Future Observing Capabilities

J. Wilms
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X-Ray Astronomy: The Present

XMM-Newton (ESA): launched 1999 Dec 10

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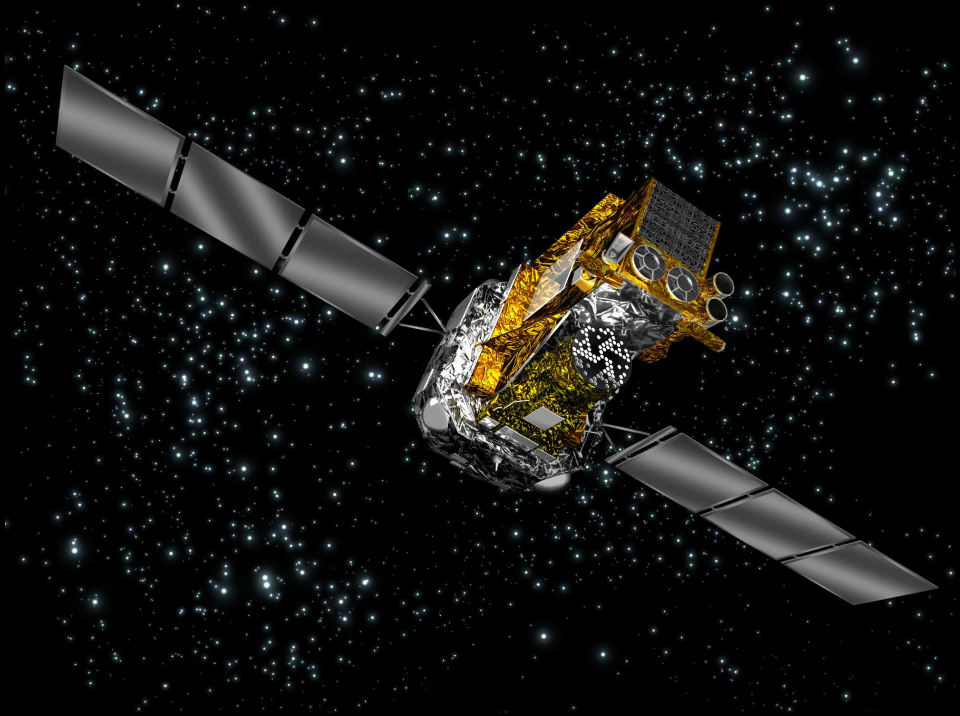

INTEGRAL (ESA): launched 2002 Oct 17

X-Ray Astronomy: The Present

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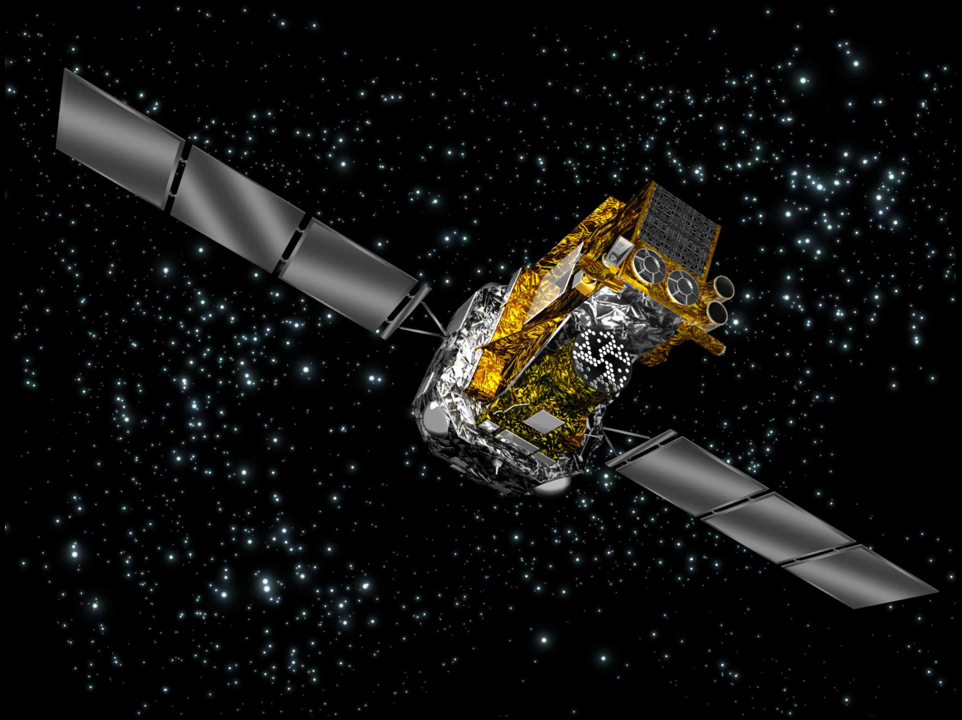

INTEGRAL (ESA): launched 2002 Oct 17

Currently Active Missions: X-ray Multiple-Mirror Mission (*XMM-Newton*; ESA), International Gamma-Ray Laboratory (*INTEGRAL*; ESA), *Chandra* (USA), *Swift* (USA), Rossi X-ray Timing Explorer (*RXTE*) (USA), High Energy Transient Explorer (*HETE-2*; USA), Fermi (USA), High Energy Solar Spectroscopic Imager Spacecraft (*RHESSI*; USA), Suzaku (Japan, USA), *AGILE* (Italy), MAXI (Japan).

X-Ray Astronomy: The Present

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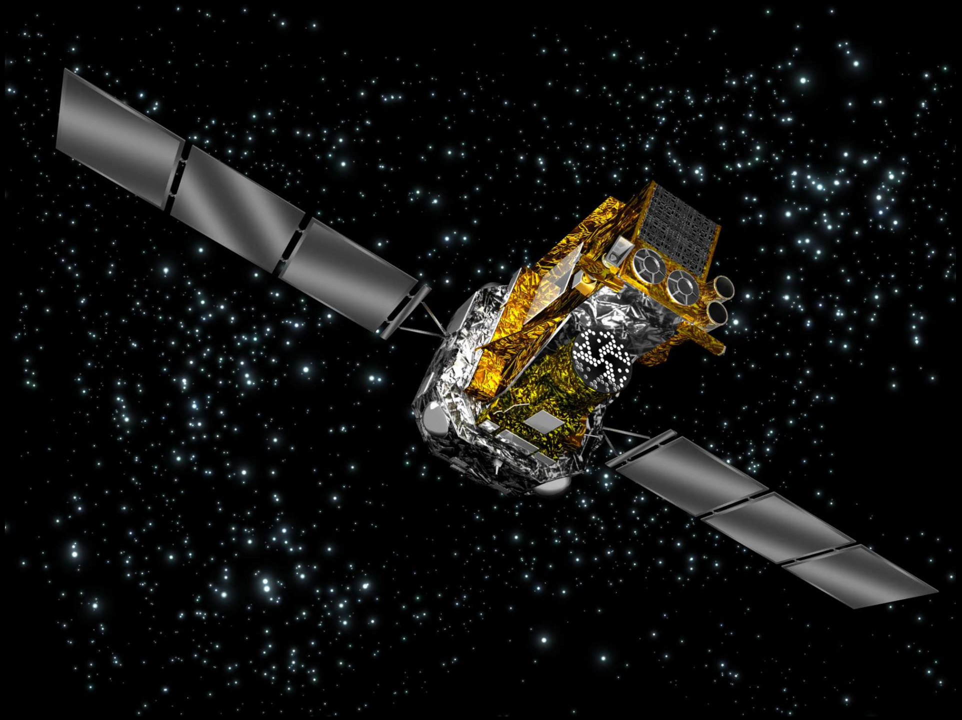

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We are living in the "golden age" of X-ray and Gamma-Ray Astronomy

In order to allow us to continue studying accreting neutron stars we need the following capabilities:

- Wide energy band – 0.5–150 keV

  to measure continuum parameters

- Good time resolution ($\ll$1 s)

  to obtain pulse period, phase resolved spectroscopy,. . .

- Polarization?

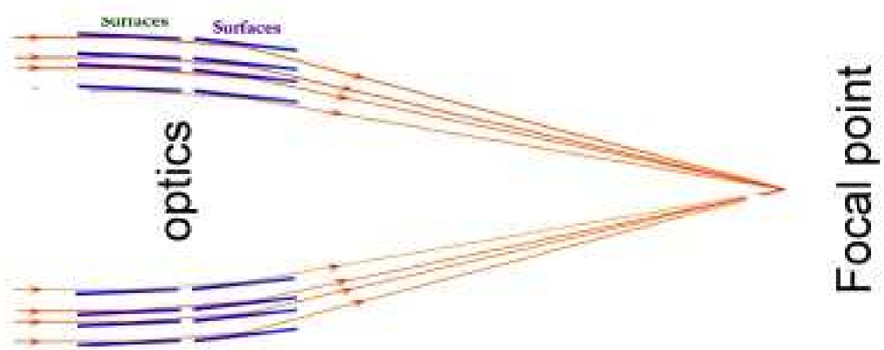
  more diagnostical possibilities – no real theoretical predictions yet.

- All Sky Capabilities

  to find outbursts

NuSTAR will be the first focusing hard X-ray satellite

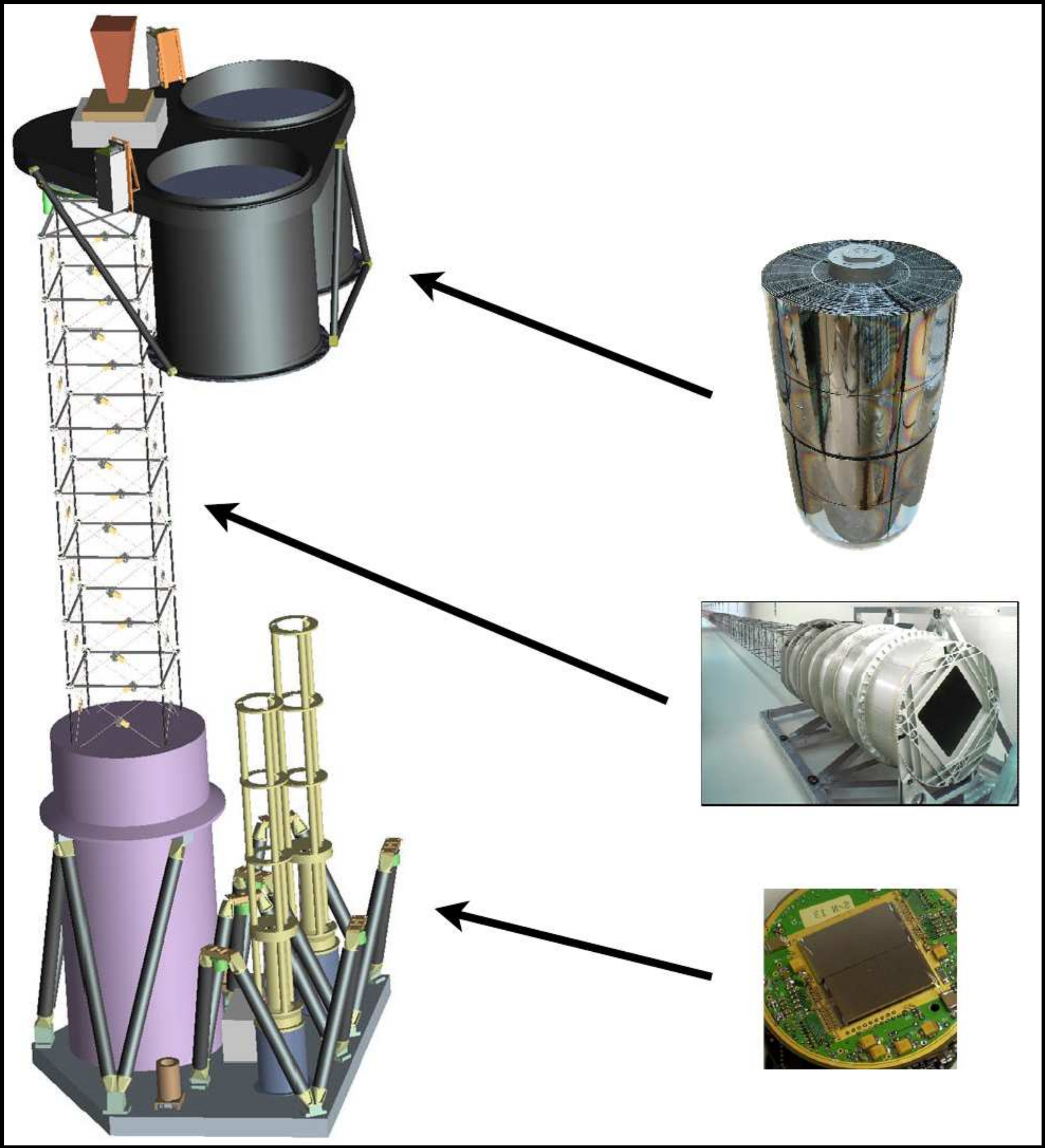
Coded Aperture Optics:
high background, large detector



Focusing Optics:
low background, compact detector

D. Stern

NuSTAR (Nuclear Spectroscopic Telescope Array): Imaging above 10 keV



- Launch: August 2011 (Pegasus)
- Caltech, NASA, Columbia, DTU-Space, . . .
- grazing incidence optics, multilayers ($2\times$ 120 shells), 10 m focal length
- 8 32×32 CZT detectors

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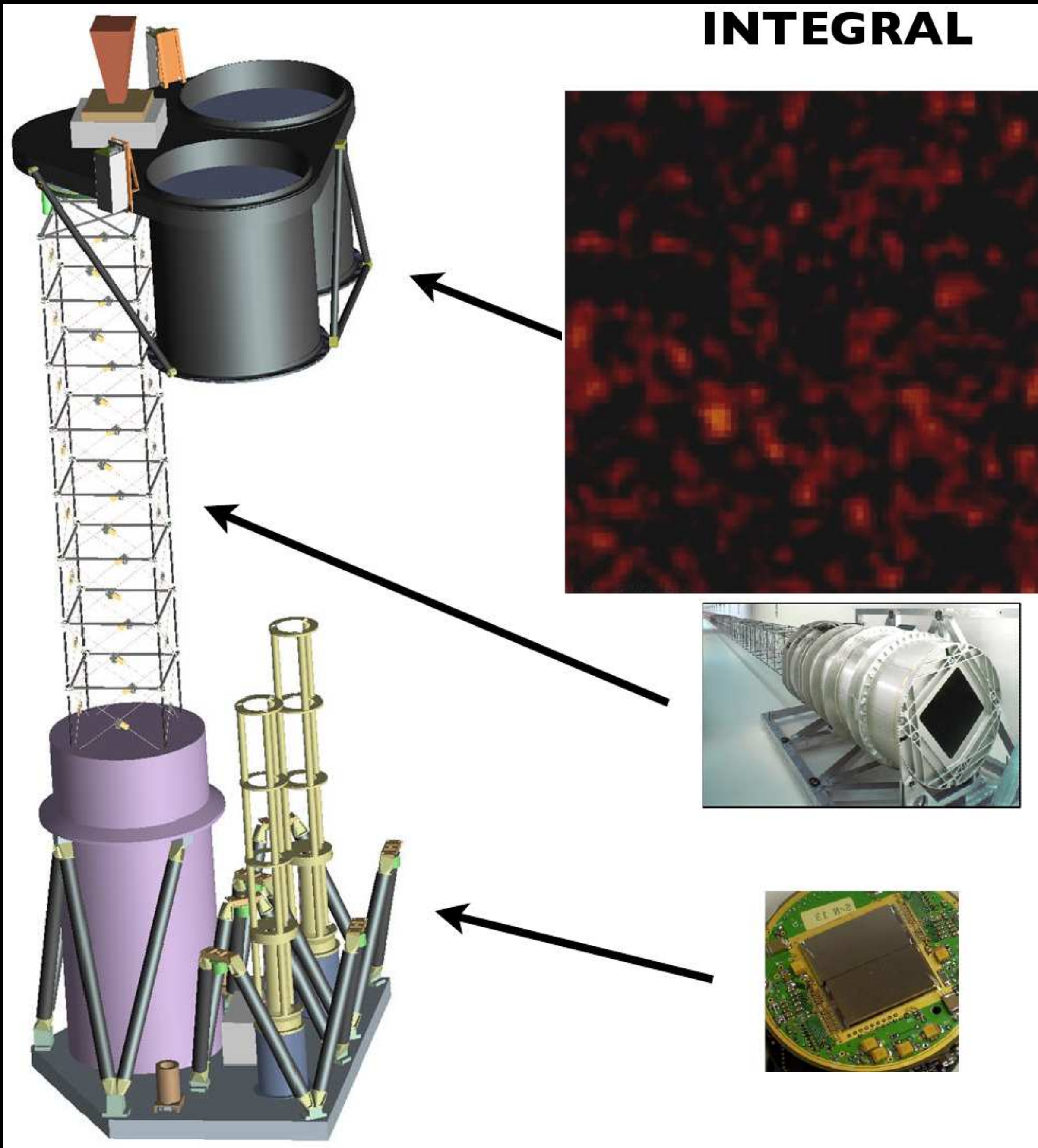

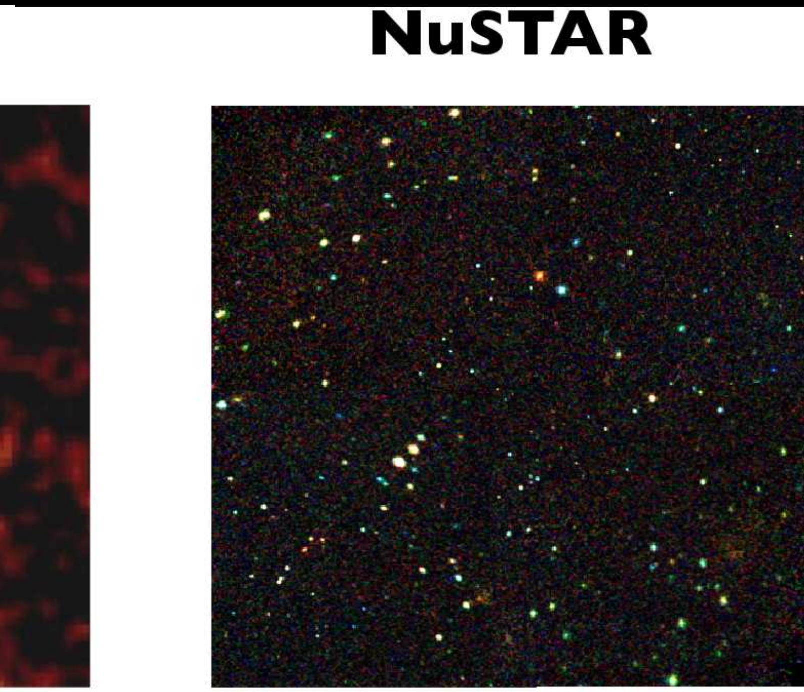

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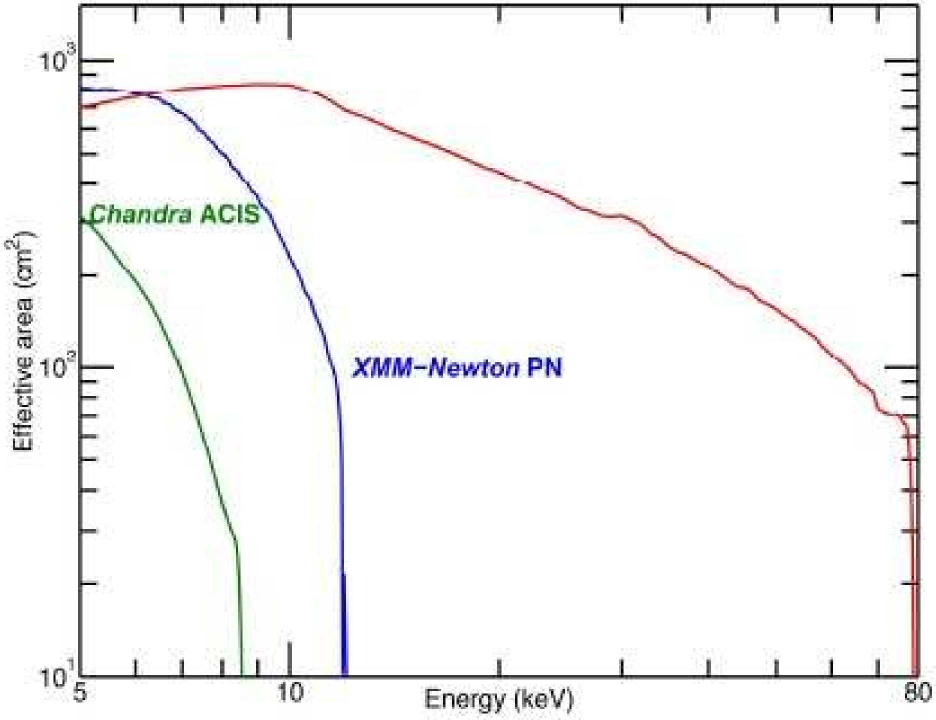
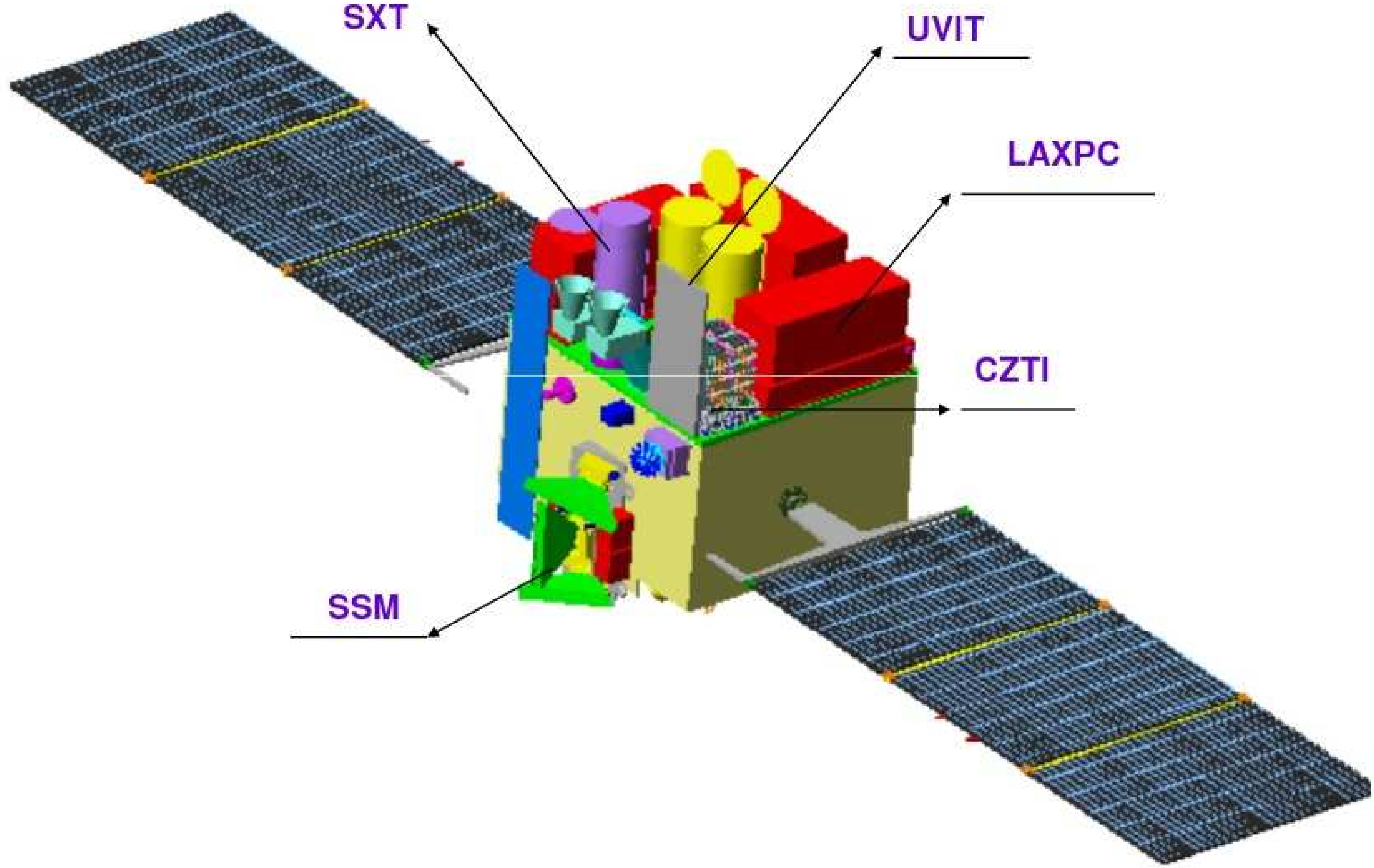


Energy Range:	6-80 keV
Angular Resolution:	45 arcsec (HPD)
Field of View:	12 × 12 arcmin
Spectral Resolution:	1.2 keV at 68 keV 600 eV at 6 keV
Sensitivity (3σ, 1 Ms):	2×10^{-15} erg/cm^2/s (6-10 keV) 1×10^{-14} erg/cm^2/s (10-30 keV)
Timing Resolution:	1 msec
ToO Response:	<24 hr
Launch Date:	August 2011
Orbit:	6 degree inclination 550 km × 600 km
Mission Lifetime: **Orbit Lifetime:**	2 years baseline >7 years orbit lifetime

current best estimates (CBEs), as of September 2009

D. Stern

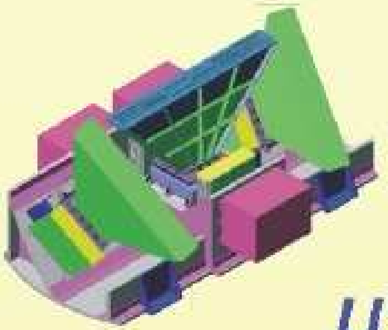
ASTROSAT



P. O'Brien

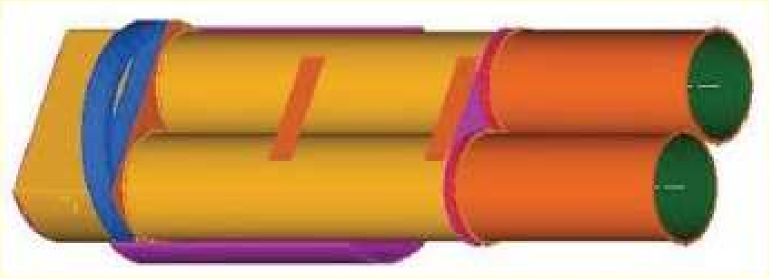
ASTROSAT payload

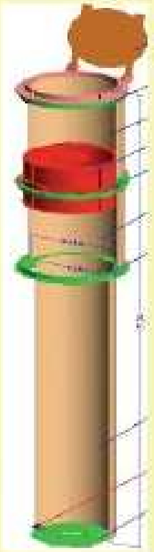
Large Area X-ray Proportional Counter



Scanning Sky Monitor (SSM)

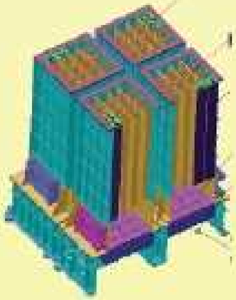
UV Imaging Telescope





Soft X-ray telescope (SXT)

Cadmium Zinc Telluride Imager



Charged Particle Monitor

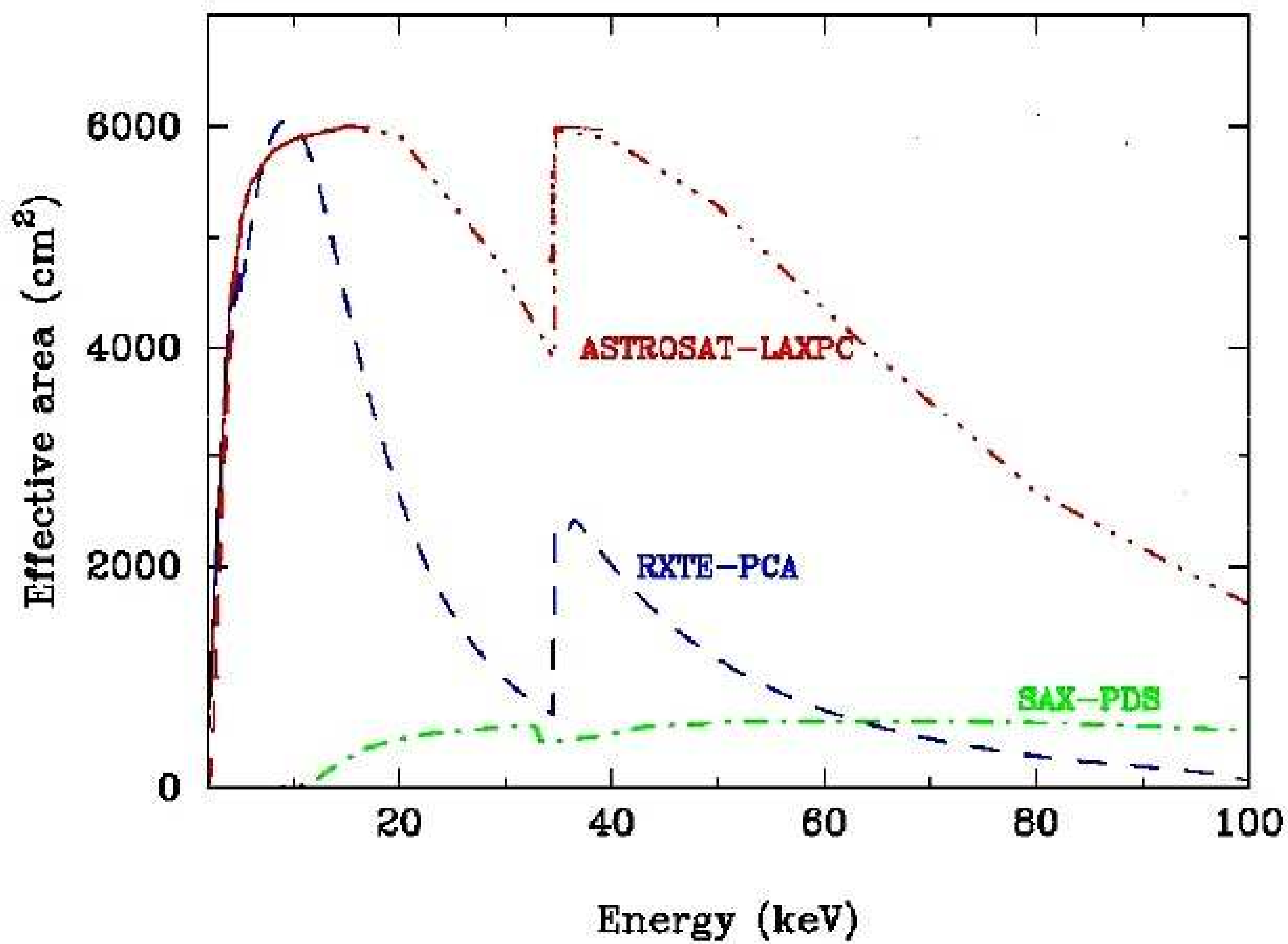
P. O'Brien

ASTROSAT instrument details

	UVIT	SXT	LAXPC	CZTI	SSM
Description	Twin, RC, 38cm telescopes	Focussing X-ray conical foil mirrors	Proportional counters	CZT array	3 PSPCs with 1-D coded mask
Energy range	125-550 nm (NUV, FUV, VIS)	0.3-8 keV	2-80 keV	10-150 keV	2-10 keV
Energy Resolution (FWHM)	< 100 nm (depends on choice of filters + R~100 grisms)	3% @ 6 keV	10% @ 22 keV	5% @ 60 keV	19% @ 6 keV
Angular Resolution	1 arcsec	3-4 arcmin (HPD)	~ 1 to 5 arcmin (scan mode)	8 arcmin	5 – 10 arcmin
Time Resolution	few ms	2.6 s, 0.3 s, 1 ms	10 microsec	1 ms	1 ms
Sensitivity (Obs.Time in ks)	20 magnitude (4 σ) in 50 nm band (1Ks)	0.1 milliCrab (3 σ) (1 Ks)	0.1 milliCrab (3 σ) (1 Ks)	0.5 milliCrab (5 σ) (10 Ks)	~30 milliCrab (3 σ) (0.3 Ks)

P. O'Brien

ASTROSAT hard X-ray effective area



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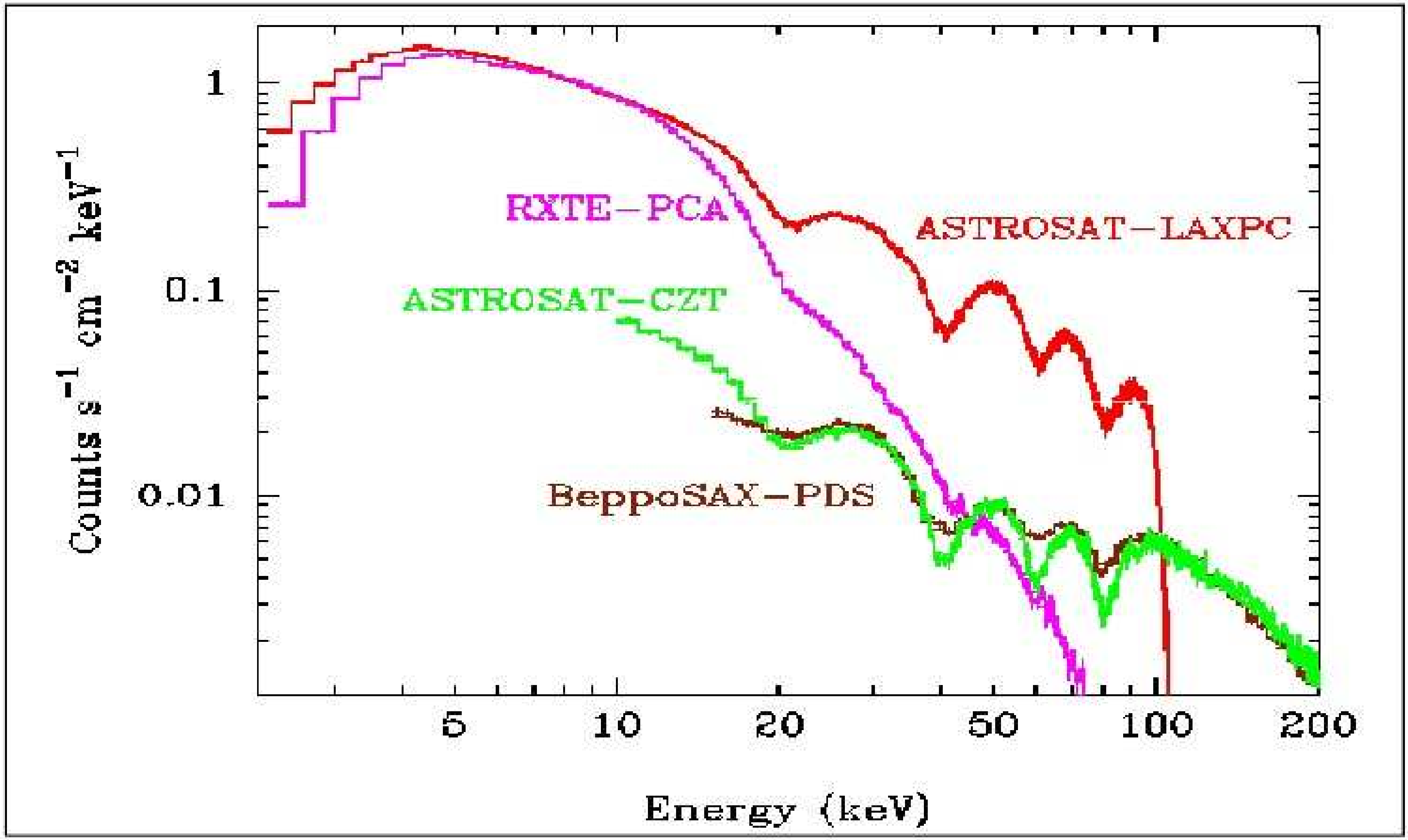
Be/X-ray transient pulsar 4U 0115+63 (10ks)



P. O'Brien

Polar Satellite Launch Vehicle (PSLV)

ASTROSAT will be launched on a PSLV from the Satish Dhawan Launch Center at Shriharikota (India).

Well-proven rocket (e.g. AGILE)

Date: 2010

Orbit: ~600 km with inclination of 8 degrees (stable radiation environment)

Mission life: at least 5yrs

Spacecraft: 3-axis stabilised + star trackers, slew rate up to 4 degrees min^{-1}

Chandrayaan-1 launch 12/11/08

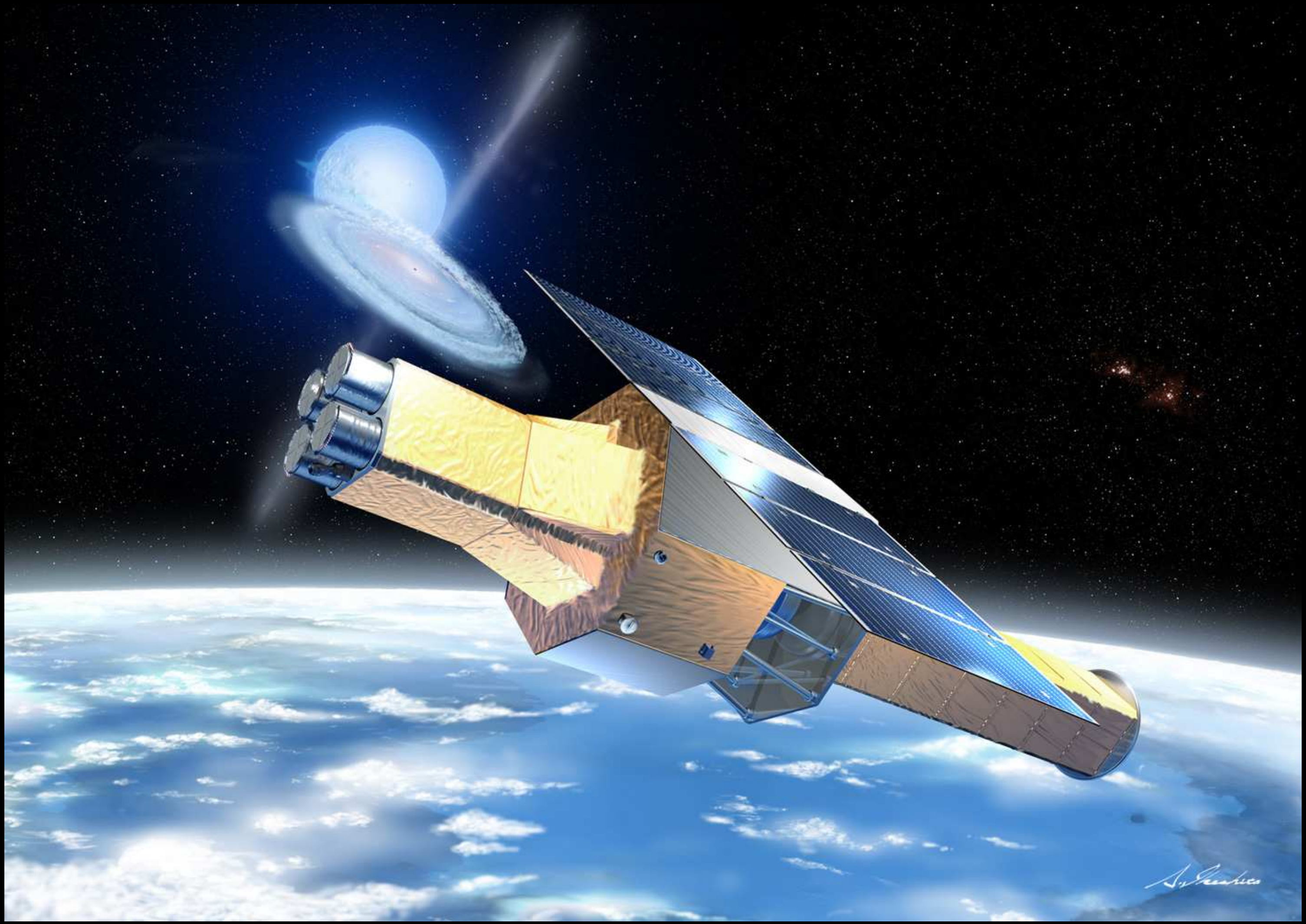
P. O'Brien

ASTROSAT observing time

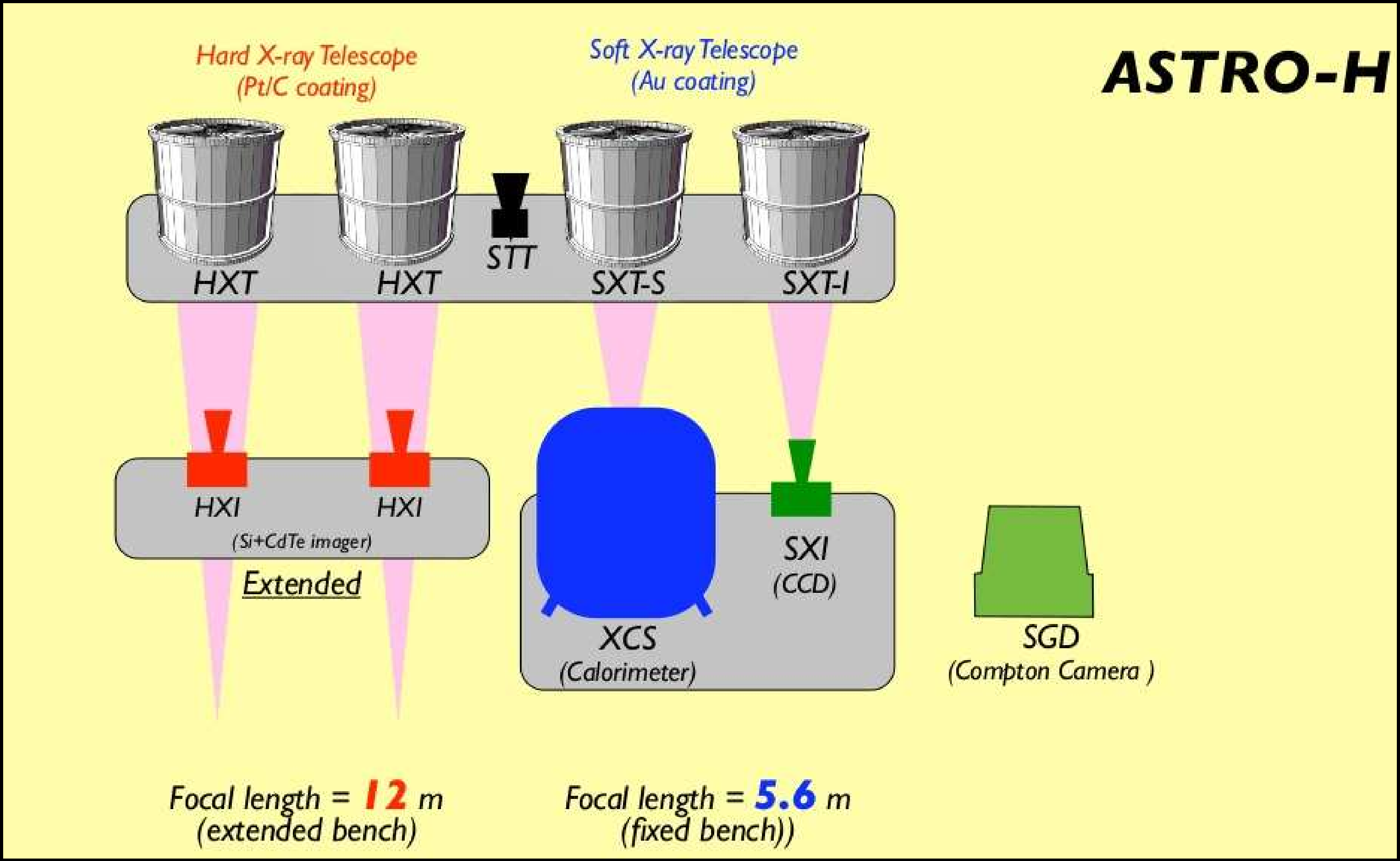
T0 +	1st yr	2nd yr	3rd yr	4th yr
Instrument teams	6m - PV 6m - GT	50%	30%	-
CSA		5%	5%	5%
Leicester		3%	3%	3%
Open IND	-	35%	45%	65%
Open Intl	-	-	10%	20%
TOO	-	5%	5%	5%
Calib	-	2%	2%	2%

All Science Data archived to a National Space Science Data Archival Centre (ISRO) accessible to the world.

Astro-H: High-Resolution Spectroscopy



- Launch: 2013, JAXA/NASA
- multi layers, wide energy range (2–800 keV)

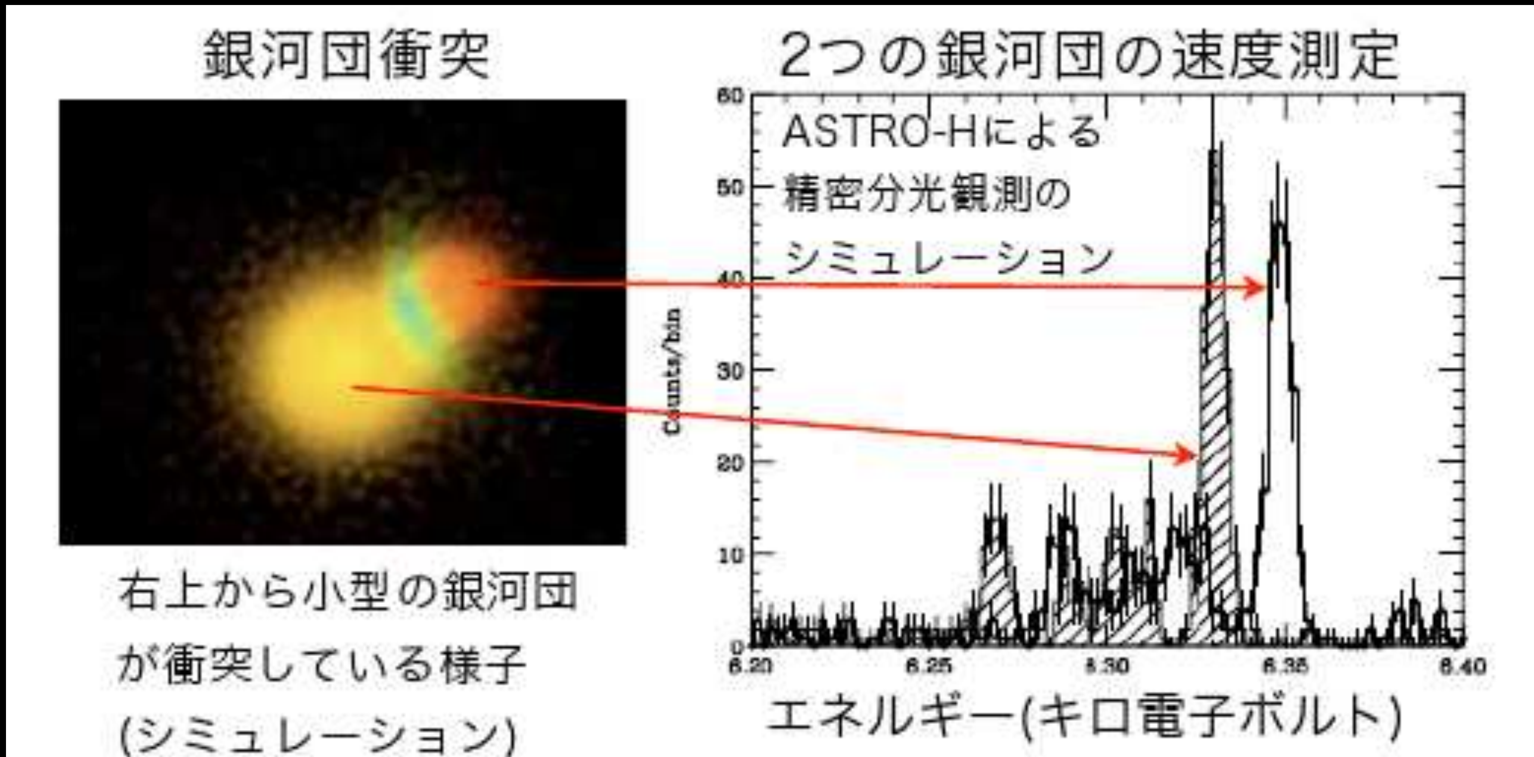

ASTRO-H
Hard X-ray Telescope
(Pt/C coating)
Soft X-ray Telescope
(Au coating)
HXT
HXT
STT
SXT-S
SXT-I
HXI
HXI
(Si+CdTe imager)
Extended
SXI
(CCD)
XCS
(Calorimeter)
SGD
(Compton Camera)
Focal length = 12 m
(extended bench)
Focal length = 5.6 m
(fixed bench))

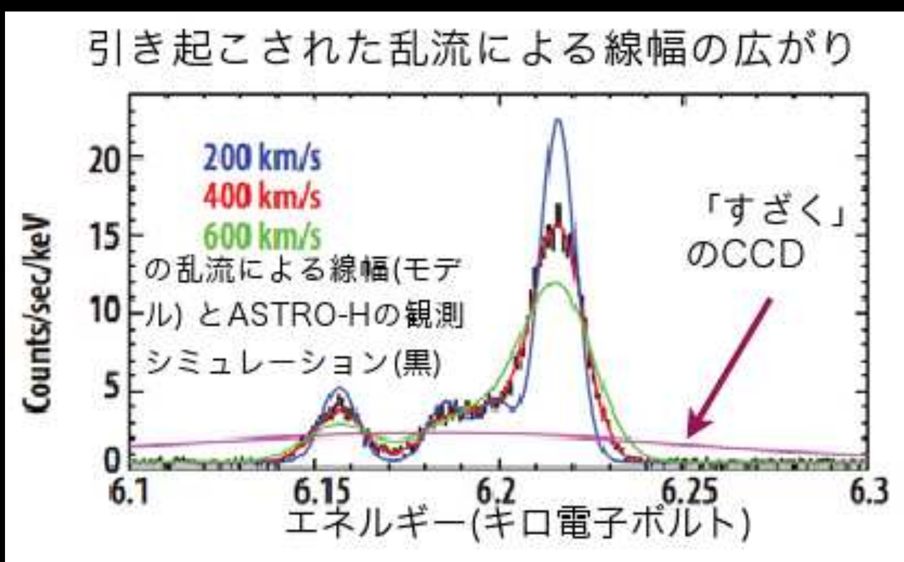
Takahashi

	Specifications
Hard X-ray Imaging System (HXT+HXI) 5-80 keV	Effective area : 300 cm^2 (@30 keV) Spatial resolution : 1.7 arcmin (HPD) Energy resolution : 2 keV Field of view : 9 arcmin @30 keV
Soft X-ray Spectrometer System (SXT-S+SXS) 0.3-10 keV	Energy resolution : 7 eV Spatial resolution : 1.7 arcmin (HPD) Effective area : 210 cm^2 (@6 keV) Field of view : 3 arcmin @6 keV
Soft X-ray Imaging System (SXT-I+SXI) 0.5-12 keV	Spatial resolution : 1.7 arcmin (HPD) Effective area : 360 cm^2 @6 keV Energy resolution : 150 eV Field of view : 38 arcmin @6 keV
Soft γ-ray detector (SGD) 10-600 keV	Effective area : 100cm^2 @100 keV Energy resolution : 2 keV @40 keV Astrometric accuracy : <0.6 arcdeg (E<150 keV)

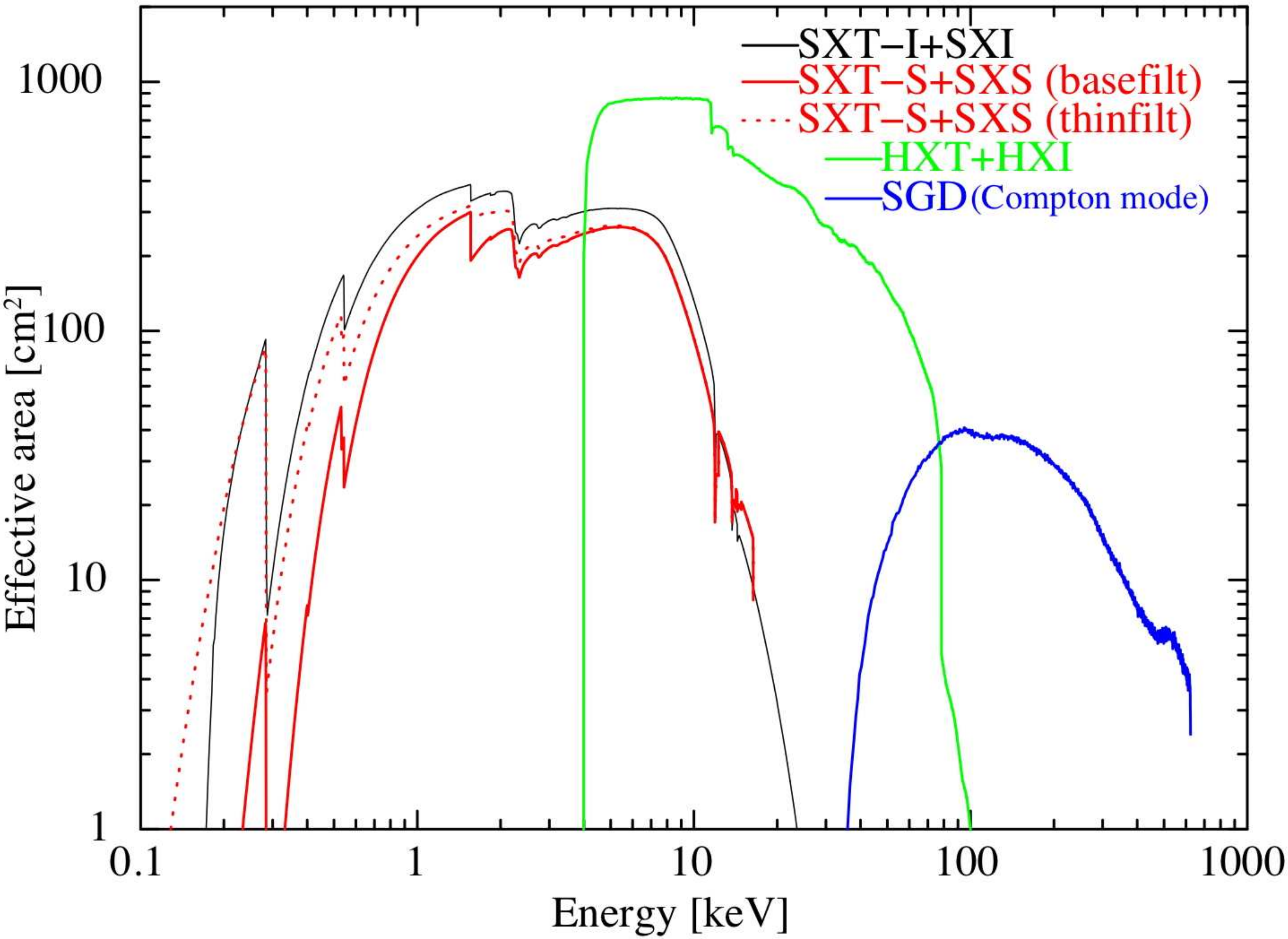
Takahashi

HXI: hybrid silicon strip and CdTe

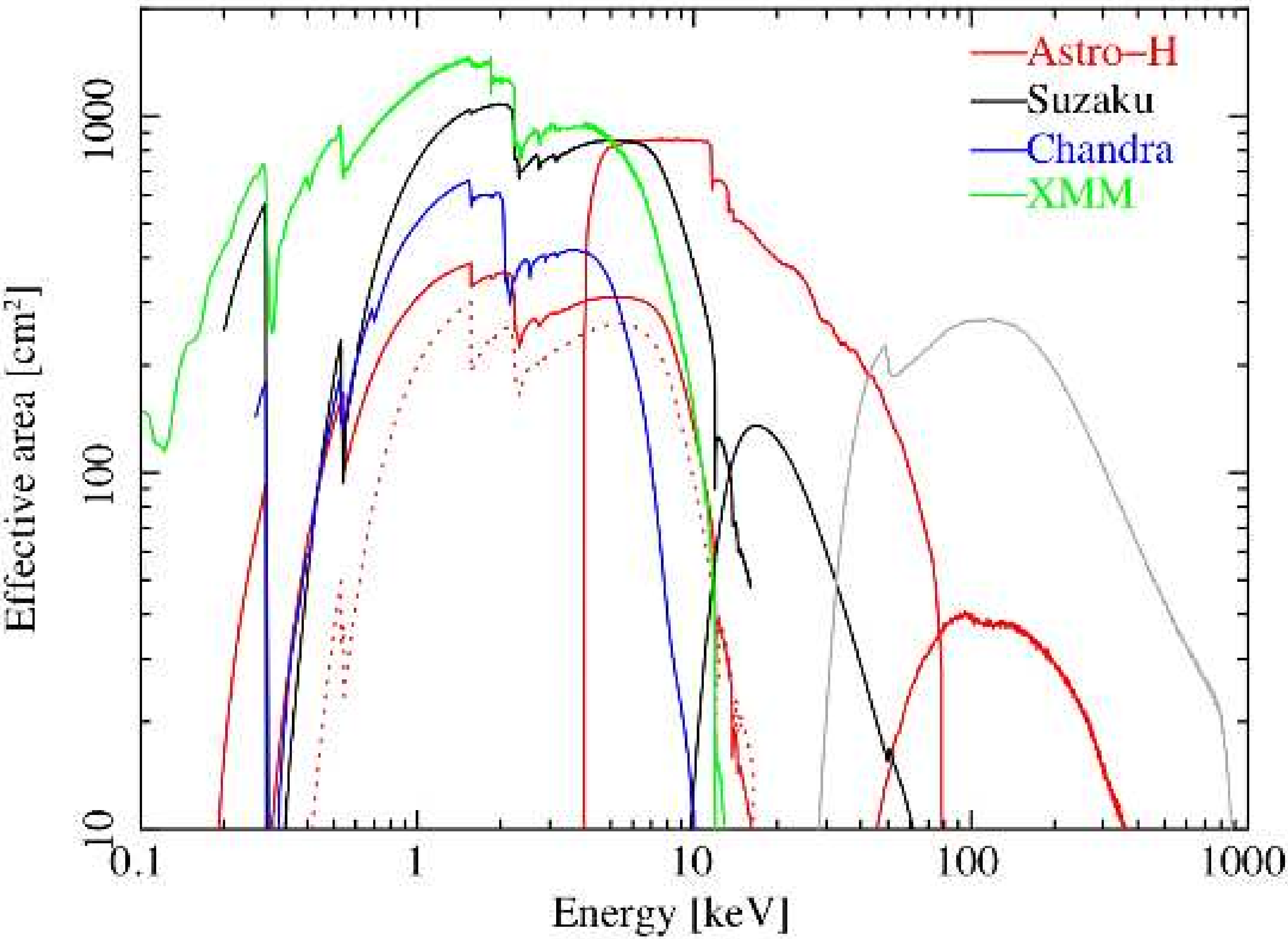




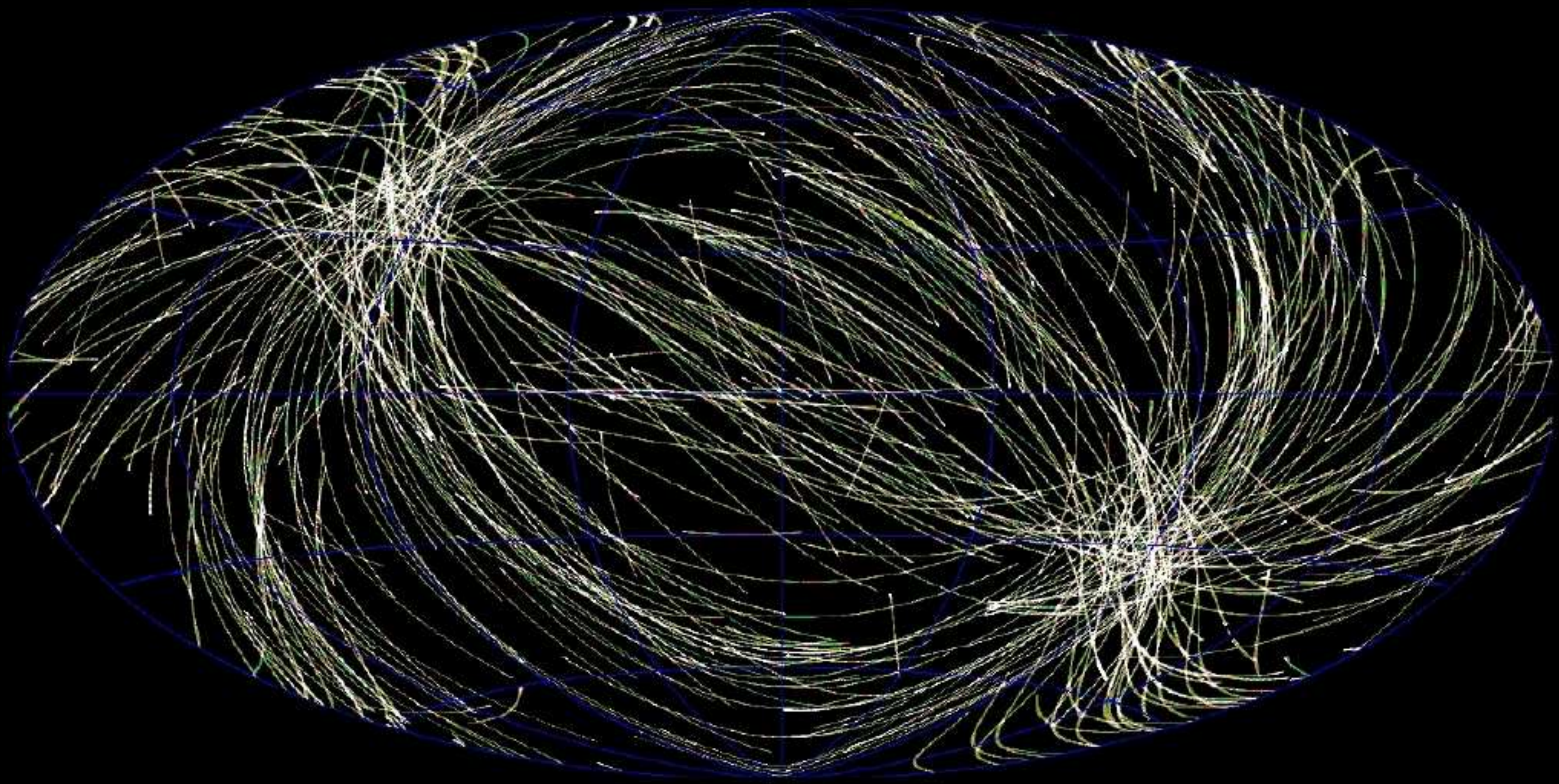
most important instrument on Astro-H:
calorimeter ($\Delta E \sim$7 eV)



SXT−I+SXI
SXT−S+SXS (basefilt)
SXT−S+SXS (thinfilt)
HXT+HXI
SGD(Compton mode)
1000
100
10
1
0.1
1
10
100
1000
Effective area [cm^2]
Energy [keV]



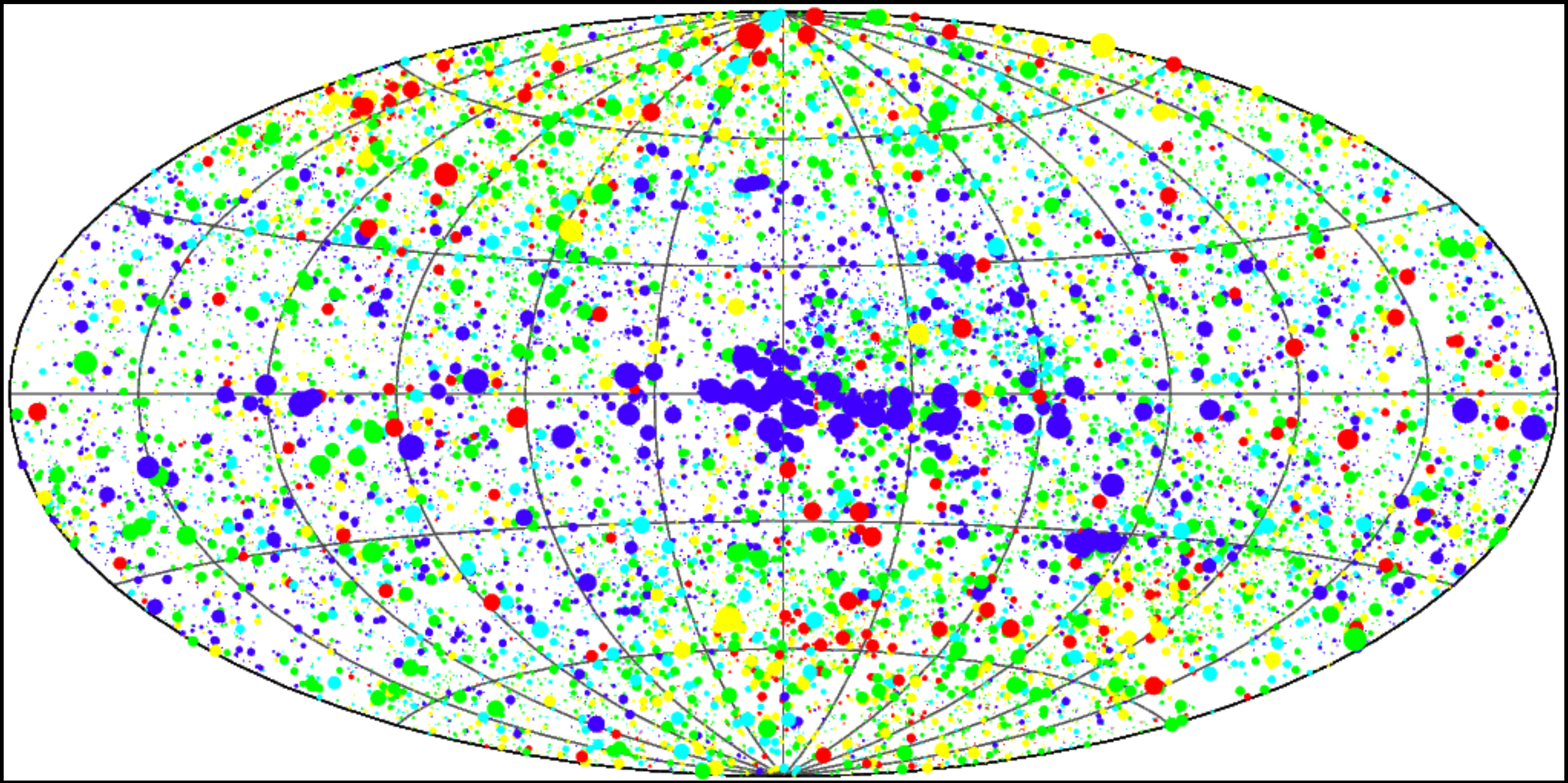
Astro–H
Suzaku
Chandra
XMM
Effective area [cm²]
1000
100
10
0.1
1
10
100
1000
Energy [keV]



A. Read, *XMM-Newton* Slew Survey

To observe X-ray sources, we need to know that they exist

$\Longrightarrow$ All Sky Surveys



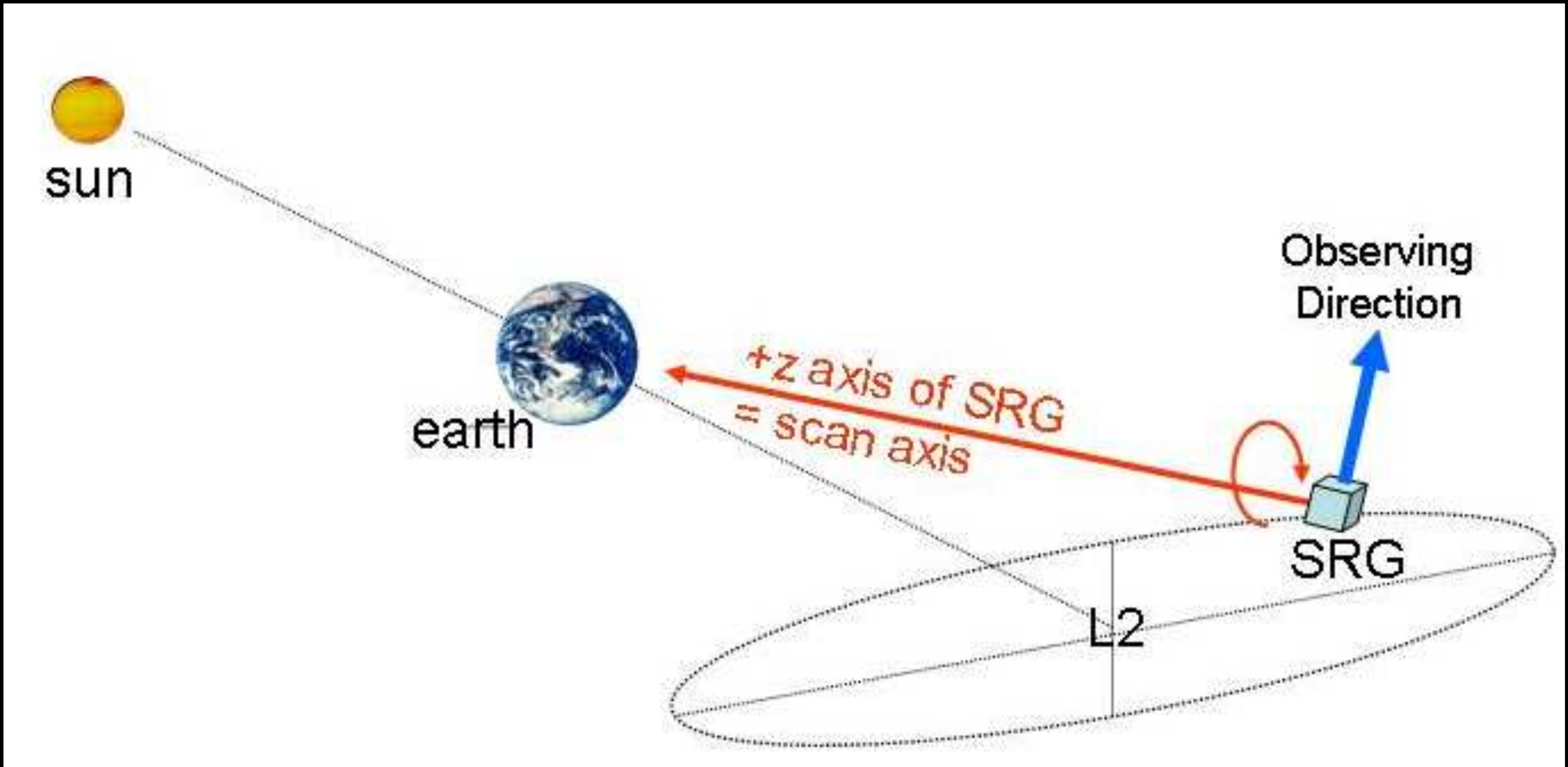
To observe X-ray sources, we need to know that they exist

$\Longrightarrow$ All Sky Surveys

There is only *one* complete X-ray sky survey: *ROSAT* All Sky Survey

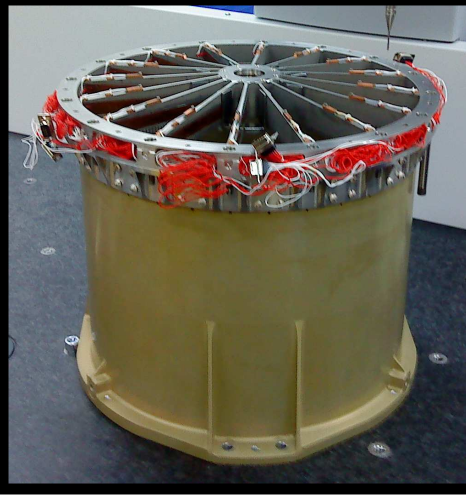
- limited to soft X-rays $\Longrightarrow$ misses absorbed sources!
- "shallow" $\Longrightarrow$ contains only the brightest sources

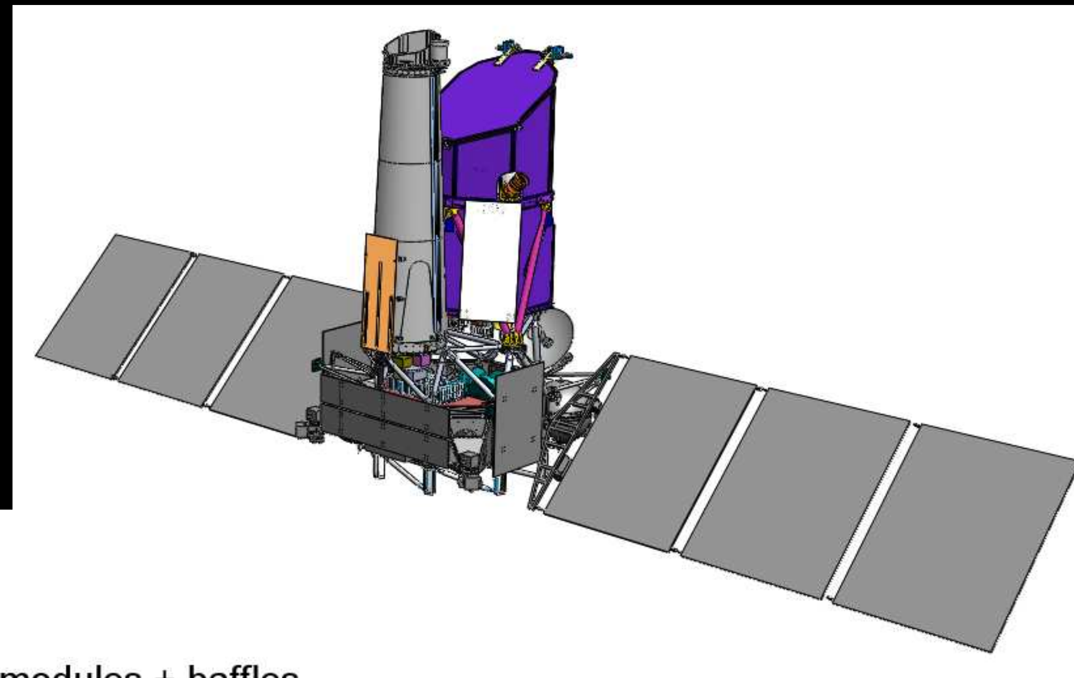
A large fraction of X-ray sky accessible to *XMM-Newton* is unknown!

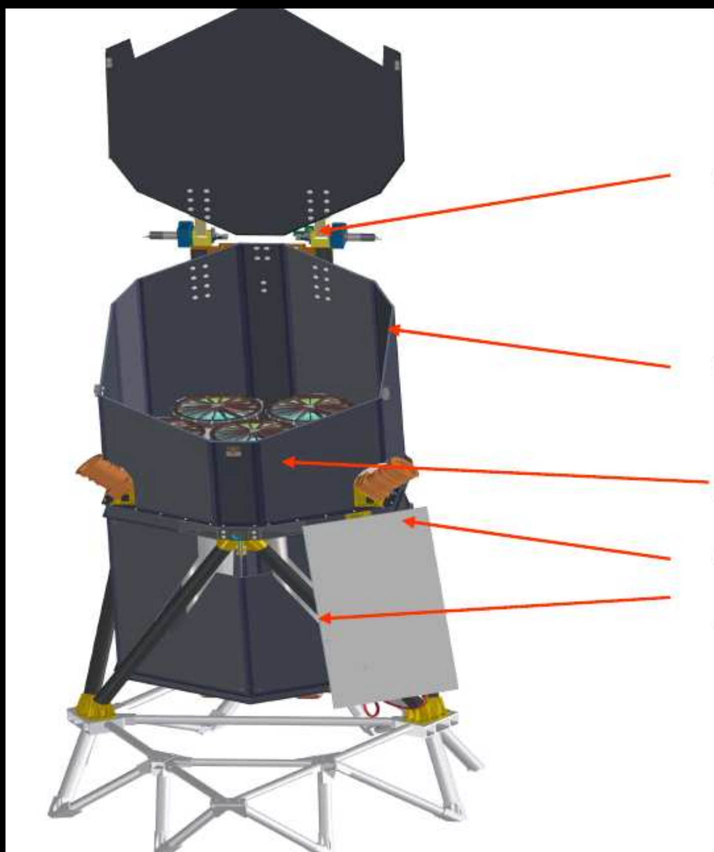


eROSITA (extended ROentgen Survey with an Imaging Telescope Array) on Spectrum-XG

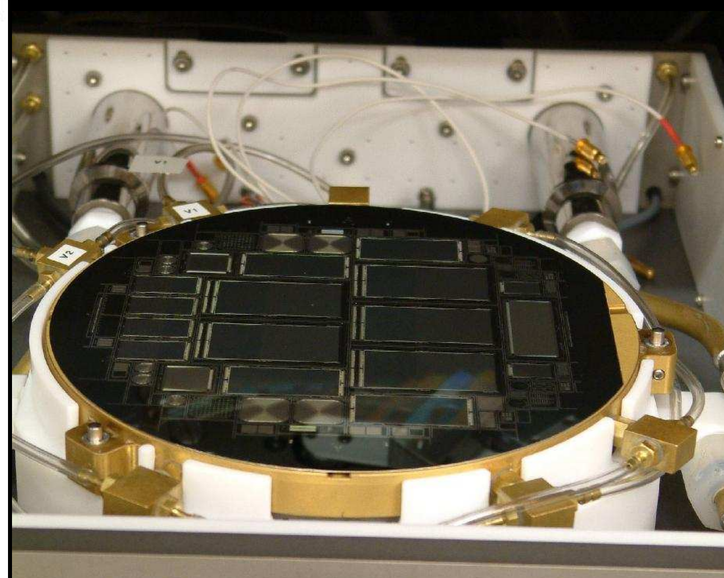
- Launch: Fall 2012, 4 year survey + pointed phase.
- Collaboration: Germany (MPE, IAAT, AIP, FAU, Hamburg)+Russia
- Extends *ROSAT* survey to 10 keV, 30$\times$ deeper
- 3 000 000 supermassive black holes
- 100 000 galaxy clusters $\Longrightarrow \Lambda$, w

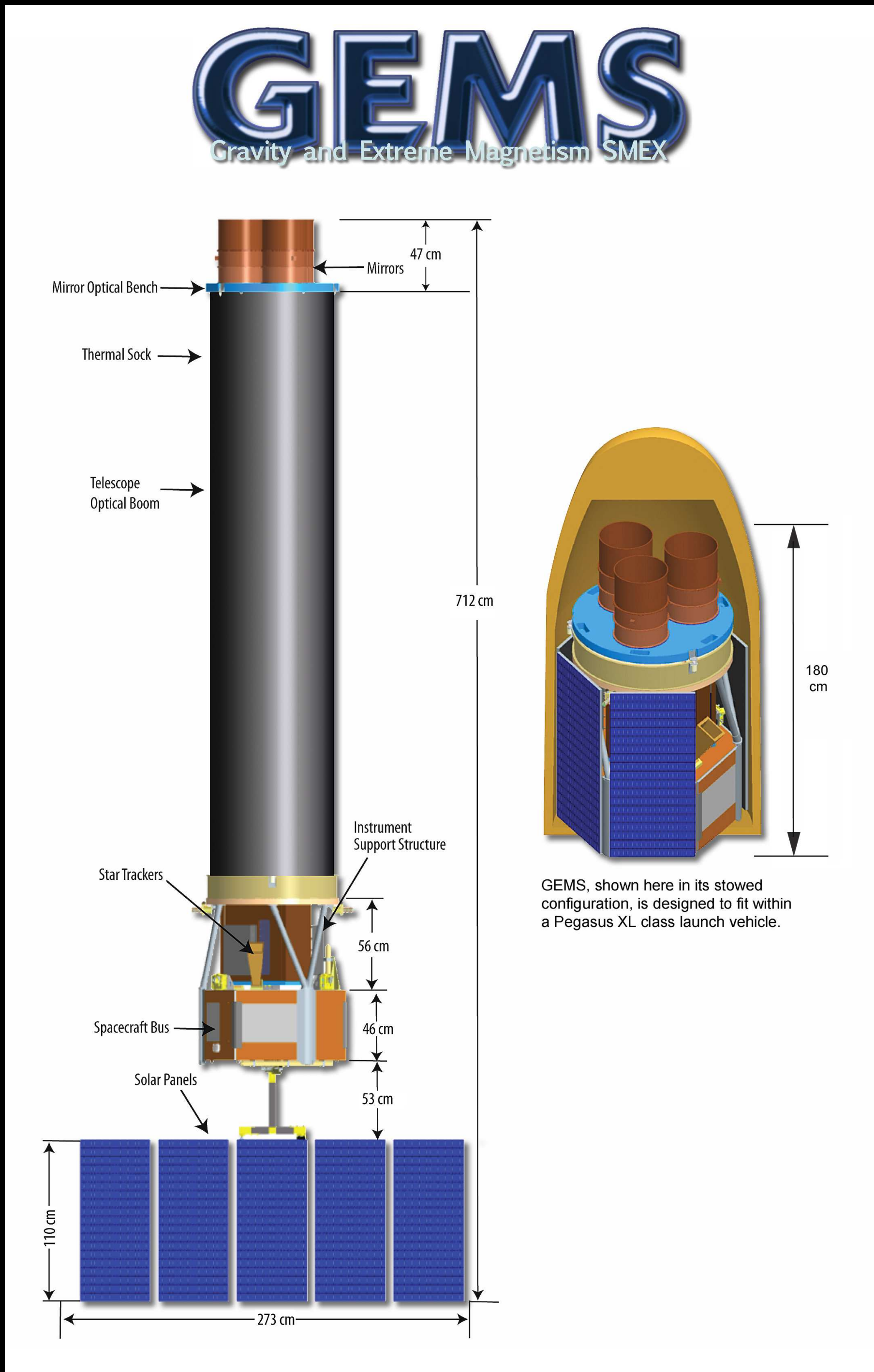


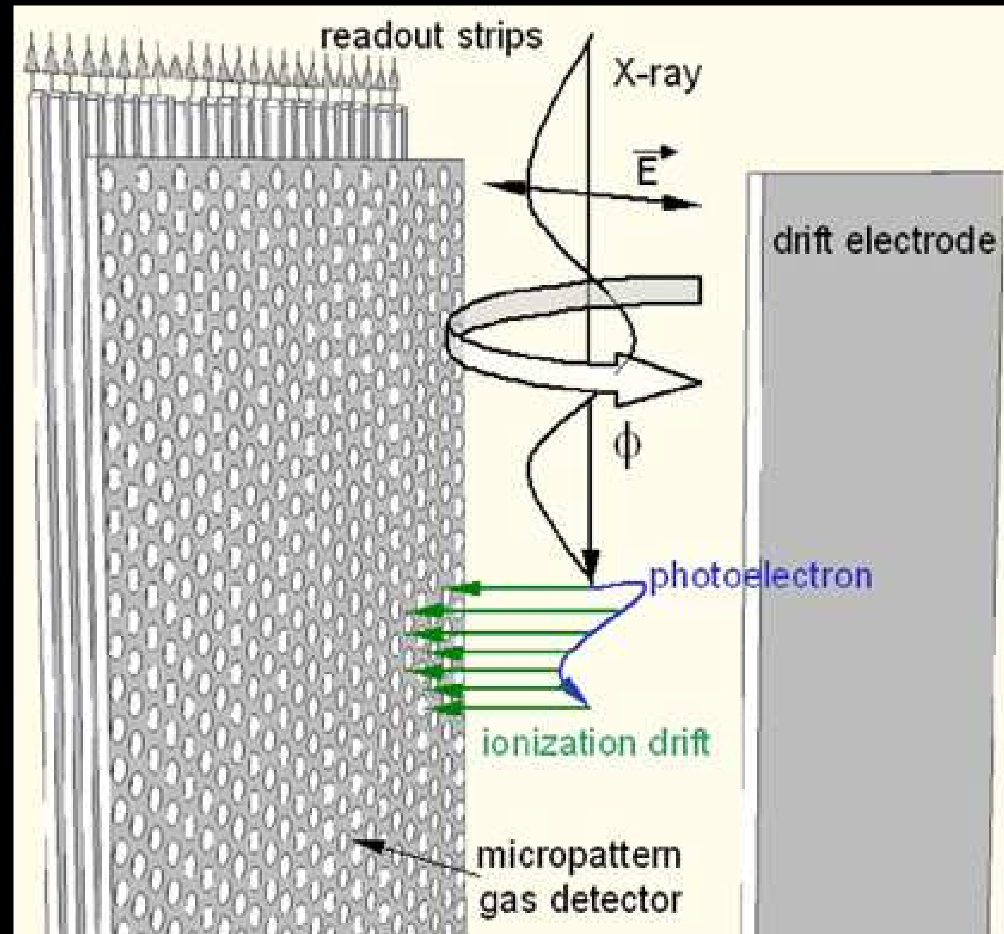




- 7 mirror modules + baffles, 54shells, $7 \times 350 cm^2$, f=160cm
- 2 (redundant) startrackers
- hexapod mounting for stability
- radiator for cooling cameras
- 7 pn-CCD cameras



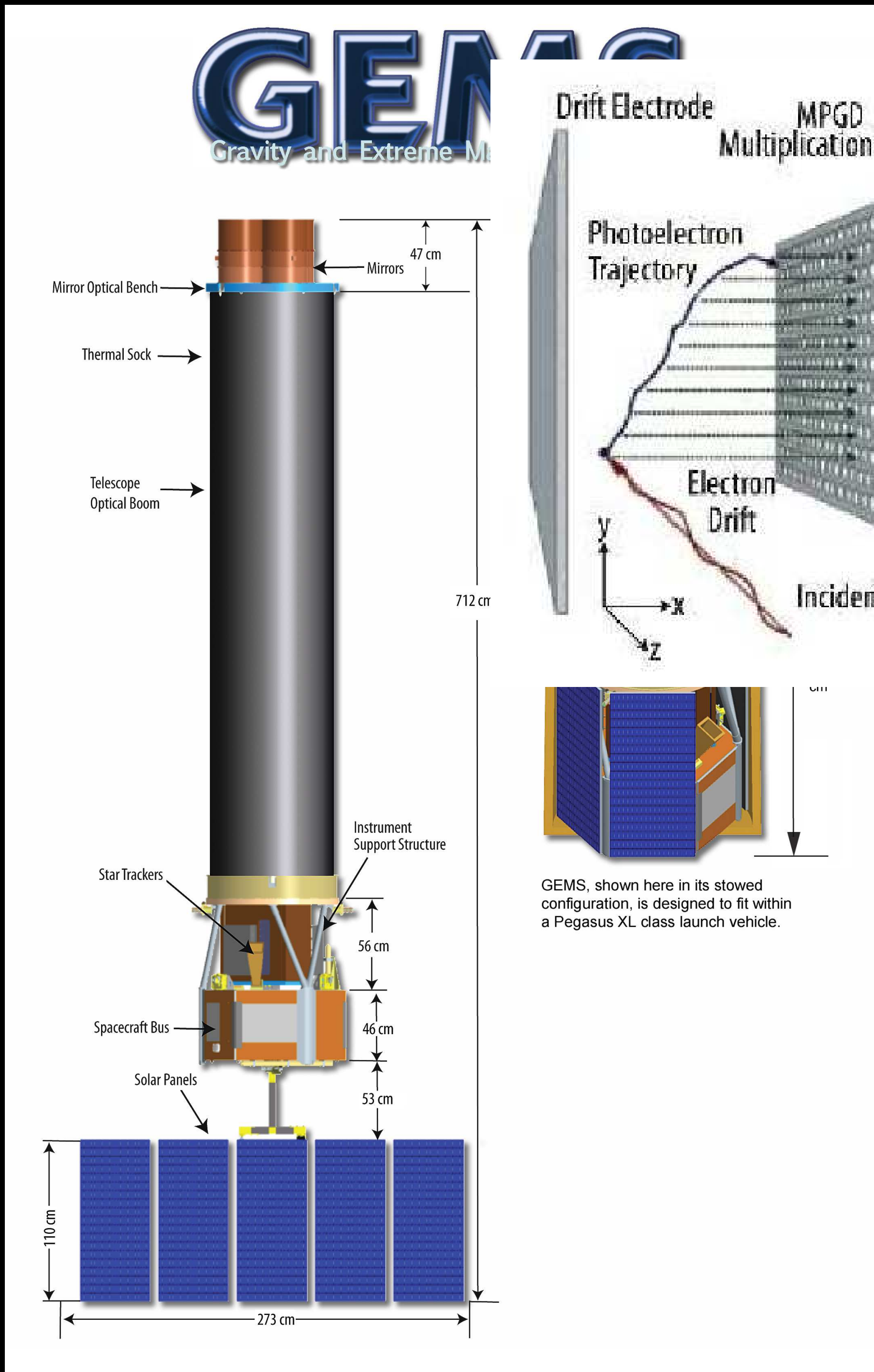




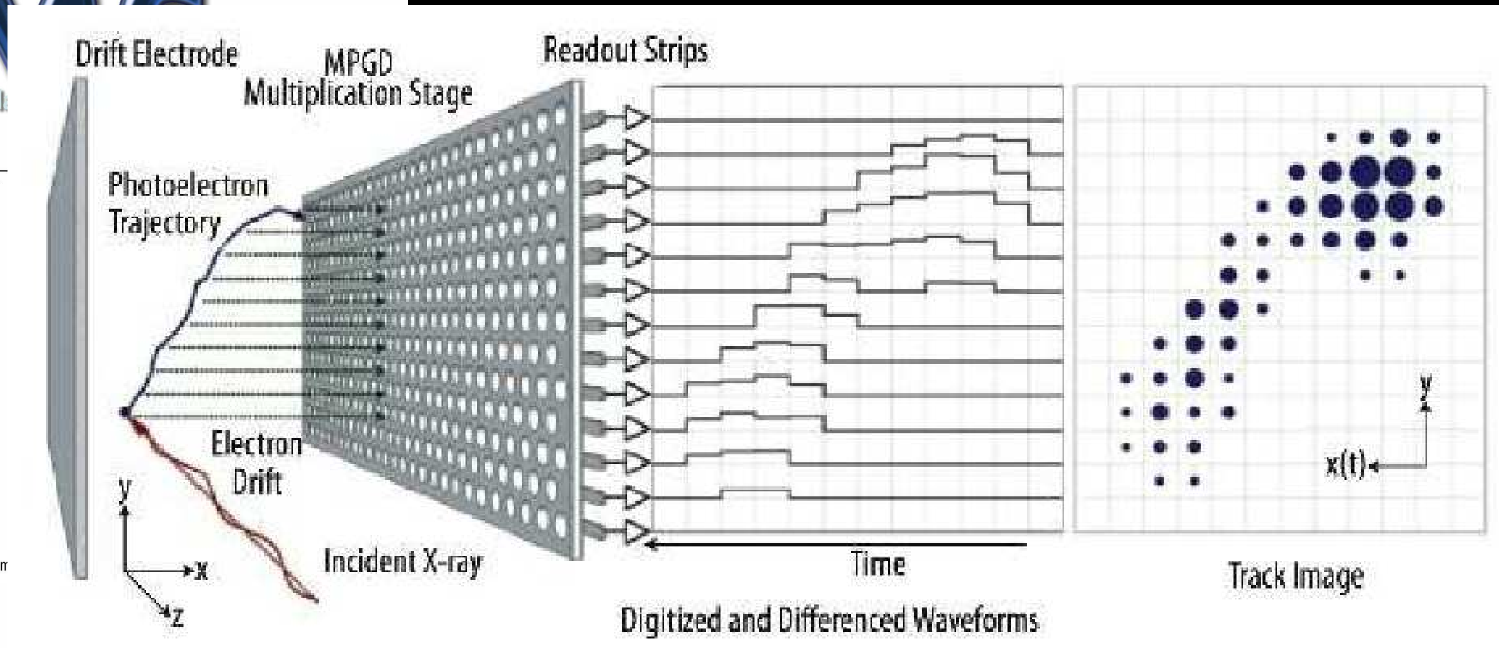
K. Black/SPIE

GEMS:

- Launch: 2014/2015
- polarization to ∼1% for ∼40 sources
- 2–10 keV
- foil mirrors



GEMS, shown here in its stowed configuration, is designed to fit within a Pegasus XL class launch vehicle.



J. Swank

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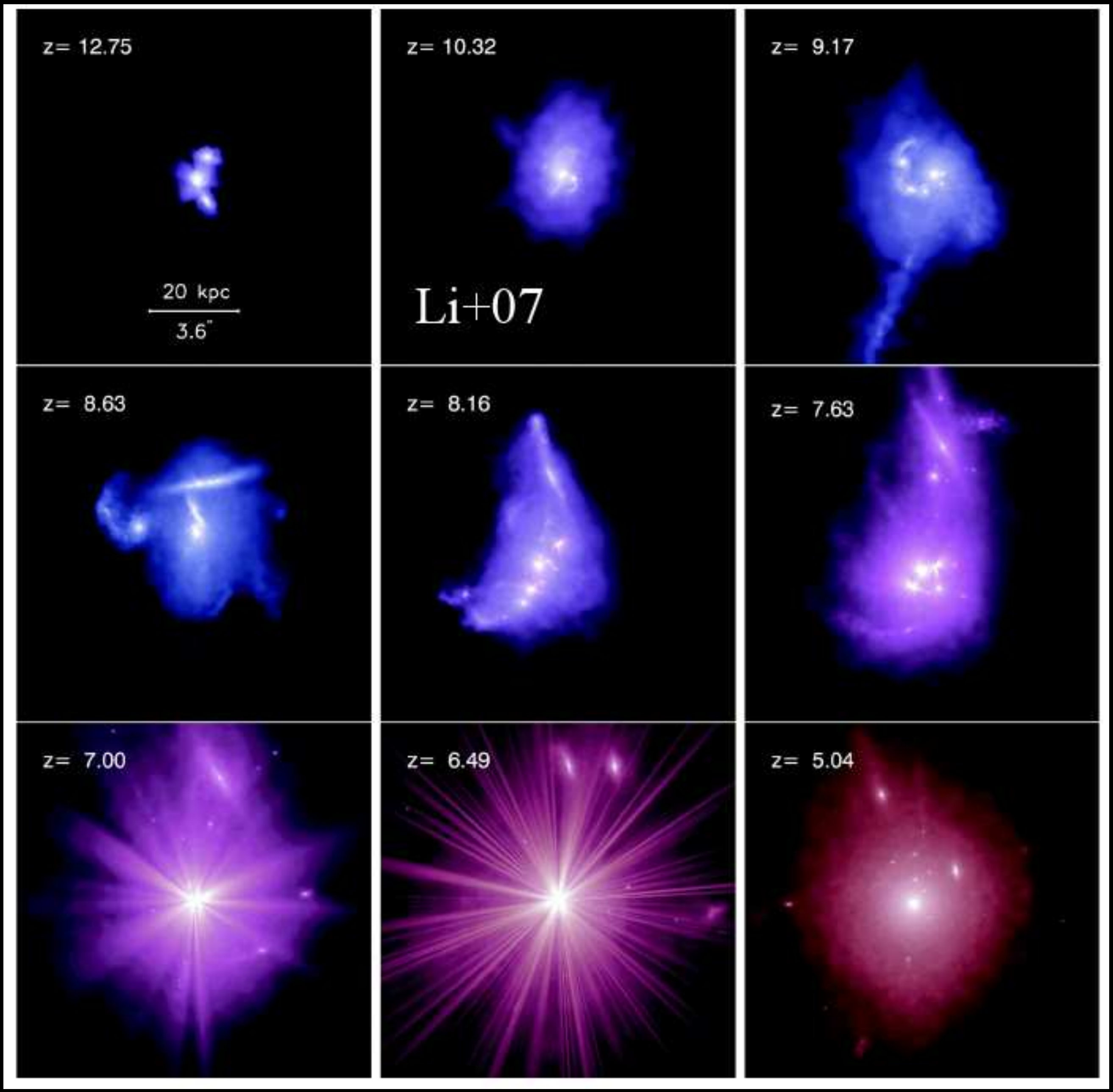


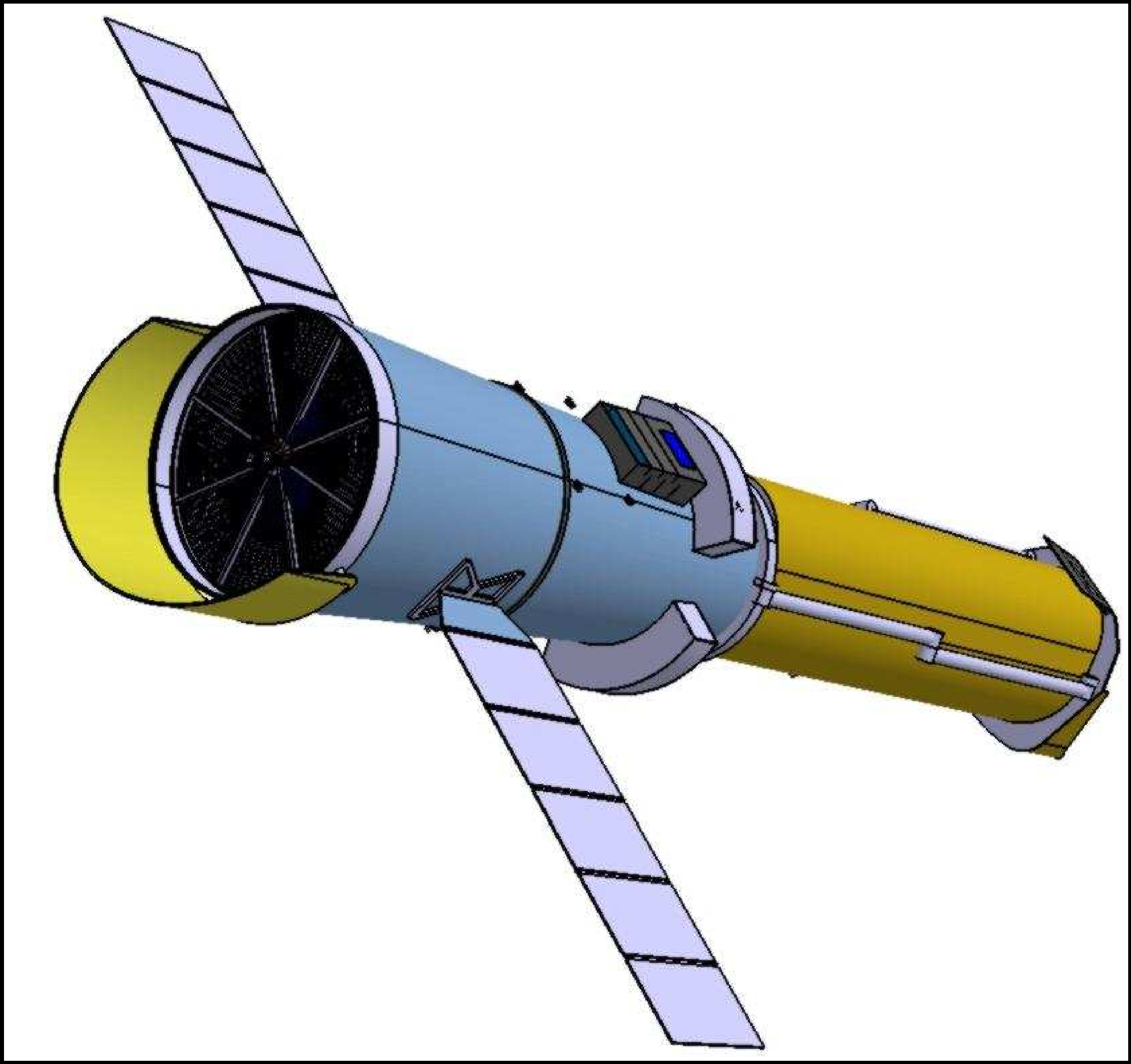
Major driver cosmology.

Black Hole Feedback:

Early Universe: gas merges to form galaxies

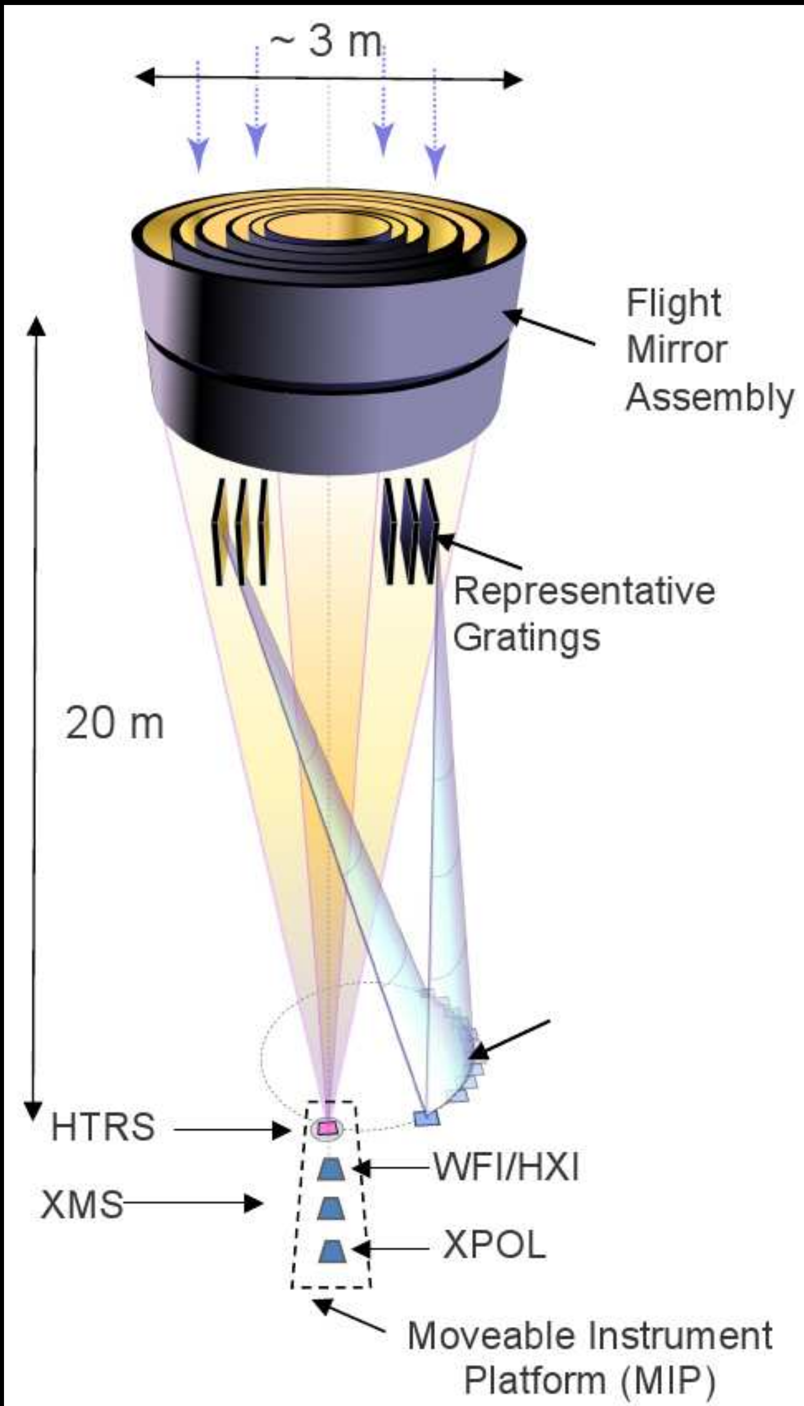
1. gas flows inwards onto small black hole
2. X-rays are produced, heating gas
3. gas swept away
4. star formation and black hole X-ray emission quenched
5. gas flow starts again
6. goto 1

$\Longrightarrow$ X-rays are ideal probe to study evolution of universe.

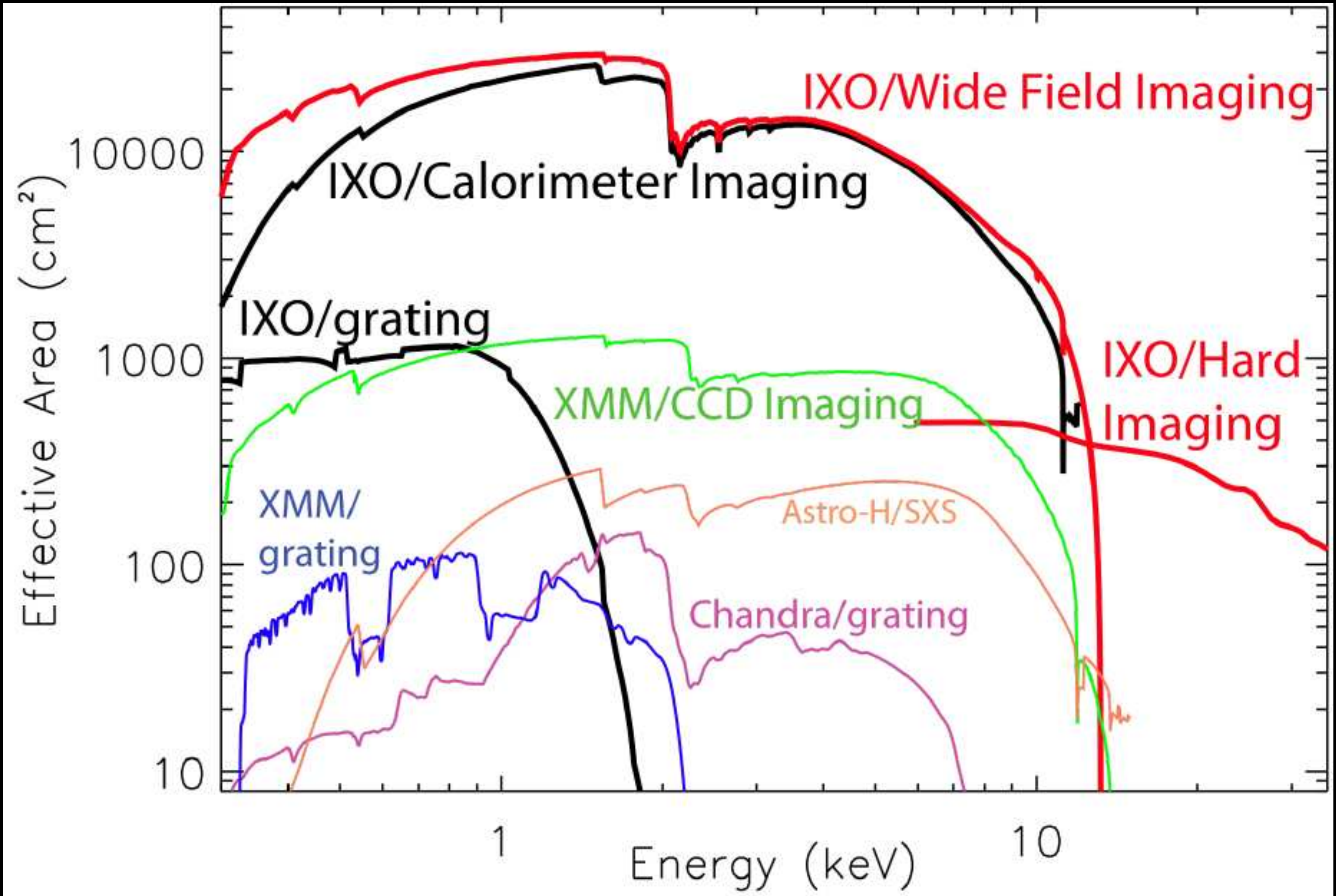


Current observations allow real diagnostics only for objects close to us

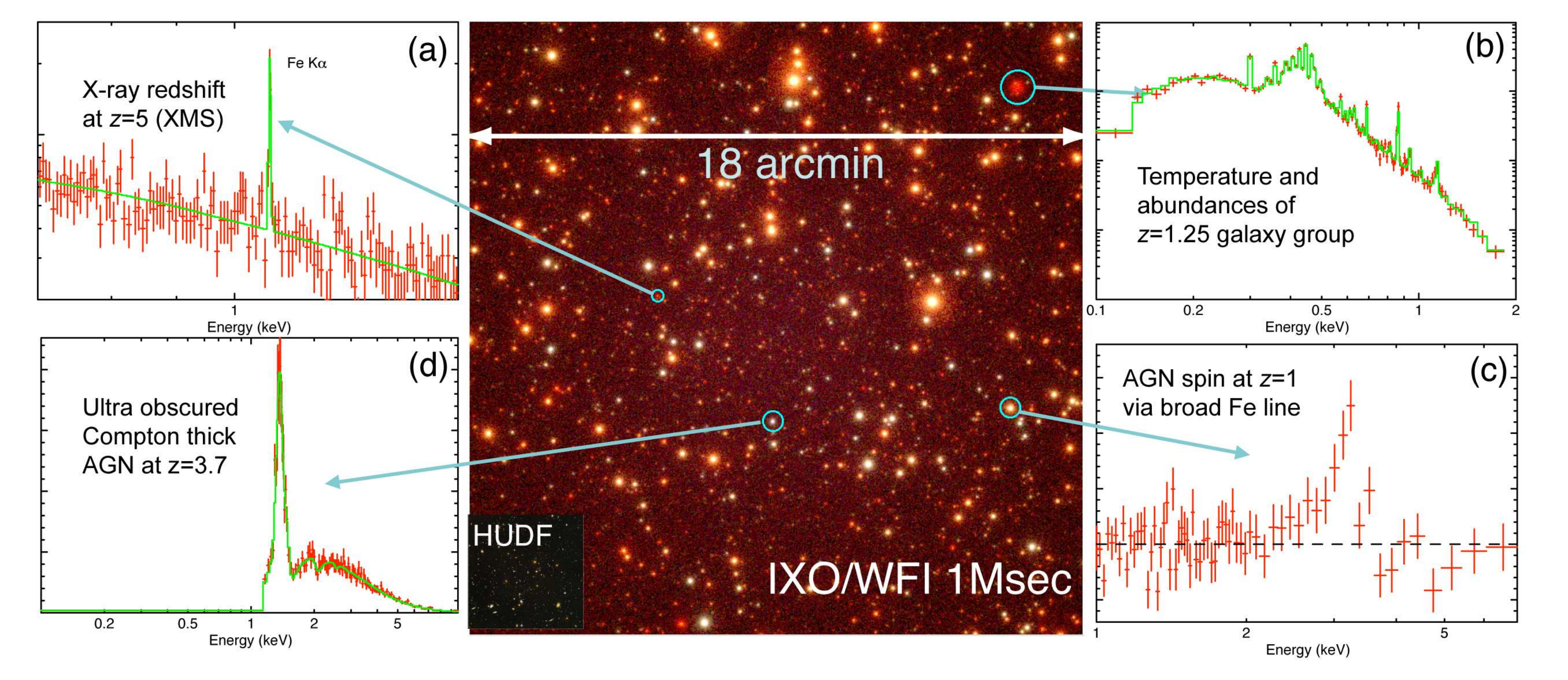
$\Longrightarrow$ International X-ray Observatory (ESA/NASA/JAXA)



- Launch: $\sim$2021
- L_2-Orbit (800 000 km radius)
- Highly nested grating incidence optics: 3 m^2 at 1.25 keV, $5''$ resolution
- Instruments
  - Wide Field Imager & Hard X-ray Imager
    CCDs, $18'$ FoV, 0.3–40 keV
  - X-ray Grating Spectrometer
    $R =$ 3000 with 1000 cm^2
  - X-ray Microcalorimeter Spectrometer
    2.5 eV with $5'$ FoV
  - High Time Resolution Spectrometer
    1 Crab = 300000 counts/sec
  - X-ray Polarimeter



Collecting Area: tremendous improvement on existing missions (∼30 wrt *XMM*).

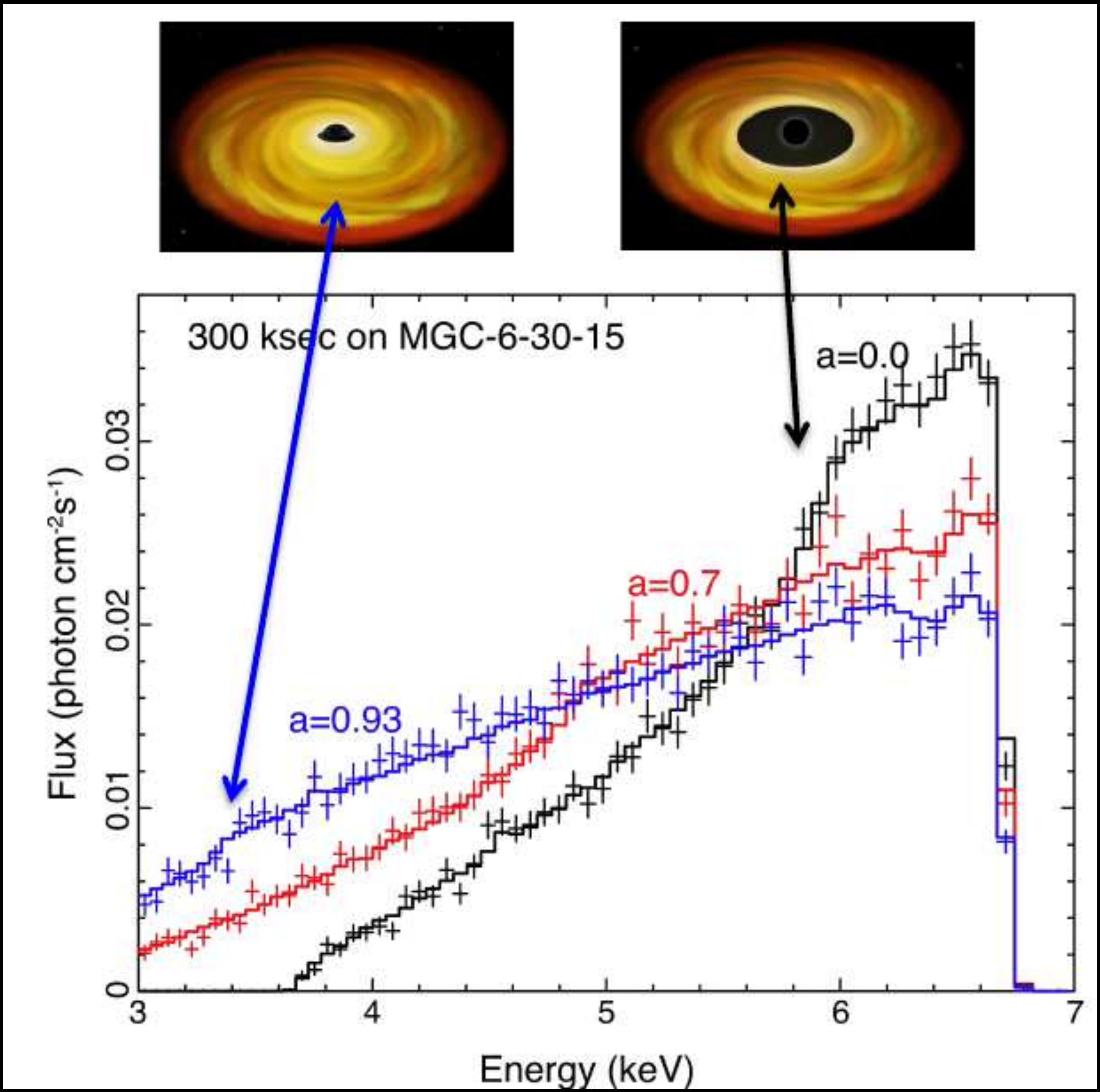


a) determine z from X-rays alone

b) determine temperatures of hot gas out to high z

c) make spin measurements of Black Holes out to $z = 1$

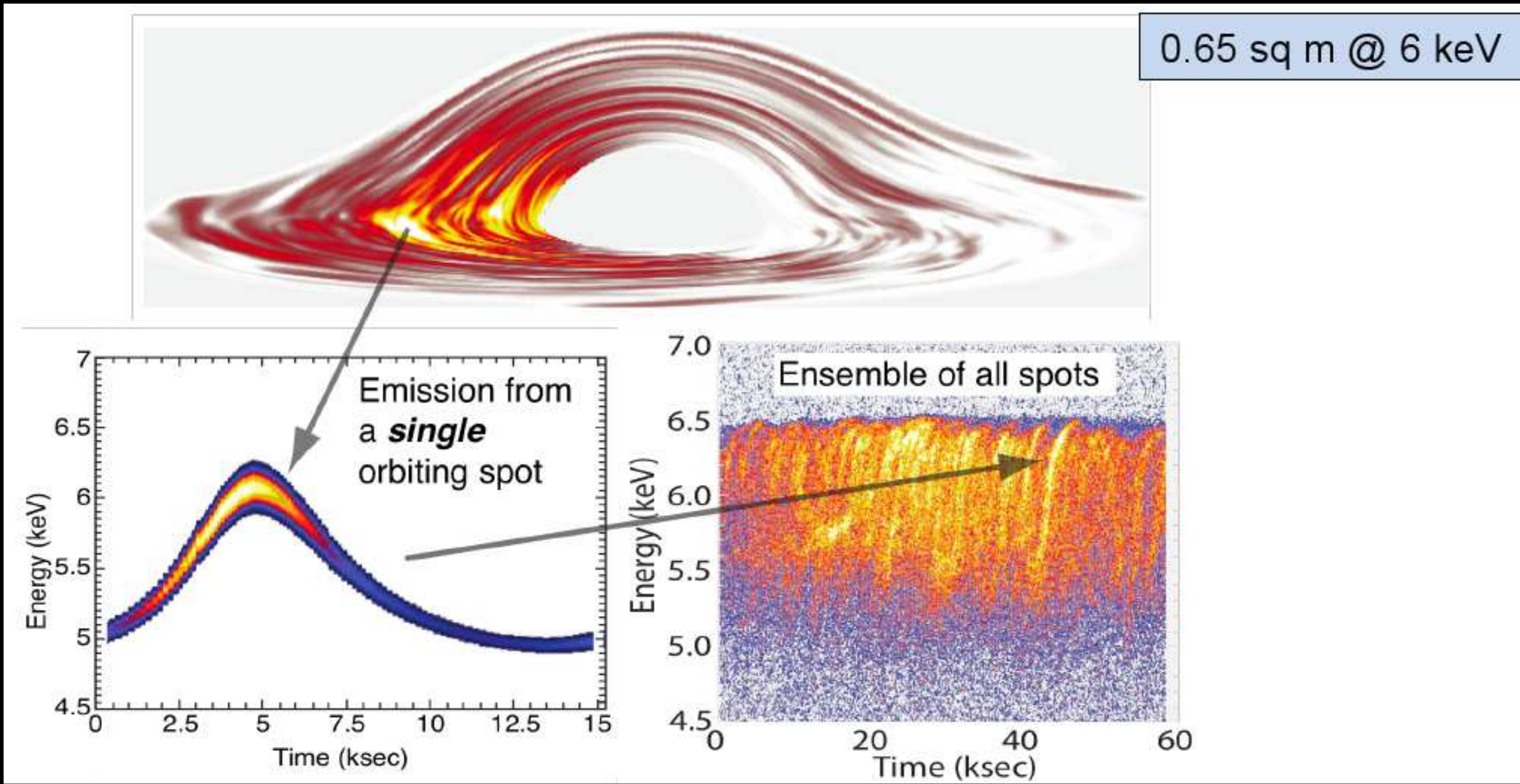
d) detect faint, strongly absorbed Black Holes



Measure black hole spin for $\sim$200 AGN

$\Longrightarrow$ spin up history of black holes

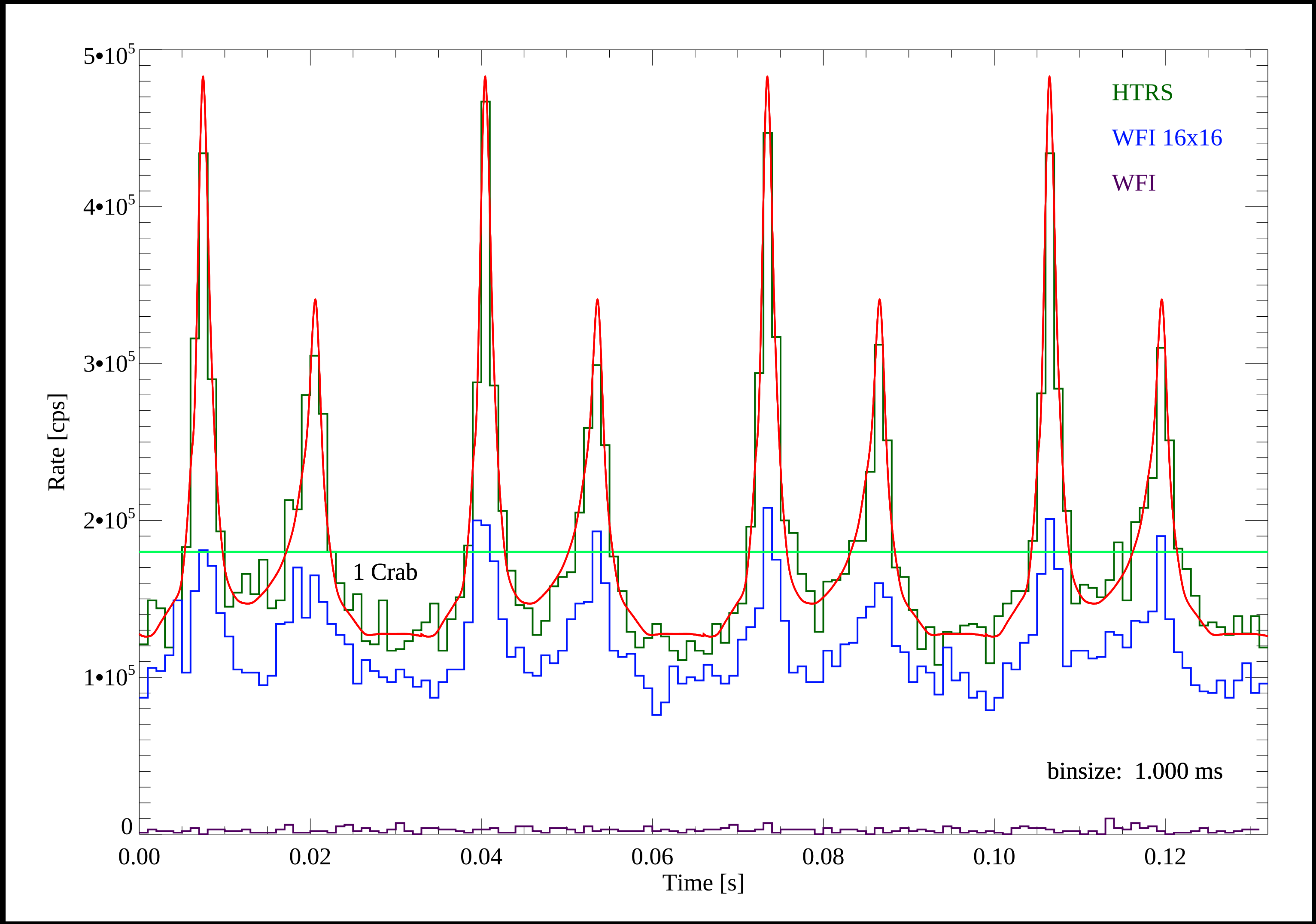
chaotic accretion vs. simple accretion



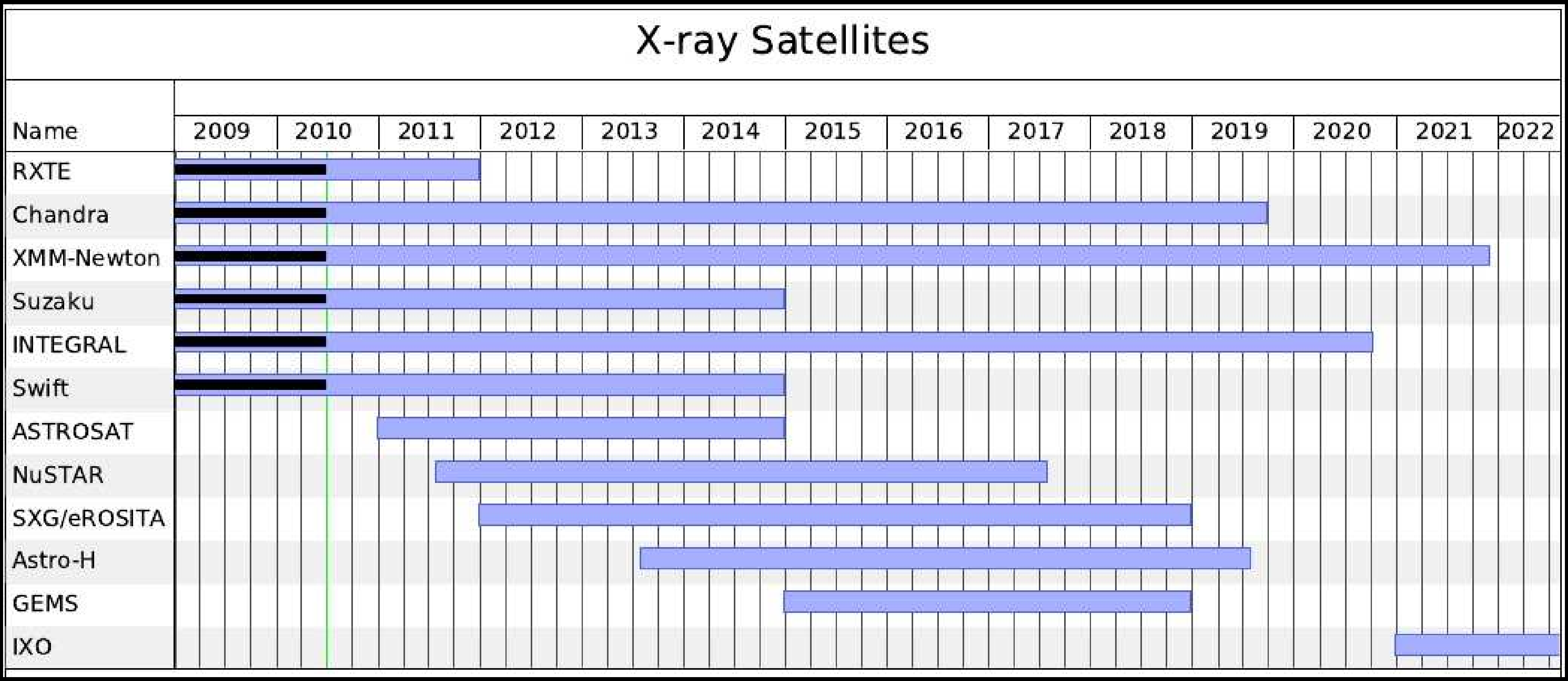
Time variation of Fe line

$\Longrightarrow$ measure properties of metric, BH

$\Longrightarrow$ test general relativity & accretion models



1 Crab = 180 000 counts/sec



The future of neutron star astronomy looks good!

. . . but we need an X-ray monitor (EXIST?!?)