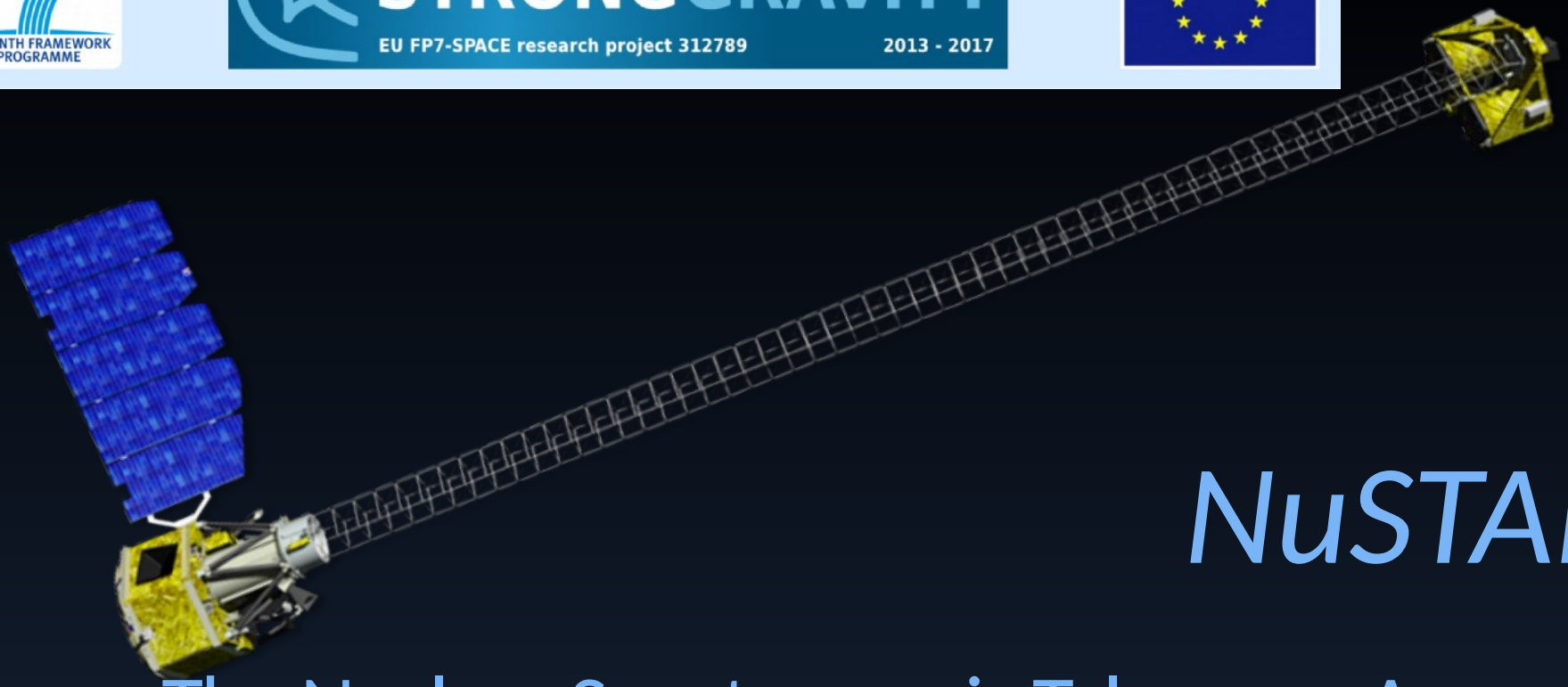


NuSTAR

The Nuclear Spectroscopic Telescope Array Extragalactic Program

Andrea Marinucci
Università degli Studi Roma Tre
on behalf of the NuSTAR team

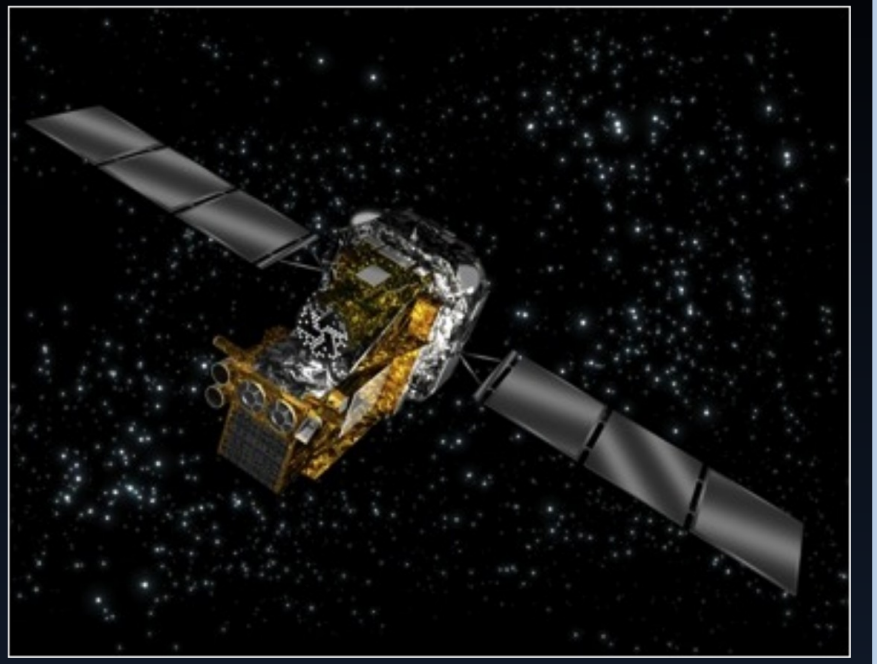
INTEGRAL Workshop 2013

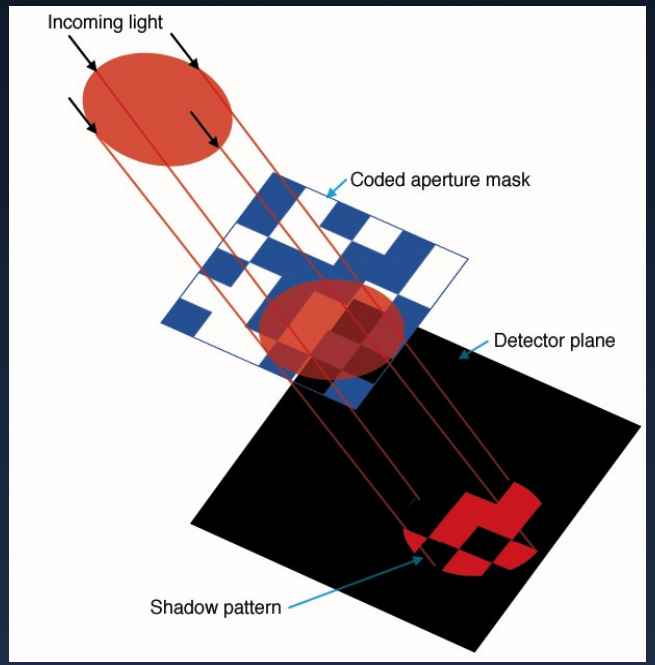
NuSTAR

bringing the high energy universe into focus

NASA Small Explorer (SMEX) mission
Launch Date: June 13, 2012
Phase E (science operations) Start Date: August 1, 2012
P.I.: Fiona Harrison (Caltech)
Project Scientist: Daniel Stern (Caltech)
http://nustar.caltech.edu

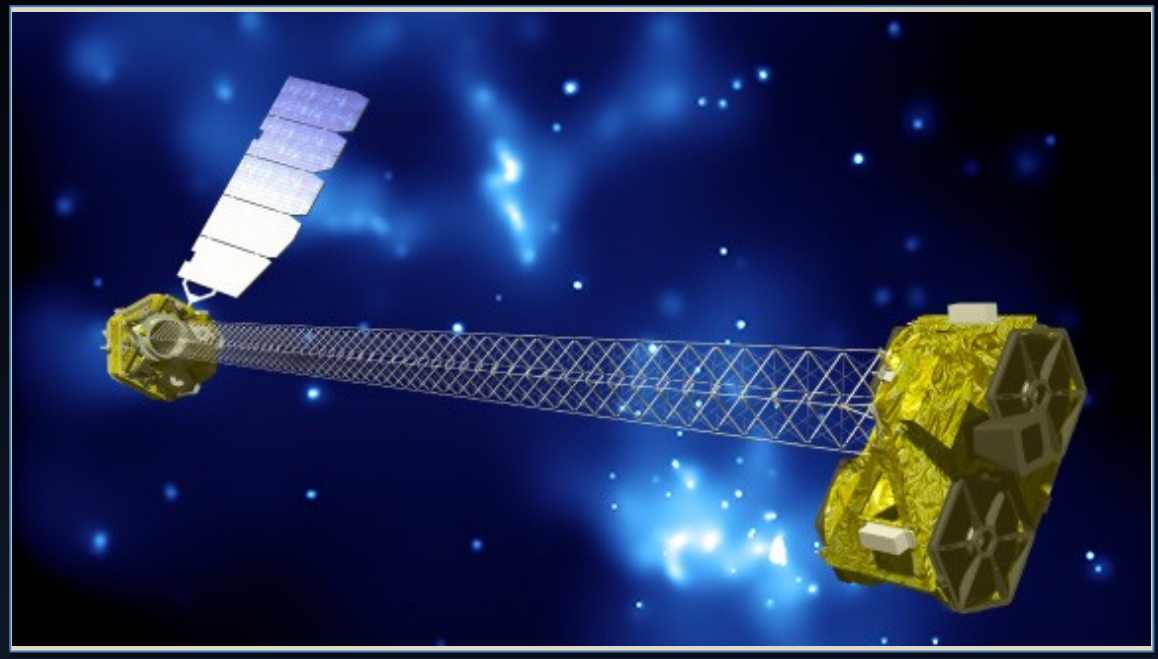
INTEGRAL, Swift BAT

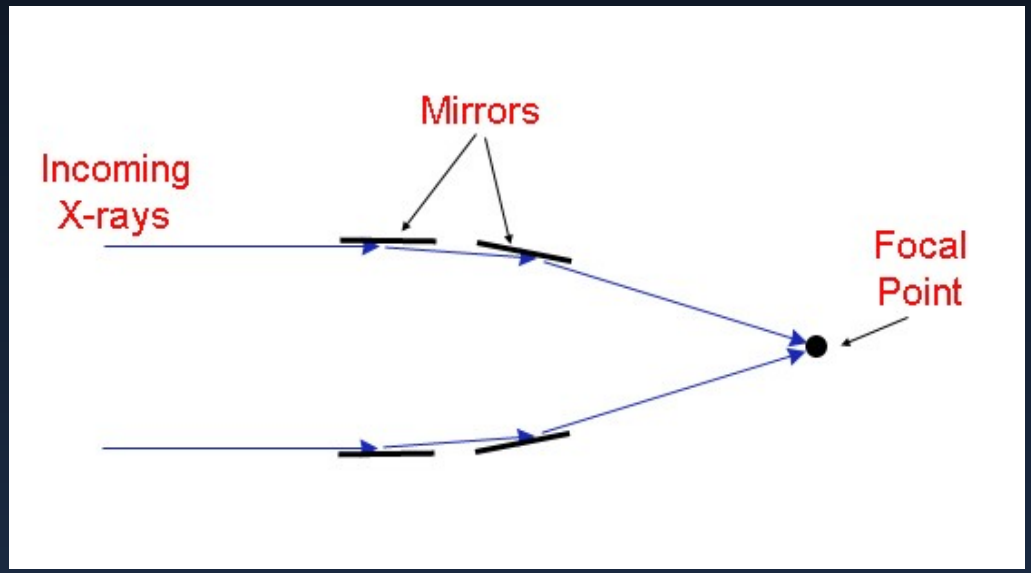




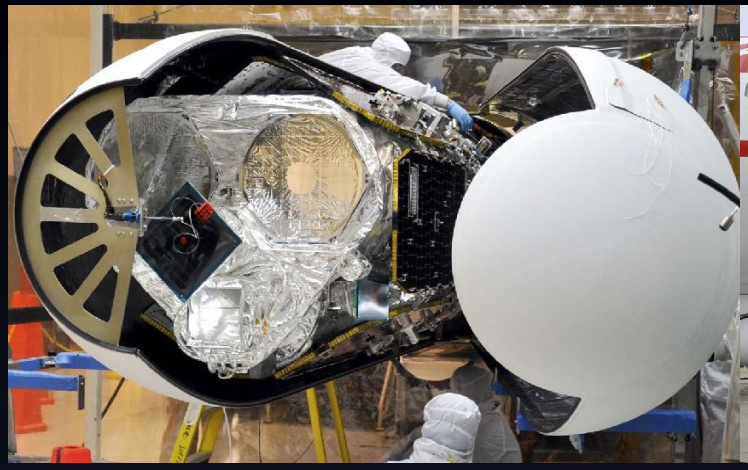
high background, large detector

NuSTAR



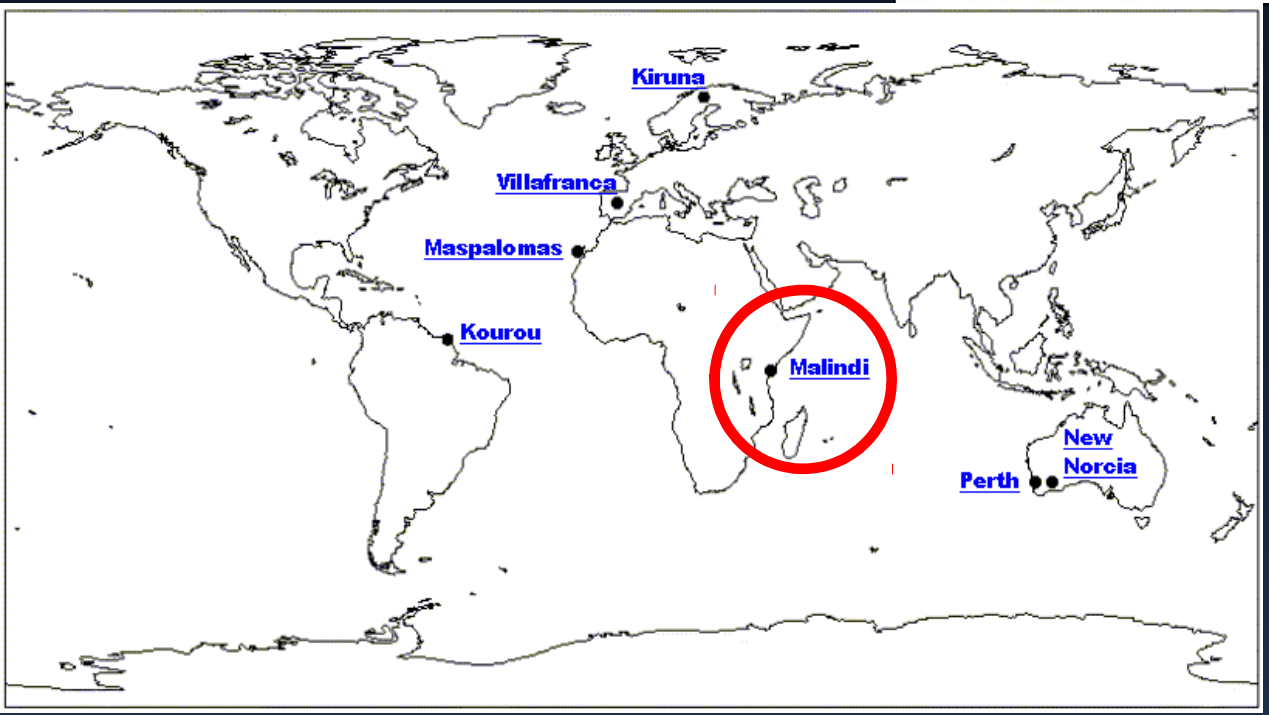


low background, compact detector

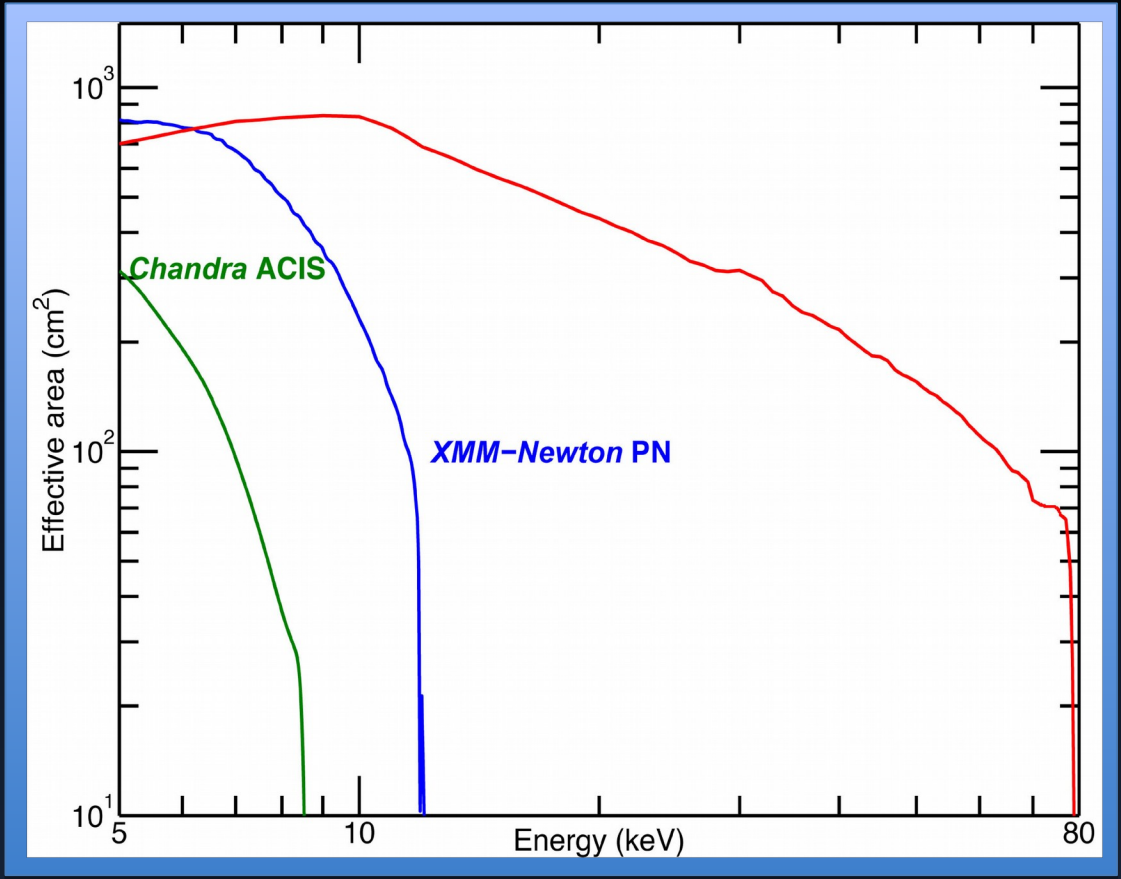


Pegasus launch from Kwajelein (June 13 2012): low earth orbit, 550x600 km low inclination, 6°

Ground Station: Malindi, Kenya (thanks!)



Collecting Area



NuSTAR two-telescope total collecting area

Satellite (instrument)	Sensitivity
INTEGRAL (ISGRI)	~0.5 mCrab (20-100 keV) with >Ms exposures
Swift (BAT)	~0.8 mCrab (15-150 keV) with >Ms exposures
NuSTAR	~0.8 μCrab (10-40 keV) in 1 Ms

Sensitivity comparison

1 Ms Sensitivity

3.2 x 10^{-15} erg/cm^2/s (6 – 10 keV)

1.4 x 10^{-14} (10 – 30 keV)

Imaging

HPD	58”
FWHM	18”
Localization	2” (1-sigma)

Field of View

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

Timing

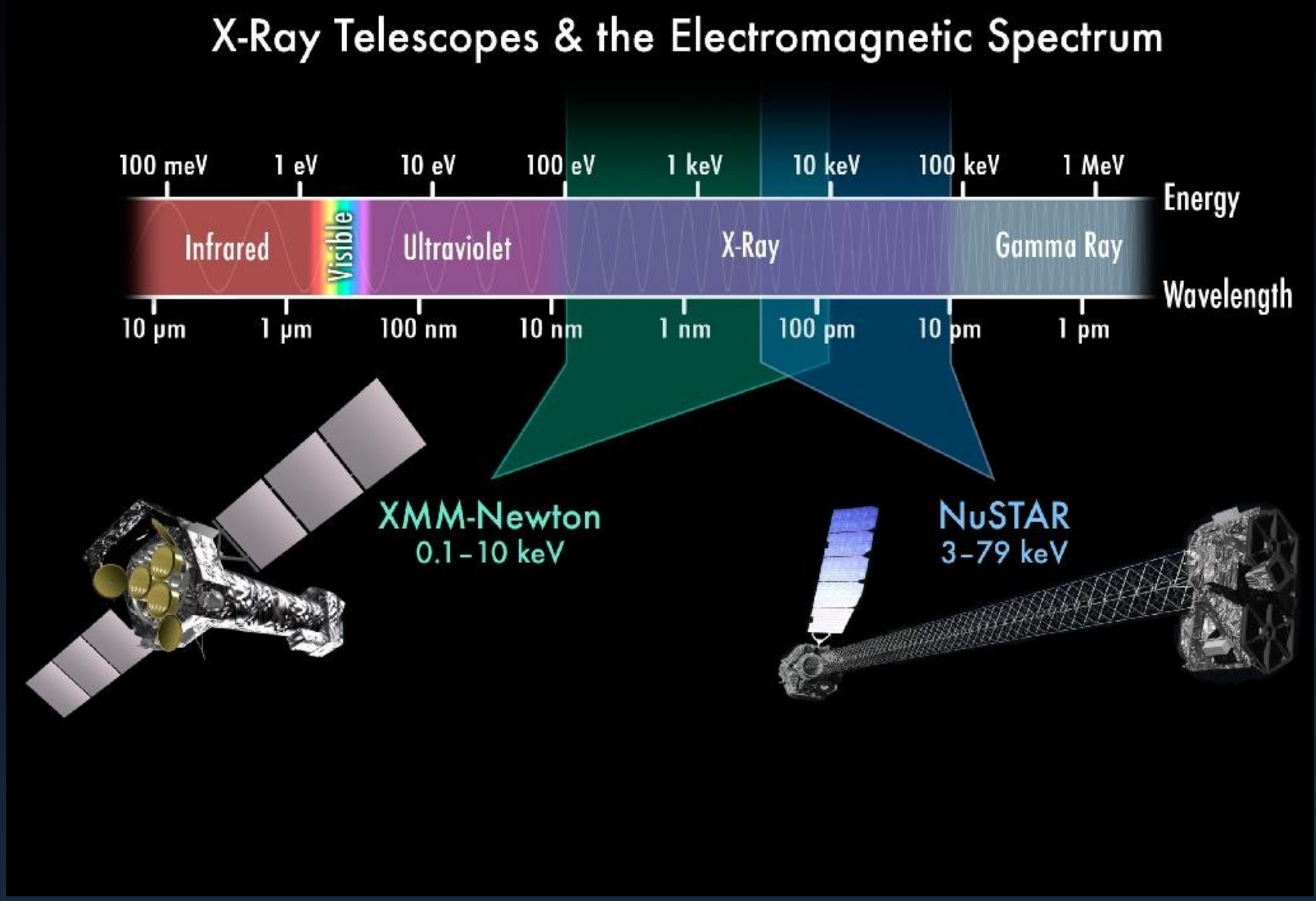
relative	100 microsec
absolute	3 msec

Spectral response

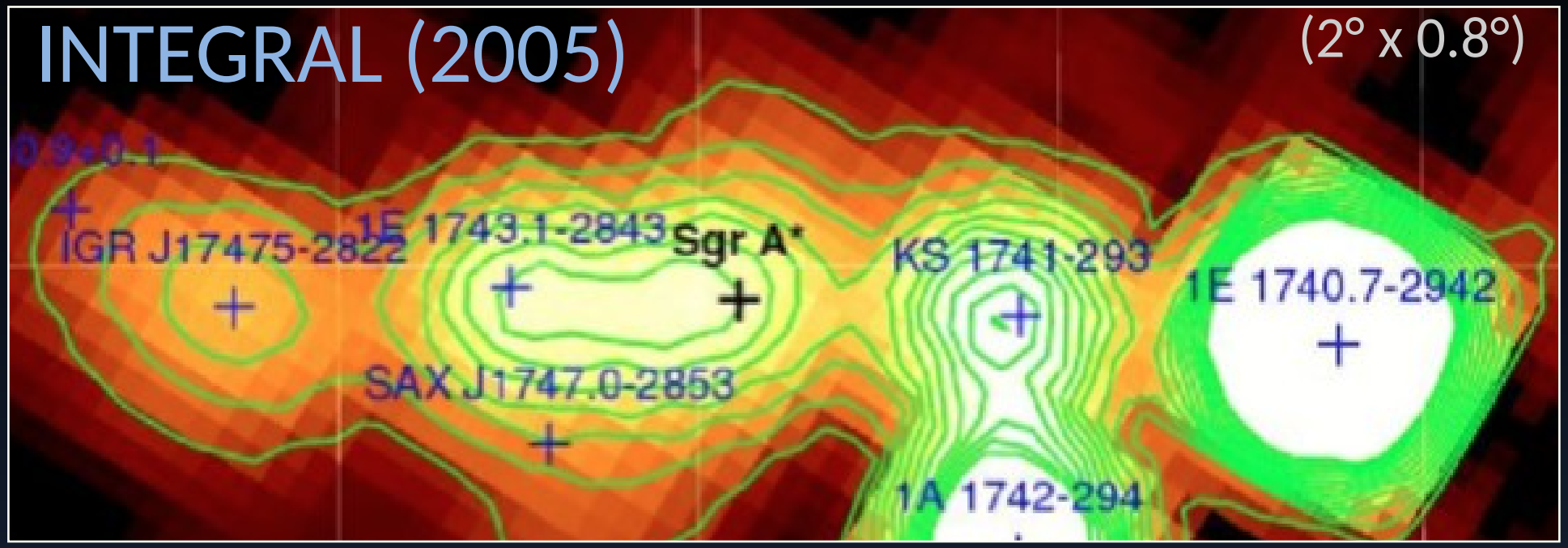
energy range	3-79 keV
threshold	2.0 keV
ΔE @ 6 keV	0.4 keV FWHM
ΔE @ 60 keV	1.0 keV FWHM

Target of Opportunity

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


X-Ray Telescopes & the Electromagnetic Spectrum
100 meV
1 eV
10 eV
100 eV
1 keV
10 keV
100 keV
1 MeV
Energy
Infrared
Visible
Ultraviolet
X-Ray
Gamma Ray
Wavelength
10 μm
1 μm
100 nm
10 nm
1 nm
100 pm
10 pm
1 pm
XMM-Newton
0.1–10 keV
NuSTAR
3–79 keV

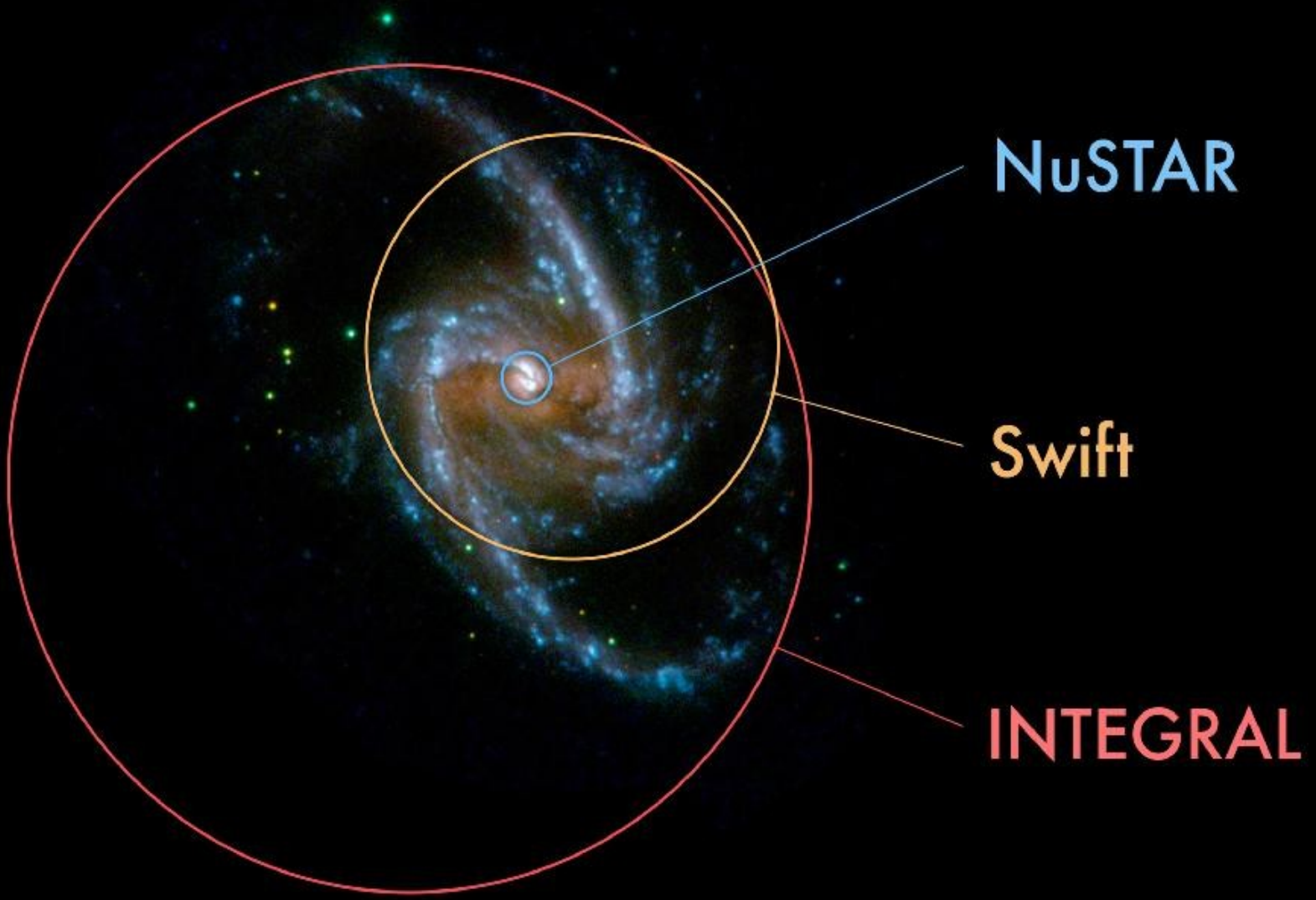
The Galactic Center



NuSTAR simulation (2012)

Galactic surveys: *locate remnants of collapsed stars (white dwarfs, neutron stars, black holes) to study the endpoints of stellar evolution*

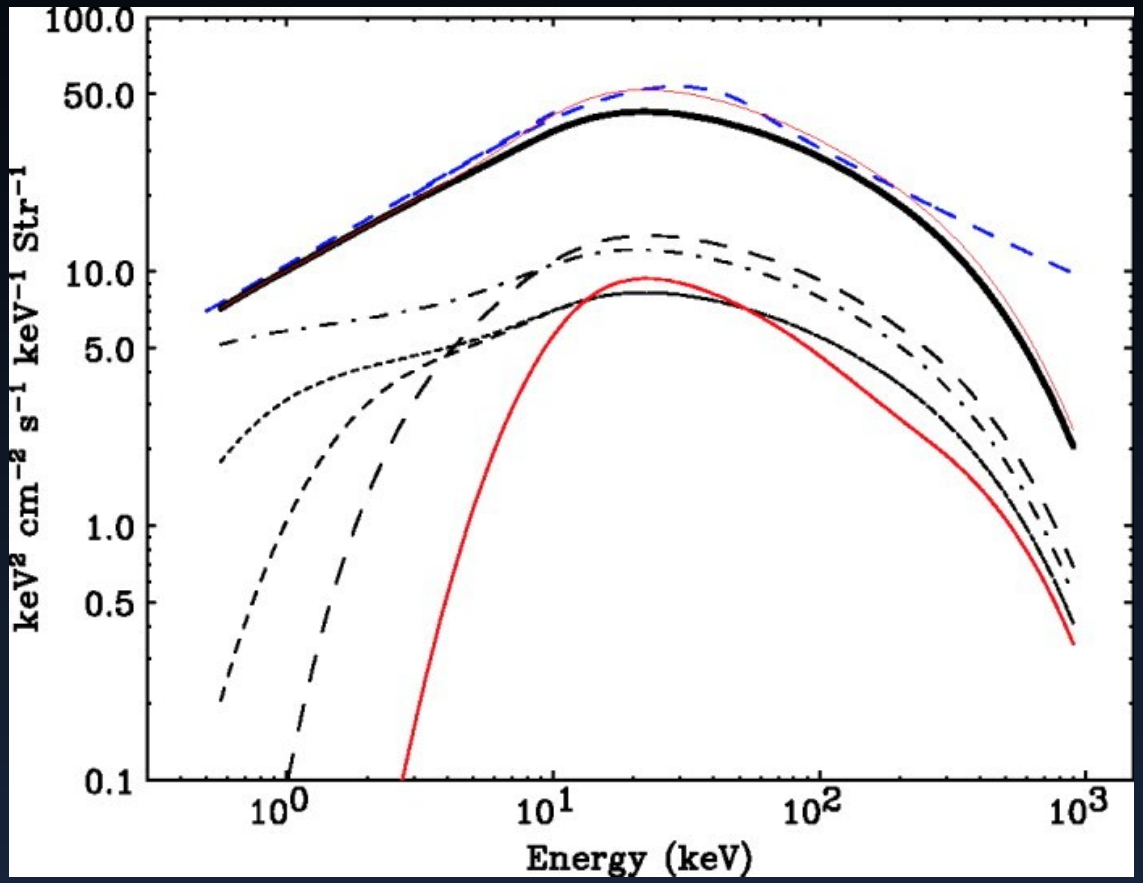
Resolving the Core of NGC 1365 in High Energy X-Rays



Imaging – IC342

The galaxy IC 342, ULX-1/2 resolved for the first time above 10 keV

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background



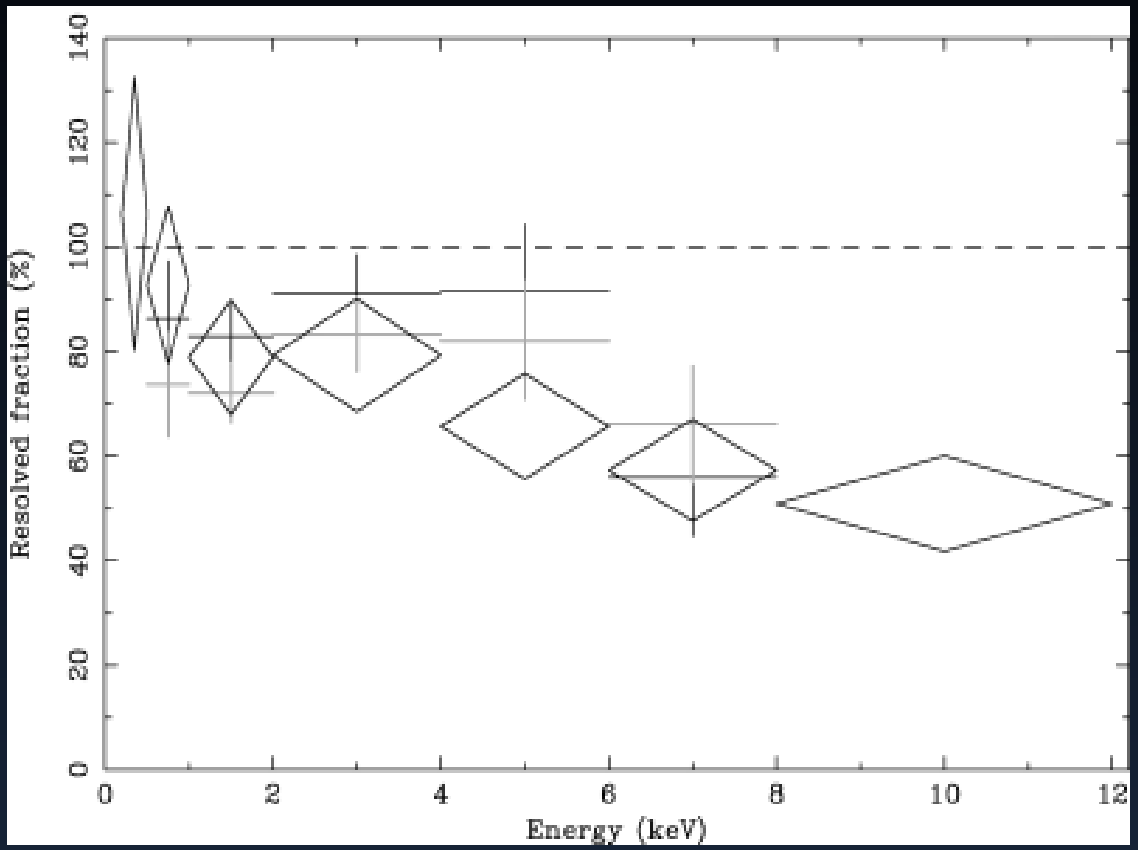
peaks at ~30 keV

constrains the accretion history of the universe, e.g., the formation history of supermassive black holes

requires a population of heavily obscured AGN

Ueda et al. 2003, ApJ, 598, 886

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background



pluses = Chandra Deep Fields/GOODS

diamond = XMM Lockman Hole

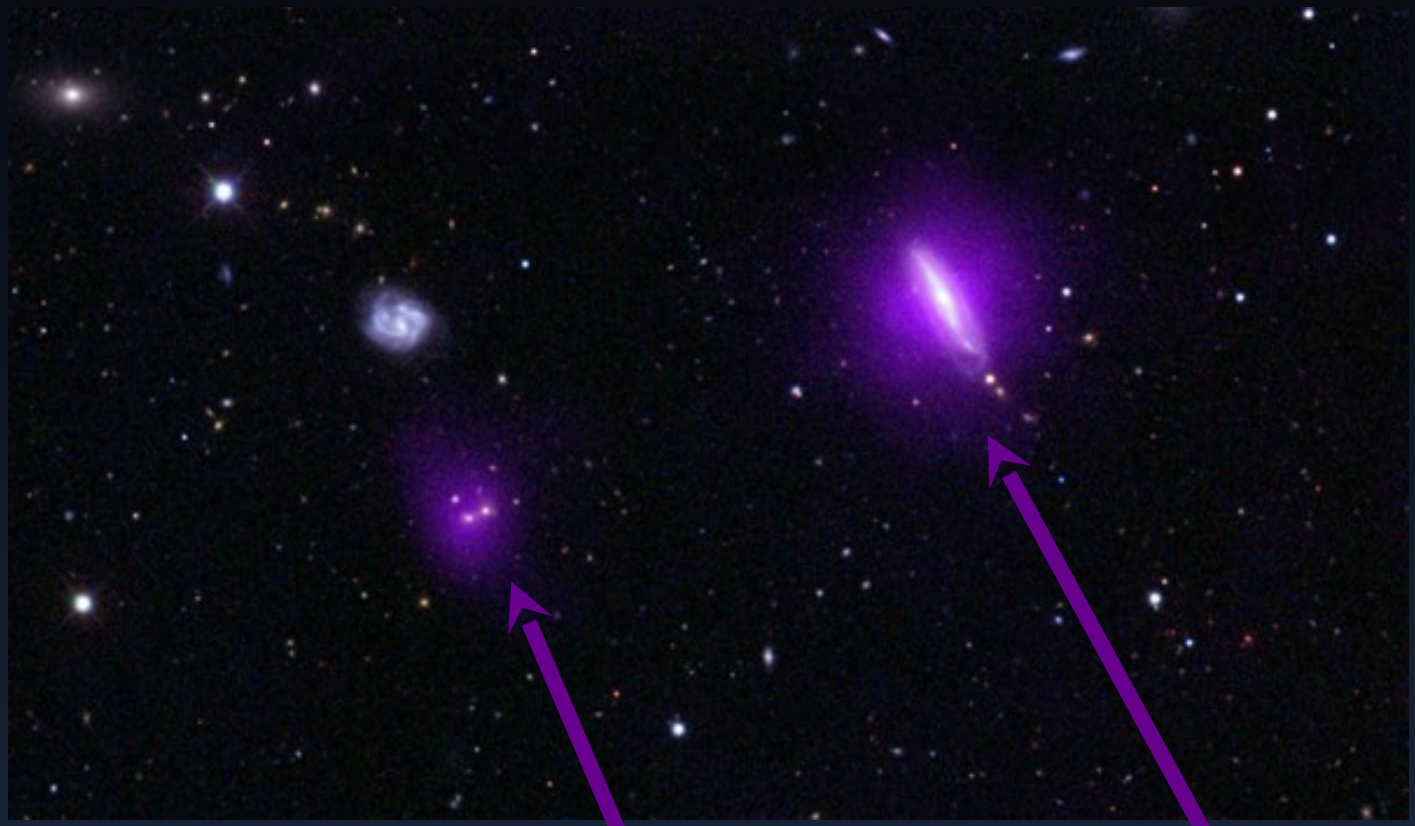
INTEGRAL/Swift

1-2 %

30 keV

Worsley et al. 2005, MNRAS, 357, 1281

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background

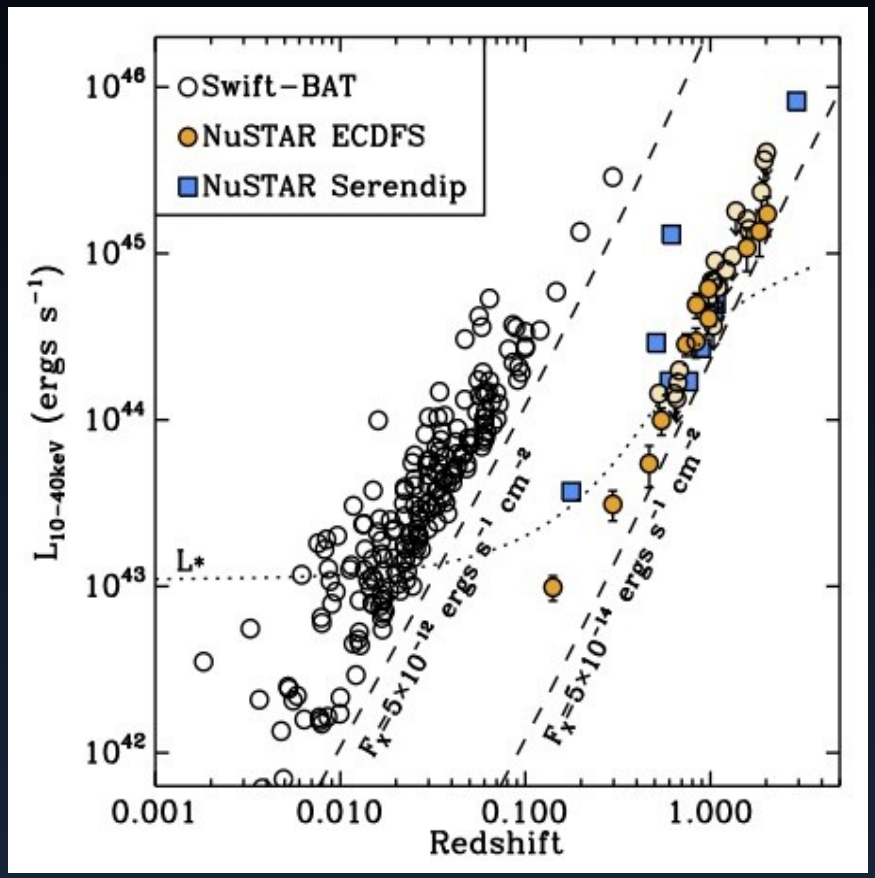


Alexander, Stern et al. 2013 ApJ, 773, 125

NuSTAR's "first born"

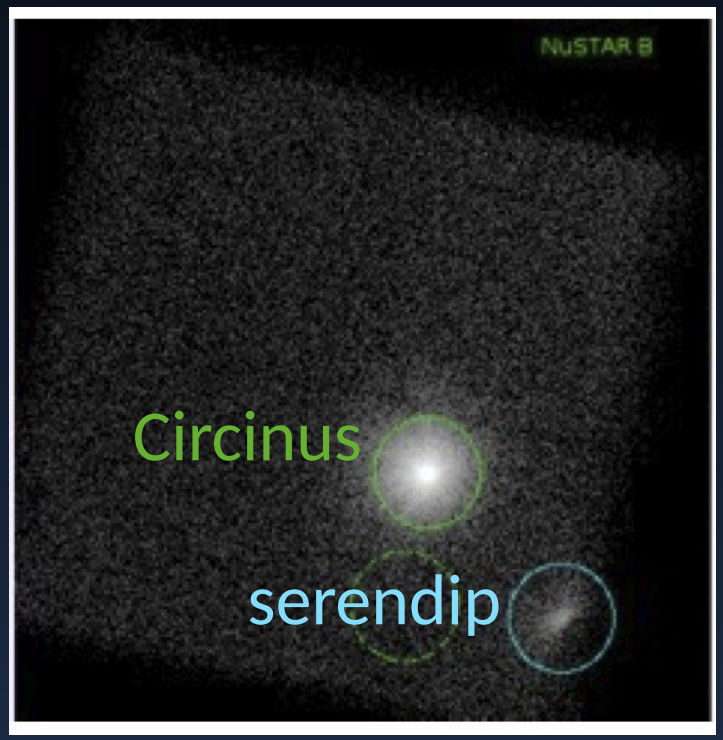
- NuSTAR (in purple) serendipitous source in field of IC751

NuSTAR Extragalactic Surveys: Resolving the Hard X-Ray Background



Alexander et al. 2013, ApJ, 773, 125
Mullaney et al., in prep.

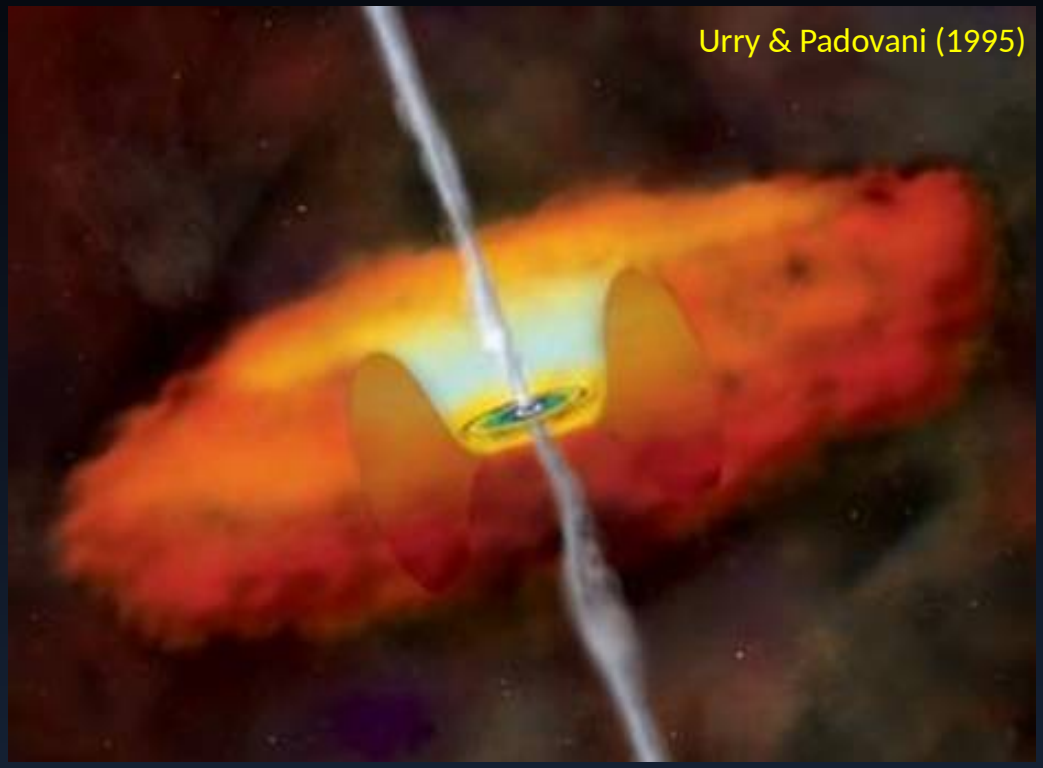
- 3-tiered survey:
- ECDFS - deep
- COSMOS - medium
- Swift/BAT serendipitous survey (+ all NuSTAR fields) - “shallow”

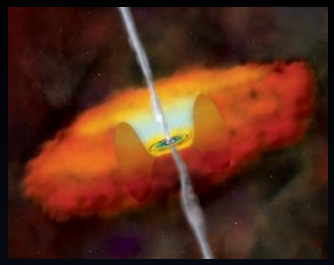


- median redshift for Swift/BAT: z ~ 0.03
- median redshift for NuSTAR: z ~ 0.7

NuSTAR AGN Physics: fundamental questions

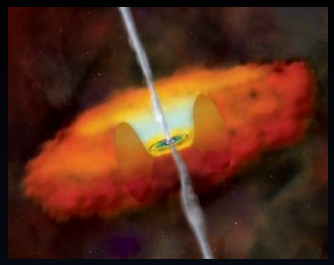
- What are the physical properties of the so-called **corona**?
- What is the distribution of **SMBH spins**?
- What is the nature of the **soft X-ray excess**?
- How are **jets** triggered? What is their role in feedback?
- What physical processes create the **absorbing structures** in AGN?



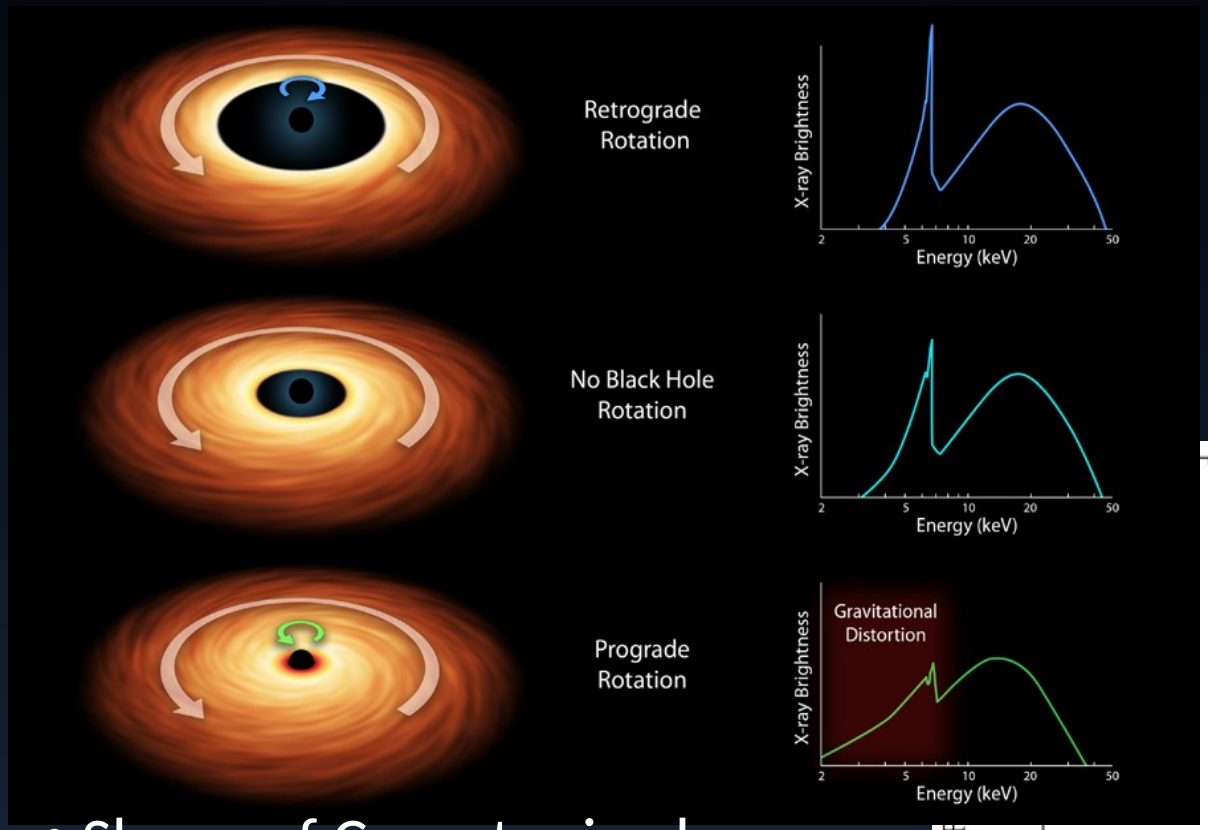


NuSTAR AGN Physics: simultaneous XMM & Suzaku campaigns

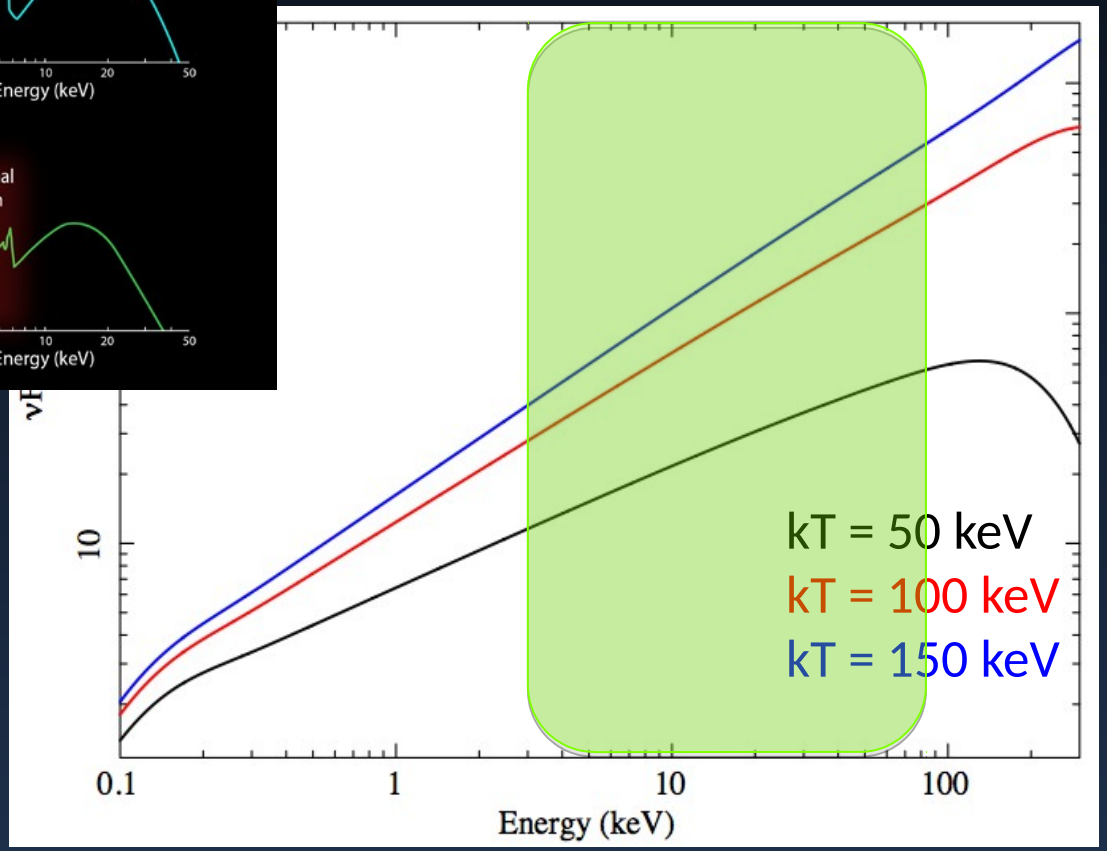
- Science goals: SMBH spin, coronal properties
- ***Suzaku* AO-7: 3 sources, ~310 ks, <u>focus on corona</u>**
  - ✓ 3C 273*
  - ✓ NGC 4151
  - ✓ IC 4329A
- ***XMM* AO-11: 6 sources, ~1.5 Ms, <u>focus on SMBH spin</u>**
  - ✓ 3C 273*
  - ✓ NGC 1365
  - ✓ MCG—6-30-15
  - ✓ Ark 120
  - ✓ 3C 120 (also *Swift* to check for inner disk disruption)
  - ✓ SWIFT J2127.4+5654



NuSTAR AGN Physics: the importance of spectral shape

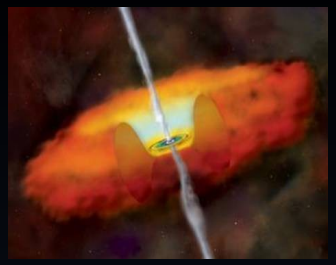


- Spin alters shape of Fe K line and Compton hump in predictable, measurable ways.

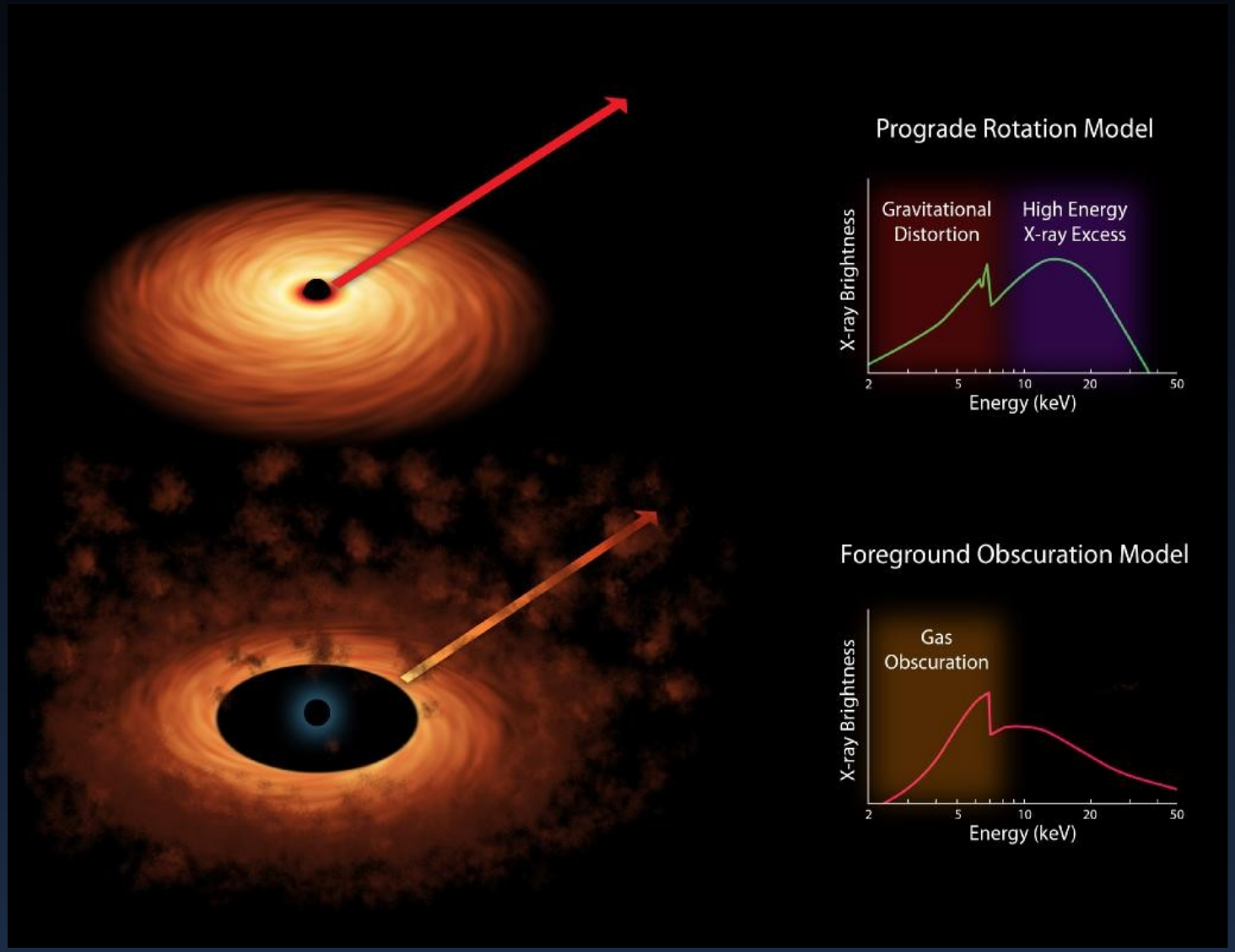


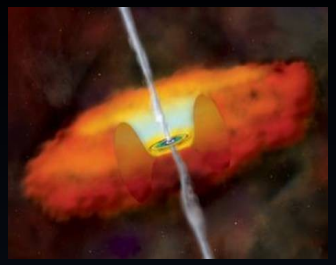
- Shape of Comptonized continuum determined by kT, τ of coronal plasma.

- We know that E_{cut} ~ 3kT, so measuring E_{cut} helps break

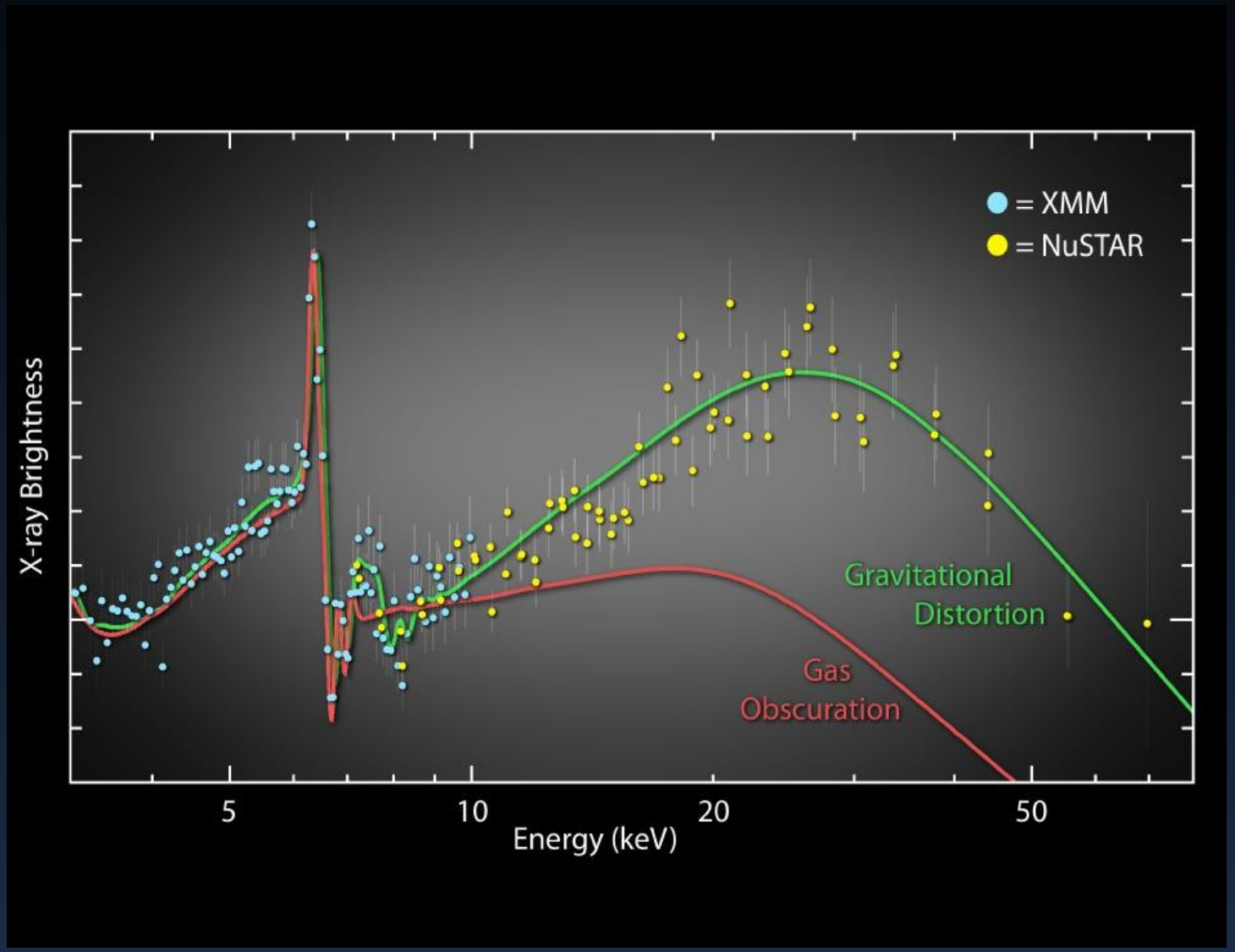


NuSTAR AGN Physics: first result on the BH spin in NGC 1365

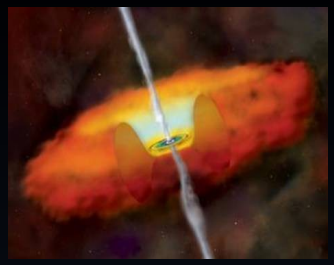




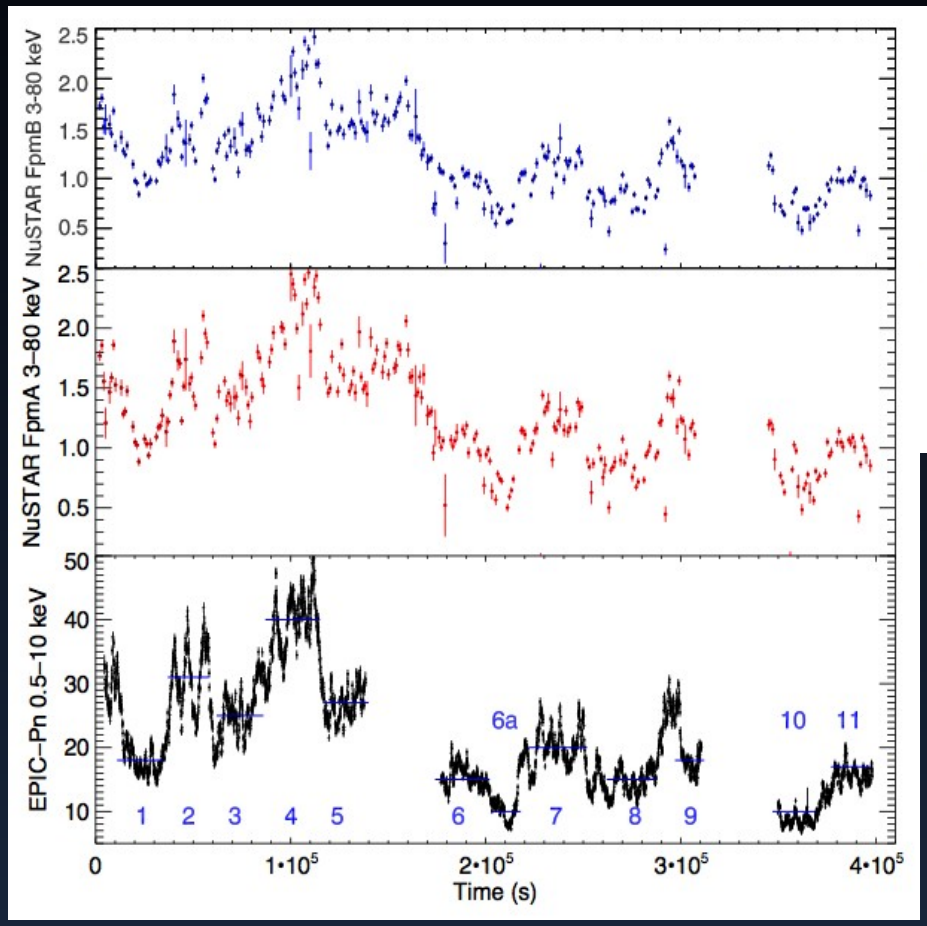
NuSTAR AGN Physics: first result on the BH spin in NGC 1365

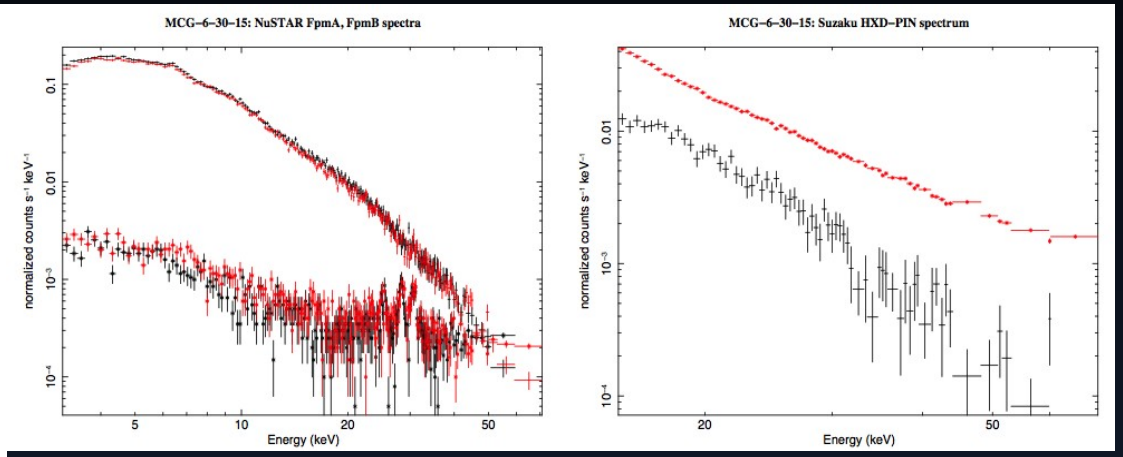


Risaliti et al. 2013, Nature



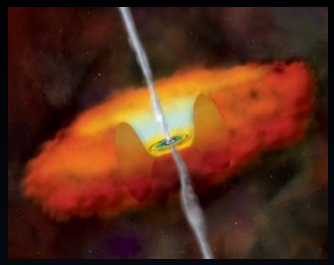
NuSTAR AGN Physics: a long look to MCG-6-30-15



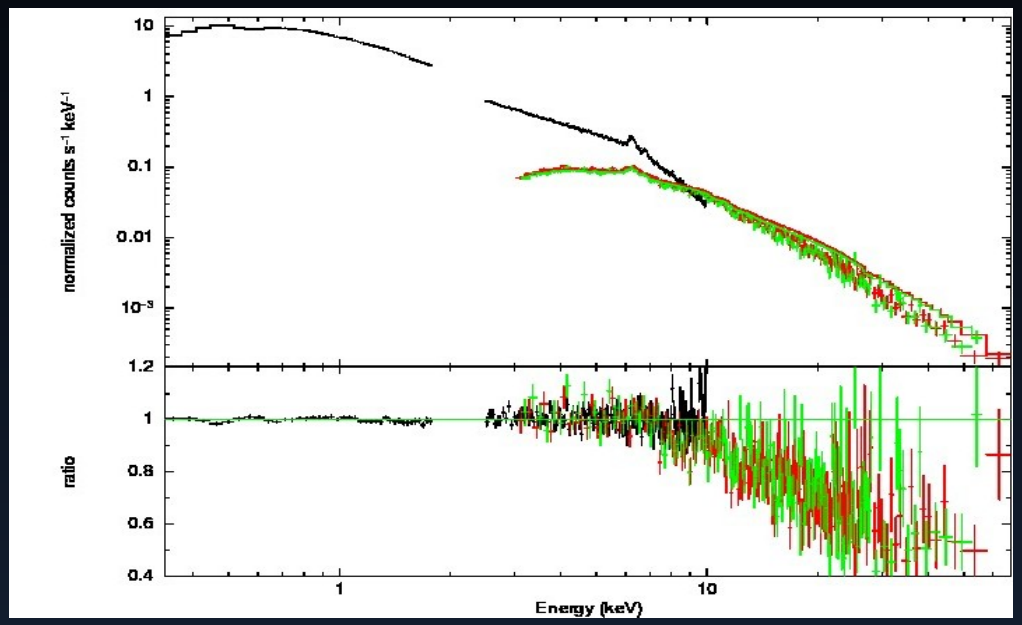


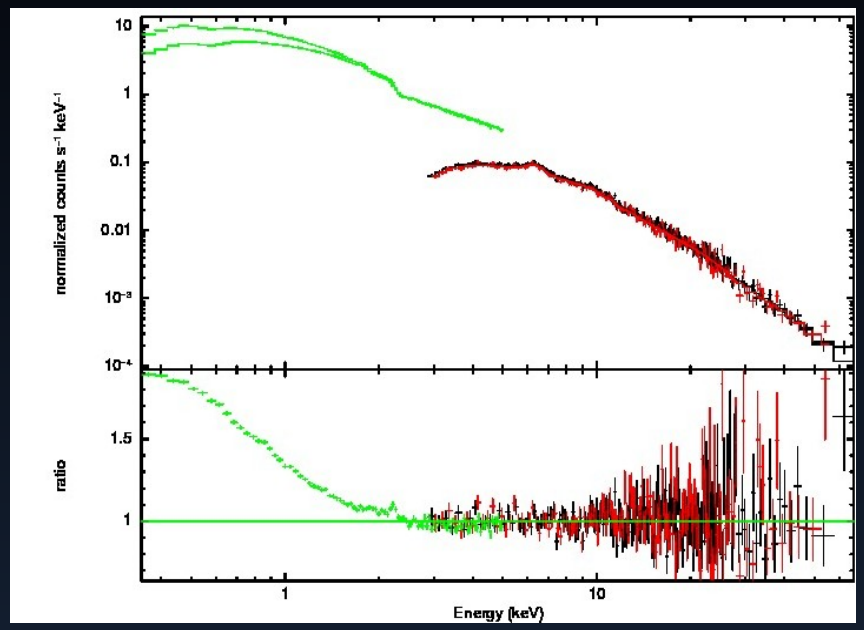
300 ks simultaneous XMM-NuSTAR
Absorption and reflection models tested in a detailed time resolved analysis

Marinucci et al., in preparation
Brenneman et al., in preparation
Kara et al., in preparation



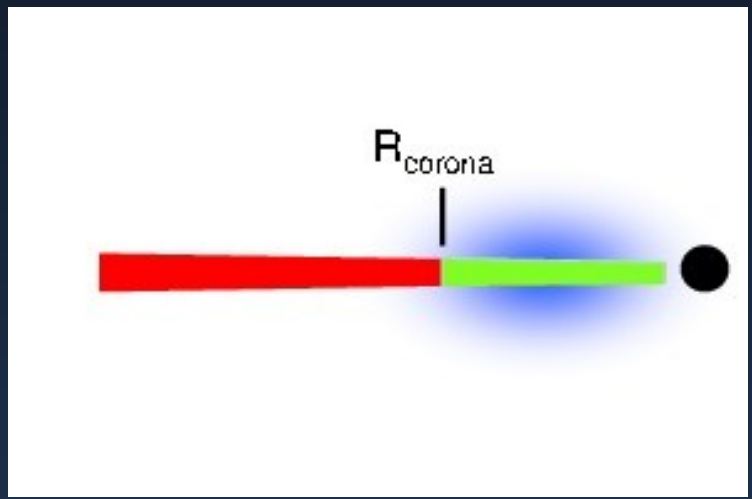
NuSTAR AGN Physics: comptonization effects in Ark 120

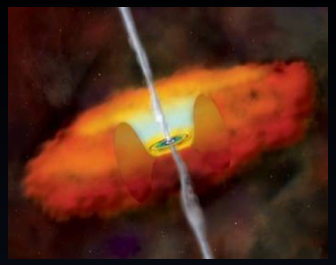




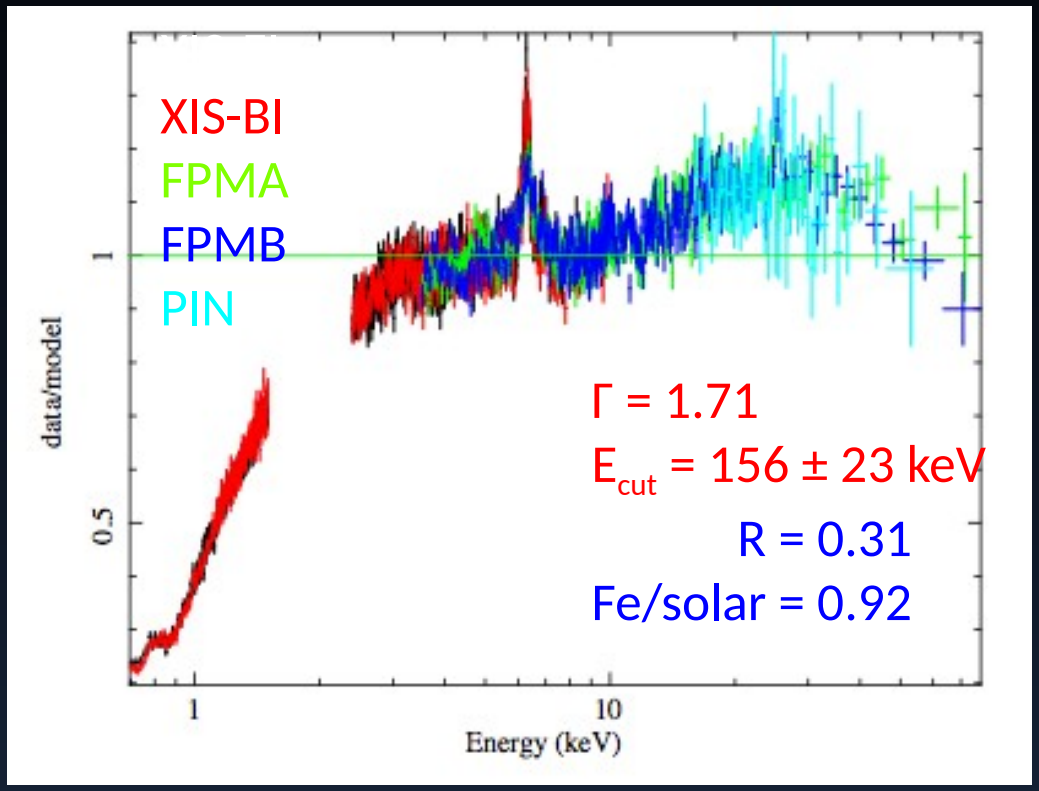
Matt et al., in preparation

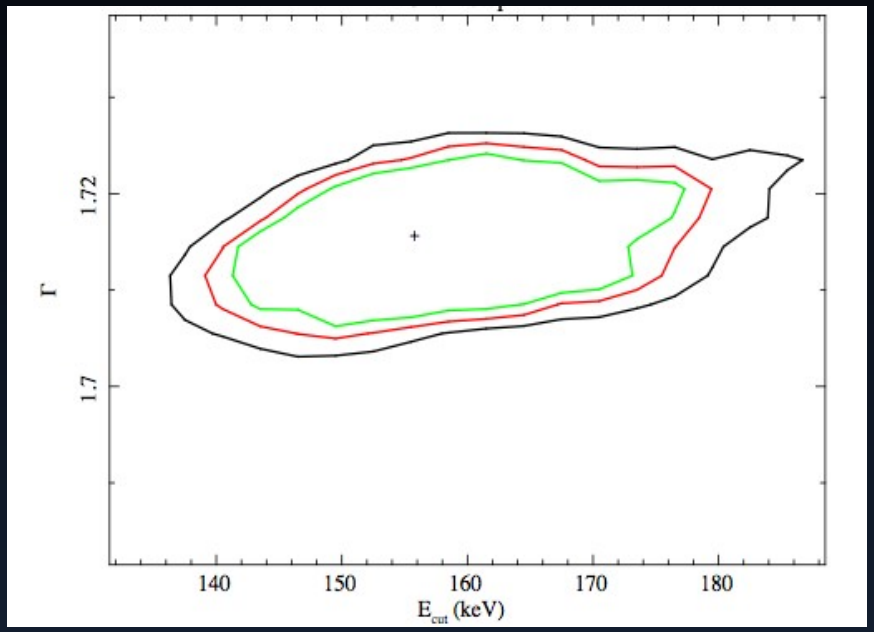
Optxagnf (*Done et al. 2012*) is a disk/corona emission model which assumes a thermal disk emission outside the coronal radius, and soft and hard Comptonization inside.





NuSTAR AGN Physics: coronal properties of IC4329 A

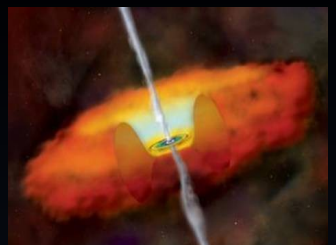




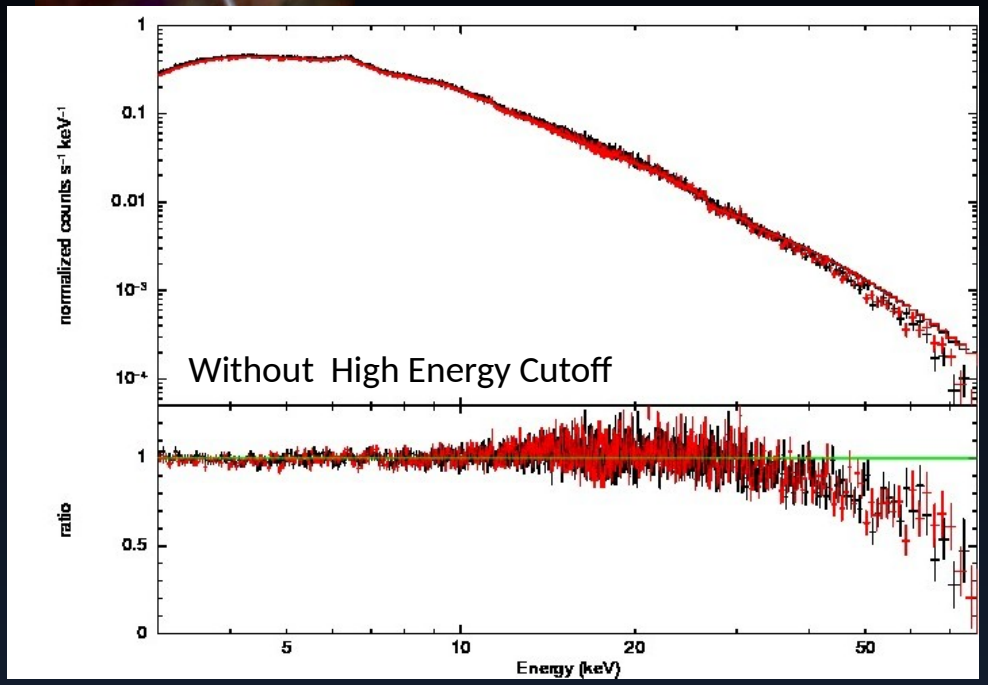
Brenneman et al., in preparation

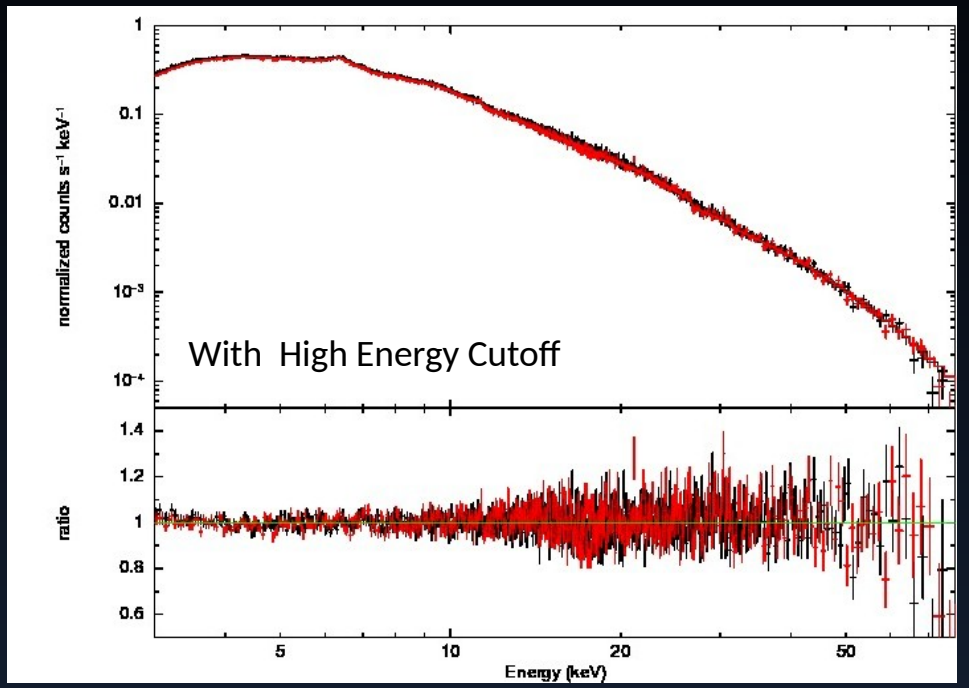
- 150 ks observation in August 2012

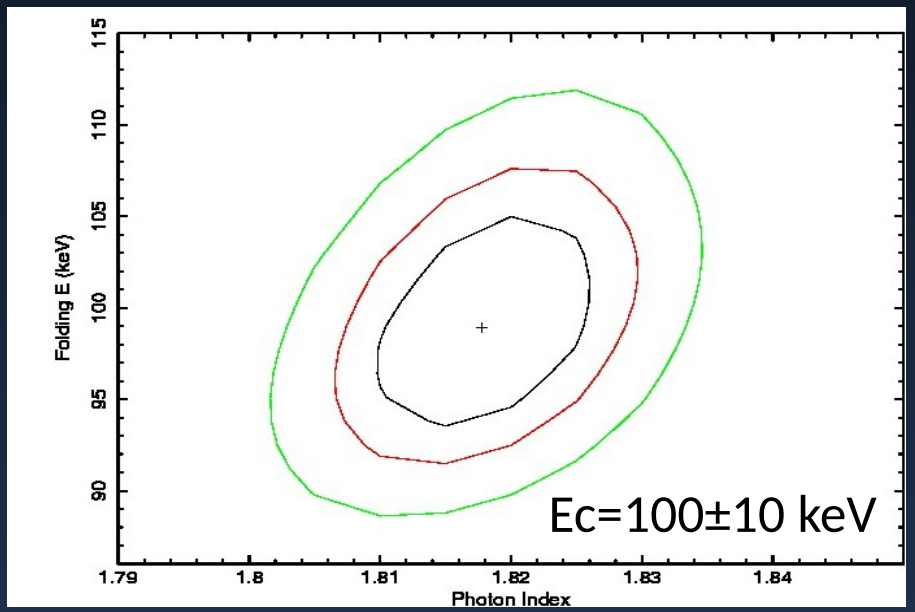
- kT = 40 ± 5 keV
- τ = 1.44 ± 0.03 (slab)
- τ = 3.41 ± 0.10 (sphere)

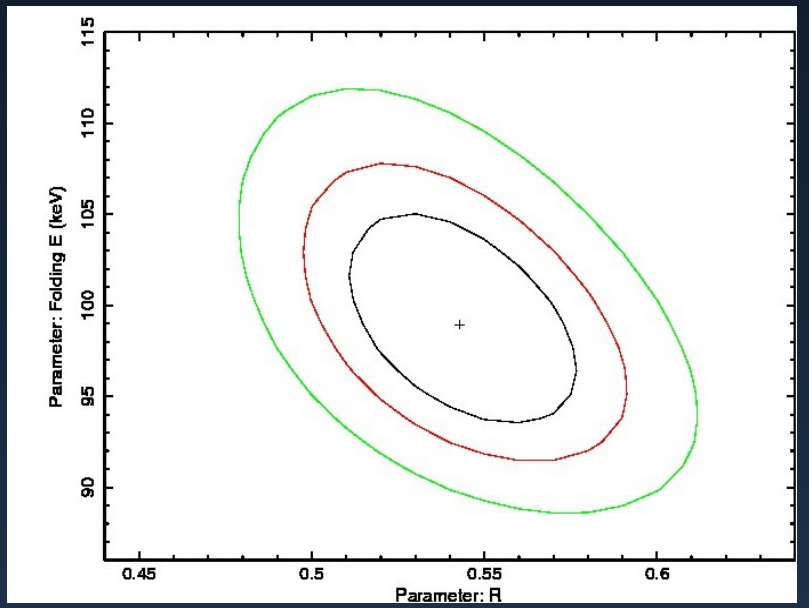


NuSTAR AGN Physics: coronal properties of MCG-5-23-16









Baseline Science Mission

- As typical for an Explorer, all baseline observations led by the science team
- mixture of Level 1 and Priority A targets (with fair amount of margin in reserve)
- After the current initial calibration period is completed, observations will go public through HEASARC two months after a data set is completed (next data release will be Oct. 31st)
- 1.5 Ms of NuSTAR to be made available for coordinated observations with next XMM AO (factor 6 oversubscription)
- A paper a week is being submitted by now, for a complete list of accepted/published paper:

http://www.nustar.caltech.edu/for-astronomers/publications/refereed-papers

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

Baseline Science Mission

Science Group	Working Group Chair
Galactic Surveys, Galactic Center	Chuck Hailey
Supernovae and ToOs	Steve Boggs
Supernova remnants and Pulsar Wind Nebulae	Fiona Harrison
Magnetars and Rotation Powered Pulsars	Vicky Kaspi
Galactic Binaries	John Tomsick
Ultraluminous X-ray Sources	Fiona Harrison
Extragalactic Surveys	Daniel Stern
Blazars and Radio Galaxies	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

http://www.nustar.caltech.edu (look under 'for astronomers')

Thanks!