The Science Programme of ESA

Alvaro Gimenez,

Director of Science and Robotic Exploration

3 March 2014

OBJECTIVES

1. Provide the best possible space tools to the scientific community to achieve and sustain excellence with discoveries and innovation.

2. Contribute to the sustainability of space skills, capabilities and infrastructures in Europe.

Basics of the Science Programme

- **The Programme is Science-driven**:

  both long-term science planning and mission calls are bottom-up processes, relying on broad community input and peer review (advisory structure with power to retain science at core).

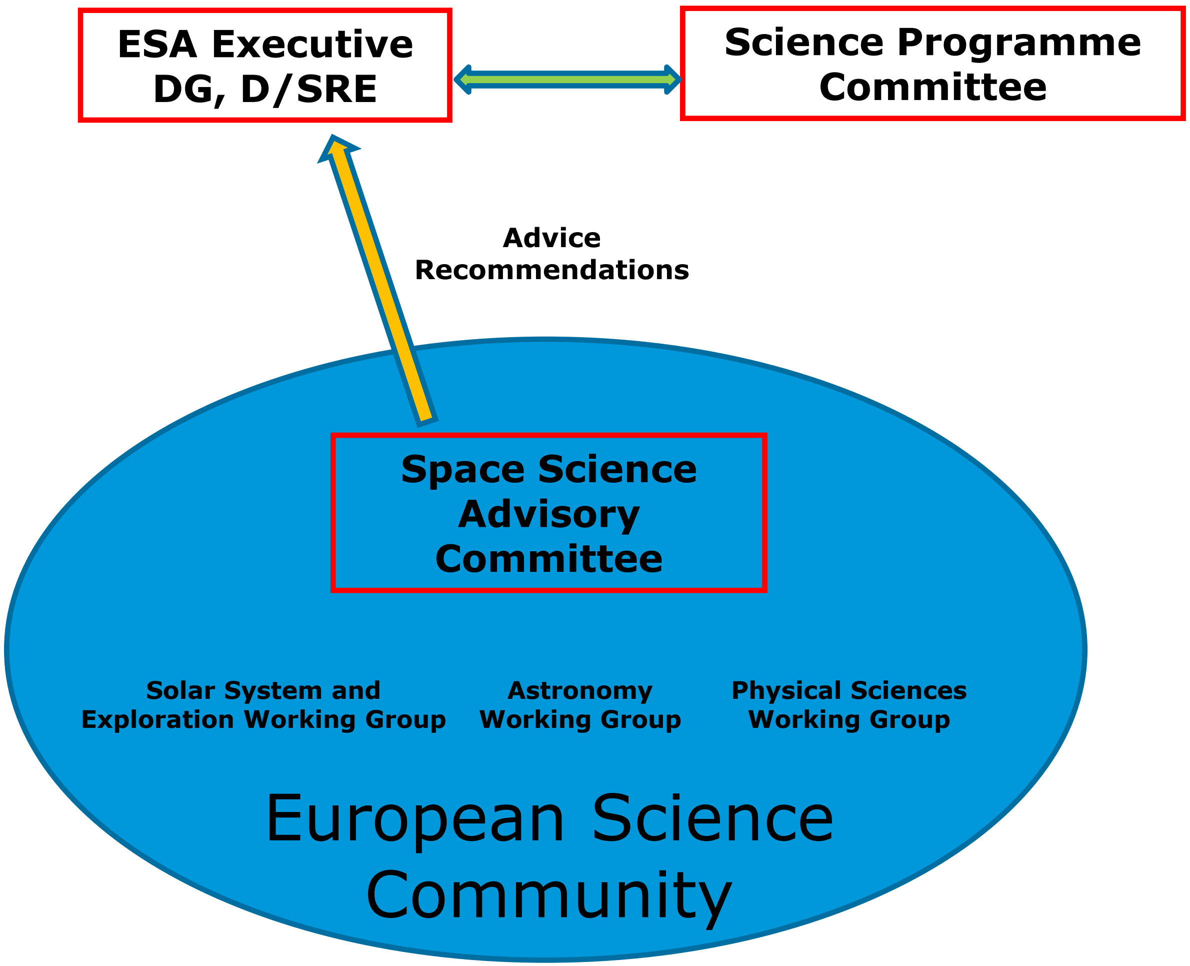
The content of the programme is decided bottom-up

- **The Programme is Mandatory**:

  all member states contribute pro-rata to GNP providing budget stability and allowing long-term planning of its scientific goals, becoming a reference as well as a flagship of the Agency.

The programme allows for long-term planning

Basics of the Science Programme



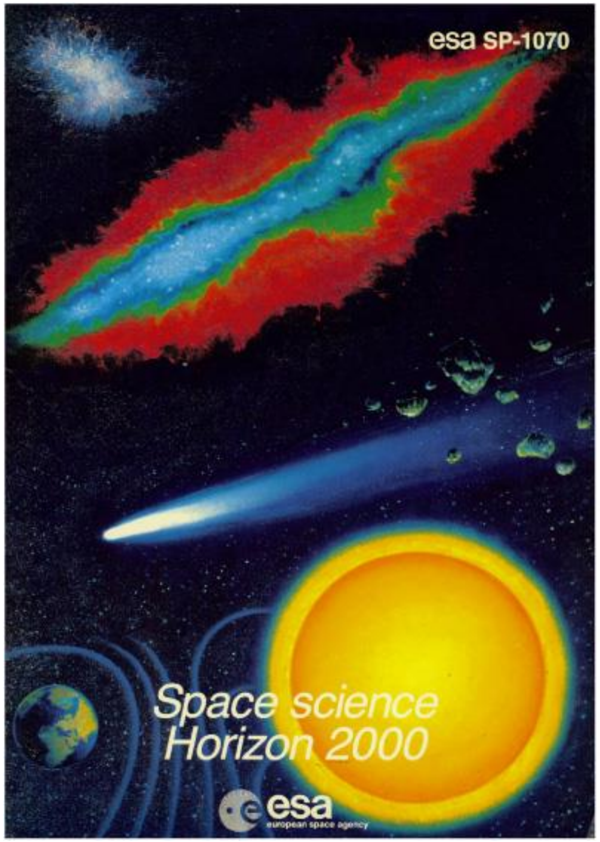
Long-term planning

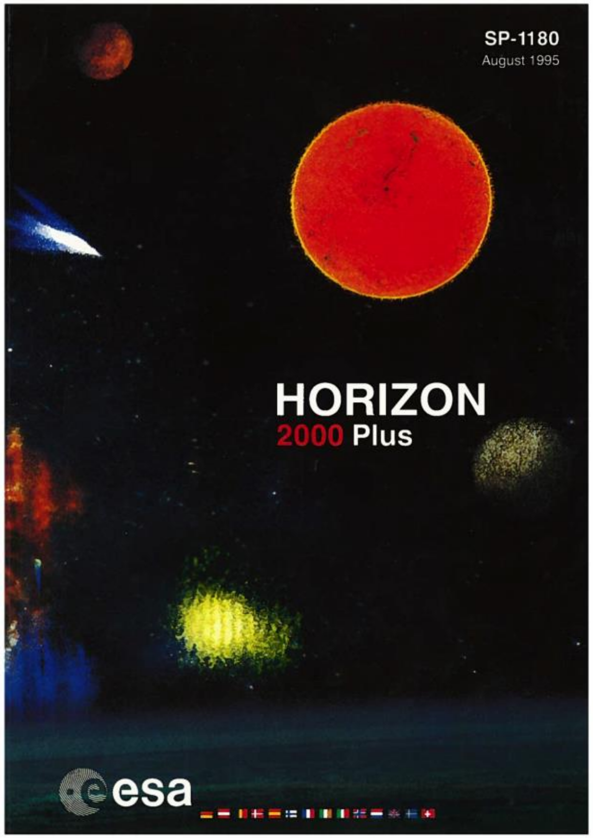
A long-term programmatic view is necessary for science missions to be manageable and to achieve the goals of a broad scientific community in order to:

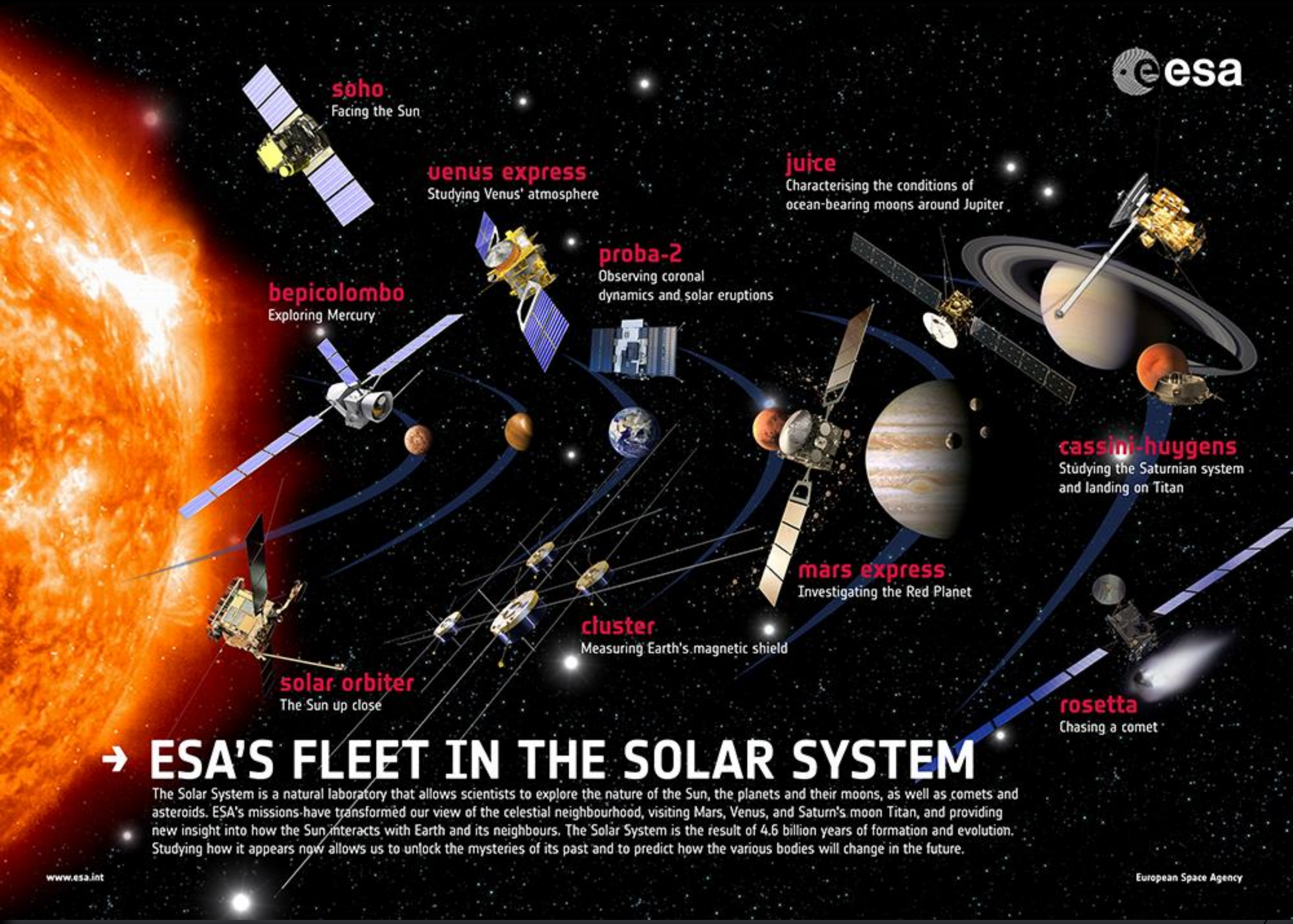
a. Maintain scientific skills and expertise in Member States
b. Maintain balance between the different scientific domains
c. Define the long-term resources needed for a sustainable programme
d. Allow for coordination with other agencies and national programmes
e. Prepare technology plans and ground infrastructures
f. Ensure a balanced industrial policy
g. The necessary flexibility to respond to the evolving development of science and technology must be kept.

Long-Term Planning

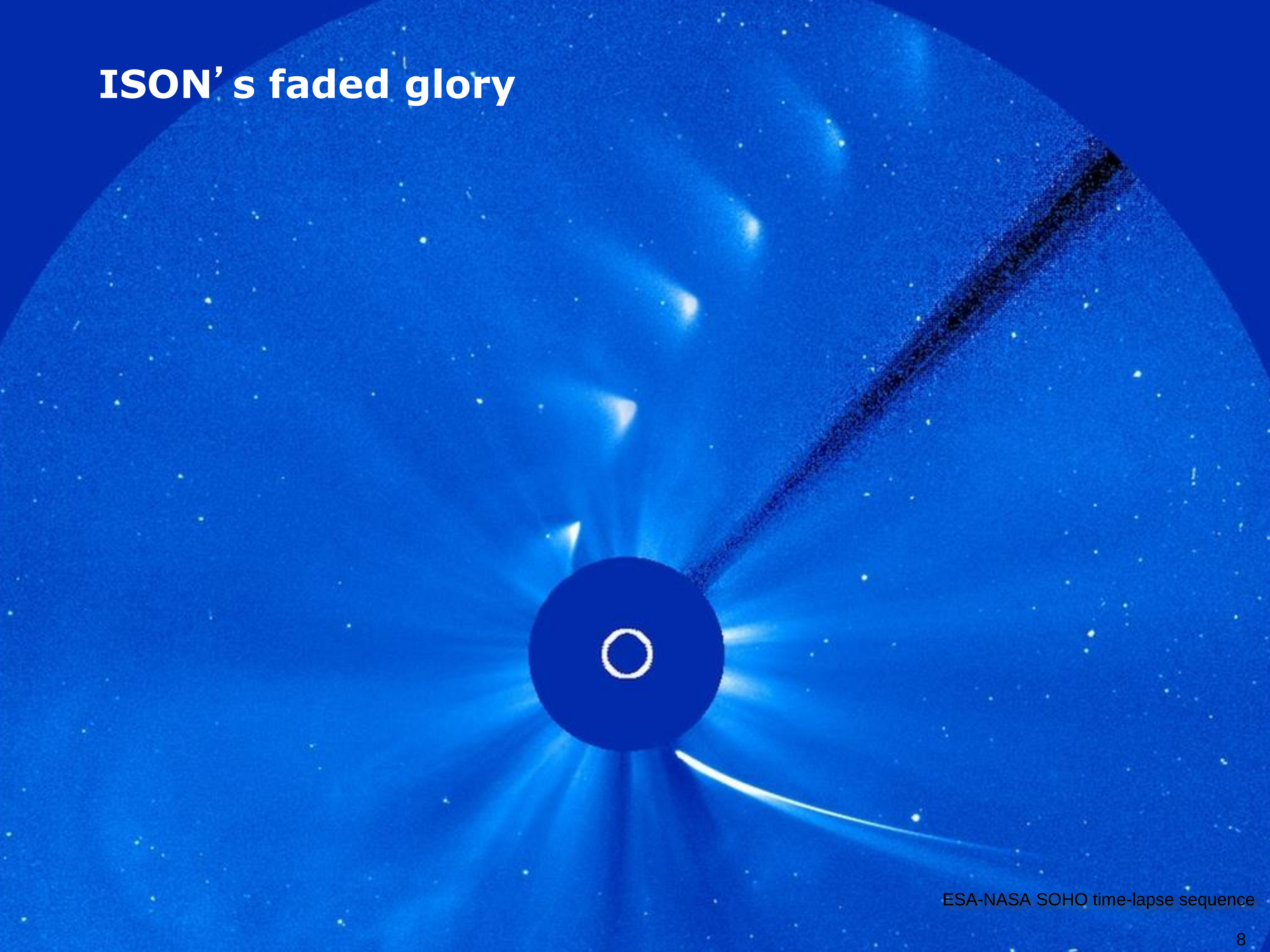
1. 1985: **Horizon 2000** Planning for 2 decades: 1985 – 2005
2. 1995: **Horizon 2000+** Extended H2000 by a decade, to 2015



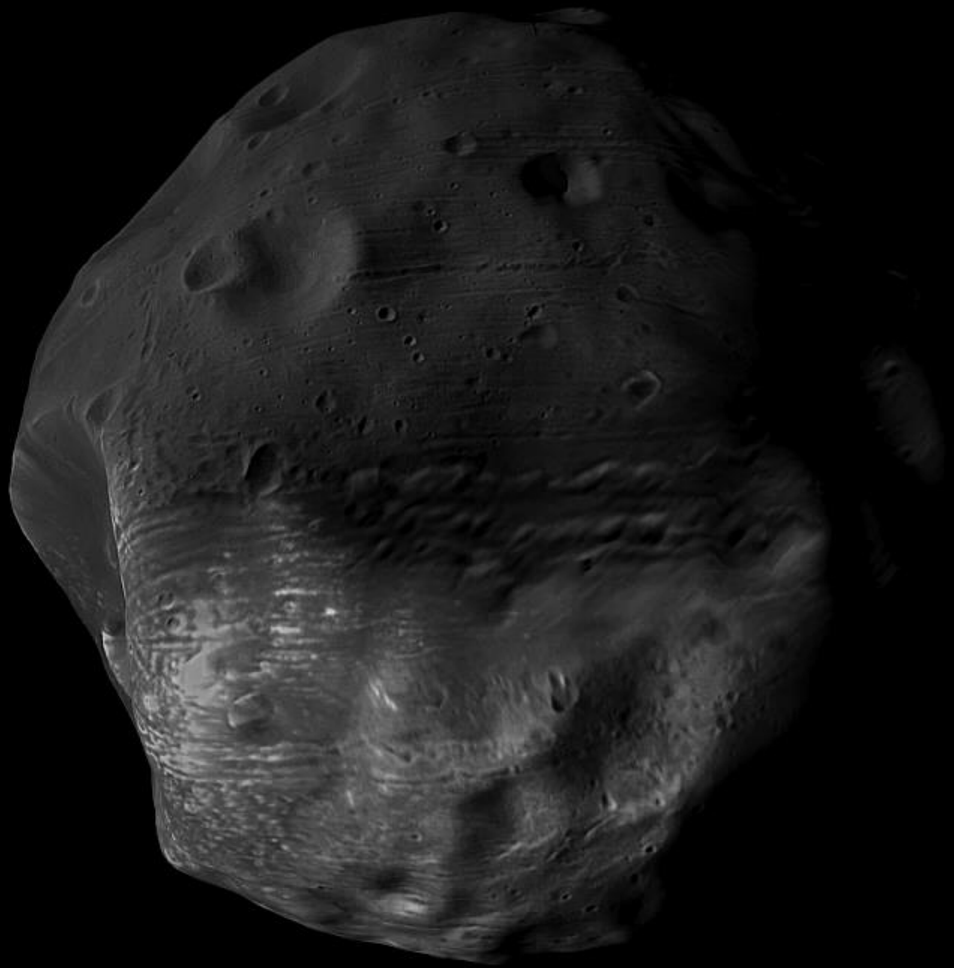



esa
soho
Facing the Sun
venus express
Studying Venus' atmosphere
juice
Characterising the conditions of
ocean-bearing moons around Jupiter
proba-2
Observing coronal
dynamics and solar eruptions
bepicolombo
Exploring Mercury
cassini-huygens
Studying the Saturnian system
and landing on Titan
mars express
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

ISON's faded glory



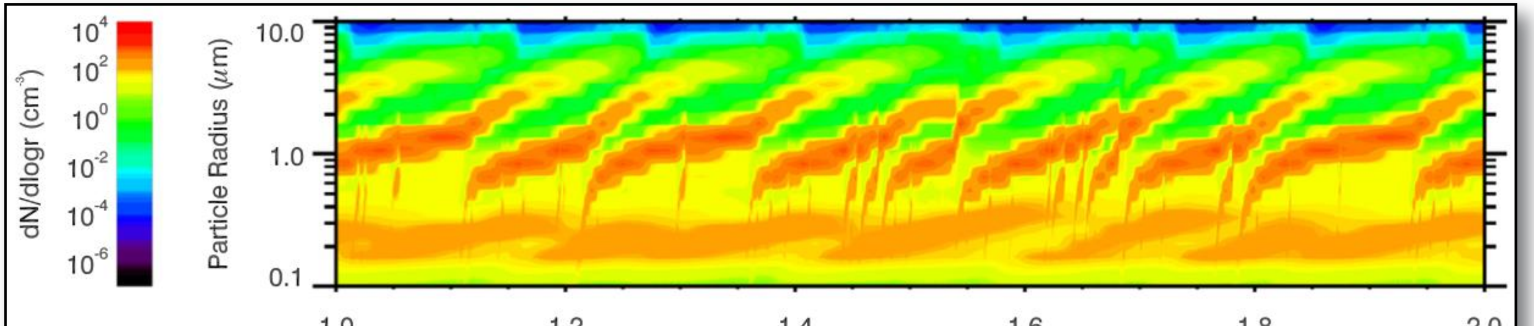
ESA-NASA SOHO time-lapse sequence



Phobos fly-around from various MEX fly-bys / ESA, DLR, FU Berlin, http://goo.gl/q5611N

Sulphuric acid particle cycling on Venus

- VEX SPICAV/SOIR observations of upper haze layer (70–90km)
  - Variable on timescale of days, populated by two particle size “modes”
- New models with microphysics + vertical transport
  - Photo-chemically produced H_2SO_4 nucleates on polysulphur condensates
  - Drops lifted by transient vertical winds + subsolar convection at cloud tops
  - Grow to ~4μm; periodic rain-out; evaporate below clouds; restart cycle



Aerosol growth at 54 km

10^8 s ~ 3 yrs

- Aerosols crucial to understanding Venus climate / chemistry
  - Vertical extent, size, properties drive radiation environment and energy budget at surface and throughout atmosphere

Gao et al. 2014, Icarus

Huygens lander at Titan

ESA Huygens lander deployed from NASA-ESA-ASI Cassini mission at Saturn, 14 January 2005

Rosetta

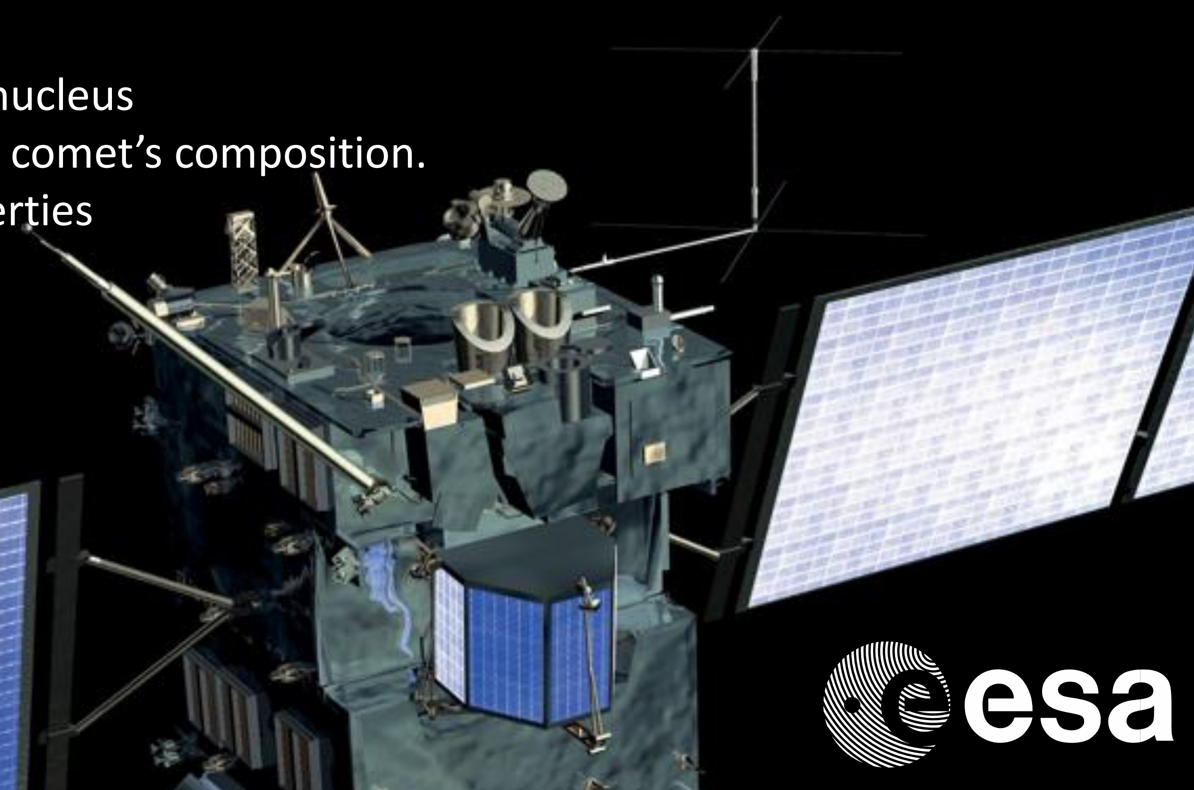
ESA Rosetta mission, launch 2004, arrival at Comet 67P/Churyumov-Gerasimenko in 2014

Primary Mission Goals

- Catch comet 67P/Churyumov-Gerasimenko in 2014 and accompany it into the interior solar system.
- Observe the comet's nucleus and coma from close range.
- Measure the increase in cometary activity during perihelion (position closest to the Sun).
- Deploy a robotic lander, Philae, to make the first controlled landing on a comet nucleus.

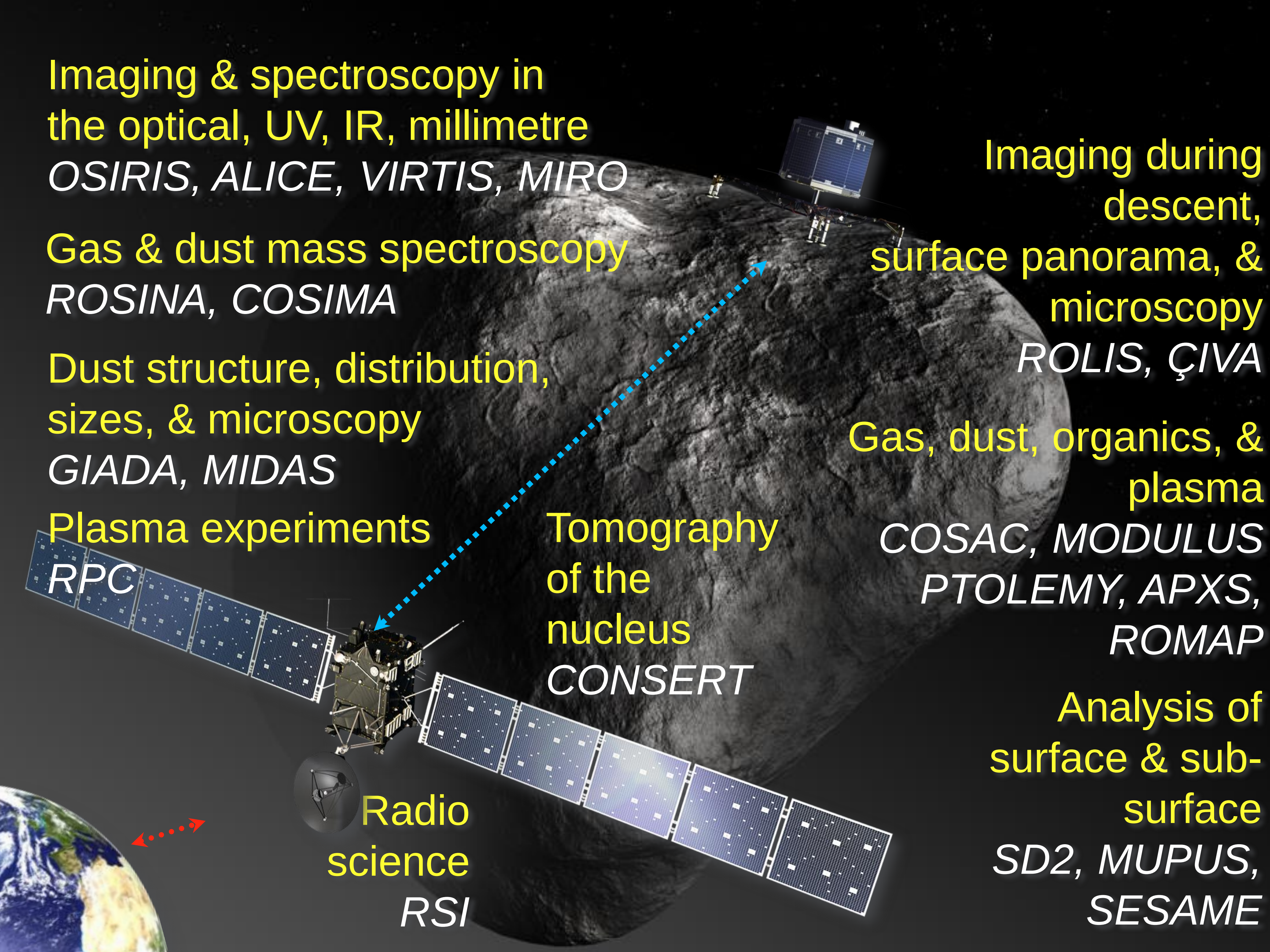
Primary Science Goals

- Create a portrait of the comet's nucleus
- Take a complete inventory of the comet's composition.
- Detail the comet's physical properties
- Examine the evolution of activity
- Explain the comet's origin
- Create portraits of two asteroids

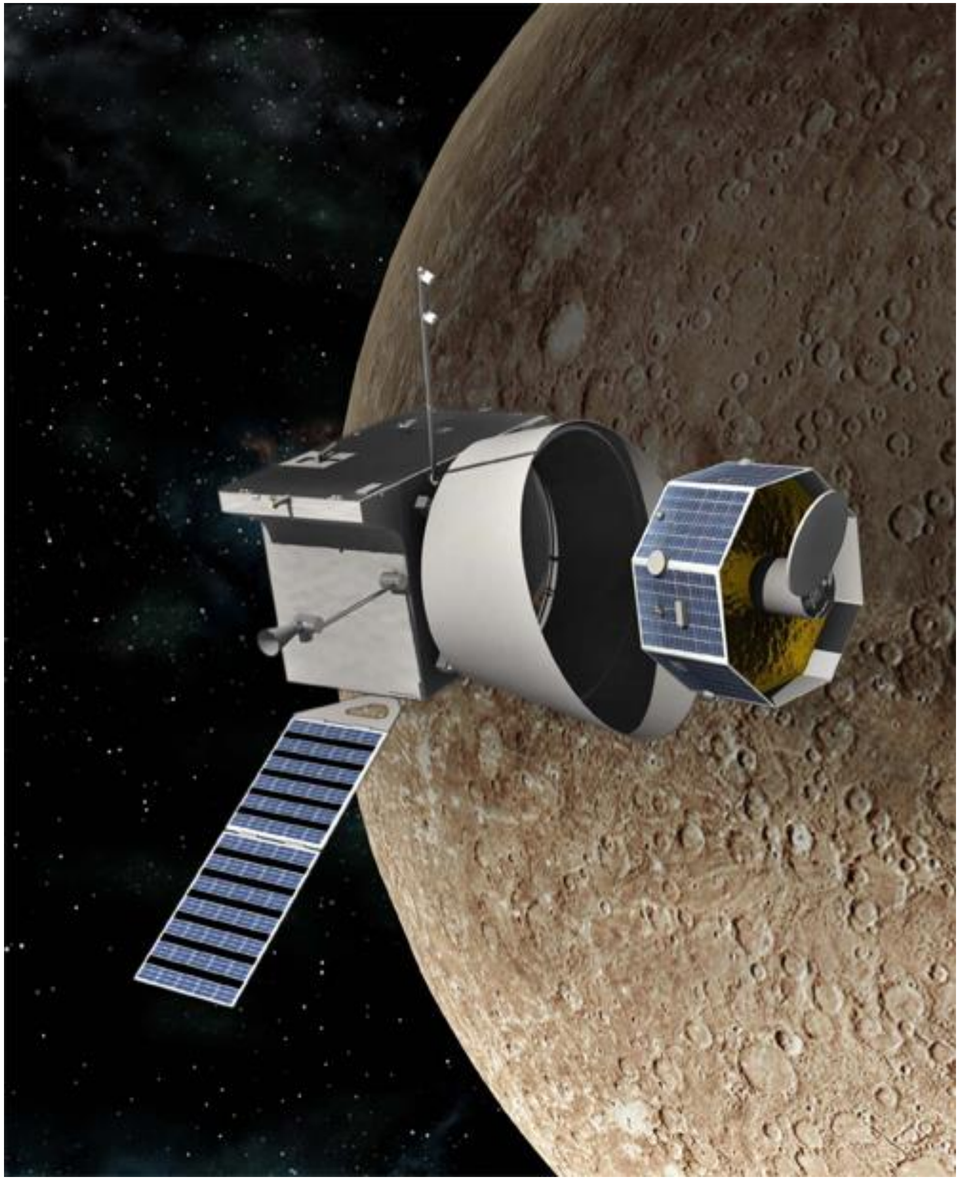



rosetta
esa

Rosetta orbiter and Philae lander at Comet 67P/Churyumov-Gerasimenko in 2014


Imaging & spectroscopy in the optical, UV, IR, millimetre
OSIRIS, ALICE, VIRTIS, MIRO
Gas & dust mass spectroscopy
ROSINA, COSIMA
Dust structure, distribution, sizes, & microscopy
GIADA, MIDAS
Plasma experiments
RPC
Tomography of the nucleus
CONSERT
Radio science
RSI
Imaging during descent, surface panorama, & microscopy
ROLIS, ÇIVA
Gas, dust, organics, & plasma
COSAC, MODULUS PTOLEMY, APXS, ROMAP
Analysis of surface & sub-surface
SD2, MUPUS, SESAME

BepiColombo, 2016
Closing in on Mercury



Joint ESA/JAXA mission, and the first dual-satellite enterprise to Mercury

First European mission to orbit a planet in the hot regions of the Solar System, to make the most extensive study of Mercury – from the interior to the exosphere

Helping to reveal the evolution of Mercury and the formation of the inner planets, and to understanding the origin of Mercury's global magnetic field – the only one of a rocky planet other than Earth

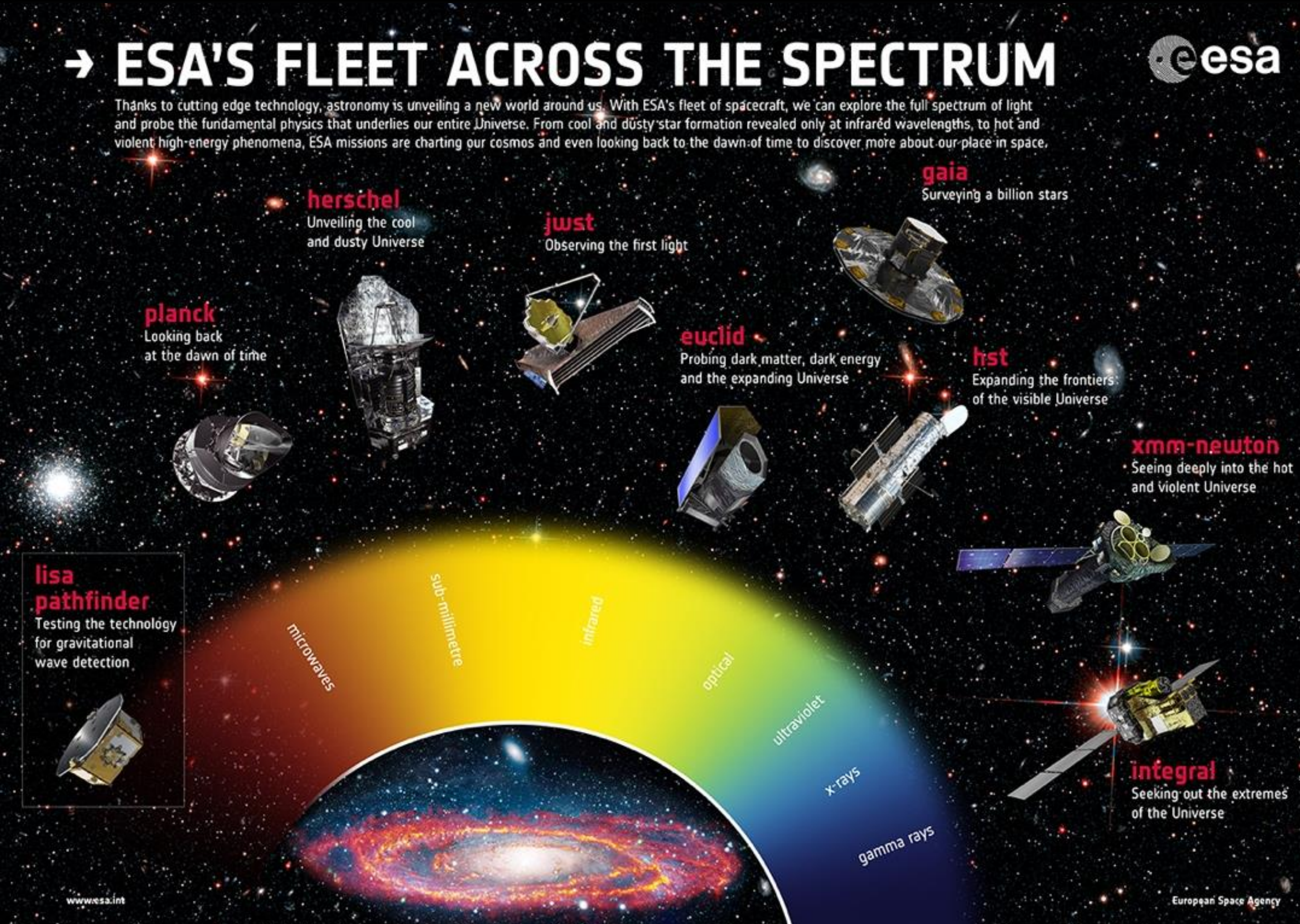
Testing Einstein's theory of General Relativity

Launch: 2016, Ariane 5

Arrival at Mercury: 2024

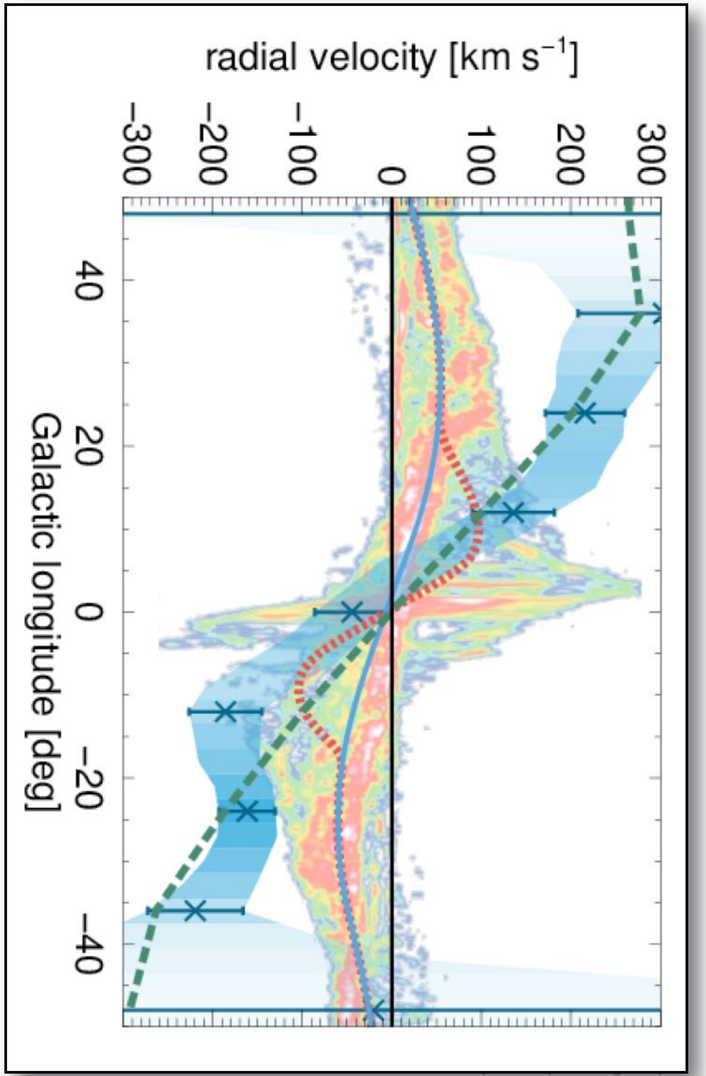
Orbits: polar, elliptical

Status: implementation


→ 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.
herschel
Unveiling the cool and dusty Universe
jwst
Observing the first light
gaia
Surveying a billion stars
planck
Looking back at the dawn of time
euclid
Probing dark matter, dark energy and the expanding 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
microwaves
sub-millimetre
infrared
optical
ultraviolet
x-rays
gamma rays
integral
Seeking out the extremes of the Universe
www.esa.int
European Space Agency

High-speed blowouts from massive stars

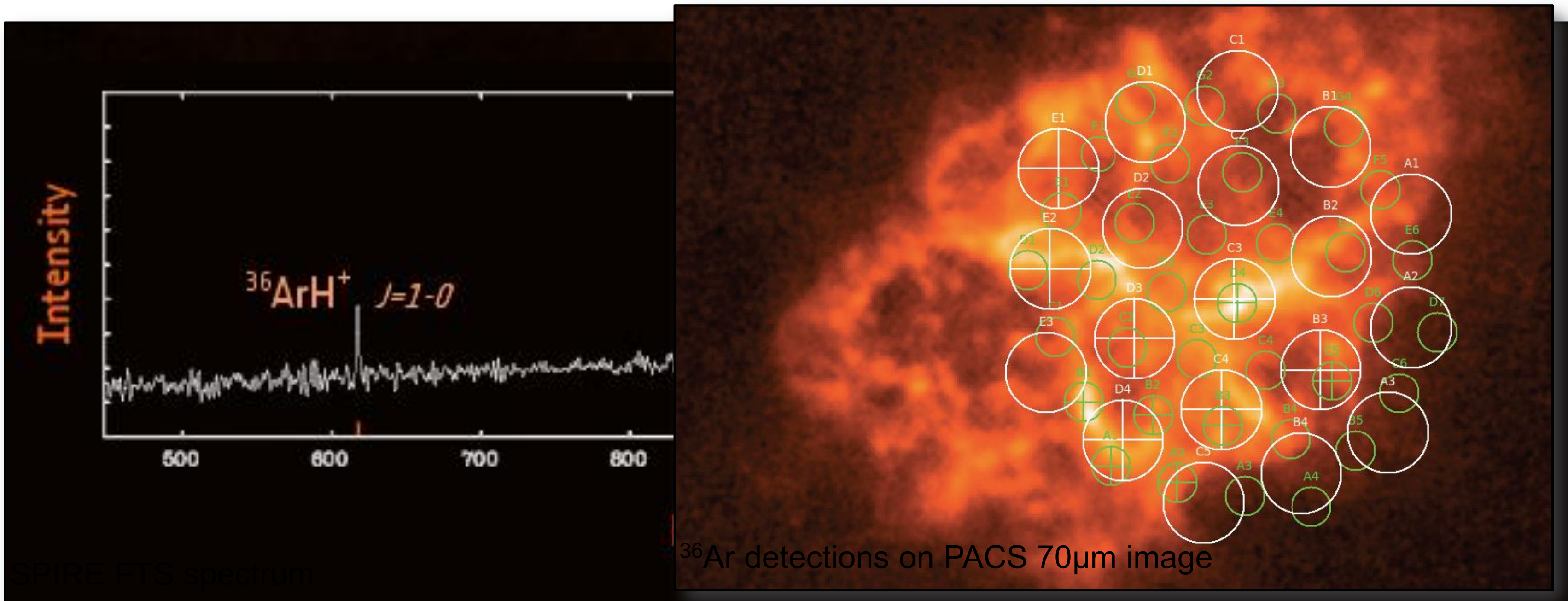
- Massive stars are key part of cosmic reprocessing cycle
  - Winds and supernovae generate superbubbles and kpc scales
  - Important for dynamics of ISM and chemical evolution models
- SPI observations of ^{26}Al velocities
  - Generated by massive stars
  - Decays on ~1Myr timescales
  - Compare to galactic rotation velocities
- Moves at ~200 km s^{-1} faster than CO
  - Blown off leading edges of spiral arms
  - Implies angular momentum transfer in disk-halo system and radial gas flows



Kretschmer et al. 2013, A&A

Noble gas molecules in the Crab Nebula

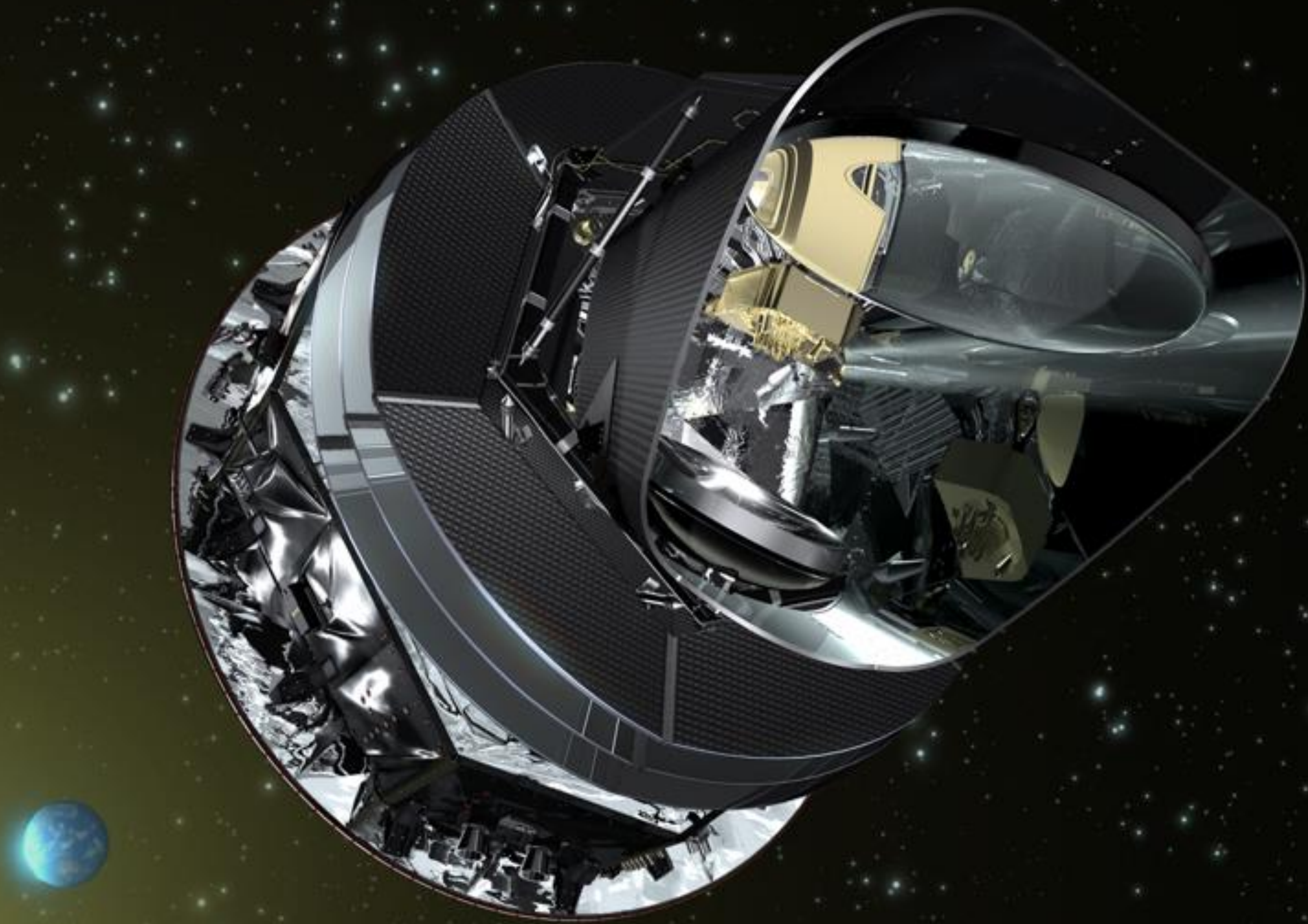
- Serendipituous detection of $^{36}ArH^{+}$ lines in SPIRE FTS spectrum
  - First detection of noble gas molecules in space



- Association of ^{36}Ar isotope with Crab consistent with formation via explosive nucleosynthesis in a core collapse supernova
  - Confirmation that the Crab is a remnant of 8–16$M_\odot$ star

Barlow et al. 2013, Science

Planck

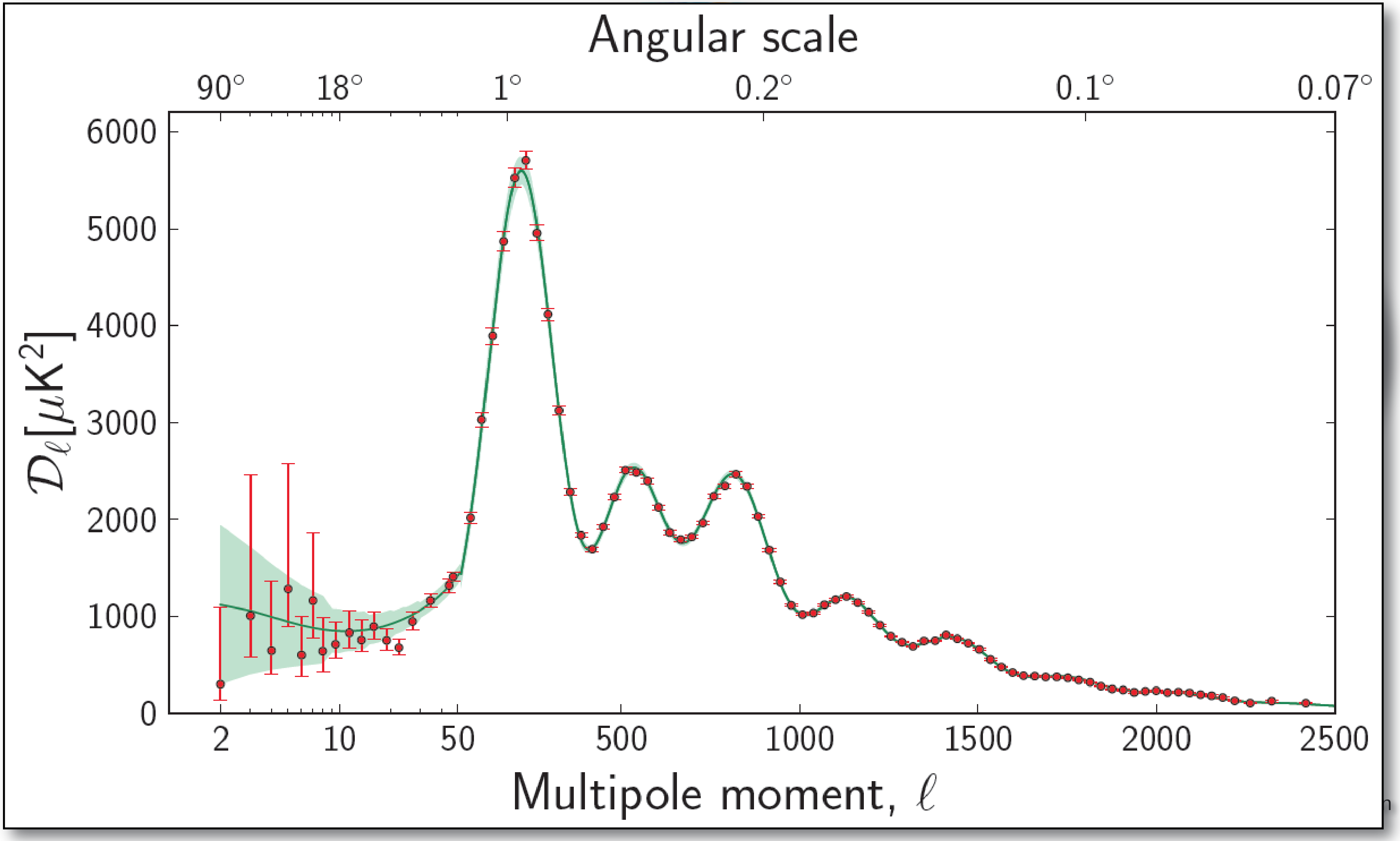


Launched in May 2009 towards L2.
Scanned entire sky in 9 wavebands from 27 GHz to 1 THz with:

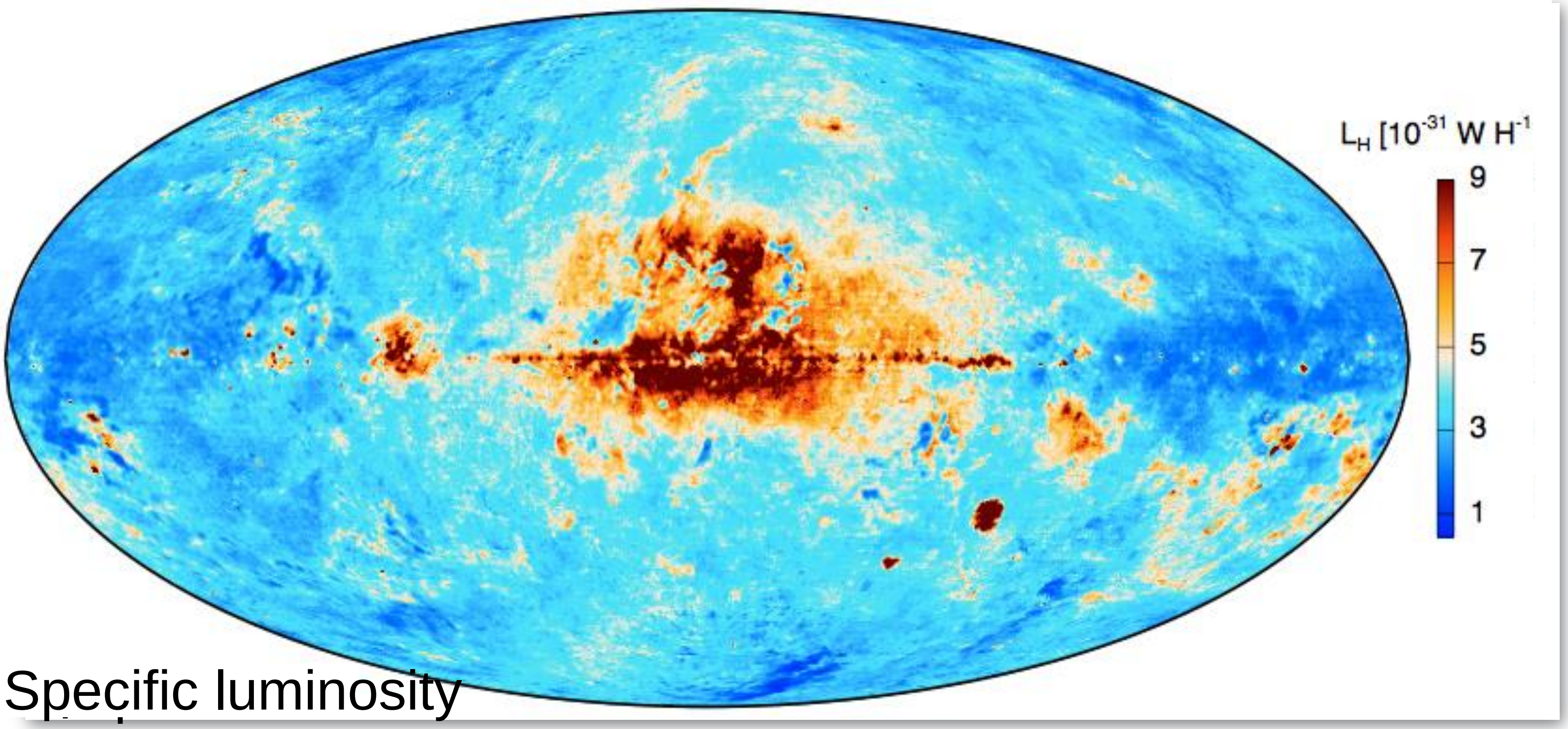
- HFI (0.1K) completed 5 sky surveys before the LHe cryogen expired.
- LFI (20k) completed 8 sky surveys in August 2013.

First science results and compact source catalogue (>15,000 unique objects) was released in Jan 2011.
In March 2013, the first Planck all-sky image of the CMB was released (from first 15 months of data).

Decoding the Cosmic Microwave Background



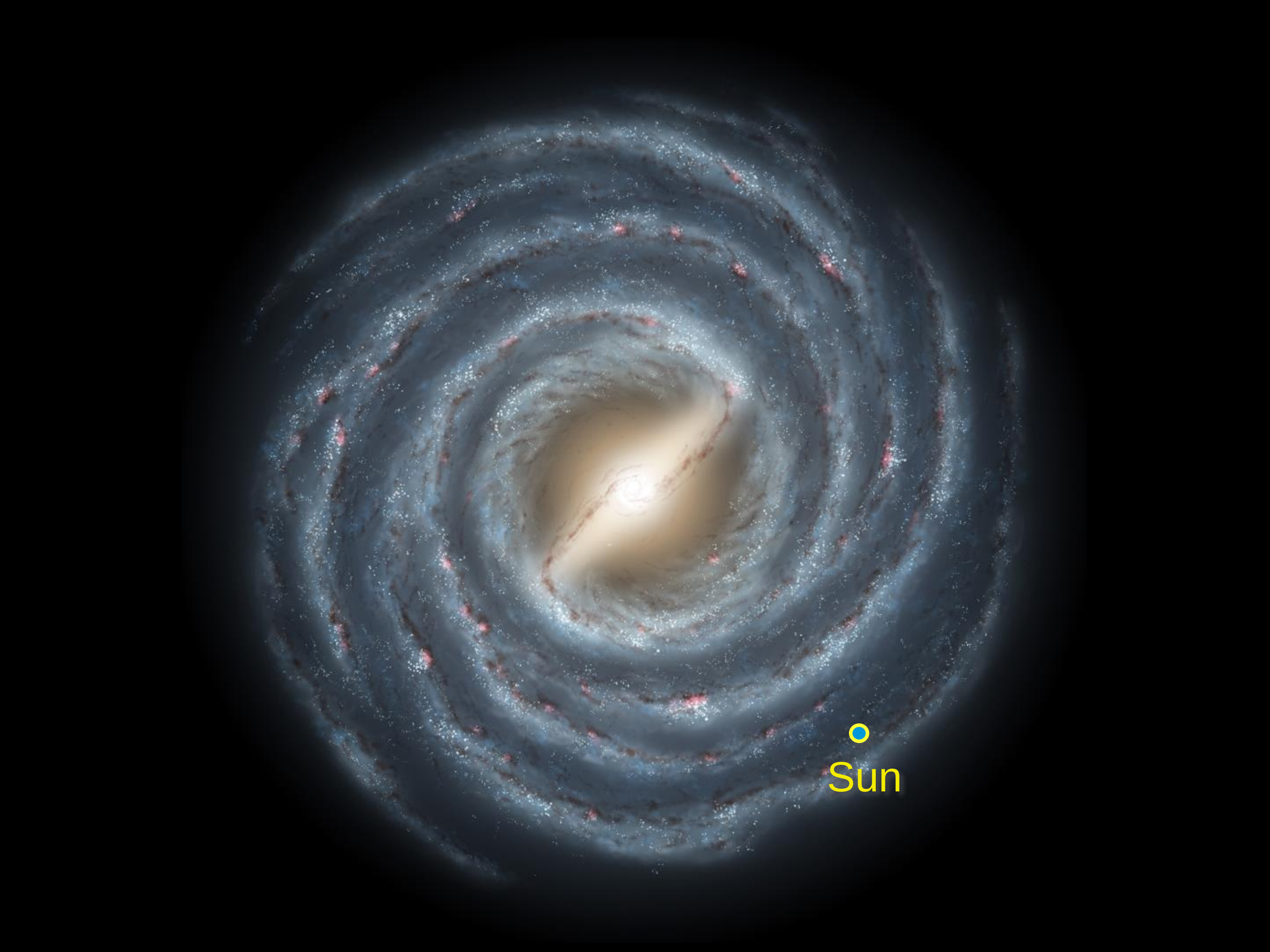
All-sky model of thermal dust emission



Specific luminosity

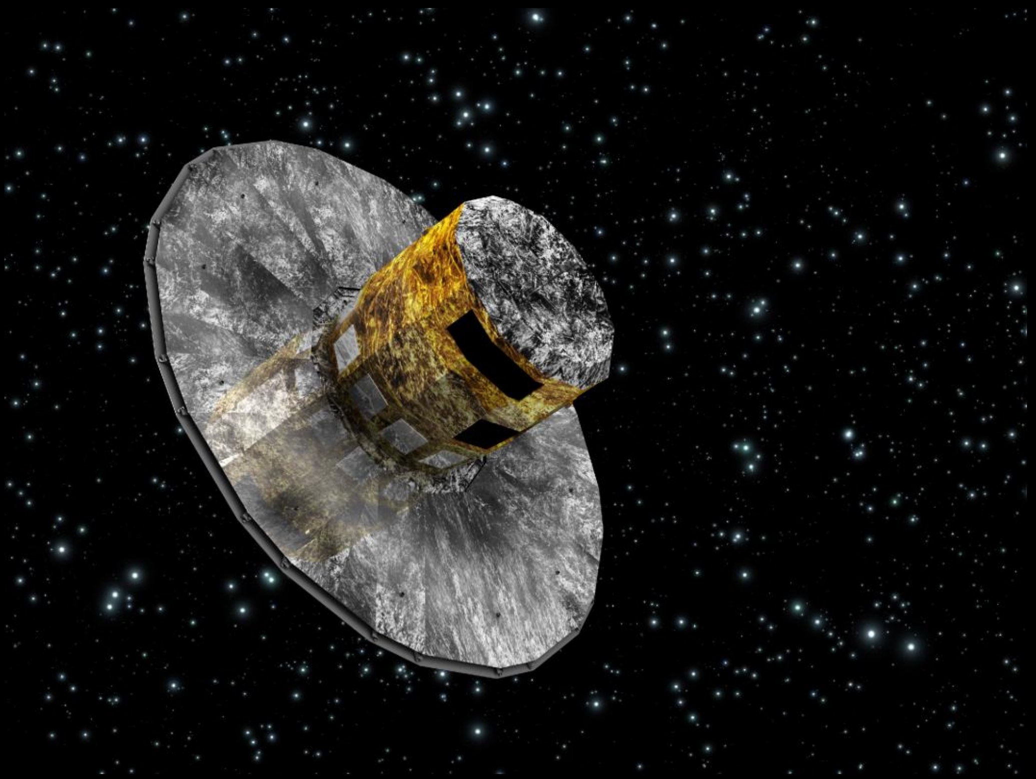
- Modified black-body fit: Planck 353–857GHz + IRAS 100μm
- Yields dust temperature, opacity, spectral index at 5” res over whole sky
- Also specific luminosity (per unit column of H), good tracer of the ISRF

ESA, Planck collaboration, arXiv:1312.1300, 2013

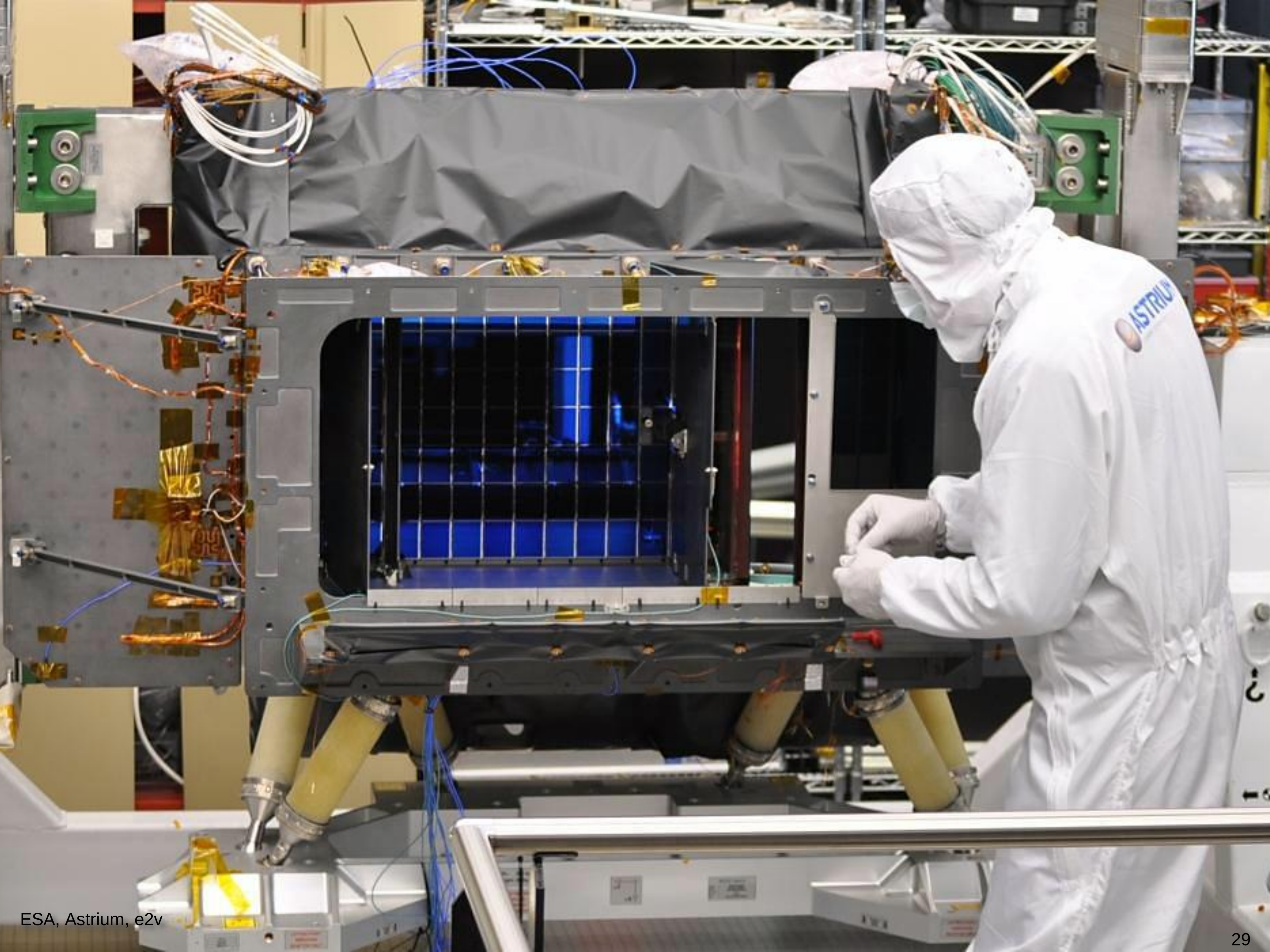

Sun

Gaia

- Gaia will map the 3-dimensional structure of the galaxy surveying one billion stars brighter than 20th mag.
- Accuracy:10–25 μarcsec at 15 mag (Hipparcos: 1 milliarcsec at 9 mag)
- Primary goal is to study the origin and evolution of our Galaxy.
- Will also detect between 10,000 and 50,000 exoplanets, numerous asteroids, KPOs, SNe, and test GR.



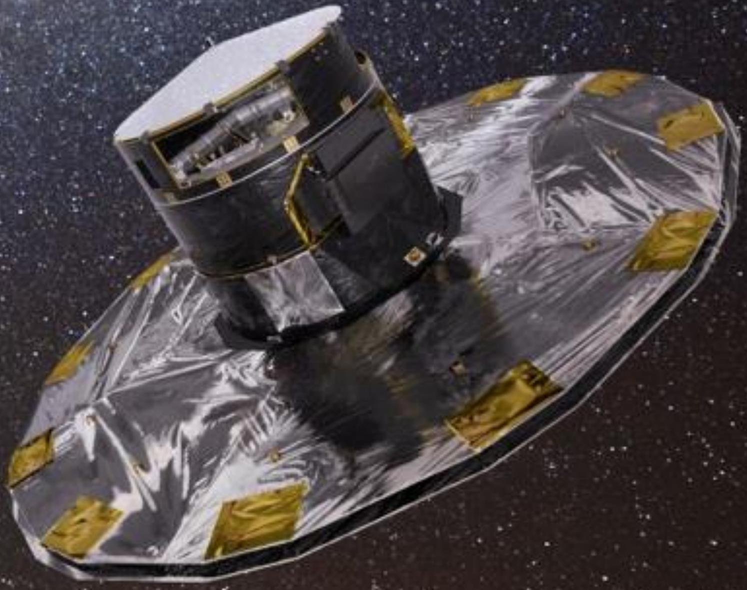
European Space Agency



ESA, Astrium, e2v

But even beyond that:

Gaia will provide a fundamental underpinning to *all* astronomy for the next century



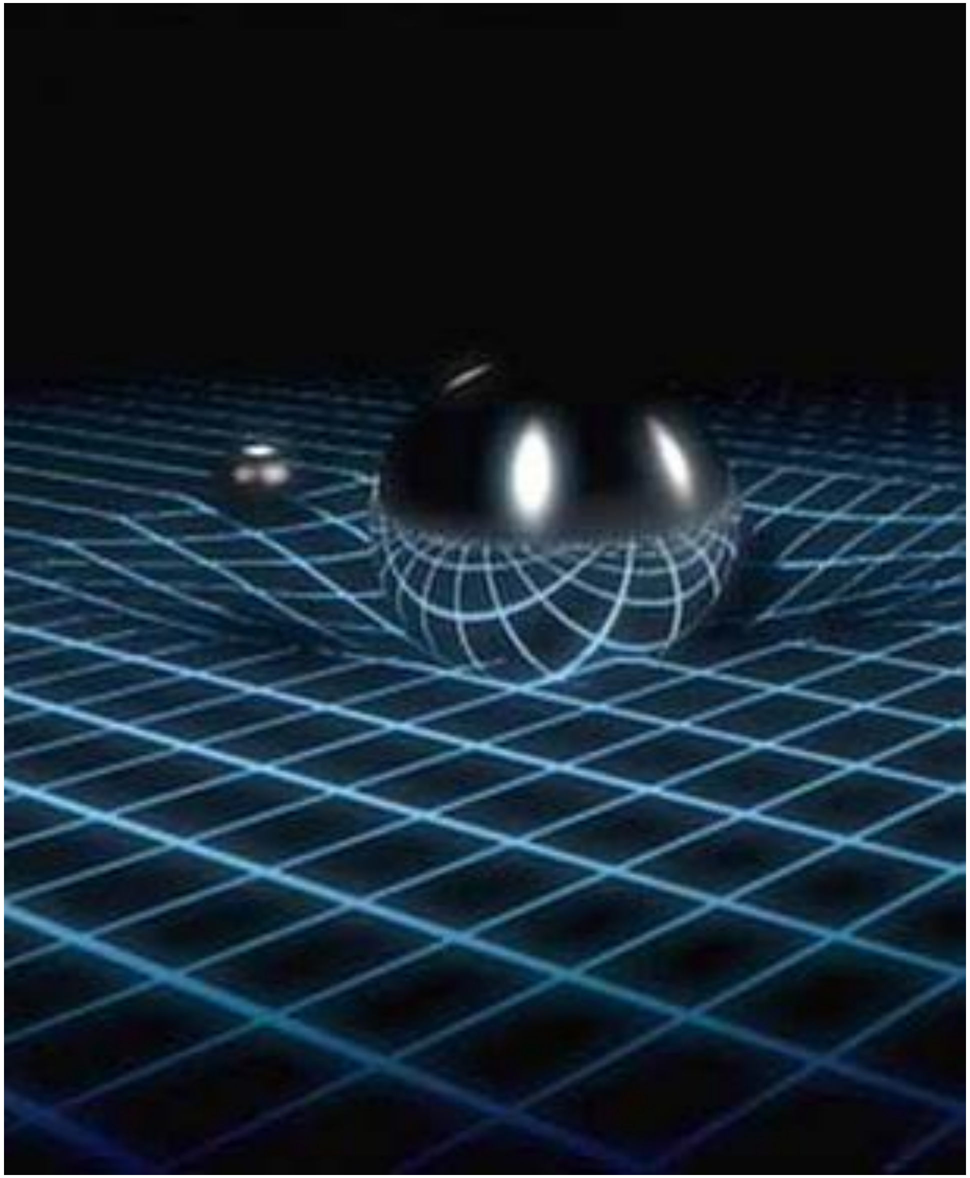
Gaia “first image”

ESA, DPAC, Airbus DS

NGC1818 in LMC / 212 x 212 arcsec / 2.85 s int. time / white light SM data


Mare Nostrum supercomputer, Barcelona

LISA Pathfinder, 2015
Technology for gravitational wave detection



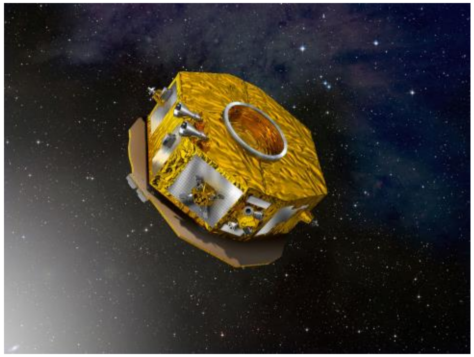
Testing the concept of gravitational wave detection in space.

Paving the way for future missions to test Einstein's General Relativity and understand the fabric of 'space-time'.

Controlling motion of two masses in gravitational free-fall with unprecedented accuracy.

State-of-the-art technology, including inertial sensors, laser metrology and an ultra-precise micronewton propulsion system.

Launch: 2015
Orbit: around L1
Status: implementation



James Webb Space Telescope, 2018
As far as our imagination takes us

Joint NASA/ESA/Canadian Space Agency infrared space observatory.

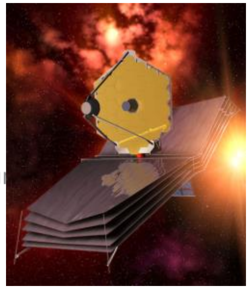
Successor to Hubble, with a primary mirror more than twice as large and with superb image quality.

Studying the very distant and old Universe, looking for the first stars and galaxies.

Exploring how galaxies formed, and peering into dusty clouds to see stars and planets being born in proto-planetary systems.

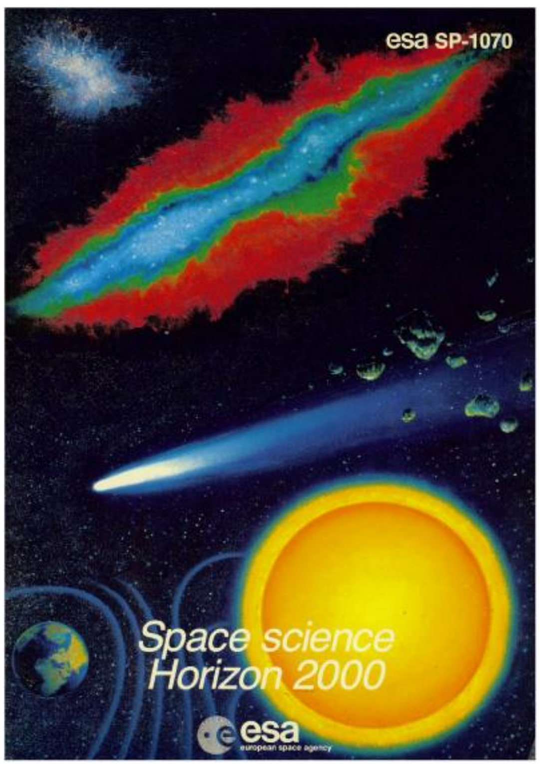
Studying planets around other stars and investigating the origins of life.

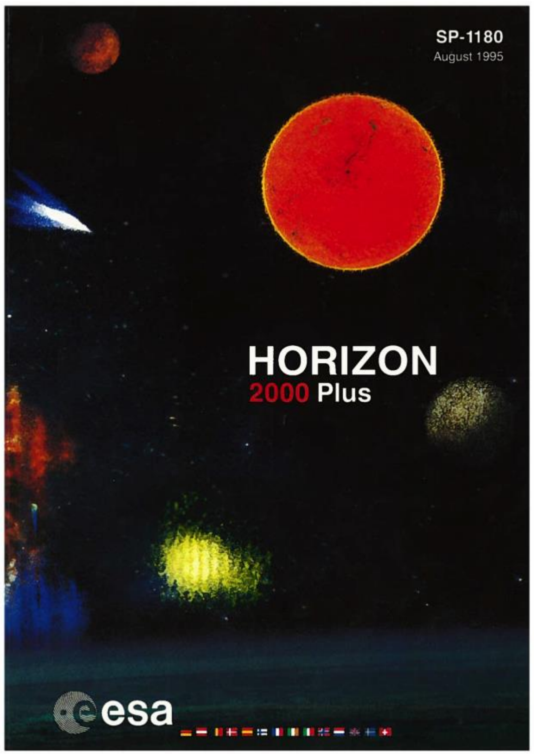
Launch: 2018, Ariane 5 ECA
Orbit: around L2
Status: implementation

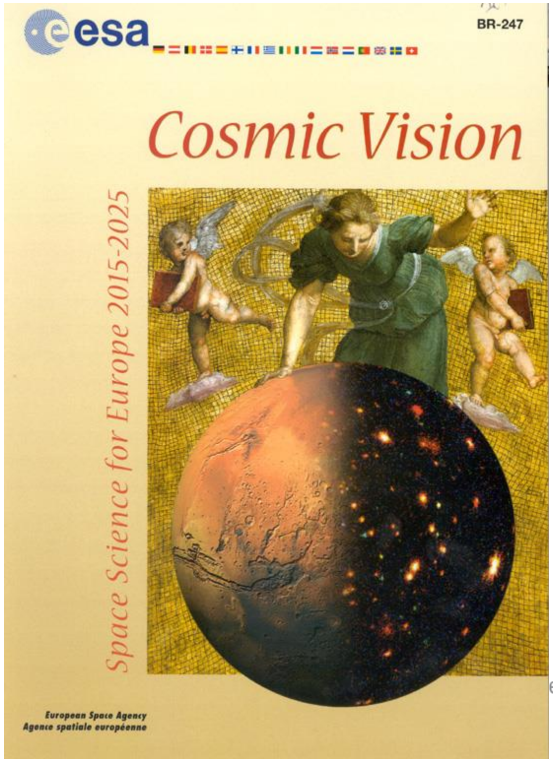


Long-Term Planning

1. 1985: **Horizon 2000** Planning for 2 decades: 1985 – 2005
2. 1995: **Horizon 2000+** Extended H2000 by a decade to 2015
3. 2005: **Cosmic Vision** Initial planning for a decade: 2015 - 2025

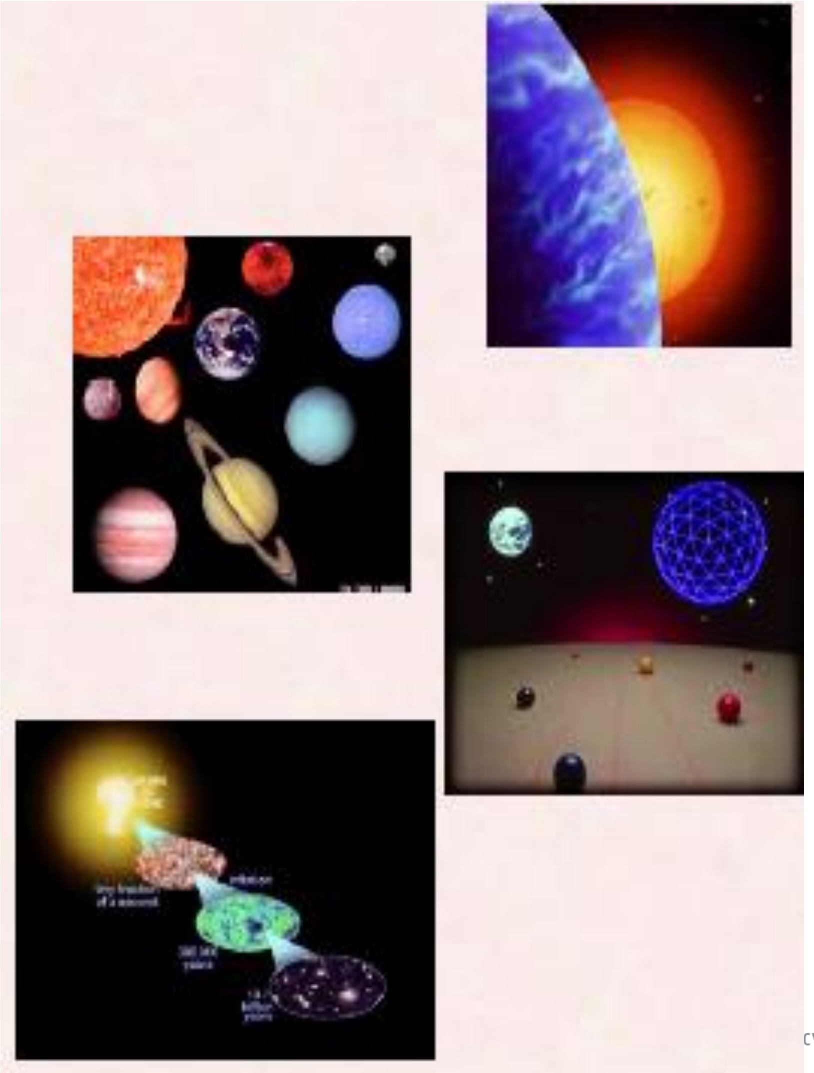






COSMIC VISION

1. What are the conditions for planetary formation and the emergence of life?
2. How does the Solar System work?
3. What are the physical fundamental laws of the Universe?
4. How did the Universe originate and what is it made of?

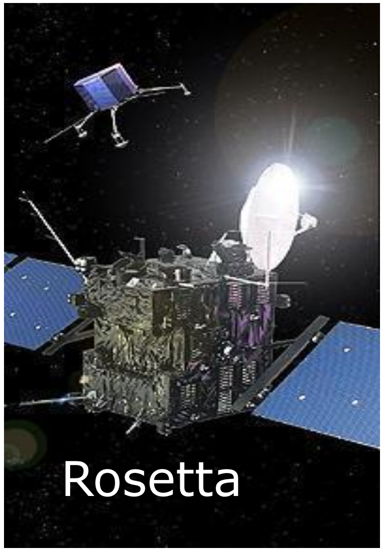


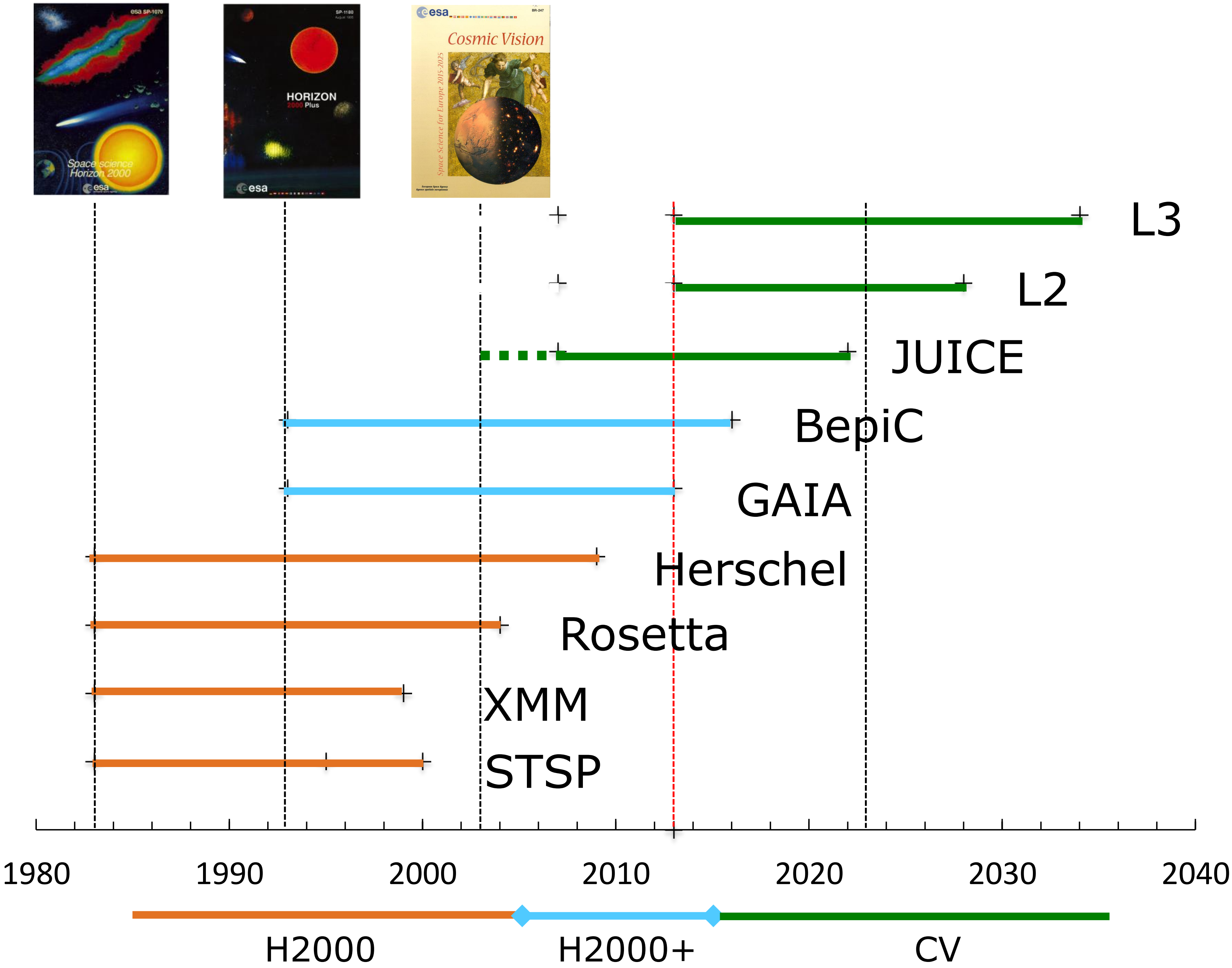
Budget

1. Close to an average of 5 b€ per decade over the last 40 years in constant e.c.
2. Represents around 12% of the total ESA budget
3. Between 20 and 30 % additional budget for payloads is provided Member States,
4. Moreover, National and European funding is used for the scientific exploitation.
5. Overall a budget close to 1 b$ per year is devoted to the Science Programme,

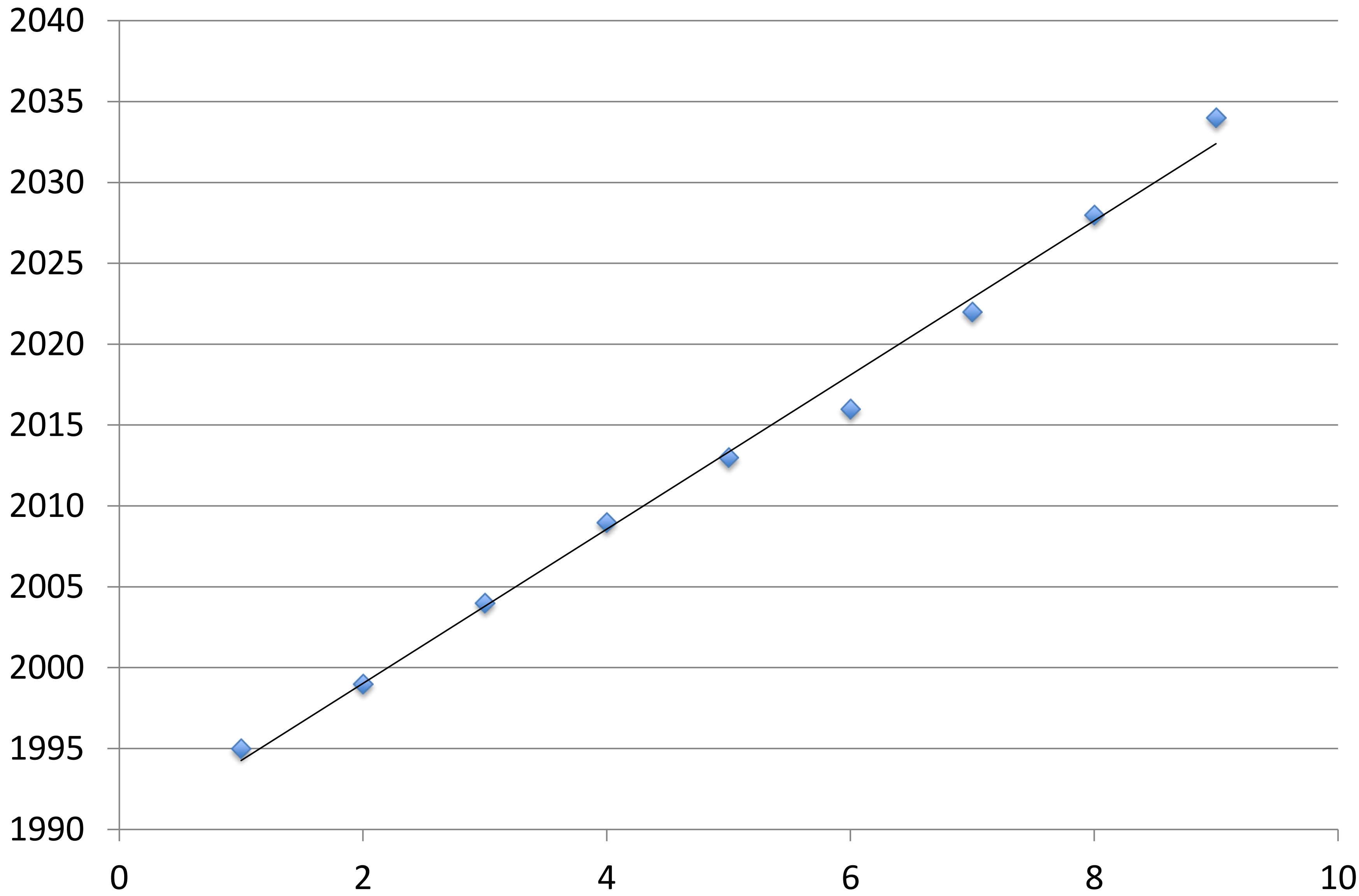
Science Programme’s building blocks

- **Large missions**
    a. Typical ESA CaC 2 yearly budgets
    b. Lead in respective areas, pillars of the science programme
    c. ESA-led (<20% partnership)
    d. Typically planned long in advance (up to two decades) => predefined themes
    e. Likely to require technological developments: rely on innovative European technology developed
    f. Examples: XMM-Newton, Herschel, Rosetta, BepiColombo, …





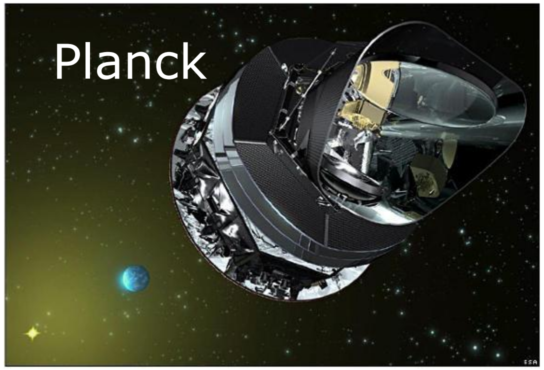
esa SP-1070
Space science Horizon 2000
esa
SP-1180
HORIZON 2000 Plus
esa
esa
Cosmic Vision
Space Science for Europe 2015-2025
L3
L2
JUICE
BepiC
GAIA
Herschel
Rosetta
XMM
STSP
1980
1990
2000
2010
2020
2030
2040
H2000
H2000+
CV

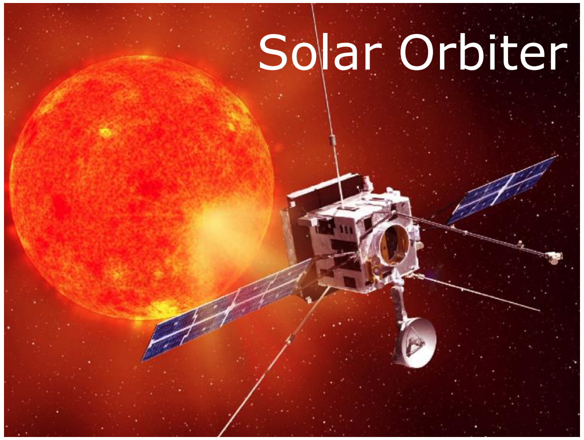


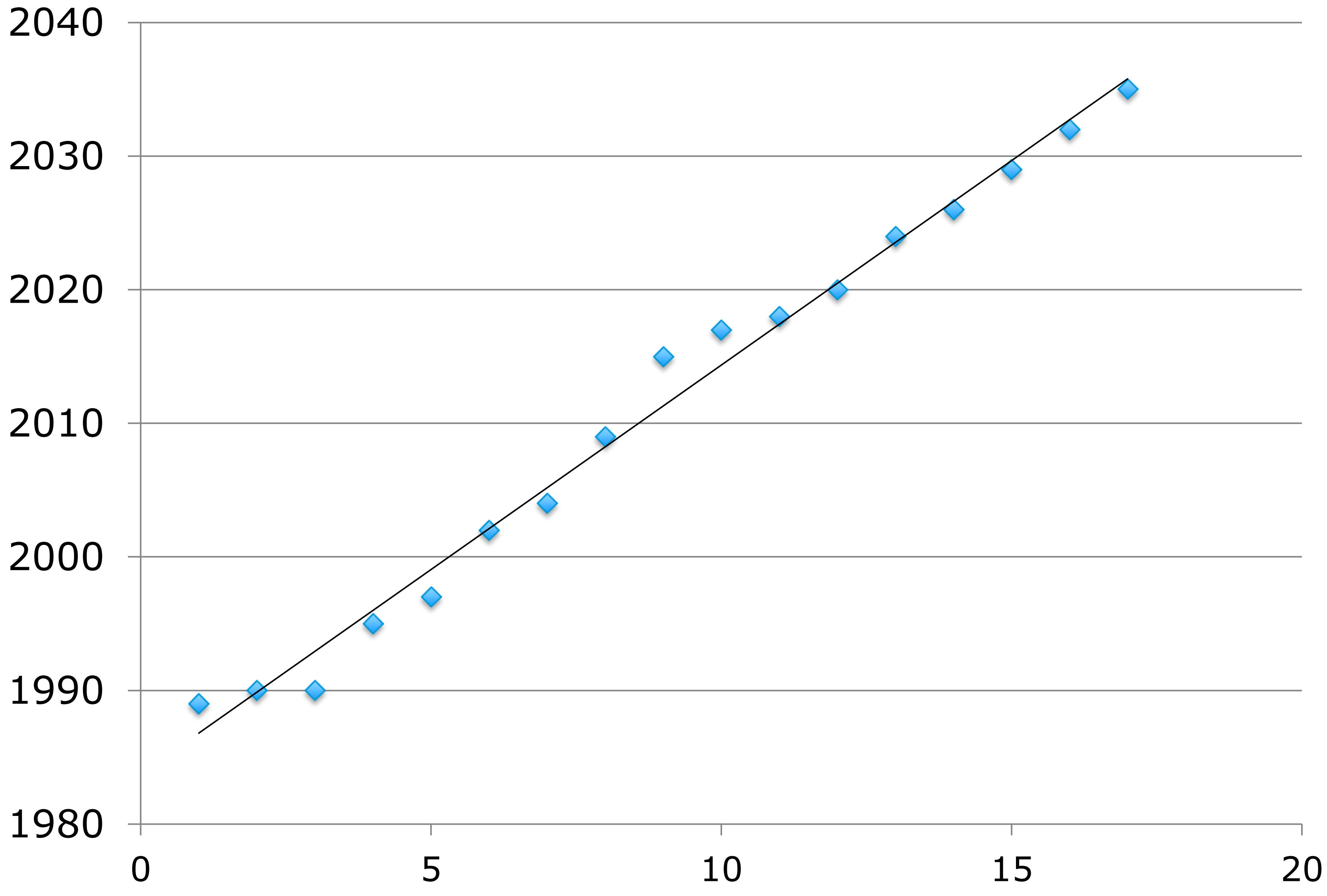
2040
2035
2030
2025
2020
2015
2010
2005
2000
1995
1990
0
2
4
6
8
10

Science Programme's building blocks

- **Medium missions**
  a. Typical ESA CaC 1 yearly budget
  b. Can be, ESA-led, ESA-only, or participation in missions led by partners
  c. Flexibility to react to evolving science landscape
  d. As short a lead time as possible (typically a decade)
     – Implies little mission-specific techno developments
  e. Examples: Huygens, Planck, Mars Express, INTEGRAL, Solar Orbiter, …

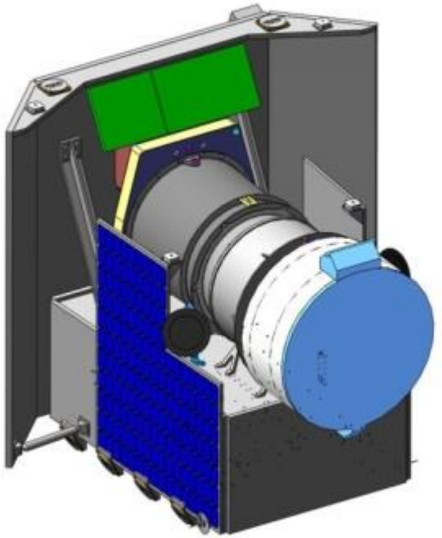


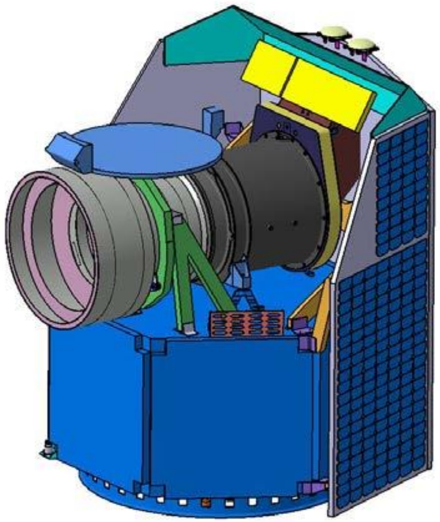



2040
2030
2020
2010
2000
1990
1980
0
5
10
15
20

Science Programme's building blocks

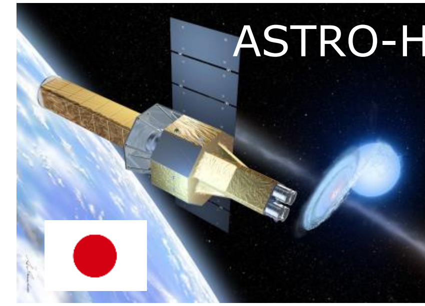
- **Small Missions**
    a. New Programme element, still "experimental"
    b. Typical ESA CaC <= 0.1 yearly budget
    c. Member State partnership opportunity
    d. Increase flight opportunities
    e. Provide opportunity for small member states
    f. Example: CHEOPS

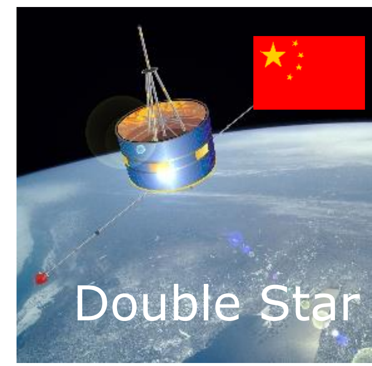


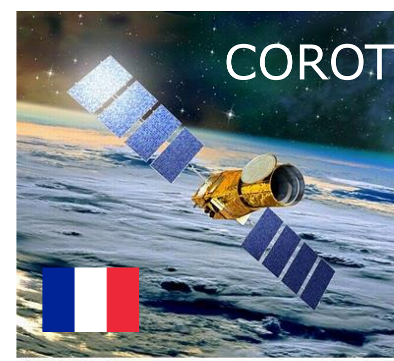


Science Programme’s building blocks

- **Missions of Opportunity**
  a. Typical ESA CaC <= 0.2 yearly budget
  b. Per definition participation in missions led by third party
     – Leadership with international partner or with Member State
  c. Increase flight opportunities for European scientists
  d. Give access to world-wide science
  e. Examples: ASTRO-H, Corot, Double Star, Microscope.







Current planning levels

1. L&M missions take the lion's share of the Programme's budget

1. In steady state, Basic activities (including preparation of the future) + S missions + O Missions will take 16% of the LoR.

1. Hence, 84% of LoR to be used for the implementation of L & M missions (development and operations),
    a. This includes a Programme-level contingency.
    b. It also includes the mission extensions.

Planning years

- Tentative planning for mission calls:

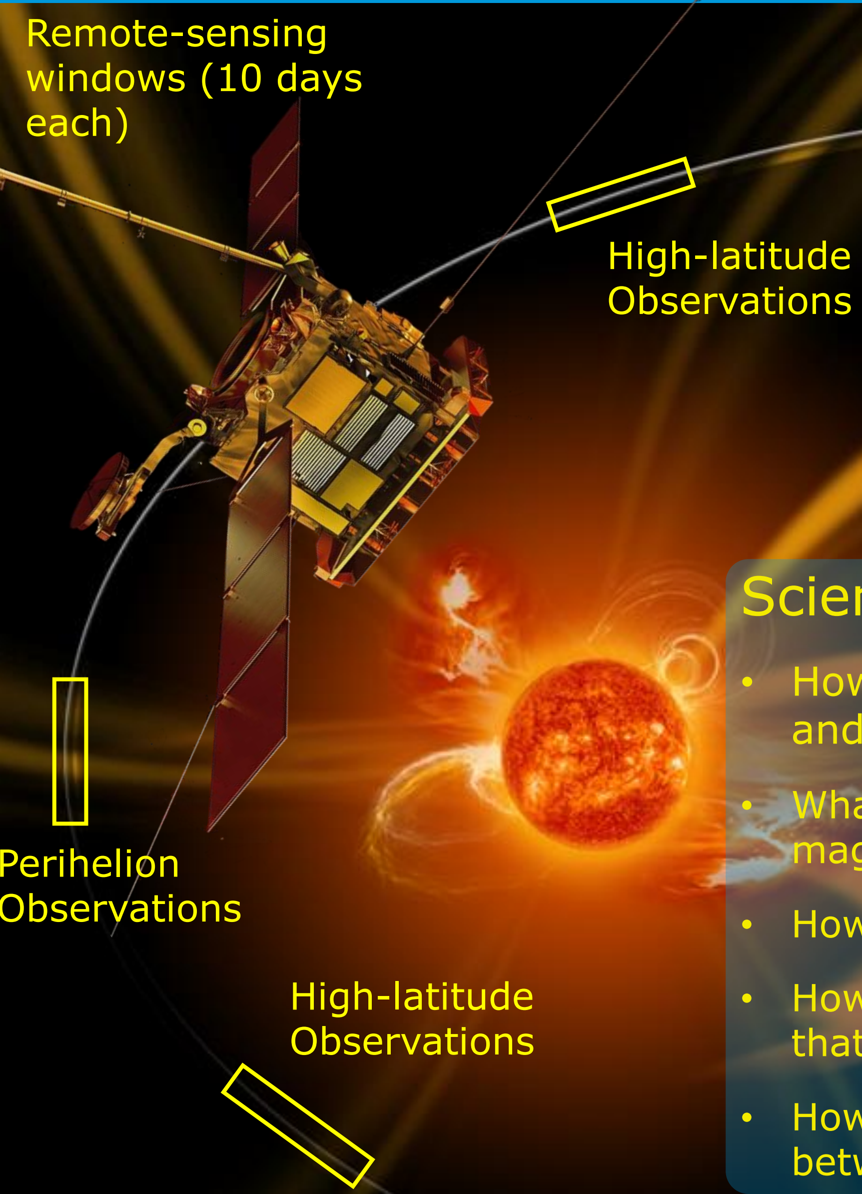
a.	M1, M2, L1	done, done, done	slice 1
b.	M3, M4, L2	done, 2014, done	slice 2
c.	M5, M6, L3	2016, 2018, 2018	slice 3
d.	M7	2022	

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

- Tentative planning for mission launches:

a.	M1, M2, L1	2017, 2020, 2022
b.	M3, M4, L2	2024, 2026, 2028
c.	M5, M6, L3	2030, 2032, 2034
d.	M7	2035

Solar Orbiter
Exploring the Sun-Heliosphere Connection



Mission Summary

Launch: 2017

Cruise Phase: 3 years

Nominal/Extended Mission: 3.5/2.5 years

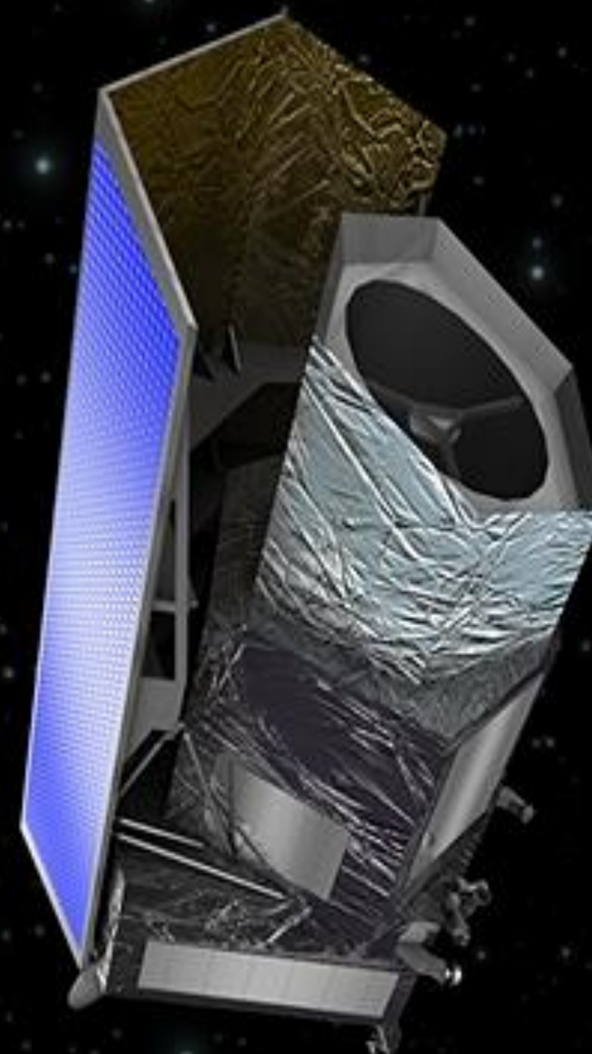
Orbit: 0.28–0.91 AU (P=150-168 days)

Out-of-Ecliptic View:
Multiple gravity assists with Venus to increase out-of-ecliptic inclination to >34°

Science Focus

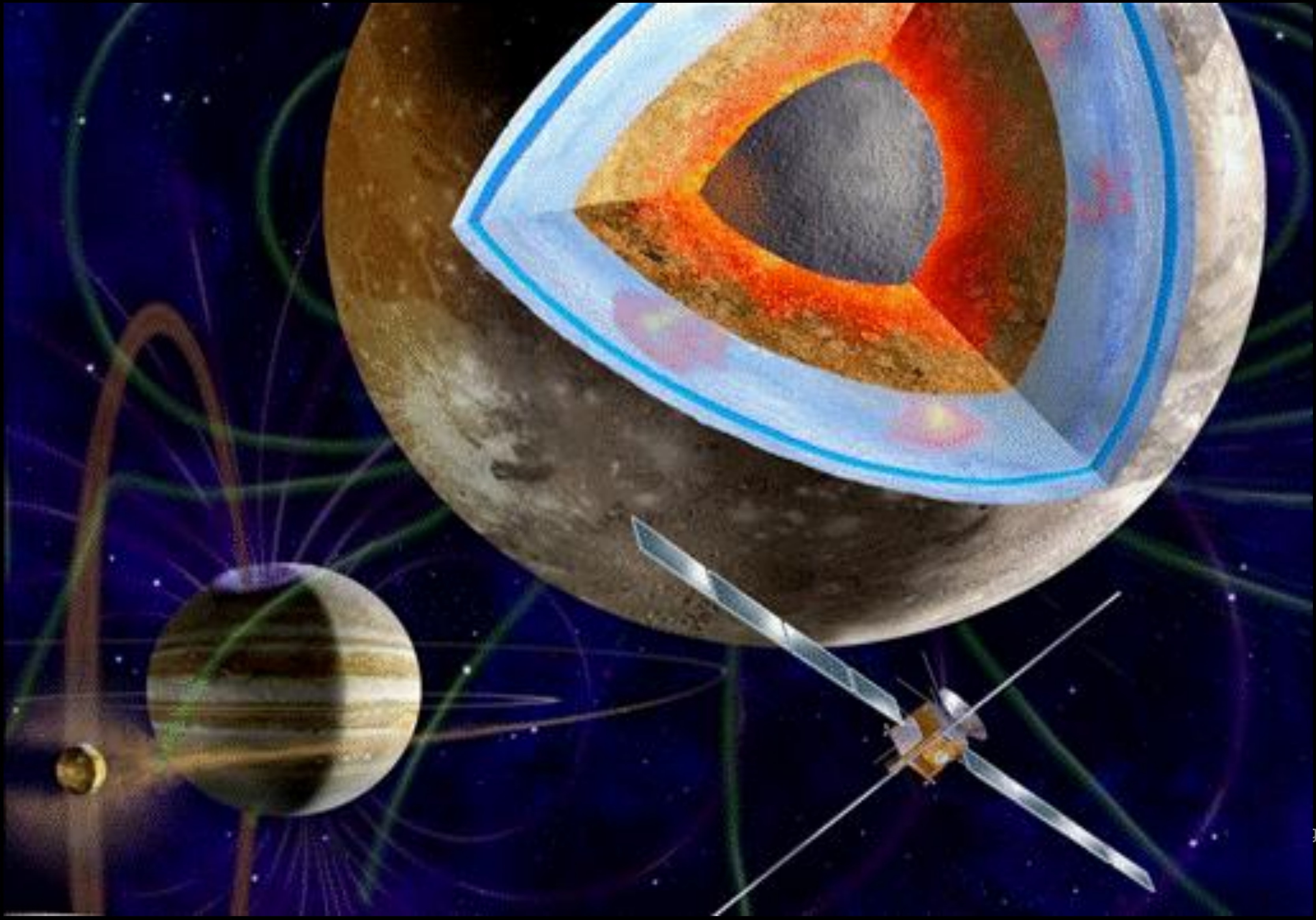
- How does the Sun create and control the Heliosphere – and why does solar activity change with time ?
- What drives the solar wind and where does the coronal magnetic field originate from?
- How do solar transients drive heliospheric variability
- How do solar eruptions produce energetic particle radiation that fills the heliosphere?
- How does the solar dynamo work and drive connections between the Sun and the heliosphere?

Euclid – Mapping the Dark Universe



et for launch in 2020, Euclid will nvestigate the evolution of cosmic tructure by measuring galaxy shapes, ositions and redshifts of galaxies and usters of galaxies out to redshifts of ~2

JUICE – The icy moons of Jupiter



jency

JUICE: JUpiter Icy moons Explorer

Emergence of habitable worlds around gas giants

Jupiter system as an archetype for gas giants

esa

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*

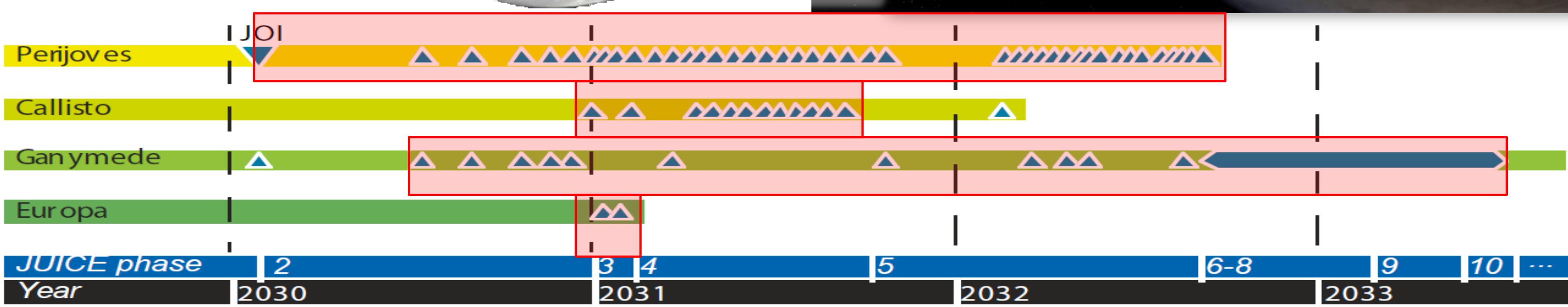
Ganymede:

planetary object and potential habitat

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

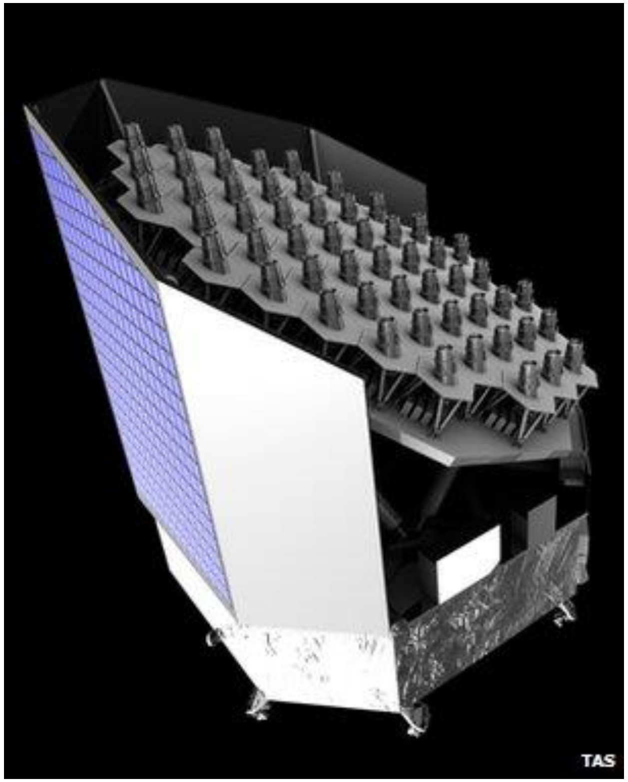
Jupiter System:

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



M missions decision process

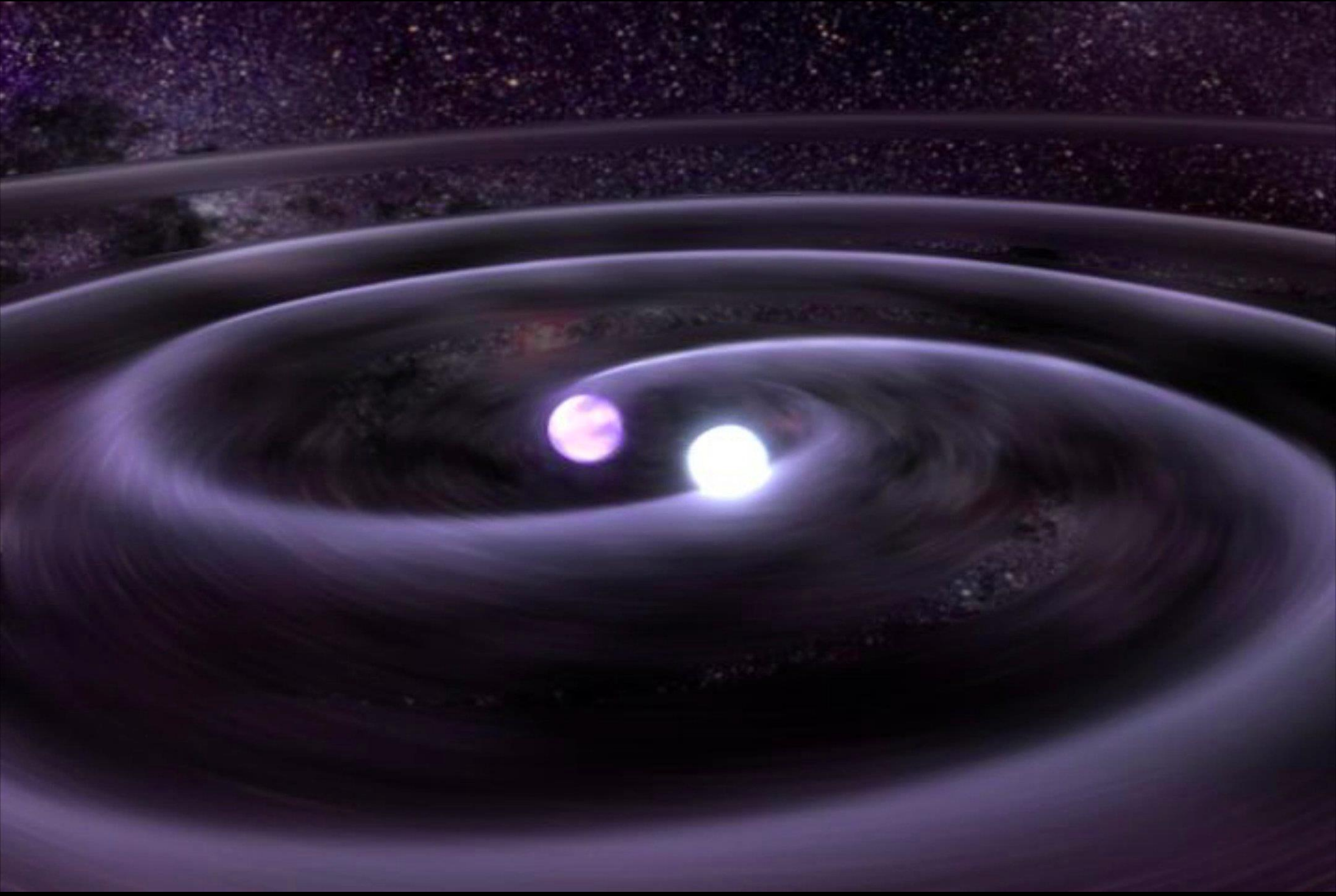
Decision on M3 (launch 2024) taken by SPC in February 2014 to be PLATO

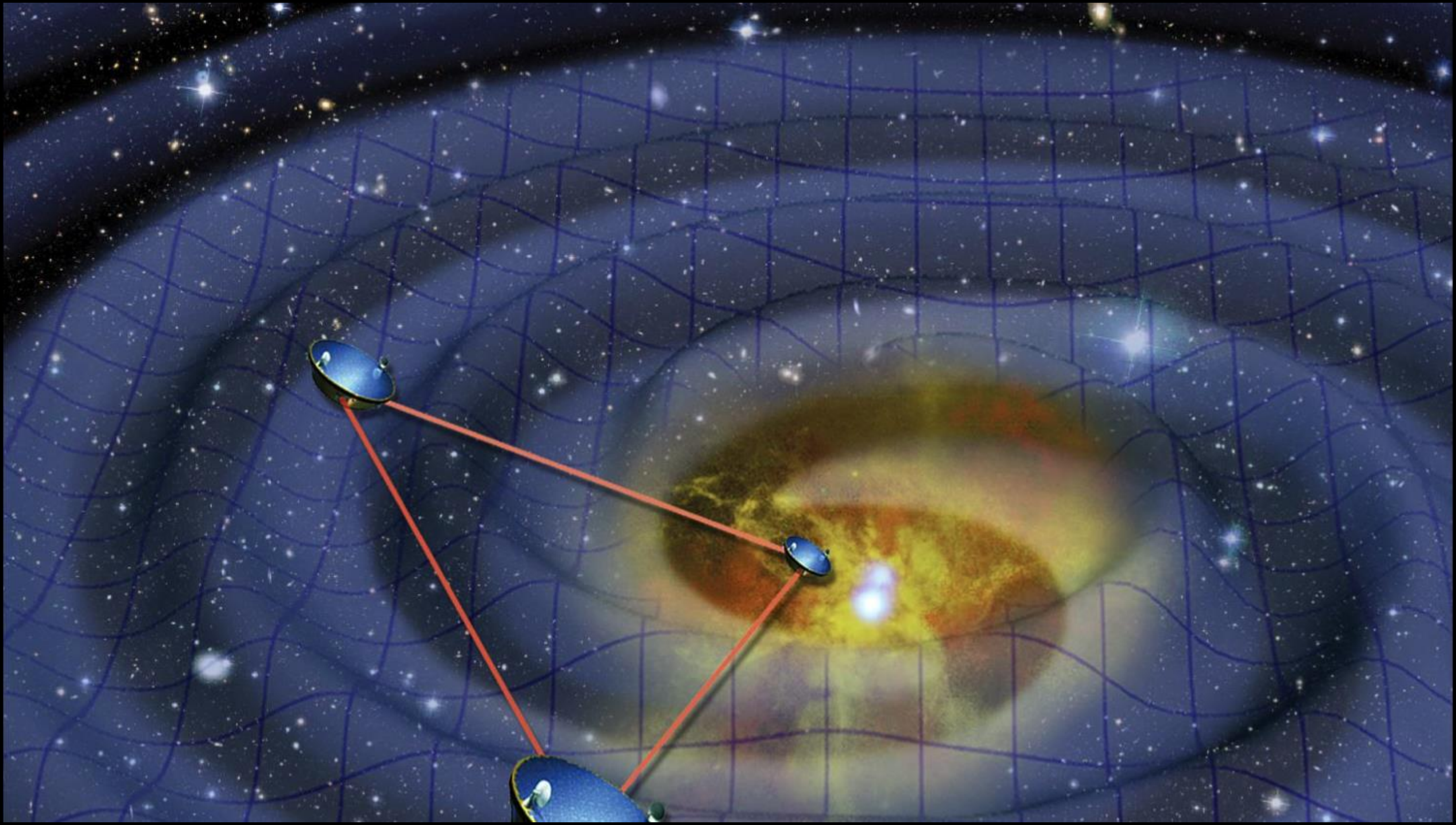


M missions decision process

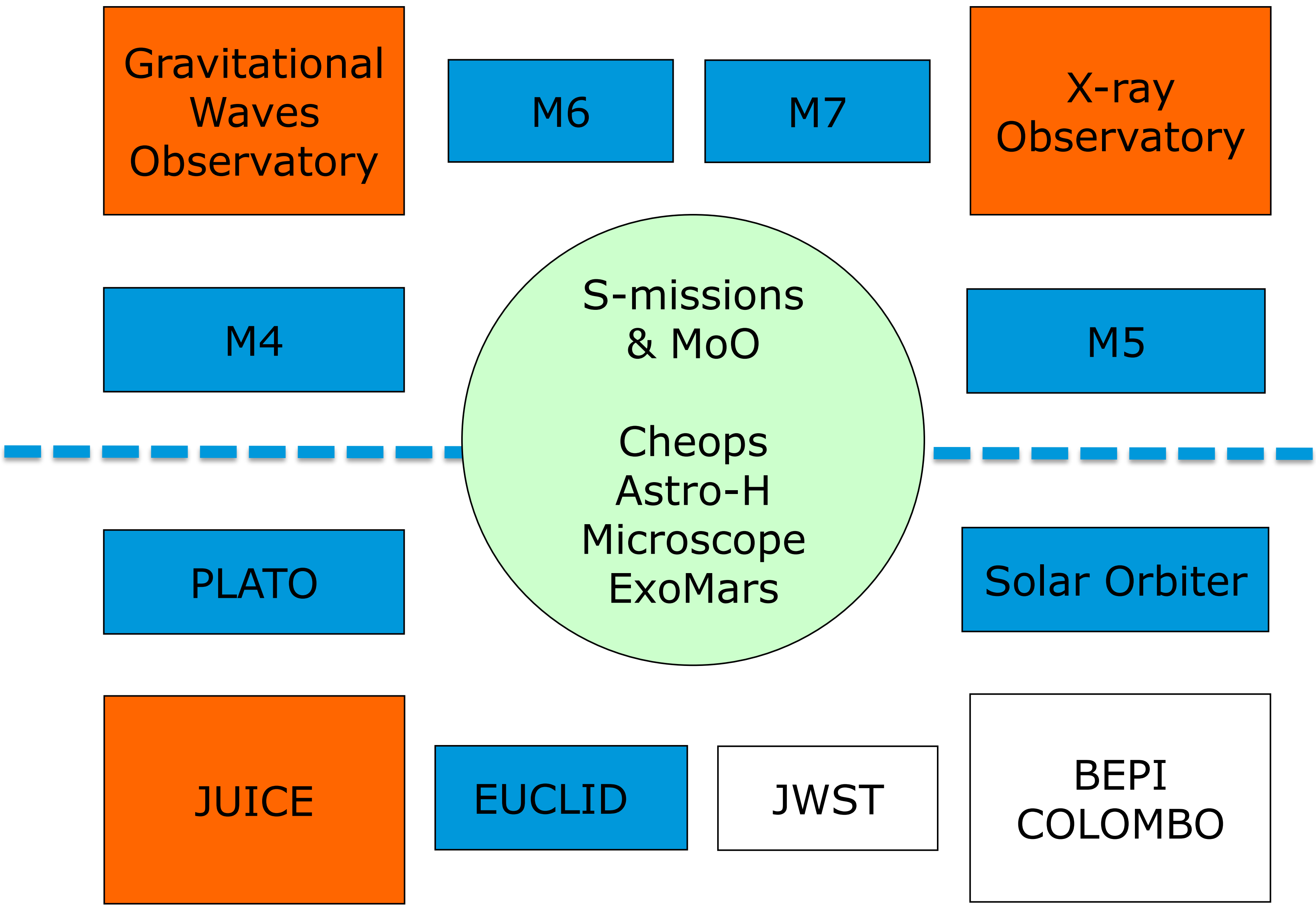
Call for M4 mission (launch 2025) to be issued in mid 2014

a. Call will solicit mission proposals to scientific community
b. Peer review by ESA's Advisory Structure
c. Selection of 3-4 concepts for initial study (18-24 months)
d. Decision on mission for implementation in 2016 – again based on peer review
e. International cooperation will most probably be fostered

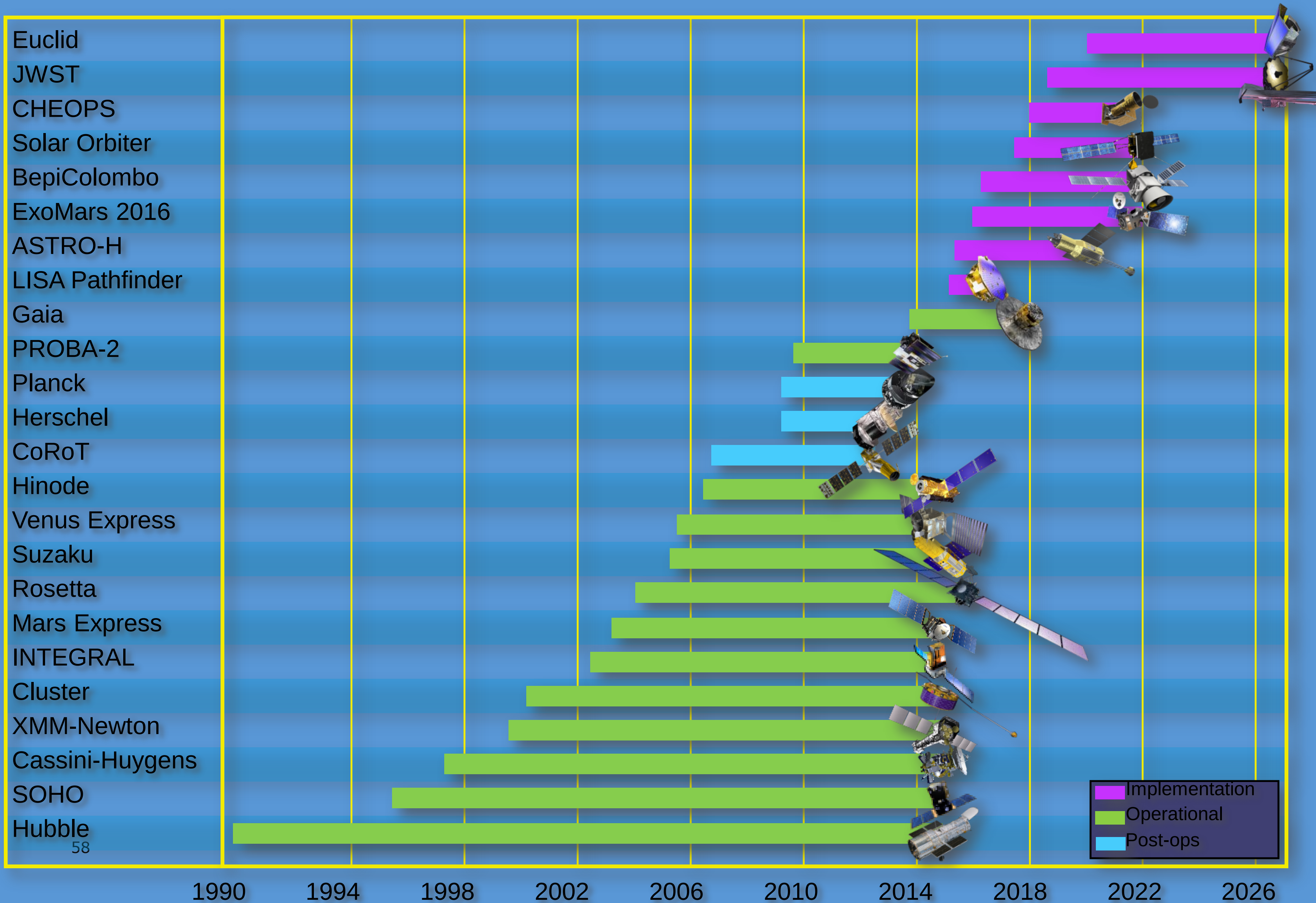


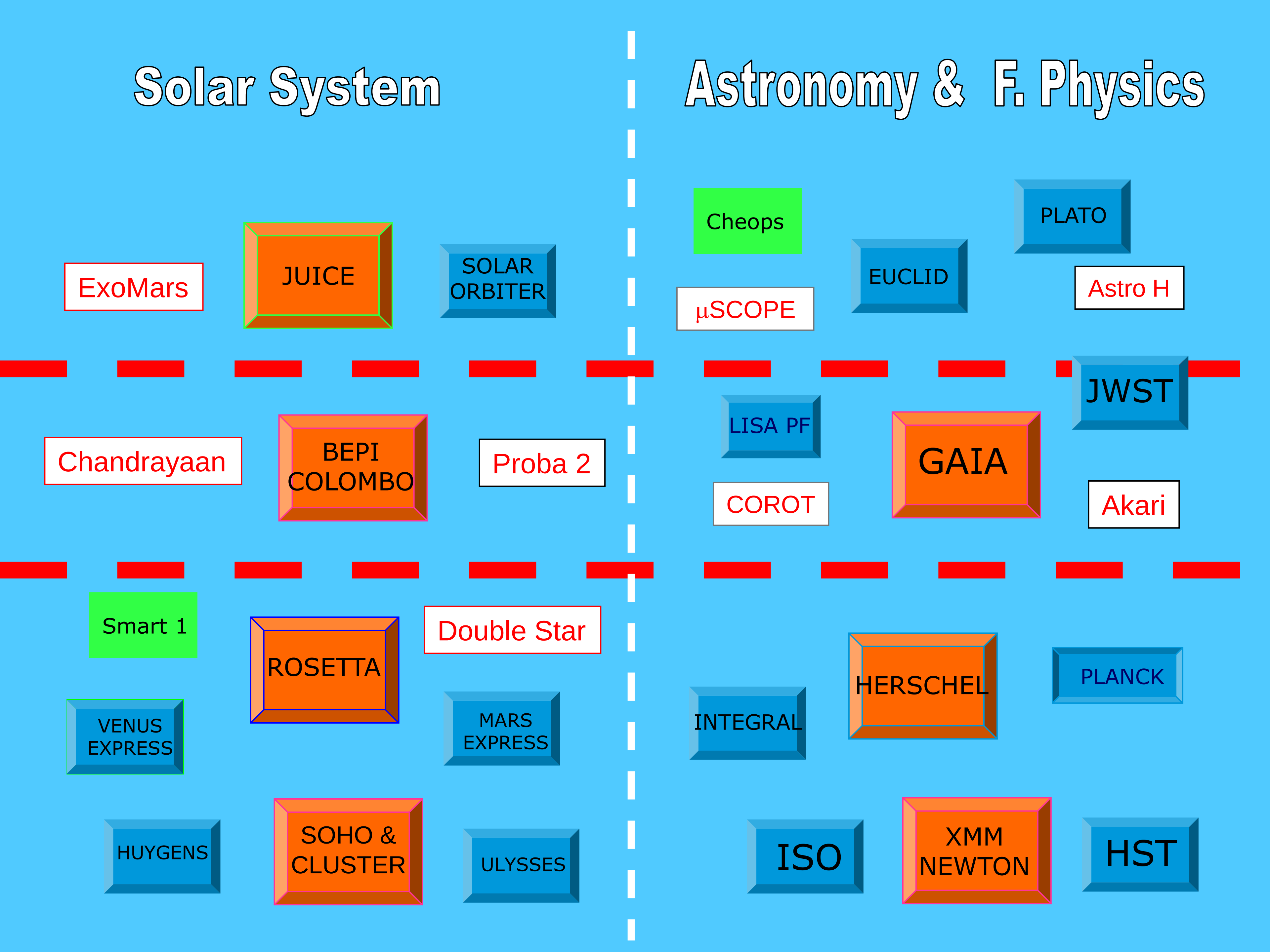


COSMIC VISION (2015-2035)



Current ESA space science missions




Solar System
Astronomy & F. Physics
ExoMars
JUICE
SOLAR ORBITER
Cheops
µSCOPE
EUCLID
PLATO
Astro H
Chandrayaan
BEPI COLOMBO
Proba 2
LISA PF
COROT
GAIA
JWST
Akari
Smart 1
ROSETTA
Double Star
VENUS EXPRESS
MARS EXPRESS
HUYGENS
SOHO & CLUSTER
ULYSSES
INTEGRAL
HERSCHEL
PLANCK
ISO
XMM NEWTON
HST

Conclusion

- The Science Programme is a flagship and symbol for the Agency. It is the only mandatory element of the ESA programme.
- Community- and science-driven. Many highly successful missions in orbit delivering new scientific results back to scientists world-wide,
- Many challenging missions in development and under study: Flood of new results will continue..


Thank you!
www.esa.int/science
European Space Agency