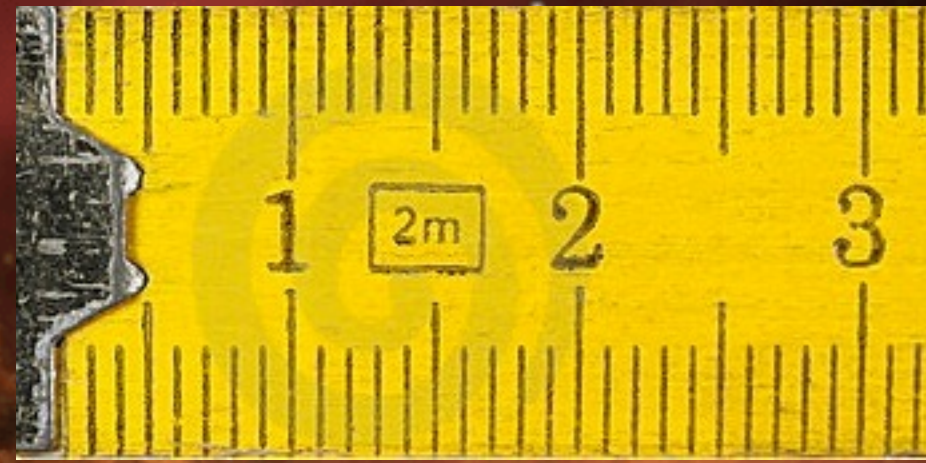


X-ray variability as an "AGN ruler"

featuring: "The Markarian 3 case"

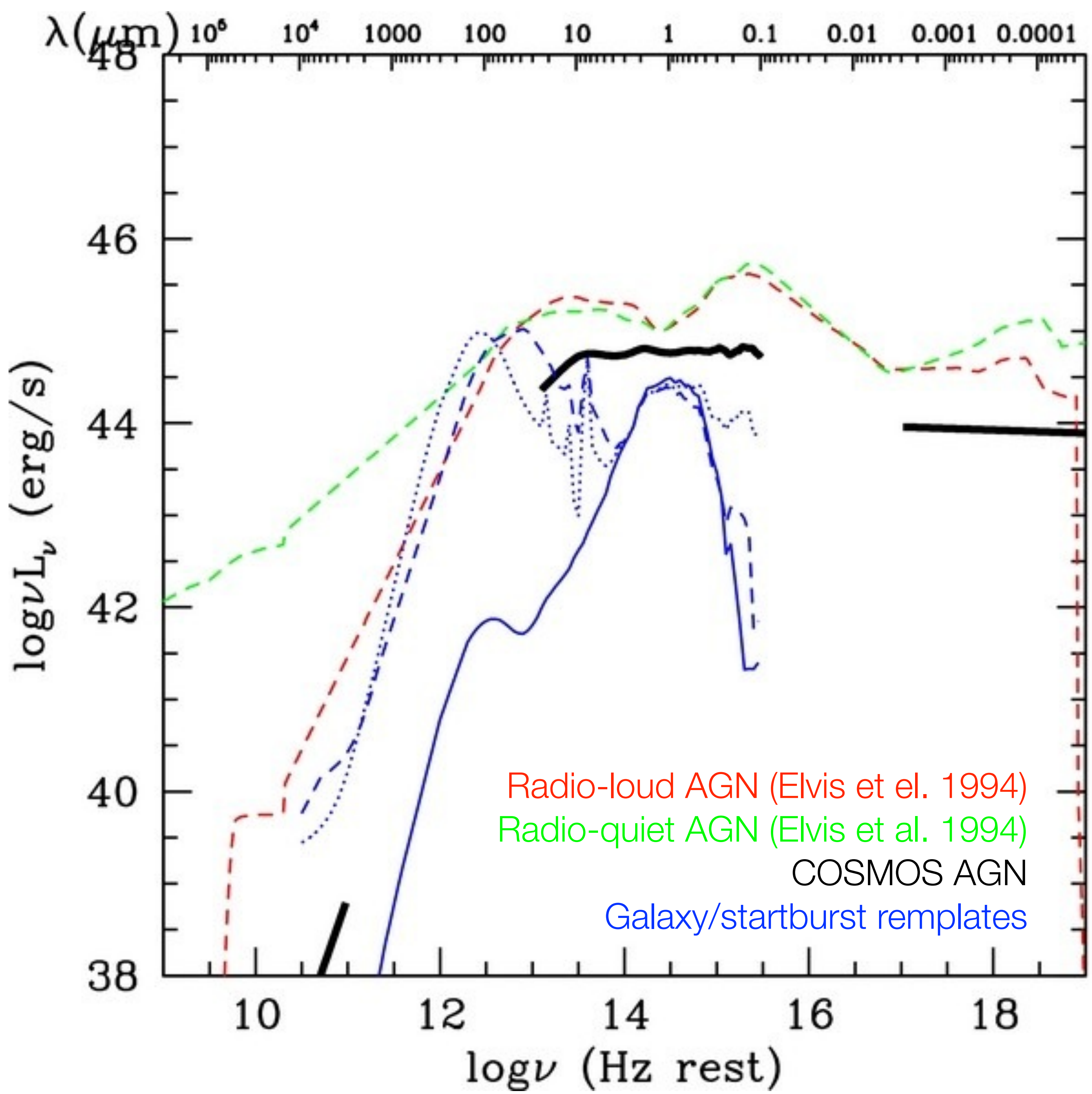
Matteo Guainazzi
ASTRO-H Science Operation Team (SOT) - ISAS/JAXA
ASTRO-H ESA Science Operation Center (SOC) - ESA/ESAC

AGN Spectral Energy Distribution

Ho et al., 1995, ApJ

Elvis et al., 2012, ApJ, 759. 6; Detmers 2011, A&A, 534, A37

Talk question: how and where are these components emitted?



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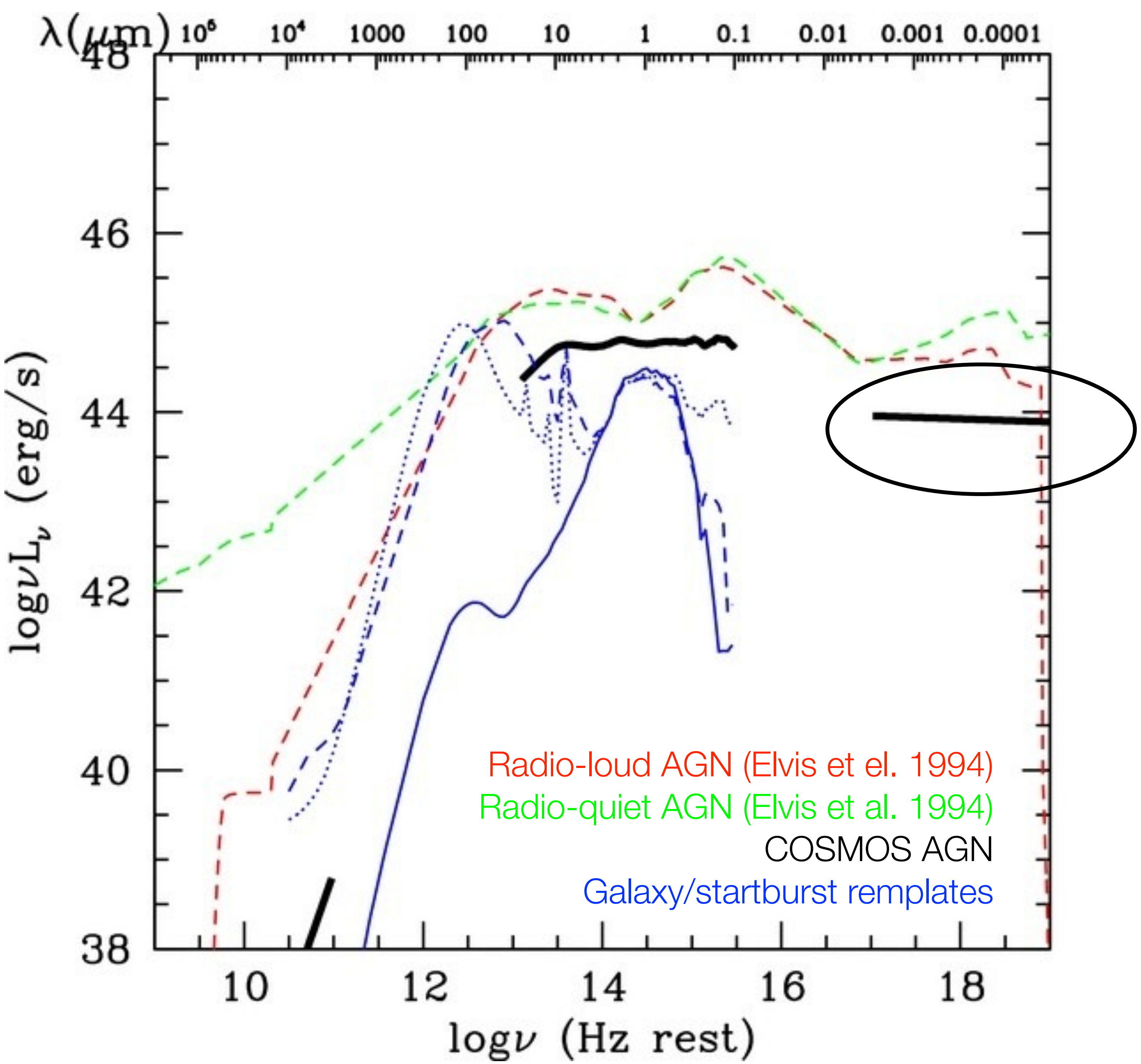

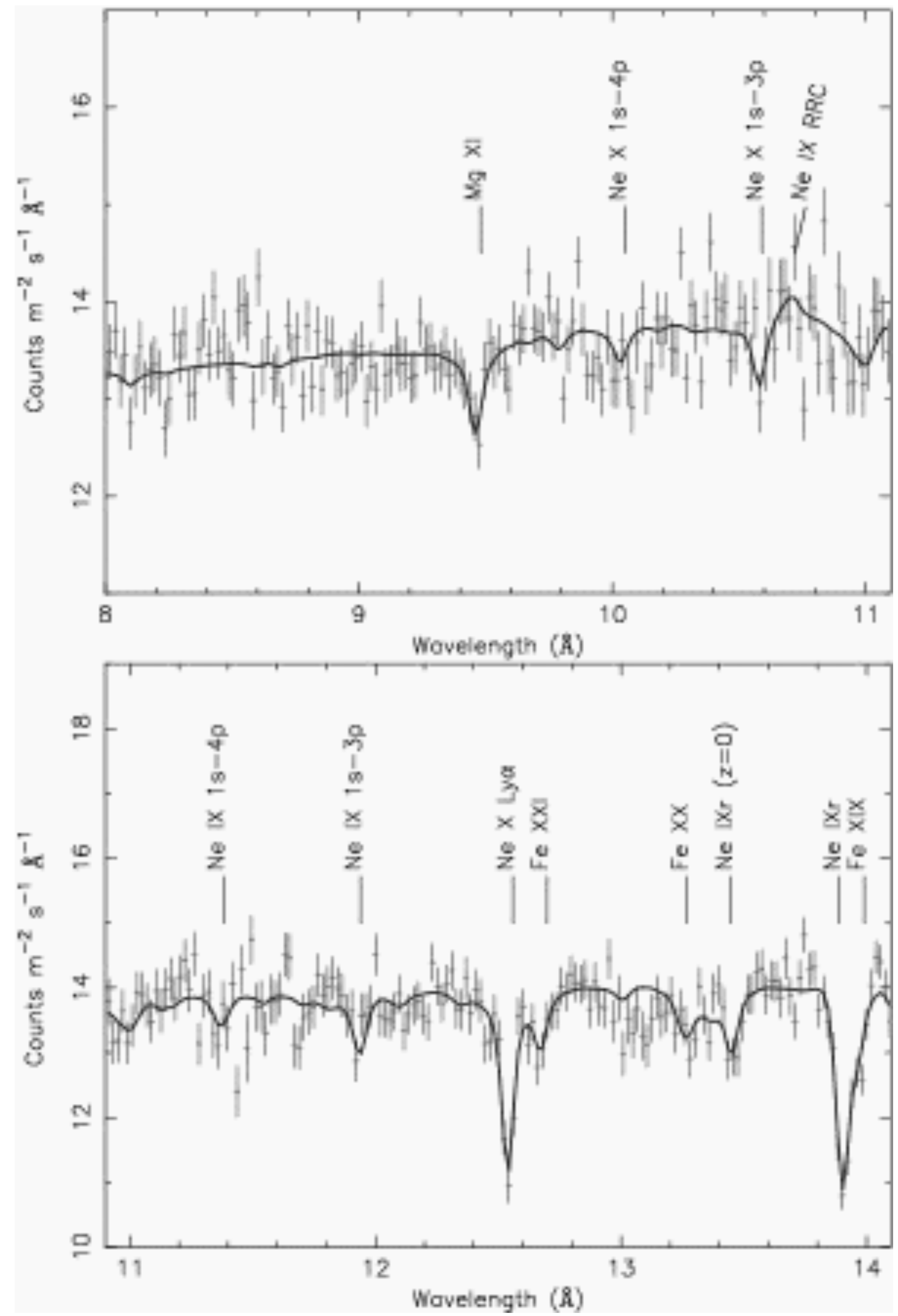

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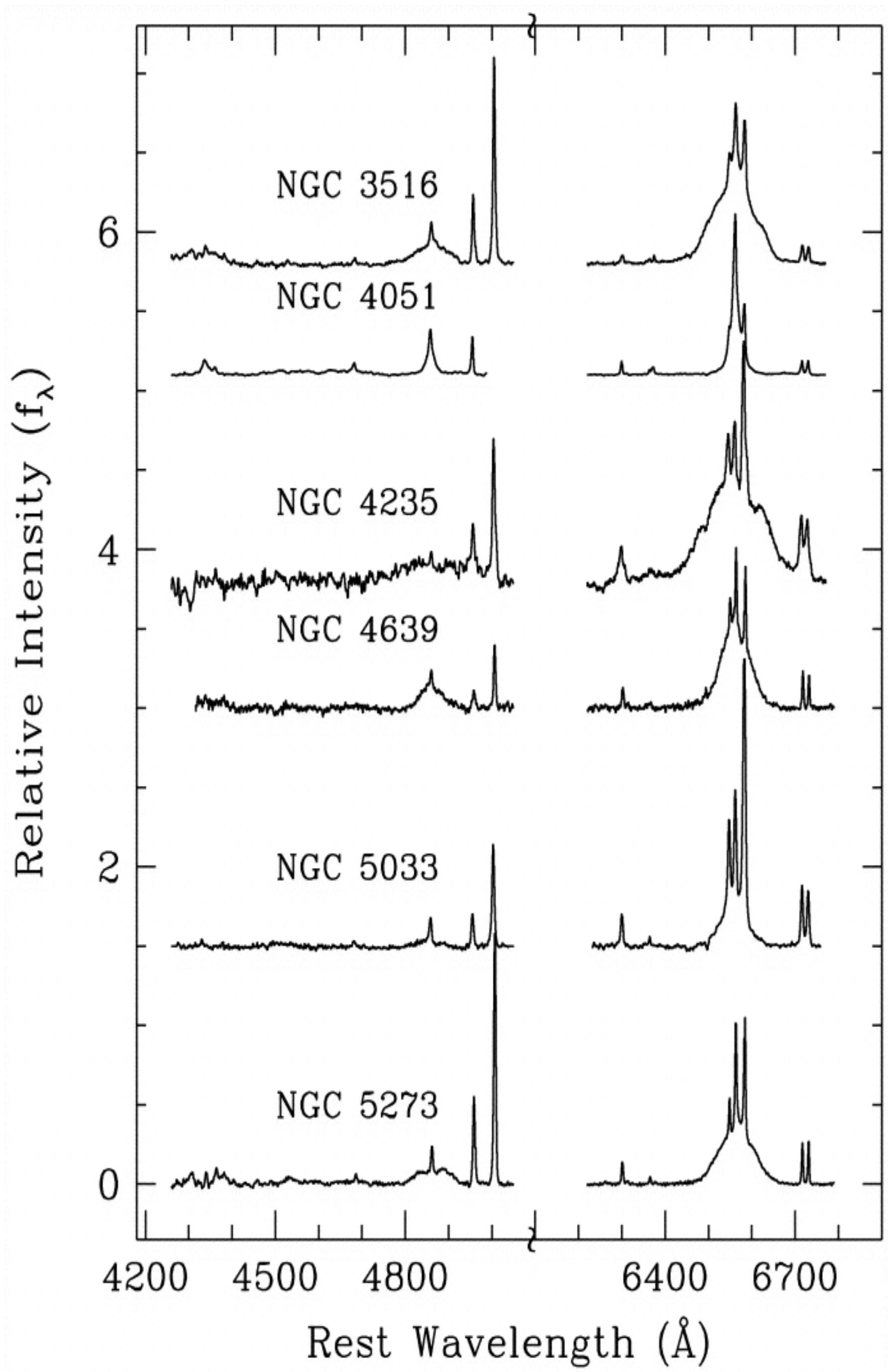
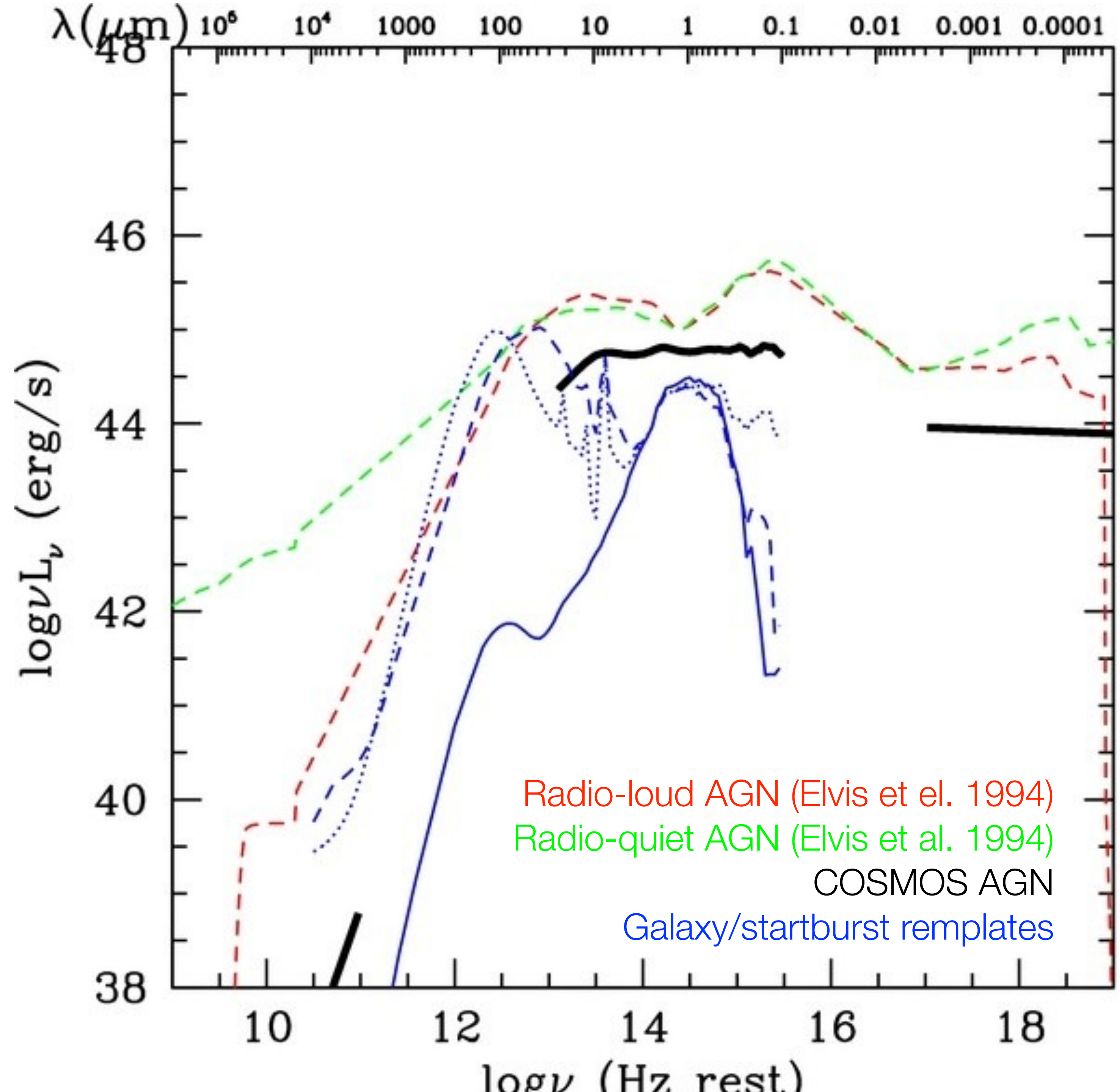




Outline

Subject: the innermost parsec around the accretion black hole

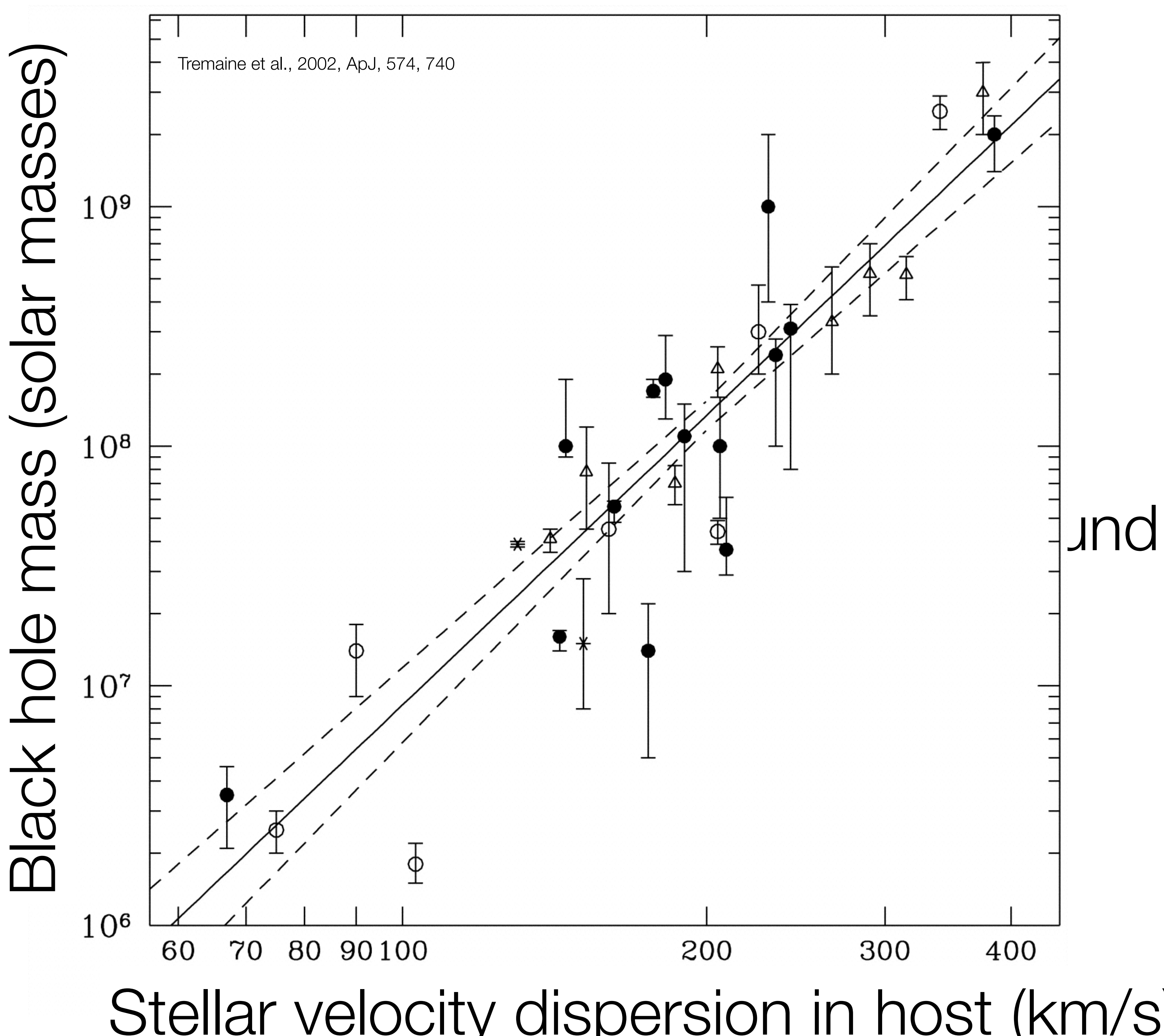
- Estimates of spatial scales in AGN: optical, IR
- Estimates of spatial scales in AGN: X-ray methods
- New results: the monitoring campaign on Markarian 3
- New perspectives with ASTRO-H

Why is this important?

- AGN innermost parsec structure
- AGN feeding from the host galaxy
- AGN feed-back to the host galaxy
- Synthesis models of the Cosmic X-ray Background

Why is this important?

- AGN inr
- AGN fee
- AGN fee
- Synthes … und



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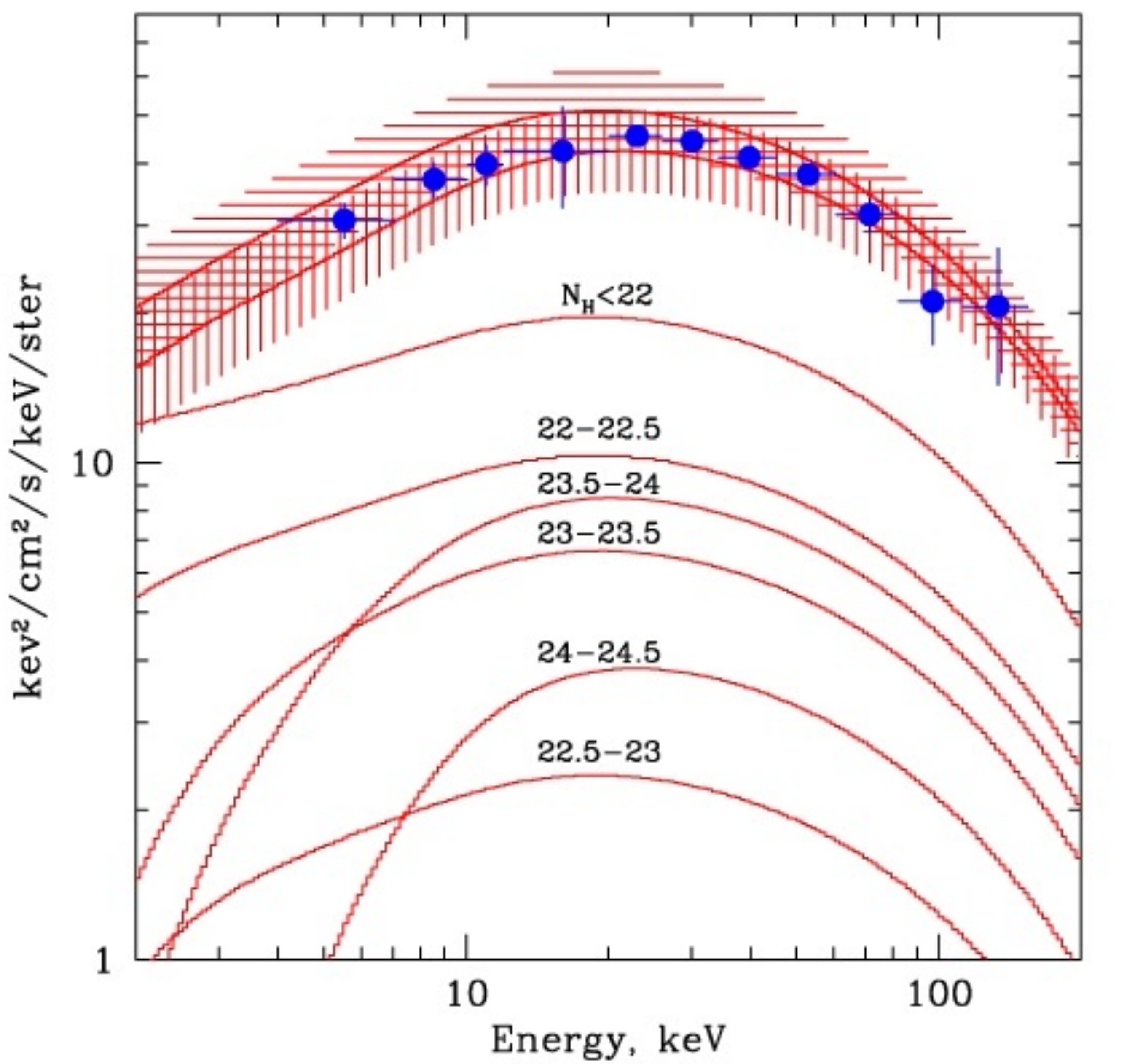
Sazonov et al., 2007, 462, 57



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How to determine spatial scales in AGN

- optical imaging: ~10^2 pc (Note: radio imaging ignored in this talk)
- IR interferometry: ~10 pc
- IR reverberation: ~1 pc
- optical lines reverberation: ~10^{-1}pc
- X-ray absorption variability: ~10^{-1}-10 pc
- X-ray reverberation: ~10^{-4} pc (~10 r_g)
- optical/X-ray μlensing: ~10^{-2}/10^{-4} pc (~10^2/10 r_g)
- X-ray continuum variability: ~10^{-4} pc (~10 r_g)

[r_g=gravitational radius]

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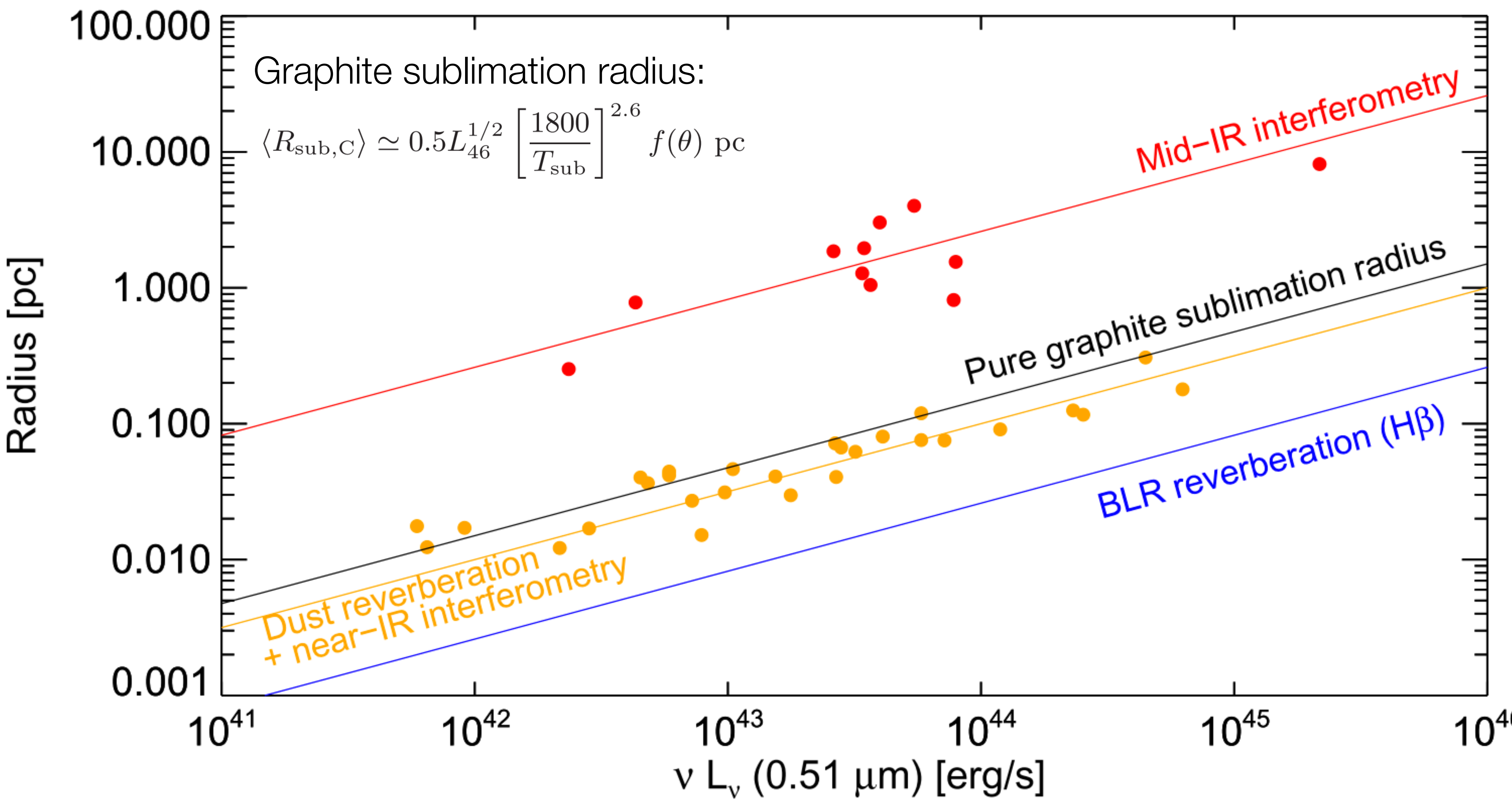
Reverberation+(IR) interferometry

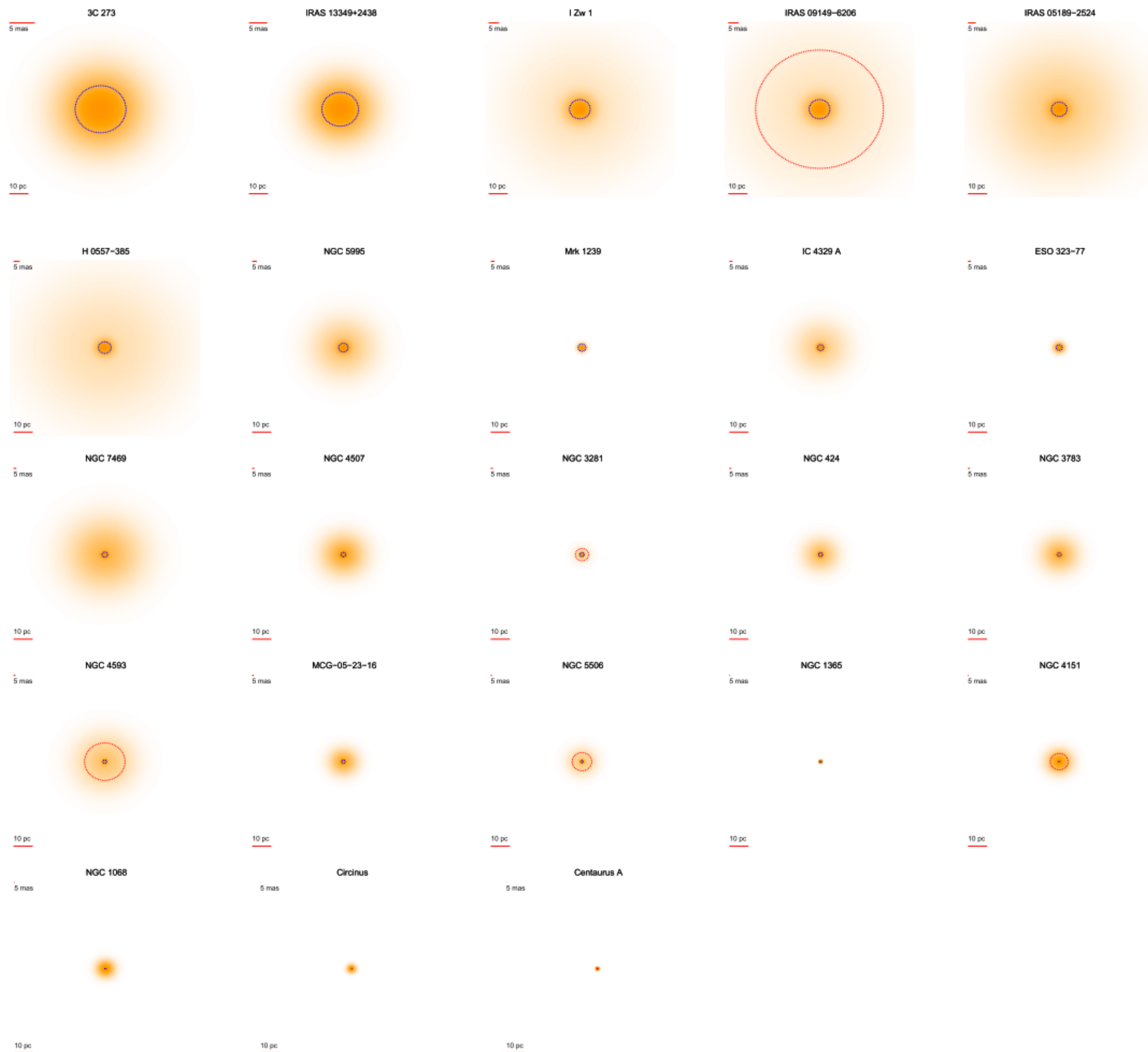
Burtscher et al., 2015, A&A, 558, A8149



Dust shape (IR interferometry)

Burtscher et al., 2013, A&A, 558, 149

Tristram et al., 2014, A&A, 563, 82



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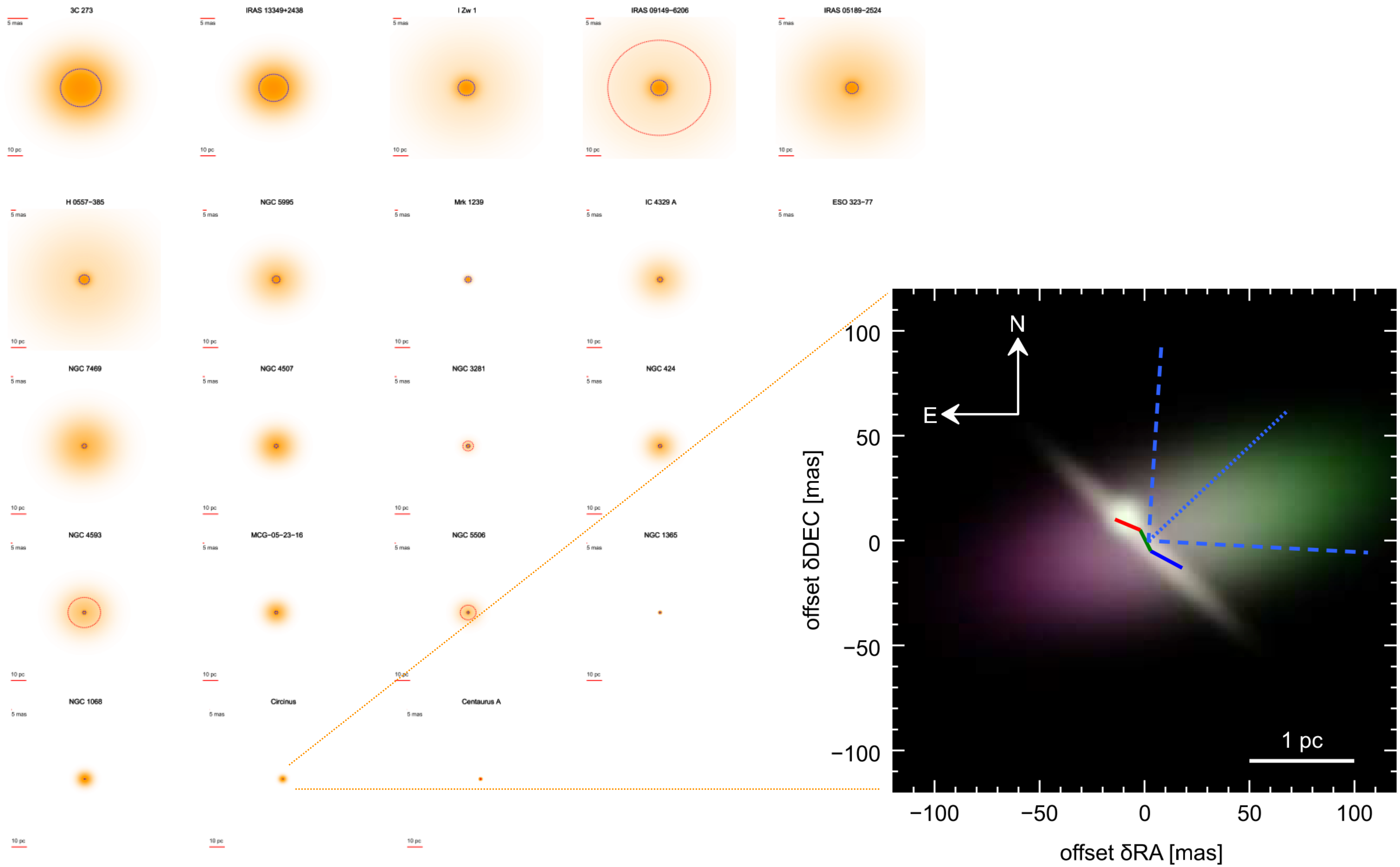

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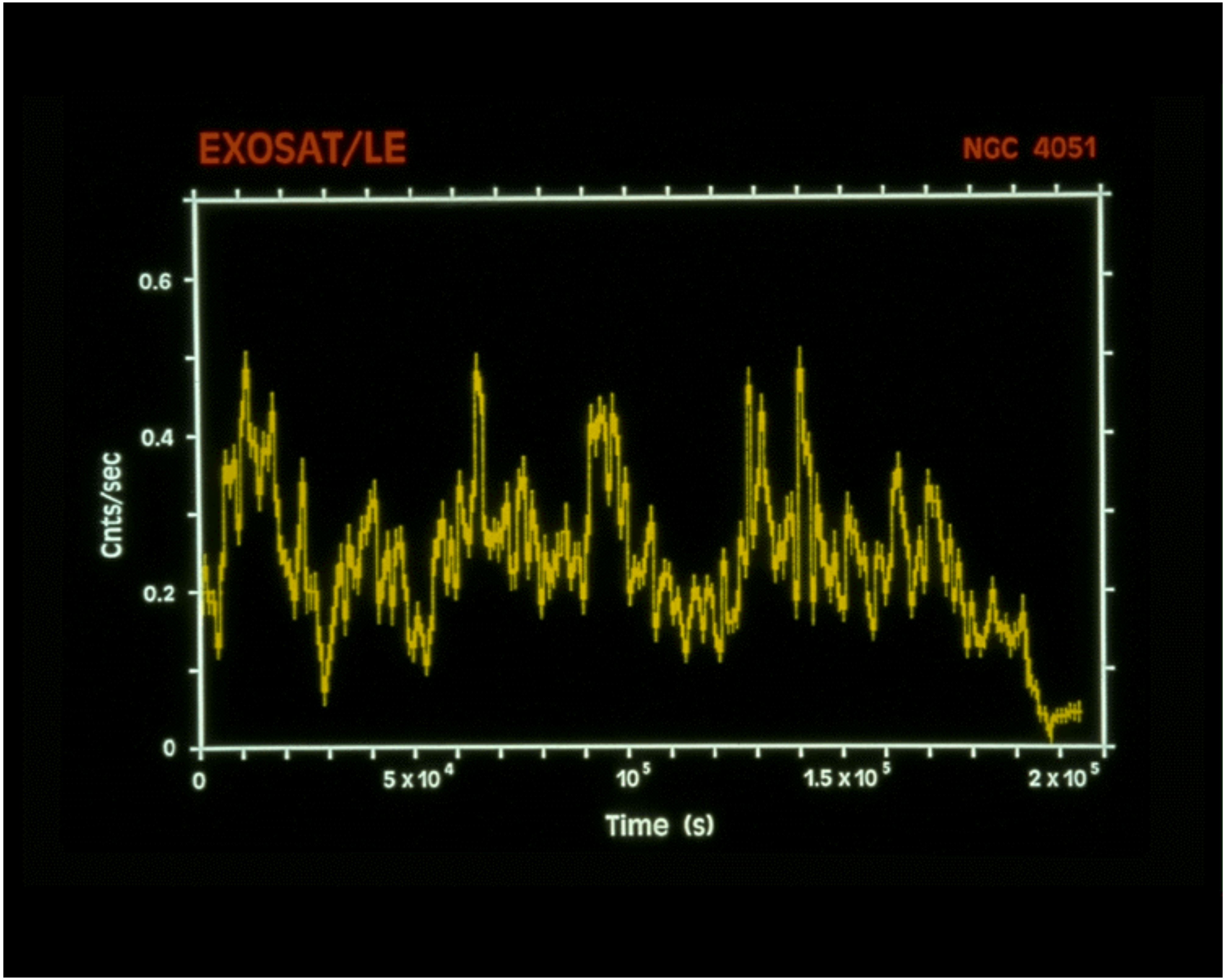
X-rays: a very compact corona

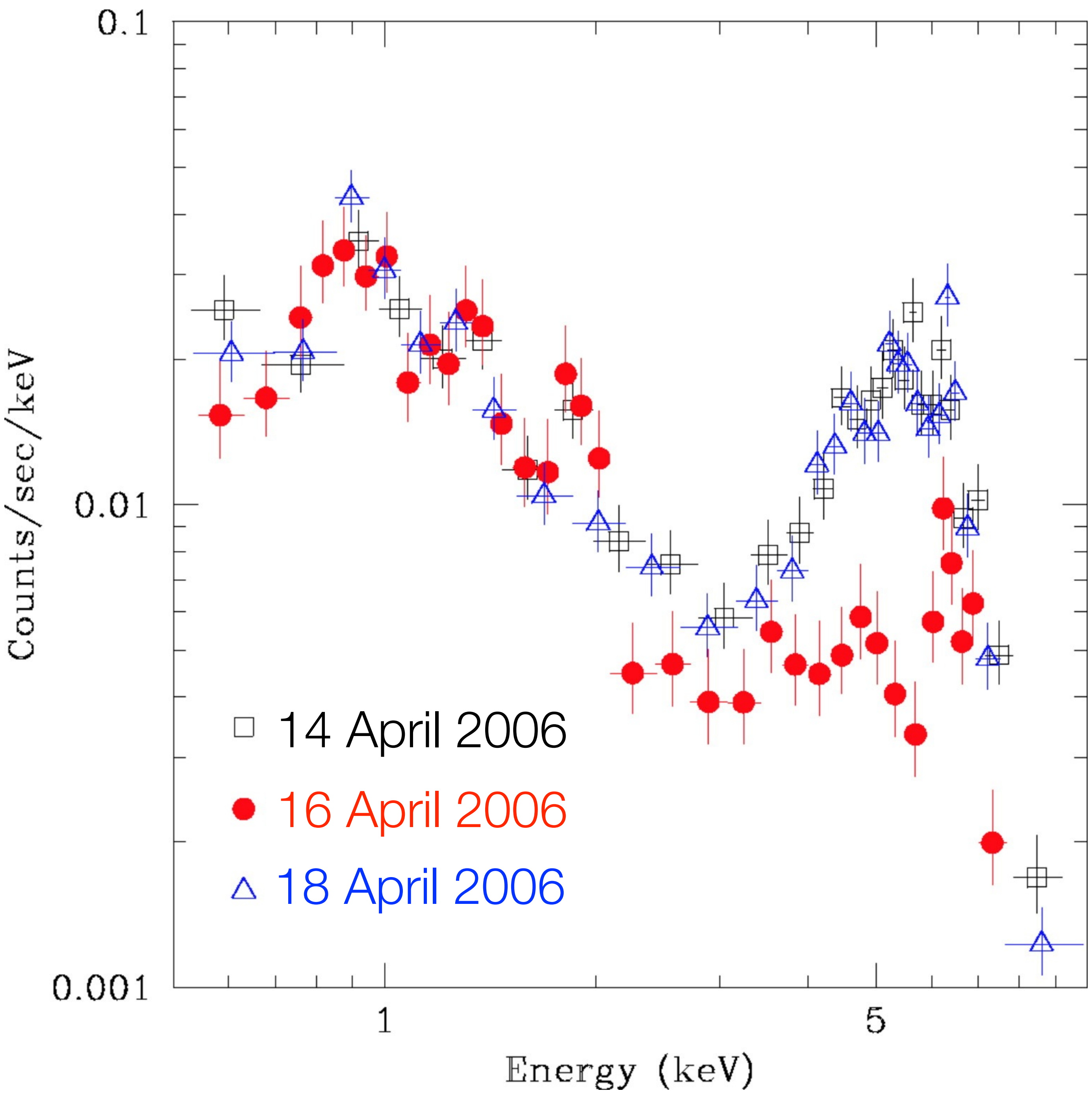
Lawrence et al., 1987, Nat, 325, 694; Barr & Mushotzky, 1986, Nat, 320, 421

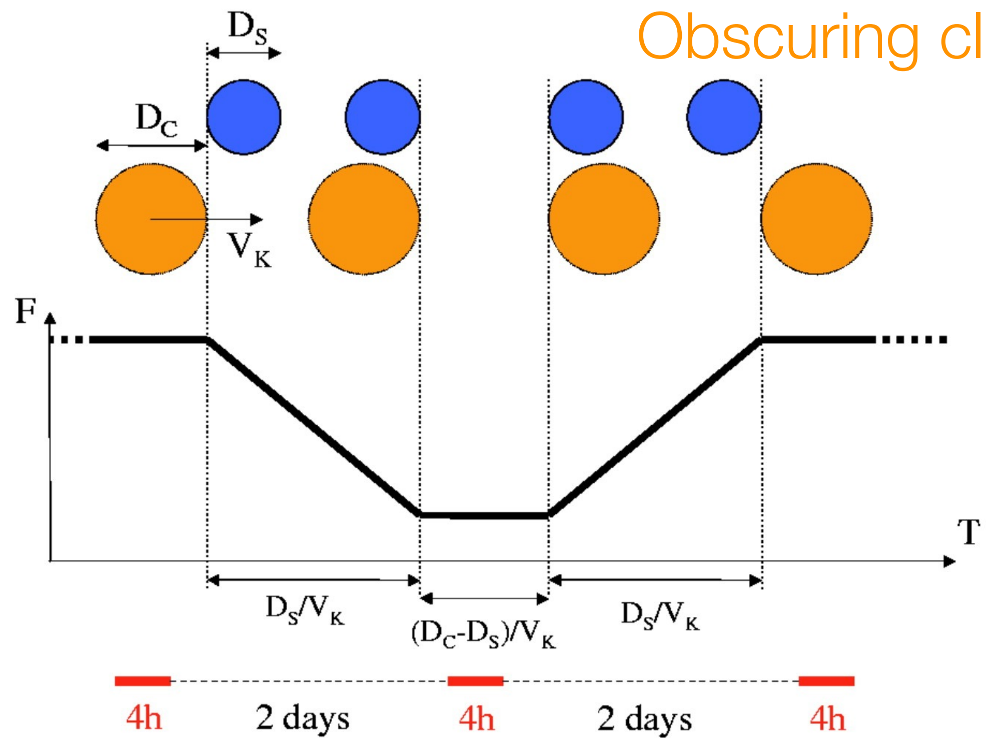


Occultation by "cold" clouds

Risaliti et al., 2007, ApJ, 659, L111

NGC1365/Chandra



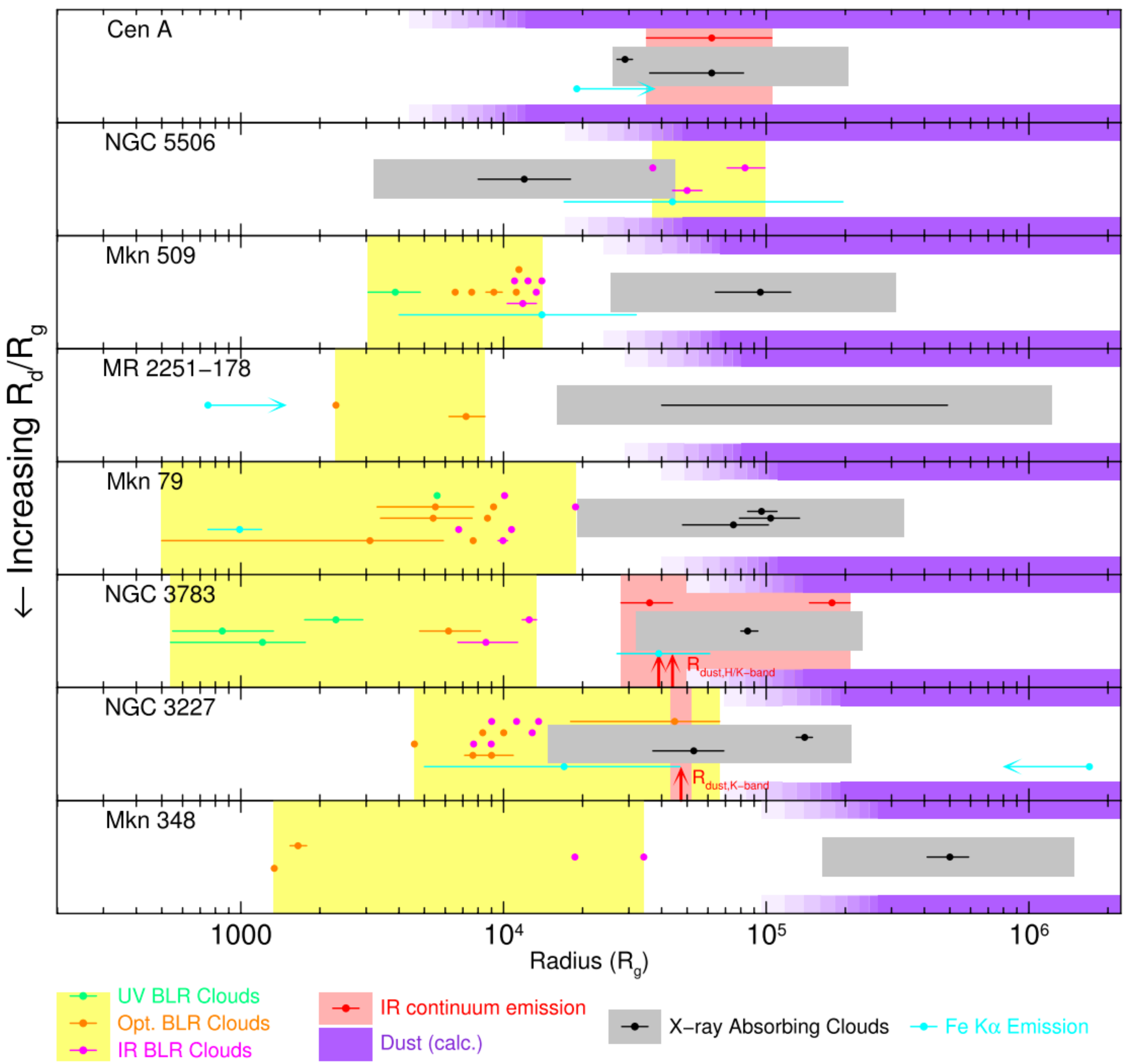


Assuming a cloud in: a) Keplerian motion; b) virial turbulent motion; c) ionization equilibrium with the AGN:

- Source Linear size D~$10^{13\text{-}14}$ cm
- Distance from the AGN d~10^{-1} pc

Occultation event statistics

Markowitz et al,. 2014, MNRAS, 439, 1403



8 AGN with occultation events in the RXTE archive (~270 years in the AGN life)

BLR clouds

IR continuum

Dust (0.4-1 x sublimation radius, R_d)

X-ray clouds

Time-dependent photo-ionisation

ionisation parameter (measured)

$$\xi = \frac{L}{nr^2}$$

ionising luminosity (observable)

unknowns: density & distance

Time-dependent photo-ionisation

ionisation parameter (measured)

ionising luminosity (observable)

$$\xi = \frac{L}{nr^2}$$

unknowns: density & distance

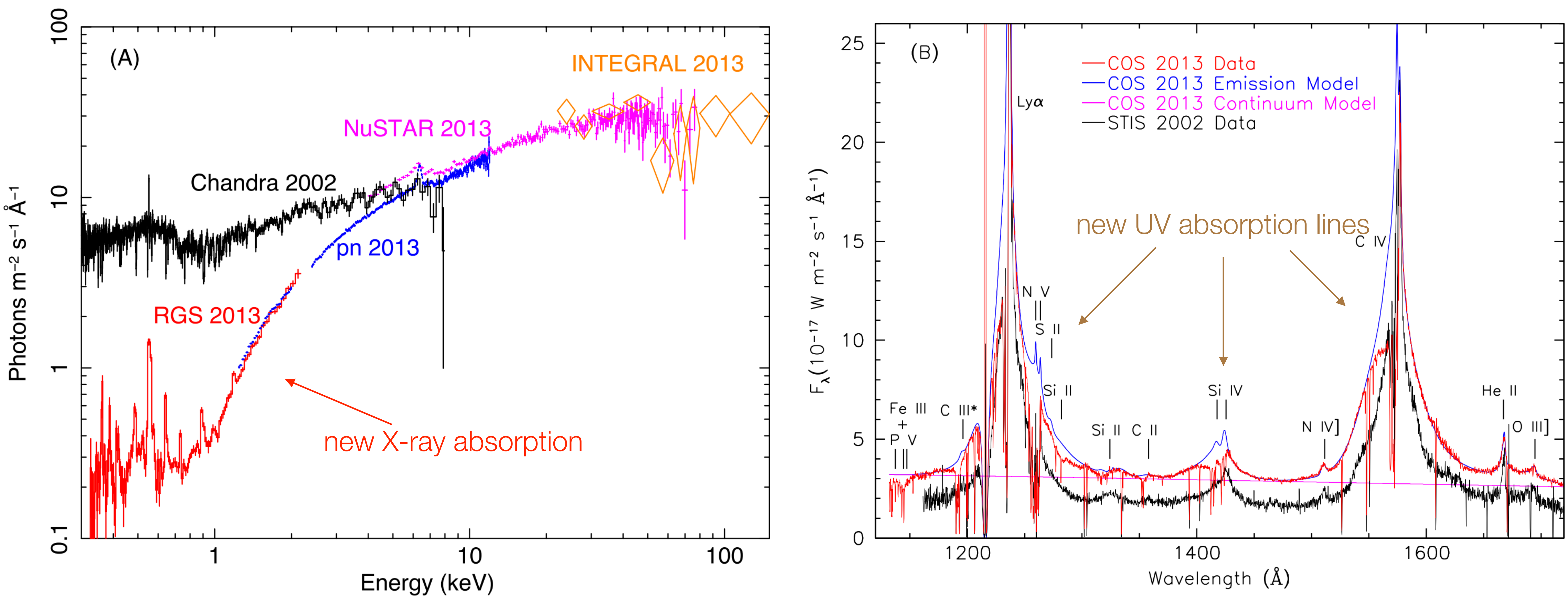
recombination time

$$t_2^{X^i} = \frac{1}{\alpha_{\mathrm{rec}}(X^i,\ T_e)n_e}$$

BLR/torus winds: NGC5548

Kaastra et al., 2014, Science, 345, 74

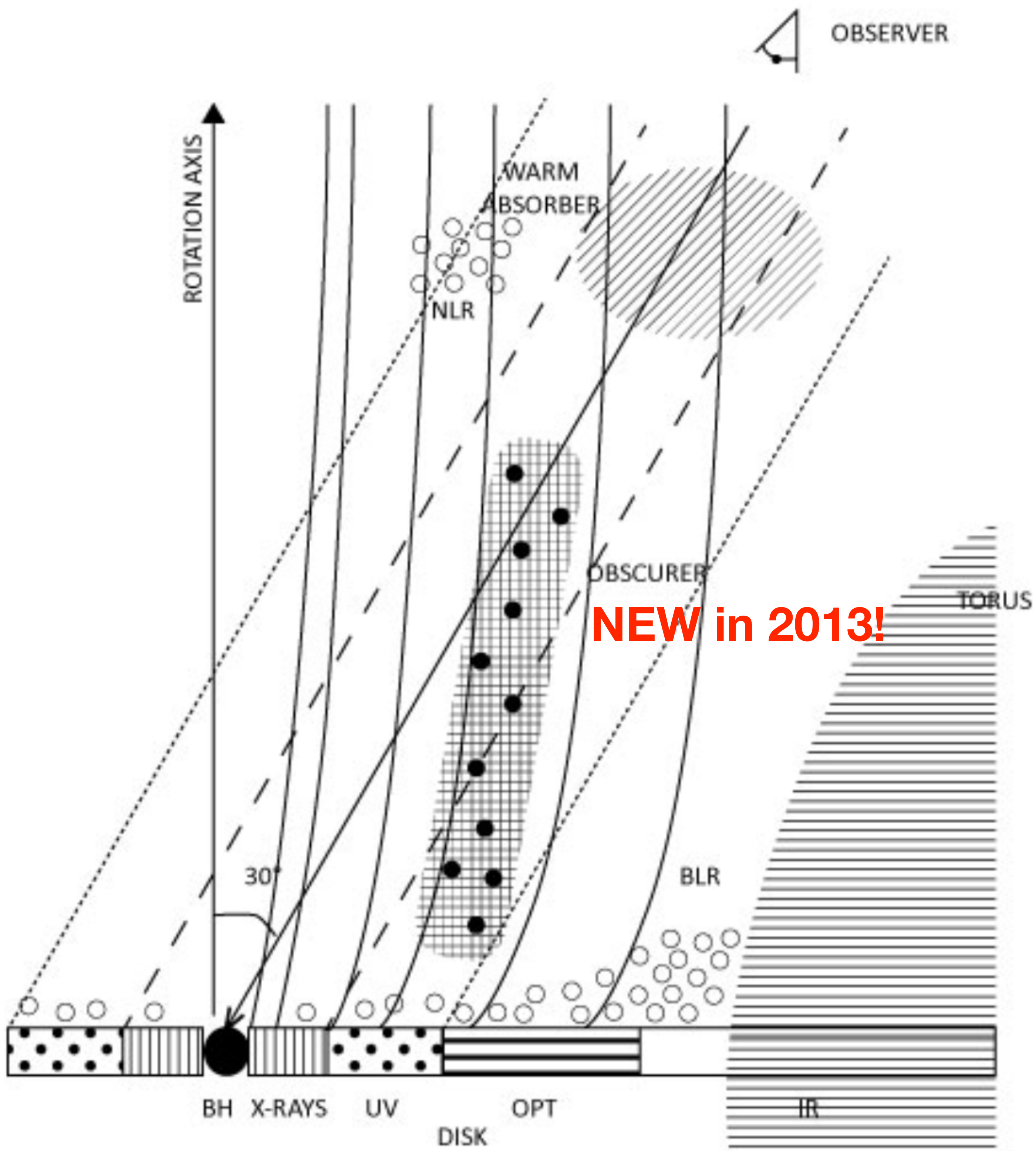
Strongly absorbed X-ray state in 2013, simultaneous to the appearance of broad UV absorption lines



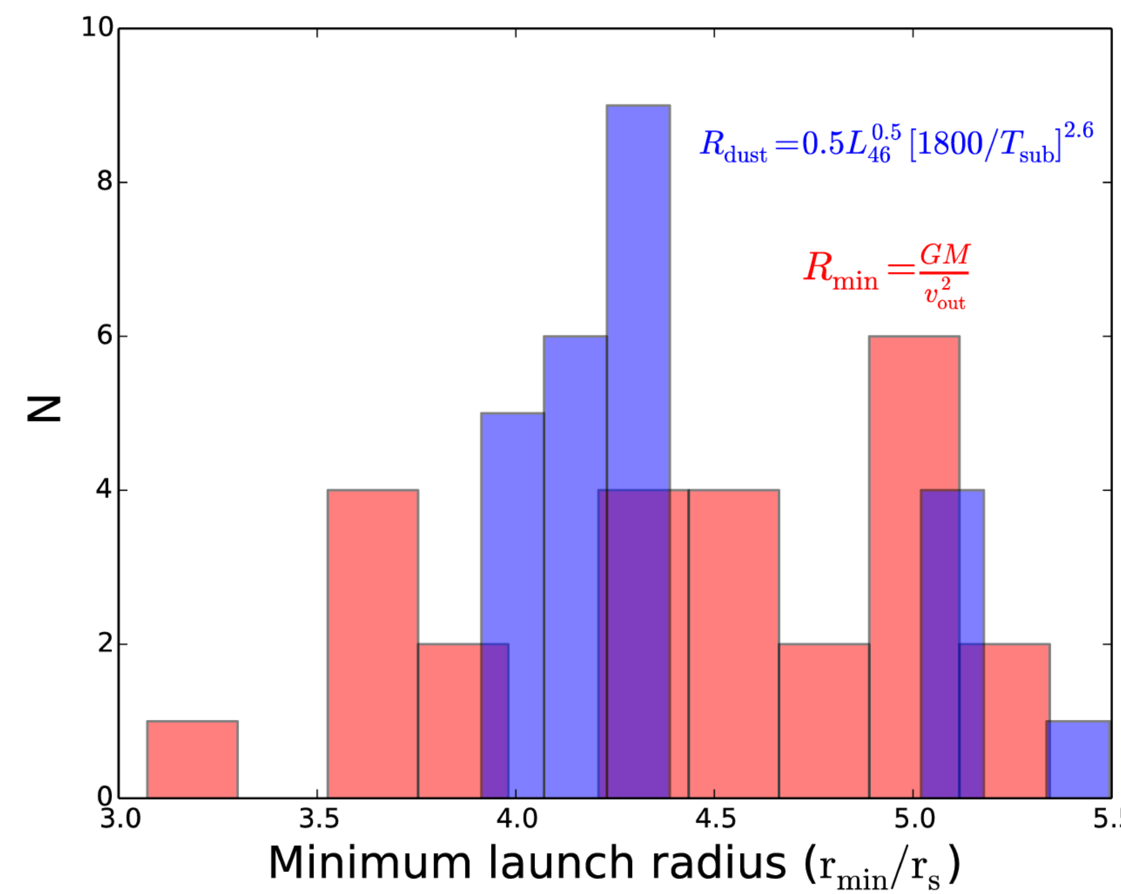
Ionised outflow launching radius

Kaastra et al., 2014, Science, 345, 74

Laha et al., in preparation



Ionised outflows launching radius versus dust sublimation radius in a large sample of AGN



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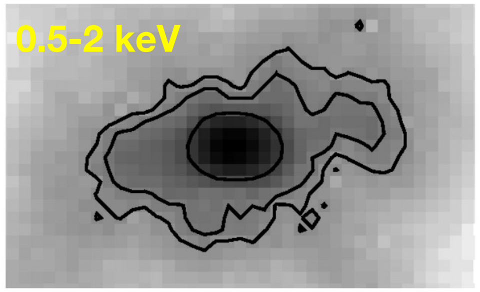
Markarian 3

- Heavily obscured ($N_H \geq 7 \times 10^{23}$ cm^{-2}) Seyfert 2 (Awaki et al. 1991, Cappi et al. 1999)
- 3-7 keV band dominated by Compton-reflection + ~1 keV EW Fe K$_\alpha$ fluorescent line
- Extended soft X-ray emission (*Chandra*/ACIS; Sako et al. 2000)

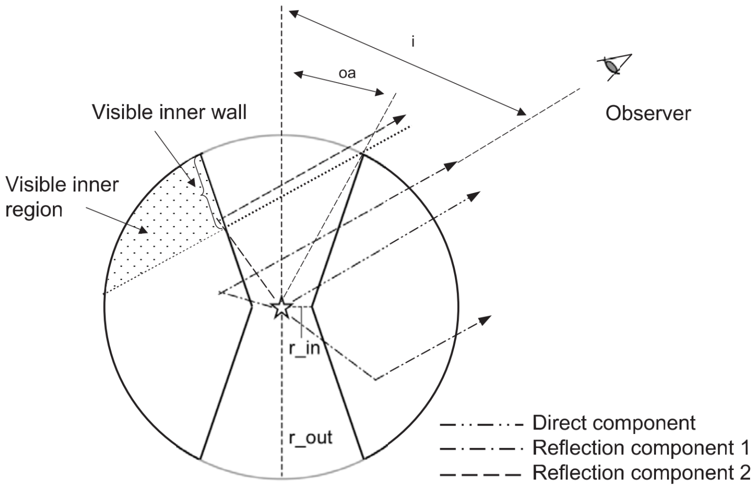


  - ⇒ AGN photo-ionised XNLR (Pounds et al. 2005, Bianchi et al. 2005)
- Iwasawa et al. (1993) discovered variability of the Compton-reflection component (factor of ~3 in ~3.6 years)
- Studying the (sparse) X-ray history, Guainazzi et al. (2012) propose that X-ray variability may prove the dust clumpy nature (almost at the same time, Marinucci et al. 2012 reach the same conclusion studying the ACIS images of the Circinus Galaxy)

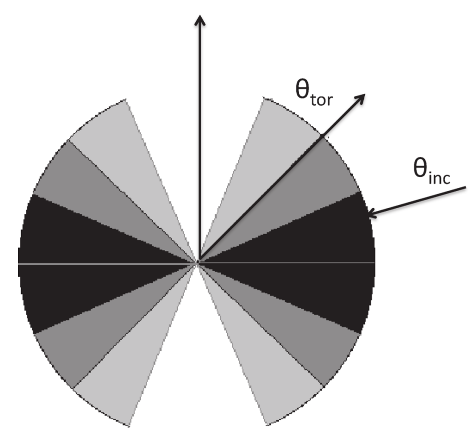
Markarian 3: hard X-ray spectrum

Yaqoob et al., 2015, arXiv:1508.07685

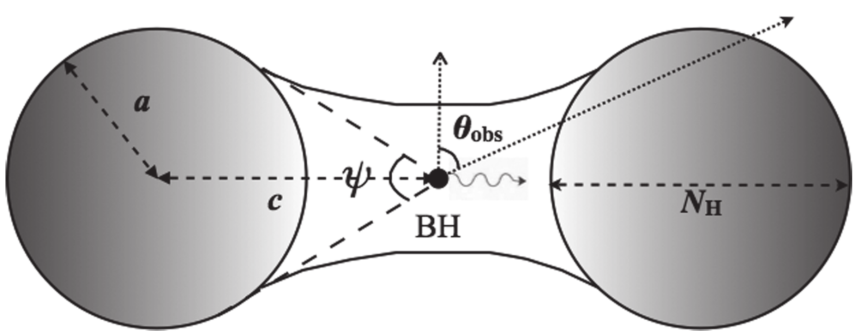
Ikeda, PASJ, 2009, 692, 608

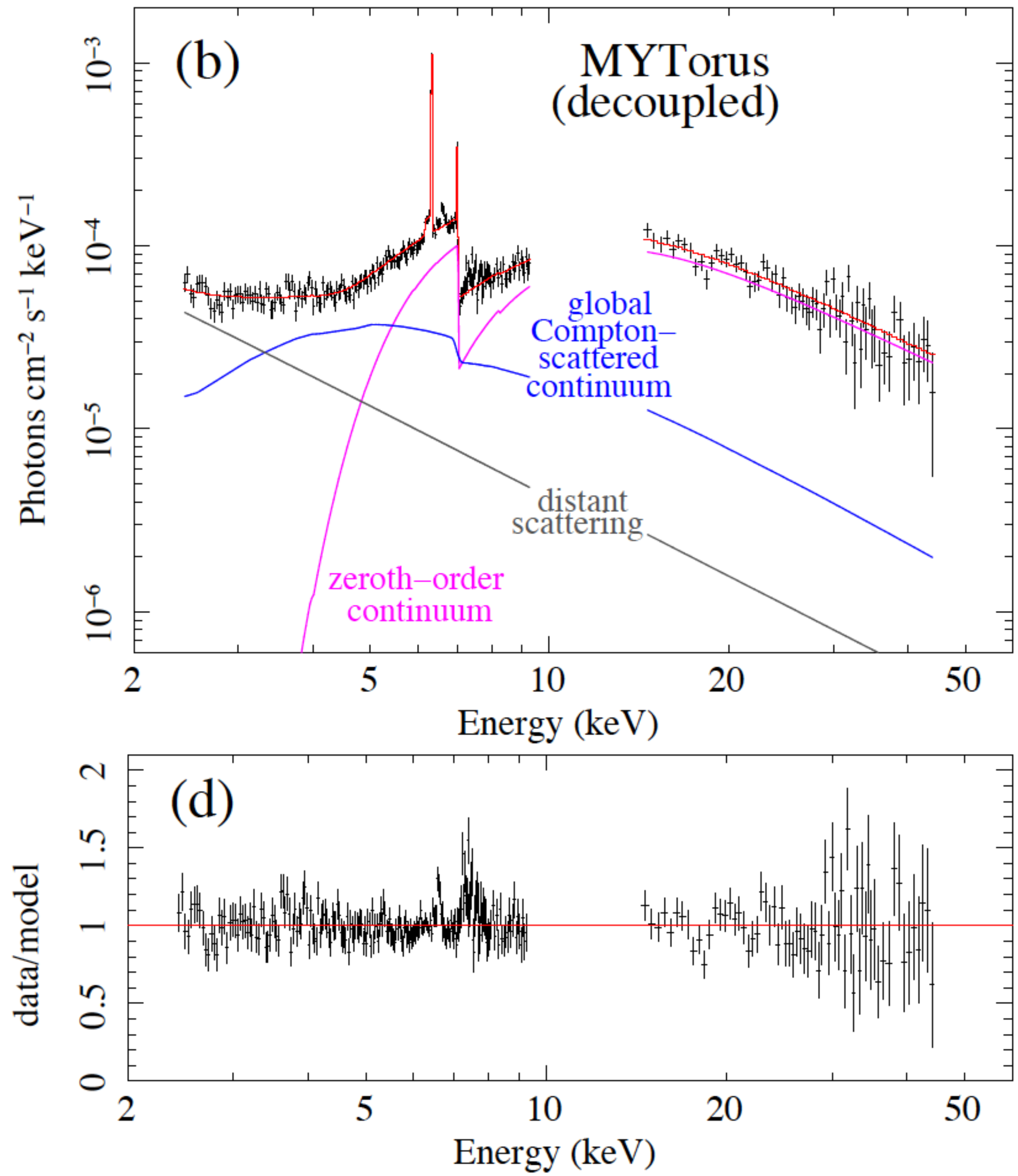


torus, Brightman & Nandra 2011, MNRAS, 413, 1206



mytorus, Murphy & Yaqoob, 2009, MNRAS, 397, 1549





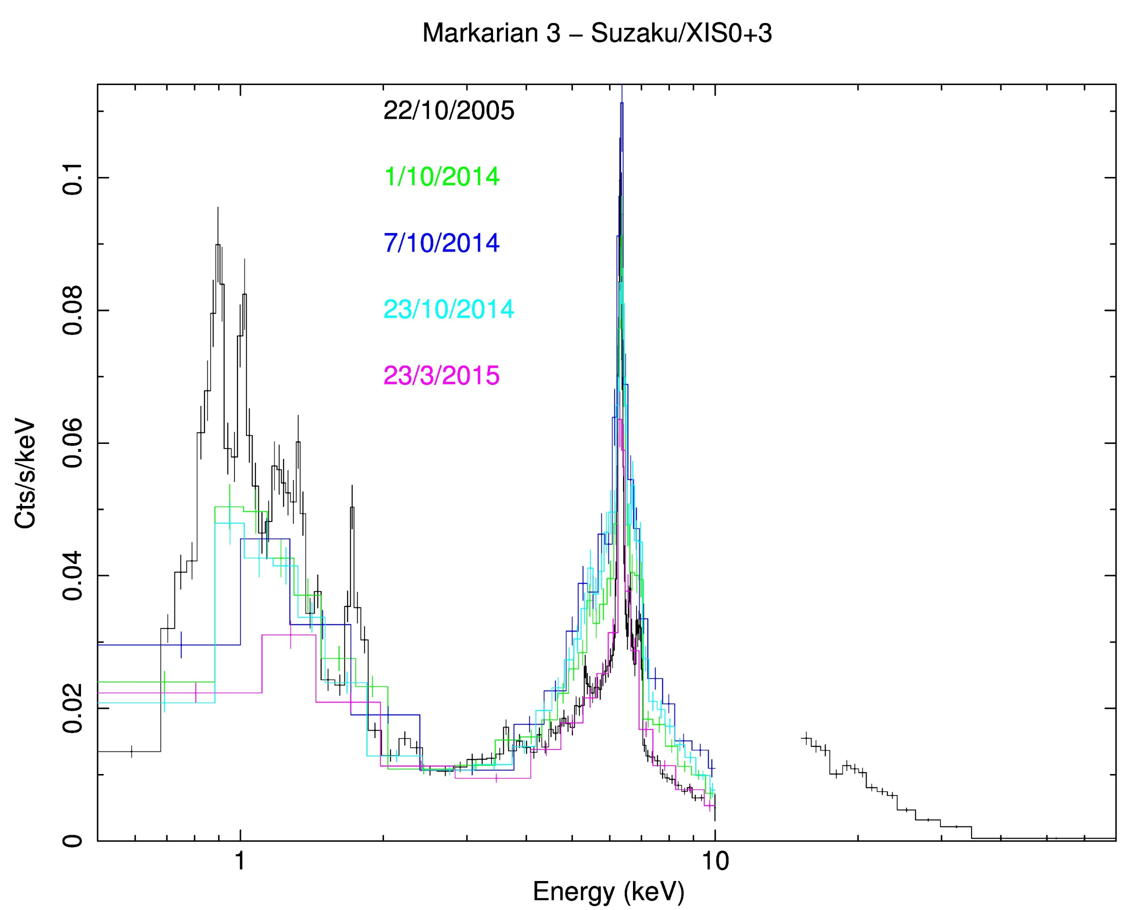
Fitting for:

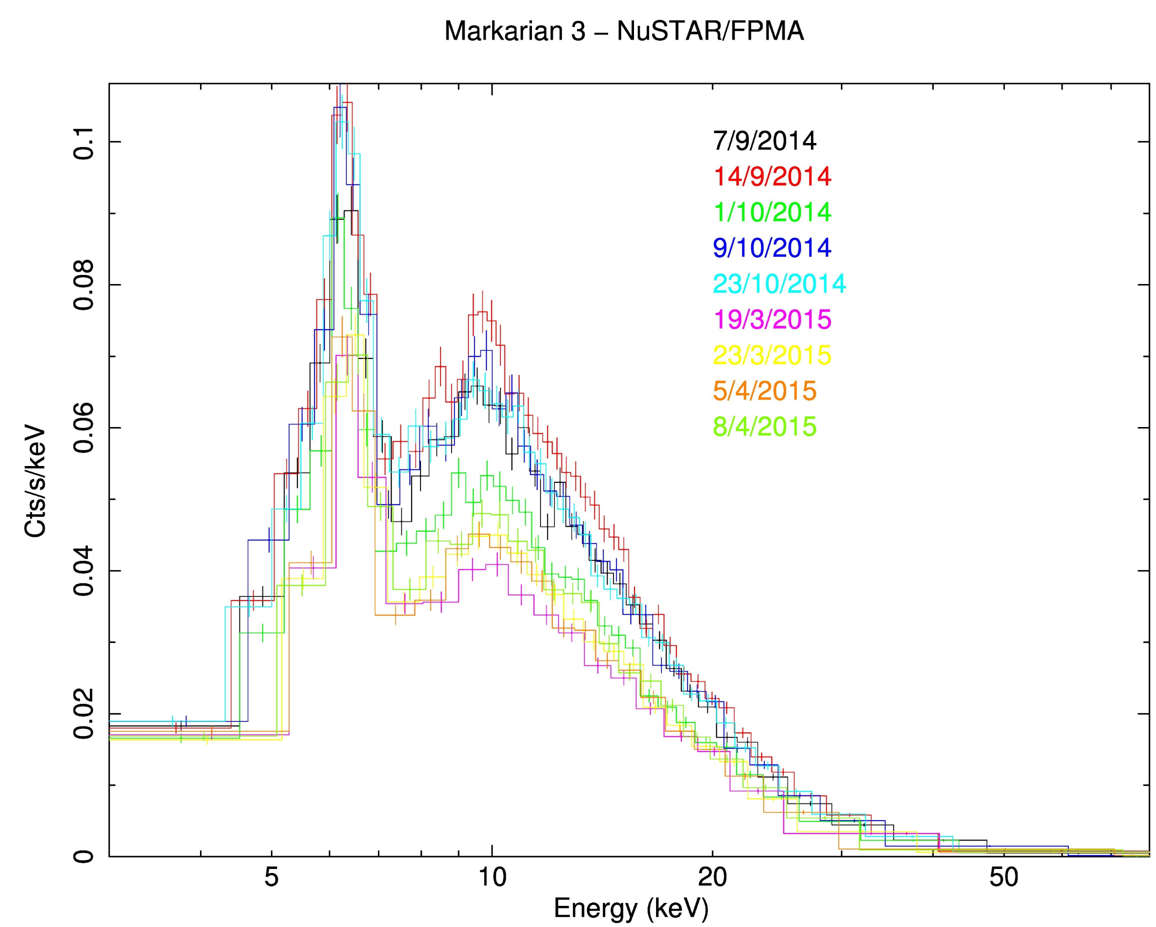
- line-of-sight column density ($N_{H,abs}$)
- global column density ($N_{H,global}$)
- inclination angle (θ_{incl})
- half-opening angle (θ_{op})

Mkn3 2014-2015 NuSTAR campaign

Guainazzi et al., in preparation

9 observations: 5 in autumn 2014 (7, 14 Sep, 1, 9, 23 Oct), 4 in spring 2015 (19, 22 Mar, 5, 8 Apr). NuSTAR + Suzaku or XMM-Newton

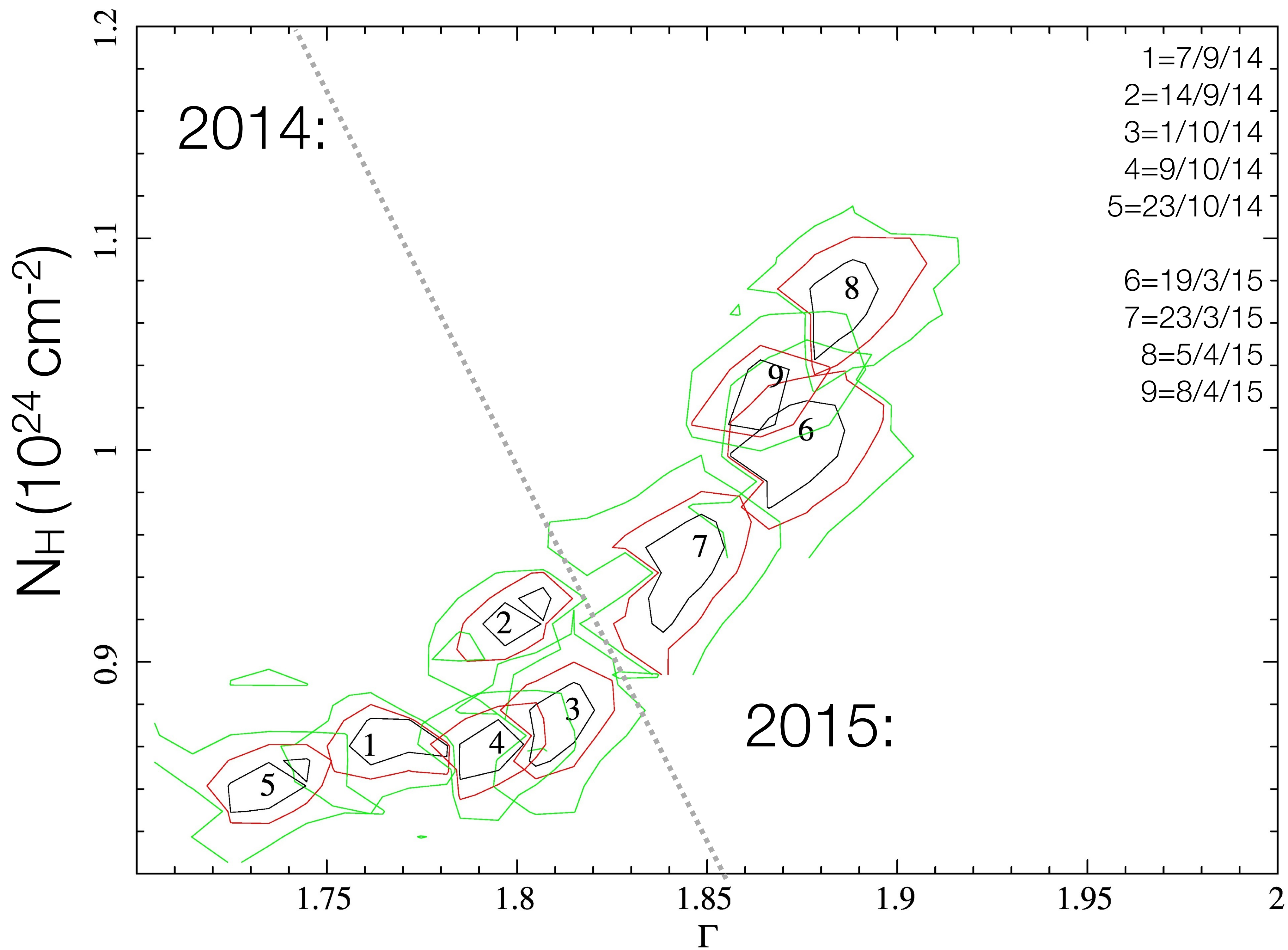




The spectra of Markarian 3 above ~3 keV show variability on all time-scales down to ~2 days

Absorber column density variability

Guainazzi et al., in preparation



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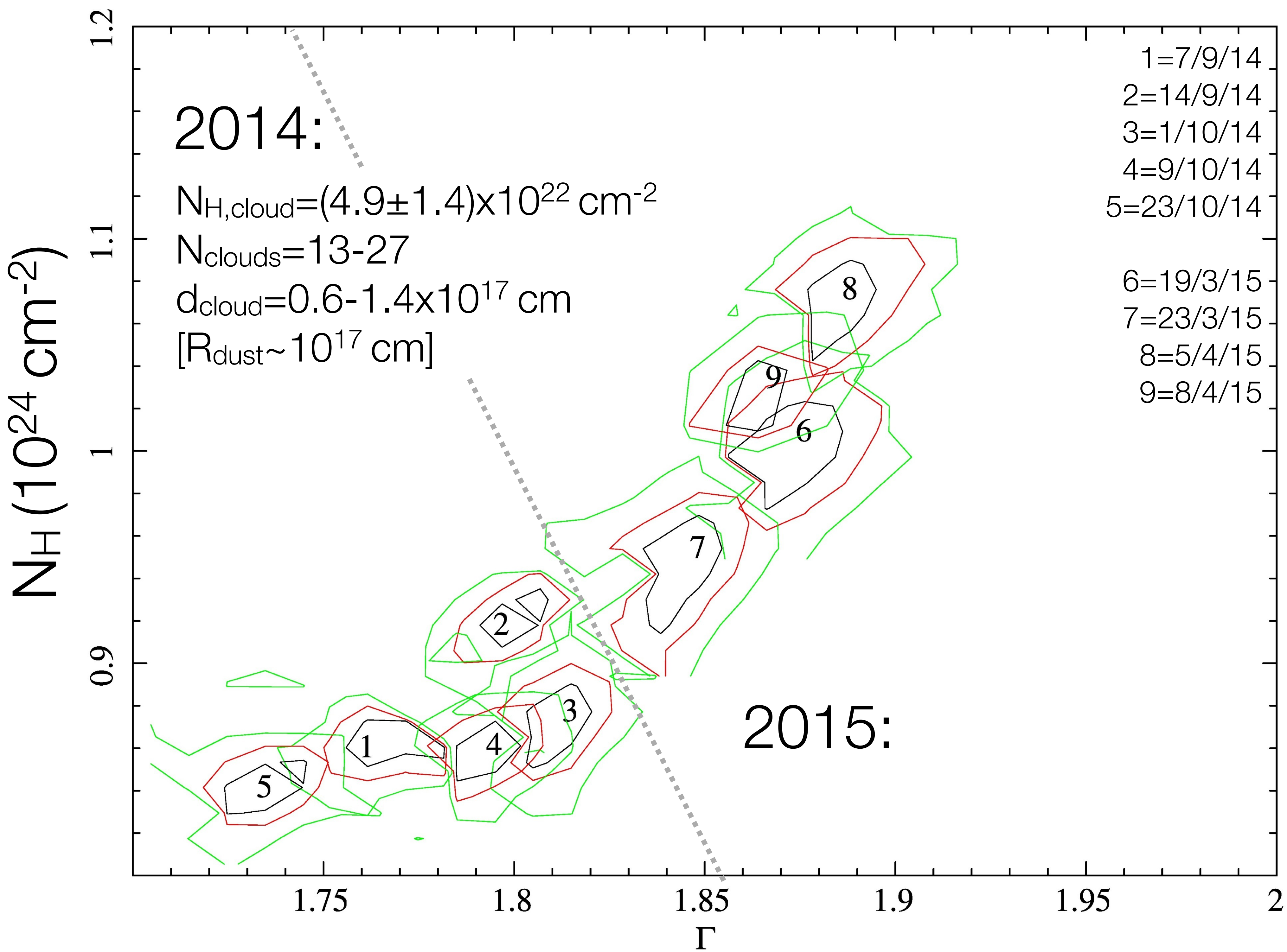

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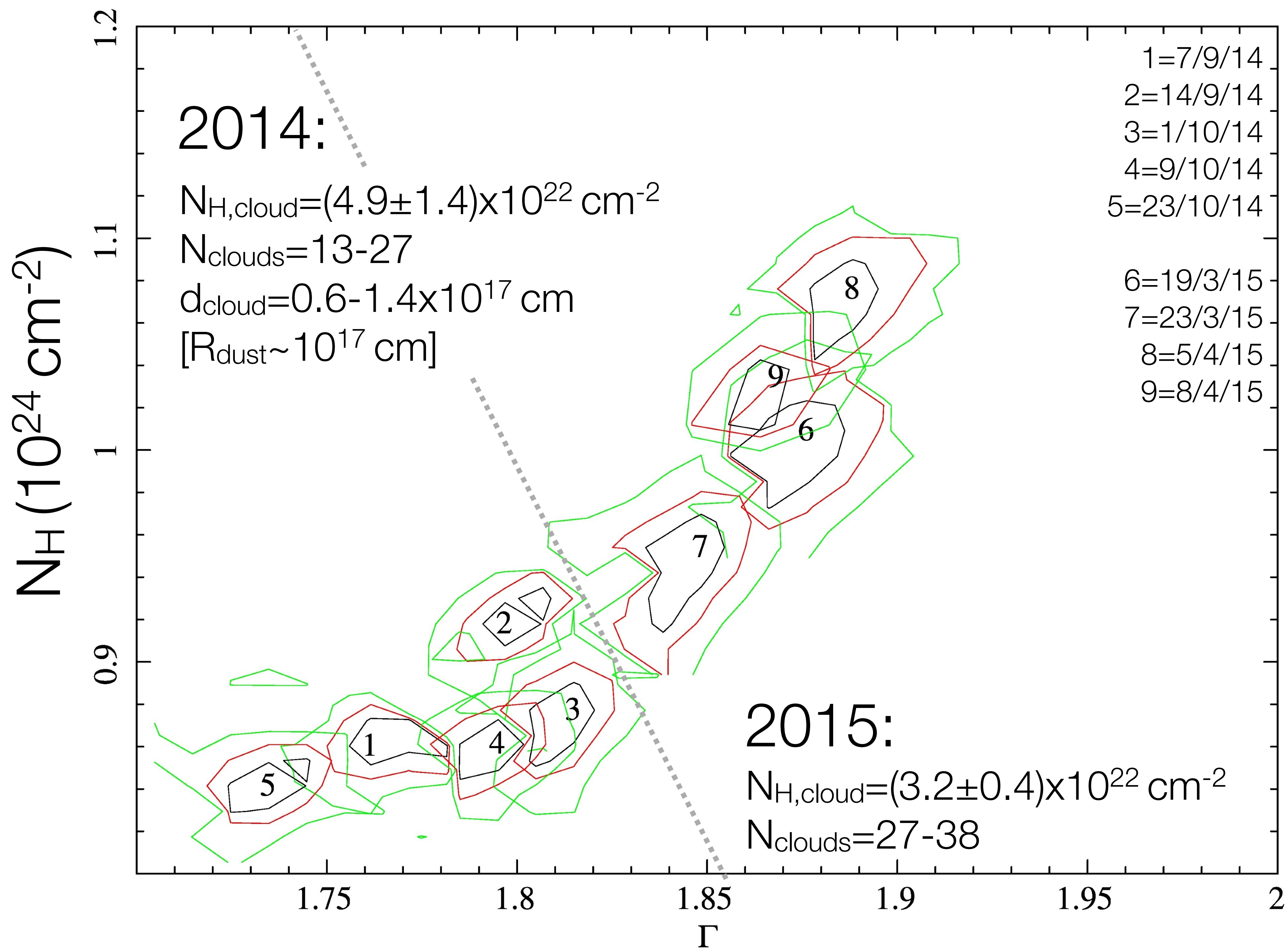


Mkn3: X-ray vs. IR absorber/reprocessor

Guainazzi et al., in preparation; IR results from Sales et al., 2014. 441. 630

	X-rays (gas+dust)	IR (dust)
N (10	2.2±0.9	0.5±0.3
N	13-38	9±3
θ	66.0	50
θ	68.9	61

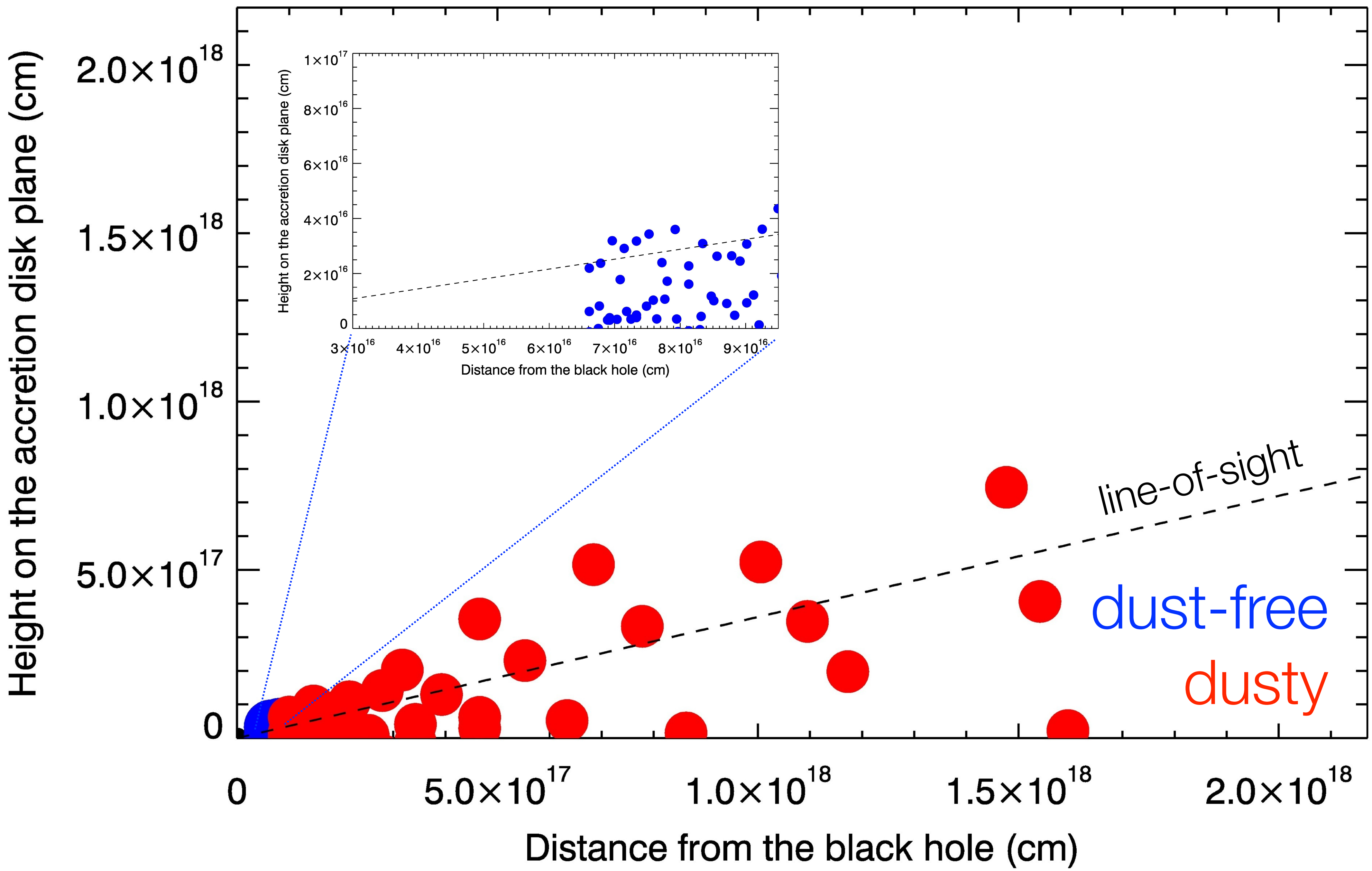
Still poorly known:

- X-ray cloud size/volume filling factor ($R_{cloud} \lesssim 2000\ R_S$)
- X-ray cloud density ($n \gtrsim 10^5\ cm^{-3}$)
- radial profile of gas and dust (no idea)

IR analysis suggests that the torus extends up to ~7-8 pc

A possible structure of the gas in Markarian 3

Guainazzi et al., in preparation



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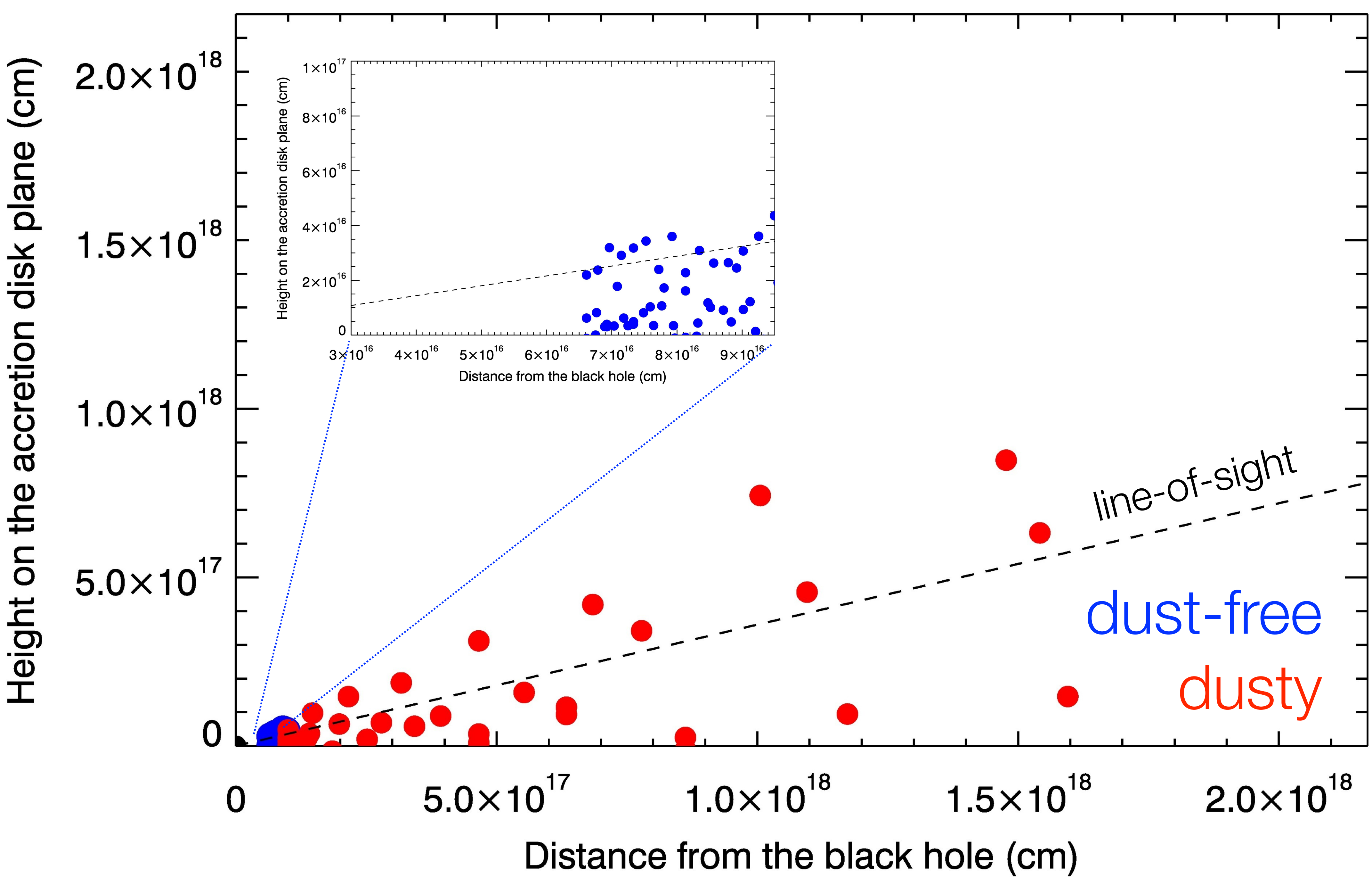

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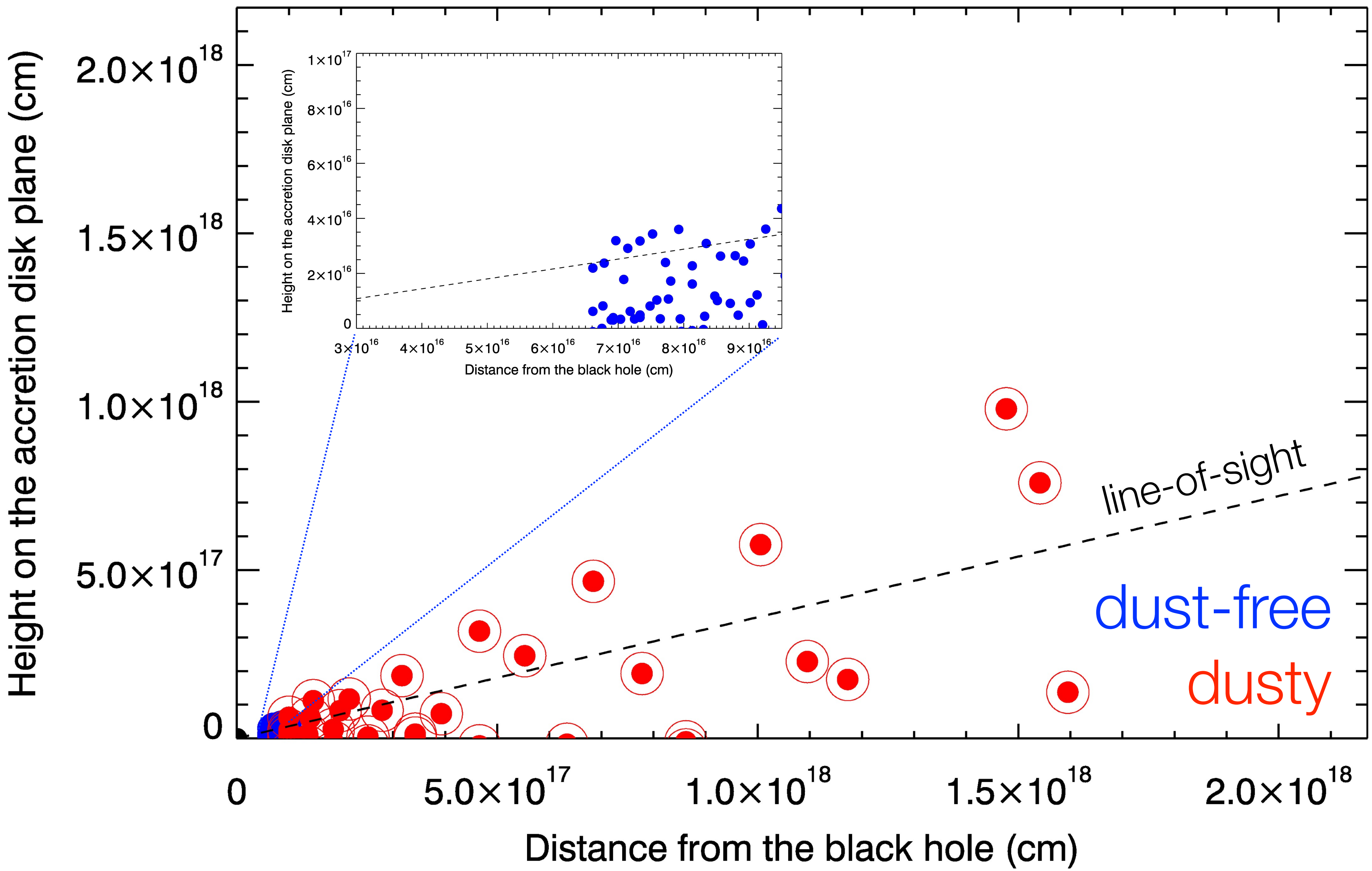
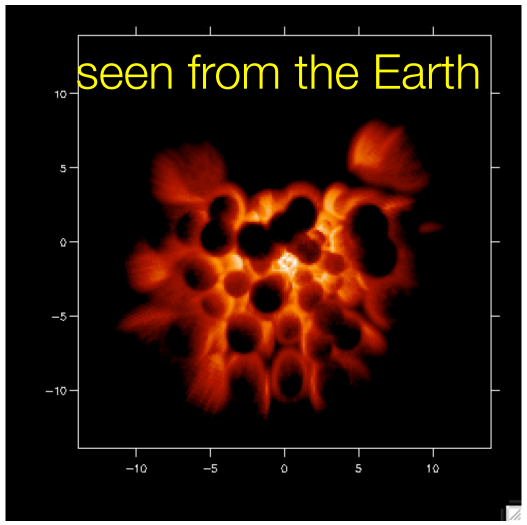
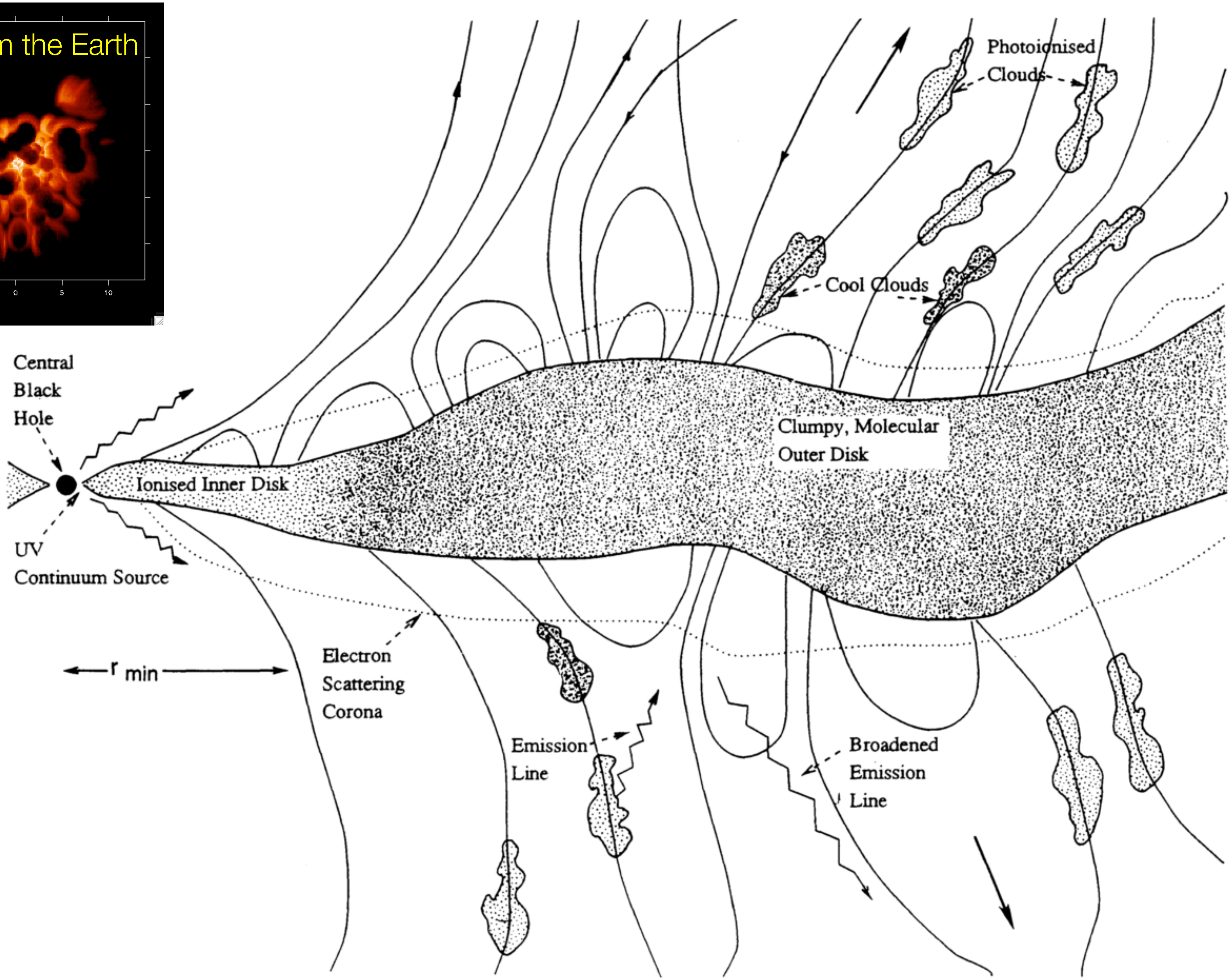


Structure of the absorber

Ennering et al., 1992, ApJ, 385, 460





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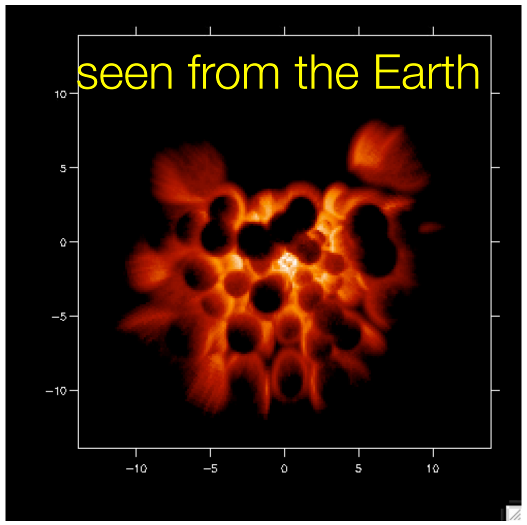
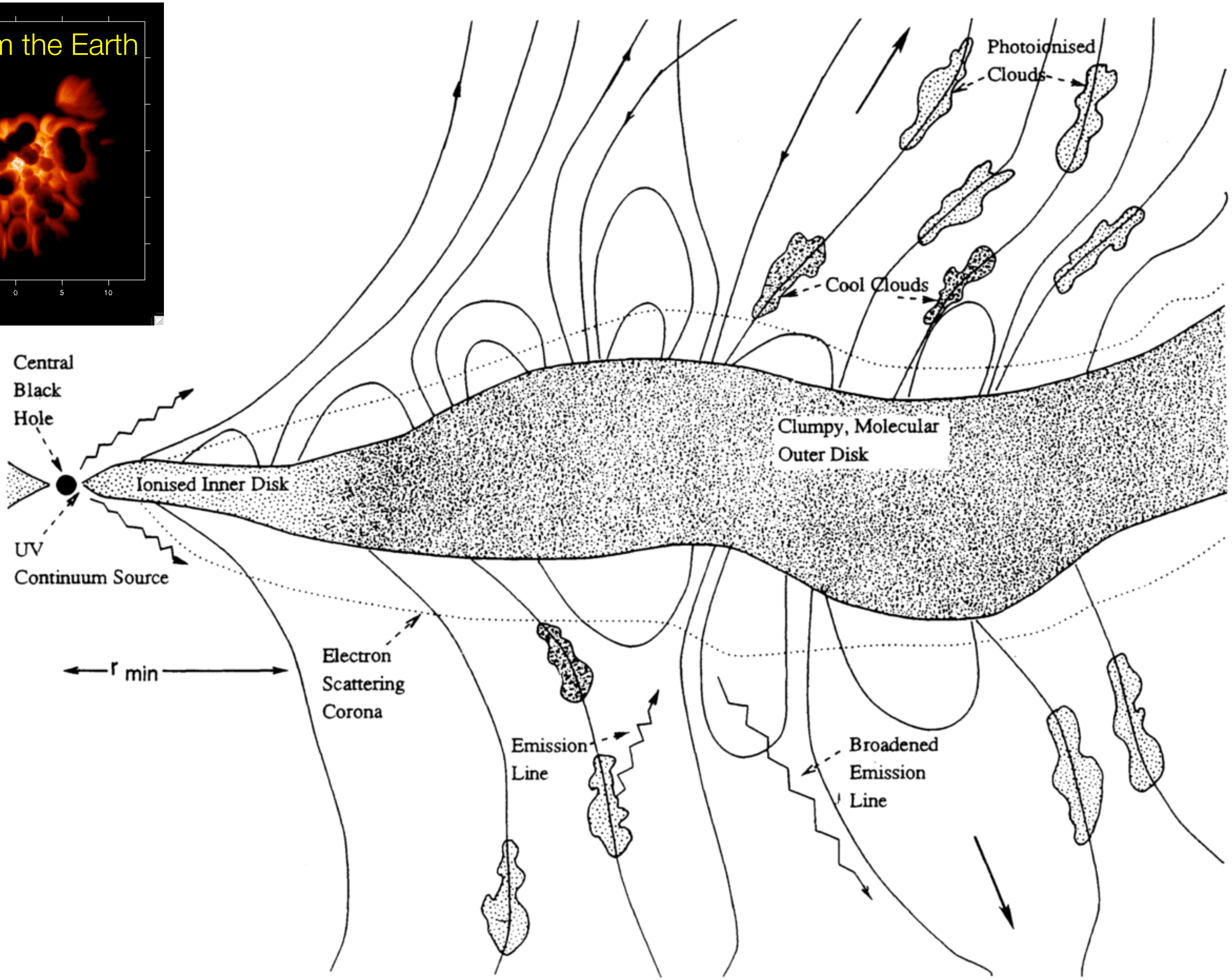
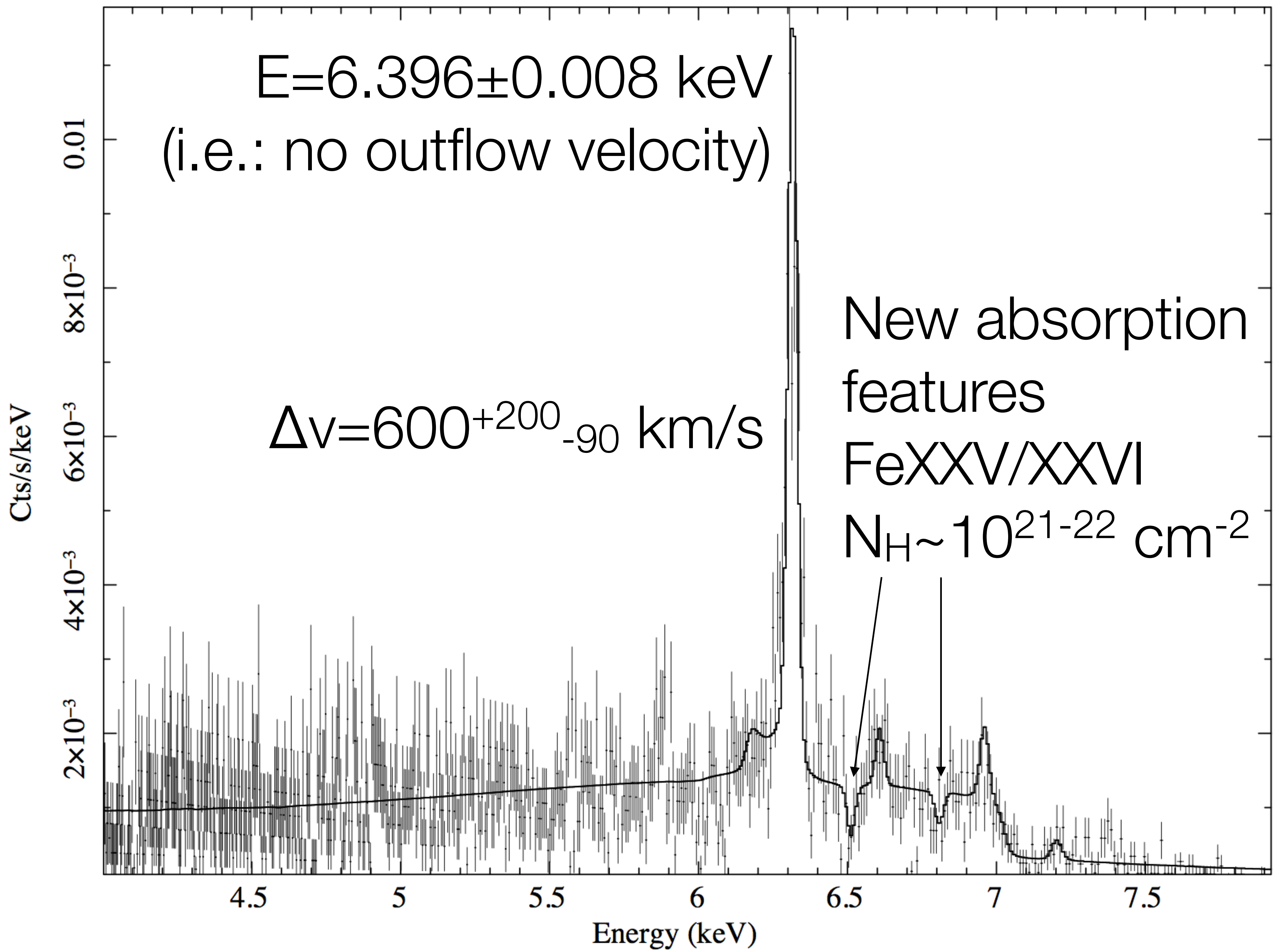




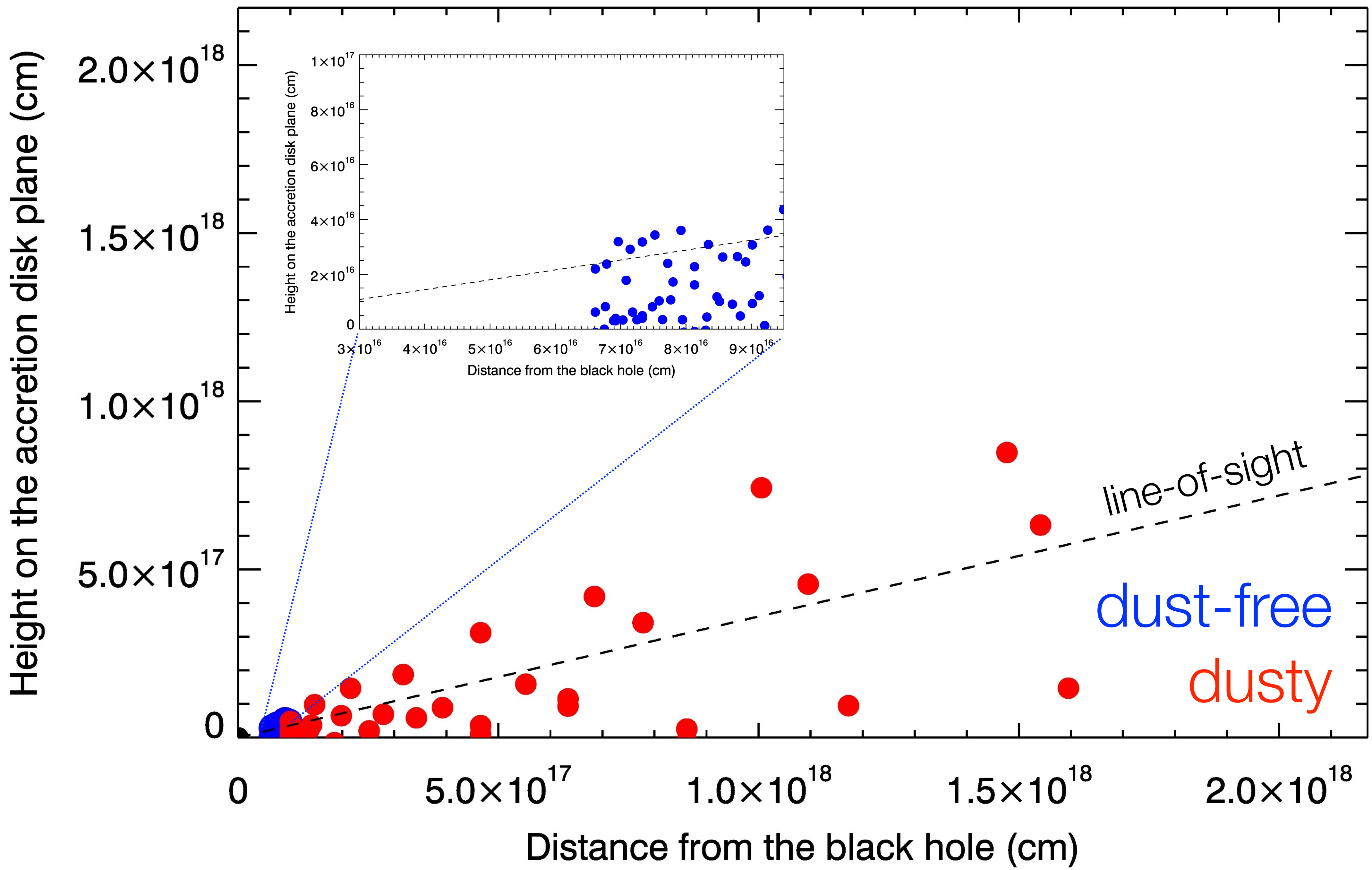
Markarian 3 HETG spectrum (770 ks)

Guainazzi et al., in preparation



A possible structure of the gas in Markarian 3

Guainazzi et al., in preparation



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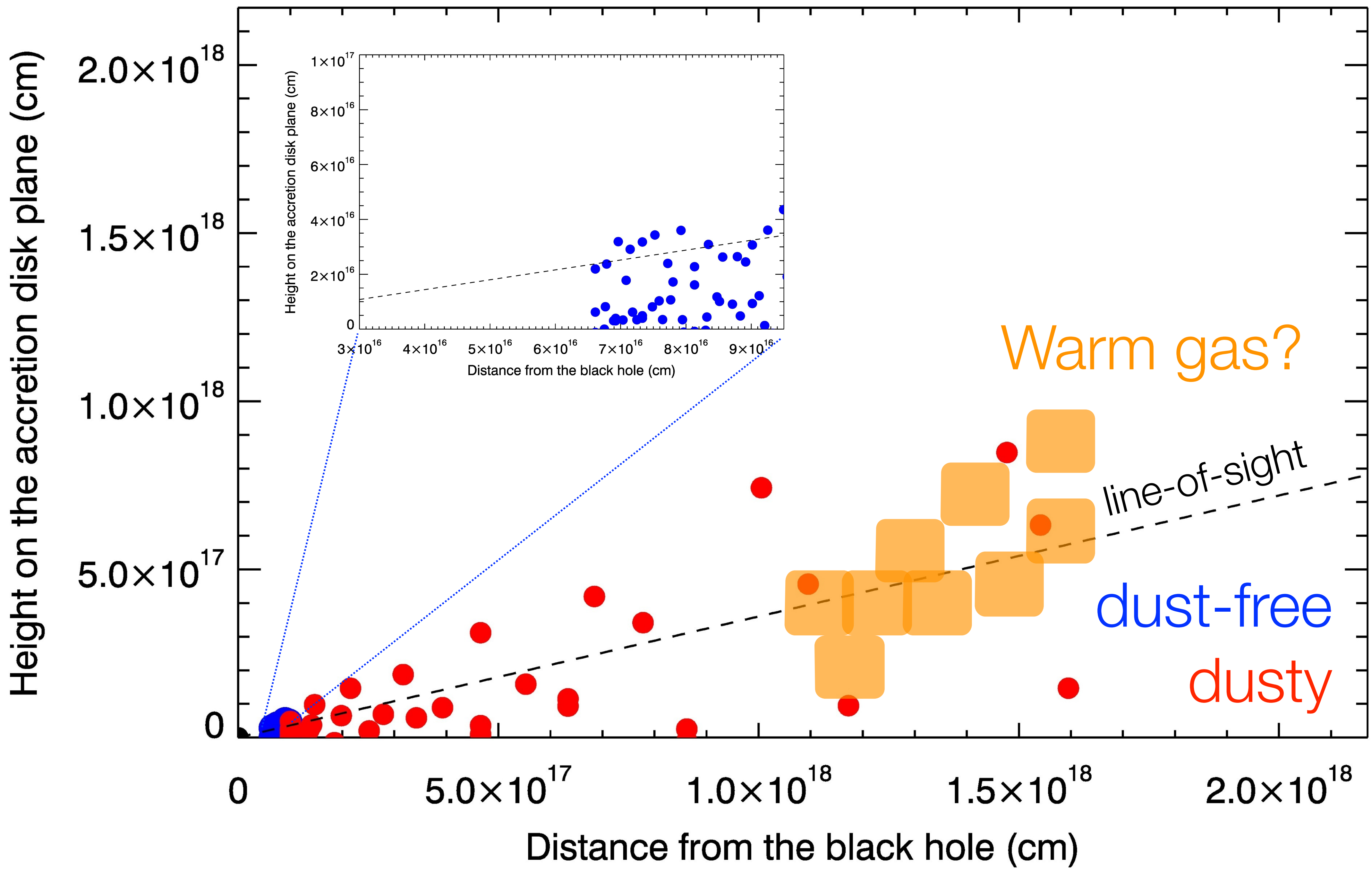
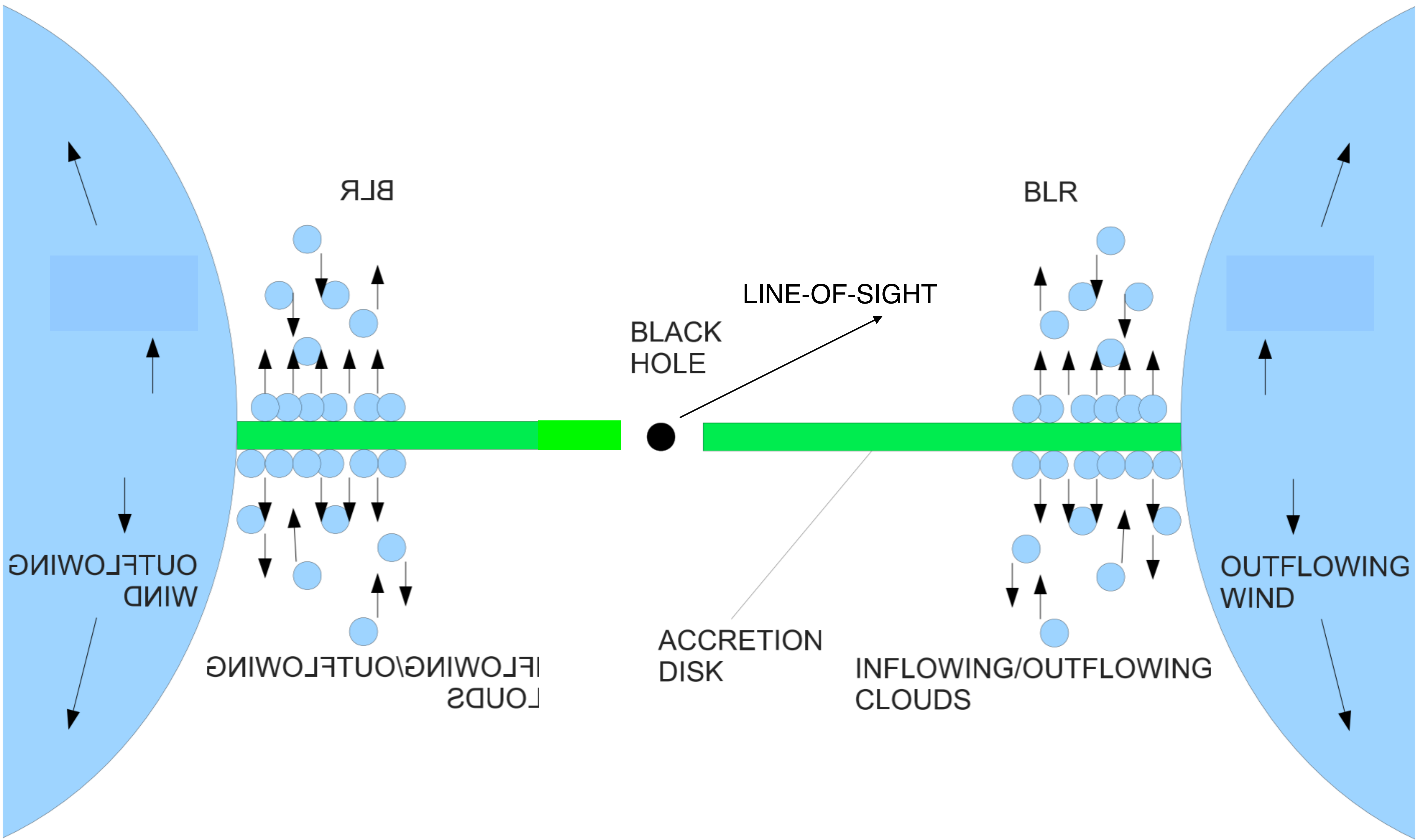


Failed winds and the origin of BLRs

Czerny & Hryniewicz, 2011, A&A, 525, L8



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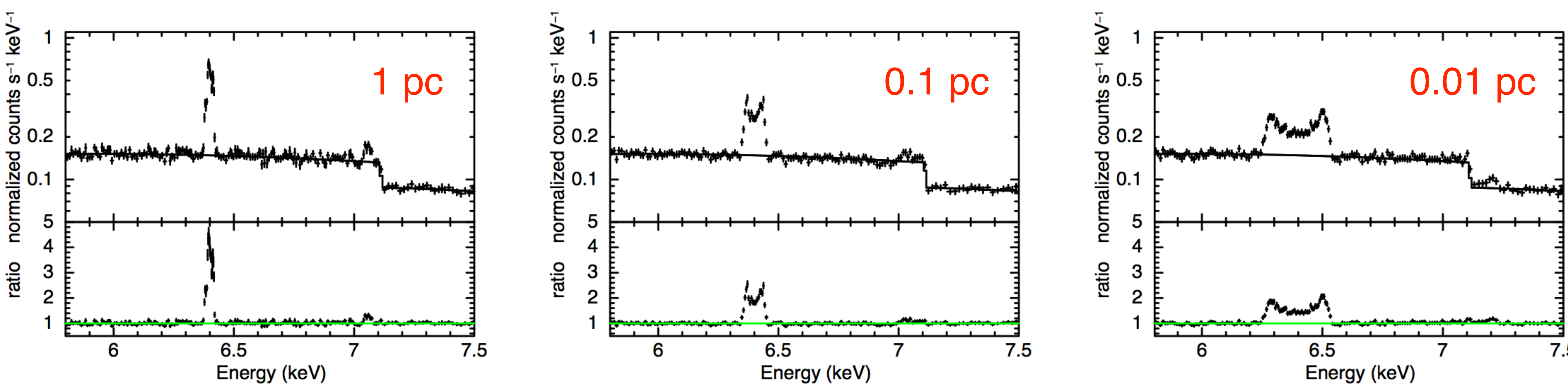
Spectroscopy of optically thick nuclear gas

Reynolds et al., 2014, arXiv:1412.1177

To verify if this model is correct we need to know at which scale Compton scattering and Fe K_α fluorescence line are produced

Measurements of the profile of the K_α iron line with the SXS!



simulation of 100 ks on NGC4388 (very similar AGN to Markarian 3)

Conclusions

Courtesy A.Merloni & S.Bonoli, MPE