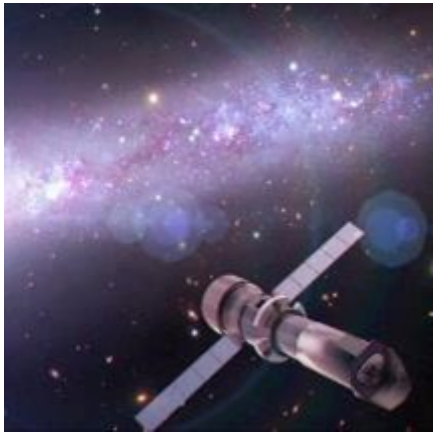
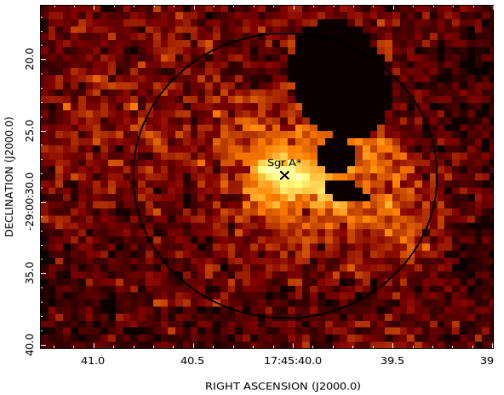
ATHENA

New generation X-ray telescope



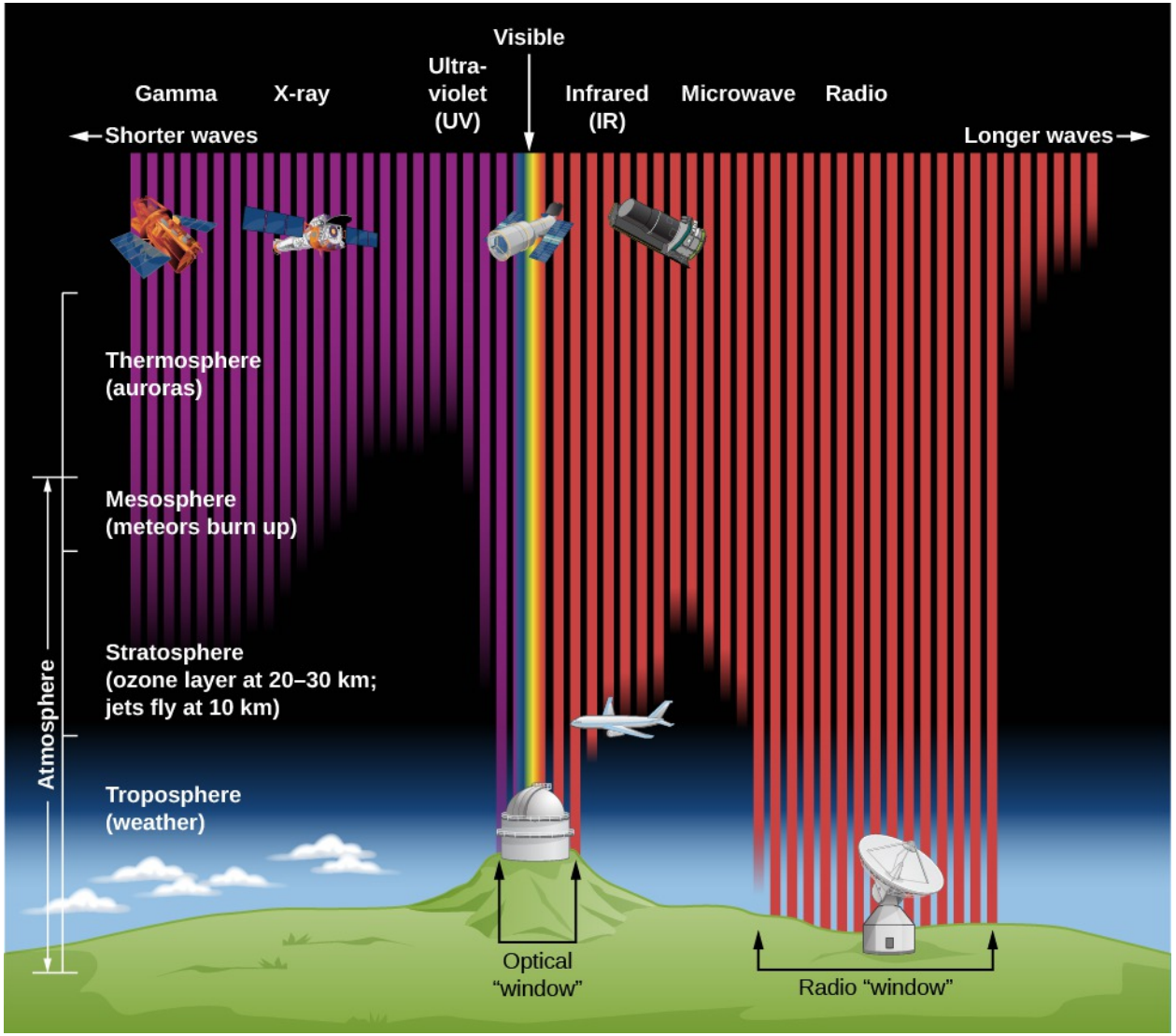


Agata Różańska

CAMK PAN, Warsaw

21.09.2017, Kraków, Astrofizyka Cząstek

Atmosphere is not transparent to X-rays



ATHENA – L2 mission of ESA Cosmic Vision (2015-2035)

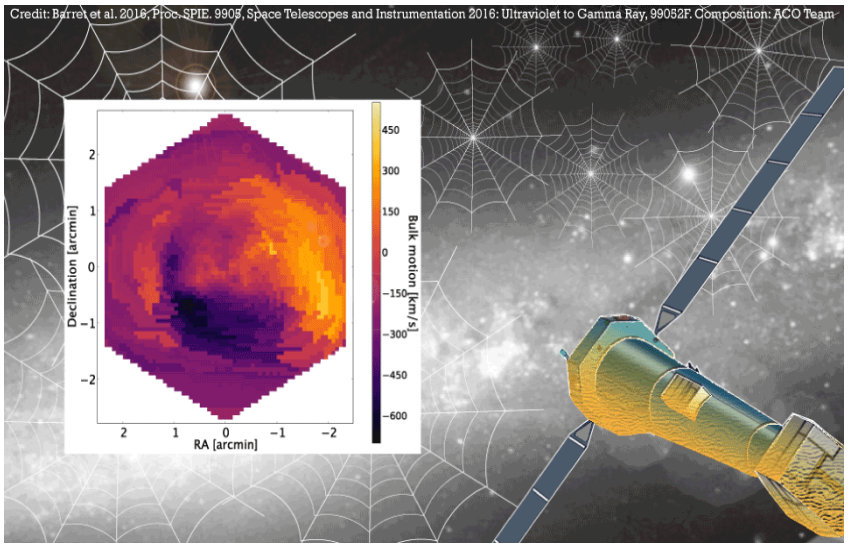
X-RAY SPECS

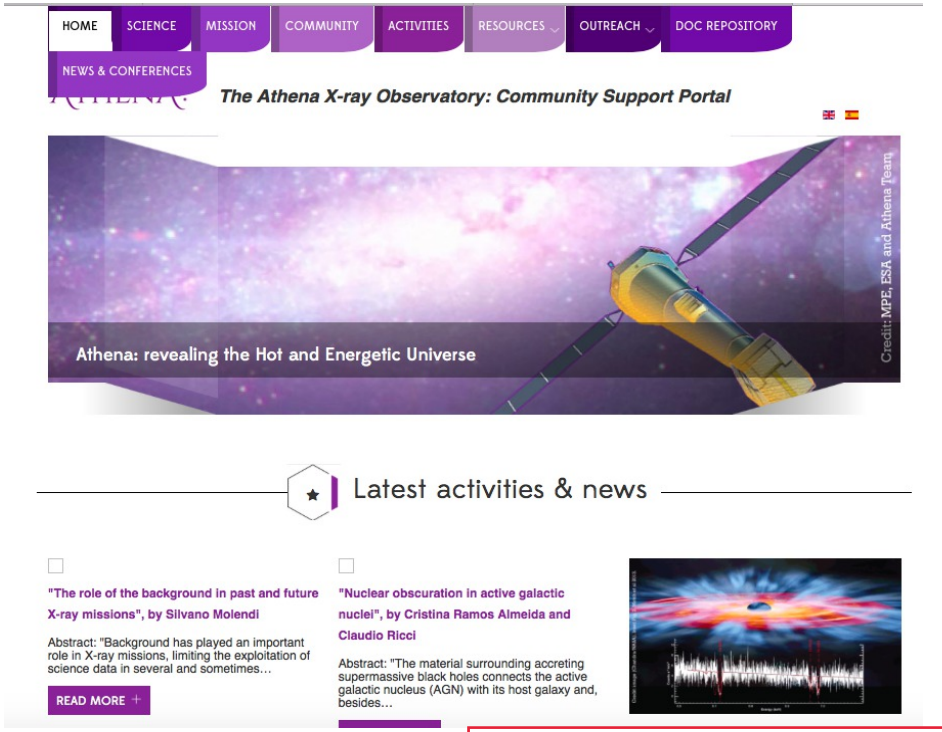
The European Space Agency is very close to finalizing the following line-up of large (L-class) missions.

Mission	Name	Launch date	Study targets
L1	JUICE	2022	The magnetic field of Jupiter's moon Ganymede
L2	Athena+	2028	Black holes and galaxy clusters.
L3	eLISA	2034	Gravitational ripples from black-hole mergers.

800+ scientist in ATHENA community

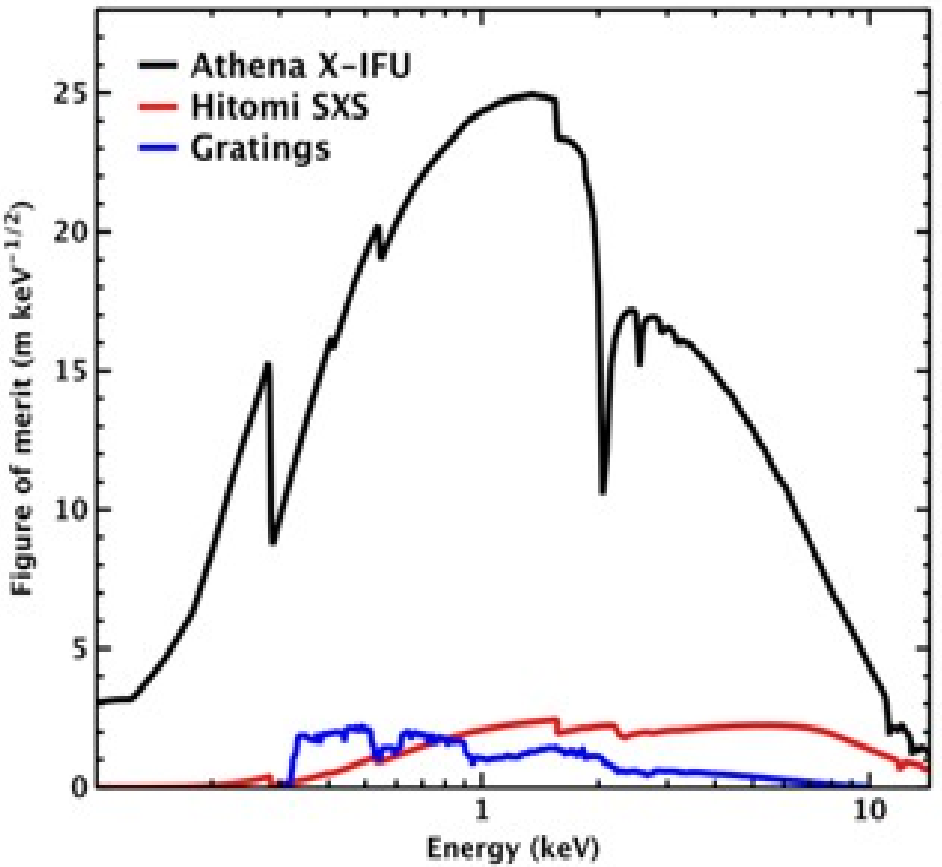
More info at: http://www.the-athena-x-ray-observatory.eu



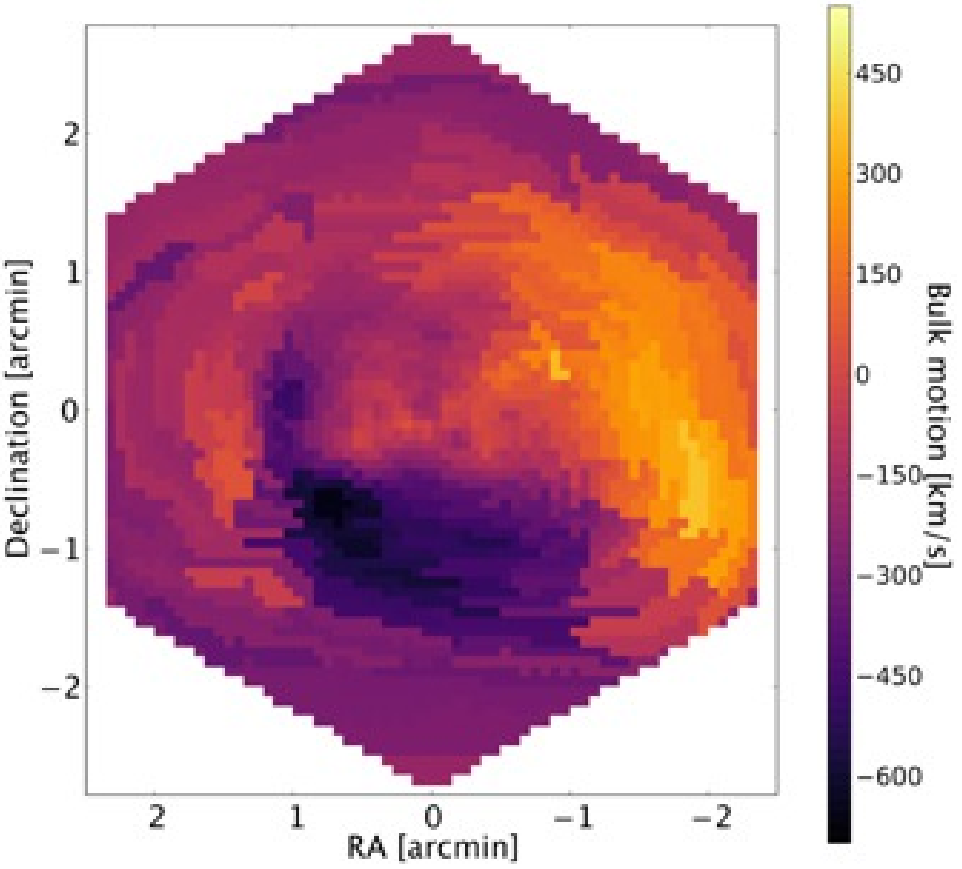


A revolutionary mix of science performance

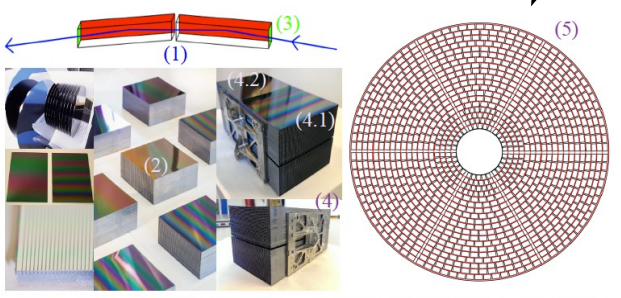
Effective area per energy resolution element



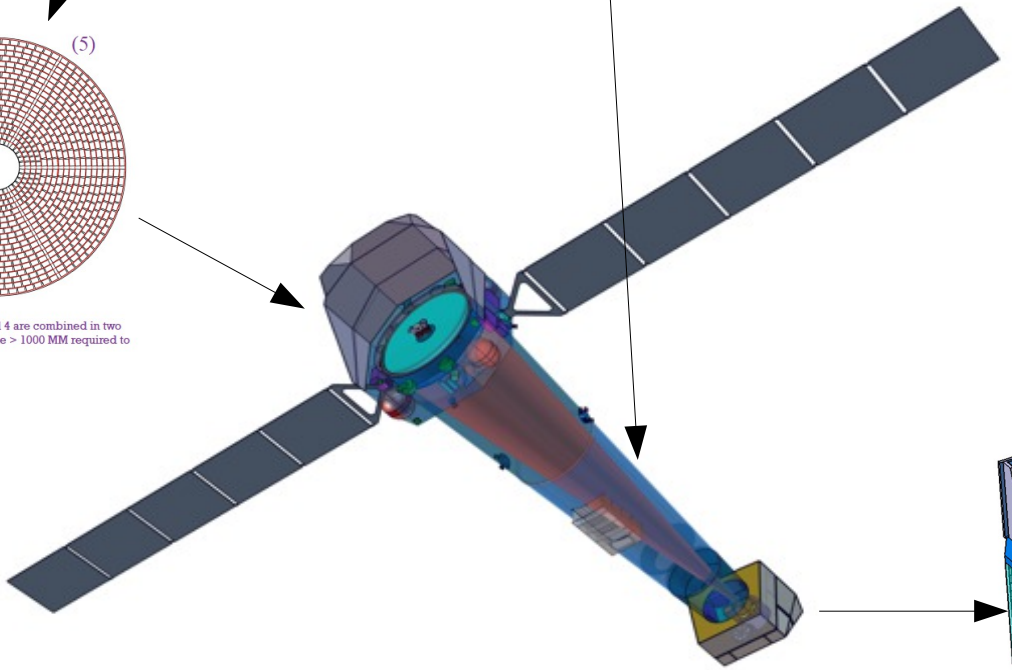
Simulated velocity map at a 5" pixel resolution



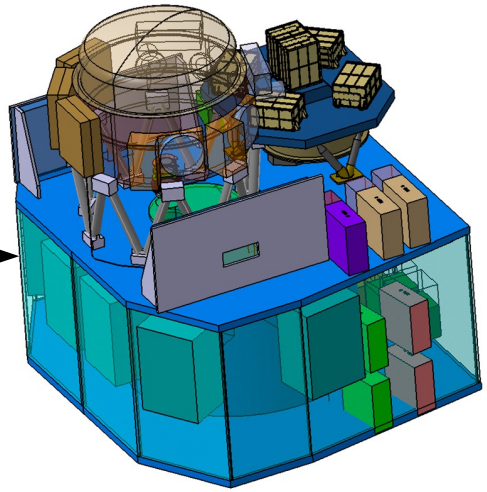
ATHENA is a single telescope with 12 m focal length



Left: the production of a Mirror Module: ribbed wafers are stacked in an SPO module and 4 are combined in two pairs to form a Mirror Module. Right: front view of the Mirror Assembly Module showing the > 1000 MM required to reach the 2m² effective area at 1 keV.
Credit: R. Willingale and ACO Team



Focal plane

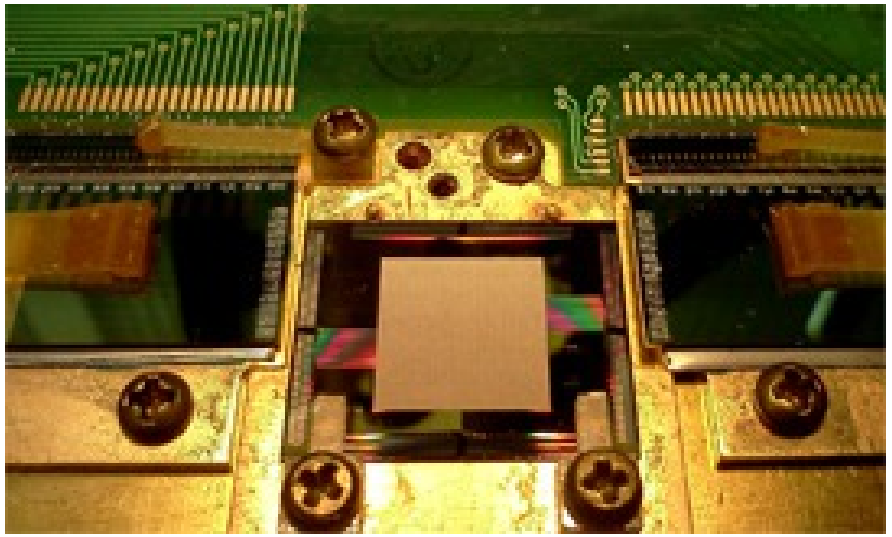


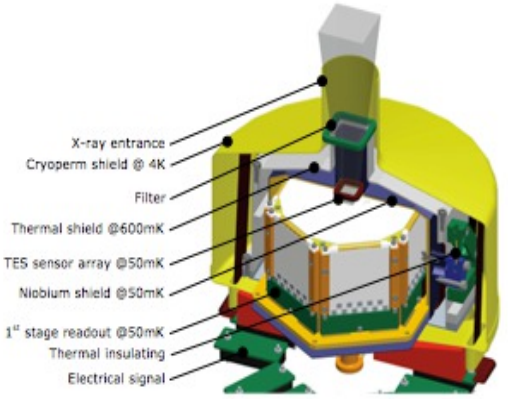
Two X-ray detectors in the focal plane:

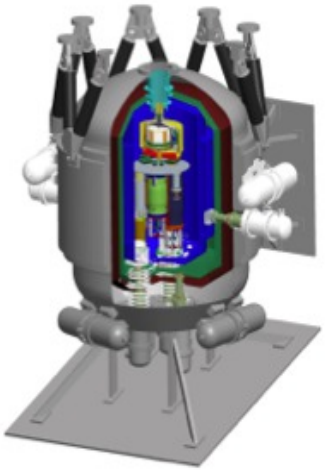
1. X-IFU – X-ray Integral Field Unit 0.3-12. keV
2. WFI – Wide Field Monitor 0.1-15. keV

X-IFU, 0.3 – 12.0 keV

- X-ray Micro-calorimeter Spectrometer (XMS)
- The detector consists of an array of 3840 absorbers (TES)
- Limited FoV – 5' x 5' (goal is 7' x 7')
- Count rate capability – 1 mCrab point source with 90%
- Energy resolution: 2.5 eV at 1 keV. Cryogen free cooling techniques: 50 mK







JAXA three times have tried to use micro-calorimeter

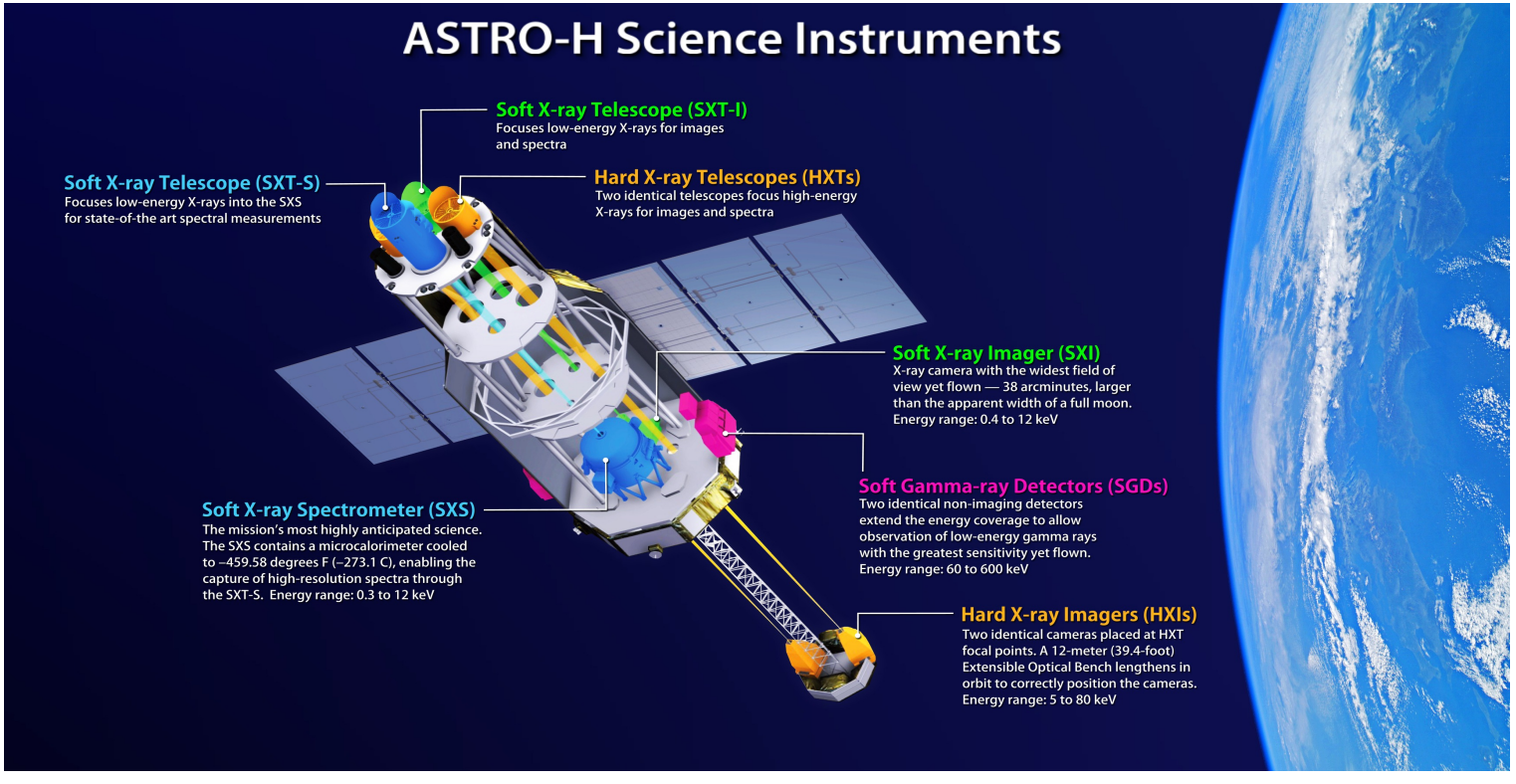
- 2000 – ASTRO-E has been lost in the ocean during launch

JAXA three times have tried to use micro-calorimeter

- 2000 – ASTRO-E has been lost in the ocean during launch
- 2005 – SUZAKU (ASTRO-EII) has lost all liquid helium, and micro-calorimeter does not work

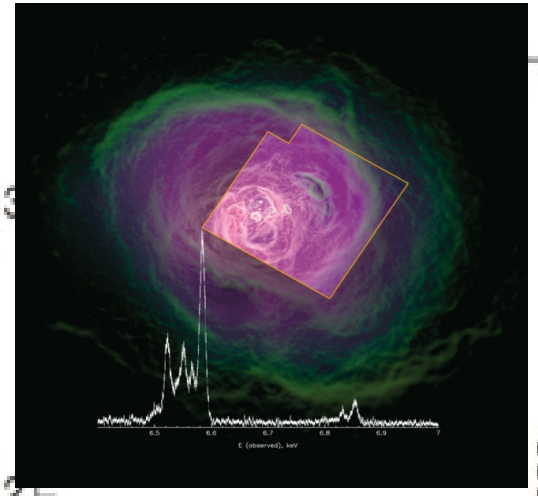
JAXA three times have tried to use micro-calorimeter

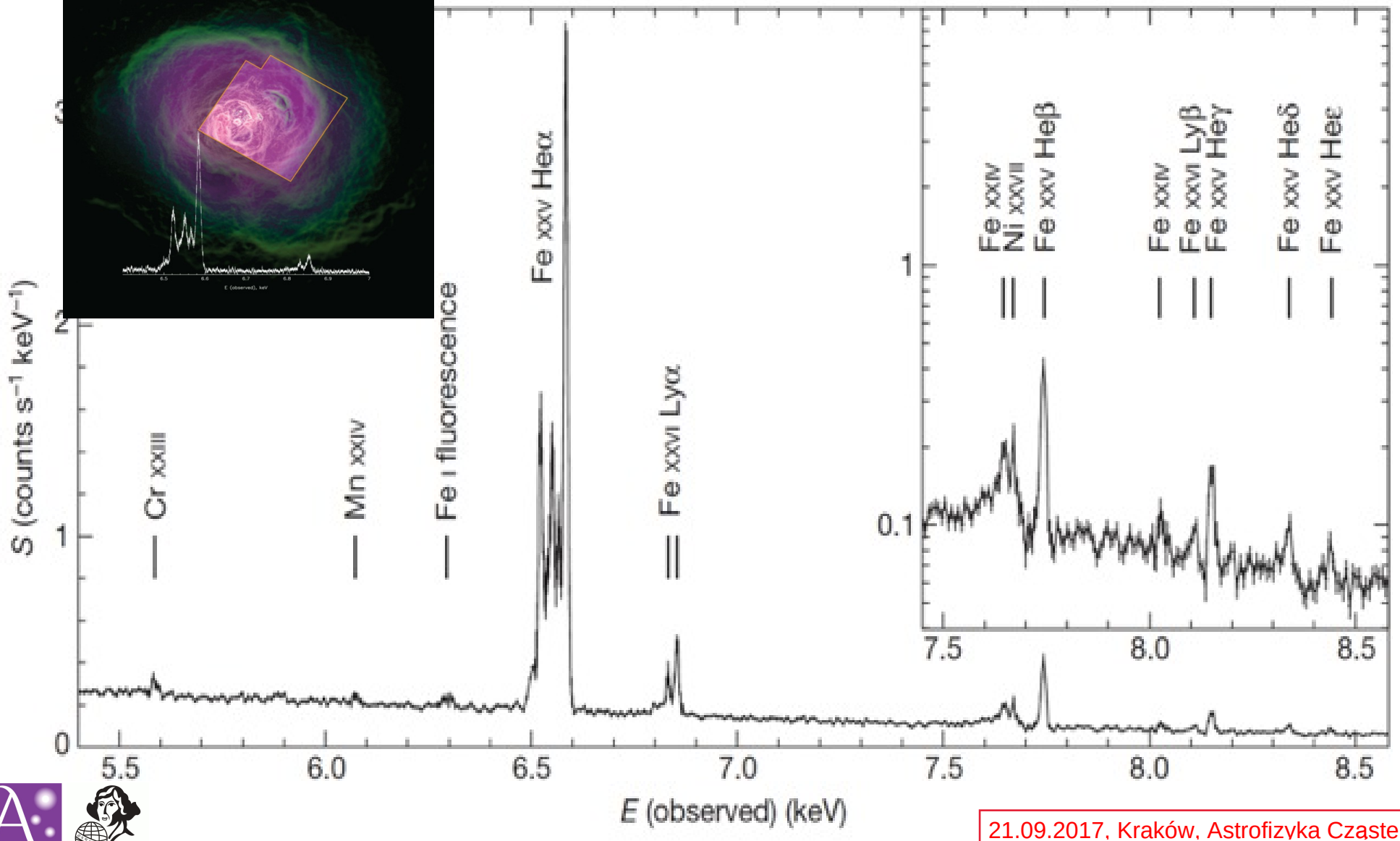
- 2000 – ASTRO-E has been lost in the ocean during launch
- 2005 – SUZAKU (ASTRO-EII) has lost all liquid helium, and micro-calorimeter does not work
- 2016 – ASTRO-H, launched on Feb. 2016, renamed as HITOMI, lost on March 2016 due to the software mistake



The best X-ray spectrum ever seen by human eye

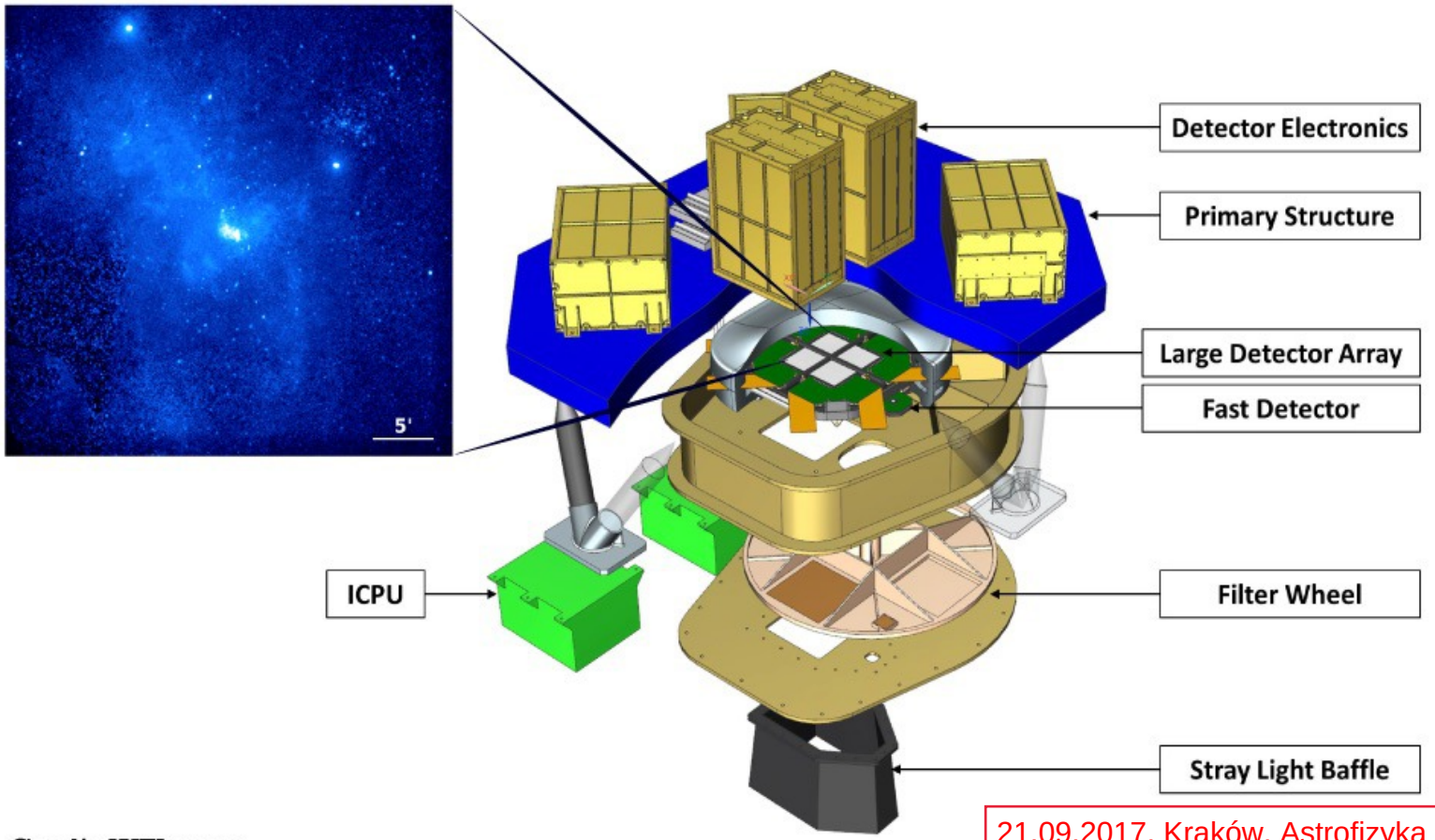
- The core of the Perseus Cluster with HITOMI/SXS – **Nature 2016**





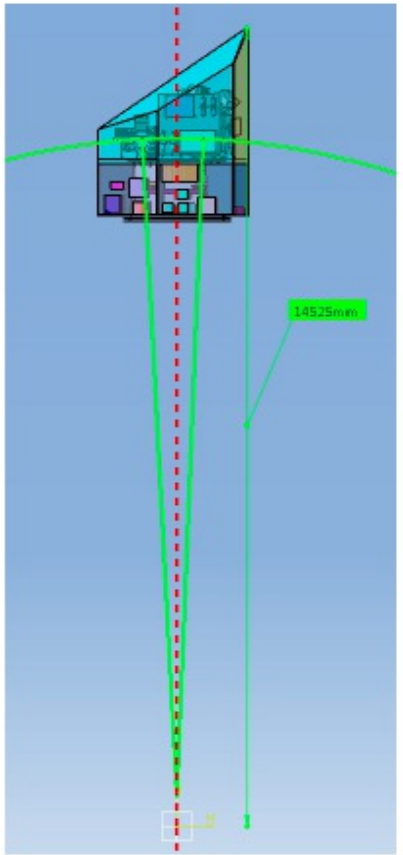
WFI (wide field imager) 0.1-15.0 keV

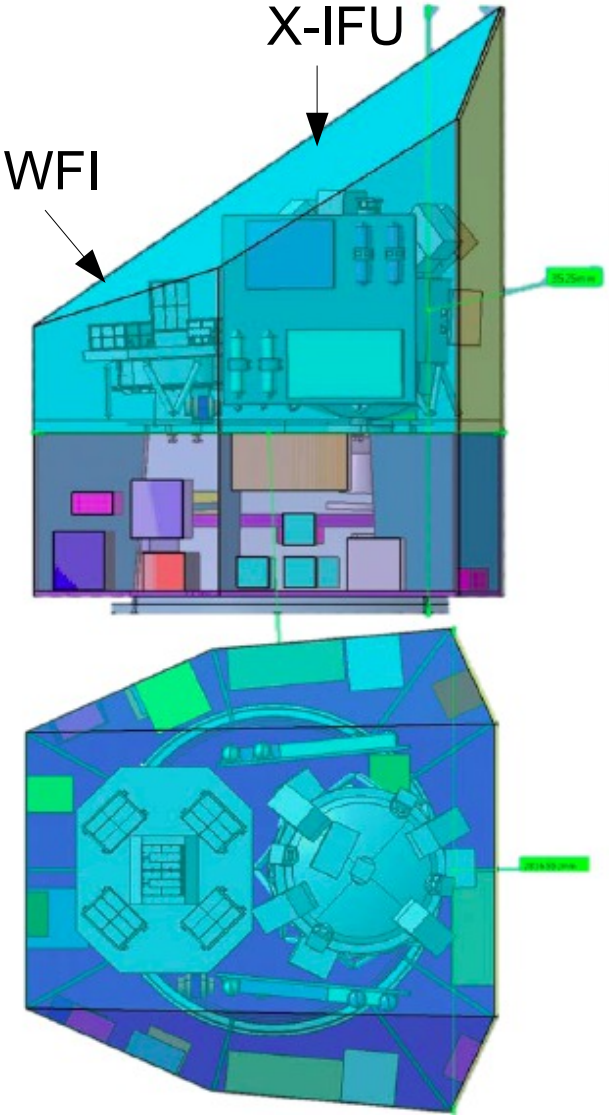
- FoV 40' x 40', Energy resolution 150 at 6 keV
- Readout time of 8 μs and a count rate capability of > 1 Crab with 80% throughput

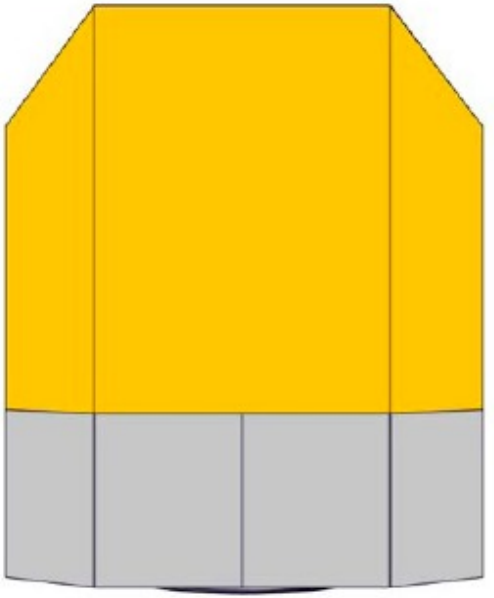


Credit: WFI team

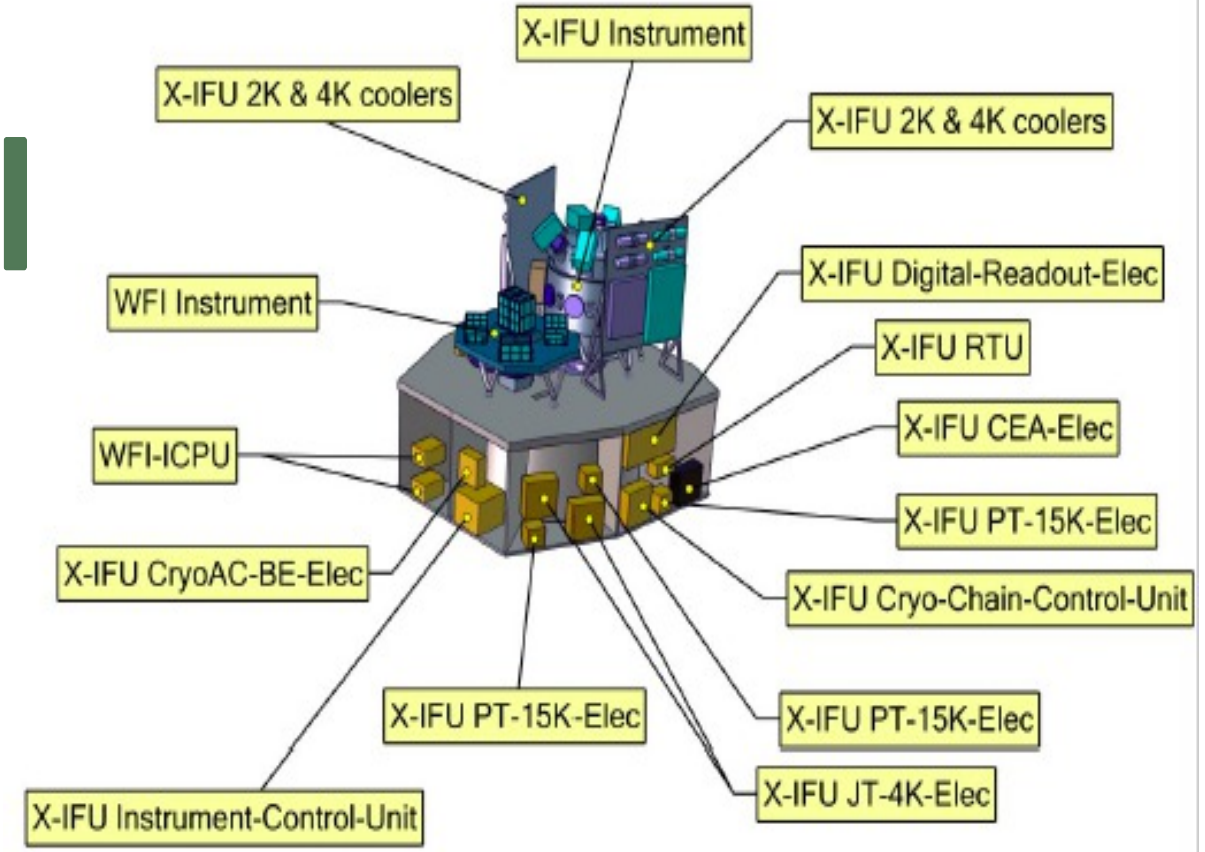
Focal plane concept by ESA





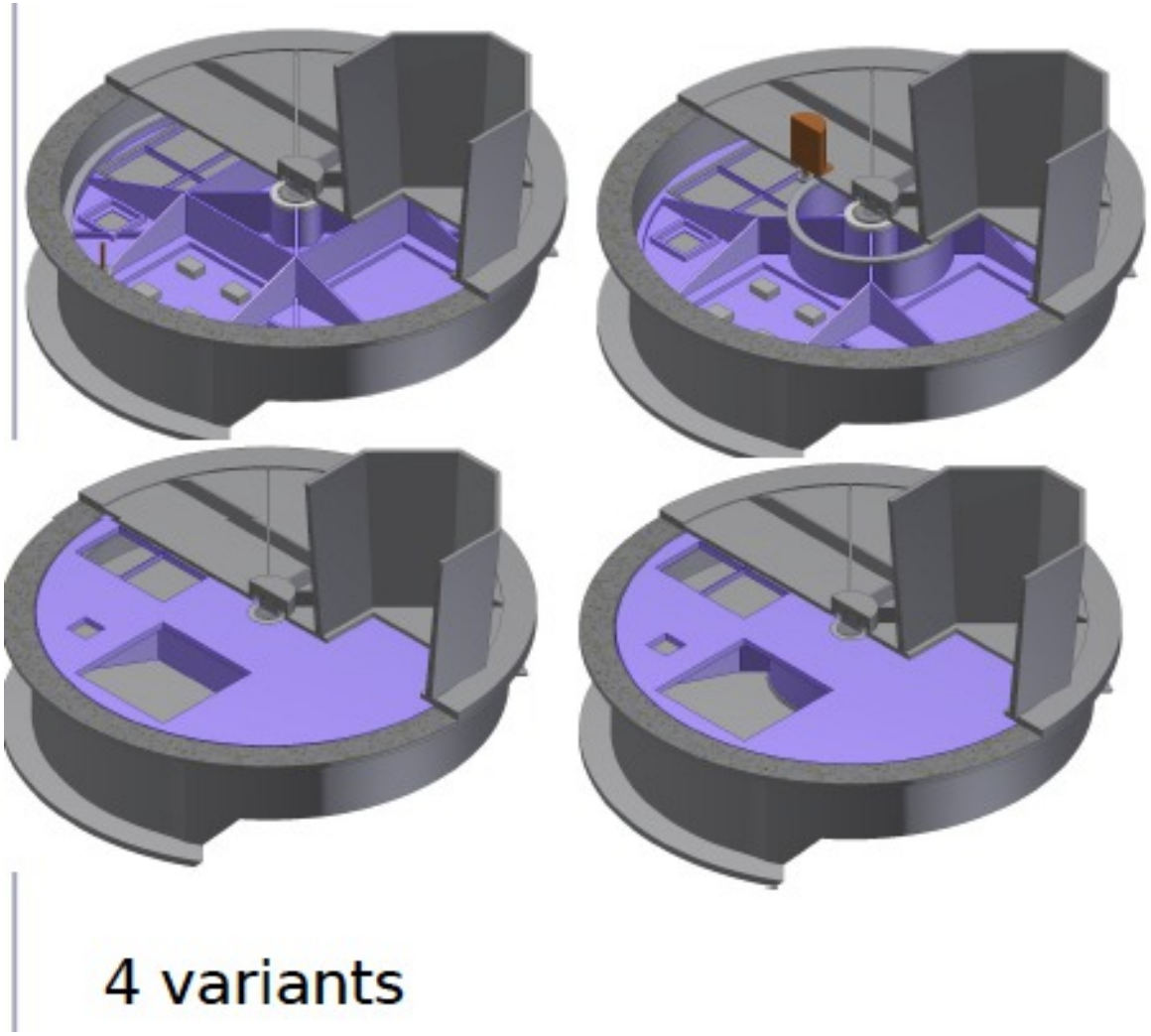


Focal plane concept by ESA



WFI team invited us to make

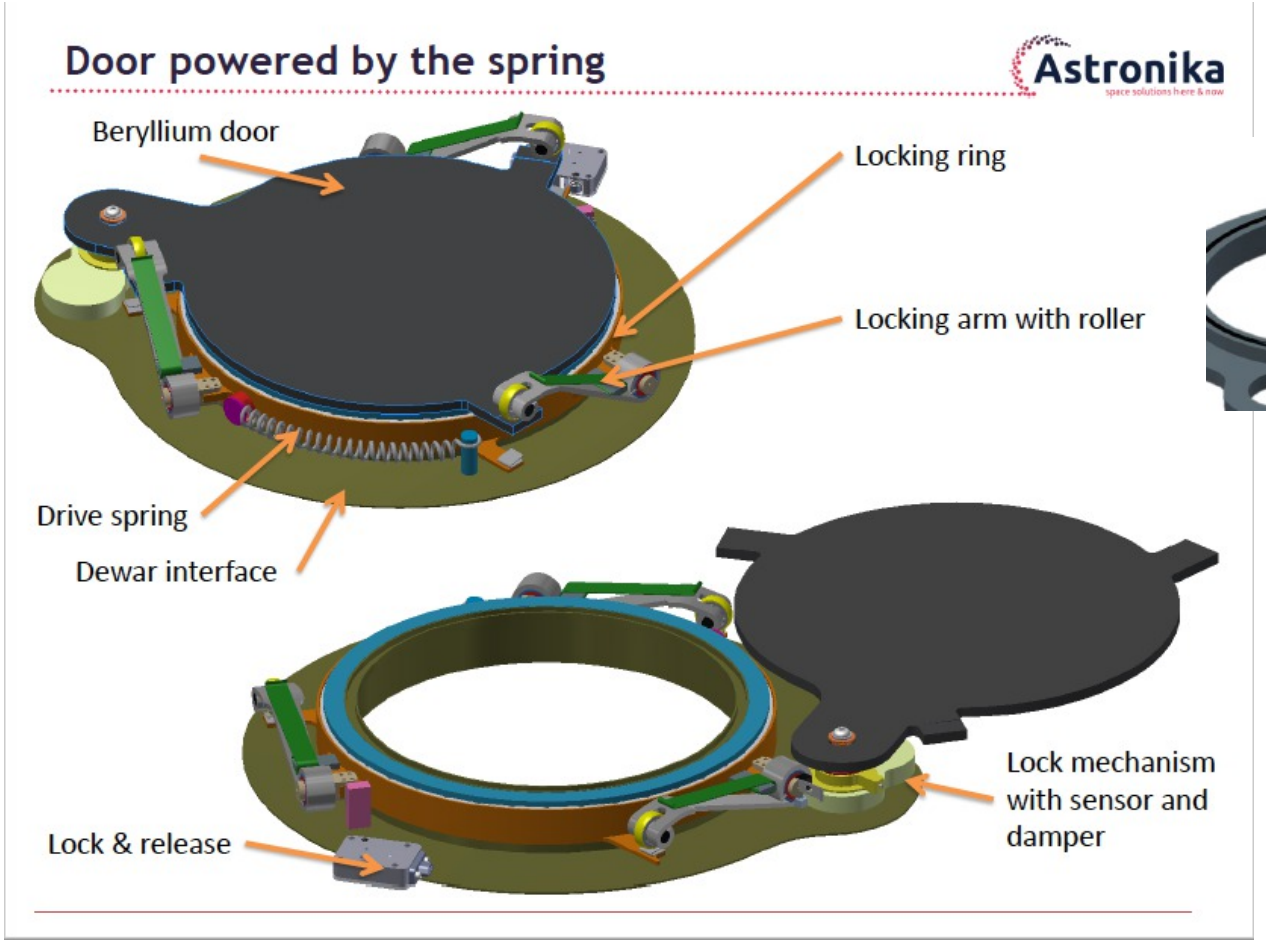
Filter Wheel
Assembly by
Mirosław Rataj
From CBK PAN



4 variants

X-IFU team invited us to make

- Dewar door for cylinder by Bartosz Kędziora



X-IFU and WFI teams invited us to make

- Power distribution unit by Konrad Skup from CBK PAN

PDU Concept

			Primary Power W							
			OFF	COOLDOWN (Detector)	INITIALIZE	READY	OBSERVE	EXPERTISE	REGENERATE	COOLDOWN (Shield)	STANDBY
X-FU	UNIT	Number unit									
	PT15K	4 or 5	0	1500	1200	1200	1200	1200	1200	1500	0
	JT4K (JAXA)	1	0	90	90	90	90	90	90	90	0
	JT2K	1	0	100	100	100	100	100	100	100	0
	Total Coolers		0	1690	1390	1390	1390	1390	1390	1690	0
	ADR (50mK) Electronics	1	0	0	5	5	5	5	5	0	0
	PT15K Electronics	5	0	750	600	600	600	600	600	750	0
	JT4K Electronics	1	0	45	45	45	45	45	45	45	0
	JT2K Electronics	1	0	50	50	50	50	50	50	50	0
	Total Coolers Electronics		0	845	700	700	700	700	700	845	0
	Total Coolers Electronics + 20 % DMM		0	1014	840	840	840	840	840	1014	0
	Total Coolers + Electronics with 20 % DMM		0	2704	2230	2230	2230	2230	2230	2704	0
	Filter Wheel	1	0	0	36	36	36	36	36	0	0
	Modulated X Ray Source	1	0	0	16	16	16	16	16	0	0
	WFEE	6	0	0	20	20	20	20	20	0	0
	CryoAc WFEE (x4)	4	0	0	6	6	6	6	6	0	0
	CryoAc BEE	1	0	0	15	15	15	15	15	0	0
	DRE (functionnal chain x6)	6	0	0	438	438	438	438	438	0	0
	ICU	1	0	20	20	20	20	20	20	20	20
	CCCU	1	0	20	20	20	20	20	20	20	20
	PDU	1	0	5	5	5	5	5	5	5	5
	Total Warm Units		0	45	576	576	576	576	576	45	45
	Total Warm Units + 20 % DMM		0	54	691	691	691	691	691	54	54
	TOTAL		0	2580	[illegible]					2580	45
	TOTAL with 20% DMM		0	2758	2921	2921	2921	2921	2921	2758	54

DRAFT

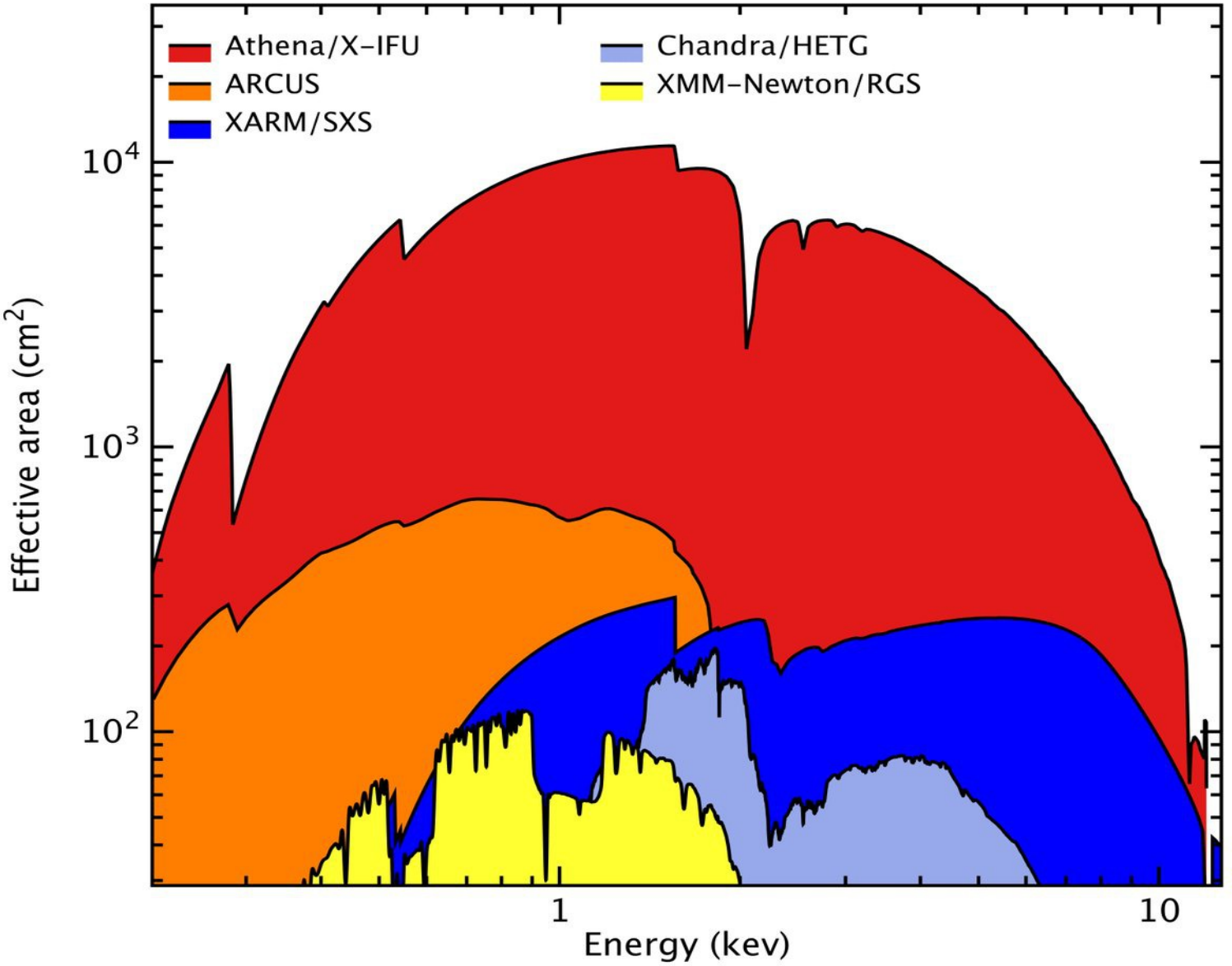
Note: *If optimistic assumed the PDU has efficiency of 90%, then ~200W would be dissipated on PDU, may not be atrivial task from thermal point of view to remove this heat.* ***Assumption is it will dissipate 2.5-5W.***

ATHENA has great collaboration

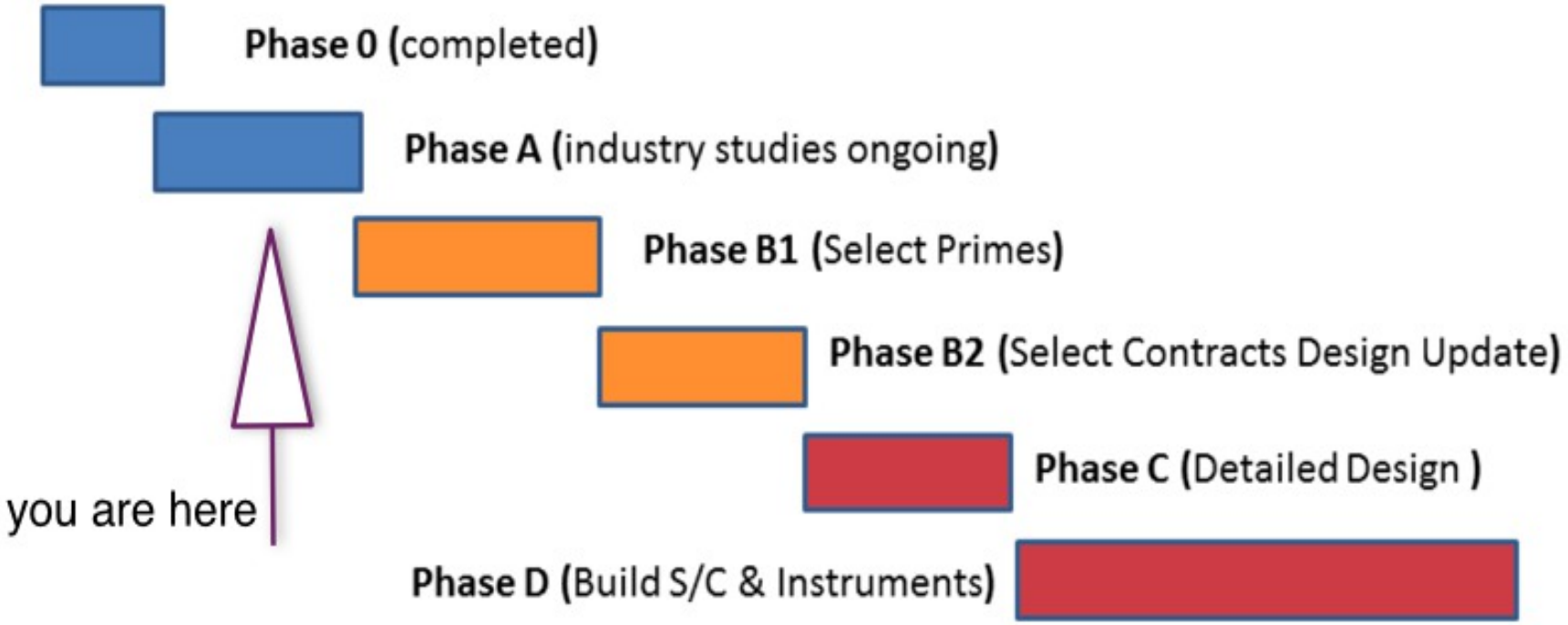
- Polish ATHENA-PL scientific consortium is under construction
- We have been invited to make satellite components
- Our hardware development will be paid by PRODEX ESA project
- Since 2014 we have participated in about 24 meetings

More info at: http:/www.athena.camk/edu.pl

Effective area of the ATHENA telescope



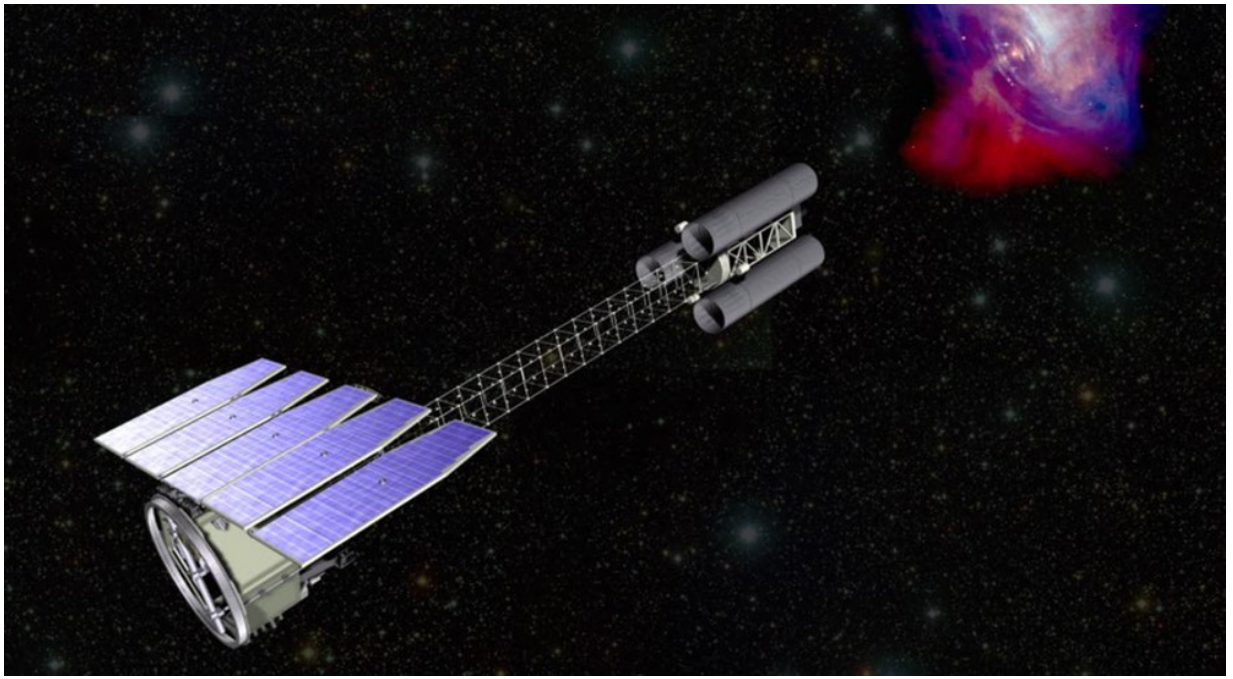
Effective area of the ATHENA telescope



Next key date: Athena "adoption" in the ESA Science Program: 2020

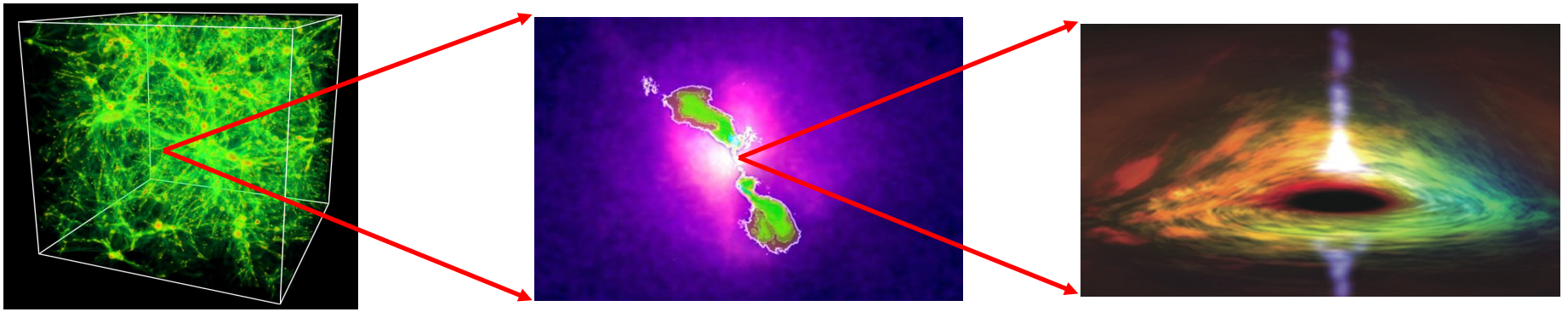
The other X-ray missions:

- HARM/SXS - new Hitomi – by JAXA
- ARCUS with gratings – 2023 by NASA
- XIPE – polarimeter by ESA – M4 mission not yet selected
- IXPE – polarimeter by NASA – selected to by launch at 2020
- eXTP – new timing and polarimetry mission – by China + ESA



Science scheme - The Hot Energetic Universe

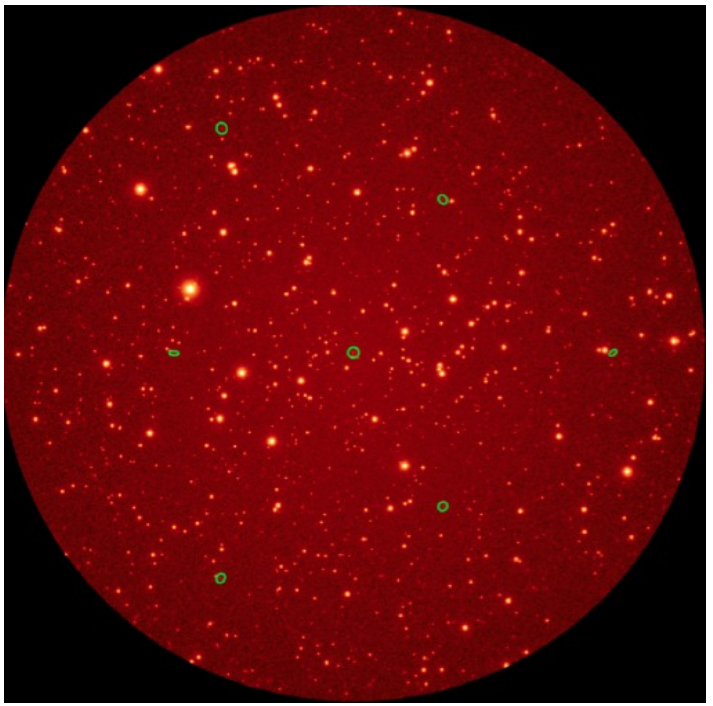
- Hot Universe: How does ordinary matter assembles in large scale structures that we see today?
- > 50 % of the baryons today are in a hot (>106 K) phase
- There are as many hot (>107 K) baryons in clusters as in stars over the entire Universe
- Energetic Universe: How do black hole grows and shape the Universe?
- 15 % of the (luminous) energy in the Universe is from accretion



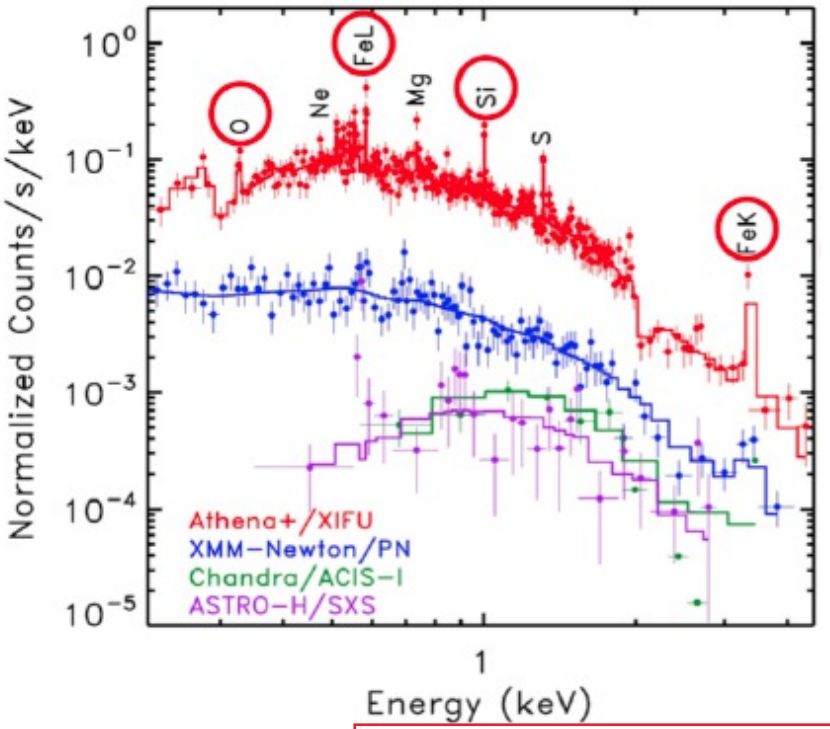
The formation and evolution of clusters

- What is the interplay of galaxy, SBH and intergalactic gas?
- What are the processes driving the evolution of chemical enrichment of the hot diffuse gas in large-scale structure?
- How and when did the first galaxy groups form?

WFI 100 ks 50'x50'

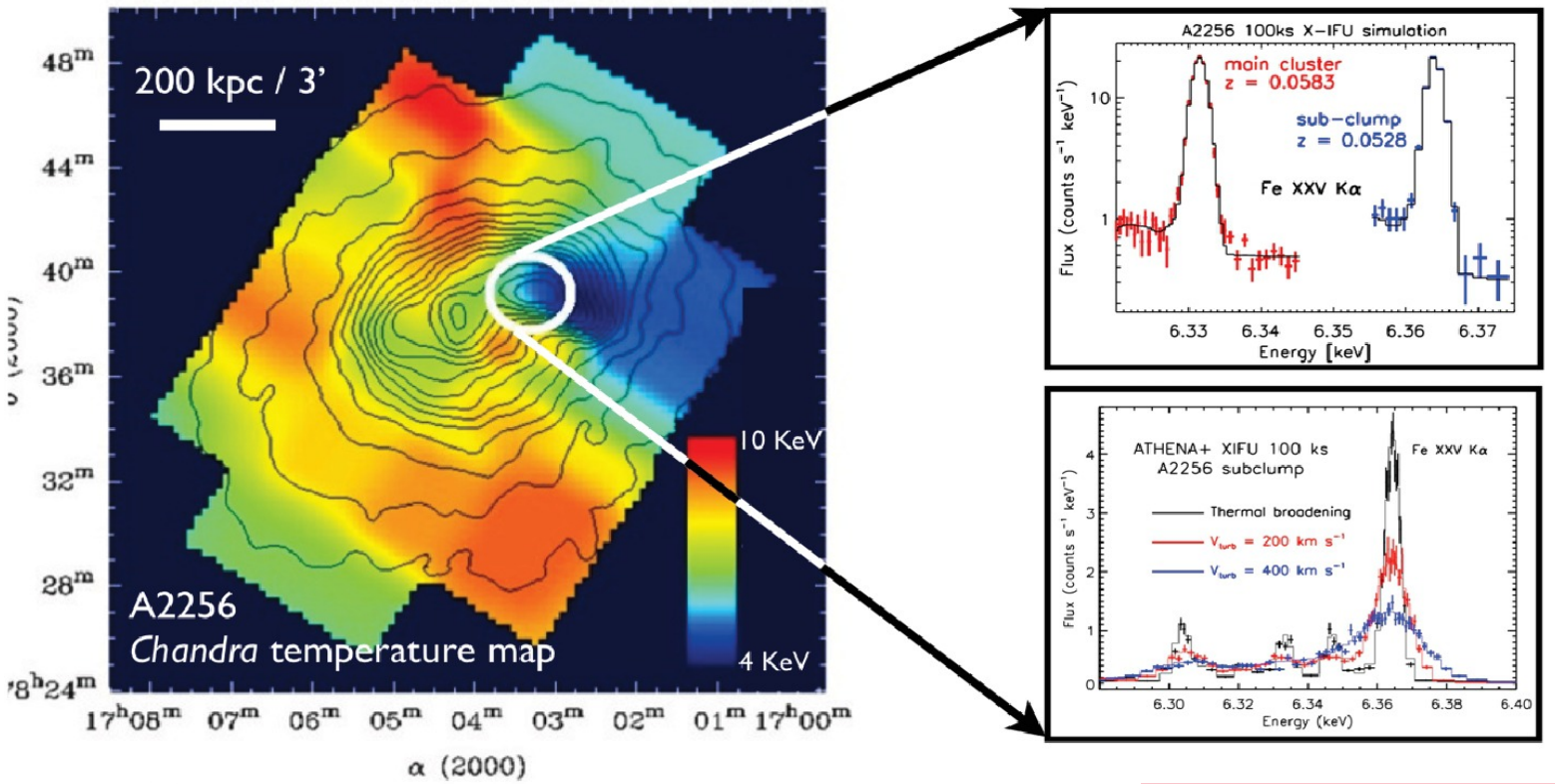


Cluster z=1 kT = 3 keV



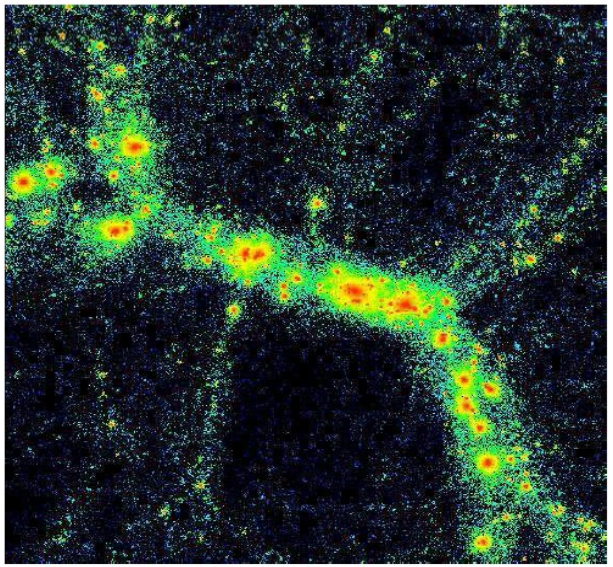
The formation and evolution of clusters

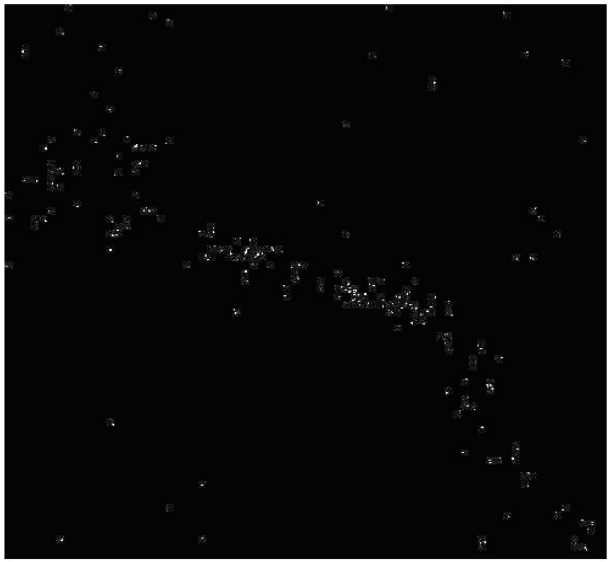
- How do hot diffuse baryons accrete and dynamically evolve?
- How and when was the energy in the ICM generated?
- Where and when are heavy elements produced?



Missing baryons in simulations, Suto et al. 2004

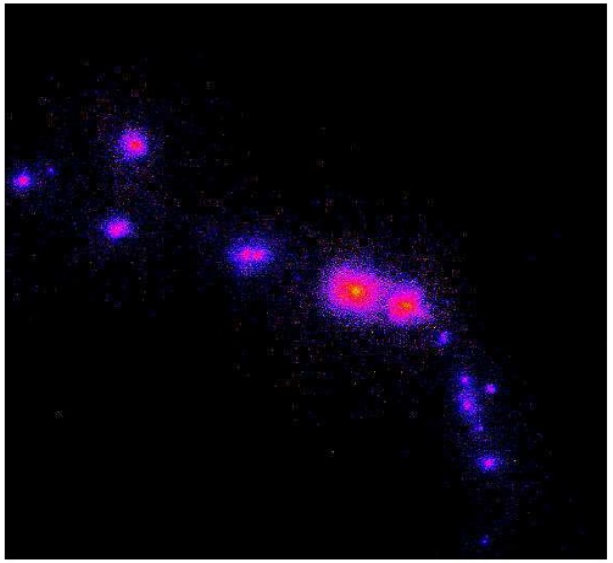
Dark Matter
26.8 %

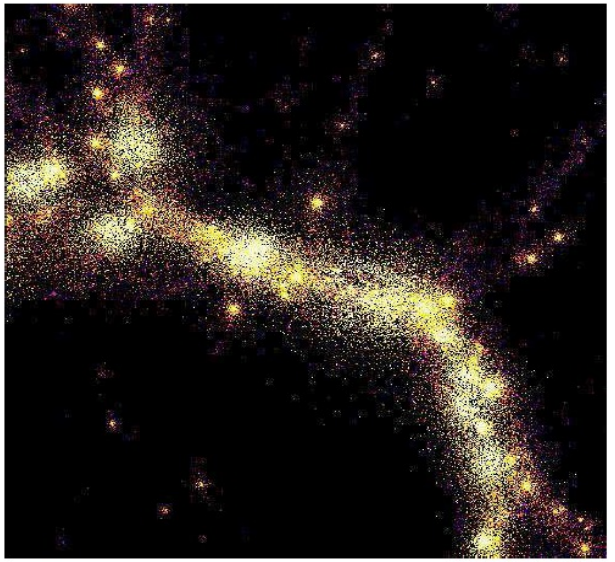




Galaxies,
incl. Stars
$T \leqslant 10^4\ K$

Clusters
$T > 10^7\ K$

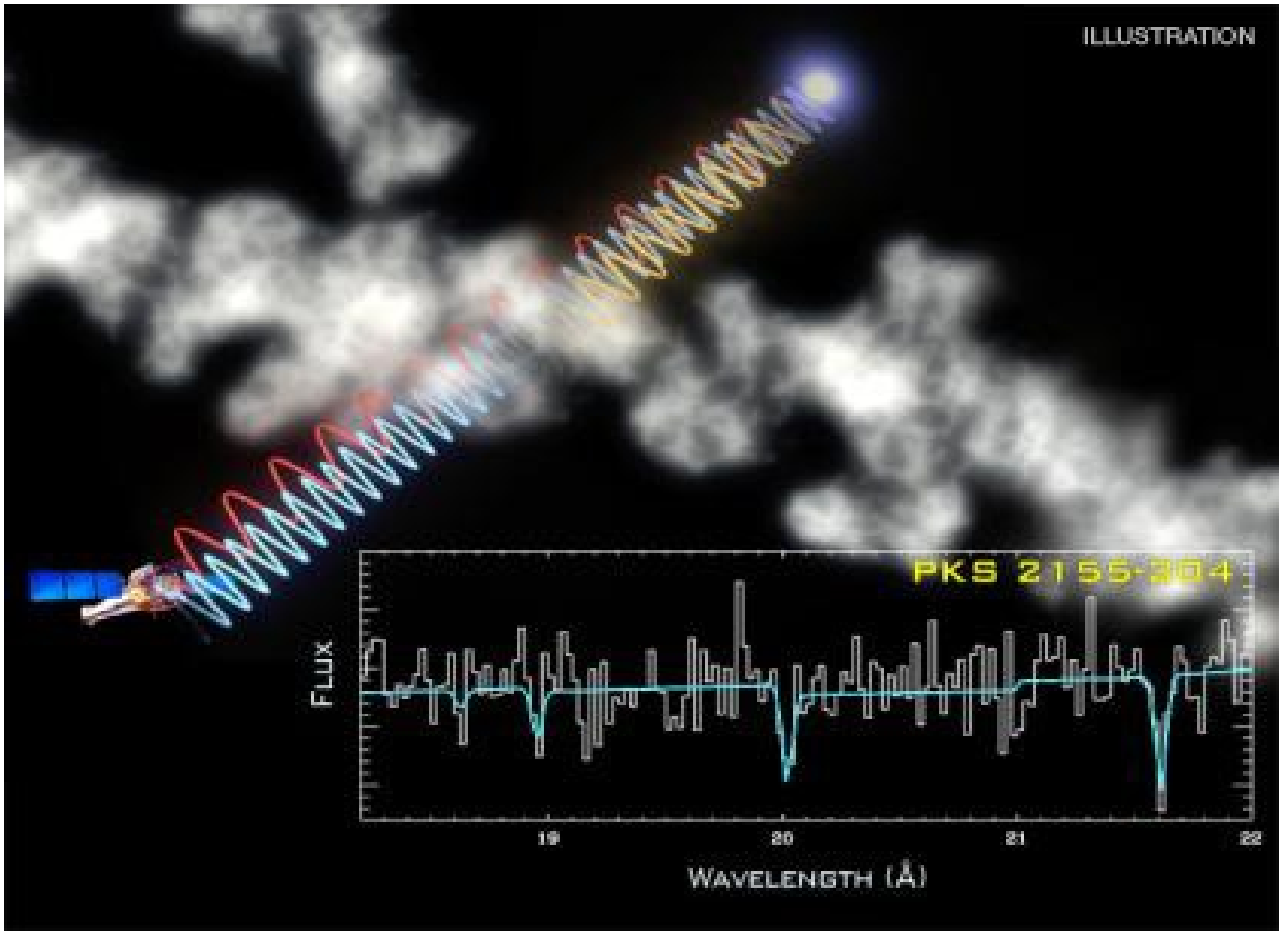




WHIM
$10^5 < T < 10^7\ K$

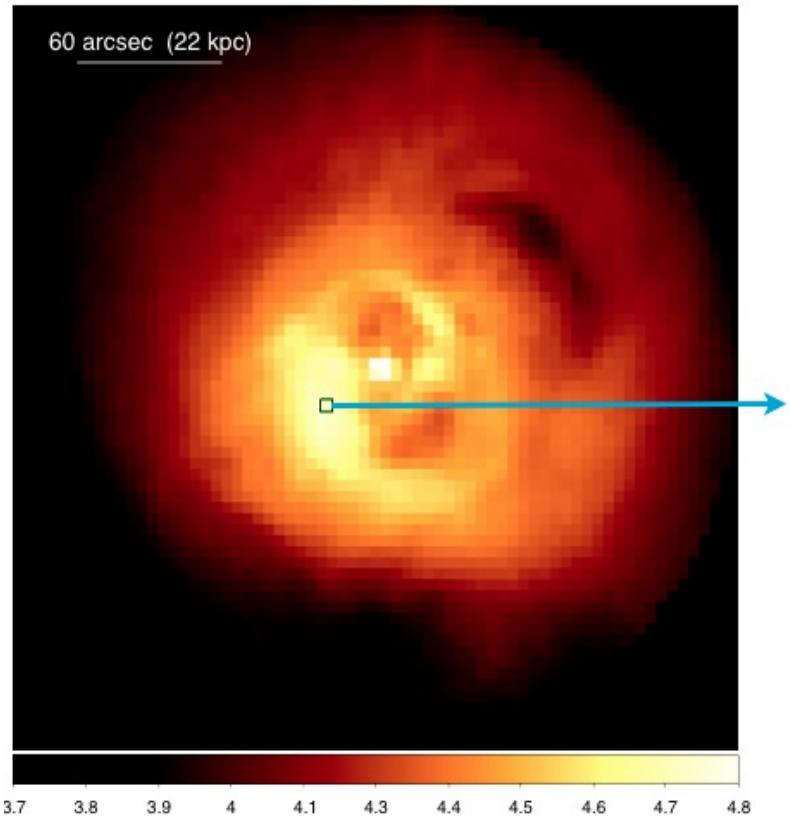
Missing baryons

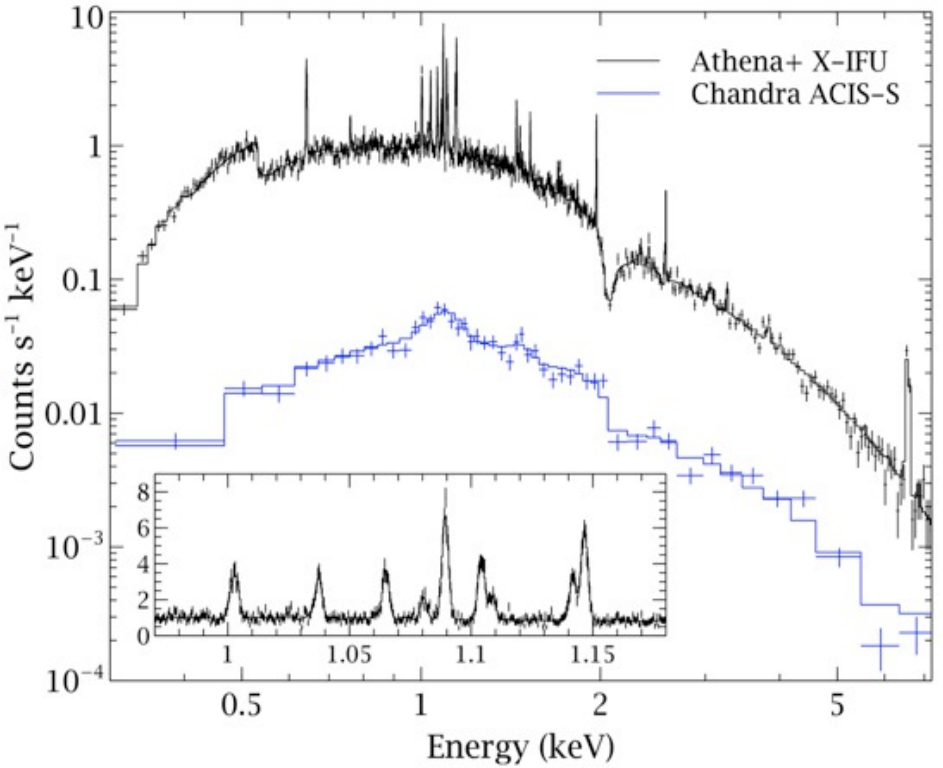
- How to detect WHIM? All atomic spectral features are narrow
- Need for high spectral resolution



The AGN feedback in cluster of galaxies

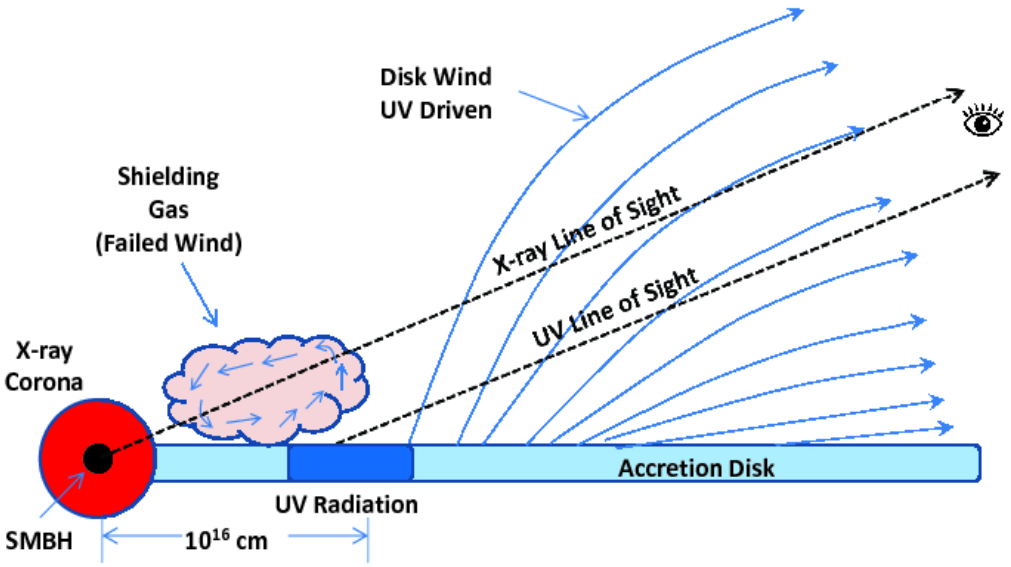
- How do jets from AGN dissipate their mechanical energy in hot intracluster medium? How it affects hot gas distribution?
- Establish how AGN feedback regulates gas cooling in groups and clusters

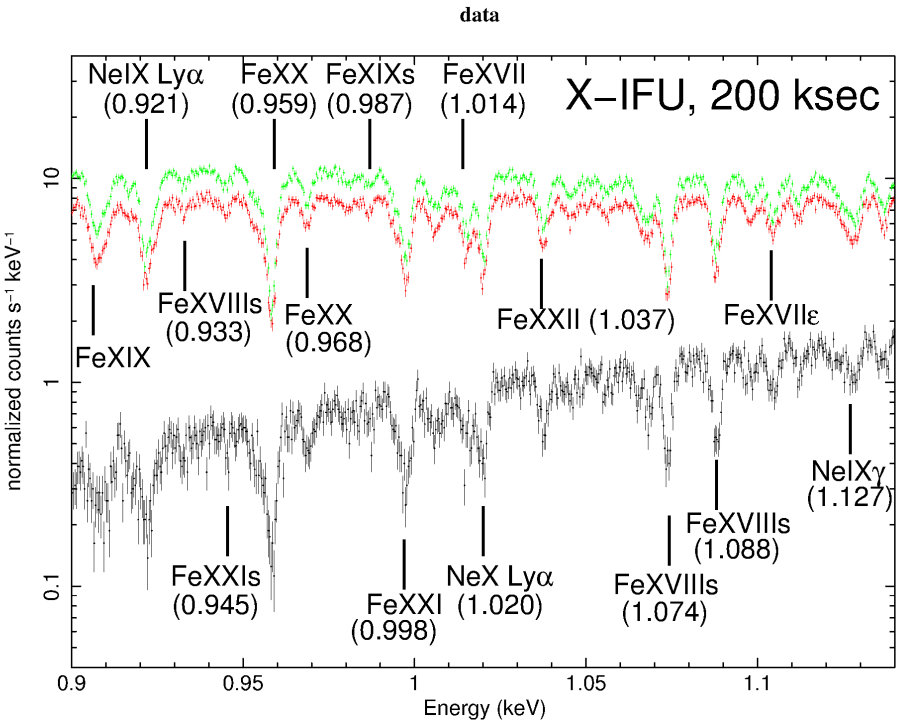




Astrophysics of feedback, outflows and winds in AGN

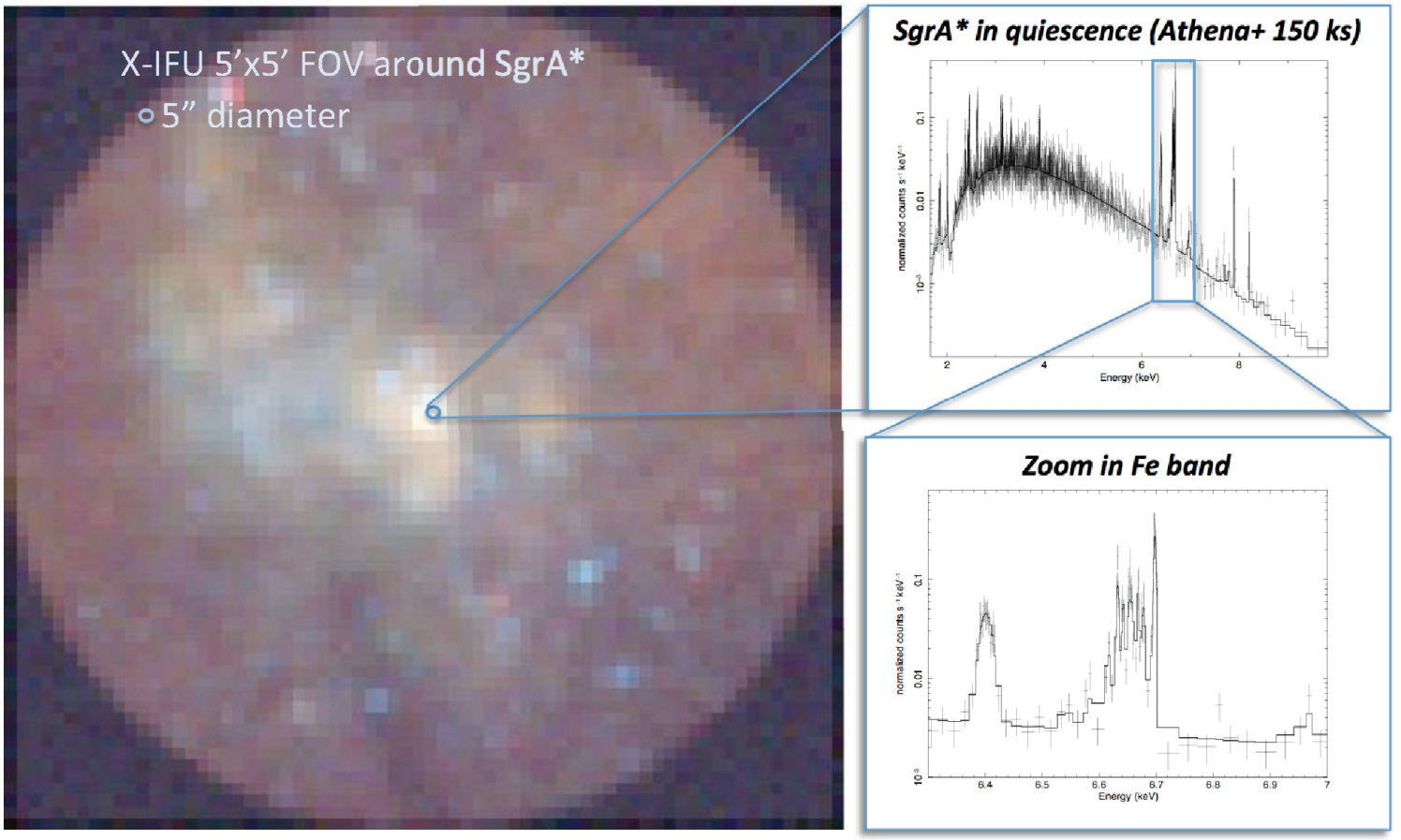
- How do accretion disks around black holes launch winds and how much energy do these carry?
- How are the energy and metals transferred into the medium?





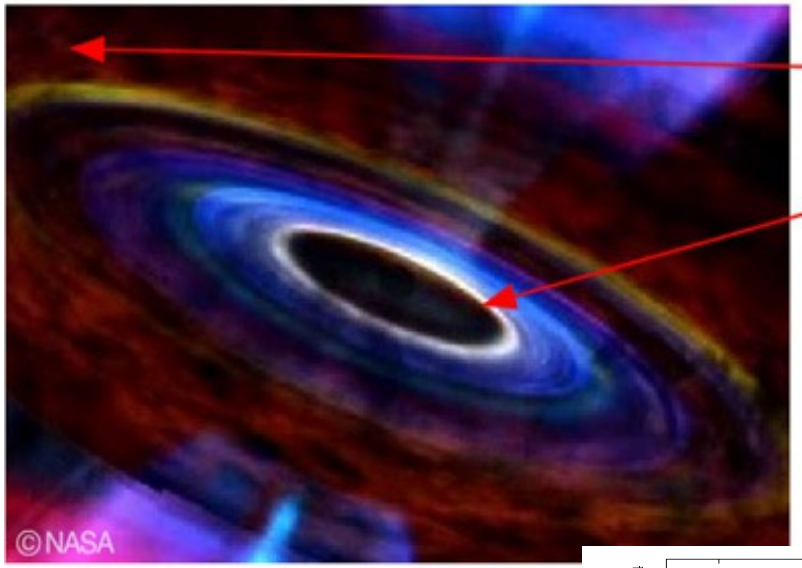
Astrophysics of feedback, outflows and winds in AGN

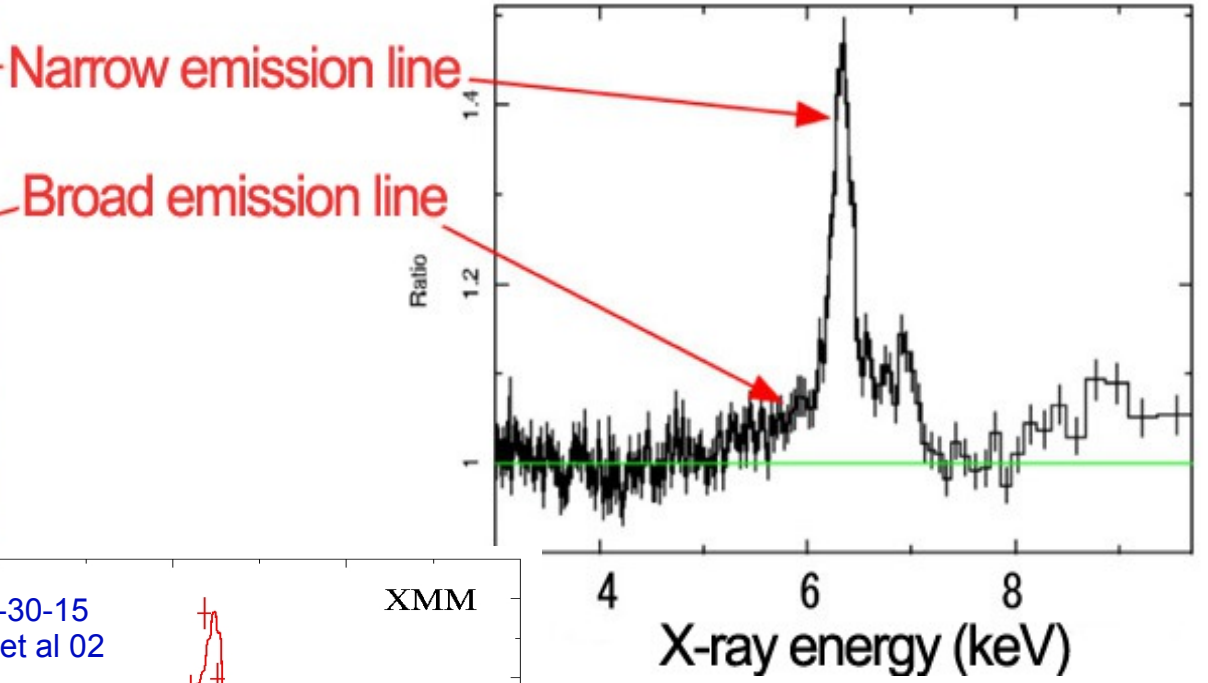
- How do accretion disks around black holes launch winds and how much energy do these carry?
- How are the energy and metals transferred into the medium?

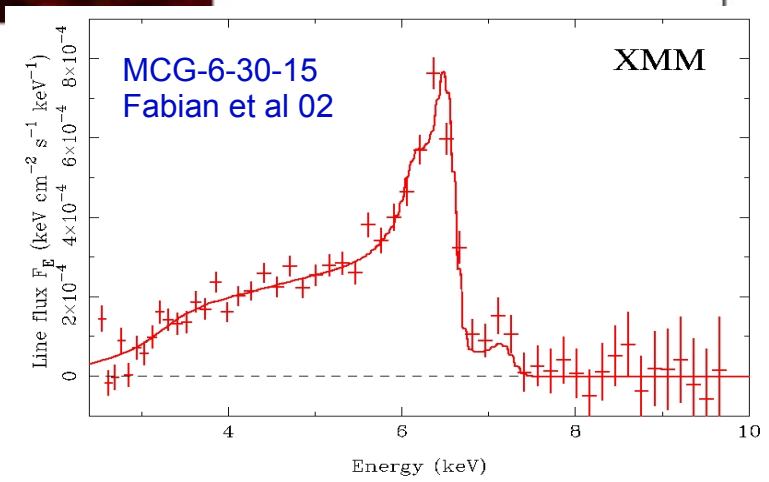


Close environment of supermassive black holes

- Fluorescent iron line profile from accreting black holes
- Black hole spin

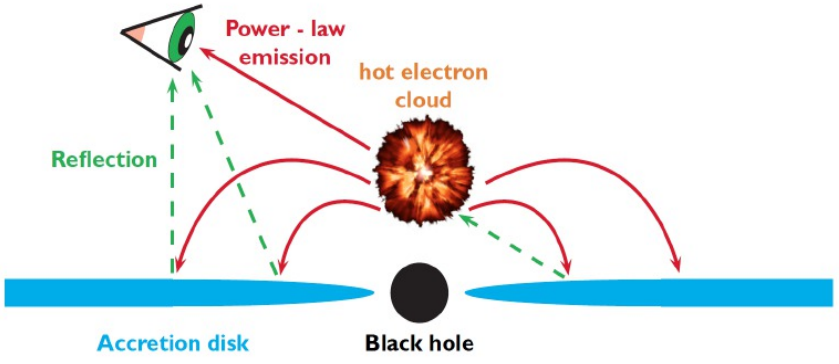


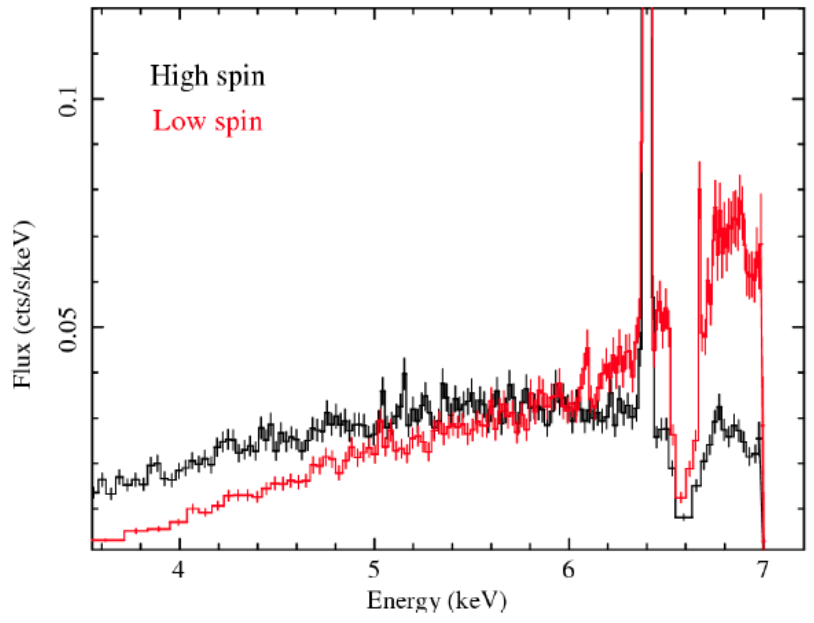


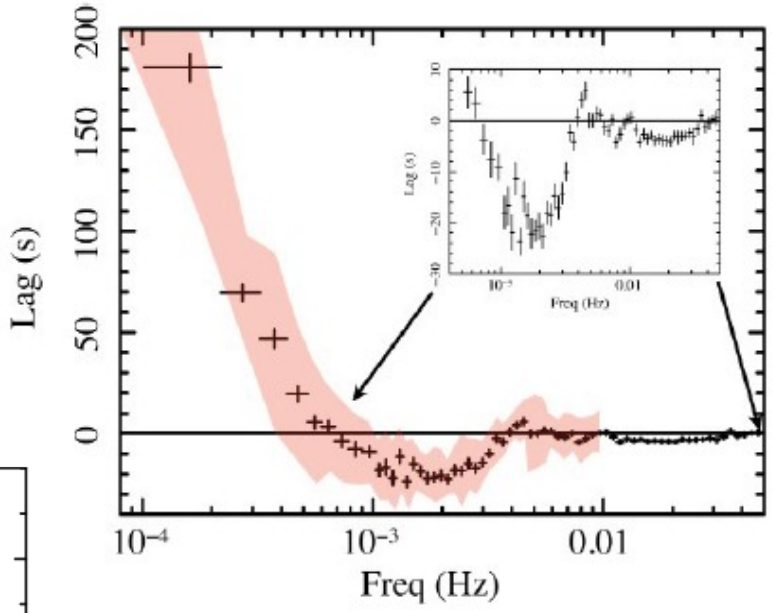


Close environment of supermassive black holes

- Fluorescent iron line profile from accreting black holes
- Black hole spin

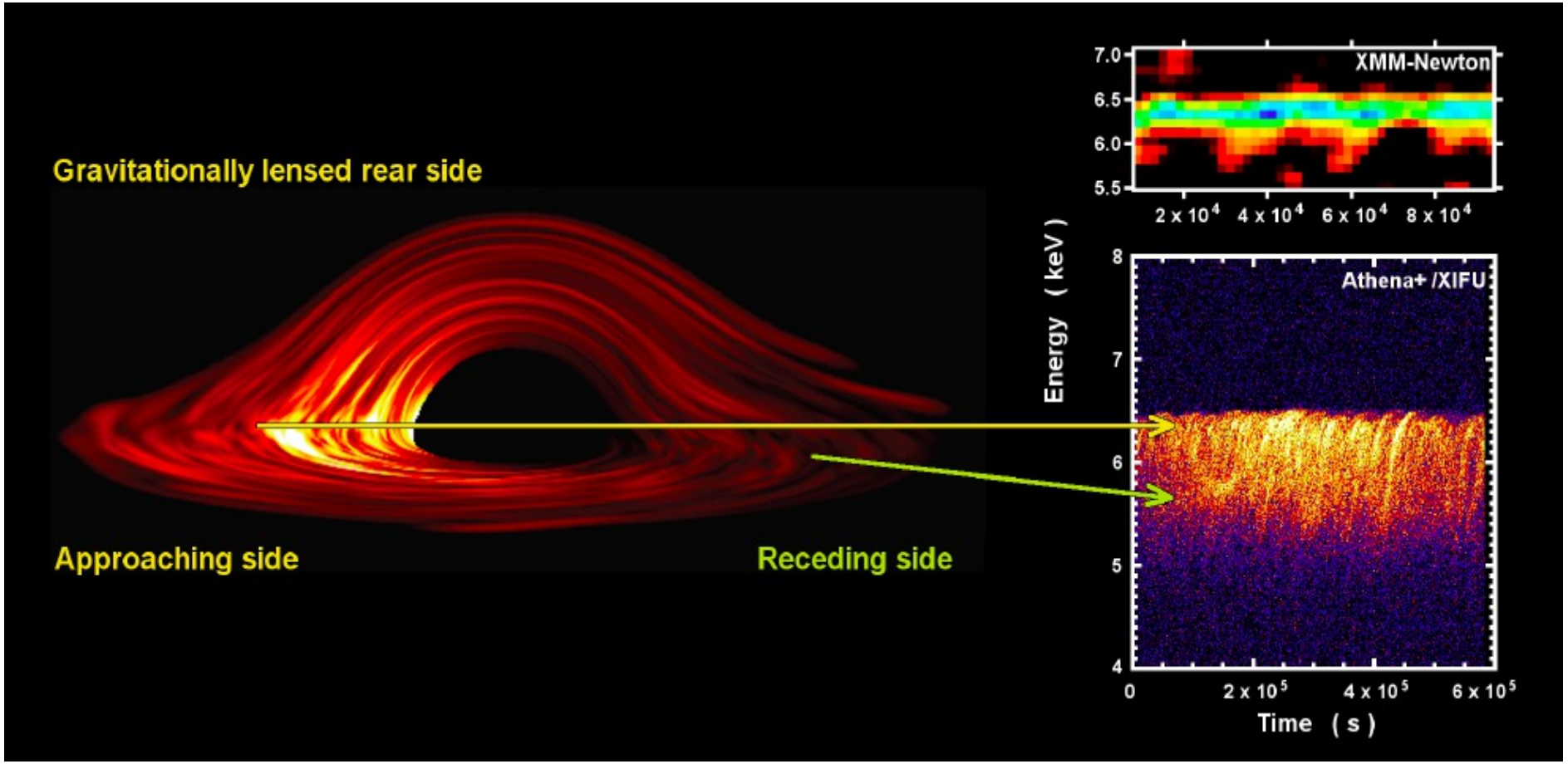






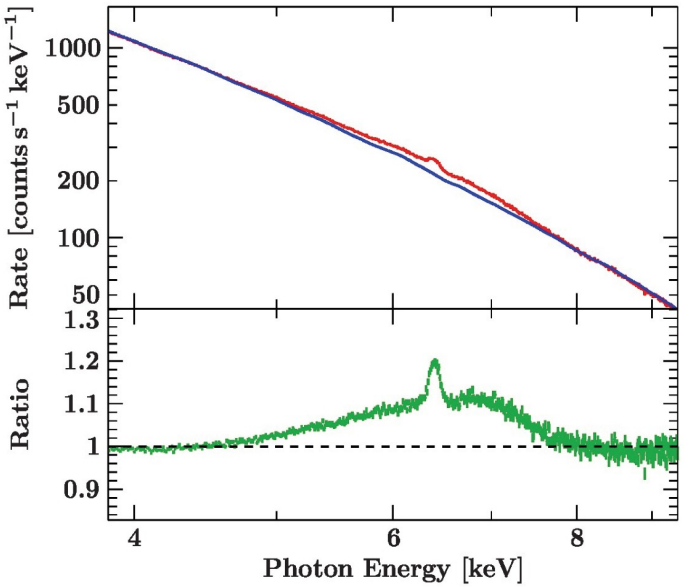
Close environment of supermassive black holes

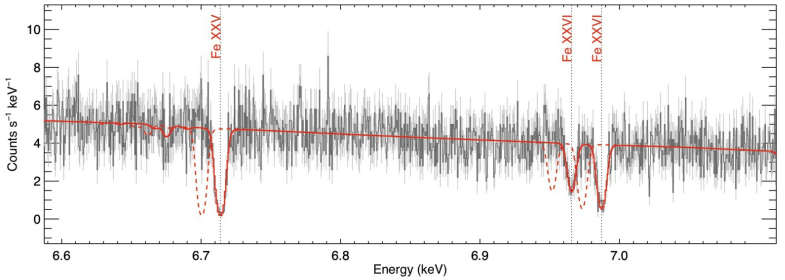
- Time resolved spectroscopy puts constrains on the geometry of disk and corona

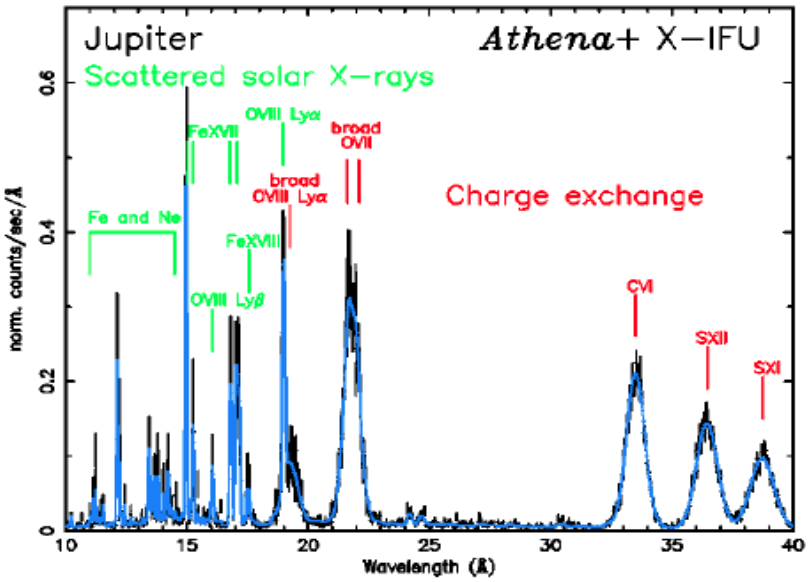


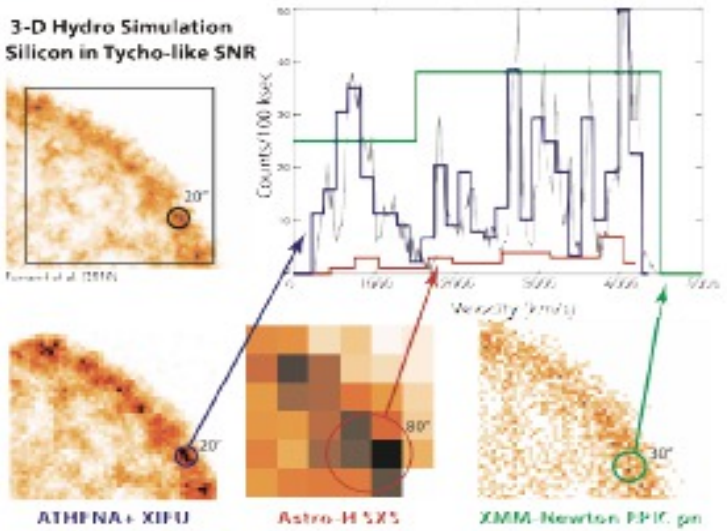
Observatory science questions

- Solar system and exoplanets
- End points of stellar evolution
- Supernova remnants

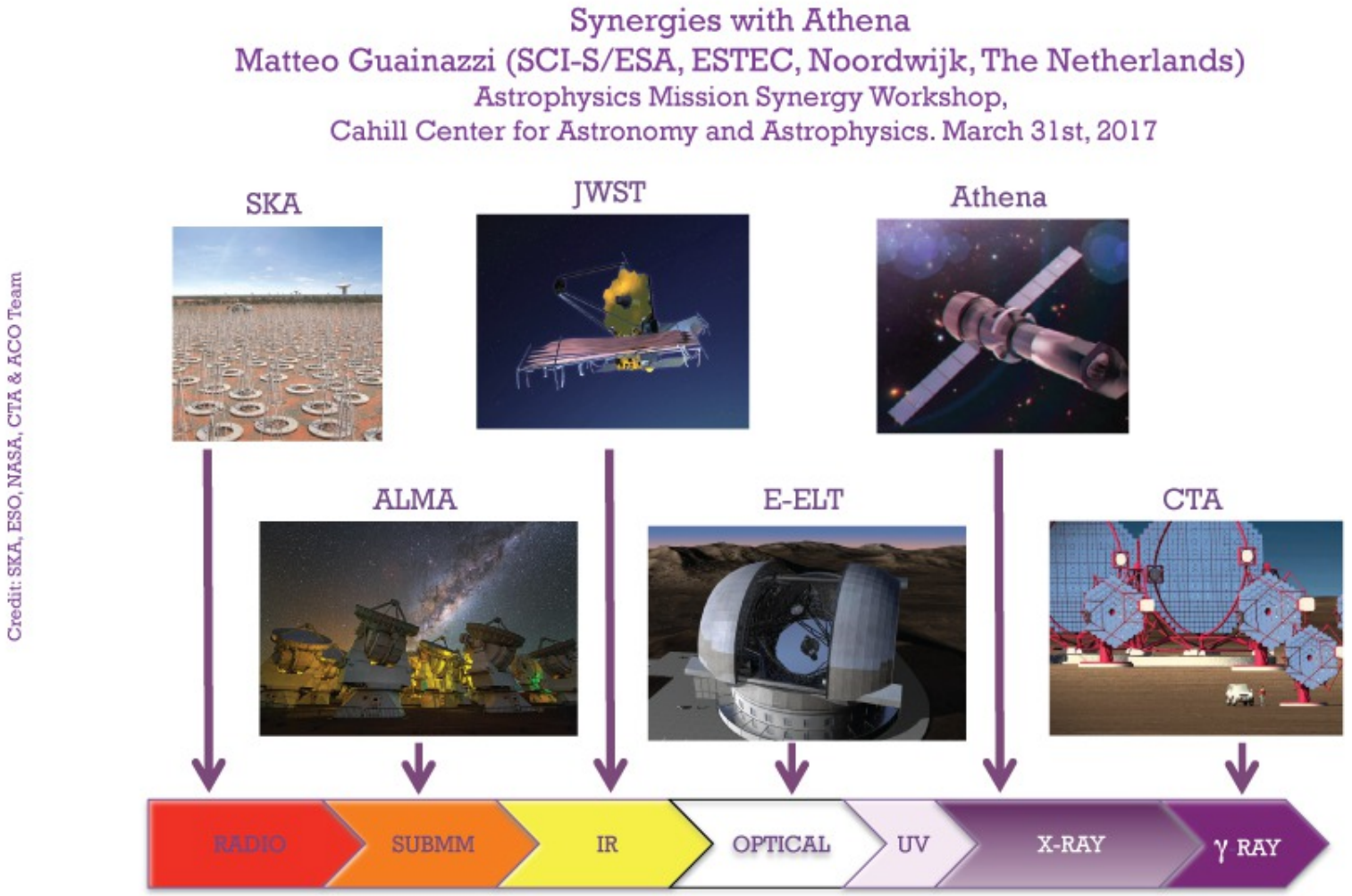








Conclusions – ATHENA in the context of 2020s



Conclusions – ATHENA in the context of 2020s