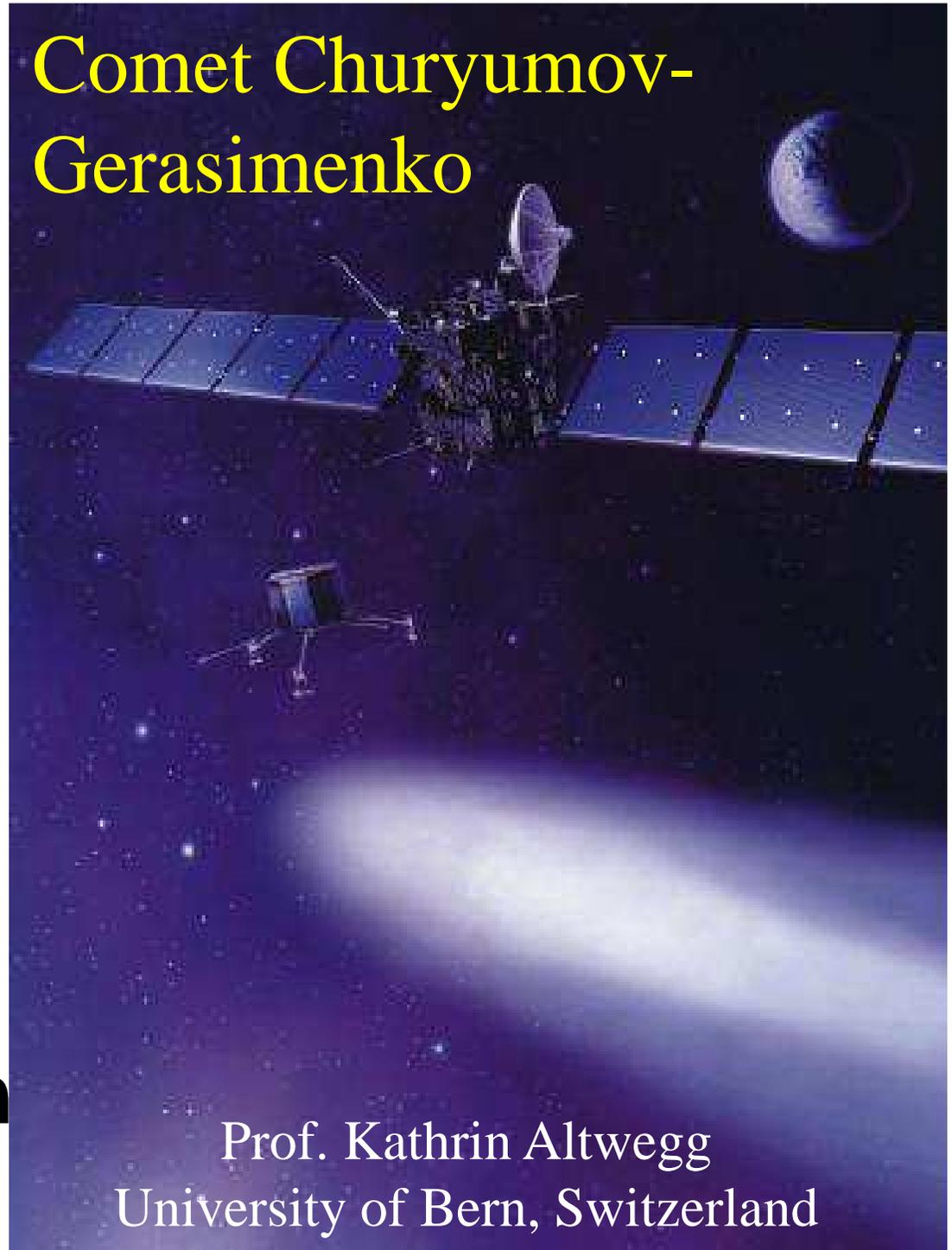




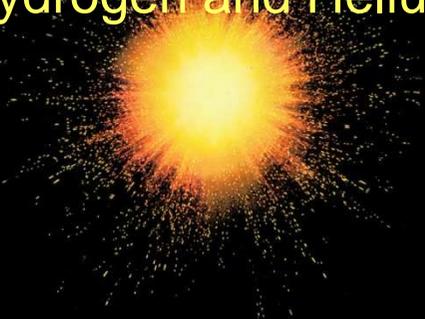
**A long voyage  
back to our origin**

# Comet Churyumov- Gerasimenko

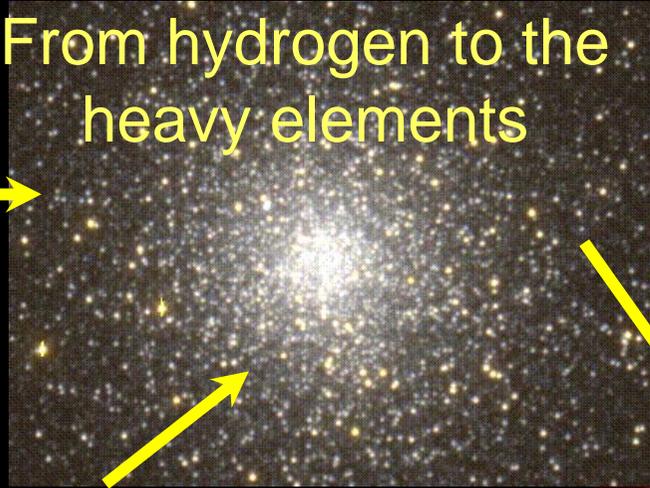


Prof. Kathrin Altwegg  
University of Bern, Switzerland

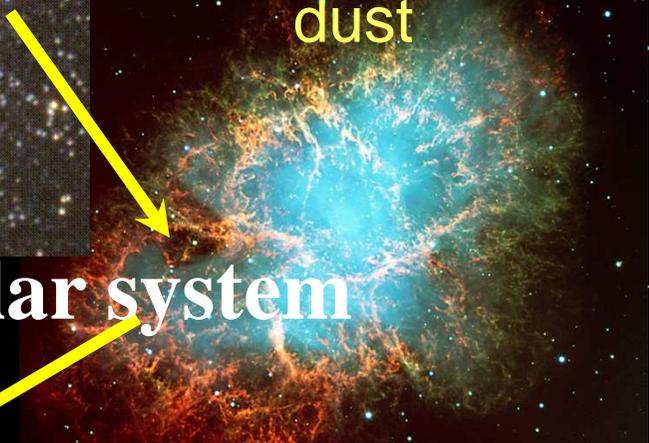
Big Bang, 13 Billion years,  
Hydrogen and Helium



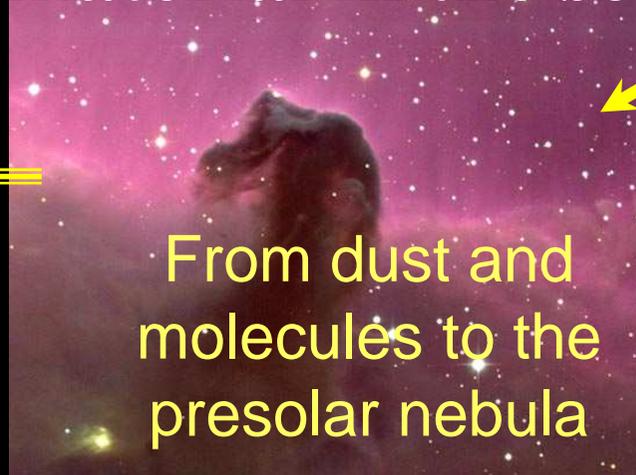
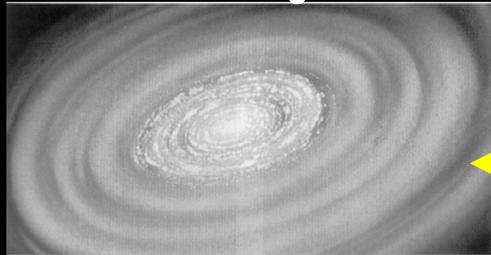
From hydrogen to the  
heavy elements



From the elements  
to molecules and  
dust

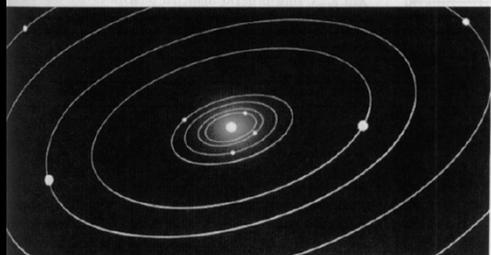
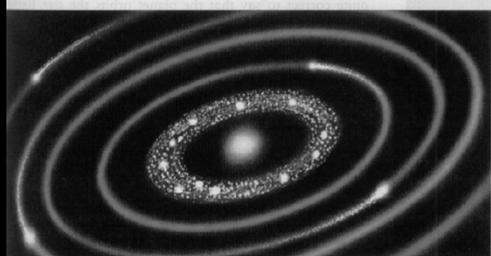


# History of the material in the solar system



From dust and  
molecules to the  
presolar nebula

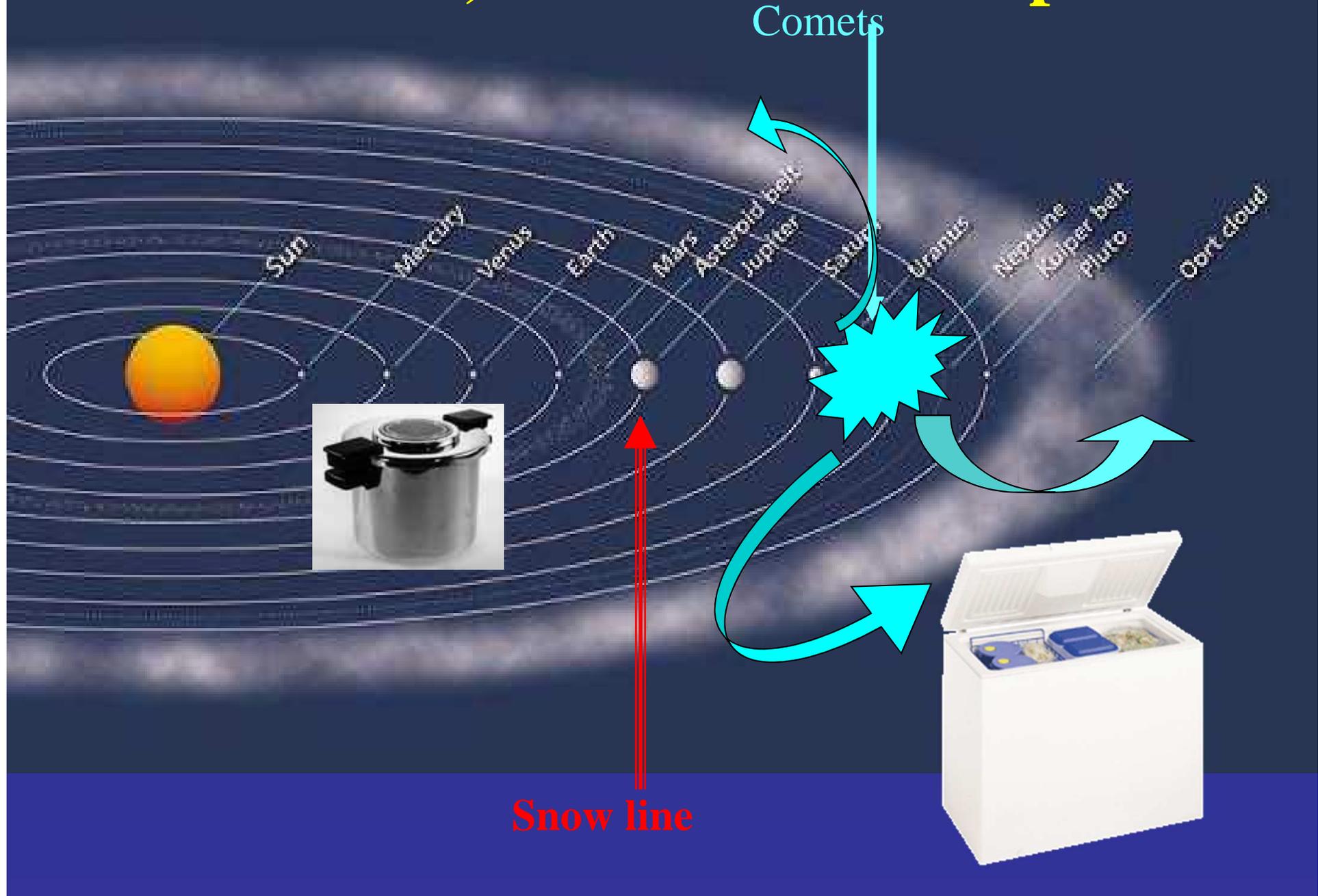
Krebs Nebula



From the presolar  
nebula to the solar  
system of today



# Comets, Witnesses of our past



Comets



Snow line





The Earth 4-4.5  
billion years ago



4.6 billion years ago:  $T > 200\text{ C}$

# Did comets bring terrestrial water?



**Mass Earth:  $10^{24}$  kg**

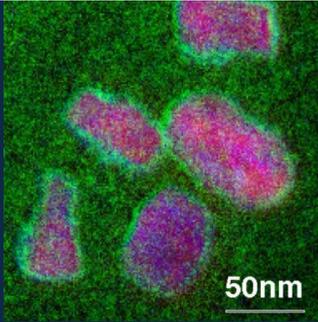
water thereof: 1‰

**Mass comet:  $10^{14}$  kg**



**$10^7$  Comet impacts**





# Did comets bring the building blocks of life, the organic material?



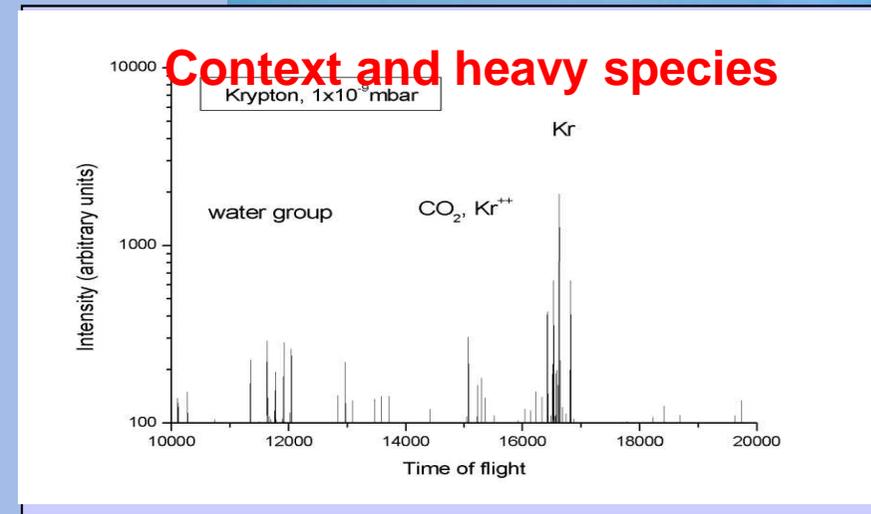
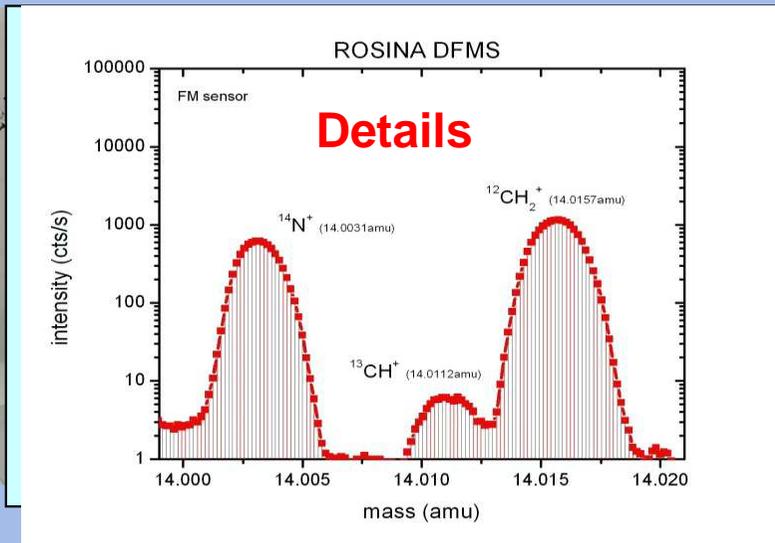
- ✓ In space, there exists organic chemistry
- ✓ Molecules up to amino-acids exist outside of our Earth and of the solar system
- ✓ Comets preserve organic material
- ✓ Comets can serve as carrier for water and organic material

# ROSINA

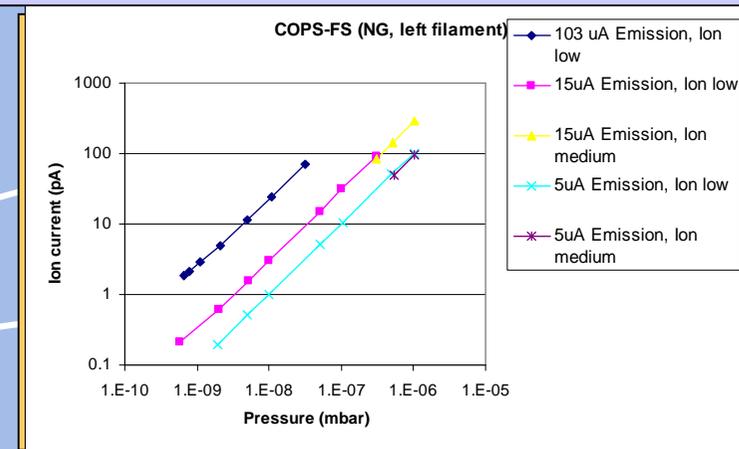


$u^b$

<sup>b</sup>  
UNIVERSITÄT  
BERN



**DPU**  
Digital data processing  
unit, fully redundant  
2.2 kg, 5 W



ETH Zürich

GVE  
EMPA

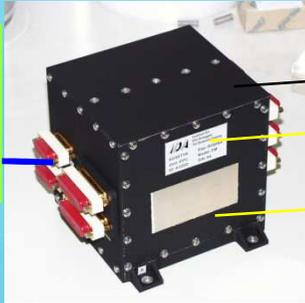
FS Biel

CNES  
Toulouse, F

APCO  
Hauptverantwortung

Max Planck,  
Lindau, D

PSI Elektronenstrahl-  
schweisstechnik



Montena  
EMC

FS Bern

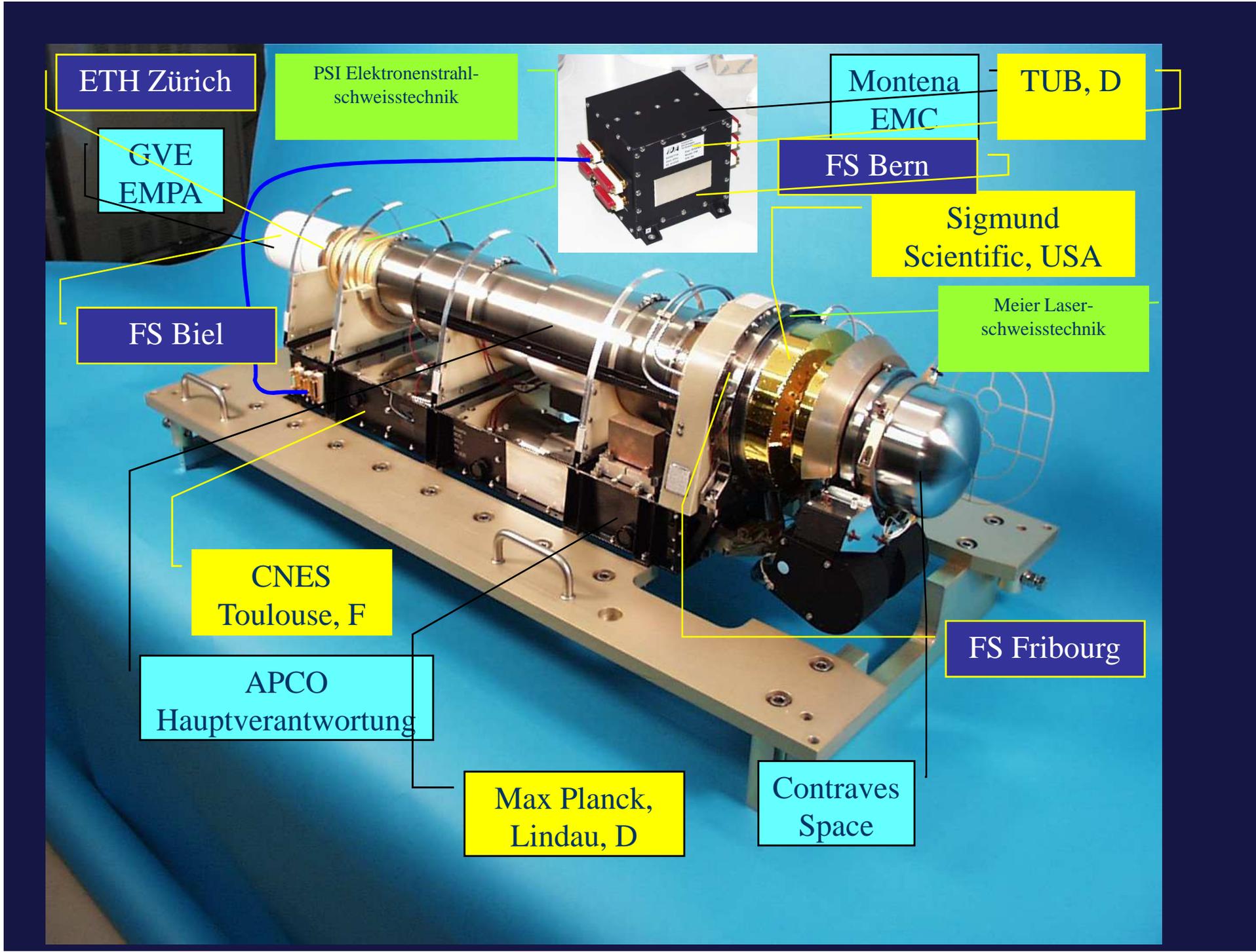
Sigmund  
Scientific, USA

Meier Laser-  
schweisstechnik

FS Fribourg

TUB, D

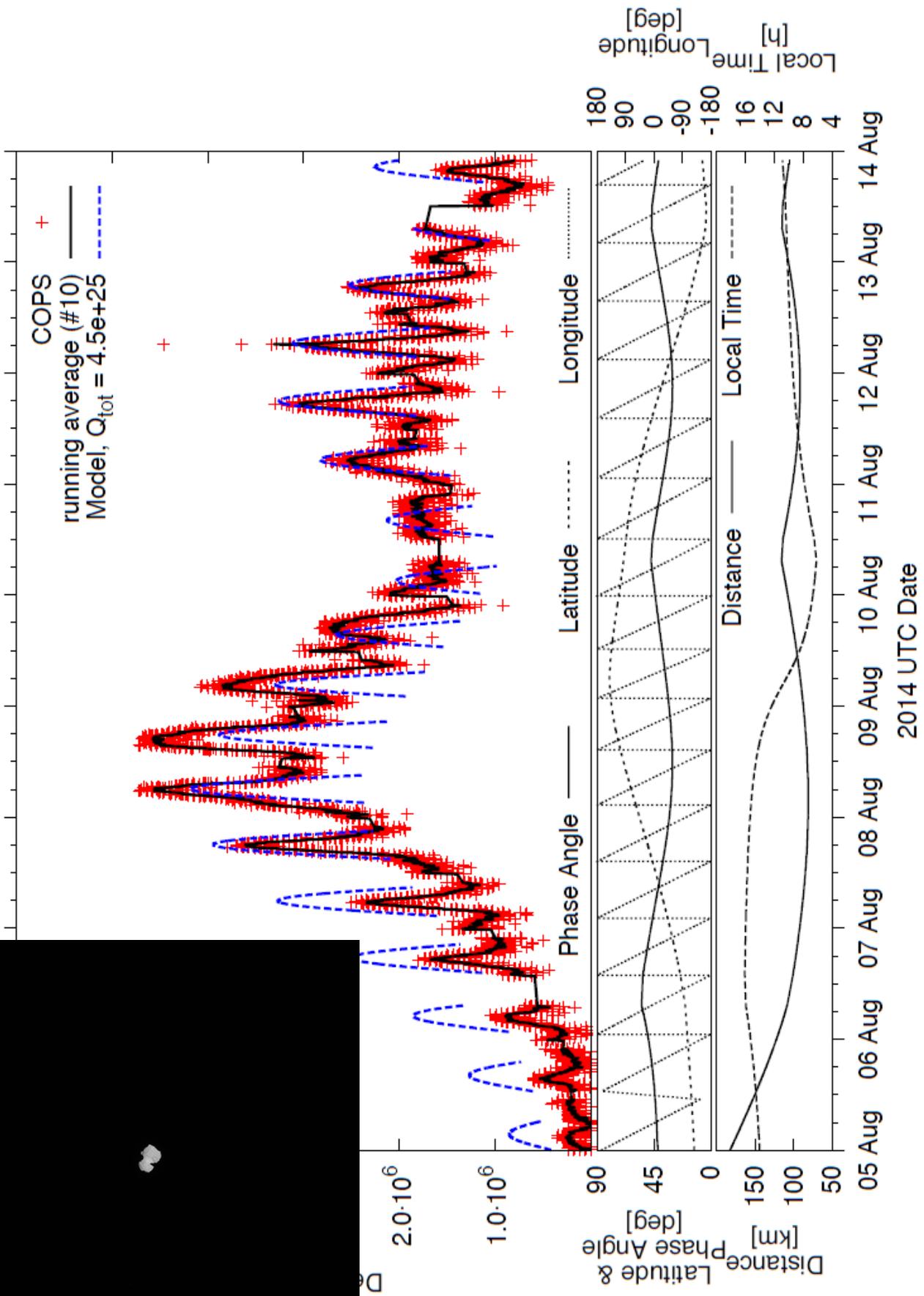
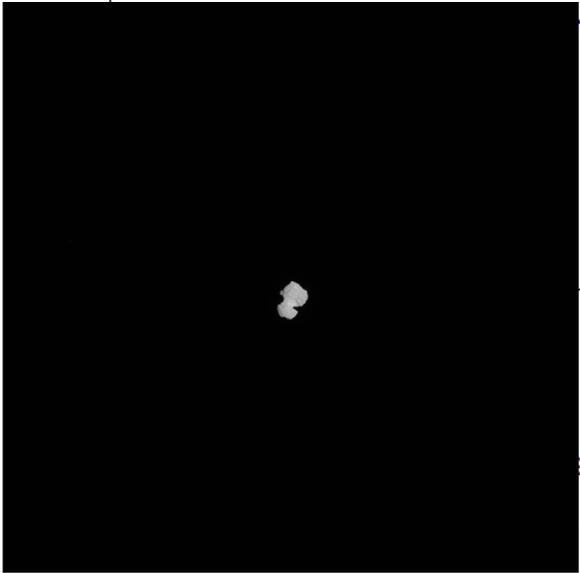
Contraves  
Space



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



Chury – the rubber duck



“The perfume of 67P/C-G is quite strong, with the odour of rotten eggs (hydrogen sulphide), horse stable (ammonia), and the pungent, suffocating odour of formaldehyde. This is mixed with the faint, bitter, almond-like aroma of hydrogen cyanide. Add some whiff of alcohol (methanol) to this mixture, paired with the vinegar-like aroma of sulphur dioxide and a hint of the sweet aromatic scent of carbon disulphide, and you arrive at the ‘perfume’ of our comet.”

methanol

methane

hydrogen sulphide

water

carbon disulfide

carbon monoxide

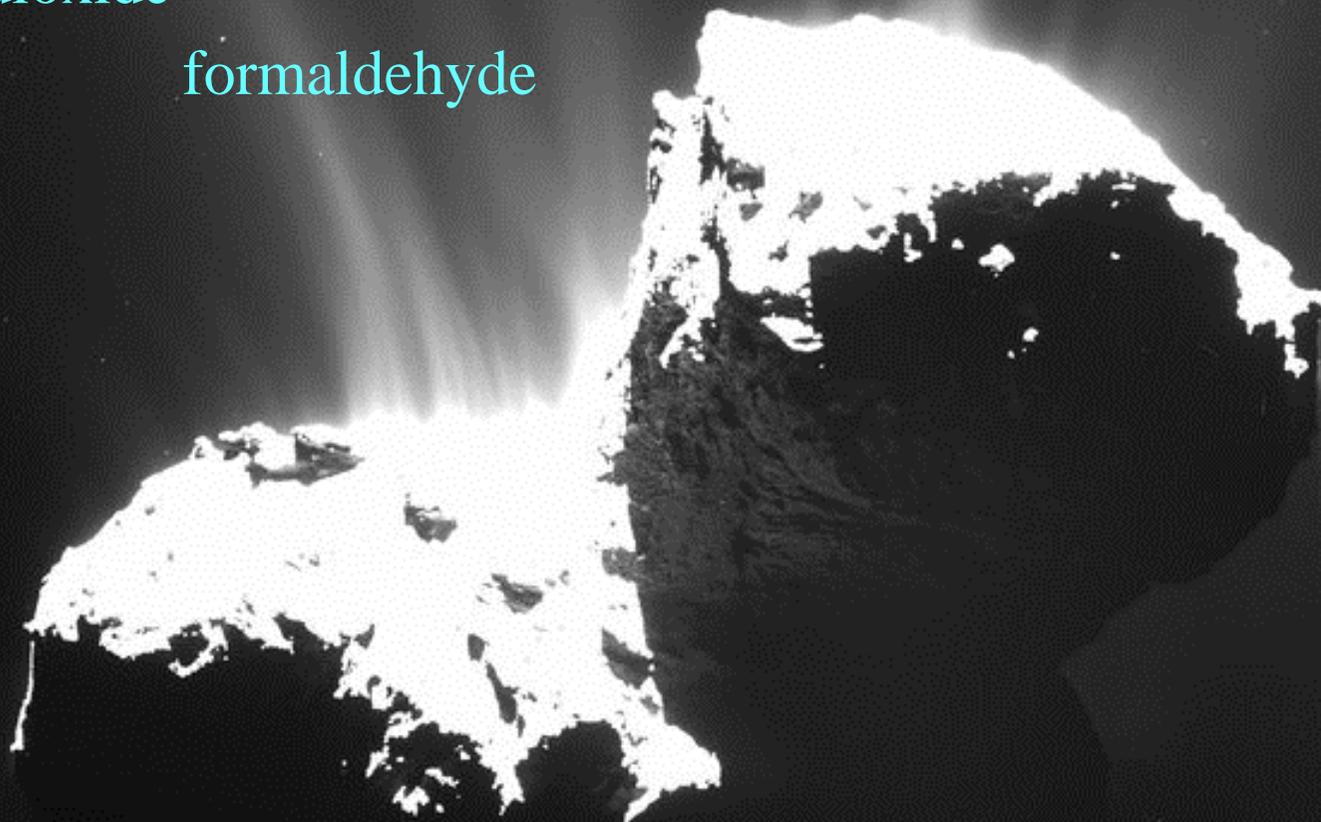
sulphur dioxide

ammonia

cyanide

carbon dioxide

formaldehyde



**23.10.2014, 14:11 - Loisirs et culture**  
Actualisé le 23.10.14, 15:25

## La comète Tchourioumov-Guérassimenko pue, selon le "nez" de la sonde Rosetta

ESPACE



ePaper | Agenda | Abo |

**schweizerbauer.ch**  
Landwirtschaft online

WETTER POLITIK & WIRTSCHAFT MARKT & PREISE TIERE PFLANZEN LANDTECHNIK GALERIEN  
ALLERLEI BAUERKALENDER BEKANNTSCHAFTEN BAUERLEDIG, SUCHT AGROPREISE SCHWEIZERLAND UND LEB

DE BUNDKANTONSSTÄDTE ALS KISSFRIED ANNOBIENEN

Quelle: schweizerbauer.ch - stla

Weitfall

## Komet riecht nach Pferdestall



• mehr Wetter

MEISTGELESEN NEUES OFT KOMMENTIERT



Where are the grifters? Arctic gales bring travel phase as snow rumbles in.



Woman, 19, who converted to Islam, 'slabbed her Muslim boyfriend to death.



Building society cashier who stole £40,000 from elderly customer to fund

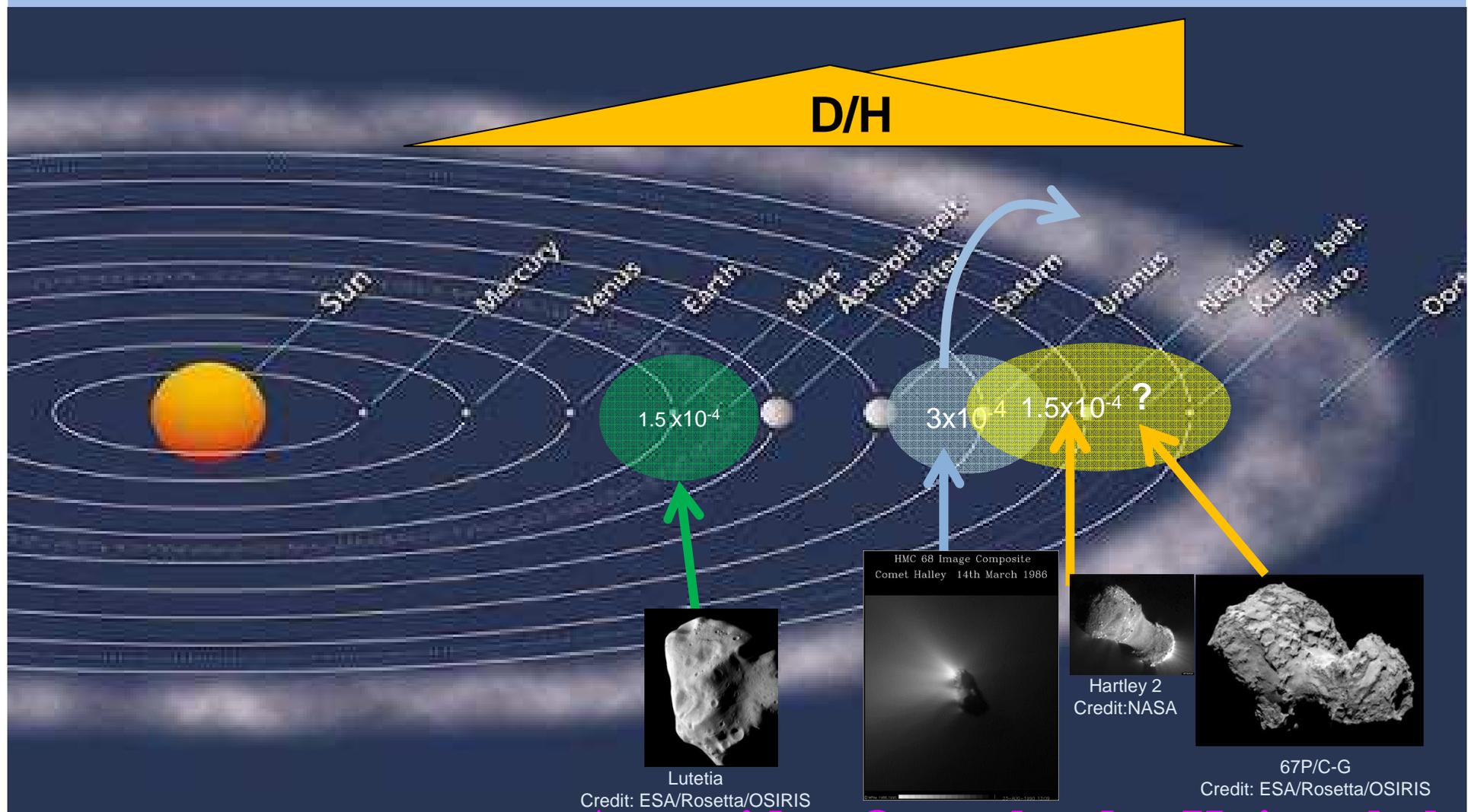


Female school governor is banned from contacting headteacher for four

## Rotten eggs, horse pee, alcohol and bitter almonds: Astronomers reveal what the comet Rosetta is set to land on smells like

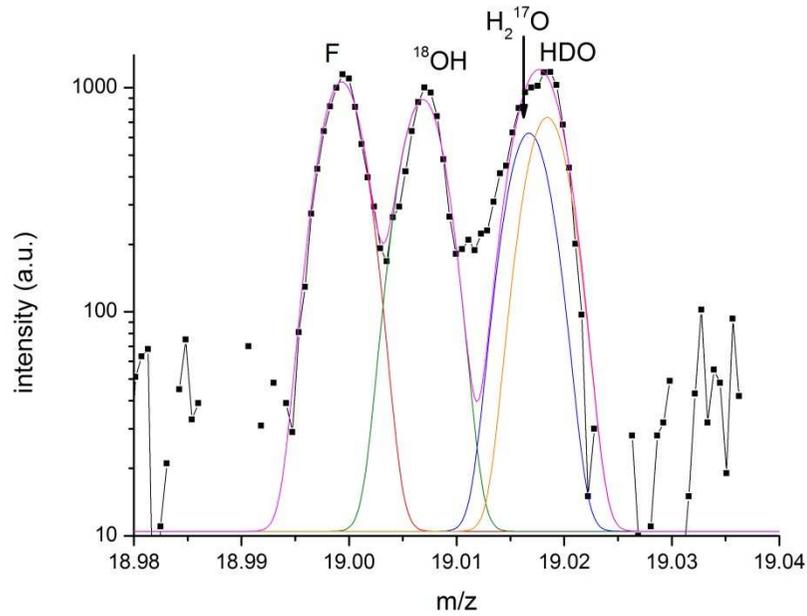
- The bouquet of unique smells was sniffed out by the Rosetta probe
- It identified ingredients after analysing chemicals in comet's coma
- The aroma will get stronger as comet 67P/C-G gets closer to the sun
- Esa has confirmed Rosetta will attempt to land on a comet on 12 November
- The daring descent of its Philae probe will take seven hours from separation
- The region, named Site J, is around 2.4 miles (4km) at its widest point
- **However Esa says the Philae mission is still 'high-risk' and should be seen as a bonus to the overall Rosetta mission**
- Scientists hope the spider-like probe will send back data that could answer questions on the origin of Earth's water and perhaps even life

# Which small bodies brought the terrestrial water?

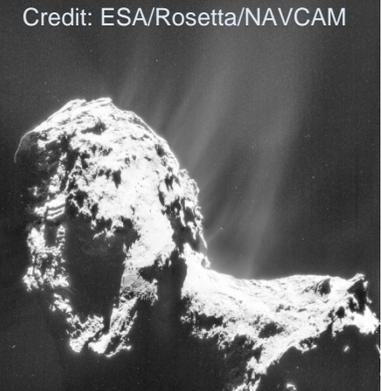


**Asteroids**   **Oort cloud**   **Kuiper belt**

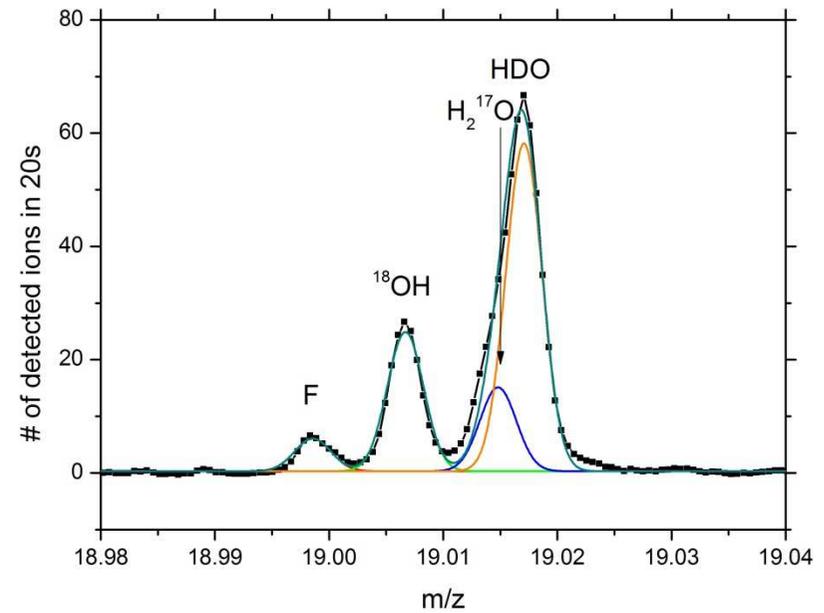
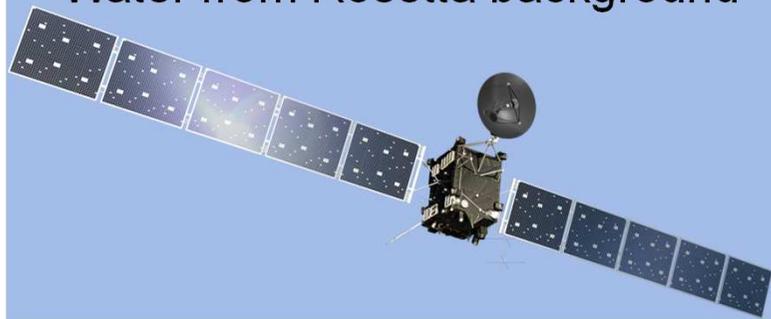
# Deuterium to hydrogen ratio measurements



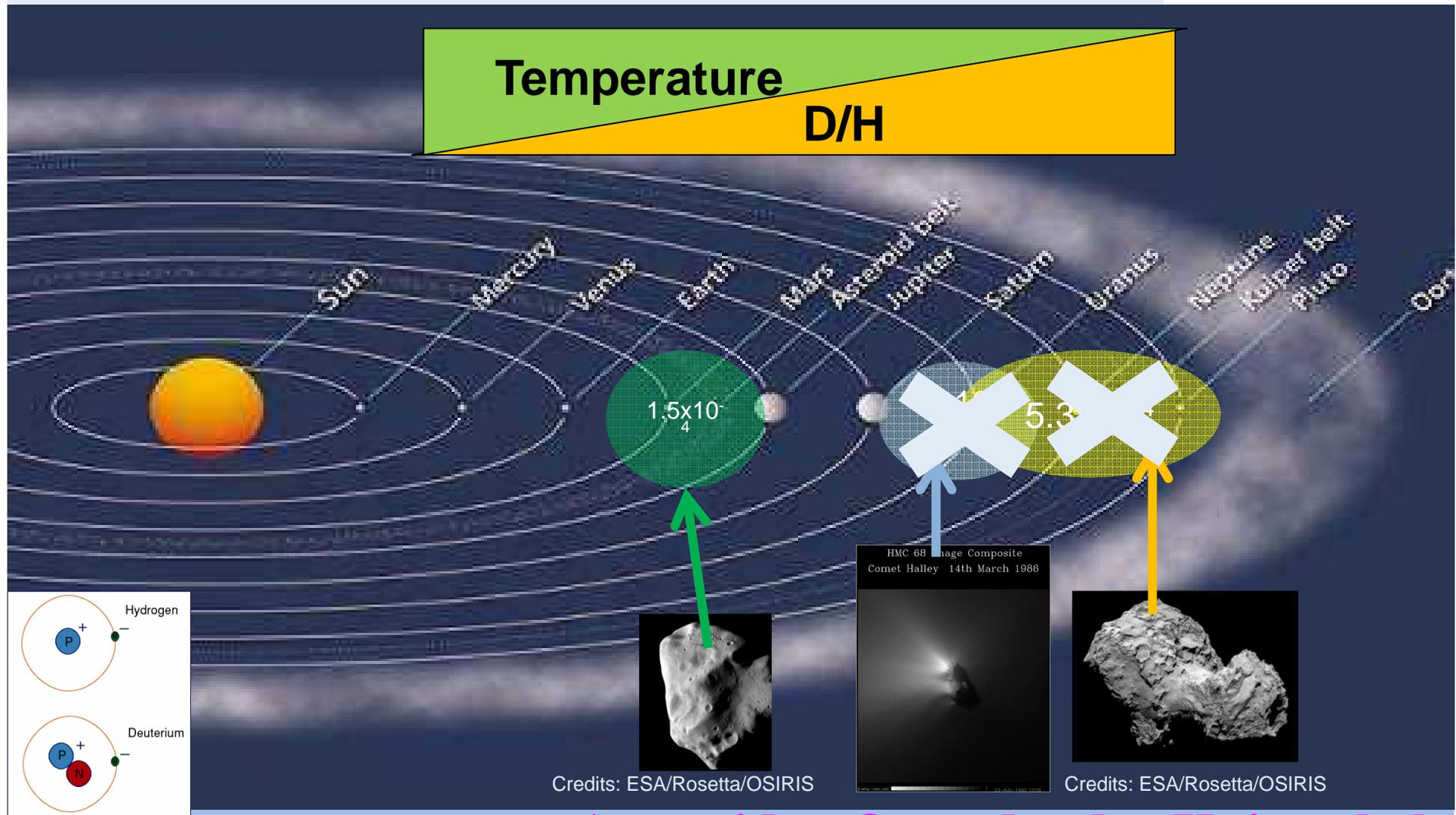
Water from the comet



Water from Rosetta background



# Asteroids, Oort comets, Kuiper belt comets: which small bodies brought terrestrial water?



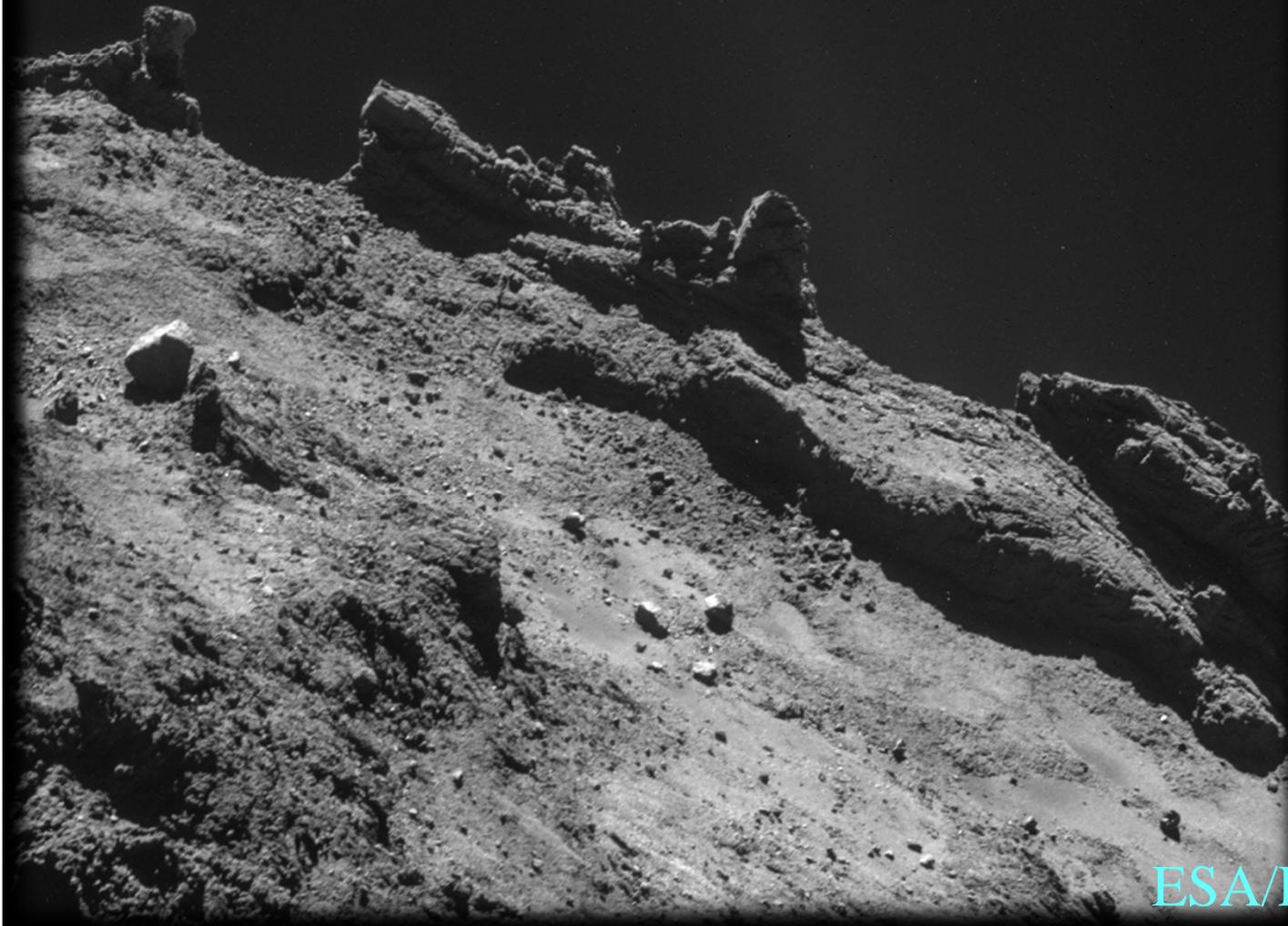
Asteroids Oort cloud Kuiper belt

# Atoms: Sodium, Magnesium, Silicon und Calcium

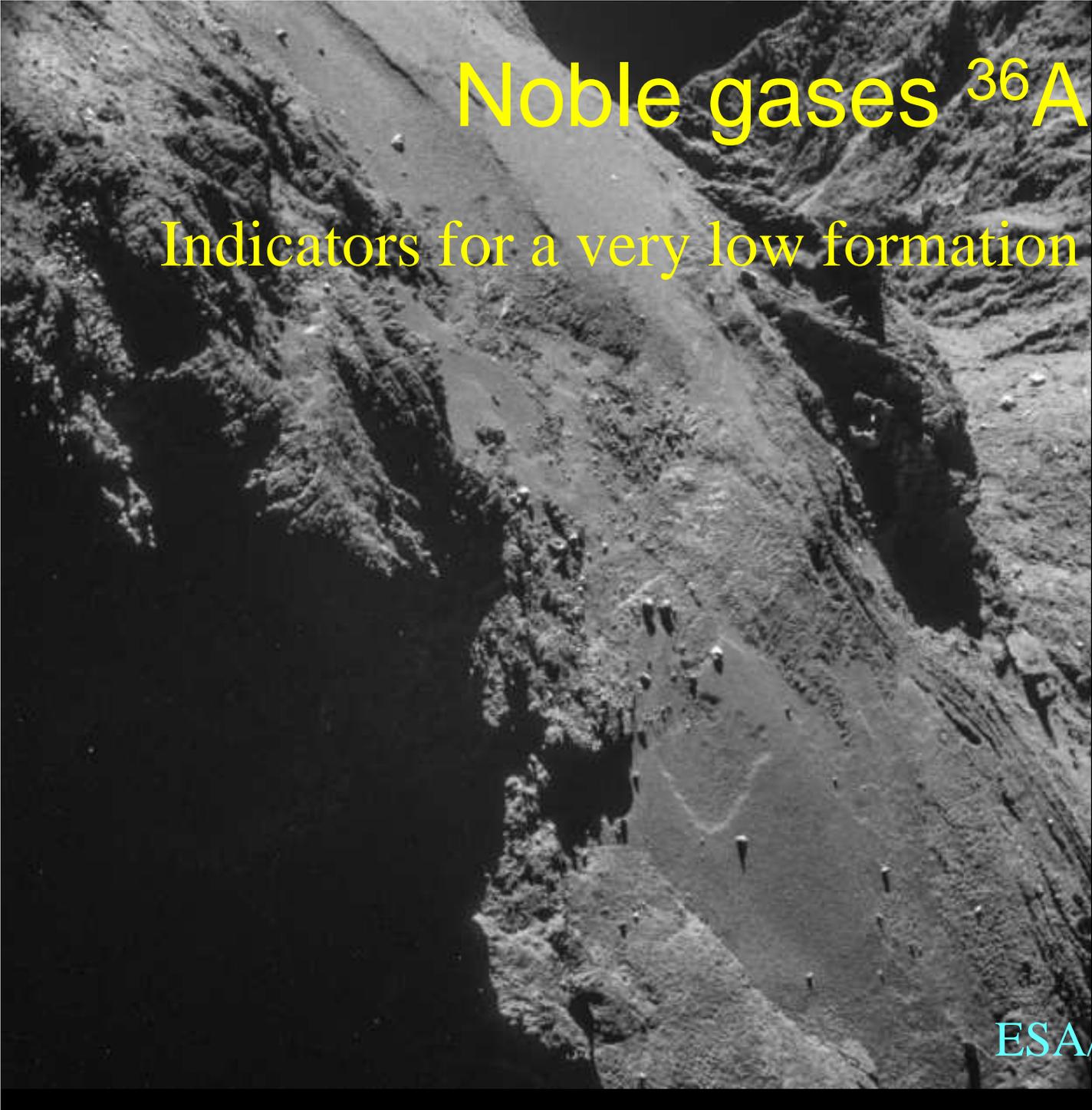
Sputtering by solar wind particles



2001/03/04 01:05



ESA/Rosetta/NAVCAM

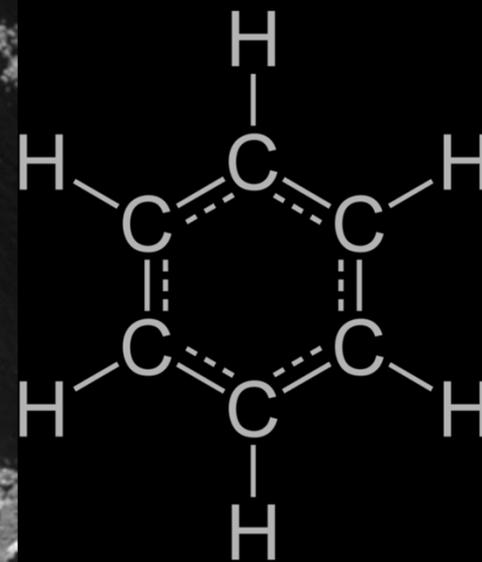


# Noble gases $^{36}\text{Ar}$ & $^{38}\text{Ar}$

Indicators for a very low formation temperature

ESA/Rosetta/NAVCAM

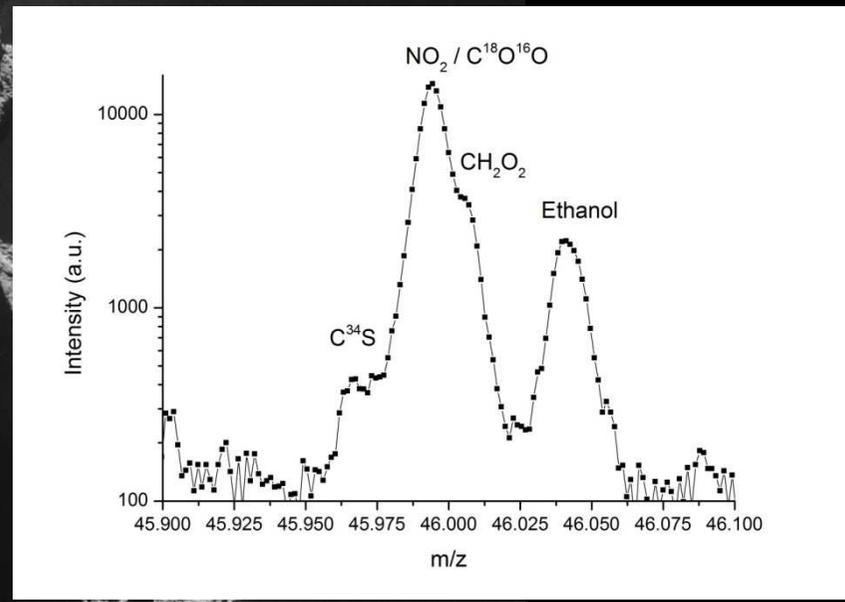
# Benzene



ESA/Rosetta/NAVCAM

# Conclusion on habitability

> The comet stinks due to a lot of Sulfur, but there is molecular oxygen and water and there is even alcohol to drink -> it is habitable!



## Acknowledgements

The ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis) instrument package was designed and built by an international consortium led by the Space Research and Planetary Sciences Division, Physics Institute, University of Bern, Switzerland. Hardware subsystems were delivered by:

- > the Belgian Institute for Space Aeronomy (BIRA-IASP),
- > Research Institute in Astrophysics and Planetology (IRAP)
- > Institut Pierre Simon Laplace (IPSL), Paris, France,
- > Lockheed Martin Advanced Technology Center (LMATC), Palo Alto, MPS, Göttingen, Germany,
- > Institute of Computer and Network Engineering at the TUB
- > University of Michigan - Atmospheric, Oceanic and Space Sciences.

**Thanks to the Rosetta team at ESA, especially the operations team in Darmstadt for taking excellent care of Rosetta and ROSINA.**