XMM and Chandra observations of AGN with low mass black holes

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Low mass black hole (LMBH) AGN

- M_{BH} ~ the order of 10^6 $M_\odot$ or less (or IMBH)
- So far, a few hundreds LMBH AGN known (from SDSS)
  - Greene & Ho 2004 (19 AGN), 2007 (229 AGN, $\leqslant 2\times10^6$ $M_\odot$)
  - The low-Mbh subsample (60 AGN) in the SDSS NLS1 sample (Zhou, Wang, Yuan, + 2006)
- X-ray properties: less explored, except for NGC4395
  - NGC4395: Mbh=$3\times10^5 M_\odot$ $L_{bol}/L_{edd}=1.2\times10^{-3}$, <0.2 (Peterson, +'05)

short-T large variability, PL continuum, warm absorber, Fe line

(e.g. Iwasawa, + 2005, Vaughen, + 2005, Dewagnen, + 2009)

- GH04 objects (biased to high L_{bol}/L_{edd}): soft X-ray excess

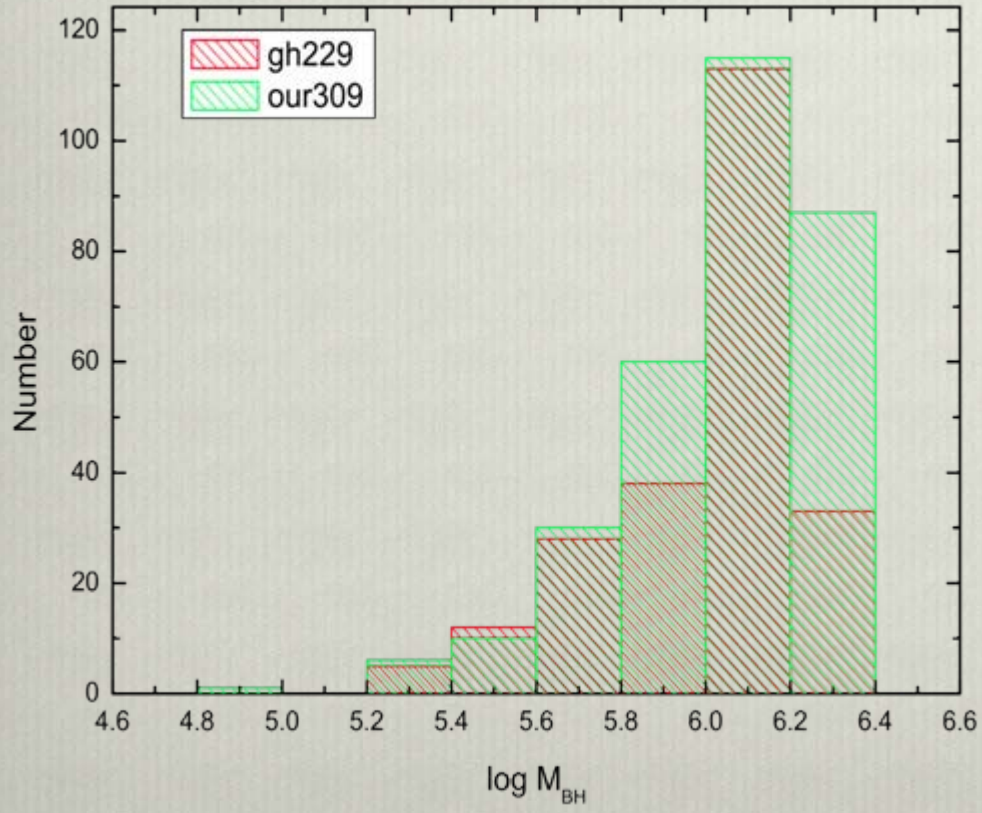
(e.g. Miniutti, + 2009, Dewangen 2009, Desroches + 2009)

LMBH AGN: extension of Seyfert AGN to low Mbh

Our ongoing work on LMBH AGN

A new LMBH AGN sample from SDSS DR4 (Dong, Ho, Yuan + 2011 in prep.)

- Uniformly selected and statistically complete
- Recover more low-L_{bol}/L_{edd} AGN



- On-going X-ray studies:

  XMM, Chandra, ROSAT

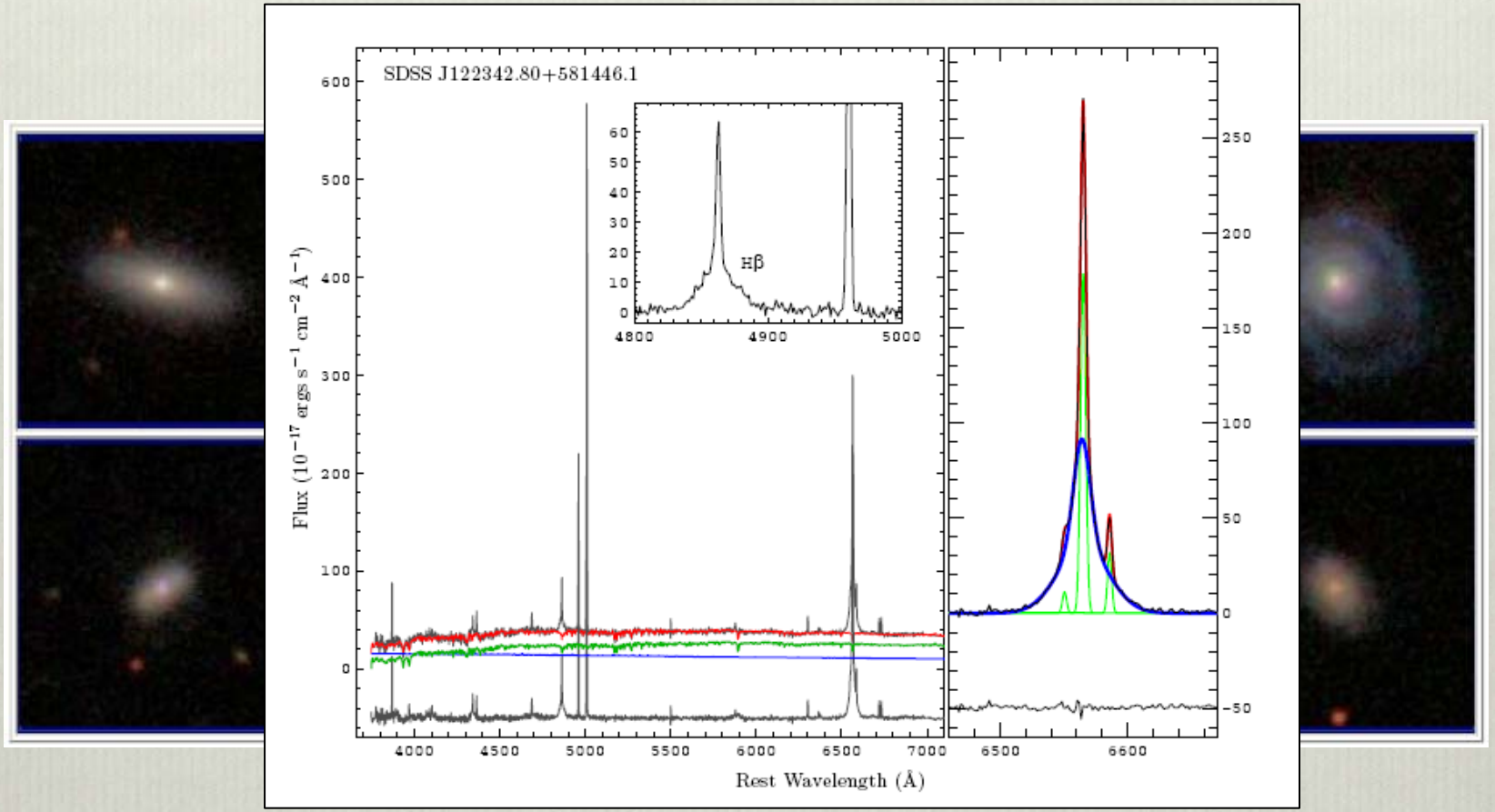
- This talk (preliminary results)
  1. Soft X-ray excess: examine emission of A.D.
  2. huge X-ray variability
  3. Verify low accretion rates

60 in Zhou'06 SDSS NLS1 sample, high L_{bol}/L_{edd} (E.R.)

Yuan + 2010, ApJ, 723, 508

Ai, Yuan, Zhou, + 2011, ApJ, 727, 31

Examples SDSS images and spectra of our LMBH AGN



M_{bh} and L_{bol}/L_{edd} derived from the broad H α in optical

Z=0.014 Sy1

$M_{BH} = 3.7\ 10^5\ M_\odot$ (c.f. NGC4395)

L/Ledd ~ 0.1

I. Soft X-ray excess
&
thermal X-ray emission from accretion disc

Thermal X-ray emission from accretion disc

max disc $kT_{max} \approx kT_{in}$ @inner edge of disc

$kT_{max} \propto M_{bh}^{-1/4}$

❖ (

$$T_{max} = 11.5 \left(\frac{M_{bh}}{10^8 M_\odot} \right)^{-1/4} \dot{m}^{1/4} \text{ (eV)}.$$

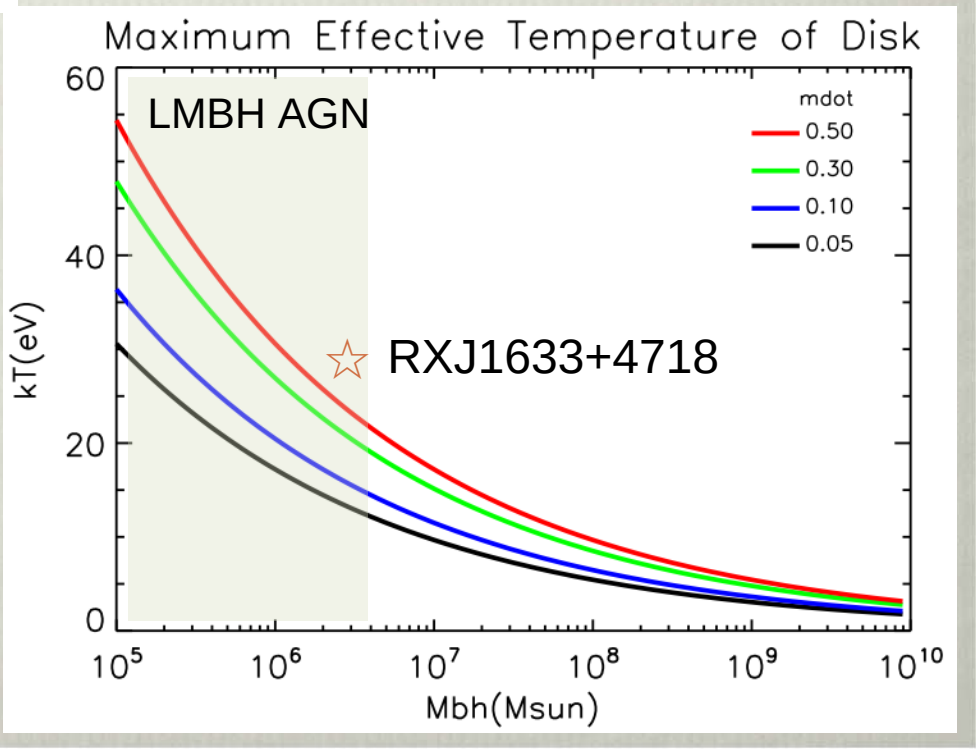
max kT_{max} (inner disc kT_{in}) <~10 eV

❖ LMBH AGN $M_{BH} \leqslant \sim 10^6 M_\odot$

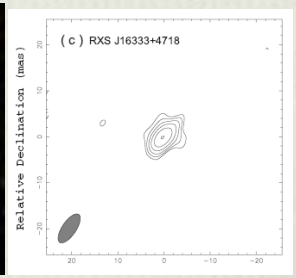
inner disc kT_{max} several tens eV

Peak of disc blackbody emission shifted into soft X-ray band, and might be detectable

Test accretion disc models !



A promising case: RXJ1633+4718

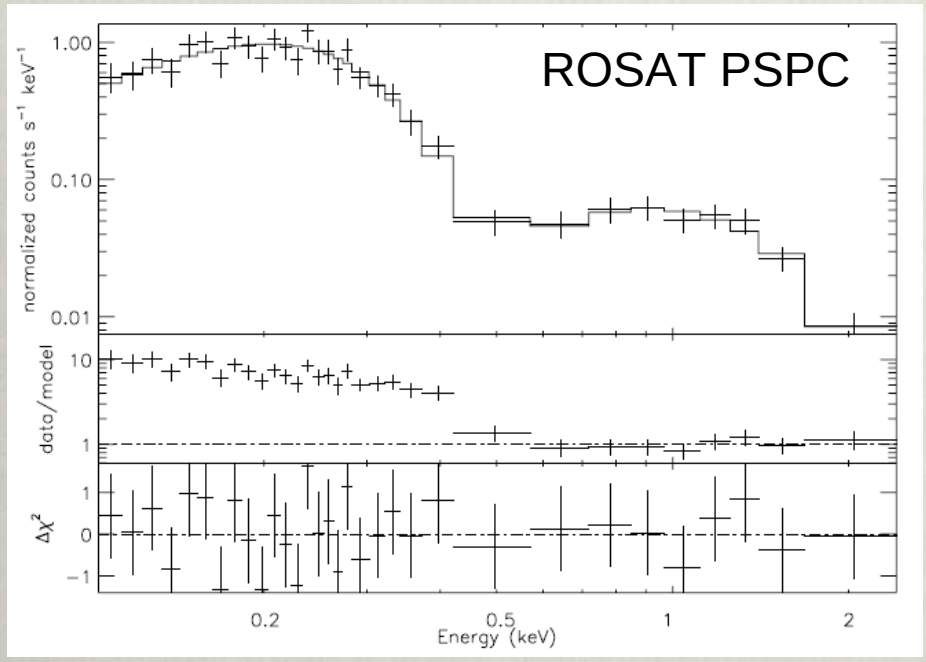


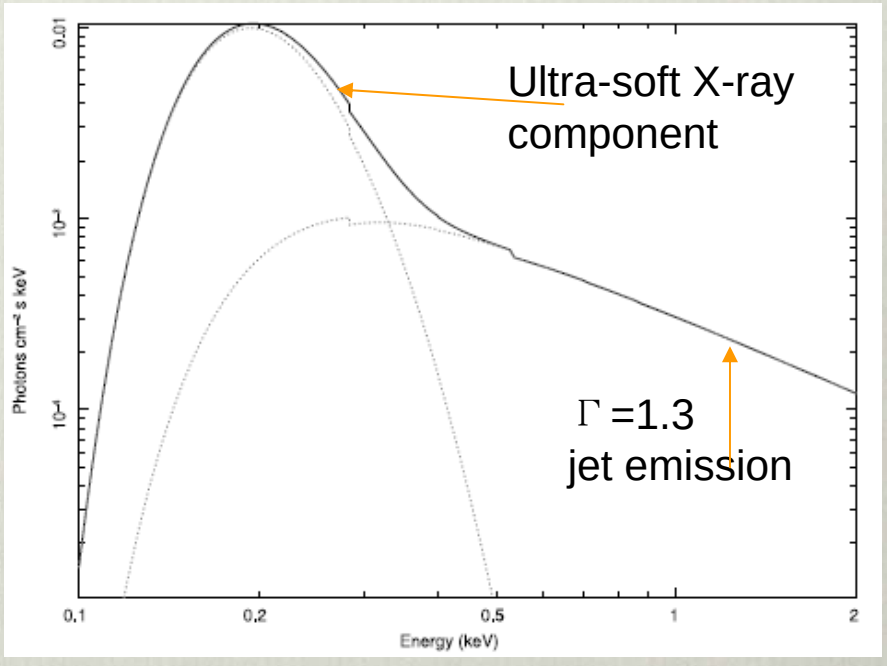
radio-loud/blazar (Yuan, Zhou, Komossa + 2008)

BH mass = 3 (2-4) $\times 10^6$ $M_\odot$

Thermal L_{bol} = 2.8 ($\pm$0.6) $\times 10^{44}$ erg/s (from H β)

L_{bol}/L_{edd} ~ 0.69 (+0.73,-0.35)





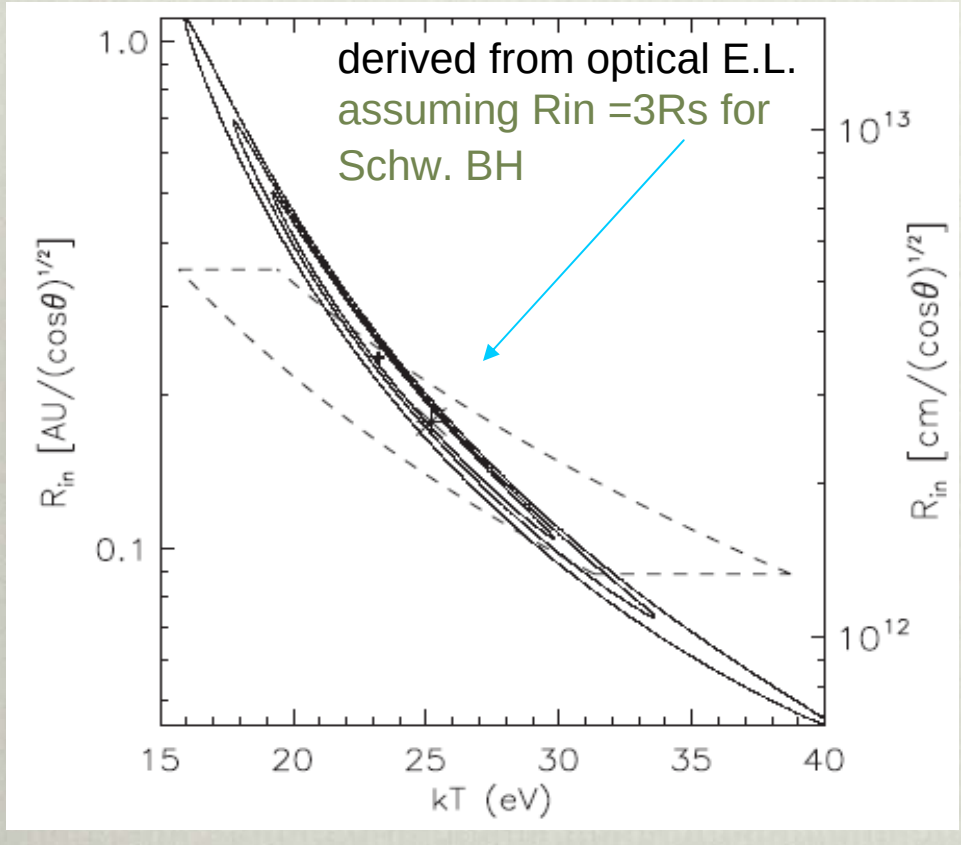
Prominent soft X-ray excess: extremely soft

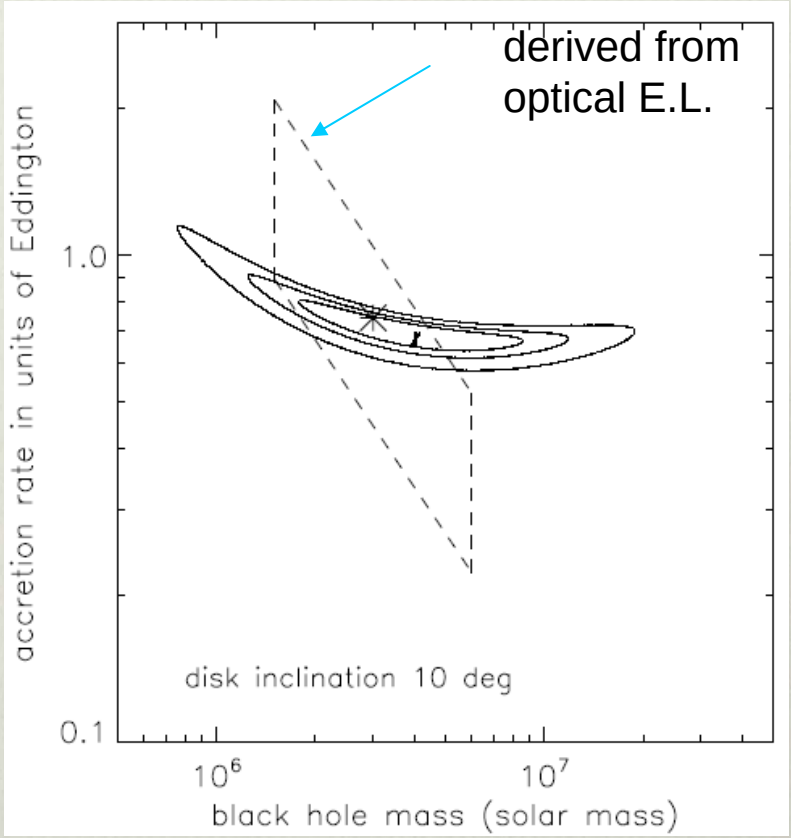
Black body kT = 32 eV ! unprecedented !

Lbb = 3.5(+3.3,-1.5) $\times 10^{44}$ erg/s

Derived BH/AD parameters from fitting with disc blackbody model

Yuan, Liu, Zhou, Wang 2010, ApJ, 723, 508; see poster #51





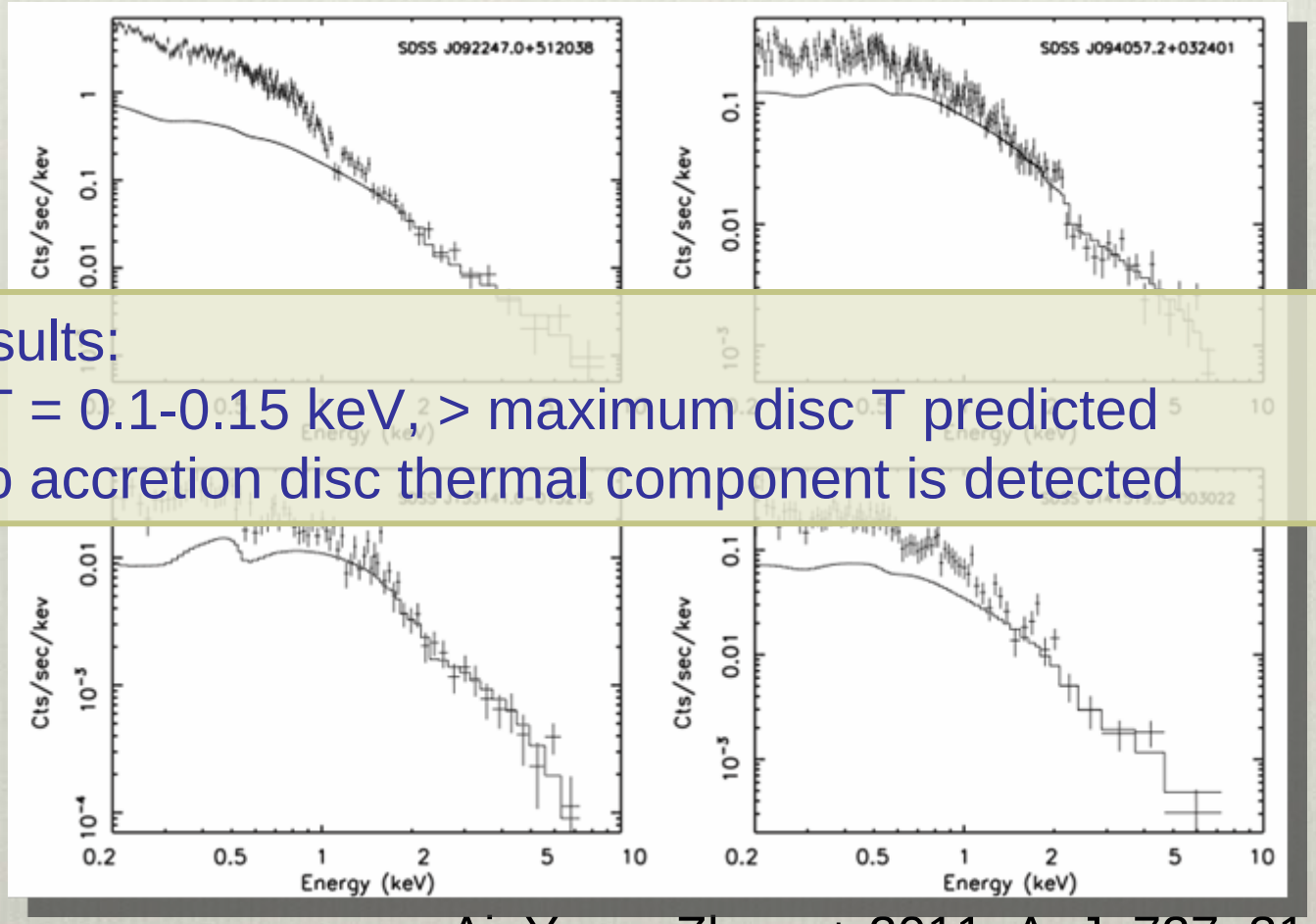
Evidence for accretion disc around SMBH in AGN

Are there other AGN similar to RX J1633+4718?

XMM this AO

LMBH AGN with high accretion rates

XMM data of 9 LMBH AGN analysed, prominent soft X-ray excess
(see also Miniutti +'09, Dewangen+'09), also as NLS1



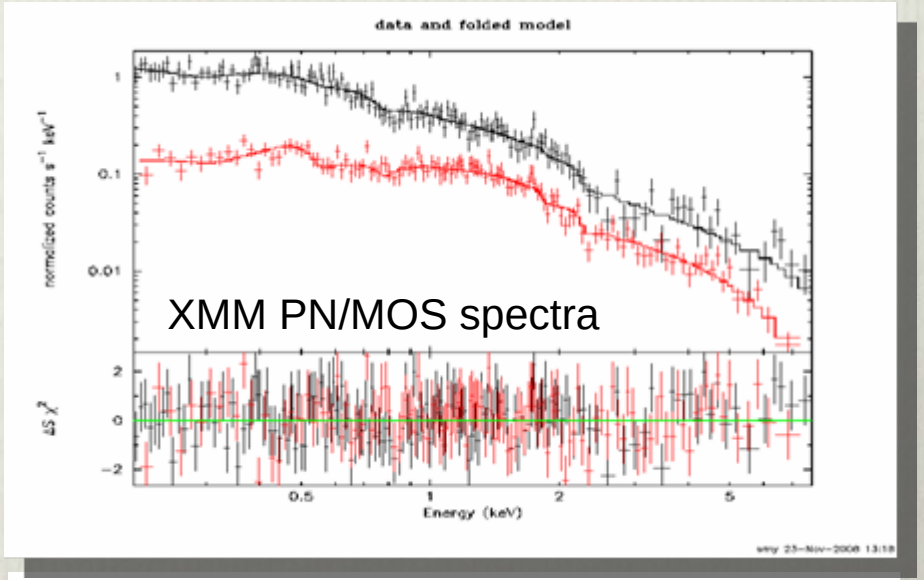
Results:
- kT = 0.1-0.15 keV, > maximum disc T predicted
- no accretion disc thermal component is detected

Ai, Yuan, Zhou, + 2011, ApJ, 727, 31

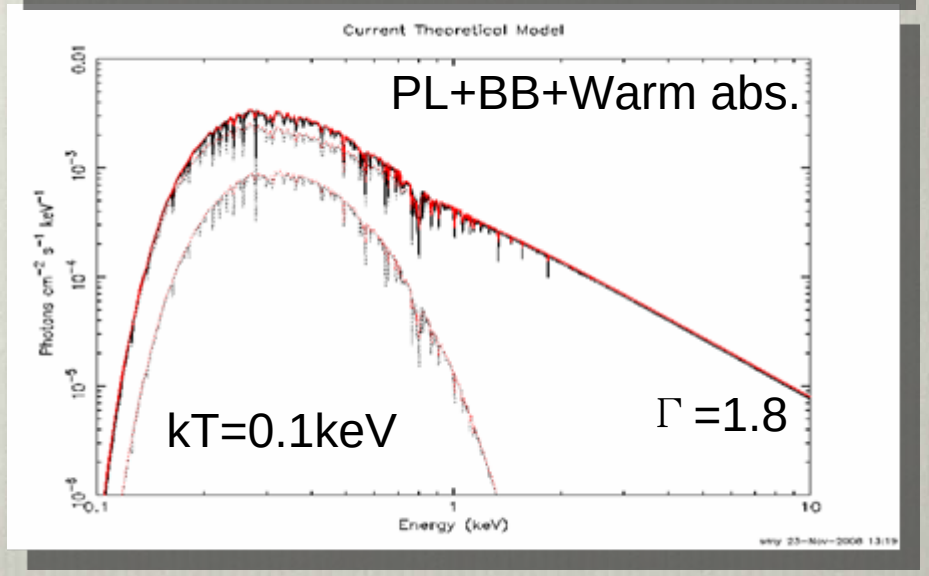
one of the lowest Mbh with L_{bol}/L_{edd} typical of Seyferts

$M_{BH} = 3.7\ 10^5\ M_\odot$
$L_{bol}/L_{edd} \sim 0.1$

expected: kTmax~30eV, should be detectable above 0.2keV

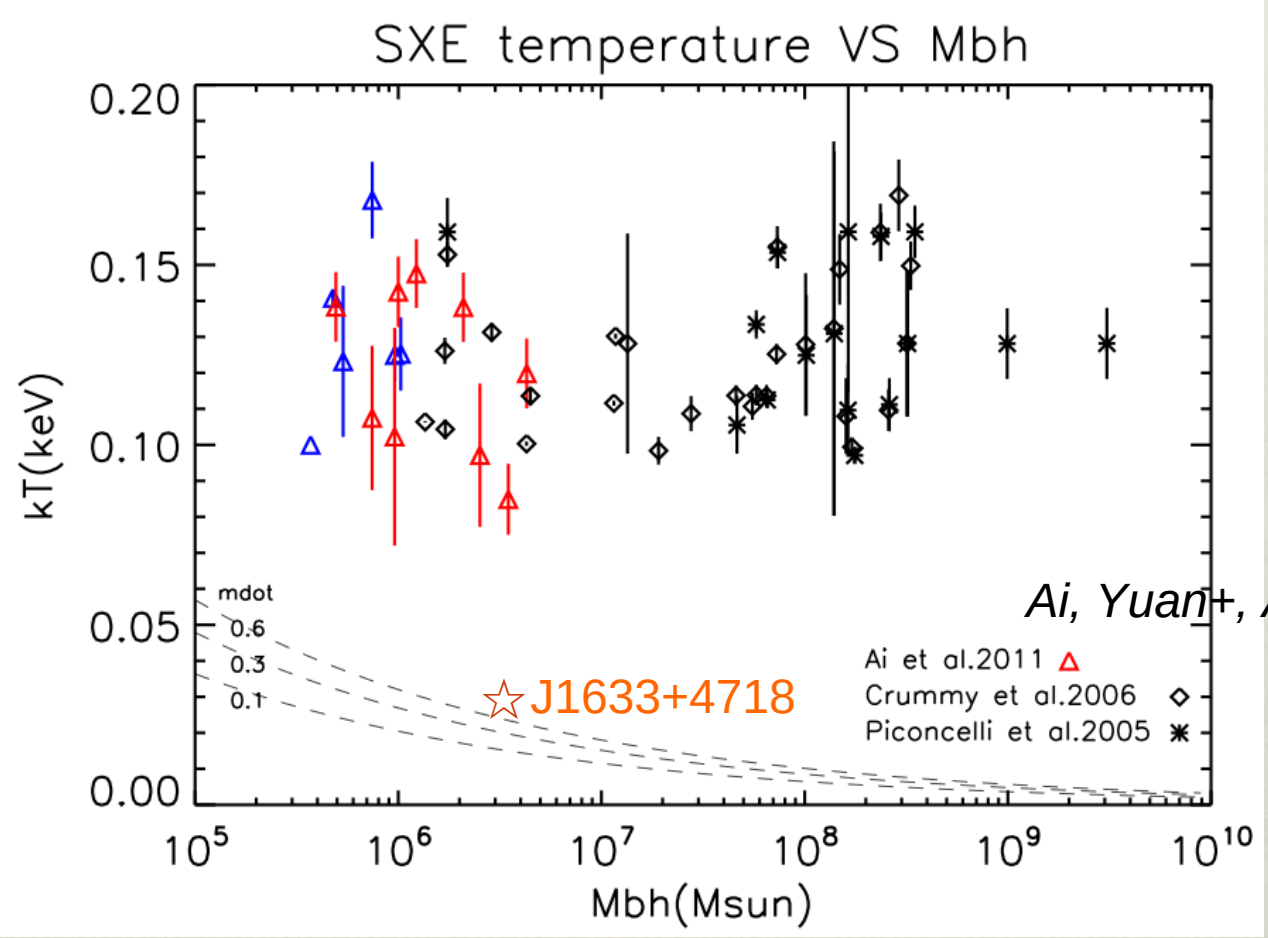


- Soft X-ray excess: weak
  kT=0.1keV
- mild warm absorption
- Lx= $7.3X10^{41}$ erg/s (2-10keV)
- Fe line ?, at least weak
- A typical spectrum of Seyfert 1



Yuan et al. in prep.

Independence of kT on Mbh: extended to low Mbh

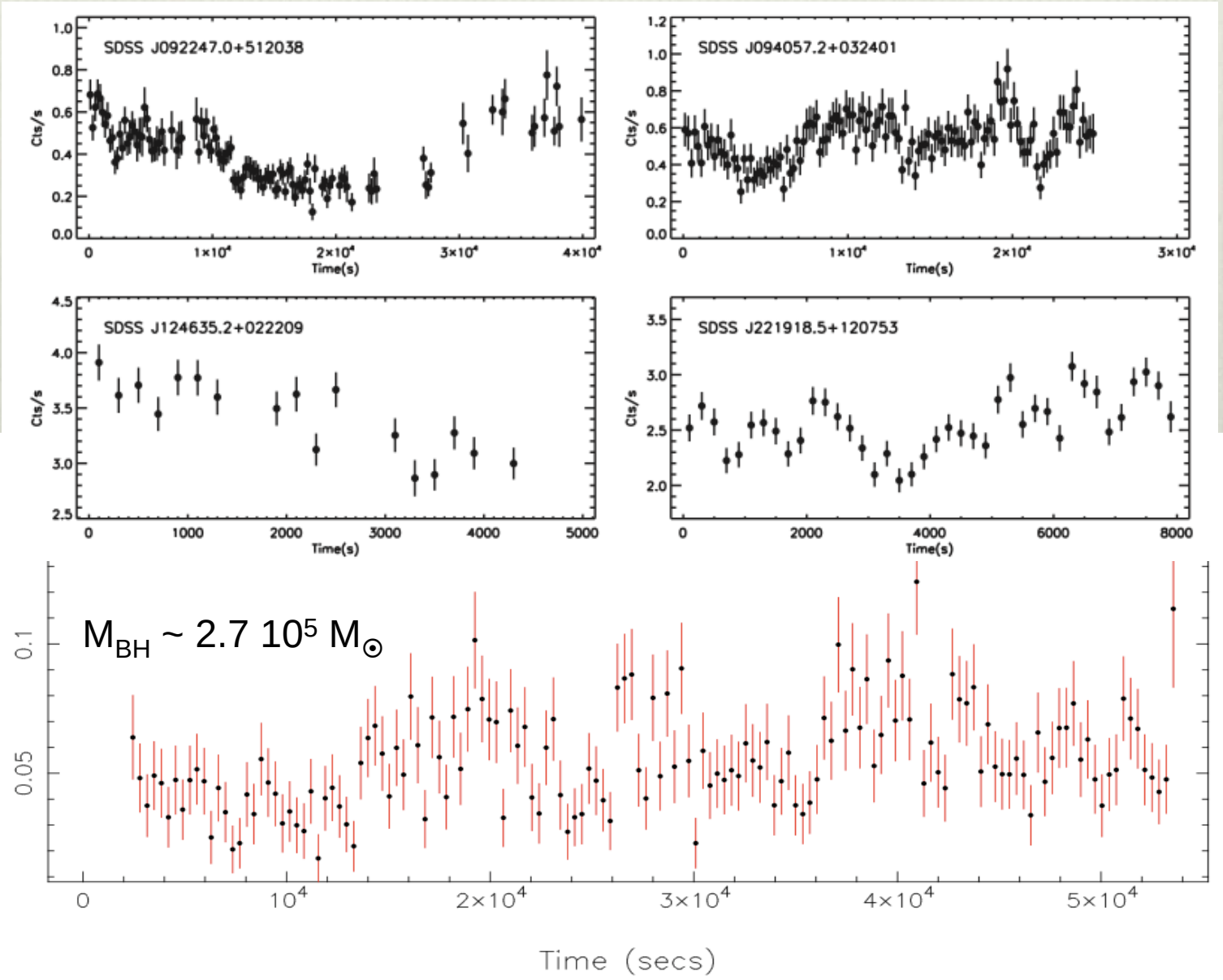


Ai, Yuan+, ApJ 2011,727,31

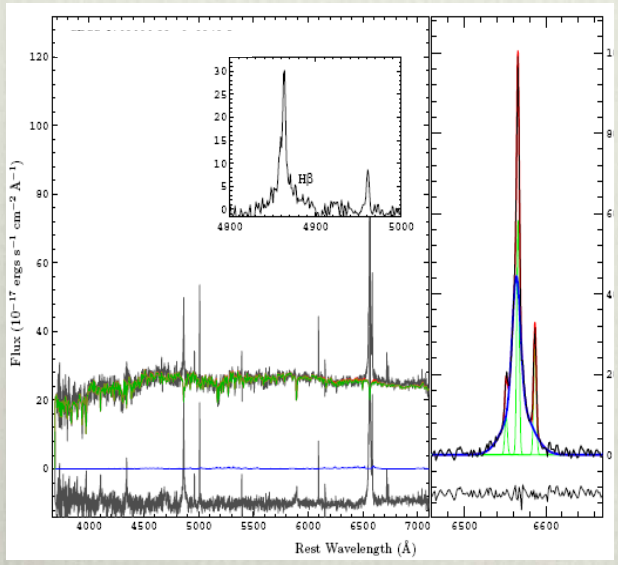
- No lower kT from disc emission detected down to 3×10^5 $M_\odot$
- No RXJ1633+4718-like objects found within database of XMM (90, blue triangles) and ROSAT (187) (LMBH AGN + NLS1 samples)

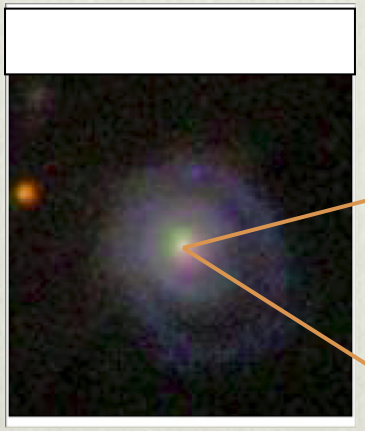
X-ray variability of LMBH AGN

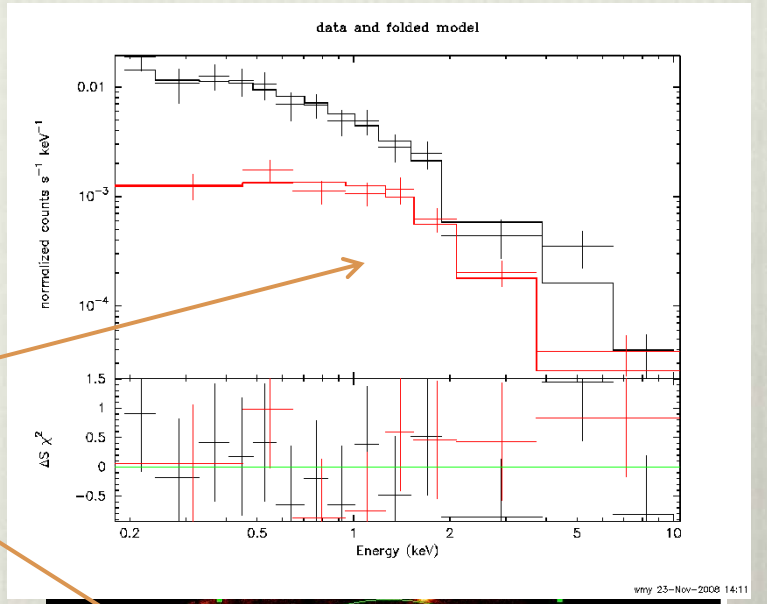
short timescale variability ubiquitous

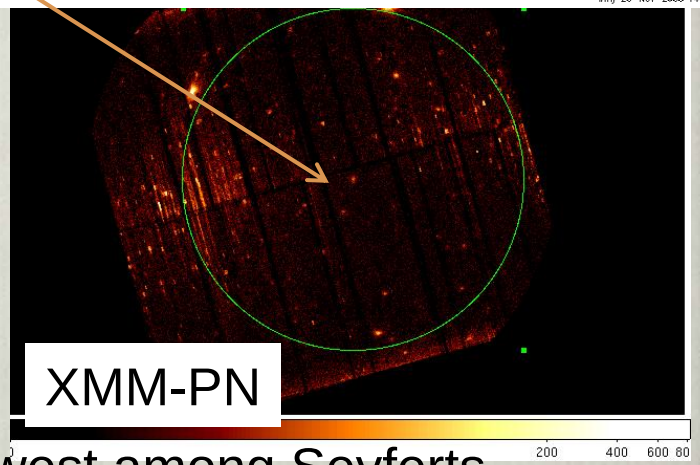


X-ray variability: long-term — a remarkable one









Flux drop by a factor of 37 or more !

XMM spectrum: simple power-law
(Gal. abs), Γ =1.95
No absorption/reflection
→ True flux decrease

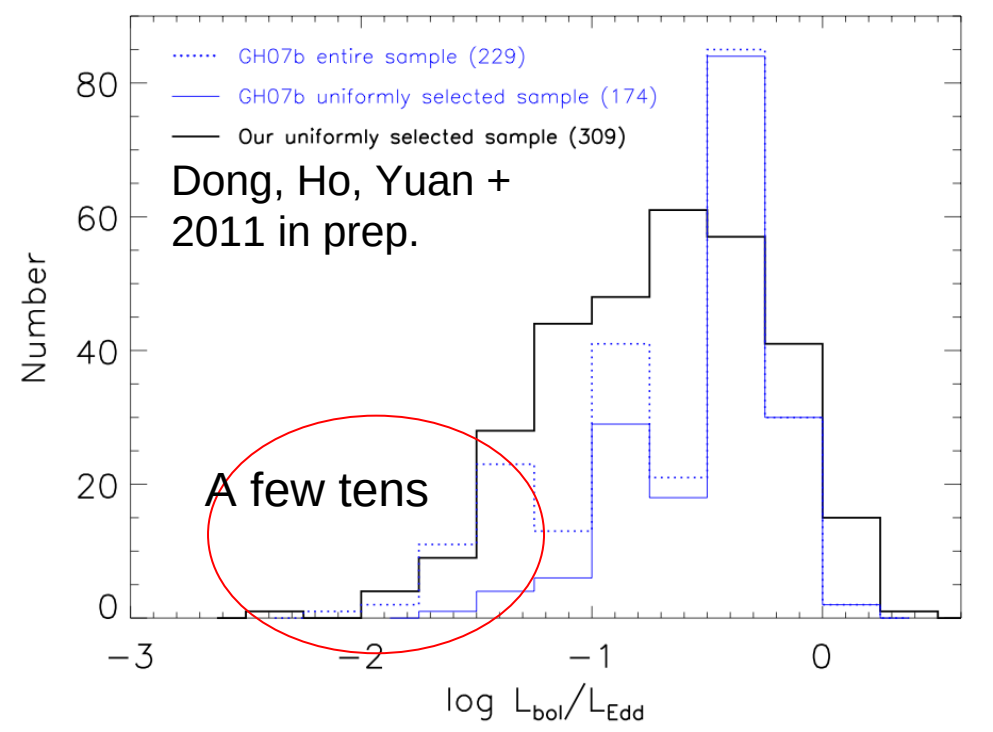
Low state: Lx=3.8x10^{40} erg/s (2-10keV) → lowest among Seyferts
L_{bol}/L_{edd}~1-2% ~ critical accretion rate for standard disc to exist!
State transition (similar to BH binaries)?

LMBH accreting at low mass rates

Are LMBH intrinsically rare in local universe?

NGC4395 (8Mpc): the only low L_{bol}/L_{edd} LMBH AGN known previously

L_{bol}/L_{edd}~1.2×10^{-3} (? <0.2) (Peterson +'05)



L_{bol}=9.8 L(5100A) McLure & Dunlop '04

L(5200A) derived from H α luminosity

LMBH AGN are rare in observations, either

- LMBH rare
- LMBH AGN rare (e.g. short lived)
- Many accreting at low rates (missing in surveys)

- detecting more low-accretion LMBH AGN essential (difficult!)

L_{bol}/L_{edd} derived from optical H α

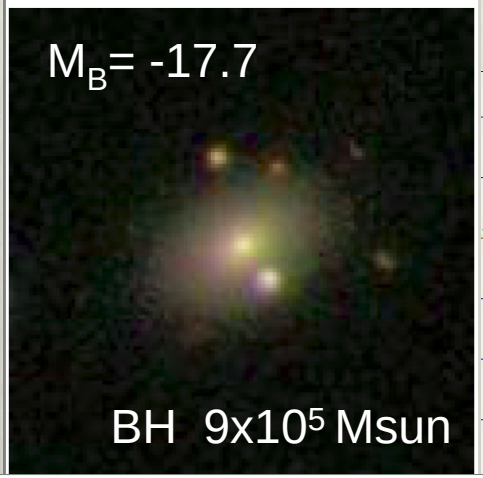
Important to verify their low L_{bol}/L_{edd} with X-ray observation

- dust extinction ?
- different SED ?

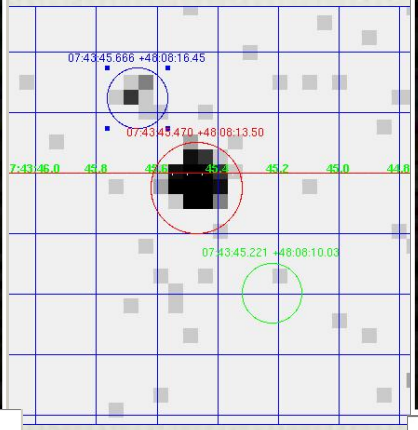
Chandra observations of 4 LMBH with low L_{bol}/L_{edd}

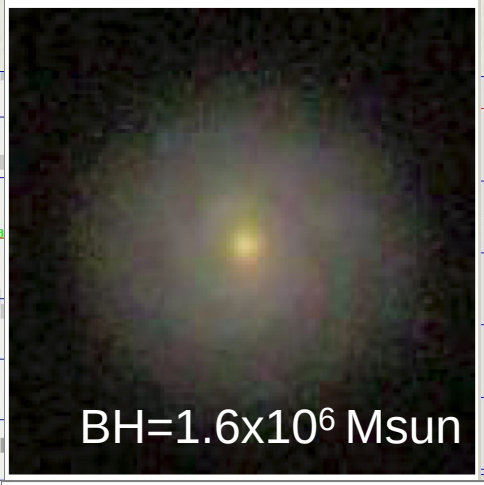
NGC 4395 Lx~1-2x10^{40} erg/s (2-10keV)

20 kpc

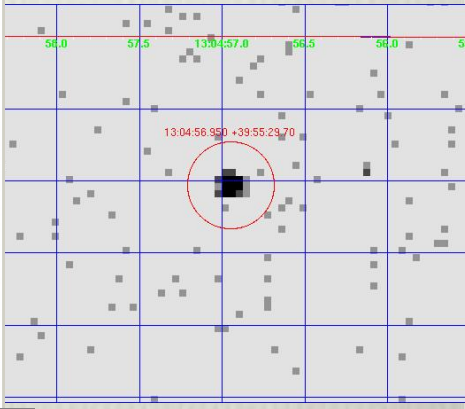


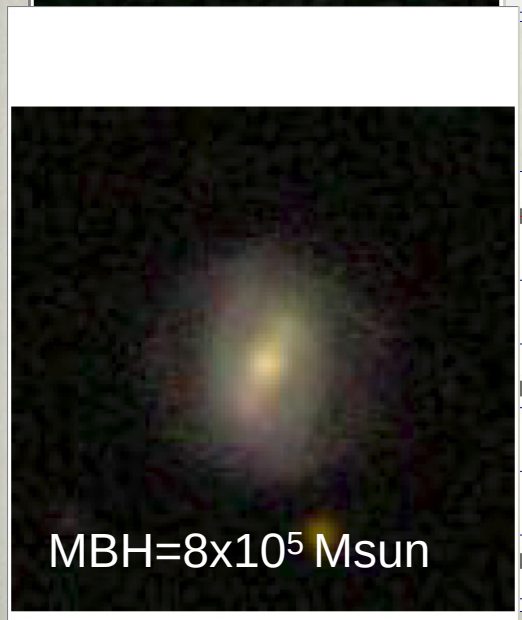
Lx=3x10^{41} erg/s



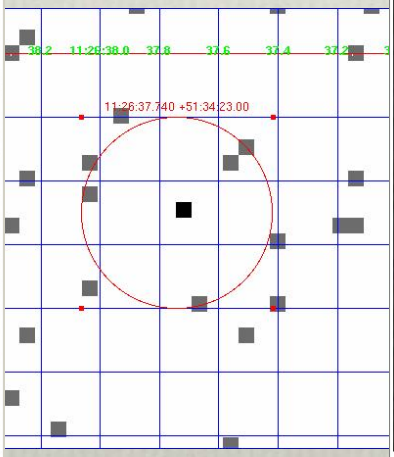


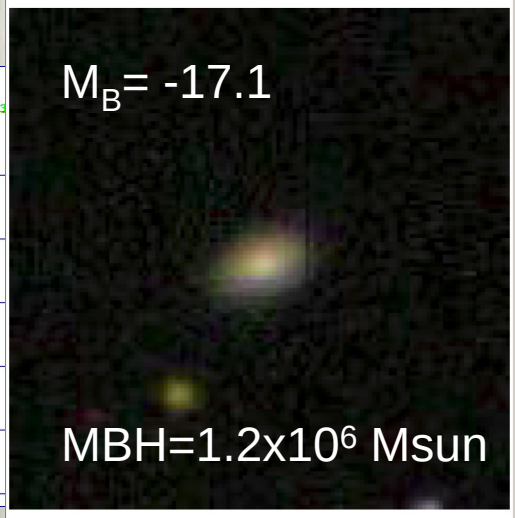
Lx=2x10^{41} erg/s



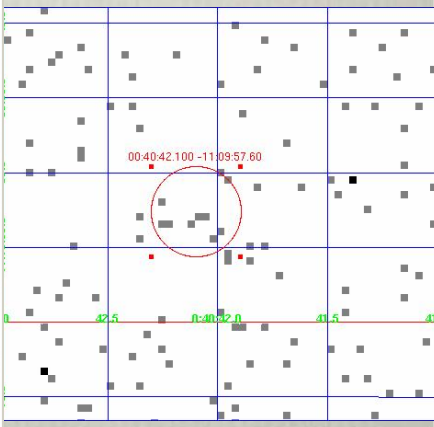


Lx<7x10^{39} erg/s

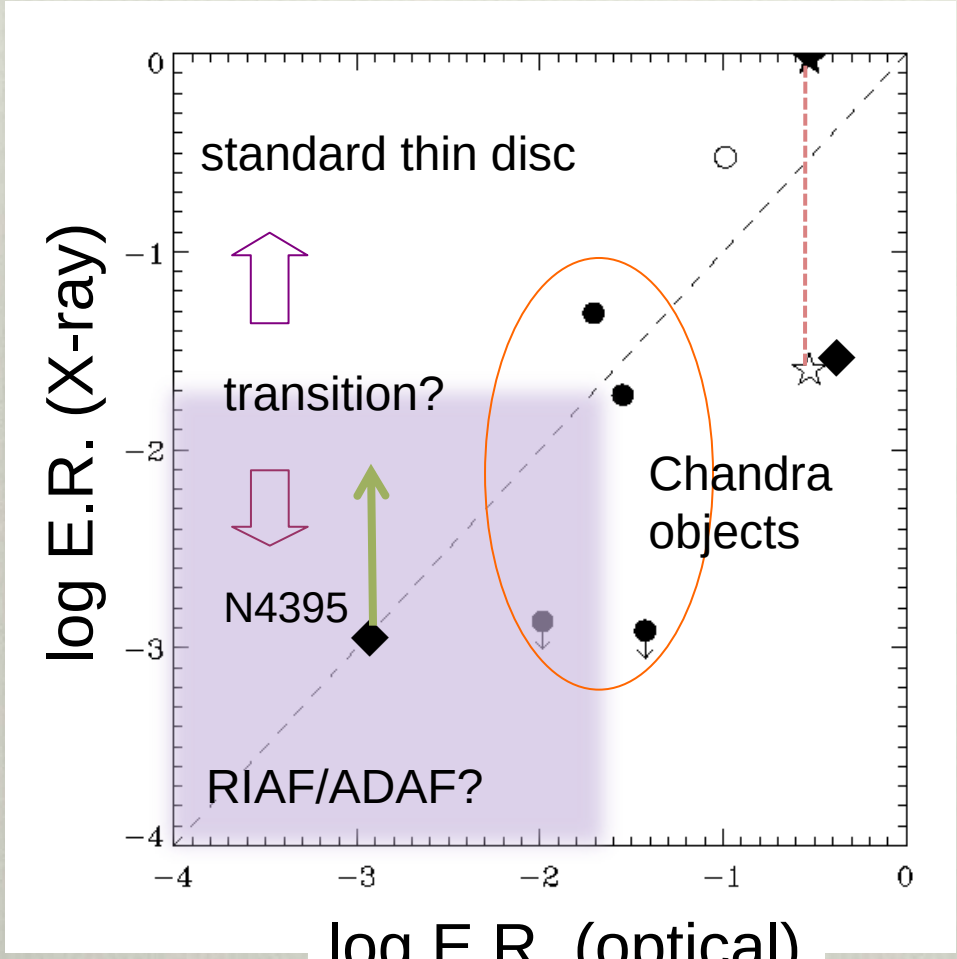




Lx<1x10^{40} erg/s



Comparison of L_{bol}/L_{edd} derived from X-ray and from optical



Assuming L_{bol} = 20 Lx(2-10keV)
(Vasudevan & Fabian'07)

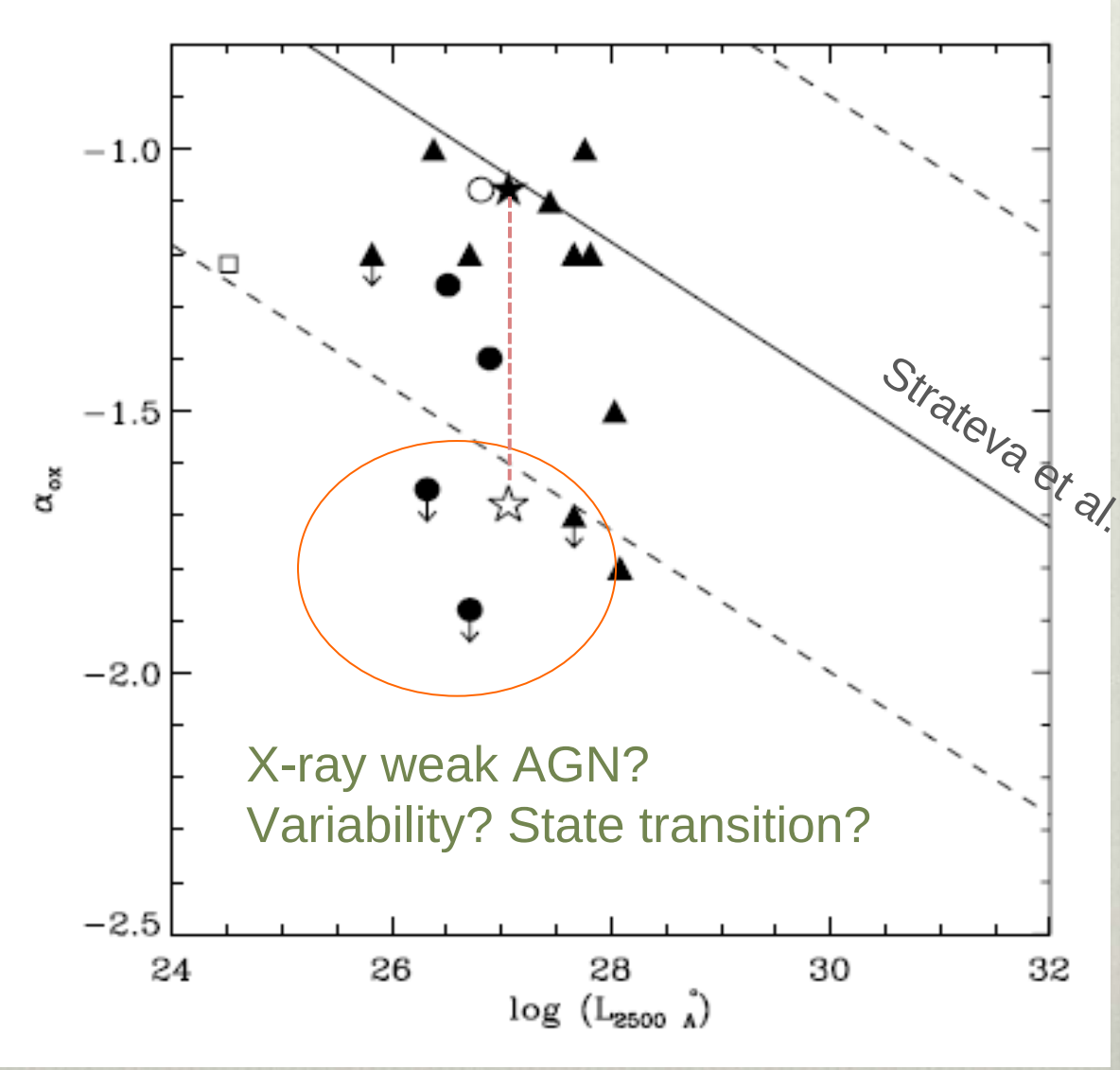
2 objects: E.R.(x) ≈ E.R. (o)
2 objects: E.R.(x) < E.R. (o)

The (optical) low E.R. confirmed, or pushed to even lower in X-ray

There may be a population of under-luminous IMBH AGN yet to be discovered!

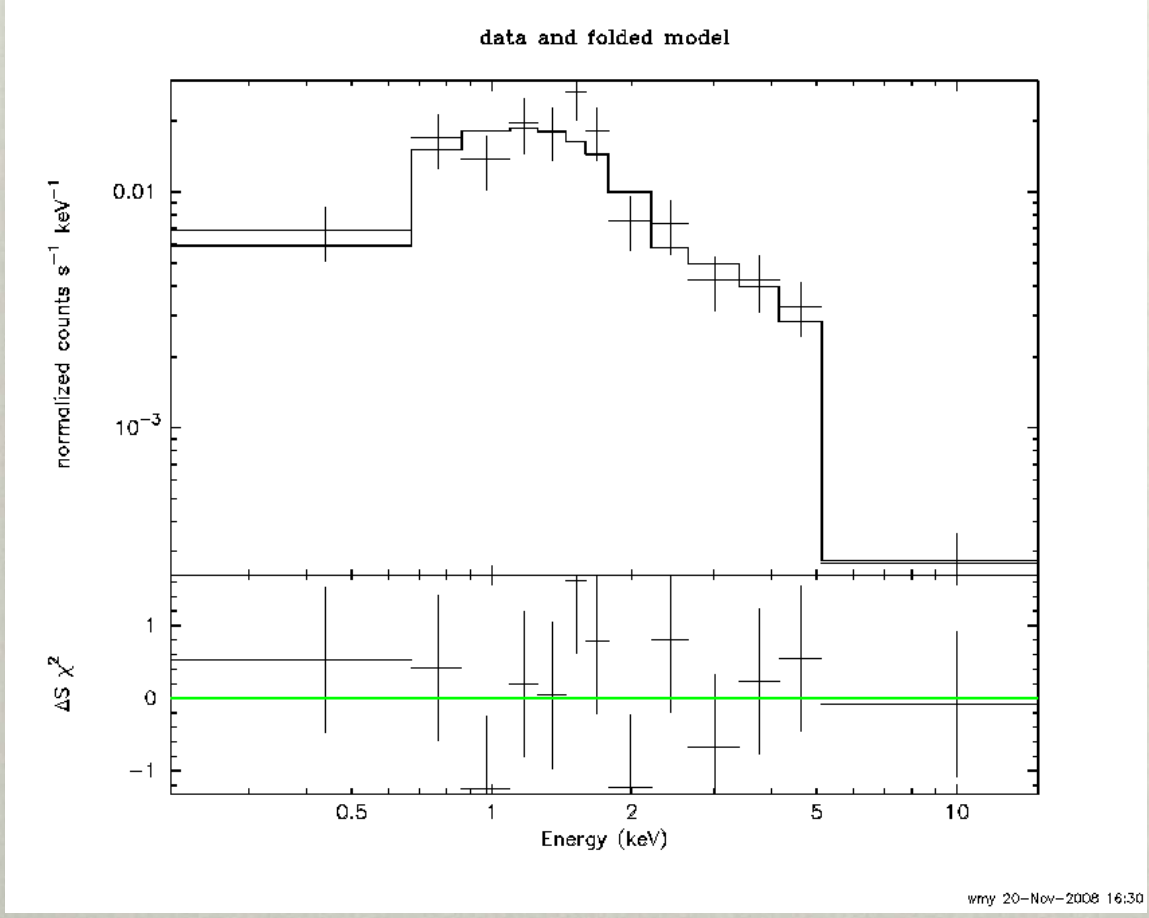
Low X-ray flux:
- X-ray weak AGN?
- large variability (state transition)

α_{ox} vs. optical/UV luminosity



Chandra spectrum of one low-E.R. LMBH AGN

L_{bol}/L_{edd} =0.02



Best fitted with
P.L. + Gal. abs.

Γ = 1.06 (+/-0.2)

A flat X-ray spectrum

Summary

- In general, X-ray emission similar to typical Seyferts

  power-law, Soft X-ray excess, warm abs., Fe line (?),

- Soft X-ray excess
  - kT~0.1-0.15keV down to M_{BH} ~ 3x 10^5 $M_\odot$
  - J1633+4718 (~32eV): evidence for BH/AD, the only case so far

- X-ray variability
  - Short timescale common: consistent with small M_{BH}
  - Long timescale: large variability found, state transition?

- Low accretion rate LMBH AGN: confirmed with Chandra
  - a population of under-luminous LMBH AGN to discover!
  - Intrinsically X-ray weak? State transition?

- LMBH AGN: possibly the key to bridge SMBH and stellar BH

  in the context of understanding a unified BH accretion paradigm