Black Hole Winds

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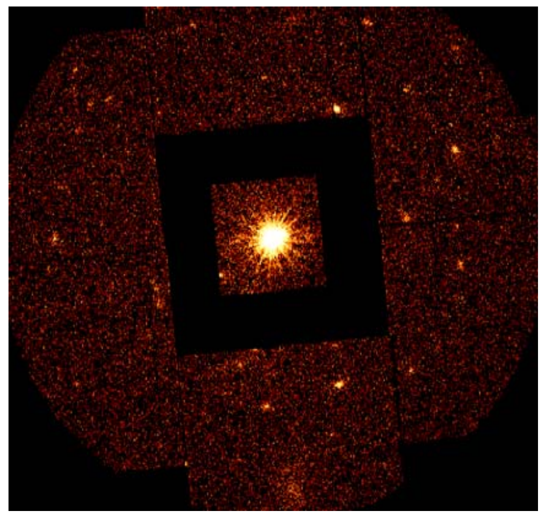

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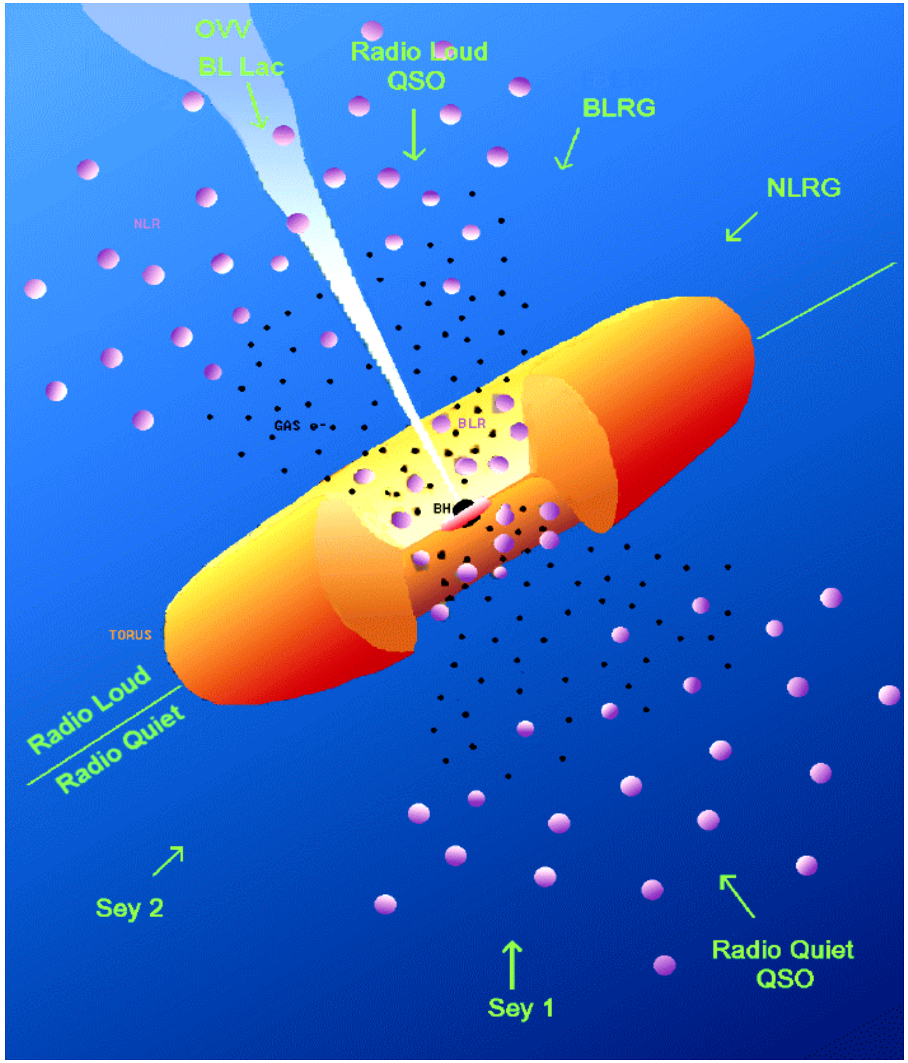
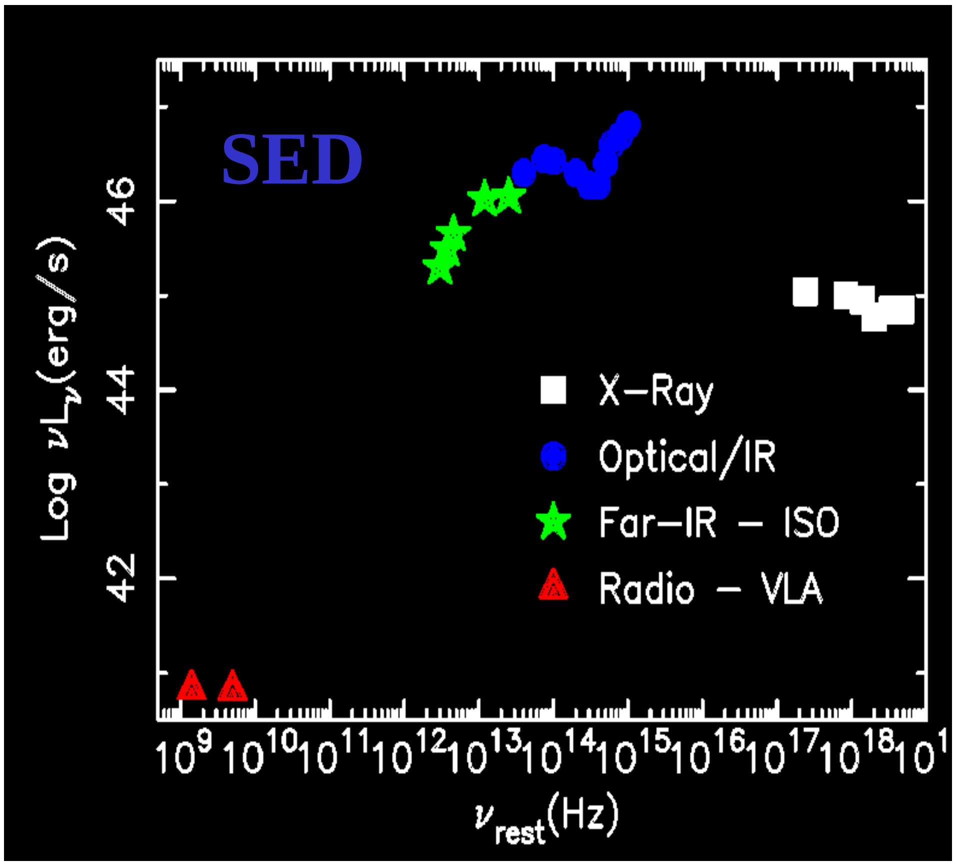
AGN – the standard model

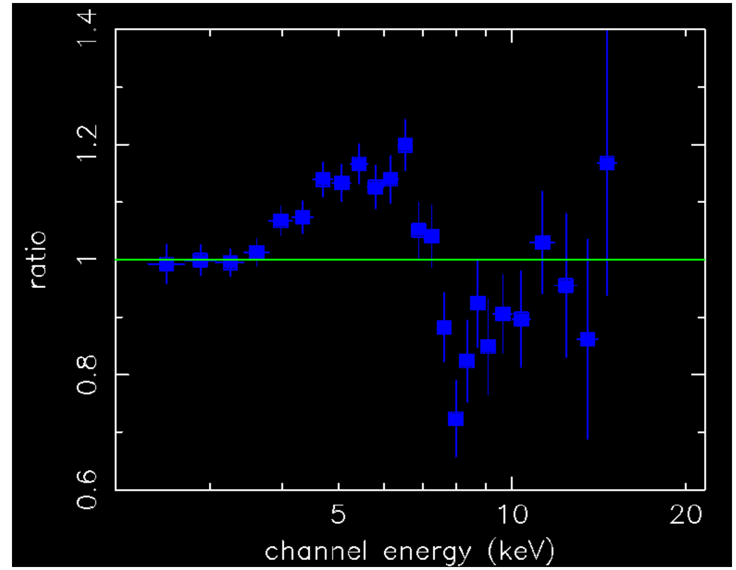


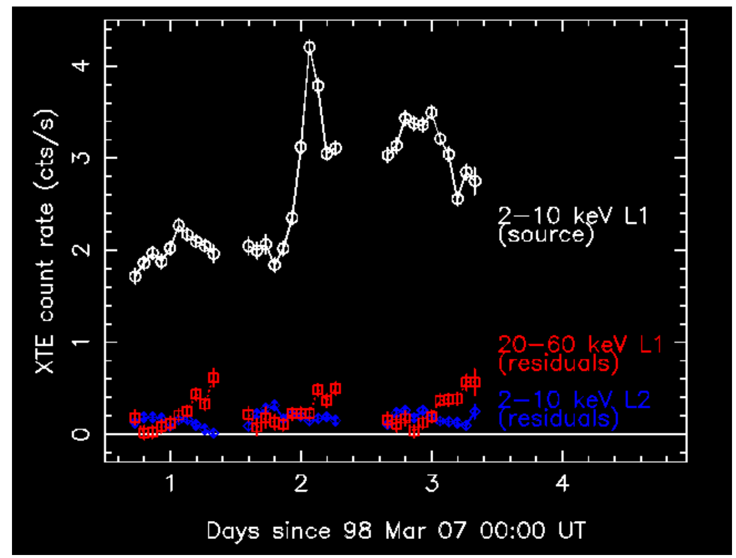
RXTE Spectrum + Lightcurve

PDS456: Most luminous nearby QSO

Radio-quiet, $L_{BOL} = 10^{47}$ erg s^{-1} , z= 0.184







XMM-Newton & Beppo-SAX Observations

- ***RXTE/ASCA:***

1. ***Strong iron K edge at 8.7 keV***
2. ***Rapid variability***
3. ***Strong "hot" (ionised) absorber***

Consistent with high accretion rate object

- ***XMM-Newton:***

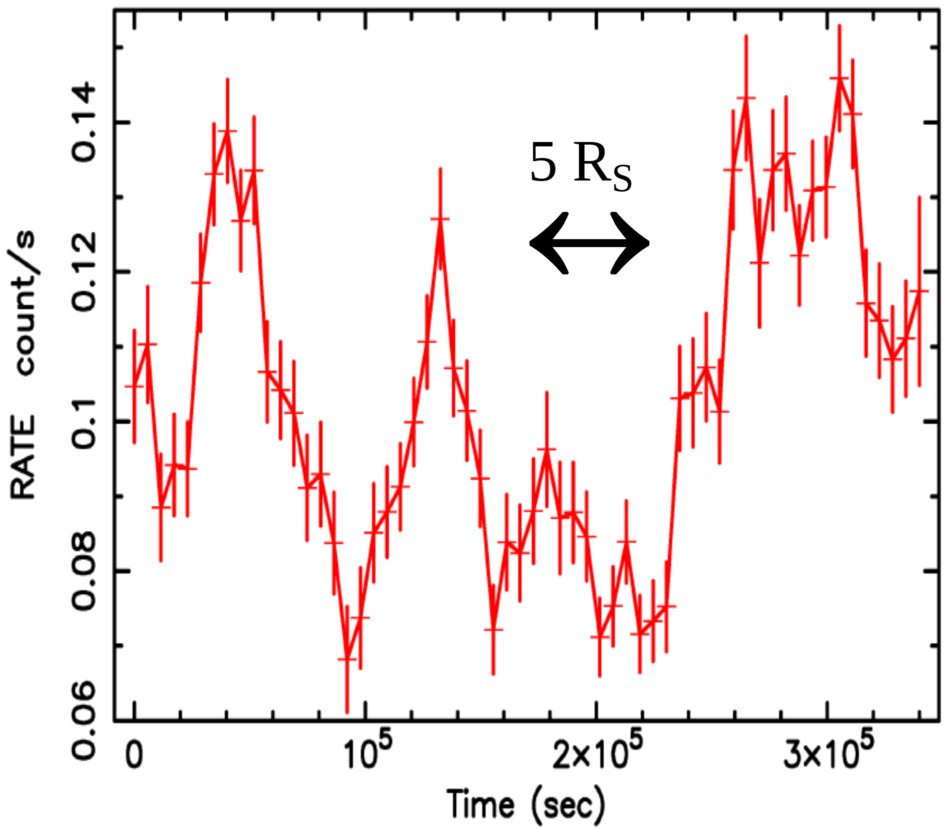
  - ***EPIC*** CCD Images and Spectra to study iron edge
  - ***RGS grating spectroscopy*** to study the absorber

- ***Beppo-SAX:***

  - monitor the variable X-ray continuum

X-ray variability of PDS 456

MECS: 2-10 keV



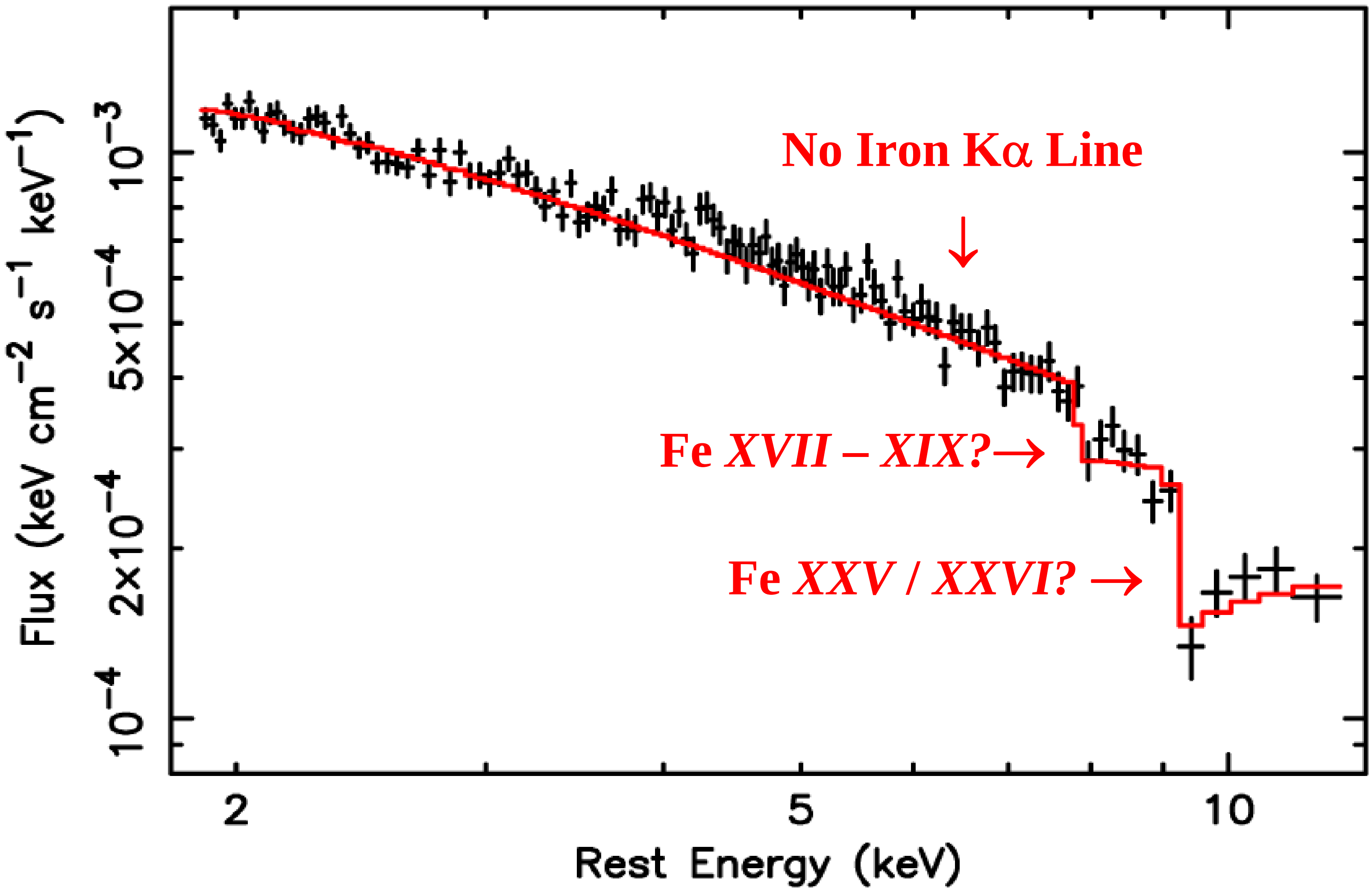
Observed properties

- **Large flares ~ 10^{50} – 10^{51} erg d^{-1}**
- **MECS flux ×2 increase in 30 ksec**
- **Implies size < $3R_S$ (for ~ 10^9 $M_{\odot}$)**

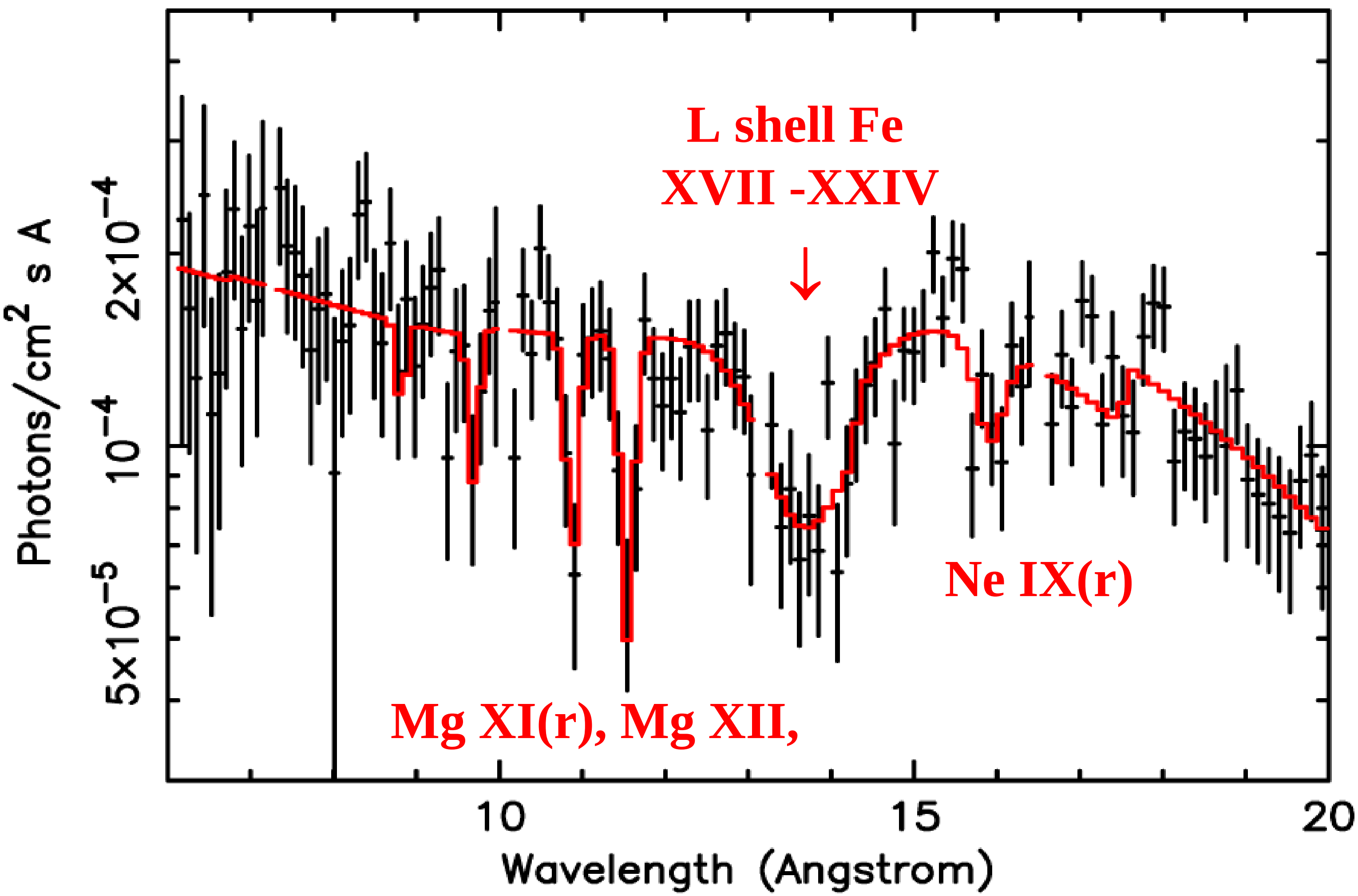
Magnetic reconnection in corona

- **Driven by K.E. of inner disc**
- **Enhanced by high accretion-rate and mass**
- **Radial flux tubes shear in inner disc then reconnect ⇒energy**

XMM-Newton EPIC hard X-ray spectrum of PDS 456



XMM-Newton RGS Spectrum of PDS 456



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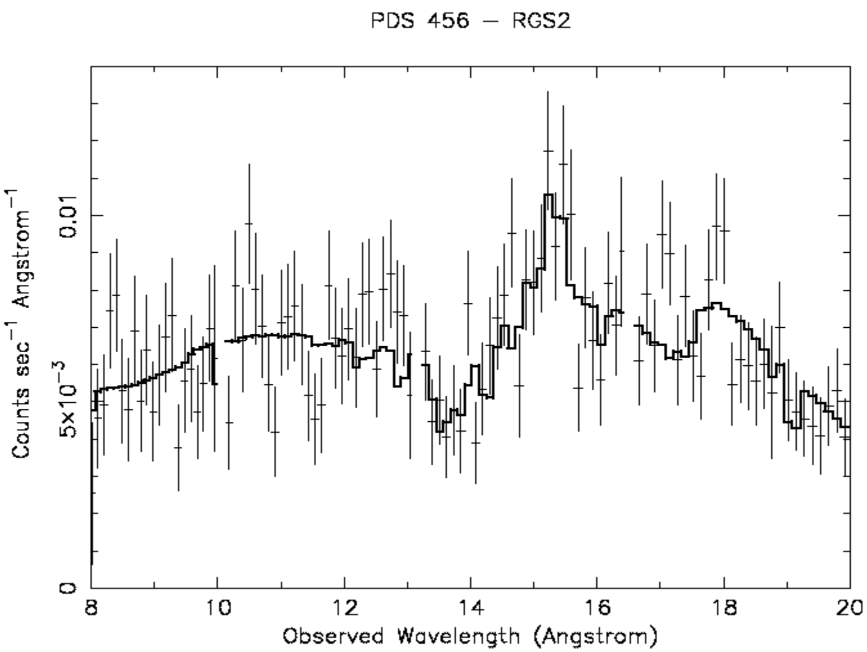
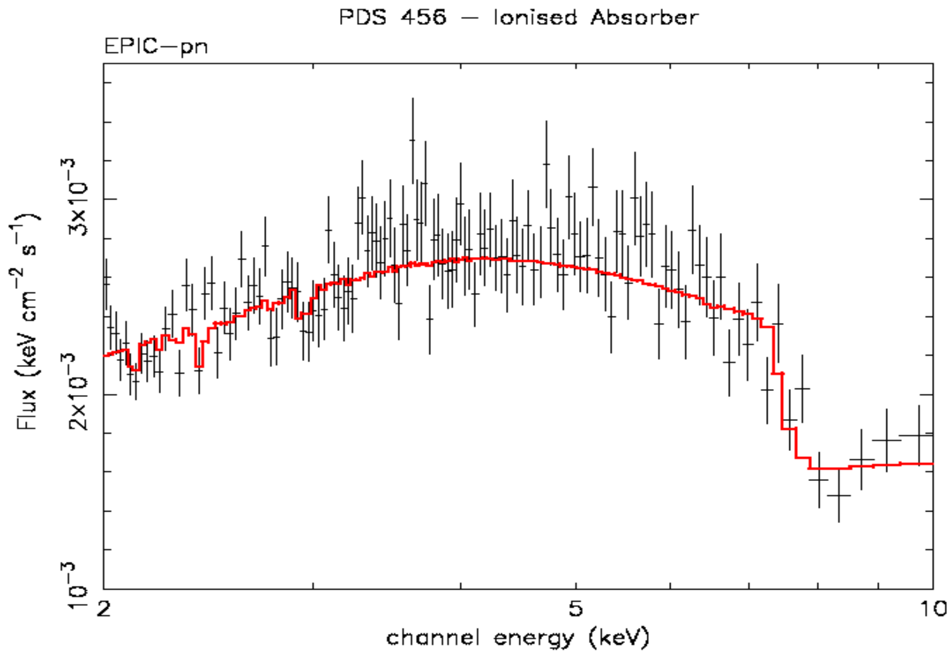
XSTAR model fit to PDS 456



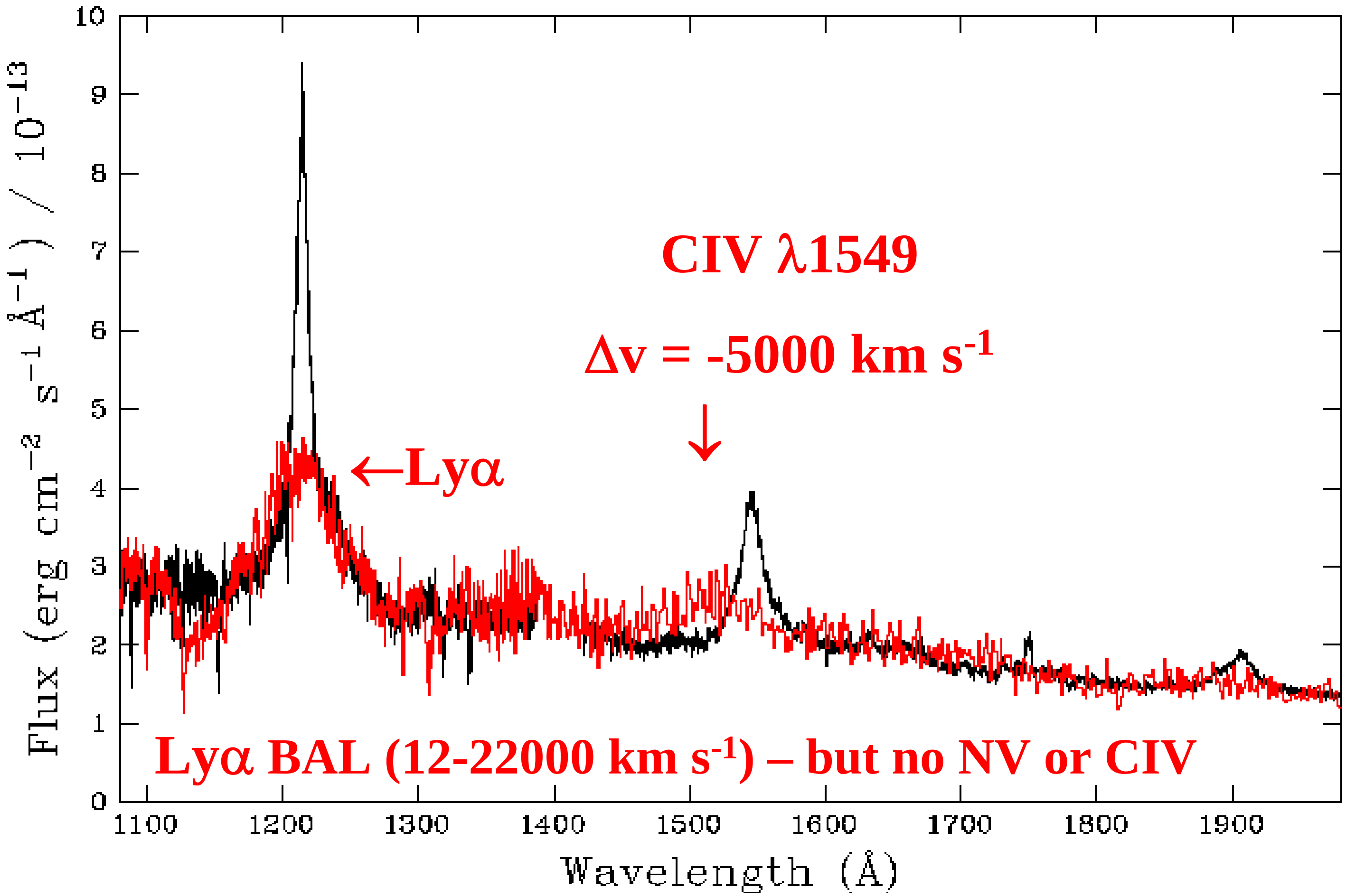


Derive $\xi \sim 10^3$ and $N_H \sim 10^{24}$ cm^{-2} outflowing at ~0.15c !

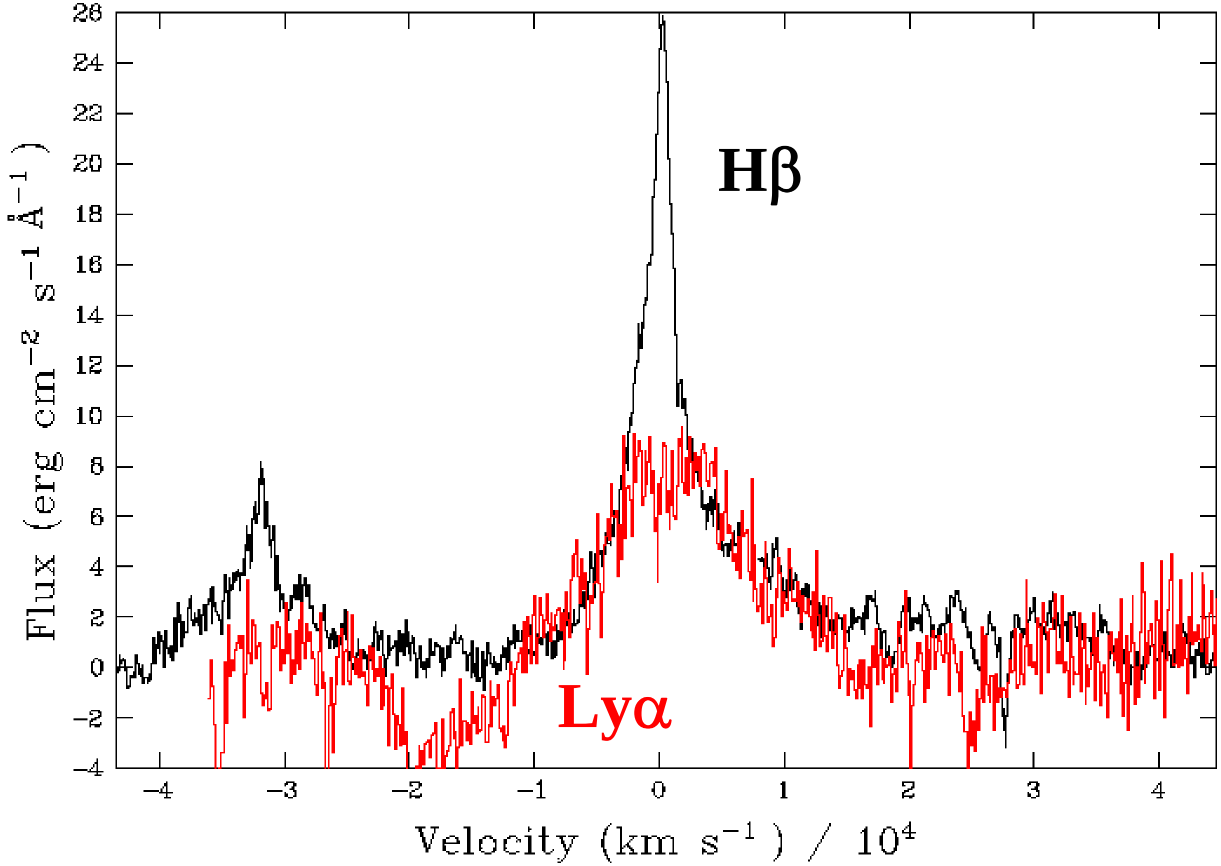
If hard X-rays driving outflow, mass-loss rate ~ 10 $M_\odot$ yr^{-1}

For 10% covering factor, outflow K.E. ~ 10^{46} erg s^{-1} (10% L_{bol})

HST Spectra of PDS 456 & 3C273



Comparison of Hβ and Lyα in PDS 456



Is PDS 456 unique?

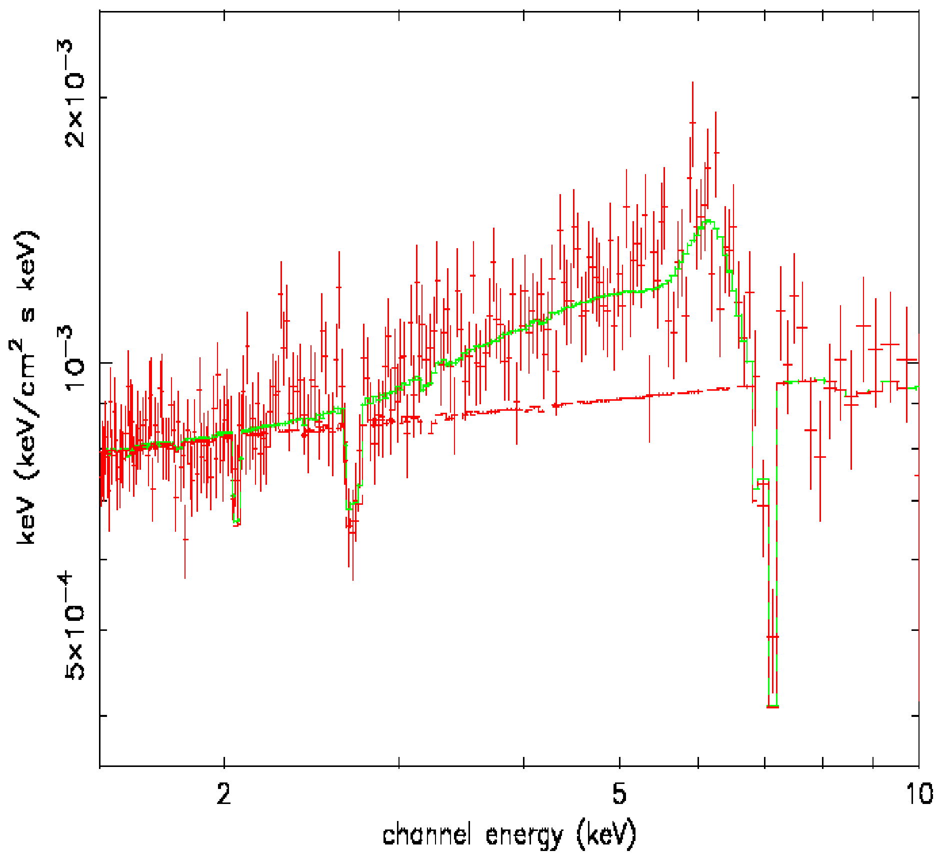
Quasar PG1211+143 (z=0.0809)
(Pounds et al. 2003)

XMM-Newton data reveal a large, highly ionised outflow

$\xi \sim 10^{3.4}$ and $N_H \sim 5x10^{23}$ cm^{-2} outflowing at ~0.1c

Mass-loss rate ~ 0.1 $M_\odot$ yr^{-1}

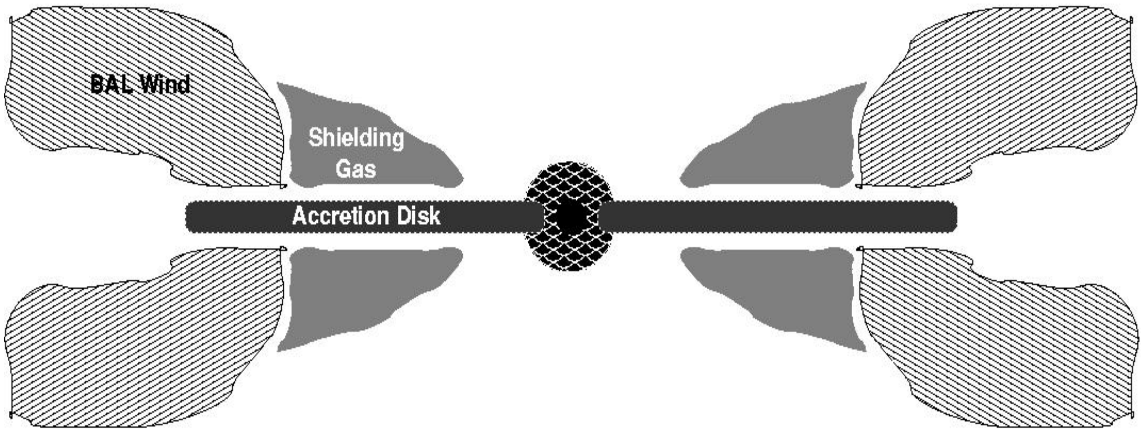
K.E. ~ 10^{43} erg s^{-1} (10% L_x)



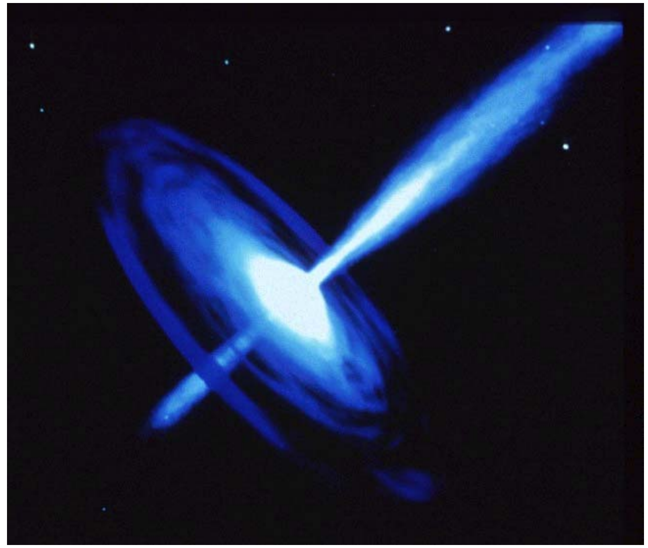
Similar flows in PG0844+349 (Pounds et al. 2003) and in the BAL quasars APM08279+5255 & PG1115+080 (Chartas et al. 2003)

Outflow geometry and driving mechanism

Flow along disk plane (BAL) ?



Flow along BH axis?



- **Radiation driven wind? Usual model for BALs. But, hard to drive large, high-ionisation, outflows. Need bound-free and/or Compton scattering. Implies large fraction of photon energy driving flow.**

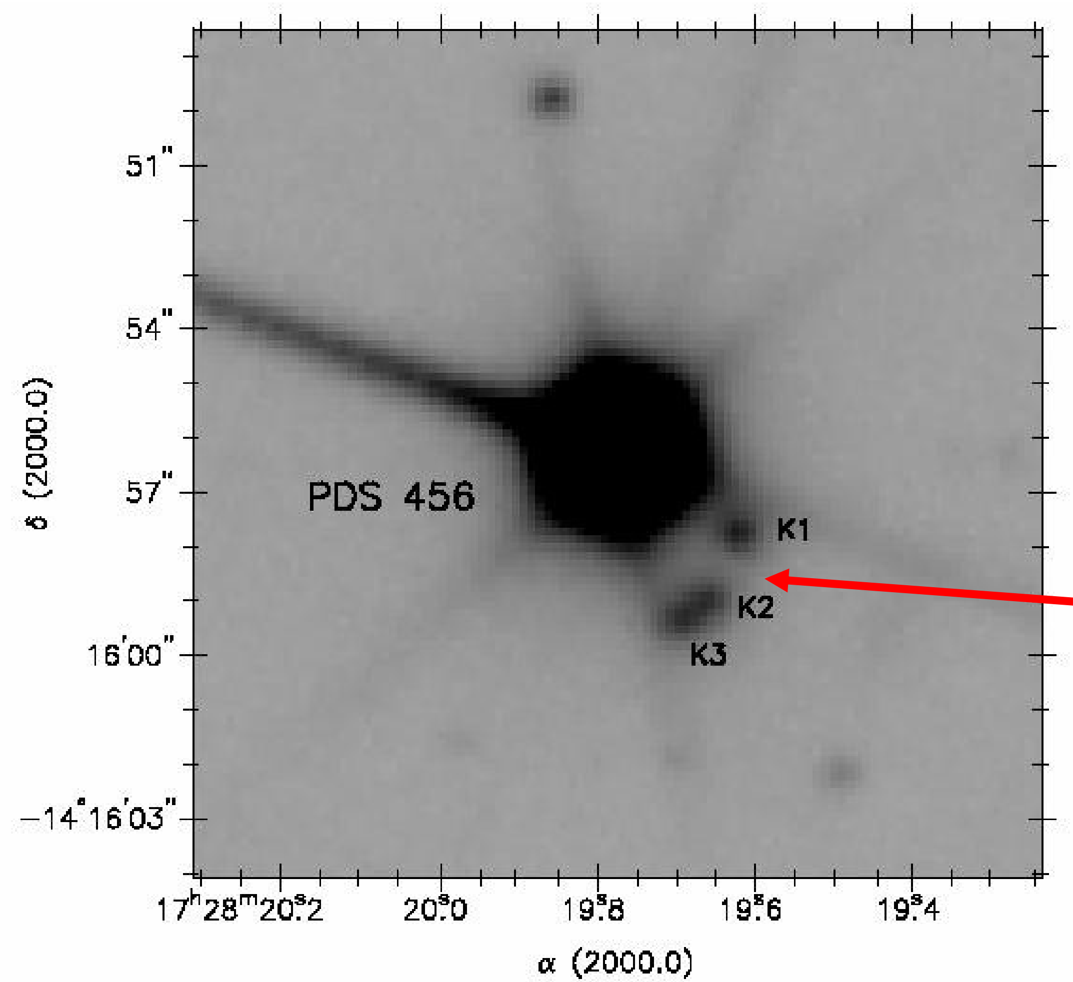
- **Magnetic field driven wind? Significant energy in magnetic field in PDS456. 'Low velocity' version of 'radio jets'?**

Implications of Black Hole Winds

- **Observed flows extract significant fraction of bolometric luminosity.**
- **Large amount of matter and energy driven into surroundings.**
- **Could "create" BLR, NLR, warm absorbers etc.**
- **Outflows may occur during build-up of black-hole mass – period of super-Eddington accretion.**
- **Most galaxy central BH growth thought to occur in early Universe. PDS456 an exceptional low-redshift quasar.**
- **Outflows could link growth of central BH with galaxy bulge mass (King, 2003, ApJ, 596, L27).**

Keck K-band image of PDS 456

(Yun et al., 2003)



Stellar "clumps"

~9kpc from QSO

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Open questions

- **What does outflow depend on (accretion-rate, B-field, BH spin…)?**
- **Outflow direction: along the BH rotation axis or disk plane?**
- **What do outflows do to the BLR, NLR, host galaxy, etc.?**
- **Do outflows link radio-quiet/radio-loud AGN (outflow ⇔ jet)**
- **Require spatially-resolved data on scale of outflows, BLR, NLR…**
- **Must understand outflows in relation to fueling+host galaxy structure.**
- **How do AGN outflows relate to other systems (e.g. ULXs)?**

Require high spatial-resolution observations