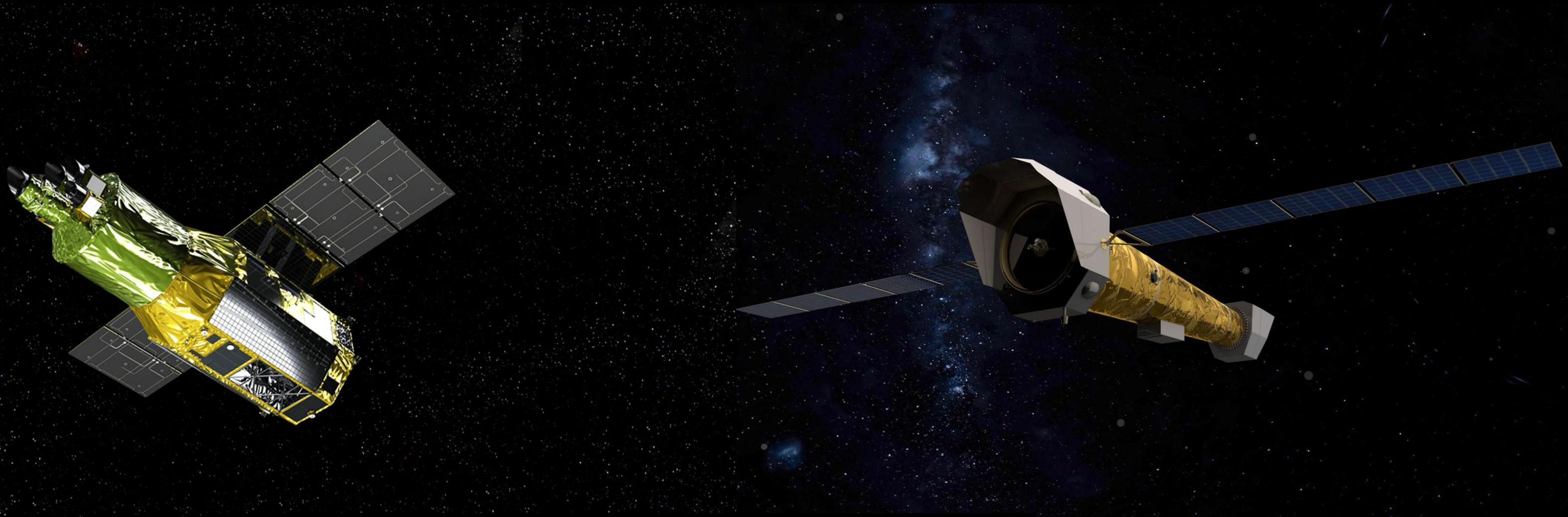
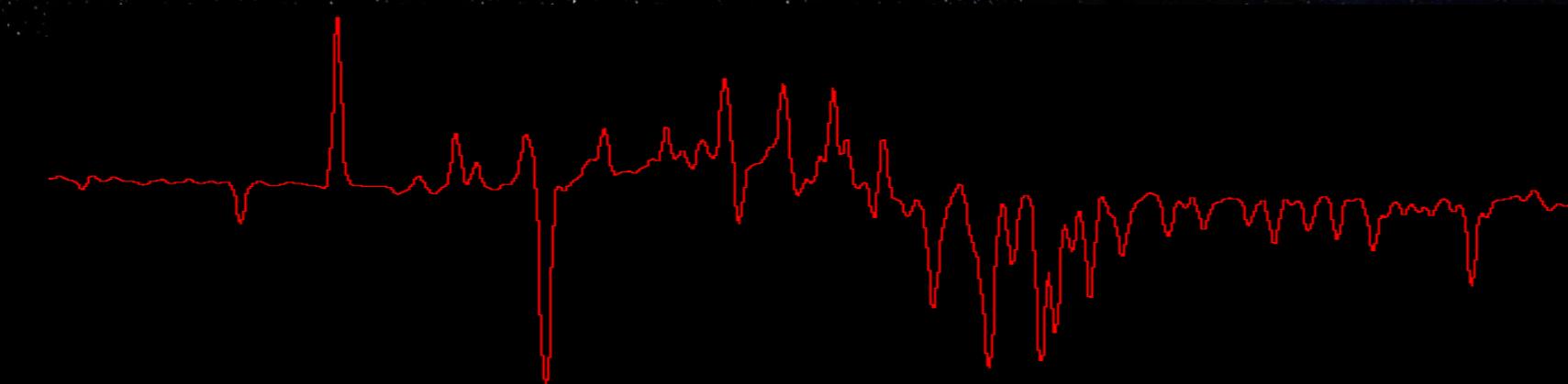


# Unveiling ULXs winds with XRISM and ATHENA



INAF / IASF  
Palermo



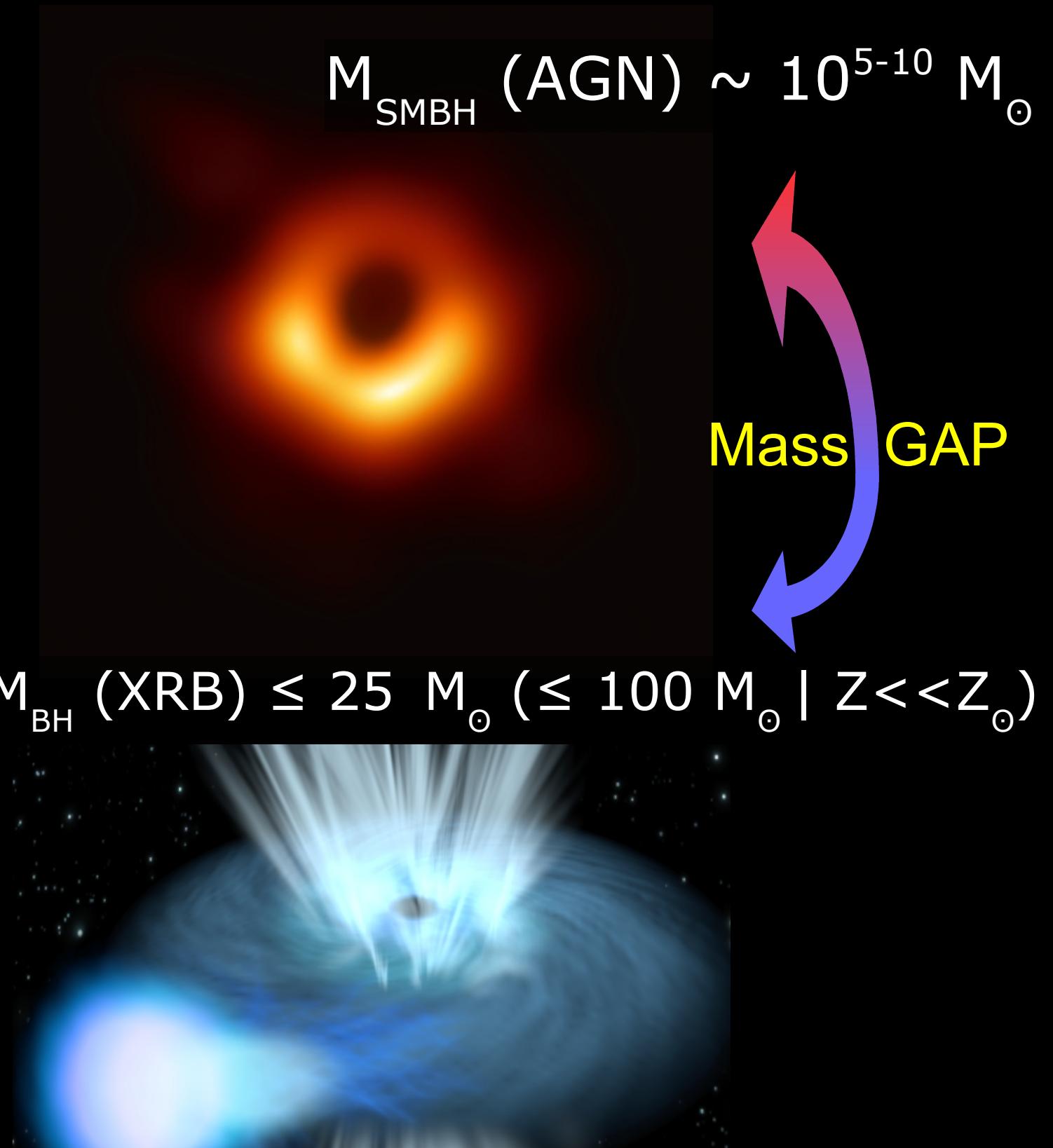
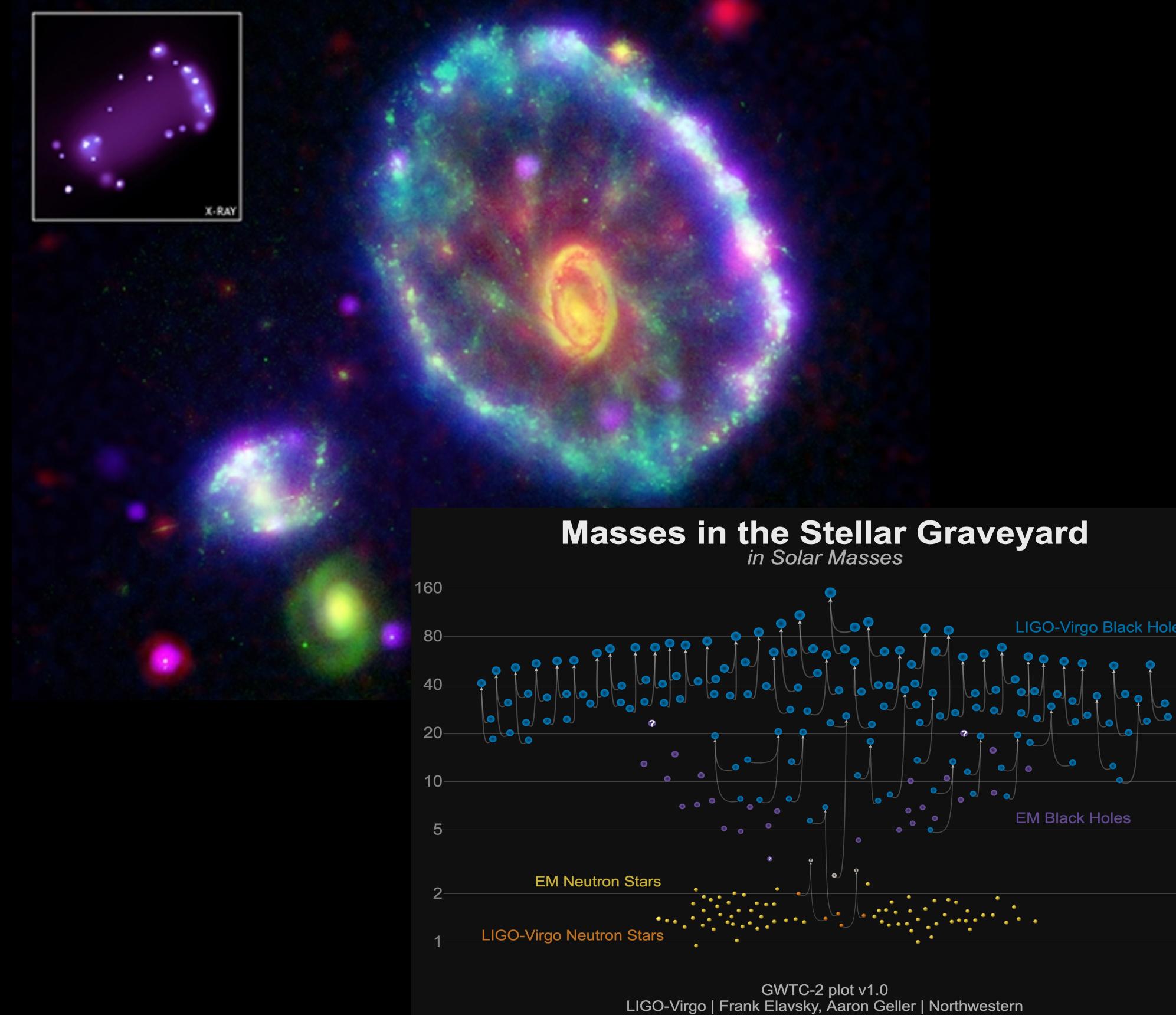
Ciro Pinto



A. Robba, A. D'Aì, M. Del Santo, F. Pintore, E. Ambrosi, F. Barra (INAF), P. Kosec, D. Walton, W. Alston, M. Parker, A. Fabian (IoA), M. Middleton (Soton), R. Sathyaprakash (ISS), R. Soria (NAO), T. Roberts (Durham), F. Fürst, J. Ness, M. Guainazzi (ESA), E. Kara (MIT), M. Nowak (WUSTL), H. Earnshaw (Caltech), M. Mehdipour (STScI), D. Barret (IRAP)

# Ultra-Luminous X-ray sources (ULXs)

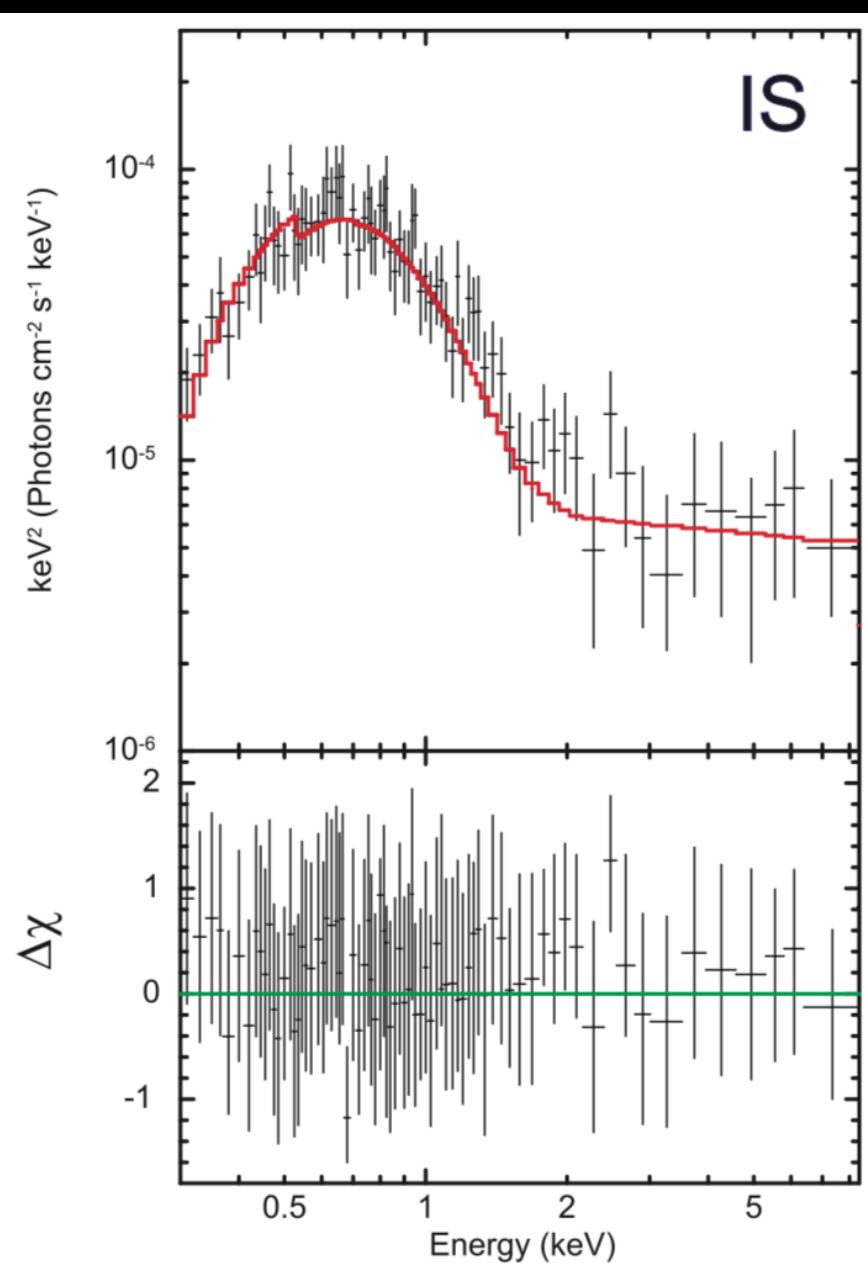
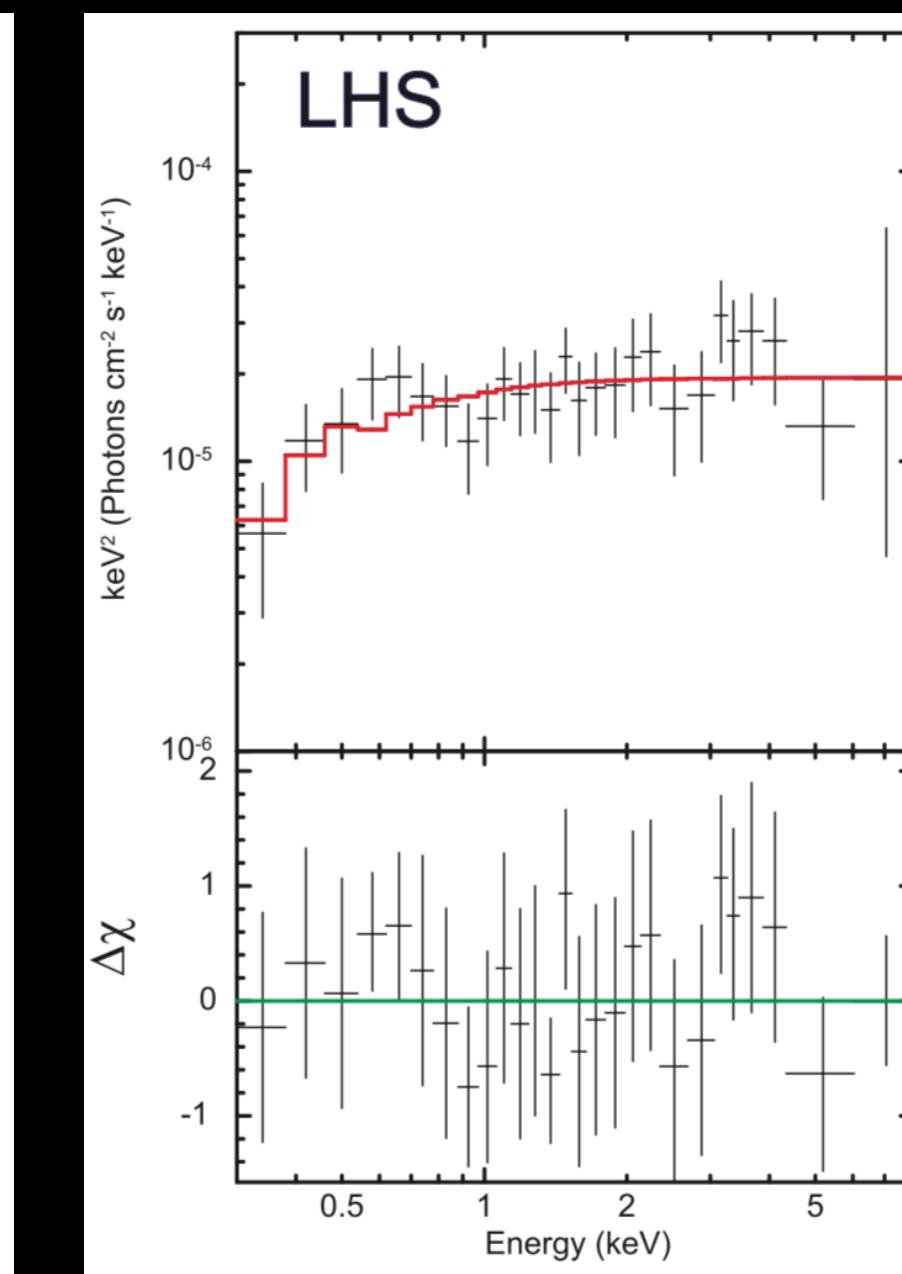
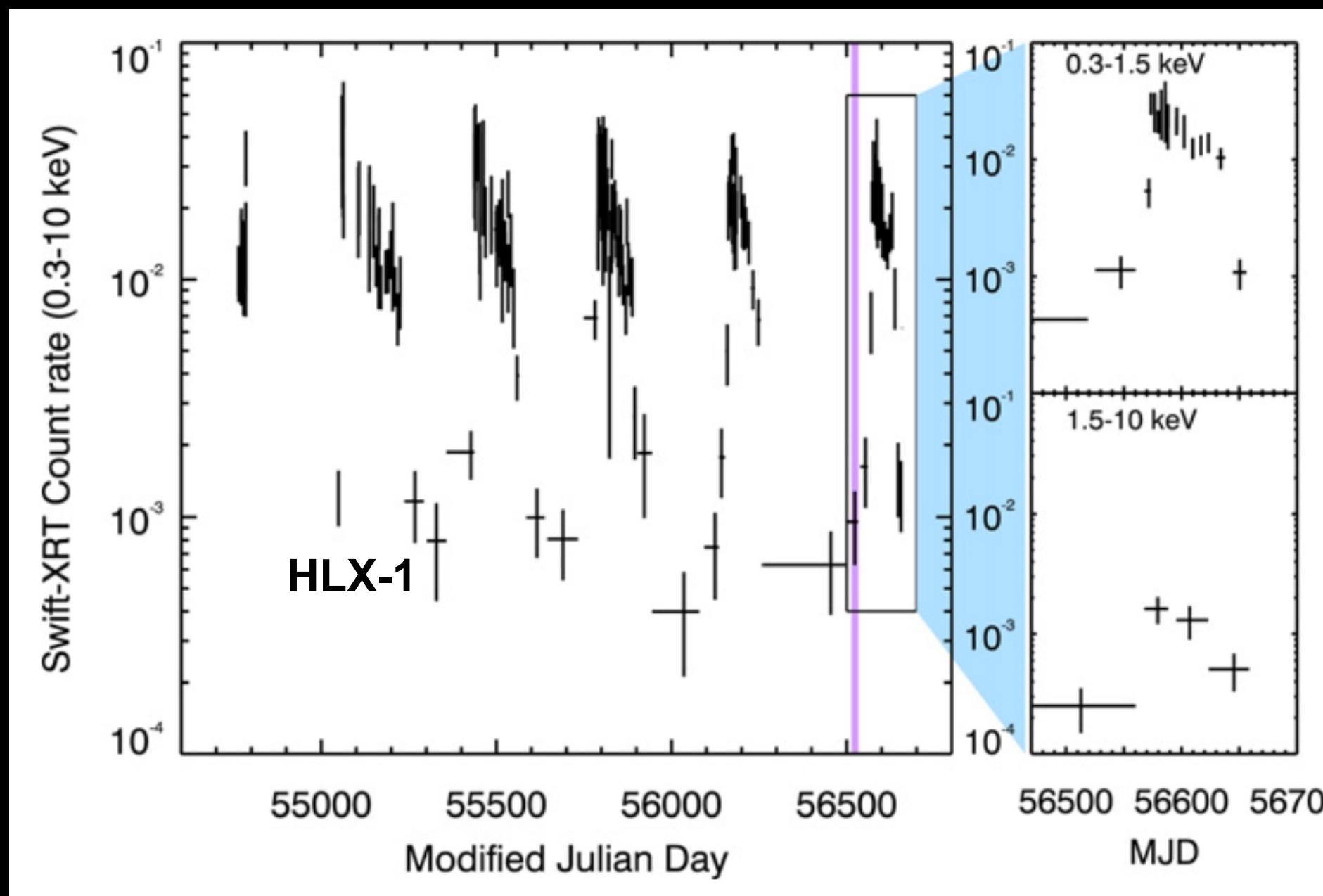
Brighter than a  $10 M_{\odot}$  black hole accreting at the Eddington limit ( $10^{39-41}$  erg/s) & off-nuclear.



# X-ray luminosity: Intermediate-mass black holes?

$\text{IMBH} \sim 10^{2-5} M_{\odot}$  ... maybe some ULXs

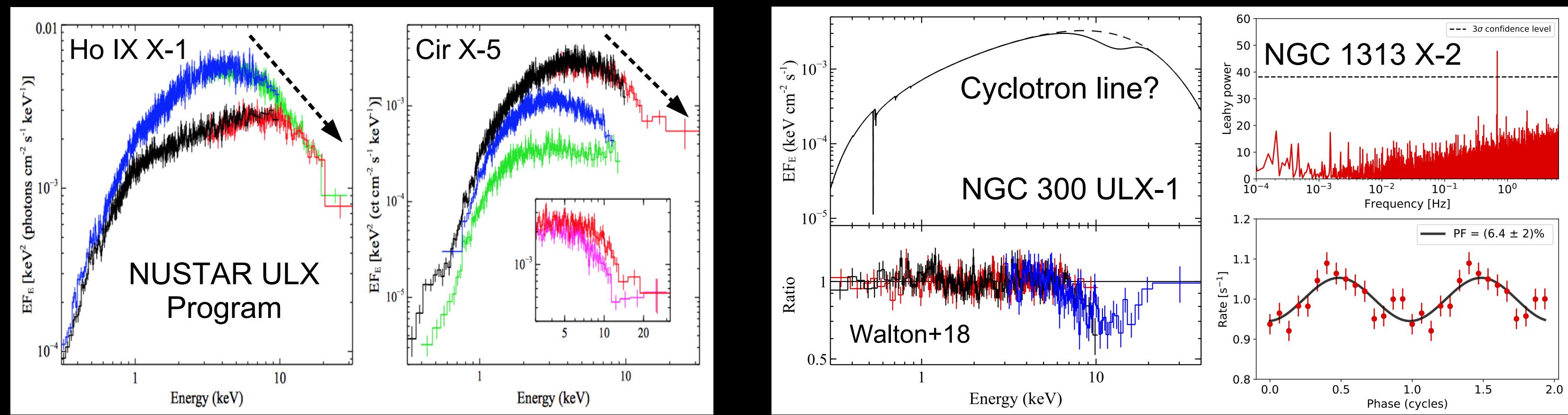
$L_x \leq 4 \times 10^{42} \text{ erg/s}$   
 $\text{Mass} \geq 7 \times 10^4 M_{\text{sun}}$   
 (Titarchuk+16)



Farrell+09, Webb+12, Mezcua+18

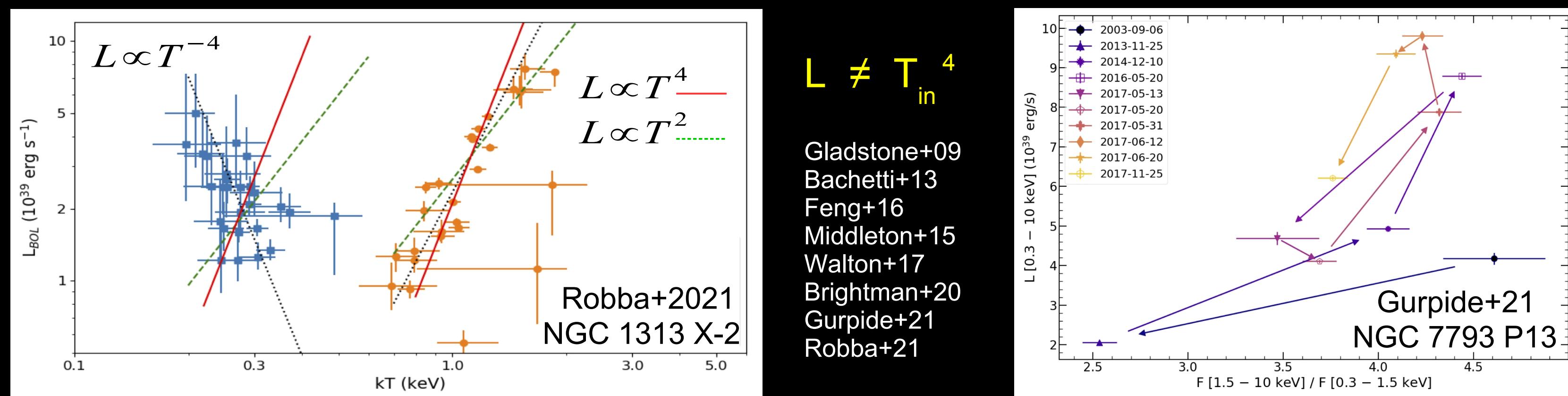
Other λ bands / dwarf galaxies, globular clusters to probe IMBHs  
 (Miller+02, Blecha+11, Greene&Ho04, Mezcua17, Wrobel+21)

# Spectral curvature / pulsations: Super-Eddington accreting NS,BH



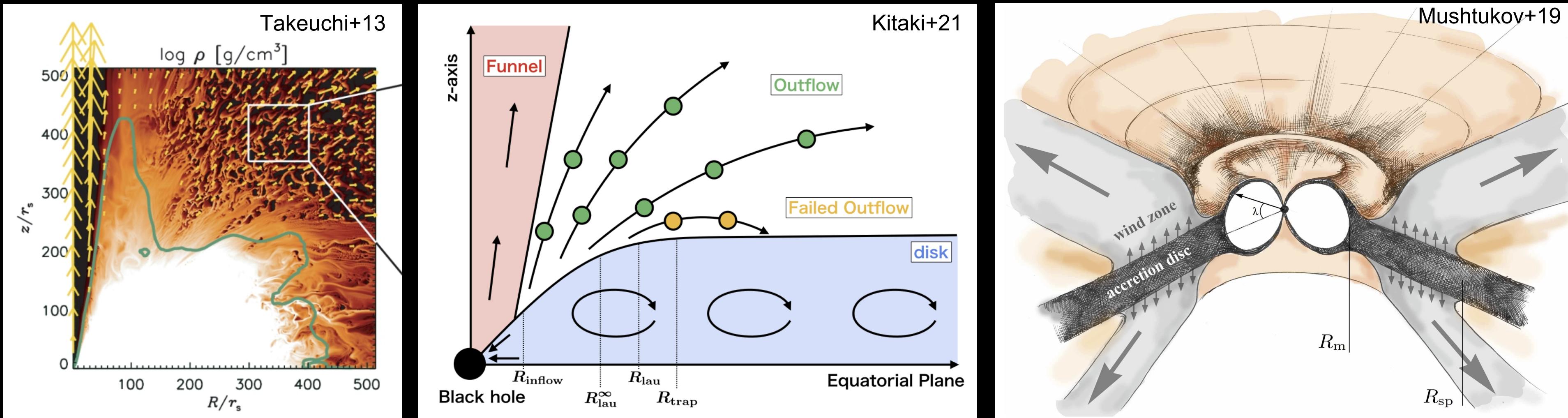
**Pulsations NS (>20%)**

- Bachetti+14
- Fürst+16
- Israel+17a,b
- Carpano+18
- Tsygankov+18
- Sathyaprakash+19
- Rodriguez-C+20
- Vasilopoulos+20
- Song+20
- Chandra+20



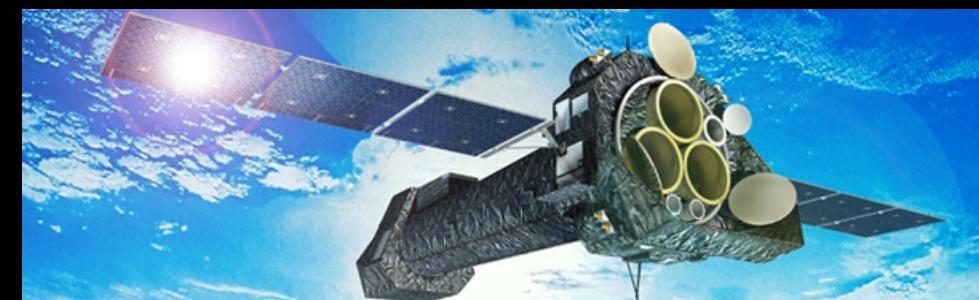
# Powerful relativistic winds: Super-Eddington accreting NS,BH

Radiation thickens the disk & launches winds, the system looks like a funnel



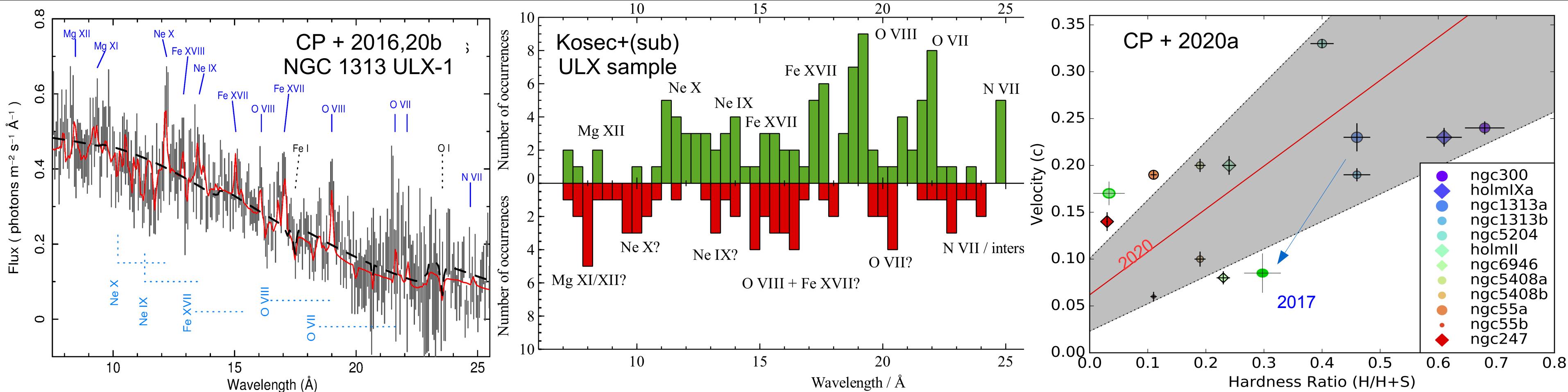
More face-on LOS → Harder the spectra → Hotter and faster the wind

# Powerful relativistic winds: Blueshifted absorption lines



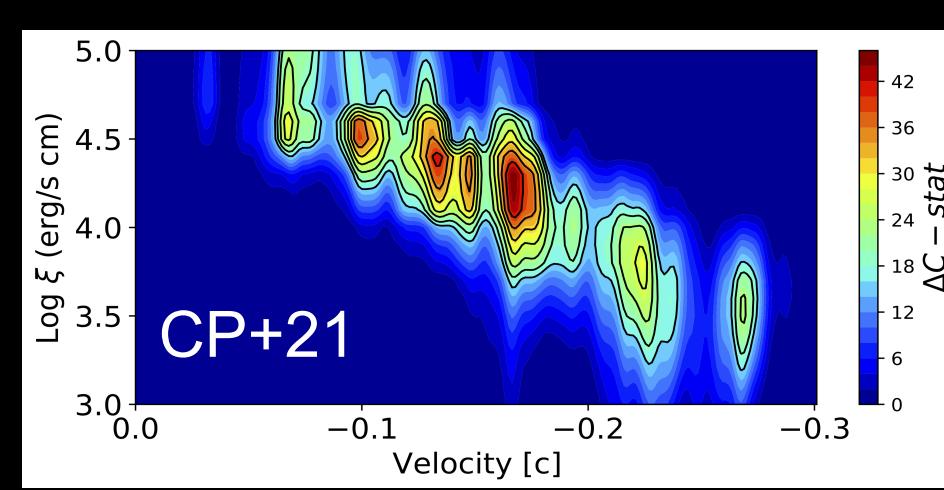
XMM – RGS – ULX sample (Kosec+18a,sub)

Mainly photo-ionised gas outflowing at 0.1-0.3c (emission lines ~ at rest) > 60% (>75%)

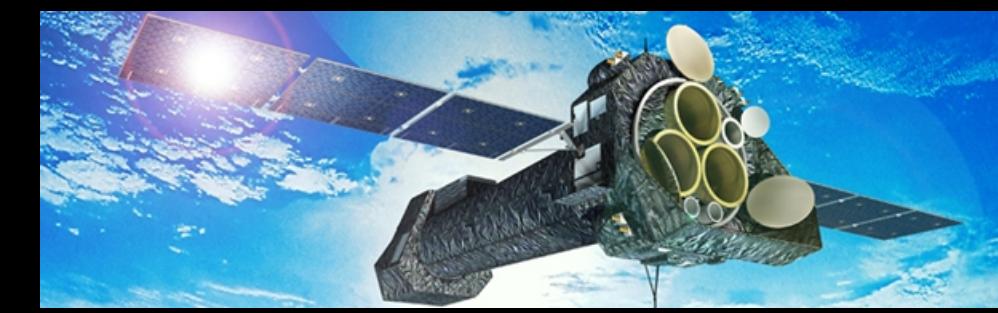


MM+14,15 - CP+16,17,20ab,21 – Walton+18 – Kosec+18ab – Koliopanos+18 – Wang+19

More face-on LOS → Harder the spectra → Hotter and faster the wind

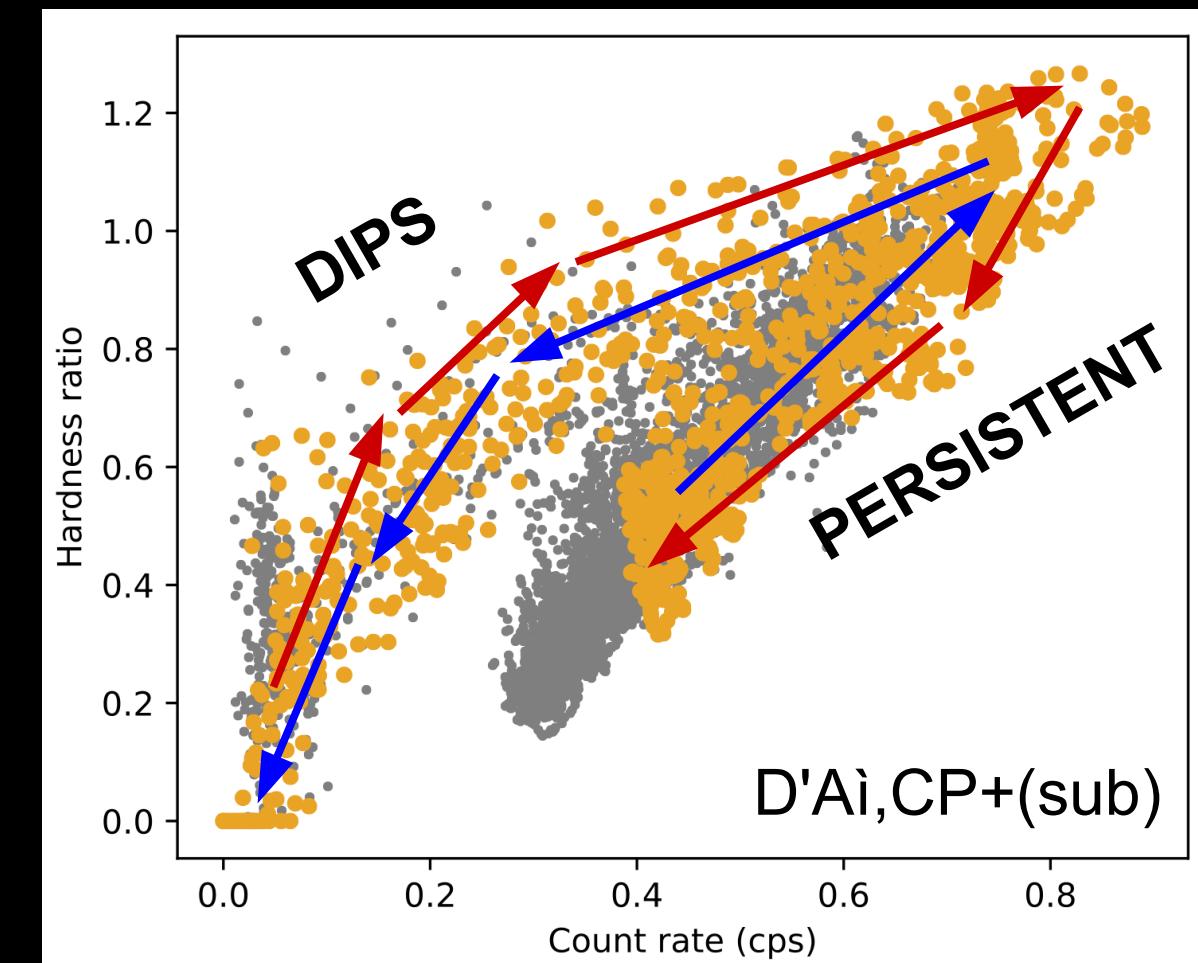
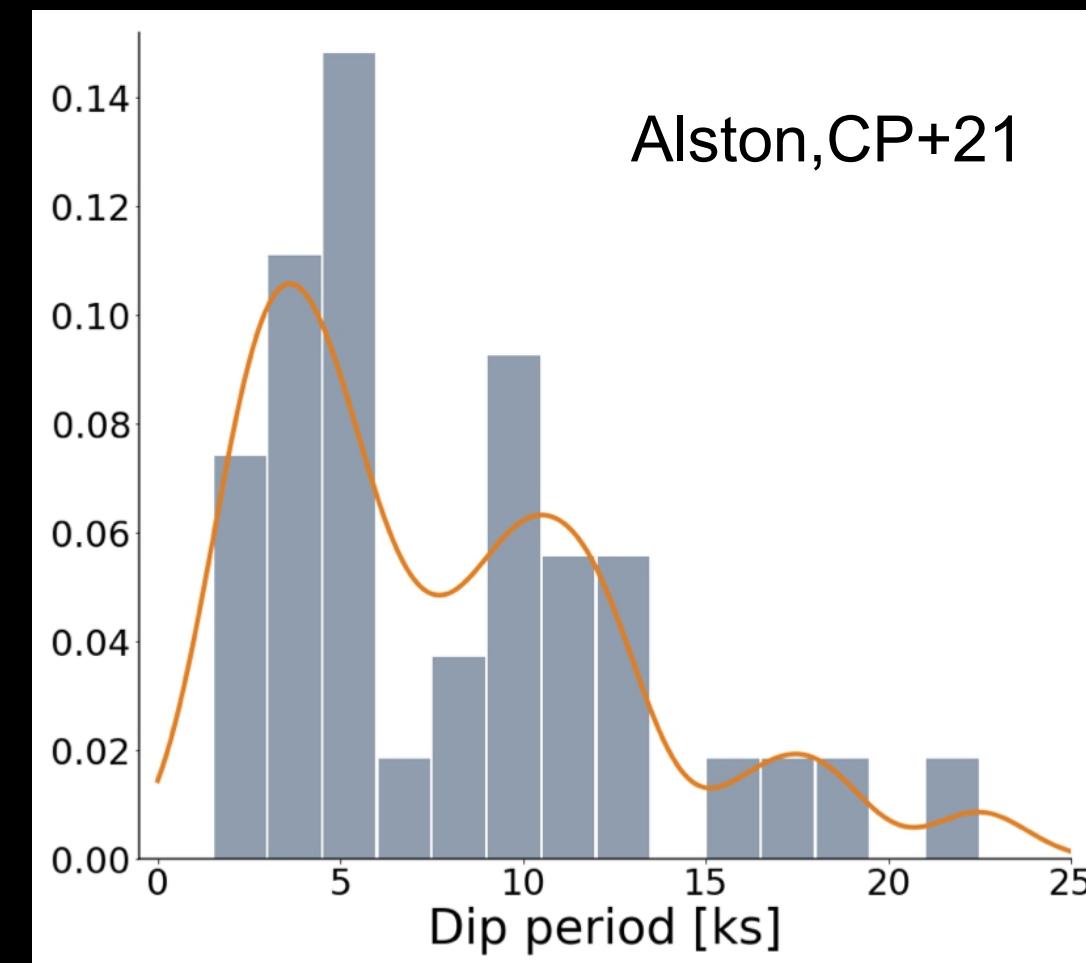
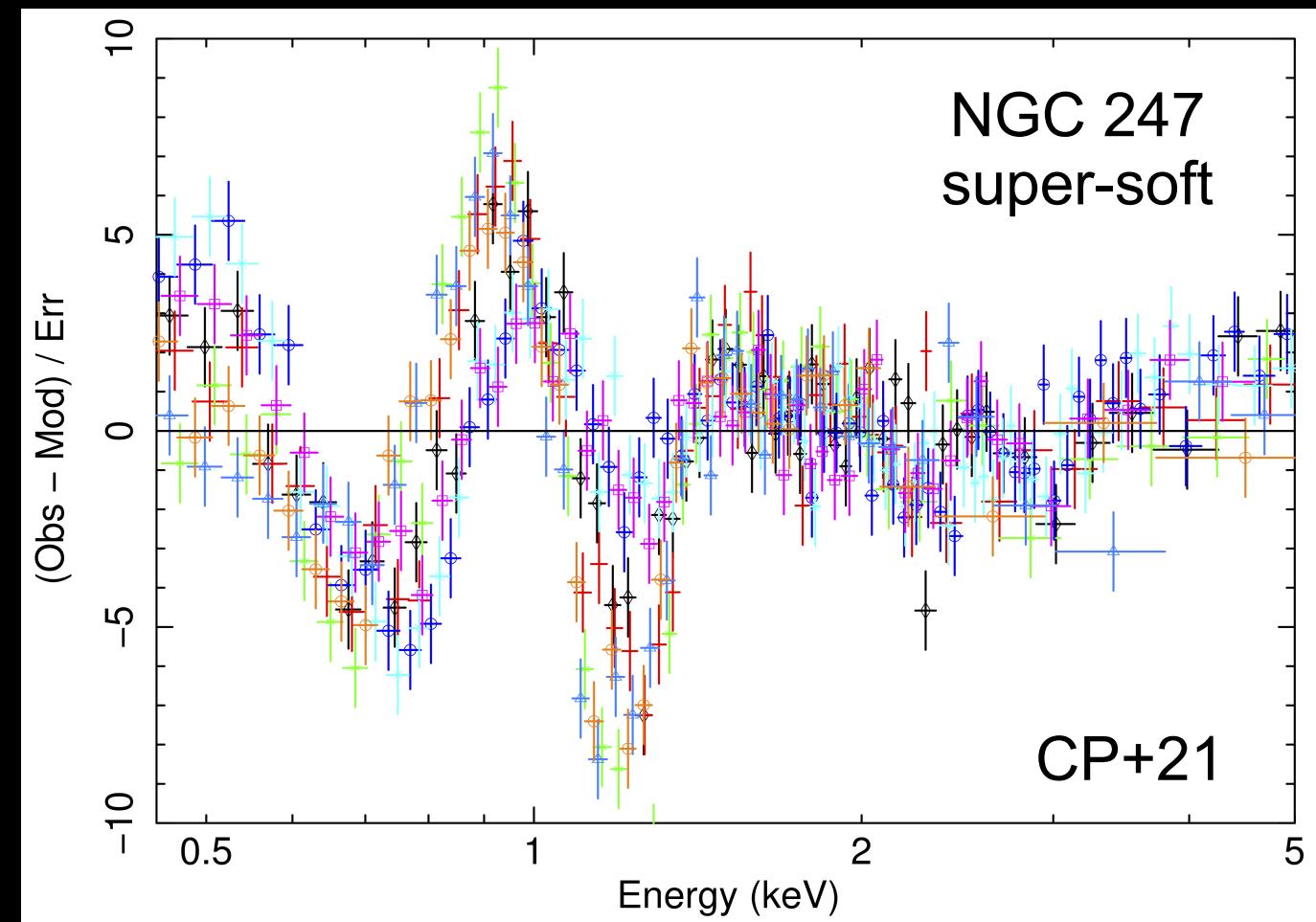


# Powerful relativistic winds: Blueshifted absorption lines



XMM-Newton – Campaign – NGC 247 ULX-1

Both wind and continuum have complex variability patterns



MM+14,15 - CP+16,17,20ab,21 – Walton+18 – Kosec+18ab – Koliopanos+18 – Wang+19

See also Gurpide+21 for a ULX sample

At higher  $L_x$  winds features weaken & dips (sometimes) appear

# Current limitations

Pulsations transient, possible for  $> 40$  ks ( $< 20$  ULX)

Winds detected & resolved for  $> 100$  ks ( $< 10$  ULX)

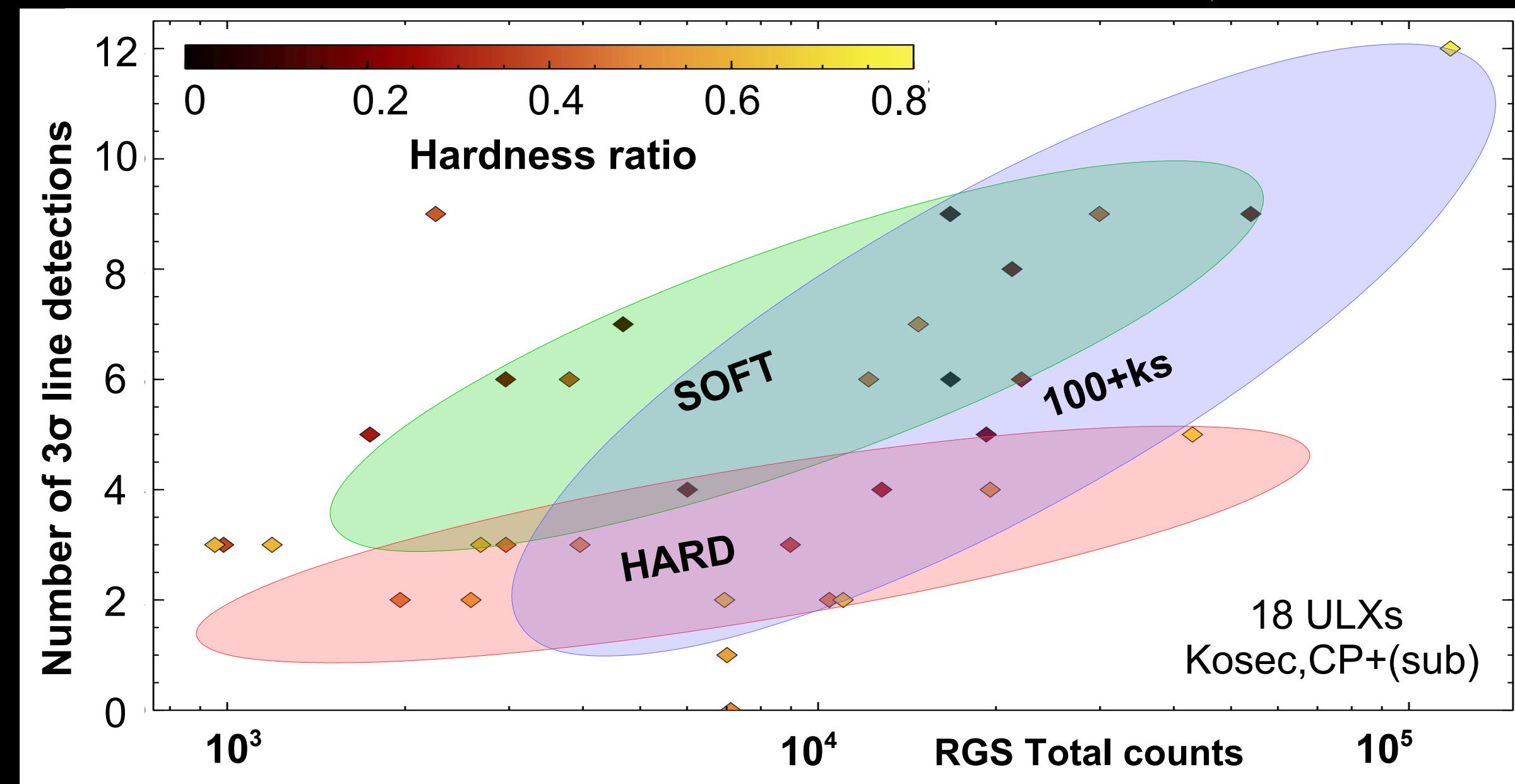
$L-T^\alpha$  relationship & CR for  $> 40 \times N$  ks ( $< 20$  ULX)

# Future requirements

Higher ( $> 2x$ ) Effective area above 2 keV

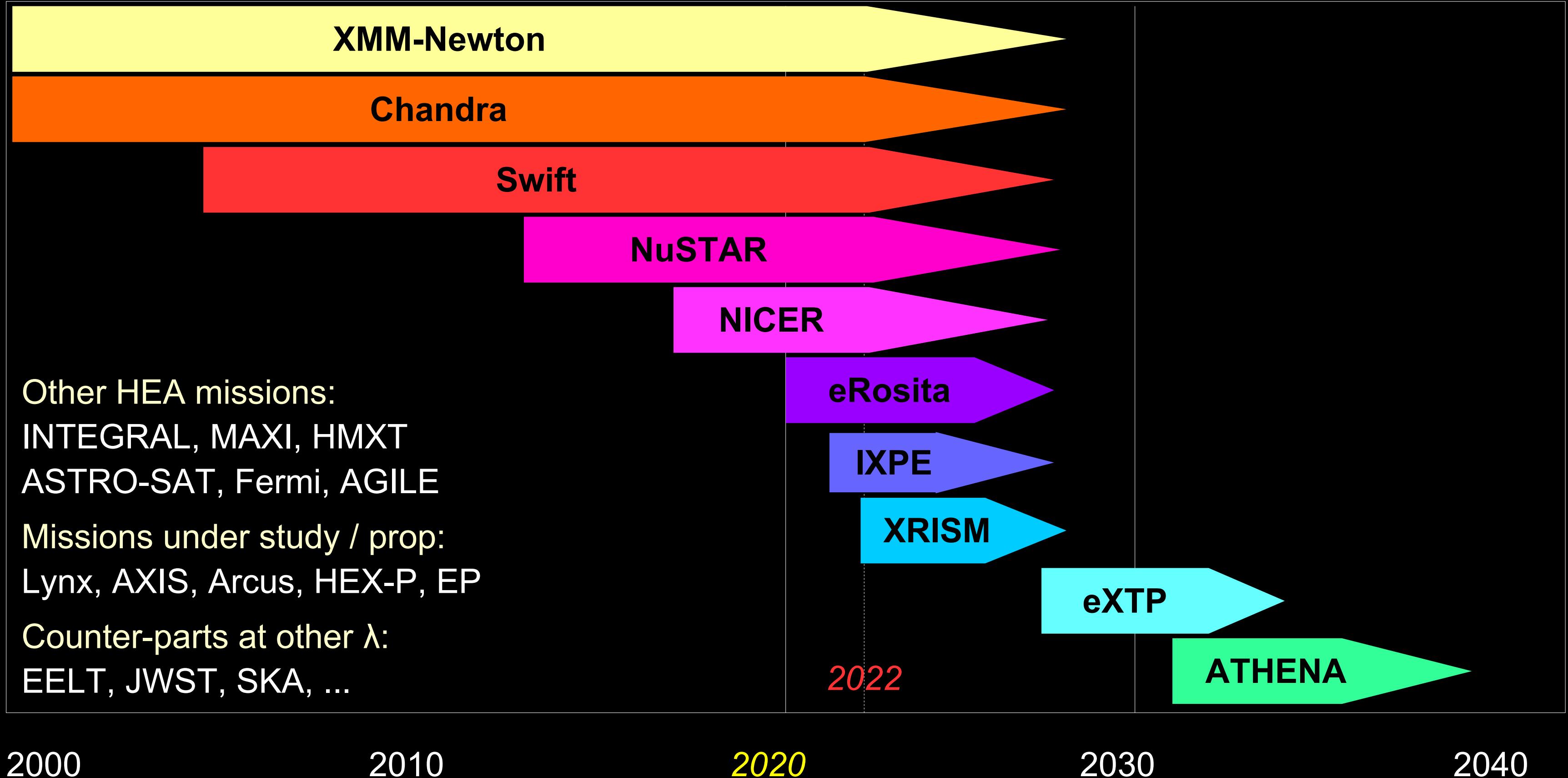
Higher ( $> 4x$ ) Effective area (& spec-res) at  $\sim 1$  keV

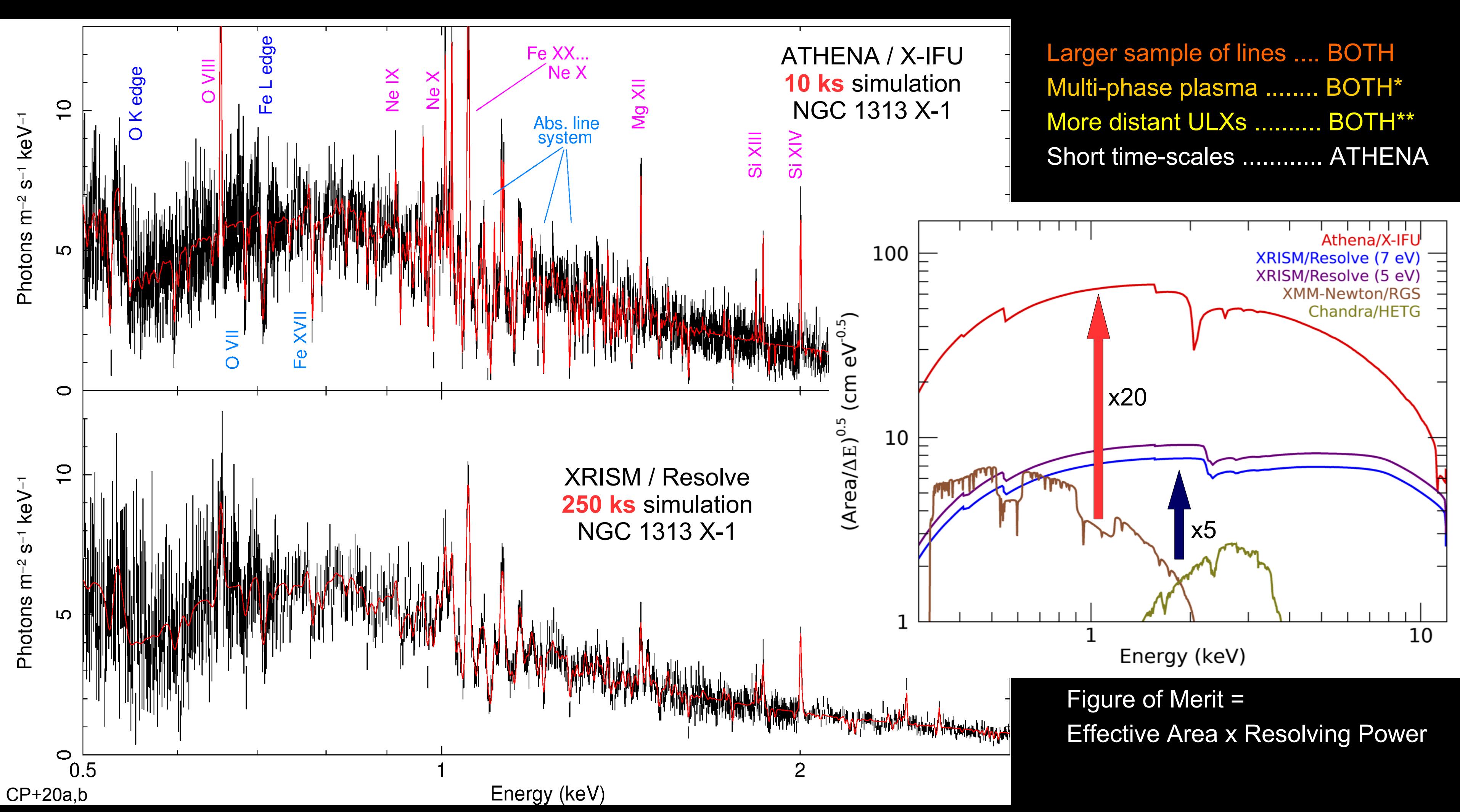
Higher ( $> 2x$ ) Effective area & X-ray broad band



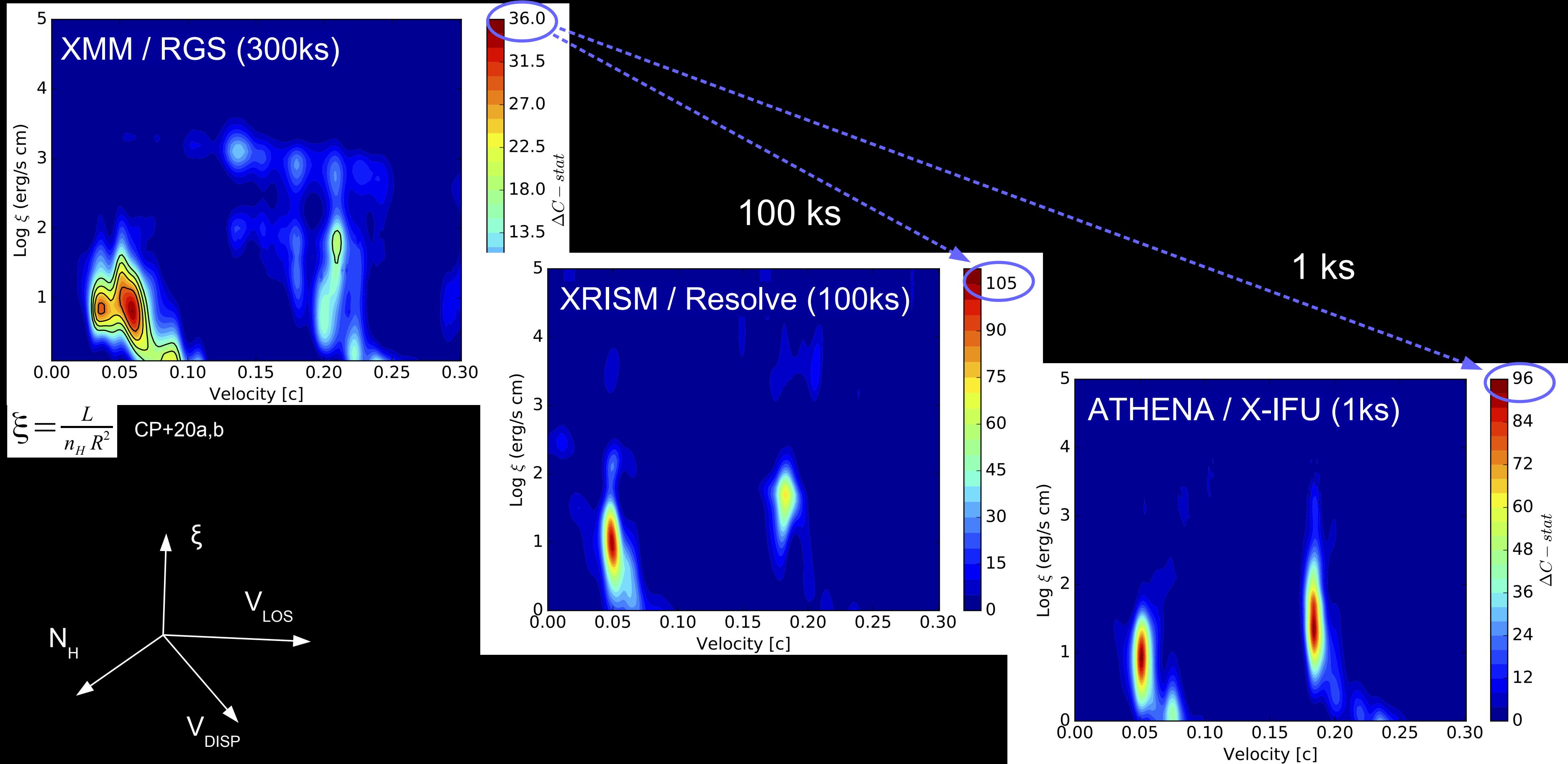
# Present & Future X-ray missions

(Involved in ULX & NS/BH science)





# Wind variability with the source flux / state



# Take away message

ULXs are excellent probes of **extremes** ( $\dot{M}_{\odot}$ ,  $M_{\odot}$ ) in accretion

$30'' = 500 \text{ pc}$

Past & present satellites unveiled ULX **characteristics**:

winds, pulsations, variability, opt-counterpart, ...

Current **limitations** prevent a complete understanding

The **future** is bright thanks to new superb missions

**ATHENA**, **XRISM**, eROSITA, eXTP, etc.

