AGN X-RAY SPECTROSCOPIC POPULATION STUDIES

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Basic AGN ingredients and questions

(Courtesy ESA)

Supermassive black hole + accretion disk

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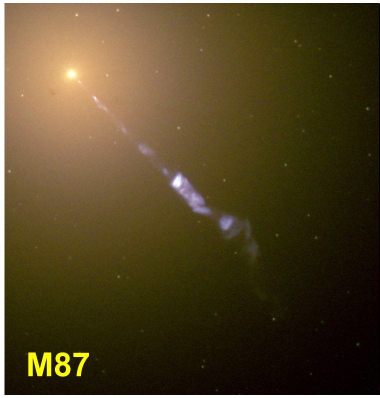
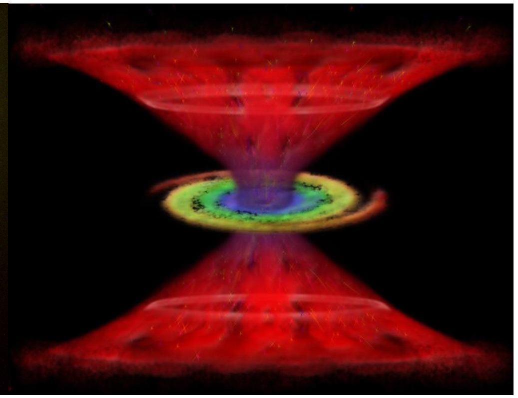
(Courtesy NASA & HHT)



(Elvis et al. 2000)



Jets and outflows

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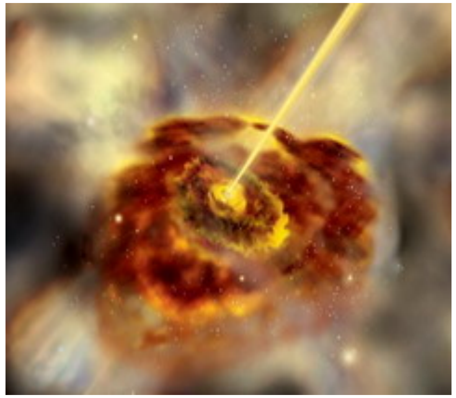
(Courtesy NASA & A.Simonet)



Gas and dust

- To which extent do AGN share the same engine?
- To which extent are AGN relativistic machines?
- To which extent do AGN affect their environment?

- ESA “large-scale” X-ray observatory
- Operational since January 2000
- Allow simultaneous:
  - medium ($\Delta E \cong 40$ @6 keV) resolution imaging spectroscopy in the 0.2-10 keV band (EPIC)
  - high-resolution ($\Delta E \cong 300$ @1 keV) dispersive spectroscopy in the 0.2-2 keV band (RGS)
  - optical photometry and spectroscopy in the 180-600 nm range (OM)

Today’s focus: X-ray spectroscopic samples of AGN

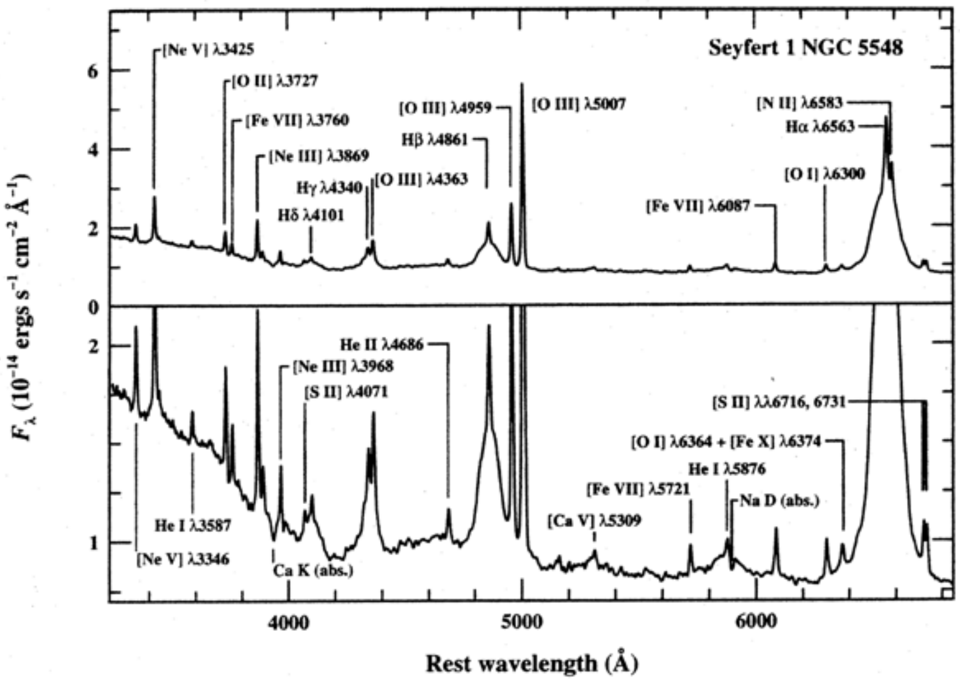
X-ray versus optical spectra

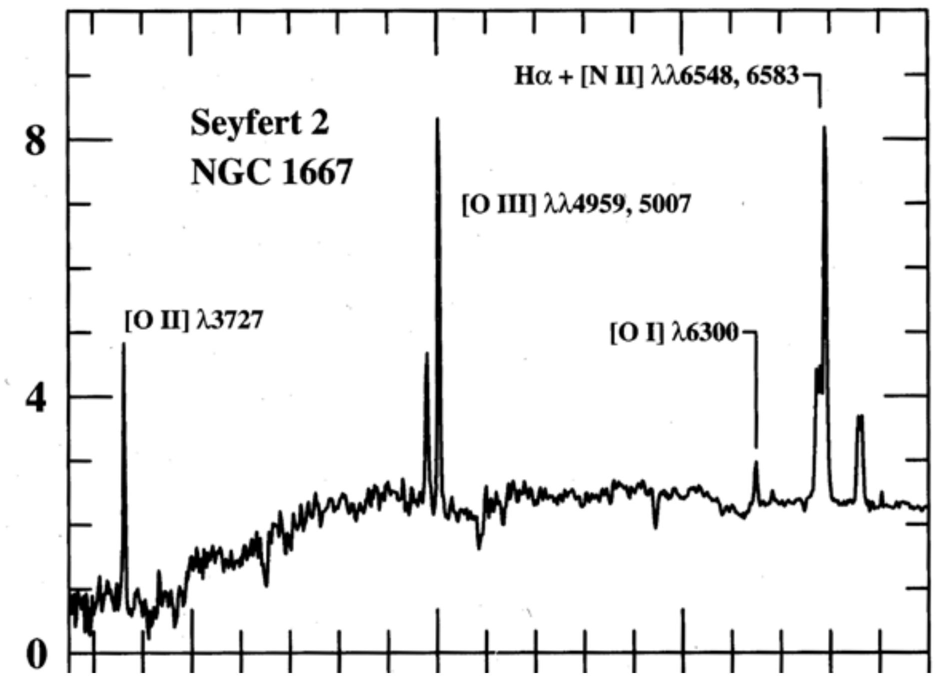
Optical spectrum of a “type 1 AGN”	Optical spectrum of a “type 2 AGN”

$\Gamma^{E>15\ kev}_{type1}=1.96\pm0.04$

$\Gamma^{E>15\ kev}_{type1.5}=1.97\pm0.05$

$\Gamma^{E>15\ kev}_{type2}=1.97\pm0.05$



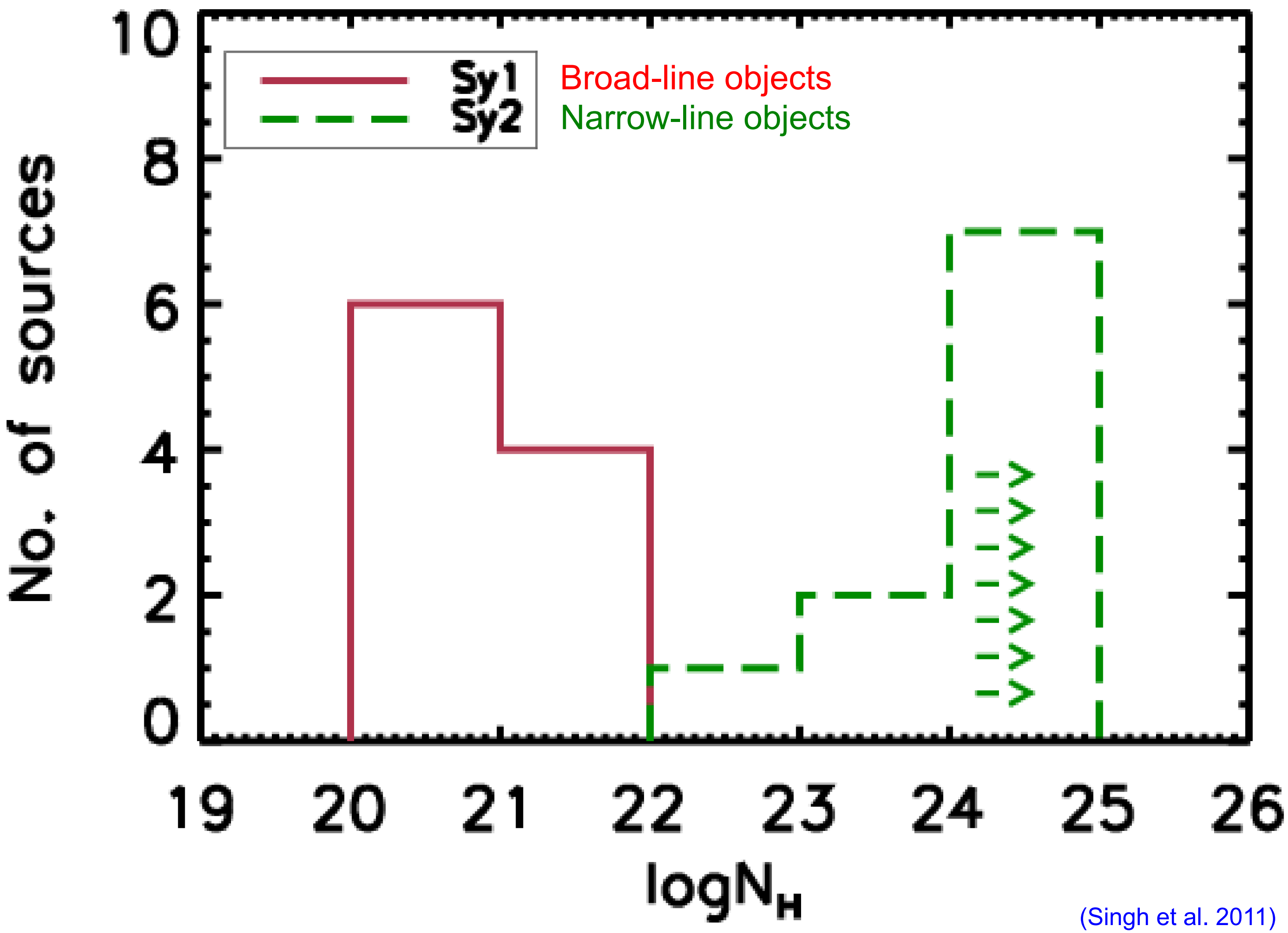


Data from an analysis of 165 Seyfert galaxies in the INTEGRAL/IBIS catalogue, Ricci et al. (2011)

Different observed X-ray spectra

- Optically “broad line” objects are typically X-ray *unobscured*
- Optically “narrow-line” objects are typically X-ray *obscured*
- Common wisdom: in “narrow-line” objects, the gas emitting the broad lines as well as the AGN is covered by optical thick matter

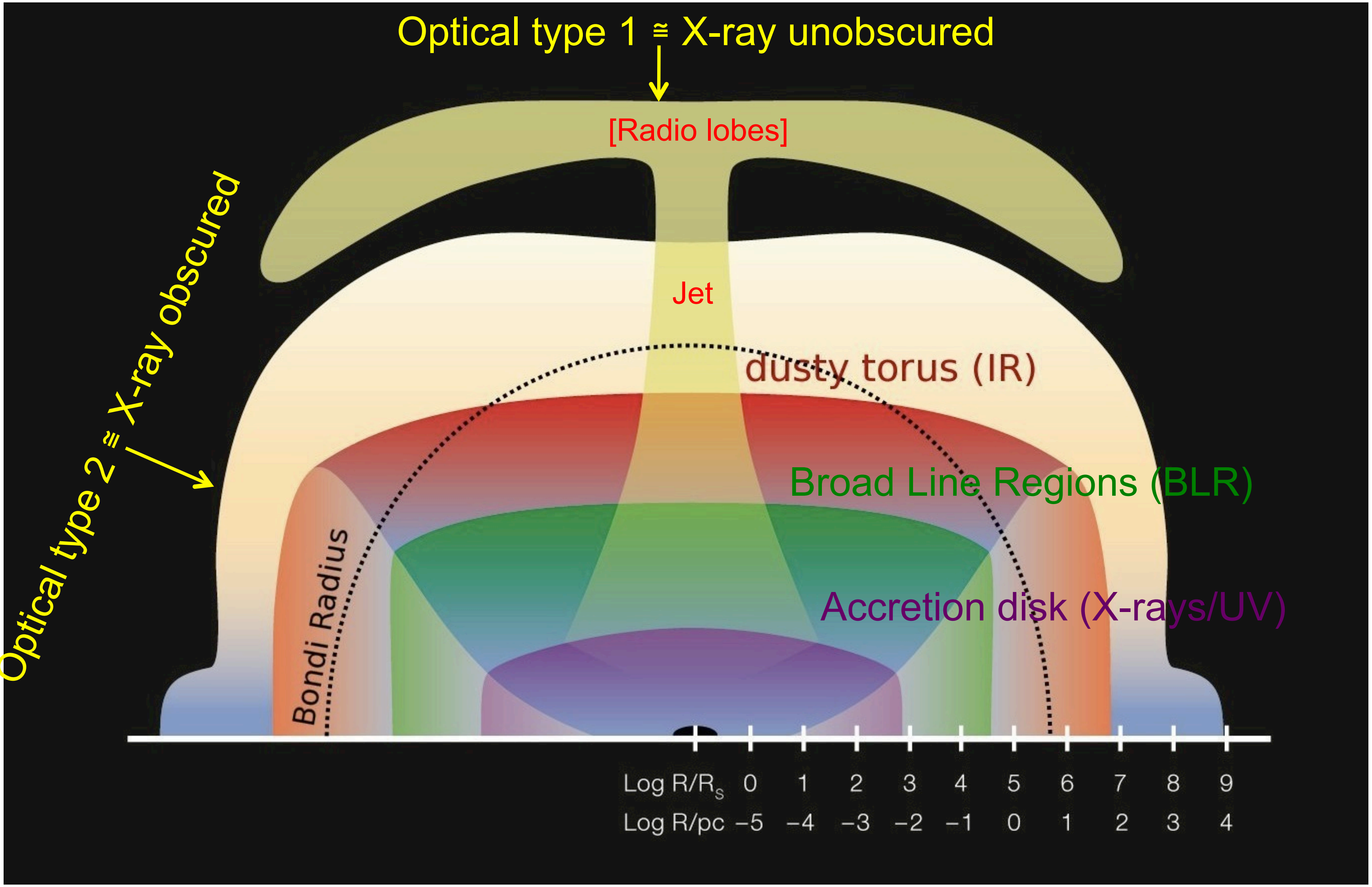
Sample of 20 Seyferts, well matched in orientation-independent multi observables



(Singh et al. 2011)

This is the X-ray view of a basic AGN "truth"

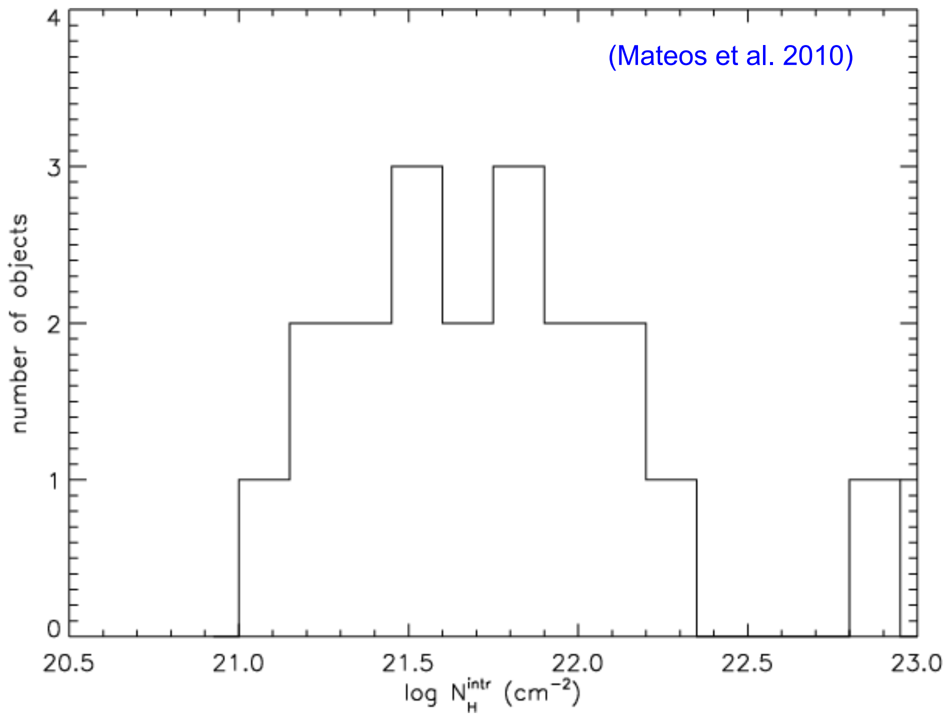
(Courtesy A.Merloni & S.Bonoli)



Solution: 3%

- The 0-th order unified scenario is verified at the 97% level:
- 3% of *X-ray obscured* “type 1”
  - Host galaxy
  - Variability/classification issues
  - Ionizing continuum anisotropy
- 3% of *X-ray unobscured* “type 2”
  - Minimum accretion rate to generate BLRs and/or torus (Nicastro 2000, 2003, Eliztur & Shloshman 2006i)
  - Variability/classification issues

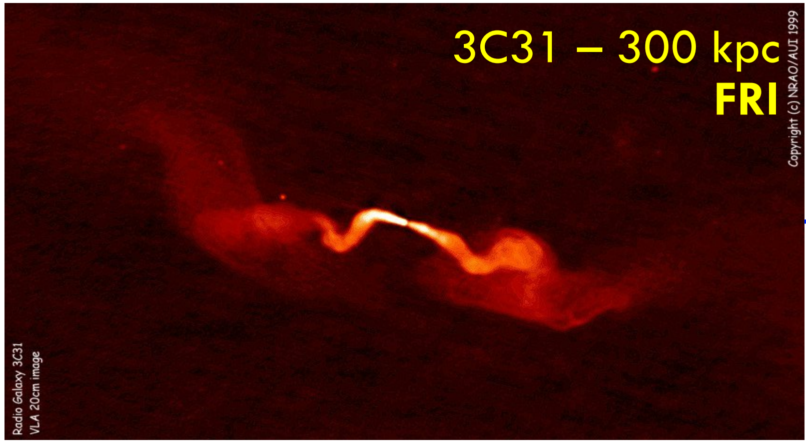
N_H distribution of type 1 X-ray obscured AGN of 486 type 1 AGN in the XMM-Newton Wide Area Survey (XWAS) AGN

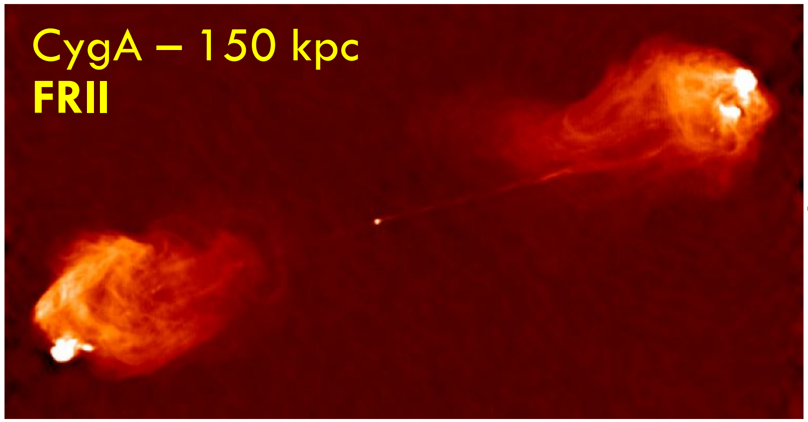


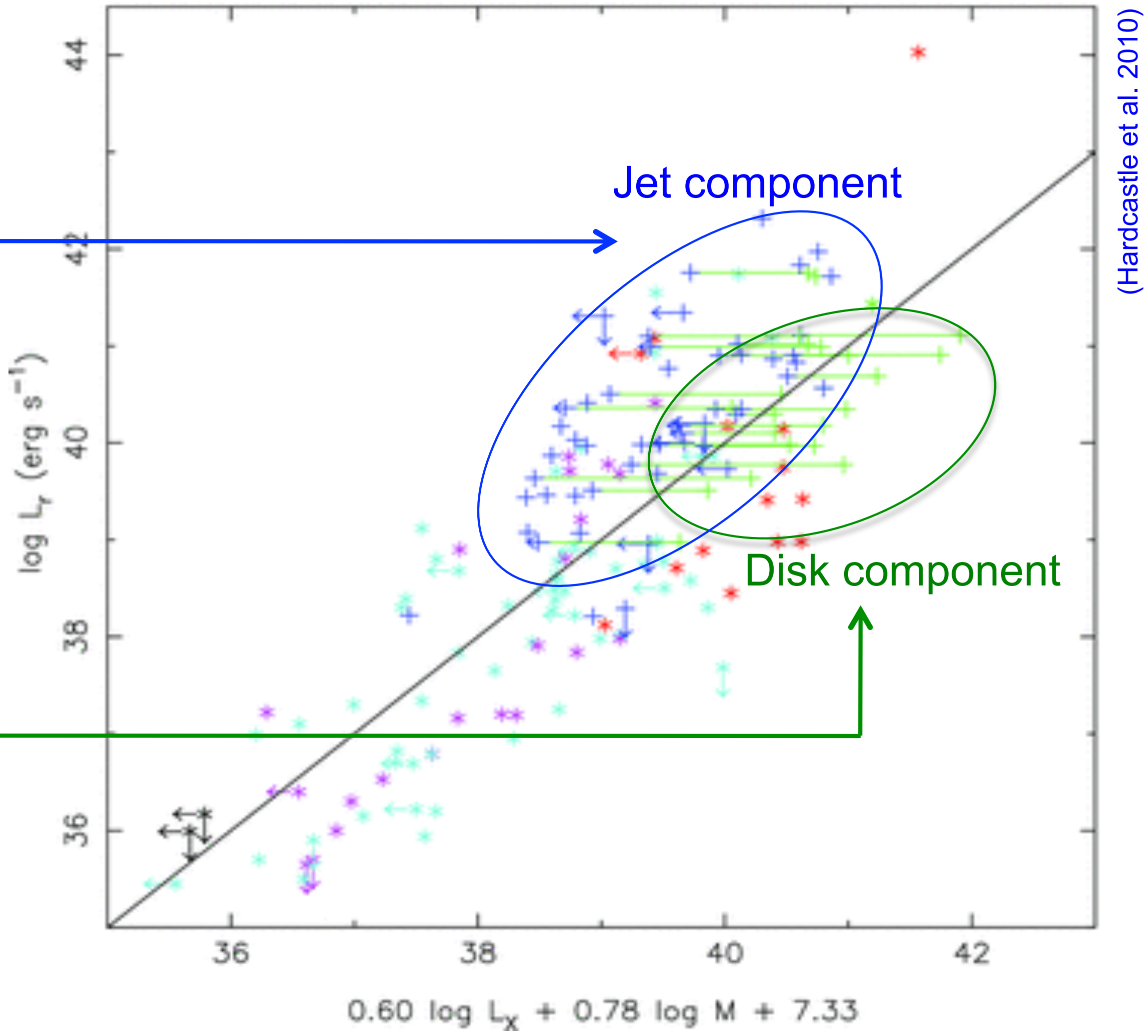
[Earlier works – yielding a wide range of results – by Pappa et al. 2001, Panessa & Bassani 2002, Barcons et al. 2003, Perola et al. 2004, Mateos et al. 2005, Beckmann et al. 2009, LaMassa et al. 2009, 2011, Corral et al. 2011]

Where are radio-galaxies?

Fundamental plane of BH activity , relating the radio, X-ray luminosity and BH mass

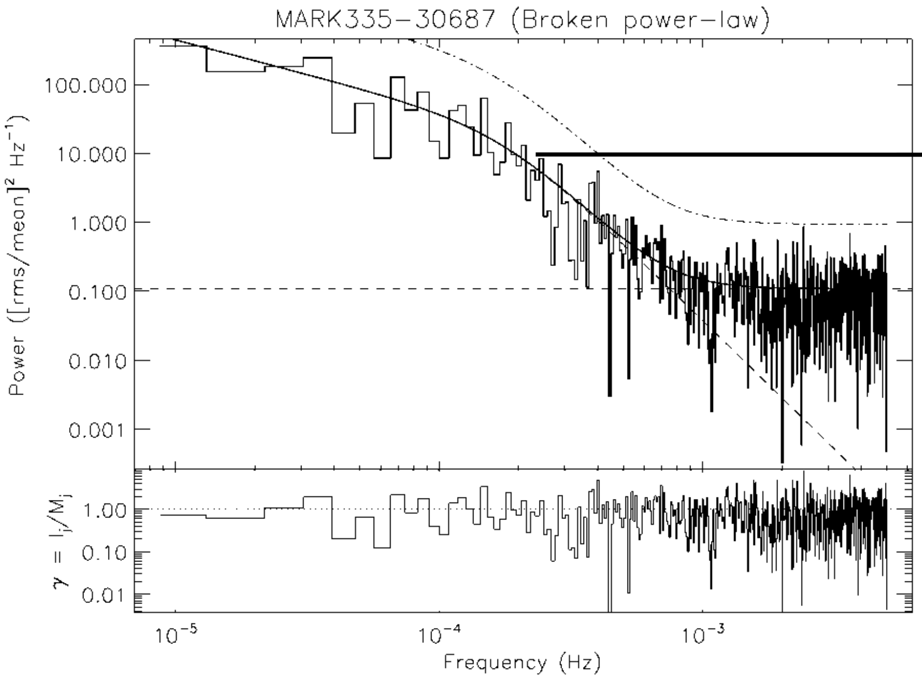




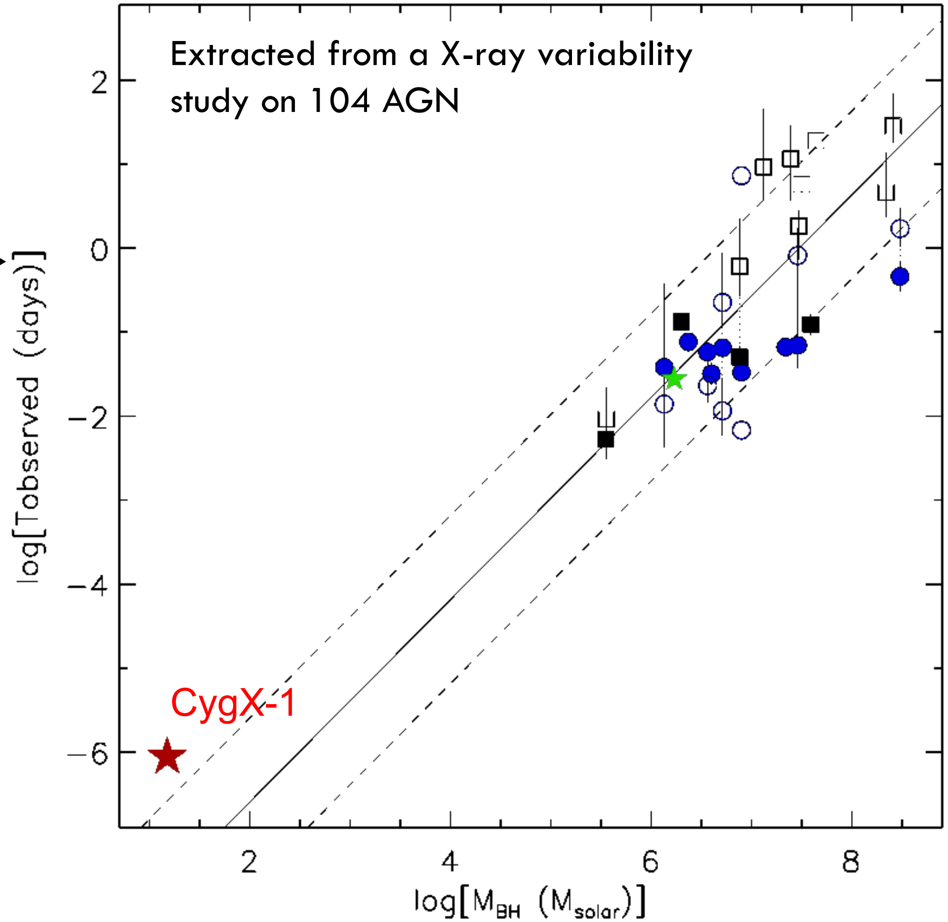


BH scaling laws

Typical AGN Power Spectrum Density



Scaling law between AGN and CygX-1

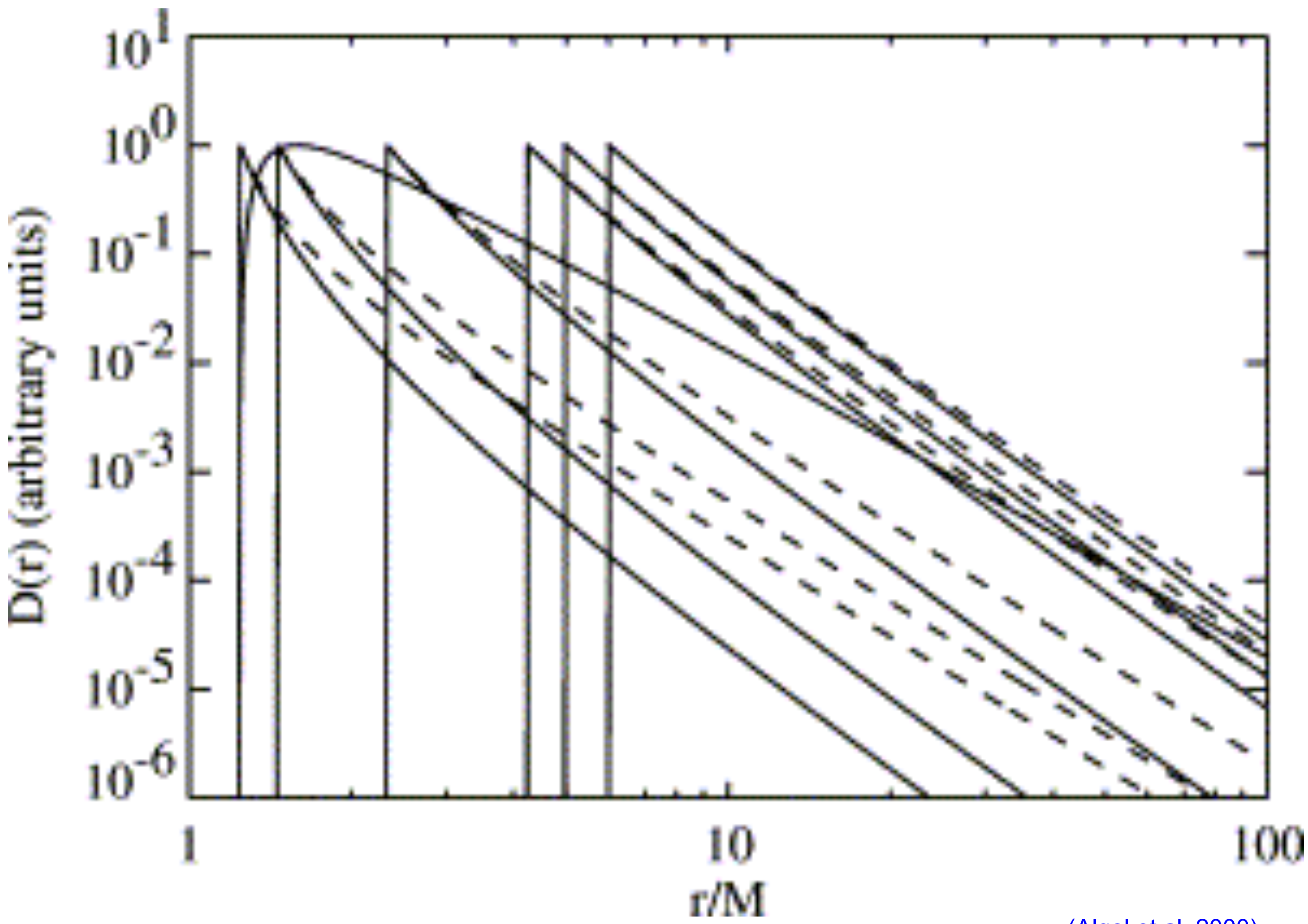


(González-Marín & Vaughan 2012; original results from McHardy et al., 2006)

Why do X-rays come from very close to the BH?

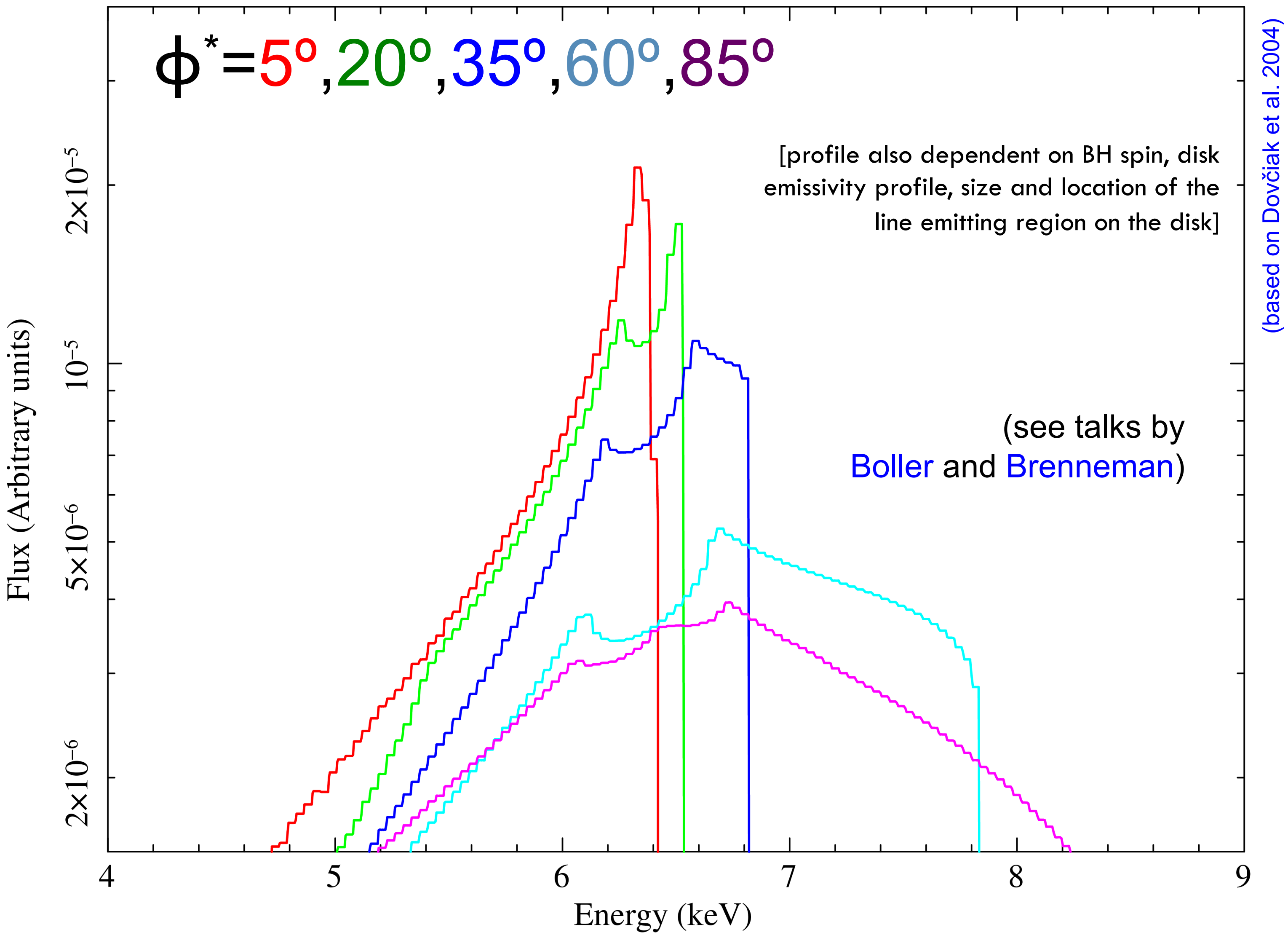
- X-ray variability on time scales ≥hours (Barr & Mushotzky 1986 …)
- Direct measurement of the X-ray size through: occultation: $\leq 10^{14}$ cm (Risaliti et al. 2007, 2009) or microlensing: $\leq 6 r_g$ (Chartas et al. 2007)
- Theoretical prejudice on the accretion flow

Accretion disk dissipation profiles as a function of disk radius



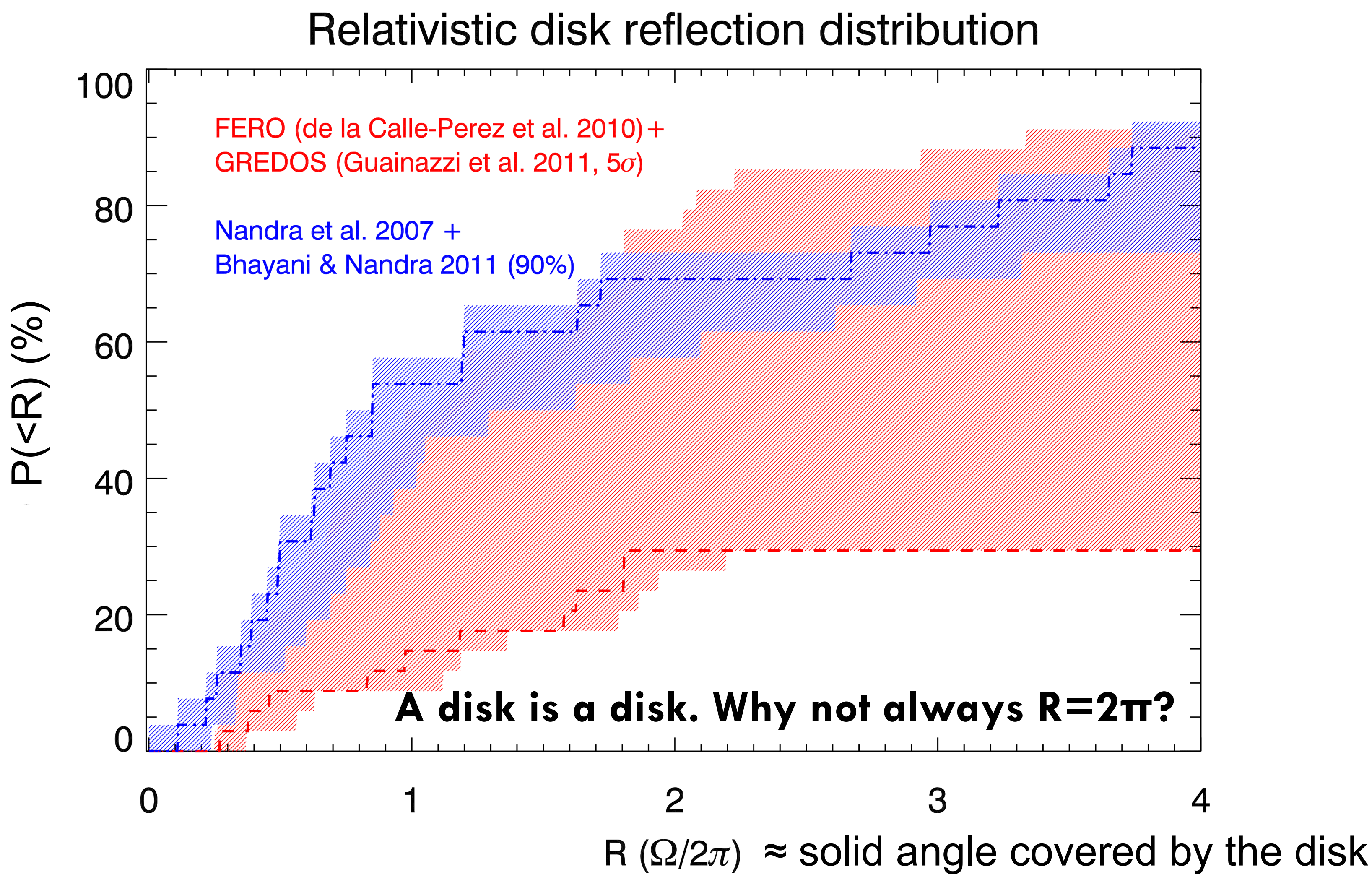
(Algol et al. 2000)

Refresh on relativistic spectroscopy



* angle between the disk axis and the line-of-sight

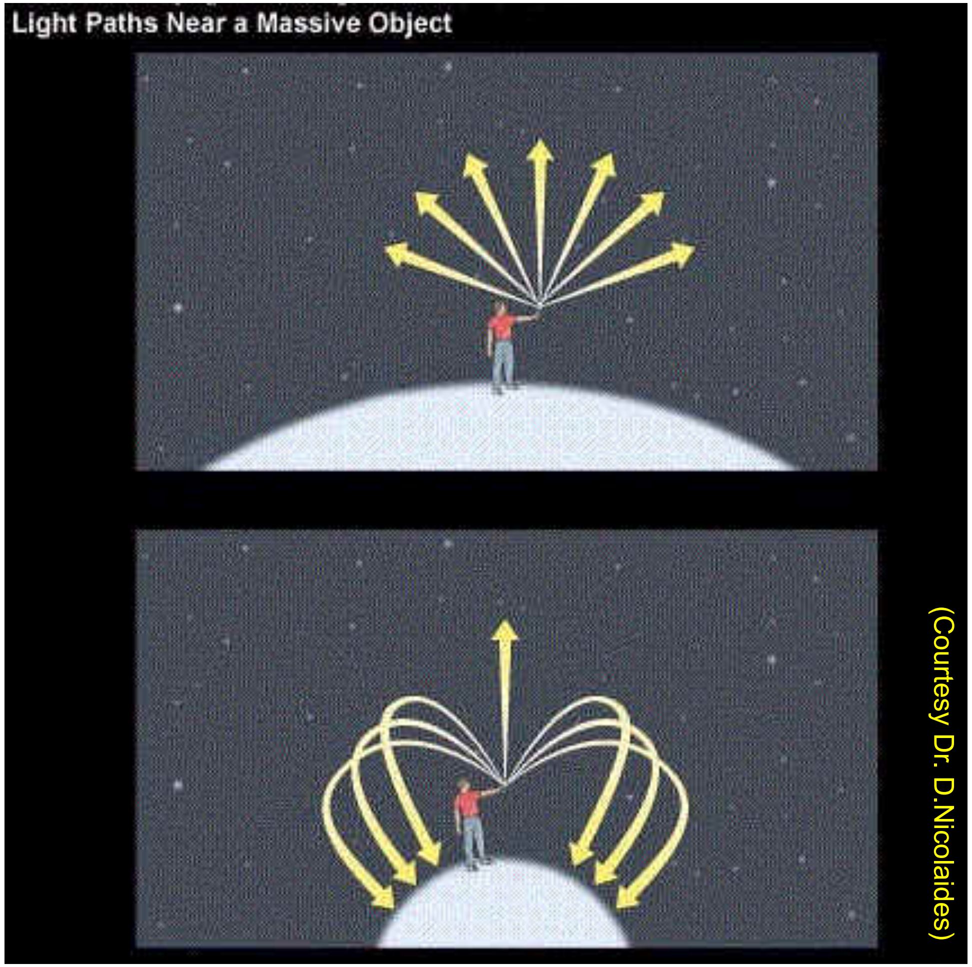
Frequency of relativistic broadened Fe K_{α} lines in AGN



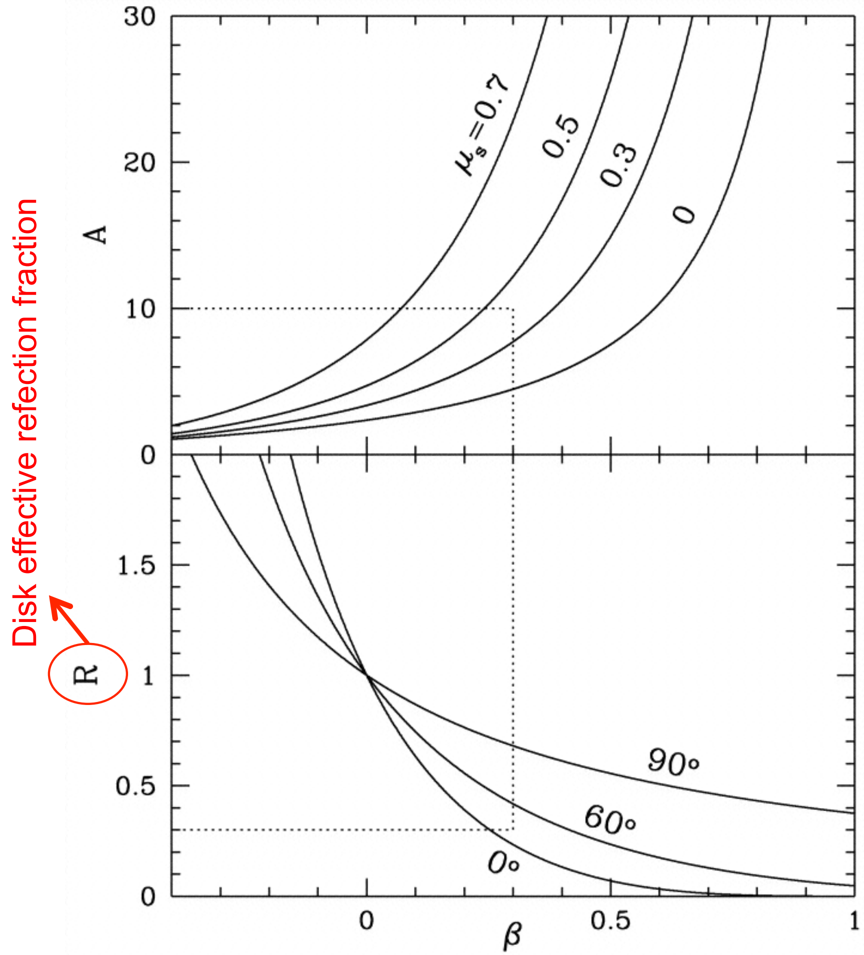
Caveats: common (de Marco et al. 2009) and not understood variability (Bhayani & Nandra 2009).

Wide spread in reflection strength

High EW: Light bending (Minutti & Fabian 2004)



Low EW: Aberration in a midly outflowing corona (Beloborodov 1999)

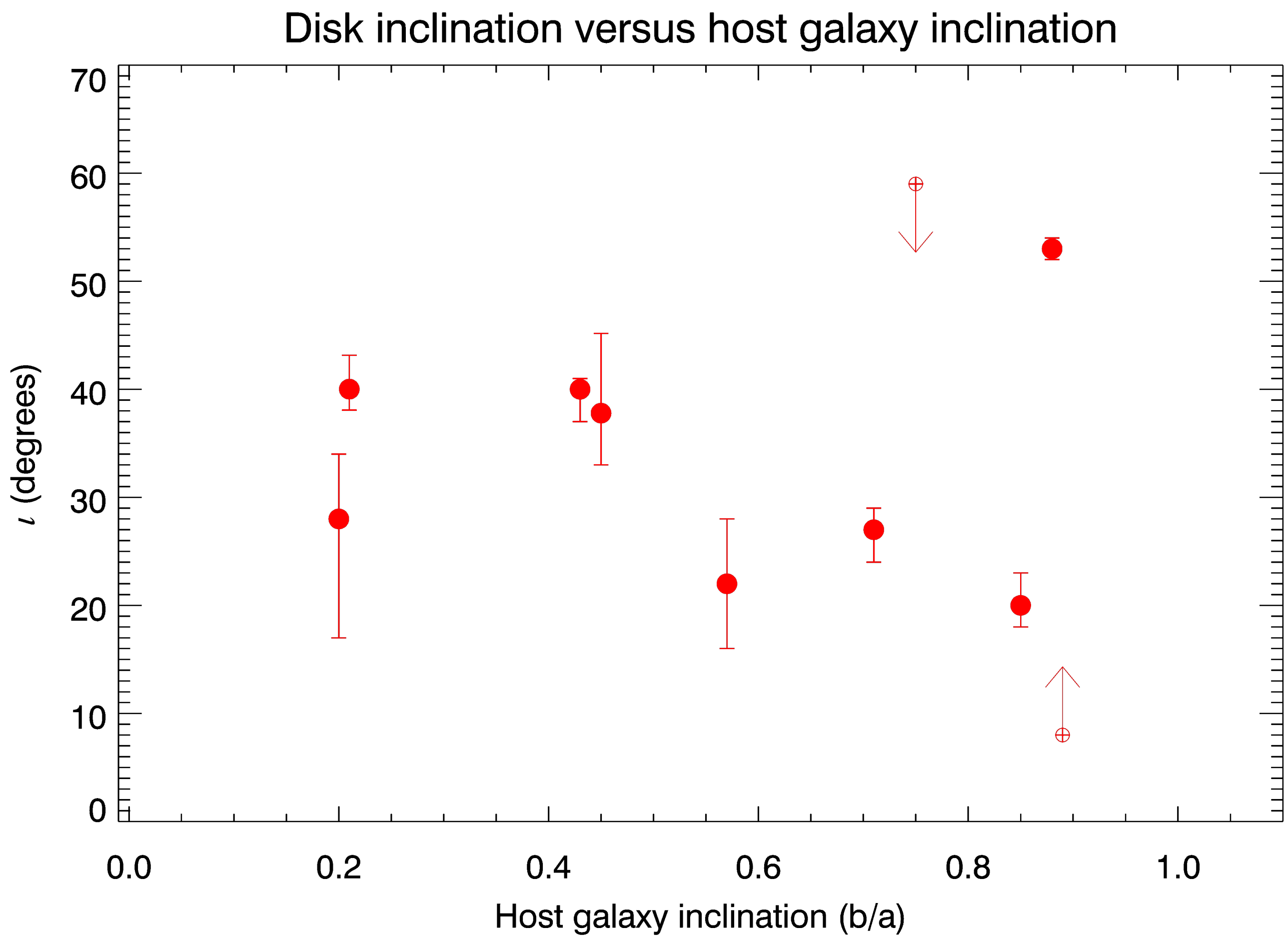


Accretion disk inclination

Similar conclusions:

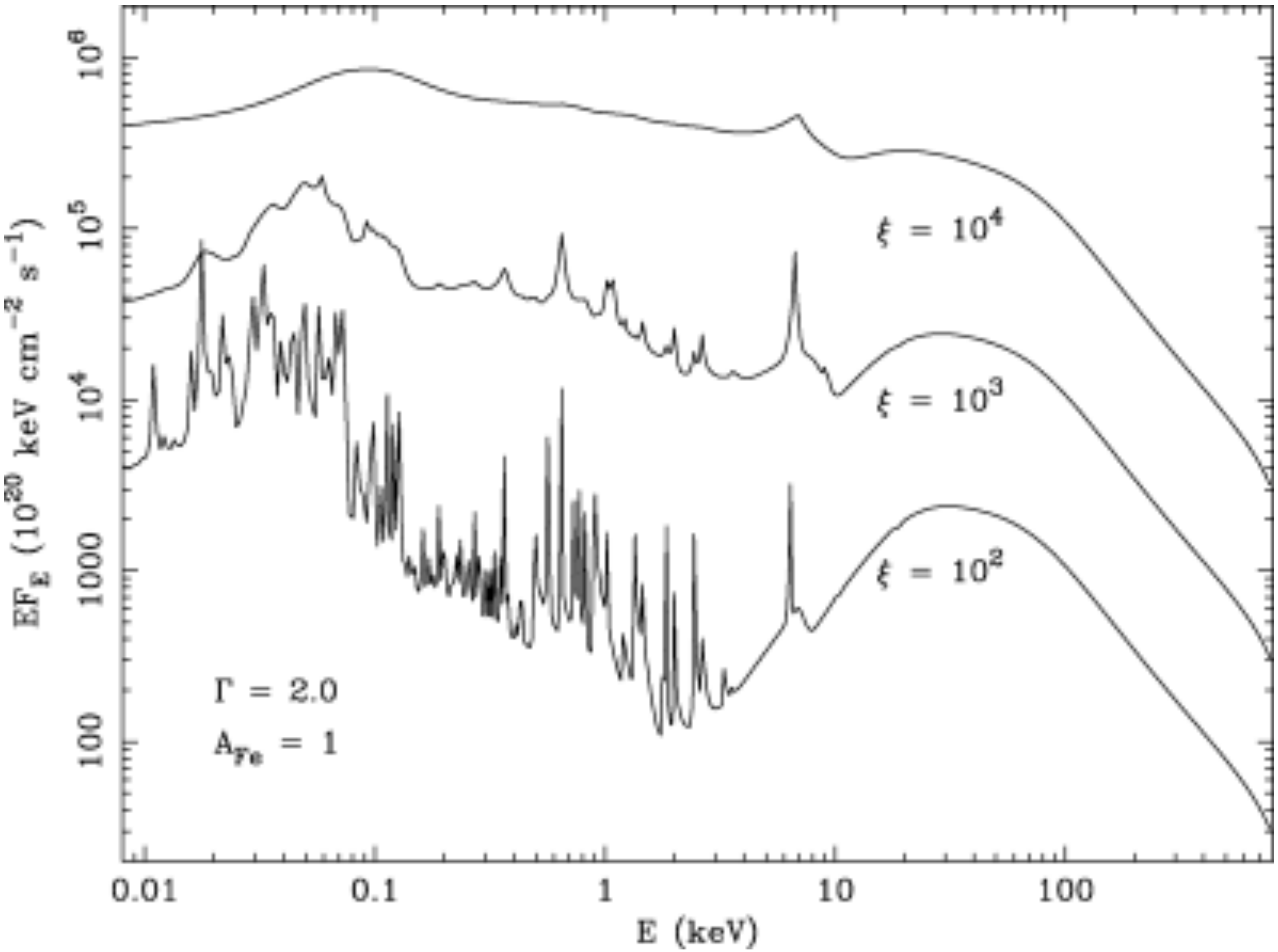
- Disk inclination is random in the range ϕ=0-80° (from X-ray spectra fit with self consistent ionized disk refection: Crummy et al. 2006)

- Distribution of angles between radio jets and host galaxy disks consistent with being random (Kinney et al. 2000, Schmitt et al. 2001)



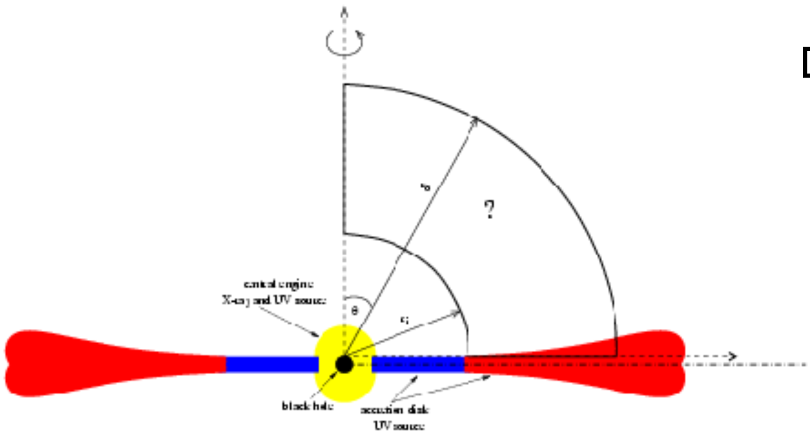
(Guainazzi et al. 2011)

The X-ray reflection spectrum



(Ross & Fabian 2005)

Disk and outflows

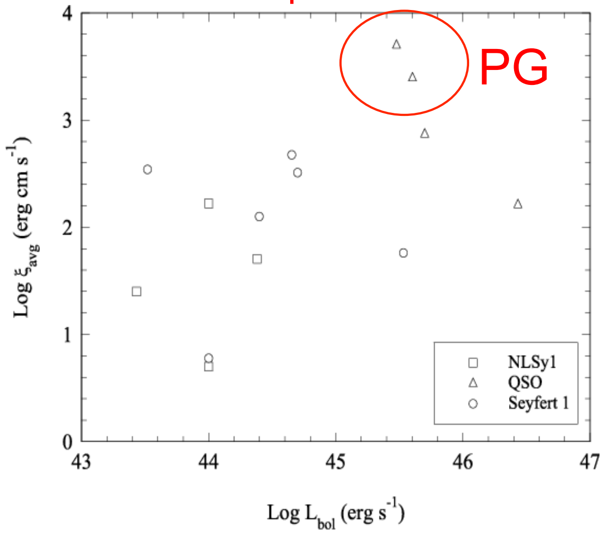


Density profile in a coordinate system centered on the BH

2-D MHD and line-drivens model of accretion disk naturally predict massive outflows (Proga et al. 2000, King & Pounds 2003, Proga & Kallmann 2004, Dorodnitsyn et al.2008, Sim et al. 2008, 2010, 2012, Schurch et al. 2009)

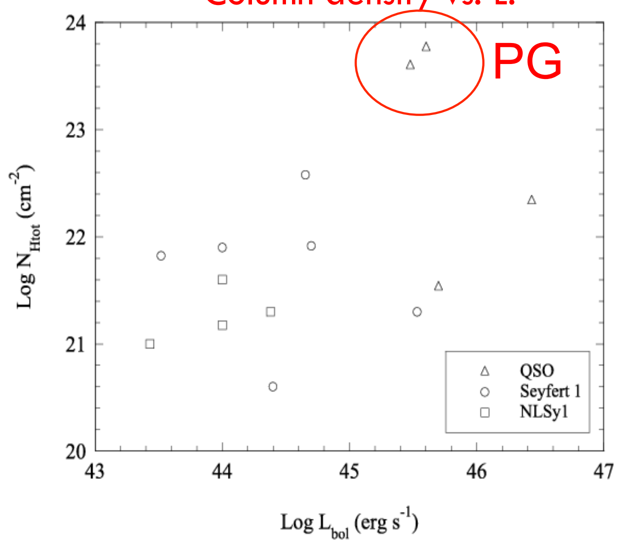
Summary of warm absorbers properties

Ionization parameter vs. L.



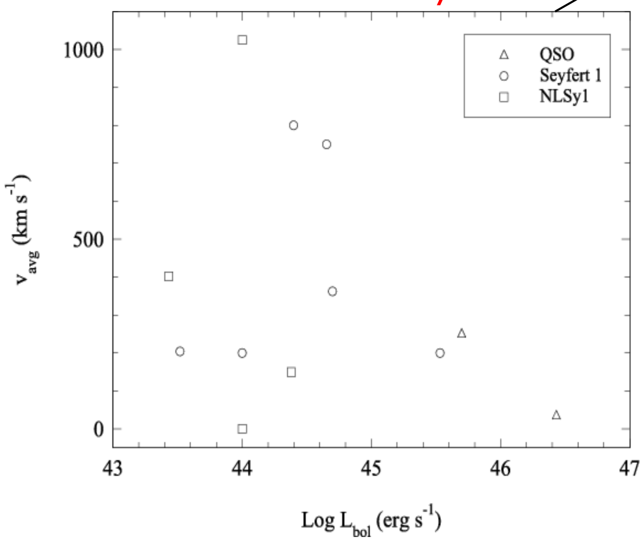
Sample of 23 warm-absorbed AGN observed by the RGS [see also McKernan et al. 2007 for a *Chandra* view]

Column density vs. L.



Two PG quasars lay above this plot

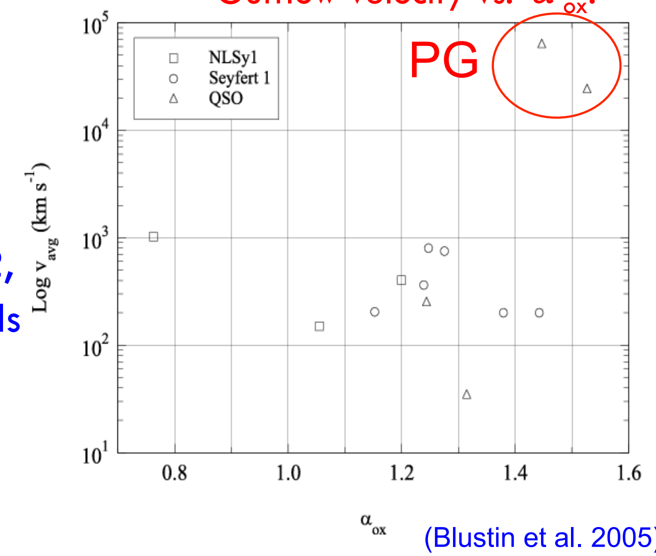
Outflow velocity vs. L.



Typical distances between 0.1 pc-100 pc (see also Blustin et al. 2007)

10^{-4}-10^{-6} pc (Turner et al.2002, Pounds et al. 2003, King & Pounds 2003, Reeves et al. 2004)

Outflow velocity vs. α_{ox}.



(Blustin et al. 2005)

Fraction of outflows

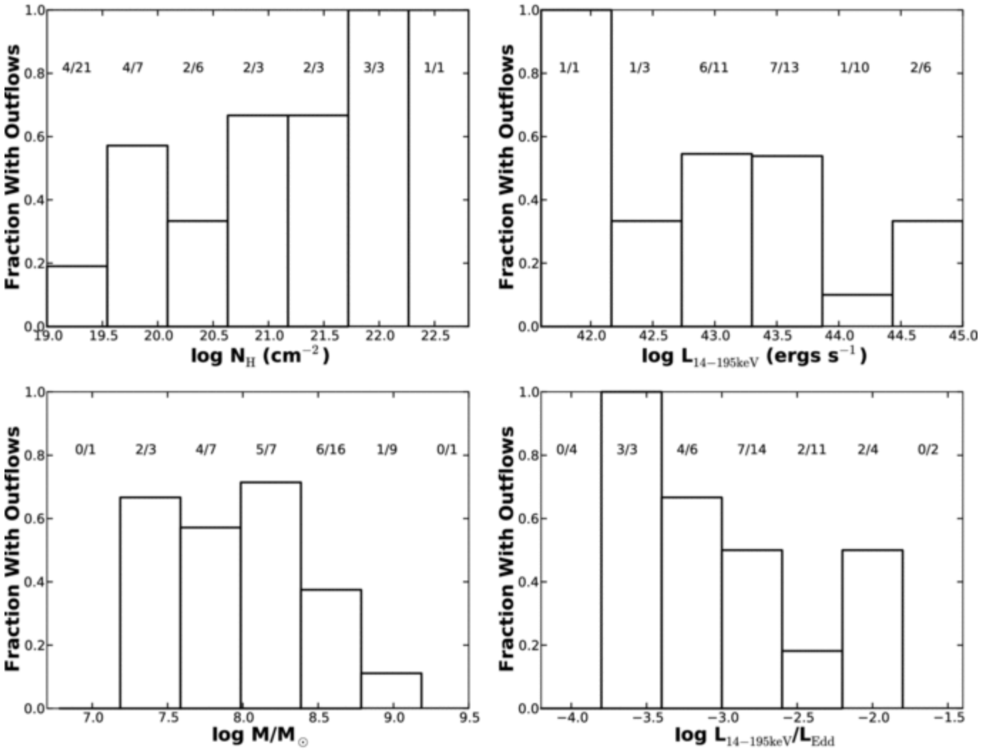
“Seyfert-like” warm absorbers:

≥80% in hard X-ray selected samples

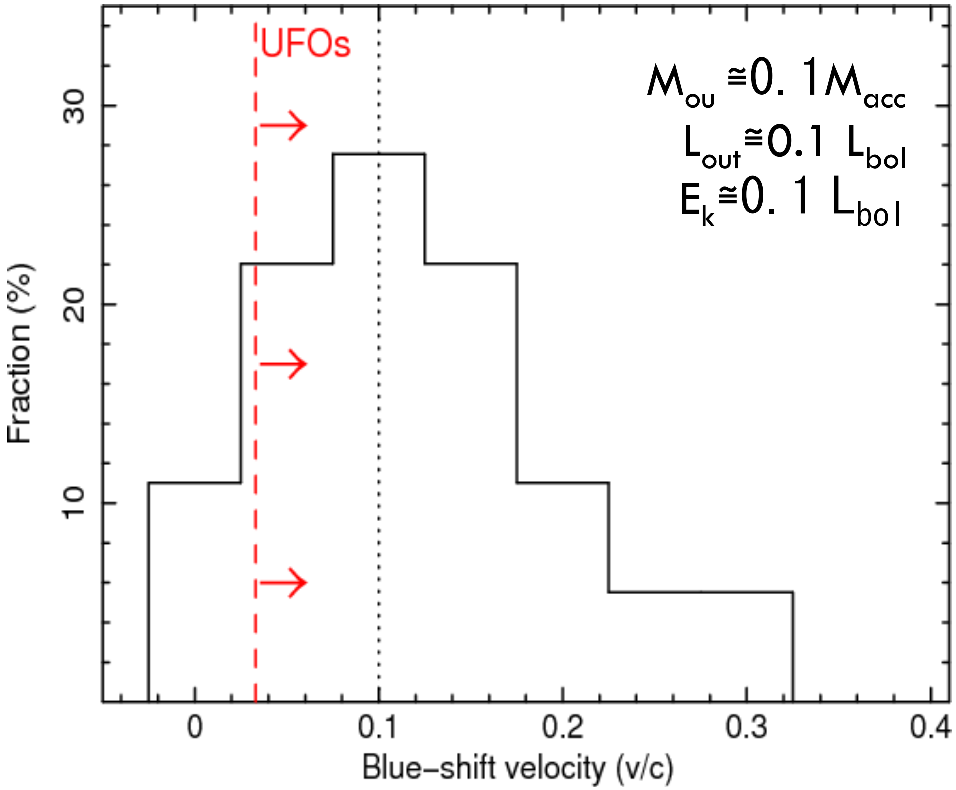
PGQSO-like outflows:

40%-60% in the FERO sample

(Winter et al. 2010)



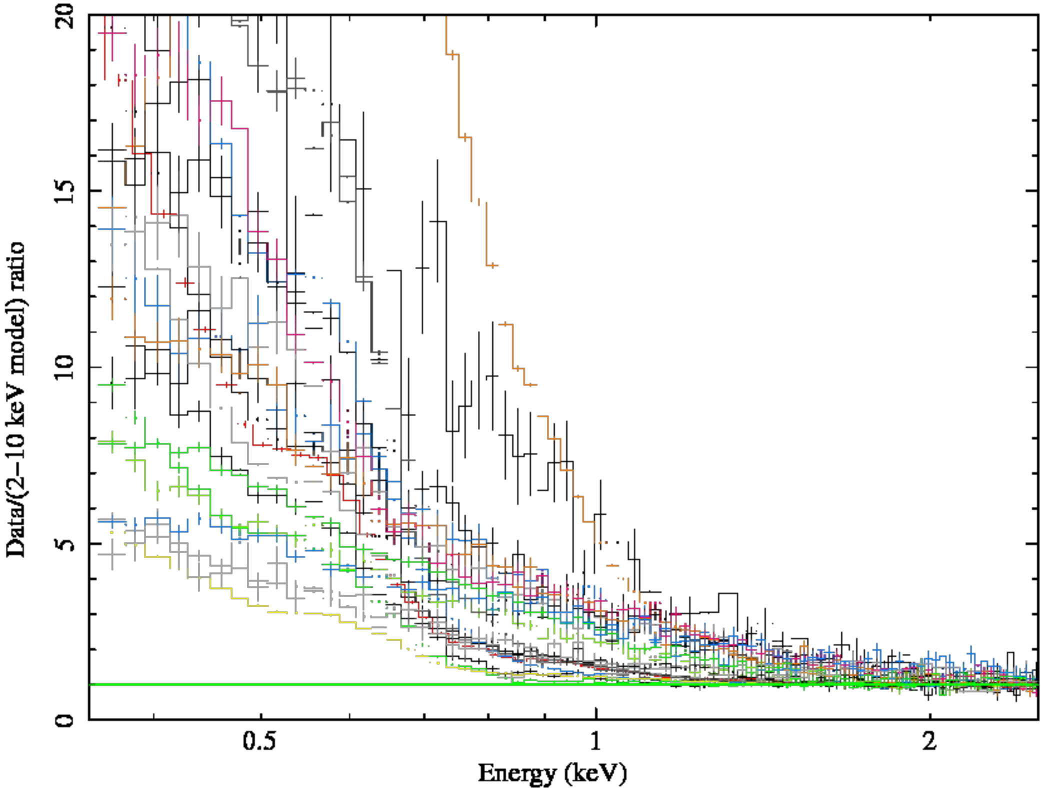
(Tombesi et al. 2010)



[Earlier works by Reynolds 1997, George et al. 1998, Porquet et al. 2004, Piconcelli et al. 2005, Brocksopp et al. 2006]

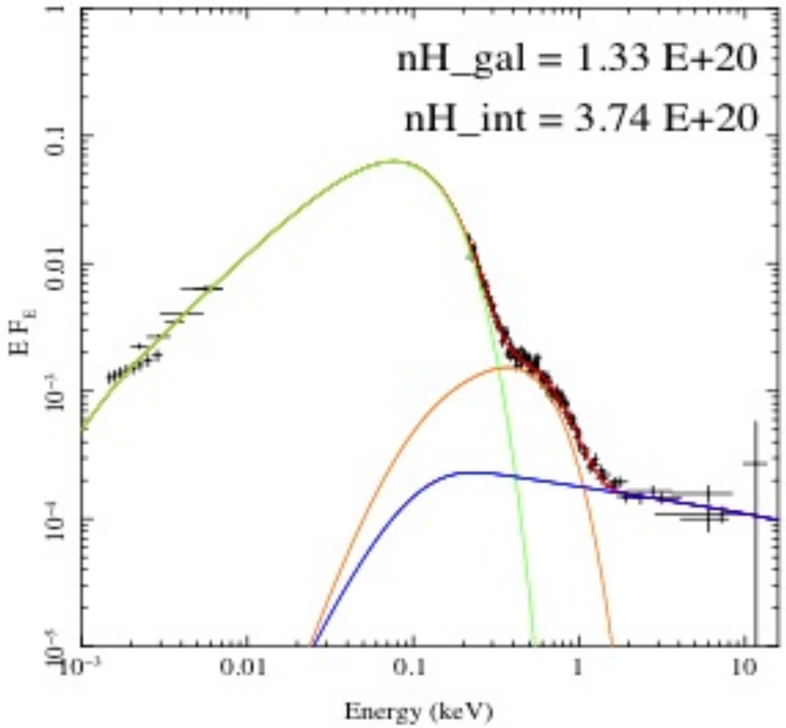
Soft excess: disk reflection or corona?

“Soft excess” in a sample of PG-QSO



(Piconcelli et al. 2005; Guainazzi 2009)

Extracted from a sample of 51 low-N_H AGN



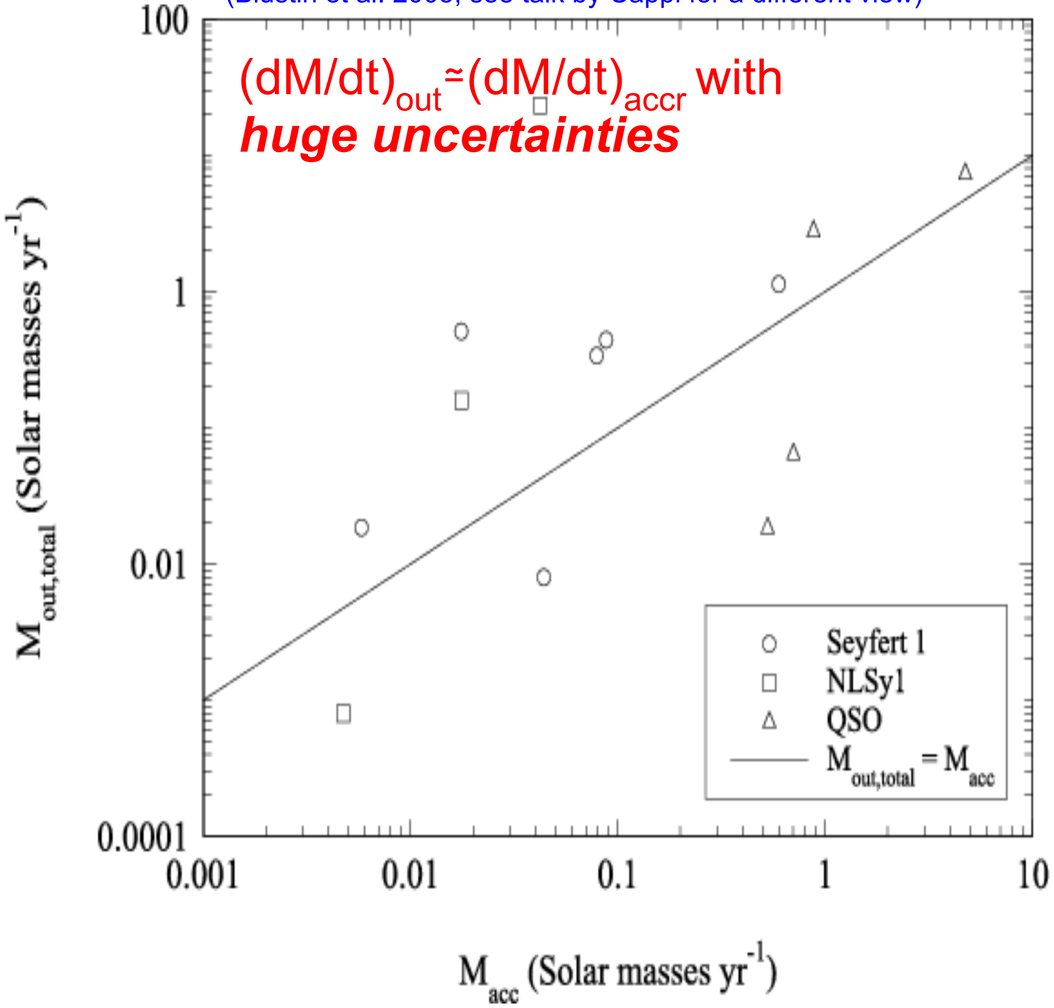
(Jin et al. 2011)

Three-component model:

1. optically-thin, high-temperature disk Comptonization corona
2. Optically-thick, low temperature disk Comptonization
3. Multi-temperature disc emission

Outflow mass rates

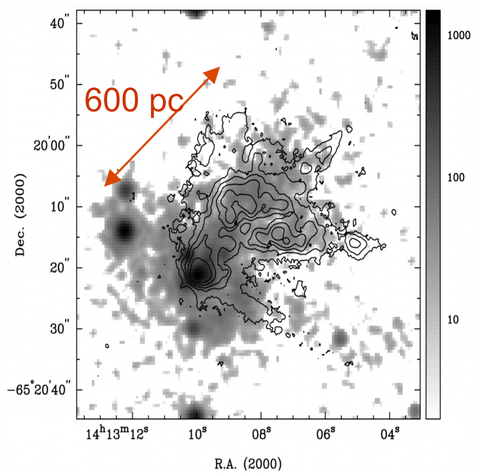
(Blustin et al. 2005, see talk by Cappi for a different view)



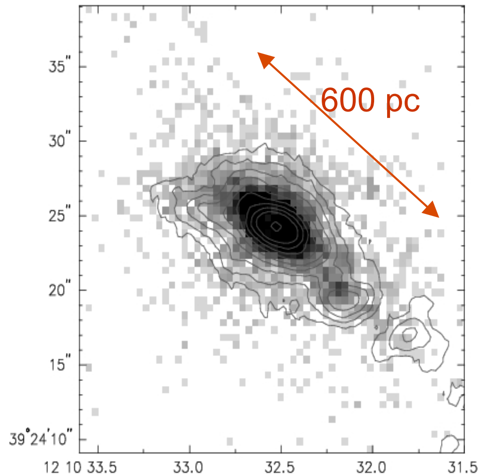
- At least the most powerful AGN, and maybe even more prosaic Seyferts, could release to the ISM the required 10^8 $M_\odot$ of hot gas in bulges across their lifetime
- Standard Seyferts ($\approx 10^{43}$ erg/s) could release enough energy to heat the ISM gas to a temperature (10^7K) sufficient to evaporate it
- Powerful QSOs ($\gtrsim 10^{44}$ erg/s) could release more than the binding energy of a $10^{11} M_\odot$ bulge with $\sigma \sim 300$ km/s, or the energy necessary to control host galaxy and surrounding IGM evolution (King 2003, Scannapieco & Oh 2004, Hopkins et al. 2005, Natarayan et al. 2006, Hopkins & Elvis 2010)

Narrow Line regions in optical and X-rays

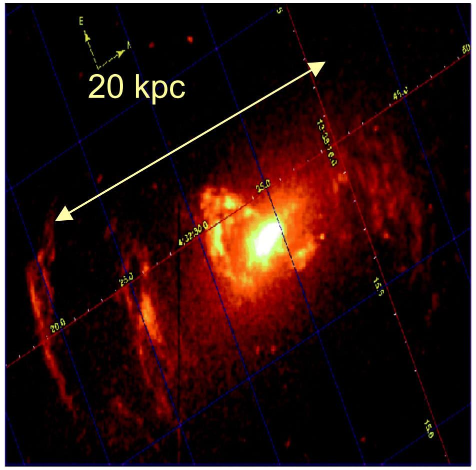
Images: O[III] – Contours: soft X-rays



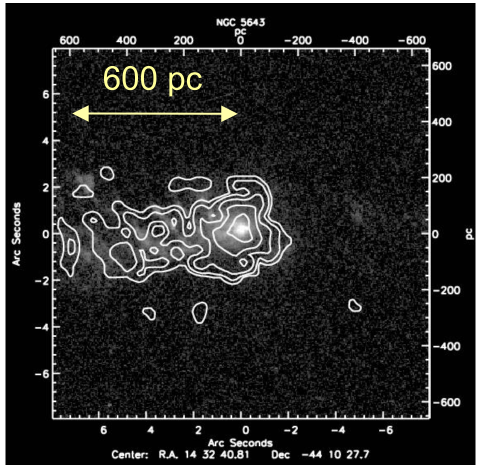
Circinus Galaxy
(Smith & Wilson 2001)



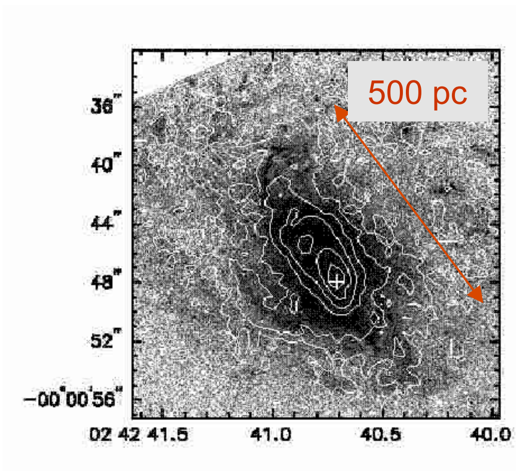
NGC4151
(Yang et al. 2001, Wang et al. 2009, 2010)



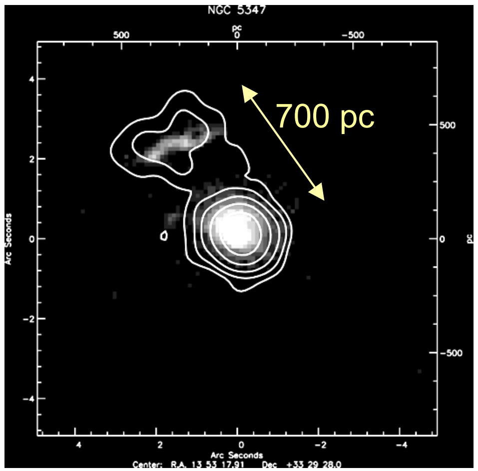
NGC5252
(Dadina et al. 2010)



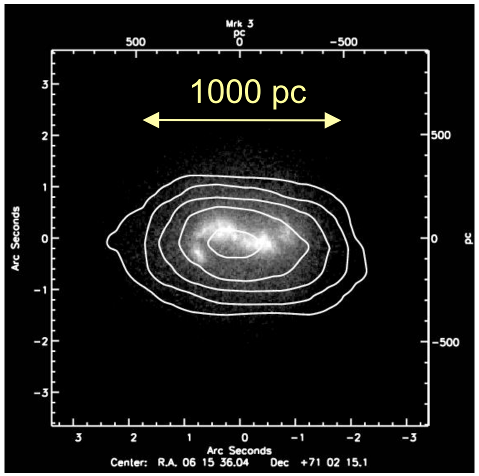
NGC5643
(Bianchi et al. 2006)



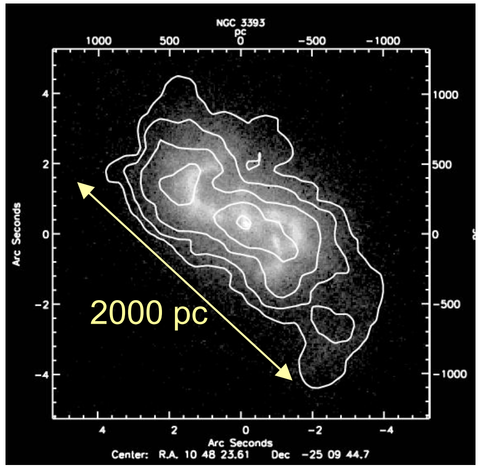
NGC1068
(Young et al. 2001)



NGC5347
(Bianchi et al. 2006)



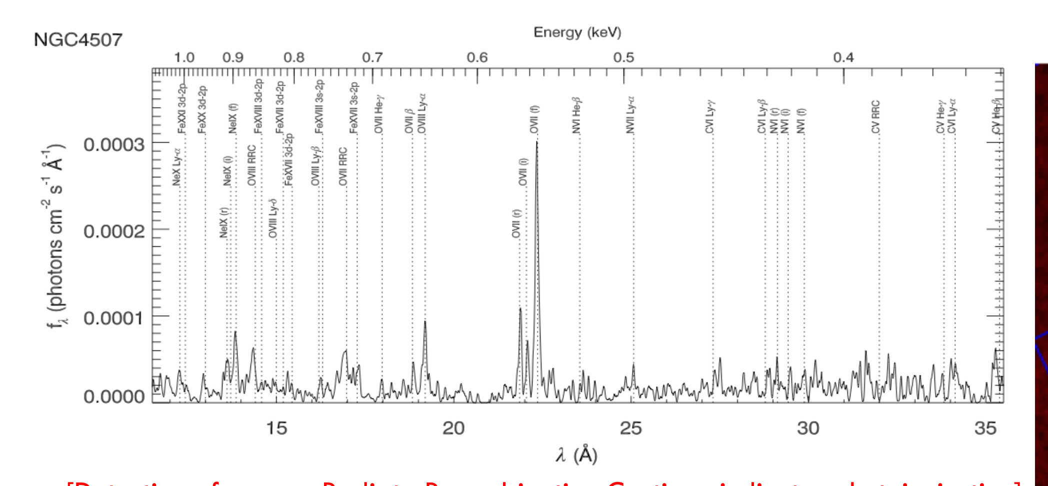
Mkn3
(Sako et al. 2000)



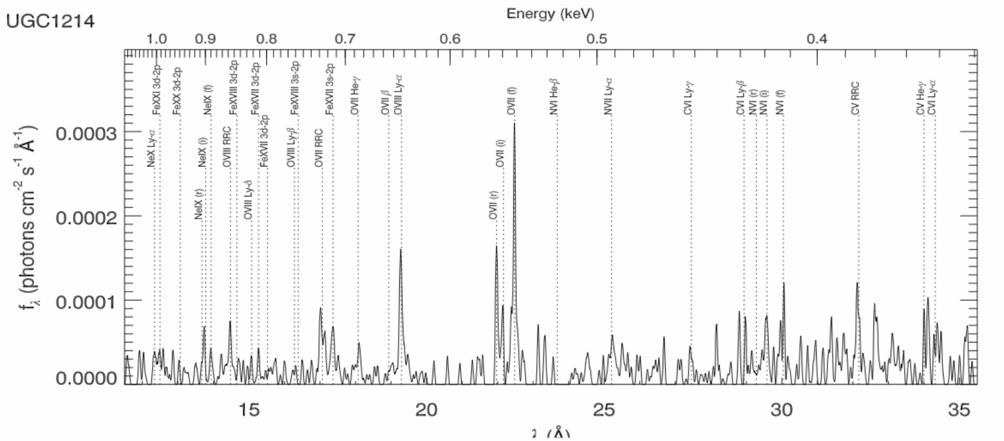
NGC3393
(Bianchi et al. 2006)

The X-ray NLRs are AGN-photoionised

CIELO-AGN: *Catalogue Ionized Emission Lines in Obscured AGN* (92 Seyferts)

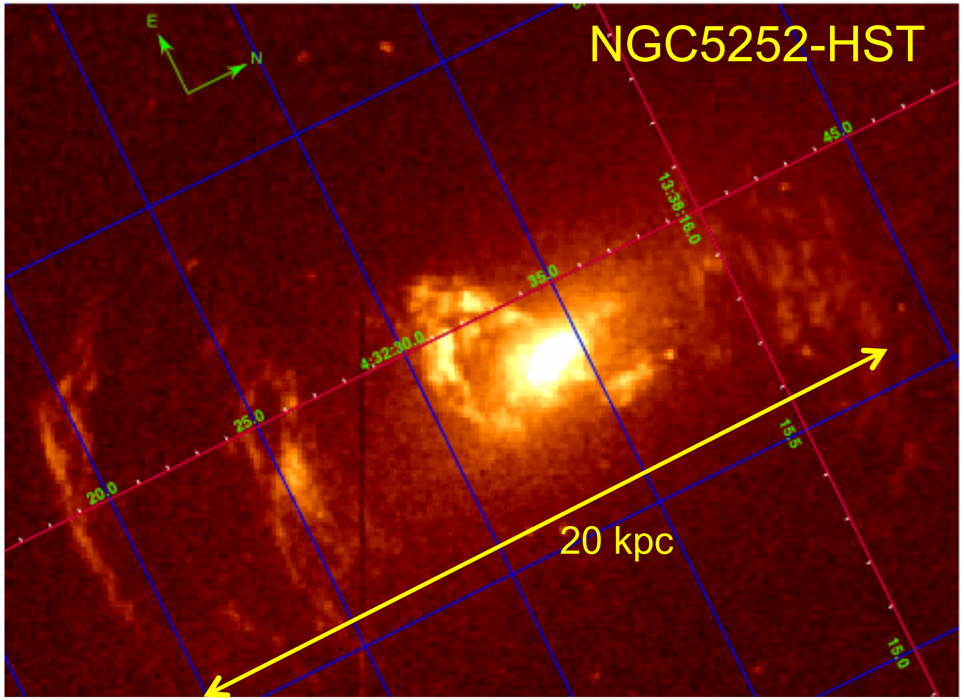


[Detection of narrow Radiate Recombination Continua indicates photoionisation]



(Guainazzi & Bianchi 2007)

X-ray NLR Inhomogeneities carry imprinting of the AGN history in the last 10^4 yrs



NGC5252 is a “relic” QSO, probably accreting now in an inefficient way

(Dadina, Guainazzi et al., 2010)

Conclusions

- To which extent do AGN share the same machine?
  - Exceptions to the orientation-dependent scenario at the 3-4%
- To which extent are AGN relativistic machines?
  - A interpretative scenario exists, which is consistent with the bulk of activity in AGN occurring within 10s of gravitational radii from the BH, and shaped by General Relativity effects
- To which extend do AGN effect the environment
  - Direct evidence of AGN driving the ionization on scales as large as several kpc. Even moderately relativistic outflows in powerful QSOs may have an impact on the evolution of the host galaxy and surrounding IGM
- To understand the astrophysics, we need the global view provided by large samples of good quality spectroscopic measurements