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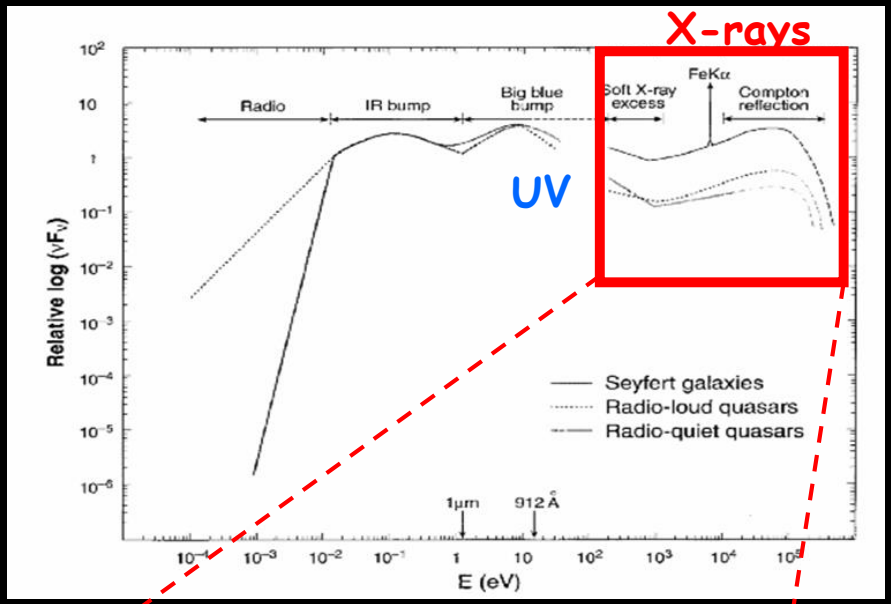
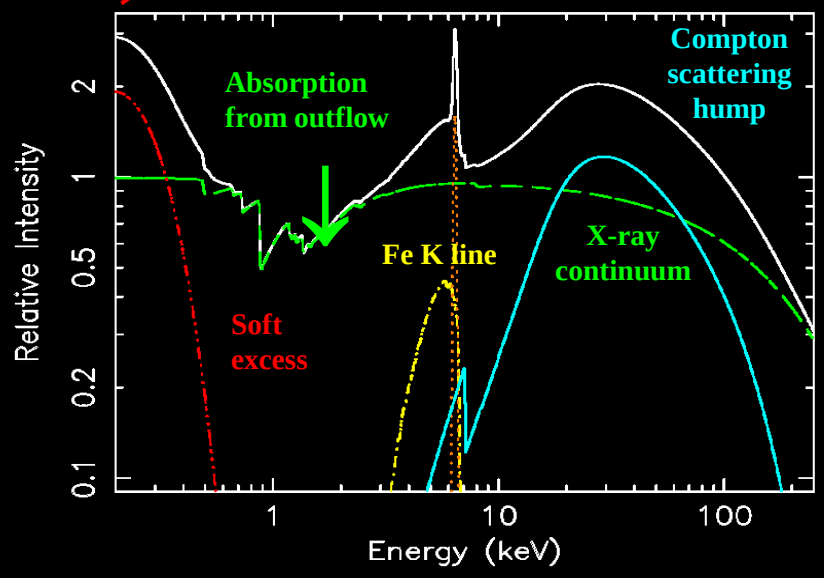
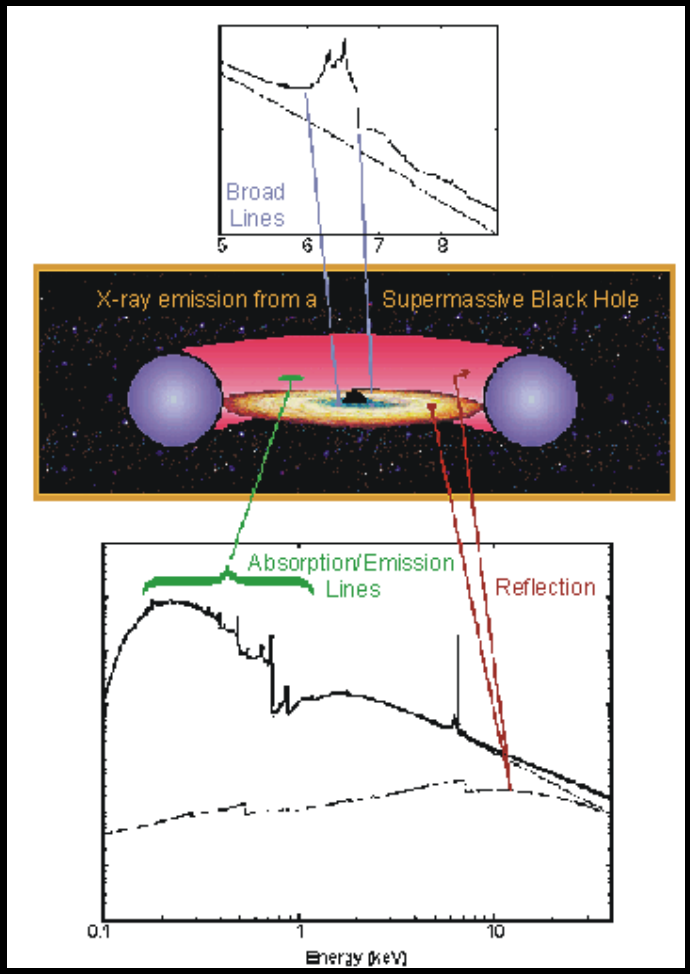
X-ray observations of AGN

STRONGGRAVITY
EU FP7-SPACE research project 312789 2013 - 2017

Spectral Energy Distribution of AGN



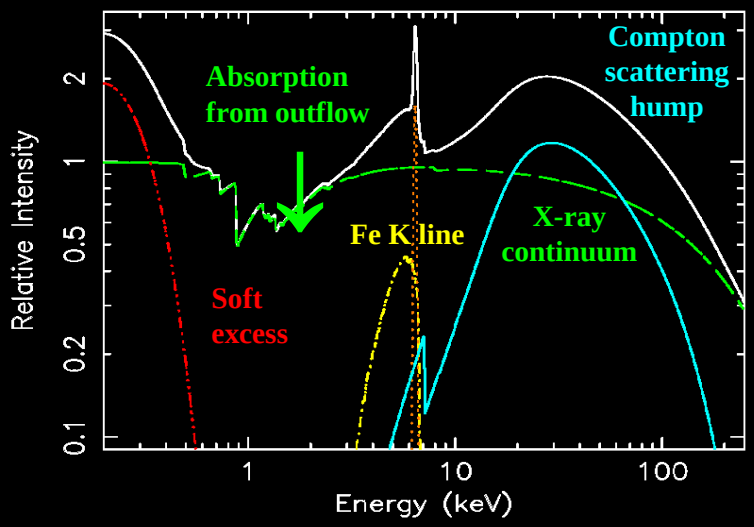


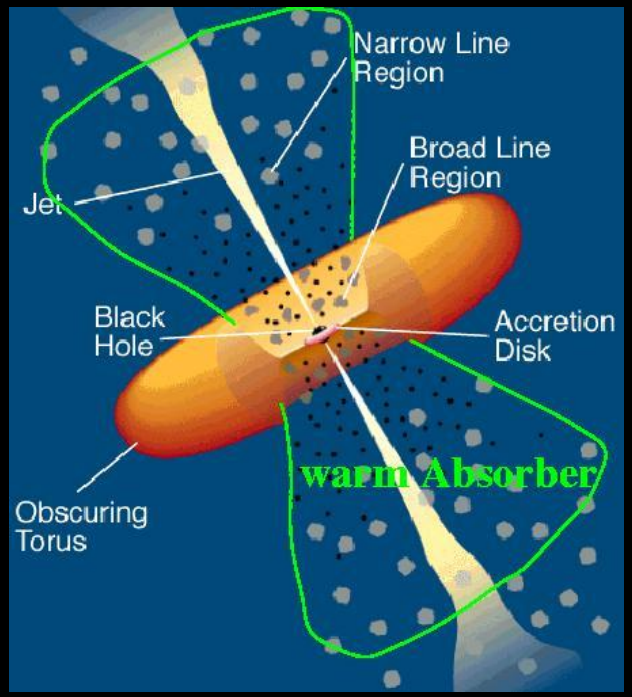


The study of X-ray spectral features:

⇨ probe AGN from the inner part of the accretion disc to much larger scales :

BLR, NLR, torus, Warm absorber, outflows, …





Main properties and statistical detections:

- Soft excess: ~80% of the sources

If fitted with a a black-body shape kT~150-200 eV over several decades of black hole mass but if due to thermal emission from the disc: $kT \propto M_{BH}^{-1/4}$
(Gierlinski & Done 2004, Porquet et al. 2004a)
⇨ not the X-ray tail of the « Big Blue Bump » observed in UV

- The Fe K complex line

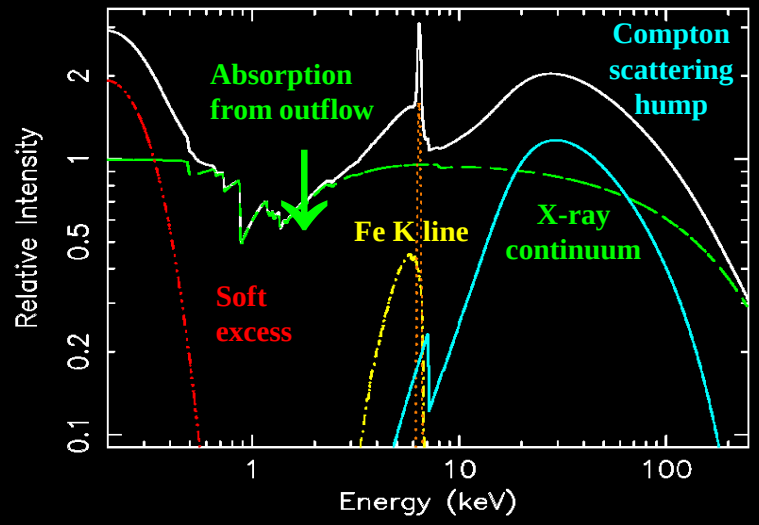
- A Compton hump peaking near ~30 keV

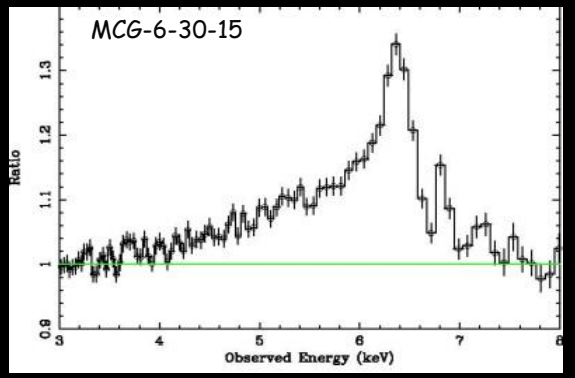
- Warm absorber/emitter: ~50% of the sources

Hot media supposed to be located between the BLR and the NLR.
+ Ultra Fast Outflows : ~25% of the sources.
Accretion disc disc wind ?

I. Probing « relativistic effects » and the inner part of AGN:

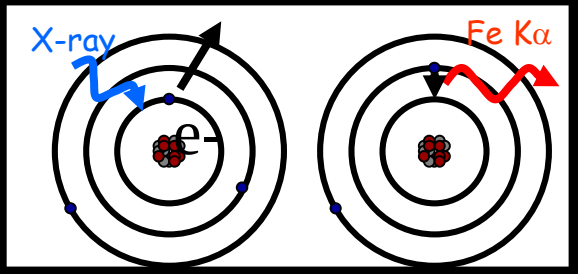
The « relativistic » Fe Kα line, the soft excess and the Compton hump





The FeK emission line complex:

FeKa line is the most prominent spectral line in the X-ray spectra of AGN

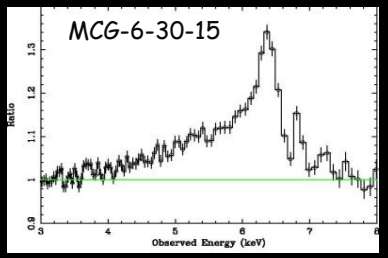


* Energy: ionization degree of the medium emitting it :
- 6.4 keV (<FeXVII),
- 6.7 keV (He-like: FeXXV),
- 6.97 keV (H-like: FeXXVI)

* Profile (and variability time-scale) ⇨ location
close (« relativistic » FeK line) or far from the SMBH (narrow "neutral" FeK line)

Current X-ray observations:

- The narrow "neutral" FeKa emission line seems to be ubiquitous in AGN (e.g., Yaqoob & Padmanabhan 2004, Nandra et al. 2007)



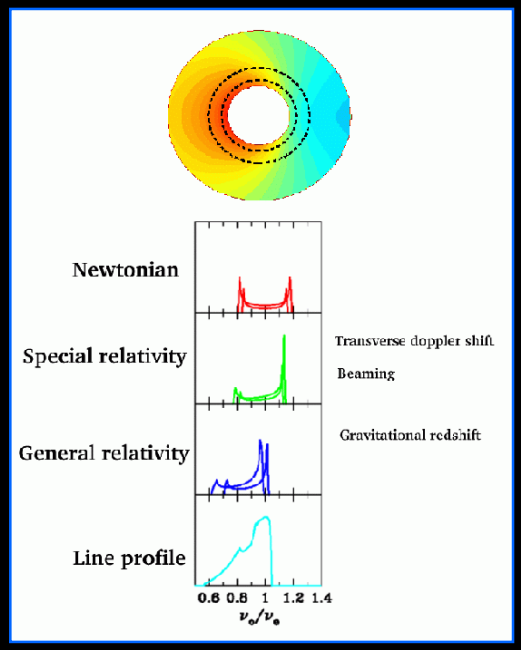
Miniutti et al. (2007)

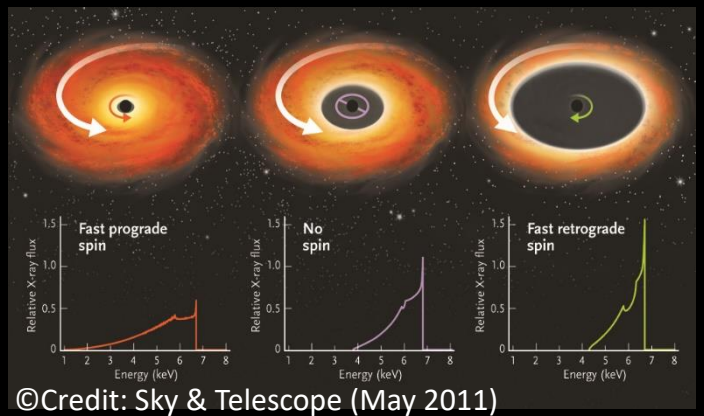
- FeXXV and FeXXVI emission lines are observed (e.g. Bianchi et al. 2009, Patrick et al. 2011)

- The broad Fe K line -- alias the « relativistic » line -- is detected in a large number of AGN : ~36% of the local Radio-quiet Type 1 AGN observed with XMM-Newton (de La Calle et al. 2010; Patrick et al. 2012):

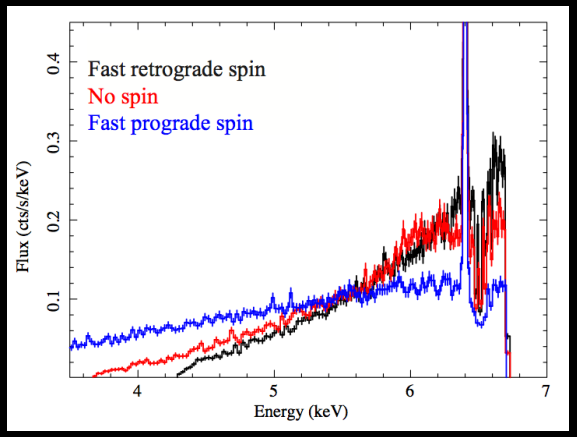
Note: Need a very large count number in the 2-10keV range for robust detection and measure.

The « relativistic » FeKα line

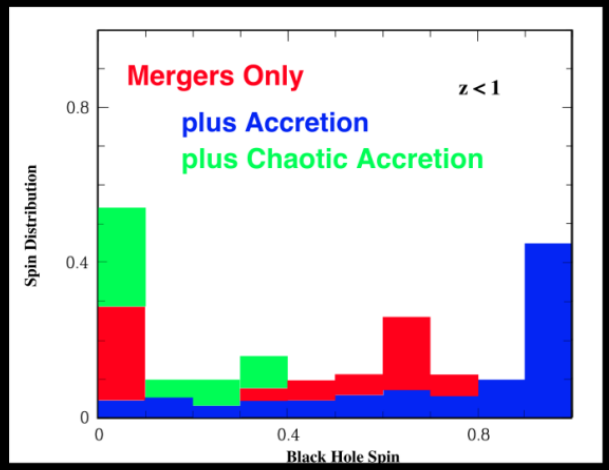




©Credit: Sky & Telescope (May 2011)



The shape of the Fe Kα line ⇨ BH spin

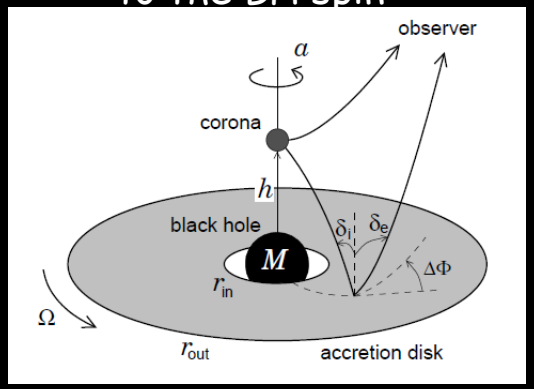


SMBH Spin
⇨ accretion mode : chaotic versus prolonged, plus mergers ?

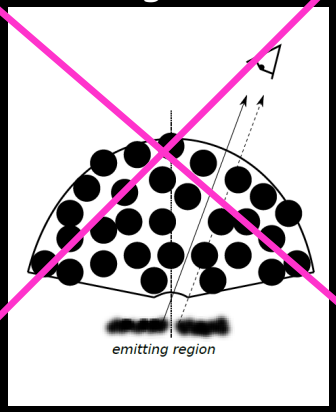
⇨ galaxy evolution.

BUT at least 2 interpretations for the apparent broadening of the FeK line ….

Relativistic reflection on the disc
-> FeK broadening directly related to the BH spin



Warm absorber(s) which distorts the underlying continuum and mimicks an apparent broadening of the FeK line

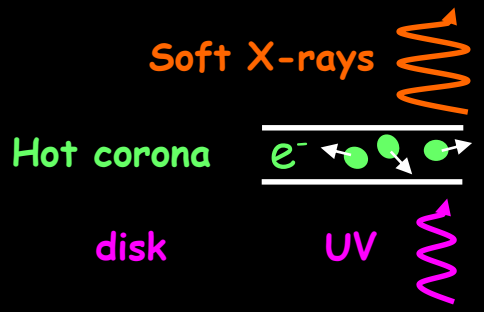


⇨ Study of the broad-band continuum (XMM-Newton+Suzaku+Swift) of a sample of **bare AGN** (i.e. without Warm absorber):

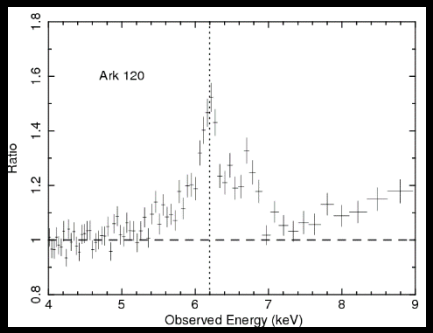
Spin determination is strongly model-dependent, i.e. how the soft X-ray excess is modeled :

- If due to Comptonisation :
  low spin values ⇨ chaotic accretion
- If due to relativistic reflection :
  high spin values ⇨ prolonged accretion
  (Patrick et al. 2011a)

Comptonization of the UV disc photons by the hot e^- of the corona



Forthcoming deep observations of a « bare » AGN



PI: D. Porquet

Observations on early 2014 of the « bare » AGN type 1 Ark 120 (no «contamination» due to Warm absorber or outflows on the line-of-sight)

⇨ A direct view of the inner part of the AGN
⇨ break the degeneracy between relativistics and WA effects

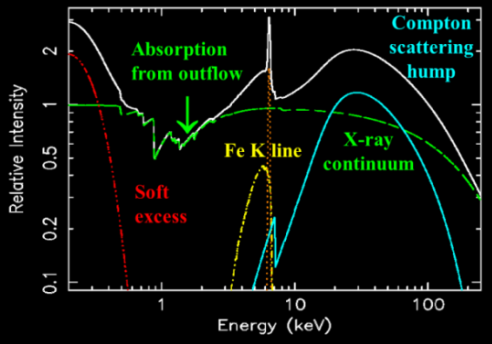
✓ The soft excess origin

✓ The properties of the accretion disc and the black hole spin:

- 480 ks (~5.5 j) XMM-Newton Large program (OM + EPIC + RGS);
- + a 120 ks simultaneous Chandra/HETG observation.

This will be the highest S/N data for such object,
and will serve as a template for AGN in general.

Spin of SMBH in deep Suzaku observations



Study of 46 Seyfert 1 ($z \lesssim 0.2$) over a **broad-band range** (0.6-100keV) thanks to deep Suzaku observations (>30 000 counts; 84 observations) combined with Swift/BAT observations (Patrick et al. 2012)

Here not only 'bare' AGN but all type-I AGN (including those with Warm Absorber and « UFOs »)

Main results:

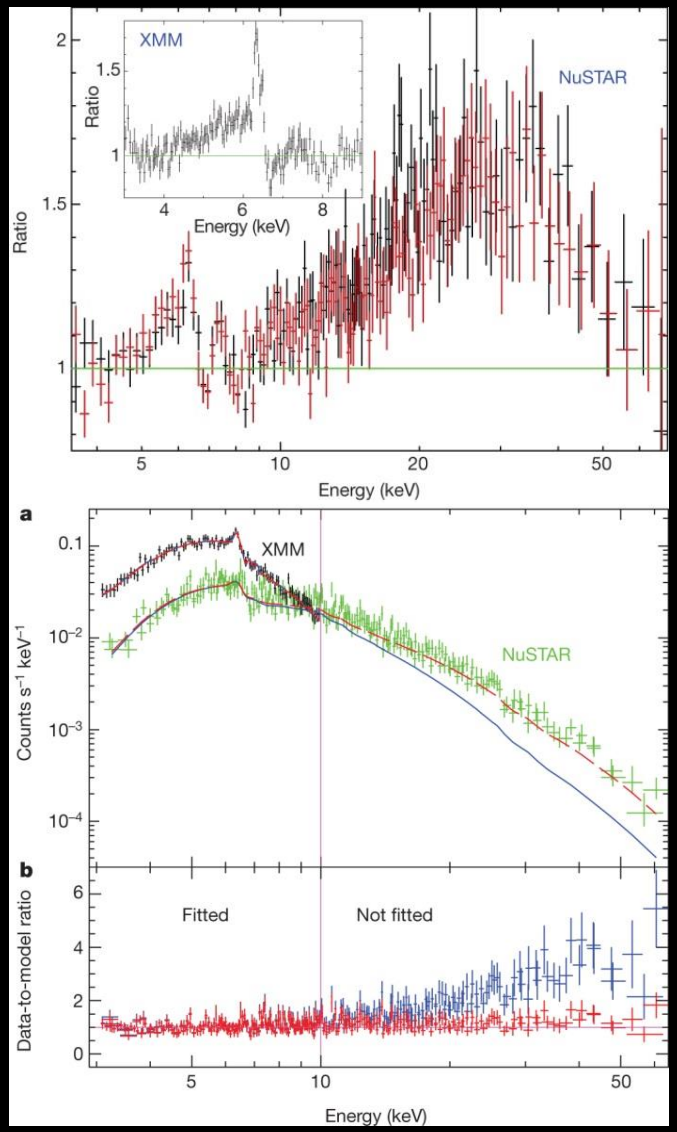
- Presence of complex warm absorber in 59% of the objects of this sample.
- High velocity, high ionization outflows (up to 0.3c) – "UFOs" - in 22% of the objects
  ⇨ importance on feedback between the SMBH and its galaxy host.
- Fe K complex :

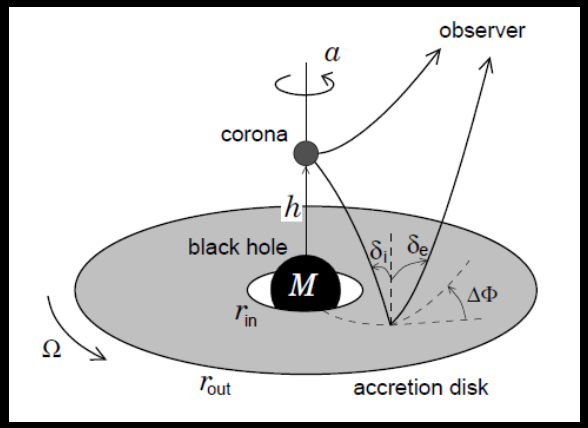
- The FeK narrow component (@6.4 keV): almost ubiquitous
- Narrow emission lines from FeXXV (@6.7keV) and FeXXVI (@6.97keV): in 52% and 39%, respectively
- Statistically significant « relativistic » FeK line detected in about 50% of the sample.

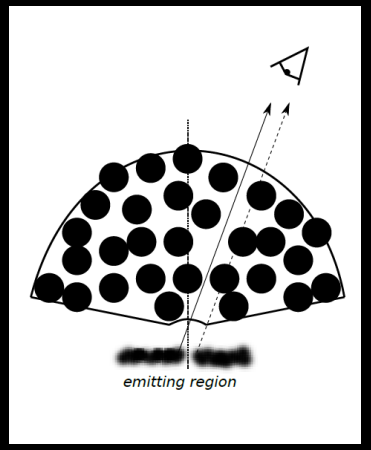
+ Confirmed our previous studies (Patrick et al. 2011a, 2011b):
As shown in this work the spin determination is model-dependent, i.e. depends how the soft excess is modeled, i.e. Comptonization or relativistic reflection

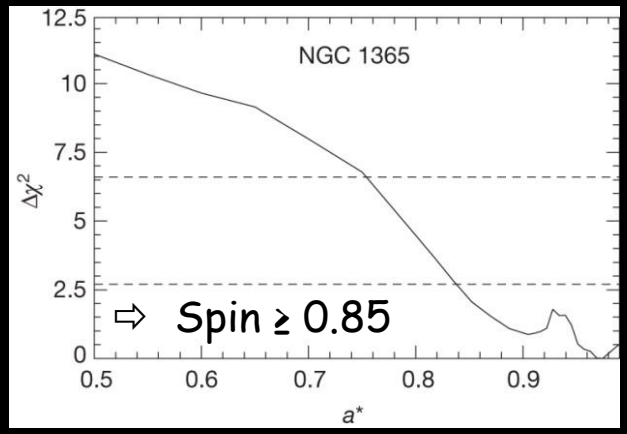
NuSTAR (+XMM-Newton) observations of the Seyfert 1.8 NGC 1365

Risaliti et al. (2013)





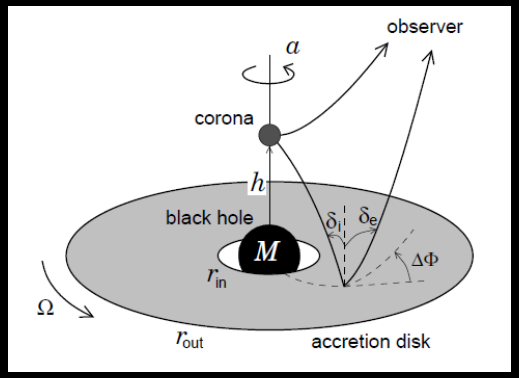




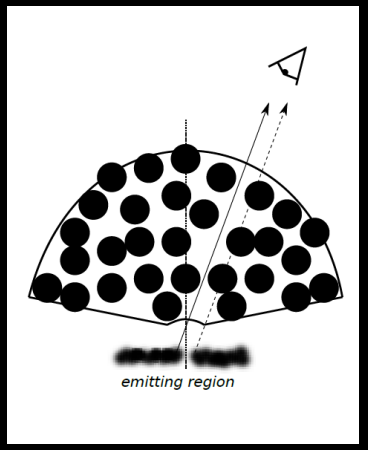
But, Miller & Turner (2013) :
« The Hard X-Ray Spectrum of NGC 1365: Scattered Light, Not Black Hole Spin »

X-ray polarimetry as a complementary powerful tool

Relativistic reflection on the disc
-> FeK broadening directly related to the BH spin



Warm absorber(s) which distorts the underlying continuum and mimicks an apparent broadening of the FeK line



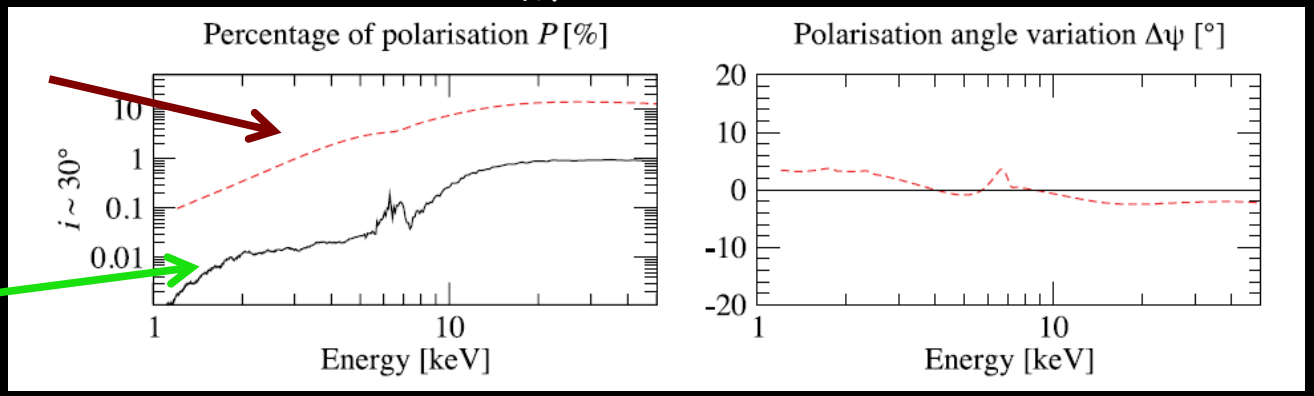
⇨ Currently: X-ray spectral and timing analysis …

+ X-ray polarimetry : A complementary new tool to distinguish between the 2 scenarios

MCG-6-30-15

Relativistic reflection

Absorption

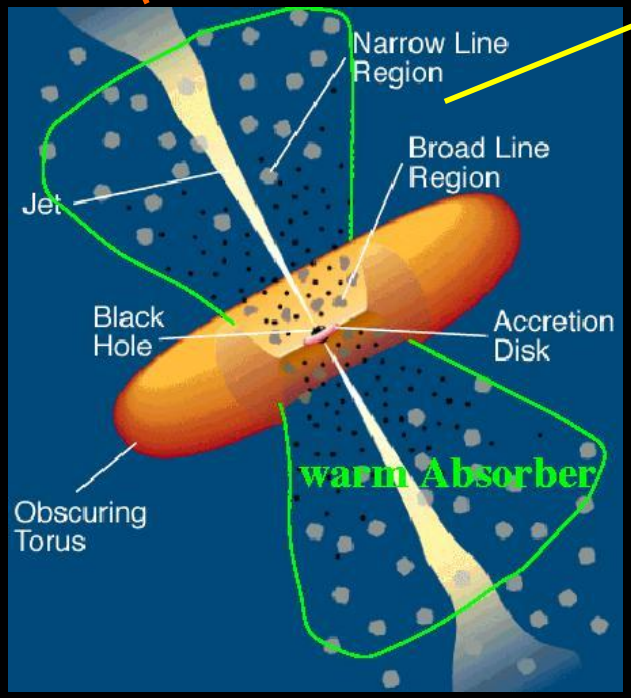


(Marin et al. 2012)

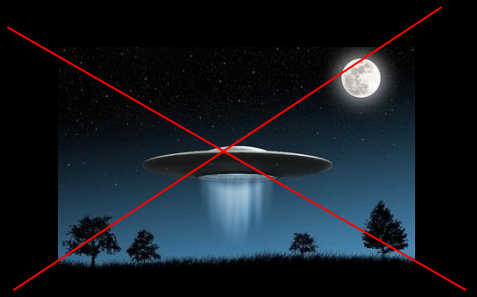
II. Warm absorber-emitter and ultra-fast outflows (UFOs) in AGN

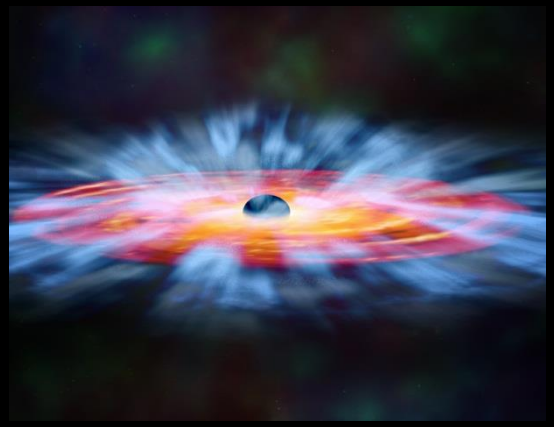
Type 1:
Absorption + emission features

Type 2:
Only emission features



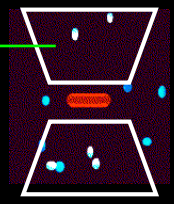
Warm absorber/emitter





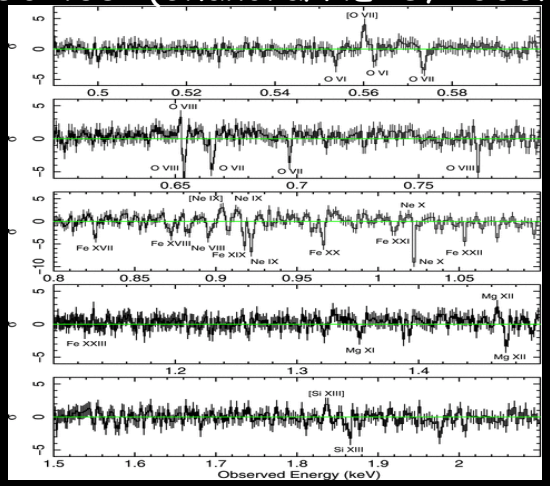
« UFOs »

Warm Absorber/emitter



Type 1

NGC 4051 (Chandra/HETG; ~300ks)



Lobban et al. (2010)

- Absorption lines for C to Fe
- present in ~50% of Seyfert 1 and low-z quasar

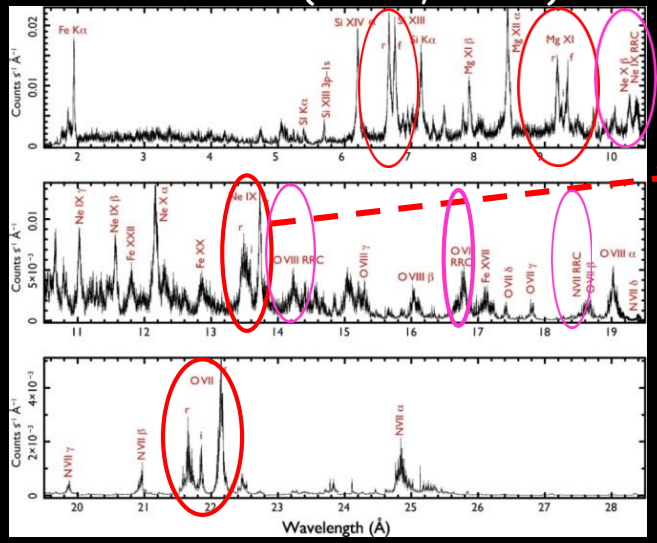
- In general more than one component
- Low N_H: $N_H \sim 10^{20}$-10^{22} cm^{-2}
- Low ξ (≡L/n R^2): log ξ ~ 0-3
- V_{out} ~ 100 - 2000 km/s

- Kinetic luminosity: L_{out} ~ 1% L_{bol}

(but the amount of matter processed over the lifetime could be significant)

Type 2

NGC 1068 (HETG, 440ks)



Evans et al. (2010)

X-ray plasma diagnostics:

* He-like « triplet » (e.g. O VII, Ne IX):

⇨ $R(n_e) = F/I$ $\quad G(T_e) = (F + I) / R$

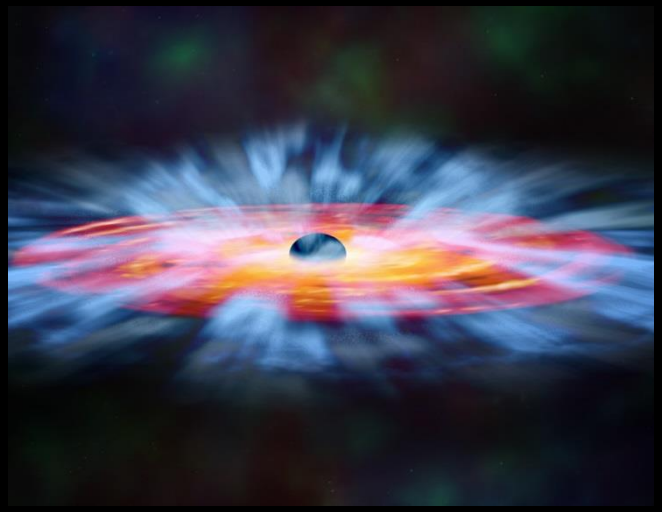
(Gabriel & Jordan 1969; Porquet & Dubau 2000)

Density + ionization processes:

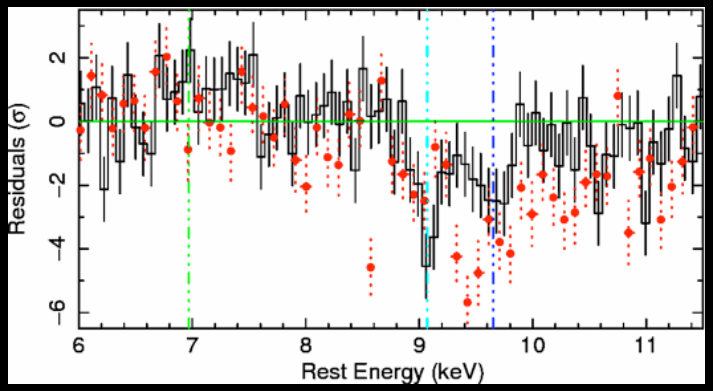
Photo-ionization/collisional ionization

See Porquet et al. (2010) for a review

Ultra-fast outflows (UFO): accretion disc wind ?



PDS 456 (Suzaku; 190ks)



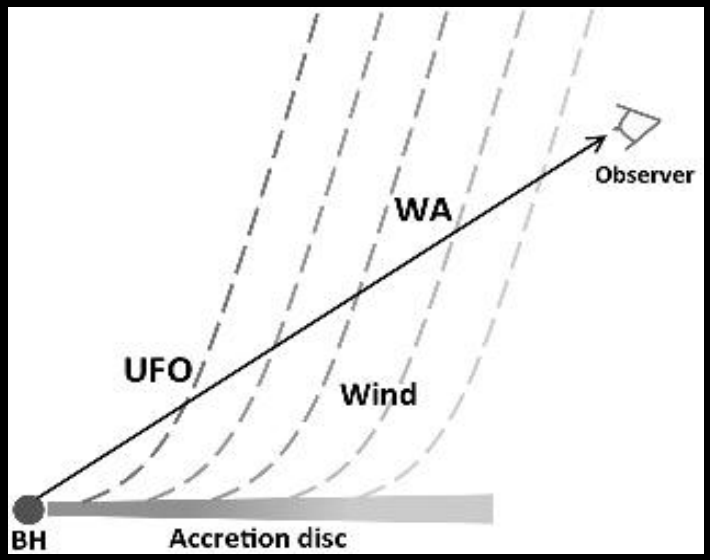
Reeves et al. (2009)

- Highly blueshifted FeXXV-FeXXVI lines (> 7 keV)
- Observed in ~40% in Seyfert and quasar type 1
- High Log ξ ~ 3-6
- High $N_H \sim 10^{22}$-10^{23} cm^{-2}
- $V_{out} \sim 0.03$-0.3 c (accretion disk wind ?)

- $L_{out} \sim 5$-10% L_{bol}

(e.g., Tombesi et al. 2012, 2013;
Patrick et al. 2012, Gofford et al. 2013)

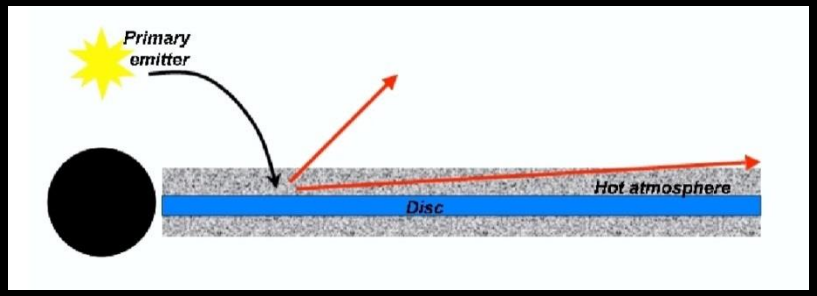
⇨ Prime candidates for feedback and SMBH-galaxy host relation ?

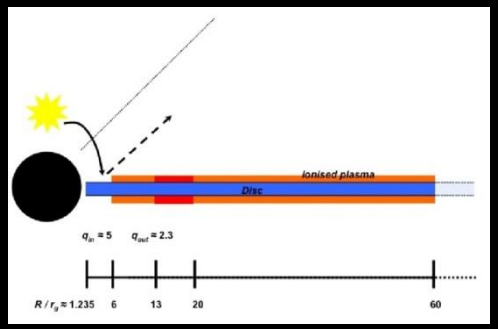


Tombesi et al. (2013)

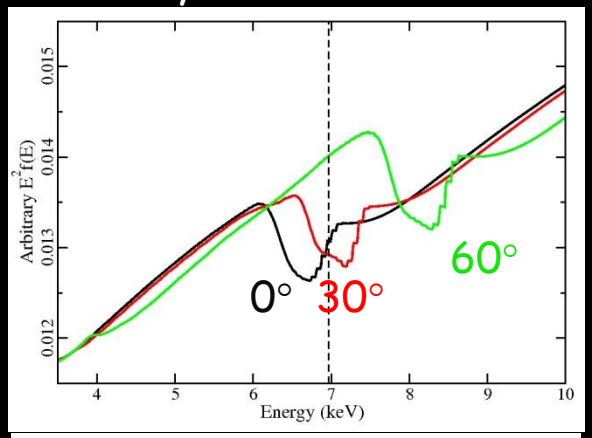
Alternative explanation for UFOs: effects of resonant absorption

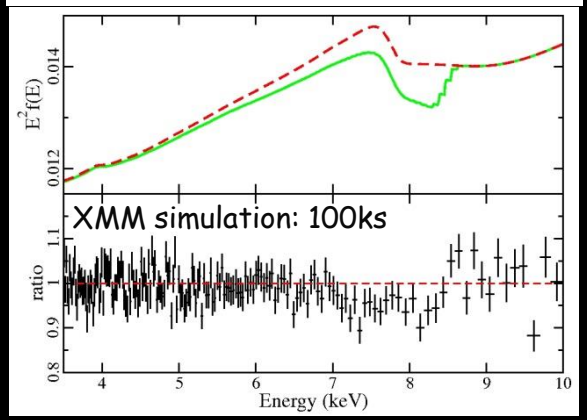
Gallo & Fabian (2011, 2013)



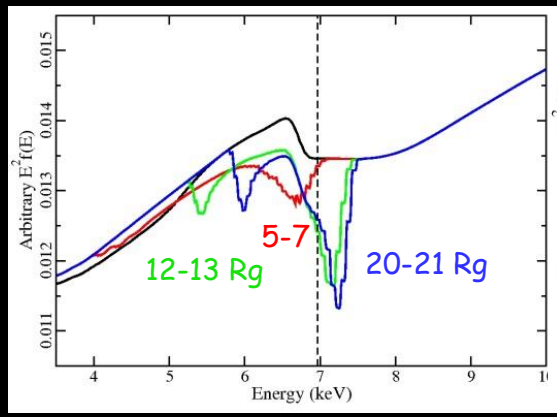


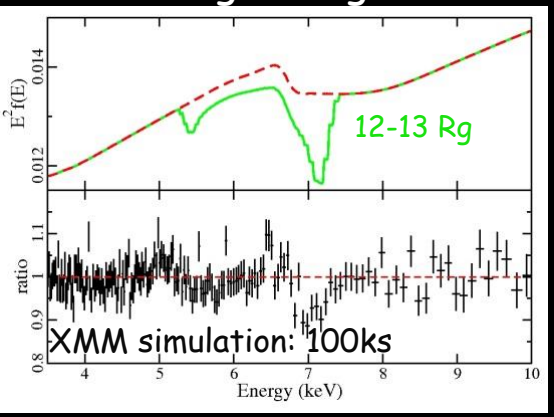
Fully covered disk



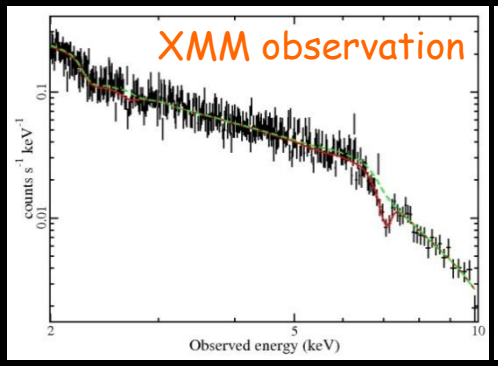


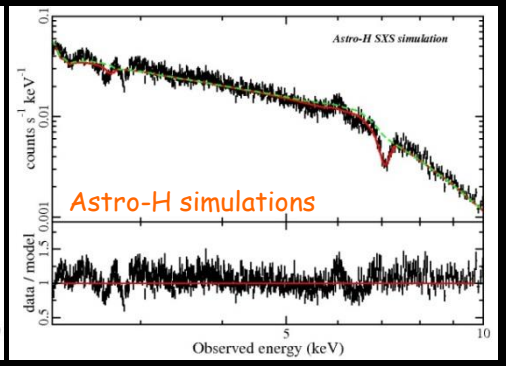
θ=30° but for different rings in Rg





PG 1211+143 (z~ 0.08; M~ 10^8 Msun)





III. From short-term to long-term perspectives of X-ray observations

XMM-Newton (ESA), Chandra(NASA), and Suzaku (JAXA)
+ NuSTAR (2012, NASA)

Astro-H (2015, JAXA): first calorimeter (R=7eV @ 6keV)
eROSITA (2015, Germany)

Projects:
LOFT (2020+, ESA)
ATHENA+ (2022+, ESA)

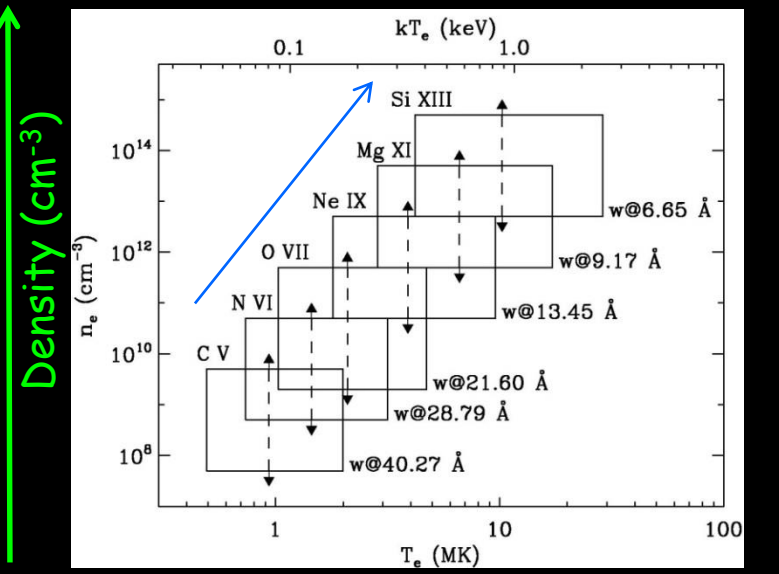
X-ray plasma diagnostics over a large domain of density and temperature

First calorimeters : Astro-H (2015, R=7eV) and ATHENA+ (2022+; R=2-3eV):

Will resolve the He-like triplet/quadruplet from CV to Ni XXVII

⇨ Plasma diagnostics over several decades of density (and temperature for CIE plasmas) for <u>all types of objects: from stellar coronae to AGN</u>

He-like ions: domains of density and temperature



Porquet, Dubau & Grosso (2010)

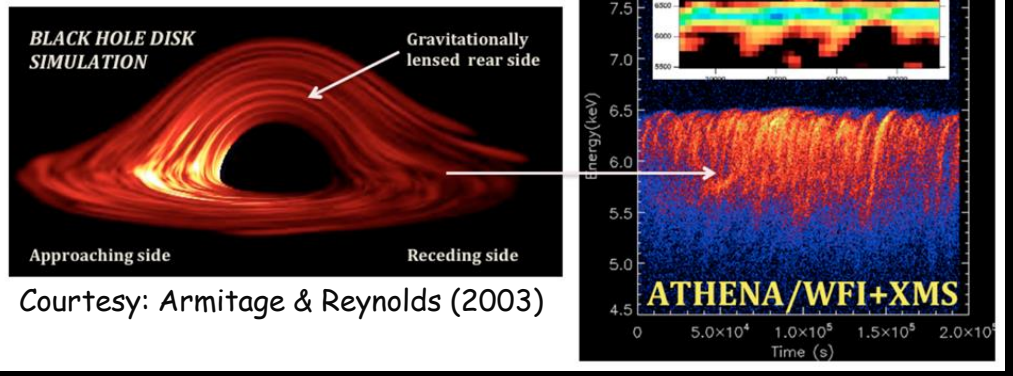
+ Some satellite lines for high-Z ions
+ detection of the RRC from C to Ni.

⇨ Complementary diagnostics of ionization processes (photo-ionization, CIE, NIE)

Plus, determination of the electron distribution shape (thermal versus non-thermal)

Time-resolved spectroscopy for FeK line and « UFOs »: LOFT and ATHENA+

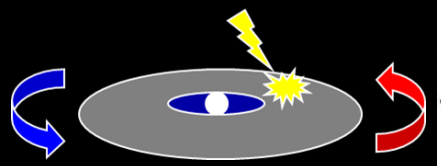
Energy-time map

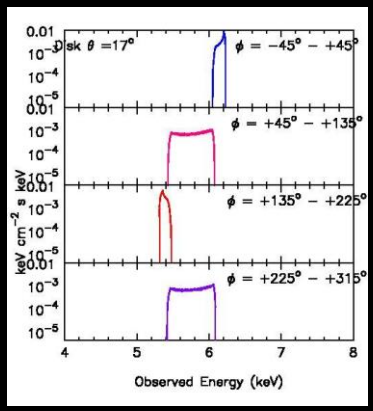


Courtesy: Armitage & Reynolds (2003)

Hot spot

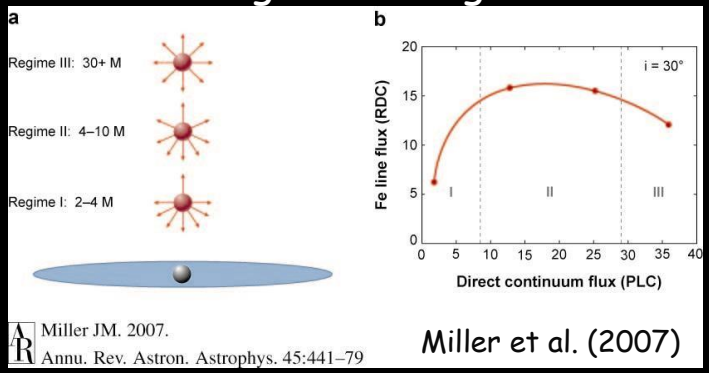
Credit: M. Dovciak





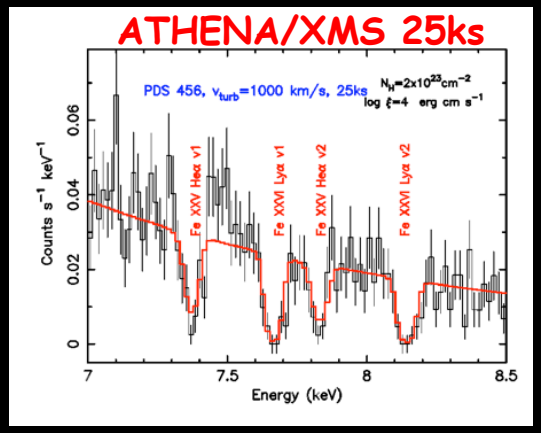
⇨ M_{BH}, BH spin, disc inclination

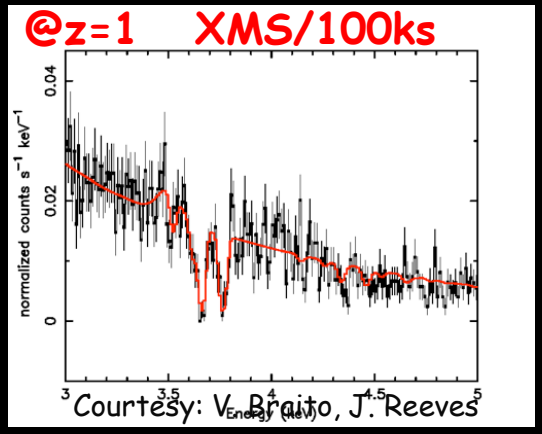
Light bending



Miller et al. (2007)

UFOs





Courtesy: V. Braito, J. Reeves

Monitoring of the evolution of the outflows on short-time scales and AGN feedback up to z=1-2