# The importance of taking the broad view: NuSTAR observations of radio-quiet AGN

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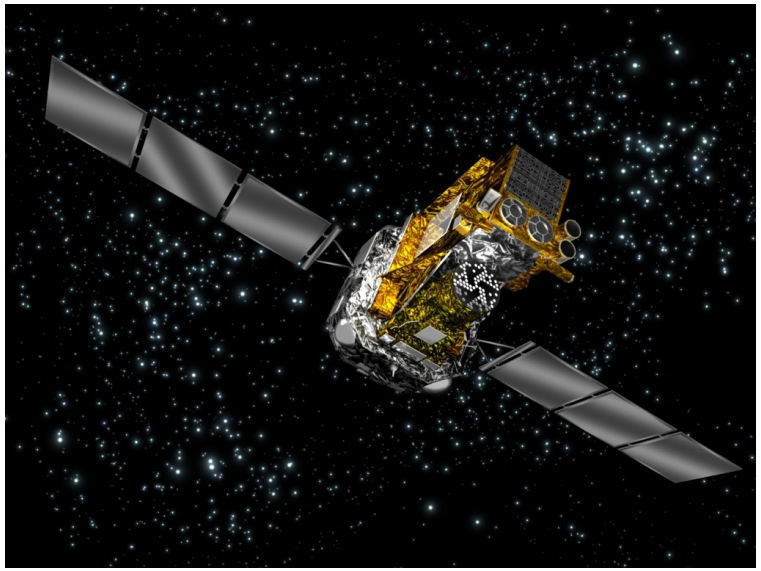
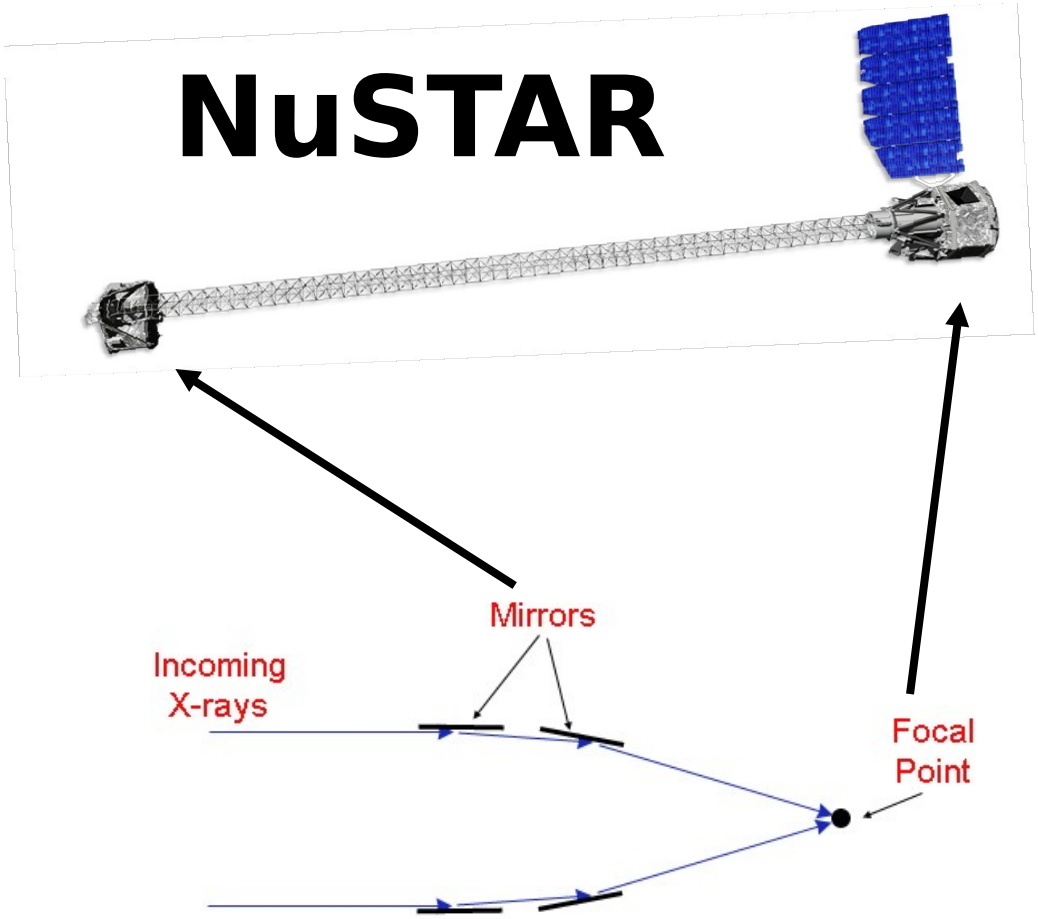
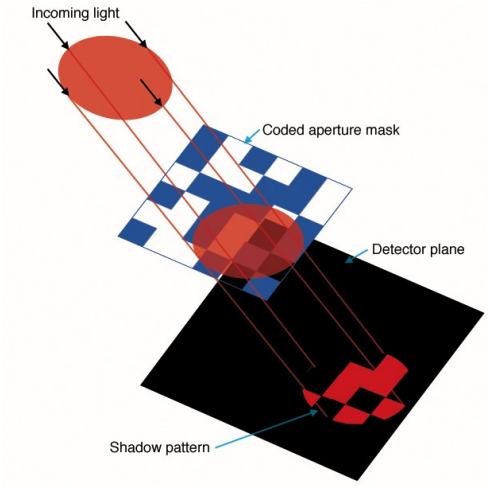
*On behalf of the NuSTAR AGN Physics WG*

# NuSTAR is the **first** focusing hard X-ray satellite



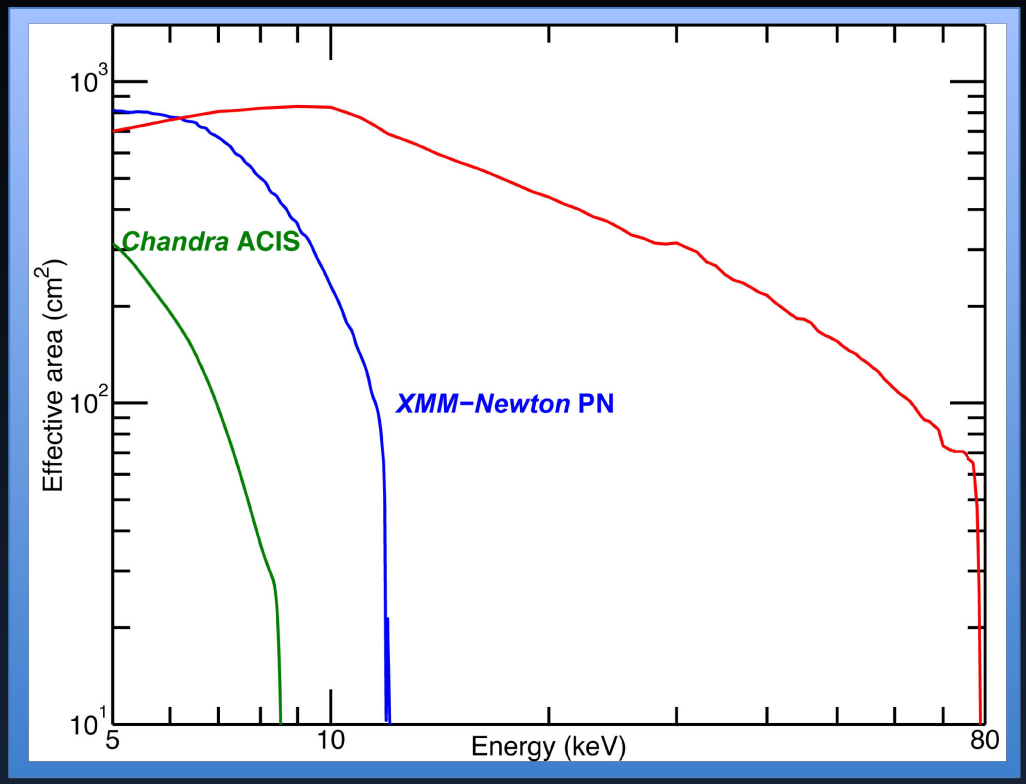



Coded Aperture Optics:
high background, large detector

Grazing Incidence Optics:
low background, compact detector

# Collecting Area




*NuSTAR two-telescope total collecting area*

***Sensitivity comparison***

| | |
|---|---|
| ***INTEGRAL (ISGRI)*** | ***~0.5 mCrab (20-100 keV) with >Ms*** |
| ***Swift (BAT)*** | ***~0.8 mCrab (15-150 keV) with >Ms*** |
| ***NuSTAR*** | ***~0.8 μCrab (10-40 keV) In 1 Ms*** |

## 1 Ms Sensitivity

$3.2 \times 10^{-15}$ erg/cm2/s
(6 – 10 keV)
$1.4 \times 10^{-14}$ (10 – 30 keV)

## Imaging

| | |
|---|---|
| HPD | 58” |
| FWHM | 18” |
| Localization | 2” (1-σ) |

## Field of View

| | |
|---|---|
| FWZI | 12.5’ x 12.5’ |
| FWHI | 10’ @ 10 keV |
| | 8’ @ 40 keV |
| | 6’ @ 68 keV |

## Timing

| | |
|---|---|
| relative | 100 microsec |
| absolute | 3 msec |

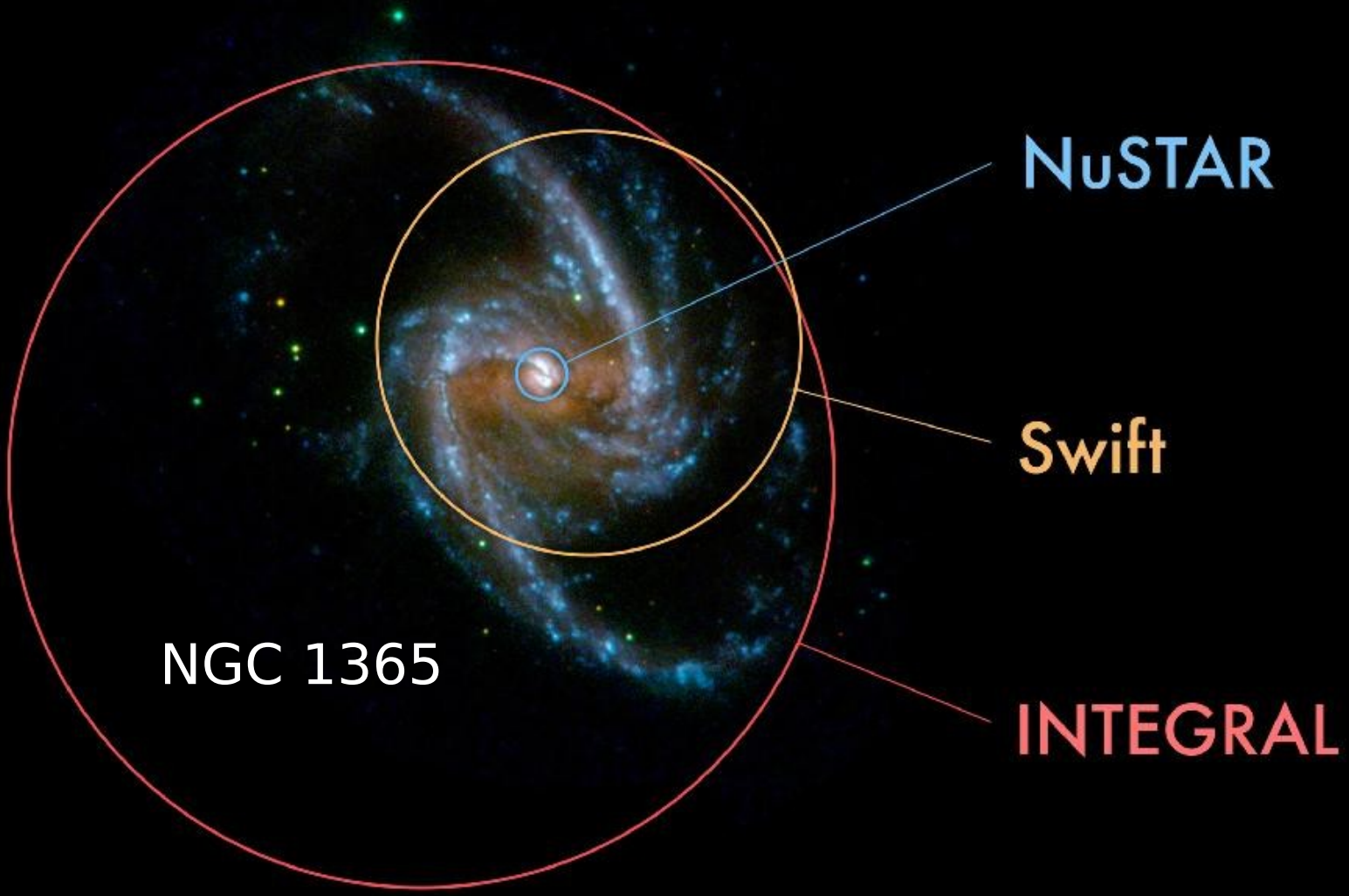
## Spectral response

| | |
|---|---|
| energy range | 3-79 keV |
| threshold | 2.0 keV |
| ΔE @ 6 keV | 0.4 keV FWHM |
| ΔE @ 60 keV | 1.0 keV FWHM |

## Target of Opportunity

response <24 hr (reqmt)
typical 6-8 hours
80% sky accessibility

# High-Energy Missions in Orbit:
## comparison of pixel scales

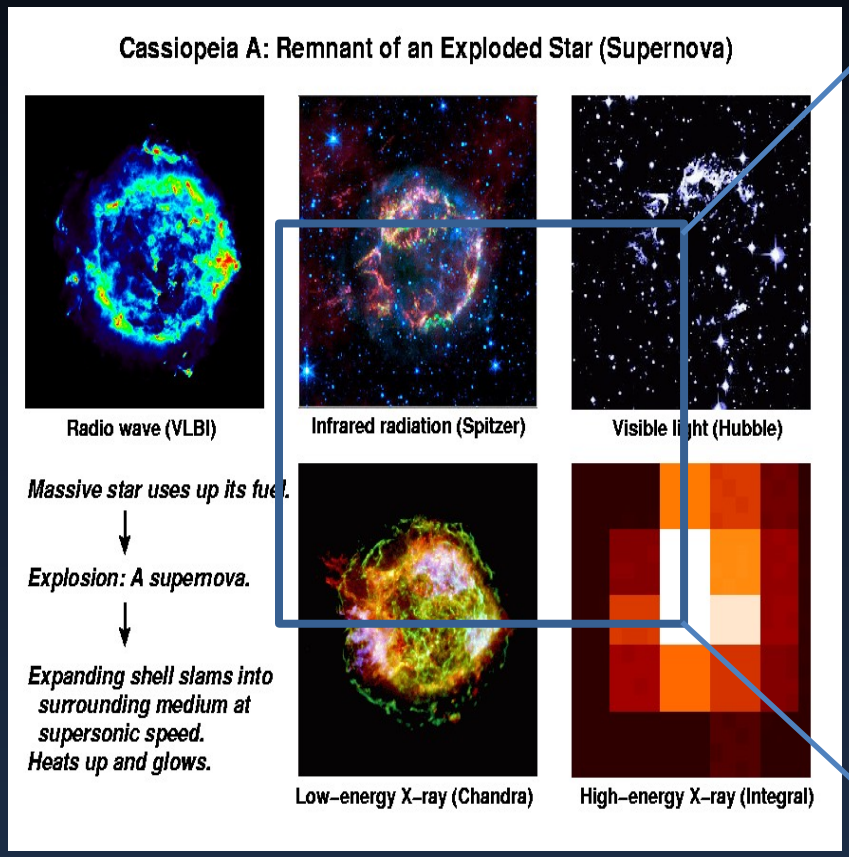


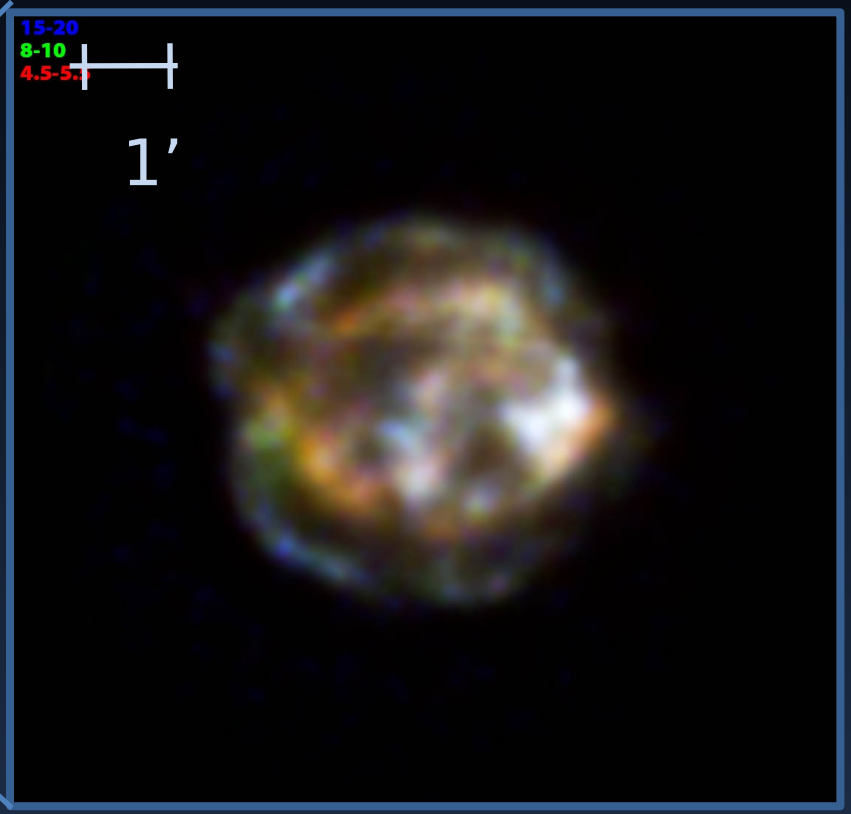
# Imaging

## *Cas A supernova remnant*

*INTEGRAL ISGRI*
E>15 keV

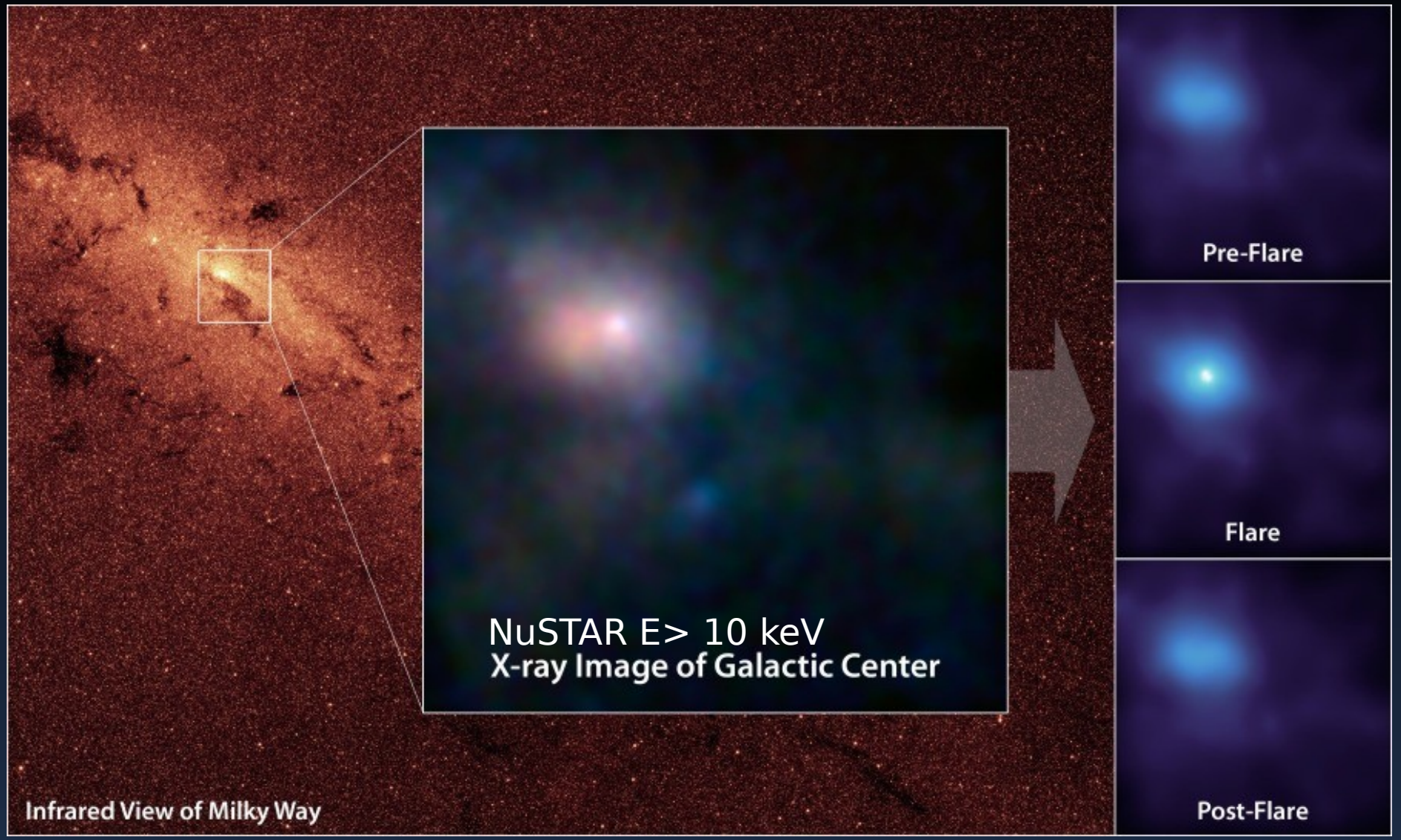
*NuSTAR Image*
Red : 4.5 – 5.5 keV
Green: 8 – 10 keV
Blue: 10 – 25 keV

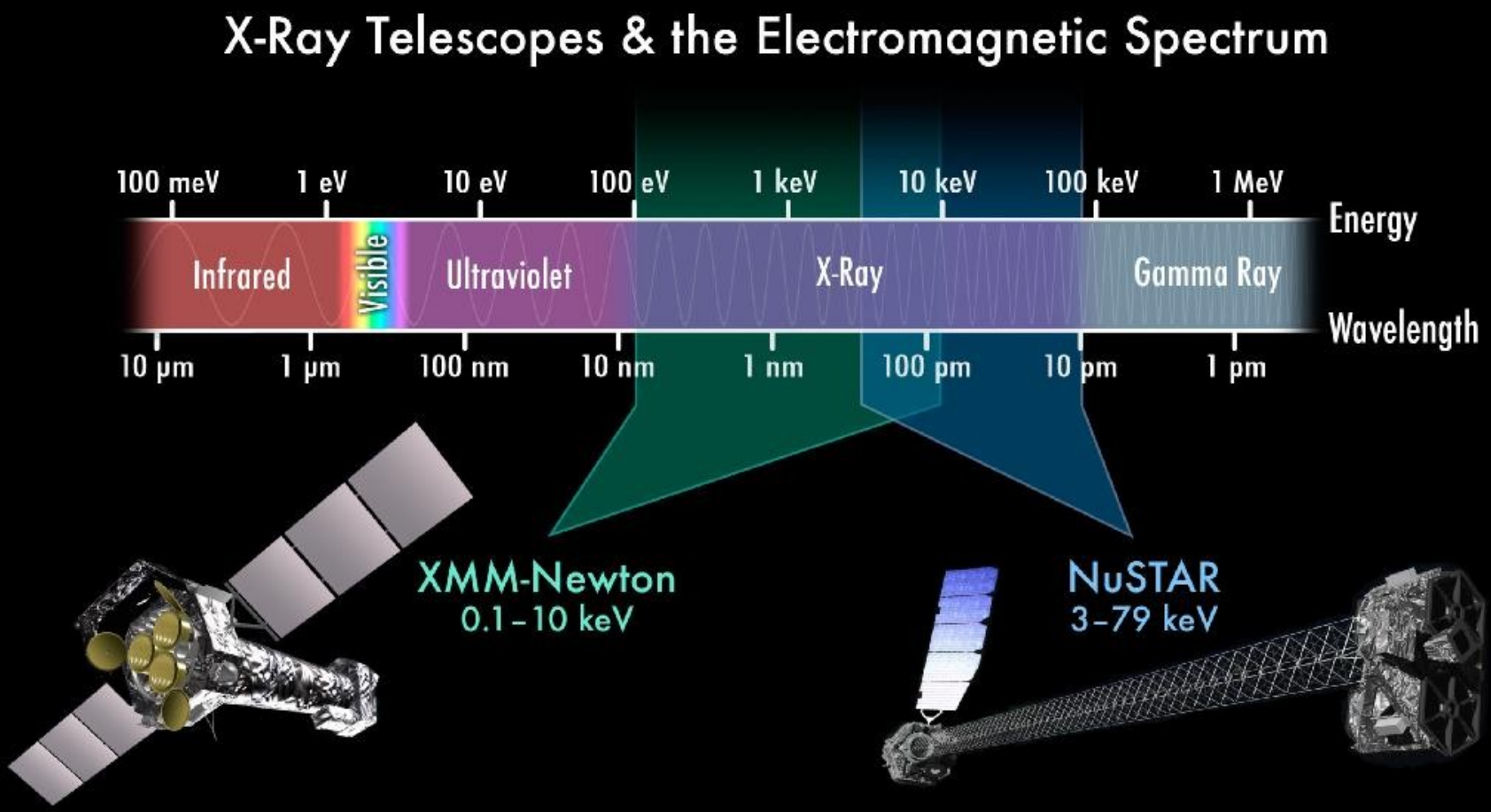



*Grefenstette et al. (2014)*

# Imaging


NuSTAR E> 10 keV
X-ray Image of Galactic Center
Infrared View of Milky Way
Pre-Flare
Flare
Post-Flare




low-energy X-rays
“soft” X-rays

high-energy X-rays
“hard” X-rays

# Baseline Science Mission

- SMall Explorer Mission (SMEX), launched in June 2012
- As typical for an Explorer, all baseline observations led by the science team
- After the current initial calibration period has been completed, observations became public through HEASARC two months after a data set is completed
- 1.5 Ms of NuSTAR made available for coordinated observations with XMM in AO13 (with a factor 6 oversubscription)
- Mission extended to 2015-16 with allocated budget for two more years
- GO program will start in early 2015 (call for proposals in fall 2014)

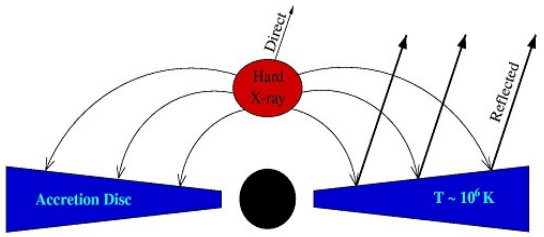
- ~140-person international science team broken into 13 science working groups:

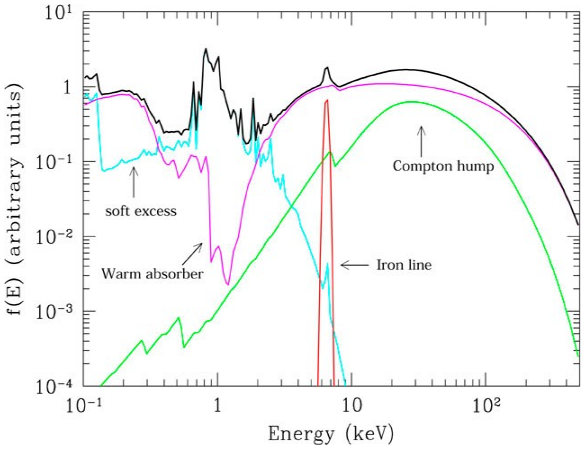
# Science Working Groups

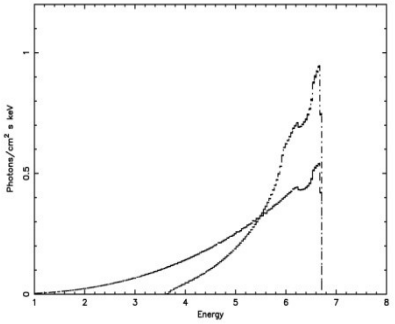
| Science Group | Working Group Chair |
| --- | --- |
| Galactic Survey | Chuck Hailey |
| Supernovae and ToOs | Steve Boggs |
| Supernova Remnants and PWN | Fiona Harrison |
| Magnetars and RPP | Vicky Kaspi |
| Galactic Binaries | John Tomsick |
| Ultraluminous X-ray sources | Fiona Harrison |
| Extragalactic Surveys | Daniel Stern |
| Blazars | Greg Madejski/Paolo Giommi |
| Obscured AGN | Daniel Stern |
| AGN Physics | Giorgio Matt |
| Galaxy Clusters | Allan Hornstrup/Silvano Molendi |
| Starburst Galaxies | Ann Hornschemeier |
| Solar Physics | David Smith |

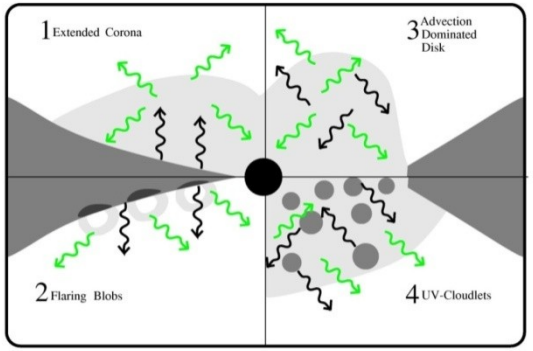
# *AGN Physics: Scientific rationale*

- Determine the physical parameters of the hot corona (temperature, optical depth)
- Measure the spin of the Black Hole
- Search for similarities and differences between radio quiet and radio loud AGN



# *RQ objects in the AGN Physics NuSTAR Program*

- 4 sources observed simultaneously with XMM [Swift J2127.4+5654, MCG-6-30-15, 3C120, Ark 120] for BH spin and corona T
- 2 sources observed simultaneously with Suzaku [IC4329A, NGC4151] for BH spin and corona T
- MCG-5-23-16 observed twice, the second time simultaneously with Suzaku
- Mrk 335 observed twice, in coordination with Suzaku, during an extended low state
- A monitoring campaign to study the spectral variability of NGC4051
- NuSTAR joined the XMM-led monitoring campaign on NGC5548 and on PDS 456
- 1H0707+495 and Fairall 9 just observed (the latter simultaneoulsy with XMM)

# *Content of this talk*

- **The relativistic reflection in NGC1365 *(Risaliti et al., 2013, Walton et al. 2014)* and the BH spin of SwiftJ2127.4+5654 and MCG-6-30-15 *(Marinucci et al., 2014a,b)***

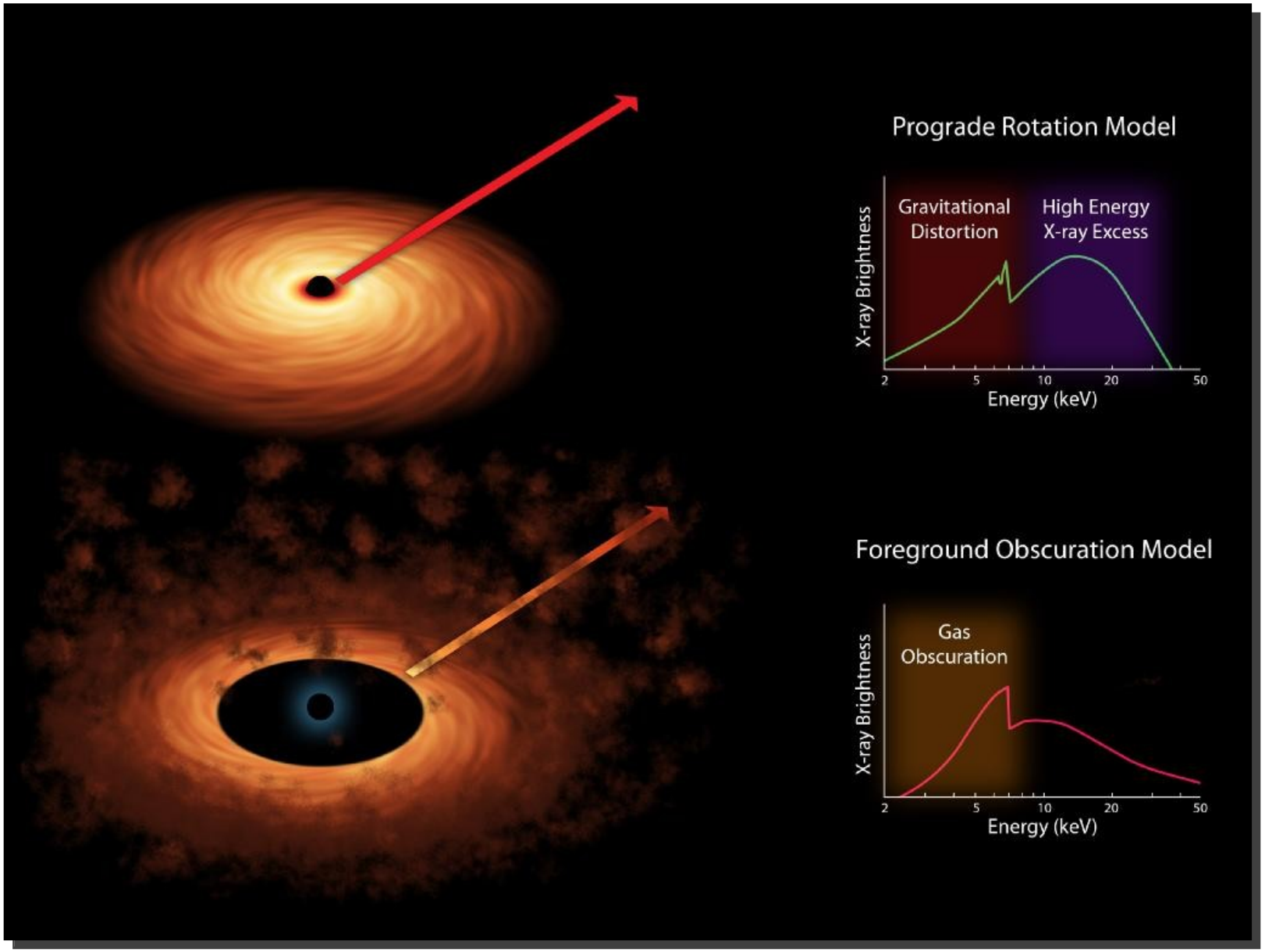
- **The hard X-rays time lags of MCG-5-23-16 *(Zoghbi et al., 2014)***

- **The soft excess of Ark 120 *(Matt et al., 2014)***

***The powerful wind of PDS 456 ➡ talk by Emanuele Nardini***

***AGN coronal properties ➡ talk by Andrea Marinucci***

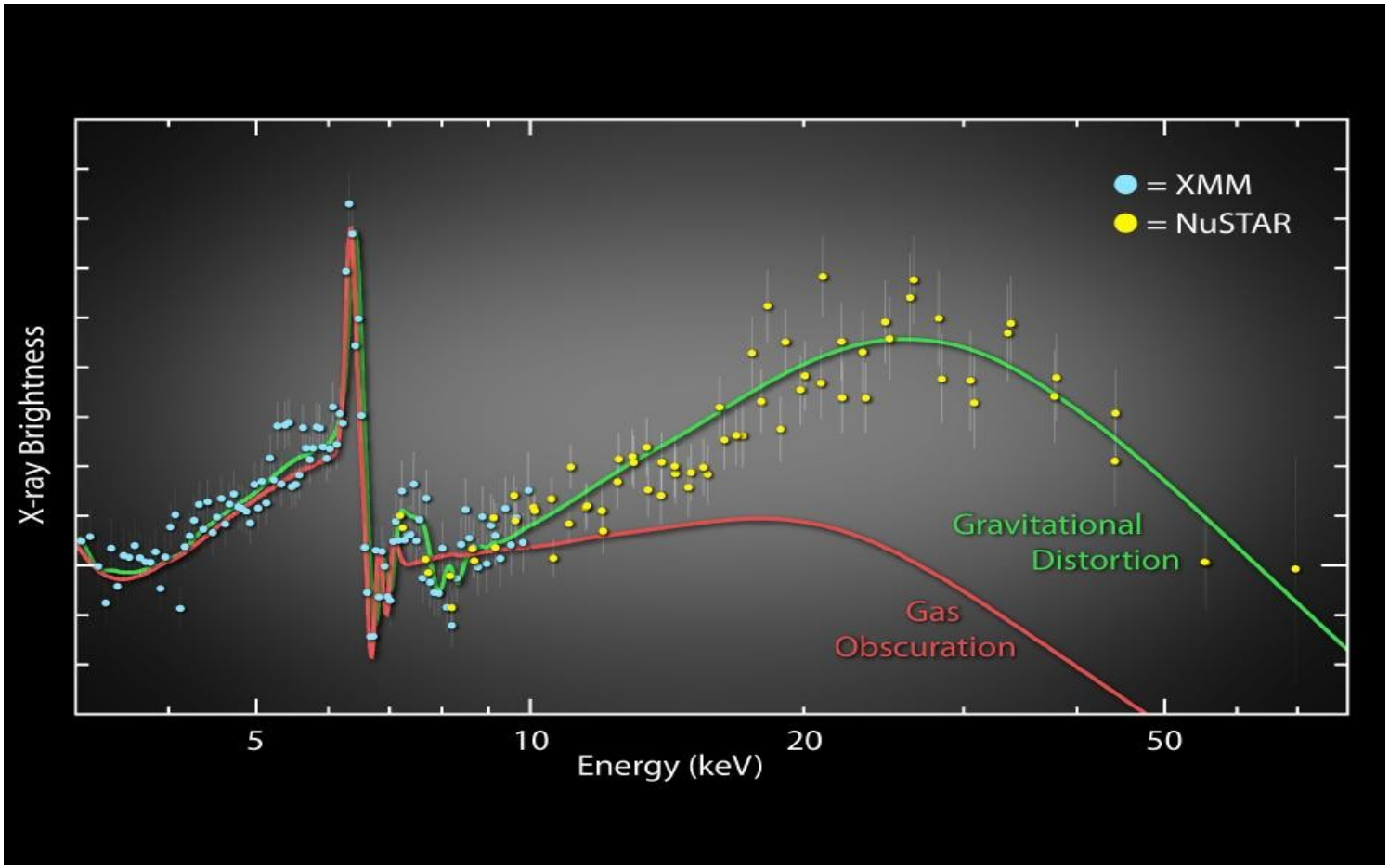
# *The relativistic reflection in NGC1365*



# *The relativistic reflection in NGC1365*

Observed simultaneously by XMM and NuSTAR.

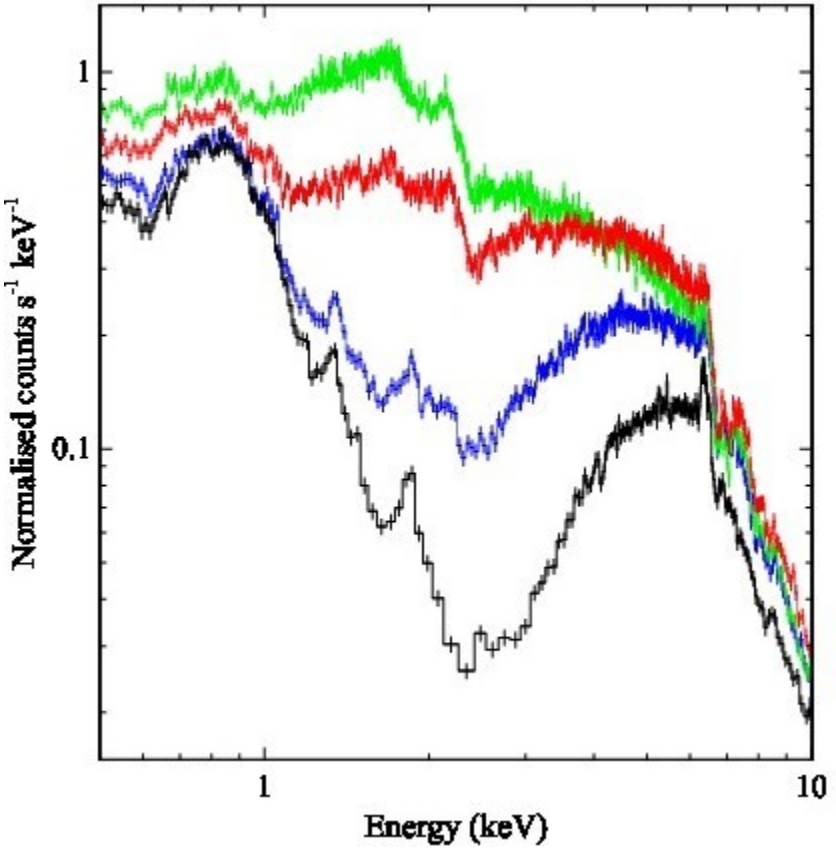
Both absorption and reflection models fit well the XMM data, but only reflaction also the NuSTAR data (Risaliti et al. 2013)

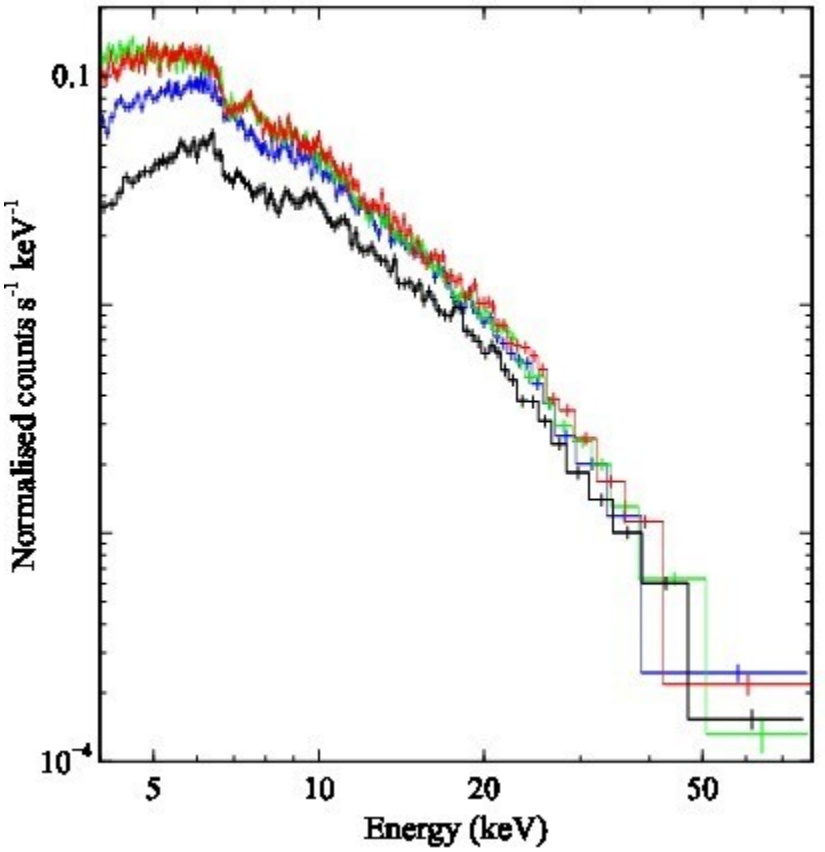


# *The relativistic reflection in NGC1365*

Observed simultaneously by XMM and NuSTAR.

Consistent results are found in all observations, despite huge differences in the absorption parameters (Walton et al. 2014)



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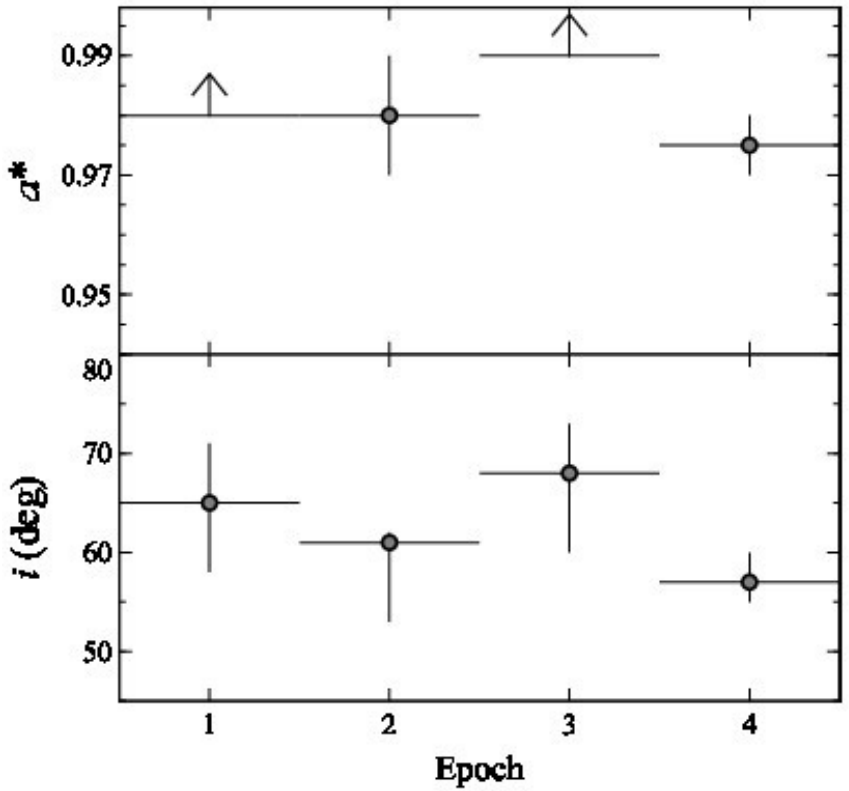
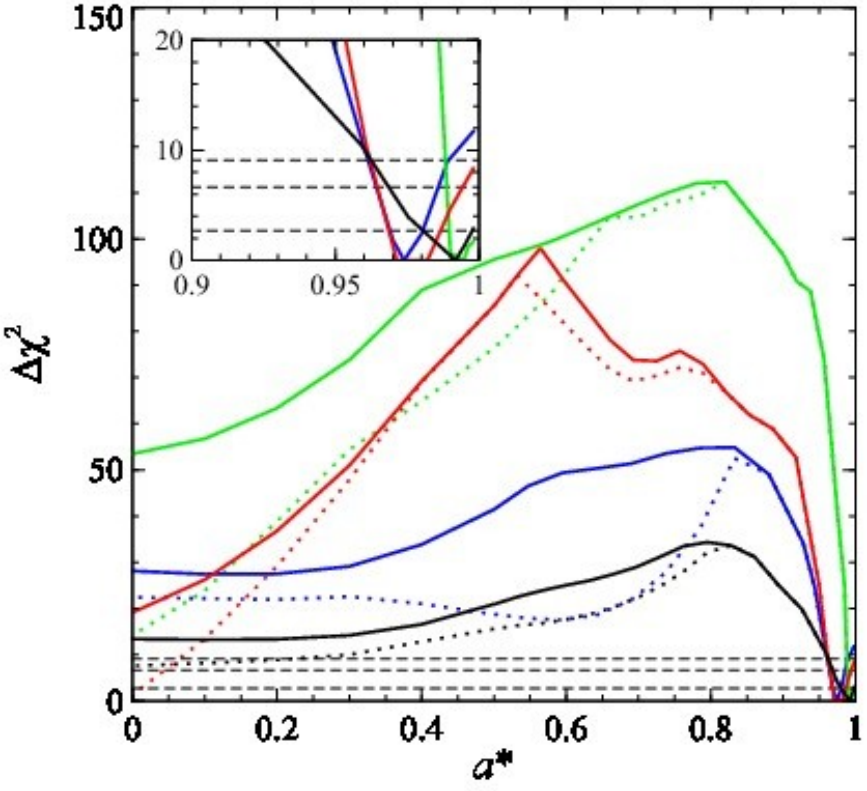
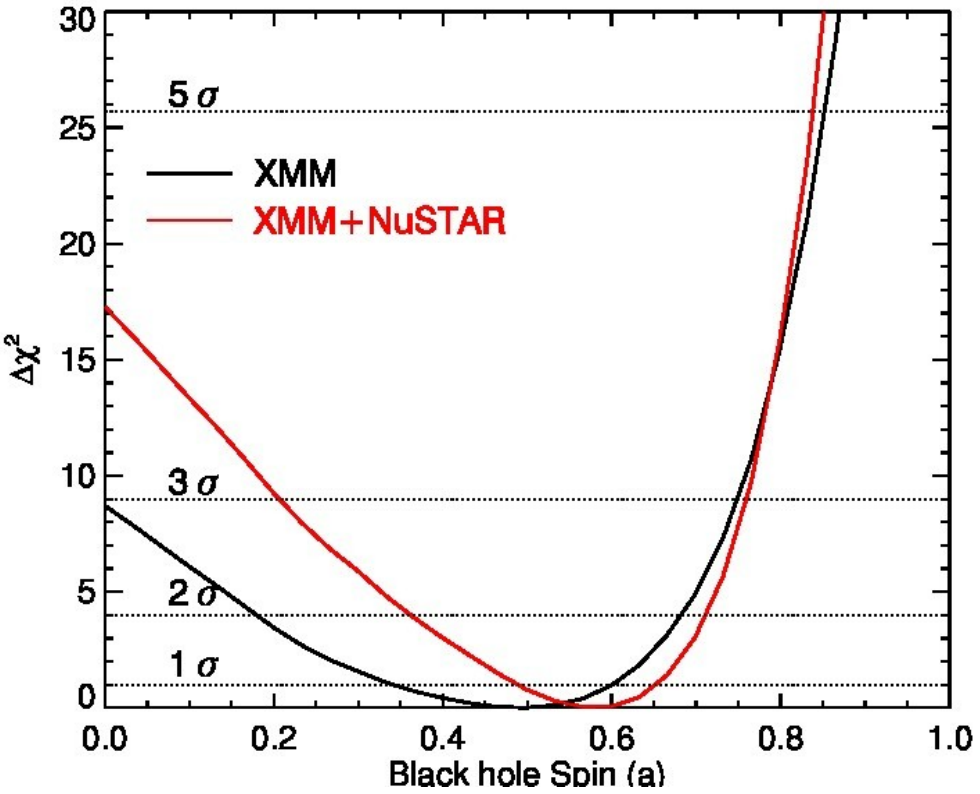


# *BH spin measurements*

The broad band provided by NuSTAR + XMM (or Suzaku) allows a good estimated of the continuum spectrum, and so a robust measurements of the BH spin via relativistic effects on the iron line and the reflection component




Spin ~1 confirmed in MCG-6-30-15 (Marinucci et al. 2014b)

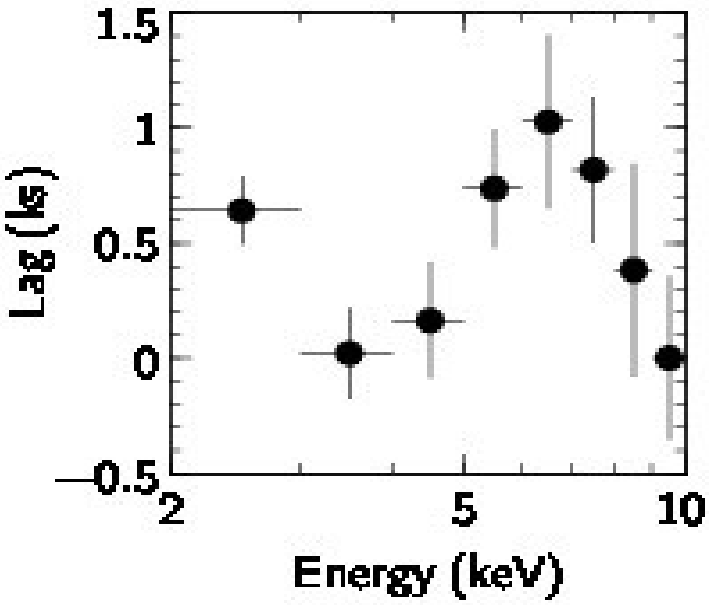
*SwiftJ2127.4+5654 (Marinucci et al. 2014a)*

# *The hard X-ray time lag in MCG-5-23-16*

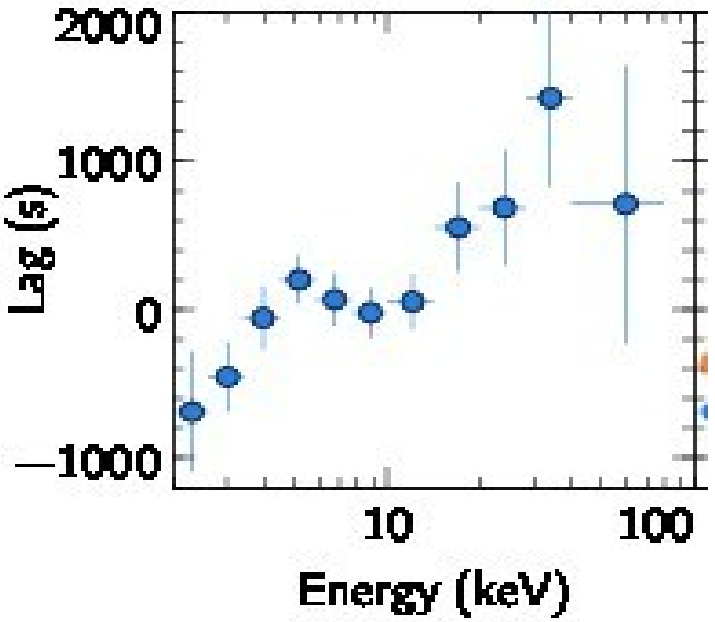
Soft time lags observed in many AGN (e.g. Fabian et al. 2009, De Marco et al. 2013, Uttley et al. 2014) --> Reflection from inner disc

More recently, reverberation of iron lines have also been observed (e.g. Zoghbi et al. 2012, Kara et al. 2014)

Compton hump reverberation expected !!

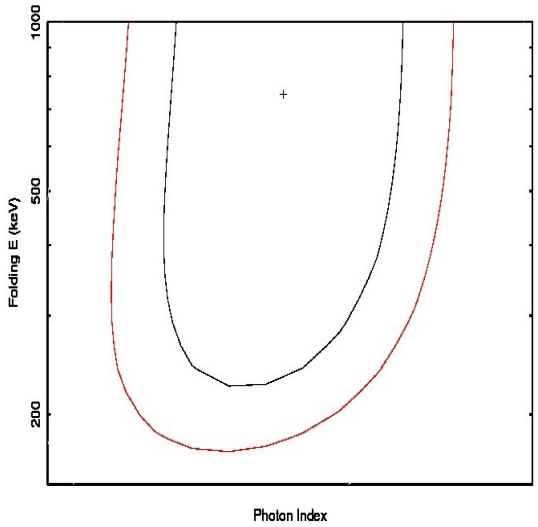



**XMM (*Zoghbi et al. 2013*)**




**NuSTAR (*Zoghbi et al. 2014*)**

# *The soft excess of Ark 120*

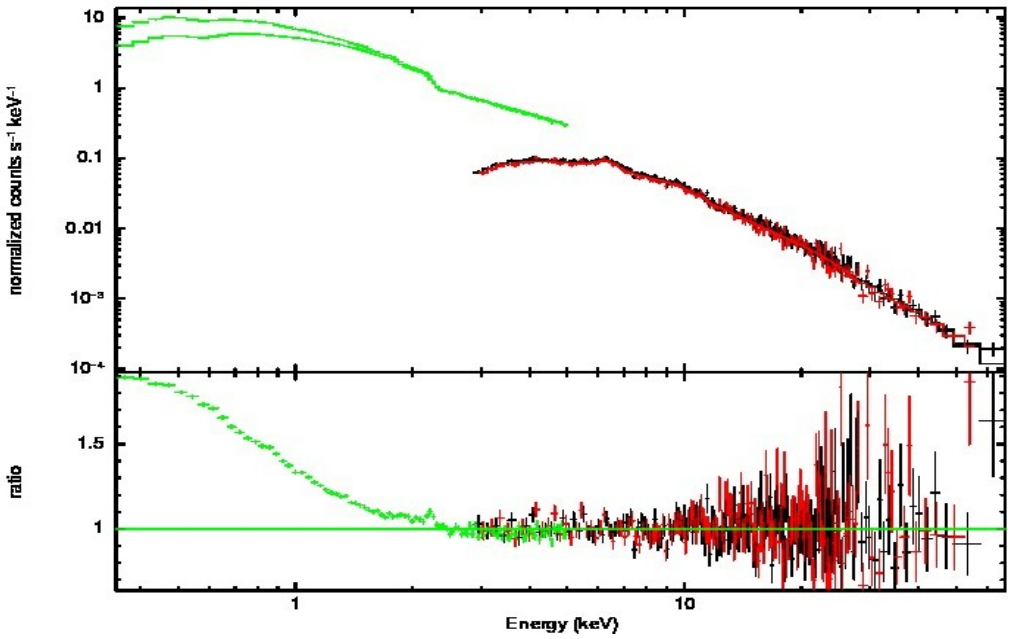



Bright, “bare” Seyfert 1 galaxy

Fit with NuSTAR data only (power law + reflection + iron line)

No High Energy Cutoff detected

Extrapolation to XMM shows strong excess

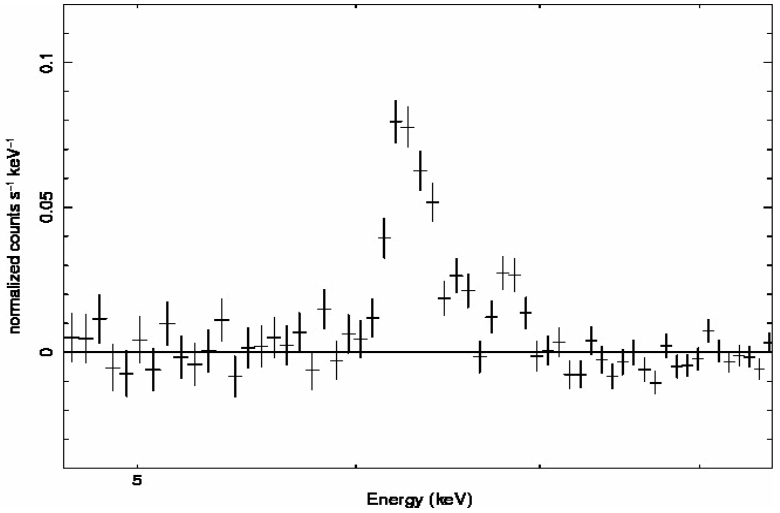


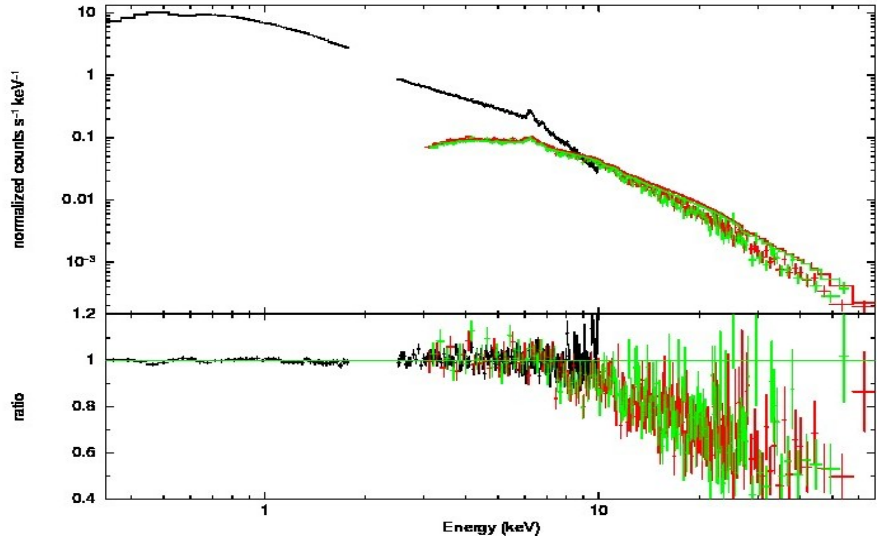

***(Matt et al. 2014)***

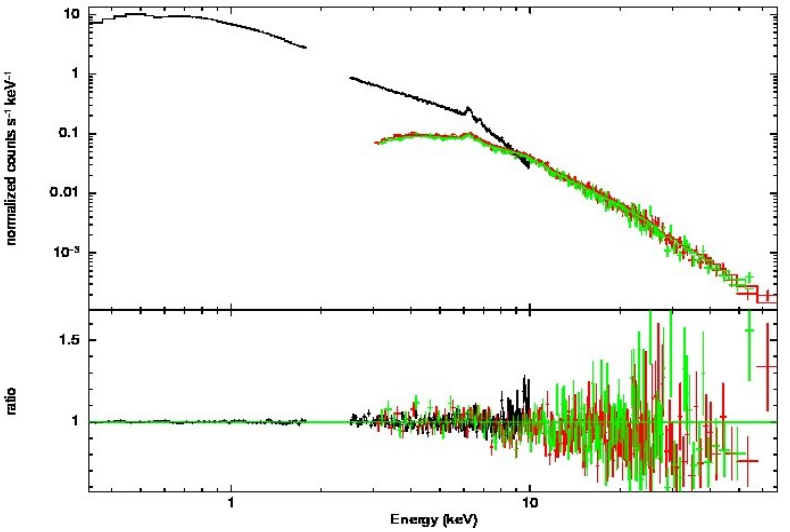
# *The soft excess of Ark 120*

XMM: no obvious evidence for rel. Line
(differently from a previous Suzaku obs,
Nardini et al. 2011)

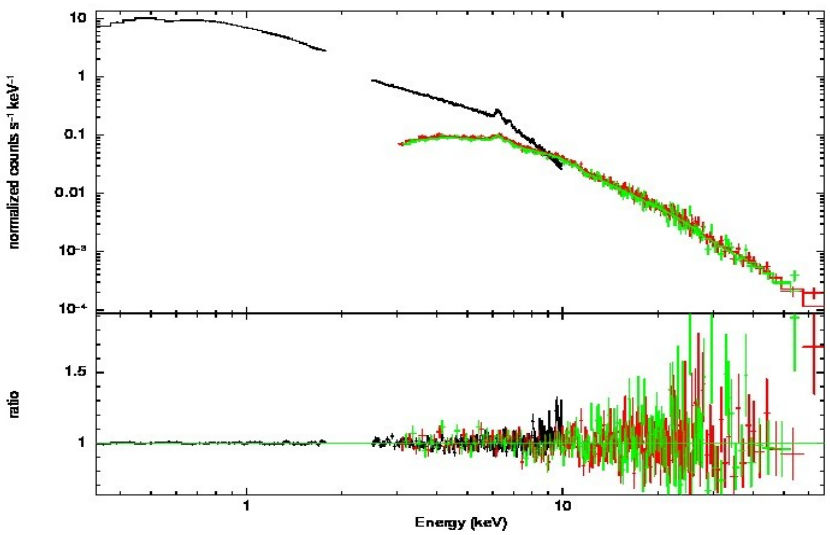
Soft excess with a simple power law or with
a Comptonization model give comparable
fits to the XMM spectrum, but
very different extrapolation to NuSTAR
(cold and ionized reflection included in the fit)



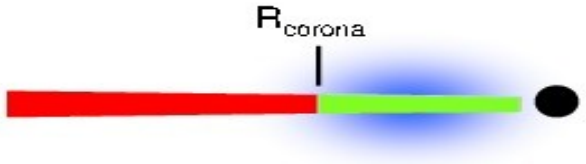



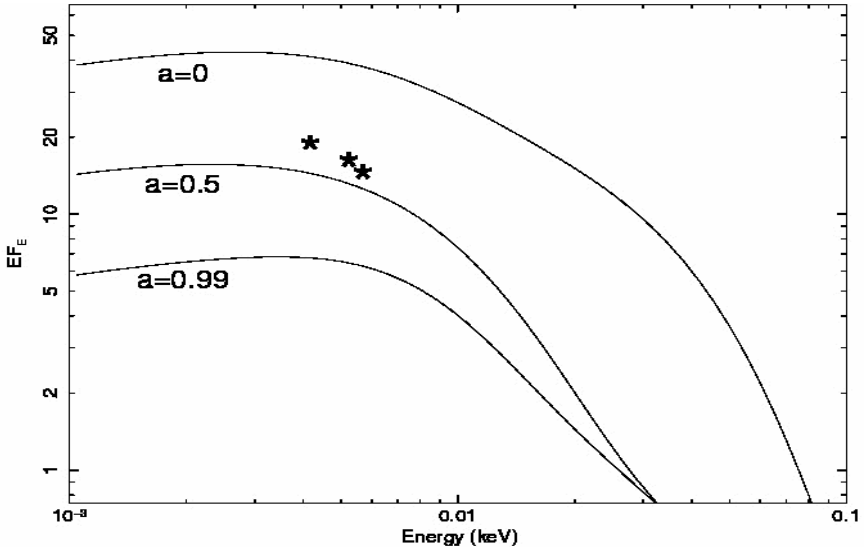



# *The soft excess of Ark 120*




Indeed, the broad-band best fit is with a Comptonization model for the soft excess. A *cutoff p.l.*, *compTT, nthcomp* or ***optxagnf*** provide fits of comparable quality.




***Optxagnf*** (*Done et al. 2012*) is a disk/corona emission model which assumes a thermal disk emission outside the coronal radius, and soft and hard Comptonization inside.

Extrapolating the best fit X-ray model to the OM UV data, an estimate of the black hole spin is possible

# *Summary*

**NuSTAR is providing AGN spectra of unprecedented quality above 10 keV**

**The very broad band spectra from observations coordinated with XMM or Suzaku allow us to disentangle the various spectral components (including relativistically distorted reflection) and shed light to poorly known components like eg the soft excess**