Challenges to the AGN Unified Model

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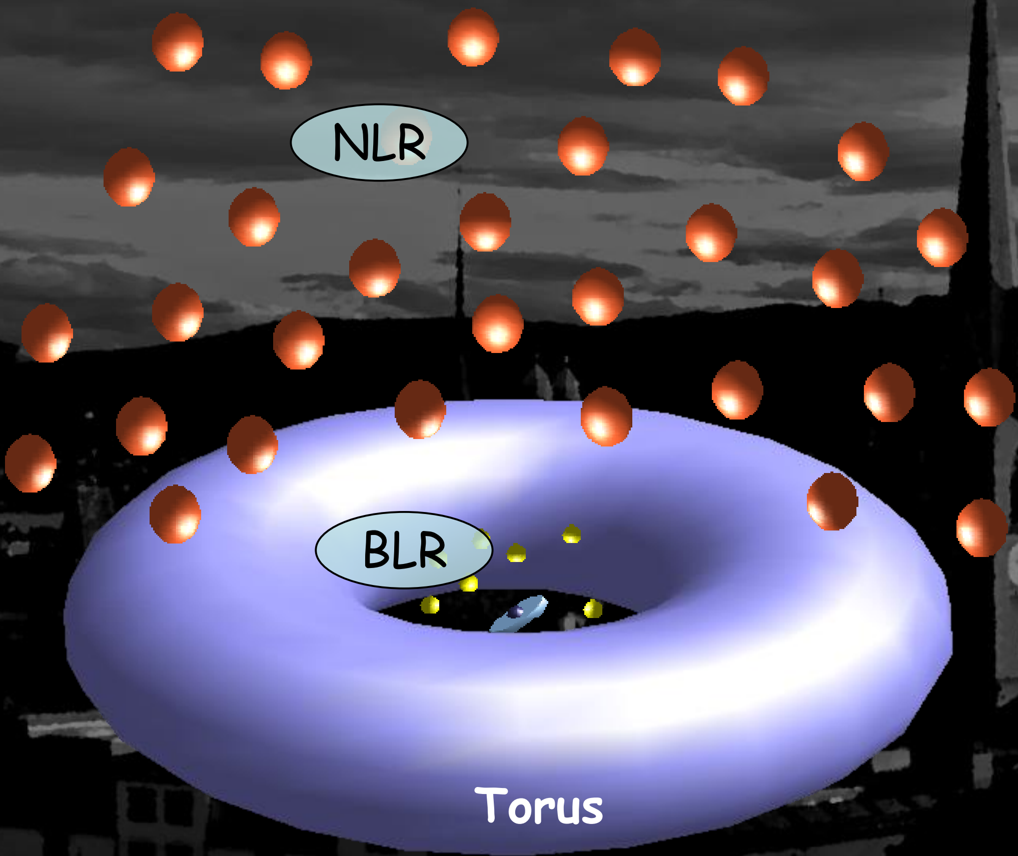
SEVENTH FRAMEWORK PROGRAMME
STRONGGRAVITY
EU FP7-SPACE research project 312789 2013 - 2017

The Geometry of Absorption

The absorber: The Unification Model view



The absorber must break the symmetry of the polarization angles:

a "torus" is the most natural configuration

The size of the torus was postulated to be on the parsec scale
(Krolik & Begelman, 1986, 1988)

Large enough to obscure the BLR
Small enough not to obscure the NLR

From Galactic to Sub-Pc Scale: Absorption at Different Scales

The presence of nonspherically symmetric absorbers at the origin of the type 1/type 2 dichotomy remains a valid scenario, but several new observations and models suggest that **multiple absorbers are present, on quite different physical scales**

Absorption within the Sublimation Radius

Absorption from pc-scale Tori

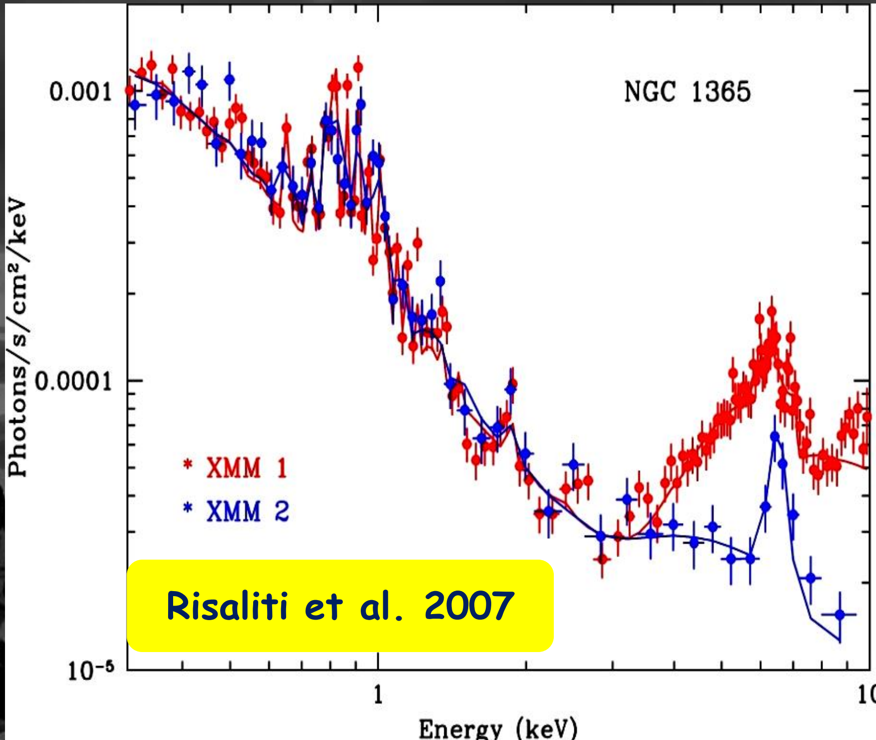
Absorption by Gas in the Host Galaxy

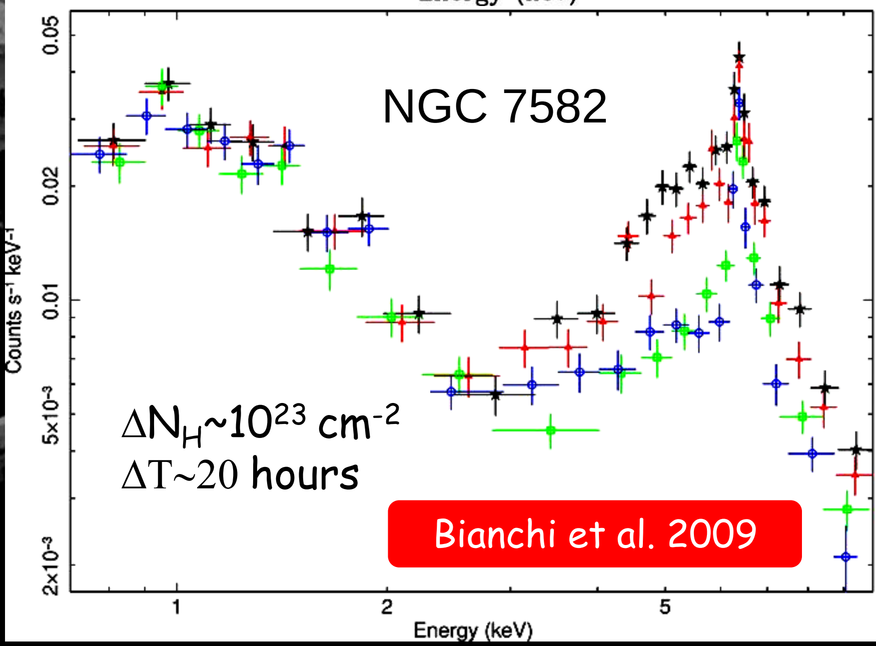
Absorption within the Sublimation Radius

X-ray absorption variability is common in AGN: **the circumnuclear X-ray absorber** (or, at least, one component of it) **must be clumpy and located at subparsec distance**

N_H variations on scales from months to hours are found in a growing number of sources: NGC 1365 (Risaliti et al. 2005, 2007, 2009), NGC 4388 (Elvis et al. 2004), NGC 4151 (Puccetti et al. 2007), NGC 7582 (Bianchi et al. 2009), Mrk 766 (Risaliti et al. 2011)

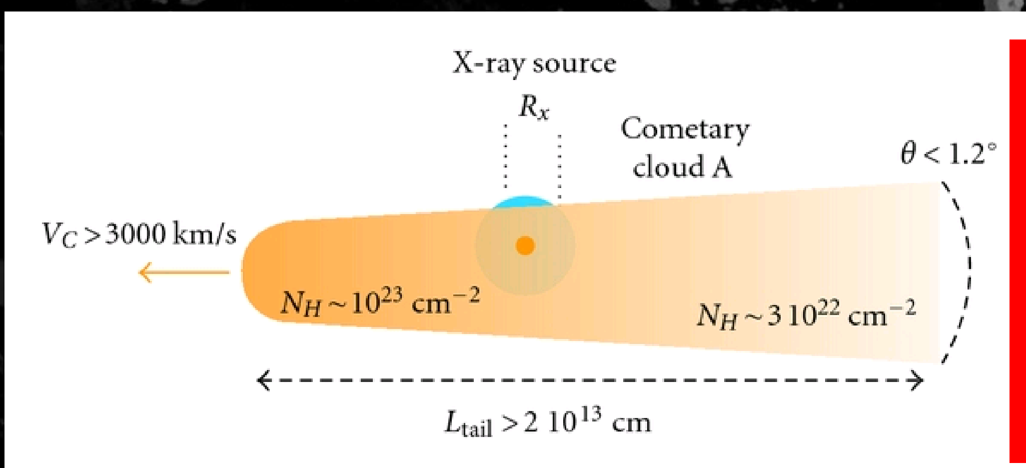
See also the exceptional case of NGC1068! (Marinucci's talk)





NGC 1365 shows absorption variability down to ~10 hours: absorption is due to clouds with velocity >10^3 km s^{-1}, at distances of ~10^4 r_g. Their physical size and density are ~10^{13} cm and ~10^{10}-10^{11} cm^{-3}

<u>All these physical parameters are typical of BLR clouds: the X-ray absorber and the clouds responsible for broad emission lines in the optical/UV are one and the same</u>

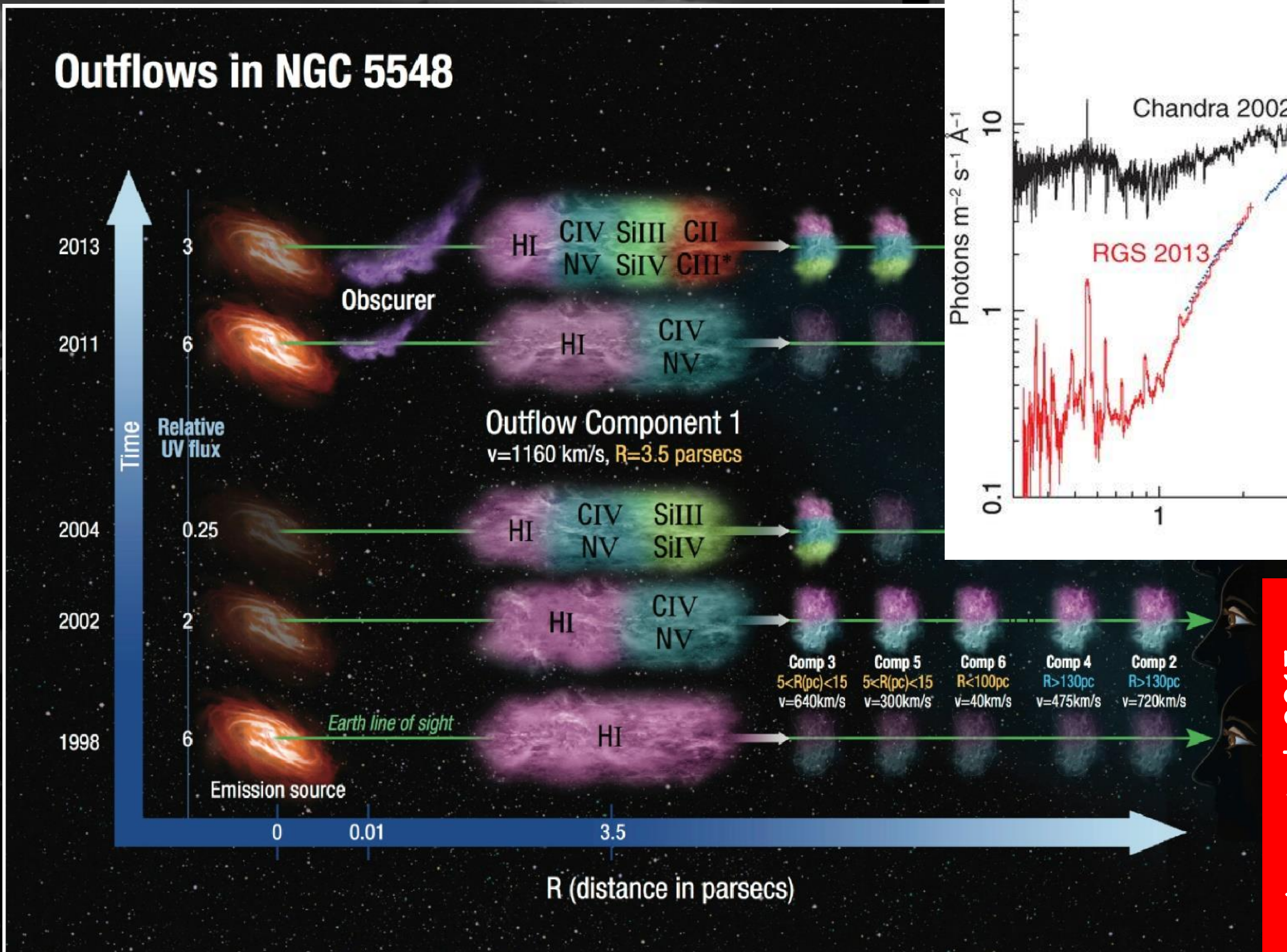


Maiolino et al. 2010

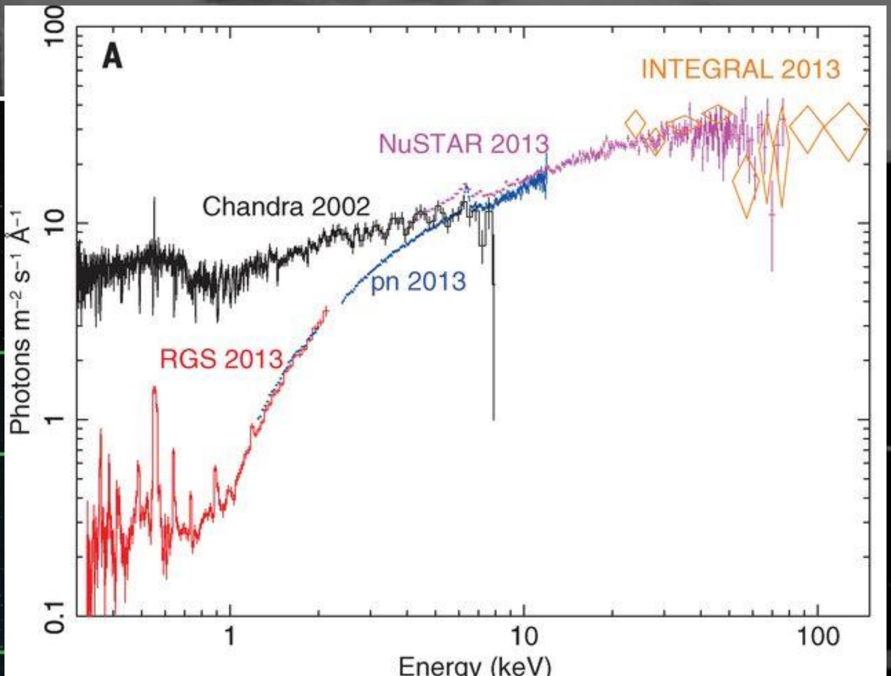
The obscuring clouds appear to have **<u>a "cometary" shape: a high-density head, and an elongated, lower-density tail</u>**

Such events are possible even in on-average unobscured sources

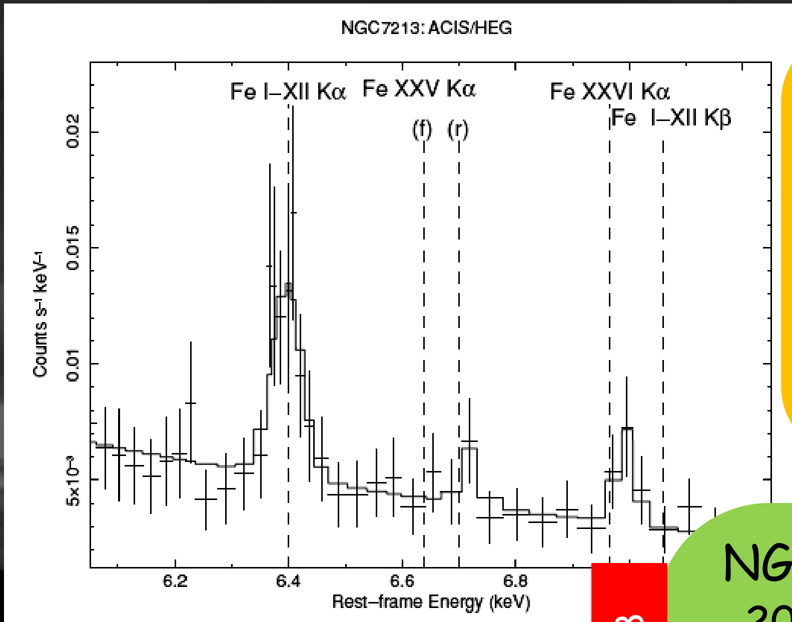
(e.g. Mrk 766: Risaliti et al. 2011; NGC5548: Kaastra et al. 2014)

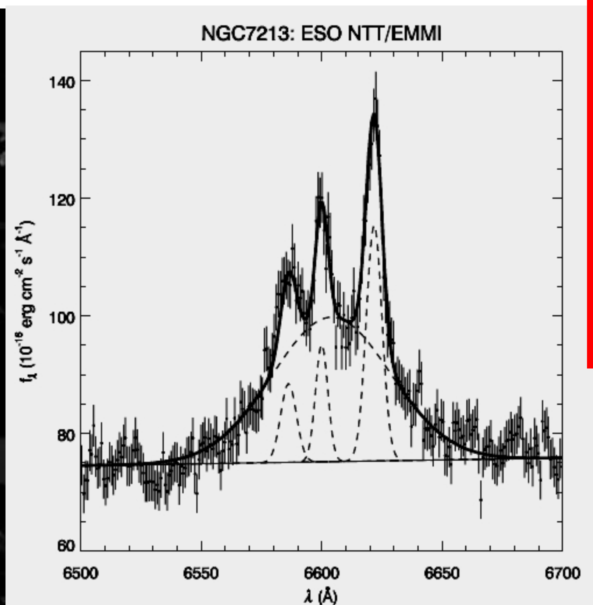


Arav et al. 2015



Kaastra et al. 2014





Bianchi et al. 2008

<u>If the covering factor and the optical depth of the BLR are large enough, a significant fraction of the iron Ka emission line should be produced there</u>

NGC 7213 has no Compton reflection (Bianchi et al. 2003, 2004, Lobban et al. 2010): the observed iron line cannot be associated to a Compton-thick material, like the torus or the disc

<u>Simultaneous</u> optical/X-ray (Chandra HEG) observations show that the FWHM of the iron line Ka and that of the Ha are both ~2500 km/s

<u>The iron Ka in NGC7213 is produced in the BLR!</u>

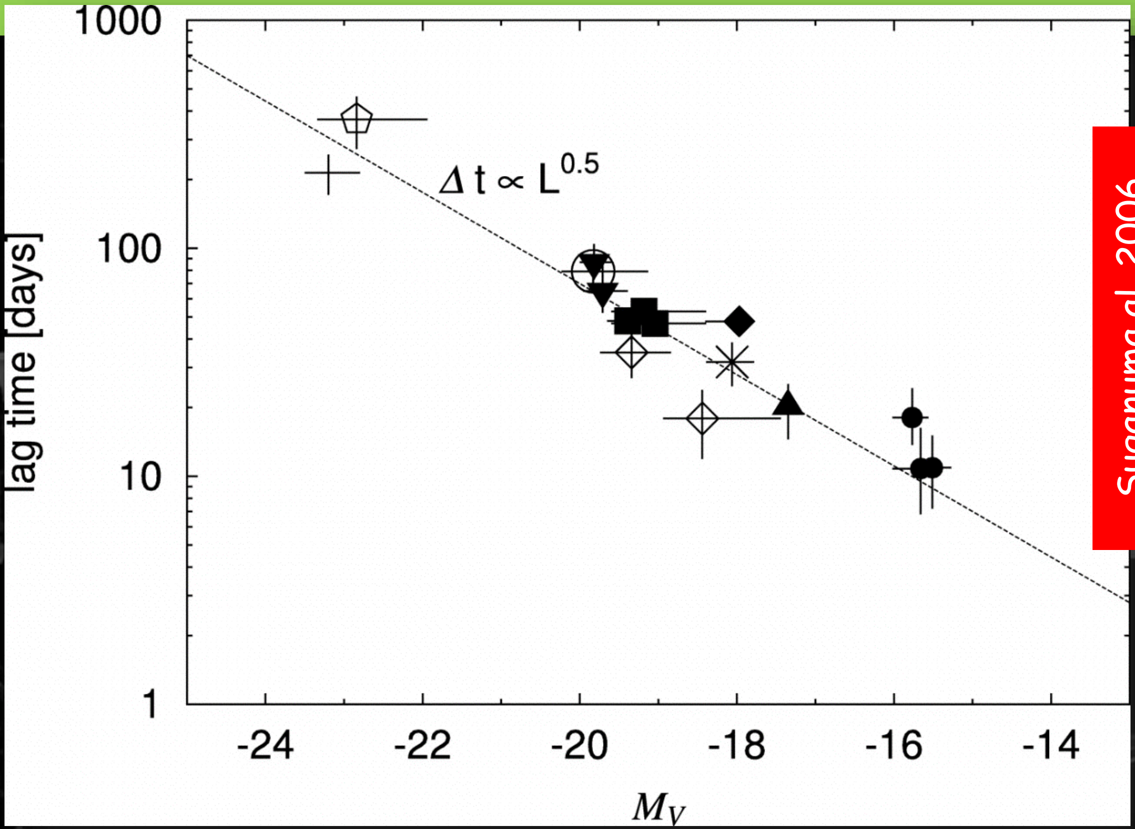
(see also NGC2110: Marinucci et al 2015)

<u>High resolution X-ray spectroscopy with microcalorimeters (Astro-H, Athena) will be extremely powerful in tackling this issue</u>

Absorption from pc-scale Tori

Early evidence for a circumnuclear dusty medium on (sub)parsec scales was obtained from near-IR studies, which revealed the presence of very hot dust, close to the sublimation temperature
(Storchi-Bergmann et al. 1992, Alonso-Herrero et al. 2001, Oliva et al. 1999)

Extensive reverberation observational campaigns also confirmed the expected $L^{1/2}$ dependence of the sublimation radius (Suganuma et al. 2006)



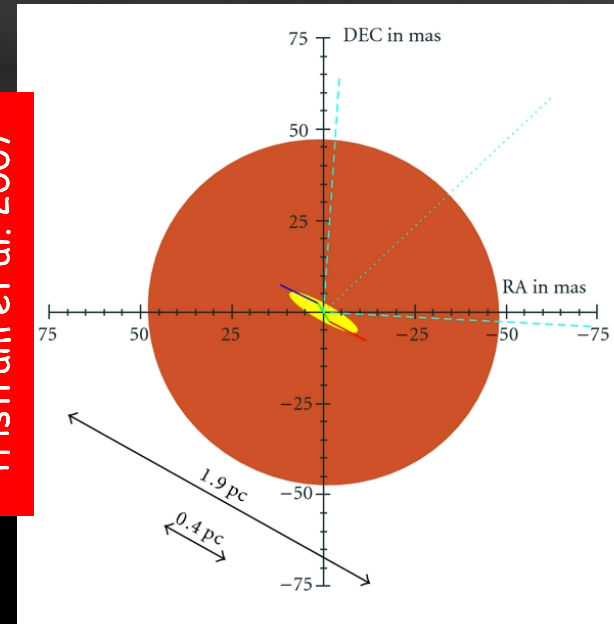
Suganuma al. 2006

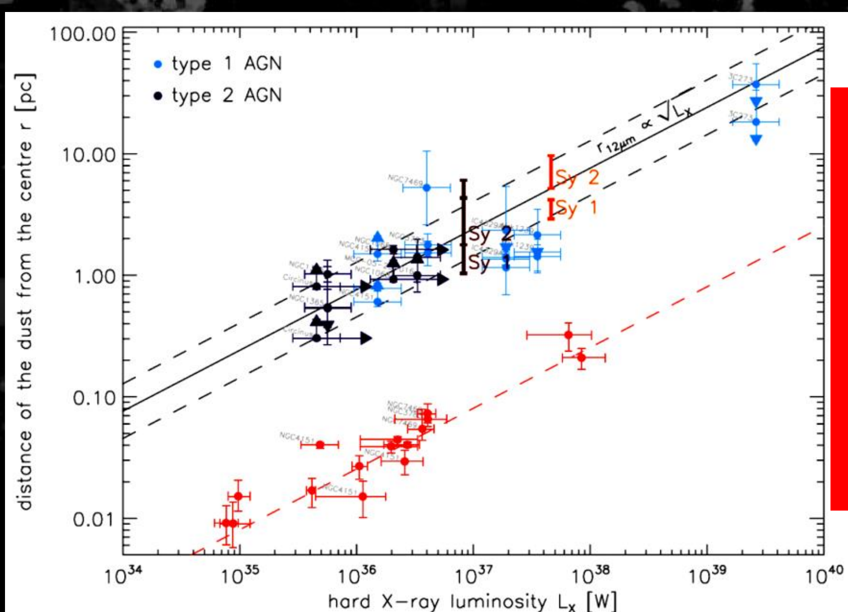
Mid-IR interferometry of NGC 1068 is consistent with a two-component dust distribution: an inner (0.5 pc) elongated hot (T>800 K) component, and a more extended (3-4 pc), less elongated colder (T~300 K) component (Jaffe et al. 2004)

Most of the absorption is located outside 1 pc.

A similar result was found for Circinus: again two components, an inner and more compact (0.4 pc), and an outer (2 pc) component (Tristram et al. 2007)

Tristram et al. 2007



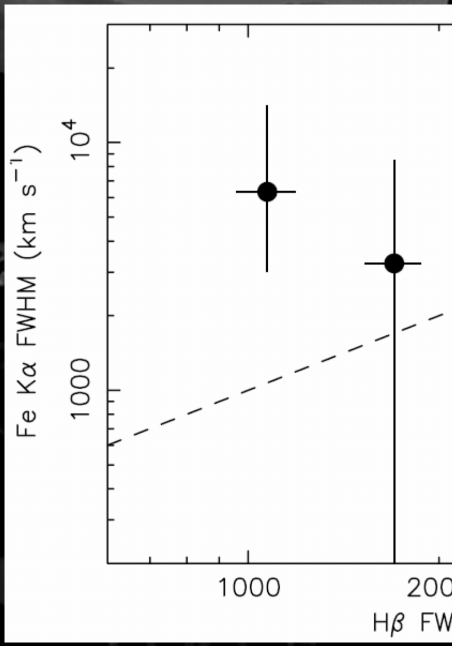


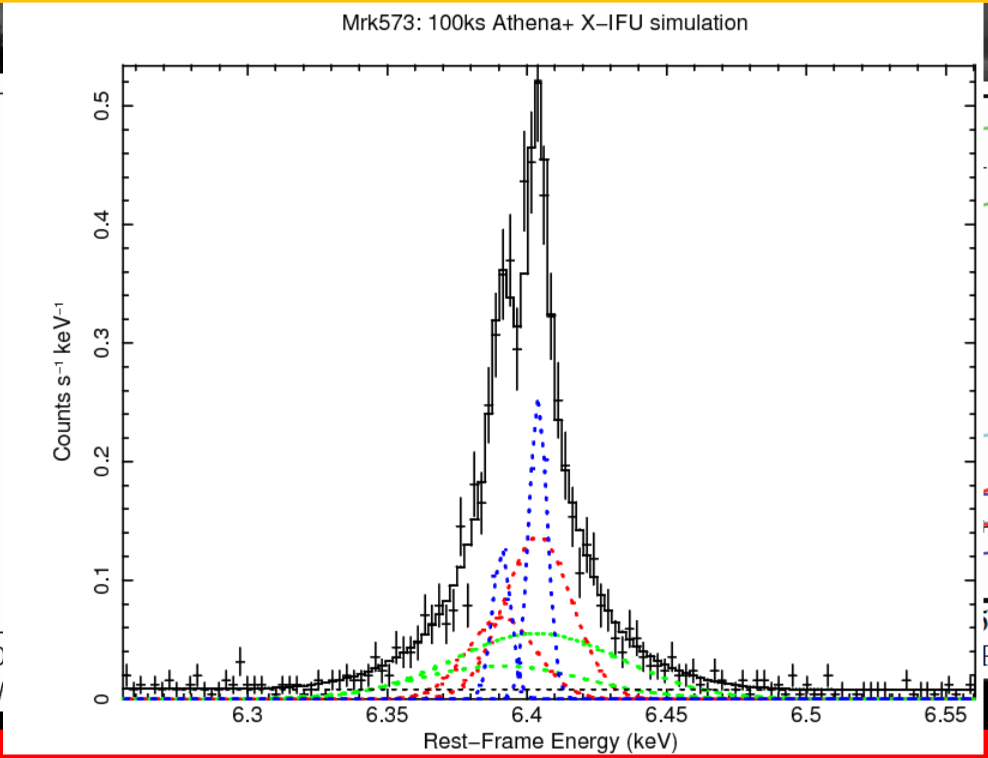
Tristram et al. 2011

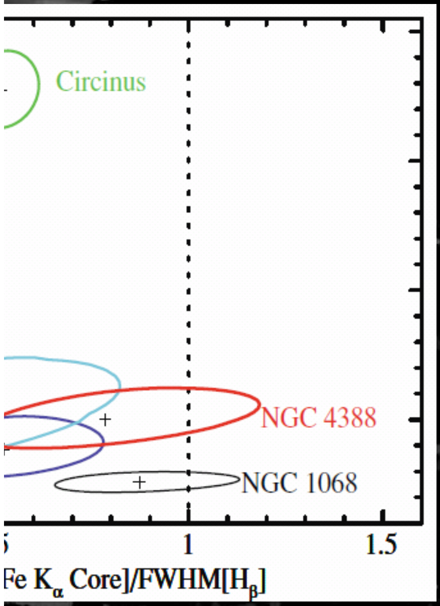
No significant differences are found between type 1 and 2 sources and the size of the dusty emitter scales with the square root of the luminosity (Tristram et al. 2009, 11; Kishimoto et al. 2011)

Compton-thick material with large covering factor is needed by the ubiquitous presence of the iron line and the Compton reflection component
(Perola et al. 2002; Bianchi et al. 2004, 2009)

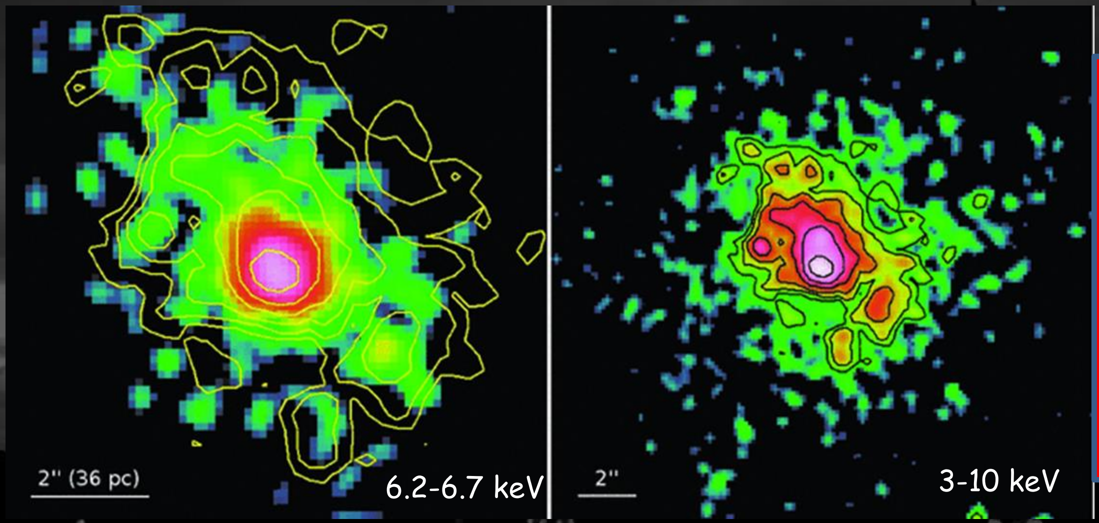
The line, typically unresolved (FWHM < thousands km/s), must be produced far (BLR/torus/NLR). Current X-ray satellites resolve its FWHM only in a few objects and with limited information, generally leading to inconclusive estimates on its location
(Nandra 2006, Shu et al. 2011)







<u>**X-ray microcalorimeters (Astro-H, Athena) will represent a breakthrough, to deconvolve all the components of the iron line, as for the optical lines**</u>



Marinucci et al. 2012

In NGC4945 the iron line and reflection component are imaged, on projected scales of ~200×100 pc. The central 30 pc accounts for about 50% of the whole emission. The structure is non-homogeneous, with visible clumps and empty regions with sizes of the order of tens of pc (see also Bauer's talk)

X-ray spectra of Compton-thick sources are completely dominated by reflection features, and they typically do not show any variability even on long time scales: the narrow iron line and the Compton reflection component are mostly produced on parsec-scale distance

In principle, the geometry and distance of the torus could be estimated by doing accurate **X-ray reverberation analysis** of the iron line and the Compton reflection component (possible with **eXTP**)

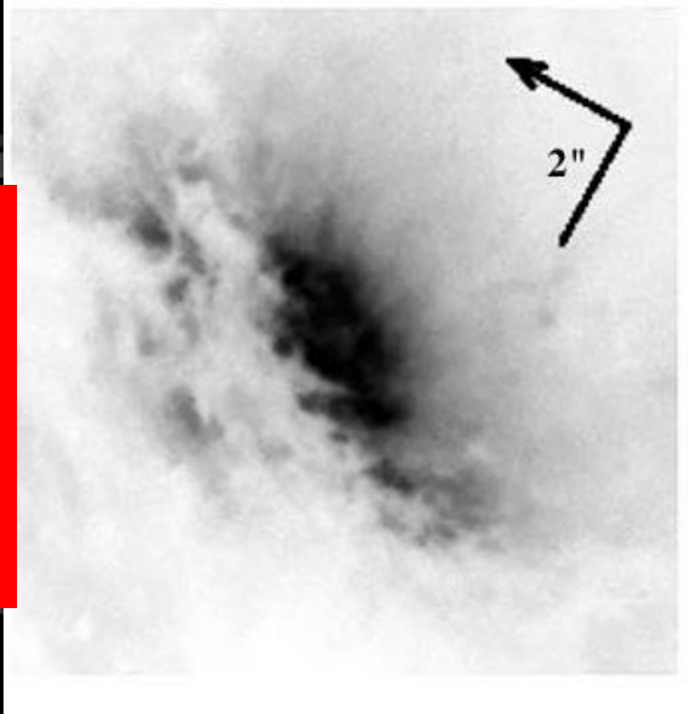
Absorption from gas in the Host Galaxy

The lowest column densities are consistent with the optical reddening in the host galaxy

Early evidence of obscuration by the host galaxy gaseous disk came from optically selected AGN samples, which avoid edge-on systems, confirmed by the SDSS survey (Maiolino & Rieke 1995, Lagos et al. 2011)

Further direct evidence for obscuration on large scales was obtained through high-resolution HST images, showing that dust lanes at distances of hundreds of parsecs are very common in Seyfert galaxies (Malkan et al. 1998)

Malkan et al. 2008

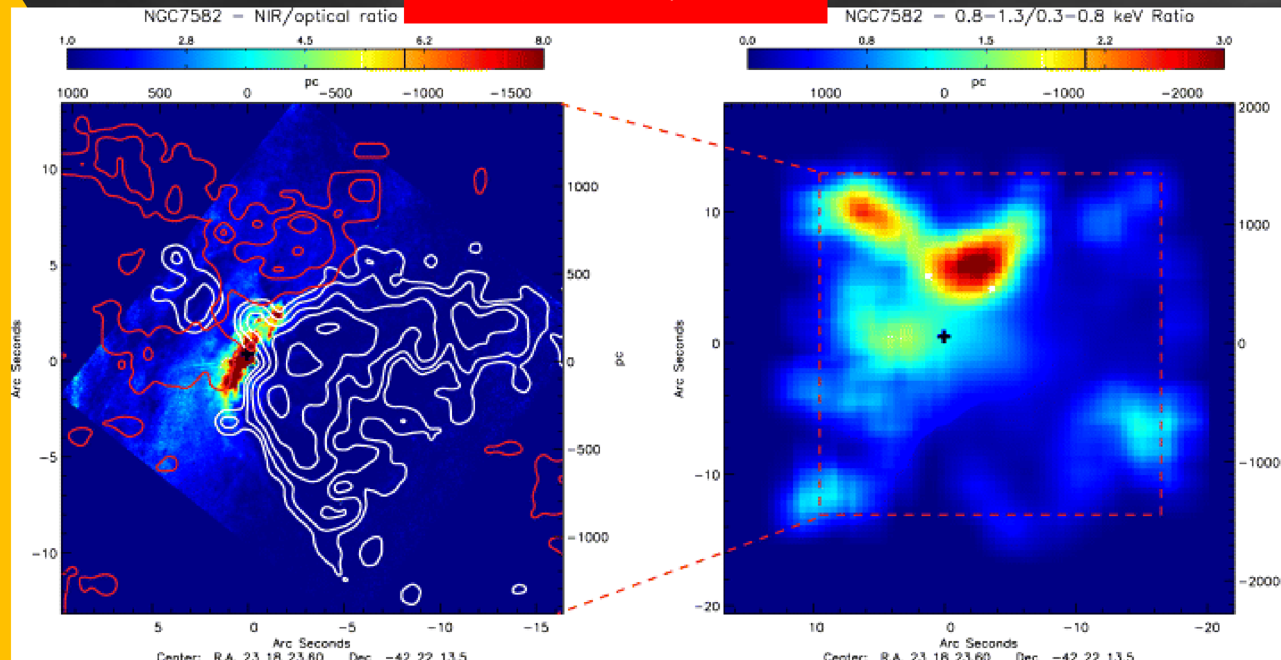


NGC 7582 (145 pc/")

These structures are (indirectly) correlated with Compton-thin X-ray obscuration (Guainazzi et al. 2005)

The effect of dust lanes can be also seen directly as X-ray obscuration towards the NLR soft X-ray emission (Bianchi et al. 2007)

Bianchi et al. 2007



<u>The obscuration occurring on such large scales is limited by dynamical mass constraints</u>, in order not to exceed the dynamical mass and have a covering factor large enough to account for the high number of observed Compton-thick sources: the bulk of the ubiquitous Compton reflection component and narrow neutral iron Ka line must come from a more compact region (Risaliti et al. 1999)


(Selected) Open Issues

True Type 2 Seyfert galaxies

About **<u>half of the brightest Seyfert 2 galaxies appear not to have hidden BLR in their optical spectra</u>**, even when high-quality spectropolarimetric data are analysed (Veilleux et al. 1997, Tran 2001)

They may be associated with inefficient (low covering factor/column density) or obscured mirrors (Heisler et al. 1997)

A stronger contribution/dilution from the host galaxy or from a circumnuclear starburst can also make the detection of polarized broad lines harder (Alexander 2001, Gu et al. 2001)

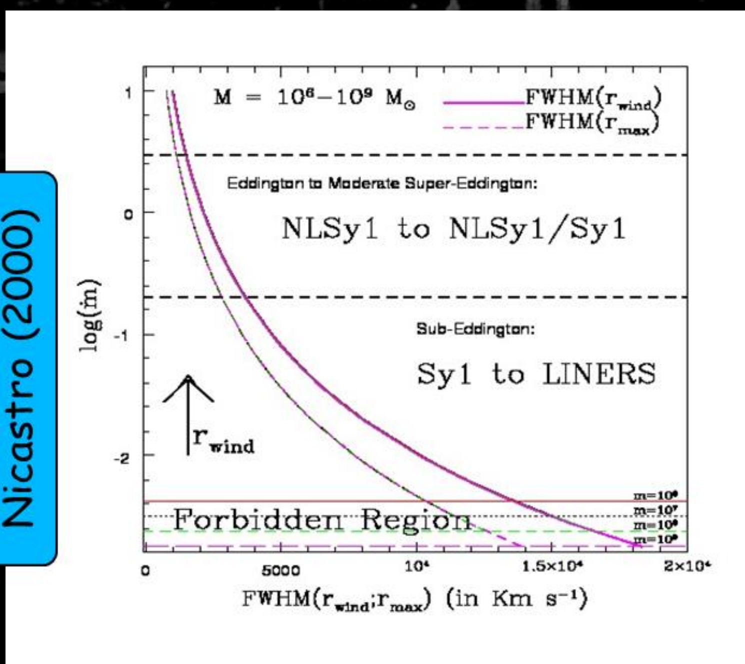
<u>A number of Sy2s without polarized broad lines may be genuine type 2 Seyferts: they intrinsically lack a BLR</u>

Sy2s with polarized broad lines are more easily associated with truly obscured Sy1s, while Sy2s without polarized broad lines preferentially host weak AGN, possibly incapable of generating a classical BLR (Veilleux et al. 1997, Tran 2001)

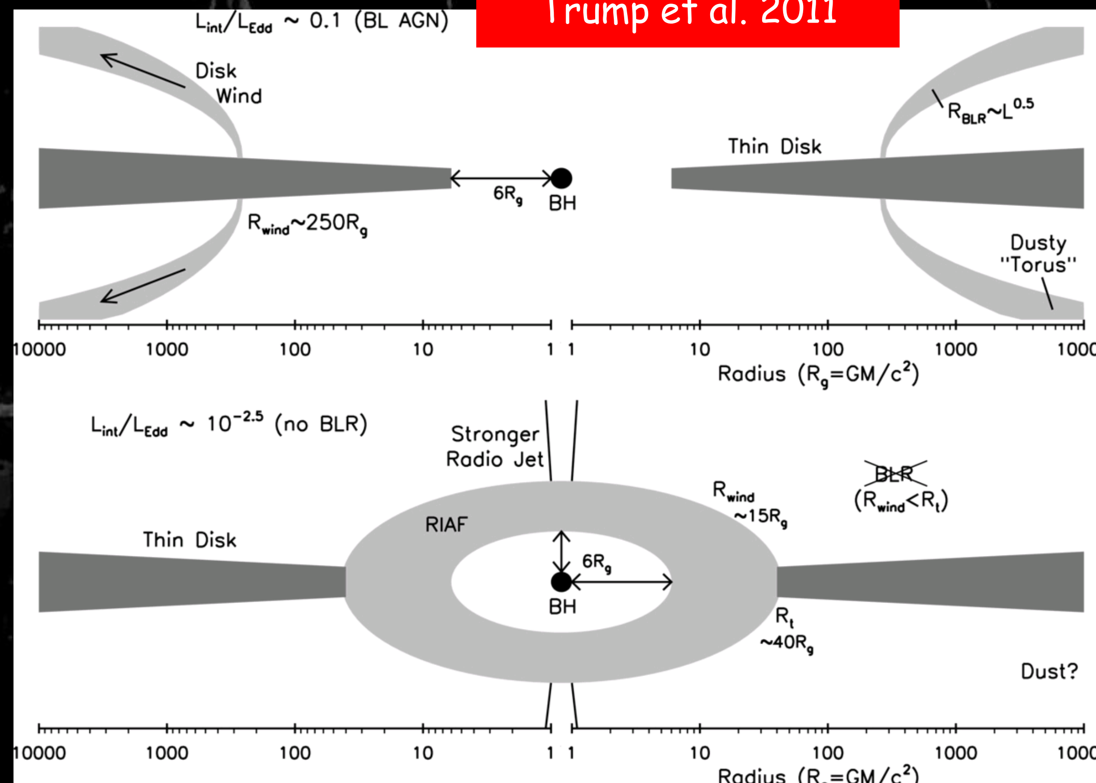
If the BLR is part of a disk wind, it cannot form if its launching radius falls below a critical radius: the innermost orbit of a classic Shakura & Sunyaev (1973) disk (Nicastro 2000), or the transition radius to a radiatively inefficient accretion flow (Trump et al. 2011)

<u>No BLR is formed for Eddington rates lower than a critical value</u> ($\sim 2\times10^{-3}\ M_8^{-1/8}$)

Nicastro (2000)



Trump et al. 2011



If the BLR cannot form in weakly accreting AGN, **we expect the existence of "true" Seyfert 2 galaxies: optically Type 2 objects, without obscuration**

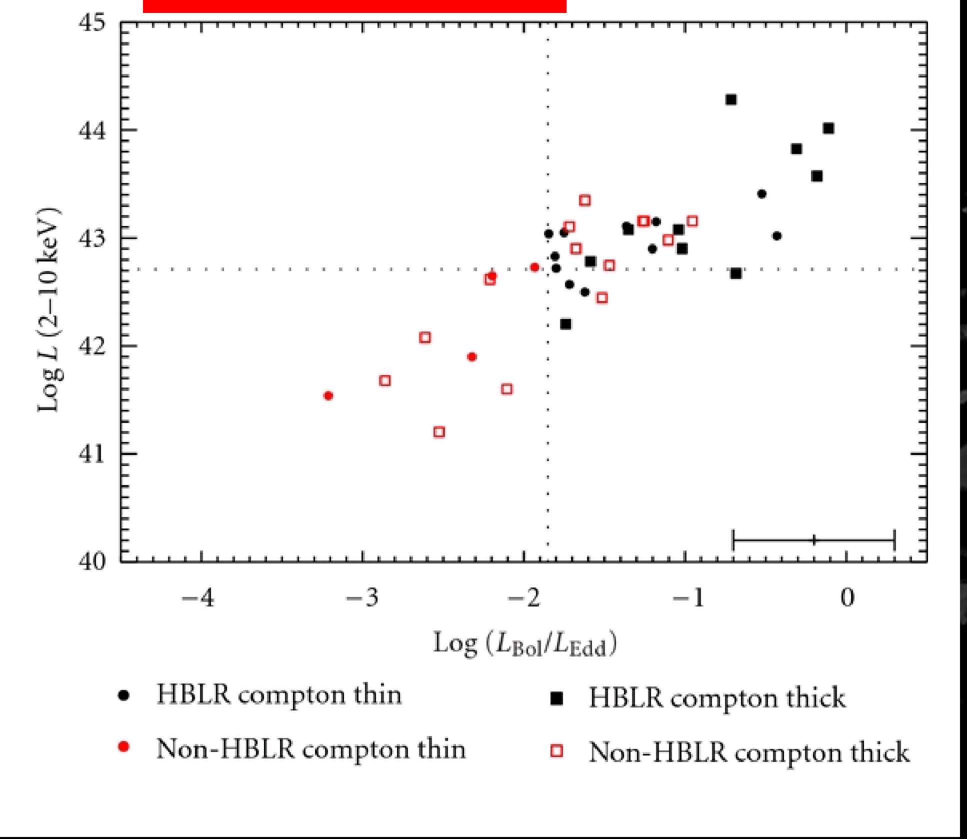
The best examples of these objects are found with simultaneous optical/X-ray observations, and have low Eddington rates: NGC 3147 (4×10^{-5}-3×10^{-4}: Bianchi et al. 2008), Q2131427 (2-3×10^{-3}: Panessa et al. 2009), and NGC 3660 (4×10^{-3}-2×10^{-2} : Bianchi et al., 2012)

Broad optical lines are generally absent in the spectra in polarized light of Seyfert 2s with low Eddington rates

(Nicastro et al. 2003; Bian & Gu 2007;Wu et al. 2011)

The threshold in Eddington rate is generally found at ~0.01, both for optical/Xray surveys (Trump et al., 2011) and spectropolarimetric data (Marinucci et al., 2012)

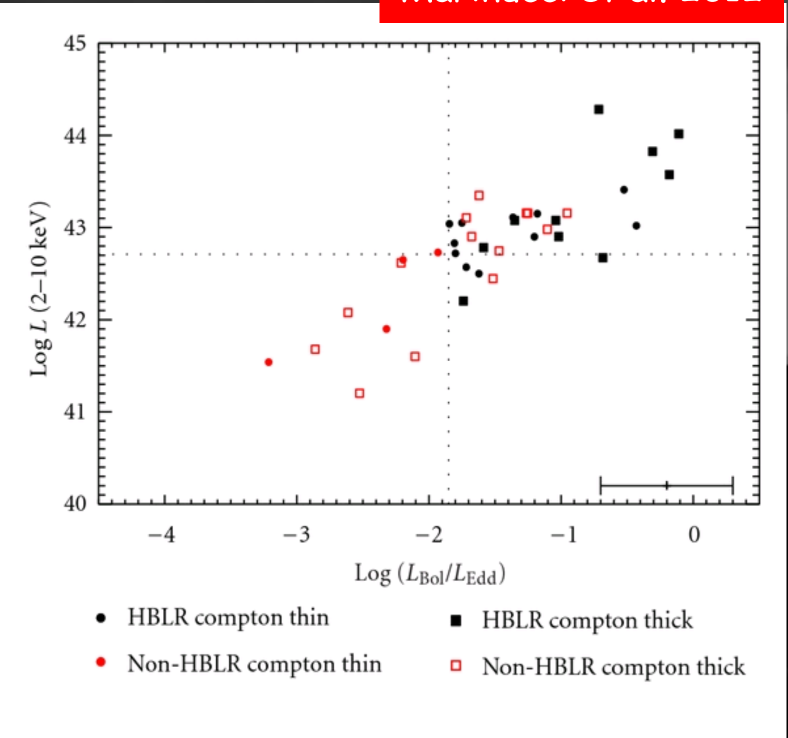
Marinucci et al. 2012

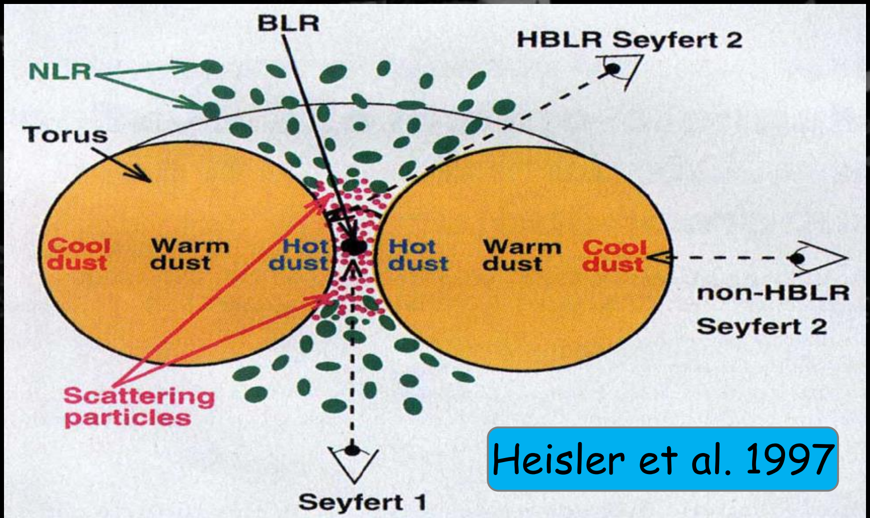


Below this threshold no broad lines are detected (either in total or polarized light), but **<u>above the threshold the BLR still cannot be detected in many Sy2s</u>**

These sources should possess a BLR, something prevents us from observing it: more inclined sources (with respect to the line of sight) should intercept a larger column density of the torus and may obscure the medium responsible for the scattering of the BLR photons (Shu et al. 2007)

Marinucci et al. 2012





Heisler et al. 1997

<u>It appears that there are two classes of non-HBLR:</u>

- those with low accretion rates, really lacking the BLR,
- those with higher accretion rate, likely hosting the BLR, but something prevents us from observing it

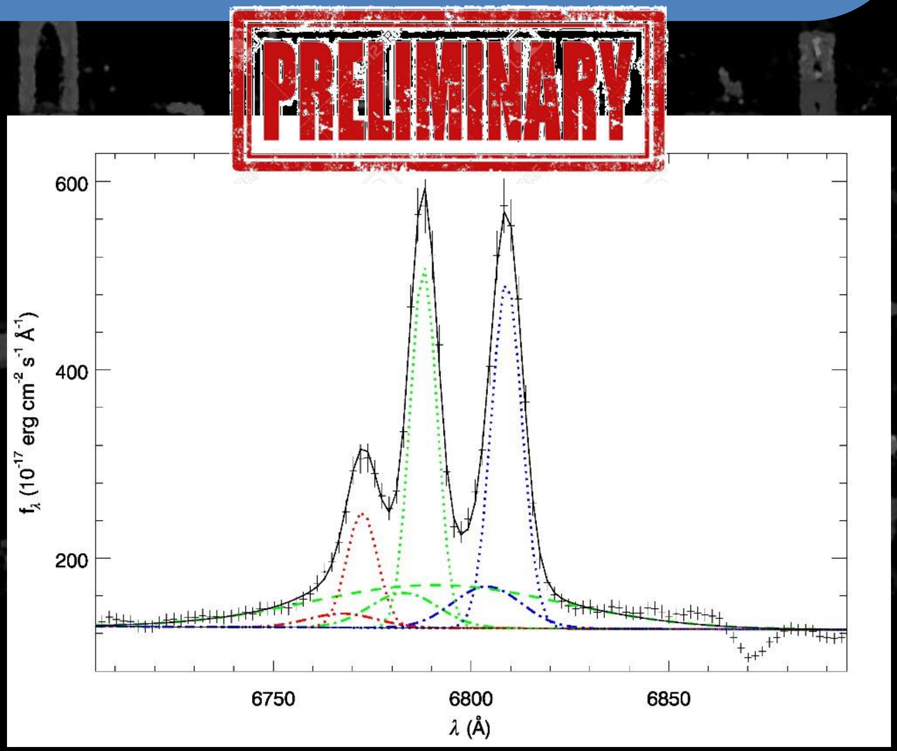
Are true type Seyfert 2s rare objects?

Few high SNR X-ray unobscured radio-quiet AGN (< 5%) lie below $L_{bol}/L_{Edd} \simeq 0.01$ (CAIXA: Bianchi et al. 2009)

Low-accreting unabsorbed Sy2 candidates rise up to 30% in surveys (COSMOS: Trump et al. 2011), but it is difficult to say they are genuine true type 2 AGN. Similarly, ≃25% of low-accreting objects lack a hidden BLR in polarized light in obscured AGN (Marinucci et al. 2012)

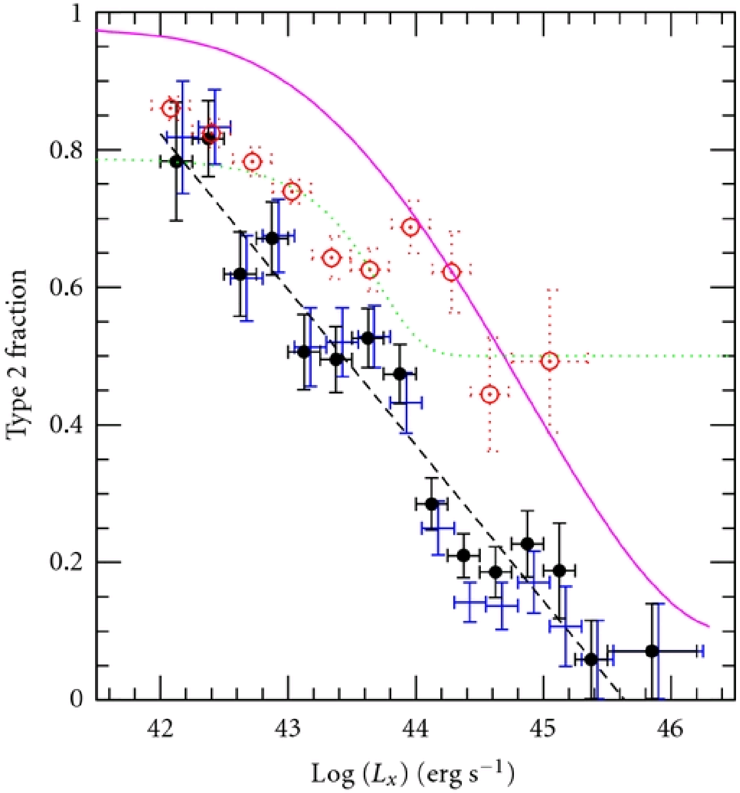
We have recently found an object without X-ray obscuration and (simultaneously) a very weak broad (~2000 km/s) Hα line (and no Hβ): a **True Type 1.9** source!

It appears that BLR emission is intrinsically weak in this object, at odds with models explaining True Type 2s, where the BLR disappears moving towards large FWHMs



Luminosity and Redshift Dependence of the Covering Factor

Hasinger 2008



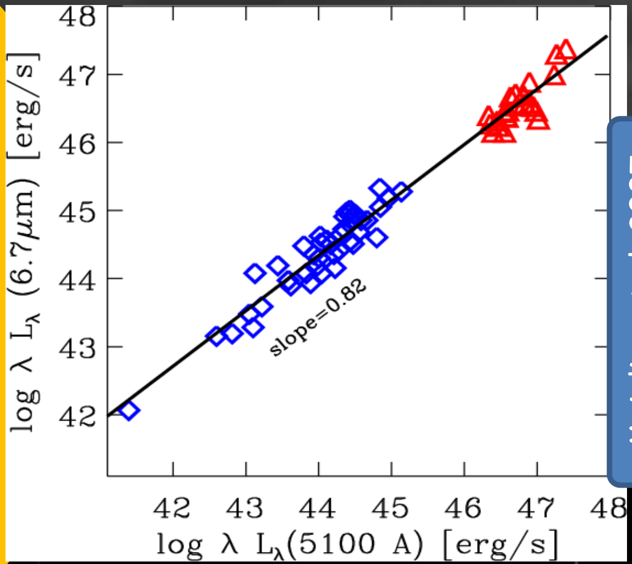
The covering factor of the obscuring medium shows a significant decrease with luminosity

This effect is present in various hard X-ray studies (Ueda et al. 2003, Steffen et al. 2003, La Franca et al. 2005, Akylas et al. 2006, Barger & Cowie 2005, Tozzi et al. 2006) and optical surveys (Simpson 2005), which have measured the relative fraction of obscured and unobscured AGN as a function of the bolometric luminosity

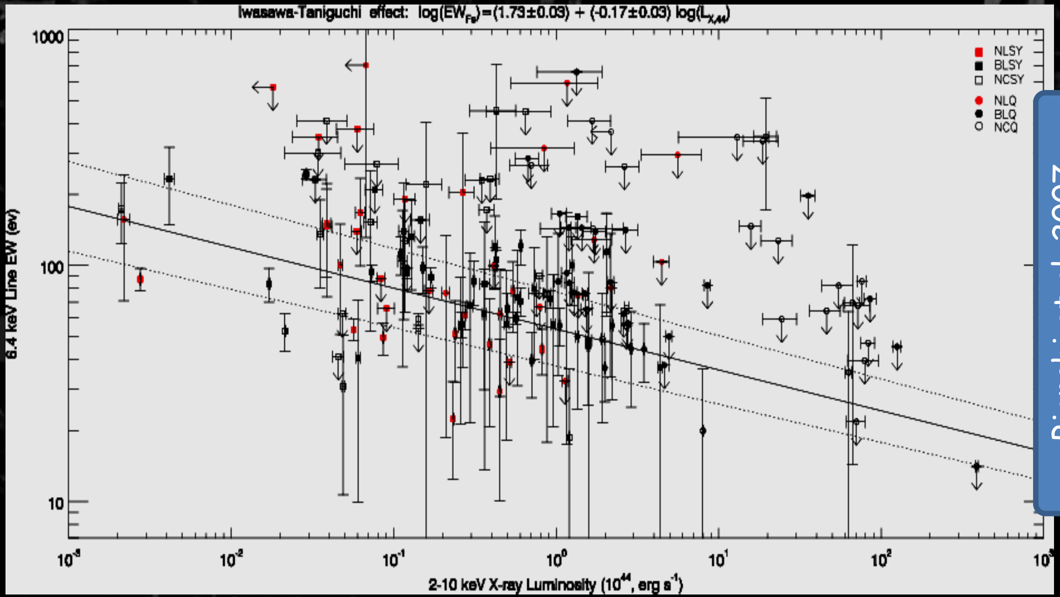
The ratio between the hot dust emission (near/mid-IR) and the primary AGN bolometric emission is proportional to the covering factor of the obscuring medium

<u>Various studies have confirmed that the covering factor of the absorbing medium decreases as a function of luminosity</u>

(Treister et al. 2008, Maiolino et al. 2007, Wang et al. 2005, Mor & Trakhtenbrot 2011)



Maiolino et al. 2007



Bianchi et al. 2007

<u>The EW of the (narrow) Fe Ka anti-correlates with luminosity</u> ("Iwasawa-Taniguchi effect"), again interpreted in terms of decreasing covering factor of the circumnuclear absorbing medium as a function of luminosity (Iwasawa & Taniguchi 1993, Page et al. 2004, Jiang et al. 2006, Guainazzi et al. 2006, Bianchi et al. 2007)

Receding torus scenario (Lawrence 1991): higher luminosities imply larger dust sublimation radii and, if the torus has a constant height as a function of radius, a smaller covering factor of the dusty medium

This scenario cannot explain the decreasing covering factor inferred from X-ray studies, which do not trace the dusty component of the absorber

If the **X-ray obscuration is due to interstellar gas**, distributed in a rotationally supported disk on ~100 pc (Lamastra 2006), its covering factor diminishes as the gravitational pull from the SMBH and the bulge increases with the BH mass (hence luminosity)

However, this model can explain the anti-correlation only for **Compton-thin** sources

The lower covering factor in luminous AGN can be a consequence of the stronger **AGN radiation pressure** impinging onto the circumnuclear medium and expelling larger fractions of material

In support of this scenario growing evidence for massive outflows in luminous AGN has been reported in the recent years

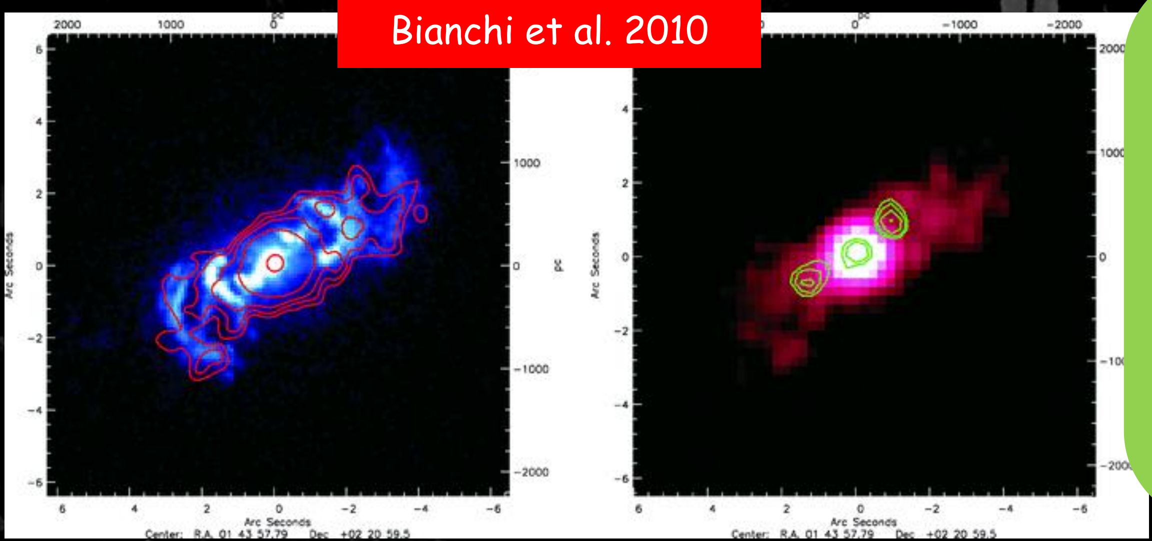
Disk-Torus Alignment

The most natural assumption on the geometry of the circumnuclear matter is that it is coaxial with the BH spin

This is an angular conservation argument: if they are all related to the inflowing material, the torus (and the collimated NLR), the accretion disk, the radio jet, and the BH spin should share the same axis

However, if the BH growth is due to multiple, unrelated accretion events, the BH spin may not reflect the rotation axis of the accretion disk. Another possibility is that the obscuring torus is not within the BH gravitational sphere of influence

Bianchi et al. 2010



When large scales are imaged, the radio jet and the optical/X-ray NLR are generally in agreement with this simple picture

(Capetti et al. 1996, Bianchi et al. 2010)

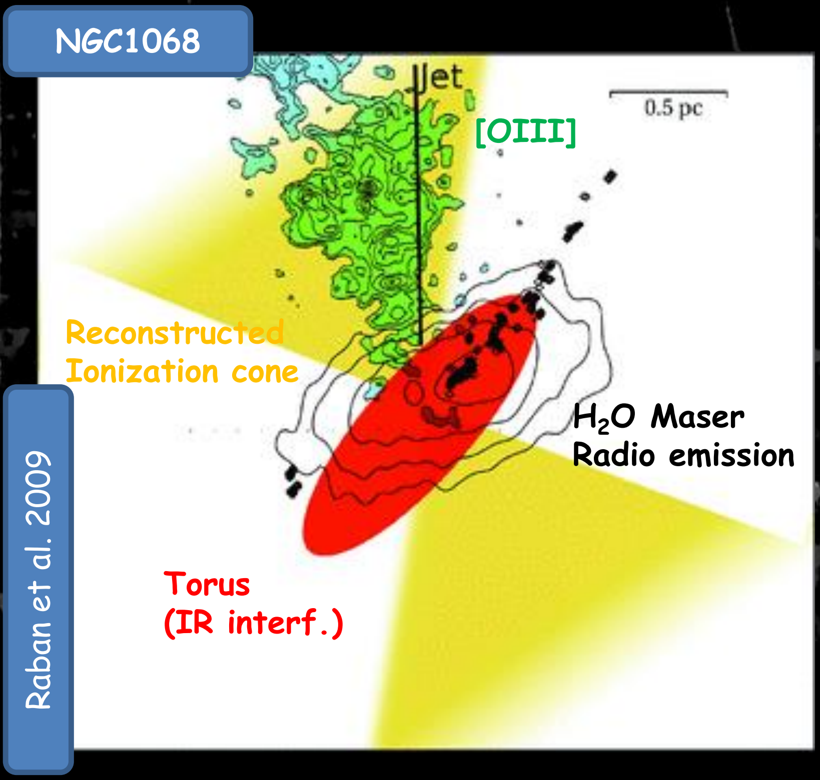
Mid-IR interferometric studies allow us to directly image the geometry of the torus with respect to the optical cones

<u>In NGC1068 the torus and the ionization cones are misaligned!</u>
(Raban et al. (2009)

The direction of the radio jet is also clearly tilted with respect to both the NLR and the torus

Similar analysis on other sources is clearly needed in order to shade some light on this issue

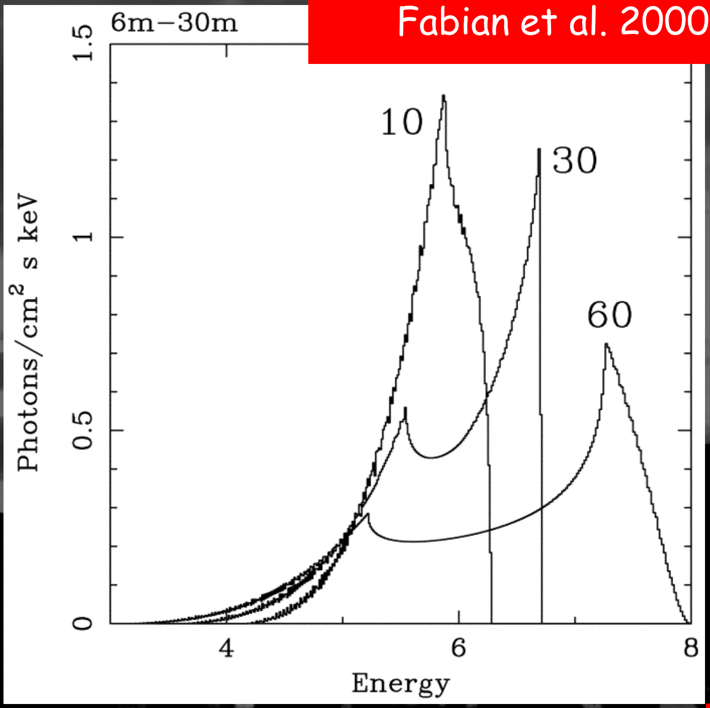
A promising, independent, method to test the torus/ionization cones misalignment is via
<u>X-ray polarimetry (e.g. XIPE)</u>
(Goosmann & Matt 2011
see also Matt's talk!)



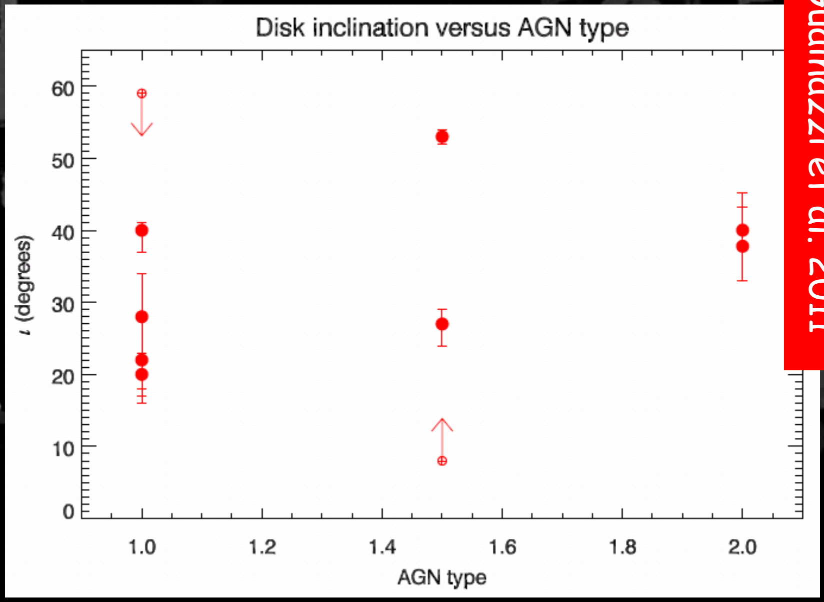
The inclination angle of the accretion disk can be estimated via the relativistic profile of iron lines produced in its inner regions

A simple relation between the inclination of the nuclear obscuring matter (as measured by the optical type) and that of the accreting matter should be ruled out (Guainazzi et al. 2011)

Fabian et al. 2000



The distribution of the equivalent widths of the [OIII] emission line in a large sample of AGN is also not compatible with the presence of a torus coaligned with the accretion disk, unless the torus covering factor is extremely small (Risaliti et al., 2011)



Guainazzi et al. 2011

http://eas.unige.ch/EWASS2016/session.jsp?id=SS5

ABSTRACT DEADLINE: 15 MARCH!