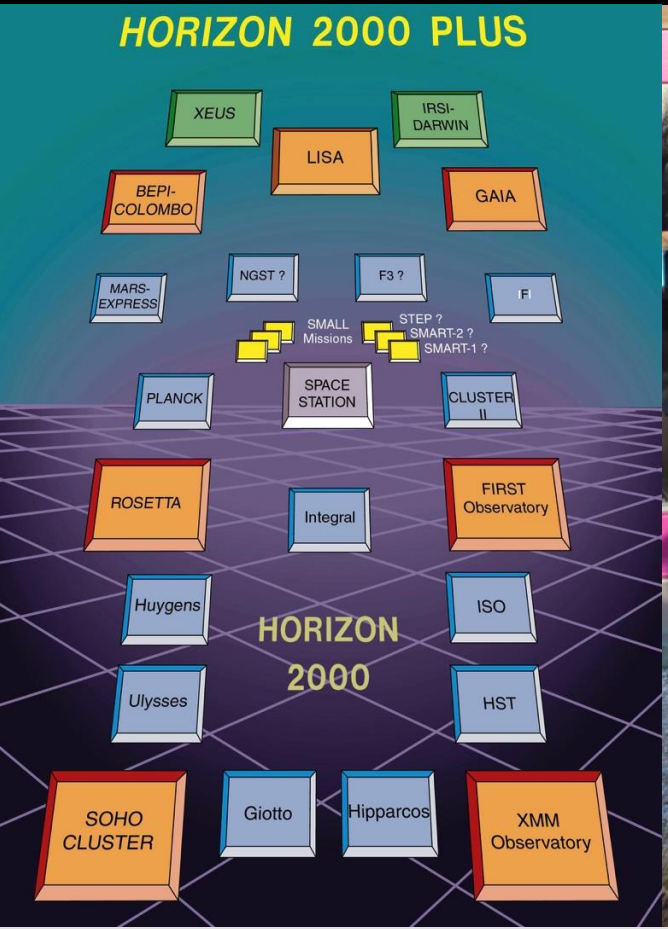
# The ESA Science Programme

Günther Hasinger D/SCI

ESSC Plenary Meeting, Geneva Observatory, 23. May 2018

# Four generations of ESA Science Directors

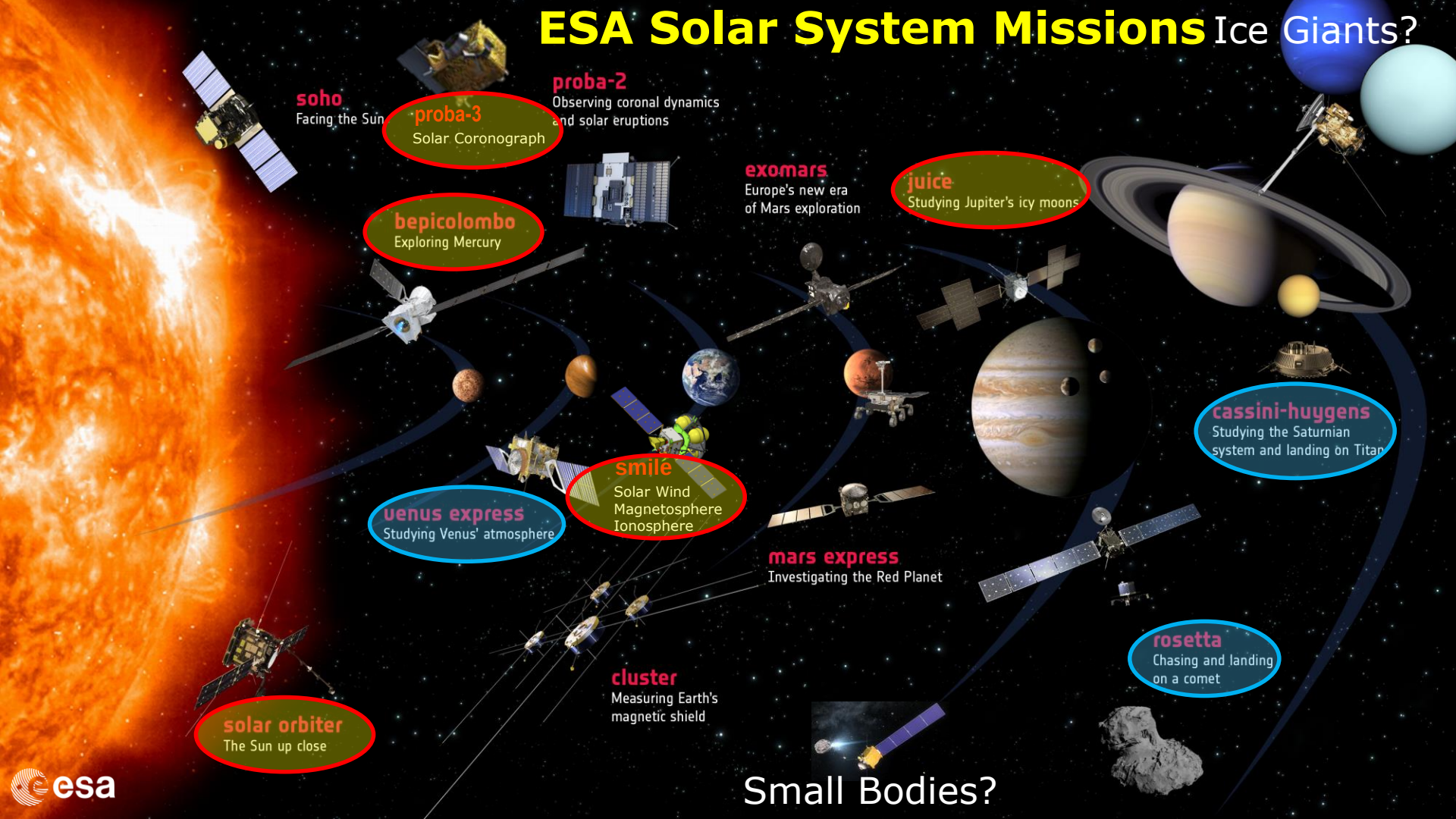




On the occasion of Roger Bonnet's 80th Birthday Symposium ESTEC, 8.2.2018.

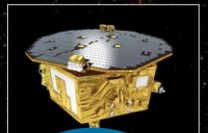
Celebrating the success of Horizon 2000.

# ESA Solar System Missions




esa

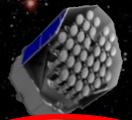
# ESA Astrophysics Missions

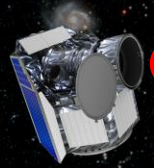


**lisa pathfinder**
Testing the technology for gravitational wave detection

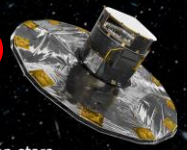
**jwst**
Observing the first light

**herschel**
Unveiling the cool and dusty Universe



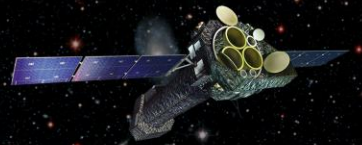


**plato**
Exoplanets & stars

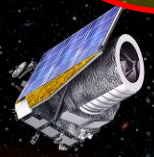


**gaia**
Surveying a billion stars

**cheops**
Characterising exoplanets



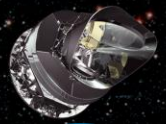
**euclid**
Exploring the dark Universe



**xmm-newton**
Seeing deeply into the hot and violent Universe

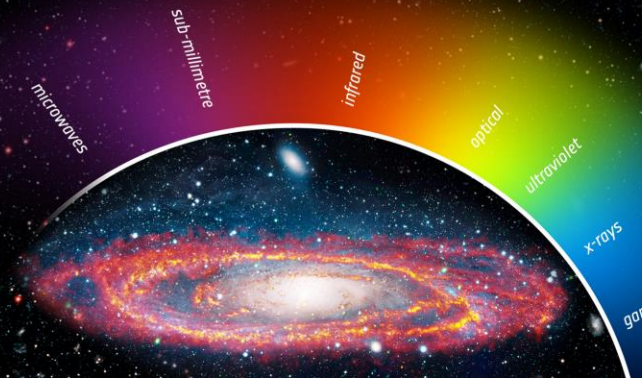
**xarm**
Formation of the elements

**hst**
Expanding the frontiers of the visible Universe



**planck**
Looking back at the dawn of time

**integral**
Seeking out the extremes of the Universe

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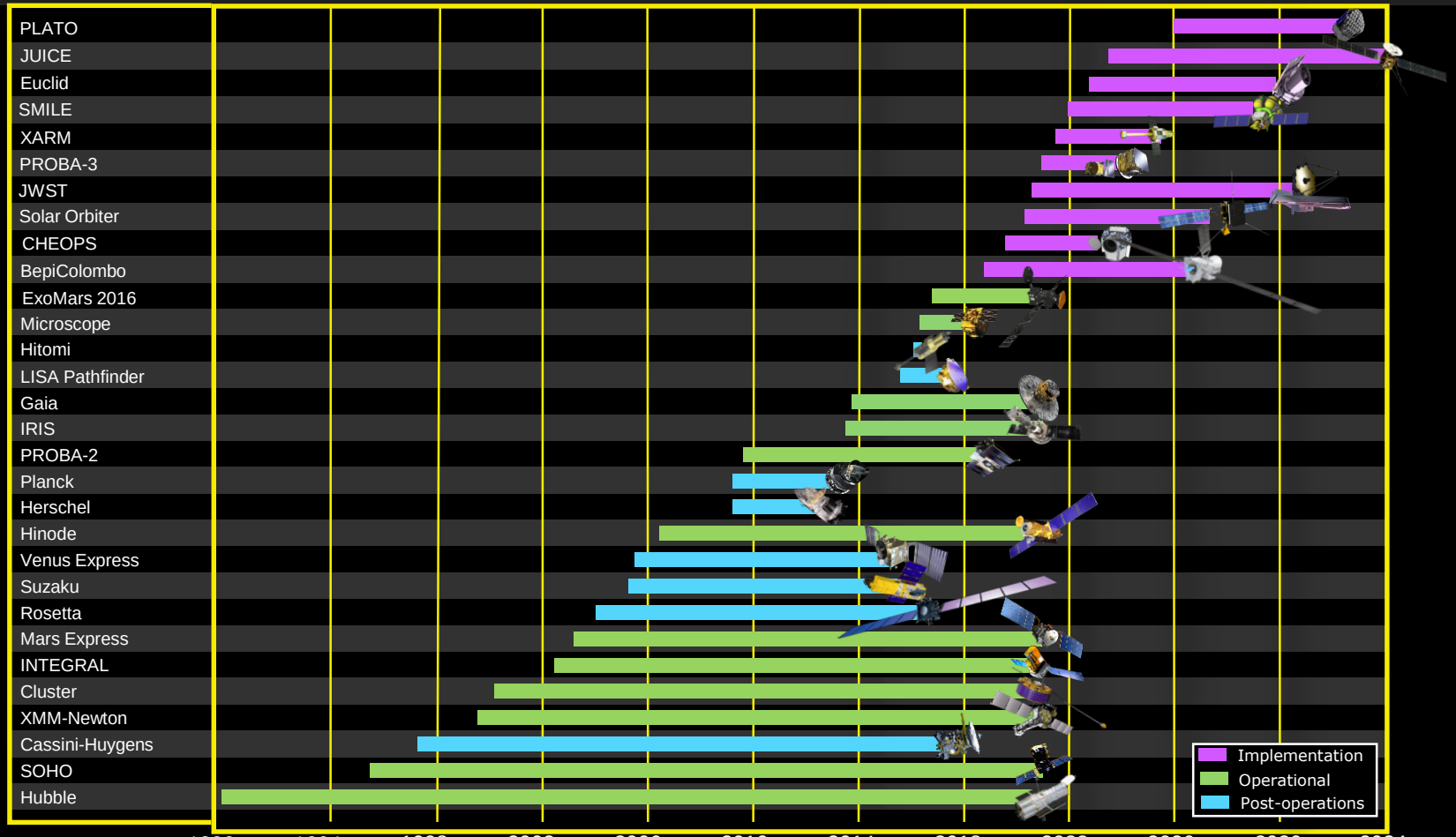
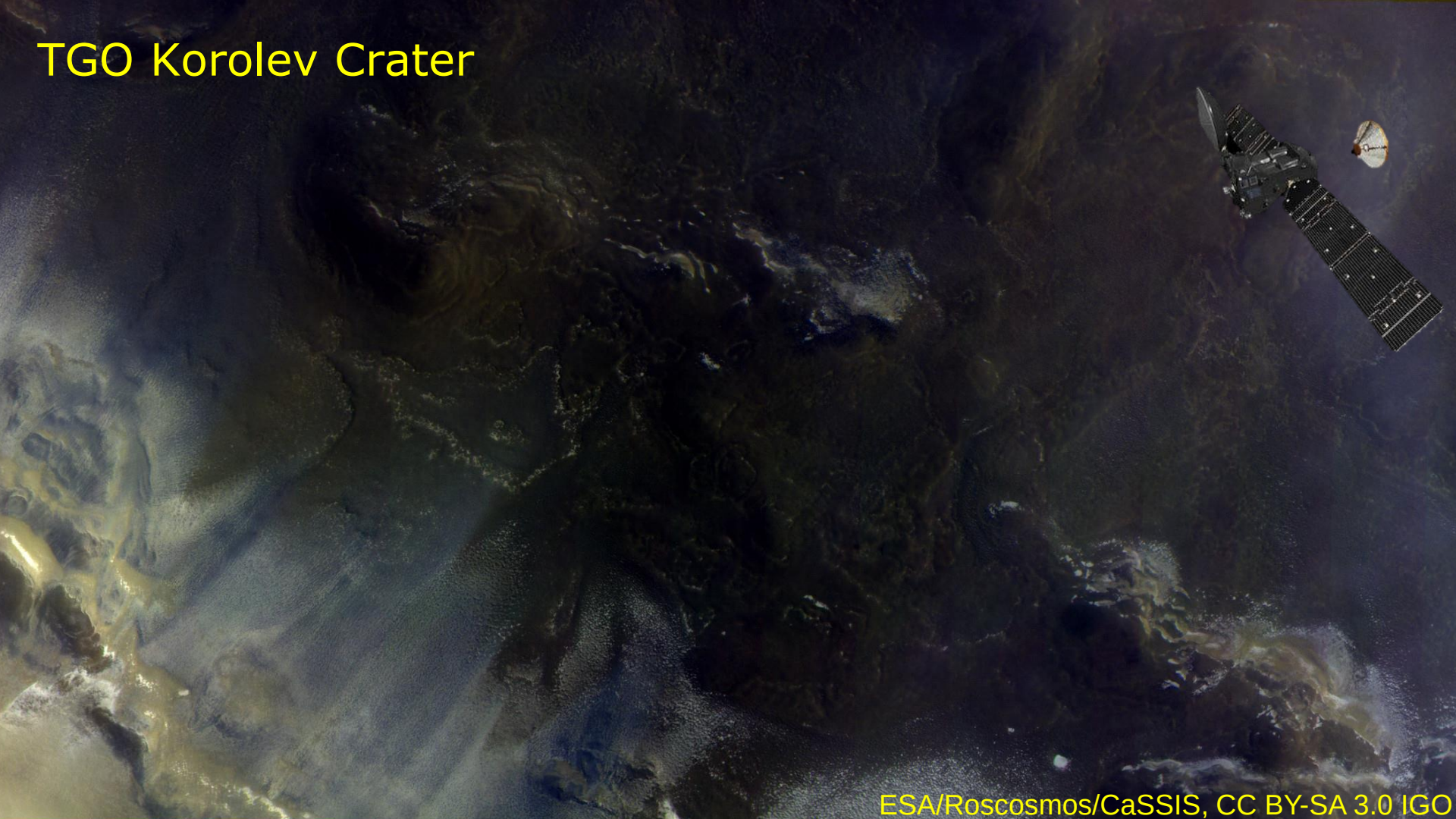
# ESA Space Science Missions

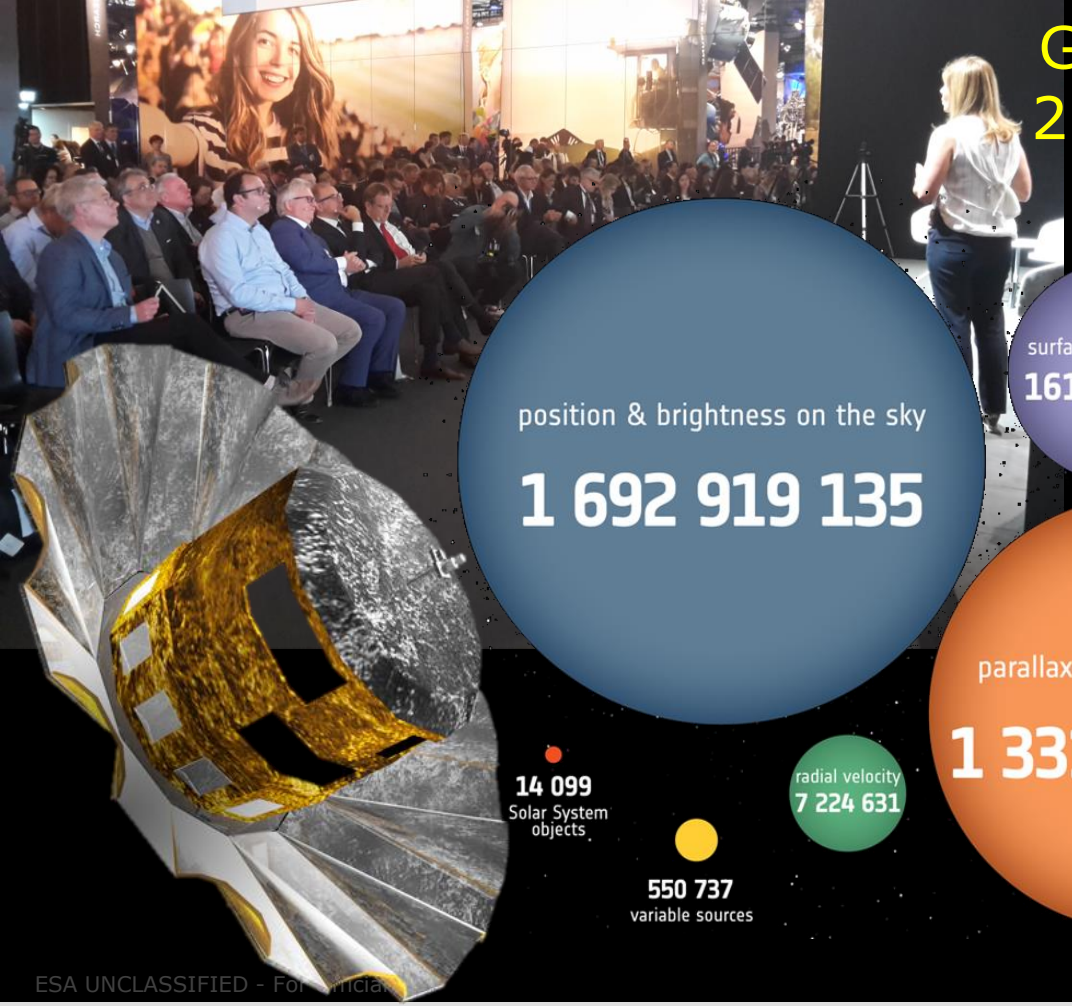



Last update: March 2018

# TGO Korolev Crater



# Gaia Data Release 2
25.4.2018, ILA Berlin



position & brightness on the sky
1 692 919 135

surface temperature
161 497 595

red colour
1 383 551 713

blue colour
1 381 964 755

parallax and proper motion
1 331 909 727

radius & luminosity
76 956 778

amount of dust along the line of sight
87 733 672

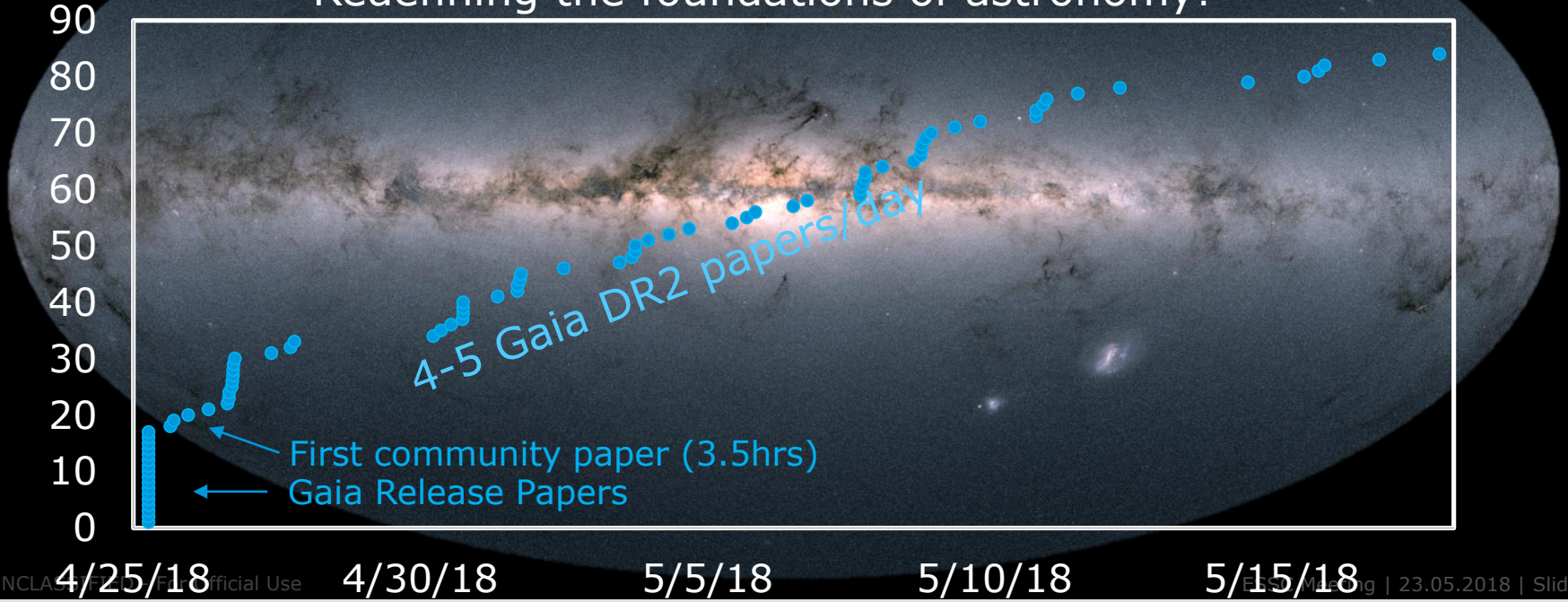
radial velocity
7 224 631

14 099
Solar System objects

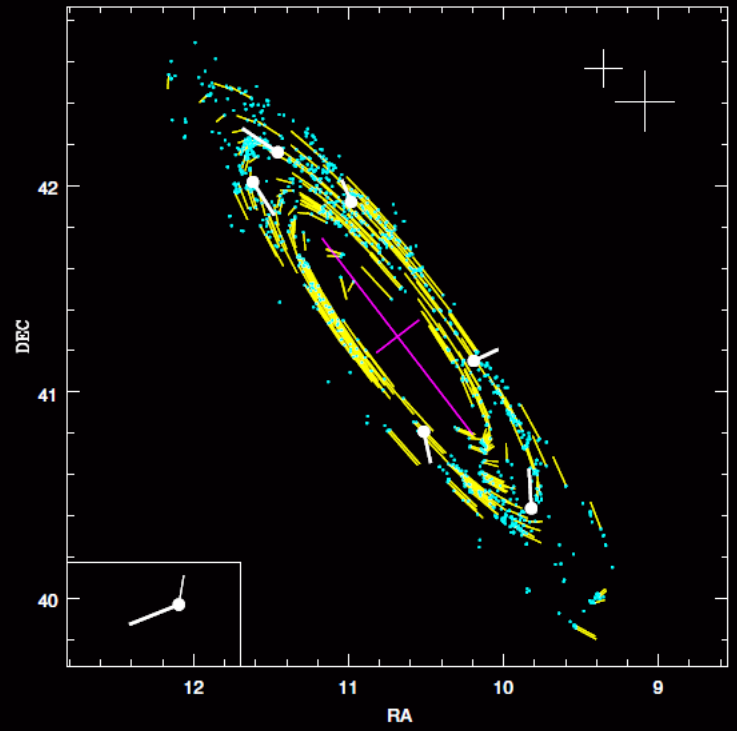
550 737
variable sources

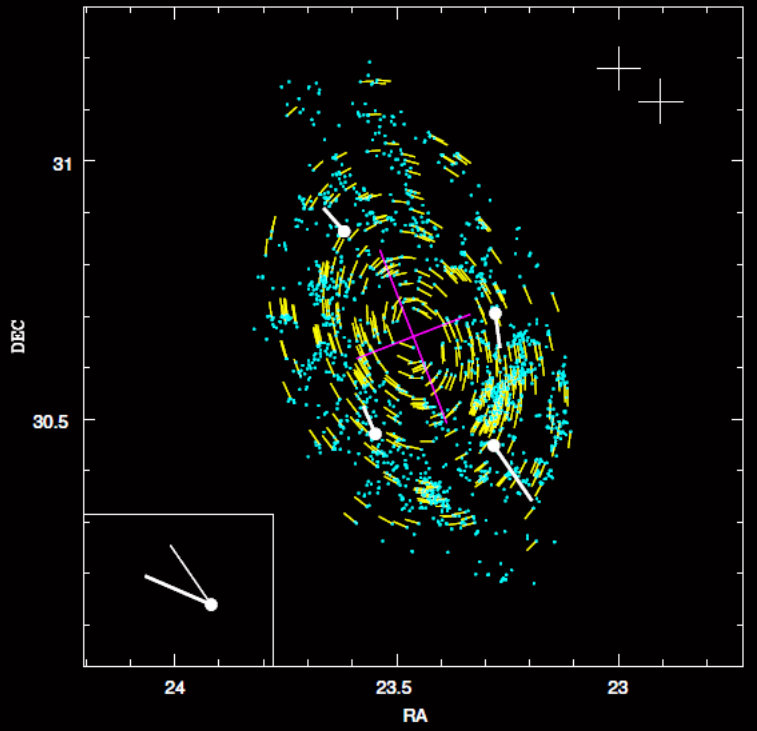
# Gaia DR2


## Redefining the foundations of astronomy!



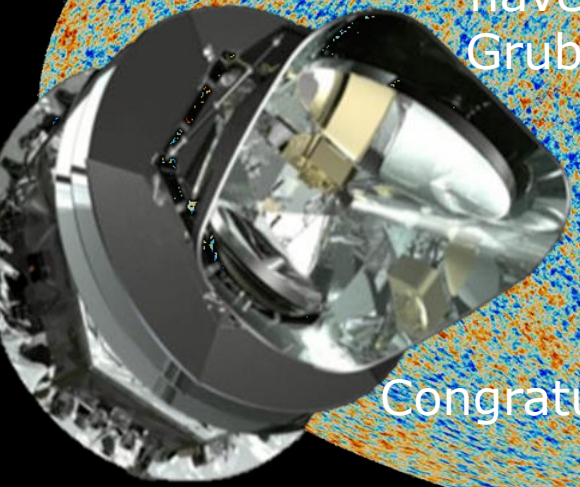
# Gaia DR2 Rotation of M31 and M33 from Proper Motion




van der Marel et al., 10.5.2018

# Gruber Cosmology Prize for the ESA Planck Team



The ESA Planck Team as a whole, and its principal science team leaders, Nazzareno Mandolesi and Jean-Loup Puget, have been awarded the prestigious 2018 Gruber Cosmology Prize on May 9, 2018!

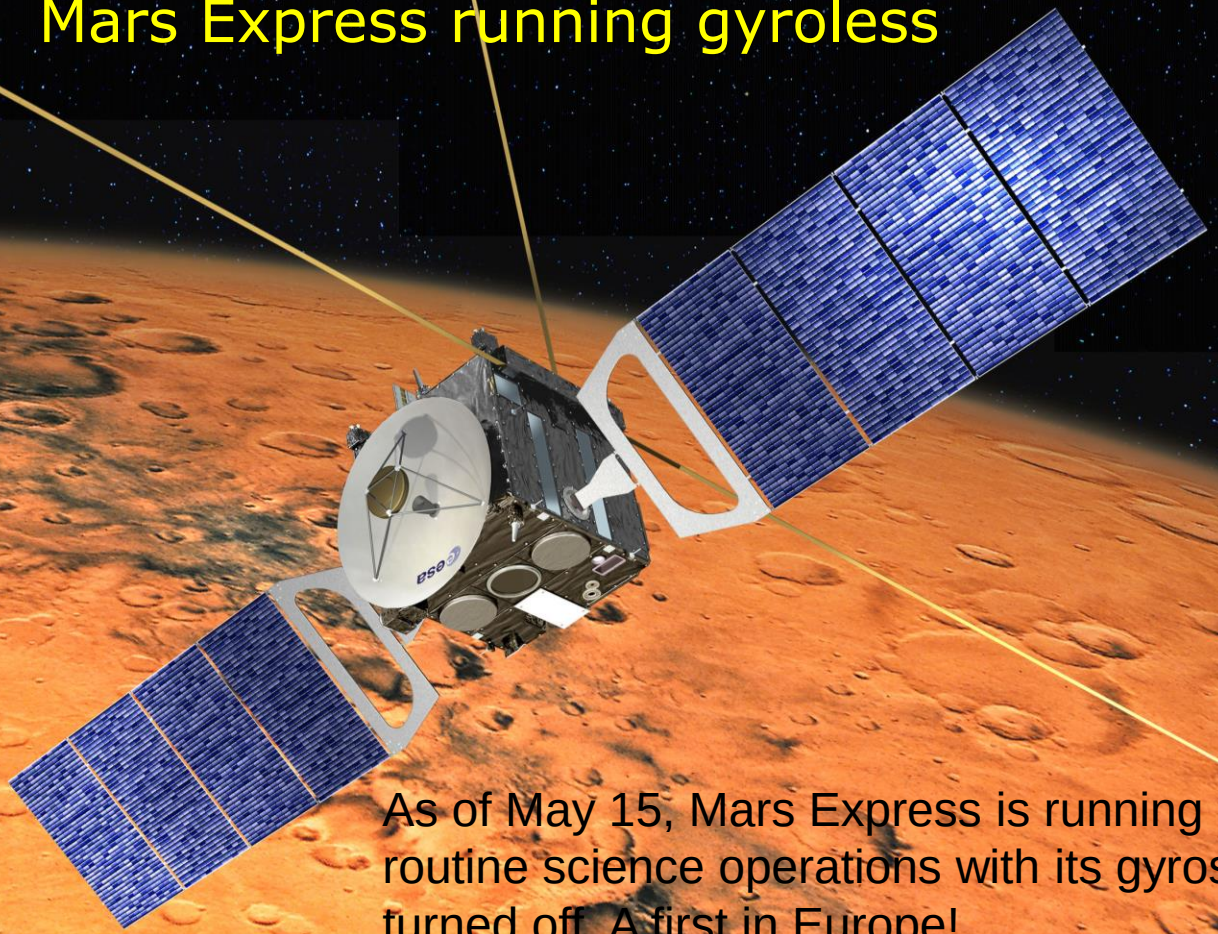
Congratulations for this wonderful achievement!

# BepiColombo at Kourou Spaceport





# Mars Express running gyroless



As of May 15, Mars Express is running routine science operations with its gyros turned off. A first in Europe!

# Scientific Highlights

The scientific discoveries are just raining down on us and we live in a wonderful age for astrophysics and space science

Here I show some examples of recent breakthrough discoveries and new quests.

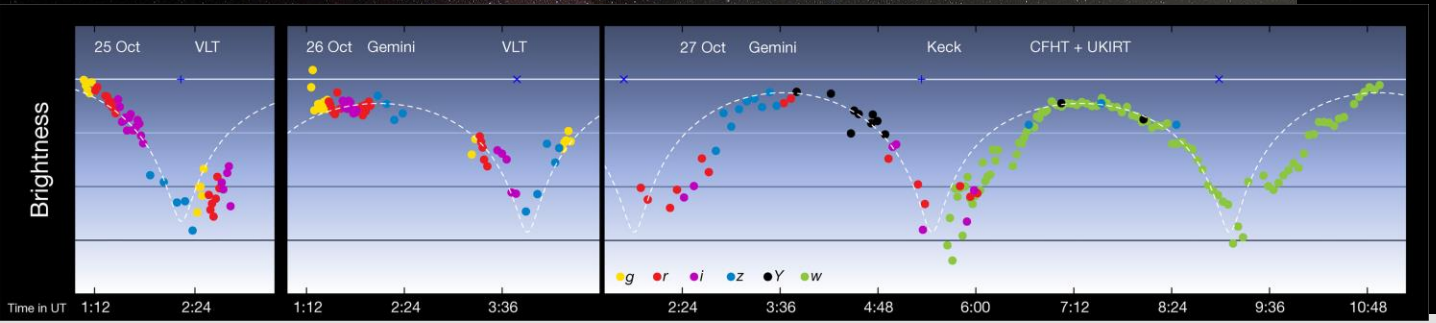
The ESA Cosmic Vision Programme is already in an excellent position to embark on some of the major new scientific challenges, and will be developed to address more.

# 1I ʻOumuamua

Karen Meech
U Hawaii

ESO animation






About 25,000 such objects at any time in our solar system. Next discoveries possible in the near future.

Huge press coverage! Most visible scientific result of 2017 (competing with Kilonova)

Excellent "dual use" of NASA NEO and ESA ops activities!

Wonderful cooperation among observatories.

Watch this space! Exciting new results from HST expected soon!

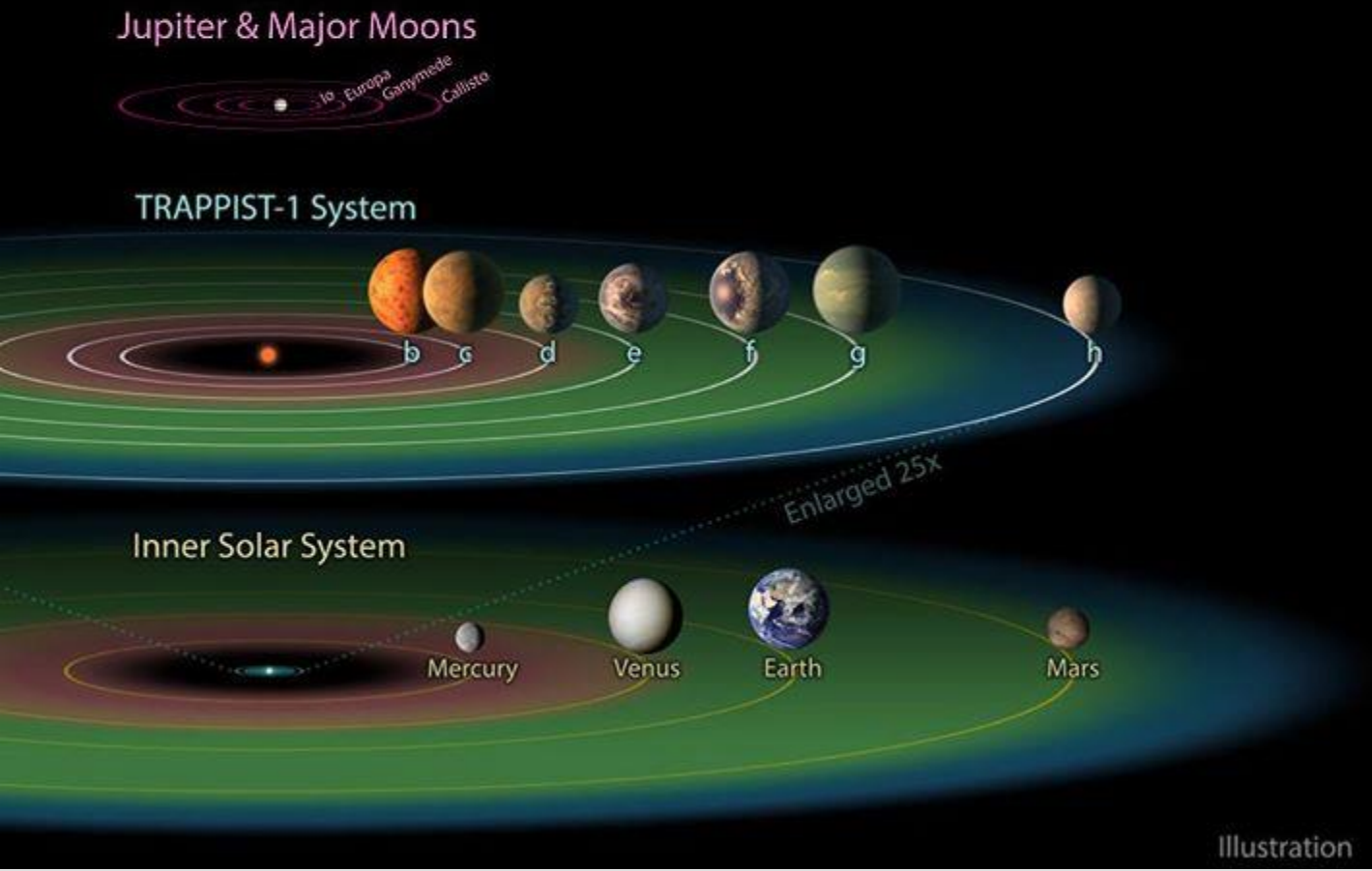
# 'Oumuamua Trajectory

The objects gets much fainter as it travels back to outer space. Hubble observations and precision astrometry are necessary to pin down its trajectory.

Recent Hubble data have revealed possibly a tumbling disk instead of a cigar shape.

Belton et al., 2018, ApJ 856, 21

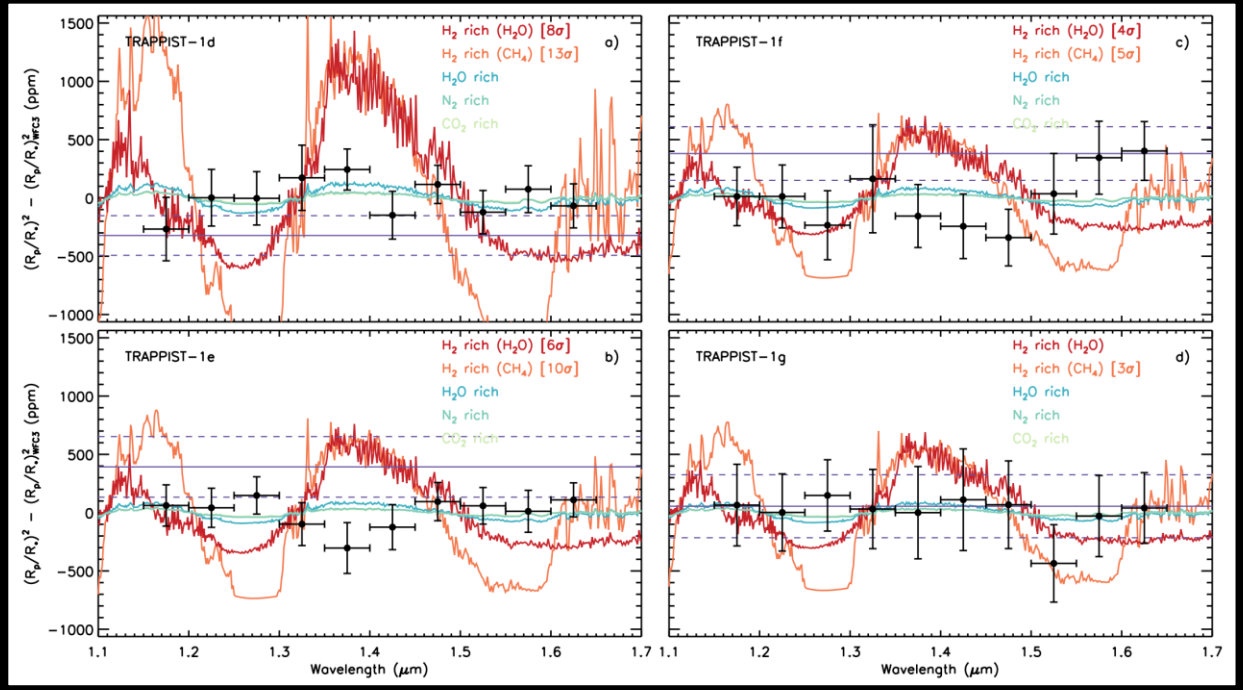
# Exoplanets: The Trappist-1 System




Seven temperate Earth-like planets around a Jupiter-size red dwarf star at a distance of 40 light years

M. Gillon et al., Nature 2017

# HST transmission spectroscopy of four TRAPPIST-1 planets




de Wit et al. 2018, Nature

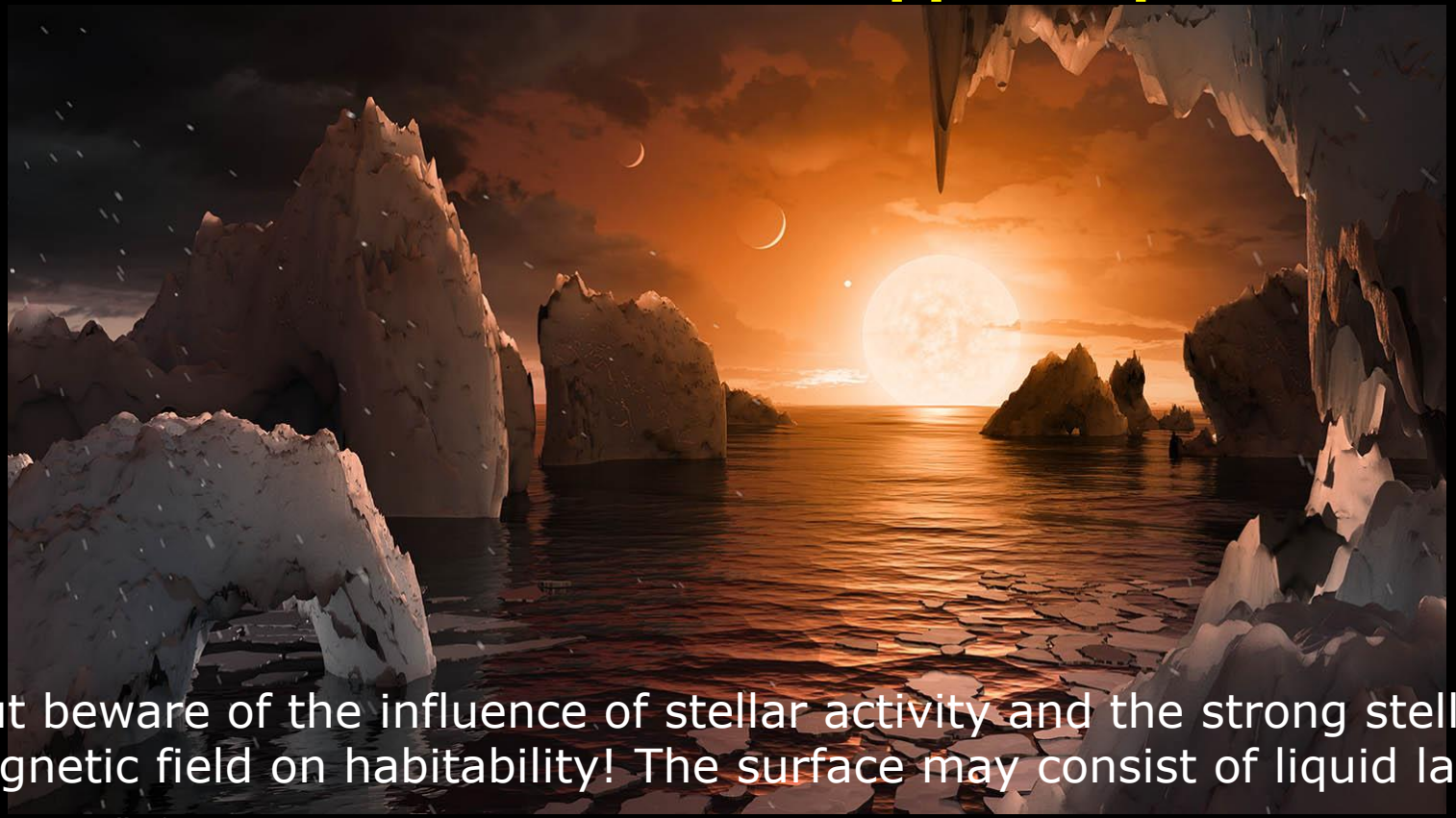
Planets e, f, & g in the habitable zone in the TRAPPIST-1 system

No prominent near-IR spectral features, ruling out cloud-free $H_2$-dominated atmospheres for d, e & f

High-altitude cloud & haze not expected in $H_2$-rich atmospheres under these illumination conditions

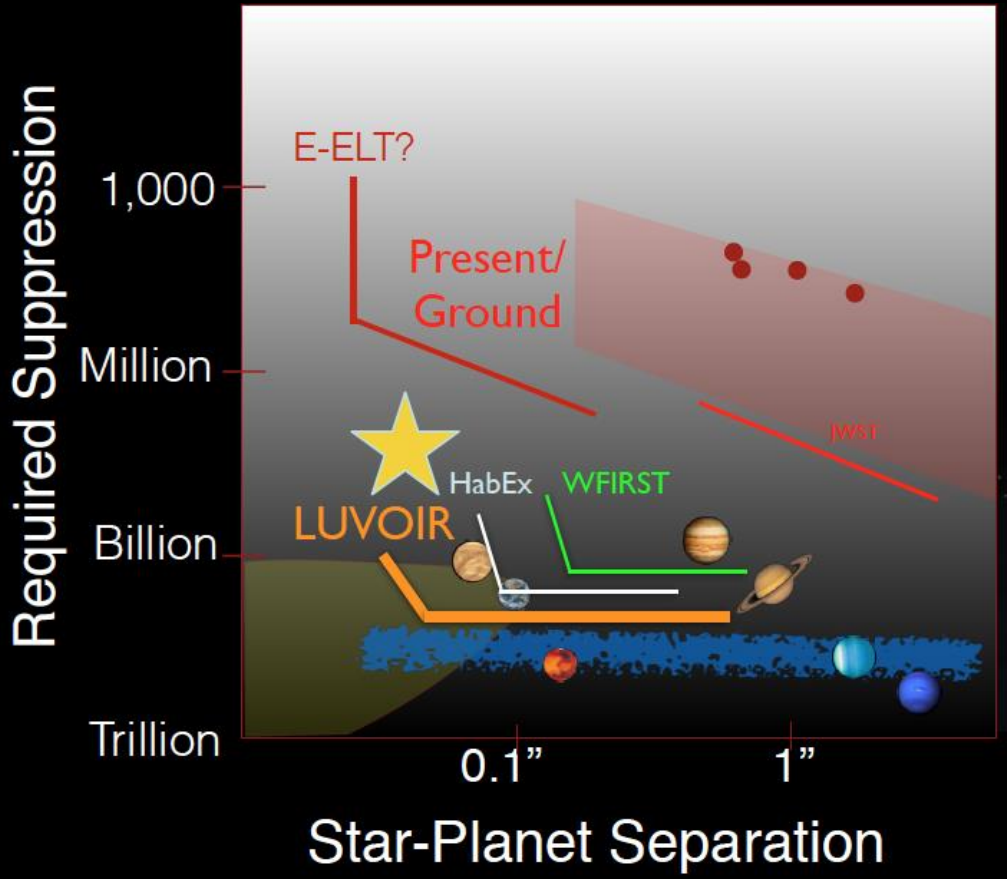
Conclusion: consistent with terrestrial & potentially habitable nature

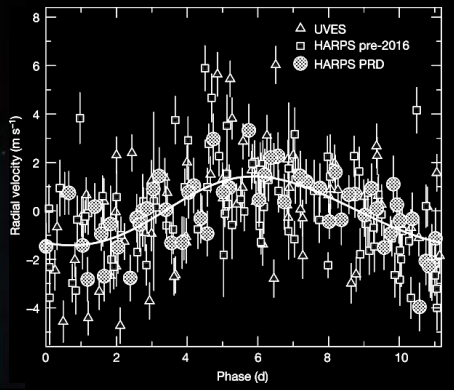
# From the surface of one of the Trappist-1 planets



But beware of the influence of stellar activity and the strong stellar magnetic field on habitability! The surface may consist of liquid lava!

# Proxima B: Will future telescopes be able to image it?



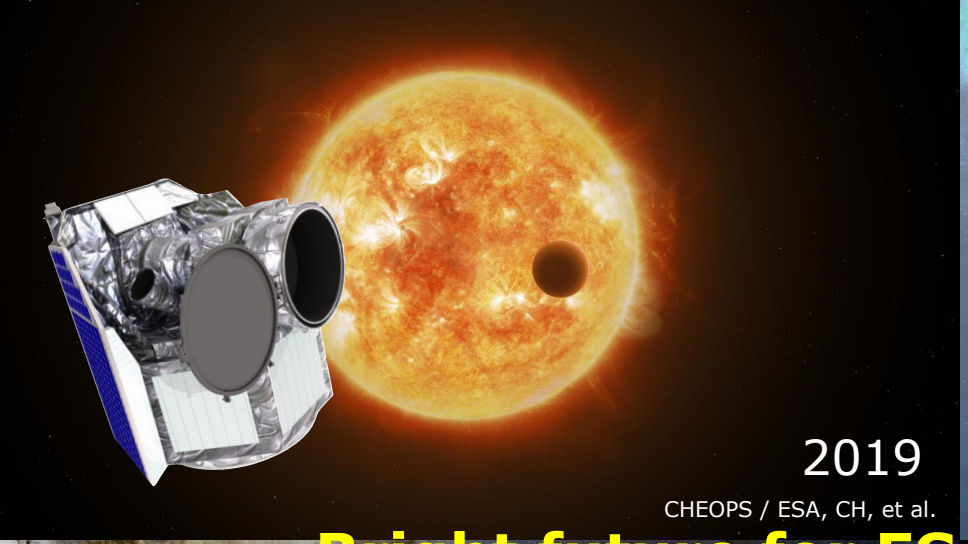




Proxima B

To find “Earth-2” is the Holy Grail of contemporary astrophysics.

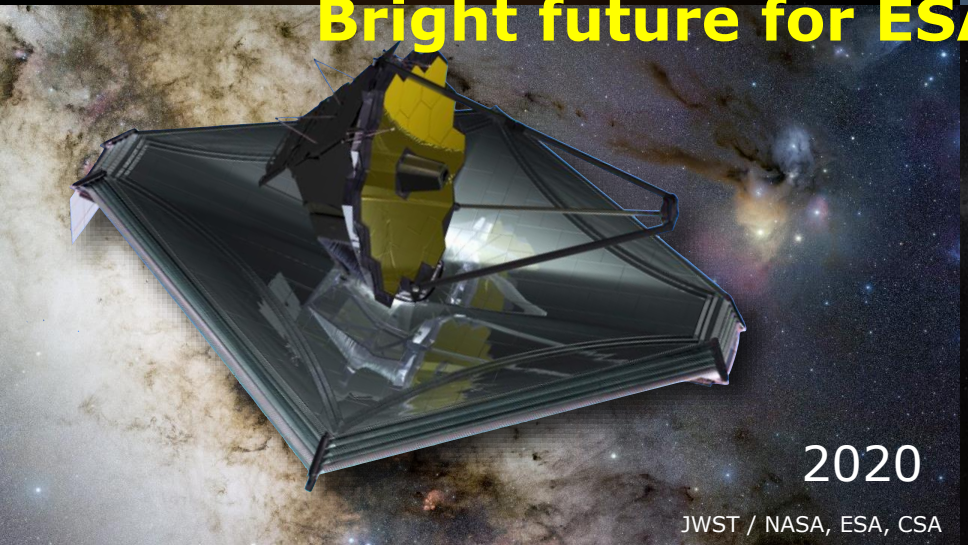
Students are voting with their feet.

The vision to some time in the future fly to a nearby habitable planet catches the imagination.

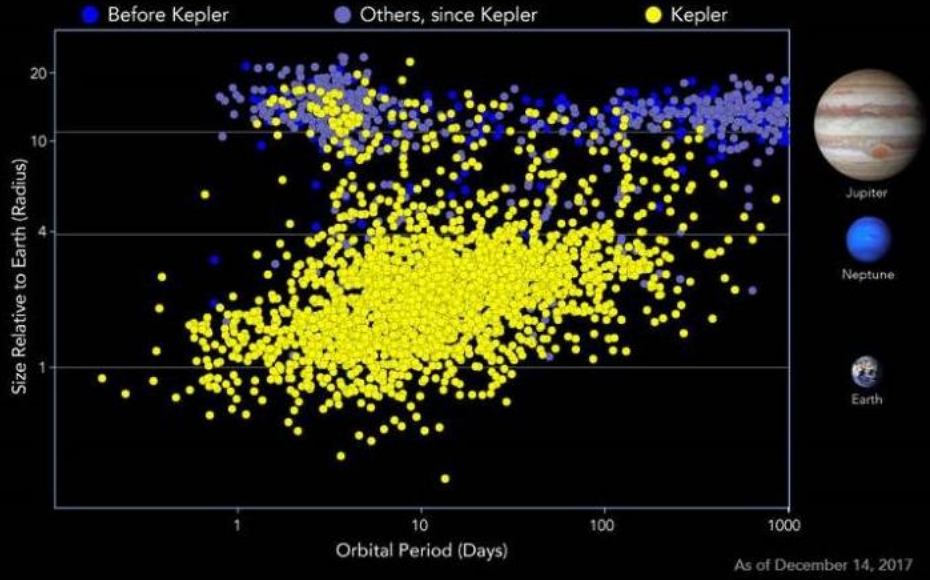




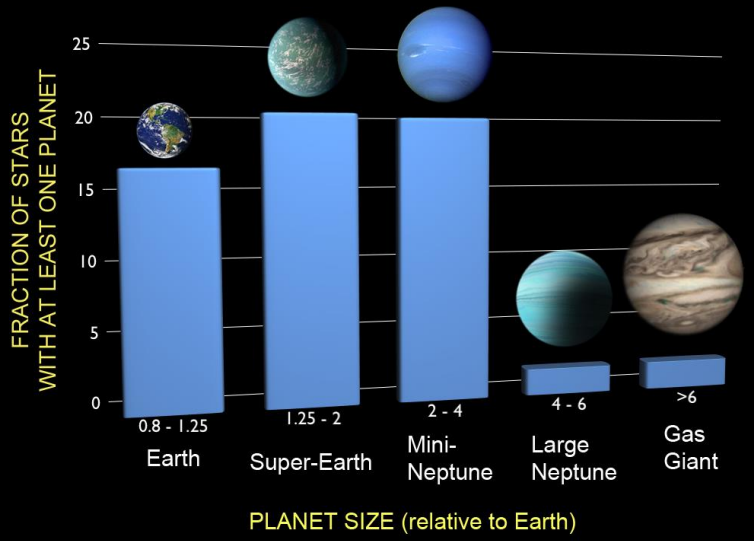
**Bright future for ESA Exoplanet studies!**




# Exoplanet and Solar System Synergies



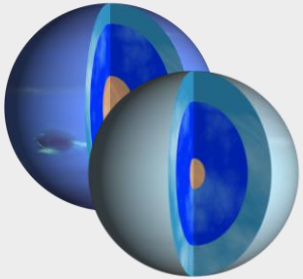

Uranus/Neptune-size planets and super-Earths are the most abundant classes of exoplanets.



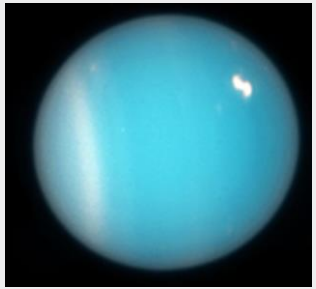

The only ground-truth we have on these types of objects thus far is from Voyager 2 flybys of Uranus (1986) and Neptune (1989). An exploration mission to our ice giants will play a critical role understanding our own planetary system and those beyond

# Scientific Themes for a Mission to the Ice Giants

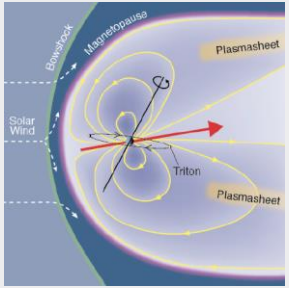
## INTERIORS



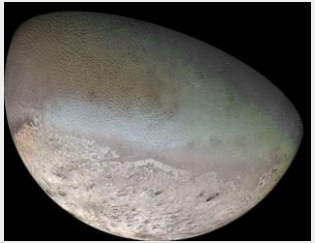
## ATMOSPHERES



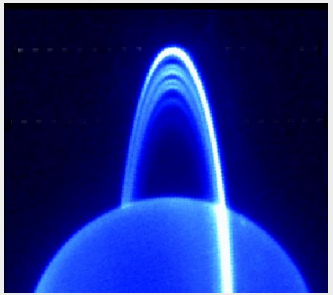
## MAGNETOSPHERES



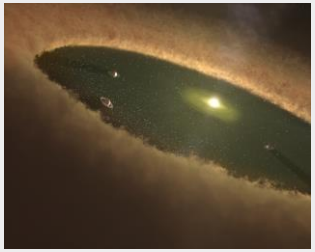

## MOONS



## RINGS



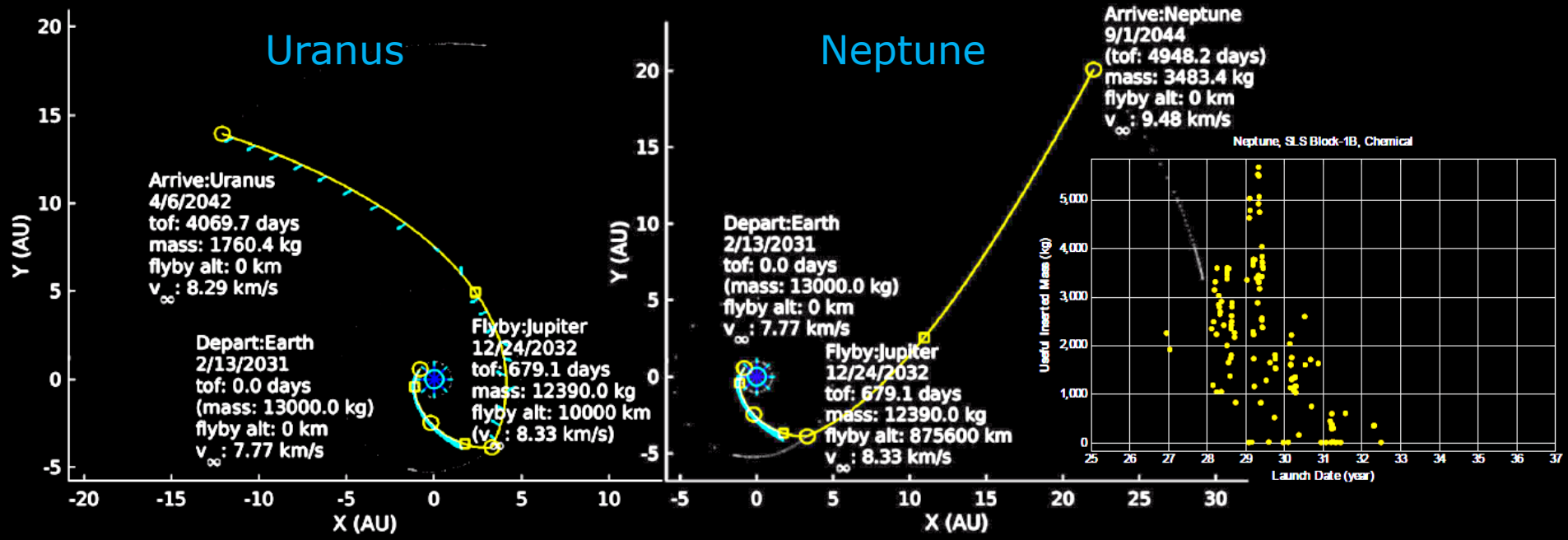
## ORIGINS



From L2 and L3 Science Themes Meeting, Paris September 2013

C. Arridge 2013

# M*:Uranus & Neptune Trajectories with Jupiter Flyby



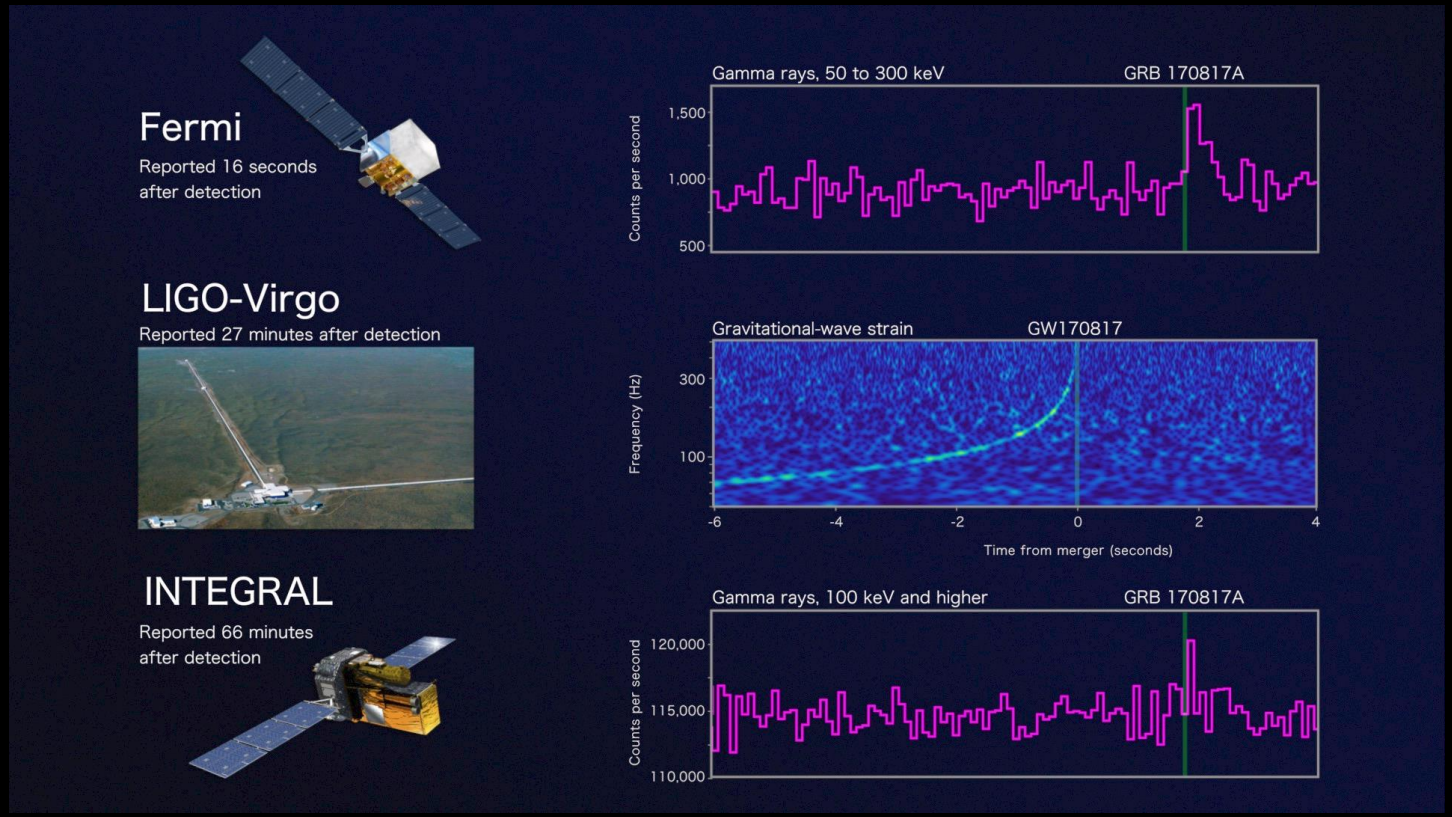

NASA Ice Giant pre-decadal study final report (2017)

# Next Steps

- NASA-ESA joint study to extend the NASA Ice Giants study keeping in mind potential future collaboration

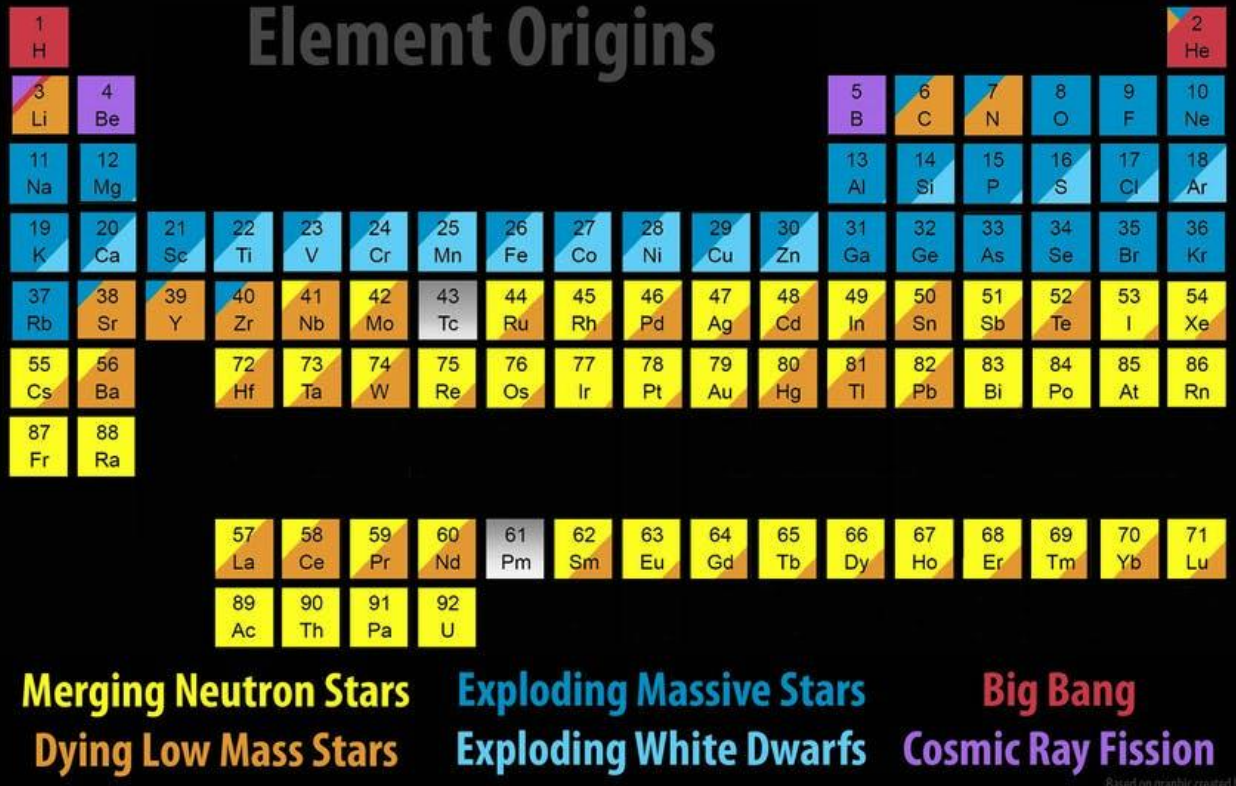
- Joint study to define the potential options
  - Refine trajectories to reach all target bodies
  - Identify technology needs

# Bringing Sound to the Movies! First GW/GRB!




LISA/Athena Synergy!

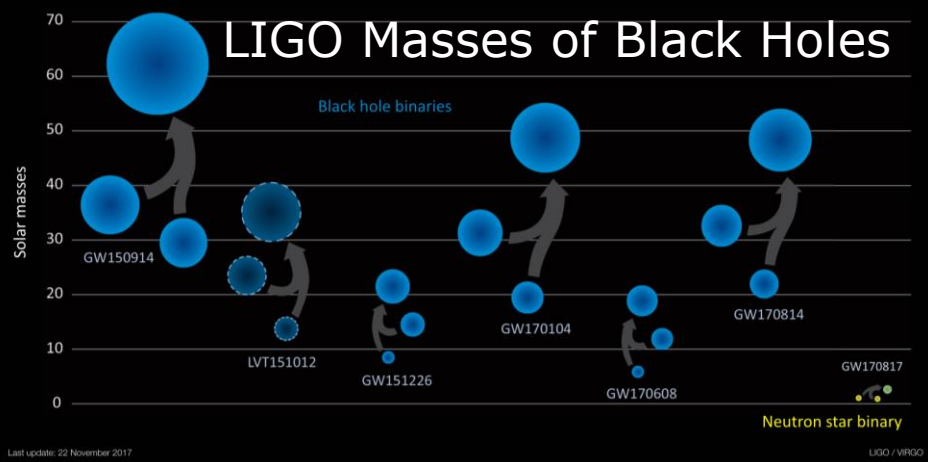
# Text books have to be re-written!

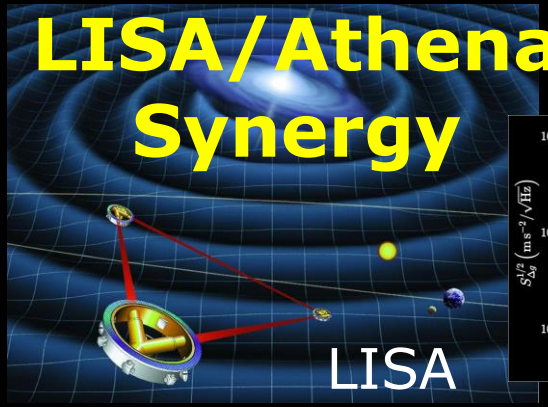


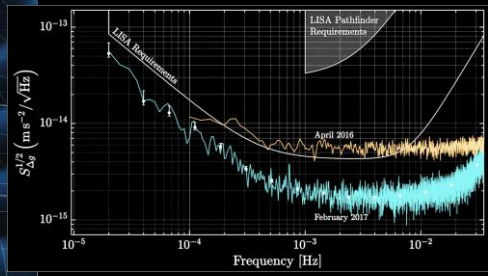

Neutron-star merger produces the heavy elements:

We are not only stardust, but also neutron-star dust …

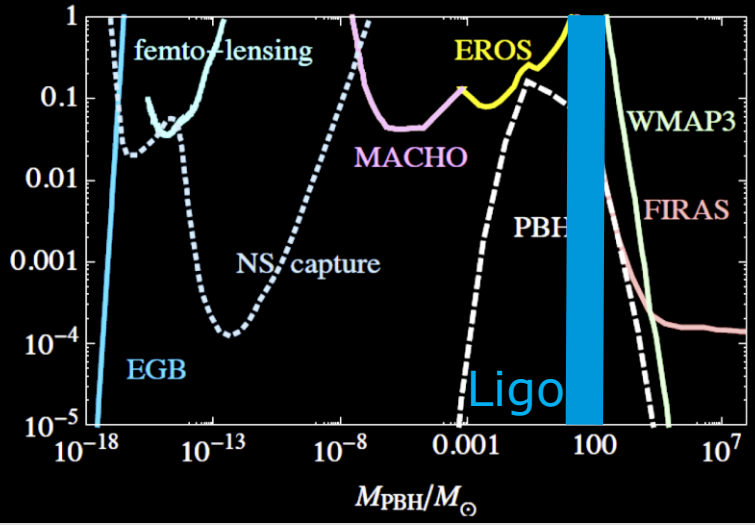
… and about 10% from the Big Bang !







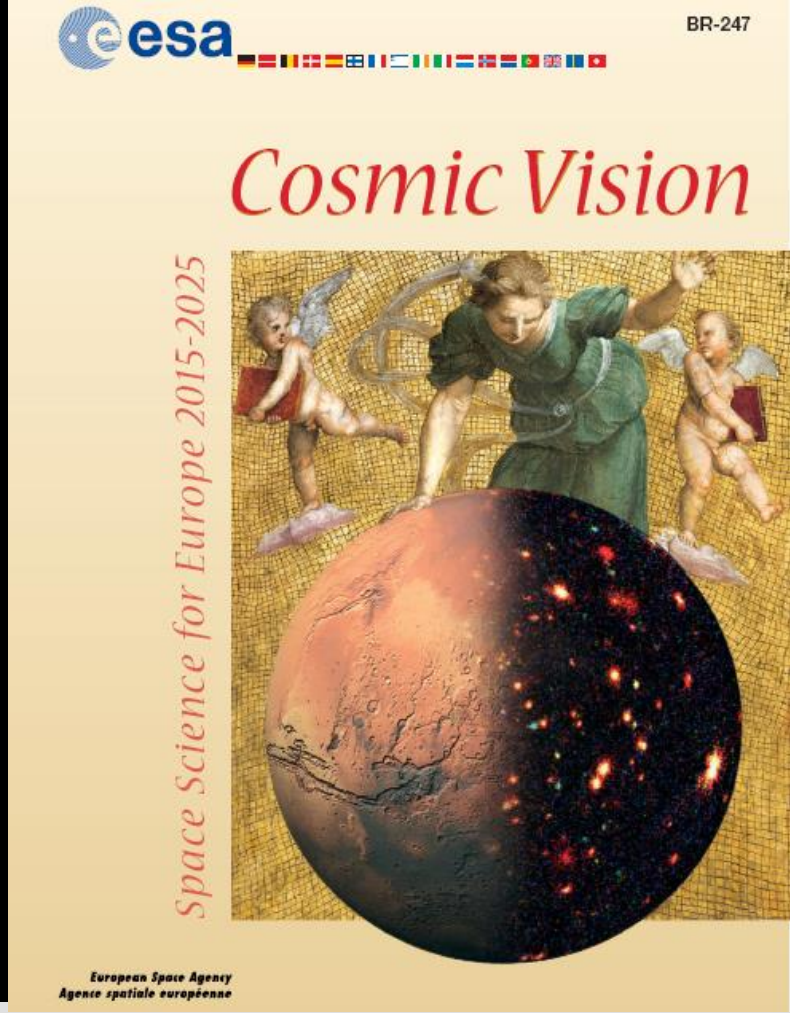

- Are primordial Black Holes part of the Dark Matter?
- How are Black Holes formed?
- How are the heavy elements formed?

Athena & LISA need to fly close together

# Athena and LISA synergy

- The hot and violent universe: Strong gravity produces high energy radiation and gravitational waves.
- "Bringing sound to the movies": crucial orthogonal information on physical processes, e.g. neutron star and black hole mergers.
- Black holes may contribute to the mysterious Dark Matter, solving two riddles simultaneously.

The Athena and LISA team are working jointly on a study about these synergies.



# Vision for Science and CM19

Ambition: strengthen Science both through dedicated missions spanning a range of sizes, as well as through synergies with other activities.

A ~20% increase of the Science Program LoR will enable:

- Maximum synergy between LISA and Athena (their flying together will create a unique science opportunity);
- A new M-Mission to our ice-giants, Uranus and Neptune, utilizing a unique celestial constellation 2028-2032 in the frame of a cooperation with NASA;
- A line of F-missions in sync with M-missions (to exploit the joint launch), creating a series of new opportunities with special emphasis on novel implementations;
- Payload system responsibility/provision ➔ alleviate/facilitate/support Member State provision (also relative to LISA/Athena synergy);

Science & Technology Preparation for the next set of L & M Missions (CV 2050)

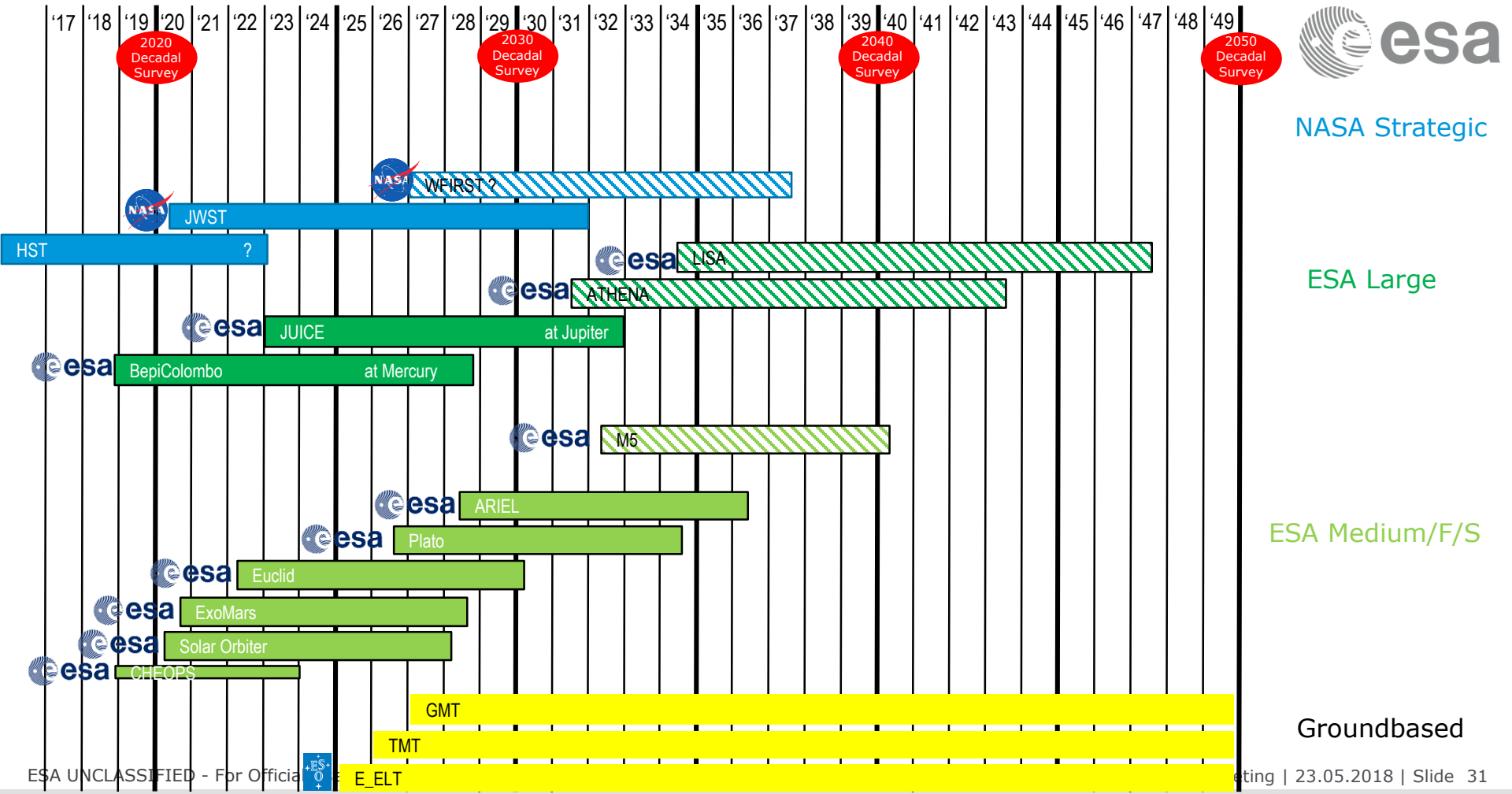
# Papers discussed at SPC/HoD workshop May 16/17

## 1. Provision of scientific instrumentation for Science Programme missions

- Broad consensus on the need for an early (limited) engagement of ESA in the payload system engineering and procurement support, but details need to be better defined.
- Way forward: bilateral discussions with individual member states and formation of a working group of specialists from ESA and MS.

## 2. Towards a Call for an "F" mission

- Agreement on the attractiveness of a special opportunity (F1) mission with innovative implementation scenario, but wish to broaden the range of scientific topics.
- Inclusion of a line of F missions into the program requires an increase of the science budget.
- Further Discussion at June SSAC and SPC meetings.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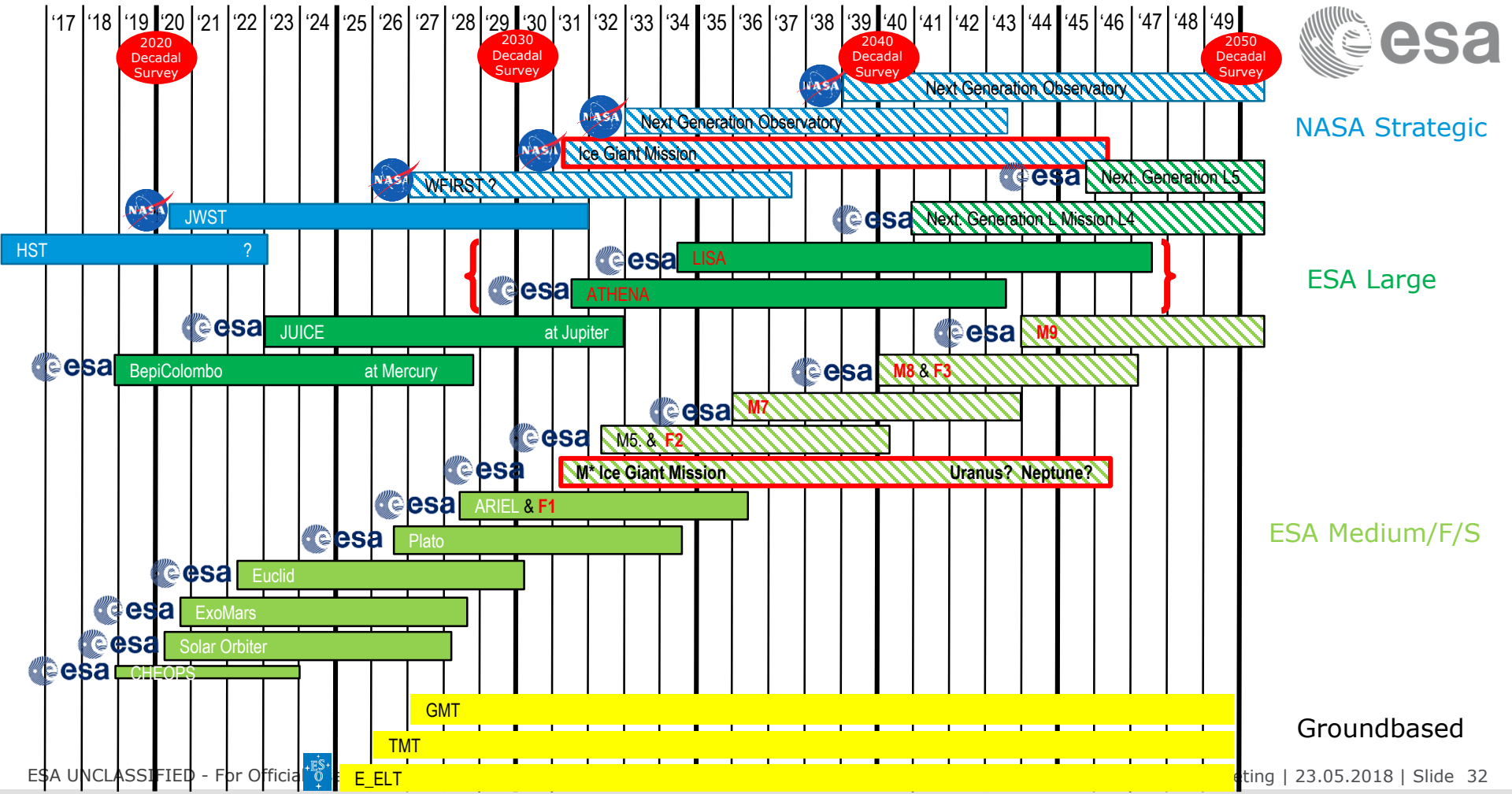
2020 Decadal Survey
2030 Decadal Survey
2040 Decadal Survey
2050 Decadal Survey
NASA Strategic
WFIRST ?
JWST
HST ?
ESA Large
LISA
ATHENA
JUICE at Jupiter
BepiColombo at Mercury
M5
ESA Medium/F/S
ARIEL
Plato
Euclid
ExoMars
Solar Orbiter
CHEOPS
Groundbased
GMT
TMT
E_ELT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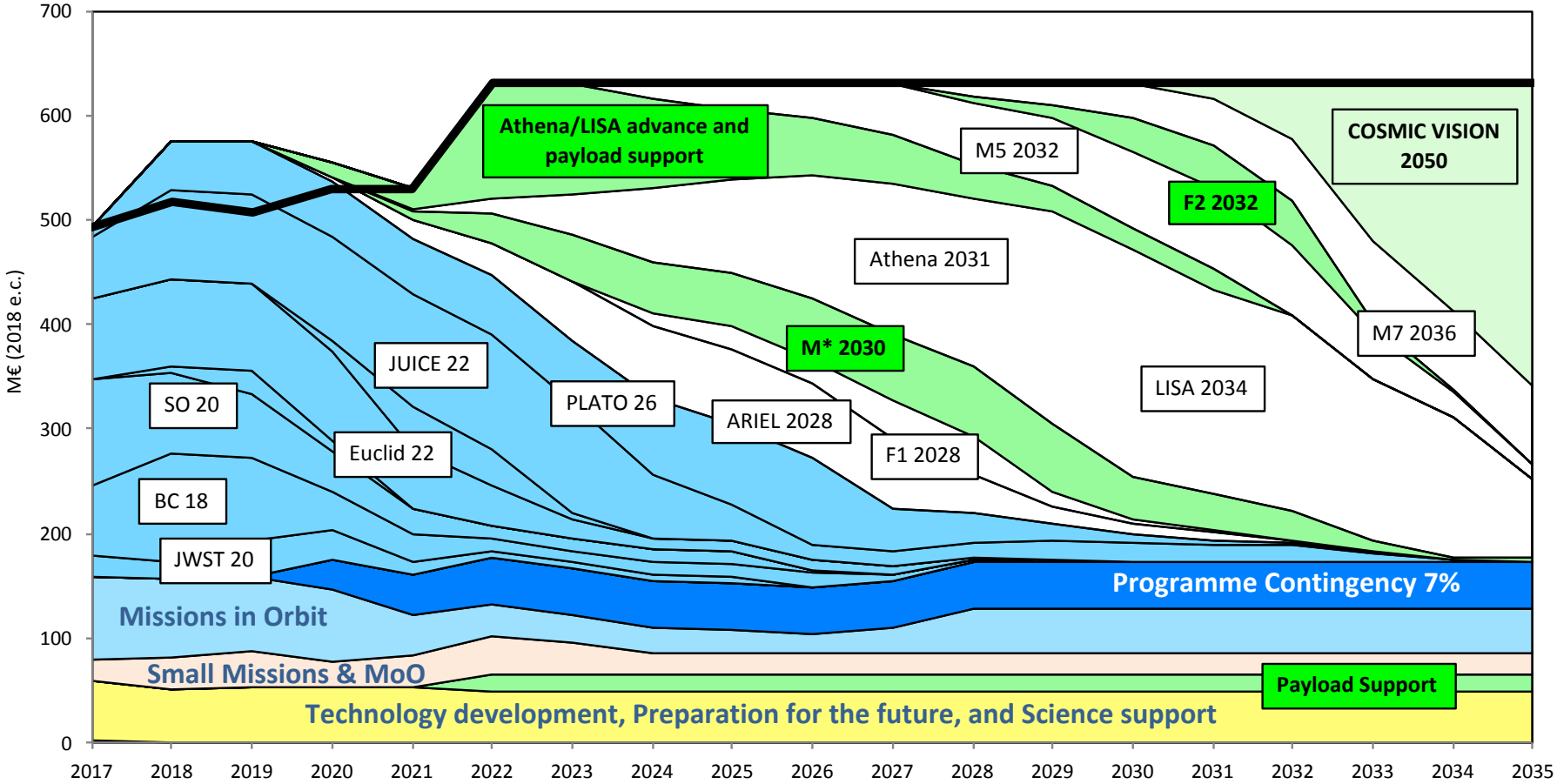
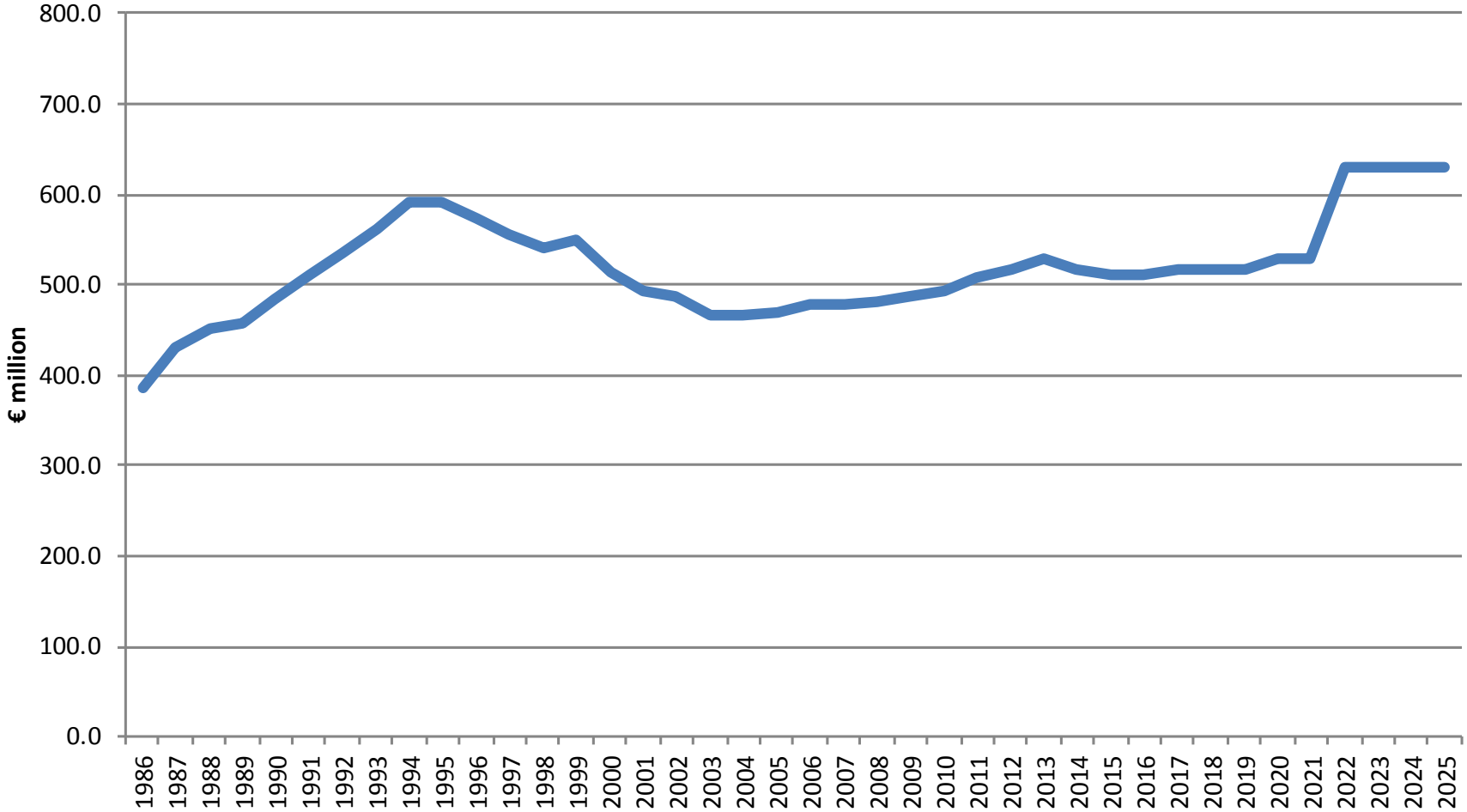
2020 Decadal Survey
2030 Decadal Survey
2040 Decadal Survey
2050 Decadal Survey
Next Generation Observatory
Next Generation Observatory
Ice Giant Mission
WFIRST ?
Next. Generation L5
JWST
Next. Generation L Mission L4
HST ?
LISA
ATHENA
JUICE at Jupiter
M9
BepiColombo at Mercury
M8 & F3
M7
M5 & F2
M* Ice Giant Mission Uranus? Neptune?
ARIEL & F1
Plato
Euclid
ExoMars
Solar Orbiter
CHEOPS
GMT
TMT
E_ELT
NASA Strategic
ESA Large
ESA Medium/F/S
Groundbased

# COSMIC VISION Long Term Plan: new activities in green

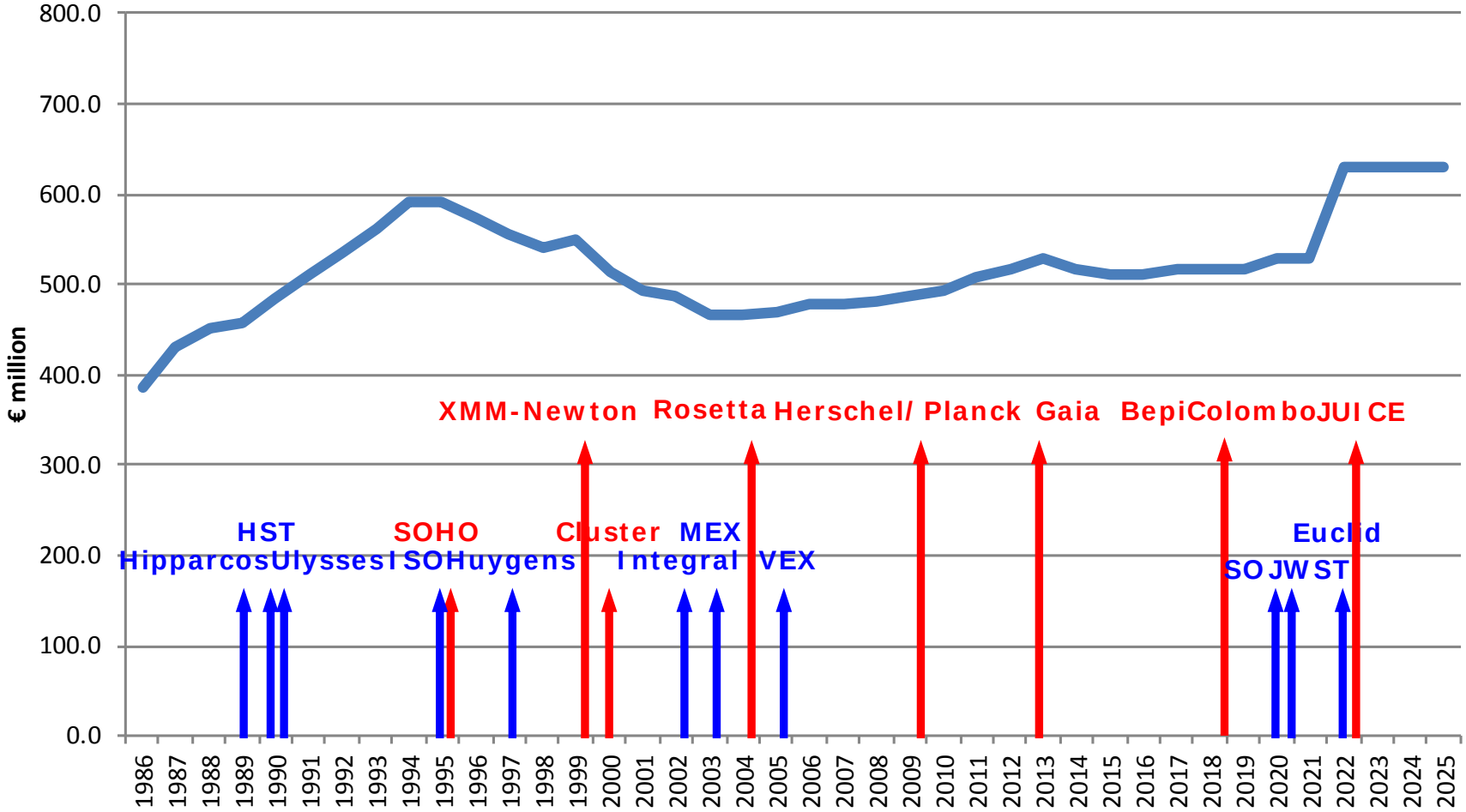
**Payload Support - Athena/LISA advance and payload support - M* to icy giants in 2030 - F2 in 2032**



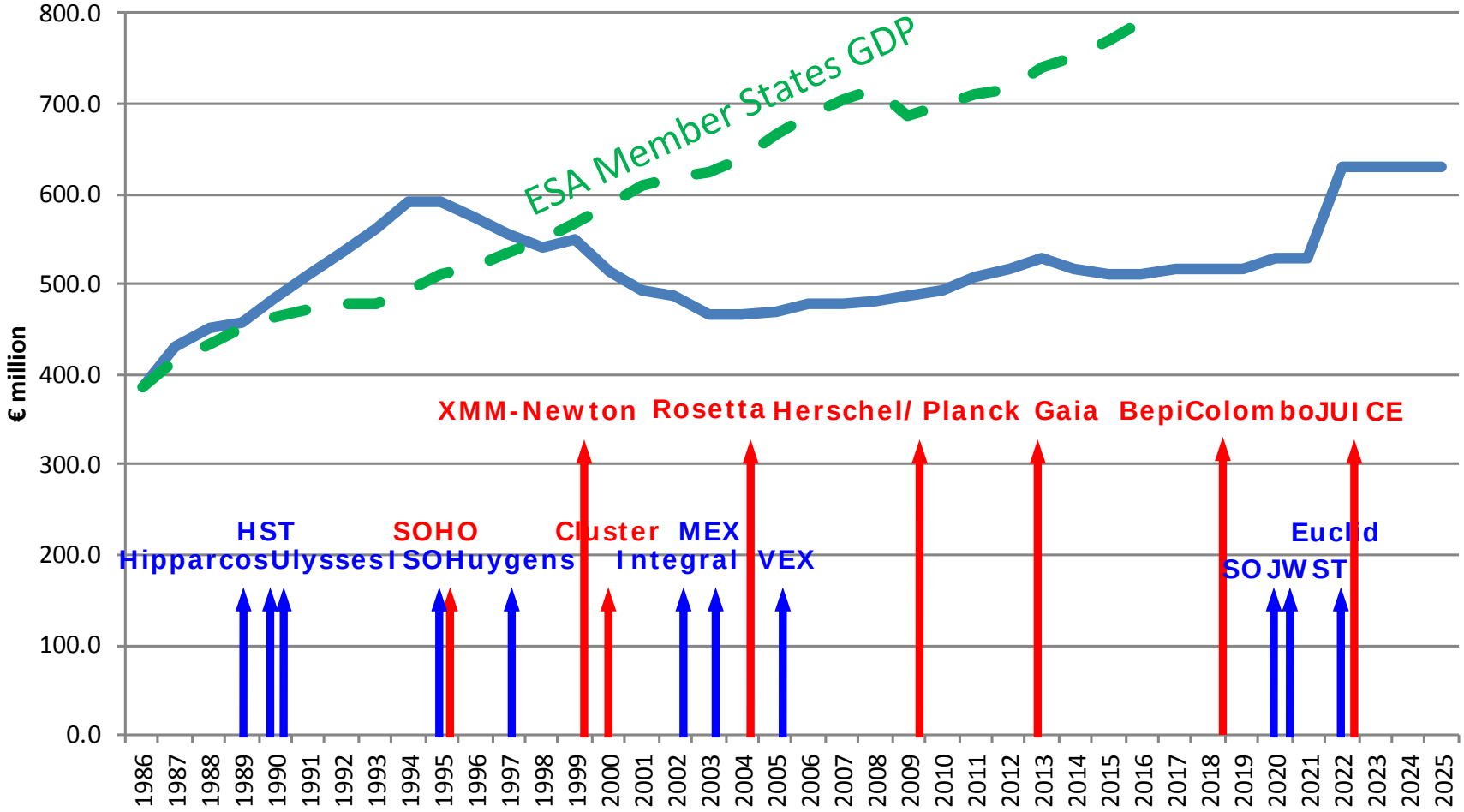
# Science Programme Level of Resources evolution (2018 ec)



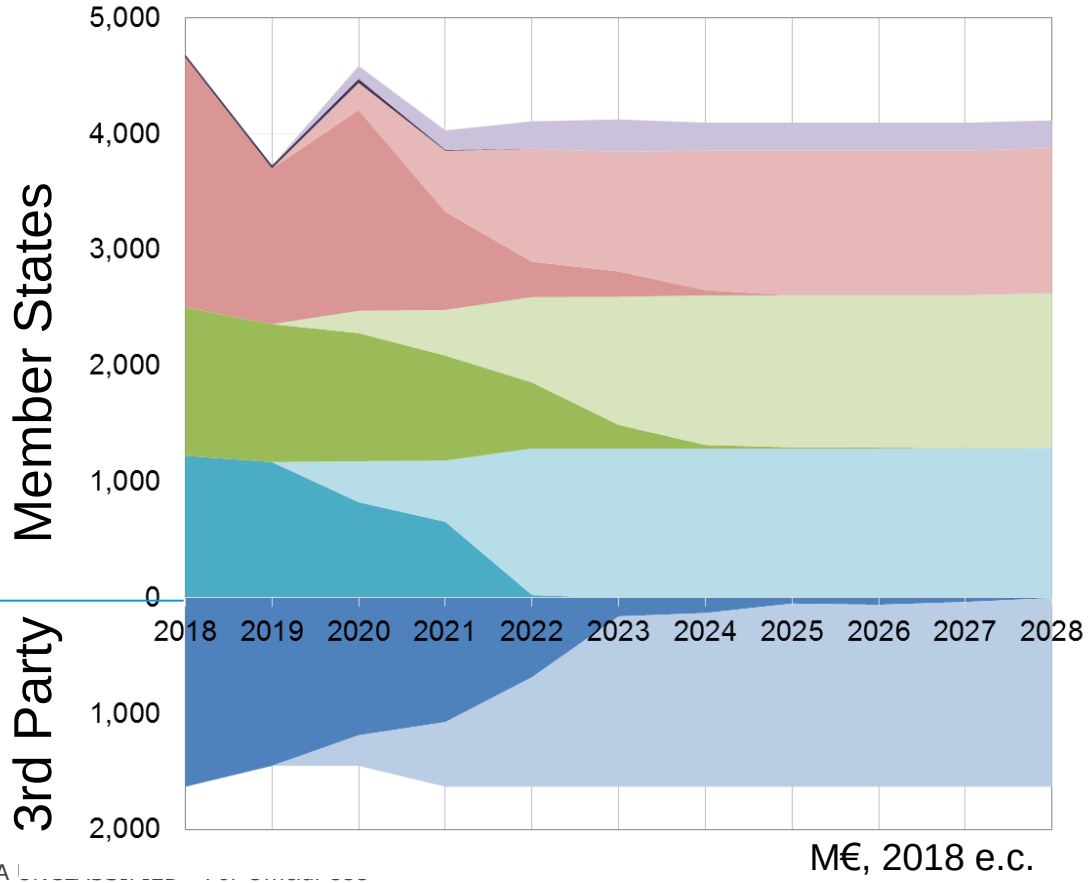
# Science Programme Level of Resources evolution (2018 ec)



# Science Programme Level of Resources evolution (2018 ec)



# ESA Long Term View




## Safety and Security

## Enabling and Support

Transportation, Operation, Technology

## Applications

Earth Observation, Navigation, Telecommunication

## Science and Exploration

## 3rd Party

EC, Eumetsat…


Thank you very much!