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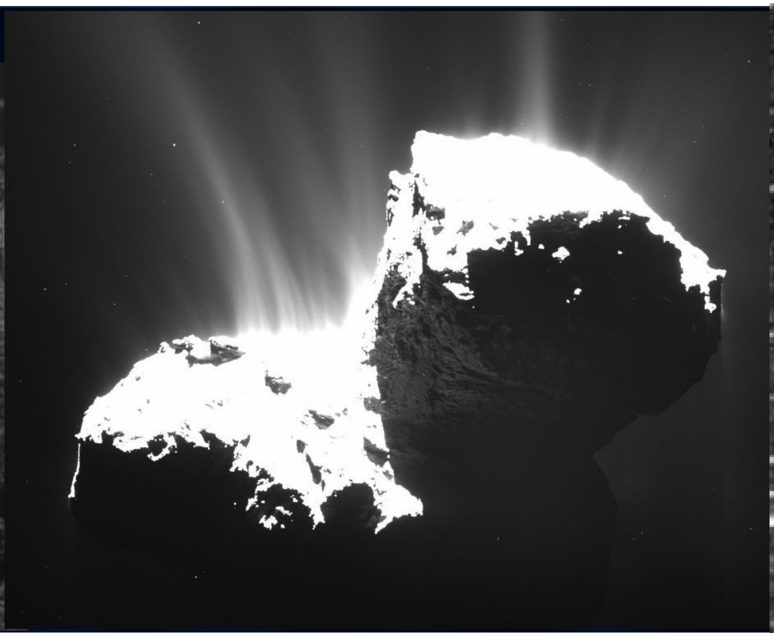

Small bodies in our solar system

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Radio2024, Erlangen

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Overview

- Introduction: Small solar system objects
- Orders of magnitude:
  - Temperatures
  - Spatial and angular scales
  - Flux
- Examples of radioastronomic observations:
  - Cometary dust
  - Subsurface properties of a large asteroid

Small solar system bodies are remnant planetesimals stored in three reservoirs.

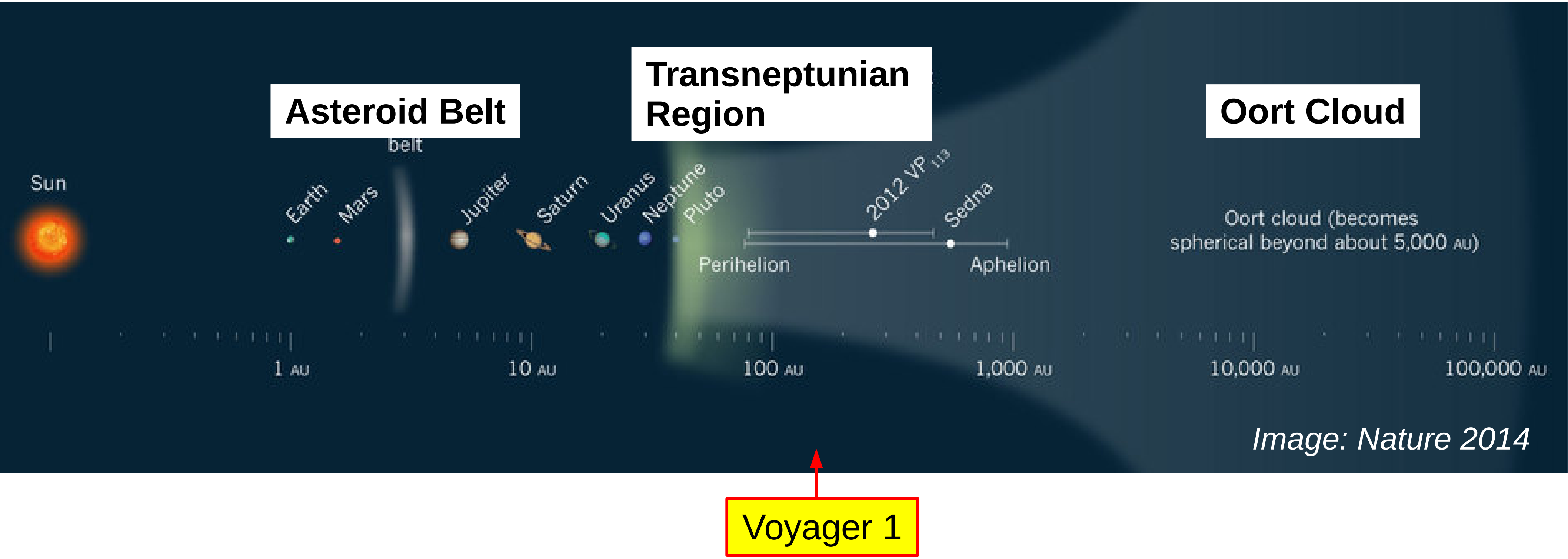
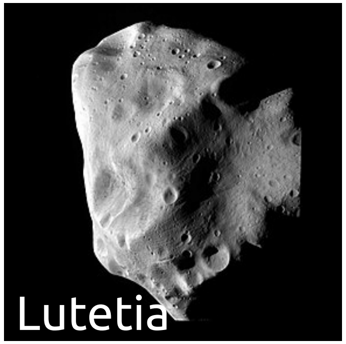


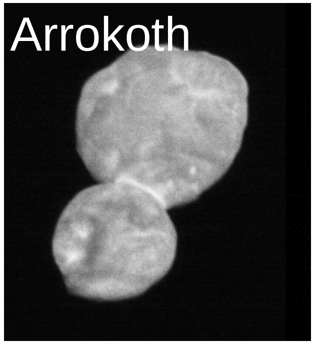
Bild Ryugu: JAXA, University of Tokyo, Kochi University, Rikkyo University, Nagoya University, Chiba Institute of Technology, Meiji University, University of Aizu, AIST

Bild Itokawa: ISAS/JAXA

Bild Ultima Thule: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

Members of the asteroid belt and the Transneptunian region are directly accessible to spacecraft and telescope observations.





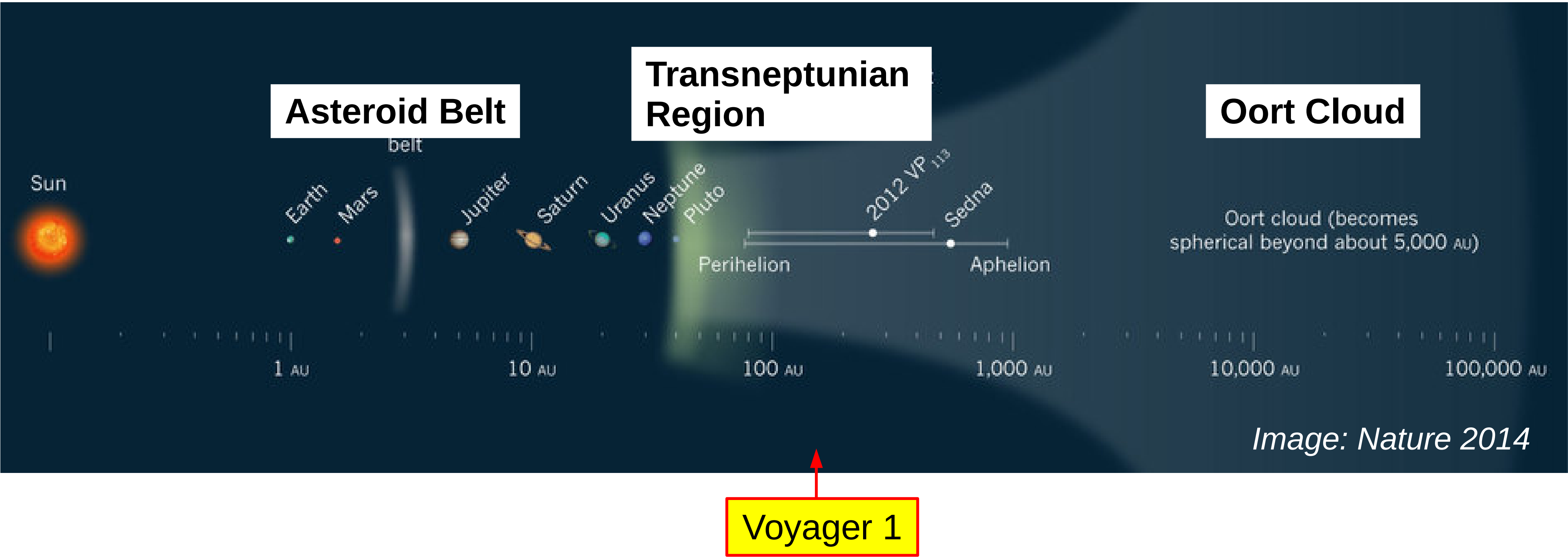


Image Lutetia: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Image Arrokoth: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

Cometary nuclei are deep-frozen remnants from the early solar system arriving from the two outer reservoirs.

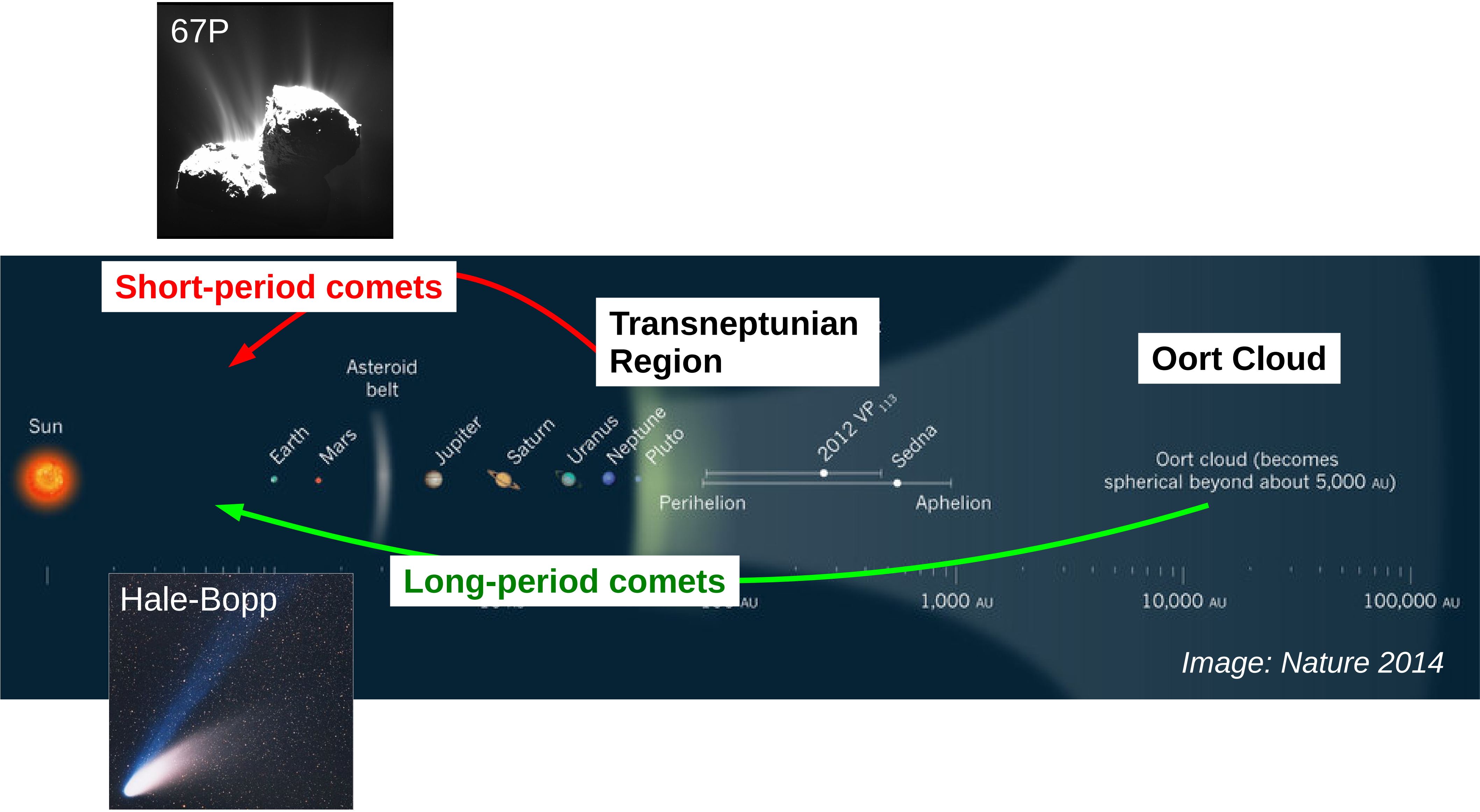
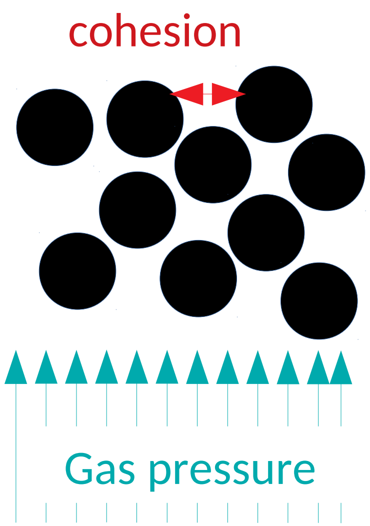


Image 67P: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

Image Hale-Bopp: ESO/E. Slawik

We want to know how volatiles and refractories are intermixed in comets and asteroids, and how dust gets ejected.

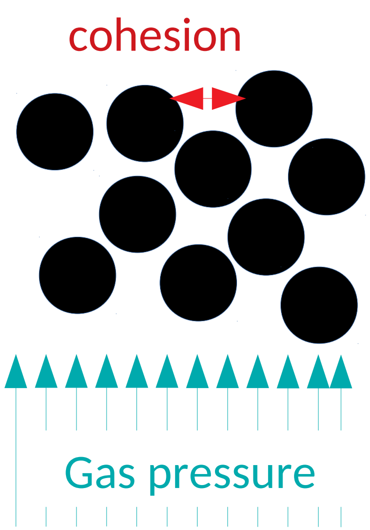


Challenge:

cohesion > gas pressure

Why are comets active at all?

We want to know how volatiles and refractories are intermixed in comets and asteroids, and how dust gets ejected.

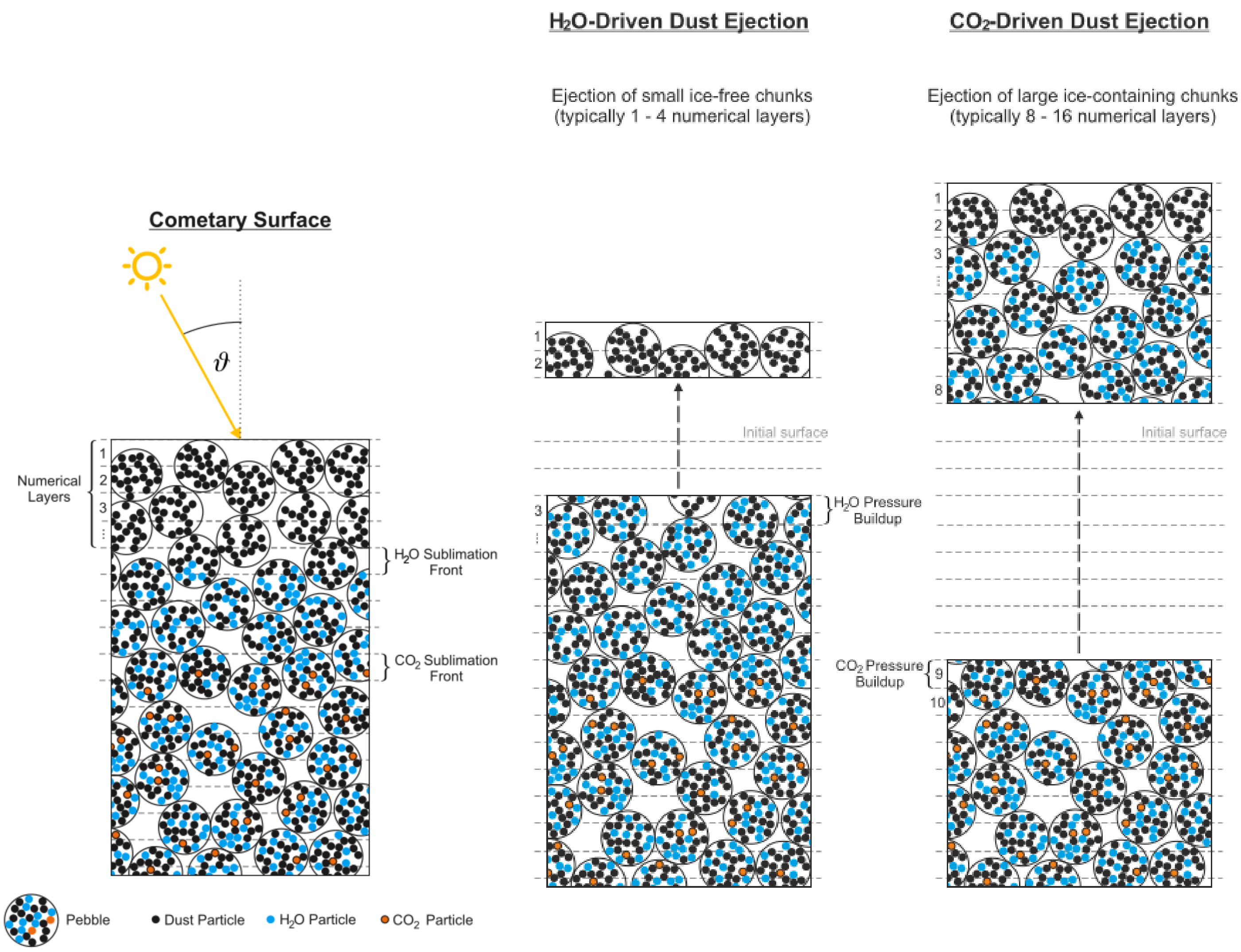


Challenge:

cohesion > gas pressure

Why are comets active at all?

Possible work-around: “Pebbles”

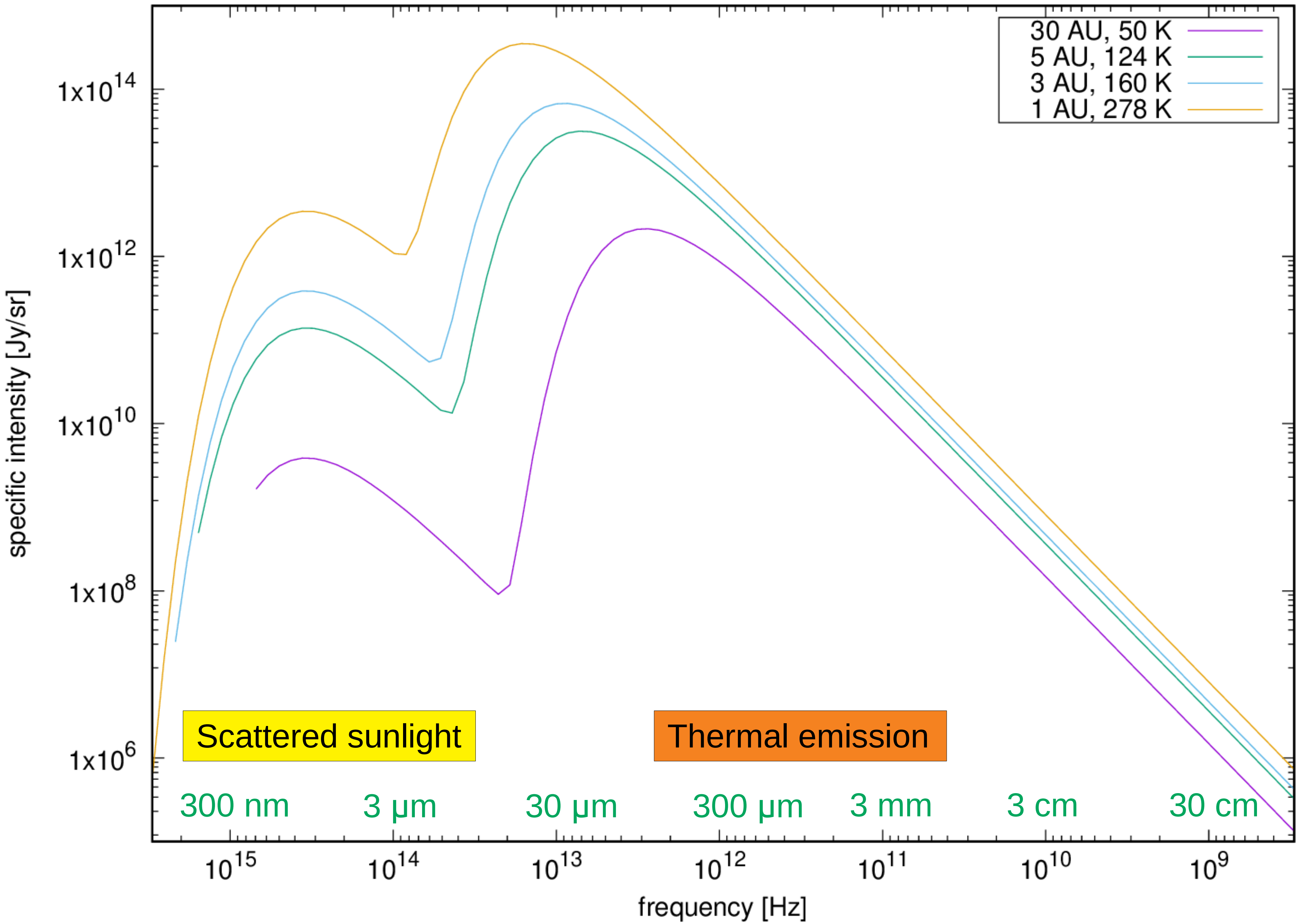


Gundlach et al. (2020)

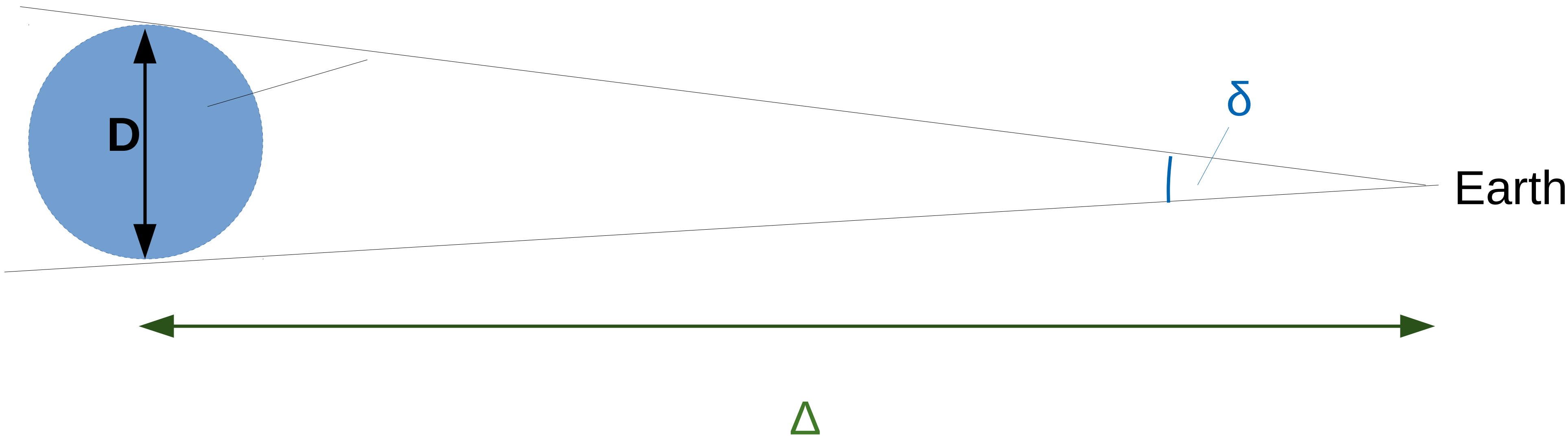
Orders of magnitude:

Temperature, size, flux

The peak thermal emission from small solar system bodies lies in the mid- and far infrared.



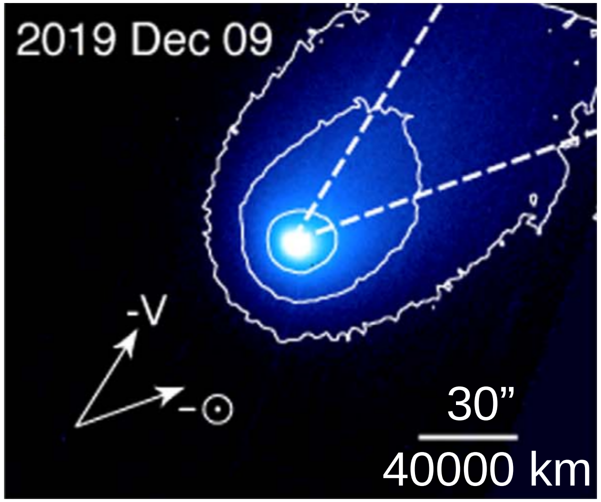
Most asteroids and comet nuclei are not spatially resolved by Earth-based telescopes.



	Diameter	Distance	Angular size	Optical depth	Flux at 1000 GHz (0.3 mm)	Flux at 10 GHz (3cm)
Large main-belt asteroid	100 km	3 AU	0.05”	1	200 mJy	20 μJy
Comet nucleus	2 km	1 AU	0.003”	1	1 mJy	0.1 μJy
Cometary coma	10000 km	1 AU	14”	1e-7	10 mJy	1 μJy

Cometary dust at radio wavelengths: millimetre continuum emission

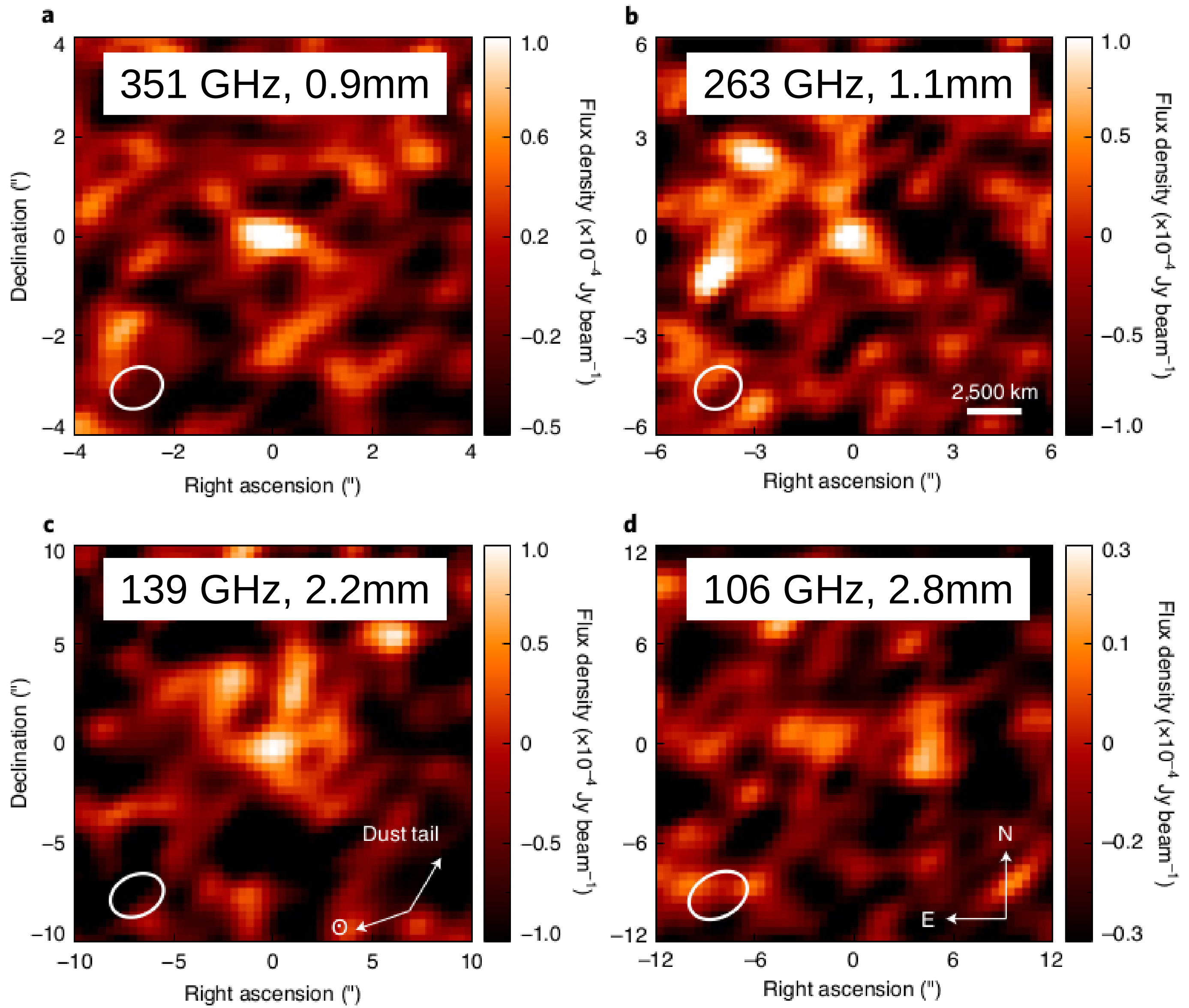
Continuum emission from interstellar comet 2I/Borisov was observed in 4 ALMA bands.



HST image *(Kim et al., 2020)*

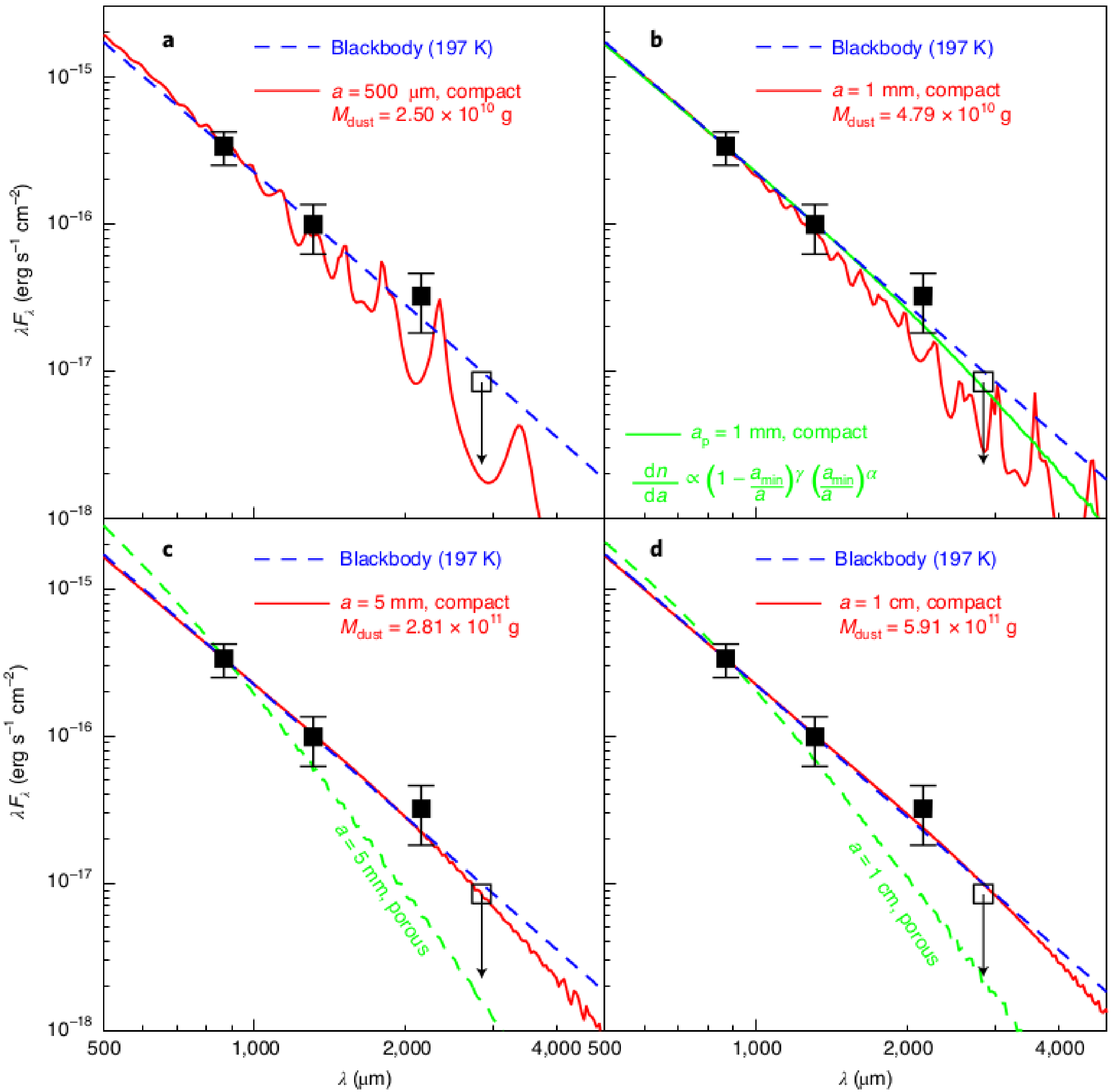
Total cross-section in 2000km aperture:

HST: ~ 30 km^2
ALMA: ~ 15 km^2



ALMA *(Yang et al., 2021)*

The mm-wavelength SED is consistent with large (mm-sized), compact dust particles.



Yang et al. (2021)

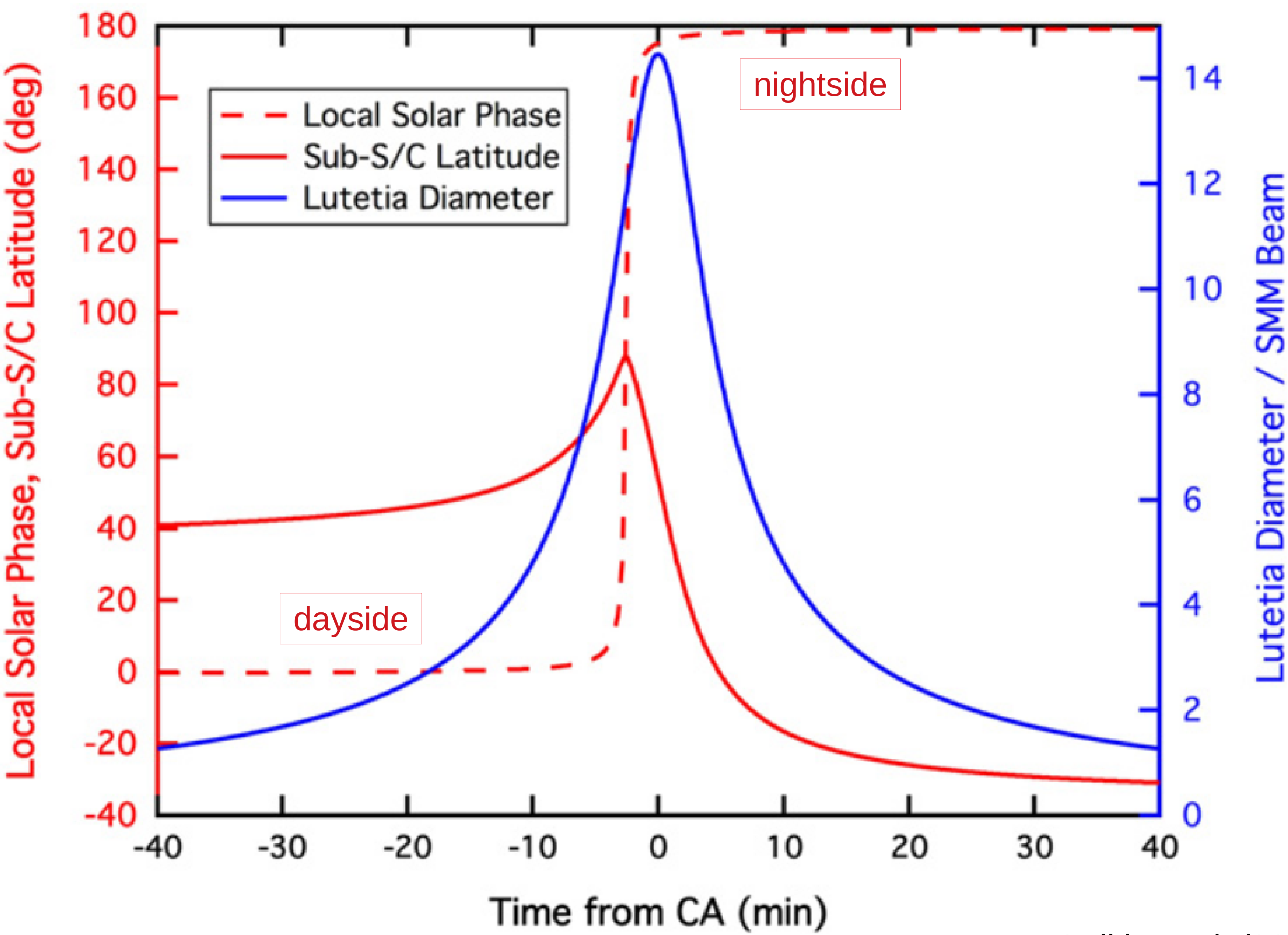
Subsurface properties

The MIRO instrument on Rosetta was equipped with a submm and a mm-band receiver.

Parameter	Millimeter	Submillimeter
Receiver frequency	190 GHz	562 GHz
Receiver temp	$\sim$810 K	$\sim$3600 K (double sideband)
Bandwidth (IF)	550 MHz	1100 MHz
HPBW	23.8 ± 1.5 arcmin	7.5 ± 0.25 arcmin
Sensitivity (continuum)	<1 K (1 s, 550 MHz)	$<$ 1 K (1 s, 1100 MHz)
Spectrometer	–	4096 channels/44 kHz channel width
Sensitivity (spectral)	–	<2 K (120 s, 300 kHz)
Gain stability	0.00004	0.00005
Accuracy	3%	3%

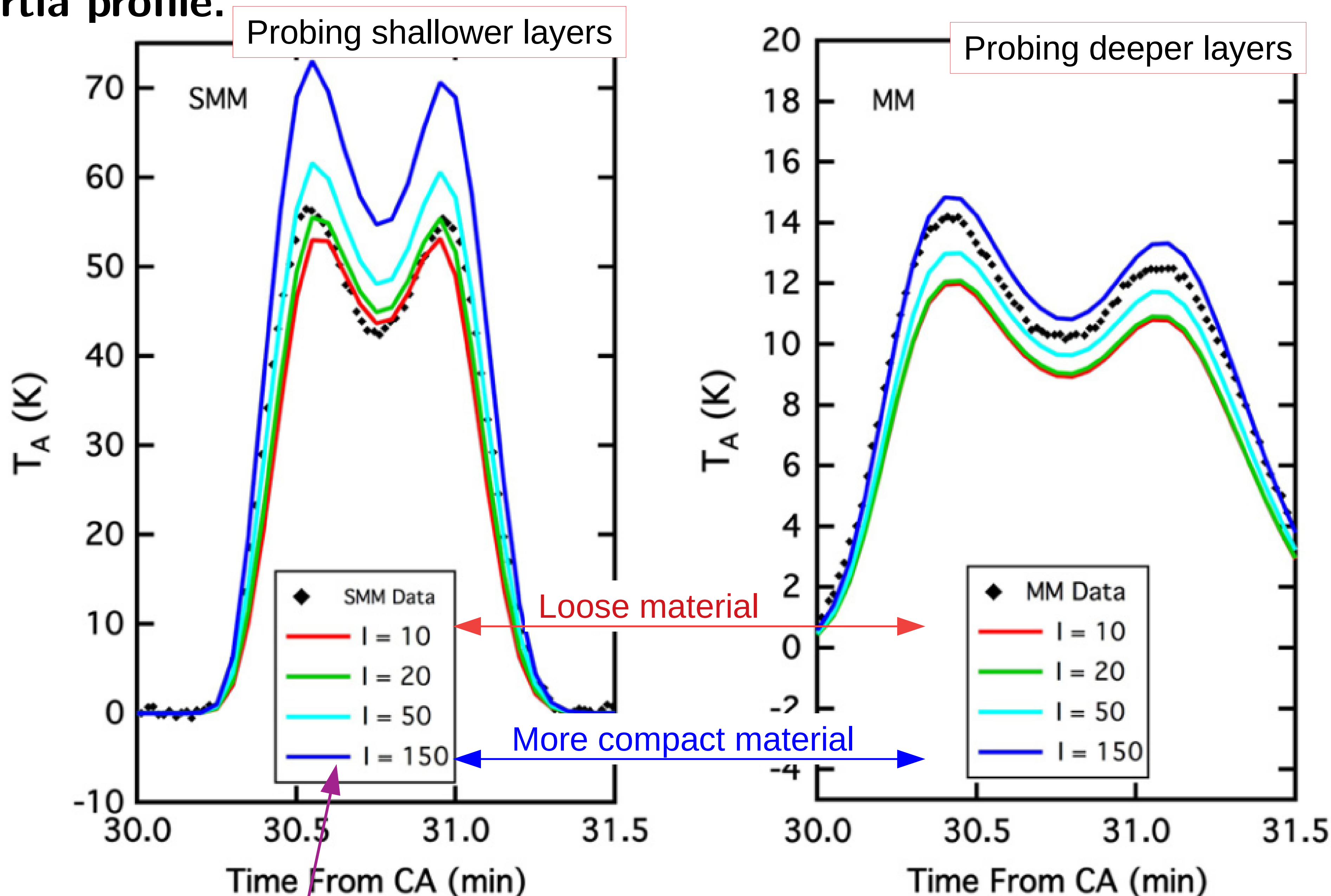
Gulkis et al. (2012)

Asteroid Lutetia was spatially resolved during Rosetta's flyby.



Gulkis et al. (2012)

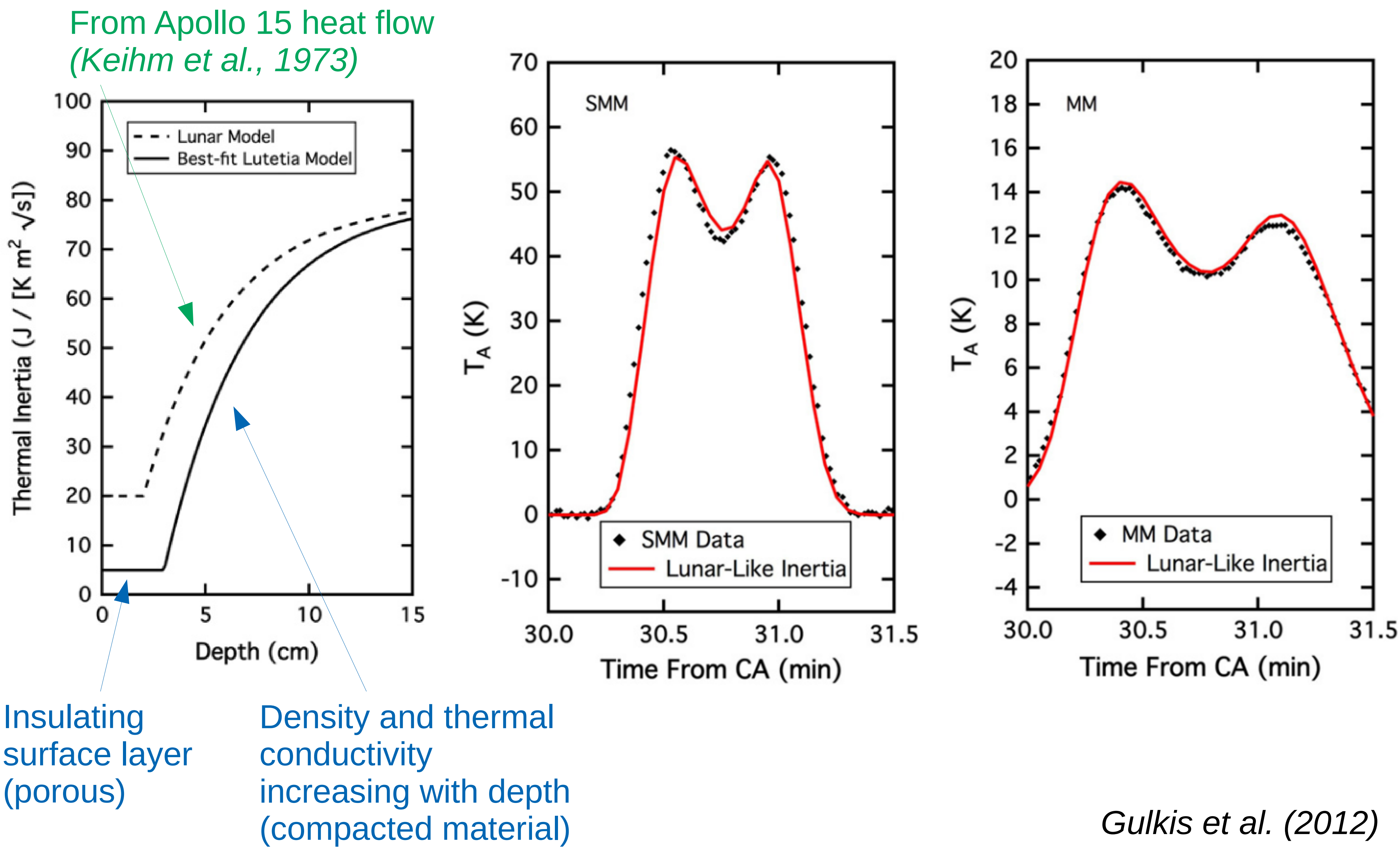
Lutetia's nightside emission is inconsistent with a constant thermal inertia profile.



I: thermal intertia in J/(K m² s^0.5), and I² = density * heat conductivity * heat capacity

Gulkis et al. (2012)

A model with thermal inertia increasing with depth reproduces the asteroid and lunar data well.



Gulkis et al. (2012)

Summary

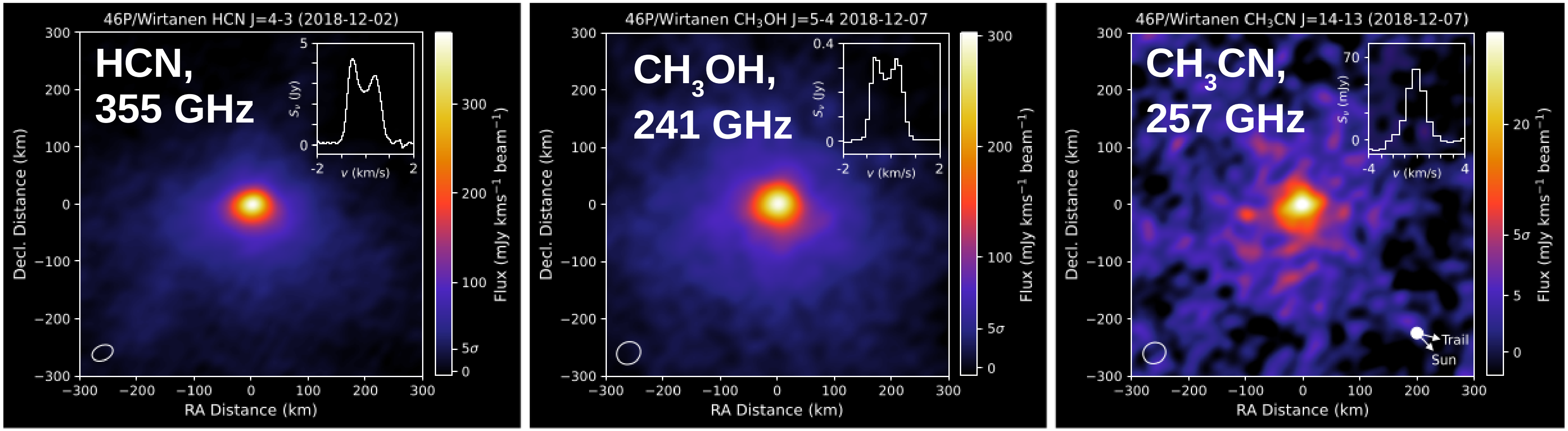
Observations at radio wavelengths can address some of the open questions in small body science:

1. Dust size distribution and porosity
2. Subsurface properties (directly and indirectly from 1.)
3. Gas composition and chemical evolution
4. ….

Spatially resolved maps of the gas coma:

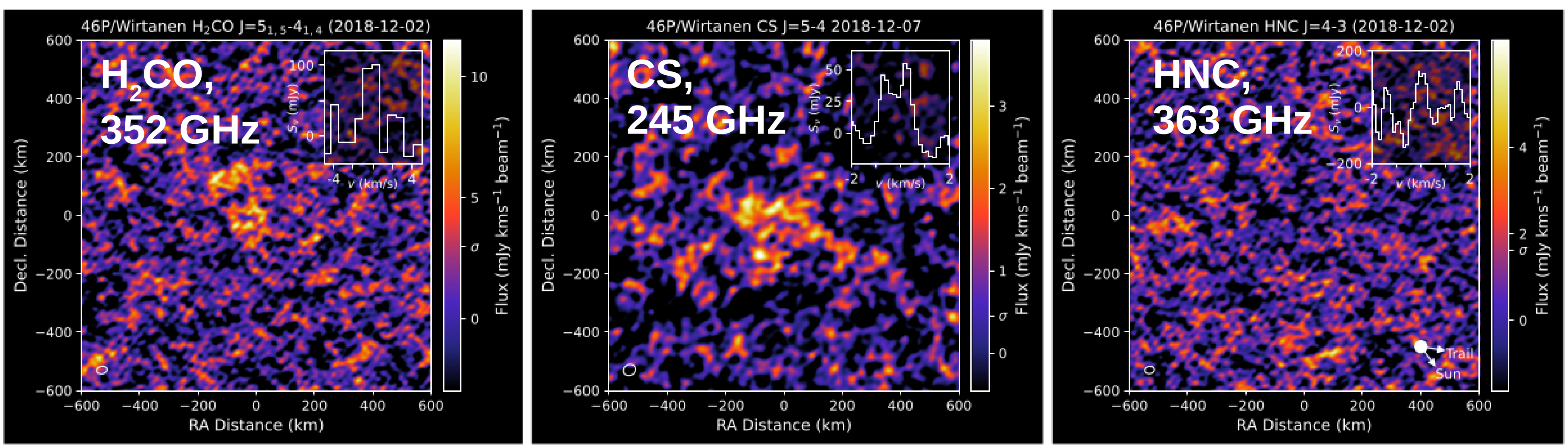
Line emission

The 0.1 AU passage by Earth of comet 46P/Wirtanen facilitated a spatial resolution of 25km.



Source on or very close to the surface

“Distributed“ source in the coma



Cordiner et al. (2023)