Belgian Institute for Space Aeronomy (BIRA-IASB)
Institut d'Aéronomie Spatiale de Belgique (IASB)
Belgisch Instituut voor Ruimte-Aeronomie (BIRA)

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

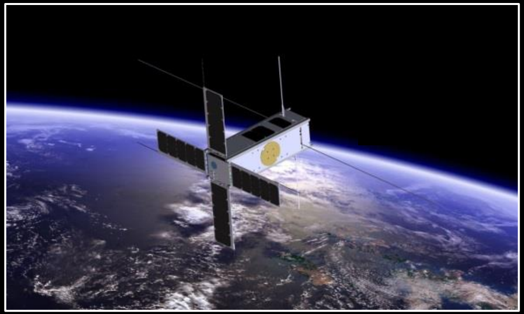
Atmospheres

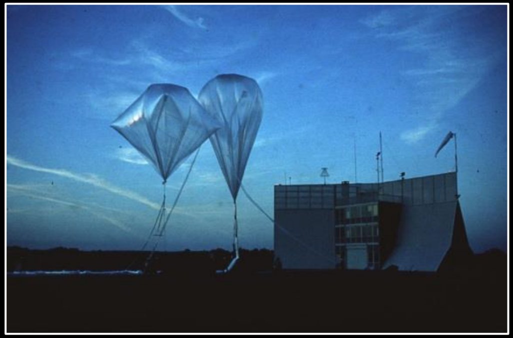
on Earth

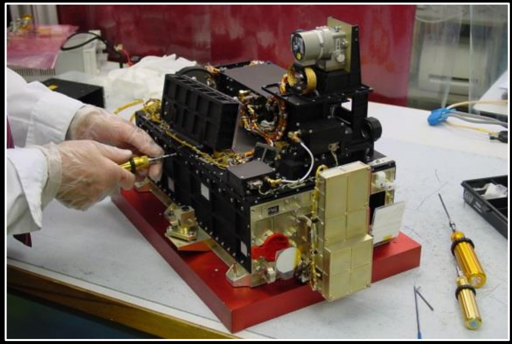
above Earth

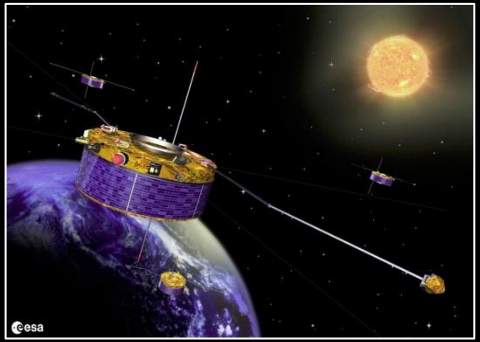
from space

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 :

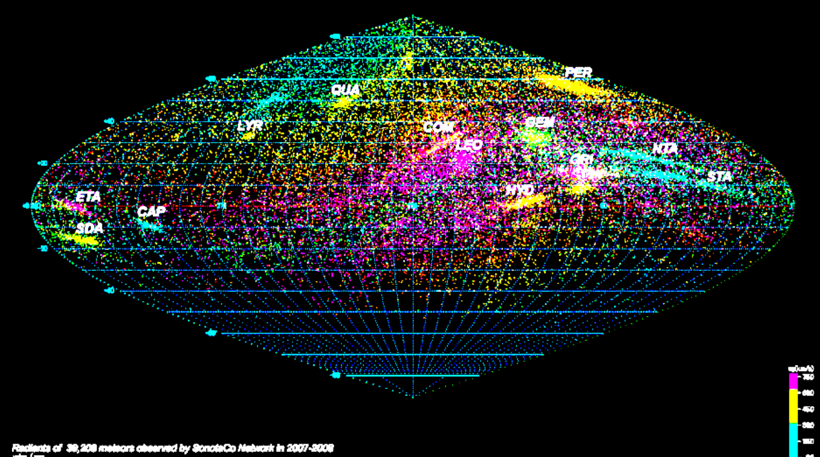
- Meteoroid entry leads to meteors – a plasma physics phenomenon
- Impact on the ionosphere
- Impact on the mesosphere

Effect on the space environment :

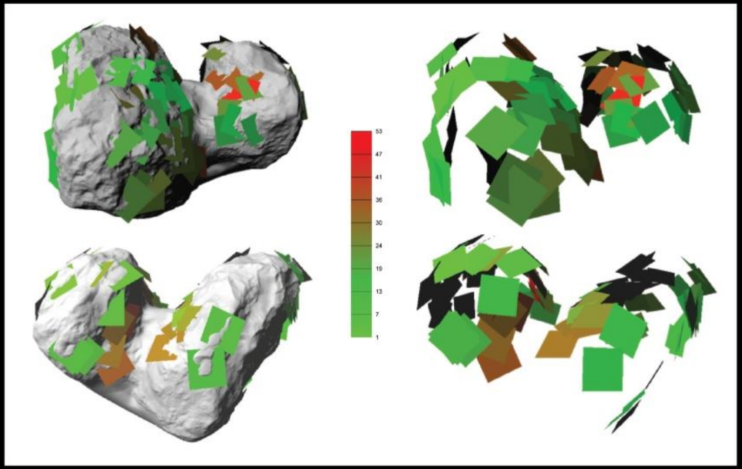
- Meteors form a space weather risk

Meteors and Comets

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.

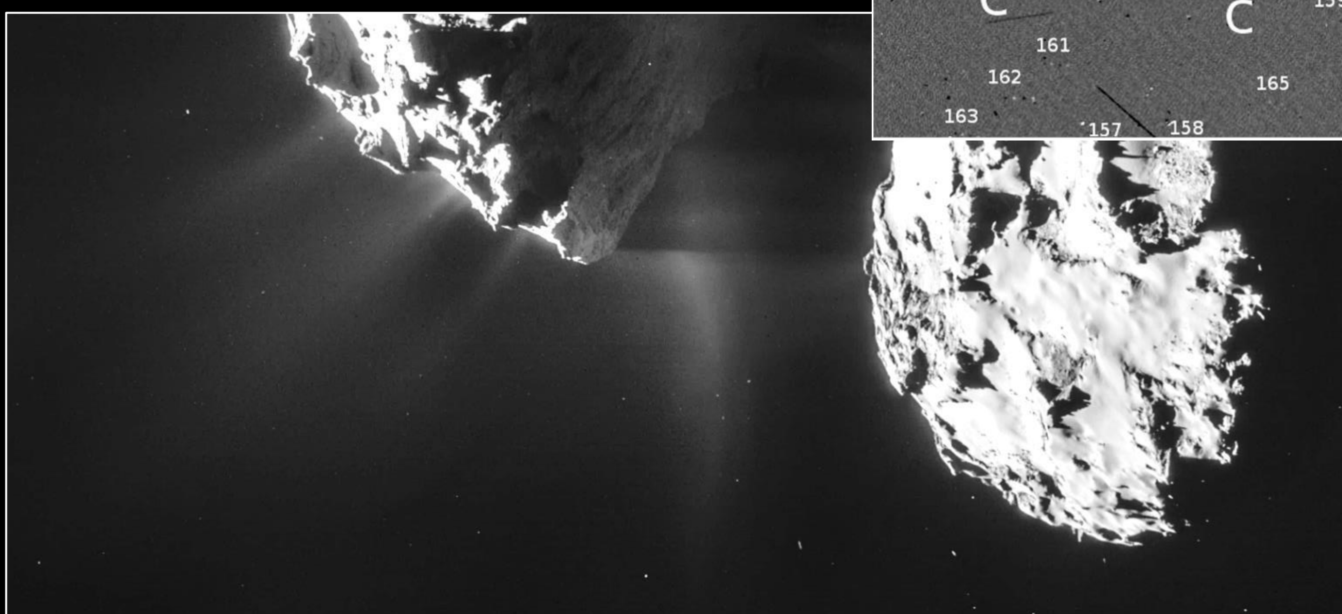


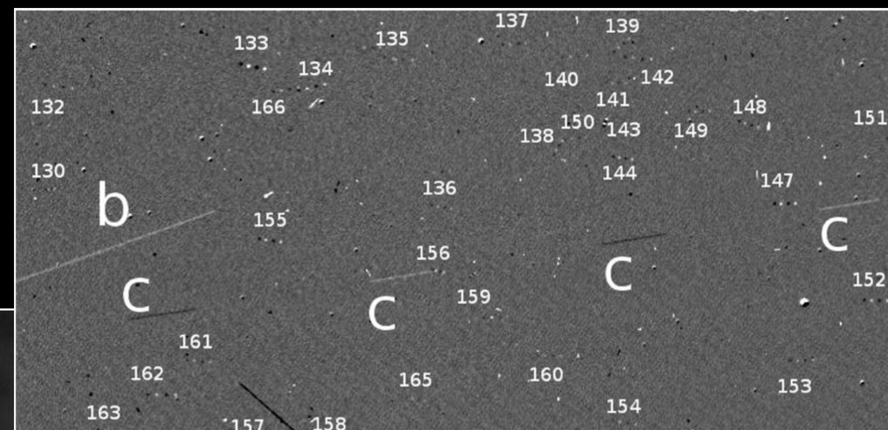
You can view the comet itself as a "meteoroid" – in fact, it appears to be the result of a soft collision of two bodies.

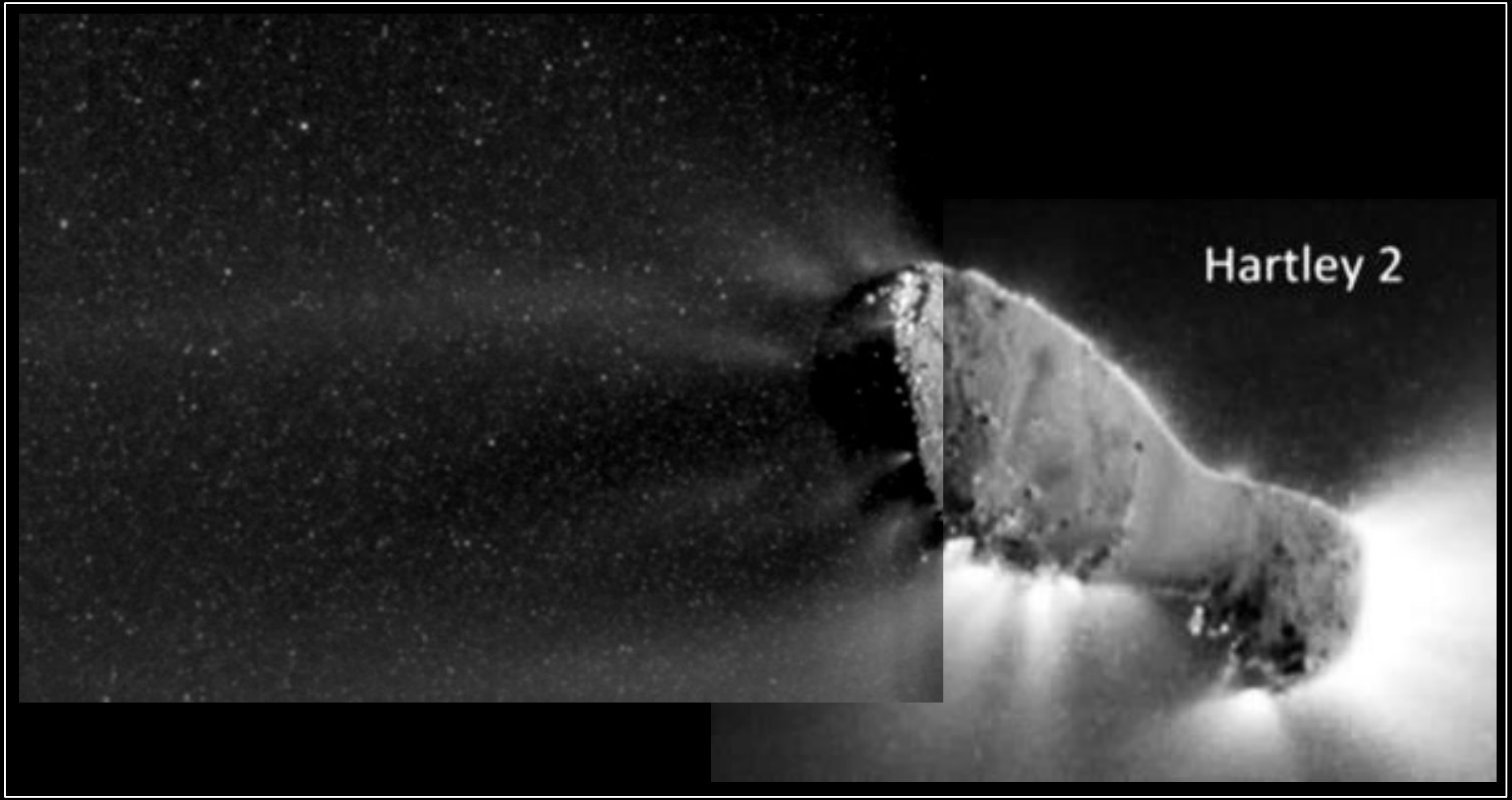


Coma images show dust jets, some with curvature due to gas pressure …

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







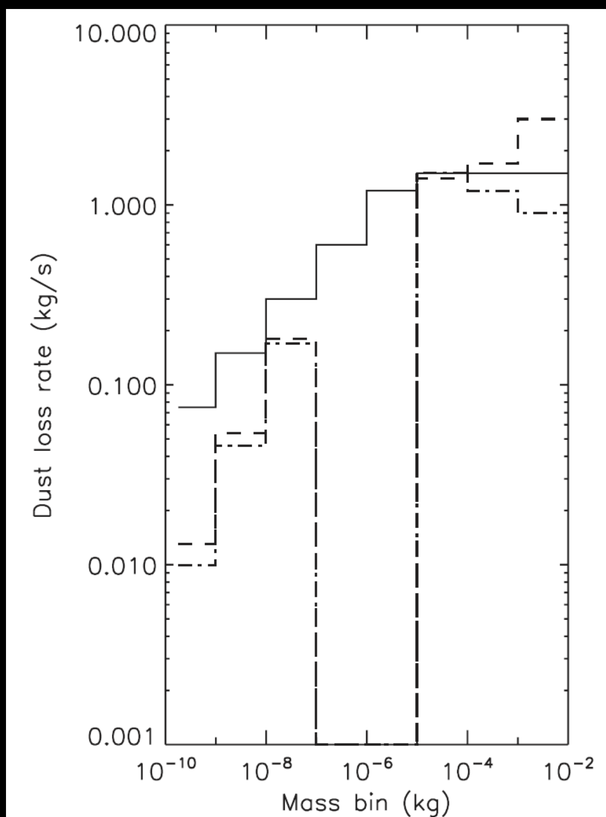
EPOXI found the same at 103P/Hartley.

Attention:

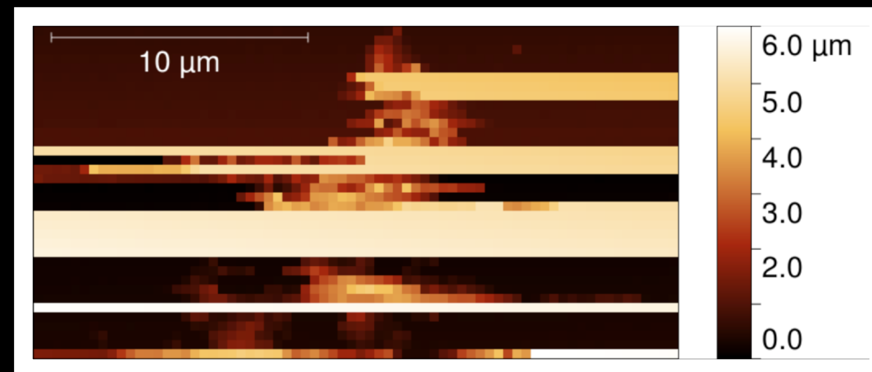
these "dust" particles may for a large part be volatile material – ices.

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

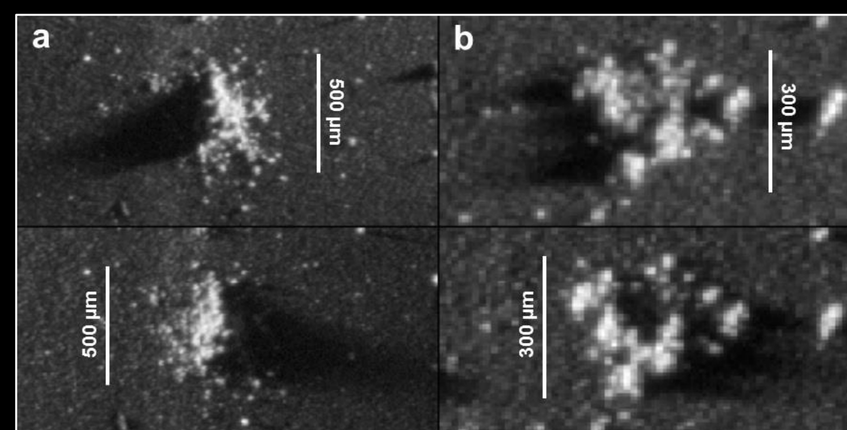
GIADA determines the dust size distribution, most of the mass is in particles of ~1 mg.



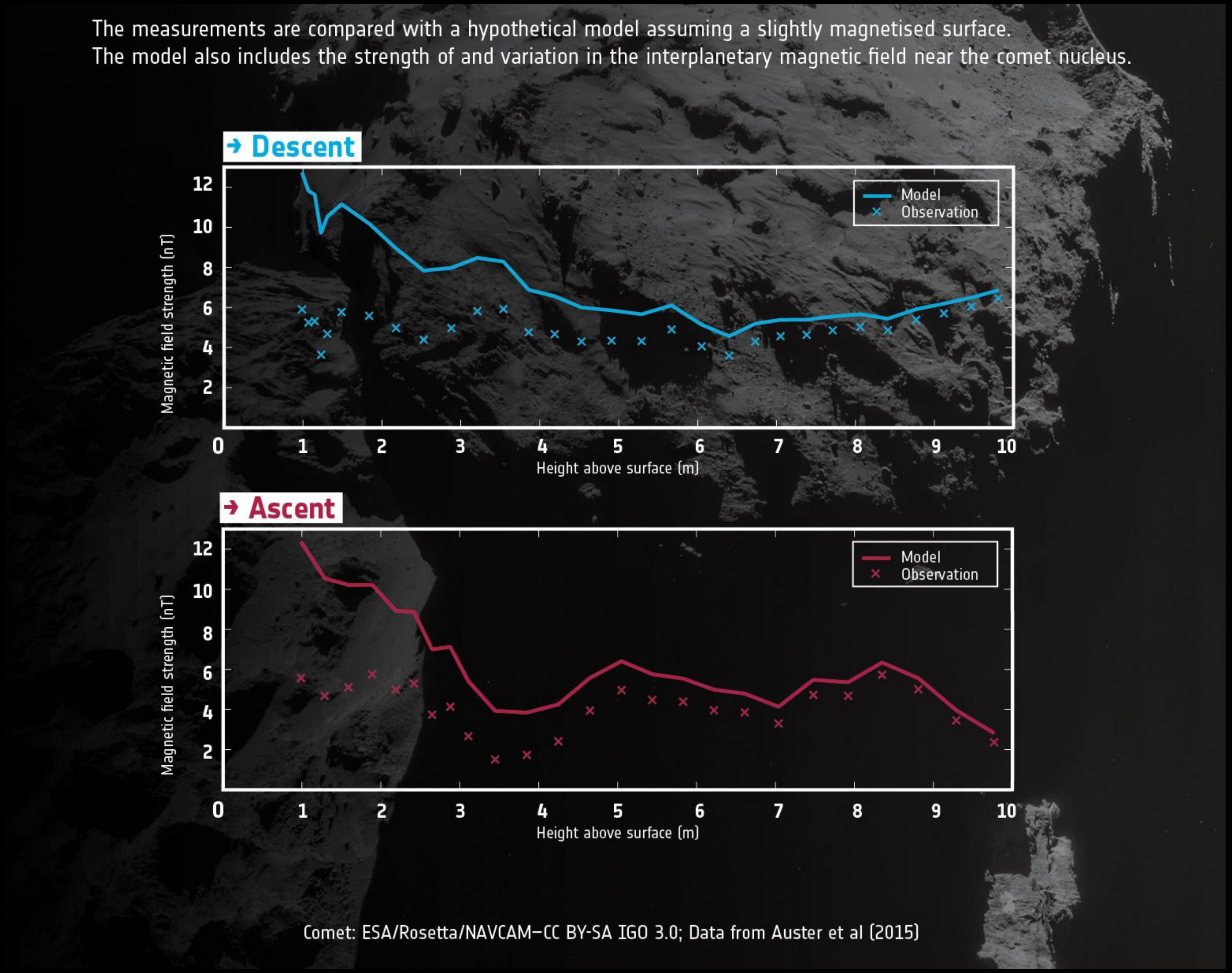
MIDAS is an Atomic Force Microscope for imaging a grain surface.

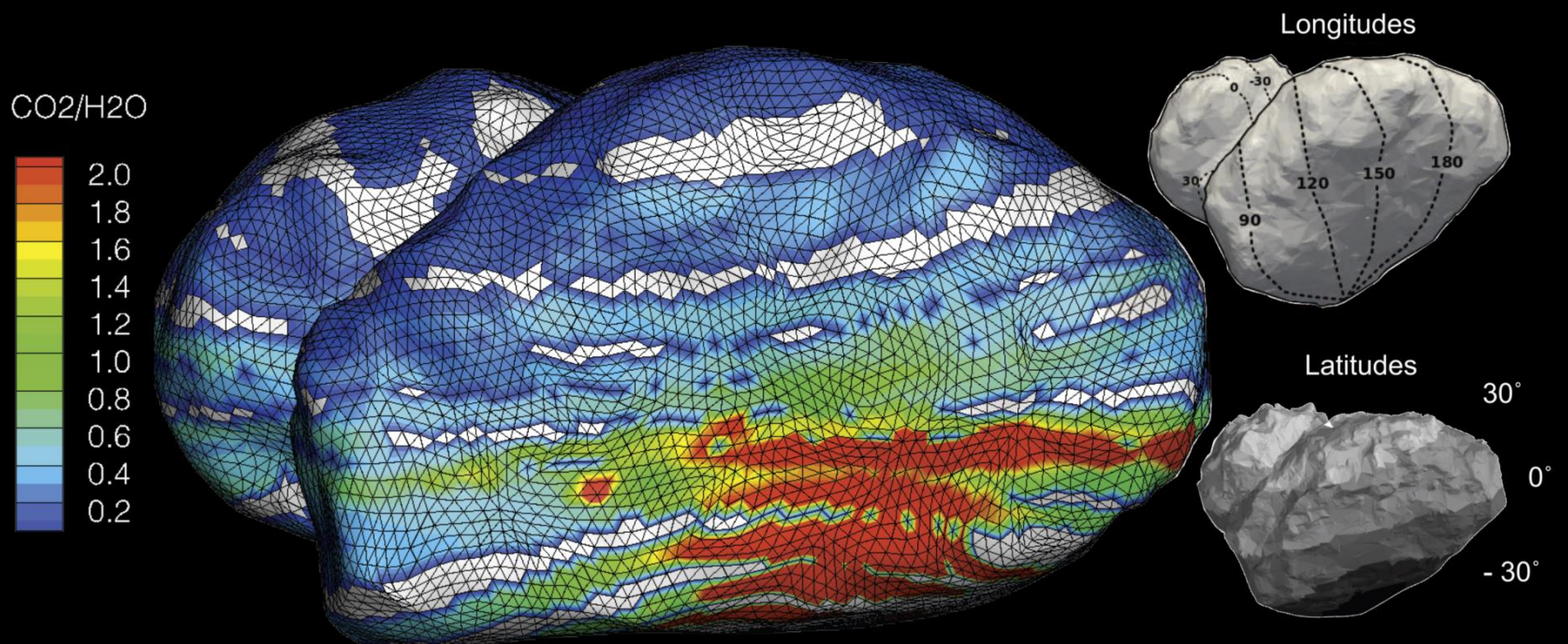


COSIMA images dust grains and performs a chemical analysis.



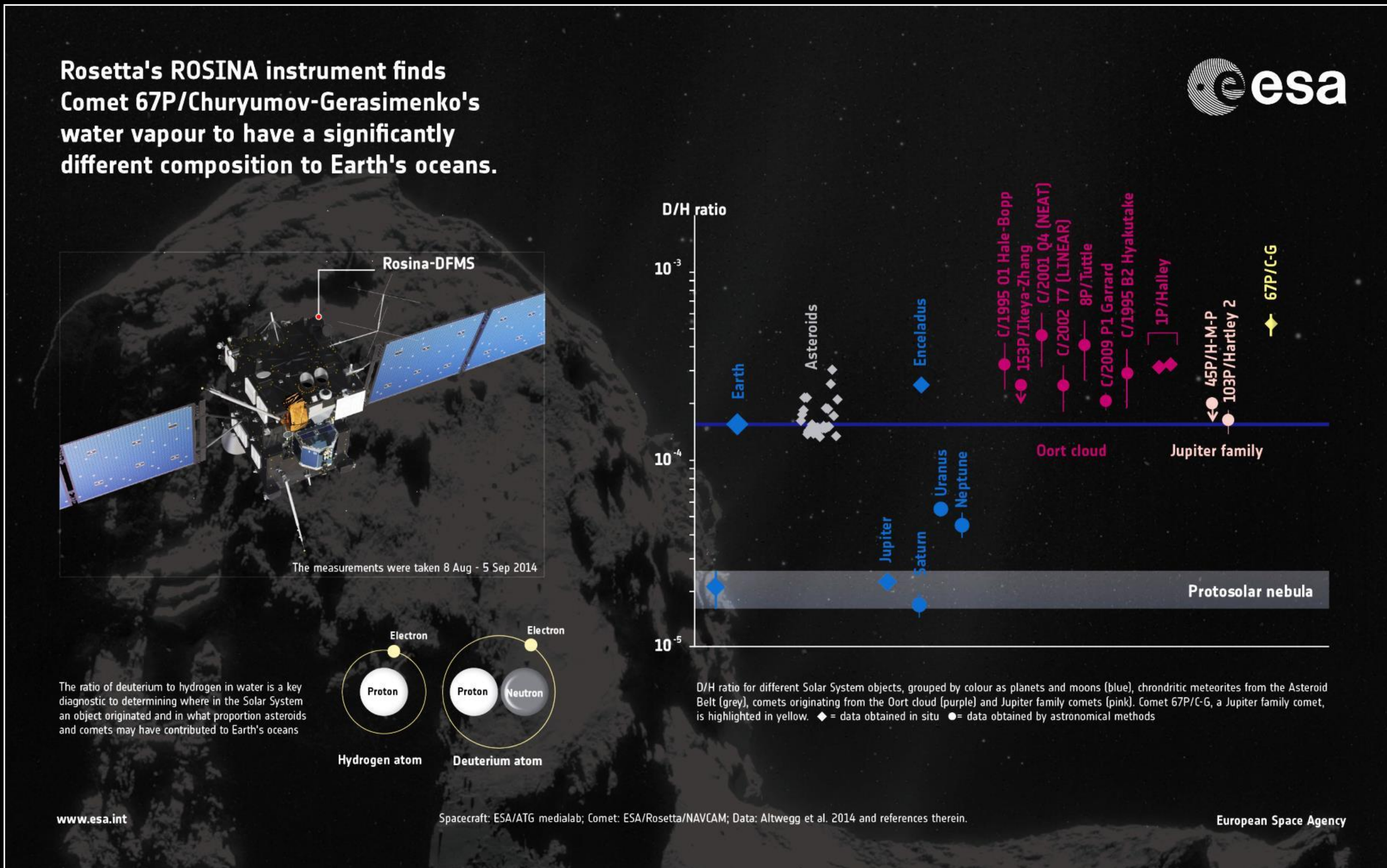
The nucleus material appears to be non-magnetised.



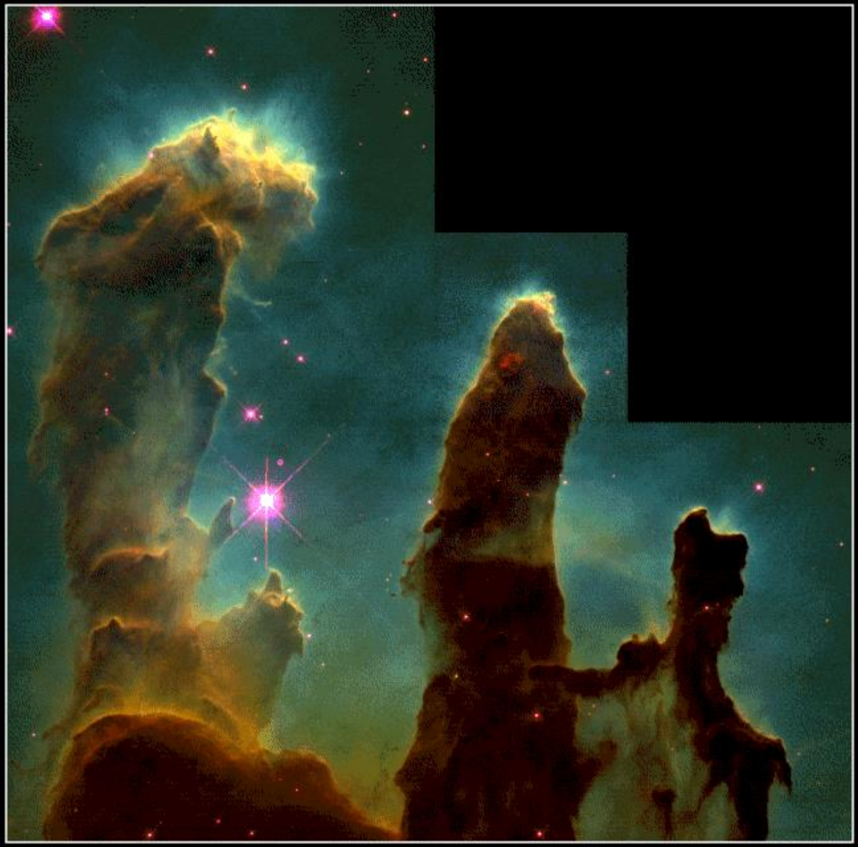


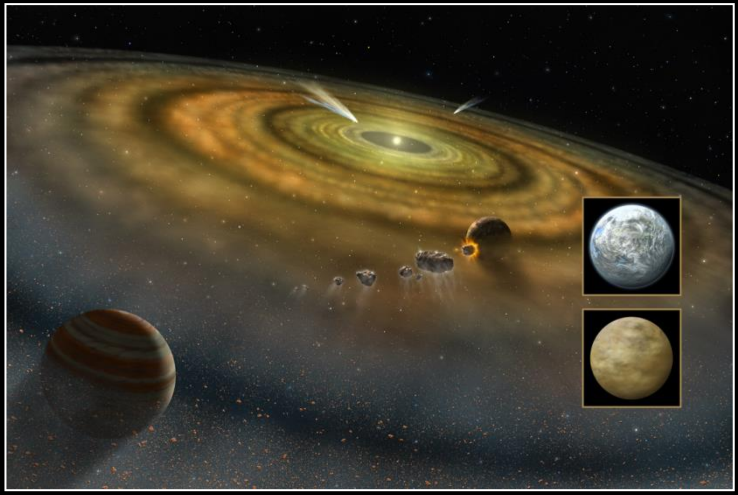
The heterogeneity of the coma indicates that the nucleus is indeed an aggregate. During solar system formation there was

- 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.
esa
Rosina-DFMS
The measurements were taken 8 Aug - 5 Sep 2014
D/H ratio
10⁻³
10⁻⁴
10⁻⁵
Earth
Asteroids
Enceladus
Jupiter
Saturn
Uranus
Neptune
C/1995 O1 Hale-Bopp
153P/Ikeya-Zhang
C/2001 Q4 (NEAT)
C/2002 T7 (LINEAR)
8P/Tuttle
C/2009 P1 Garrard
C/1995 B2 Hyakutake
1P/Halley
45P/H-M-P
103P/Hartley 2
67P/C-G
Oort cloud
Jupiter family
Protosolar nebula
Electron
Proton
Neutron
Hydrogen atom
Deuterium atom
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), chrondritic 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
www.esa.int
Spacecraft: ESA/ATG medialab; Comet: ESA/Rosetta/NAVCAM; Data: Altwegg et al. 2014 and references therein.
European Space Agency

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



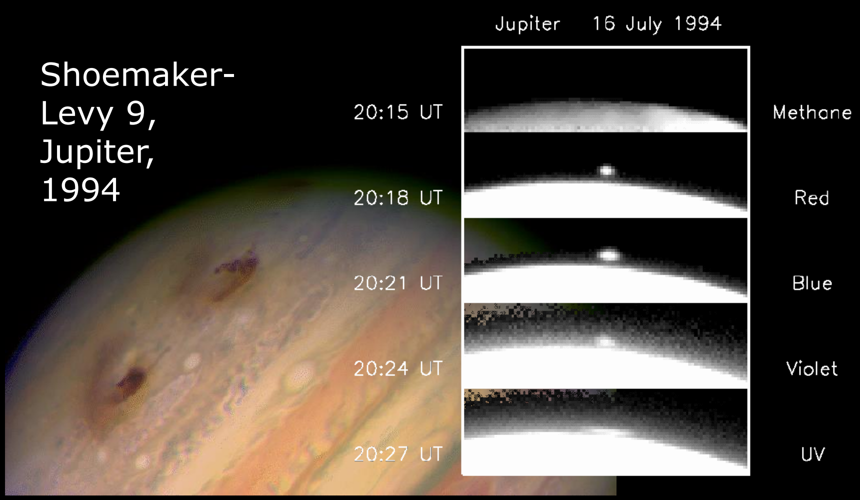


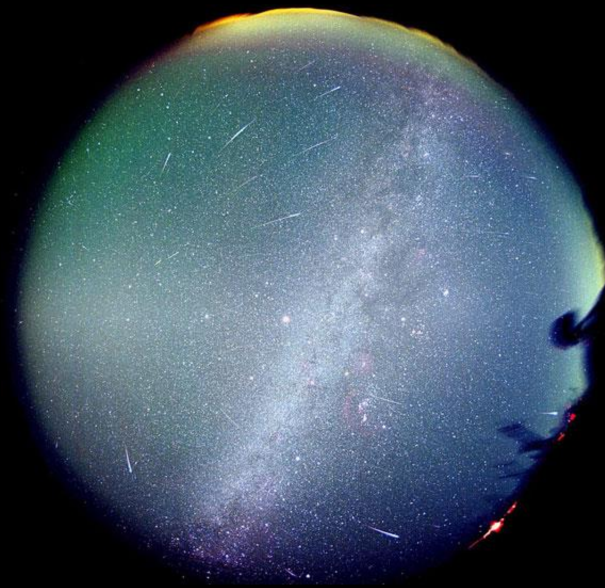
Meteors and the Atmosphere

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

Shoemaker-Levy 9, Jupiter, 1994





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).

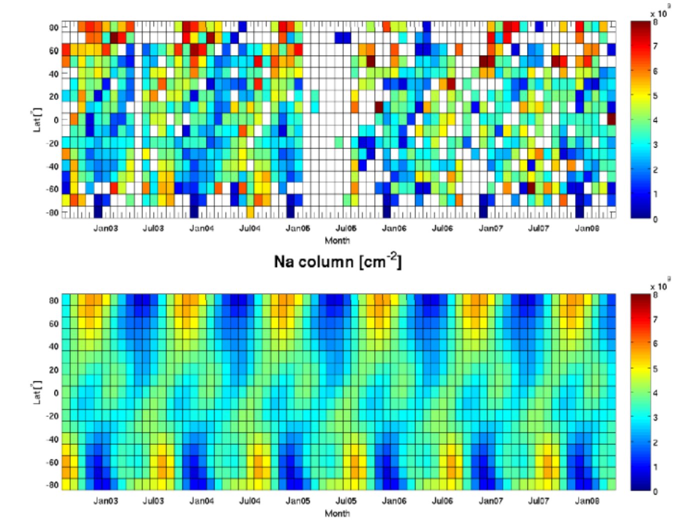


Fig. 9. Top: raw GOMOS Na columns (in units of cm^{-2}) retrieved between August 2002 and June 2008. Bottom: best fit according to Eq. (8). Notice the semi-annual cycle at low latitudes and the annual cycle in the polar regions.

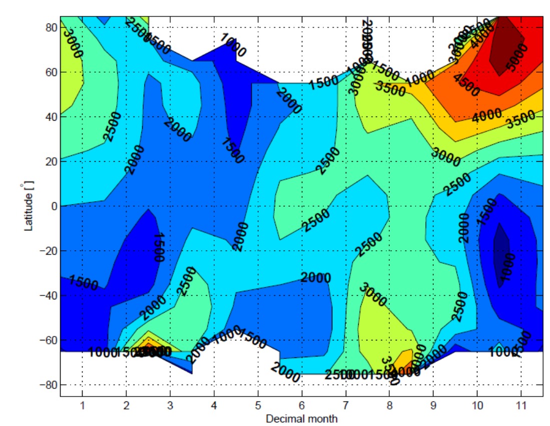


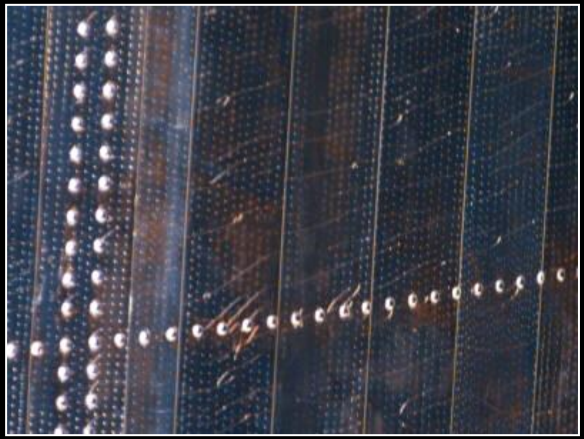
Fig. 13. Peak concentration of mesospheric sodium [atoms/cm^{-3}] as a function of time and latitude.

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.

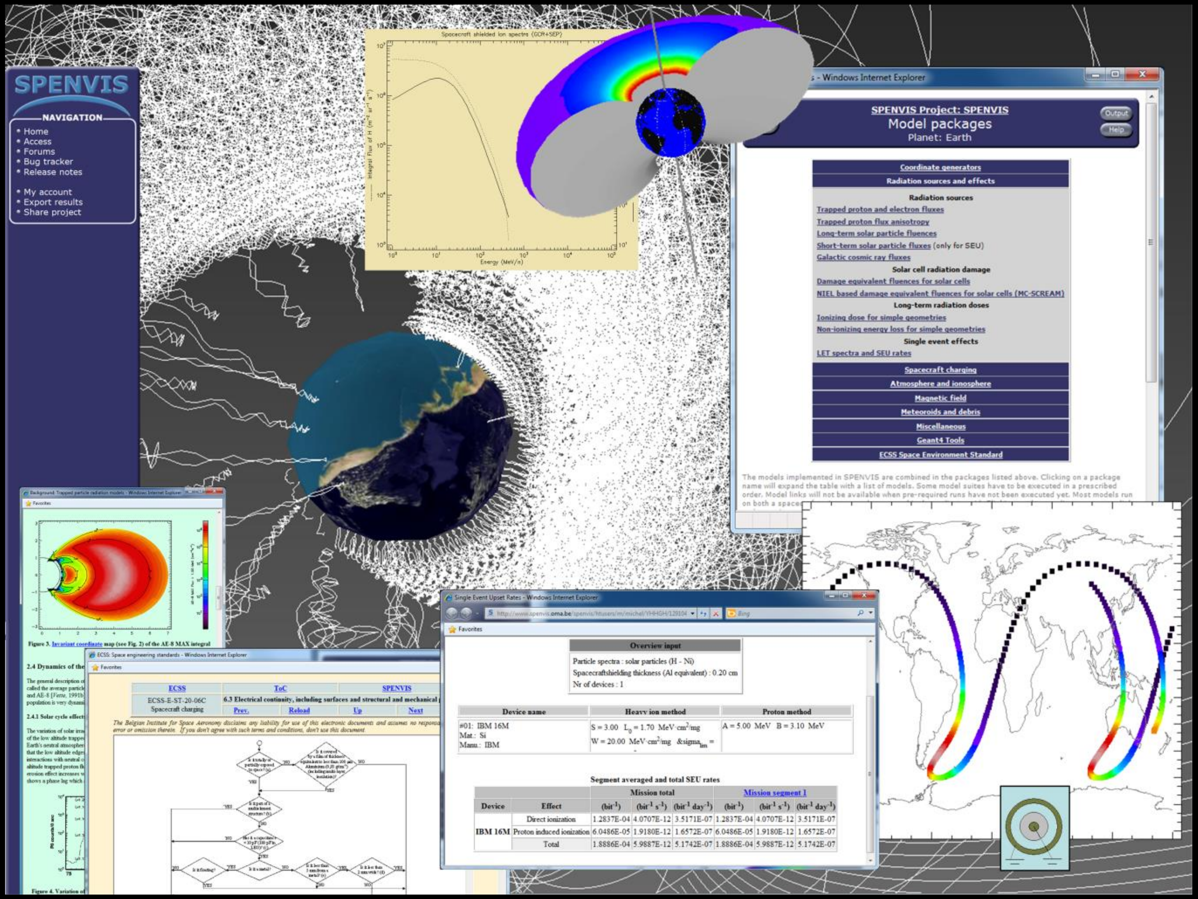
Meteors and Space Weather

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 or 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.



Thanks for your attention!

More info: www.aeronomie.be