The future of high energy astrophysics from space

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The landscape

NuSTAR (U.S.A., launched on June 13, 2012)

ASTROSAT (India, 2013)

e-ROSITA (Germany/Russia 2014)

ASTRO-H (Japan/U.S.A. 2014)

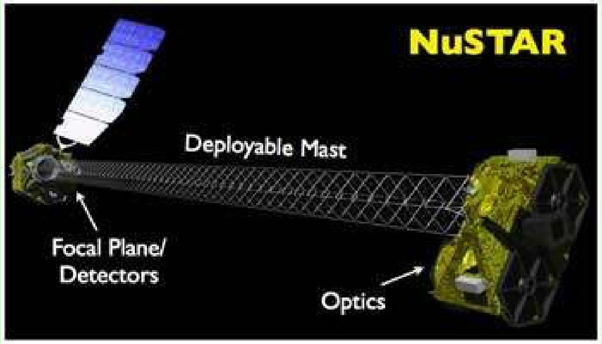
XIPE (ESA, ?, 2017)

LOFT (ESA, ?, 2022)

Large X-ray observatory (formerly XEUS/IXO/ATHENA,
ESA, U.S.A, Japan ???? , >2028)

WFXRT, Pharos, etc.

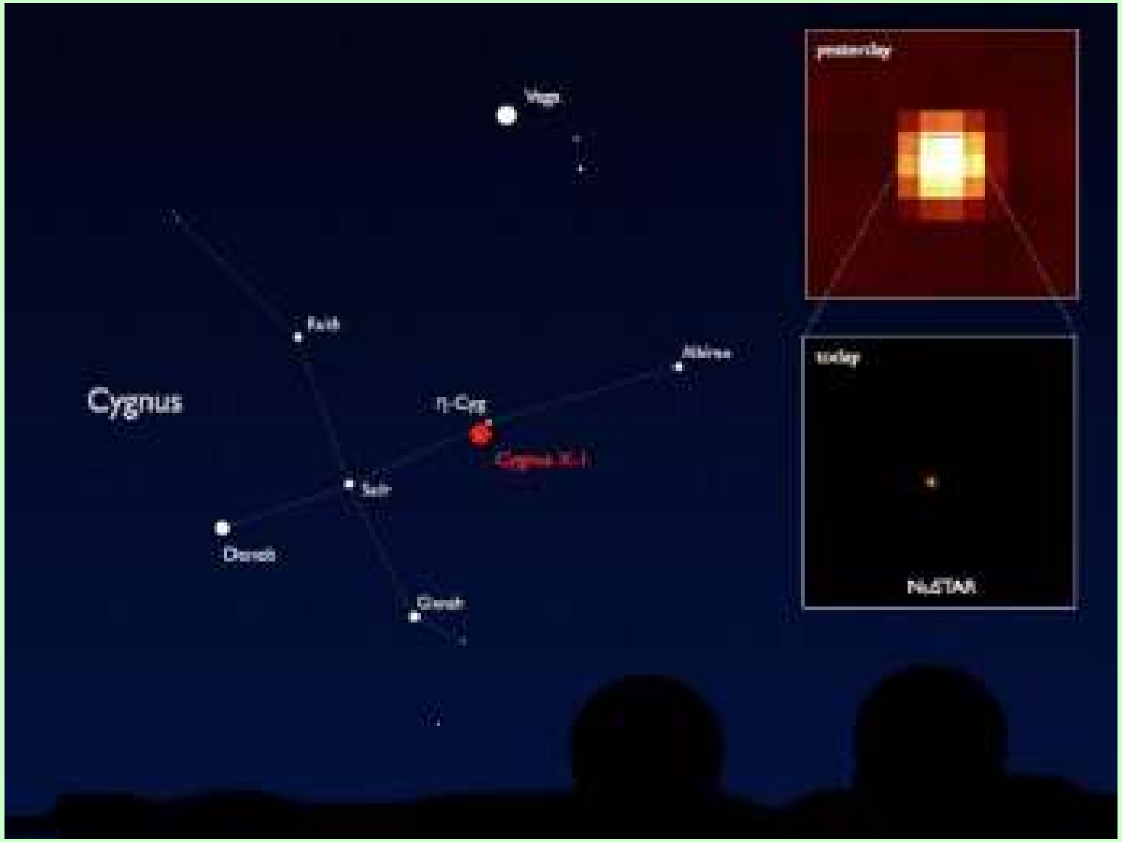
NuSTAR



NuSTAR deploys the first focusing telescopes to image the sky in hard X-rays (6-79 keV), with an improve in sensitivity of 2 orders of magnitude.

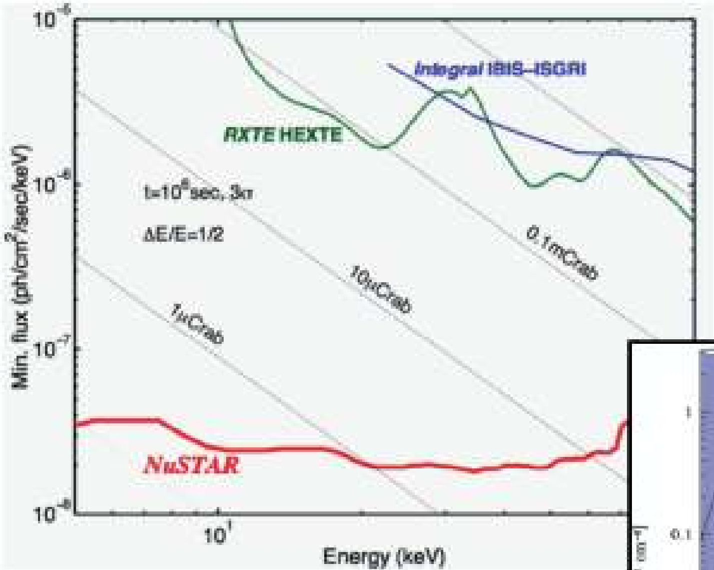
Launched on June 13

First light on June 28

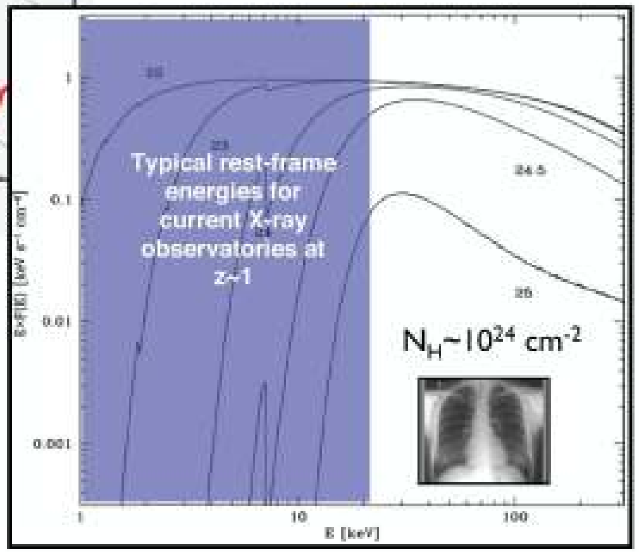


NuSTAR and the CXB

Background: extend >10 keV surveys and complement <10 keV surveys



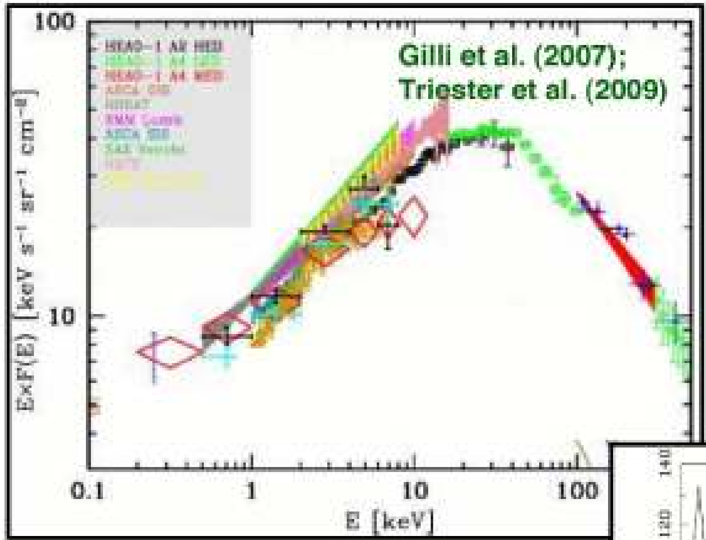
~50-100 times deeper than
current >10 keV surveys



Clean AGN selection function
compared to Chandra/XMM

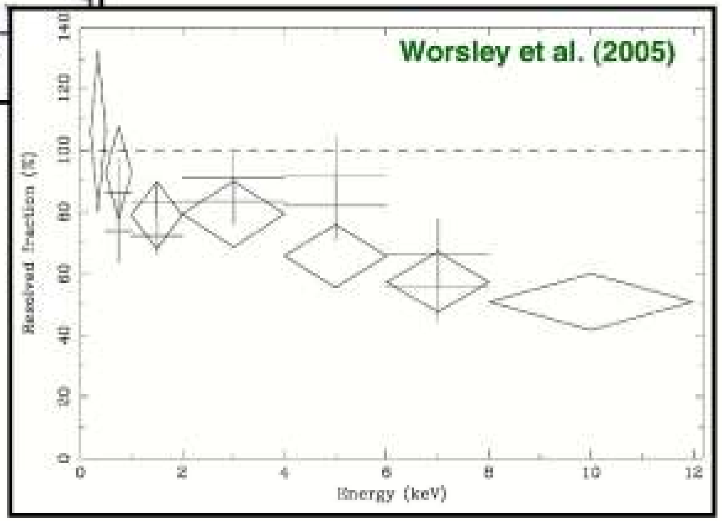
NuSTAR and the CXB

Science: resolving the X-ray background



Current status:

- ~100% directly resolved at <6 keV and >50% at 6-10 keV by Chandra & XMM
- But only ~1-2% directly resolved at 30 keV peak by Swift-BAT/INTEGRAL etc

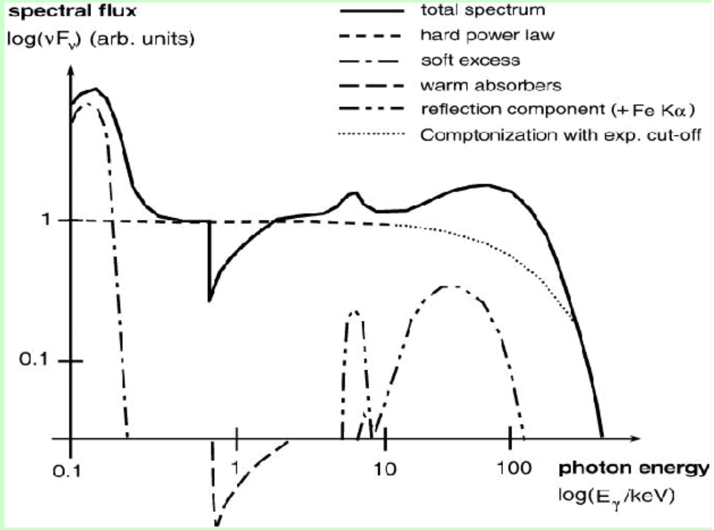


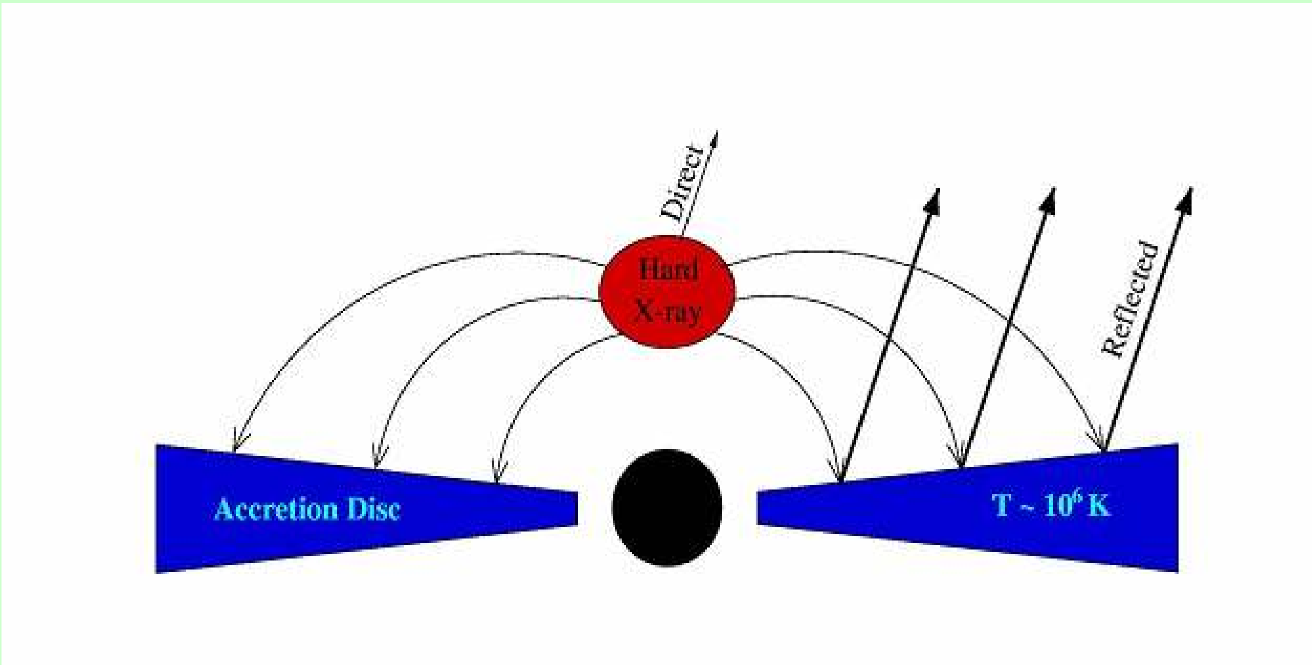
Two approaches:

- Direct NuSTAR-detected sources: expect to resolve ~30-50% of XRB
- Stacking NuSTAR data of Chandra+XMM+infrared sources: first measurement of total resolved XRB

The innermost regions of Radio-quiet AGN

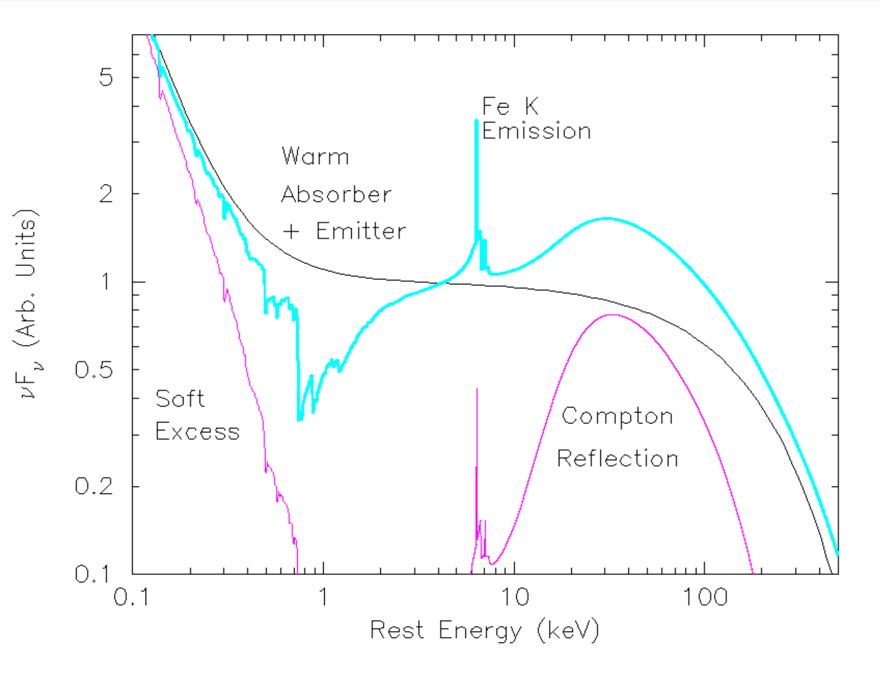
i. The primary X-ray emission
ii. The spin of the black hole

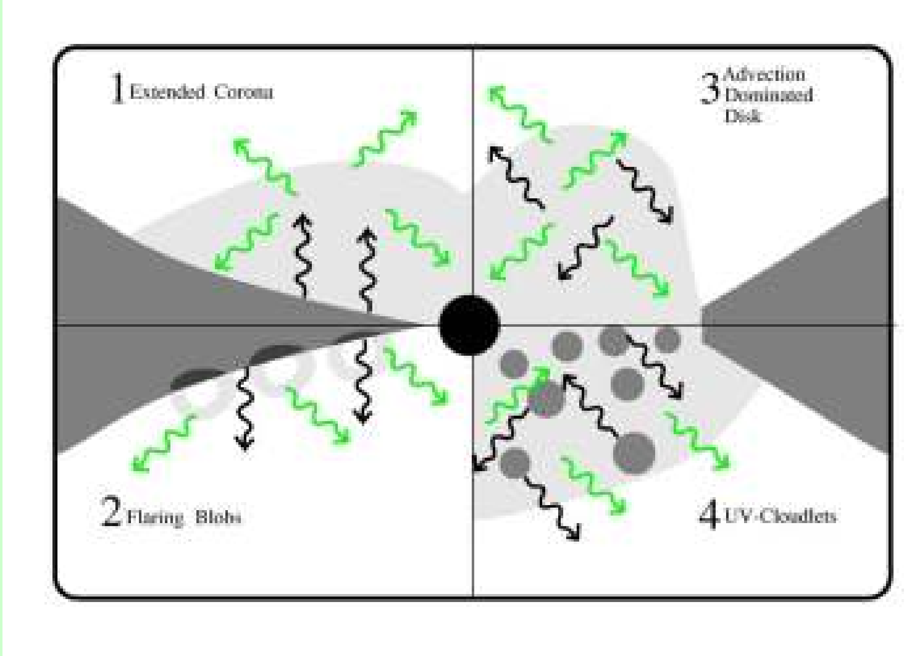




Corona Temperature and τ

Corona properties are largely unknown. Only phenomenological parameters have been measured so far



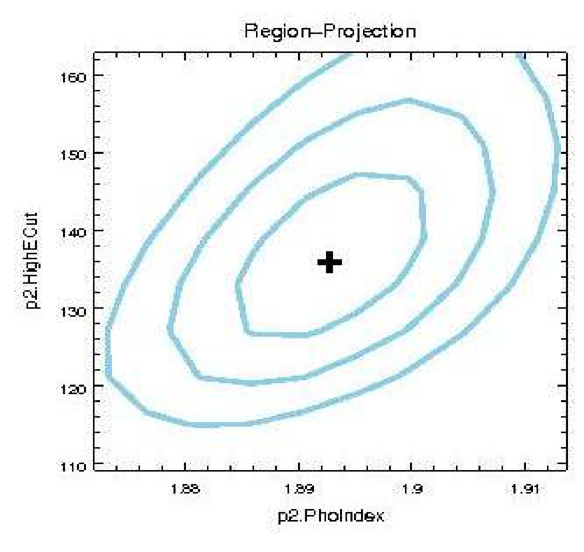


Haardt 1997

Compton Reflection further complicates the measurement

Corona Temperature and τ

NuSTAR will measure cut-off energies with much better precision (ΔE/E < 10-20% for the brightest Seyferts, if E_c < 200 keV).



MCG-5-23-16

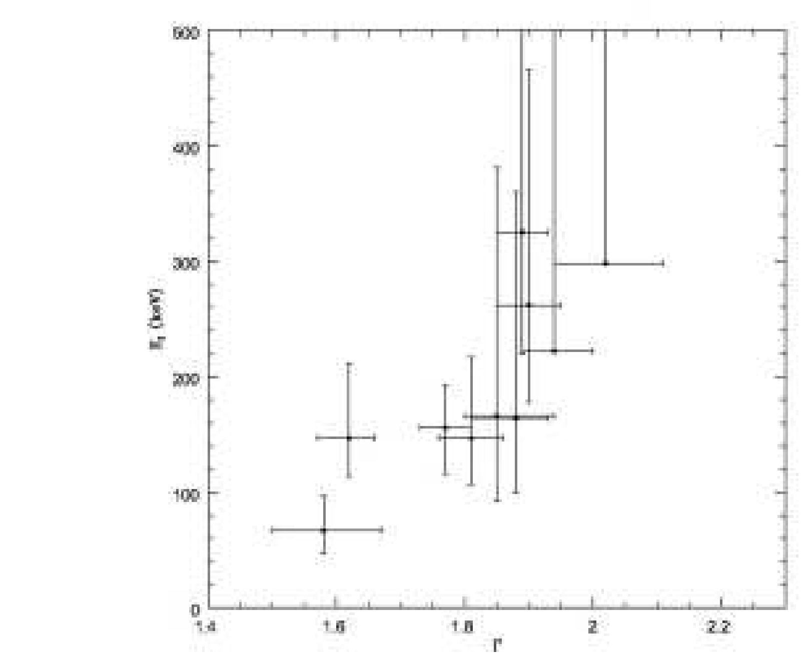


Fig. 4. The cut-off energy E_f plotted versus Γ.

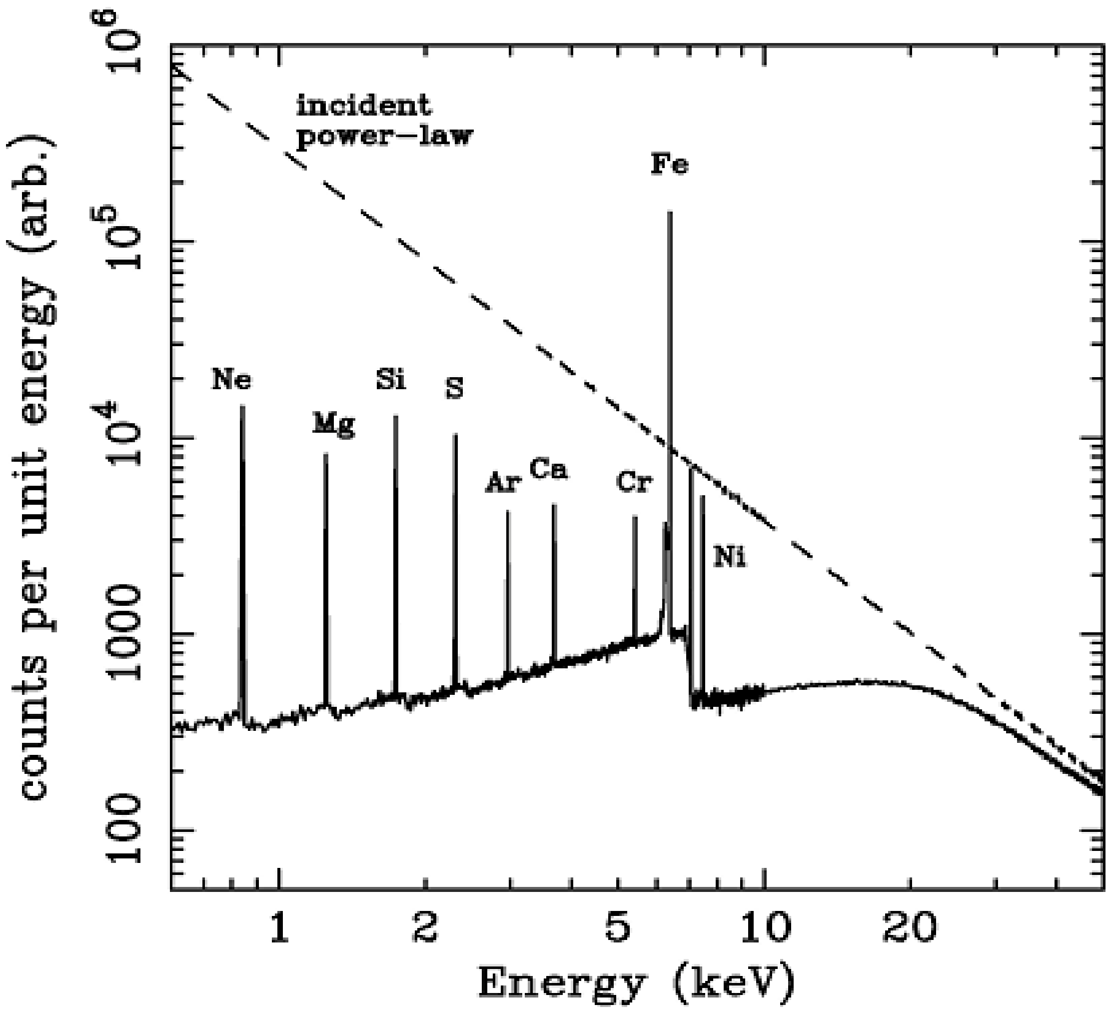
BeppoSAX *(Perola et al. 2002)*

T and τ will be measured separately

(simultaneous soft X-ray measurements will certainly help)

X-ray reprocessing

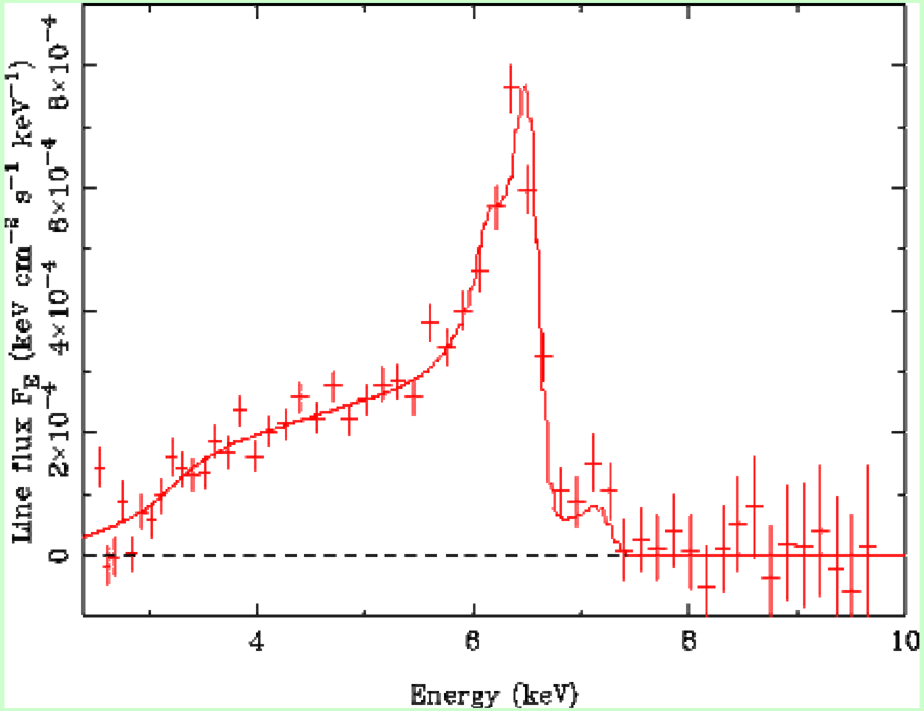
X-ray illumination of cold matter produces the so-called 'Compton reflection' continuum plus several fluorescent lines, Fe Kα being by far the most prominent (e.g. Matt et al. 1991, George & Fabian 1991)



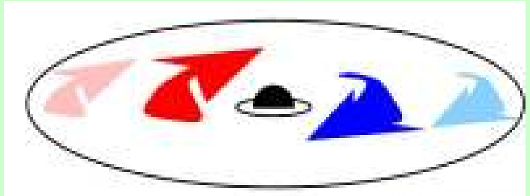
(Reynolds et al. 1995)

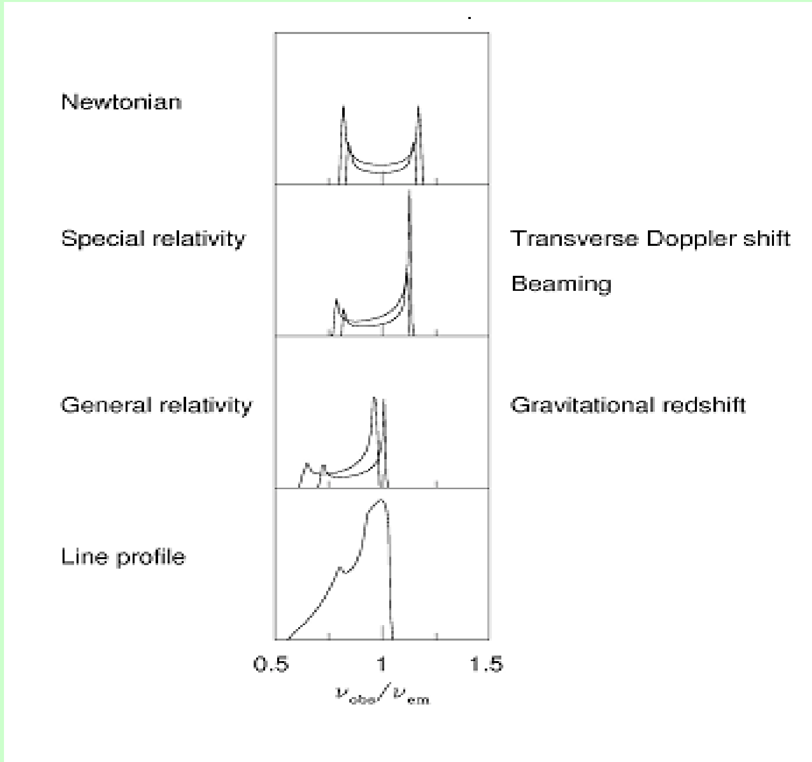
Relativistic lines

Broad 'relativistic' lines are observed in several AGN



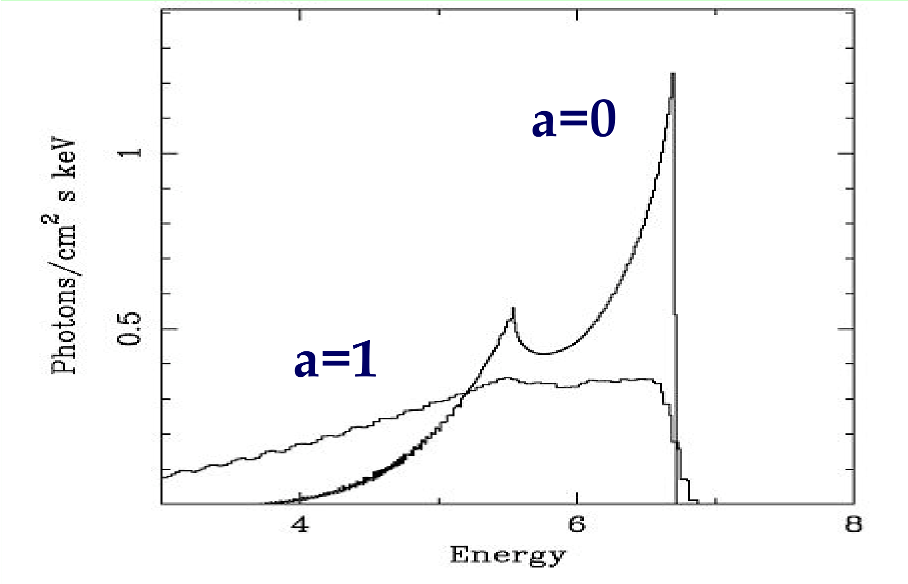
MCG-6-30-15
(Fabian et al. 2002)



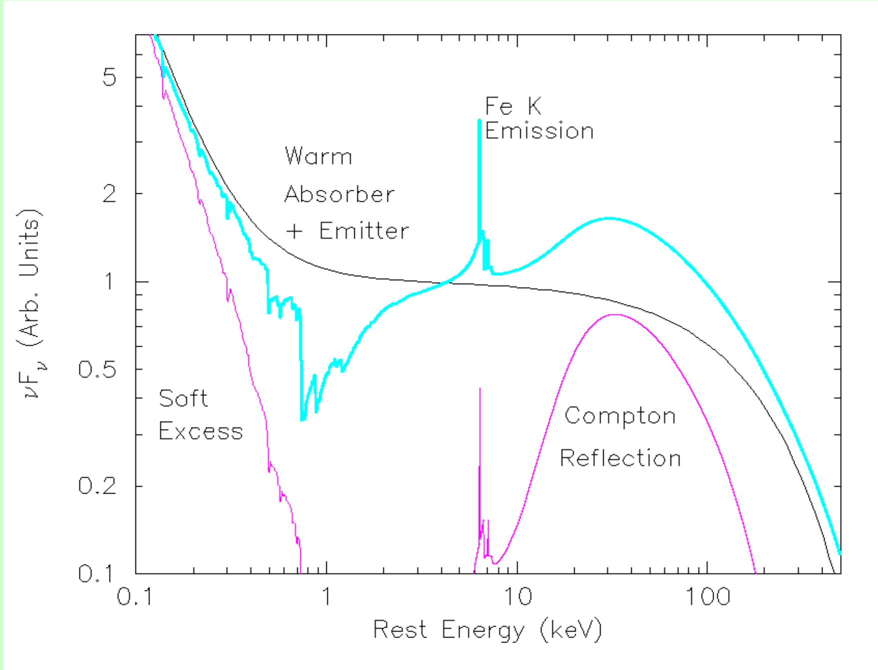


Fabian et al. 2000

Black hole spin measurement



The line profile depends on the black hole spin (in particular on the red tail)

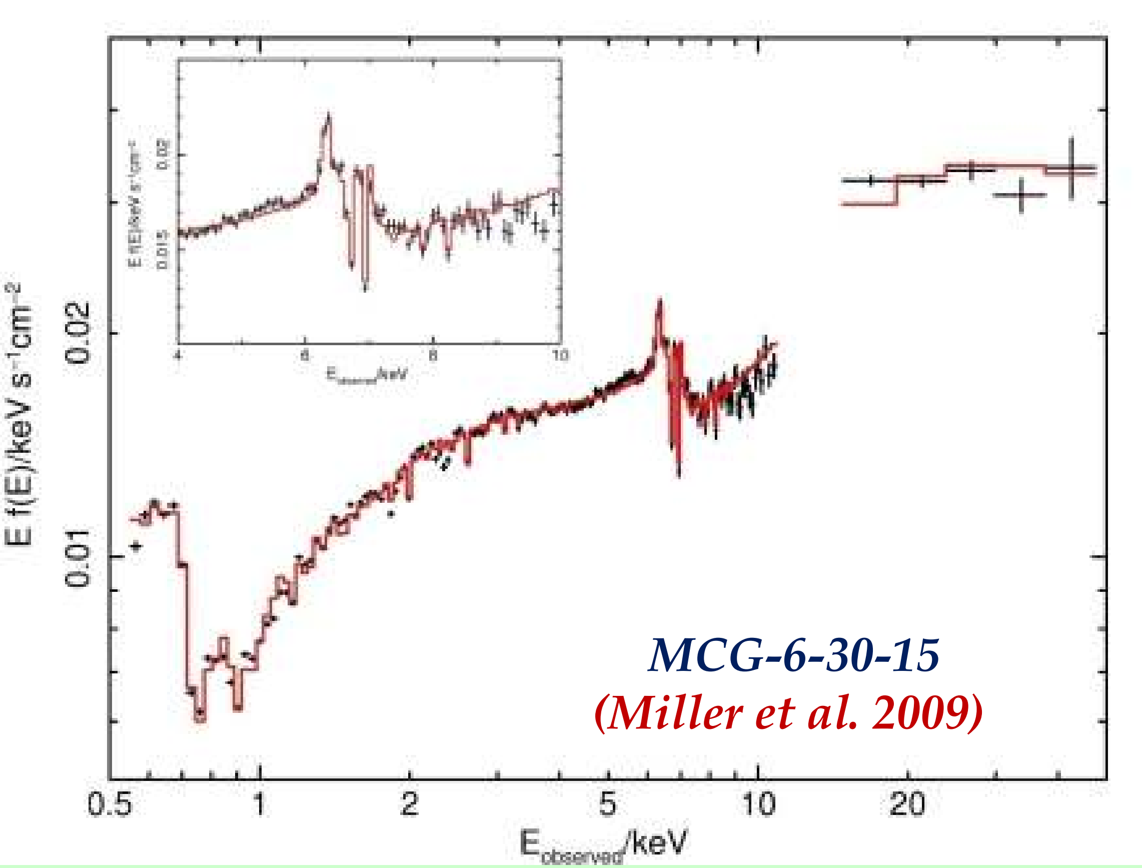


The statistical precision is already (with XMM and Suzaku) very good - a few percent in the best cases. The real uncertainties are systematic!
A good measurement of the continuum is crucial.

→ Broad band measurements !!
XMM-NuSTAR simultaneous observations (XMM Large Program)

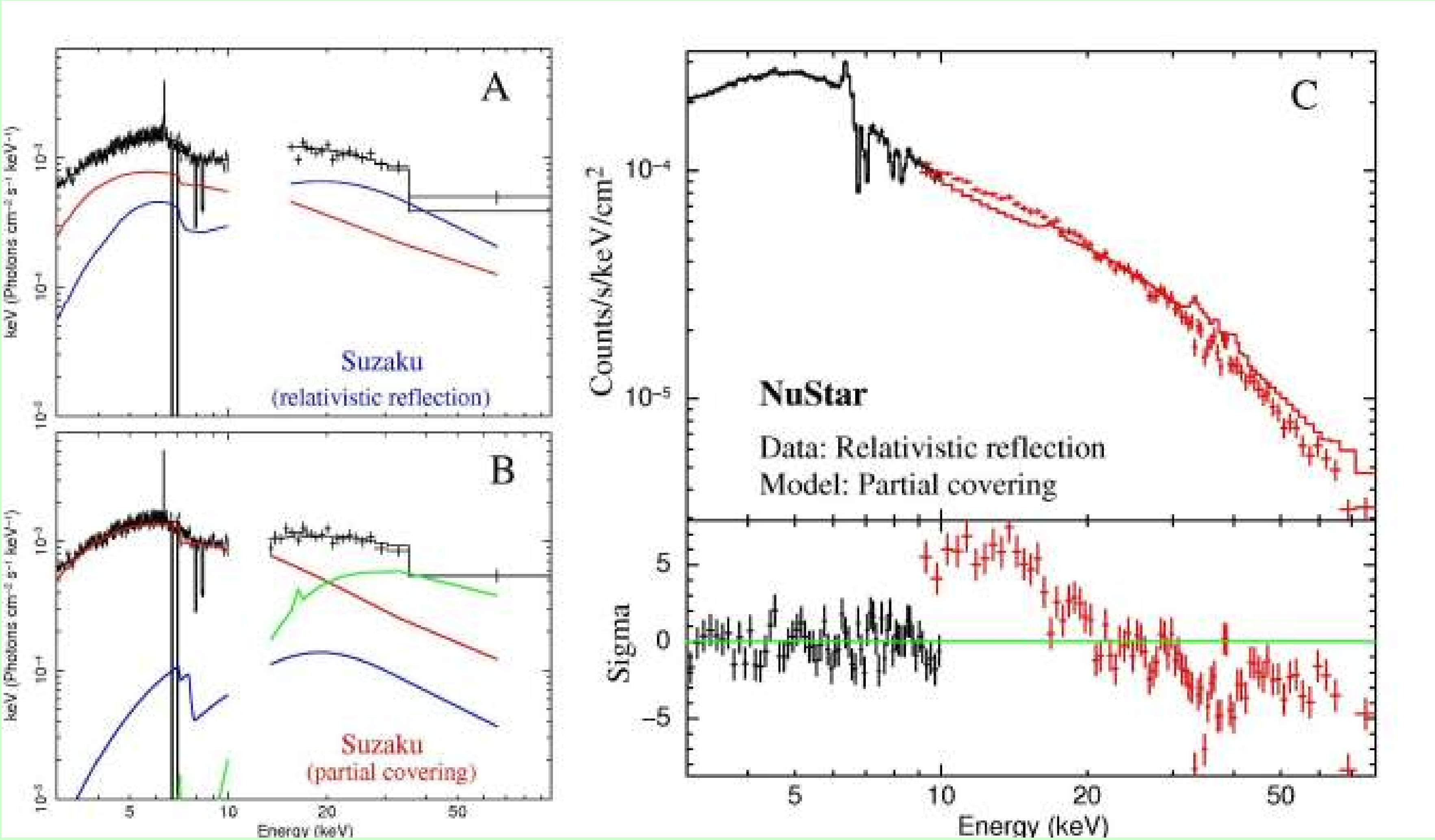
Is relativistic reflection the right model ?

Caveat: the broad feature - usually interpreted as a relativistic iron line - can be fitted equally well with a sufficient number of partial, ionized absorbers (Turner & Miller 2009).



NuSTAR
will solve the issue !!!

Is relativistic reflection the right model ?

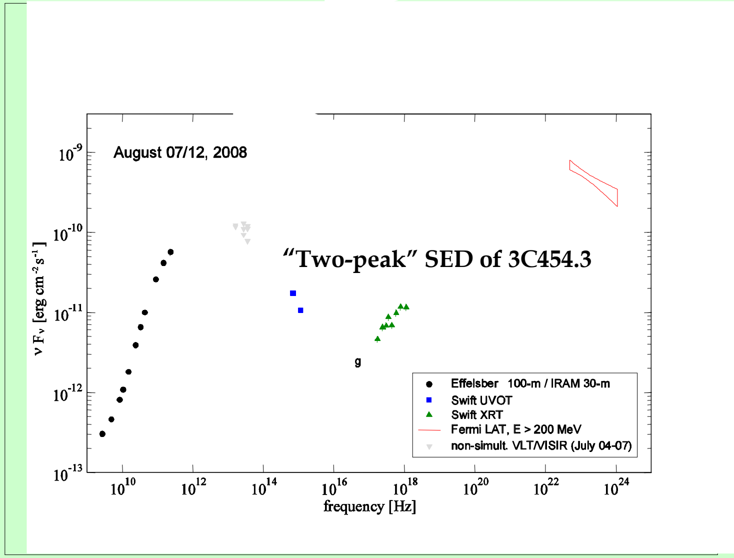


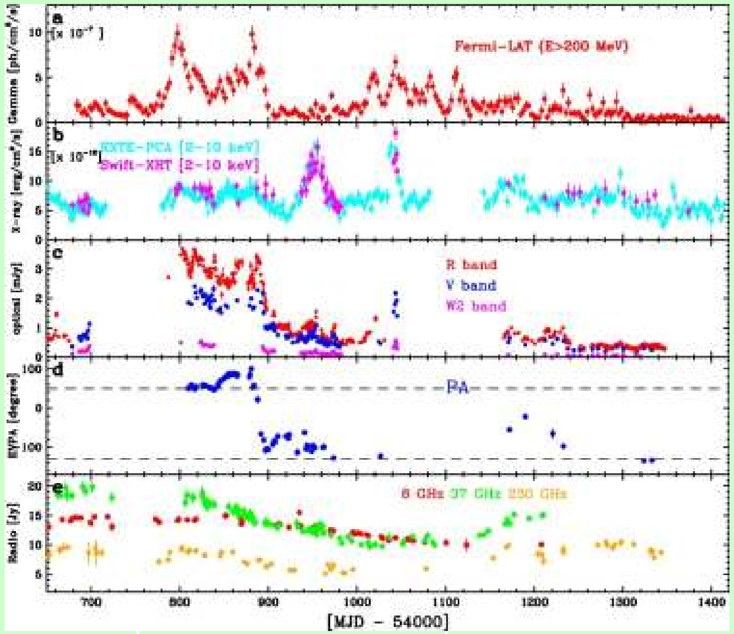
NGC 1365 *(Courtesy of G. Risaliti)*

Blazars

Multifrequency (radio to γ-rays) monitoring campaigns.

→ Structure of the jet, emission mechanisms (IC peak)





Multi-band time series for blazar 3C279

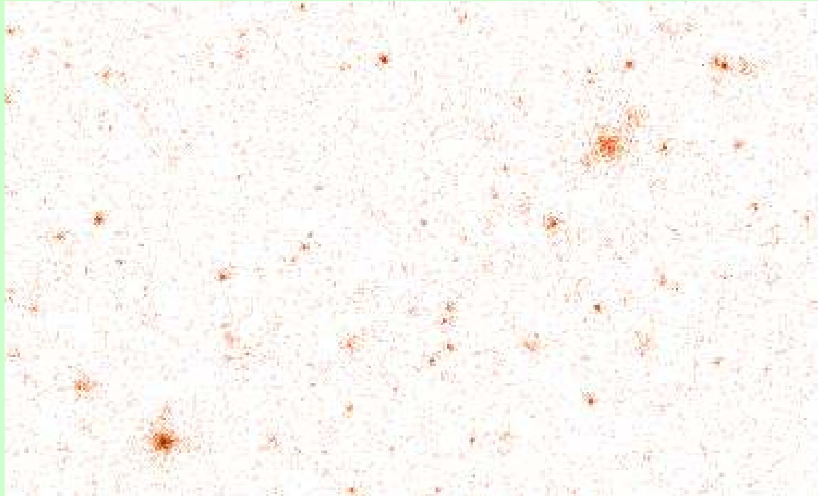
ASTROSAT

ASTROSAT will carry five astronomy payloads for simultaneous multi-band observations:

- **Twin 40-cm Ultraviolet Imaging Telescopes (UVIT) covering Far-UV to optical bands**
- **Three units of Large Area Xenon Proportional Counters (LAXPC) covering medium energy X-rays from 3 to 80 keV with an effective area of 6000 sq.cm. at 10 keV**
- **A Soft X-ray Telescope (SXT) with conical foil mirrors and X-ray CCD detector, covering the energy range 0.3-8 keV. The effective area will be about 200 sq.cm. at 1 keV**
- **A Cadmium-Zinc-Telluride coded-mask imager (CZTI), covering hard X-rays from 10 to 150 keV, with about 10 deg field of view and 1000 sq.cm. effective area**
- **A Scanning Sky Monitor (SSM) consisting of three one-dimensional position-sensitive proportional counters with coded masks. The assembly will be placed on a rotating platform to scan the available sky once every six hours in order to locate transient X-ray sources.**

eROSITA

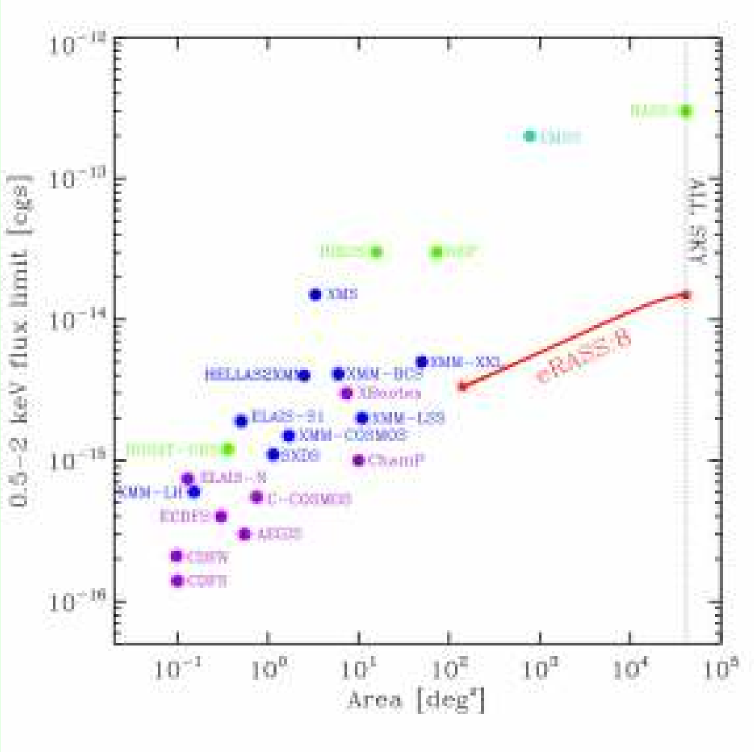
Seven identical Wolter-1 mirror modules, with CCD detectors. 0.5-10 keV energy range. Angular resolution of 15″ on-axis, up to 30″. F.o.v. 1 deg. in diameter. Eff. Area 1500 cm^2@1 kev



3 ks pointing

Complemented by ART-XC, coded masked telescopes with angular resolution of about 1′, f.o.v. of 30′, 6-30 keV energy range.

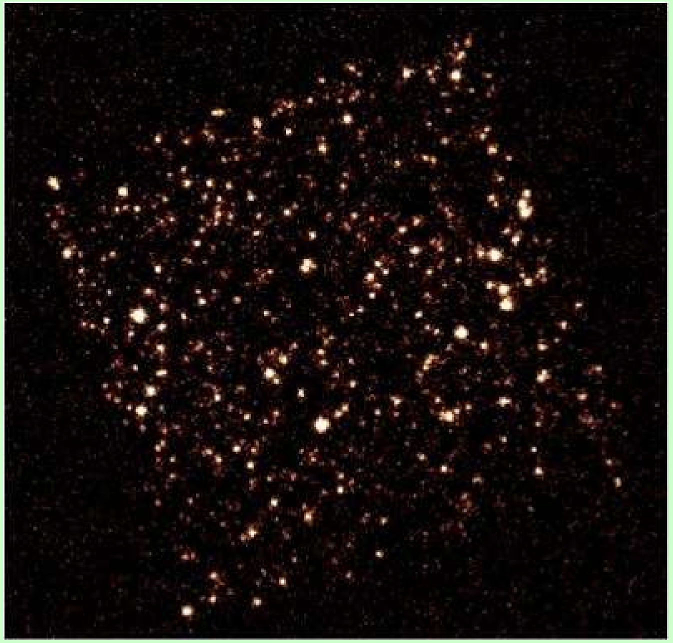
eROSITA



All Sky Survey (2-3 ks per field)
Deep surveys (200 deg^2, 20-30 ks)

Main goal: Large scale structure and dark energy with clusters of galaxies

COSMOS field



Expected # of AGN (0.5-2 keV)	1.76×10^6 (ASS)	60000 (DS)
Expected # of AGN (2-10 keV)	130000 (ASS)	15000 (DS)

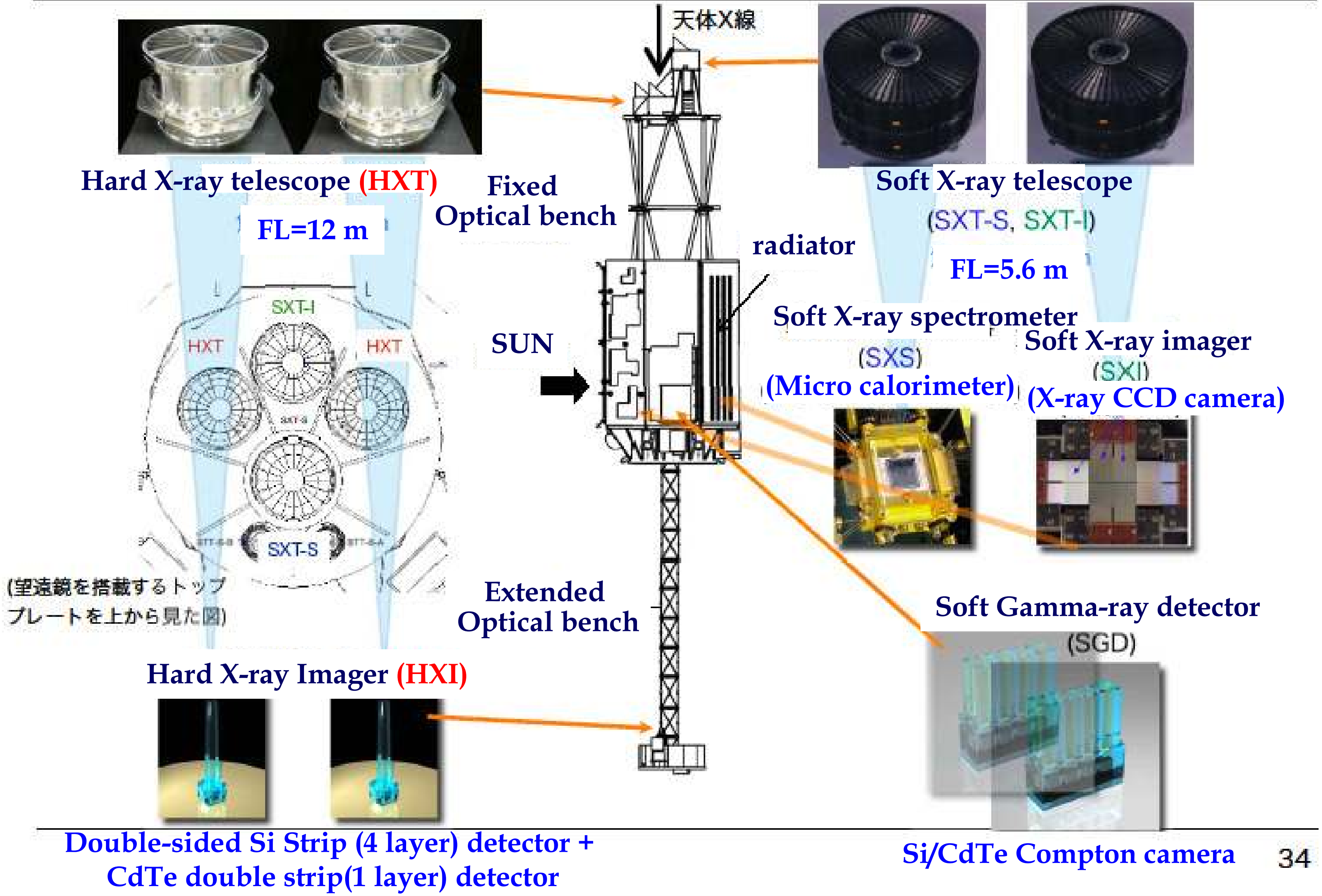
ASTRO-H

Third Japanese mission with Microcalorimeter - first two failed, but the microcalorimeter was tested successfully in Suzaku. Energy resolution of about 5 eV. It will revoluzionize the iron line studies.

Many instruments and telescopes, covering overall the 0.3-600 keV band.

Similarly to ASCA and Suzaku, a fraction of observing time will be available to ESA member states via GO program.

ASTRO-H instruments



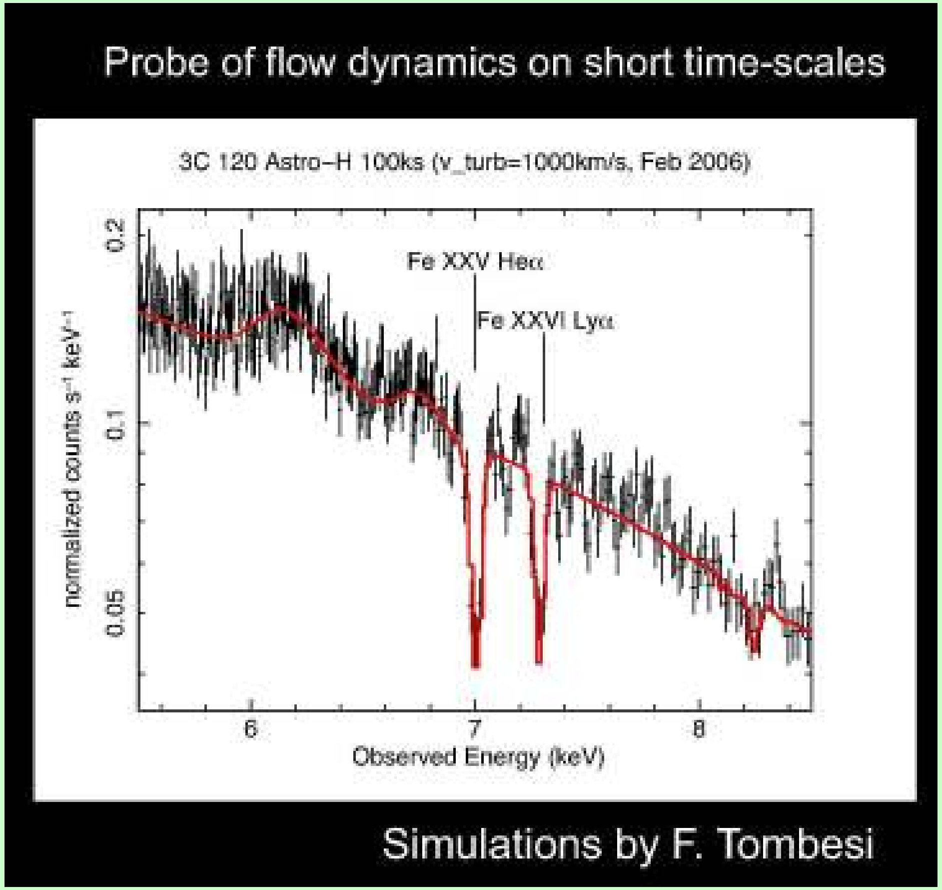
Astro-H will cover the bandpass between 0.3 keV to 600 keV.

ASTRO-H - AGN Science

Excise any narrow iron line component from broad lines

Resolve the narrow iron lines (BLR, Torus)

Physics and kinematics of highly ionized outflows (UFOs)

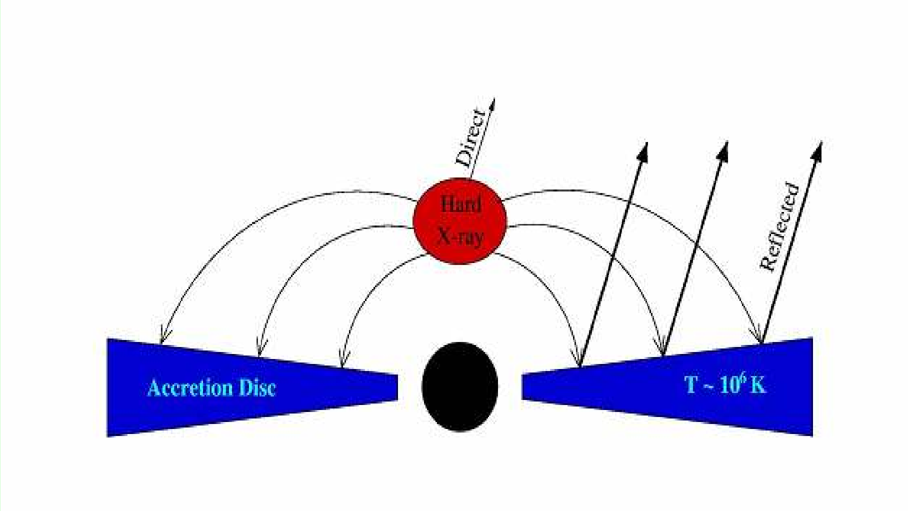


XIPE and AGN

- **Probe <u>strong gravity effects</u>**
- **Determine the geometry of the <u>emitting corona</u>**
- **Probe the geometry of the <u>torus</u>**
- **Understand the nature of seed photons for the IC peak in <u>Blazars</u>**
- **Disclose the past activity of the <u>Black Hole in the Galaxy</u>**

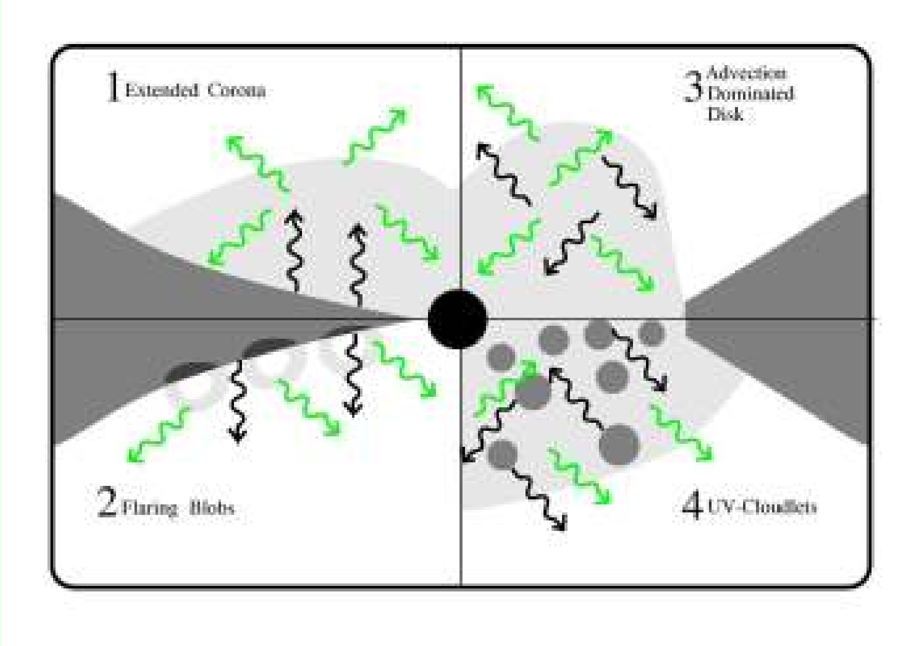
Primary emission from the hot corona

The geometry of the hot corona is unknown. Emission is expected to be polarized <u>if the corona OR the radiation field are not spherical</u>



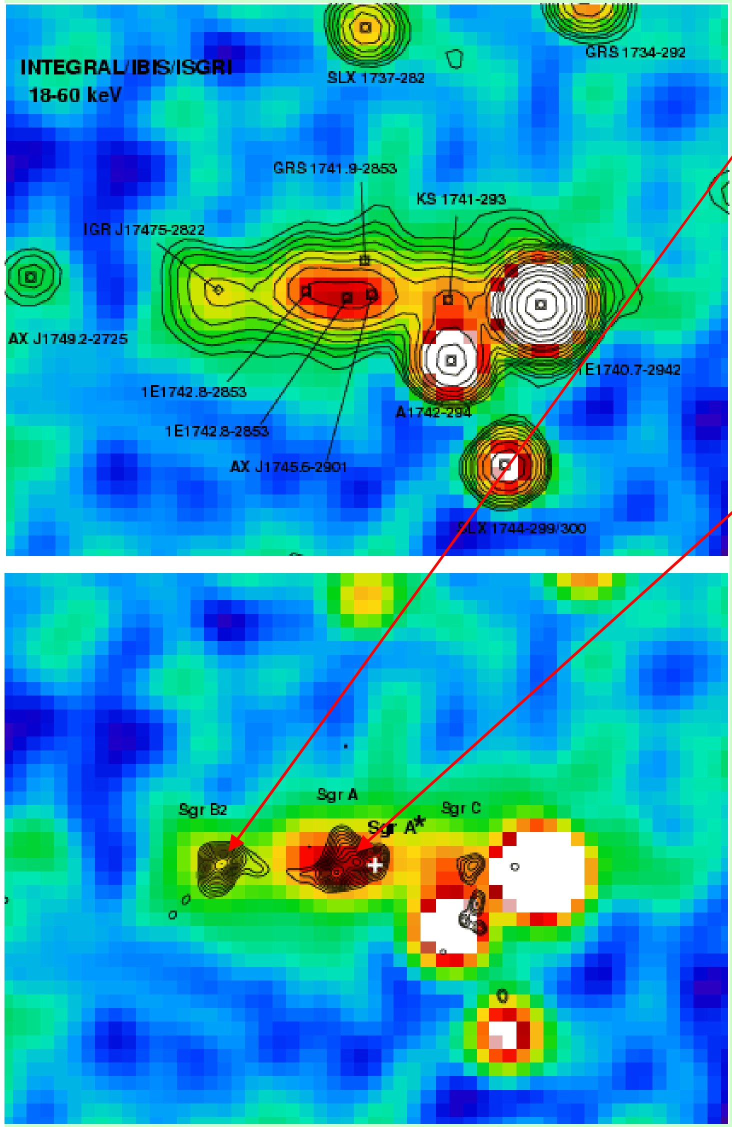
Polarimetry will help understanding the geometry of the emitting region

<u>NB: in ADAF models, no significant polarization is expected (LLAGN should be unpolarized)</u>



Haardt (1997)

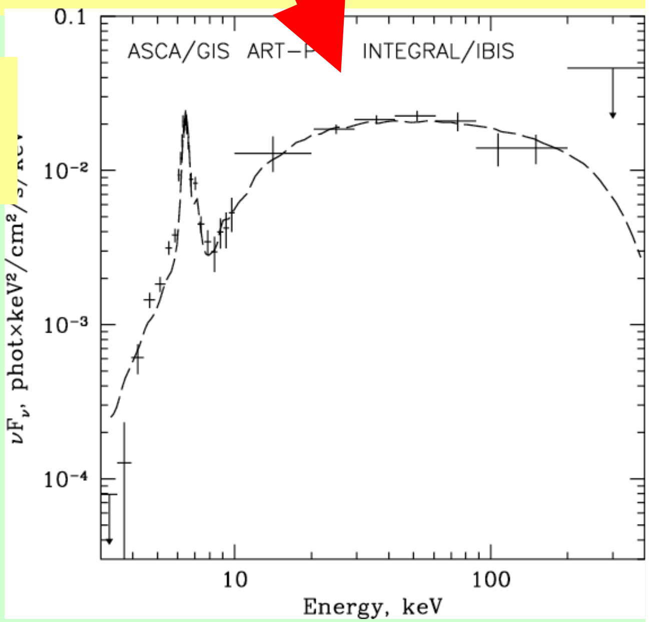
The strange case of Sgr B2



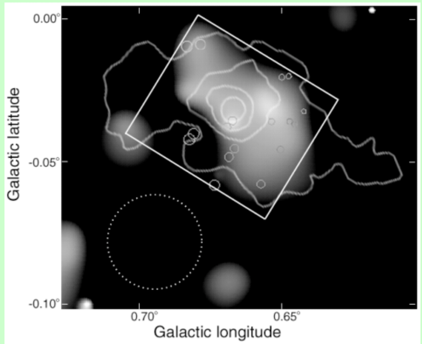
INTEGRAL Image of GC (Revnivtsev 2004)

SgrB2 is a giant molecular cloud at ~100pc projected distance from the Black Hole

The spectrum of SgrB2 is a pure reflection spectrum (Sunyaev et al. 1993)



But no bright enough source is there !!!



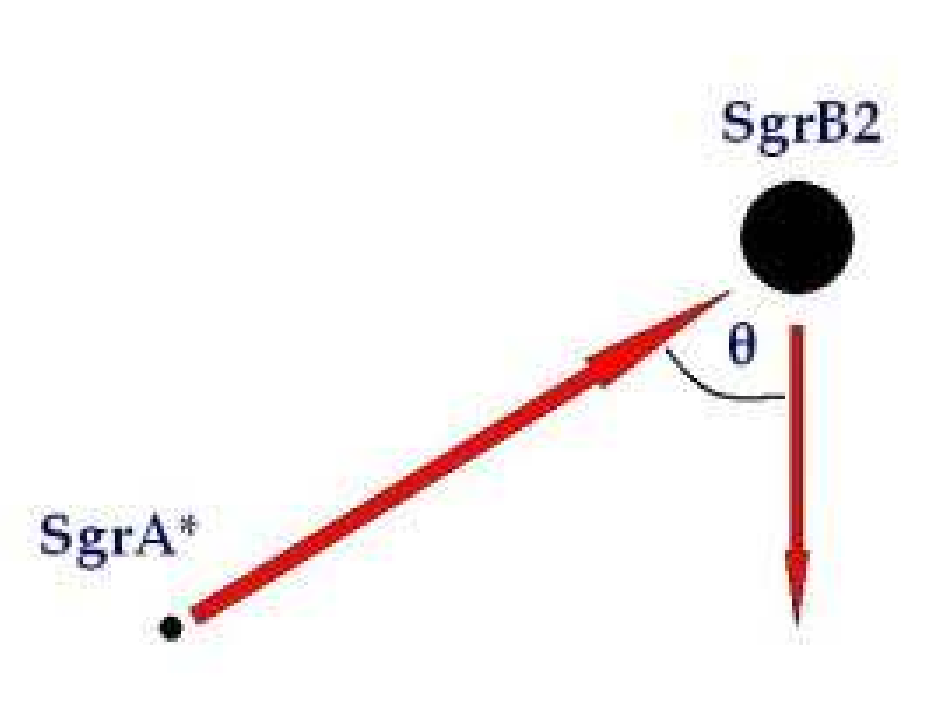
The emission from SgrB2 is extended and brighter in the direction of the BH (Murakami 2001). It is also varying in time (Inui et al. 2008).

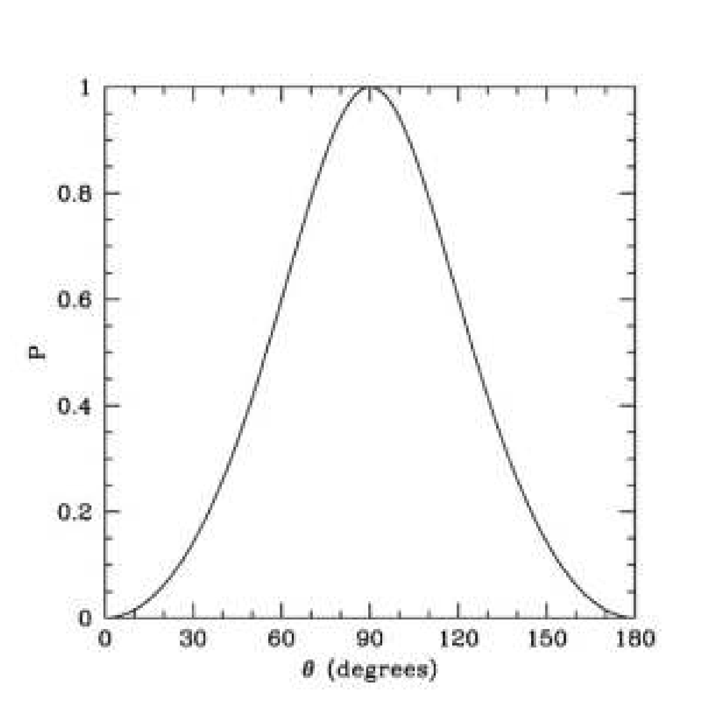
Is SgrB2 echoing past emission from the BH, which was therefore one million time more active (i.e. a LLAGN) ~300 years ago ??? (e.g. Koyama et al. 1996)

Was the GC an AGN a few hundreds years ago?

X-ray polarimetry can definitively proof or reject this hypothesis.

SgrB2 should be highly polarized with the electric vector perpendicular to the line connecting the two sources.





The degree of polarization would measure the angle and provide a full 3-d representation of the clouds (Churazov et al. 2002)

The LOFT Mission (A. De Rosa's talk)

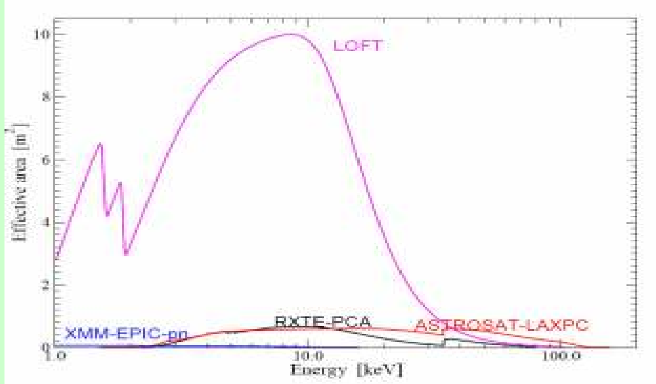
LOFT is specifically designed to exploit the diagnostics of very rapid X-ray flux and spectral variability in compact objects, yielding unprecedented information on strongly curved spacetimes and matter under extreme conditions of pressure and magnetic field strength.

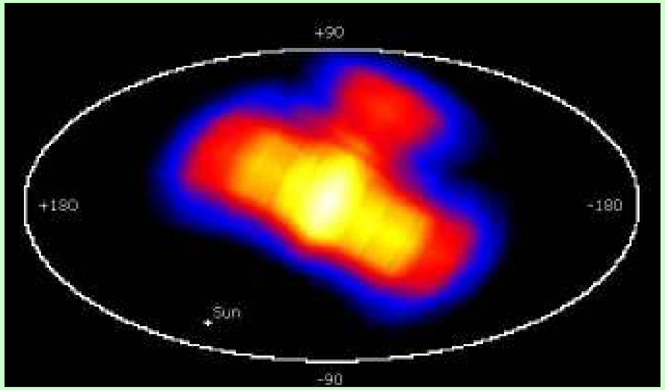
LOFT will investigate variability from submillisecond QPO's to years long transient outbursts.

The LOFT LAD has an effective area ~20 times larger than any largest predecessor and a "CCD-class" energy resolution.

The LOFT WFM has a few steradian field of view and will discover and localise X-ray transients and impulsive events and monitor spectral state changes, triggering follow-up observations and providing a wealth of science in its own.

Key Instruments Features





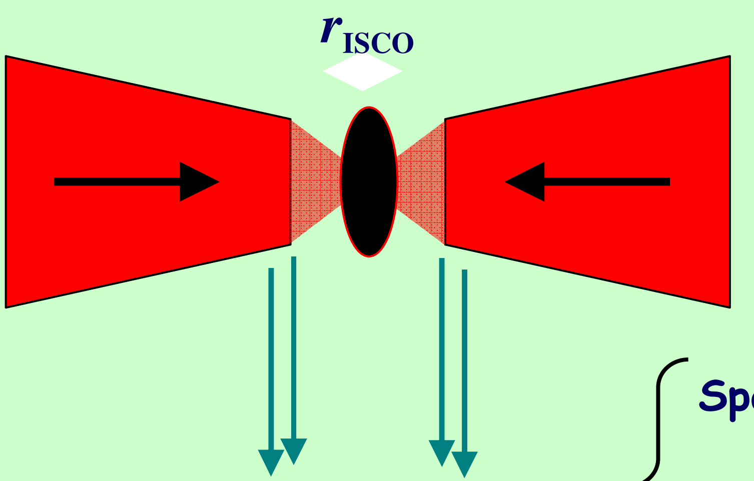
LAD – Large Area Detector	
Effective Area	4 m² @ 2 keV 8 m² @ 5 keV 10 m² @ 8 keV 1 m² @ 30 keV
Energy range	2-30 keV primary 30-80 keV extended
Energy resolution FWHM	260 eV @ 6 keV 200 eV @ 6 keV (45% of area)
Collimated FoV	1 degree FWHM
Time Resolution	10 μs
Absolute time accuracy	1 μs
Dead Time	<1% at 1 Crab
Background	<10 mCrab (<1% syst)
Max Flux	500 mCrab full event info 15 Crab binned mode

WFM- Wide Field Monitor	
Energy range	2-50 keV primary 50-80 keV extended
Active Detector Area	1820 cm²
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) Galactic Center, 3 s Galactic Center, 1 day	 270 mCrab 2.1 mCrab
Standard Mode	5-min, energy resolved images
Trigger Mode	Event-by-Event (10μs res) Realtime downlink of transient coordinates

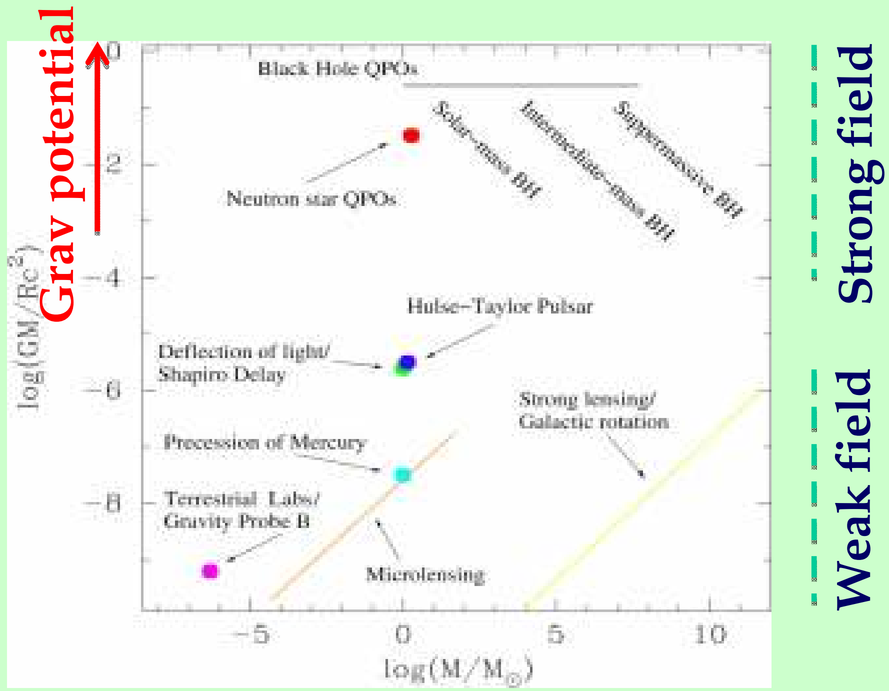
LOFT- Strong Field Gravity (SFG): What are the laws of physics in extreme conditions?

General Relativity (GR) has been probed in the so-called weak-field regime at scales of the order of 10^5-10^6 R_g (R_g=GM/c^2)

Regions at the scales of a few R_g need to be probed to detect GR in its most extreme conditions: matter accretion into black holes and neutron stars provide the best tools.



Photons (mainly EUV + X-rays)



Psaltis 2004

Spatial (x,y) - unresolved (interferometry)

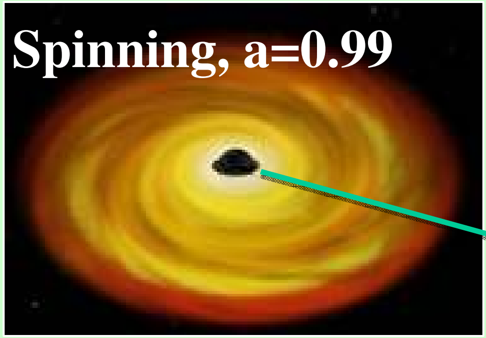
Timing (t)

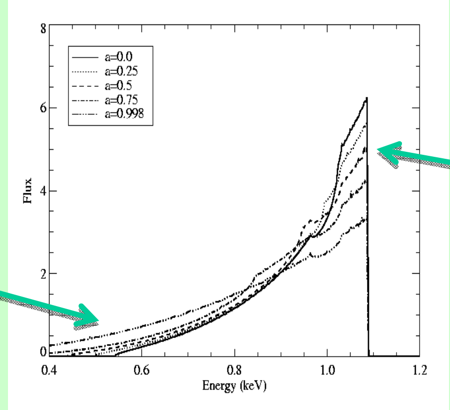
Spectroscopy (E)

LOFT!!

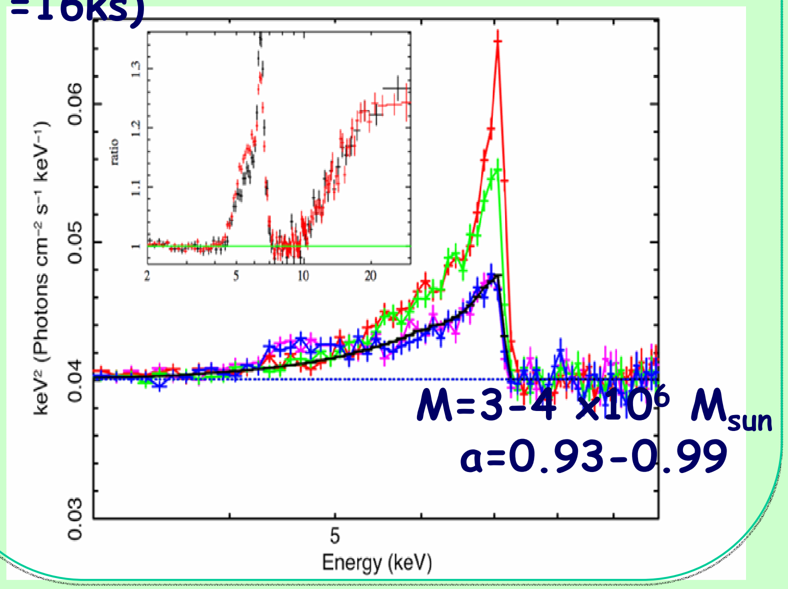
Polarization (PA) - unresolved (polarimetry)

LOFT-Strong Field Gravity with Spectroscopy

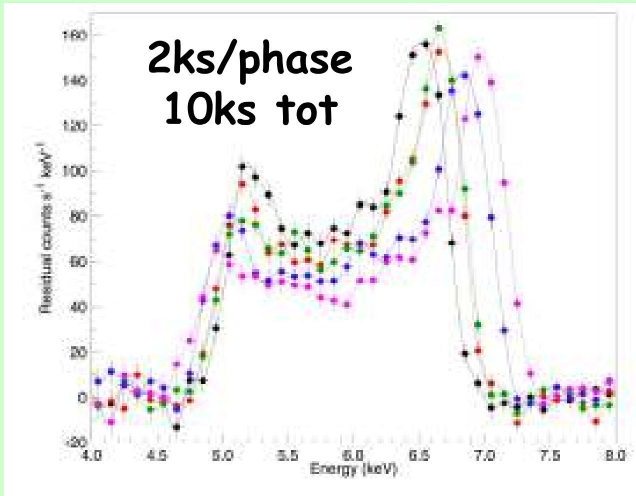




<u>3mCrab AGN. Supermassive BH</u> offer unique opportunity: more photons per dynamical time scale than Galactic BH (4 ks/phase. T=16ks)



<u>300 mCrab NS. Lense-Thirring precession.</u> The truncated disc/precessing model for the spectral timing properties of XRBs predicts a phase dependence of the Feline profile.



Athena Science Requirements

Effective Area	1 m² @1.25 keV (goal 1.2 m²) 0. 5 m² @ 6 keV (goal 0.7 m²)	Black hole evolution, large scale structure Strong gravity, cosmic feedback
Spectral Resolution (FWHM)	ΔE = 3 eV (@6keV) within 2 x 2 arc min (goal 2.5 eV and 4x3 arc min) ΔE =150 eV at 6 keV within 25 arc min diam (goal of 125 eV and >30 arc min)	Large scale structure, Cosmic Feedback Black Hole evolution, Large scale structure
Angular Resolution	10 arc sec HPD (0.1 – 7 keV) (goal of 5 arc sec)	Black hole evolution, Cosmic feedback, Large Scale Structure
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV @ 6keV (0.3 – 15 keV)	Strong gravity
Astrometry	1.5 arcsec at 3σ confidence	Black hole evolution
Absolute Timing	100 μsec	Compact Objects

ATHENA SCIENCE

Black holes, compact objects and accretion physics → **The physics of feedback** → **Cosmic evolution of SMBH in galaxies and large-scale structure of the Universe**

Study the behaviour of matter moving around black holes and other compact objects. Probe matter under strong gravity and high density conditions.

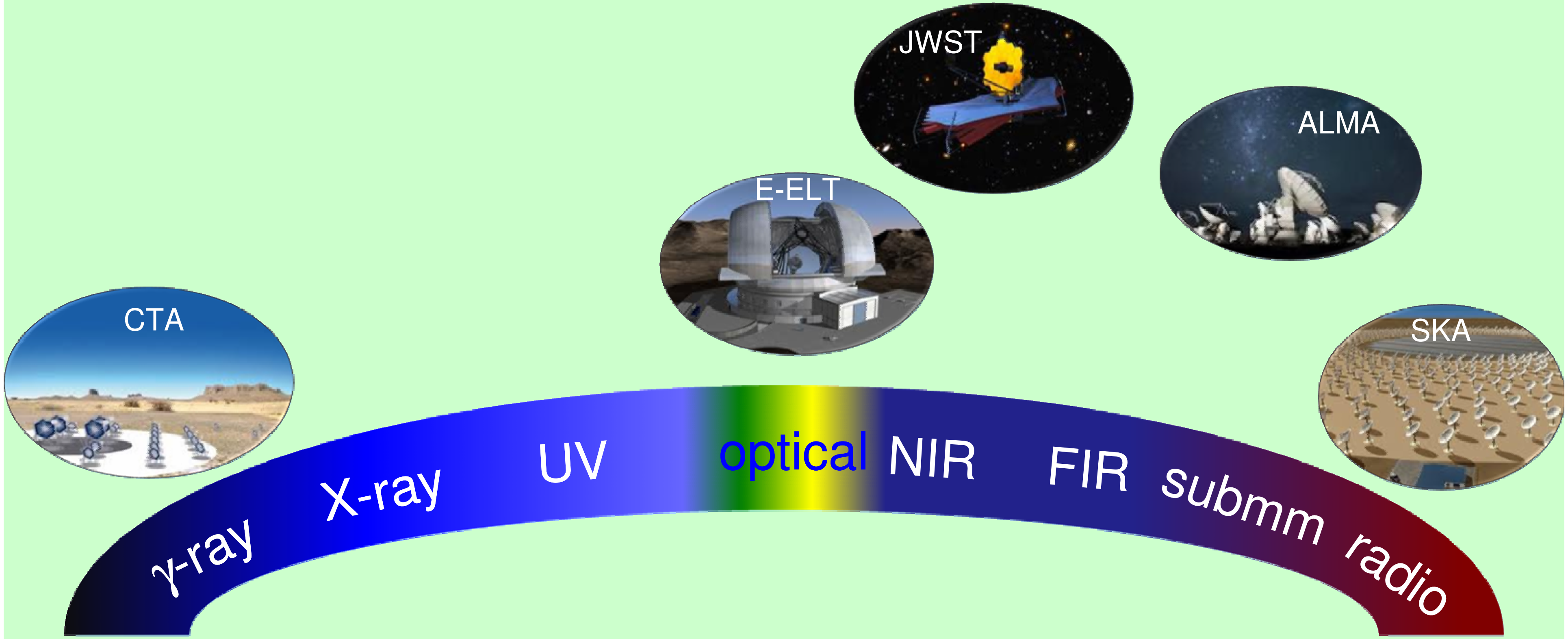
Study the physics of feedback on all astrophysical scales, from stars and compact objects to galaxies and clusters.

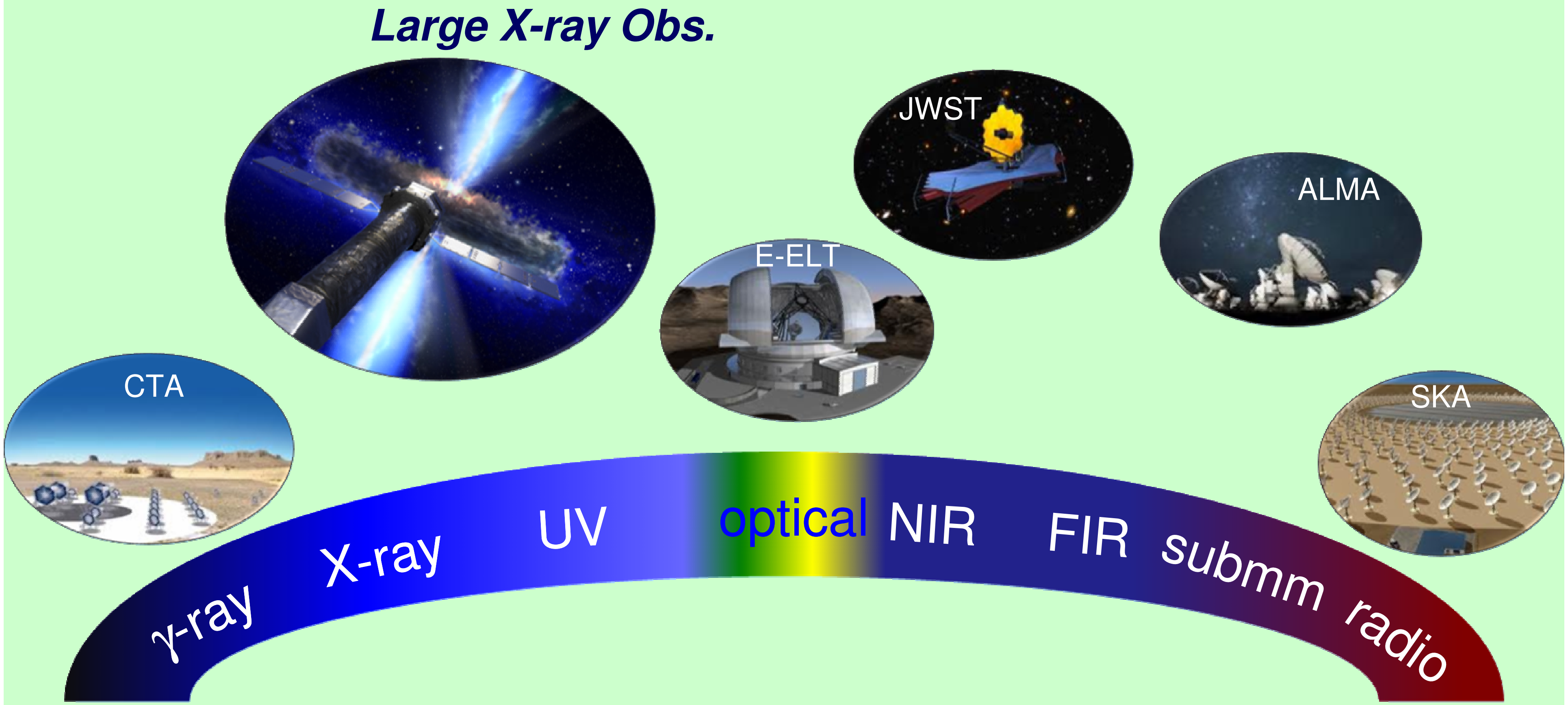
Determine how SMBH grow, often in obscured envrironments and trace the formation of Large Scale Structure through the fate of hot baryons in galaxy clusters, studying their structure and evolution.

Astrophysics of hot cosmic plasmas

Diagnose hot cosmic plasmas on all astrophysical environments via spatially resolved

high resolution X-ray spectroscopy


JWST
ALMA
E-ELT
CTA
SKA
γ-ray
X-ray
UV
optical
NIR
FIR
submm
radio



Large X-ray Obs.
JWST
ALMA
E-ELT
CTA
SKA
γ-ray
X-ray
UV
optical
NIR
FIR
submm
radio