**Missions to Habitable Worlds**

28-29 October 2015
Budapest, Hungary

International conference
on astrobiology issues related
to next European space missions.

Organized by COST TD 1308 action

# Astrobiology in ESA missions

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ESA-ESTEC

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# Plan of the talk

- The ESA Scientific Programme
- Running missions
- Missions under development & study
- Plans for the future

# 22 Member States and growing

**ESA has 22 Member States: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland and the United Kingdom.**

Canada also sits on the Council and takes part in some projects under a Cooperation Agreement. Other EU states also have Cooperation Agreements with ESA, such as Bulgaria, Cyprus, Lithuania and Malta. Latvia, Slovenia and Slovakia are participating in the Plan for European Cooperating States (PECS).

# SCIENCE & ROBOTIC EXPLORATION

esa

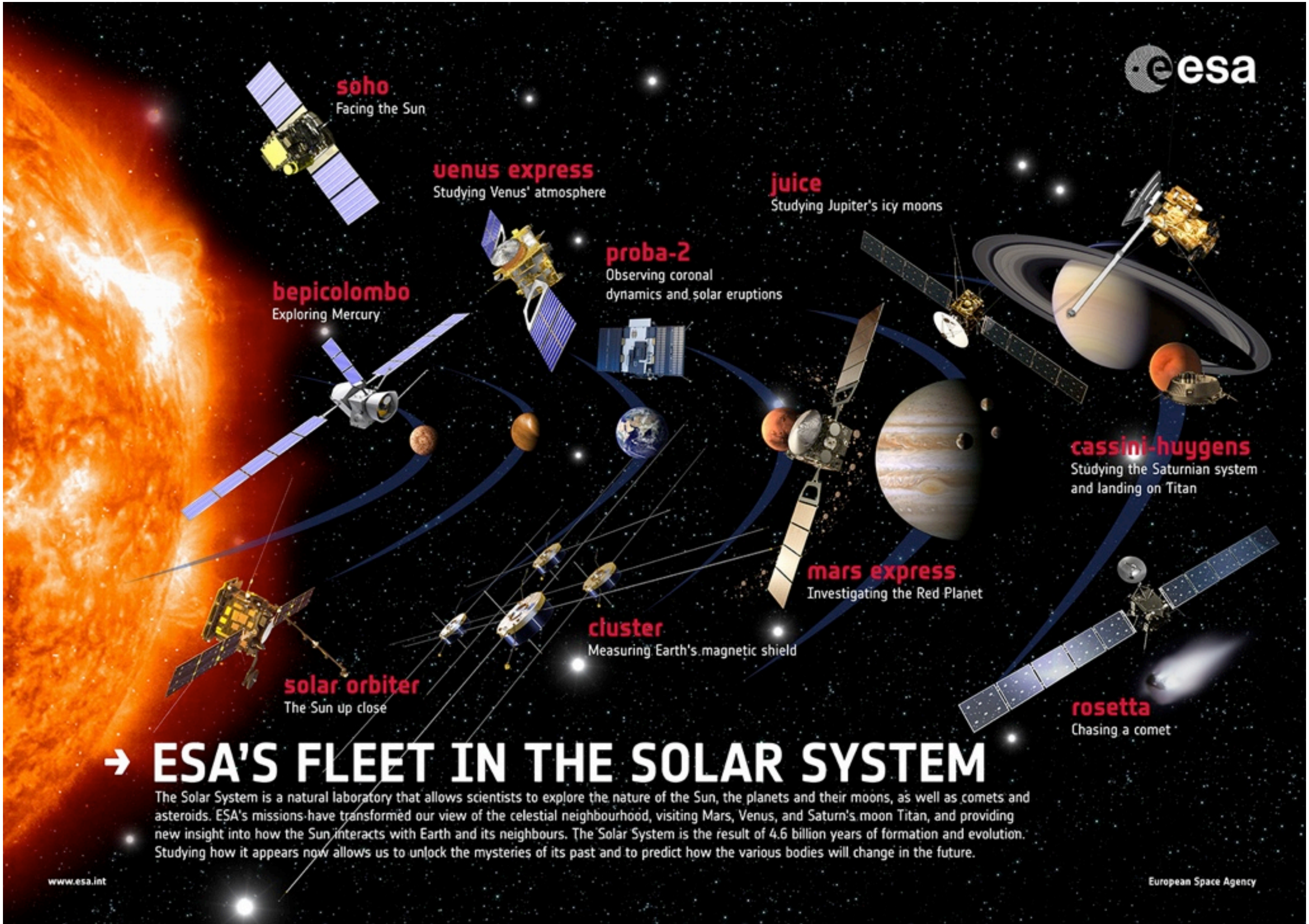
***Science-driven***

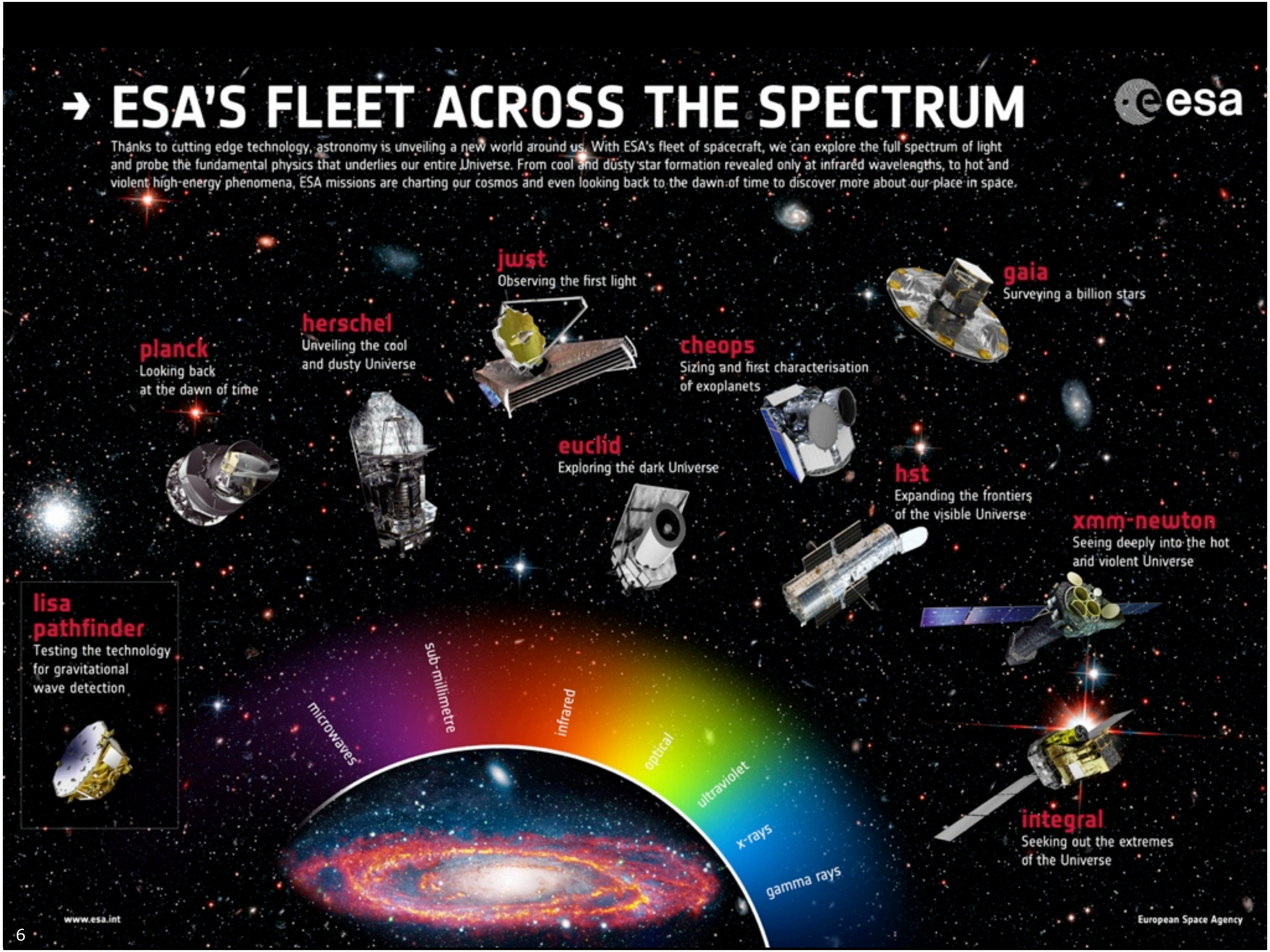
***both long-term science planning and mission calls are bottom-up processes, relying on broad community input and peer review.***

***Mandatory***

***all member states contribute pro-rata to GNP providing budget stability, allowing long-term planning of its scientific goals and being the backbone of the Agency.***

European Space Agency


esa
soho
Facing the Sun
venus express
Studying Venus' atmosphere
juice
Studying Jupiter's icy moons
proba-2
Observing coronal
dynamics and solar eruptions
bepicolombo
Exploring Mercury
cassini-huygens
Studying the Saturnian system
and landing on Titan
mars express
Investigating the Red Planet
cluster
Measuring Earth's magnetic shield
solar orbiter
The Sun up close
rosetta
Chasing a comet
→ ESA'S FLEET IN THE SOLAR SYSTEM
The Solar System is a natural laboratory that allows scientists to explore the nature of the Sun, the planets and their moons, as well as comets and asteroids. ESA's missions have transformed our view of the celestial neighbourhood, visiting Mars, Venus, and Saturn's moon Titan, and providing new insight into how the Sun interacts with Earth and its neighbours. The Solar System is the result of 4.6 billion years of formation and evolution. Studying how it appears now allows us to unlock the mysteries of its past and to predict how the various bodies will change in the future.
www.esa.int
European Space Agency


ESA'S FLEET ACROSS THE SPECTRUM
esa
Thanks to cutting edge technology, astronomy is unveiling a new world around us. With ESA's fleet of spacecraft, we can explore the full spectrum of light and probe the fundamental physics that underlies our entire Universe. From cool and dusty star formation revealed only at infrared wavelengths, to hot and violent high-energy phenomena, ESA missions are charting our cosmos and even looking back to the dawn of time to discover more about our place in space.
jwst
Observing the first light
gaia
Surveying a billion stars
herschel
Unveiling the cool and dusty Universe
planck
Looking back at the dawn of time
cheops
Sizing and first characterisation of exoplanets
euclid
Exploring the dark Universe
hst
Expanding the frontiers of the visible Universe
xmm-newton
Seeing deeply into the hot and violent Universe
lisa pathfinder
Testing the technology for gravitational wave detection
integral
Seeking out the extremes of the Universe
microwaves
sub-millimetre
infrared
optical
ultraviolet
x-rays
gamma rays
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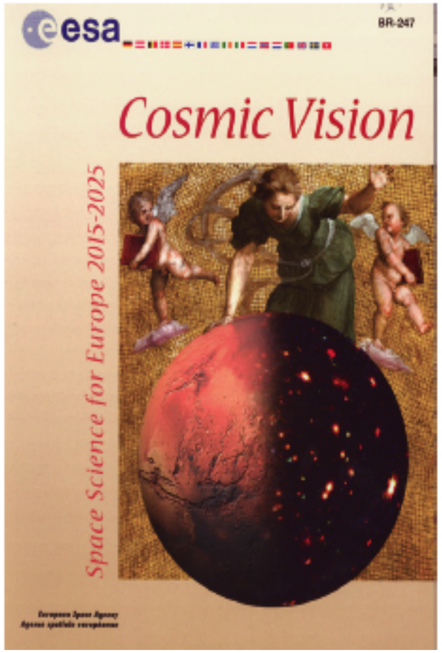
European Space Agency

# COSMIC VISION

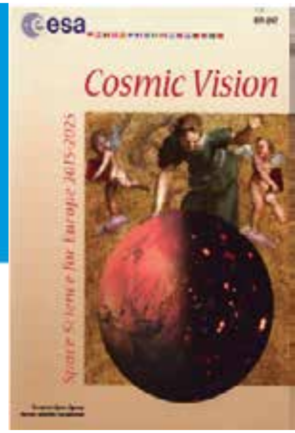
ESA's long-term scientific programme is based on a vision.

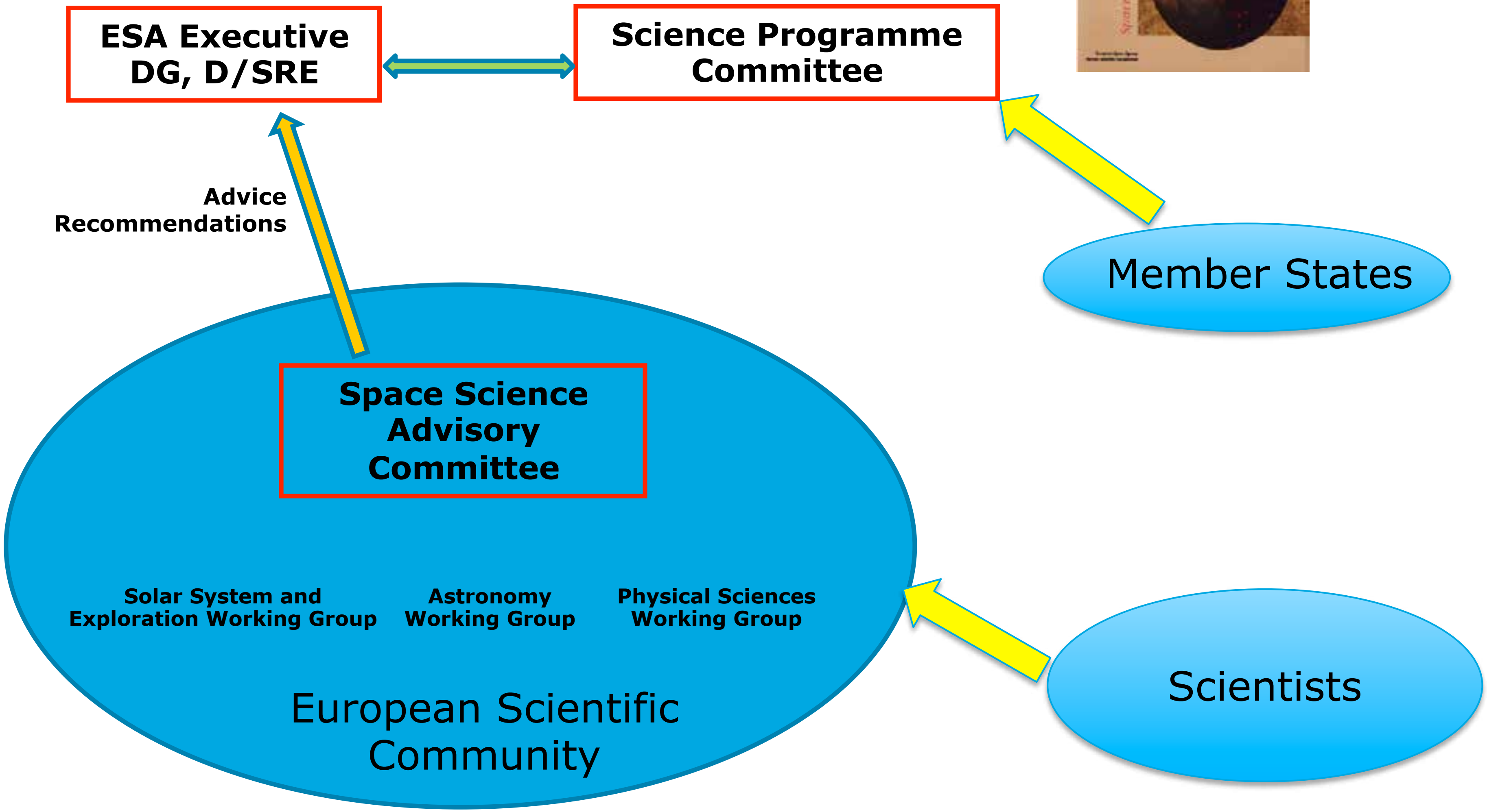
The 'Cosmic Vision' looks for answers to mankind's fundamental questions:

- What are the conditions for planet formation and the emergence of life?
- How does the Solar System work?
- What are the fundamental physical laws of the Universe?
- How did the Universe originate and what is it made of?



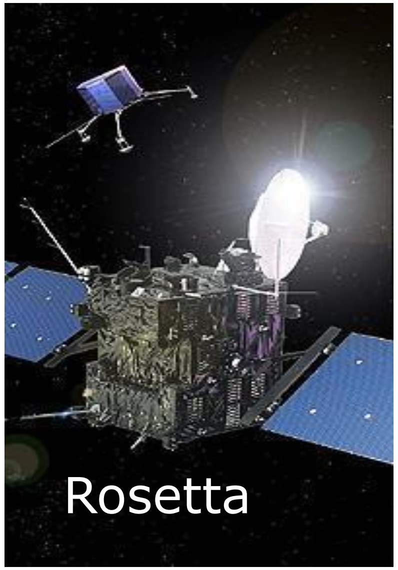

# COSMIC VISION
# A bottom-up approach



# Science Programme building blocks
# "Large" (Ariane 5-class) missions

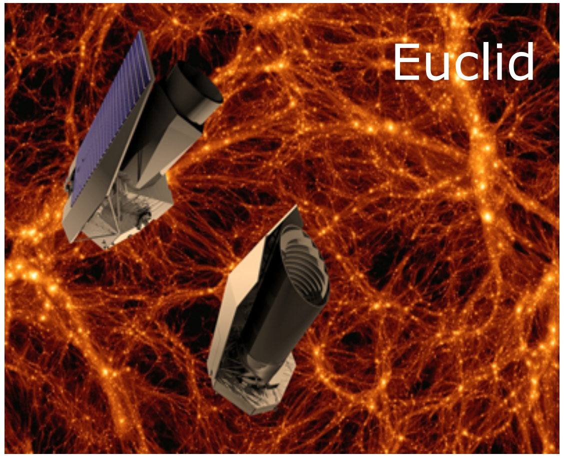
1. High innovation content
2. European flagships
3. 3 per 20 years

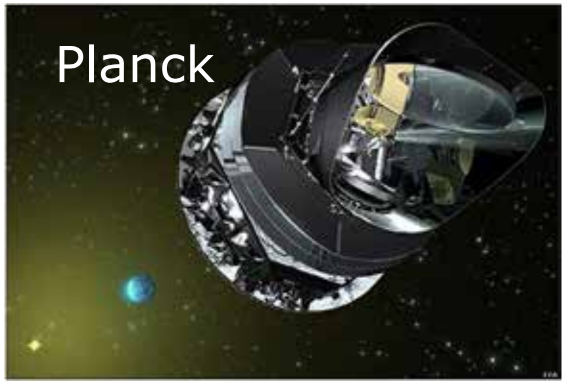


# Science Programme building blocks
# "Medium" (Soyuz-class) missions

1. Makes use of current cutting-edge technology
2. Programme workhorse
3. 3-4 per 10 years

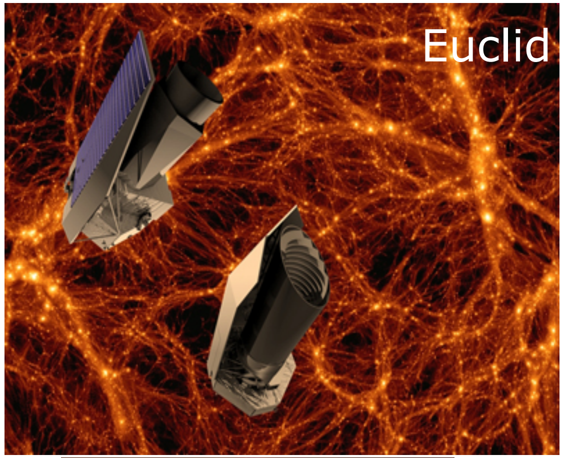





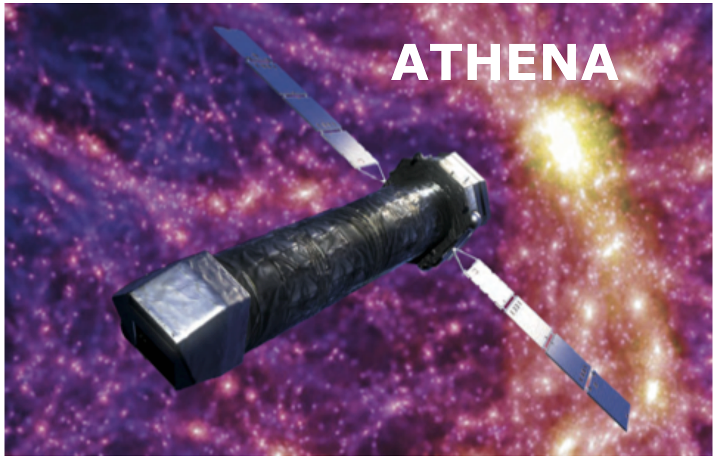


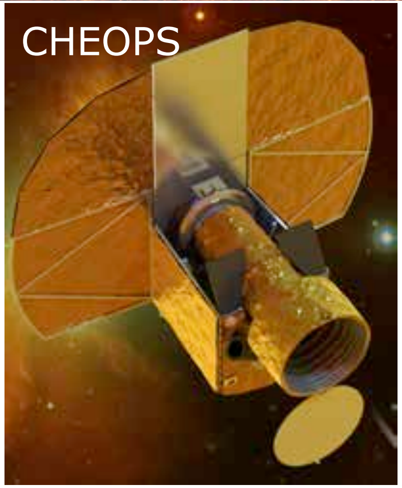

# COSMIC VISION

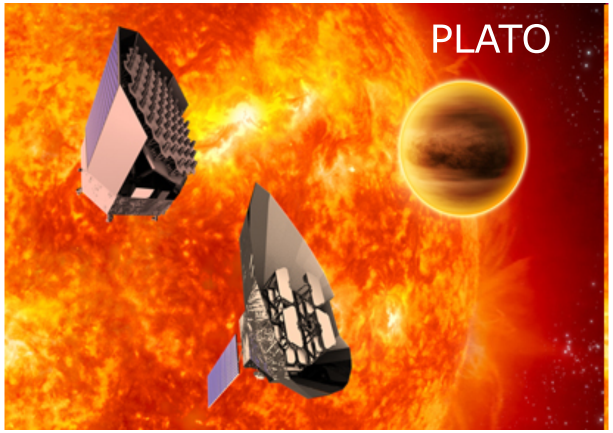
- Selection of Solar Orbiter as M1 and Euclid as M2 in 2011
- Selection of JUICE as L1 in 2012
- Selection of CHEOPS as S1 in 2012
- Selection of PLATO in early 2014 as M3
- Selection of ATHENA in June 2014 as L2

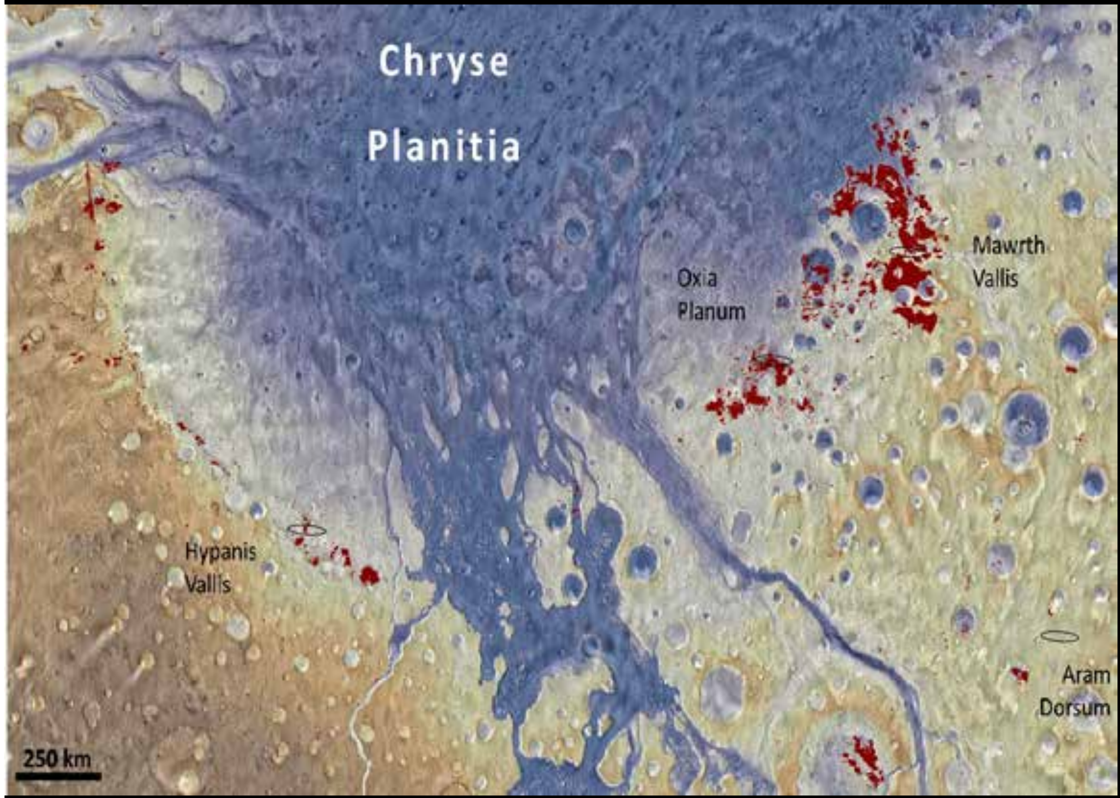




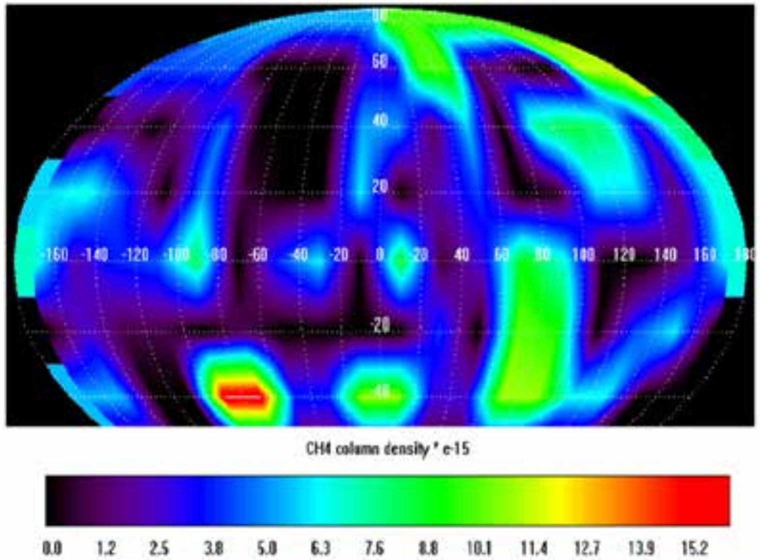



# OMEGA: Mapping hydrated minerals and sulfates



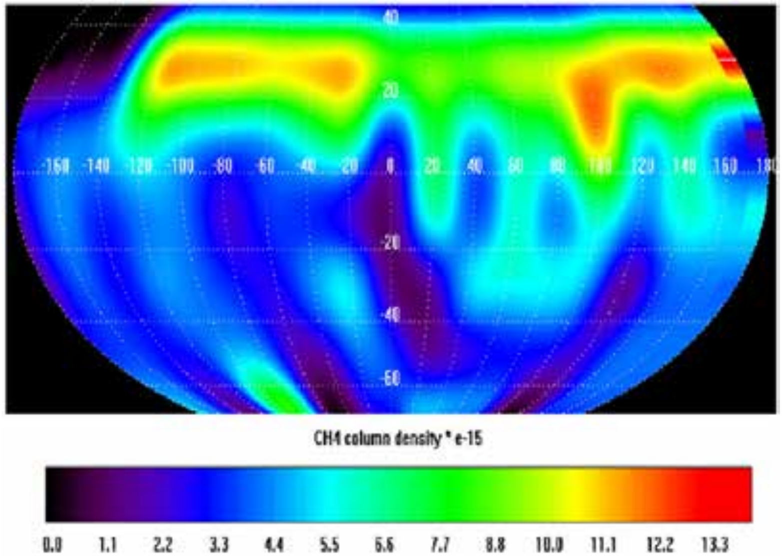

- **Reconstruction of the Martian paleo-climate**
  - Clays formed in Noachian (4.2-3.7 Gy) → wet and warm climate
  - Sulfates formed in Hesperian (3.7-3.0 Gy) → dry and more acid climate

# PFS:
# Seasonal variations of methane




Northern summer

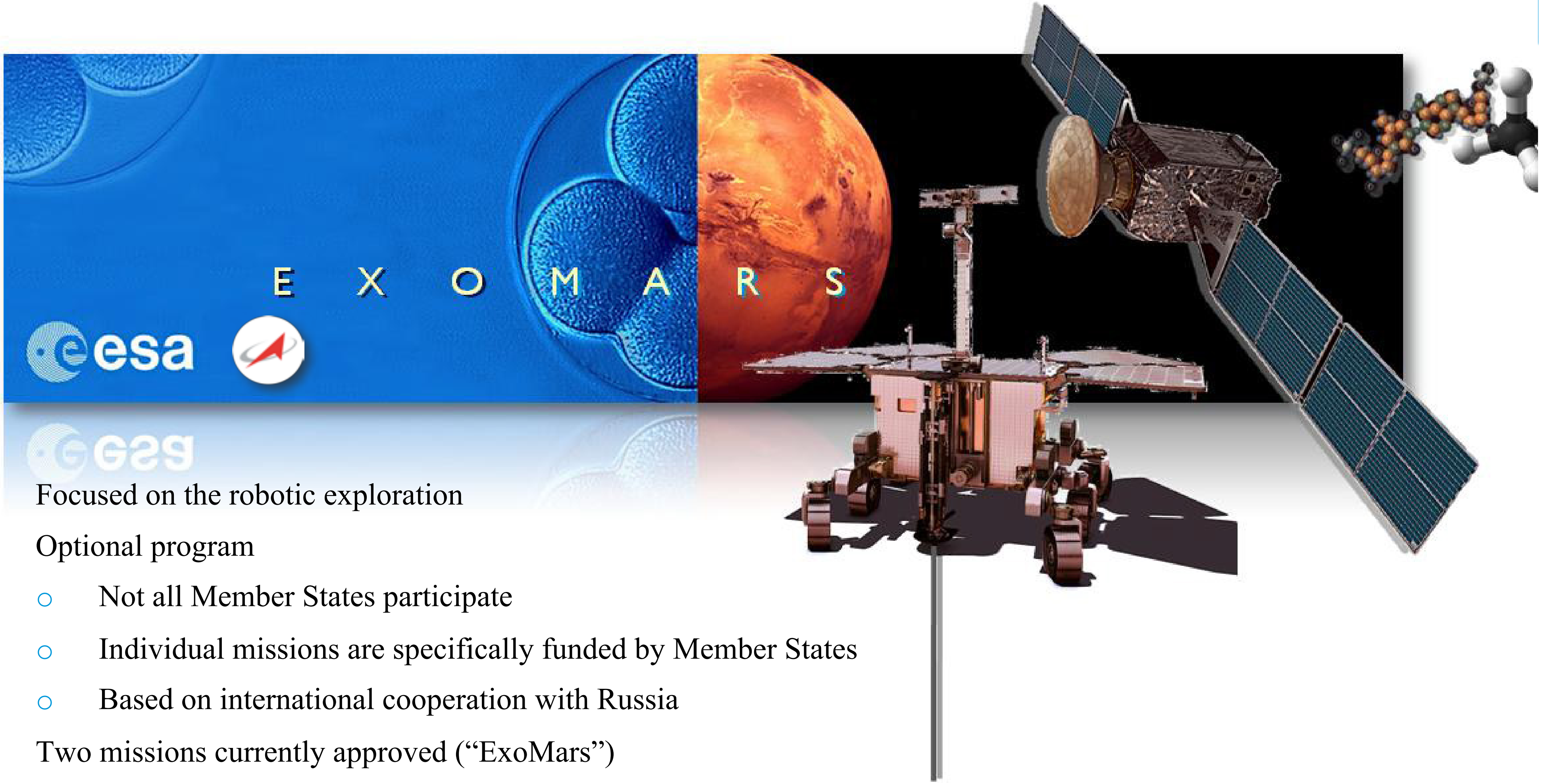
- **Methane mixing ratio 0-45 ppb**
- **Non-homogeneous distribution suggesting sources and sinks**
- **Increase of methane column density occurs in the winter hemisphere**
- **Observations of methane in Gale crater (Curiosity)**




Northern winter

*Formisano et al., 2004; Geminale et al., 2008, 2011*

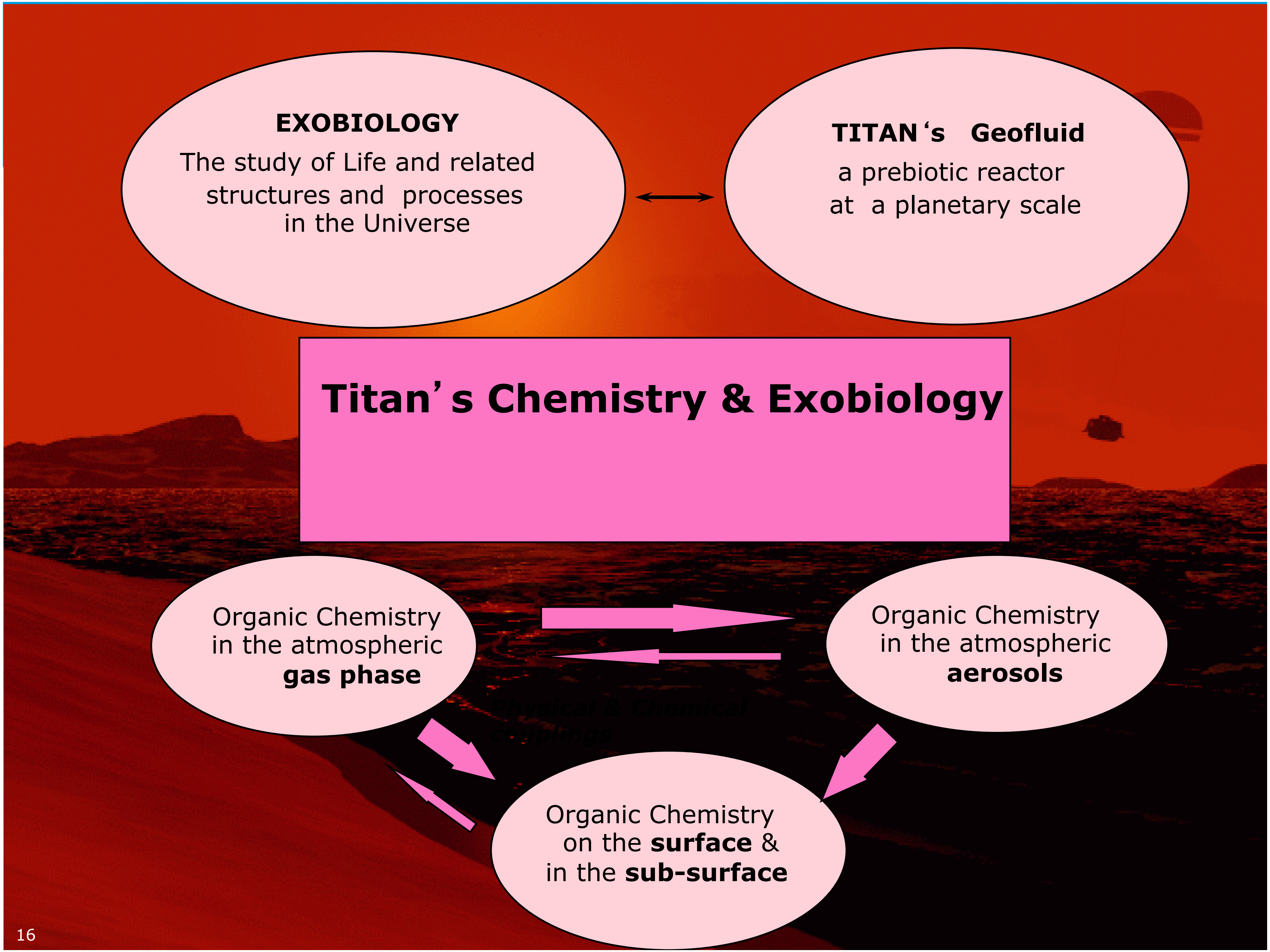
# The (optional)
# European Robotic Exploration Program



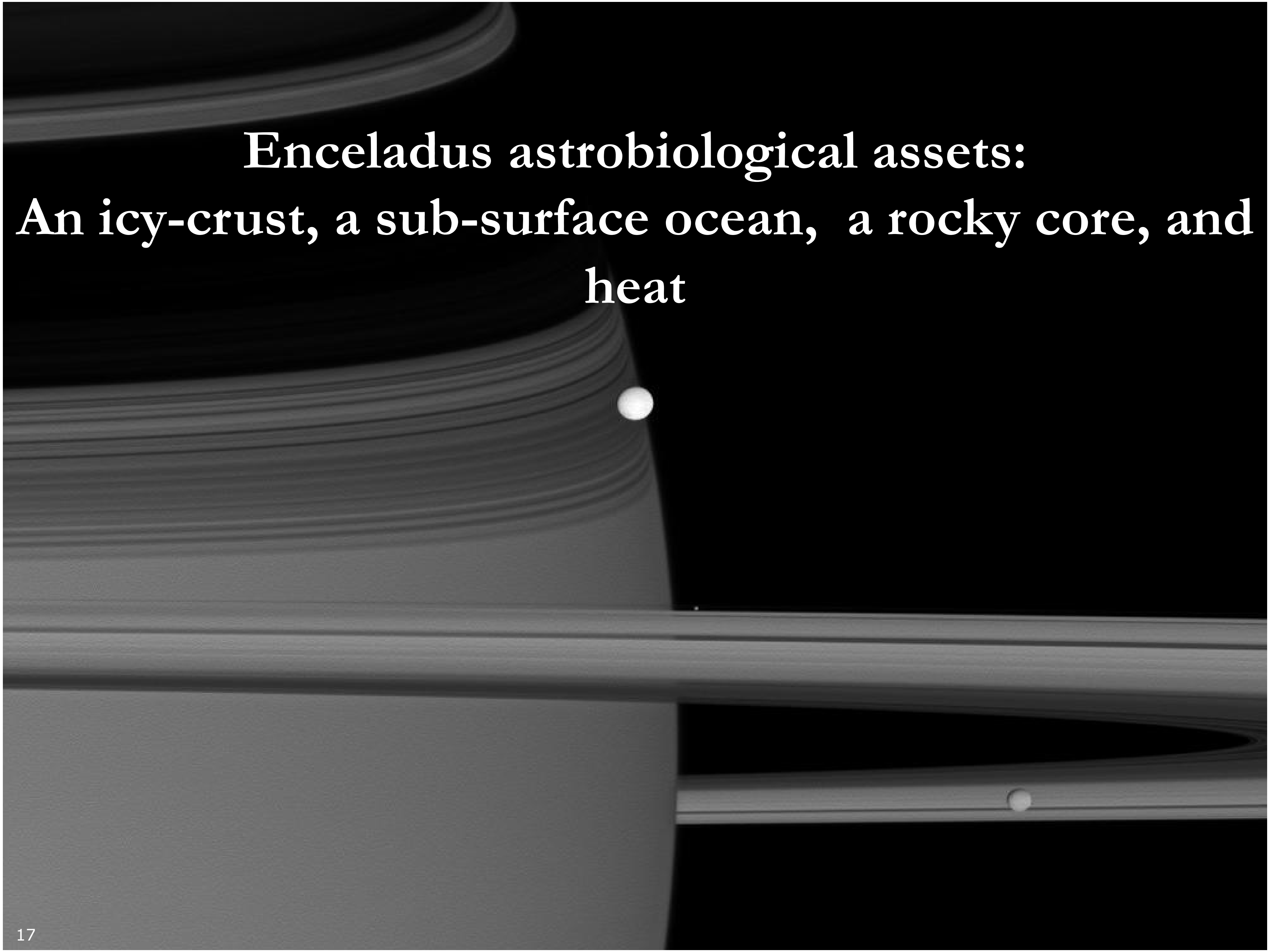

- Focused on the robotic exploration
- Optional program
  - Not all Member States participate
  - Individual missions are specifically funded by Member States
  - Based on international cooperation with Russia
- Two missions currently approved (“ExoMars”)
  - Trace gas orbiter (TGO) and Entry, Descent, and Landing Demonstrator Module (EDM) (2016)
  - Exo-biology rover with Pasteur P/L plus Surface Platform (2018)
- Long-term goal is Mars Sample Return

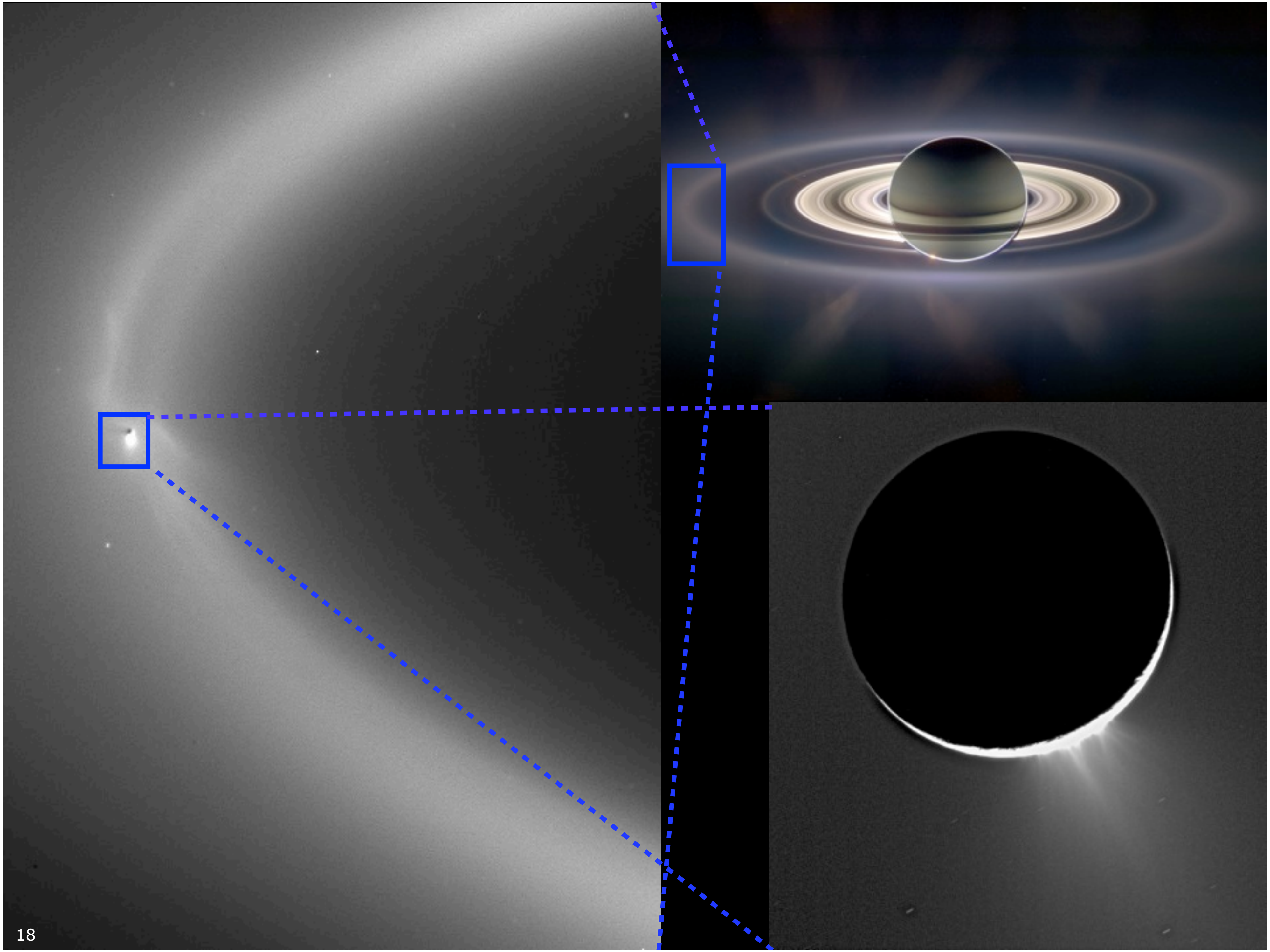
**First landing on a world in the outer Solar System**

In 2005, ESA's Huygens probe made the most distant landing ever, on Titan, the largest moon of Saturn (about 1427 million km from the Sun).

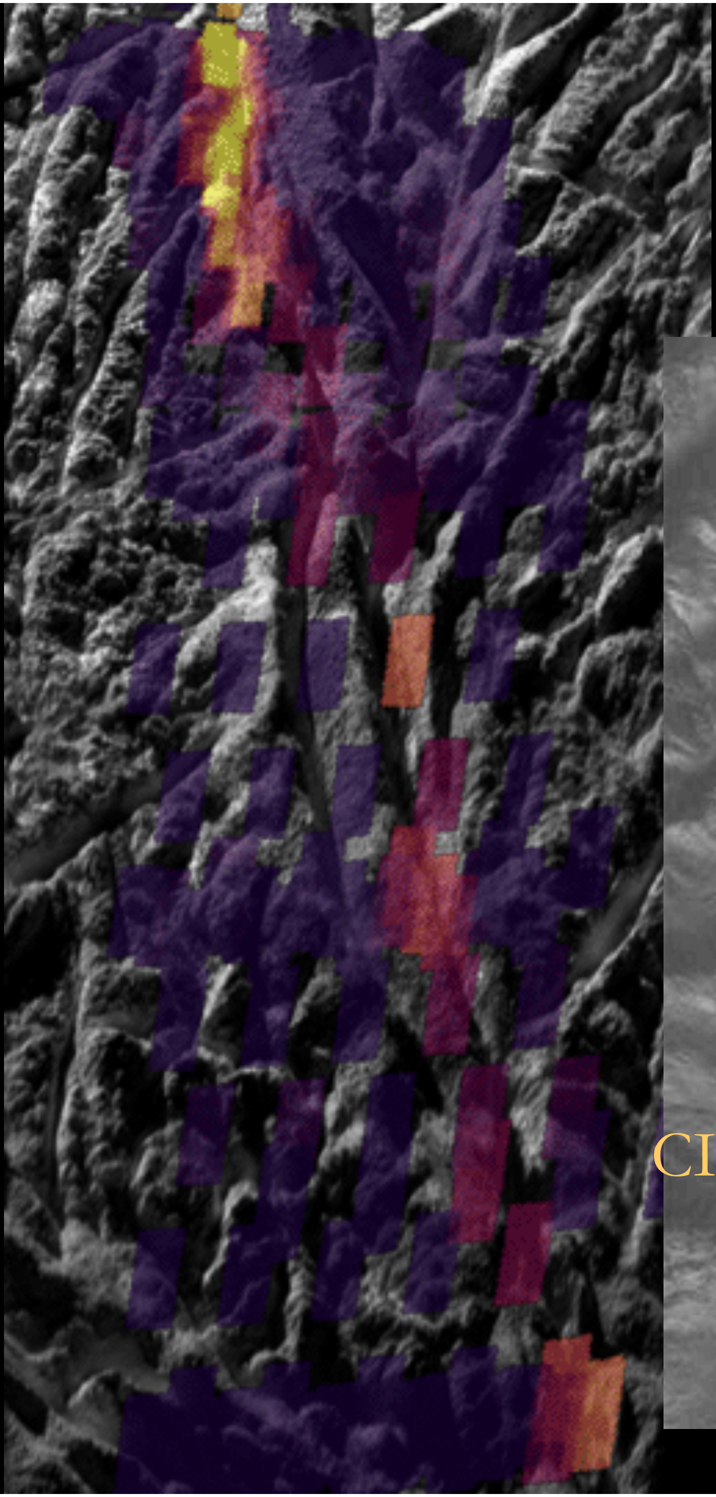

EXOBIOLOGY
The study of Life and related structures and processes in the Universe
TITAN's Geofluid
a prebiotic reactor at a planetary scale
Titan's Chemistry & Exobiology
Organic Chemistry in the atmospheric gas phase
Organic Chemistry in the atmospheric aerosols
Organic Chemistry on the surface & in the sub-surface

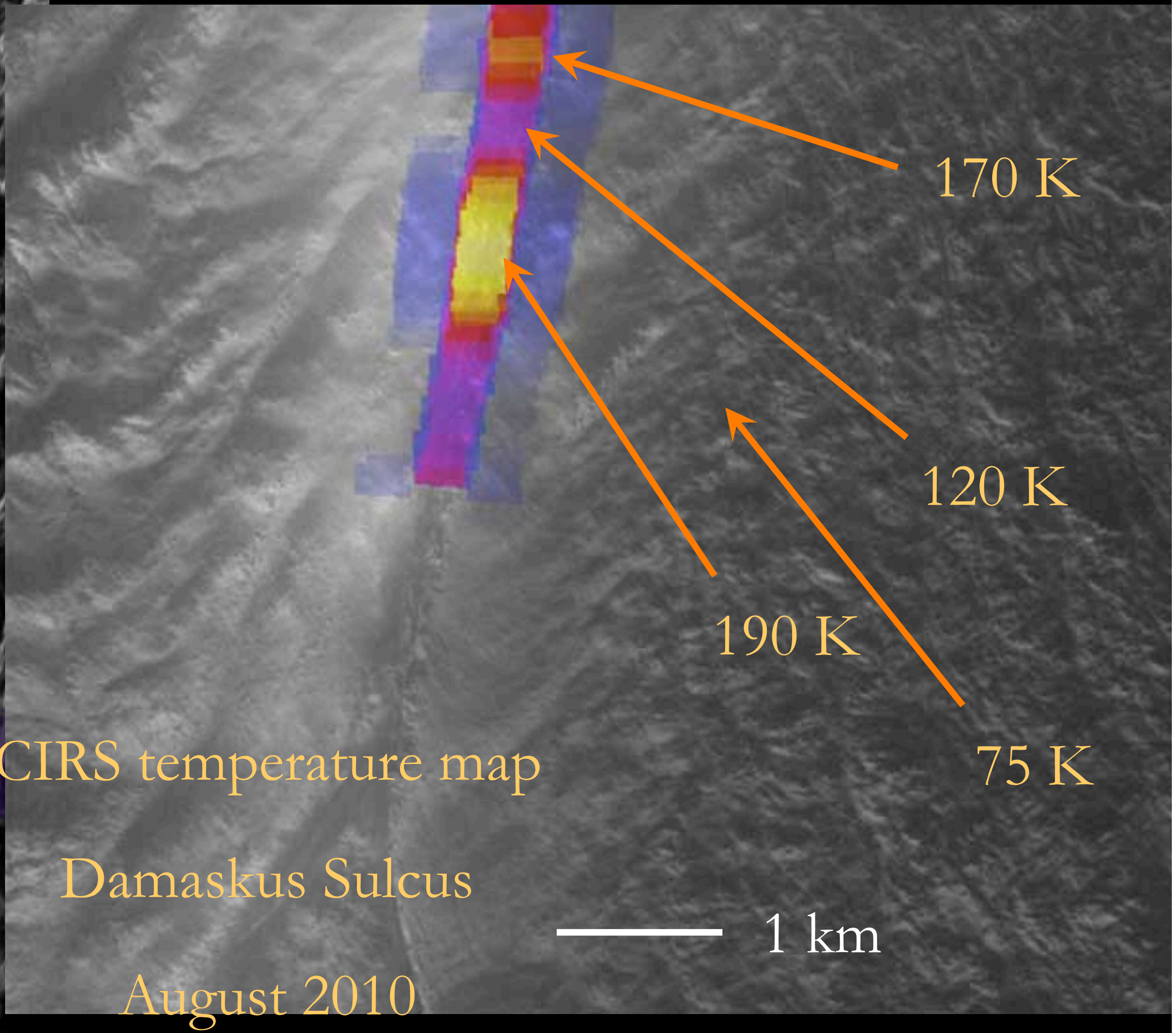
# Enceladus astrobiological assets: An icy-crust, a sub-surface ocean, a rocky core, and heat





Heat: generated by tidally driven frictions, due to Enceladus small orbit eccentricity around Saturn

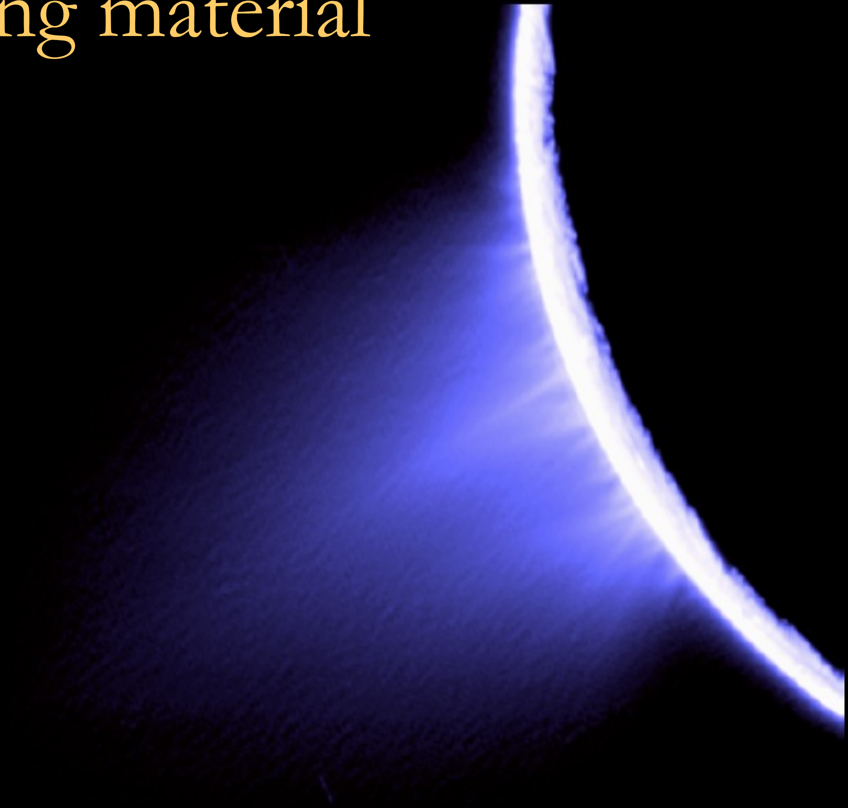




# Composition of escaping material

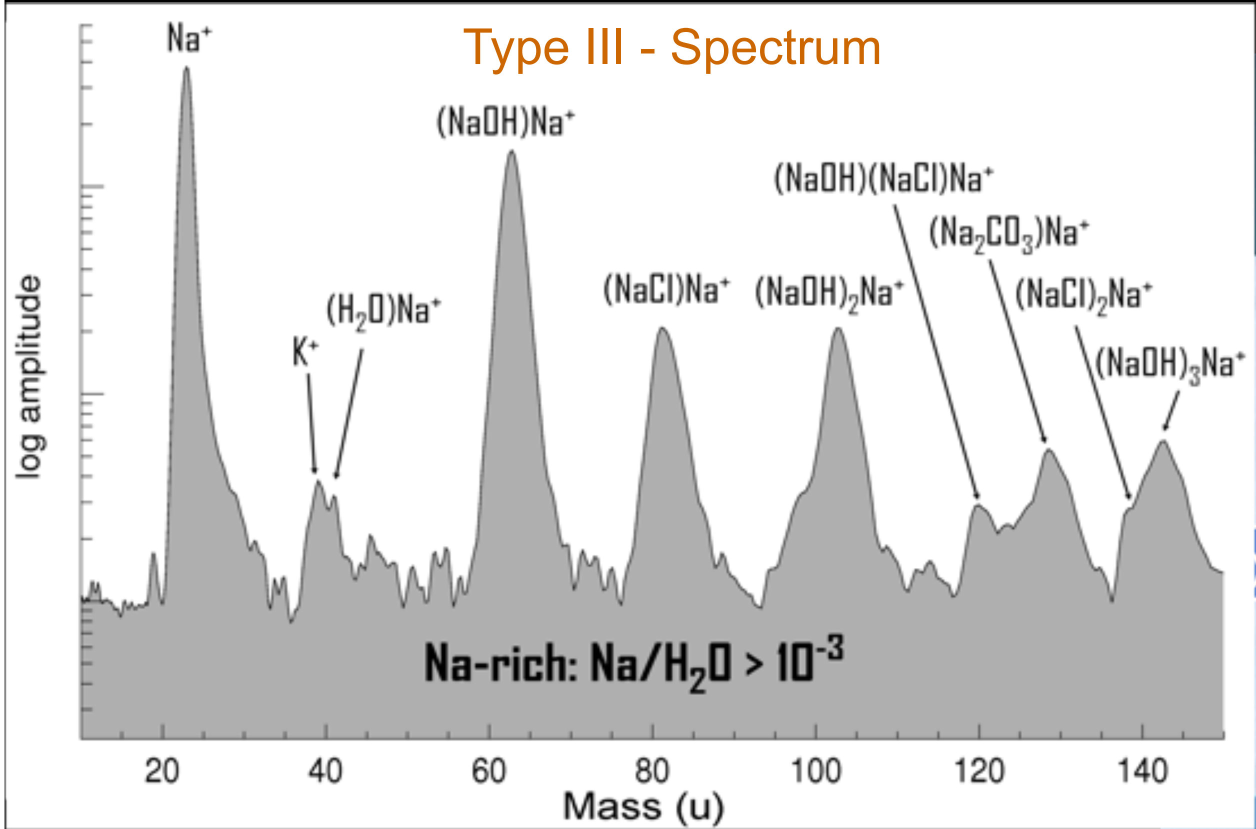
- Gas phase:
  - $H_2O$ > 92 %
  - $CO_2$ ~ 0.5 - 5%
  - volatile organics ~ 1 – 3 %
  - $NH_3$ ~ 1%
  - CO < 3%
  - $N_2$ < 0.5 %
  - Na < 0.0001 %

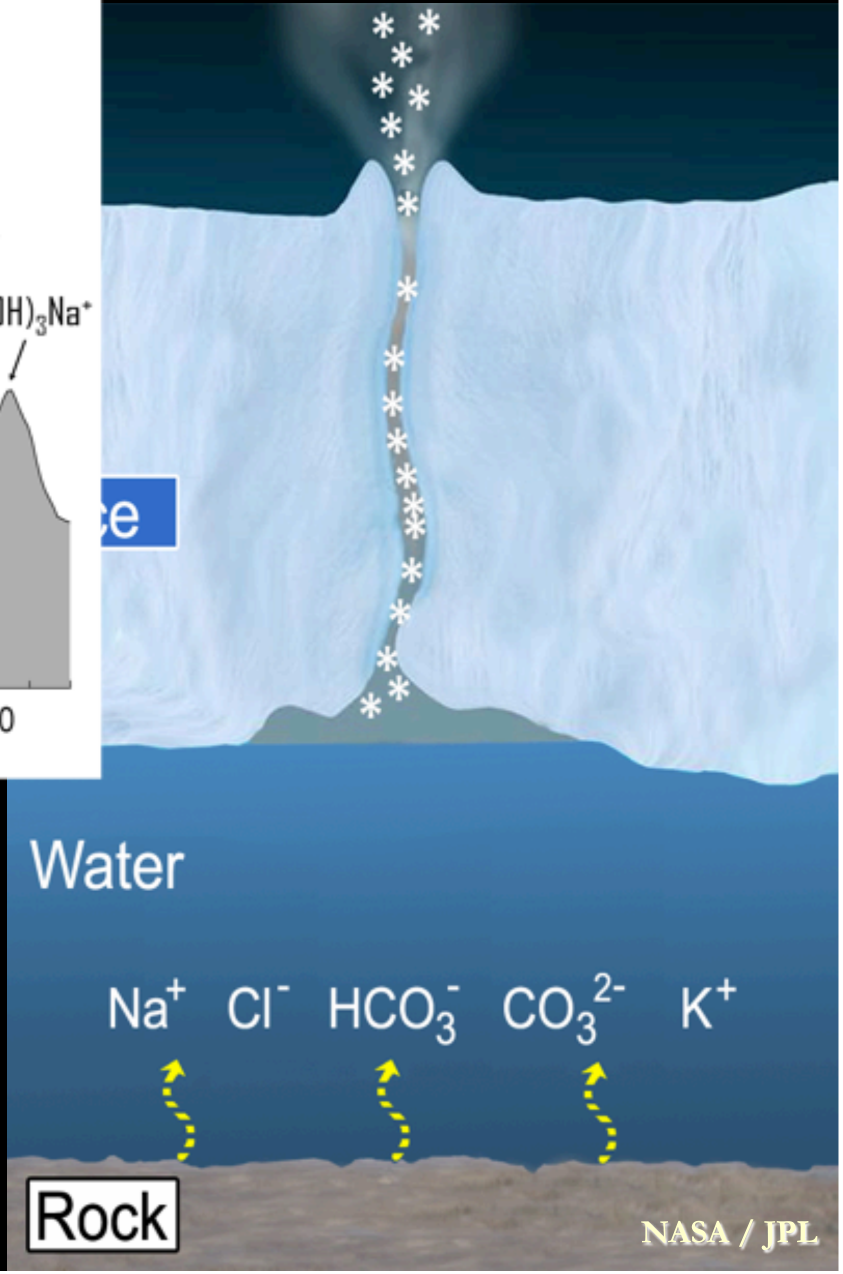
Waite et al, Science, 2006



# Composition of escaping material: solid phase

Postberg et al. Nature, 2011

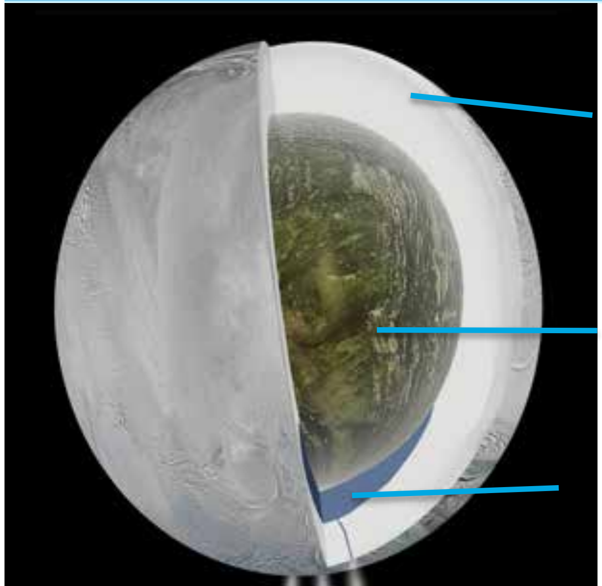



- 98% ice, 1 - 2% salts
- NaCl , $NaHCO_3$ / $Na_2CO_3$, KCl
- → saltwater with alkaline pH (8 – 9)

→ The water must be in contact with rocky core

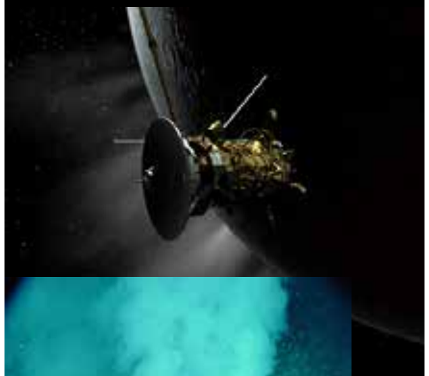
# Characterizing Enceladus sub-surface ocean Ocean extent and hydrothermal activity



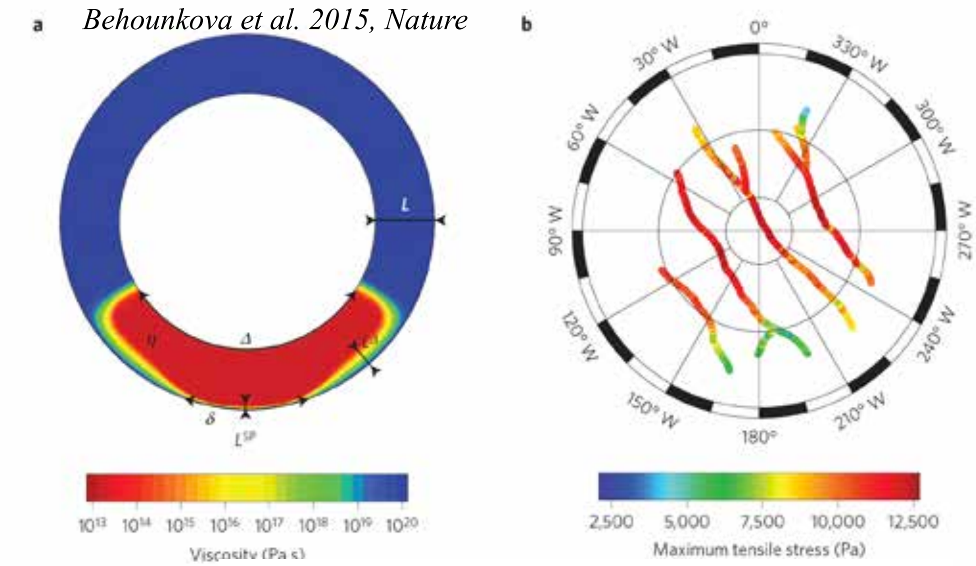
Outer ice shell
50 km thick

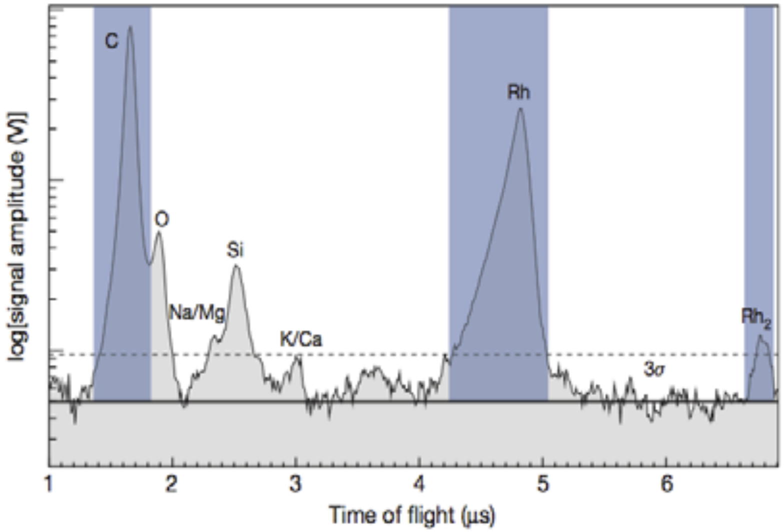
Silicate core
density 2.4
radius 200 km

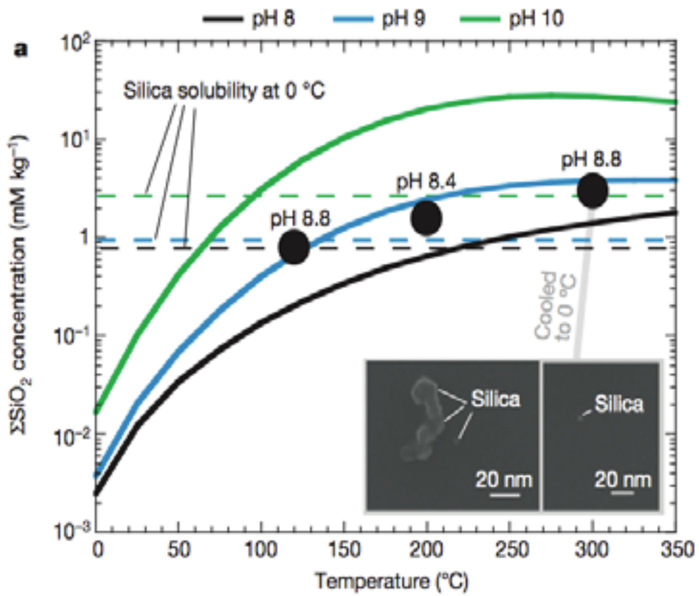
Regional ocean (**??**)
8-10 km deep, extending
to $50^0$ S



*Behounkova et al. 2015, Nature*



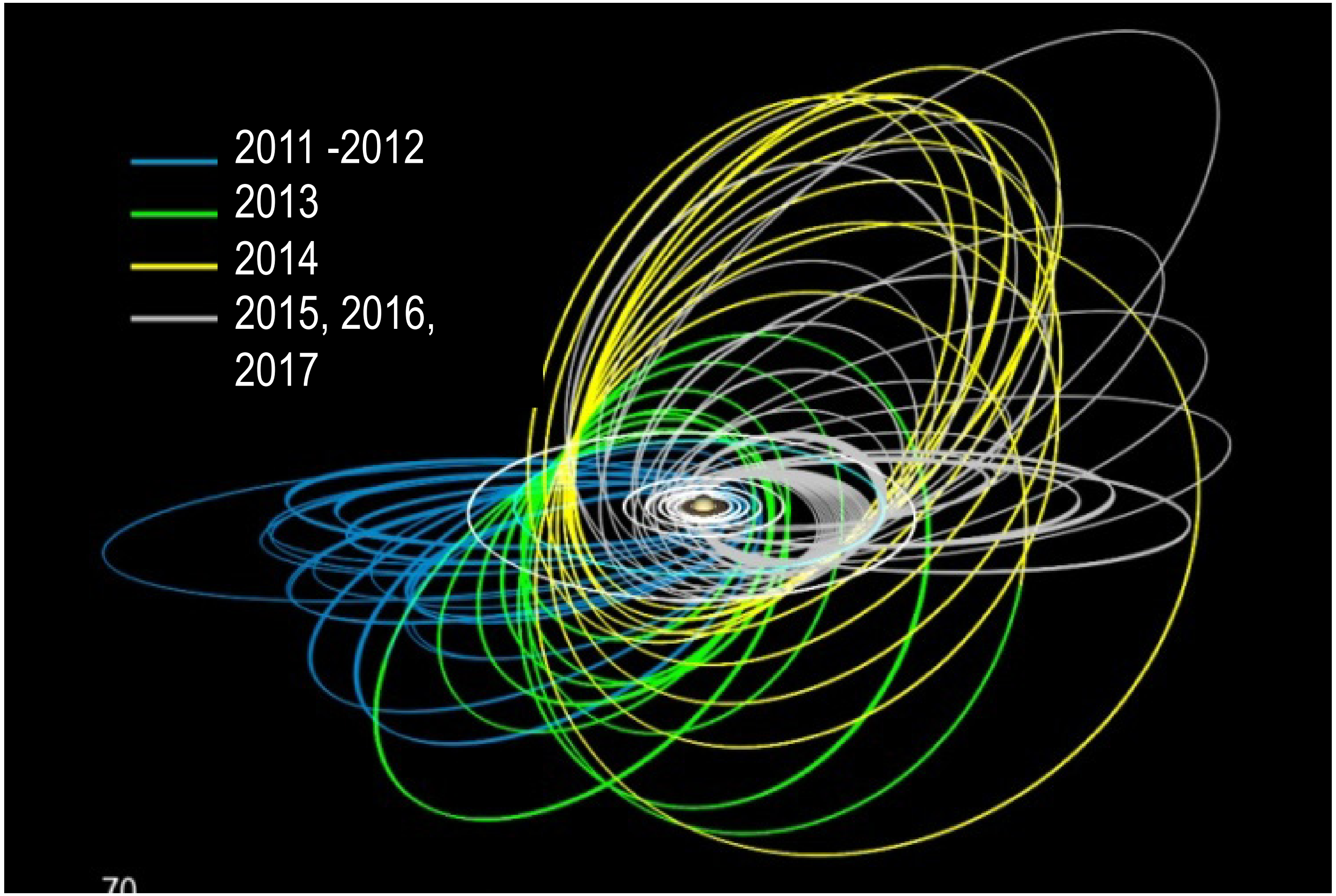




*Hsu et al. – Cassini-CDA team, 2015, Nature*

# Cassini Mission Overview: Trajectory

- Cassini is a 'Touring' mission
- Large variety of orbits, within and outside the equatorial plane
- Inclination steps changes reached through Titan targeted flybys [scientific purposes/fuel efficient navigation]



# JUICE: JUpiter Icy moons Explorer

esa
European Space Agency
Agence spatiale européenne

*Emergence of habitable worlds around gas giants*

*Jupiter system as an archetype for gas giants*

## Callisto:

*remnant of the early solar system*

- *Icy shell, ocean*
- *Geology, surface composition*
- *Past activity*

## Europa: *recently active zones*

- *Surface non-water-ice material*
- *Search for liquid water*
- *Recent activity*

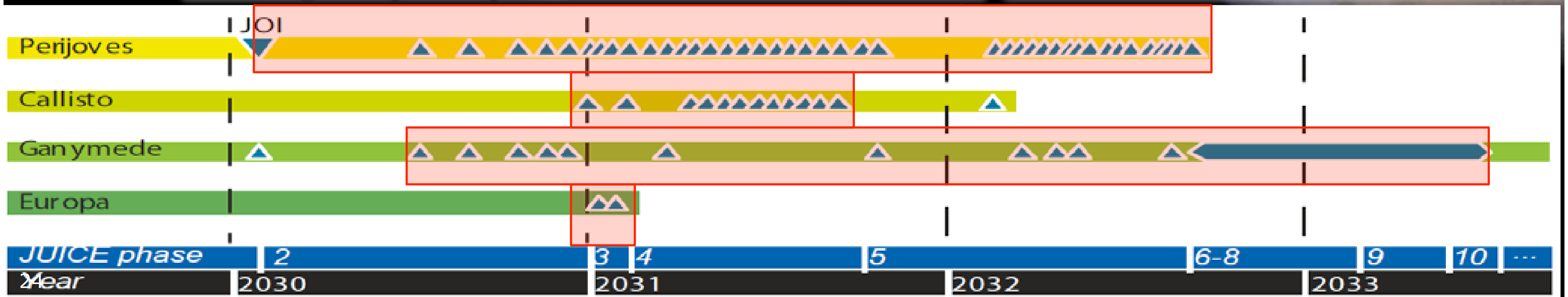
## Ganymede:

*planetary object and potential habitat*

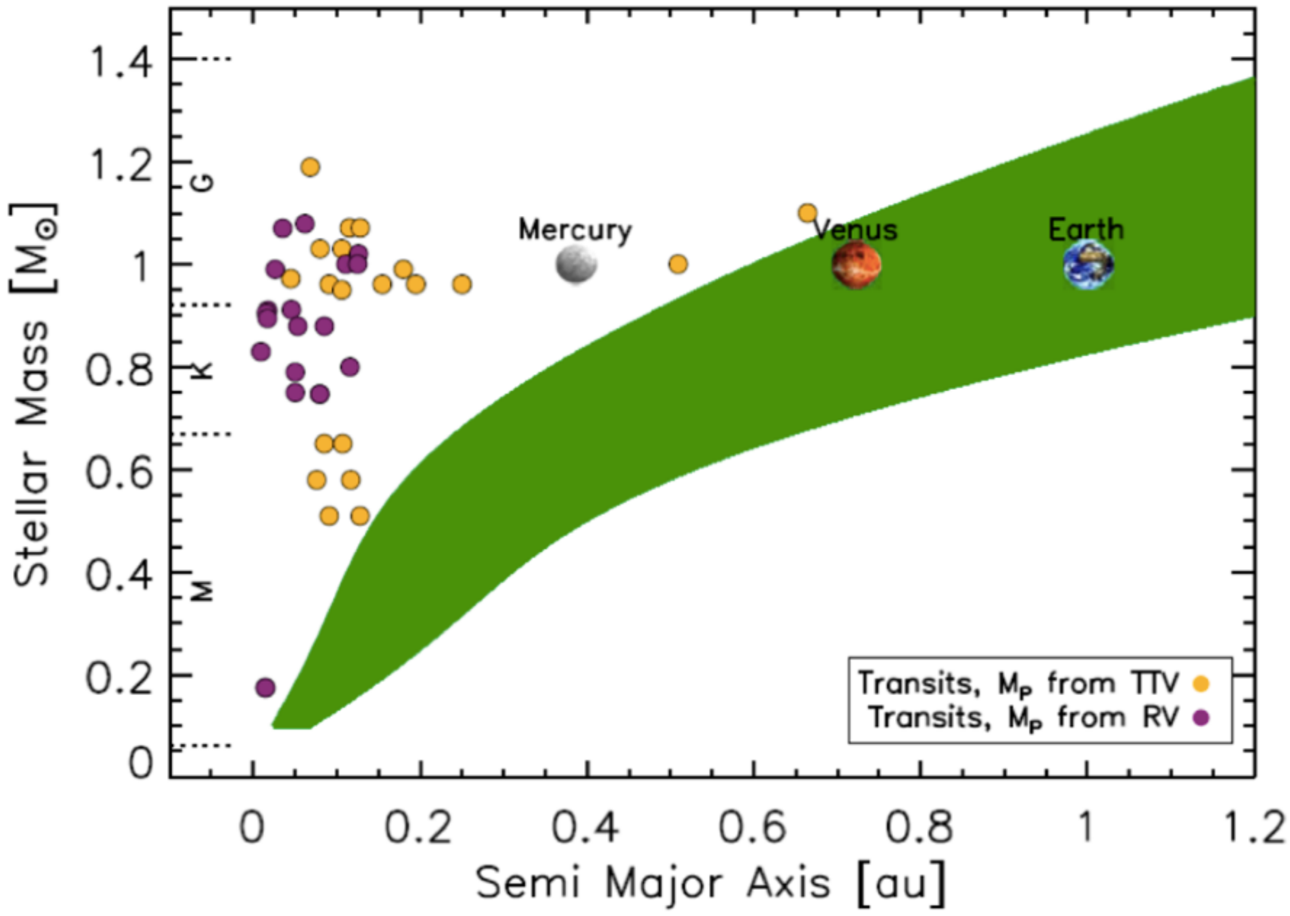
- *Sub-surface, ice shell, ocean, interiors*
- *Geology, surface composition*
- *Atmosphere, ionosphere*
- *Magnetosphere, plasma environment*

## Jupiter System:

- *Atmospheric structure, chemistry and dynamics*
- *Magnetosphere as fast rotator and giant accelerator*
- *Moons as plasma sources and sinks*
- *Couplings and interactions*



# Exo planets



Stellar Mass [M⊙]
Semi Major Axis [au]
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
1.2
G
K
M
Mercury
Venus
Earth
Transits, $M_P$ from TTV
Transits, $M_P$ from RV

# CHEOPS: an S-class mission

- First S (small) - class mission in the ESA Science Programme
- Implemented in partnership with Switzerland, with a consortium comprising a large number of ESA member states (Austria, Belgium, France, Germany, Hungary, Italy, Portugal, Spain, Sweden, UK)
- Boundary conditions:
    - High TRL for platform and payload→ development time < 3.5 – 4 yrs
    - Total cost to ESA limited to about 0.1 yearly budget

- Selected December 2012, adopted June 2014, launch-ready end 2017 – fast!

CHEOPS

cheops

esa

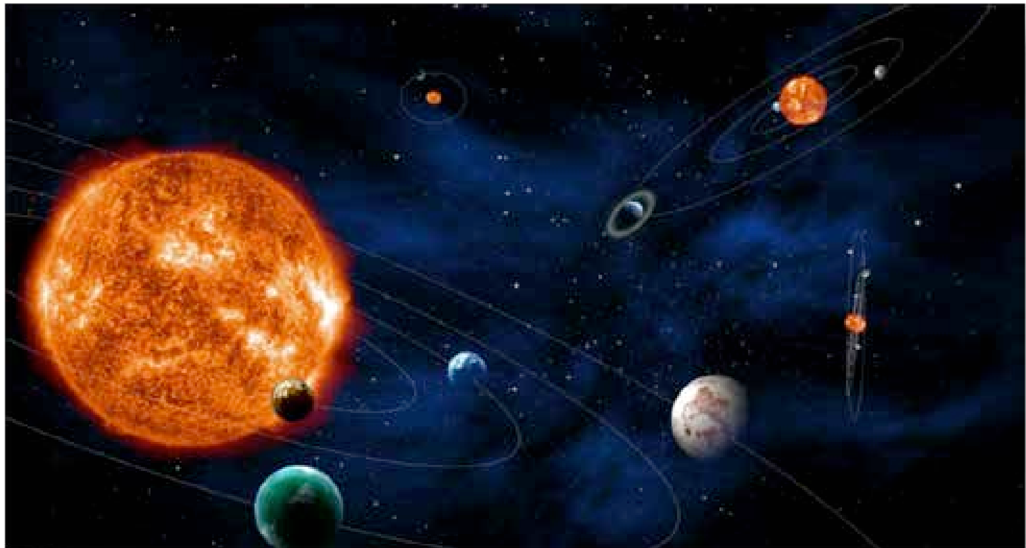
# CHEOPS science

- CHEOPS (CHaracterising ExOPlanet Satellite) – a mission dedicated to the search for exoplanet transits of local, bright stars already known to host exoplanets:

  - Detection and characterisation of transiting exoplanets with masses < 30 $M_{earth}$ through precision, wideband transit photometry
  - Follow-up, pointed observations:
    - Known exoplanets → Follow-up mission → Pointed observations, know where and when to point
    - Bright host stars (V<12) → precise mass measurements available /feasible, detailed knowledge of the star
  - First-step characterisation of super-Earths and Neptunes: precision masses+radii → measurement of bulk density
    - Insight into physics and formation of planets
    - Identification of planets with atmospheres
    - Constraints on planet migration
  - Identification of "golden targets" for spectroscopic characterisation
  - Probing atmospheres of hot-Jupiters using phase curve measurements
    - Study of physical mechanisms and efficiency of energy transport

# PLATO
# Scientific Objectives

- Detect and characterise Earth-like planets (1-10 Earth masses, 1-2 Earth radii) in the habitable zone of bright solar like stars:
    - radii (down to 2% accuracy, photometric transit method)
    - masses (~10% accuracy, from radial velocity follow-up at ground-based telescopes)
    - mean densities
    - ages (~10% accuracy, astero-seismology analysis)
    - host stars knowledge
- Detect and characterise thousands of rocky, icy and giant planets, the architecture of their planetary system and their host star
- Advance stellar science

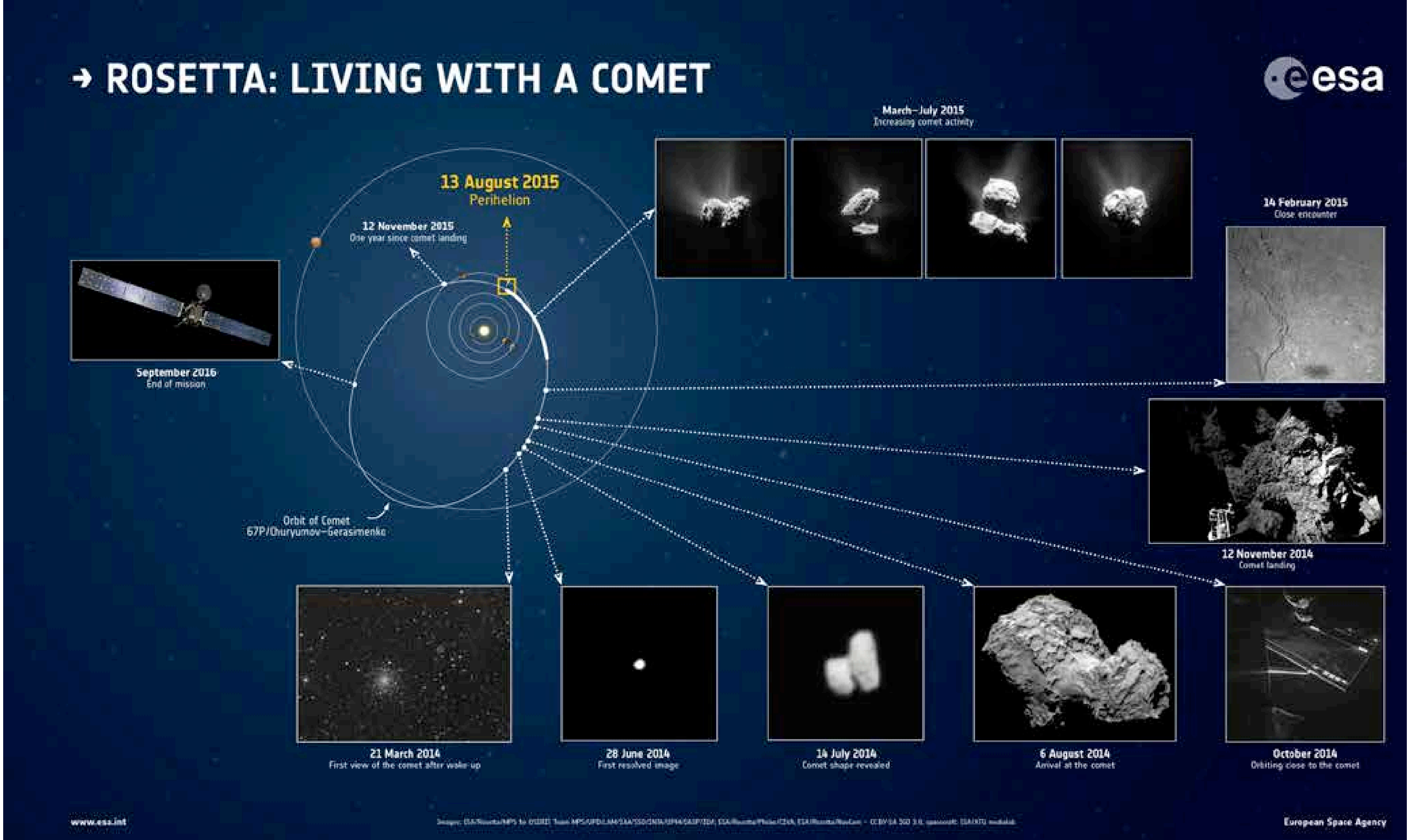


# PLATO targets and habitability

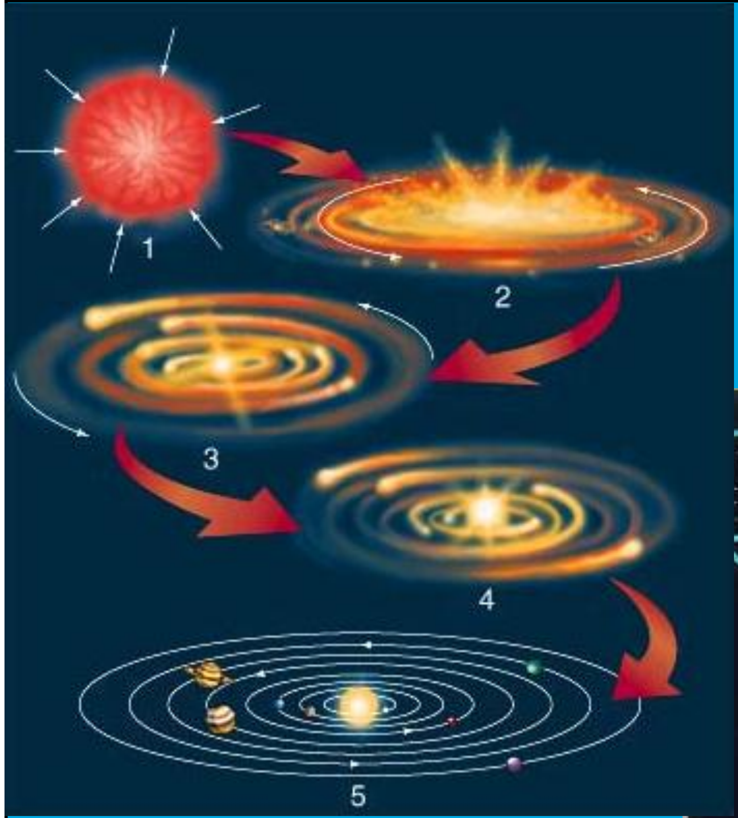
- Planets in the habitable zone of solar like stars (F5V-K7V)
  - Enough precision in radius and mass to distinguish terrestrial planets from mini-gas planets

    => Identify prime candidates for potentially habitable worlds
  - Enough precision in age to study Earth-like planets at different epochs
- Well characterised planets around the brightest stars for atmospheric spectroscopic observations with other facilities
- Host stars studied with unprecedented accuracy-> Influence of stellar age, stellar type and stellar activity in habitability
- Populations of planets in circumbinary systems and around late type stars
- Exo-moons and their environment

# The ESA Rosetta Mission



# Why comets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2
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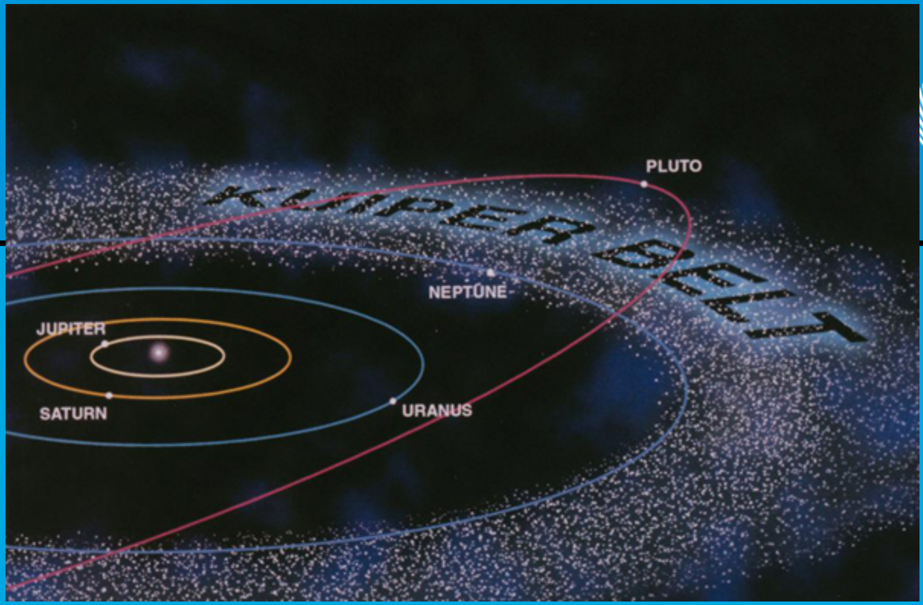
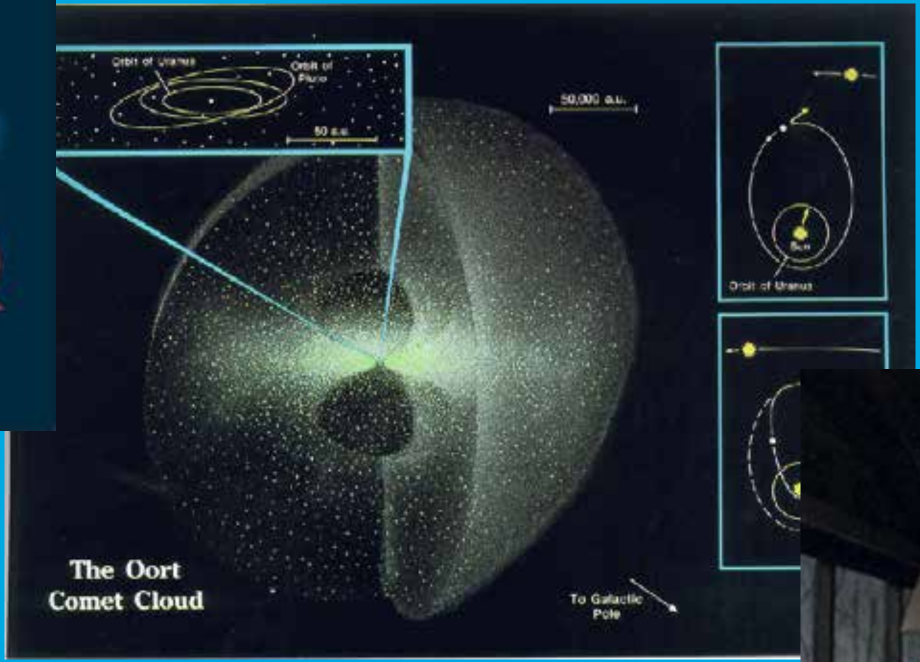
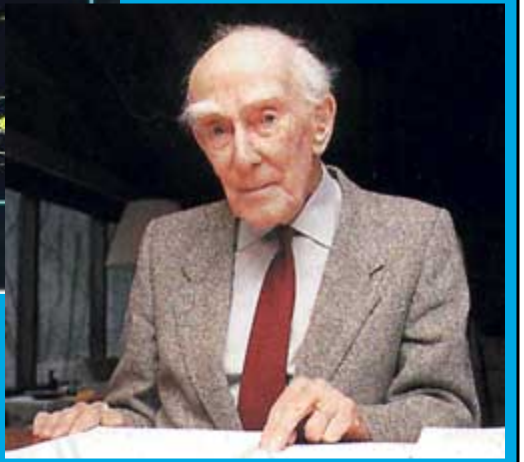
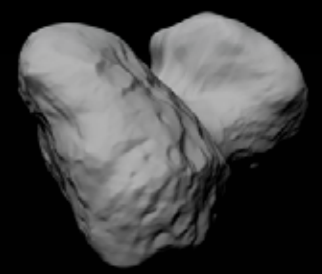
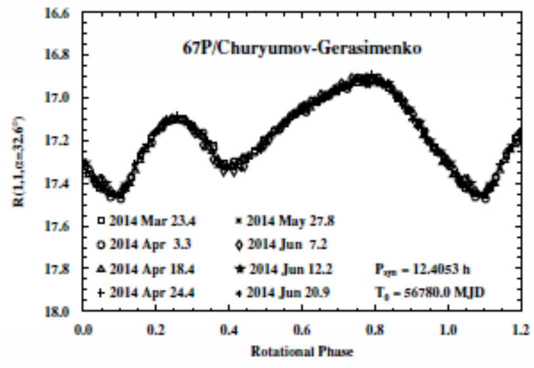

KUIPER BELT
PLUTO
NEPTUNE
JUPITER
SATURN
URANUS


50,000 a.u.
The Oort
Comet Cloud
To Galactic
Pole

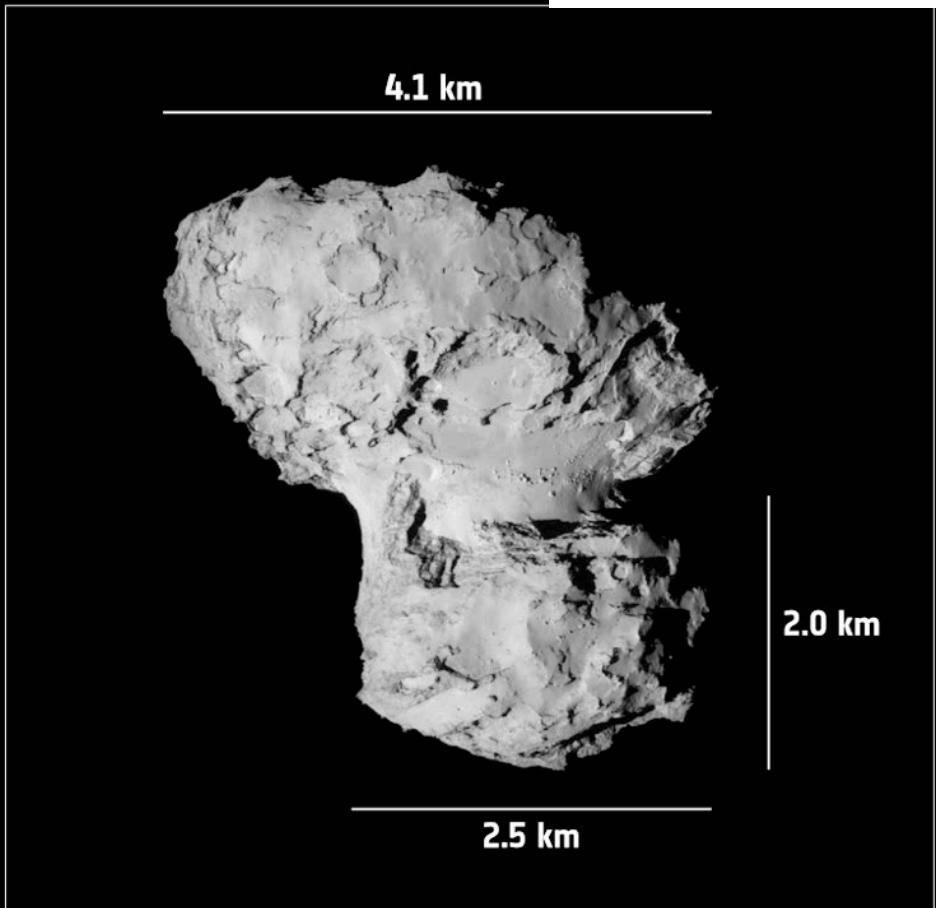


# Target: 67P/Churyumov-Gerasimenko






Mass ~ $10^{13}$ kg
Volume ~ 25 $km^3$
Density ~ 0.4g/$cm^3$
Rotation ~ 12.4 hour



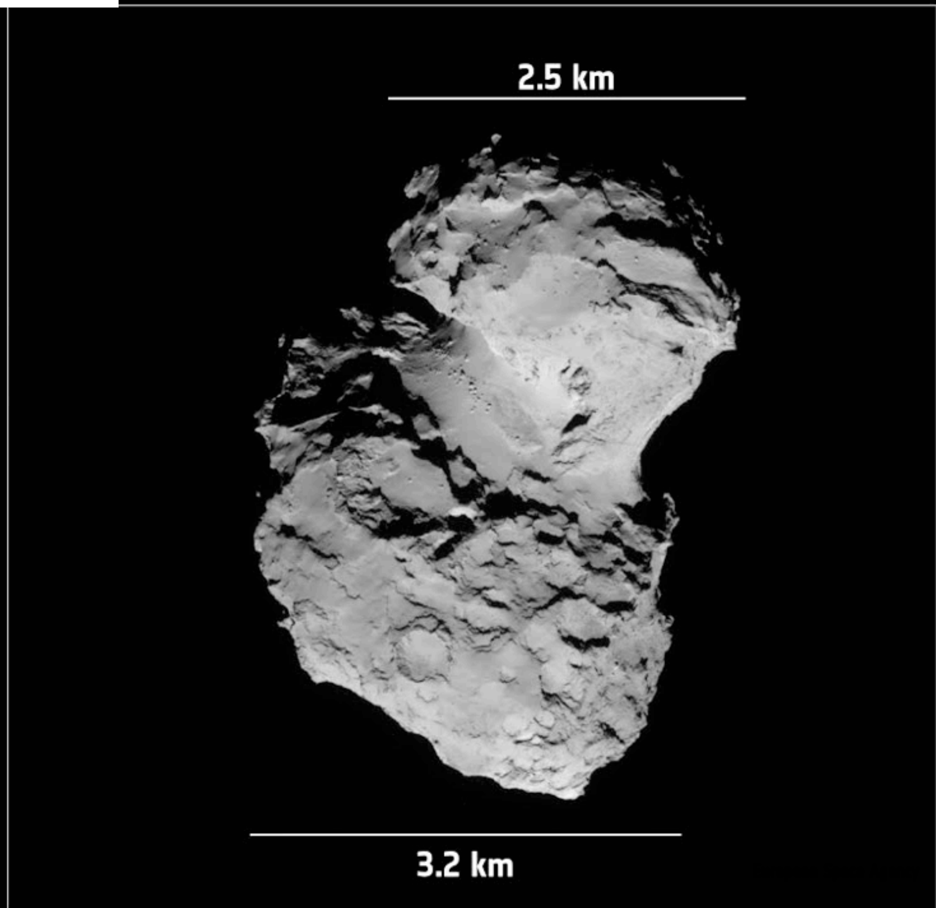
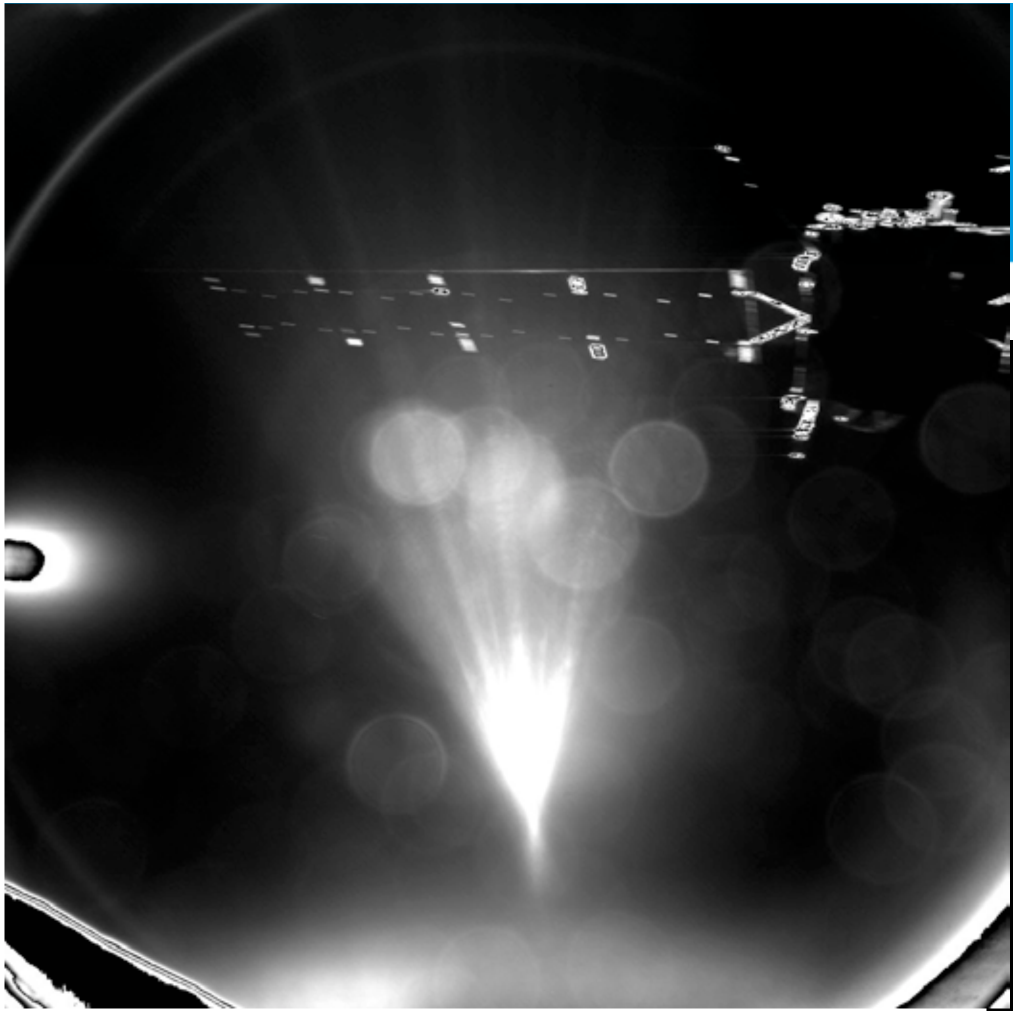
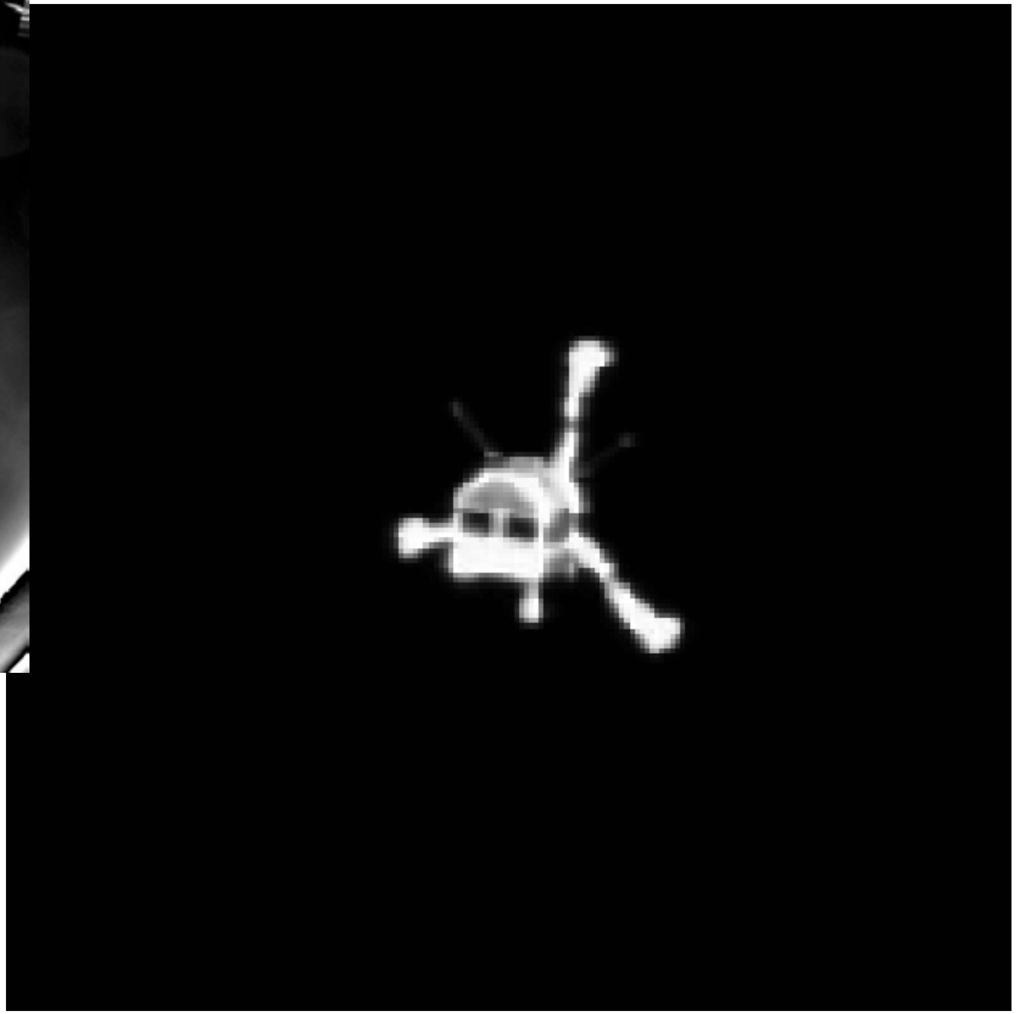



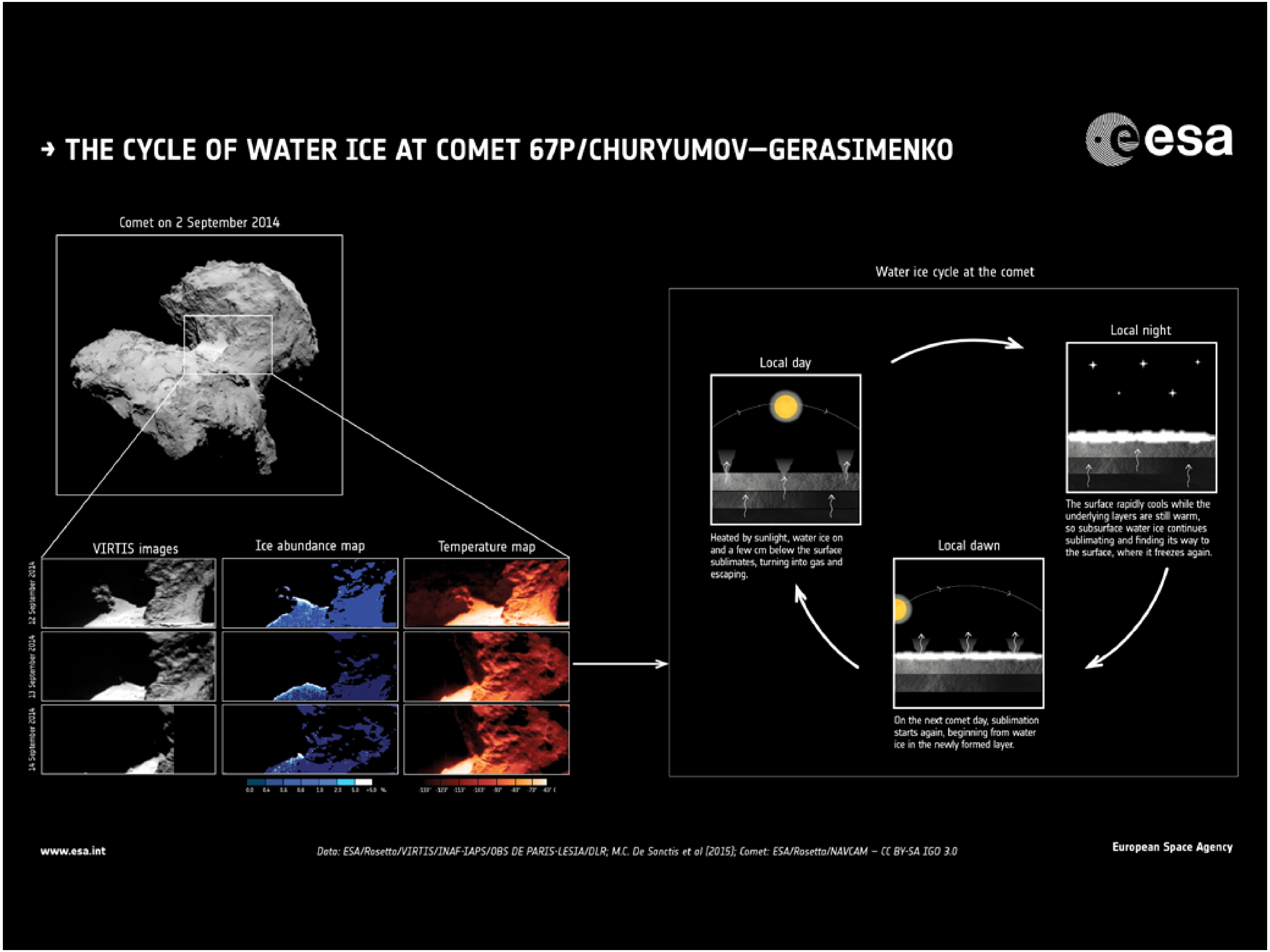

Image: ESA/Rosetta/NAVCAM; Dimensions: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA



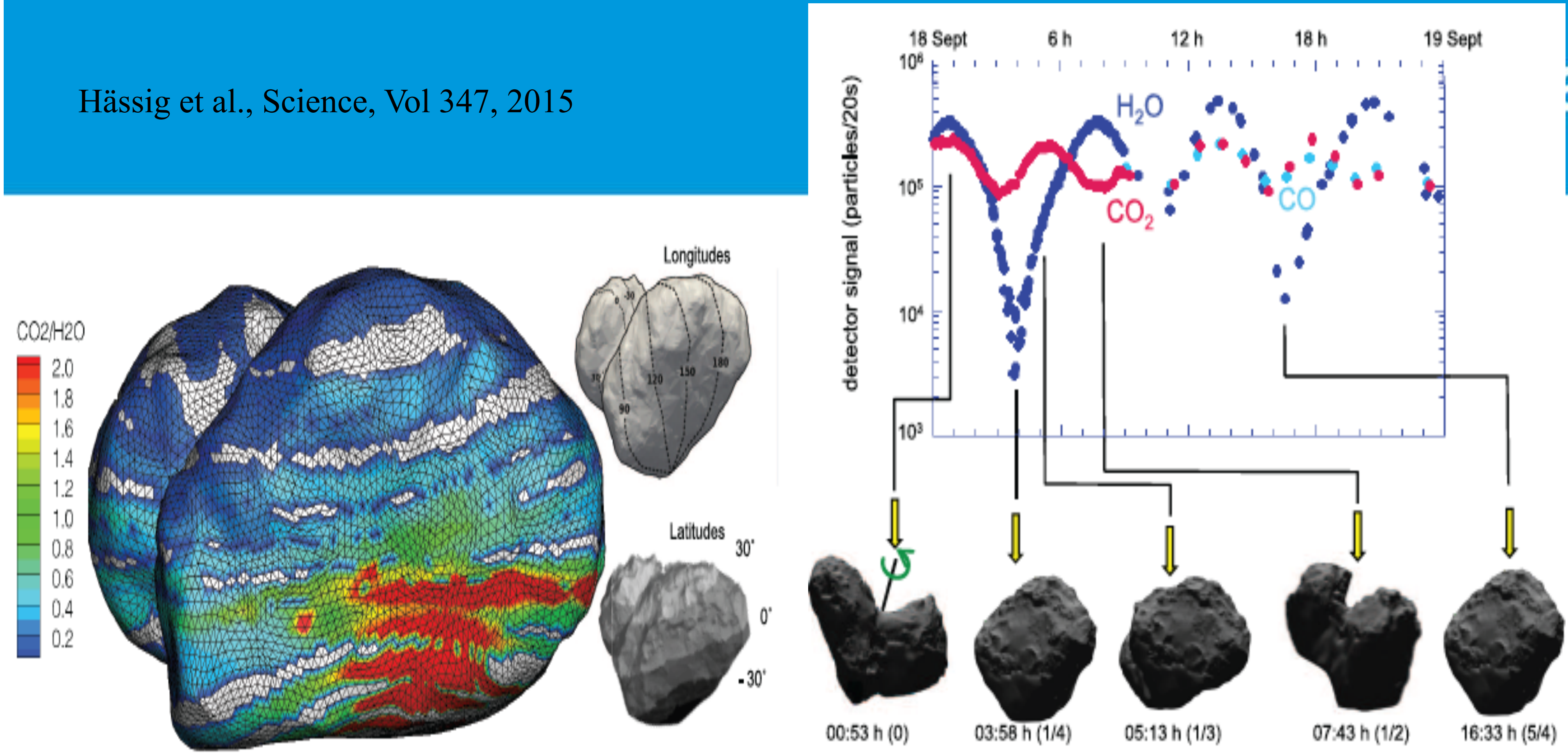
ESA/Rosetta/Philae/CIVA



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


→ THE CYCLE OF WATER ICE AT COMET 67P/CHURYUMOV–GERASIMENKO
esa
Comet on 2 September 2014
VIRTIS images
Ice abundance map
Temperature map
12 September 2014
13 September 2014
14 September 2014
Water ice cycle at the comet
Local day
Heated by sunlight, water ice on and a few cm below the surface sublimates, turning into gas and escaping.
Local night
The surface rapidly cools while the underlying layers are still warm, so subsurface water ice continues sublimating and finding its way to the surface, where it freezes again.
Local dawn
On the next comet day, sublimation starts again, beginning from water ice in the newly formed layer.
www.esa.int
Data: ESA/Rosetta/VIRTIS/INAF-IAPS/OBS DE PARIS-LESIA/DLR; M.C. De Sanctis et al (2015); Comet: ESA/Rosetta/NAVCAM – CC BY-SA IGO 3.0
European Space Agency

Hässig et al., Science, Vol 347, 2015

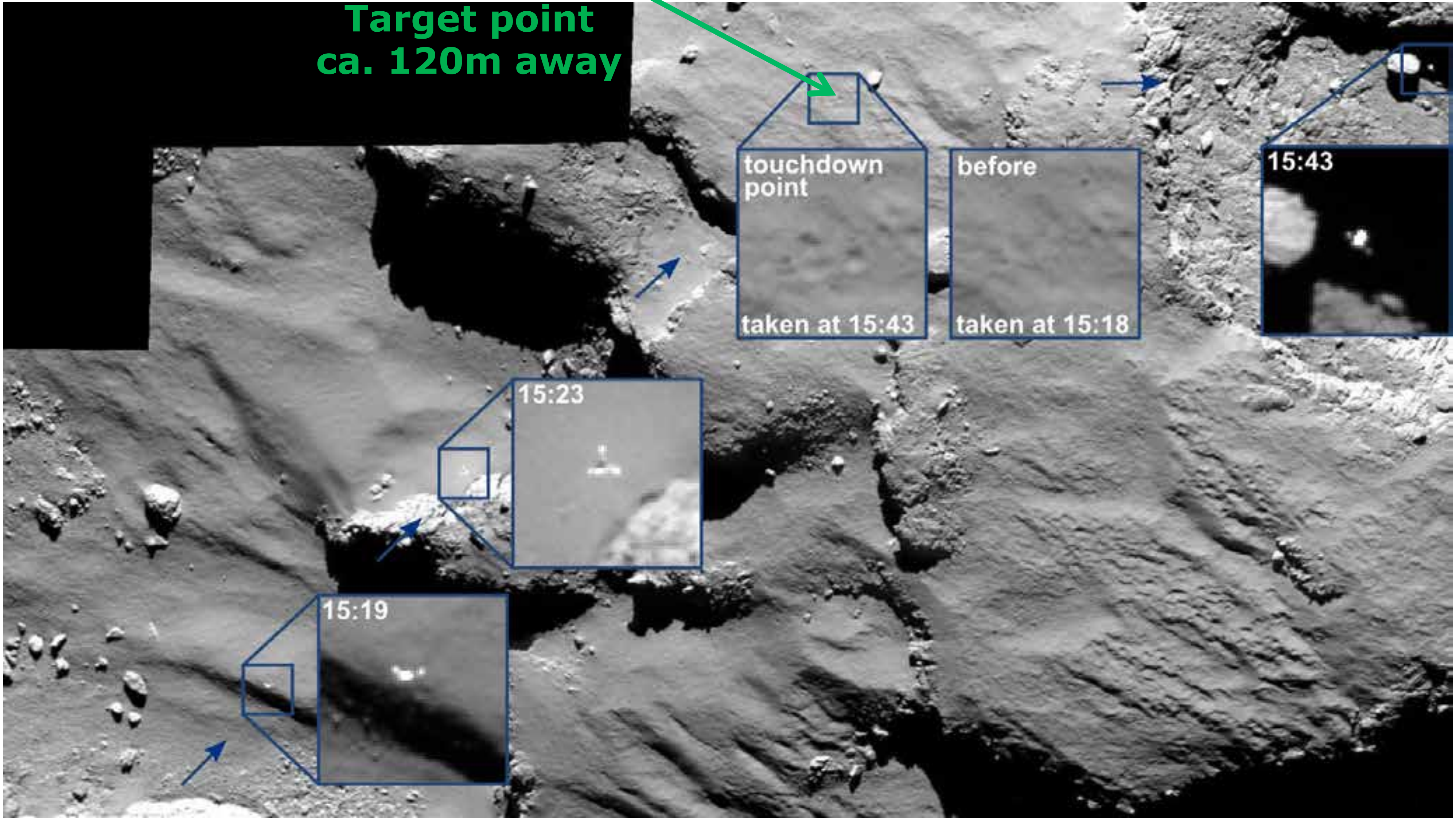


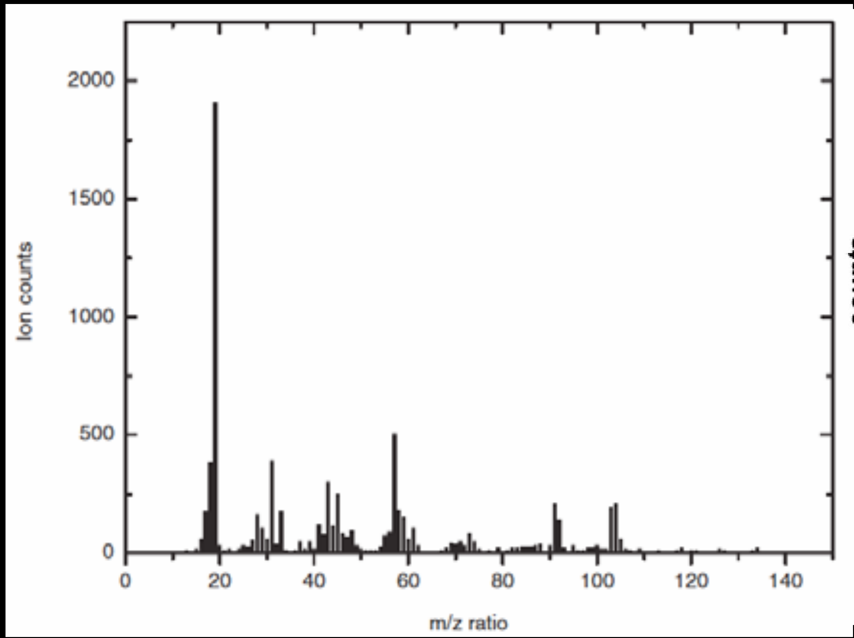

ESA/ROSETTA/ROSINA

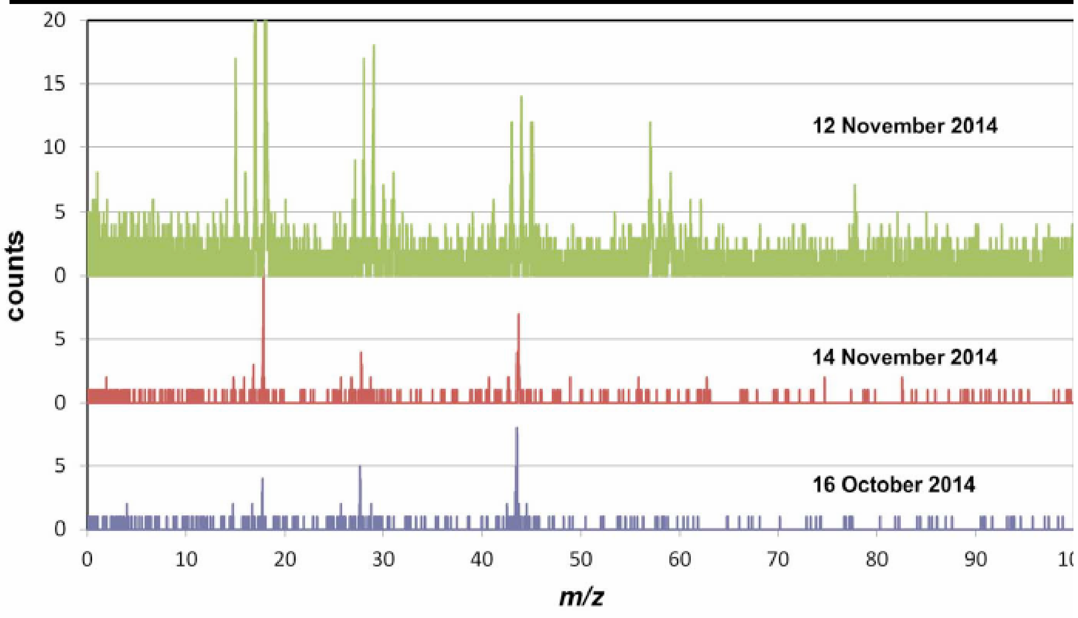
Water ($H_2O$)
Carbon monoxide (CO)
Carbon dioxide ($CO_2$)
Ammonia ($NH_3$)
Methane ($CH_4$)
Methanol ($CH_3OH$)

Formaldehyde ($CH_2O$)
Hydrogen sulphide ($H_2S$)
Hydrogen cyanide (HCN)
Sulphur dioxide ($SO_2$)
Carbon disulphide ($CS_2$)

# Landing


Target point
ca. 120m away
touchdown point
taken at 15:43
before
taken at 15:18
15:43
15:23
15:19




Wright et al., 2015    Goesmann et al., 2015

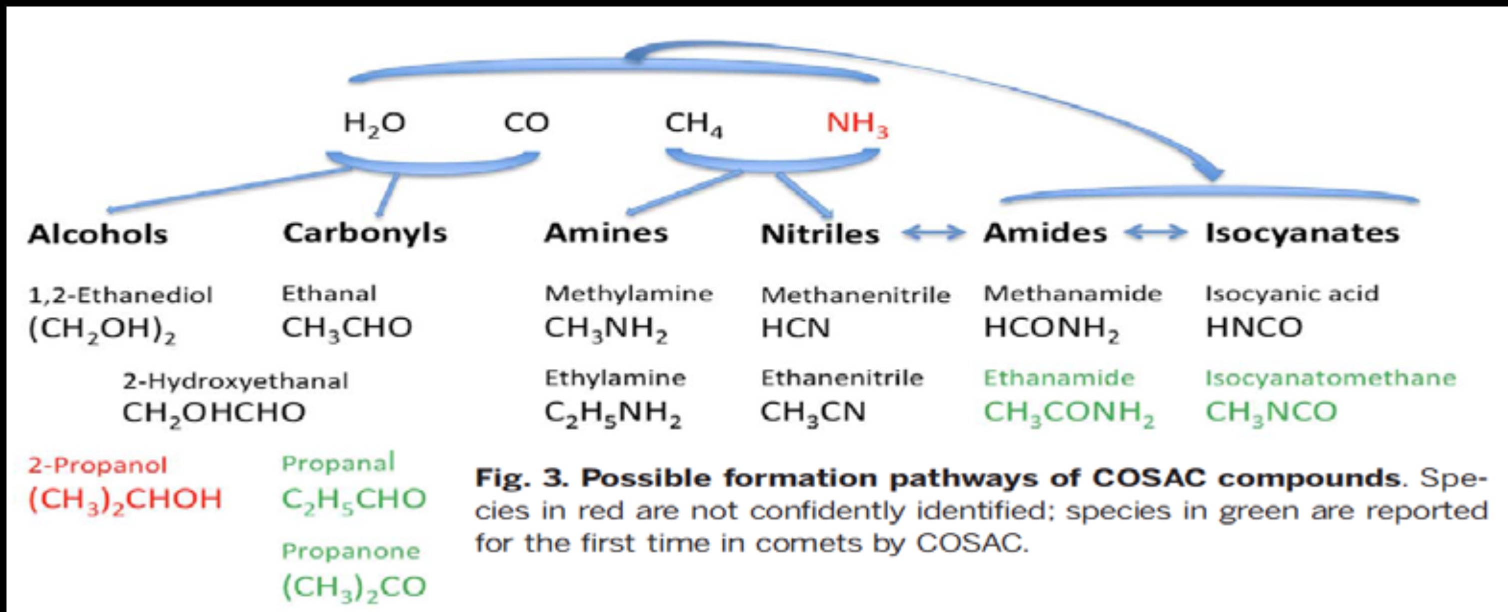
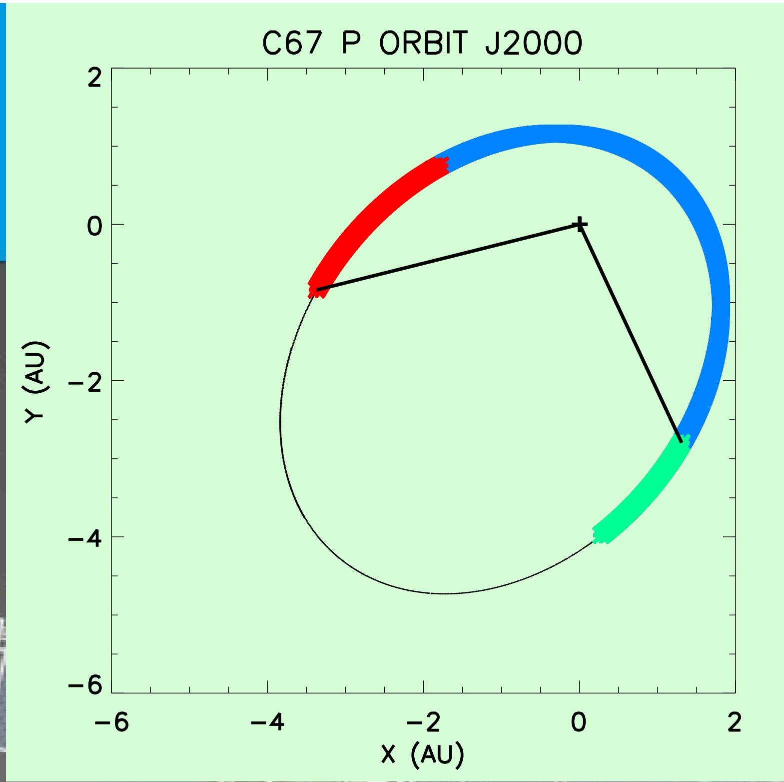



**Fig. 3. Possible formation pathways of COSAC compounds**. Species in red are not confidently identified; species in green are reported for the first time in comets by COSAC.

rosetta

esa

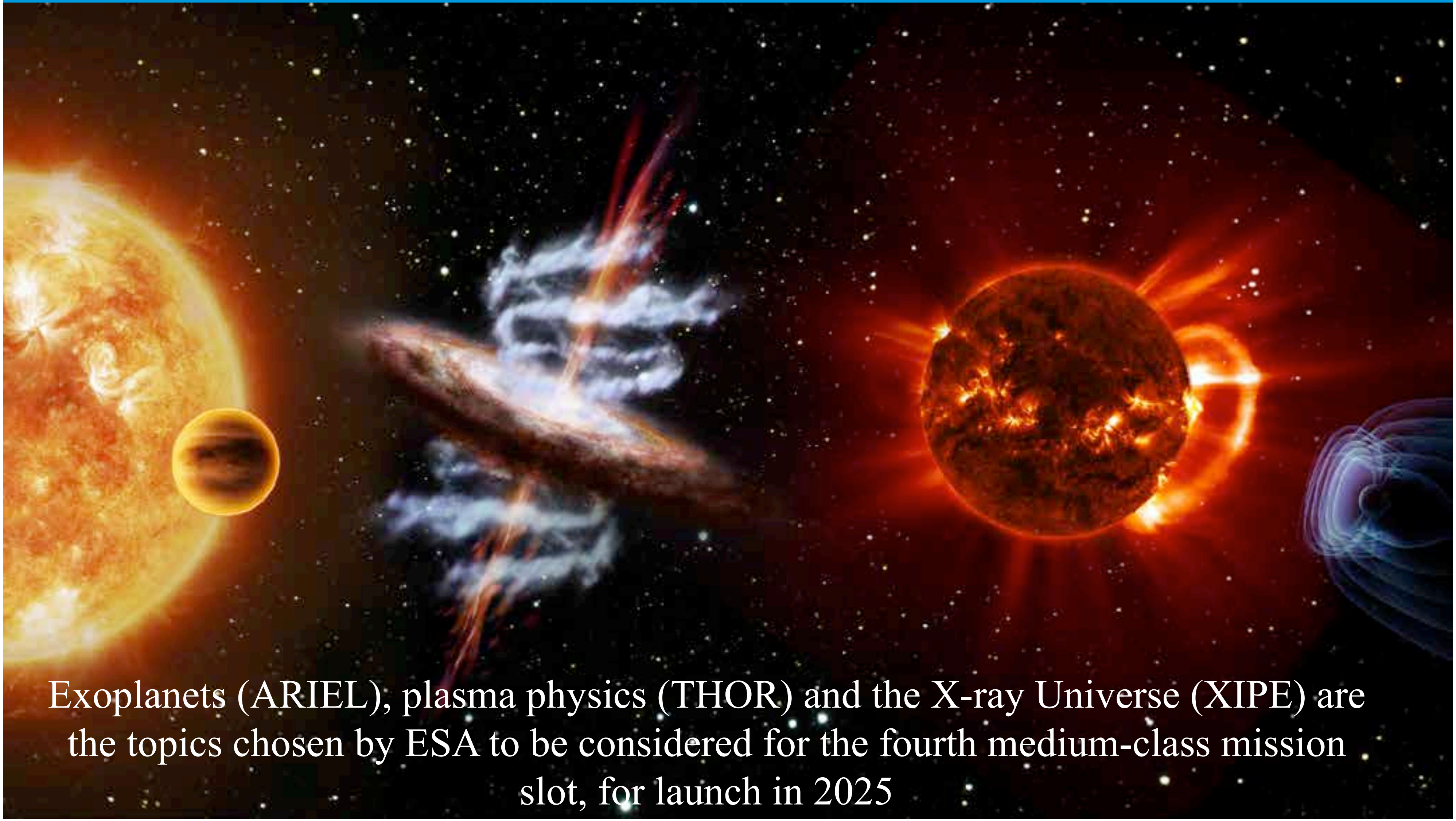
http://blogs.esa.int/rosetta/




January - August 2014
August 2014-December 2015
January – July 2016

| | |
|---|---|
| Summer 2014 | Arrival at comet |
| 12 November 2014 | Lander deployment |
| August 2015 | Perihelion |
| ~~December 31, 2015~~ | ~~Nominal end of mission~~ |
| September 2016 | End of extended mission |

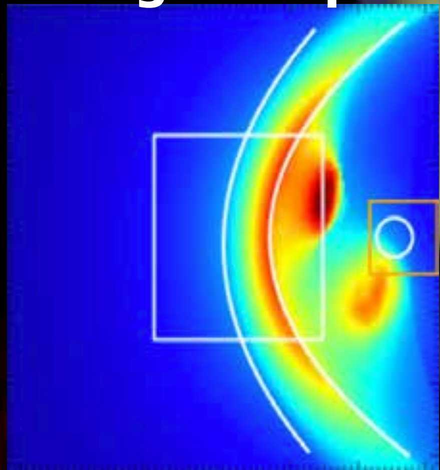
# M4 call
# Selection of missions for study

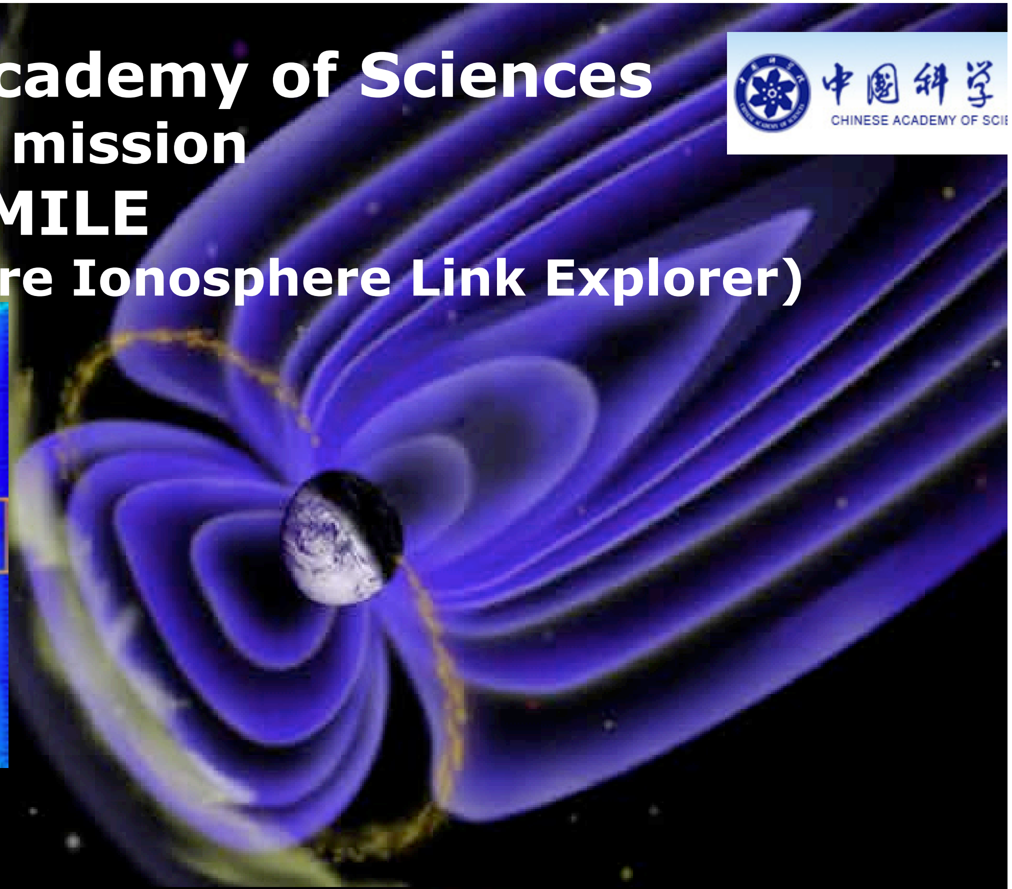


# M4 mission
# Present plan

| | |
|---|---|
| Phase 0 (ESA internal CDF) | June to September 2015 |
| Phase 0 completed | End September 2015 |
| ITT for Phase A industrial studies | October 2015 |
| Phase A kick-off | March 2016 |
| Mission Selection Review completed (ARIEL, THOR, XIPE) | April 2017 |
| Selection of M4 mission (SPC) | June 2017 |
| Phase B1 kick-off of the selected M4 mission | July 2017 |
| Phase B1 completed | September 2018 |
| Mission Adoption Review | September/October 2018 |
| Adoption of the M4 mission (SPC) | November 2018 |
| Phase B2/C/D kick-off | July 2019 |
| Launch | 2026 |

# ESA – Chinese Academy of Sciences
## Joint mission
## SMILE
## (Solar wind Magnetosphere Ionosphere Link Explorer)





**Co-Pis: G. Branduardi-Raymont and C. Wang**

Smile will investigate the interaction between Earth's protective shield – the magnetosphere – and the supersonic solar wind

Goal: understanding the physical processes taking place during the continuous interaction between the solar wind and the magnetosphere

*Aurora: NASA Polar*

# Mission planning

- Planning of mission calls:

| | | | |
|---|---|---|---|
| a. | M1, M2, L1 | 2007, 2007, 2007 | slice 1 |
| b. | M3, M4, L2 | 2010, 2014, 2014 | slice 2 |
| c. | M5, M6, L3 | 2015, 2017, 2017 | slice 3 |
| d. | M7 | 2020 | … |

*All missions adopted during the first decade, leaving room for the preparation of the future beyond Cosmic Vision 10 years before.*

- Planning of mission launches:

| | | |
|---|---|---|
| a. | M1, M2, L1 | 2018, 2020, 2022 |
| b. | M3, M4, L2 | 2024, 2026, 2028 |
| c. | M5, M6, L3 | 2030, 2032, 2034 |
| d. | M7 | 2035 |

# Planning for M5

ESA | SCIENCE & TECHNOLOGY | COSMIC VISION

Missions
- Show All Missions

Cosmic Vision 2015-2025
- Cosmic Vision
- Candidate Missions
- M-class Timeline
- L-class Timeline

Cosmic Vision themes
- Planets and Life
- The Solar System
- Fundamental Laws
- The Universe
- The Hot and Energetic Universe

S-class mission
- CHEOPS [S1]

## ANNOUNCEMENT OF THE PLANS FOR THE ISSUING OF A CALL FOR A MEDIUM-SIZE MISSION FOR LAUNCH IN 2029-2030 (M5)

20 July 2015

**The Director of Science and Robotic Exploration of the European Space Agency plans to release, in late 2015 or early 2016, a Call for the M5 "Medium-size mission" with a planned launch date of 2029-2030 ("M5 Call" in the following).**

The purpose of the present announcement is to inform the scientific community about the current planning, and to offer the scientific community the possibility of consulting the ESA Executive about their possible plans to submit proposals in response to the M5 Call.

The present announcement solicits non-binding Statements of Interest (SoI) from potential proposers. These Statements will allow the Executive to gauge the interest from the scientific community in the Call and to size the process accordingly. Submission of a SoI is not a pre-requisite for the eventual submission of a proposal in response to the actual M5 Call.

The content of the present announcement is non-binding, and does not commit ESA to release the M5 Call on any specific schedule. Also, the content and condition of the M5 Call, when finally released, may vary from the approach currently planned and described here. Thus, any information given here has to be considered as tentative and potentially subject to evolution, also as a function of the interaction between the Executive and the scientific community following the present announcement.

Search here

22-Oct-2015 07:21 UT

Shortcut URL

http://sci.esa.int/jump.cfm?oid=56198

# The future

- The annual budget over five years is decided by unanimity at ESA Council at Ministerial level.
- Last full Ministerial was in 2012 in Naples.
- The ESA Council at Ministerial level, in Luxembourg in 2014, did not include the Science Programme in the Agenda.
- Next Ministerial meeting dealing with the Science Programme is planned before the end of 2016 (in Switzerland).
- The next Council at Ministerial level is an important opportunity, the first to take place during the implementation time of Cosmic Vision.