# ATHENA

THE ADVANCED TELESCOPE FOR HIGH ENERGY ASTROPHYSICS

*www.the-athena-x-ray-observatory.eu*

# FACT SHEET

**X-ray observatory mission selected by ESA (Cosmic Vision programme)**

**The second large-class mission**

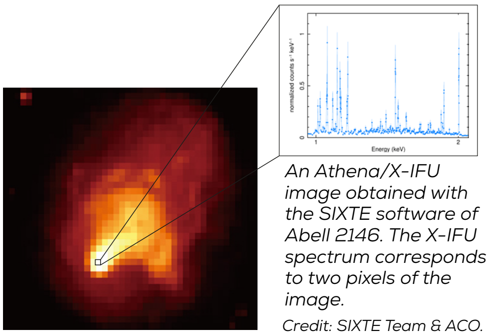
**Addresses the Hot and Energetic Universe scientific theme**

## SCIENCE THEME

### THE HOT AND ENERGETIC UNIVERSE

The *Athena* observatory will pursue three main scientific objectives:

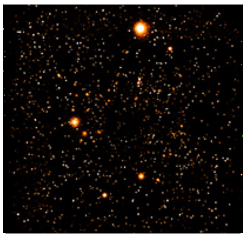
**1. Determine** how and when large-scale structures formed in the Universe and track their evolution from the formation epoch to the present day.



*An Athena/X-IFU image obtained with the SIXTE software of Abell 2146. The X-IFU spectrum corresponds to two pixels of the image.*

*Credit: SIXTE Team & ACO.*

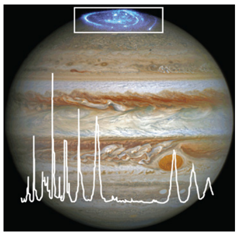
**2. Perform** a complete census of black hole growth in the Universe, determine the physical processes responsible for that growth and its influence on larger scales, and trace these and other energetic and transient phenomena to the earliest cosmic epochs.



*Deep Athena WFI images such as this simulation, will reveal growing supermassive black holes out to the edge of the observable Universe*

*Credit: WFI Team.*

**3. Provide** a unique contribution to astrophysics in the 2030s by exploring high energy phenomena in all astrophysical contexts, including those yet to be discovered.



*Jupiter's aurora (blue glow at the pole) imaged by Chandra and simulated Athena X-IFU spectrum (white line) superposed to an optical image of the planet.*

*Credit: NASA/ESA, and J. Nichols (Leicester Univ.) Spect.: G. Branduardi-Raymont (UCL).*


## MISSION

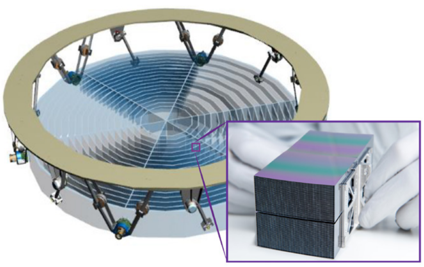
### OBSERVE X-RAYS FROM ASTRONOMICAL SOURCES

*Athena* will be ESA's next large X-ray observatory offering breakthrough capabilities in spatially-resolved high-resolution spectroscopy and deep wide-field spectral imaging greatly exceeding current facilities.

- Due to launch in the early 2030s with an Ariane 64 rocket.
- Halo orbit at 1st Sun-Earth Lagrangian Point (L1).
- 4 year baseline mission plus possible extensions.
- Proposal-driven observing program.
- Two complementary state-of-the-art instruments.
- ≥ 1.4 $m^2$ collecting area at 1 keV.

### MIRROR

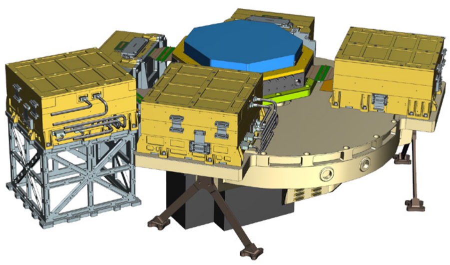
**Large-aperture grazing-incidence telescope, utilising a novel high-performance Silicon pore optics technology developed in Europe.**



*Credit: Cosine and ESA.*

### WIDE FIELD IMAGER (WFI)

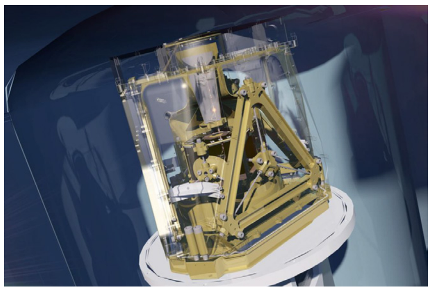
**Providing sensitive wide field imaging and spectroscopy and high count-rate capability with a 40'x 40' field of view.**



*Credit: WFI Team.*

### X-RAY INTEGRAL FIELD UNIT (X-IFU)

**Delivering spatially-resolved high-resolution X-ray spectroscopy over a field of view of 5 ' equivalent diameter.**



*Credit: IRAP/CNRS/UT3/CNES/SRON/NASA GSFC/Fab&Fab.*

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***Athena* is the X-ray observatory selected by ESA within its Cosmic Vision programme, to address the Hot and Energetic Universe scientific theme. It is the second large class mission within that programme.**

## THE HOT AND ENERGETIC UNIVERSE

Thanks to its **unprecedented spectroscopic and imaging capabilities** in the 0.2 -12 keV range, *Athena* will lead the quest to solve several key questions of modern astrophysics, relevant to the Hot and Energetic Universe science theme.

Our current understanding is that most of the ordinary matter in the Universe is today locked in Mpc-scale filamentary structures of gas at million degree temperatures, both inside the potential wells of groups and clusters of galaxies and in the so-called Warm Hot Intergalactic Medium (WHIM). Investigating how **such hot gas structures formed and evolved**, and how and when the **material** trapped **in them was energised and chemically enriched**, is possible only through observations in the X-ray band, combining wide-field imaging with high resolution spectroscopy, both of high sensitivity. Such capabilities will also reveal the physical properties of the WHIM, both via its emission, and in absorption against bright background targets.

Performing a **complete census of black hole growth** in the Universe has become a most pressing issue since the realisation that all nearby massive galaxies harbour a Super-Massive Black Hole (SMBH) with a mass intriguingly proportional to that of the galaxy bulge. Furthermore, the cosmic evolution of galaxy growth through star formation and SMBH growth via accretion (shining as Active Galactic Nuclei or AGN) follow parallel tracks, increasing back in time from the present time to its heyday at redshifts z ~ 1-3. Do these fascinating clues imply that AGN actually shape their host galaxies? How does this happen? How far back does this start? Wide field X-ray observations have the ability to pinpoint AGN among the myriad sources in the sky, even if they are heavily obscured. This capability will enable the detection of even the most elusive specimens of this population, such as the most heavily obscured or those at higher redshift. X-ray spectroscopy and time variability will reveal the workings of the inner parts of the AGN engine (and those of other stellar-mass accreting engines in our Galaxy) as well as the outflows of ionised gas that may carry sufficient momentum and kinetic energy to regulate star formation in the host galaxy. Finally, **the fast Target of Opportunity capabilities** of *Athena* will enable studies of Gamma Ray Bursts and other transient phenomena to the earliest cosmic epochs.

Aside from these topics, the singular and outstanding capabilities of ***Athena* as an observatory** are expected to make a profound impact in essentially all fields of Astrophysics. For instance they will allow understanding the structure and energetics of stellar winds and their interplay with atmospheres and magnetospheres of planets. They will also permit exploring the behaviour of matter under extreme conditions of density and magnetic fields in stellar binaries and neutron stars. Additionally, *Athena* will be an important tool for exploring physics beyond the standard model. As a final example, *Athena* will probe the physics of the enrichment and heating of our Galaxy's Inter-stellar Medium by supernova explosions.

This will not happen in isolation, but taking full advantage of ***Athena*'s synergies** with the set of multi-wavelength and multi-messenger astronomical facilities in operation in the early 2030s (e.g. LOFAR, SKA, ALMA, ELT, Vera C. Rubin Observatory, CTA, LISA, to name but a few).

## AN OBSERVATORY FOR WHOLE ASTRONOMICAL COMMUNITY

*Athena* will be a **large X-ray observatory** offering **spatially-resolved X-ray spectroscopy** and **deep wide-field** X-ray **spectral imaging** with performance greatly exceeding that offered by current X-ray observatories like XMM-*Newton*, *Chandra*, and SRG/eROSITA, or by missions to be launched shortly like XRISM.

*Athena* will be launched by an Ariane 6 vehicle, with equivalent or larger lift capability and fairing size to that of the Ariane 5. It will operate at the first Sun-Earth Lagrangian point (L1) in a large halo orbit. Such orbits offer a very stable thermal environment as well as good instantaneous sky visibility and high observing efficiency.

*Athena* has a **baseline mission lifetime of 4 years**, although it will be designed and have consumables for a longer time. Operations will be performed as in standard ESA science missions, with the Mission Operations Centre (MOC) at ESOC (Darmstadt, Germany) and the Science Operations Centre (SOC) at ESAC (Villafranca del Castillo, Spain). Two Instrument Science Centres (one each for the X-IFU and WFI) will complement the SOC in performing scientific ground segment activities.

*Athena* will be operated as an observatory, in a similar fashion to prior missions such as XMM-*Newton* and *Herschel*. **Users will access the observatory via open proposal calls**.

## A STATE OF THE ART PAYLOAD

The *Athena* observatory consists of a single X-ray telescope with a fixed 12 m focal length, with an effective area of 1.4 m² (at 1 keV) and a spatial resolution of 5'' on axis. The mirror is based on **ESA's Silicon Pore Optics (SPO) technology**. SPO provides an excellent ratio of collecting area to mass, while still offering good angular resolution. It also benefits from a high technology readiness level and a modular design highly amenable to mass production, necessary to achieve the unprecedented telescope collecting area. A movable mirror assembly can focus X-rays onto either one of *Athena*'s two instruments at any given time.

The **Wide Field Imager (WFI)**, is a Silicon-based detector using DEPFET Active Pixel Sensor technology with a field of view of 40' x 40', offering < 170 eV spectral resolution at 7 keV, with a pixel size of 2.2'' and a frame time of 5 ms. The large field of view of the instrument is provided by a Large Detector Array consisting of four DEPFETs. A further, smaller DEPFET detector is optimised for observations of the brightest X-ray sources in the sky with time resolution of 80 μs.

The **X-ray Integral Field Unit (X-IFU)**, provides spatially-resolved high resolution spectroscopy. The instrument is a cryogenic X-ray micro-calorimeter, based on a large array of Transition Edge Sensors (TES), offering 2.5 eV spectral resolution, with ~ 5'' pixels, over a field of view of 5' in equivalent diameter and a timing resolution of 10 μs. An active anti-coincidence detector placed underneath the main TES array aims at reducing the non X-ray background. The focal plane assembly holding the detectors is cooled at 50 mK by a series of mechanical coolers.