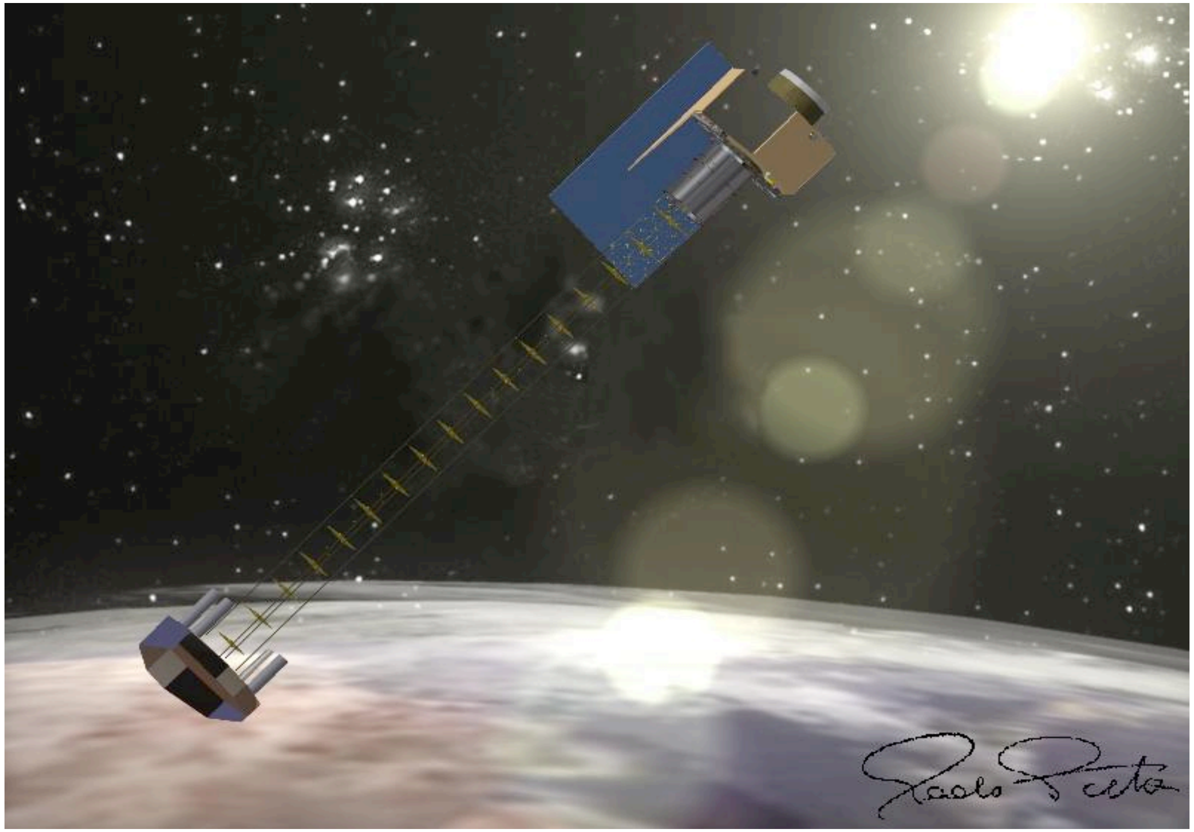
The New Hard X-ray Mission

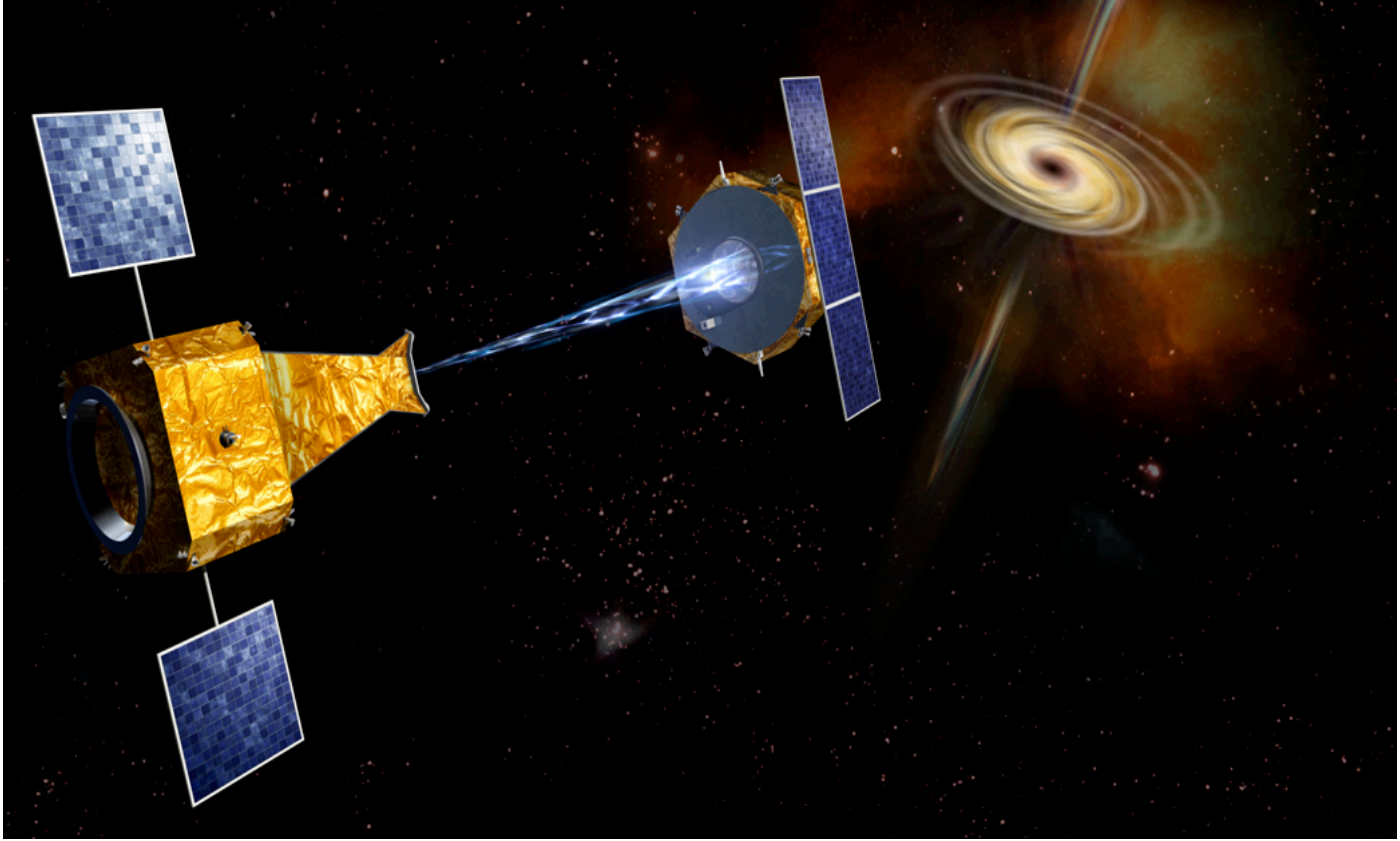


G.Pareschi, G. Tagliaferri, F. Fiore, E. Costa, G. Cusumano, G. Malaguti, G. Matt,
S. Mereghetti, G. Micela, G. C. Perola, G. Villa

(on behalf of a large group of scientists from the Italian community)

Preliminary name after the first contac with the organizers:

The SIMBOL-X hard X-ray mission based on formation flight



Début du message réexpédié :

De : "Casoli Fabienne" <fabienne.casoli@cnes.fr>

Date : 25 mars 2009 09:06:08 HNEC

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Objet : **Simbol X situation: proposition of a telecon on april 3**

Dear all,

We have very bad news to report on Simbol X. Last friday, the "comité des programmes scientifiques" of CNES recommanded not to start phase B, in view of the bad CNES budgetary perspectives for the next years.

Desperate astrophysicists! However….

- Phase B contract for optics started in Italy just few days before CNES decision!
- Phase A study for the alternative project New Hard X-ray mission (NHXM – ex HEXIT-SAT) was been successfully carried by ASI in parallel to Simbol-X
- Simbol-X was one of the highest priorities in the ASTRONET roadmap: can Simbol-X science be recovered/improved?
- Simbol-X was also very highly recommended by the NASA board in the context of the last SMEX/MoO call
- Is SX science still valid in the framework of current approved HEA missions?
  - **NuStar; Astro-H; GEMS**

IXO

Italian

X-ray

Observatory

But the copyright was already taken by K. Nandra and the **International X-ray Observatory** Team

- What is missing or what can be improved with respect to the already approved missions?

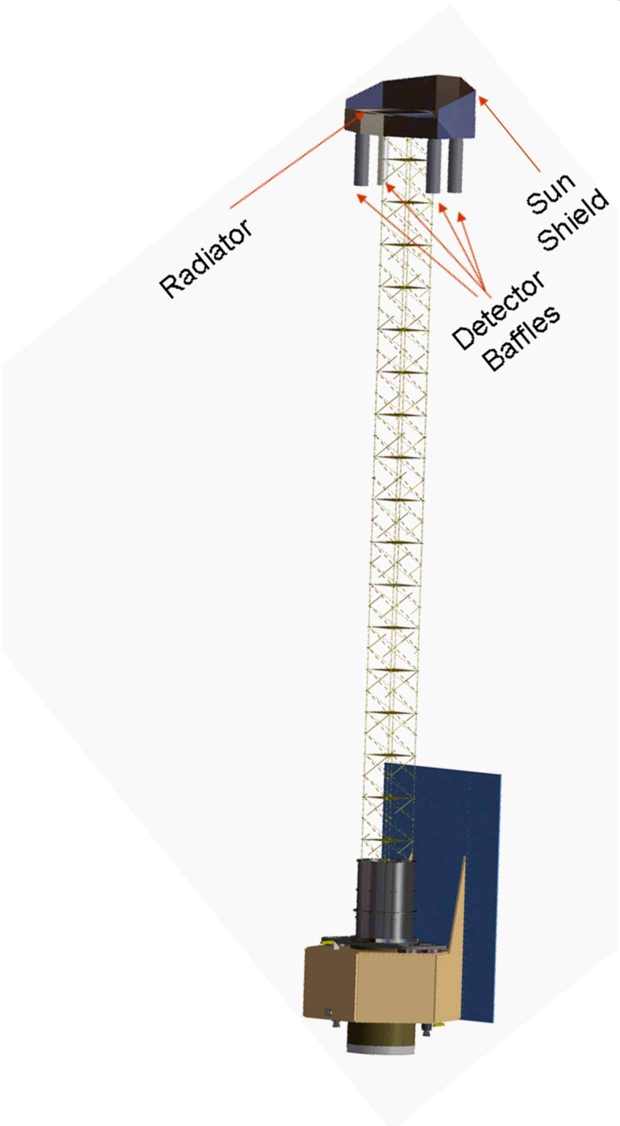
  - ❑ **High resolution optics**

  - ❑ **BB Spectroscopy with similar sensitivity over >2 decades (0.5-80 keV) with simultaneous imaging polarimetry**

New Hard X-ray Mission main features

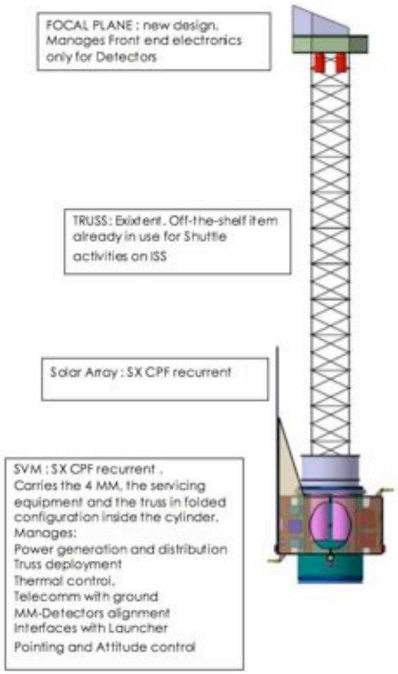
- Single satellite with extendable bench (NO Formation Flight!)
  - **Four high quality (XMM-like) mirrors with multilayer coatings (0.1-80 keV)**
  - **Three Telescope Modules dedicated to broad band imaging & spectroscopy**
  - **One telescope Module dedicated to imaging polarimetry (2-35 keV)**
    - **➔ extendable up to 100 keV with a scattering polarimeter**
  - **LEO (equatorial) ➔ low internal background**

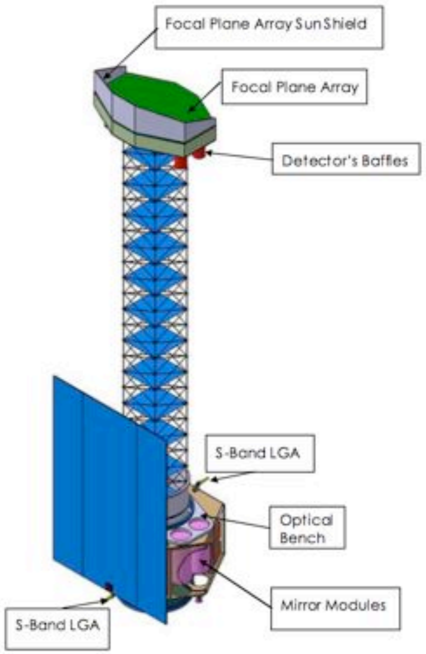
NHXM Parameters



NHXM Mission Profile	
Orbit	600 km, circular
Orbit period	95 min
Orbit inclination	Equatorial (<5°)
Visibility (Malindi)	650 s/orbit (>150 min/day)
Launcher	Vega (compatible with Soyuz, Long-March, ...)
Launch date	2016
Mass budget (payload + spacecraft)	< 1500 kg
Power budget (payload + spacecraft)	600 W
Mission lifetime	3 (+2 goal) Years
Ground Stations	Malindi
MOCC and SOC	Fucino + ASI/ASDC in Frascati
Mission science	X-ray Observatory

Mission Configuration





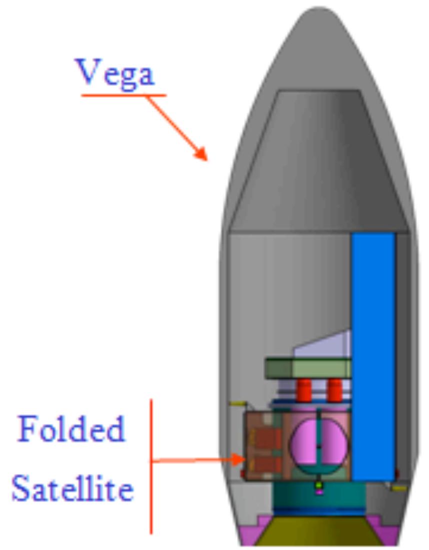
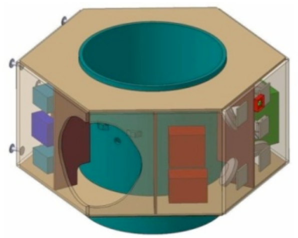
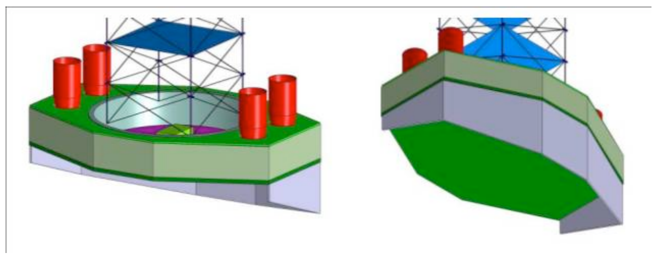


Figure 28: The folded satellite inside the VEGA fairing



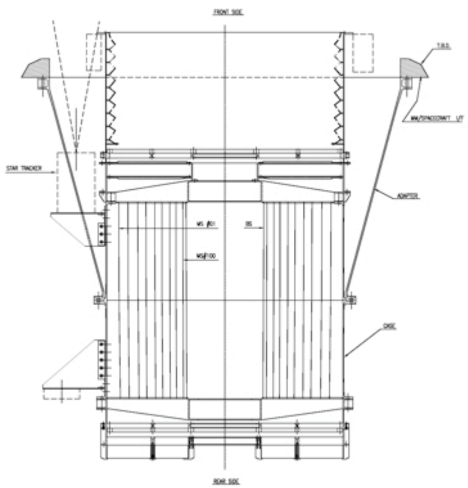


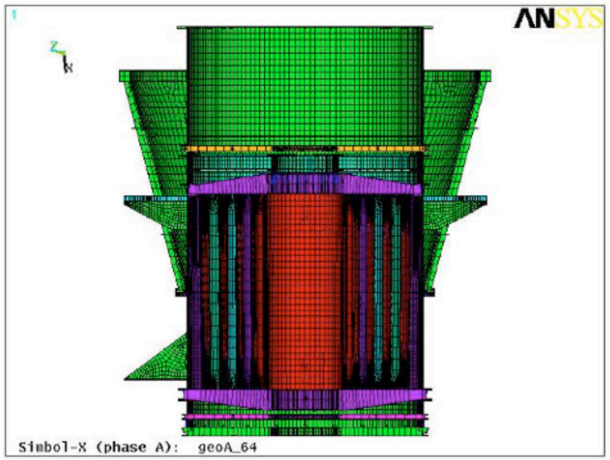
Service module (PRIMA Science platform)

Focal plane module

Optics module configuration

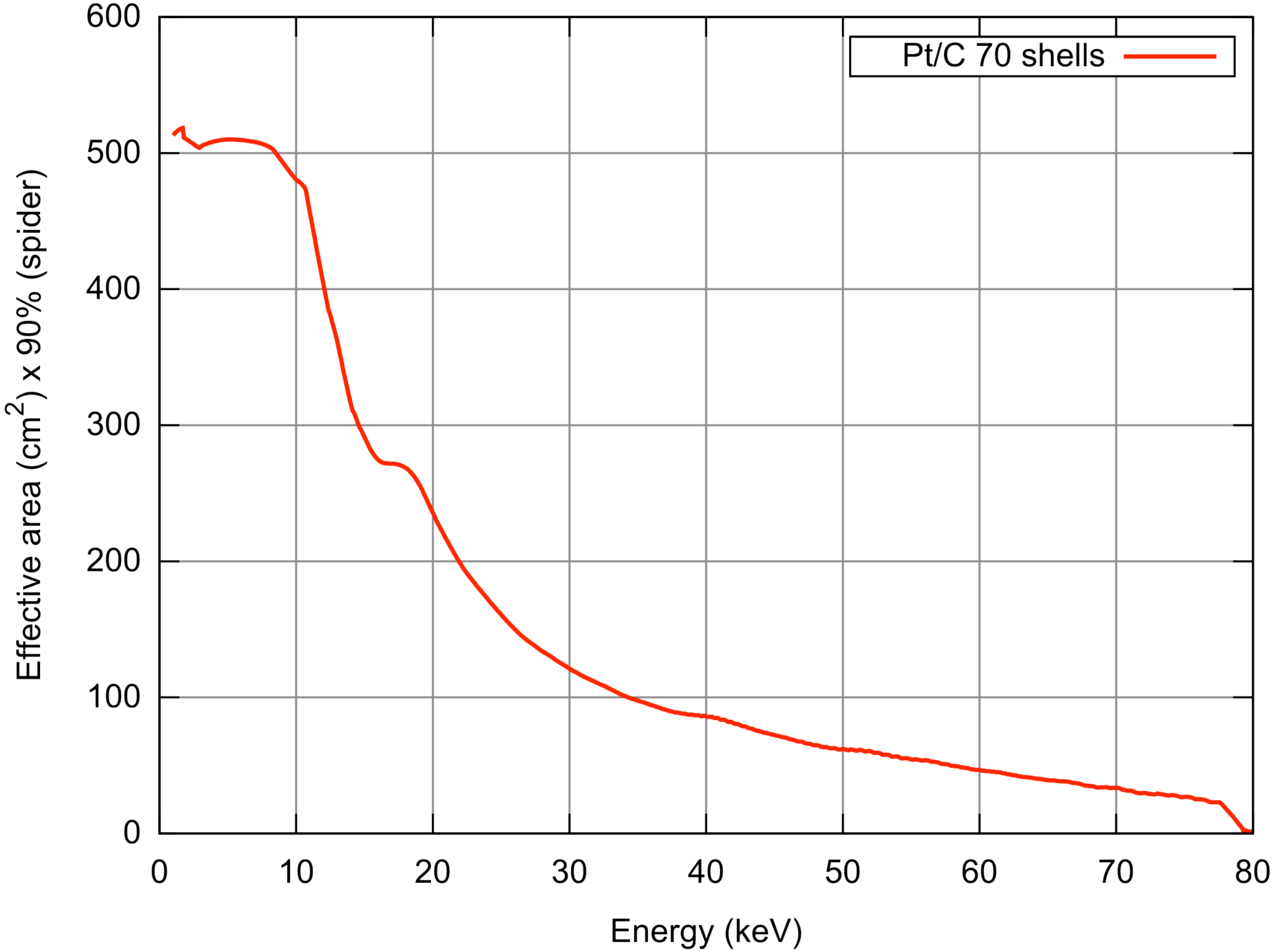
Number of mudules	4
Focal length	10 m
MAX/min shell diameter	15 - 40 cm
# shell/module	70
Wall material	NiCo
Wall thickness (MAX/min)	0.35 – 0. 15 mm
Coating	Pt/C (or W/Si + Pt/C) multilayer
Total weight including structures	400 kg





Effective Area

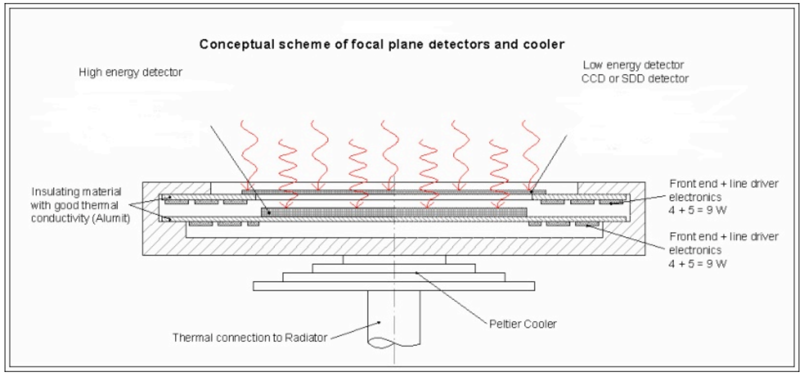
1 module



12 arcmin FOV (diameter, 50% vignetting @ 30 keV)

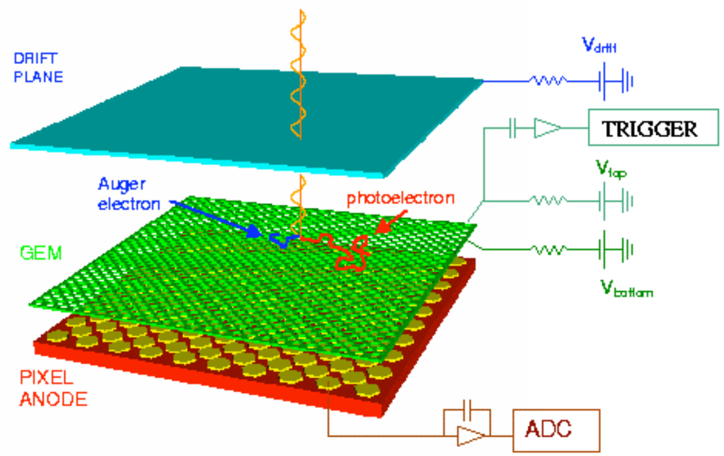
NHXM Focal Planes

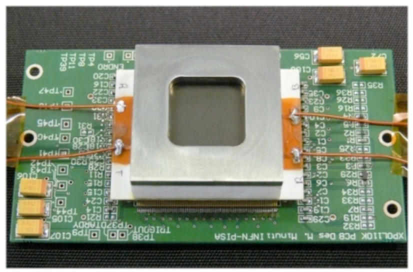
3 mirror modules with a hybrid focal plane



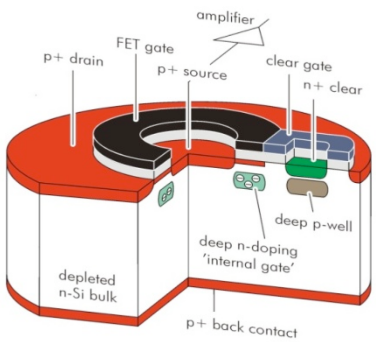
- Silicon based detector (MOS CCD or DEPFET)
- CdTe array
- anticoincidence system (NaI or CsI)

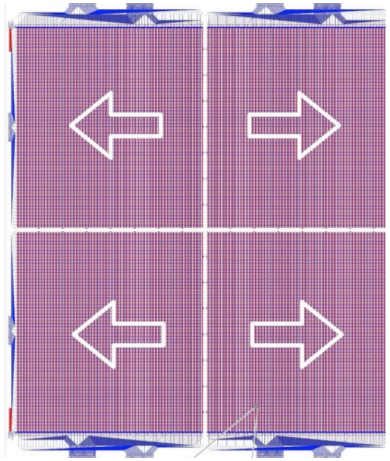
1 mirror module with a photoelectric imaging polarimeter

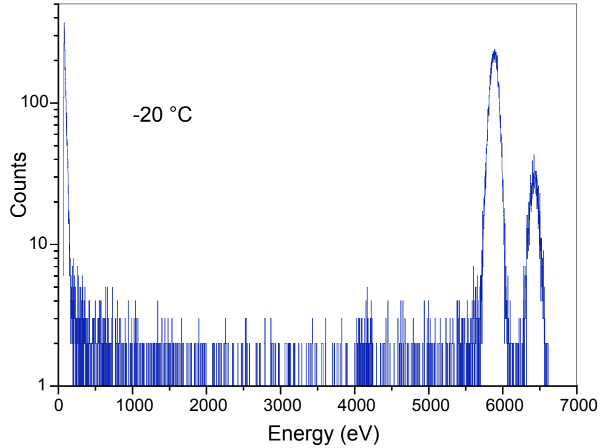




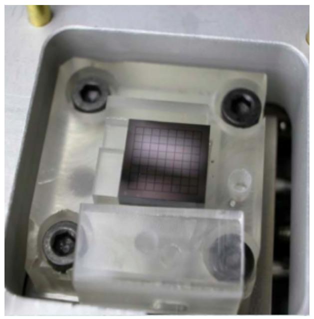
Low & High Energy Detectors for BB spectroscopy



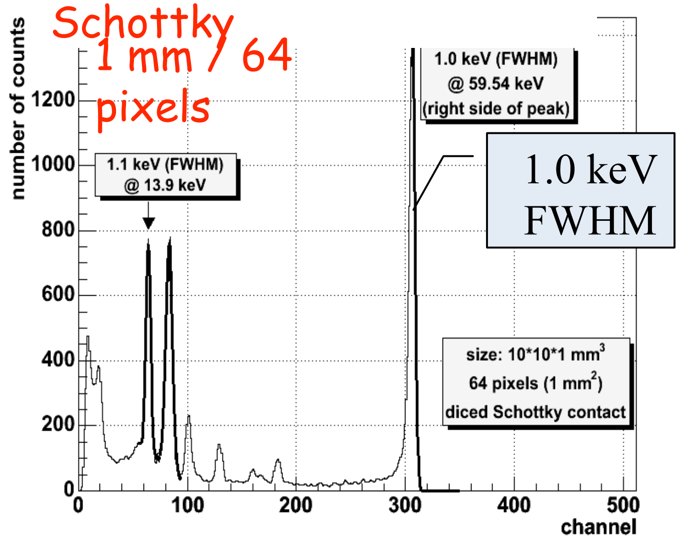




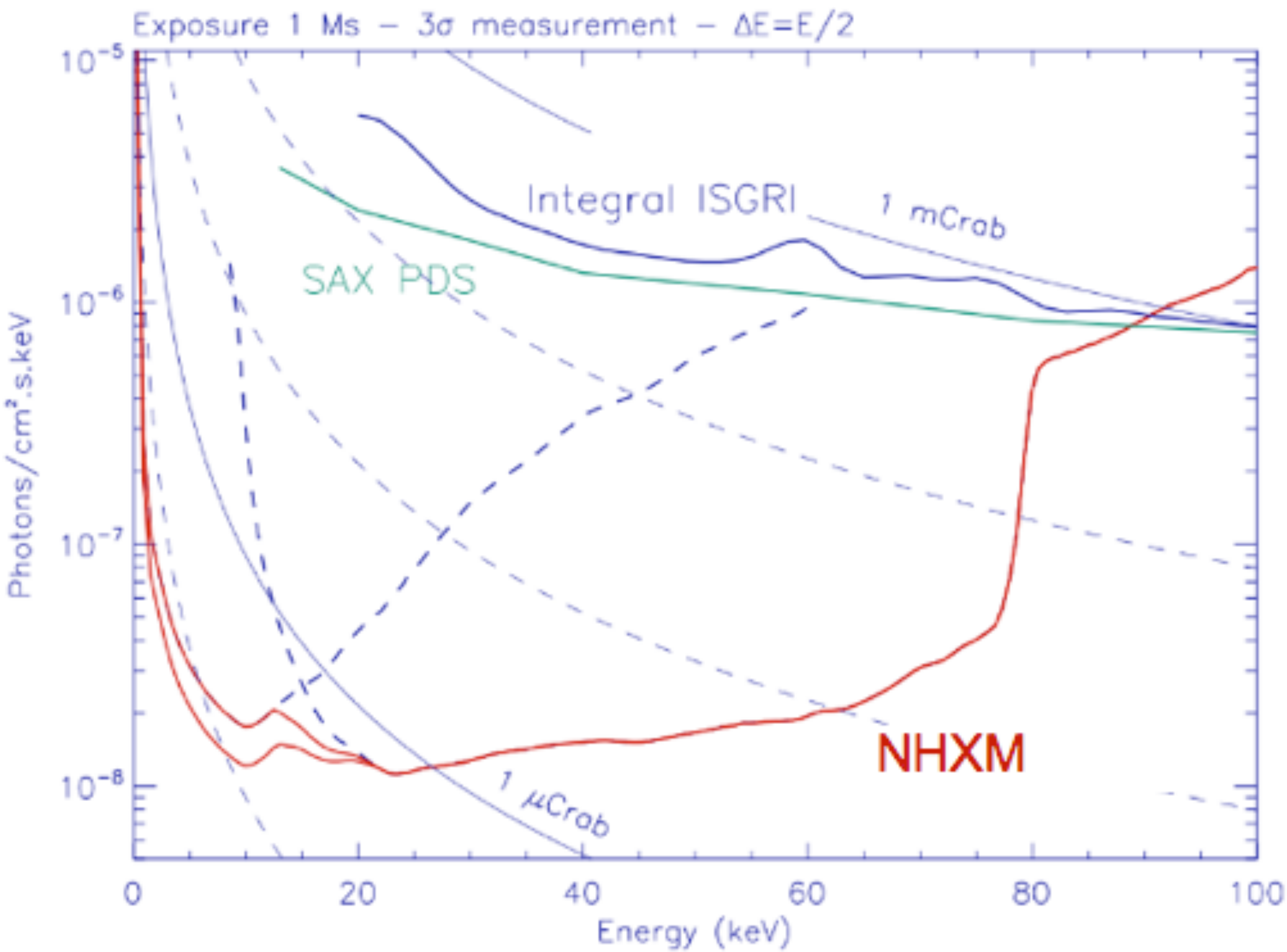
- CdTe detectors : 1 mm thick pixellated CdTe



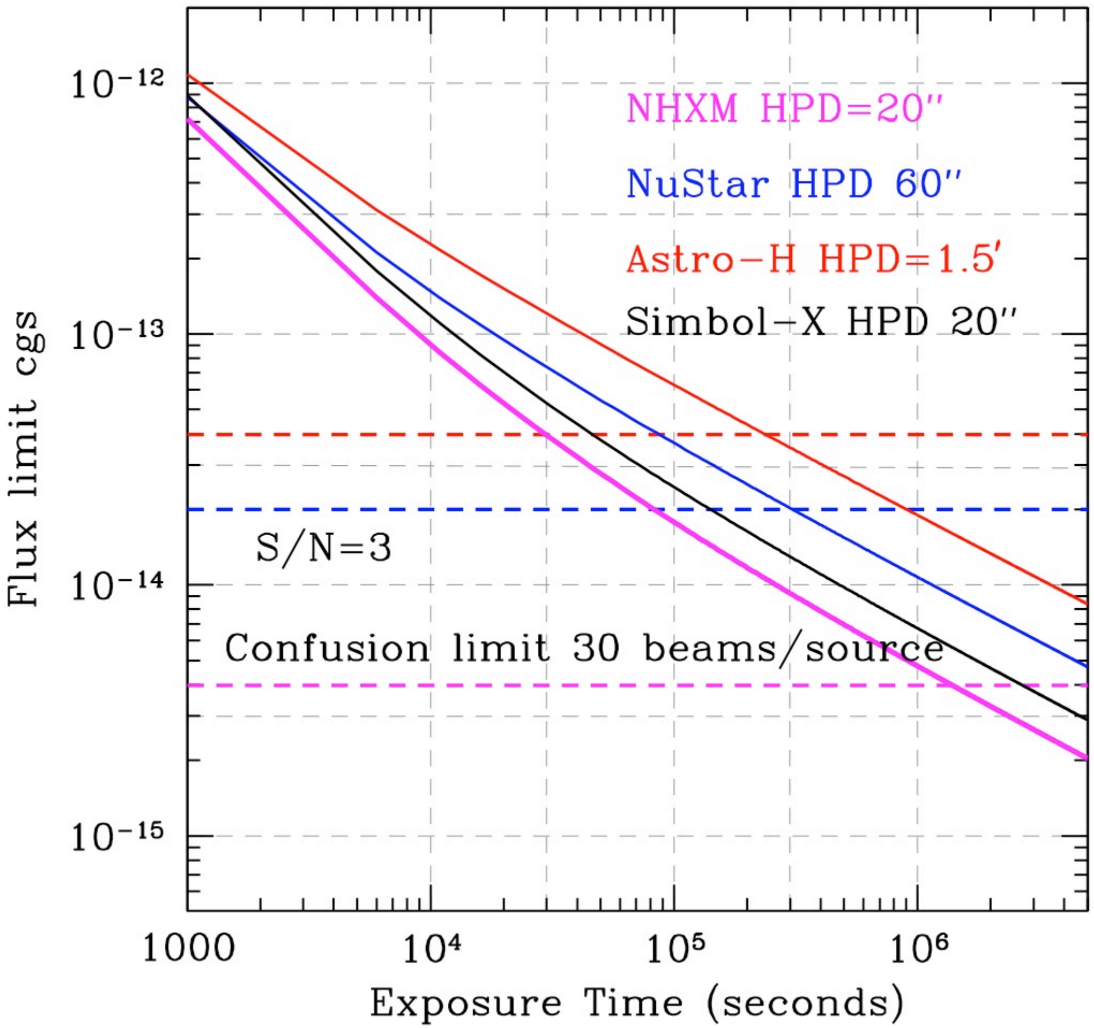
-18° / 400V / CdTe Schottky
1 mm / 64 pixels



Flux Sensitivity (I)

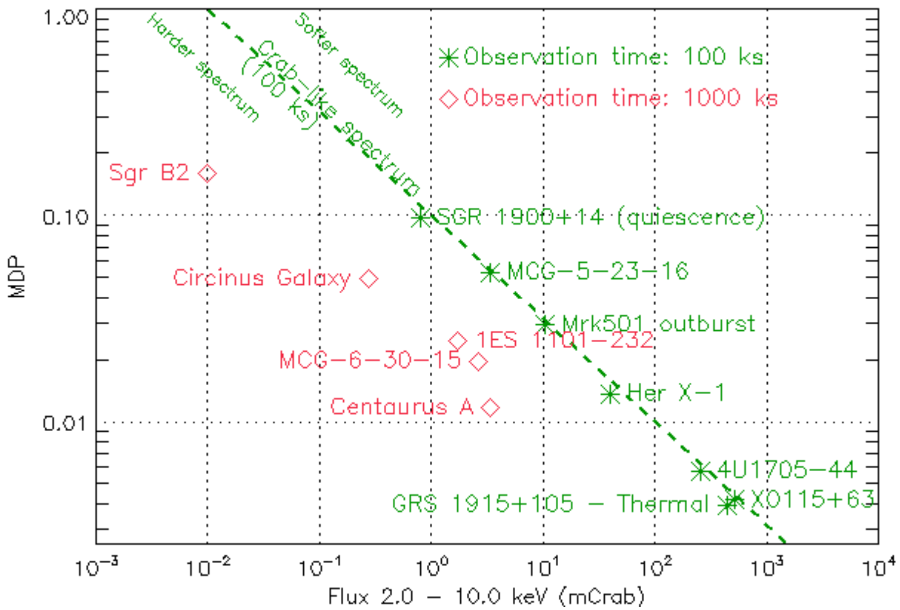


Flux sensitivity (II)



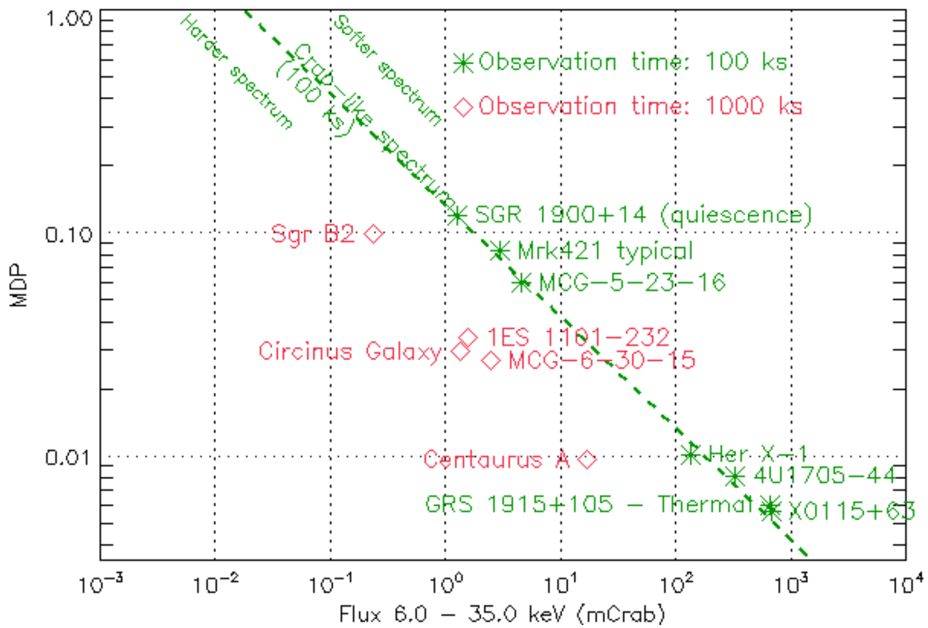
Polarimetric sensitivity

Soft X-ray channel



Two polarimetric channels (2 – 10 keV and 10 – 35 keV) for an effective diagnostic of the emission mechanisms

Hard X-ray channel



Cross correlation with the spectroscopy data between 2 and 36 keV!

Key parameters of future hard X-ray missions

		NHXM	NuSTAR	Astro-H
# of Telescopes		3+1	2	2
Energy band (keV)		0.5 ÷ 80	7 ÷ 80	0.5 ÷ 80
Effective area (cm^2)	at 30 keV	350	300	320
	at 5 keV	1500	0	500
Orbit, inclination		Low Equatorial <5°	Low Equatorial ~6°	Low Equatorial ~30°
Focal Length (meters)		10	10.14	12
Field of View diameter (arcmin)		12	12	9
Half Power Diameter (arcsec at 30 keV)		20	60	100
10-40 keV flux sensitivity at confusion limit (erg cm^{-2} s^{-1})		3×10^{-15}	2×10^{-14}	4×10^{-14}
Sources per field		40	6	1

Synoptic performance parameters comparison with NuSTAR and ASTRO-H

	NHXM	NuSTAR	Astro-H
Hard X-ray fine imaging	YES	NO (only moderate)	NO
Wide field of view	YES	YES	NO
Broad band X-ray spectroscopy	YES	NO	YES
Deep sensitivity	YES	Only moderate	No (Confusion limited)
X-ray Polarimetry	YES	NO	AT VERY HIGH ENERGY (no imaging)

Science with NHXM

- Increasing by 3 orders of magnitude the discovery space at E=10-80 keV with respect to INTEGRAL / Swift / BeppoSAX / Suzaku

- Performing for the first time **imaging polarimetry**

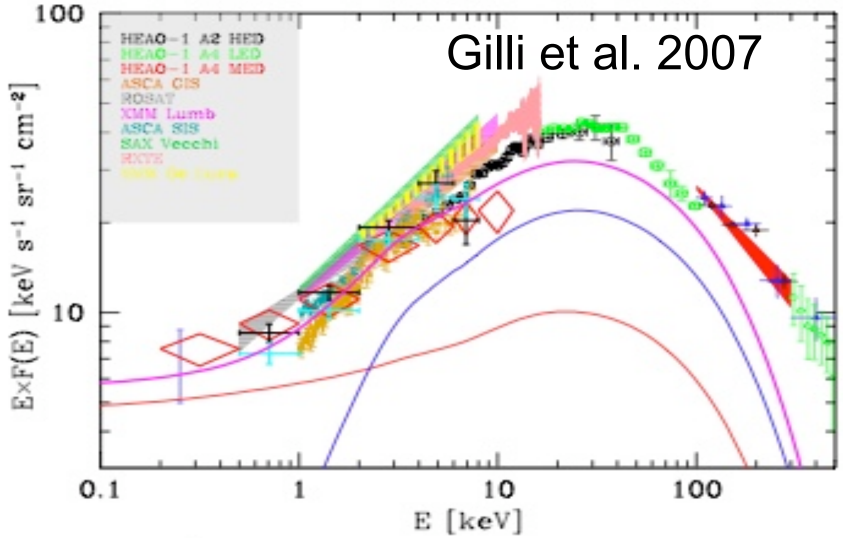
- Opening the new window of broad band (0.5-80keV) spectroscopy and simultaneous polarimetric observation

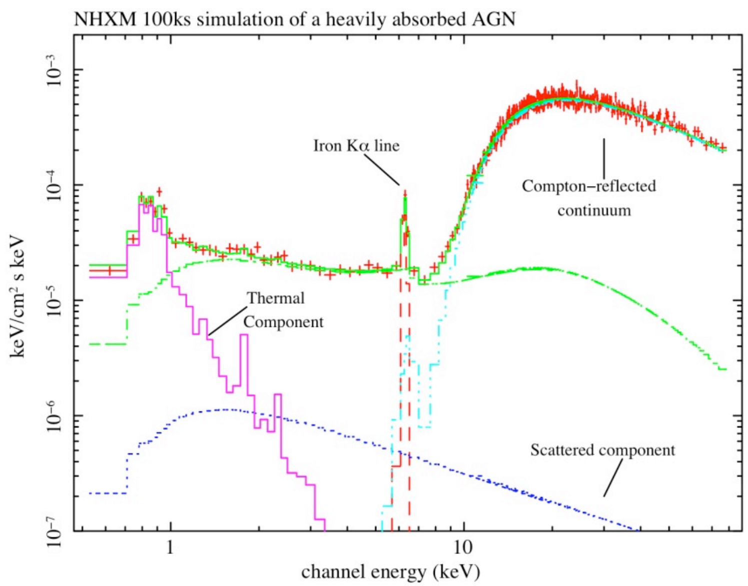
  - Probing BH census and accretion physics
  - Non-thermal emission and acceleration mechanisms
  - radiative processes in strong electromagnetic and gravitational fields

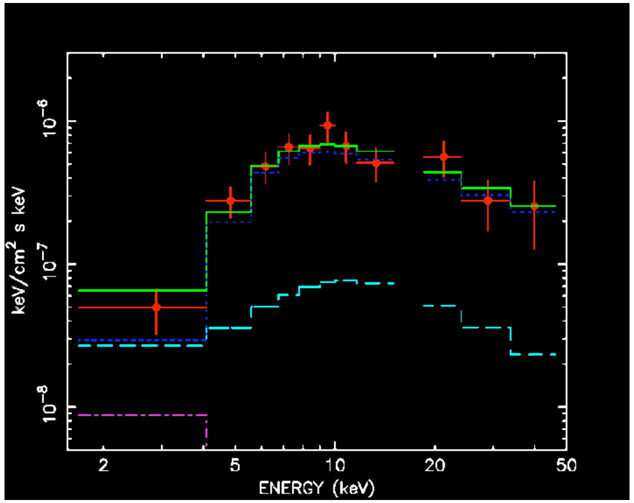
These three broad topics define the core scientific objectives of NHXM

Missing SMBH

- Strong evidences for missing SMBH
- Complete SMBH census needed, including CT AGN
- Obscured AGN: probe of early galaxy evolution phases, when feedback must be in action





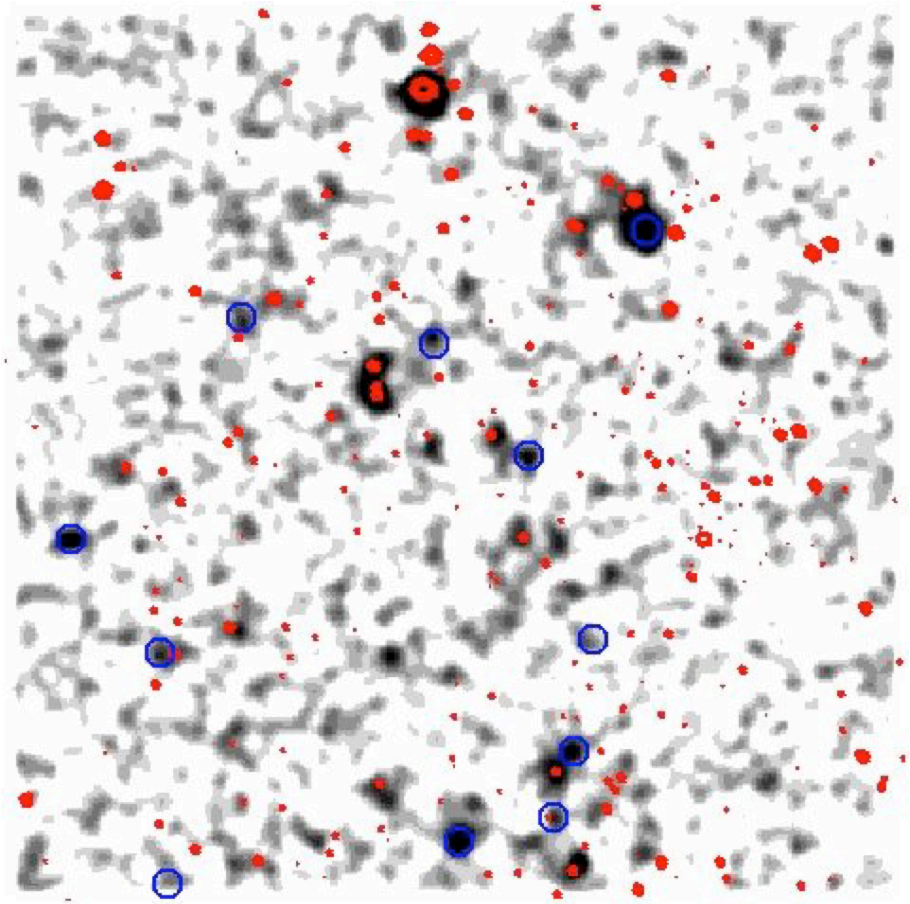


NHXM and the CXB

IR selected AGN, how big the obscuration is?
➔ Only high energy X-ray observations can tell, thus assessing the real power of the active nucleus and probing the BH growth in these galaxies and its feedback.

CDFS 1 Msec SX simulations 10-40 keV.

- Chandra sources (red contours);
- IR selected CT AGNs (blue circles) at z=0.5-2 assumingNH=10^{24} cm^{-2} and a reasonable IR/X-ray luminosity ratio



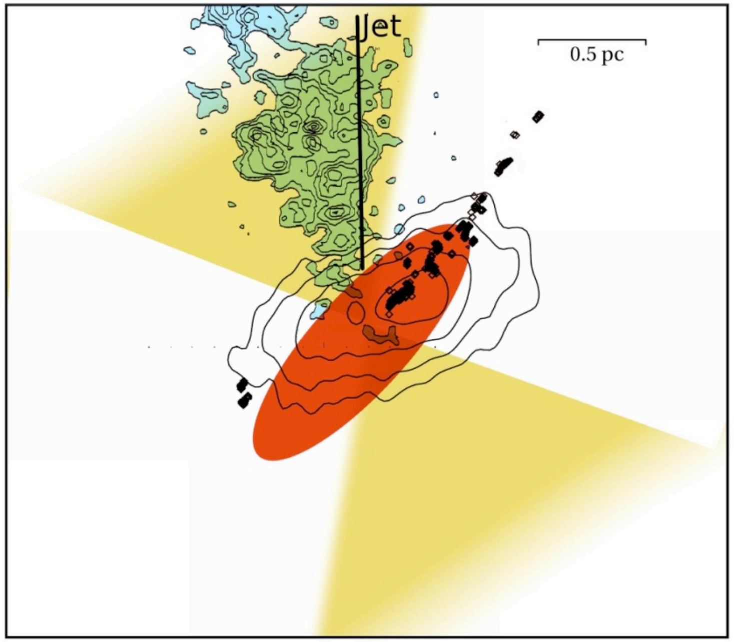
HEW<20” >65% CXB resolved @30keV

SWIRE AGN Z=1, N_H = 2 10^{24} cm^{-2}

F(2-10 keV) = 7.1 10^{-15} cgs

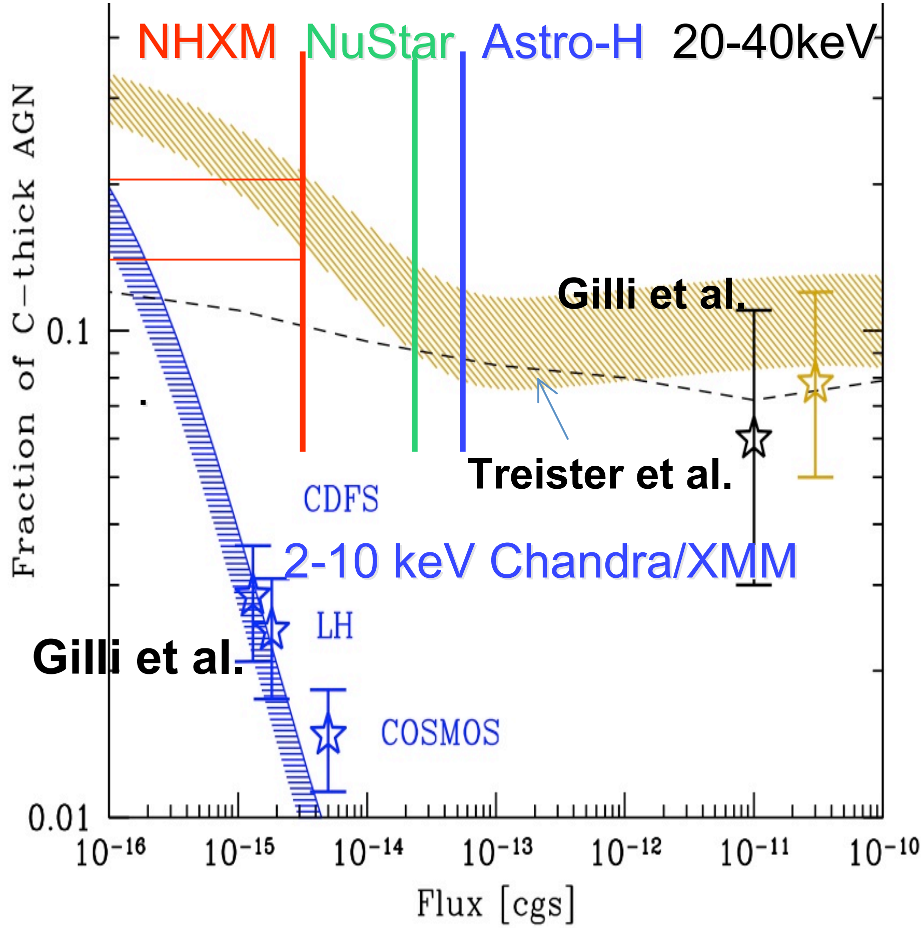
F(20-40 keV)=1.7 $^{-14}$ cgs

CXB fraction and CT AGN



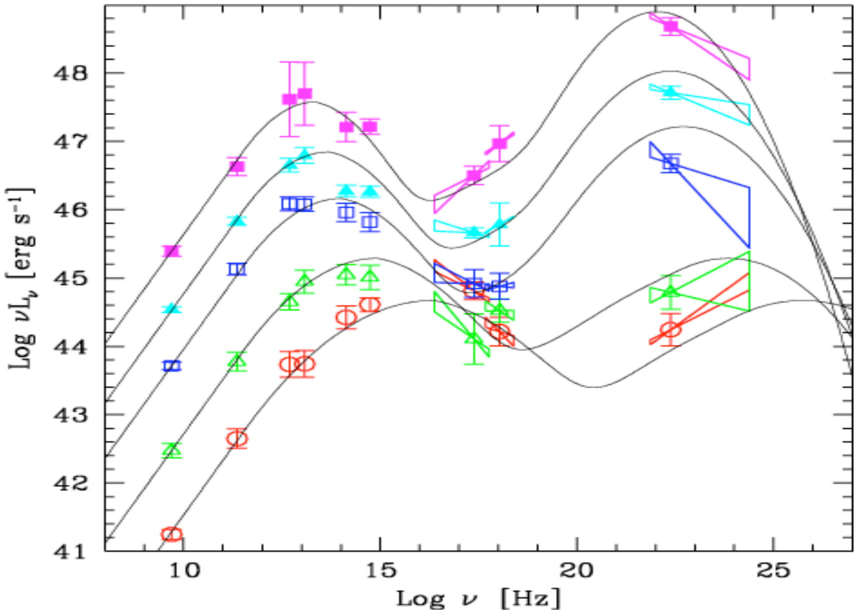
Geometry of the torus:

the polarization angle will give us the orientation of the torus, to be compared with IR results, and with the ionization cones

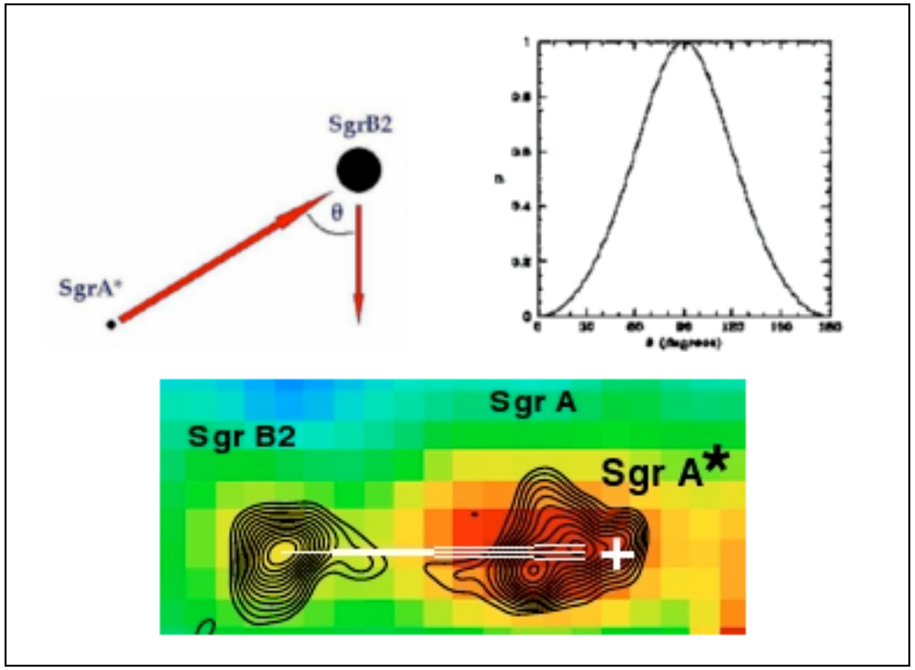


Acceleration mechanisms

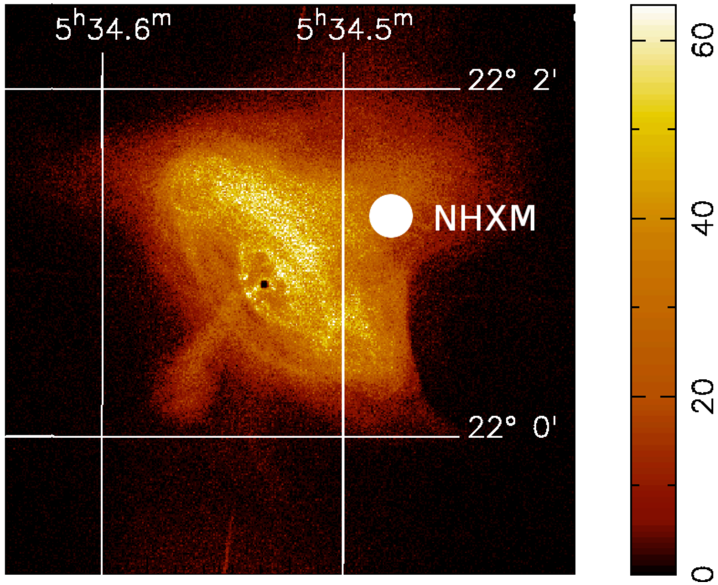
- Jet emission is due to both synchrotron and IC, both BB components and strongly polarized.
- Therefore, multi-band (IR,O,X-ray) spectroscopy and polarimetry can probe
  - jet structure
  - jet power
  - nature of jet seed photons
- Imaging polarimetry of PWN: mapping the B field.



X-ray Polarimetry with imaging capabilities



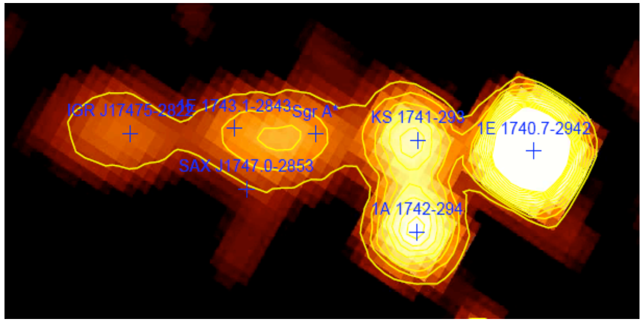
The possibility to associate to the polarimetric sensitivity also an imaging capability is of paramount importance in the case of extended sources investigation, like e.g. the SN remnants and the GC region.



Accretion physics

• Nature of the primary X-ray emission in both highly accreting BH and starved BH

- Corona physical parameters (T, τ) via BB spectroscopy
- Corona geometry via polarimetry (geometrically thick, optically thin disks should not be polarized, while accretion disk coronae should be)

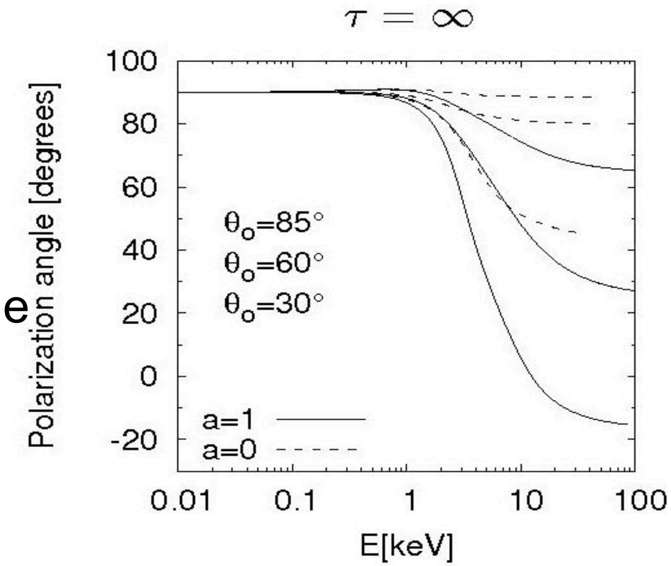


• Sensitive BB spectroscopy:

➔ allows a full control of the continuum, which is a key point to reliable iron line profile diagnostics

• Polarimetry:

➔ will allow an independent test of the relativistic model and a further way to estimate the black hole spin.



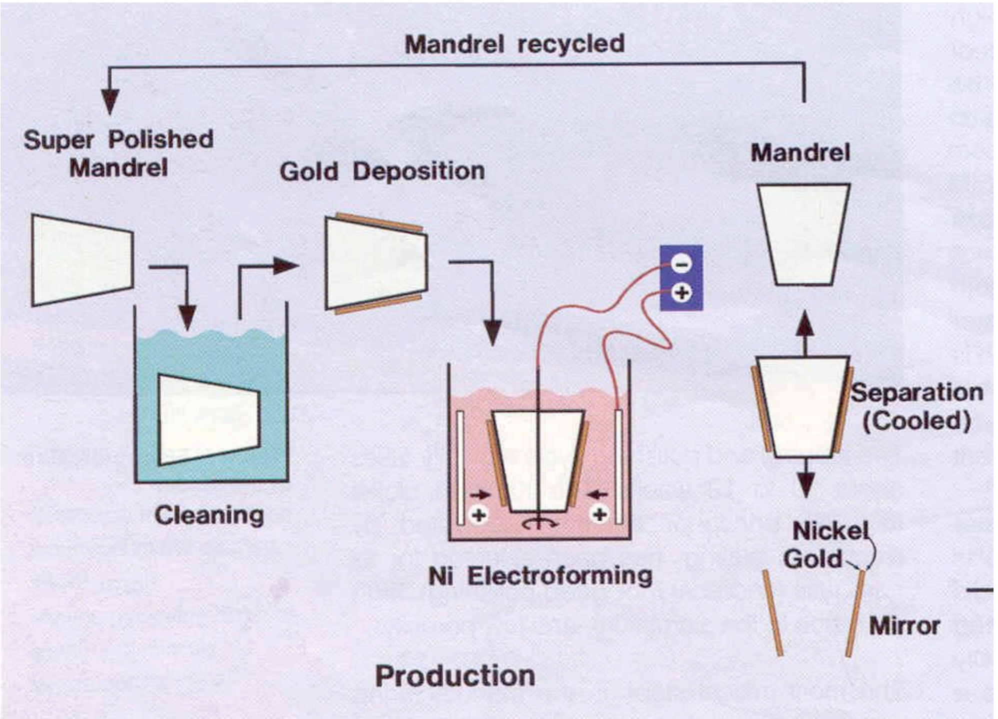
Acceleration mechanisms

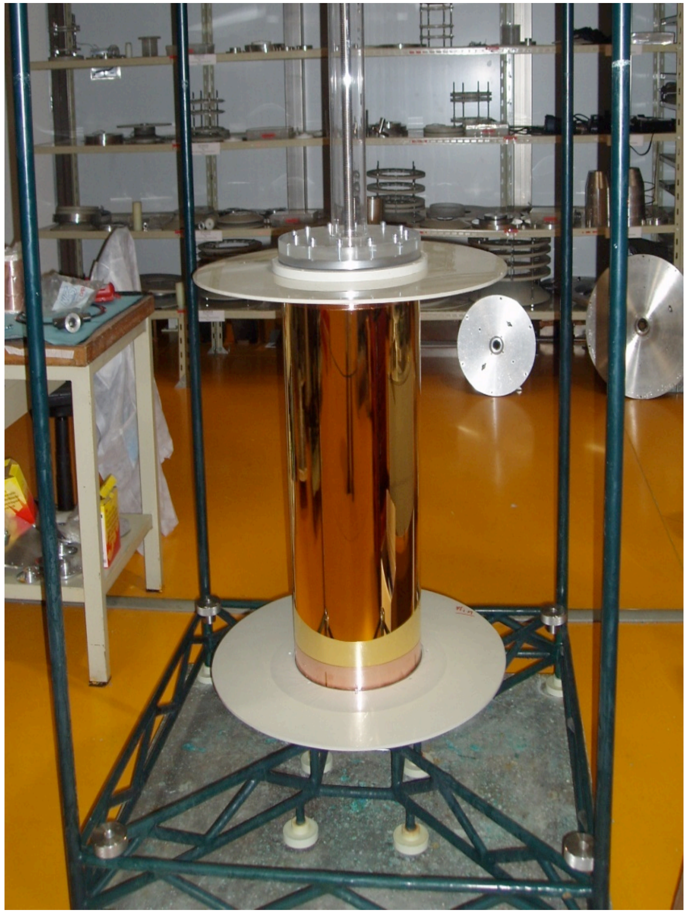
- Measuring the cut-off frequency of the synchrotron emission of SNR, its polarization and azimuthal variation
  - provides the maximum energy of the electrons *and* the B field orientation,
  - understanding the mechanism of diffusive shock acceleration, which is believed to be the **source of the Galactic Cosmic Rays up to an energy of order 10^{15} eV**.

- Measure the non-thermal IC emission in cluster of galaxies
  - The AGN contributions will be resolved and could be excised from the analysis.
  - IC emission in radio relics, located at the cluster periphery.
  - Map the non-thermal emission as a function of the radius

- Low background and good PSF allow the search and study of shocks up to virial radius and beyond

Mirror Shells Production via electroforming replication





Credits: Media Lario Techn.

Optics development

eForming - General

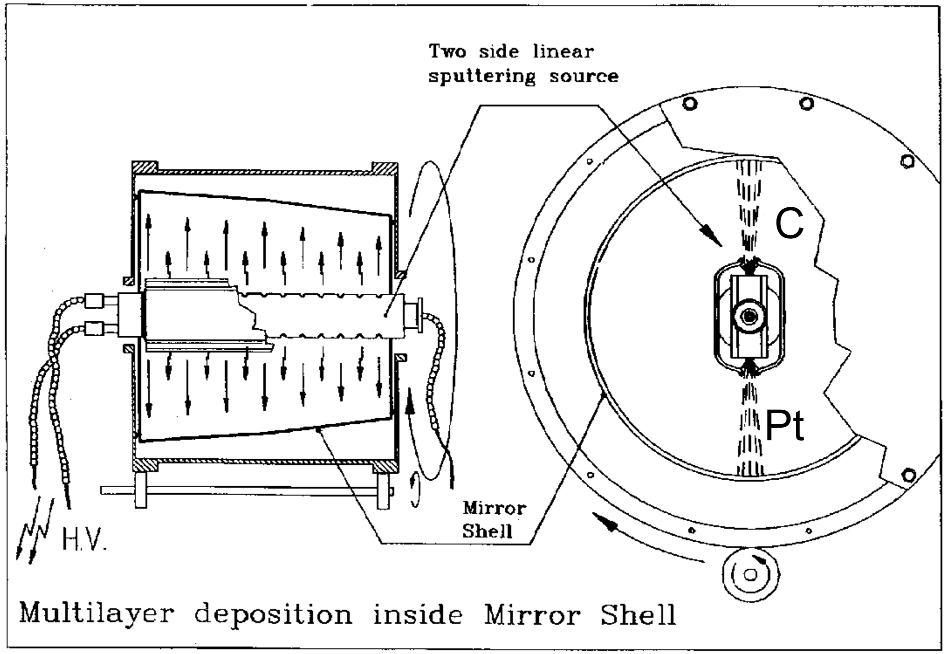
Typical design for mirror shell produced via is eForming (starting from Al mandrel, NiP coated and superpolished)

- Gold separation film applied on the mandrel before eForming
- Nickel (or Nickel-Cobalt) eFormed bulk material → **MUCH THINNER THAN XMM**
- Multilayer applied after replication

The Nickel process has been demonstrated as still applicable and used to produce the first batch of shells for EM 1 and EM 2

The NiCo process has been demonstrated as feasible, three NiCo shells has been produced and integrated in EM 3

Multilayer deposition concept



Credits: Media Lario Techn.

Deposition of the multilayer film onto the internal surface of a replicated mirror shell (development activity previously carried out so far in collaboration with the Harvard-Smithsonian CfA and NASA/MSFC) used to carry out the Phase A study.

Mandrels development

•three Engineering mandrels developed with the **classical way** (Zeiss lapping machines): M#295, 291, 286.

•one Engineering mandrel developed with **the diamond turning technique** and **traditional polishing**: M#297

• one under preparation based on **diamond turning + jet/bonnet polishing** (a much faster process)

Mandrel	HEW (Ray-tracing)	HEW UV (replicated shell)
M295	12”	17”
M291	18”	19”
M286	7”	16”
M297	5”	N.A.

See oral paper 7437-29 Vernani et al., Wed. 5

Zeeko IRP 1200 Bonnet and Jet polishing machine

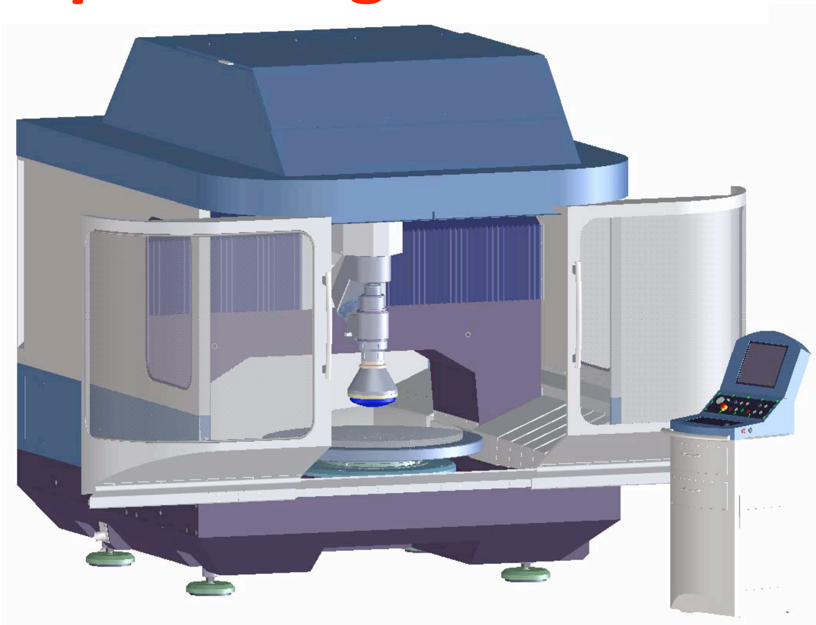
INAF

✓ The Jet polishing process replaces the variable geometry soft polishing tool with a controlled “jet” of slurry to create a polishing “spot” on the surface being polished.

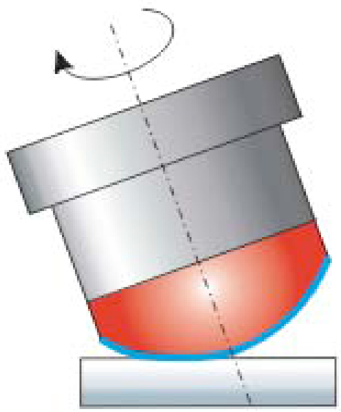
✓ The position and pressure of that “spot” is controlled by a 7 axis CNC machine tool controller

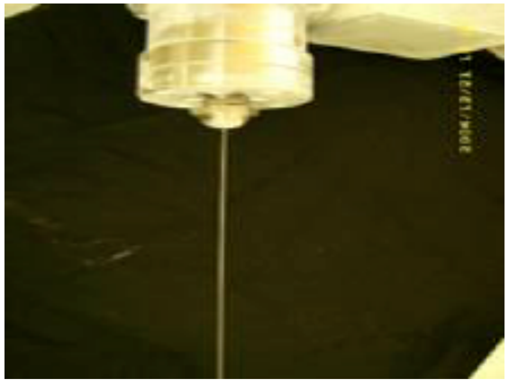
✓ The same machine can be operated with the so called “Bonnet tool”

✓ Jet polishing is preferable for precise figuring, while Bonnet polishing is more appropriate for final polishing



IRP 1200 machine developed by the ZEEKO UK company





Mandrel Jet - Bonnet polishing

Credits: Media Lario Techn

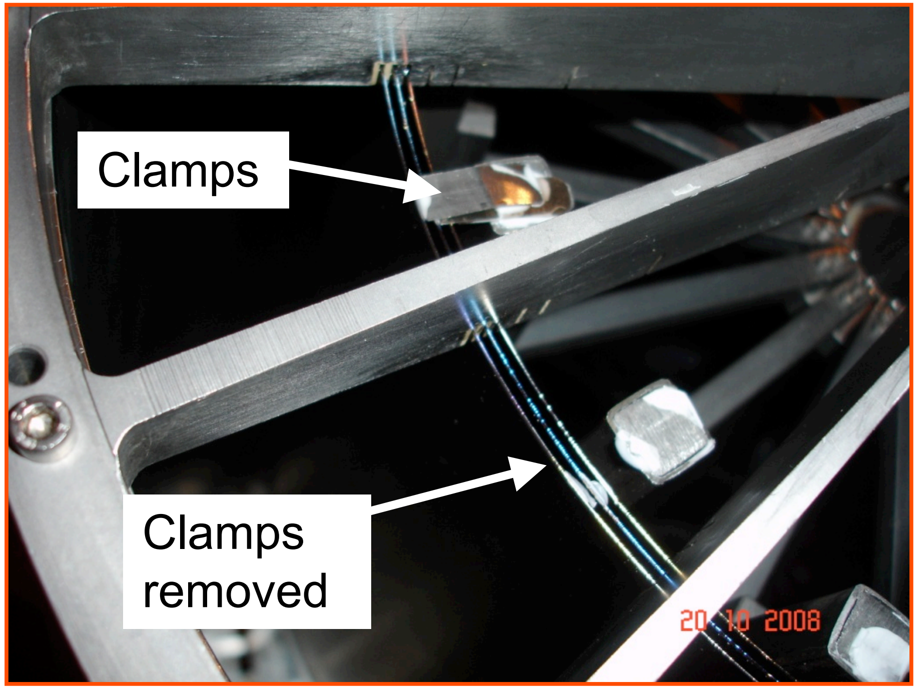
Wolter I profile mandrel
150 + 150 mm long.

Multilayer deposition

The magnetron sputtering machine at Media Lario

The multilayer is deposited on the electroformed shell on top of the gold surface

Integration of the EM3



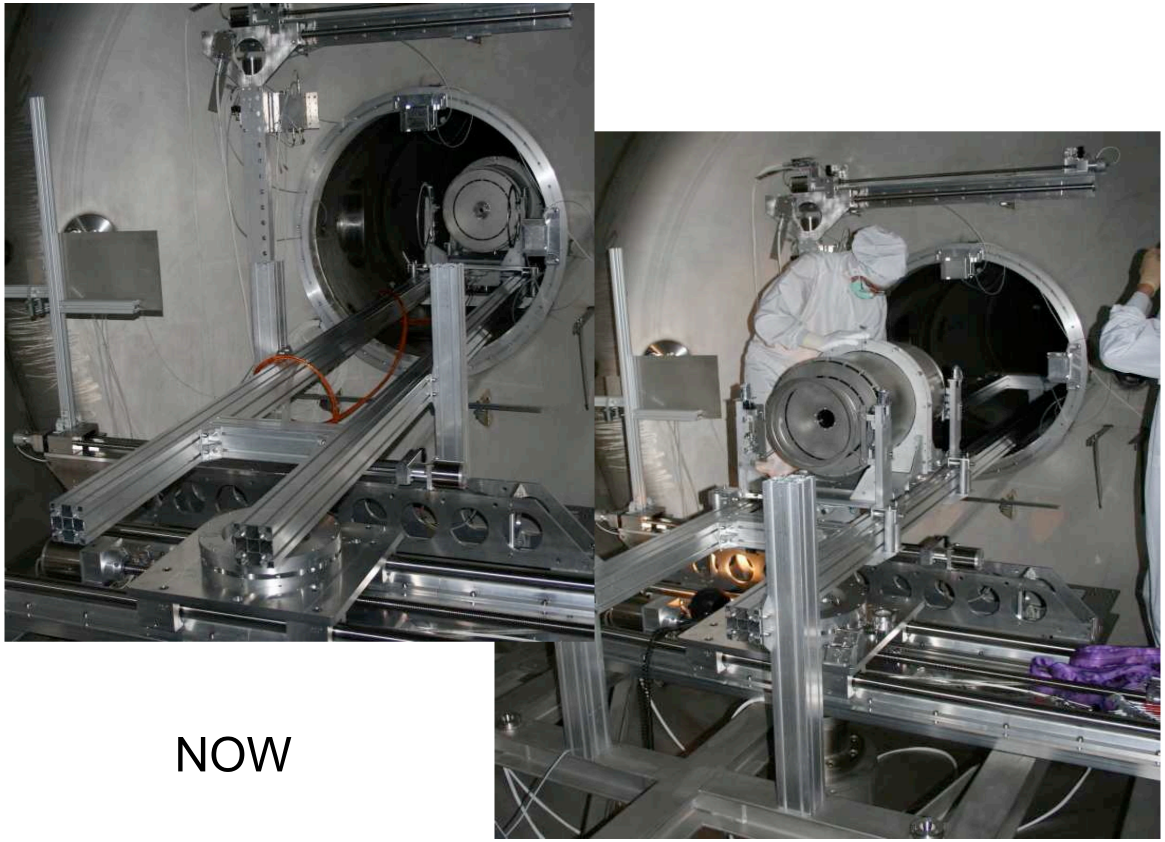
New Jig for Panter tests

Special jigs have been manufactured and implemented at PANTER/MPE for:

• making easier the insertion inside the vacuum tube in PANTER facility with a long guiding system (4m)

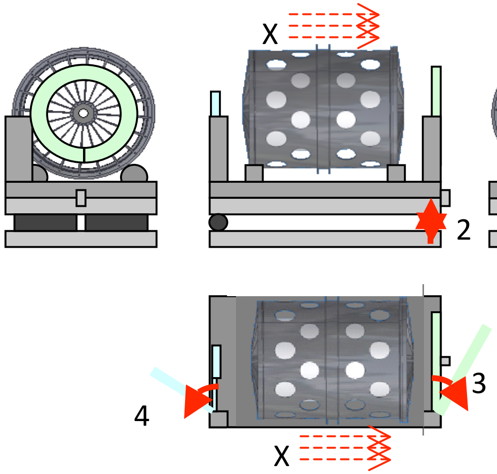
• possibility to test each shell (S291 or S295) or both (S291+S295) with masking windows

BEFORE….



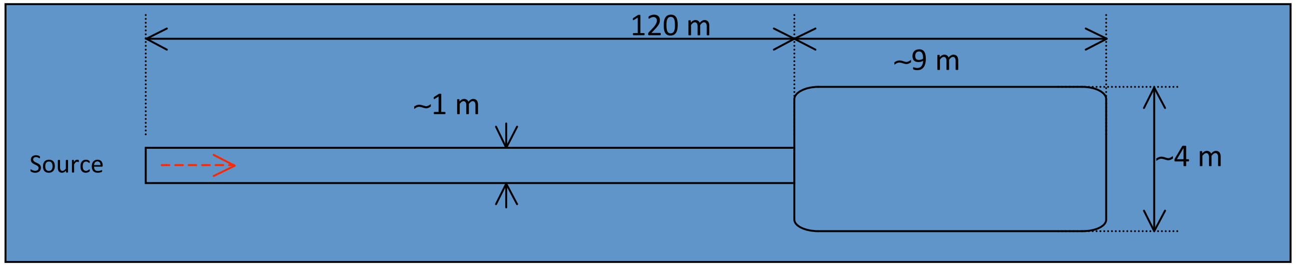
NOW

Optics calibration @ Panter/MPE - I

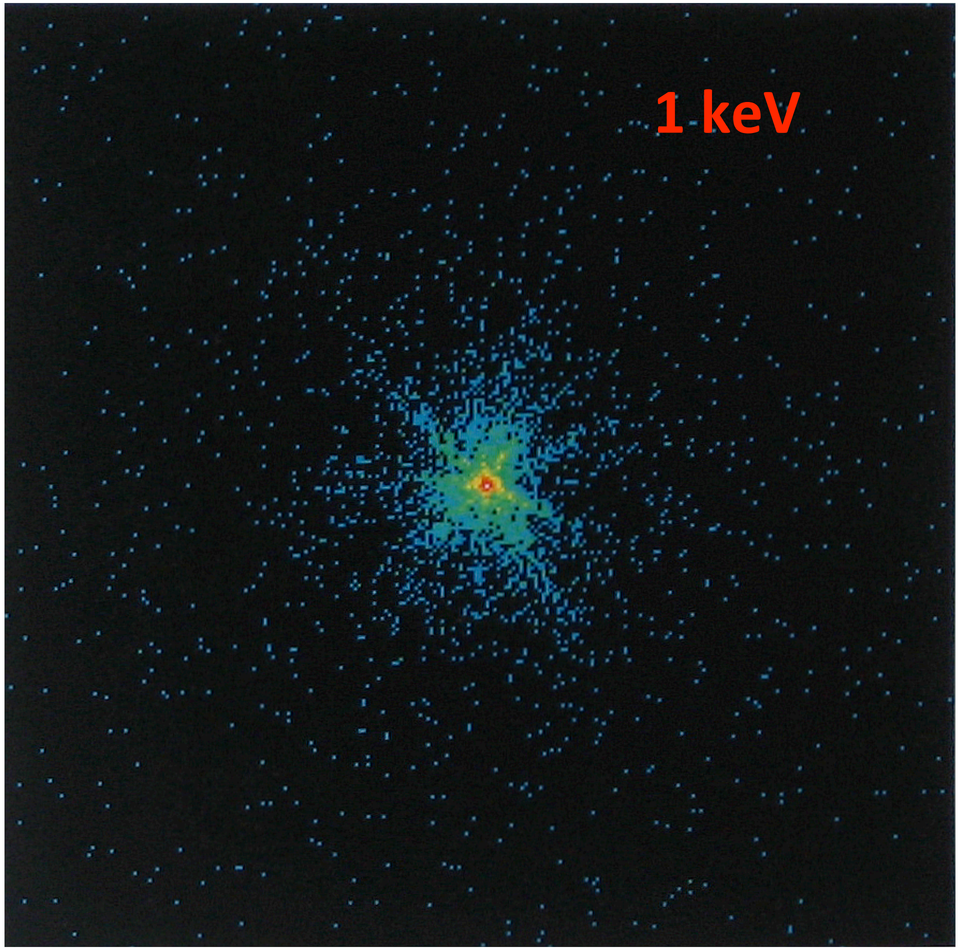


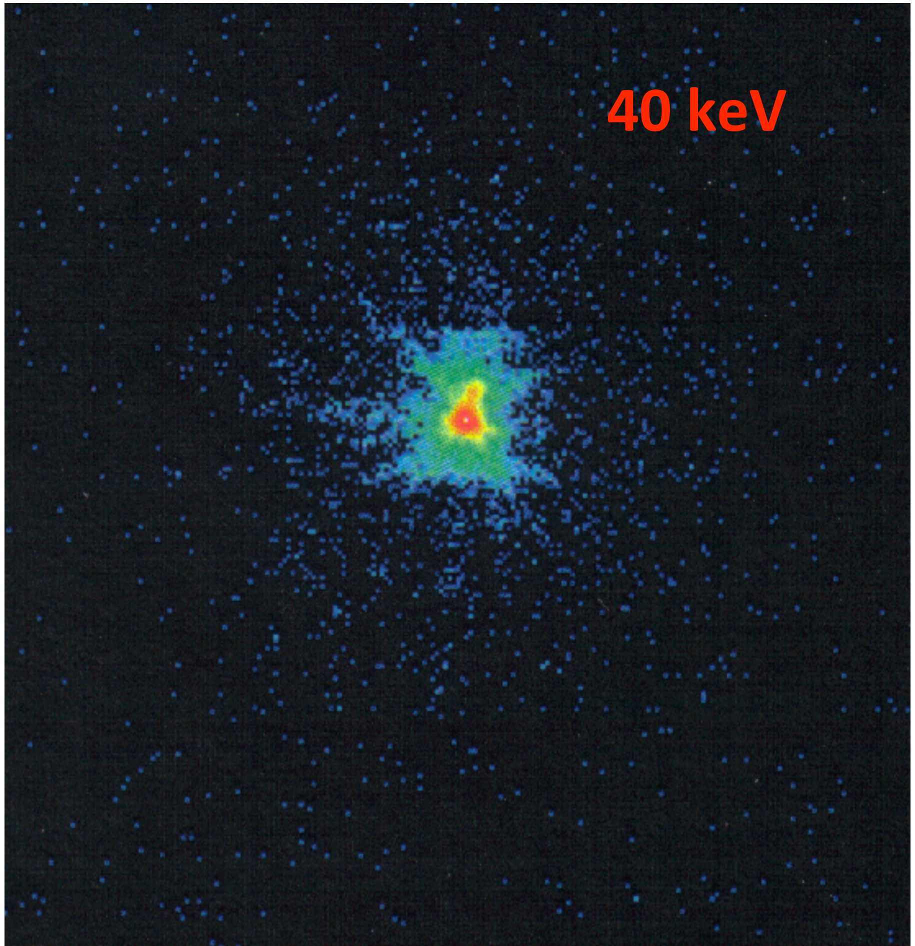
1. Horizontal alignment
2. Vertical alignment

3. – 4. Other movements

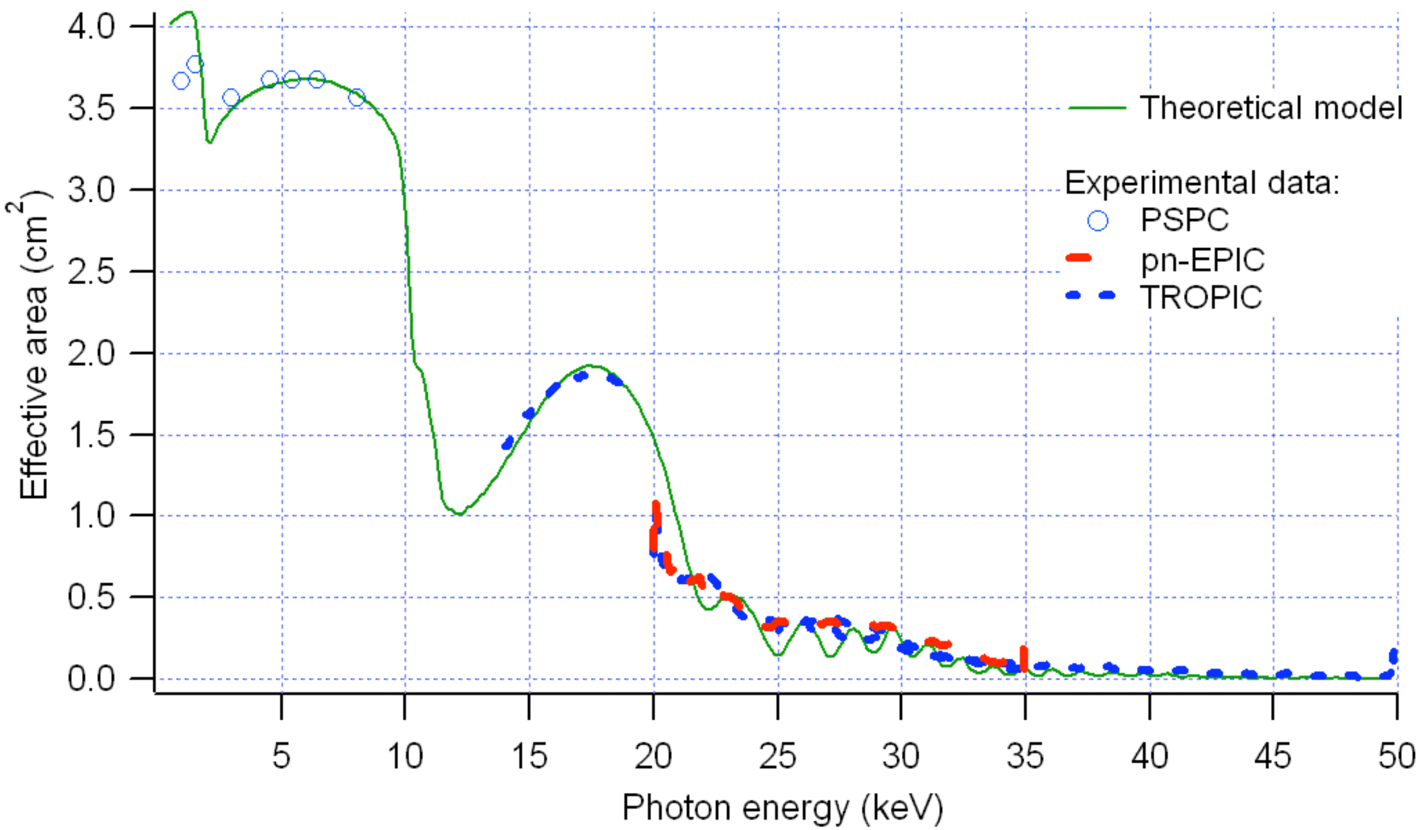


Optics calibration @ Panter/MPE - II

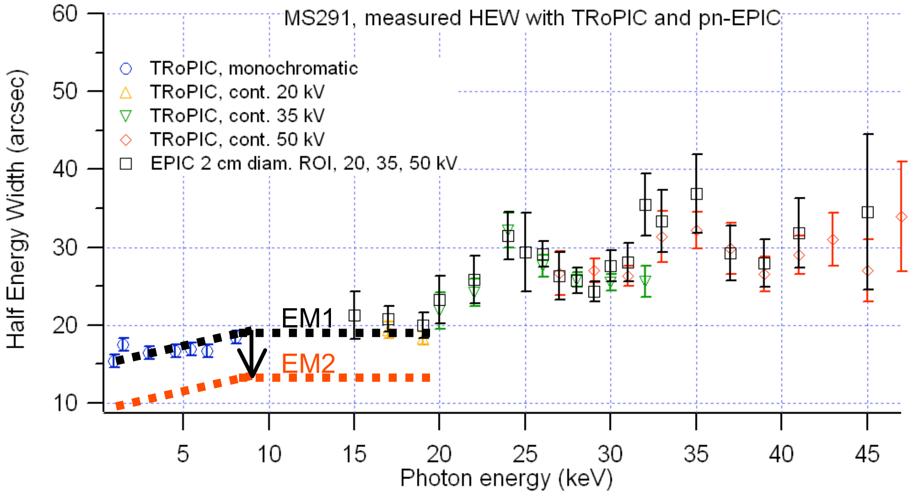




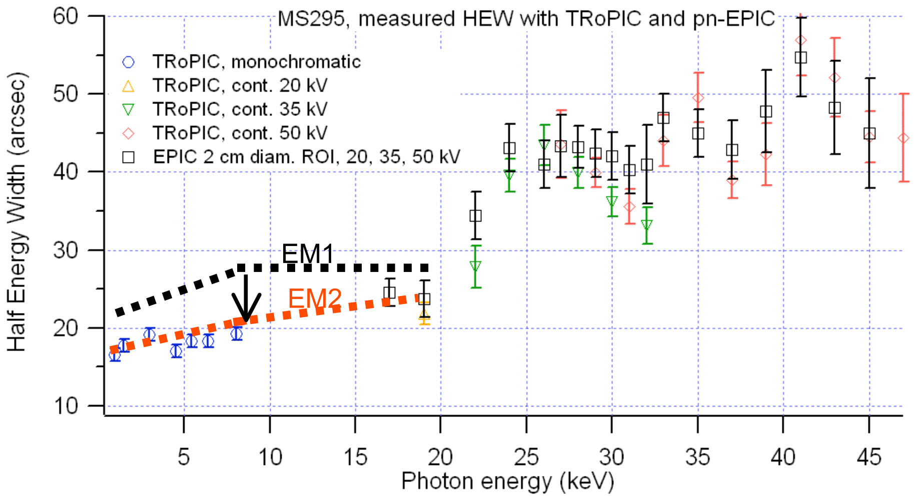
Measured Effective Area



Panter measurements of EM1 and EM2

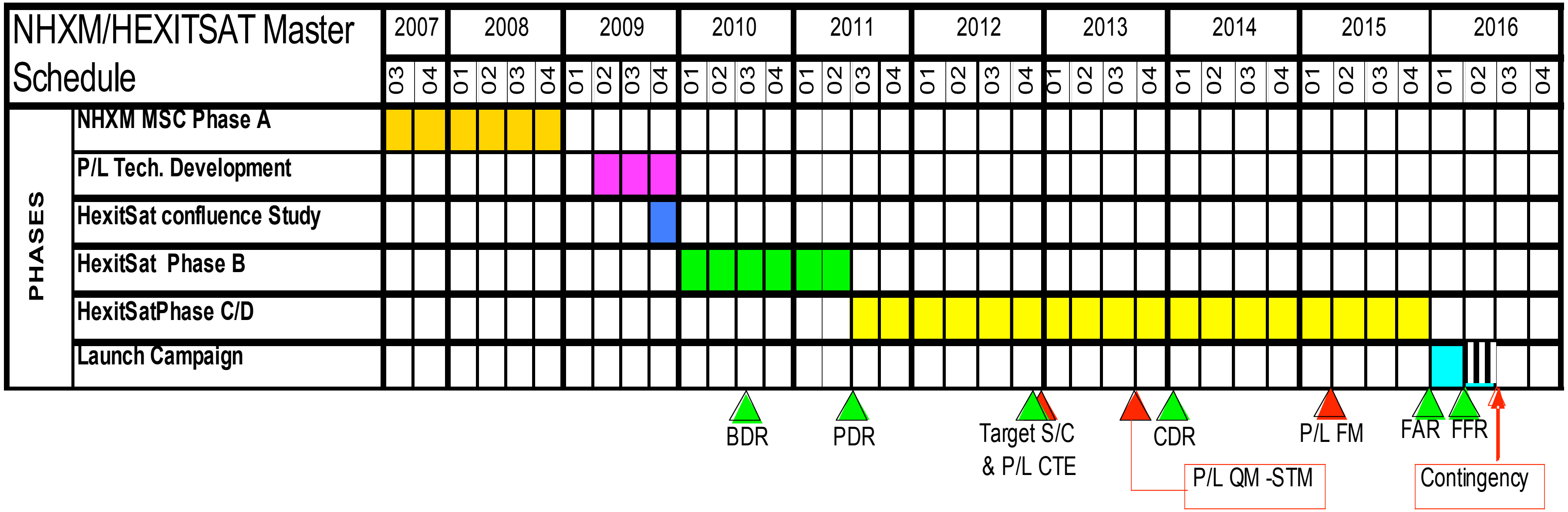


MS 291



MS 295

NHXM schedule



Summary

- Simbol-X was shut down, but the discovery space of an Simbol-X-like mission is still extremely wide,
- it can be further enhanced by the addition of simultaneous **imaging polarimetry**.

- This is achievable by a medium-size mission concept, exploiting already available technology in mirror and detector manufacturing, well within the next decade.

- Both technologies have old and strong roots in Italy, building up on the BeppoSAX, INTEGRAL & XMM heritage

- NHXM not only complementary to the hard X focusin missions NUSTAR and ASTRO-H, but also to the coeval WFXT and EXIST wide fild X-ray and gamma ray missions. NHXM will be also a good precursor for IXO.