Determining the torus covering factor in Compton-thick AGN with NuSTAR

Murray Brightman

DETERMINING THE COVERING FACTOR OF COMPTON-THICK ACTIVE GALACTIC NUCLEI WITH NUSTAR

M. Brightman[1,2], M. Baloković[1], D. Stern[3], P. Arévalo[4,5], D. R. Ballantyne[6], F. E. Bauer[4,7,8], S. E. Boggs[9], W. W. Craig[9,10], F. E. Christensen[11], A. Comastri[12], F. Fuerst[1], P. Gandhi[13,14], C. J. Hailey[15], F. A. Harrison[1], R. C. Hickox[16], M. Koss[17], S. LaMassa[18], S. Puccetti[19,20], E. Rivers[1], R. Vasudevan[21], D. J. Walton[3,1], and W. W. Zhang[22]

Brightman et al, 2015, ApJ 805 41

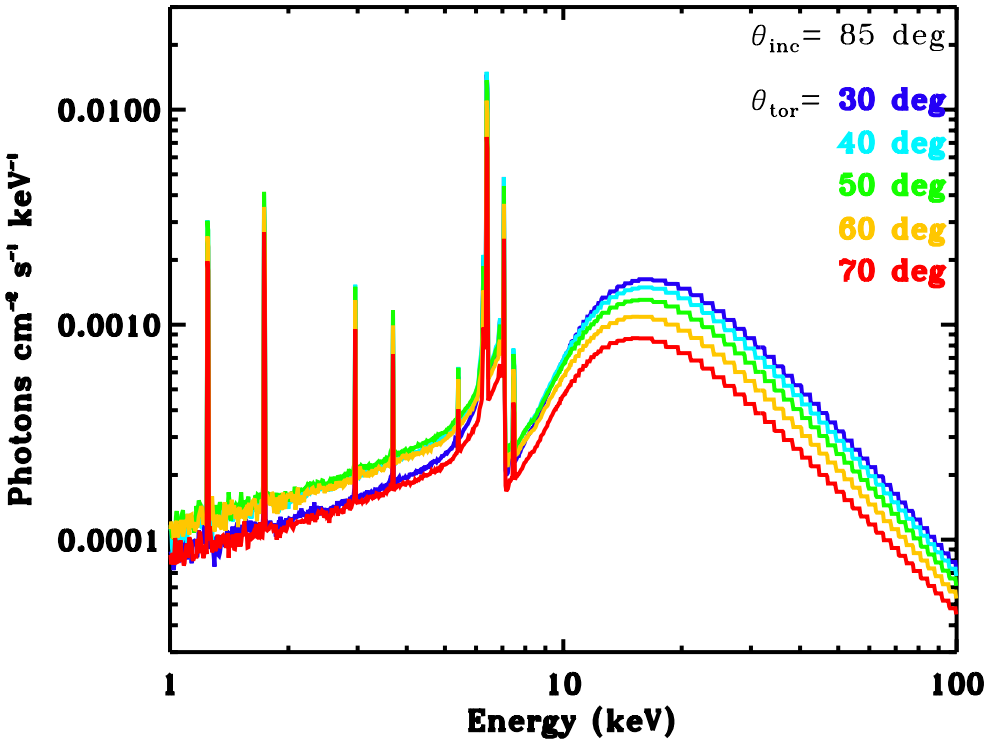
What can we learn about the AGN torus with NuSTAR?

Torus covering factors

Several X-ray torus models in the literature (Ghisellini et al 1994)… Ikeda et al (2009), Murphy & Yaqoob (2009), Brightman & Nandra (2011), Li & Liu (2014)

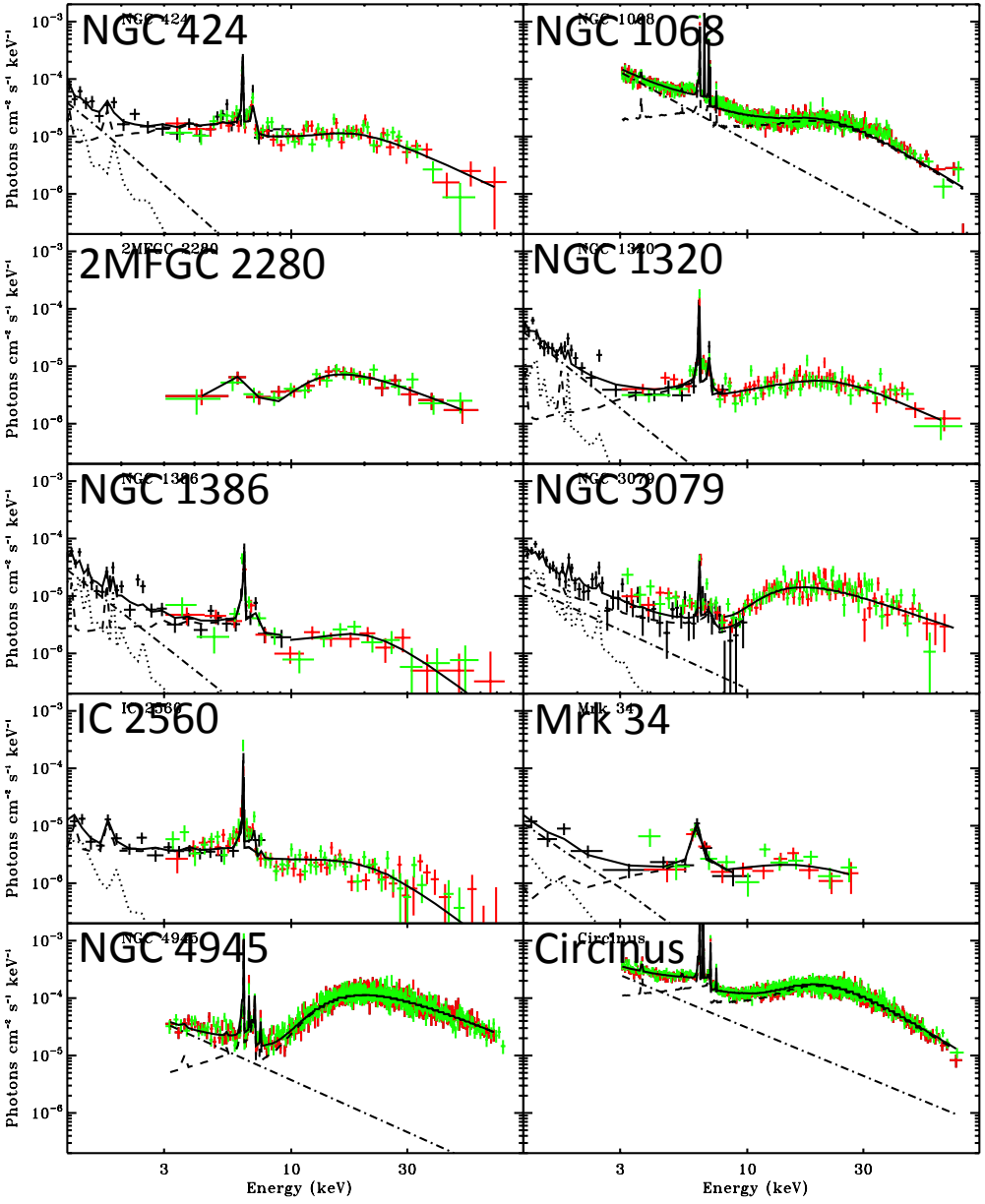
Models employ Monte-Carlo methods to simulate X-ray reprocessing in a torus geometry. Include Compton scattering, photo-electric absorption and Fe fluorescence.

X-ray spectra of CT AGN dependent on the torus opening angle (covering factor), especially >10 keV ➔ NuSTAR



Brightman & Nandra (2011). Only public model to include torus opening angle as a free parameter

Spectral fitting results



BN11 model fitted to NuSTAR+XMM spectra of 10 local CT AGN

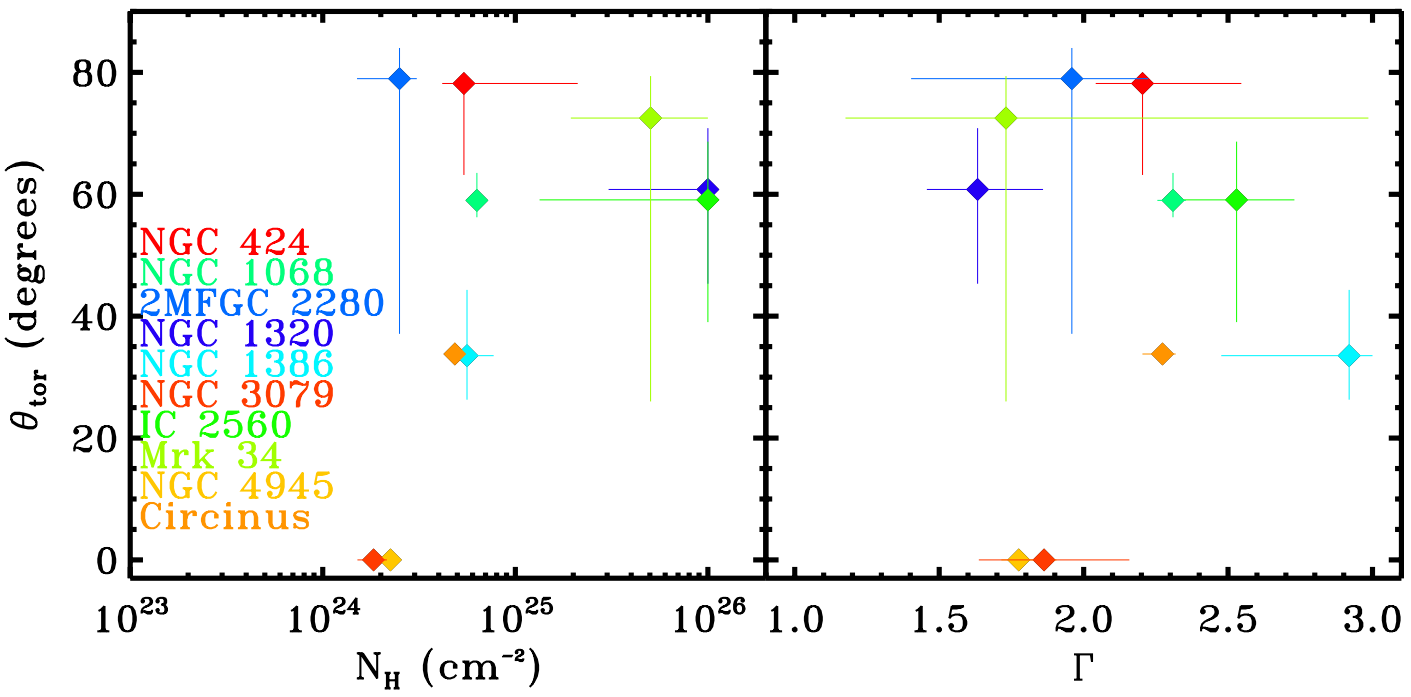
Covering a large range in luminosity $10^{41.5}$-10^{44} ergs s^{-1}

N_H=10^{24}-10^{26} cm^{-2}

See also Arevalo+14, Balokovic+14, Bauer+15, Gandhi+14, Puccetti+14

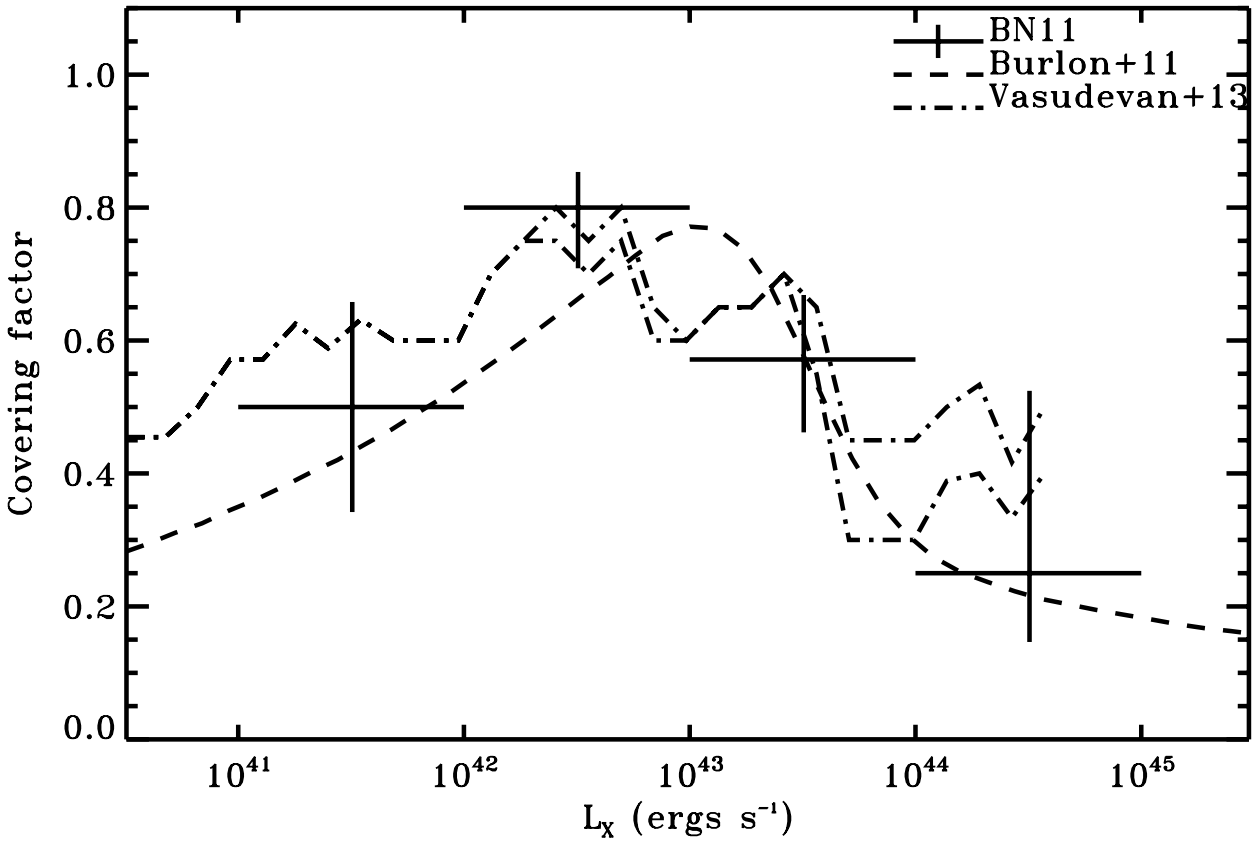
See also Kawamuro+13 who compute θ_{tor} using Ikeda+09 model on Suzaku data.

Spectral fitting results



A wide range of opening angles are derived from the X-ray spectral fits

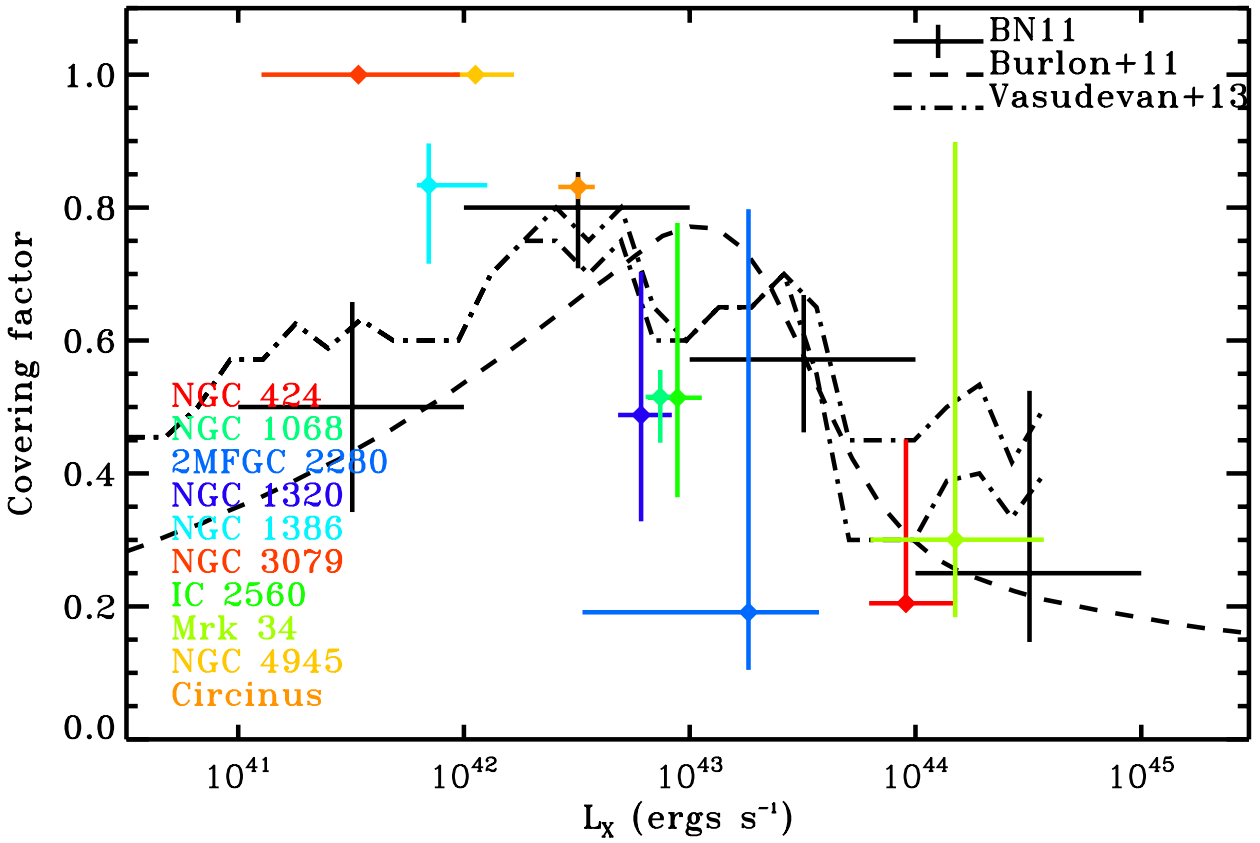
How do the covering factors depend on L_X?



See also:
Buchner+15,
Georgakakis+15

The X-ray obscured fraction (average covering factor) is a strong function of L_X. How do the derived covering factors compare?

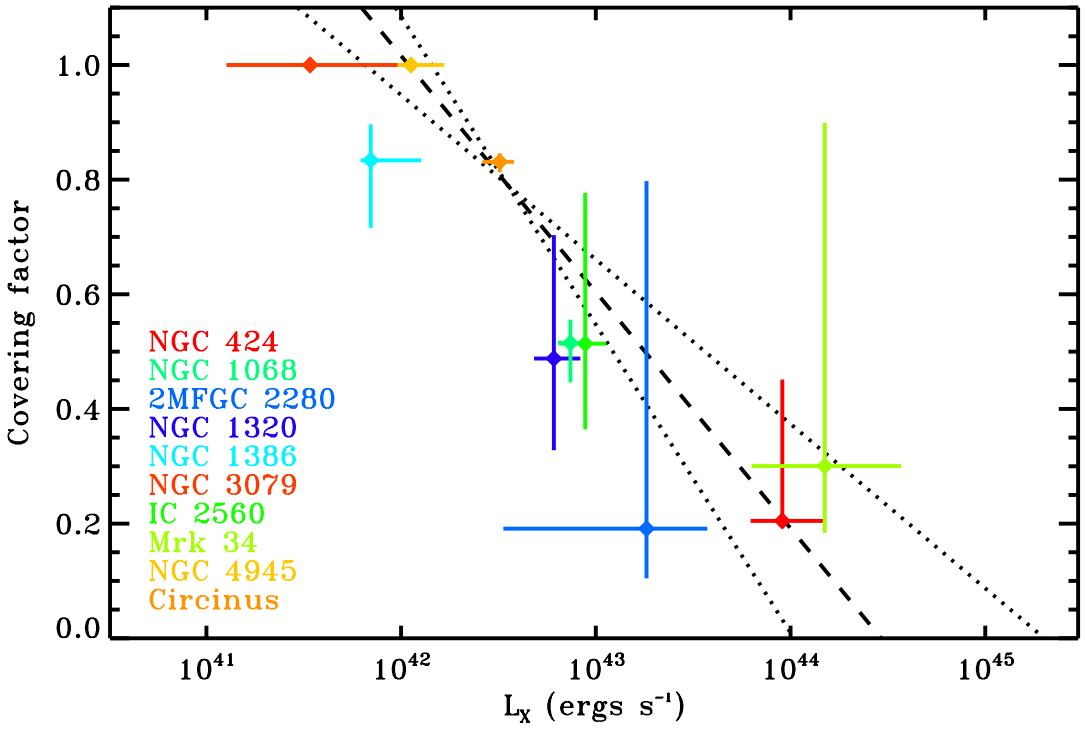
How do the covering factors depend on L_X?



The covering factors compare well, showing a decrease with increasing L_X (receding torus). Possible tension at low L_X.

How do the X-ray covering factors compare to IR estimates?

Several works have applied IR torus models to many of our sample (e.g. Alonso-Herrero+11, Lira+13 and Ichikawa+15)



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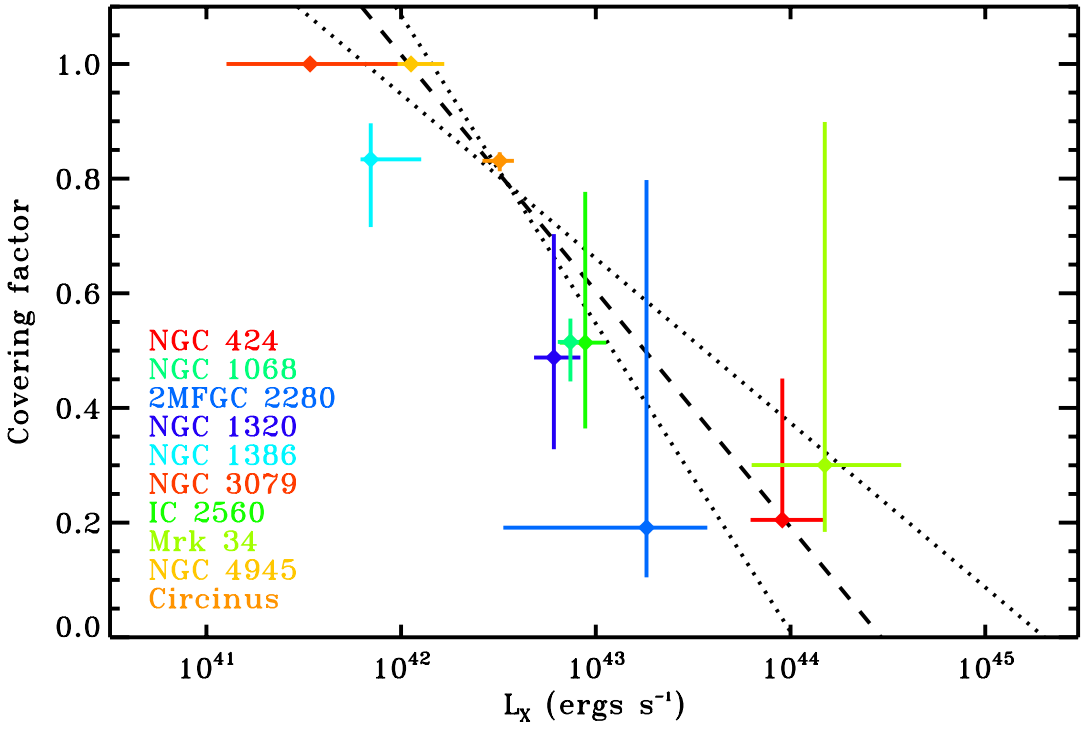
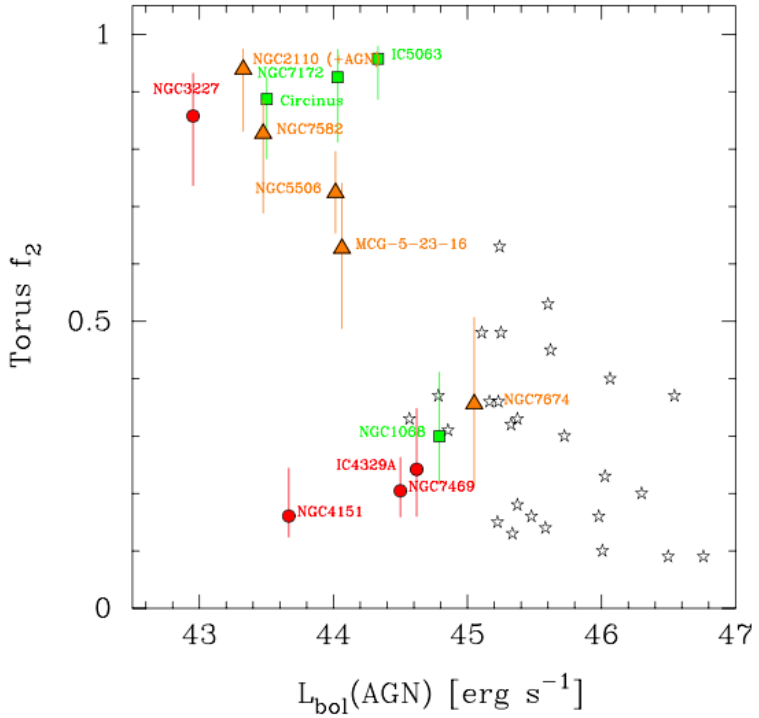


Alonso-Herrero+11 used IR clumpy torus models of Nenkova+08



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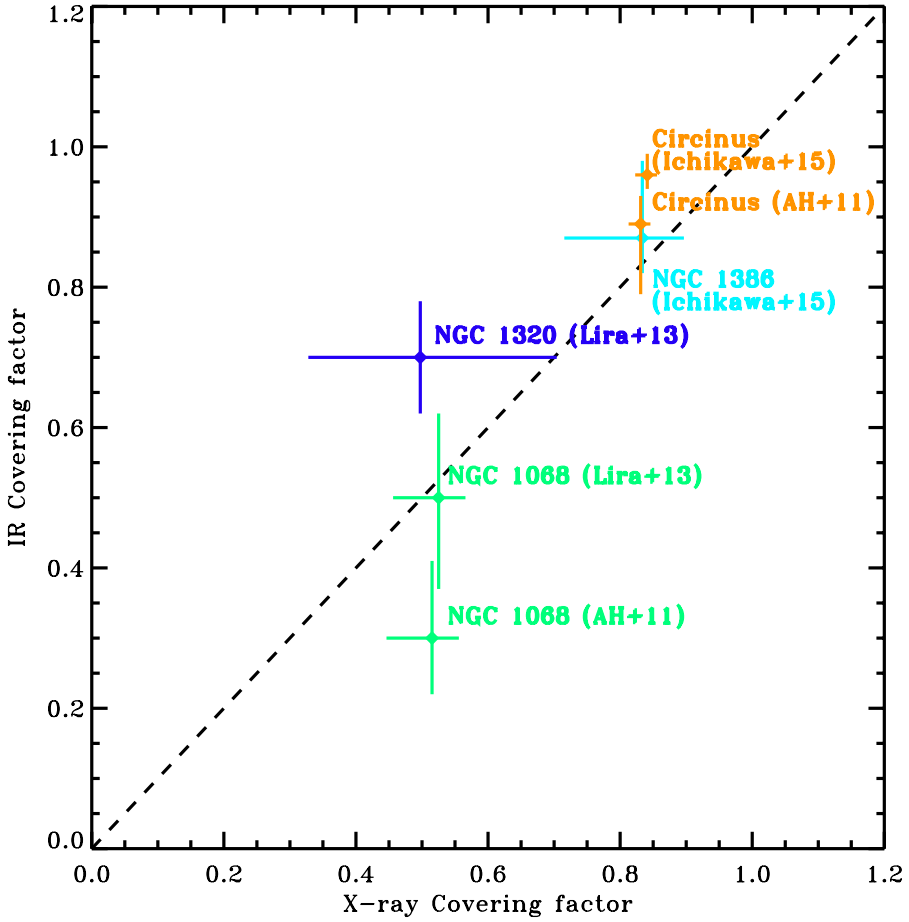
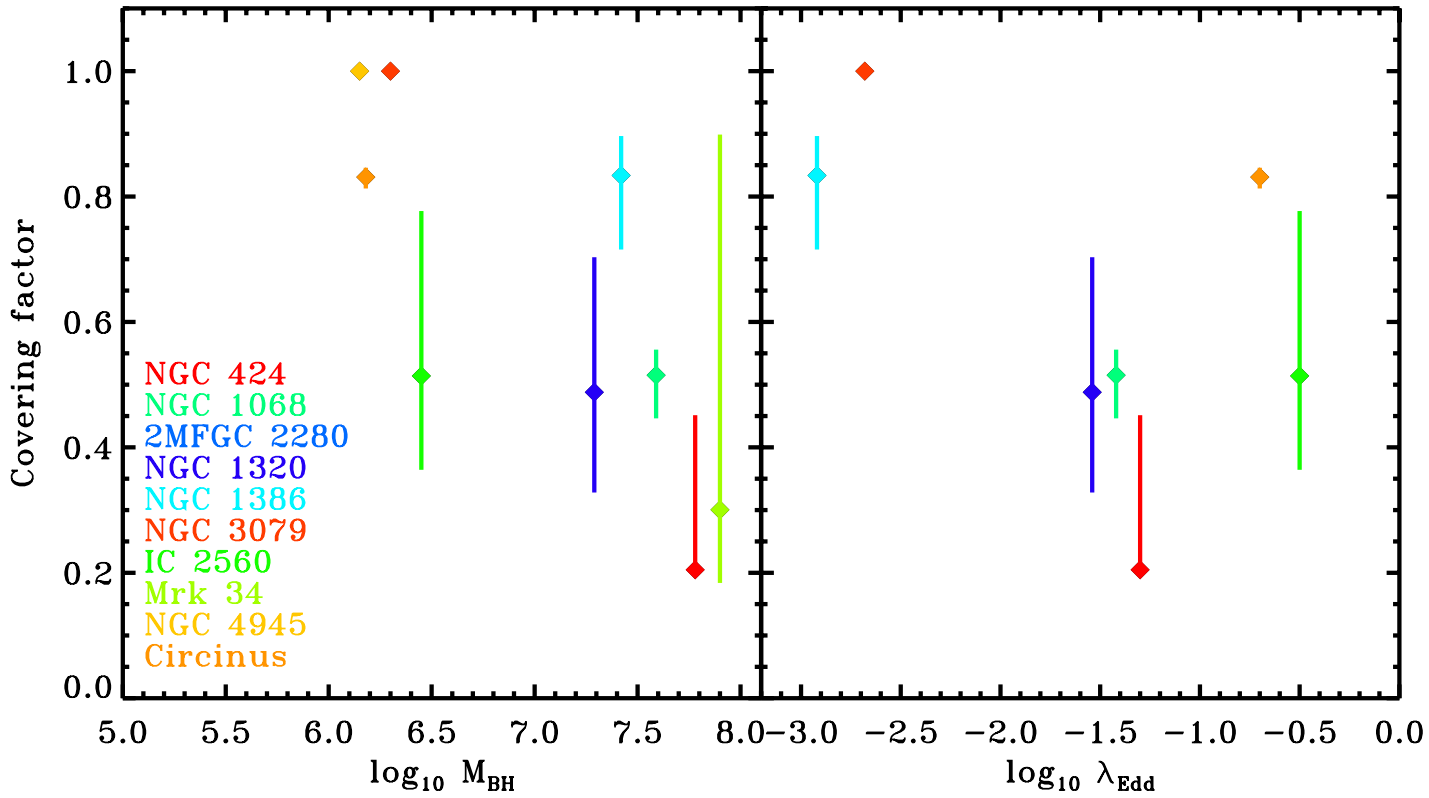


X-ray and IR estimates in good agreement inspite of difference in smooth/clumpy models

See also Davide Lena's poster on NGC 1386 – good agreement from ionisation cone.

How do the covering factors depend on accretion parameters?



- Dependence on black hole mass?
- Bimodel dependence on Eddington ratio?

Conclusions

- NuSTAR observes a wide variety of spectral shapes above 10 keV for local CTAGN, interpreted as changes in the covering factor of the torus.
- The derived covering factors agree well with the local obscured fraction from X-rays.
- The derived covering factors determined from X-ray torus models agree remarkably well with IR estimates, despite the differing clumpy/ smooth torus assumptions.