

Athena and its synergy with Theseus

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Summary

- Athena mission
- Science themes: synergy with Theseus
 1. Cosmic Filaments (WHIM) and GRBs
 2. High-z GRBs
 3. GW counterparts and MM astronomy
 4. Transient Universe (TDEs, Galactic BHs and XRB, Magnetars, Novae, CVs, Sne,...)
- Observational strategy

Athena Science Themes

- ✓ Formation and Evolution of hot gaseous cosmological structures
- ✓ Growth of black holes over cosmic time and their influence on galaxies
- ✓ Discovery science: the Transient and Multimessenger Universe
- ✓ Observatory Science

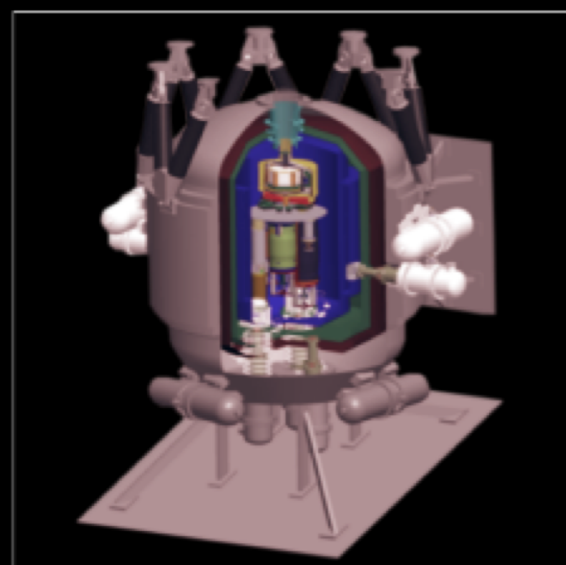


The Athena Observatory

Willingale et al, 2013
arXiv1308.6785

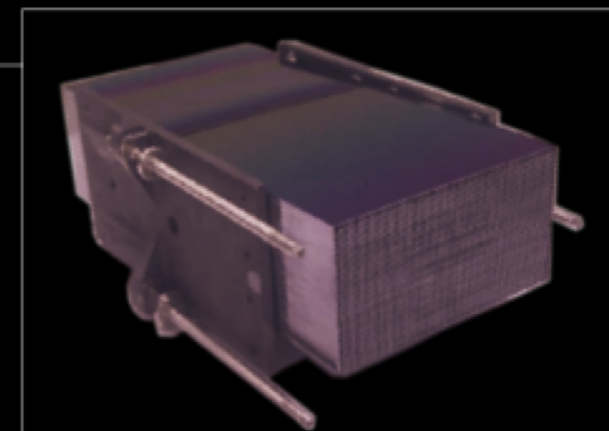
L1 orbit Ariane VI

Mass < 7.1 ton
Power 2500 W
4+6 year mission
ToO 4 hrs



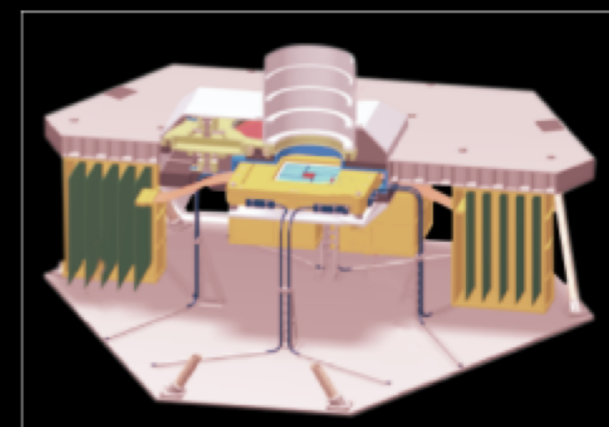
X-ray Integral Field Unit:

ΔE : 2.5 eV
Field of View: 5 arcmin
Operating temp: 50 mk



Silicon Pore Optics:

1.4 m² at 1 keV
5 arcsec HEW
Focal length: 12 m
Sensitivity: $3 \cdot 10^{-17}$ erg cm⁻² s⁻¹



Wide Field Imager:

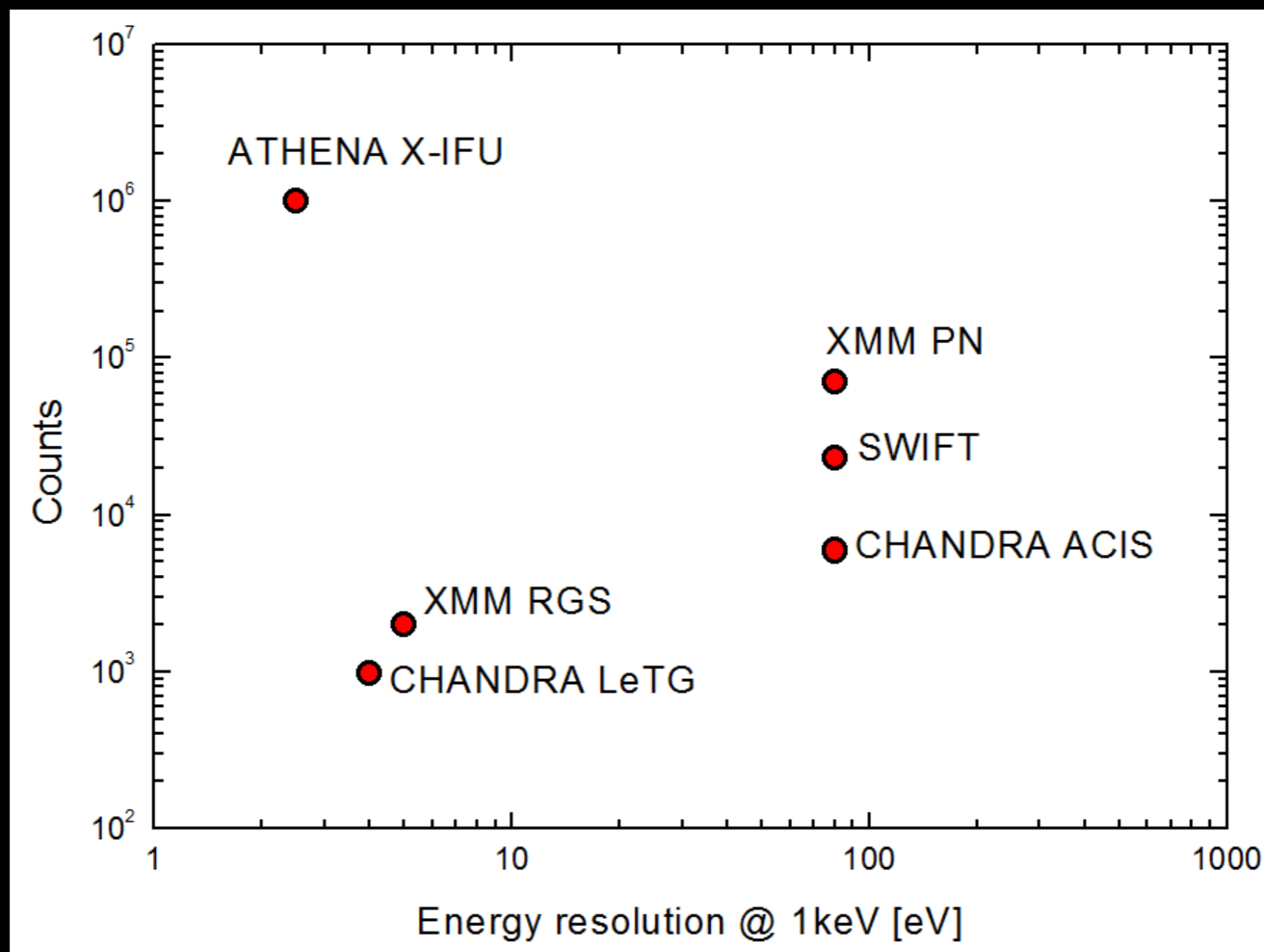
ΔE : 125 eV
Field of View: 40 arcmin
High countrate capability

Barret et al., 2013 arXiv:1308.6784

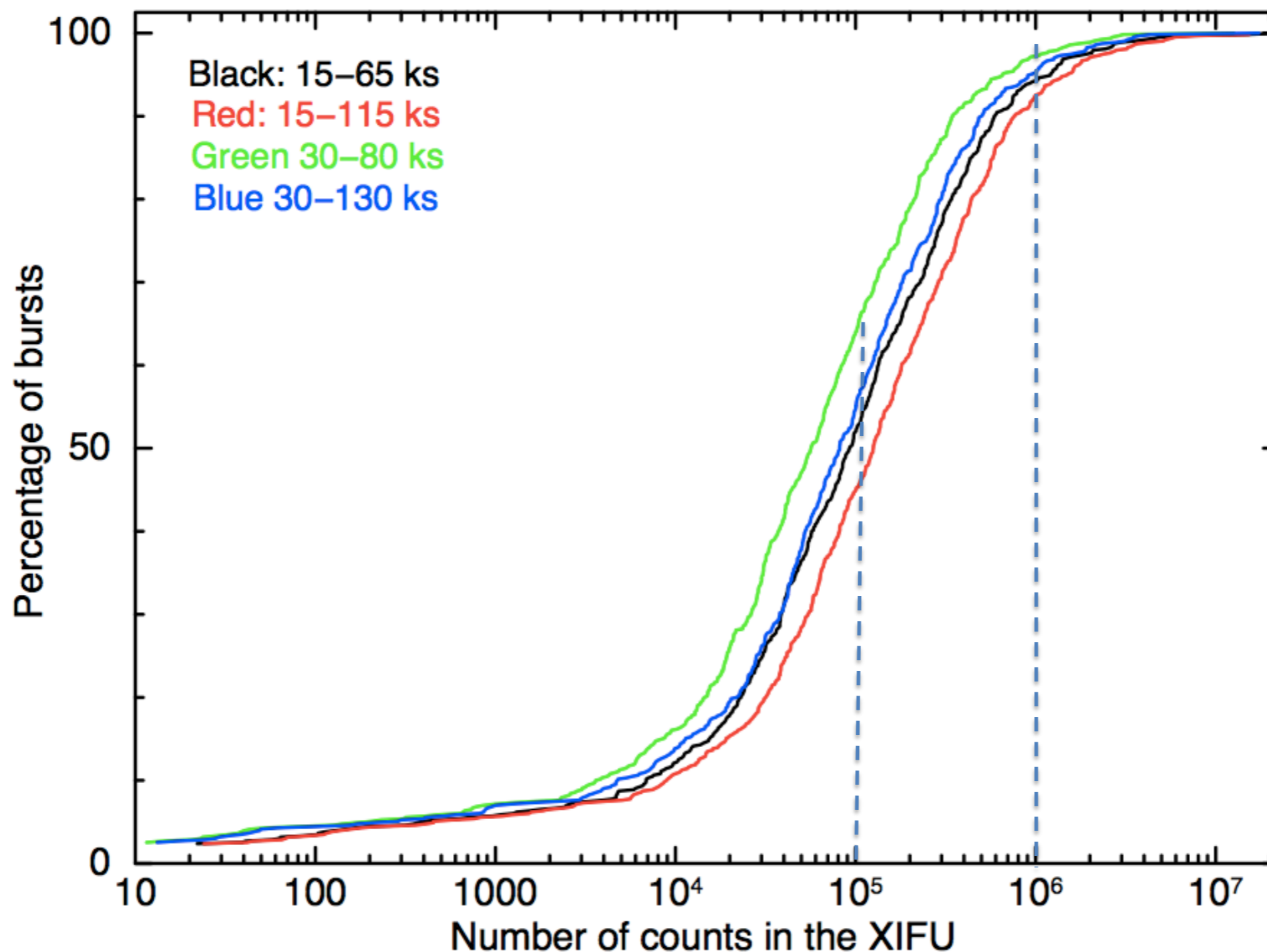
Rau et al. 2013 arXiv1307.1709

Athena TOO

enabling high spectral resolution and high sensitivity in
the Transient Universe



GRB total counts

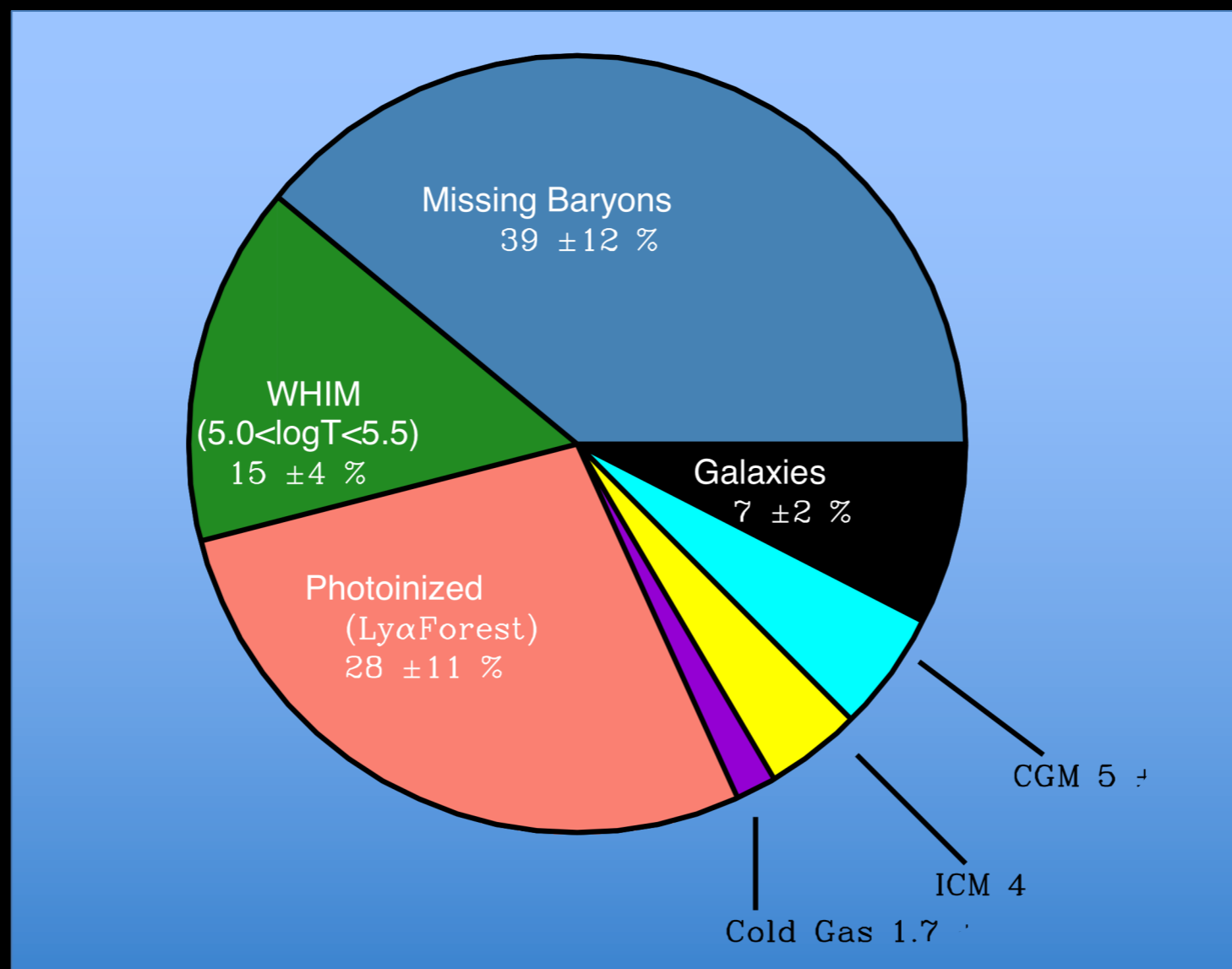


The missing baryons

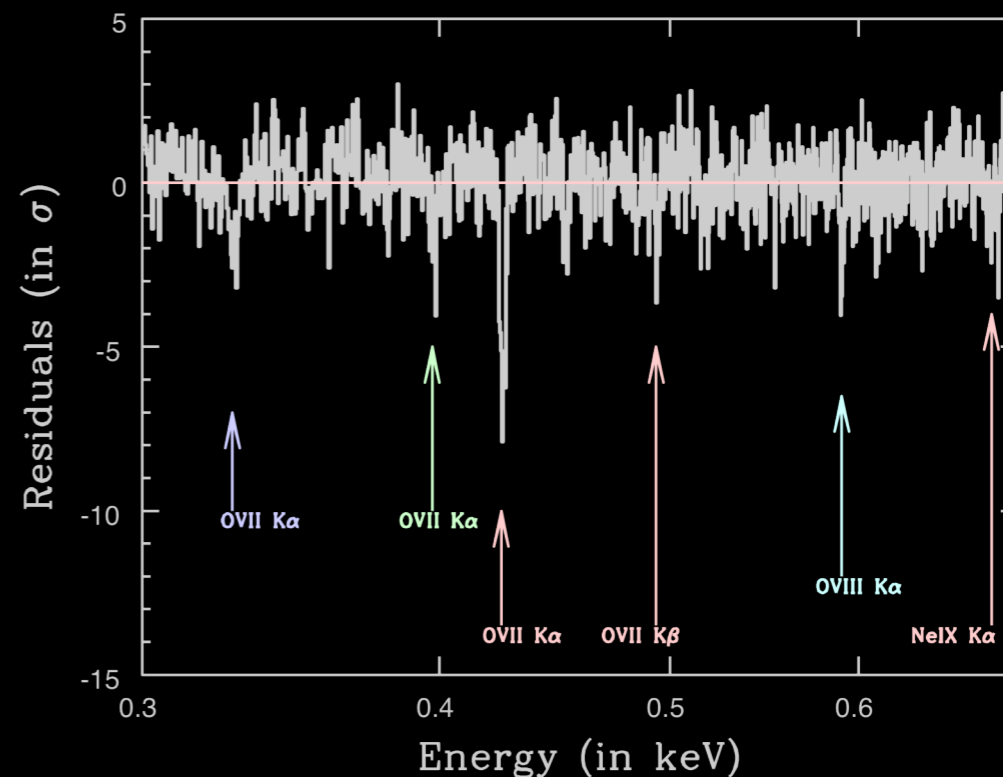
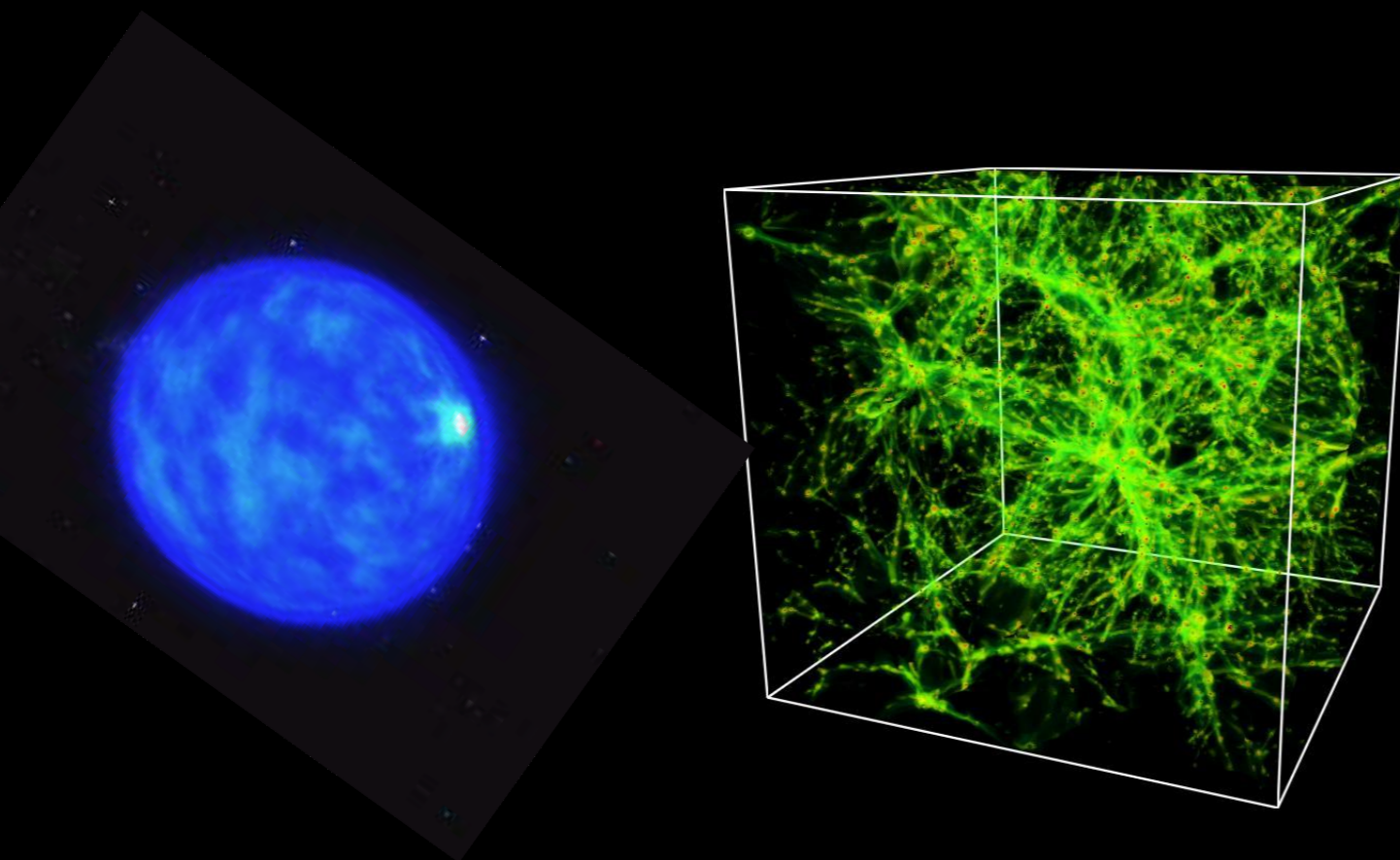
Big Bang Nucleosynthesis (& CMB): $\Omega_b = 4.5\%$

Consistent with Ly α (HI) forest @ $z > 2$

But at $z < 1$:



GRB as probes of the missing baryons

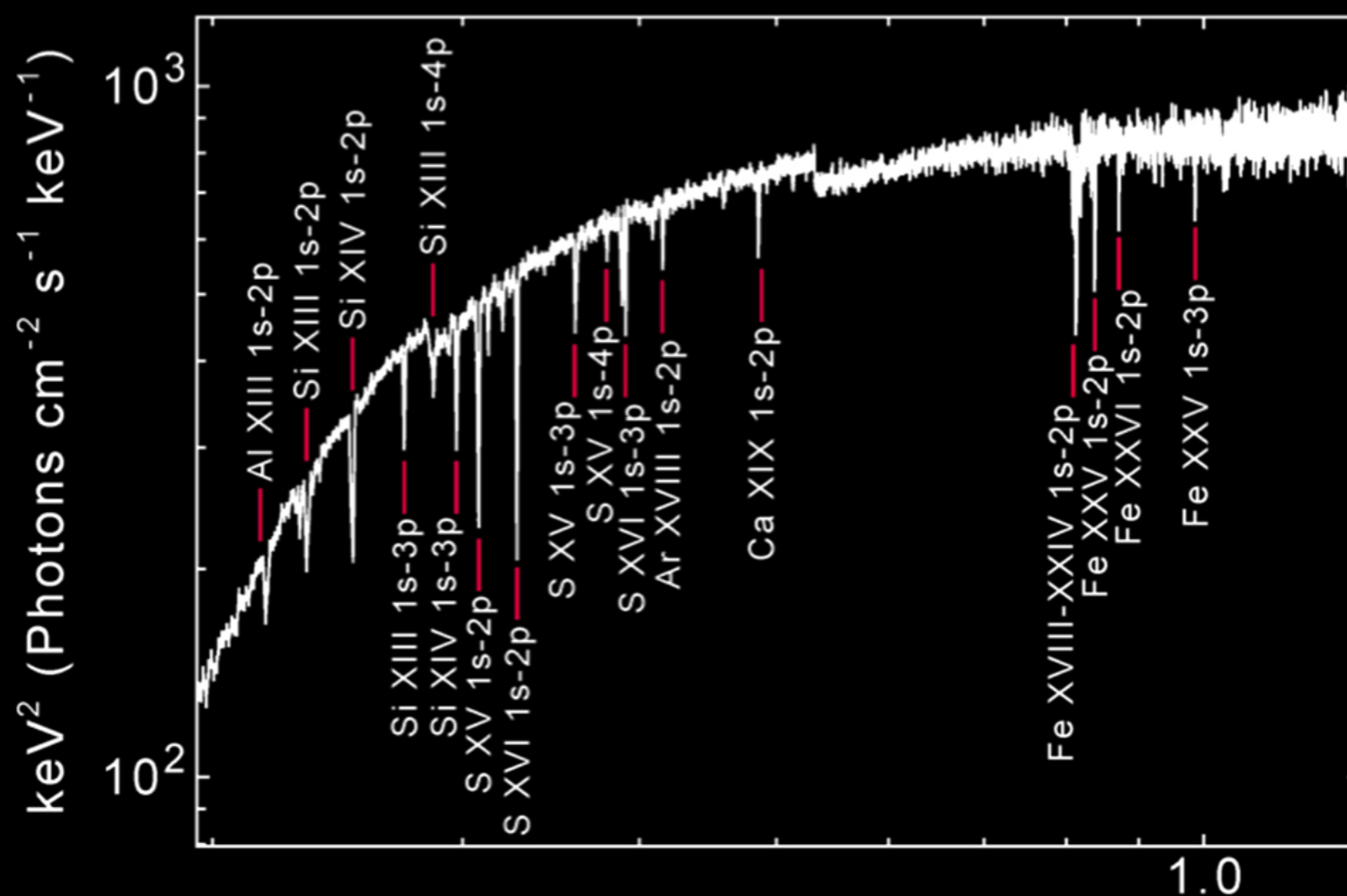


Detect 200 WHIM filaments in absorption, 100 towards BL Lacs and 100 towards
50 bright GRB afterglows to sample the WHIM up to $z=1$. Determine metal
abundances from emission lines in targeted regions

High-Z GRBs: The first stars and black holes

When did the first generation of stars explode to form the first seed black holes and disseminate the first metals in the Universe?

Gamma Ray Burst at $z=7$

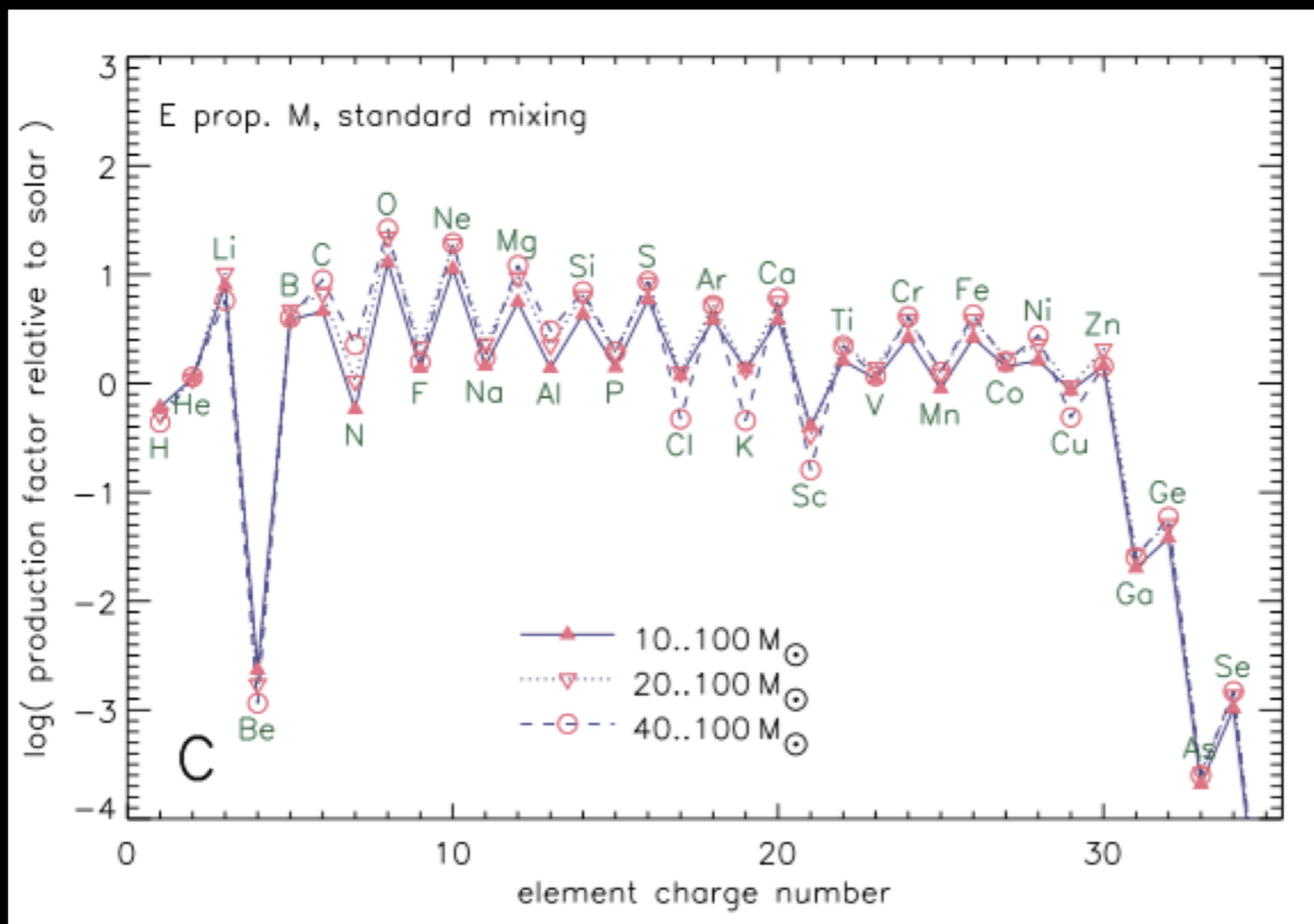


Athena requirement: 25 high-z events
Theseus: 40-50 high-z events in 4 years

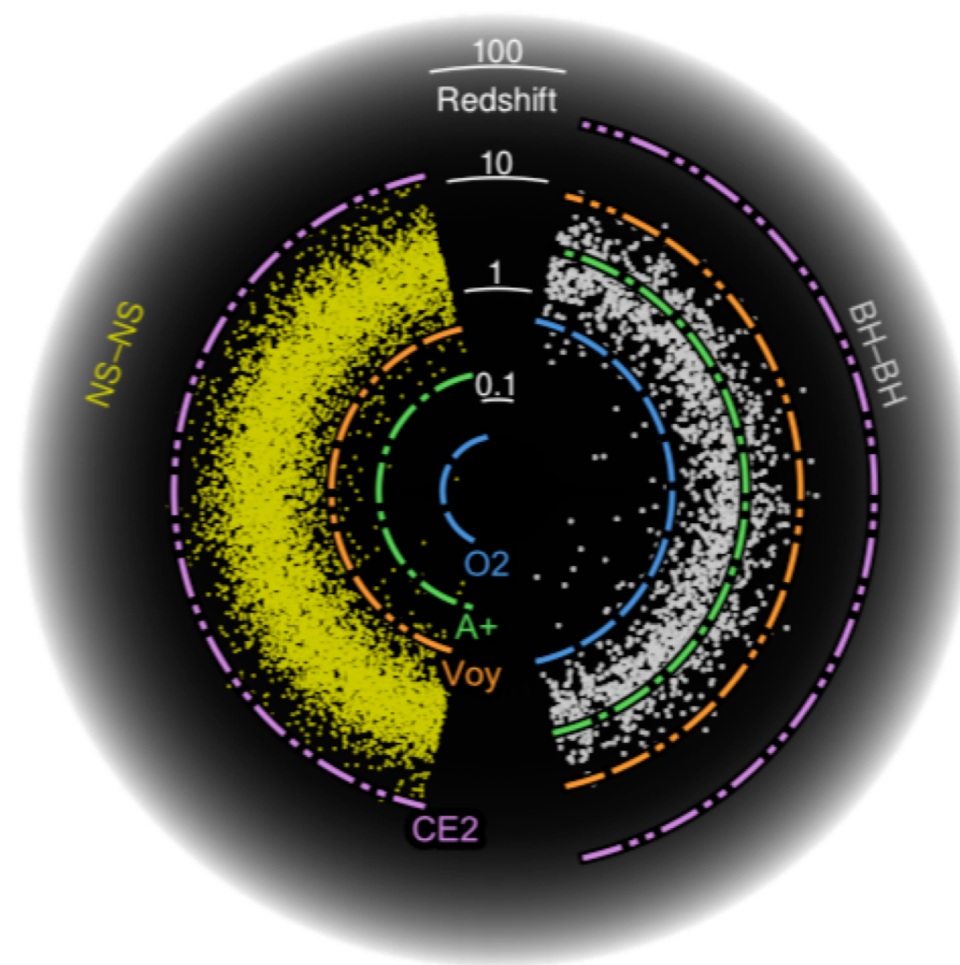
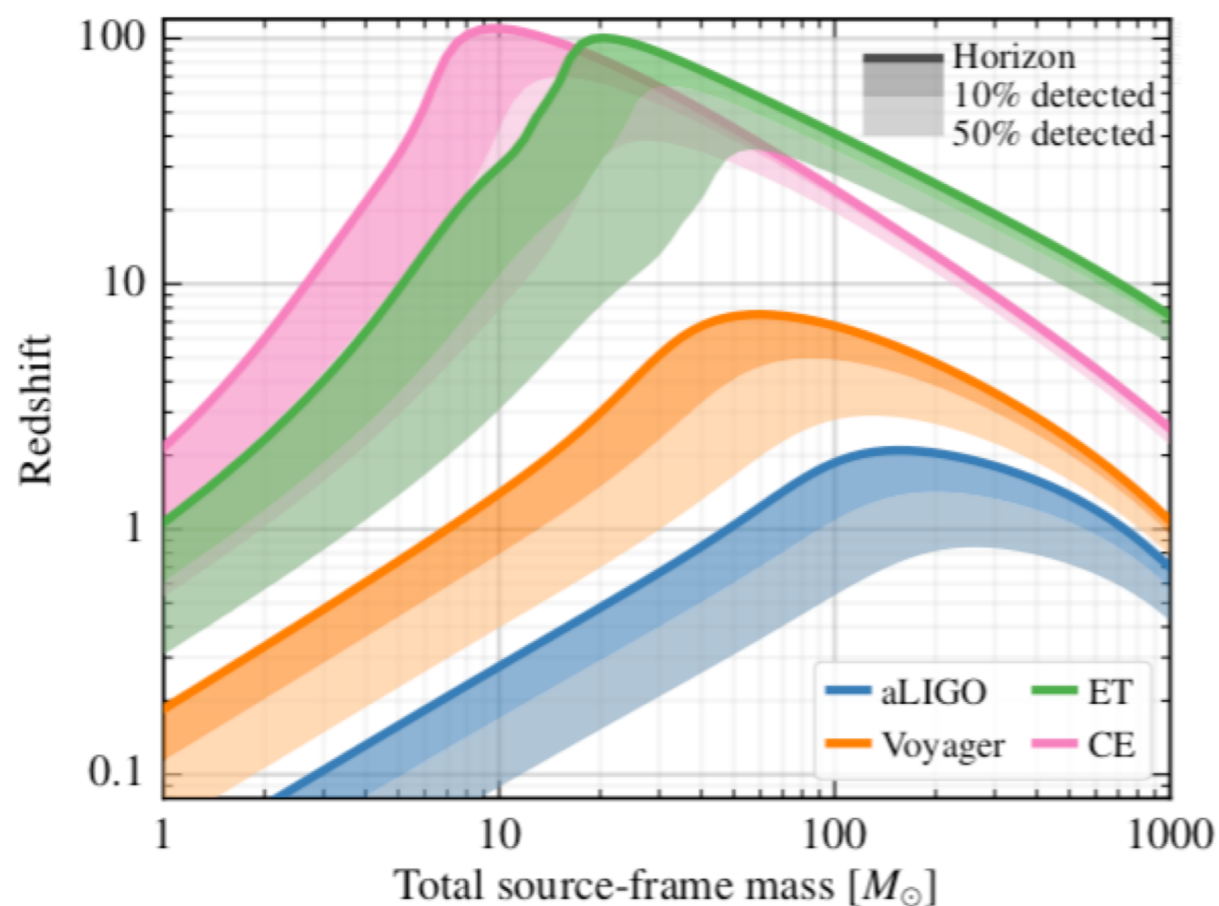
How do black holes grow and shape the Universe?

PopIII enrichment chemical abundance

Chemical enrichment from popIII explosions is roughly solar with a strong odd/even effect



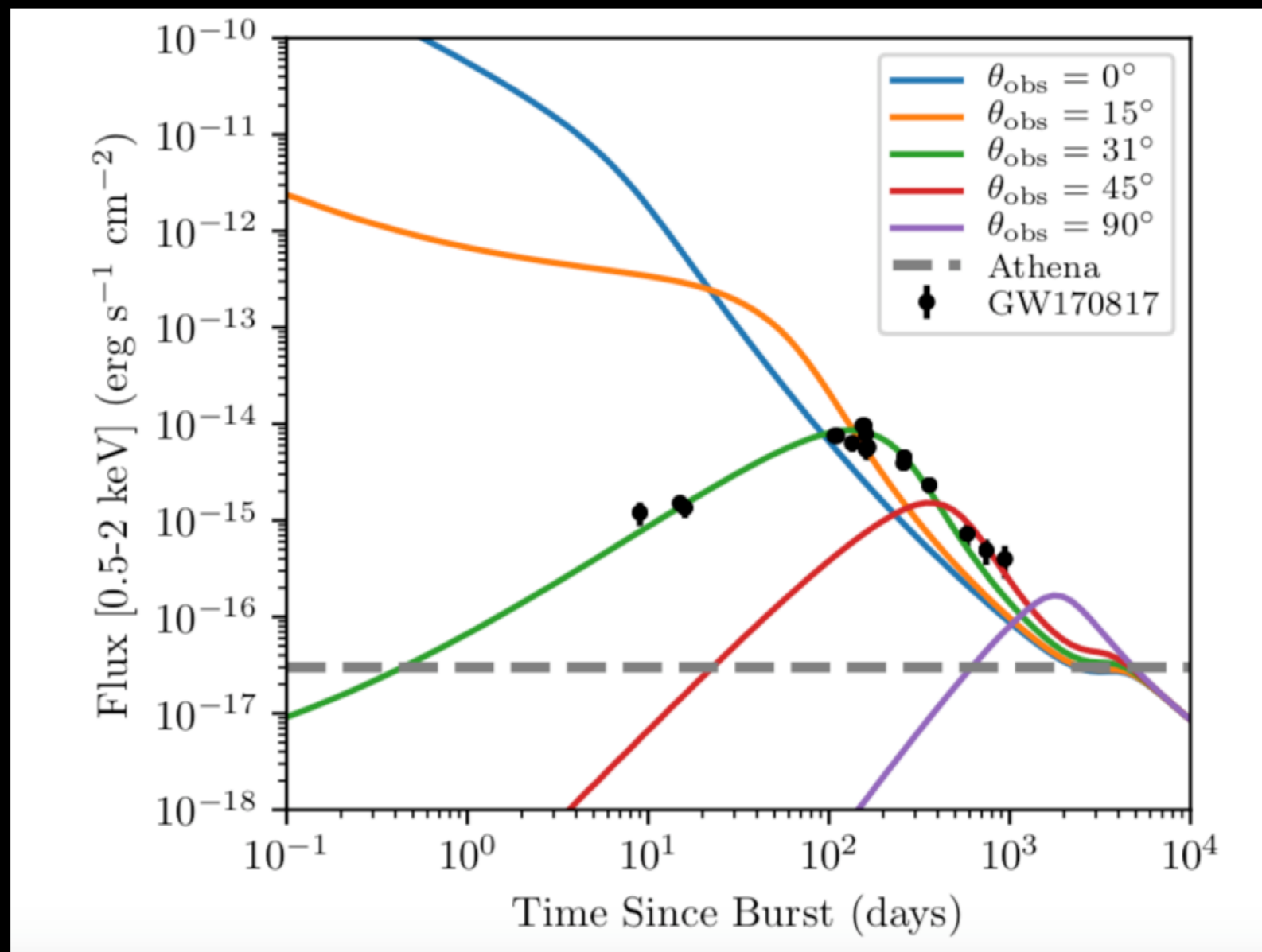
The horizon of GW interferometers



Network	N(detected) [yr ⁻¹]	Median loc. [sq.deg]	N(<1 sq.deg.) [yr ⁻¹]	N(<10 sq.deg.) [yr ⁻¹]	N(<100 sq.deg.) [yr ⁻¹]
HLVKI	15	7	0	15	15
3Voyager	800	20	5	170	770
1ET+2Voyager	6,100	21	20	960	6,100
1ET+2CE	320,000	12	4,500	130,000	310,000

Extending the EM horizon of off-axis jet from GW mergers

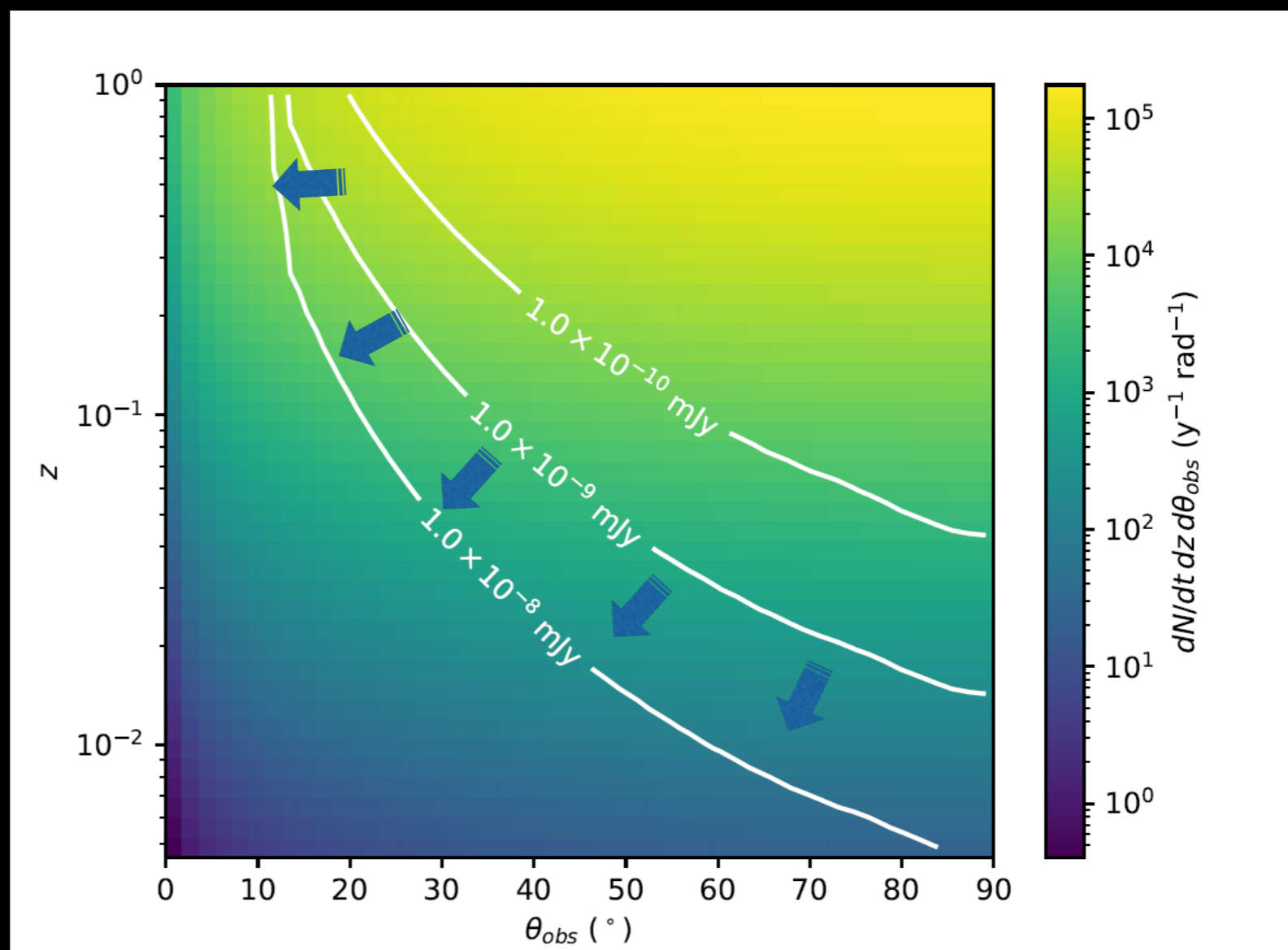
Rate of chocked jets
Jet geometry, launch
Shock acceleration
Calorimetry of the jet explosion
Properties of the environment and stellar evolution



GW170817

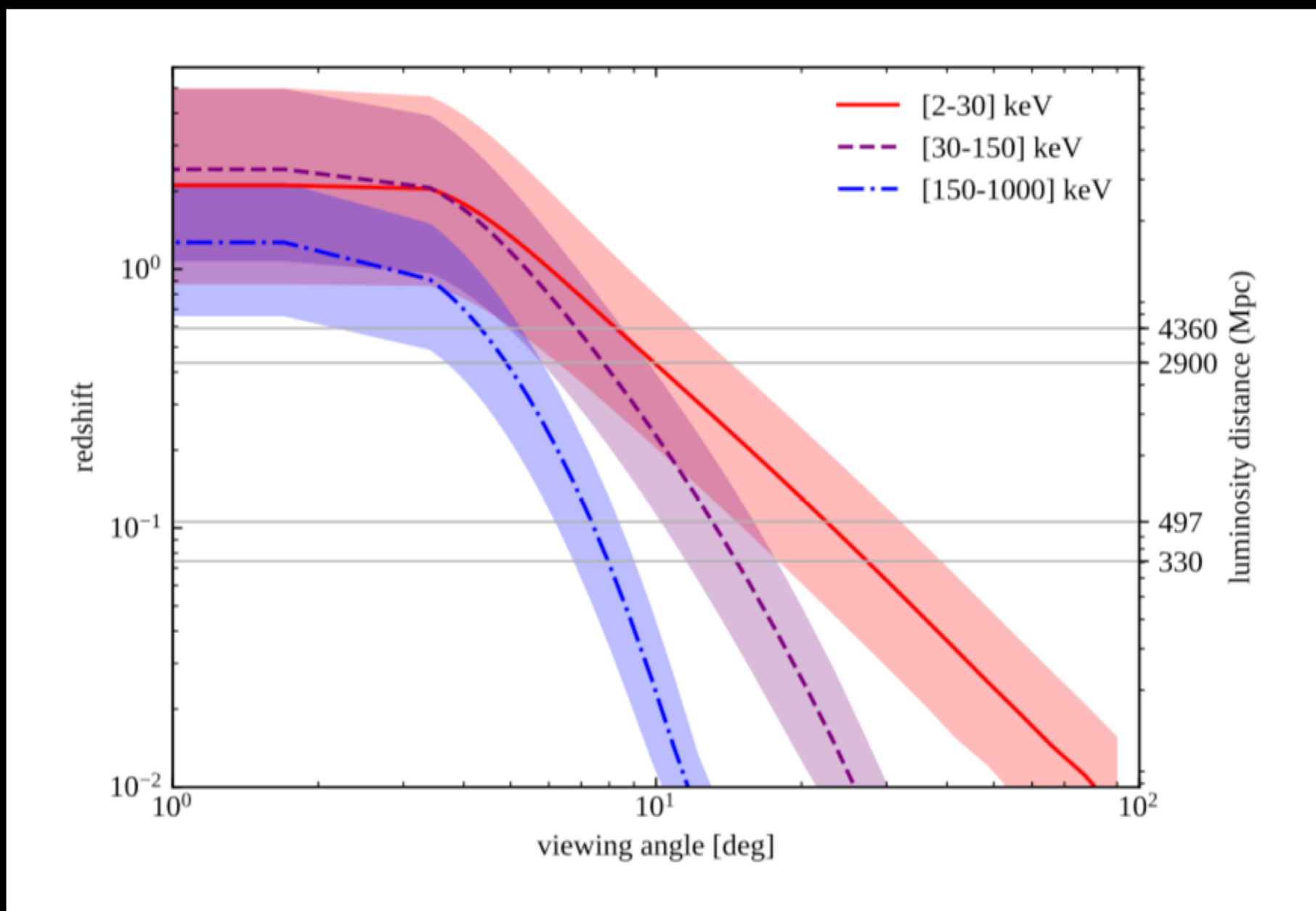
Extending the EM horizon of off-axis jet from GW mergers

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GW170817-like upto 40 deg for 2G and 15 deg for 3G

Theseus: Prompt emission from NS mergers off-axis emission from a structured jet



Increase the rates of GW events to be followed-up by Athena by providing accurate locations for XIFU follow-up

Observational Synergy

- **Theseus providing triggers (time, location, flux, redshift) to Athena** for GRBs (high-z Universe, pop-III stars, WHIM studies), additional e.m. counterparts of GW sources (short GRBs, soft X-ray emission) and other transients relevant to Athena core and observatory science (TDEs, Magnetars, SNe, Nova, flare stars, SgrA*)
- **Athena providing triggers for Theseus IRT for follow-up** of transients found in the WFI, including triggering campaign on AGN in outburst.
- **Simultaneous Athena/Theseus broad band observations** of relatively bright sources
- Cross Calibration of Theseus SXI instrument on Athena sources

Conclusions

- Athena and Thesus science cases are outstanding per-se
- Boosted by synergy operation including:
 1. Missing baryons and WHIM
 2. The high- z Universe with GRBs
 3. GW counterparts and MM astronomy
 4. Transient Universe (TDEs, Galactic BHs and XRB, Magnetars, Novae, CVs, SNe,...)