X-IFU

X-ray Integral Field Unit

The Hot and Energetic Universe

The ESA Athena X-ray Observatory and its X-ray Integral Field Unit (X-IFU)

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On behalf of the X-IFU consortium

Outline

- The Hot and Energetic Universe: scientific goals
- The Advanced Telescope for High ENergy Astrophysics (Athena)
  - The second Large mission of the Cosmic Vision program of the European Space Agency
- The X-ray Integral Field Unit for Athena

The Content of the Universe

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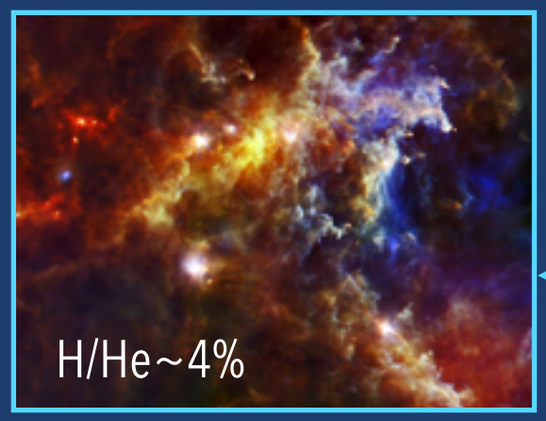
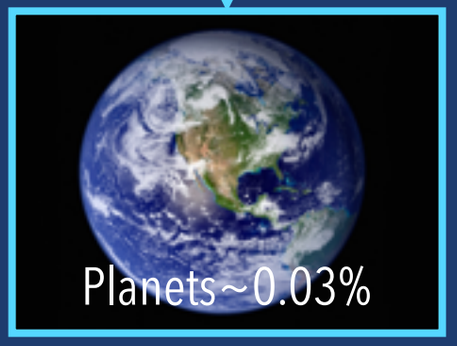
X-ray Integral Field Unit



Normal matter
5 %

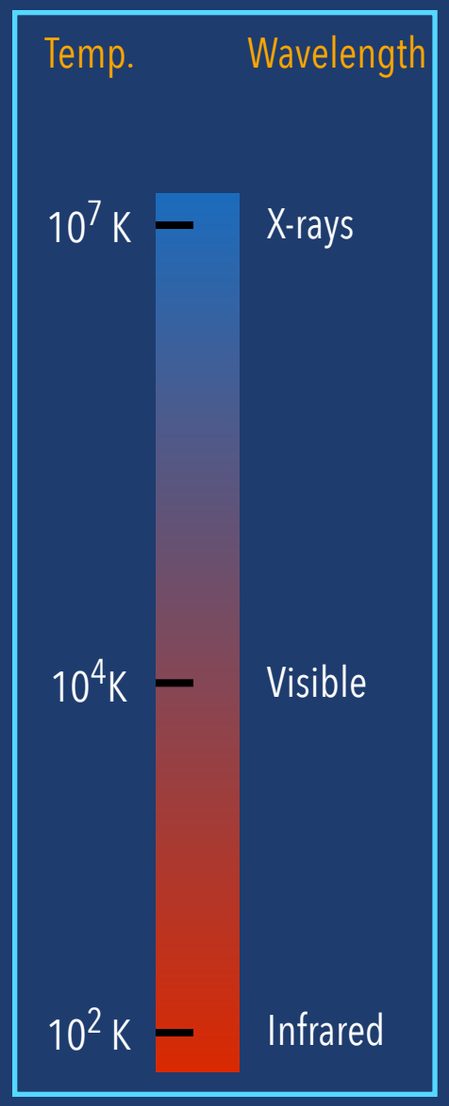
Dark matter
27 %

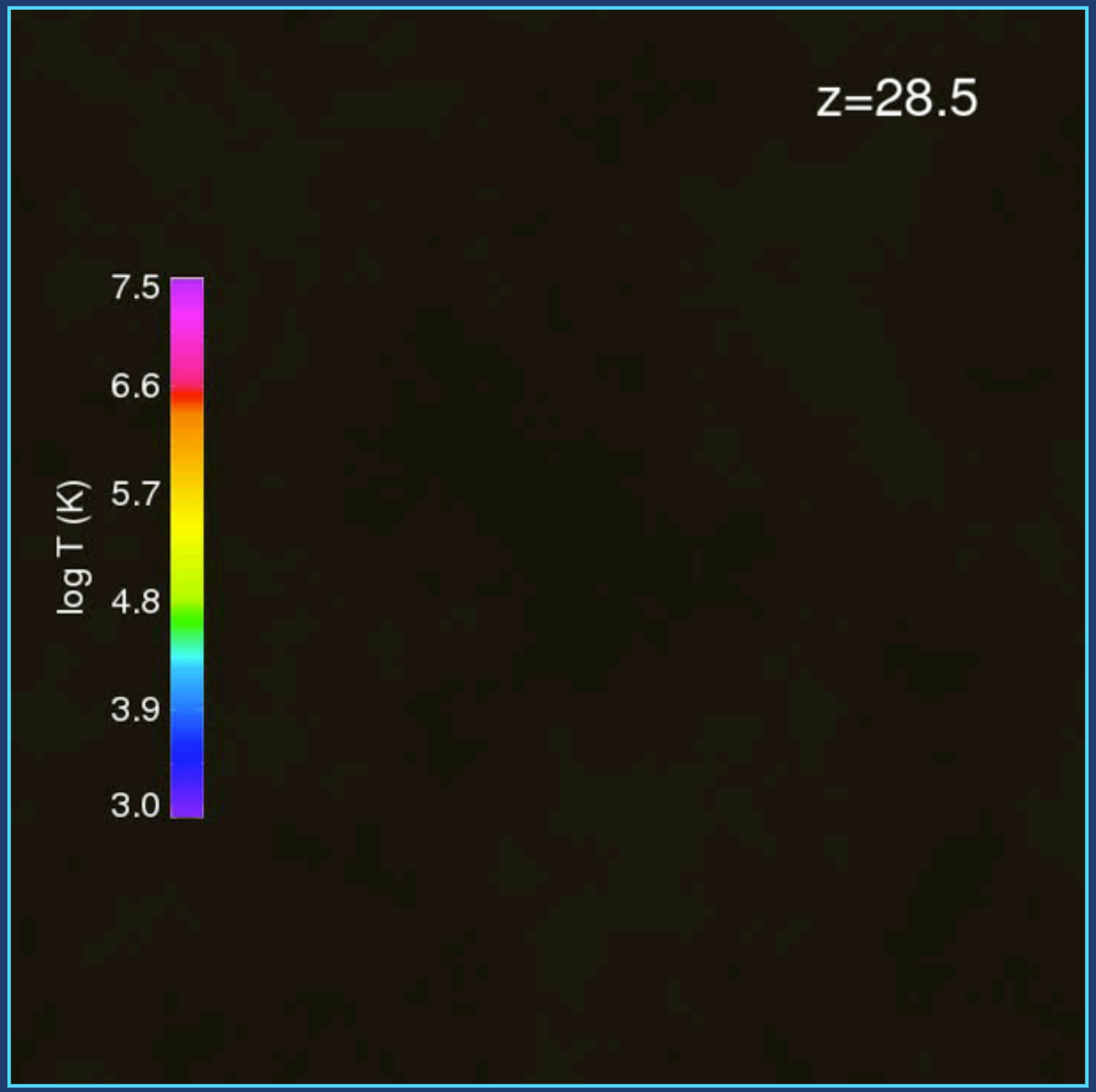
Dark energy
68 %

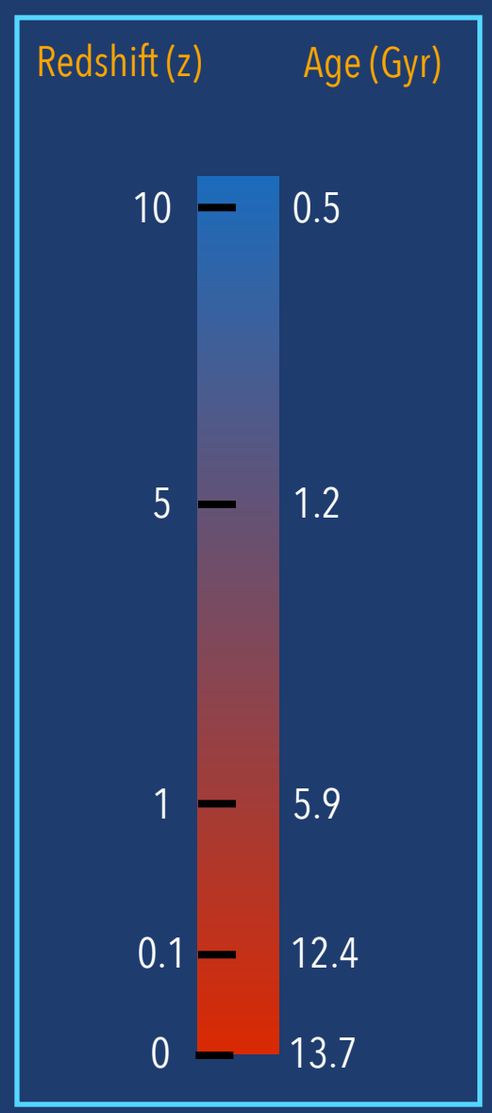


The Hot Universe: galaxy cluster gas

X-IFU
X-ray Integral Field Unit







Chemical enrichment of the Universe

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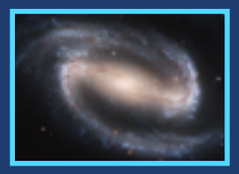
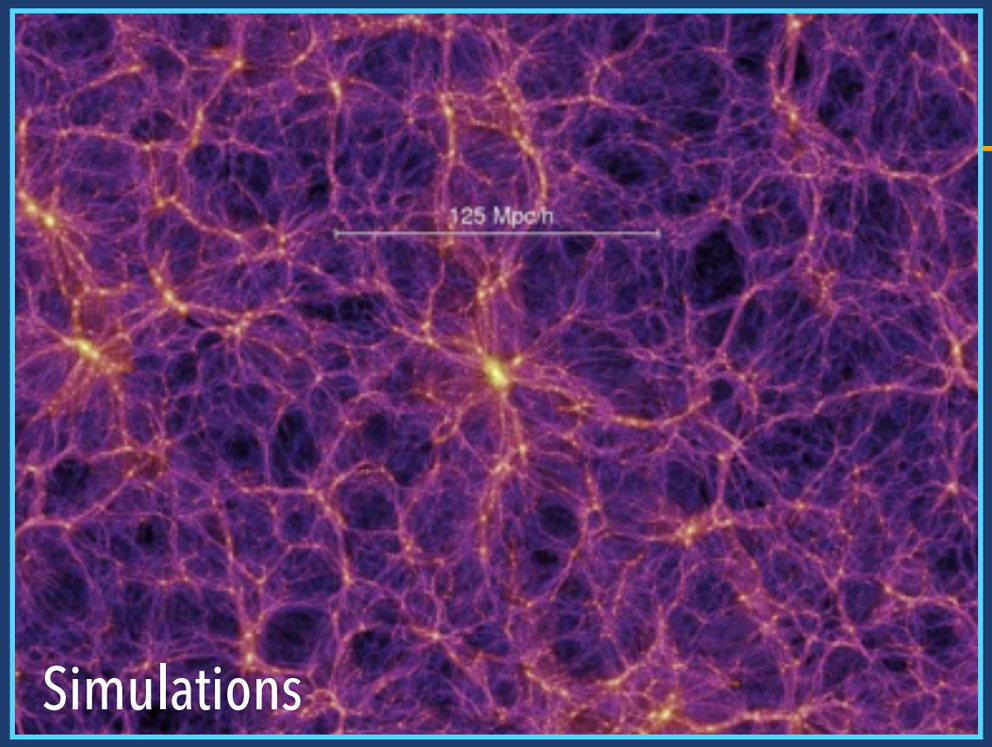
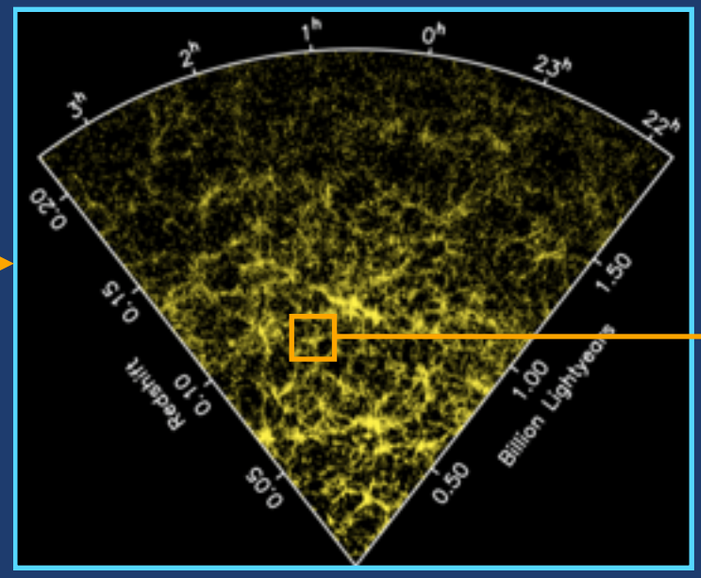
X-ray Integral Field Unit



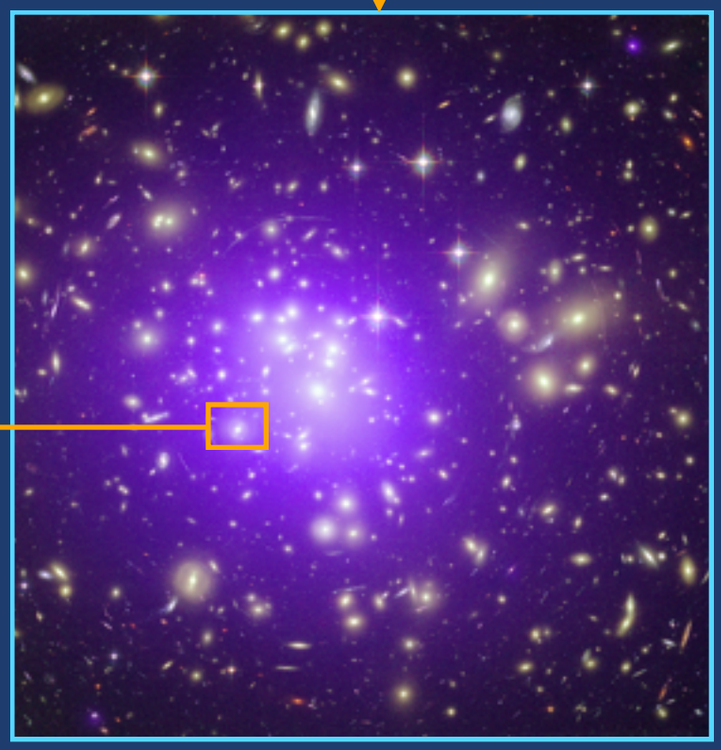
Milky way ~ 25 kpc
1 kpc~3 10^{16} km



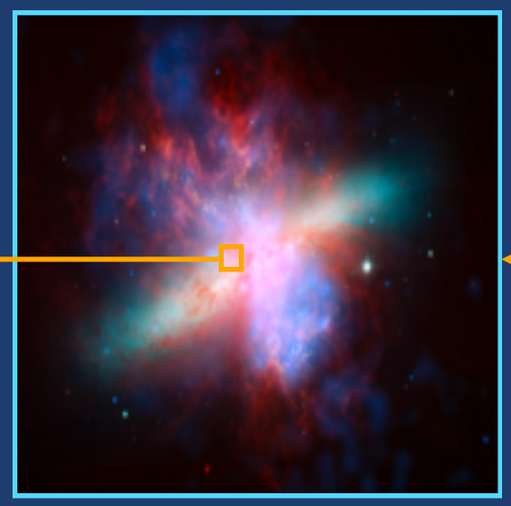
Large galaxy surveys



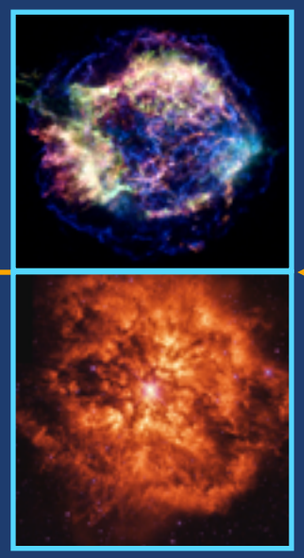
Clusters of galaxies



Starburst galaxy

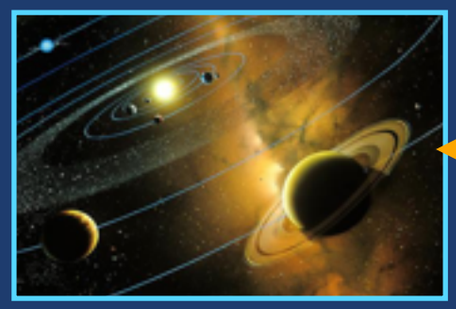


Supernova remnant



Winds from massive stars

Formation and
evolution of planets



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Energetic Universe: black holes

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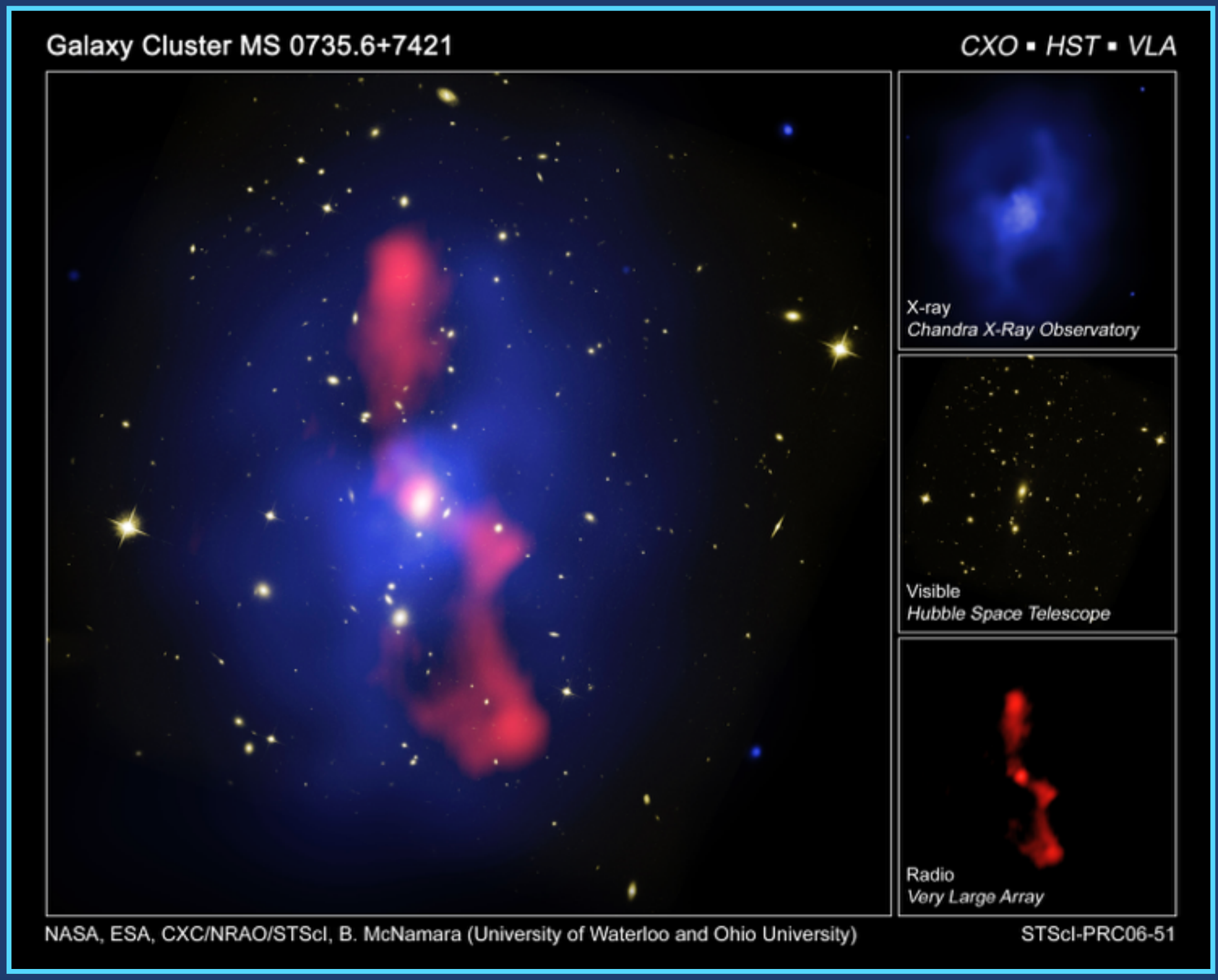
X-ray Integral Field Unit



Galaxy size ~ 10^{18} km

Cluster size ~ 10^{20} km

Black hole size ~ 10^{9} km
(1 billion of solar masses)

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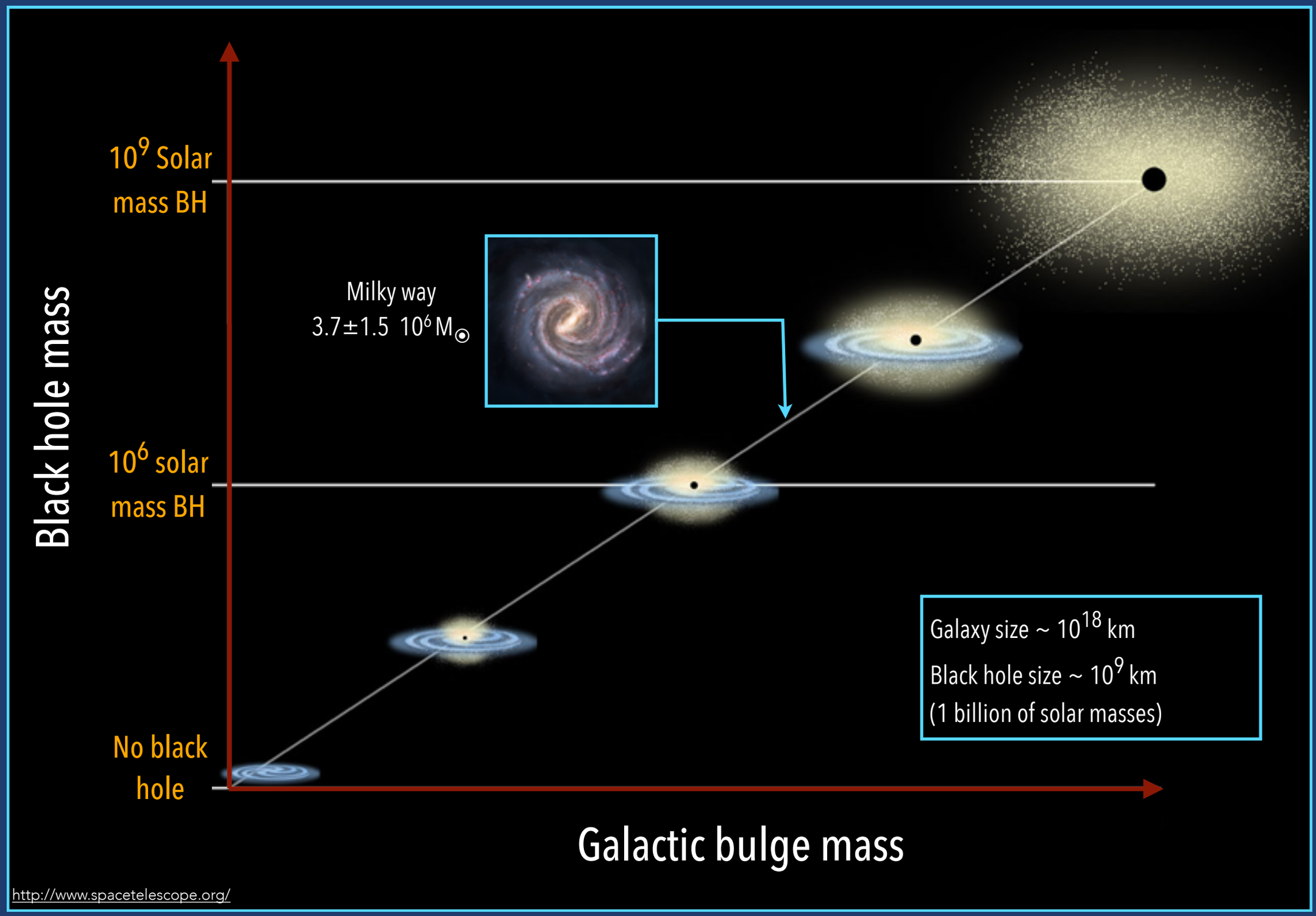
Galaxy-black hole regulation

X-IFU
X-ray Integral Field Unit



The Athena science case

X-IFU
X-ray Integral Field Unit

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Why looking in X-rays

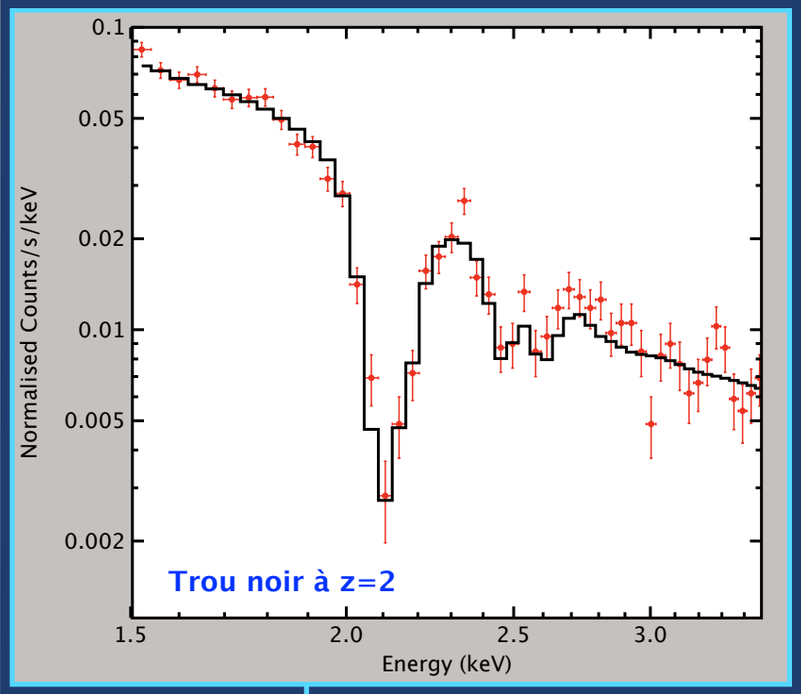
X-IFU
X-ray Integral Field Unit

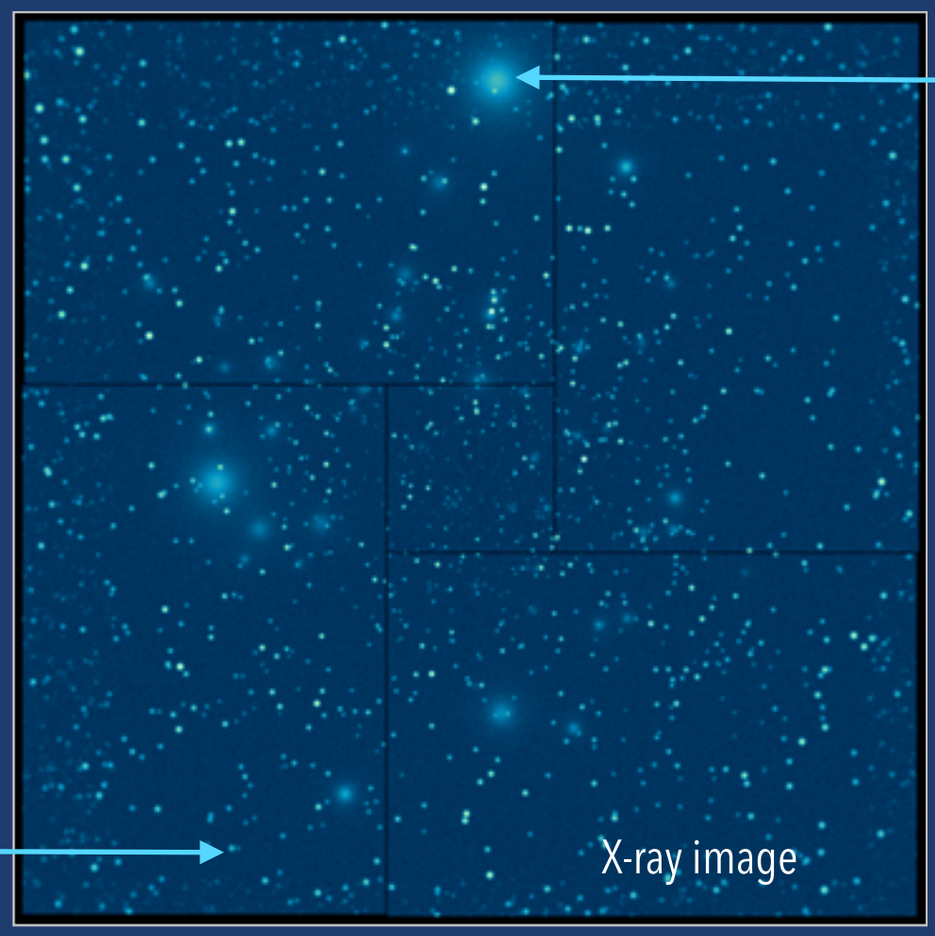
50% of the baryons in the Universe are trapped in hot gas radiating predominantly in X-rays

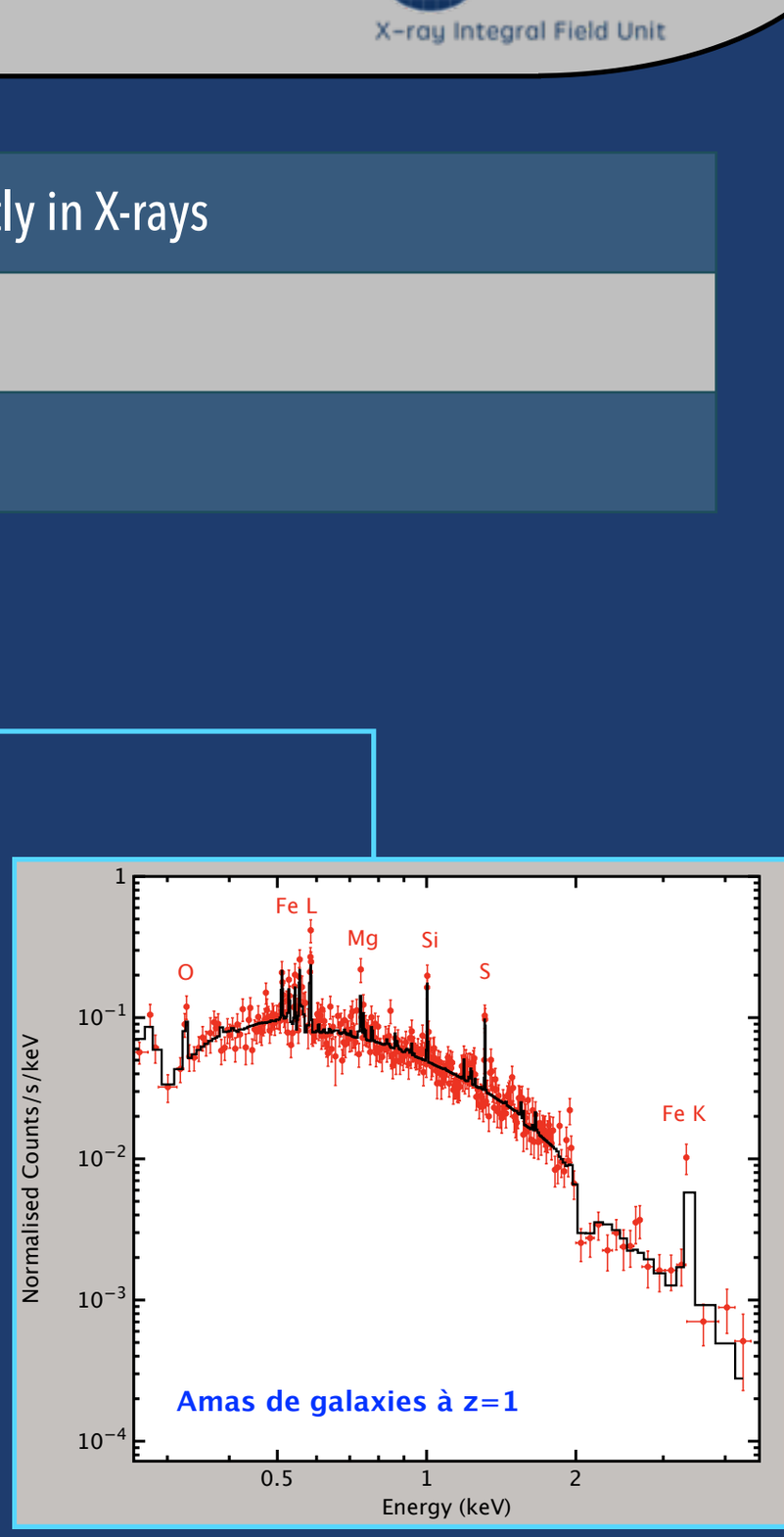
Metals have characteristic emission/absorption lines in X-rays

Accretion powered black holes radiate 90% of their energy in X-rays

Absorption in quasar winds







Excited atom emission in hot cluster gas

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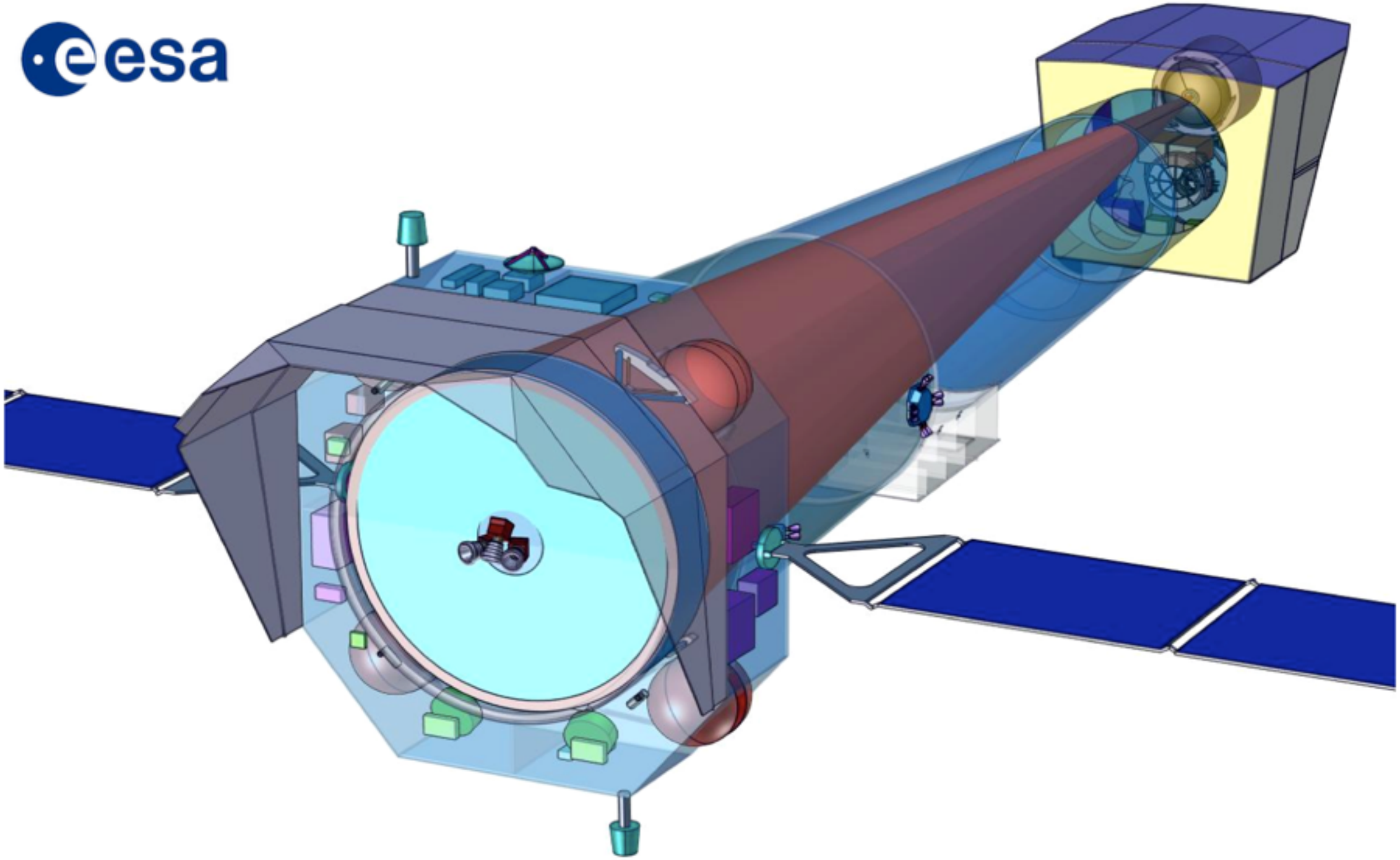
The Athena X-ray Observatory

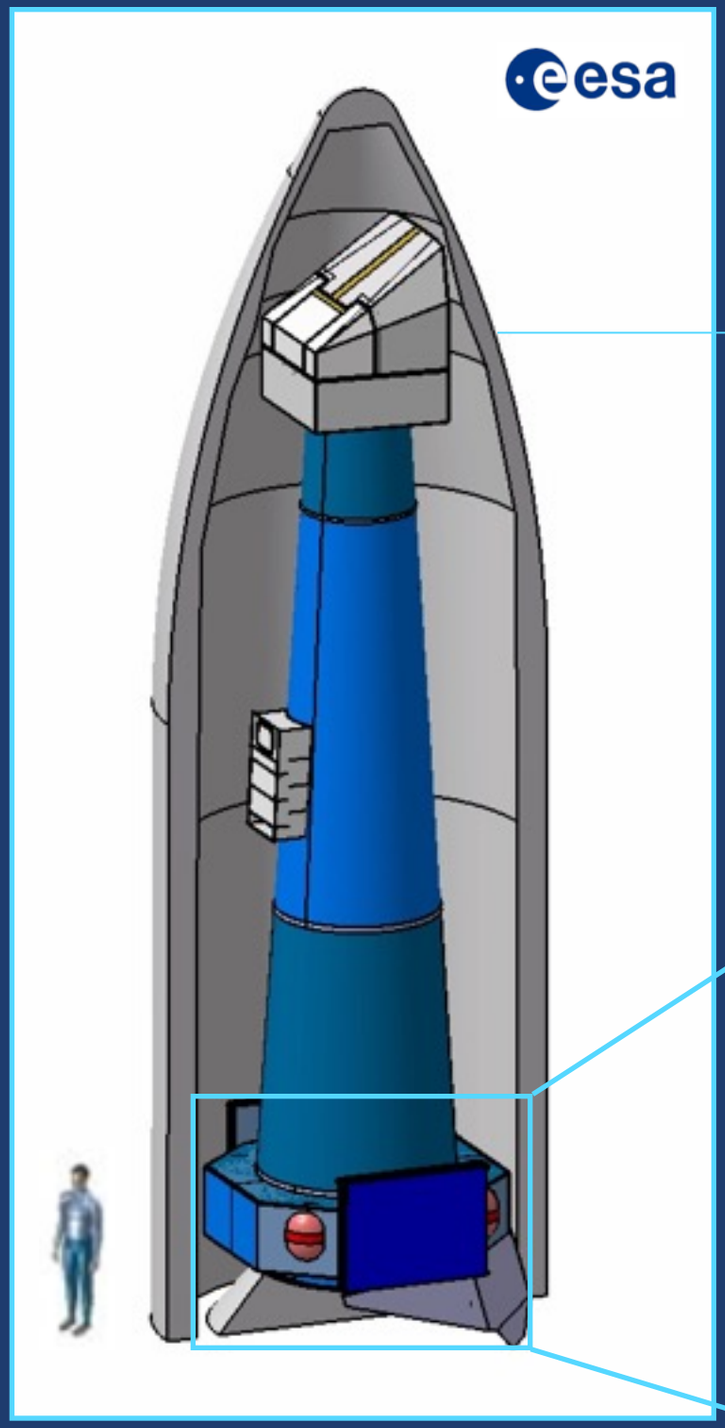
X-IFU
X-ray Integral Field Unit

esa

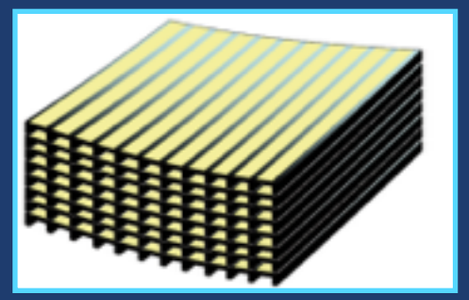


Athena – An X-ray telescope

X-IFU
X-ray Integral Field Unit

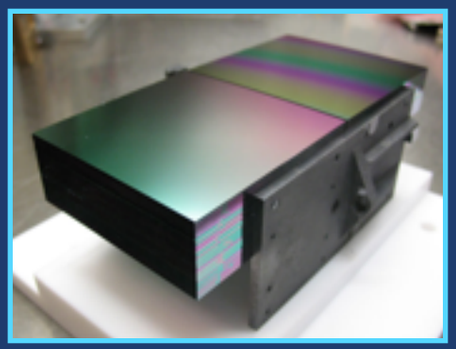


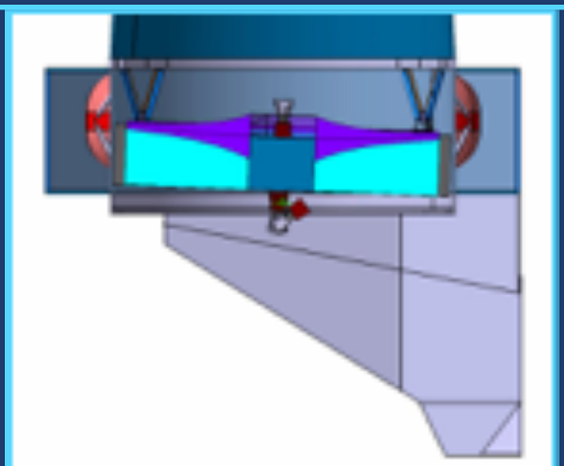
Launcher Ariane 5 ECA (Ariane 6)
Mass: 6.1 tons
Power: 4.5 kW
Focal length: 12 mètres
Lifetime: 5 years (+ 5 years)
Orbit L2 (without eclipse)
Launch date: 2028



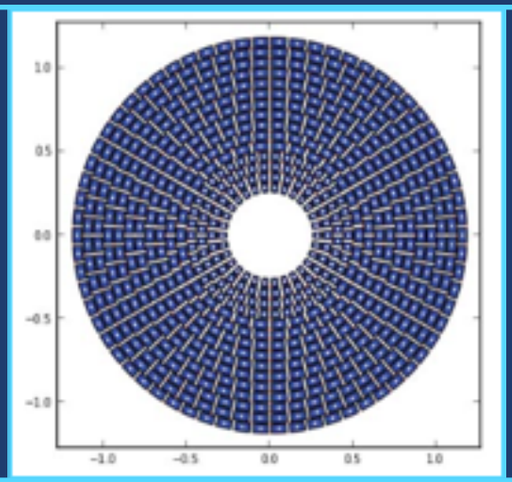
Double reflexion in silicon pore

1 mirror module





X-ray optics: Silicon pore
Double reflexion
Angular resolution: 5″
Field of view: 40′ x 40′
Mirror diameter: 3 meters
Effective area: 2 m^2 at 1 keV
Movable mirror assembly
ESA technology development



Athena – science payload

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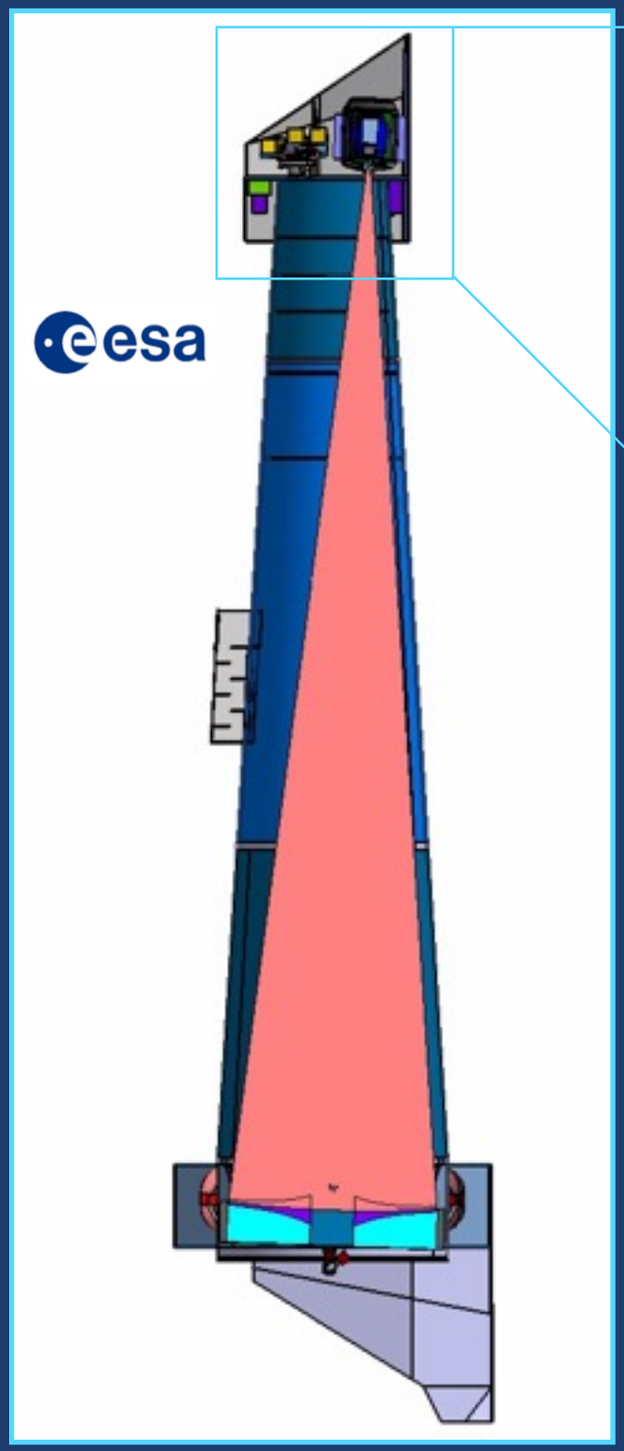
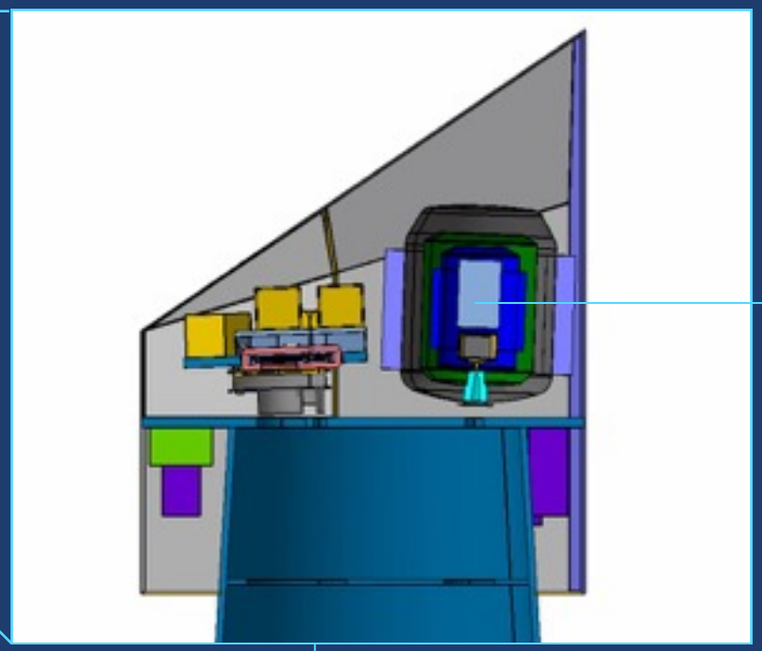
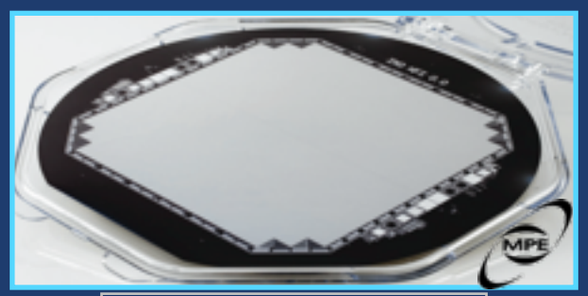
X-ray Integral Field Unit



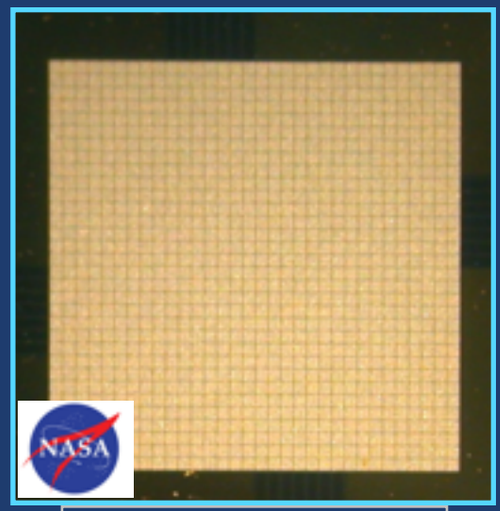


X-ray Integral Field Unit
Transition Edge Sensor (TES)
Field of view: 5′
Pixel: 5″
Spectral resolution: 2.5 eV
Actif cooling at 50 mK
International consortium

Wide Field Imager
Active Pixel Sensor
Field of view 40′ x 40′
Pixel: 1″
Spectral resolution: 125 eV
Passive cooling



Large format APS



Large format TES array

X-IFU - Representative design

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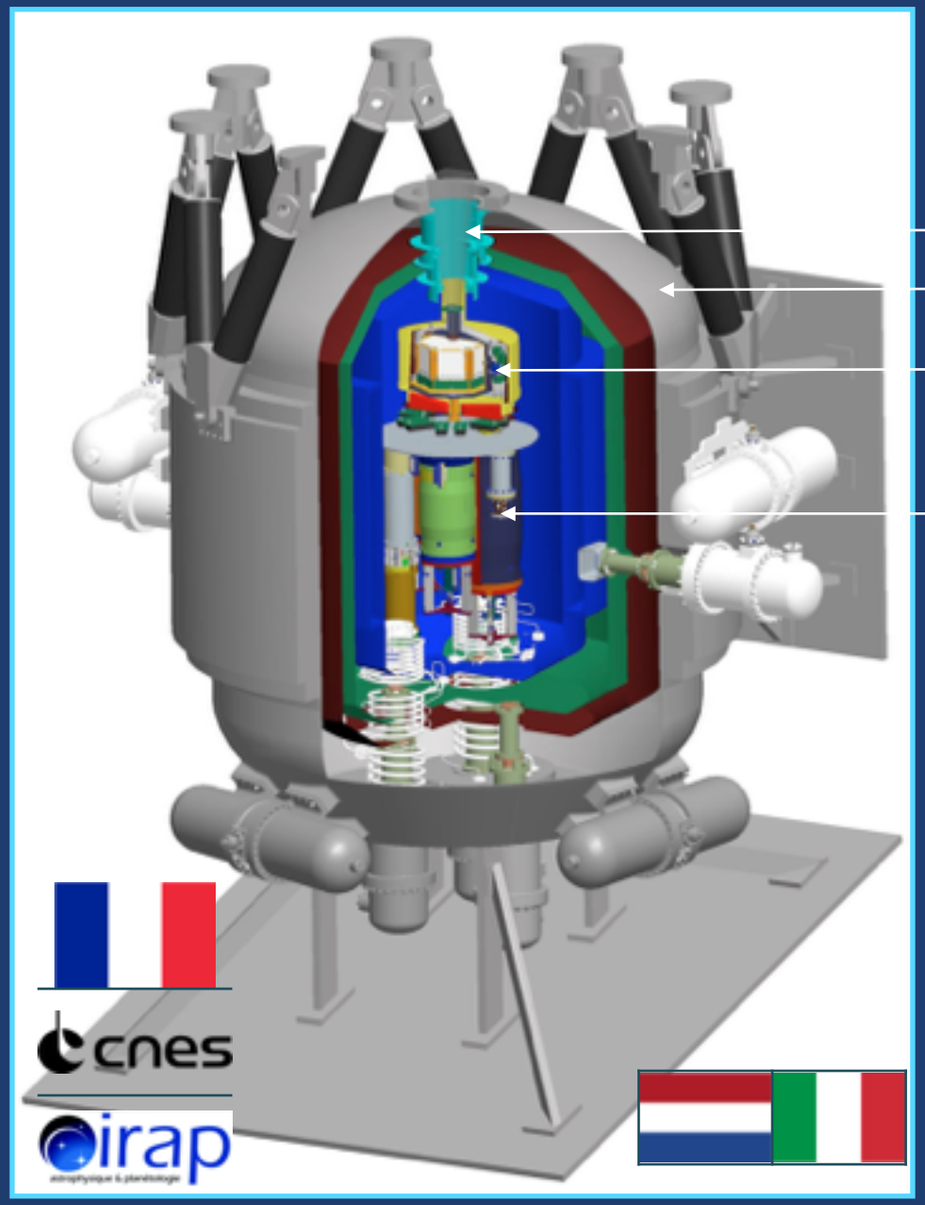
X-ray Integral Field Unit

« One of the most challenging instrument ever built for a space astrophysics mission» - CNES Astronomy Working Group, 2014

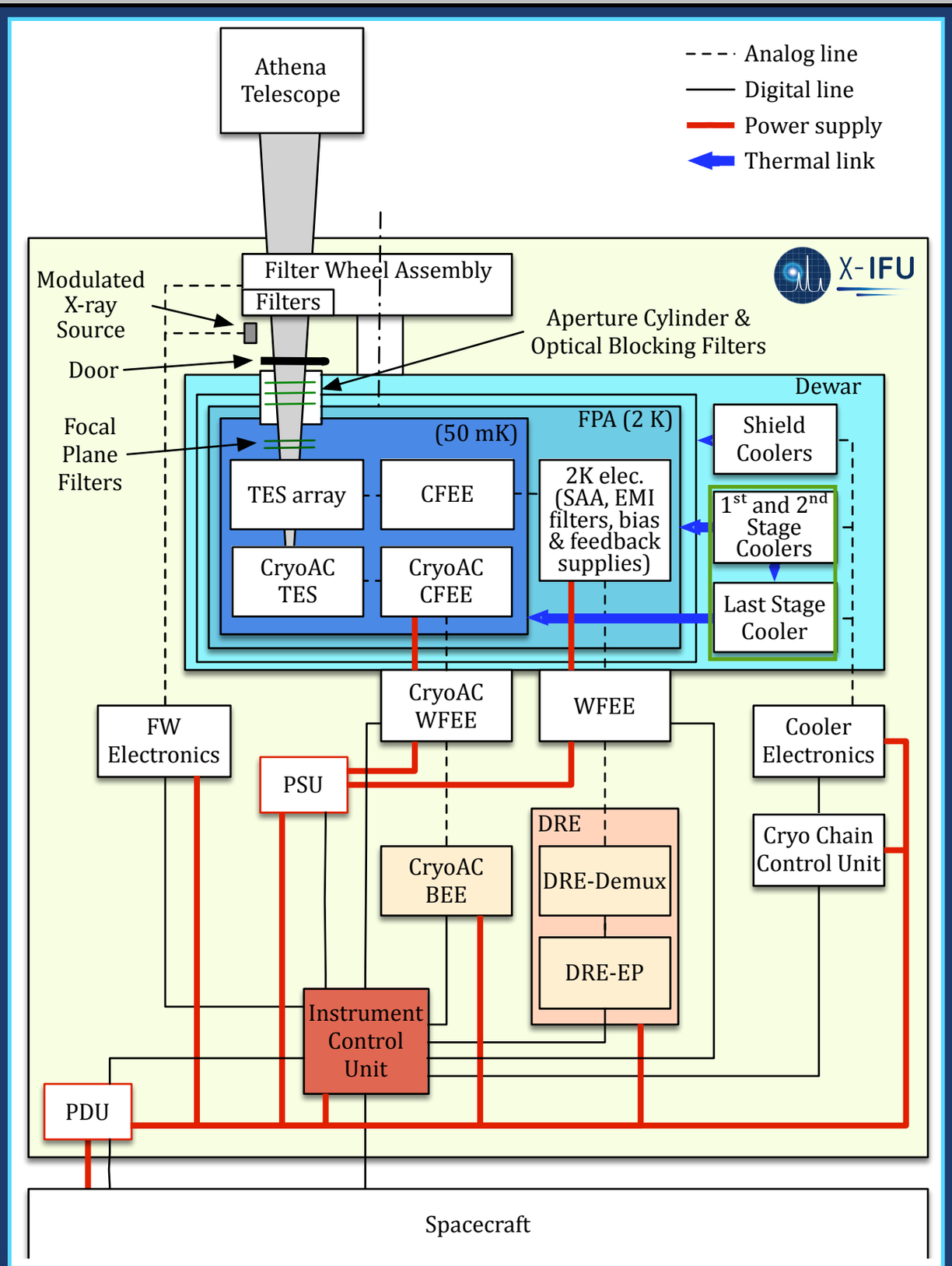


Design from a previous NASA/ESA/JAXA study

Focal plane assembly mass	6 kg
Sensor array dimension	1.7 x 1.7 cm
Mass & power of cryogenic chain	320 kg/580 W
Mass & power of electronics	180 kg/300 W
Mass & power (with margins)	~800 kg/1700 W

Numbers to be consolidated

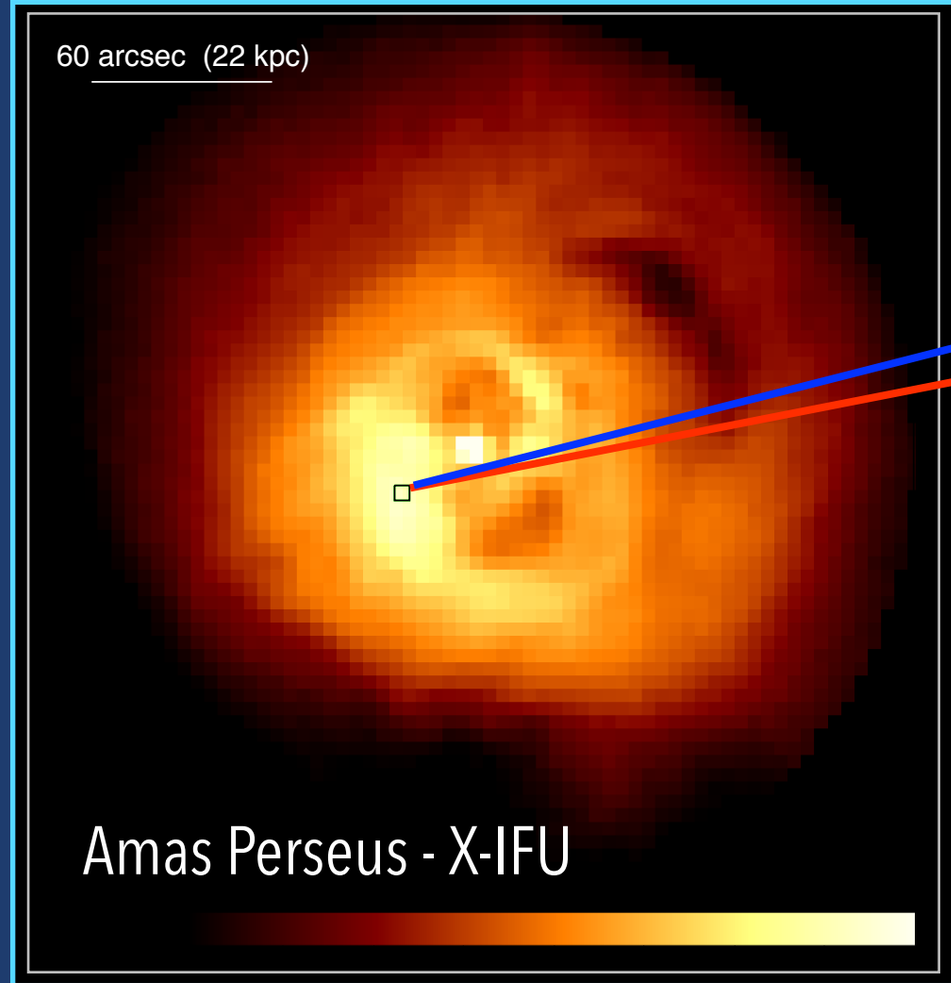
X-IFU functional diagram

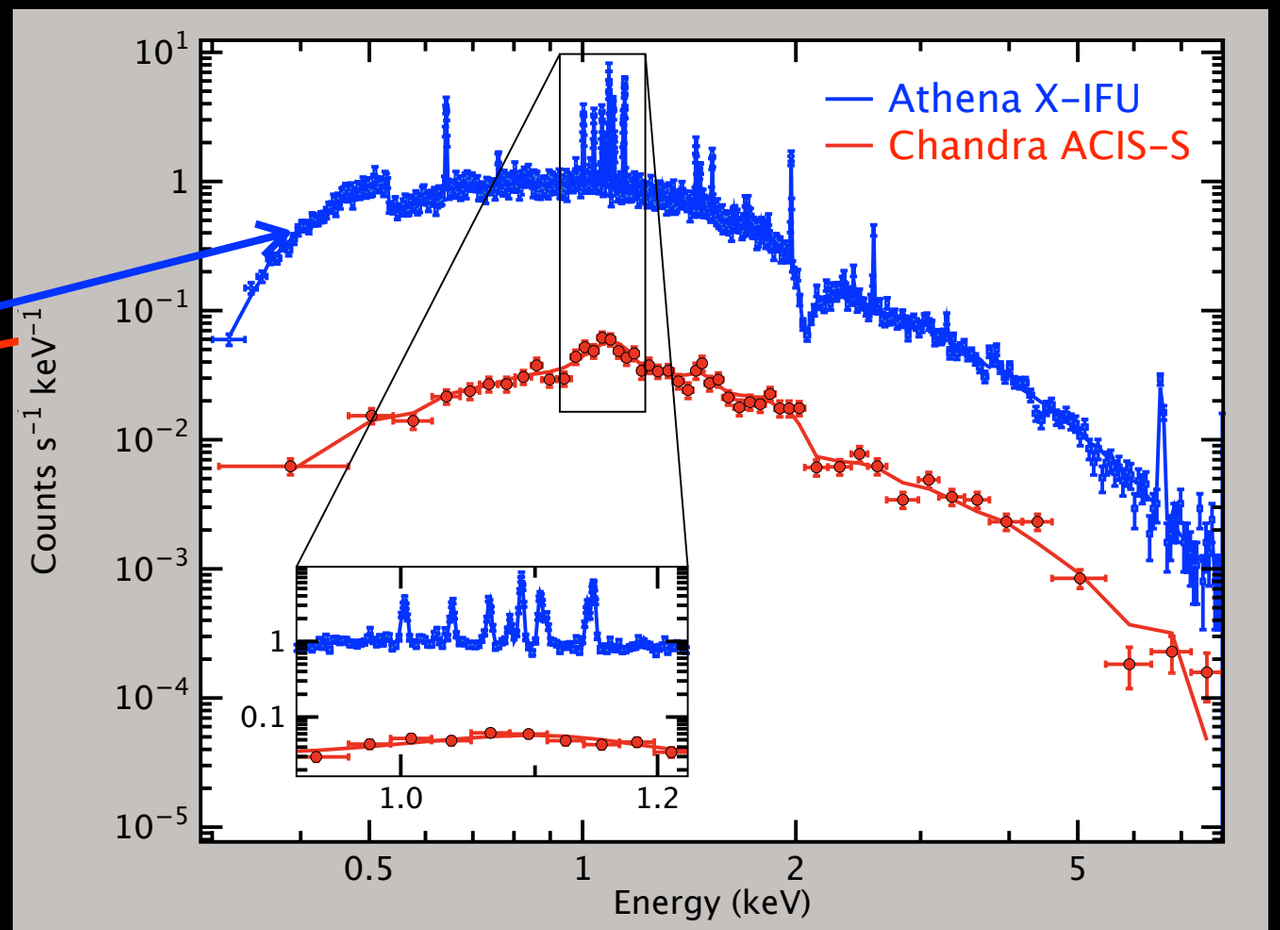


- Filter wheel & calibration source
- Aperture with thermal/optical blocking filters
- Multi-stage mechanical coolers:
  - Shield coolers (from 300 K to 4 K) : combination of ST and JT coolers provided by Japan
  - 1st and second stage coolers (down to 2 K) : combination of 15 K PT (ALAT) and 2 K JT (RAL)
  - Last stage cooler : Sorption-ADR (CEA-SBT)
    - Dilution (CDDR) considered as an alternative (Néel/ALAT)
  - Redundant architecture
- Large array of Au-Bi absorbers and Mo-Au TES with a cryogenic active anti-coincidence TES based
- LC filters + 2 stage SQUID readout + LNAs
- Frequency Domain Multiplexing (96 channels of 40 pixels)
- Digital pulse shape analysis in the event processor to recover energy, time, grade

A revolutionary instrument

First high resolution X–ray spectrometer on arcsecond scale over a field of view of 5′





Give access to the gas dynamics, metal abundance, ionization state, black hole energy dissipation mechanism…

X-IFU consortium

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X-ray Integral Field Unit

X-IFU consortium meeting #2, Roma

Athena flying in 2028

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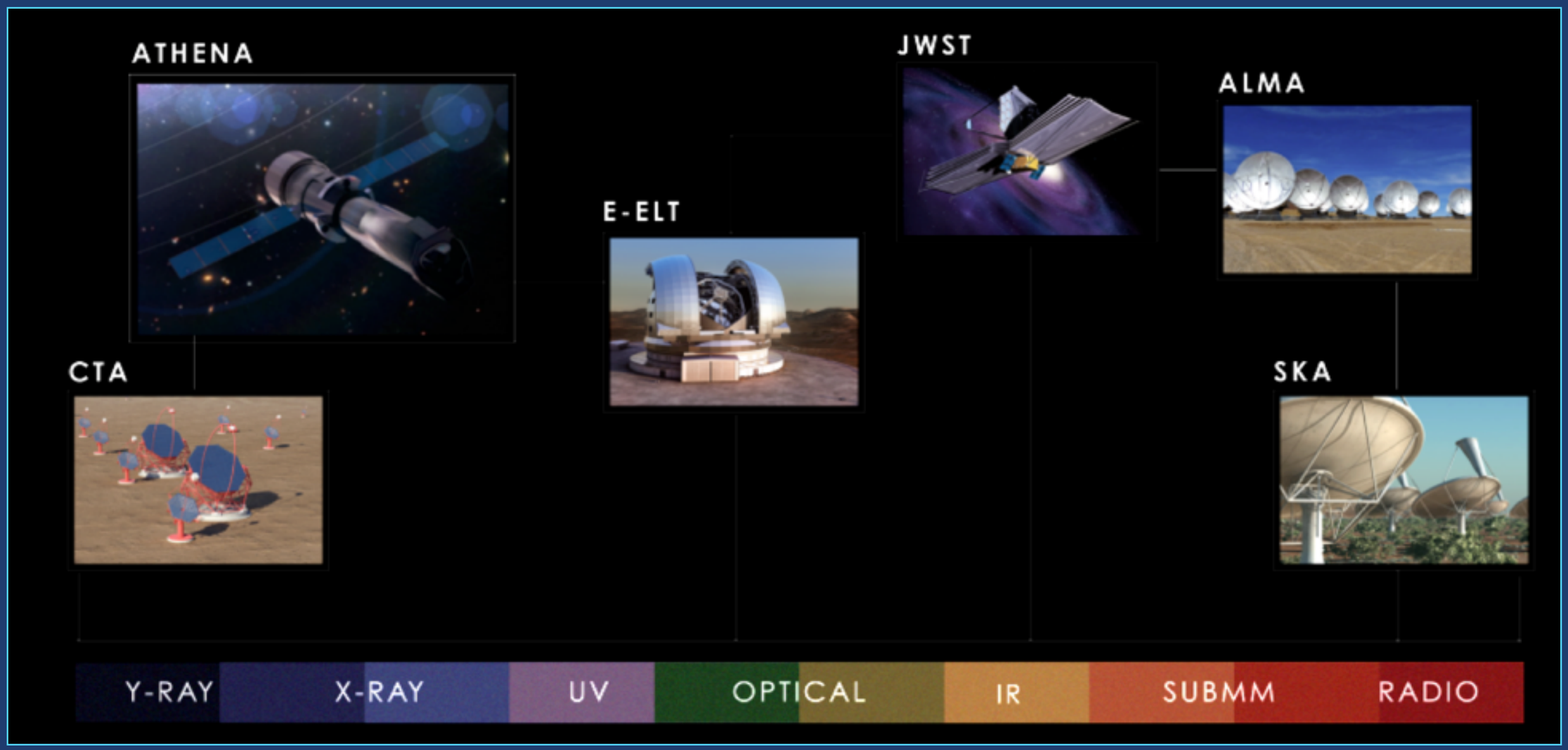
- All astrophysical phenomena require a panchromatic view to be fully understood. Various wavelengths provide complementary information to capture the fundamental physical processes at work.



Conclusions

- By observing the Hot and Energetic Universe, we wish to understand
  - How matter assembled under the gravitational influence of dark matter and how the Universe progressively formed metals
  - How black holes work, grow, interact with their surrounding and regulate the formation and evolution of galaxies
    - The X–ray window, uniquely accessible from space, provide direct and unique information on the most extreme phenomena that can be observed in the Universe

- The Athena X–ray observatory and its X–ray Integral Field Unit will revolutionize our view of the Universe
  - Developed under CNES management, the X–IFU is a technological challenge requiring the development of a cryogen free cooling chain down to 50 mK (the X-IFU will be the coldest spot in distant space)
  - French labs (CEA/SBT, Néel) and French industry (ALAT) will provide key components of the cooling chain, together with their expertise in defining the architecture, in assembling and testing such a cooling chain