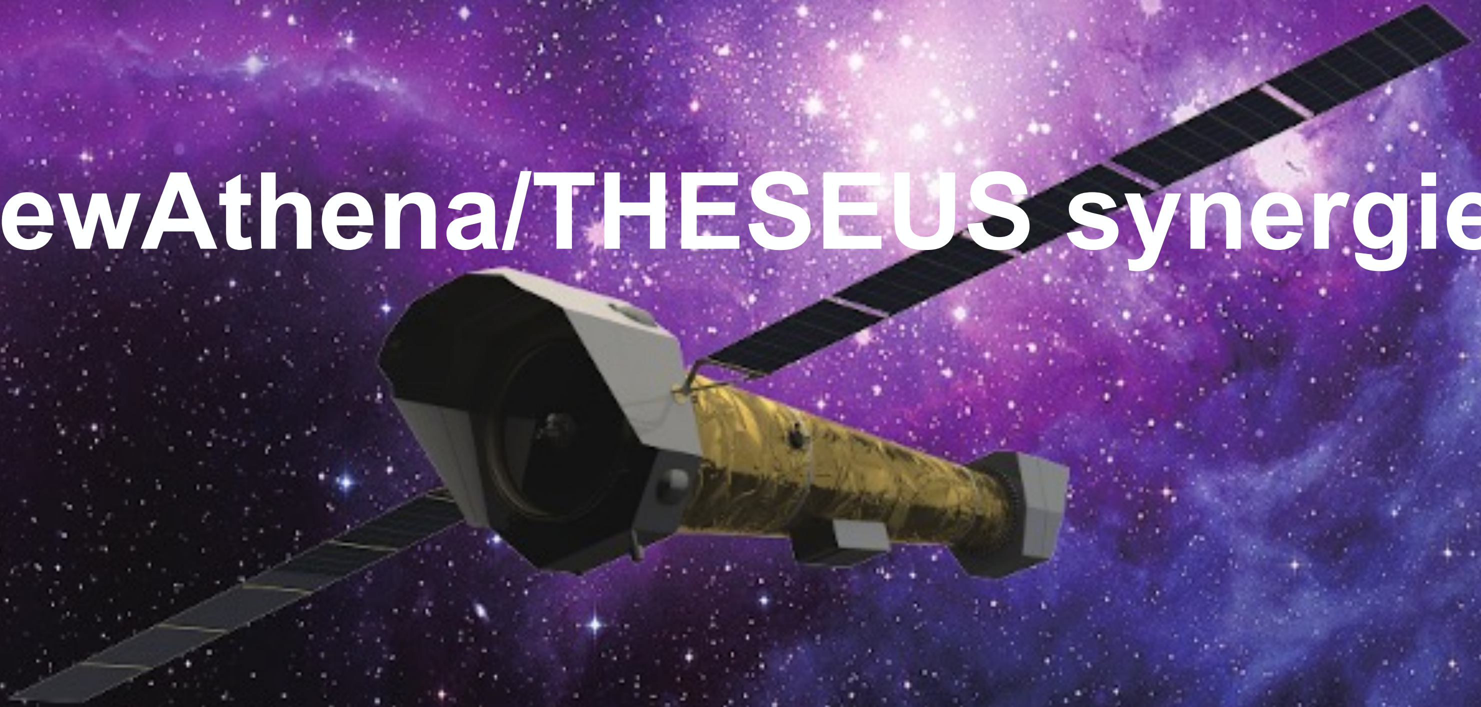
NewAthena/THESEUS synergies



Matteo Guainazzi

NewAthena ESA Study Scientist

Credit: IRAP, CNES, ESA & ACO

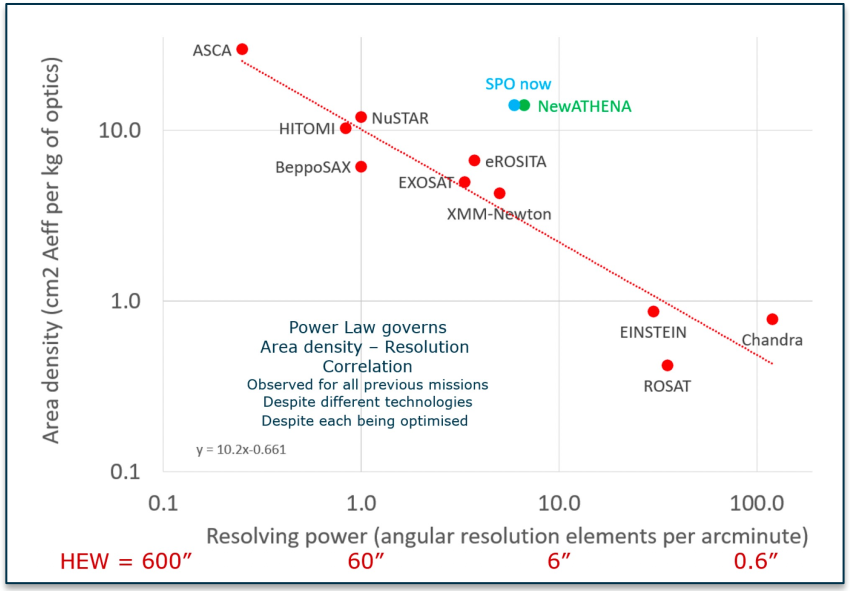
NewAthena: three key science-enabling innovations

Bavdaz et al. 2023. SPIE, 1267902-1

Credit: D. Barret (IRAP)

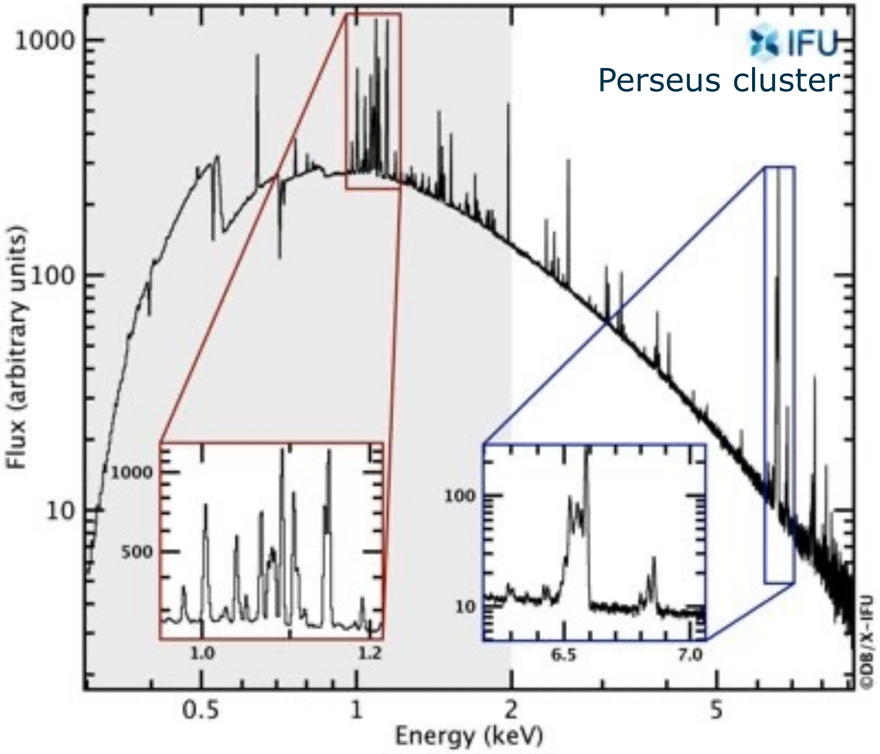
Credit: A. Rau (MPE)

The largest space-qualified X-ray mirror for astronomy



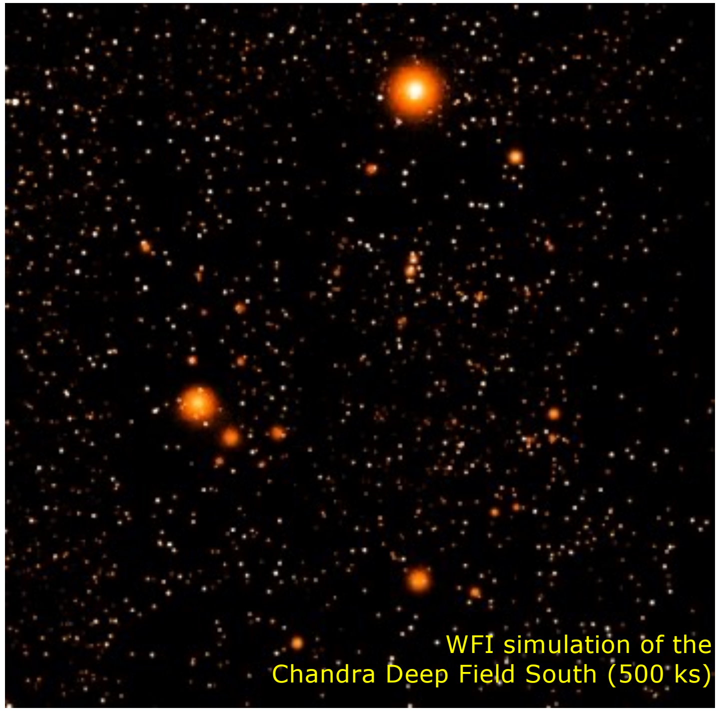
X-ray telescope based on Silicon Pore Optics technology (ESA), 9” HEW, 1.0 m^2 area @1 keV

Unprecedented spectroscopic capabilities



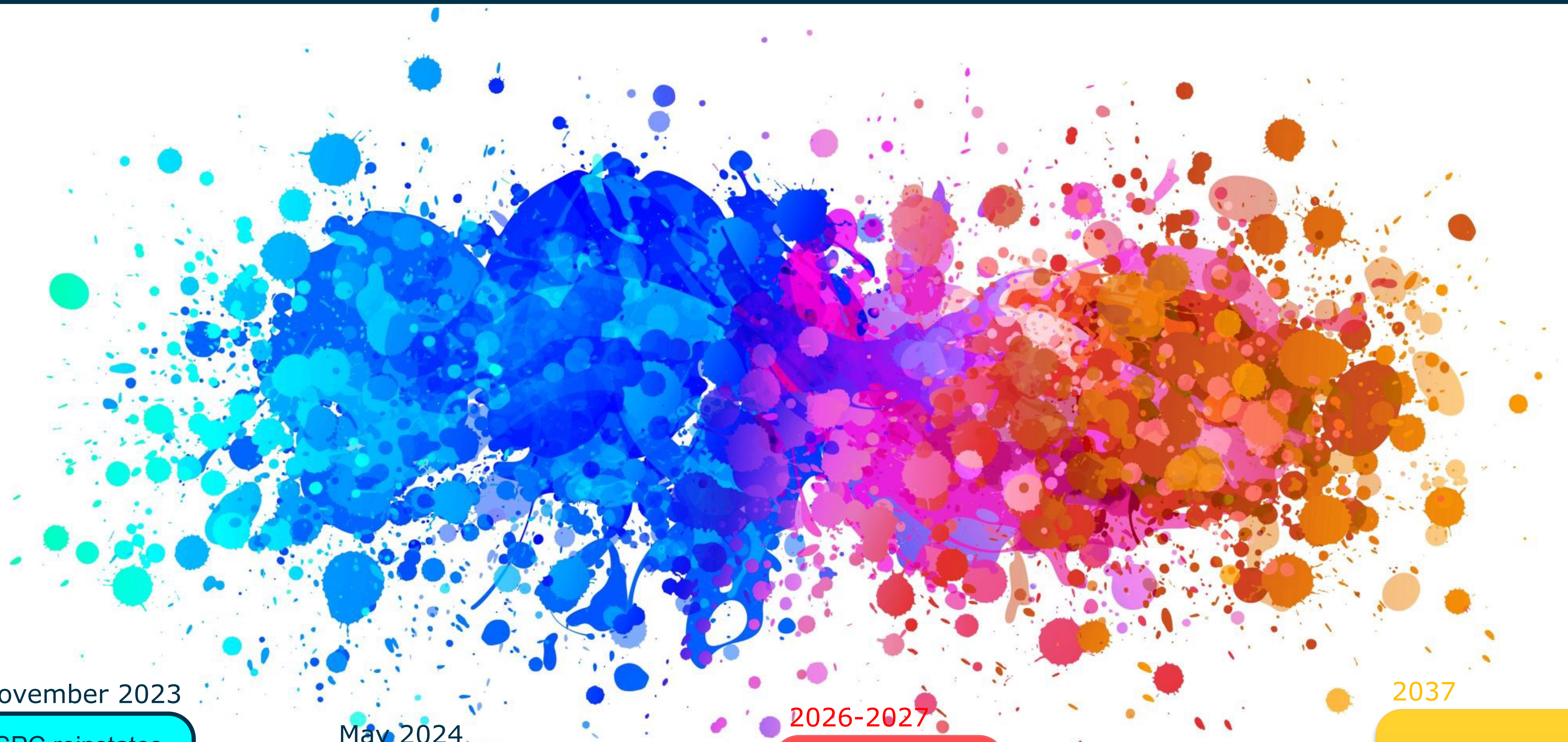
X-Ray Integral Field Unit (X-IFU) (CNES/IRAP-led), ≤4 eV energy resolution over >1500 pixels, ~5” each (4’ effective diameter FoV)

The fastest sky X-ray survey machine



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

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

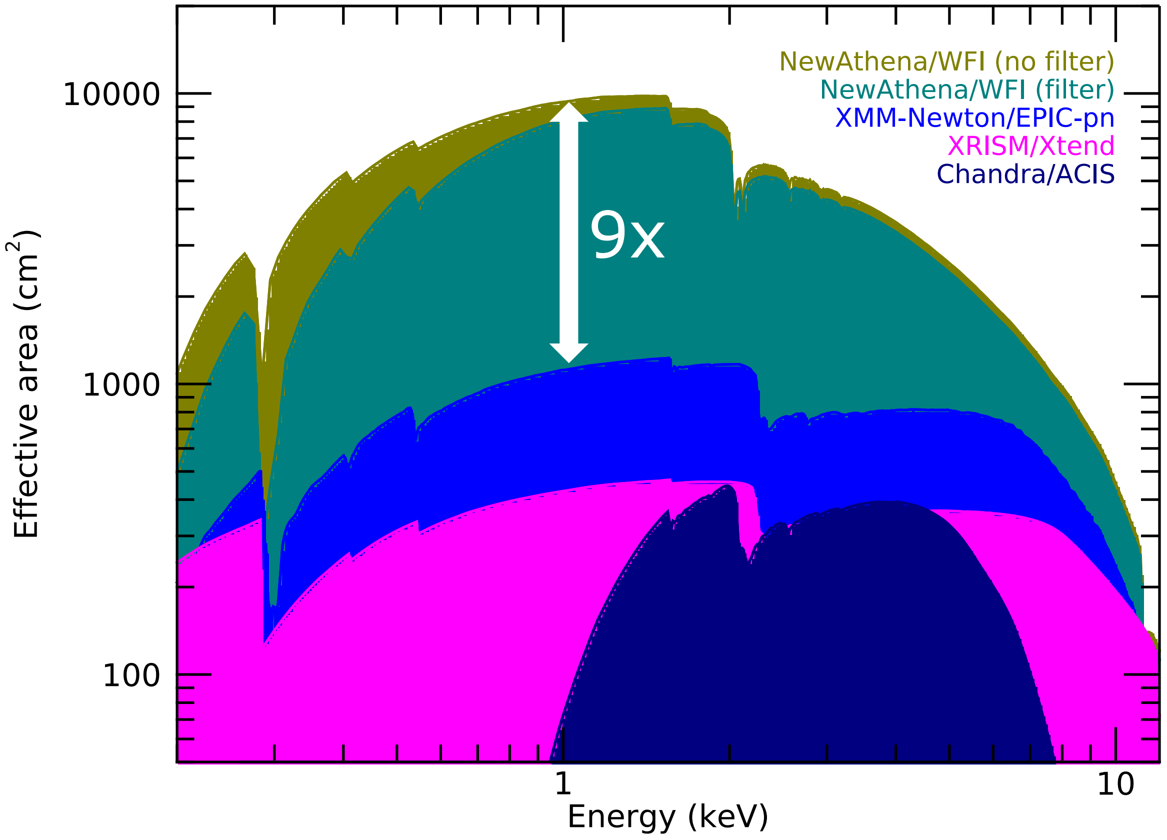
Adoption

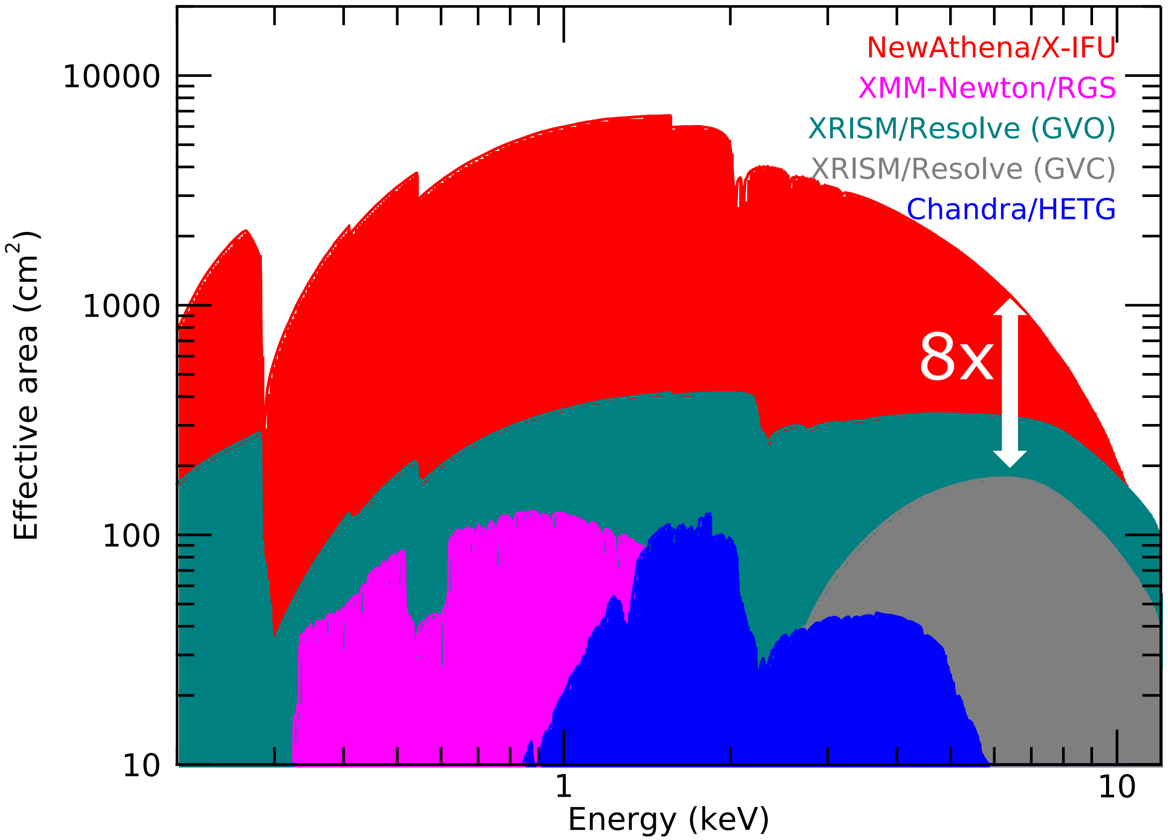
2037

Launch

A large mirror area mission

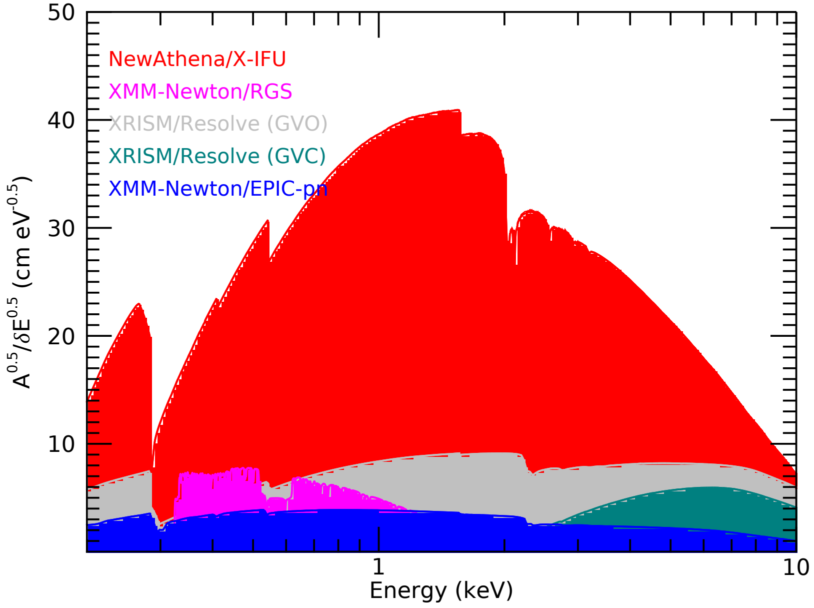
Comparison with commensurate operational X-ray observatories



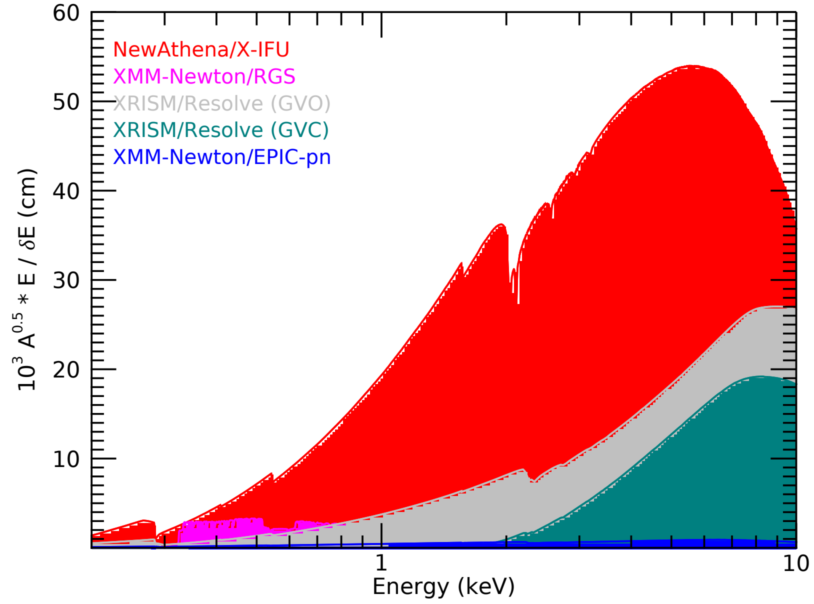


X-IFU spectroscopic capabilities in context

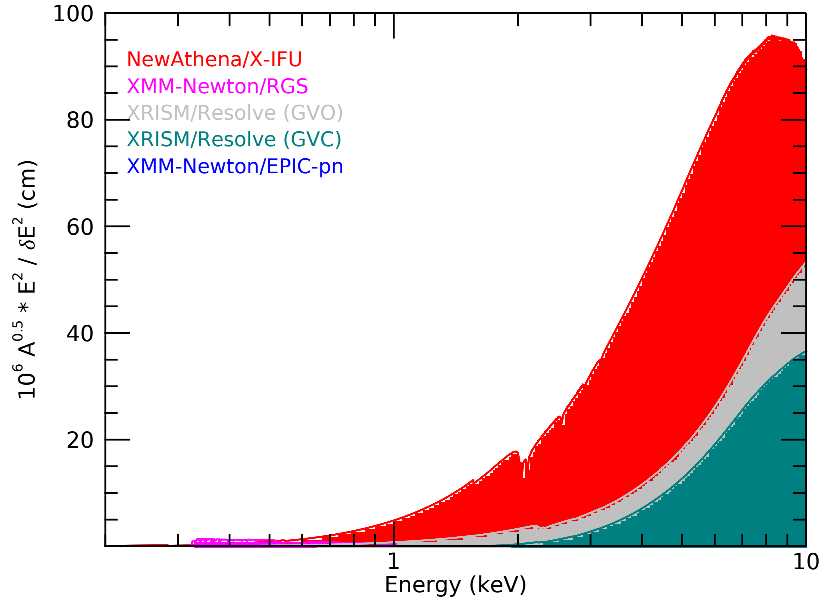
Detection weak lines



Velocity strong lines



Broadening strong lines



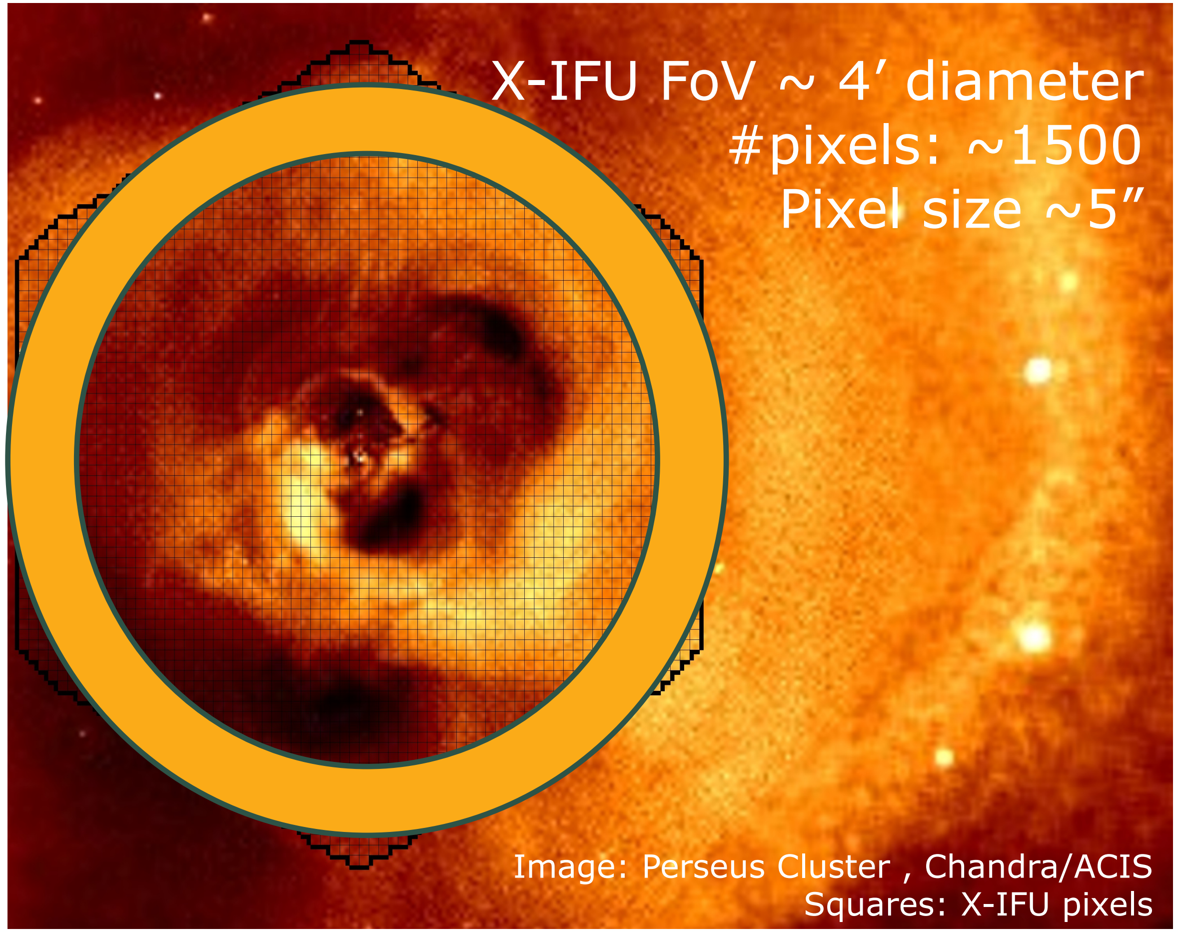
	FoM	Strong line	Weak line
Detection	M_l	6.1	6.8
Velocity	M_v	7.5	8.4
Broadening	M_σ	9.1	10.2

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

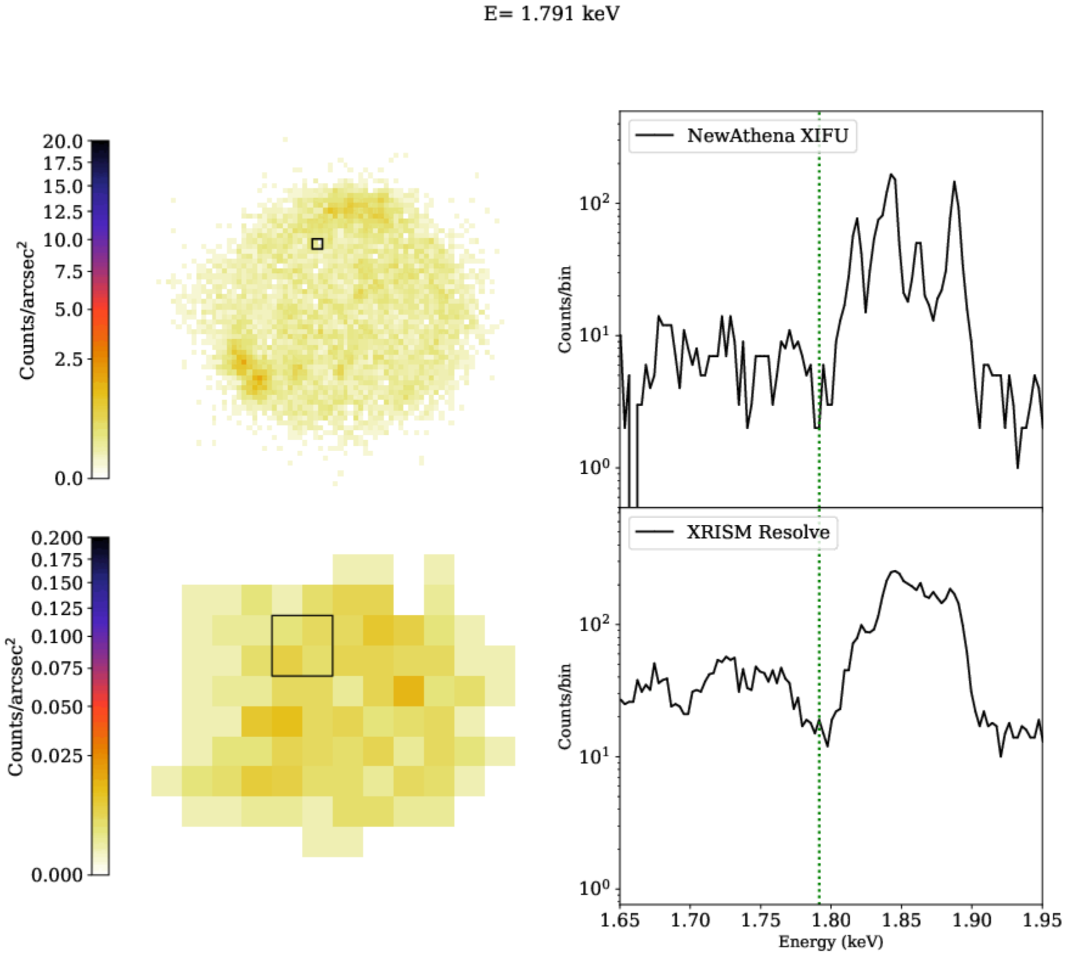
Fully X-ray Integral Field Unit capabilities

Credit: J. de Plaa (SRON)

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



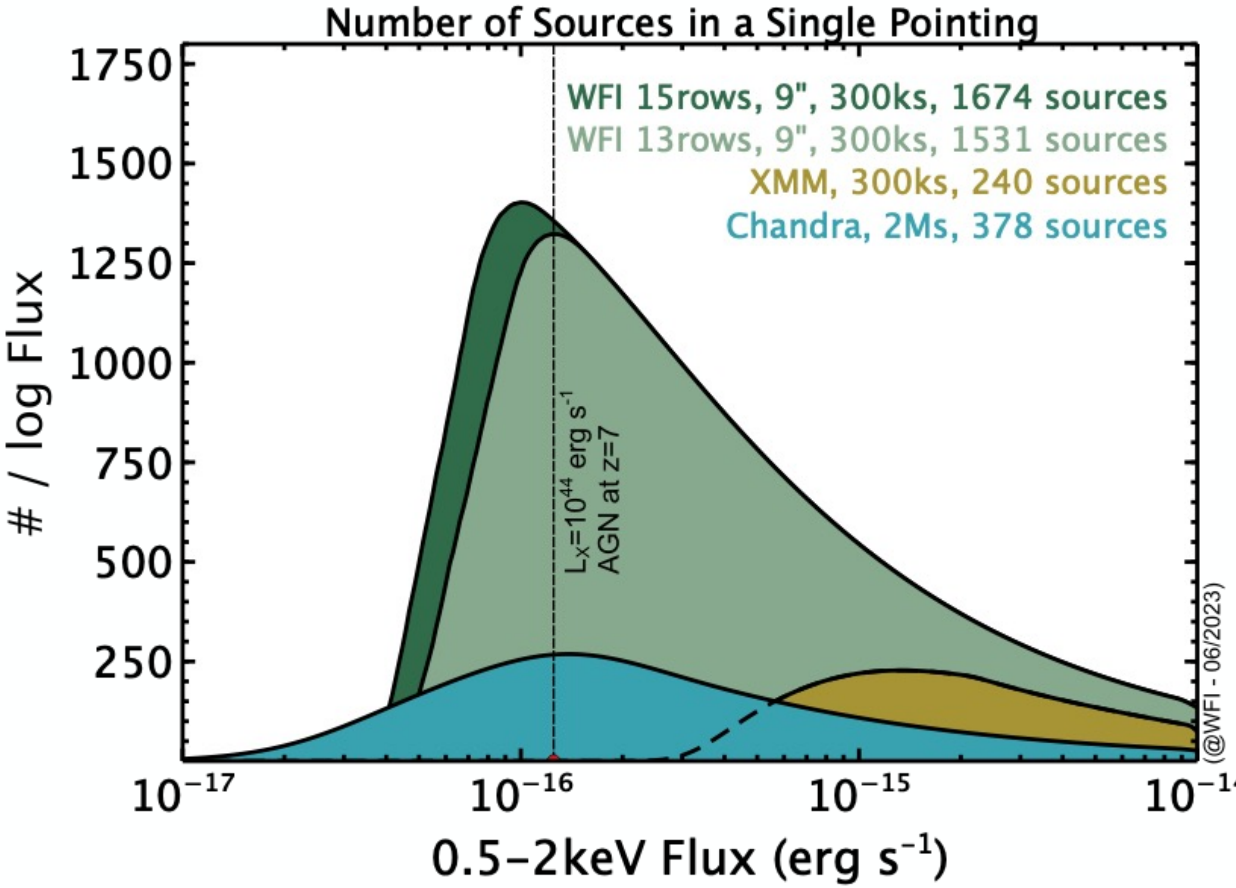
Cas A: NewAthena/X-IFU vs. XRISM/*Resolve*

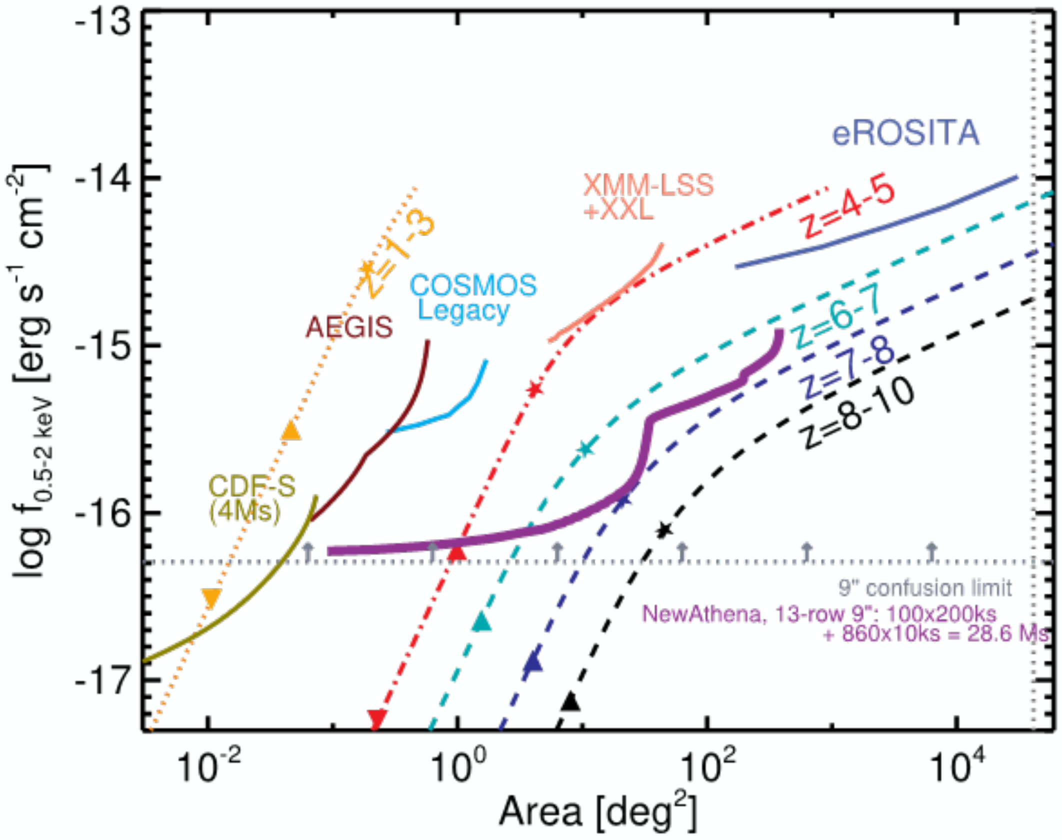


NewAthena X-ray survey performance (WFI)

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

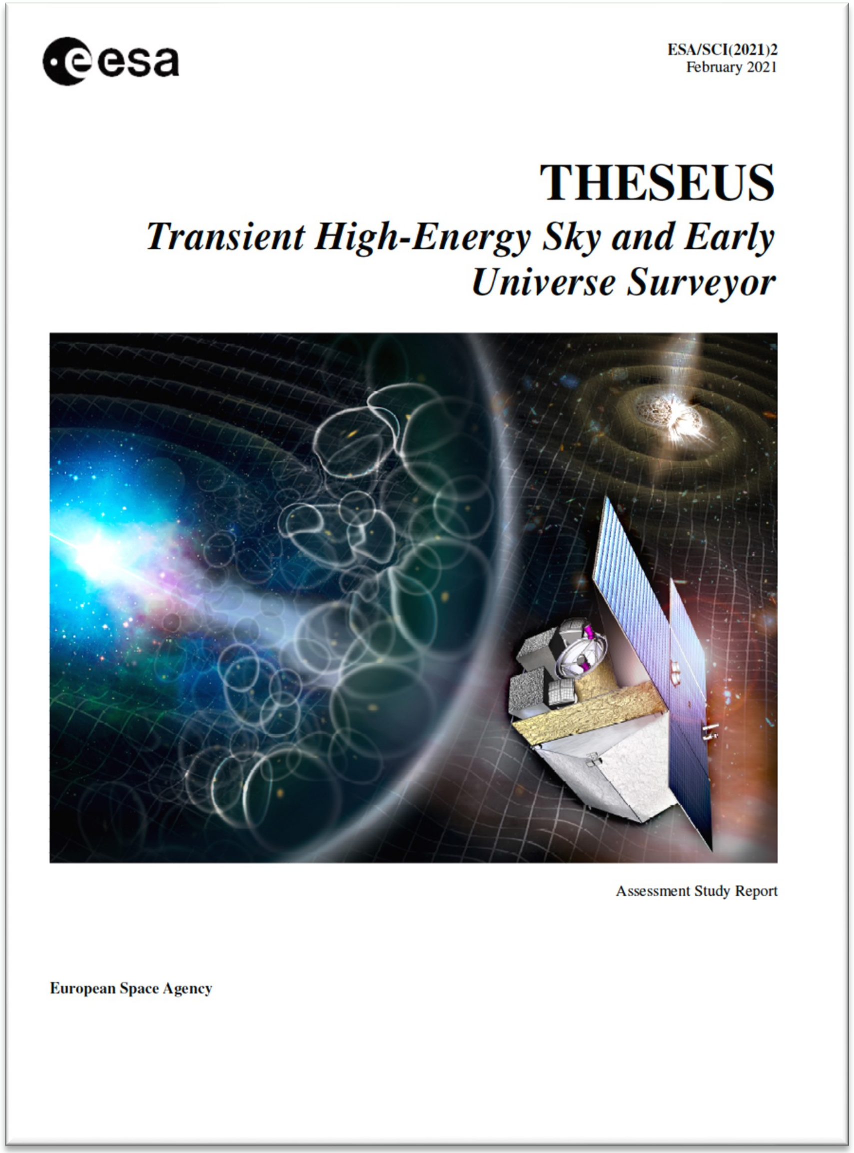
Credit: J. Aird (UoE)

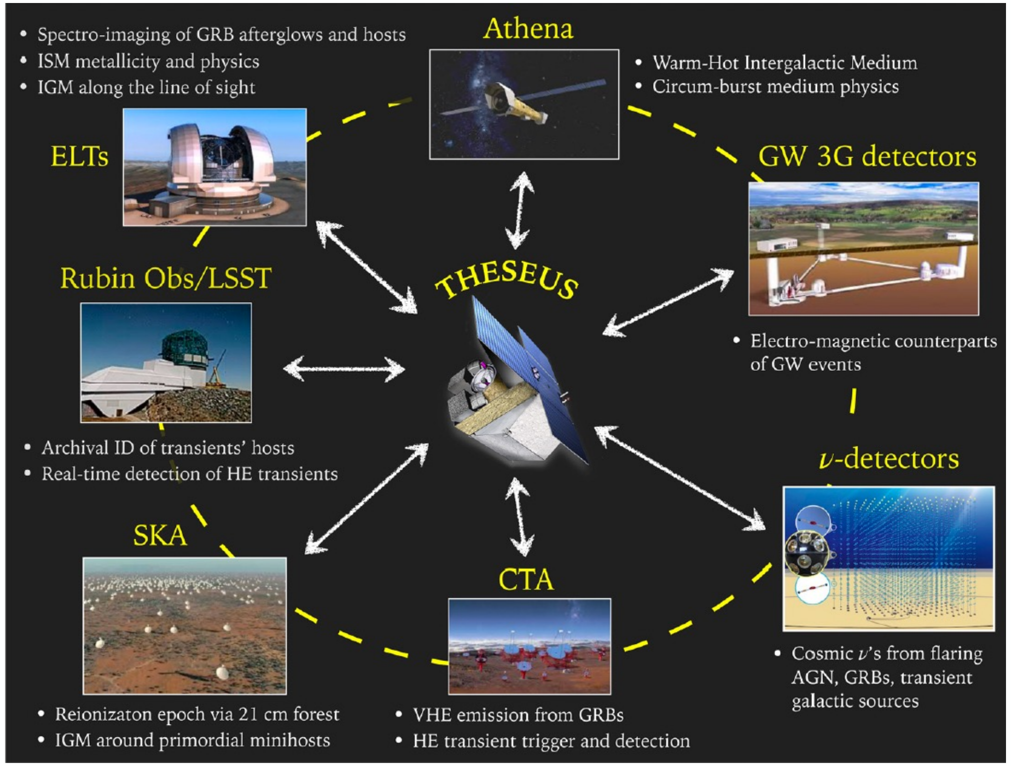




Hint: the NewAthena/WFI grasp exceeds that of eROSITA by a factor ~2

Athena/THESEUS synergies





- Probe stellar population in the early Universe
- Using GRB as backlight to probe the WHIM
- Galactic and extra-galactic transient sources
- Multi-messenger astrophysics

High-z Gamma-Ray Bursts (GRBs)

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

Fundamental science question

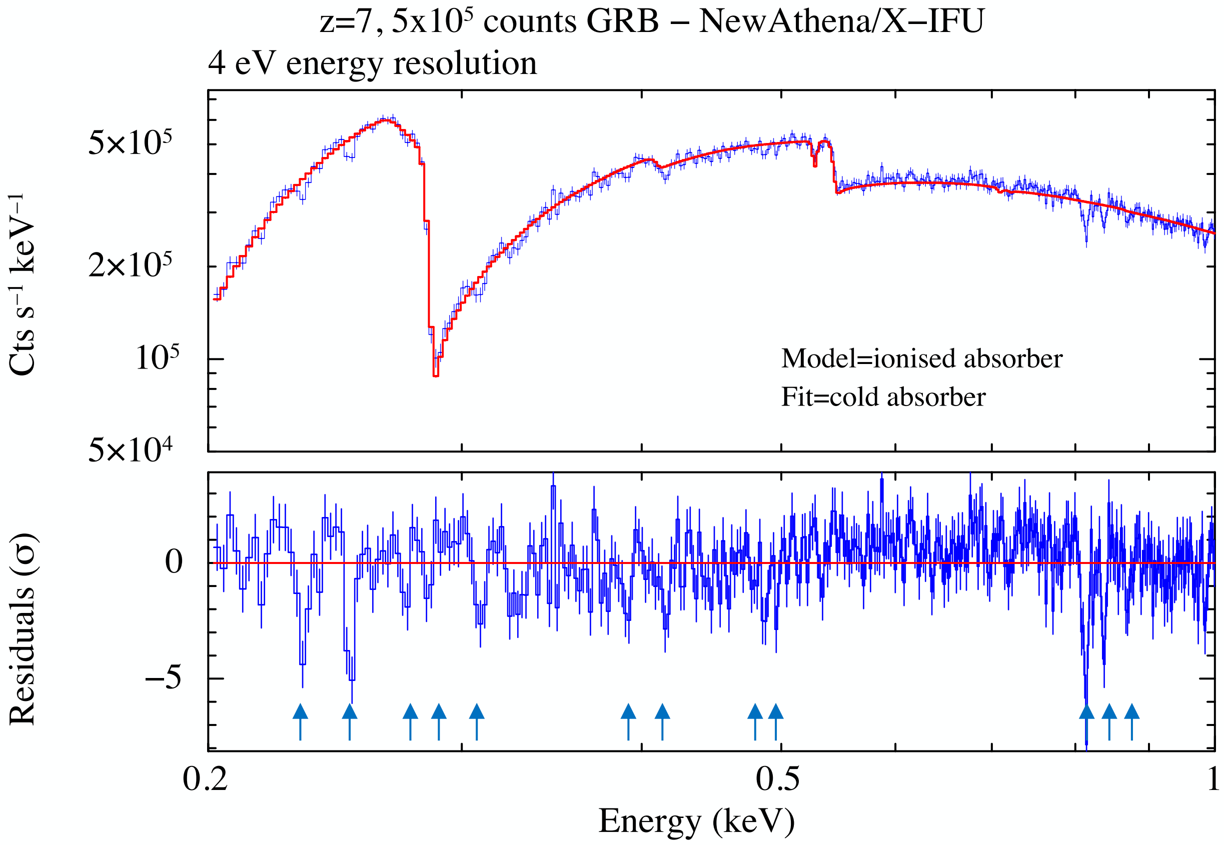
First generation of stars, generation of the first BH, dissemination of the first metals

Experiments

Measure the elemental abundance of the medium around high-z GRBs

Key X-IFU and mission performance

X-IFU area and energy resolution, ToO response time (≤12 hours), FoR (34%)



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

Map baryonic reservoirs: WHIM spectroscopy

Credit: F. Nicastro (OAR)

Fundamental science question

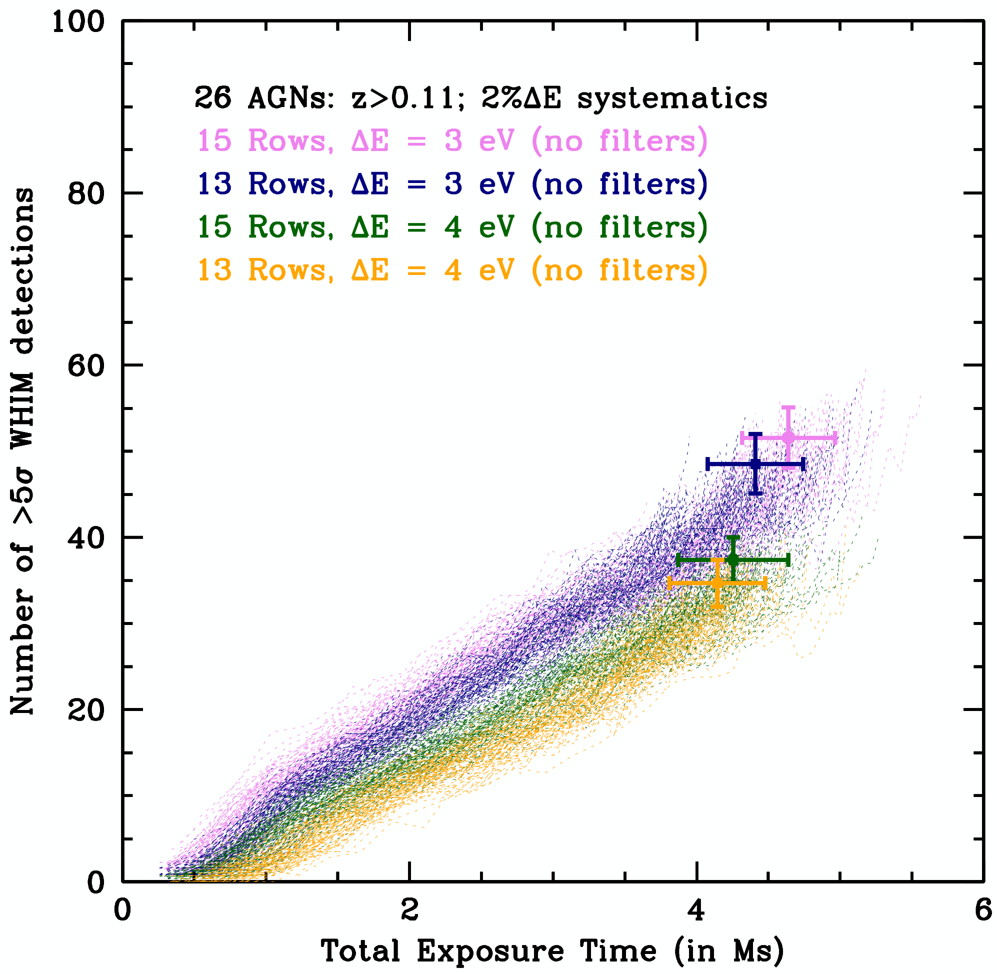
Map baryonic reservoirs, and probe their evolution and connection to the cosmic web

Experiments

Warm-Hot Intergalactic Medium absorption spectroscopy

Key X-IFU and mission performance

X-IFU area, FoV, energy resolution, relative effective area calibration accuracy



25 WHIM detections against blazars with 4 Ms

[assumes 2% uncertainty on relative effective area calibration]

The transient Universe

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

List of *Athena* science goals requiring ToO observations

MOP=Mock Observing Plan

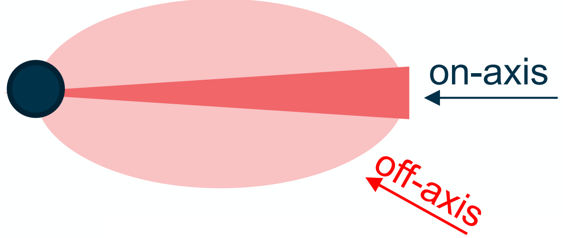
SCIOBJ	Topic	Number of sources	MOP time (Ms)
251	Galactic Black Hole Candidate and X-ray Binaries	20	1.72
252	Ultra-Luminous X-ray Sources, SgrA*	26	1.28
262	Tidal Disruption Events	25	1.79
323	Magnetospheric accretion in low-mass stars	1	0.06
333	Accreting White Dwarfs	2	0.25
334	Magnetars	1	0.16
336	Novae	1	0.21
338	Supernovae	5	0.36

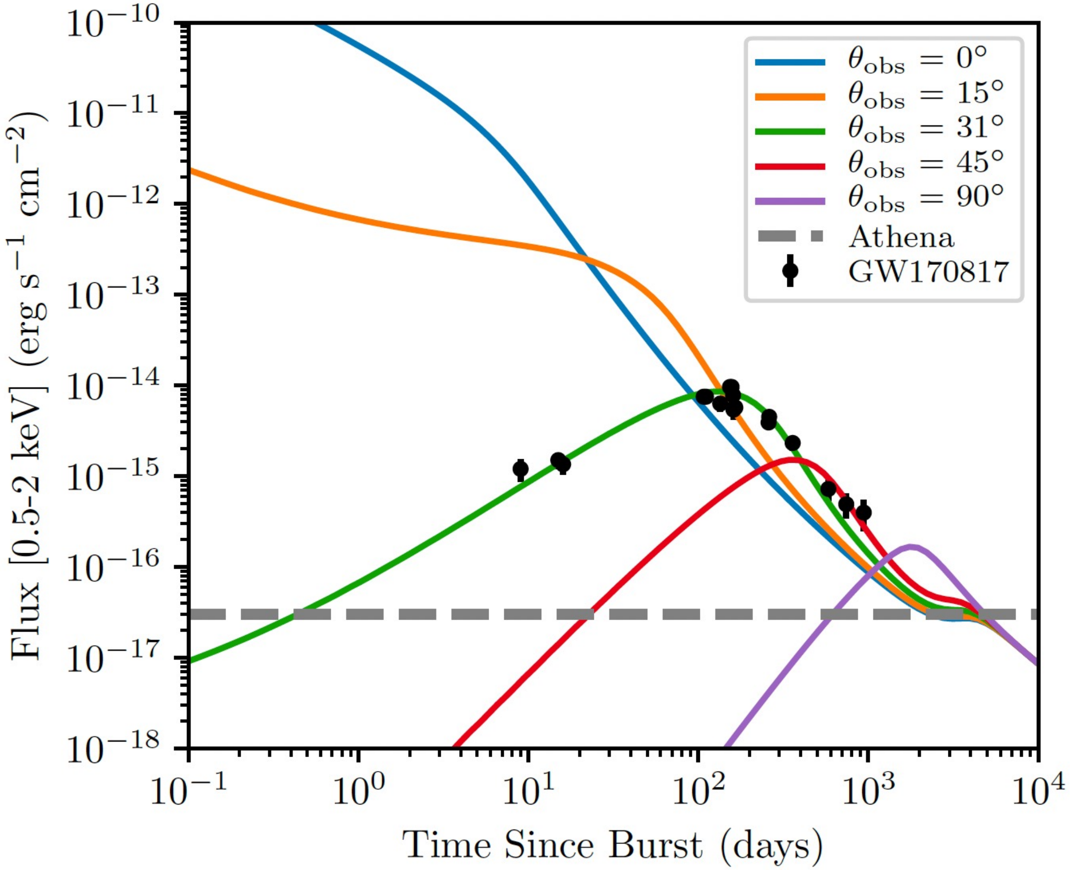
All these goals remain applicable with NewAthena

Full census of GRB jets

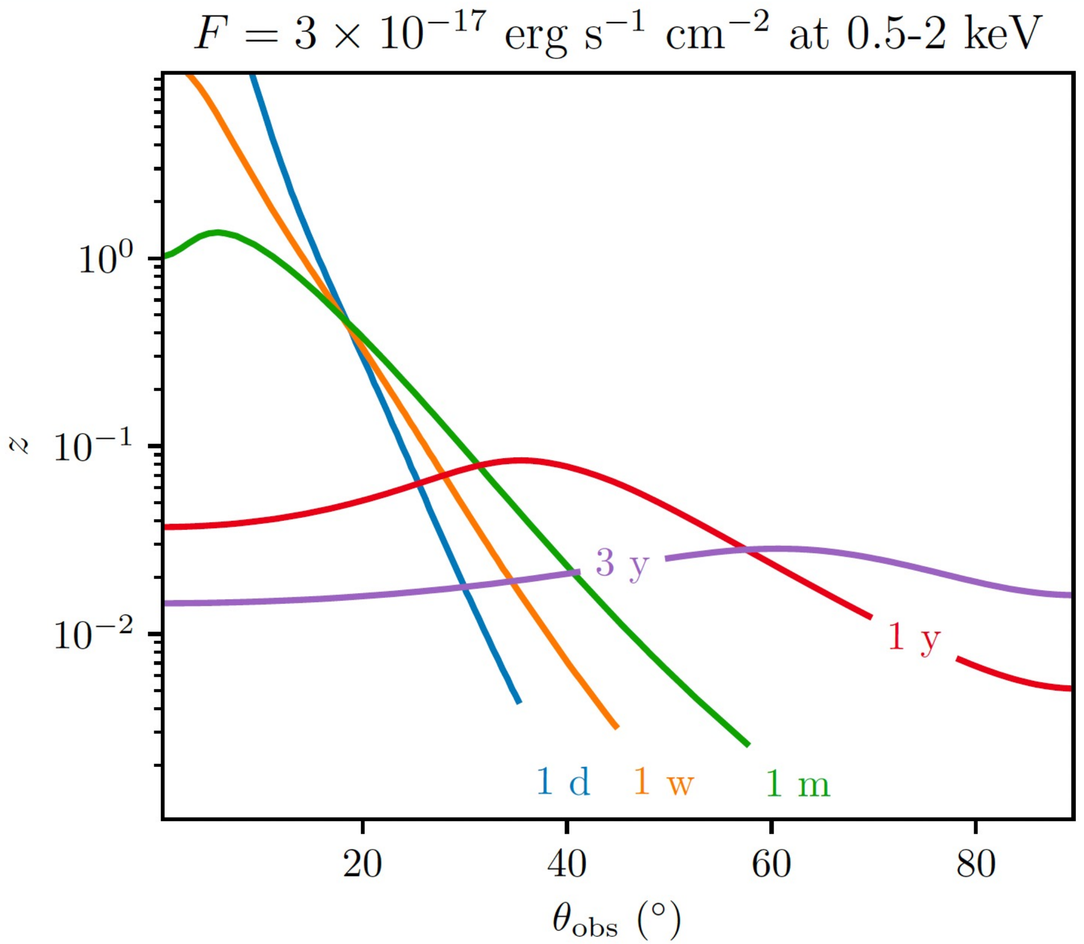
Troja et al., 2020, MNRAS, 498, 5643

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





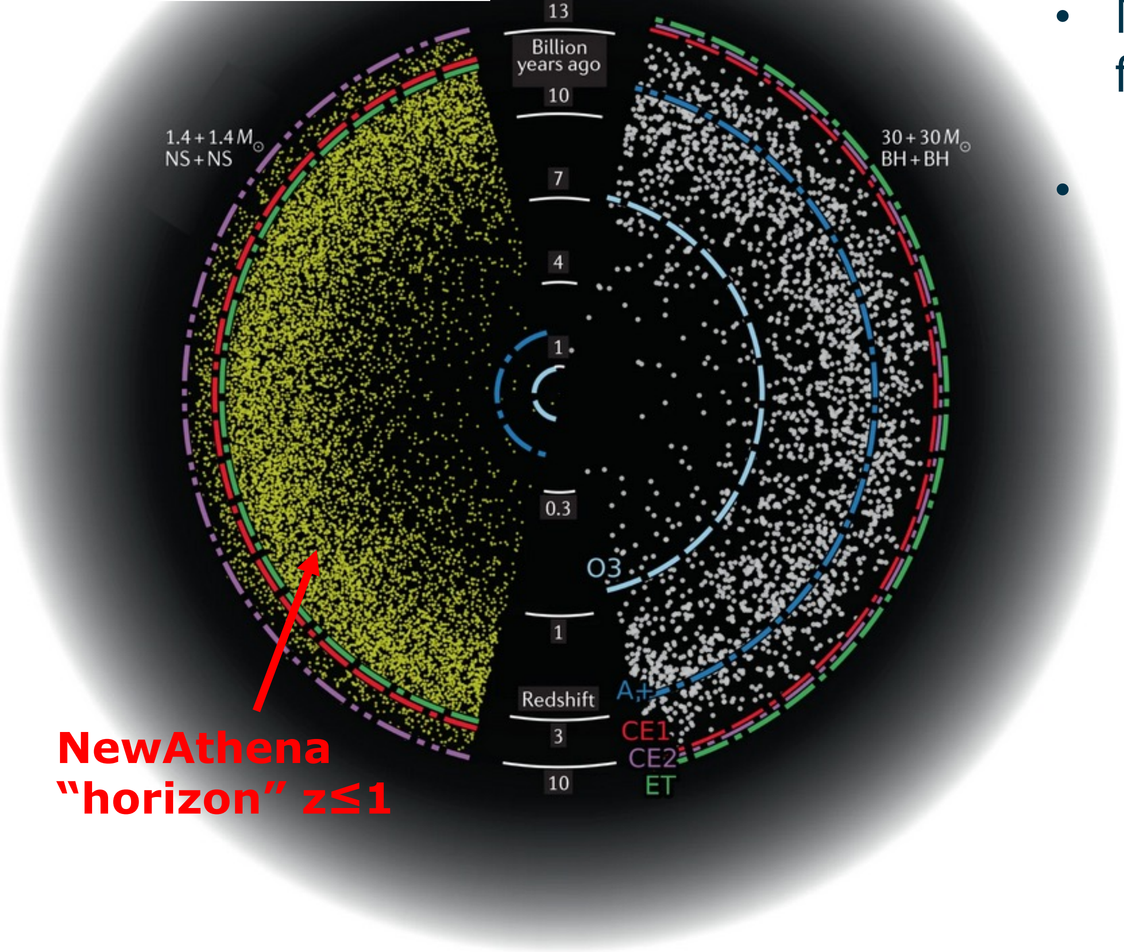
Detectability of a GW170817A-like event by *Athena*



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

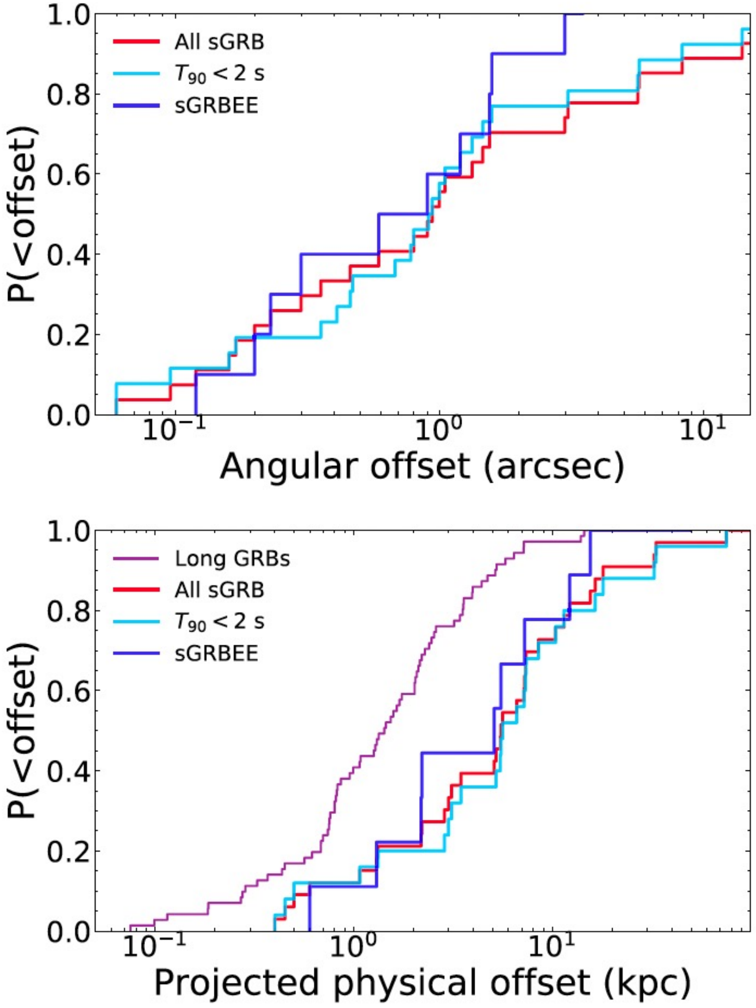


- **Accurate jet inclination for most binary systems**
- NewAthena may enable arcseconds locatization on a few targets per year
- Main science areas:
  - Cosmology (through joint Gravitational Wave and electromagnetic observations)
    - X-rays break the degeneracy between inclination and luminosity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

Confusion limit for GRBs in the local Universe

O'Connor et al., 2022, MNRAS, 515, 4890

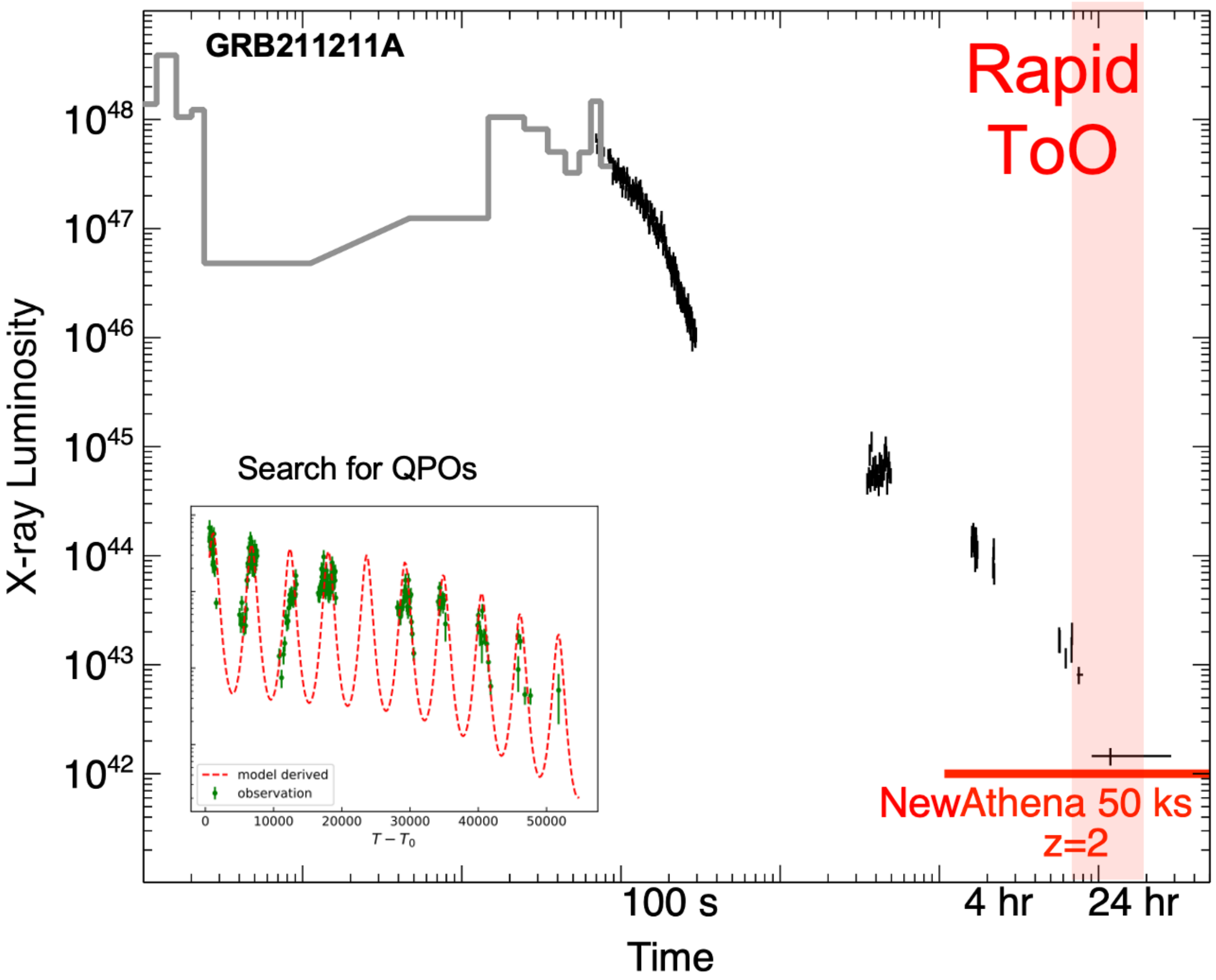
Location of a GRB in the host galaxy



- Prompt emission, afterglows, plateaux, X-ray flares are safe against main contaminants (AGN, XRBs)
- Off-axis afterglows and kilonovae have slow variability and a luminosity (<10^{40} erg s^{-1}) prone to confusion
- Confusion for the closest events (<100 Mpc) unlikely to be an issue
  - Hint: GW170817A was at 10" offset in a 40 Mpc galaxy
- For a 200 Mpc (400 Mpc) galaxy, ~50% (65%) of events could be missed at a HEW~10"

Hybrid GRBs? The birth of a magnetar?

Troja et al., 2022, Nat, 612, 228



- Recent discovery of an “hybrid GRB” (long + kilonova)
- Possible interpretation as a WD+NS merger, with a magnetar as an end product
  [Yang et al., 2022, Nat, 612, 232]
- A NewAthena ToO could prove X-ray photometry and timing up to z~2

Take-home messages

- NewAthena is a Large-class X-ray observatory, recently reinstated in the ESA Science Program
  - Adoption: 2026-2027
  - Launch: ~2037
- Spectroscopic and survey capabilities exceeds existing X-ray observatories by ~1 order-of-magnitude over several parameter spaces simulteneously
- Response time (<12 hours) and Field-of-Regards (34%) enable an L-class observatory ToO program
- All science cases originally identified as *Athena*/THESEUS synergies *remain in the NewAthena science case*
  - Probe stellar population in the early Universe
  - Using GRB as backlight to probe the WHIM
  - Galactic and extra-galactic transient sources
  - Multi-messenger astrophysics