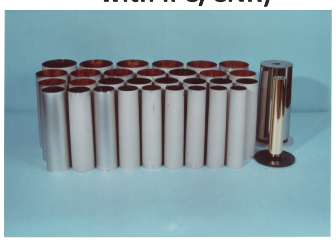
Progresses & perspectives in X-ray optics and possible applications in future missions

Giovanni Pareschi
INAF – Osservatorio Astronomico di Brera

Italian experience, expertise & facilities for asyronomical X-ray optics development

1988 | 1990 – 2003 | 1990 -1997 | 1998 | 2006 - 2007 | 2010 | 2010 - 2013

Beppo SAX (ASI, with IFC/CNR)

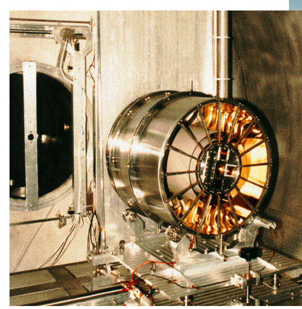


- Optics design
- Ray-tracing
- Development of mandrels and mirrors
- Metrology and calibrations

JET-X - SWIFT (NASA-ASI)

- Optics design
- Ray-tracing
- Development of mandrels and mirrors
- Metrology and calibrations

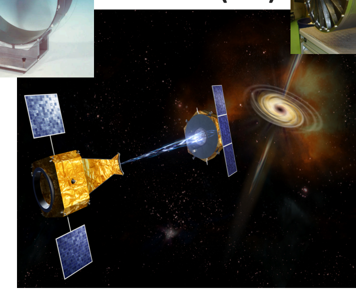
XMM (ESA)



- Optics design
- Ray-tracing
- Development of the first prototypes
- Metrology and calibrations

WFXT

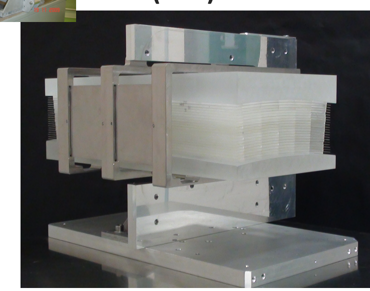
Simbol-X (ASI)



- Mission concept
- Optics design
- Ray-tracing
- Development of the prototypes
- Metrology and calibrations

NHXM

XO (ESA)
HENA (ESA)



- Optics design
- Ray-tracing
- Development of the galss slumping technology
- Prototypes
- Metrology and oratio

agenzia spaziale italiana

OSSERVATORIO ASTRONOMICO DI BRERA

INAF ISTITUTO NAZIONALE DI ASTROFISICA

Media Lario Technologies

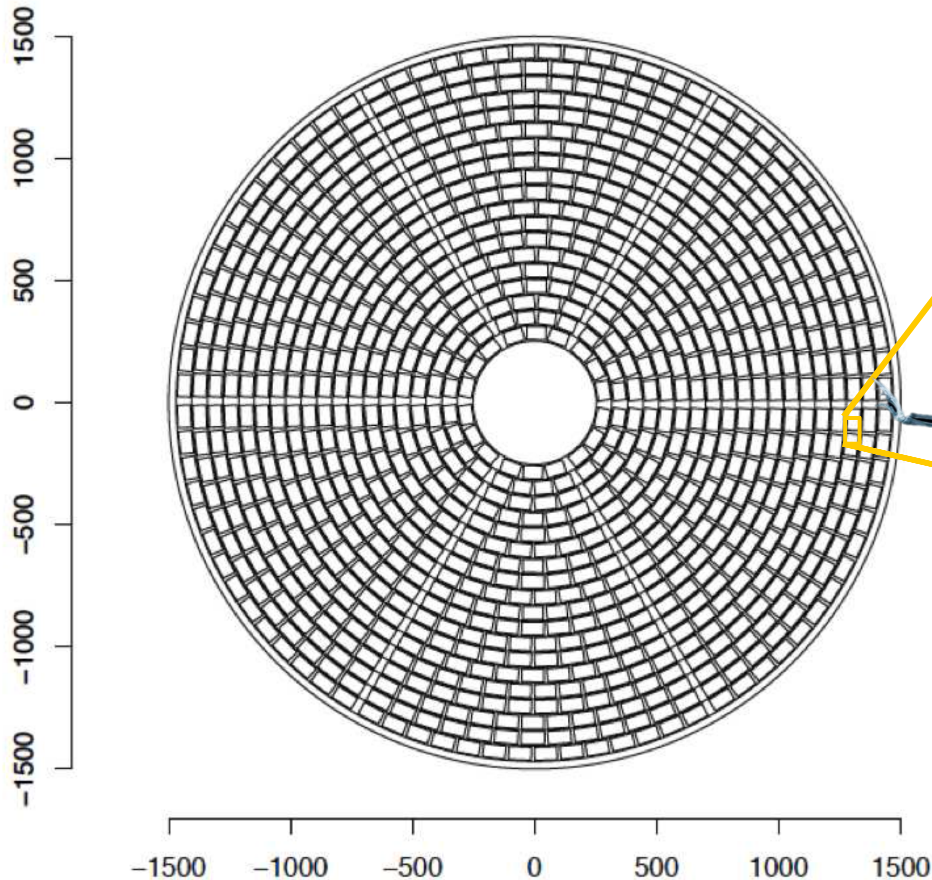
BCV progetti s.r.l

ThalesAlenia Space
A Thales / Finmeccanica Company

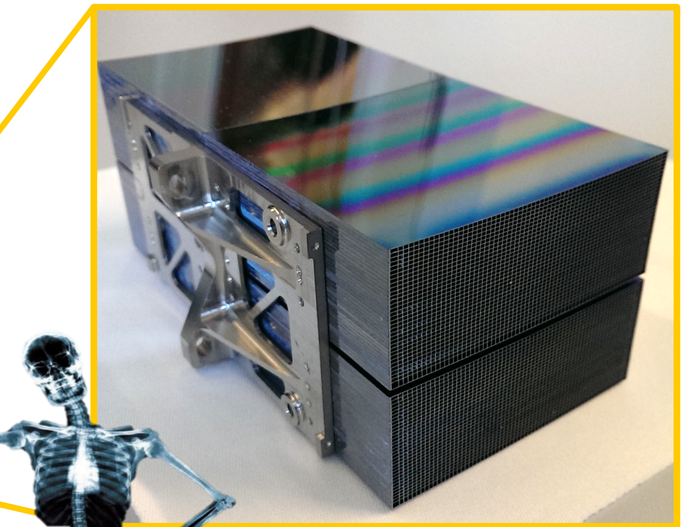
ADS

ATHENA optics

2 m^2 A_{eff} @ 1 keV



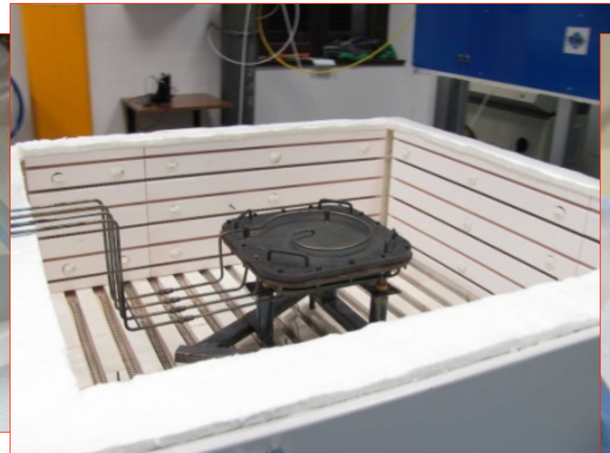
SPO technology (ESA/Cosine)

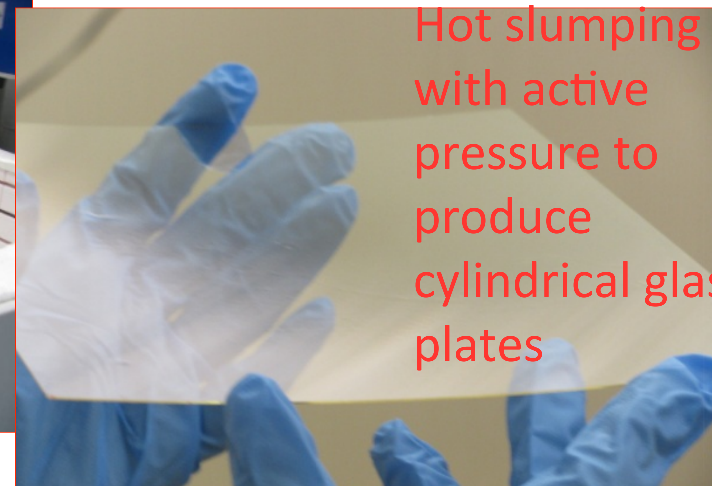


~ 900 mirror modules
~136.000 mirror plates
~ 408 m^2 mirror area
Mass production using semiconductor tool-chain

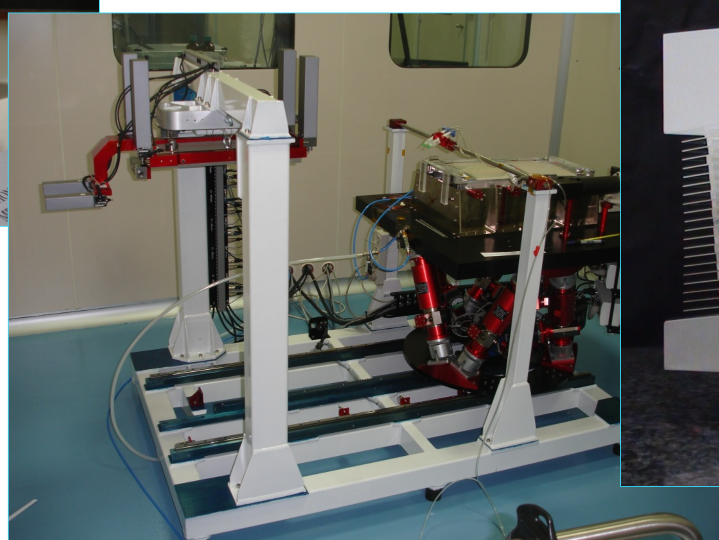
INAF currently involved in design and calibration activities (but role difficult to be defended in the implementation phase, ➔ see the XMM lesson!)

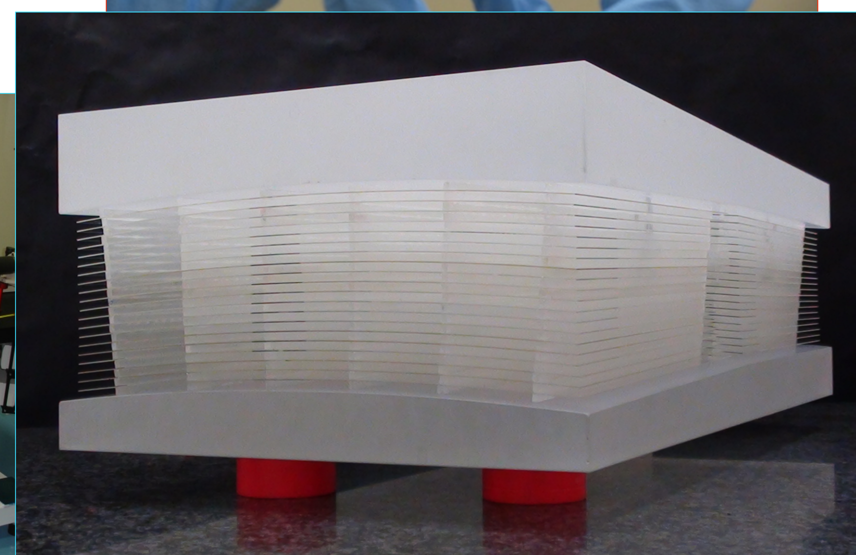
IXO/ATHENA: hot slumping “spare” technology developed by INAF for ESA





Hot slumping with active pressure to produce cylindrical glass plates





“Cold” integration for plates shaping to Wolter I & alignement

M.M. Civitani et al. [SPIE 2014, 9141-41]

Tecnologia del vetro per le ottiche in raggi X di prossima generazione

Glass Technology for the next generation X-ray optics

Proposal approved by ASI (first ranked, after peer review by external referees) in the context of the Call on new Technologies 2014.
KOM meeting March 2016 → INAF + POLIMI

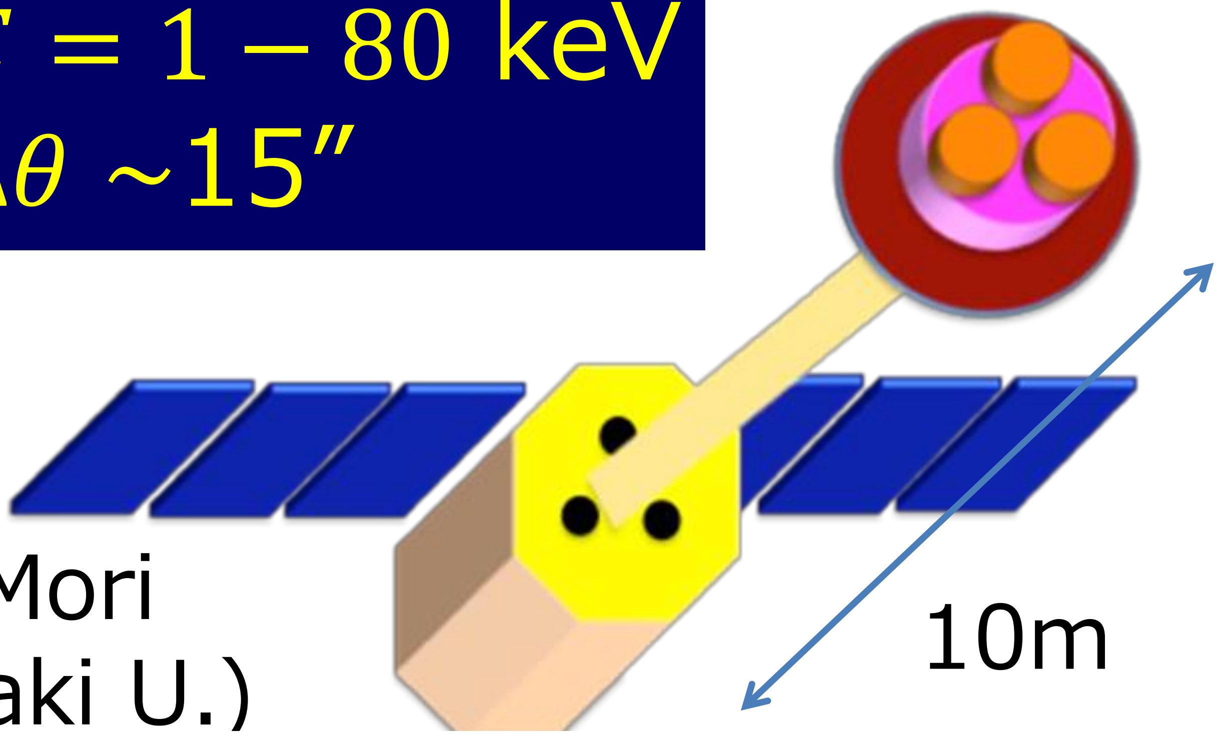
NGHXT

(now. FORCE,.. It was too similar to NHXT)

Next Generation Hard X-ray Telescope

$E = 1 - 80$ keV

$\Delta\theta \sim 15''$



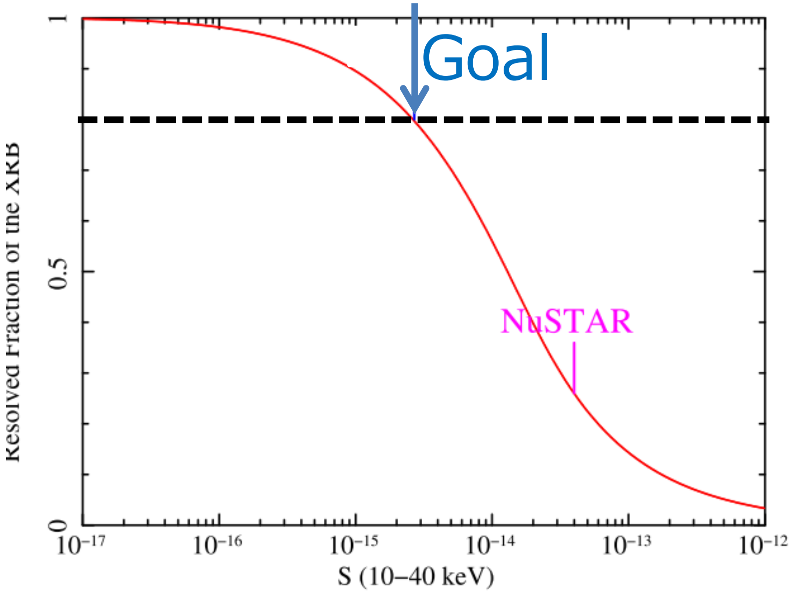
PI: K. Mori
(Miyazaki U.)

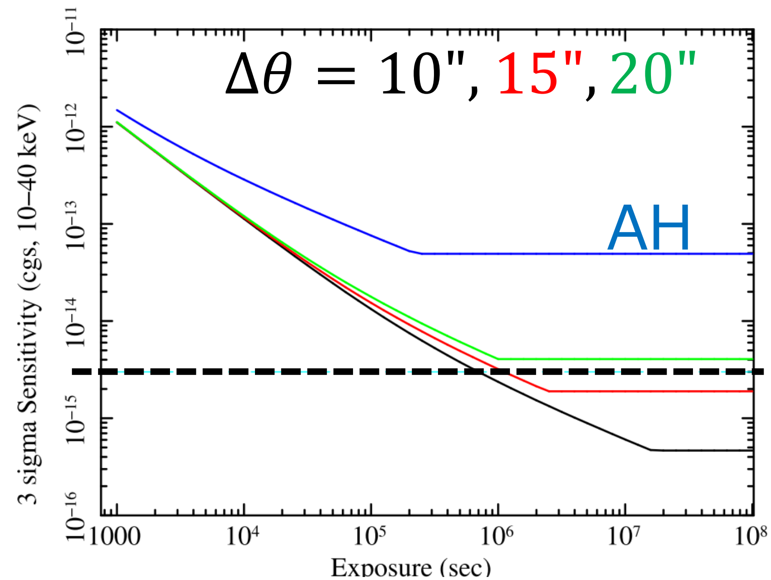
JAXA – M4 call 2016 (confirmed after the Himomi's disater?)

FORCE scientific goal

Resolve 80% of CXB in 10-40 keV

$S = 3 \times 10^{-15}$





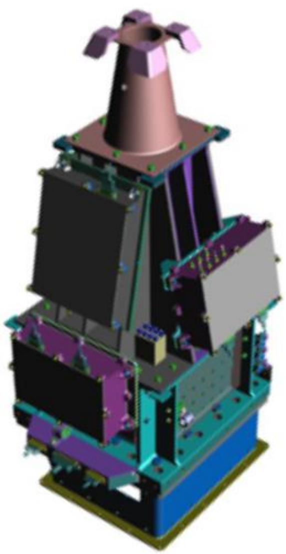
Based on a CXB model constructed below 10keV

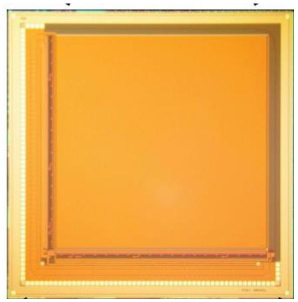
$$\Delta\theta < 15''$$

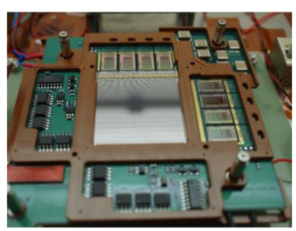
FORCE payload

Detector

Active shield
+ Si SOI & CdTe



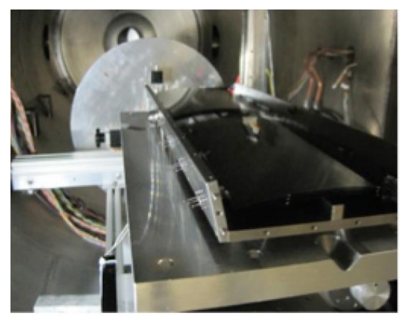


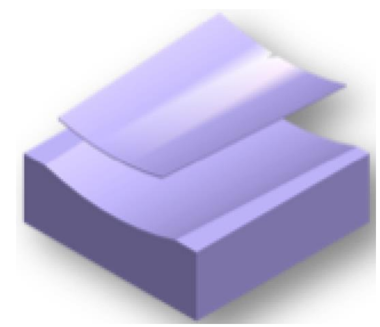


AH successor

Mirror

Glass or Si foils etc.
+ multi-layer





Possible
collabora
NASA/GS

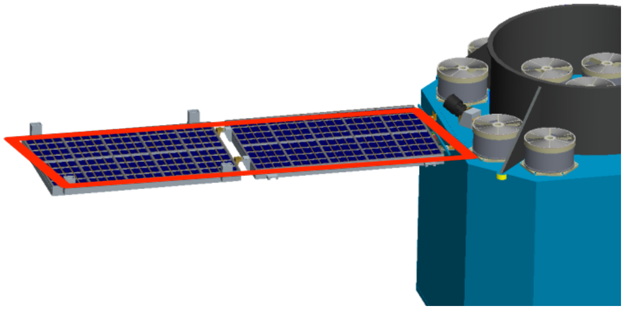
Also possible collaboration with ASI and INAF

eXTP – enhanced X-ray Timing and Polarization mission

CHINA + MPE + ASI/INAF

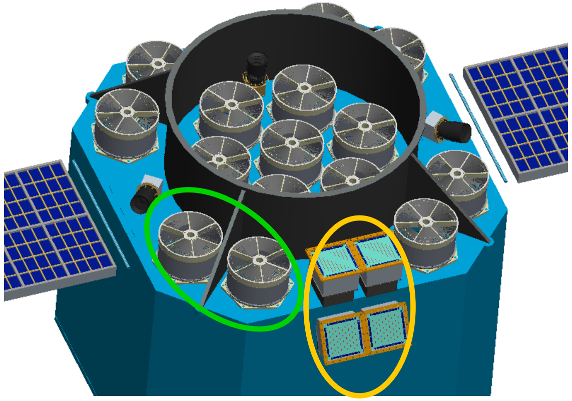
Scientific objectives:

- *Test General Relativity in strong-field regime*
- *Study state and nature of matter at supernuclear densities*
- *Test physics in the presence of ultra-strong magnetic fields*



Potential for ASI/ESA-CAS collaboration:

- X-ray optics
- Large Area Detector (ref., LOFT)
- Wide Field Monitor (ref., LOFT)
- GPD polarimeter
- Malindi ground station



XTP optics compared to previous high-throughput telescopes

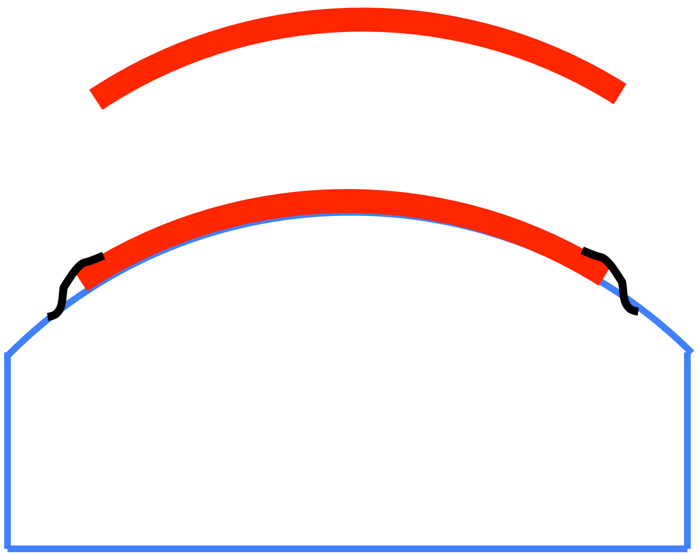
Parameter	XTP/ LFA	XTP/ HXA	e-Ros	Nustar/ HEFT	ASTRO-H /LET	ASTRO-H HET	NHXM
Area @1 & 6 keV (cm^2)	5000-500	?/ 4000	1750/200	1000/800	600/470	600/600	2400/ 2200
Reflecting Area (m^2)	339	311	98	100	26	68	100
Weight (kg)	320	250	280	74	46	80	400
HEW (arcsec)	60	60	15	60	75	180	15/20
Areal Density (cm^2/kg)	15	NA	6	13	13	7.5	6
Number of equivalent Wolter I shells	100 X 8	120 X 5	54 X 7	133 X 2	128 X 2	216 X 2	70 x2
Configuration/ number of pieces	Segm 6000/ 8000	Segm 5000	Monolith/ 378	Segm/ 5000	Segm/ 1536	Segm/ 2592	Monol/ 140

NB for LFA just 8 modules considered

SGO: toward cost reduction

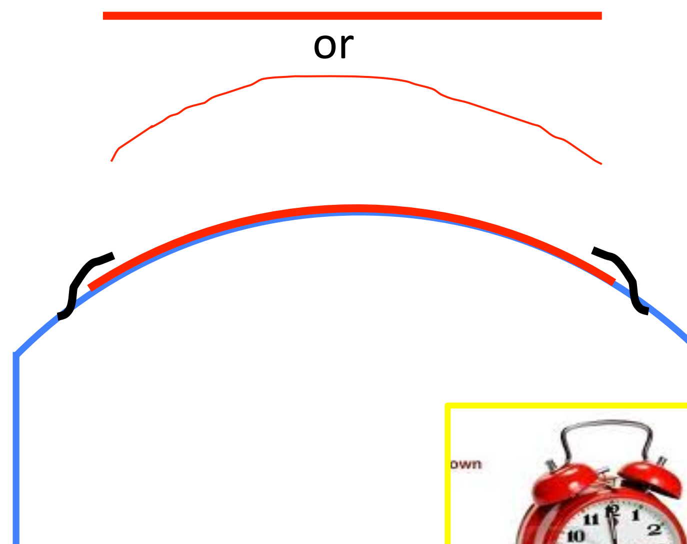
NB: Hot&Cold slumping to reach high angular resolution ≈5''

0.4mm preshaped glass
With high accuracy
cylindrical shape



Cold slumping to reach high angular resolution ≈ 60''

<0.2mm FLAT or RAW PRESHAPED glass with
cylindrical shape

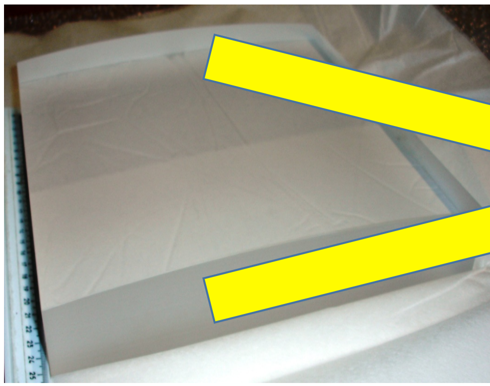


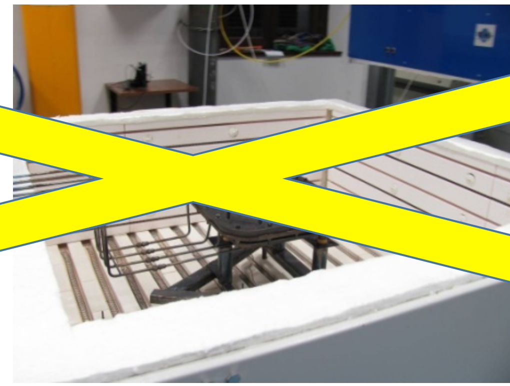
ONLY COLD INTEGRATION
WITH REINFORCING RIBS

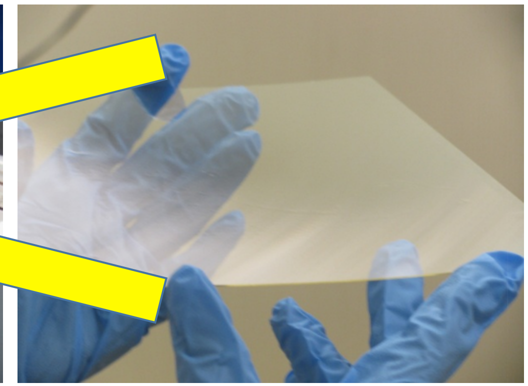
Cold Slumped Glass Optics

Forming molds | Slumping process | Result

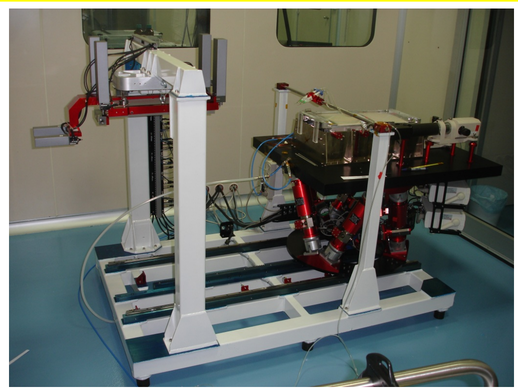
Hot slumping with active pressure to produce cylindrical glass plates

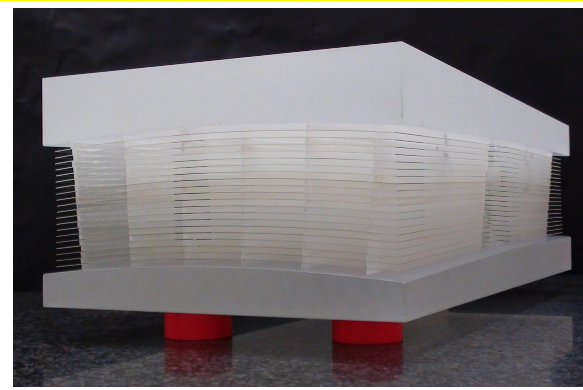






Cold slumping for plates shaping to Wolter I & alignement





Need of flexible glass: Willow as example

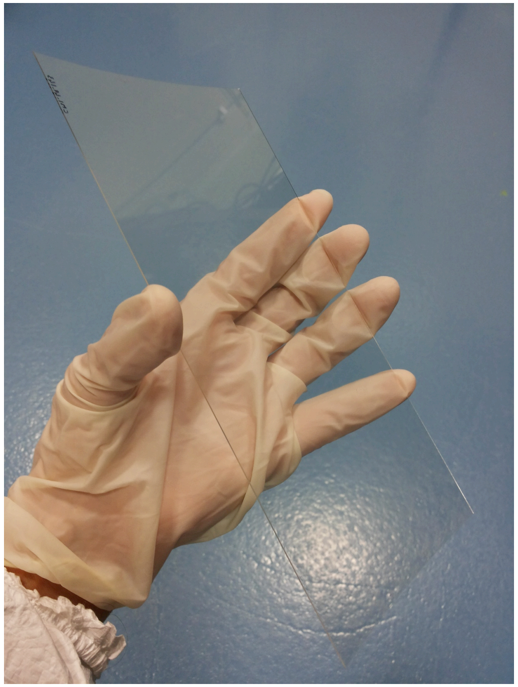
Ultra-slim flexible glass is a 50-200µm thick glass

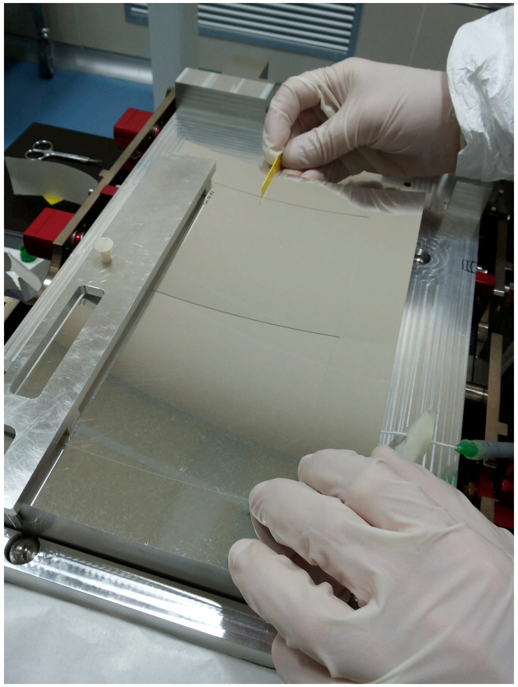
Fusion process

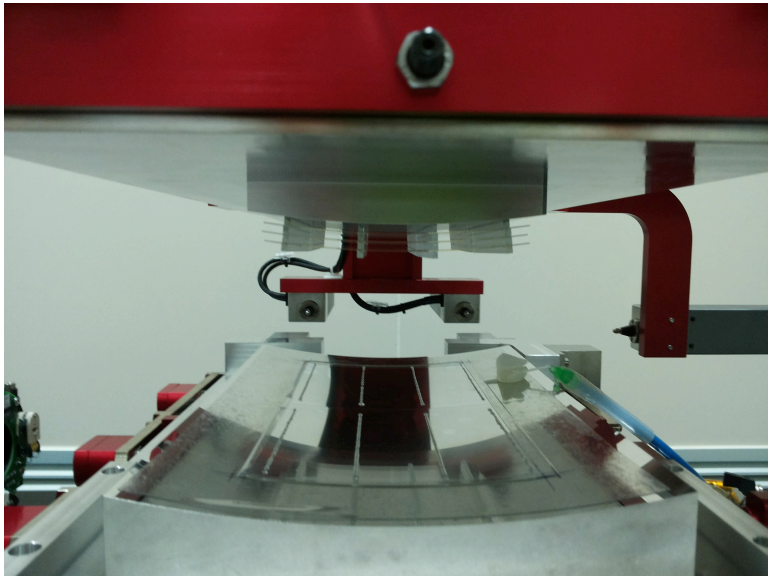
Sheets	250mm x 300mm
Rolls	10m long x 300mm wide
Quantity	Development quantities

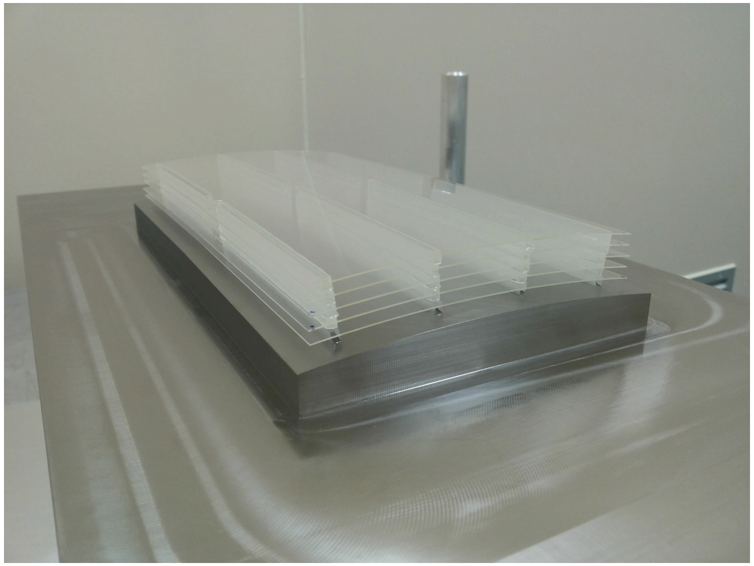
CORNING

Indirect integration on IMA: JIM1 MPE SGO





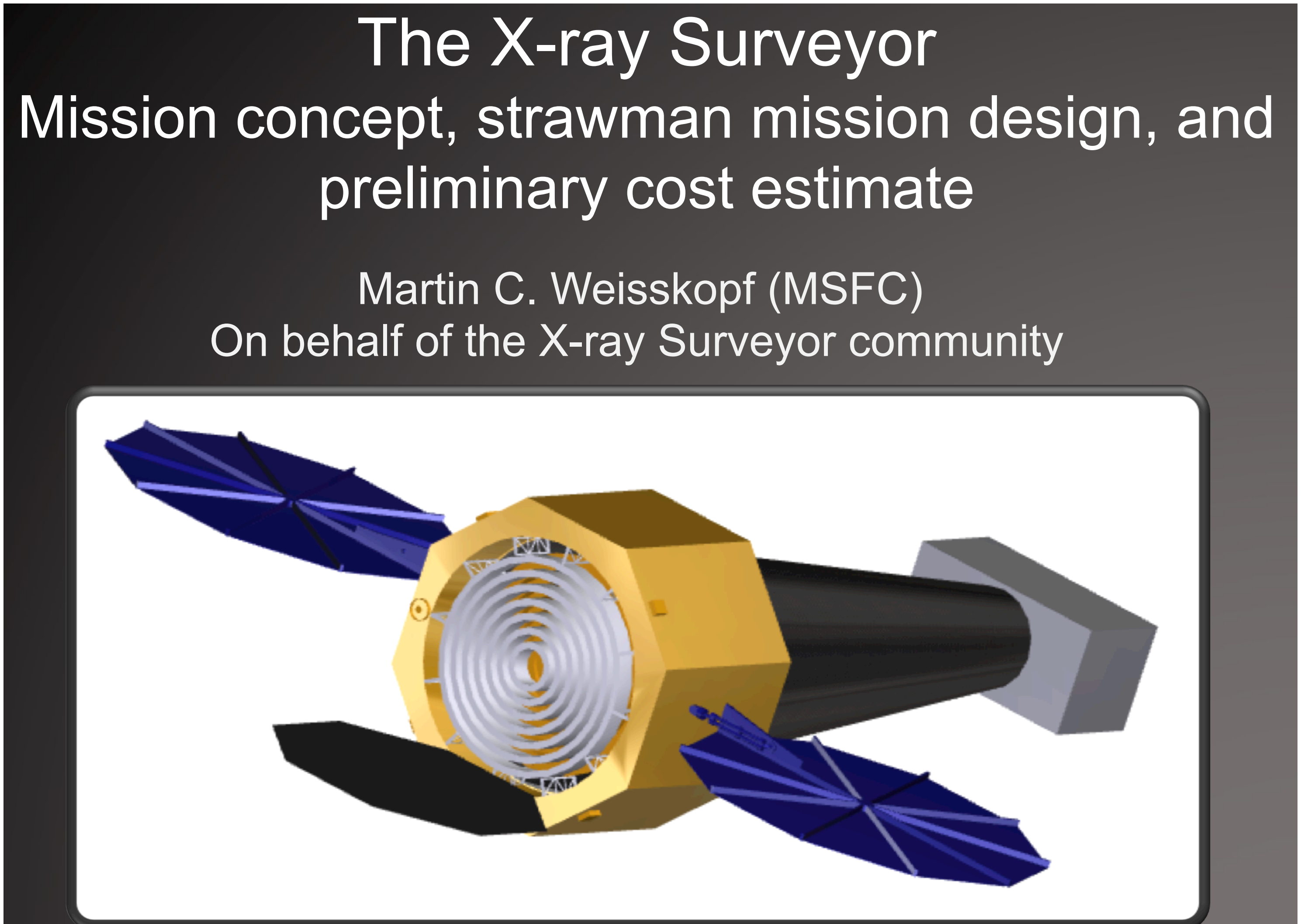




Indirect slumped glass
Monolithic indirect integration mold

Realized 02/2015
details in Proserpio/Winter presentations

Reference Mission for high resolution optics



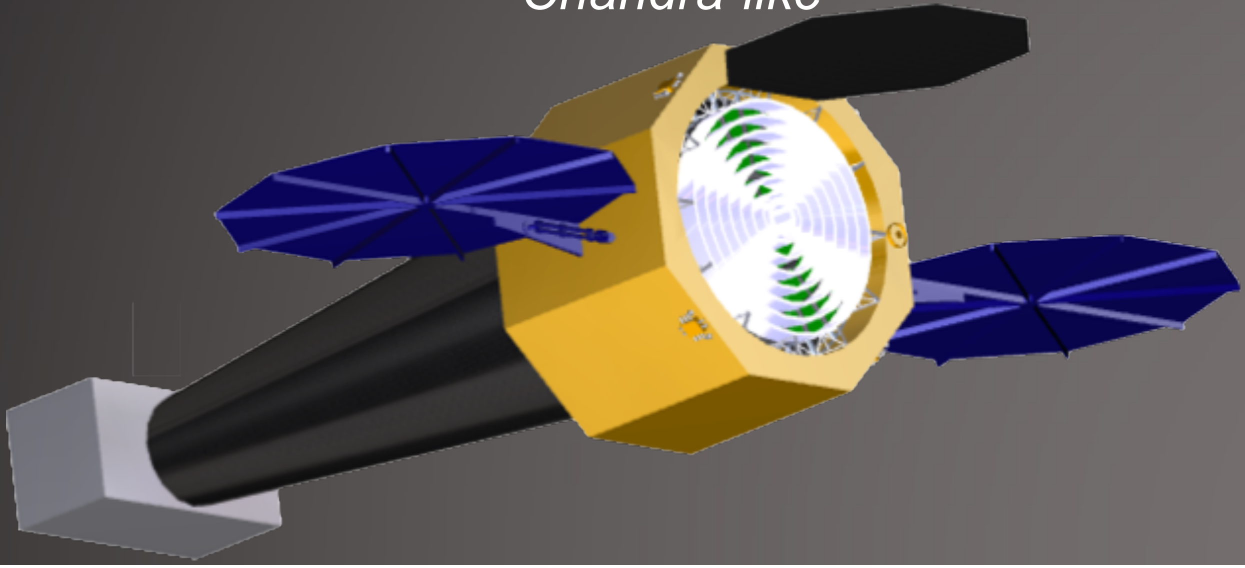
The strawman X-ray Surveyor concept is a successor to *Chandra*

- Angular resolution at least as good as *Chandra*
- Much higher photon throughput than *Chandra*

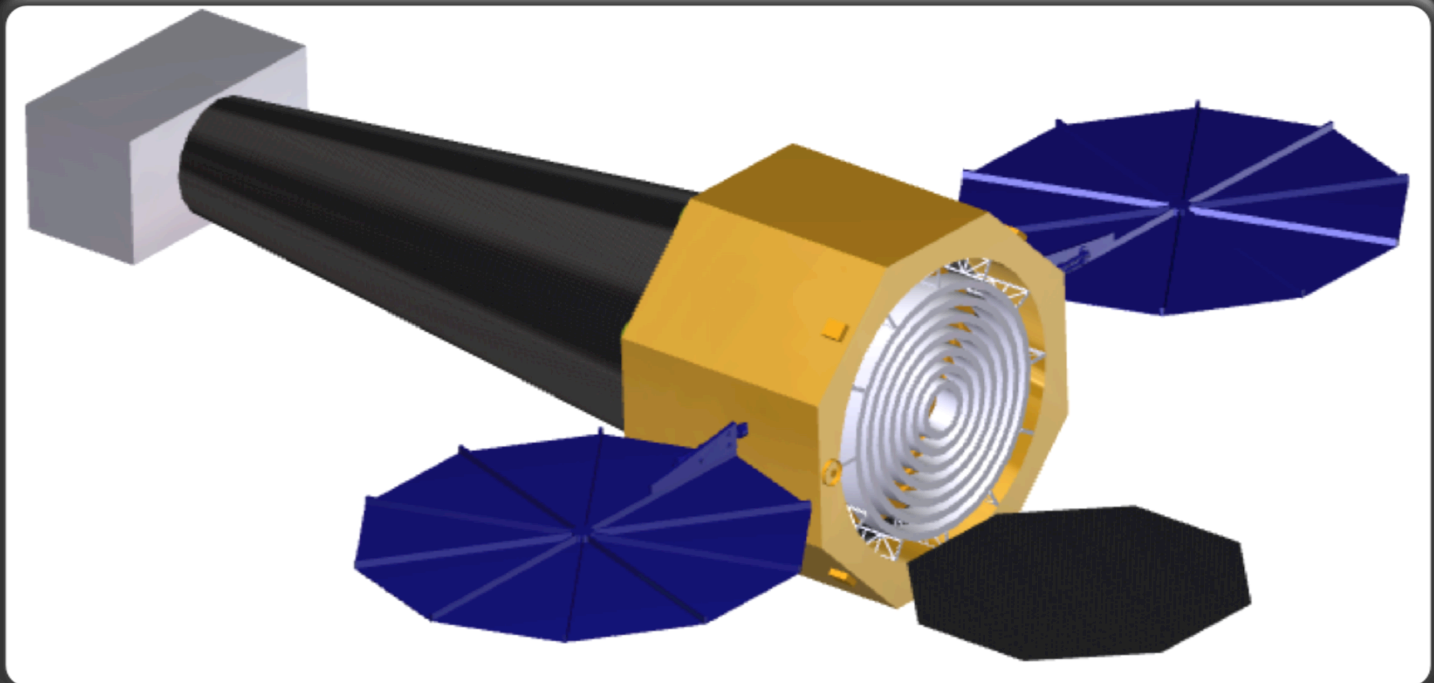
✓Incorporates relevant prior (Con-X, IXO, AXSIO) development and *Chandra* heritage

✓ Limits most spacecraft requirements to *Chandra-like*

✓ Achieves *Chandra-like* cost



Next-generation instruments that exploit the telescope's properties to achieve the science



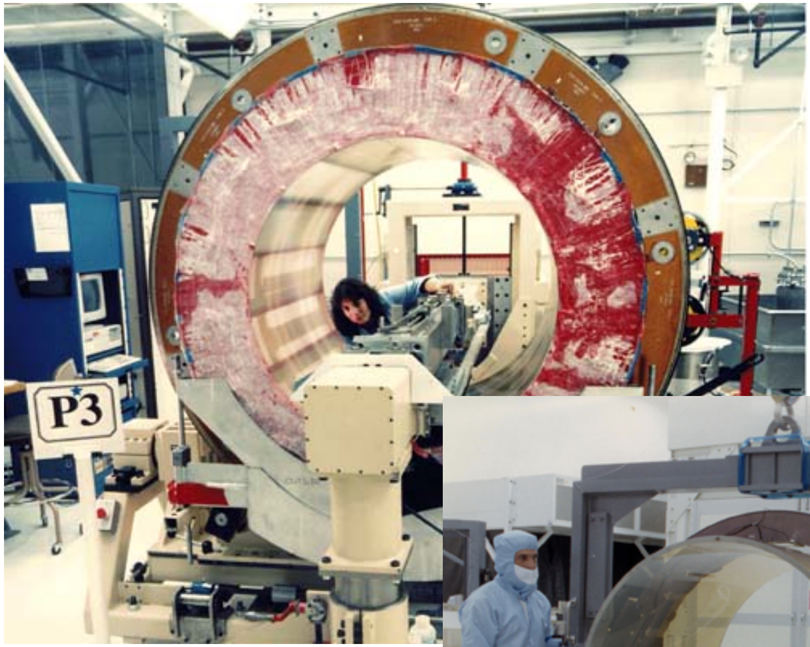
Strawman instrument payload

5′×5′ microcalorimeter, 1″ pixels, 0.2–10 keV

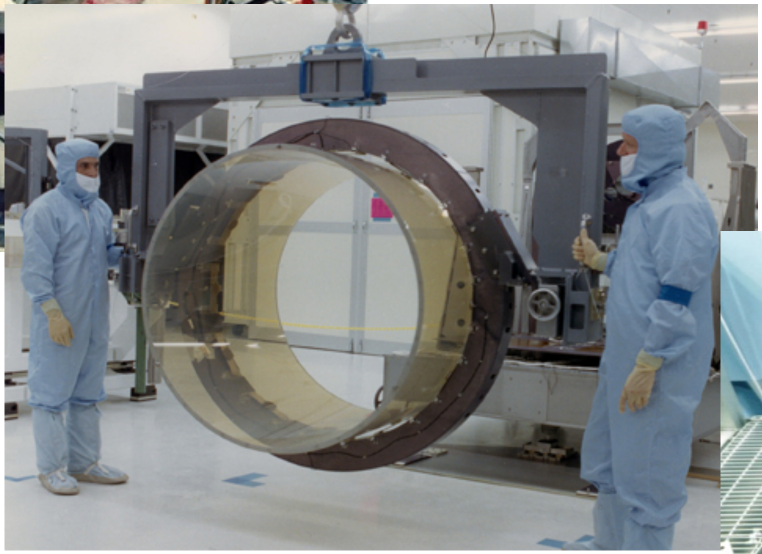
22′×22′ CMOS imager with 0.33″ pixels, 0.2–10 keV

Gratings, R = 5000, 0.2–2.0 keV

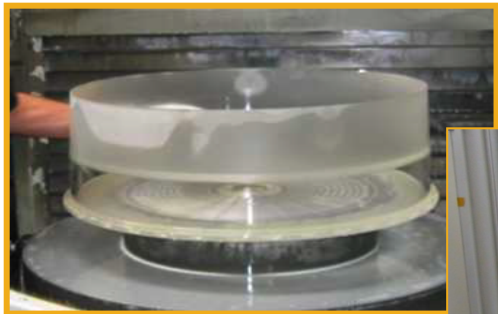
Polishing of the Chandra shells

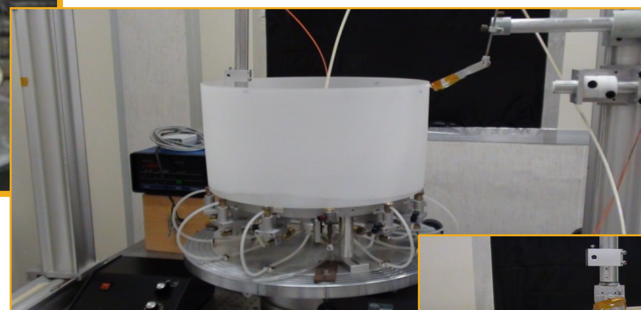


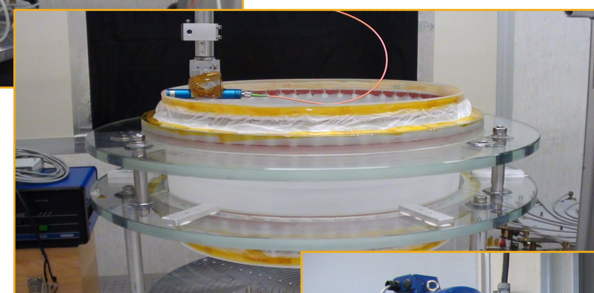
20 mm thick shells !

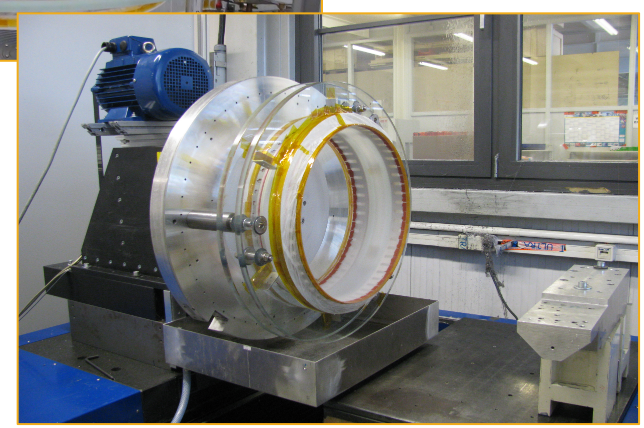


New process flow (I)



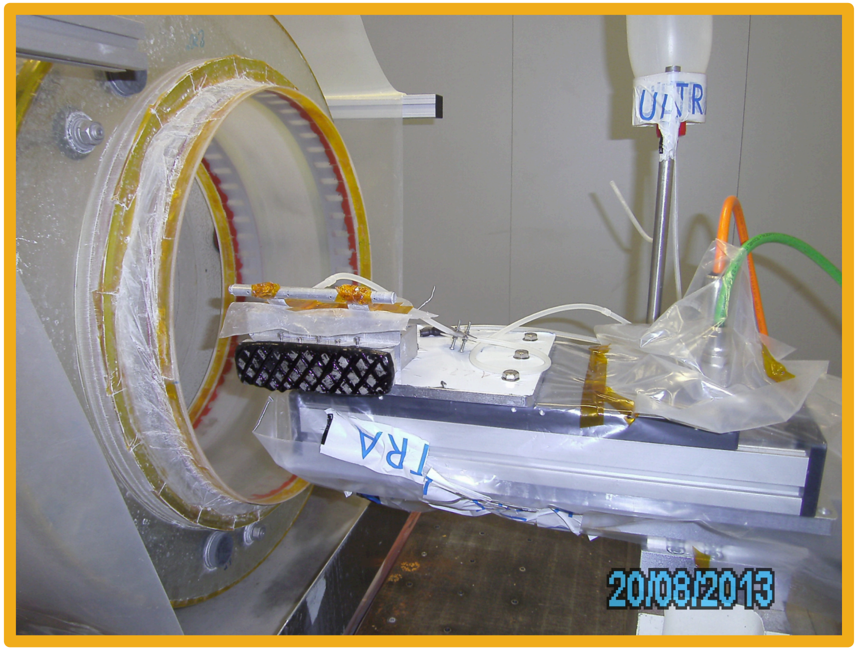






The first part is the same, up to fine grinding

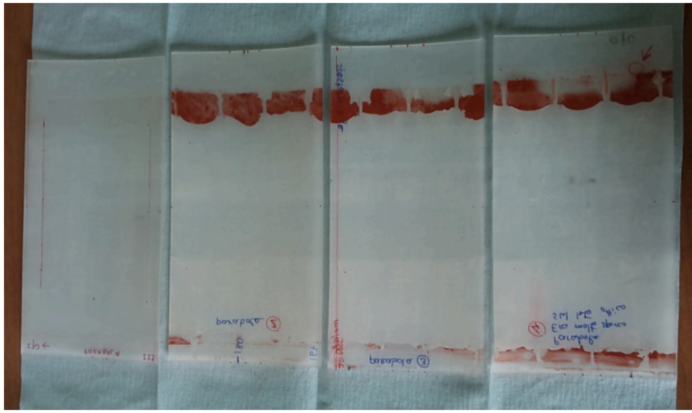
New process flow (II)

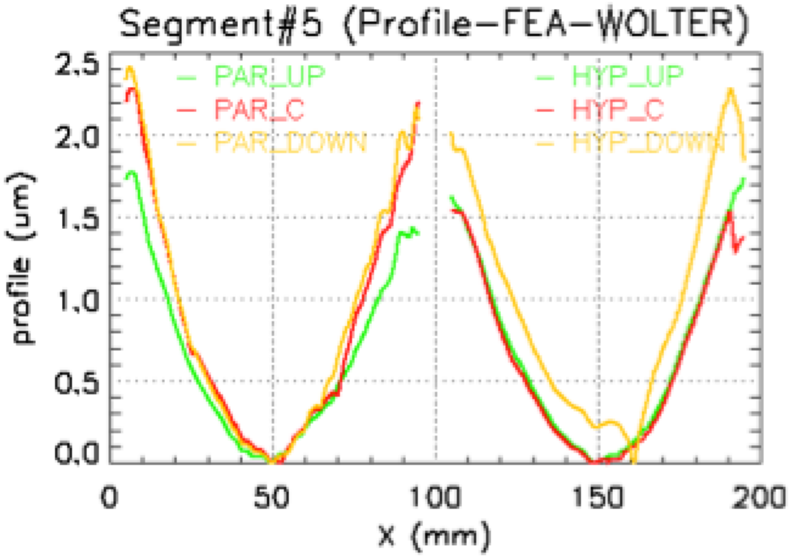


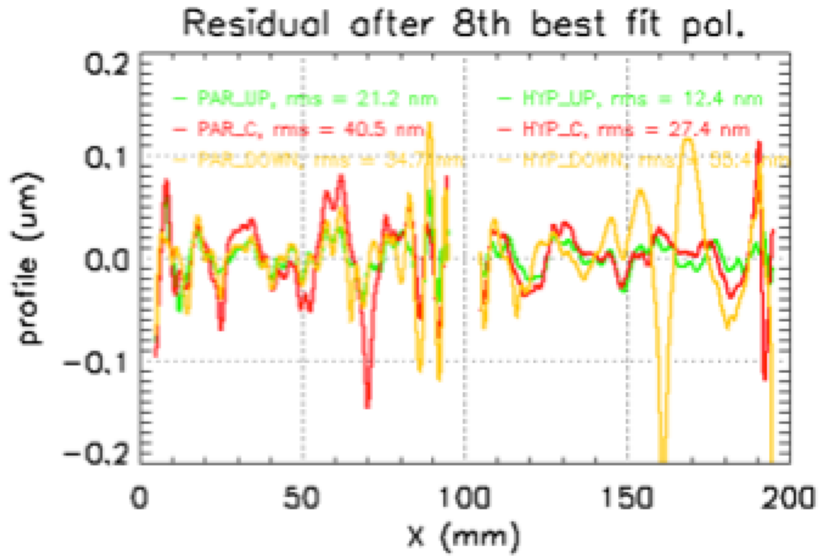
No polishing machine, but Pitch tool directly mounted on the grinding lathe

Final Ion Beam Correction of residual low frequency longitudinal and OOR errors

Segments under development







Expected HEW from LTP mid freq. errors @ 0.27 keV

	HEW segm#1	HEW segm#2	HEW segm#3	HEW segm#4	HEW segm#5
Hyp X=0	0.75	0.60	0.75	0.75	1.05
Hyp X=+10mm	0.75	0.60	0.60	0.75	0.6
Hyp X=-10mm	0.90	0.75	0.60	0.60	8.03
Par X=0	0.75	7.5	7.2	0.75	8.1
Par X=+10mm	4.0	7.4	1.2	1.05	0.9
Par X=-10mm	6.0	1.1	1.1	0.90	1.5

June 6):
report dal meeting di Frascati (18-19 aprile 2016) "Axions in the Universe and the
IAXO experiment"

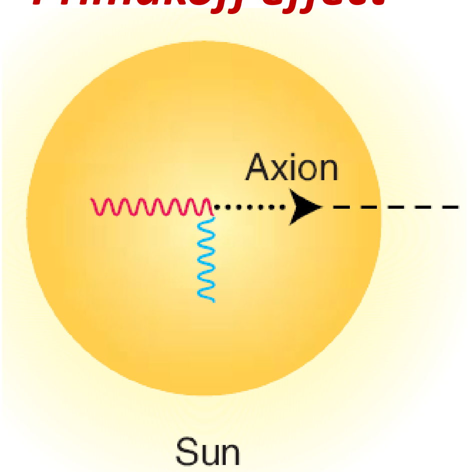
Axion – Production and detection mechanism

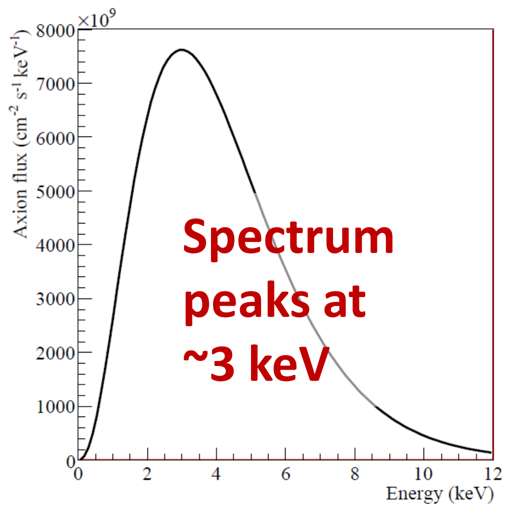
- First axion helioscope proposed by P. Sikivie

Sikivie *PRL* **51**:1415 (1983)

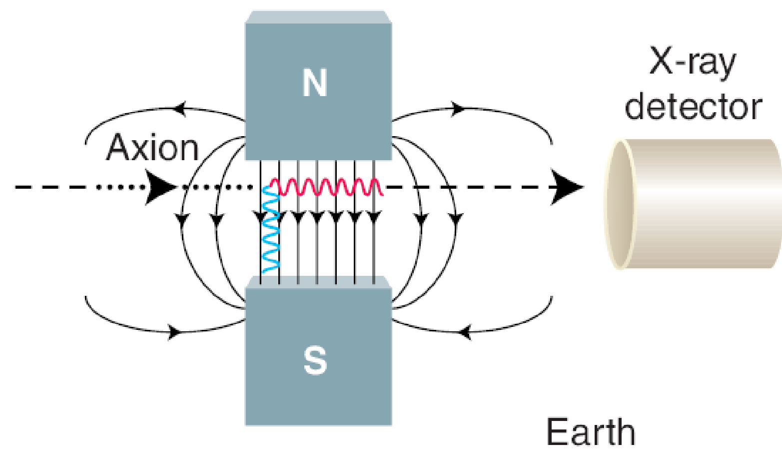
  - Blackbody photons (keV) in solar core can be converted intoaxions in the presence of strong EM fields in the plasma
  - Reconversions of axions into x-ray photons possible in strong laboratory magnetic field

Primakoff effect





Primakoff effect



- Idea refined by K. van Bibber by using buffer gas to restore coherence over long magnetic field

Van Bibber et al. *PhysRevD* **39**:2089 (1989)

IAXO: the first X-ray telescope "ground based"

IAXO – conceptual design

Large toroidal **magnet**, L = 20 m

8 bores: 600 mm diameter each

8× {**x-ray optics** + **x-ray detectors**}

Rotating platform
with services