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Meteor Trajectories and Origin

Why do we study meteors?



Johan De Keyser

Space Physics Division

METRO meeting

27 October 2015

Belgian Institute for Space Aeronomy

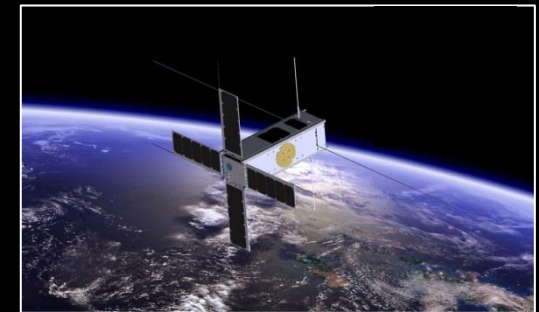


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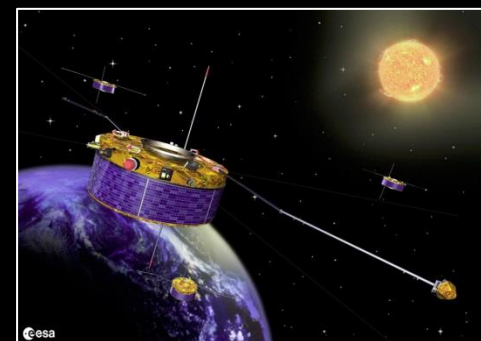
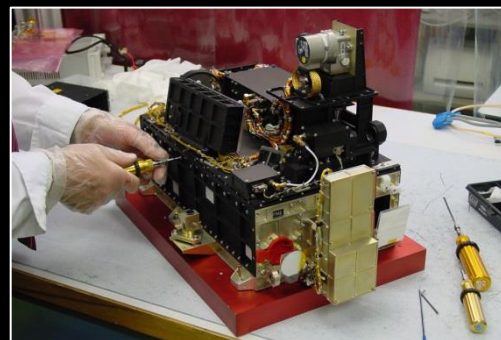
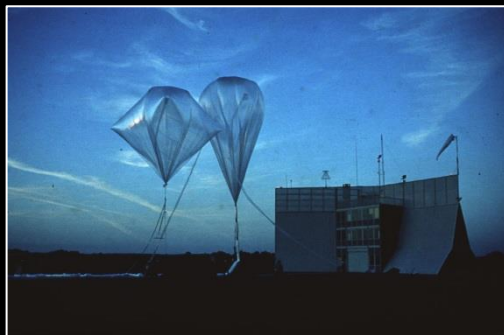


Atmospheres

on Earth
above Earth
from space



around other planets



Our good reasons



Origin of atmospheres :

- Meteoroids are raw materials of solar system formation: how did they contribute to planetary atmospheres?
- A special place to study this is in comets – what is the role of dust in comet atmospheres?

Effect on Earth's atmosphere :

- Meteoroid entry leads to meteors – a plasma physics phenomenon
- Impact on the ionosphere
- Impact on the mesosphere

Effect on the space environment :

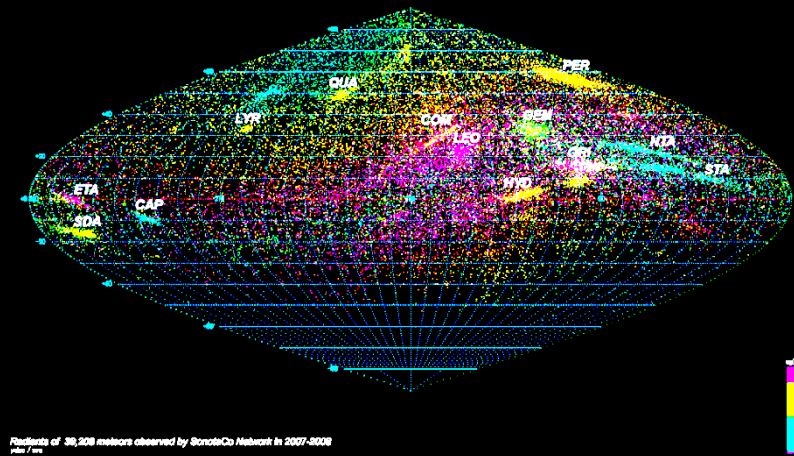
- Meteors form a space weather risk

Meteors and Comets



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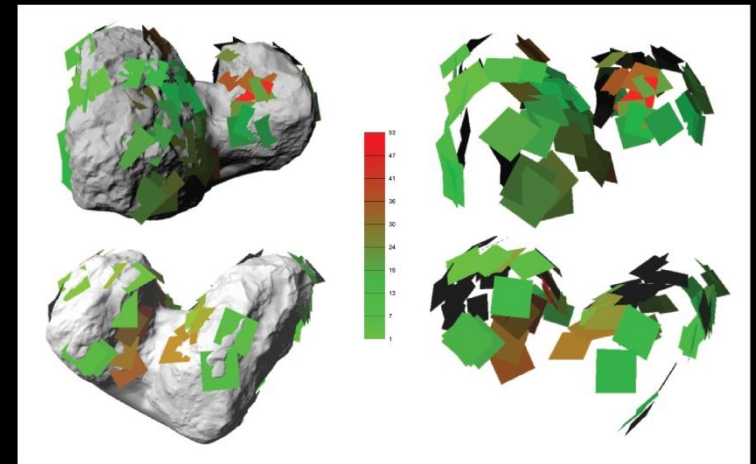
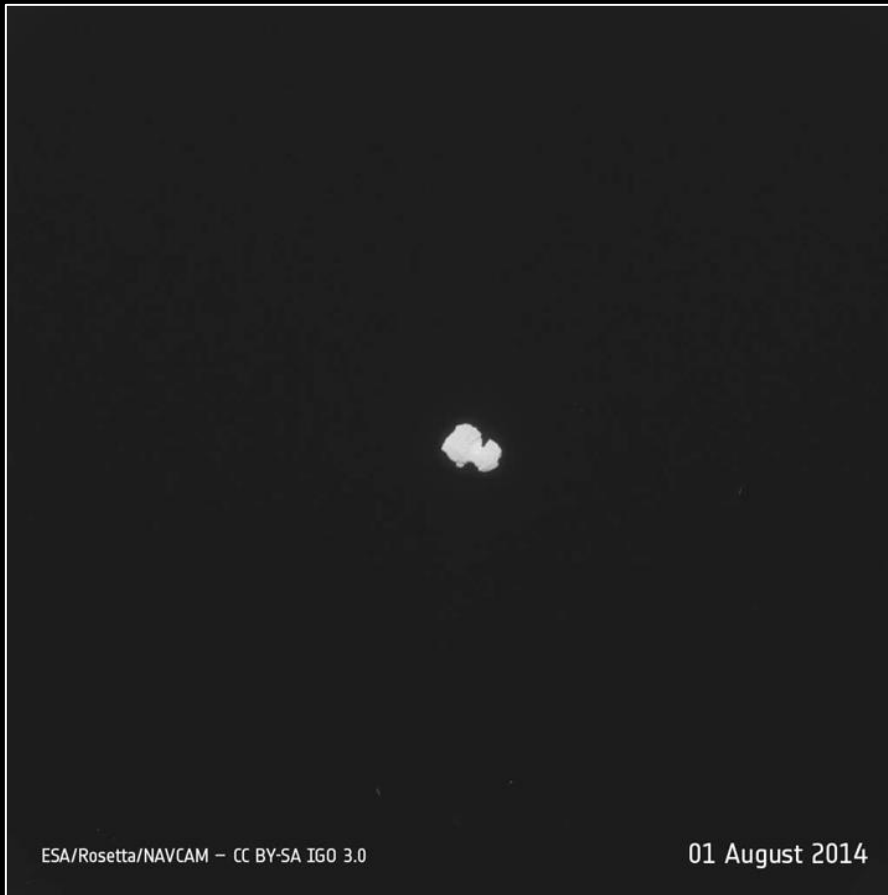
The relation between comets and meteor streams is well established. It is therefore interesting to try to understand meteoritic material by looking at comets and their composition – as we're doing with Rosetta at 67P / Churyumov-Gerasimenko.



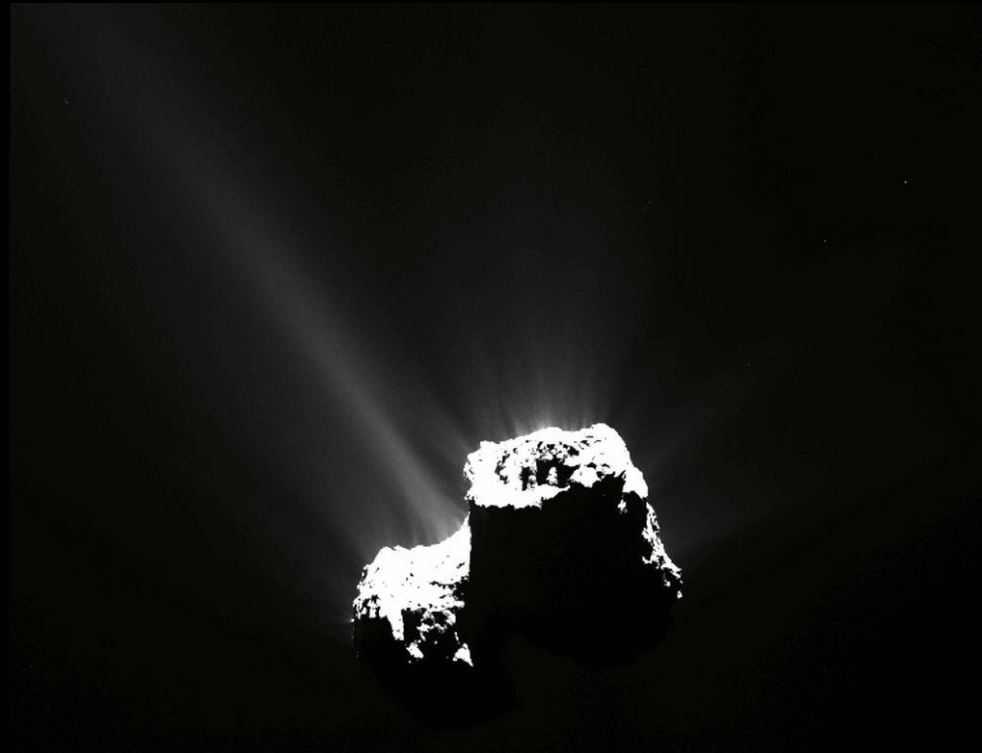
Plazenta of 38,328 meteorites observed by Sonoteco Network in 2007-2008



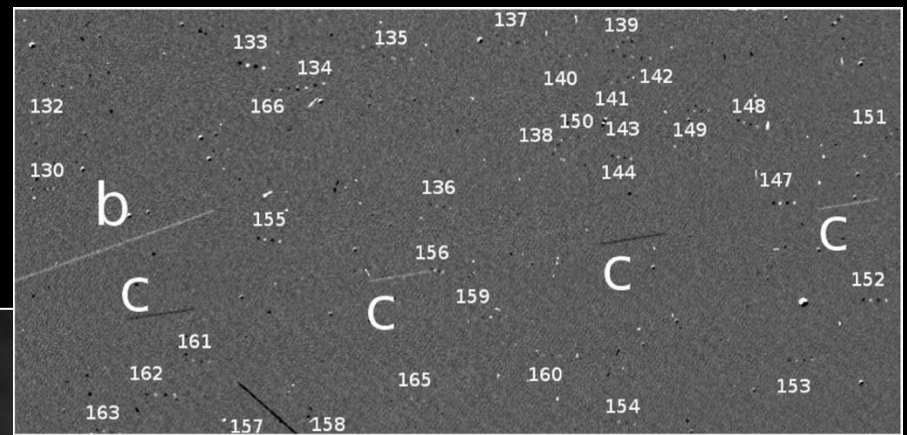
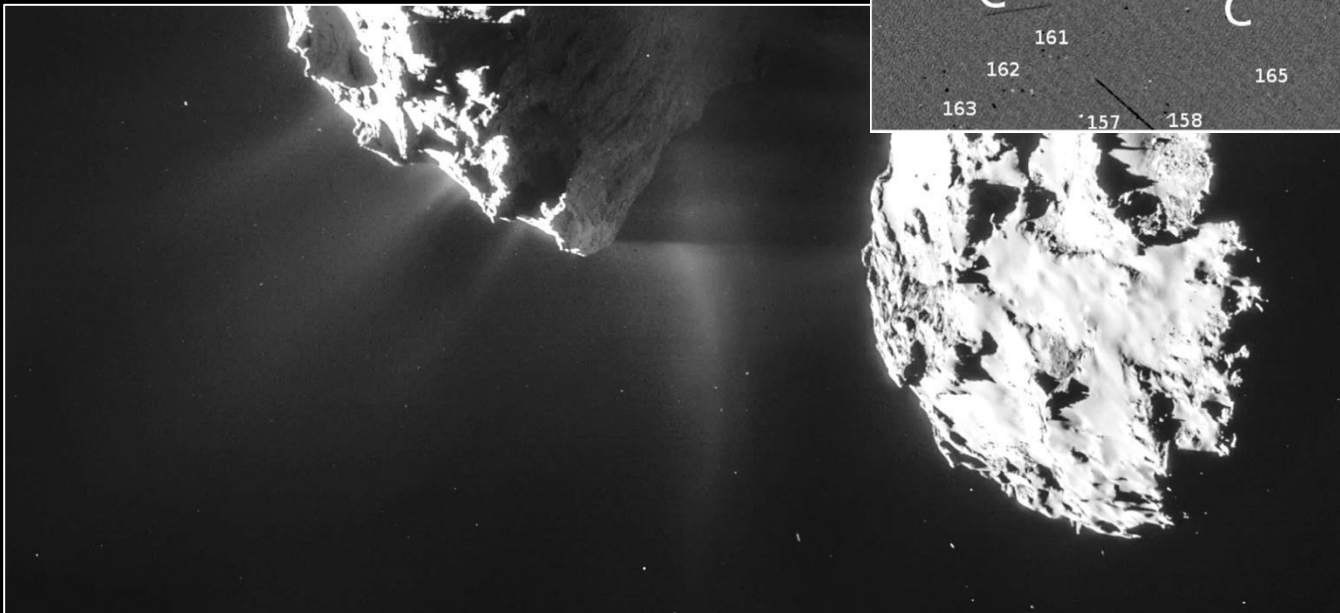
You can view the comet itself as a “meteoroid” – in fact, it appears to be the result of a soft collision of two bodies.

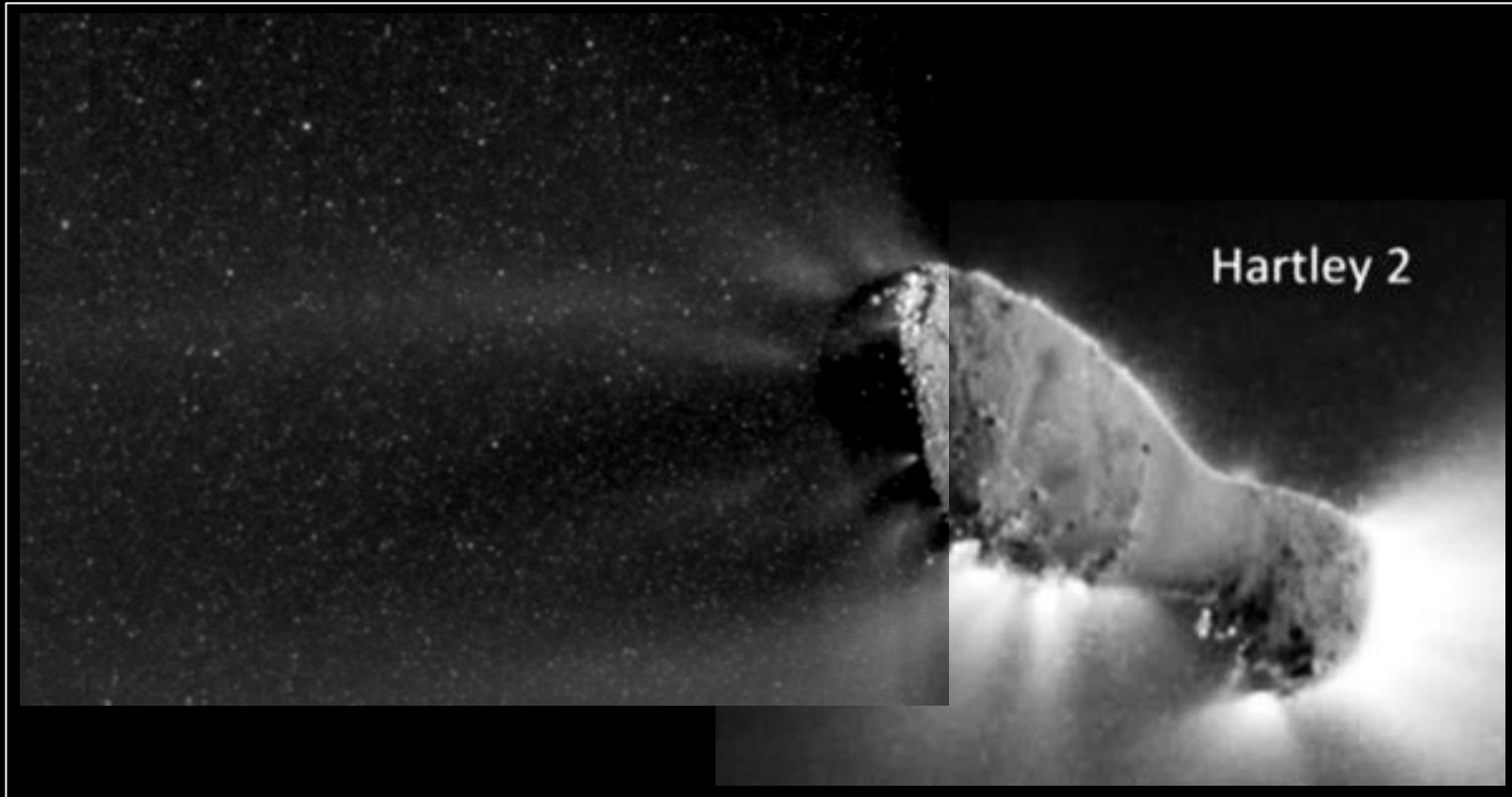


Coma images show dust jets, some with curvature due to gas pressure ...



Rosetta : OSIRIS and NAVCAM images show larger individual dust particles – both escaping ones (1-10 m/s) and gravitationally bound particles (“moons”).





EPOXI found the same at 103P/Hartley.

Attention:

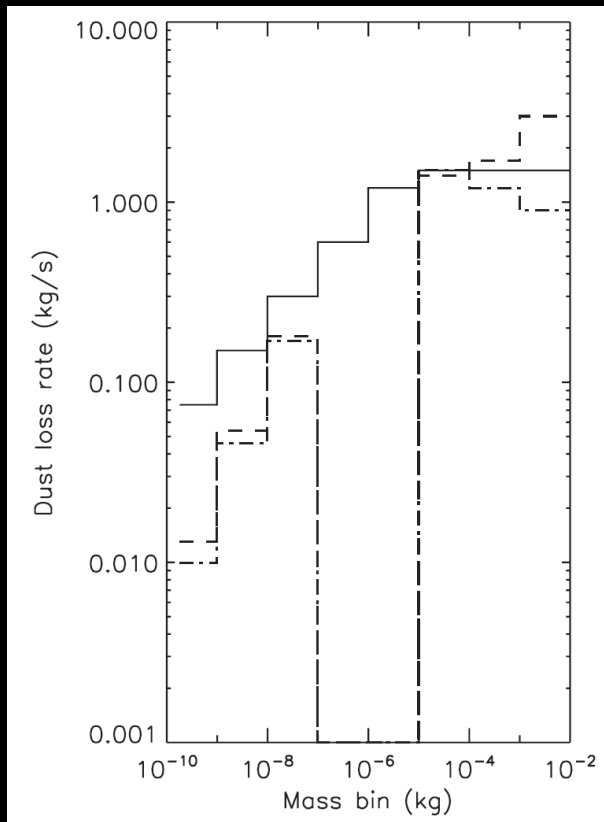
these “dust” particles may for a large part be volatile material – ices.



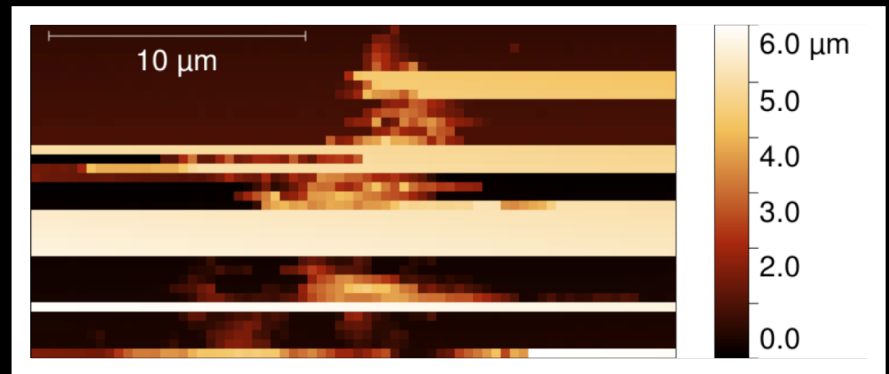
One Degree

Released dust particles are subject to gravity and radiation pressure, so they stay essentially in the orbital plane, producing the “neck line”.

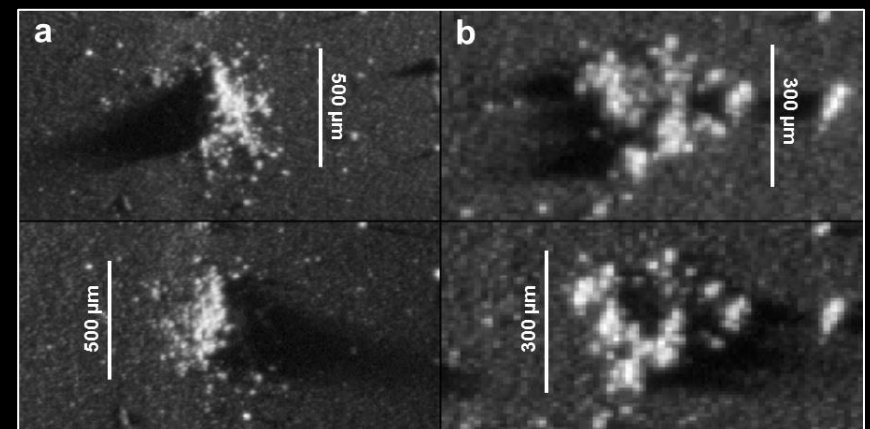
GIADA determines the dust size distribution, most of the mass is in particles of ~ 1 mg.



MIDAS is an Atomic Force Microscope for imaging a grain surface.

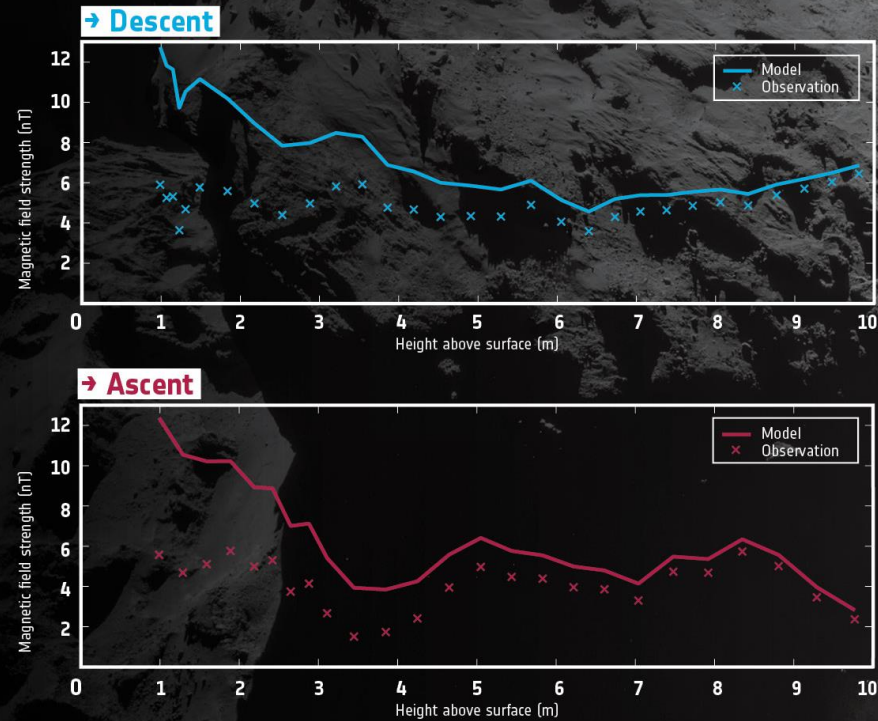


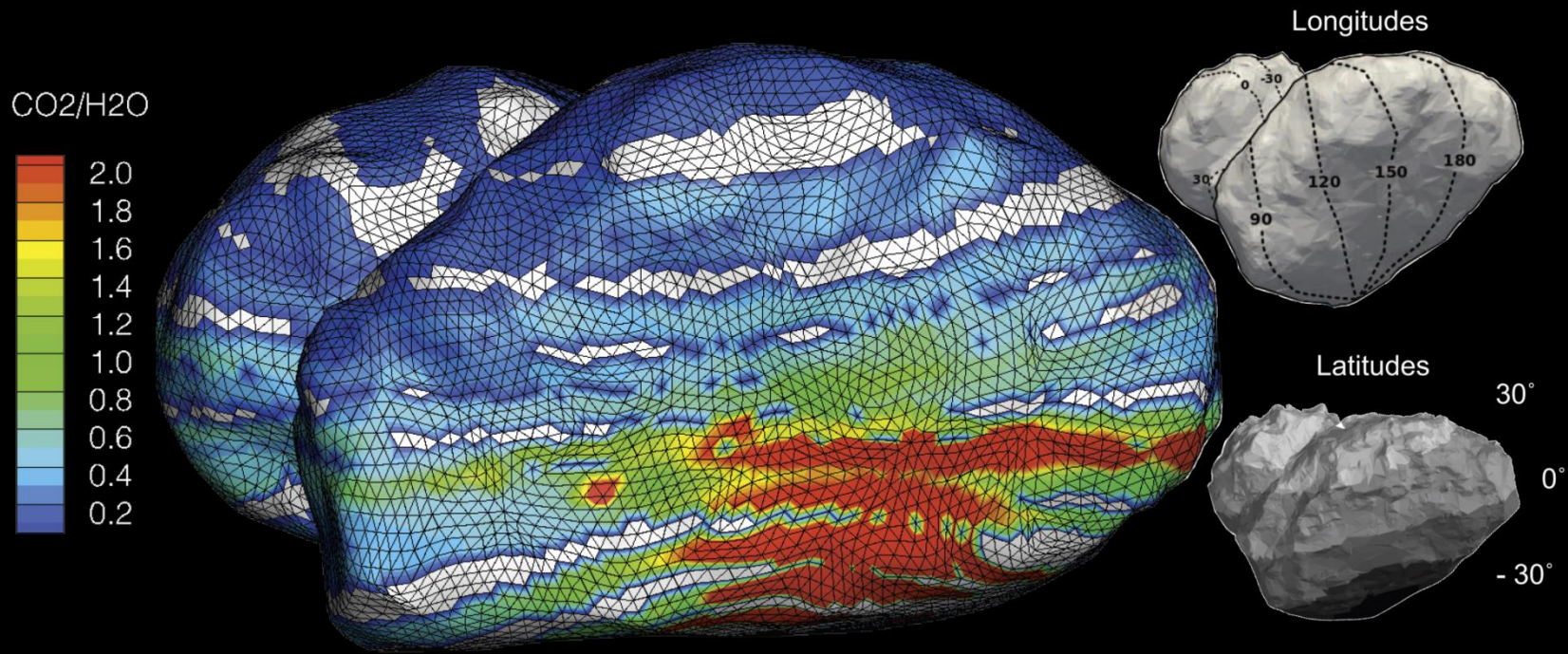
COSIMA images dust grains and performs a chemical analysis.



The nucleus material appears to be non-magnetised.

The measurements are compared with a hypothetical model assuming a slightly magnetised surface. The model also includes the strength of and variation in the interplanetary magnetic field near the comet nucleus.



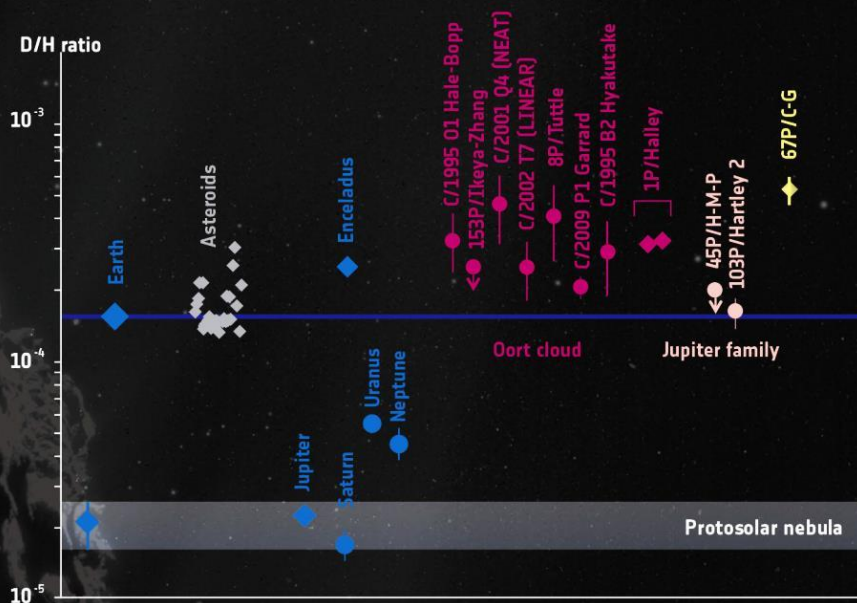
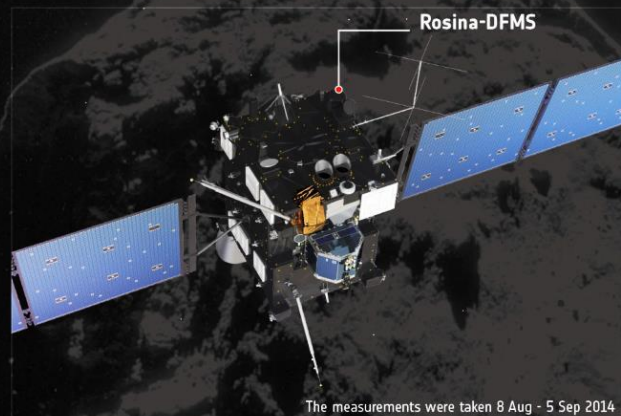


The heterogeneity of the coma indicates that the nucleus is indeed an aggregate. During solar system formation there was

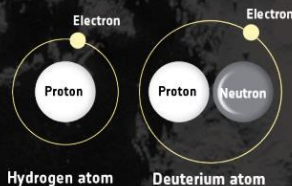
- enough mixing in the protoplanetary disk to bring pieces with different composition together.
- not too much mixing, otherwise composition would be uniform.



Rosetta's ROSINA instrument finds Comet 67P/Churyumov-Gerasimenko's water vapour to have a significantly different composition to Earth's oceans.



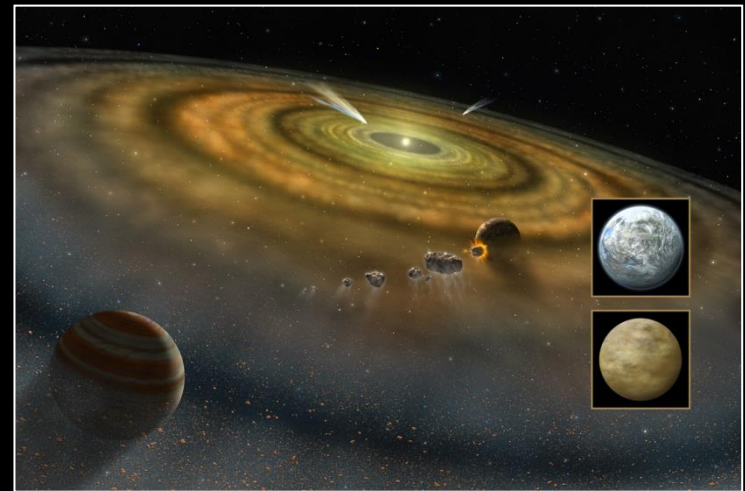
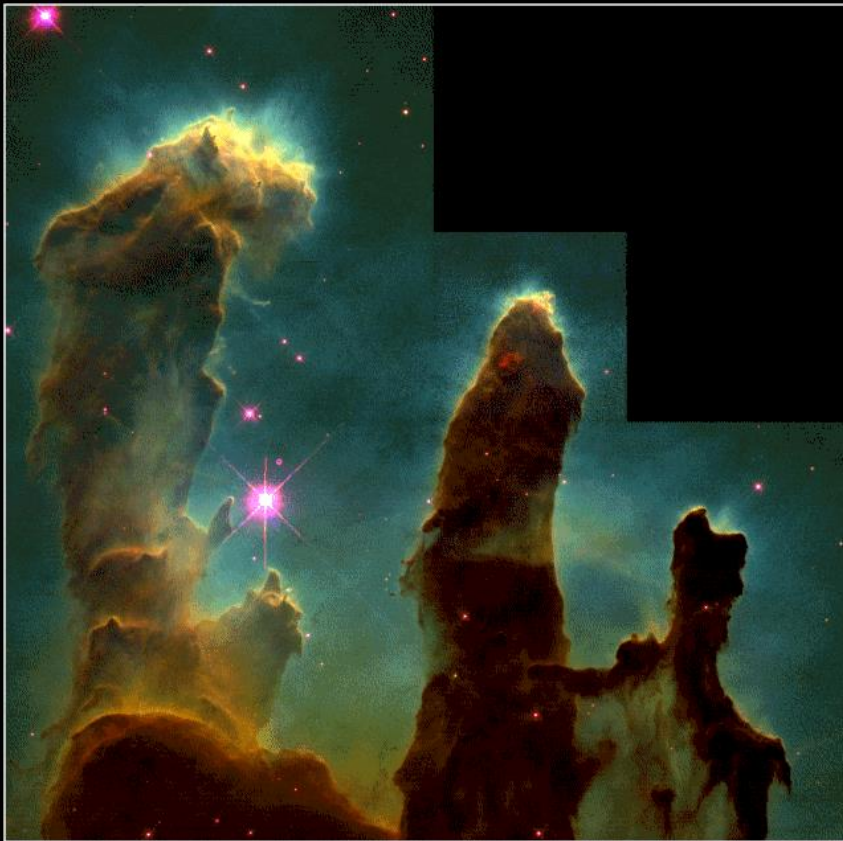
The ratio of deuterium to hydrogen in water is a key diagnostic to determining where in the Solar System an object originated and in what proportion asteroids and comets may have contributed to Earth's oceans.



D/H ratio for different Solar System objects, grouped by colour as planets and moons (blue), chondritic meteorites from the Asteroid Belt (grey), comets originating from the Oort cloud (purple) and Jupiter family comets (pink). Comet 67P/C-G, a Jupiter family comet, is highlighted in yellow. ◆ = data obtained in situ ● = data obtained by astronomical methods



All of this tells us a part of the story of the grains – interstellar grains, processing in the protoplanetary disk, inclusion into comets and planets ...



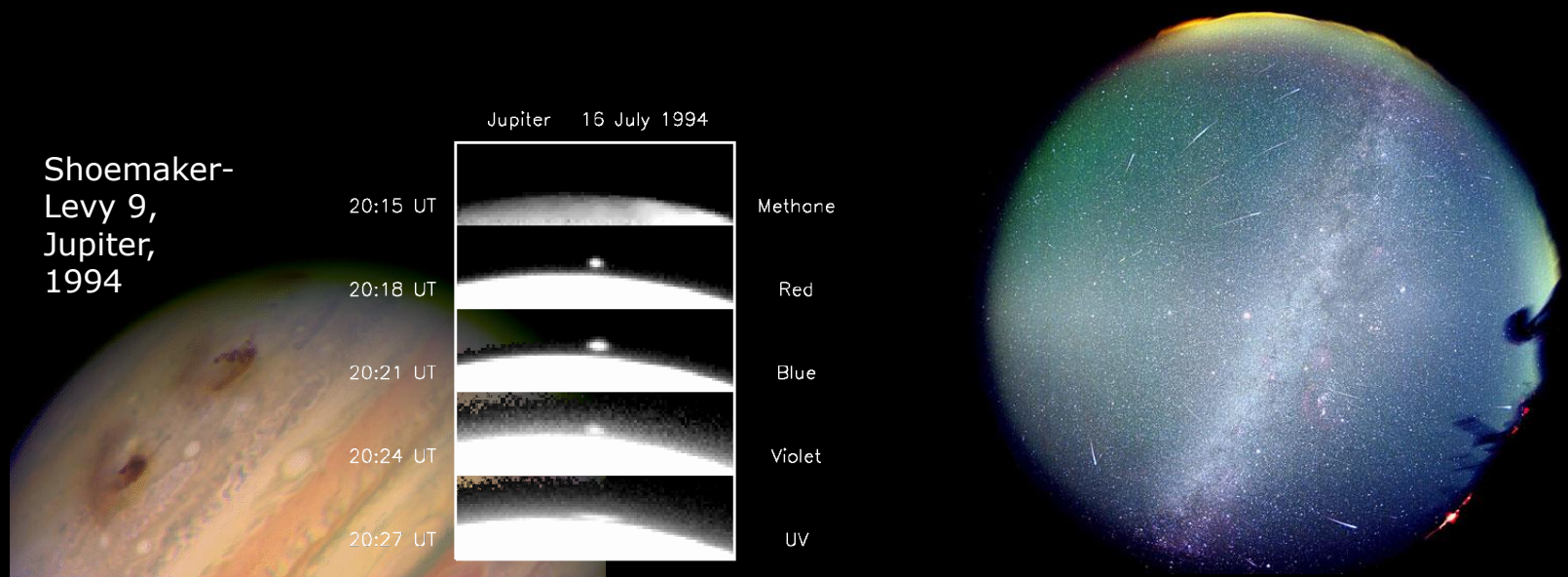
Meteors and the Atmosphere



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A meteor burning up in the atmosphere : this is a plasma physics phenomenon. This is what is observed and modeled in METRO. The other speakers will highlight the state of the project.

Atmospheric consequences



Meteors are a source of metals at 60-100 km altitude. That affects the composition of the upper atmosphere. Fine dust can also serve as condensation nuclei for high-altitude clouds (noctilucent clouds).

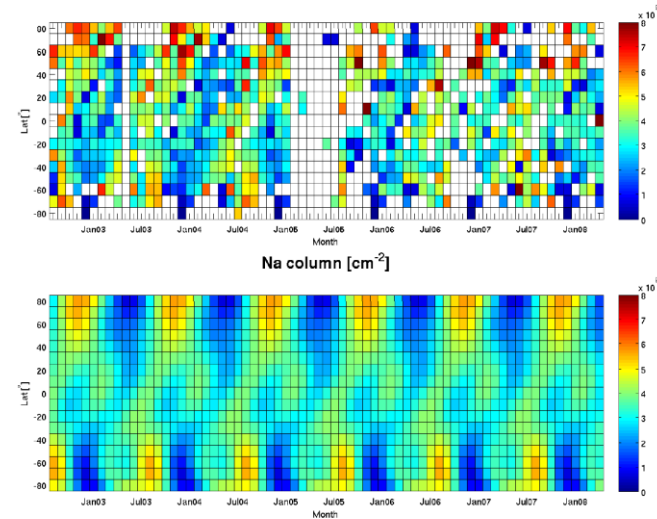


Fig. 9. Top: raw GOMOS Na columns (in units of cm^{-2}) retrieved between August 2002 and June 2008. Bottom: best fit according to Eq. (8). Notice the semi-annual cycle at low latitudes and the annual cycle in the polar regions.

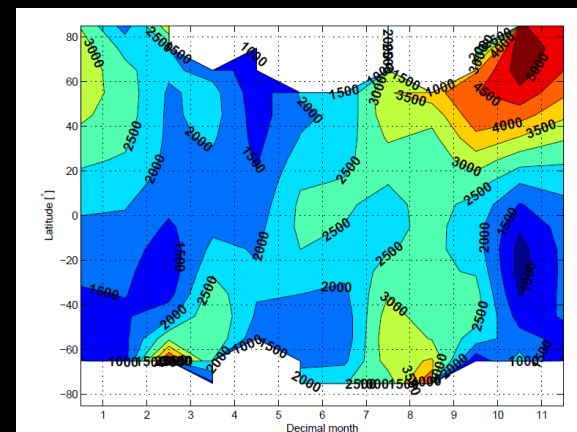


Fig. 13. Peak concentration of mesospheric sodium [$\text{atoms}/\text{cm}^{-3}$] as a function of time and latitude.

Meteors also constitute a source of ionisation in the ionosphere. They are believed to play a role in the formation of the “sporadic E layer” in the ionosphere which plays a role for long distance radio communication.

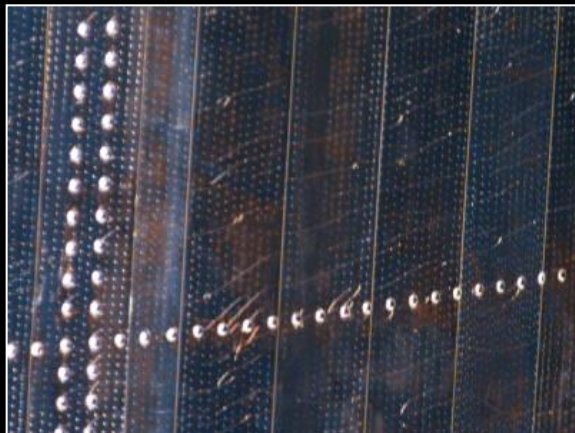


Meteors and Space Weather



The flux of meteors is a space weather risk. The impact of micro-meteorites with high speed causes a degradation of the external surfaces of spacecraft, in particular on solar panels and windows.

Precautions: re-orient the spacecraft along the influx direction of meteor streams (e.g. the HST), offer protection through multiple layer walls, multi-layer window panes ...



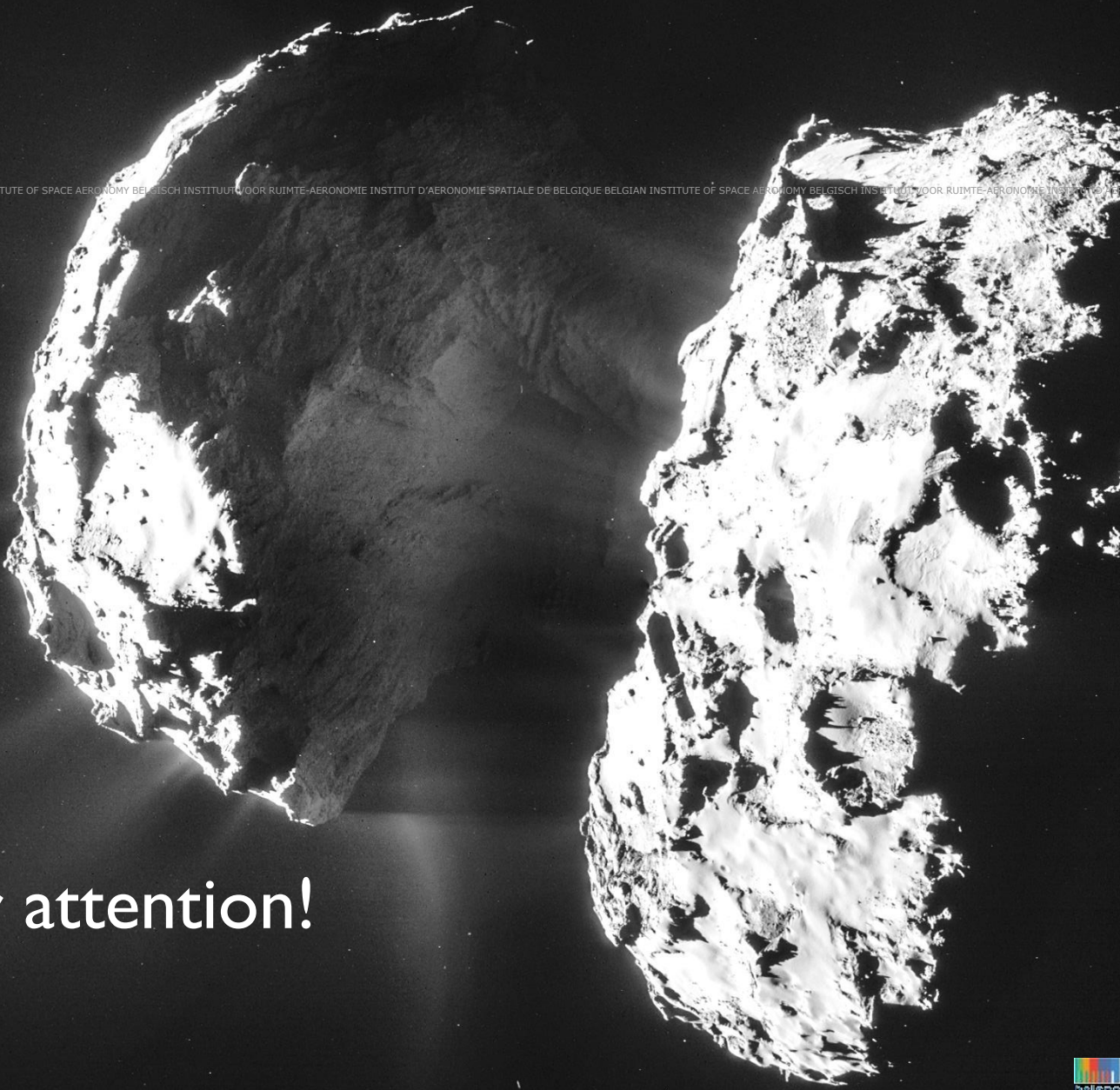


Dust flux models are available in SPENVIS, a web-based environment that allows one to make space weather predictions.

The screenshot displays the SPENVIS web-based environment. The main interface features a central 3D visualization of Earth with various radiation models overlaid, including a rainbow-colored ring representing a radiation belt and a grid of lines representing particle trajectories. A navigation menu on the left includes links for Home, Access, Forums, Bug Tracker, Release notes, My account, Export results, and Share project. A central plot shows a graph of 'Spectral shifted ion spectra (ICM-SEP)' with 'Energy (MeV/s)' on the x-axis and 'Flux (ions/cm²/s)' on the y-axis. A right-hand panel titled 'SPENVIS Project: SPENVIS Model packages Planet: Earth' lists various radiation sources and effects, such as 'Trapped proton and electron fluxes', 'Trapped proton flux anisotropy', 'Long-term solar particle fluxes', 'Short-term solar particle fluxes (only for SEU)', 'Galactic cosmic ray fluxes', 'Solar cell radiation damage', 'Damage equivalent fluences for solar cells', 'NIEL based damage equivalent fluences for solar cells (MC-SCREAM)', 'Long-term radiation doses', 'Ionizing dose for simple geometries', 'Non-ionizing energy loss for simple geometries', 'Single event effects', 'LET spectra and SEU rates', 'Spacecraft charging', 'Atmosphere and ionosphere', 'Magnetospheric field', 'Meteoroids and debris', 'Miscellaneous', and 'Grant Tools'. A bottom-left window shows a '2.4 Dynamics of the' section with a diagram of a radiation belt. A bottom-center window displays 'Single Event Upset Rates' for an IBM 16M device, including a table of mission total and mission segment 1 SEU rates. A bottom-right window shows a world map with a rainbow-colored path representing a particle trajectory.

Segment averaged and total SEU rates										
Device	Effect	Mission total				Mission segment 1				
		(hr ⁻¹)	(hr ⁻¹ s ⁻¹)	(hr ⁻¹ day ⁻¹)	(hr ⁻¹)	(hr ⁻¹ s ⁻¹)	(hr ⁻¹ day ⁻¹)	(hr ⁻¹)		
IBM 16M	Direct ionization	1.2837E-04	4.0707E-12	3.5171E-07	1.2837E-04	4.0707E-12	3.5171E-07	1.2837E-04	4.0707E-12	3.5171E-07
	Proton induced ionization	0.0486E-05	1.9180E-12	1.6972E-07	6.0486E-05	1.9180E-12	1.6972E-07	6.0486E-05	1.9180E-12	1.6972E-07
	Total	1.8888E-04	5.9887E-12	5.1742E-07	1.8888E-04	5.9887E-12	5.1742E-07	1.8888E-04	5.9887E-12	5.1742E-07

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Thanks for your attention!

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