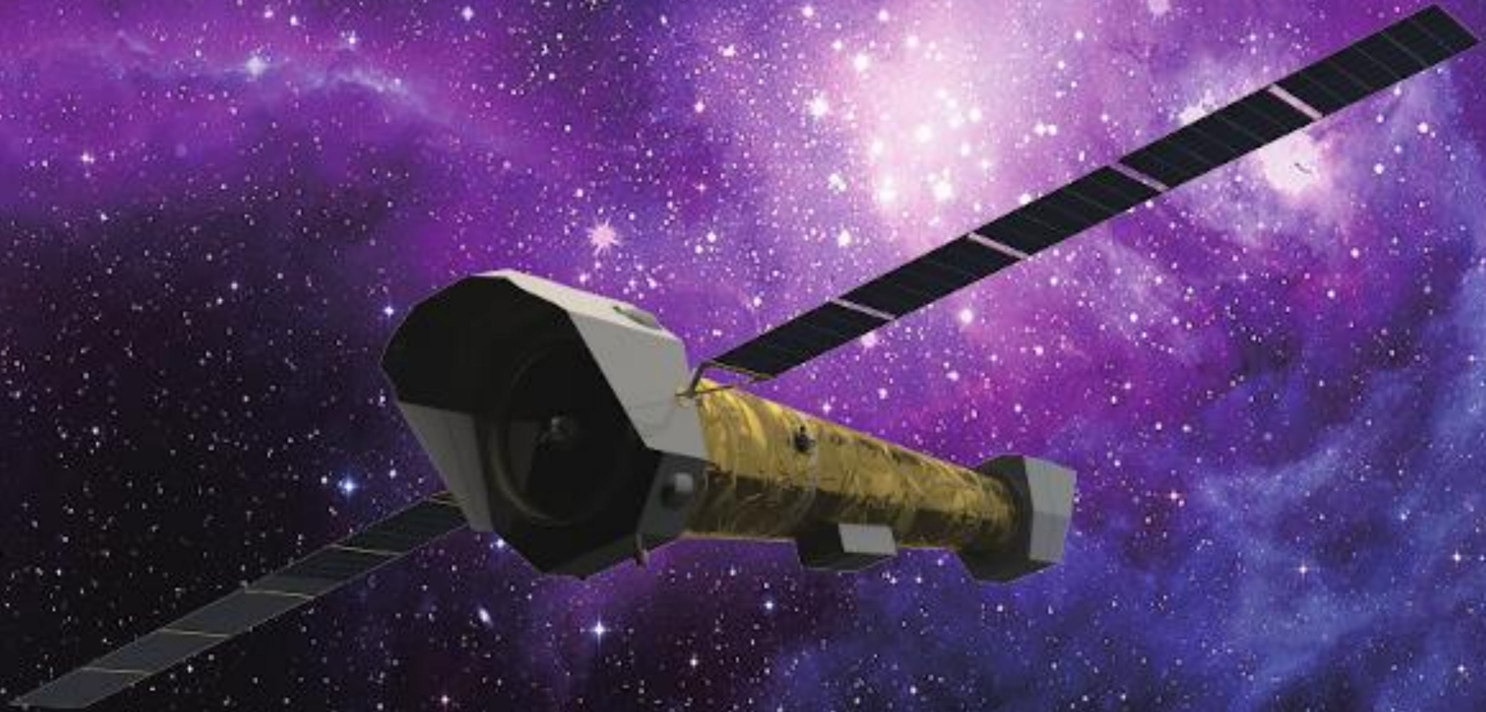
NewAthena

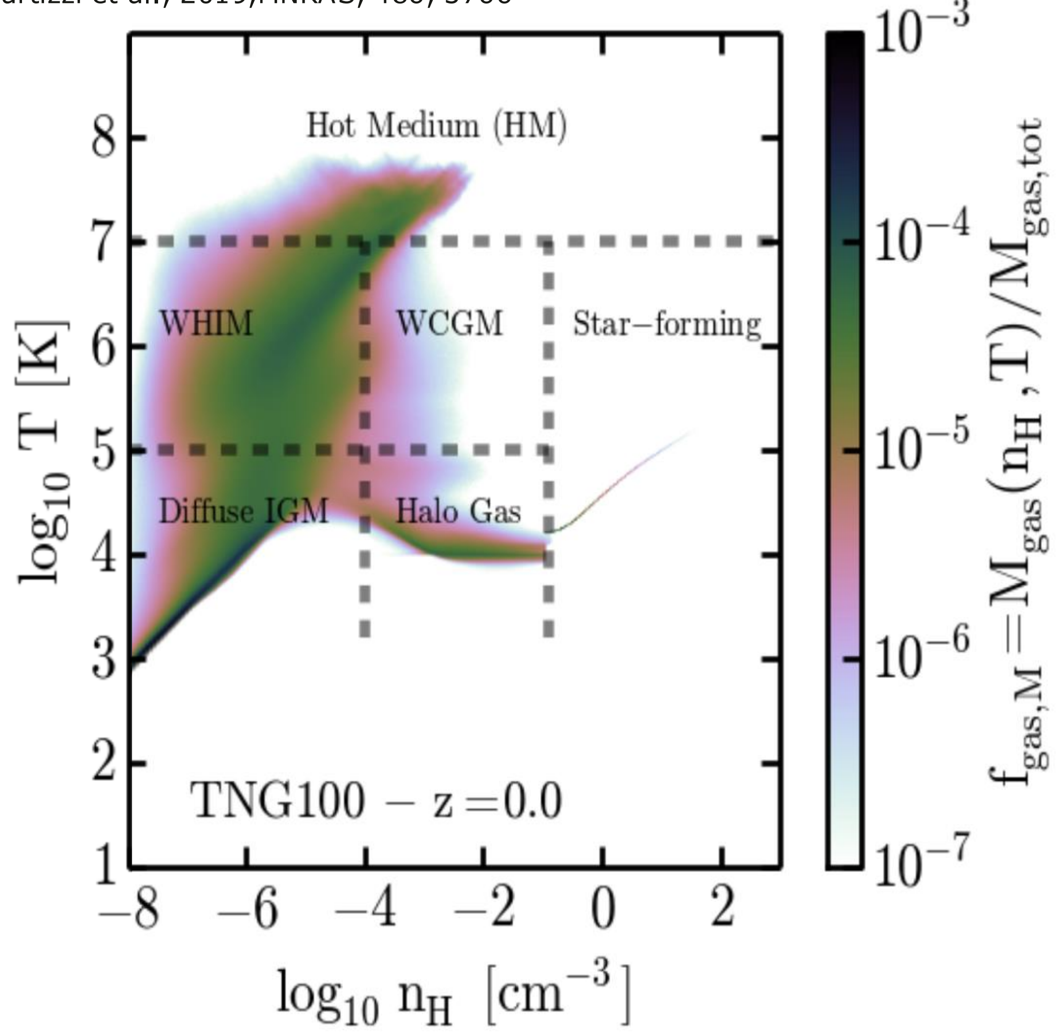


Matteo Guainazzi

NewAthena Study Scientist (ESA/ESTEC)

Credit: IRAP, CNES, ESA & ACO

Martizzi et al., 2019,MNRAS, 486, 3766



Key questions to address via high-energy astrophysics

Cruise et al., NatAst, in press

1. How does the stellar radiation field affect the habitability of planetary systems, and is in turn influenced by the presence of nearby planets?
2. What is the Equation-of-State regulating matter in neutron stars?
3. What is the origin of the high-energy processes in the close environment of black holes?
4. What distribution of supernovae and supernova explosions leads to the mixture of metals we measure in the local Universe? How are metals distributed through the Cosmos?
5. What drives the cosmological co-evolution of galaxies and super-massive black holes?
6. How does supermassive black hole feedback shape the large-scale baryon distribution?
7. How do large-scale structures in the Universe form and evolve? What physics defined their hot gas content?
8. What is the astrophysical nature of the most common celestial sources of neutrinos and gravitational waves?

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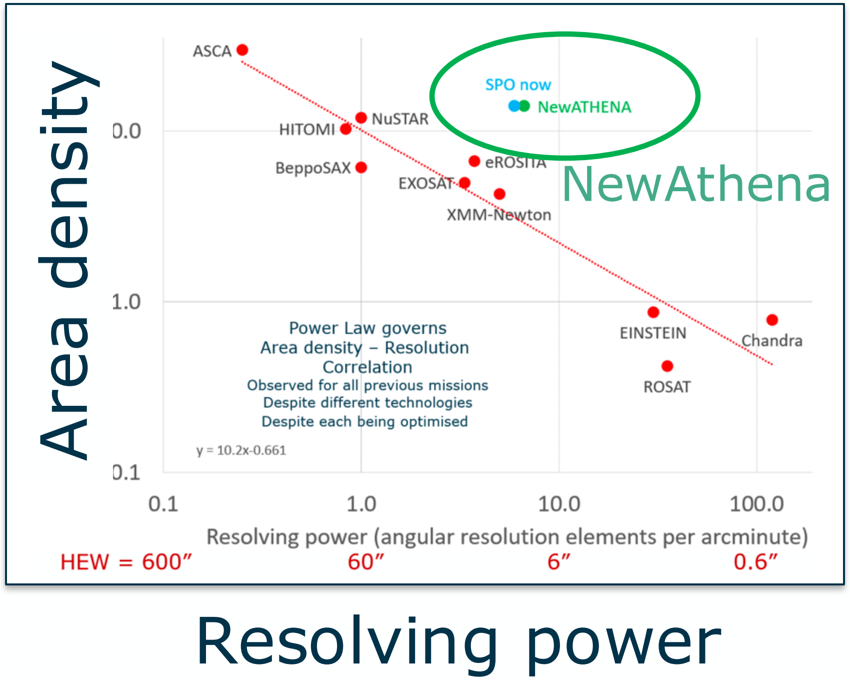
NewAthena: three key science-enabling innovations

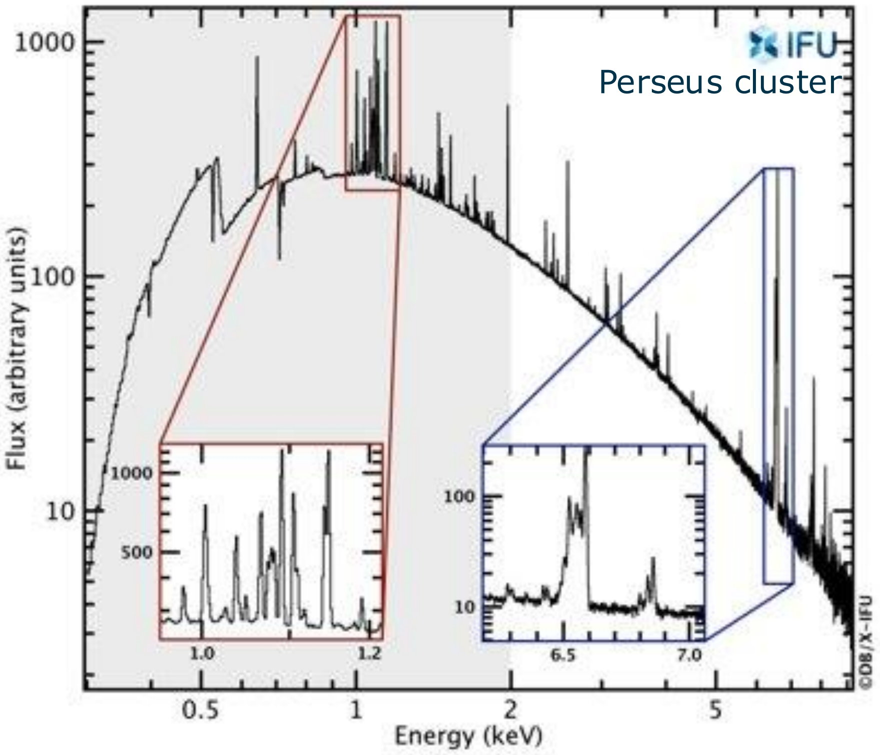
The largest space-qualified X-ray mirror for astronomy



Bavdaz et al. 2023. SPIE, 1267902-1

X-ray telescope based on **Silicon Pore Optics** technology (ESA), 9″ HEW, 1.0 m^2 area @1 keV

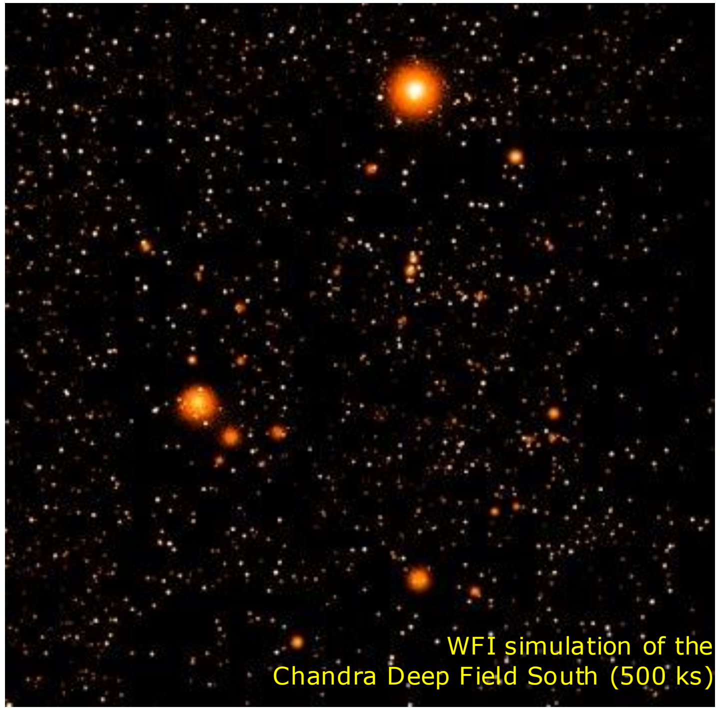
Unprecedented spectroscopic capabilities



Credit: D. Barret (IRAP)

X-Ray Integral Field Unit (**X-IFU**) (CNES/IRAP-led), ≤4 eV energy resolution, >1500 pixels, ~5″ side (4′ effective diameter FoV)

The fastest sky X-ray survey machine


WFI simulation of the Chandra Deep Field South (500 ks)

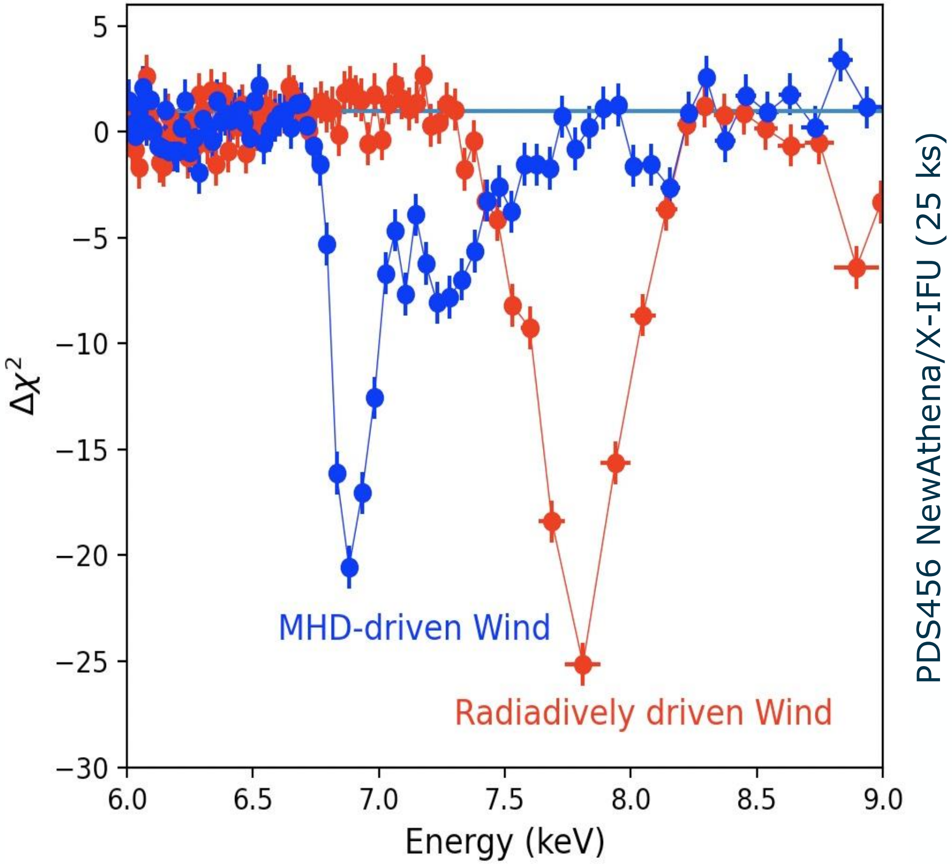
Credit: A. Rau (MPE)

Wide Field Instrument (**WFI**) (MPE-led), DEPFET, <170 eV resolution @7 keV, 40′x40′ FoV

AGN feedback

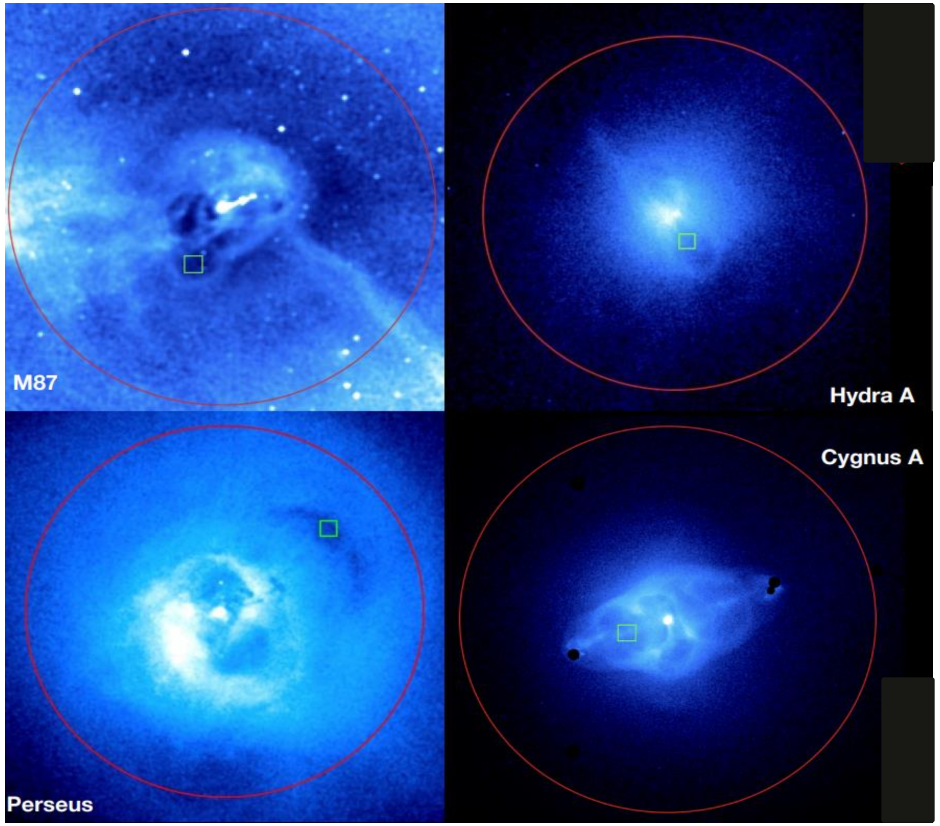
Credit: A. Simionescu (SRON)

Quasar mode



Evolution of accretion disk outflows on their dynamical time-scale

Radio mode



Measurements of turbulence ~100±20 km s^{-1} in nearby cluster cavities

AGN population

Credit: J. Aird (UoE), F. Carrera (IFCA)

Fundamental science question

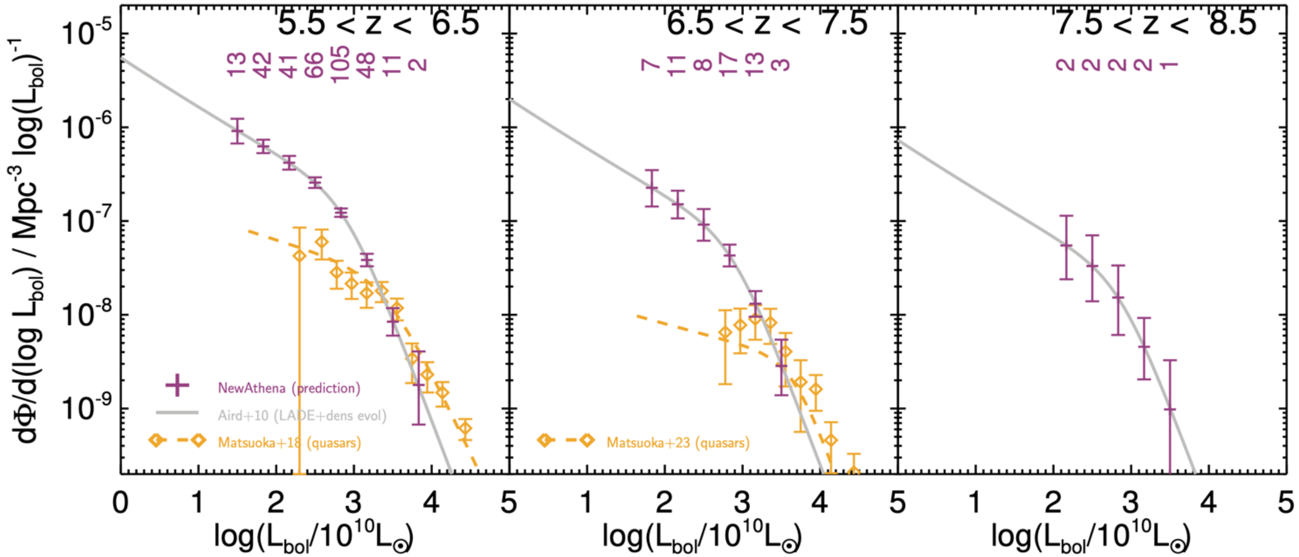
Determine the space density of AGN that dominate black hole growth up to the EoR*

*Epoch-of-Reionization

Experiment

Measure the population of moderatley obscured (N_H=10^{22} cm^{-2}) AGN up to z~8

High-z X-ray versus optical luminosity function for the most conservative NewAthena WFI



This defines an optimized WFI survey strategy: **70*x*200 ks + 30*x*300 ks** (~40 degrees^2) to determine the AGN space density *and* L_X, N_H and z in ≥10 sources per luminosity bin

Particle acceleration in SNRs

Credit: L. Godinaud, A. Decourchelle, F. Acero (CEA)

Fundamental science question

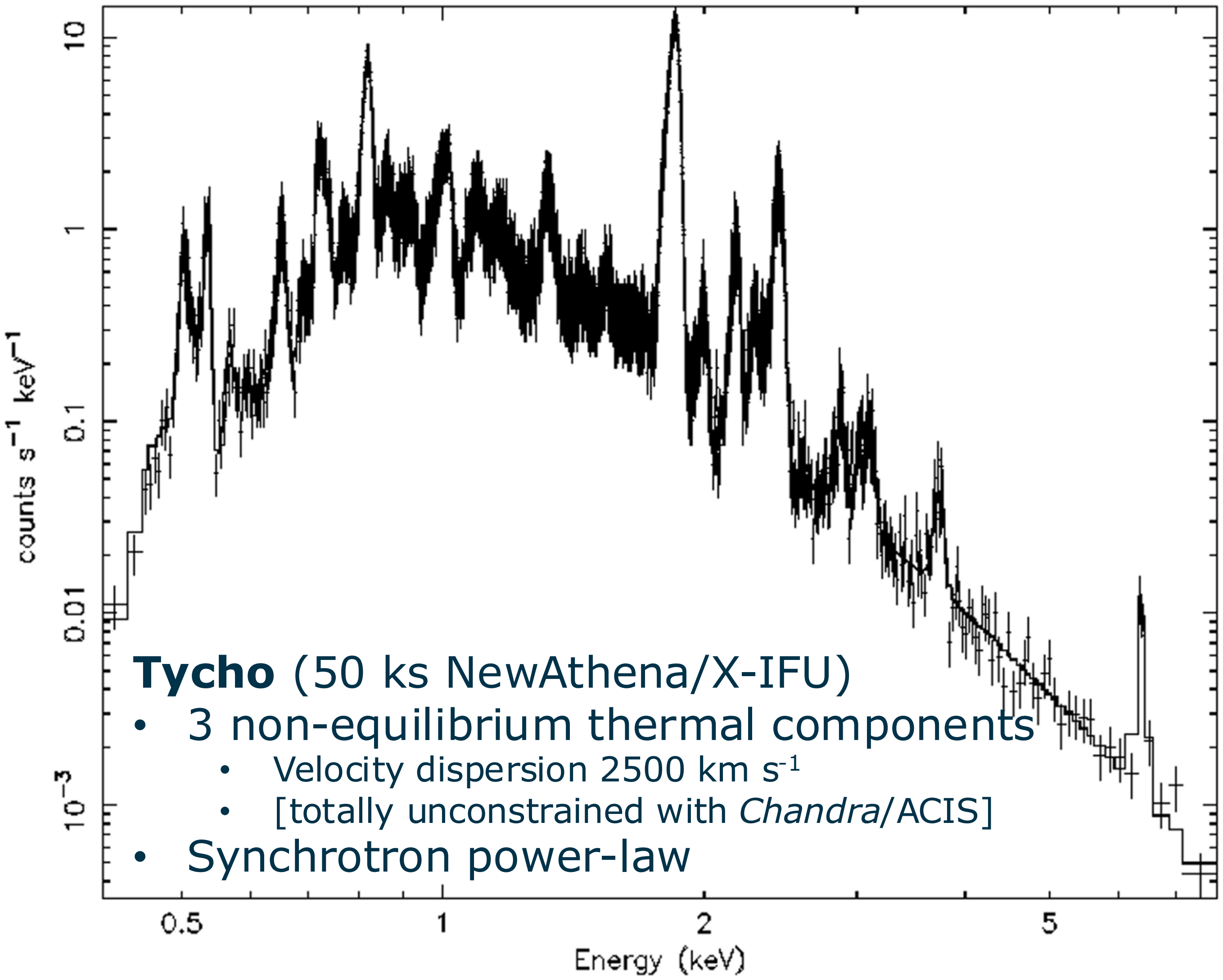
Particle accelleration in SNR

Experiments

Determination of non-thermal (synchrotron) emission due to non-thermal accelerated e$^-$

Addtional science

SN explosion mechanisms, progenitor and neutrino models via rare metals metallicity

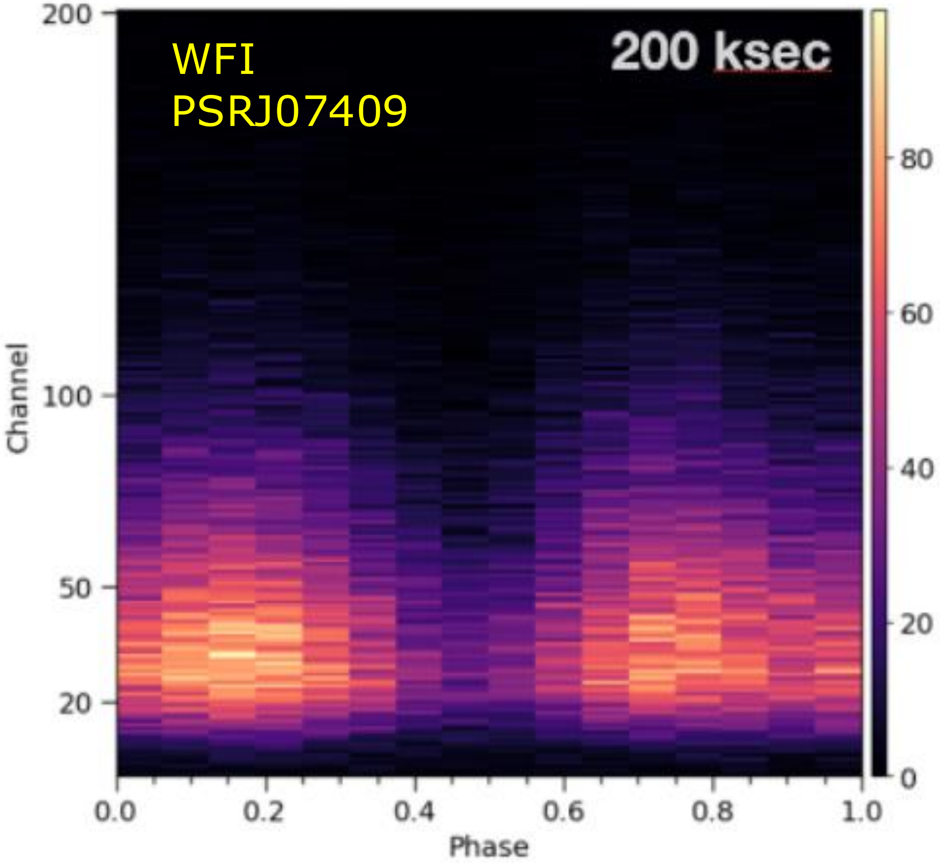


Tycho (50 ks NewAthena/X-IFU)

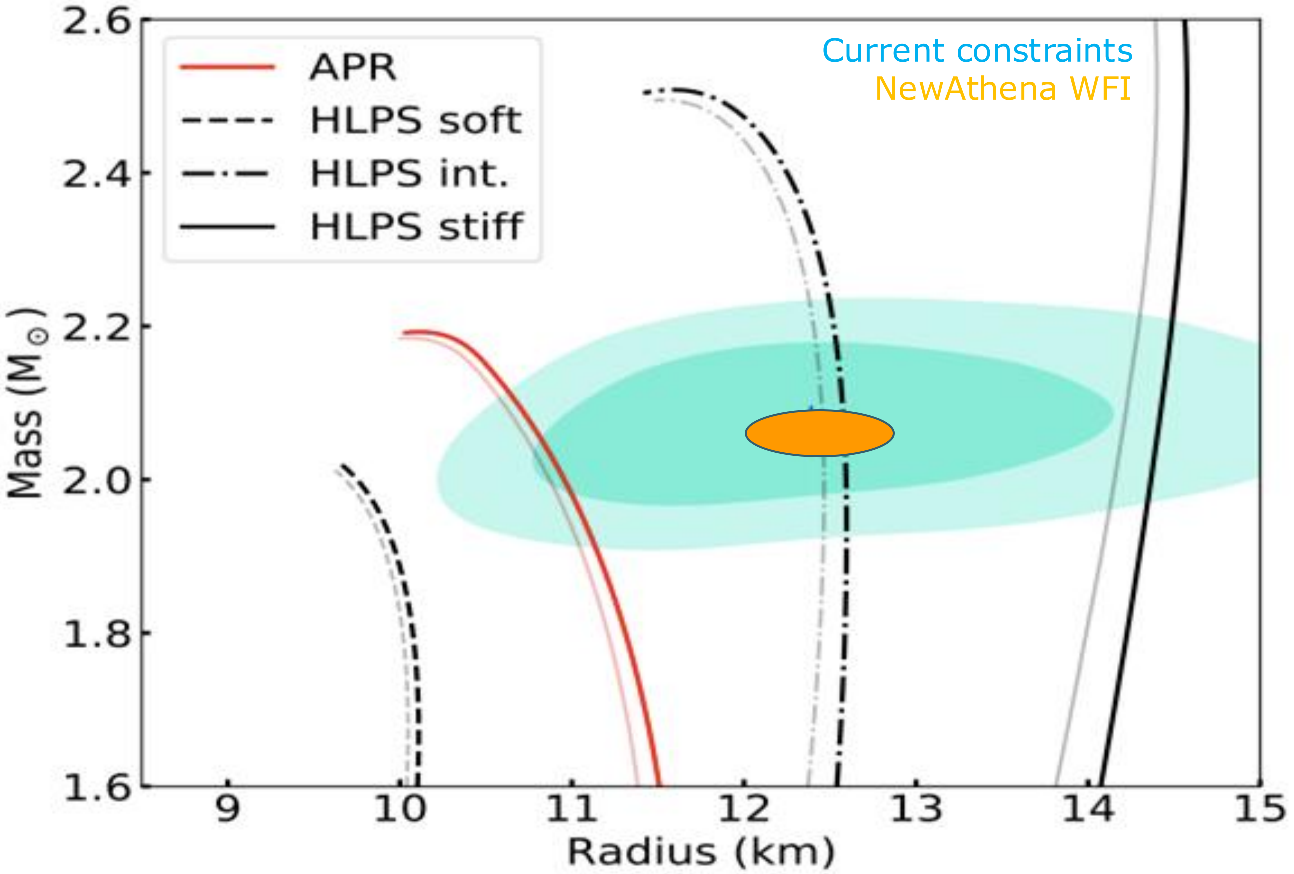
- 3 non-equilibrium thermal components
  - Velocity dispersion 2500 km s^{-1}
  - [totally unconstrained with *Chandra*/ACIS]
- Synchrotron power-law

Equation of State of NSs with [New]Athena

Credit: N.Rea/S. Vinciguerra/T. Salmi/S. Guillot/A. Watts



NewAthena/WFI simulation of an energy-dependent pulse profile for a msec pulsar



Comparison of the NICER/XMM-Newton versus NewAthena constraint on the NS mass/radius plane

High-z Gamma-Ray Bursts (GRBs)

Credit: A. Thakur, L. Piro (IAPS), M. Guainazzi (ESA)

Fundamental science question

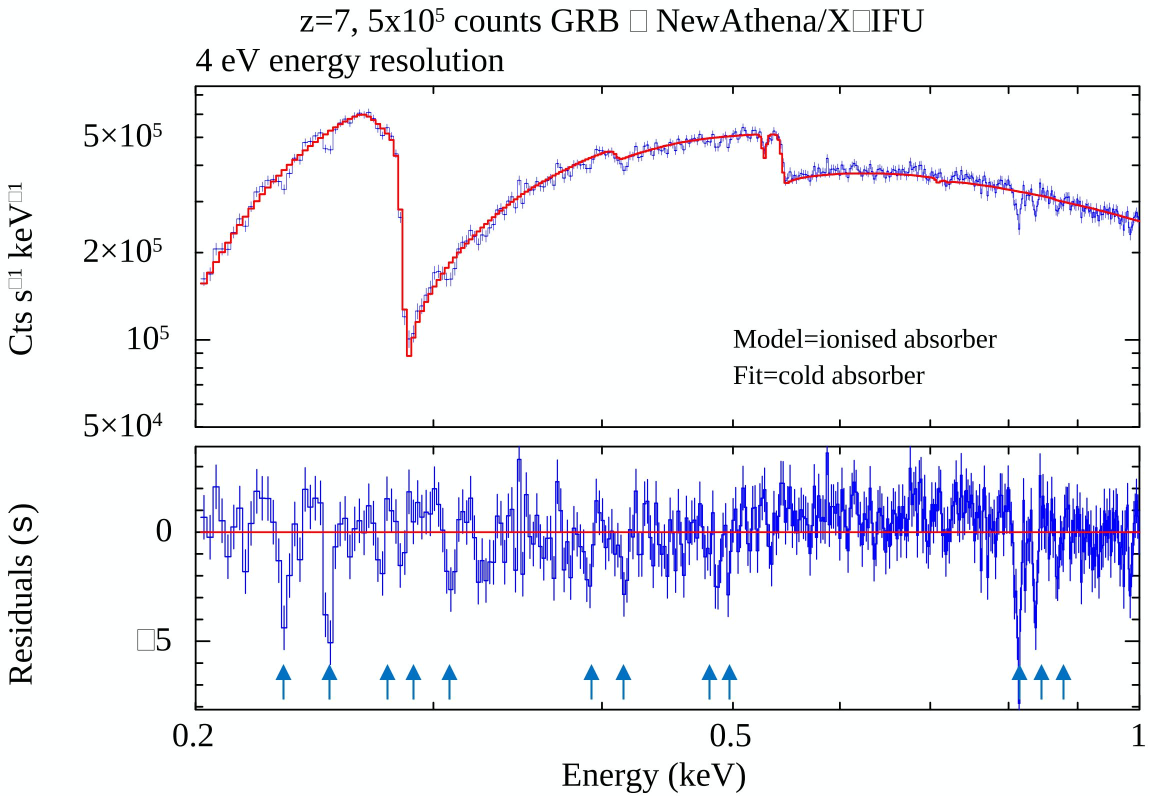
First generation of stars, generation of the first BH, dissemination of the first metals

Experiments

Absorption spectroscopy [ionised gas] of high z GRBs

Transient science mission performance

ToO response time <12 hours
Field-of-Regard: 34%

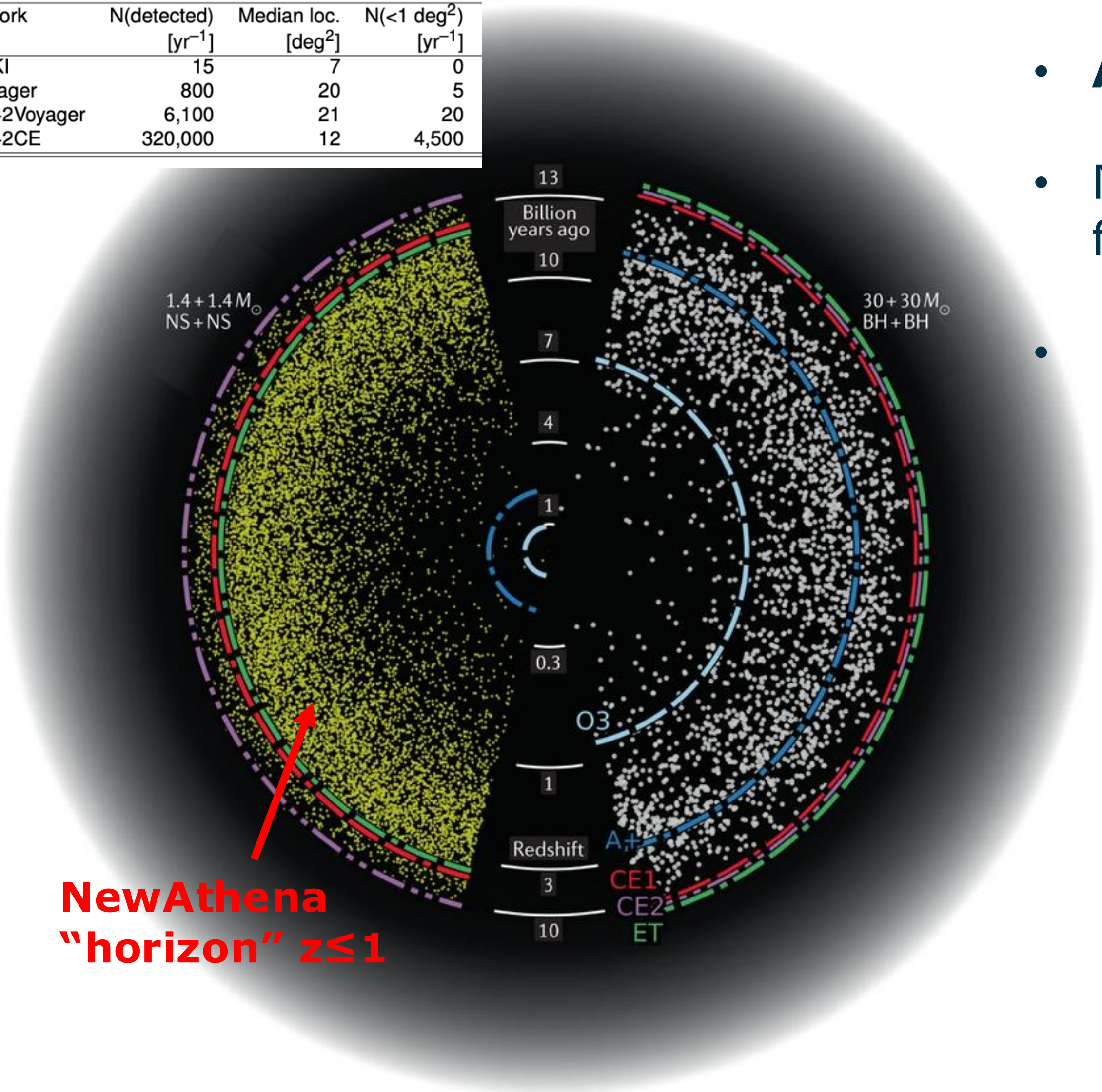


Typical error on a 10^{22} cm^{-2} column density: 10%-15%

Multi-messenger astrophysics

Bailes et al., 2021, Nat.Rev.Phys., 3, 344

Network	N(detected) [yr^{-1}]	Median loc. [deg^2]	N(<1 deg^2) [yr^{-1}]
HLVKI	15	7	0
3Voyager	800	20	5
1ET+2Voyager	6,100	21	20
1ET+2CE	320,000	12	4,500



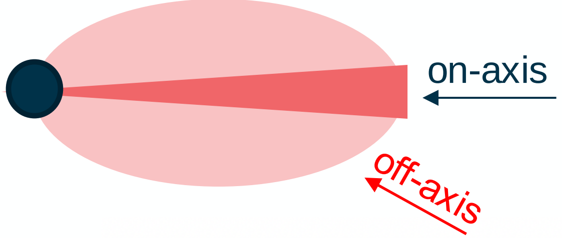
NewAthena “horizon” z≤1

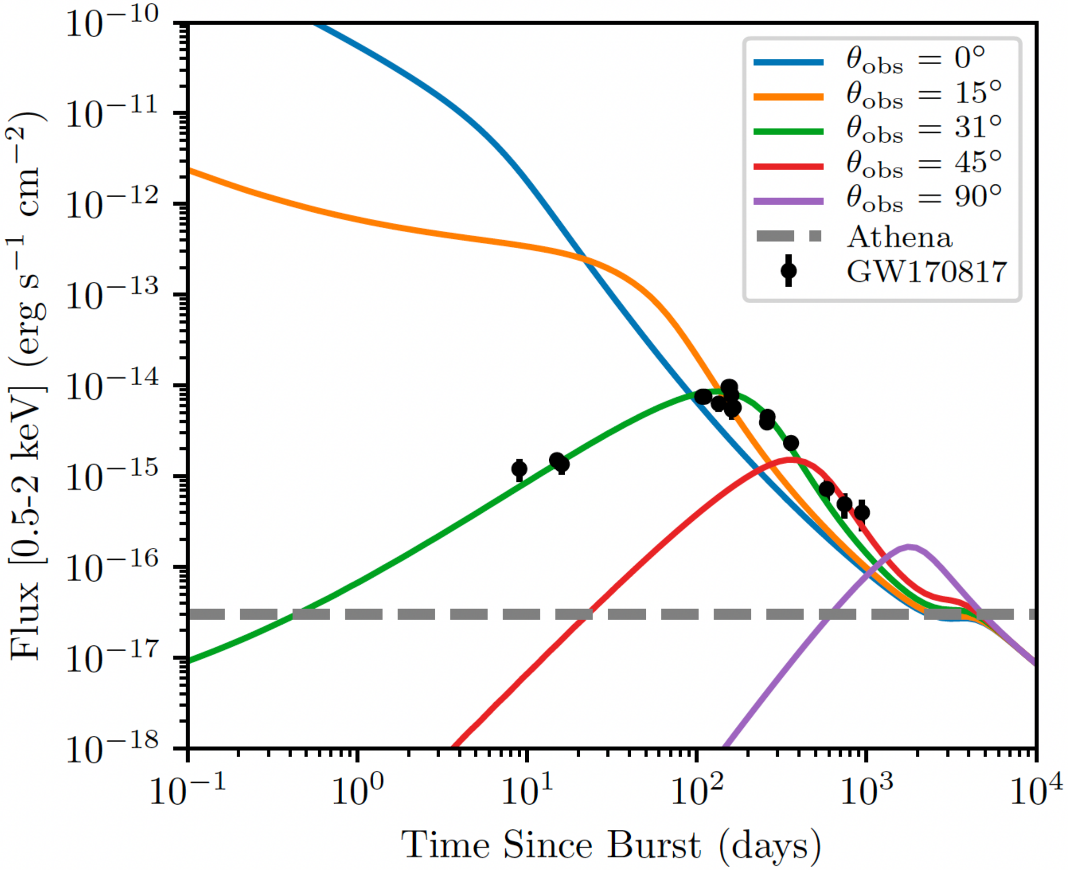
- **Accurate jet inclination for most binary systems**
- NewAthena may enable arcseconds locatization on a few targets per year
- Main science areas:
  - Cosmology (through joint Gravitational Wave and electromagnetic observations)
    - X-rays break the degeneracy between inclination and luminosity distance
  - Nature of the remnant compact object through X-ray variability
  - Accurate metallicity in kilonovae through disentangling non-thermal contribution

Full census of GRB jets

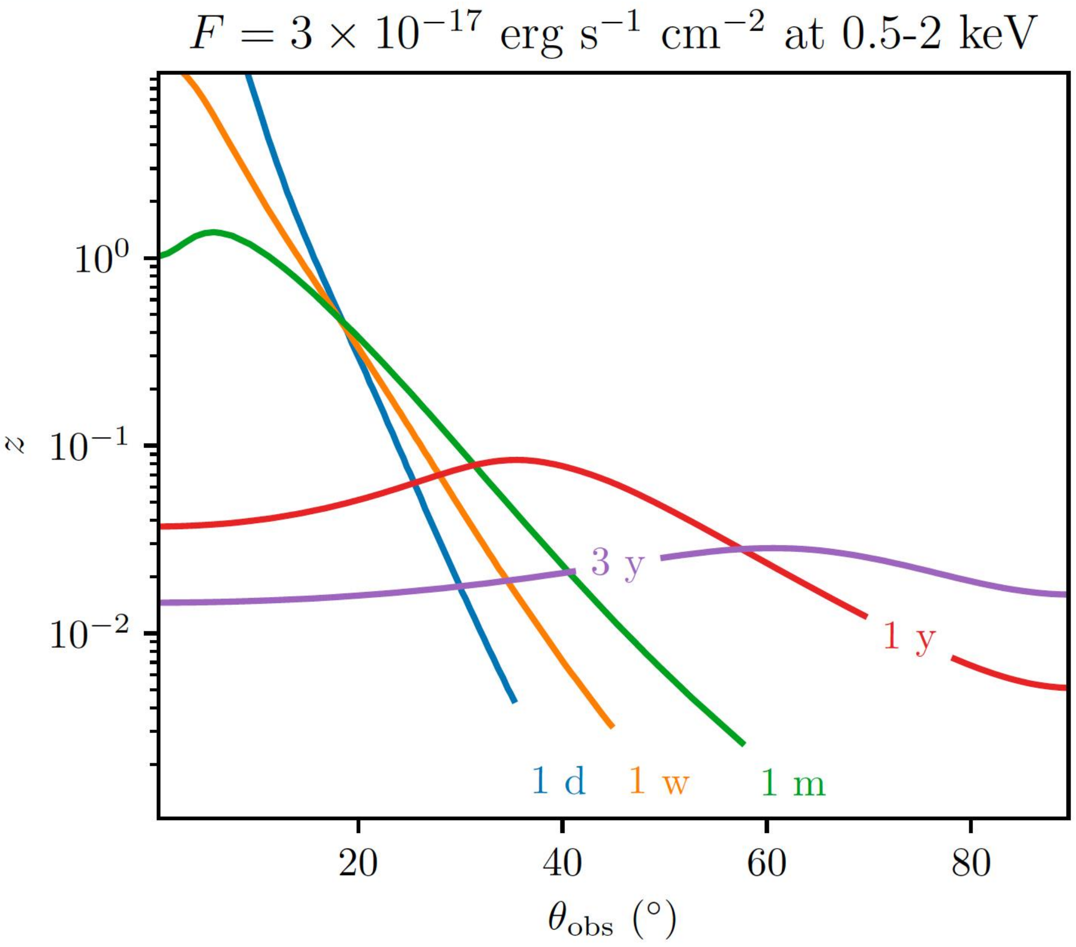
Troja et al., 2020, MNRAS, 498, 5643

Piro et al., 2022, ExA, 54, 23





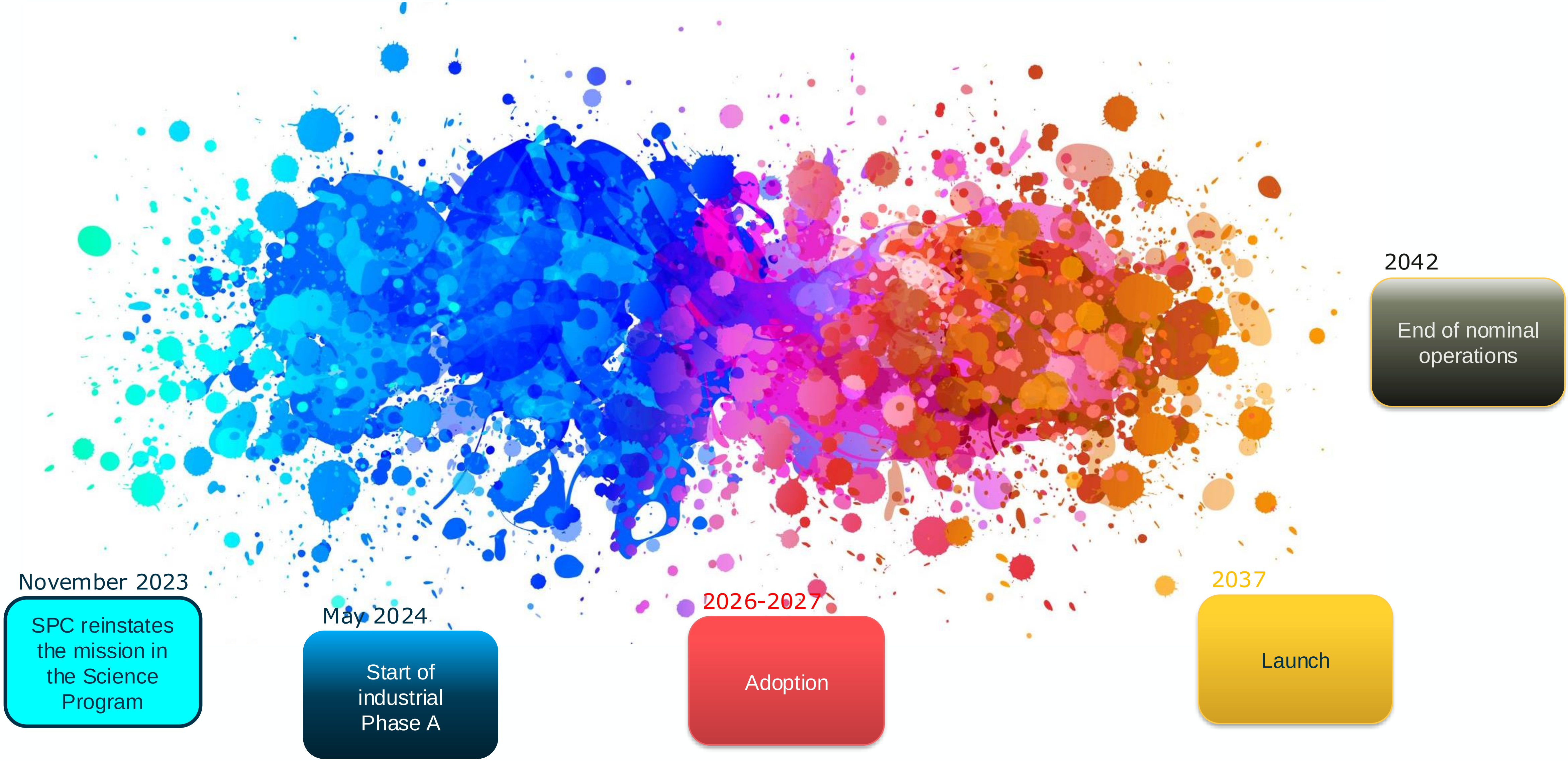
Detectability of a GW170817A-like event by *Athena*


$F = 3 \times 10^{-17}$ erg s^{-1} cm^{-2} at 0.5-2 keV

Full list of NewAthena science cases

- Map the properties of the most common baryonic reservoirs in the Universe, and probe their evolution and connection to the cosmic web
- Chemical enrichment over cosmic time
- Probe the accretion physics and accretion flow models at high and low accretion rates, and its change at different time scales
- Probe feedback mapping (stellar or AGN)
- Redshift evolution of entropy profiles in cluster outskirts
- Residual cooling and thermal instabilities in cool core clusters
- Star-planet interactions
- SN population
- Colliding winds in binaries
- Magnetospheric activity in low mass stars
- Mass loss in massive stars
- Masses of accreting white dwarfs
- Magnetars
- Pulsar-wind nebulae
- Novae and Pne
- Double-degenerate binaries
- Chemistry of the cold, warm and hot ISM
- Dust-scattering halos
- Physics beyond the standard model
- Extragalactic transients and TDEs

NewAthena status (diagram created by AI, not in scale)



November 2023

SPC reinstates the mission in the Science Program

May 2024

Start of industrial Phase A

2026-2027

Adoption

2037

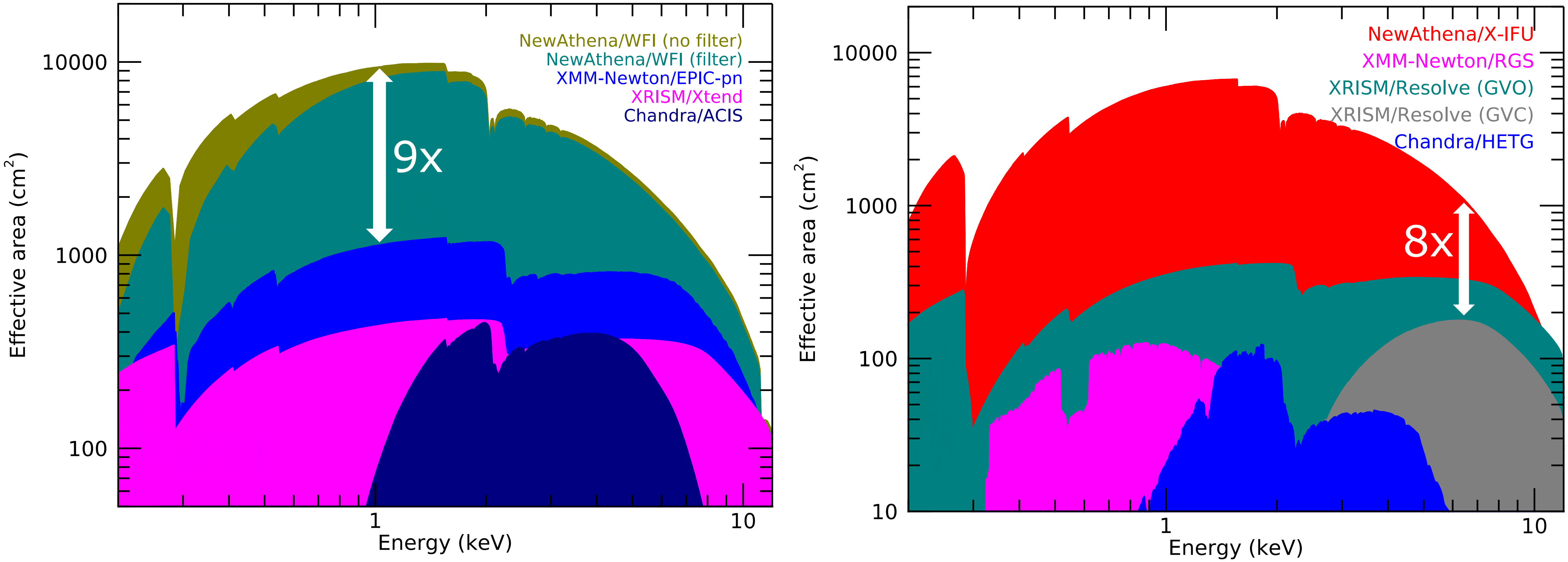
Launch

2042

End of nominal operations

A large mirror area mission

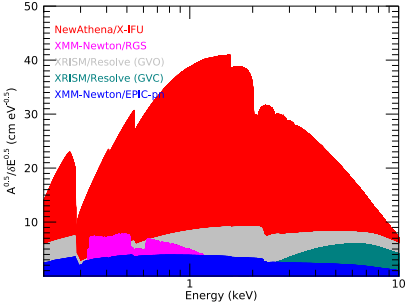
Comparison with commensurate operational X-ray observatories



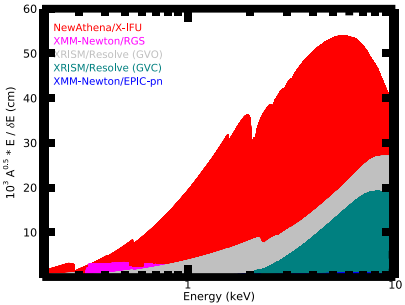
Matteo Guainazzi, "NewAthena"
INTEGRAL Conference, ESAC, 24 October 2024

X-IFU spectroscopic capabilities in context

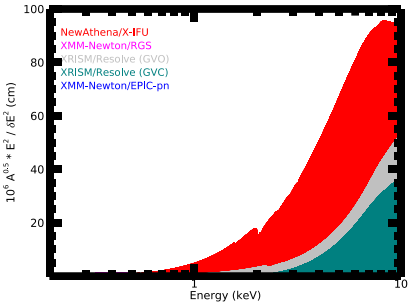
Detection weak lines



Velocity strong lines



Broadening strong lines



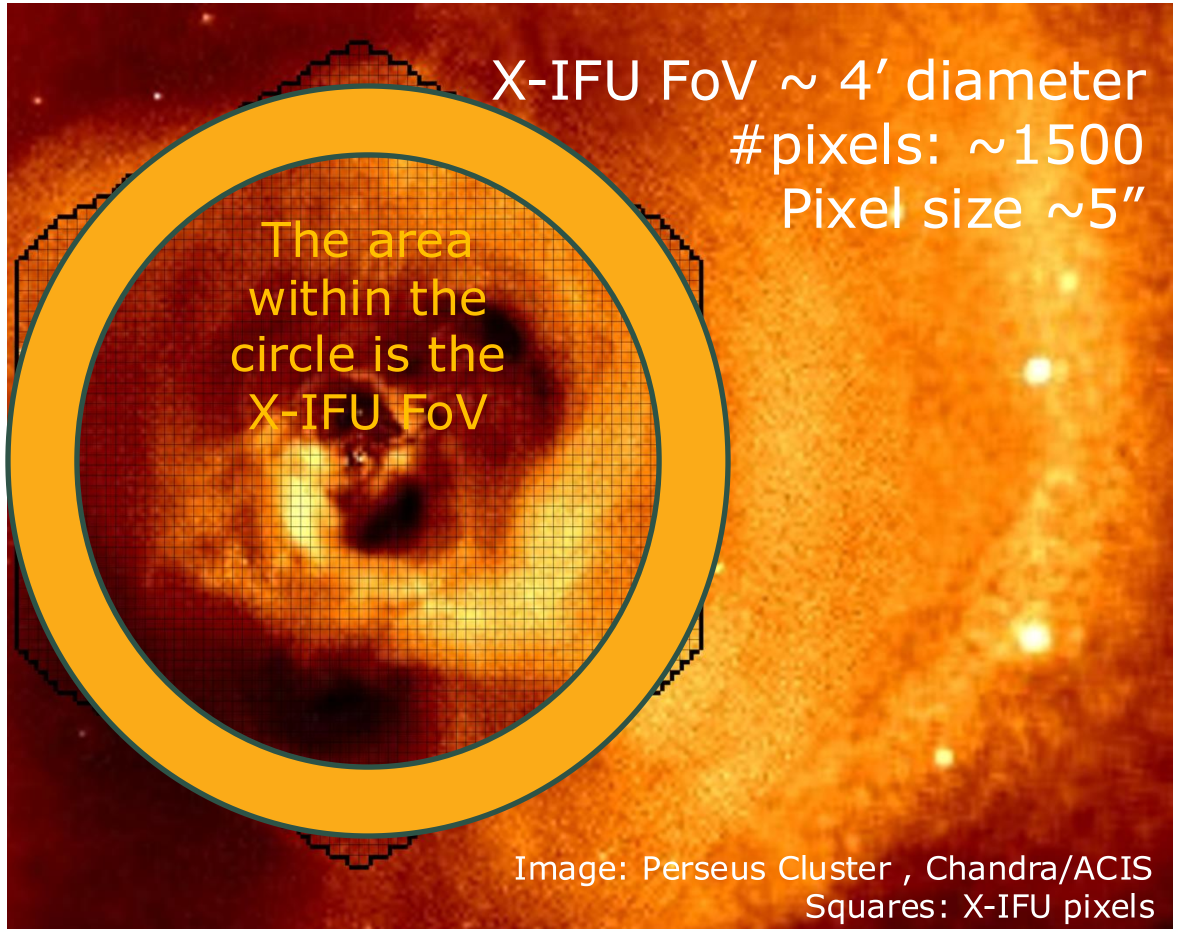
	FoM	Strong line	Weak line
Detection	M_l	6.1	6.8
Velocity	M_v	7.5	8.4
Broadening	M_σ	9.1	10.2

Energy-weighted 2-9 keV ratio between X-IFU and *Resolve* FoMs

Fully X-ray Integral Field Unit capabilities

Credit: J. de Plaa (SRON)

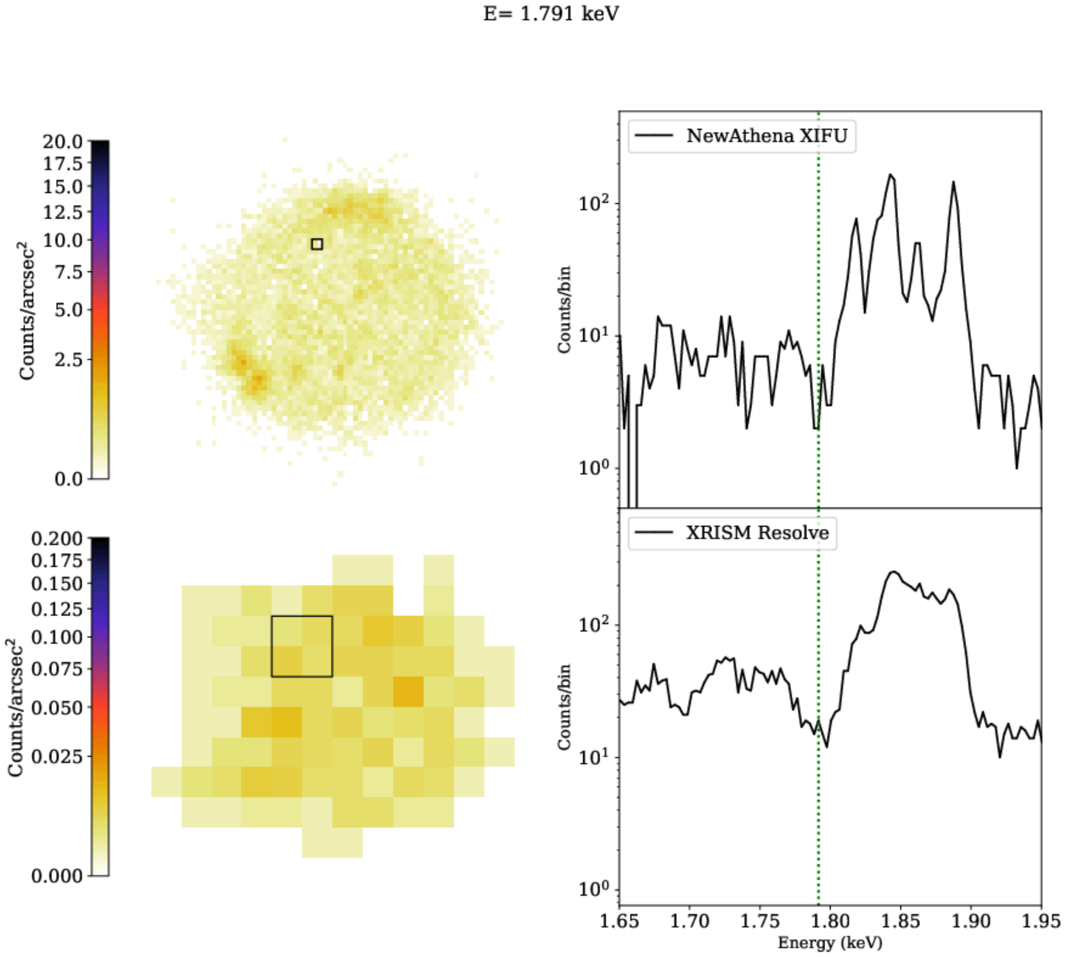
Credit: F. Acero (CEA) & C. Kirsch (FAU)


X-IFU FoV ~ 4′ diameter
#pixels: ~1500
Pixel size ~5″

The area within the circle is the X-IFU FoV

Image: Perseus Cluster , Chandra/ACIS
Squares: X-IFU pixels

Cas A: NewAthena/X-IFU vs. XRISM/*Resolve*



NewAthena X-ray survey performance (WFI)

Credit: A. Rau (MPE), J. Aird (UoE)

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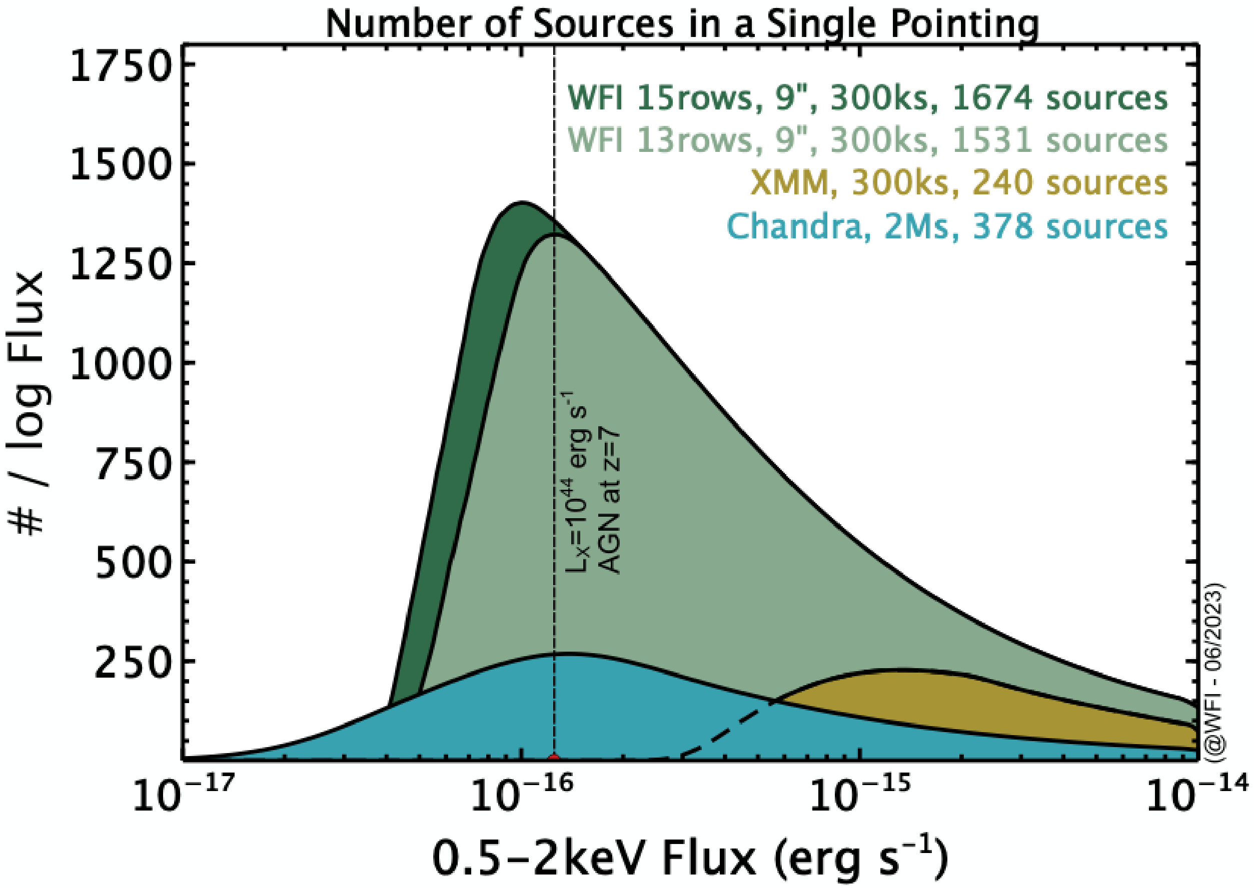
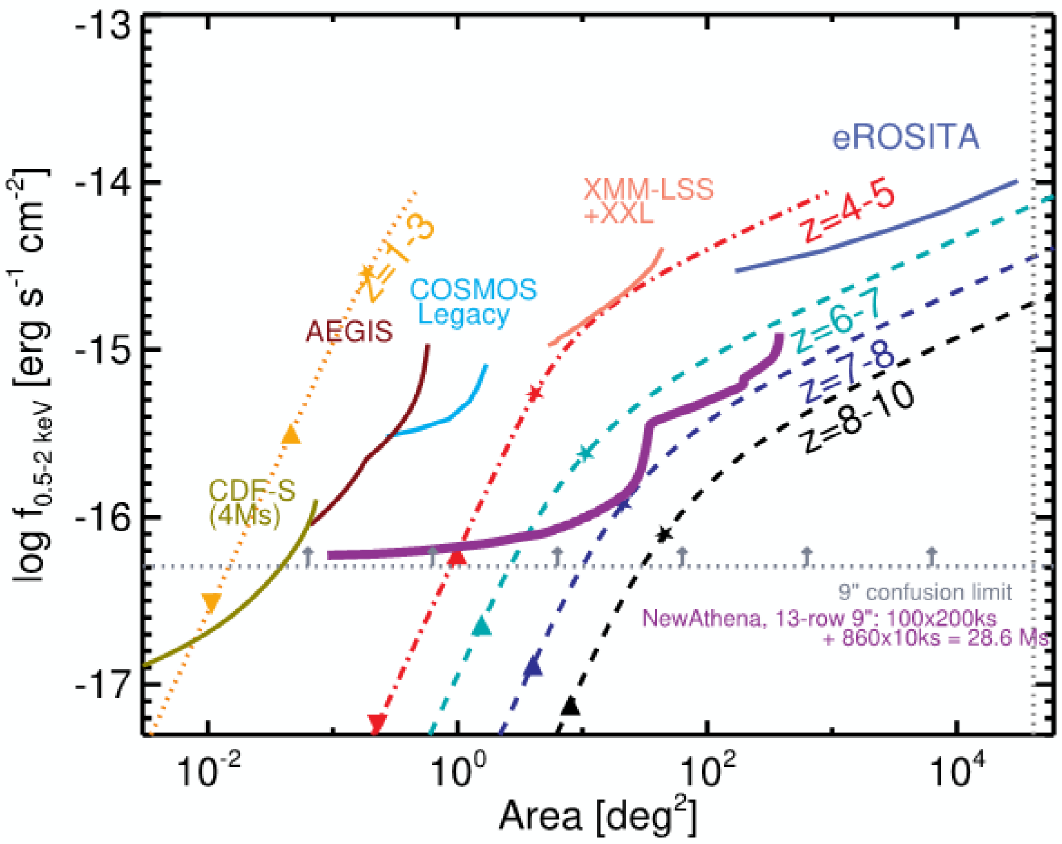
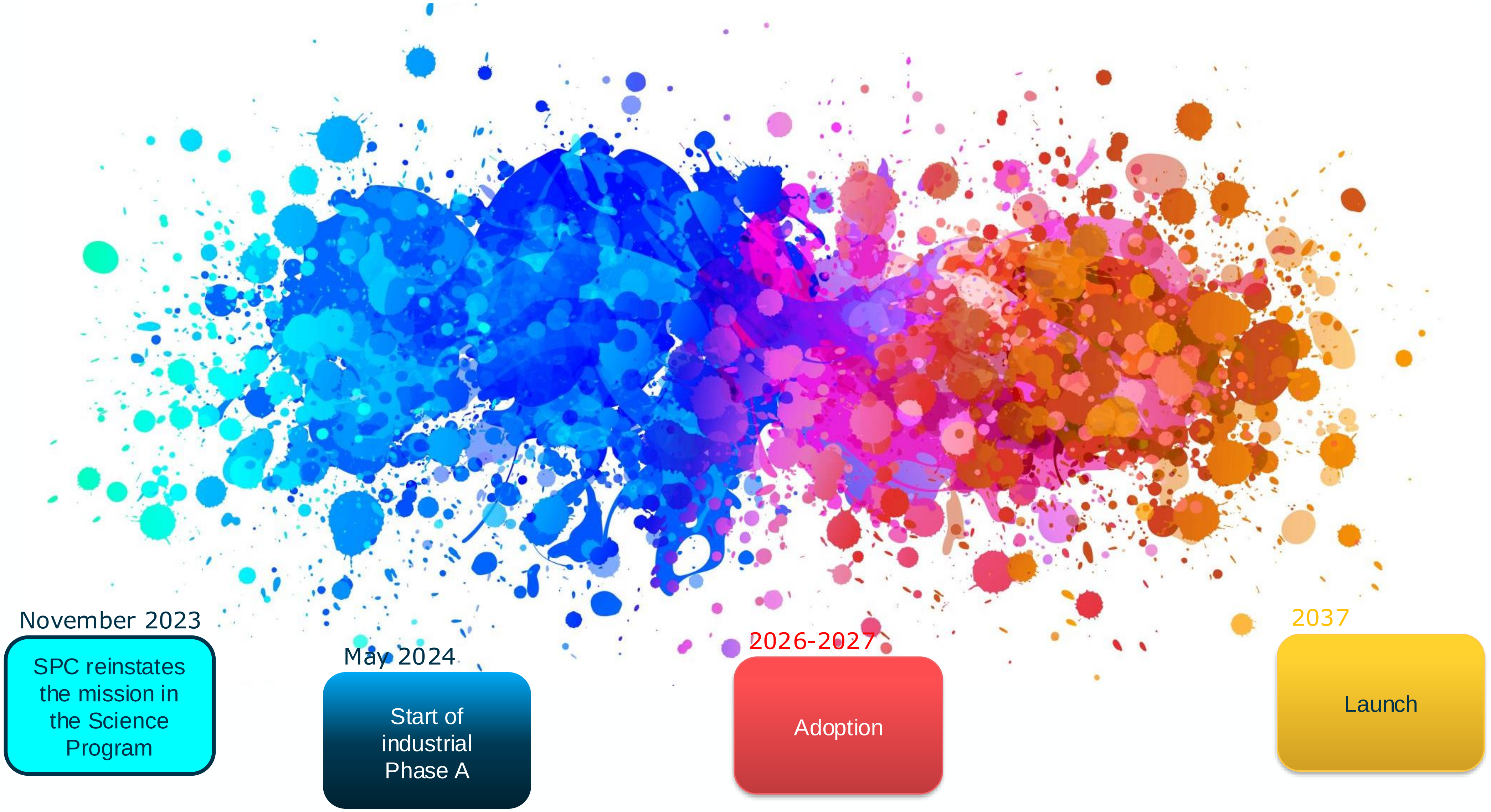




Hint: the NewAthena/WFI grasp exceeds that of eROSITA by a factor ~2

NewAthena status (diagram created by AI, not in scale)



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