Rings, Moons and Water-Worlds

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Cassini investigates Saturn‘s spectacular moon Enceladus

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& the CDA Science Team

Pictures: NASA / JPL

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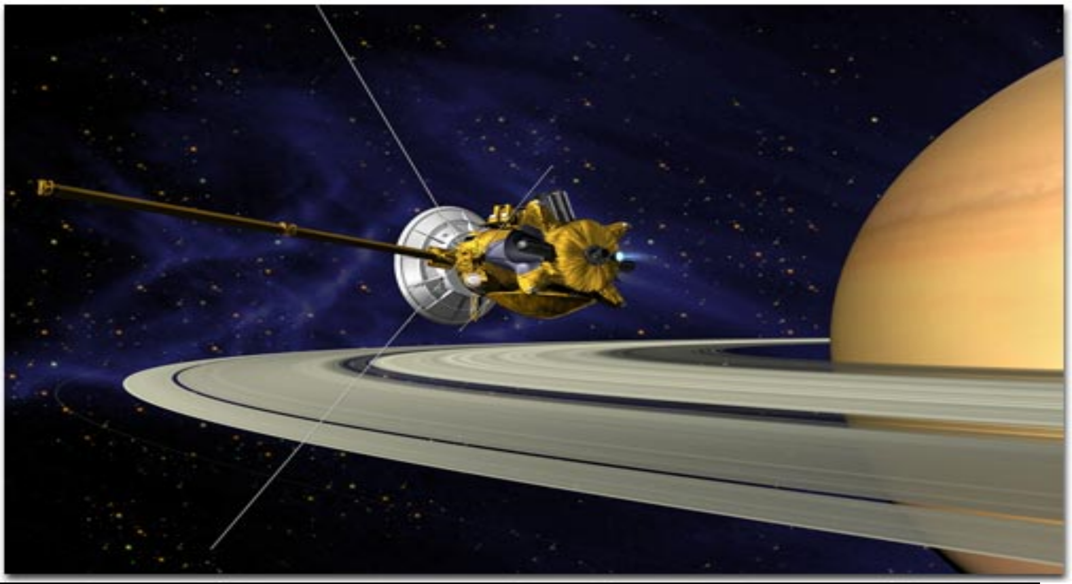
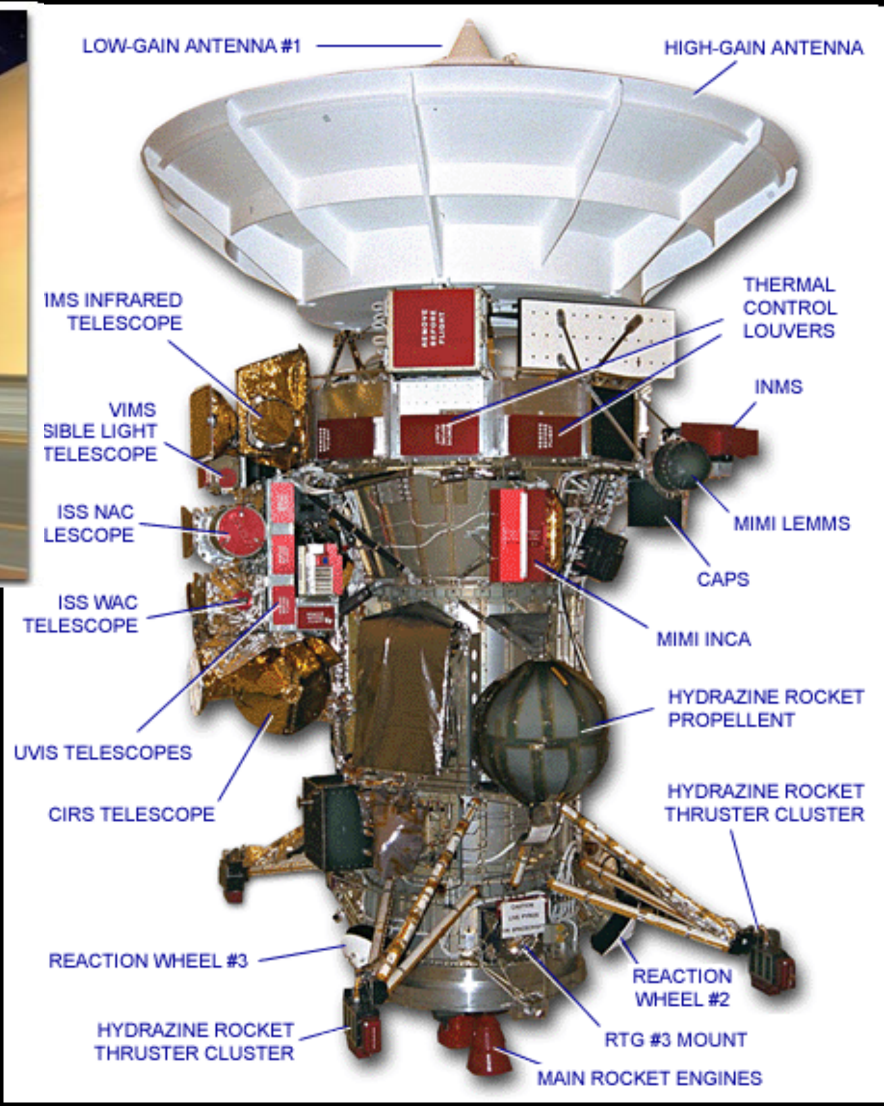
3) LASP, University of Colorado, Boulder

Our Analytical Lab at Saturn: Cassini-Huygens



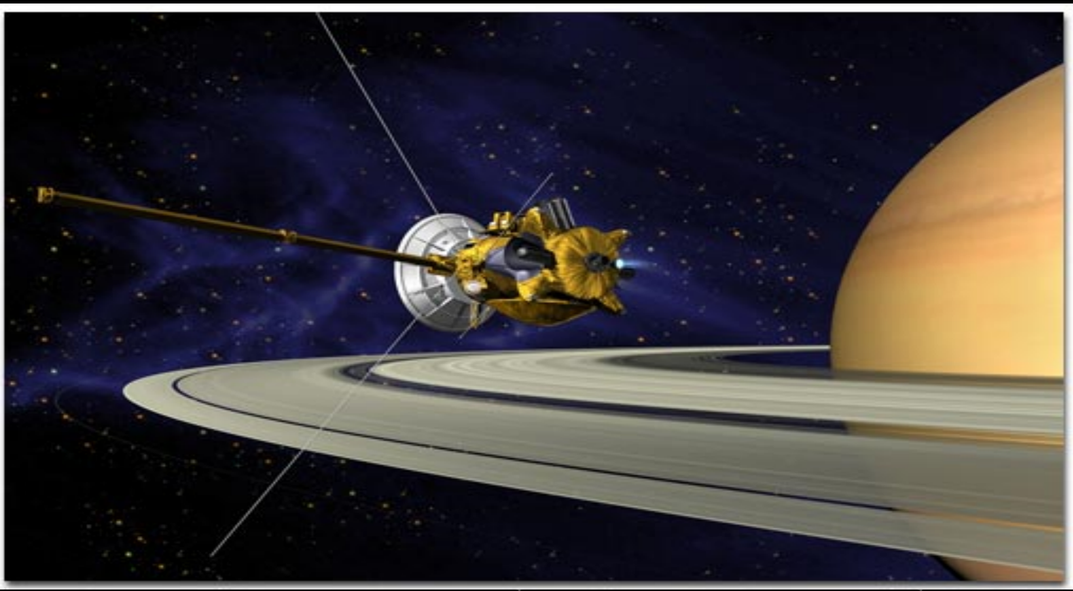


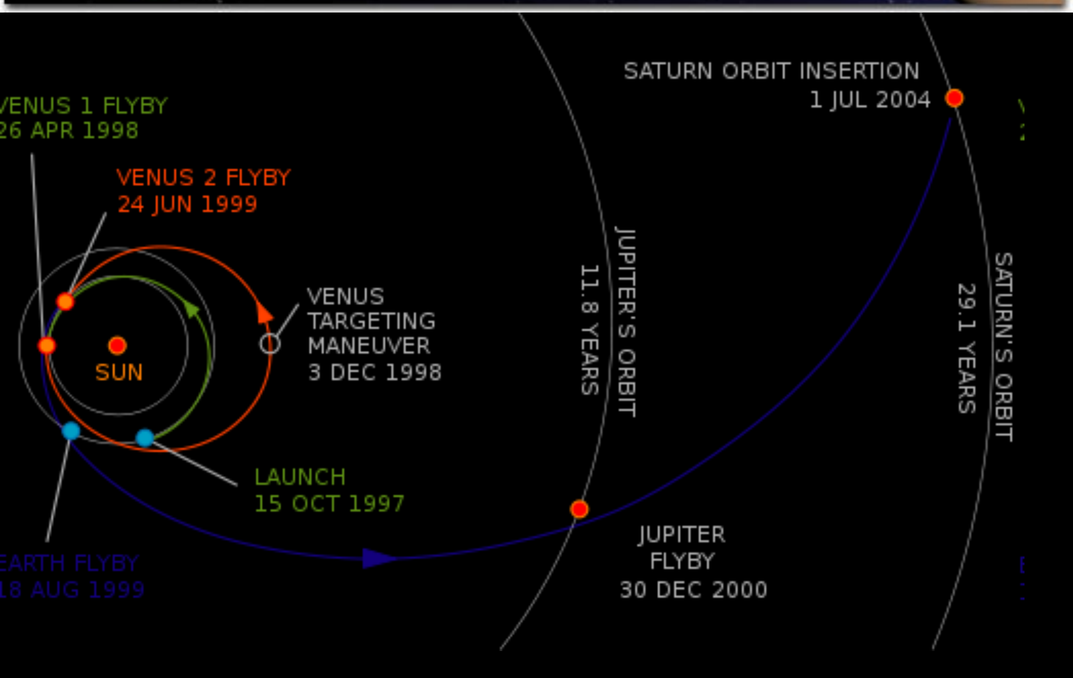
The Cassini-Huygens space craft:

• size	6,7m x 4 m
• mass:	5700 kg (2500 kg dry)
• launch → arrival Saturn:	Okt 1997 → Jun 2004
• mission end:	~ Sept. 2017

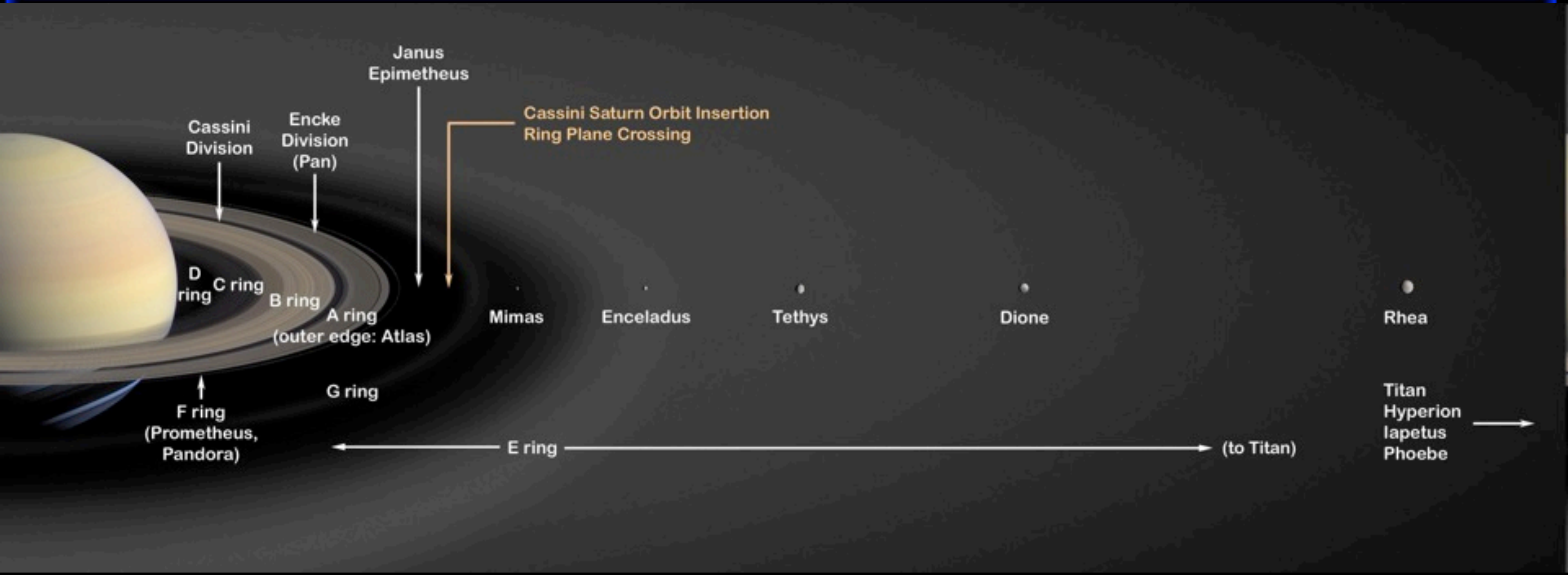
- 11 scientific instruments
- 3 – axis stabilized

Our Analytical Lab at Saturn: Cassini-Huygens

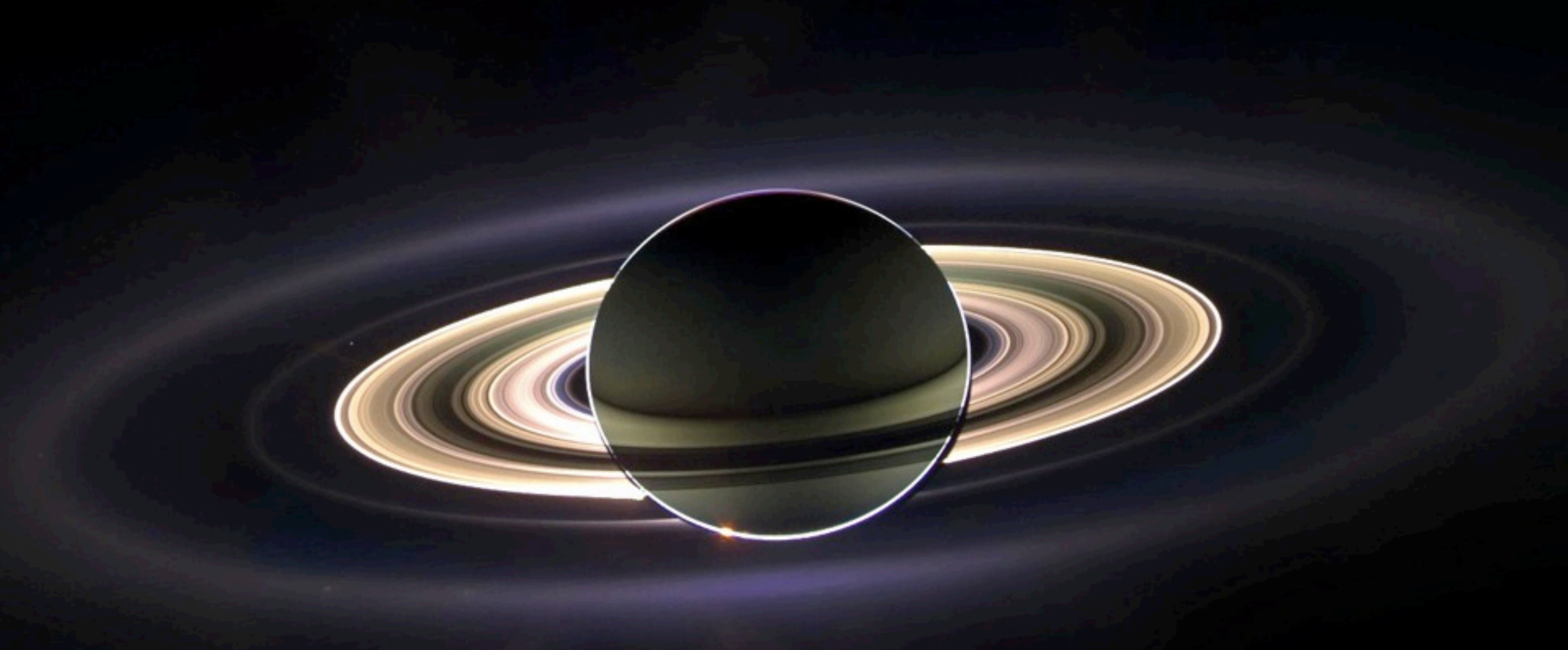


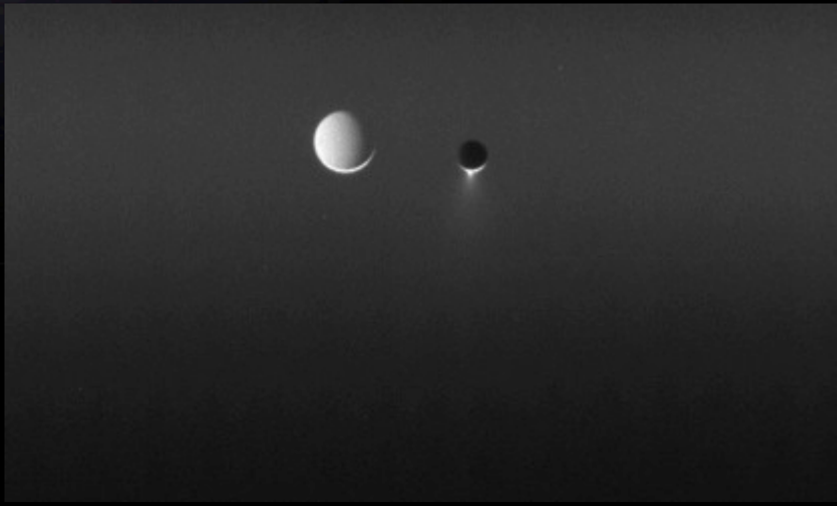


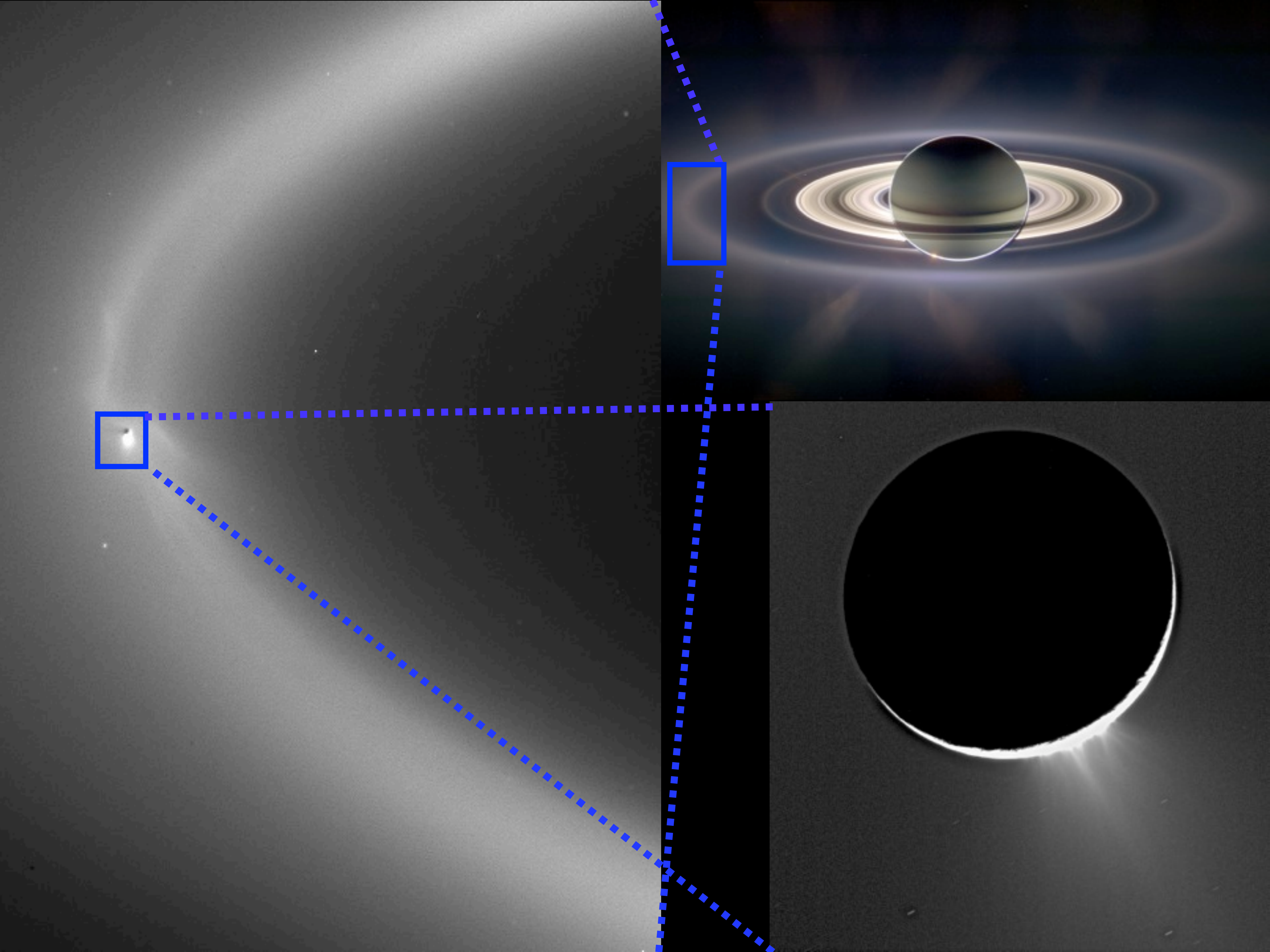
Saturn's Satellites and Ring Structure



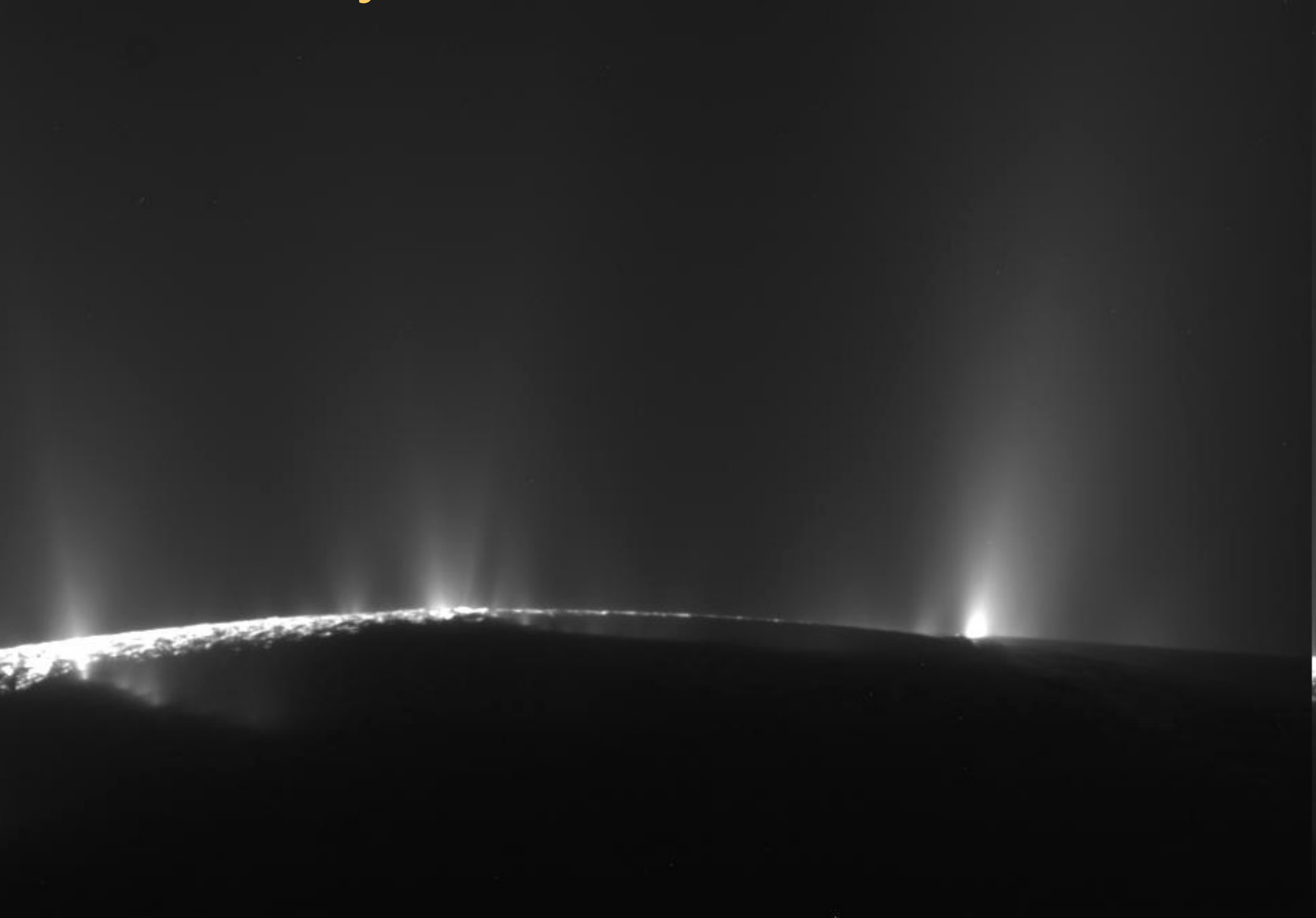
Enceladus

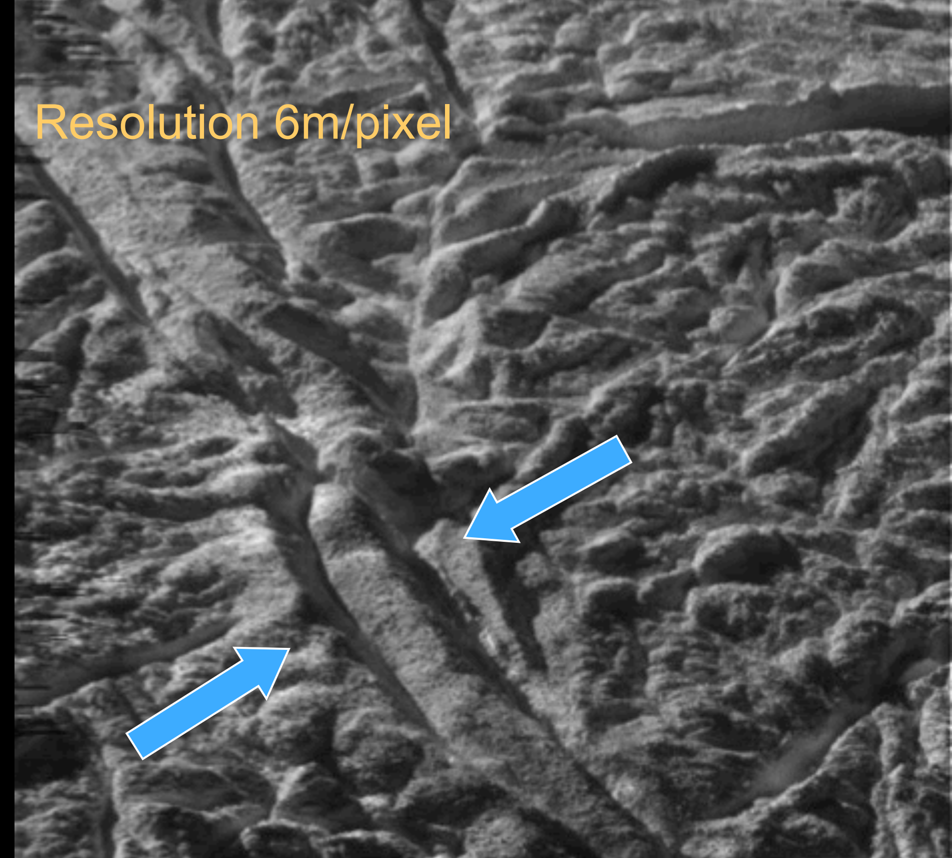

SATURN ECLIPSE
OF THE SUN
YEAR: 2006
MISSION: CASSINI
TARGET: SATURN





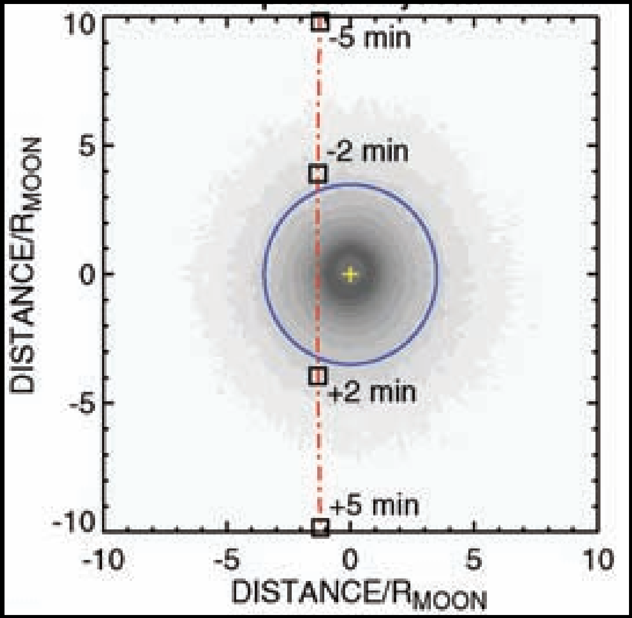
Icy Jets of Enceladus

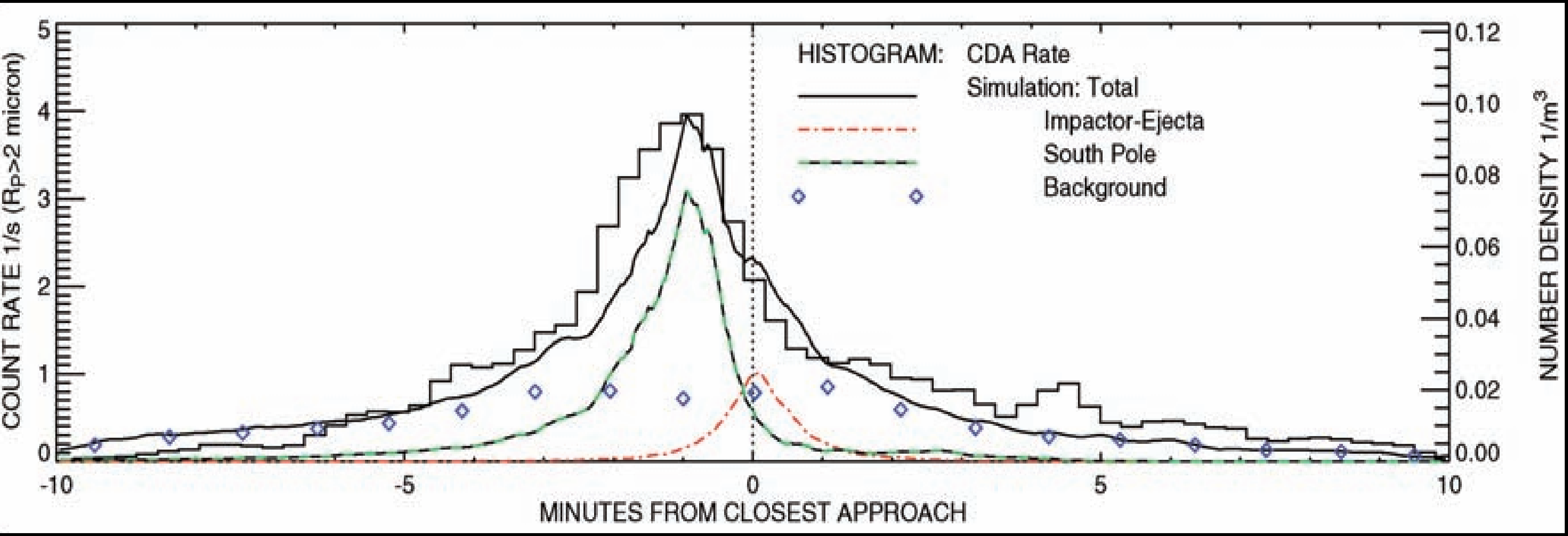



Resolution 6m/pixel

Cassini Flyby 14 Juli 2005

closest approach: 270 km





Enceladus properties

- eff. Diameter: $D = 502$ km
- density: $\rho = 1610$ kg/m^3

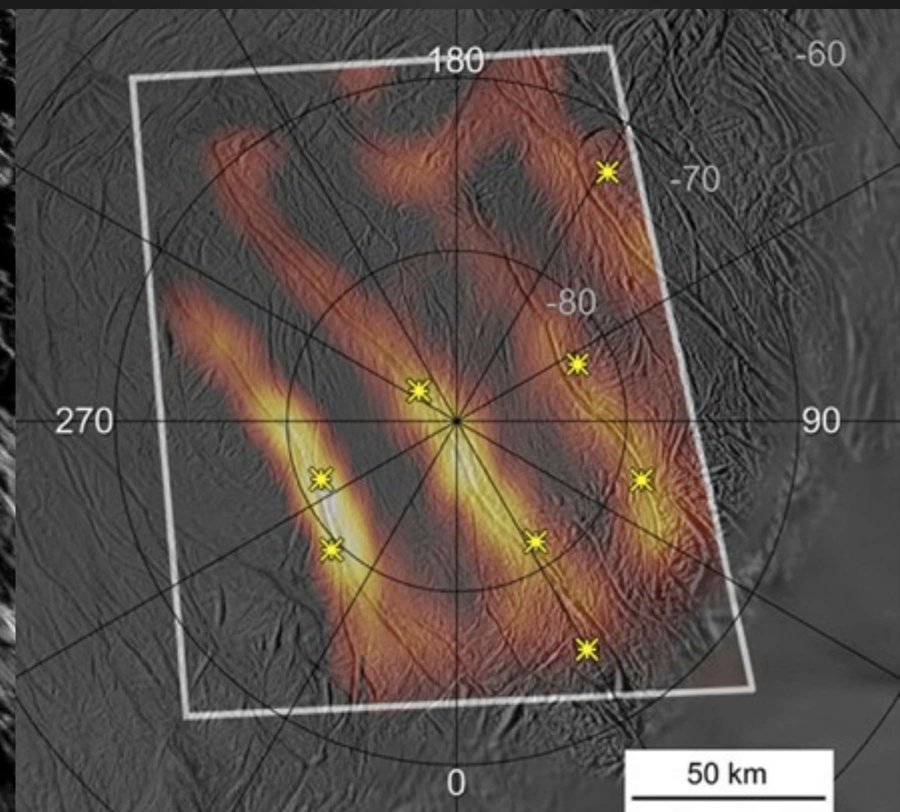
  → rocky core: $D \sim 330 - 400$ km
- temperature: $T_{Aequator.} \approx 75$ K

  $T_{Tiger\ Str.} \approx 190$ K
- south polar emission > 15 GW
- energy sources

  radio activity: < 0.5 GW

  tidal forces: ~ 1.0 GW

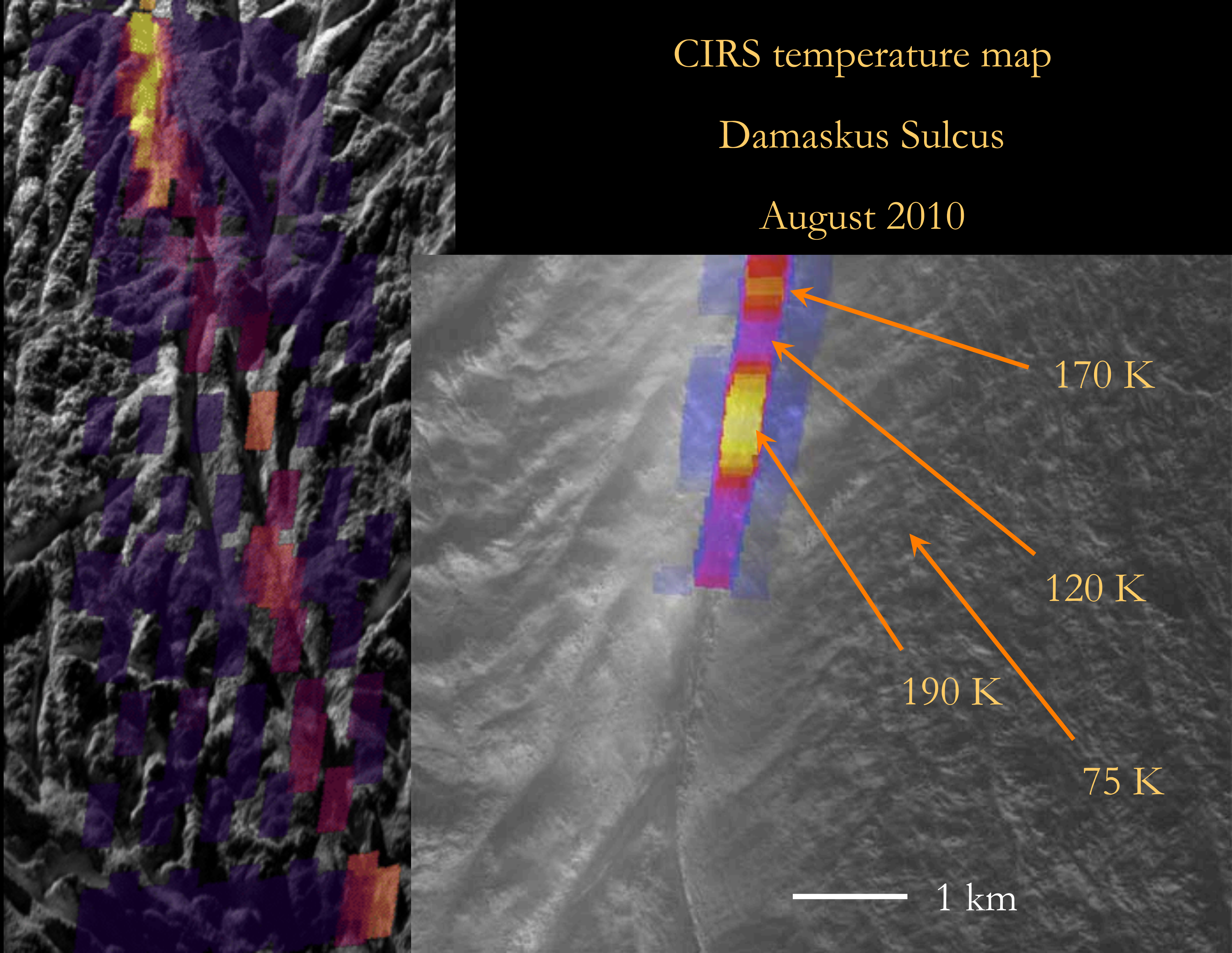
→ no steady state possible!



CIRS temperature map

Damaskus Sulcus

August 2010



Plume properties

- gas emission 150 - 250 kg/s

  gas speed ~ 400 – 1500 m/s

- ratio: gas/icy dust ~ 2 - 5

- dust particel size 0.001 – 10 µm

- dust particle speed 10 - 300 m/s

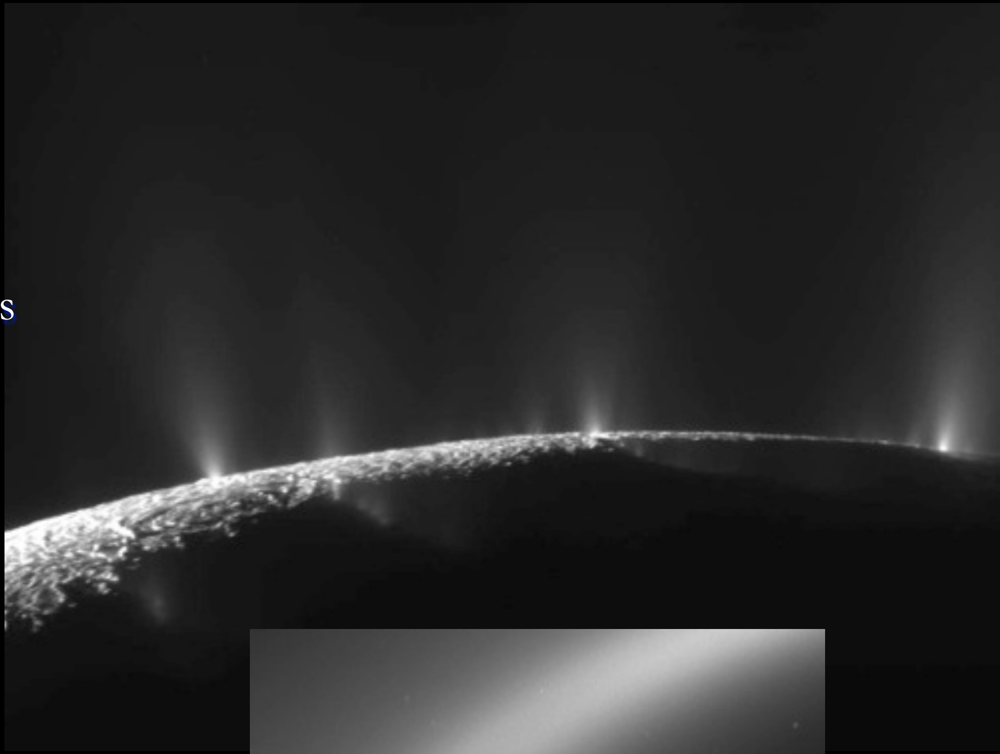
  escape speed ≈ 230 m/s

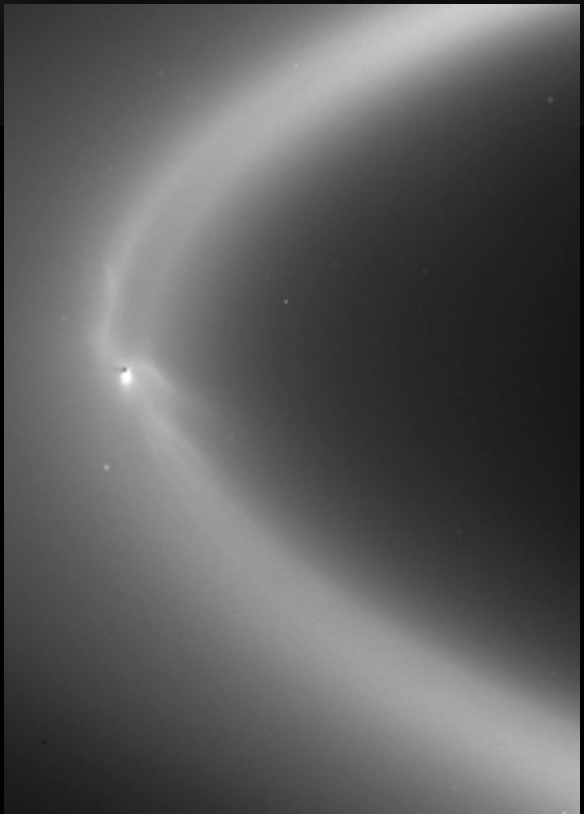
  → gas- and dust flux are decoupled

  → 0.5% - 5 % escapes and forms Saturn's E-ring (~1 kg/s)

- relatively steady emission over years

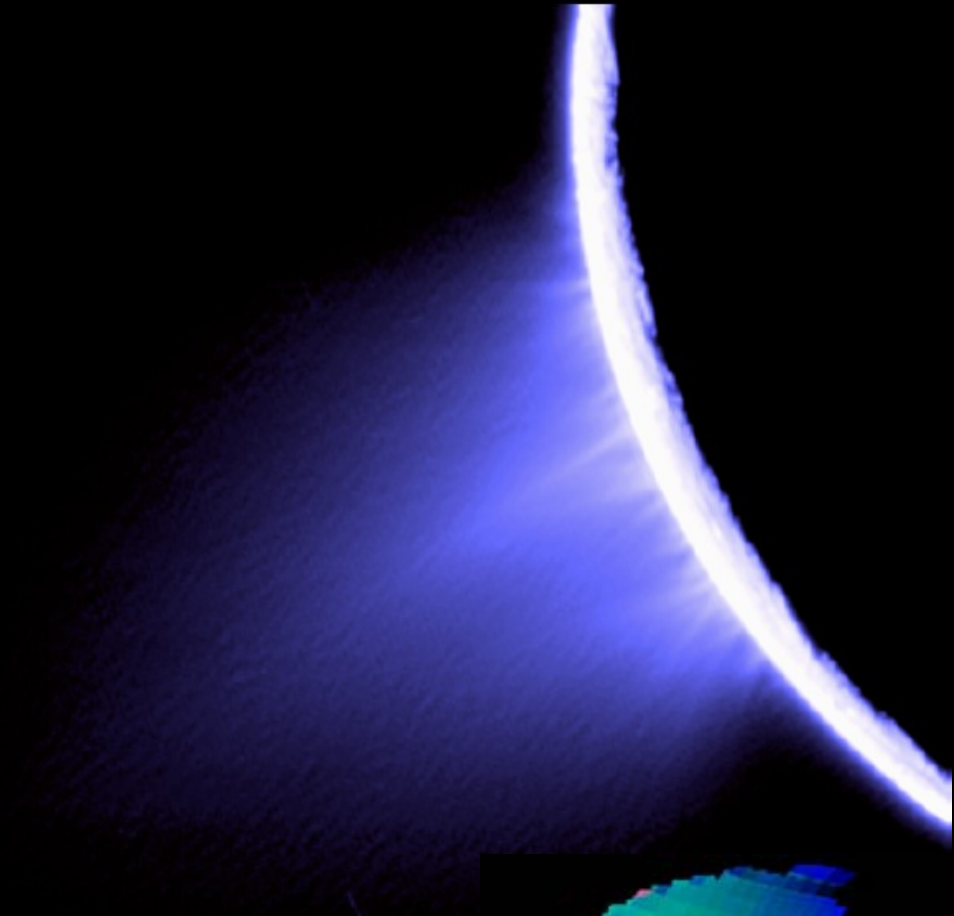
- matter emitted by Enceladus dominates Saturn's environment even beyond Titan!



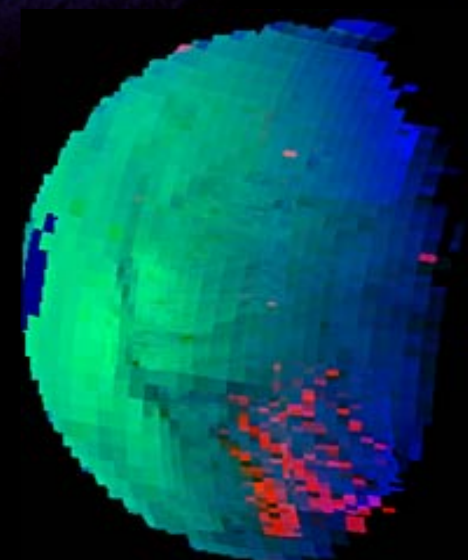


Composition

- Gas phase:
  - H_2O > 92 %
  - CO_2 ~ 0.5 - 5%
  - volatile organics ~ 1 – 3 %
  - NH_3 ~ 1%
  - CO < 3%
  - N_2 < 0.5 %
  - Na < 0.0001 %



- surface (from IR-spektroscopy):
  - almost the entiry surface is pure water ice
  - exception: CO_2 inclusions and traces of organic material at the Tiger Stripes



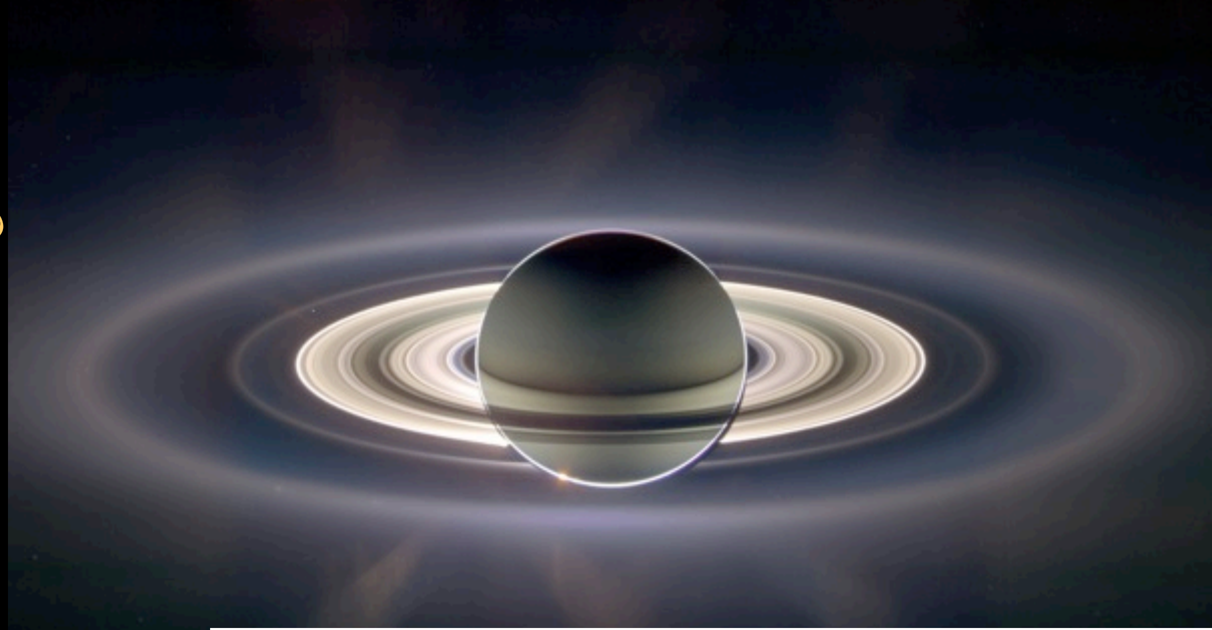
Since when is Enceladus active?

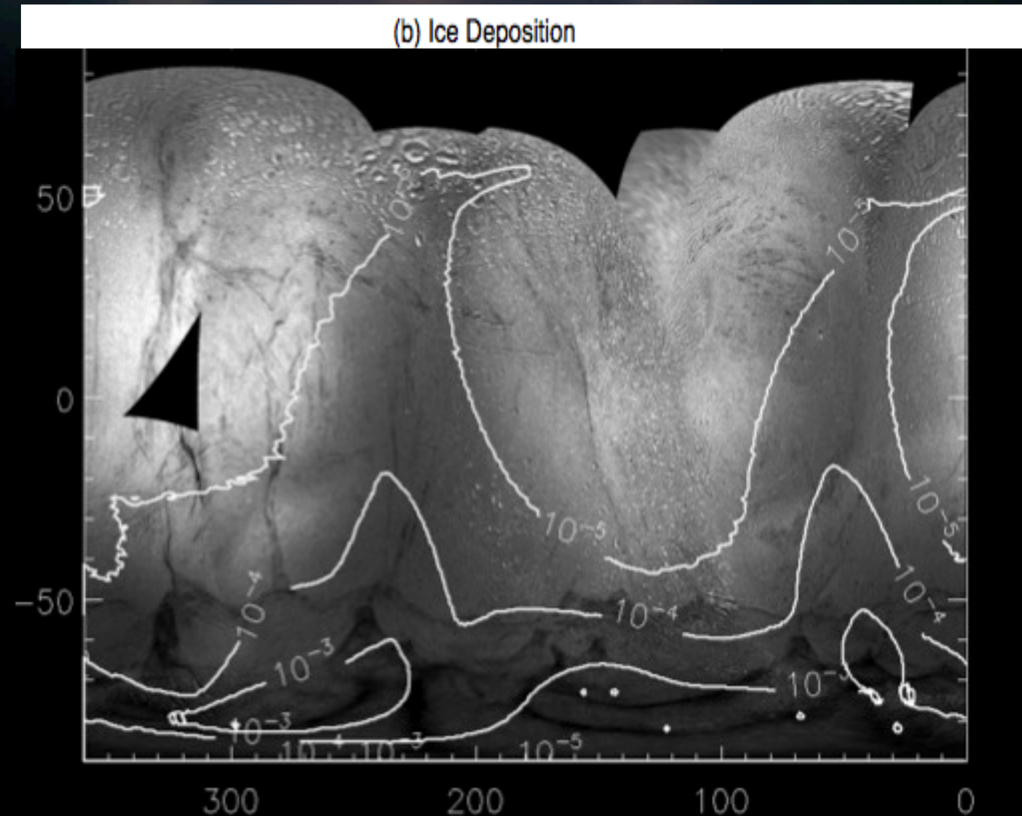
Estimate:

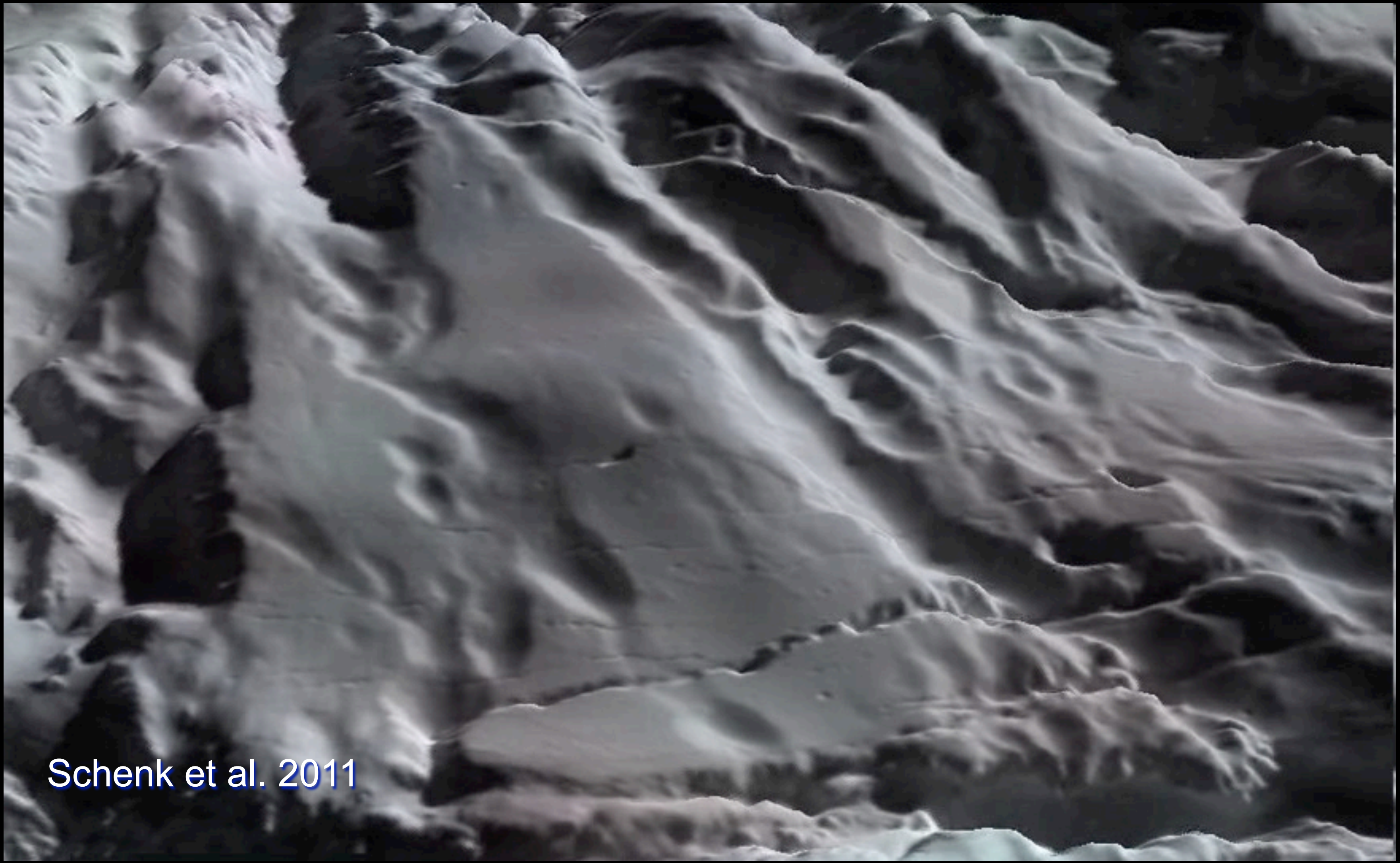
- from E ring profile

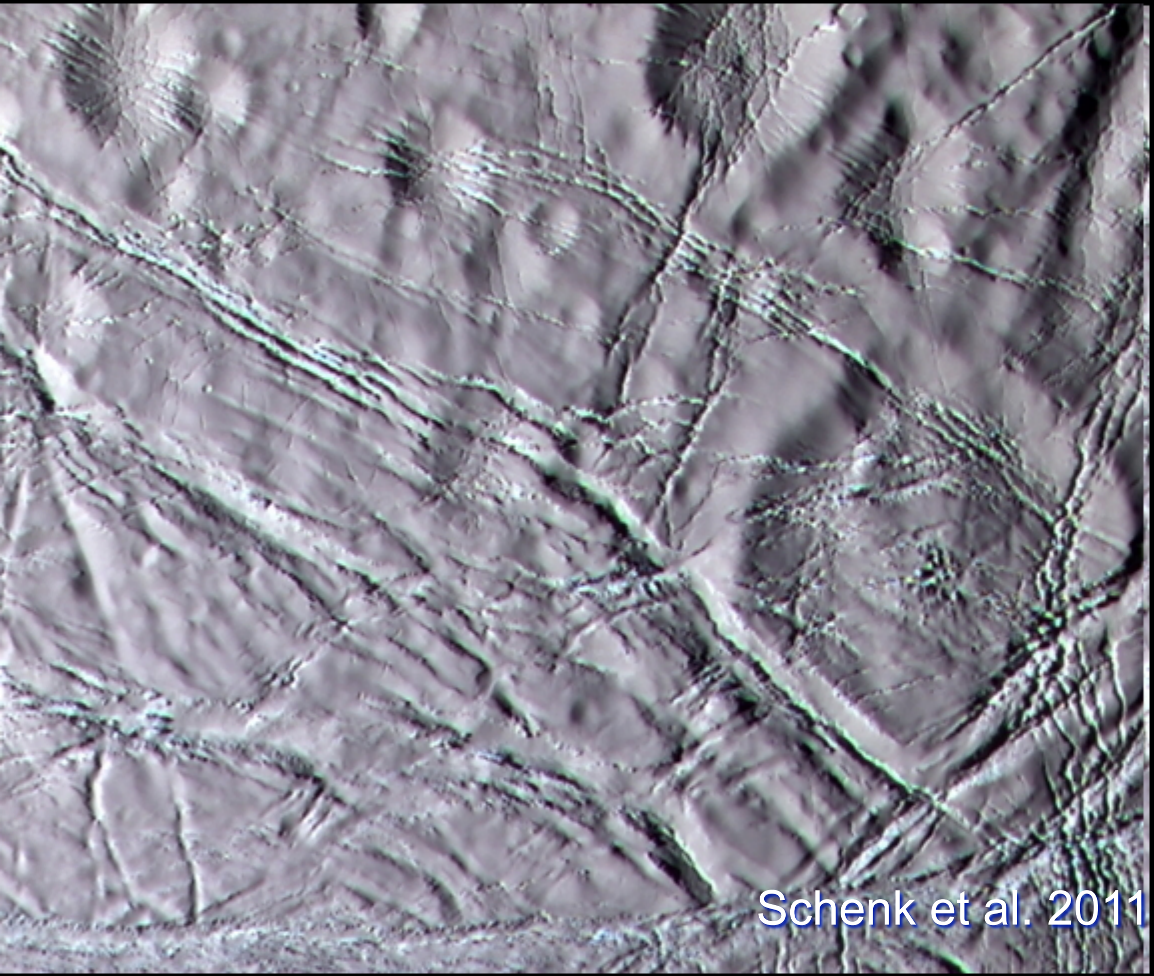
→active since > 1000 Jahren

- from „depth of snow“





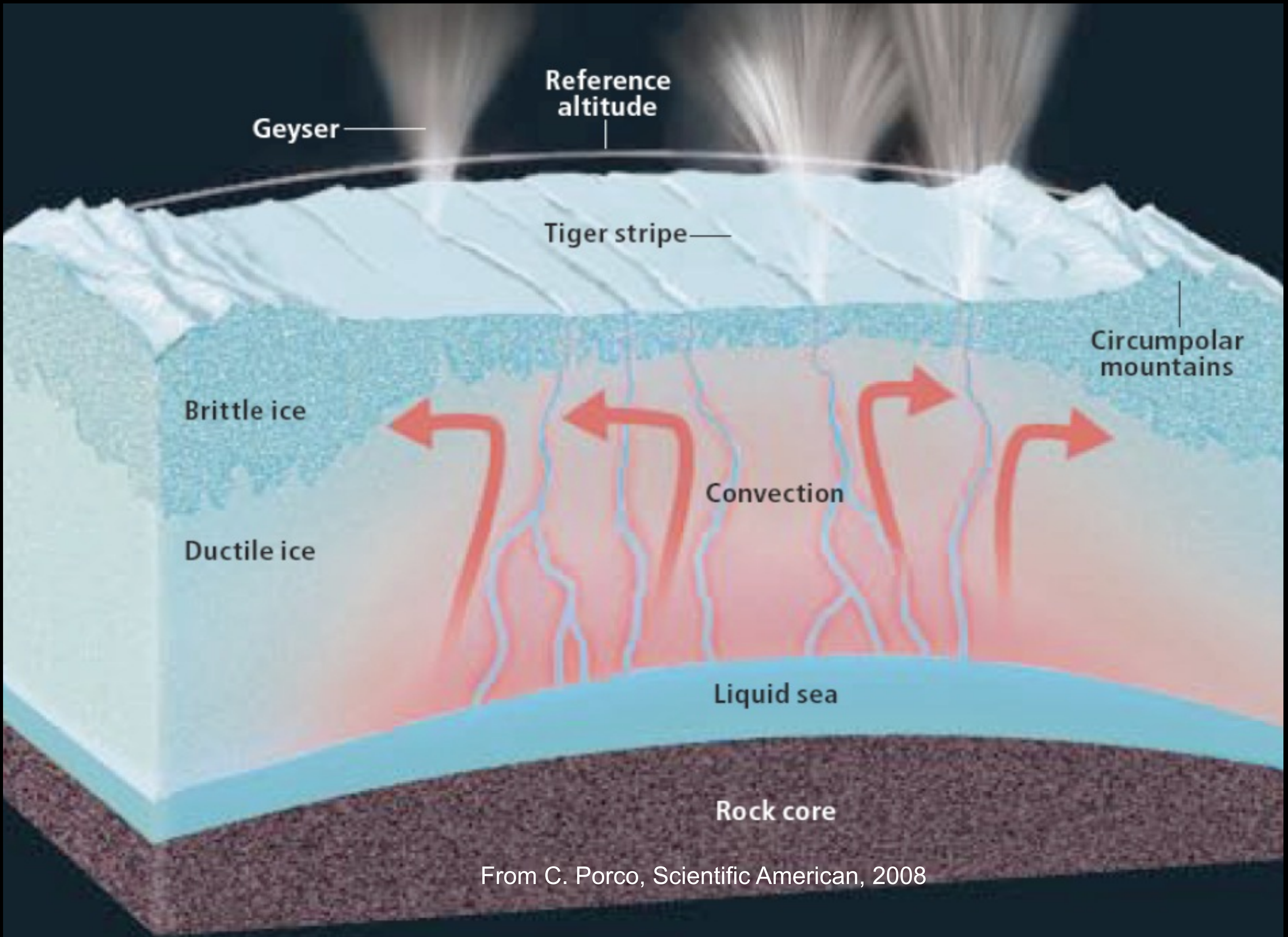

Schenk et al. 2011



Since when is Enceladus active ?

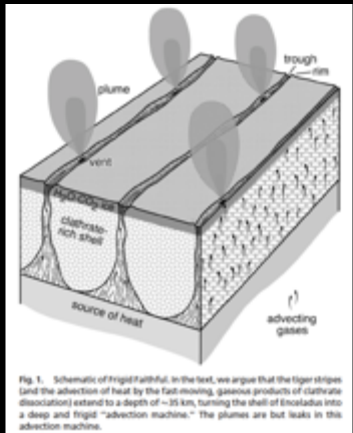
- snow layer > 100 m more than 100 km away from sources
- → requires activity of > 10.000.000 years

Liquid Water ?



From C. Porco, Scientific American, 2008

Water ?



“boiling” water

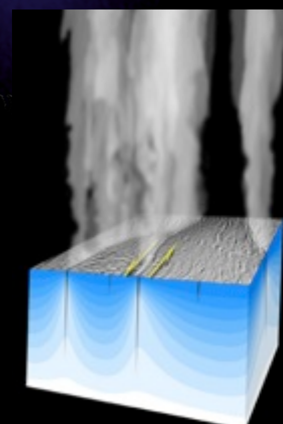
-> fracture exposes liquid suddenly to vacuum

-> explosive boiling produces H_2O gas, liquid, and particles

clathrate decomposition

-> volatile gases are suddenly “set free” and drag along ice particles

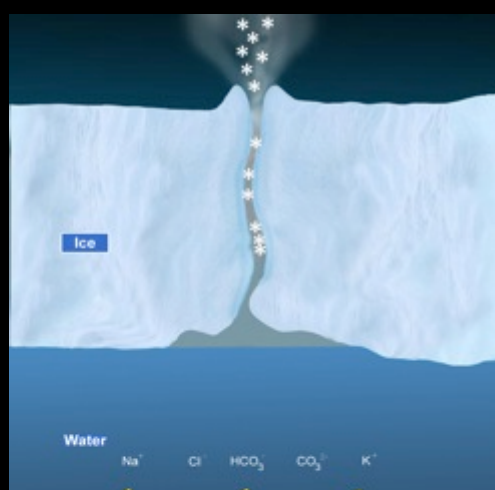
-> H_2O fomrs from sublimation of entrained ice particles



sublimation of warm ice

-> H_2O gas

-> icy particles from through recondensation from vapour



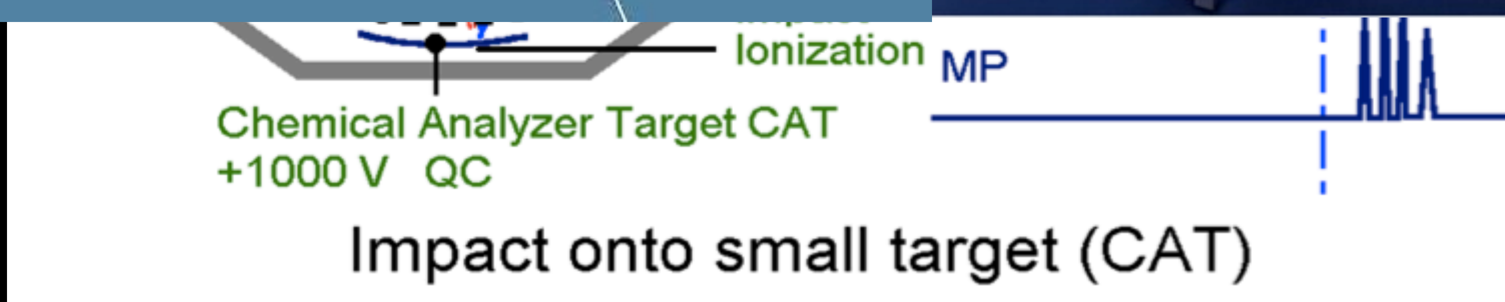
water reservoir(s)

-> slow evaporation

-> ice particles from frozen spray (aerosols)

-> … and vapor condensation

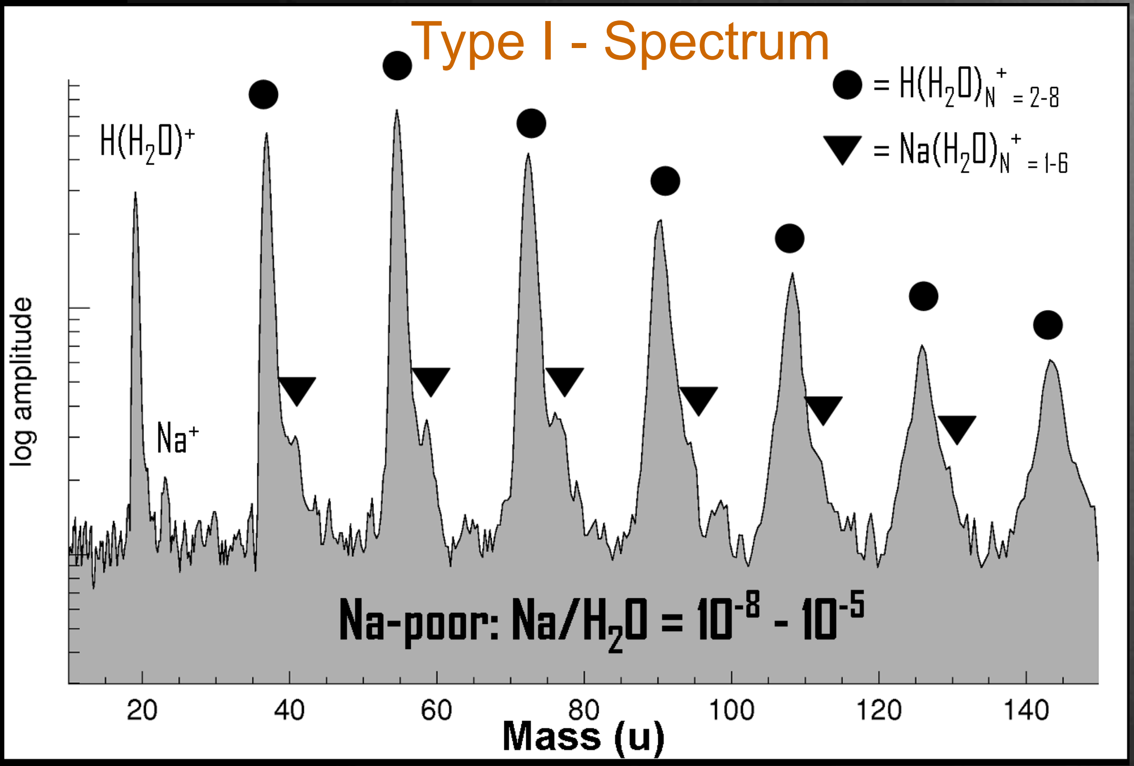
Chemical and Dynamic Characterisation of Saturn's Dust Environment: Cosmic Dust Analyser (CDA)



CDA measurements of E-Ring populations

Postberg et al. (2008, 2009)

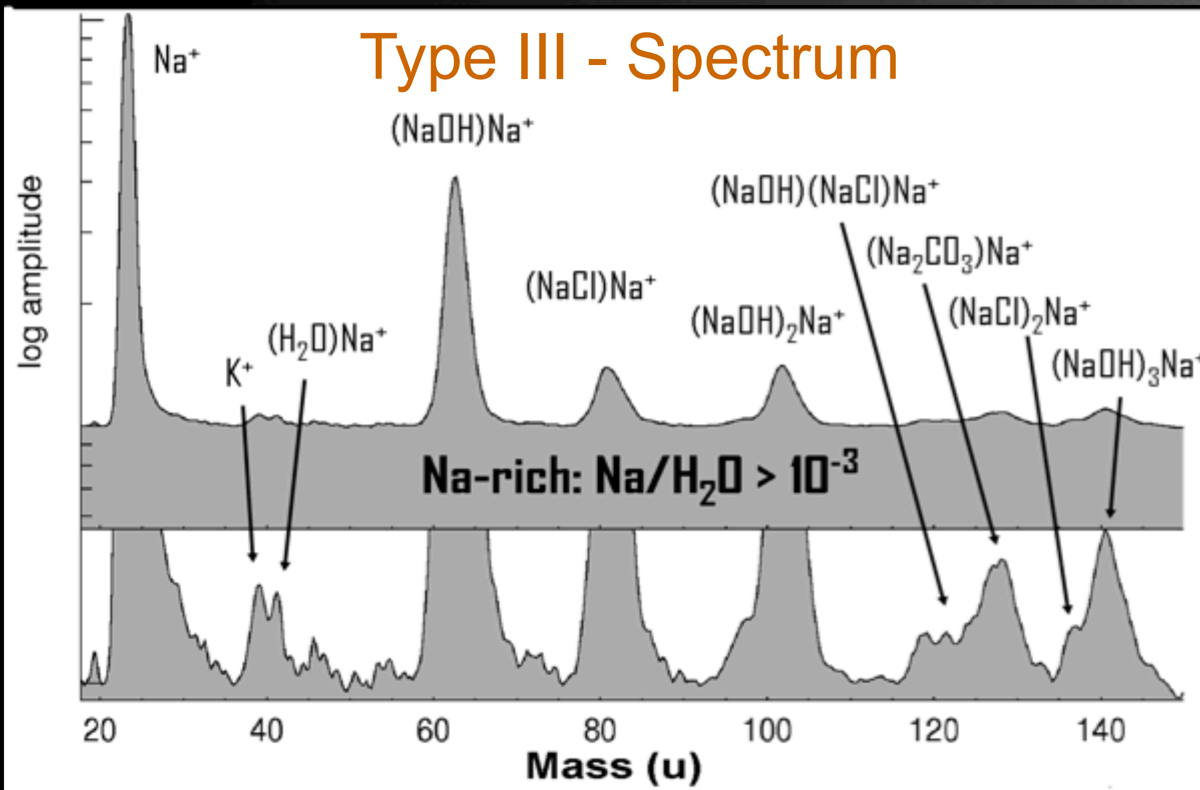
- ~ 90% of E ring spectra show almost pure water ice
- $(H_2O)_nH^+$ cluster from defining pattern → pattern strongly varies with impact velocity



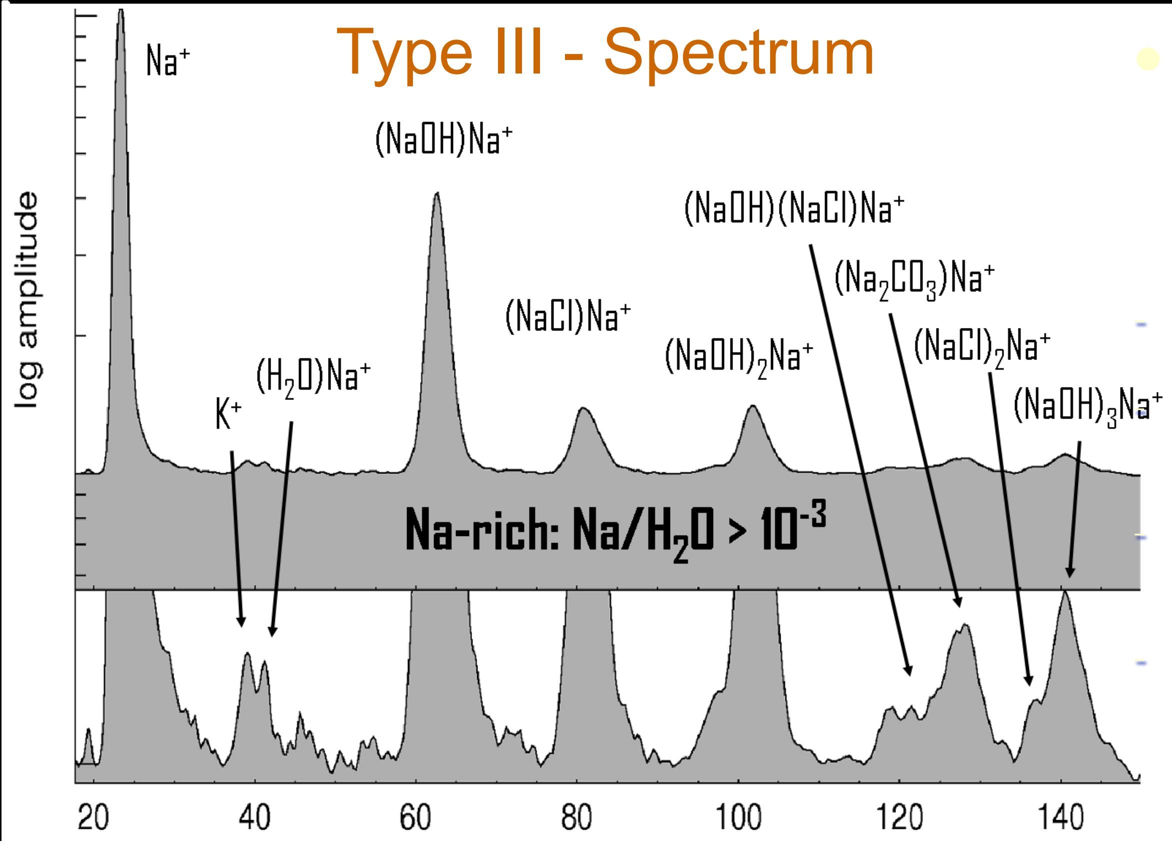
CDA measurements of E-Ring populations

Postberg et al. (2008, 2009)

- ~ 6% of all E ring Spectra



- $(NaOH)_nNa^+$ cluster indicate strongly enhanced Na abundance ($Na/H_2O > 10^{-3}$)
- $(NaCl)_nNa^+$ and $Na(Na_2CO_3)\ Na^+$ cluster:
  - ⇨ $NaCl + NaHCO_3\ /\ Na_2CO_3$ are the Na bearing compounds
- K-salts at much lower concentration



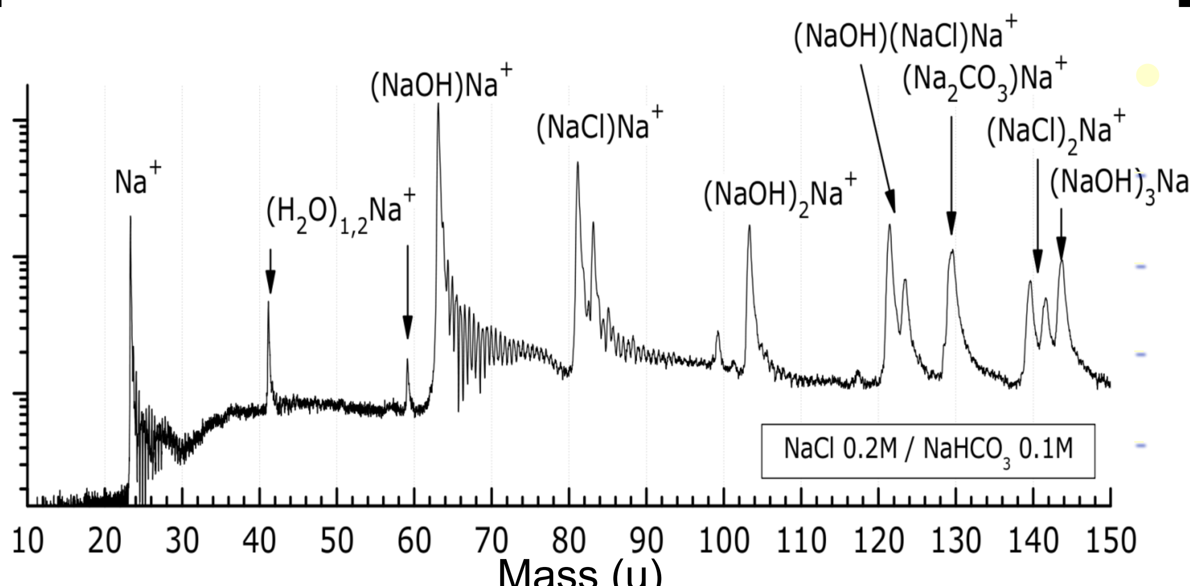
Reproduction of CDA spectra in the laborartory

simulation of impact-ionisation:

→ IR-Laser on µm water droplets

→ High-res TOF mass spectra

→ Test with different salty solutions

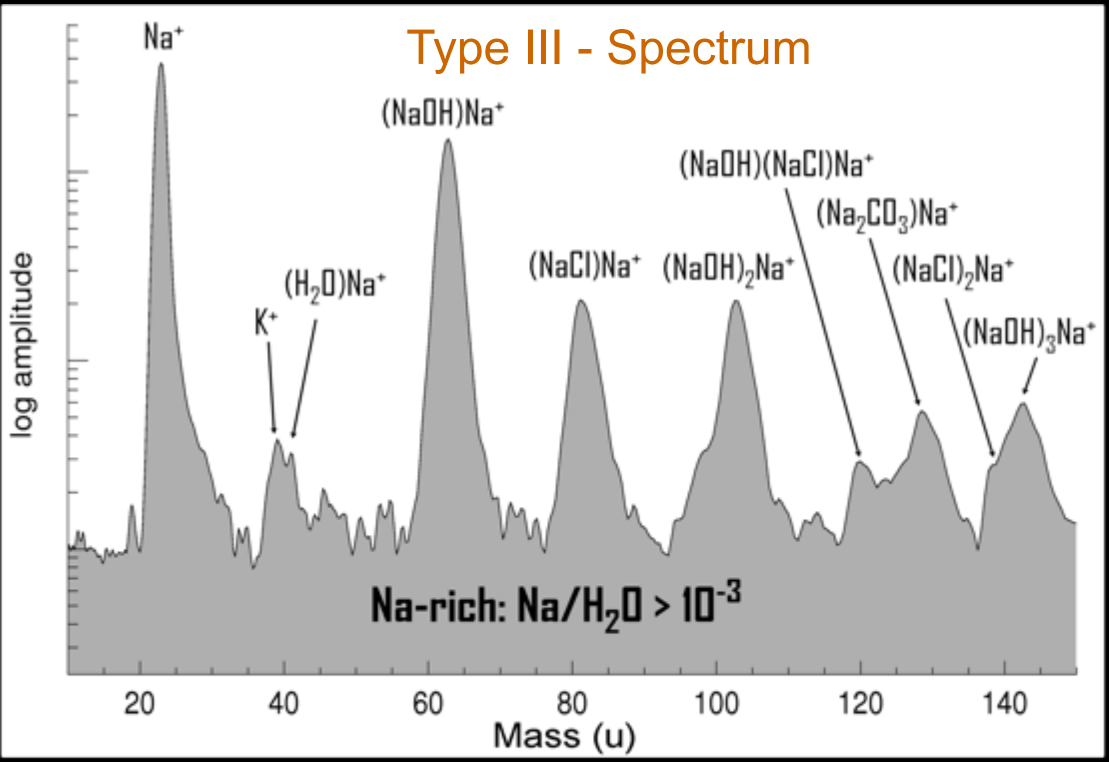


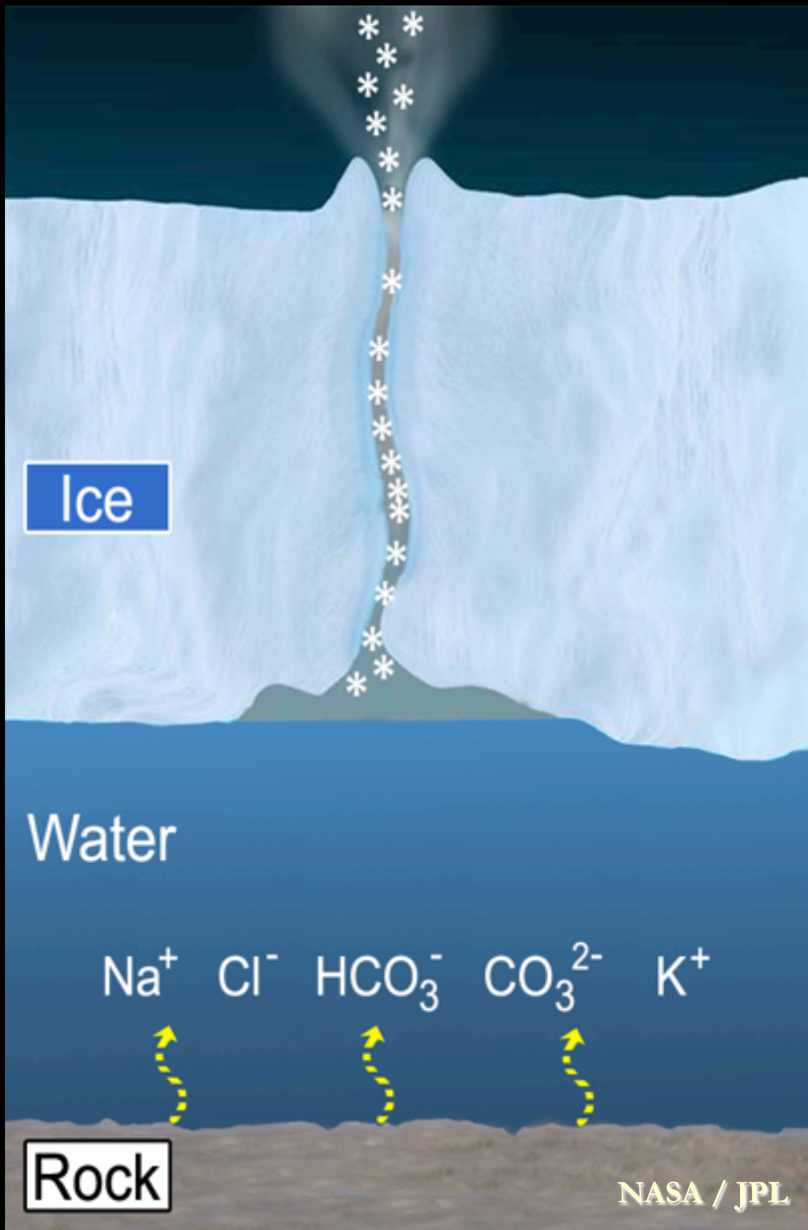
Best Fit:

NaCl:	0.1 - 0.2 M/L
$NaHCO_3$:	0.05 - 0.1 M/L
pH :	~ 8.5
Na/K:	~ 100

salt-rich water ice

Postberg et al. (2008, 2009)





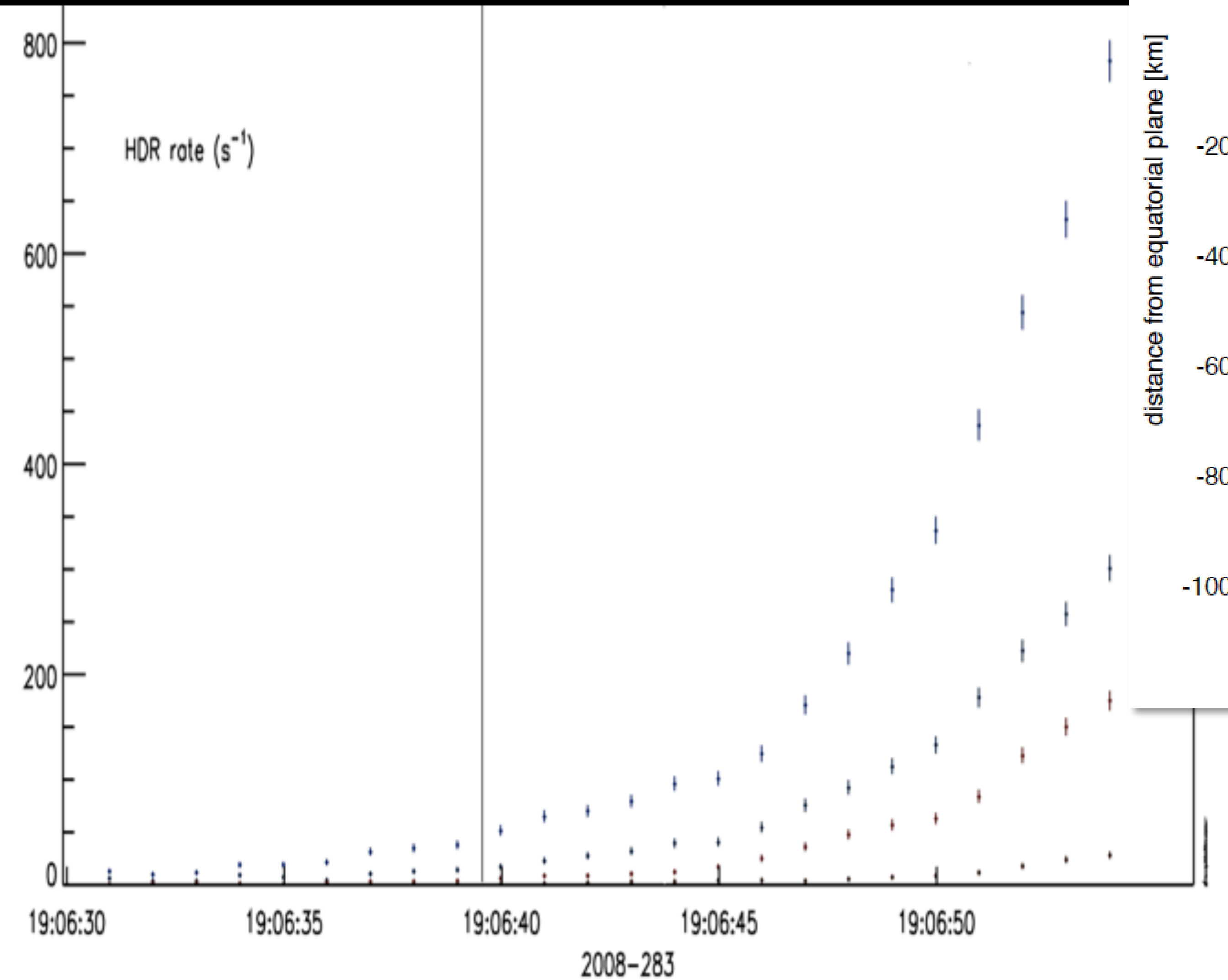
- ➪ 98% ice, 1 - 2% salts
- ➪ $NaCl$, $NaHCO_3$ / Na_2CO_3, KCl

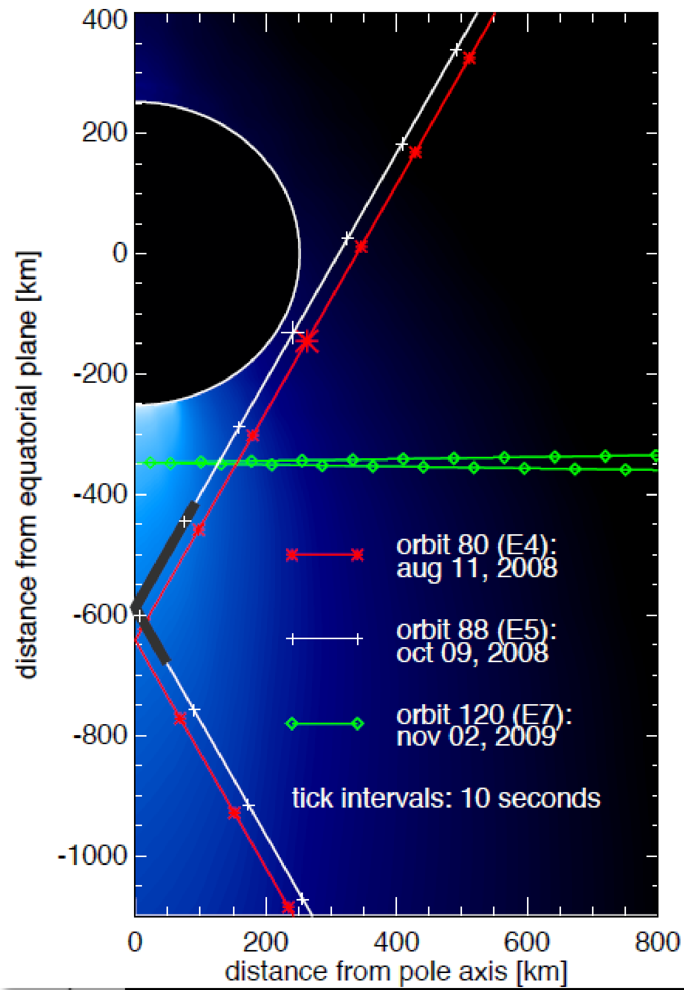
→ saltwater with alkaline pH (8 – 9)

➪ Exactly these components were predicted for an Enceladus Ocean! (Zolotov, GRL 2007)

CDA measurements at close encounters

Postberg et al. (2011)

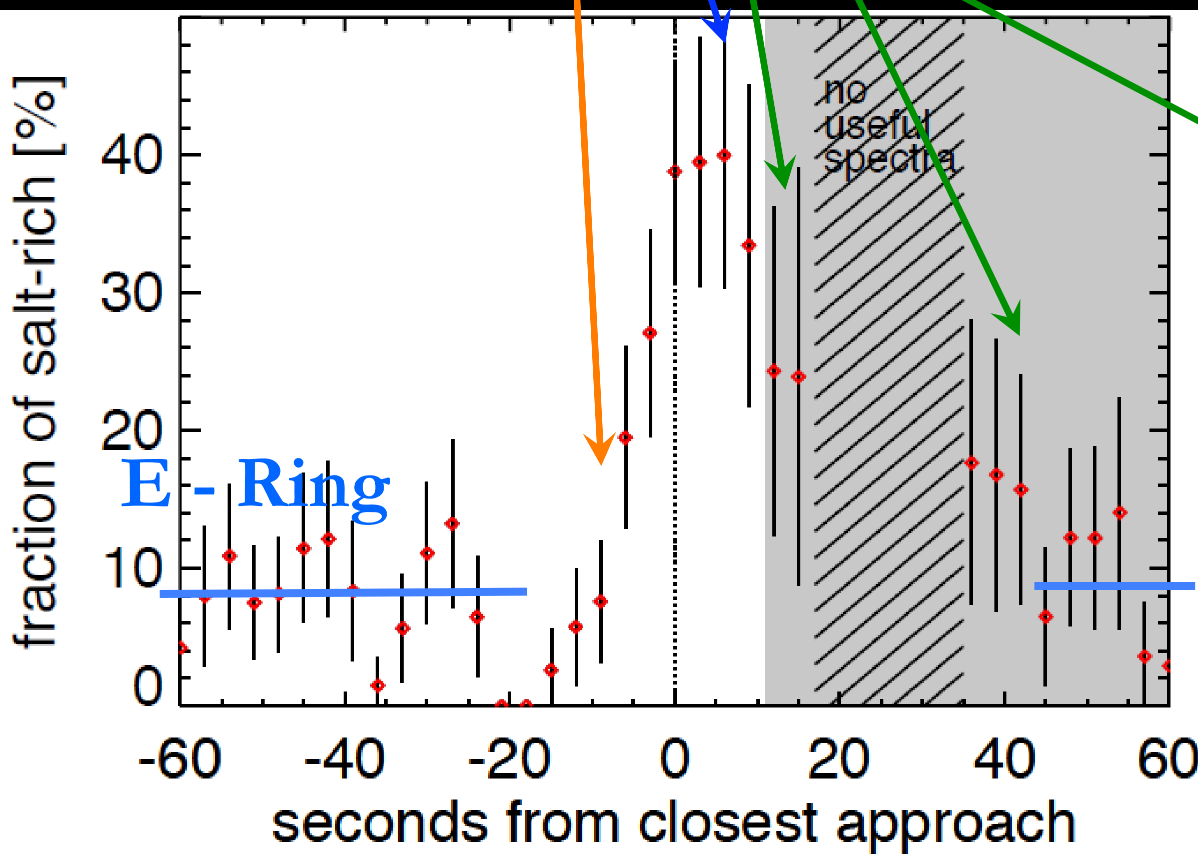


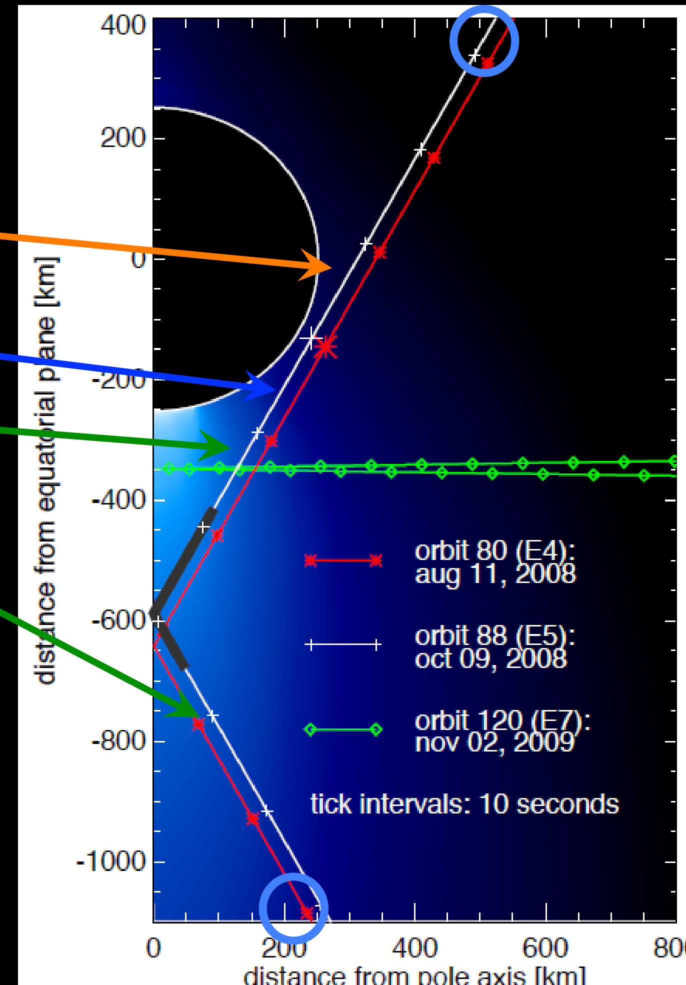


CDA measurements at close encounters

Postberg et al. (2011)

- before closets approach: increase of percentage of salt rich particles
- Maximum ~5 s after closest approach
- salt rich fraction goes down again



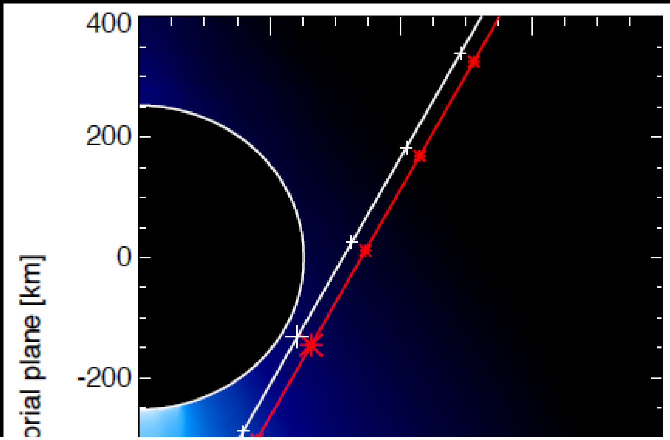


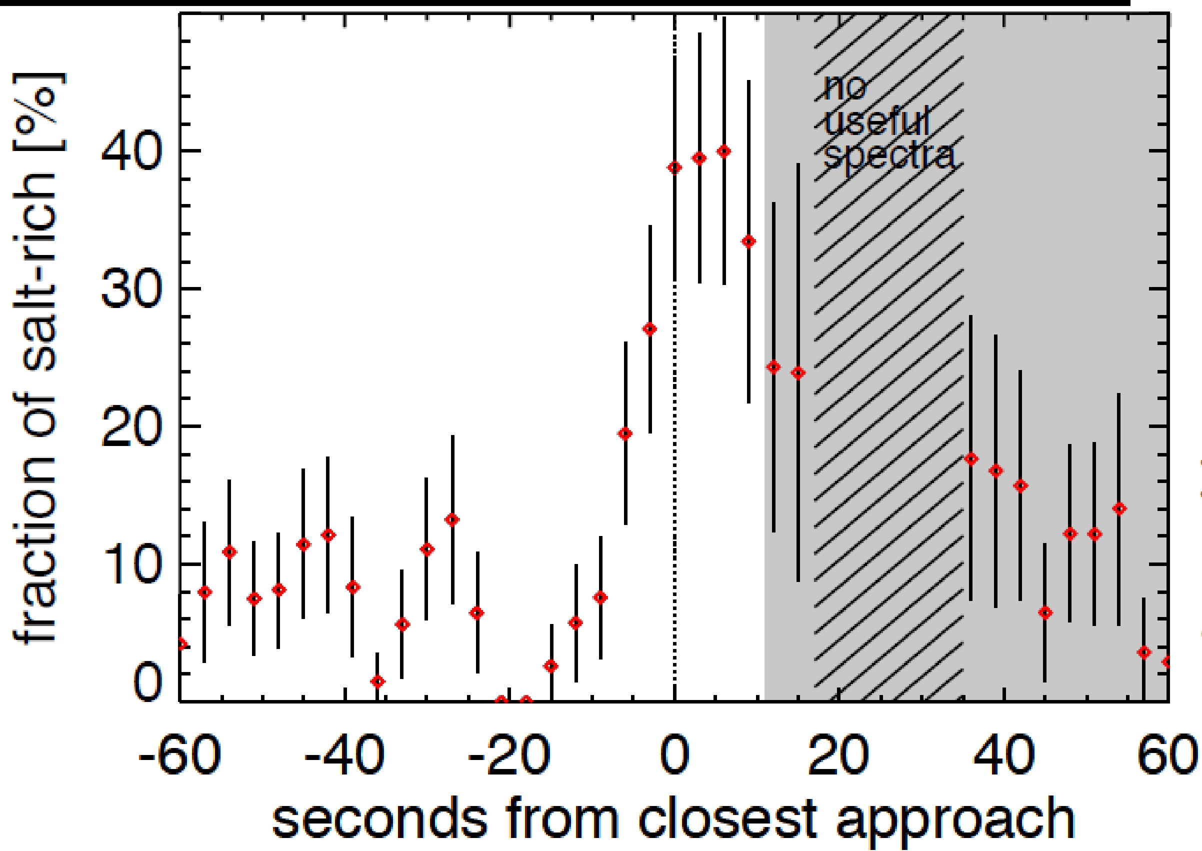
CDA measurements at close encounters

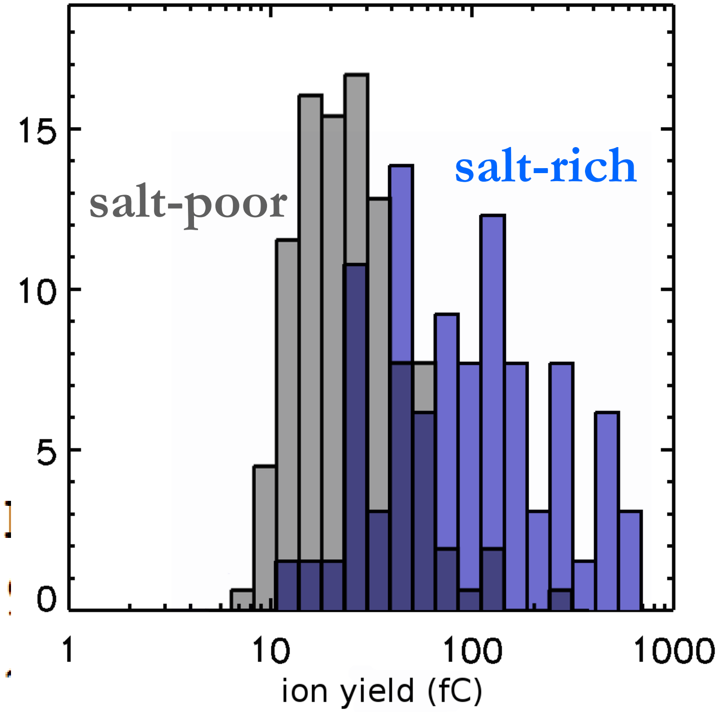
Postberg et al. (2011)

→ salt-rich particles are larger and heavier than salt-poor particles

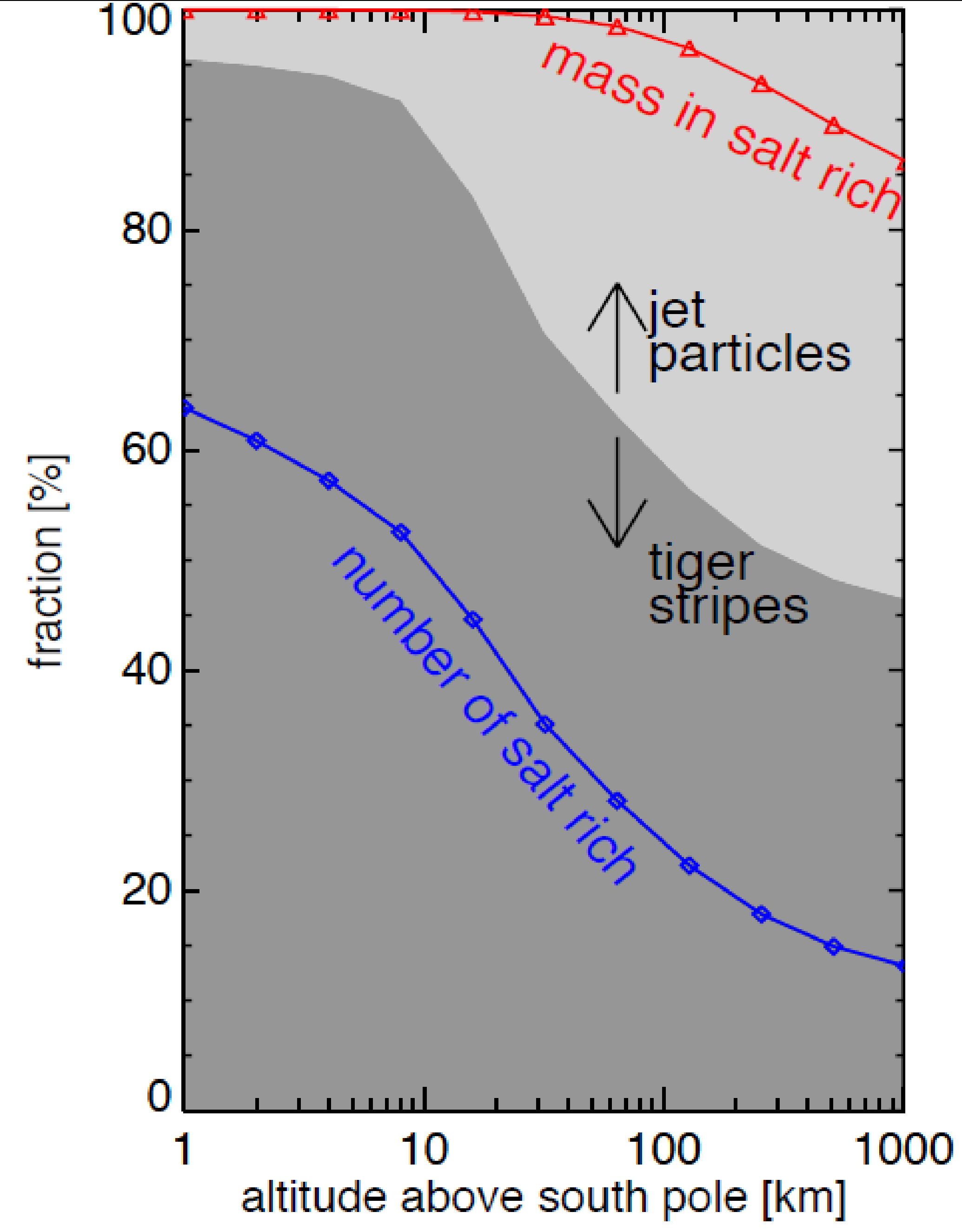
→ heavy particles → lower ejection speed → populate plumes preferably closer to the surface







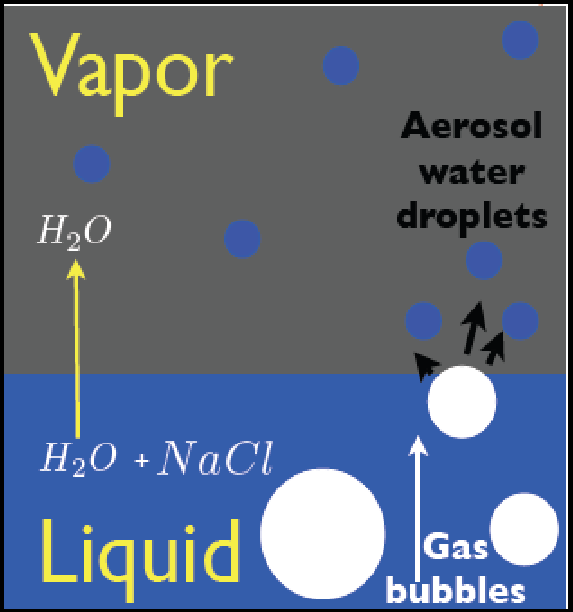
A compositionally stratified plume

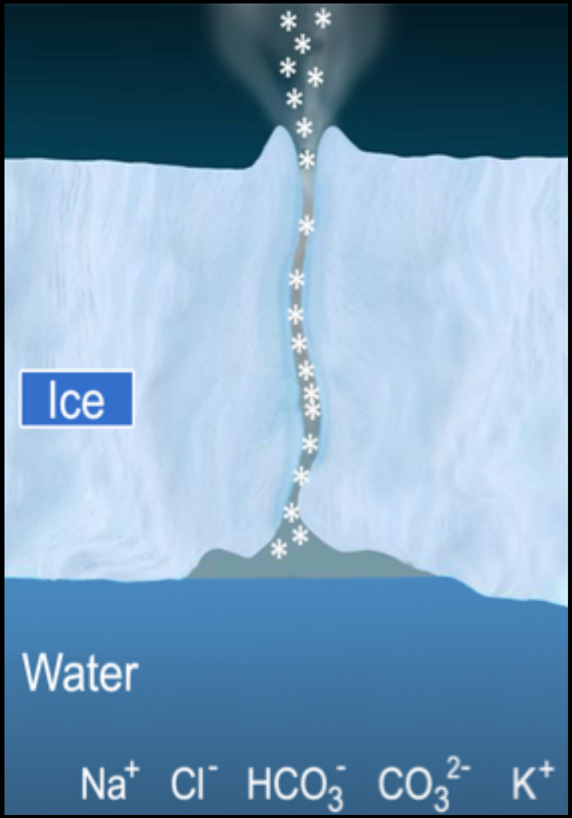


→Enceladus preferably produce salt-rich grains

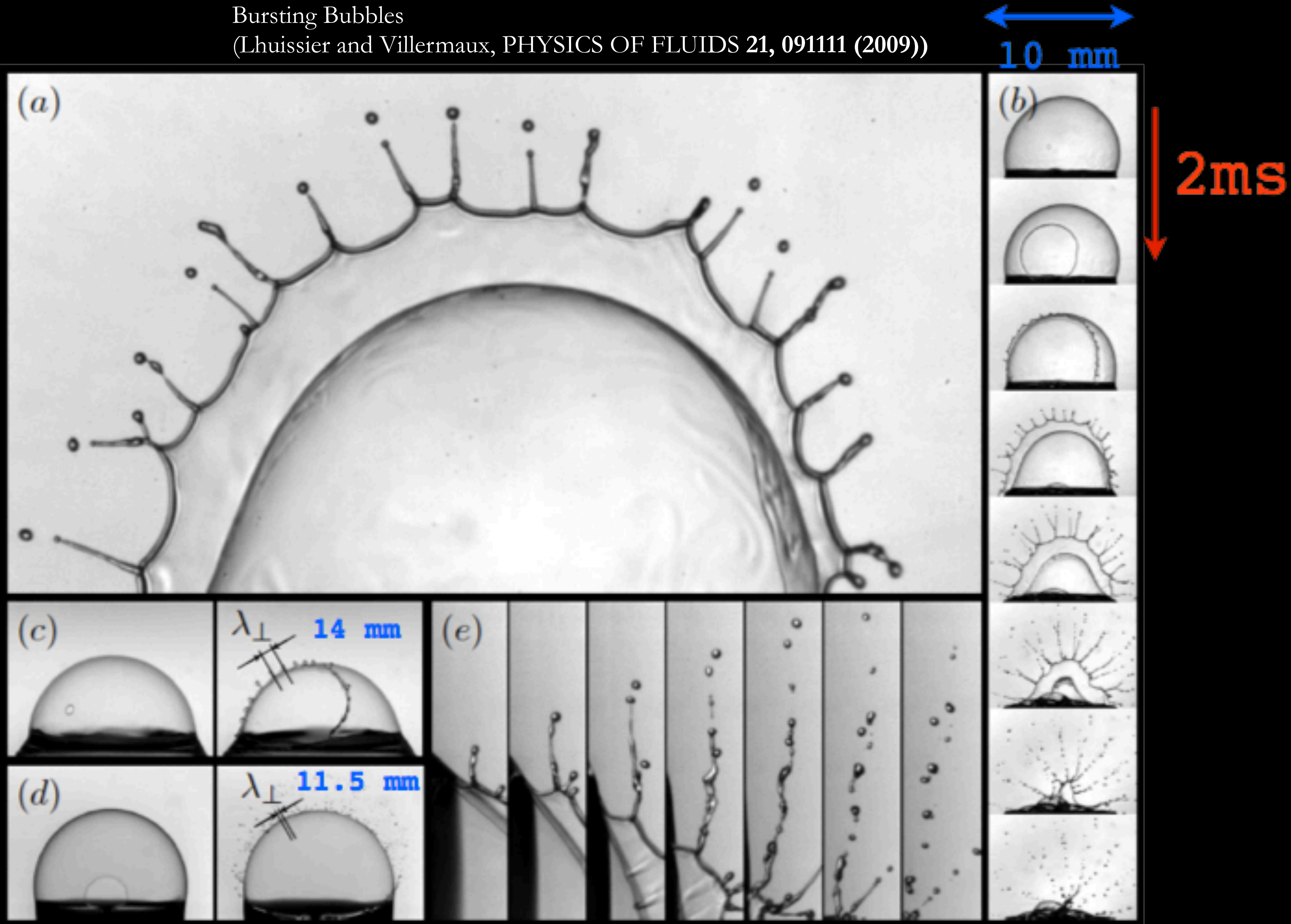
→liquid water (not ice) must be the main source

How salt-rich particles form ?





Bursting Bubbles
(Lhuissier and Villermaux, PHYSICS OF FLUIDS **21, 091111 (2009)**)



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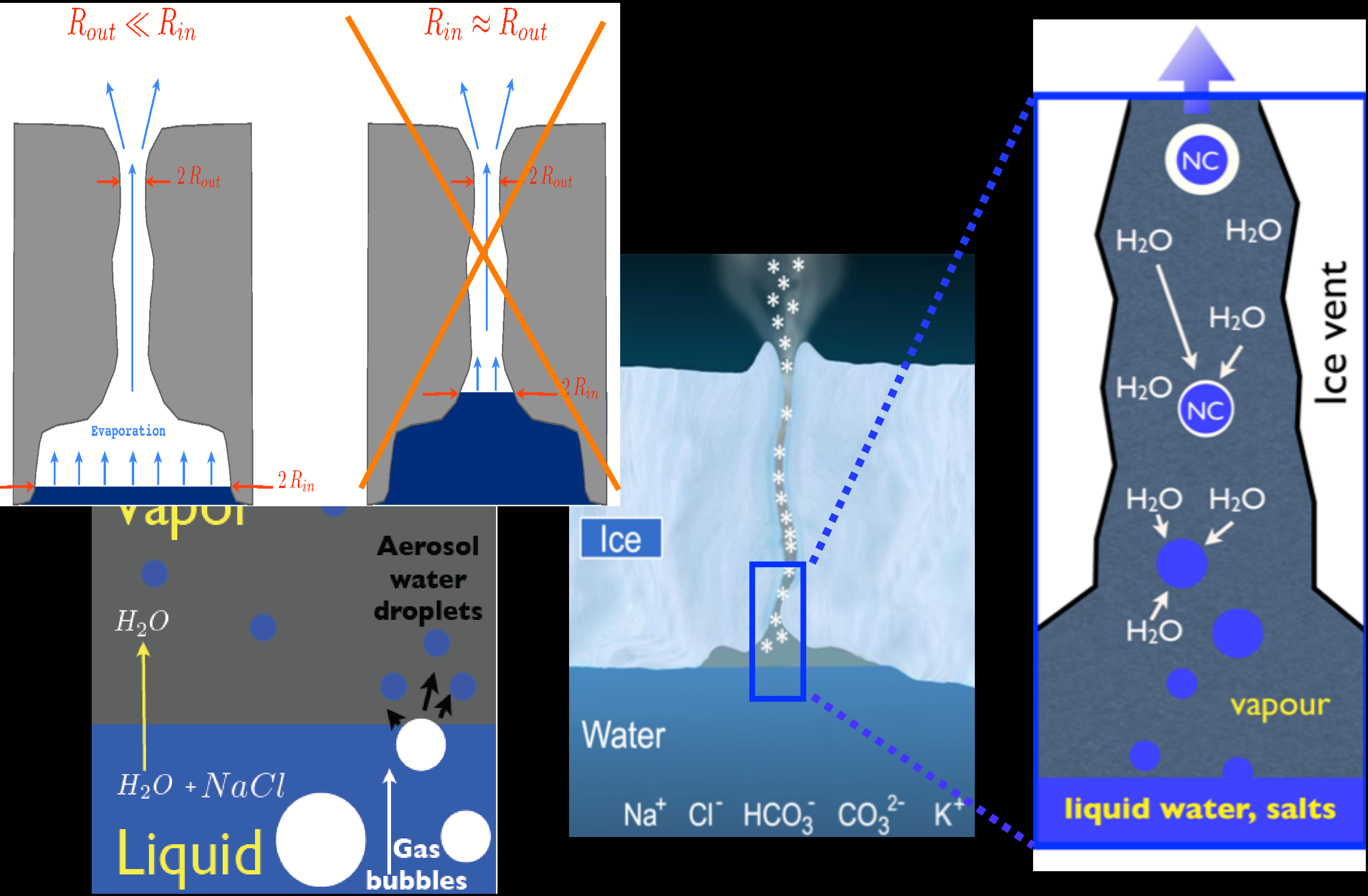
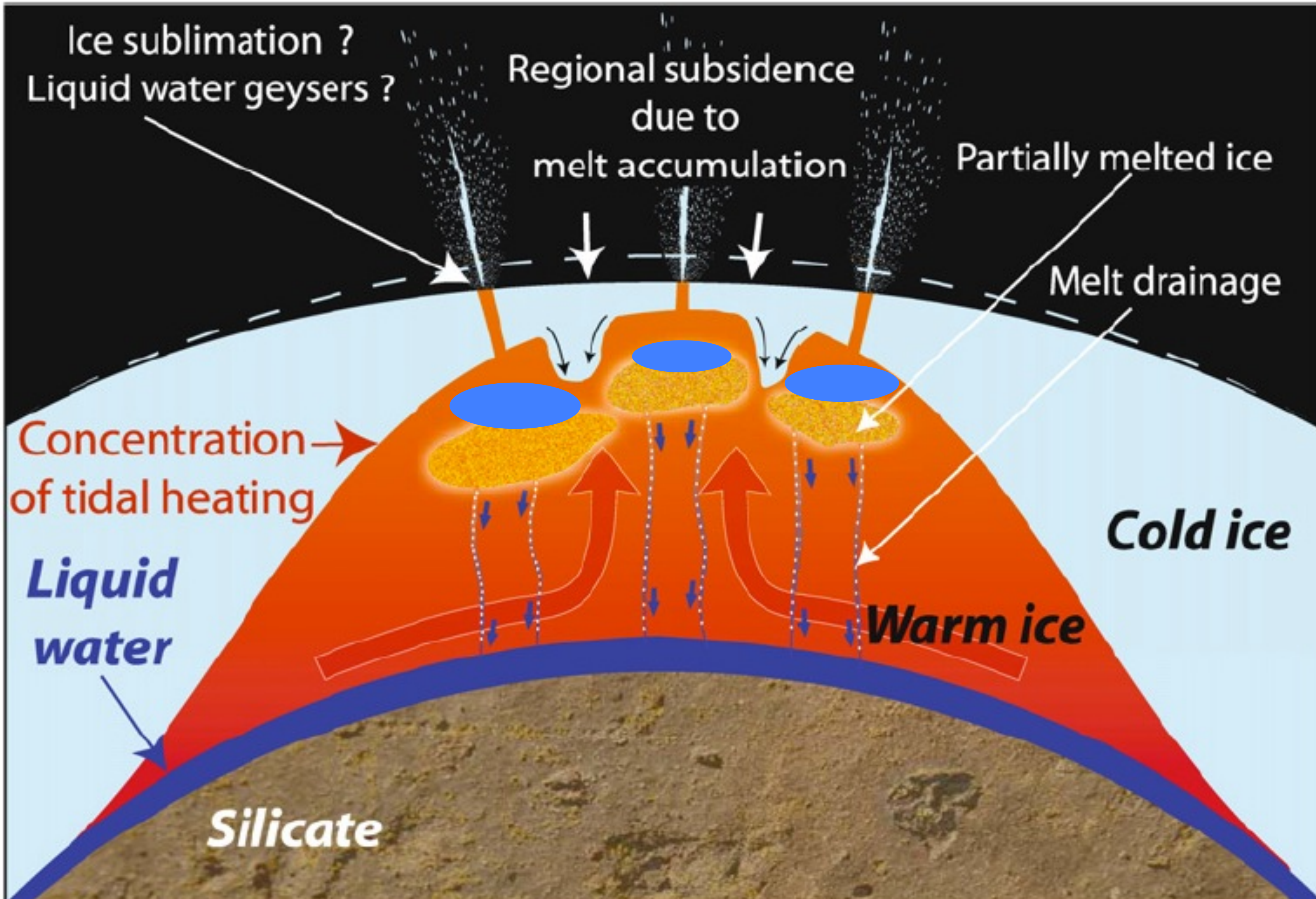
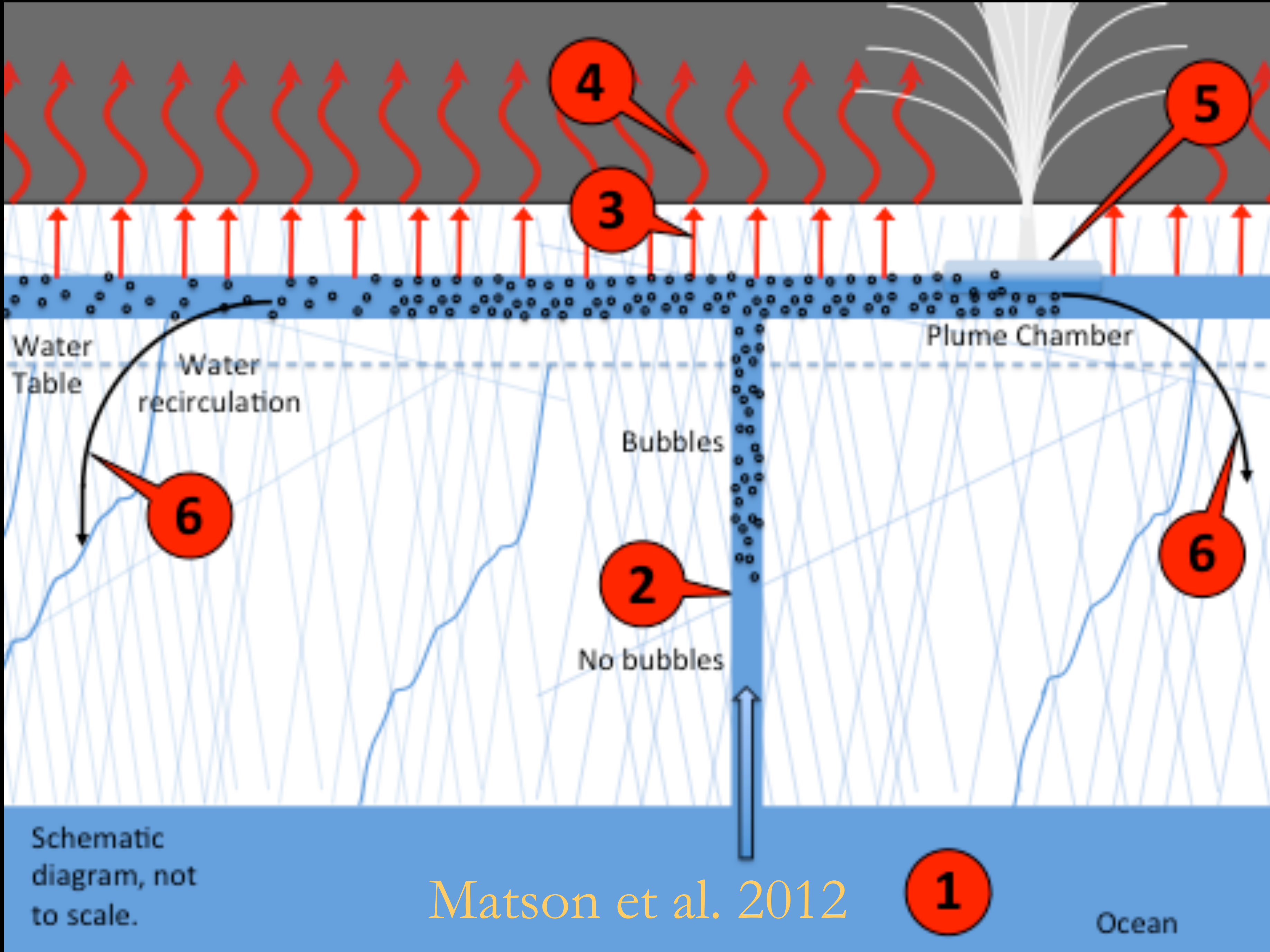
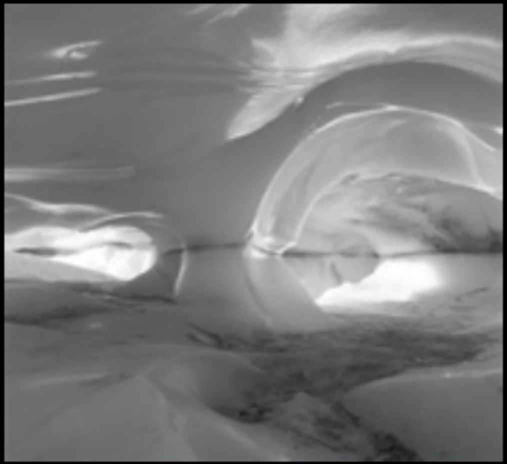




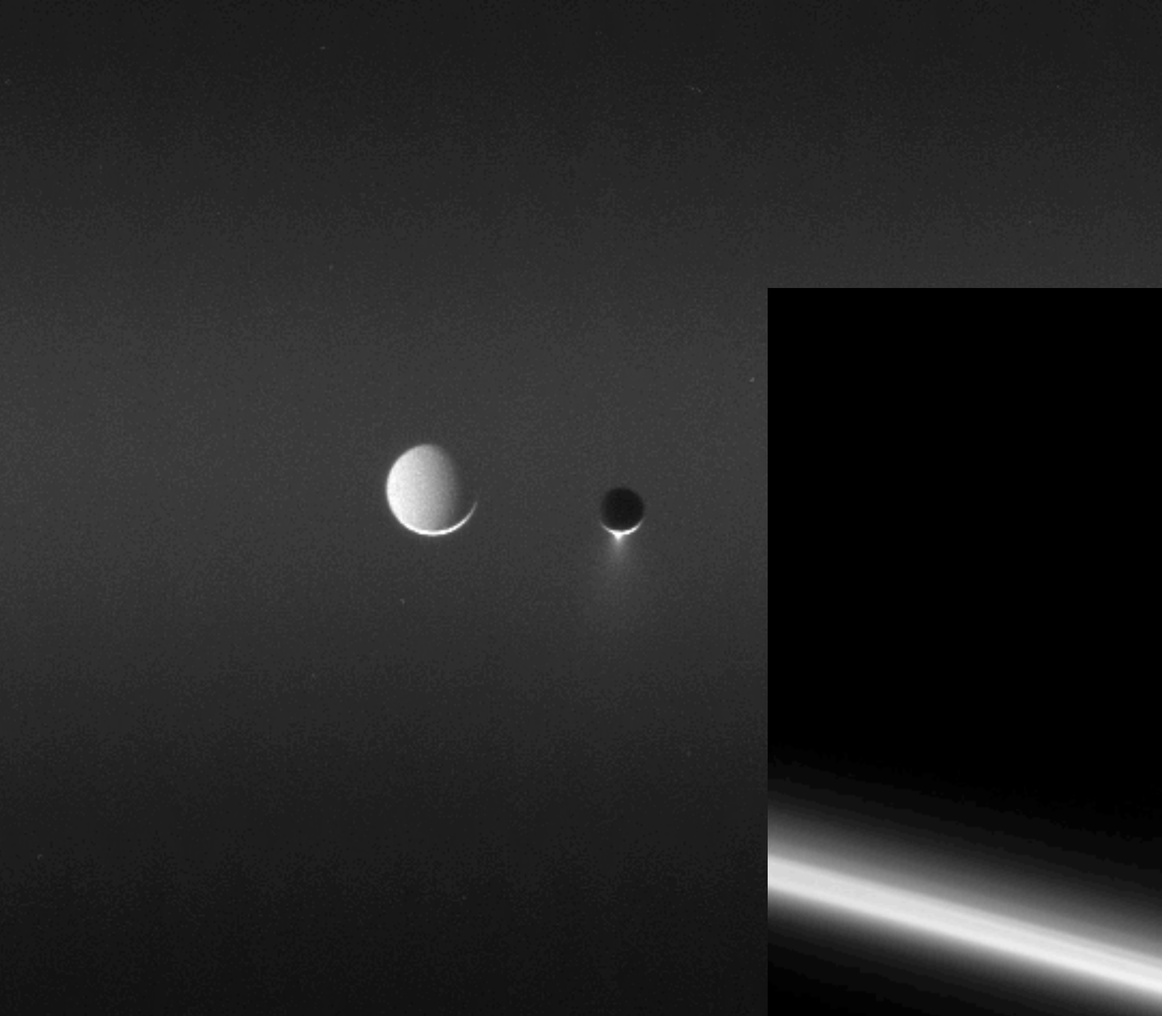
Ice sublimation ?
Liquid water geysers ?
Regional subsidence
due to
melt accumulation
Partially melted ice
Melt drainage
Concentration
of tidal heating
Cold ice
Liquid
water
Warm ice
Silicate



Matson et al. 2012



DANGER
THIN ICE

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