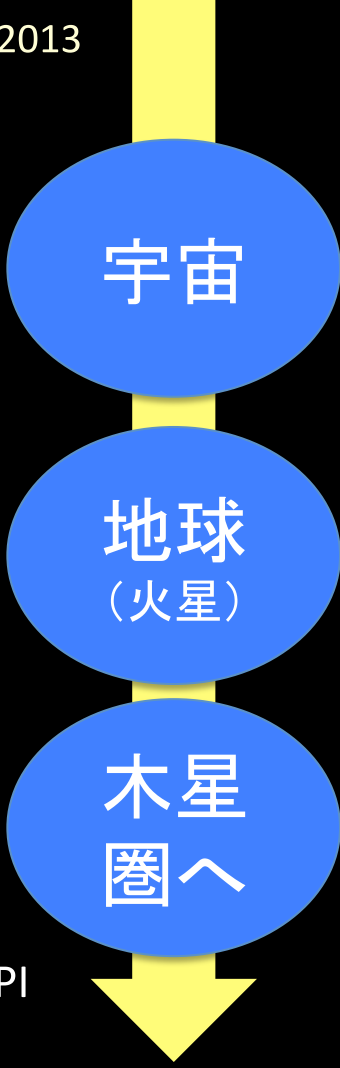
自己紹介

東工大　理工学研究科　化学専攻
専門:　分子科学・地球惑星分光リモセン観測
卒研-修士:　塩素分子の可視紫外レーザー分光
博士:　星間分子の化学とマイクロ波分光
　（野辺山45m 電波望遠鏡観測と実験室マイクロ波分子分光）
　- 赤色巨星 IRC+10216でNegative ion C6H– 分子を検出(星間で初めて)
　- 暗黒星雲TMC-1で炭素鎖C5N分子を初検出

現在:　国際宇宙ステーション搭載超伝導サブミリ波サウンダ　SMILES
　目的:　超伝導サブミリ波技術実証. 地球大気の分子を高感度に観測.
　　NICT（情報通信研究機構）とJAXAの共同ミッション
- SMILESのNICT側のリーダ
- JUICE/SWI　日本側PI (代表研究者)
- ISS地球観測研究所　APOLLO（Air Pollution Observation Mission）ミッションPI
- 東工大　総合理工学研究科　化学環境専攻　連携教授

笠井研究室の学生（D4, D3, D1x2, M2, M1x2, B4 =8名 ）学生研究テーマ例: 太陽大気COの酸素同位体比観測、SMILESで観測したオゾン同位体比、地球上層大気の塩素化学、GOSATによるグローバルメタン同位体の導出など



好きなこと　新規観測手法の開拓で見える新しい発見. 地球も惑星も宇宙も好きだ.
得意なこと　分子

Overview of
SWI (Submillimetre Wave Instrument)
for JUICE (JUpiter ICy moons Explorer)

Submillimeter-wave spectrometer

JUICE/SWI
Japanese team
Y. Kasai (NICT)

サブミリ波観測

JUICE/SWI 観測ではどのような情報が得られそうか

↑

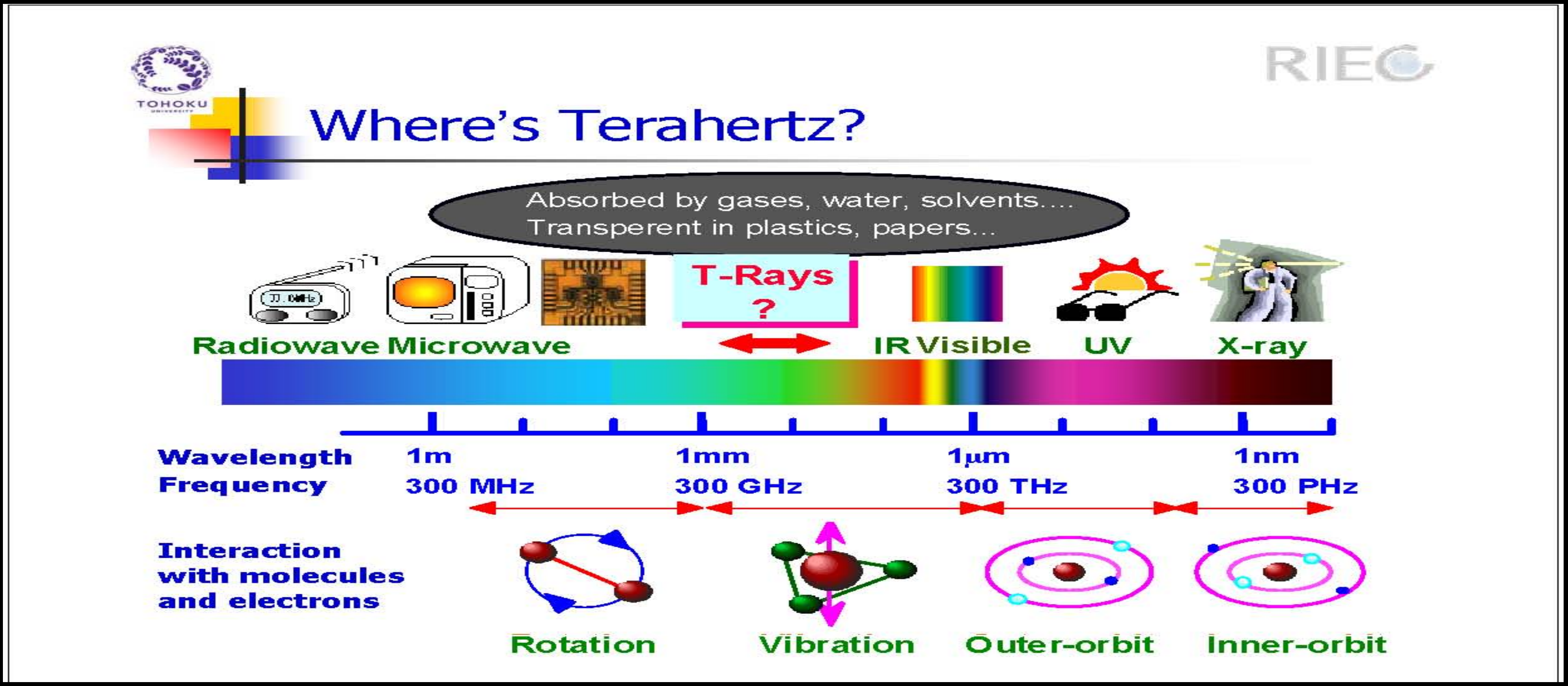
サブミリ波地球観測などで得られている情報

↑

サブミリ波リモセン観測とは

サブミリ波(テラヘルツ)とは何か？

電波と光の境界領域 → 未踏領域 → 観測例に限りがある



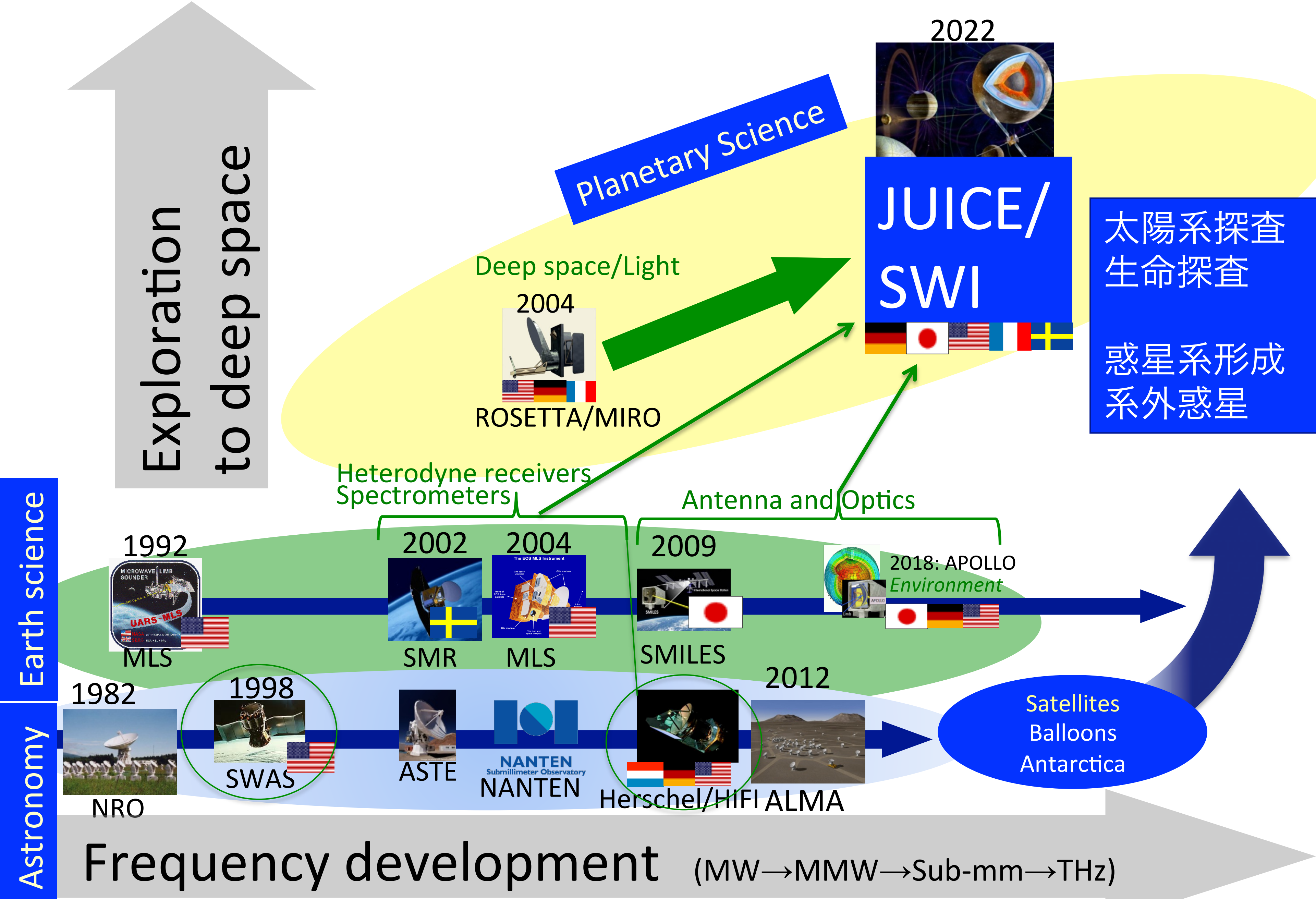
http://db.tohoku.ac.jp/whois/view?l=ja&u=4fbc5d764b50754c2acff947b2b28ed7&c=1

分子の純回転遷移を周波数高分解に計測

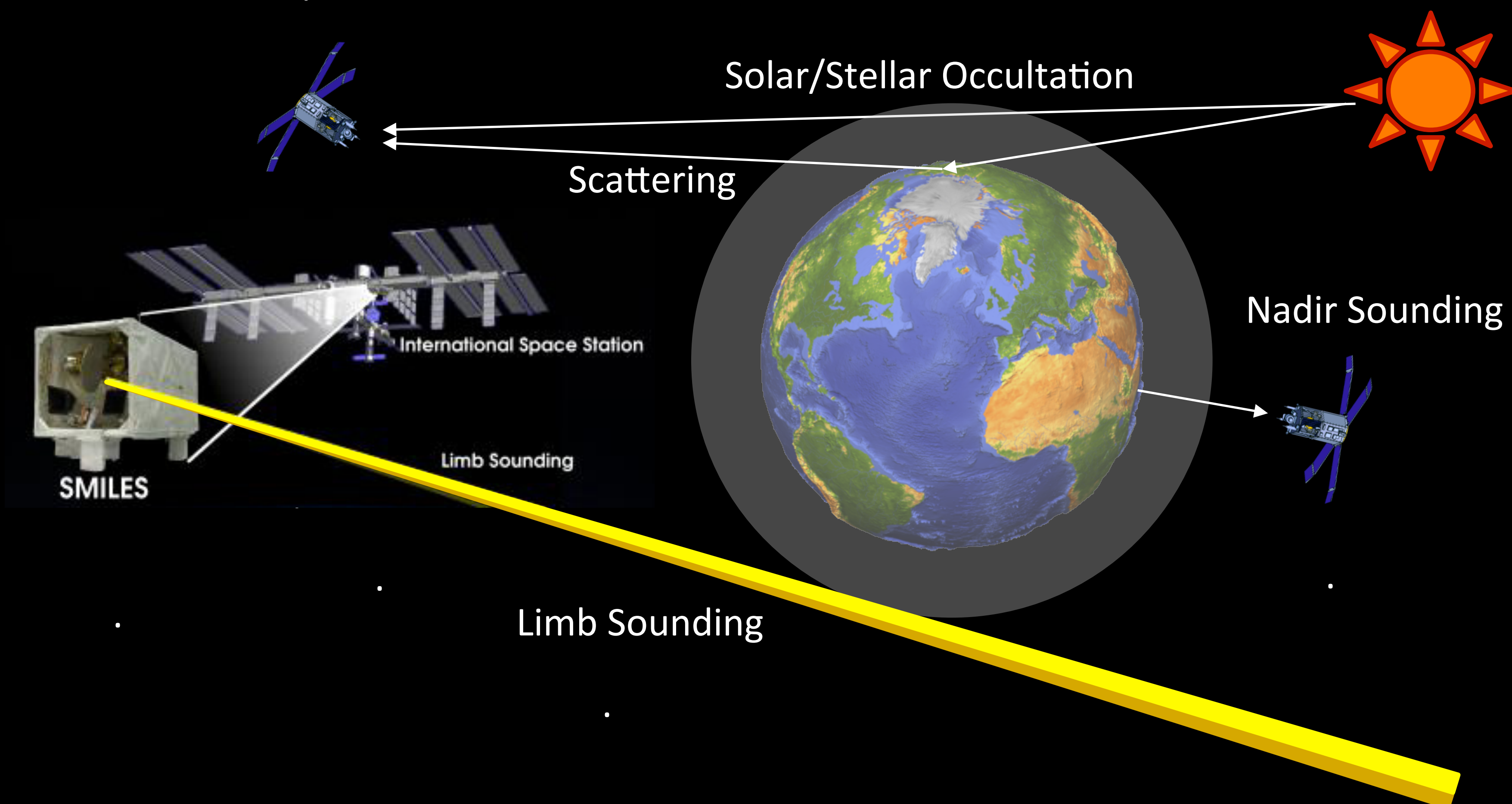
光の影響を受けない. ラジカルや不安定なものを観測可能,

C+, C, SH, OH, NH3, HCN, H2O, 同位体比, O/P 比

Planetary Science and Sub-mm/THz Observation



Observation Geometry



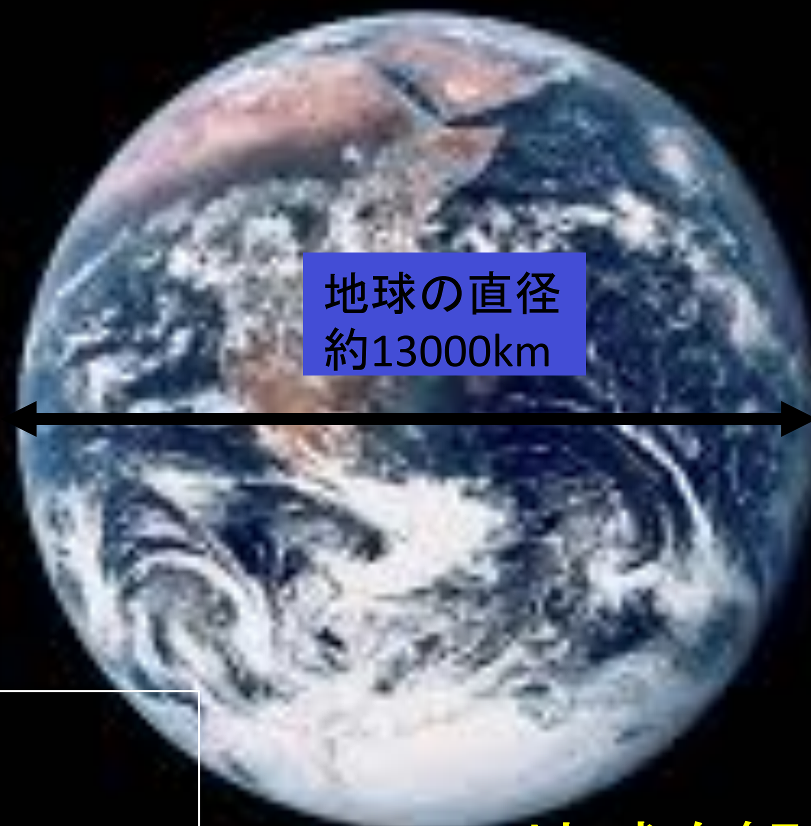
Earth from ISS (International Space Station) at 400km

Photo of the Earth taken by the moon

地球大気の厚み　非常に薄い

地表面付近気圧
1/10になる高度　　約16km
1/100になる高度　約32km

観測カラム長
Nadir 観測　30km程度
Limb 観測　300km 以上



氷衛星Limb観測
(H_2O, O_2, 同位体、O/P比の)
- グローバル分布導出
- 10倍以上感度向上
- 高度分布

地球を観測するように
氷衛星を観測

サブミリ波観測

JUICE/SWI 観測ではどのような情報が得られそうか

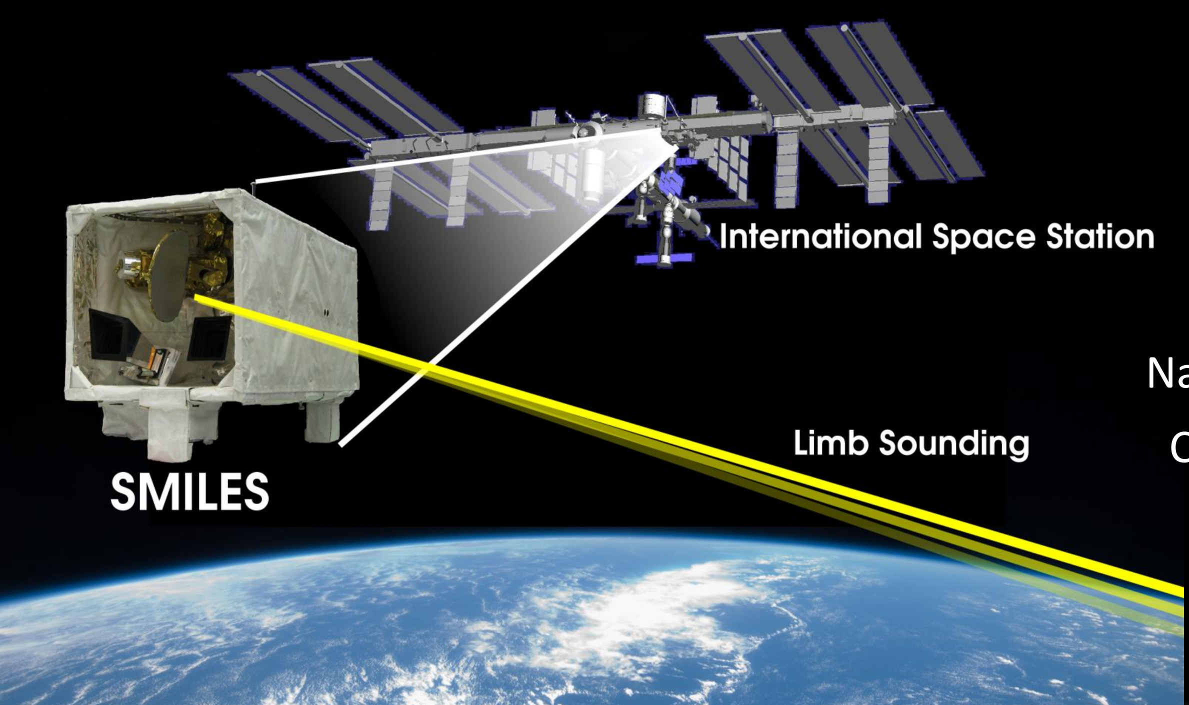
↑

サブミリ波地球観測などで得られている情報

↑

サブミリ波リモセン観測とは

Diurnal chemistry of minor atmospheric compositions in upper atmosphere



Yasko KASAI

National Institute of Information and Communications Technology (NICT)

Tokyo Institute of Technology

Thanks to SMILES Project Members

SMILES is a Collaboration project of NICT and JAXA

NICT SMILES members

Leader: Yasko Kasai (NICT/ Tokyo Institute of Tech)

Instrument and L1b: Satoshi Ochiai, Ken Kikuchi,

L2 research: Hideo Sagawa, Tomohiro Sato, Jana Mendrok(Lulea U.), Joachim Urban, Patrick Eriksson, Donal Murtagh (Chalmers U.)

Validation and Science: Kengo Yokoyama, Kota Kuribayashi, Takayoshi Yamada, Nawo Suzuki, Mona Mahani, Bengt Rydberg

Climatology: Daniel Kreyling

Modeling: Ralph Lehmann, Miriam and B-M Sinnhubers

JAXA SMILES members

Leader: Masato Takayanagi, Masato Shiotani (Kyoto U.)

Instrument: Toshiyuki Nishibori,

L2: Takuki Sano, Makoto Suzuki,

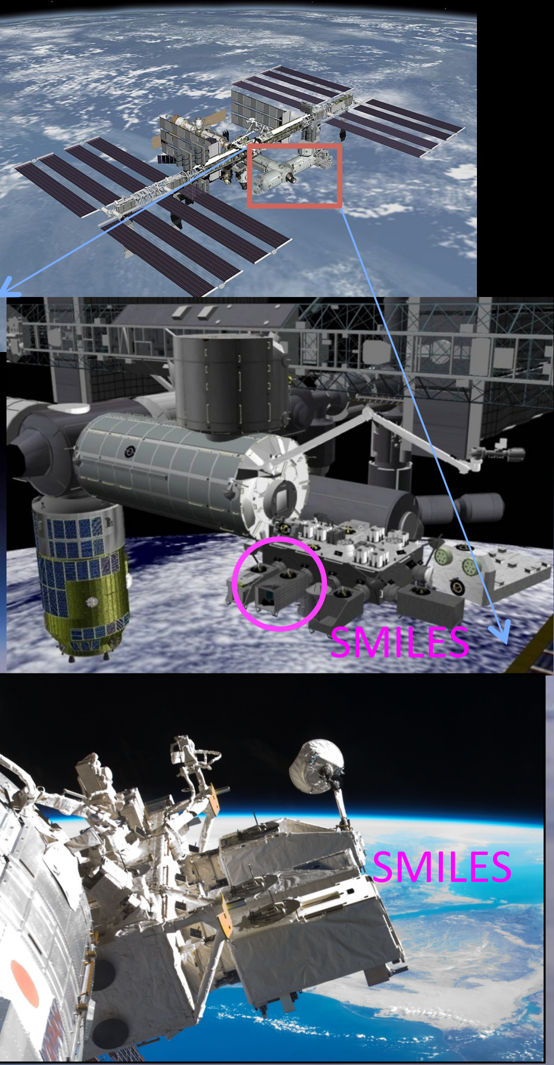
SMILES Motivation

1. Demonstration of the 4K super sensitive sub-mm sensor in space

2. Reveal the current status of atmospheric composition in the Earth's upper atmosphere with 10-20 times better sensitivity

SMILES

Superconducting Sub**mi**llimeter-Wave **L**imb-**E**mission **S**ounder



Frequency region: 600 GHz (624.32-626.32, 649.12-650.32GHz)

Receiver system: Super-conductive SIS receiver

Tsys = about 350K

Obs. height region: UT – lower ionosphere

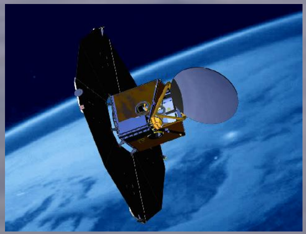
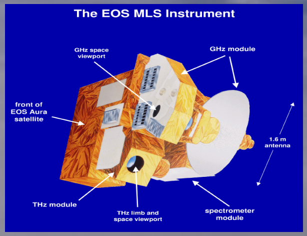
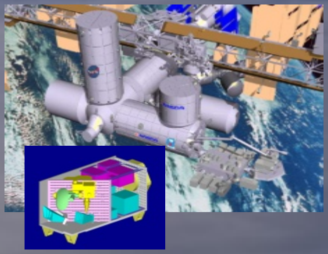
Latitude coverage: 65N-38S (Nominal)

(38N-65 total 4 weeks)

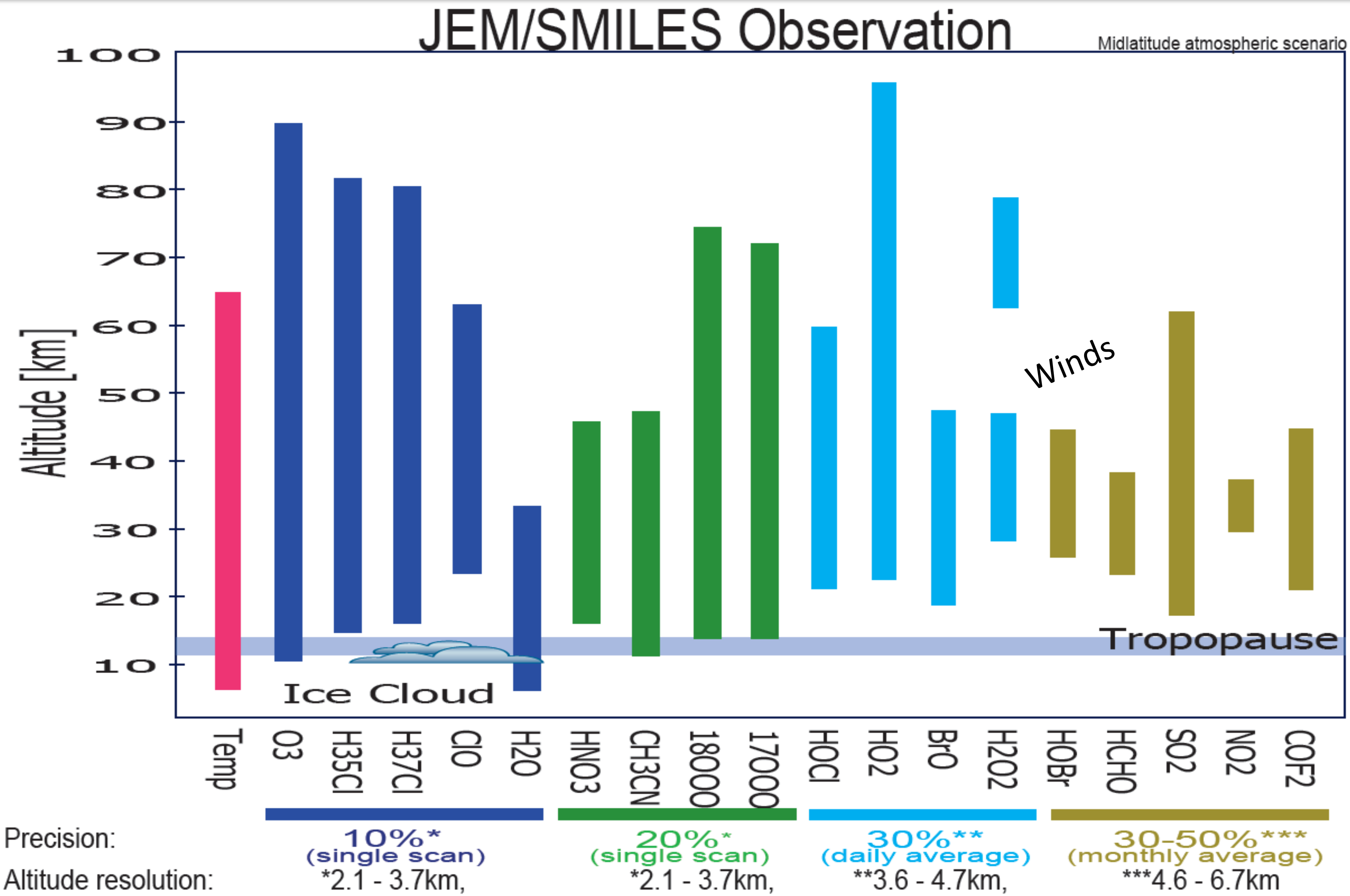
ISS Orbit: Non sun-synchronized orbit

Obs. period: 12 Oct. 2009 – 21 Apr. 2010

One order magnitude better sensitivity

Odin/SMR	Aura/MLS	JEM/SMILES
		
Tsys: 3000K (SSB@500GHz)	Tsys: 6000K (DSB@650GHz)	Tsys: 350K (SSB@650GHz)

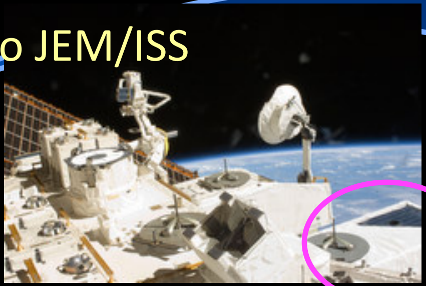
SMILES observed wide height region between upper troposphere and lower ionosphere



Courtesy JAXA

Launch and install to ISS in September 2009

SMILES installed to JEM/ISS
Sept 25



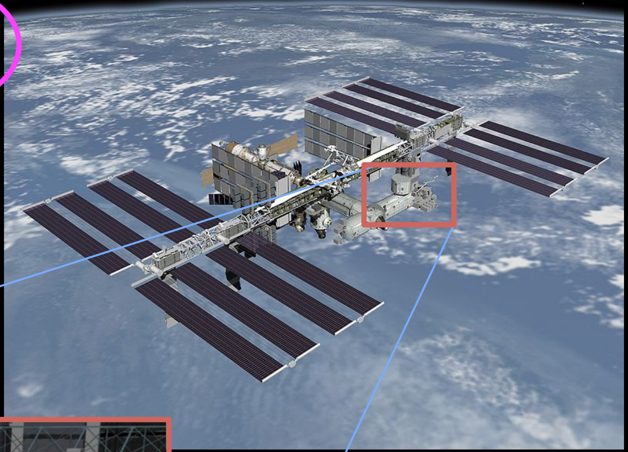
Courtesy NASA

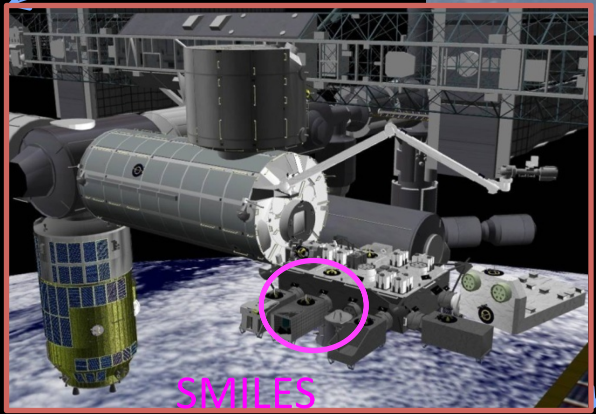
SMILES

Courtesy NASA

HTV installed to ISS
Sept 18

Courtesy NASA



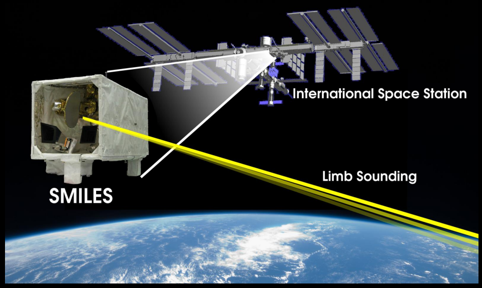


Observation started from October 12, 2009

Observation stopped at 21 April 2010.

HTV/HIIB
Launch
Sept 11

Status of SMILES

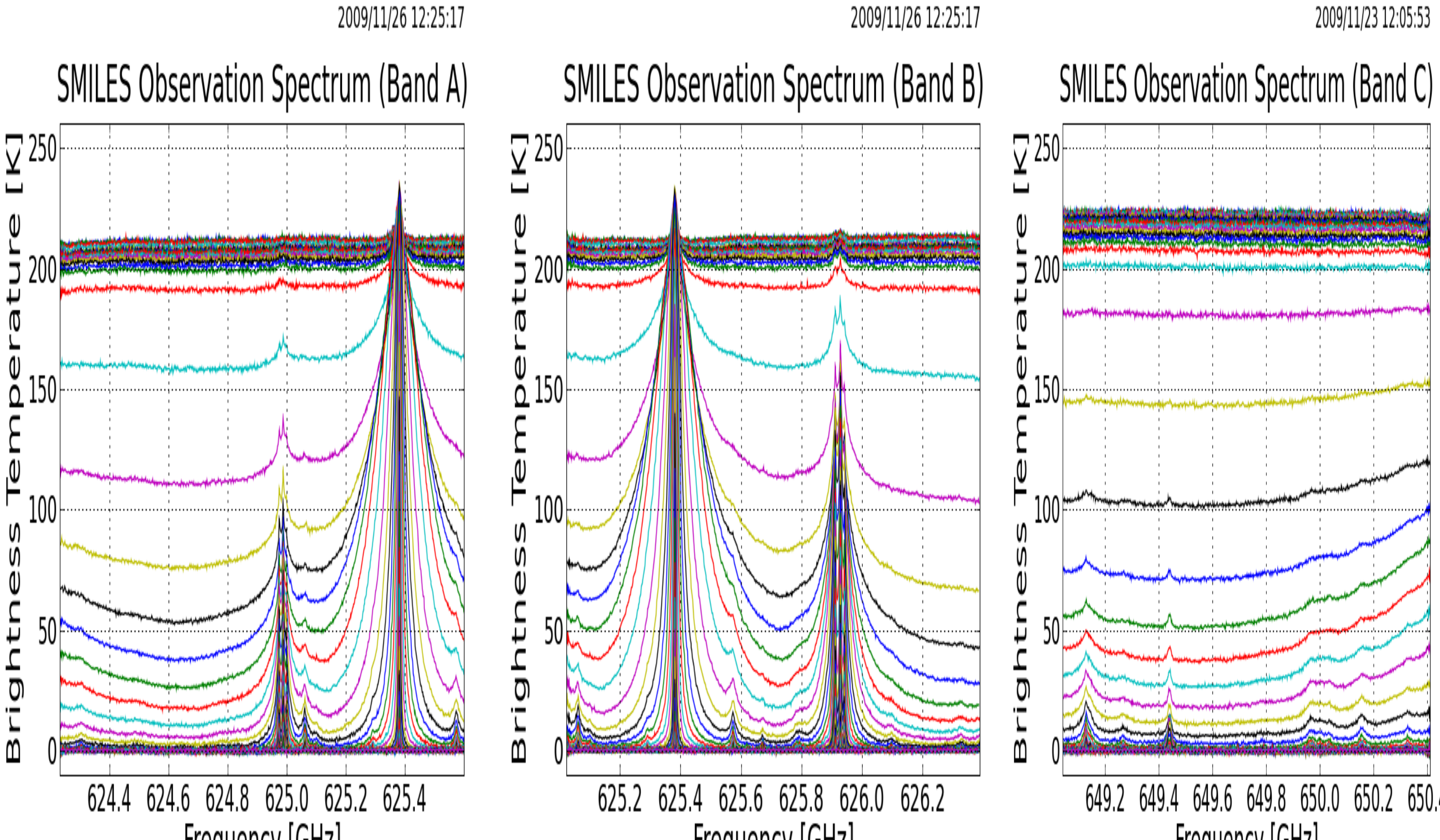


- Launch: 11 September 2009
- Observation period: 12 October 2009 – 21 April 2010
- SMILES Project (JAXA-NICT) plan to finish FY 2013,

BUT!

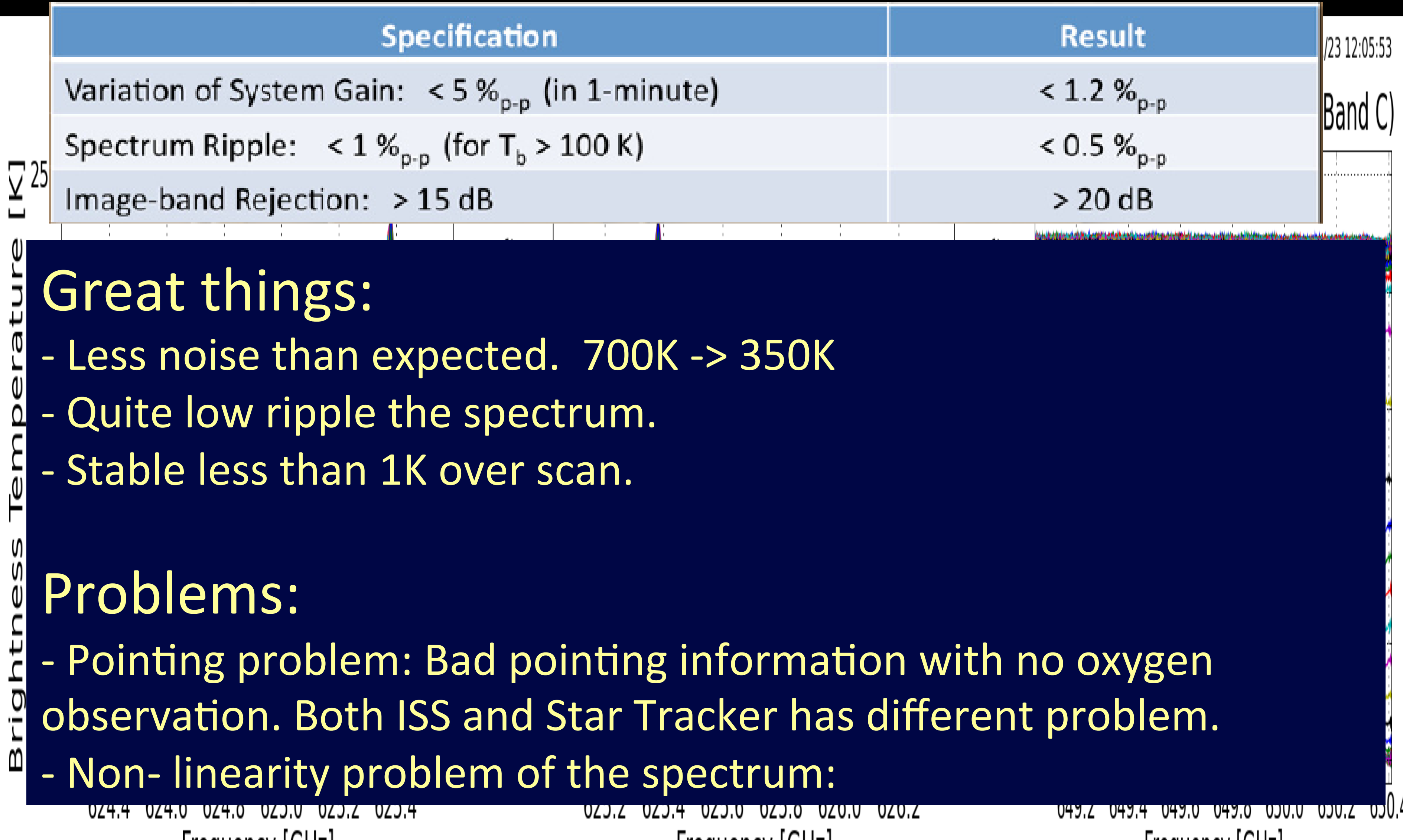
NICT continue the current SMILES research on
- ✓ L1b calibration algorithm and data processing
- ✓ L2 retrieval algorithm and data processing
- ✓ L3 = Climatology development
- ✓ Future mission study (Anu/APOLLO, JUICE/SWI)

as a center research institute for sub-mm/THz technology in Japan



Temperature control system on JEM/ISS was quite stable

Specification	Result
Variation of System Gain: $< 5\ \%_{p\text{-}p}$ (in 1-minute)	$< 1.2\ \%_{p\text{-}p}$
Spectrum Ripple: $< 1\ \%_{p\text{-}p}$ (for $T_b > 100$ K)	$< 0.5\ \%_{p\text{-}p}$
Image-band Rejection: > 15 dB	> 20 dB



Great things:

- Less noise than expected. 700K -> 350K
- Quite low ripple the spectrum.
- Stable less than 1K over scan.

Problems:

- Pointing problem: Bad pointing information with no oxygen observation. Both ISS and Star Tracker has different problem.
- Non- linearity problem of the spectrum:

Temperature control system on JEM/ISS was quite stable

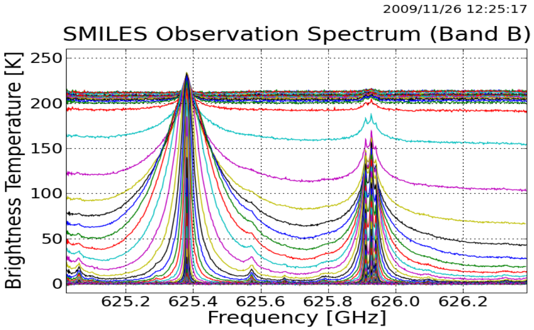
L2 analysis of SMILES spectrum

What we have to care for the SMILES retrieval

1. SMILES Characteristics: Ultra good signal to noise ratio

→ Required 'accurate'

- instrumental functions.
- radiative transfer calculation including spectroscopic parameters and continuum model.



2. ISS problem: Large uncertainty of the tangent he and SMILES has no O2 observation.

→ Required appropriate retrieval method.

3. Characteristics of Heterodyne passive sub-mm sensor

Not accurate calibration (compared solar occultation for example) and problems such as non-linearity of the spectrum are exist. AOS spectrometers have frequency drift.

→ Required appropriate retrieval method.

Atmos. Meas. Tech. Discuss., 6, 2643–2720, 2013
www.atmos-meas-tech-discuss.net/6/2643/2013/
doi:10.5194/amtd-6-2643-2013
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77pages!

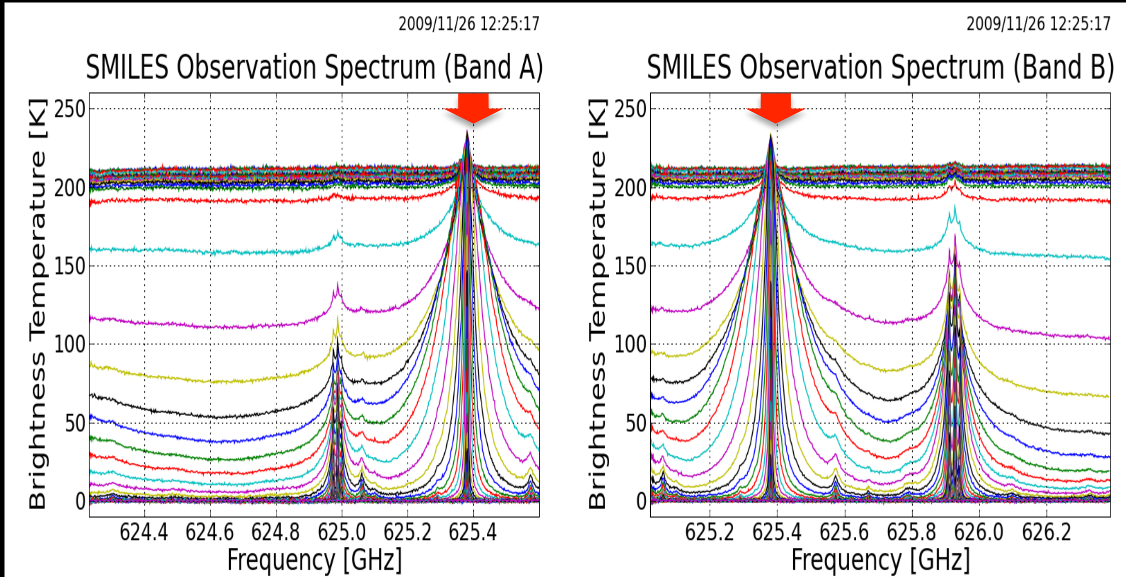
Atmospheric Measurement Techniques Discussions
Open Access

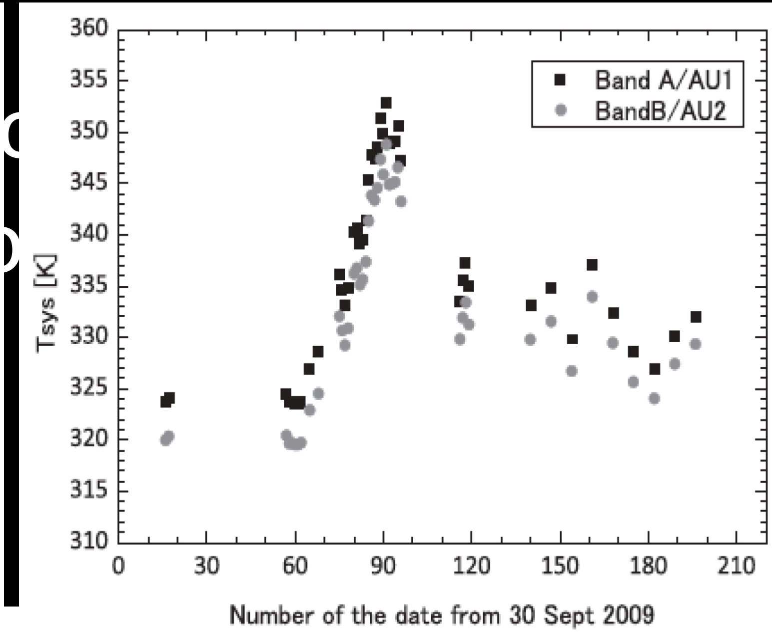
This discussion paper is/has been under review for the journal Atmospheric Measurement Techniques (AMT). Please refer to the corresponding final paper in AMT if available.

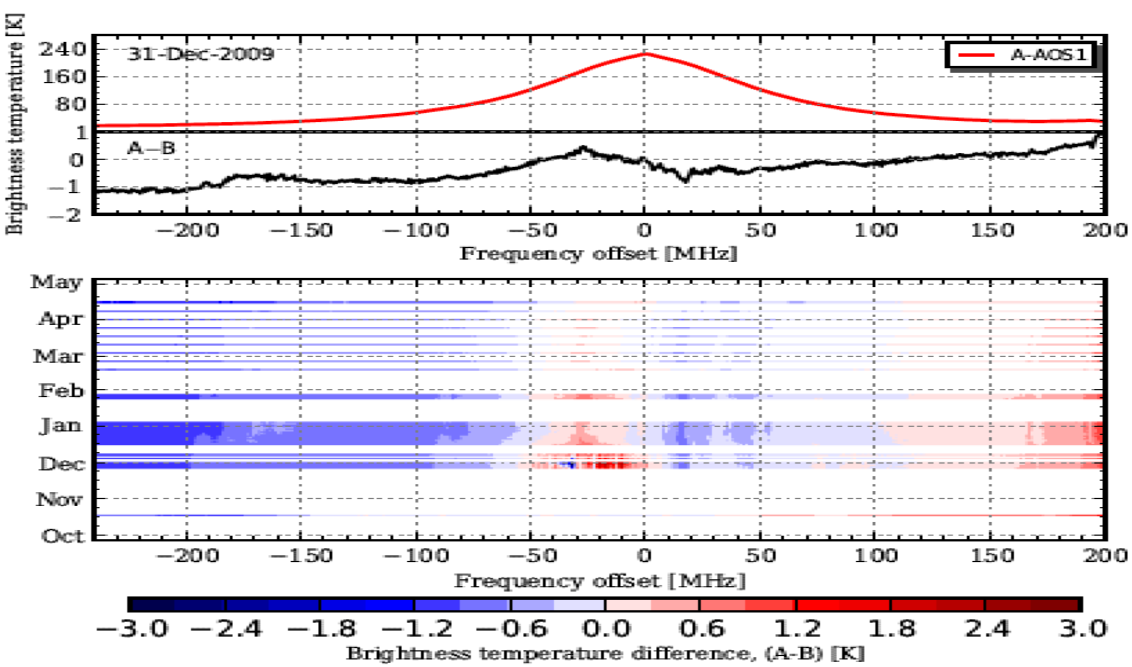
Validation of stratospheric and mesospheric ozone observed by SMILES from International Space Station

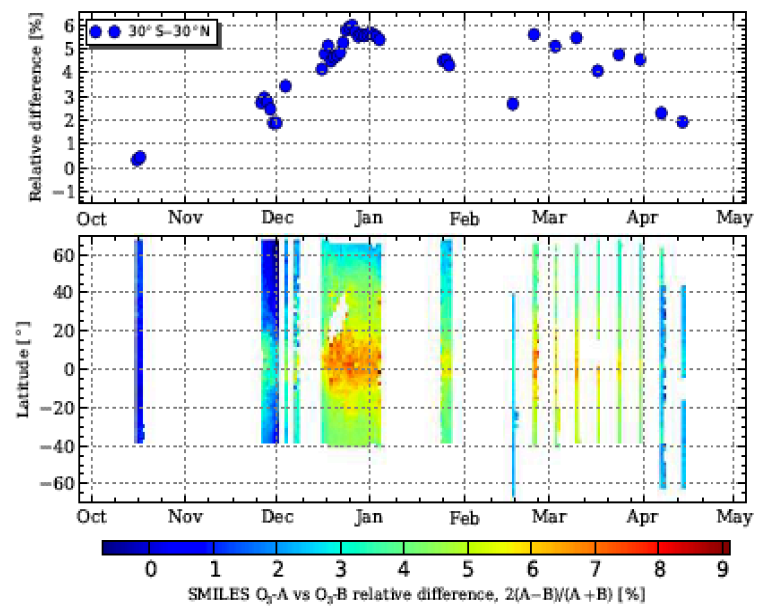
Y. Kasai[1,2], H. Sagawa[1], D. Kreyling[1], K. Suzuki[1,3], E. Dupuy[1,4], T. O. Sato[2,1], J. Mendrok[5,1], P. Baron[1], T. Nishibori[6,1], S. Mizobuchi[6], K. Kikuchi[1], T. Manabe[7], H. Ozeki[8], T. Sugita[4], M. Fujiwara[9], Y. Irimajiri[1], K. A. Walker[10,11], P. F. Bernath[12], C. Boone[11], G. Stiller[13], T. von Clarmann[13], J. Orphal[13], J. Urban[14], D. Murtagh[14], E. J. Llewellyn[15], D. Degenstein[15], A. E. Bourassa[15], N. D. Lloyd[15], L. Froidevaux[16], M. Birk[17], G. Wagner[17], F. Schreier[17], J. Xu[17], P. Vogt[17], T. Trautmann[17], and M. Yasui[1]

[1]National Institute of Information and Communications Technology (NICT), Koganei, Tokyo, Japan
[2]Tokyo Institute of Technology, Yokohama, Kanagawa, Japan
[3]The University of Tokyo, Graduate School of Arts and Sciences, Meguro, Tokyo, Japan
[4]National Institute for Environmental Studies, Tsukuba, Ibaraki, Japan
[5]Luleå University of Technology, Kiruna, Sweden
[6]Japan Aerospace Exploration Agency (JAXA), Tsukuba, Japan
[7]Osaka Prefecture University, Naka, Sakai, Osaka, Japan


2009/11/26 12:25:17
SMILES Observation Spectrum (Band A)
2009/11/26 12:25:17
SMILES Observation Spectrum (Band B)
Brightness Temperature [K]
Frequency [GHz]
624.4 624.6 624.8 625.0 625.2 625.4
625.2 625.4 625.6 625.8 626.0 626.2
0 50 100 150 200 250


Band A/AU1
BandB/AU2
Tsys [K]
Number of the date from 30 Sept 2009
310 315 320 325 330 335 340 345 350 355 360
0 30 60 90 120 150 180 210


31-Dec-2009
A-AOS1
A−B
Brightness temperature [K]
Frequency offset [MHz]
Oct Nov Dec Jan Feb Mar Apr May
Brightness temperature difference, (A-B) [K]
−3.0 −2.4 −1.8 −1.2 −0.6 0.0 0.6 1.2 1.8 2.4 3.0


30° S–30° N
Relative difference [%]
Latitude [°]
Oct Nov Dec Jan Feb Mar Apr May
SMILES O3-A vs O3-B relative difference, 2(A−B)/(A+B) [%]
0 1 2 3 4 5 6 7 8 9

SMILES NICT project activity

L1b, L2, validation, and Climatology

L1b S. Ochiai, K. Kikuchi, S. Mizobuchi	**L2/Molecules, T,** H. Sagawa T. Sato (O3 isotopes) Y. Kasai K. Yokoyama(HCl)	**L2/Ice cloud** H. Sagawa R. Bengt P. Eriksson	**Validation/ Comparison Error analysis** Y. Kasai, H. Sagawa, T. Sato, K. Yokoyama, R. Bengt	**L3/ Climatology** D. Kreyling
v700 (Aug 2011-)	v215 (Oct 2011-) O3, HCl, ClO, HO2, HOCl, BrO, CH3CN, HNO3, T, wind 24 -100km	---	O3, HCl, ClO, HOCl, HO2, BrO, T	O3, HCl, ClO, HO2, HOCl, BrO, T
v800 (Dec 2012-) Current version Tangent height, calibration for non-linearity problem, AOS parameters improve a lot.	v300 (Aug 2013) + O3 isotope 12 -100km	V300 (Aug 2013)	+ O3 isotopes	
V900 (2013) Freq. collection required.	v310		+ CH3CN, HNO3	

SMILES
NICT v215 Validation/Evaluation Status

Molecule	Precision and Accuracy	Papers
Ozone	5%, 20% (100-0.01 hPa)	**Y. Kasai et al.,** “Validation of stratospheric and mesospheric ozone observed from SMILES onboard International Space Station” Atmos. Meas. Tech. Discuss., 6, 2643-2720, 2013
ClO	10%, 20% (60–0.1hPa)	**T. O. Sato et al.,** “Strato-Mesospheric ClO Observations by SMILES: Error Analysis and Diurnal Variation”(2012) Atmos. Meas. Tech. Discuss., 5, 4667-4710, 2012 **H. Sagawa et al.,** “Validation ClO observed from SMILES onboard International Space Station” Atmos. Meas. Tech. Discuss., 6, 613-663, 2013
HCl	5%, 20% (100-0.01 hPa)	**K. Yokoyama et al.,** “Validation of HCl observed from SMILES onboard International Space Station”2013 to be submitted to JGR
HOCl, HO2, BrO, winds, ice cloud/ humidity	30%, 30% (100 – 0.1 hPa)	**P. Baron et al.,** “Observation of horizontal winds in the middle-atmosphere between 30S and 55N during the northern winter 2009/2010.” (2012) Accepted to ACP **K. Kuribayashi et al.,** “Evaluation of ClO + HO2→HOCl+O2 reaction in the atmosphere by SMILES observation”, Atmos. Chem. Phys. Discuss., 13, 12797-12823, 2013 **R.A. Stachnik et al.,** “Stratospheric BrO abundance measured by a balloon-borne submillimeterwave radiometer” (2012) Accepted ACP **E Millan et al.,**“SMILES Ice Cloud Products”, (2012), Accepted JGR

What SMILES found?

Earth from ISS (International Space Station) at 320km

Summary

- SMILES successfully performed the observation during 12 October 2009 and 21 April 2010 with one order magnitude better sensitivity than past instrument. The spectrum performance is absolutely good.

- SMILES observation revealed the chlorine chemistry up to TOA
  1) Found HCl reached to the top of atmosphere
  2) found ClO layer in the atmosphere
  3) Defined the Cl chemistry in the Earth atmosphere

Water vapor isotope observation by satellite-born submillimetre radiometer

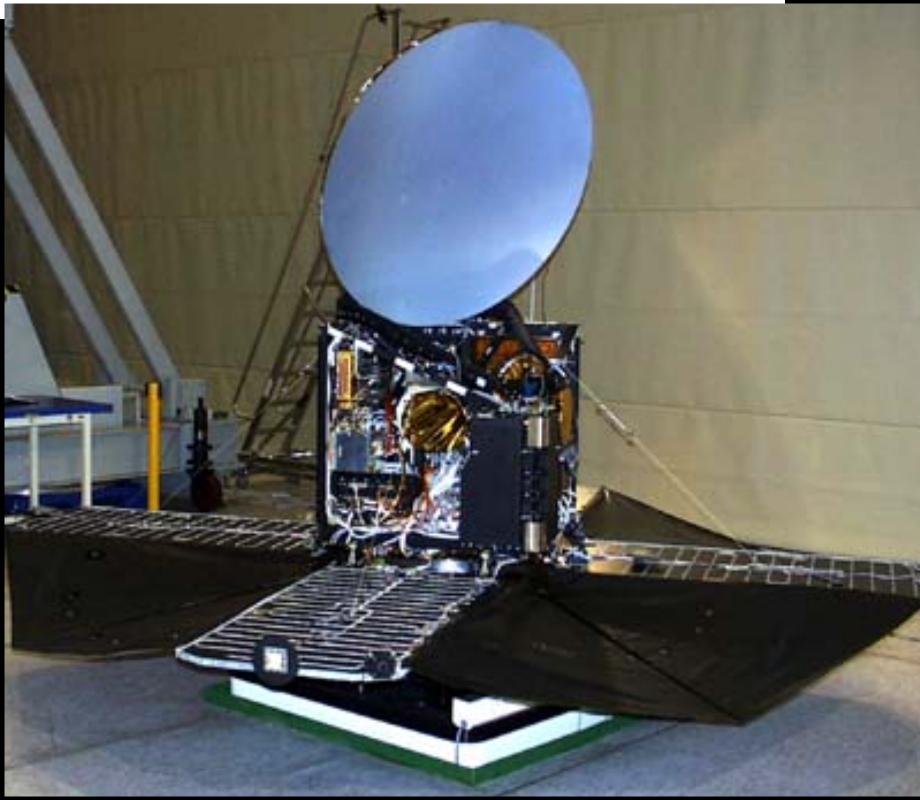
Yasuko Jessica Kasai[(1)],

Odin/SMR team
Joachim Urban[(2)], Donal Murtagh[(2)], Philippe Ricaud[(3)], Patrick Erikkson, and Odin/SMR group[(2,3,5)]

SMILES team
Satoshi Ochiai [(1)], Hiroshi Kumagai [(1)], Philippe Baron [(1)], Jana Mentrok [(1),], Yoshihisa Irimajiri[(1)]
Stefan. A. Buehler [(4)], Masato Shiotani [(6)], and JEM/SMILES Mission Team

1 National Institute of Information and Telecommunications Technology (NICT), Japan
2 Radio and Space Science Department, Chalmers University of Technology, Sweden
3 Laboratoire d'Aerologie, CNRS, Universite Paul Sabatier, France
4 University of Bremen, Germany
5 Swedish Space Corporation, PO Box 4207, 171 04 Solna, Sweden
6 Kyoto University, Japan

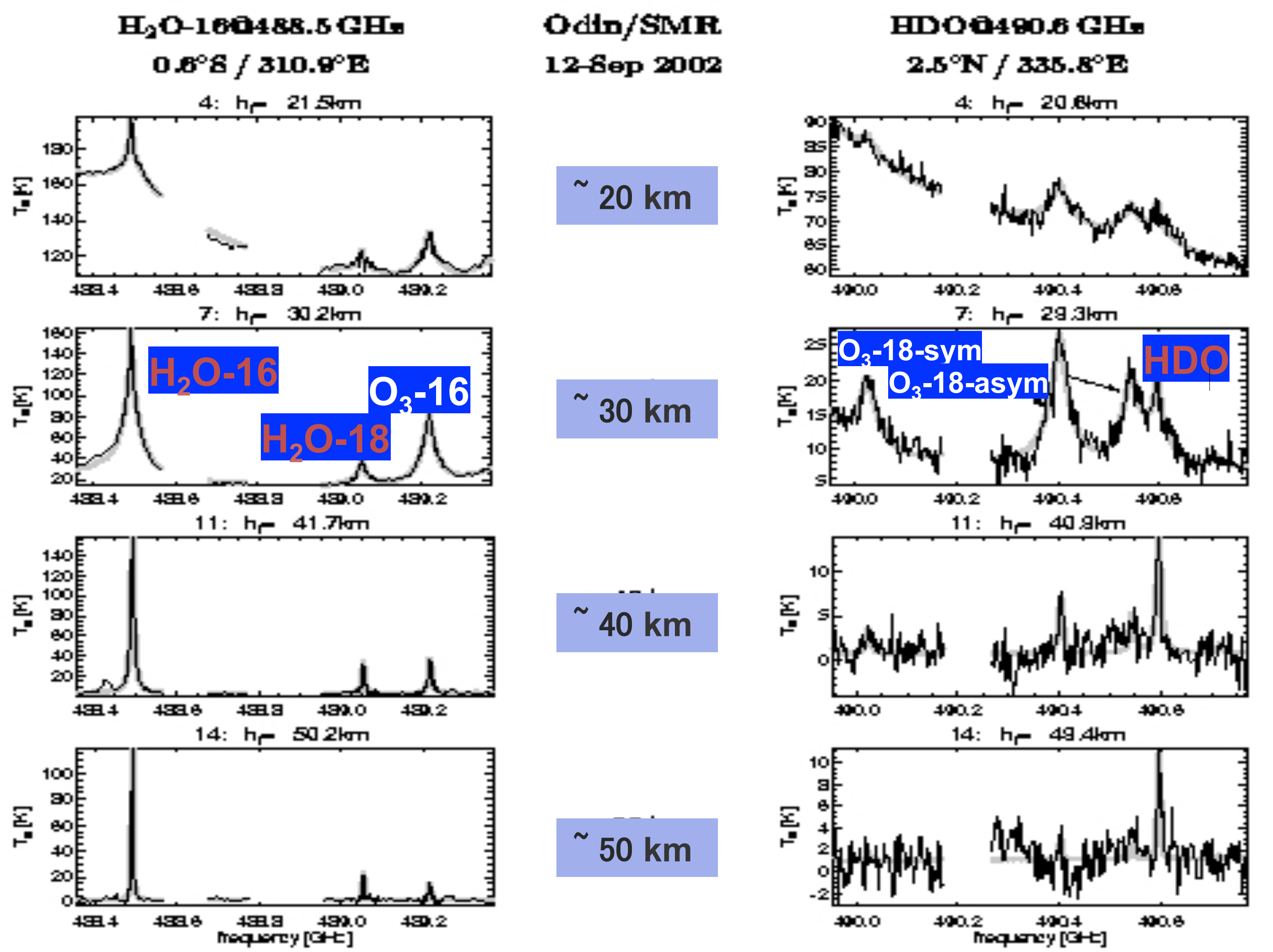
The Odin satellite



- Swedish led **mini-satellite**.
  Cooperation with Canada, Finland, France.
- **Launched in February 2001**.
  Design lifetime: 2 years.
- **Circular quasi-polar sun-synchronous orbit**:
  625km altitude, 96min/orbit,
  6h/18h equator crossing.
- Time sharing: **50% astronomy, 50% aeronomy**.
- **Limb-sounding** in aeronomy mode:
  ~45-65 scans/orbit, ~15 orbits per day.
- 2 instruments:
  SMR (*Sub-Millimetre Radiometer*),
  OSIRIS (Optical Spectrograph and Infrared Imaging System)
- Aeronomy science objectives**:**

  ***stratospheric mode* (ClO, N_2O, HNO_3, O_3), *water isotope mode* (H_2O, HDO, H_2O-18, H_2O-17),**
  ***odd hydrogen / summer mesosphere mode* (H_2O, O_3, CO), *odd nitrogen mode* (NO, HNO_3, NO_2)**

Odin/SMR
H_2O, HDO, $H_2^{18}O$ Observation

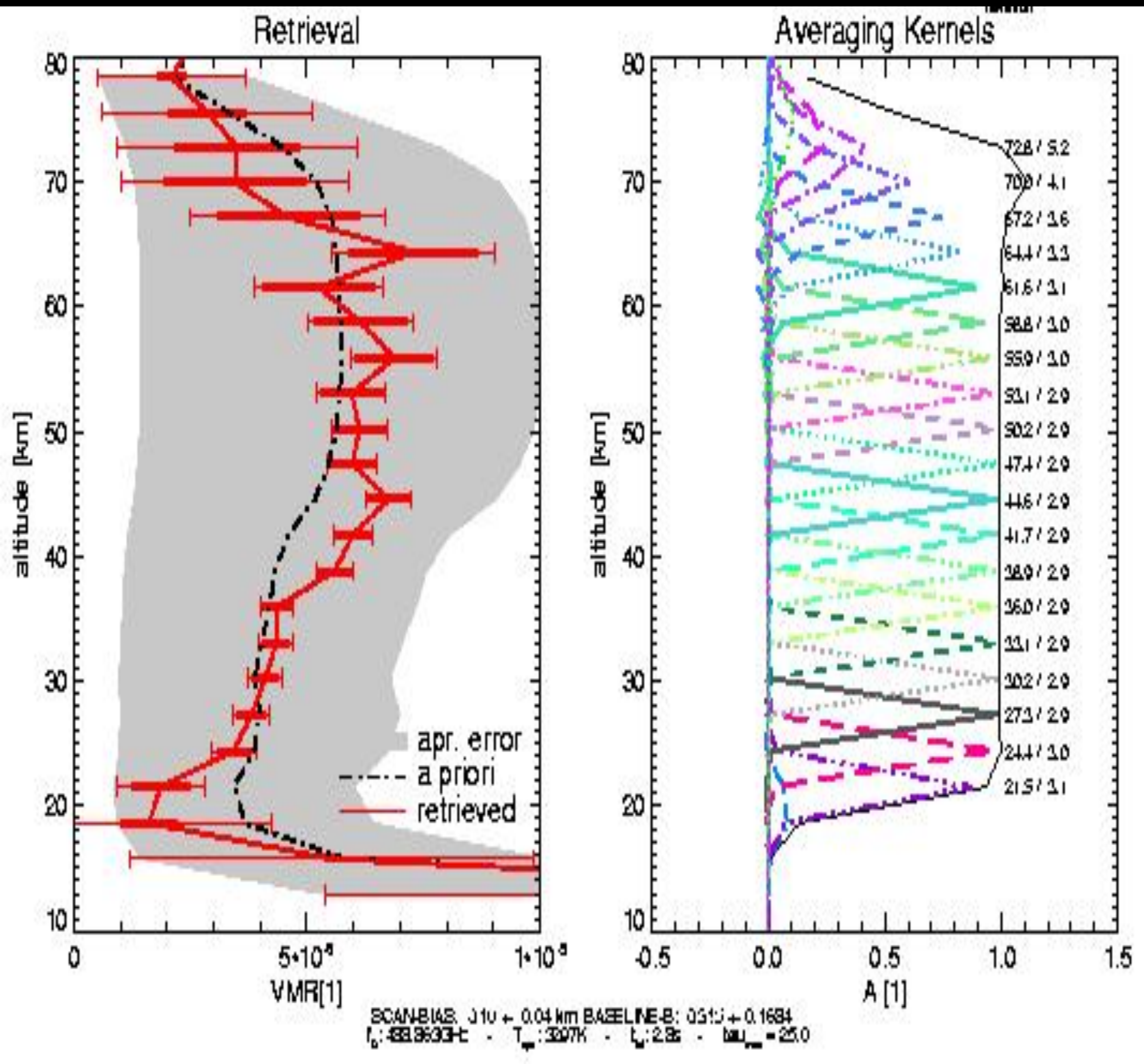


488.9 GHz band

490.4 GHz band

An Example of the Retrieved profile H_2O

$H_2{}^{16}O$



Altutude Range

20-70km

for the single scan (single point)

16-80km

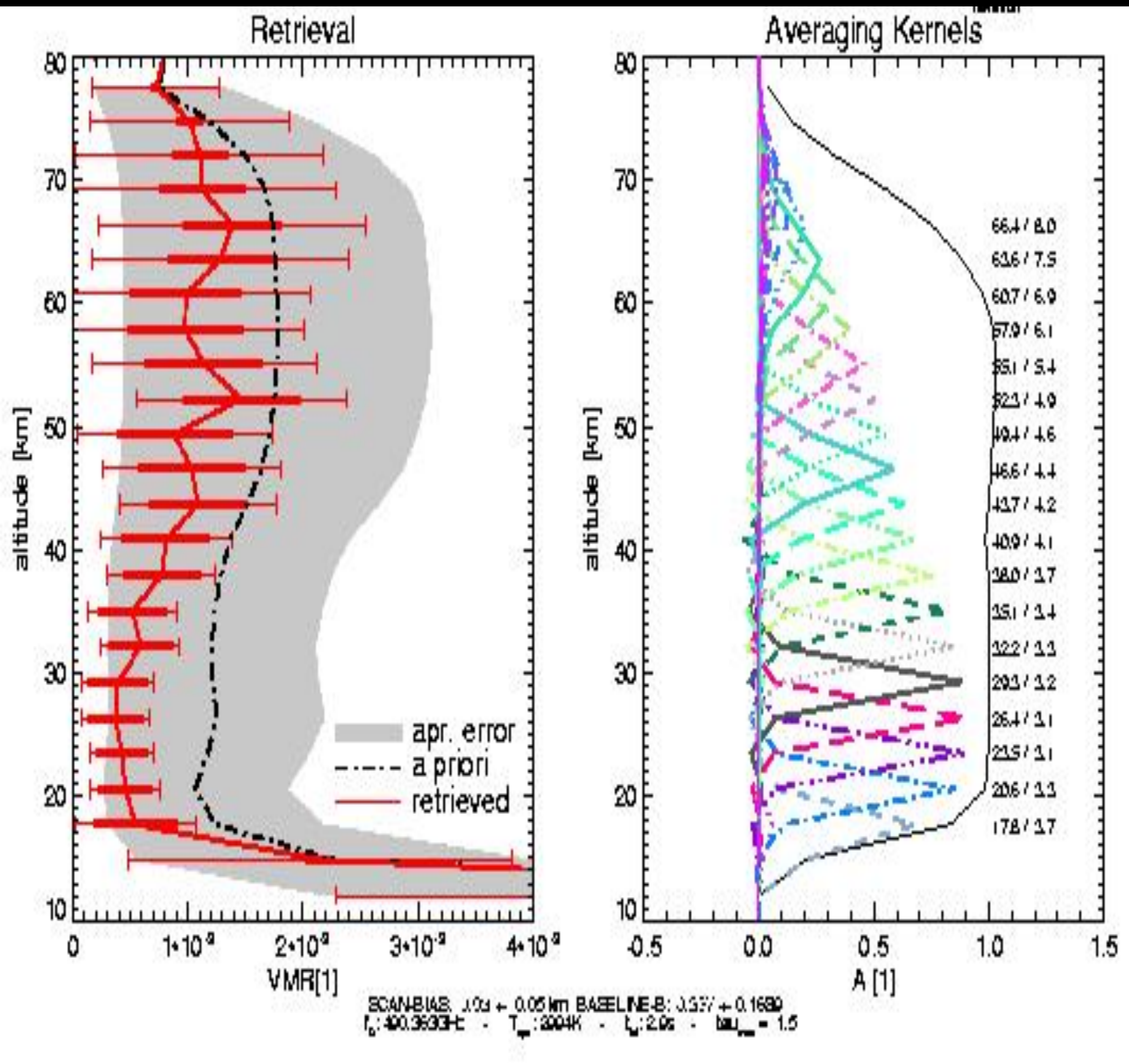
for the averaged profiles, such as zonal mean

Altutude Resolution

3km

An Example of the Retrieved profile HDO

HDO



Altutude Range

18-60km

for the single scan (single point)

16-70km

for the averaged profiles, such as zonal mean

Altutude Resolution

3km

Errors of Odin/SMR measurements

Measurement: Precision (1σ) for single scan

H_2O-16	15-20 % (0.5-1ppmv)
HDO	～20 % (<1ppbv)

Requirement for the isotope study: Precision (1σ)

H_2O-16	less than 2 %
HDO	less than 2 %

⇩

SHOULD accumulate the retrieved profiles more than 100

→ Three month profiles averaged.

δD comparisons

-Depletion express as :

$$\delta D(\%) \equiv (\frac{R_s}{R_0} - 1) \times 100$$

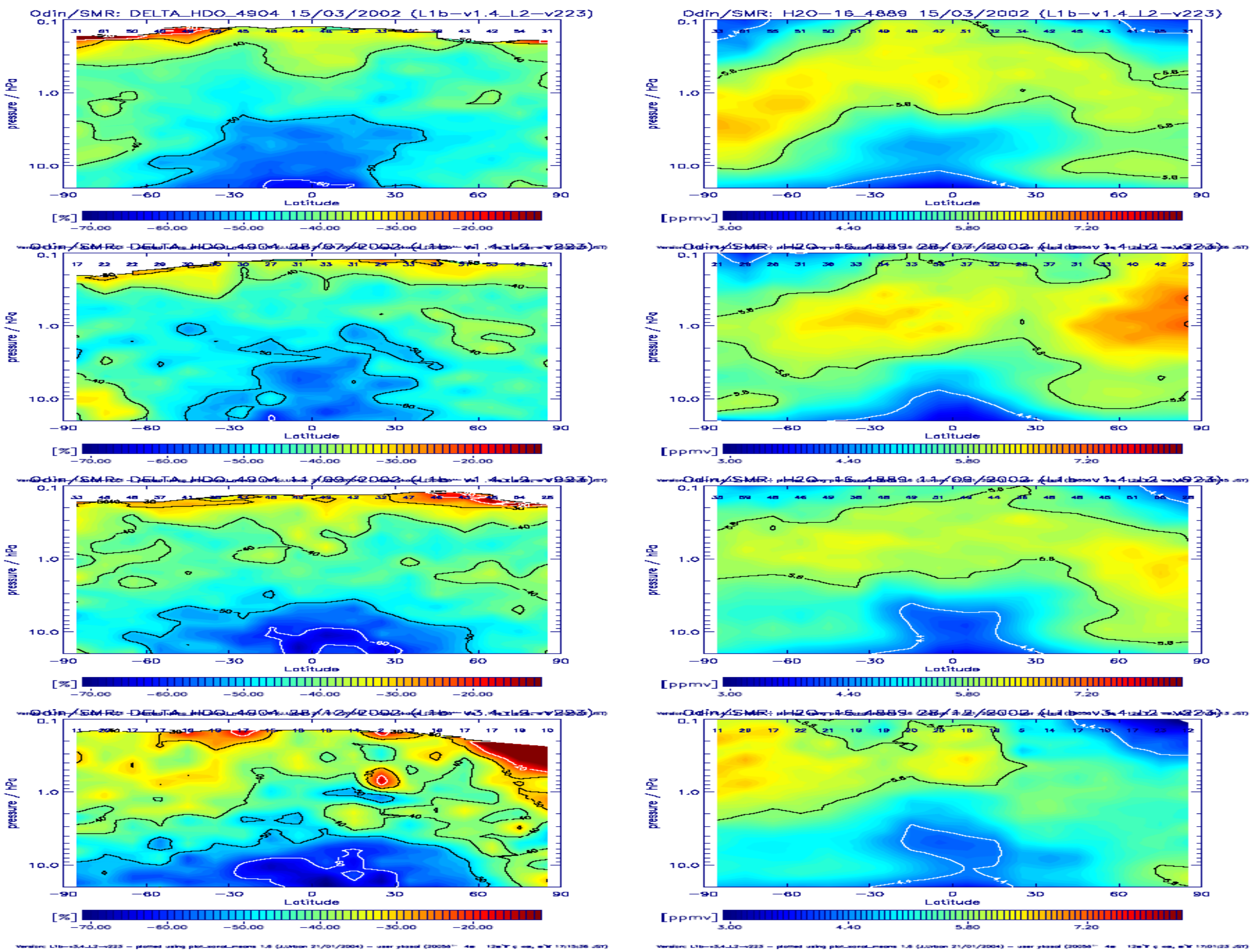
R_s : Observed isotopic ratio [HDO]/2[H_2O]

R_0 : measured in Std Mean Water (SMOW) $[HDO]_{SMOW}/2[H_2O]_{SMOW}$

Some bias may remove by taking ratio HDO/H2O

3 month mean (2002)

δD | H_2O



Mar.- May

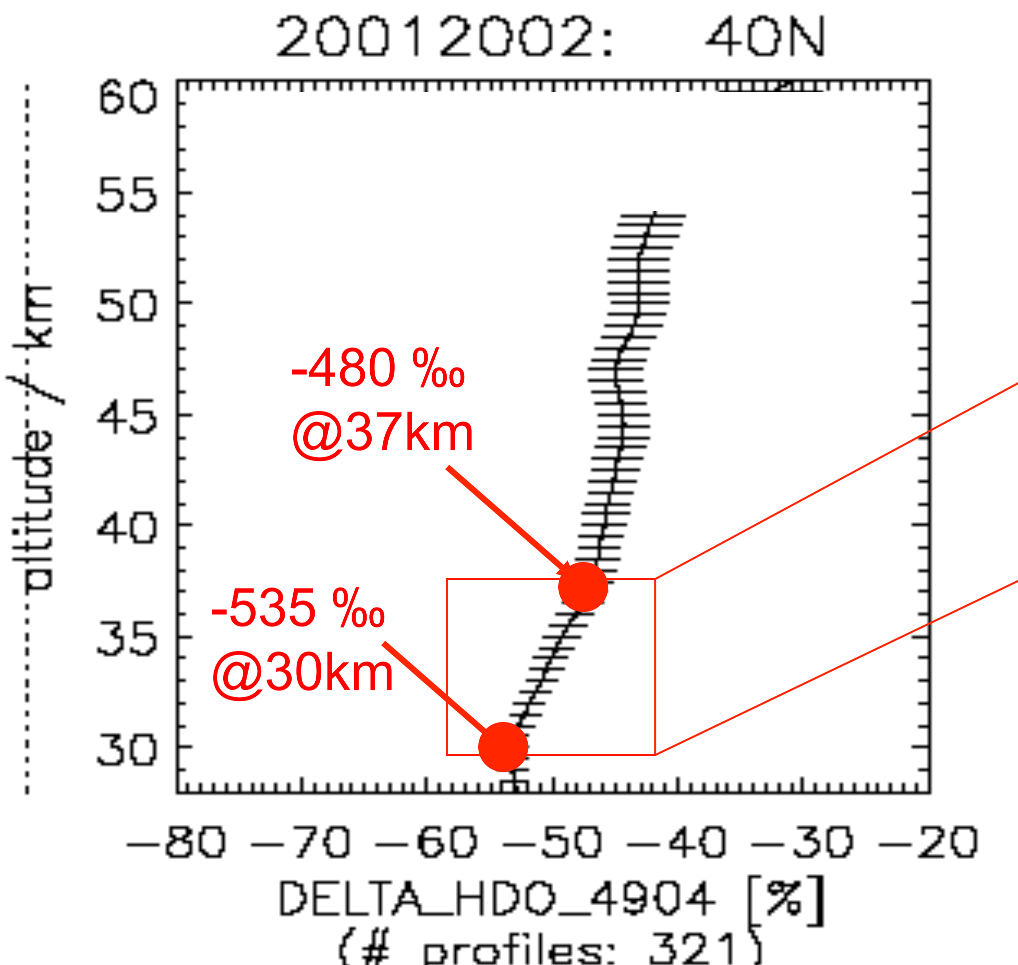
Jul.- Aug.

Sep.- Nov.

Dec.- Feb.

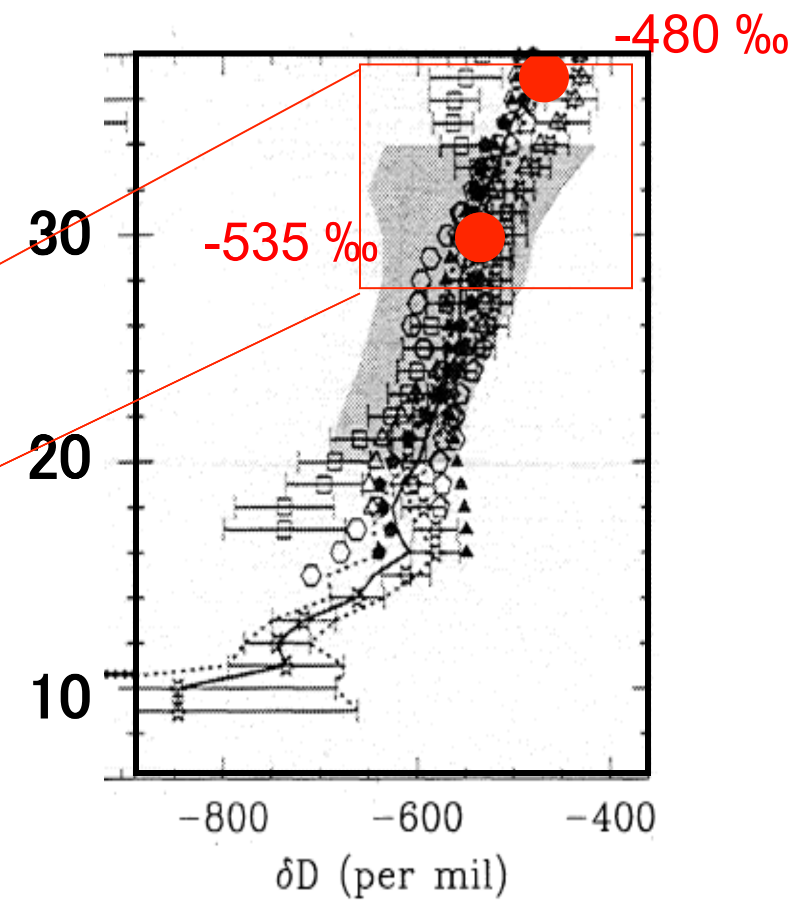
Comparison of δD with past measurements
1. Mid-latitude region

Odin/SMR measurements 60N to 20N



FIR-Emission (balloon born)
6 flight for 33N, 1 for 68N

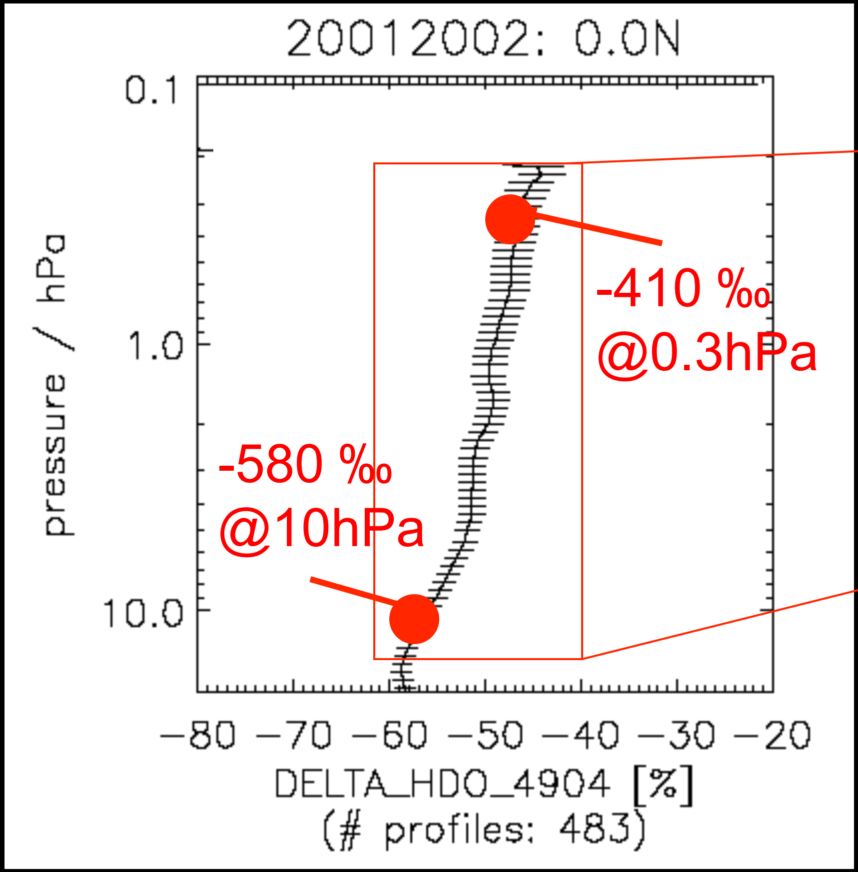
D.G.Johnson et al., (2001)



Comparison of δD with past measurements and 2D model

2. Equator Region (-20°to 20°)

Odin/SMR measurements



ATMOS

Ridal, 2002

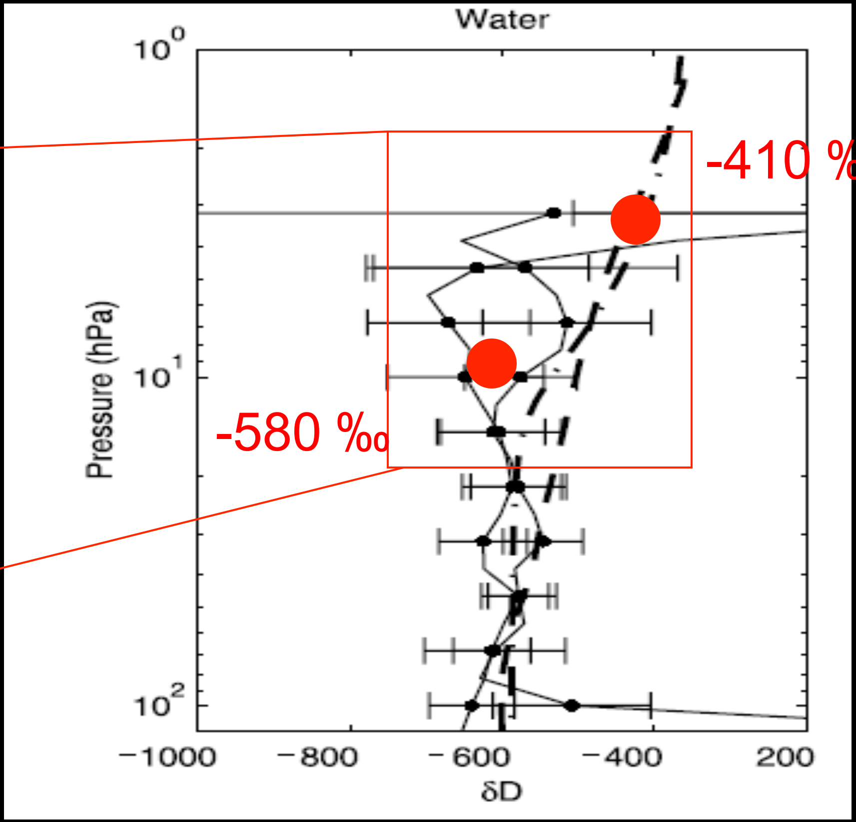
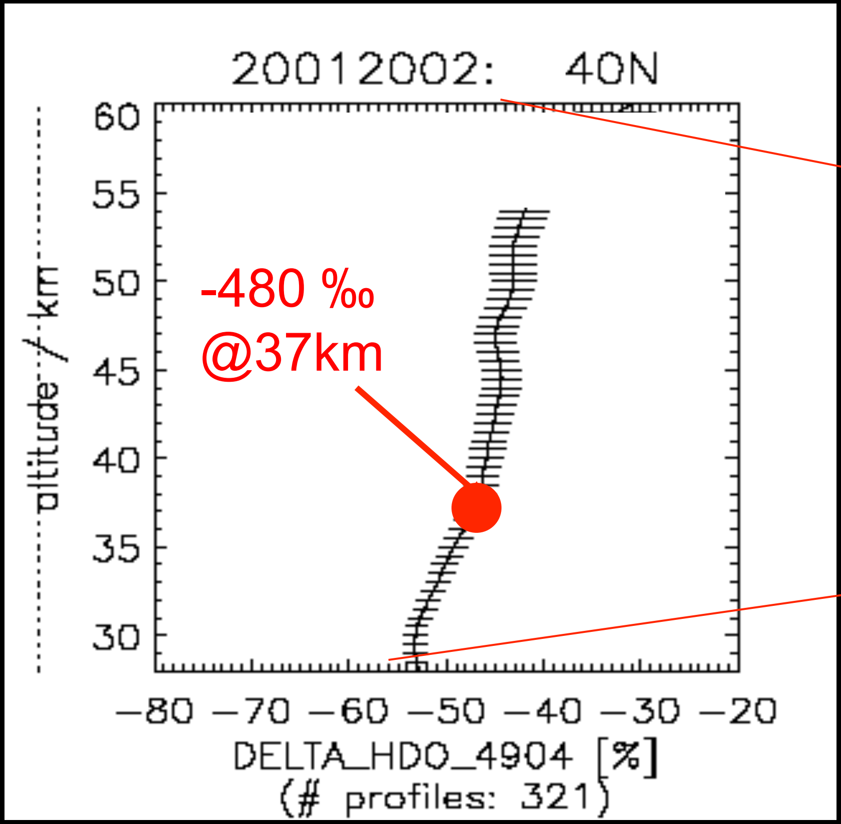


Figure 6. Isotopic ratios of water vapor (left panel) and methane (right panel). The solid lines are measured daily mean profiles by the ATMOS instrument from the tropical region (−20° to 20°) in November 1994. The error bars indicate the 1σ standard deviation. The dashed lines are simulations by the CHEM2D model (equator) and the dot-dashed lines are simulations by the 1-D model.

δD Comparison with 1D model

Odin/SMR Mid-Latitude



Bechtel, 2003

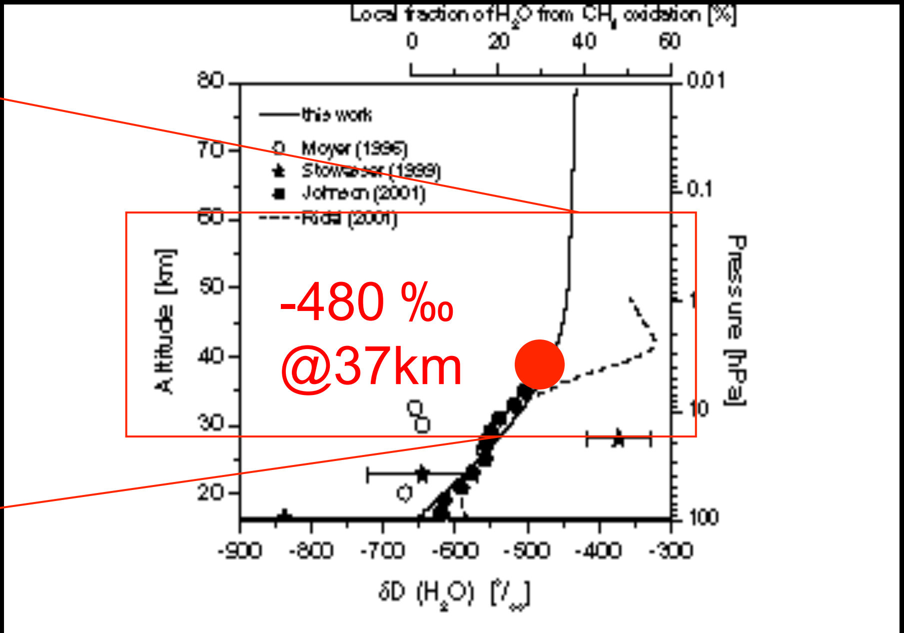
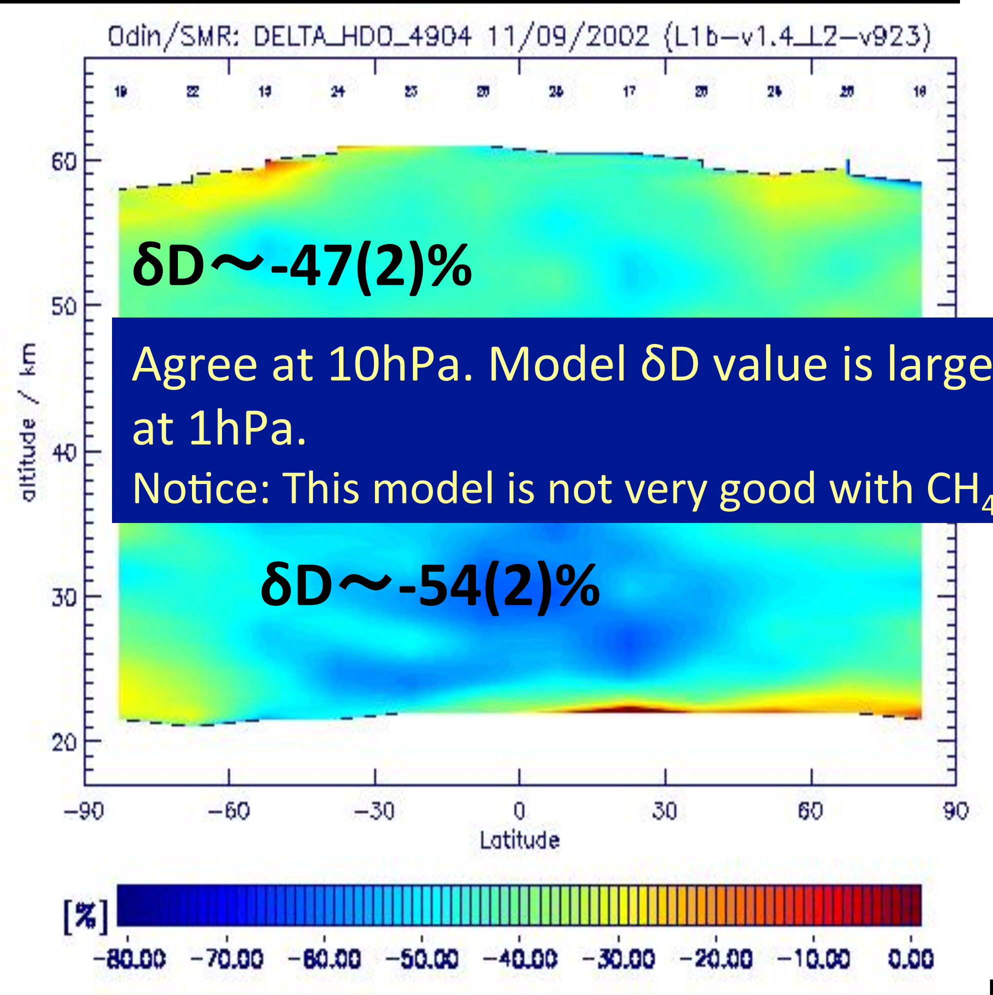
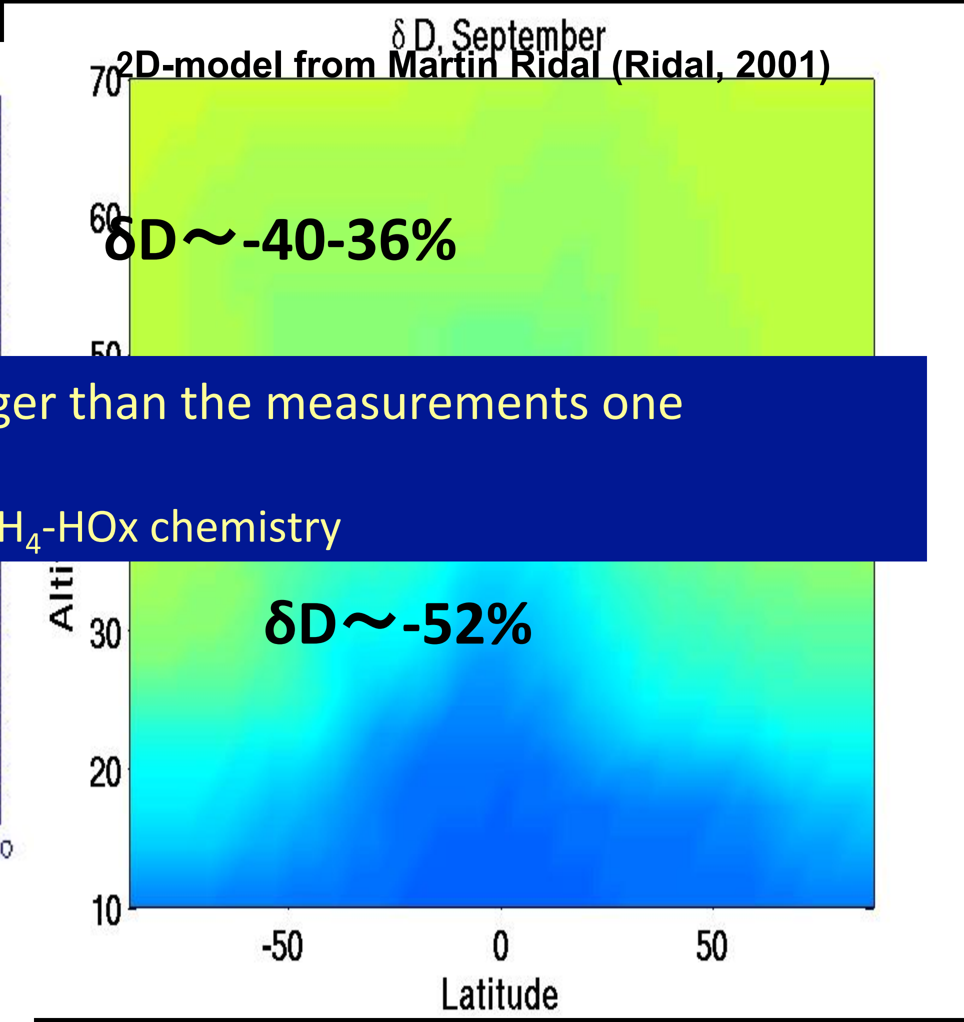


Fig. 2. Calculated vertical profile of δD(H_2O) (solid line) compared to measurements. Open circles: ATMOS FTIR data of near-global latitudinal coverage (Moyer et al., 1996). Full circles: Smithsonian Astrophysical Observatory's far-infrared data by Johnson et al. [2001a]. Stars: Balloon-borne FTIR data inside the Arctic vortex at 68°N (Stowasser et al., 1999). Dashed line: 1-D model result by Ridal et al. (2001). Upper *x* axis indicates the approximate fraction of H_2O from the CH_4 oxidation inferred from the δD(H_2O) value (explanation, see Sect. 6.2).

δD Comparison with 2D model
zonal mean comparison

SEPTEMBER 2002



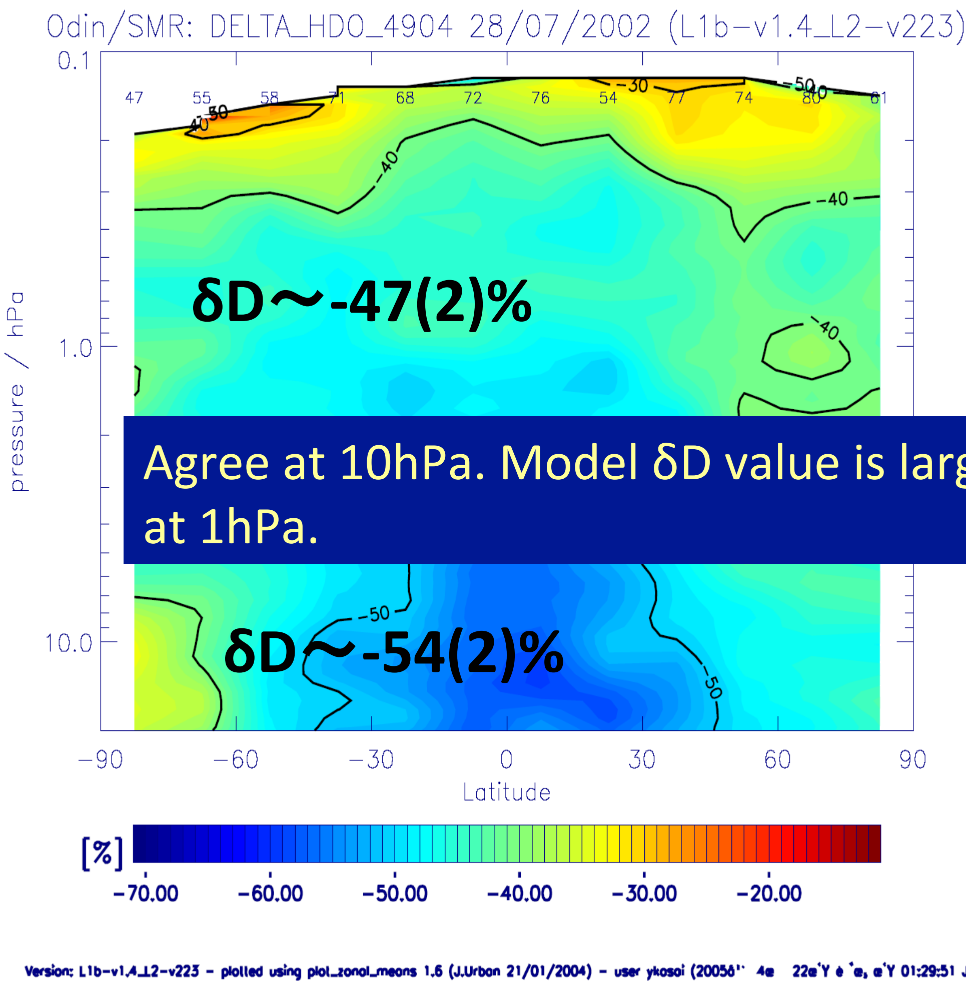


Agree at 10hPa. Model δD value is larger than the measurements one at 1hPa.

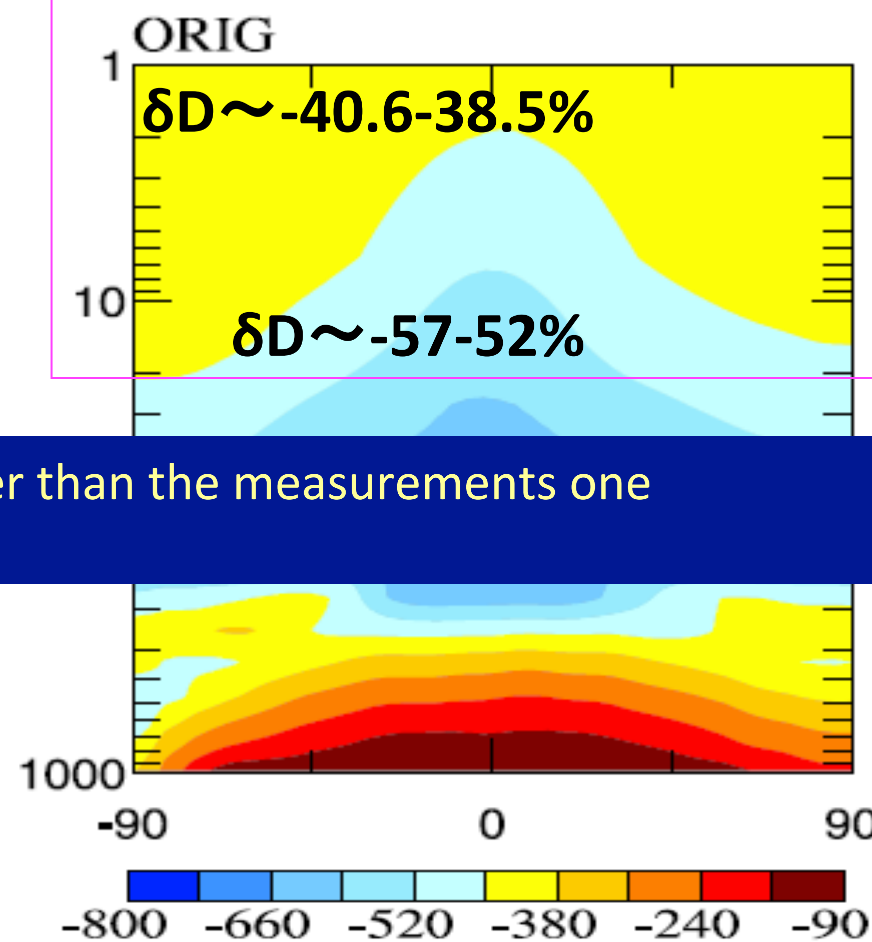
Notice: This model is not very good with CH_4-HOx chemistry

δD Comparison with model 3
zonal mean comparison

Half year means
March-April-July-Aug-Sep (2002)



Schmidt 2005
Annual mean



Agree at 10hPa. Model δD value is larger than the measurements one at 1hPa.

Summary of δD comparisons

in the middle stratosphere

-Comparison with past measurements

FIR(mid-latitude): Excellent Agreement

ATMOS(equator): Agree very well

-Comparison with model calculations

- Bechtel 1D model : Agree very well

  (this model includes no H2 chemistry)

- Ridal 2D model:

  1hPa--Model value is larger than measurements

  10hPa—Model value is slightly larger than obs.

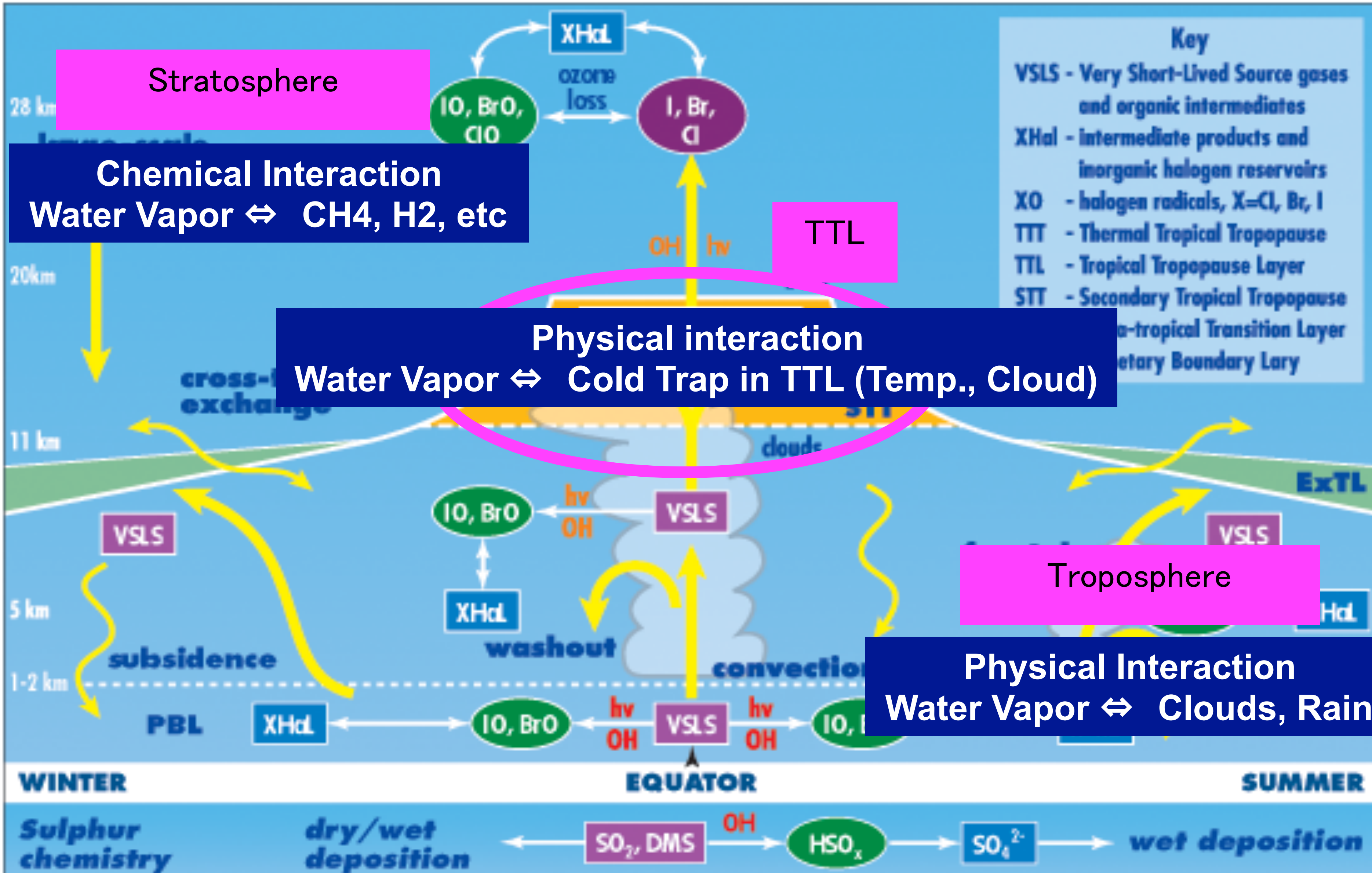
  (this model is not very good with CH_4-HOx chemistry)

- Schmidt model:

  1hPa--Model value is larger than measurements

  10hPa—Model value is consistent with obs.

δD value in the atmosphere



Origin

δDini～-65%

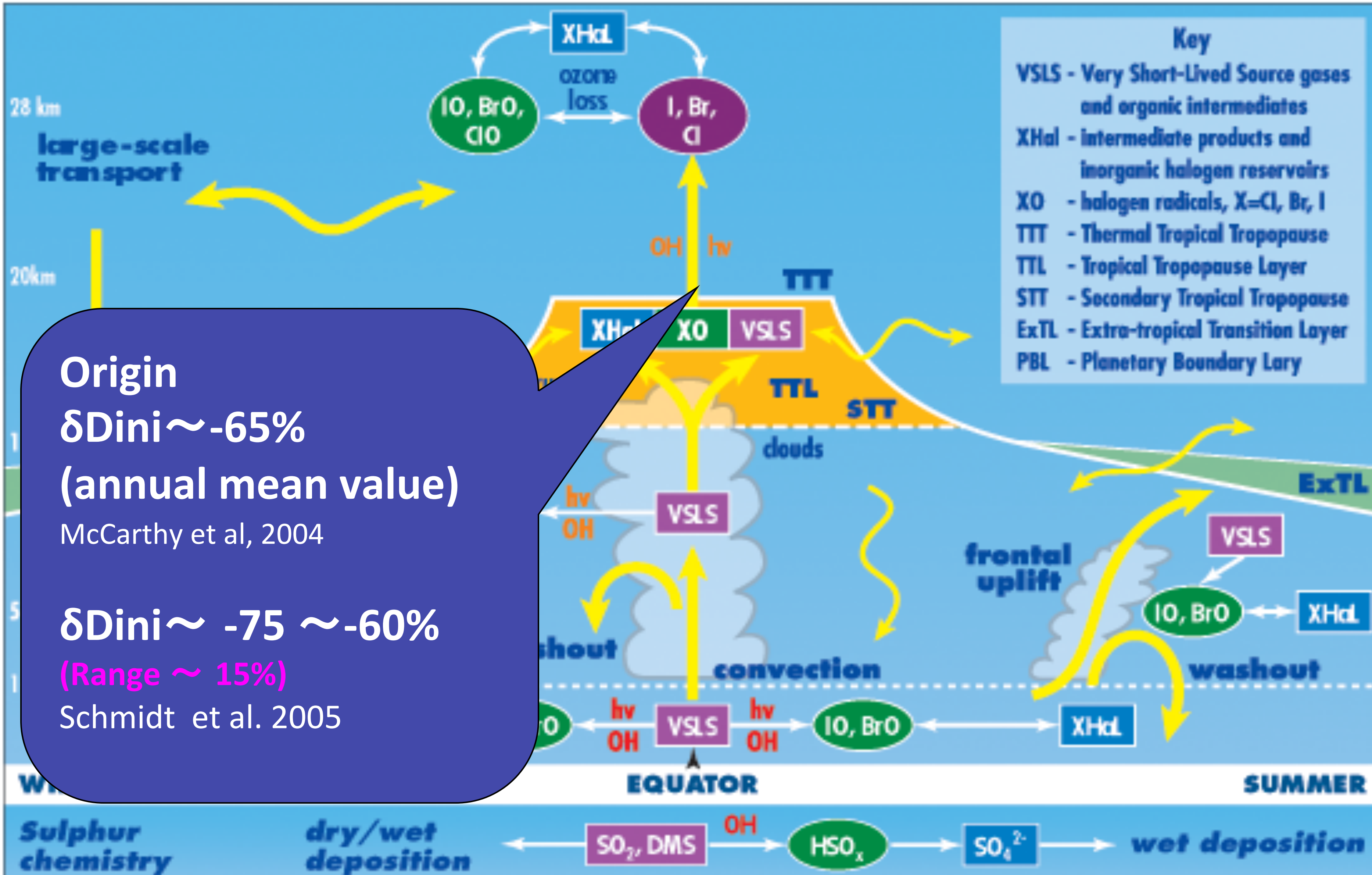
(annual mean value)

McCarthy et al, 2004

δDini～ -75 ～-60%

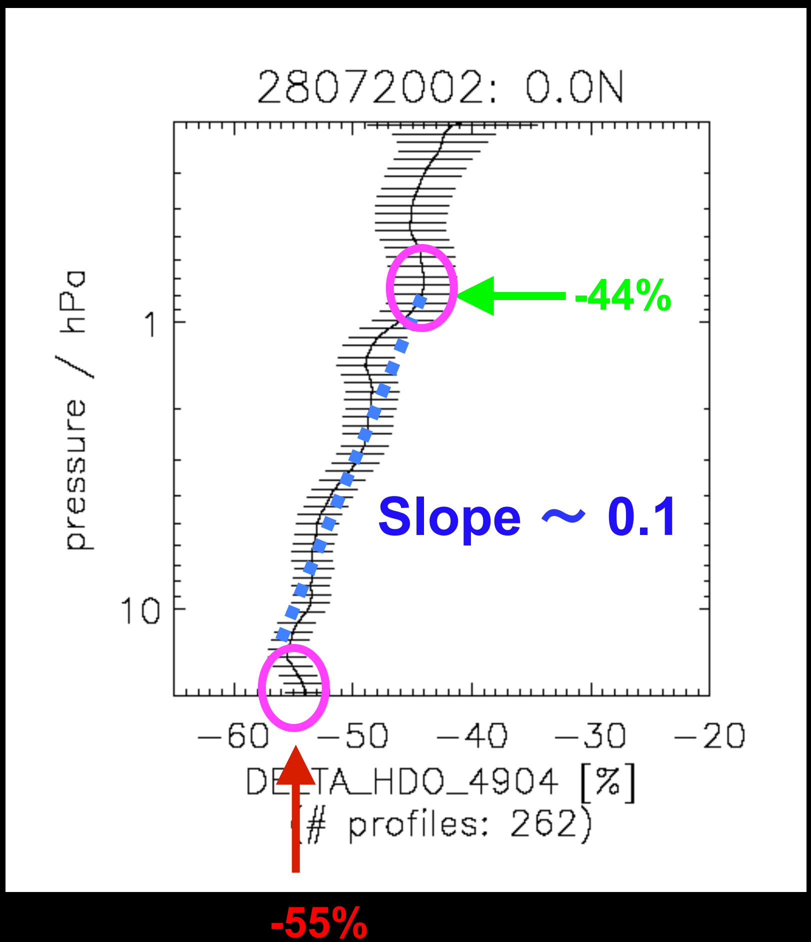
(Range ～ 15%)

Schmidt et al. 2005

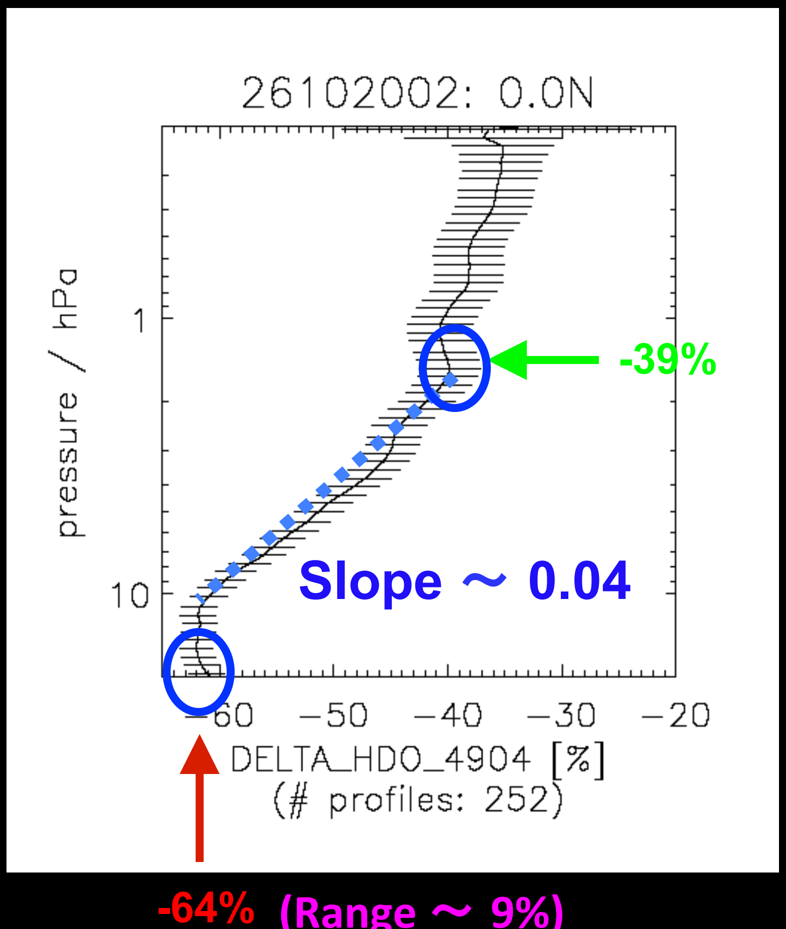


δD - 20S-20N mean

3 month mean
July-Aug-Sep 2002



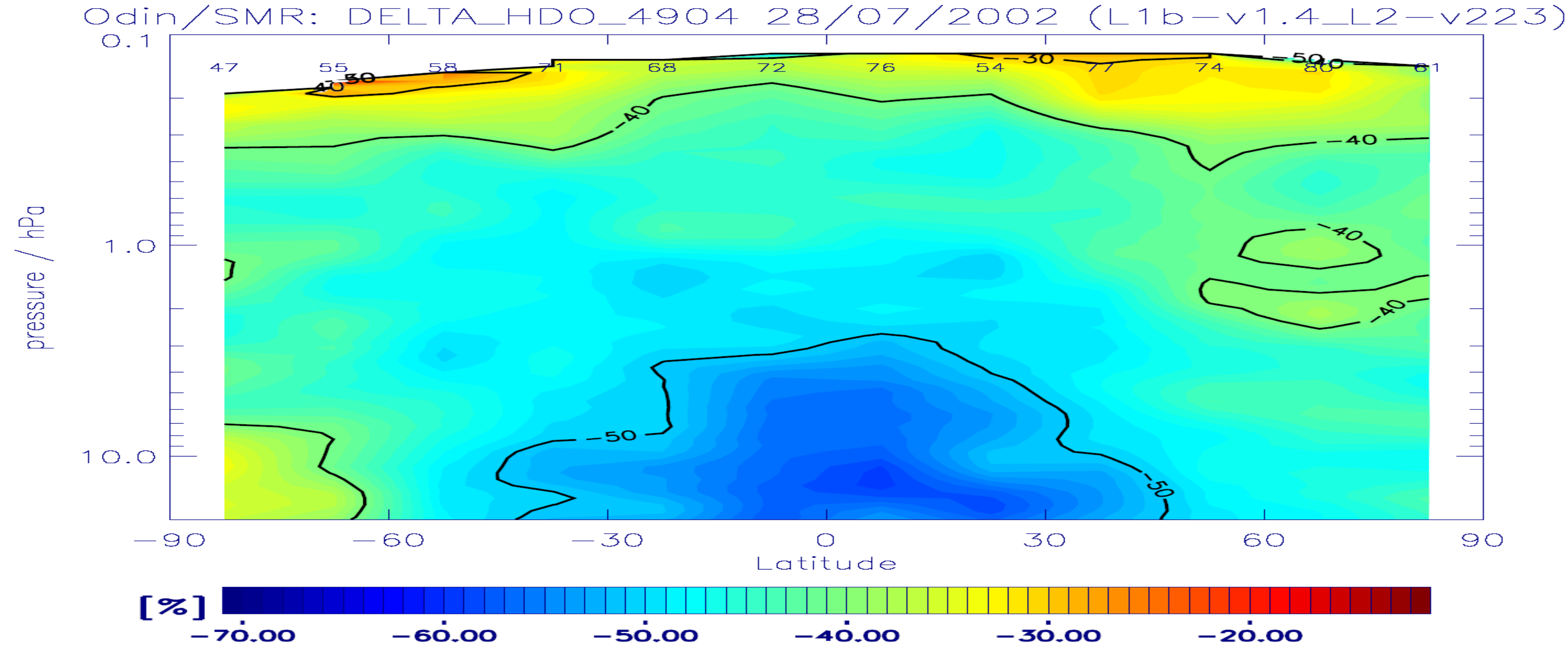
3 month mean
Oct-Nov-Dec 2002

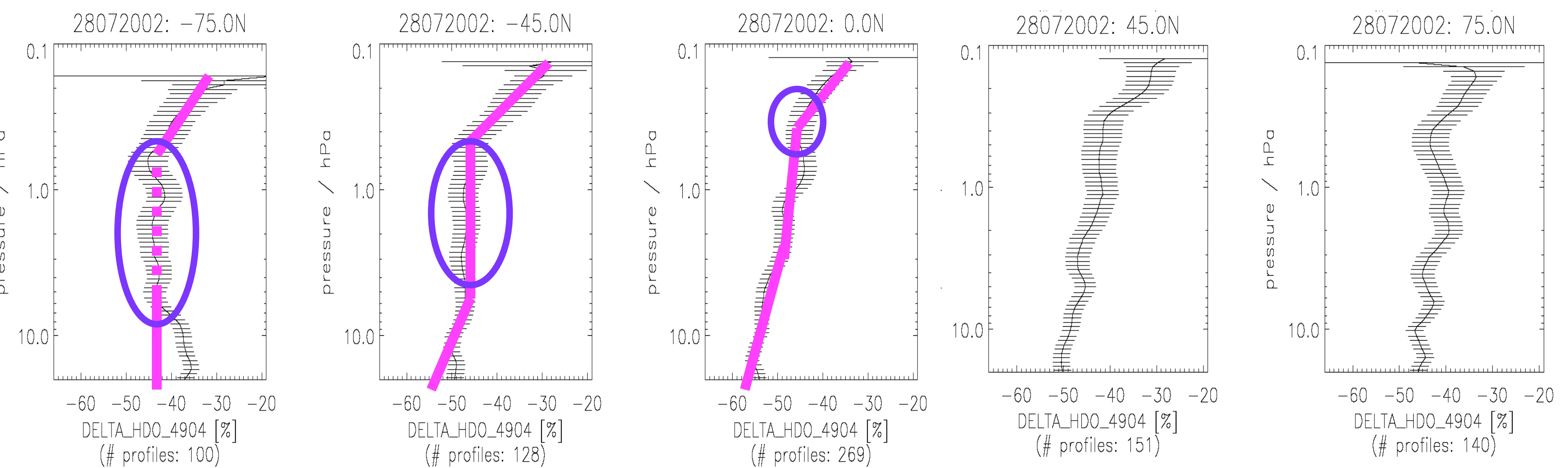


Wet Air-> high δD, Dry air-> lower δD

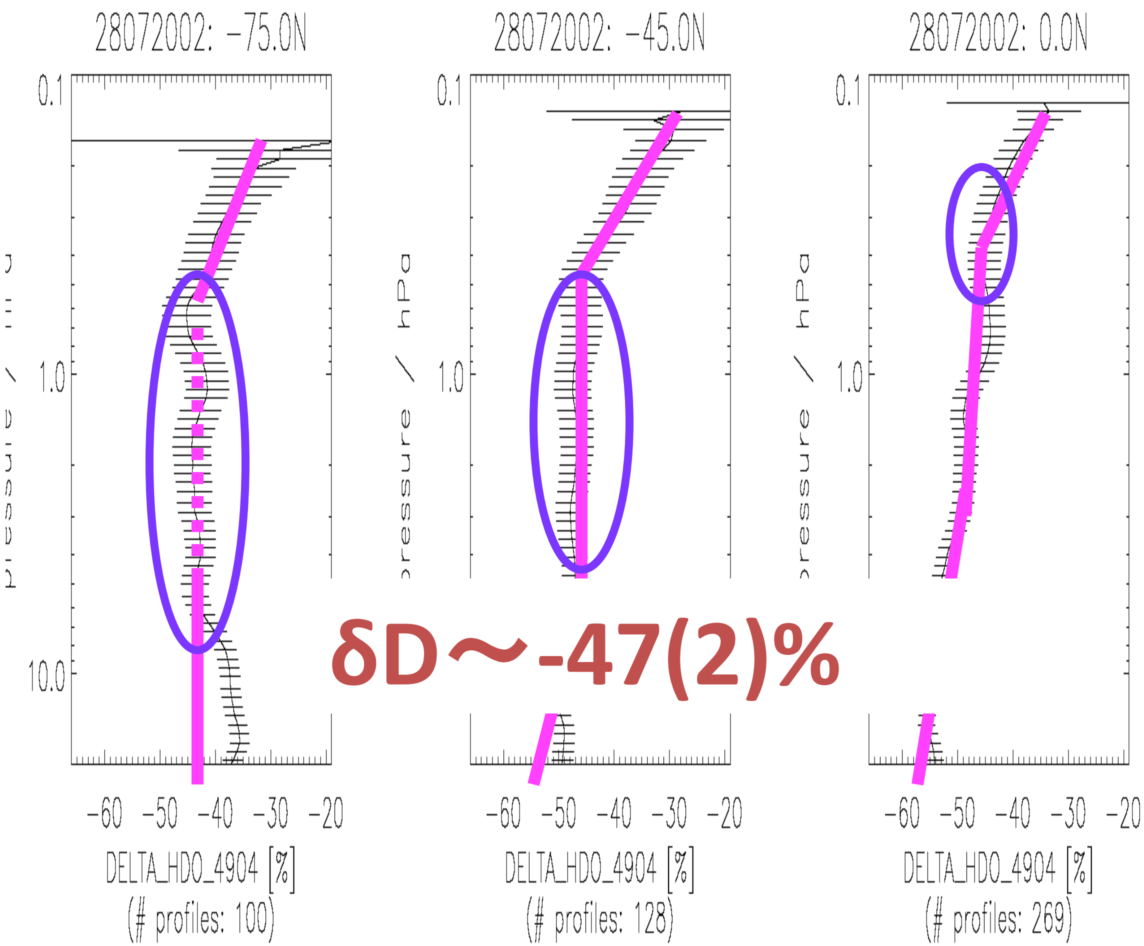
δD – zonal mean

Half year means
March-April-July-Aug-Sep (2002)

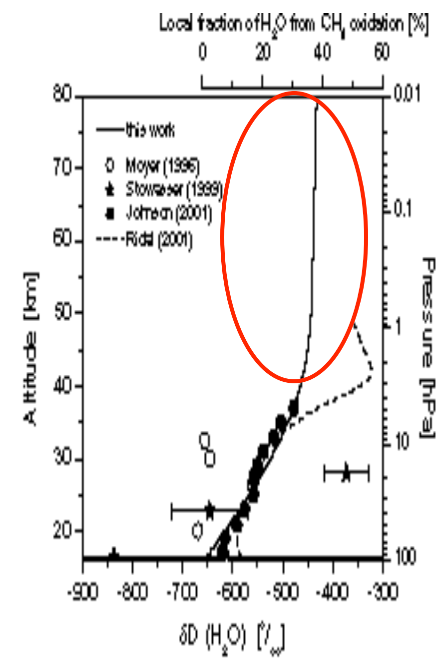




Upright structure of δD in the middle stratosphere



δD～-47(2)%



Similar with 1-D model calculation with no H_2 chemistry

May write

$$\delta D_{total}(\%) = \delta\ \mathrm{D}_{ini} + \delta\ \mathrm{D}\,(\mathrm{CH}_4) + \delta\ \mathrm{D}(\mathrm{H}_2) + \delta\ \mathrm{D}([O^1D]) + \delta\ \mathrm{D}(hv)$$

Origin (Dynamical)

Source (Chemical)

Sink (Chemical)

δD ini: Input from TTL

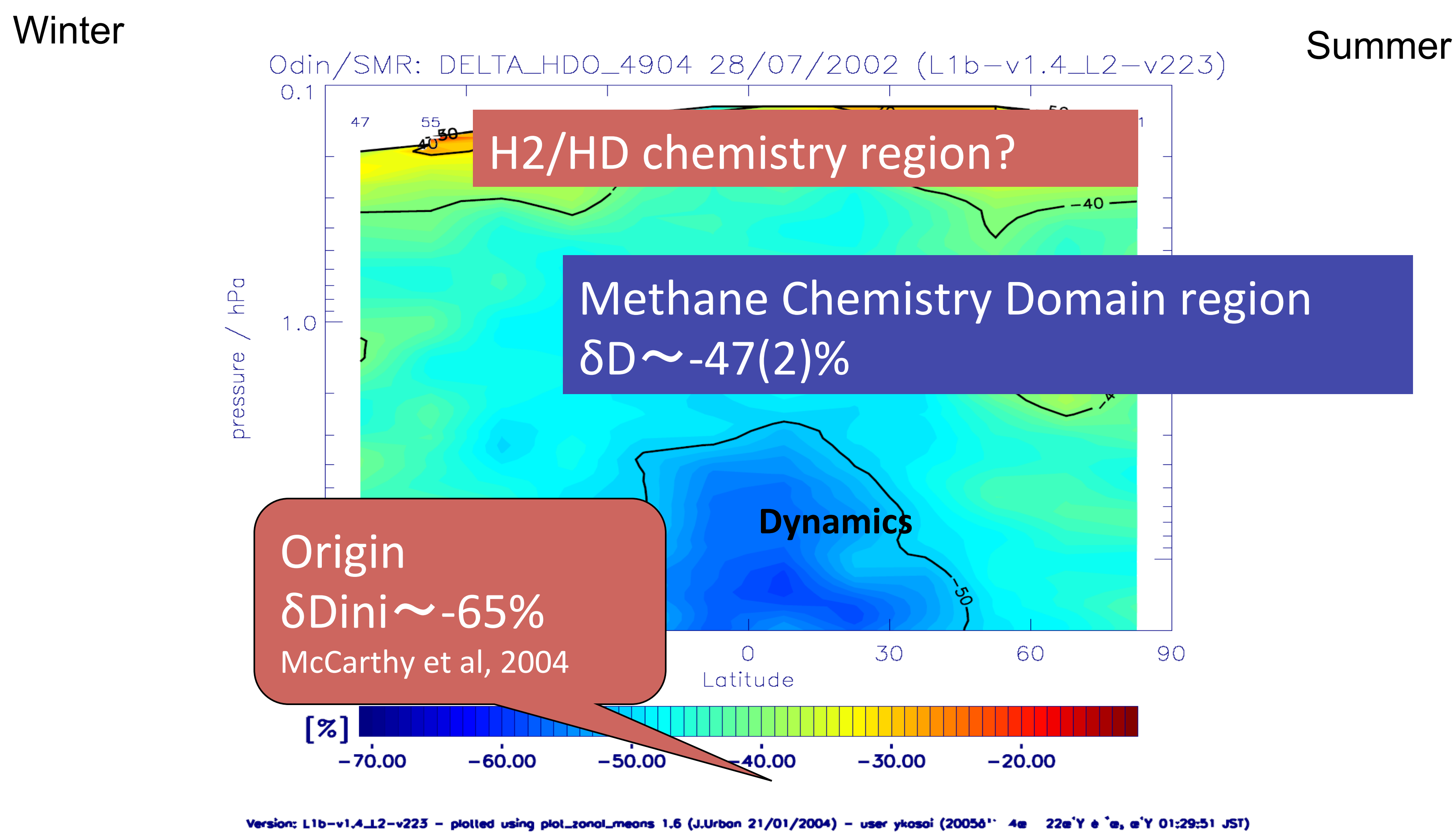
δD (CH_4): δD source from CH4 oxidation

δD (H_2): δD source from H2 oxidation

δD (O^1D): δD sink due to OH reaction

δD (hv): δD sink due to photolysis

δD – Global distribution



δD distribution in the stratosphere

$$\delta D_{total}(\%) = \delta\, D_{ini} + \delta\, D(CH_4) \cancel{+\delta\, D(H_2)} + \delta\, D(O^1D) \cancel{+\delta\, D(h\nu)}$$

Origin (Dynamical)

Source (Chemical)

Sink (Chemical)

δD total: -47% (from Odin measurement)

δD ini: Input from TTL, ～-65% (McCarthy et al, 2004)

δD (CH_4): δD source from CH_4 oxidation

δD (O^1D): δD sink due to OH reaction

δD distribution in the stratosphere

$$\delta D_{total}(\%) = \delta D_{ini} + \delta D(CH_4) + \cancel{\delta D(H_2)} + \delta D([O^1D]) + \cancel{\delta D(h\nu)}$$

Origin (Dynamical) **Source (Chemical)** **Sink (Chemical)**

δD total: -47% (from Odin measurement)

δD ini: Input from TTL, ～-65% (McCarthy et al, 2004)

$$-47(\%) = -65(\%) + \underline{\delta D\ (CH4) + \delta D\ ([O^1D])}$$

+ 18%

Conclusion
δD distribution in the stratosphere

[δD (CH_4) + δD (O^1D)] may roughly estimate **+ 18%** for the half year mean in the methane chemistry region

Future investigation may allow to carry out the correction for δD with methane oxidation in the stratosphere

Summary

Isotope measurements

-Odin/SMR has been measure HDO and H2O, (Also, UTH and Ice cloud)

Comparisons

-Comparison of H2O with satellites data
  Generally agree but there are bias in lower stratosphere
-Comparison of δD with past measurements, FIR and ATMOS
  Agree very well
-Comparison of δD with several models data
  10hPa –consistent
  1hPa – models data were larger than observation
 (CH4, HOx Chemistry of δD in these models?)
-Qualitative validation need

From Odin Data

-Seasonal variation of δD observed
-**Methane Chemistry Region in the stratosphere may has**
 [δD (CH4) + δD (O(^{1}D))] = + 18% as a first assumption

Overview of
SWI (Submillimetre Wave Instrument)
for JUICE (JUpiter ICy moons Explorer)

Submillimeter-wave spectrometer

JUICE/SWI
Japanese team
Y. Kasai (NICT)

JUICE/SWI Science objectives

Goals	Science objectives	SWI objectives
S1. Exploration of the habitable zone: Ganymede, Europa, and Callisto	S1-1 : Characterise Ganymede as a planetary object and possible habitat	Structure, dynamics and composition of atmospheres/exospheres of Galilean satellites Important isotopes in the atmospheres of Jupiter and the Galilean satellites Thermophysical properties of Ganymede and Callisto surfaces
	S1-2 Explore Europa's recently active zones	
	S1-3 : Study Callisto as a remnant of the early jovian system	
S2. Explore the Jupiter system as an archetype for gas giants	S2-1 : Characterise the Jovian atmosphere	Structure, dynamics and composition of the Jovian stratosphere from 400 to 0.01 hPa. *Direct wind measurements!*
	S2-2 : Explore the Jovian magnetosphere	No contribution
	S2-3 : Study the Jovian satellite and ring systems	Remote sensing observation of Io's atmosphere and surface

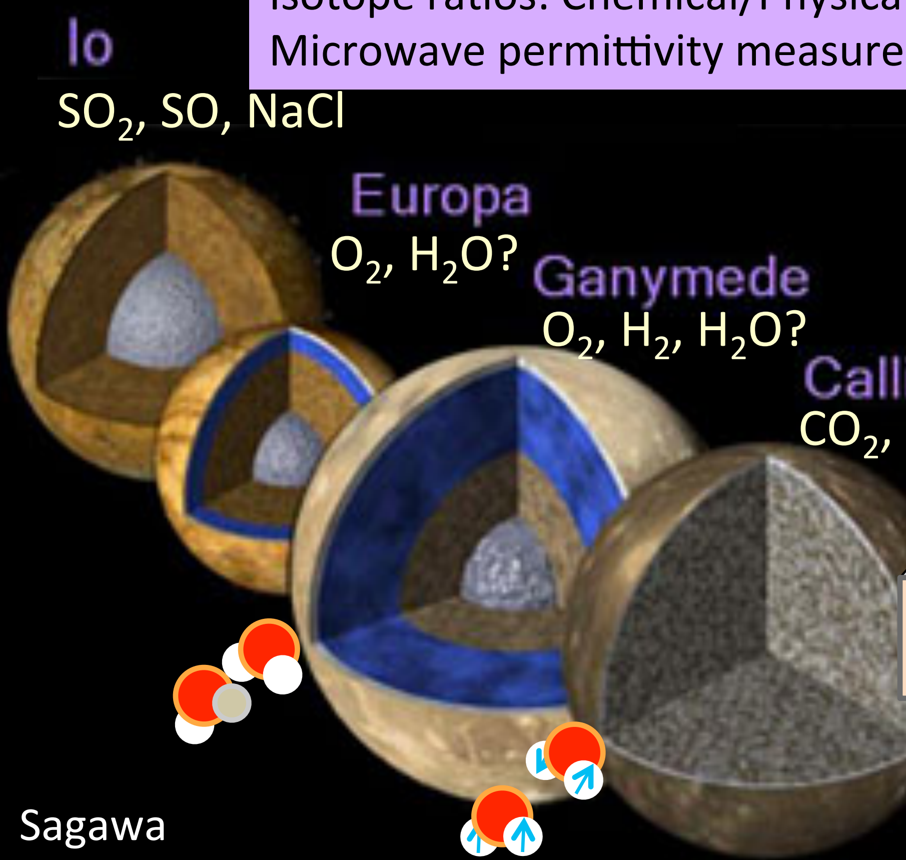
期待している
サイエンエンス例

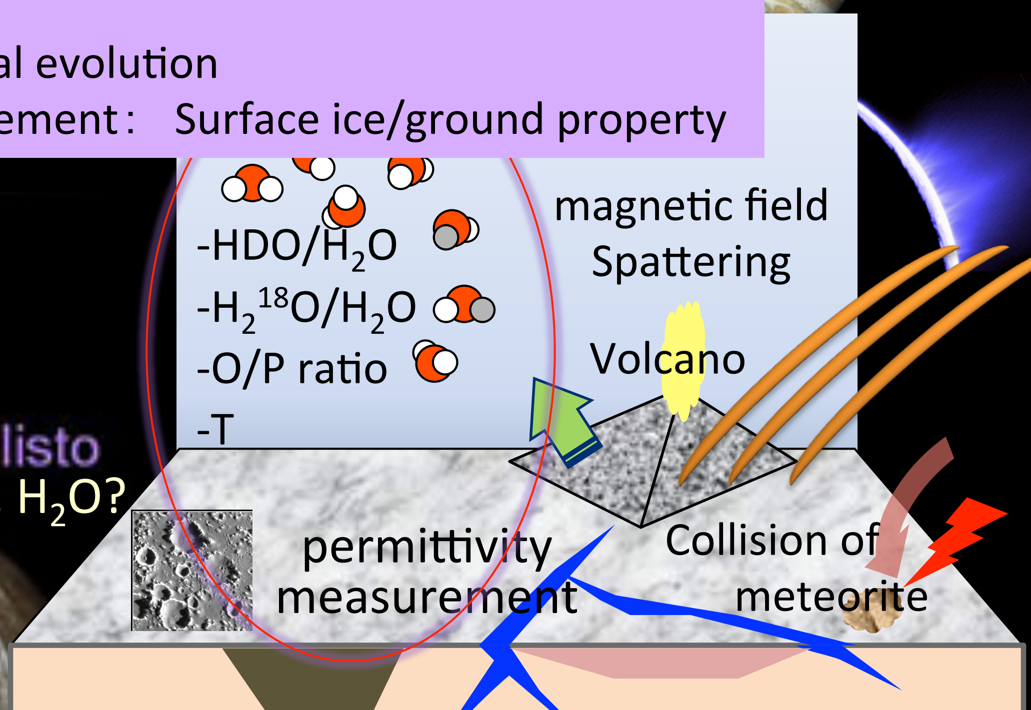
日本チーム

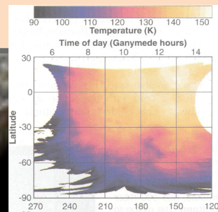
Understand the atmospheric inventory to address origin and its development of atmosphere

Four (icy) moons have different atmospheric structures from different inner structures and circumstances

Molecular tools to trace history of icy moons
O/P: Origin of Ganymade
Isotope ratios: Chemical/Physical evolution
Microwave permittivity measurement： Surface ice/ground property







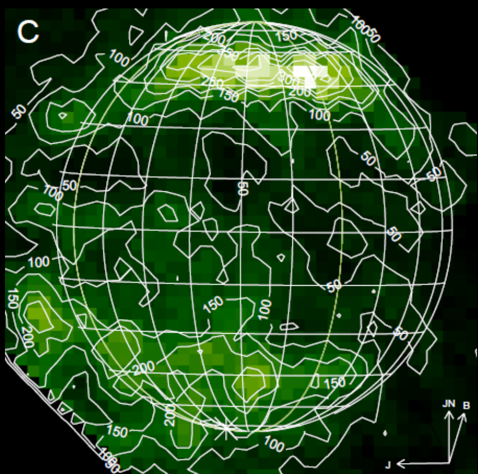
Dau/night temperature change of Ganymede ice surface
Day time 150 K, Night time 80 K (Orton et al. 1996)

Sagawa

JUICE/SWIによる氷衛星観測

氷衛星の外気圏大気構造 ＆ それを支配する物理諸過程の理解

↓ ハッブル望遠鏡によって観測されたガニメデ O I 発光強度分布(Feldman et al.,2000).

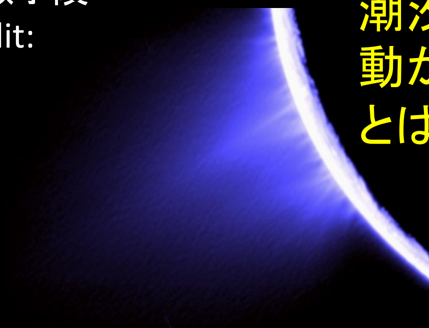


高緯度帯で強い発光
→ 木星からの重イオンによるスパッタリング効果を示唆.

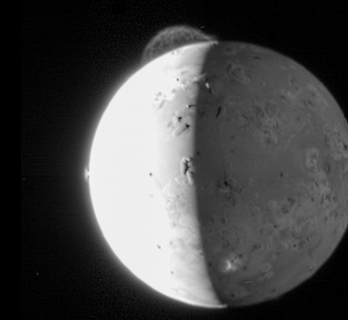
← ガリレオ探査機によって観測されたカリスト表面の無数の微小隕石孔 [credit: NASA/JPL]

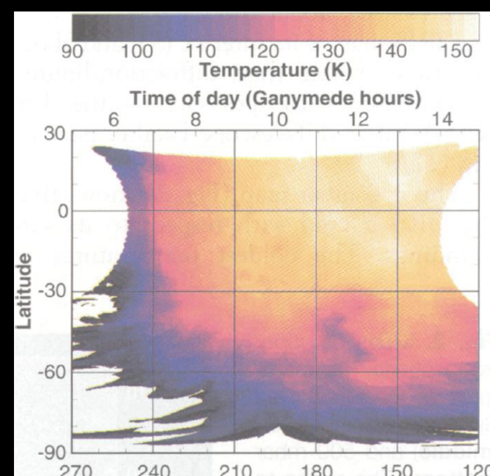
微小隕石の衝突・蒸発による大気放出はどの程度効いているのか？

↓ (上) カッシーニ探査機による土星氷衛星エンセラドスの氷火山噴火活動; (下) イオ火山活動 [credit: NASA/JPL]



潮汐加熱よる地殻活動が存在する条件とは？





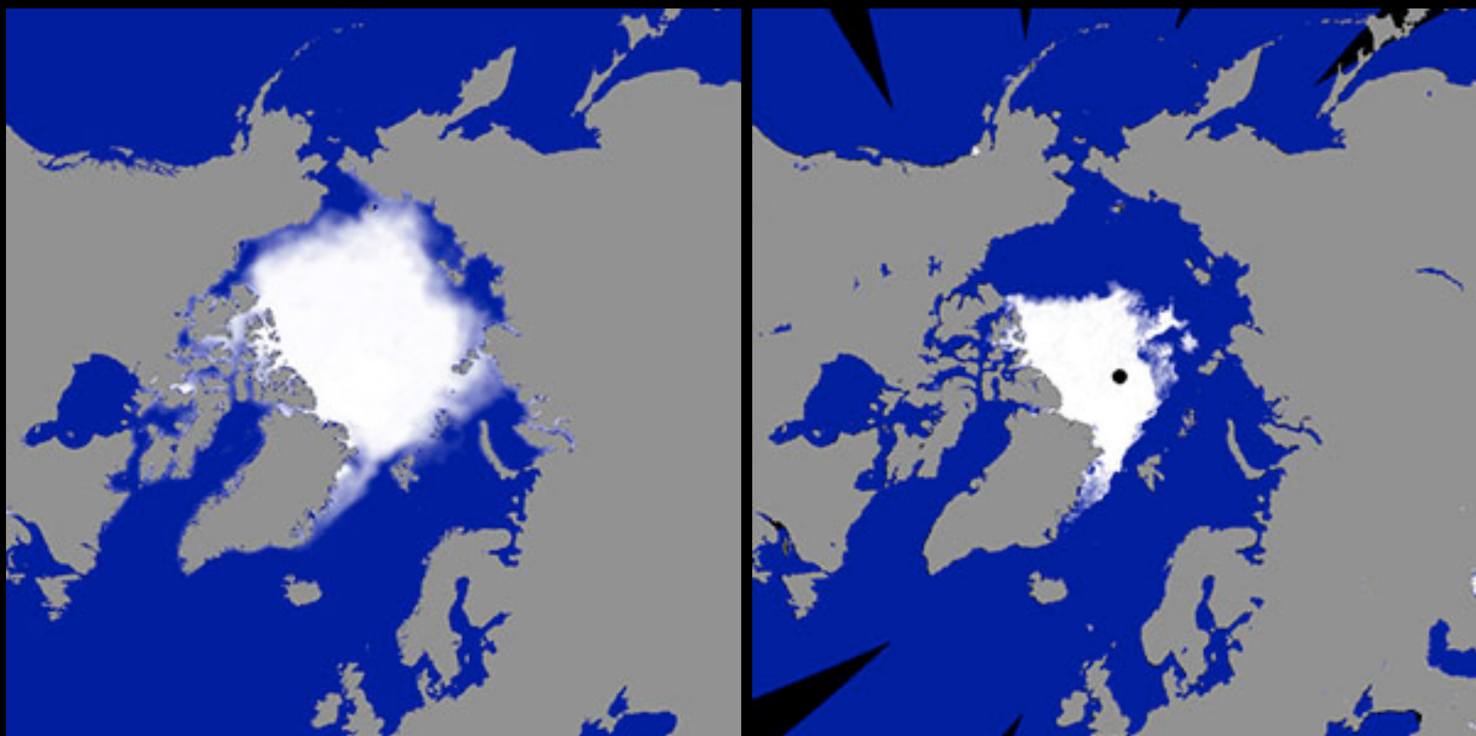
← ガニメデ氷表面温度の日変化. 昼間 は 150 K, 夜間 は 80 K (Orton et al. 1996).

表層氷からの水蒸気昇華？

氷衛星(およびイオ)の希薄大気:何が, どこからきてどこに行くのか？
→ 氷衛星内部や木星磁気圏との相互作用の理解へ

地表面観測　(GCOM-Wホームページより)

北極海海氷の観測データ解析結果について
～北極海海氷の面積 観測史上最小記録更新～



1980年代の9月最小時期の平均的分布
（米国衛星搭載マイクロ波センサの解析結果）

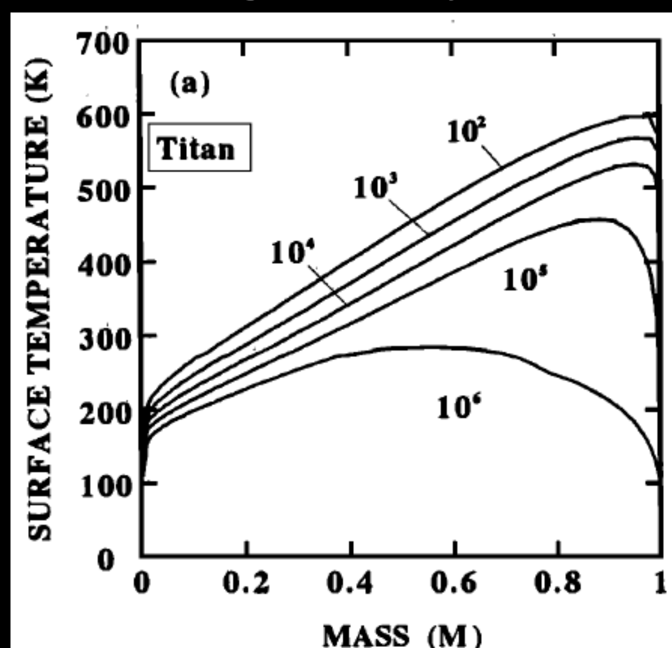
2012年9月16日
「しずく」/AMSR2（アムサー・ツー）[検証中]
（観測史上最小分布）

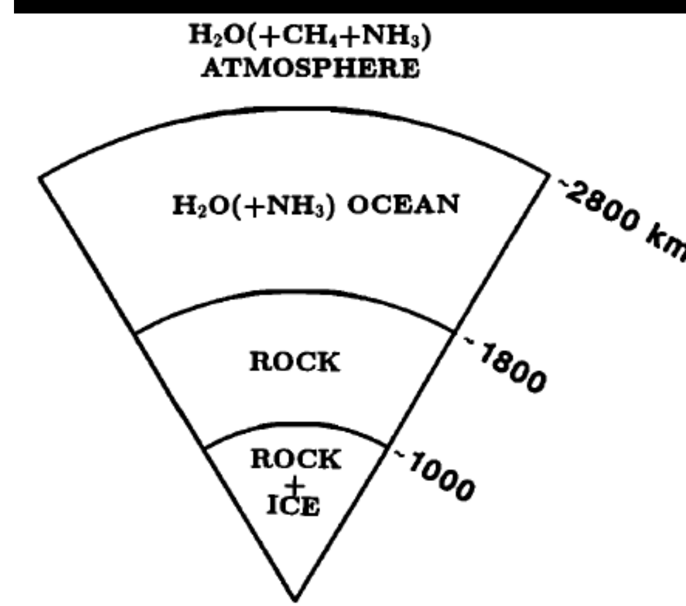
Importance as an "ocean planet": planetary processes and chemical evolution
→ Comparison of Ganymede and Callisto (and Titan, Enceladus…) chemical reactions in the deep ocean

Similarity in size and difference in thermal evolution between them allow us to understand planetary processes

- Deep-water magma ocean on Ganymede during accretion? Active water-rock interactions? → **O isotopes**
- Massive escape of proto-atmosphere → **D/H ratio**
- Chemical evolution (organic synthesis) on Ganymede?

Formation model of large icy satellite
(Kuramoto & Matsui, 1994)

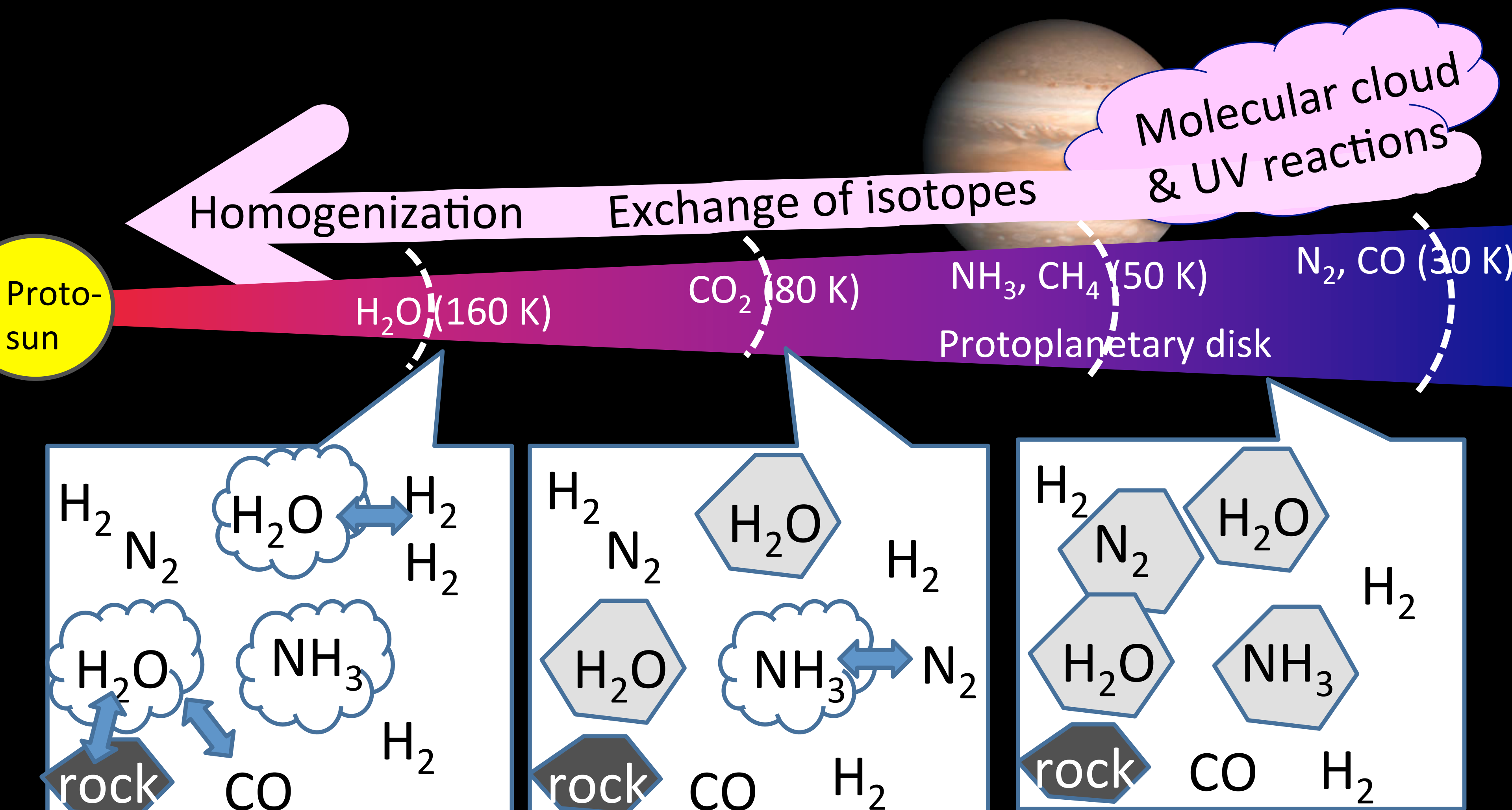




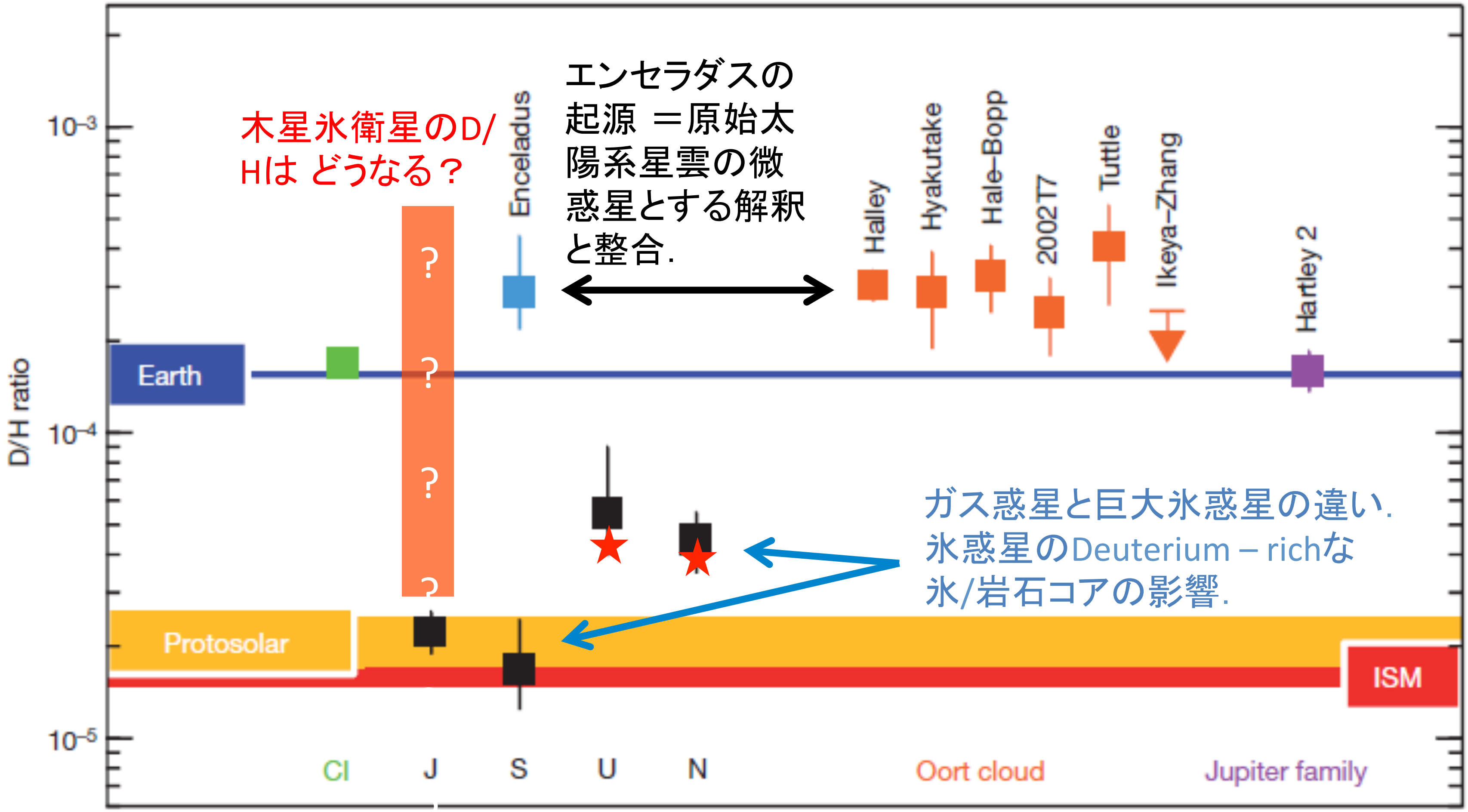
Sekine

Isotopic compositions of ice at Jupiter

Snowlines & isotopic exchanges in the solar nebula → Indicator of the disk conditions



同位体比，オルト・パラ比の観測



太陽系天体における D/H の値 [Hartogh et al. 2010].

★ = New results from Herschel/PACS [Feughtgruber et al. 2013].

JUICE/SWIでは H2O/HDOのほか、18O /17O, O/P比の議論も可能

JUICEとしてのミッション

JUICE/SWIによる木星大気観測

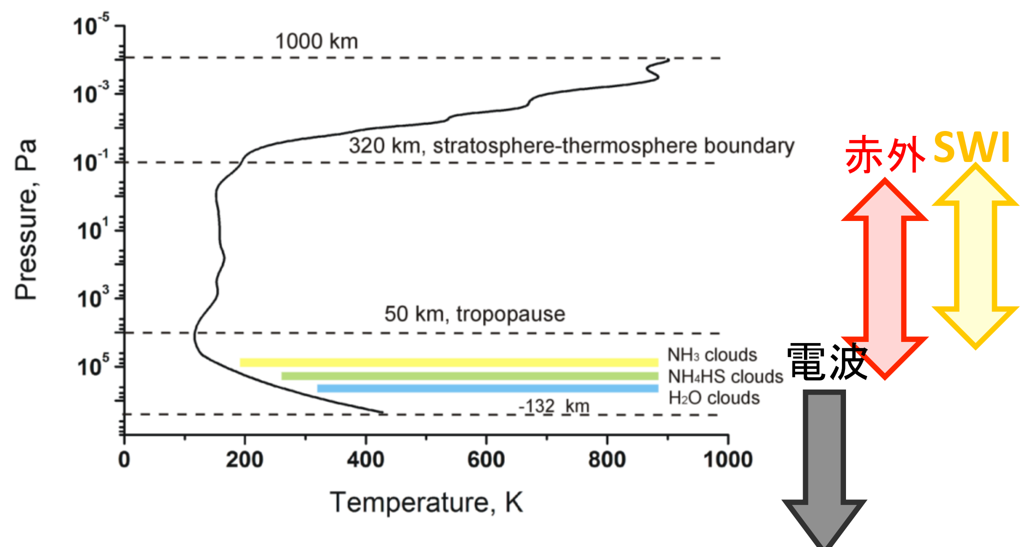
巨大ガス惑星大気を支配する物理過程の理解に向けて

放射	力学(循環)	大気化学
気温構造 エネルギー収支 雲微物理	物質・運動量輸送 大気散逸	大気組成，進化 雲微物理

赤外	気温 CH4-IR	CnHn系分子	温度風近似	CnHn系分子
SWI	気温 CH4-THz		ドップラー風速	外的起源分子
電波	気温 マイクロ波	対流圏H2O		

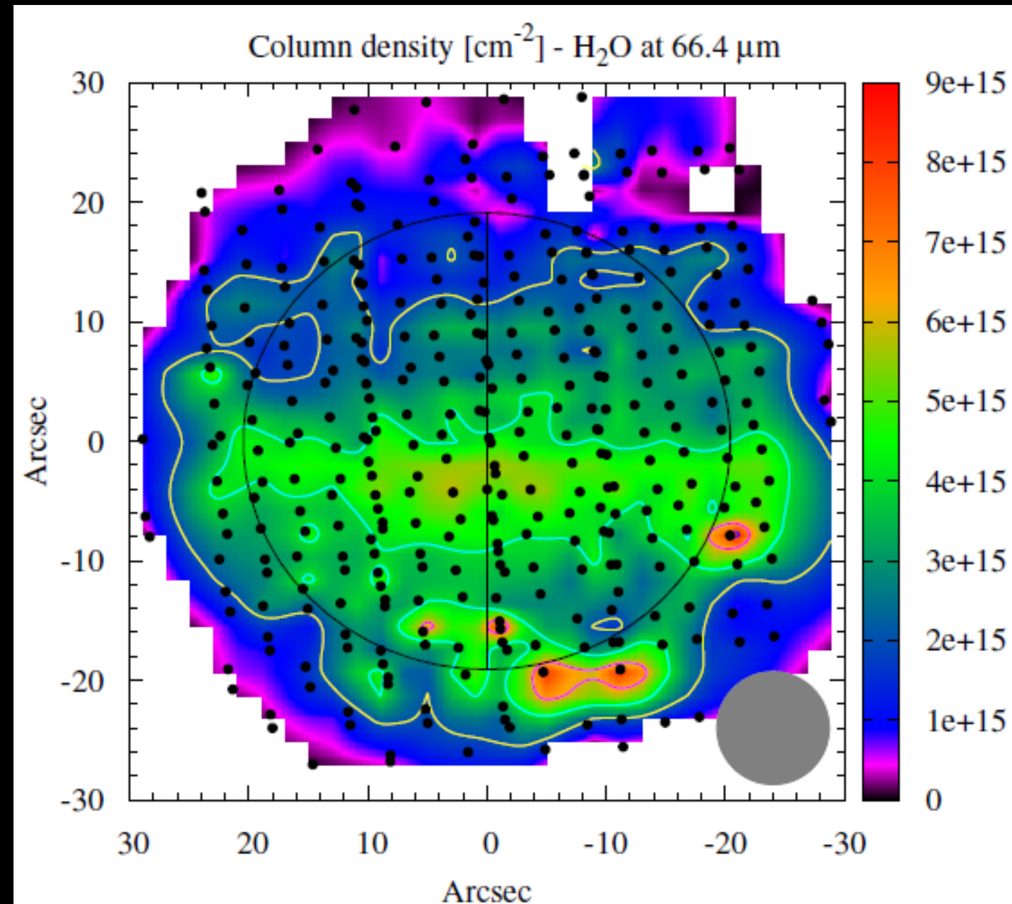
SWIによる高周波数分解能観測

→ 成層圏の大気循環を初めて直接観測.



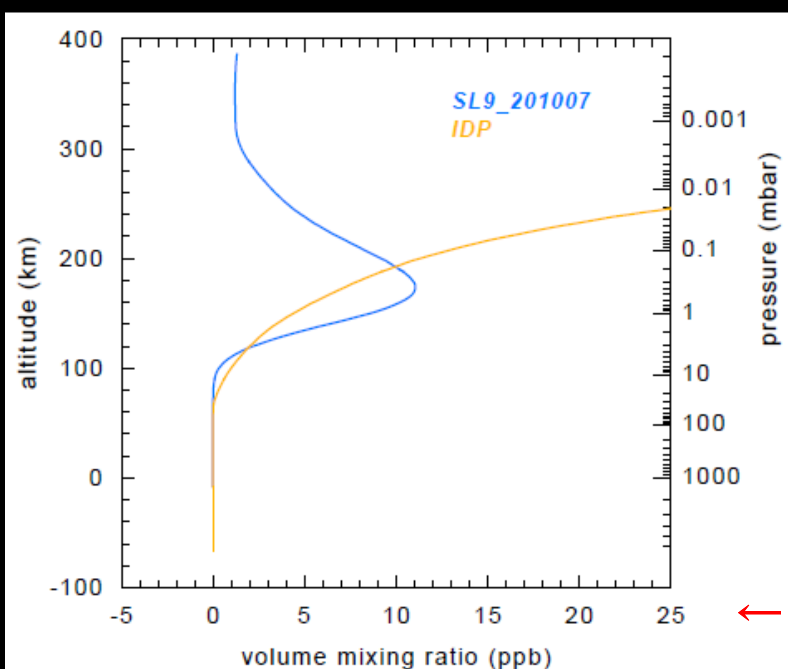
木星成層圏:外的起源による大気組成の変化

- 酸素化合物は何処からきたのか？ → 惑星間塵(IDP)説，リング・氷衛星起源説，彗星衝突(e.g. SL9)説と諸説あり.
- 木星成層圏のH2O三次元分布＆時間変動を抑えることで起源の定量的な分離が可能に.



[Cavalie et al., 2013]

↑ Herschel/PACS（＝中・低分散分光器＠遠赤外）による木星成層圏におけるH2Oカラム分布.



← 起源の違いによってH2Oの鉛直分布は異なるはず！

Interior Structure of Europa, Ganymede and Callisto

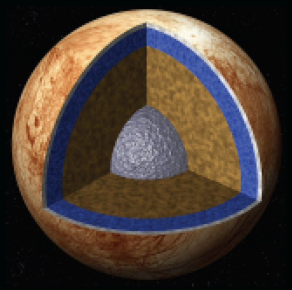
Galileo Mission Achievements:

Gravity data indicate different levels of differentiation of the interior of Europa and Ganymede, and suggest the presence of a metallic core in the interior of Ganymede and possibly of Europa

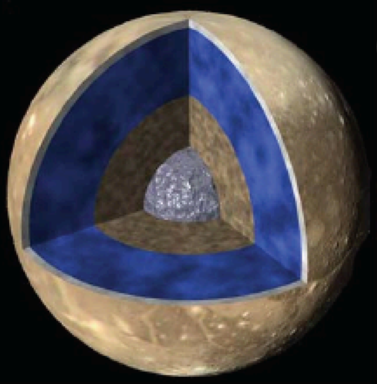
Gravity data suggests that Callisto is most likely partially differentiated with a deep interior composed of a mixture of ice and rock

Magnetometer data provided evidence of an intrinsic magnetic field on Ganymede likely produced by a dynamo action of a metallic core

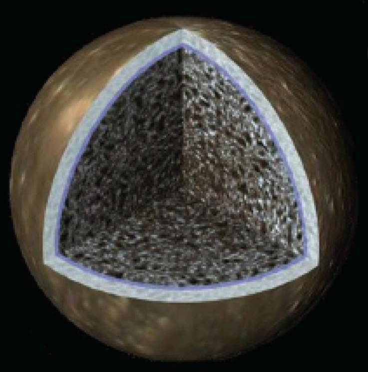
Magnetometer data indicated the presence of induced magnetic fields on Europa, Ganymede and Callisto likely produced by subsurface oceans



Europa
R = 1,569 km
$M = 4.8 \times 10^{22}$ kg



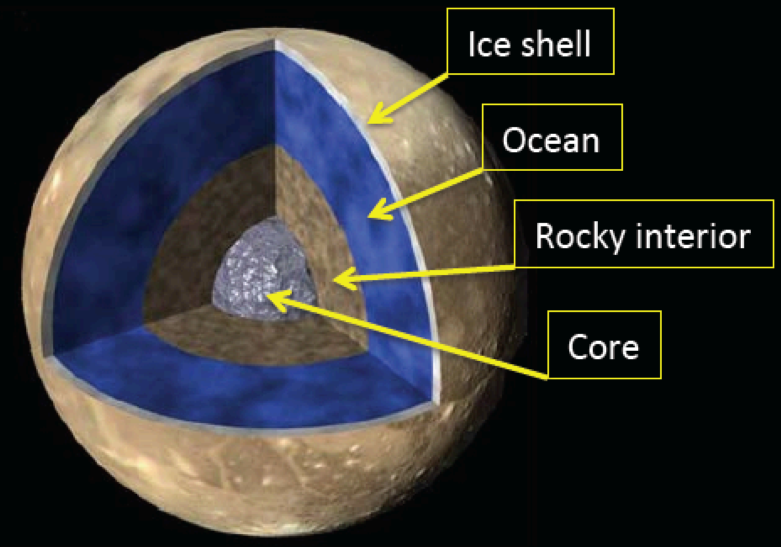
Ganymede
R = 2,634 km
$M = 1.48 \times 10^{23}$ kg

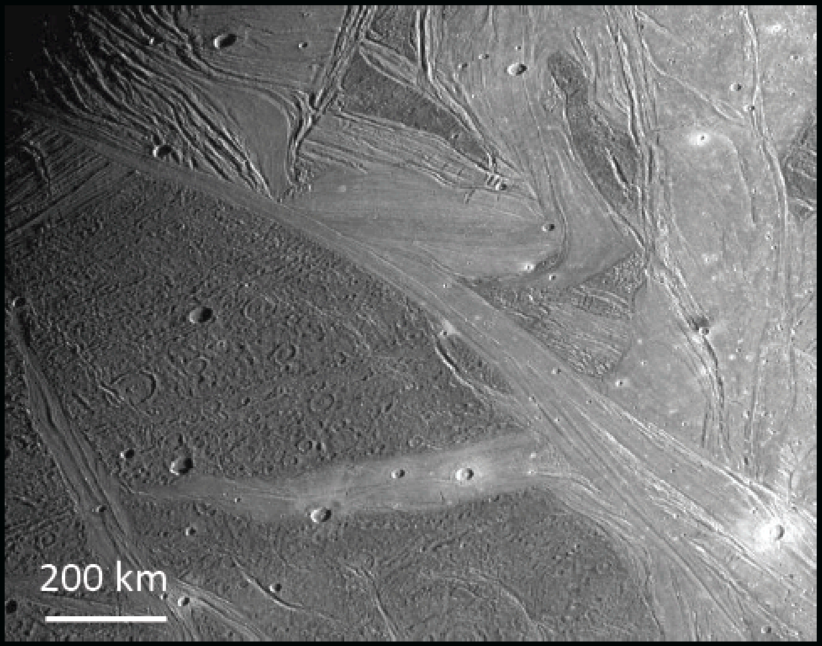


Callisto
R = 2,410 km
$M = 1.08 \times 10^{23}$ kg

Ganymede: Key Questions

- What is its interior structure, and what is its mass distribution?
- Is Ganymede in hydrostatic equilibrium?
- How does it generate its intrinsic magnetic field?
- Is liquid water and a global subsurface ocean present on Ganymede?
- What is the thickness of the outer ice shell?
- Is the ice shell convecting?
- What is the relationship between the surface geology and the interior?
- What is the role of tidal heating in the evolution of Ganymede?
- Is material exchange present between the interior and surface of Ganymede, and how does it work?

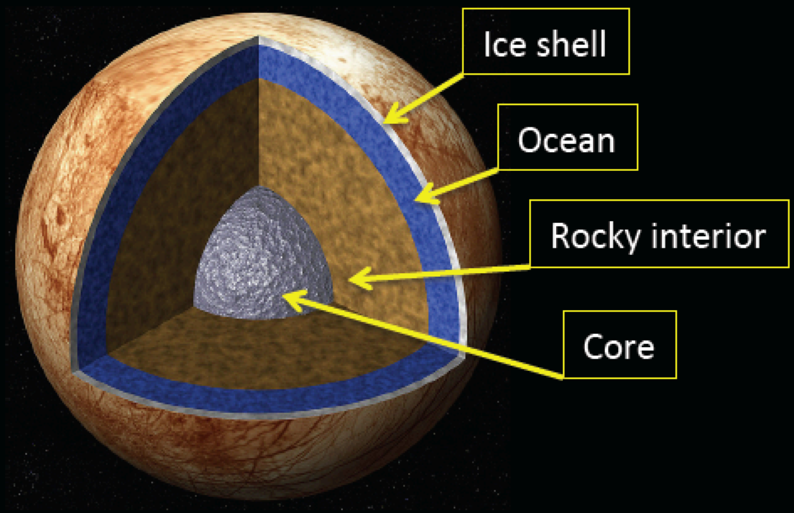


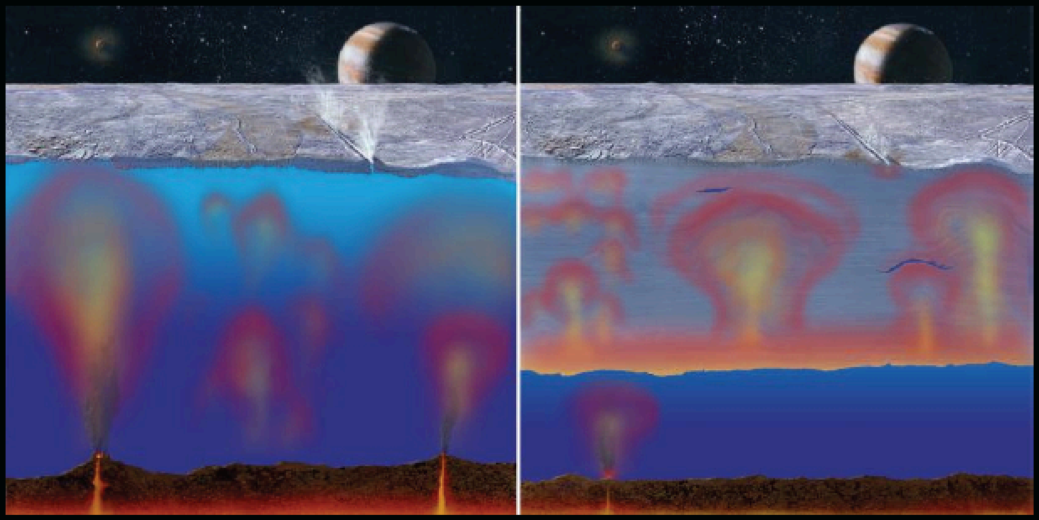


Europa: Key Questions

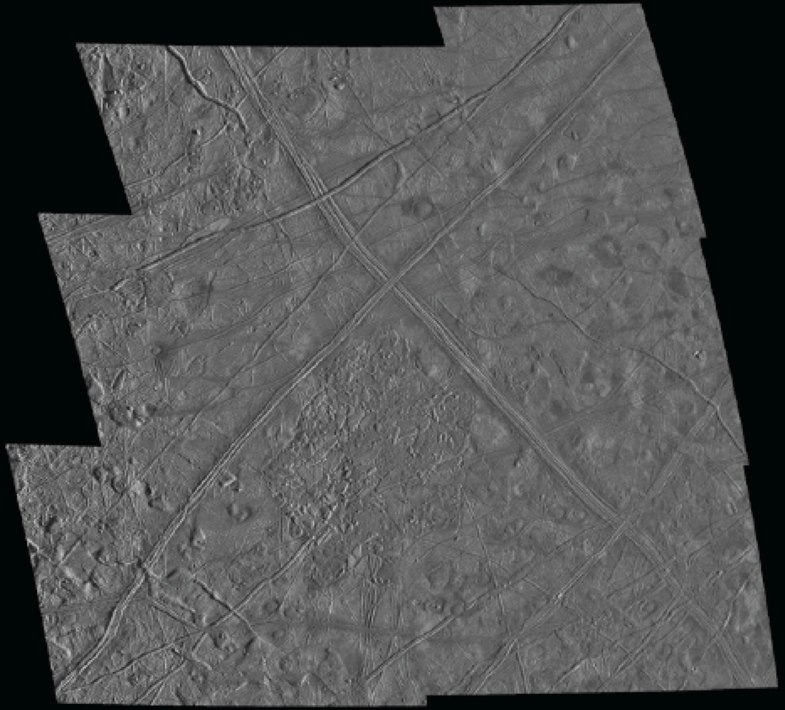
(To which JUICE will not provide answers)

- Is liquid water and a global subsurface ocean present within Europa?
- How thick is the outer ice shell?
- What is the relationship between the surface geology and the internal dynamics?
- Is the ice shell convecting?

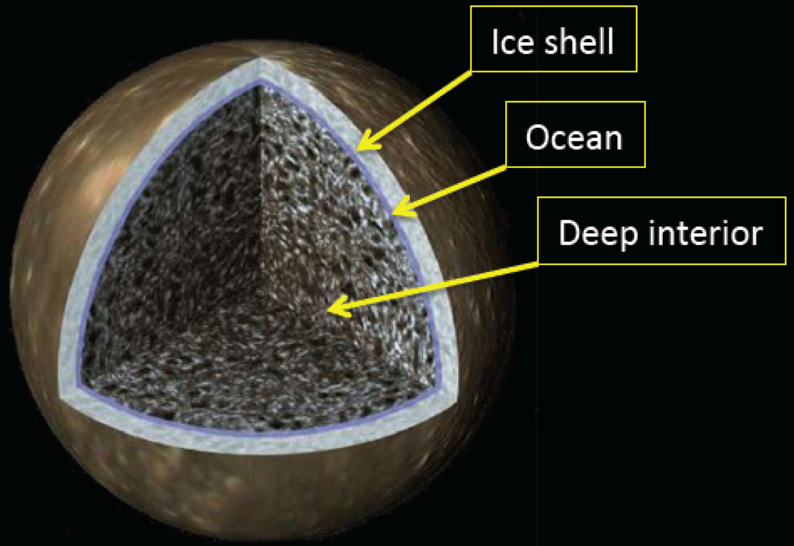




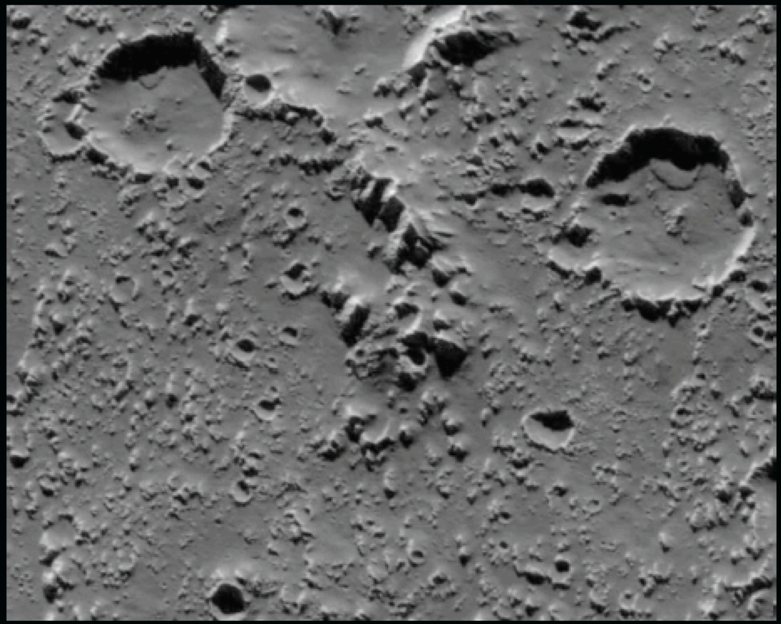
thin-conductive ice shell   thick-convecting ice shell



Callisto: Key Questions



- What is the internal structure of Callisto?
- Is its interior partially differentiated with a deep interior composed of a mixture of ice and rock?
- Is liquid water and a global subsurface ocean present on Callisto?
- What is the thickness of the outer ice shell?
- Is the ice shell convecting?
- What is the relationship between the lack of surface geology and the evolution of Callisto?
- What has produced the difference in geology and interior structure between the Galilean satellites (e.g. formation, accretion, tidal evolution)?

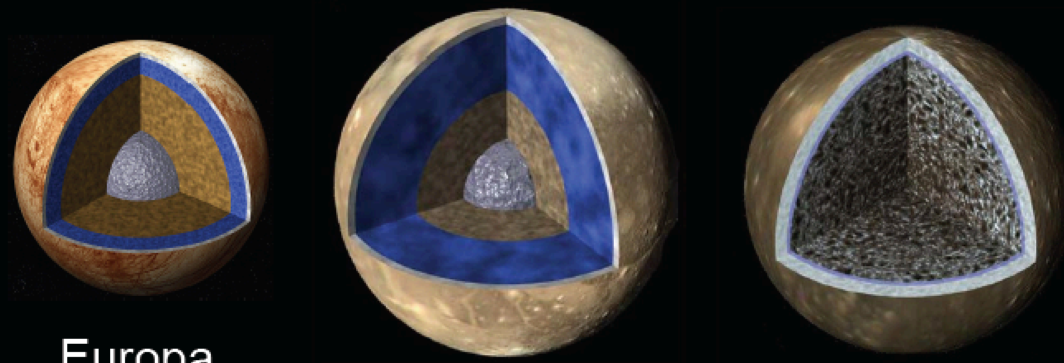


3GM JUICE

- Interior structure of solar system bodies holds the key to their formation processes.
- In the absence of seismic data, interior structure may be inferred only from gravity, rotation and magnetic fields.
- Galileo's data marred by plasma noise (100 times larger than JUICE)

Main science goals of 3GM:

- Determination of the static gravity field (20x20) and geoid of Ganymede.
- Determination of Ganymede's tidal Love number k2 (to 0.1-1%)
- Measurement of the unconstrained quadrupole field of Europa.
- Determination of the static gravity field (3x3 or 4x4) of Callisto.
- Determination of Callisto's tidal Love number k2 (to 10%)



Europa
Ocean likely

Ganymede
Ocean ?

Callisto
Ocean ?

- What is the interior structure of the satellites, and what is their mass distribution?
- Are the satellites in hydrostatic equilibrium?
- Is liquid water and global subsurface oceans present on Ganymede and Callisto?
- What is the thickness of the outer ice shell? Is it convecting?
- What is the relationship between the surface geology and the interior?
- What is the role of tidal heating in the evolution of Ganymede?

Scientific requirements of SWI

Icy moon			Jupiter
Surface	Atmosphere *3-D profiles of temperature, winds, and atmospheric compositions*		
Ganymede regolith studies: Determine surface brightness temperatures in 600 and 1200 GHz bands with high spatial resolution Constrain amplitude and phase of thermal wave within the first centimeter of the regolith Determine thermo-physical properties of the regolith Correlate surface features with atmosphere features	Highly resolved 3-D monitoring of tracers:	Ganymede/ Callisto: 17-O, 18-O, D, O/P, O2	SL-9 impact: CS, HCN, CO external oxygen/water supply of uncertain origin
	Search for new species	13-C, NH3, CH3OH, H2CO, CN, C3N, CS, C3S,	CH_3OH, H_2CO,HC_3N, CH_3CCH halides(HCl…)… 17-O, 18-O, D, 13-C, 15-N, 34-S(HCN, CO, CS)
	Vertical res.	1 km	~ scale height
	Spatial res.	2 – 10 km	< 5 degrees,
	T [K]	< 2 K (accuracy) in collisional range	<5K
	Doppler winds:	10 m/s	Direct (Doppler) wind measurements (3-D): 10 m/s accuracy (CH_4, H_2O)

Instrument characteristics

- Baseline
  - Telescope D ~ 30 cm
    - » Spatial resolution ~ 1000 km @ 15 RJ distance
    - » Vertical resolution: < ~ scale height
  - Two spectral bands: 530-605 and 1080-1275 GHz
  - Instantaneous bandwidth ~1 GHz, resolution ~100 kHz
  - Tunable LO
  - Passive cooled Schottky receivers: T_{sys} (DSB) ~3000 K at 1.2 THz, 1500 K at 600 GHz

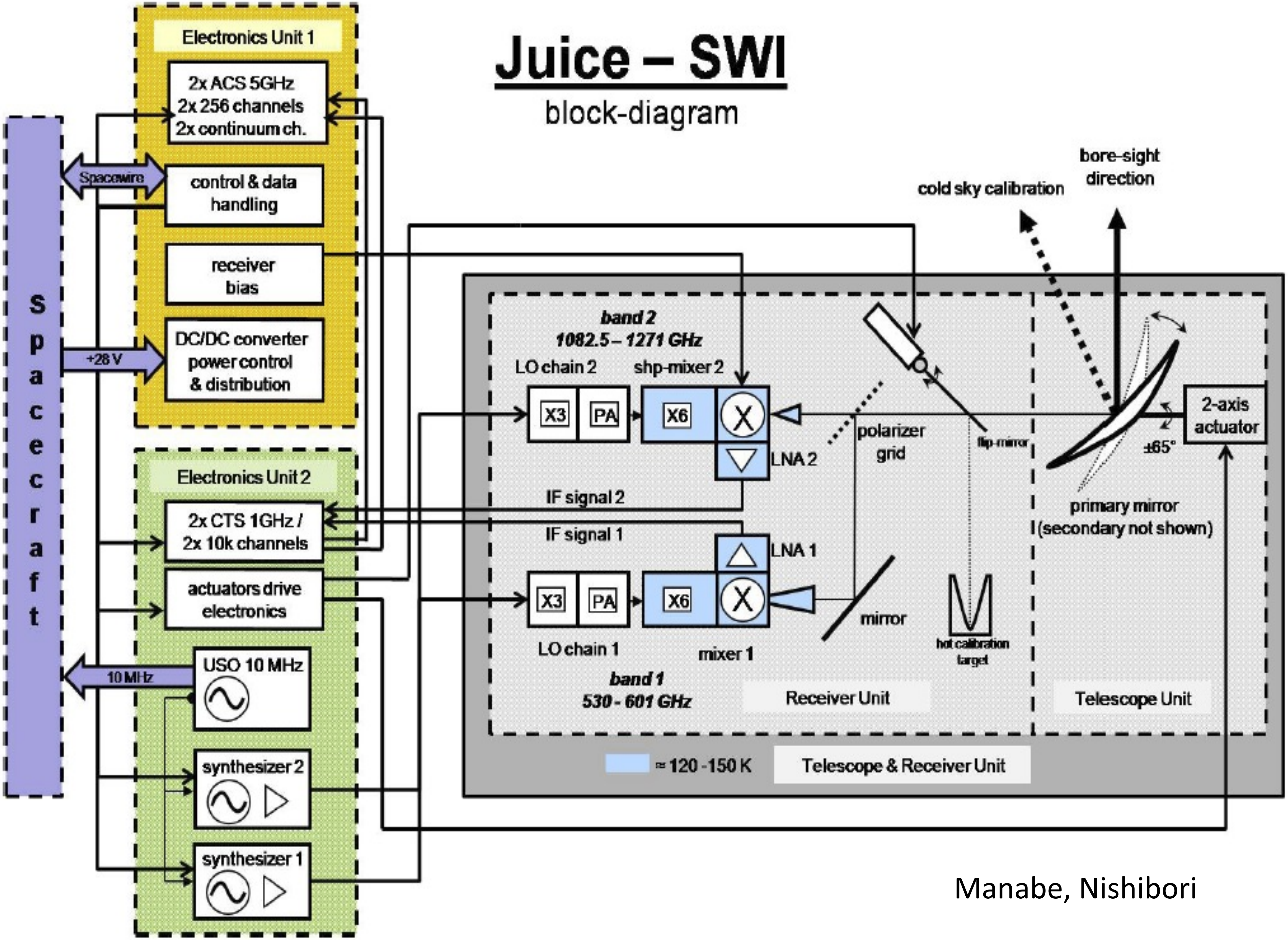
    Detection capabilities:

    1 min: line contrast ~ 0.3 – 0.8 K

    1 hour: line contrast ~ 0.05 – 0.15 K
  - Heritage: MIRO/Rosetta Herschel-HIFI, SMILES, Odin/SMR
  - ~10 kg, 35 - 50 W

Juice – SWI

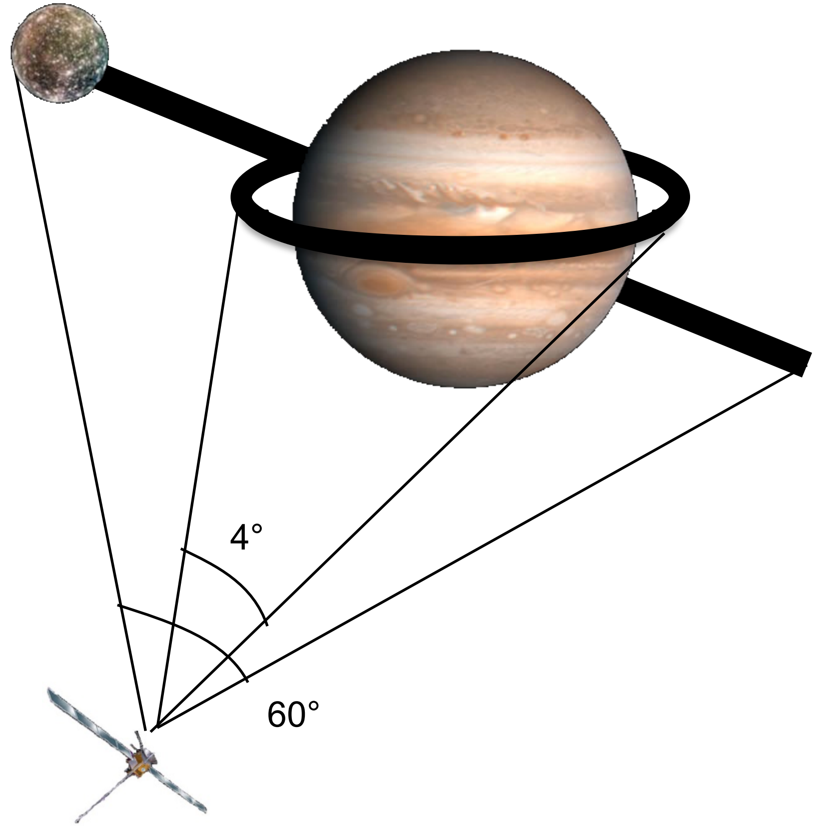
block-diagram



Manabe, Nishibori

Optics – requirements

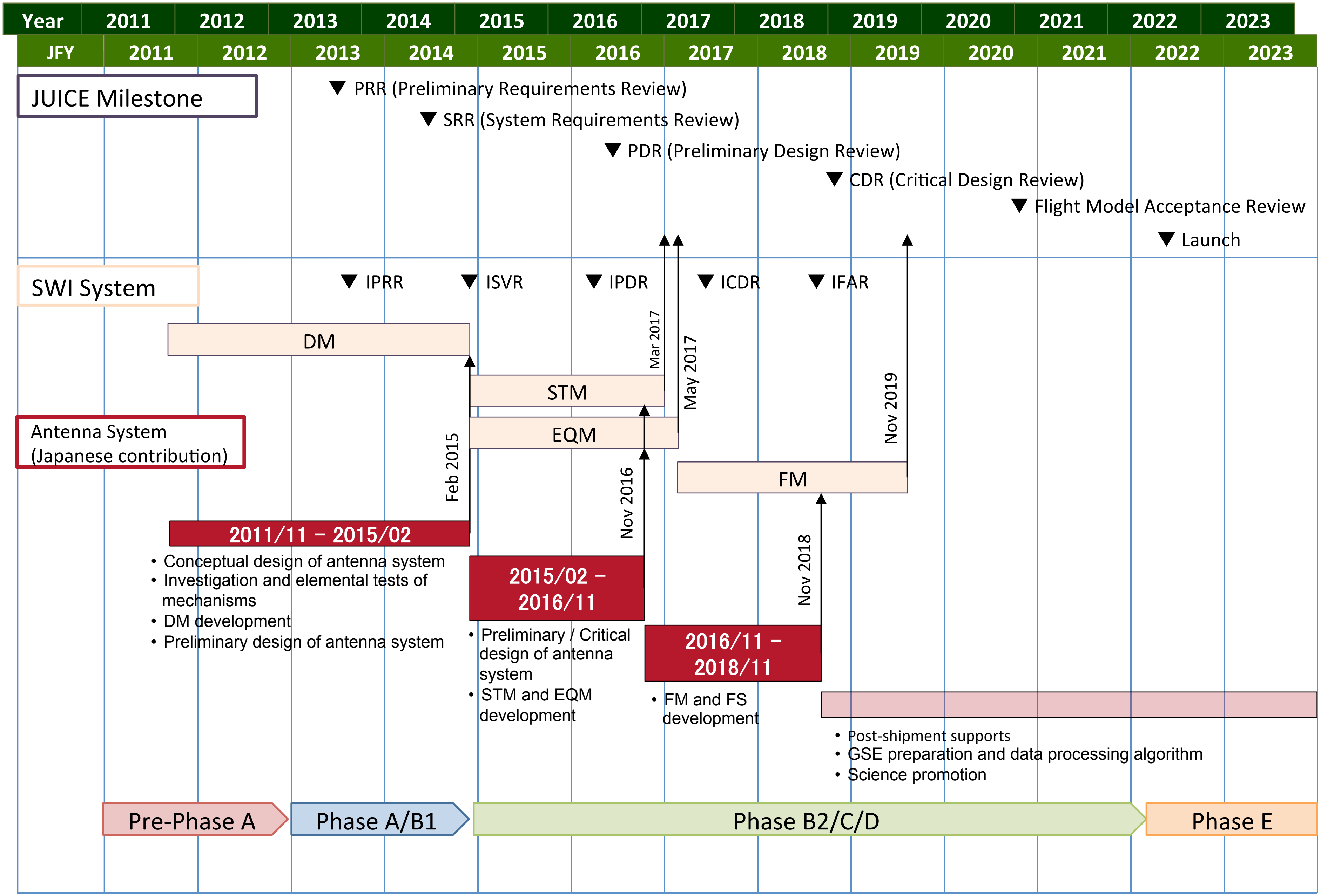
-> Mechanical design driven by optics!
-> Optics design driven by science!



<u>Situation</u>

Distance to Jupiter: 10^6 km (15 RJ)
Primary: 30cm
Scanning: 2-axis: +/- 4° (limb)
1-axis: +/- 60° (moons)
Science requirement: 10 m/s (winds in limb)
Pointing knowledge: 11.5 arcsec

SWI Development Schedule



Member

Herschel/HIFI

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P. Hartogh (PI)

Rosetta/ MIRO

Uni. Bern
A. Murk

JEM/SMILES

Japan
Y. Kasai

esa SWI

SOAR JAXA FIRE

Odin/SMR

JPL
S. Gulkis

Chalmers
D. Murtagh

IRF
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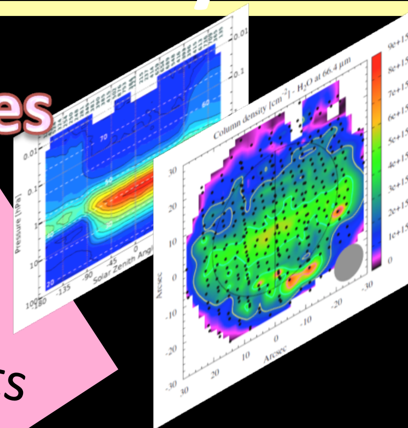
Red: SWI Co-I

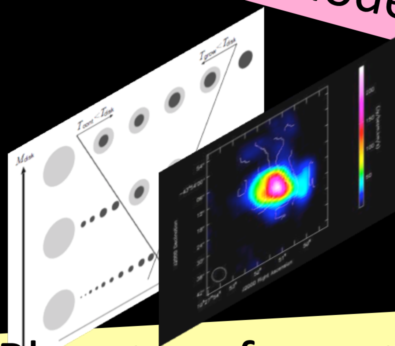
To understand the origin, evolution, diversity of our solar system.

Sekine and Sagawa

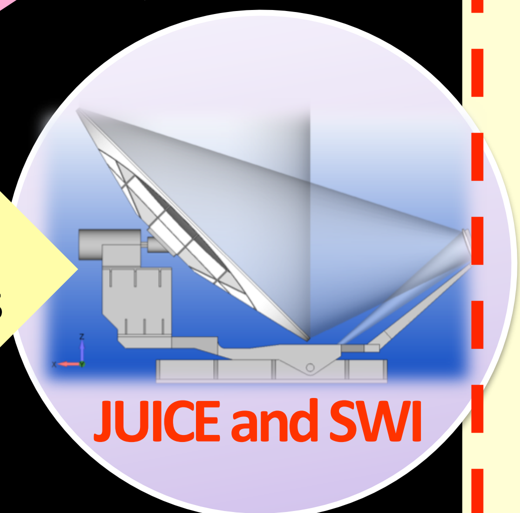
planetary atmospheres

Composition observations & Numerical model experiments



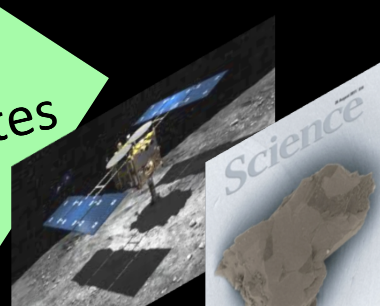


Planetary formation theory & Observations of exosolar disks



theory & material science for the origin of the solar system

Sample-return missions & Microanalyses of meteorites



Characterization of our solar system

- Material-based formation theory of our solar system.
- Factual evidence of mixing of volatiles in solar nebula.
- Insights for the snowline & the origin of water on Earth.
- Planetary & geochemical processes on icy satellites.
- Process studies on the planetary surfaces.

If you are interested in to join JUICE/SWI

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