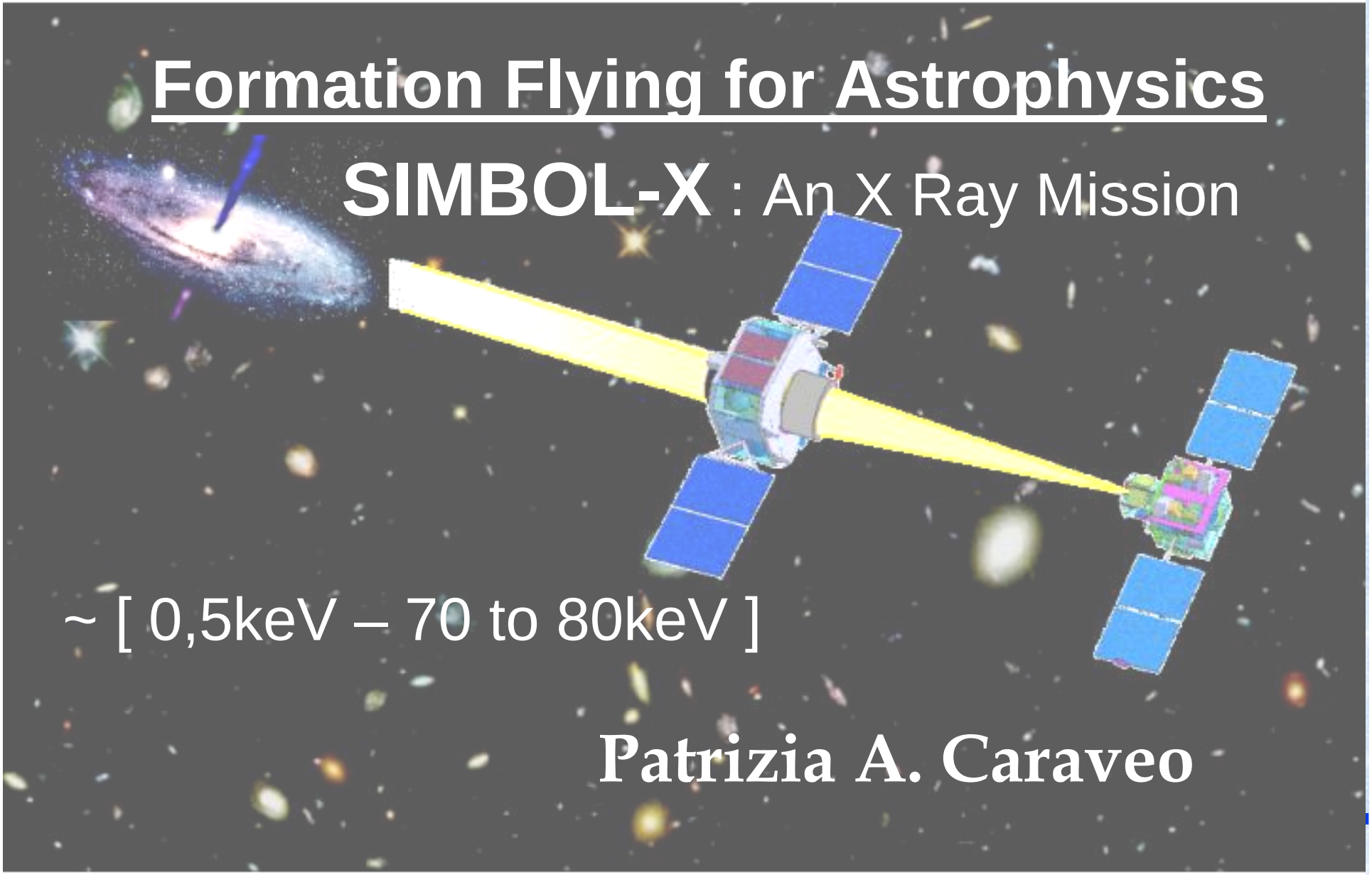
Formation Flying for Astrophysics

SIMBOL-X : An X Ray Mission

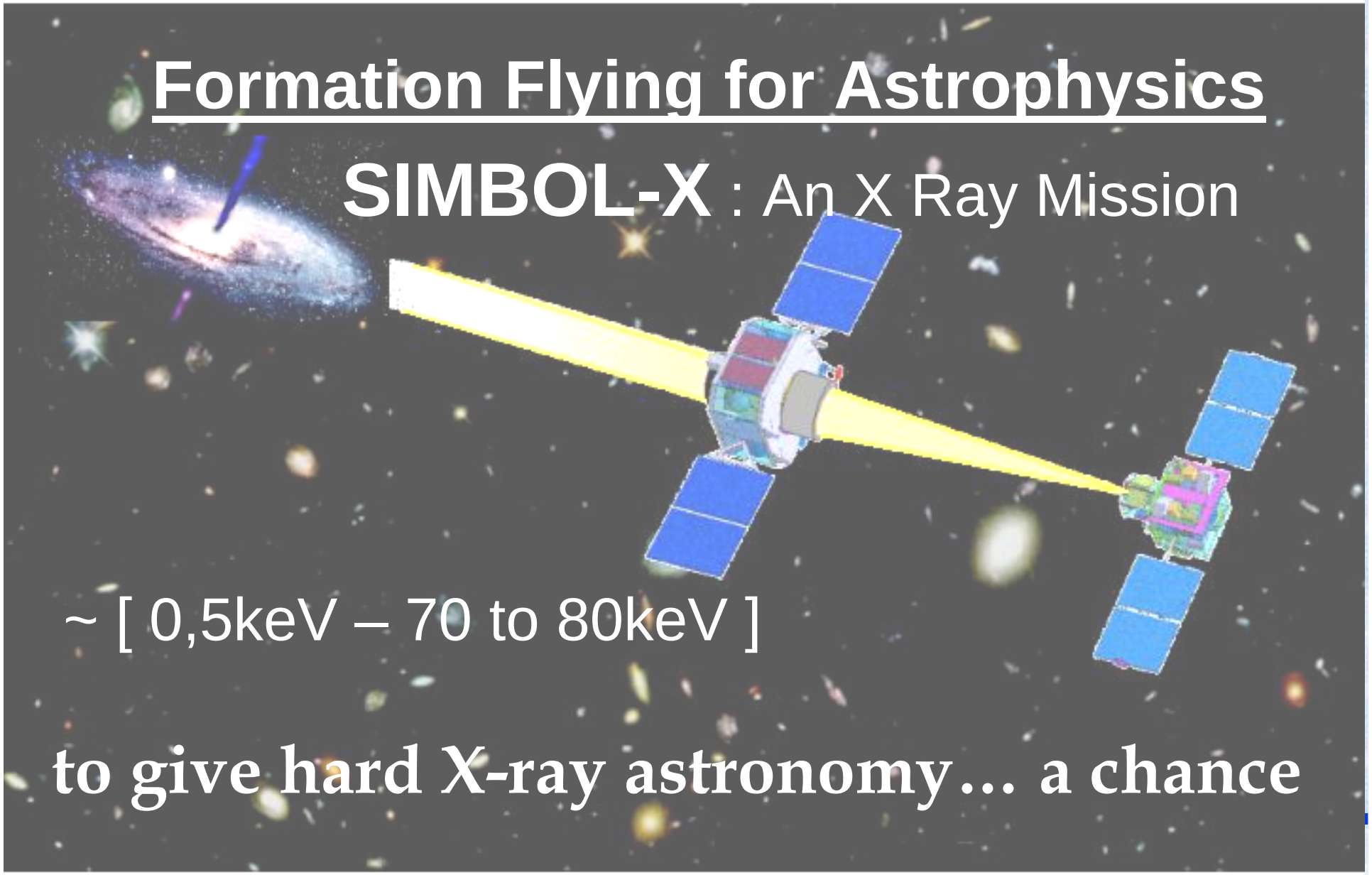


~ [0,5keV – 70 to 80keV]

Patrizia A. Caraveo

Formation Flying for Astrophysics

SIMBOL-X : An X Ray Mission

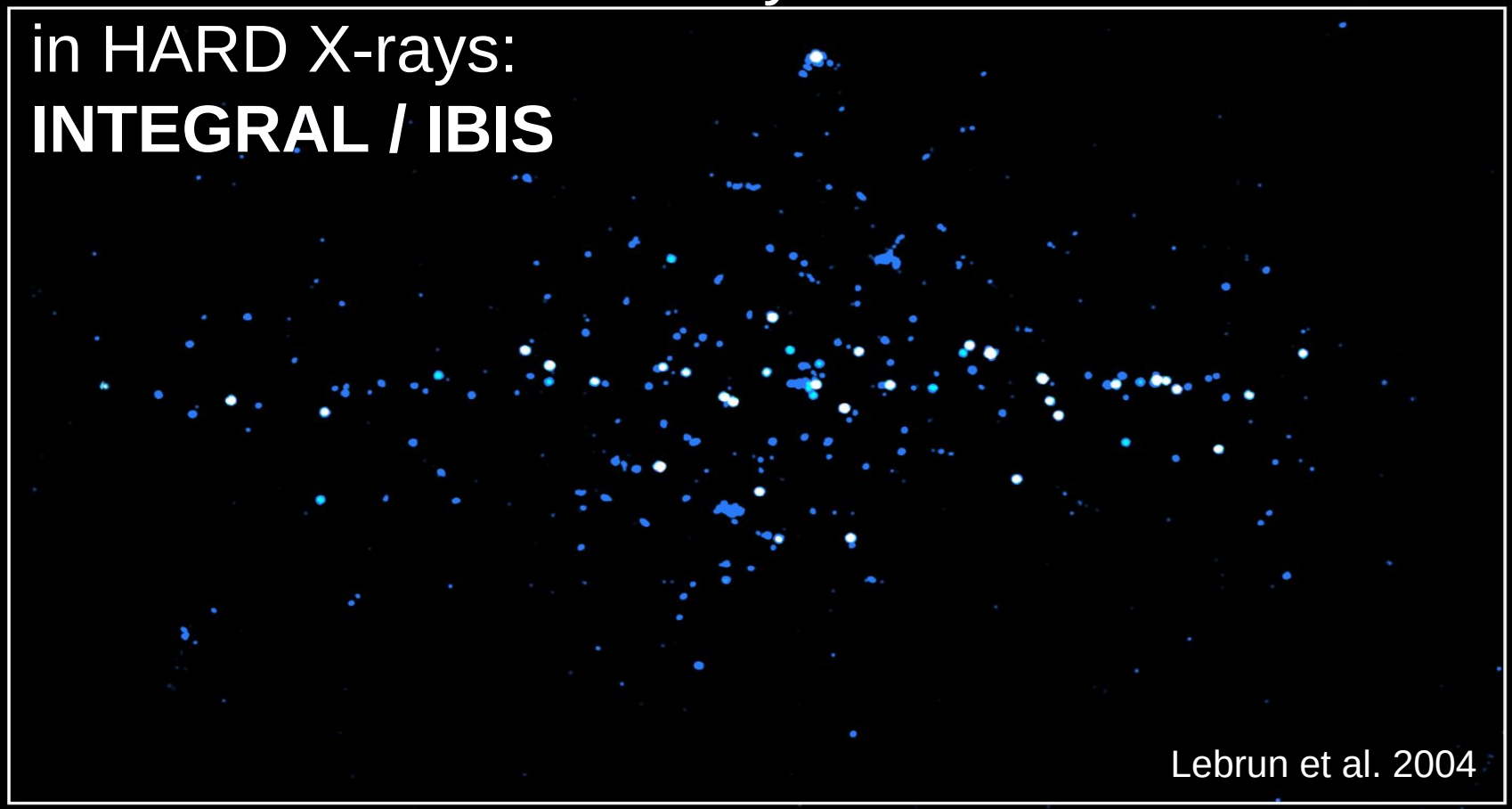


~ [0,5keV – 70 to 80keV]

to give hard X-ray astronomy… a chance

HARD X-ray astronomy is lagging behind SOFT X-ray astronomy

State of the art astronomy
in HARD X-rays:
INTEGRAL / IBIS



Also SWIFT BAT will produce a survey

INTEGRAL

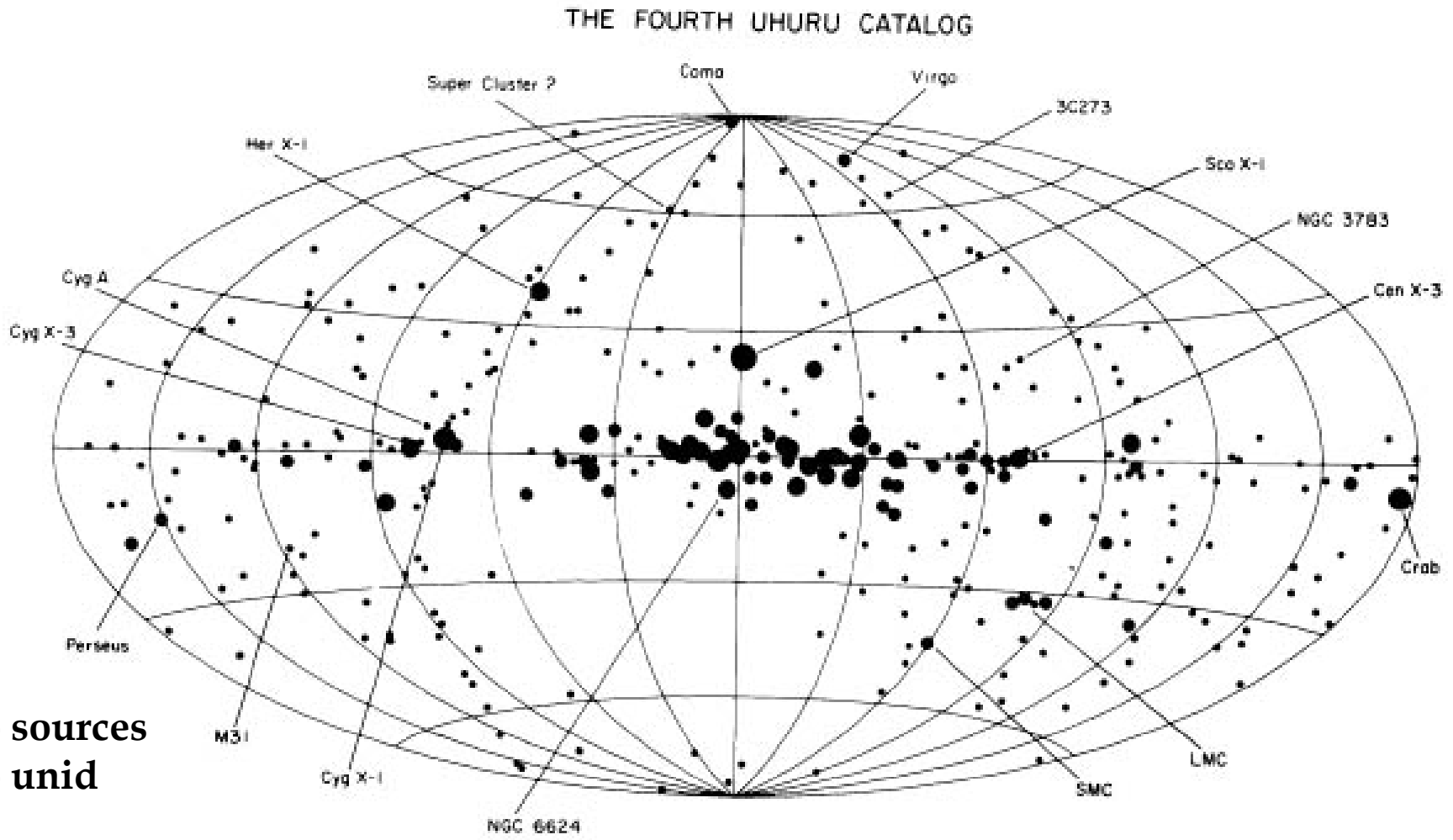
~ 1 milliCRAB sensitivity 20-100 keV

~ 200 sources in the whole sky

Bird et al. 2006, ApJ

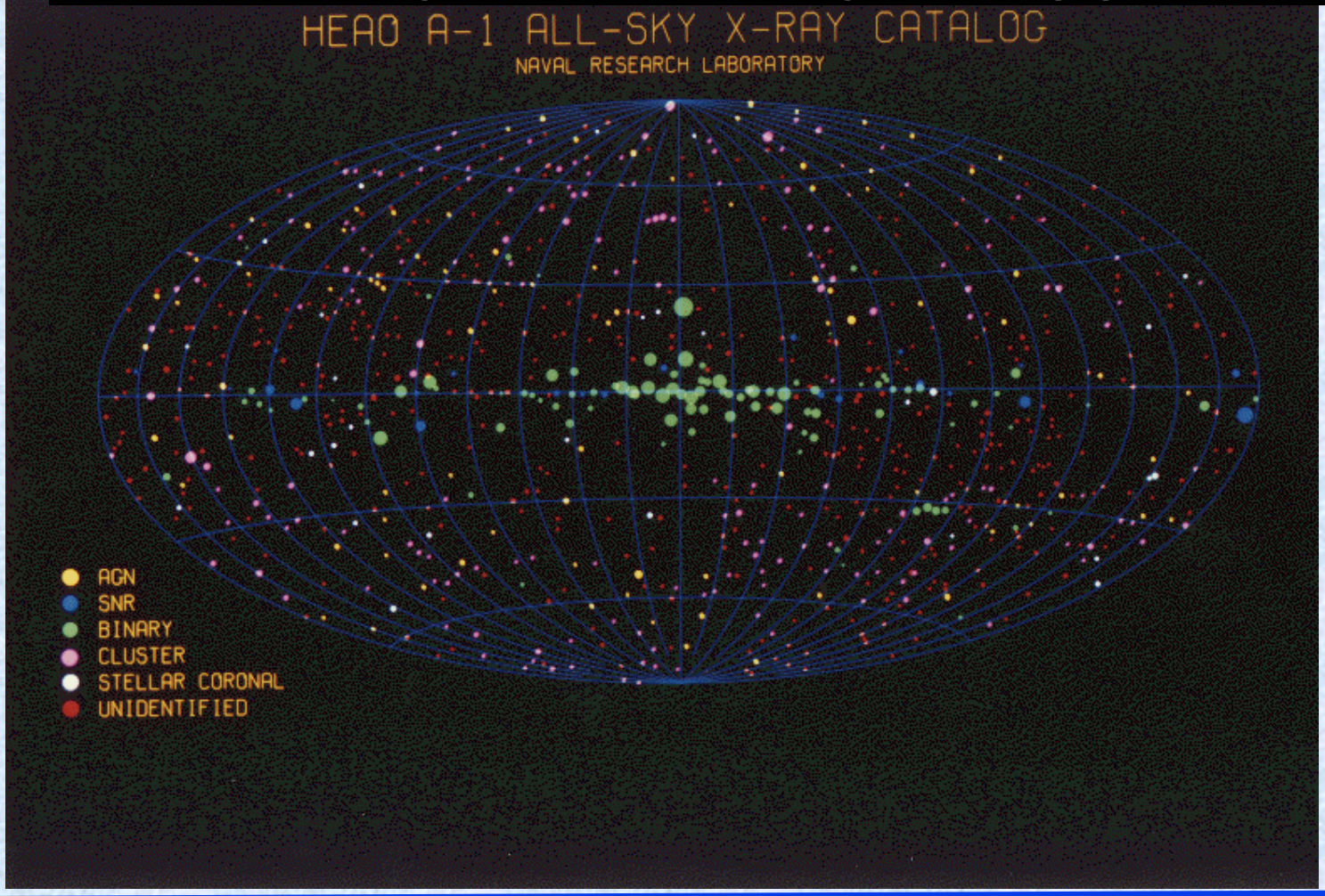
→ We are now in HARD X-rays in the same situation as Soft X-ray astronomy before the Einstein Observatory

Soft X-ray astronomy: the beginning



336 sources
206 unid

Soft X-ray astronomy…bigger instruments



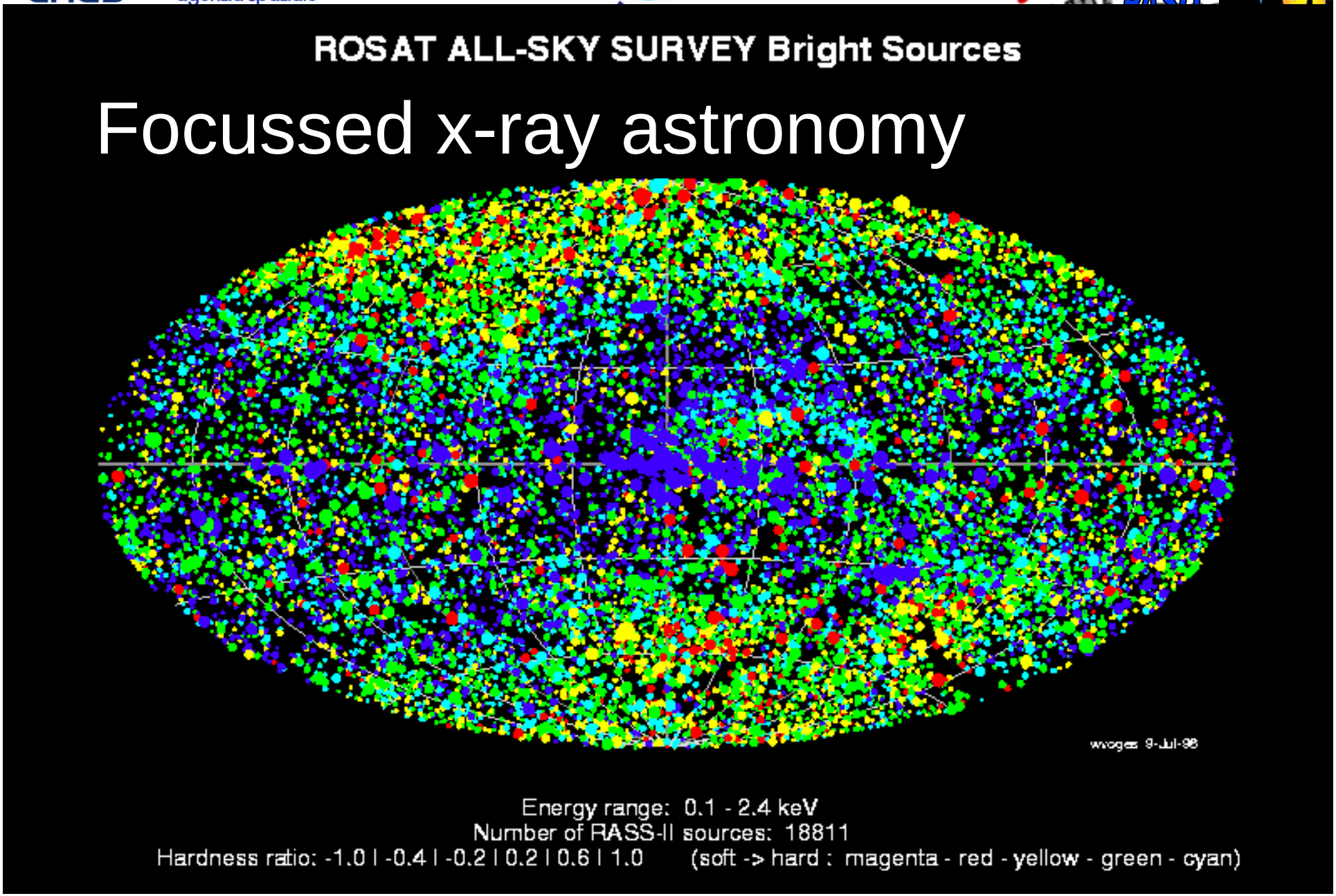
HEAO 1

~ 1977-1979

~ 1 milliCRAB

842 sources in the whole sky

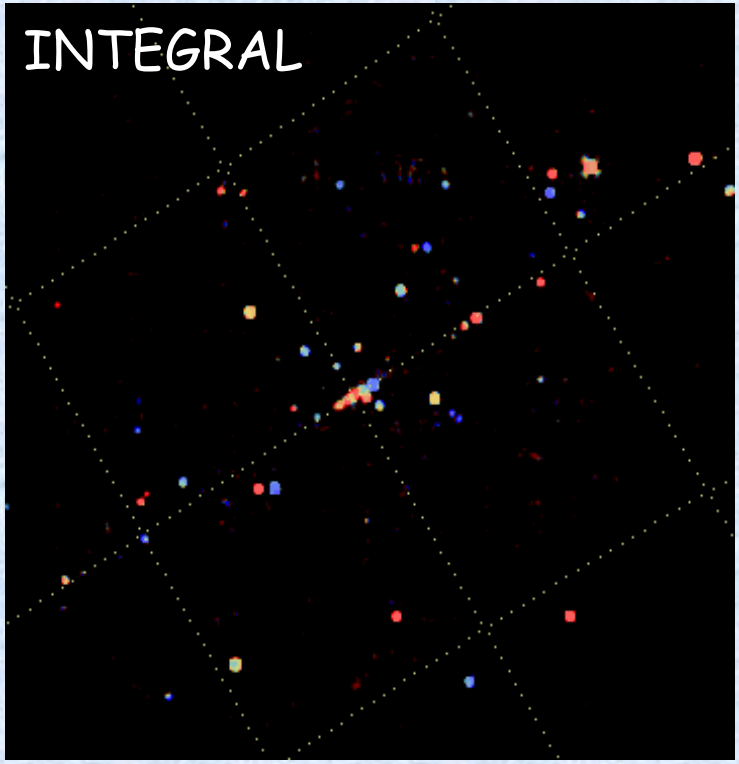
Focussed x-ray astronomy



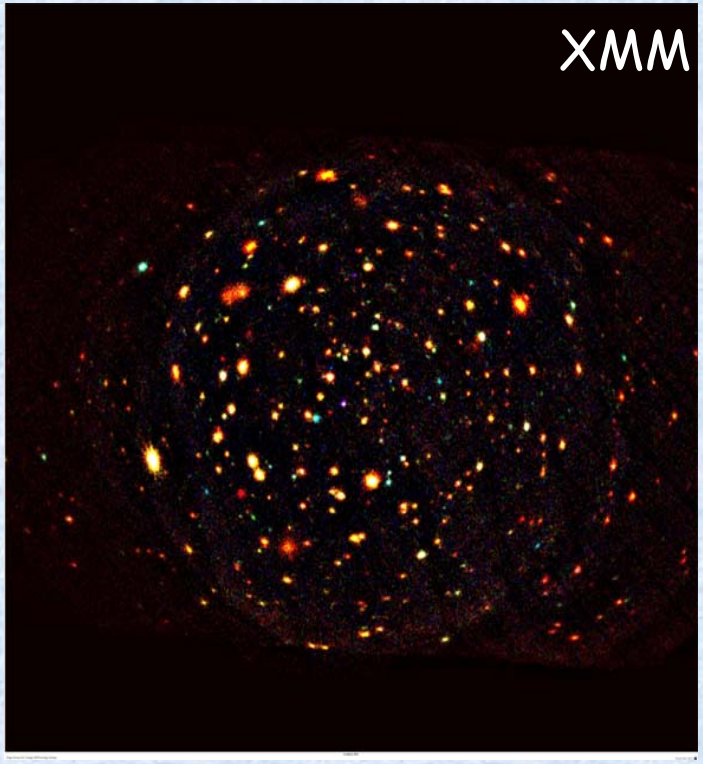
Why astrophysics in HARD X-rays is always behind that in SOFT X-rays ?

- Sources
  - → less photons at high energy
- Instruments
  - → smaller cross section
  - → difficulty of focusing

Hard X-ray astronomy is still in an “exploratory” phase

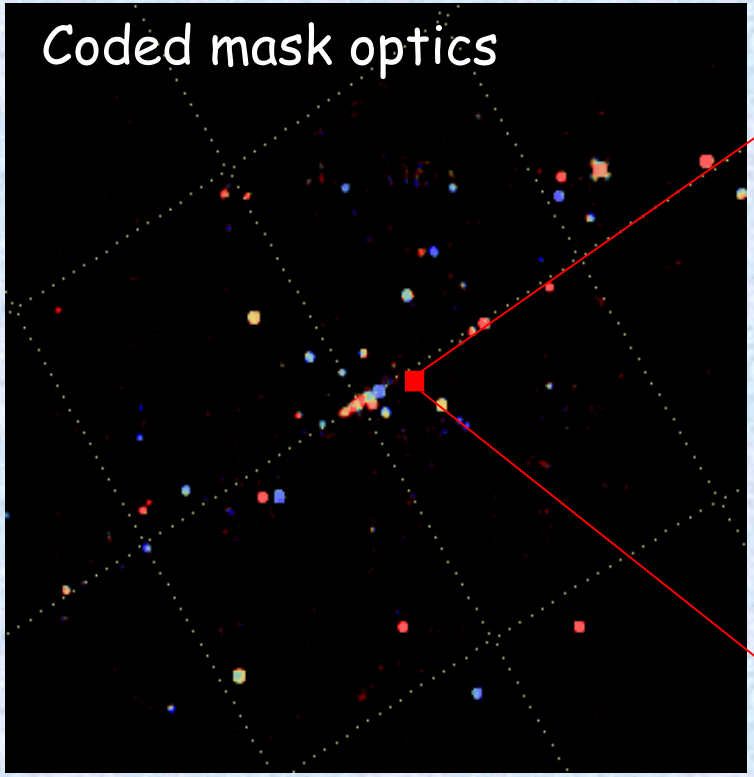


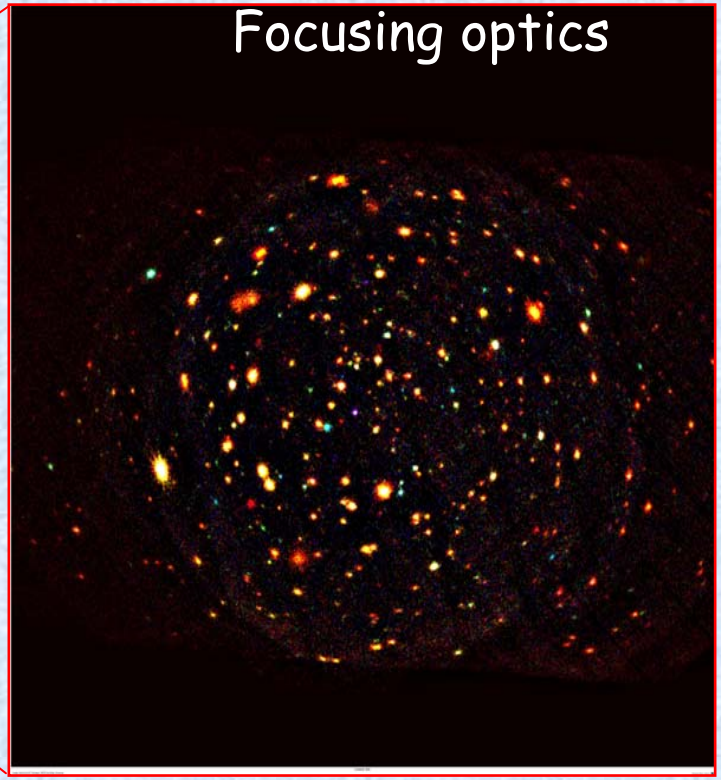
30 degrees



30 arcmin

A sensitivity and angular resolution similar to XMM-Newton but in the INTEGRAL energy range would give a tremendous advance in the study of compact objects





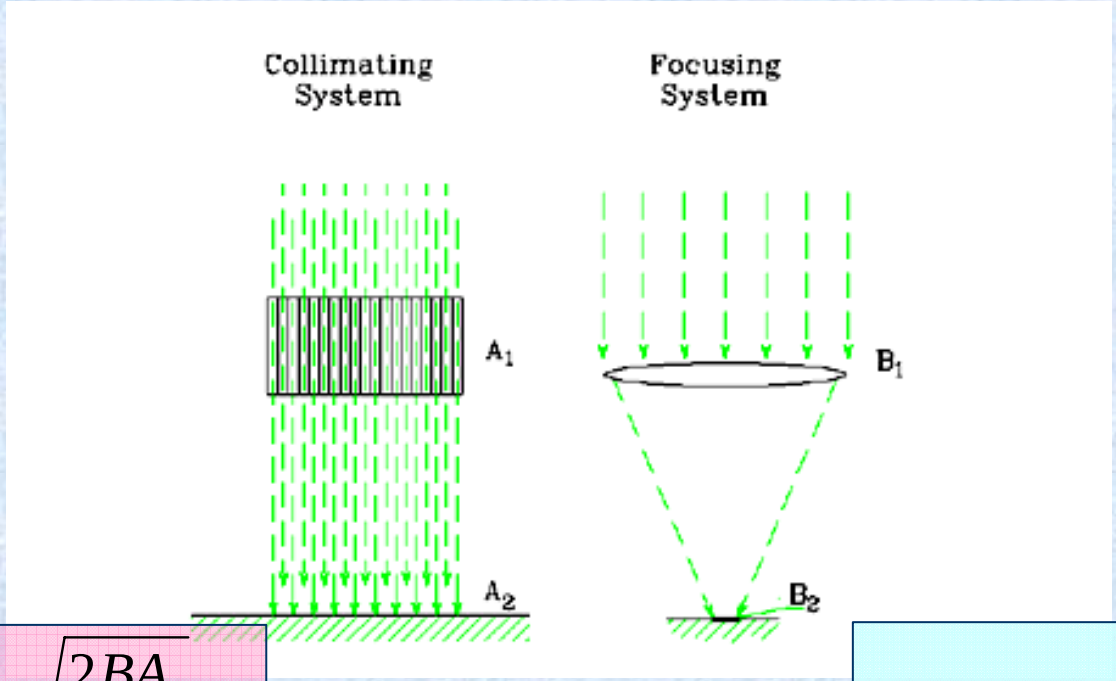
Scientific Requirements for a competitive hard X-ray mission

- **Good sensitivity over broad E range:**
  - 1-10 microCRAB (i.e. a factor >~ 100 improvement)
  - from ~<1 keV to >~80 keV
- **Good imaging:**
  - Angular resolution in the 15-30 arcsec range
  - Over a field of view of ~10 arcmin diameter
- **Spectral resolution:** ~100 eV @ 6 keV, ~1 keV @ 60 keV
- **Timing capability:** ~ ms level, possibly better

Advantages of focusing systems

Imaging is not the only advantage:

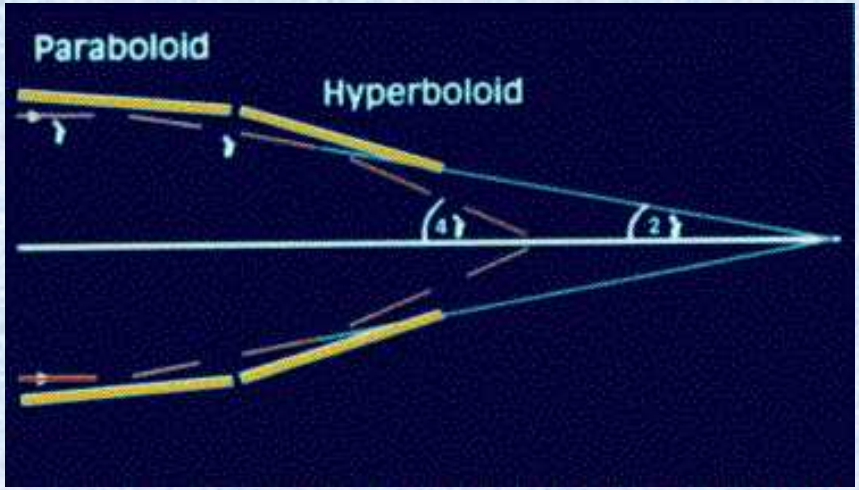
much smaller background permits a large improvement in sensitivity

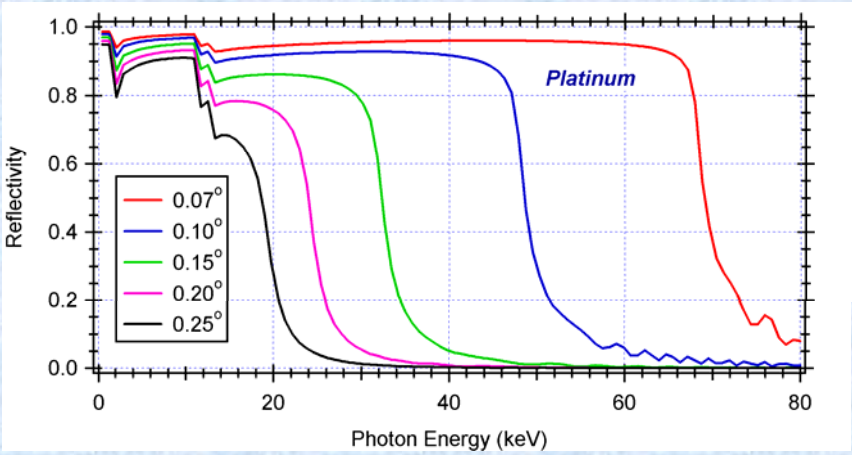


$$F_{\min} = n_\sigma \frac{\sqrt{2BA}}{A\sqrt{T_{\text{int}}\,\Delta E}}$$

$$F_{\min} = n_\sigma \frac{\sqrt{A_{spot}\,B}}{0.5 * A_{eff} * \sqrt{T_{\text{int}} * \Delta E}}$$

Grazing incidence X-ray reflection



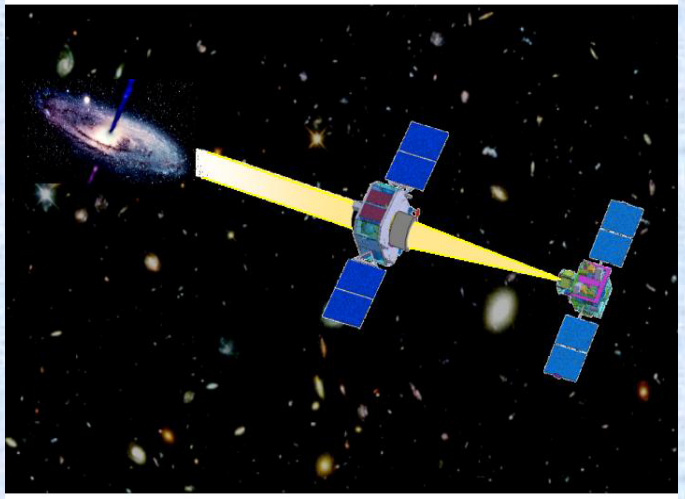


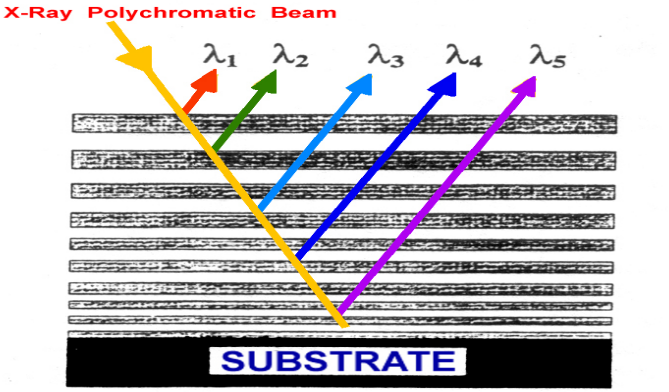
How to go to higher energies ?

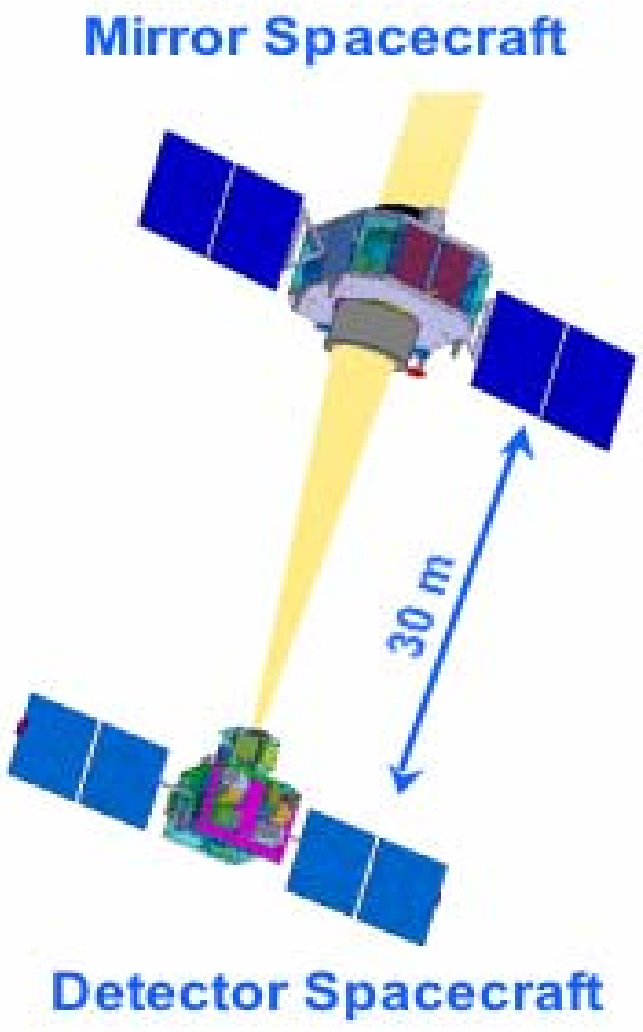
1) Increase focal length

… or / and…

2) Increase reflectivity using multi-layer mirrors







Formation flight concept

Mirror Spacecraft :

- focalizes the X-rays with Wolter mirror (f~30 m),
- participate to the baffling against diffuse X-ray sky,
- super-fine attitude control to the observed targets,

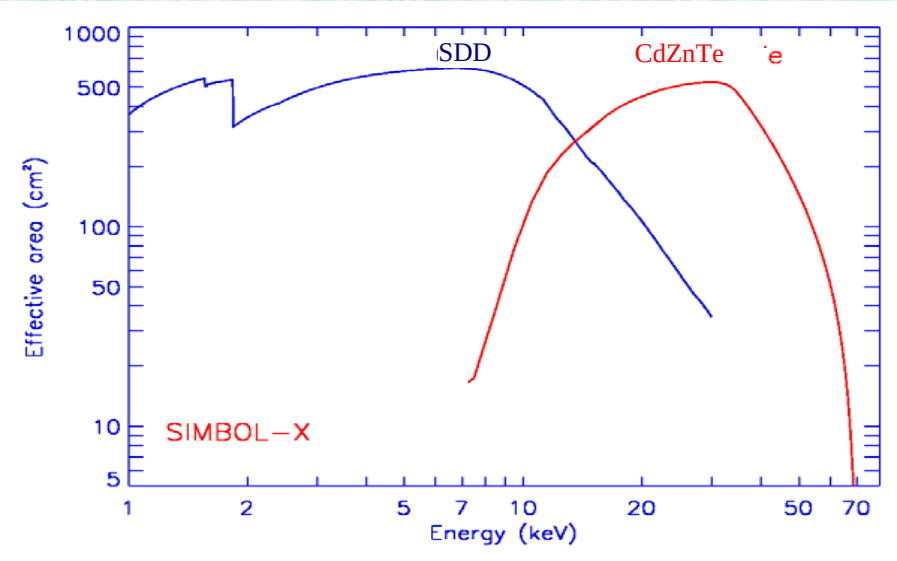
Detector Spacecraft :

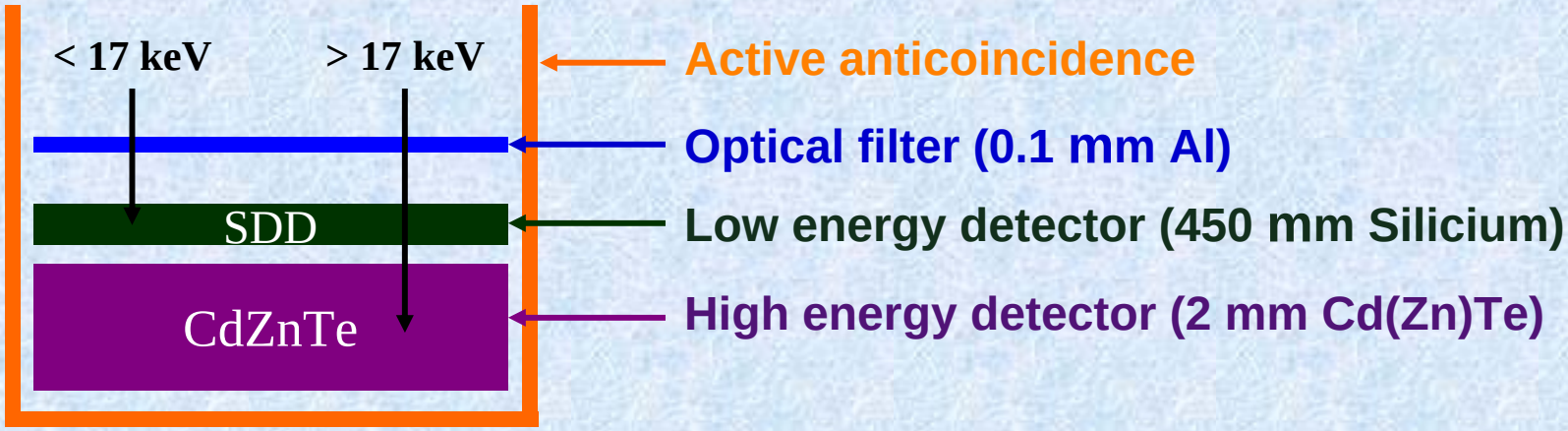
- carries focal plane detectors & transmit data to Ground
- participate to the baffling against diffuse X-ray sky,
- formation flying control with respect to the mirror s/c

Mission scenario :

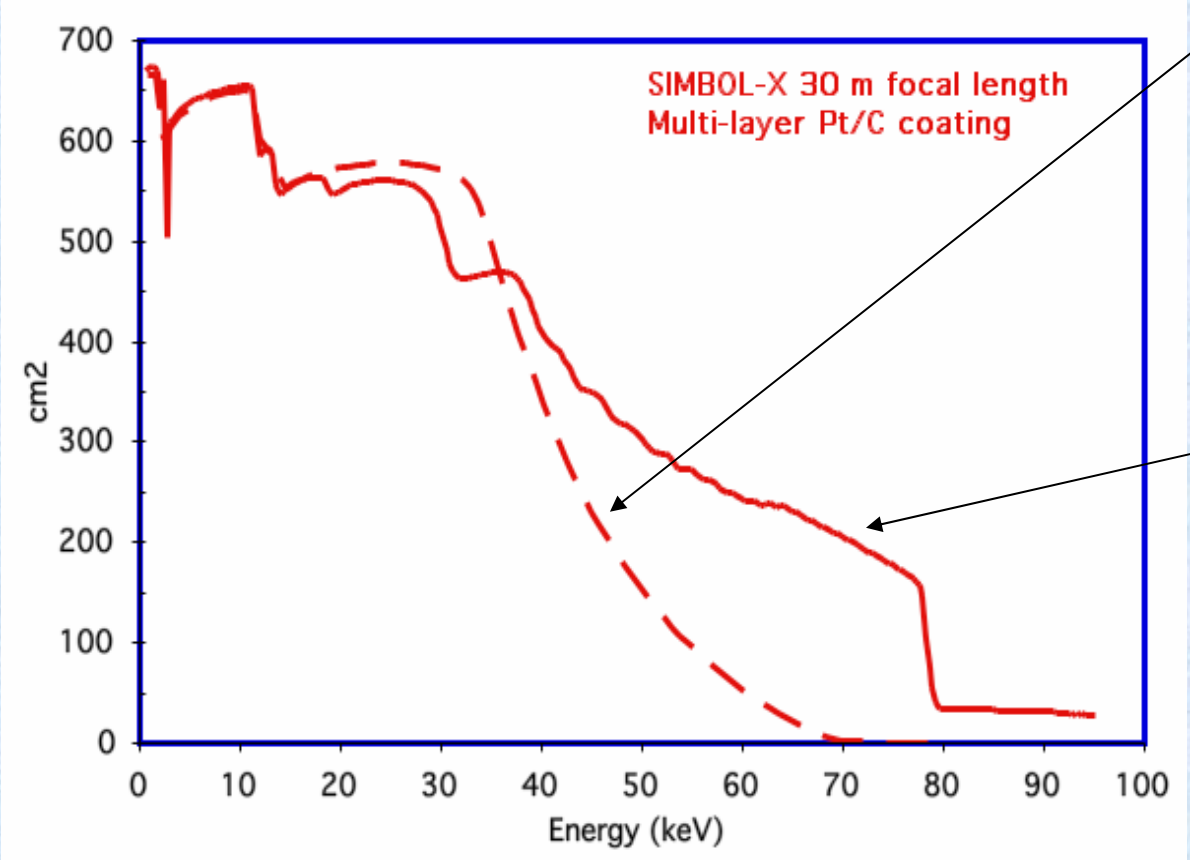
- High elliptical orbit :
  7 days period, and at launch :
  perigee : 44,000 km
  apogee : 253,000 km
  inclination : 5 degrees
- Pointing perpendicular ± 20 deg to Sun - S/C line
- 2 antennas on ground

2 different detectors to cover the broad energy range





Much larger area above 40 keV (and small increase in FOV) can be obtained with multilayer optics



Baseline

30 m focal length
100 Wolter I shells with
diameters from 29 to 60 cm
213 kg Pt coating

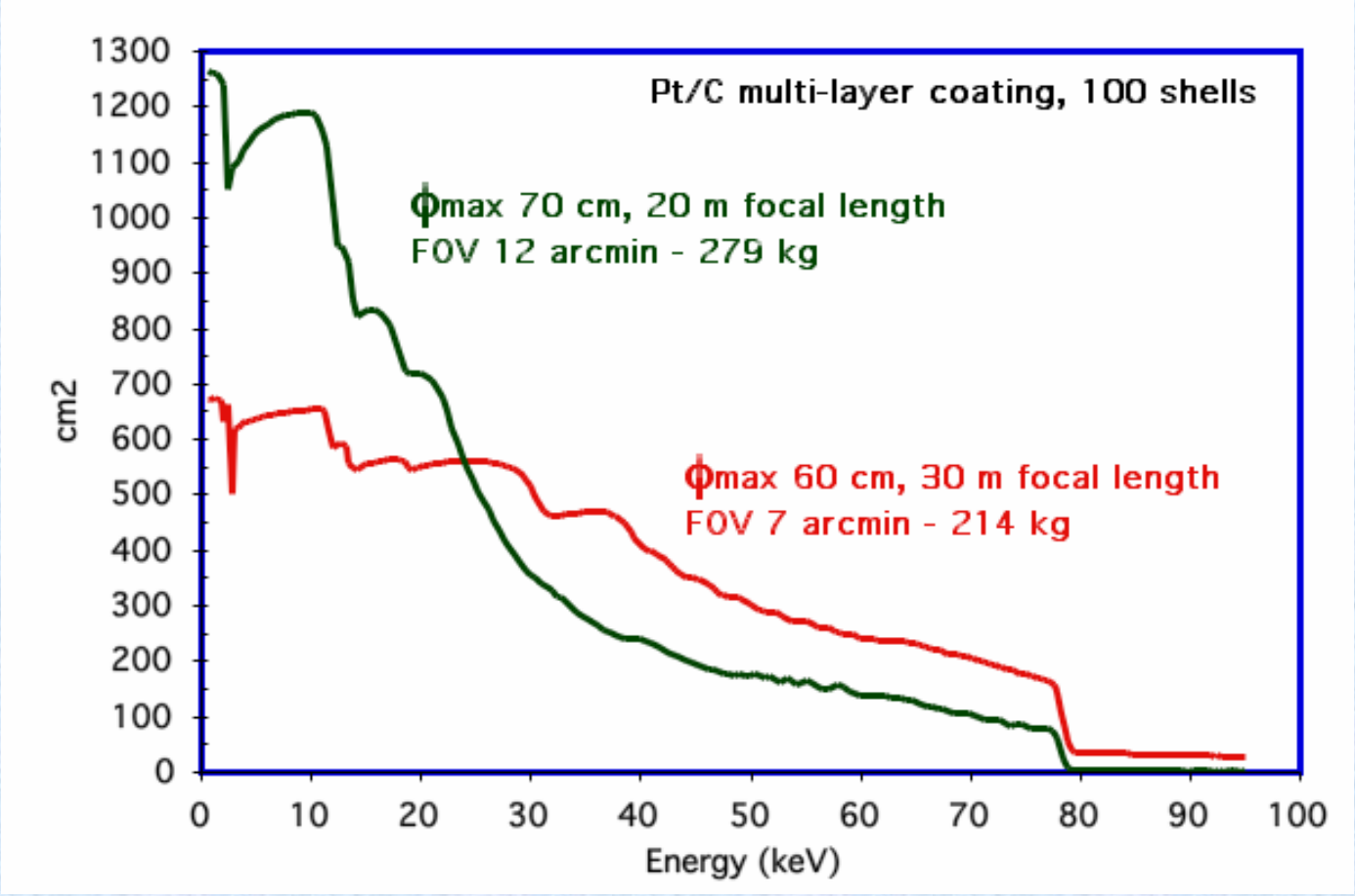
HEW ~ 30 arcsec
FOV ~ 6 arcmin FWHM

Super Mirror

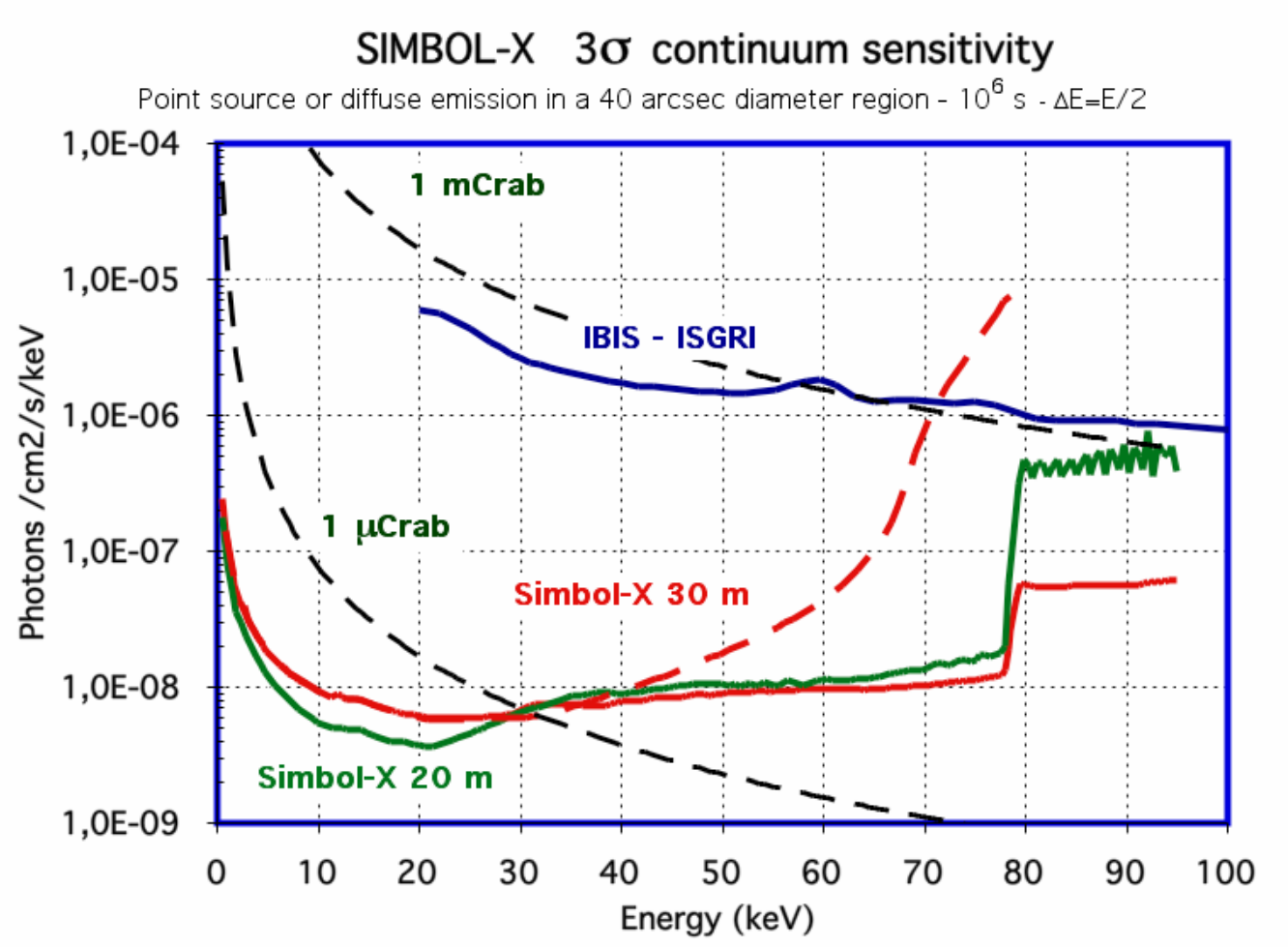
As above but with Pt/C
multilayer mirrors

FOV ~ 7 arcmin FWHM

A further increase in effective area at low energy and a larger FOV can be obtained by reducing the focal length



Note: the smaller area at high energy is compensated by the lower BKG since the plate scale with a 20 m FL is smaller (see next slide)


SIMBOL-X 3σ continuum sensitivity
Point source or diffuse emission in a 40 arcsec diameter region - 10^6 s - ΔE=E/2
Photons /cm2/s/keV
1,0E-04
1,0E-05
1,0E-06
1,0E-07
1,0E-08
1,0E-09
0
10
20
30
40
50
60
70
80
90
100
Energy (keV)
1 mCrab
IBIS - ISGRI
1 μCrab
Simbol-X 30 m
Simbol-X 20 m

SIMBOL-X Programmatic Status

- Originally proposed to CNES (Sept.2001) as collaboration between French and Italian laboratories (with participation from Germany) in response to call for ideas for formation flight demonstration mission
- Scientific case updated by Italian/French scientists in Summer 2005
- Now proposed as CNES-ASI collaboration and selected for Phase A to be carried out in 2006

CONCLUSIONS

- **The "Formation Flight" architecture opens the opportunity to realize hard X-ray (E > 10 keV) telescopes based on low grazing angles and large focal lengths Wolter I optics**

- **The Ni electroforming replication is the consolidated approach assumed for the realization mirror shells based on single layer mirrors. The up grade of the method to the fabrication of multilayer mirrors is under development and funded by ASI**

- **Different trade-offs must be evaluated…**

  e.g. angular resolution / field of view / low energy response / time and energy resolution / etc…

…this will be done during the phase A in order to design a competitive hard X-ray mission operating in 2013-2016

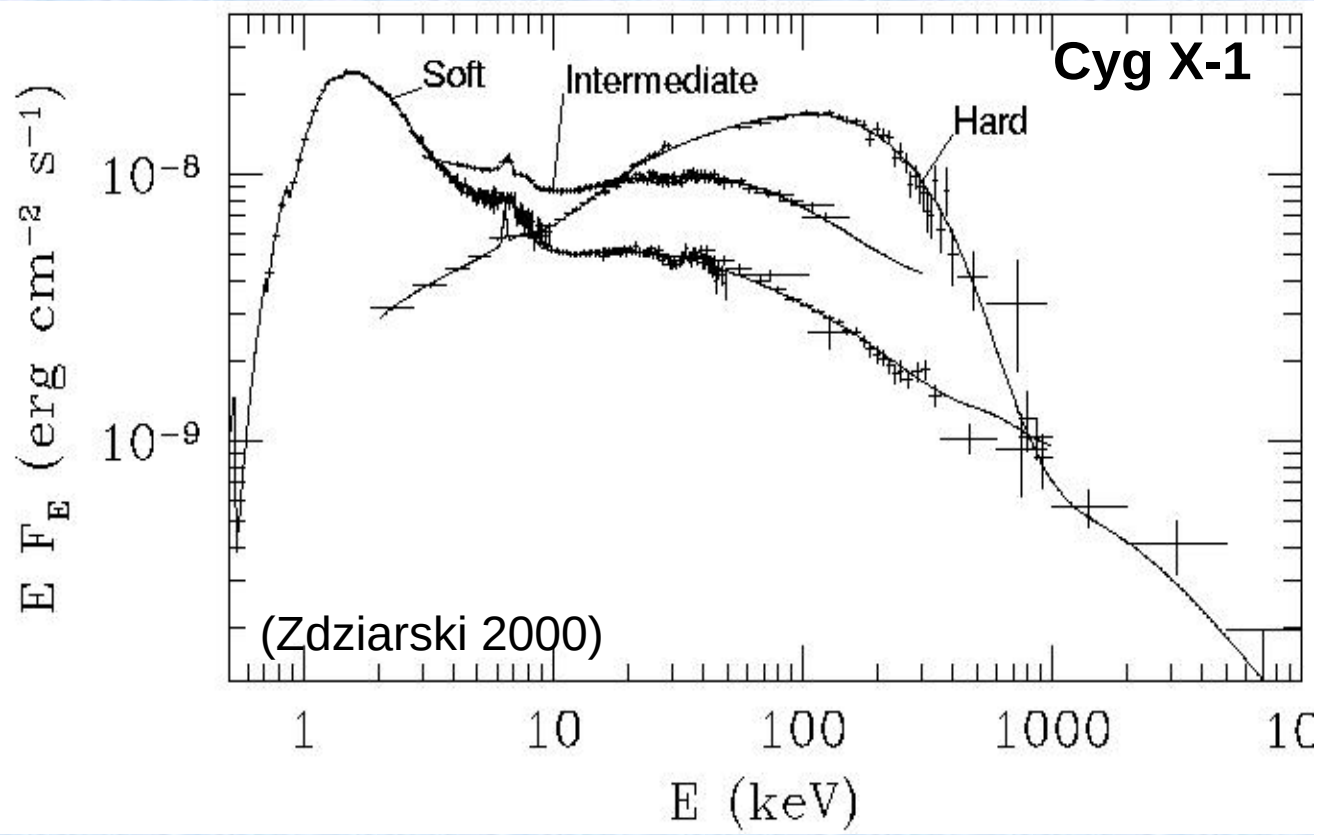
SCIENTIFIC OBJECTIVES

Just a few obvious examples…

Spectral states of NS and BH systems

"hard tails" currently studied only in ~20 sources

(brightest persistent sources and initial part of transients outbursts)



Spectral states of NS and BH systems

More accurate spectral modeling of the bright sources

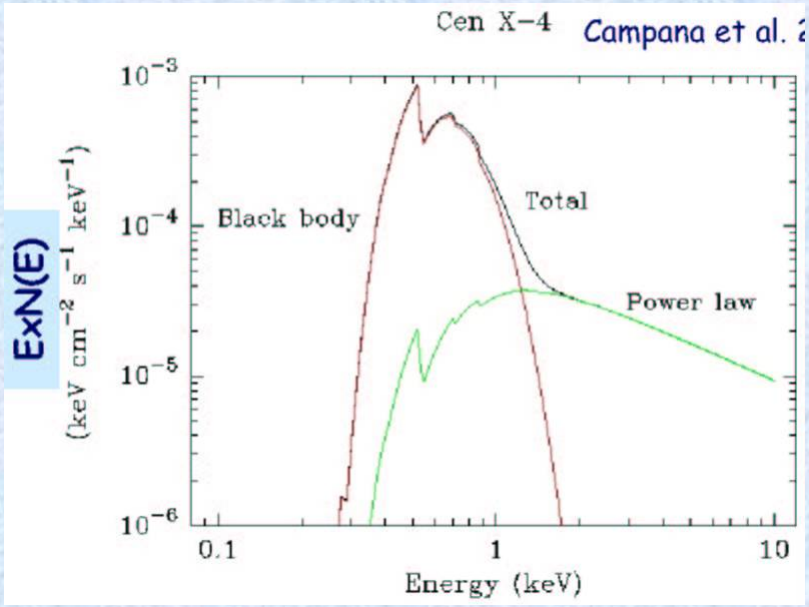
Enlarge sample of sources going to fainter fluxes

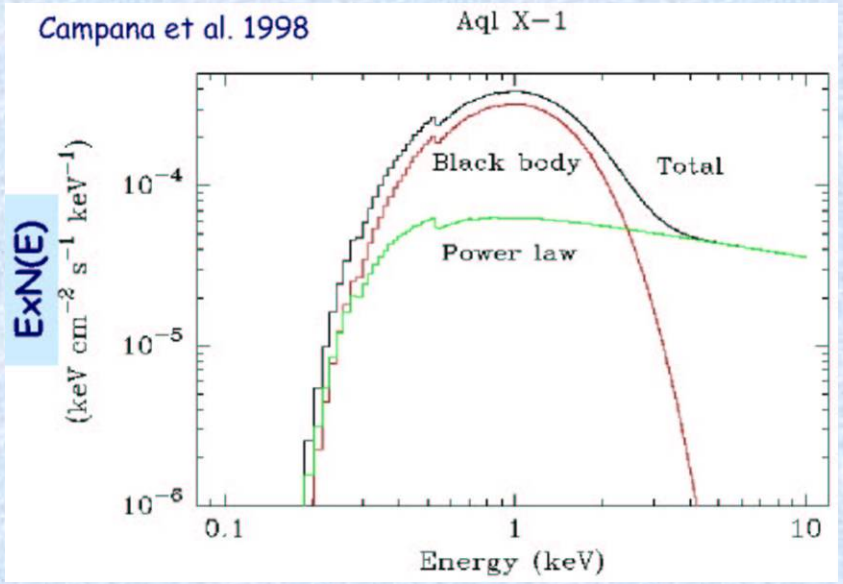
Study variability (e.g. QPOs) at higher energies

NS and BH transients in quiescence

Origin of quiescent emissions:

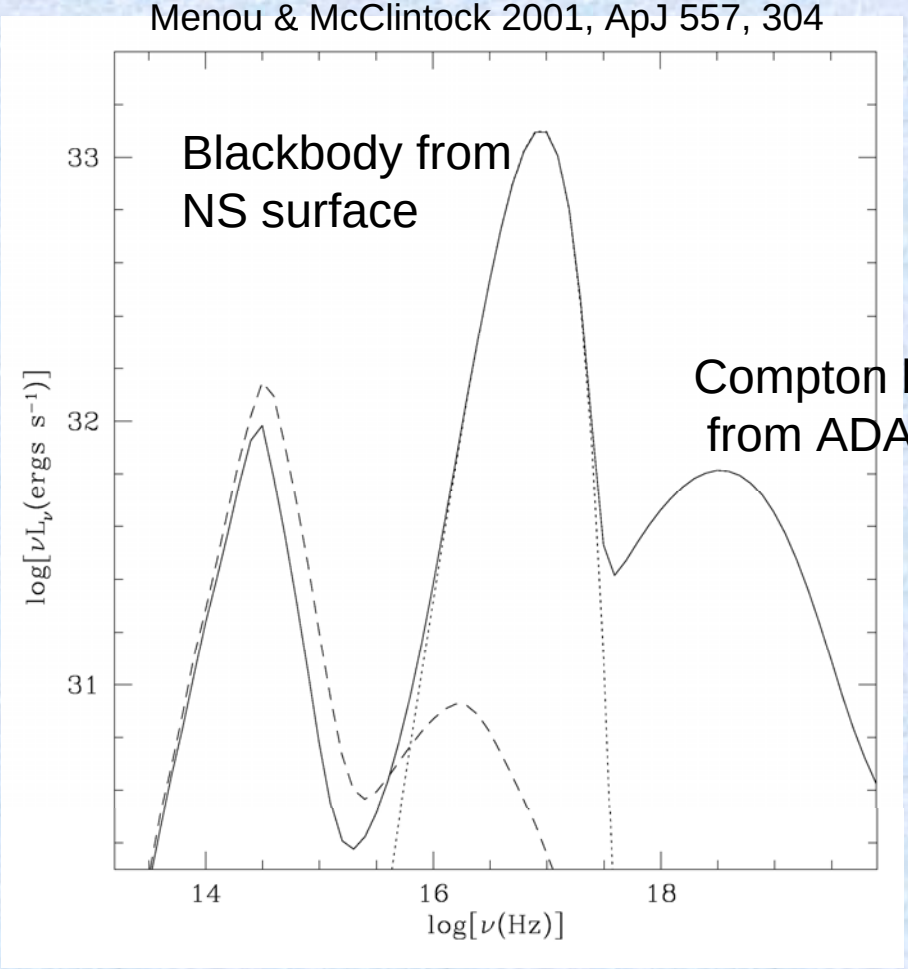
- ADAF?
- NS cooling ?
- Propeller ?
- Radio PSR shock ?





NS and BH transients in quiescence

Menou & McClintock 2001, ApJ 557, 304



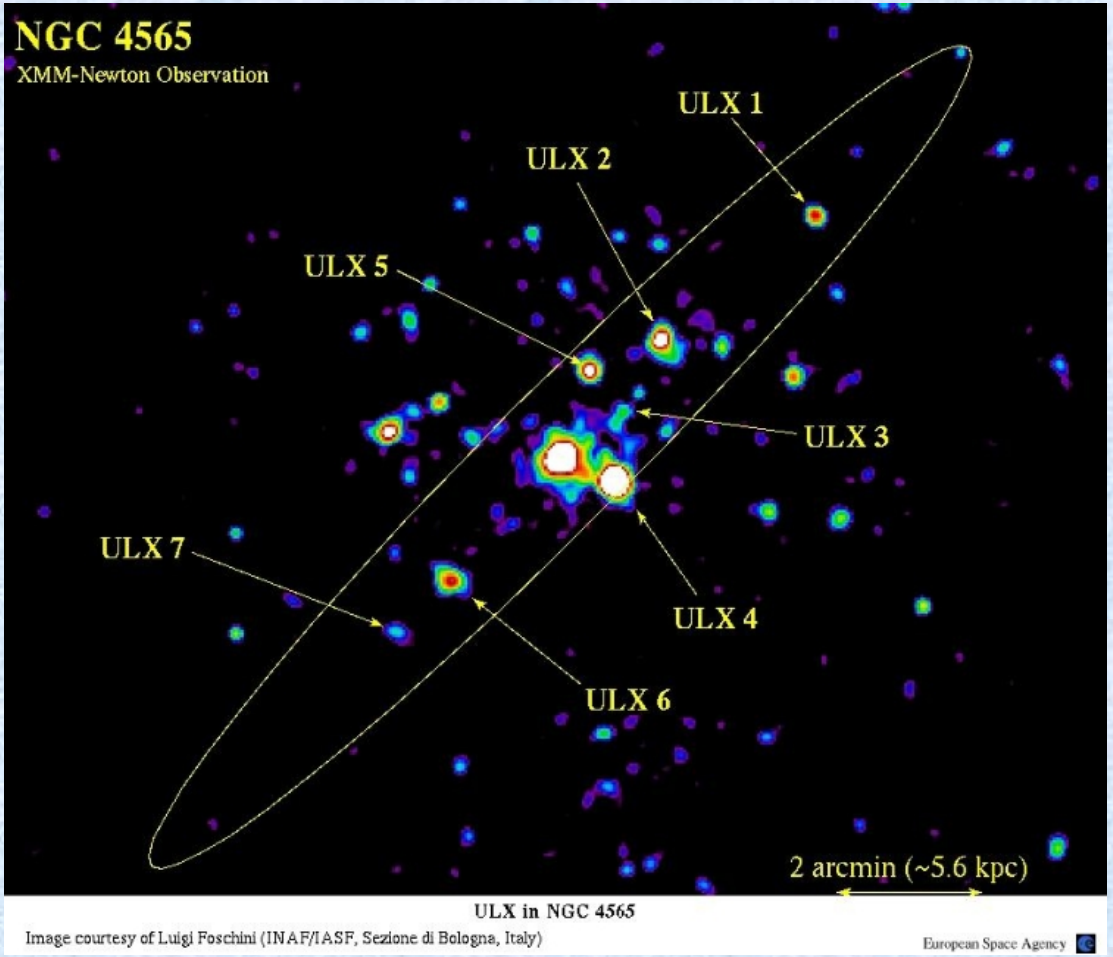
Ultra Luminous X-ray sources

- Stellar mass black holes ?
  - super-Eddington luminosity
  - sub-Eddington + anisotropy

or

- Intermediate mass black holes ?

Ultra Luminous X-ray sources



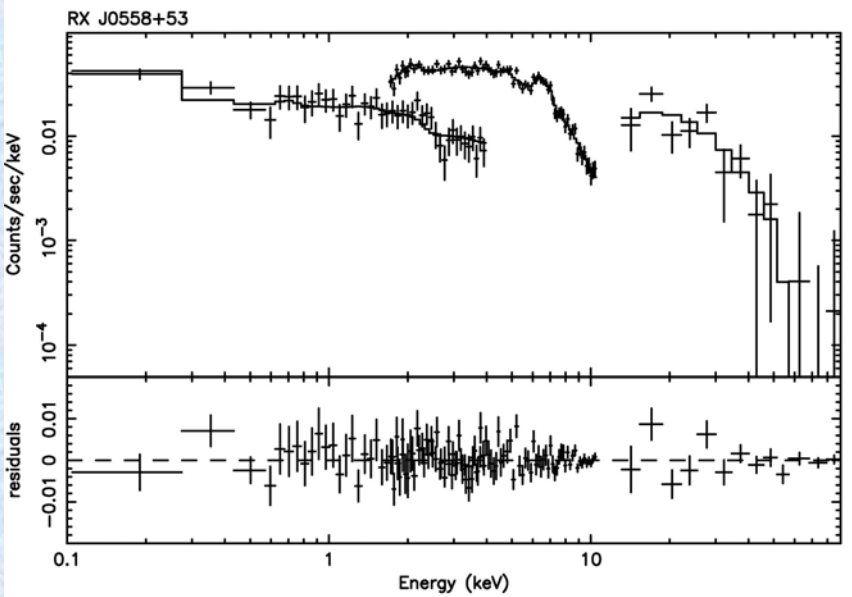
ULX in NGC 4565

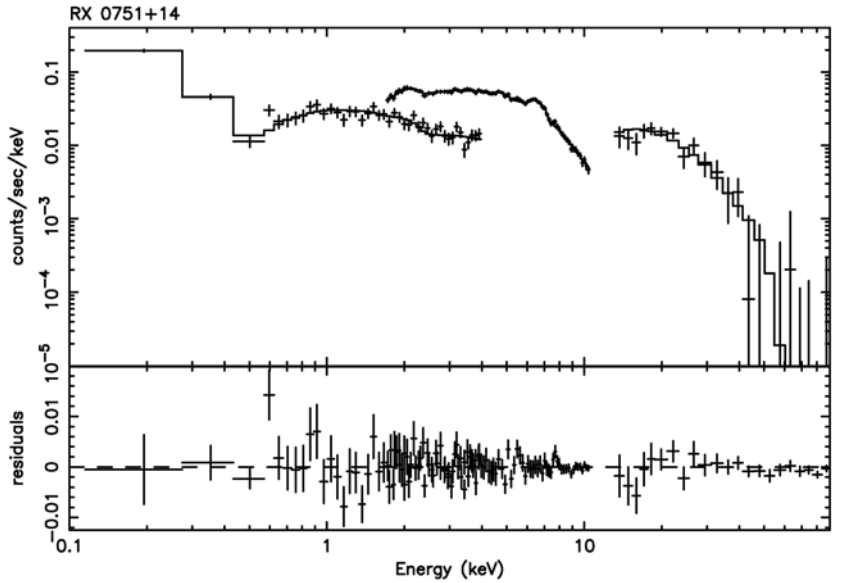
Image courtesy of Luigi Foschini (INAF/IASF, Sezione di Bologna, Italy)

European Space Agency

Hard X-rays from CVs

De Martino et al.





Not much has been done after the pioneering work with BeppoSAX…