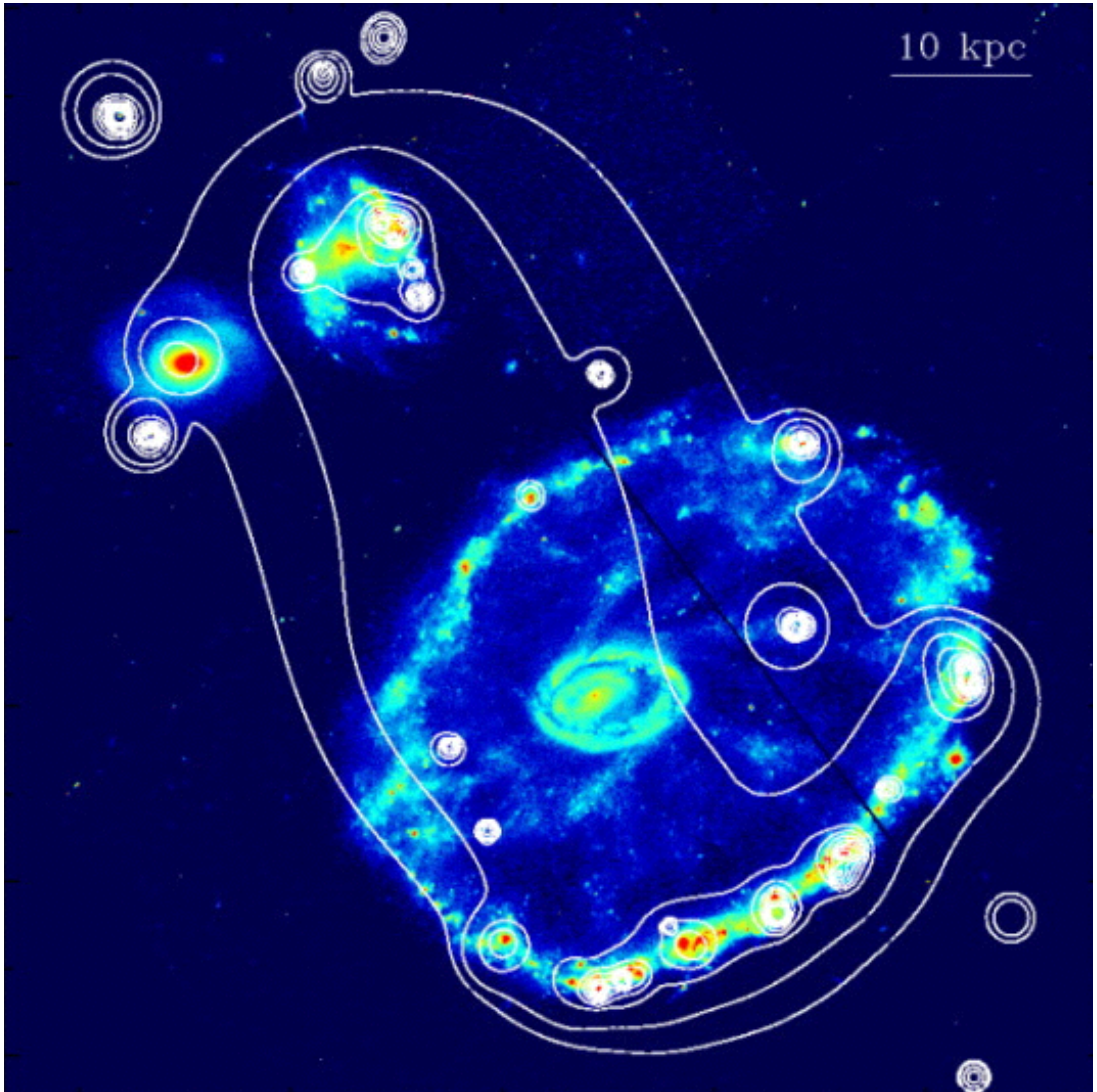
Broad strokes introduction to ULXs:

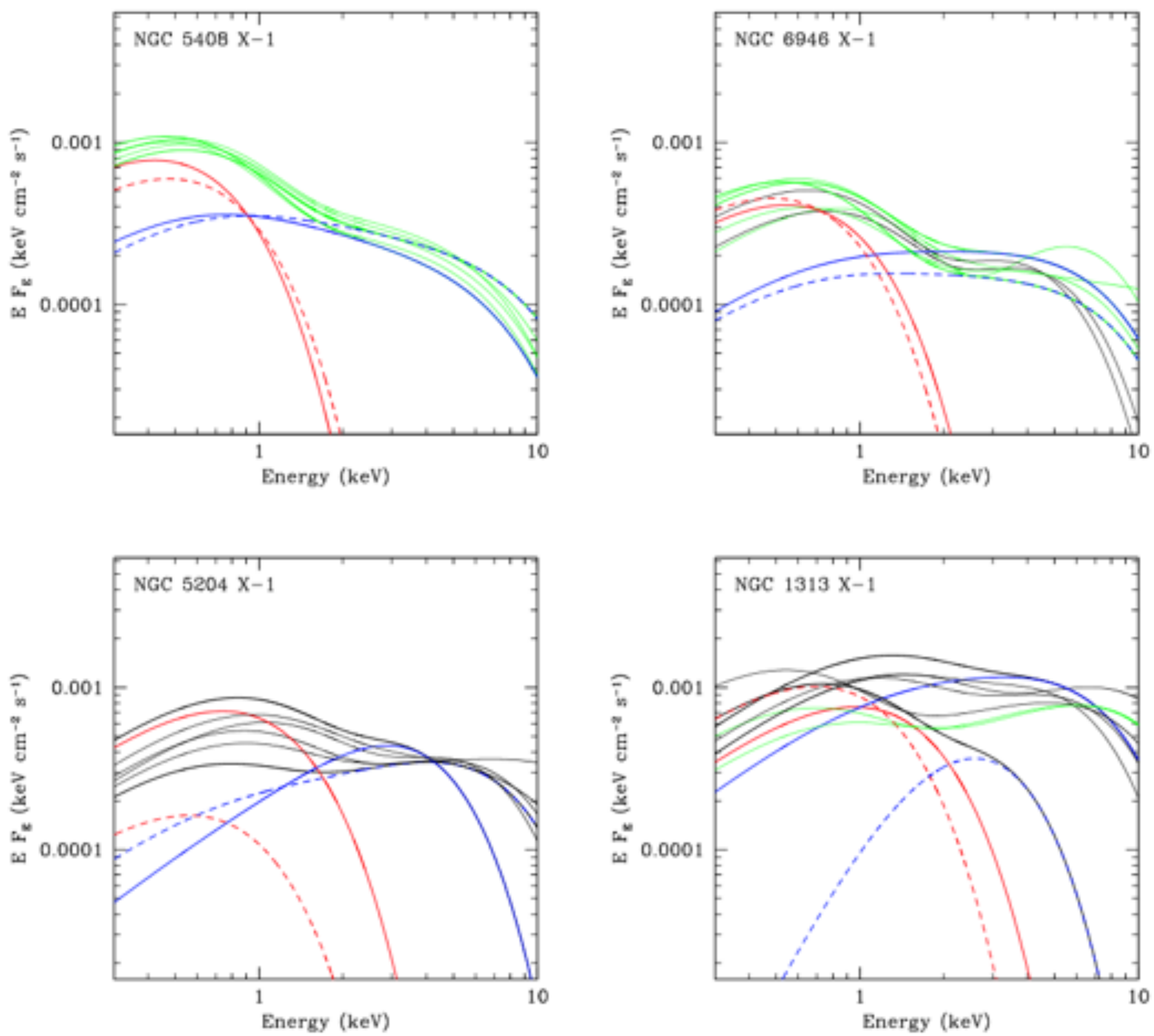


<u>Define ‘canonical’</u>

- Found in other galaxies (though we have at least 1 in our own)
- Usually we expect the source to be inside the host’s B_{25} isophote but away from the centre (but some will still be bkg AGN)
- <u>Empirical</u> cut off is de-absorbed 10^{39} erg/s usually over the 0.3-10keV (XMM) bandpass

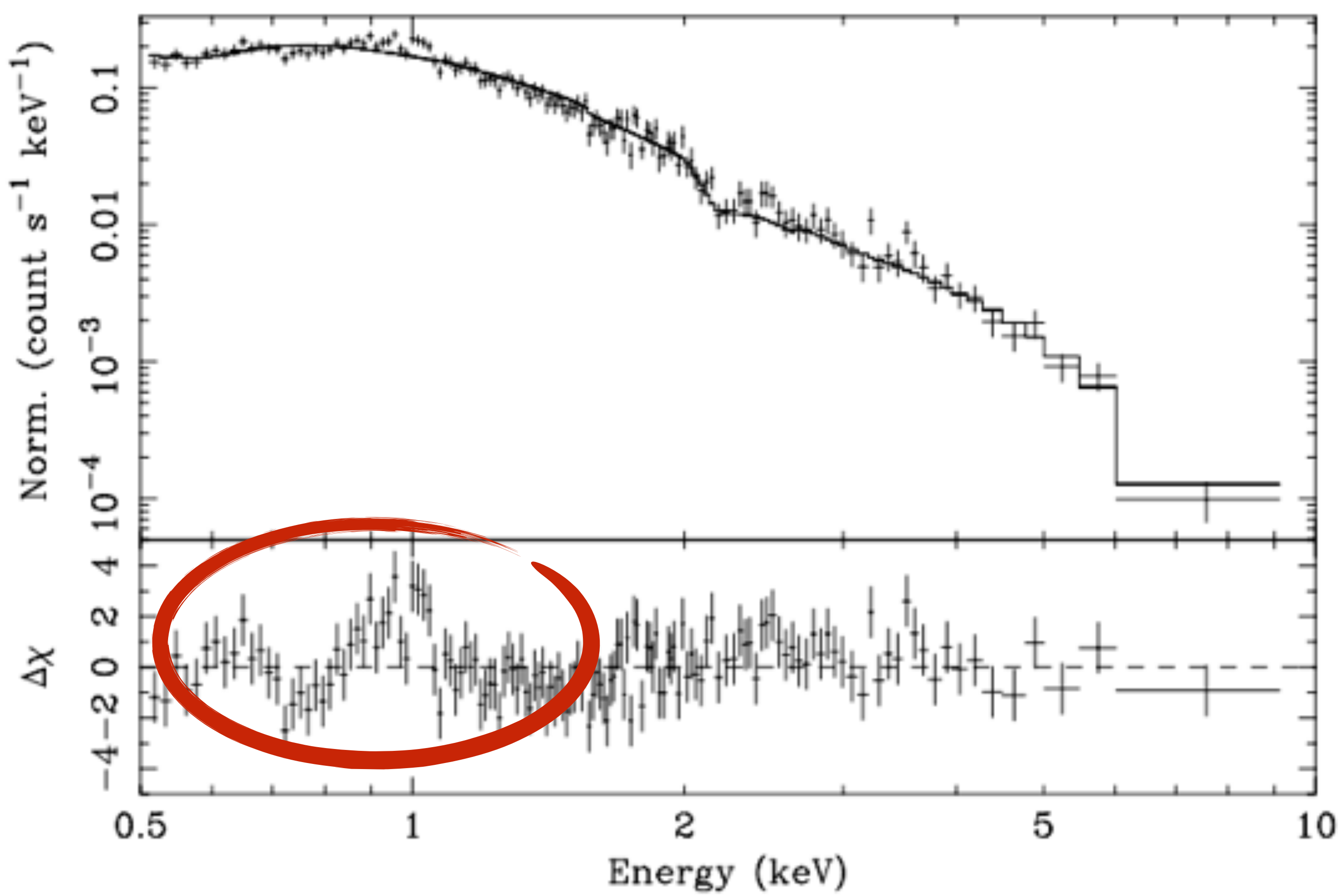
Show two component X-ray spectra (even if not immediately obvious)

Break usually found in XMM bandpass but can be a bit above it (e.g. M82 X-2 has E_{cut} ~ 14 keV)

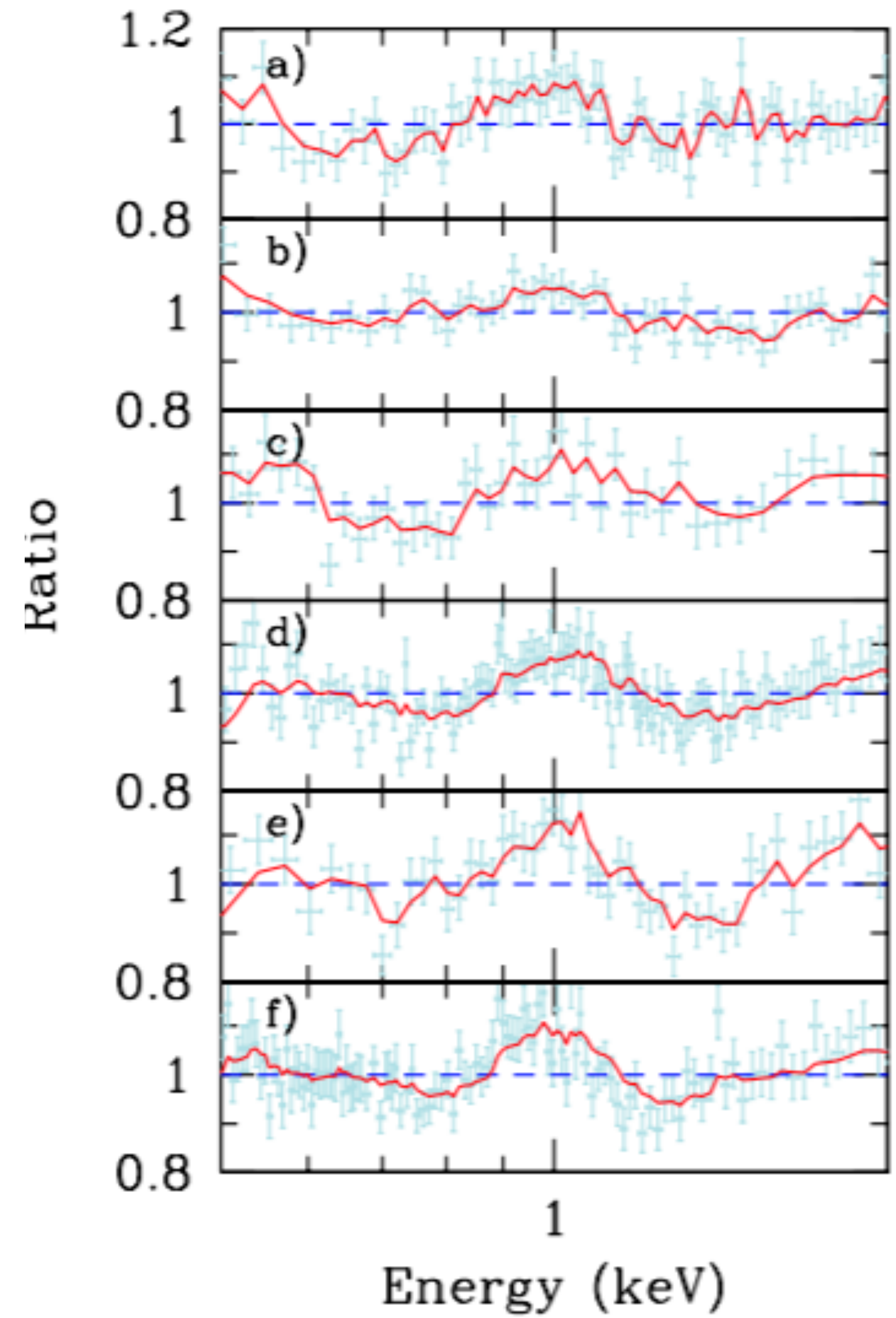


Middleton et al. (2015a)

CCD residuals to best-fitting model seem fairly (low number stats) ubiquitous where SNR allows

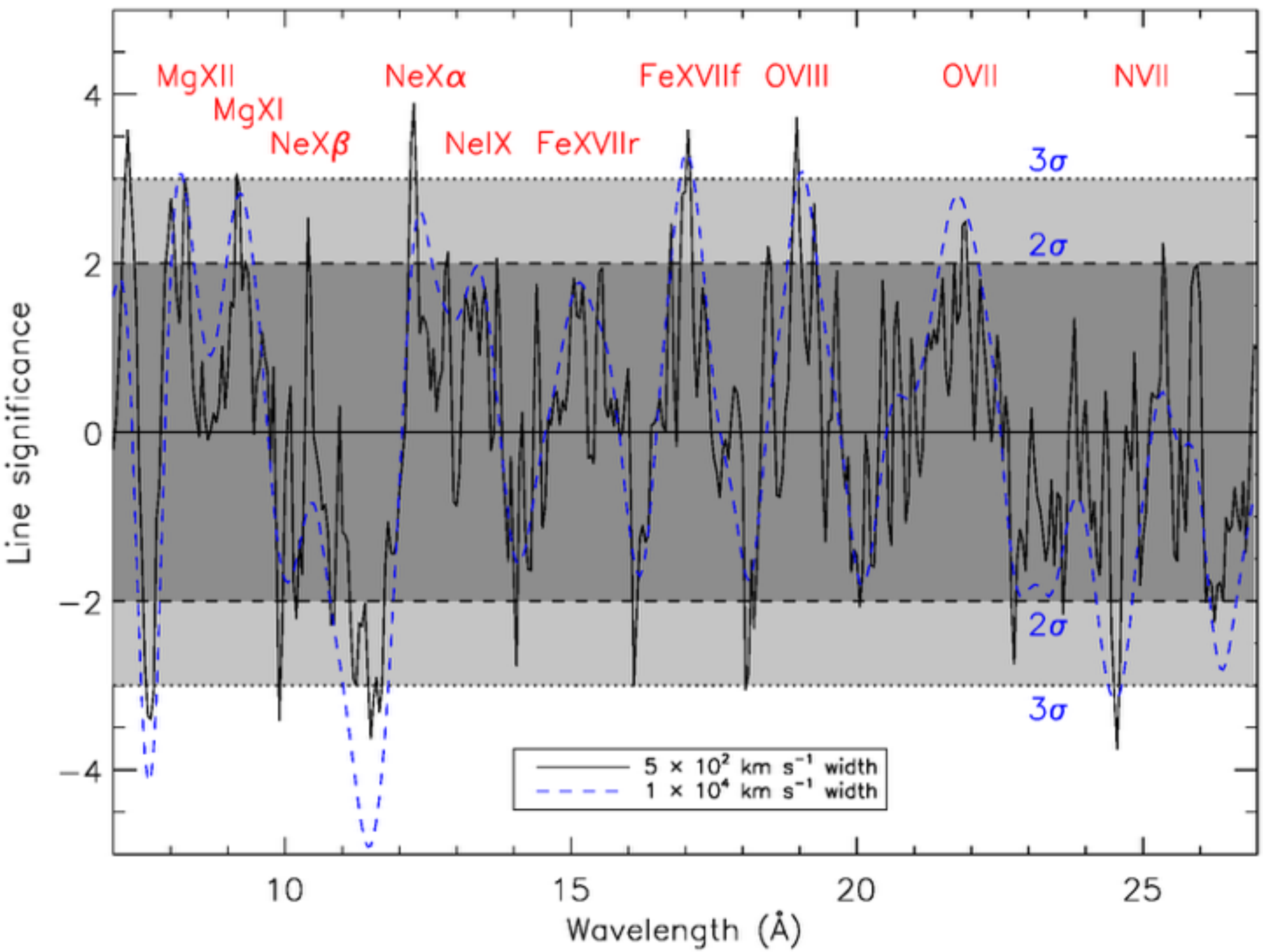


Roberts et al. (2006)



Middleton et al. (2015b)

All the available evidence points towards outflows (probably equatorial) at ~0.1-0.2c



Pinto, Middleton & Fabian (2016)

Competing ideas to explain brightness:

1. IMBHs - high mass, low accretion rate

Black holes with masses in the range several 100+ M_{solar}

Important if present as building blocks for SMBHs

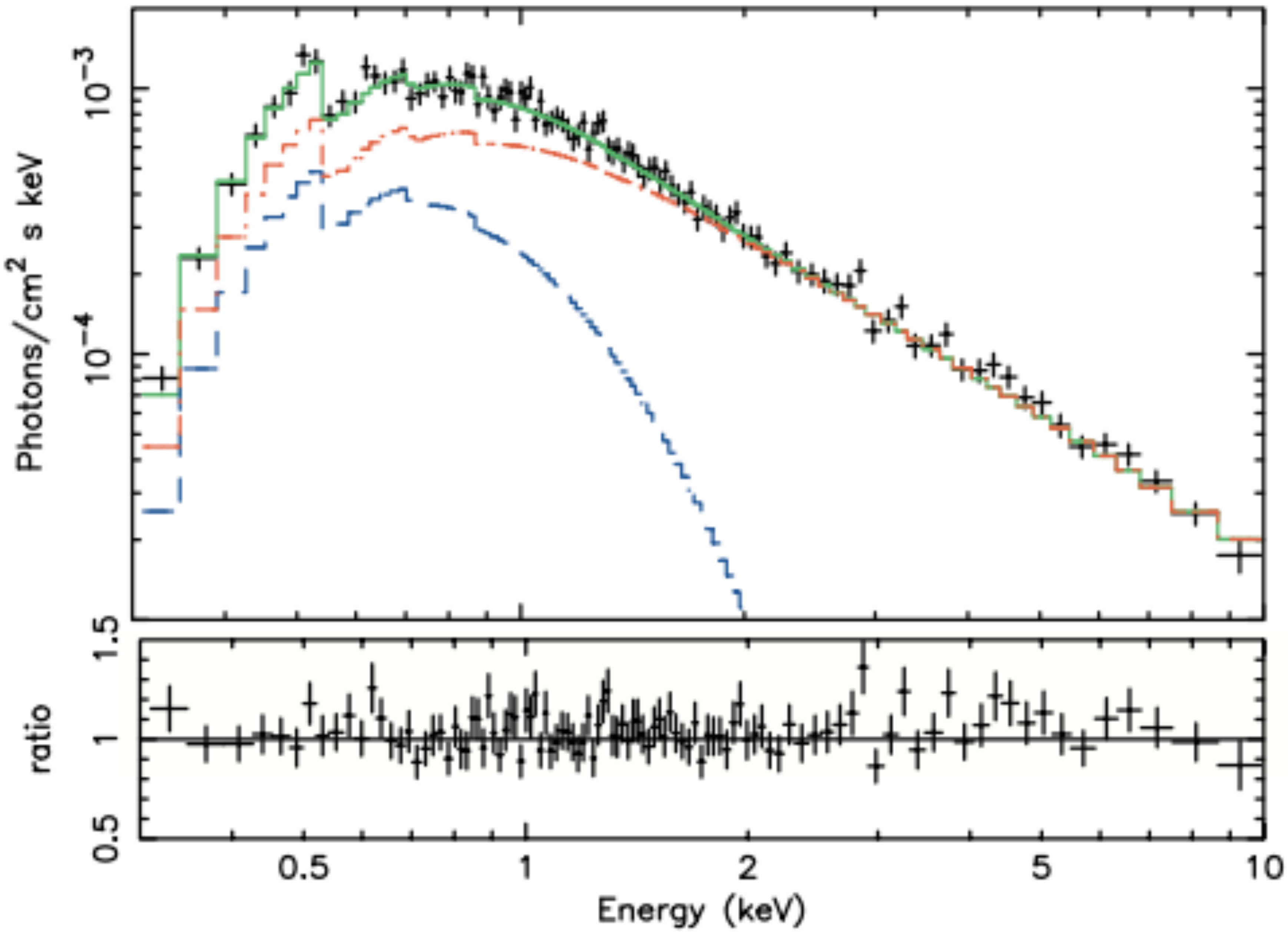
Properties that you *could* predict:

i) assuming we see thin disc emission with $R_{in} \sim R_{isco}$ then kT_{in} should be low

ii) timing features (by which I mean PDS breaks, QPOs, lags) if scaling by mass should be at lower freqs than in BHBs

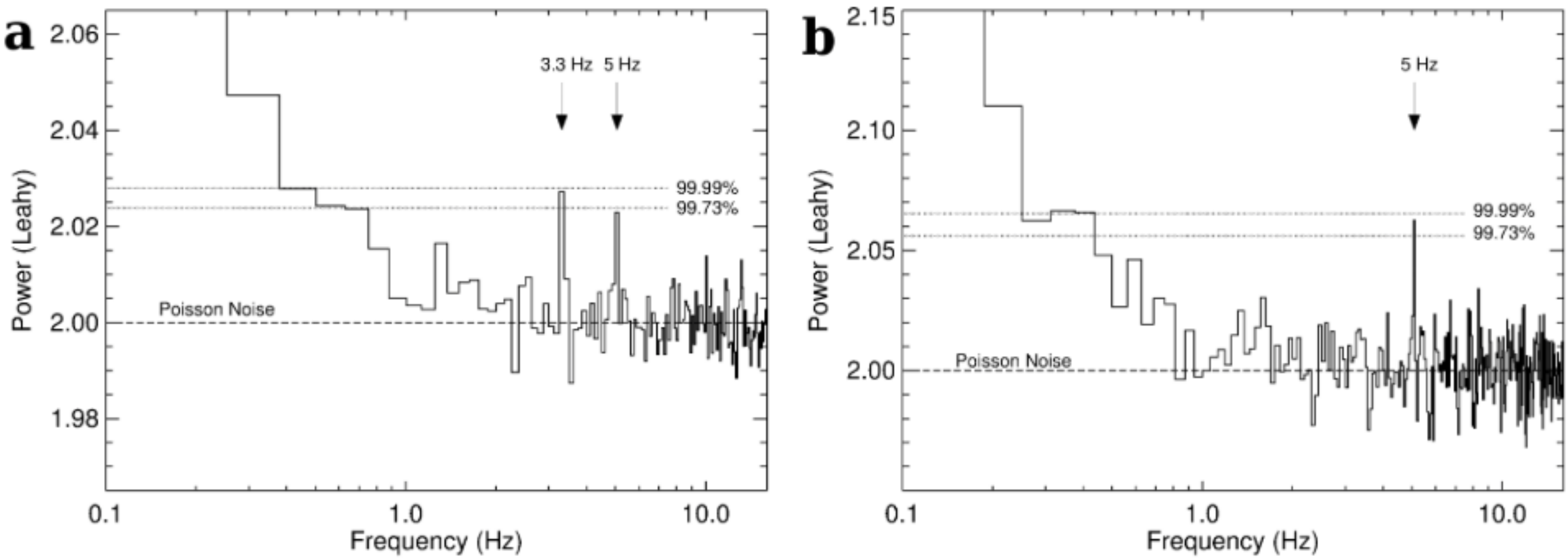
iii) if very low accretion rates (i.e. high mass IMBHs) then we should be able to place the source on the fundamental plane

Evidence in support of this scenario:



Miller et al. (2004)

Evidence in support of this scenario:



Pasham et al. (2014)

Harmonic ratio (3:2) QPOs in M82 X-1

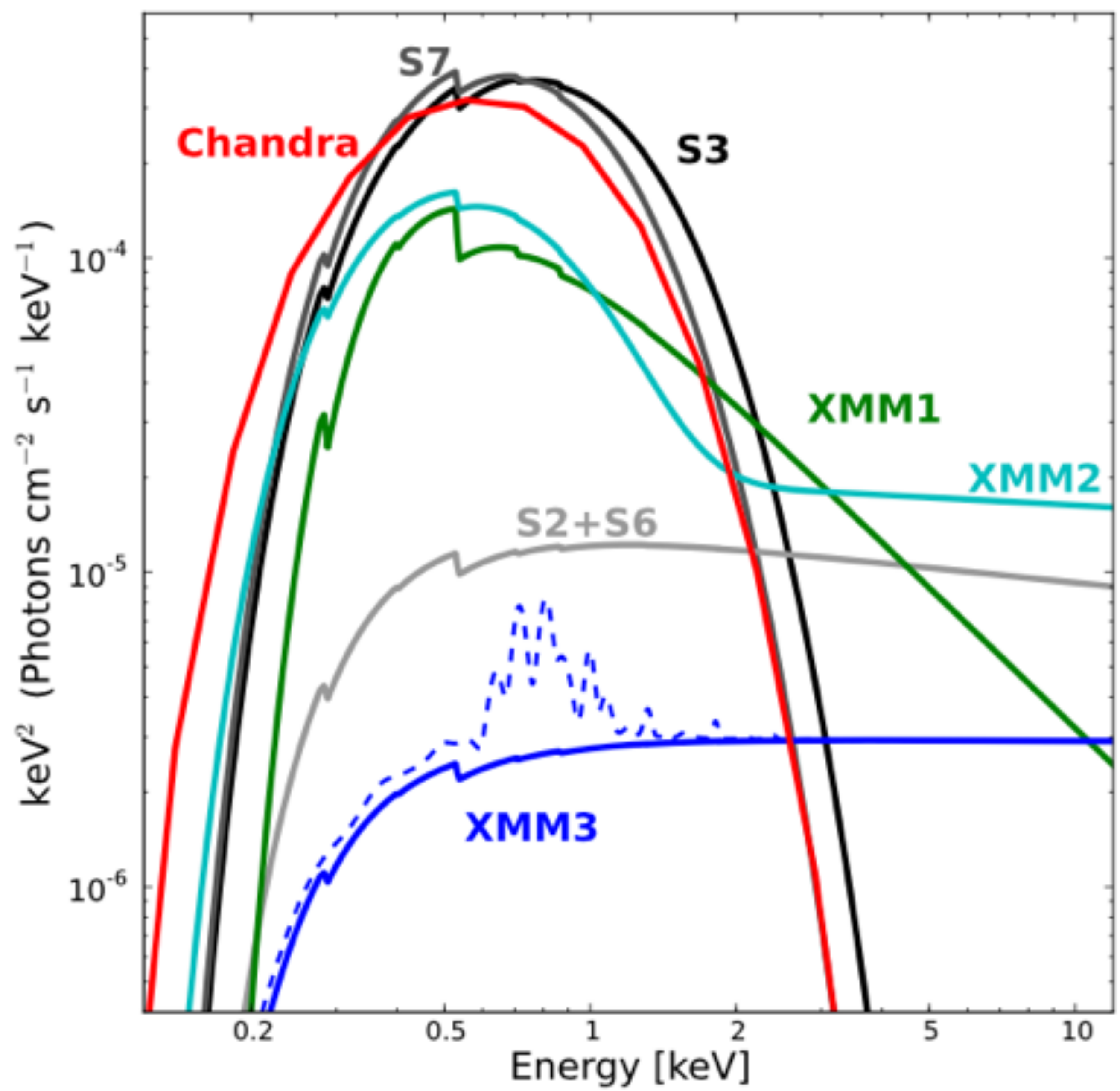
If we scale QPO frequencies by mass then (assuming these are analogous to HFQPOs in BHBs) we may have a mass ~400 M_{solar}

Hyperluminous X-ray sources:

In the case of HLX-1 which appears to undergo outbursts every ~500 days, the spectra appeared to be analogous to BHBs at sub-Eddington rates

$M \sim 3000 - 3 \times 10^5 M_\odot$

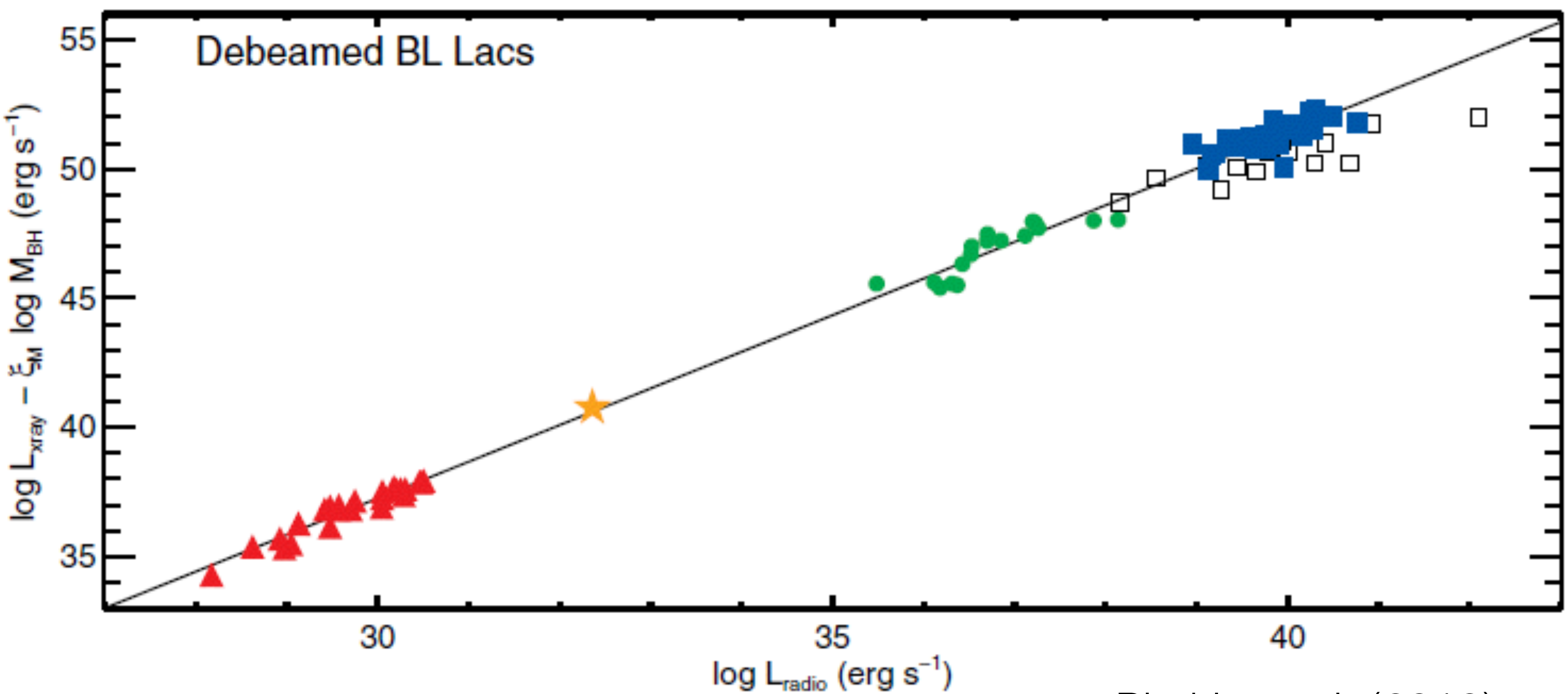
Davis et al. (2011)



Servillat et al. (2004)

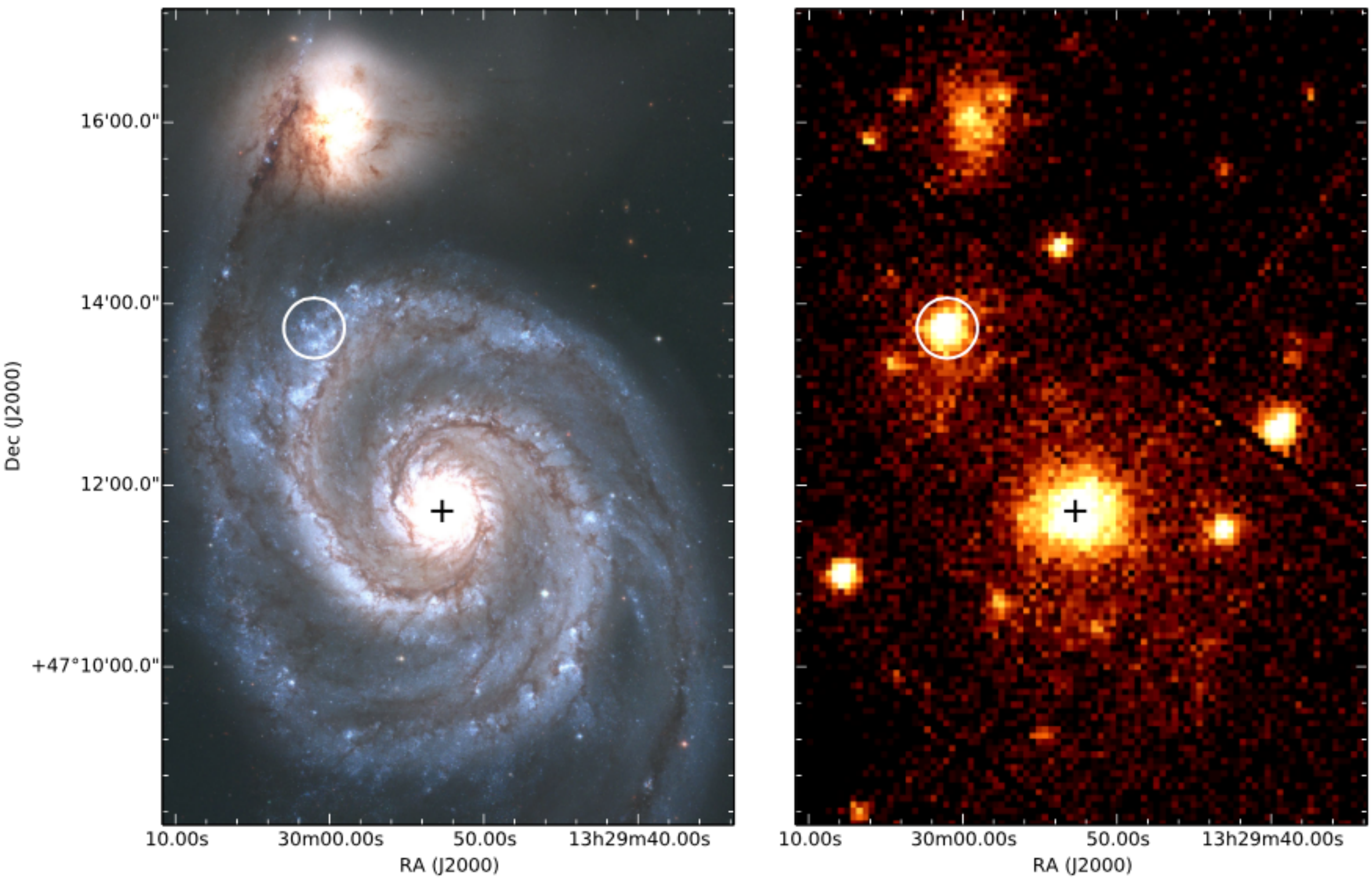
Hyperluminous X-ray sources:

ATCA constraints when in the 'LHS' and fundamental plane would indicate $M < 2x10^6\ M_{solar}$ (Cseh et al. 2015)



Plotkin et al. (2012)

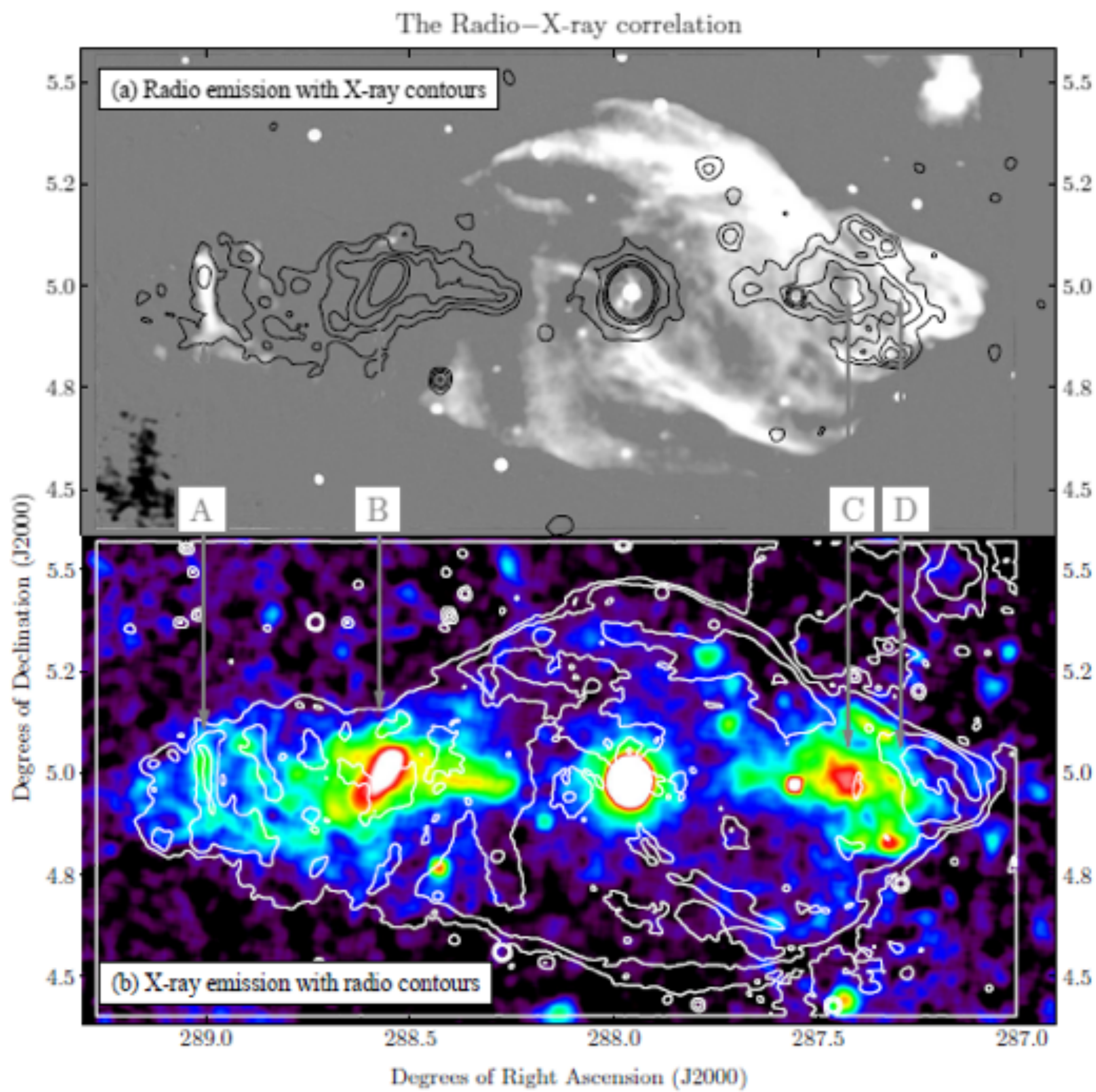
A sample of HLX candidates is starting to take shape



Earnshaw et al. (2016)

2. Stellar remnants (sMBHs, NSs and WDs) - low mass, super-critical (i.e. > Eddington) accretion rates

We know that this happens in our Galaxy

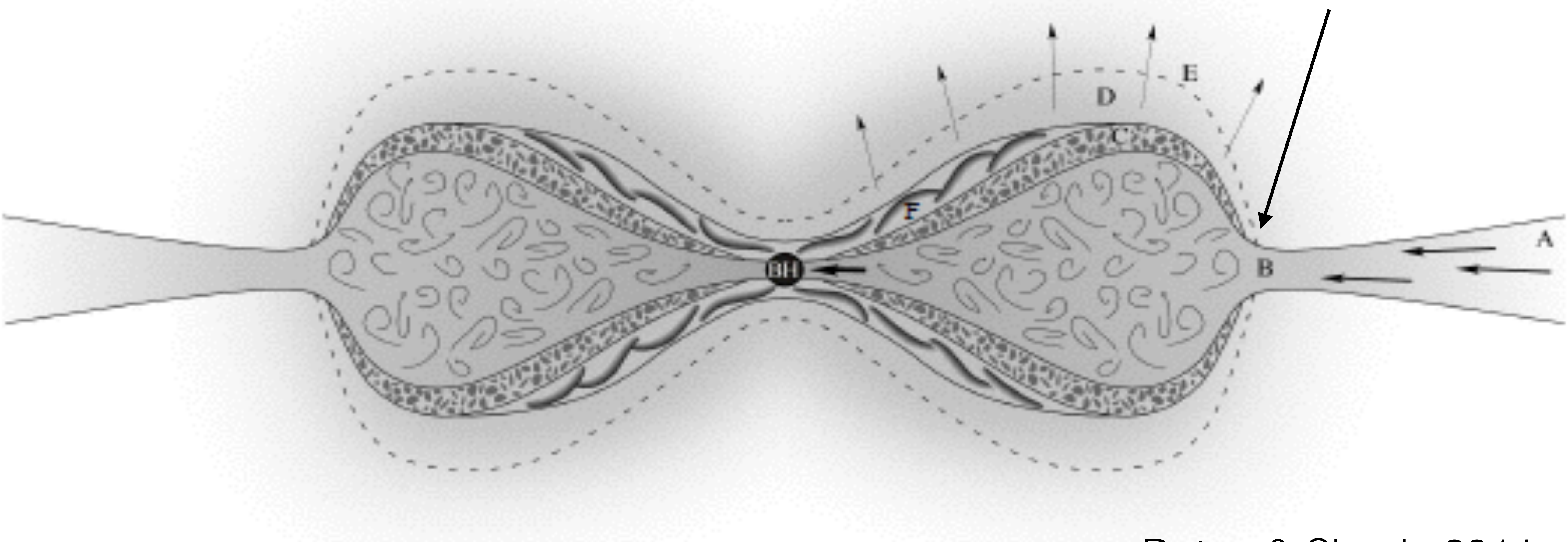


Mass being transferred on thermal timescale of secondary

$$\dot{m} \sim \frac{M_2}{t_{KH}}$$

At the 'spherization radius' r_{sph} the accretion disc is locally Eddington (Shakura & Sunyaev 1973) - we say that the flow is **super-critical**

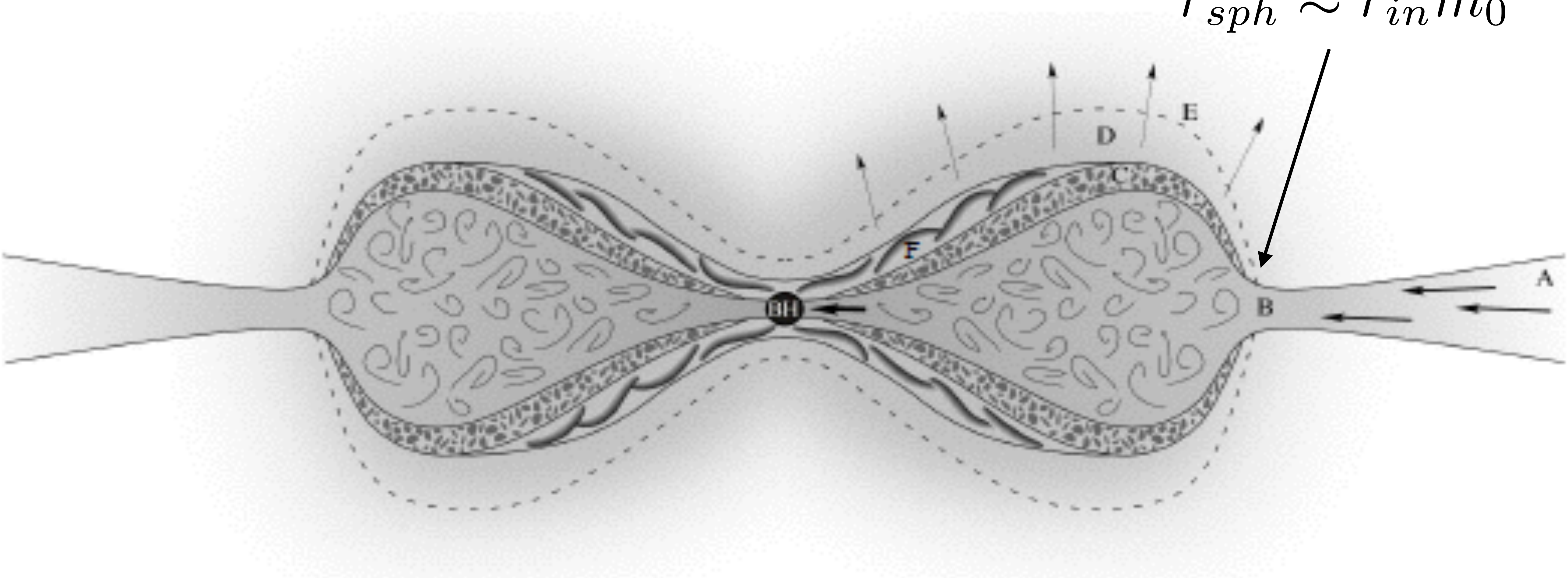
$$r_{sph} \approx r_{in}\dot{m}_0$$



Dotan & Shaviv 2011

Disc inflates (H/R ~1) and mass is then lost via mass loaded winds (~0.1c) or advected so that the inflow remains locally Eddington limited - forms a ‘wind-cone’

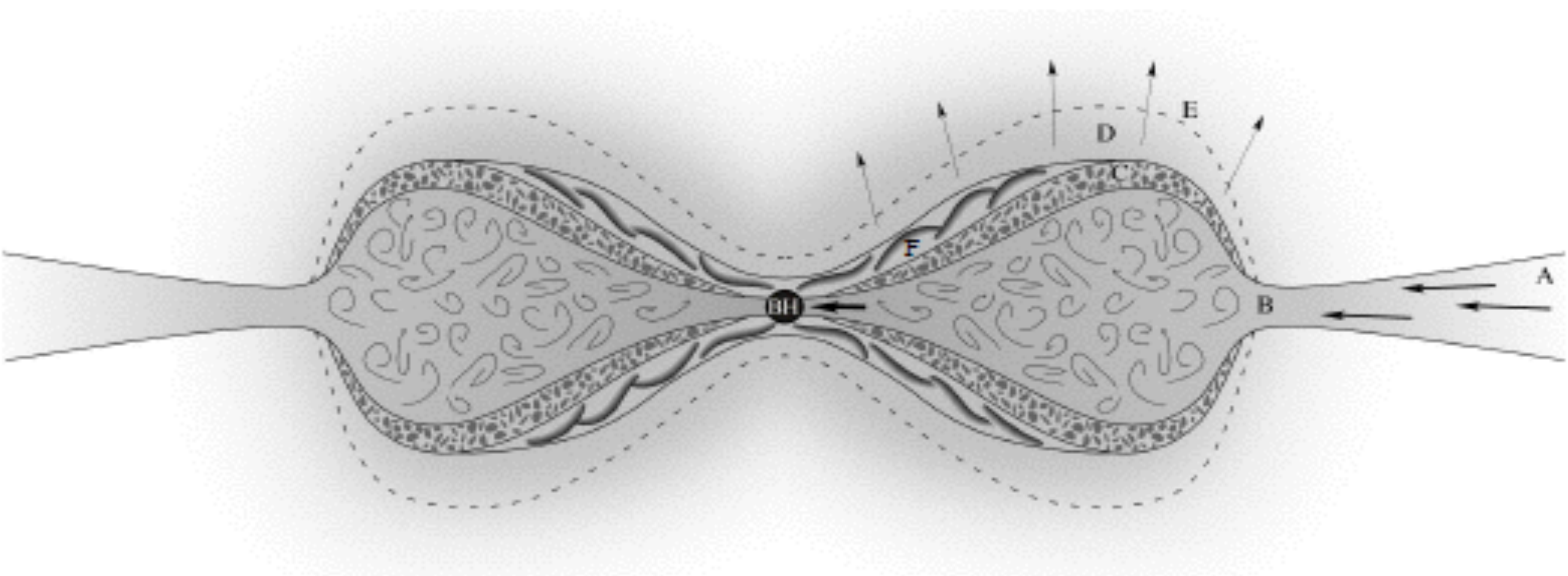
$$r_{sph} \approx r_{in}\dot{m}_0$$



Dotan & Shaviv 2011

$$L \approx L_{Edd}[1 + ln(\dot{m}_0)]$$

Some of this will emerge as radiation, some will be used to power the outflow (see Poutanen et al. 2007)



Dotan & Shaviv 2011

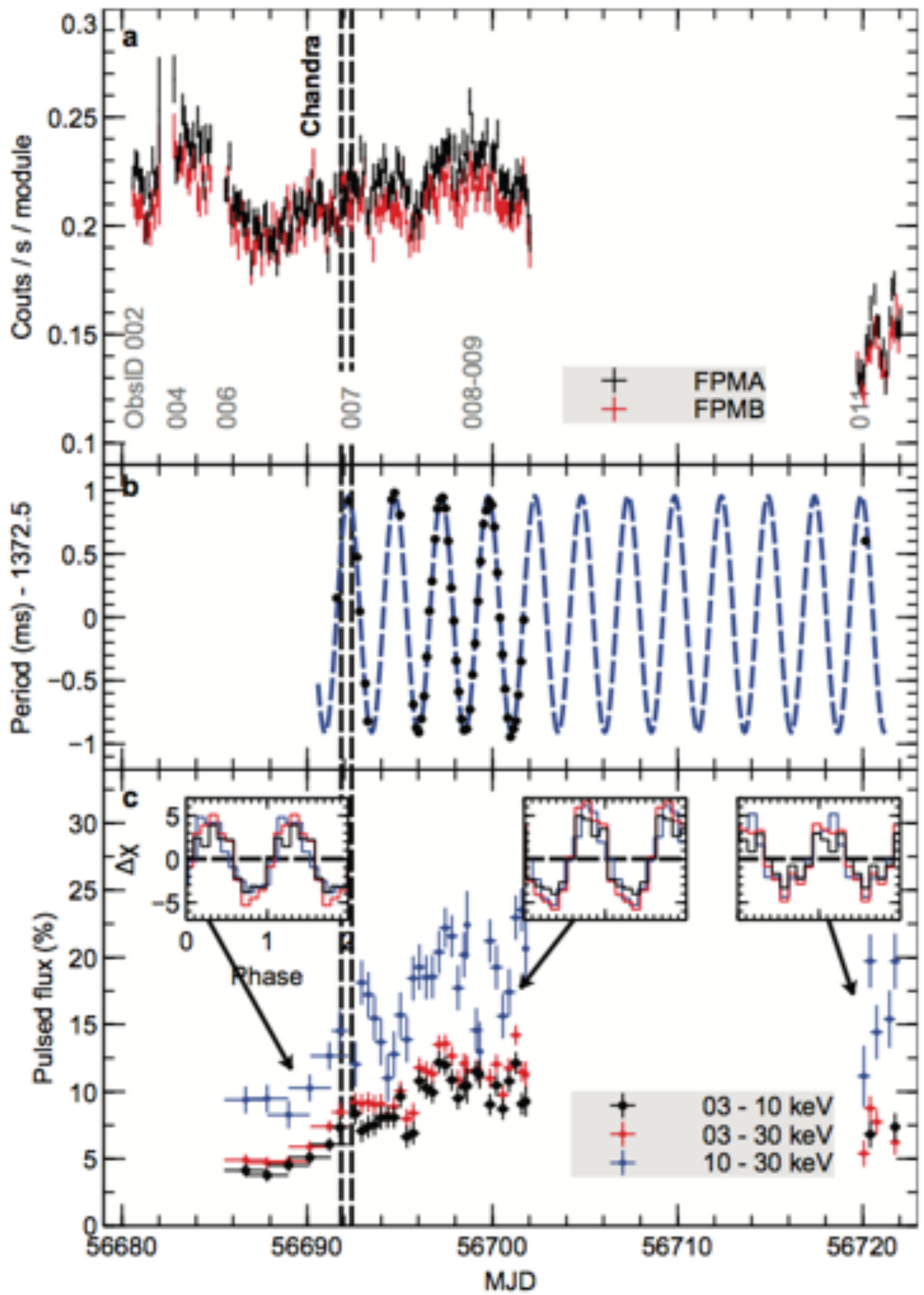
Idea of geometrical (not relativistic) beaming

Looking into the cone of the wind, we should see the trapped radiation = geometrical beaming

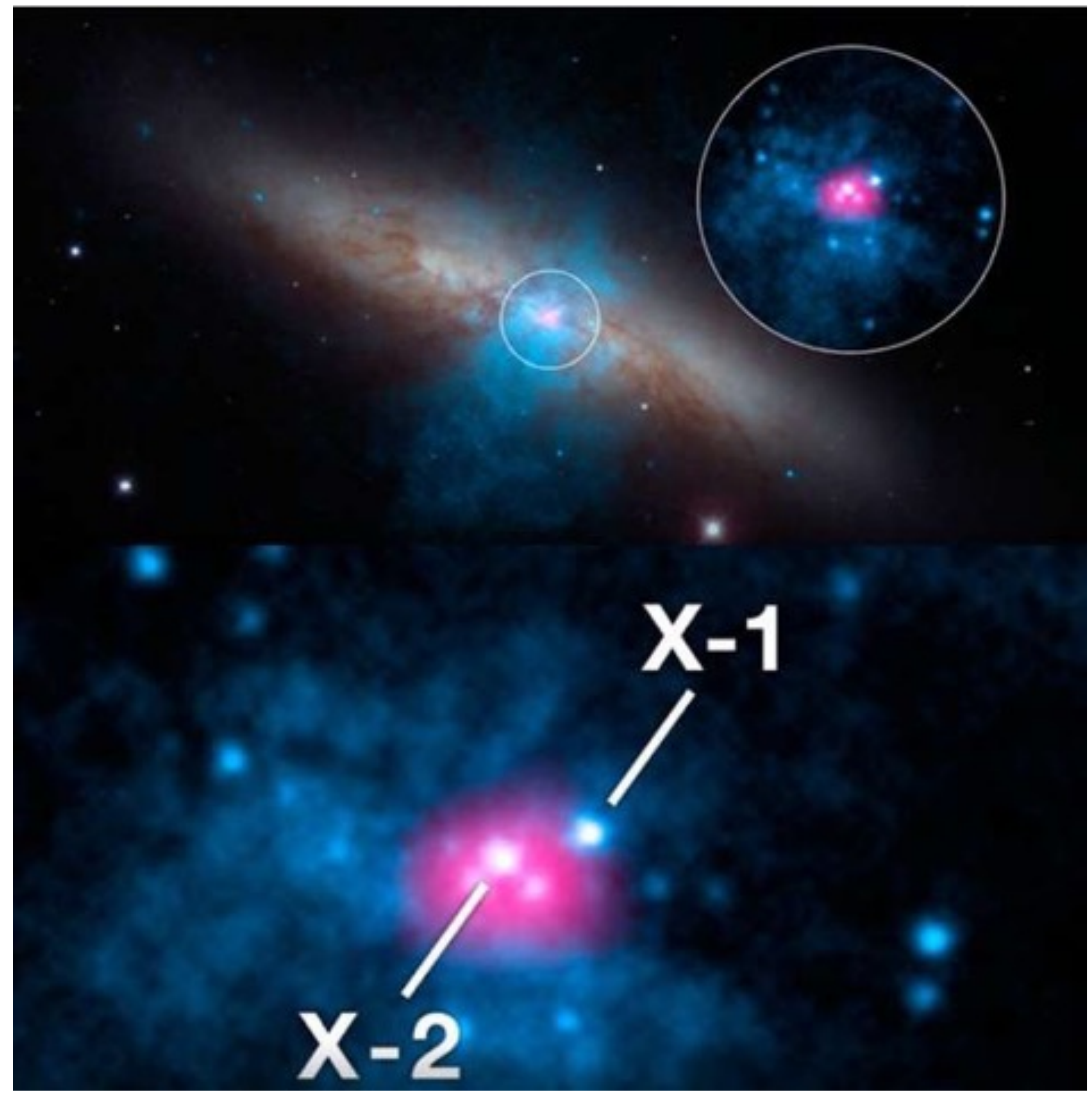
So very bright X-ray sources

Leads to the inevitable conclusion that if occurring, edge-on sources may be < 10^{39} erg/s but the same objects experiencing the same regime of accretion

No need to speculate - discovery of ULPs

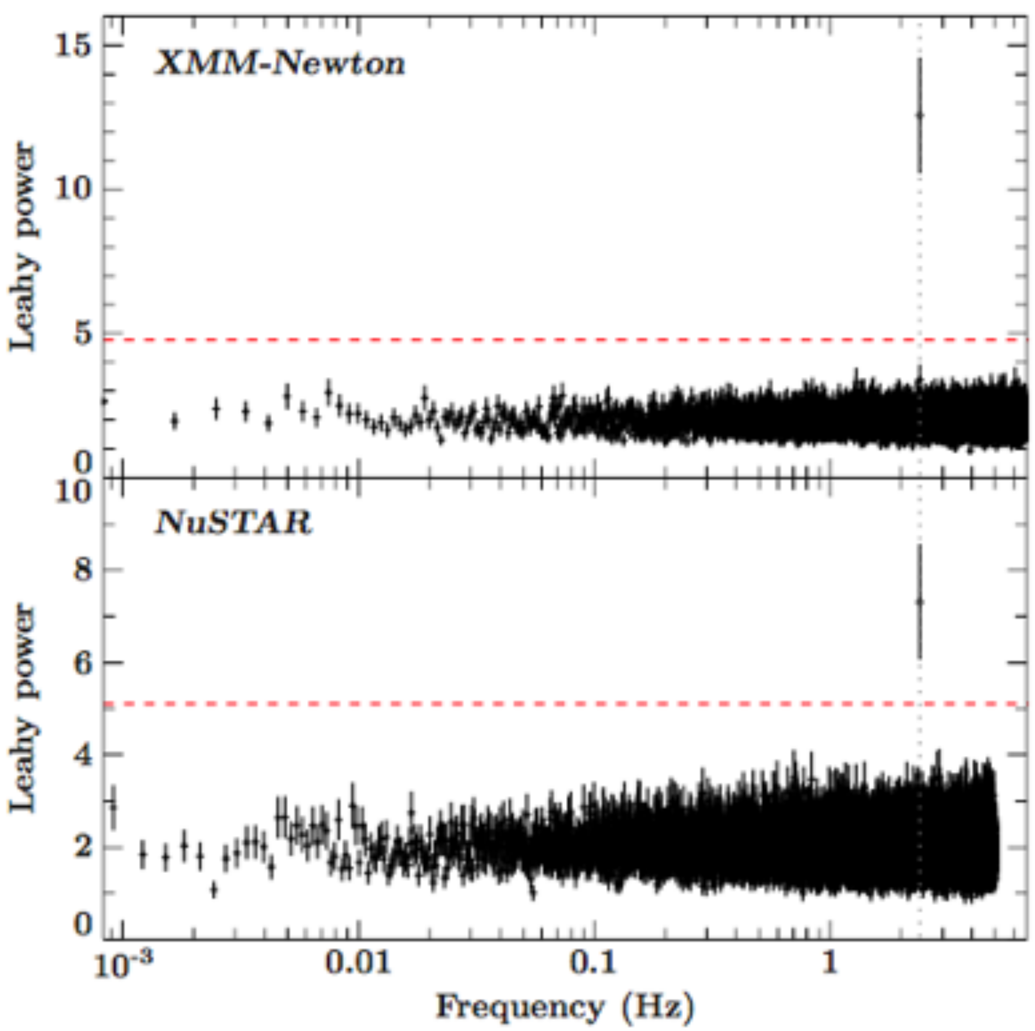


Bachetti et al. (2014)



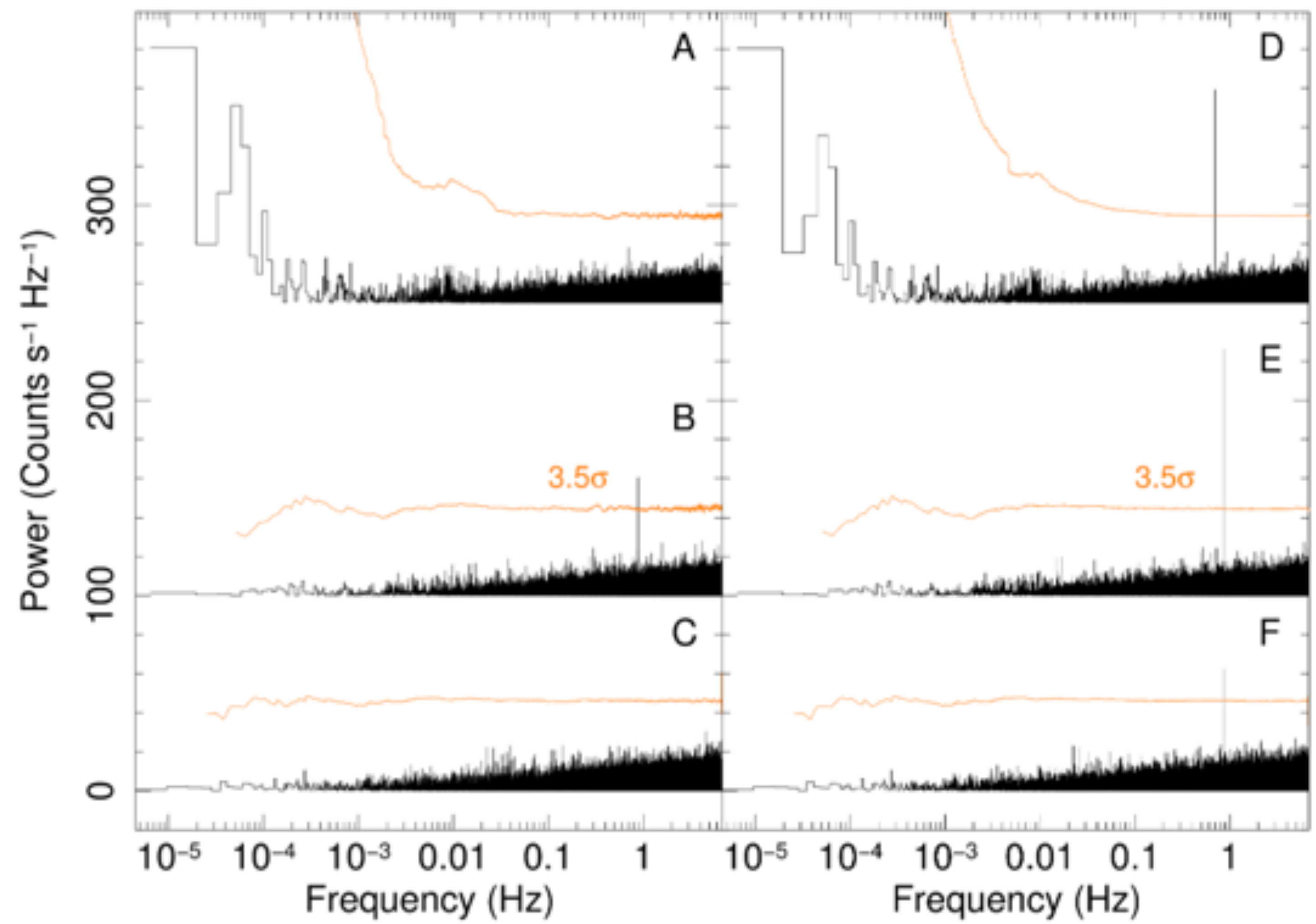
No need to speculate - discovery of ULPs

NGC 7793 P13



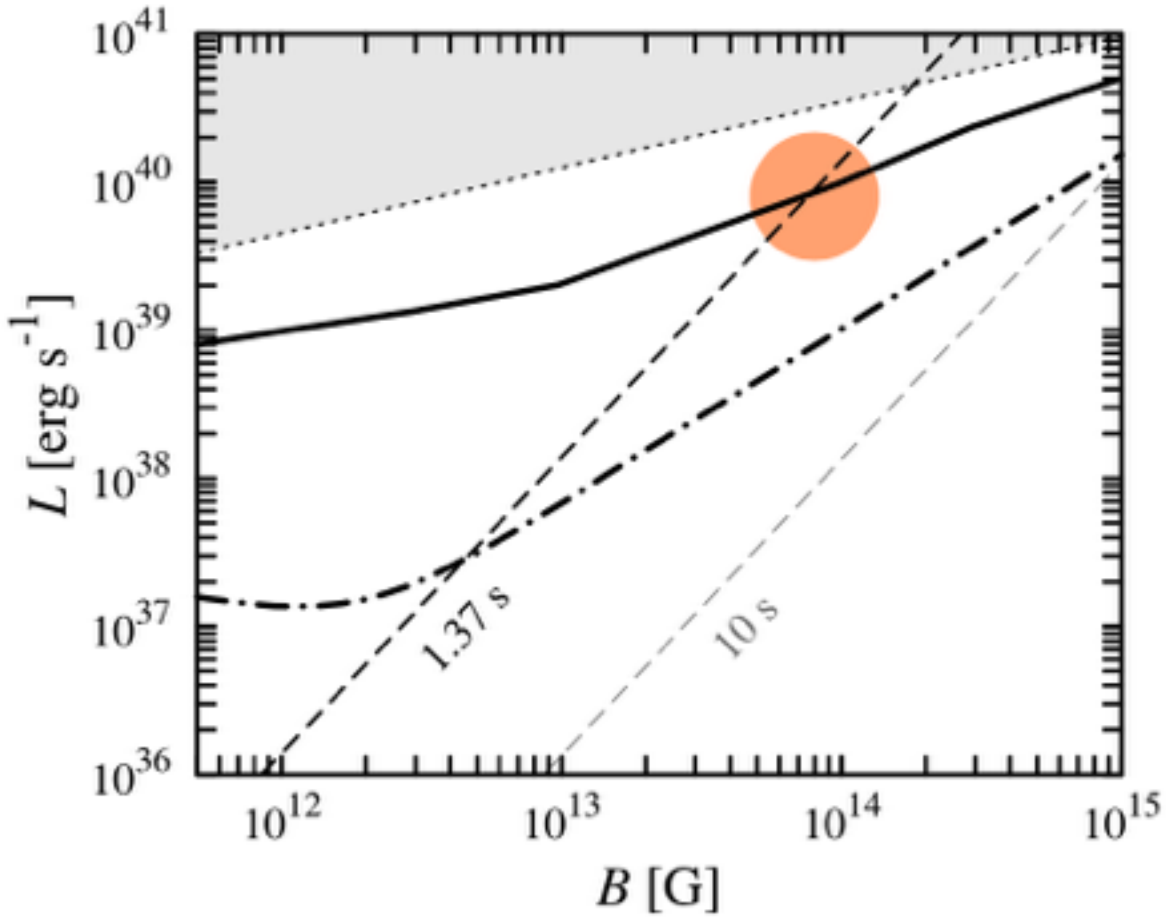
Fuerst et al. (2016)

NGC 5907 ULX-1

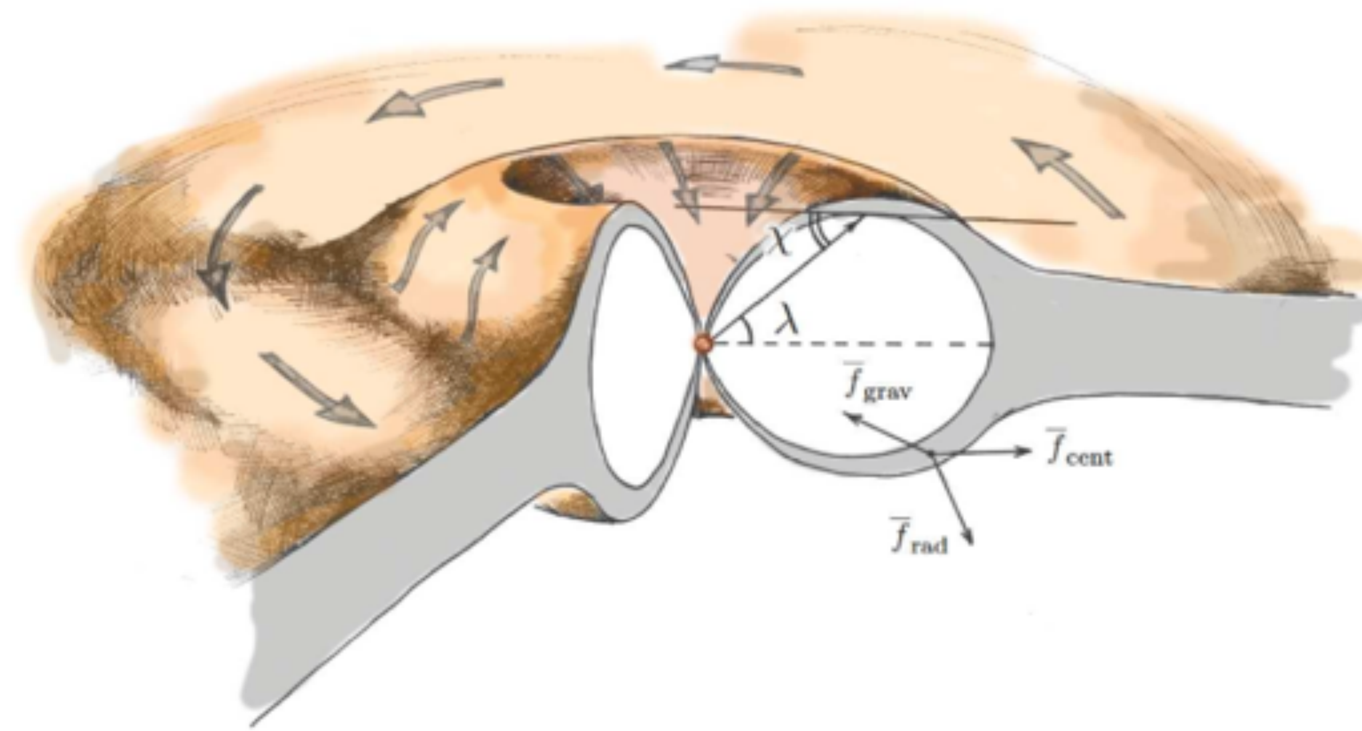


Israel et al. (2017)

Are these beamed ($R_M < R_{sph}$) or is the field strength (dipole or otherwise) high enough to drop the scattering opacity and lead to super-Eddington luminosities?



Mushtukov et al. (2015)



Mushtukov et al. (2017)

There are ways to test this based on variability arguments, spectral evolution etc

Open questions:

1. How many NS/BHs? Gauge relative numbers of ULPs (Middleton & King 2017, assuming geo. beaming)

2. Nature of QPOs - are these telling us about material close to ISCO (e.g. BHBs) or a limit cycle in wind (e.g. GRS 1915+105)? Need to i) find more ii) study phase resolved properties

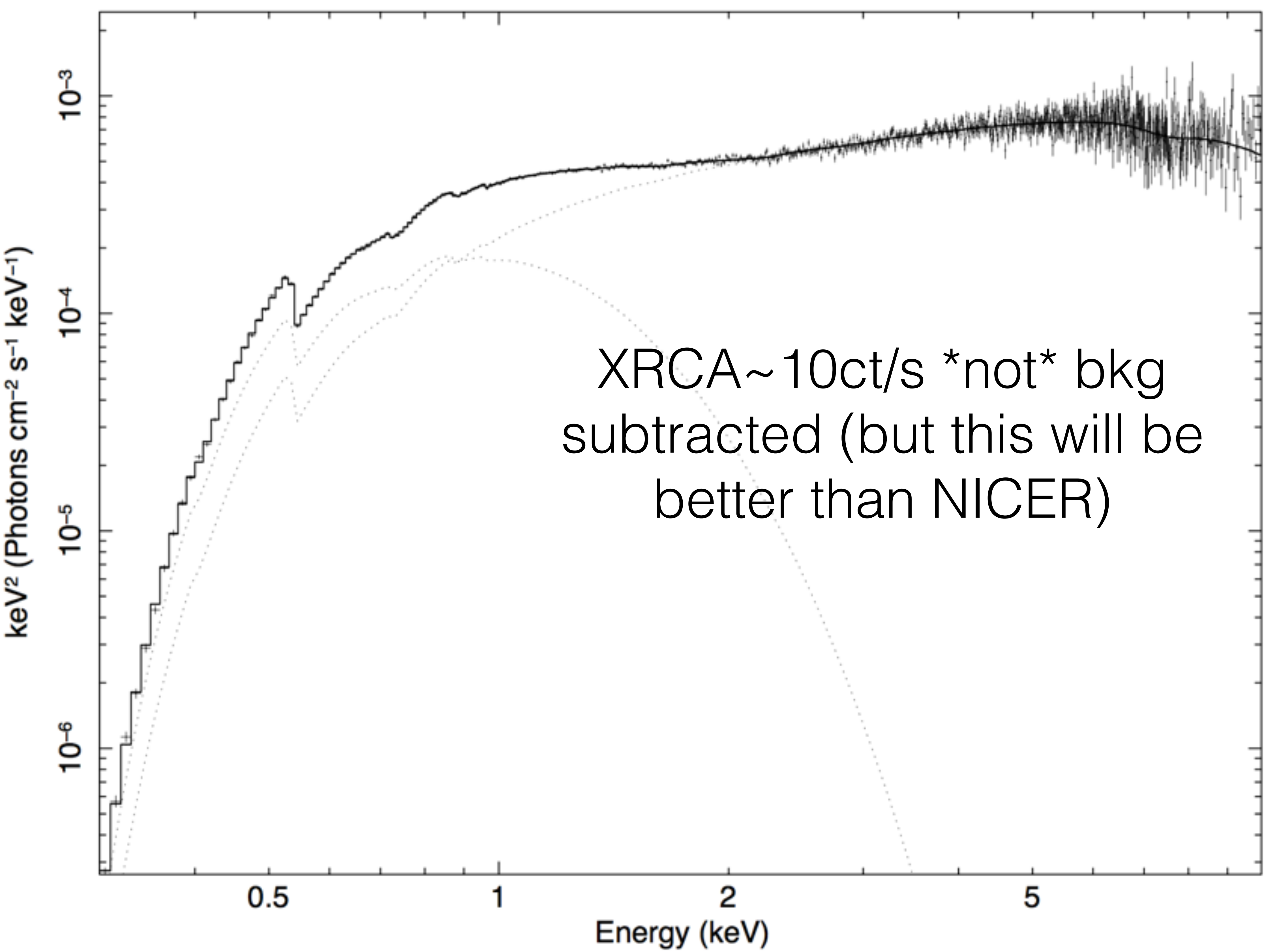
3. Structure of the wind - how does this compare to RMHD simulations (—> a handle on mass/energy budget)? e.g. model the residuals as function of spectral evolution

4. What is the B field strength in ULPs (tells us about accretion flow)? Need to locate more and measure spin-up or find eCRFs

Open questions:

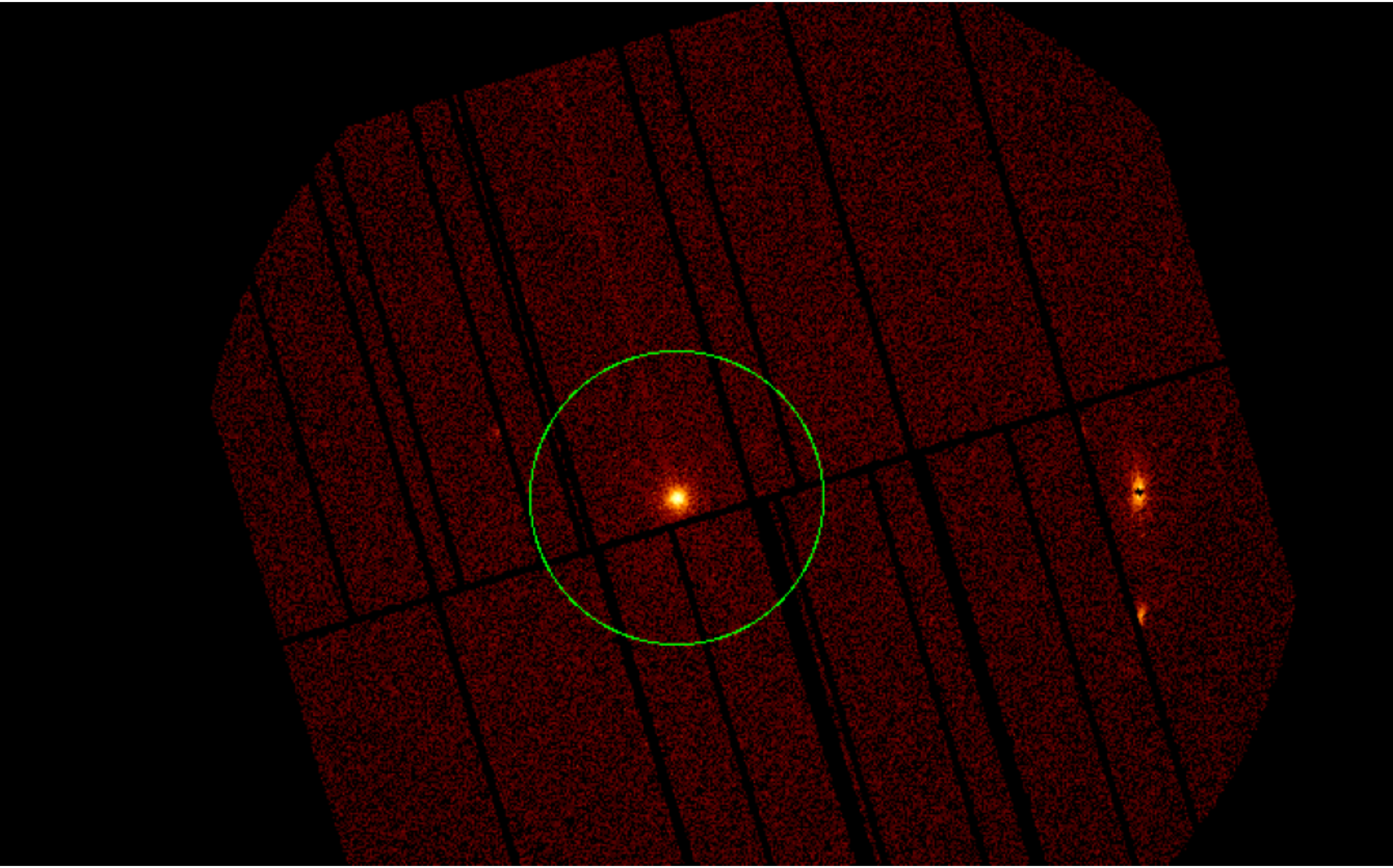
5. Where are all the IMBHs? As STROBE-X can go deeper we will no doubt find more candidates (will need multi-messenger approaches to use FP, get redshift of host etc)

Idea of the sorts of data quality we might achieve: tbabs*xstar*(diskbb+nthcomp) [NGC 1313 X-1]

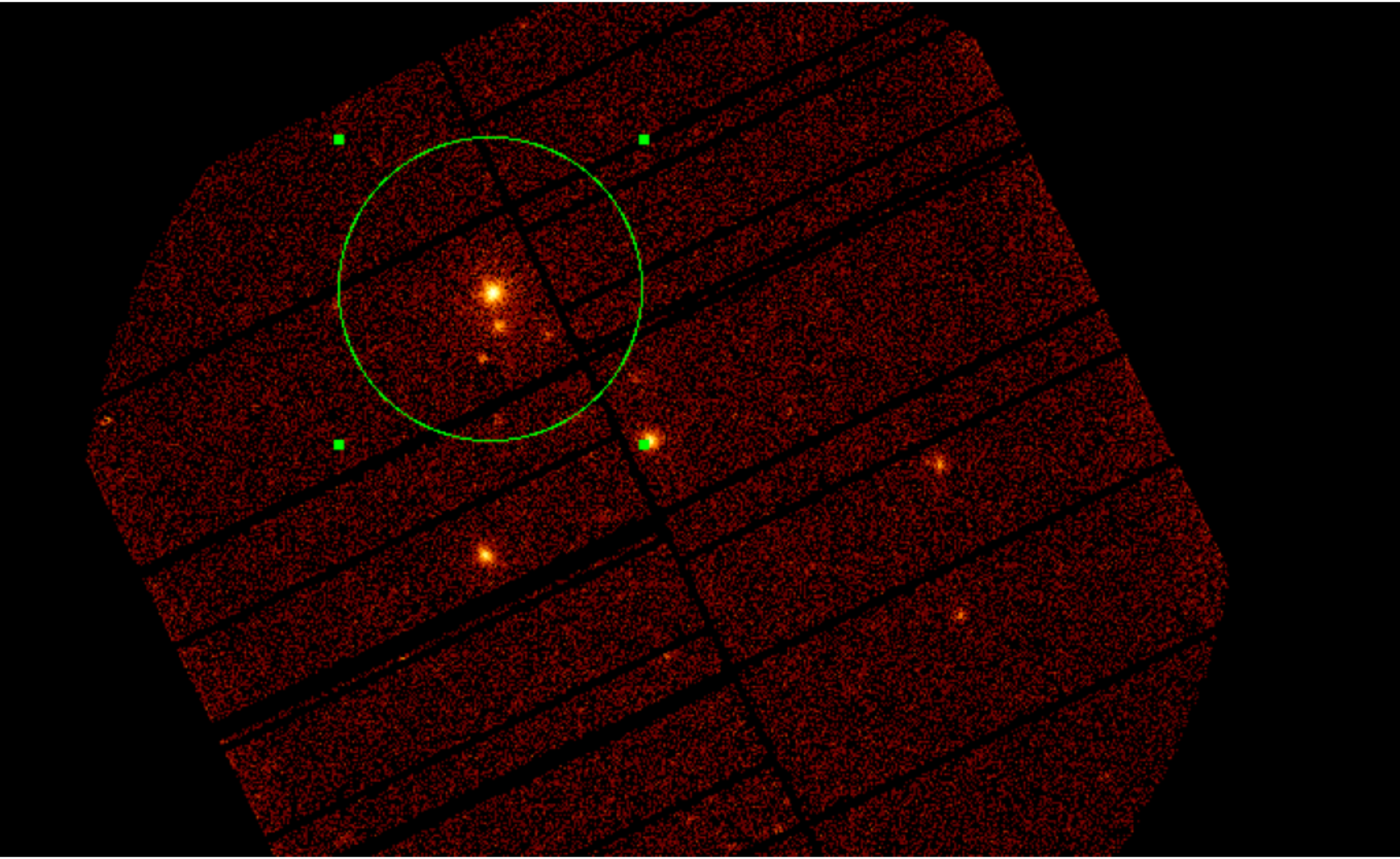


XRCA~10ct/s *not* bkg subtracted (but this will be better than NICER)

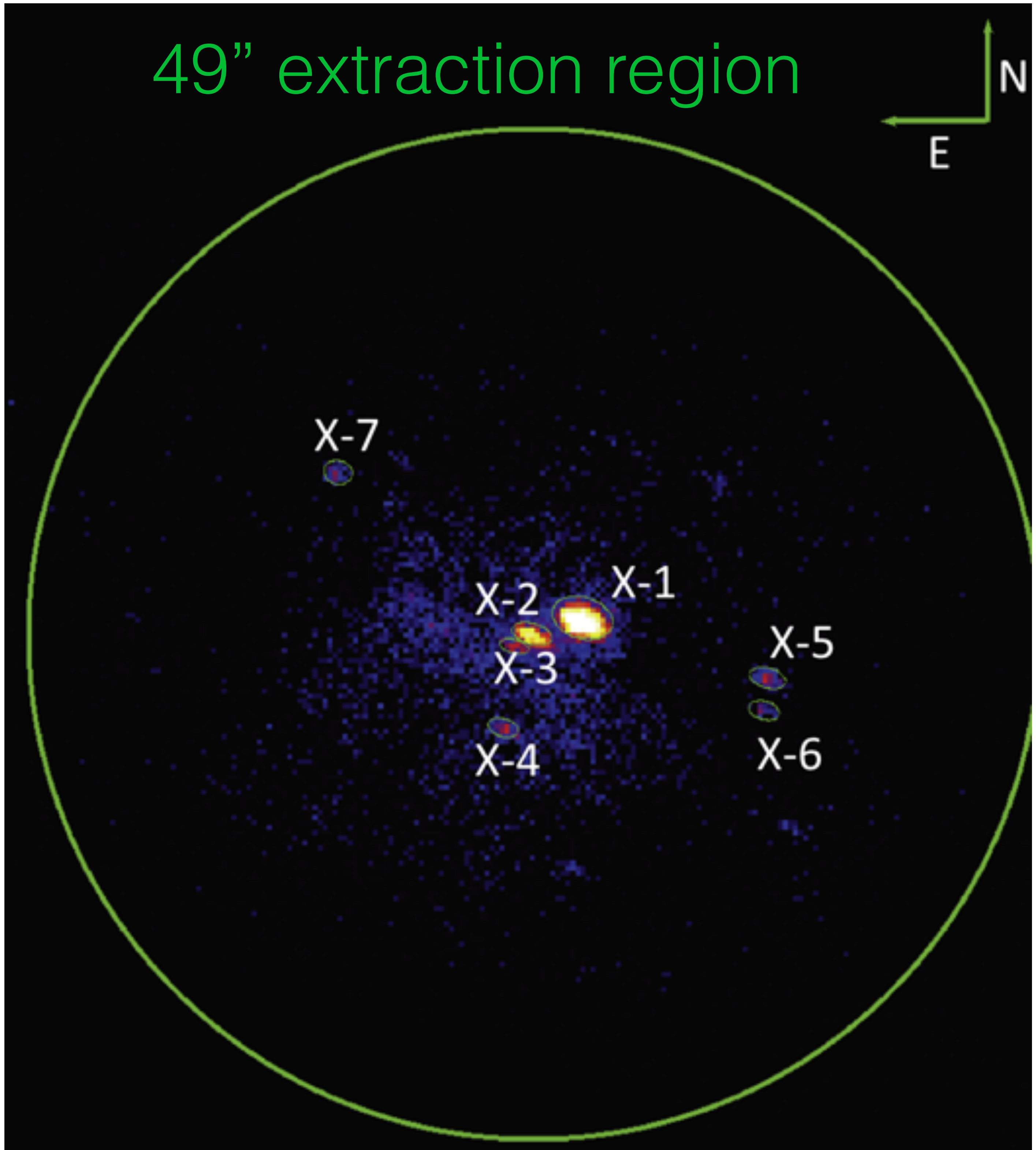
Issue of angular resolution (4’ in XRCA) - sometimes we’ll do great - case of Ho IX X-1



Issue of angular resolution (4’ in XRCA) - sometimes we’ll do well - case of NGC 1313 X-1



Issue of angular resolution (4’ in XRCA) - sometimes we’ll do badly - case of M82 X-2



Brightman et al. (2016)

Bottom line: STROBE-X will likely lead to an enormous improvement in studying ULXs (where they can be reliably separated from nearby sources or if contaminating sources can be modelled out).