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Athena: Mission and Spanish participation.

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Abstract

Athena (Advanced Telescope for High ENergy Astrophysics) is the X-ray observatory mission selected by ESA to address the Hot and Energetic Universe theme, due for launch in the early 2030s. *Athena* addresses three key scientific objectives: 1) Determine how and when large-scale hot gas structures formed in the Universe and track their evolution from the formation epoch to the present day. 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. 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.

From the unique perspective endowed to *Athena* by its unprecedented spectroscopic and imaging capabilities in the 0.5-12 keV range, this mission will lead the quest into solving these questions from its launch.

The *Athena* mission concept is that of a single large-aperture grazing-incidence X-ray telescope, utilising a novel technology (Si pore optics) developed in Europe, with 12 m focal length and 5 arcsec HEW angular resolution. The focal plane contains two instruments. One is the Wide Field Imager (WFI) providing sensitive wide field of view imaging and low resolution spectroscopy, as well as bright source observation capability. The other one is the X-ray Integral Field Unit (X-IFU) delivering spatially resolved high-resolution X-ray spectroscopy over a limited field of view. Synergies with other facilities (ESO, SKA, CTA, LISA, etc.) are being identified and developed.

Spain has an important role in *Athena*, with a significant contribution to the X-IFU instrument, including the dewar for the detector cooling system, the algorithms for the on-board pulse detection software, and a leading scientific contribution. Spain also leads the *Athena* Community Office, set up to help optimising the participation of the more than 800 scientists which are helping to shape up the mission through its working groups.

1 Introduction

Thanks to its unprecedented spectroscopic and imaging capabilities in the 0.5-12 keV range, *Athena*[1] [18] 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 (baryons) 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 [21, 9] and in the so-called Warm Hot Intergalactic Medium (WHIM) [15]. 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 $z \sim 1-3$. 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 [13] or those at higher redshift [1]. X-ray spectroscopy and time variability will reveal the workings of the inner parts of the AGN engine [12] (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[8, 5]. 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 [14].

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 [4, 24]. They will also permit exploring the behaviour of matter under extreme conditions of density and magnetic fields in stellar binaries and neutron stars [17]. As a final example *Athena* will probe the physics of the enrichment and heating of our Galaxy's Interstellar Medium by supernova explosions [10].

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 [6], ALMA, ELT[19], LSST, CTA, LISA, to name but a few),

[1] https://www.the-athena-x-ray-observatory.eu/

see also contributions by M. Díaz-Trigo [11], M. Ribó [23] and M.A. Pérez-Torres [20] in this volume.

2 An observatory for the 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* and *Chandra*, or by missions to be launched shortly like *XRISM* and *SRG*/eROSITA.

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 second Sun-Earth Lagrangian point (L2) in a large halo orbit, although the possibility of an L1 halo orbit is also being assessed. 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.

3 A state of the art payload

The *Athena* observatory consists of a single X-ray telescope [25] with a fixed 12 m focal length, with an effective area of 1.4 m^2 (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[2]) [22, 16], is a Silicon-based detector using DEPFET Active Pixel Sensor technology with a field of view of $40' \times 40'$, offering 150 eV spectral resolution, with a pixel size of $2.2''$. The large field of view of the instrument is provided by a Large Detector Array (LDA) consisting of four DEPFET chips. A further, smaller DEPFET detector is optimised for fast readout to accommodate measurement of the brightest X-ray sources in the sky, at a time resolution of 80 μs.

The X-ray Integral Field Unit (X-IFU[3]) [2, 3], provides spatially-resolved high resolu-

[2] http://www.mpe.mpg.de/ATHENA-WFI/
[3] http://x-ifu.irap.omp.eu/

tion spectroscopy. The instrument is a cryogenic X-ray micro-calorimeter, based on a large array of Transition Edge Sensors, 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.

4 The *Athena* Community and the *Athena* Community Office

The remit of the *Athena* Science Study Team (ASST) involves multiple tasks, which include acting as a focus for the involvement of the broad scientific community. With the agreement of ESA, the ASST has established a Working Group structure populated by members of the community[4]. These Working Groups and Topical Panels are intended to bring the expertise and effort of that community to bear in support of *Athena*. The mission is currently supported by about 800 researchers.

At the moment there are 5 Working Groups (SGW1 The Hot Universe, SWG2 The Energetic Universe, SWG3 Observatory Science, TWG4 Telescope and MWG5 Mission Performance). Most of them are organised in Topical Panels (TP e.g. SWG1.3, MPG5.2, etc).

The ASST appointed the *Athena* Community Office (ACO)[5] to obtain assistance in organisational aspects and optimisation of community efforts, keeping the *Athena* Community informed and developing communication and outreach activities around *Athena*. The ACO is led by IFCA (CSIC-UC) in Spain, with contributions from IRAP (France), MPE (Germany) and the Université de Genève (Switzerland). For more details see contribution by M.T. Ceballos [7] in this volume.

5 Spanish participation in *Athena*

At mission level a total of 48 researchers from Spanish institutions serve in the TP, including 2 TP chairs (G. Miniutti and F.J. Carrera) and 2 members in SWG1, 30 in SWG2, 20 in SWG3, 2 in TWG4 and 7 in MWG5.

As mentioned just above, the *Athena* Community Office is led by IFCA (CSIC-UC).

At instrument level there is some small-scale involvement in the scientific definition of the WFI through the survey and TP 2.1 (Understanding the build-up of SMBH and their host galaxies, led by F.J. Carrera, S. Mateos and A. Corral).

However, the main participation is focussed on X-IFU in whose consortium board M. Mas Hesse represents Spain. M. Mas and M.T. Ceballos are Instrument co-Investigators. The Detector Cooling System cryostat (dewar) is being developed by INTA and CAB (Phase A) under the leadership of J. Gómez, with A. Balado as Project Manager, with the participation of: M.A. Alcacera, J. Azcue, A. Balado, L. Bastide, F. Cabrerizo, J.M. Encinas, M.

[4]https://www.the-athena-x-ray-observatory.eu/community.html

[5]See the ACO leaflet under https://www.the-athena-x-ray-observatory.eu/resources/athena-brand.html

Fernández, A. García, C. Moravec, M. Pajas, J.M. Pintado, M. Reina, J. Sanmillan and I. Vera. Additionally, IFCA is developing the Event Processor algorithms, led by M.T. Ceballos and with the participation of B. Cobo.

Spain is also participating in the science support for X-IFU J.M. Torrejón being a member of the X-IFU Science Team and X. Barcons being science co-I of that instrument.

Finally, IFCA and the U. de Alicante are members of the X-IFU Instrument Science Centre.

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