

# ESA's Science Programme

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ESA Directorate of Science

INAF/IASF-MI    16 October 2019



- Introduction to the Science Programme
- ESA Science missions
- Mission selection
- Measuring scientific success
- What is happening next in the Science Programme
- The next generation
- Interacting with the Science Programme



## EXCELLENCE IN EUROPEAN SPACE SCIENCE

- A cutting-edge Scientific Programme to meet the challenges of worldwide research maintained by a bottom-up approach to mission selection
- Sustaining European leadership in key science domains
- Providing new challenges to industry, triggering innovation
- Fascinating, inspiring and motivating European citizens

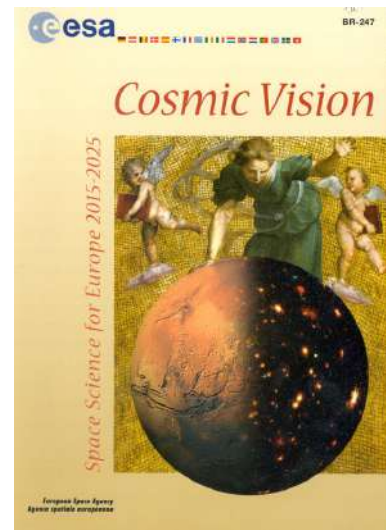


# Science Objectives



ESA's current long-term programme is "Cosmic Vision". Key science areas:

1. Understanding the early evolution of the Universe and the nature of dark energy and dark matter.
2. Understanding Physics in strong gravity conditions and establishing constraints for the formulation of quantum gravity.
3. Understanding the formation of our Solar System and its relation to a general framework valid for extra-solar planets, including the search for other habitable worlds





# Science Programme Elements



## ➤ L-missions

- European led flagships with <20% international contributions
- One every 7-8 years
- Cost to ESA of around 2 annual budgets (1.1 B€).

## ➤ M-missions

- ESA led or contribution to international collaboration.
- One every 3-4 years
- Cost to ESA of around one annual budget (550 M€)

## ➤ F-missions

- Proposed new type of “fast or flexible” mission
- Launched as a passenger
- Cost to ESA of 0.3 annual budgets (150 M€)

## ➤ O-missions

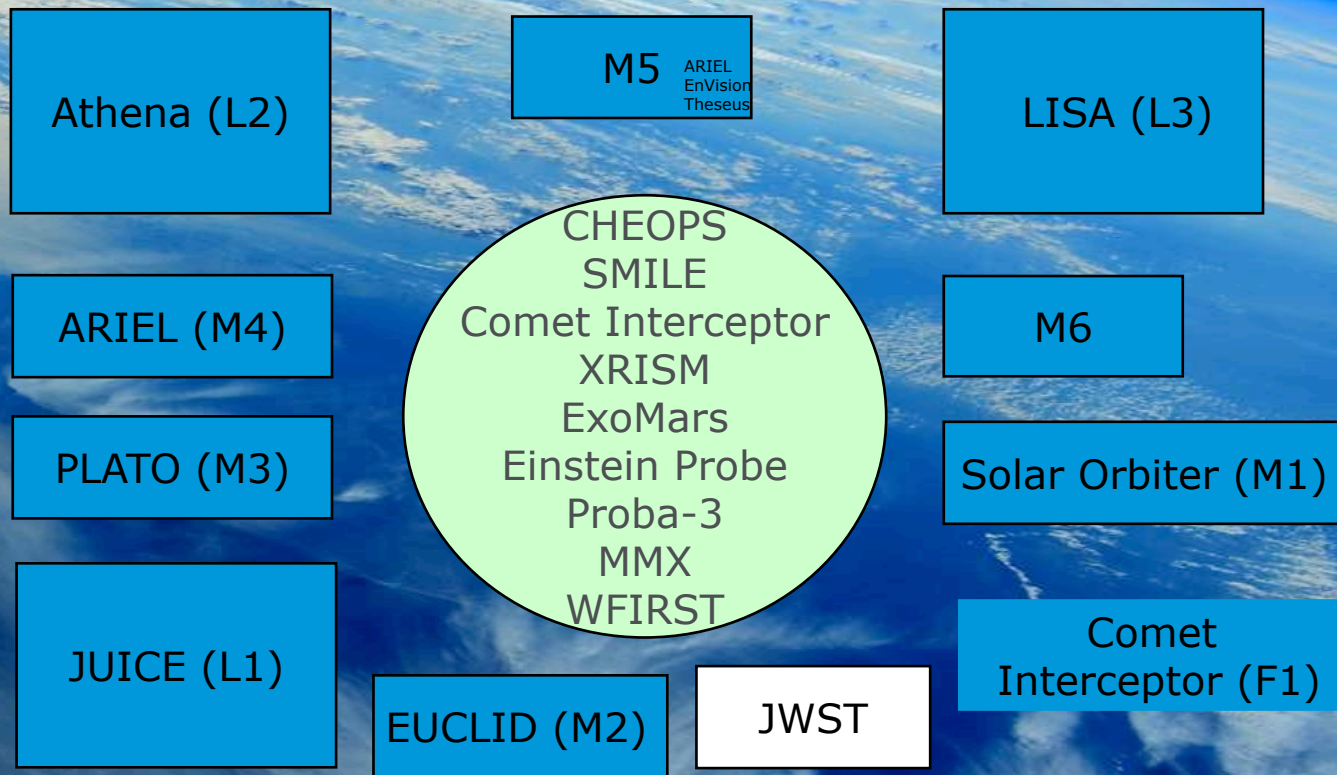
- Missions of opportunity, led by other agencies, contributions <50 M€.



# ESA's Science Missions



# Cosmic Vision (2015-2035)



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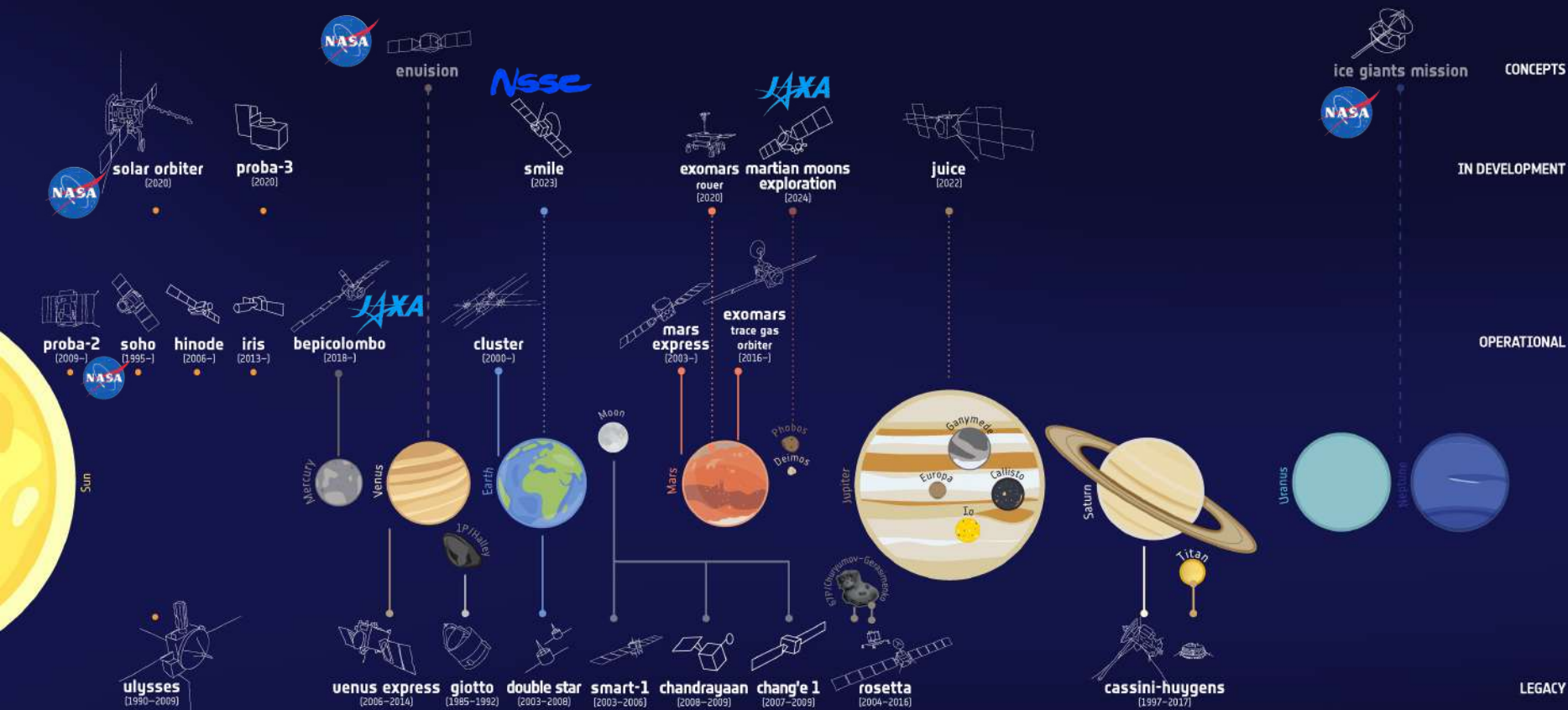


European Space Agency



# The ESA Fleet in the Solar System

## → SOLAR SYSTEM EXPLORERS

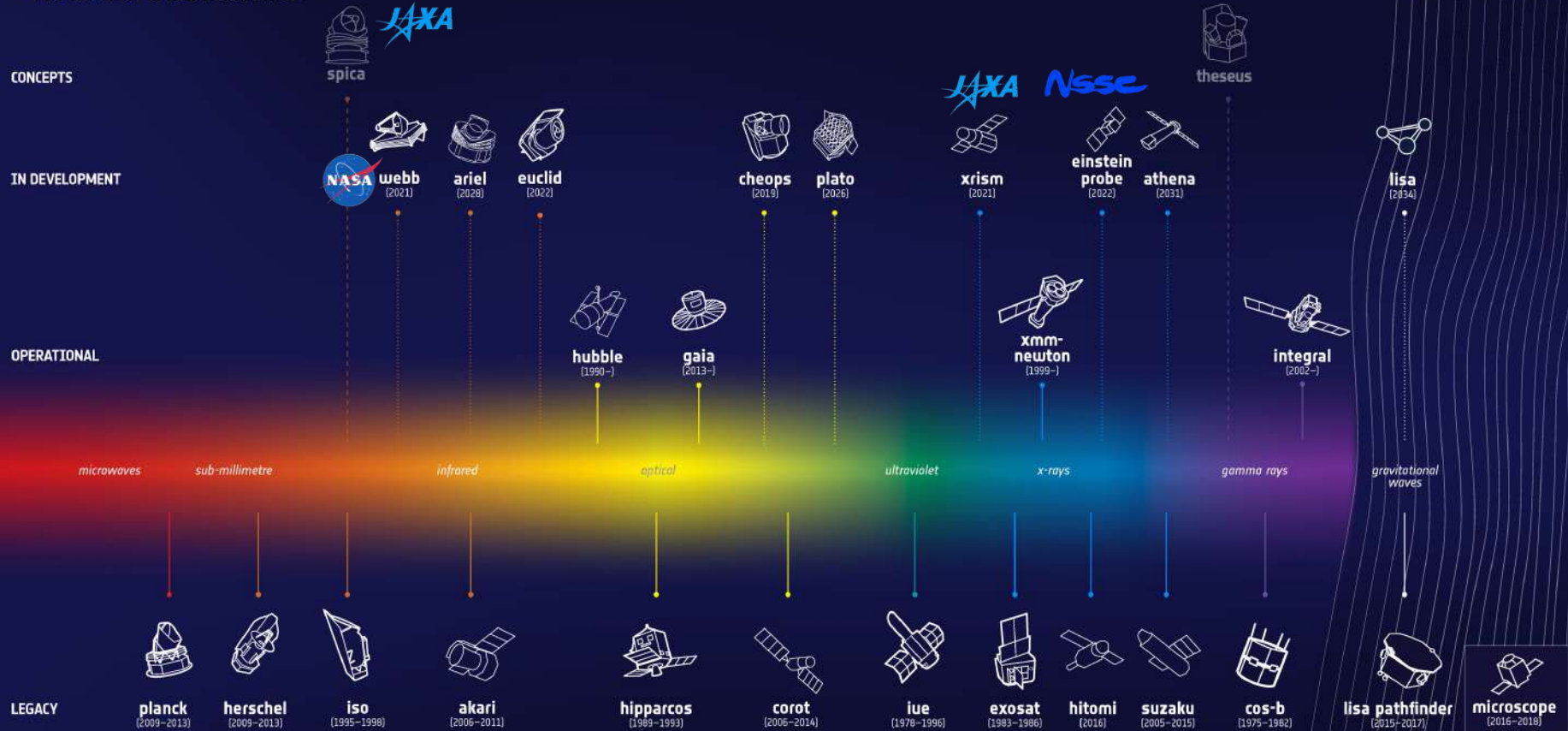




# The ESA Fleet for Astrophysics



## → COSMIC OBSERVERS

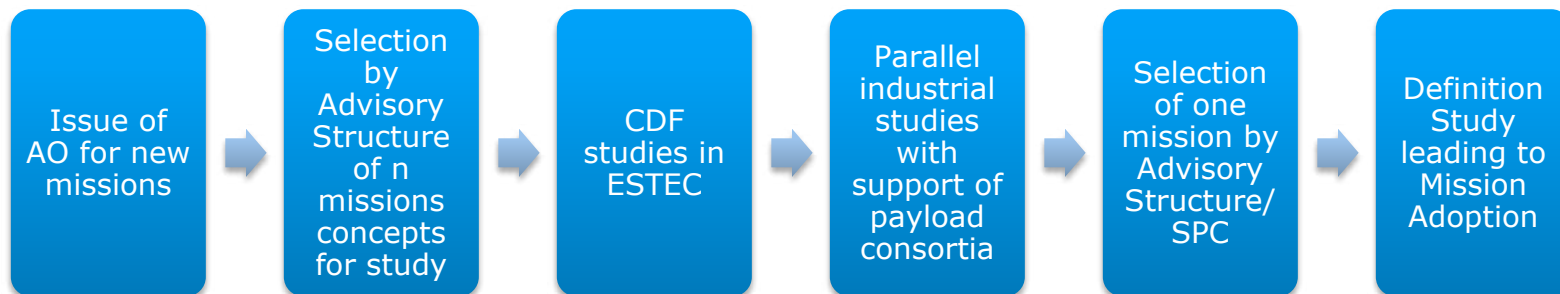




# Mission Selection



# Study Process To Final Selection



Phases	Phase 0	Phase A	Phase B1
Phases	Assessment		Definition
Reviews	PRR		SRR
ISO TRL Required	≥6		

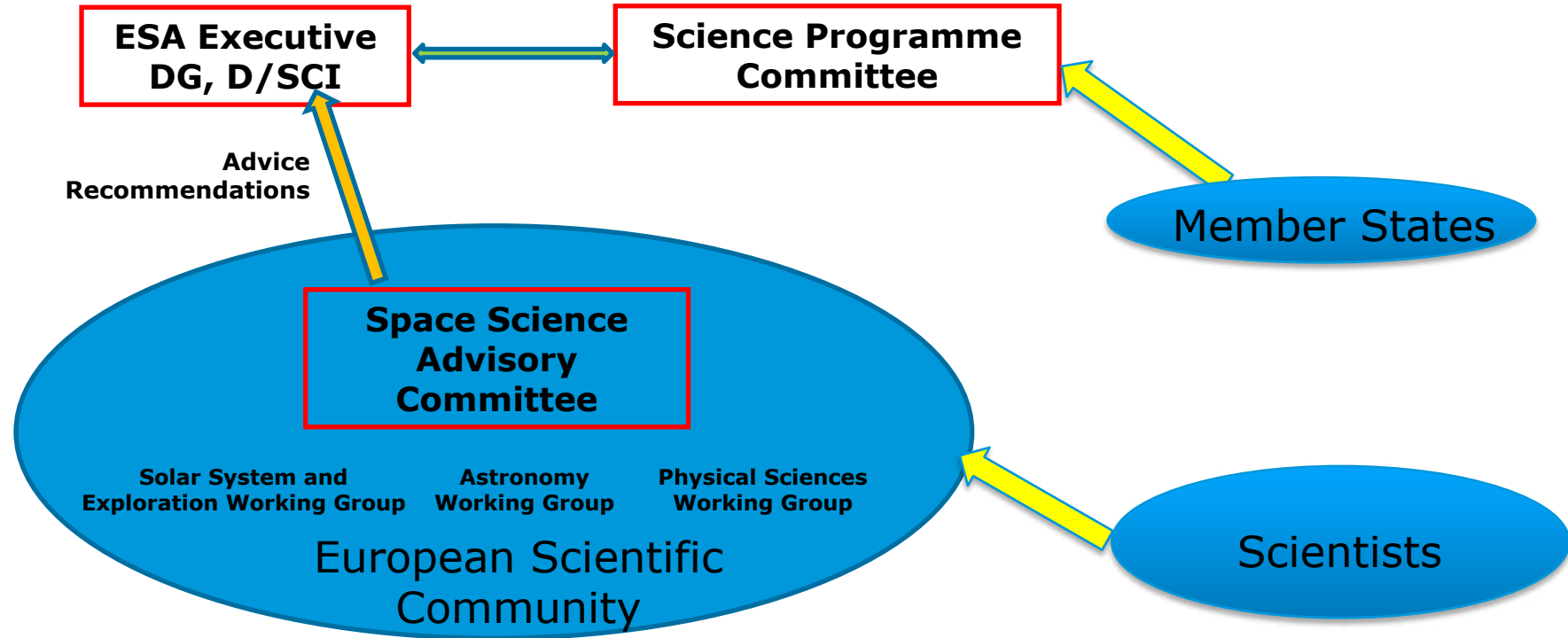


# Typical M Mission Durations and Activities

Phase	Typical Duration (years)	Activities
0	1	Early concept studies: define mission goals, study multiple approaches
A	1	Preliminary Mission Analysis and System Trade Studies: define functional requirements, choose an approach, analyse alternatives
B1	2	Definition Study: define system requirements, complete a preliminary system design allocating functions and defining interfaces
B2/C/D	8	Design, Development, Test and Evaluation: complete detailed system design, fabricate, integrate and test. Prepare for launch and operations.
E/F		Launch, Operations and Disposal (F)
Total	<b>12</b>	This is the nominal schedule assuming that each phase is successful with a smooth transfer to the next.



# Mission Selection - A Bottoms-up Approach





# Measuring Scientific Success



The “libraries” behind these publications are available on  
[www.cosmos.esa.int/web/guest/mission-publications](http://www.cosmos.esa.int/web/guest/mission-publications)

## LINKS TO THE ADS PUBLICATION LIBRARIES FOR ESA SCIENCE MISSIONS

The SAO/NASA Astrophysics Data System (ADS) is a digital library for researchers in physics and astronomy operated by the Smithsonian Astrophysical Observatory (SAO) under a NASA grant.

Refereed papers, published after launch, are included in the table below if they fulfil one or more of the following:

- Make direct use of data from a mission including from its primary catalogues
- Make quantitative predictions of results from a mission
- Describe a mission, its instruments, operations, software or calibrations

PhD theses are included in the table below if they include an analysis of data from the mission or describe hardware or software developed for the mission or its calibration. The completeness of the PhD libraries is difficult to estimate.

ESA Led Missions	ADS Library	PhD Thesis Library
COS-B	<a href="#">COS-B Refereed Publications</a>	
IUE	<a href="#">IUE Refereed Publications</a>	<a href="#">IUE PhDs</a>
Exosat	<a href="#">Exosat Refereed Publications</a>	<a href="#">EXOSAT PhDs</a>



# ESA-led Mission Refereed Publications



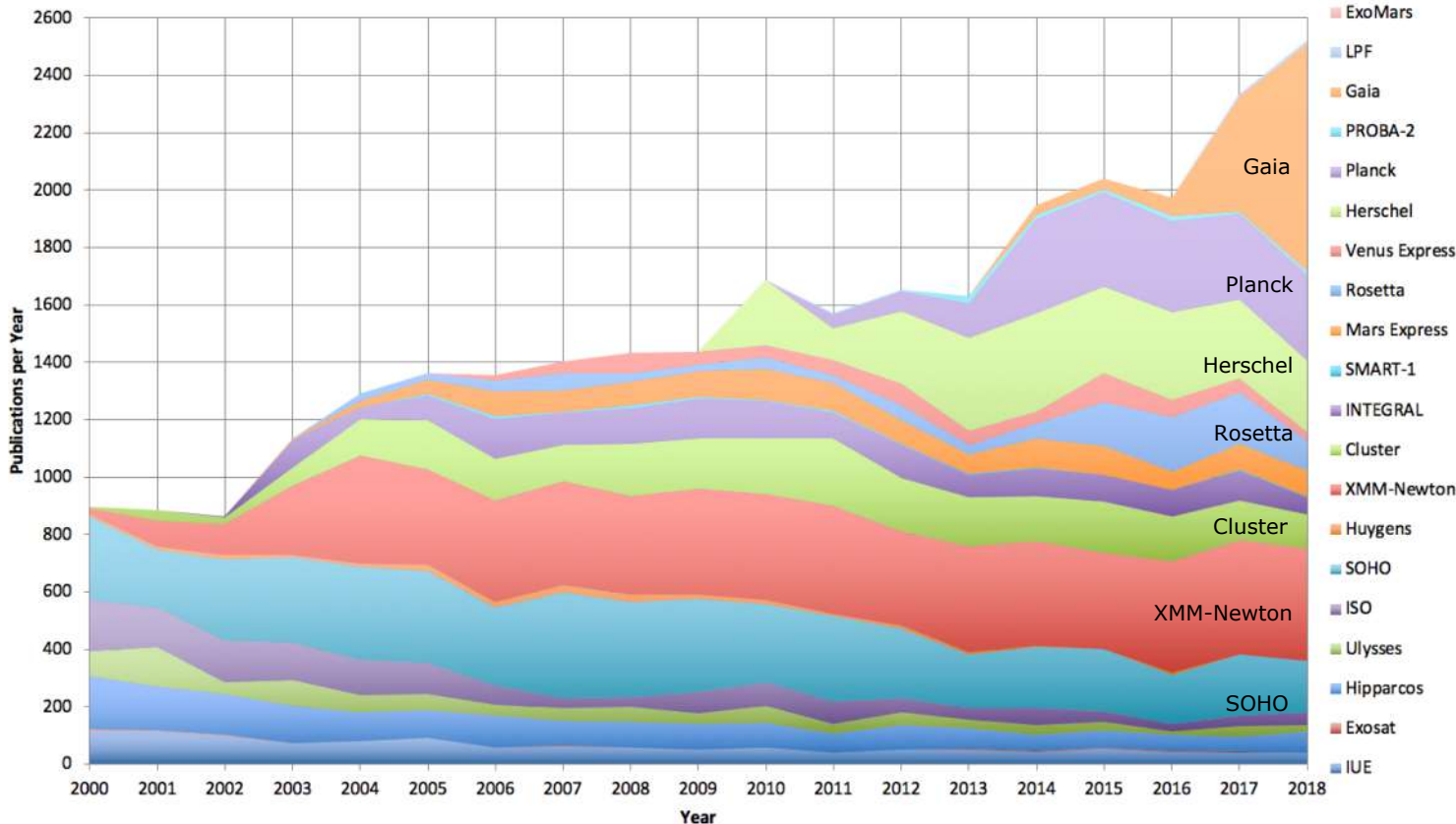
Most papers ever in 2018! (2547 if counted for each mission)

4 missions contributed ~70% of the ESA-led 2018 publications:

- Gaia (792)
- XMM-Newton (390)
- Planck (301)
- Herschel (248)

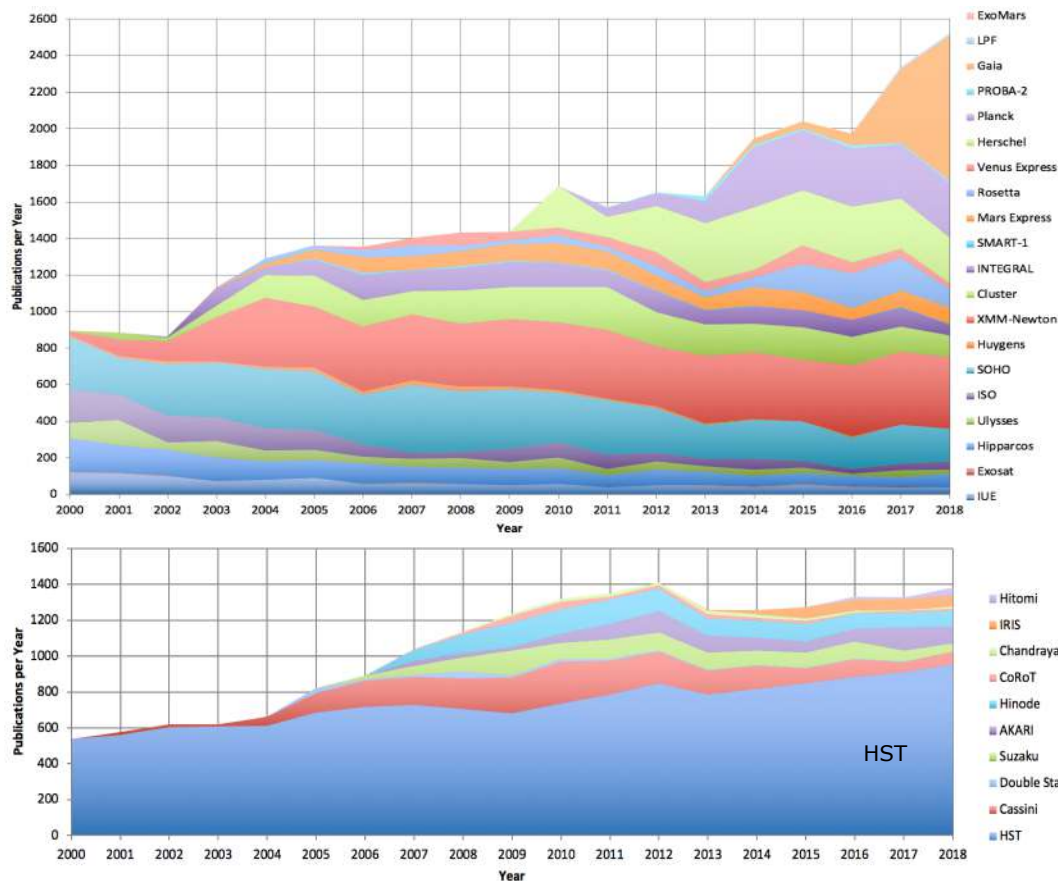
Another 15% of the ESA-led mission pubs. come from missions with >100 pubs:

- SOHO (180)
- Cluster (121)
- Rosetta (106)





# All Mission Refereed Publications



- The papers from the partner-led missions are dominated by HST.
- Accounts for around 2/3 of the partner-led publications in 2018



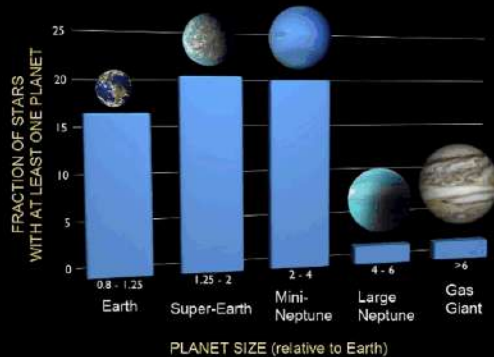
An exciting few months ahead!



## Athena & LISA

F-missions in sync with M-missions (joint launch) → new line of opportunities with special emphasis on novel implementations

Unique celestial opportunity to explore Ice Giants



Payload system provision → alleviate/facilitate/support Member State provision

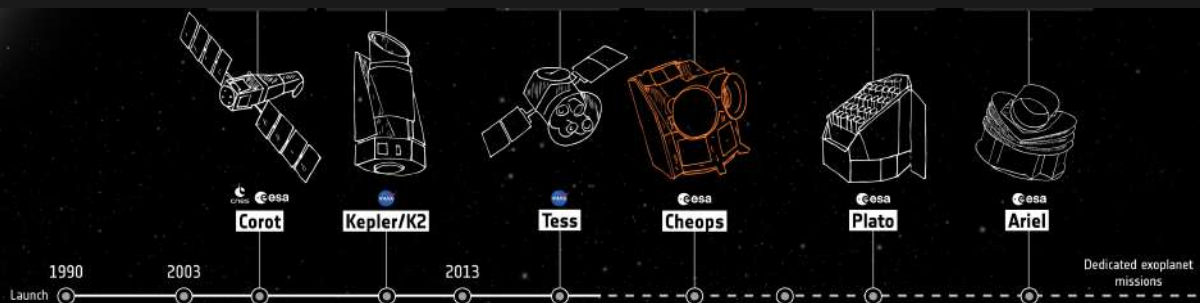
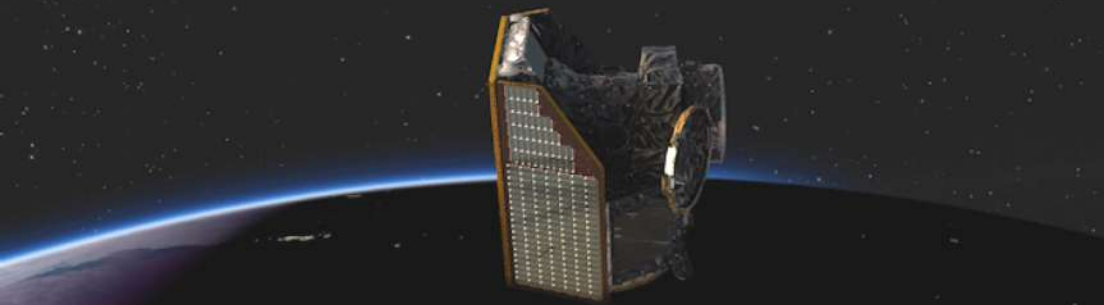
*Voyage 2050*



# CHEOPS launch planned in December 2019

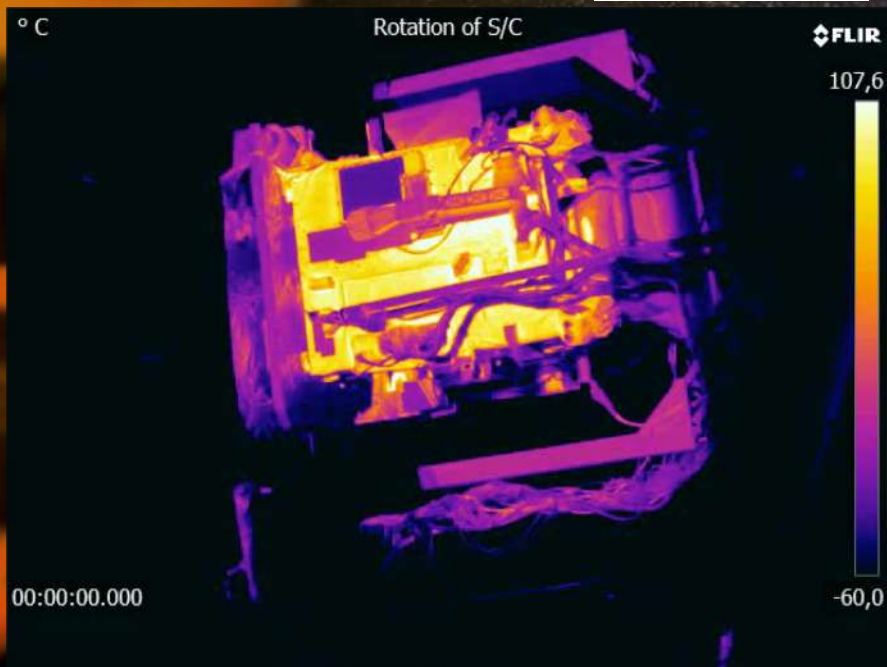
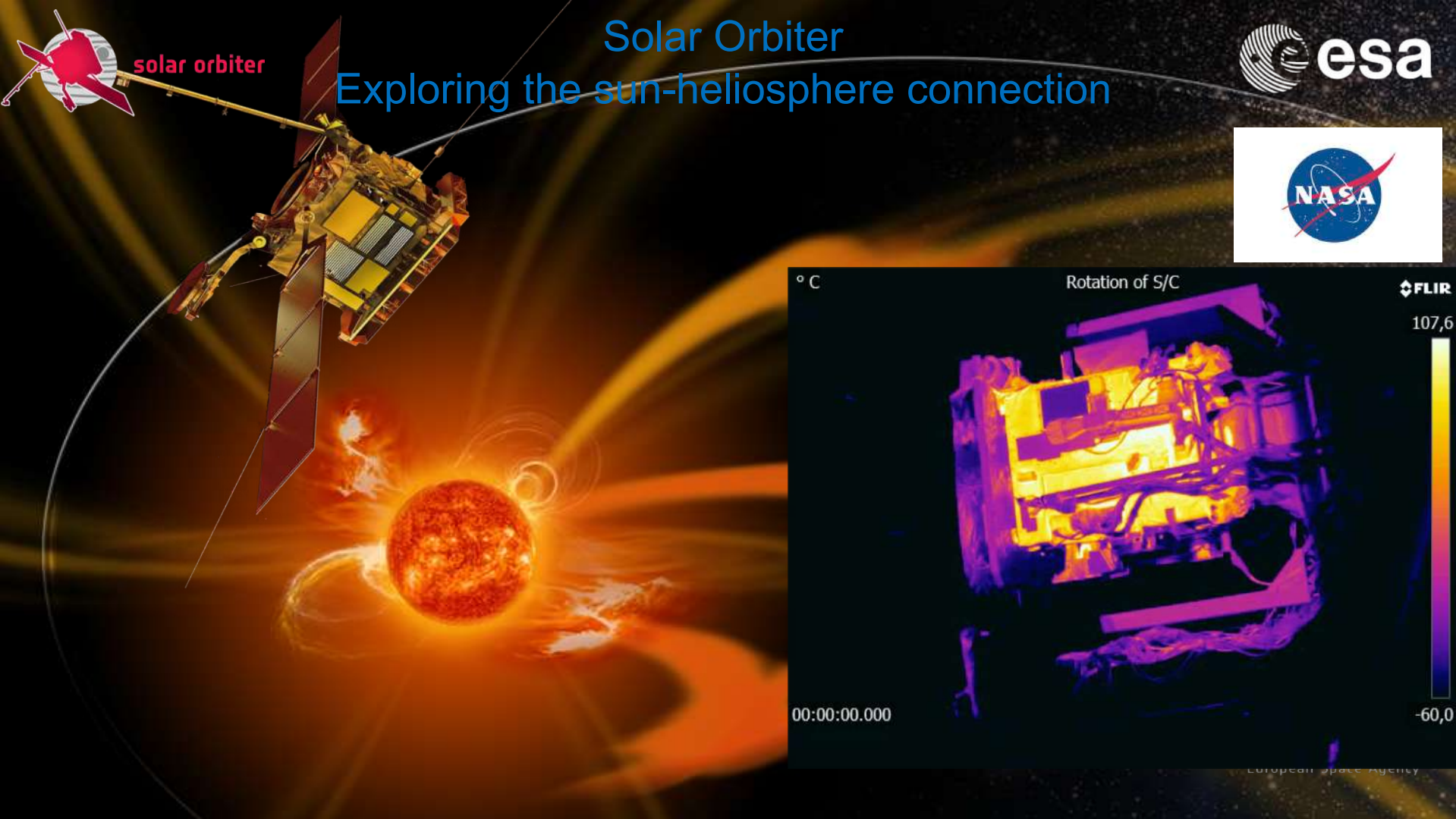


cheops



CHEOPS (2019) will measure known Earth-to Neptune size exoplanets, and will be followed by PLATO (2026, terrestrial exoplanet statistics) and ARIEL (2028, chemical composition of exoplanet atmospheres), consolidating European leadership on exoplanet science.







# The next generation



- 23 Phase-1 proposals received by October 2018 deadline.
- A number of “new” topics and “new” submitting teams/lead proposers compared to previous “M” calls. Some well-known subjects/teams as well.
- Broad topics: Asteroids, Comets, Heliophysics, Astronomy.
- 6 proposals selected for Phase-2
- Phase-2 proposals (deadline was March 2019)
- Selection of Comet Interceptor in June 2019



# Comet Interceptor

Mission to a dynamically young solar system object or to an interstellar visitor.

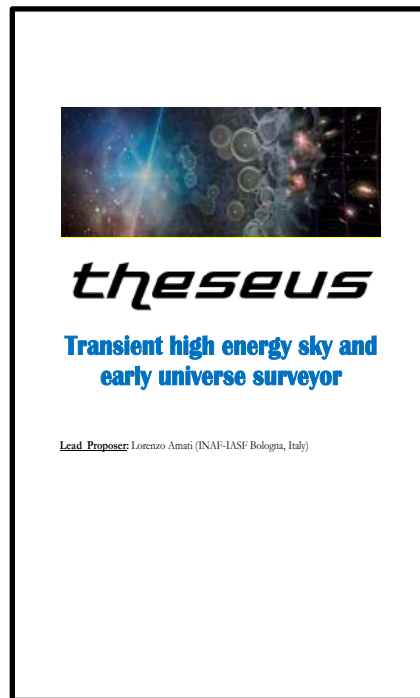


First ESA Fast/Flexi-Mission, approved in June 2019!





# M5 Candidates for Study Selected in May 2018



Phase A studies on going – Plan: M5 selection by Mid 2021 – Launch 2032

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European Space Agency



# "Athena and LISA - bringing sound to the cosmic movies"



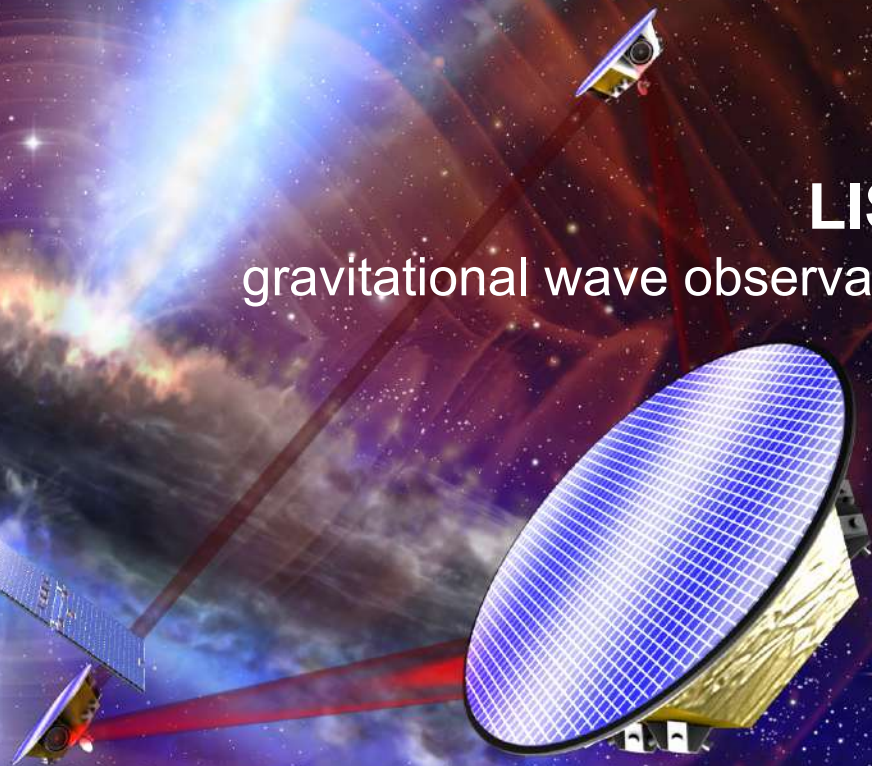
## Athena

hot gas structures  
supermassive black holes



## LISA

gravitational wave observation



European Space Agency



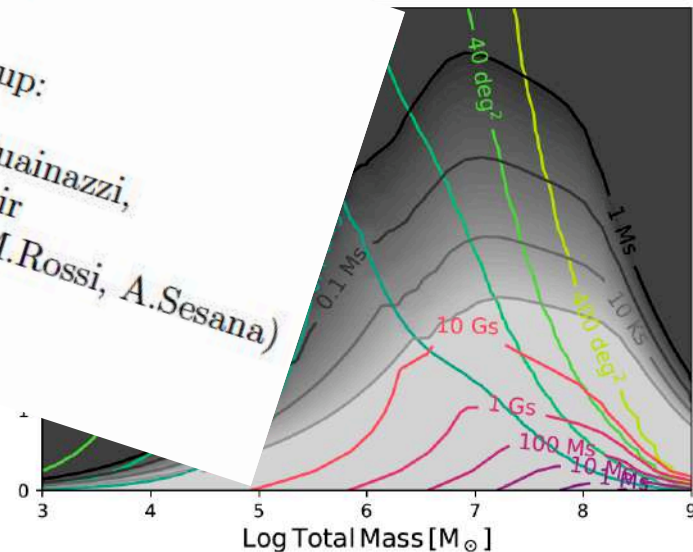
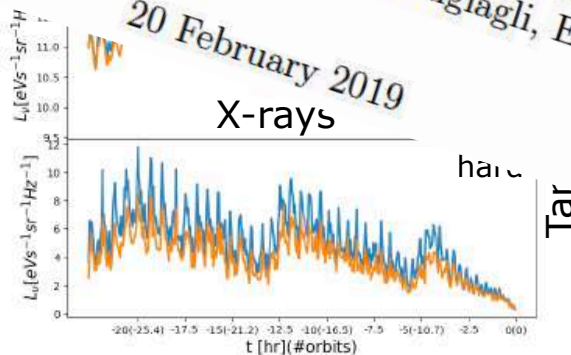
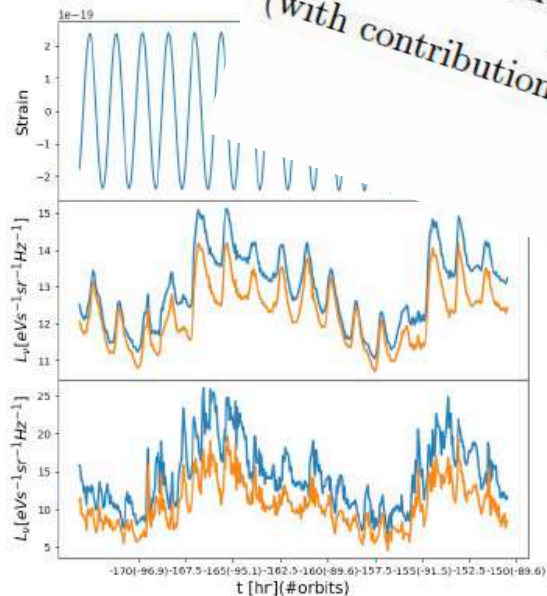
# Athena / LISA Synergies

## Athena-LISA Synergies

Athena-LISA Synergy Working Group:

Monica Colpi, Andrew C. Fabian, Matteo Guainazzi,  
Paul McNamara, Luigi Piro, Nial Tanvir  
(with contributions by J.Aird, A.Klein, A.Mangiagli, E.M.Rossi, A.Sesana)

20 February 2019  
X-rays



McGeet et al. 2018



# Multi-Messenger Quest for the first Black Holes

**INFANT UNIVERSE** 13.8 billion years ago  
with seeds of future galaxies

**COSMIC DARK AGES**  
380,000 to 400 million years  
after the Big Bang

**GRB**  
*theseus*

Athena

Black holes

JWST

First stars

Euclid

**FIRST STARS & QUASARS**  
400 million years after the Big Bang

JCMT Stray BH

**GW: LIGO/ LISA**

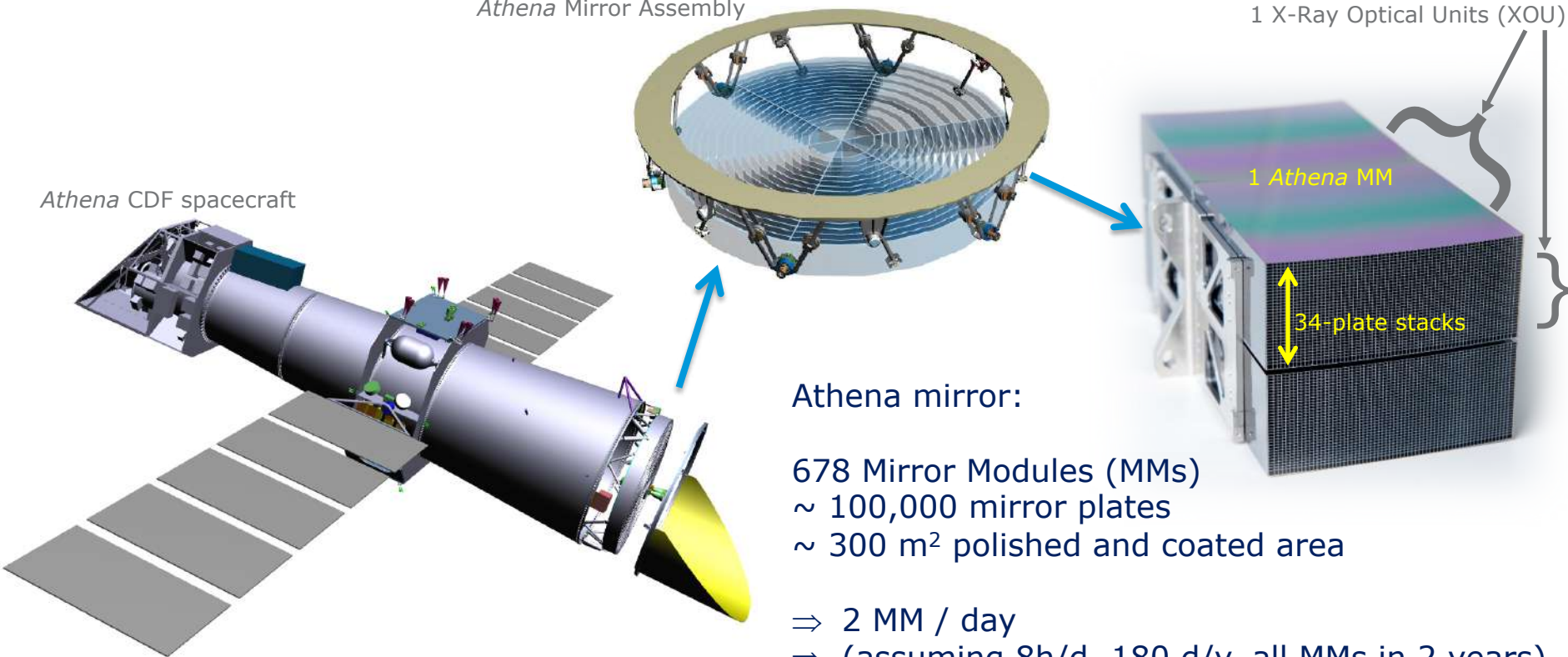


# Athena requires the largest x-ray optic ever built

Athena Mirror Assembly

1 X-Ray Optical Units (XOU)

Athena CDF spacecraft



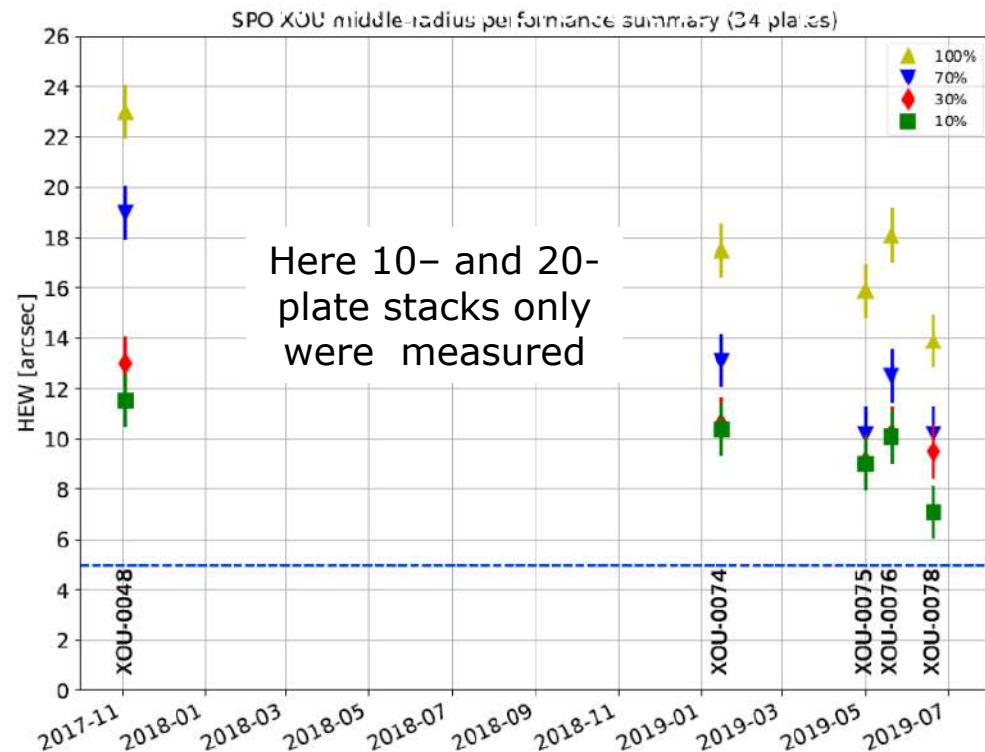
Athena mirror:

678 Mirror Modules (MMs)  
~ 100,000 mirror plates  
~ 300 m<sup>2</sup> polished and coated area

⇒ 2 MM / day  
⇒ (assuming 8h/d, 180 d/y, all MMs in 2 years)



# Angular Resolution Steadily Improving

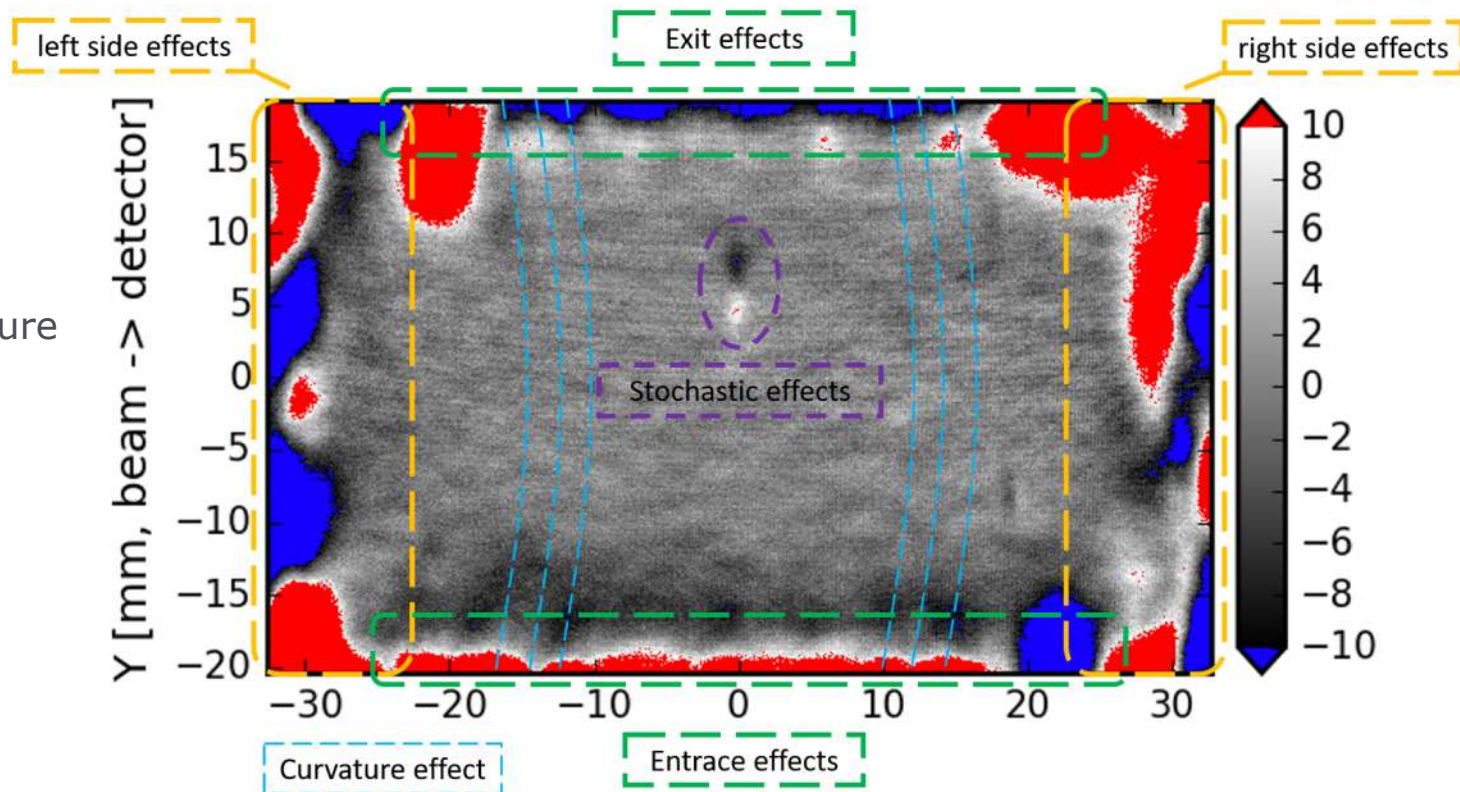


- In 2019 restarted process to make 34-plate middle radius XOUs
- 34-plate stacks performance rapidly improving, XOU-0078 best to date
  - XOU-0078 has still a number of know defects (wedge bias, curvature)
- Bad sides can be removed (see later):
  - 70% to become new 100% reference

Number of plates	HEW 100% [1, 32]	HEW 70% [5, 26]	HEW 30% [10, 20]	HEW 10% [12, 14]
34	13.9	10.2	9.5	7.1
20	12.2	9.1	8.7	5.8
10	12.3	9.6	9.5	6.0



# Contributors to angular resolution budget



Known effects:

- Meridional curvature
- "Wedge effect"
- Entry/exit effects
- Side effects
- Axial slope errors

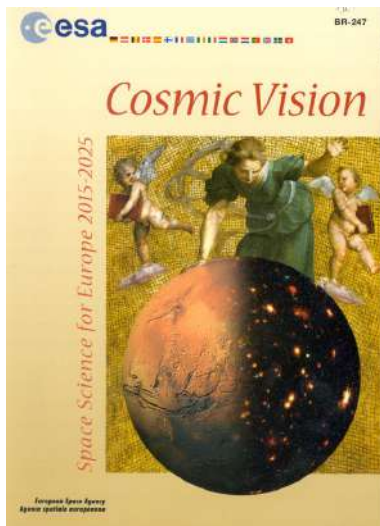


The current long-term planning for the Science Directorate (Cosmic Vision) ends with LISA in around 2035. A new long-term plan called Voyage 2050 is being prepared:

1. Definition of the science themes for three Large missions. The missions themselves, will be defined later through an open call and peer review. ESA and the member states can then start investing in the necessary technology developments.
2. Identification of compelling areas of science for future Medium missions, so that any necessary technology development can start.
3. Recommendations on any areas of blue-sky technology that should be developed, not necessarily linked to any particular mission.



# Voyage 2050



Linda Tacconi



Chris Arridge

- Senior Committee chaired by Linda Tacconi and Chris Arridge
- Supported by Topical Teams (250 self-nominations), around 50 selected
- White Papers on future science requested => about 100 received!

<https://www.cosmos.esa.int/web/voyage-2050/white-papers>



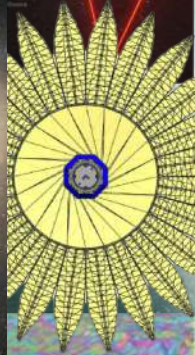
~100 Voyage 2050 White Papers



Presentation to the community  
October 29-30, 2019, CSIC Madrid.

Register at

<https://www.cosmos.esa.int/web/voyage-2050-workshop>



Longonot



# Interacting with the Science Programme

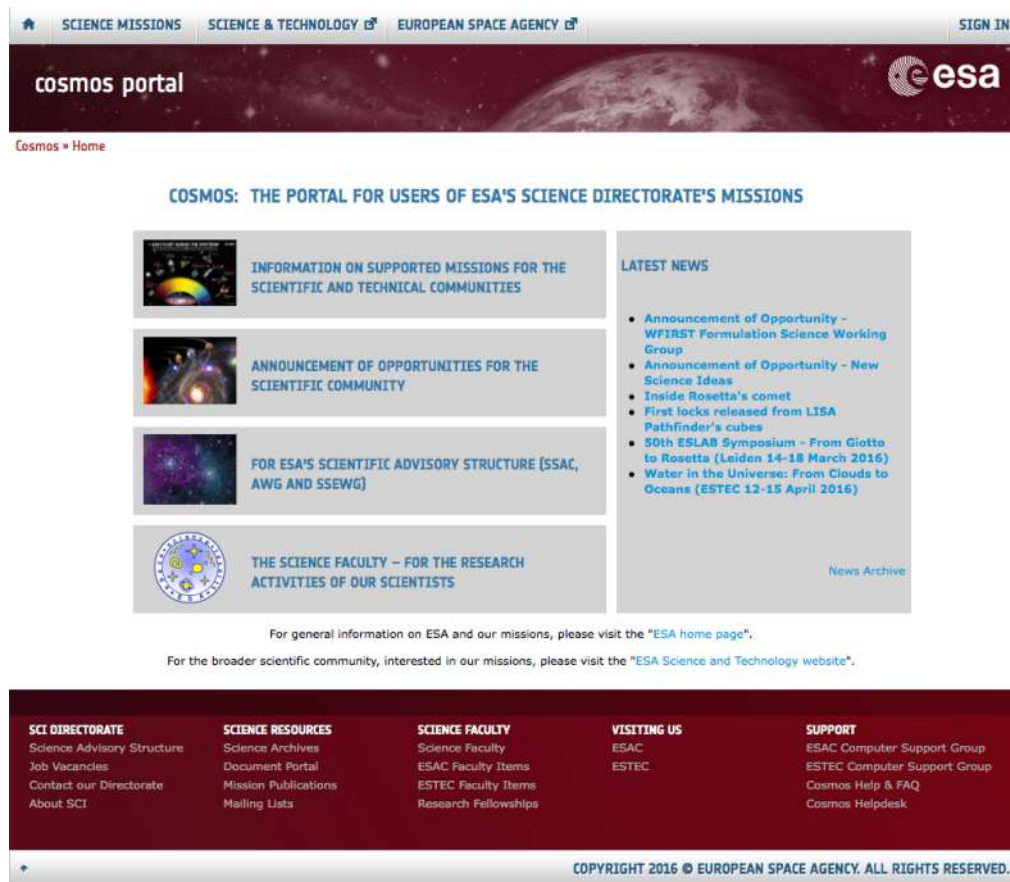


## How can I interact with ESA's Science Programme?

1. Visit our website for scientific and technical users
2. Respond to an announcement of opportunity
3. Exploit archival data from ESAC
4. Participate in an instrument or data processing consortium
5. Become a member of a User Group, TAC, science team etc
6. Become a member of one of the ESA Science Advisory Structure groups
7. Join ESA as a Research Fellow or Young Graduate Trainee



# 1. cosmos.esa.int website



The screenshot shows the homepage of the cosmos.esa.int website. At the top, there is a navigation bar with links for 'SCIENCE MISSIONS', 'SCIENCE & TECHNOLOGY', 'EUROPEAN SPACE AGENCY', and a 'SIGN IN' button. Below this is a header with the 'cosmos portal' text and the ESA logo. The main content area is titled 'COSMOS: THE PORTAL FOR USERS OF ESA'S SCIENCE DIRECTORATE'S MISSIONS'. It features several sections: 'INFORMATION ON SUPPORTED MISSIONS FOR THE SCIENTIFIC AND TECHNICAL COMMUNITIES', 'ANNOUNCEMENT OF OPPORTUNITIES FOR THE SCIENTIFIC COMMUNITY', 'FOR ESA'S SCIENTIFIC ADVISORY STRUCTURE (SSAC, AWG AND SSEWG)', and 'THE SCIENCE FACULTY - FOR THE RESEARCH ACTIVITIES OF OUR SCIENTISTS'. A 'LATEST NEWS' section on the right lists several announcements, including 'Announcement of Opportunity - WFIRST Formulation Science Working Group', 'Announcement of Opportunity - New Science Ideas', 'Inside Rosetta's comet', 'First locks released from LISA Pathfinder's cubes', '50th ESLAB Symposium - From Giotto to Rosetta (Leiden 14-18 March 2016)', and 'Water in the Universe: From Clouds to Oceans (ESTEC 12-15 April 2016)'. A 'News Archive' link is also present. At the bottom, there is a footer with links for 'SCI DIRECTORATE', 'SCIENCE RESOURCES', 'SCIENCE FACULTY', 'VISITING US', and 'SUPPORT'. The footer also includes the text 'ESA UNCLASSIFIED - For Official Use' and 'COPYRIGHT 2016 © EUROPEAN SPACE AGENCY. ALL RIGHTS RESERVED.'

cosmos portal

Cosmos » Home

COSMOS: THE PORTAL FOR USERS OF ESA'S SCIENCE DIRECTORATE'S MISSIONS

INFORMATION ON SUPPORTED MISSIONS FOR THE SCIENTIFIC AND TECHNICAL COMMUNITIES

ANNOUNCEMENT OF OPPORTUNITIES FOR THE SCIENTIFIC COMMUNITY

FOR ESA'S SCIENTIFIC ADVISORY STRUCTURE (SSAC, AWG AND SSEWG)

THE SCIENCE FACULTY - FOR THE RESEARCH ACTIVITIES OF OUR SCIENTISTS

LATEST NEWS

- Announcement of Opportunity - WFIRST Formulation Science Working Group
- Announcement of Opportunity - New Science Ideas
- Inside Rosetta's comet
- First locks released from LISA Pathfinder's cubes
- 50th ESLAB Symposium - From Giotto to Rosetta (Leiden 14-18 March 2016)
- Water in the Universe: From Clouds to Oceans (ESTEC 12-15 April 2016)

News Archive

For general information on ESA and our missions, please visit the "ESA home page".

For the broader scientific community, interested in our missions, please visit the "ESA Science and Technology website".

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ESAC Computer Support Group  
ESTEC Computer Support Group  
Cosmos Help & FAQ  
Cosmos Helpdesk

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## 2. One Stop for ESA's Announcements of Opportunity

Go to <https://www.cosmos.esa.int> and then click on Announcements



Science Announcement of Opportunities » Ho...

### ANNOUNCEMENTS OF OPPORTUNITIES AND CALLS TO THE SCIENCE COMMUNITY

To be informed about new Announcements or Calls please subscribe to the [dsciannounce mailing list](#).

Announcement of Opportunity	Status
<a href="#">XMM-Newton 19th Announcement of Opportunity: for observations to be carried out between May 2020 and April 2021</a>	<b>Open;</b> Proposals due: 11 October 2019, 12:00 UT
<a href="#">Announcement of opportunity for membership of the Science Board of the Martian Moons eXploration Mission (MMX)</a>	<b>Closed;</b> Proposals due: 20 August 2019, 12:00 (noon) CEST
<a href="#">Voyage 2050 Call for White Papers for the Voyage 2050 long-term plan in the ESA Science Programme</a>	<b>Closed;</b> White Papers due: 5 August 2019, 12:00 (noon) CEST
<a href="#">Announcement of Opportunity for Interdisciplinary Scientists and Guest Investigators in the BepiColombo mission</a>	<b>Closed;</b> Letters of Intent due: 13 June 2019, 12:00 (noon) CEST Proposals due: 15 July 2019, 12:00 (noon) CEST
<a href="#">Call for proposals for an ESA-ESO workshop in 2020</a>	<b>Closed;</b> Proposals due: 5 June 2019, 14:00 CEST



## 2. Announcement of Observing Opportunities



ESA observatories have annual calls for observing proposals:

- INTEGRAL's 17<sup>th</sup> AO closed on 5 April 2019. 63 proposals were received with an oversubscription in time of 3.5. Annual.
- XMM-Newton's 19<sup>th</sup> AO closed on 11 October. AO-18 had 442 proposals and an oversubscription of 7.7. Annual.
- CHEOPS 1<sup>st</sup> AO closed on 16 May 2019. 22 proposals received. Following successful commissioning, AO-2 is expected in Q3 2020.
- JWST first GO call is planned to be released on 23 January 2020, with a deadline of 1 May 2020. ESA is organising "master classes" across Europe to "train" scientists on how to use JWST



# ESA Space Science Open Data Policy



- Proprietary period for science data is typically 1 year
  - To instrument teams when data is being produced by instrument teams
  - To observer for observatory missions
- Data then enter the public domain
  - Freely accessible worldwide
  - Being sometimes replicated in non ESA site (European / US data centres)
- Data is made available to the scientific community
  - Through a standard web browser and through scriptable APIs
  - Search, preview, select and download



### 3. Exploit ESA's Data Archives

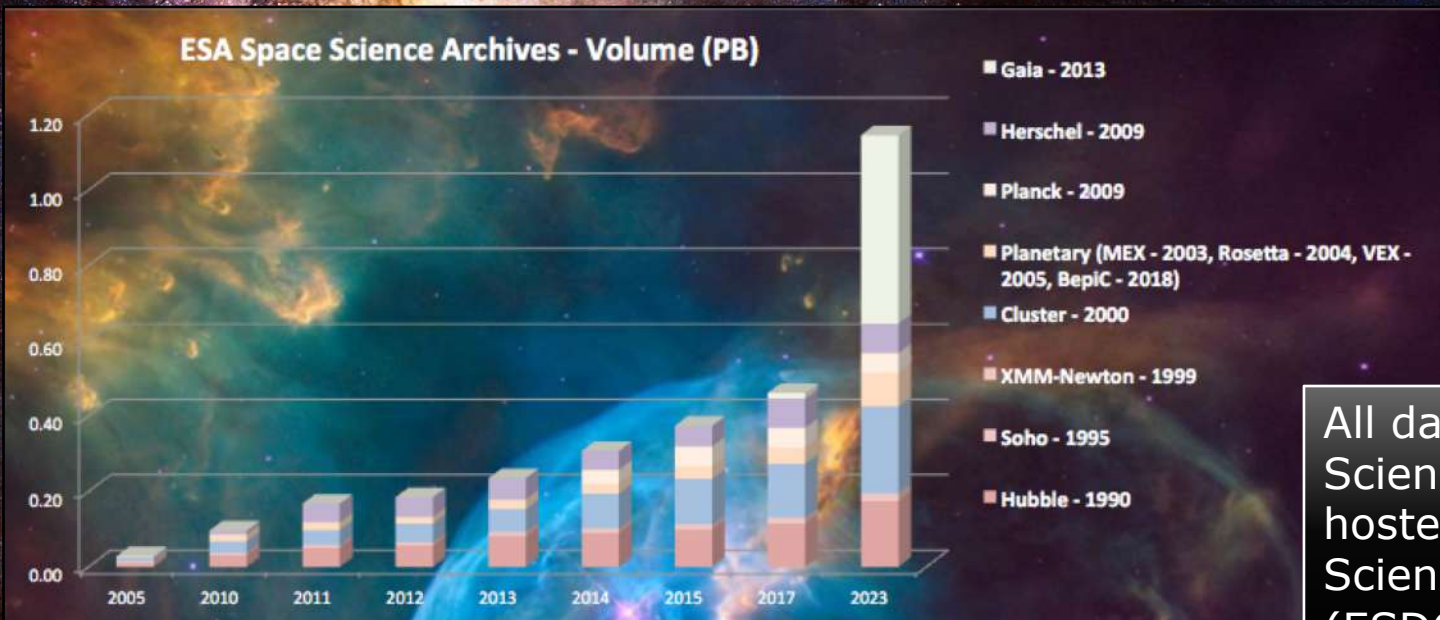


- The ESA archives at ESAC contain a treasure trove of information. They include all the public data from nearly all ESA's science missions
- You can download science-ready products such as calibrated images, light curves and spectra, as well as documentation and analysis software. Go to: <https://www.cosmos.esa.int/web/esdc>
- The archives are organised into three themes:
  - Astronomy
  - Heliophysics
  - Planetary

And data from “new” missions such as Solar Orbiter and BepiColombo etc will be added as they become available.



Find all ESA data at <http://archives.esac.esa.int>



All data from ESA Space Science Missions are hosted at the ESAC Science Data Centre (ESDC)

In partnership with



Int. Virtual  
Observatory Alliance



Int. Planetary  
Data Alliance



Int. Heliophysics  
Data Env. Alliance



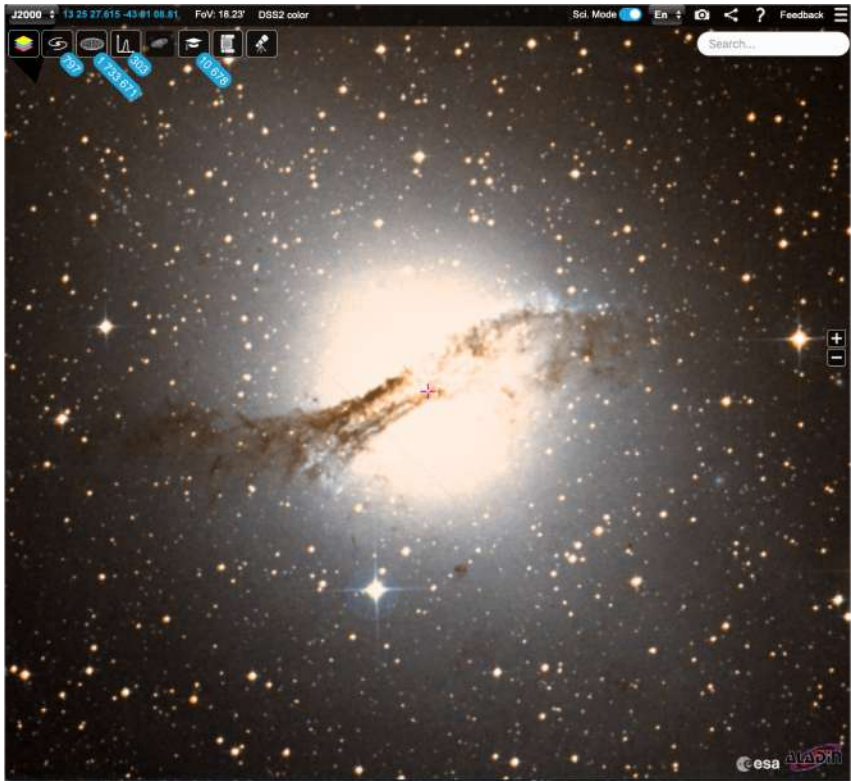
astropy



- ESA Sky (<https://sky.esa.int>) is the multi-mission portal to the astronomy mission archives.
- You don't need to be an expert to use ESA Sky!
- Provides a multi-wavelength view of the sky through accessing the data from individual archives
- A great tool for exploration!
- Similar “overarching” approaches are being developed for the planetary and heliospheric archives



# ESASky Concept: Explore, compare, select, download

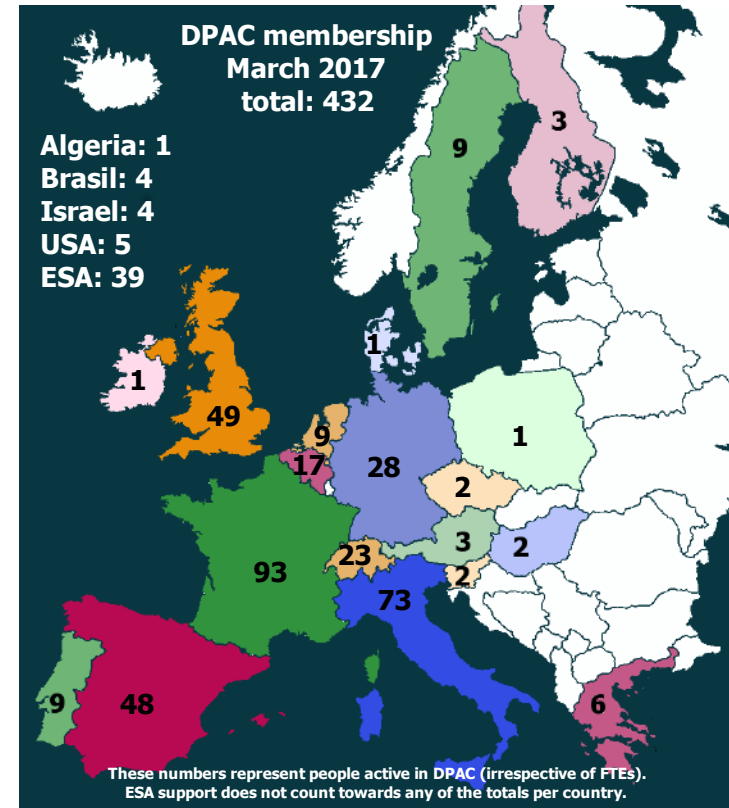




## 4. Instrument and Data Processing Consortia

An example:

- The Gaia DPAC is the consortium responsible for the (very complex) data processing for the mission
- Over 400 members. Euclid is even bigger!
- The chart to the right, shows the DPAC membership distribution
- Bring expertise to consortia.





## 5. ESA Needs Expert Help!



ESA often needs the advice of external expert bodies:

- Time Allocation Committees (TACs) for observatory missions. The XMM-Newton TAC has around 70 members who are recycled every 2 years.
- User Groups or Science Working Teams for individual missions. Members are selected from active users of the data
- Conference organising and other ad-hoc committees.



## 6. ESA Needs Scientific Advice!



### ESA's Science Advisory Structure:

- The Working Groups who are experts in Astronomy (AWG) Solar System and Exploration (SSEWG) and the Physical Sciences (PSWG) first provide science evaluations.
- The Space Science Advisory Committee (SSAC) which is the senior advisory committee.

Members serve for 3 years. We are always looking for leading astronomers and space scientists who are willing to serve.



## 7. ESA Research Fellow Programme



- This is ESA's "Post Doctoral Research Programme". See: <https://www.cosmos.esa.int/web/science-faculty/research-fellowship>
- Research Fellows (RFs) are young scientists staying for two (or possibly three) years at ESAC or ESTEC.
- A major advantage is that RFs do not have (mandatory) functional duties, so can spend most of their time doing research.
- The latest annual recruitment round closed on **1 October 2019**. We normally recruit around 8 new RFs each year.
- A similar programme exists for Master Degree graduates (The Young Graduate Trainee programme).



A composite image of Earth from space at night. The left side shows the Earth's horizon with city lights glowing against the dark landmasses. The right side features a bright, intense light source, possibly the sun or a star, creating a lens flare effect. The background is a deep blue space filled with stars and faint, glowing lines that suggest a global network or orbital paths.

**Thank you  
very much!**