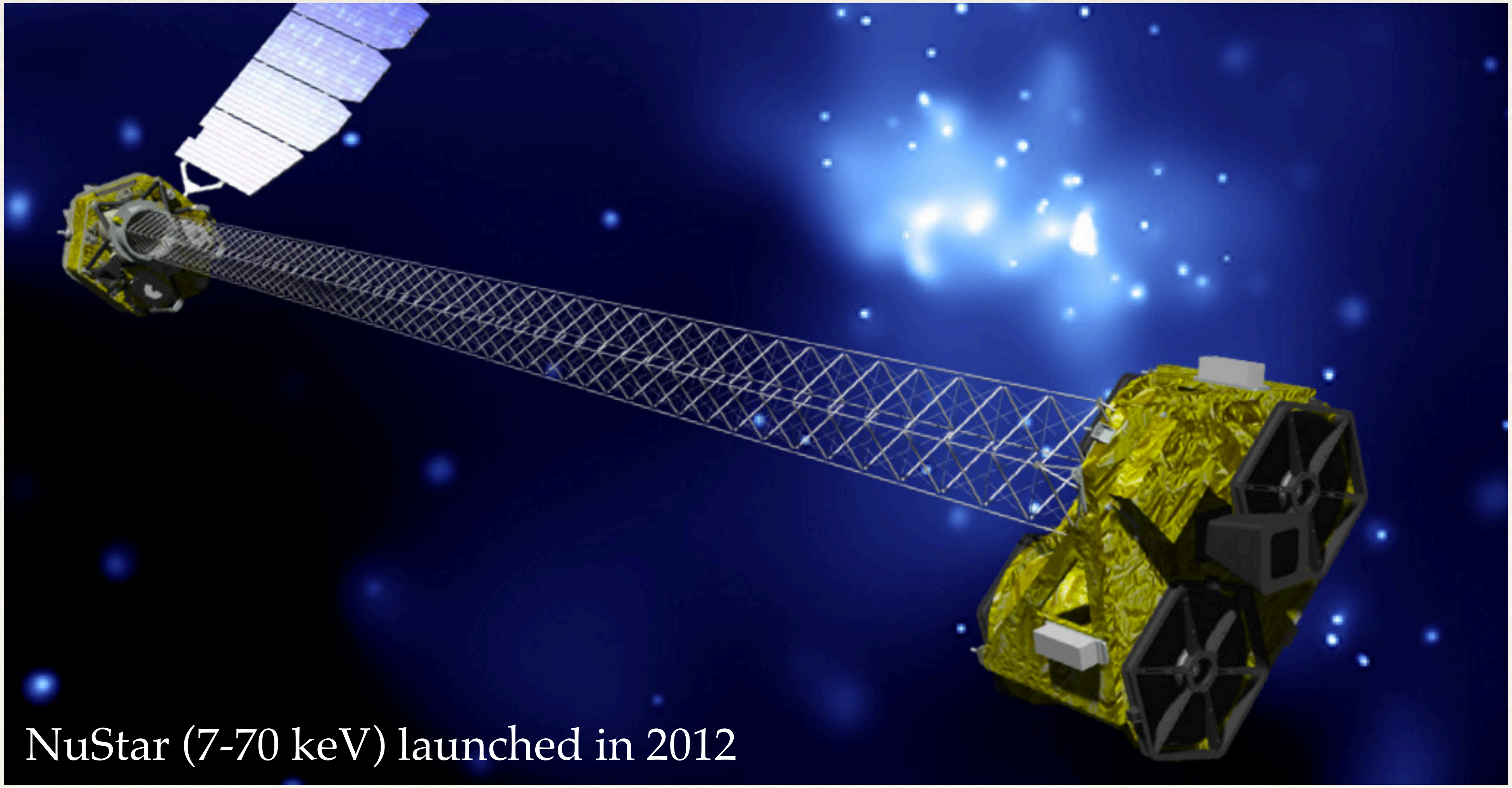
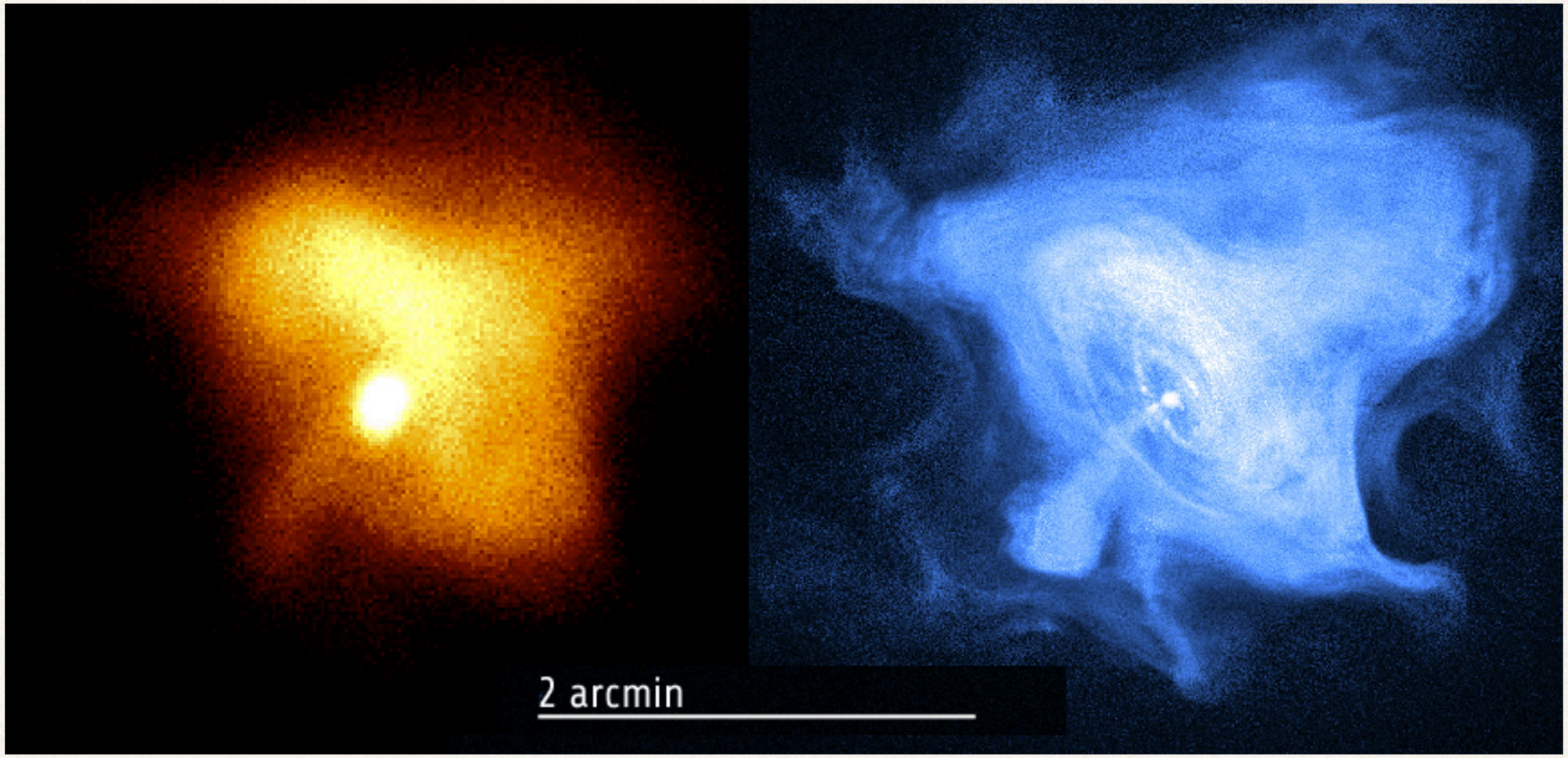


Active control of Laue lens modules for focusing celestial hard X/soft gamma-rays

Enrico Virgilli, Filippo Frontera

on behalf of the High Energy Astrophysics group - University of Ferrara

Past and present soft X-ray focusing telescopes



Credit: S. L.Snowden USRA, NASA/GSFC (ROSAT), NASA/CXC/SAO/F.Seward et al. (Chandra)

ROSAT (1990-2011)
passband: 0.2 - 2 keV
angular resolution 10″

Chandra (1999-)
passband: 0.2 - 10 keV
angular resolution 0.5″

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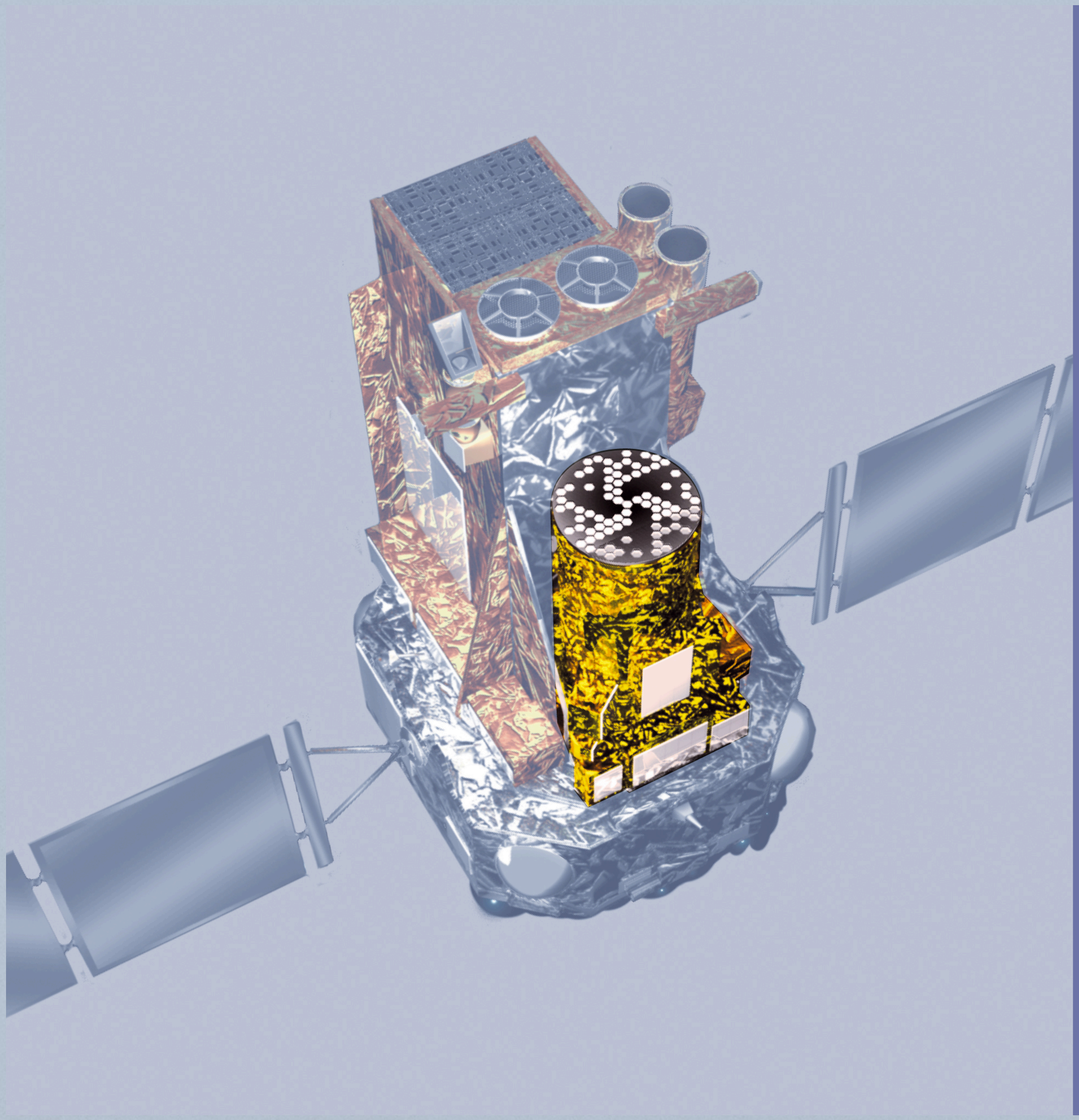
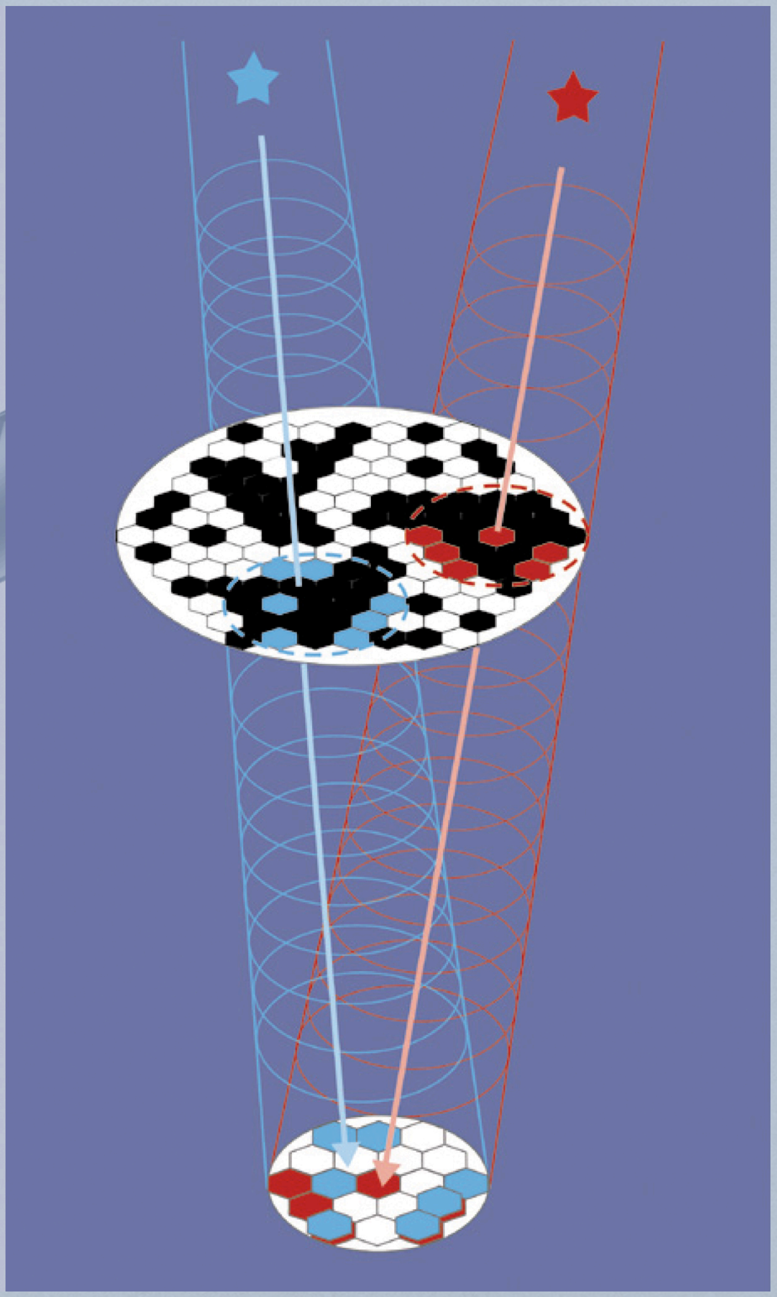
Coded-aperture imaging systems
INTEGRAL/SPI (18 keV - 8 MeV)

16° FoV
2° angular resolution





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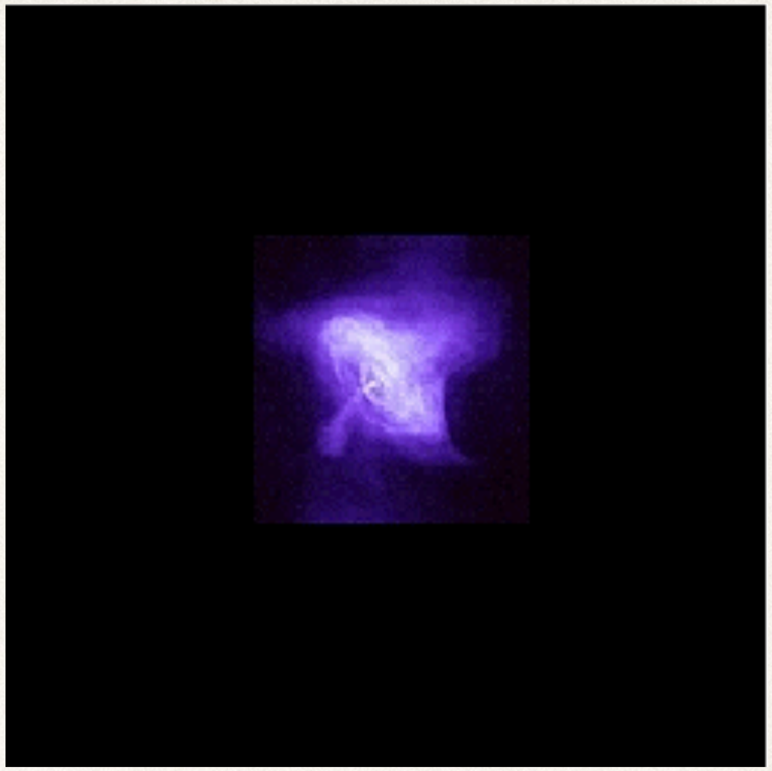
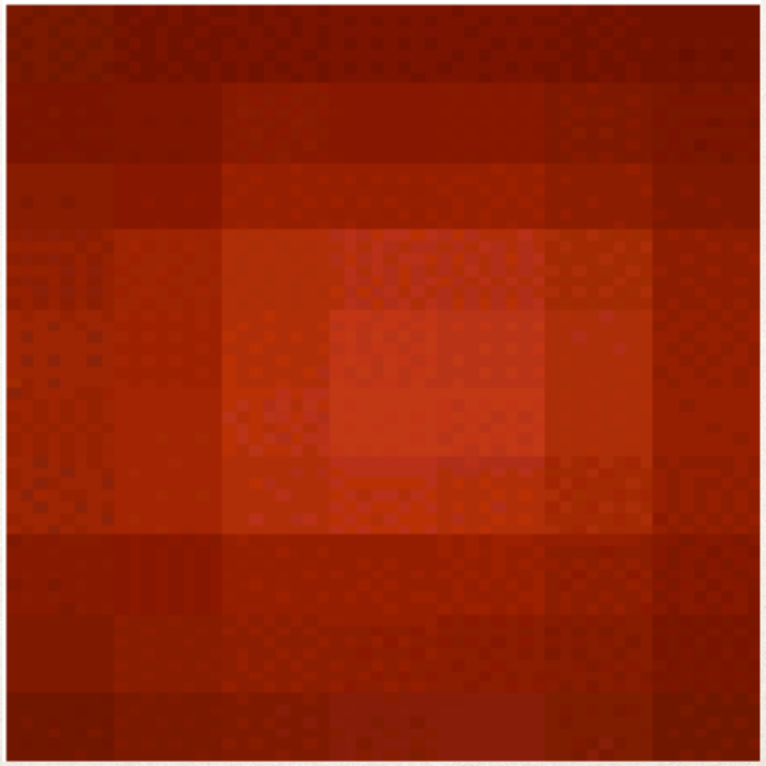
Hard X-/soft Gamma-rays images

Chandra (soft X-rays)
0.5″ angular resolution



INTEGRAL/IBIS
(hard X- soft gamma-rays)
12′ angular resolution



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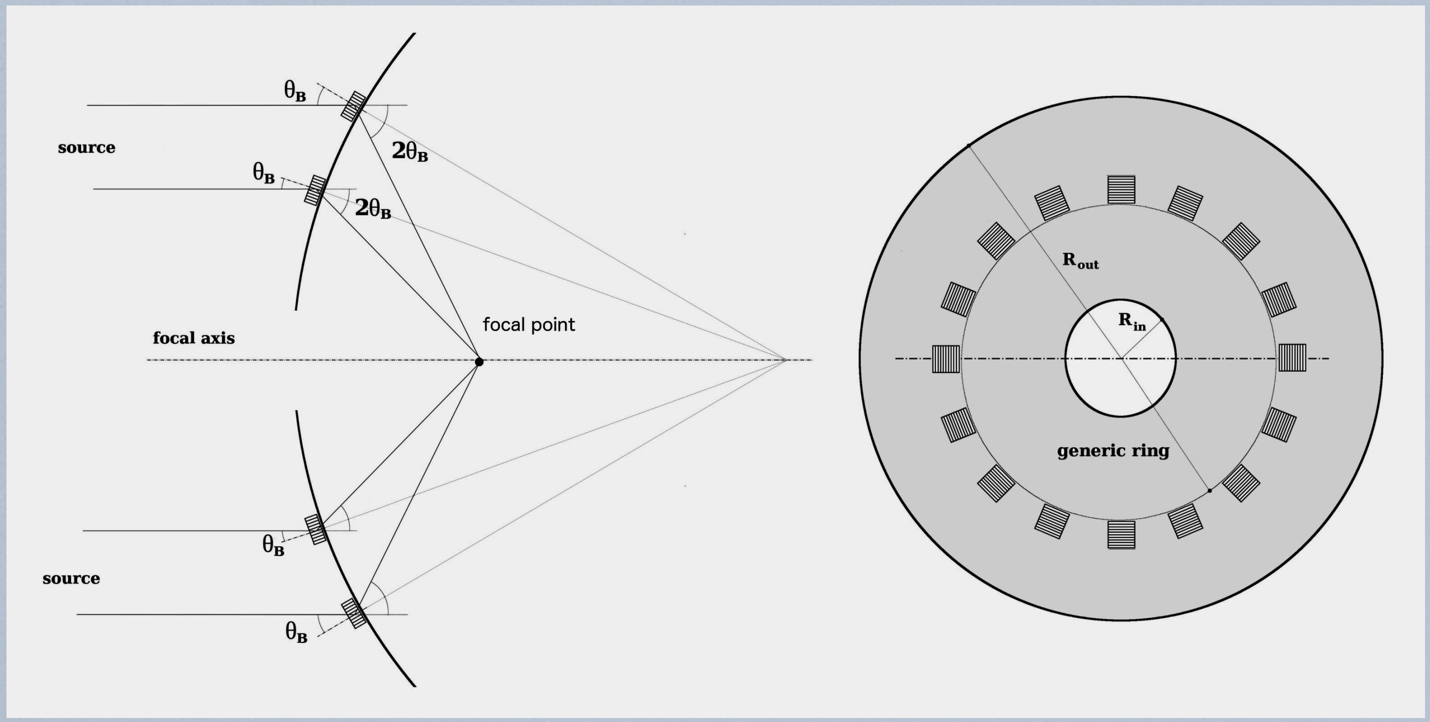
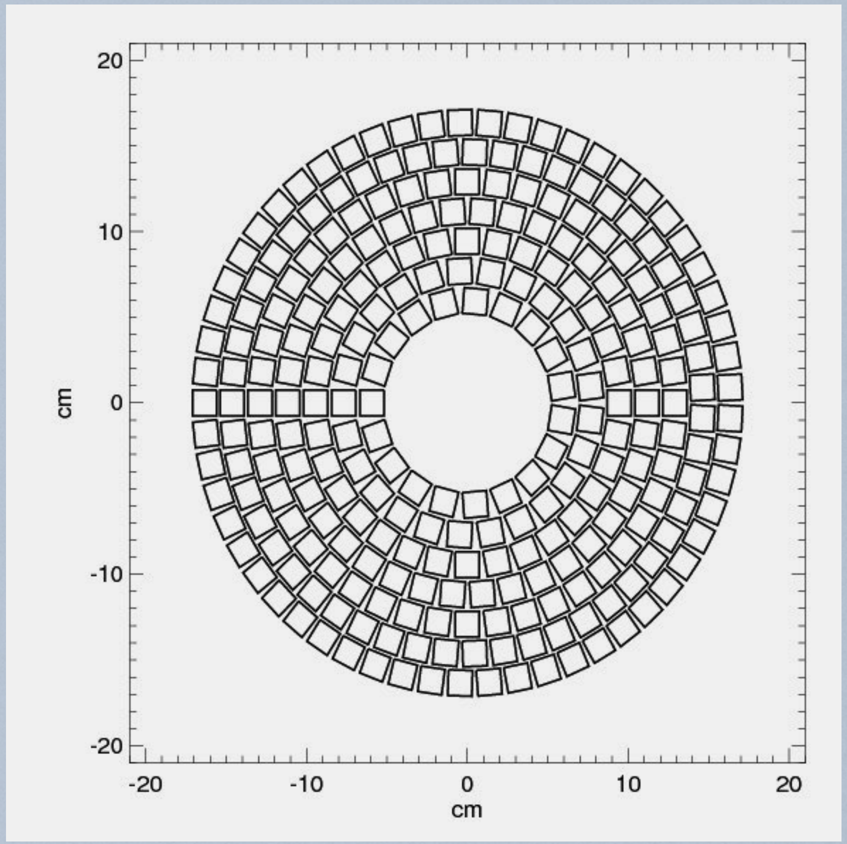
hard X-ray sky (60 - 600 keV) is relatively poorly explored (low sensitivity and low angular resolution) and yet rich in promise

Our goal is to extend the focusing capability for high Energy Astrophysics

> 60 keV

Laue lens principles





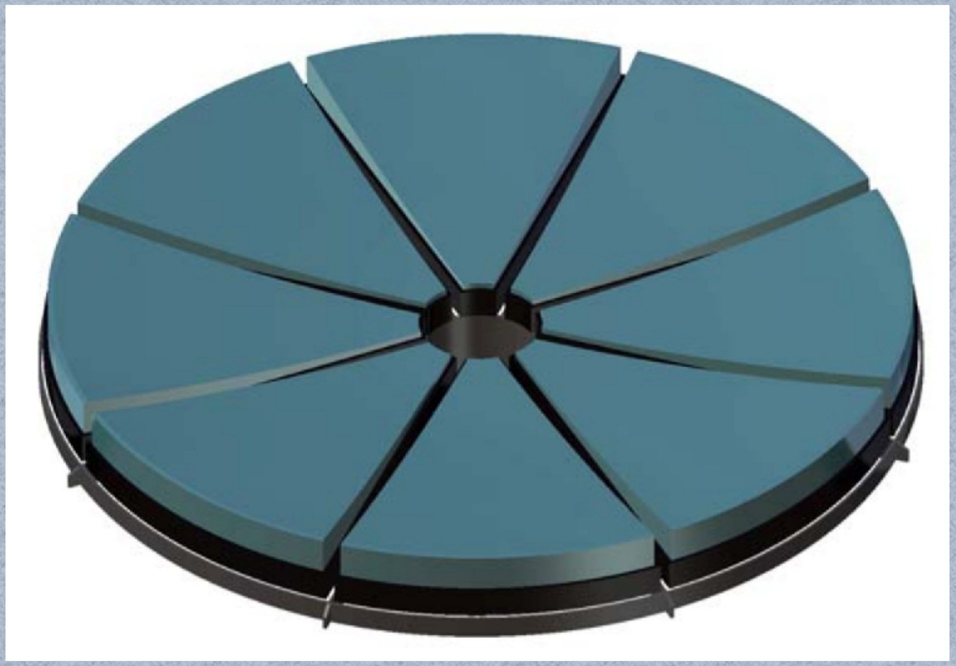
Bragg's law $2d_{hkl} sin\ \theta_B = n\frac{hc}{E}$

$$E \sim \frac{hc\ F}{d_{hkl}\ R}$$

Modular approach to the system architecture:

single crystal —> Optical Element (OE) —> sub-petal —> petal —> Laue LENS

Lens
petals
optical elements



Simulation of broad band Laue lens

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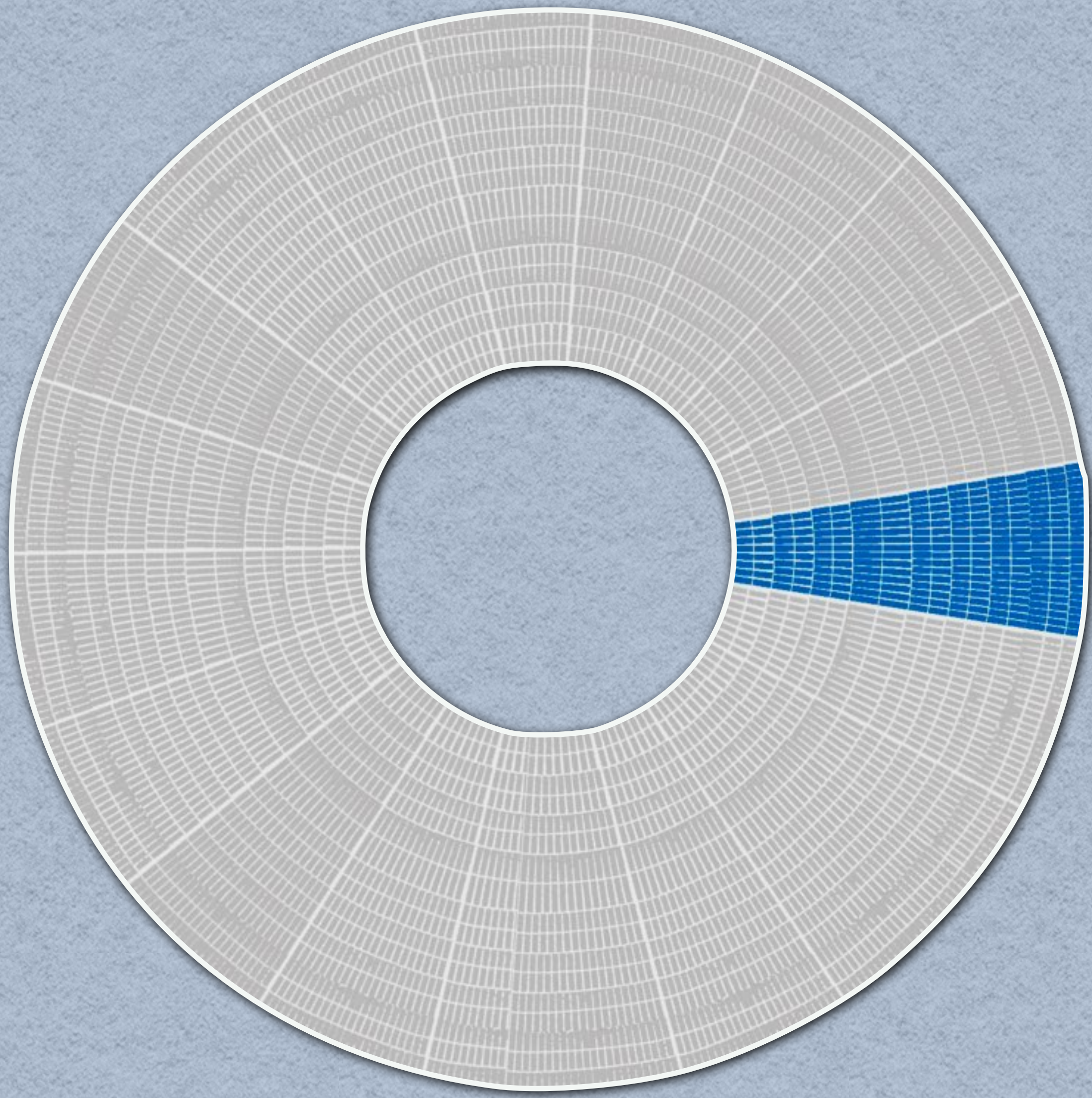

Broad band: 80 – 600 keV

Focal length: 20 m

Diameter ~ 1.8 m

N° of crystal: 9480

crystal weight: 40 kg

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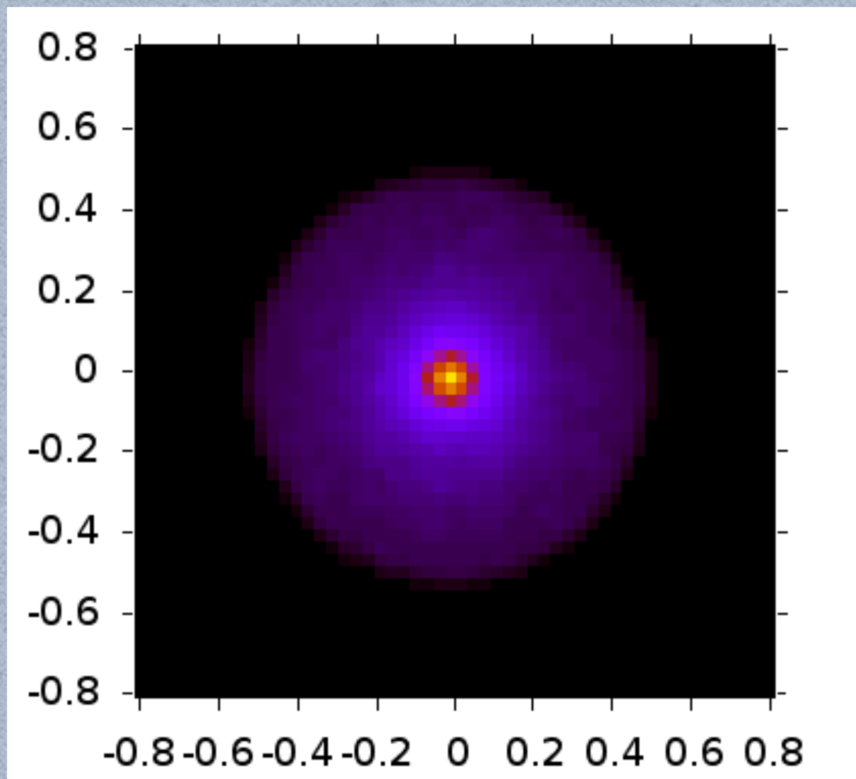
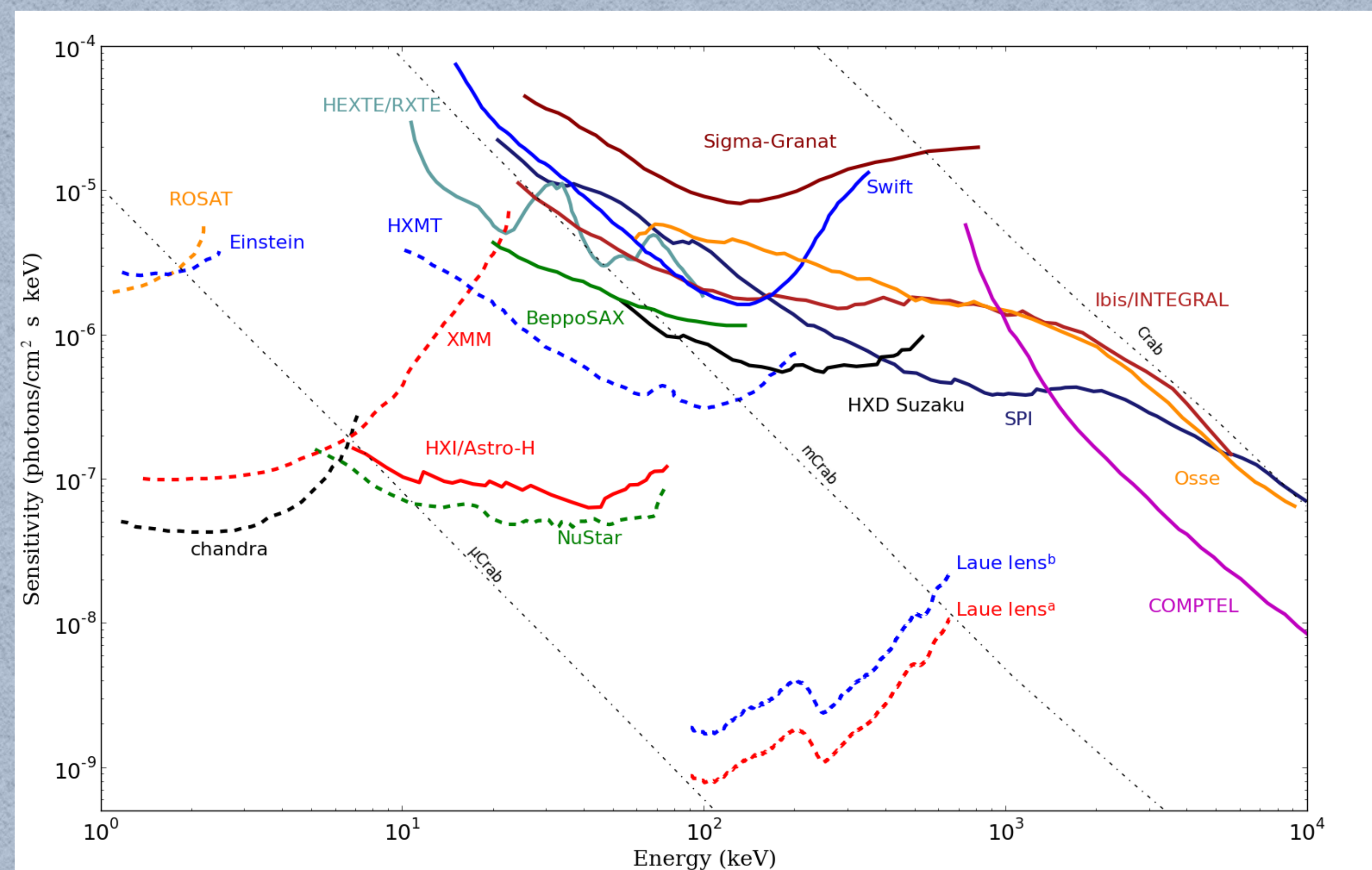
Simulation results



IDEAL PSF produced with a set of bent crystals (R=40 m) **20" angular resolution**

Expected sensitivity
10^5 sec



Experimental Activity

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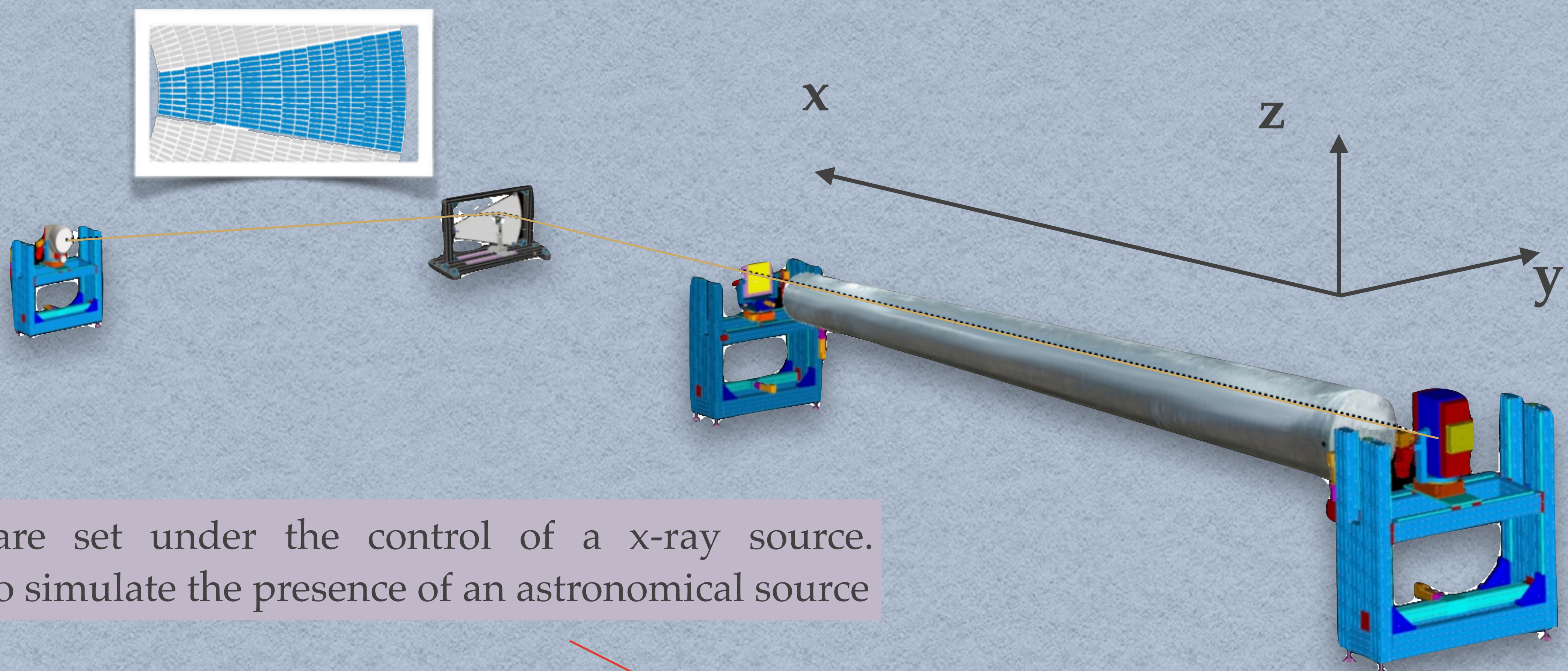
Laue Lenses @ LARIX Facility Ferrara (Italy)



crystals are set under the control of a x-ray source. Method to simulate the presence of an astronomical source

source and collimator are moved together in front of each crystal to simulate a beam parallel to the lens axis

Factors affecting the PSF

Crystals:

1. curvature radius

Assembling phase:

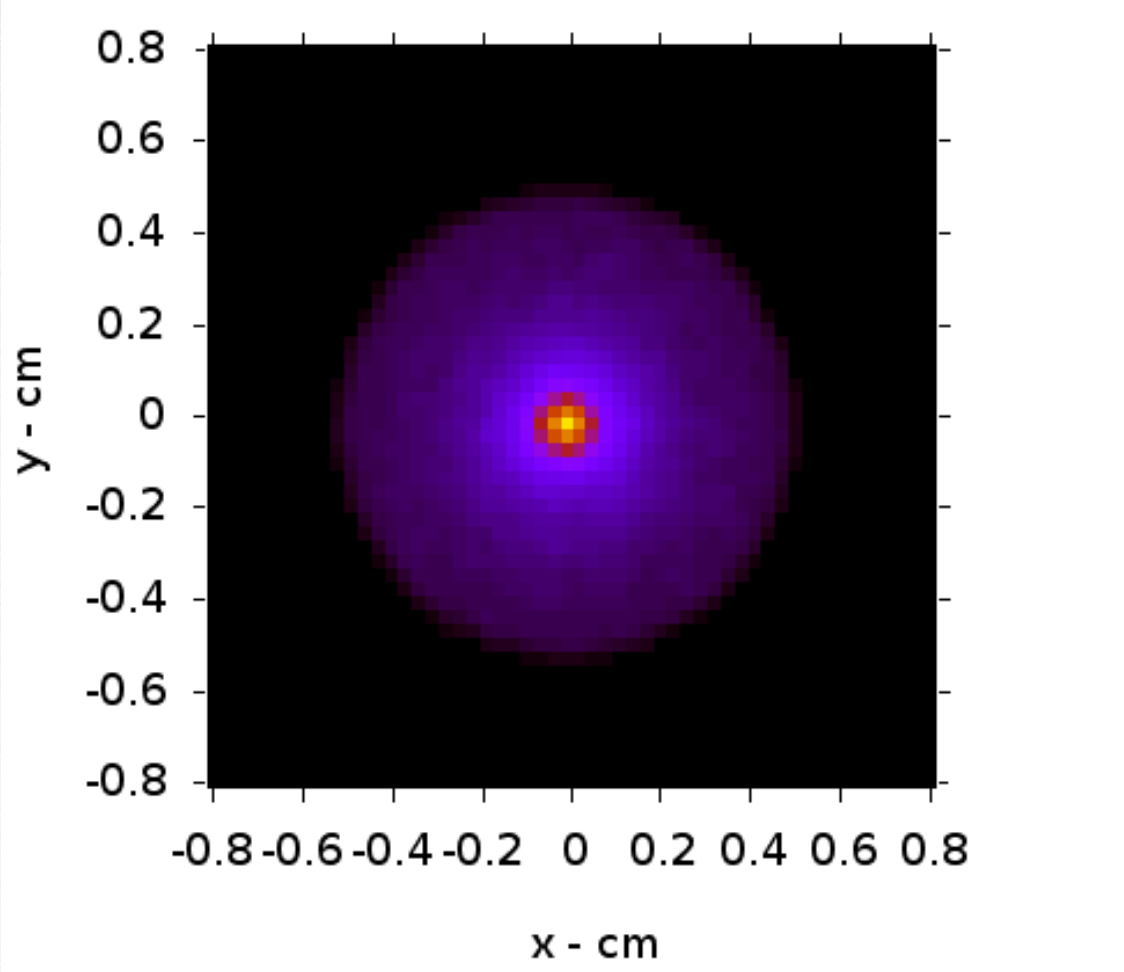
1. positioner uncertainties
2. crystals misalignment
3. adhesive polimerization

Environmental factors:

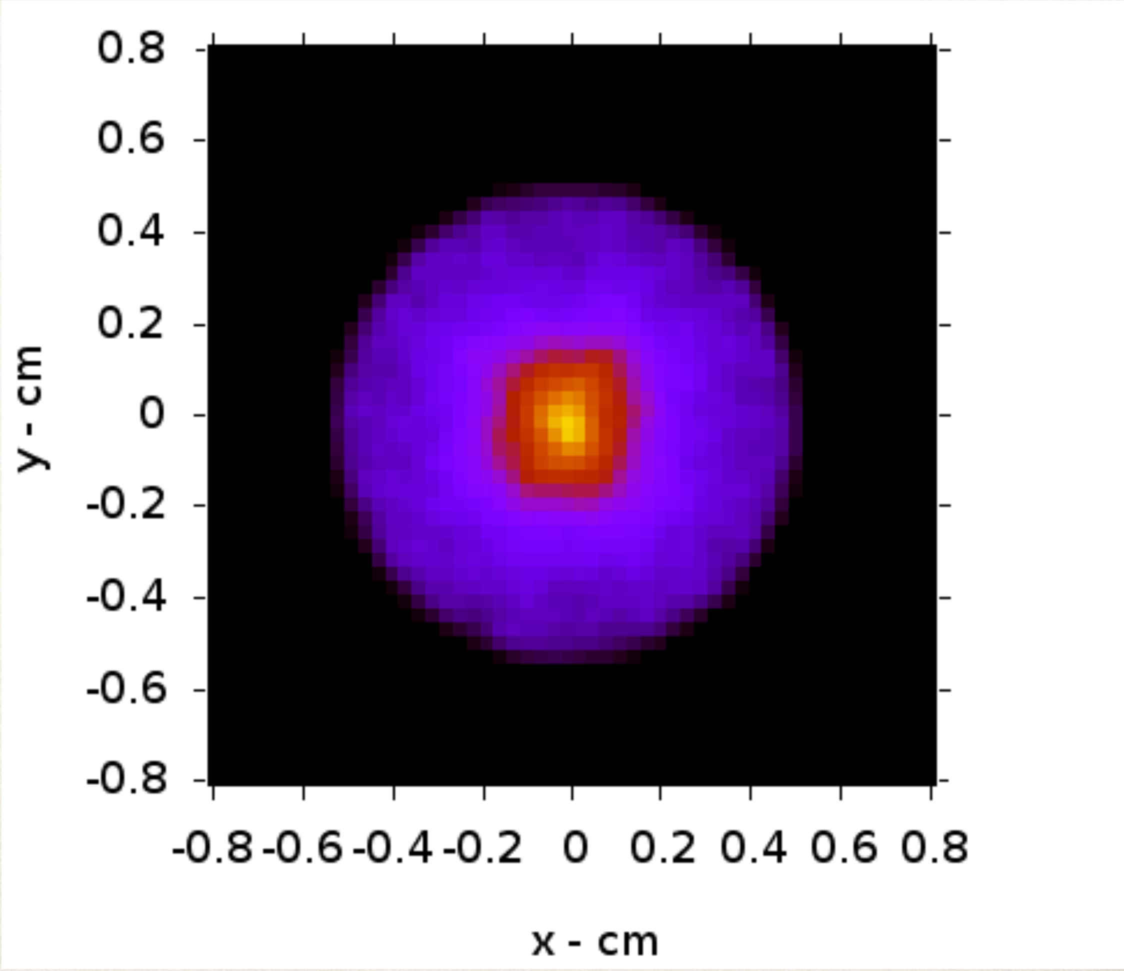
1. temperature variation
2. vibration stresses

Critical points that affect the angular resolution crystal curvature radius

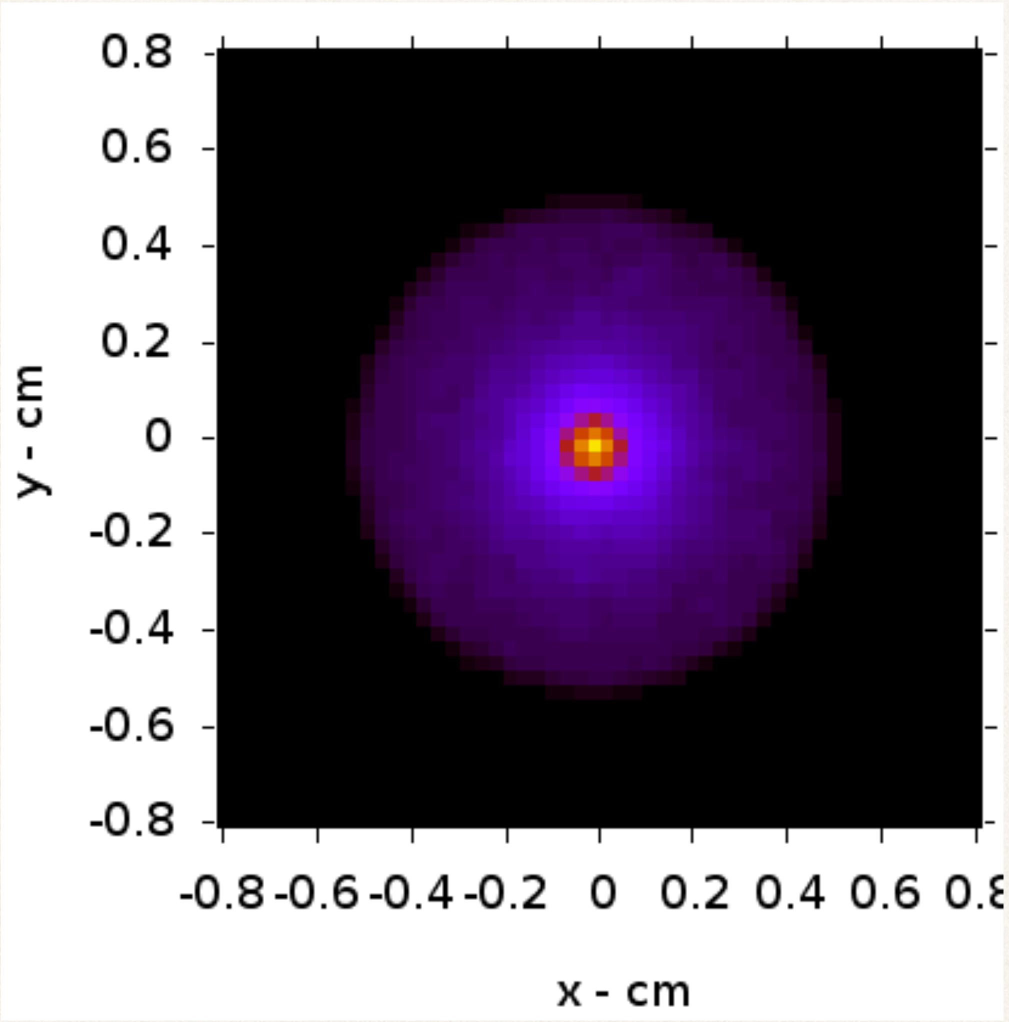
SIMULATION
PSF produced with a set of ideally bent crystals (40 m)



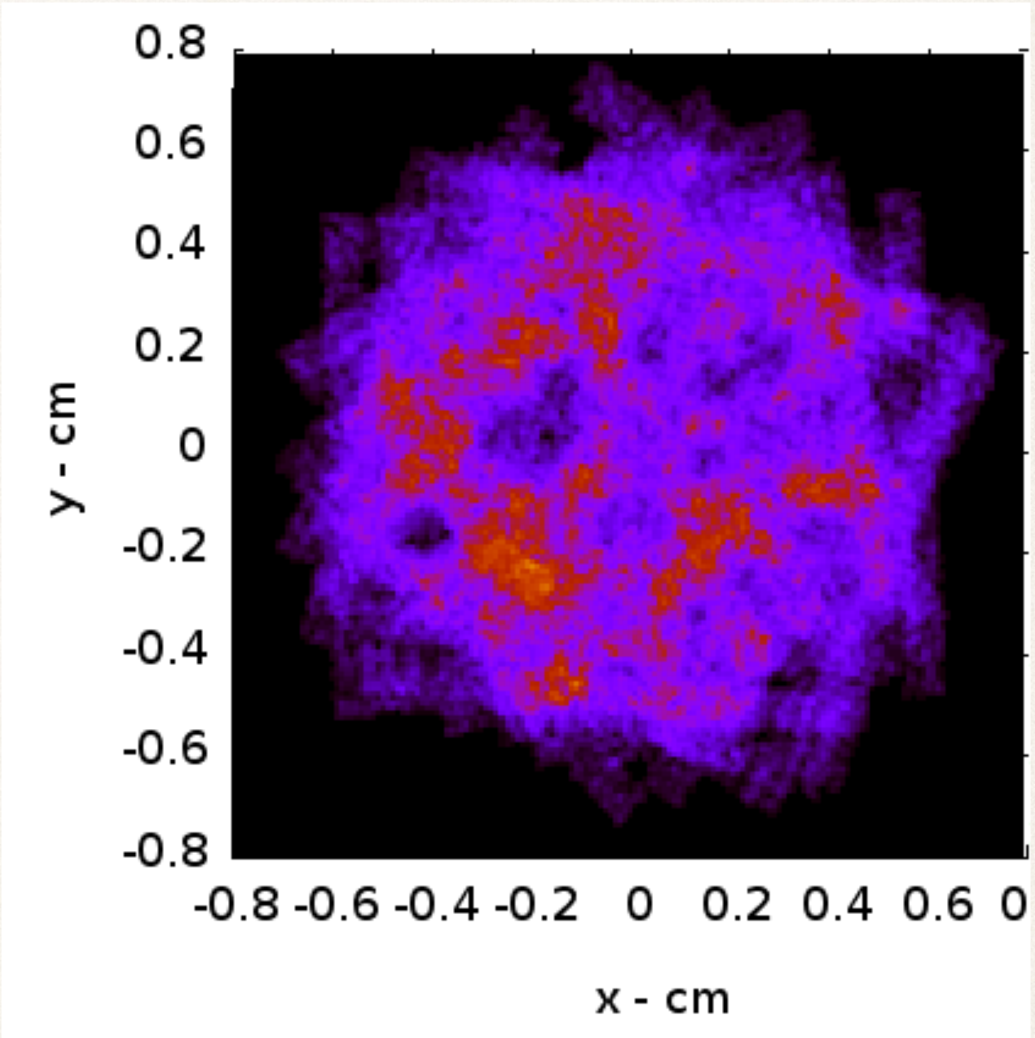
SIMULATION
PSF produced with a set of bent crystals with R following a gaussian distribution (fwhm 6 m)



Critical points affecting the angular resolution misalignment uniformly distributed in the range (−30 : +30 arcsec)



ideal



no radial deformation

Active optics applied to Laue lenses

Motivations:

Easier realization (and test) of a cluster of tens of crystals than a monolithic Laue lens.

Group crystal tiles with similar properties improve the alignment accuracy.

The relative alignment between the optical modules minimize the total PSF.

Active optics applied to Laue lenses

Requirements

1. Each single OE is not deformable

2. The radiation pass through the optics
- required thin support (low X-/gamma-ray absorption)

3. Actuators
- self locking (no power when not required)
- small

4. Space qualified devices

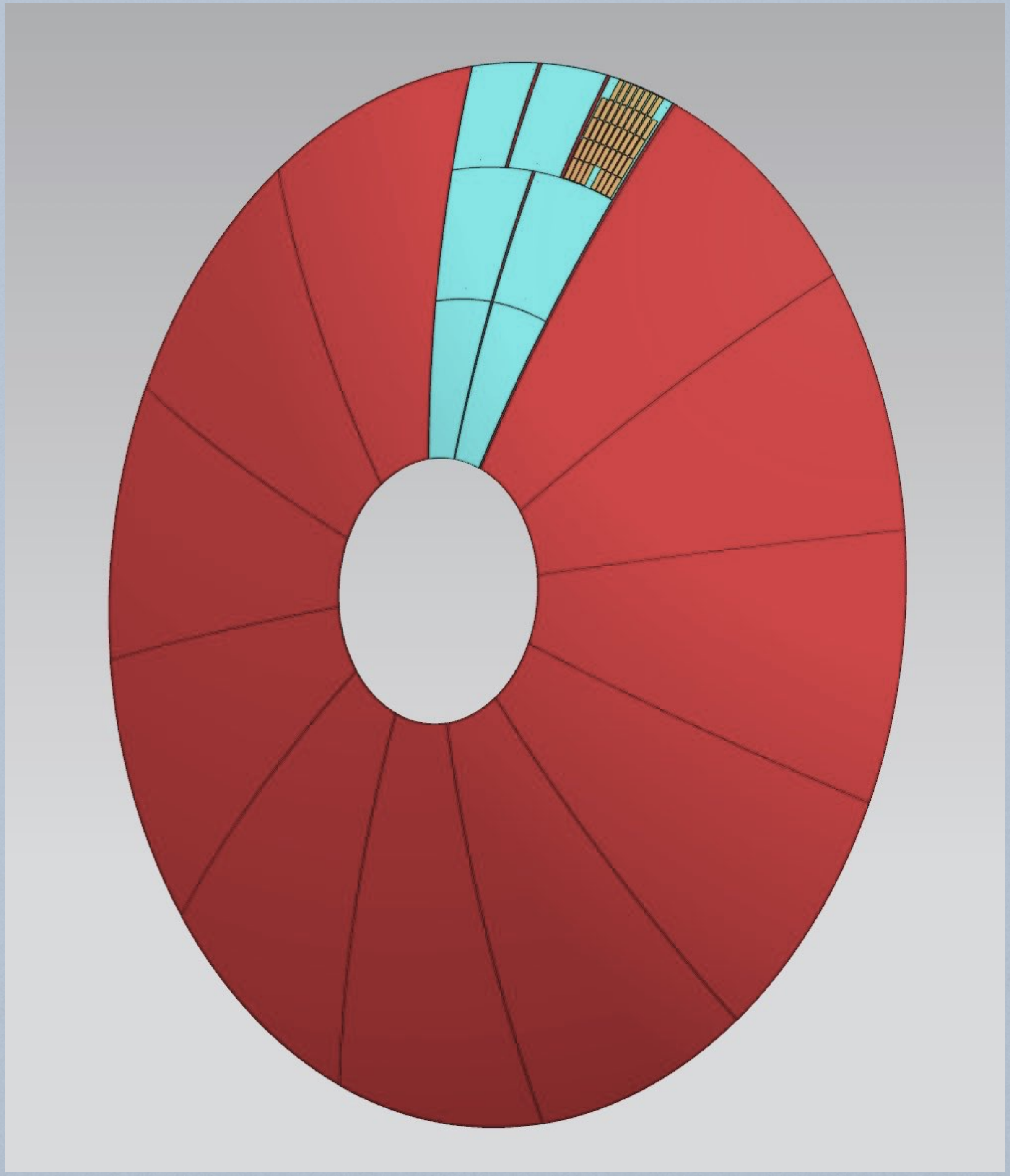
Adaptive optics applied to Laue lenses

each Optical Element (OE) is made by a subset of crystals (few tens)

Some commercial piezo is being evaluated

PI, PhiDrive, Micronix with the following properties:

volume = few cm^3
range = 50 um
accuracy = 1 um
load = 100-200 g



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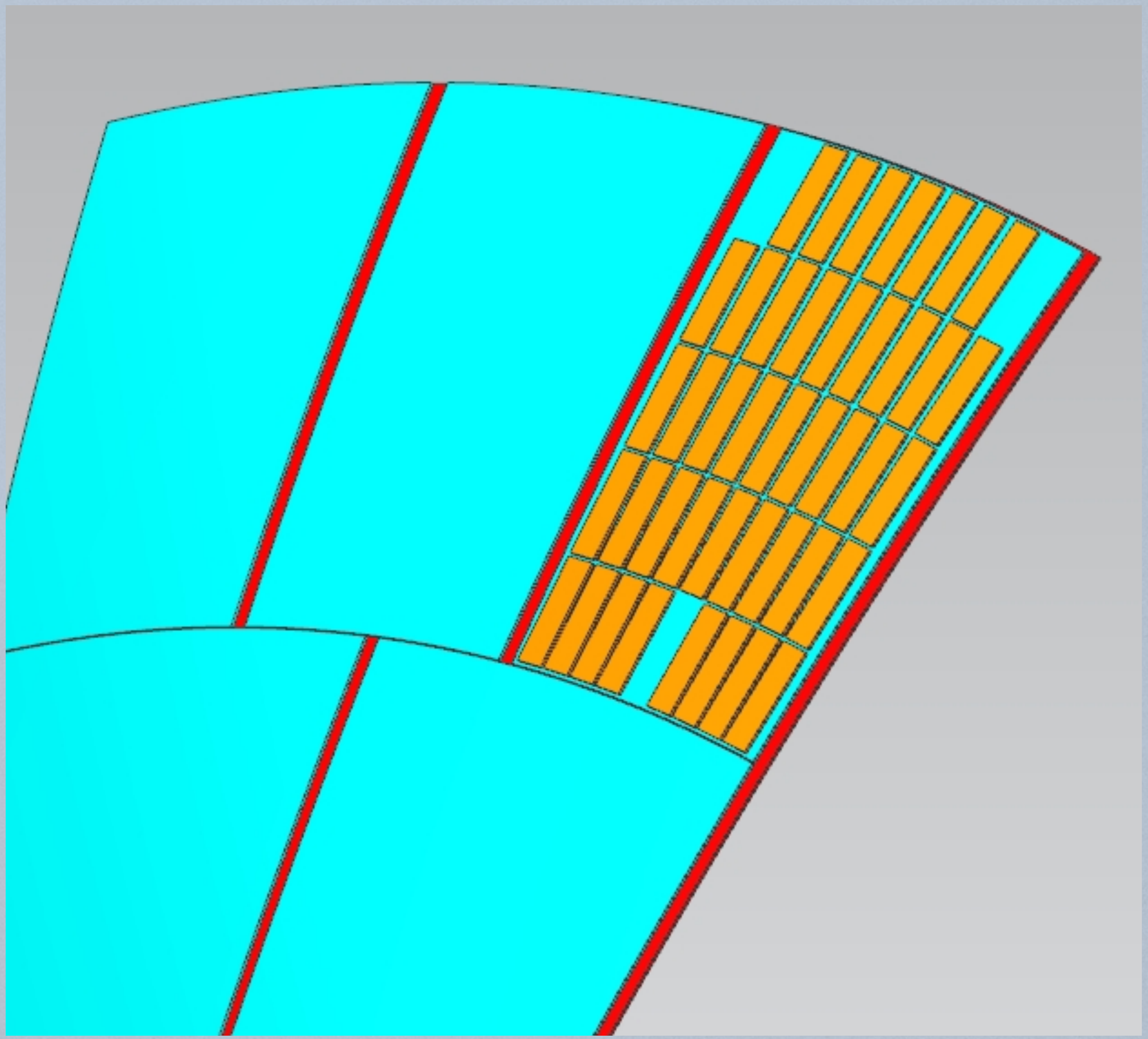

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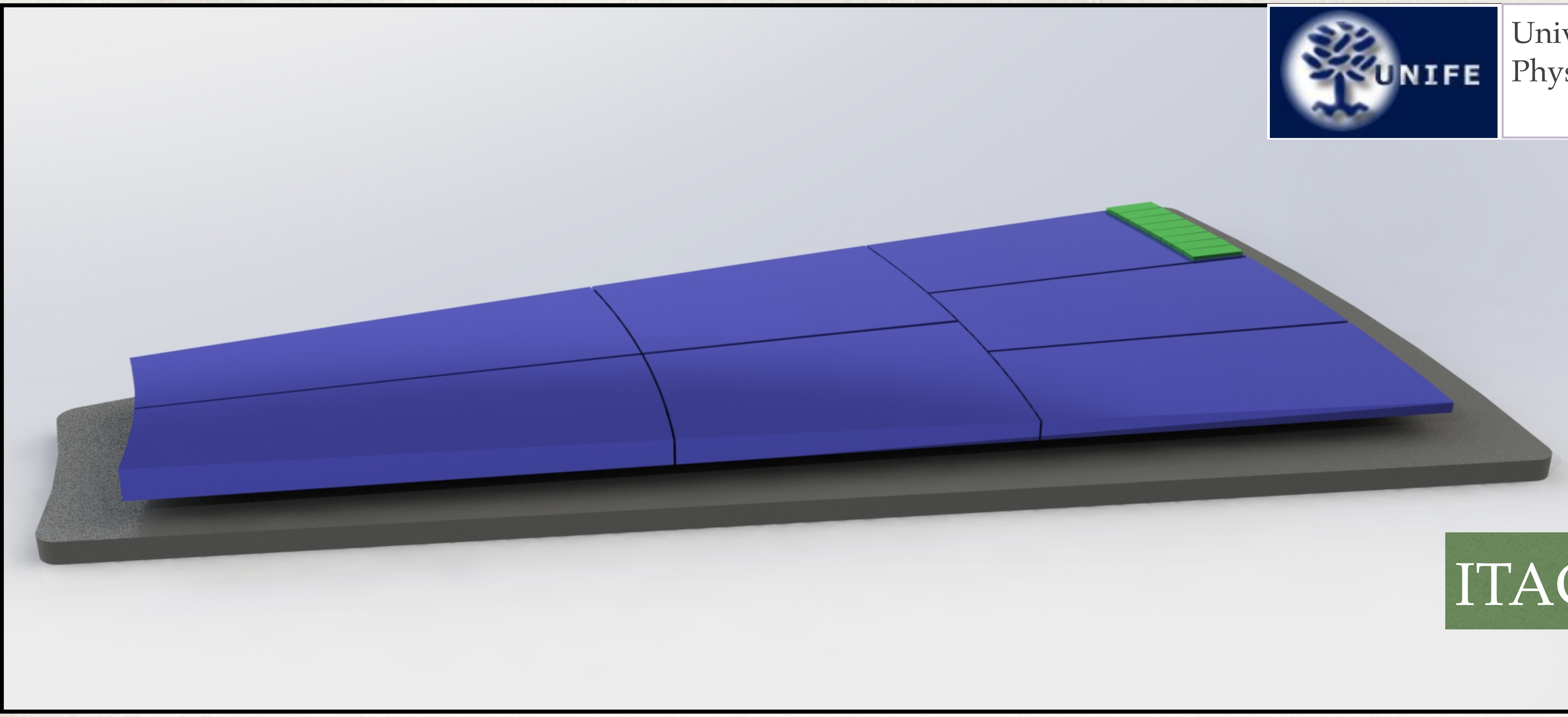
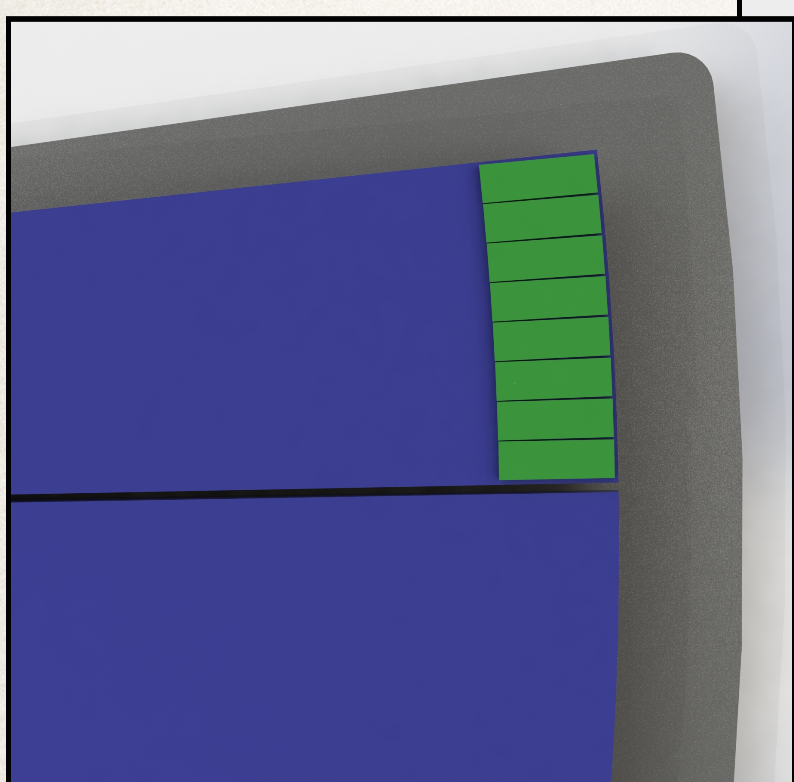
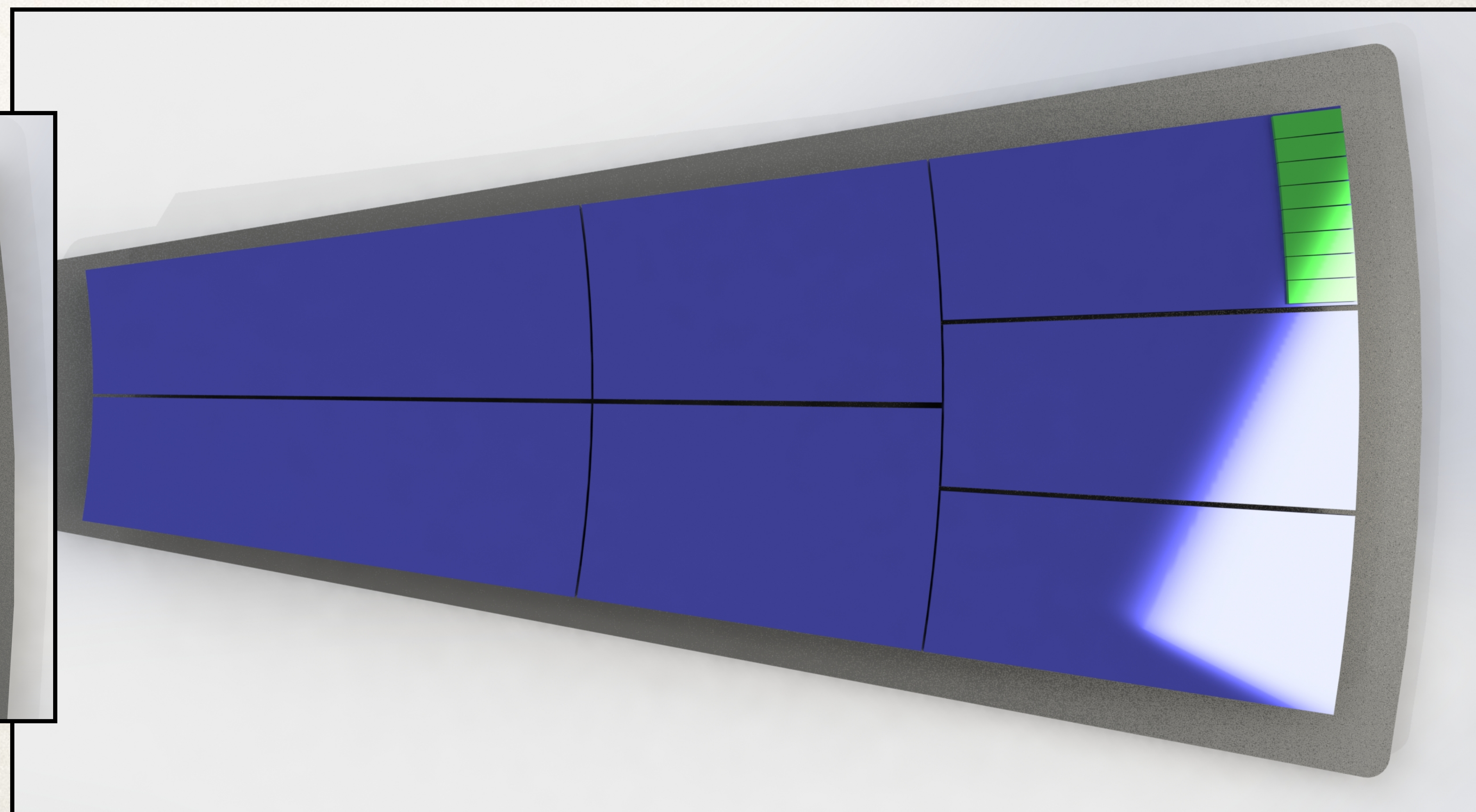


ITACNA S.r.l. (Bg)





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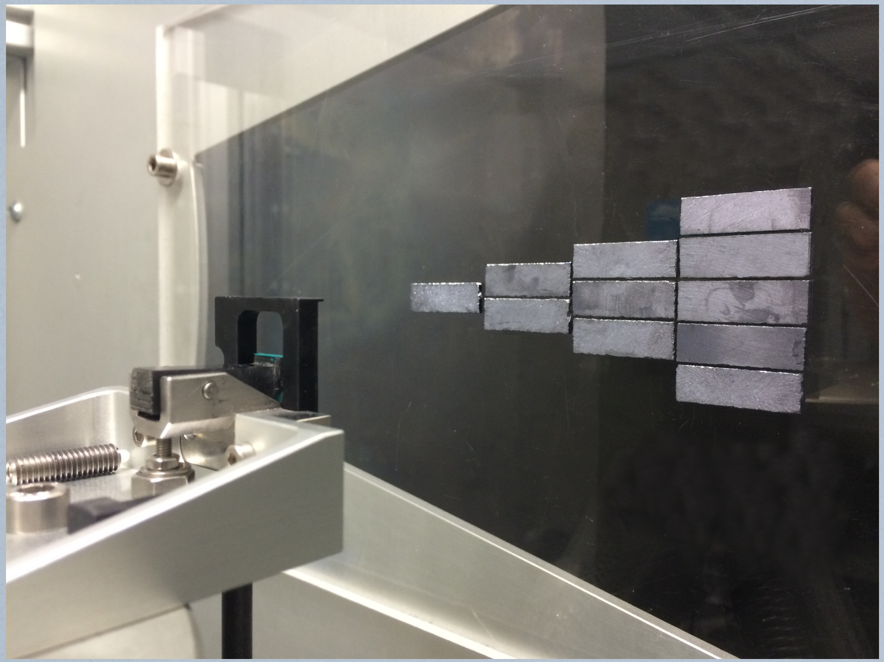
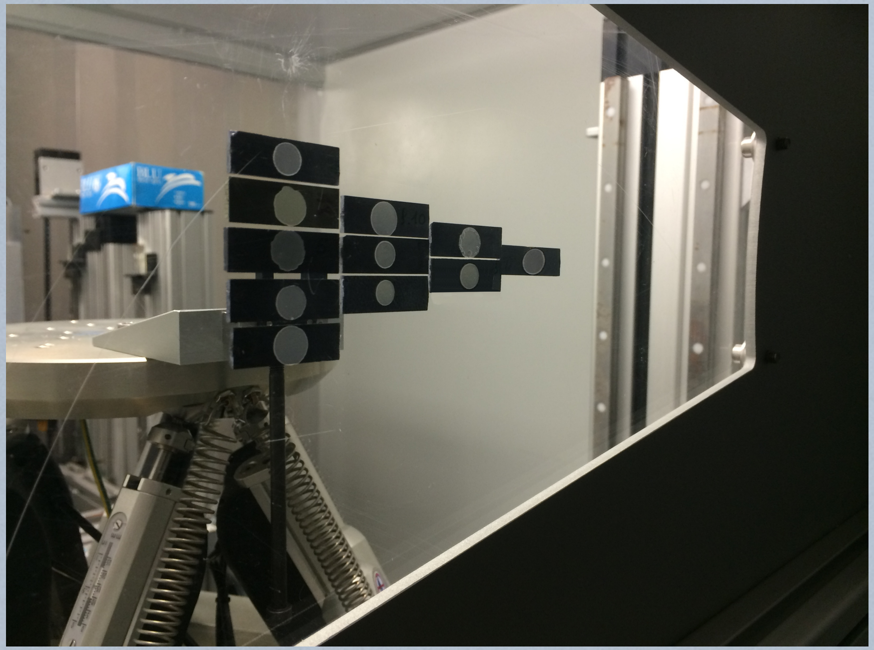
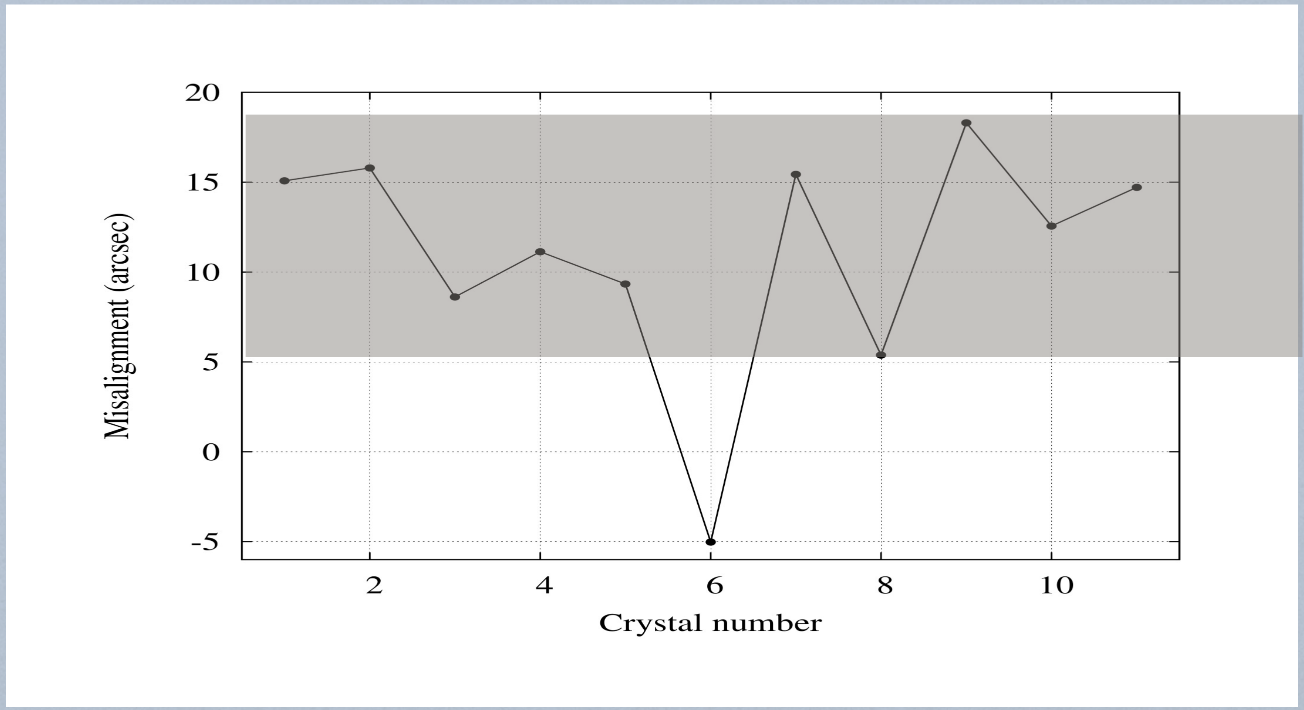
Integration of a first Laue lens module





We tested the adhesive and the procedure with 11 GaAs (220) crystals

accuracy



~13″

Conclusions

— Hard X-ray focusing optics require to be adjustable to reach the accuracy of 10-20 arcsecs

— Crystal misalignment affect the PSF more than other parameters (i.e. radial disuniformity)

— Adaptive optics can minimize the PSF enlargement. Further simulations are required to optimize the Nc per optical unit.

— Required piezo actuators with the following properties:

1. small size
2. self locking
3. appropriate range and load capacity