The Athena Project in the context of the Science Programme of ESA

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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.

• The Programme is Mandatory:
  all member states contribute pro-rata to GNP providing budget stability and allowing long-term planning of its scientific goals.
- Large “L” missions
  - ESA cost equivalent to 2 years of the LoR
  - New technology developments needed
  - ESA-led with contributions by partners up to 20%

- Medium “M” missions
  - ESA cost equivalent to 1 year of the LoR
  - No technology development
  - ESA-led, or in cooperation at any level

- Small “S” missions
  - ESA Participation to small missions with partners
  - Limited to 50 M€

- Missions of Opportunity
  - Junior participation to missions led by partners
  - Limited to 50 M€
COSMIC VISION 2016-2035

GW Observatory

M7

M6

ATHENA

M5

PLATO

CHEOPS
Astro-H
Microscope
ExoMars
IRIS

Solar Orbiter

JWST

JUICE

Bepi Colombo
Frequency of M missions
M4 Candidates
Mission Planning

- Planning of mission calls:
  - M1, M2, L1  2007, 2007, 2007  slice 1
  - M5, M6, L3  2016, 2018, 2018  slice 3
  - 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:
  - M1, M2, L1  2018, 2020, 2022
  - M3, M4, L2  2024, 2025, 2028
  - M5, M6, L3  2030, 2032, 2034
  - M7  2035
Mission Planning

- Planning of mission calls:
  - M1, M2, L1: ✔, ✔, ✔ slice 1
  - M3, M4, L2: ✔, ✔, ✔ slice 2
  - M5, M6, L3: 2016, 2018, 2018 slice 3
  - 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:
  - M1, M2, L1: 2018, 2020, 2022
  - M3, M4, L2: 2024, 2025, 2028
  - M5, M6, L3: 2030, 2032, 2034
  - M7: 2035
ESA’S HIGH-ENERGY ASTRONOMY MISSIONS

COS-B 1975-1982
EXOSAT 1983-1986
XMM-Newton 1999->
INTEGRAL 2002->
SMILE 2021
XIPE 2026
Athena 2028
Gravitational Wave Observatory 2034
ESA’S HIGH-ENERGY ASTRONOMY MISSIONS

COS-B 1975 - 1982

EXOSAT 1983 - 1986

INTEGRAL 2002 ->

XMM-Newton 1999 ->

Athena 2028
High-Energy astronomy started in ESA in 1975 with the launch of COS-B which was operated for >6 years.

A 300 kg spacecraft with a single gamma-ray spark chamber and co-aligned X-ray proportional counter.

Over 170 refereed papers. 240 authors.

Major results include:

- 2CG catalogue containing around 25 gamma-ray sources
- First full gamma-ray maps of the galactic plane
- The first gamma-ray AGN was detected (3C 273)
- Geminga positioned to 0.25 degrees allowing counterpart searches.

The gamma-ray spectrum of 3C 273 obtained by COS-B (Bignami et al, 1981)
EXOSAT (1983-1986) was ESA’s first X-ray observatory. 1800 observations.

- 500 kg. ESA’s first 3-axis stabilized spacecraft with one of the first on-board computers.
- 90-hour highly-eccentric orbit allowed long uninterrupted observations
- Over 700 refereed papers. 100 unique authors
- Three co-aligned instruments:
  - Two low-energy imaging telescopes with deployable gratings
  - Medium Energy proportional counter array ($\Delta E/E = 20\%$)
  - Gas scintillation proportional counter ($\Delta E/E = 10\%$)

ESA mission with contributions with the instruments funded directly by the ESA Member States and NASA.

Mass: 3.8 tonnes and height of 10 m, 7.5 m focal length.

Three sets of co-aligned instruments: 3 Imaging cameras, and 2 gratings behind large area optics. Optical/UV monitor.

One of the most productive ESA science missions ever with over 4100 refereed papers. 10,000 unique authors. Still ~300 papers per year.

Lifetime limited by fuel usage to ~2028 – could be very timely for Athena!
INTEGRAL, ESA’s gamma-ray observatory, has been operating since 2002 October.

ESA led mission in collaboration with Russia (Proton rocket) and the United States. Instruments and data centre funded directly by the ESA Member States

Over 850 refereed papers and 2400 unique authors

3 keV to 10 MeV energy coverage

Fuel for operations until ~2022

Mass: 4 tonnes, 5 m high, 16 m span solar panels

Two Gamma-ray instruments (coded masks) provide imaging spectroscopy of the >15 keV sky. Concurrent X-ray and optical monitoring.
THE STRENGTH OF THE SCIENCE PROGRAMME: XMM-NEWTON AND HERSCHEL COMBINED
<table>
<thead>
<tr>
<th>Mission</th>
<th>Launch</th>
<th>Status</th>
<th>Comment</th>
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<tbody>
<tr>
<td>SMILE</td>
<td>2021</td>
<td>Recommended by ESA-CAS scientific committee. Formal selection process in November 2015</td>
<td>Solar wind Magnetospheric Ionosphere Link Explorer – X-ray measurements of the aurorae</td>
</tr>
<tr>
<td>XIPE</td>
<td>2026</td>
<td>One of 3 Phase-A studies for the M4 mission slot</td>
<td>X-ray polarimetry</td>
</tr>
<tr>
<td>Athena</td>
<td>2028</td>
<td>Final approval “adoption” planned for 2020</td>
<td>X-ray observatory with 2 imaging spectrometers.</td>
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<tr>
<td>GW Obs.</td>
<td>2034</td>
<td>Final report after L-PF analysis. Mission call in 2017</td>
<td>Science theme selected to be a gravitational wave observatory</td>
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Will investigate the interaction between the solar wind and the Earth’s magnetosphere. MMS, Swarm, Cluster all address this issue *in-situ*.

- HEO 2.2 day Molniya-type orbit (63°). 300 kg.
- SMILE will provide in-situ plasma and magnetic field measurements as well as X-ray images of the magnetosheath and magnetic cusps and UV images of the auroral regions.
- Of potential importance to studies of solar wind charge exchange and the X-ray background.
- SXI is a wide field lobster-eye 0.2-5 keV X-ray imager led by a team from MSSL. CCD detectors. 25 x 28 degree FOV with 4.5 arcmin FWHM. Effective area of 13 cm$^2$ at 0.5 keV.

With thanks to Chi Wang, National Space Weather Center and Graziella Branduardi-Raymont, MSSL
XIPE is “X-ray Imaging Polarimetry Explorer” with greatly enhanced sensitivity compared to previous missions.

- X-ray polarisation is a “young” field. Opened by OSO-8 in the 1970’s with the detection of $19.2 \pm 1.0\%$ polarisation from the Crab Nebula (Weisskopf+ 1976) together with upper-limits from a number of bright sources.

- Science case includes investigations of almost every type of high-energy emitters: SNRs, Jets, CVs, Magnetars, pulsars, X-ray binaries, AGN etc.

Simulated 500 ksec XIPE observation of GRS 1915+105 in its soft state. The figure shows the angle of polarisation against energy for a range of black hole spins. Purple is for a Schwarzschild black hole and green an extreme Kerr black hole.
Athena is ESA’s large X-ray observatory, under study for a launch in 2028. Selected by the SPC in June 2014 with a cost cap to ESA of 1 B€.

Designed to fulfill the science objectives defined in the Senior Survey Committee’s “Hot and Energetic Universe” science theme for the L2 launch opportunity:

- The Hot Universe – how do large scale hot gas structures form and grow?
- The Energetic Universe – A census of black hole growth in the Universe
- Observatory and Discovery Science – providing a unique contribution to multi-wavelength astrophysics.
ATHENA INSTRUMENTS

WFI based on Si DEPFET technology
- 100 micron pixels, 140 eV FWHM @ 6 keV
- 10 mCrab without pile-up
- Field of view up to 40 x 40 arcminutes
- Investigating a second (defocussed) FAST chip providing 1 Crab source brightness with 40 µs time resolution and only 1% pile up

X-IFU based on TES microcalorimeter
- 250 micron pixels, ~2 eV FWHM @ 6 keV
- Field of view 5 x 5 arcminutes (>32 x 32 array)
- Investigating optimised array with outer field having multiple pixels per TES readout
- US provision of sensor arrays and Japanese provision of part of the cooling chain baselined
Athena is selected, is not in competition with any other mission, but it has not yet been finally approved (or adopted) by the Science Programme Committee (SPC).

Adoption occurs at the end of the Definition Study providing that:

- The Definition Study was successful
- The science case remains compelling
- The ESA costs are within the agreed ceiling
- The ESA Member States agree to fund their elements
- Any international agreements are in place
The L3 science theme was selected by ESA’s Senior Survey Committee to be “The Gravitational Universe”

ESA has appointed an advisory team to:

- Recommend on technological activities
- Identify scientific and technical milestones
- Engage with the gravitational wave community
- Evaluate and recommend on possible scientific and technical approaches for a launch in 2034.

Advisory team includes leading European and US scientists with NASA and JAXA observers.