High energy radiation and radiative feedback in AGN

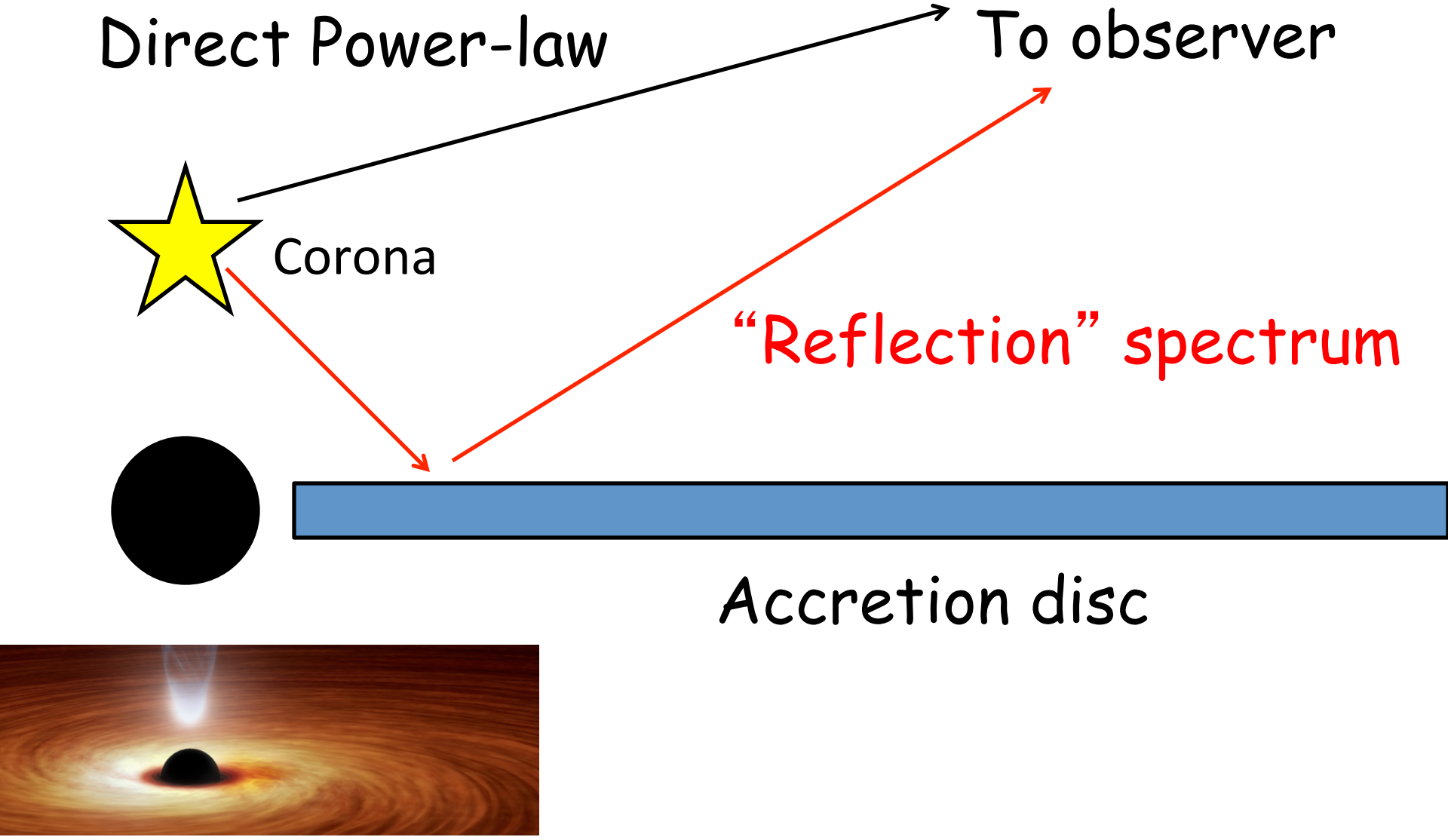
Andy Fabian

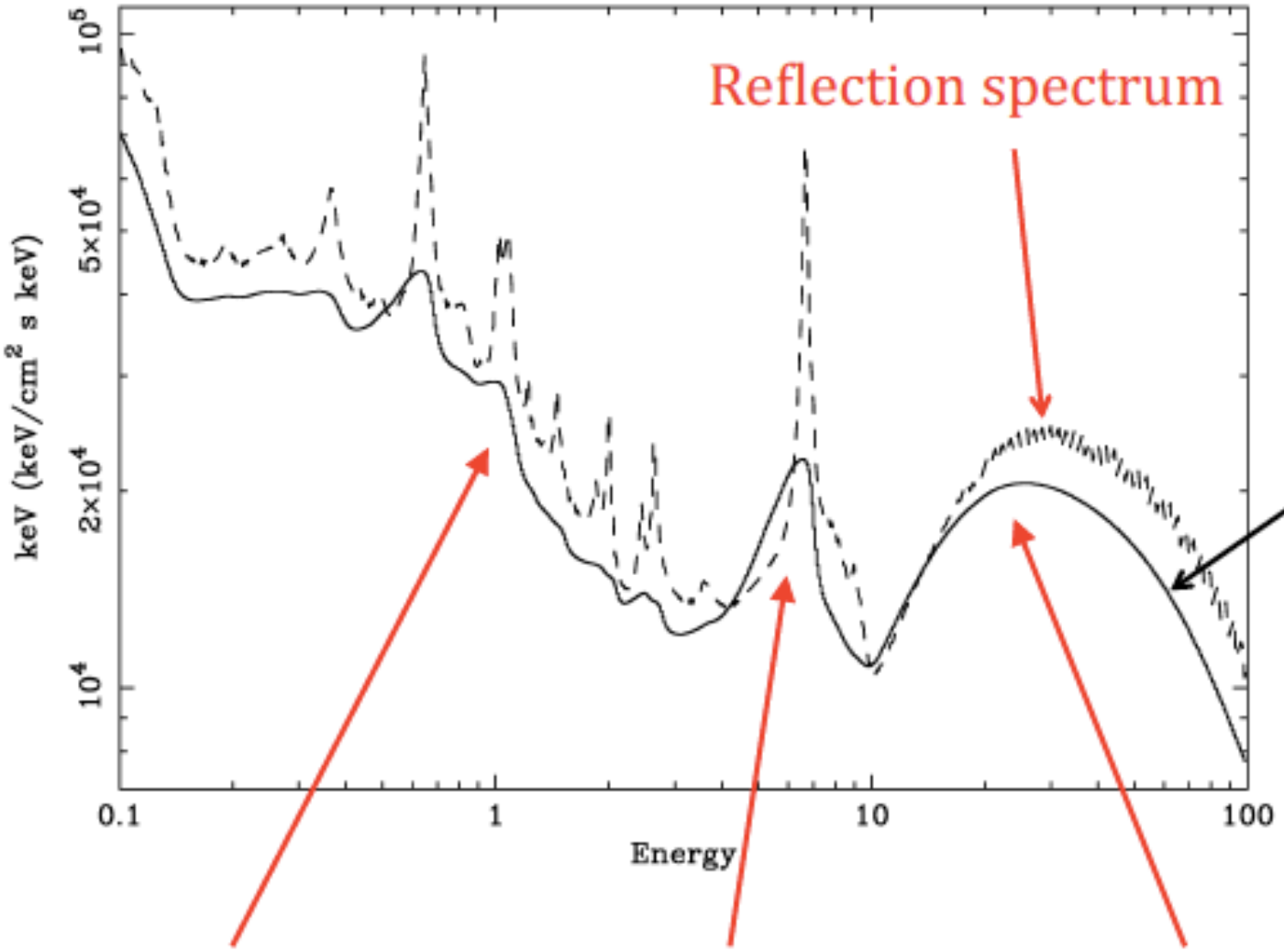
Institute of Astronomy, University of Cambridge

Some remarks on feedback from central engine to galaxy host

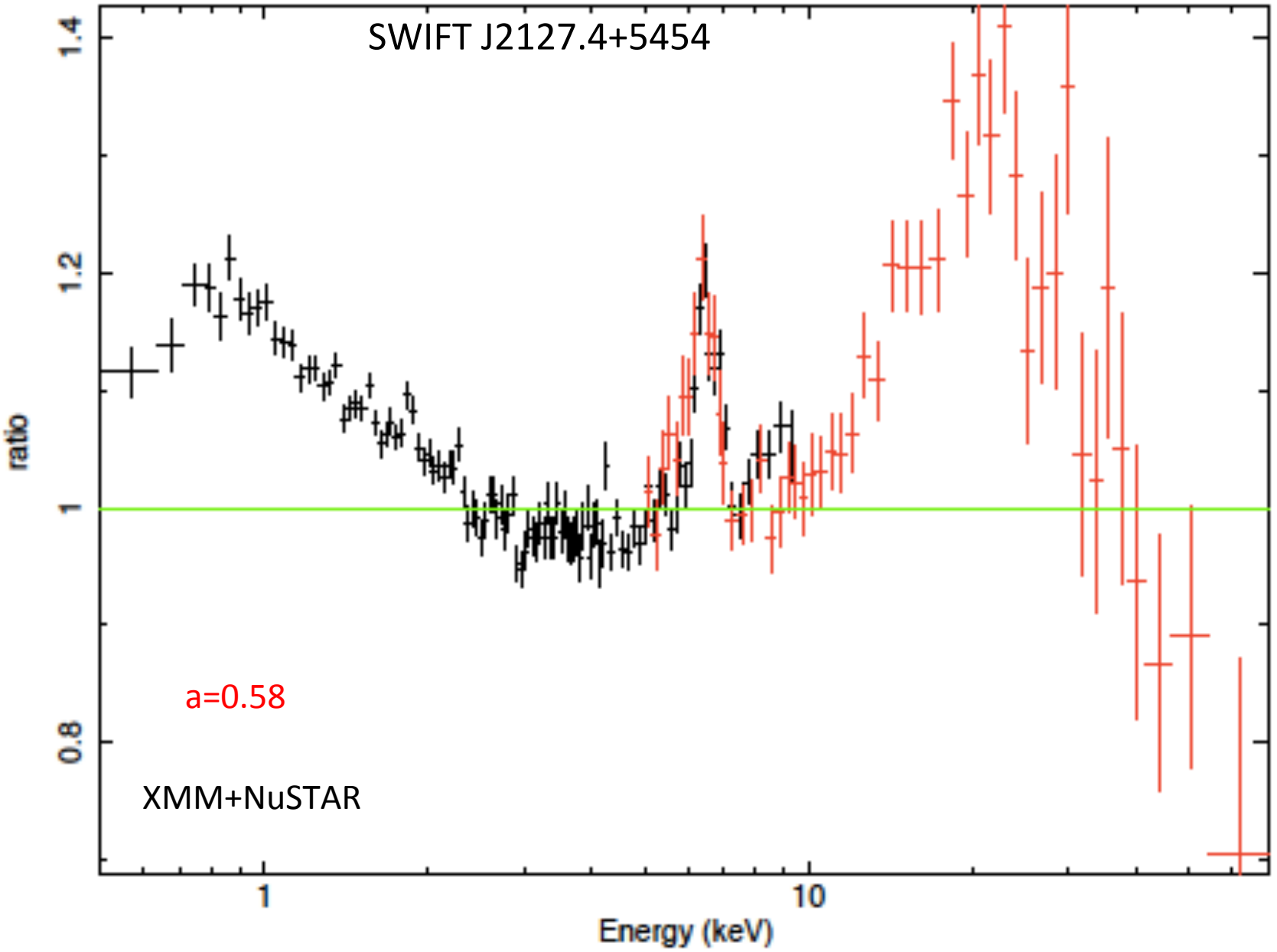
- 50% of power from 5 gravitational radii for max spinning black hole
- Hard X-ray continuum from compact corona
- Pair production may control primary X-ray spectrum

- Winds, jets and radiation pressure may all be important
- Why ignore radiation pressure on dust?
- Feedback can be both negative and positive


Direct Power-law
To observer
Corona
"Reflection" spectrum
Accretion disc

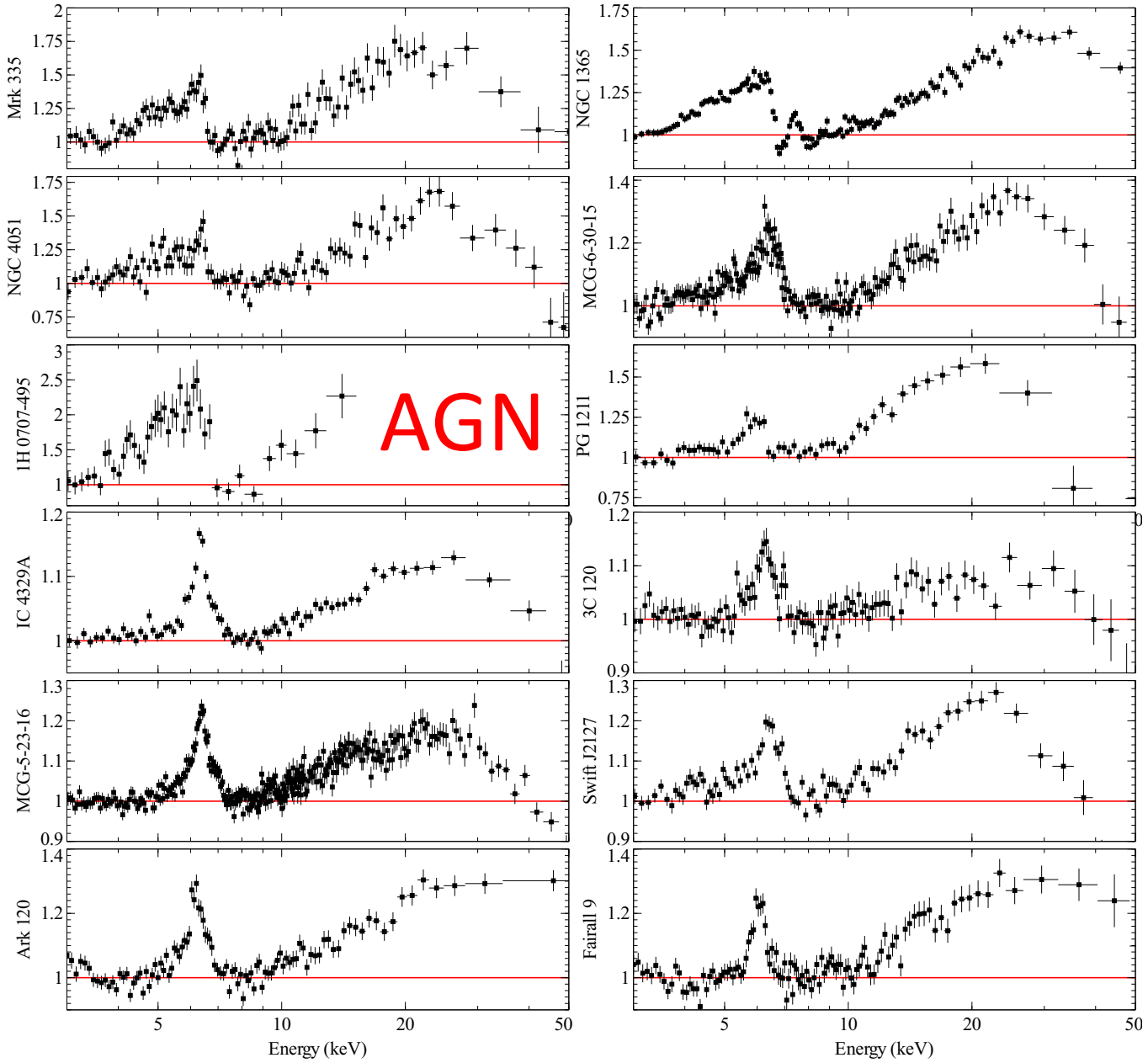


Soft excess – broad iron line – Compton hump



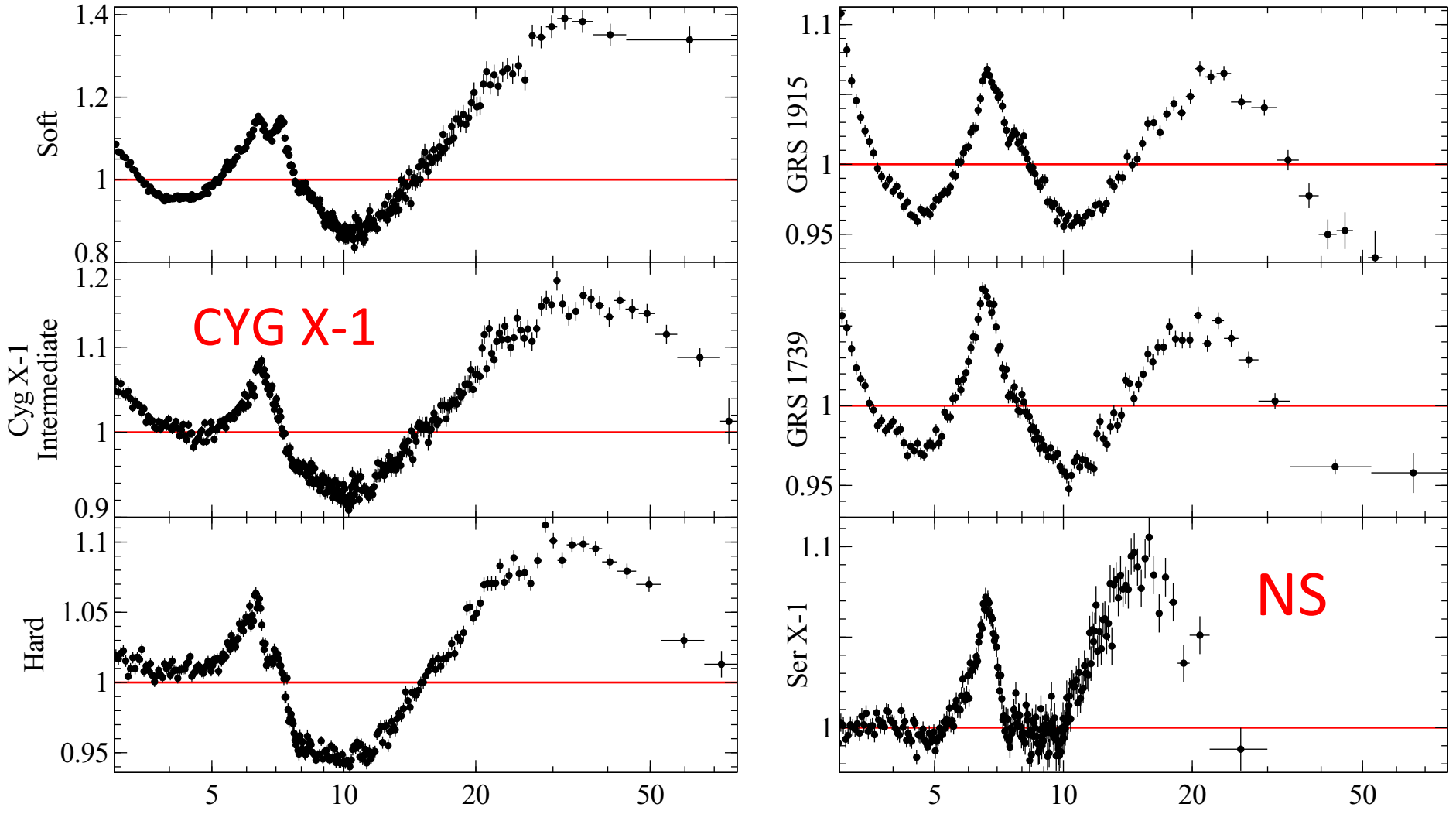
Marinucci+14

Reflection in AGN with NuSTAR

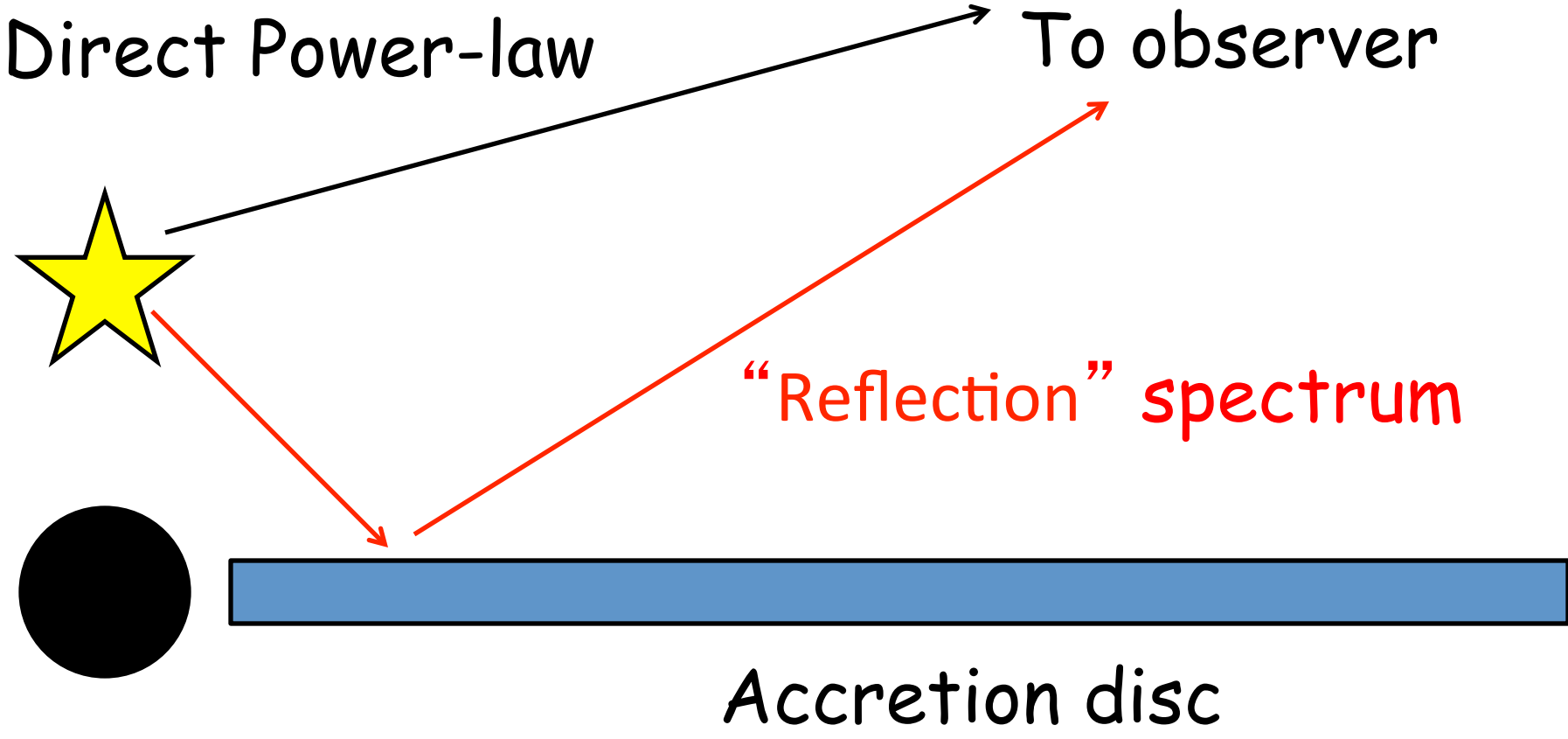


Parker, Matt+

and Galactic sources too

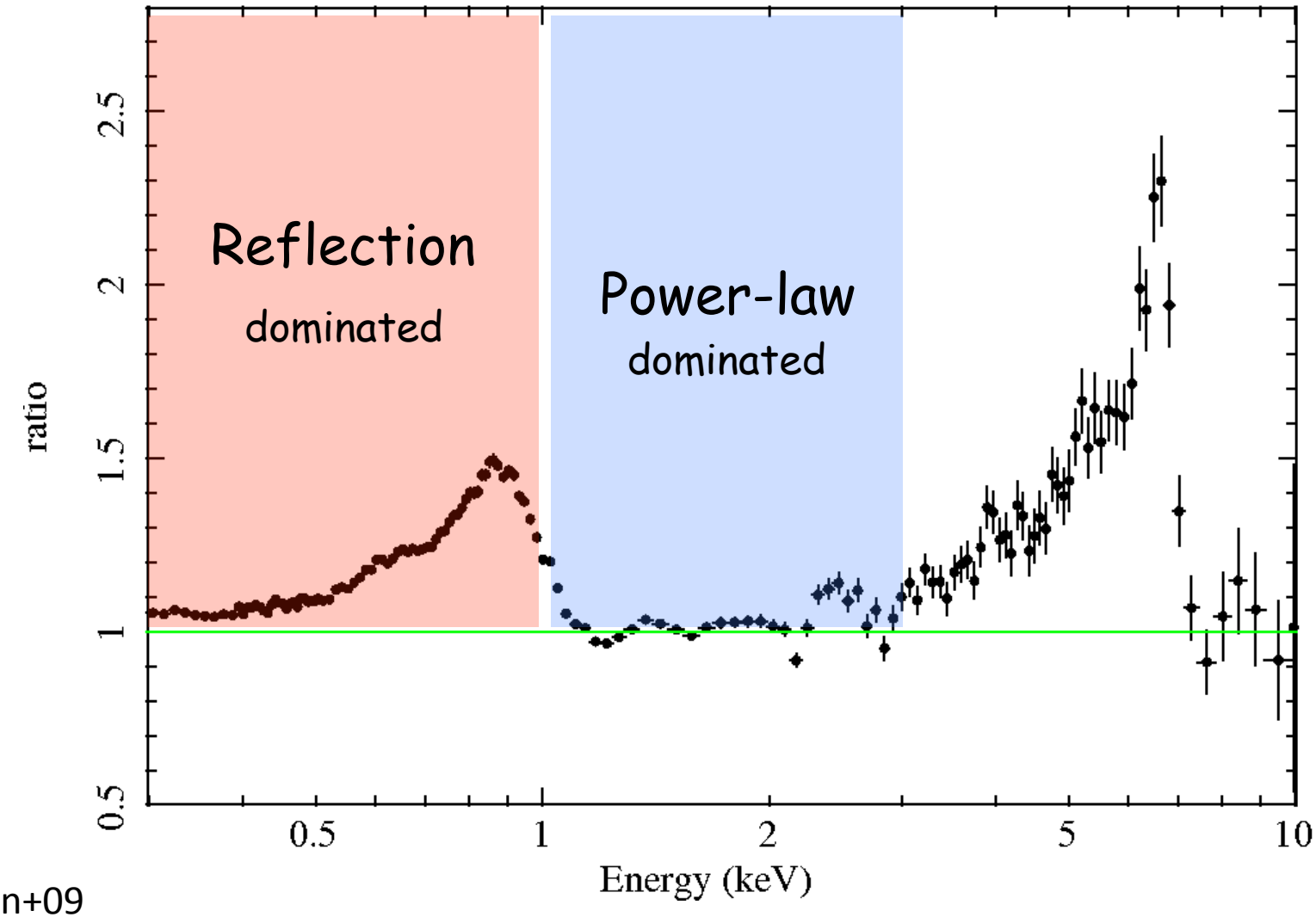


Parker, Tomsick+

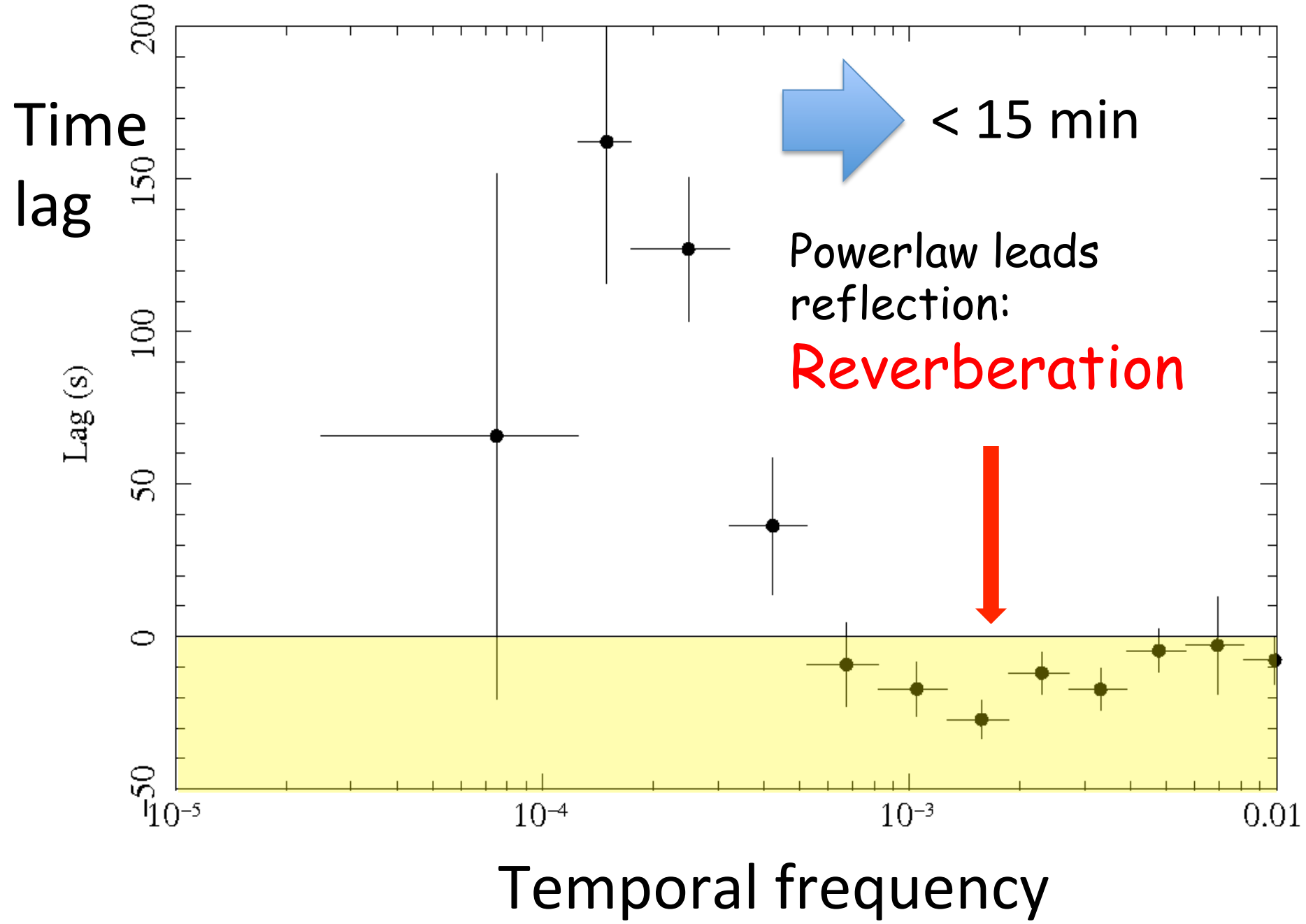


Path difference leads to *reverberation*

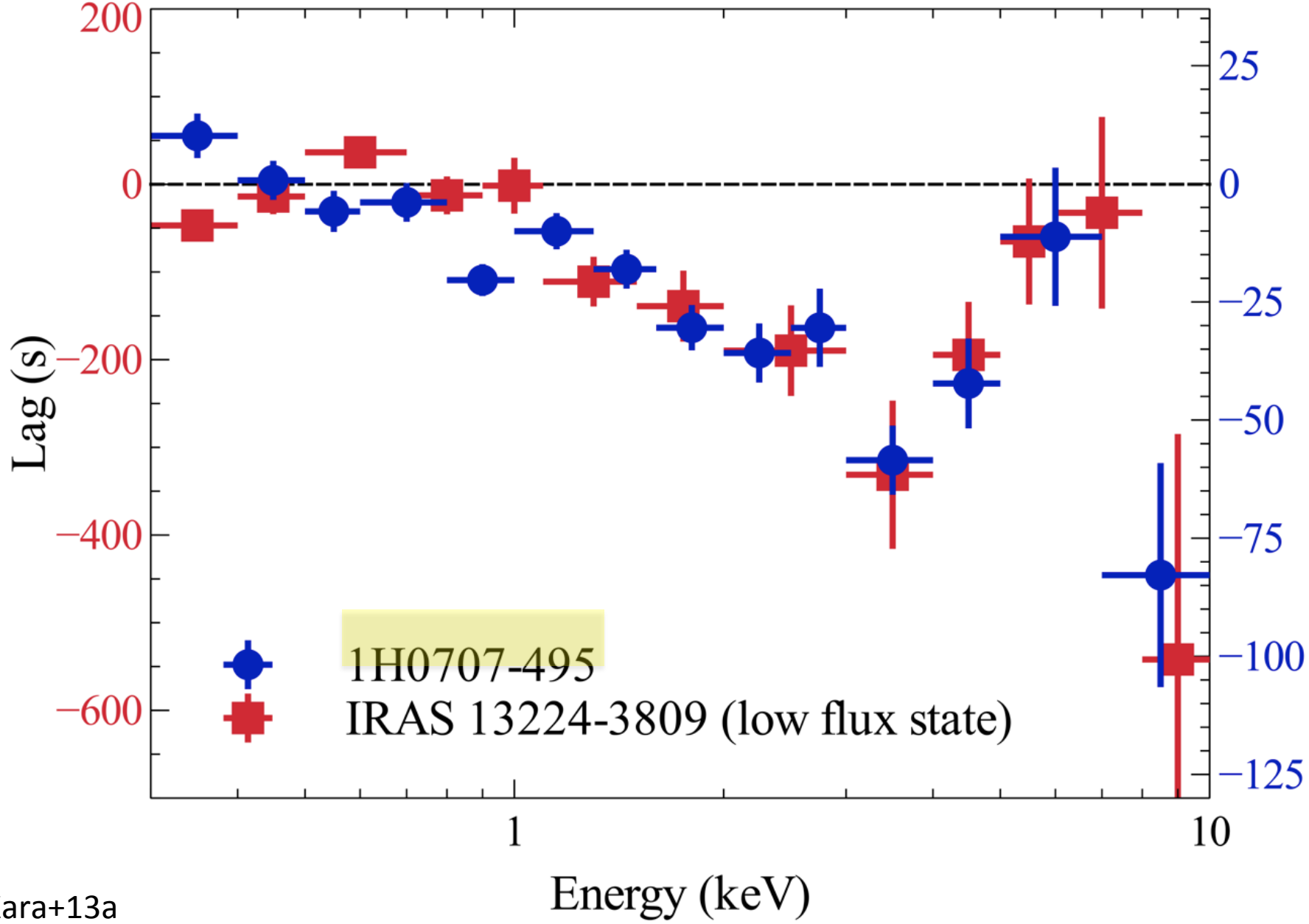
Broad iron-L and iron-K emission lines (XMM)



Fabian+09


Time lag
Lag (s)
200
150
100
50
0
−50
10⁻⁵
10⁻⁴
10⁻³
0.01
< 15 min
Powerlaw leads reflection:
Reverberation
Temporal frequency

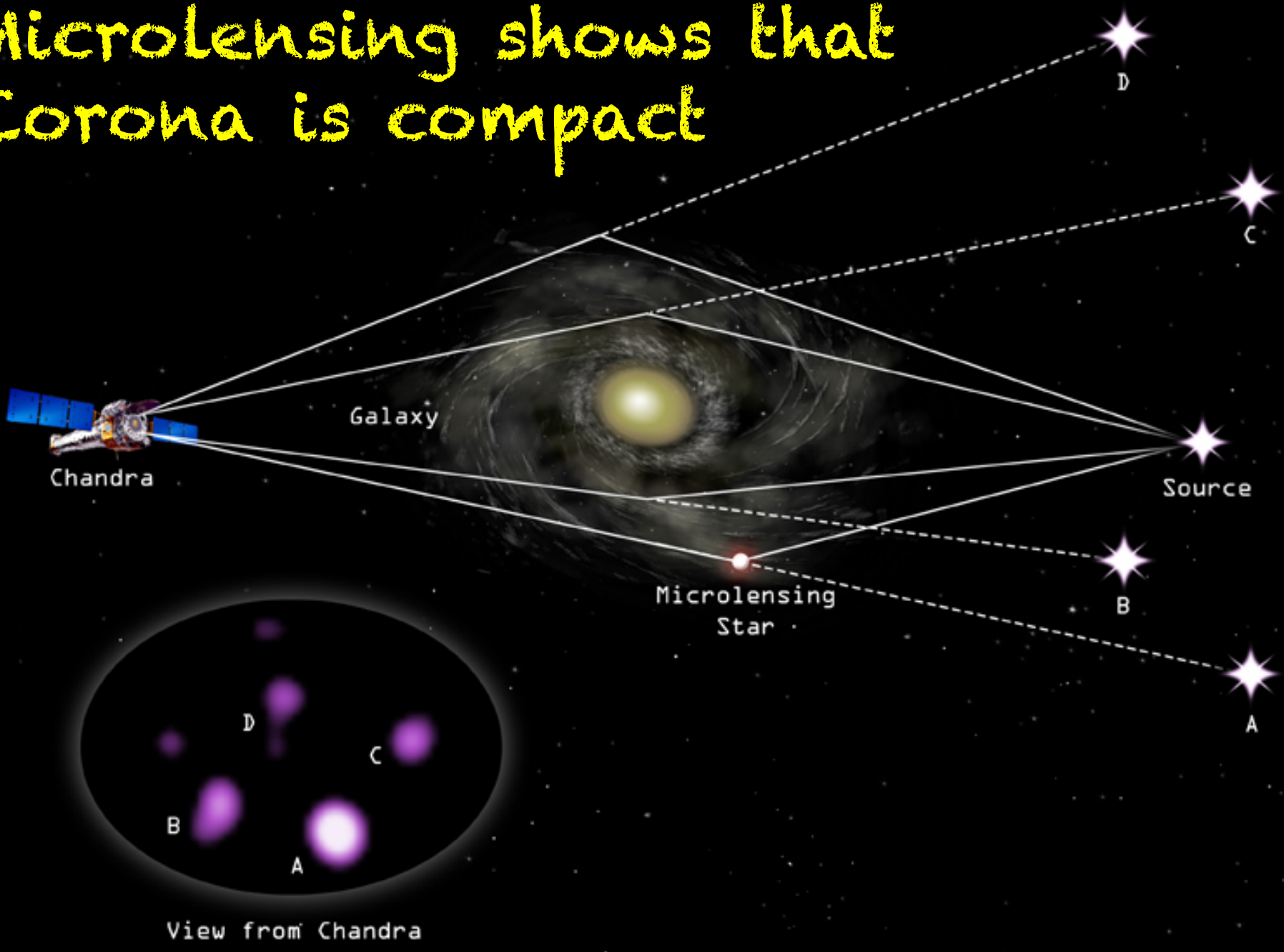
Lag Spectrum

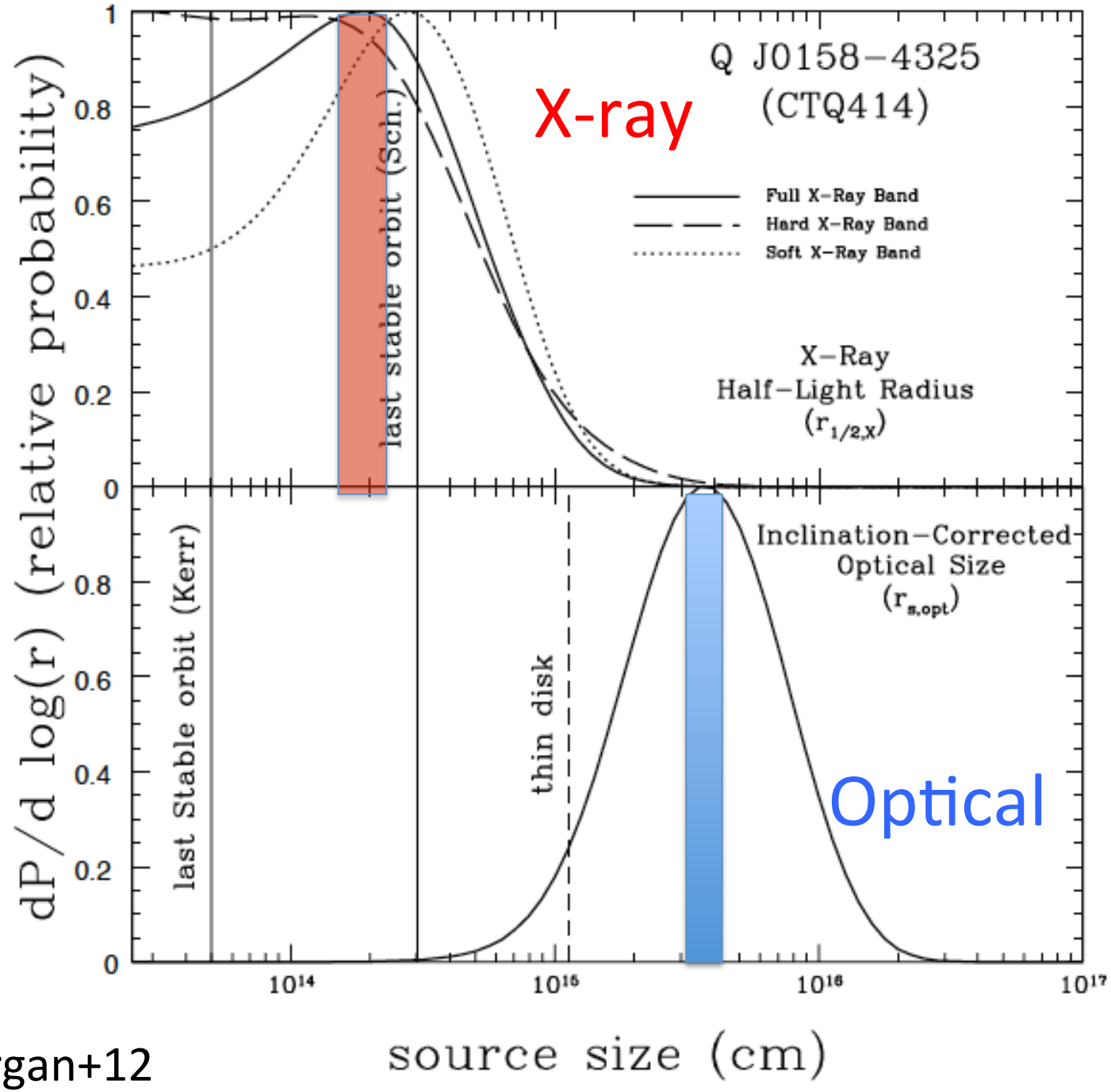


Kara+13a

Corona is compact

Microlensing shows that Corona is compact

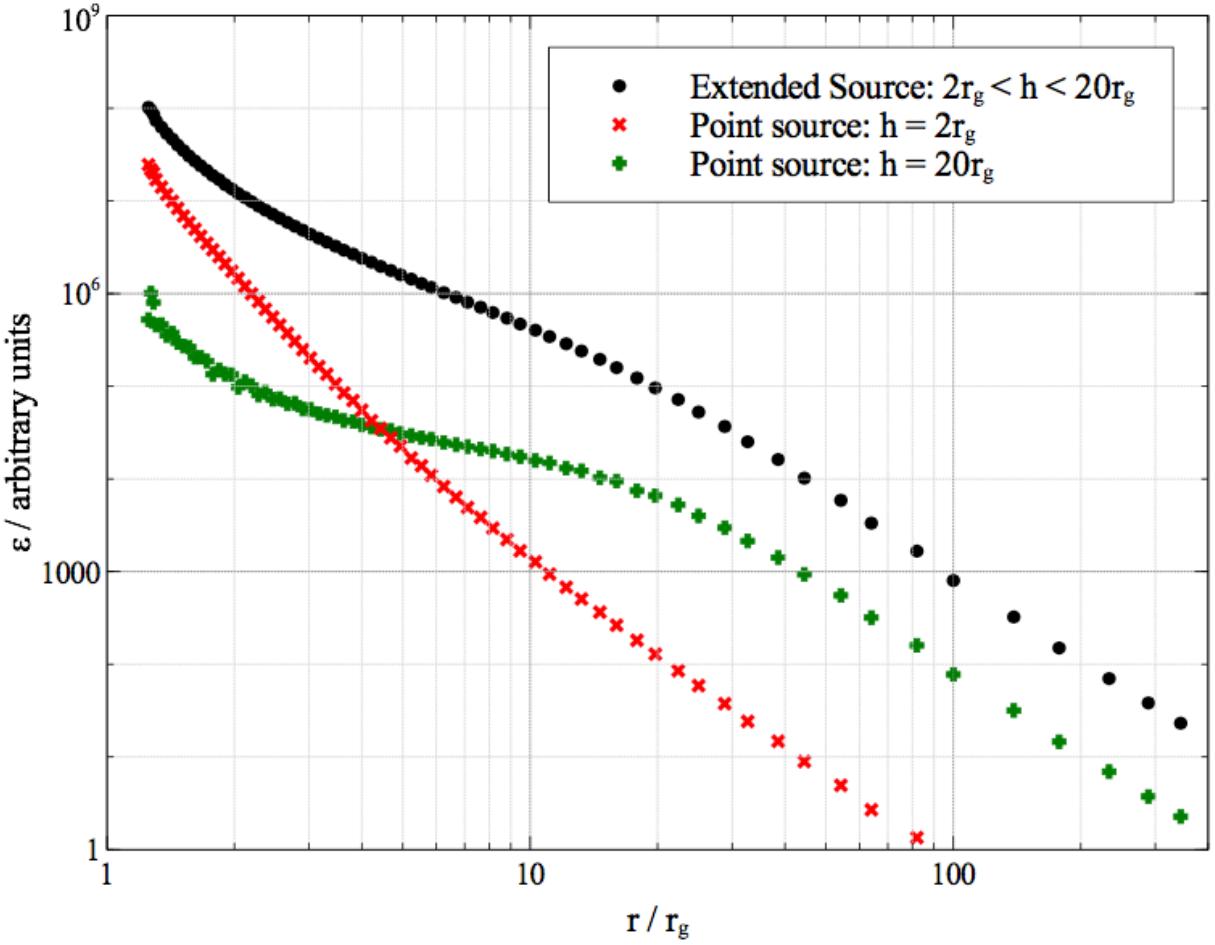


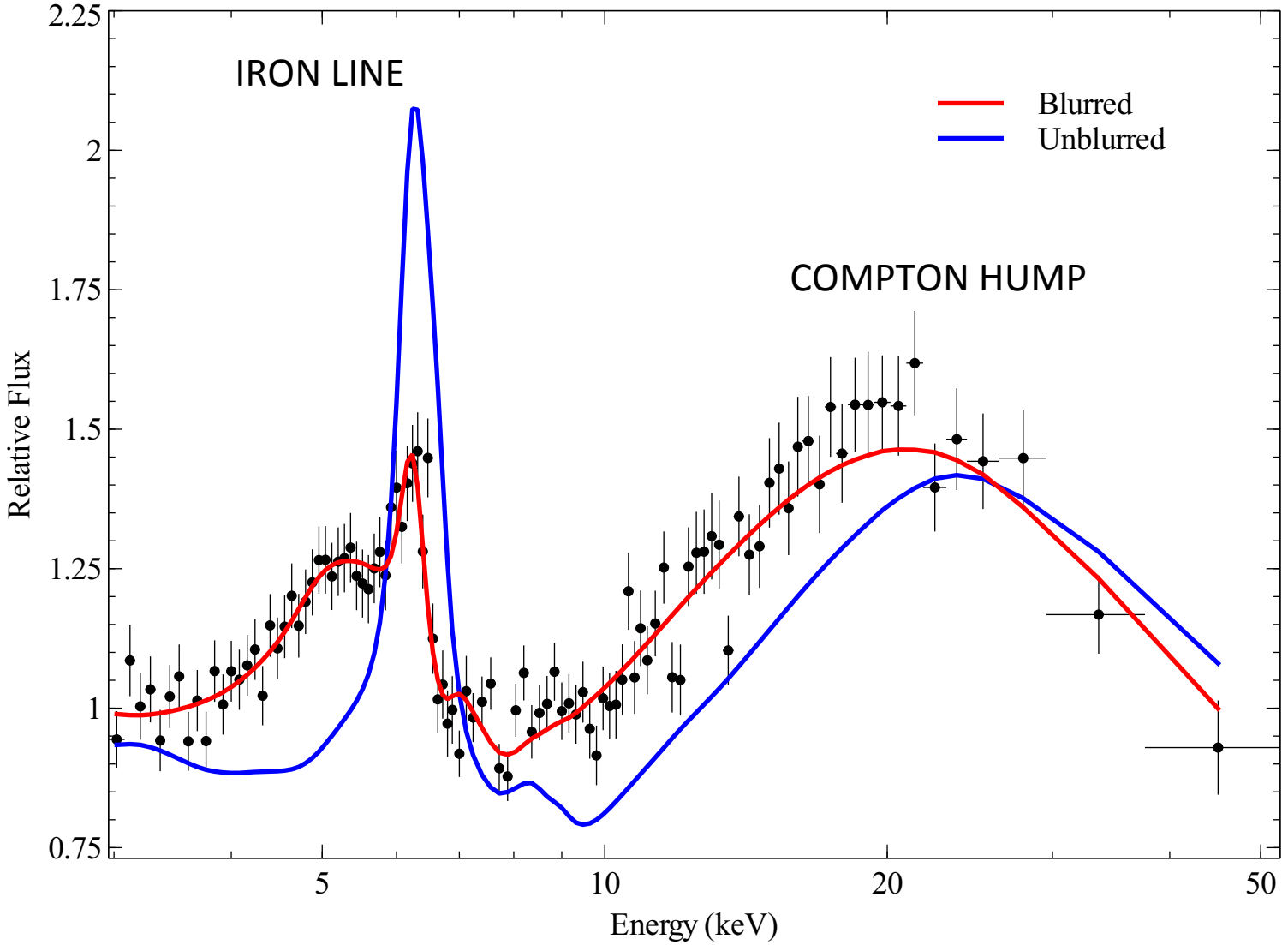

Q J0158−4325
(CTQ414)
X-ray
Full X-Ray Band
Hard X-Ray Band
Soft X-Ray Band
X−Ray
Half−Light Radius
($r_{1/2,X}$)
last stable orbit (Sch.)
Inclination−Corrected
Optical Size
($r_{s,opt}$)
thin disk
last Stable orbit (Kerr)
Optical
dP/d log(r) (relative probability)
source size (cm)
0
0.2
0.4
0.6
0.8
1
10^{14}
10^{15}
10^{16}
10^{17}

Morgan+12

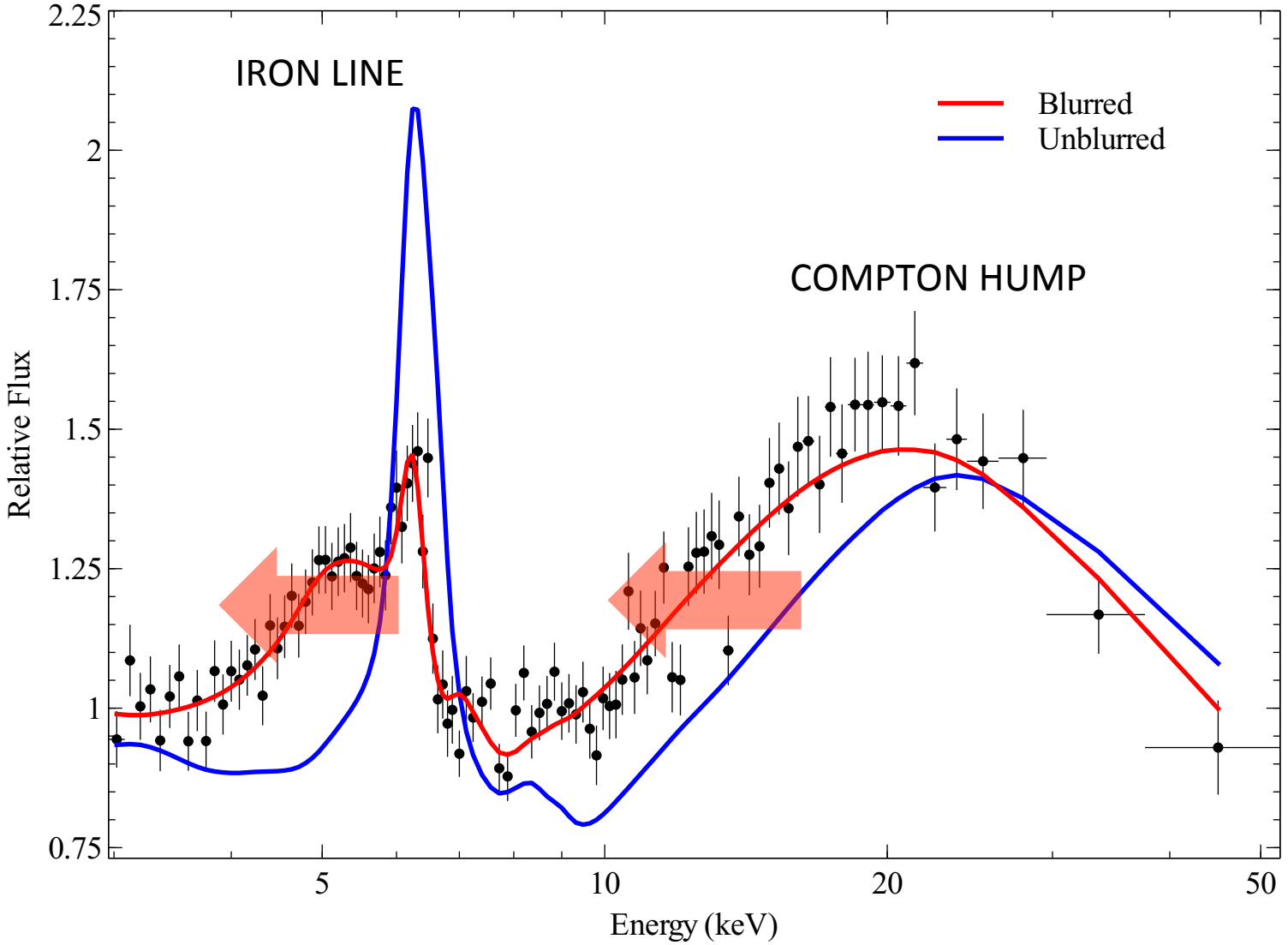
Emissivity profiles enable coronal height and radius to be determined

Wilkins&Fabian12

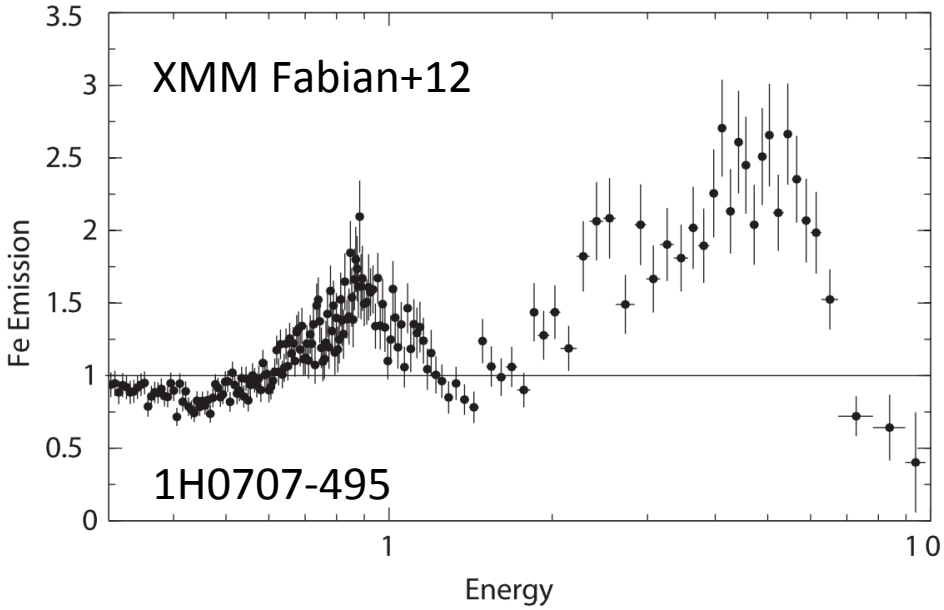


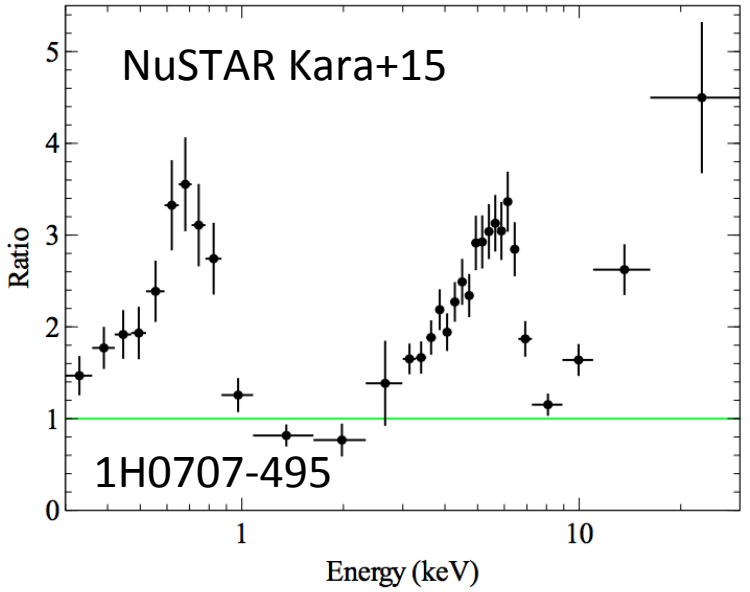


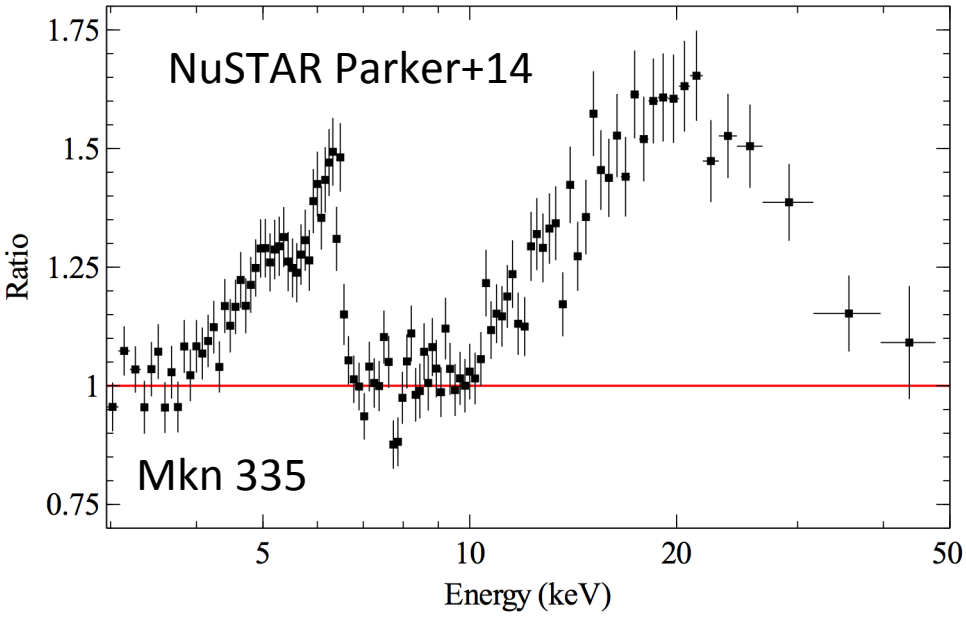
Mkn 335 Parker+14



Mkn 335 Parker+14







Results from within 2 r_g

Smaller than BH shadow

Consequence of small luminous corona

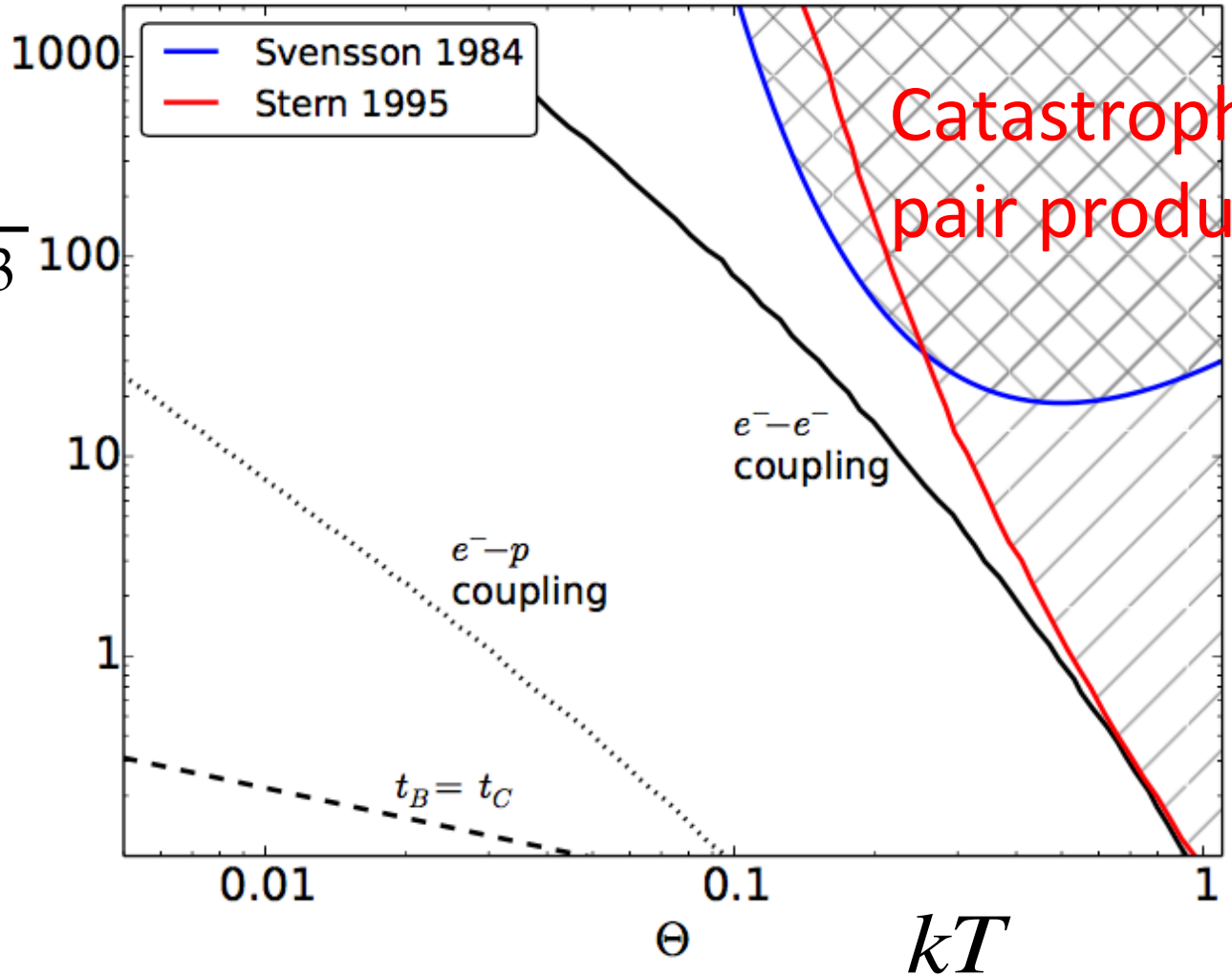
- Small luminous corona is COMPACT with high L/R
- Energetic photon-photon collisions can occur making $e^{+/-}$ pairs
- Constrains the temperature Svensson82,4, Guilbert+83, Zdziarski85….

- (Typical AGN corona has compactness > 10^{12} times Solar corona)

CORONAL PHYSICS

compactness

$$\frac{L}{R}\frac{\sigma_T}{mc^3}$$

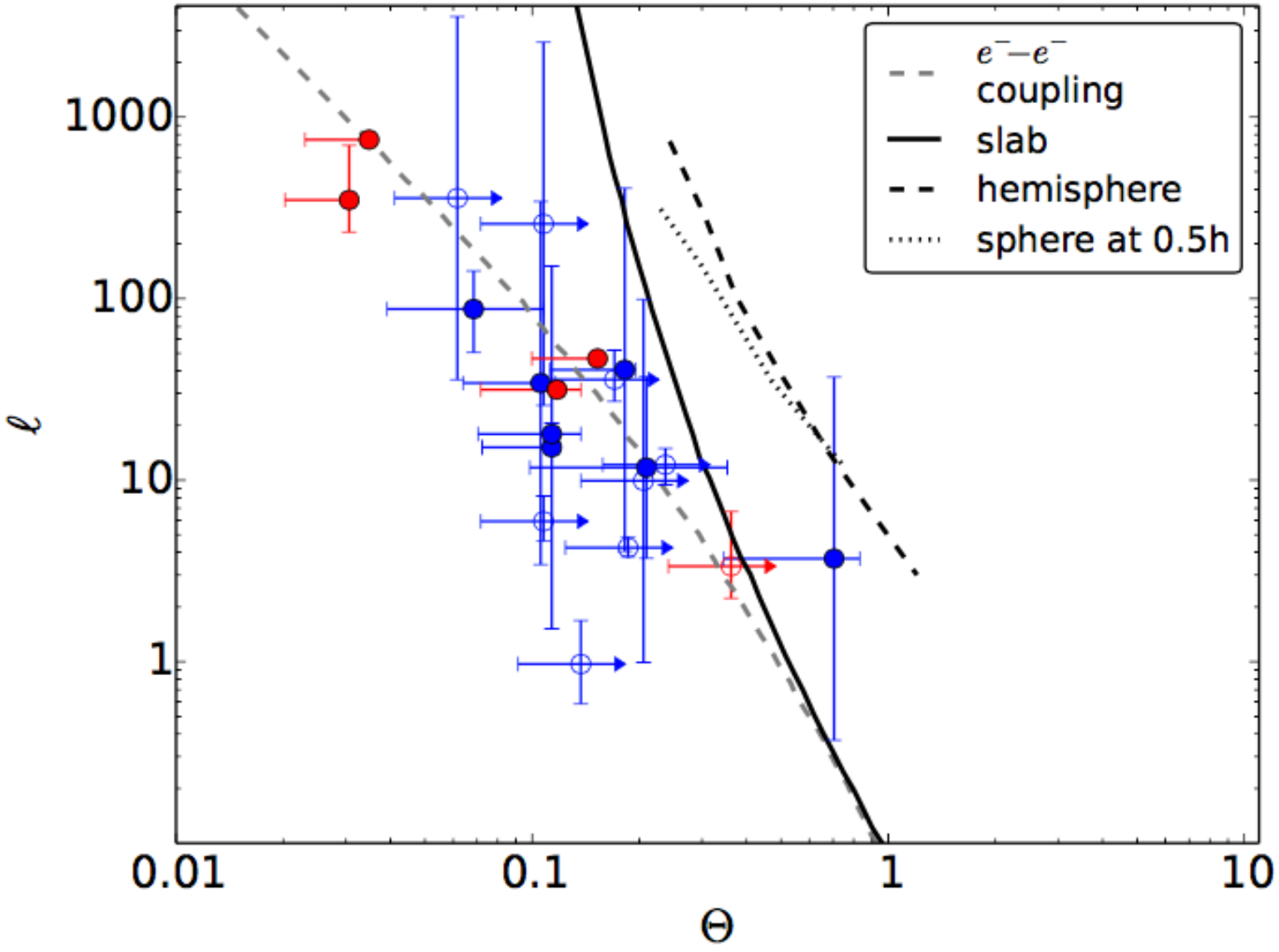


$$\frac{kT}{m_e c^2}$$

temperature

Fabian+15

NuSTAR results



SED still peaks in UV-FUV bands due to thermal disk emission.

This is particularly relevant to AGN Feedback

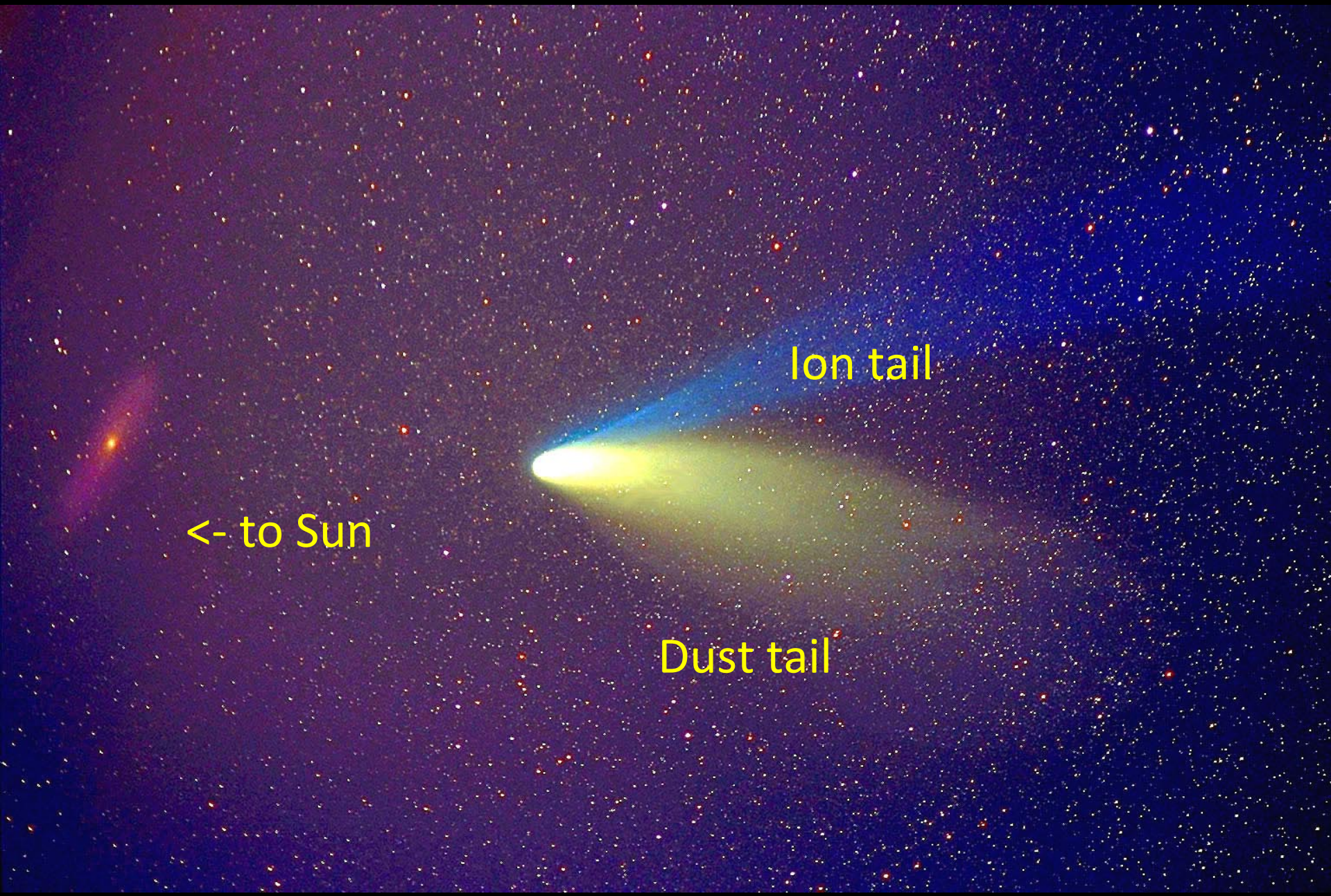

Radiative/quasar mode

Possible effect of central black hole on galaxy

$$E_{BlackHole} > 100 \times E_{Galaxy}$$

Energy released by growth of Black Hole

Gravitational Energy of Host Galaxy



Effects of radiation pressure and winds

The Eddington limit

$$L_{Edd} = \frac{4\pi G M_{bh} m_p c}{\sigma_T}$$

The effective Eddington limit

$$L_{Edd} = \frac{4\pi G M_{bh} m_p c}{\sigma_T} \qquad L'_{Edd} = \frac{4\pi G M_{gal} m_p c}{\sigma_d}$$

$$\left(\frac{M_{gal}}{M_{bh}} = \frac{\sigma_d}{\sigma_T} = 500 \right)$$

The effective Eddington limit

$$L_{Edd} = \frac{4\pi G M_{bh} m_p c}{\sigma_T} \qquad L'_{Edd} = \frac{4\pi G M_{gal} m_p c}{\sigma_d}$$

$$\left(\frac{M_{gal}}{M_{bh}} = \frac{\sigma_d}{\sigma_T} = 500 \right)$$

Black hole mass fraction set by DUST ?

$$M_{\rm gal} = 2\sigma^2 r/G$$

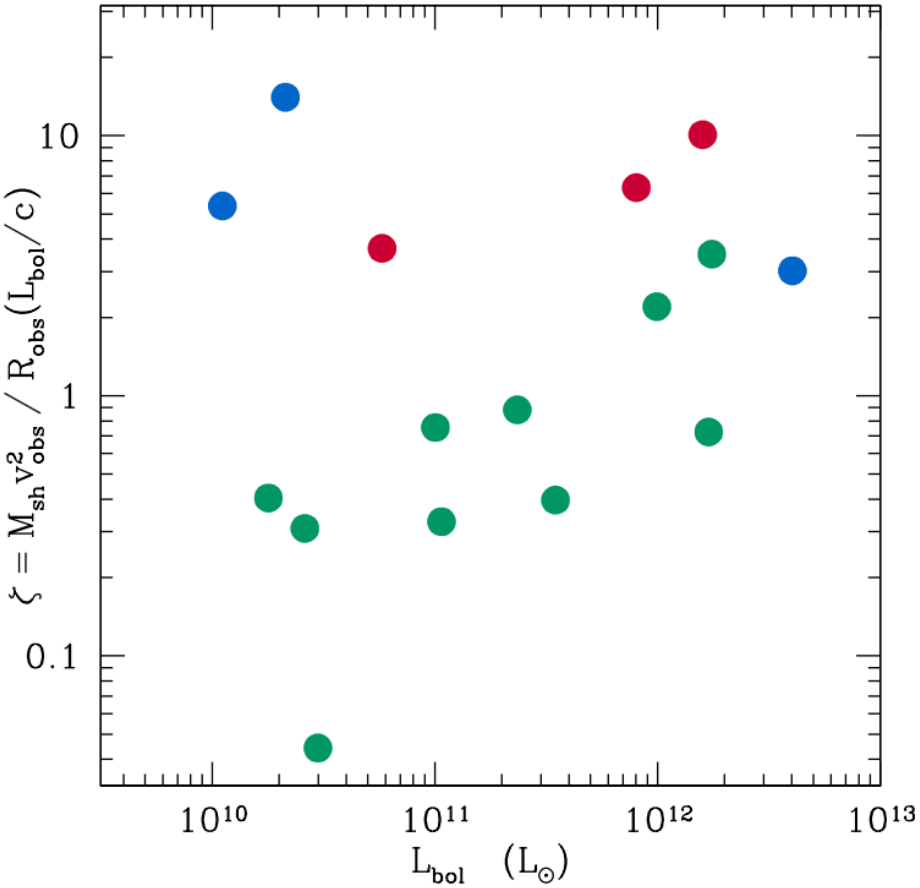
$$\frac{4\pi G M_{\rm BH} m_{\rm p}}{\sigma_{\rm T}} = \boxed{\frac{L_{\rm Edd}}{c} = \frac{G M_{\rm gal} M_{\rm gas}}{r^2}} = \frac{f G M_{\rm gal}^2}{r^2} = \frac{fG}{r^2}\left(\frac{2\sigma^2 r}{G}\right)^2,$$

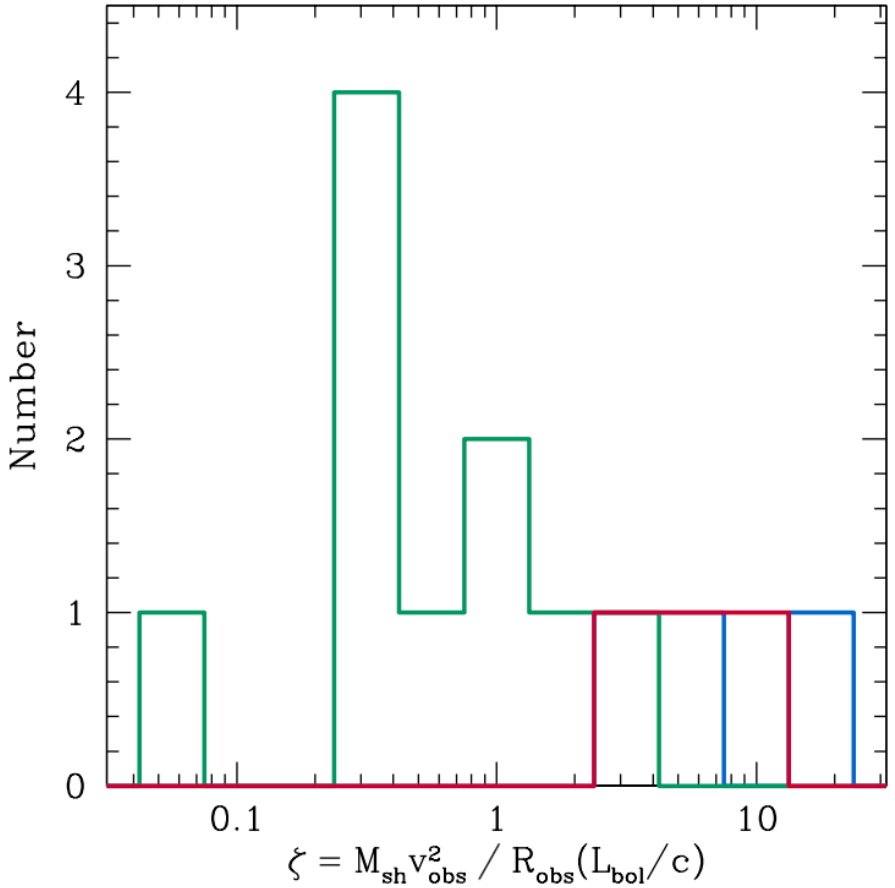
$$M_{bh} = \frac{f\sigma^4}{\pi G^2 m_p}\sigma_T$$

If correct, the basic structure of
galaxy bulges is shaped by the effects of radiation pressure on DUST

Fabian12 ARAA 50 455

Observed Momentum ratio $\zeta = \dot{M}v / (L / c)$





Data from Cicone+14

Does observing $\dot{M}v = 10\dfrac{L}{c}$

(Sturm+, Arav+, Tremonti+, Cicone+)

mean that radiation pressure cannot be the driver??

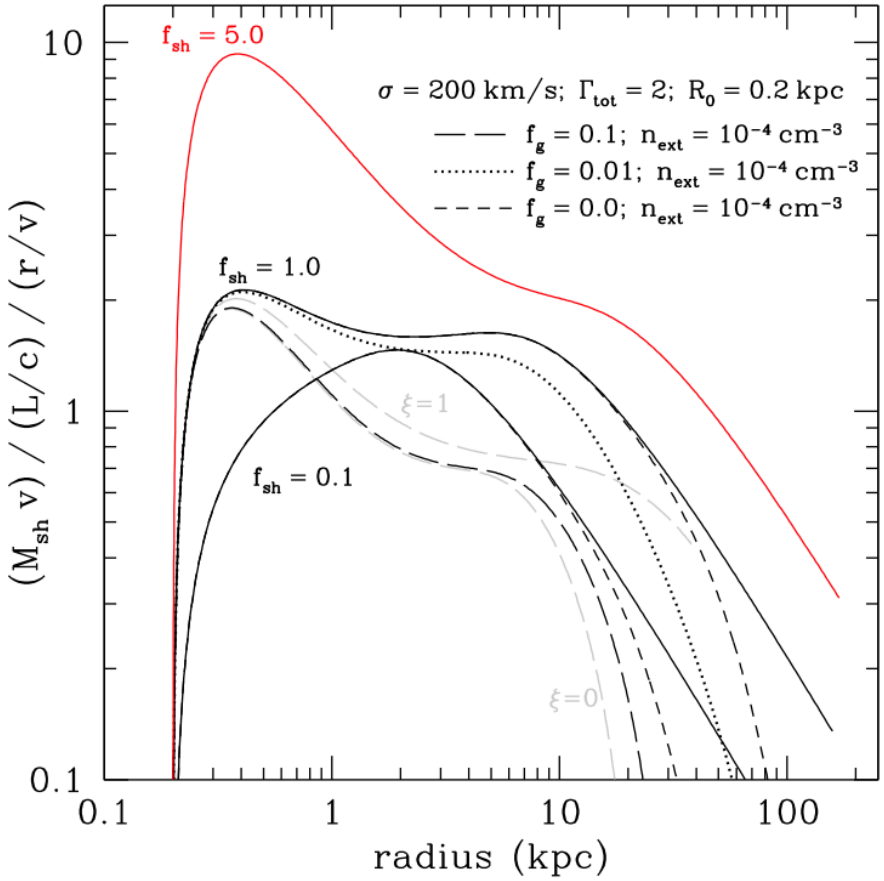
If most gas initially resides within inner 100pc
then optically thick to reprocessed IR.
L/c boosted by $(1+\tau_{IR})$.
If τ_{IR} ~ few then can obtain outgoing shell velocity
v ~ few σ so

Thompson+15

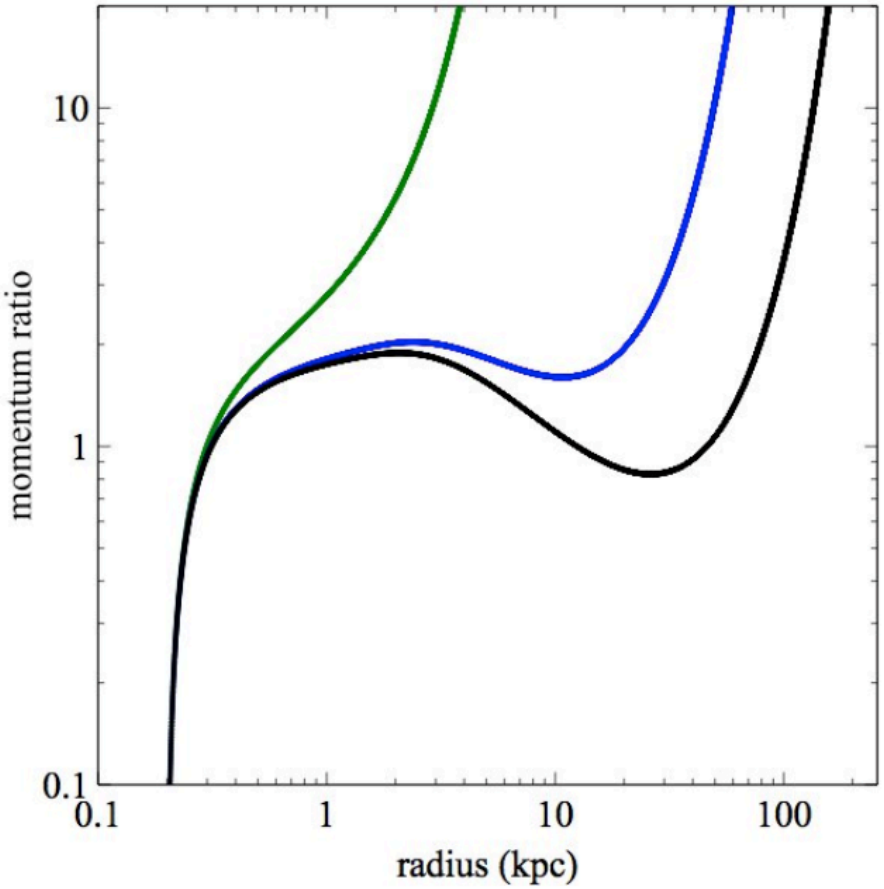
$$\dot{M}v \approx 10\frac{L}{c}$$

Momentum (thrust) ratio

L constant



L decaying



Thompson+15

Ishibashi+Fabian15

Feedback triggered Star Formation

- Stars form in expanding shells of gas pushed out by AGN
- Galaxy grows from inside out
- Feedback can both suppress and cause star formation
- See Ishibashi&Fabian12-15

Some remarks on feedback from central engine to galaxy host

- 50% of power from 5 gravitational radii for max spinning black hole
- Hard X-ray continuum from compact corona
- Pair production may control primary X-ray spectrum

- Winds, jets and radiation pressure may all be important
- Why ignore radiation pressure on dust?
- Feedback can be both negative and positive