Obscured AGN with NuSTAR

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AGN 12 – Naples, Sept. 28th 2016

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- Introduction
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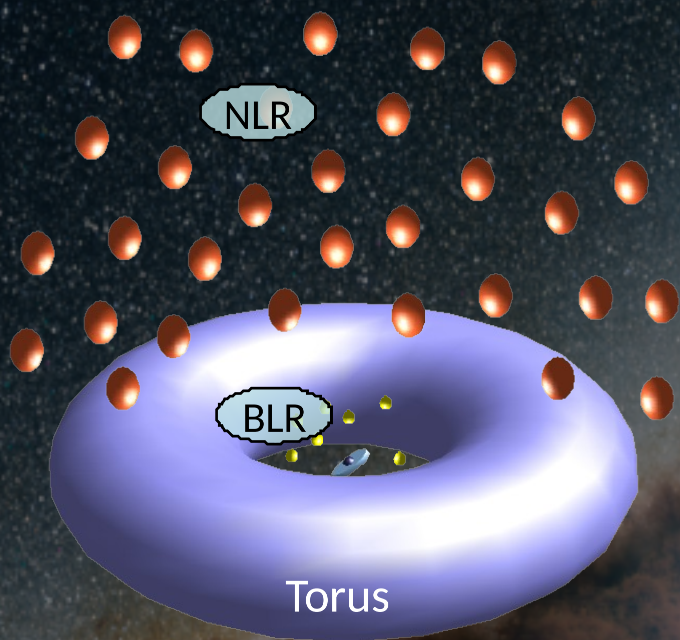
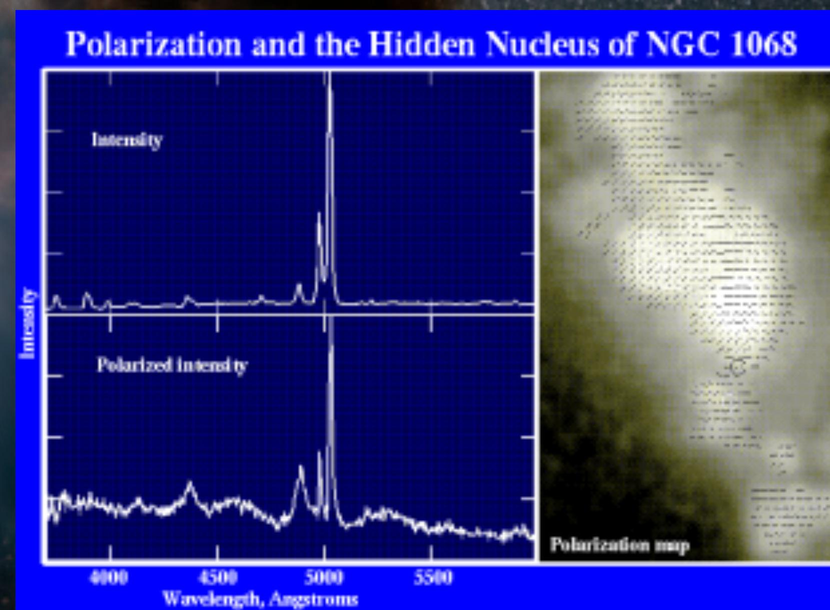
The geometry of absorption



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

The absorber must break the simmetry of the polarization angles:
a “torus” is the most natural configuration.



Antonucci & Miller, 1985

The geometry of absorption

While the AGN unified picture remains valid in its more general sense (the presence of non-spherically symmetric absorbers at the origin of the type 1/type 2 dichotomy), several new observations and models, mostly in the X-ray and infrared domain, suggest that multiple absorbers are present around the central source, on quite different physical scales (e.g. Bianchi, Maiolino & Risaliti 2012)

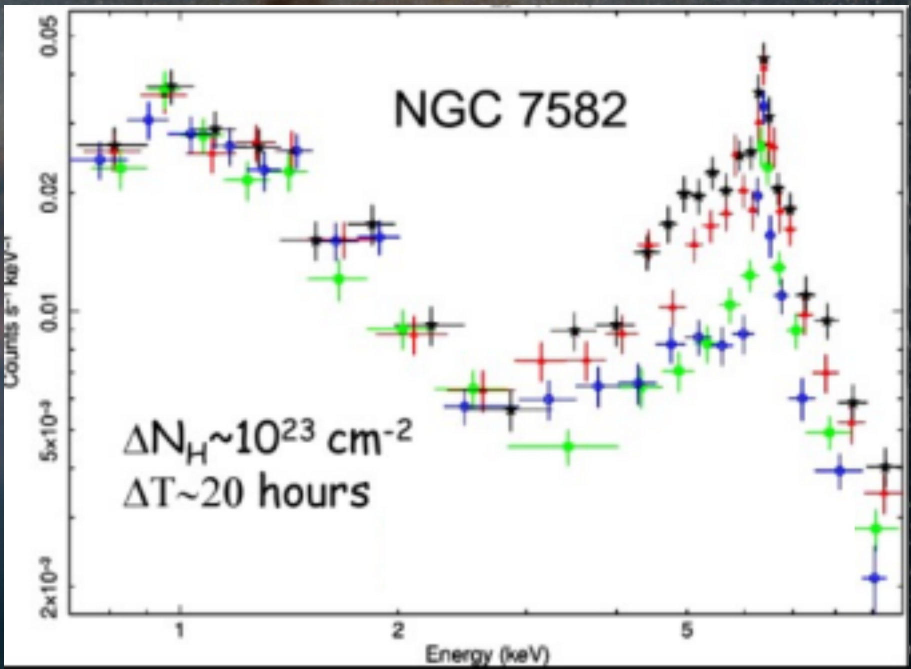
On the sub-pc scale, dust-free gas along the line of sight has been observed through X-ray absorption variability: part of the observed X-ray absorption is due to BLR clouds

On the parsec scale, and down to the dust sublimation radius, the "standard" torus has been directly imaged in a few sources with interferometric techniques, and its presence is suggested by X-ray reflection properties, and dust reverberation mapping in the near-IR

Absorption within the sublimation radius

X-ray absorption variability is common in AGN: the circumnuclear X-ray absorber (or, at least one of its components) 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), NGC 4388 (Elvis et al. 2004), NGC 4151 (Puccetti et al. 2007), NGC 7582 (Bianchi et al. 2009), Swift J2127.4 (Sanfrutos et al. 2013), MCG-6-30-15 (AM et al., 2014)

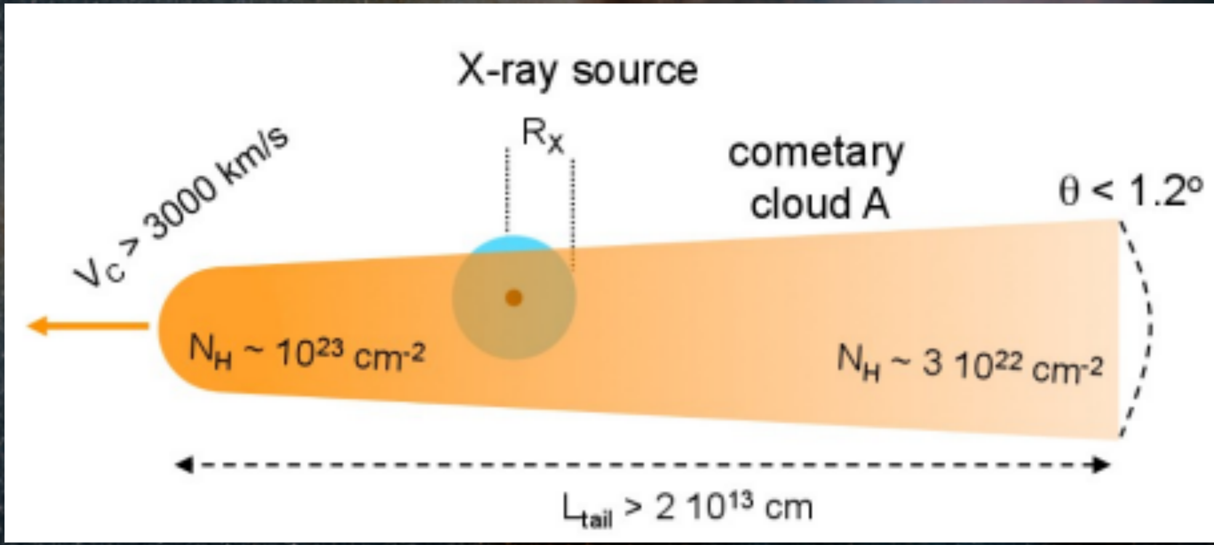


Bianchi et al. 2009

Absorption within the sublimation radius

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

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.



Maiolino et al. 2010

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

Absorption within the sublimation radius

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}

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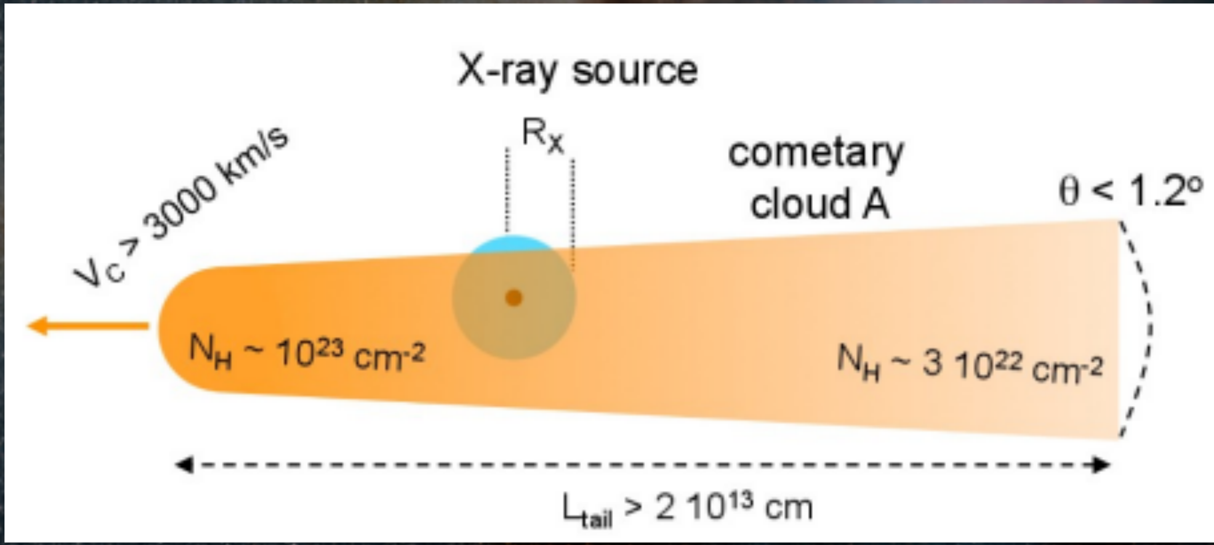

Maiolino et al. 2010

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NGC 7213

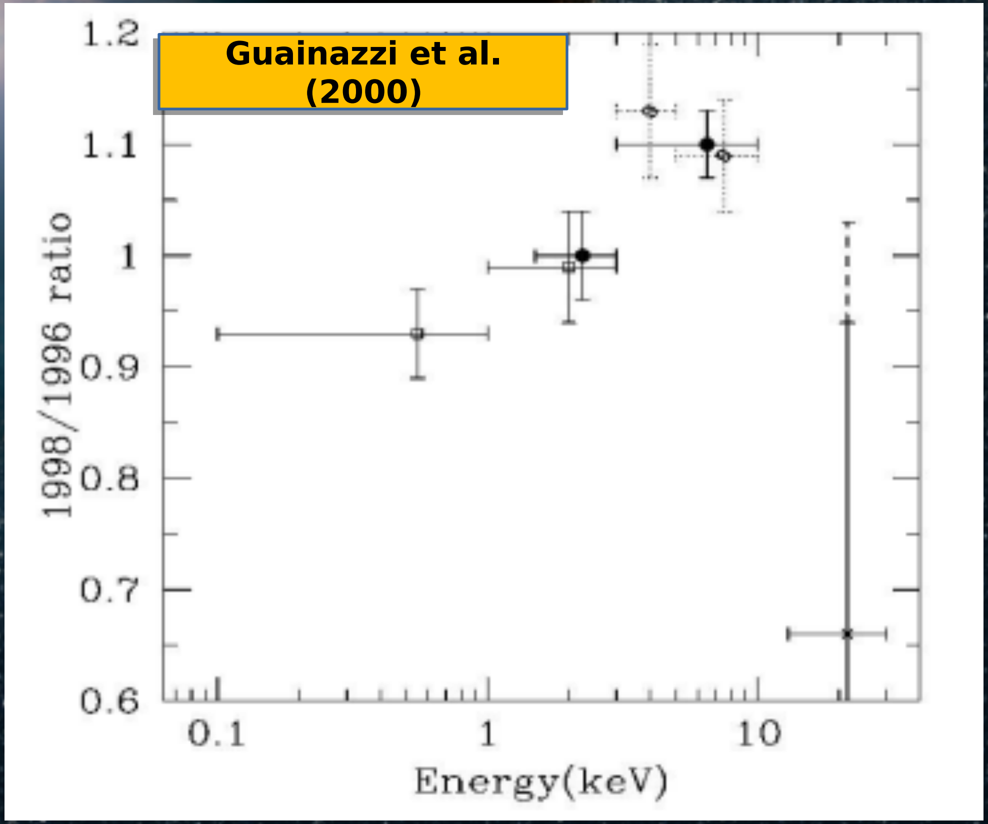
NGC 1068 is the archetypical and one of the brightest Compton-thick Seyfert 2 galaxies in the sky

It is obscured by Compton-thick material along the line of sight and its spectrum is completely dominated by reprocessing: hot (He- and H-like iron lines), warm (low-Z ionized lines) and cold (Iron Ka , EW=1.3±0.4 keV)

With a BH mass of $\sim 10^7$ M_{sun} (Kuo et al., 2011) and a bolometric luminosity of 8×10^{44} erg s^{-1} (Pier et al., 1994) the source is accreting at a high Eddington ratio and therefore it is expected to be intrinsically very variable

NGC1068 is an ideal target to study the circumnuclear material through variability!

Evidence of flux variability of both the cold and ionized reflectors has been claimed on time scales of months and years (Guainazzi et al., 2000; Colbert et al., 2002; Matt et al., 2004)



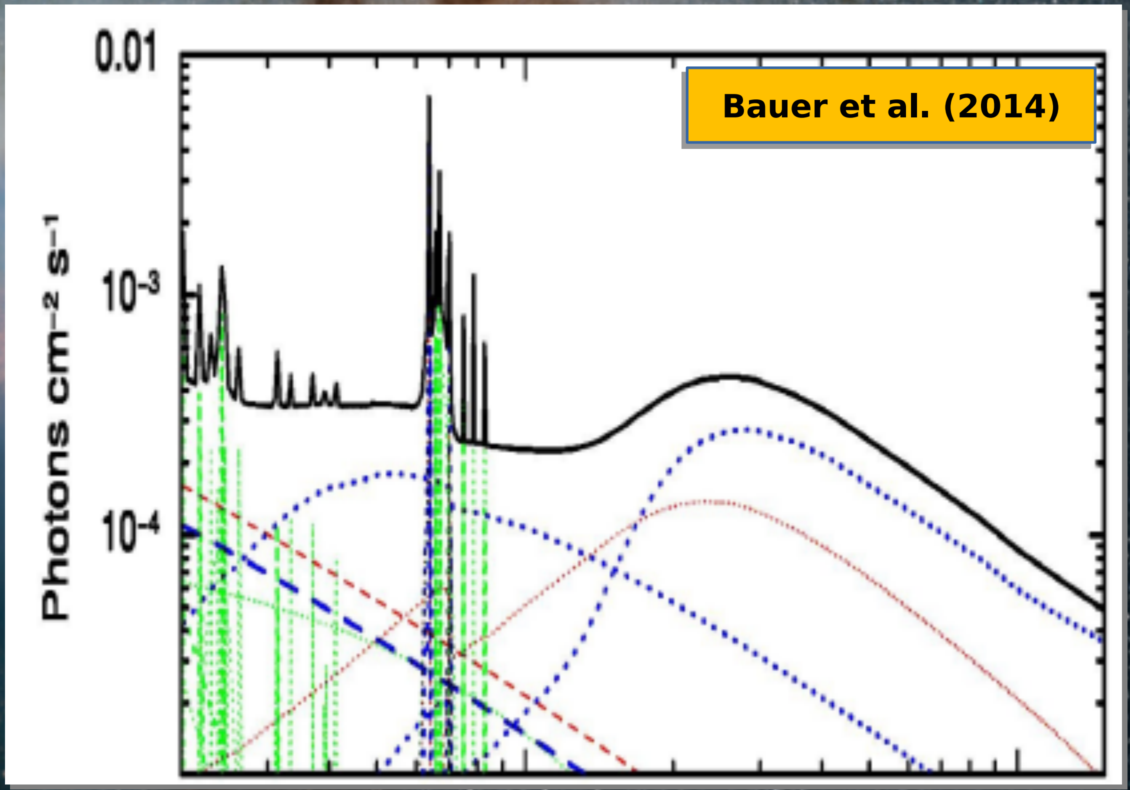
We observed NGC 1068 with a joint XMM-*Newton* and NuSTAR monitoring campaign, from July 2014 until February 2015

Longer time-scales can be probed thanks to the two previous XMM-*Newton* observations performed in 2000 (Matt et al. 2003), and the NuSTAR observation performed in 2012 (Bauer et al, 2014)

Recently, Bauer et al. (2014) analysed NGC 1068 using data from different observatories, including the 3-79 keV data from the NuSTAR 2012 observation

They interpreted the broadband cold reflected emission of NGC 1068 as originating from multiple reflectors with three distinct column densities.

The higher N_H component ($N_{H,1} \simeq 10^{25}$ cm^{-2}) contributes most to the Compton hump (and is also responsible for the total suppression of the intrinsic continuum), while the lower N_H component ($N_{H,2}$ $\sim 1.5 \times 10^{23}$ cm^{-2}) produces much of the neutral iron line emission



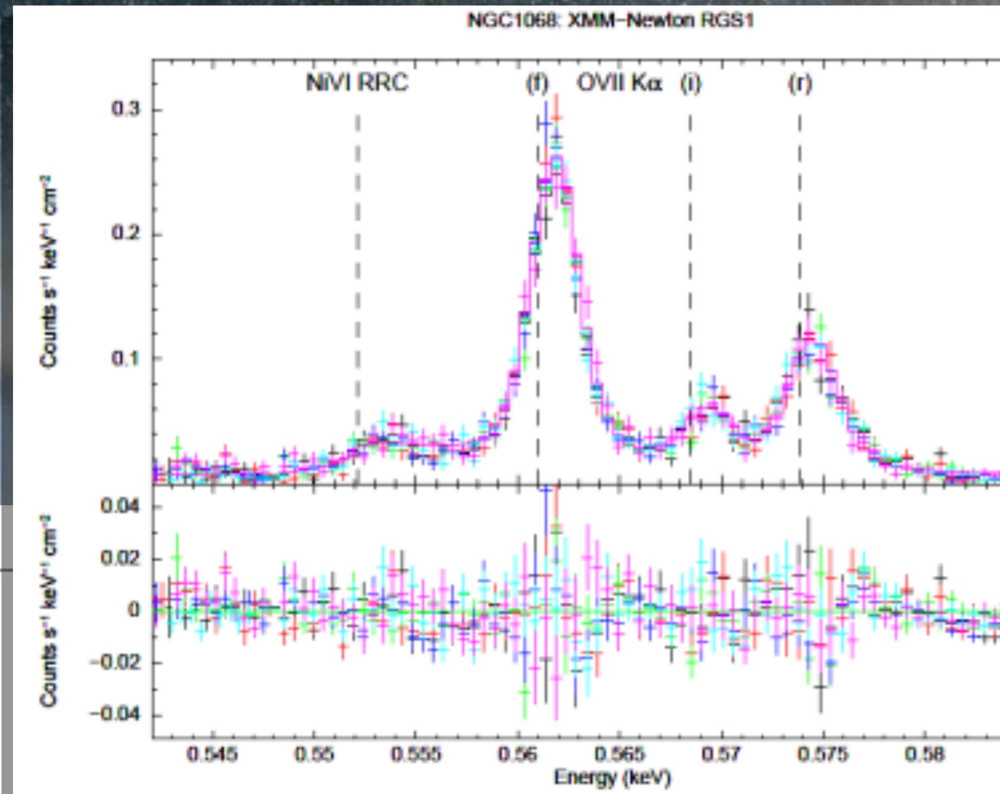
Almost 30% of the neutral Fe Kα line flux arises from regions outside the central 140 pc and is clearly extended (see also Young et al, 2001; Ogle et al., 2003)

We start our analysis checking for variability in the four XMM-*Newton* spectra of our campaign. No variability is found between them, and with respect to the spectrum taken in July 2000

The neutral Iron Kα line is constant within 5%

Although the intrinsic variability is unknown, this suggest that most of the line/reflection is produced far away

Bianchi et al., in prep.



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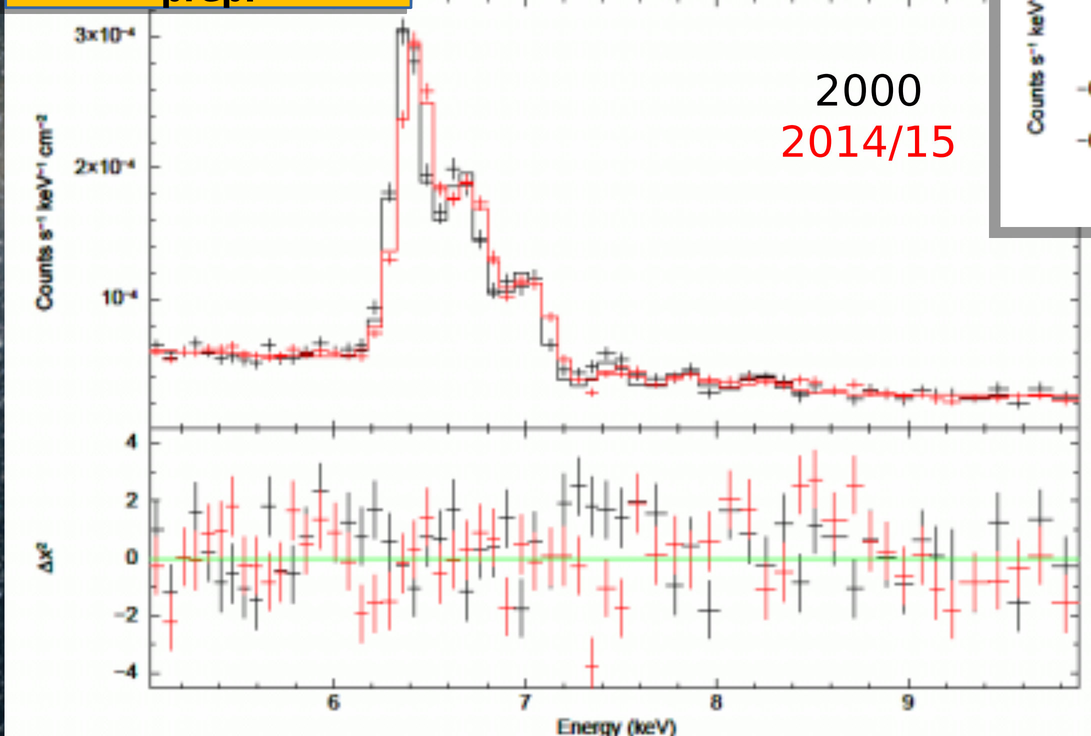
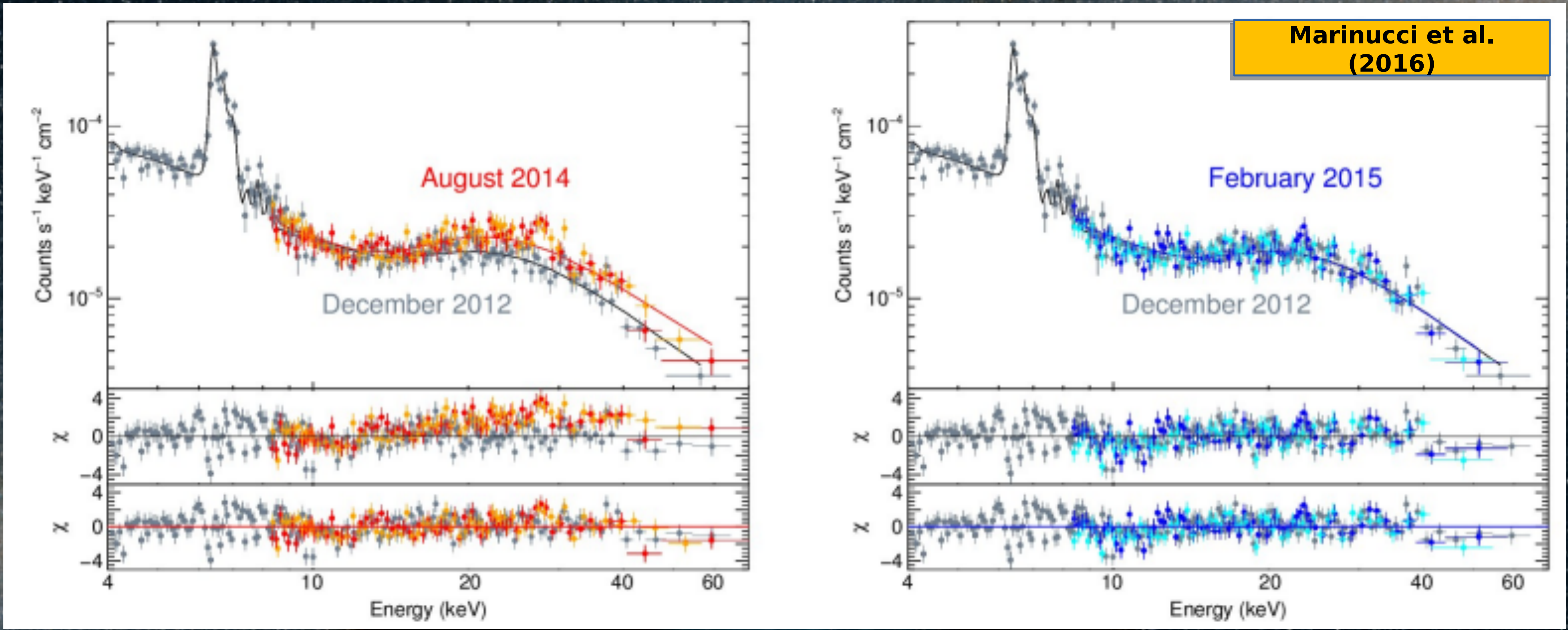


The forbidden component of the OVII Kα line triplet is constant within 1%

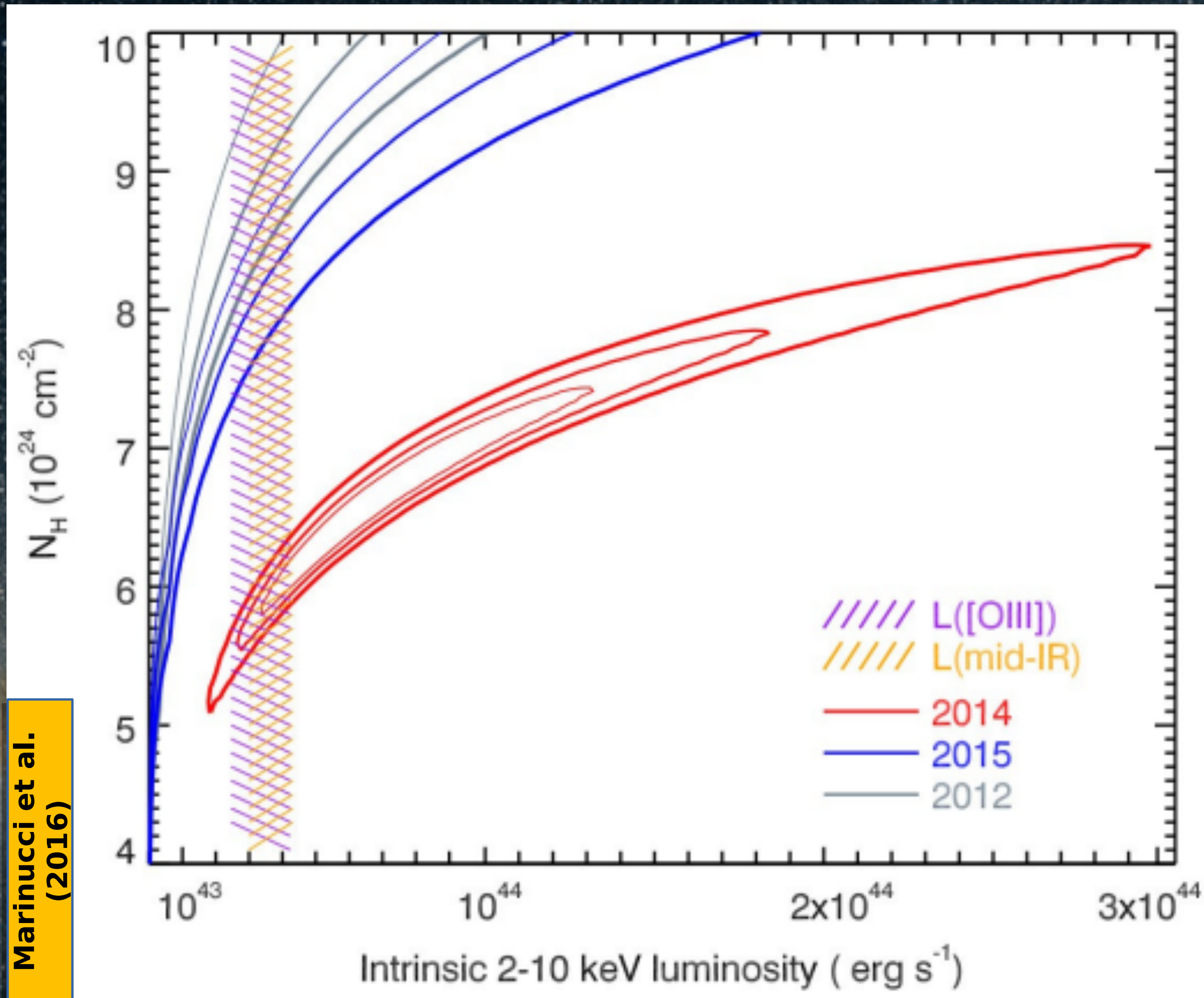
We know that it is produced in an extended emission coincident with the NLR, but e.g. NGC5548 (Detmers et al. 2009)

Above ~15 keV, a clear excess (~30%) is present in the August 2014 NuSTAR spectra!



<u>This variation strongly suggests an unveiling event in NG1068</u> due to a change of the absorbing column density along the line of sight and/or a brightening of the intrinsic continuum.

We test this scenario adopting the Bauer+14 model to fit the multi-epoch data and leaving only the primary component (N_H and flux) free to vary



The intrinsic X-ray luminosity for the three NuSTAR observations is consistent with the ones inferred using other proxies ([OIII], mid-IR) if all the spectral difference can be attributed to a change in the absorbing column density, from N_H~10^{25} cm^{-2} in 2012/2015 to N_H~6×10^{24} cm^{-2} in 2014

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We interpret the high-energy excess detected in the August 2014 NuSTAR spectra as the first unveiling event ever observed in NGC 1068, in which there is a drop in the column density along our line of sight

Other interpretations are unlikely: a variation in the Compton hump without an associated variation in the iron line requires the reflector to be almost completely self-obscured (inclination angle $> 87^\circ$)

X-ray absorption variability has been found on time scales of hours to years in several sources (e.g. Bianchi, Maiolino & Risaliti, 2015). However, thanks to the unprecedented sensitivity and broad spectral band covered by NuSTAR, this is the first time ever that a fully Compton-thick unveiling event affecting only above 10 keV is reported. This finding is another strong piece of evidence in favour of the clumpiness of the obscuring gas in AGN, and of the presence of circumnuclear material at all distance scales