# AGNs observed with LOFT: strong gravity effects and inner structure

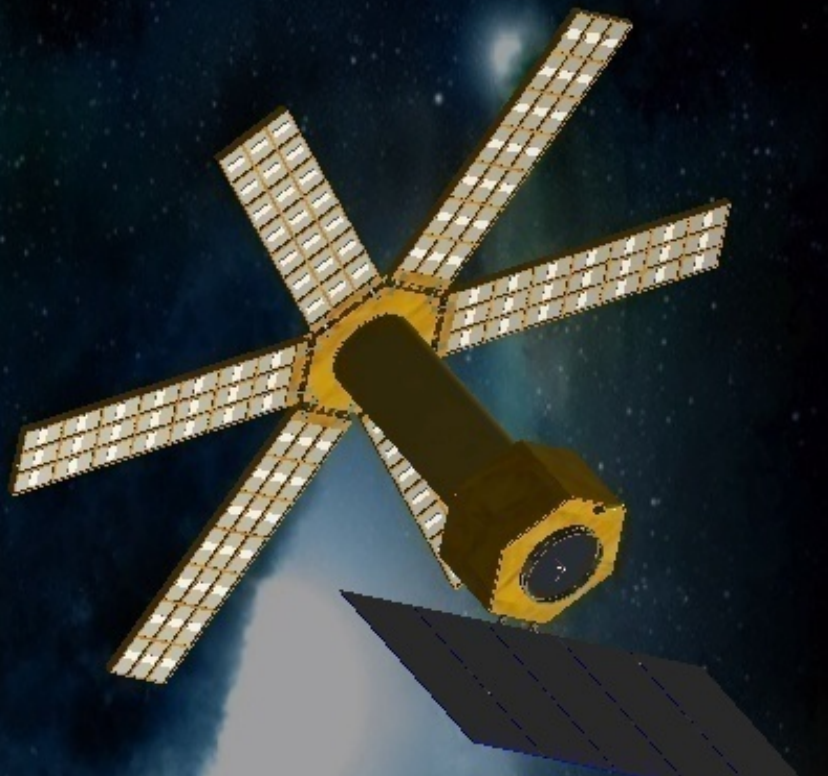
Alessandra De Rosa

INAF/Institute for Space Astrophysics and Planetology

# Outline

- LOFT: Large Observatory For X-ray Timing
- Strong Field gravity effects in AGNs: BH diagnostic
    - Relativistic Broad Fe line
    - Phase resolved Fe line
    - Continuum reverberation
- LOFT as an observatory for Radio quiet AGN (credits of S. Bianchi)
- Conclusions and future

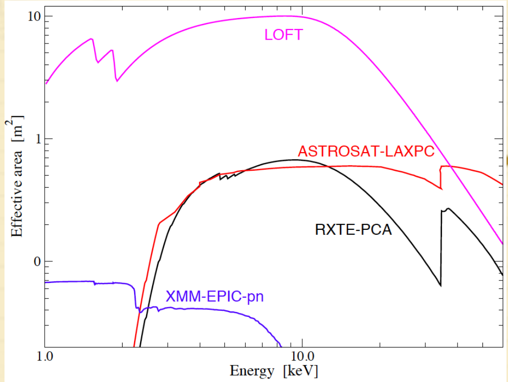
# LOFT
# Large Observatory For x-ray Timing

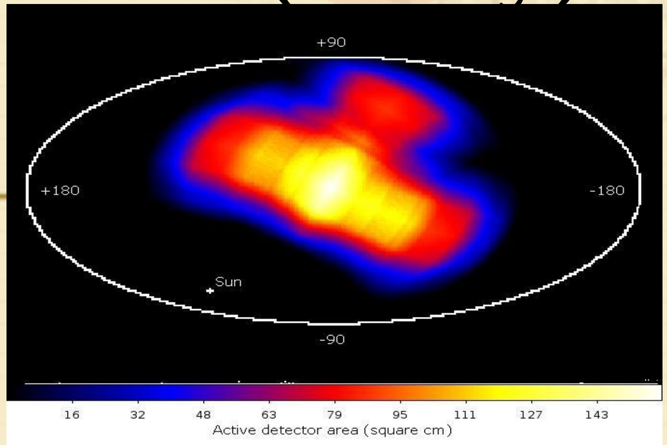


A mission proposal selected by ESA
as a candidate Cosmic Vision M3 mission
devoted to X-ray timing
and designed to investigate
the space-time around collapsed objects

**ESA Member States currently involved in the payload development:**
Czech Republic, Denmark, Finland, France, Germany, Italy, Netherlands, Poland, Spain, Switzerland, United Kingdom

# The LOFT Instruments (today)




| LAD – Large Area Detector | |
|---|---|
| Effective Area | 4 $m^2$ @ 2 keV<br>8 $m^2$ @ 5 keV<br>10 $m^2$ @ 8 keV<br>1 $m^2$ @ 30 keV |
| Energy range | 2-30 keV primary<br>30-80 keV extended |
| Energy resolution FWHM | 260 eV @ 6 keV<br>200 eV @ 6 keV (45% of area) |
| Collimated FoV | 1 degree FWHM |
| Time Resolution | 10 μs |
| Absolute time accuracy | 1 μs |
| Dead Time | <1% at 1 Crab |
| Background | <10 mCrab (<1% syst) |
| Max Flux | 500 mCrab full event info<br>15 Crab binned mode |

| WFM- Wide Field Monitor | |
|---|---|
| Energy range | 2-50 keV primary<br>50-80 keV extended |
| Active Detector Area | 1820 $cm^2$ |
| Energy resolution | 300 eV FWHM @ 6 keV |
| FOV (Zero Response) | 180°x90° + 90°x90° |
| Angular Resolution | 5' x 5' |
| Point Source Location Accuracy (10-σ) | 1' x 1' |
| Sensitivity (5-σ, on-axis)<br>Galactic Center, 3 s<br>Galactic Center, 1 day | <br>270 mCrab<br>2.1 mCrab |
| Standard Mode | 5-min, energy resolved images |
| Trigger Mode | Event-by-Event (10μs res)<br>Realtime downlink of transient coordinates |

# LOFT-STRONG FIELD GRAVITY

**AGNs: Black Hole Diagnostic**

1. Relativistic broad Fe line
2. Phase resolved spectroscopy
3. Reverberation (credits of Phil Uttley)

# Probing strong gravity effects with Fe line profile

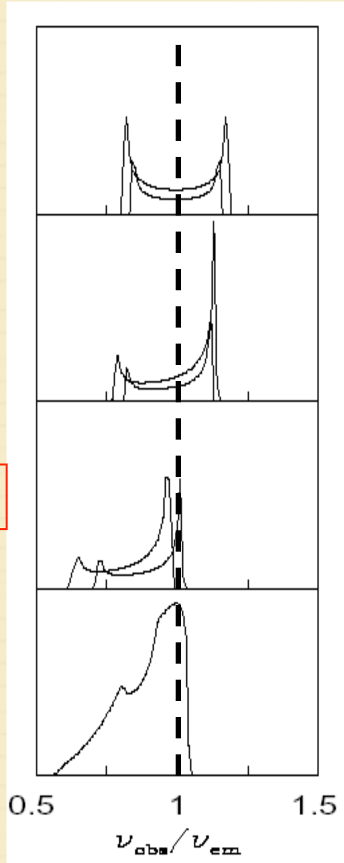
RELATIVISTIC effects modify the line profile in a characteristic and well-recoganizable way.

NEWTON

special reativity

General relativity

Line profile




DOPPLER

Transverse doppler

Relativistic beaming

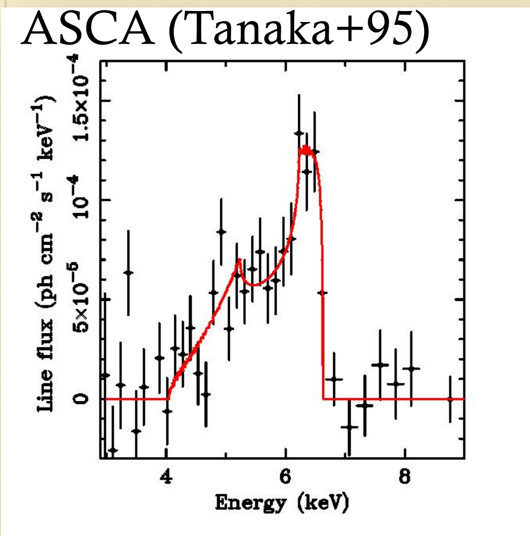
redshift

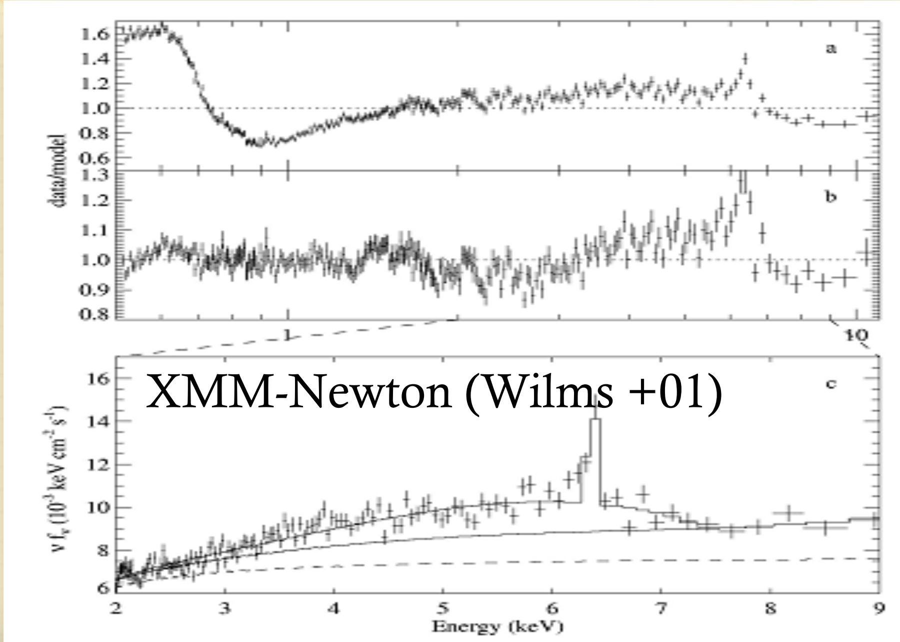
all

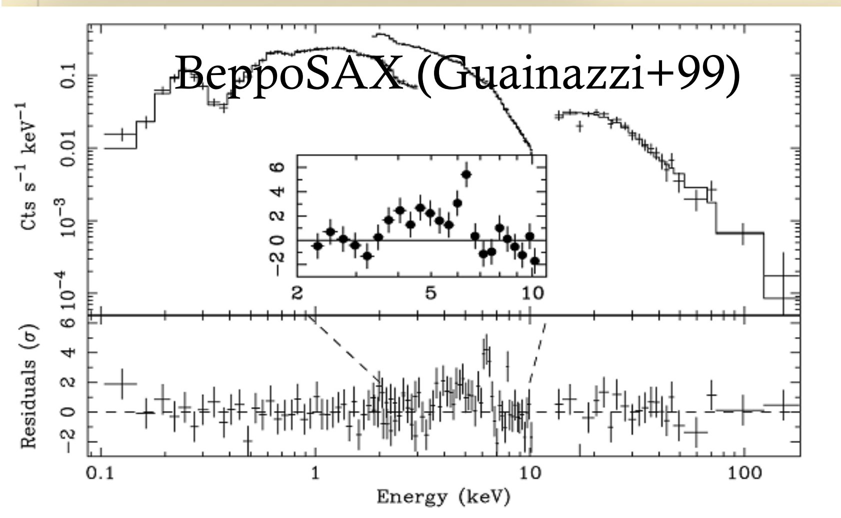
Fabian+2000

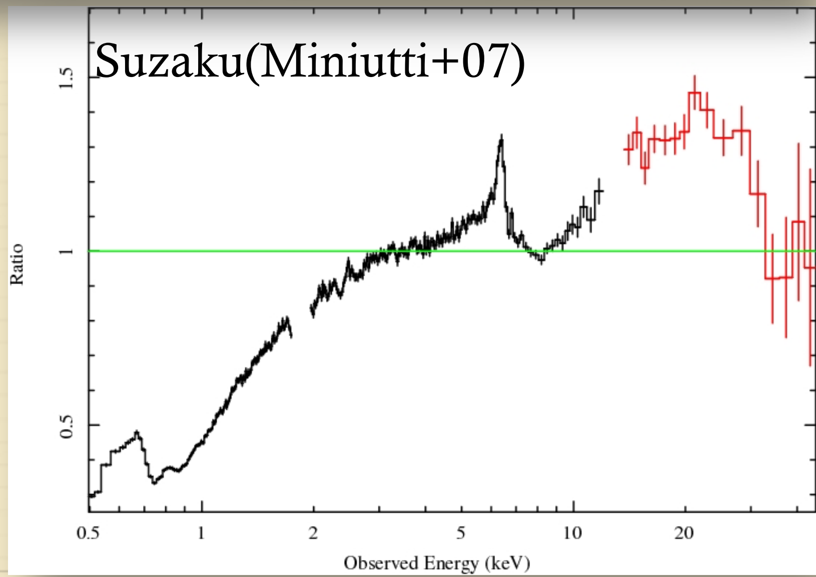
**This method has the advantage to be** *Independent* of the black hole mass (radius is measured in units of the gravitational radius)

# THE relativistic Fe line in MCG-6-30-15



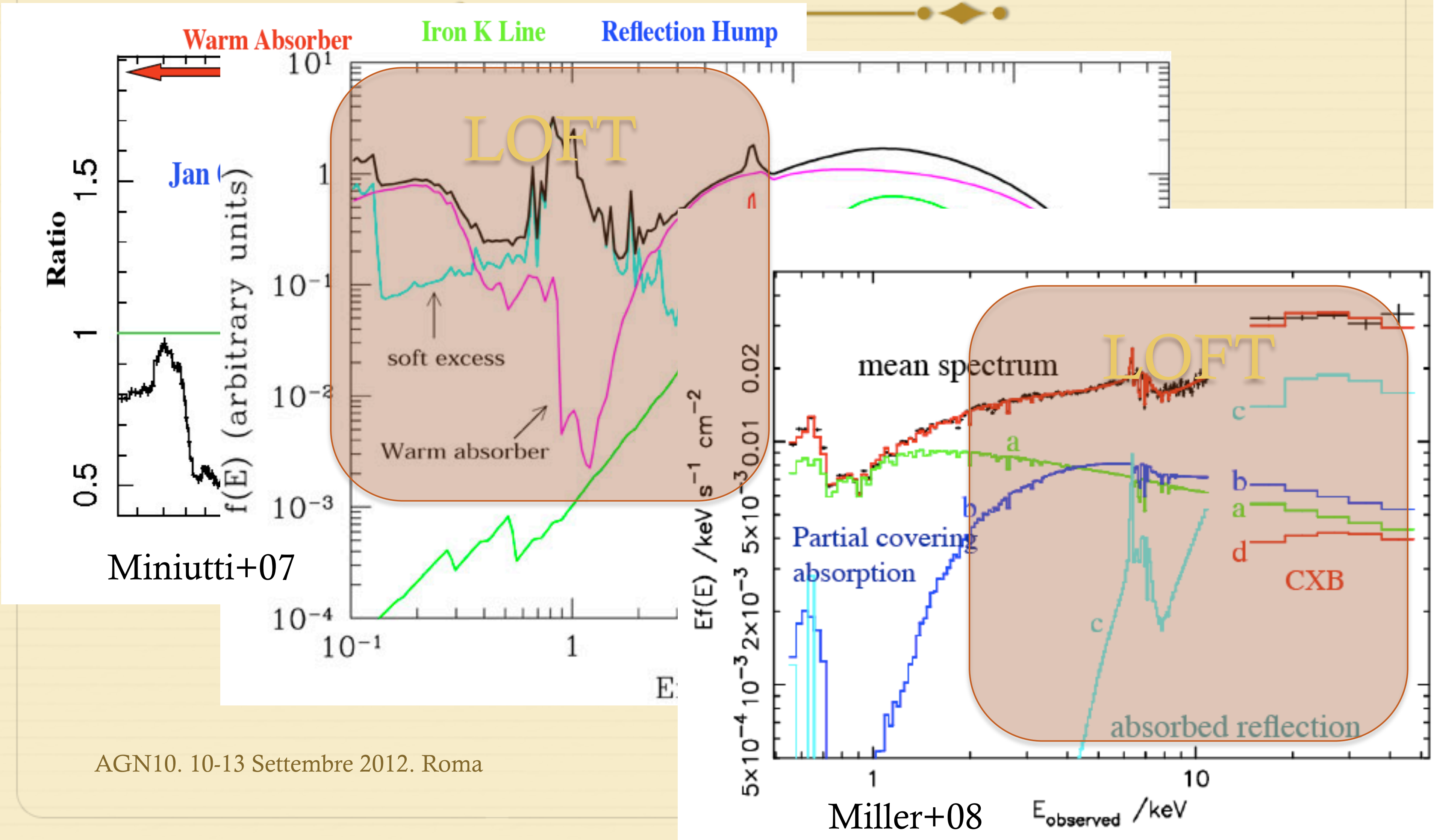



# Is really the reflection nearby a SMBH the right answer?

Complex ionized absorption has be proposed as a viable alternative (Miller+08)

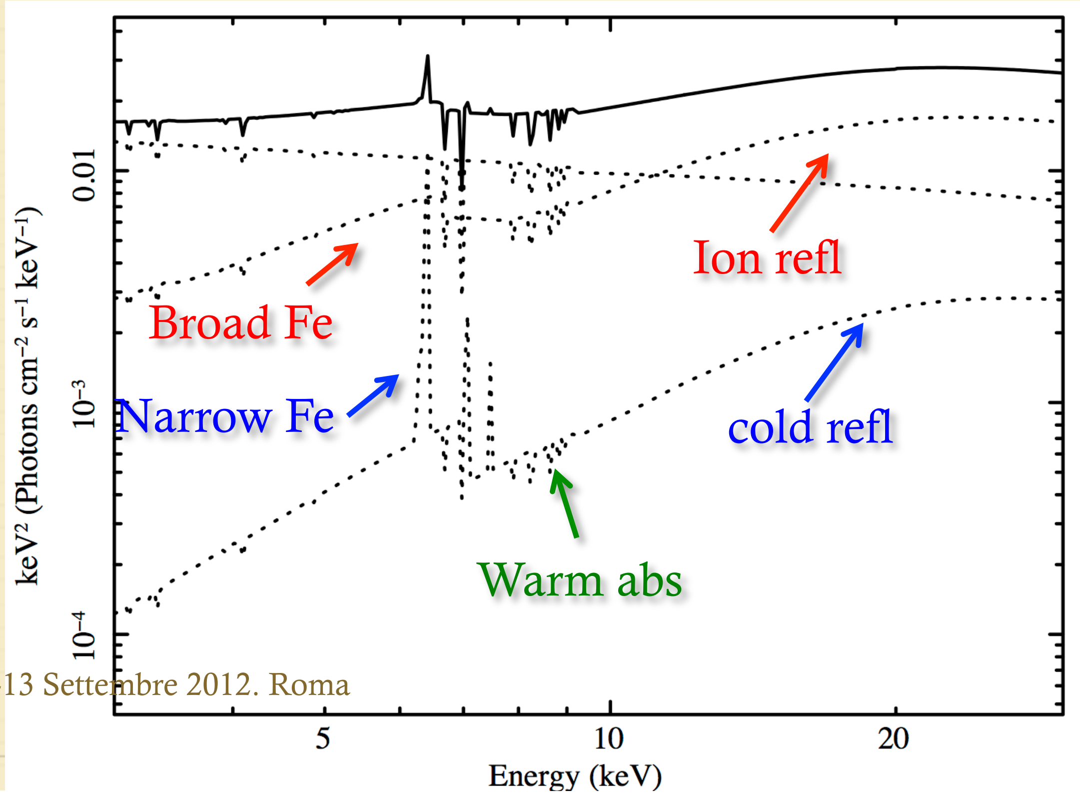
Can we distinguish between the two?

# Miniutti vs Miller scenario

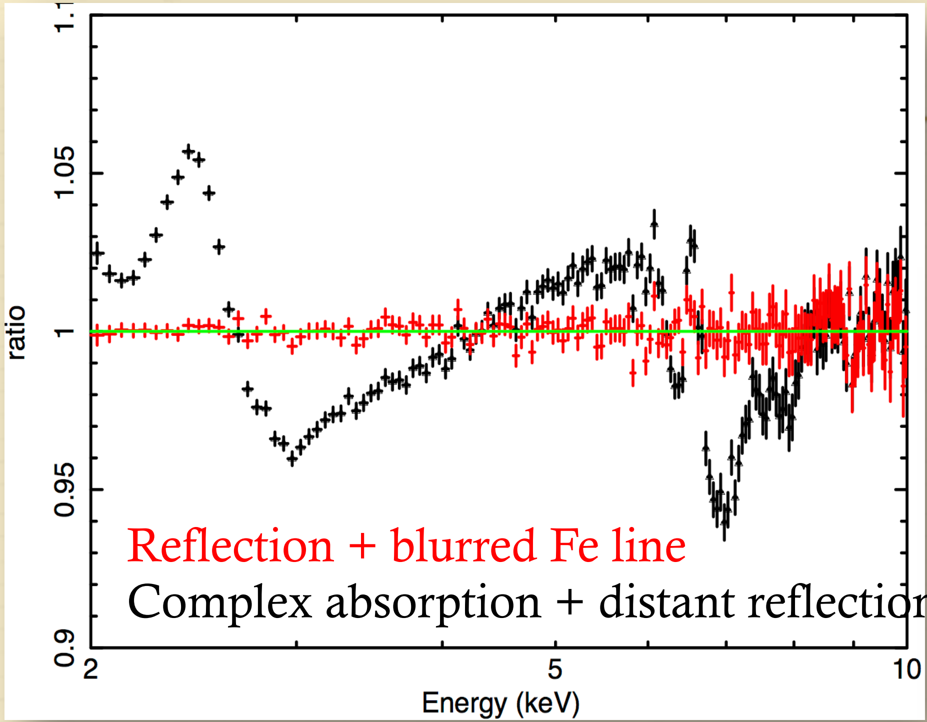


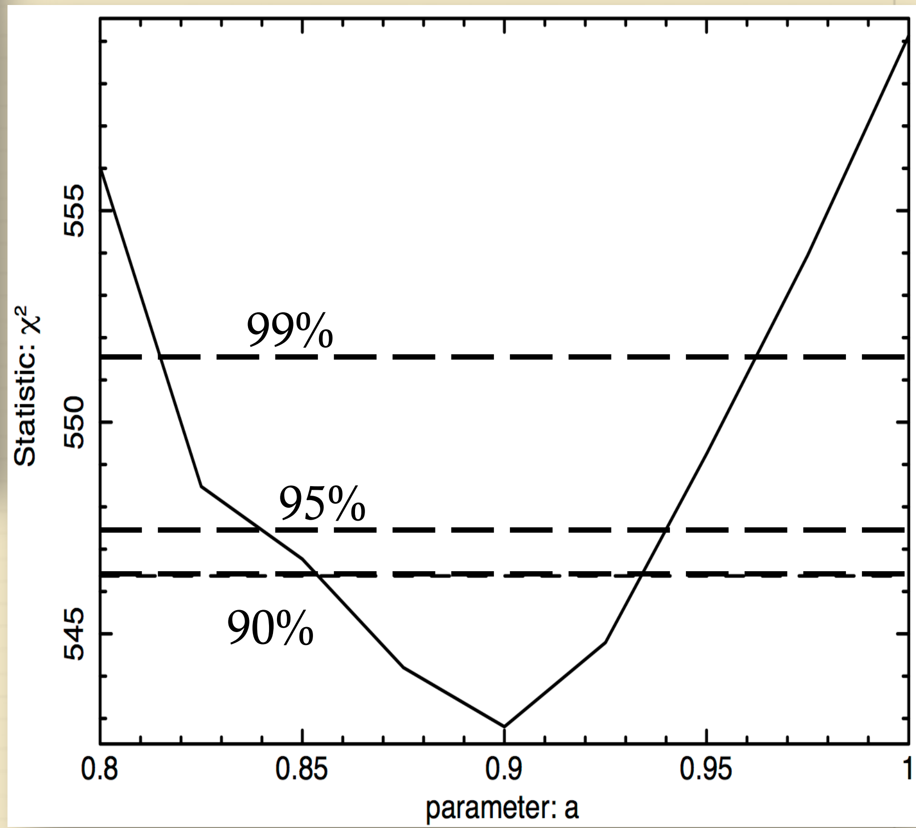
# MCG6-30.15: 1 warm absorber+2 reflecting medi

| | Flux (2-10 keV) | Flux (3-30 keV) |
|---|---|---|
| Continuum | 3.1e-11 | 3.7e-11 |
| Ionized refl | 1.3e-11 | 3.5e-11 |
| Cold refl | 1.2e-12 | 4.8e-12 |



# Reflection *vs* complex absorption model



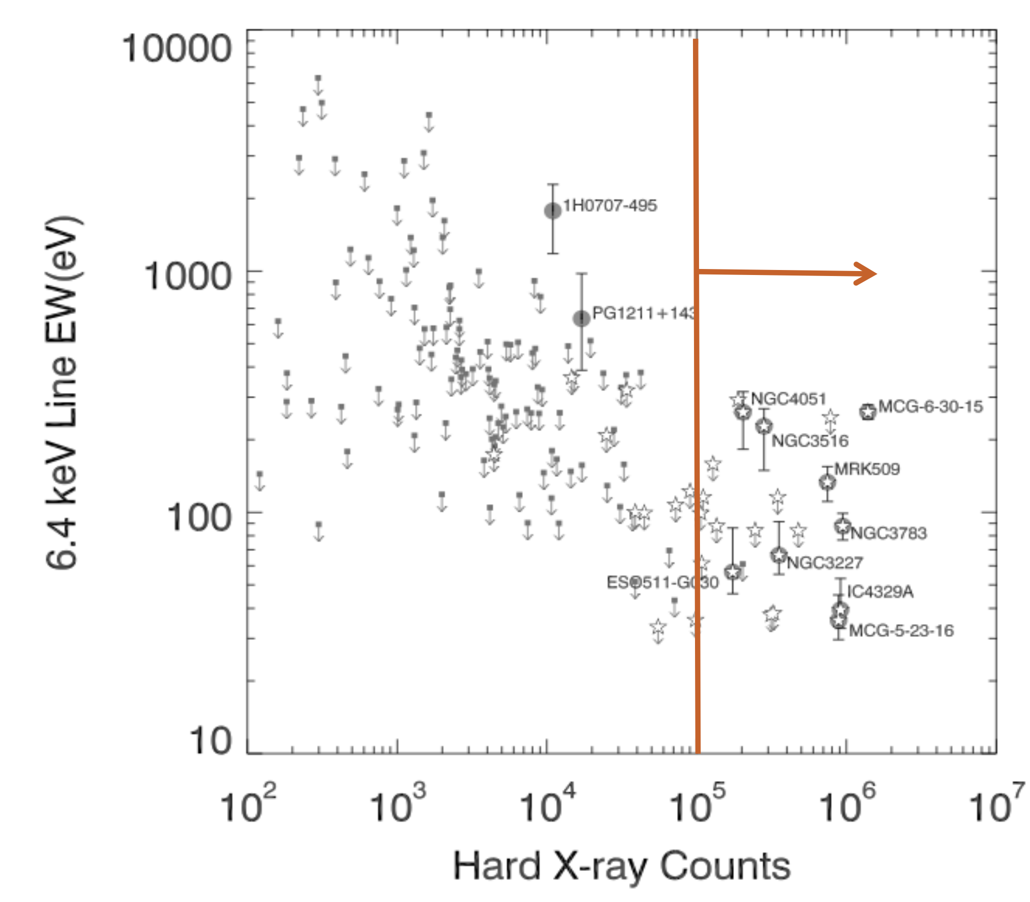

**MCG-6-30-15**
150 ks LOFT
simulated observation

# Reflection as a probe of the innermost accretion flows

Broad Relativistic iron line: measuring spin of supermassive BHs

From XMM to LOFT AGNs sample

# EW vs hard X-ray counts




FERO being made of spectra of disparate quality and by the unavailability of a well-defined complete AGN sample. Nevertheless, *the observed detection fraction can be considered as a lower limit for the intrinsic number of AGN that would show a broad Fe line* if, for example, all sources were observed with the same signal-to-noise.

● 5σ detection

↓ upper limit (90% c.l.)

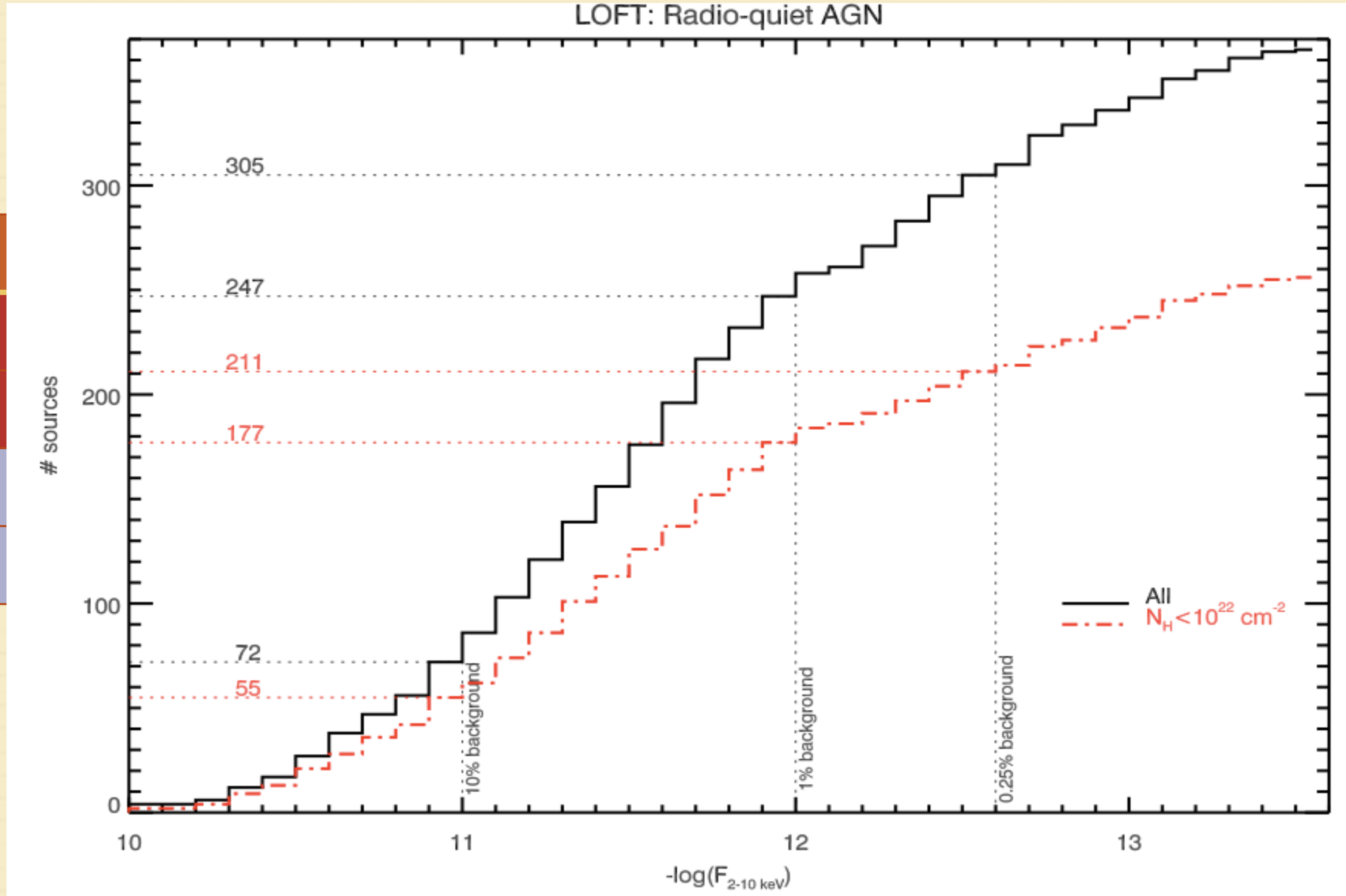
★ above 1ct/s in RXTE Slew Survey *(Revnivtsev+ 04)*

de la Calle Perez+ 2010

# Hard X-ray counts

$t_{exp}$=10 Ks

| |
|---|
| *LOFT cts(2-10keV)* |
| *LOFT S/N* |
| *XMM cts (2-10keV)* |
| *XMM S/N* |




More than 10 AGN above 2mCrab
More than 30 AGN above 1mCrab

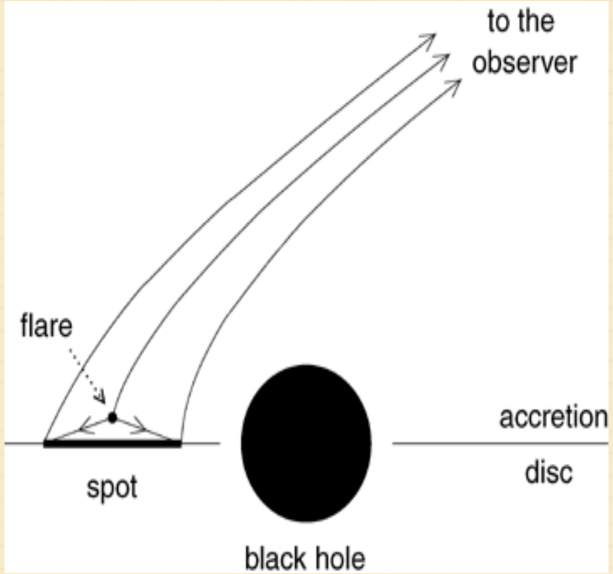
Credits S. Bianchi

# Reflection as a probe of the innermost accretion flows

## 2. Phase resolved iron line: measuring mass of supermassive BHs

# 2. X-ray Fe line from hot spot around SMBH

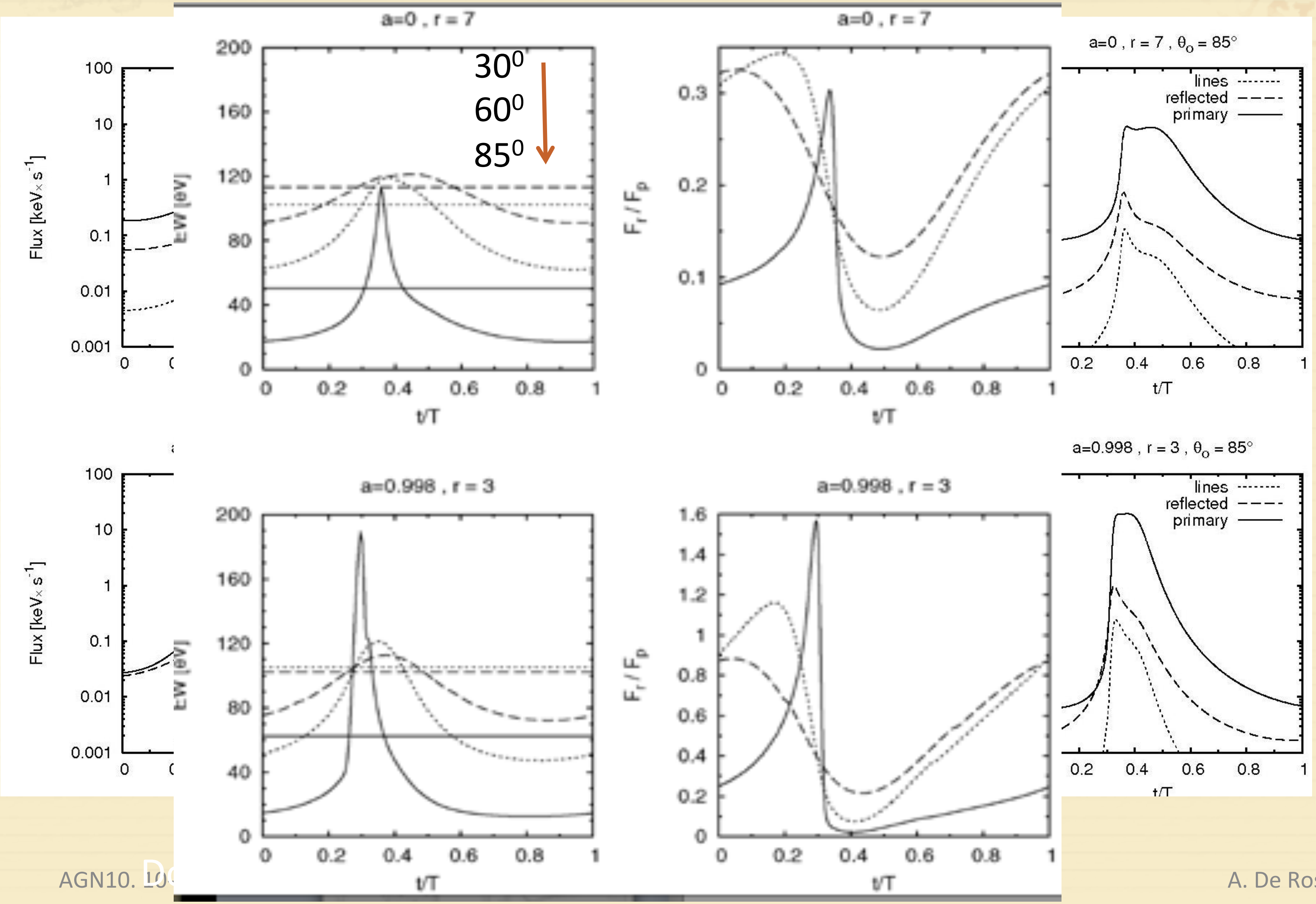
- AGN variability is likely associated to "activation" of the X-ray regions above the AD. The flares produce an echo in the observed reflection components on time-scales comparable light-crossing of a gravitational radii




✧ $t_{cr}=r_g/c=GM/c^3 \sim 50\ M_7$ s.

- While *time averaged* Fe profiles can be expressed in terms of $r_g$, losing any information about black-hole mass, assuming the 'hotspot' corotating with the disc with a Keplerian rotation, the orbital period can be measured $T_{orb}=310\ (r^{3/2}+a)M_7$ s, and then the BH mass.

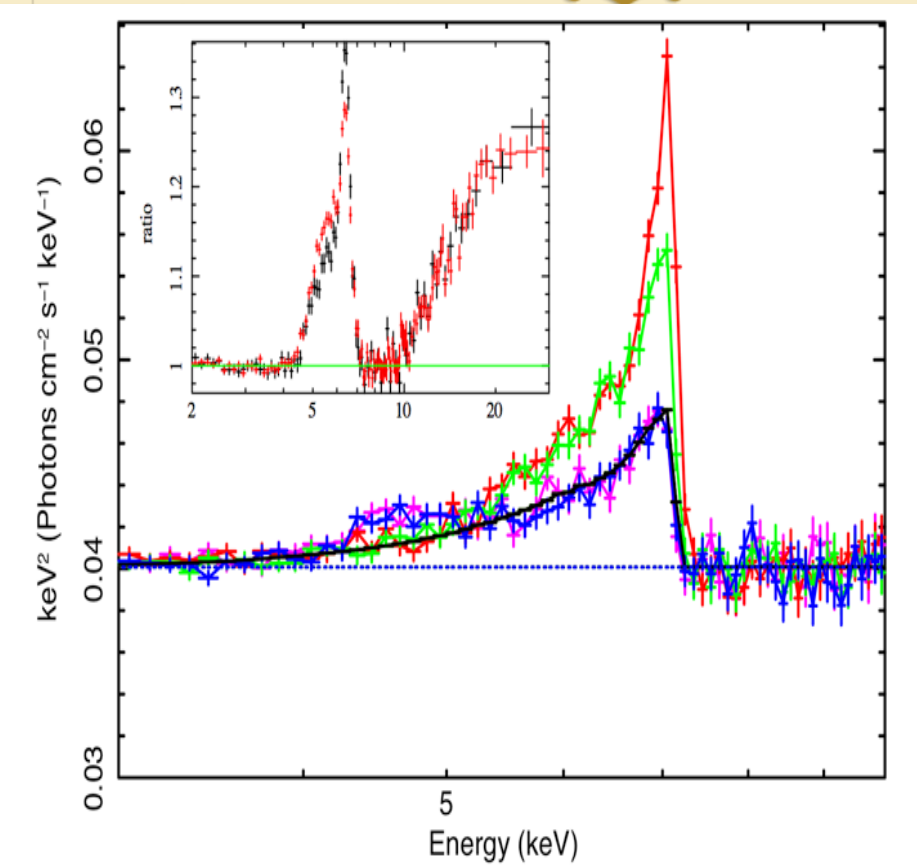
# Orbiting spots



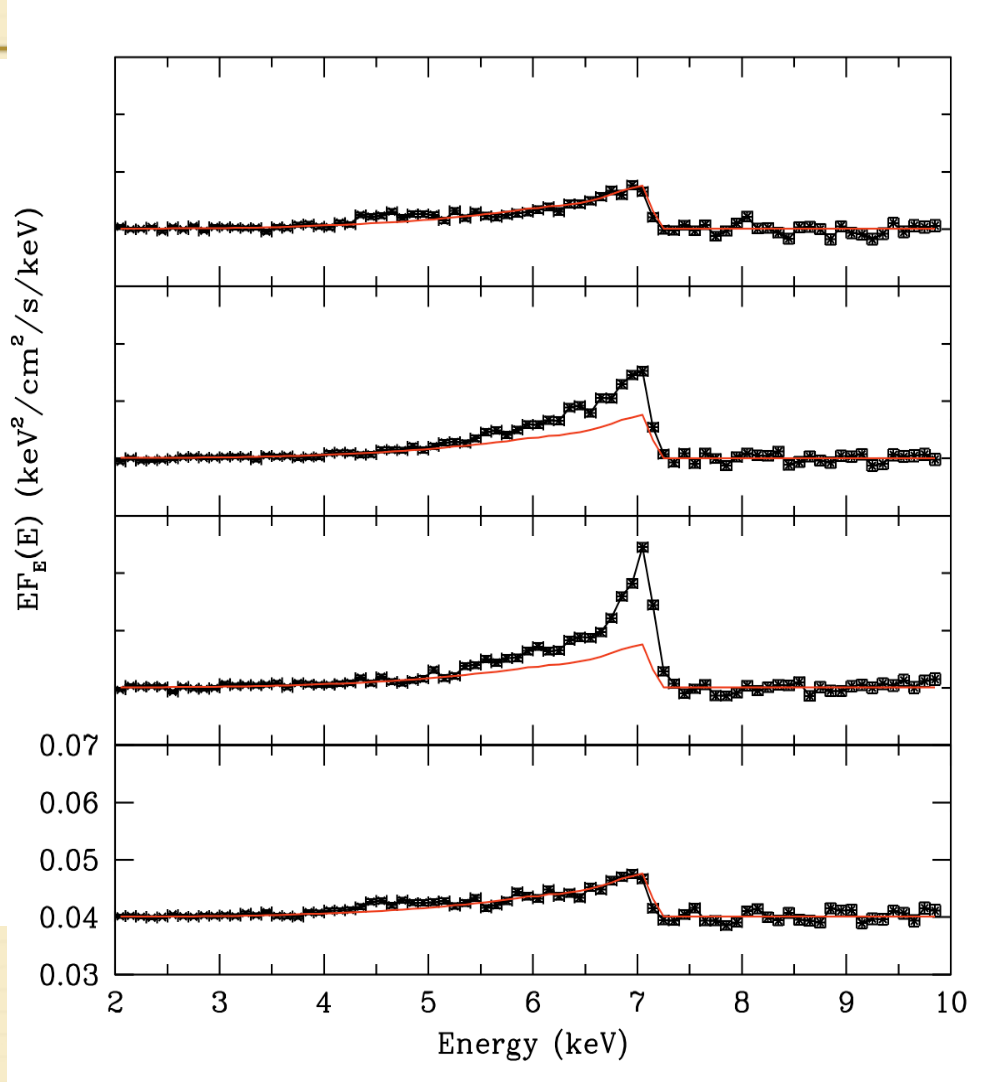
# LOFT 16 ks simulation of a steady and *variable* Fe line

MCG-6-30-15

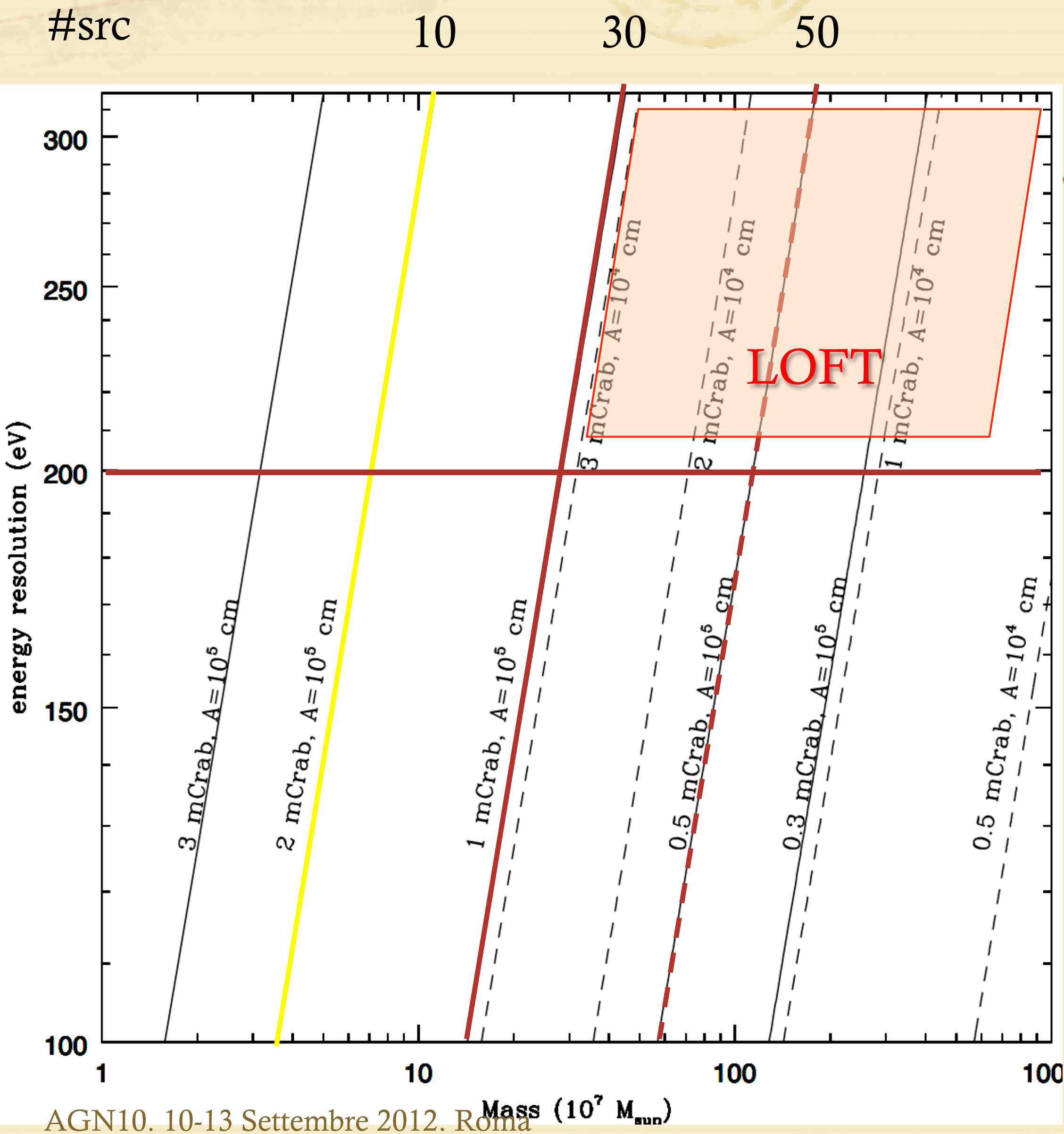
F=3mCrab, a=0.99, $r_{in}$=1$r_g$, $r_{out}$=100$r_g$




From proposal

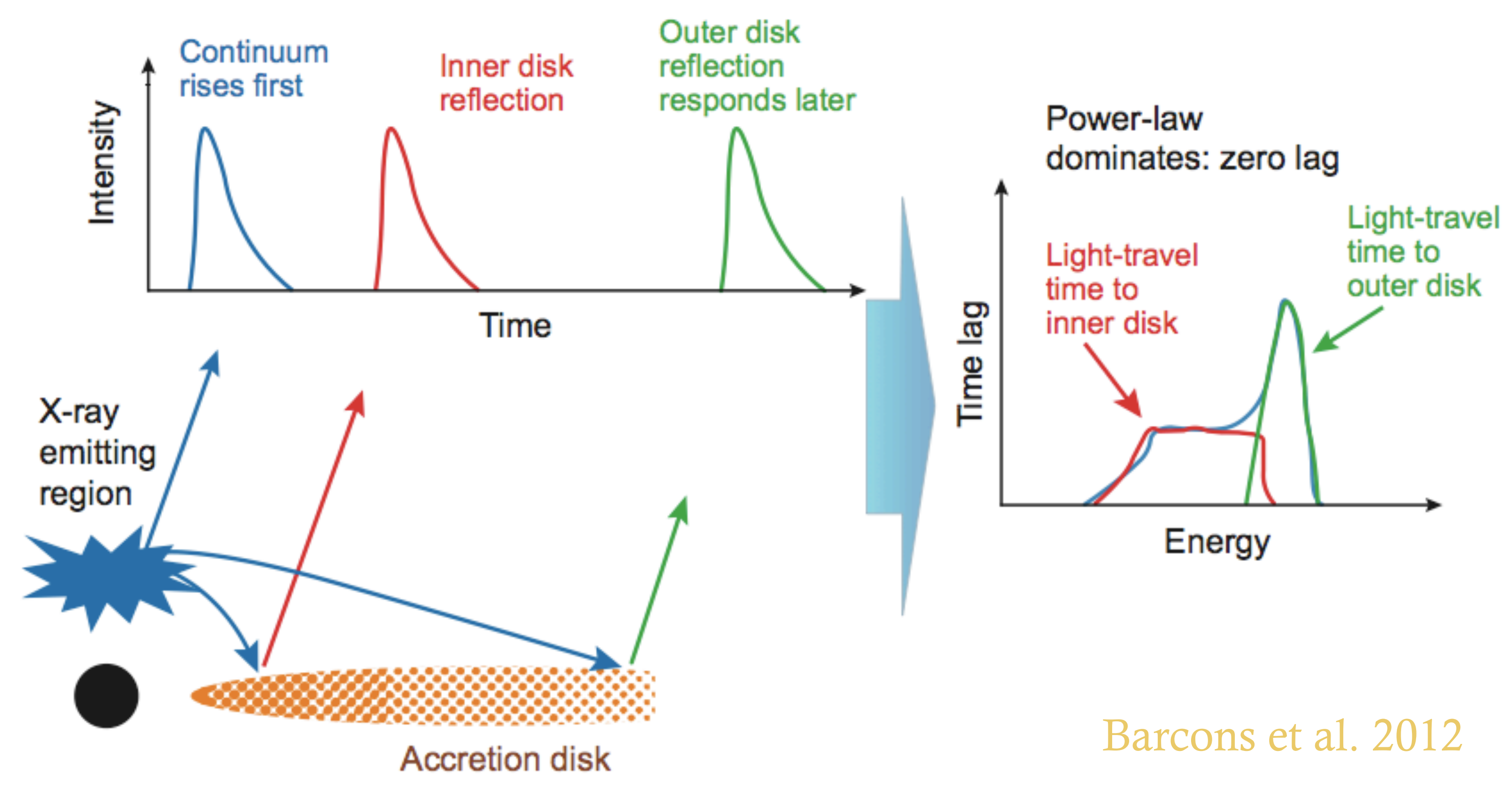


# Effective area vs Energy resolution




2 orbits, 10 phases
a=0
$R_{in}=R_{isco}$,
S/N=3
EW=30 eV
σ=100 eV

# 3. Reverberation: basic idea




Barcons et al. 2012

By modeling the lags we can measure the light travel times from the continuum emitting region and the disc, and so determine R

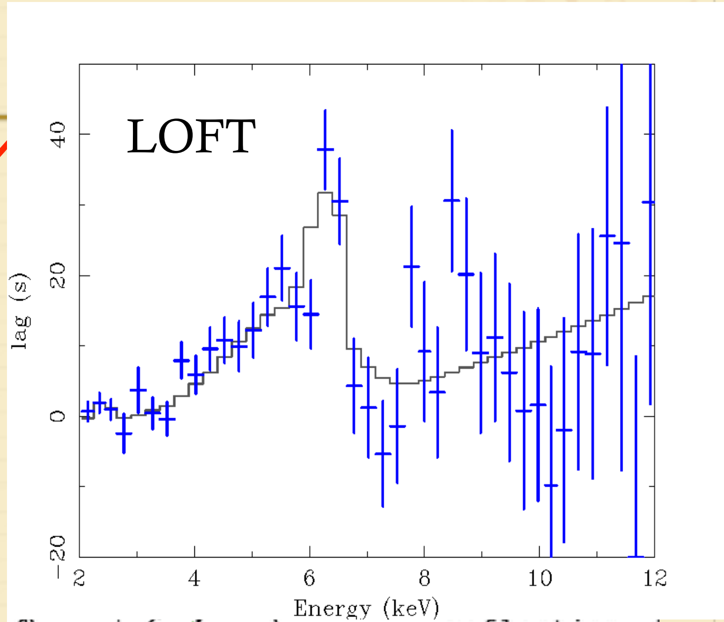
# X-ray Continuum Reverberation

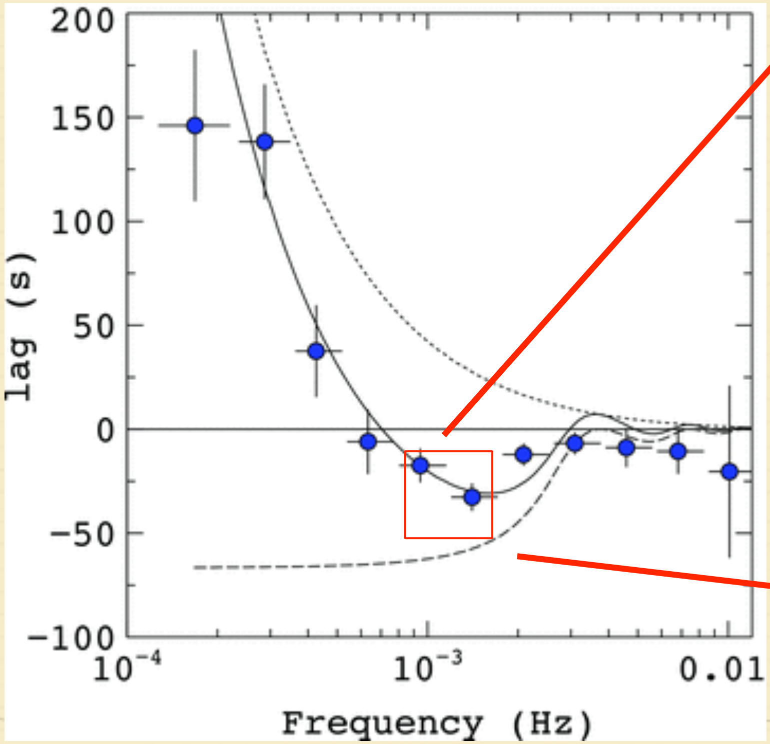
# 'THE' example: 1H0707-495

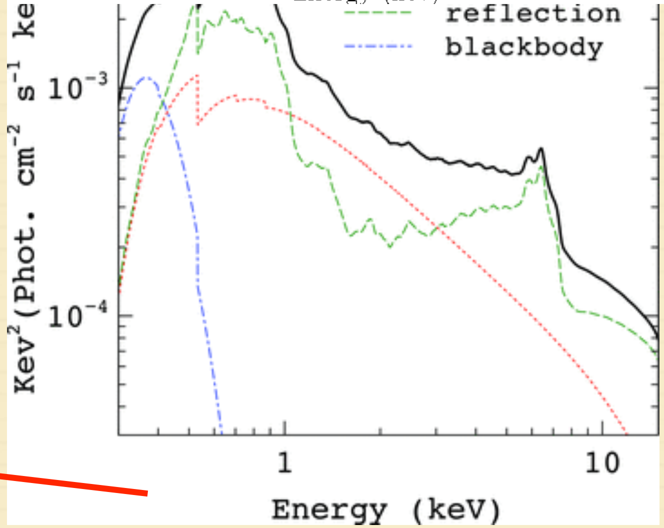
(Fabian et al. 2009; Zoghbi et al. 2010, 2011)

The negative lag means that soft (0.3-1 keV) lags the hard (1-4 keV) band: this can be interpreted as the time delay of photons reflected by the accretion disc (but it is still controversial)

The larger positive lag is difficult to interpret, but is commonly seen in GBH

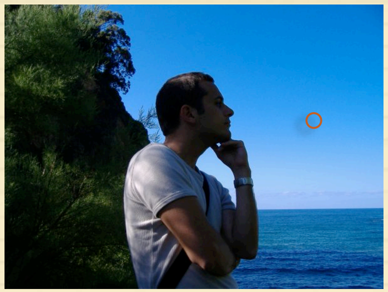


# LOFT as an observatory for radio quiet AGN

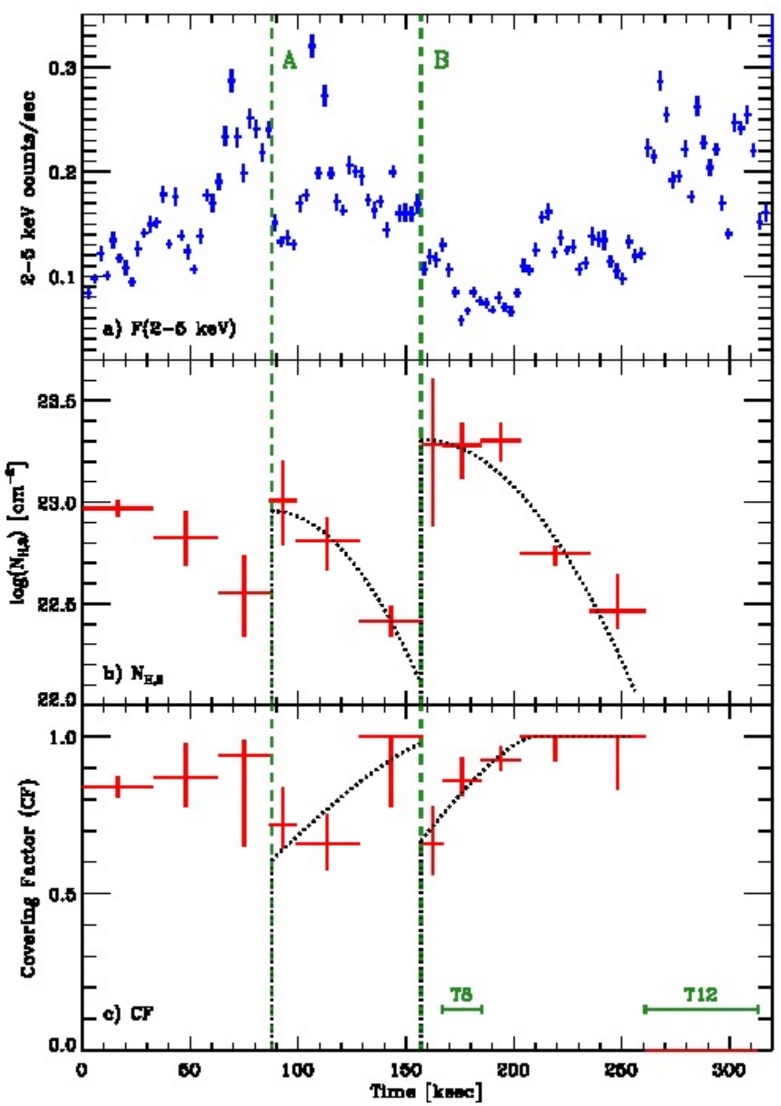
Credits of S. Bianchi



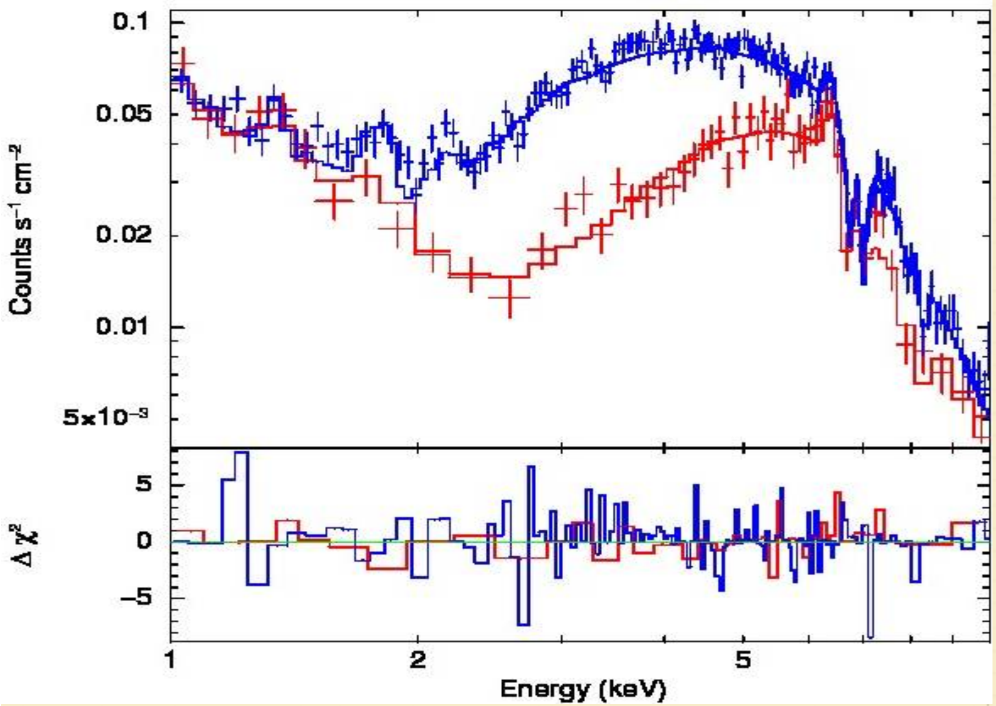
# 1. $N_H$ Variability

Rapid (from hours to weeks) $N_H$ variability has been observed in some AGN, suggesting X-ray obscuration from the inner BLR

In at least one case, a careful analysis of the occultation events points to a 'cometary' shape of the clouds




NGC1365 (Suzaku)




Maiolino et al. 2010

# 1. $N_H$ Variability

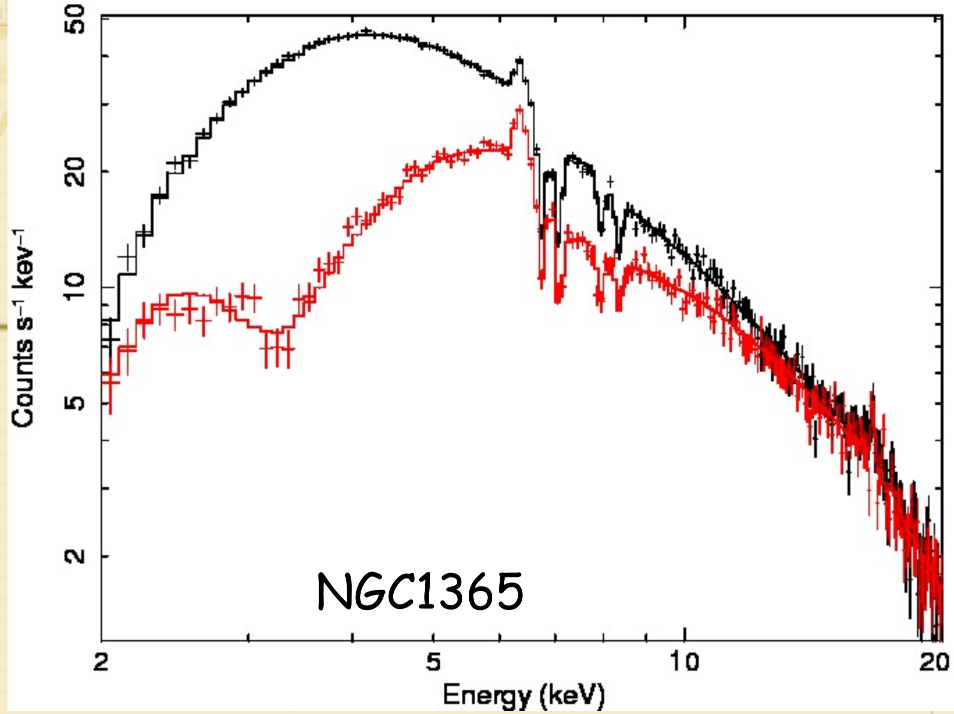
**LOFT**

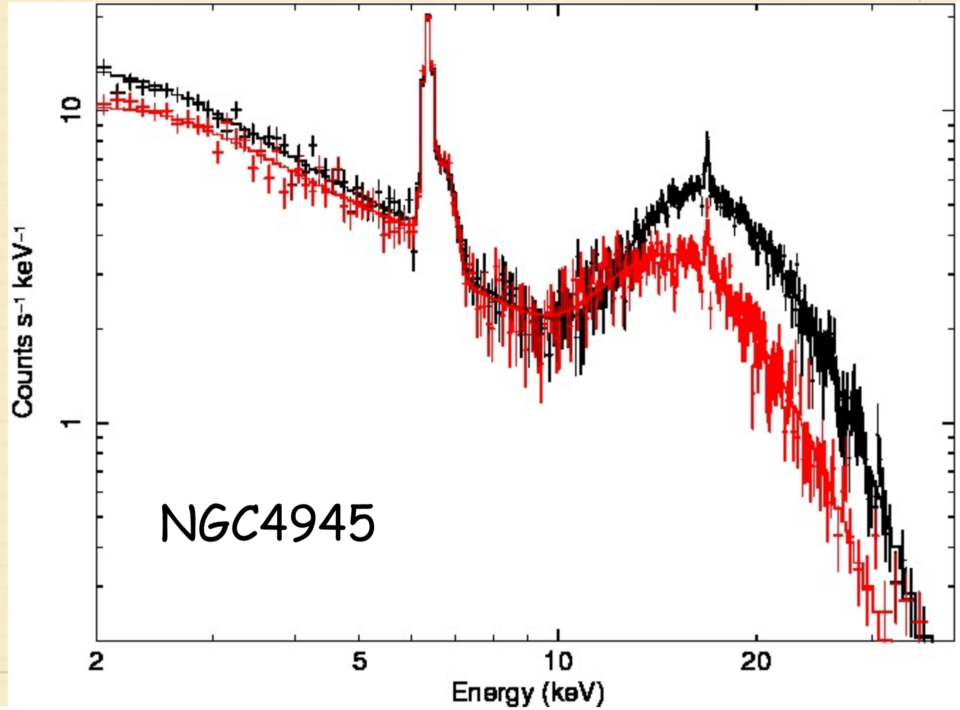
The gaps in the lightcurves are not a serious issue (they are worse in Suzaku!)

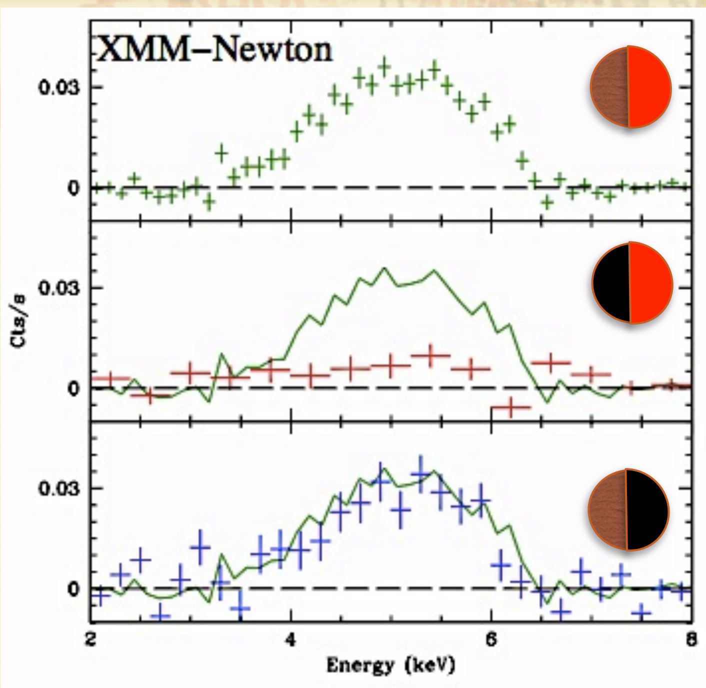
The error on the covering factor is 2%, compared to 5-10% with Suzaku

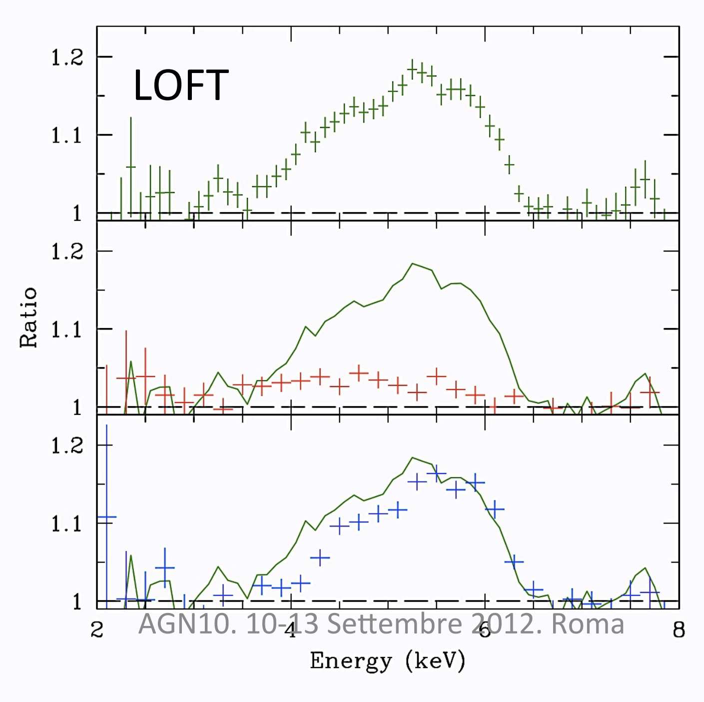
LOFT will allow us to measure with good precision variability of large $N_H$, which now can be done only with Suzaku with errors of 20% in very bright sources

LOFT will do much better (4%), the same as Astro-H






# Probing SG effects with x-ray eclipses

Credits of G. Risaliti

An obscuring cloud covers/uncovers different parts of the accretion disc at different times, allowing a direct check of the expected pattern of disc emission

E=6.68+-0.03 keV

EW=340+-35 eV

$R_{in}/R_{out}$=2.7/400 $R_g$

NH=1e25 $cm^{-2}$

T=25ks+25ks

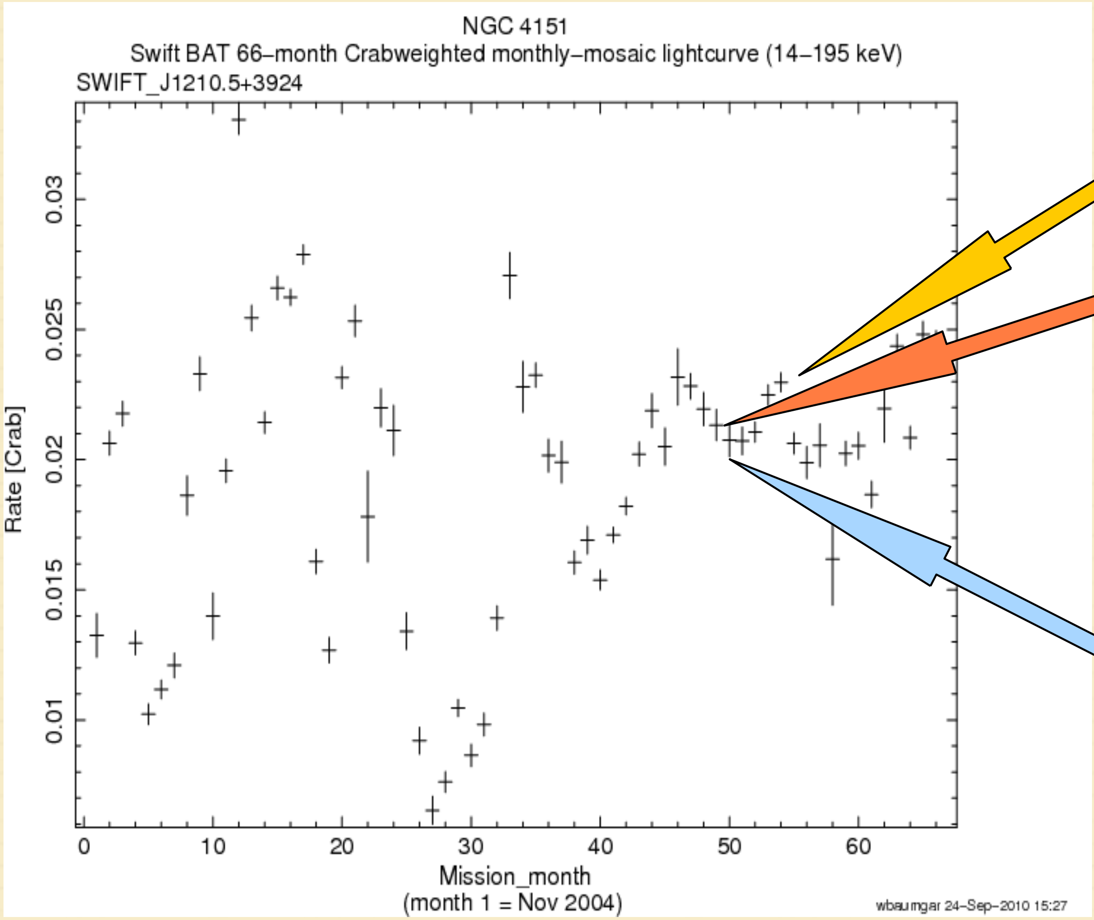
# 2. Fe line Reverberation

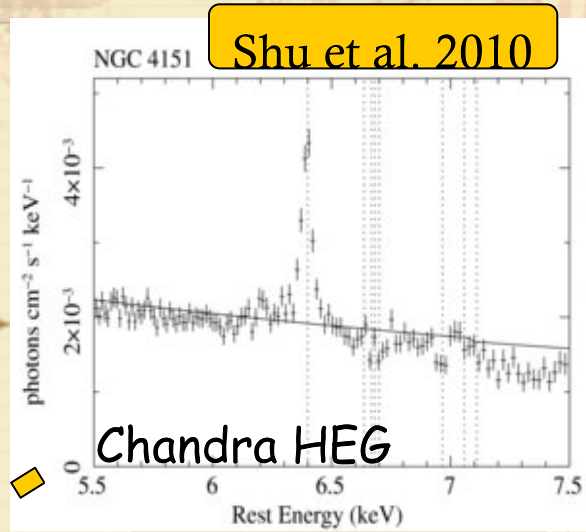
**What can be done now?**

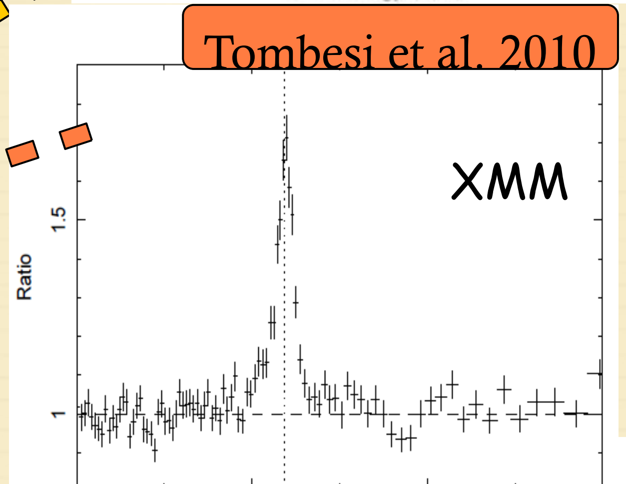
**Expected time-scales are from weeks to years**

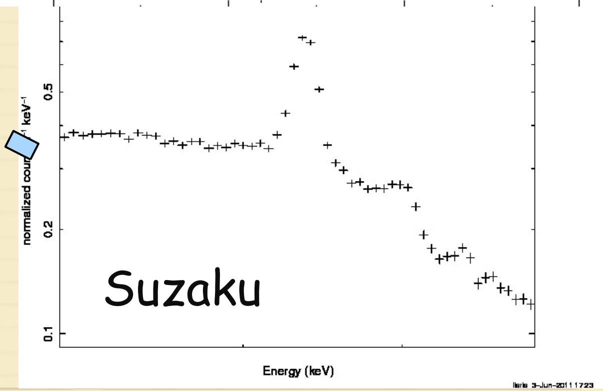
Swift BAT 'continuous' lightcurves for the continuum

Badly sampled Fe line fluxes from different instruments



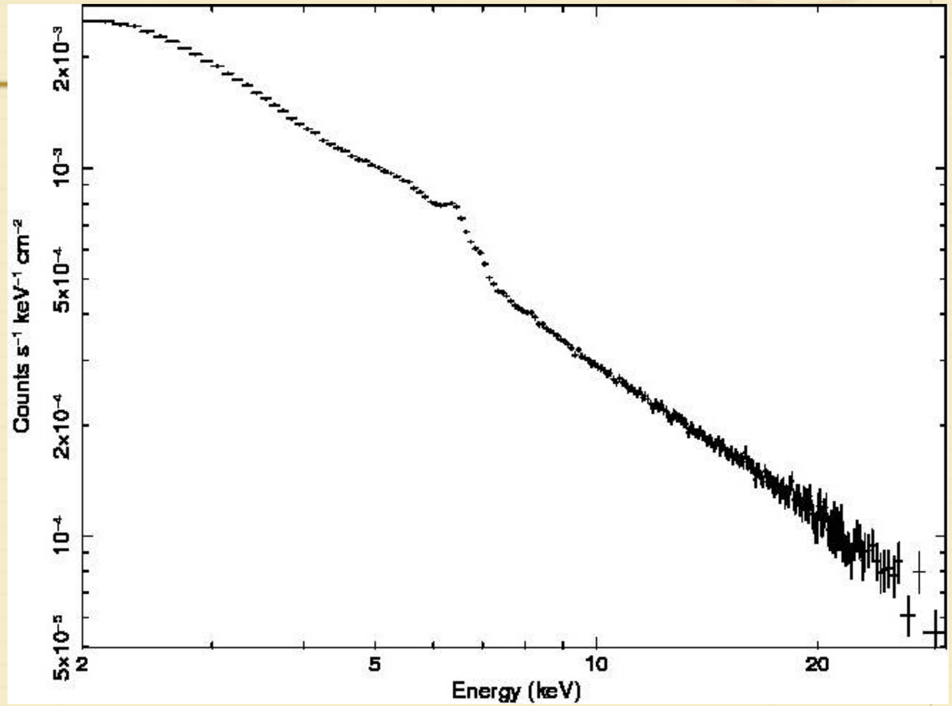



# 2. Fe line Reverberation

## *What can be done with LOFT?*

Large area allows us to perform a well-sampled monitoring for the iron line AND Compton reflection component with short observations:
in 1 ks, the Fe line flux and R can be recovered with an uncertainty of ~5% for bright sources



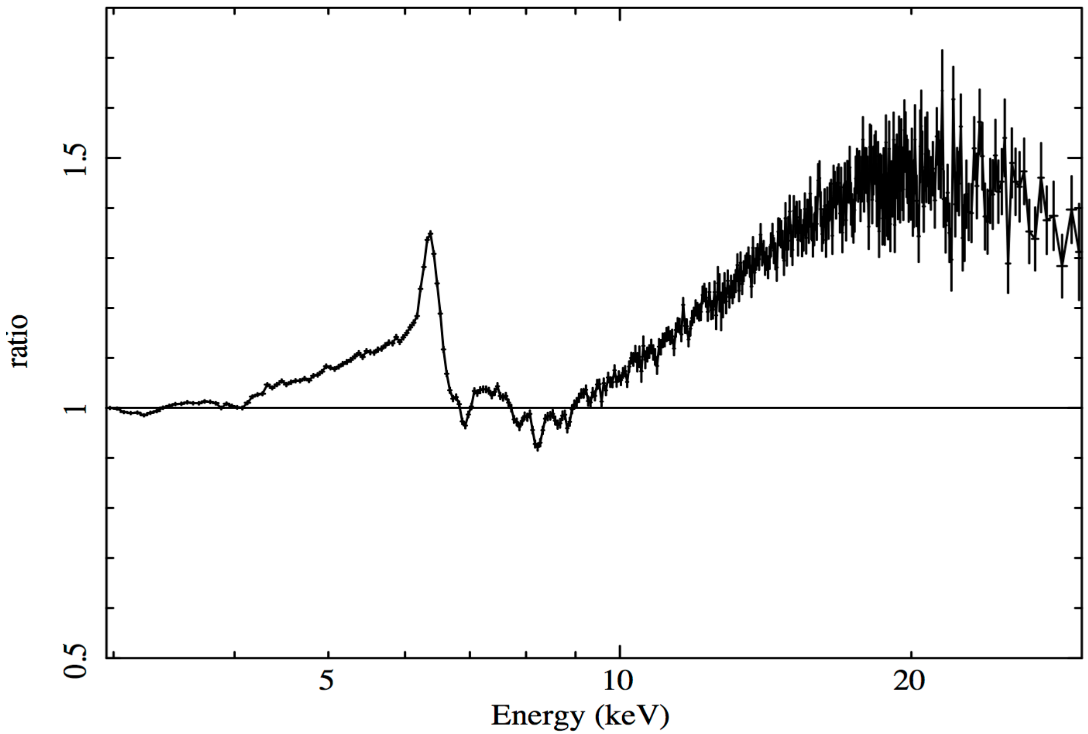

The continuum can be monitored in two ways:

- discrete sampling with the same observations
- 'continuous' sampling with the WFM

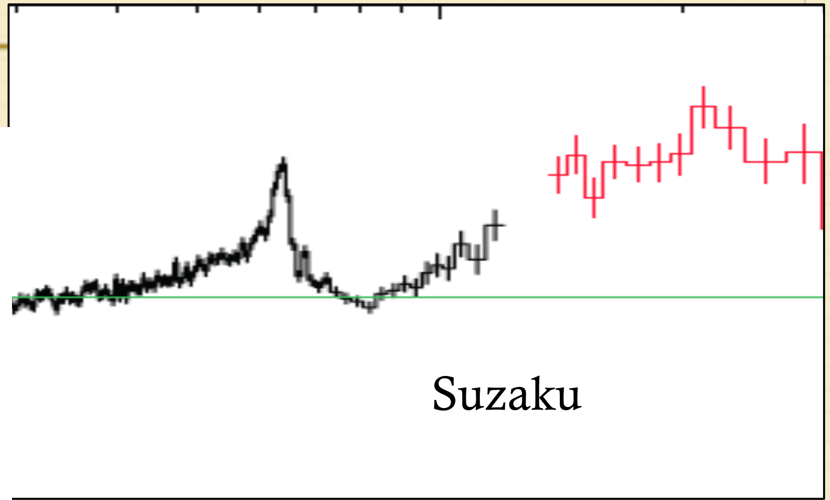
## ***Needs***

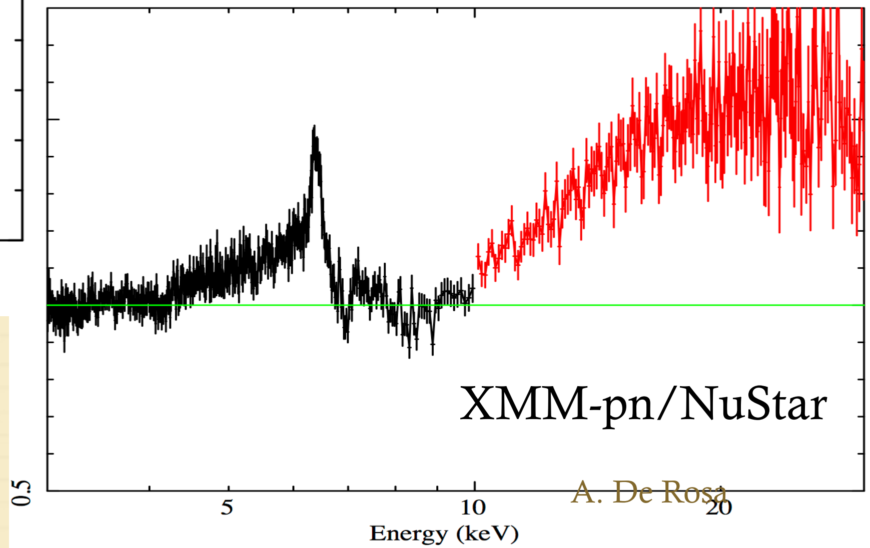
- relaxed scheduling for observatory science
- all-sky coverage of the WFM, by reducing pointing constraints and/or larger FOV

# AGNs in 2024…?




## Nearby present



# Summary and next steps

- Although it has been primary conceived for timing studies, detailed simulations have shown that LOFT will provide a major step forward in the study of GR in the strong filed regime by observing with unprecedented accuracy transient features in X-ray spectra of AGNs

- LOFT can do a lot of useful science on a sizeable sample of radio-quiet AGN, like the Swift-BAT AGN catalogue
  - Distribution of (large) $N_H$, $\Gamma$, R
  - Fraction of Compton-thick sources (in the local Universe)

- ESA M3 missions Assessment study extended. Yellow Book due Sept. 2013

http://www.isdc.unige.ch/loft/