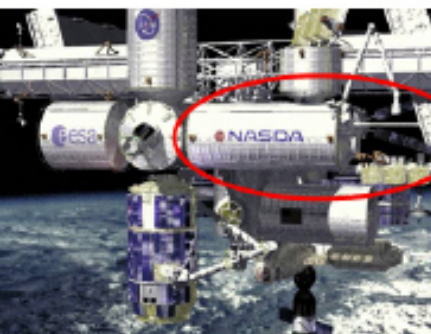
これまでの経緯

- ESA—EUSO
 - ESA 採択 2000;
 - NASA 採択 2003;
 - Phase-A 完了 2004
 - 地上公募研究: 1998 - 2001 2002 - 2004
- 2006年6月:
 - JEM-EUSO WGが宇宙理学委員会において承認ISAS/JAXA
- 2006年8月:
 - JEM-EUSO計画化委員会が理研中央研究所に設置
- 2006年11月:
 - 第二期利用ミッション候補公募開始
- 2007年2月:
 - 理研から提案書提出
- 2007年5月:
 - 採択の正式通知
- 2007年6月
 - Kick-Off会合
 - 国際アドバイザーボード会合
- 2007年7月
 - 第一回国際JEM-EUSO会合(国際宇宙線会議@メキシコ)

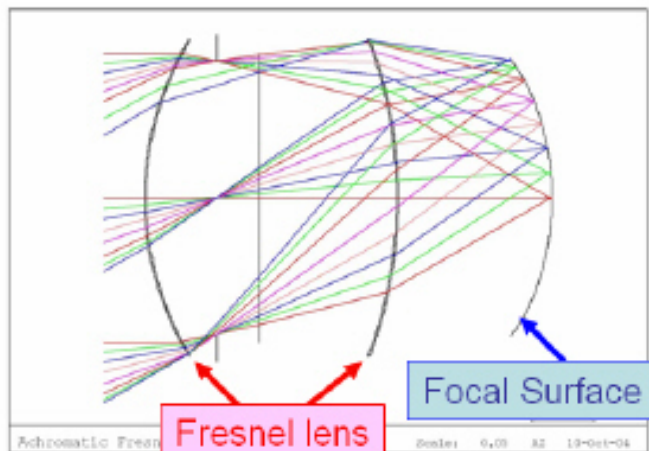
これからの予定

- 2007年度－2008年度(準備研究・概念設計)
 - 2007年10月 曝露部分科会へ報告
 - 2007年11月 国際JEM-EUSO会合
 - 2008年1月 国際アドバイザーボード会合
 - 2008年3月 国際シンポジウム開催
 - 2008年4月 中間評価
 - 2009年3月 最終評価
- 2009年度－2012年度
 - 製作段階
- 2013年 打ち上げ

日本実験棟「きぼう」

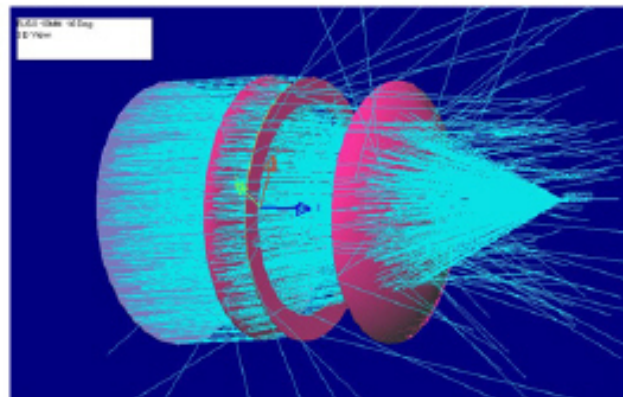


CYTOPを用いた新光学系



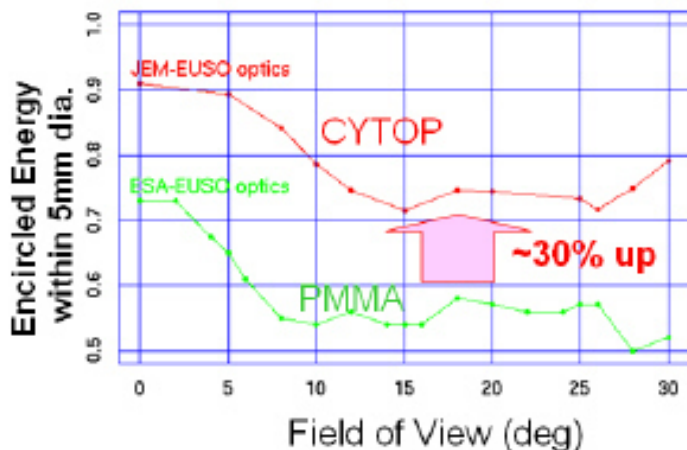
Optics Requirements

- FoV $\pm 30^\circ$
- Pupil entrance pupil ≥ 2 m
- $F/\# \leq 1.0$
- Spot dimension $\sim 0.1^\circ$ (5mm Φ)
- Spectral range 330-400 nm

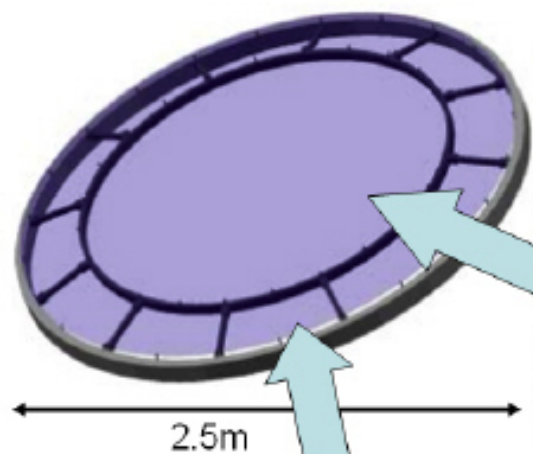


Ray trace

JEM-EUSO vs ESA-EUSO optics



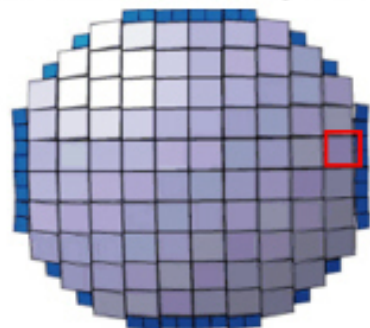
フレネルレンズ製作



JEM-EUSO 焦点面の構造

Focal Surface detector

(164PDMs = 0.2M pixels)



2.26 m max

Elementary Cell

(2x2 PMTs = 144 pixels)

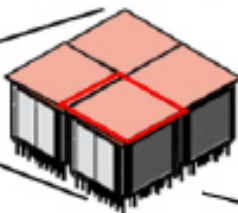
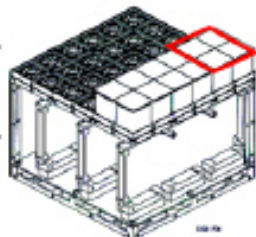


Photo-Detector Module

(3x3 ECs = 1296 pixels)



MAPMT
(6x6 pixels)

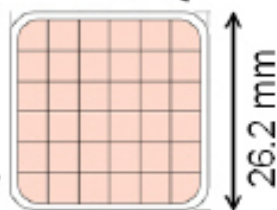


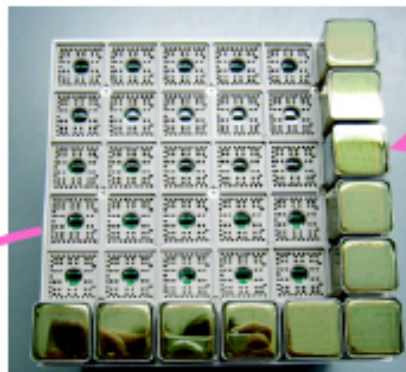
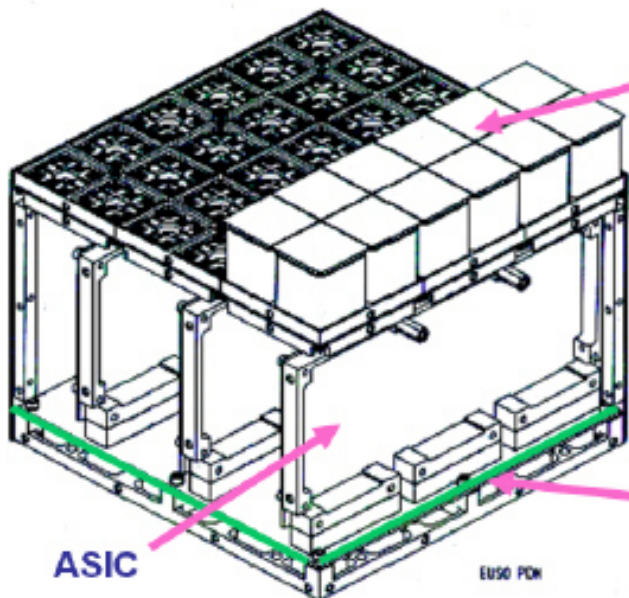
Photo Detector Module (PDM)

- 9 Elementary Cell (EC), 1 HV module, 9 HV divider

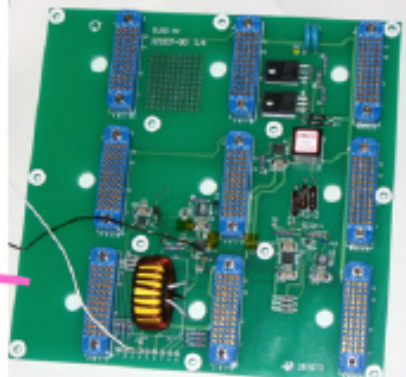
✓ 構造解析と振動試験 (済)

✓ 放射線試験 (済)

✓ 大光量保護回路 (済)

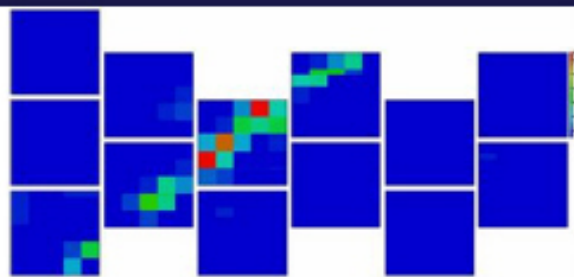


MAPMT
36PMTx36ch

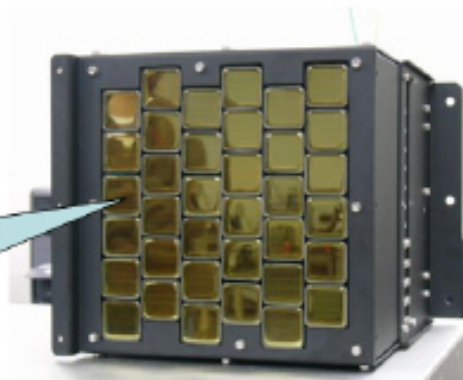
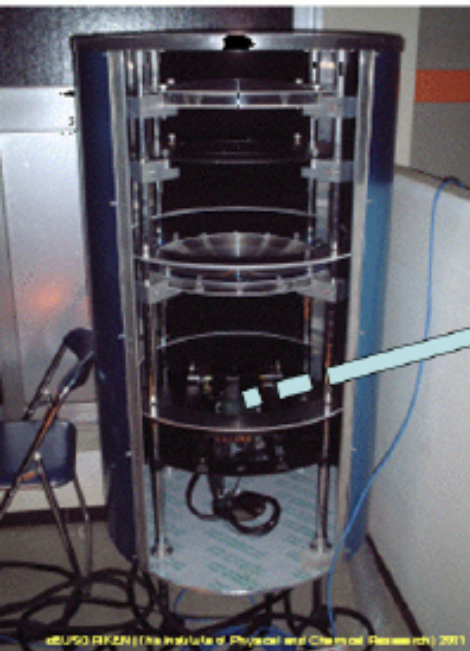


HV board

Progress: 小さなEUSOを製作

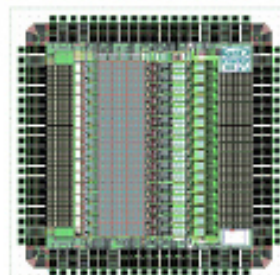


40cm Diameter



Prototype PDM

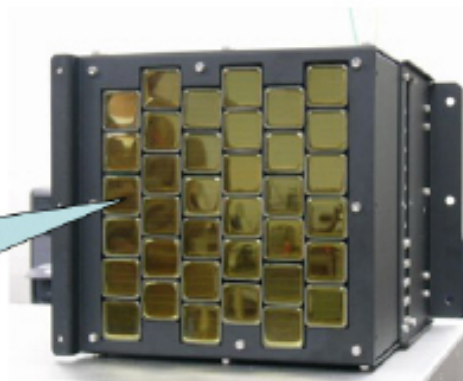
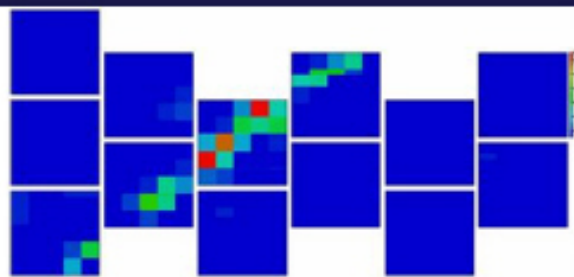
**ASIC
by Ikeda**



Progress: 小さなEUSOを製作

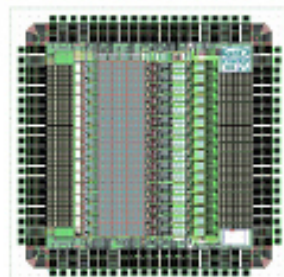
UV Laser

40cm Diameter

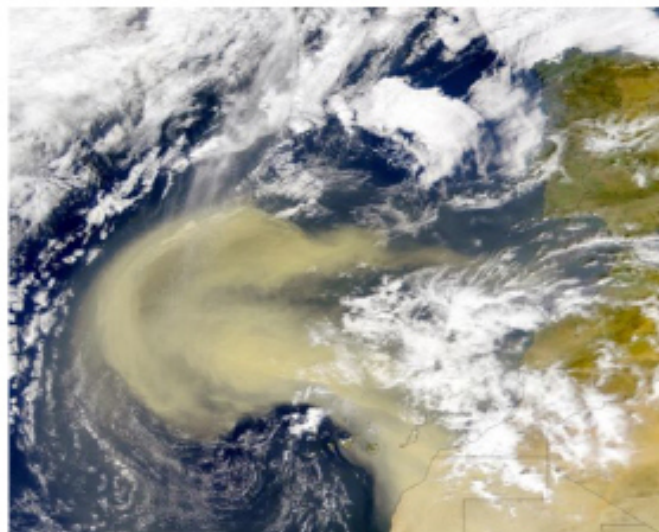


Prototype PDM

**ASIC
by Ikeda**



■ *The real atmosphere – clouds and desert dust*



Sahara dust over the Atlantic on 26.2.2000

Atmospheric Monitoring System

- **IR Camera**

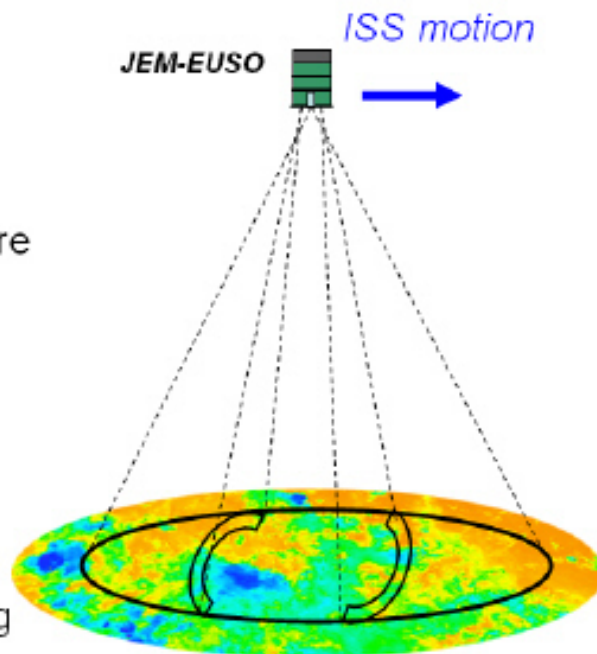
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

Ranging observation using UV laser

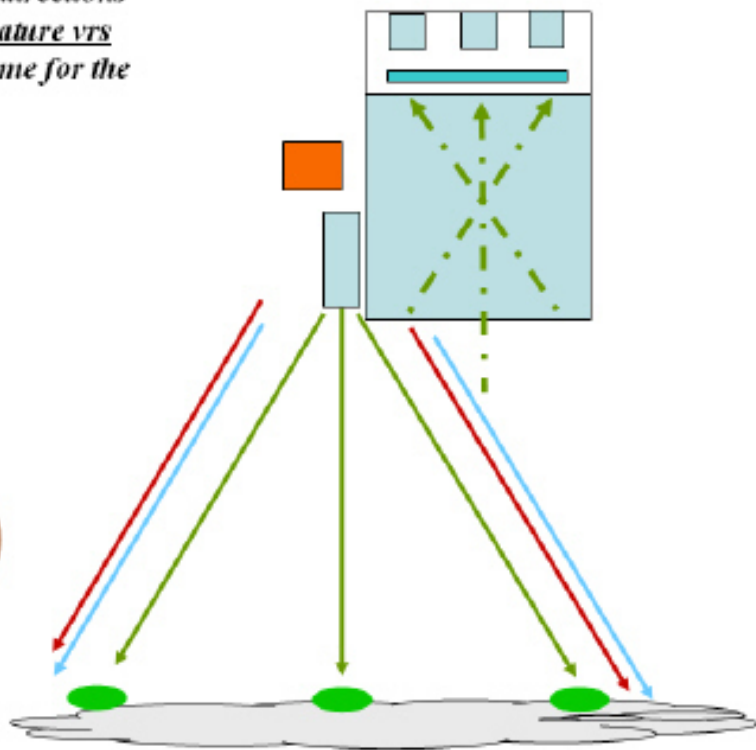
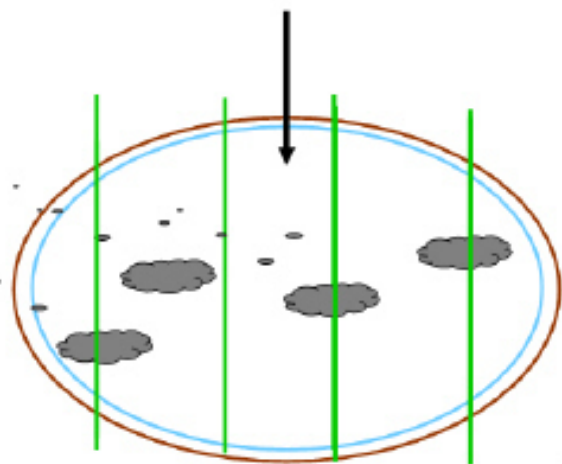
- **JEM-EUSO "slow-data"**

Continuous background photon counting



- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
- *Calibration of telescope:* (Lidar)

*Using the measurements in these three-four directions
for calibration of the IR radiometer temperature vrs
cloud top altitude – Reference lines ; the same for the
UV « slow mode »*



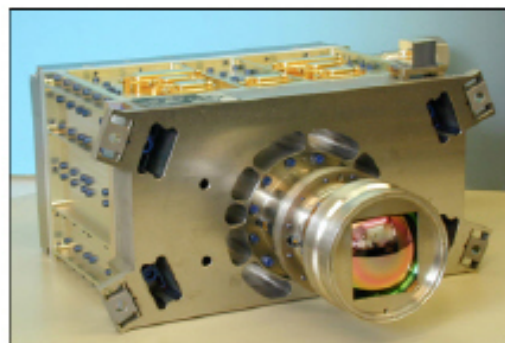
IR Camera

Requirement

Item	Value	Reason
Wavelength	10 – 13 μ m	Atmospheric transmission, S/N
FOV	> 60°	Same FOV as JEM-EUSO
Spatial Resolution	0.25°	1.8 km/pix @ nadir
Observation Temperature Range	200 – 320 K	Cloutop temperature in troposphere
Absolute Temperature Resolution	< 3 K	Altitude resolution < 500m
IR Sensor	Uncooled Microbolometer Array	Mass, Power
Exposure Time	133 msec	ISS motion within $\frac{1}{2}$ - pix of IR camera
Observation Interval	30 sec (5 sec TBC)	ISS motion of JEM-EUSO $\frac{1}{2}$ FOV

IR Camera Development with EADS/SODERN

CIM01 (or IASI) onboard METOP1 satellite



IASA Specification

- Scanning Mirror
- Sensor (CIM01)

λ : 10.3 - 12.5

μm

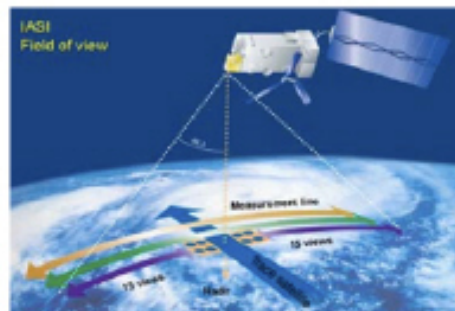
sensor: bolometer array

pix. size: 64×64

res.: 12 bit

FOV: 60×60 mrad

NETD : <80 mK



IR Camera Development with EADS/SODERN

Major Change from CIM01 to JEM-EUSO IR Camera

(1) Pixel size of detector

"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

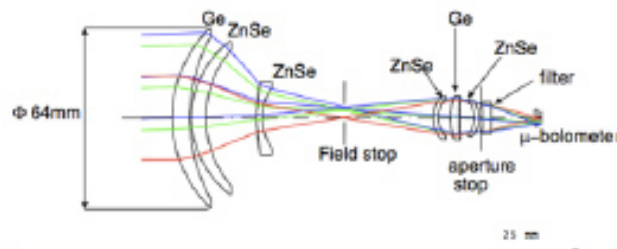
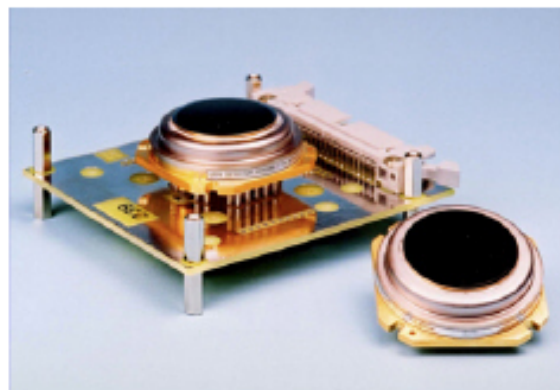
(2) FOV

Line scanning → >60°

Based on CIM01 design, they can produce FM of JEM-EUSO IR camera with 5.5MEuro within 5 years.

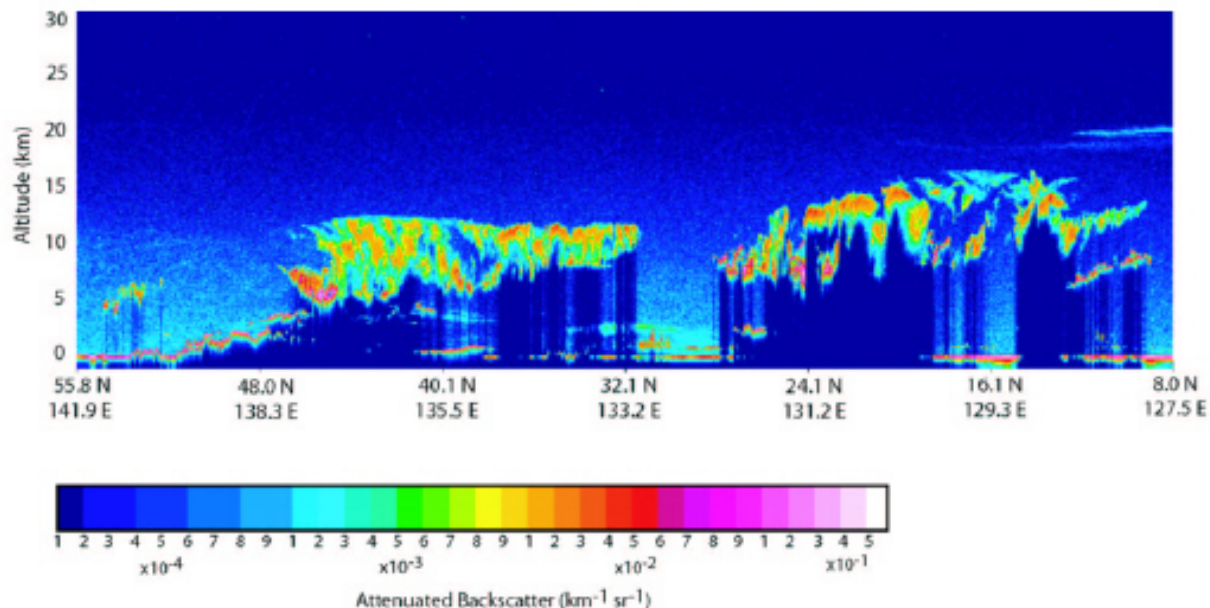
Specification of IR Camera

Should be determined before 12E, 2007



Lidar

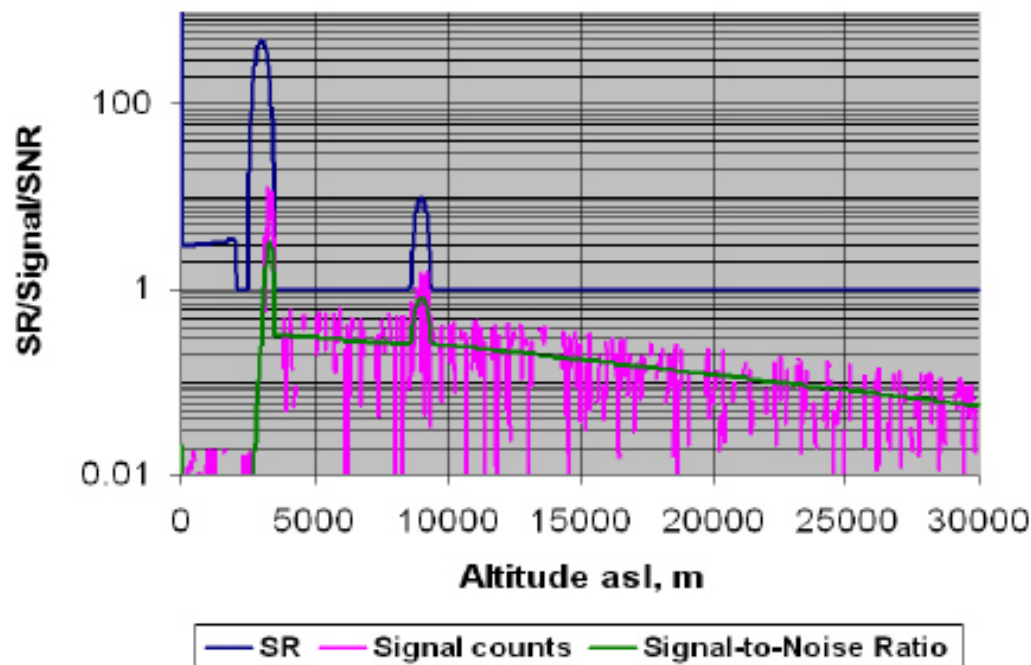
Another spaceborne lidar– first CALIPSO results (#2)



Performance simulations, #1: Subsystems

Subsystem		Lidar 1	Lidar 2
Transmitter	Wavelength, nm	355	532
	Pulse repetition rate, pps	100	100
	Averaged transmitted power, W	1	1
	Divergence full angle, mrad	0.08	0.08
	Optical efficiency	80	80
Receiver	Primary receiver aperture diam, cm	250	250
	Secondary mirror aperture, cm	0	0
	Field of View full angle, mrad	0.2	0.2
	Interference filter, FWHM	0.25	0.25
	Interference filter, transmission %	50	50
	Optical efficiency (without filter)	25	25
Detector	Quantum efficiency, %	25	25
	Dark noise, counts per second	500	500
Acquisition (ph. counting)	Range resolution, bin meters	30	30
	Integration time, sec	0.01/1	0.01/1
Satellite	Altitude, km	500	500

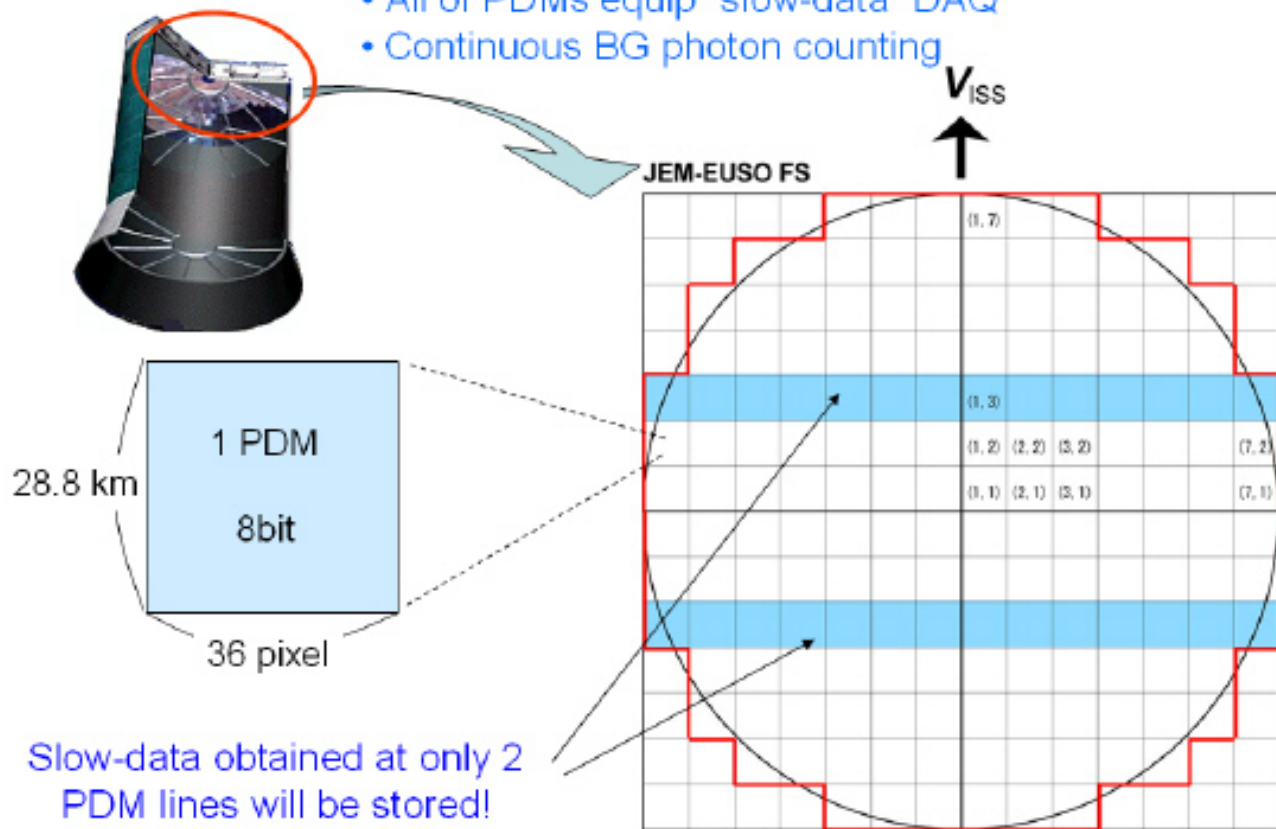
Performance simulations, #3:



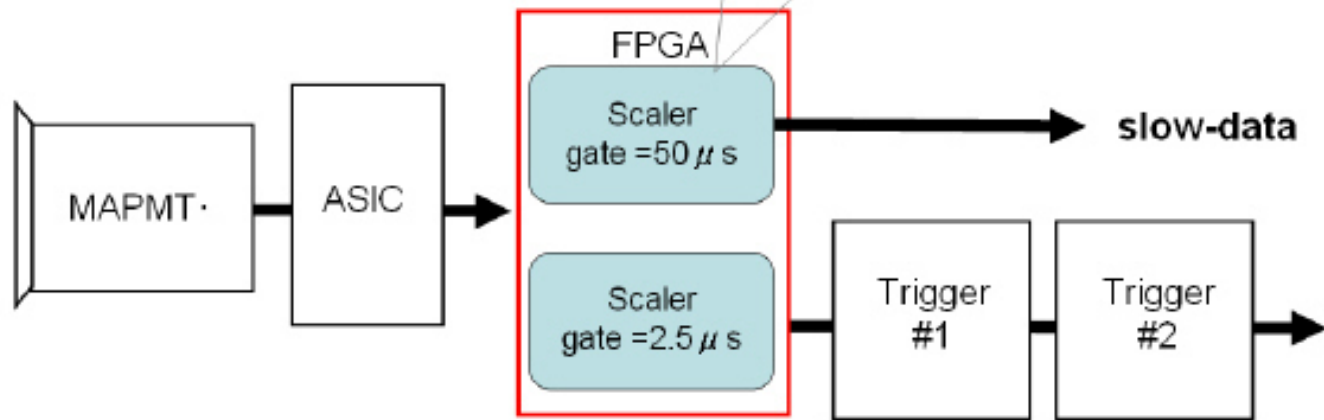
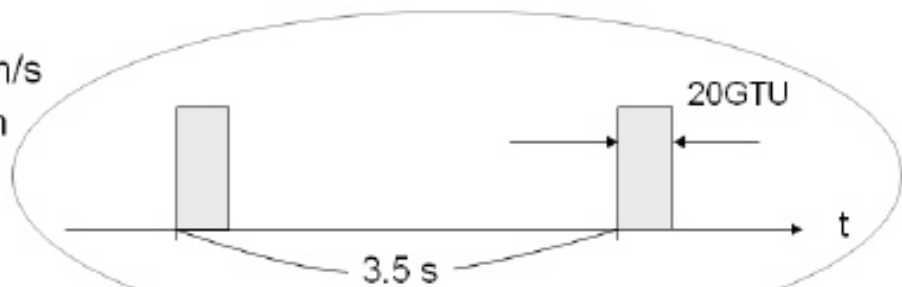
results for
355nm, 0.01sec
integration time,
30m range
resolution

Slow-Data

- All of PDMs equip "slow-data" DAQ
- Continuous BG photon counting



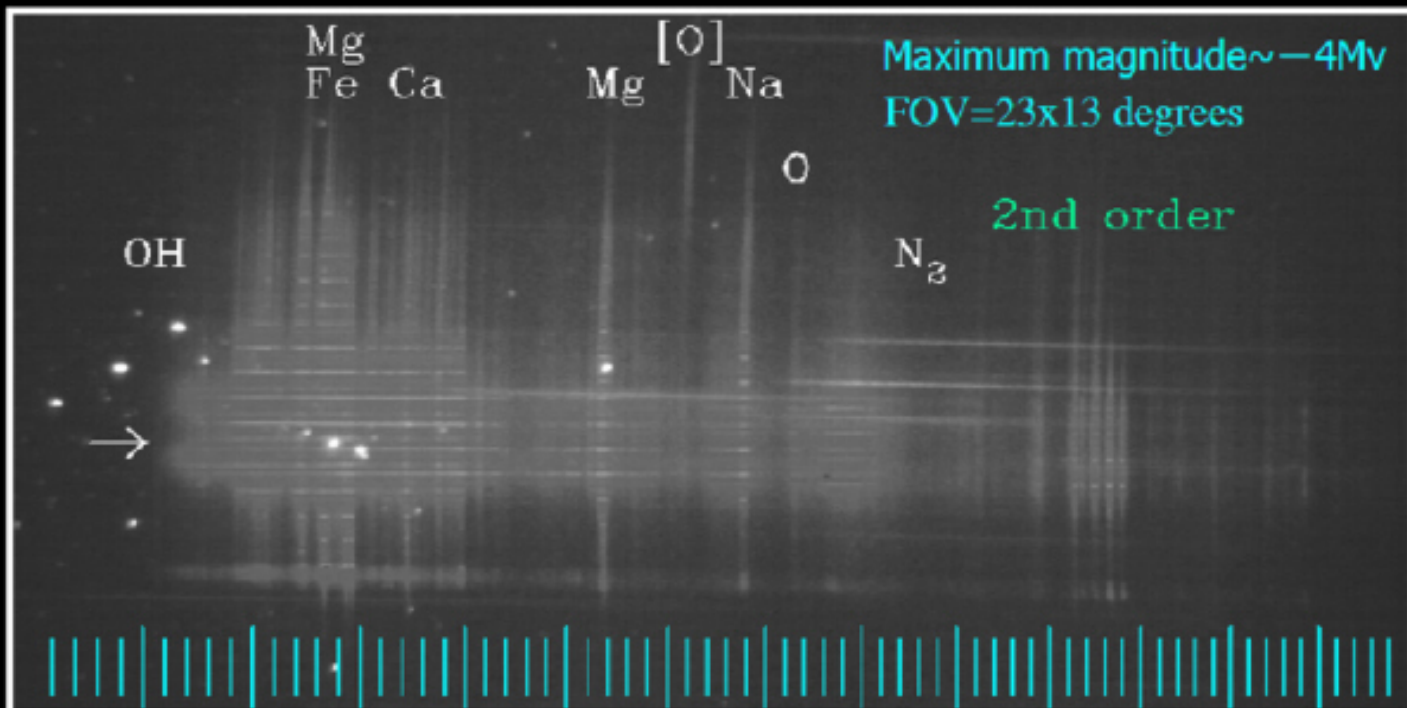
- Velocity of ISS: 7.9 km/s
- FOV of 1PDM: 28.8 km



Slow Data

- 雲頂高度
 - ステレオ測定
- 流星
 - 10等～13等(トリガによる)
 - $1 \sim 10^5$ /day
 - 散在流星数の季節変化
 - 流星群観測(入射角、速度が一定)
- 夜光
- Tatiana UV Flash

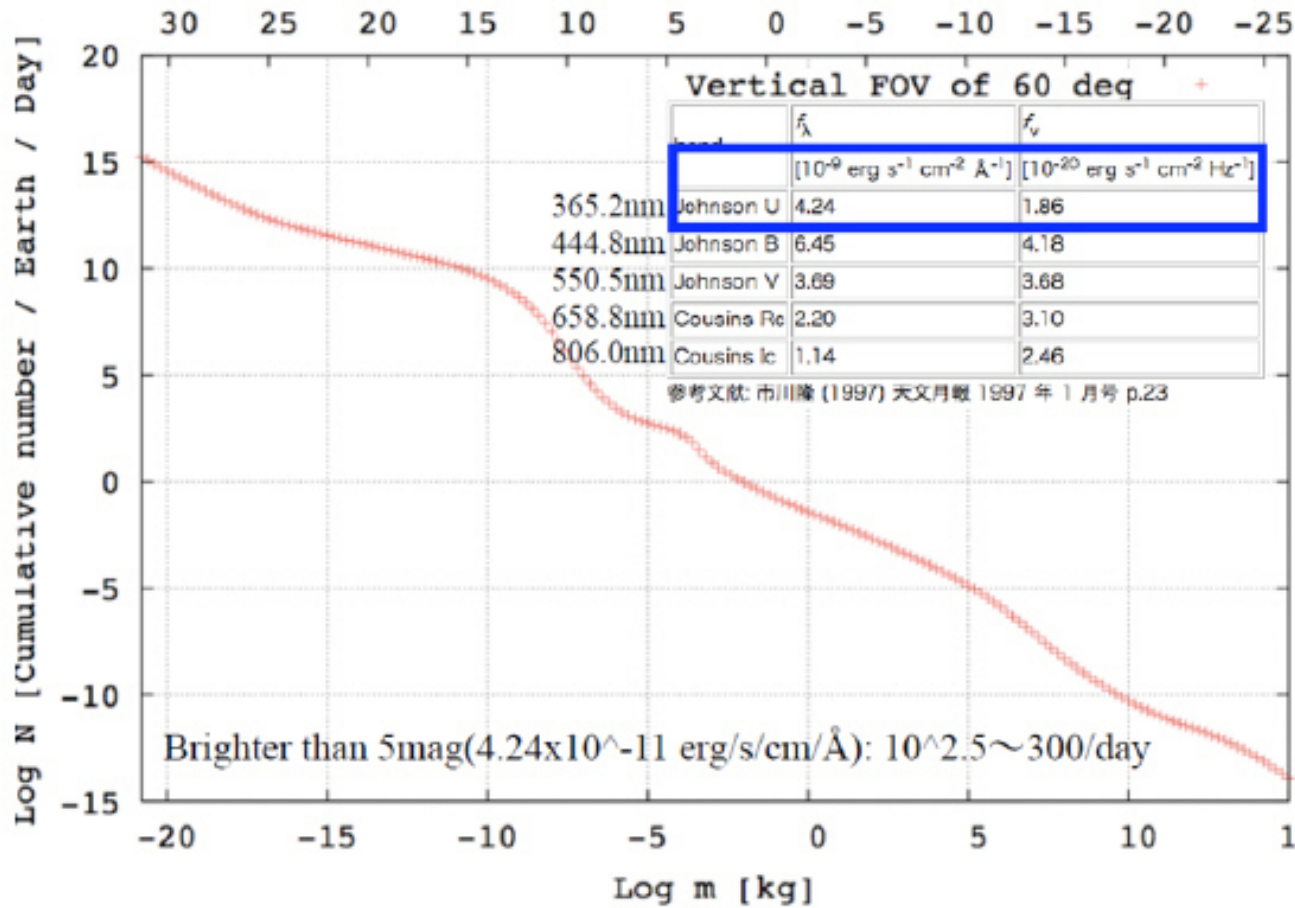
HDTV Spectrum of 2001 Leonid Meteor



300 350 400 450 500 550 600 650 700 750 800 850 900

wavelength (nm)

Magnitude from ISS



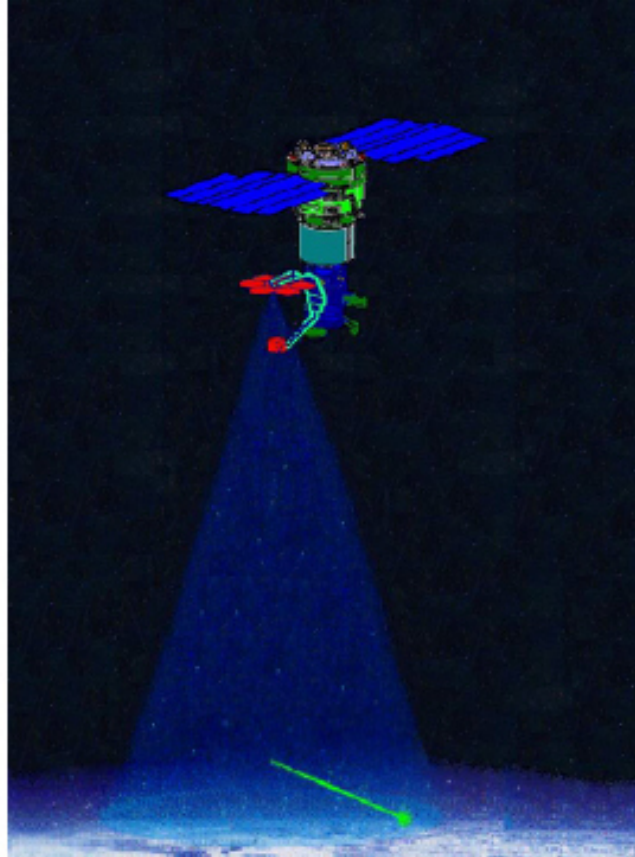
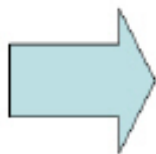
Specification

Item	Value	Reference
Wavelength	330 – 400 nm	Same as JEM-EUSO detector
Spatial res.	800m x 800m	
Detector	MAPMTs	
Resolution	8 bit	
Cloud top altitude determination res.	~ 1 km	IFOV of 1-pixel
Exposure gate time	50 μ sec	= 20GTU
Time interval	3.5 sec	ISS travel time of 1-PDM FOV
Data rate	35 kbps	

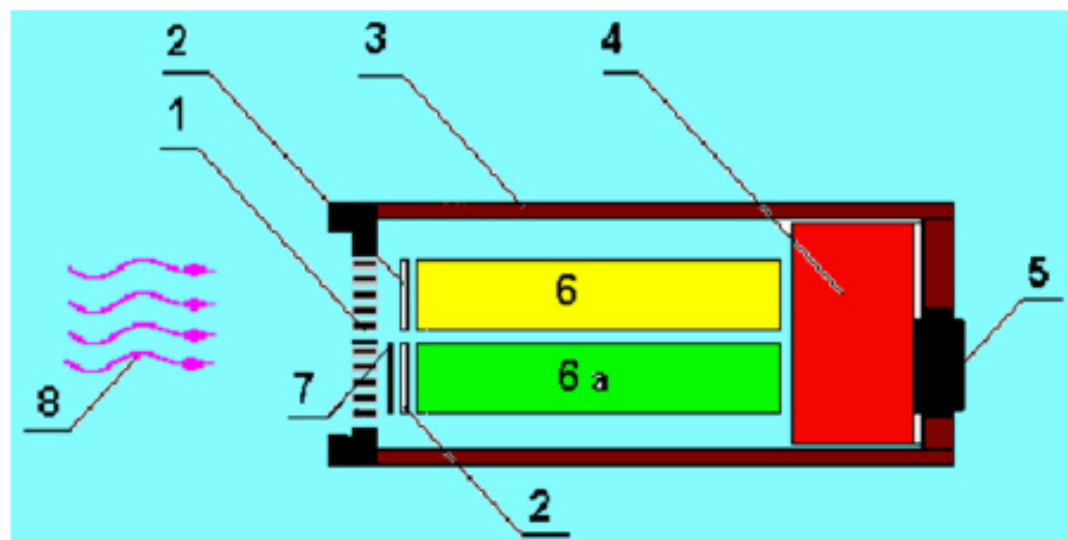
Tatiana UV Flash

- 雷雲と関係あると考えるのがもっともらしい
- 落雷との時間相関なし
- 雲-雲放電？
 - たくさんの小さな放電の寄与か

The results of satellite
"Tatiana" launched in
January 2005 are
important for planning
TUS.



The detector of UV radiation



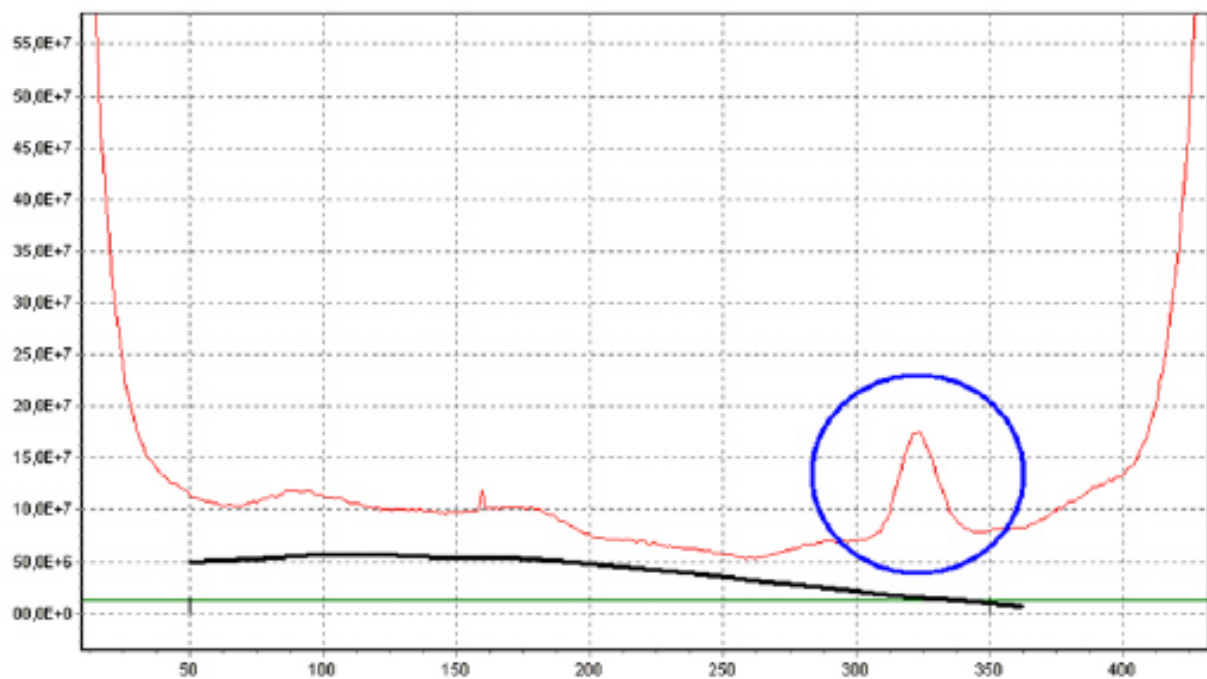
Some detector parameters:

FOV: 15°

$S = 0,4 \text{ c m}^2$.

UV filter: 200 – 400 nm

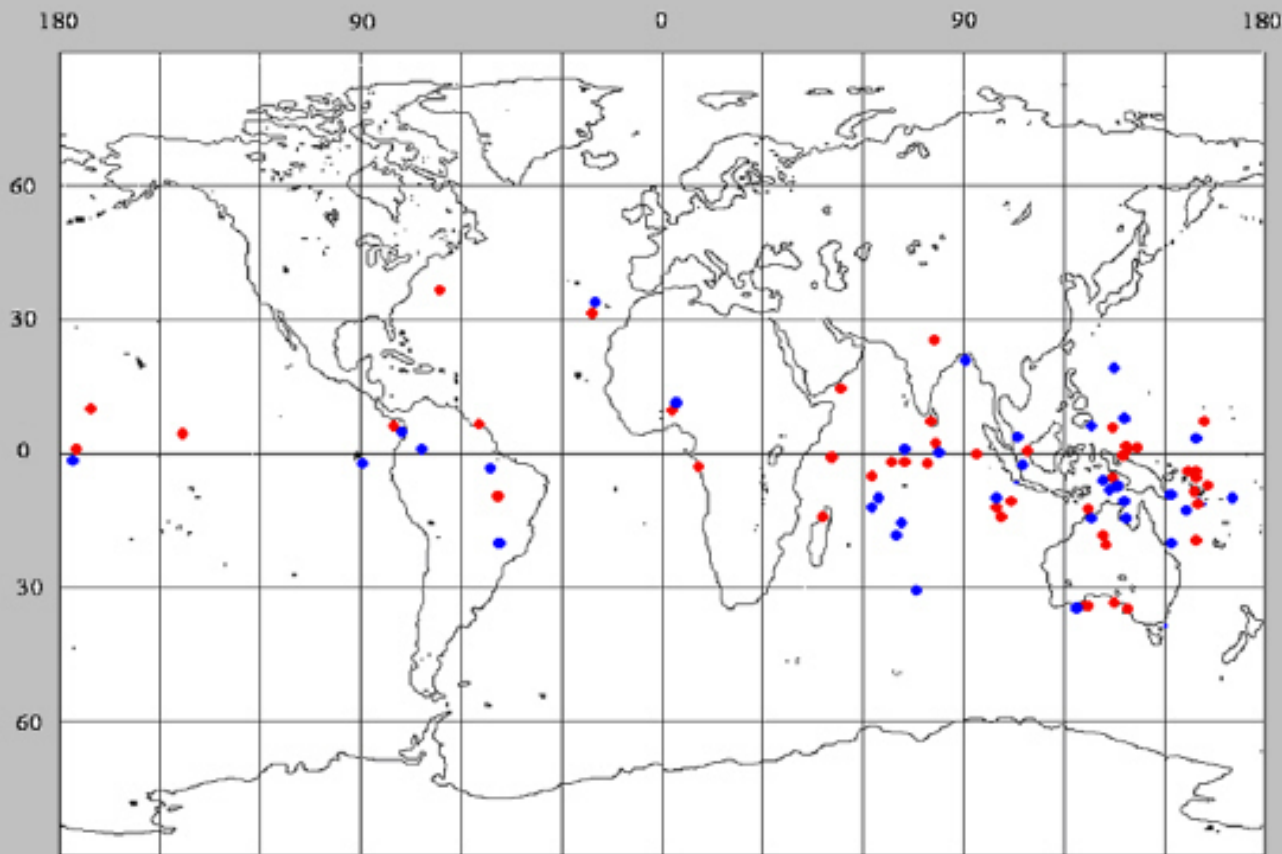
Examples of satellite "Tatiana" data



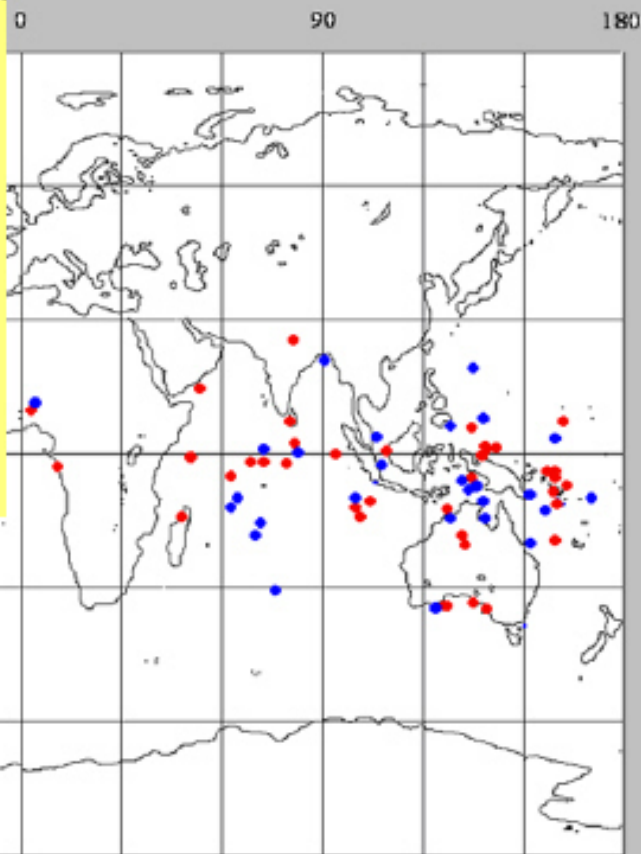
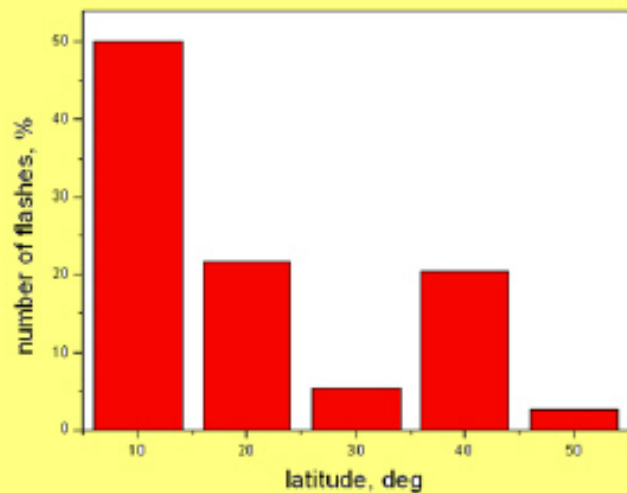
13.02.2005

Moon phase 25 %, Blue oval – the satellite is above Japan.

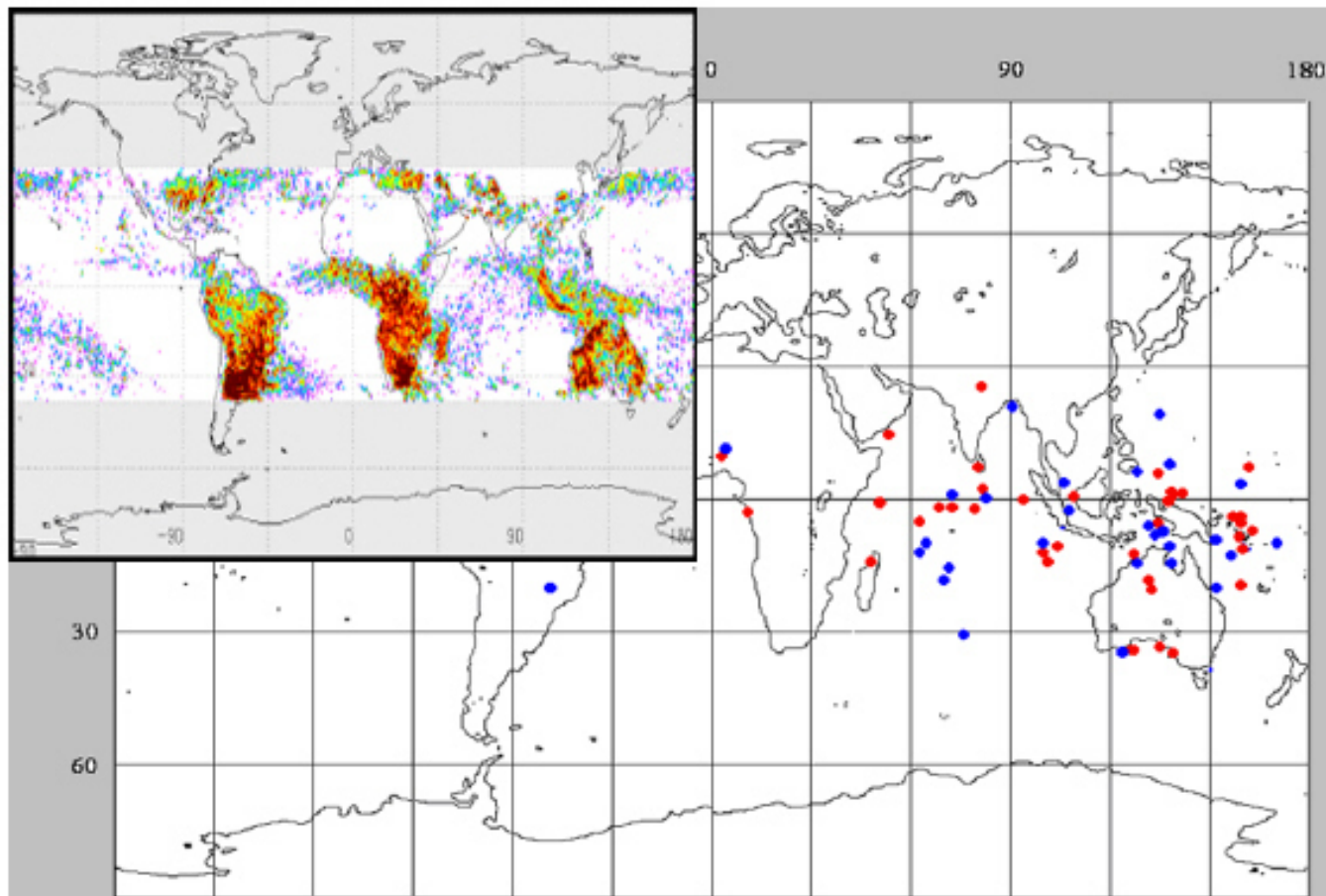
The geographical distribution of UV flashes



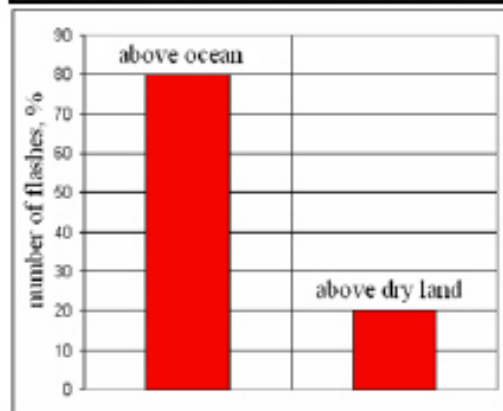
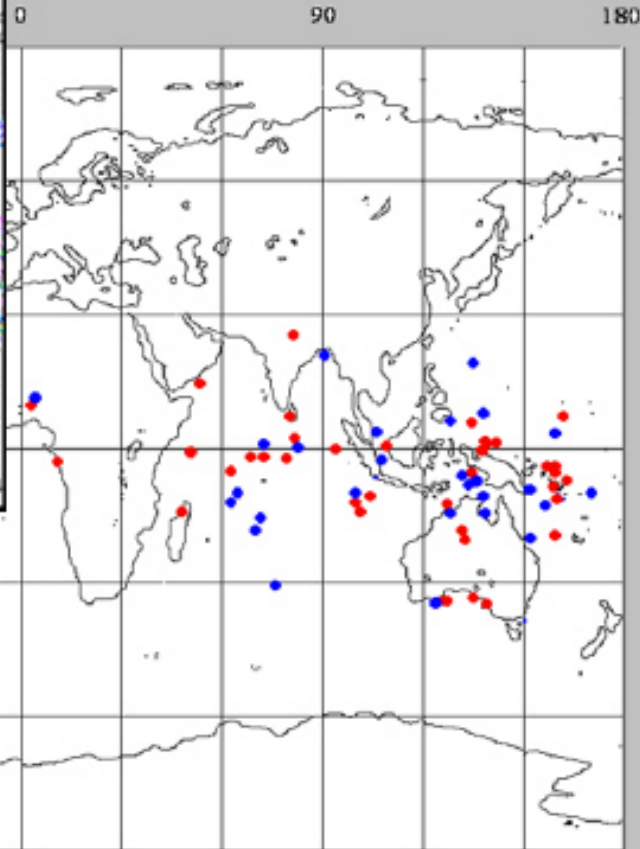
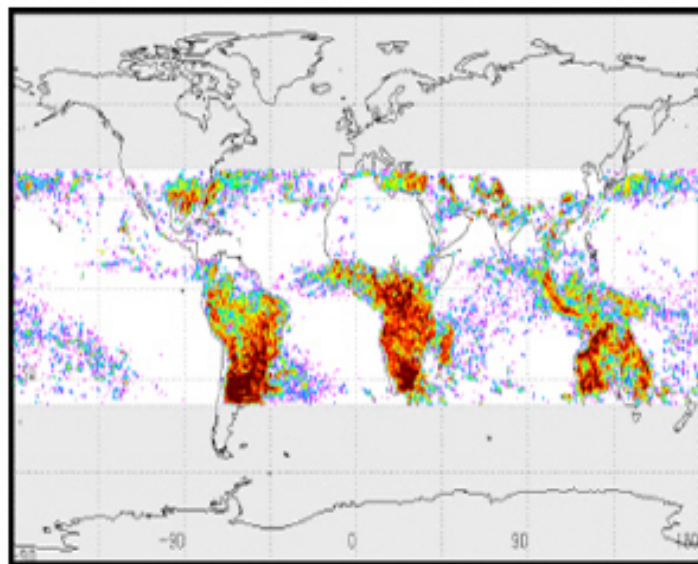
The geographical distribution of UV flashes



The geographical distribution of UV flashes



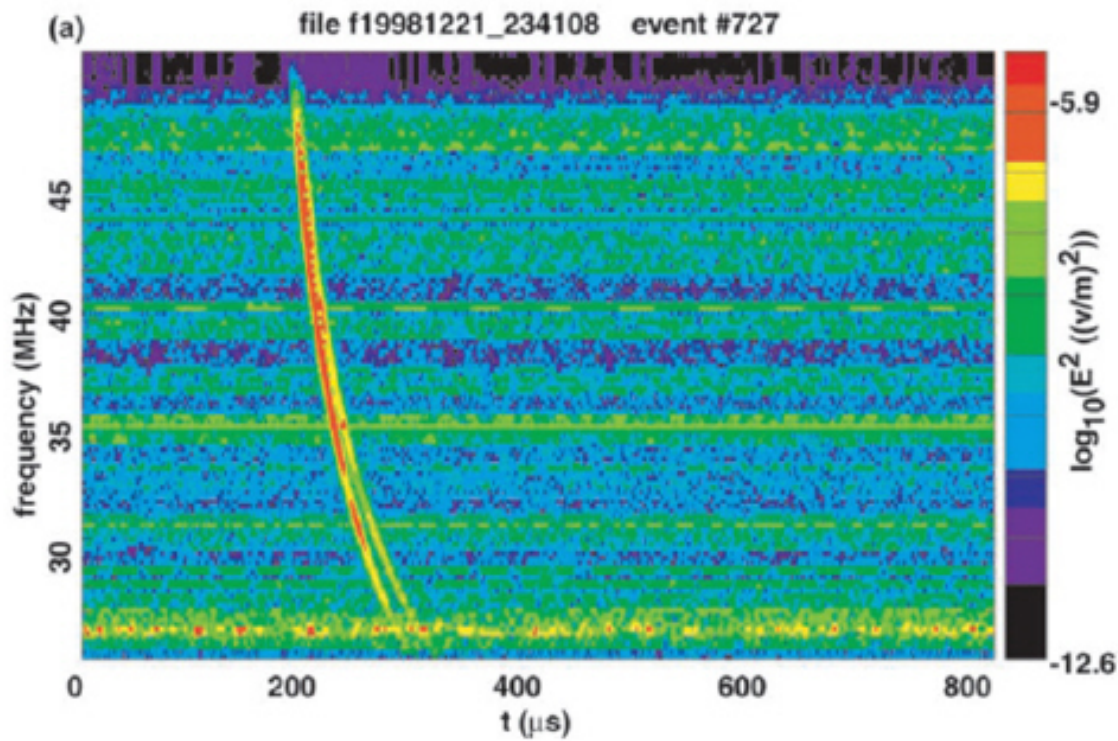
The geographical distribution of UV flashes



Narrow Bipolar Event

- FORTE衛星によるVHF観測
- 孤立した電波パルスイベント
 - 一般の雷のパルス列に先行
 - $T < 1 \mu s$
 - 10J-100J
- 可視光に対応する閃光パルスなし
- Runaway Electron Breakdown
 - Gurevich and Zybin 2004
 - 宇宙線空気シャワーがトリガ？
 - 電子が100-1000倍に増大
 - 近紫外で蛍光

NBEの伝播効果



NBEの空間分布

海上に多い?!

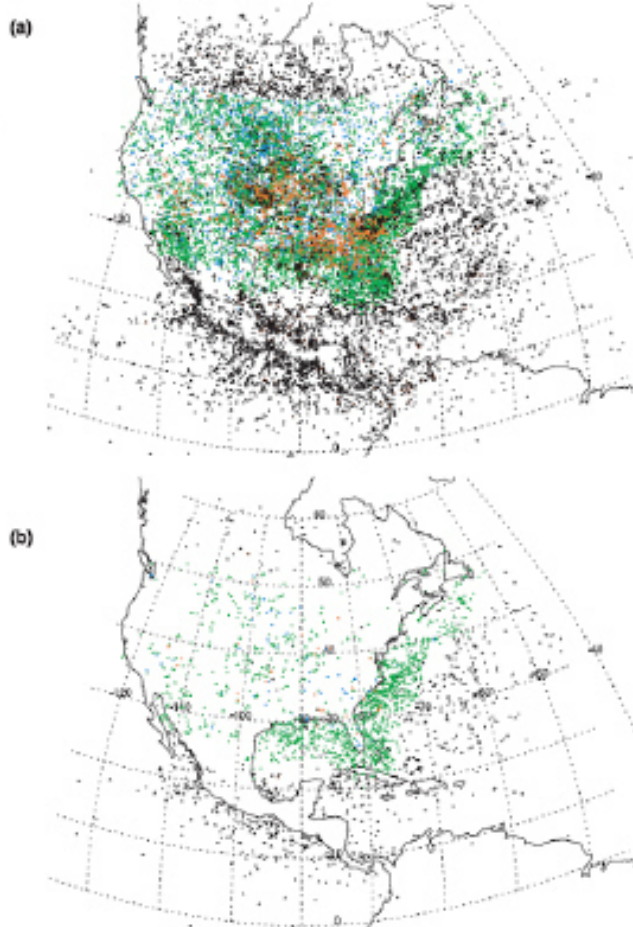
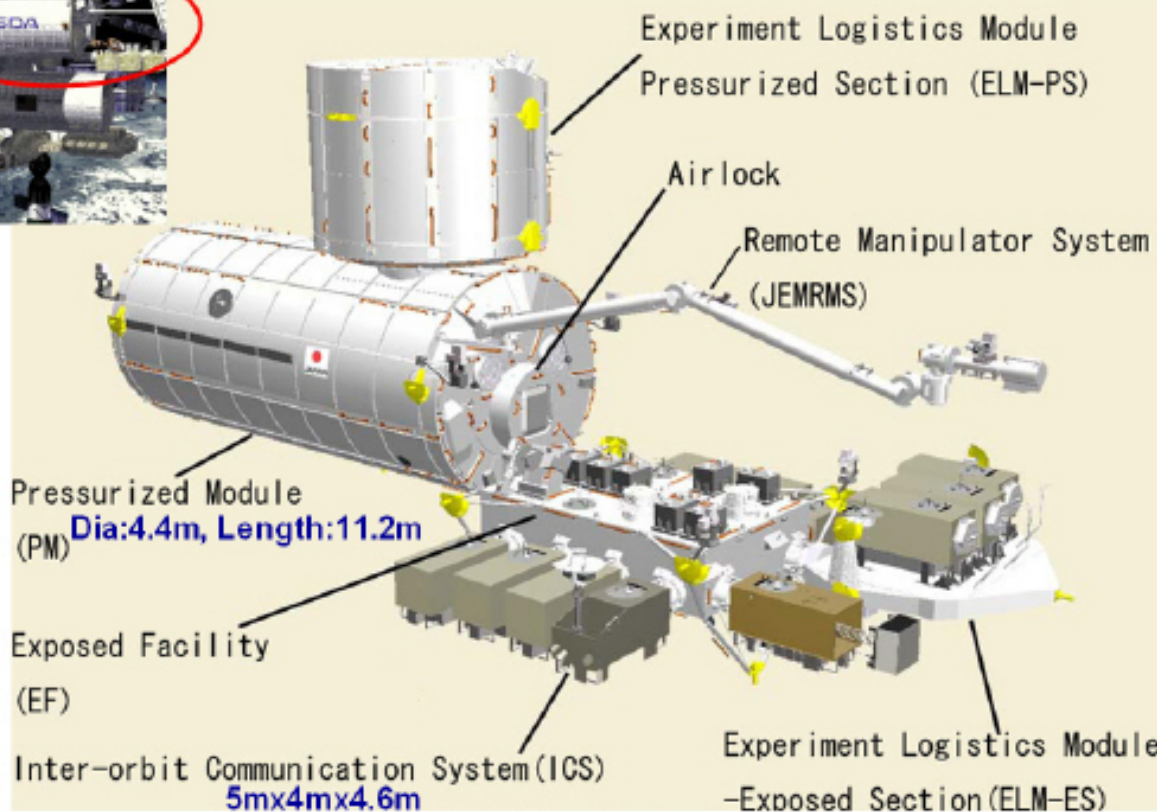
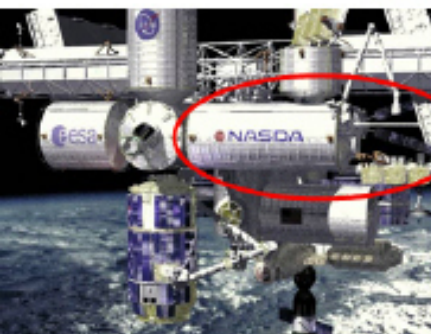


Figure 1. (a) Map of ~25,000 NLDN stroke locations that are accompanied by closely coincident FORTE VHF events. The stroke type is marked in color: green is -CG, blue is +CG, red is IC, and black is uncharacterized type (due to the nearest participating NLDN station being >625 km from the stroke). (b) Similar, but for the ~2,400 FORTE VHF events meeting the automatic selection criteria to qualify as extremely narrow pulses.

日本実験棟「きぼう」



宇宙ステーションの再定義

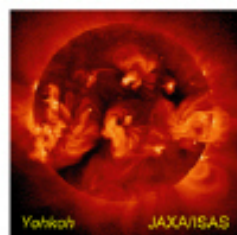
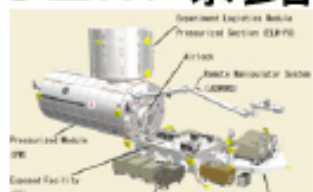
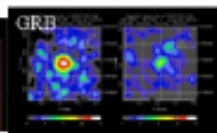
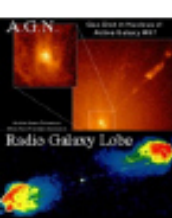
- 多波長同時地球観測プラットフォームとして再定義
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 - 曝露部利用への追加提案の可能性
 - とりあえずの地上実験の企画

まとめ

- Auger実験グループが到来方向異方性を発表
 - JEM-EUSOの目指す科学が正しいことが裏付けられた
 - 荷電粒子天文学の方向性が確立: JEM-EUSOの重要性が高まる
- 極限エネルギー粒子による天文学
 - 宇宙から空気シャワーを検出: 1000個以上の極限エネルギー事象
 - 宇宙にある巨大加速器の正体: 極限エネルギー粒子の起源天体
- JEM曝露部の再定義
 - 多波長同時地球観測のプラットフォーム
 - 新領域の立ち上げ?

地を見て天を知る天文台=地文台

JEM曝露部



極限エネルギー粒

固体微粒子

多波長同時観測

荷電粒子

紫外線
X線
ガンマ線

太陽風

ガンマ線
X線

雲の動態

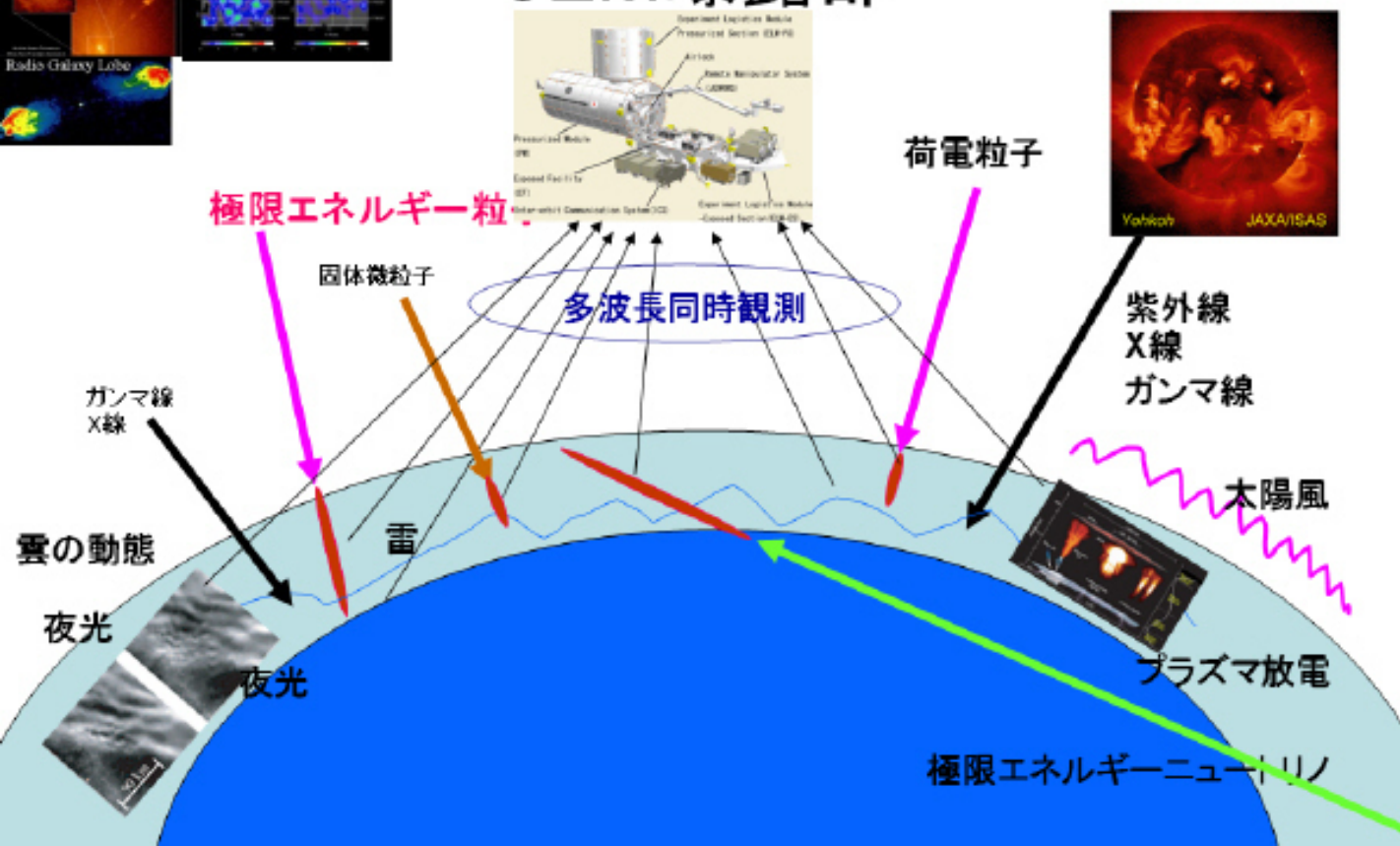
夜光

夜光

雷

プラズマ放電

極限エネルギーニュートリノ



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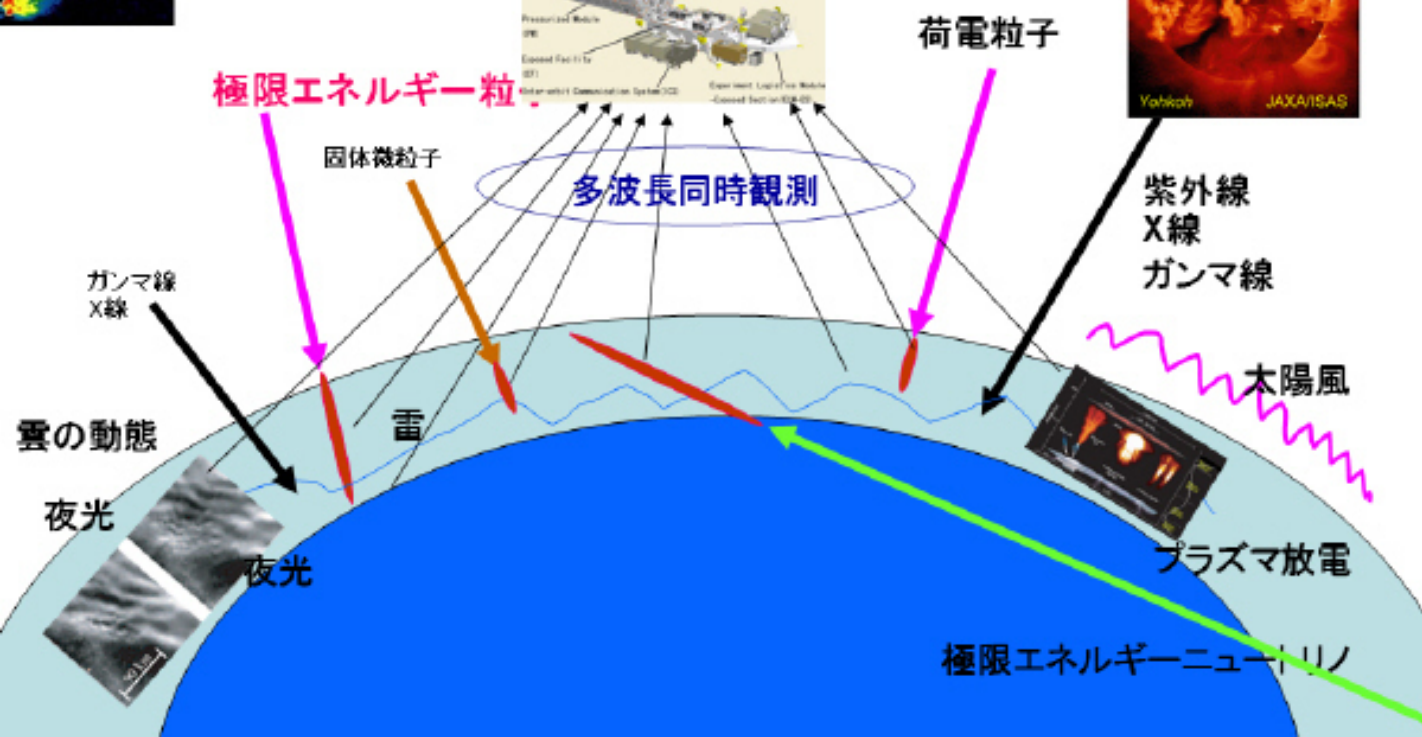
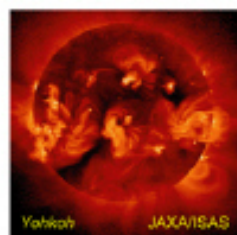
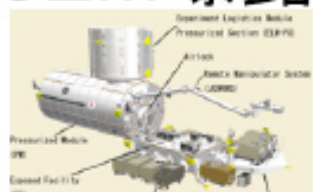
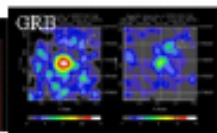
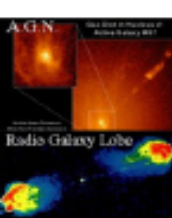
予備スライド

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地を見て天を知る天文台=地文台

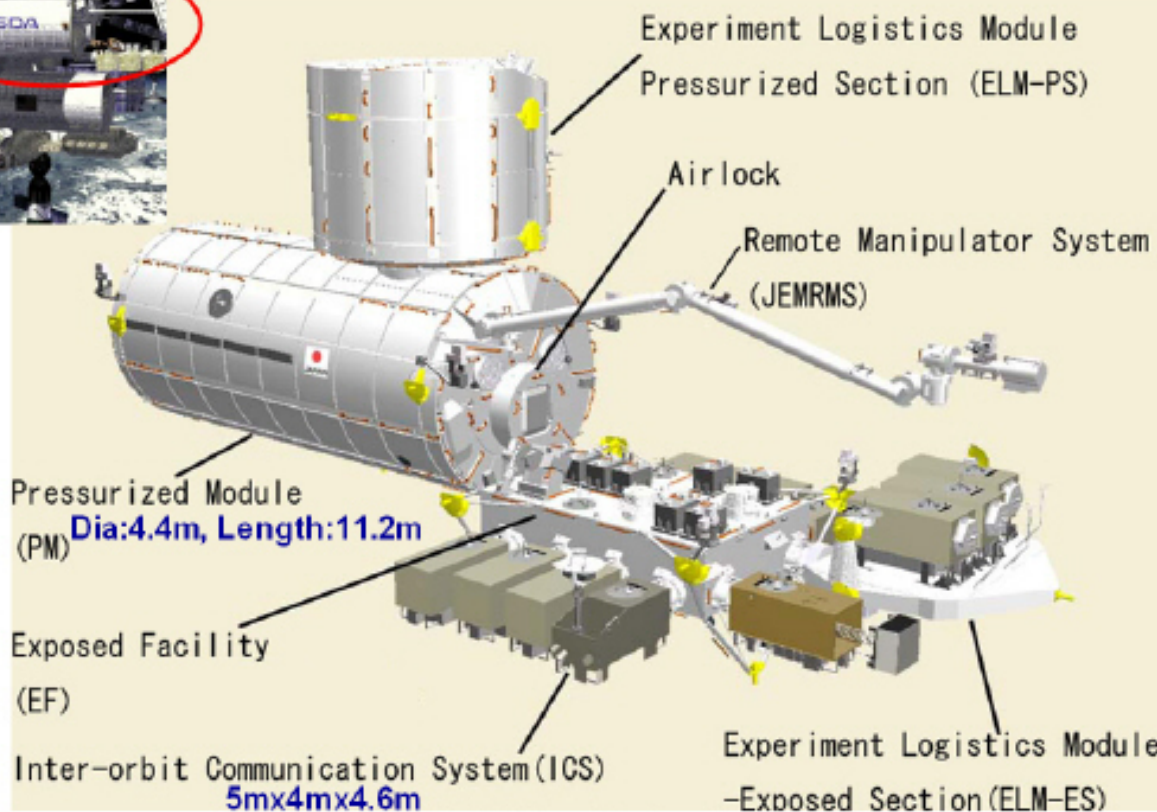
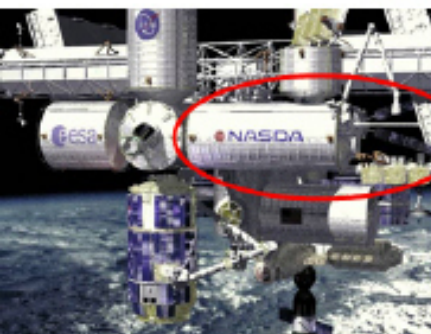
JEM曝露部



宇宙ステーションの再定義

- 多波長同時地球観測プラットフォームとして再定義
 - 惑星間空間から対流圏を串刺しにして捉える
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日本実験棟「きぼう」



NBEの空間分布

海上に多い?!

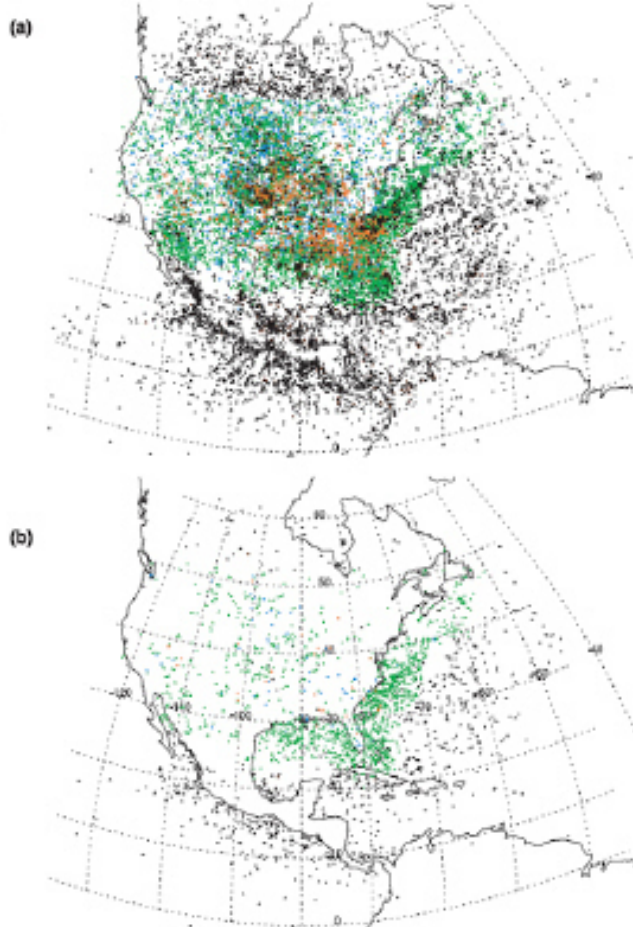
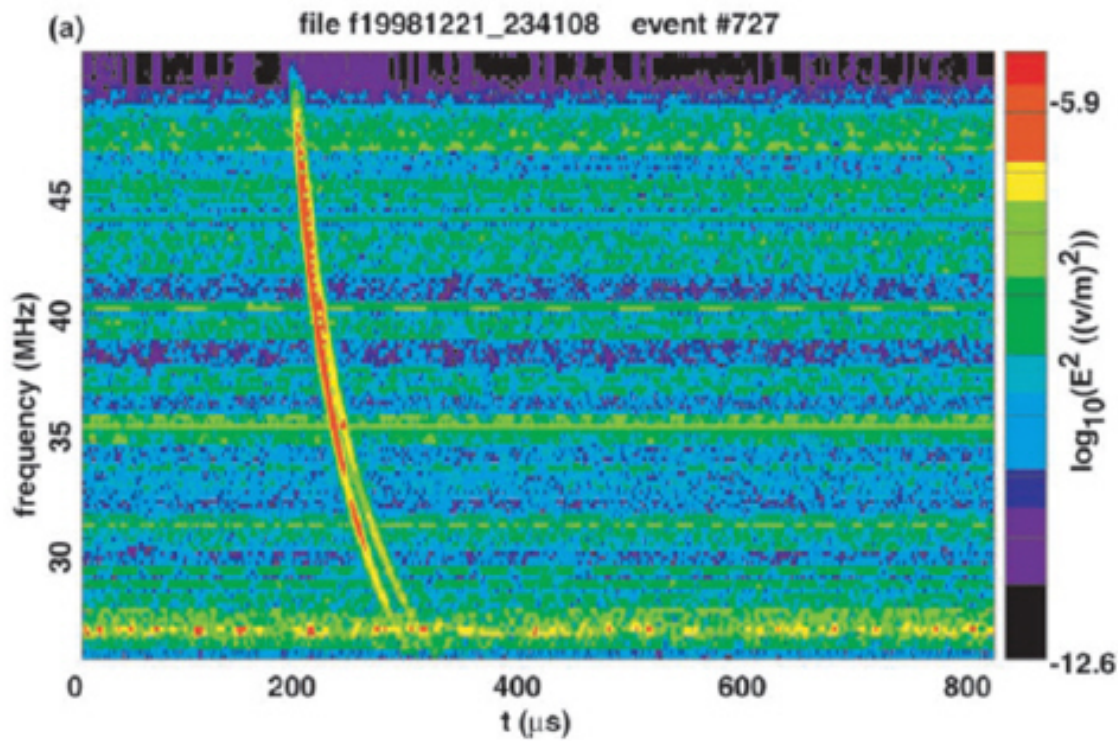


Figure 1. (a) Map of ~25,000 NLDN stroke locations that are accompanied by closely coincident FORTE VHF events. The stroke type is marked in color: green is -CG, blue is +CG, red is IC, and black is uncharacterized type (due to the nearest participating NLDN station being >625 km from the stroke). (b) Similar, but for the ~2,400 FORTE VHF events meeting the automatic selection criteria to qualify as extremely narrow pulses.

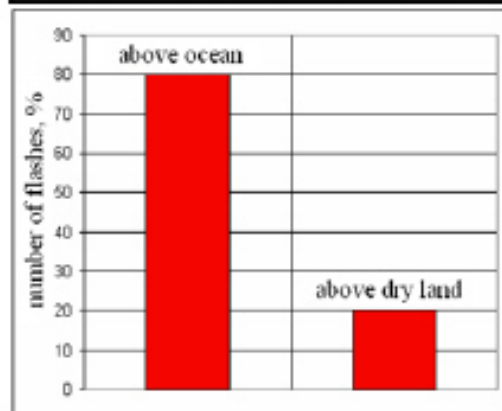
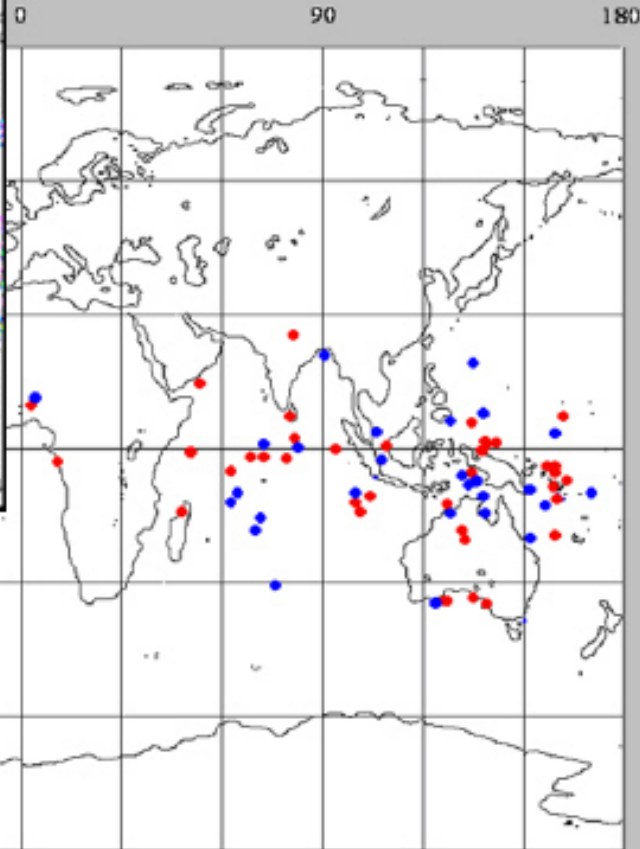
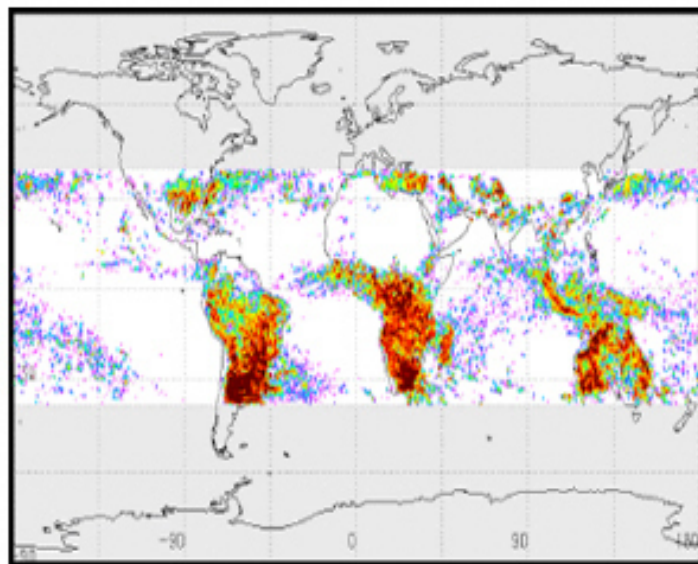
NBEの伝播効果



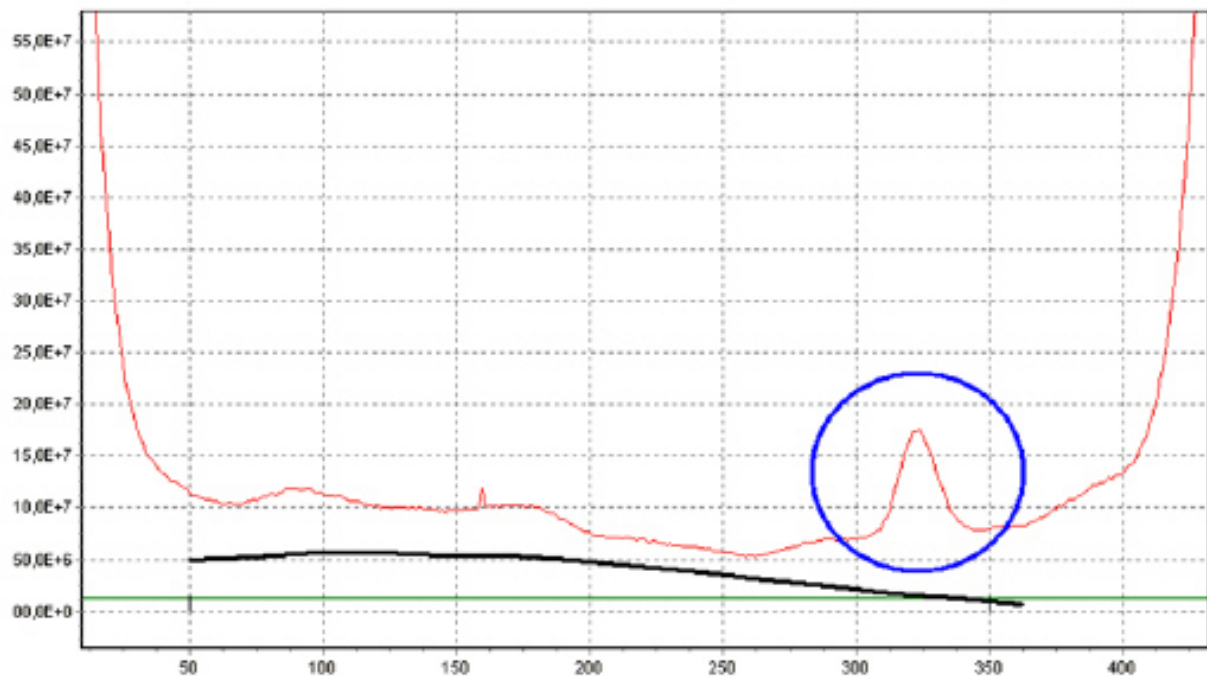
Narrow Bipolar Event

- FORTE衛星によるVHF観測
- 孤立した電波パルスイベント
 - 一般の雷のパルス列に先行
 - $T < 1 \mu s$
 - 10J-100J
- 可視光に対応する閃光パルスなし
- Runaway Electron Breakdown
 - Gurevich and Zybin 2004
 - 宇宙線空気シャワーがトリガ？
 - 電子が100-1000倍に増大
 - 近紫外で蛍光

The geographical distribution of UV flashes



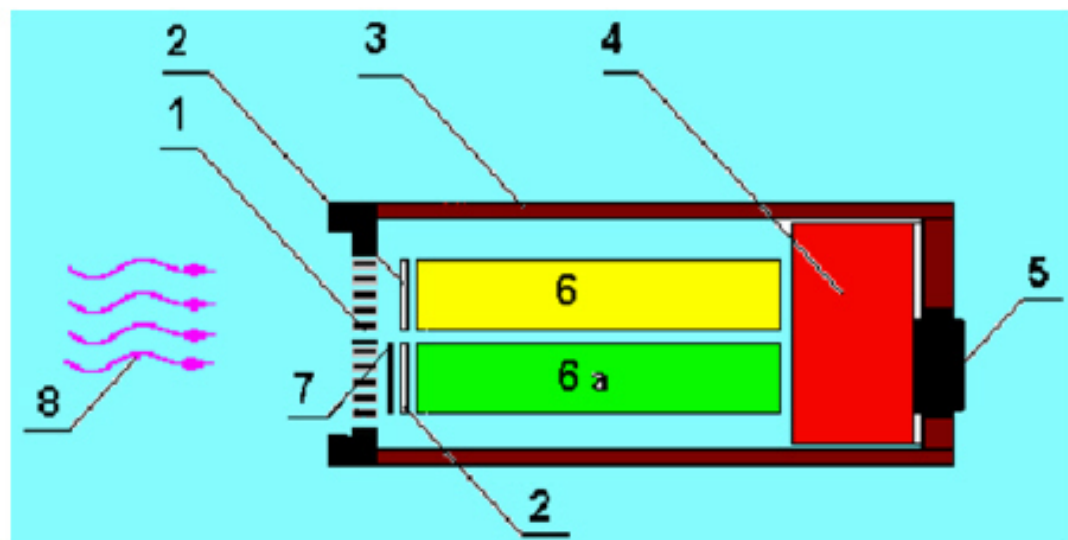
Examples of satellite "Tatiana" data



13.02.2005

Moon phase 25 %, Blue oval – the satellite is above Japan.

The detector of UV radiation



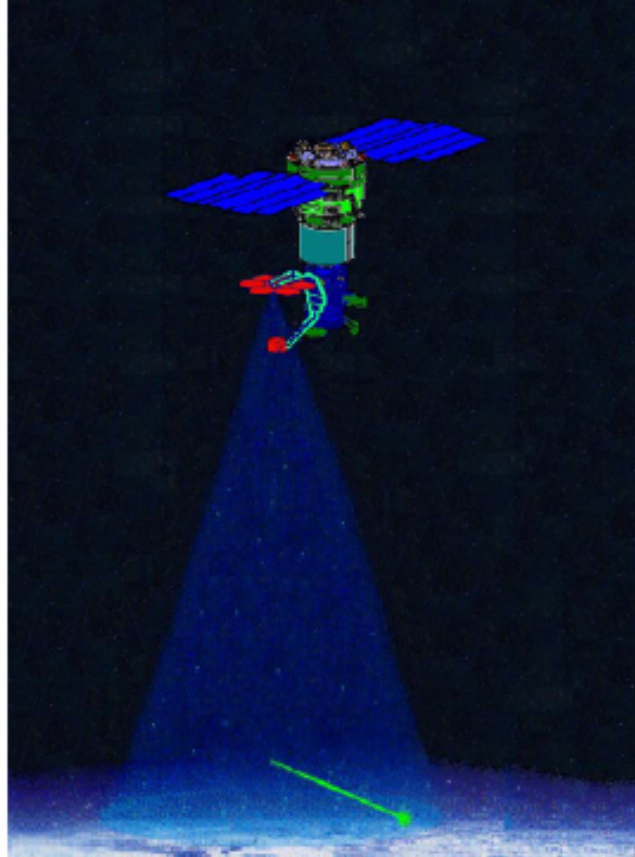
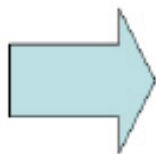
Some detector parameters:

FOV: 15°

$S = 0,4 \text{ c m}^2$.

UV filter: 200 – 400 nm

The results of satellite
"Tatiana" launched in
January 2005 are
important for planning
TUS.



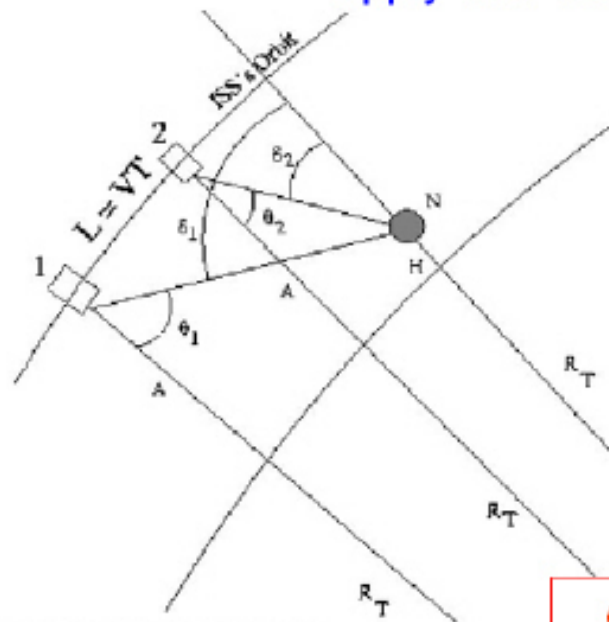
Tatiana UV Flash

- 雷雲と関係あると考えるのがもっともらしい
- 落雷との時間相関なし
- 雲-雲放電？
 - たくさんの小さな放電の寄与か

Specification

Item	Value	Reference
Wavelength	330 – 400 nm	Same as JEM-EUSO detector
Spatial res.	800m x 800m	
Detector	MAPMTs	
Resolution	8 bit	
Cloud top altitude determination res.	~ 1 km	IFOV of 1-pixel
Exposure gate time	50 μ sec	= 20GTU
Time interval	3.5 sec	ISS travel time of 1-PDM FOV
Data rate	35 kbps	

- Photon counting of background photons
 - Continuous measurements with the ISS motion
- Apply the “stereoscopic vision” method



Background photons

$$I = 500 \text{ (ph/m}^2\text{/str/ns)}$$

Detected photoelectrons

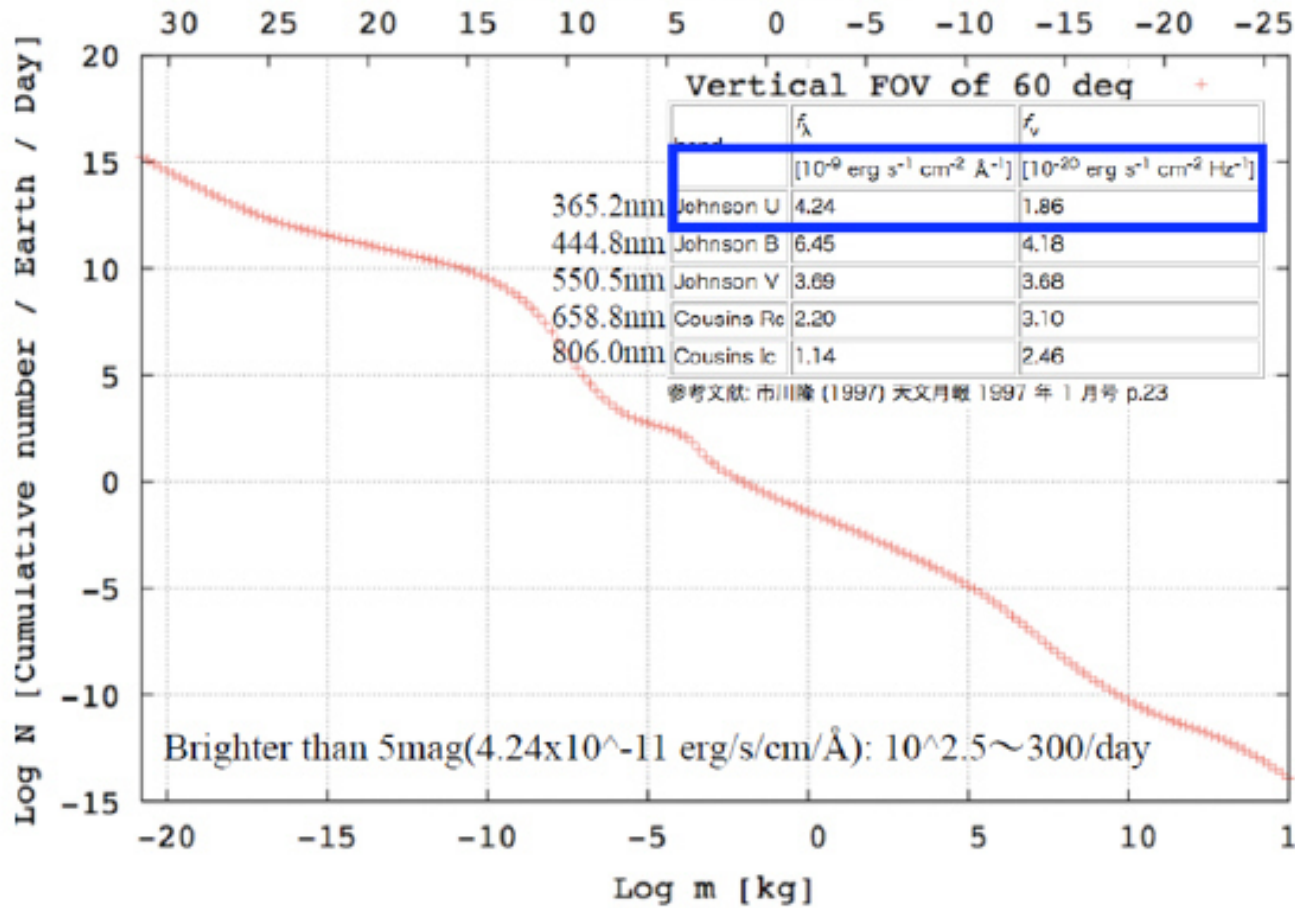
$$N_{p.e.} = 1 \text{ (p.e./pix/GTU)}$$

Expected slow-data counts

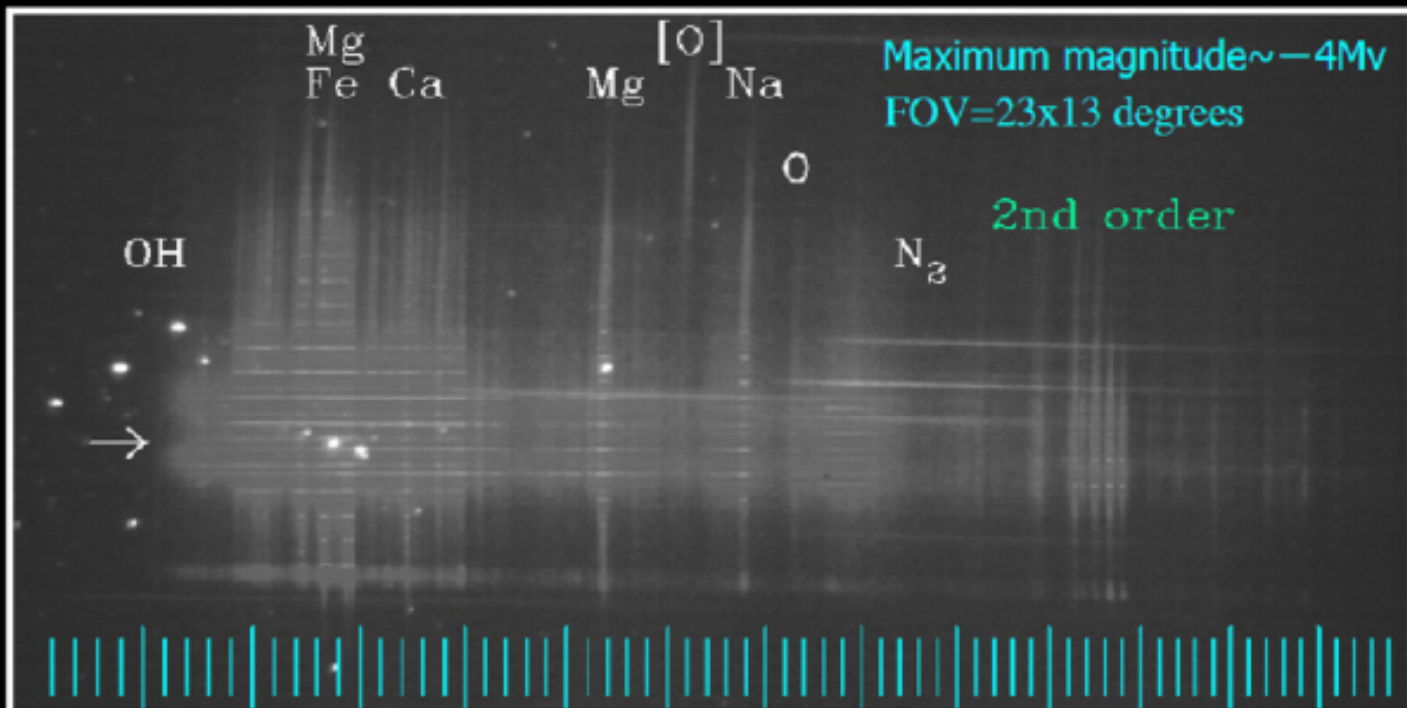
$$N_{p.e.} = 50 \text{ (p.e./pix/50 } \mu\text{s)}$$

Cloud top altitude: $\Delta h \approx 1 \text{ km}$

Magnitude from ISS



HDTV Spectrum of 2001 Leonid Meteor



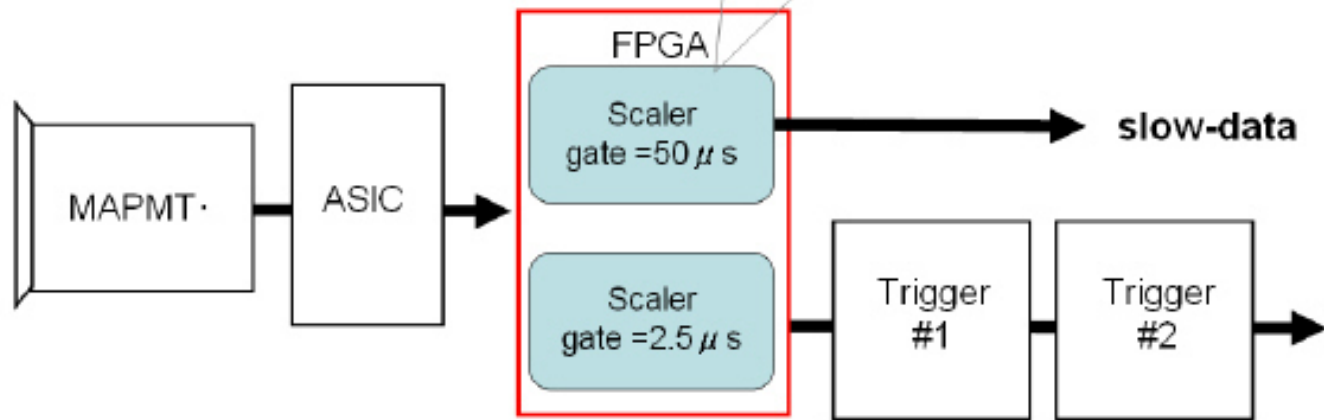
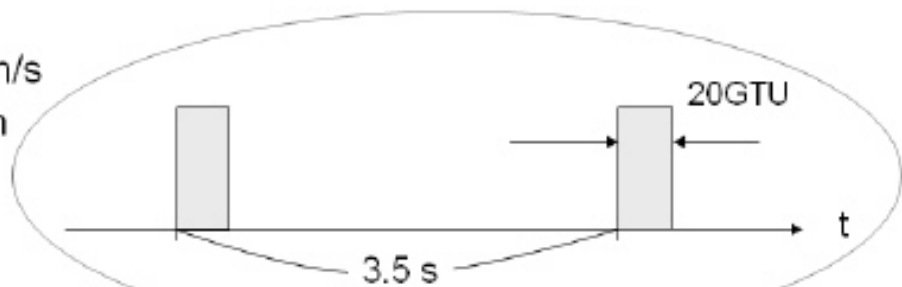
300 350 400 450 500 550 600 650 700 750 800 850 900

wavelength (nm)

Slow Data

- 雲頂高度
 - ステレオ測定
- 流星
 - 10等～13等(トリガによる)
 - $1 \sim 10^5$ /day
 - 散在流星数の季節変化
 - 流星群観測(入射角、速度が一定)
- 夜光
- Tatiana UV Flash

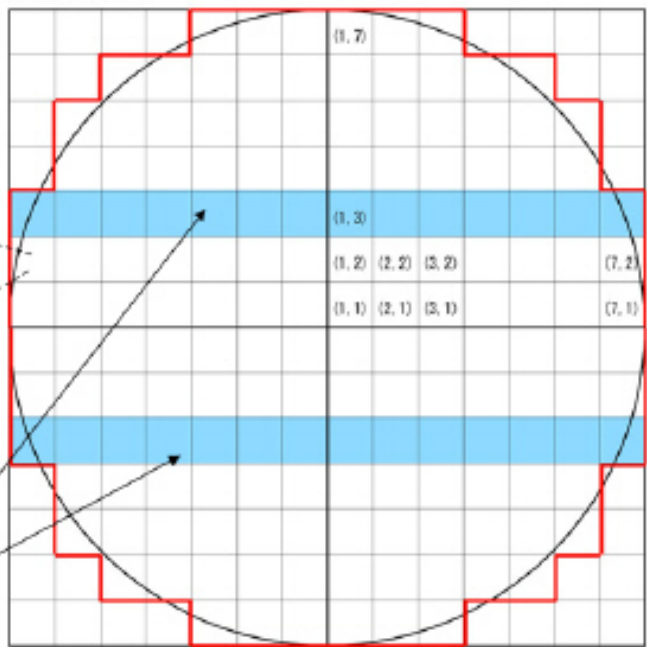
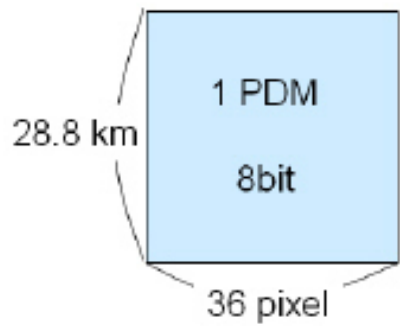
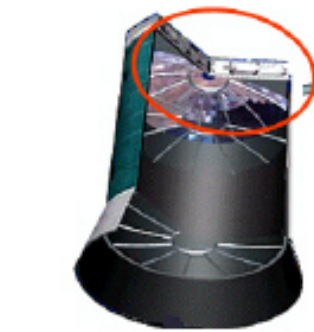
- Velocity of ISS: 7.9 km/s
- FOV of 1PDM: 28.8 km



- All of PDMs equip "slow-data" DAQ
- Continuous BG photon counting

V_{ISS}
↑

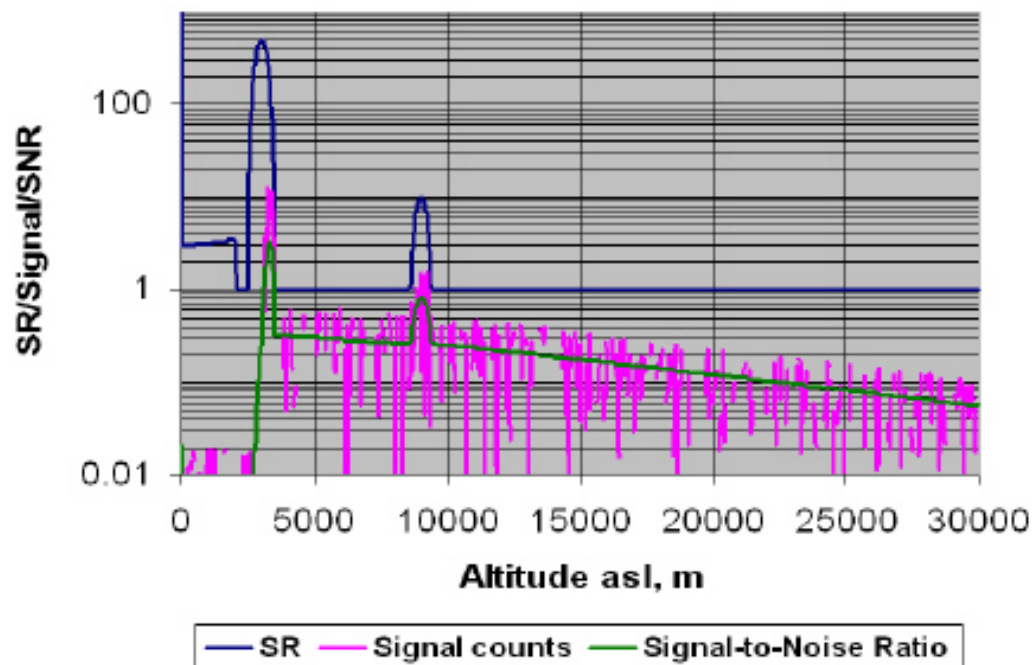
JEM-EUSO FS



Slow-data obtained at only 2 PDM lines will be stored!

Slow-Data

Performance simulations, #3:

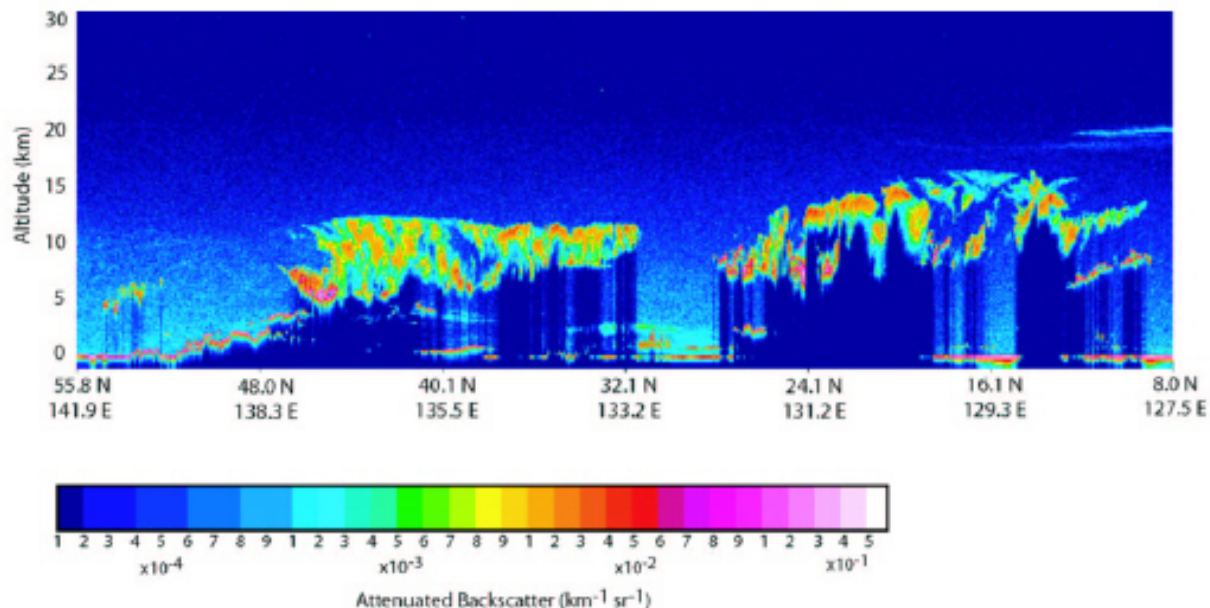


results for
355nm, 0.01sec
integration time,
30m range
resolution

Performance simulations, #1: Subsystems

Subsystem		Lidar 1	Lidar 2
Transmitter	Wavelength, nm	355	532
	Pulse repetition rate, pps	100	100
	Averaged transmitted power, W	1	1
	Divergence full angle, mrad	0.08	0.08
	Optical efficiency	80	80
Receiver	Primary receiver aperture diam, cm	250	250
	Secondary mirror aperture, cm	0	0
	Field of View full angle, mrad	0.2	0.2
	Interference filter, FWHM	0.25	0.25
	Interference filter, transmission %	50	50
	Optical efficiency (without filter)	25	25
Detector	Quantum efficiency, %	25	25
	Dark noise, counts per second	500	500
Acquisition (ph. counting)	Range resolution, bin meters	30	30
	Integration time, sec	0.01/1	0.01/1
Satellite	Altitude, km	500	500

Another spaceborne lidar– first CALIPSO results (#2)



Lidar

IR Camera Development with EADS/SODERN

Major Change from CIM01 to JEM-EUSO IR Camera

(1) Pixel size of detector

"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

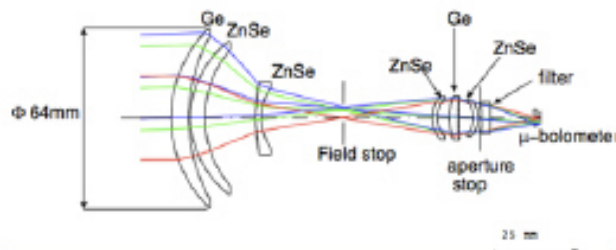
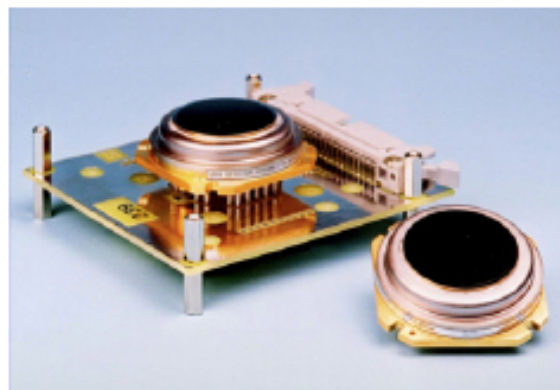
(2) FOV

Line scanning → >60°

Based on CIM01 design, they can produce FM of JEM-EUSO IR camera with 5.5MEuro within 5 years.

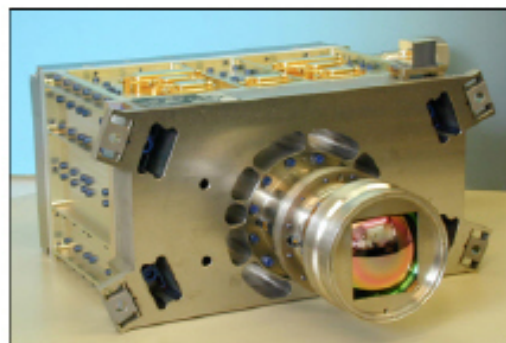
Specification of IR Camera

Should be determined before 12E, 2007



IR Camera Development with EADS/SODERN

CIM01 (or IASI) onboard METOP1 satellite



IASA Specification

- Scanning Mirror
- Sensor (CIM01)

λ : 10.3 - 12.5
 μm

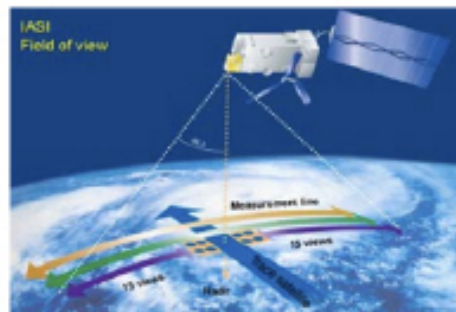
sensor: bolometer array

pix. size: 64×64

res.: 12 bit

FOV: 60×60 mrad

NETD : <80 mK

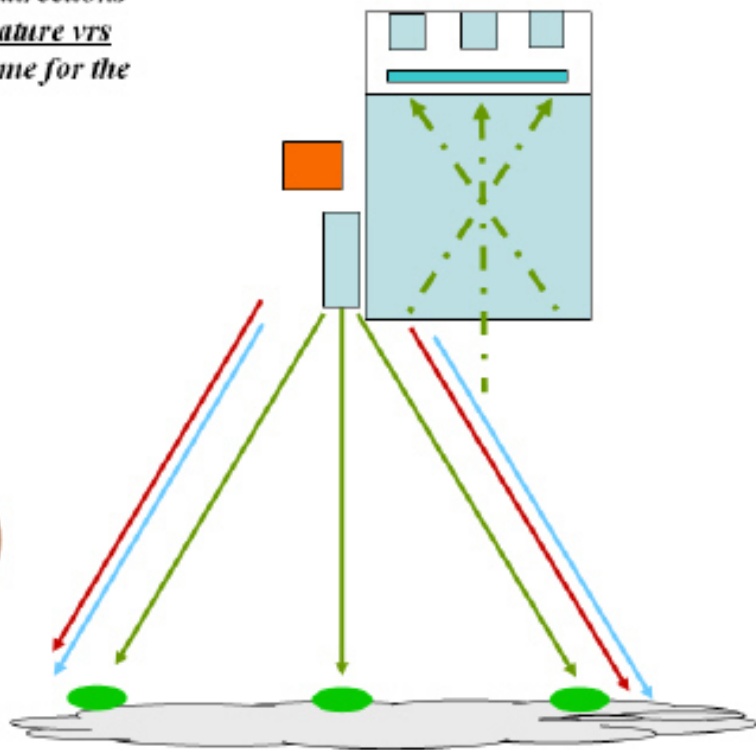
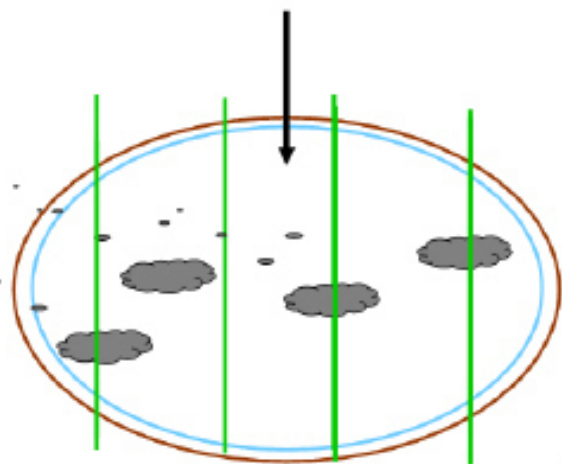


Requirement

Item	Value	Reason
Wavelength	10 – 13 μ m	Atmospheric transmission, S/N
FOV	> 60°	Same FOV as JEM-EUSO
Spatial Resolution	0.25°	1.8 km/pix @ nadir
Observation Temperature Range	200 – 320 K	Cloutop temperature in troposphere
Absolute Temperature Resolution	< 3 K	Altitude resolution < 500m
IR Sensor	Uncooled Microbolometer Array	Mass, Power
Exposure Time	133 msec	ISS motion within $\frac{1}{2}$ - pix of IR camera
Observation Interval	30 sec (5 sec TBC)	ISS motion of JEM-EUSO $\frac{1}{2}$ FOV

IR Camera

*Using the measurements in these three-four directions
for calibration of the IR radiometer temperature vrs
cloud top altitude – Reference lines ; the same for the
UV « slow mode »*



Atmospheric Monitoring System

- **IR Camera**

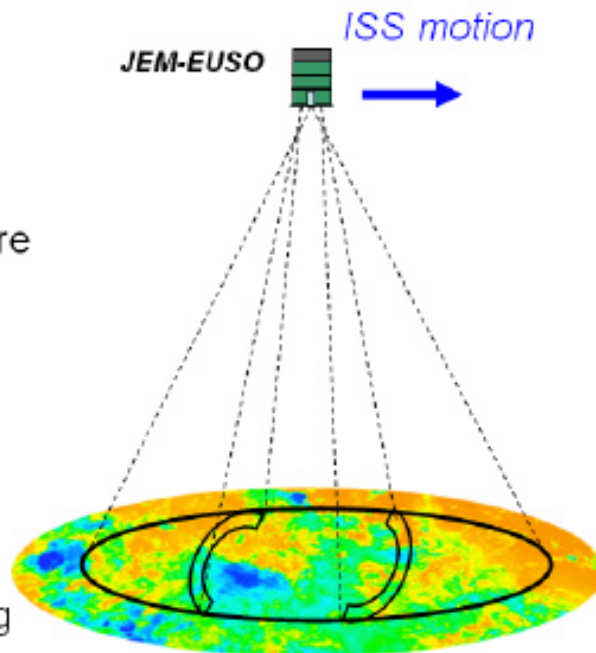
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

Ranging observation using UV laser

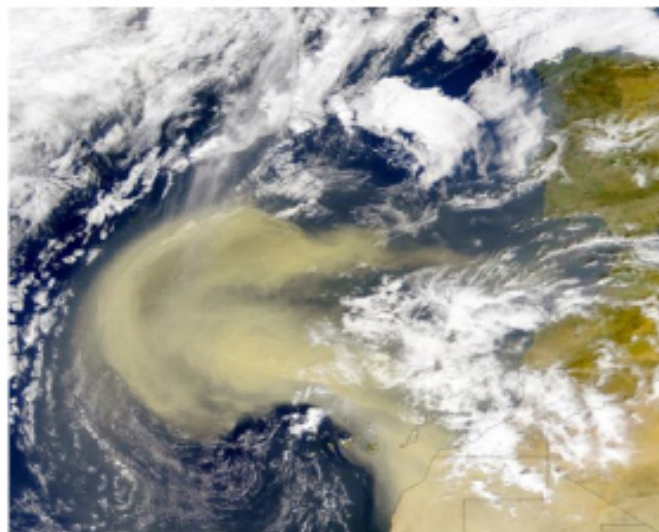
- **JEM-EUSO "slow-data"**

Continuous background photon counting



- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
- *Calibration of telescope:* (Lidar)

■ *The real atmosphere – clouds and desert dust*

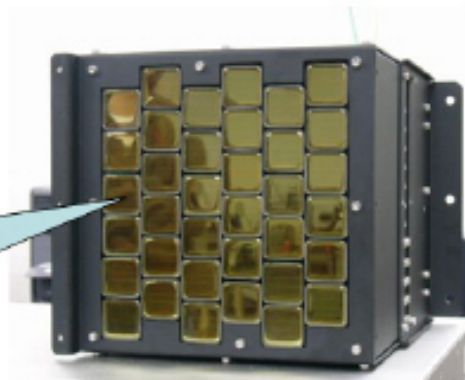
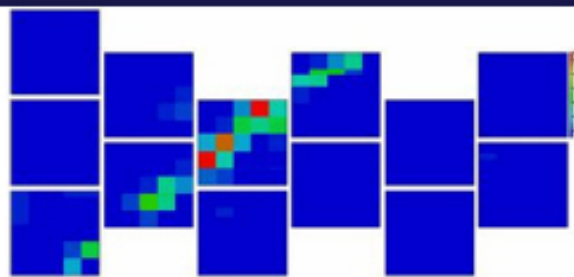


Sahara dust over the Atlantic on 26.2.2000

Progress: 小さなEUSOを製作

UV Laser

40cm Diameter



Prototype PDM

ASIC
by Ikeda

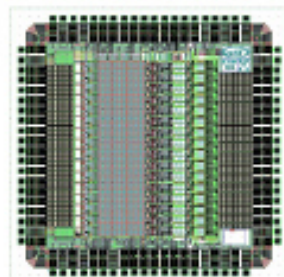


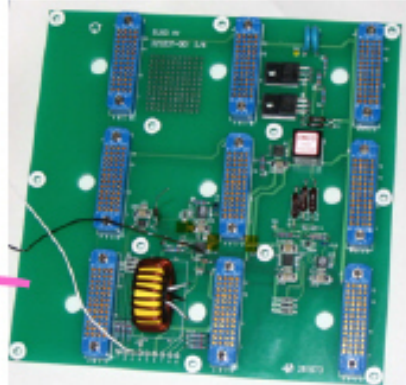
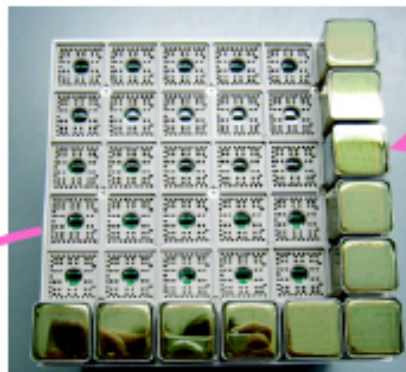
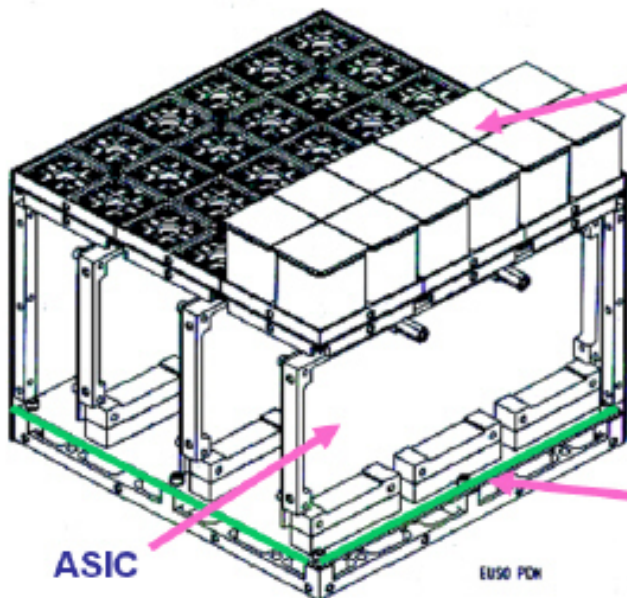
Photo Detector Module (PDM)

- 9 Elementary Cell (EC), 1 HV module, 9 HV divider

✓ 構造解析と振動試験 (済)

✓ 放射線試験 (済)

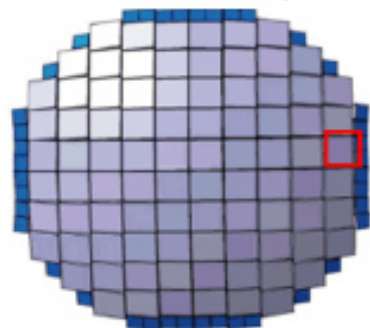
✓ 大光量保護回路 (済)



JEM-EUSO 焦点面の構造

Focal Surface detector

(164PDMs = 0.2M pixels)



2.26 m max

Elementary Cell

(2x2 PMTs = 144 pixels)

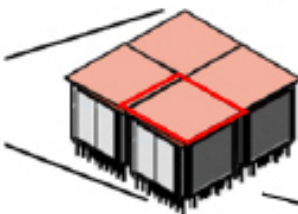
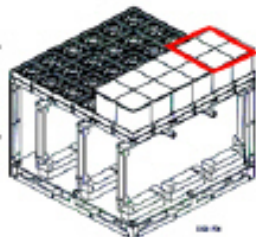
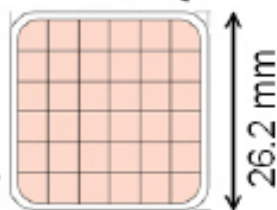


Photo-Detector Module

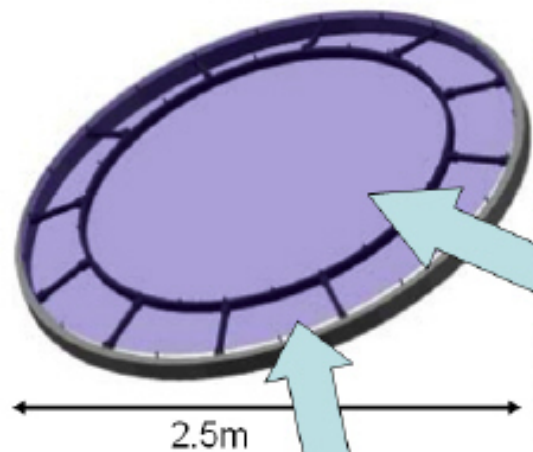
(3x3 ECs = 1296 pixels)



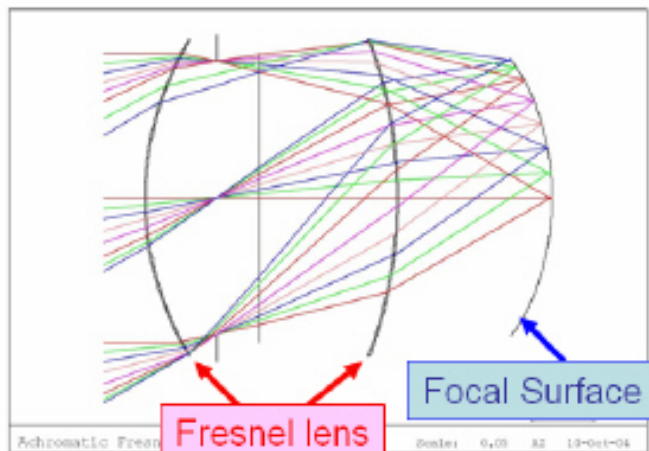
MAPMT
(6x6 pixels)



フレネルレンズ製作

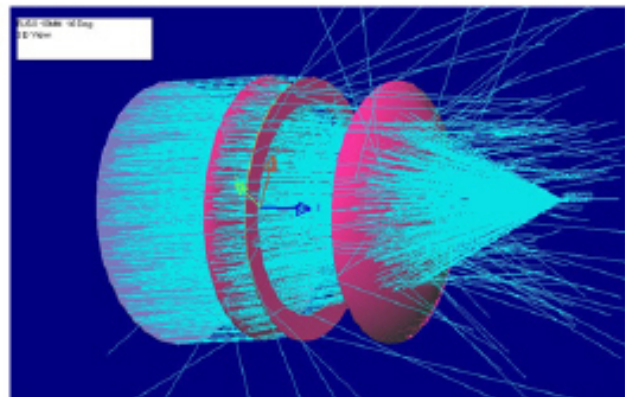


CYTOPを用いた新光学系



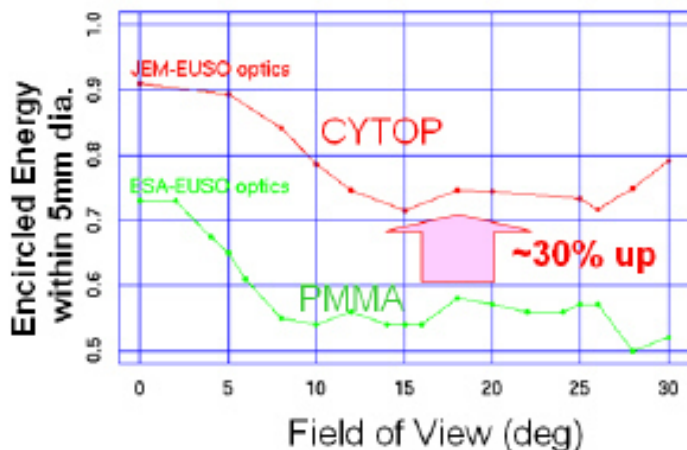
Optics Requirements

- FoV $\pm 30^\circ$
- Pupil entrance pupil ≥ 2 m
- $F/\# \leq 1.0$
- Spot dimension $\sim 0.1^\circ$ (5mm Φ)
- Spectral range 330-400 nm

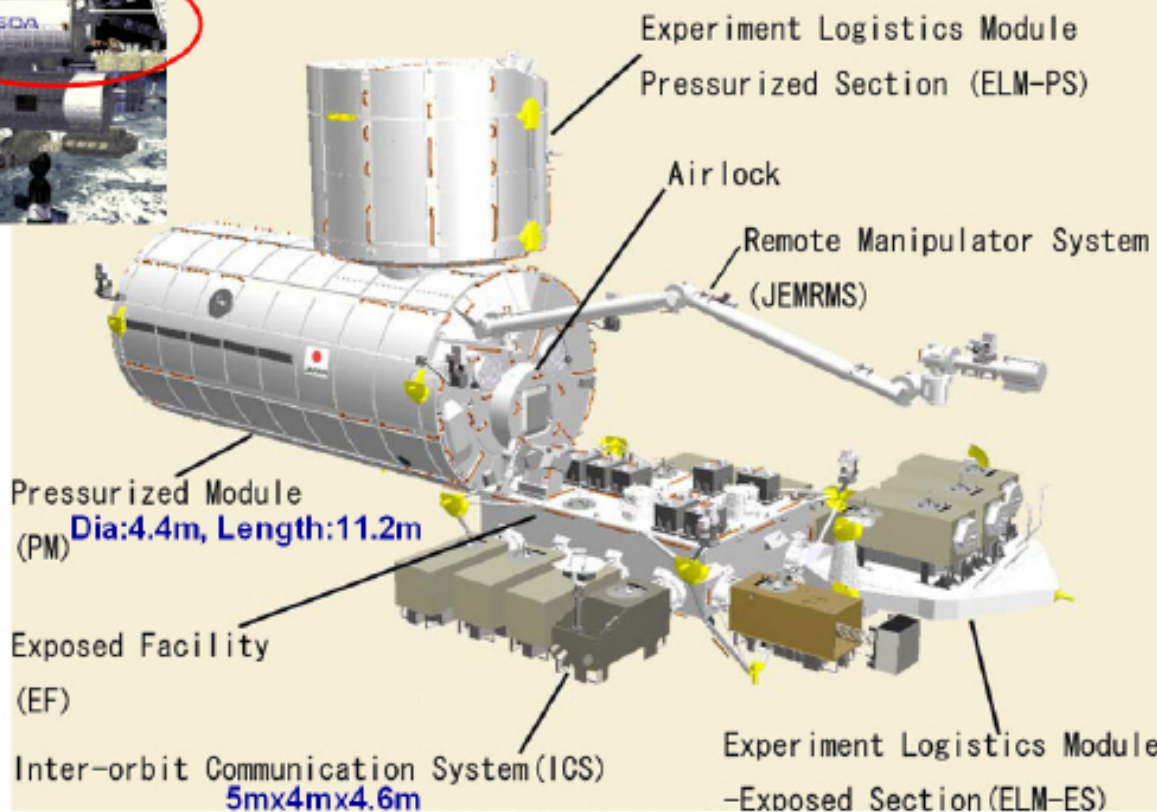
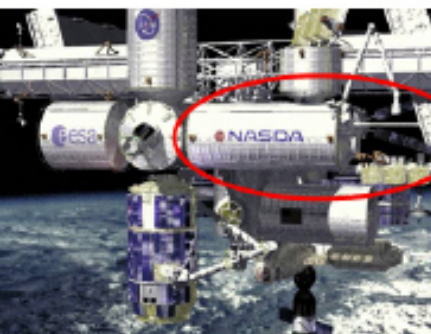


Ray trace

JEM-EUSO vs ESA-EUSO optics



日本実験棟「きぼう」



これからの予定

- 2007年度－2008年度(準備研究・概念設計)
 - 2007年10月 曝露部分科会へ報告
 - 2007年11月 国際JEM-EUSO会合
 - 2008年1月 国際アドバイザーボード会合
 - 2008年3月 国際シンポジウム開催
 - 2008年4月 中間評価
 - 2009年3月 最終評価
- 2009年度－2012年度
 - 製作段階
- 2013年 打ち上げ

これまでの経緯

- ESA—EUSO
 - ESA 採択 2000;
 - NASA 採択 2003;
 - Phase-A 完了 2004
 - 地上公募研究: 1998 - 2001 2002 - 2004
- 2006年6月:
 - JEM-EUSO WGが宇宙理学委員会において承認ISAS/JAXA
- 2006年8月:
 - JEM-EUSO計画化委員会が理研中央研究所に設置
- 2006年11月:
 - 第二期利用ミッション候補公募開始
- 2007年2月:
 - 理研から提案書提出
- 2007年5月:
 - 採択の正式通知
- 2007年6月
 - Kick-Off会合
 - 国際アドバイザーボード会合
- 2007年7月
 - 第一回国際JEM-EUSO会合(国際宇宙線会議@メキシコ)

ミッション諸元

- 打ち上げ時期: year 2013
- 運用期間: 3 years (+ 2 years)
- 打ち上げロケット: H2B
- ISSへの運搬: HTV非与圧キャリア
- 装着場所: JEM EFU#2
- 軌道高度: ~430km
- 軌道傾斜角: 51.6°
- 質量: 1896 kg
- 使用電力: 998 W (operative),
344 W (non-operative)
- データ転送量: 297 kpbs

サクセスクライテリア

フルサクセス:

極限エネルギー事例: 1000個以上
(7×10^{19} eV 以上)

ミニマムサクセス:

フルサクセスの半分の事例数を得る: 500個

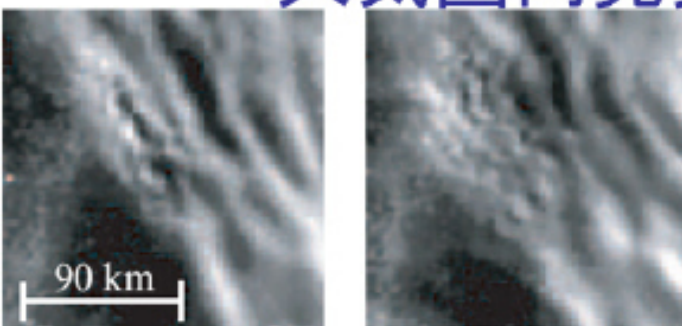
分布から起源を議論の余地なく特定できる臨界量

- 粒子到来方向解析
 - 到来方向決定精度: 2.5度以下
- スペクトル解析
 - エネルギー決定精度: 30%以下
- ハドロン／光子／ニュートリノの識別:
 - シャワー最大深さ決定精度: 120 g/cm^2 以下

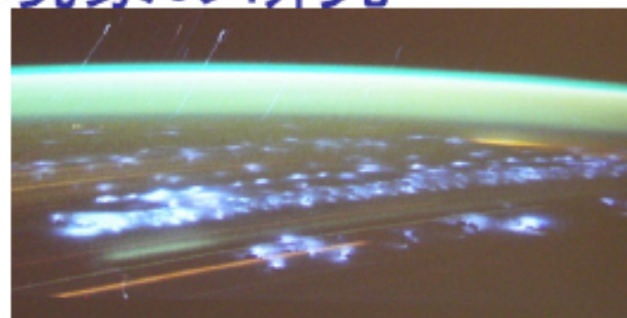
JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星

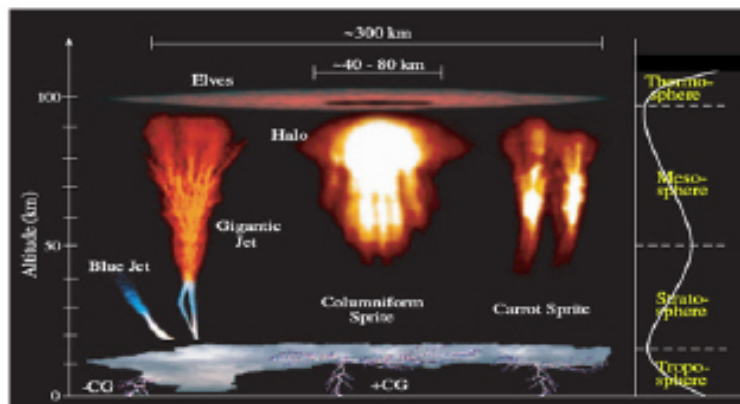
探求的試験研究3: 大気圏内発光現象の研究



地上から観測したOH 大気光の変化



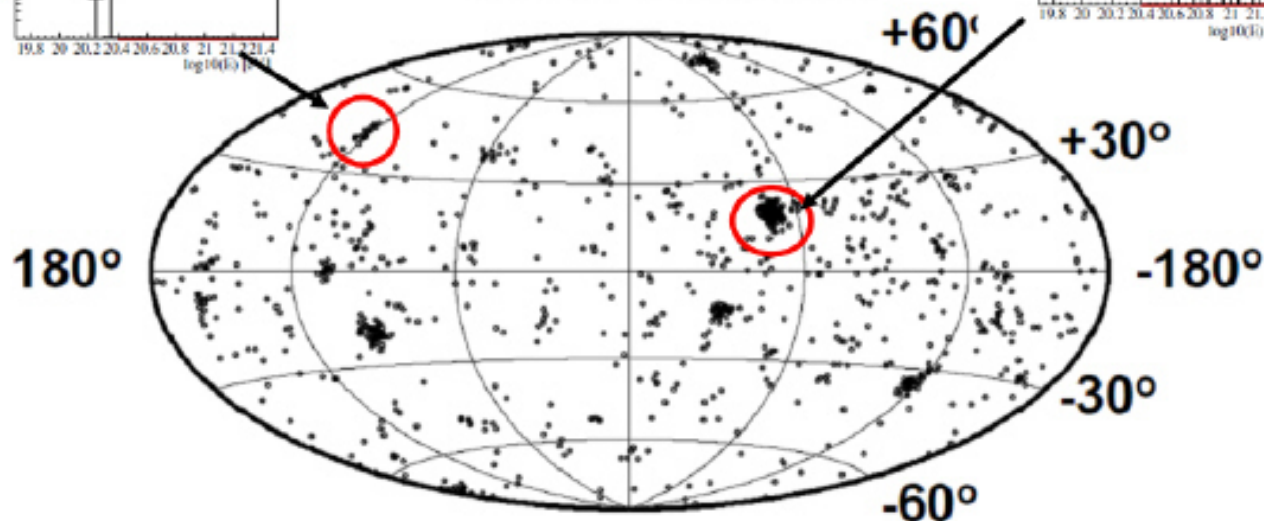
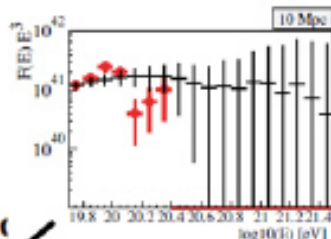
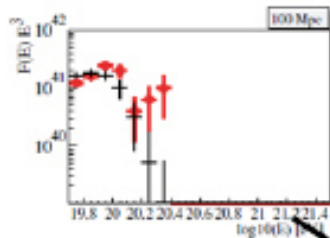
国際宇宙ステーションから連続撮影した雷光

ハイビジョンカメラによる
2001年のしし座流星群雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

極限粒子天文学

1,000事象の場合の予測

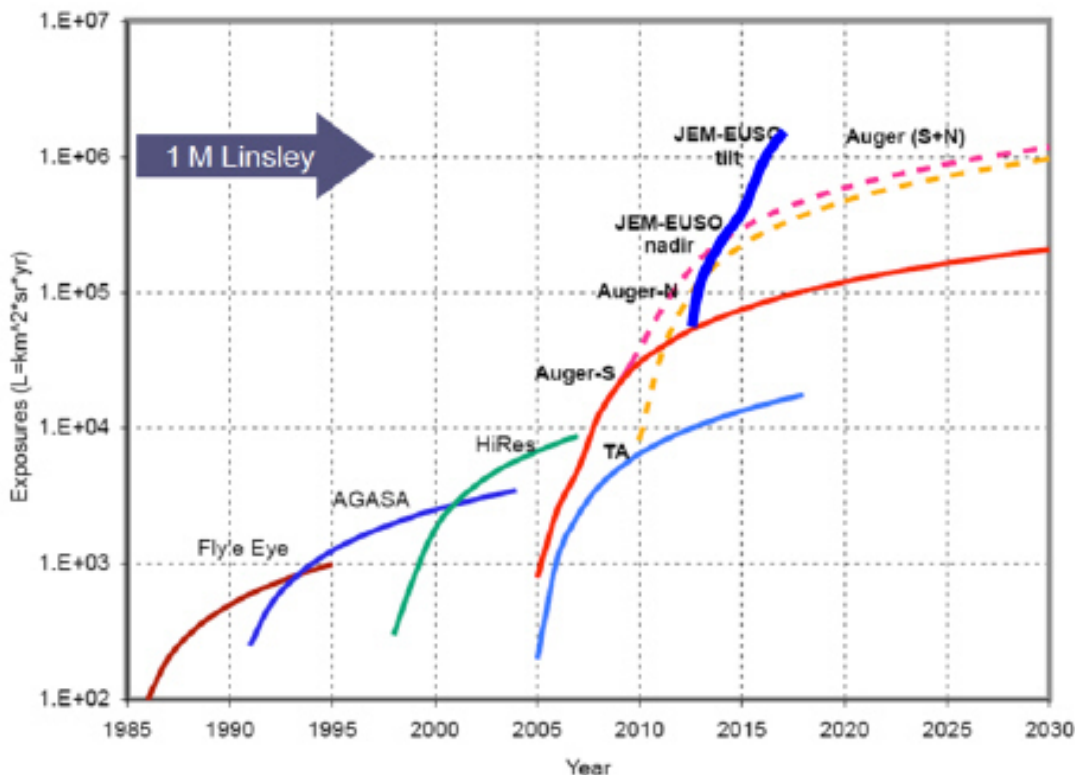
粒子光度 \propto X線光度 (AGN)



- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

Takami 2008

有効露出の増加期待値

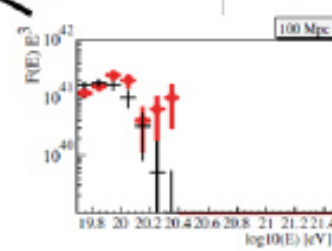
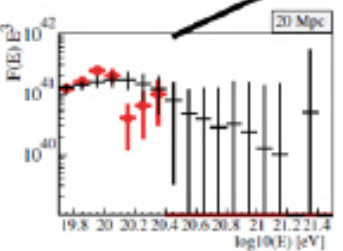
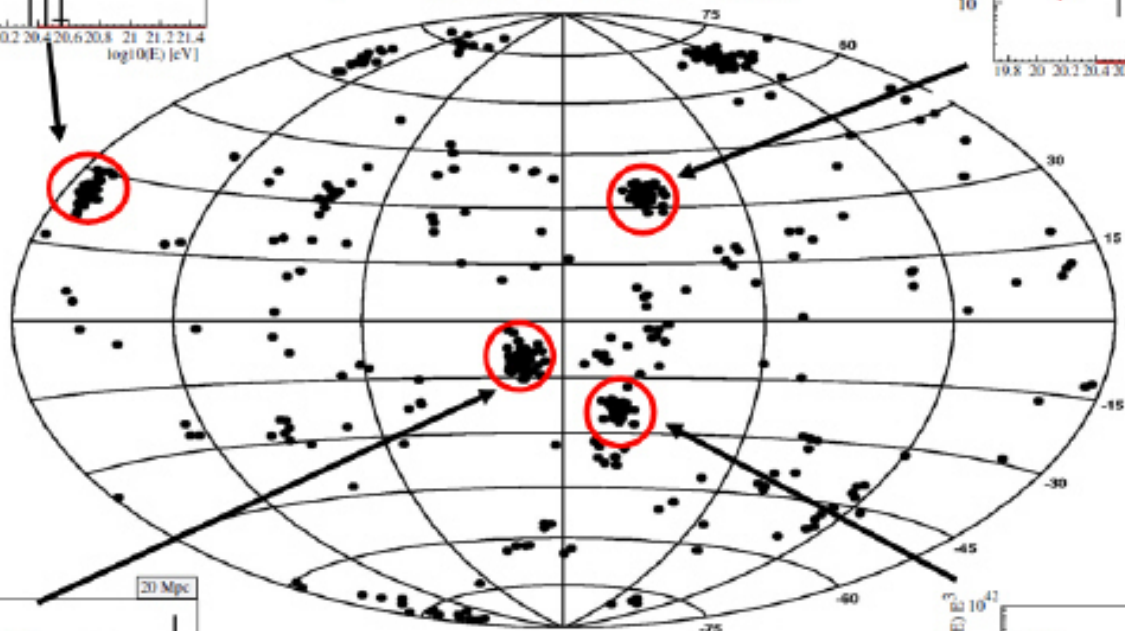
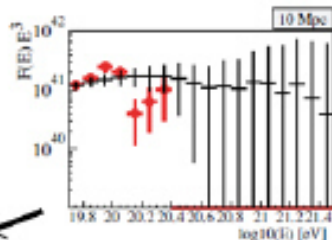
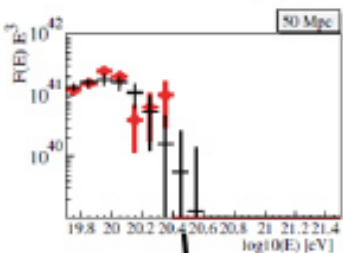


事例数: 5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

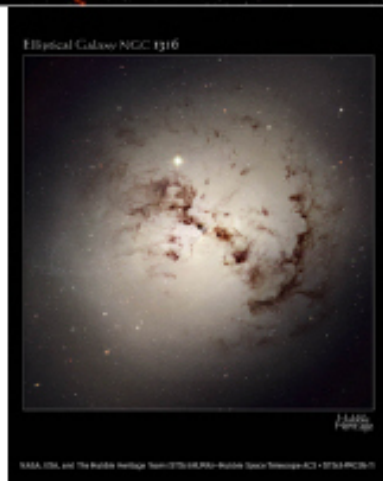
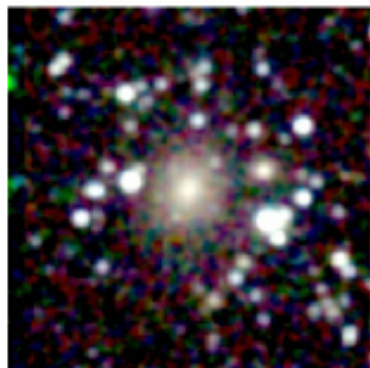
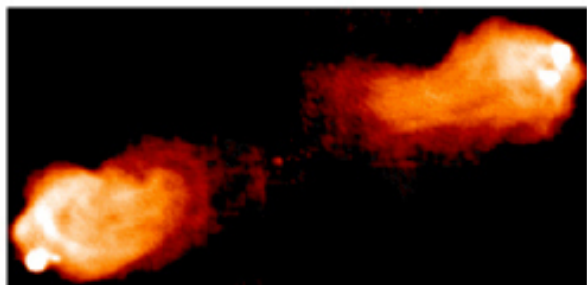
極限粒子天文学

1,000事象の場合の予測



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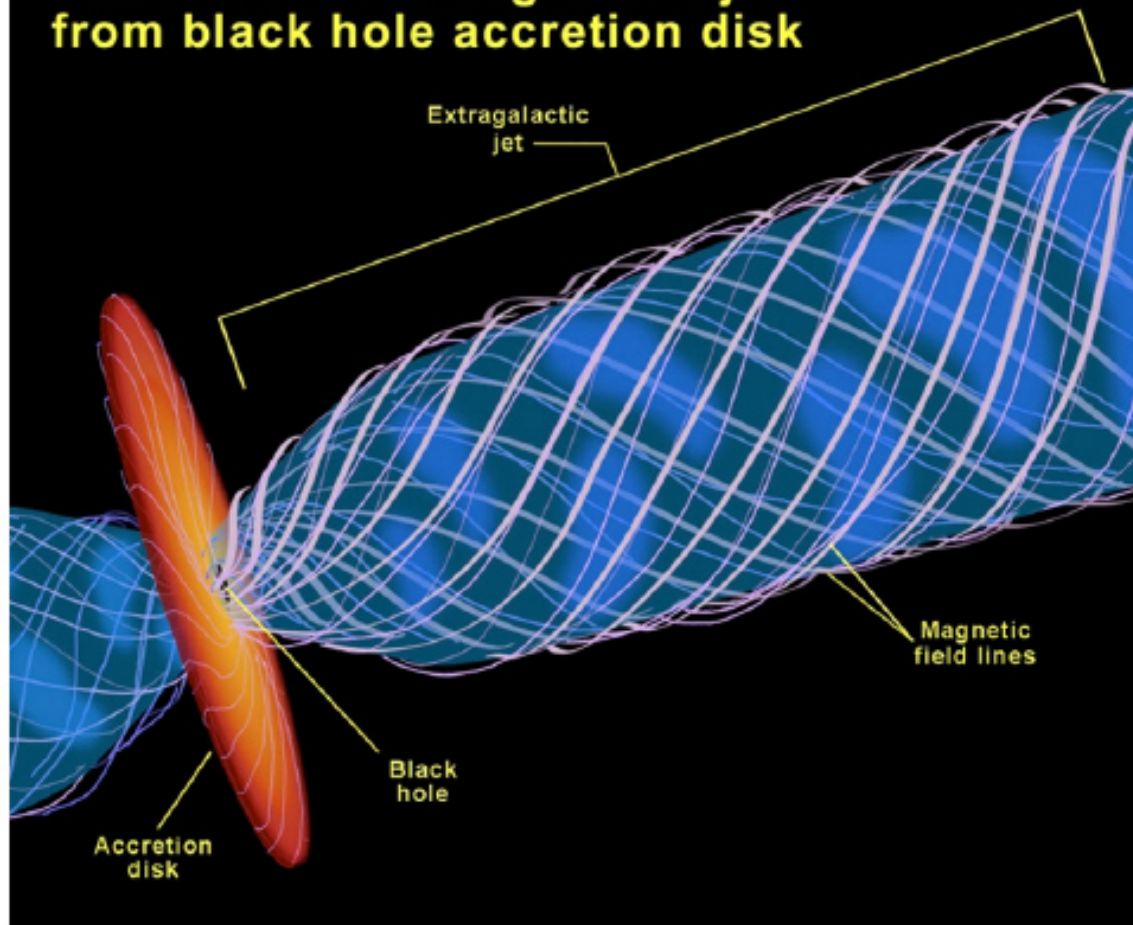
他の電波銀河



Fornax A

Cygnus A

Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



- 距離: 3.4 Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度 ~ 電波光度
~ 2×10^{41} W

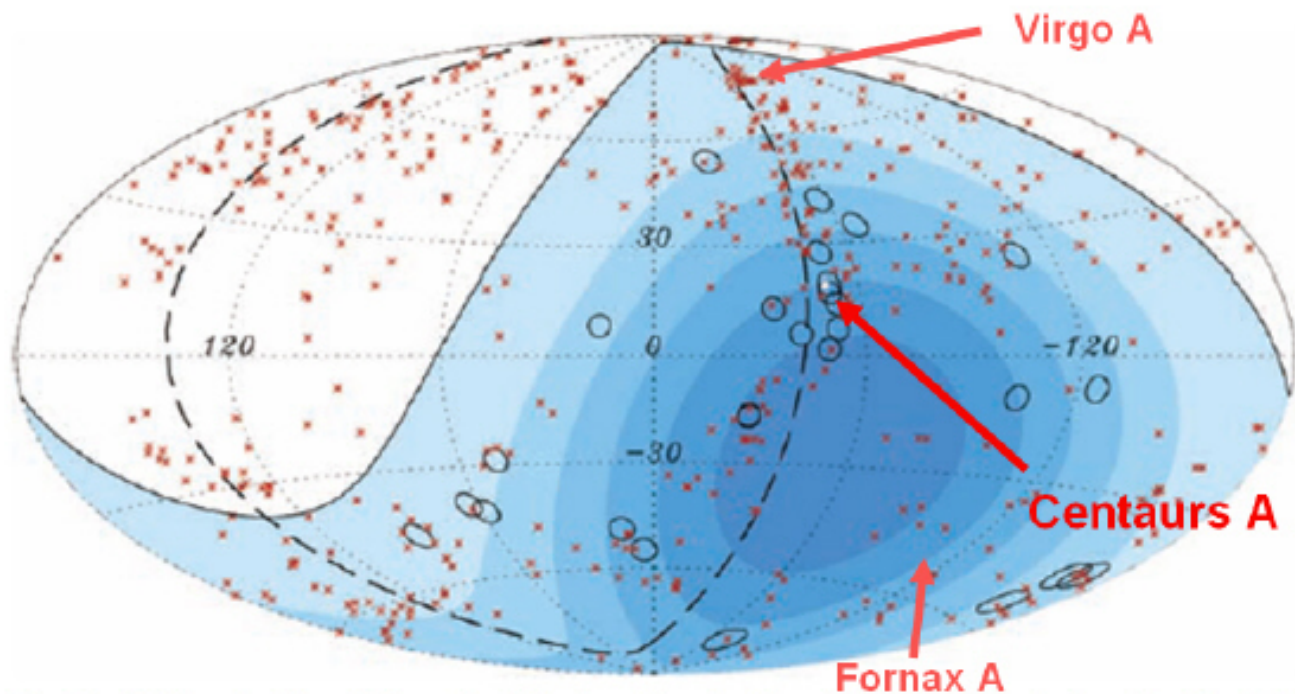
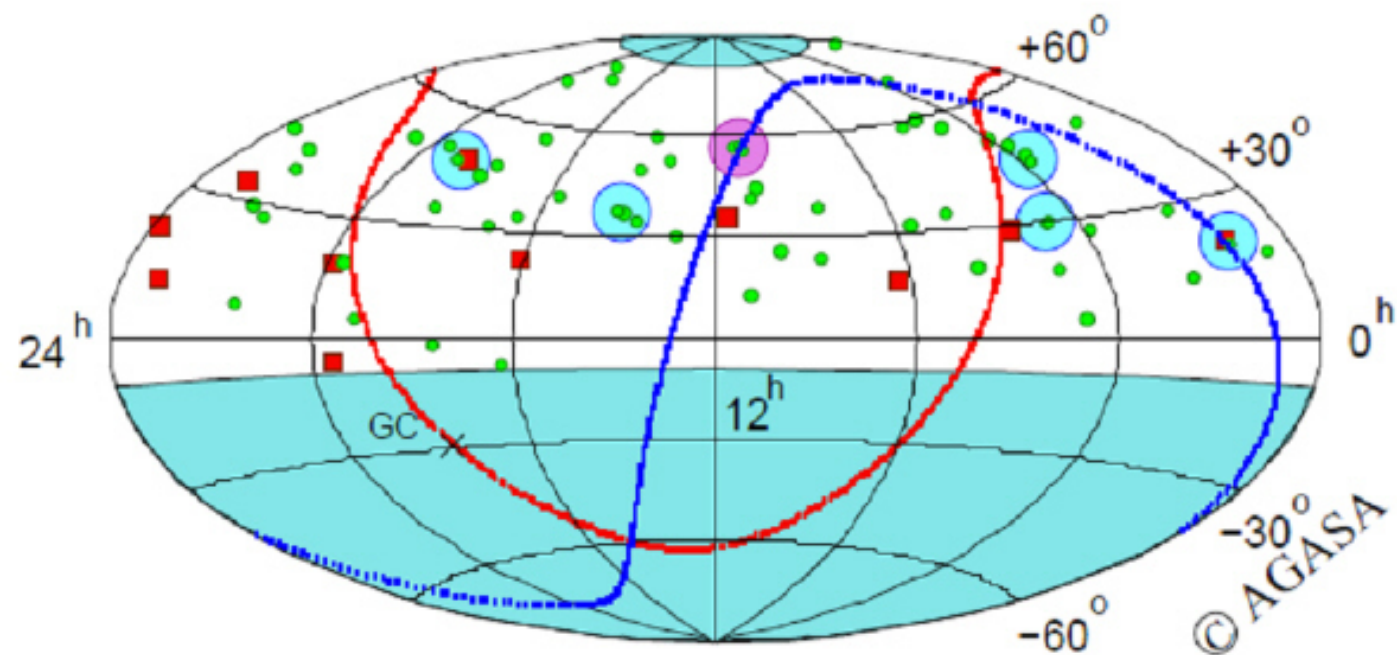


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

Arrival Directions (AGASA)



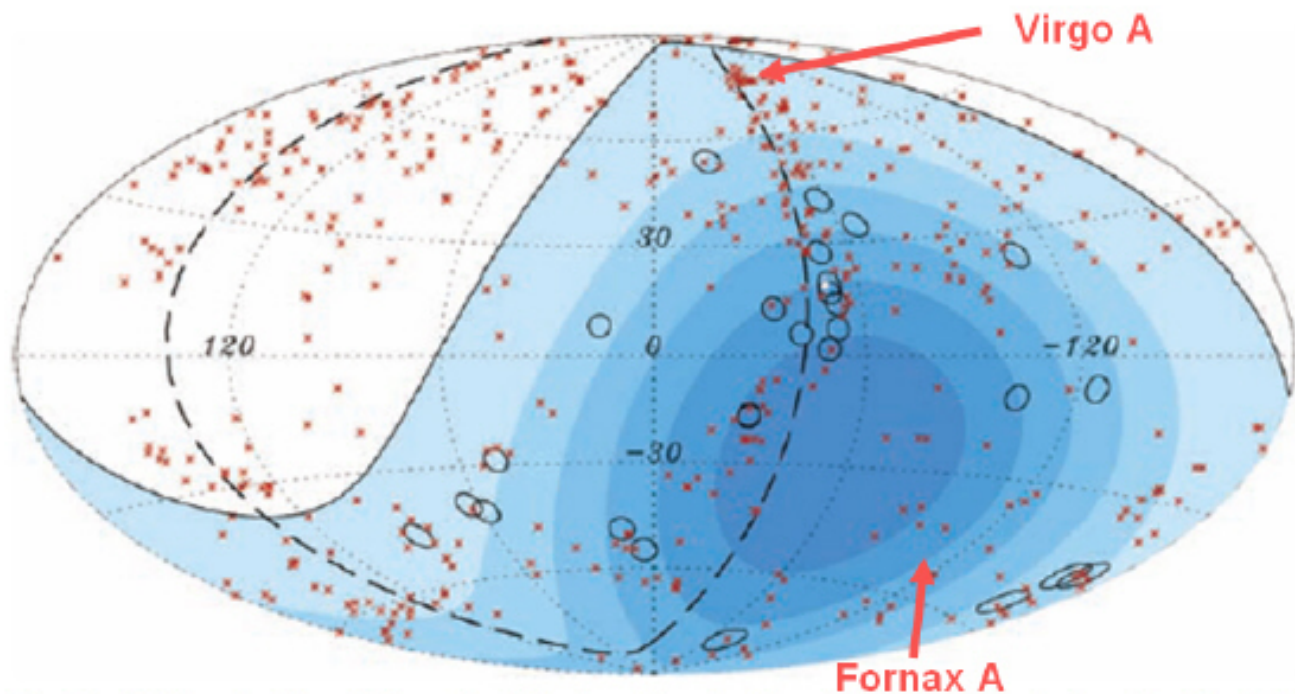


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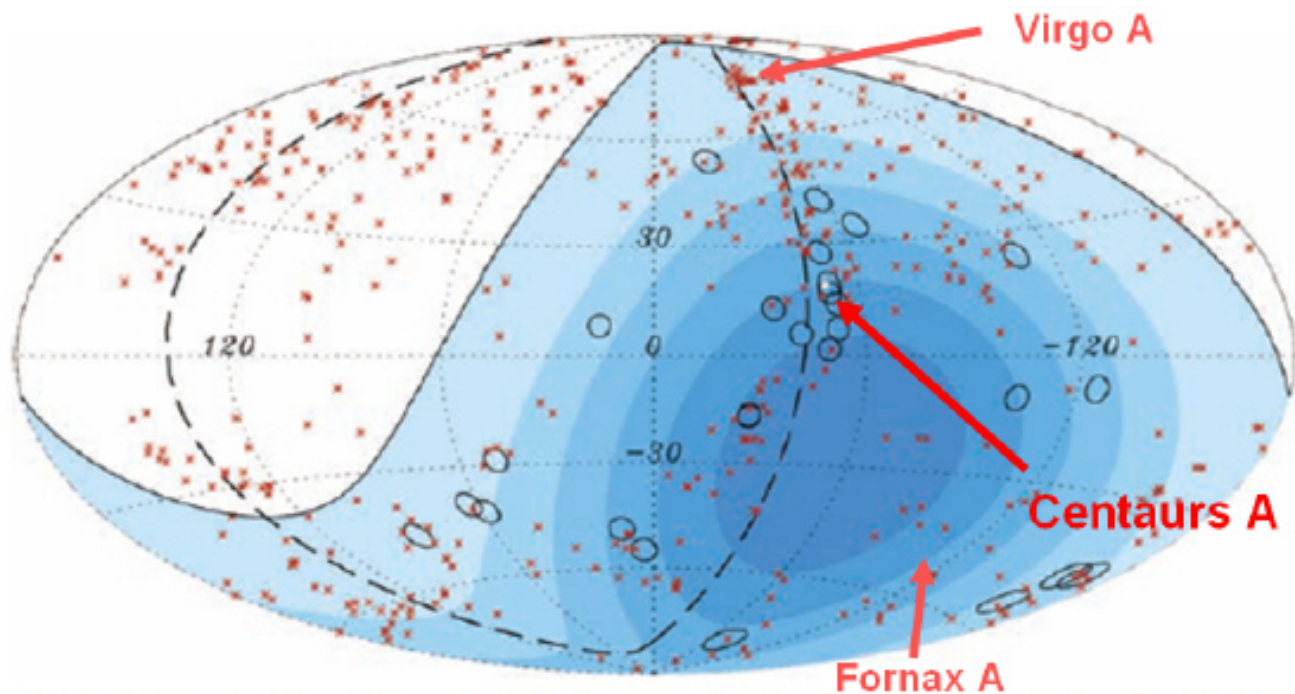


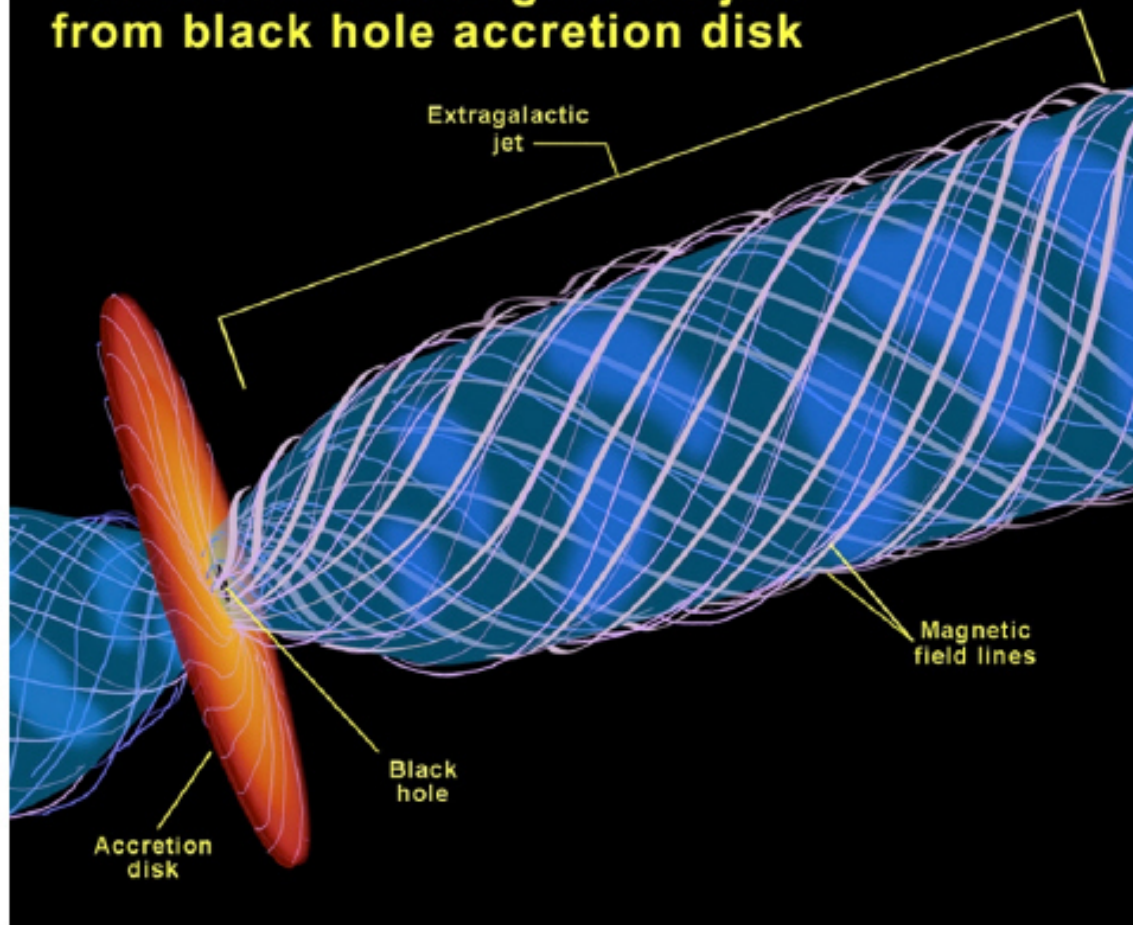
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ケンタウルス座 A

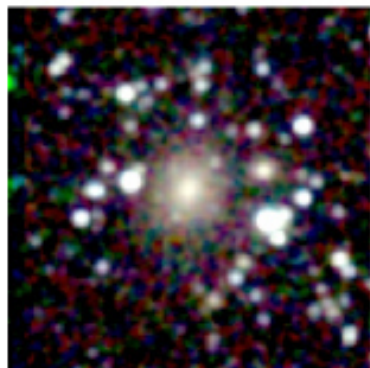
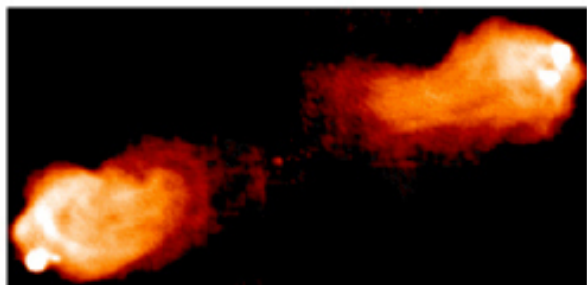


- 距離: 3.4Mpc
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 - もっとも近い
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- 荷電粒子光度～電波光度
～ 2×10^{41} W

Formation of extragalactic jets from black hole accretion disk



他の電波銀河



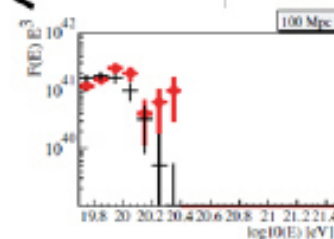
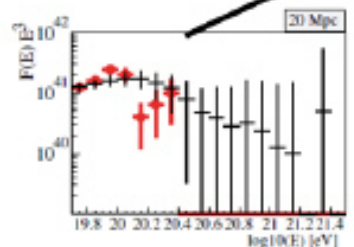
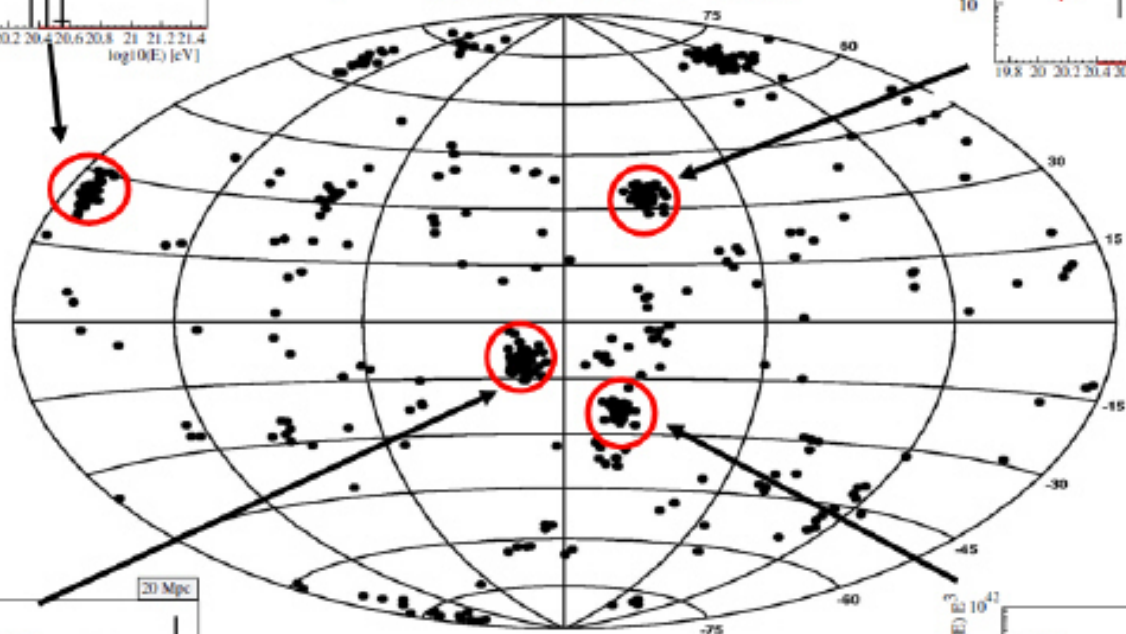
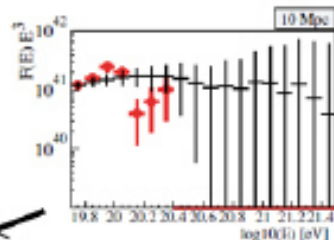
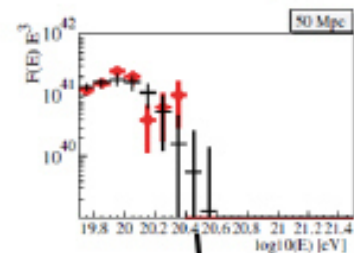
Fornax A

Cygnus A



極限粒子天文学

1,000事象の場合の予測

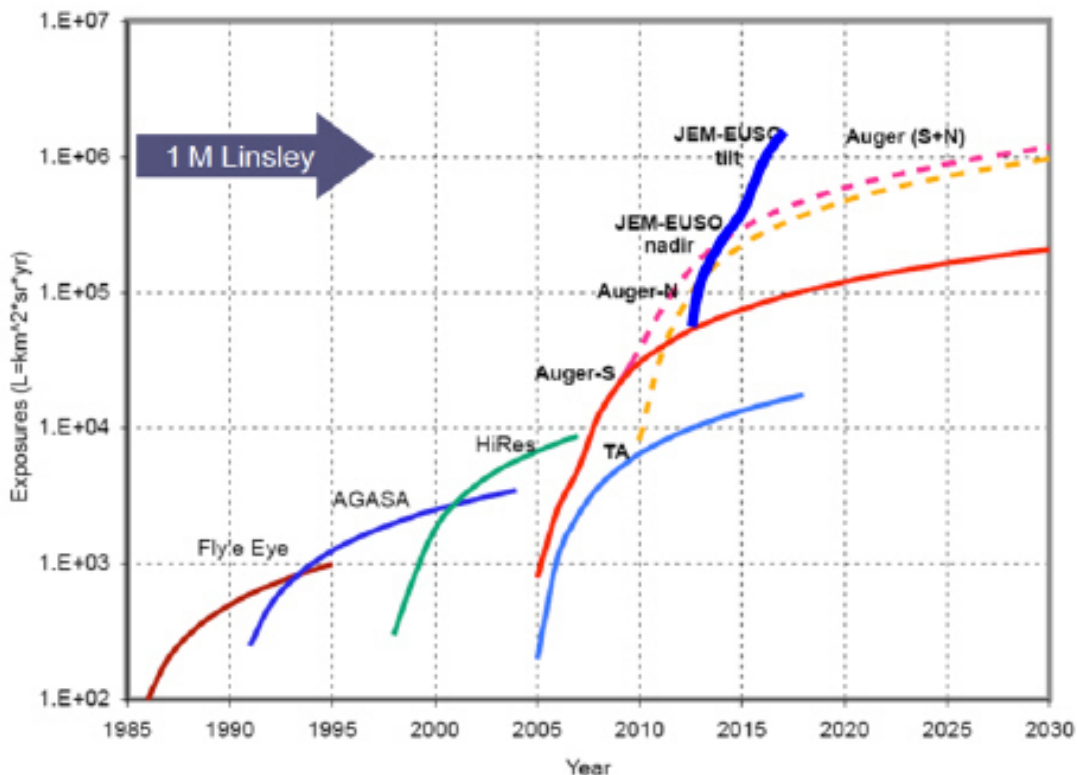


- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
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事例数: 5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

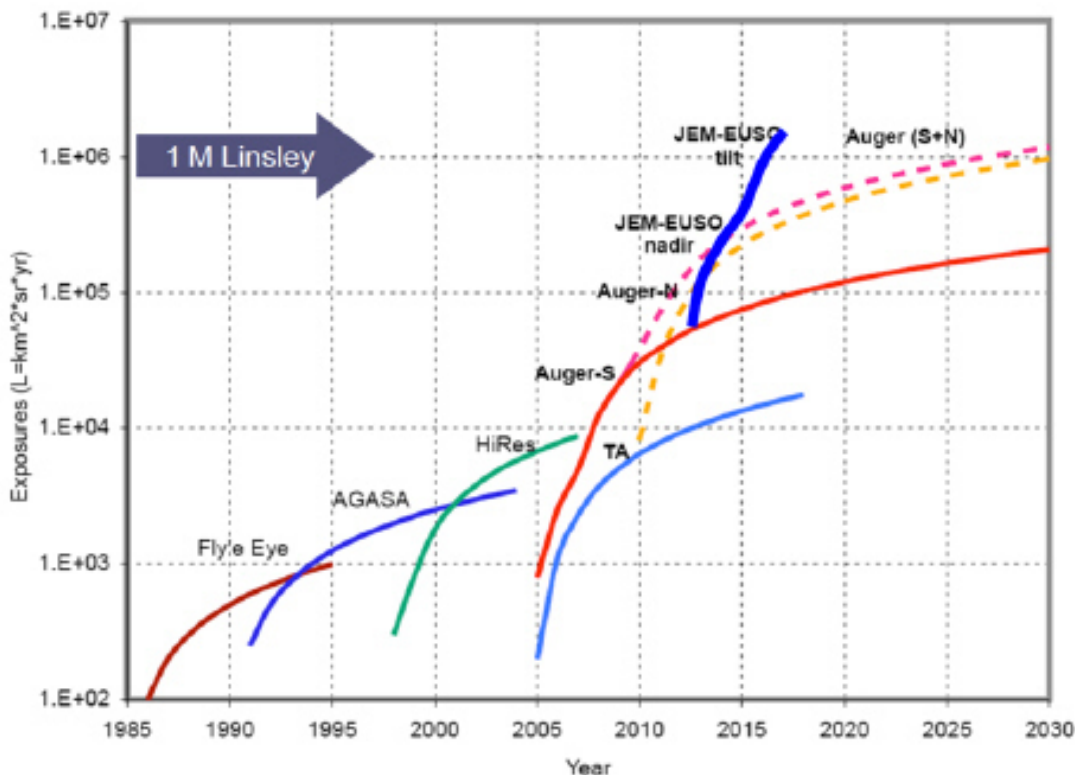
有効露出の増加期待値



事例数: 5年間の運用 End-to-Endシミュレーション

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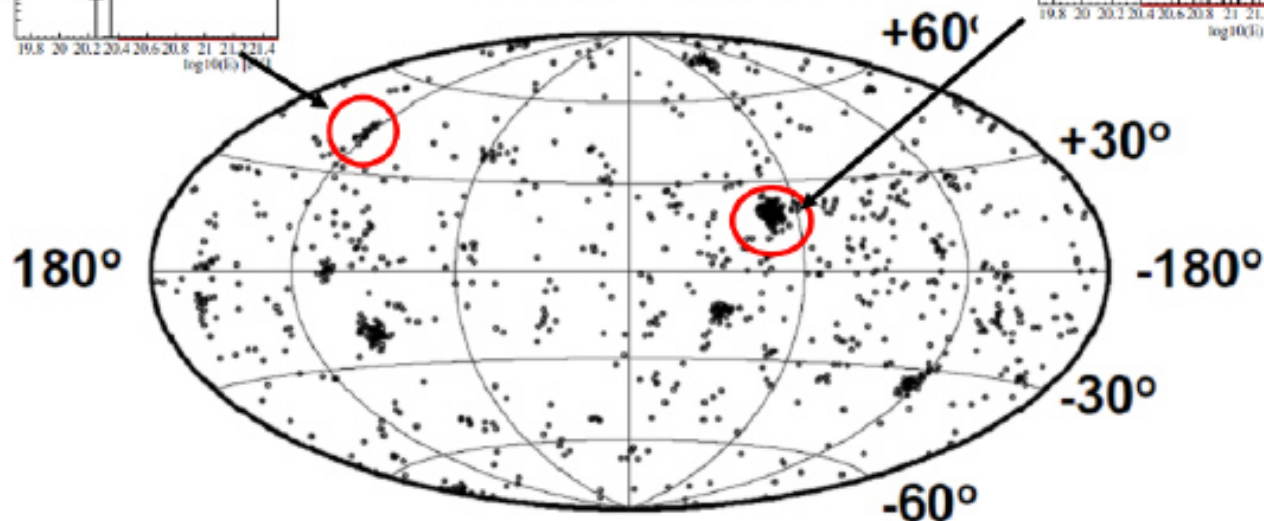
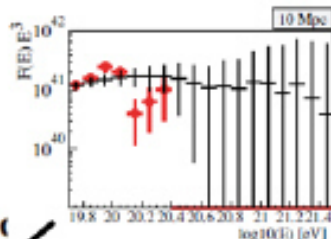
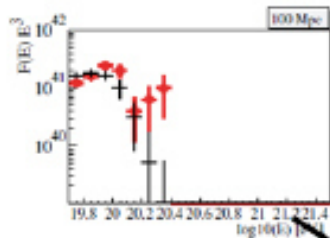
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極限粒子天文学

1,000事象の場合の予測

粒子光度 \propto X線光度 (AGN)



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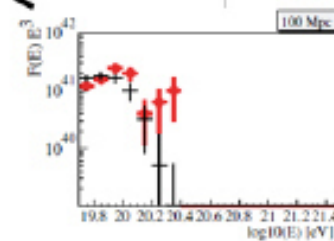
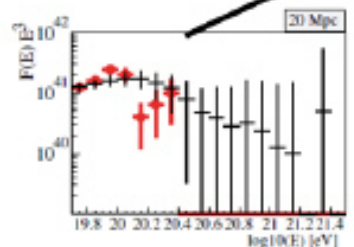
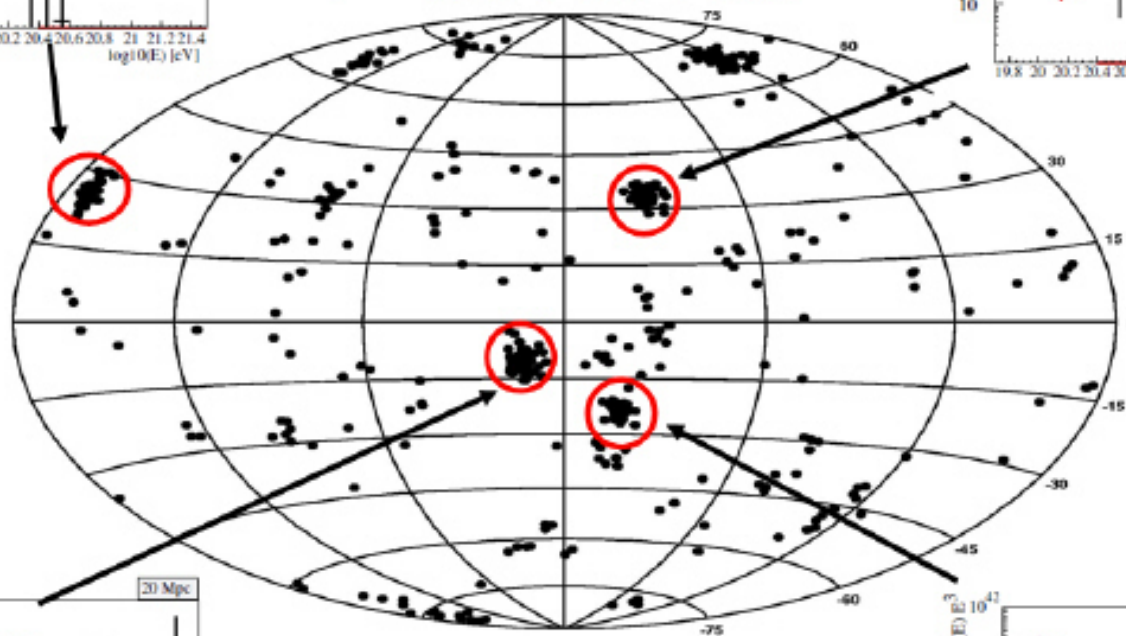
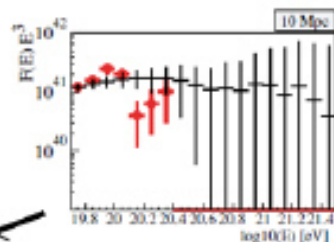
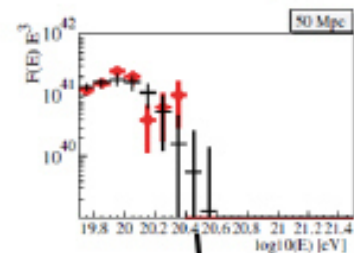
Takami 2008

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極限粒子天文学

1,000事象の場合の予測

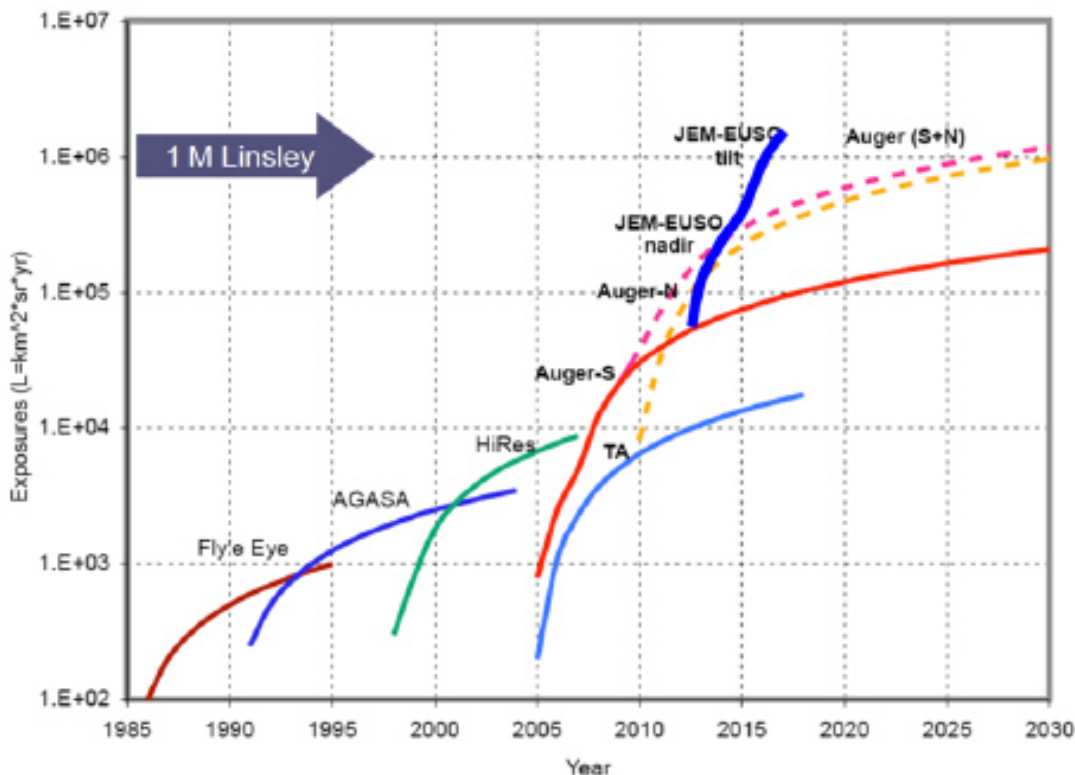


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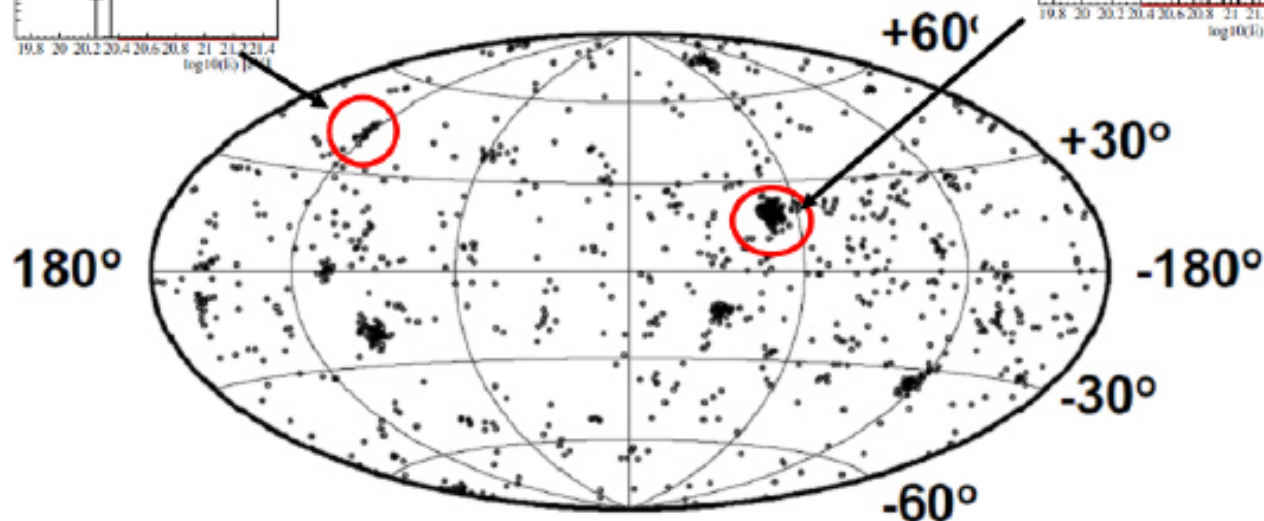
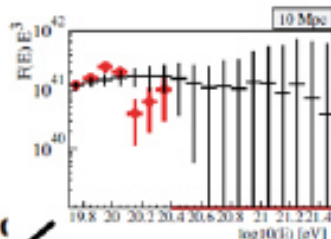
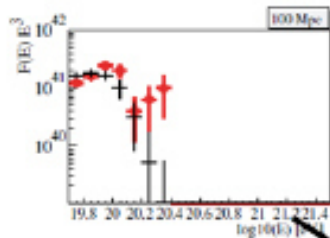
有効露出の増加期待値



極限粒子天文学

1,000事象の場合の予測

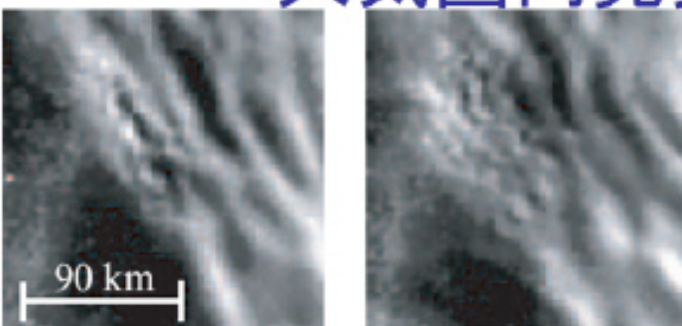
粒子光度 \propto X線光度 (AGN)



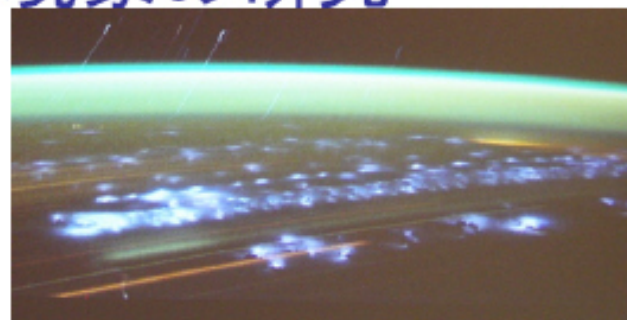
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Takami 2008

探求的試験研究3: 大気圏内発光現象の研究



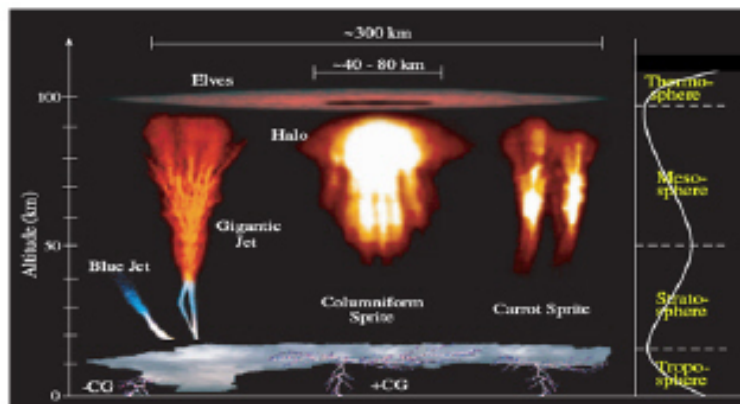
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



ハイビジョンカメラによる
2001年のしし座流星群

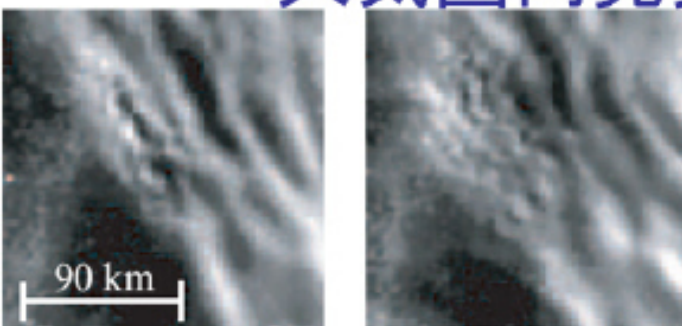


雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

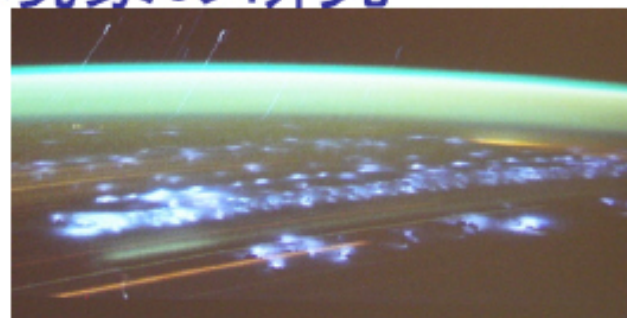
JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星

探求的試験研究3: 大気圏内発光現象の研究



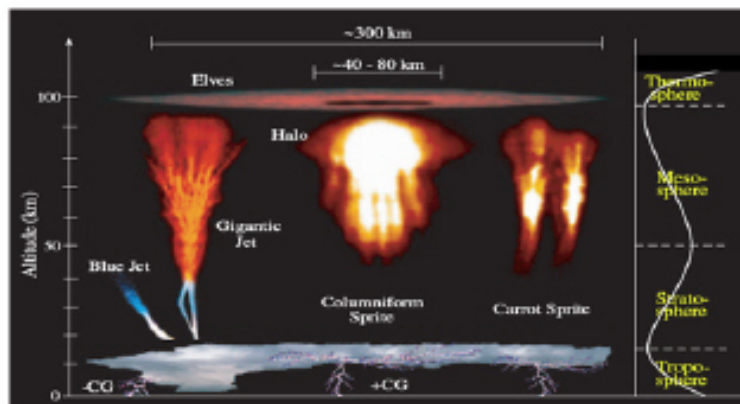
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



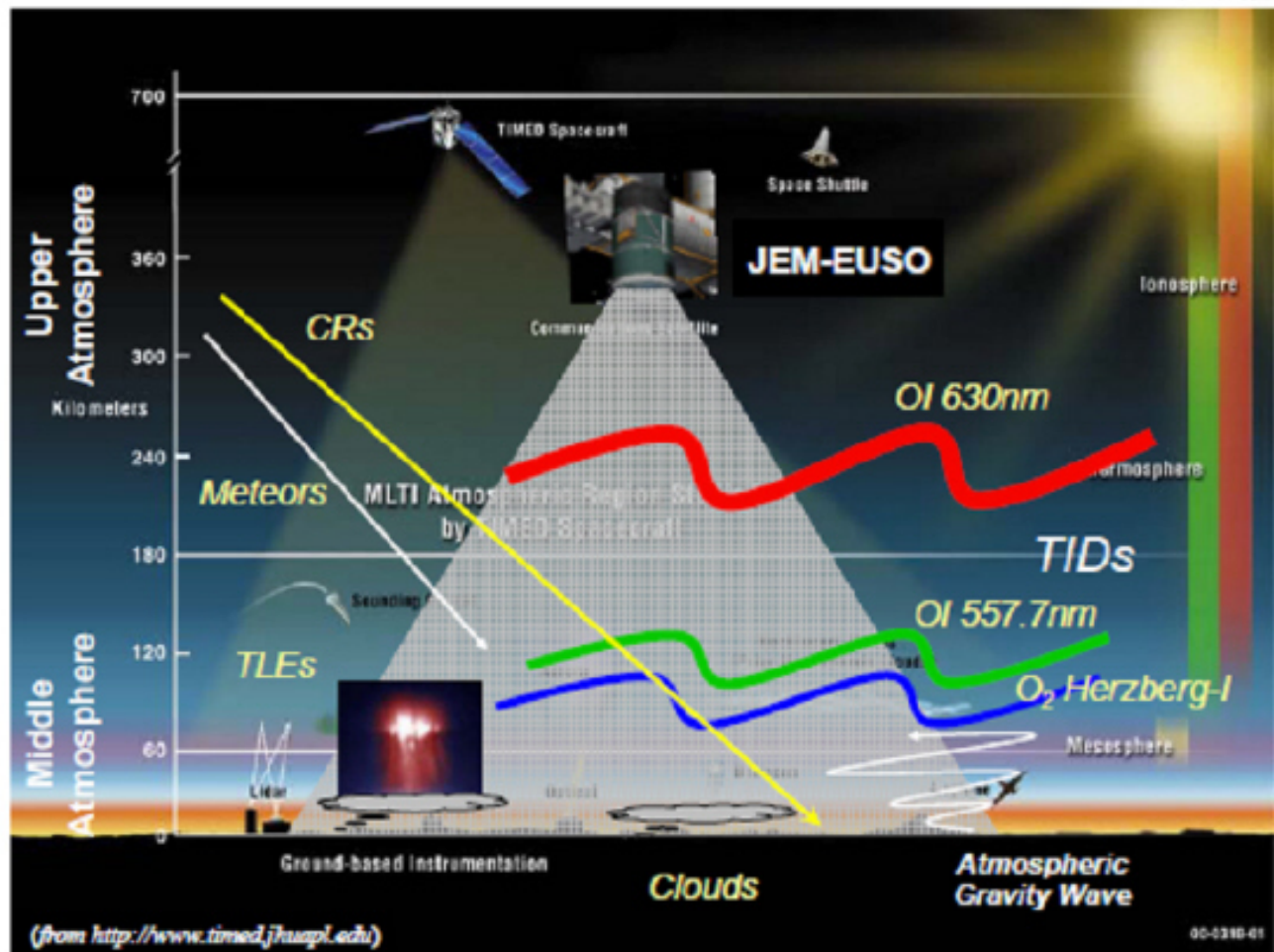
ハイビジョンカメラによる
2001年のしし座流星群



雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

JEM-EUSOによる大気圏科学

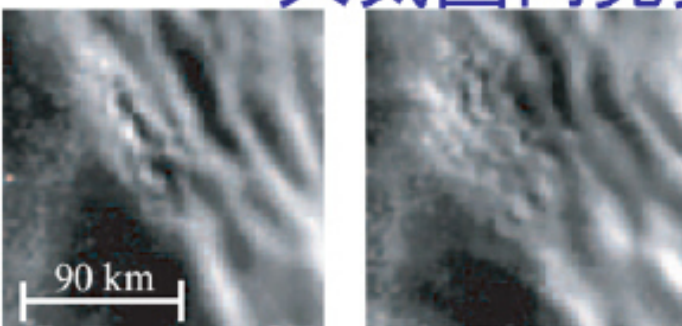
- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
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 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星



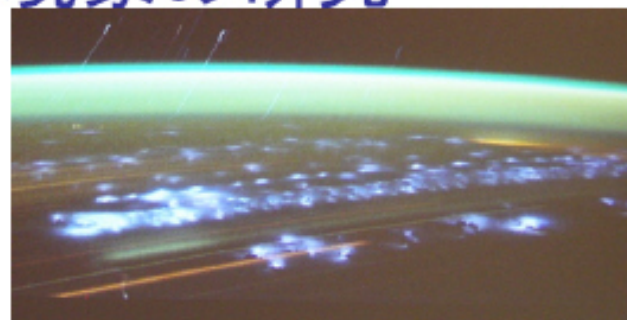
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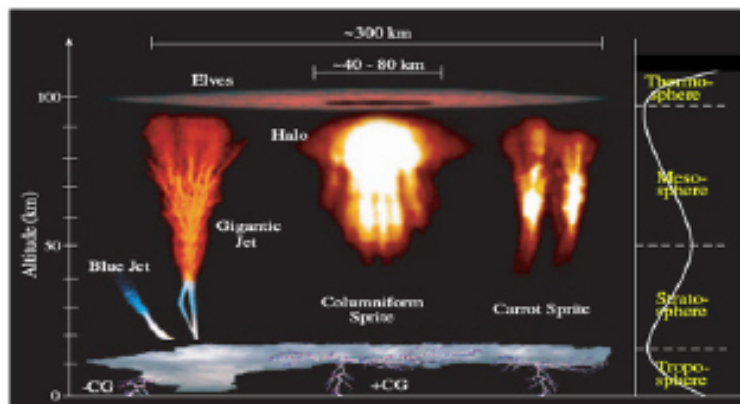
探求的試験研究3: 大気圏内発光現象の研究



地上から観測したOH 大気光の変化



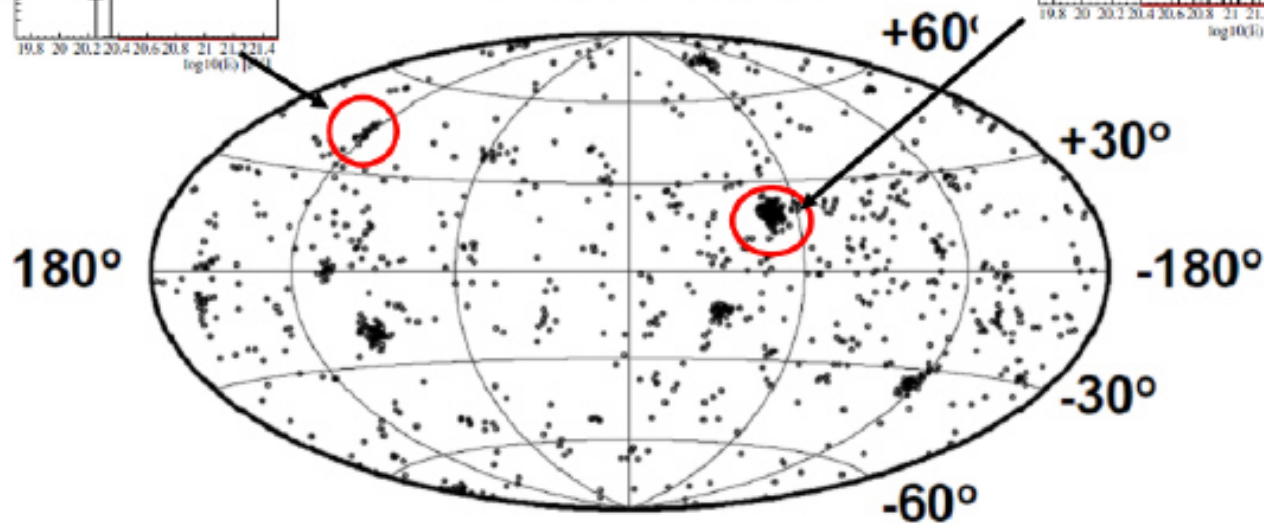
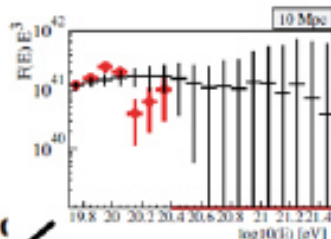
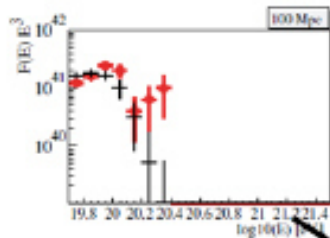
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極限粒子天文学

1,000事象の場合の予測

粒子光度 \propto X線光度 (AGN)



- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

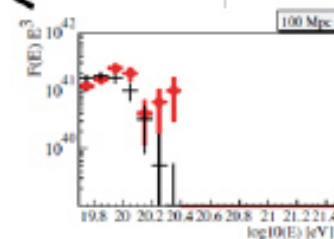
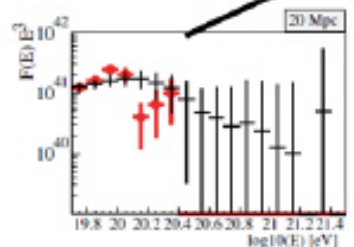
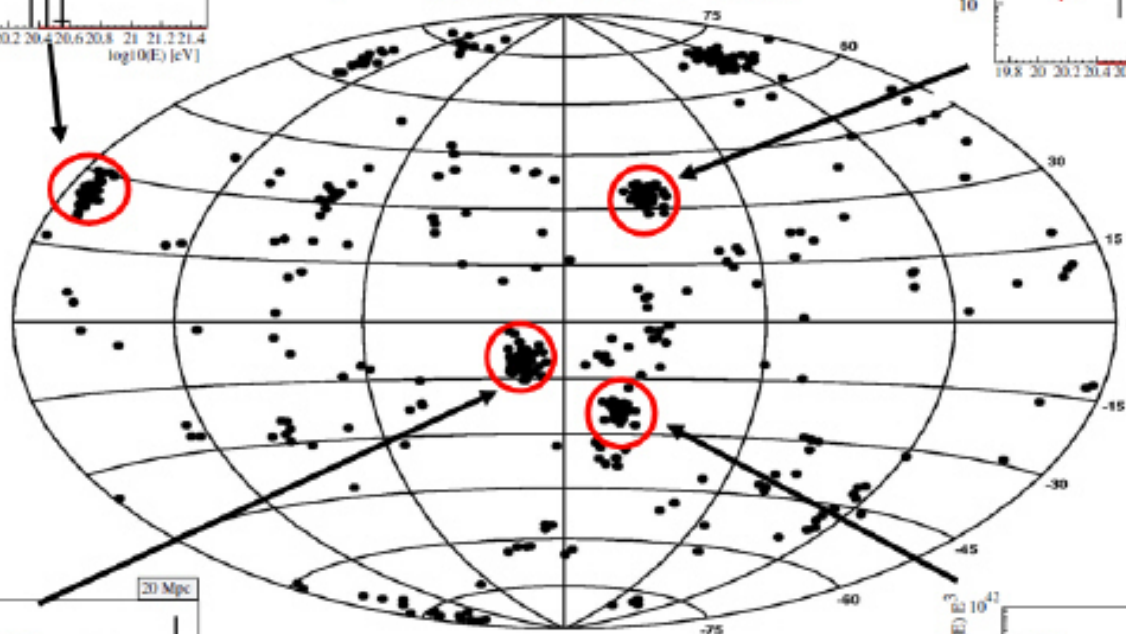
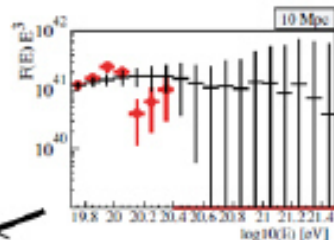
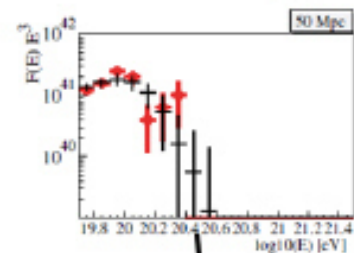
Takami 2008

事例数: 5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

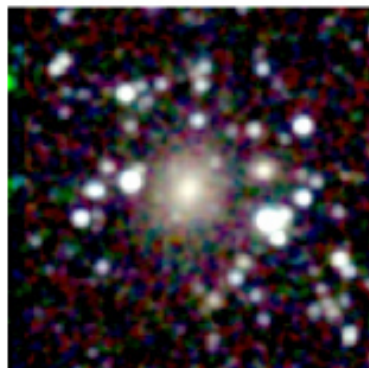
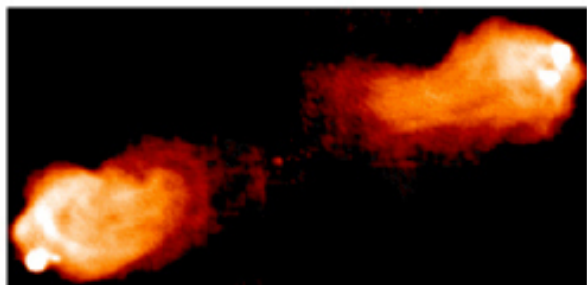
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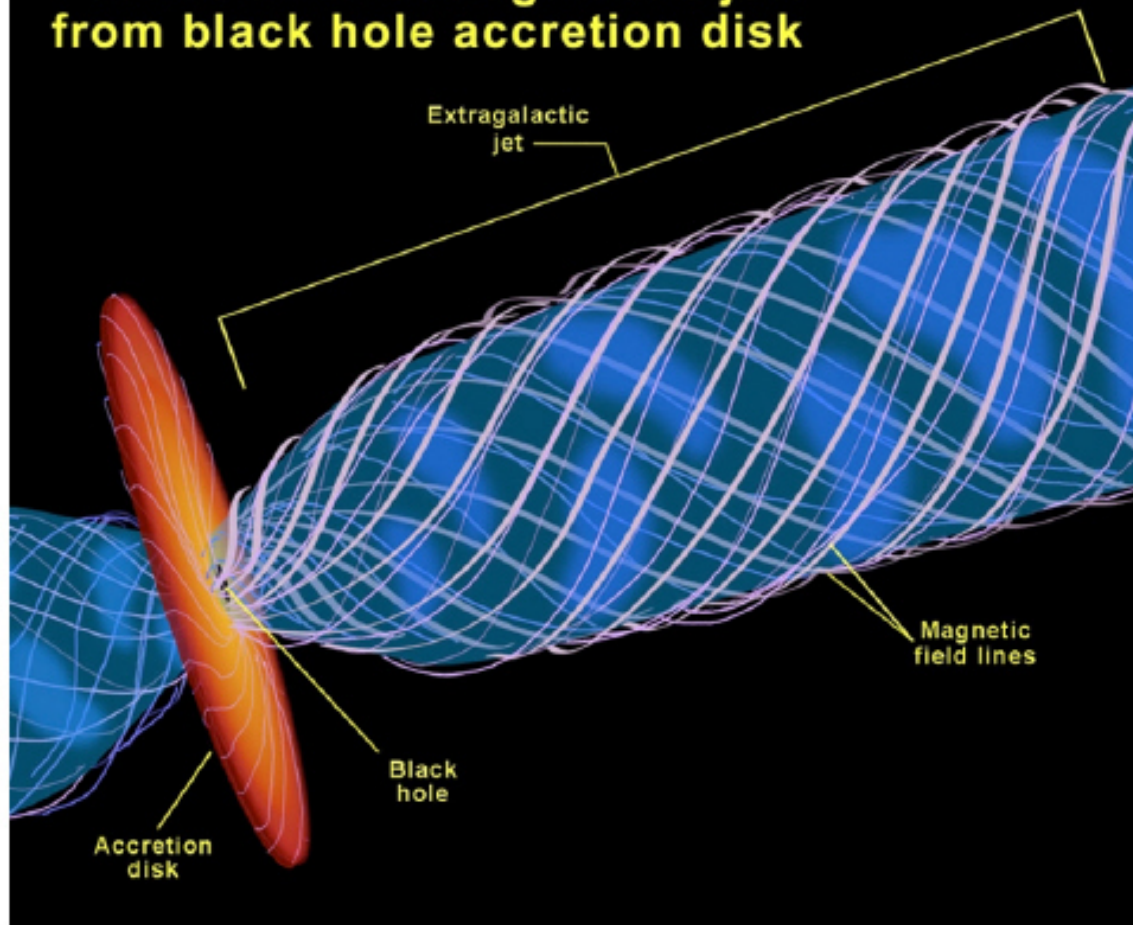
他の電波銀河



Fornax A

Cygnus A

Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



- 距離: 3.4 Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度 ~ 電波光度
~ 2×10^{41} W

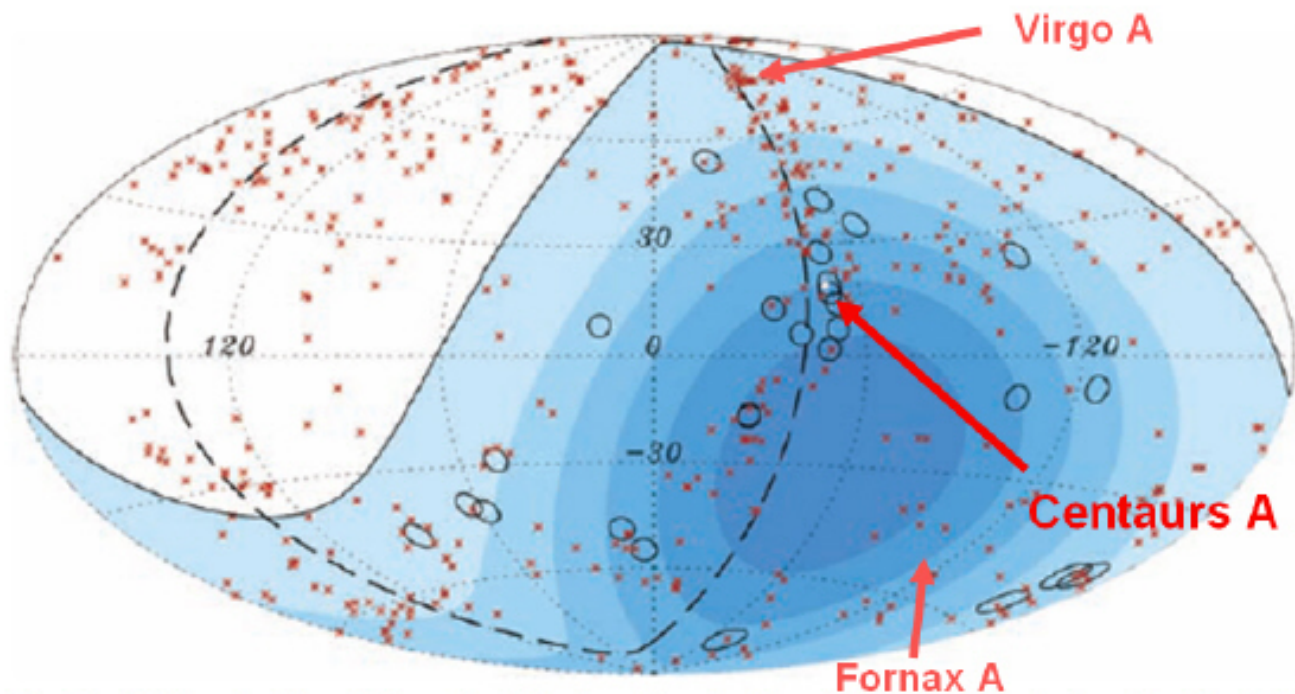
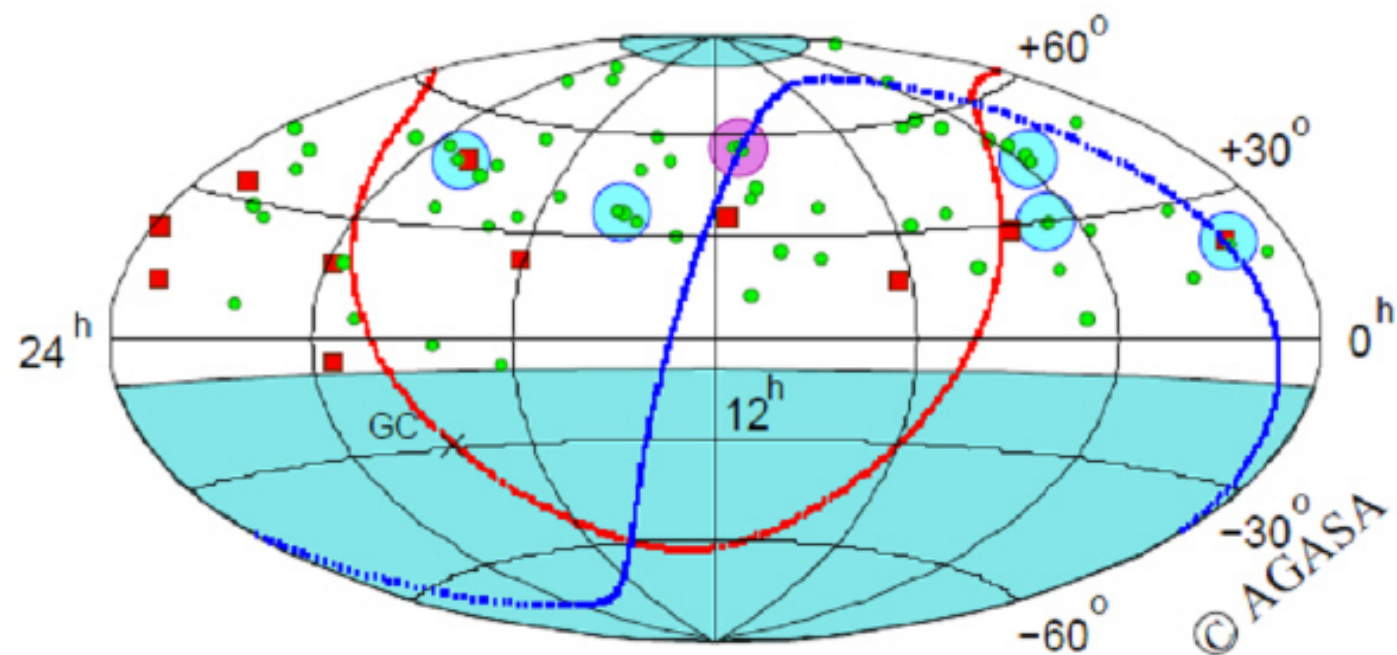
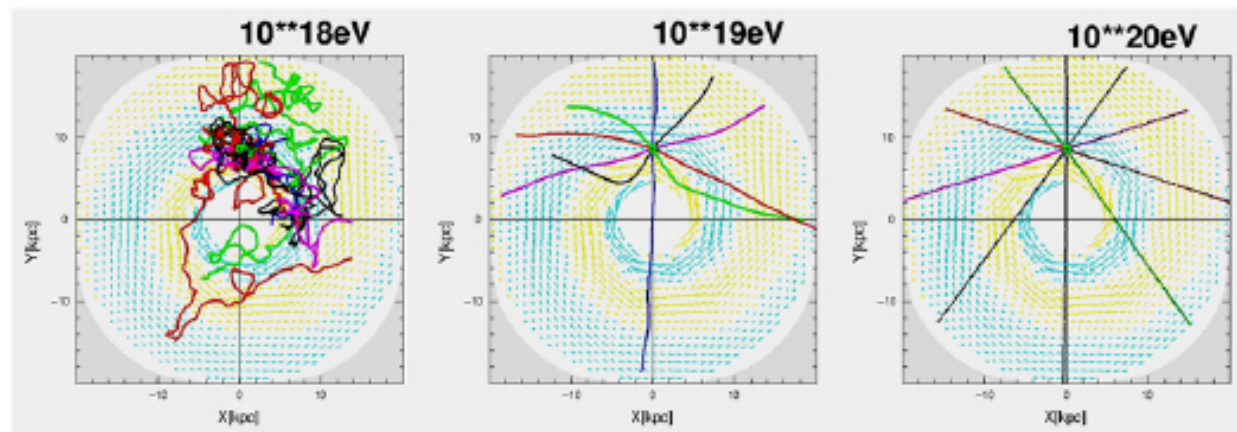


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

Arrival Directions (AGASA)



$E > 10^{20}$ eV 粒子は曲がらない



銀河内の伝播シミュレーション

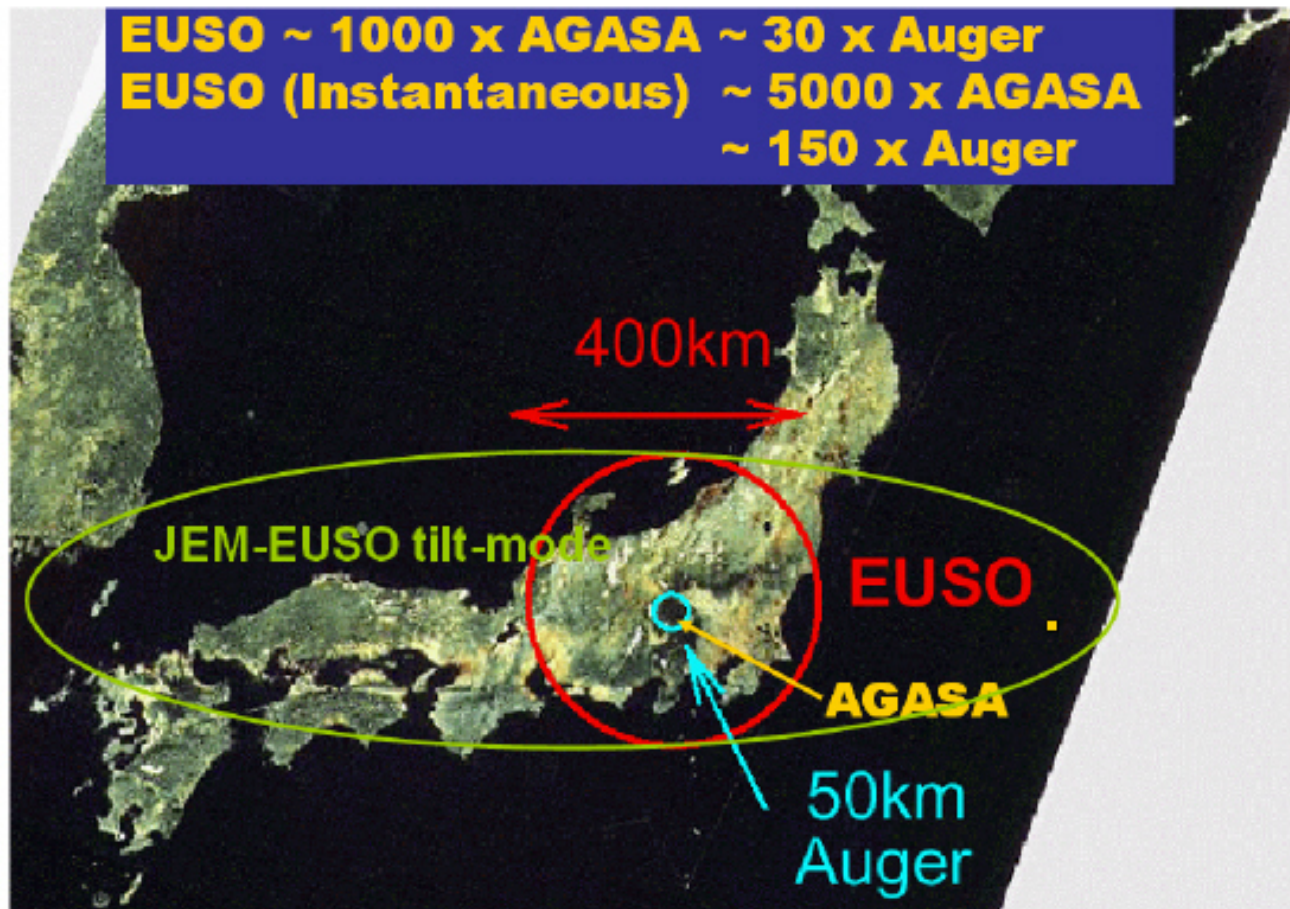
到来方向解析により起源天体を特定: 粒子天文学

科学目的

- 基本研究: 極限エネルギー—**粒子による新天文学**
 - 高統計到来方向解析による**起源天体**の同定
 - 個別天体からのエネルギースペクトル測定による**加速・放射機構**の検証
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 - 極限エネルギー—**宇宙ニュートリノ**の検出
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 - **相対論、量子重力**効果の検証
 - **大気圏**発光現象の研究

EUSOの巨大な視野

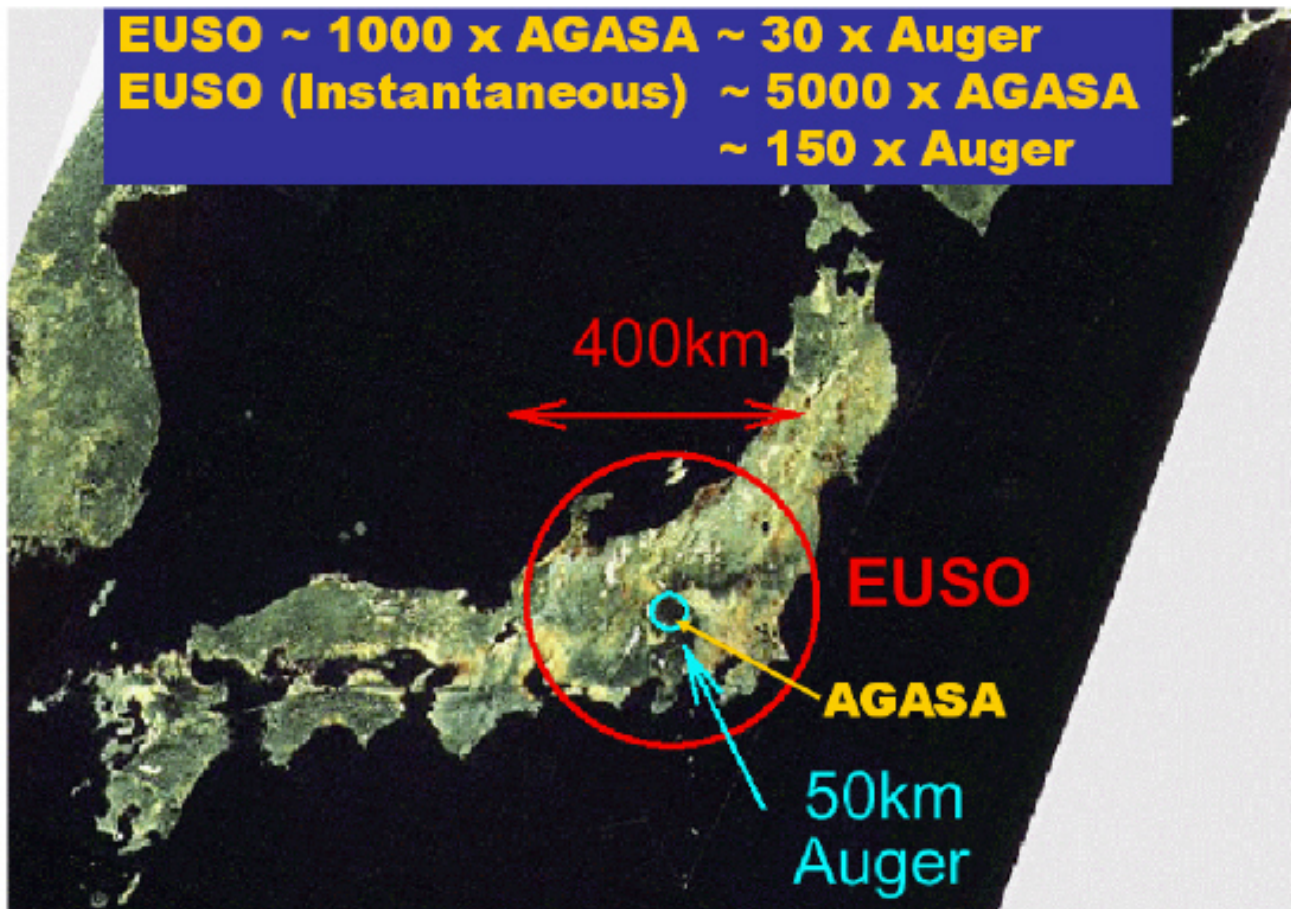
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger





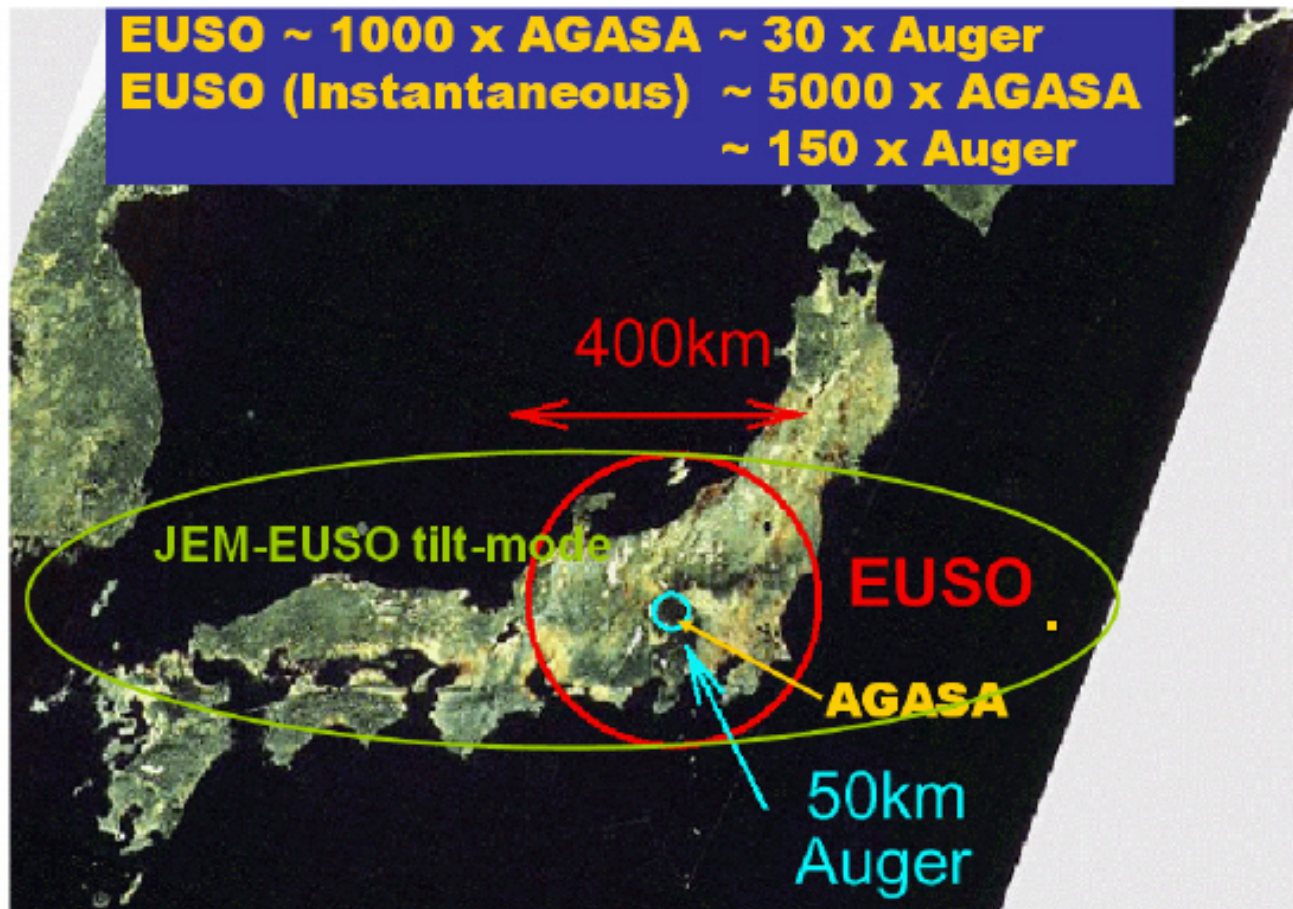
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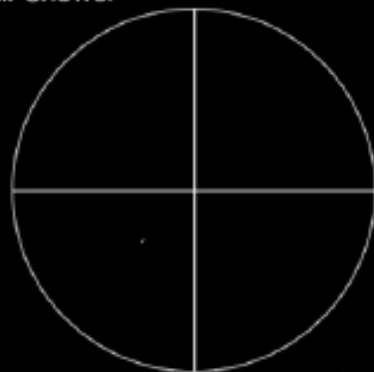
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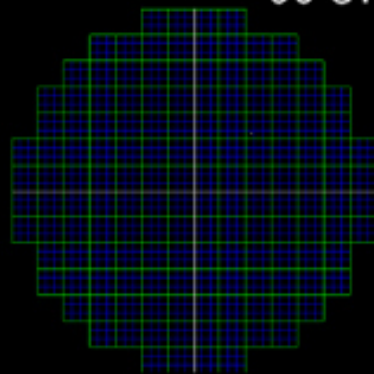


JEM-EUSOで見る空気シャワー

Air Shower

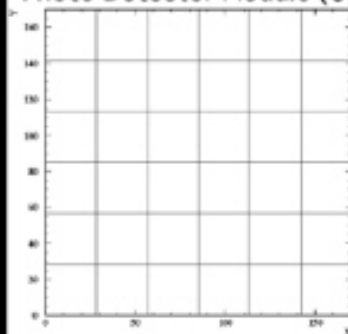


00 GTU

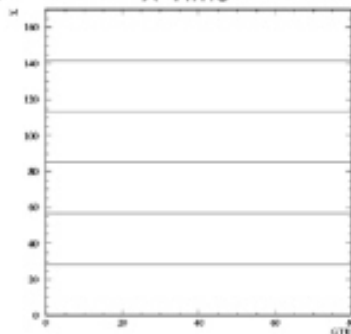


EUSO Focal Surface

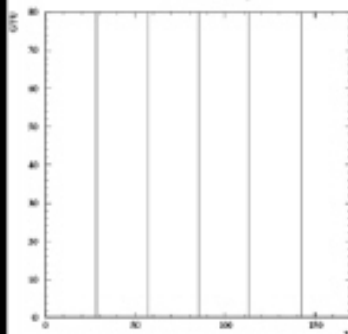
Photo Detector Module (3,3)



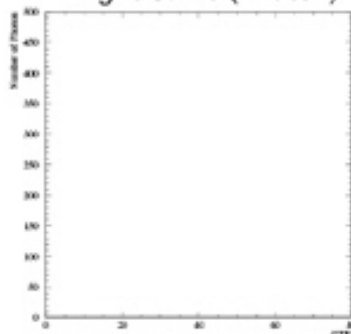
X-Time



Y-Time

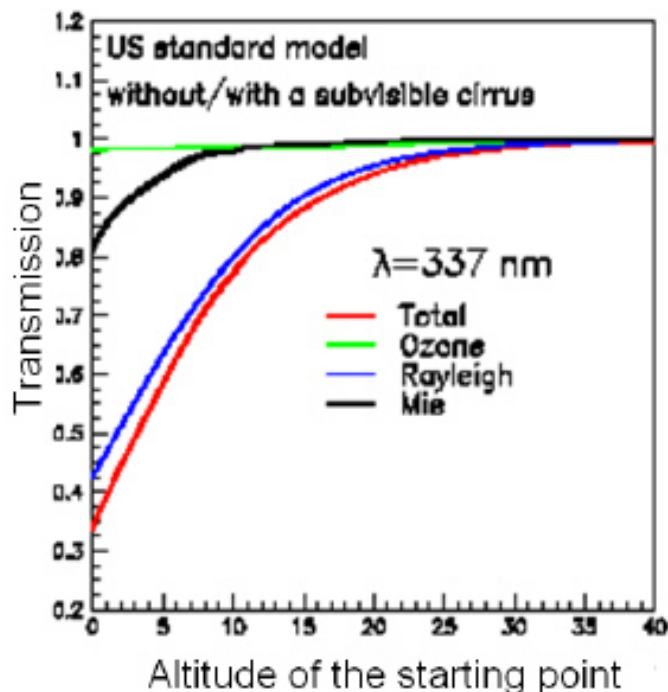


Light Curve (Photon)



宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)



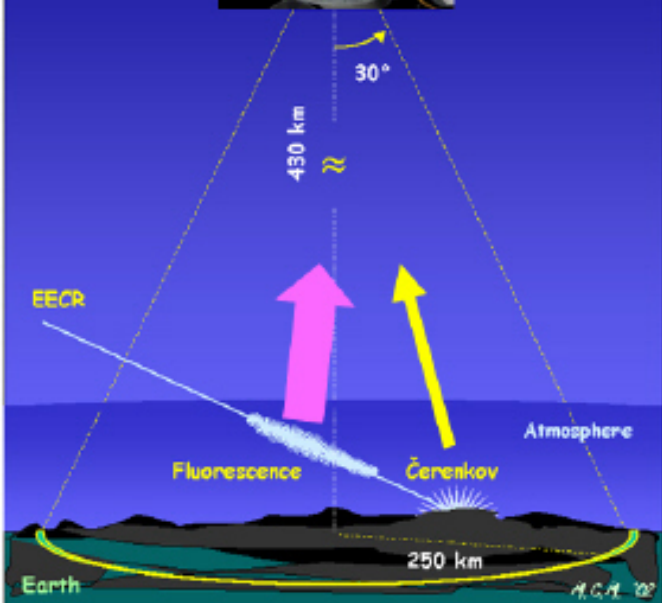
EUSOの観測方法



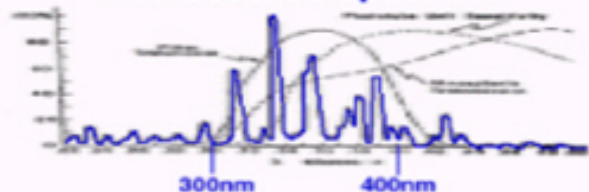
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

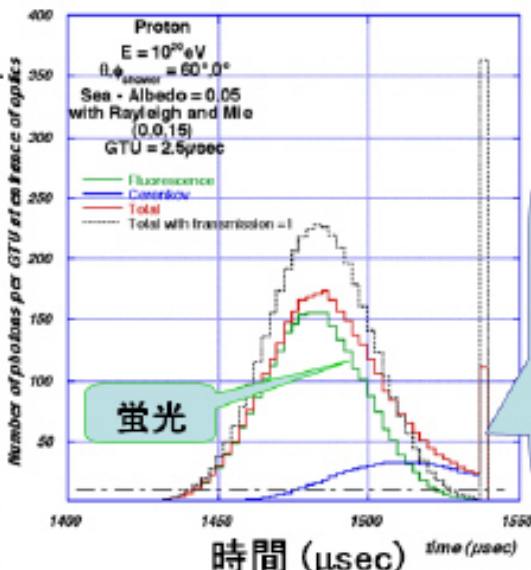
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



光学系入口径での光子数 (/2.5μsec)

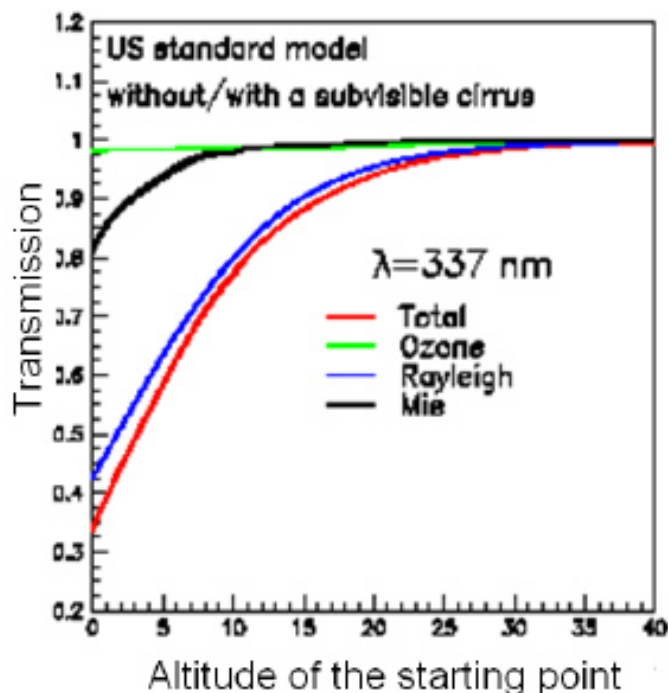


蛍光

チェレンコフ光

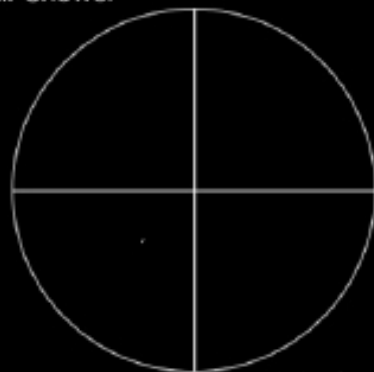
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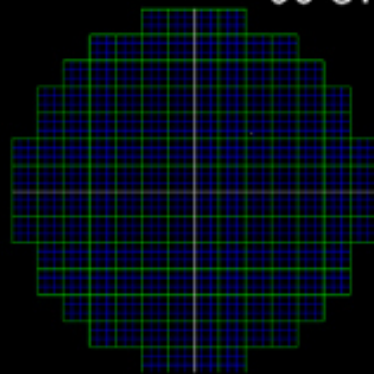


JEM-EUSOで見る空気シャワー

Air Shower

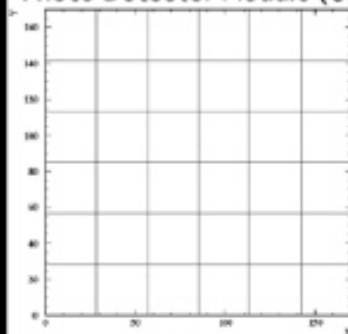


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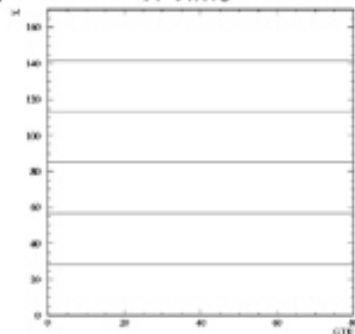


EUSO Focal Surface

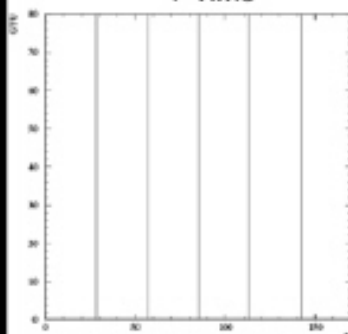
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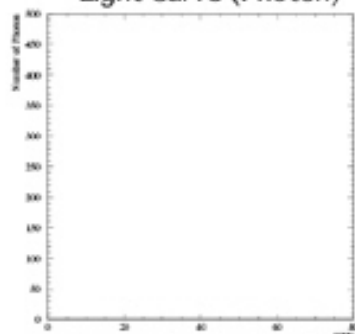
X-Time



Y-Time

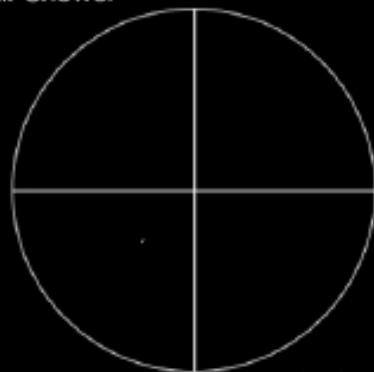


Light Curve (Photon)

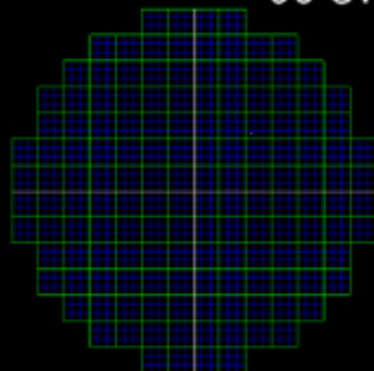


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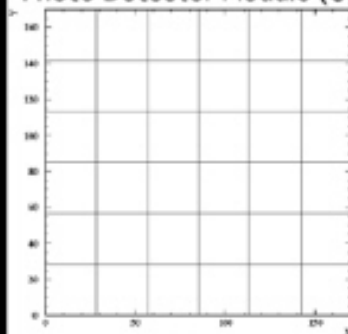


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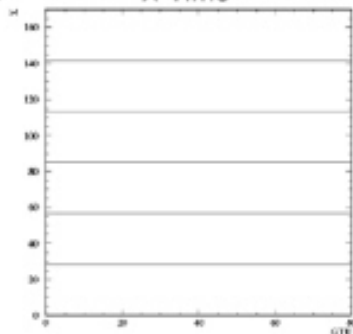


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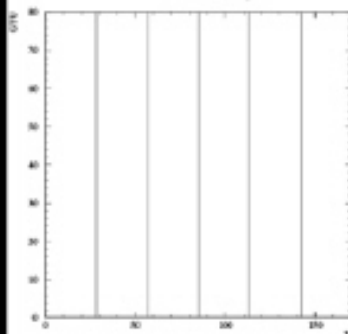
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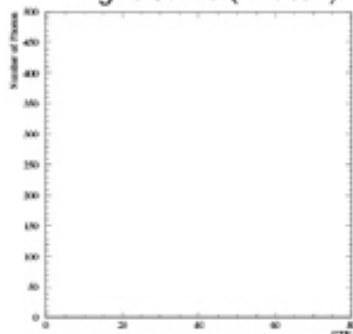
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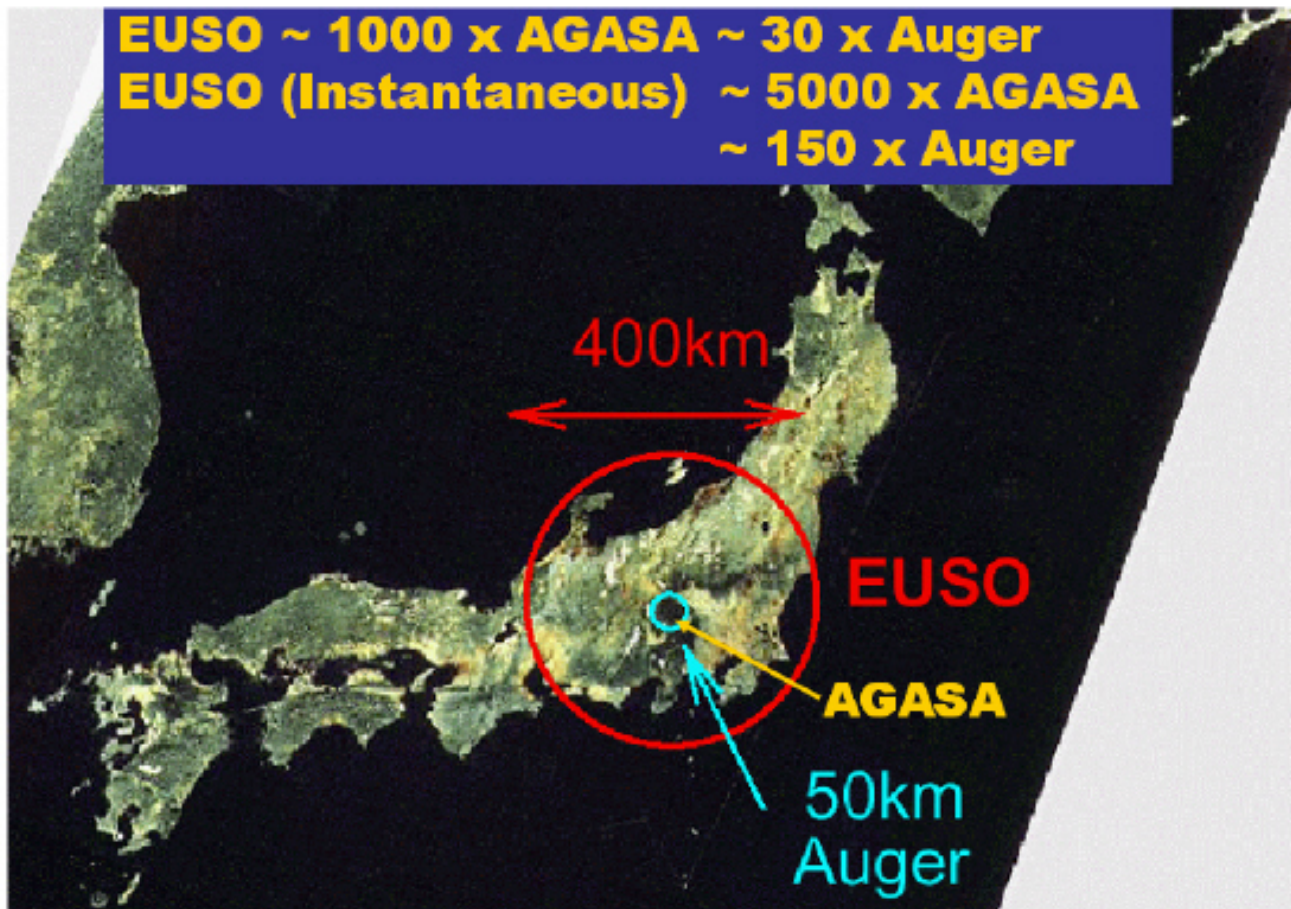






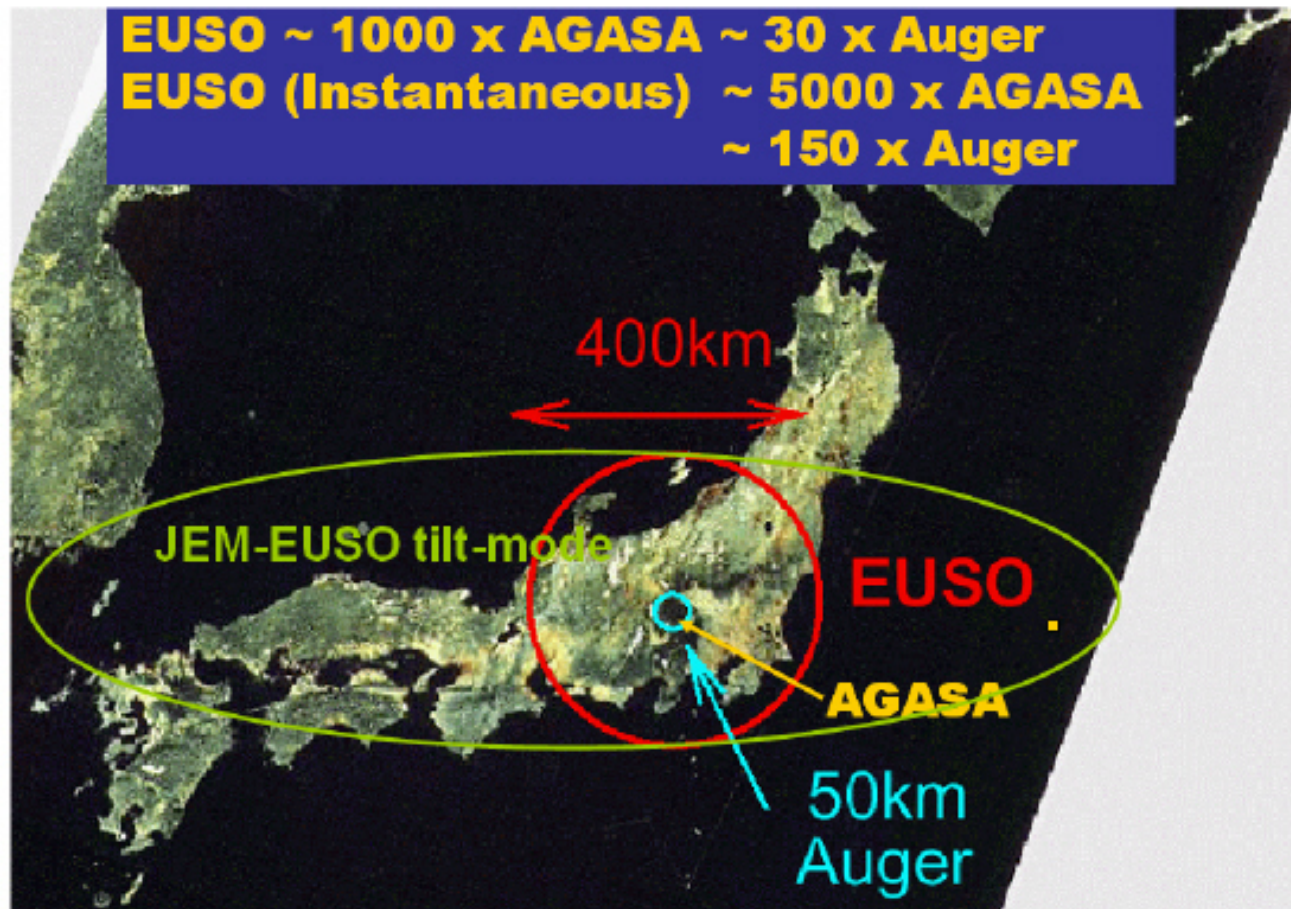
EUSOの巨大な視野

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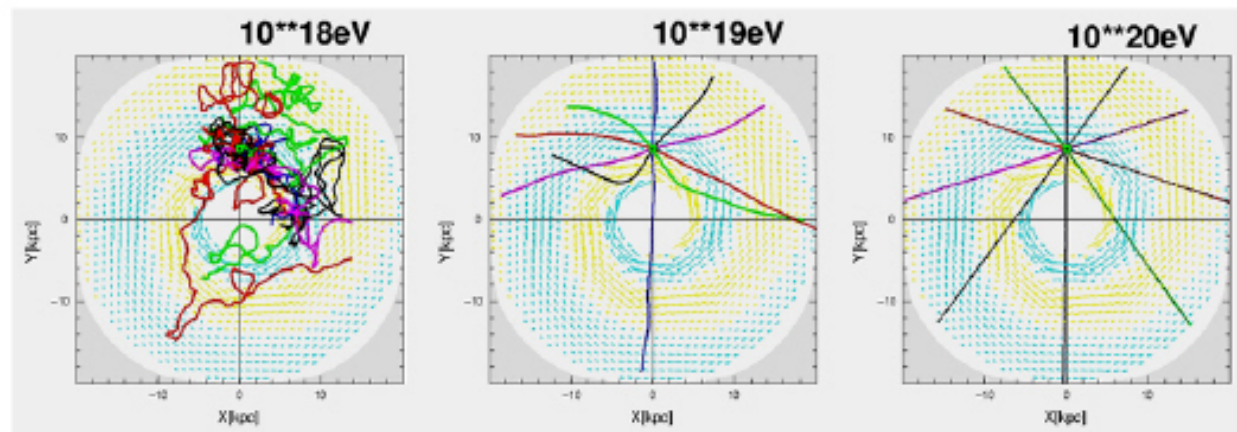
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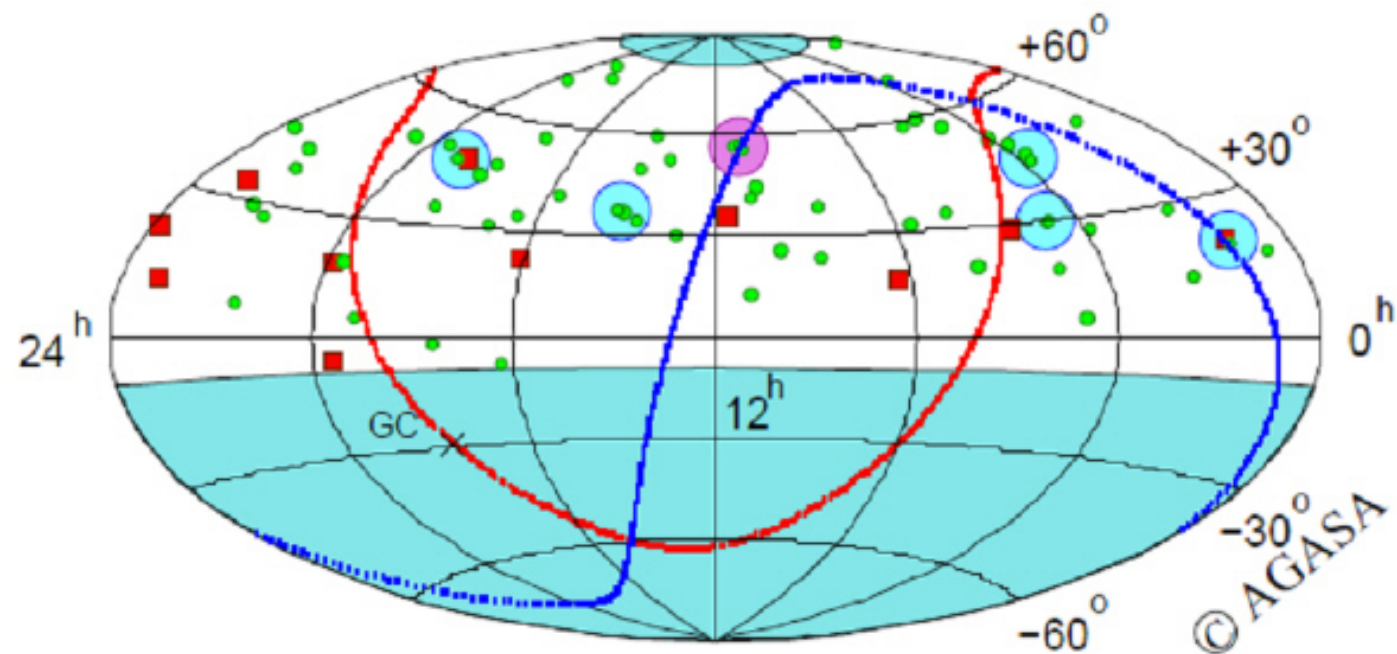
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銀河内の伝播シミュレーション

到来方向解析により起源天体を特定: 粒子天文学

Arrival Directions (AGASA)



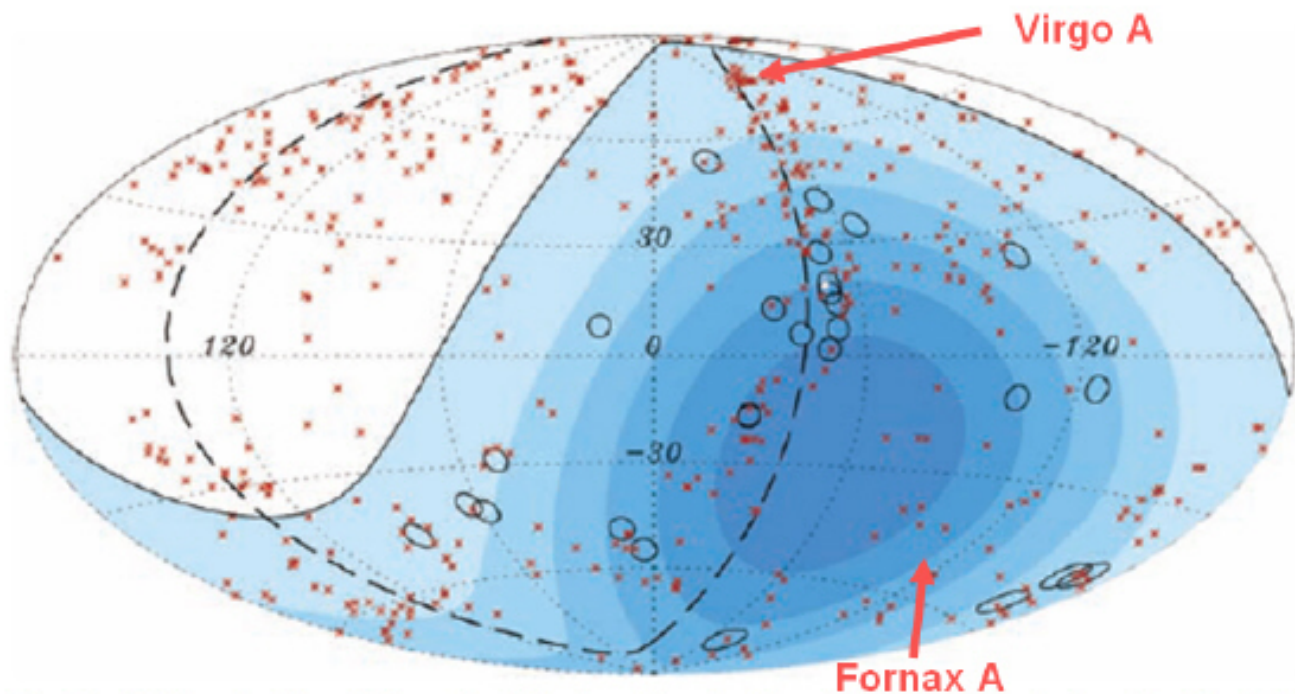


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

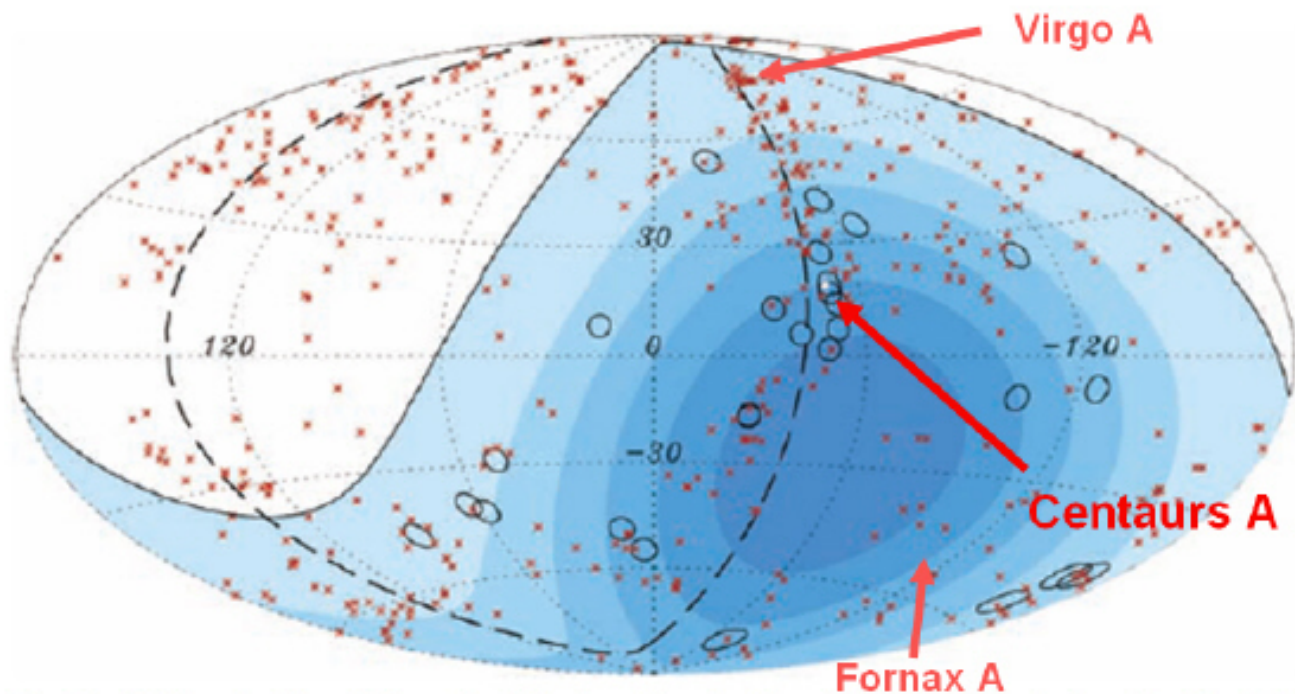


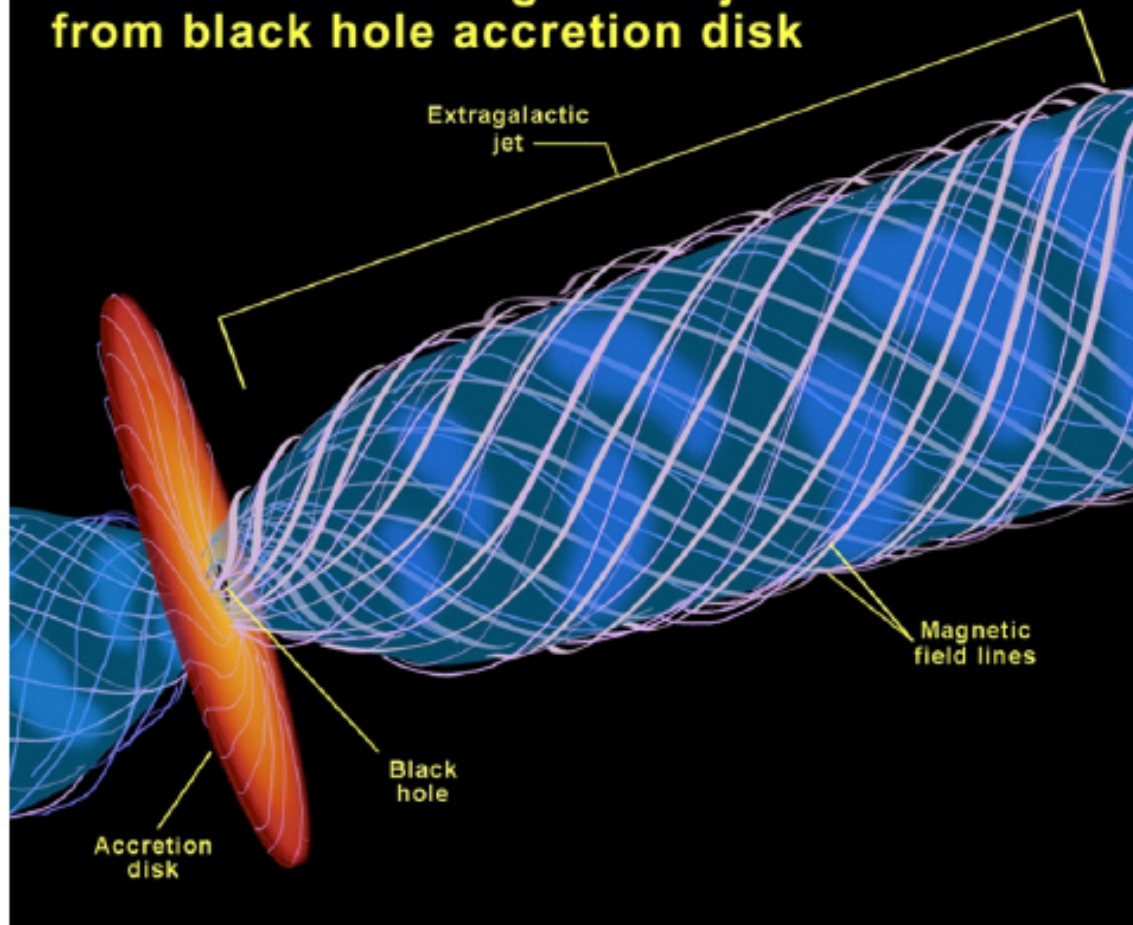
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ケンタウルス座 A

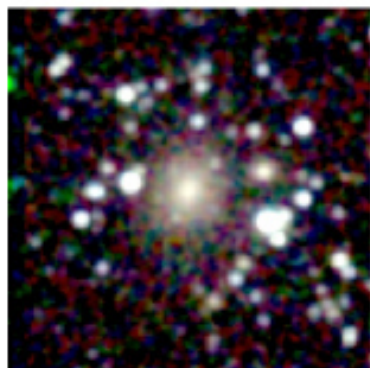
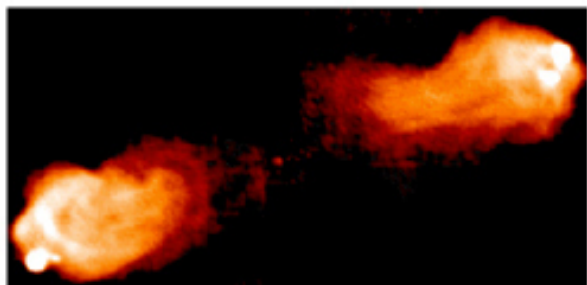


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Formation of extragalactic jets from black hole accretion disk



他の電波銀河



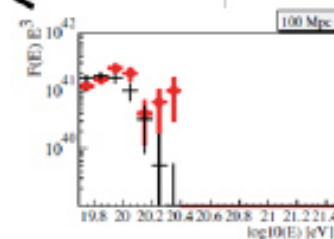
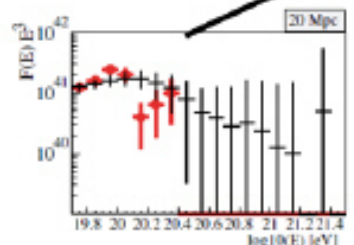
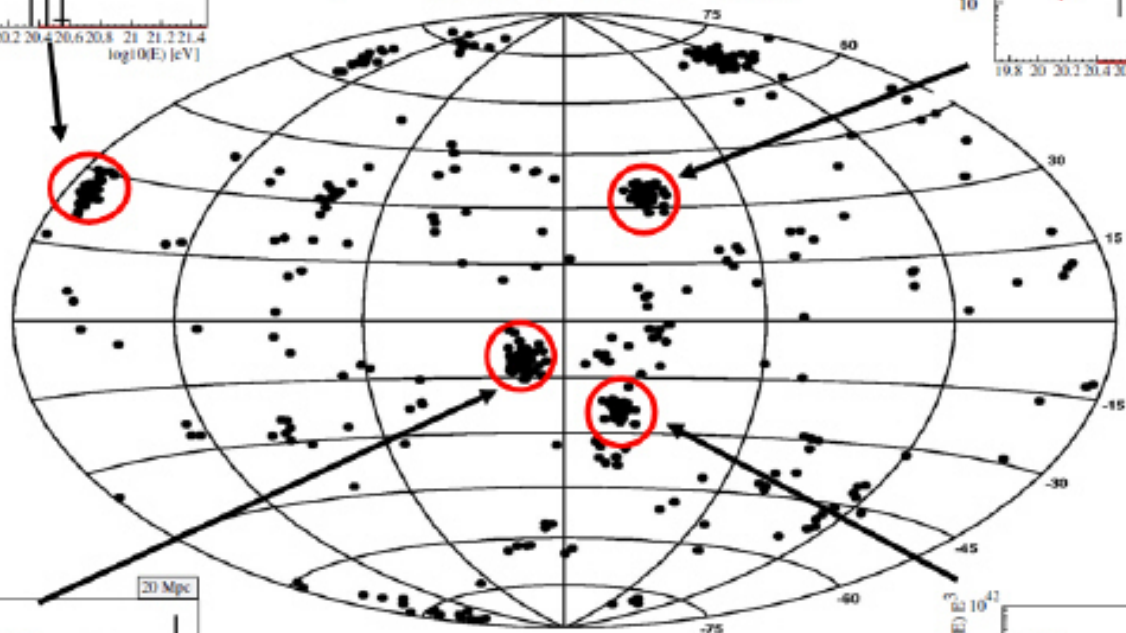
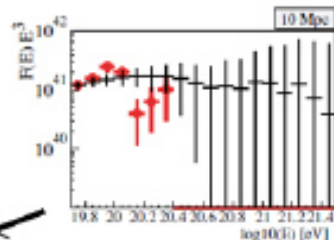
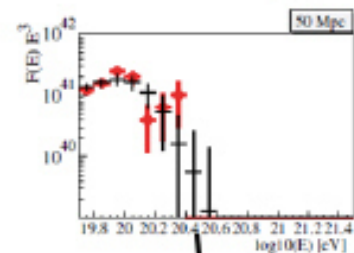
Fornax A

Cygnus A



極限粒子天文学

1,000事象の場合の予測



- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

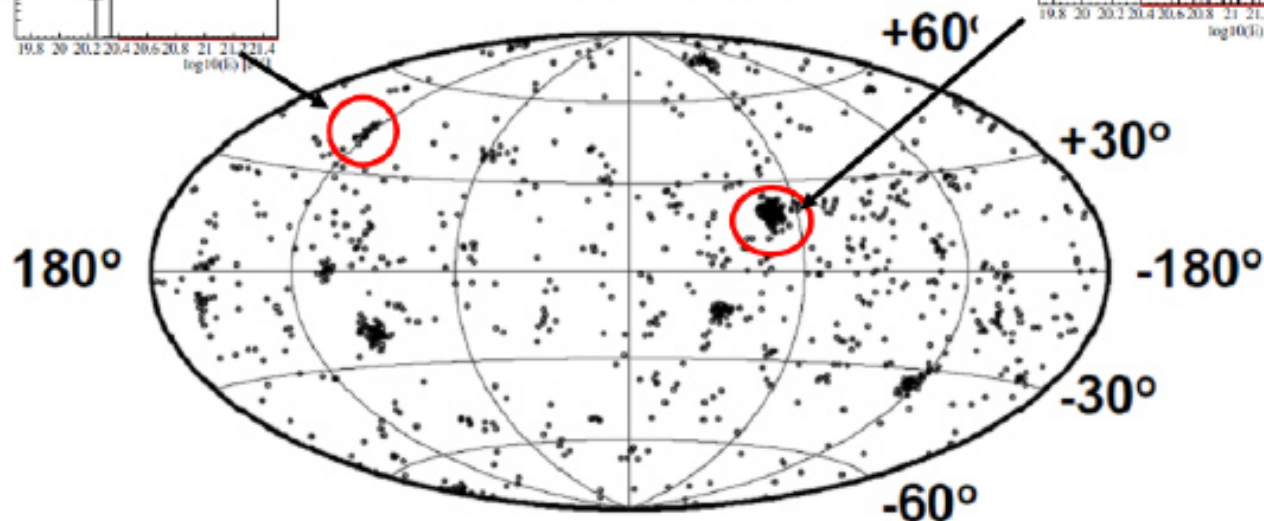
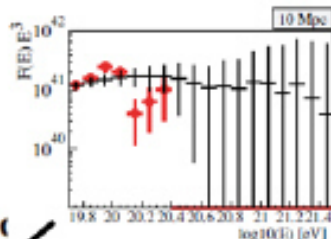
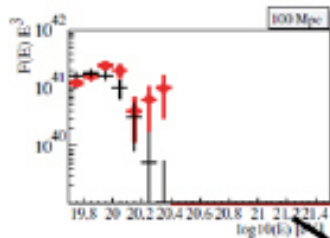
事例数: 5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

極限粒子天文学

1,000事象の場合の予測

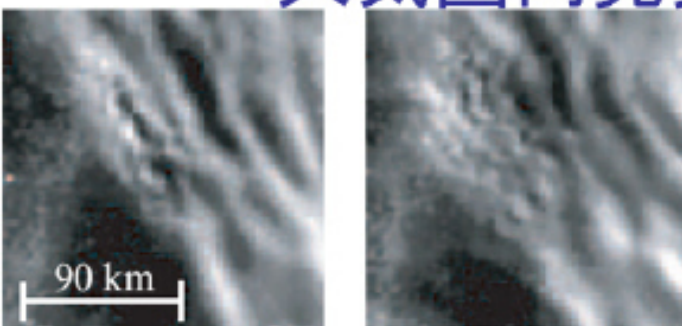
粒子光度 \propto X線光度 (AGN)



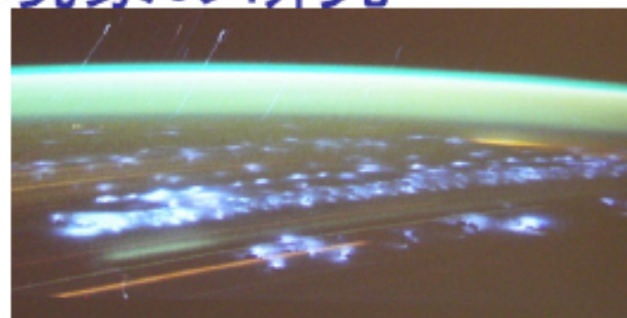
- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

Takami 2008

探求的試験研究3: 大気圏内発光現象の研究



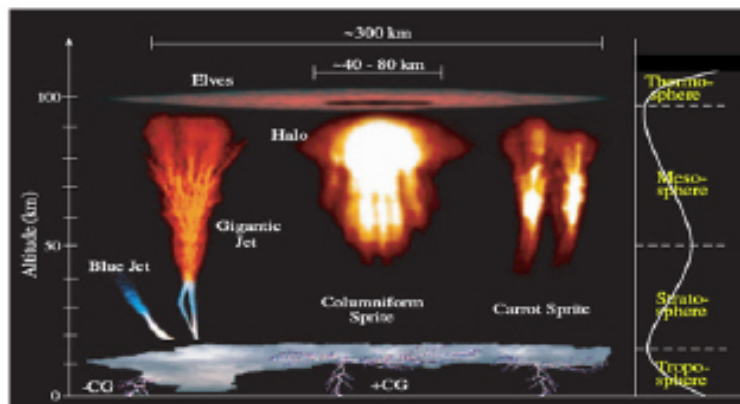
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



ハイビジョンカメラによる
2001年のしし座流星群

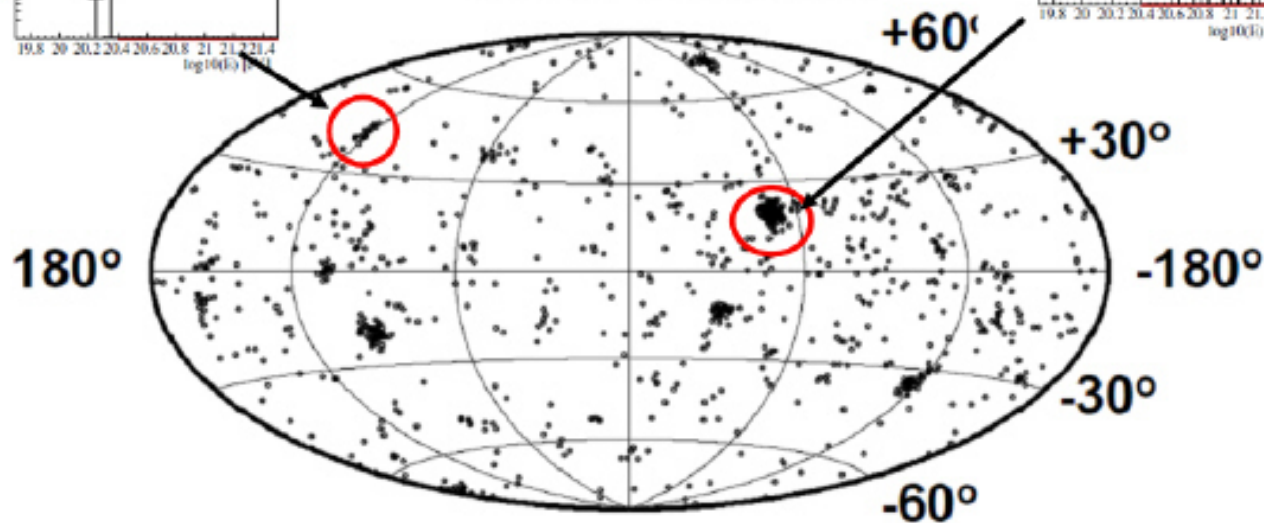
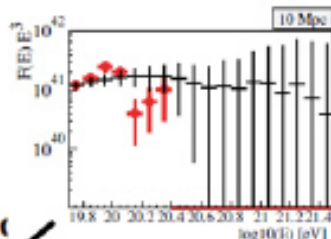
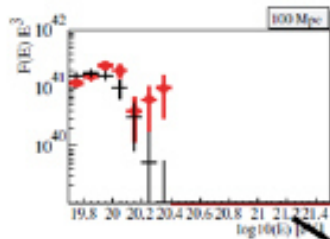


雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

極限粒子天文学

1,000事象の場合の予測

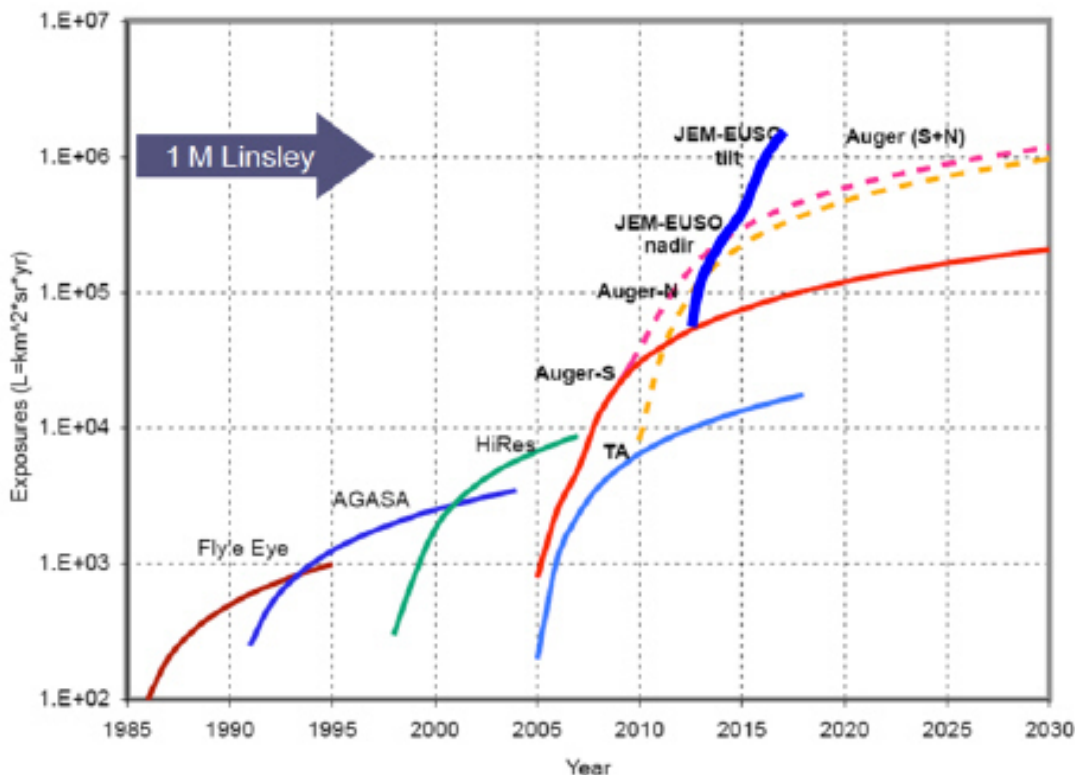
粒子光度 \propto X線光度 (AGN)



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- 数十のクラスターの発見が期待される
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Takami 2008

有効露出の増加期待値

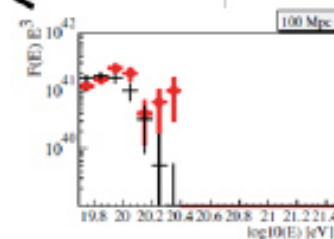
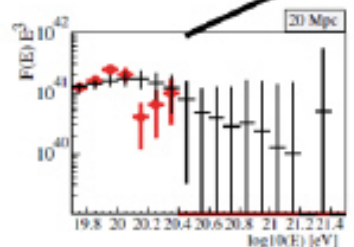
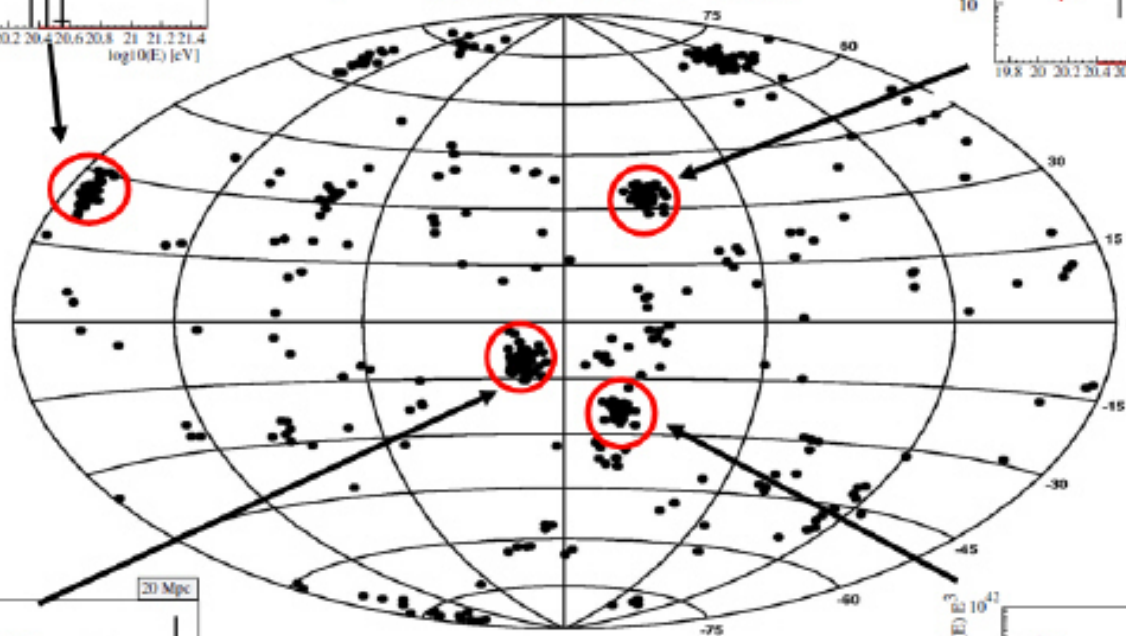
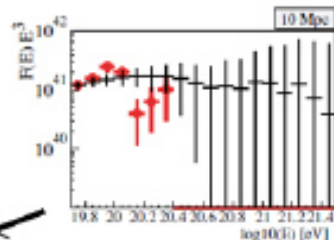
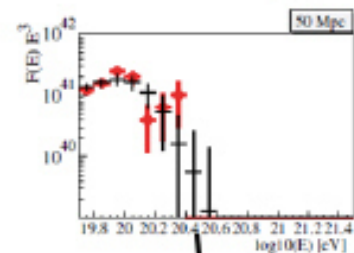


事例数: 5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
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アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
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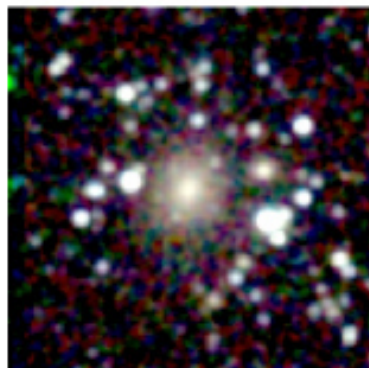
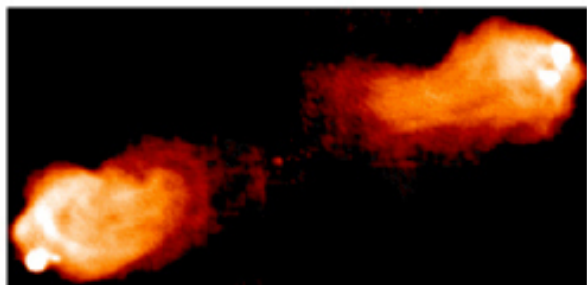
極限粒子天文学

1,000事象の場合の予測



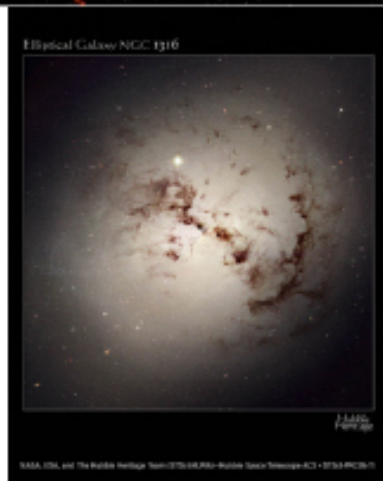
- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

他の電波銀河

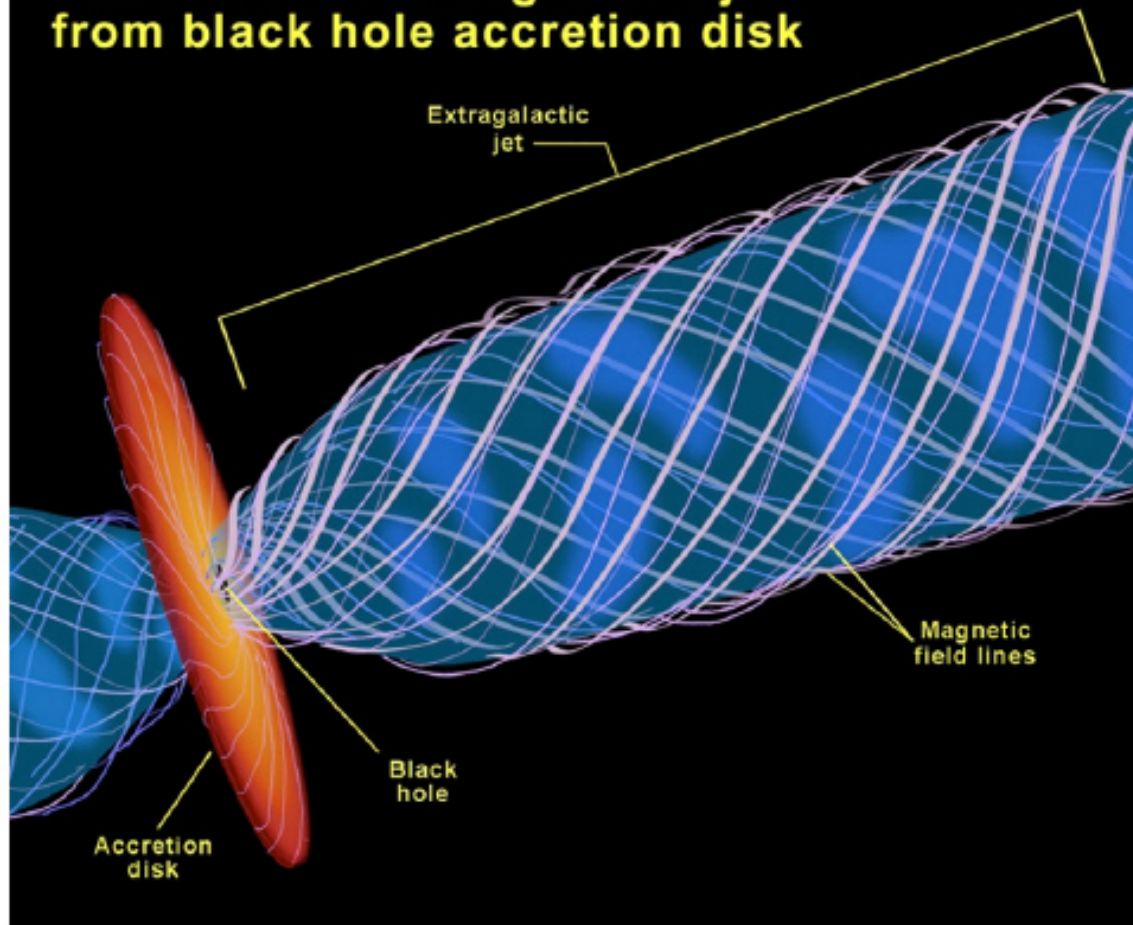


Fornax A

Cygnus A



Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



- 距離: 3.4Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度～電波光度
～ 2×10^{41} W

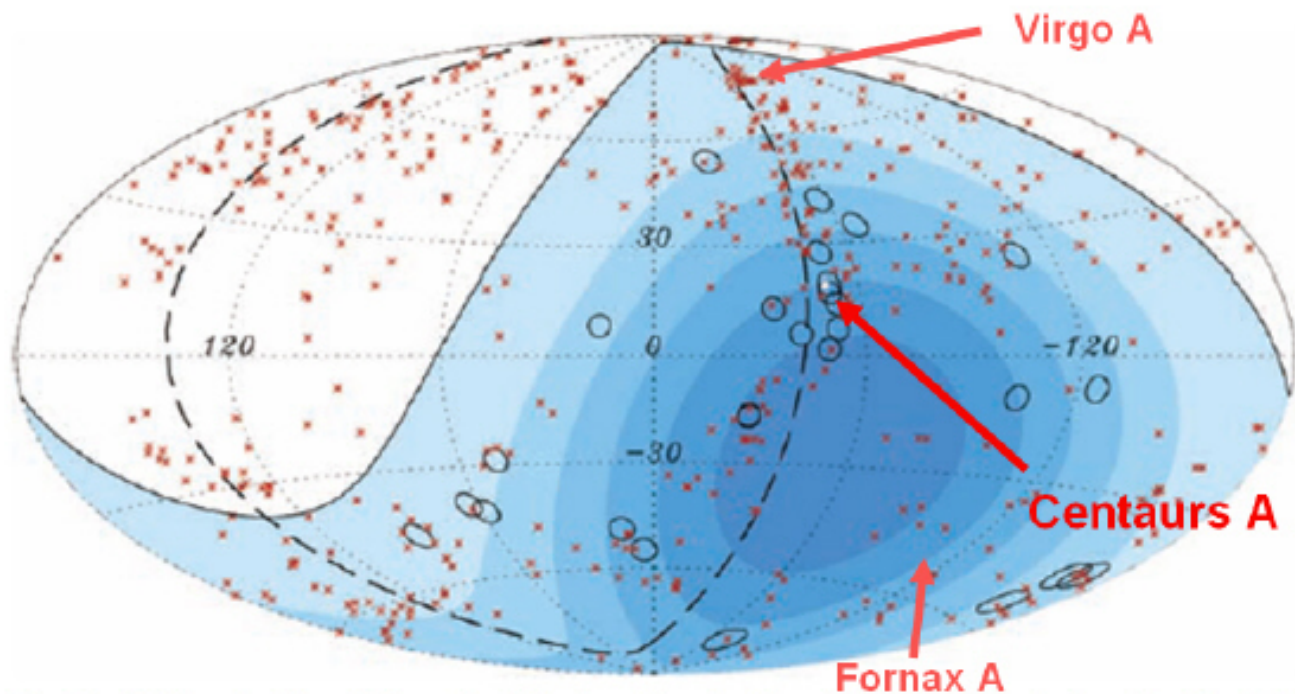
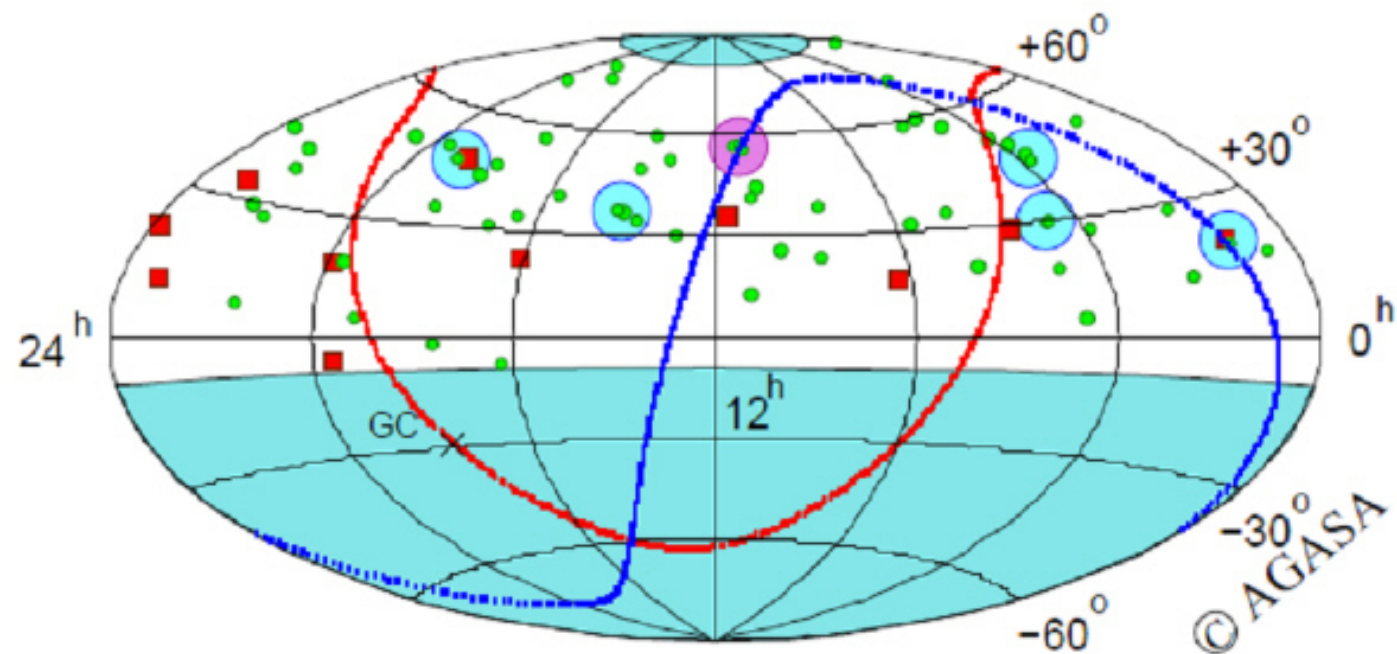
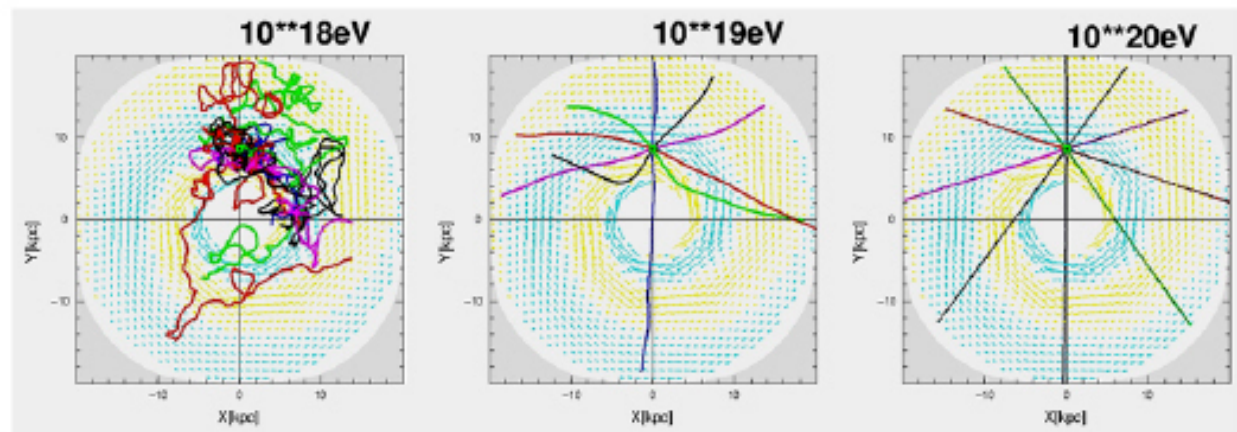


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

Arrival Directions (AGASA)



$E > 10^{20}$ eV 粒子は曲がらない



銀河内の伝播シミュレーション

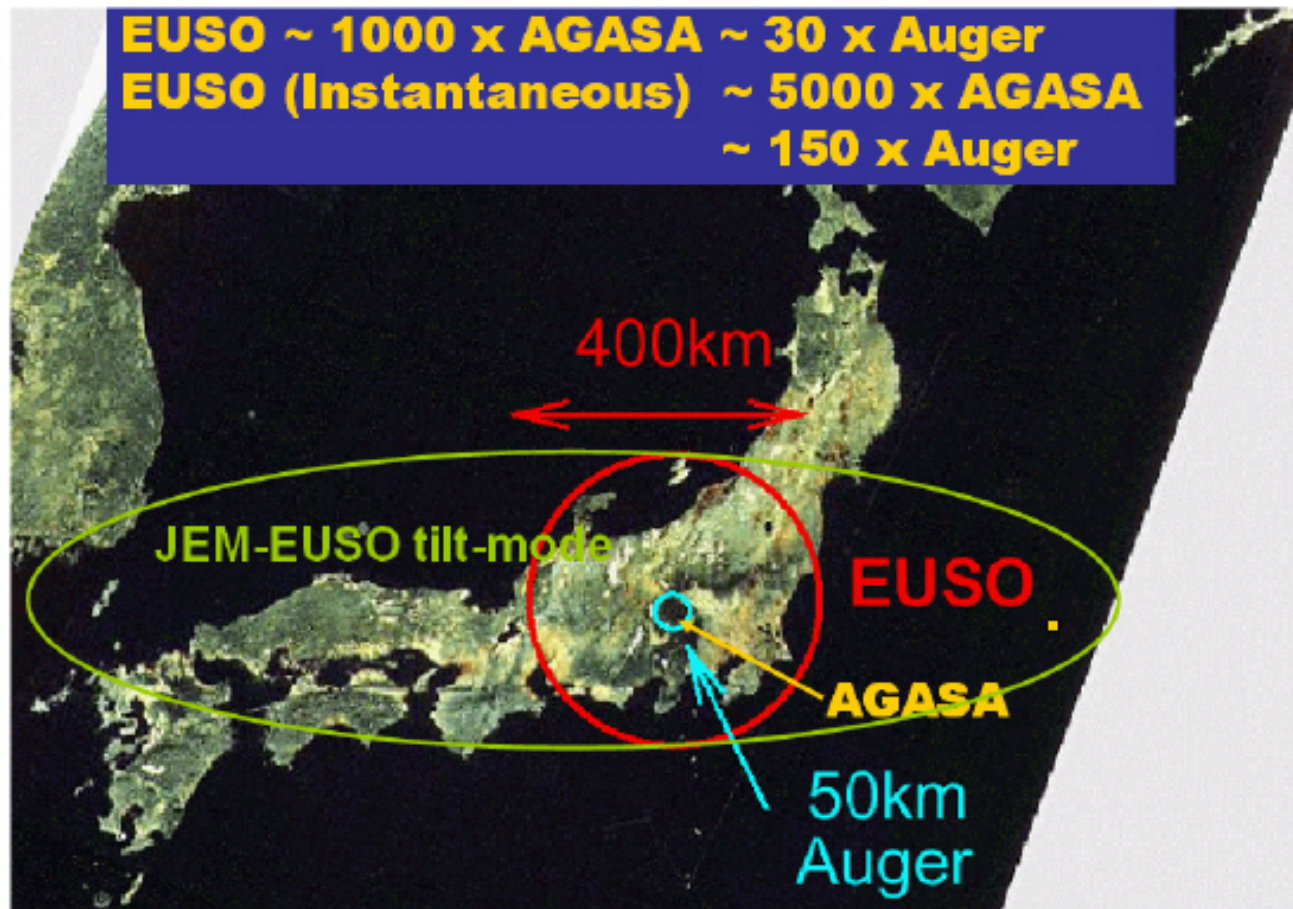
到来方向解析により起源天体を特定: 粒子天文学

科学目的

- 基本研究: 極限エネルギー—**粒子による新天文学**
 - 高統計到来方向解析による**起源天体**の同定
 - 個別天体からのエネルギースペクトル測定による**加速・放射機構**の検証
- 探求的試験研究
 - 極限エネルギー—**宇宙ガンマ線**の測定
 - 極限エネルギー—**宇宙ニュートリノ**の検出
 - **銀河磁場**の構造と強度の推定
 - **相対論、量子重力**効果の検証
 - **大気圏**発光現象の研究

EUSOの巨大な視野

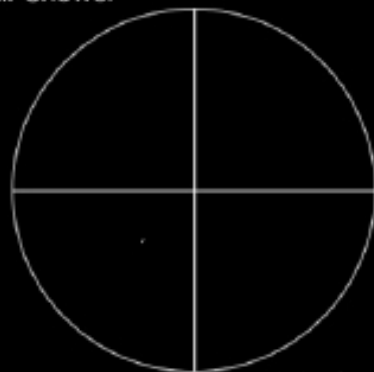
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



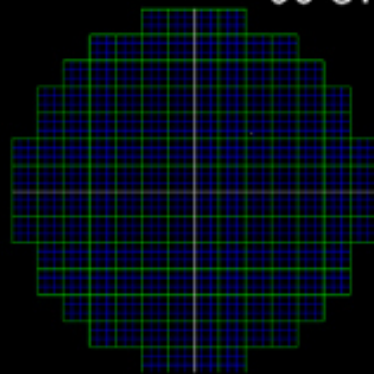


JEM-EUSOで見る空気シャワー

Air Shower

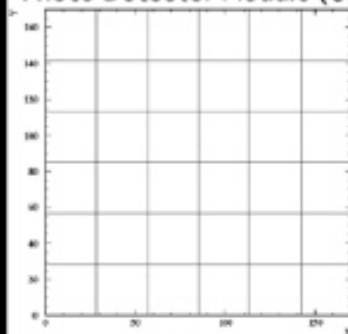


00 GTU

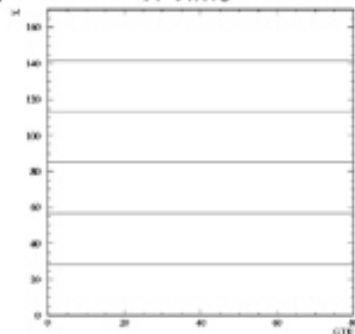


EUSO Focal Surface

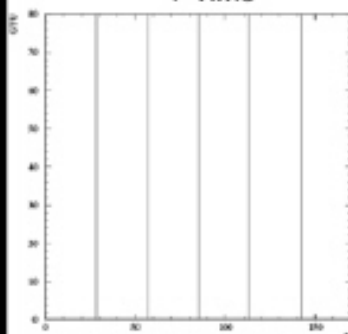
Photo Detector Module (3,3)



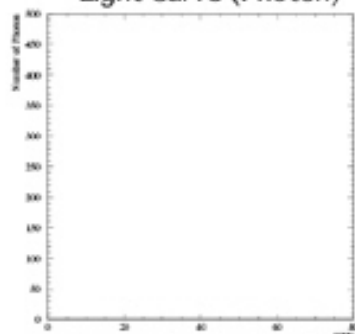
X-Time



Y-Time

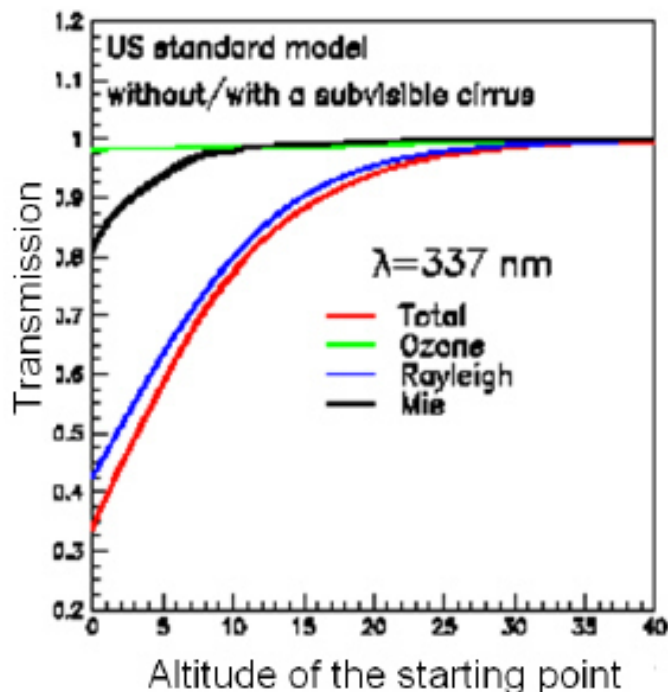


Light Curve (Photon)



宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)



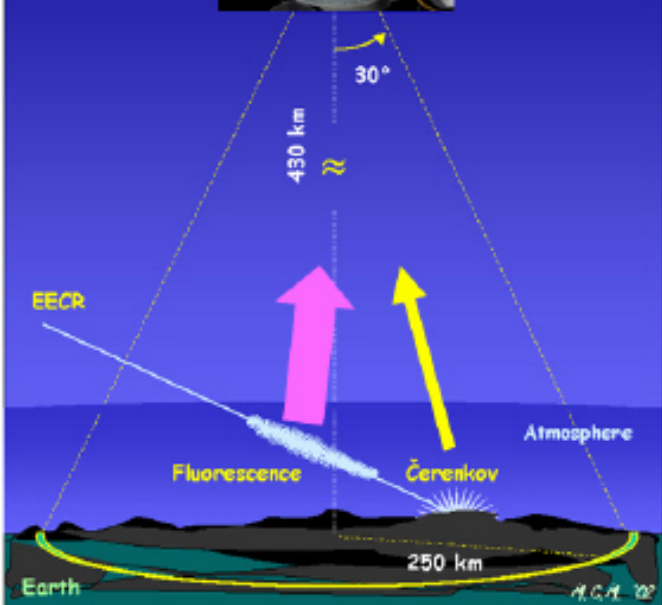
EUSOの観測方法



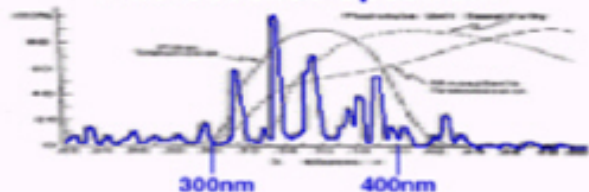
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

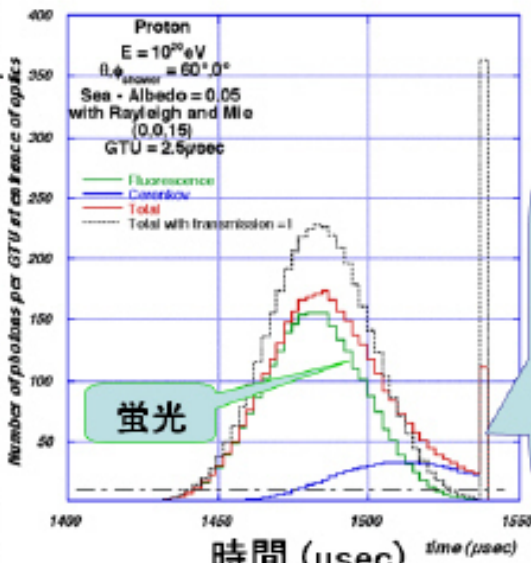
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



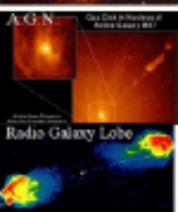
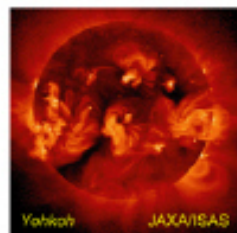
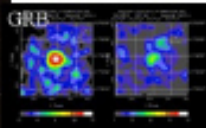
光学系入口径での光子数 (/2.5μsec)



チェレンコフ光

蛍光

地を見て天を知る天文台=地文台 JEM-EUSO



極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

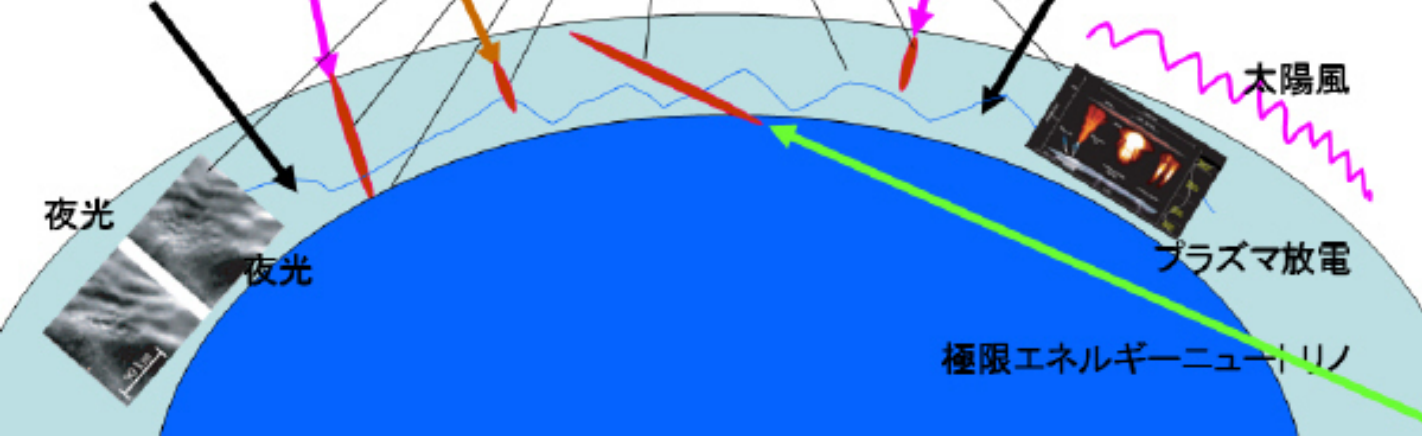
太陽風

夜光

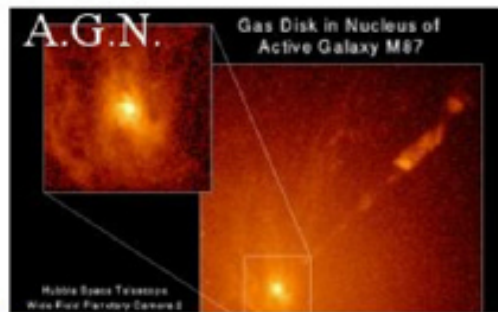
夜光

プラズマ放電

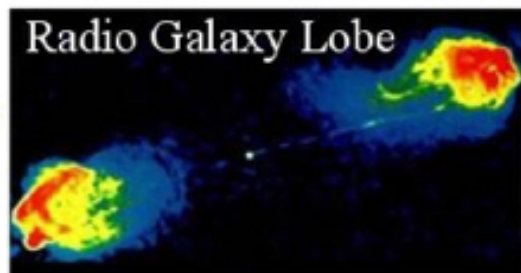
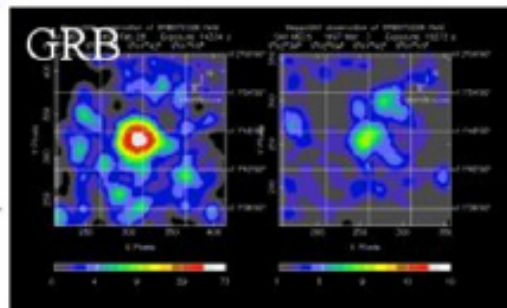
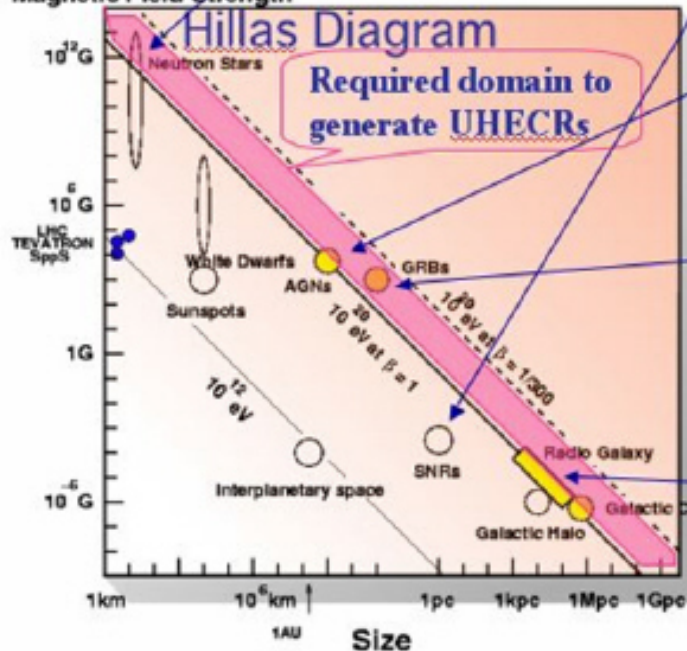
極限エネルギーニュートリノ



ヒラス 理論的加速限界 $< 10^{20}$ eV

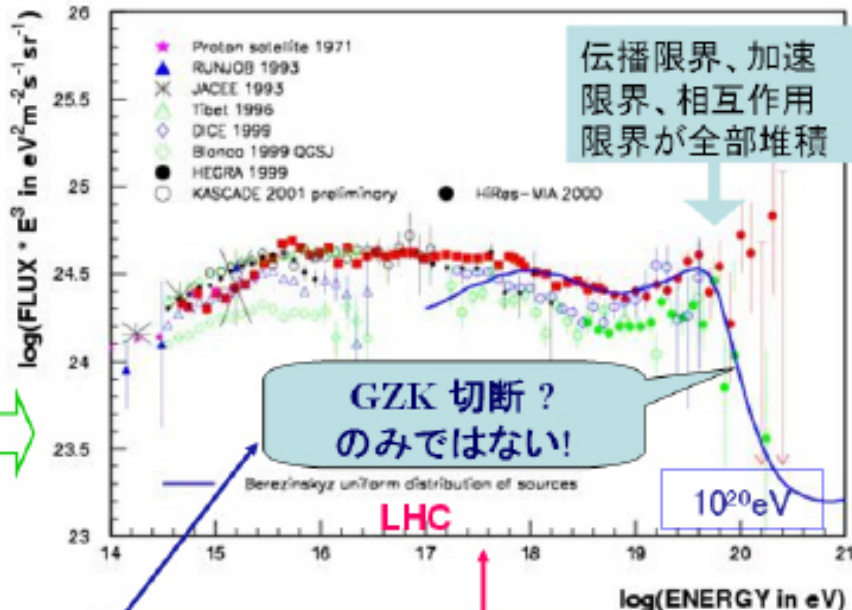
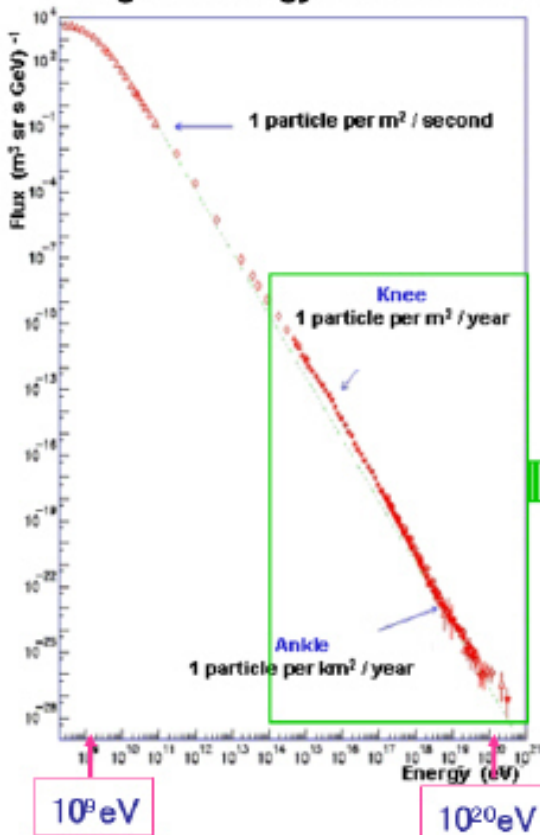


Magnetic Field Strength



Status and the challenges of the highest-energy Universe by observing cosmic rays

- LHC explores HIGGS, SUSY DM $< 7 \text{ TeV}/c^2 (\leq 10^{17} \text{ eV})$ from Dec 2007
- Highest energy CR: Unknown for origin, acceleration; physics unknown at $> 300 \text{ TeV}/c^2$



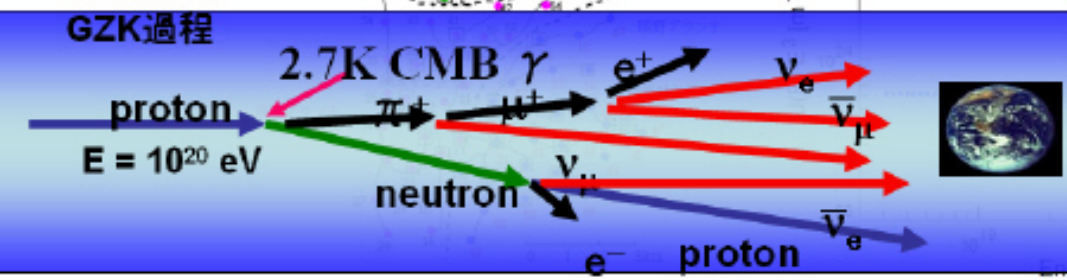
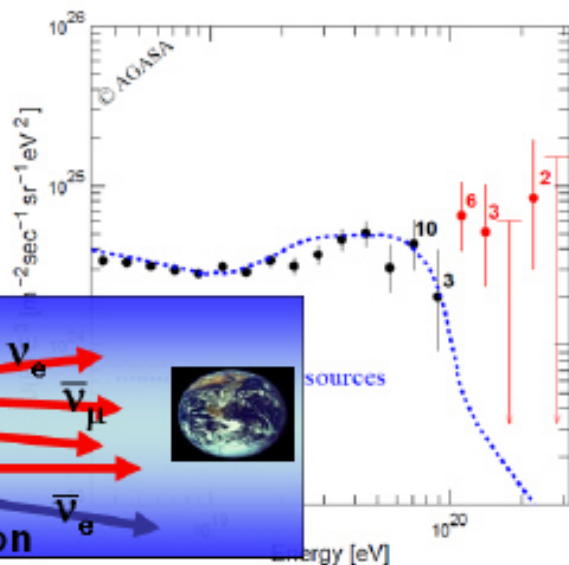
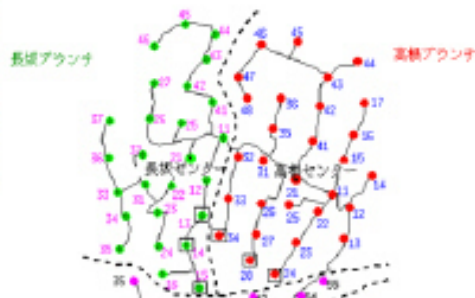
$$p + \gamma_{2.7\text{K}} \rightarrow e^+ e^- + p \text{ above LHC } 5 \cdot 10^{17} \text{ eV}$$

$$p + \gamma_{2.7\text{K}} \rightarrow \Delta^+ \rightarrow n + \pi^+, p + \pi^0$$



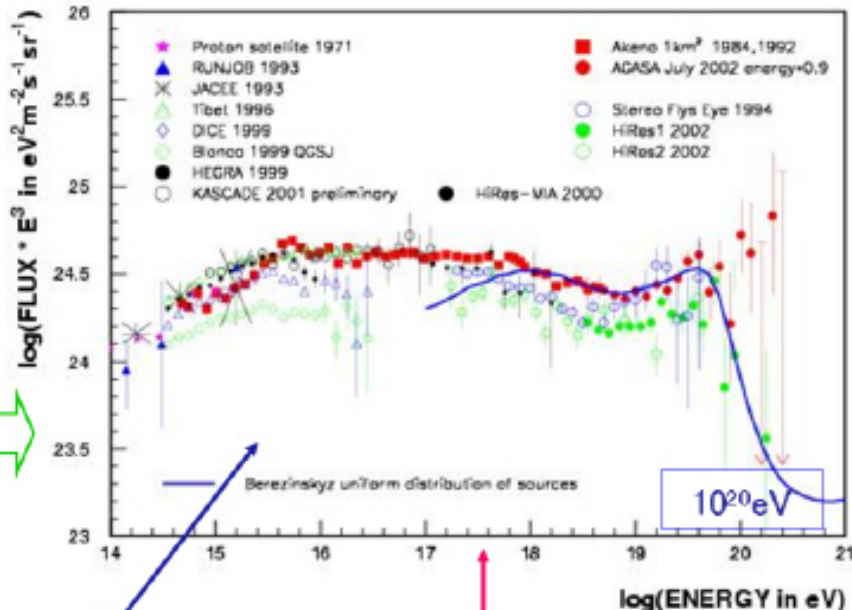
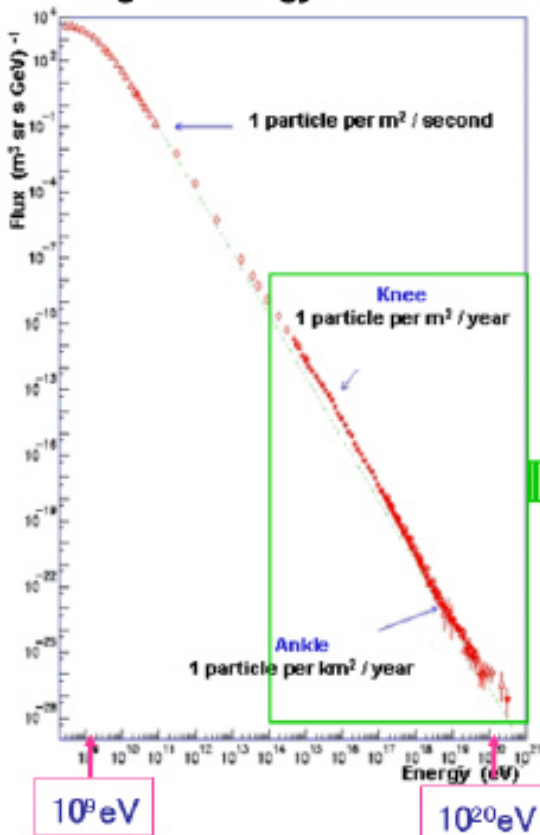
AGASA

- 地域全体を検出器とした。
- 全体で約100km²
- 13年で11個の超10²⁰eV事象



Status and the challenges of the highest-energy Universe by observing cosmic rays

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$$p + \gamma_{2.7\text{K}} \rightarrow e^+ e^- + p \text{ above LHC } 5 \cdot 10^{17} \text{ eV}$$

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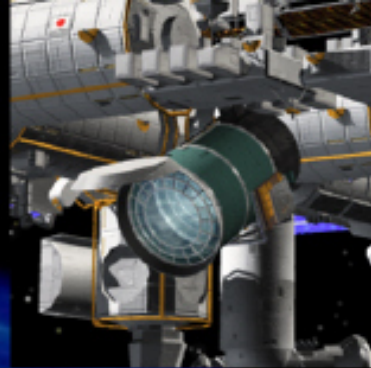
JEM-EUSO Collaboration

10 countries, 56 institutions, 149 members



- ▶ **Japan** : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin Univ.*), N. Inoue (*Saitama Univ.*), Y. Uchihori (*NIRS*), K. Nomoto (*Univ. of Tokyo*), Y. Takahashi (*Tohoku Univ.*), M. Takeda (*ICRR, Univ. Tokyo*), Y. Arai, Y. Kurihara, H.M. Shimizu, J. Fujimoto (*KEK*), S. Yoshida, K. Mase (*Chiba Univ.*), K. Asano, S. Inoue, Y. Mizumoto, J. Watanabe, T. Kajino (*NAOJ*), H. Ikeda, M. Suzuki, T. Yano (*ISAS, JAXA*), T. Murakami, D. Yonetoku (*Kenazawa Univ.*), T. Sugiyama (*Nagoya*), Y. Ito (*STEL, Nagoya Univ.*), S. Nagataki (*YITP, Kyoto Univ.*), A. Saito (*Kyoto Univ.*), S. Abe, M. Nagata (*Kobe Univ.*), T. Tajima (*KPSI, JAEA*), M. Chikawa (*Kinki Univ.*), and M. Tajima (*Hiroshima Univ.*)
- ▶ **USA** : J. H. Adams Jr., S. Mitchell, M.J. Christl, J. Watts Jr., A. English, R. Young (*NASA/MSFC*), Y. Takahashi, D. Gregory, M. Bonamente, P. Readon, V. Connaughton, K. Pittalo, J. Hadaway, J. Geary, R. Lindquist, P. Readon (*Univ. Alabama in Huntsville*), H. Crawford, C. Pennypacker (*LBL, UC Berkeley*), K. Arisaka, D. Cline, J. Kolonko, V. Andreev (*UCLA*), T. Weiler, S. Csorna (*Vanderbilt Univ.*),
- ▶ **France** : J-N. Capdevielle, P. Gorodetzky, P. Salin, J. Dolbeau, T. Patzak, F. Vanucci (*APC,CNRS*), J. Weisbard (*IN2P3*)
- ▶ **Germany**: M. Teshima, T. Schweizer (*MPI, Munich*), A. Santangelo, E. Kendziorra, F. Fenu (*Univ. Tuebingen*), P. Biermann (*MPI Bonn*), K. Mannheim (*Wuerzburg*), J. Wilms (*Univ. Erlangen*)
- ▶ **Italy** : E. Pace, M. Focardi, P. Spillantini (*U. Firenze*) V.Bratina, A. Zuccaro, L. Gambicorti (*CNR-INOA Firenze*), A. Anzalone, O. Catalano, M.C. Maccarone, P. Scarsi, B. Sacco, G. La Rosa (*IAS-PA/INAF*), G. D'All Staiti, D. Tegolo (*U. Palermo*), M. Casolino, M.P. De Pascale, A. Morselli, P. Picozza, R. Sparvoli (*INFN and Univ. Rome "Tor Vergata"*), P. Vallania (*IFSI-INAF Torino*), P. Galeotti, C. Vigorito, M. Bertaina (*U. Torino*), A. Gregorio (*Trieste*), F. Isgro, F. Guarino, D. D'urso (*U. "Federico II" di Napoli*), G. Osteria, D. Campana, M. Ambrosio, C. Aramo (*INFN-Napoli*)
- ▶ **Mexico**: G. Medina-Tanco, J.C. D'Olivo, J.F.Valdes (*Mexico UNAM*), H. Salazar, O. Martinez (*BUAP*), L. Villasenor (*UMSNH*)
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Extreme Universe Space Observatory



JEM-EUSO mission

戎崎俊一
理化学研究所

for the JEM-EUSO Collaboration



北海道大学 2008年9月10日

JEM-EUSO Collaboration

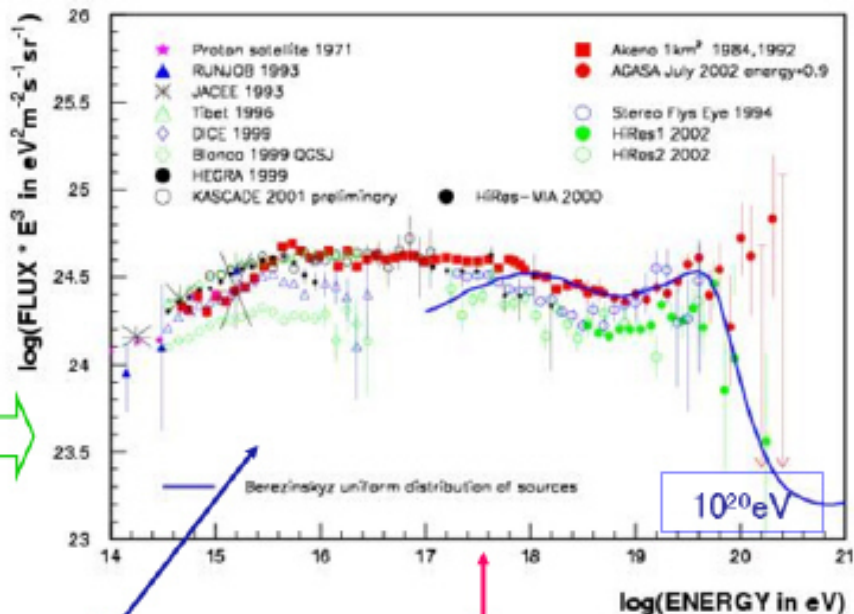
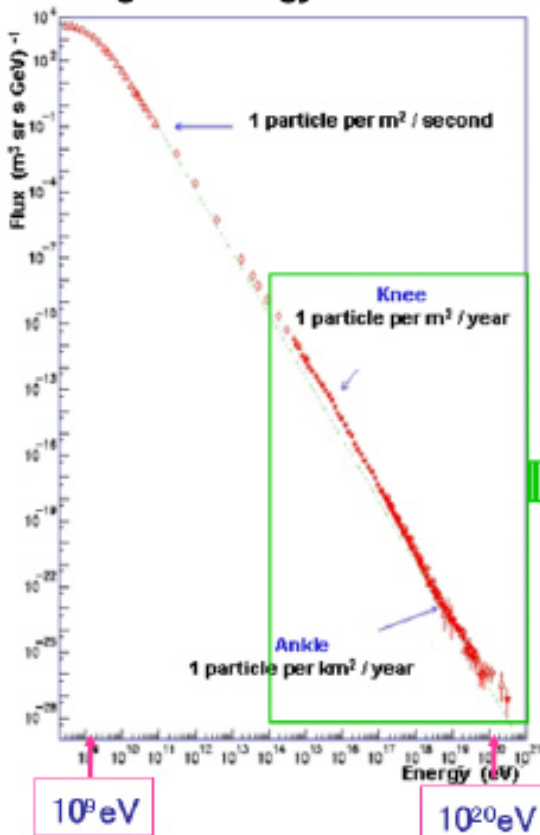
10 countries, 56 institutions, 149 members



- ▶ **Japan** : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin Univ.*), N. Inoue (*Saitama Univ.*), Y. Uchihori (*NIRS*), K. Nomoto (*Univ. of Tokyo*), Y. Takahashi (*Tohoku Univ.*), M. Takeda (*ICRR, Univ. Tokyo*), Y. Arai, Y. Kurihara, H.M. Shimizu, J. Fujimoto (*KEK*), S. Yoshida, K. Mase (*Chiba Univ.*), K. Asano, S. Inoue, Y. Mizumoto, J. Watanabe, T. Kajino (*NAOJ*), H. Ikeda, M. Suzuki, T. Yano (*ISAS, JAXA*), T. Murakami, D. Yonetoku (*Kenazawa Univ.*), T. Sugiyama (*Nagoya*), Y. Ito (*STEL, Nagoya Univ.*), S. Nagataki (*YITP, Kyoto Univ.*), A. Saito (*Kyoto Univ.*), S. Abe, M. Nagata (*Kobe Univ.*), T. Tajima (*KPSI, JAEA*), M. Chikawa (*Kinki Univ.*), and M. Tajima (*Hiroshima Univ.*)
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- ▶ **Germany**: M. Teshima, T. Schweizer (*MPI, Munich*), A. Santangelo, E. Kendziorra, F. Fenu (*Univ. Tuebingen*), P. Biermann (*MPI Bonn*), K. Mannheim (*Wuerzburg*), J. Wilms (*Univ. Erlangen*)
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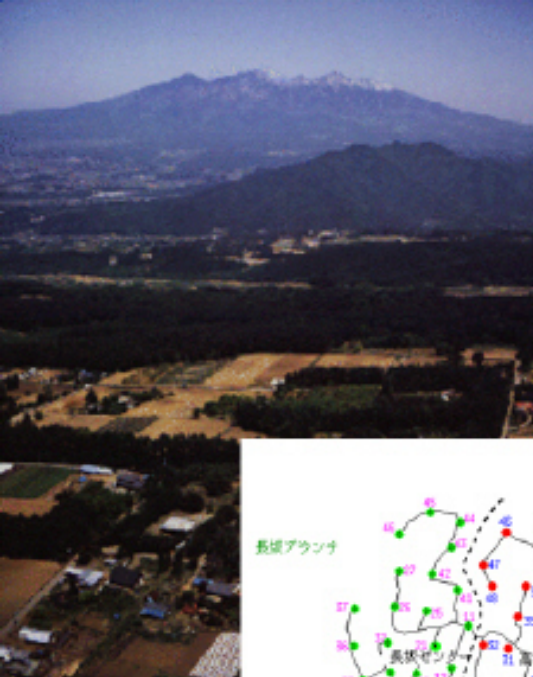
$p + \gamma_{2.7\text{K}} \rightarrow e^+ e^- + p$ above LHC $5 \cdot 10^{17} \text{ eV}$

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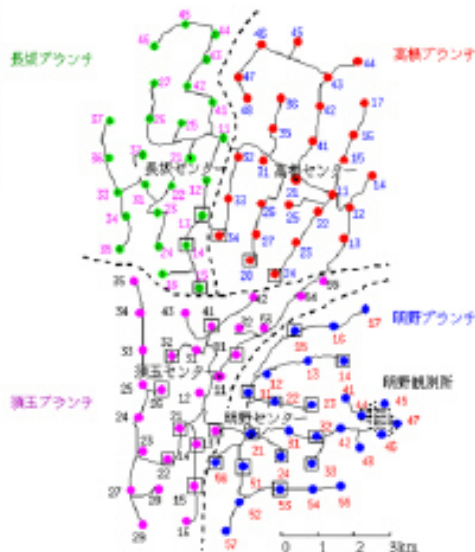
AGASA

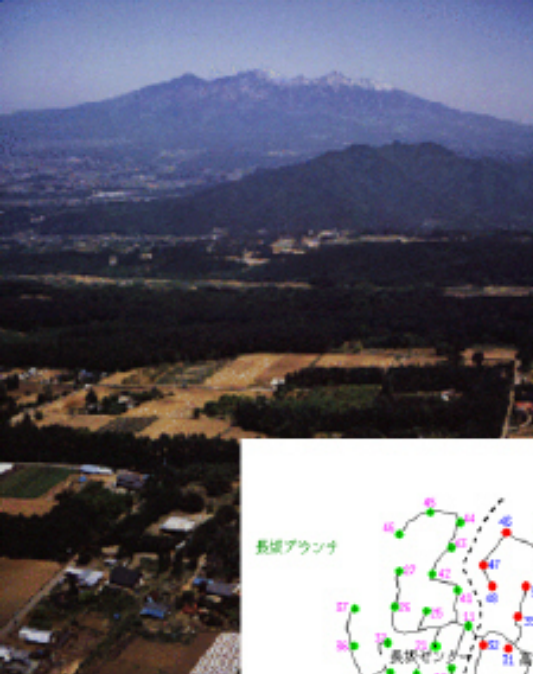
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- 13年で11個の超10²⁰eV事象



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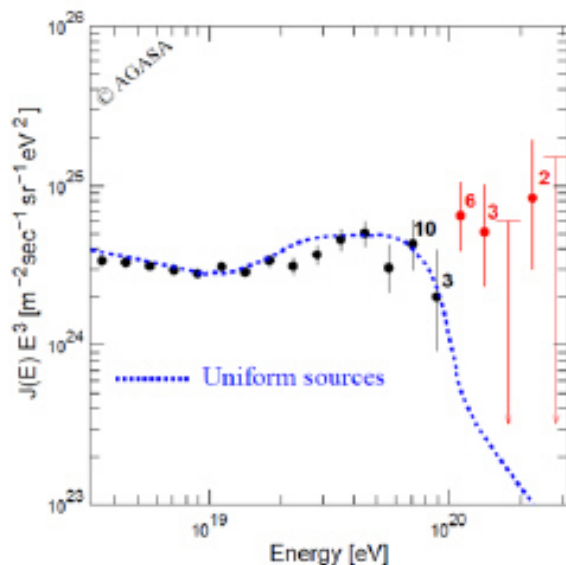
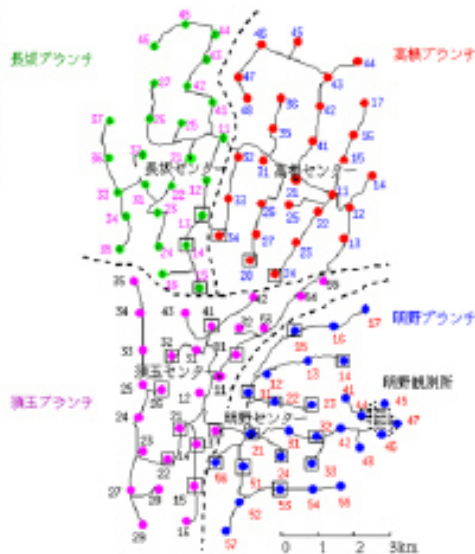
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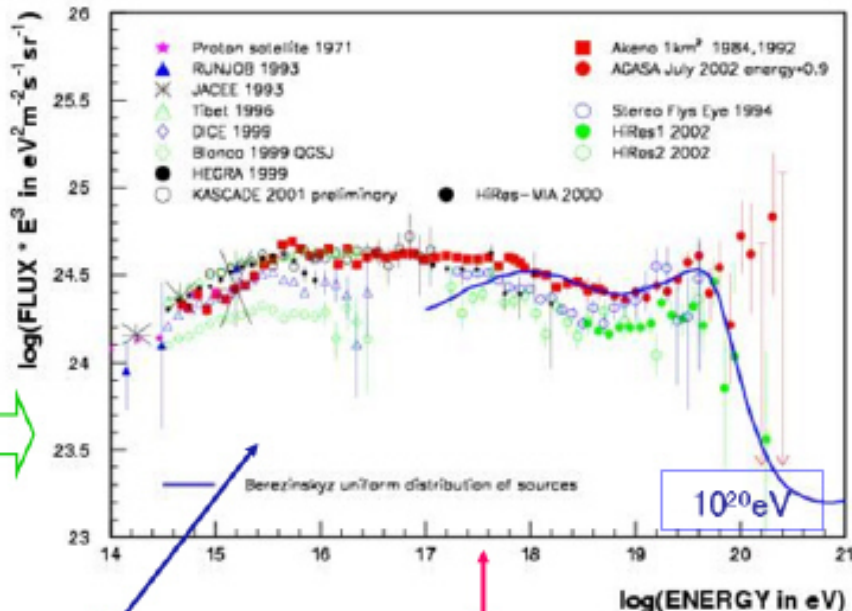
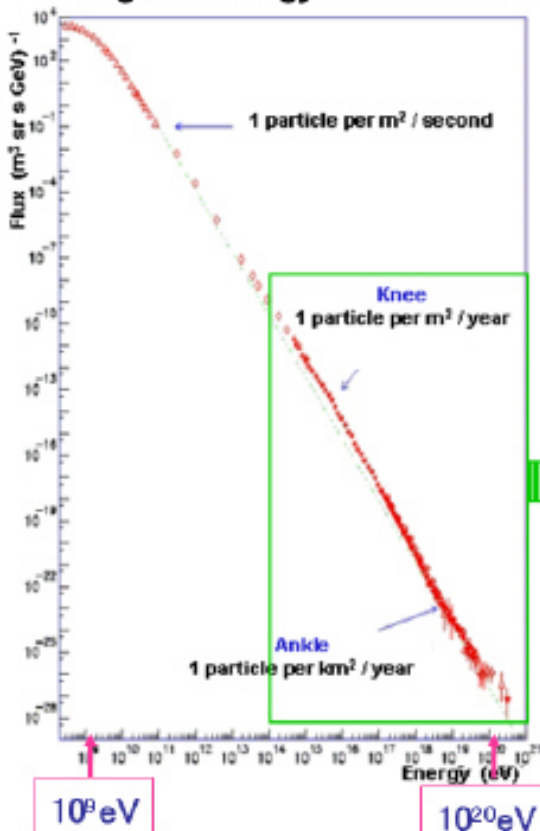
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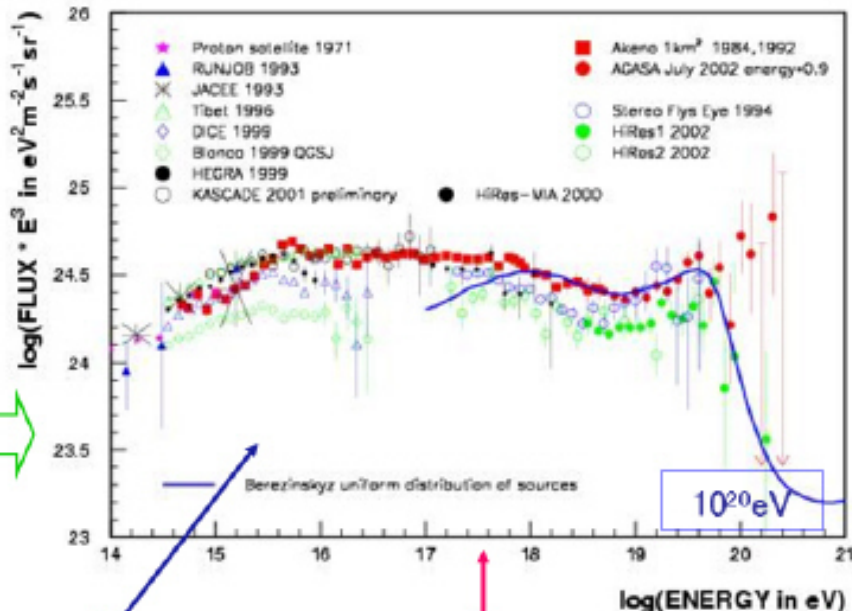
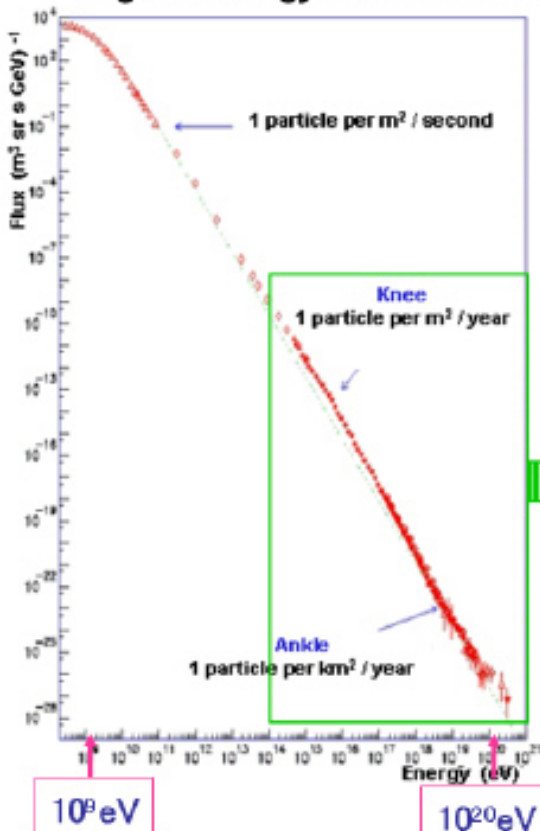
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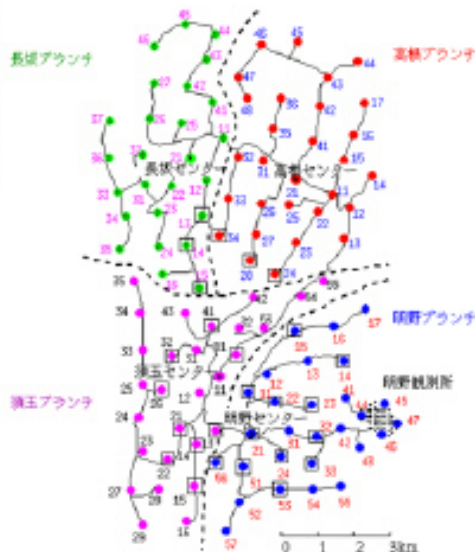
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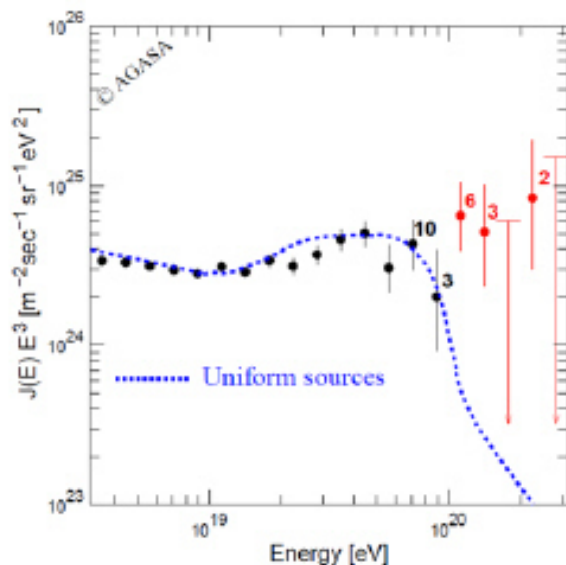
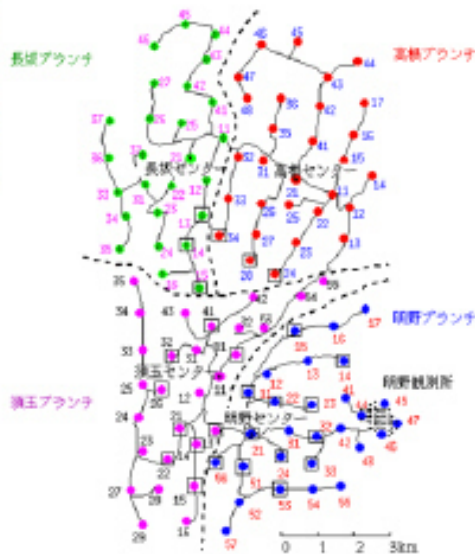
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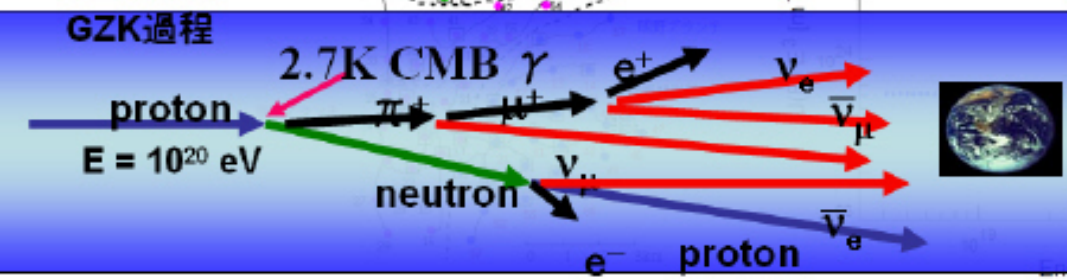
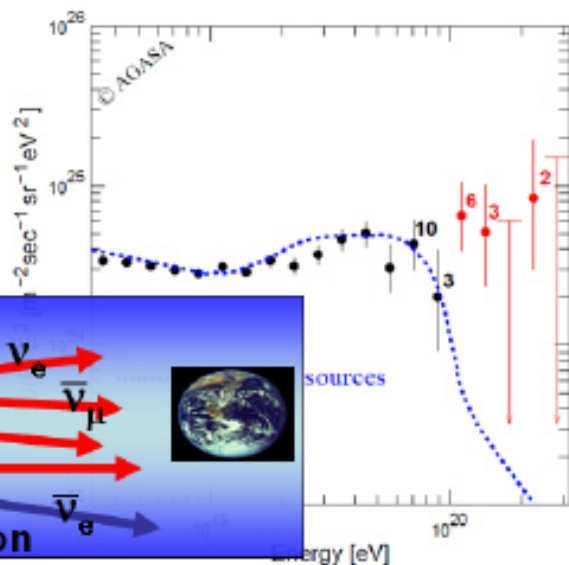
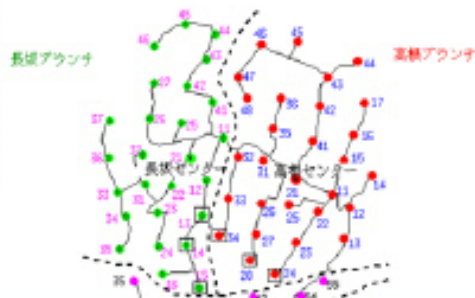
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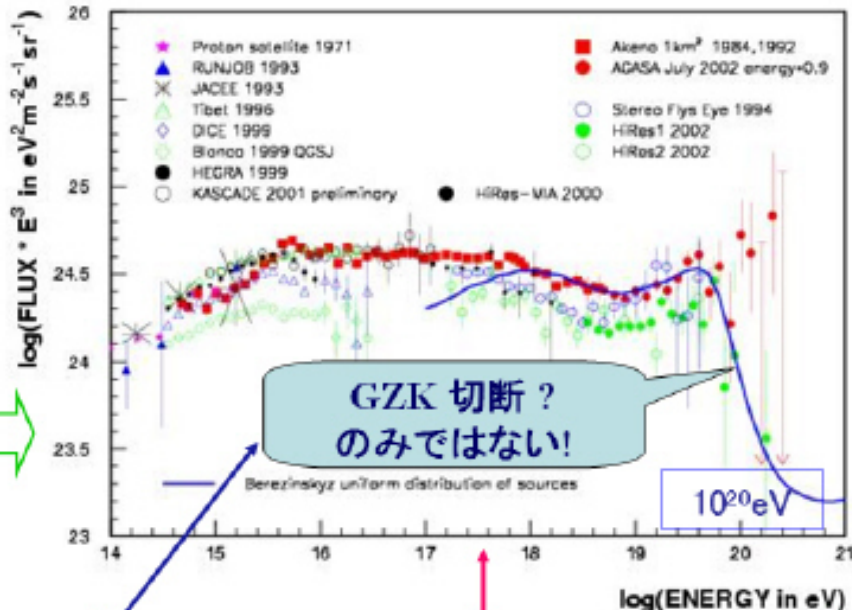
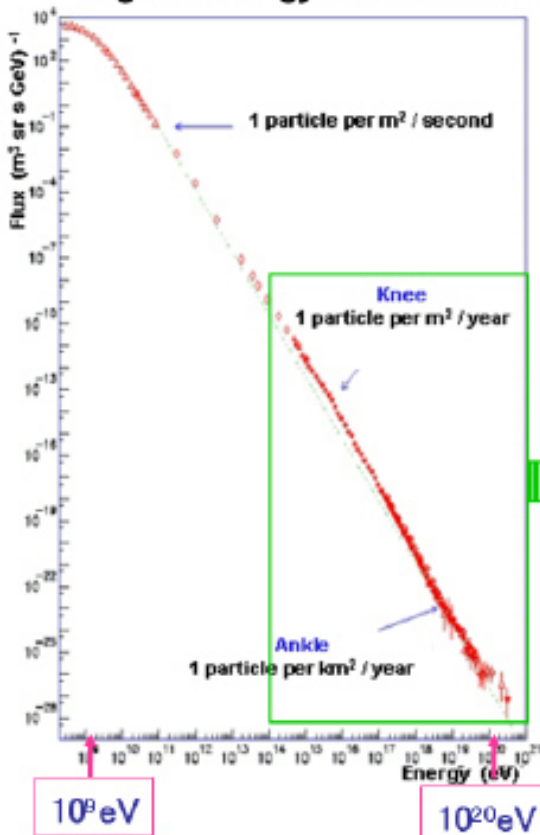
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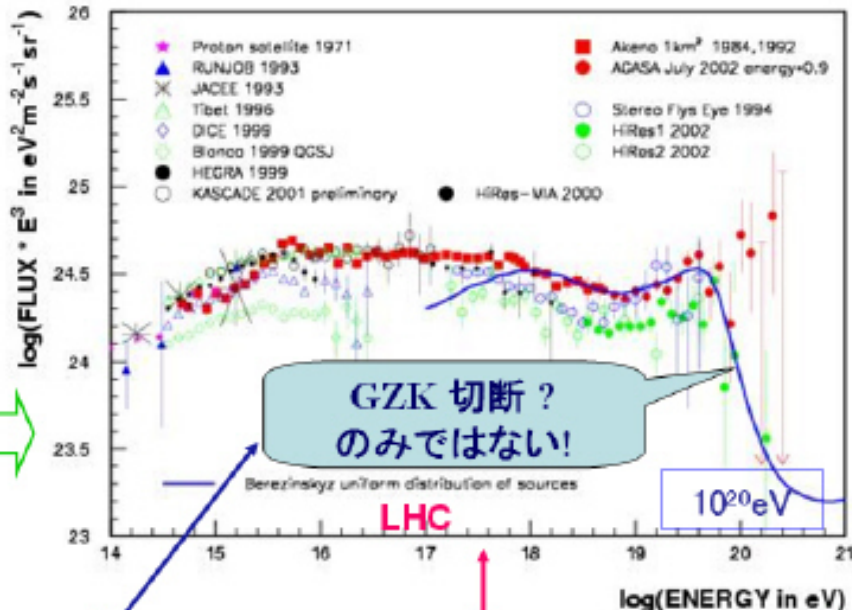
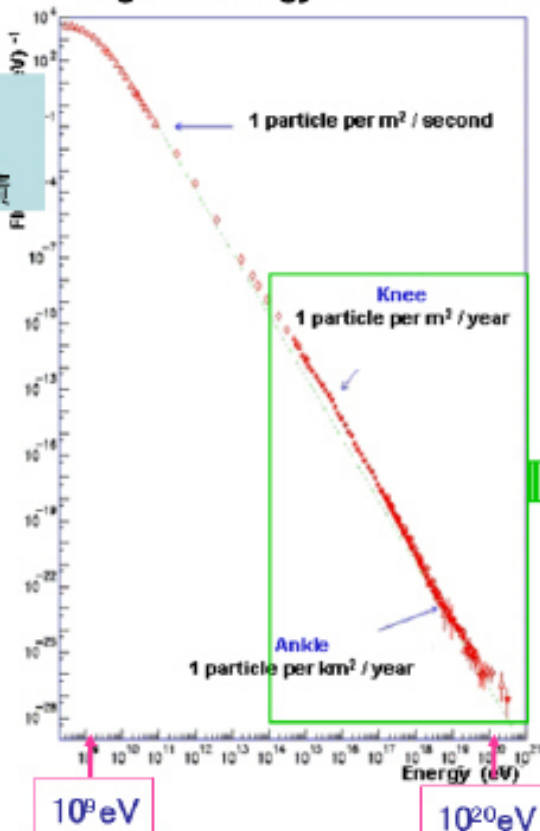


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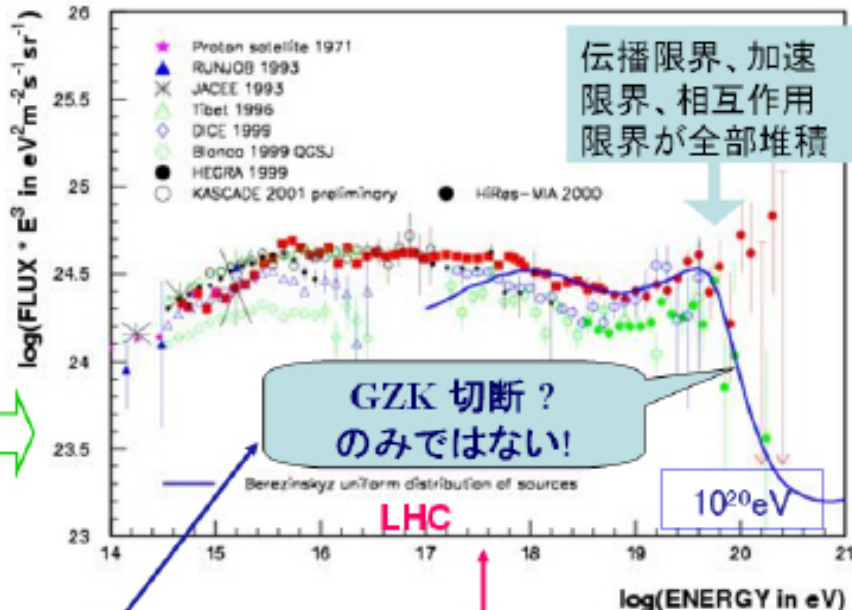
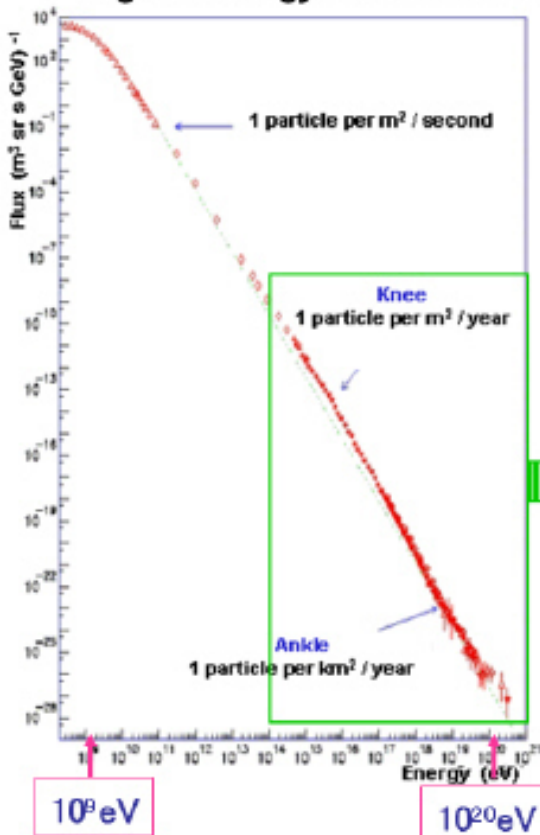


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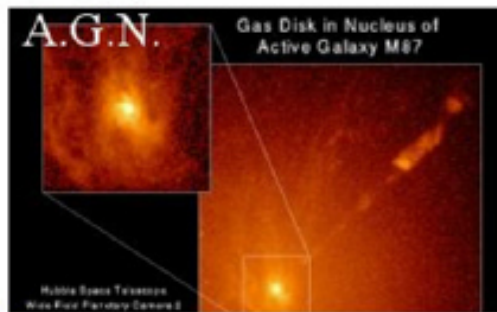
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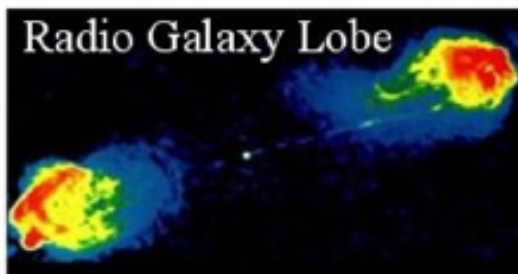
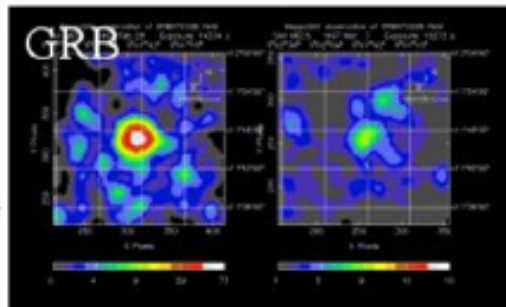
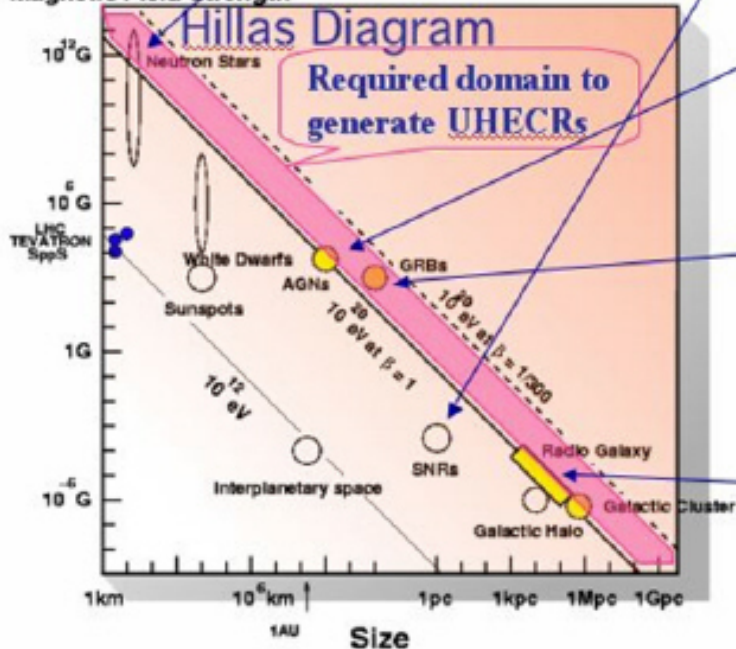
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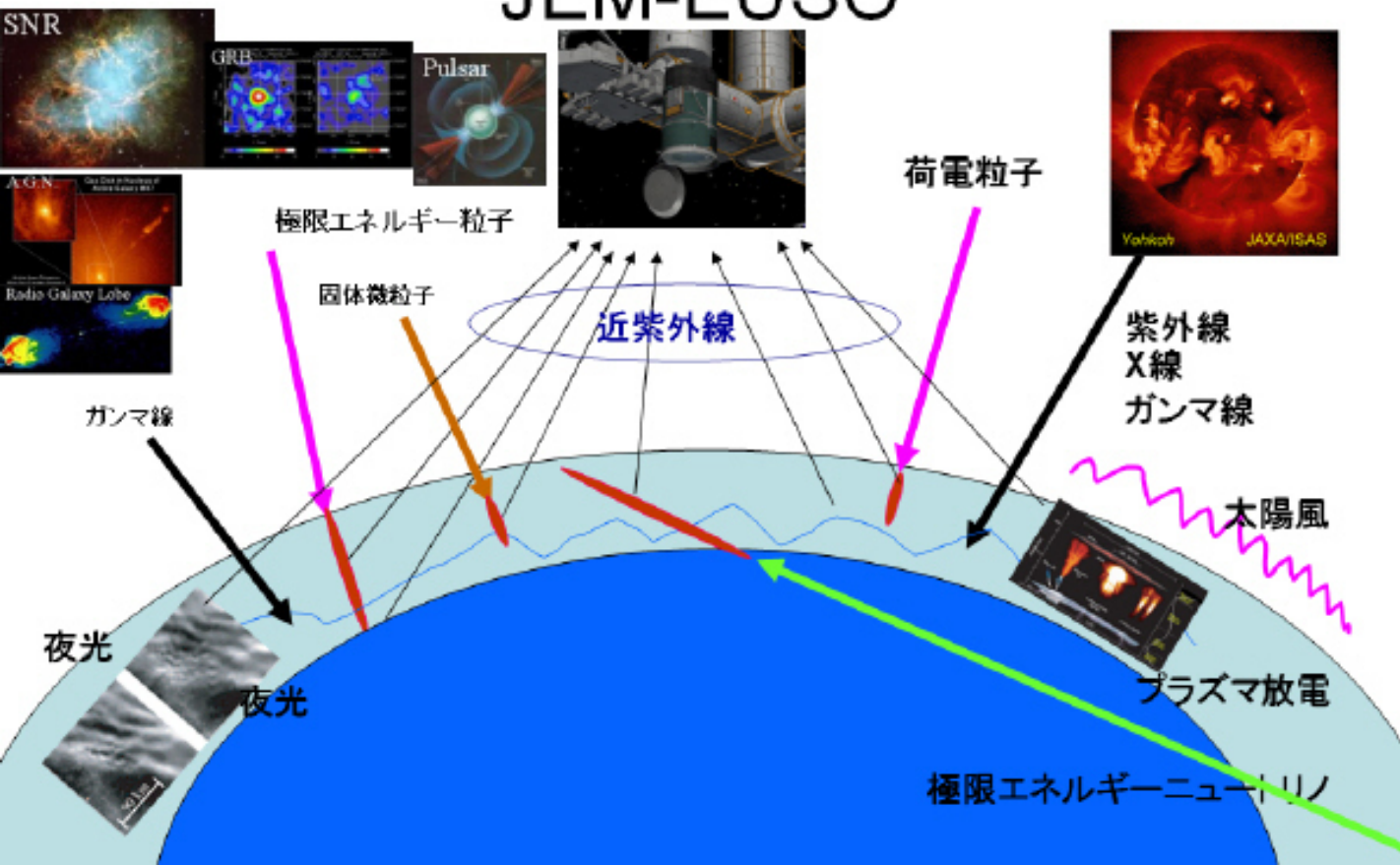
ヒラス 理論的加速限界 10^{20} eV



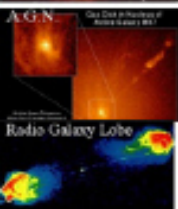
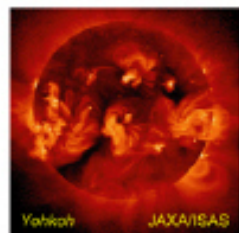
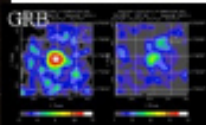
Magnetic Field Strength



地を見て天を知る天文台=地文台 JEM-EUSO



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極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

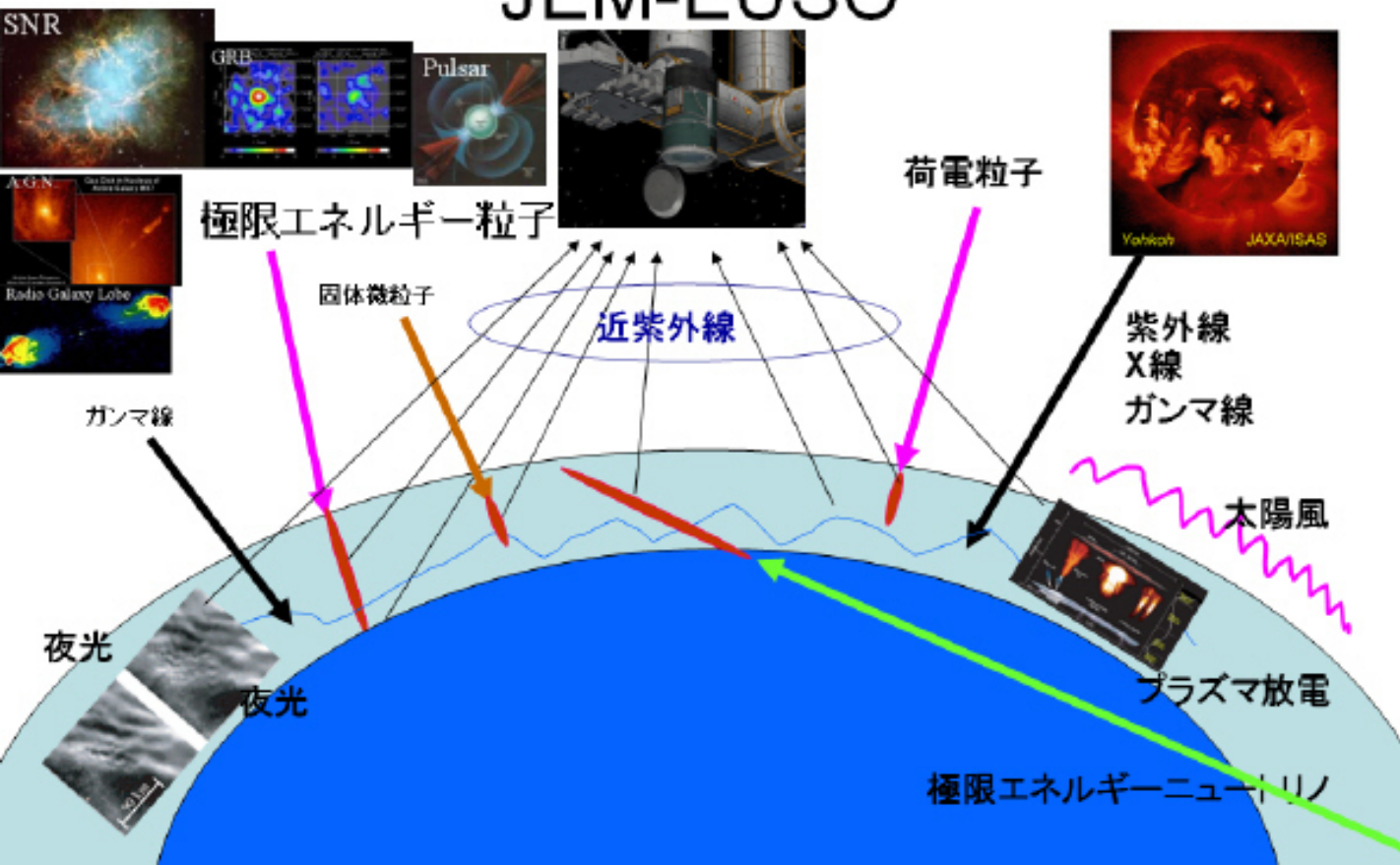
太陽風

夜光

夜光

プラズマ放電

極限エネルギーニュートリノ



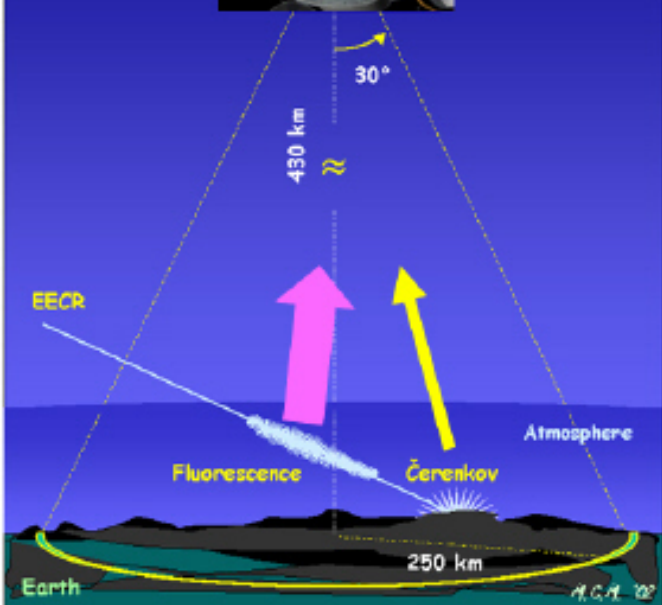
EUSOの観測方法



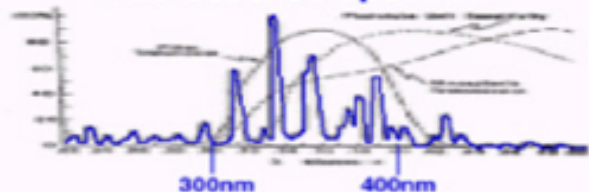
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

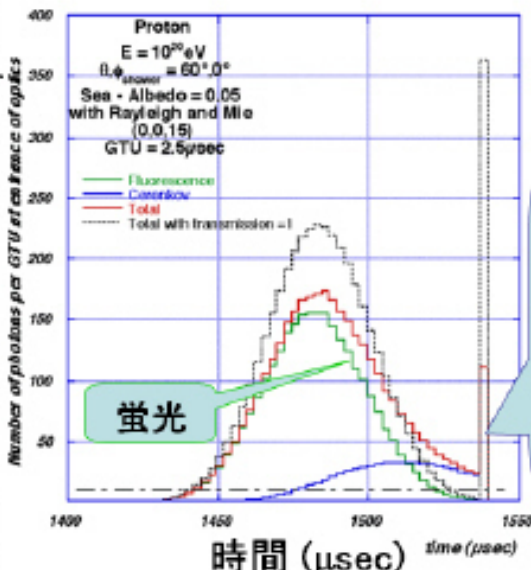
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



光学系入口径での光子数 (/2.5μsec)



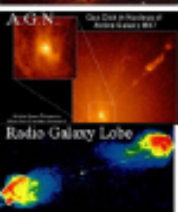
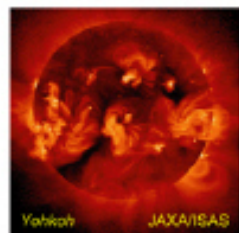
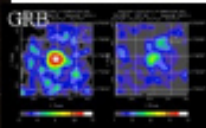
蛍光

チェレンコフ光

時間 (μsec)

time (μsec)

地を見て天を知る天文台=地文台 JEM-EUSO



極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

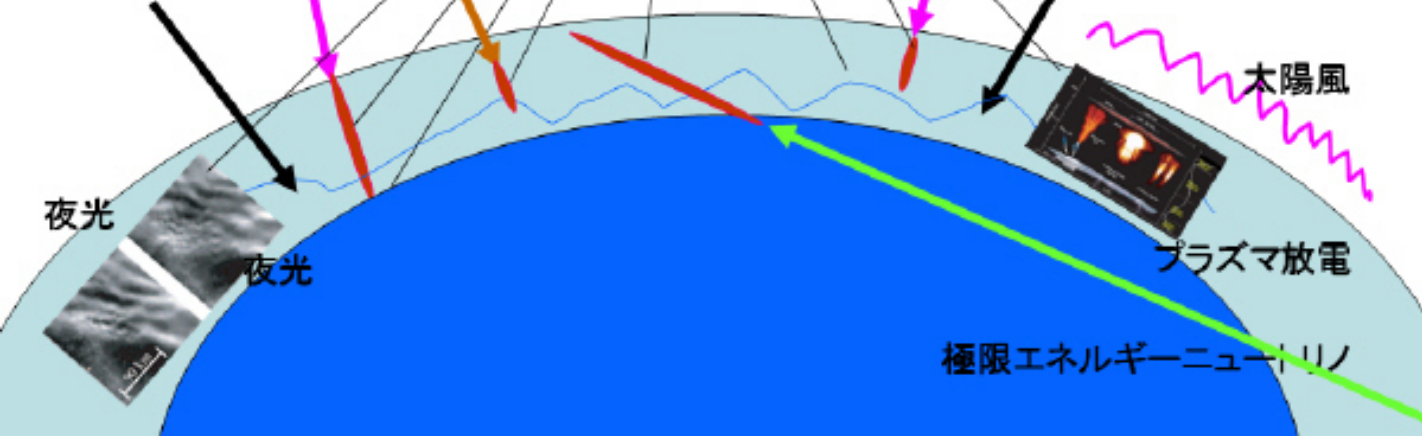
太陽風

夜光

夜光

プラズマ放電

極限エネルギーニュートリノ



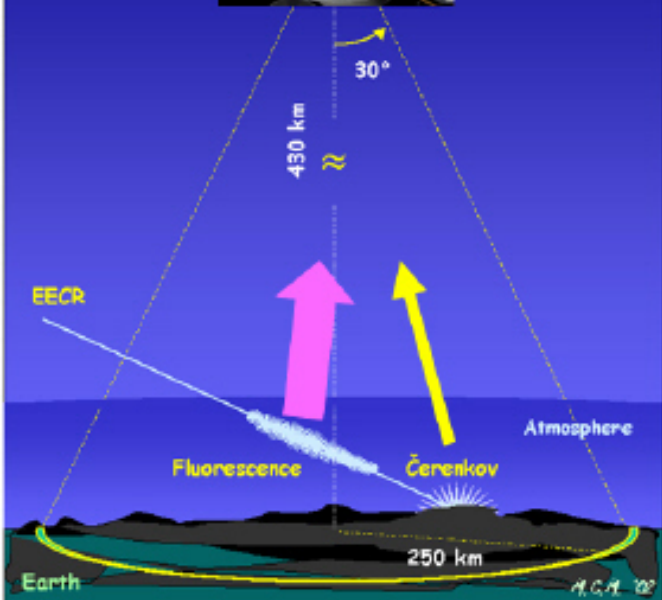
EUSOの観測方法



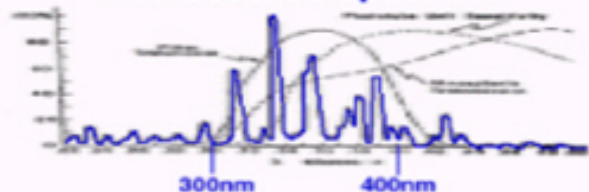
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

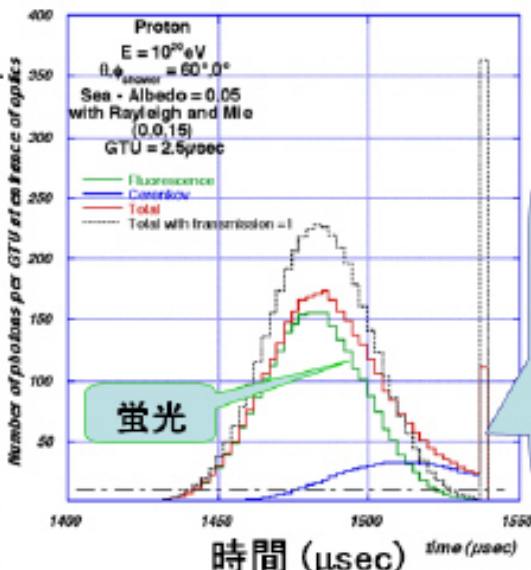
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



光学系入口径での光子数 (/2.5μsec)

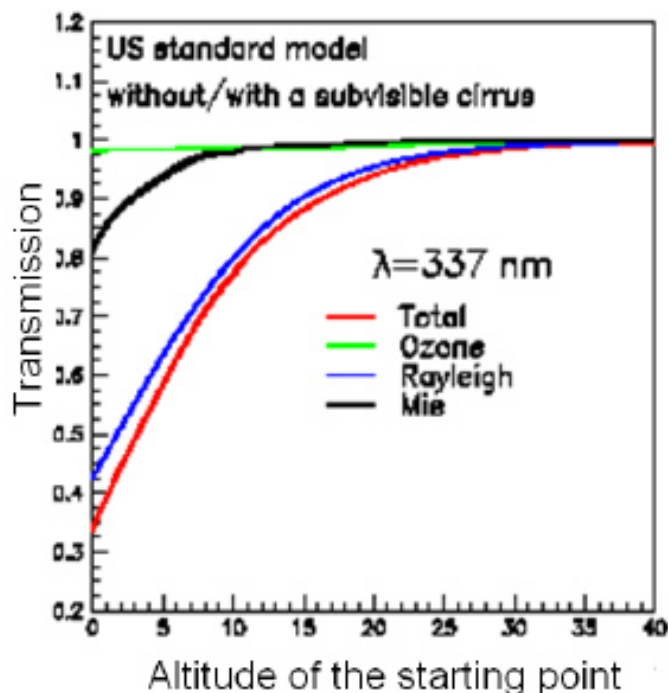


蛍光

チェレンコフ光

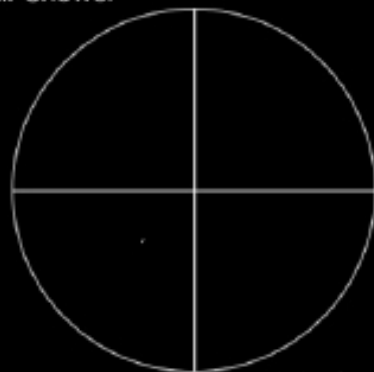
宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)

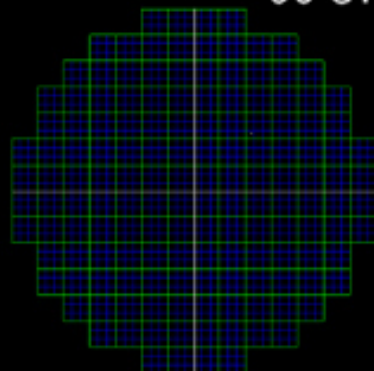


JEM-EUSOで見る空気シャワー

Air Shower

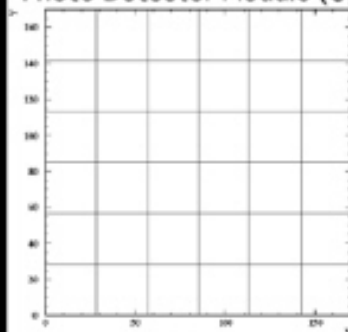


00 GTU

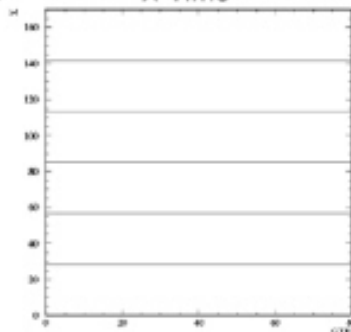


EUSO Focal Surface

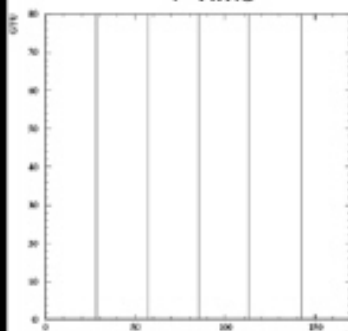
Photo Detector Module (3,3)



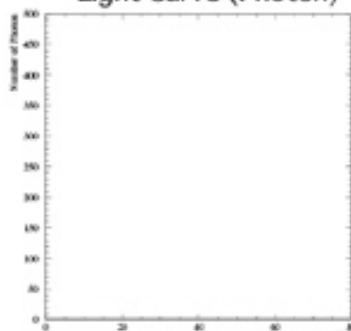
X-Time



Y-Time

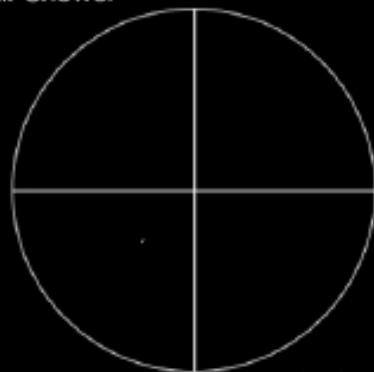


Light Curve (Photon)

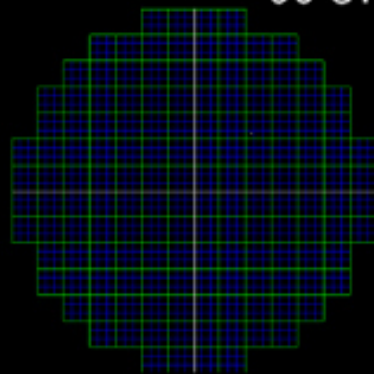


JEM-EUSOで見る空気シャワー

Air Shower

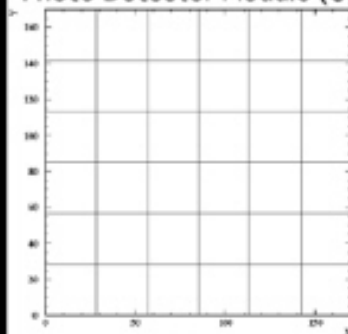


00 GTU

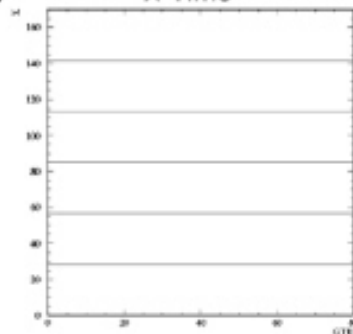


EUSO Focal Surface

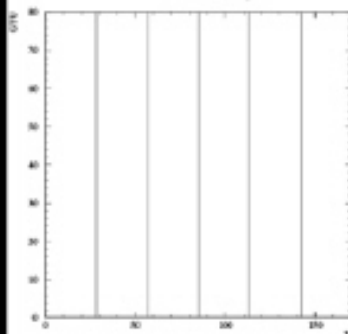
Photo Detector Module (3,3)



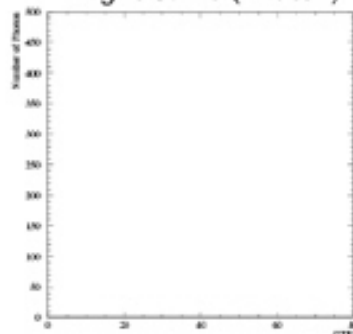
X-Time



Y-Time



Light Curve (Photon)

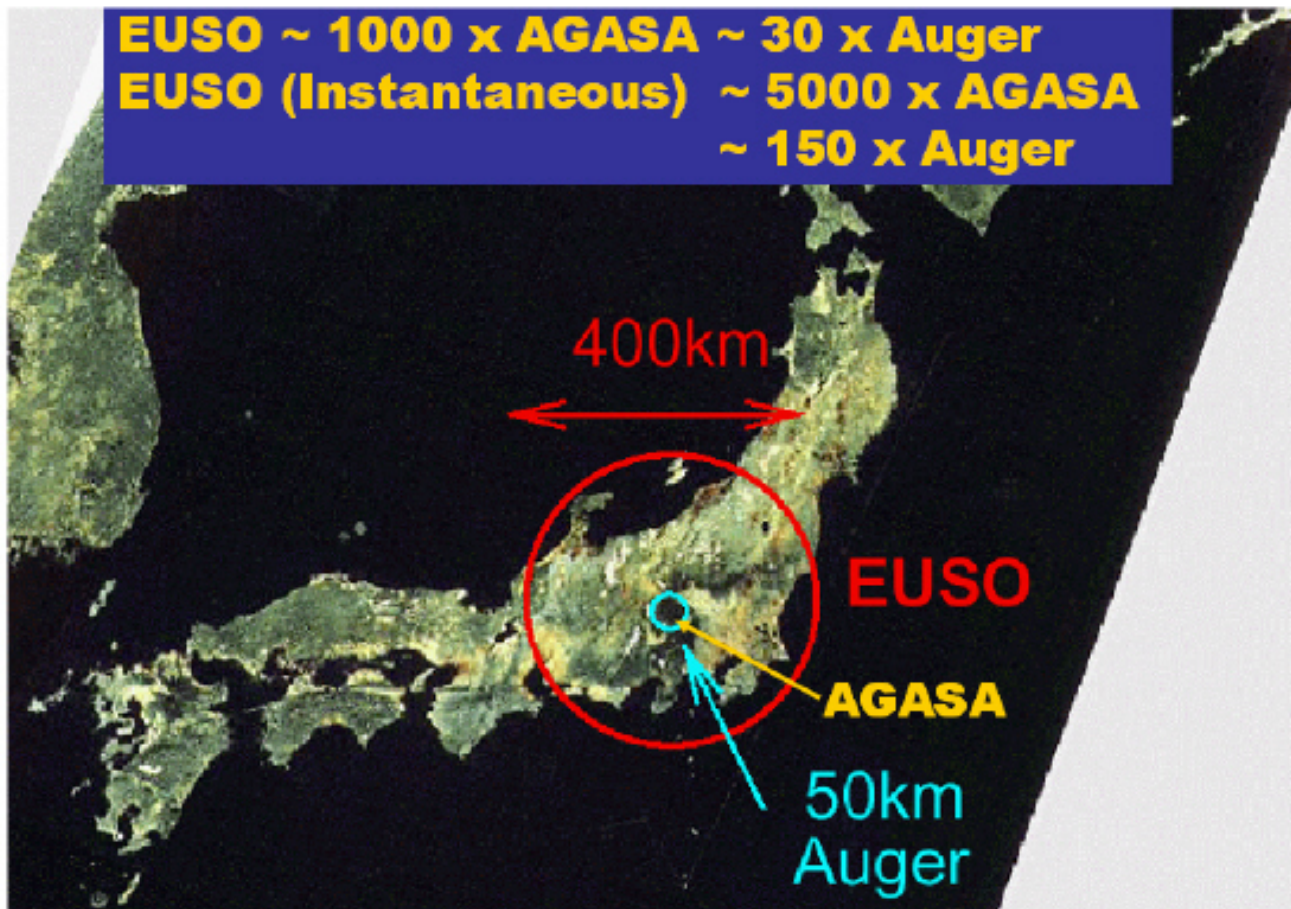






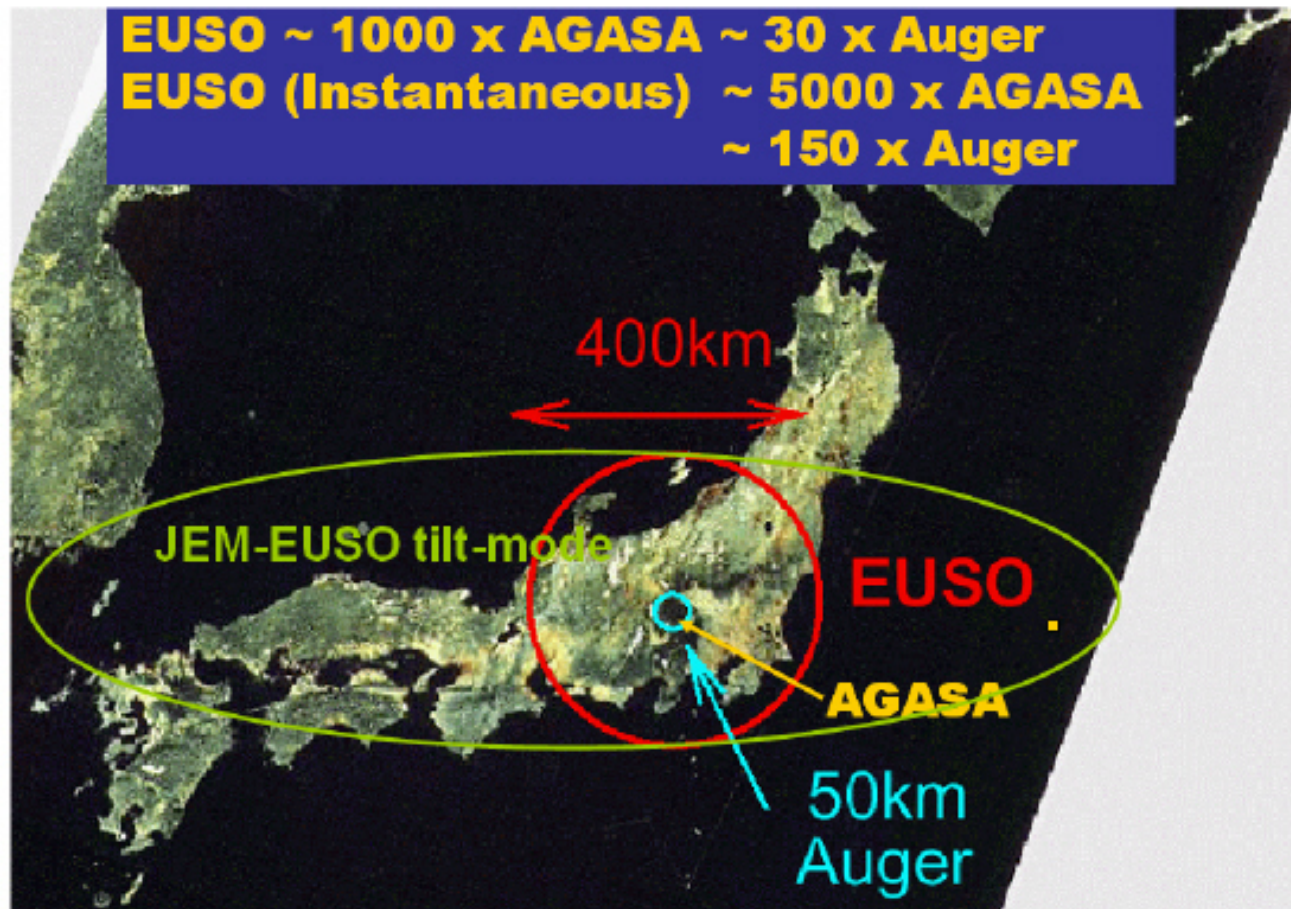
EUSOの巨大な視野

EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



EUSOの巨大な視野

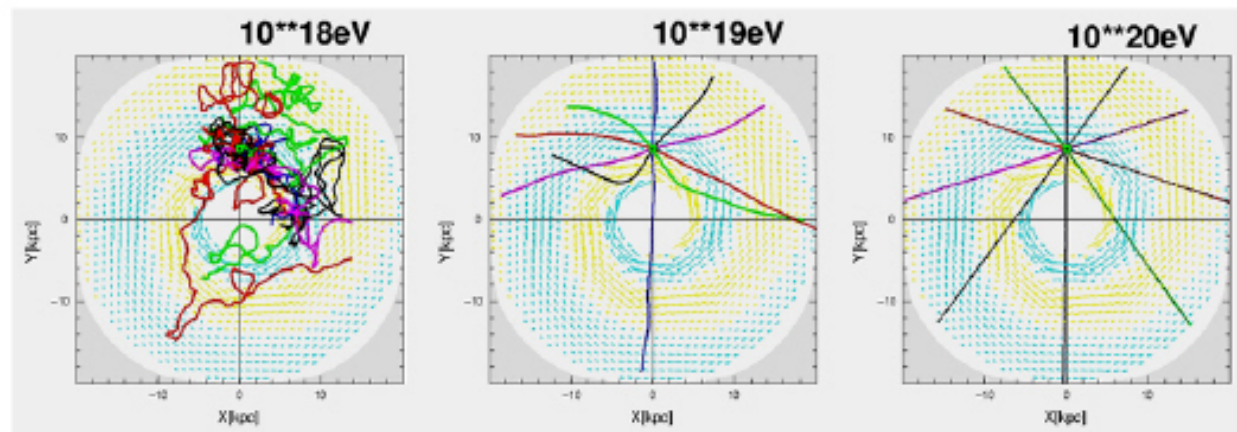
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



科学目的

- 基本研究: 極限エネルギー—**粒子による新天文学**
 - 高統計到来方向解析による**起源天体**の同定
 - 個別天体からのエネルギースペクトル測定による**加速・放射機構**の検証
- 探求的試験研究
 - 極限エネルギー—**宇宙ガンマ線**の測定
 - 極限エネルギー—**宇宙ニュートリノ**の検出
 - **銀河磁場**の構造と強度の推定
 - **相対論、量子重力**効果の検証
 - **大気圏**発光現象の研究

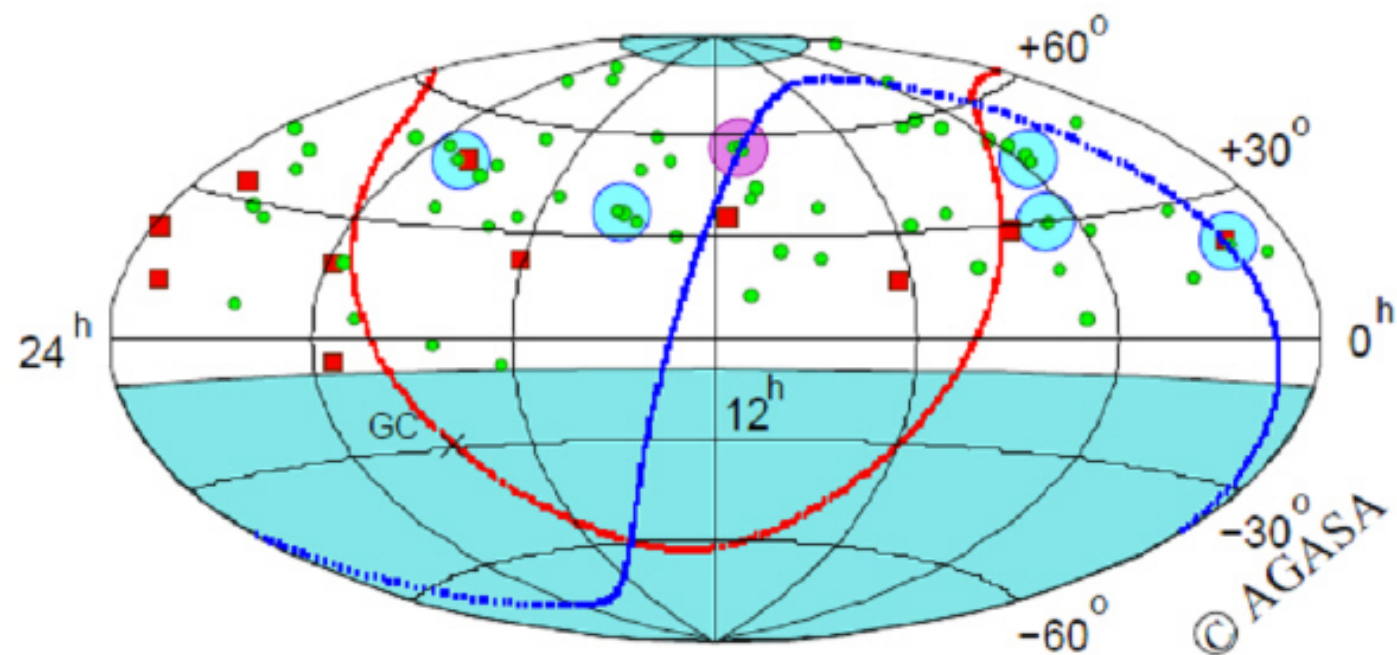
$E > 10^{20}$ eV 粒子は曲がらない



銀河内の伝播シミュレーション

到来方向解析により起源天体を特定: 粒子天文学

Arrival Directions (AGASA)



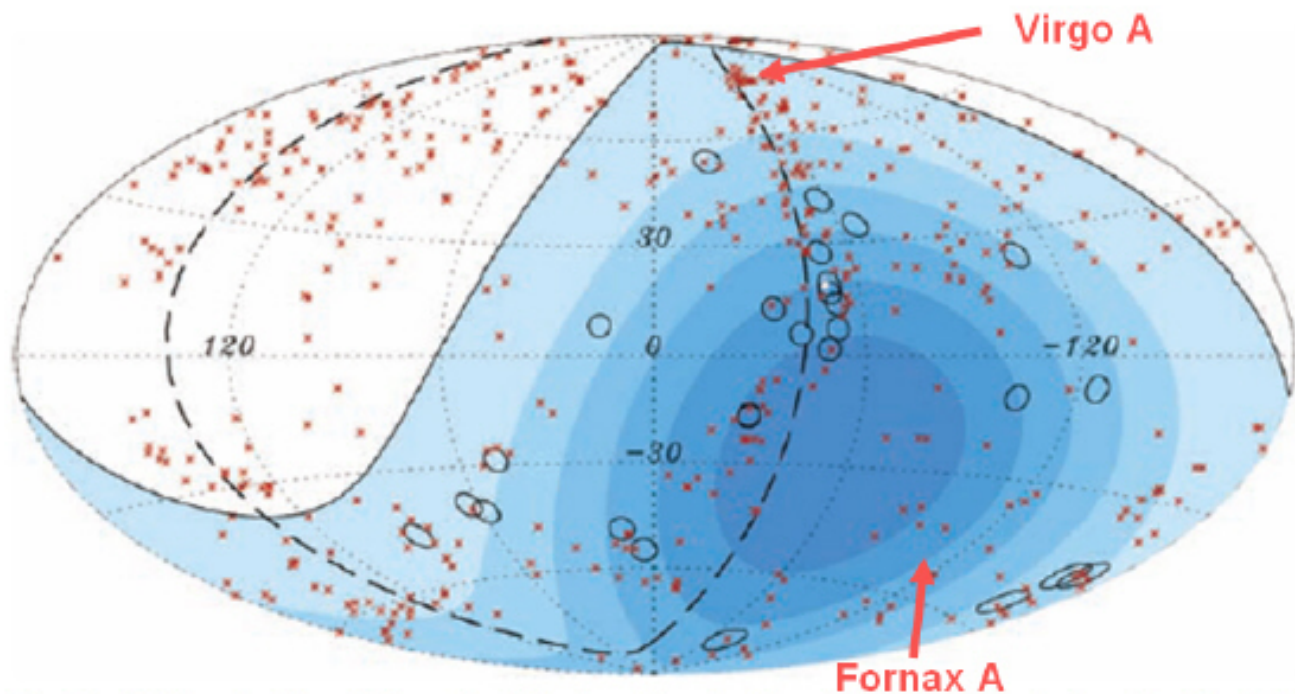


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

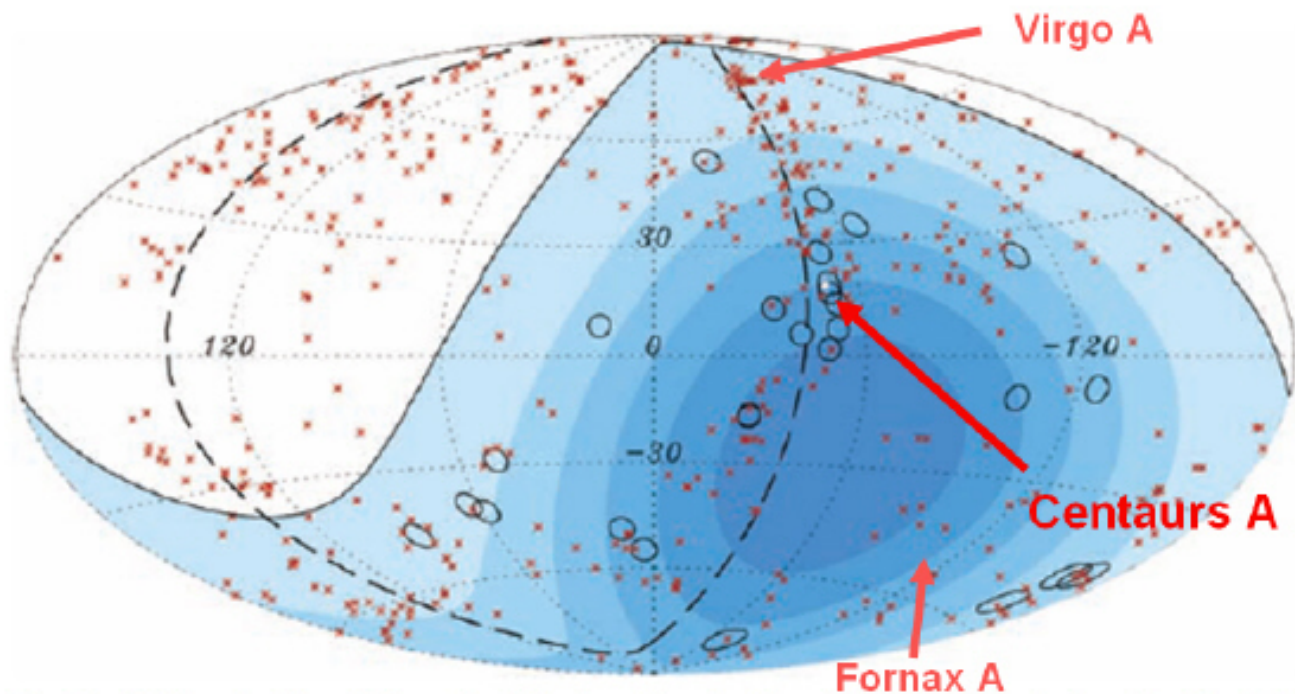


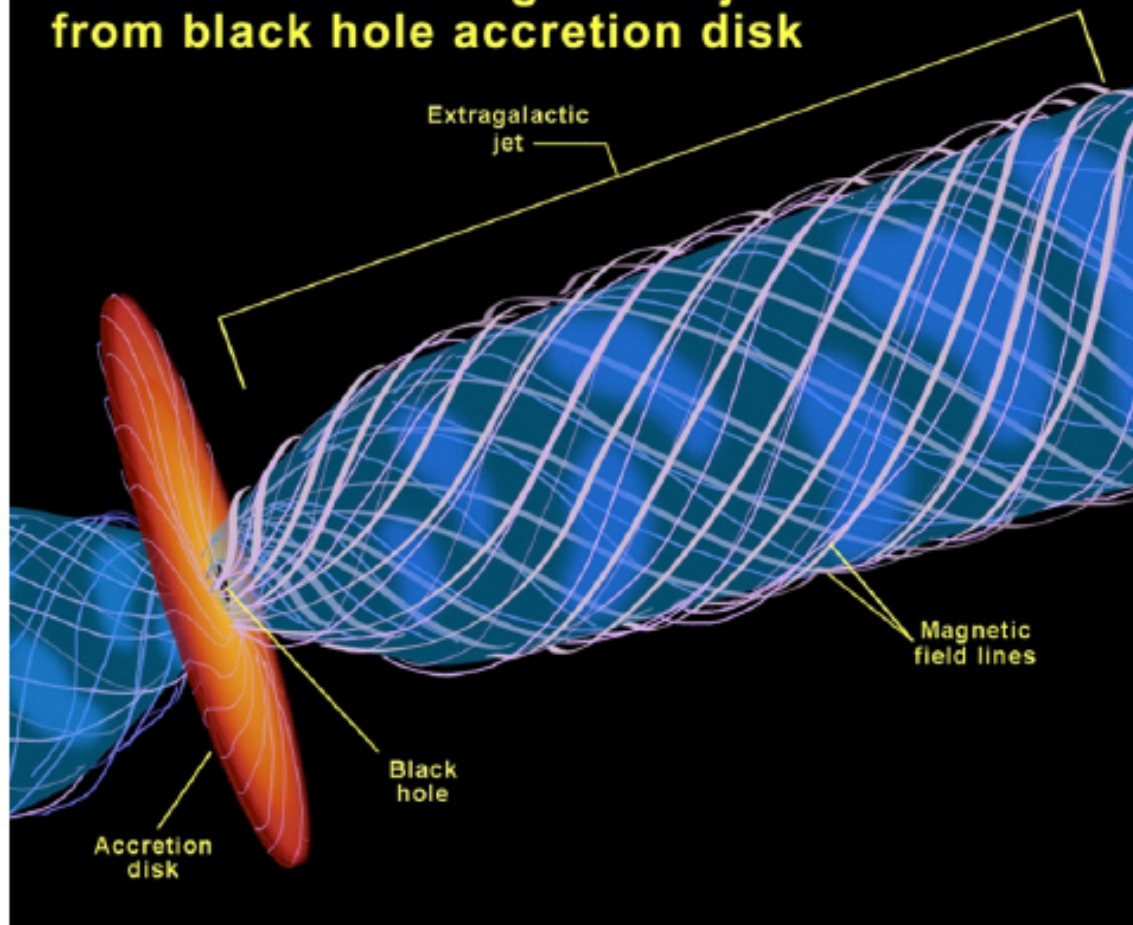
Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

ケンタウルス座 A

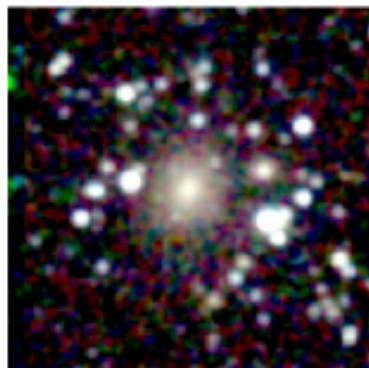
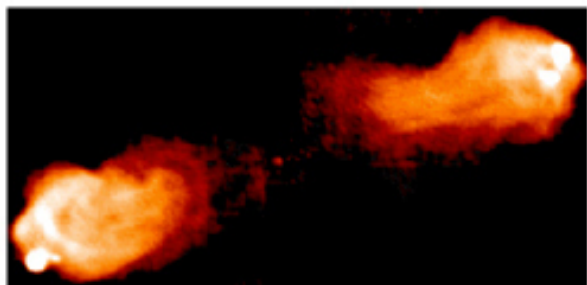


- 距離: 3.4Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度～電波光度
～ 2×10^{41} W

Formation of extragalactic jets from black hole accretion disk



他の電波銀河



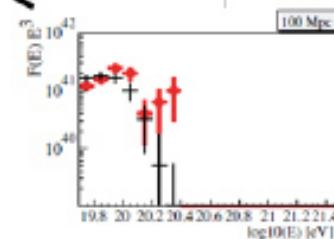
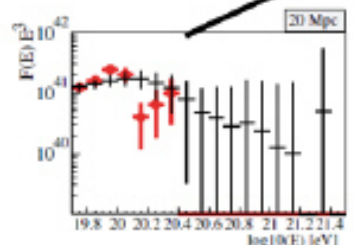
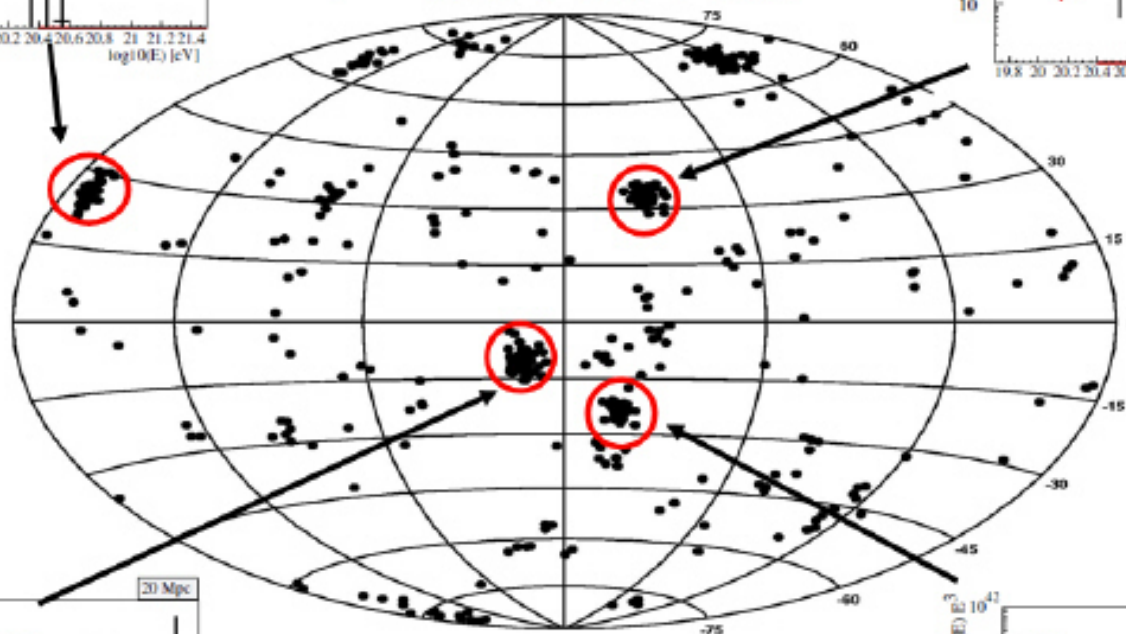
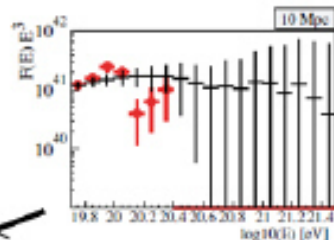
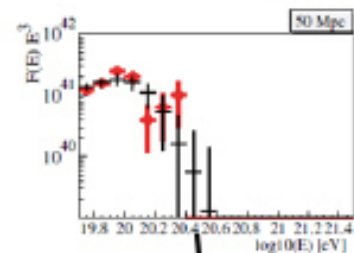
Fornax A

Cygnus A



極限粒子天文学

1,000事象の場合の予測

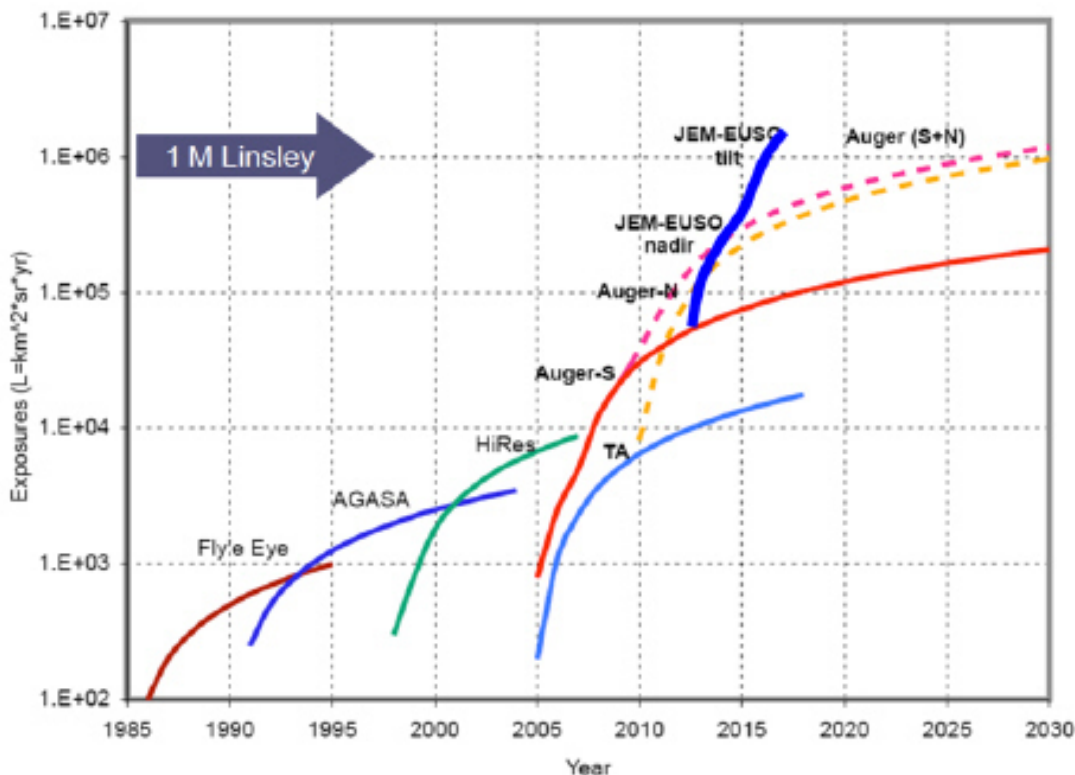


- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

事例数：5年間の運用 End-to-Endシミュレーション

		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

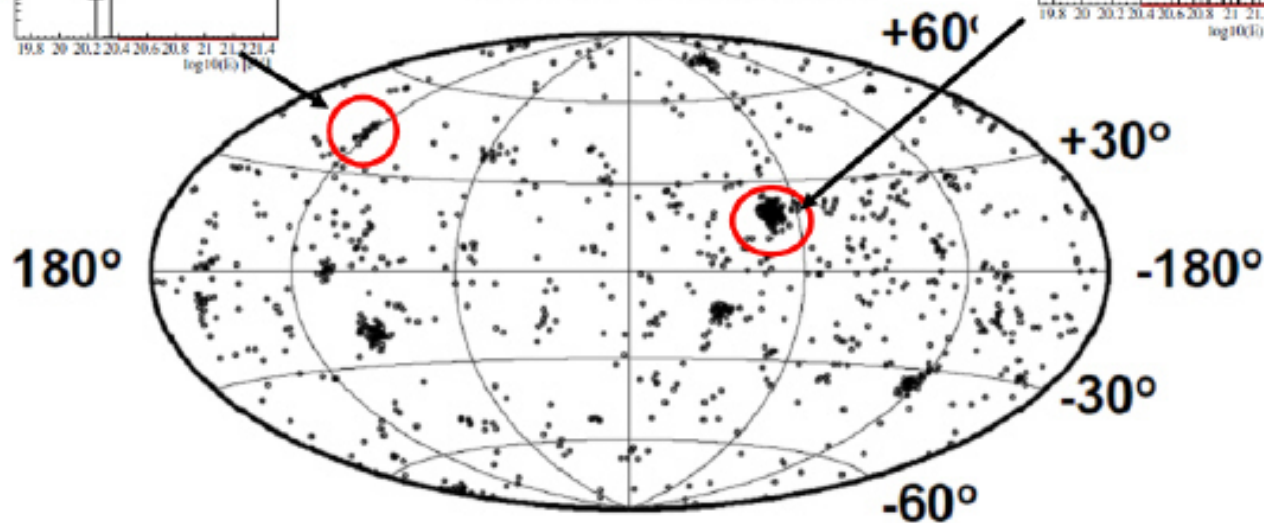
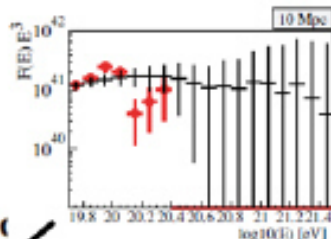
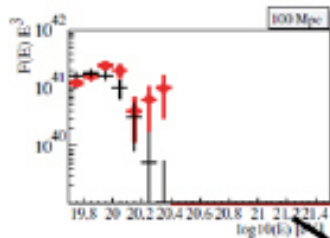
有効露出の増加期待値



極限粒子天文学

1,000事象の場合の予測

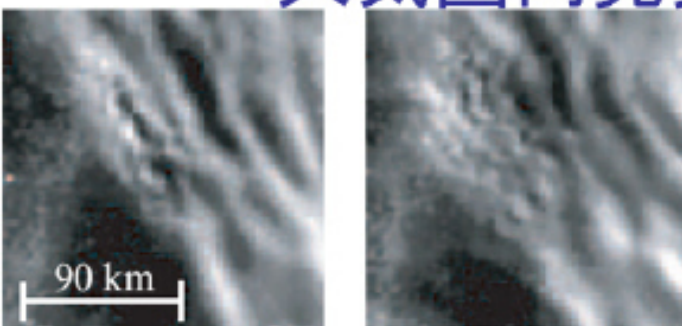
粒子光度 \propto X線光度 (AGN)



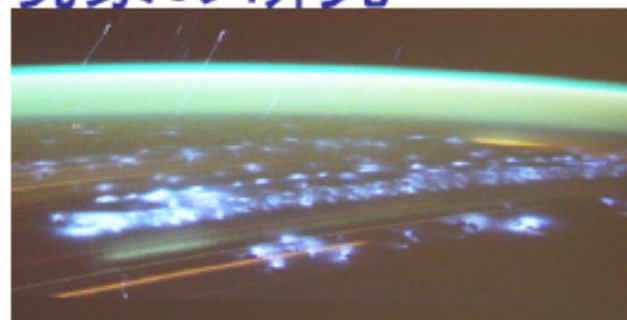
- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

Takami 2008

探求的試験研究3: 大気圏内発光現象の研究



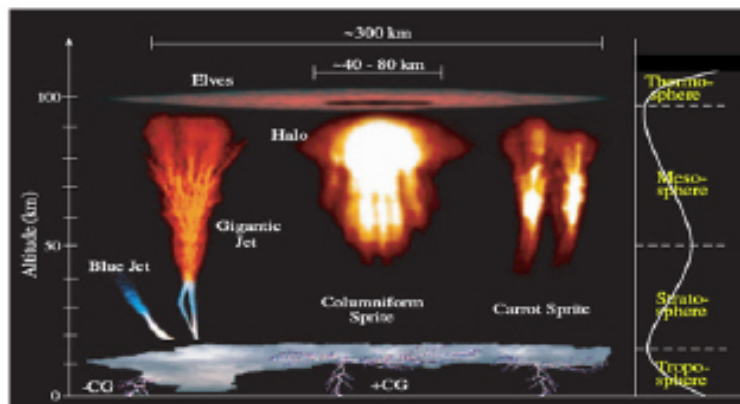
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



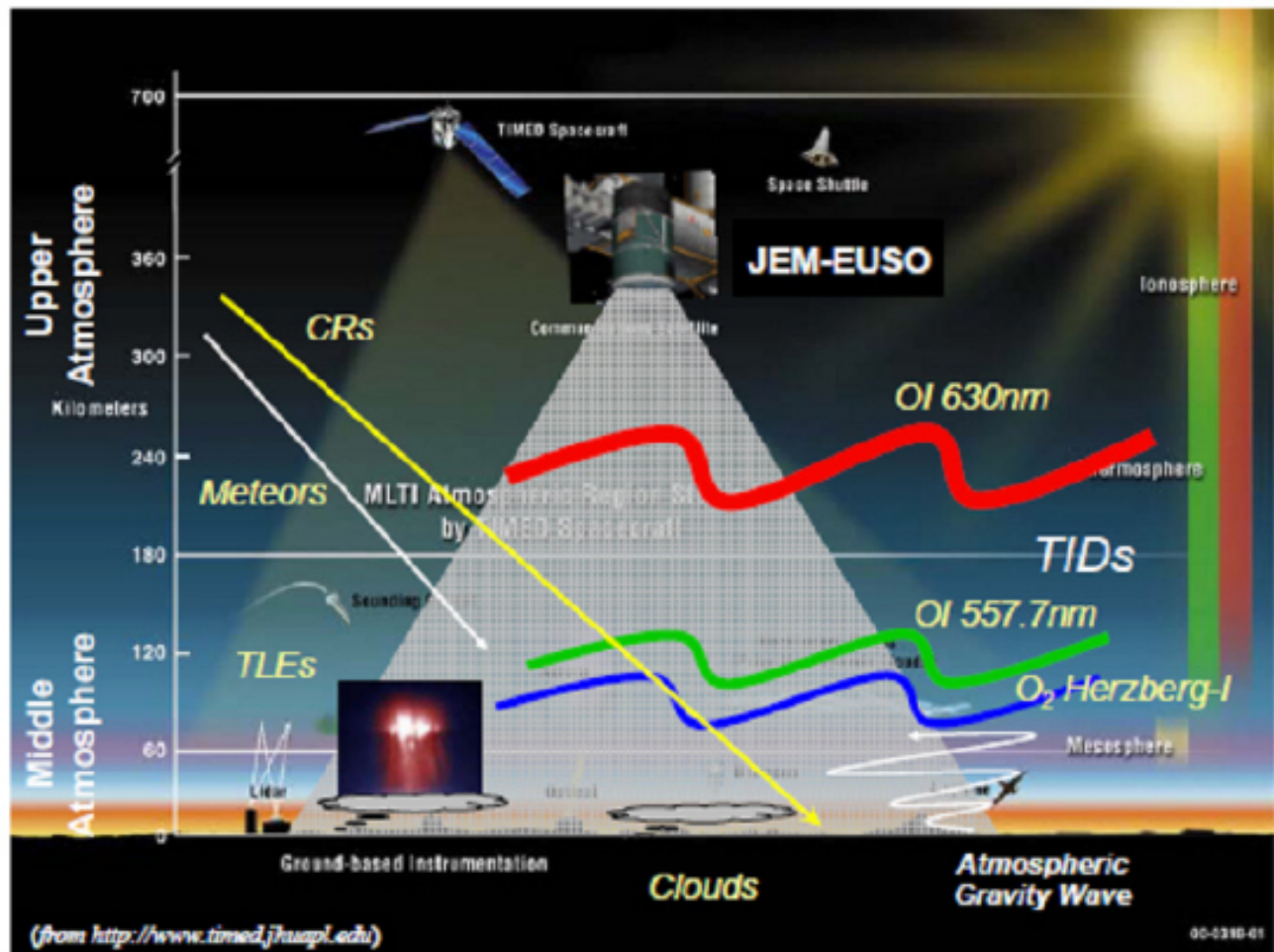
ハイビジョンカメラによる
2001年のしし座流星群



雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星



サクセスクライテリア

フルサクセス:

極限エネルギー事例: 1000個以上
(7×10^{19} eV 以上)

ミニマムサクセス:

フルサクセスの半分の事例数を得る: 500個

分布から起源を議論の余地なく特定できる臨界量

- 粒子到来方向解析
 - 到来方向決定精度: 2.5度以下
- スペクトル解析
 - エネルギー決定精度: 30%以下
- ハドロン／光子／ニュートリノの識別:
 - シャワー最大深さ決定精度: 120 g/cm^2 以下

ミッション諸元

- 打ち上げ時期: year 2013
- 運用期間: 3 years (+ 2 years)
- 打ち上げロケット: H2B
- ISSへの運搬: HTV非与圧キャリア
- 装着場所: JEM EFU#2
- 軌道高度: ~430km
- 軌道傾斜角: 51.6°
- 質量: 1896 kg
- 使用電力: 998 W (operative),
344 W (non-operative)
- データ転送量: 297 kpbs

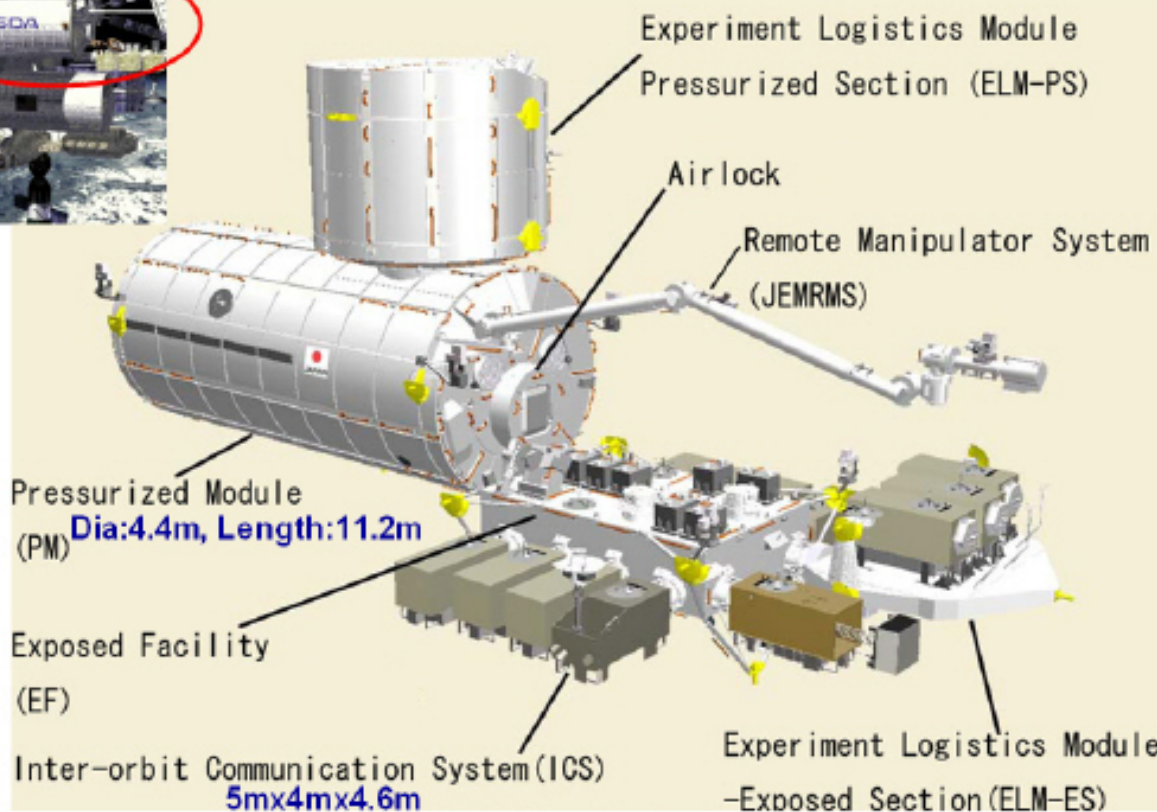
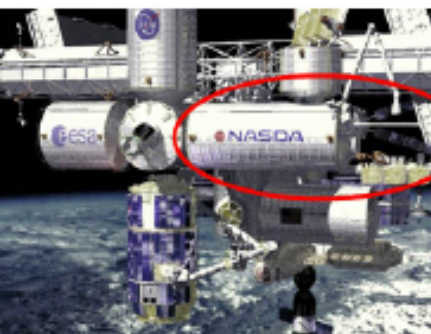
これまでの経緯

- ESA—EUSO
 - ESA 採択 2000;
 - NASA 採択 2003;
 - Phase-A 完了 2004
 - 地上公募研究: 1998 - 2001 2002 - 2004
- 2006年6月:
 - JEM-EUSO WGが宇宙理学委員会において承認ISAS/JAXA
- 2006年8月:
 - JEM-EUSO計画化委員会が理研中央研究所に設置
- 2006年11月:
 - 第二期利用ミッション候補公募開始
- 2007年2月:
 - 理研から提案書提出
- 2007年5月:
 - 採択の正式通知
- 2007年6月
 - Kick-Off会合
 - 国際アドバイザーボード会合
- 2007年7月
 - 第一回国際JEM-EUSO会合(国際宇宙線会議@メキシコ)

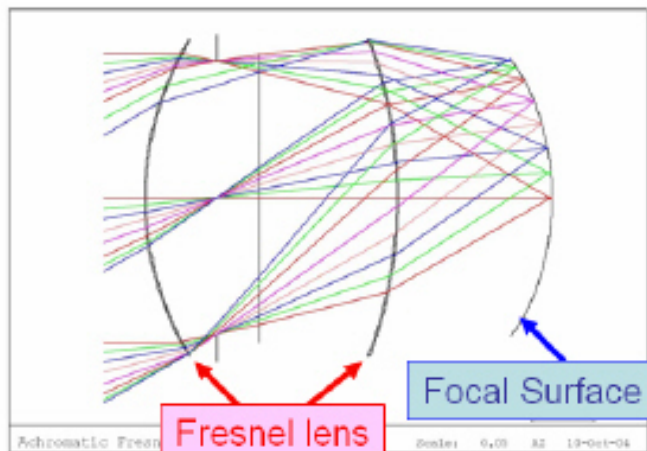
これからの予定

- 2007年度－2008年度(準備研究・概念設計)
 - 2007年10月 曝露部分科会へ報告
 - 2007年11月 国際JEM-EUSO会合
 - 2008年1月 国際アドバイザーボード会合
 - 2008年3月 国際シンポジウム開催
 - 2008年4月 中間評価
 - 2009年3月 最終評価
- 2009年度－2012年度
 - 製作段階
- 2013年 打ち上げ

日本実験棟「きぼう」

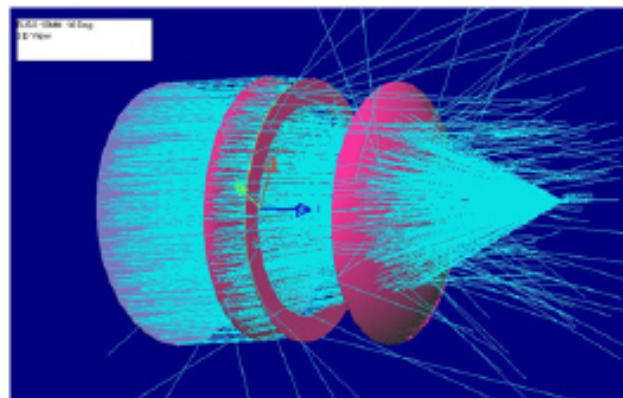


CYTOPを用いた新光学系



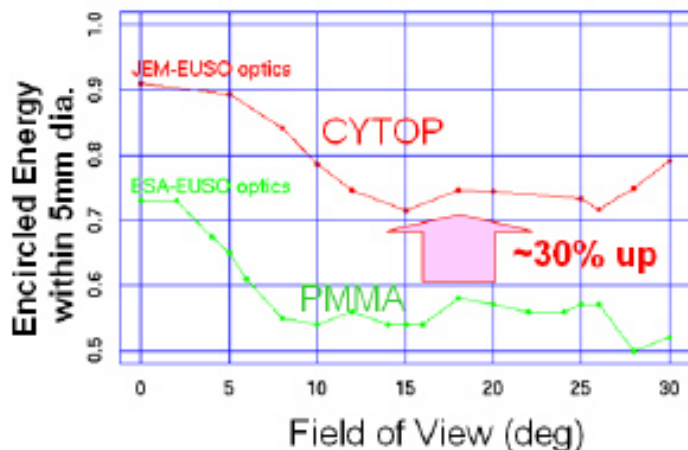
Optics Requirements

- FoV $\pm 30^\circ$
- Pupil entrance pupil ≥ 2 m
- $F/\# \leq 1.0$
- Spot dimension $\sim 0.1^\circ$ (5mm Φ)
- Spectral range 330-400 nm

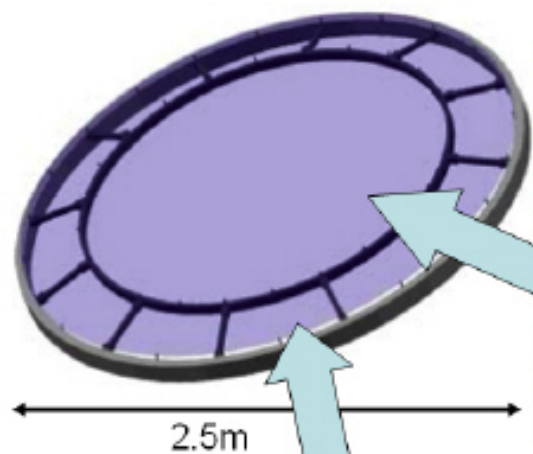


Ray trace

JEM-EUSO vs ESA-EUSO optics



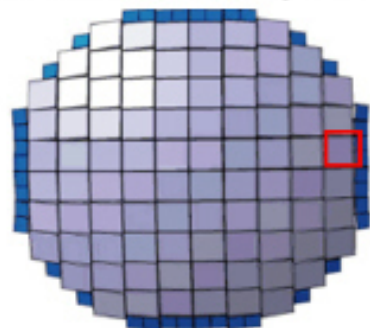
フレネルレンズ製作



JEM-EUSO 焦点面の構造

Focal Surface detector

(164PDMs = 0.2M pixels)



2.26 m max

Elementary Cell

(2x2 PMTs = 144 pixels)

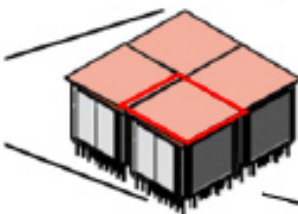
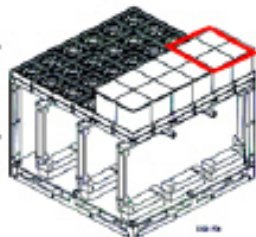


Photo-Detector Module

(3x3 ECs = 1296 pixels)



MAPMT
(6x6 pixels)

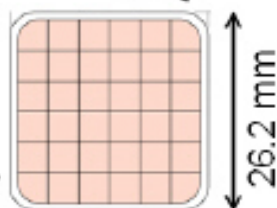


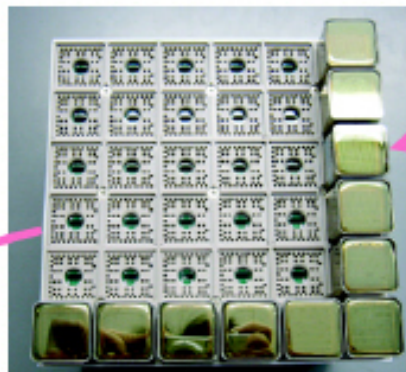
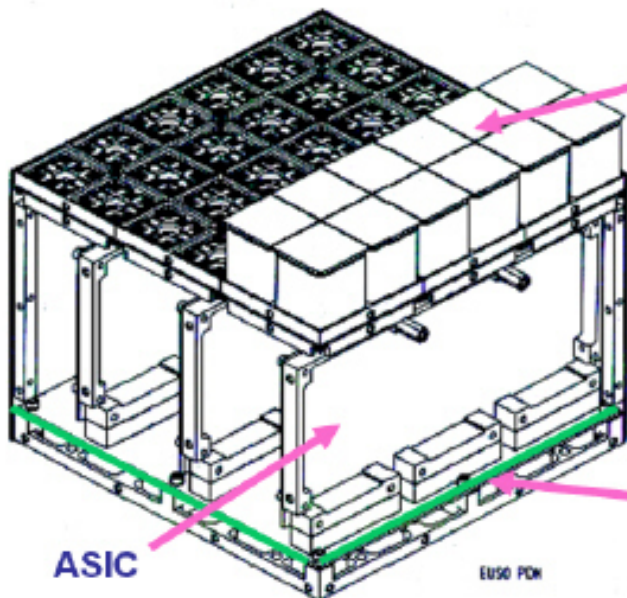
Photo Detector Module (PDM)

- 9 Elementary Cell (EC), 1 HV module, 9 HV divider

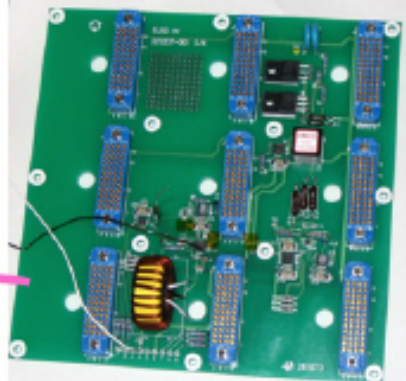
✓ 構造解析と振動試験 (済)

✓ 放射線試験 (済)

✓ 大光量保護回路 (済)

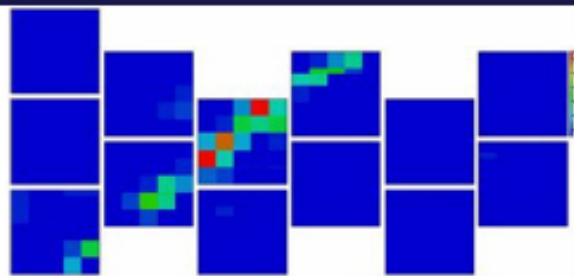


MAPMT
36PMTx36ch

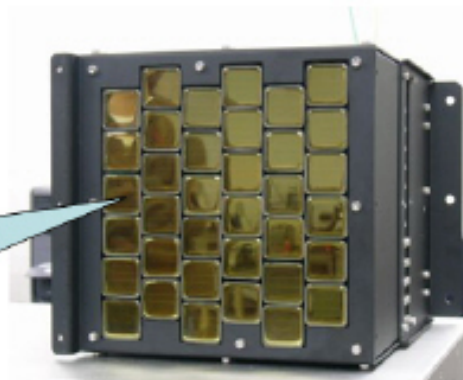
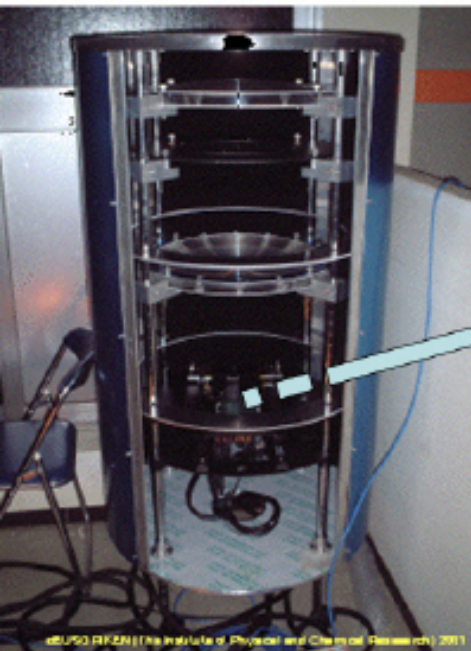


HV board

Progress: 小さなEUSOを製作

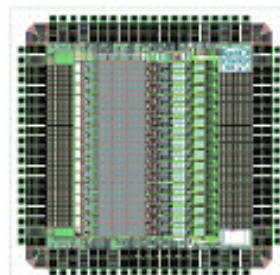


40cm Diameter



**ASIC
by Ikeda**

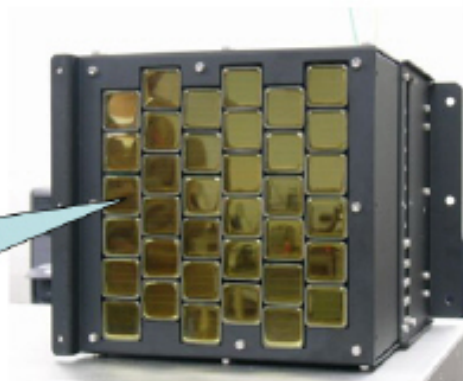
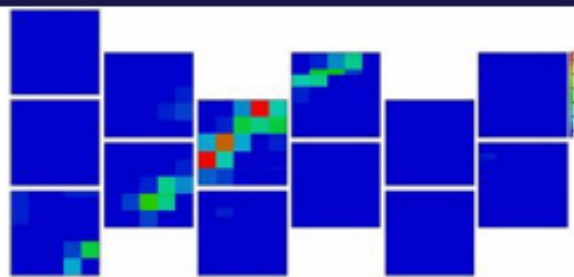
Prototype PDM



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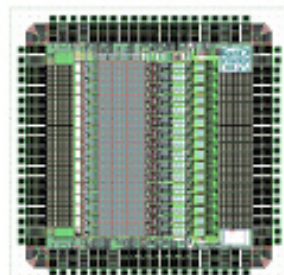
UV Laser

40cm Diameter

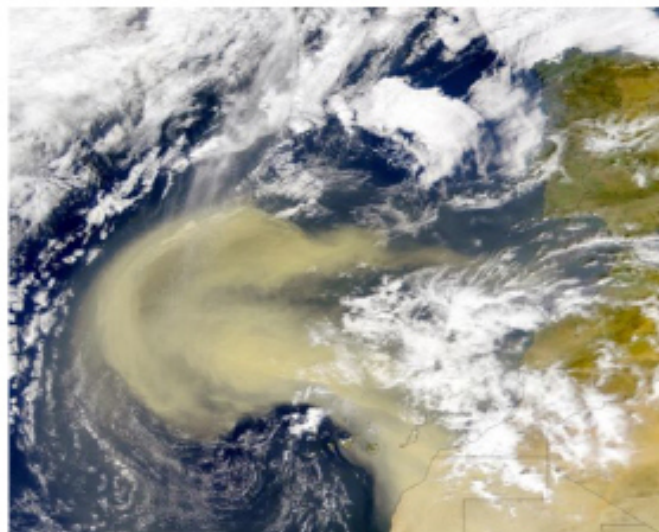


Prototype PDM

ASIC
by Ikeda



■ *The real atmosphere – clouds and desert dust*



Sahara dust over the Atlantic on 26.2.2000

Atmospheric Monitoring System

- **IR Camera**

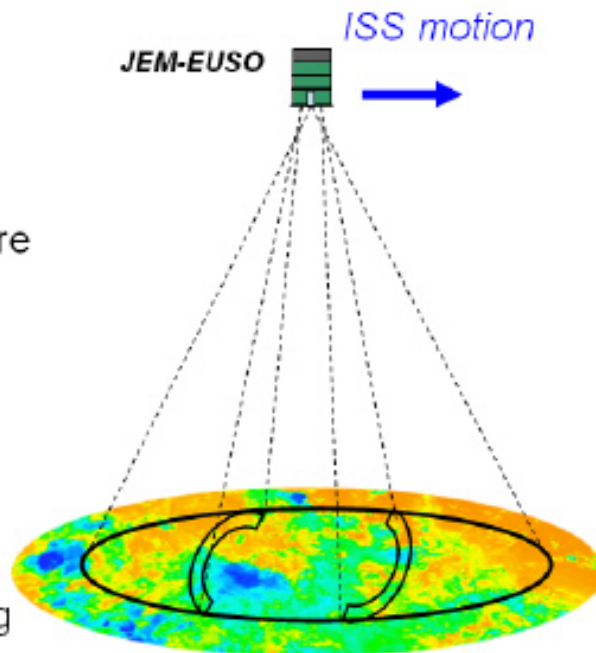
Imaging observation of cloud temperature inside FOV of JEM-EUSO

- **Lidar**

Ranging observation using UV laser

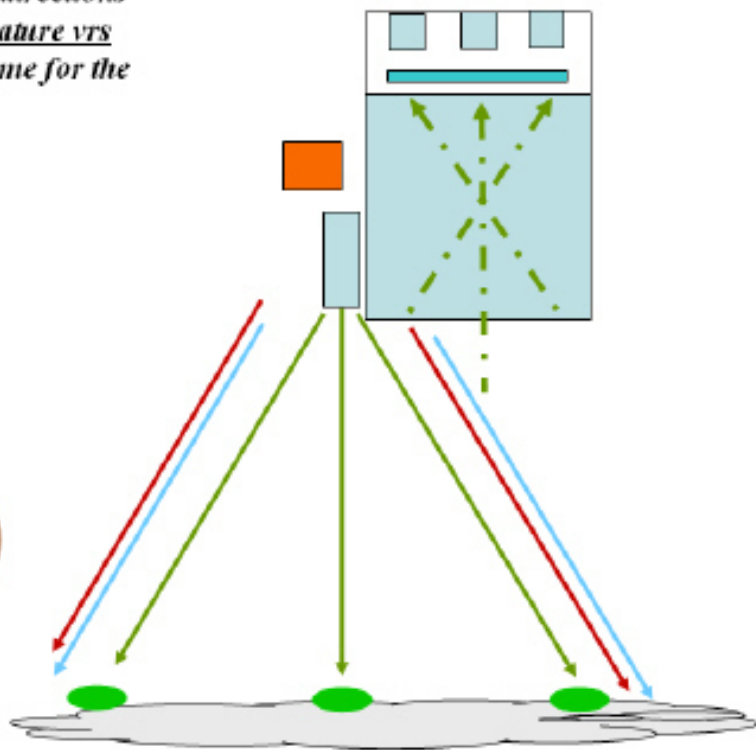
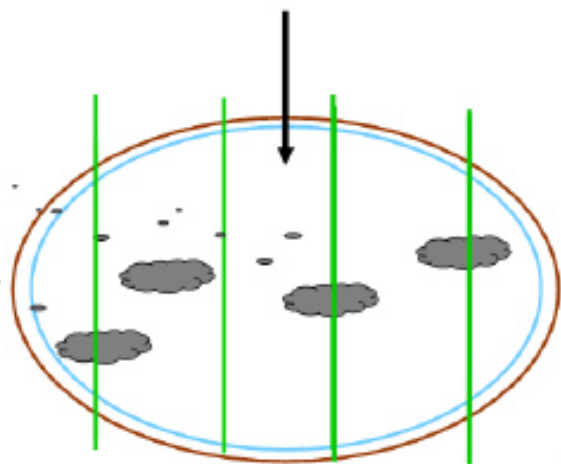
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Continuous background photon counting



- *Cloud amount, cloud top altitude:* (IR cam., Lidar, slow-data)
- *Airglow:* (slow-data)
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*Using the measurements in these three-four directions
for calibration of the IR radiometer temperature vrs
cloud top altitude – Reference lines ; the same for the
UV « slow mode »*



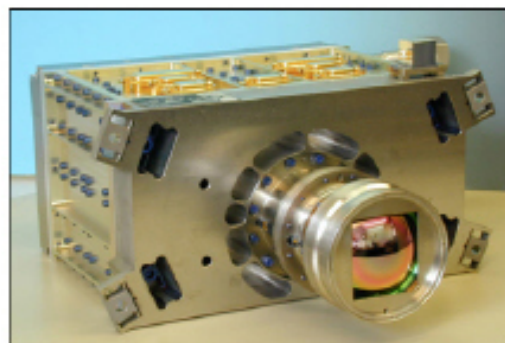
IR Camera

Requirement

Item	Value	Reason
Wavelength	10 – 13 μ m	Atmospheric transmission, S/N
FOV	> 60°	Same FOV as JEM-EUSO
Spatial Resolution	0.25°	1.8 km/pix @ nadir
Observation Temperature Range	200 – 320 K	Cloutop temperature in troposphere
Absolute Temperature Resolution	< 3 K	Altitude resolution < 500m
IR Sensor	Uncooled Microbolometer Array	Mass, Power
Exposure Time	133 msec	ISS motion within $\frac{1}{2}$ - pix of IR camera
Observation Interval	30 sec (5 sec TBC)	ISS motion of JEM-EUSO $\frac{1}{2}$ FOV

IR Camera Development with EADS/SODERN

CIM01 (or IASI) onboard METOP1 satellite



IASA Specification

- Scanning Mirror
- Sensor (CIM01)

λ : 10.3 - 12.5

μm

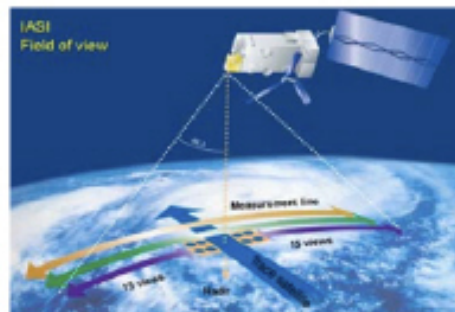
sensor: bolometer array

pix. size: 64×64

res.: 12 bit

FOV: 60×60 mrad

NETD : <80 mK



IR Camera Development with EADS/SODERN

Major Change from CIM01 to JEM-EUSO IR Camera

(1) Pixel size of detector

"64 × 64" → "320 × 240"
Boeing U3000A (320x240)

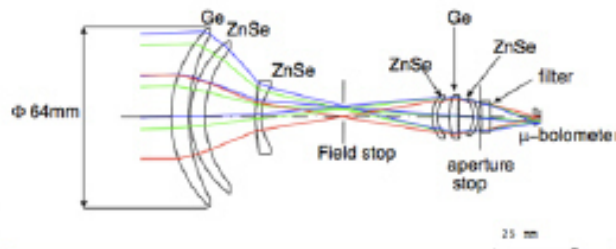
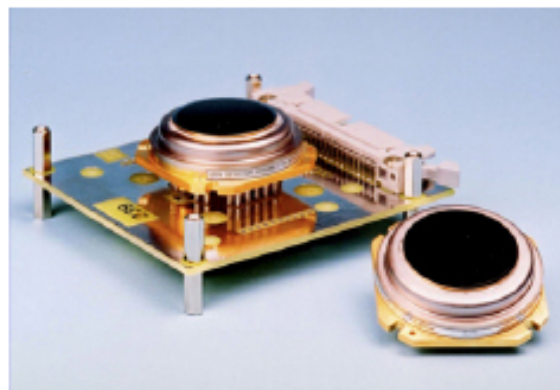
(2) FOV

Line scanning → >60°

Based on CIM01 design, they can produce FM of JEM-EUSO IR camera with 5.5MEuro within 5 years.

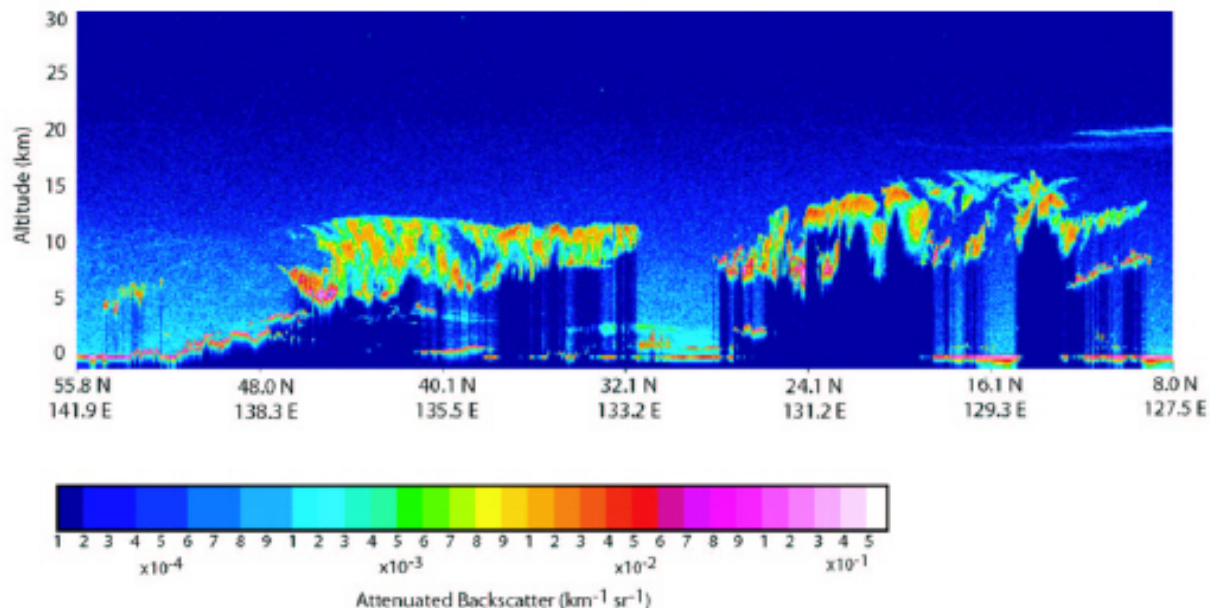
Specification of IR Camera

Should be determined before 12E, 2007



Lidar

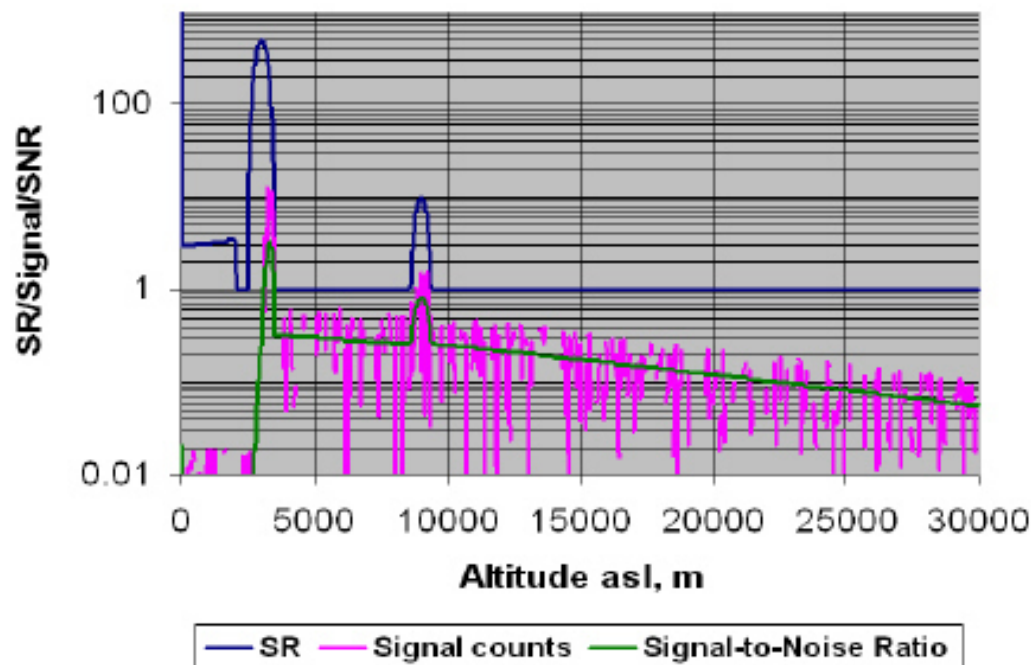
Another spaceborne lidar– first CALIPSO results (#2)



Performance simulations, #1: Subsystems

Subsystem		Lidar 1	Lidar 2
Transmitter	Wavelength, nm	355	532
	Pulse repetition rate, pps	100	100
	Averaged transmitted power, W	1	1
	Divergence full angle, mrad	0.08	0.08
	Optical efficiency	80	80
Receiver	Primary receiver aperture diam, cm	250	250
	Secondary mirror aperture, cm	0	0
	Field of View full angle, mrad	0.2	0.2
	Interference filter, FWHM	0.25	0.25
	Interference filter, transmission %	50	50
	Optical efficiency (without filter)	25	25
Detector	Quantum efficiency, %	25	25
	Dark noise, counts per second	500	500
Acquisition (ph. counting)	Range resolution, bin meters	30	30
	Integration time, sec	0.01/1	0.01/1
Satellite	Altitude, km	500	500

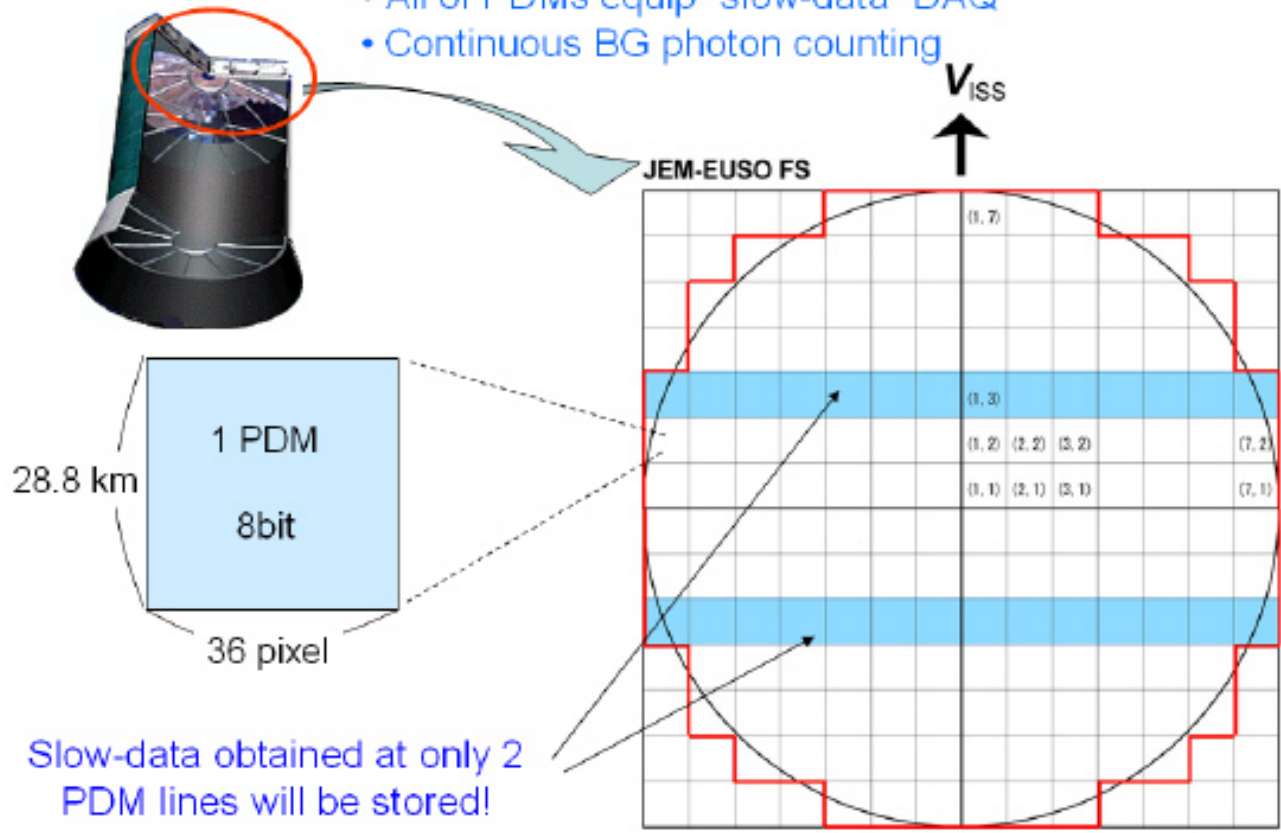
Performance simulations, #3:



results for
355nm, 0.01sec
integration time,
30m range
resolution

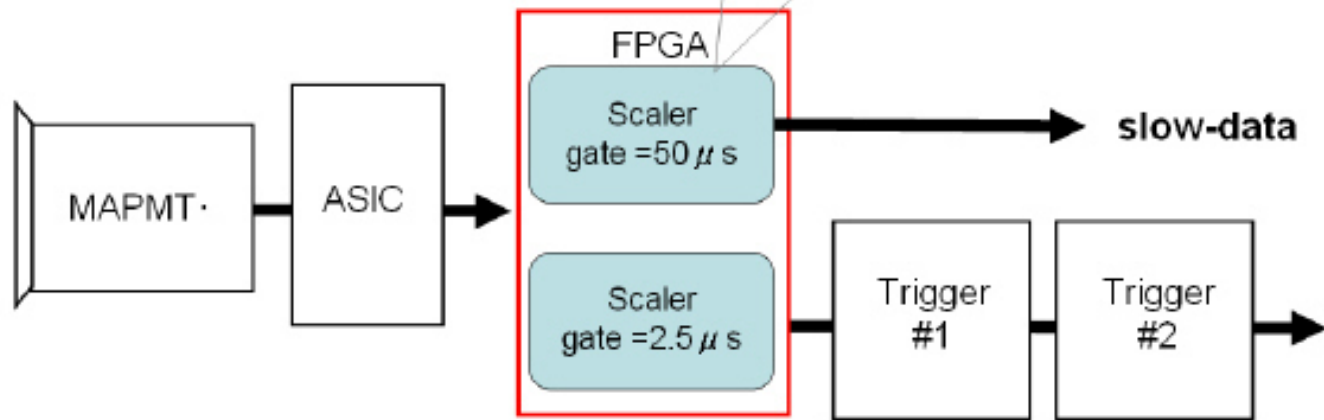
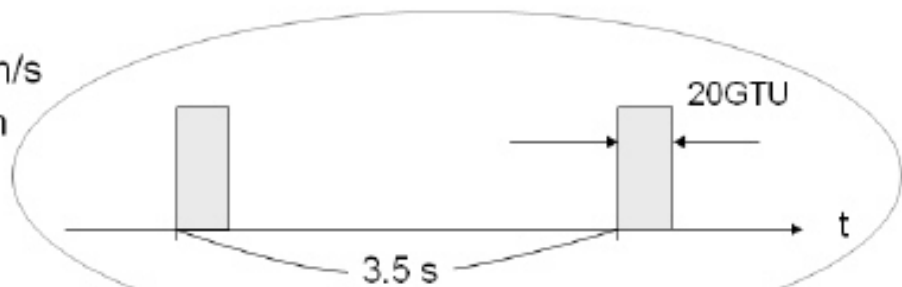
Slow-Data

- All of PDMs equip "slow-data" DAQ
- Continuous BG photon counting

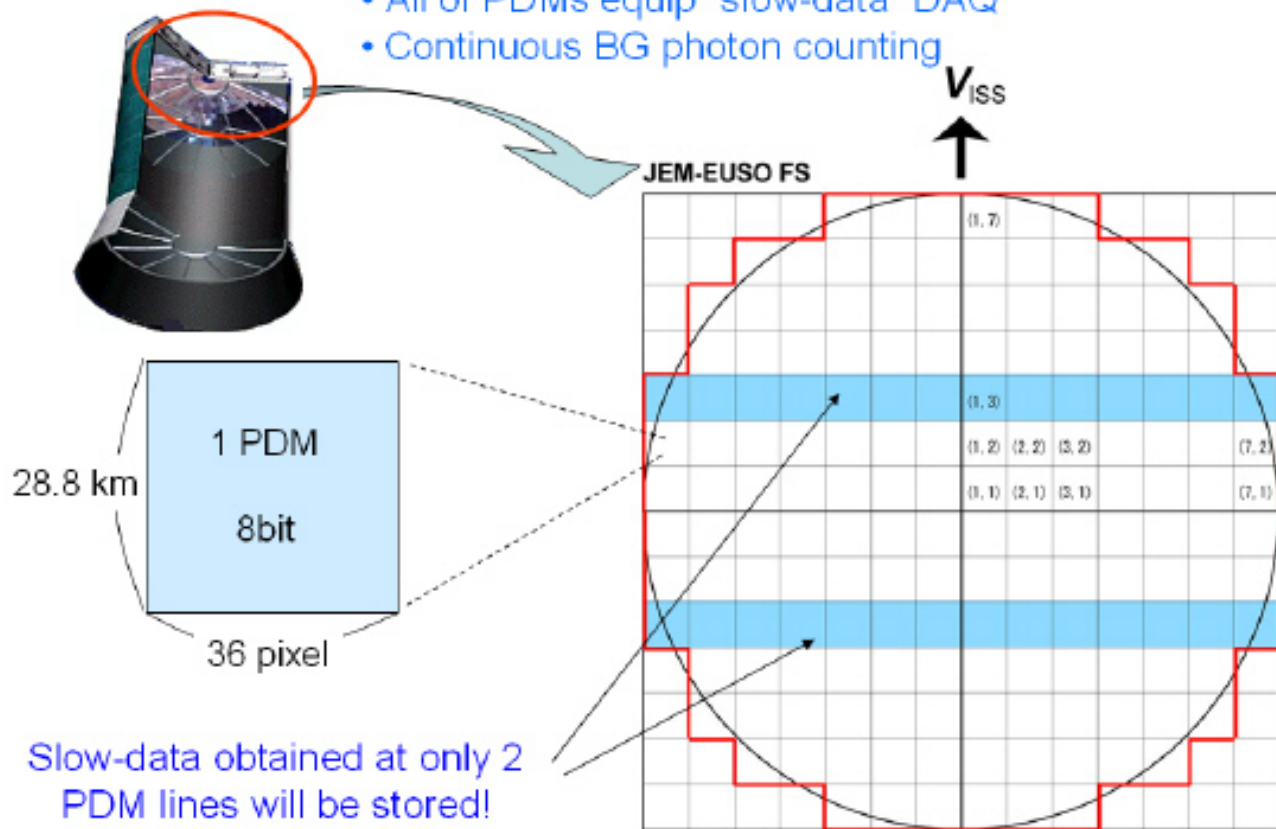


Slow-data obtained at only 2 PDM lines will be stored!

- Velocity of ISS: 7.9 km/s
- FOV of 1PDM: 28.8 km

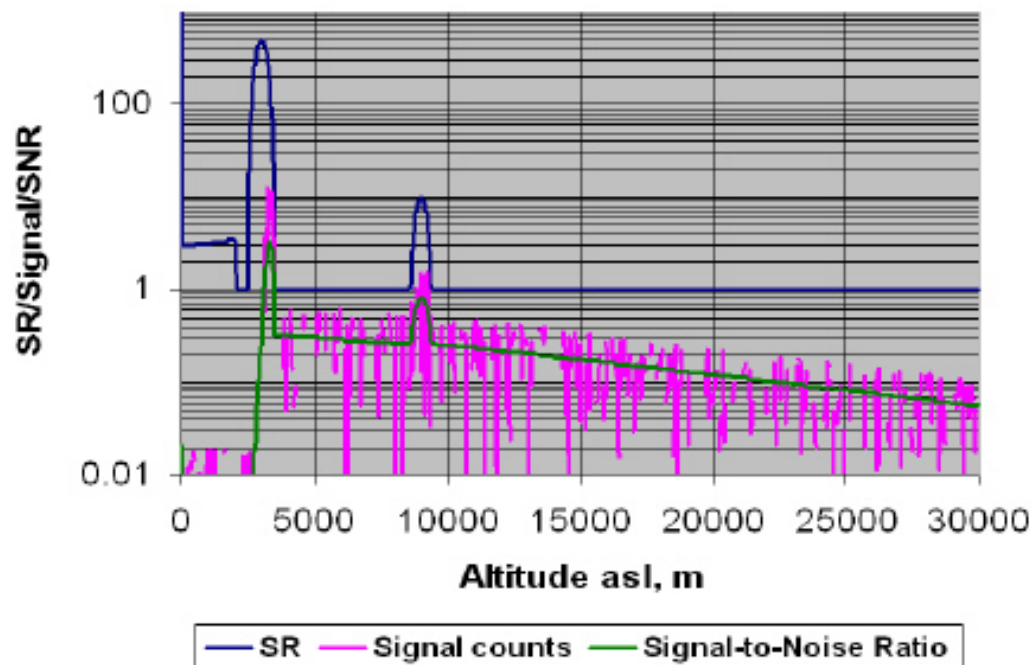


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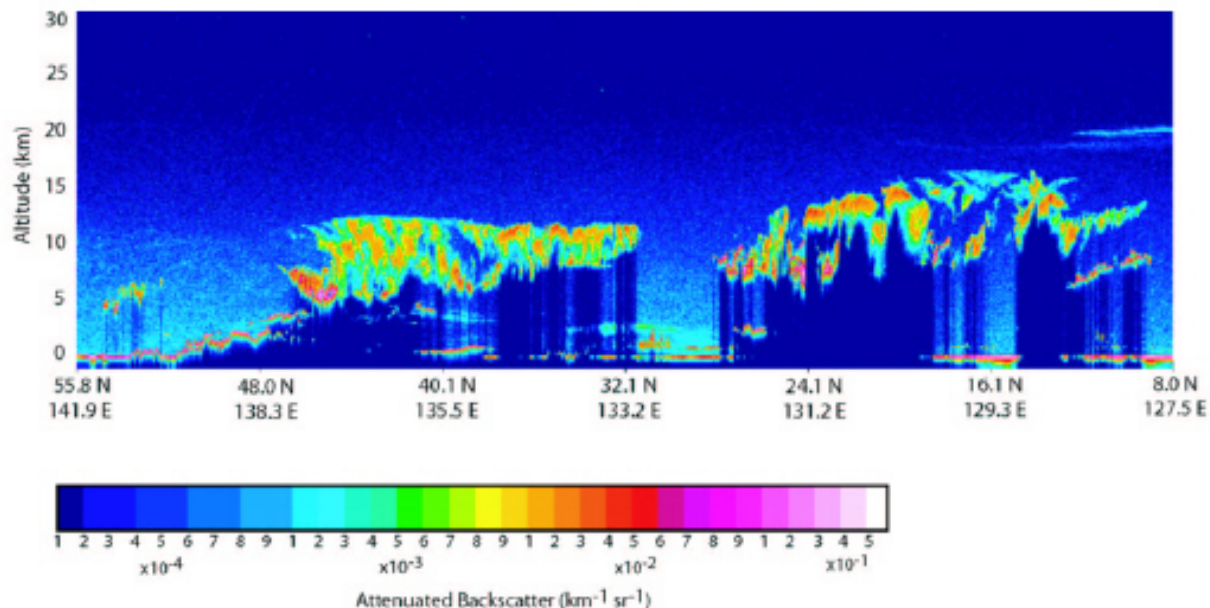


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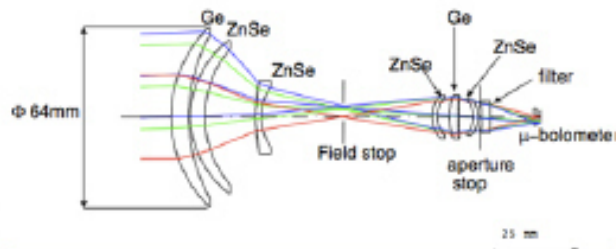
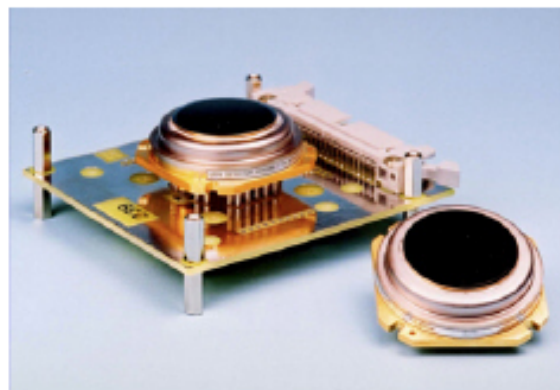
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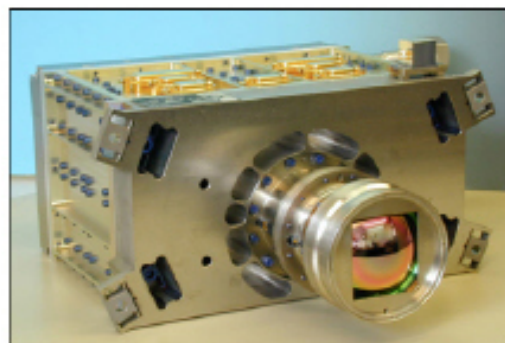
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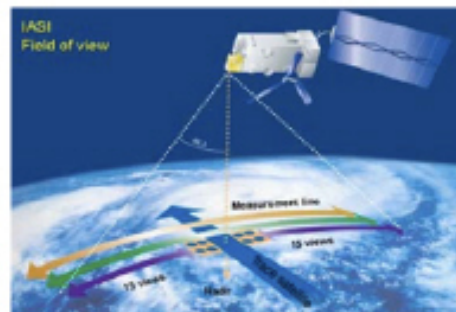
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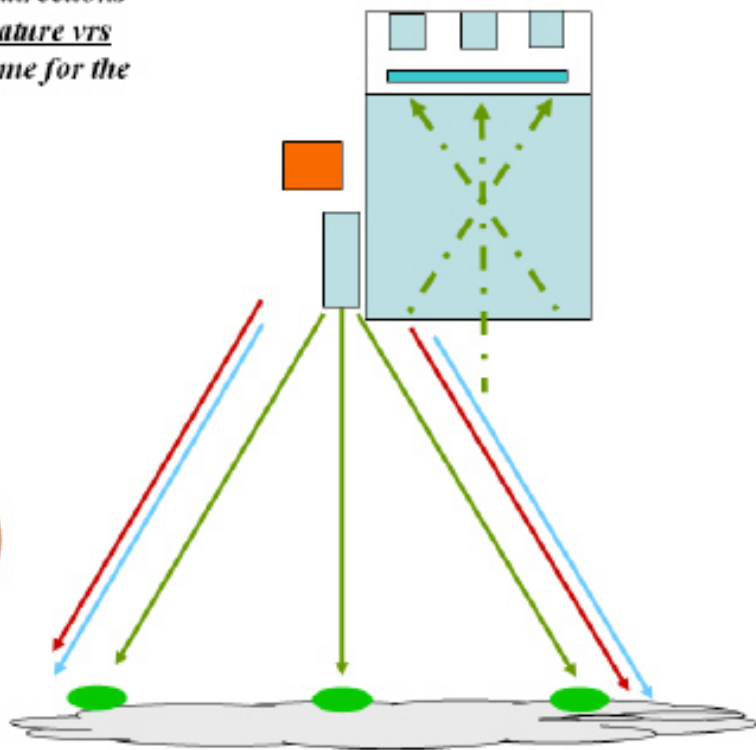
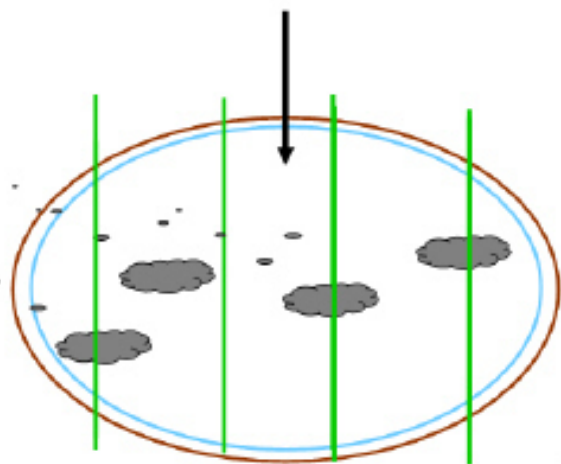


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Atmospheric Monitoring System

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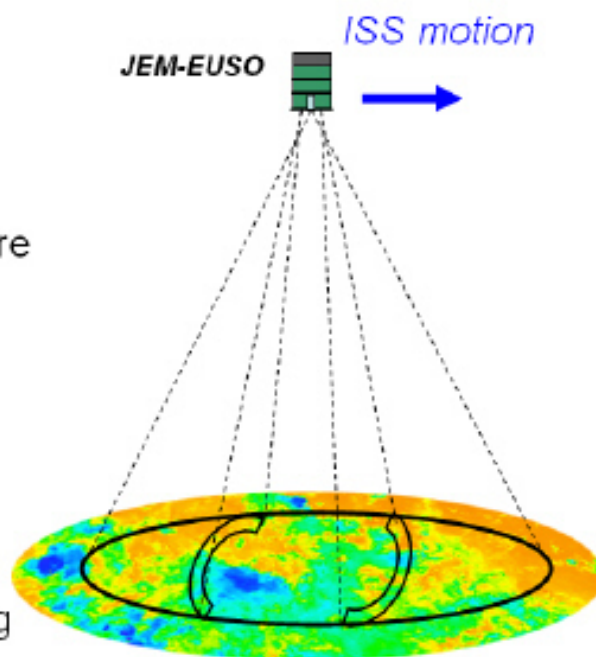
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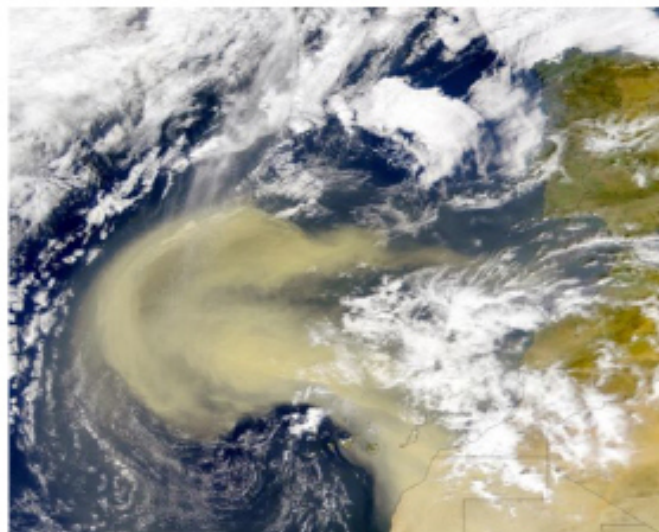
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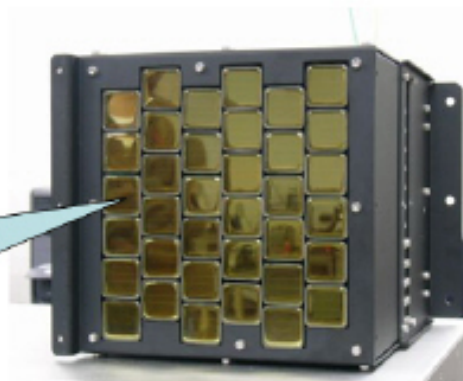
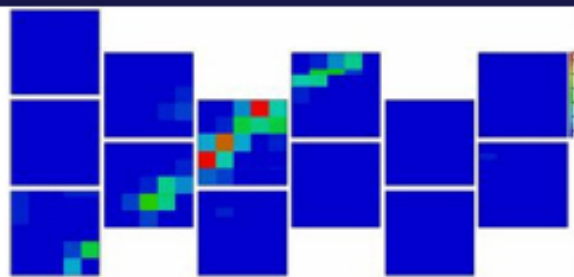


Sahara dust over the Atlantic on 26.2.2000

Progress: 小さなEUSOを製作

UV Laser

40cm Diameter



Prototype PDM

**ASIC
by Ikeda**

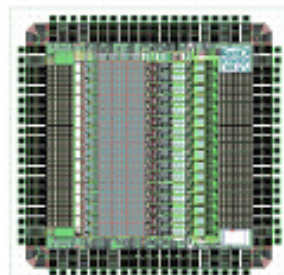


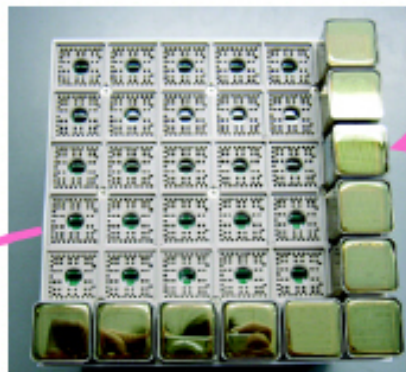
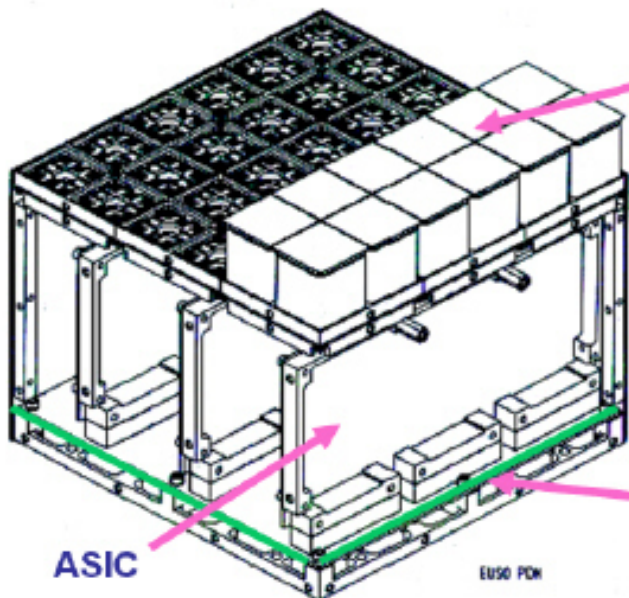
Photo Detector Module (PDM)

- 9 Elementary Cell (EC), 1 HV module, 9 HV divider

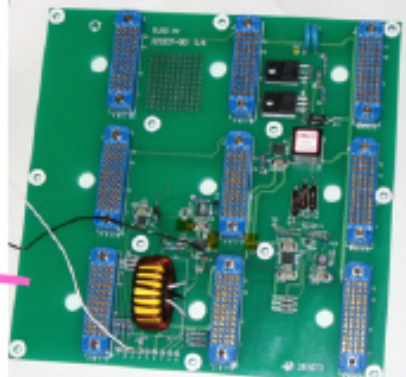
✓ 構造解析と振動試験 (済)

✓ 放射線試験 (済)

✓ 大光量保護回路 (済)



MAPMT
36PMTx36ch

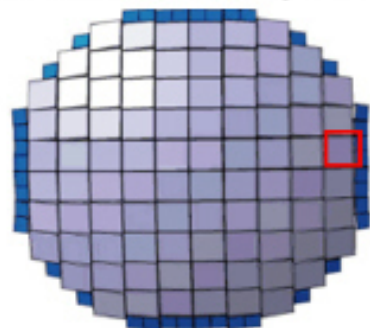


HV board

JEM-EUSO 焦点面の構造

Focal Surface detector

(164PDMs = 0.2M pixels)



2.26 m max

Elementary Cell

(2x2 PMTs = 144 pixels)

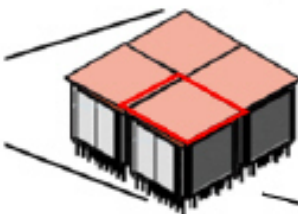
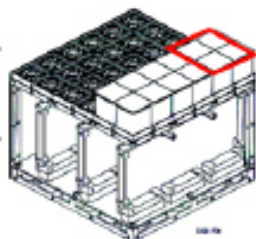
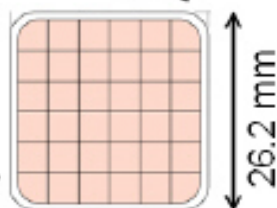


Photo-Detector Module

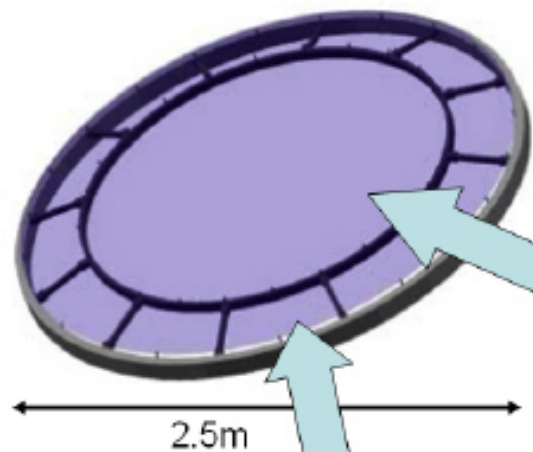
(3x3 ECs = 1296 pixels)



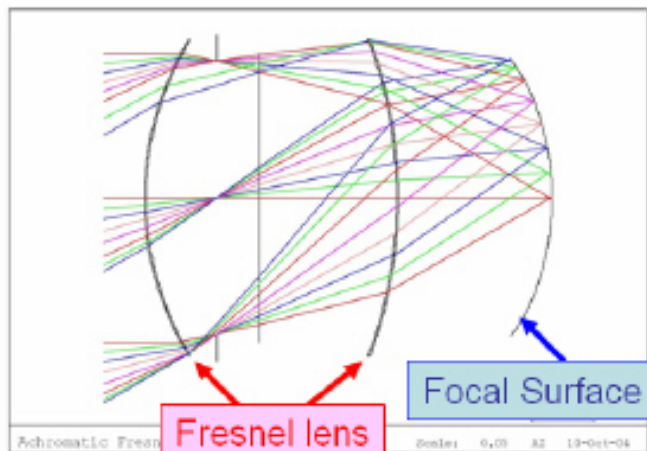
MAPMT
(6x6 pixels)



フレネルレンズ製作

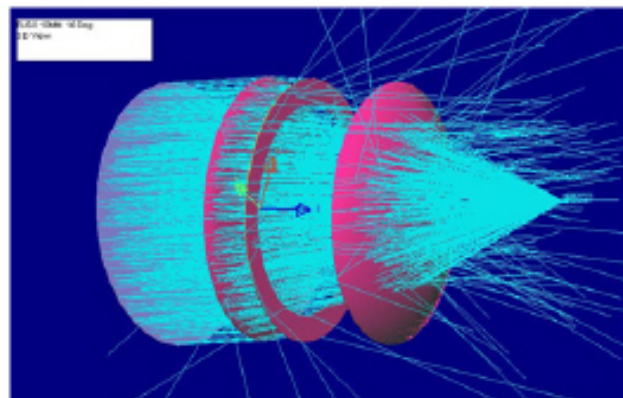


CYTOPを用いた新光学系



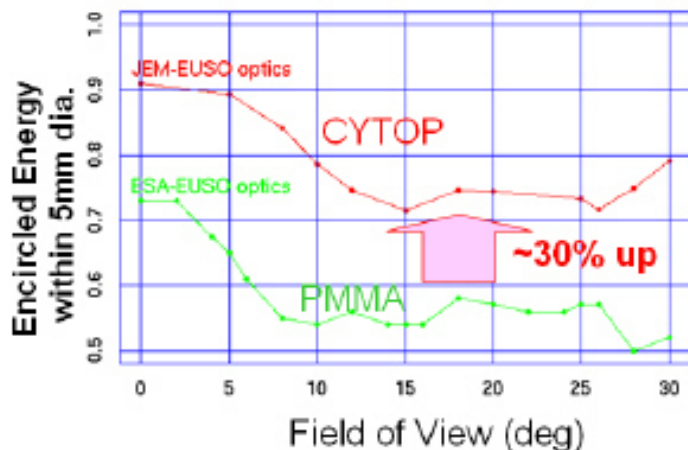
Optics Requirements

- FoV $\pm 30^\circ$
- Pupil entrance pupil ≥ 2 m
- $F/\# \leq 1.0$
- Spot dimension $\sim 0.1^\circ$ (5mm Φ)
- Spectral range 330-400 nm

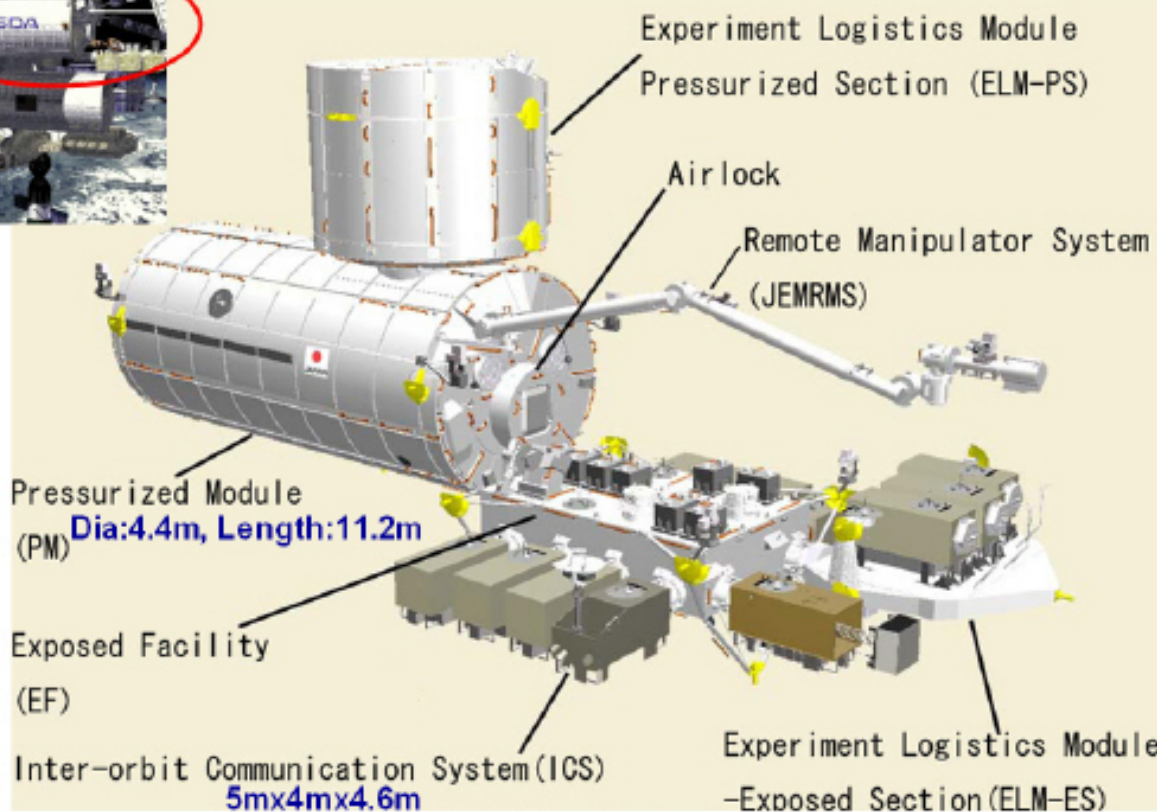
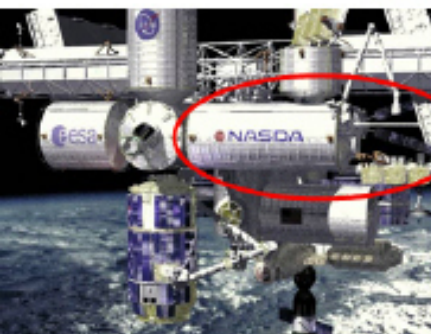


Ray trace

JEM-EUSO vs ESA-EUSO optics



日本実験棟「きぼう」



これからの予定

- 2007年度－2008年度(準備研究・概念設計)
 - 2007年10月 曝露部分科会へ報告
 - 2007年11月 国際JEM-EUSO会合
 - 2008年1月 国際アドバイザーボード会合
 - 2008年3月 国際シンポジウム開催
 - 2008年4月 中間評価
 - 2009年3月 最終評価
- 2009年度－2012年度
 - 製作段階
- 2013年 打ち上げ

これまでの経緯

- ESA—EUSO
 - ESA 採択 2000;
 - NASA 採択 2003;
 - Phase-A 完了 2004
 - 地上公募研究: 1998 - 2001 2002 - 2004
- 2006年6月:
 - JEM-EUSO WGが宇宙理学委員会において承認ISAS/JAXA
- 2006年8月:
 - JEM-EUSO計画化委員会が理研中央研究所に設置
- 2006年11月:
 - 第二期利用ミッション候補公募開始
- 2007年2月:
 - 理研から提案書提出
- 2007年5月:
 - 採択の正式通知
- 2007年6月
 - Kick-Off会合
 - 国際アドバイザーボード会合
- 2007年7月
 - 第一回国際JEM-EUSO会合(国際宇宙線会議@メキシコ)

ミッション諸元

- 打ち上げ時期: year 2013
- 運用期間: 3 years (+ 2 years)
- 打ち上げロケット: H2B
- ISSへの運搬: HTV非与圧キャリア
- 装着場所: JEM EFU#2
- 軌道高度: ~430km
- 軌道傾斜角: 51.6°
- 質量: 1896 kg
- 使用電力: 998 W (operative),
344 W (non-operative)
- データ転送量: 297 kpbs

サクセスクライテリア

フルサクセス:

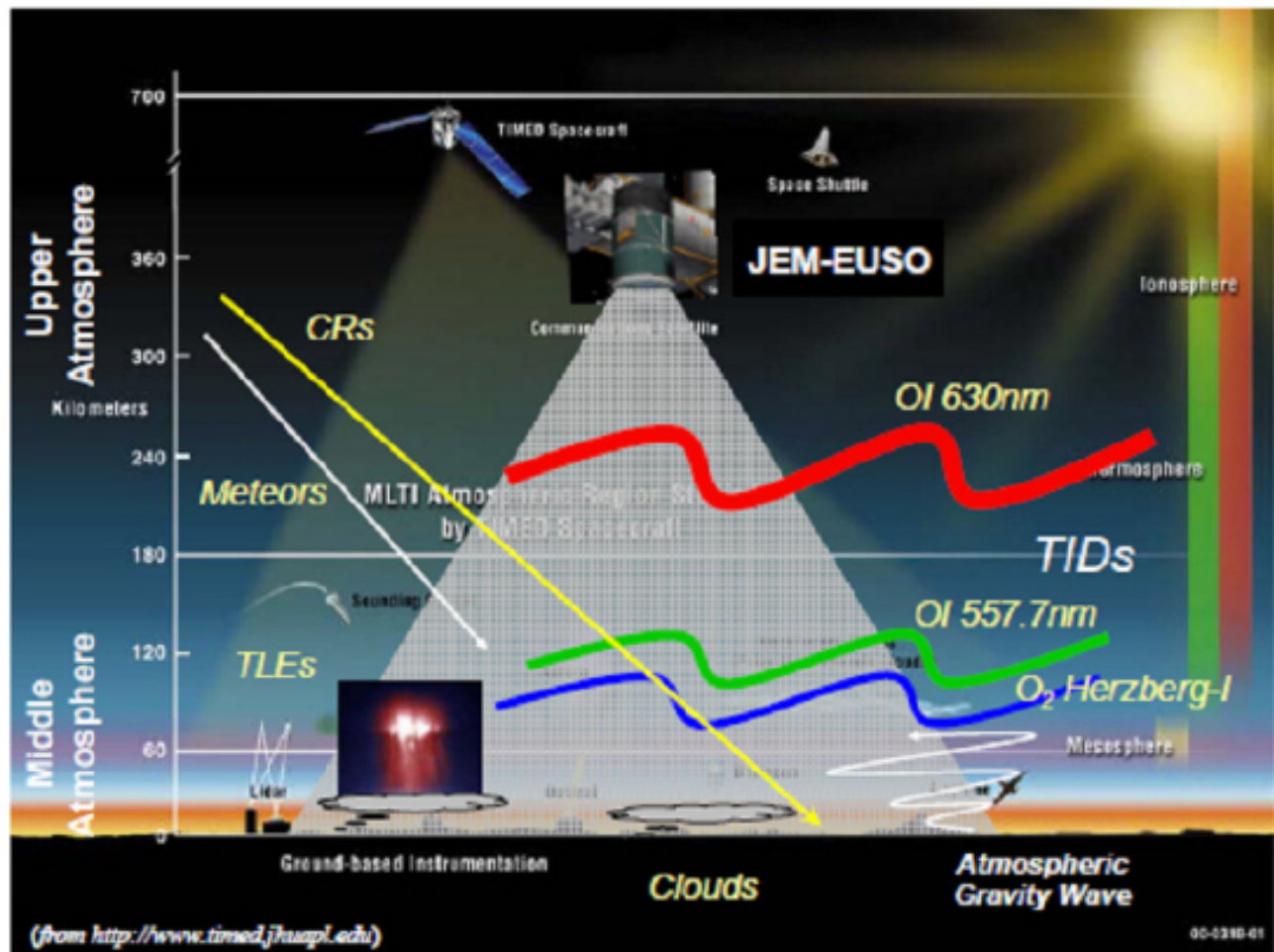
極限エネルギー事例: 1000個以上
(7×10^{19} eV 以上)

ミニマムサクセス:

フルサクセスの半分の事例数を得る: 500個

分布から起源を議論の余地なく特定できる臨界量

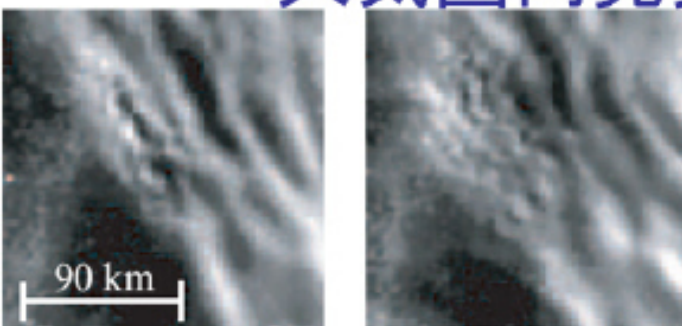
- 粒子到来方向解析
 - 到来方向決定精度: 2.5度以下
- スペクトル解析
 - エネルギー決定精度: 30%以下
- ハドロン／光子／ニュートリノの識別:
 - シャワー最大深さ決定精度: 120 g/cm^2 以下



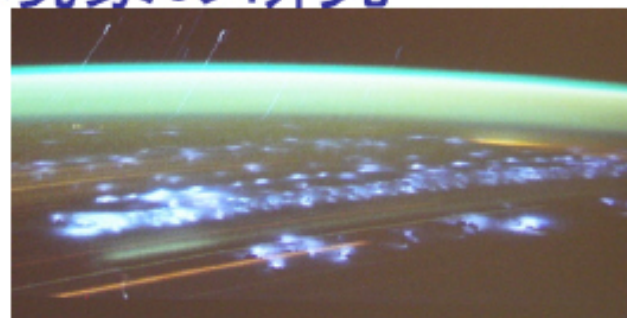
JEM-EUSOによる大気圏科学

- 雷放電とTLE
 - 雷放電・TLEの鉛直・超高速撮像@近紫外線
 - TLEの全球サーベイ
- 夜光とプラズマバブル
 - 酸素分子Hertzburg I帯夜光の全球撮像
 - プラズマバブルの形成メカニズムと
 - 高層大気における物質・エネルギー・運動量輸送
- 雲
 - 雲頂高度の全球観測
- 流星

探求的試験研究3: 大気圏内発光現象の研究



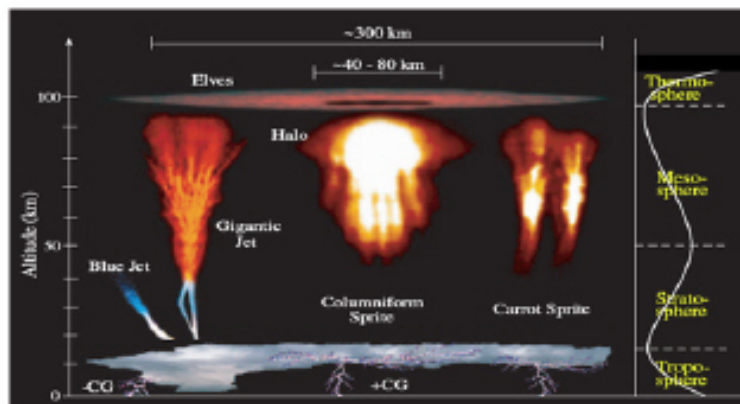
地上から観測したOH 大気光の変化



国際宇宙ステーションから連続撮影した雷光



ハイビジョンカメラによる
2001年のしし座流星群

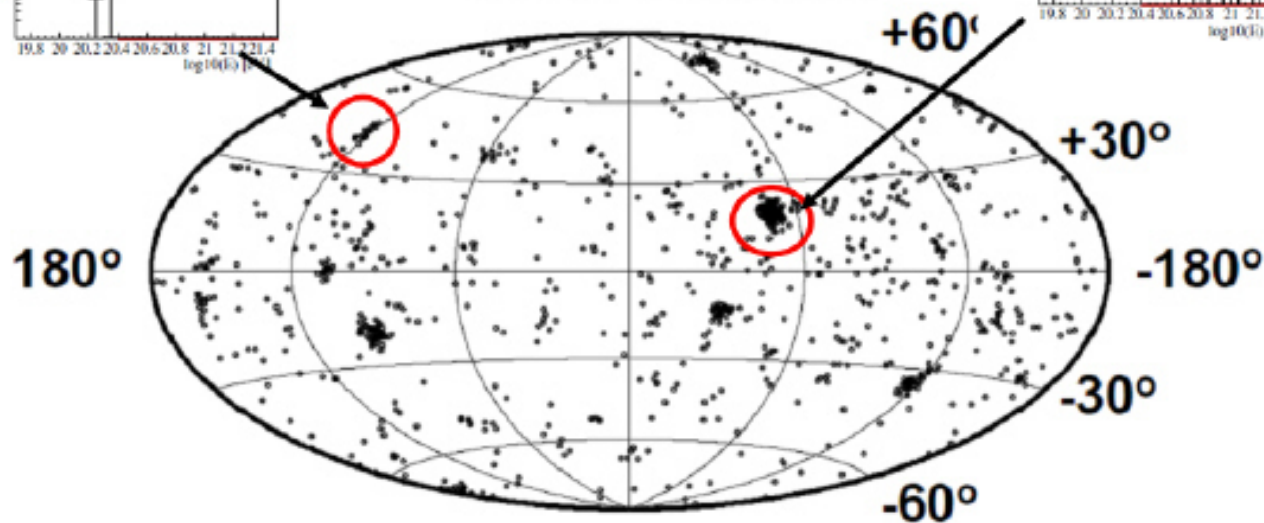
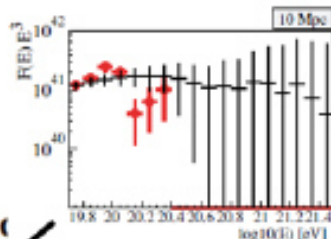
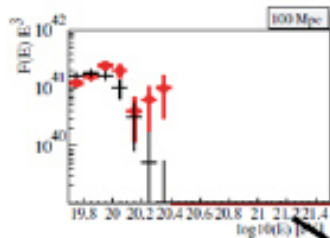


雷放電に伴う成層圏・中間圏・下部
熱圏でのトランジェントな発光現象

極限粒子天文学

1,000事象の場合の予測

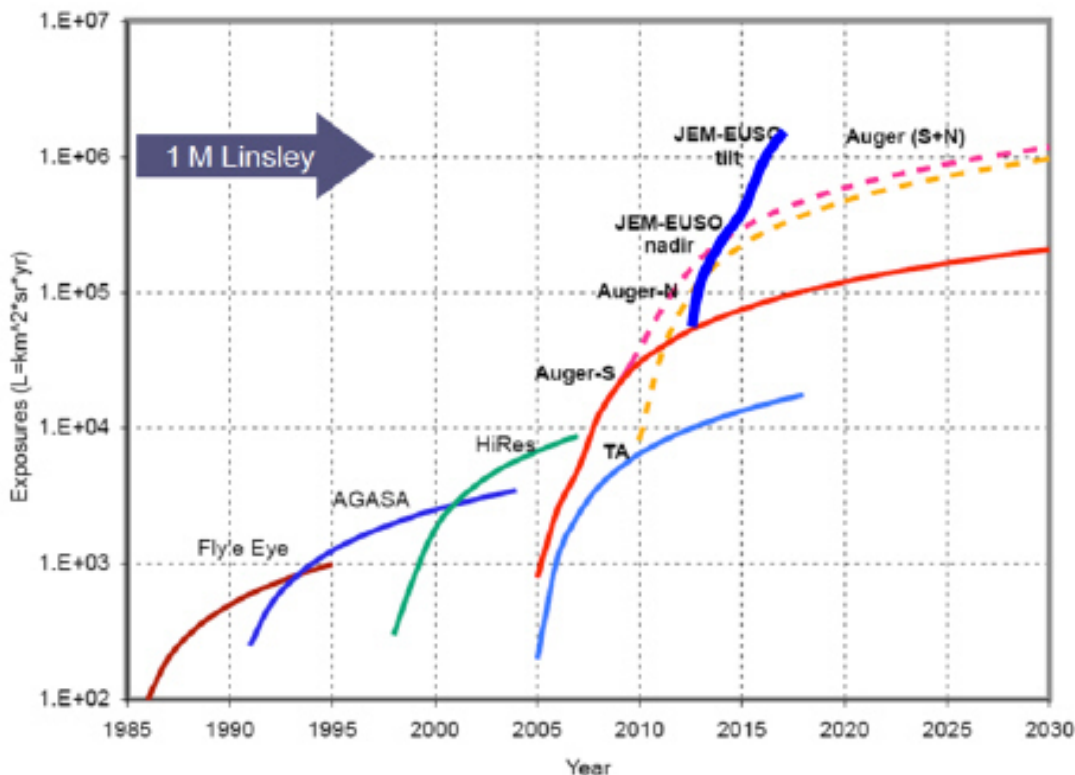
粒子光度 \propto X線光度 (AGN)



- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる

Takami 2008

有効露出の増加期待値

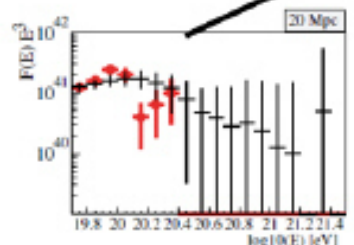
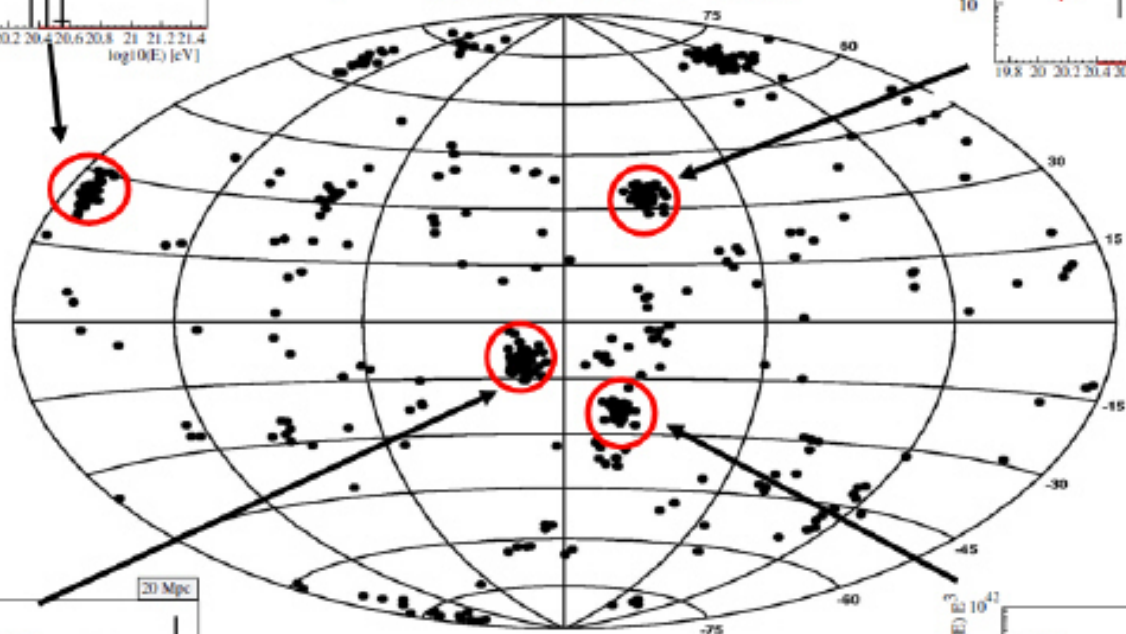
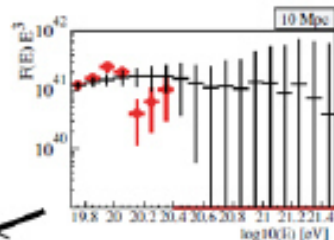
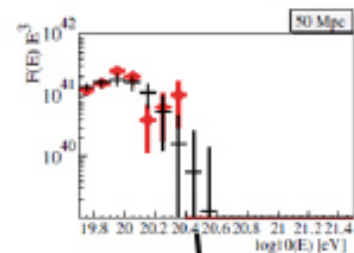


事例数: 5年間の運用 End-to-Endシミュレーション

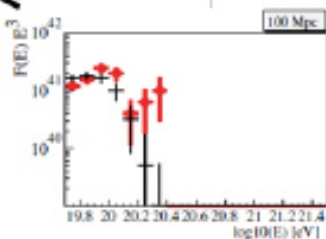
		$>7 \times 10^{19}$ eV	$>1 \times 10^{20}$ eV
2.65m ϕ 側方カット Case-C		1800	450
アドバン ストデザ イン Case-D	X2.2 (画素 微細化)	3600	680
	X2.8 (SiPM)	3800	710

極限粒子天文学

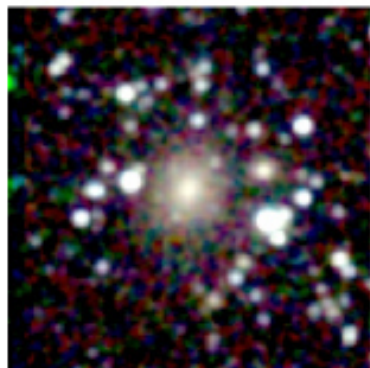
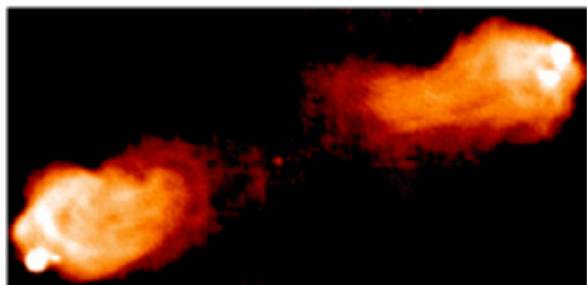
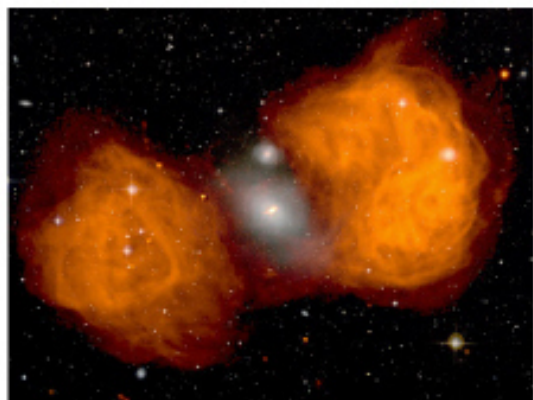
1,000事象の場合の予測



- 1,000事象以上 : $E > 7 \times 10^{19} \text{eV}$
- 数十のクラスターの発見が期待される
- 全天を観測することができる



他の電波銀河

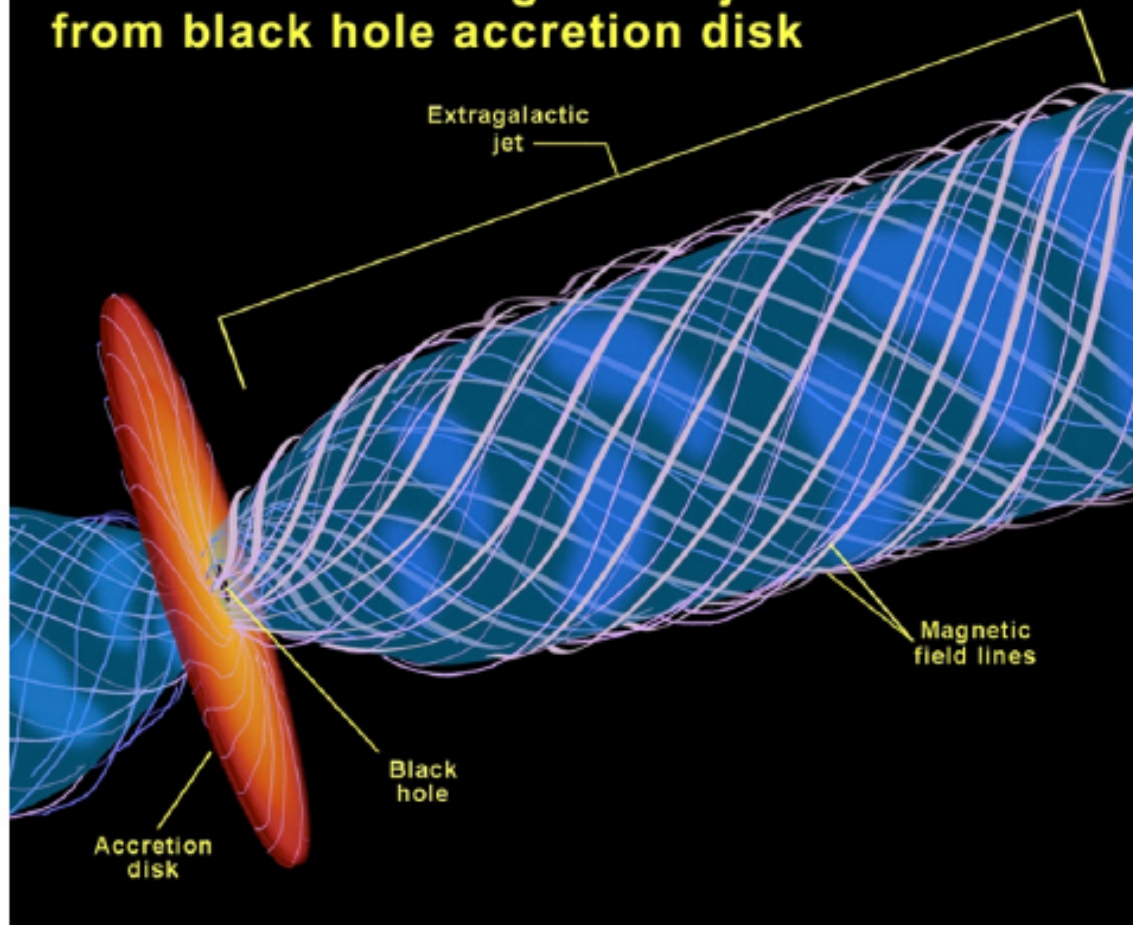


Fornax A

Cygnus A



Formation of extragalactic jets from black hole accretion disk



ケンタウルス座 A



- 距離: 3.4 Mpc
 - GZK機構は効かない
- 電波銀河
 - もっとも近い
 - 全天最も明るい電波星
- 楕円銀河ダークレーン
 - 最近ガスに富む渦巻銀河が落下
- 荷電粒子光度 ~ 電波光度
~ 2×10^{41} W

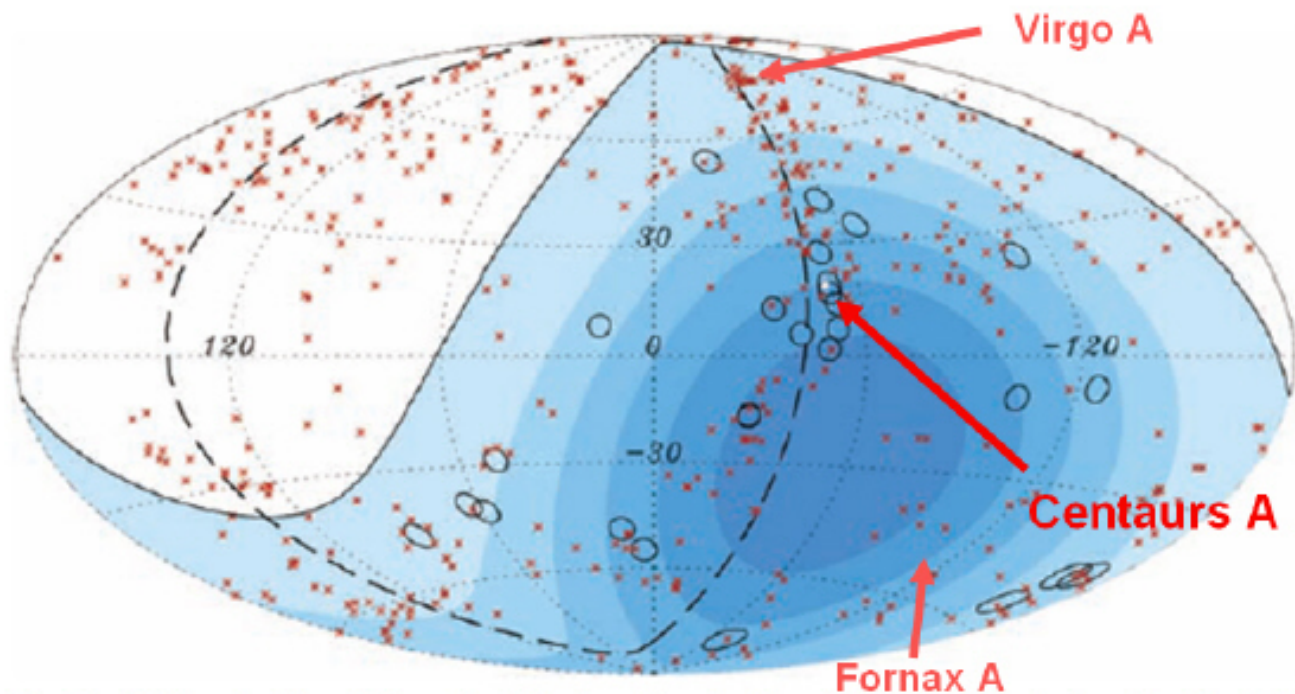
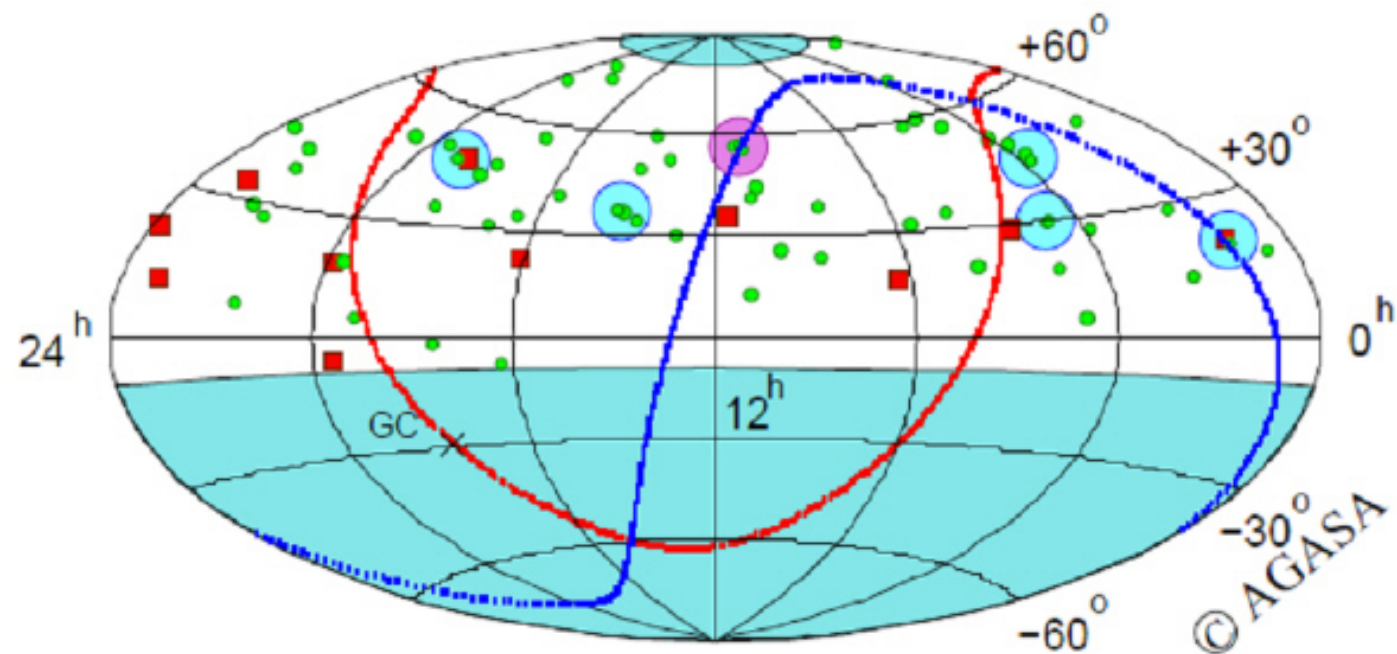
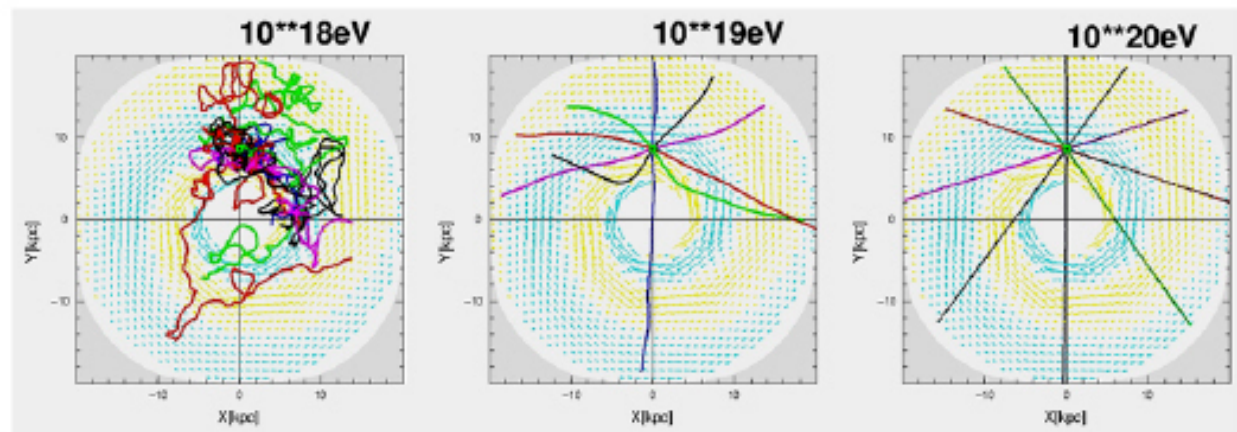


Fig. 2. Aitoff projection of the celestial sphere in galactic coordinates with circles of radius 3.1° centered at the arrival directions of the 27 cosmic rays with highest energy detected by the Pierre Auger Observatory. The positions of the 472 AGN (318 in the field of view of the Observatory) with redshift $z \leq 0.018$ ($D < 75$ Mpc) from the 12th edition of the catalog of quasars and active nuclei (12) are indicated by red asterisks. The solid line represents the border of the field of view (zenith angles smaller than 60°). Darker color indicates larger relative exposure. Each colored band has equal integrated exposure. The dashed line is the supergalactic plane. Centaurus A, one of our closest AGN, is marked in white.

Arrival Directions (AGASA)



$E > 10^{20}$ eV 粒子は曲がらない



銀河内の伝播シミュレーション

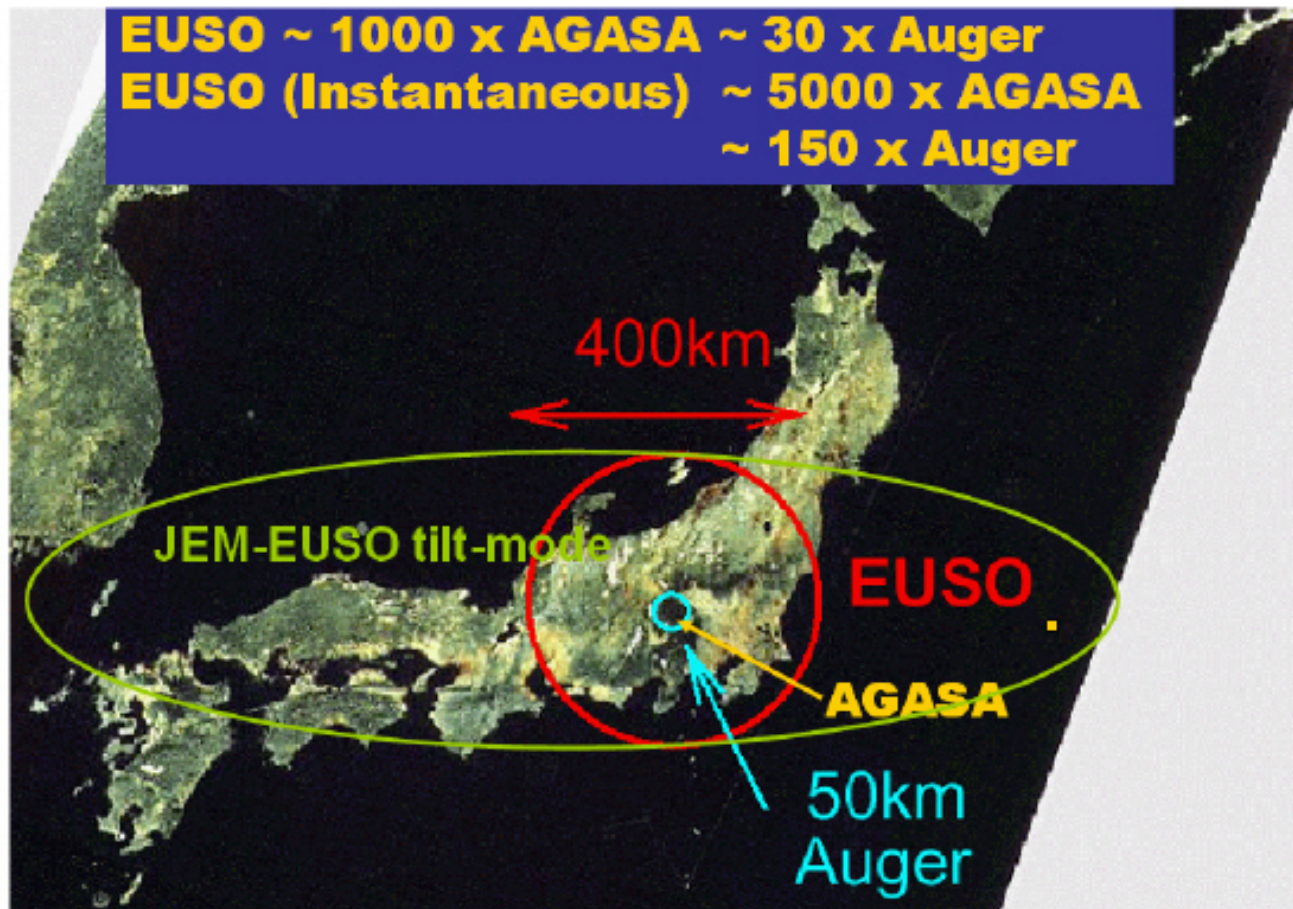
到来方向解析により起源天体を特定: 粒子天文学

科学目的

- 基本研究: 極限エネルギー—**粒子による新天文学**
 - 高統計到来方向解析による**起源天体**の同定
 - 個別天体からのエネルギースペクトル測定による**加速・放射機構**の検証
- 探求的試験研究
 - 極限エネルギー—**宇宙ガンマ線**の測定
 - 極限エネルギー—**宇宙ニュートリノ**の検出
 - **銀河磁場**の構造と強度の推定
 - **相対論、量子重力**効果の検証
 - **大気圏**発光現象の研究

EUSOの巨大な視野

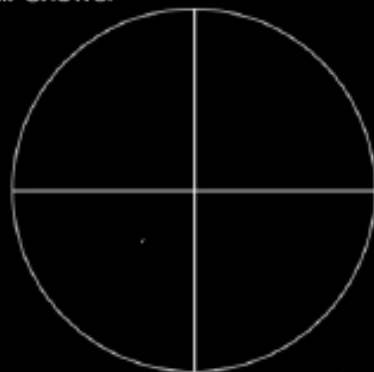
EUSO ~ 1000 x AGASA ~ 30 x Auger
EUSO (Instantaneous) ~ 5000 x AGASA
~ 150 x Auger



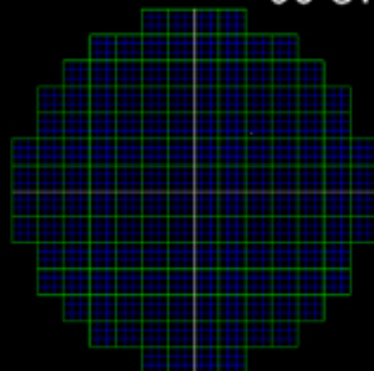


JEM-EUSOで見る空気シャワー

Air Shower

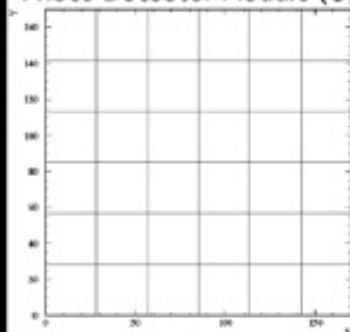


00 GTU

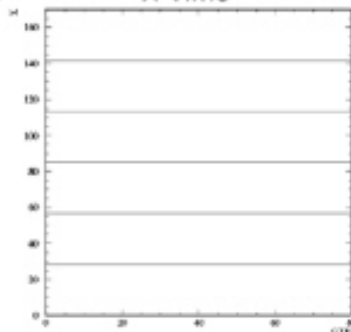


EUSO Focal Surface

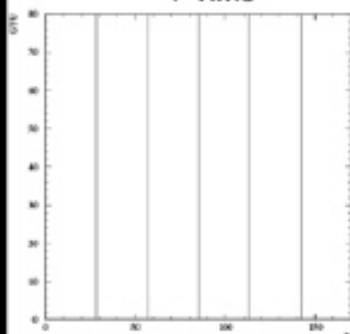
Photo Detector Module (3,3)



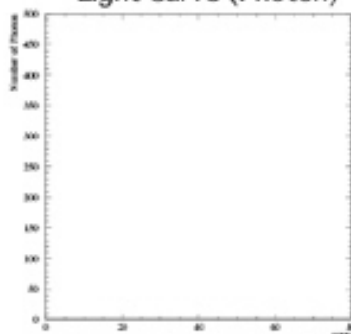
X-Time



Y-Time

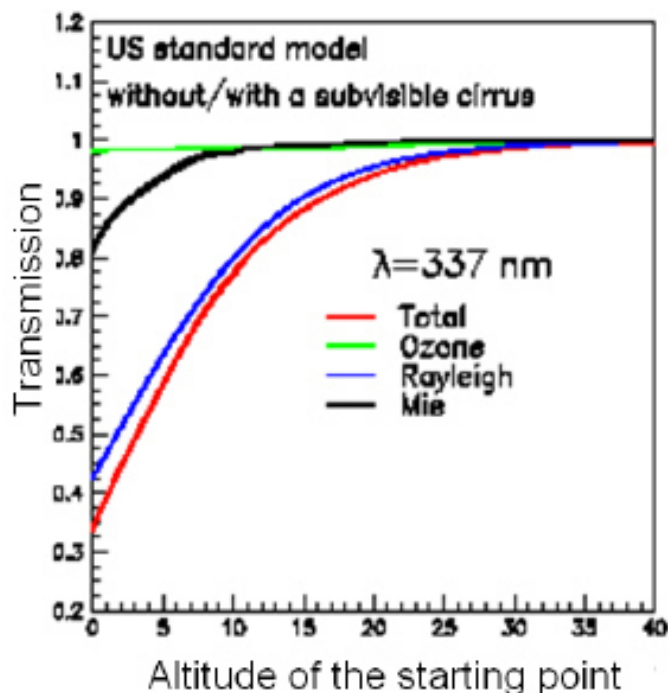


Light Curve (Photon)



宇宙から見る利点

- 上層大気は希薄で散乱が少ない
 - 地上からだると汚い下層大気の吸収をこうむる
 - 10km先だと10%以下
- 夜は雲頂高度が低い
 - ほとんどは<3km
 - 空気シャワーの大部分は雲の上で最大を迎える
- 距離が決まっている
 - 軌道高度(400km)>>大気厚さ(10km)



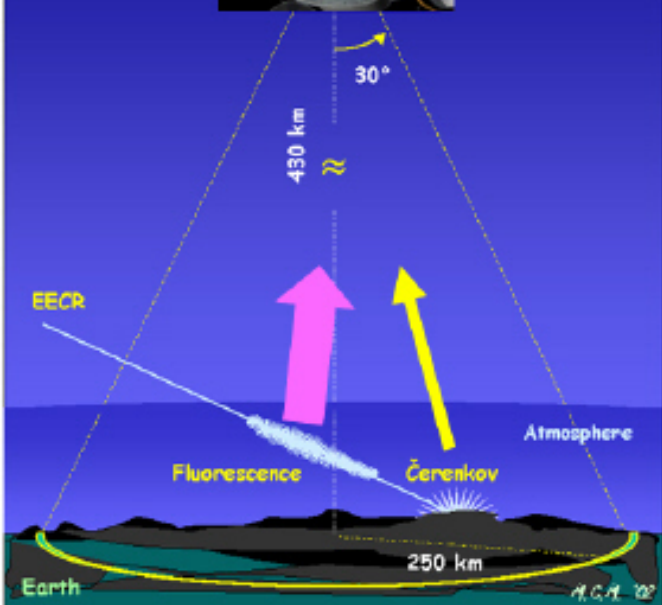
EUSOの観測方法



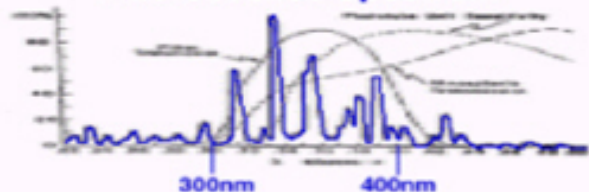
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

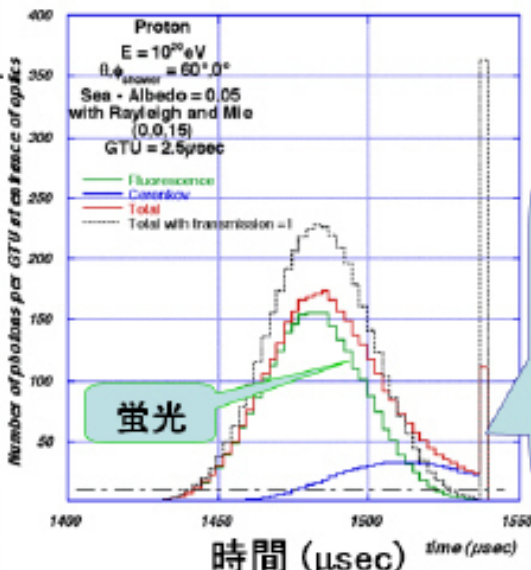
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



光学系入口径での光子数 (/2.5μsec)



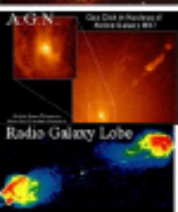
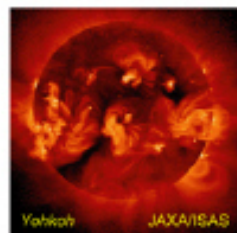
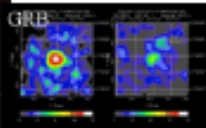
チェレンコフ光

蛍光

時間 (μsec)

time (μsec)

地を見て天を知る天文台=地文台 JEM-EUSO



極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

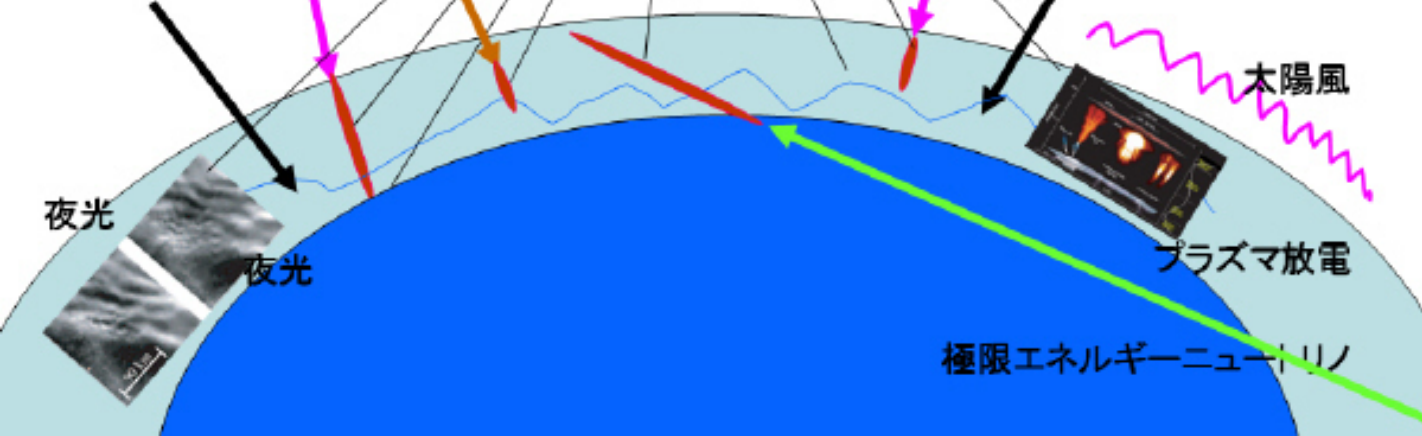
太陽風

夜光

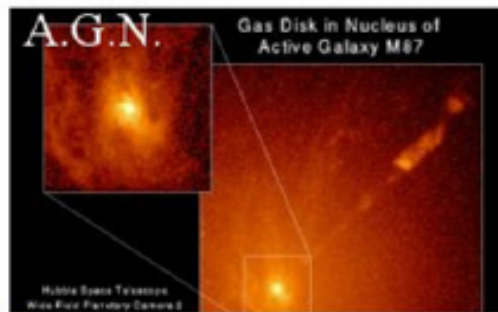
夜光

プラズマ放電

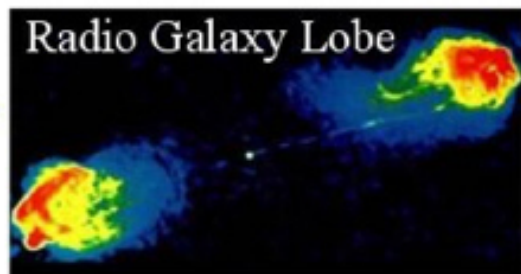
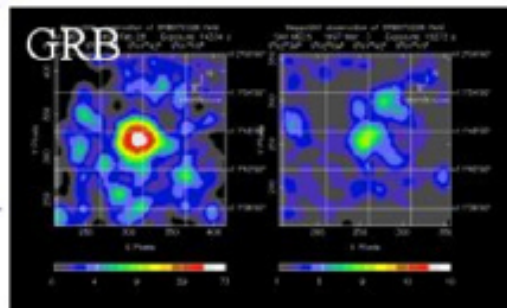
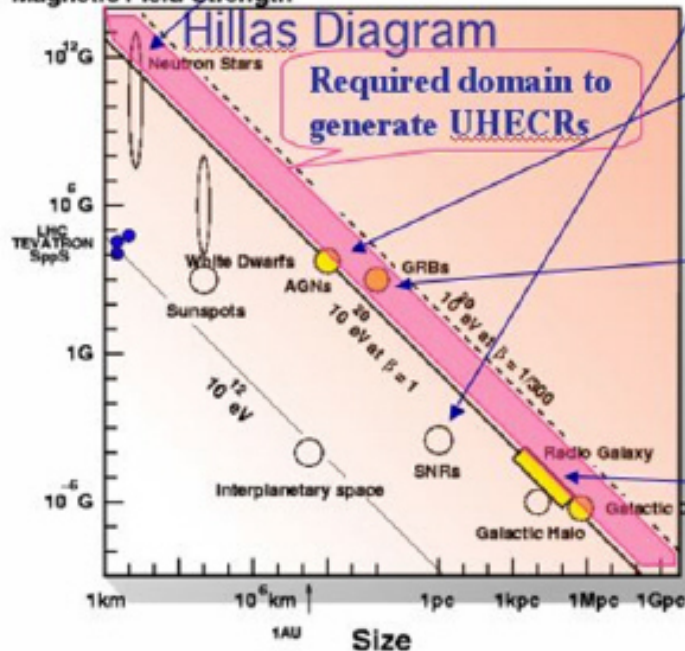
極限エネルギーニュートリノ



ヒラス 理論的加速限界 $< 10^{20}$ eV

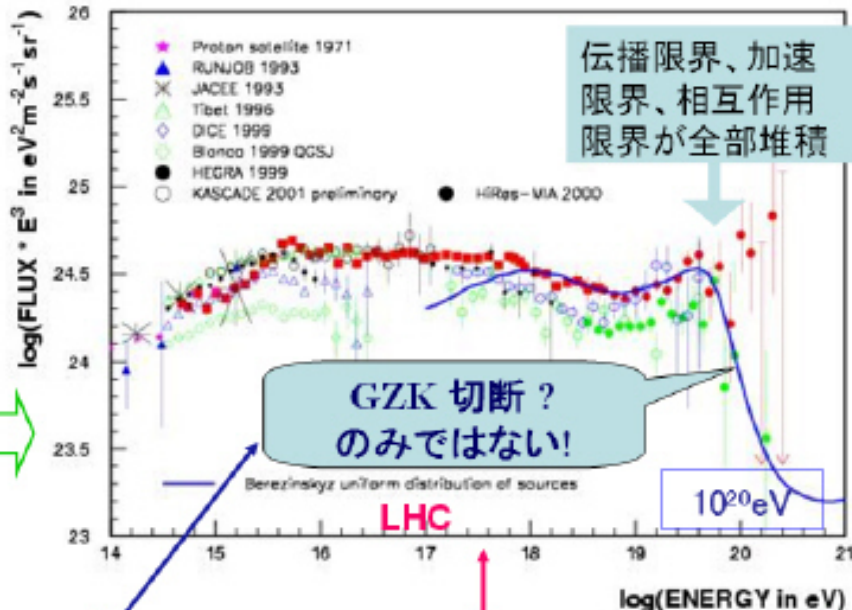
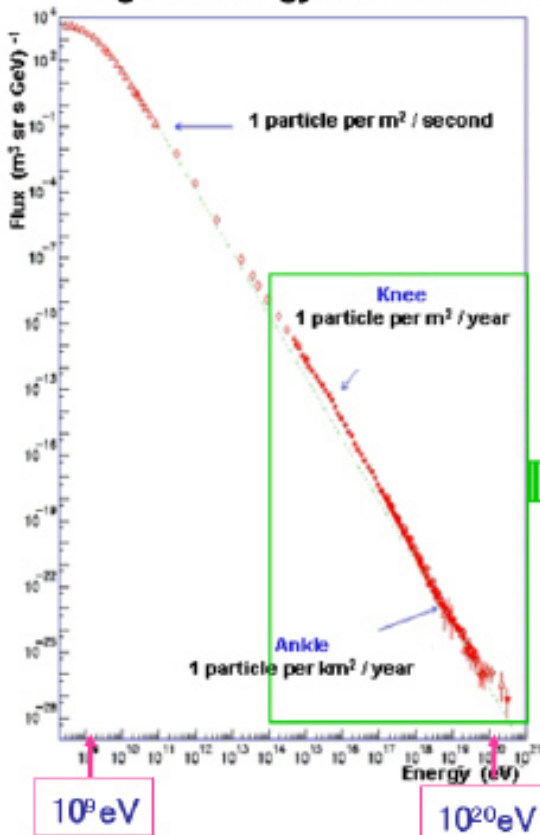


Magnetic Field Strength



Status and the challenges of the highest-energy Universe by observing cosmic rays

- LHC explores HIGGS, SUSY DM $< 7 \text{ TeV}/c^2 (\leq 10^{17} \text{ eV})$ from Dec 2007
- Highest energy CR: Unknown for origin, acceleration; physics unknown at $> 300 \text{ TeV}/c^2$



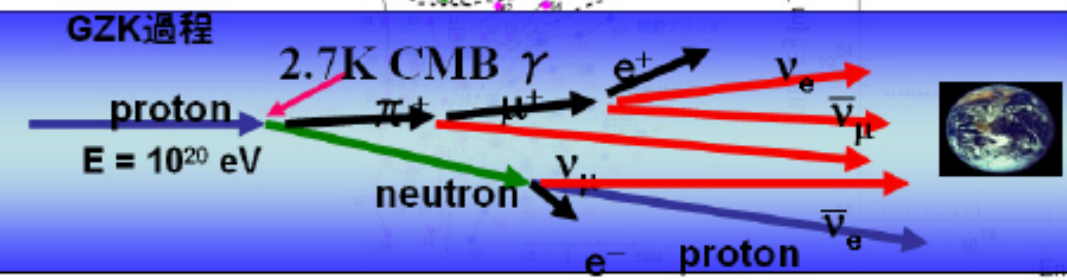
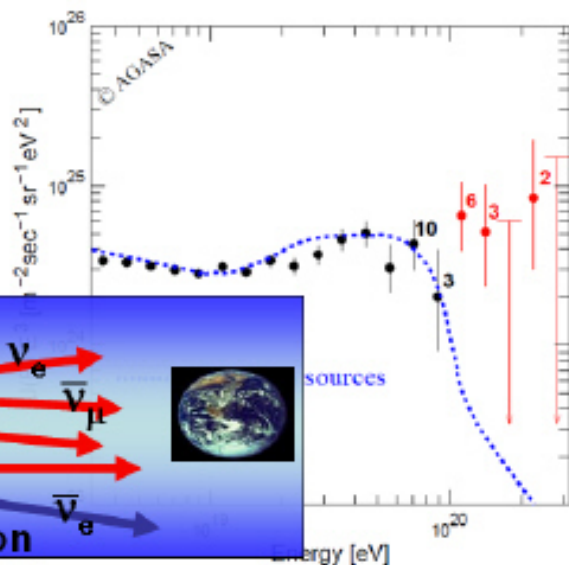
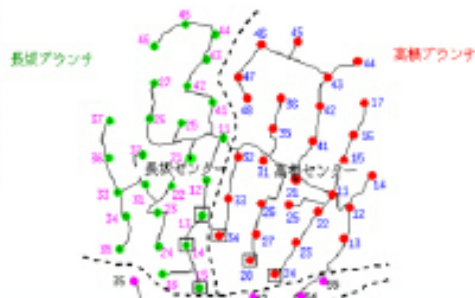
$$p + \gamma_{2.7\text{K}} \rightarrow e^+ e^- + p \text{ above LHC } 5 \cdot 10^{17} \text{ eV}$$

$$p + \gamma_{2.7\text{K}} \rightarrow \Delta^+ \rightarrow n + \pi^+, p + \pi^0$$



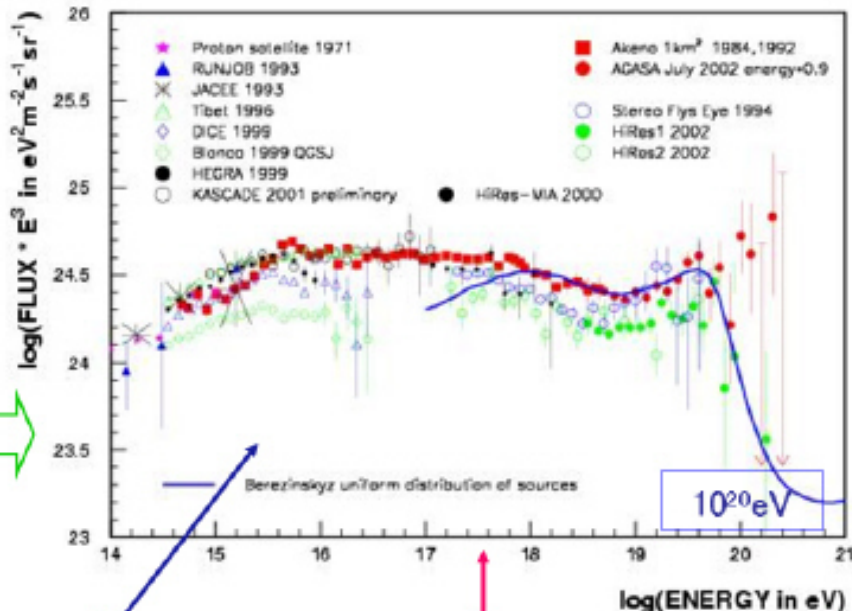
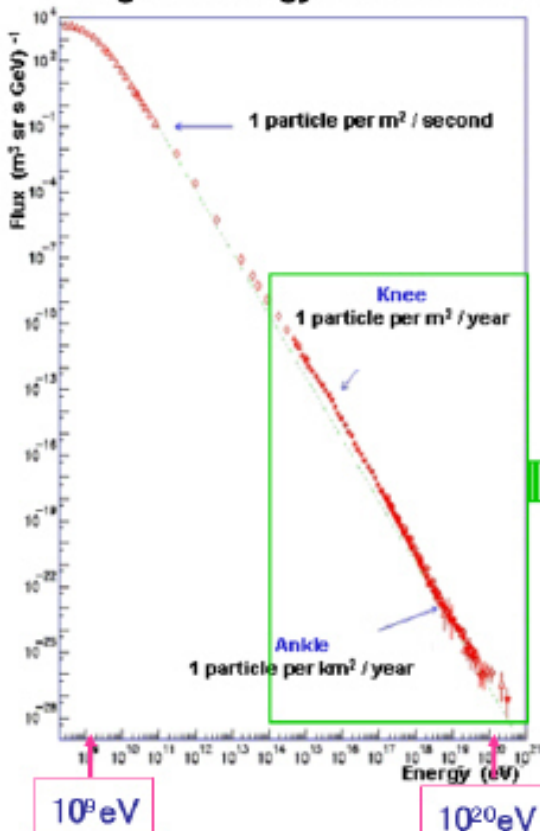
AGASA

- 地域全体を検出器とした。
- 全体で約100km²
- 13年で11個の超10²⁰eV事象



Status and the challenges of the highest-energy Universe by observing cosmic rays

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$$p + \gamma_{2.7\text{K}} \rightarrow e^+ e^- + p \text{ above LHC } 5 \cdot 10^{17} \text{ eV}$$

$$p + \gamma_{2.7\text{K}} \rightarrow \Delta^+ \rightarrow n + \pi^+, p + \pi^0$$

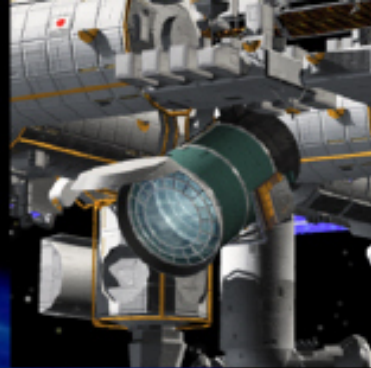
JEM-EUSO Collaboration

10 countries, 56 institutions, 149 members



- ▶ **Japan** : T. Ebisuzaki, Y. Uehara, H. Ohmori, Y. Kawasaki, M. Sato, Y. Takizawa, K. Katahira, S. Wada, K. Kawai, H. Mase (*RIKEN*), F. Kajino, M. Sakata, H. Sato, Y. Yamamoto, T. Yamamoto, N. Ebizuka, (*Konan Univ.*), M. Nagano, Y. Miyazaki (*Fukui Inst. Tech.*), N. Sakaki, T. Shibata (*Aoyama Gakuin Univ.*), N. Inoue (*Saitama Univ.*), Y. Uchihori (*NIRS*), K. Nomoto (*Univ. of Tokyo*), Y. Takahashi (*Tohoku Univ.*), M. Takeda (*ICRR, Univ. Tokyo*), Y. Arai, Y. Kurihara, H.M. Shimizu, J. Fujimoto (*KEK*), S. Yoshida, K. Mase (*Chiba Univ.*), K. Asano, S. Inoue, Y. Mizumoto, J. Watanabe, T. Kajino (*NAOJ*), H. Ikeda, M. Suzuki, T. Yano (*ISAS, JAXA*), T. Murakami, D. Yonetoku (*Kenazawa Univ.*), T. Sugiyama (*Nagoya*), Y. Ito (*STEL, Nagoya Univ.*), S. Nagataki (*YITP, Kyoto Univ.*), A. Saito (*Kyoto Univ.*), S. Abe, M. Nagata (*Kobe Univ.*), T. Tajima (*KPSI, JAEA*), M. Chikawa (*Kinki Univ.*), and M. Tajima (*Hiroshima Univ.*)
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- ▶ **Germany**: M. Teshima, T. Schweizer (*MPI, Munich*), A. Santangelo, E. Kendziorra, F. Fenu (*Univ. Tuebingen*), P. Biermann (*MPI Bonn*), K. Mannheim (*Wuerzburg*), J. Wilms (*Univ. Erlangen*)
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- ▶ **Republic of Korea** : S. Nam, I. H. Park, J. Yang (*Ehwa W. Univ.*)
- ▶ **Russia**: Garipov G.K., Khrenov, B.A., Klimov P.A. Panasyuk M.L., Yashin I.V. (*SINP MSU*), D. Naumov, Tkachev. L (*Dubna JINR*)
- ▶ **Switzerland** : A. Maurissen, V. Mitev (*Neuchatel, Switzerland*) :
- ▶ **Spain**: D.Rodriguez-Frias, L.Peral, J.Gutierrez, R.Gomez-Herrero (*Univ. Alcala*)

Extreme Universe Space Observatory



JEM-EUSO mission

戎崎俊一
理化学研究所


for the JEM-EUSO Collaboration



北海道大学 2008年9月10日

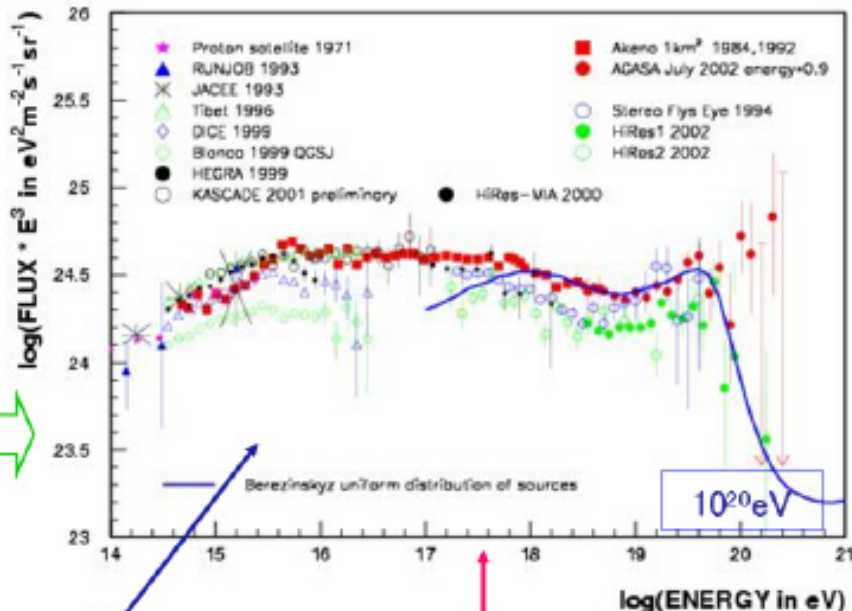
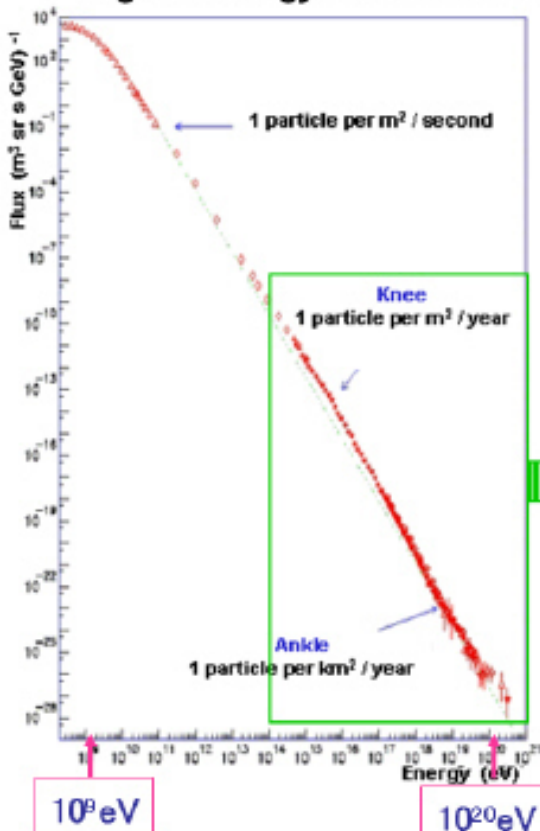
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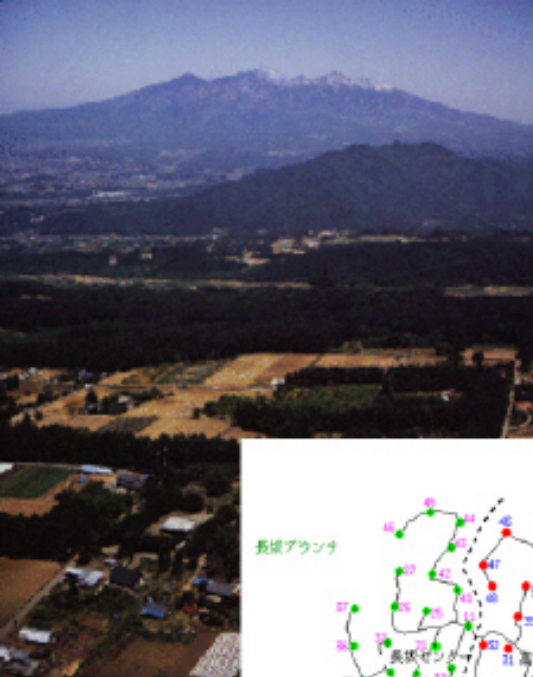
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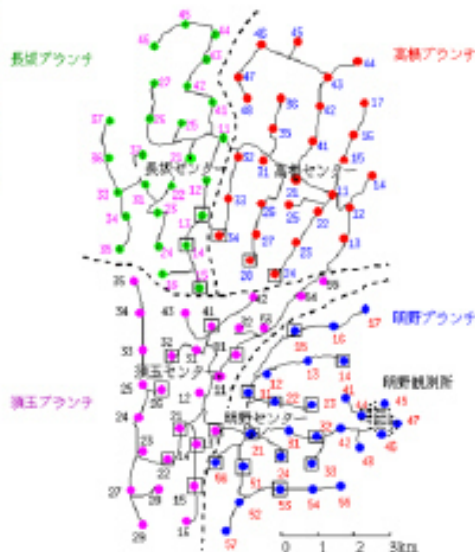
AGASA

- 地域全体を検出器とした。
- 全体で約100km²
- 13年で11個の超10²⁰eV事象



AGASA

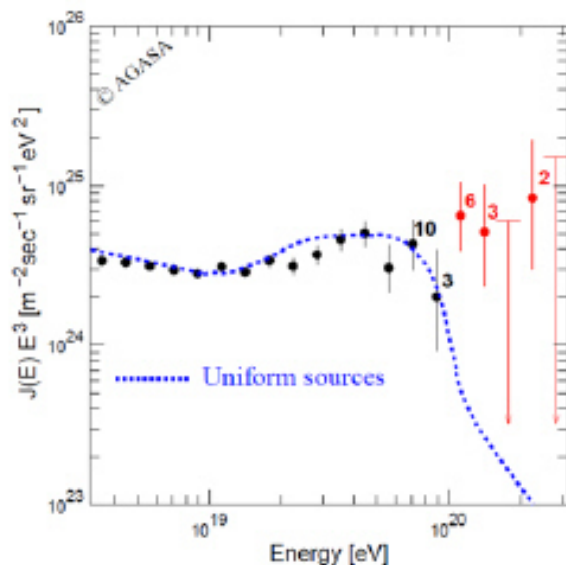
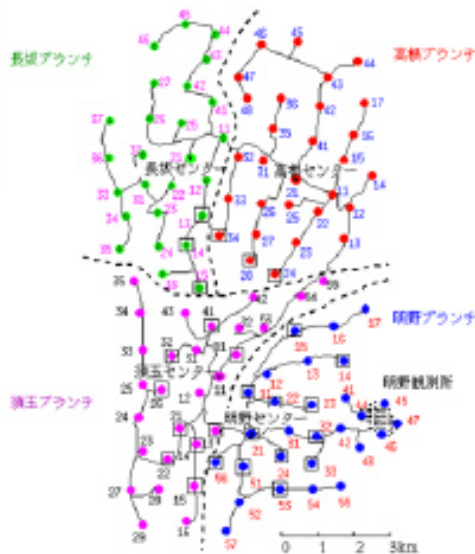
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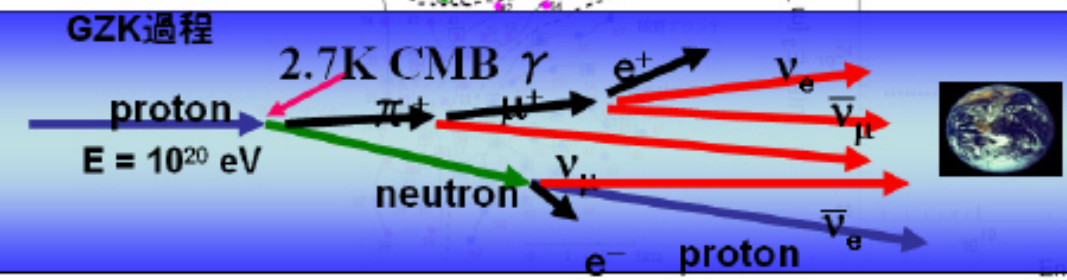
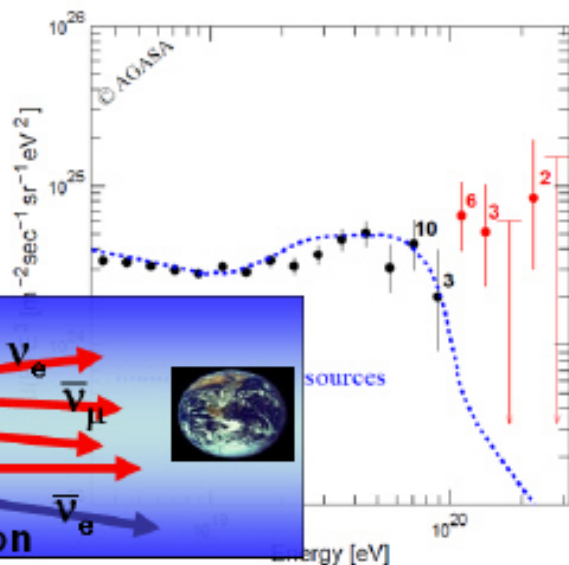
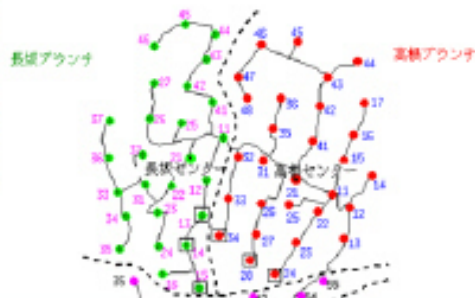
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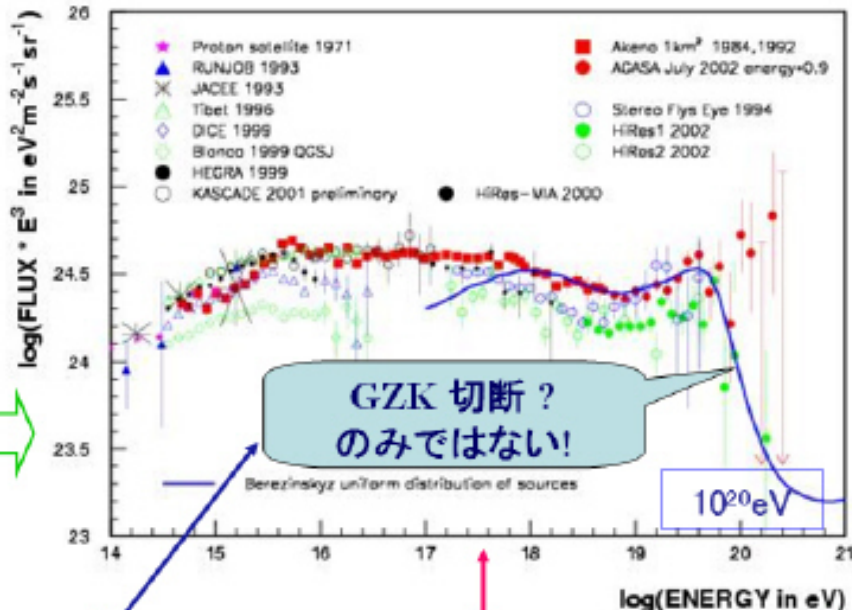
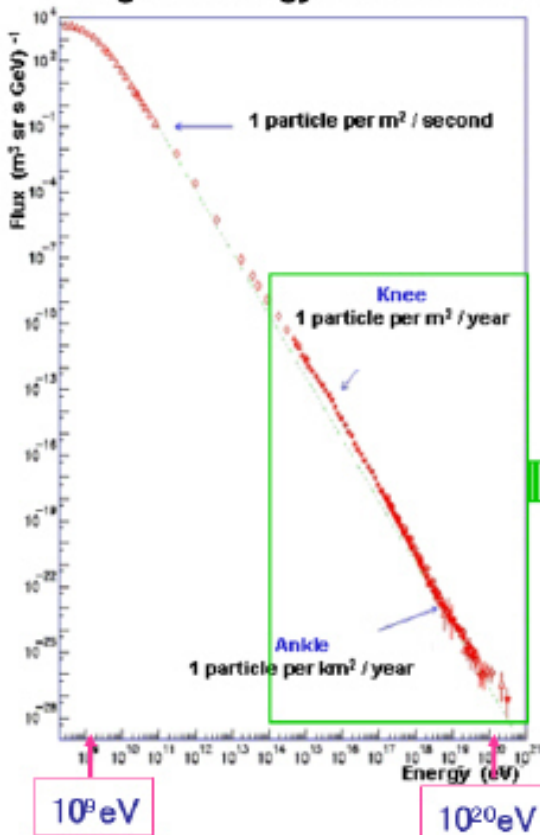
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Status and the challenges of the highest-energy Universe by observing cosmic rays

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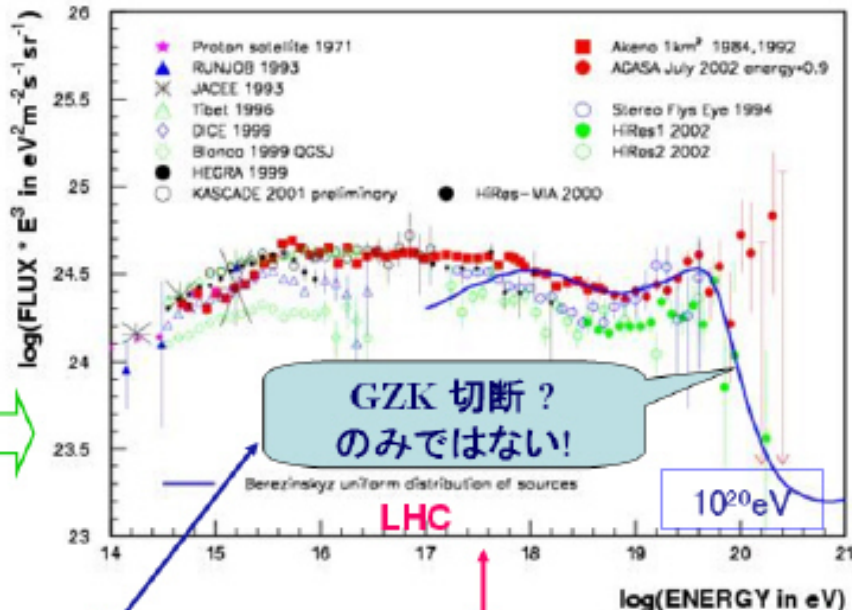
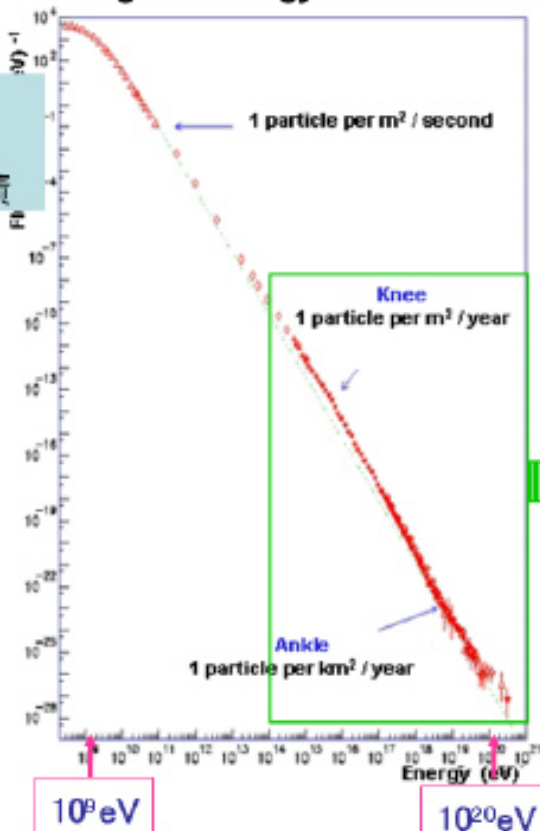


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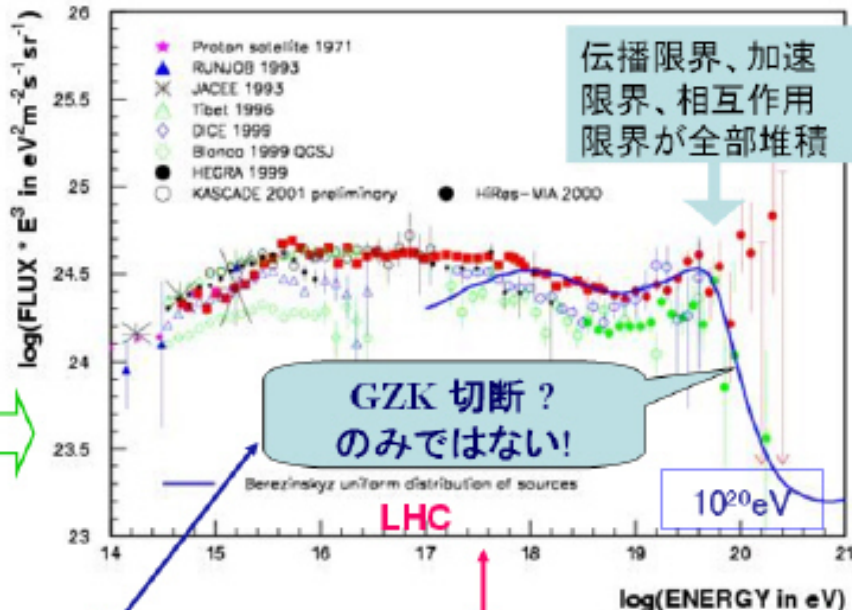
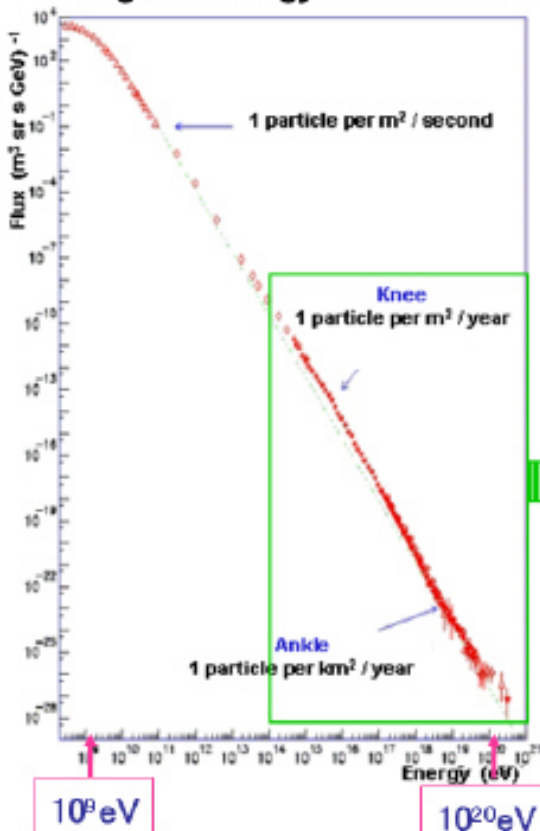


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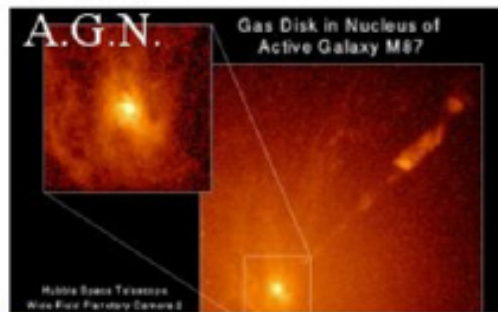
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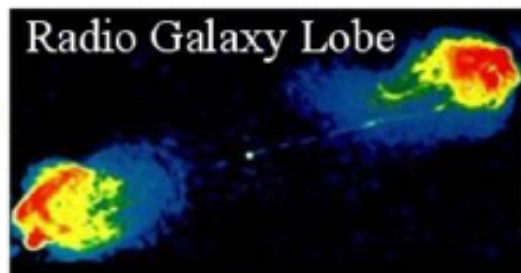
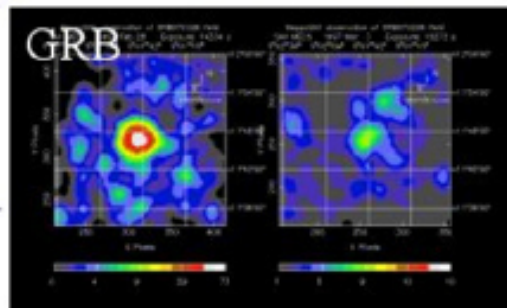
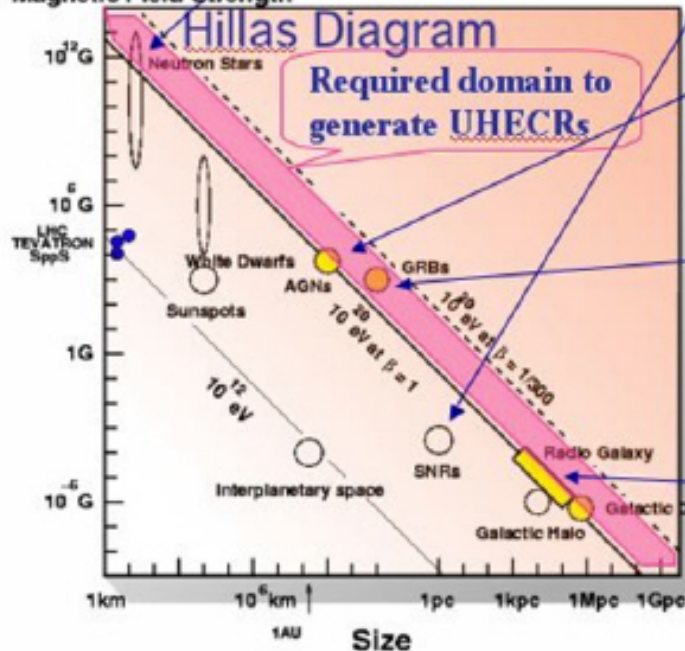
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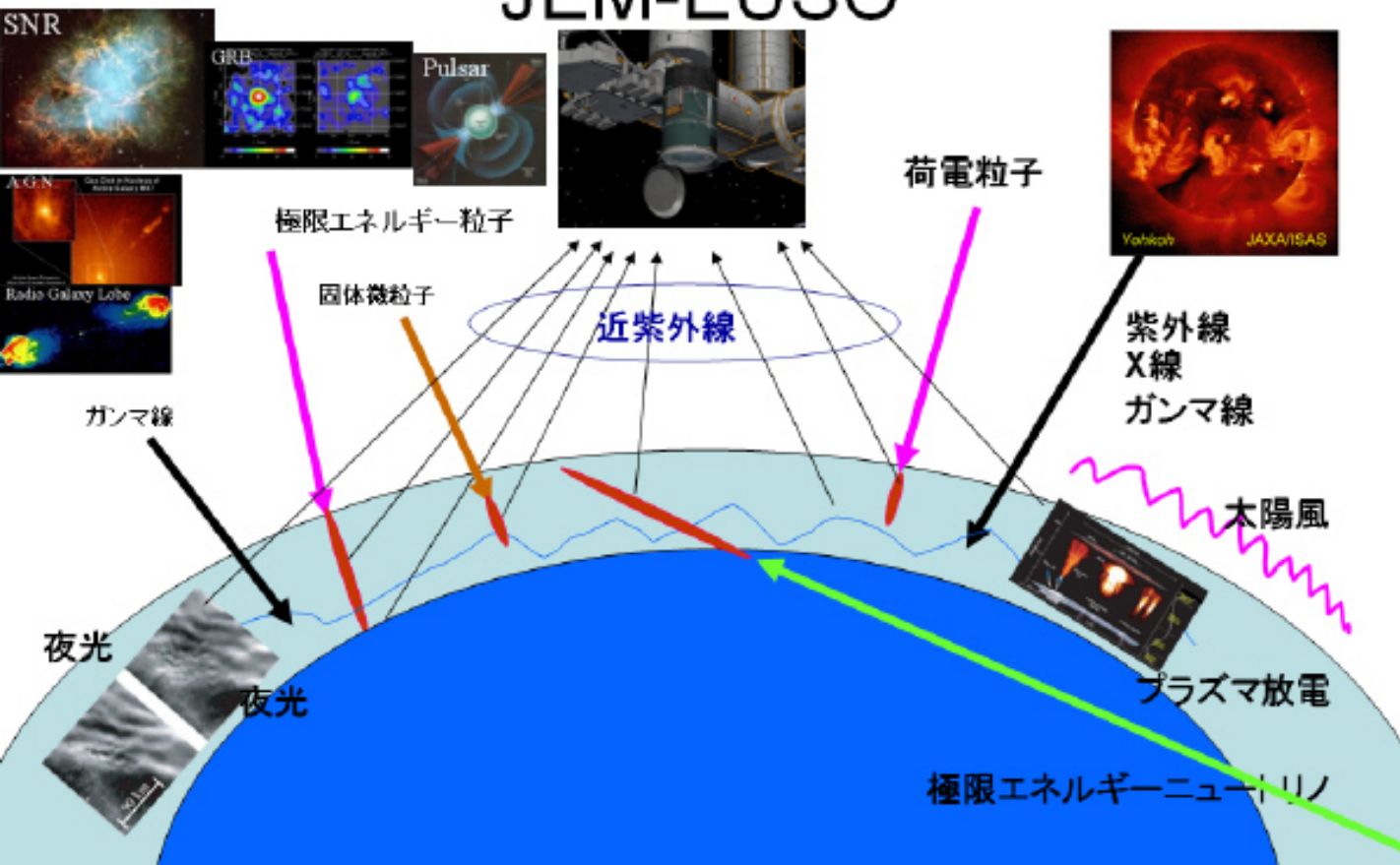
ヒラス 理論的加速限界 $< 10^{20}$ eV



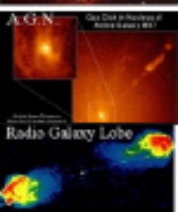
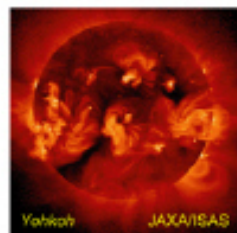
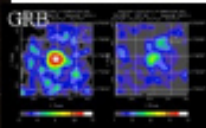
Magnetic Field Strength



地を見て天を知る天文台=地文台 JEM-EUSO



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極限エネルギー粒子

荷電粒子

固体微粒子

近紫外線

紫外線
X線
ガンマ線

ガンマ線

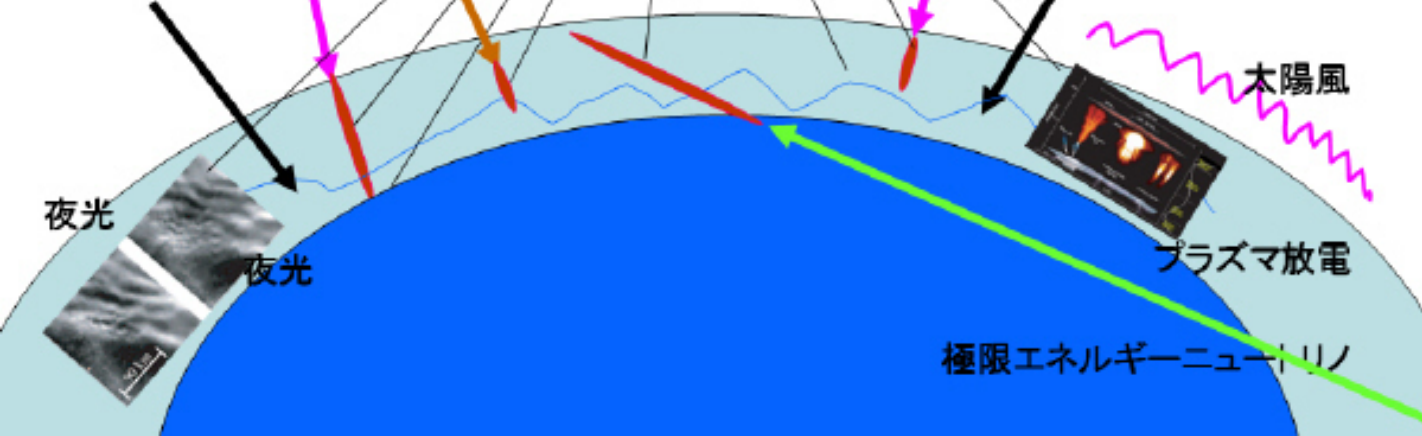
太陽風

夜光

夜光

プラズマ放電

極限エネルギーニュートリノ



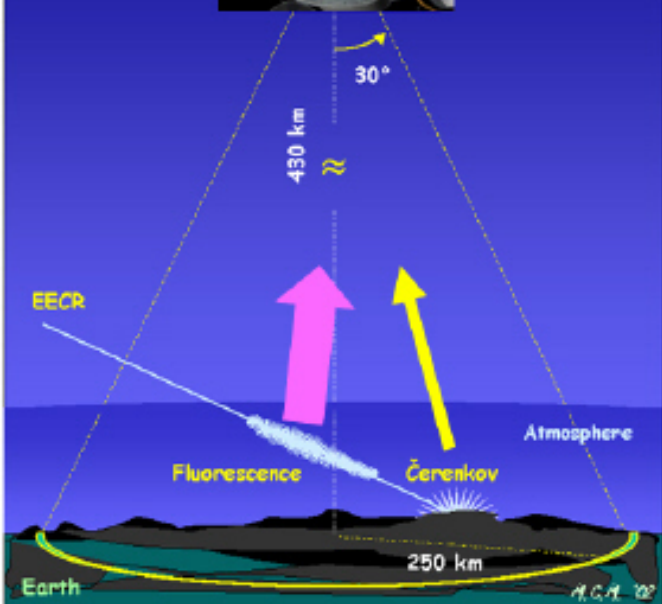
EUSOの観測方法



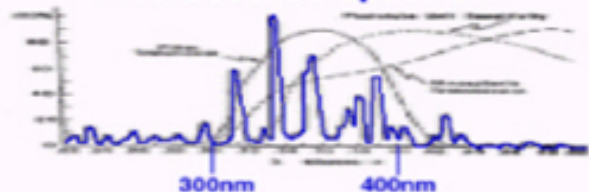
宇宙線が大気中に飛び込んで来て、空気シャワーをつくり、シャワー中の電子が窒素や窒素イオンを励起して蛍光を発する。

この蛍光を口径2.5mの望遠鏡で観測する。

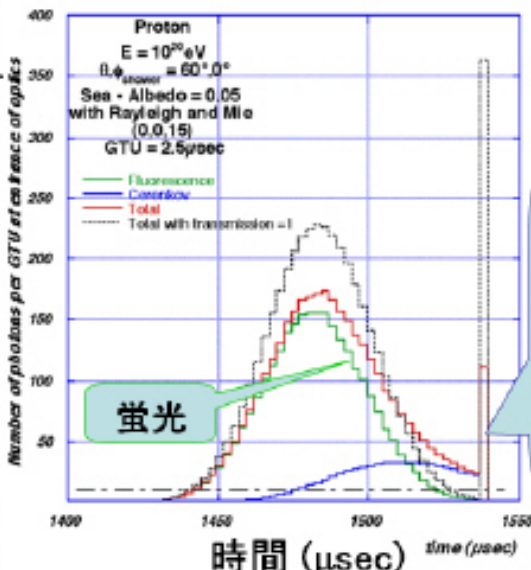
空気シャワーにそって発せられたチェレンコフ光の地上や海上での反射光を観測する。



Fluorescence Spectrum



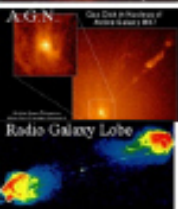
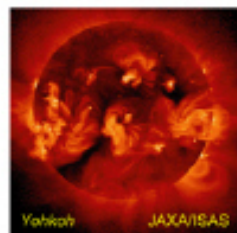
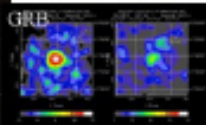
光学系入口径での光子数 (/2.5μsec)



蛍光

チェレンコフ光

地を見て天を知る天文台=地文台 JEM-EUSO



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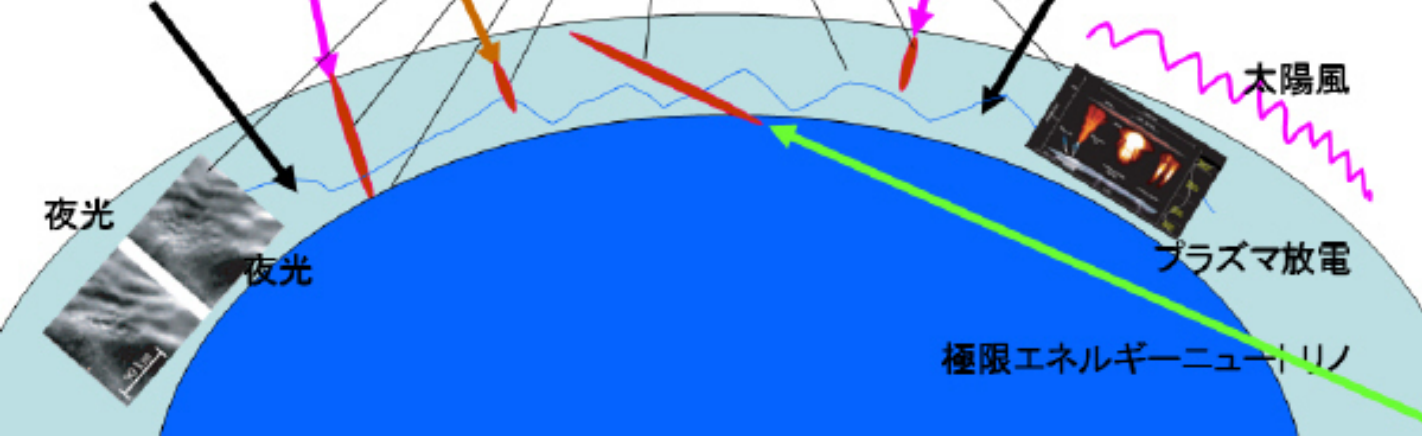
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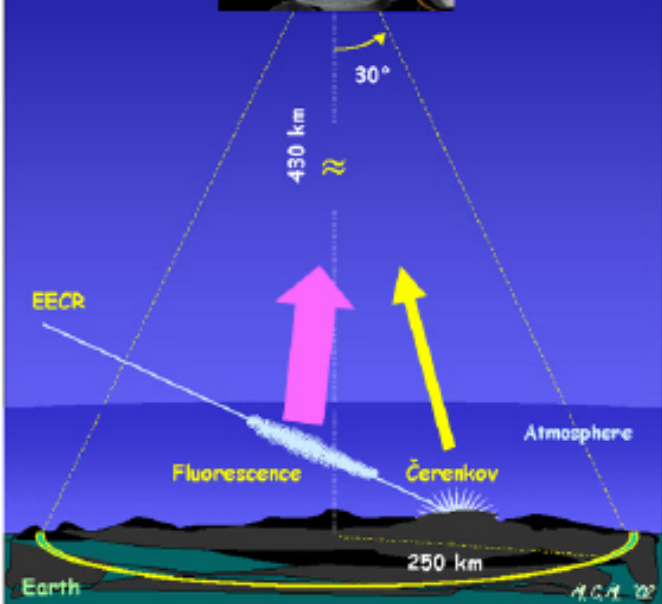
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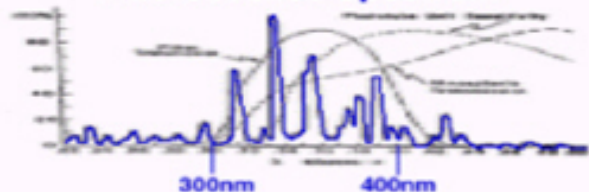
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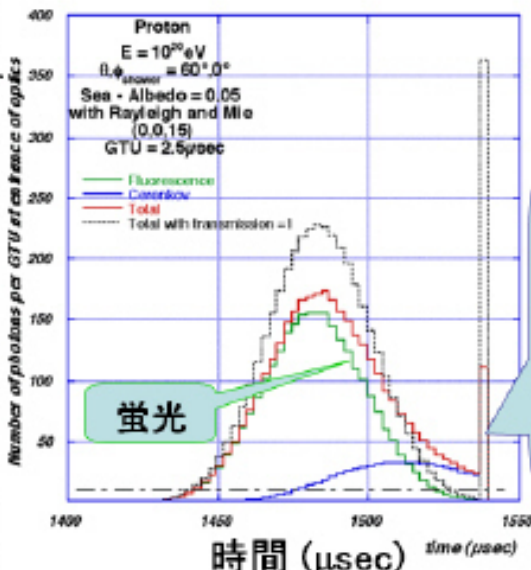
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