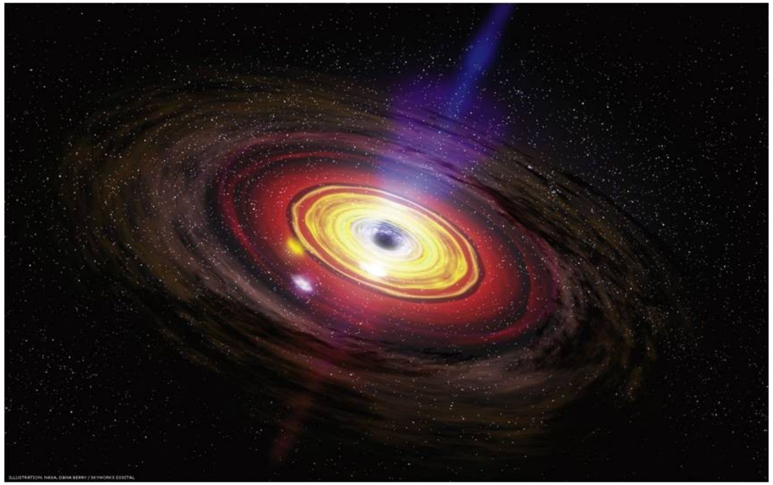
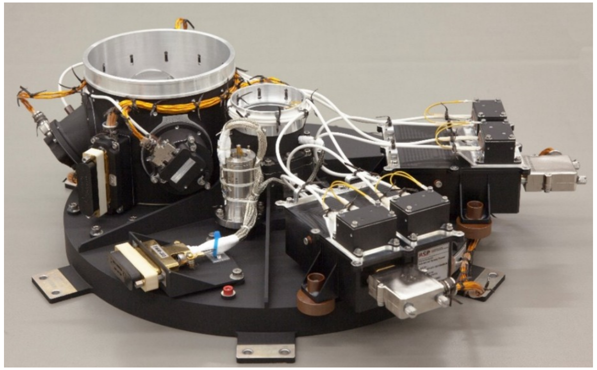
XRISM X-Ray Imaging and Spectroscopy Mission





AGN Science with XRISM

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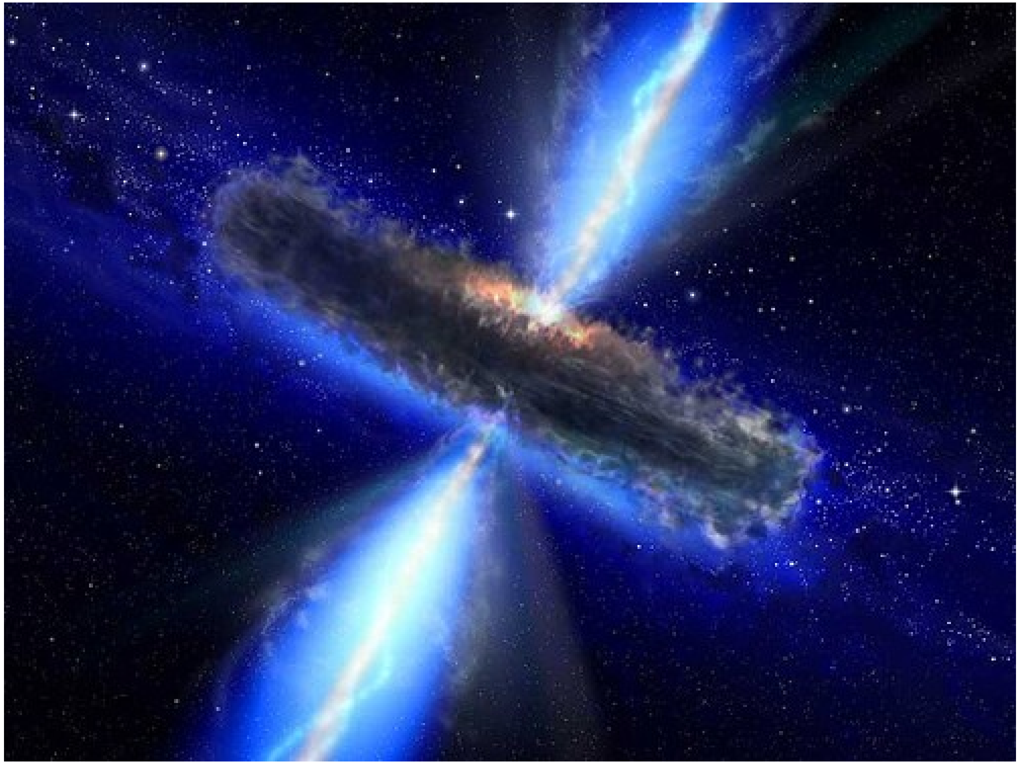
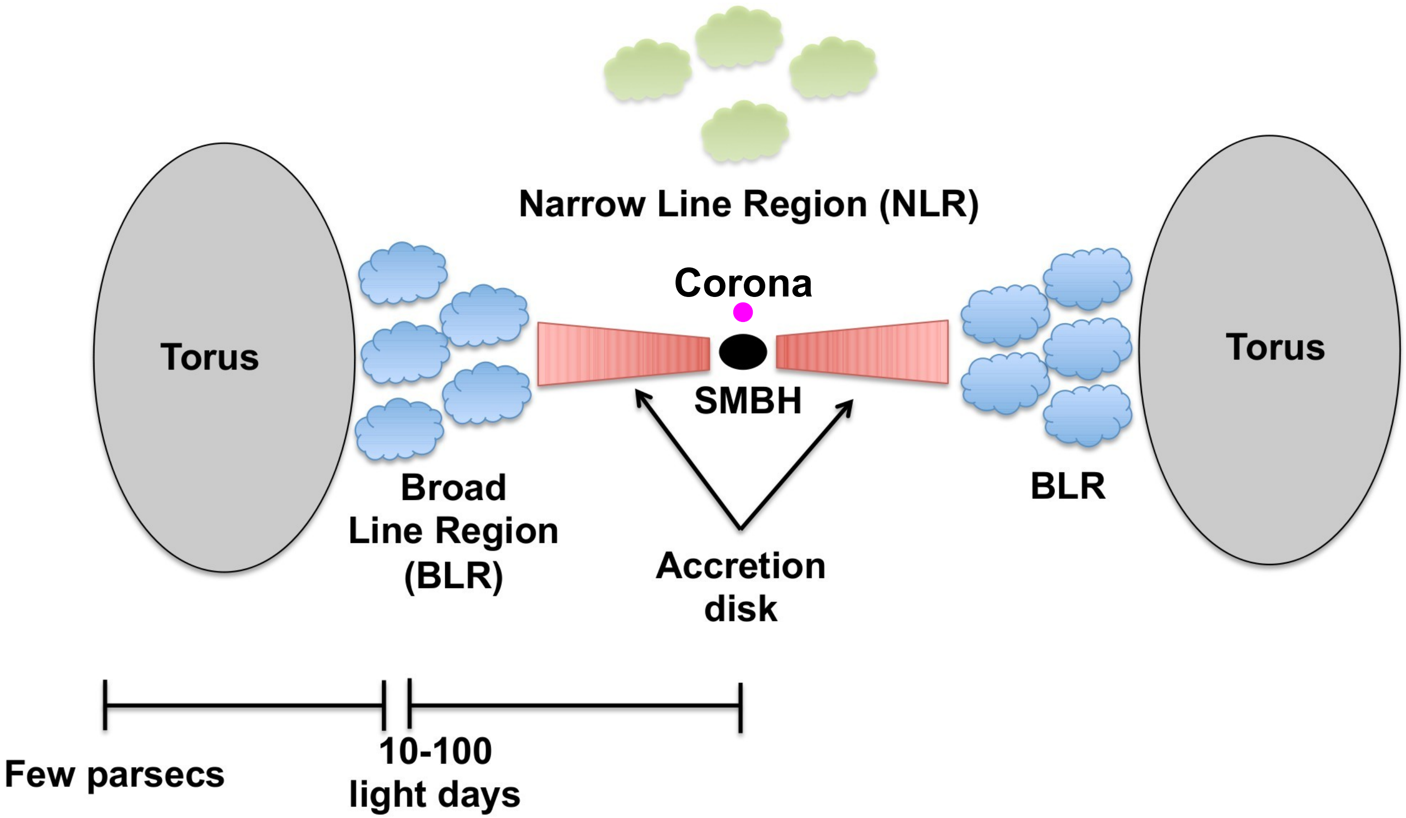
Active Galactic nuclei

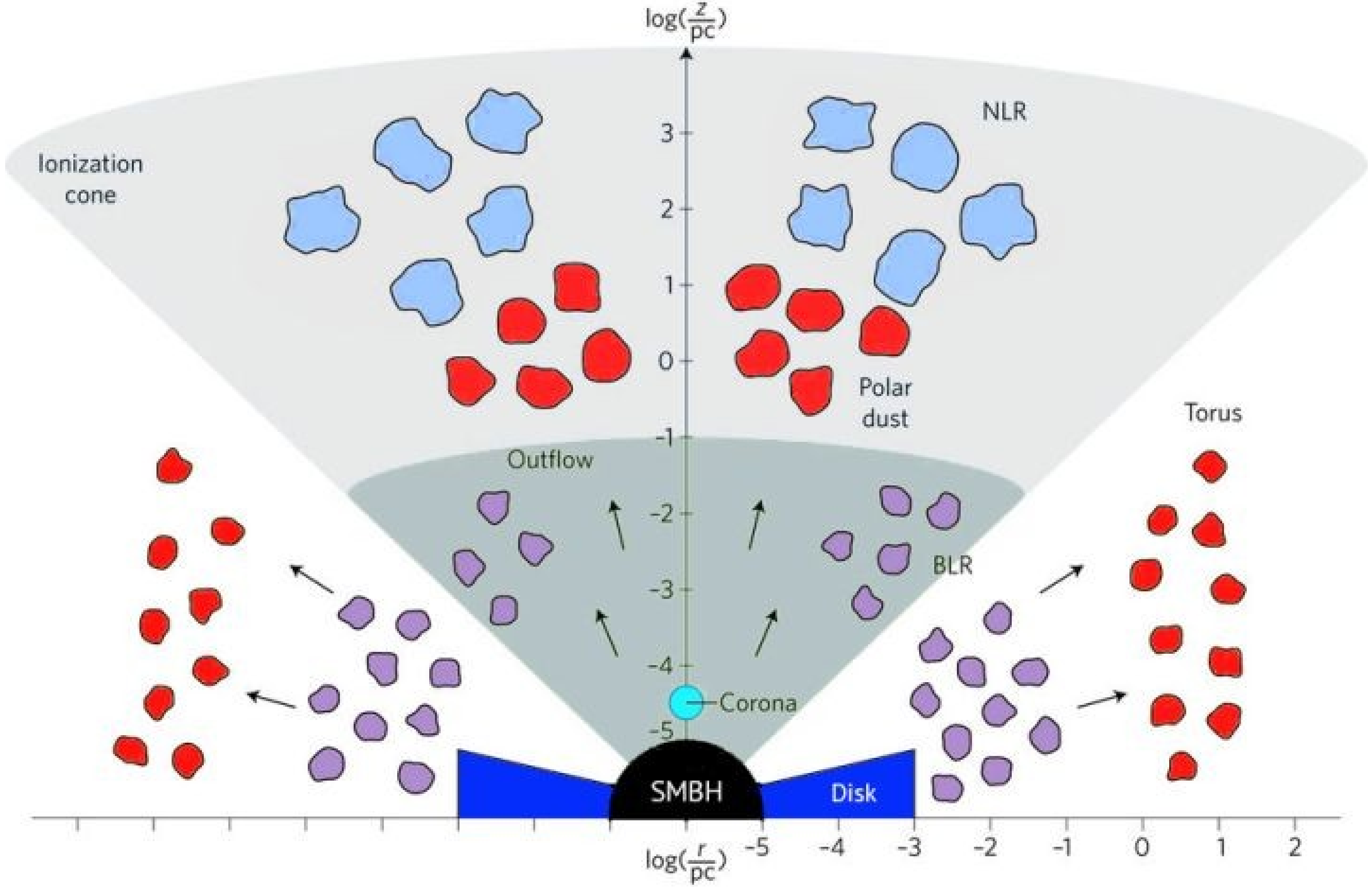


- Supermassive black hole $10^6 – 10^{10}\ M_\odot$
- Surrounded by complex distribution of matter, that is responsible for the overall AGN emission
  - Accretion disk → UV/optical emission
  - Corona → X-ray emission
  - Dusty torus → Absorption/Reflection
  - Radial structures → Absorption
  - Jet → Non-thermal emission
- X-rays are an important probe of the matter distribution
  - Spectroscopy with XRISM will provide numerous breakthroughs

AGN Structure



Outflows

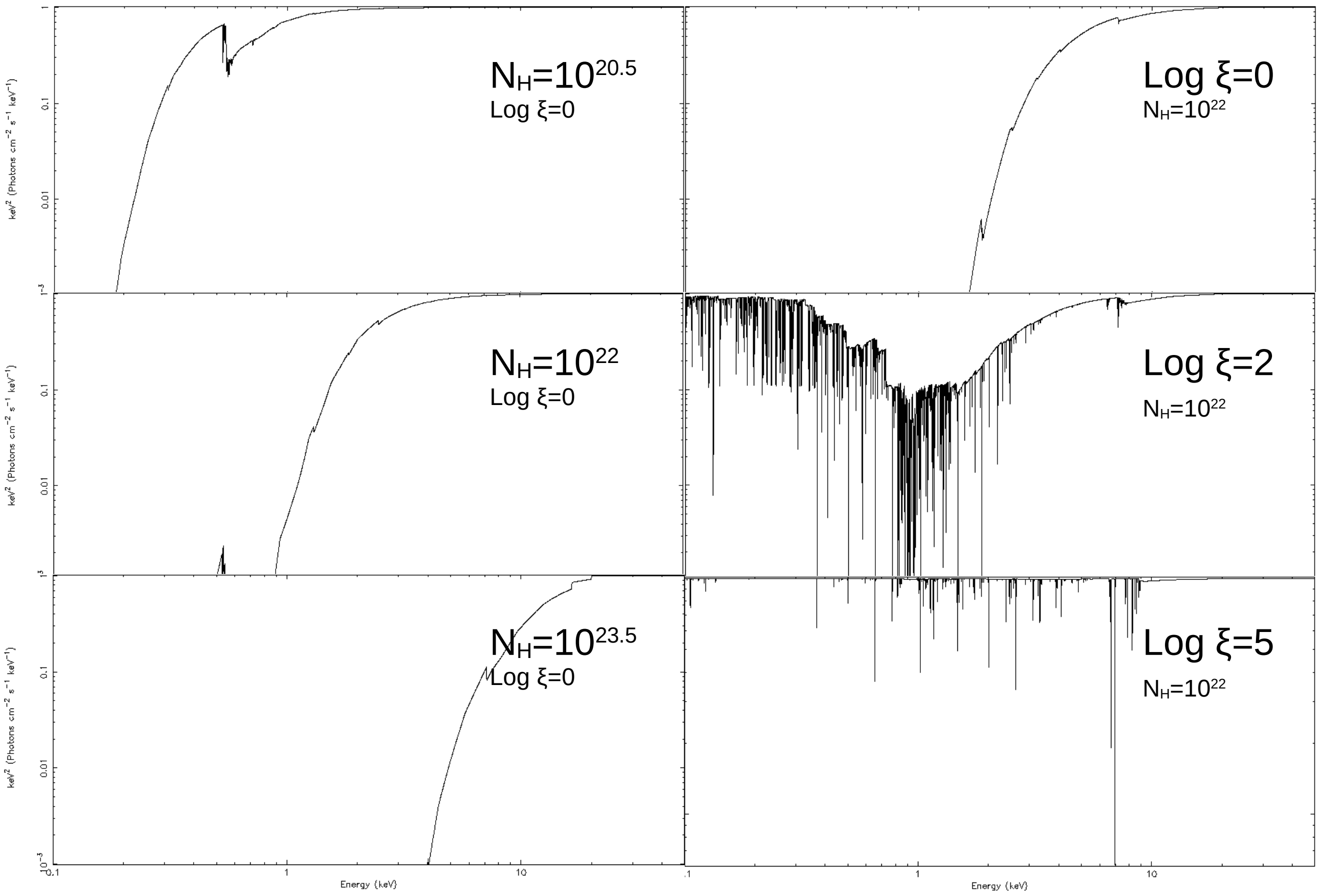


Hickox & Alexander 2018

XRISM Science Case for AGN

- Point sources: Focusing on spectroscopy with Resolve
  - Xtend important for the continuum, background
- Outflows
  - Warm absorber, but GV…
  - Ultra-fast outflows
- Reflection
  - Fe complex
  - Compton shoulder

X-ray Absorption



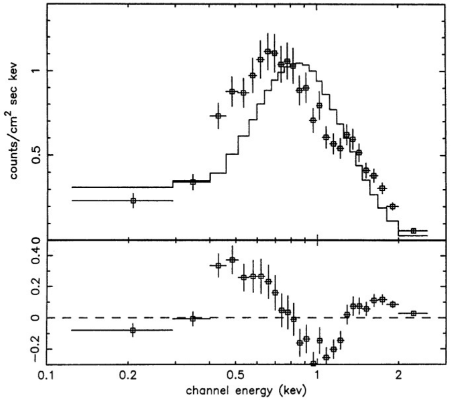
Absorption results from :

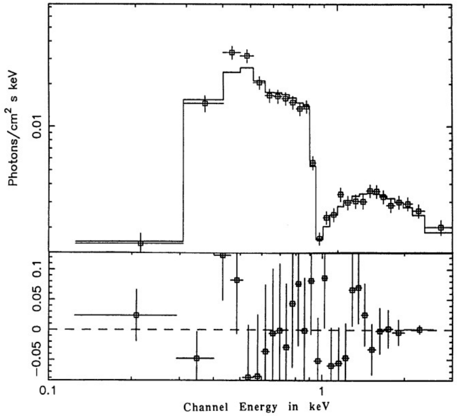
- Column density N_H (cm^{-2})
- Ionization parameter (erg cm s^{-1}):

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

- N_H, L and ξ are observables
- Degeneracy between n and R
- Velocity of ionized absorption can be measured!
  - Requires high resolution
- Accurate modeling requires $L(E)$, not just total L
  - cloudy, xstar, pion

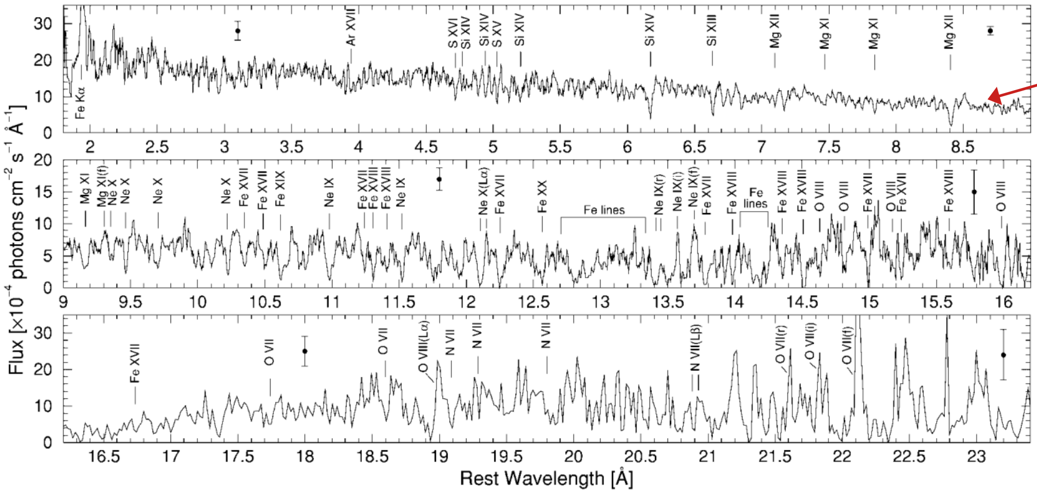
Warm Absorber





NGC 3783 / ROSAT PSPC

Turner et al. 1993



Absorption spectrum needs high sensitivity!

NGC 3783 / Chandra HETGS

Kaspi et al. 2000

MRK 509 / XMM-Newton RGS

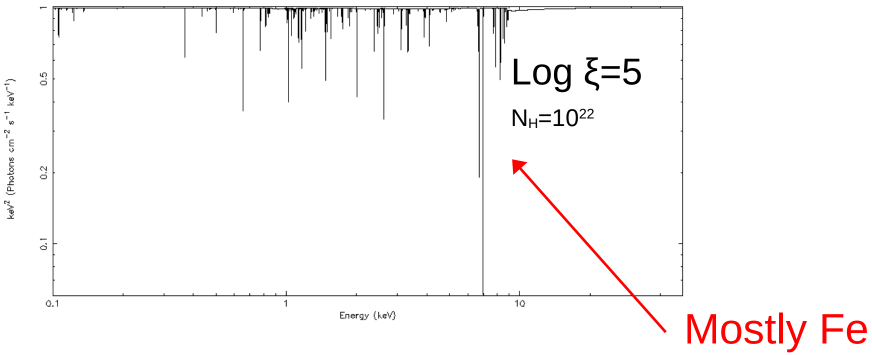
Detmers et al. 2011

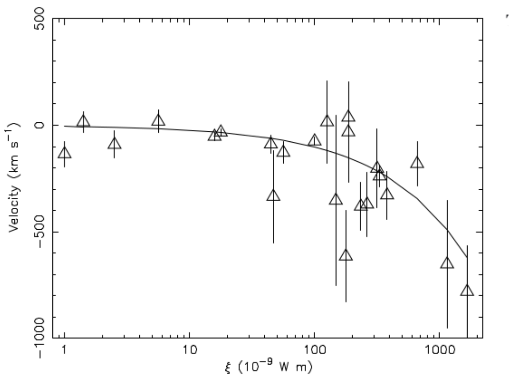
Comp	Log ξ^a	$N_H{}^b$	σ^c	v^d	Log U^e
B1	0.81 ± 0.07	0.8 ± 0.1	124 ± 20	25 ± 30	-0.73
C1	2.03 ± 0.02	2.6 ± 0.2	193 ± 14	-43 ± 20	0.49
A2	-0.14 ± 0.13	0.4 ± 0.1	79 ± 26	-180 ± 41	-1.68
C2	2.20 ± 0.02	4.4 ± 0.5	29 ± 6	-267 ± 31	0.66
D2	2.62 ± 0.08	1.8 ± 0.5	34 ± 19	-254 ± 35	1.08
E2	3.26 ± 0.06	6.3 ± 1.2	37 ± 19	-492 ± 45	1.72

In general, warm absorber can be continuous: absorption measure distribution:

$$\mathrm{AMD} = \xi \frac{\mathrm{d}N_\mathrm{H}}{\mathrm{d}\xi}$$

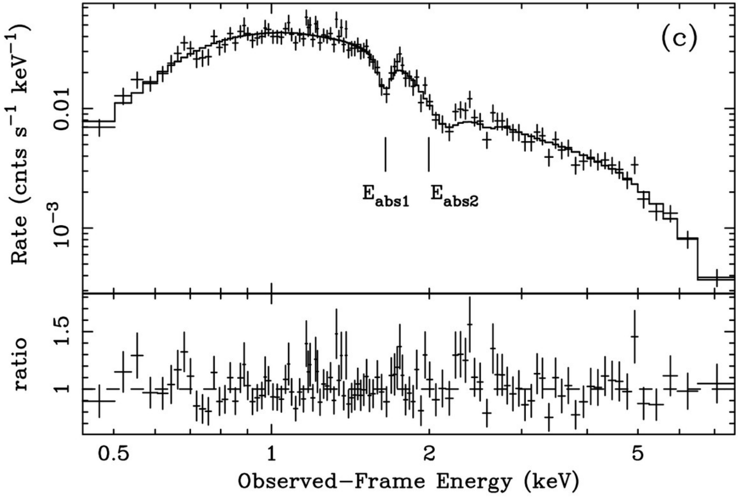
High-ionization Warm Absorbers



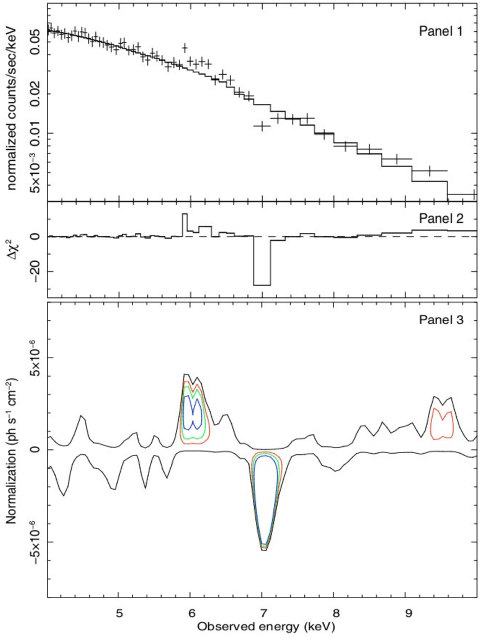


- High-ionization warm absorbers are mostly visible in the Fe K line complex
- They might also have the fastest velocities
- This is a major science case for XRISM

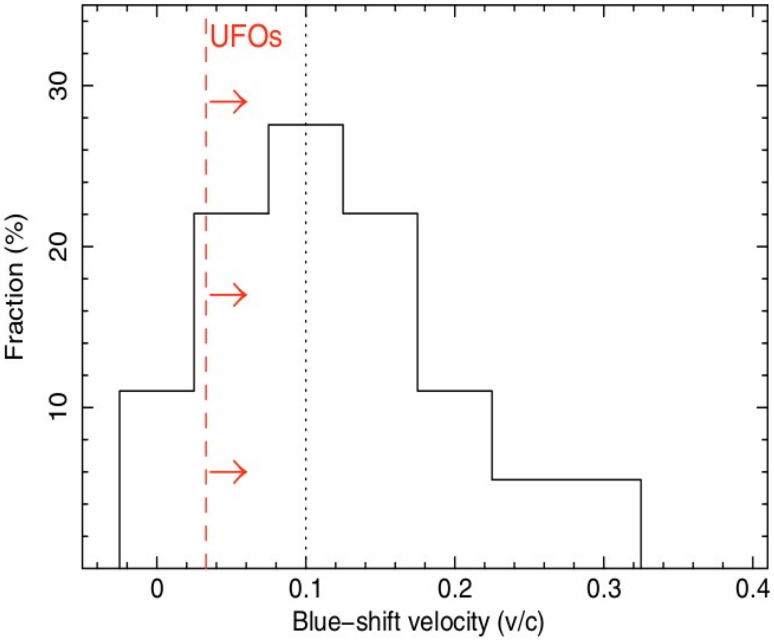
Ultra-Fast Outflows (UFOs)



APM 08279+5255
Chartas et al. 2002

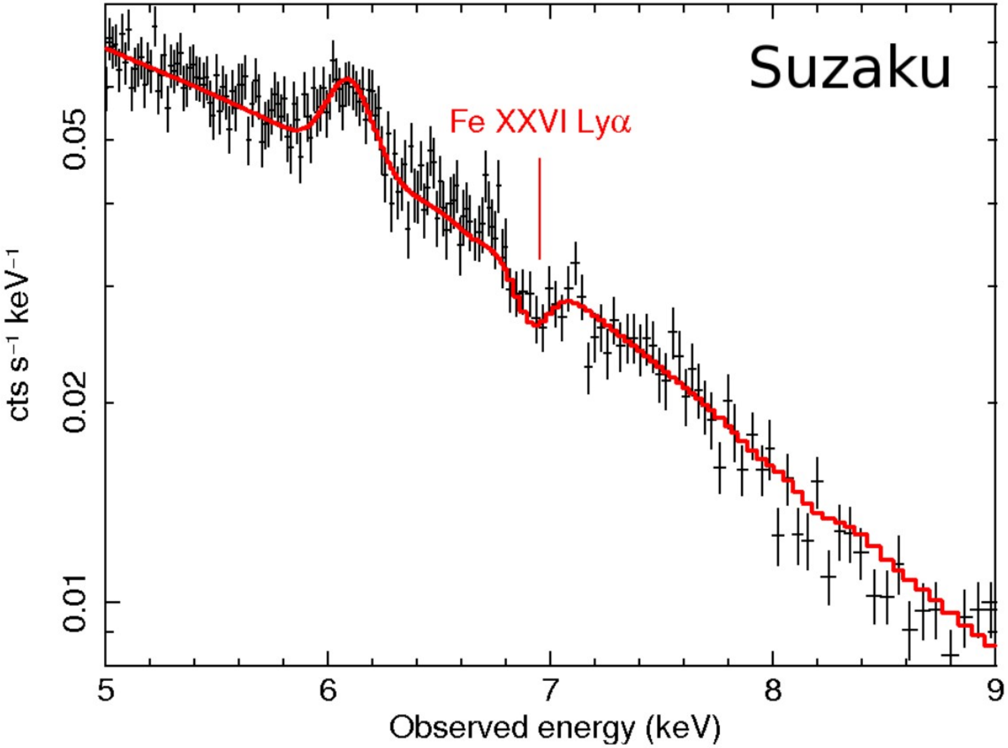


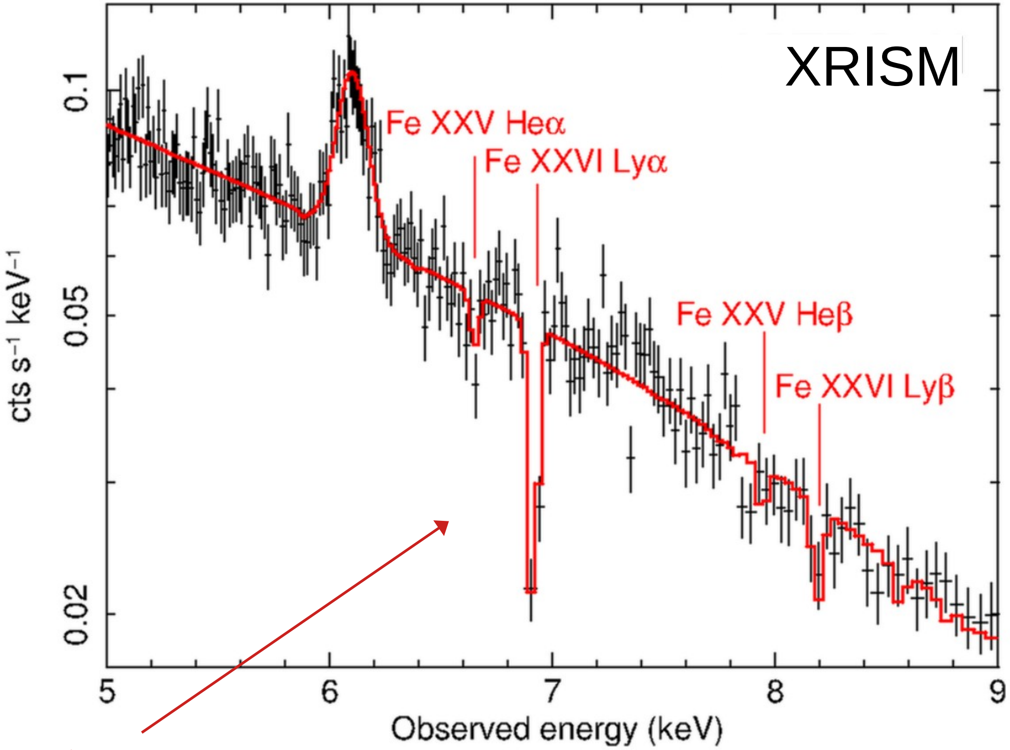
PG 1211+143
Tombesi et al. 2010



Tombesi et al. 2010

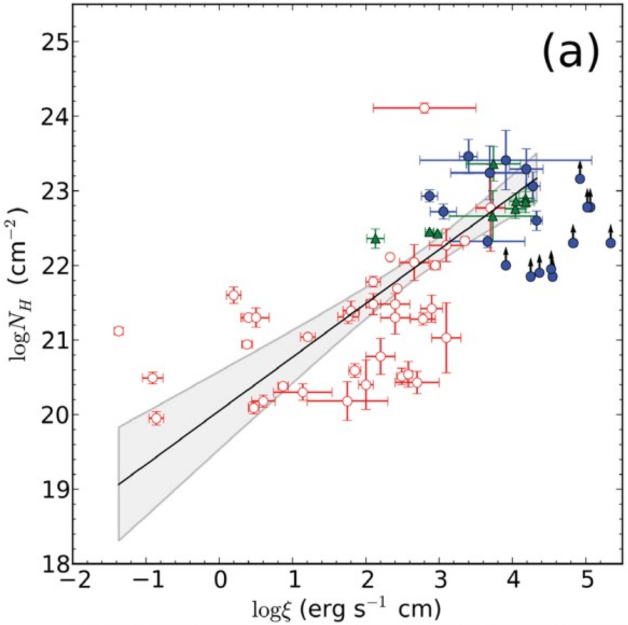
3C 111 (v~0.04c)

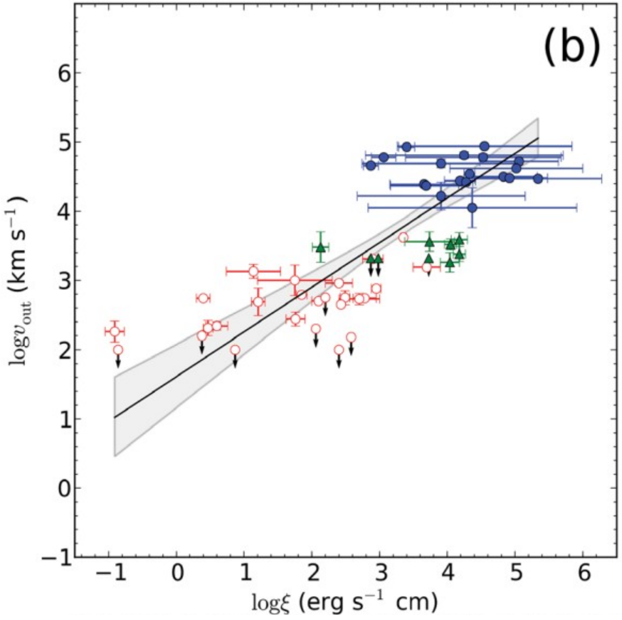


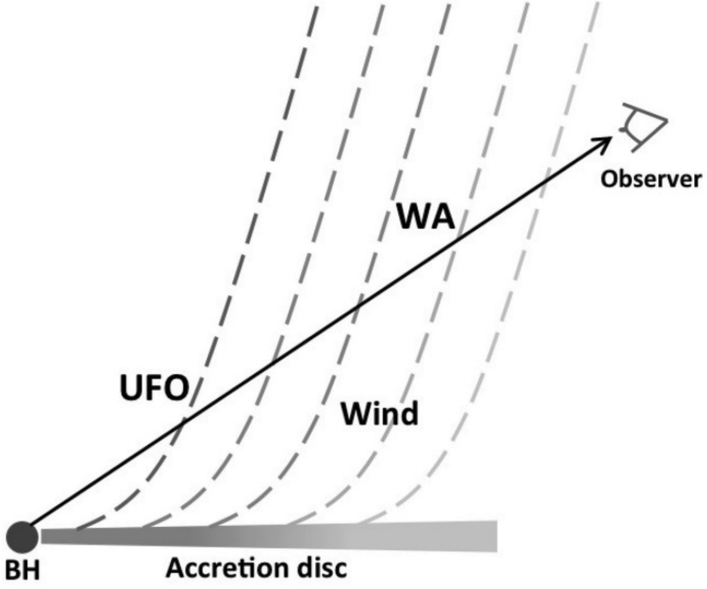


Precise characterization
of the absorber!

Outflow Unification

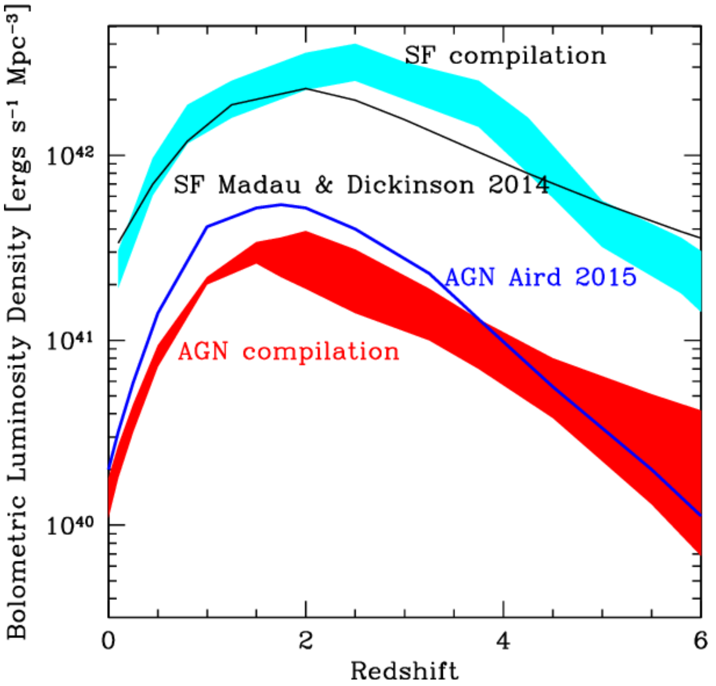






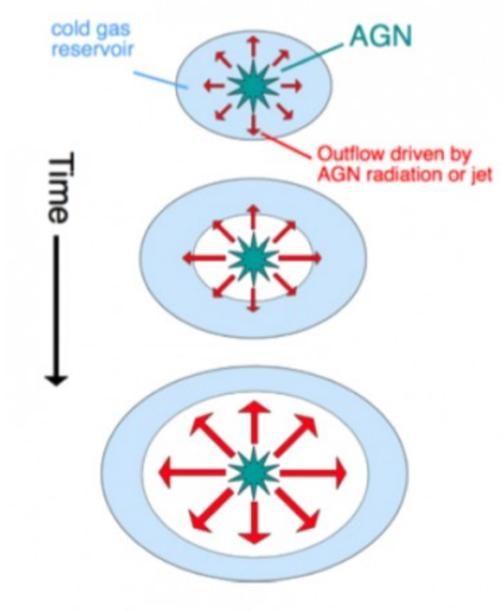
Tombesi et al. 2013

Why do we care?



Fiore et al. 2017

AGN can stop star formation if about 5% of its luminosity is deposited in the ISM

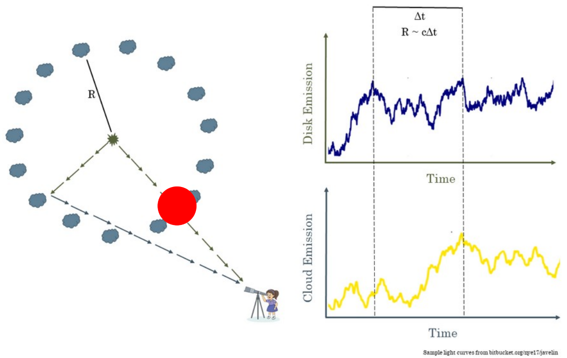


Fabian 2016

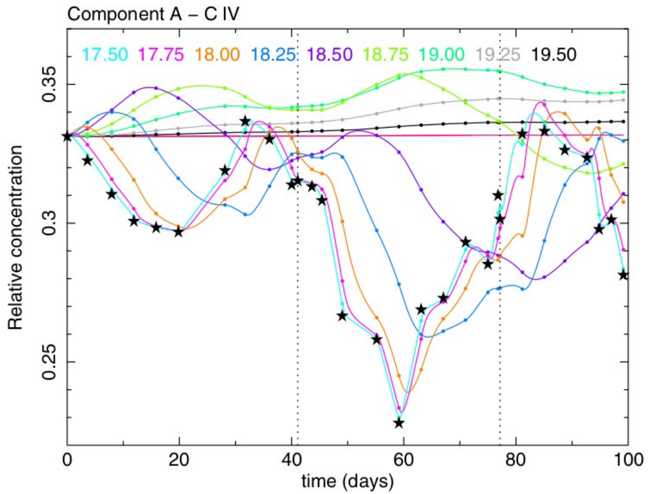
Energetics

- Outflowing mass: $$\frac{\mathrm{d}M}{dt} = \Omega\, N_{\mathrm{H}} m_{\mathrm{p}}\, R\, v$$
- Kinetic power (Luminosity): $$L_{\mathrm{kin}} = \frac{1}{2}\,\frac{\mathrm{d}M}{dt}\, v^2 \propto \Omega\, N_{\mathrm{H}}\, R\, v^3$$
- Determination of L_{kin} requires: Ω , *R*
  - Need to break *n* – *R* degeneracy $$\xi = \frac{L}{nR^2}$$
  - Covering factor Ω ?

Density–Distance Degeneracy



J. Hoormann https://jhoormann.github.io/blog/blog-1/

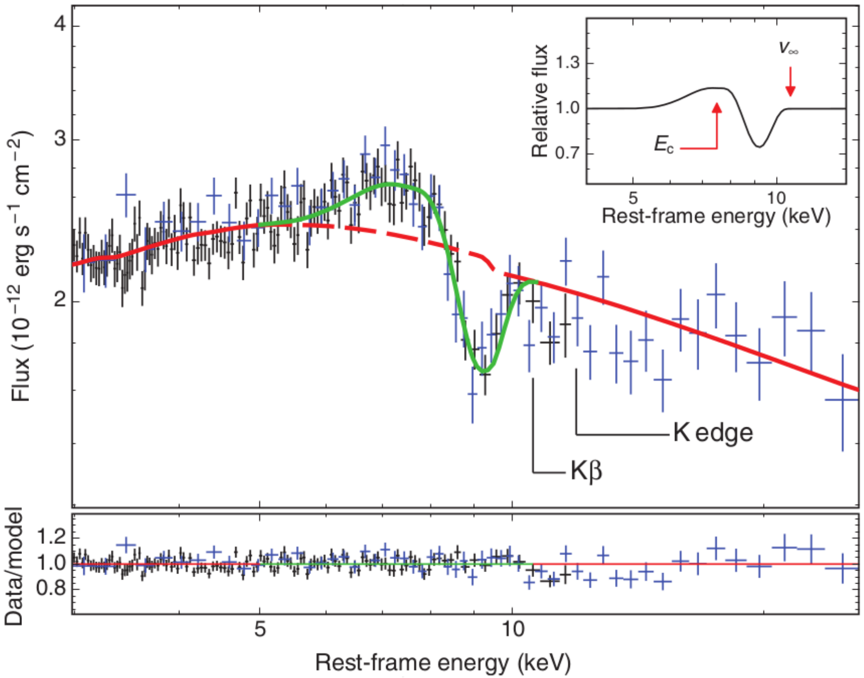


- Reverberation
- But it does not work for absorption
- Metastable states depends on density
  - Large monitoring campaign
  - Complex modeling of the density evolution of specific ions
  - But does not depend on astronomical distances!

Component	Distance (pc)	Density (10^9 m^{-3})
C	>71	<0.28
D	>4.7	<10.6
E	>4.6	<1.7

Kaastra et al. 2012

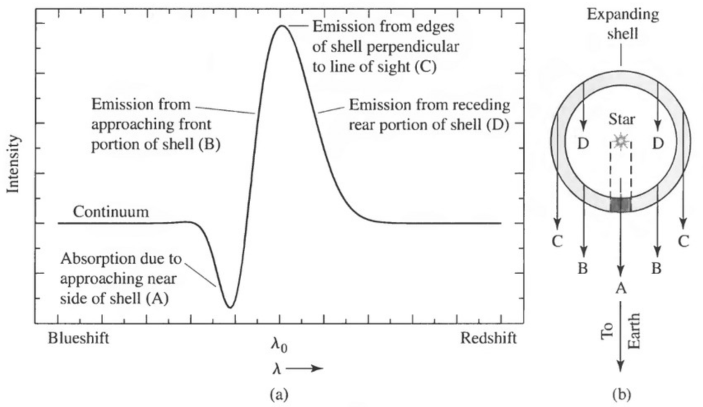
PDS 456



v ~0.35 c

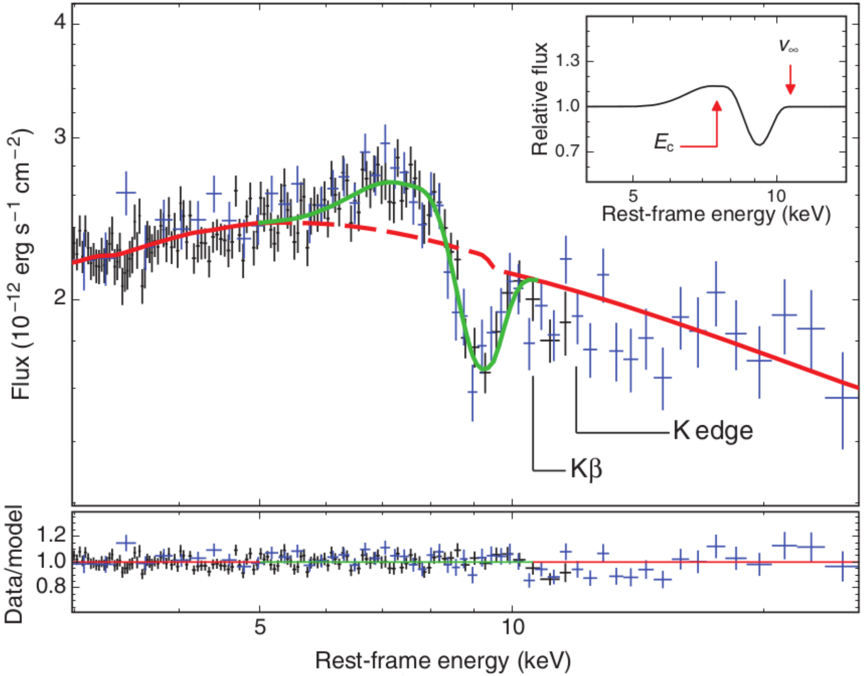
Nardini et al. 2015

P Cygni profile



- P Cygni profile implies a covering factor Ω compatible with 4π
- N_H ~ 6.9 10^{23} cm^{-2}
- NuSTAR crucial to fix the continuum
- *R* from variability of absorption feature ~100 R_G
- d*M*/d*t* ~ 10 $M_\odot$ yr^{-1}
- L_{kin} ~ 2 10^{46} erg s^{-1}, 20% of L_{bol}

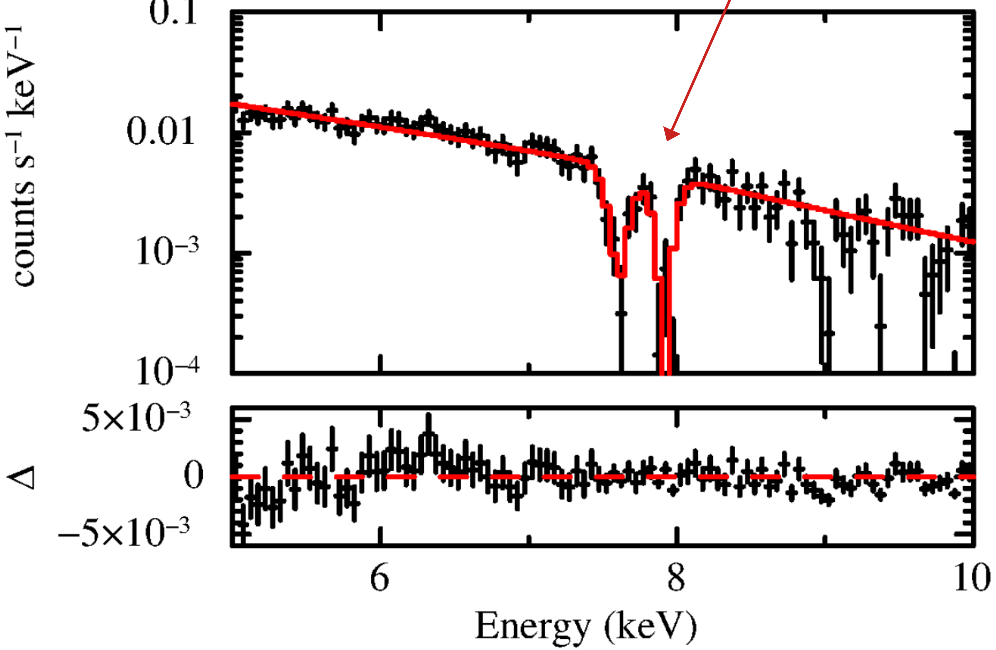
PDS 456



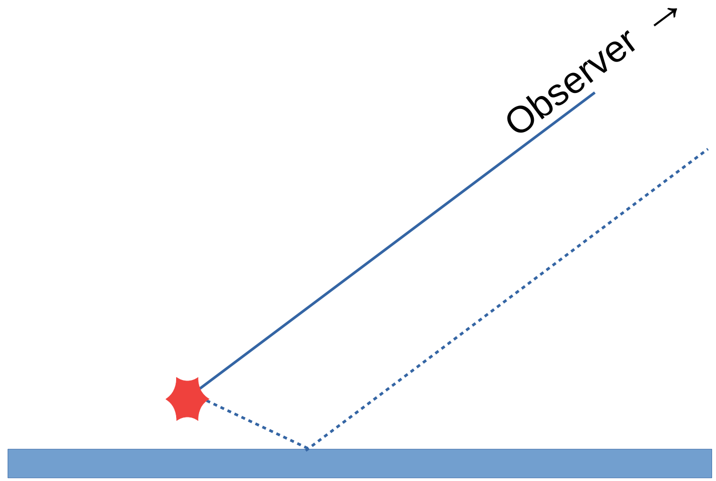
v ~0.35 c

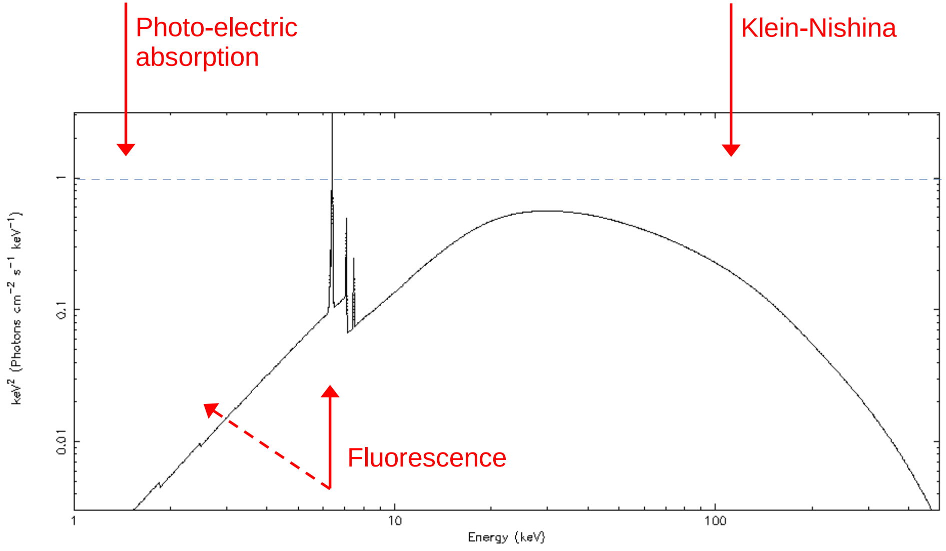
Nardini et al. 2015

Shape of the absorption lines



Reflection

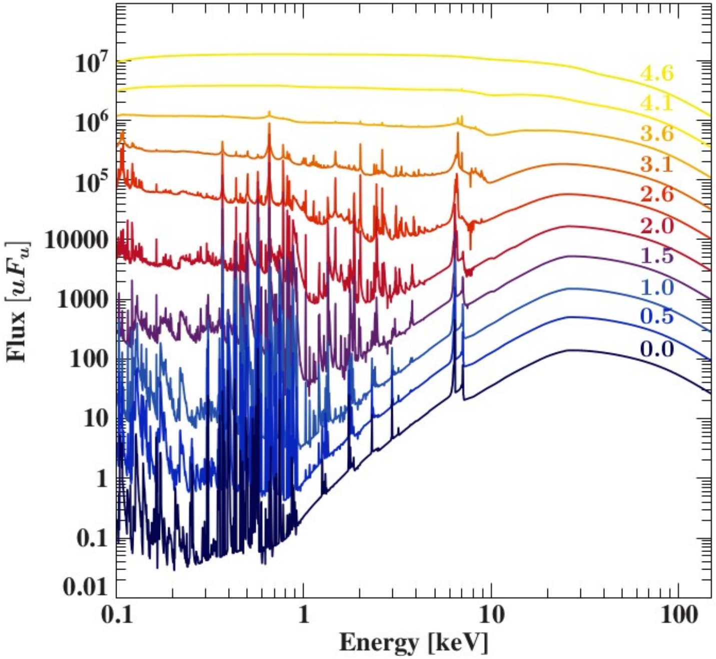




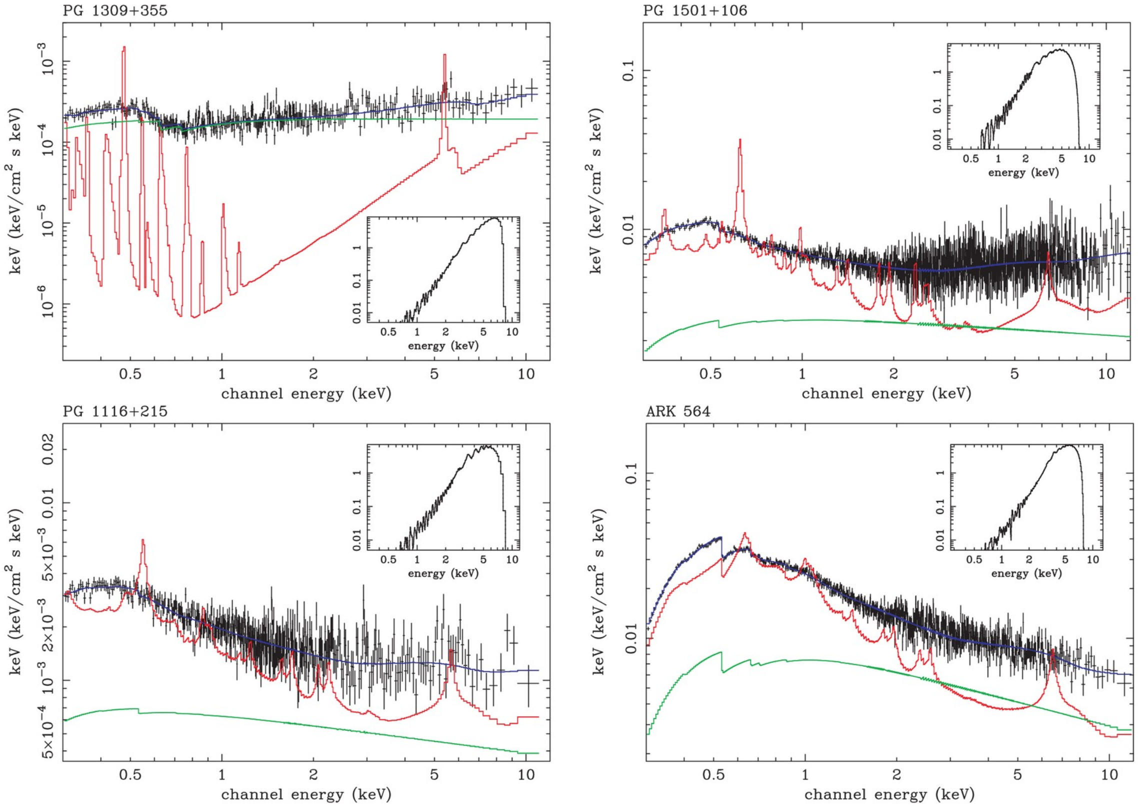
Pexmon; Nandra et al. 2007

- Scattering on electrons
  - Compton
  - Rayleigh
  - Dust
- Photo-electric absorption
- Fluorescence

Ionized Reflection

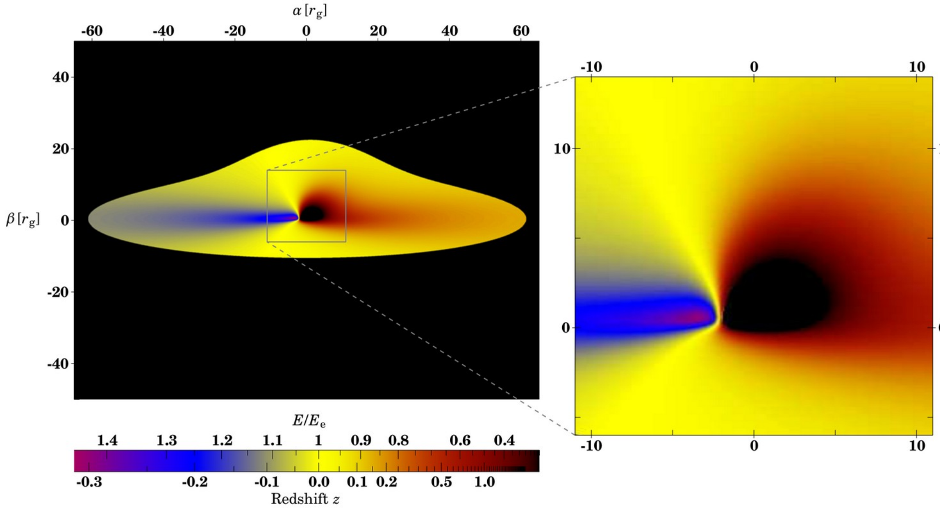


xillver; García et al. 2011

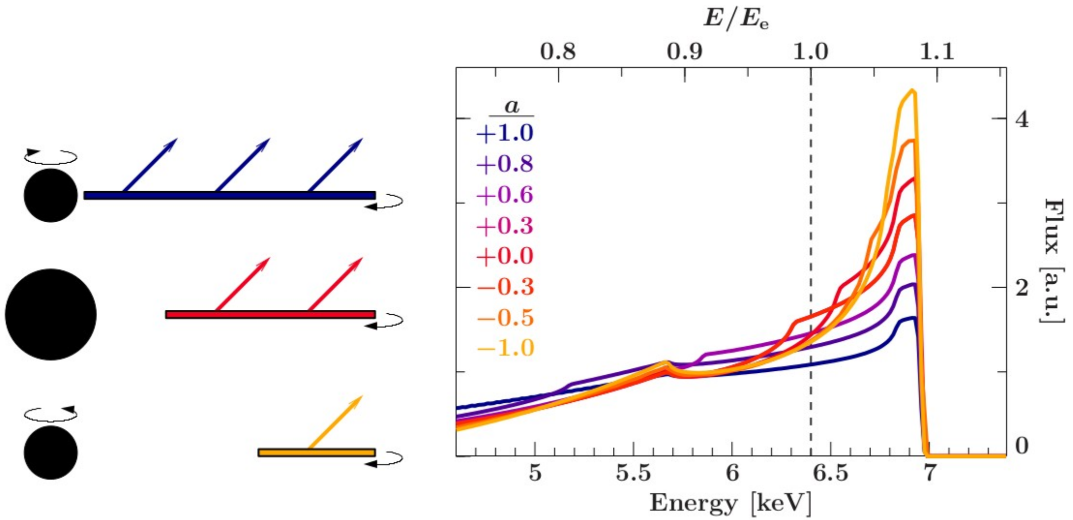


Crummy et al. 2006

Relativistic Ionized Reflection

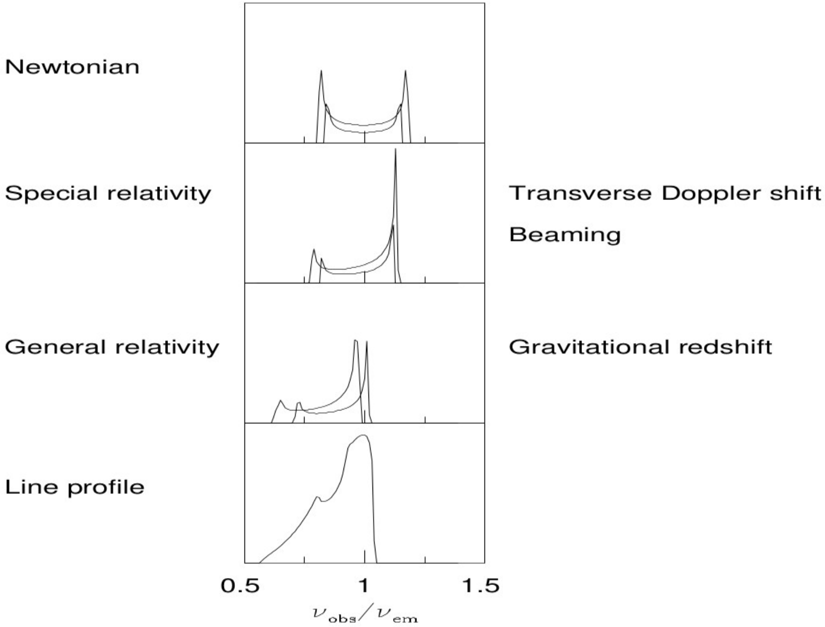


García et al. 2014

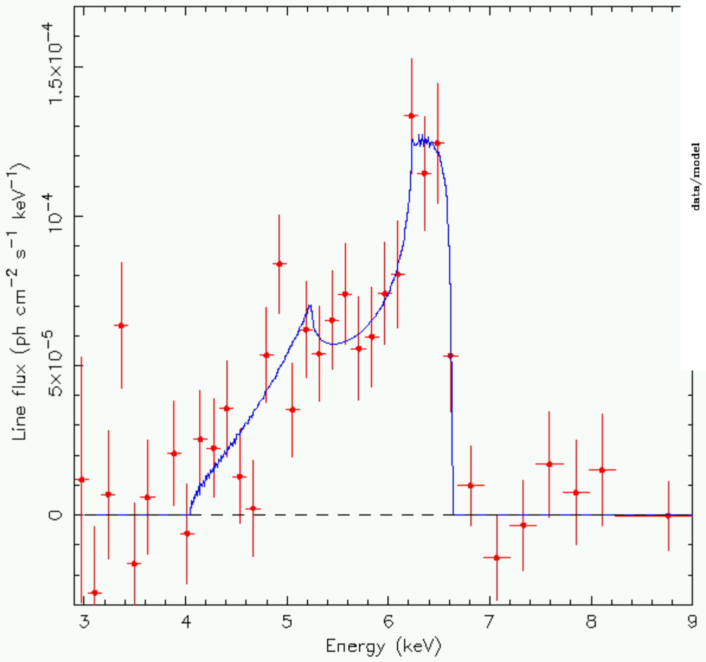


relxill; Dauser et al. 2016

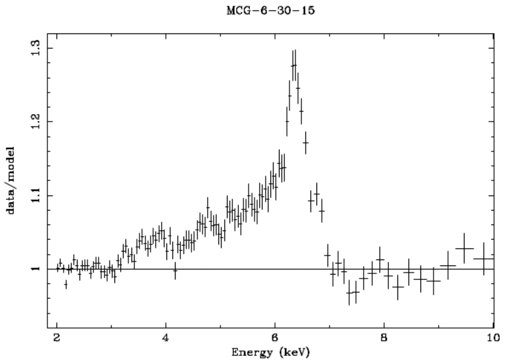
Relativistic Profile



ASCA Observation of MCG-6-30-15



XMM-Newton

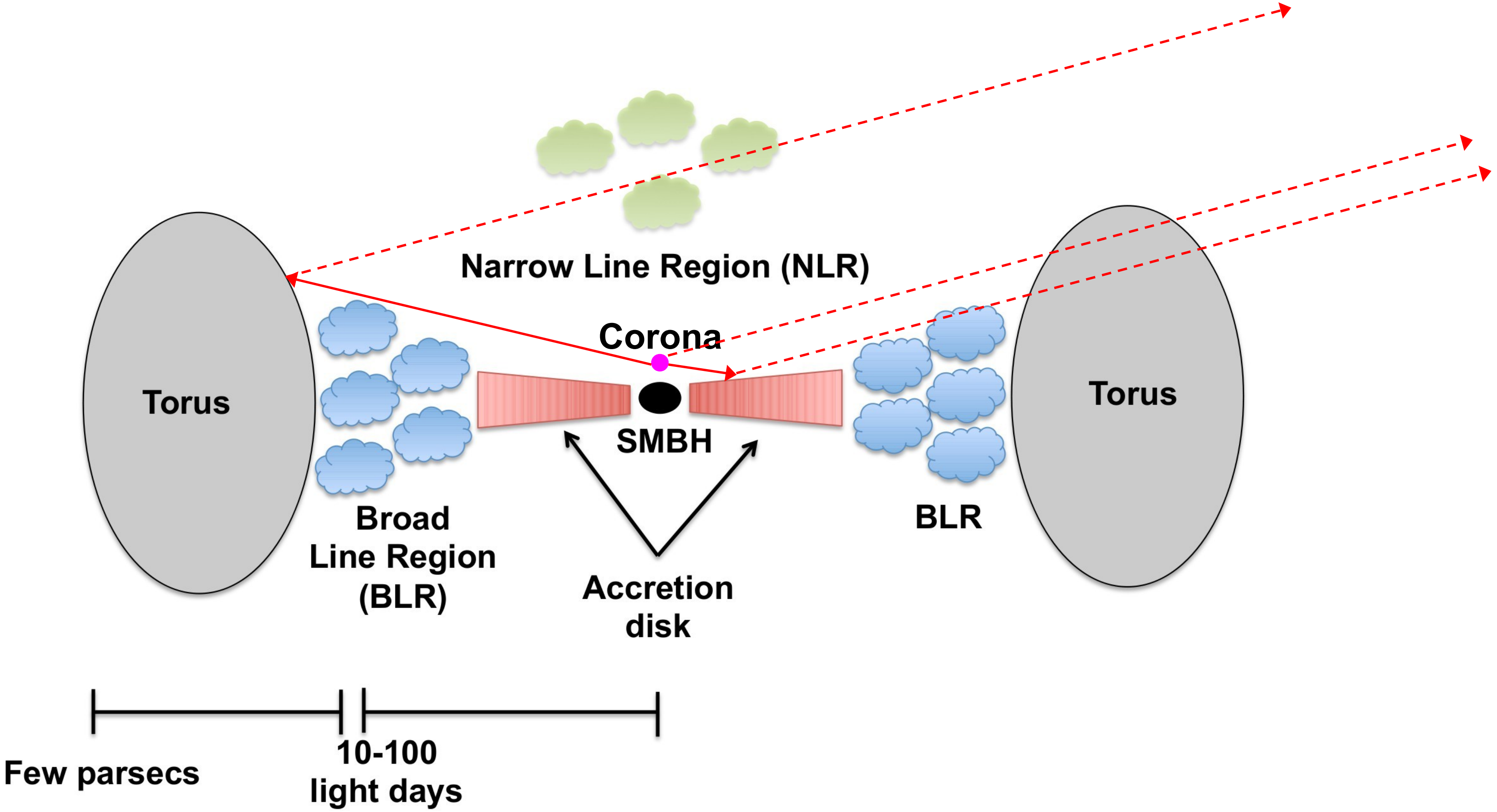


Fabian et al. 2002

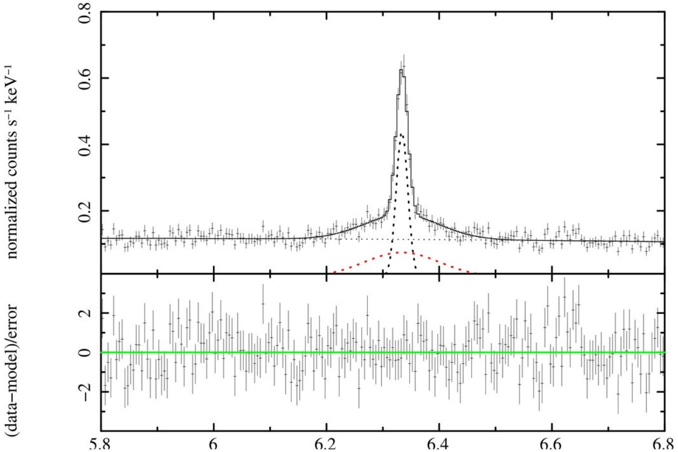
3 – 10 R_G

Tanaka et al. 1995

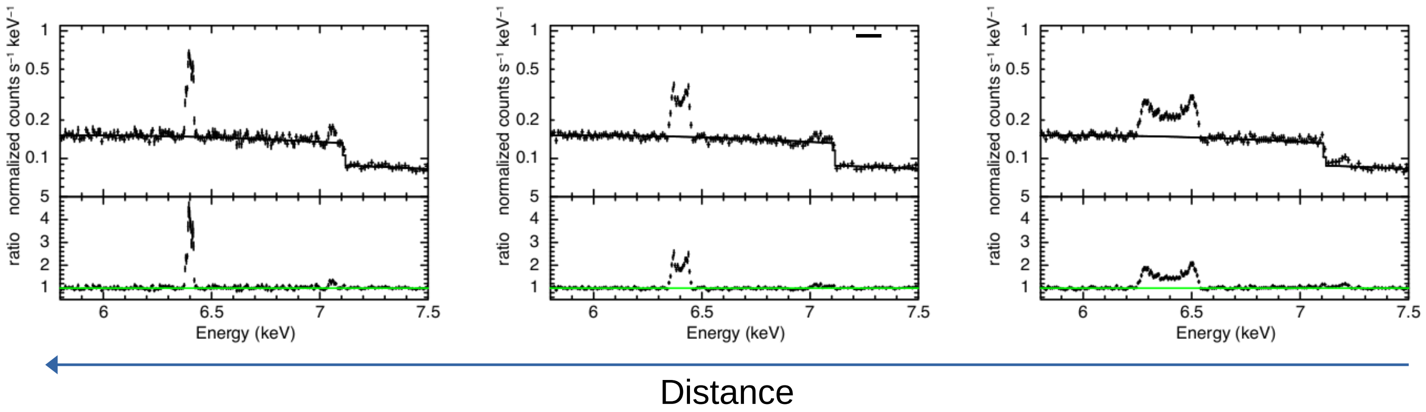
Distant Reflection



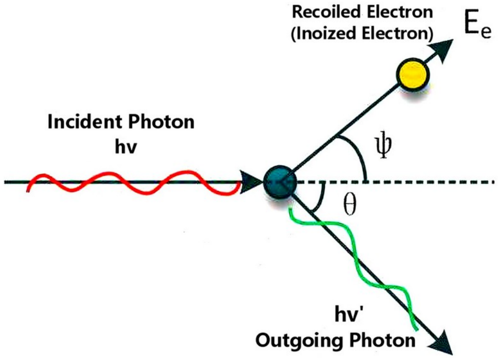
Line Width and Shape



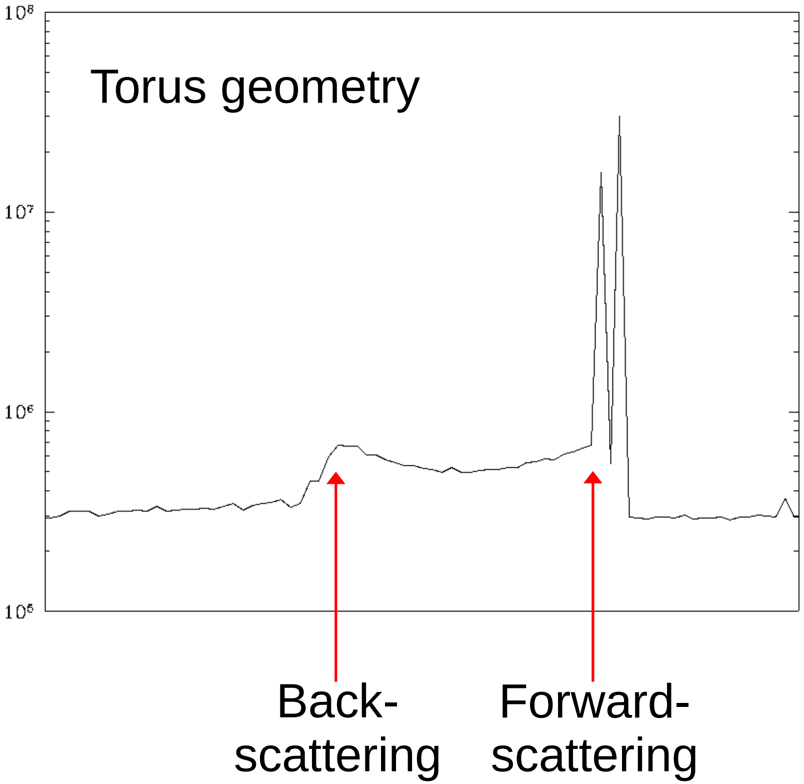
- NGC 4388: Bright, edge-on AGN
- Width seem compatible with BLR
- Disk line?
  - Precise shape indicates location of reflection



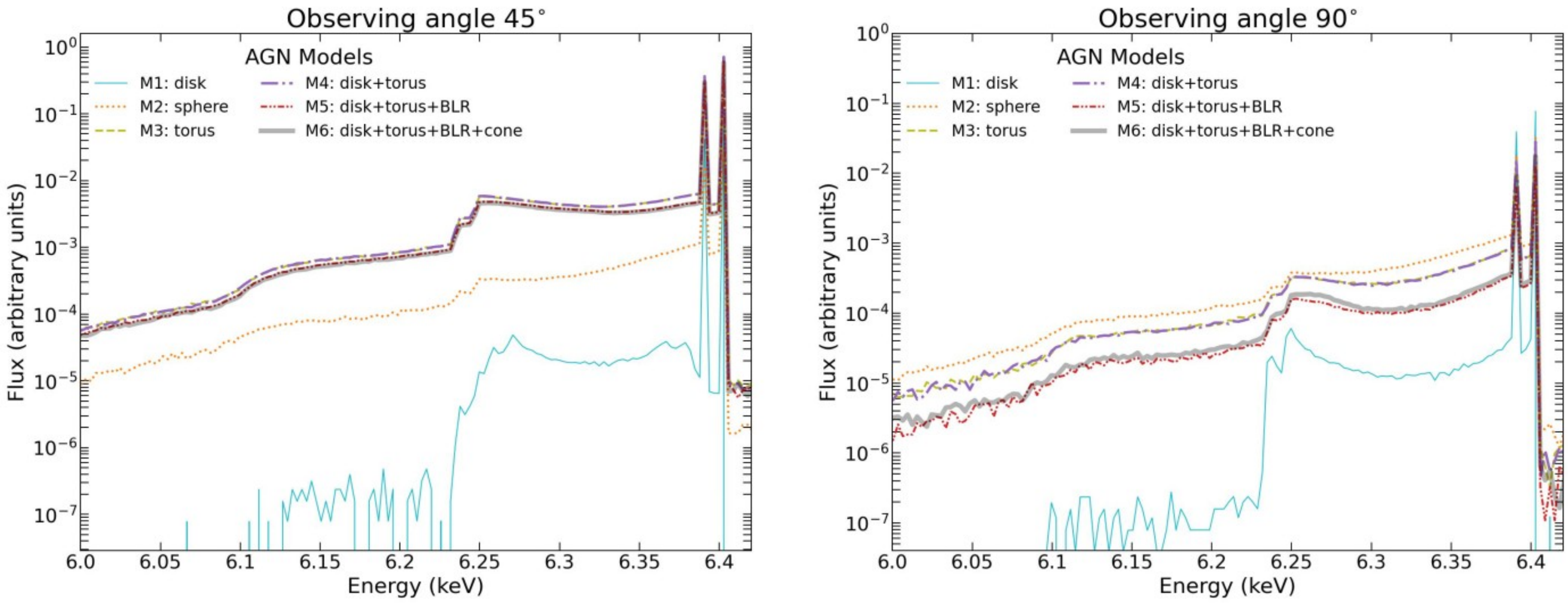
Compton Shoulder



Inelastic scattering on
“free” electrons



Compton Shoulder

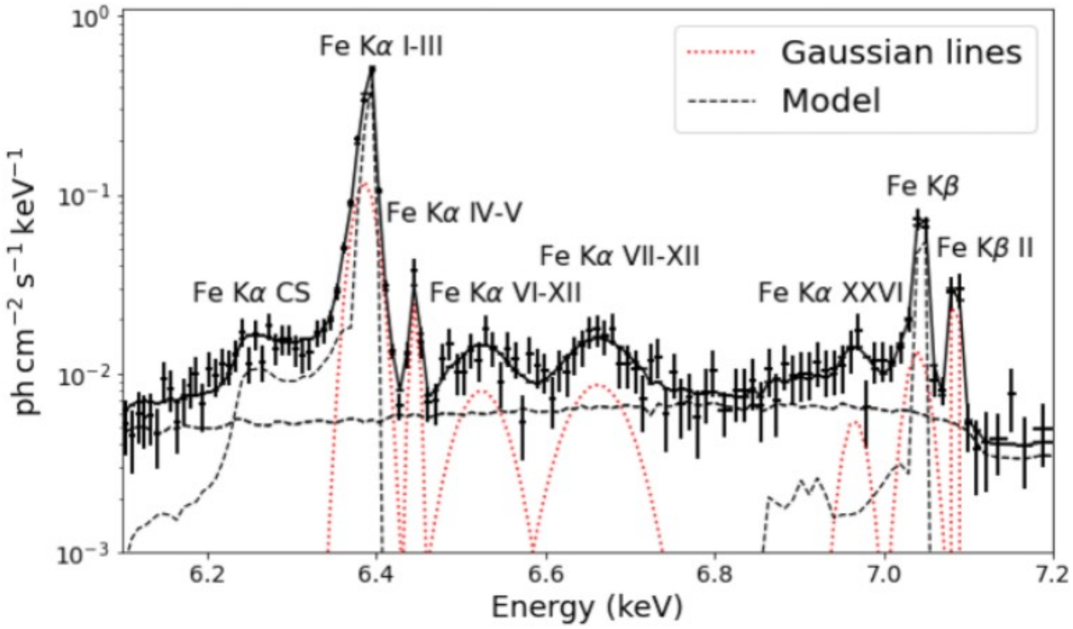


Dimopoulos et al. 2024

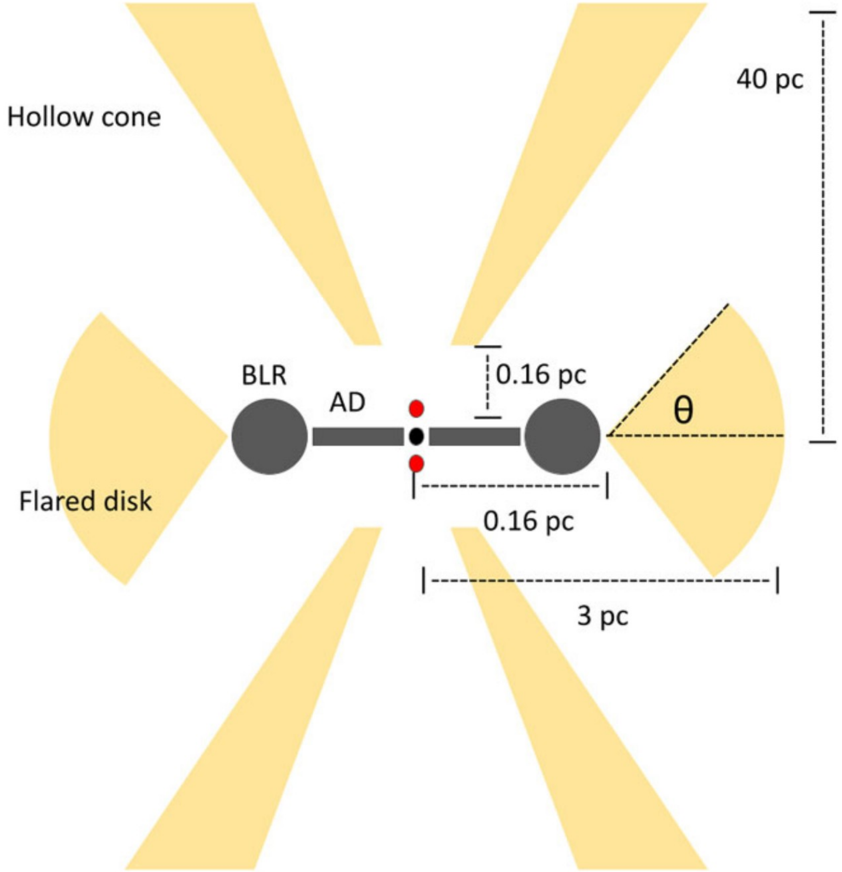
ReflеX simulations:
https://www.astro.unige.ch/reflex/

Paltani & Ricci 2017

Circinus Galaxy



Andonie et al. 2022



Conclusion

- XRISM will allow major advances in the understanding of AGN even with GV closed thanks to its high resolution and high sensitivity around 7 keV
  - Ultra-fast outflows
    - Precise characterization
    - Energetics
    - Launch mechanism
  - Fluorescence
    - AGN geometry from a few R_G to several pc
    - Velocities