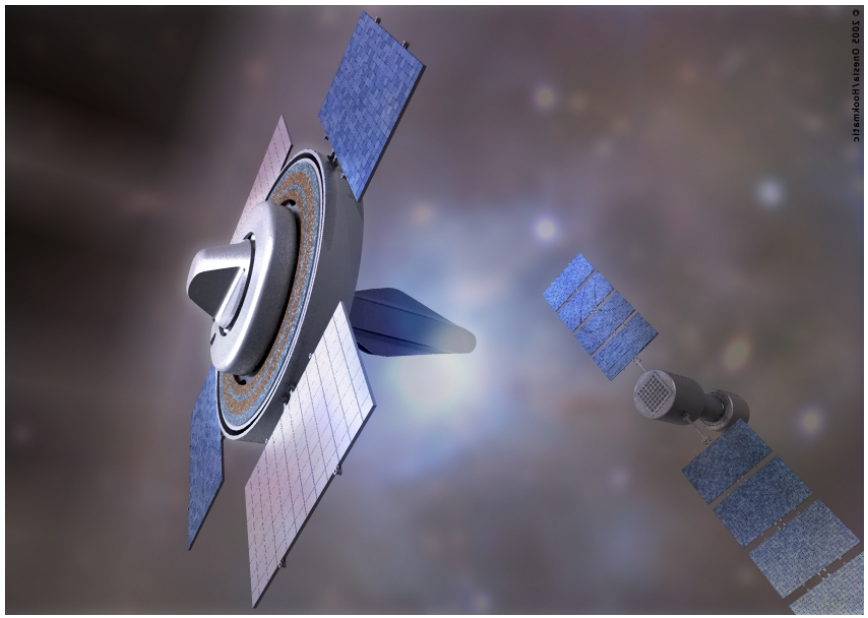
GRI: Gamma-Ray Imager Mission



Margarita Hernanz, ICE(CSIC) and IEEC (on behalf of the Spanish GRI consortium)

ICE (CSIC) - IEEC

IMB-CNM (CSIC)

IFAE

UPC

GACE-UV

Lista no cerrada

Observations of the gamma-ray sky reveal the most powerful sources and the most violent events in the Universe.

The *gamma-ray* sky provides us with a view on the *non-thermal Universe*

- ➢ particles accelerated to extreme relativistic energies by mechanisms which are still poorly understood

- ➢ nuclear reactions synthesizing the basic constituents of our world.

✓*Cosmic accelerators and cosmic explosions*: major science themes addressed in the gamma-ray regime.

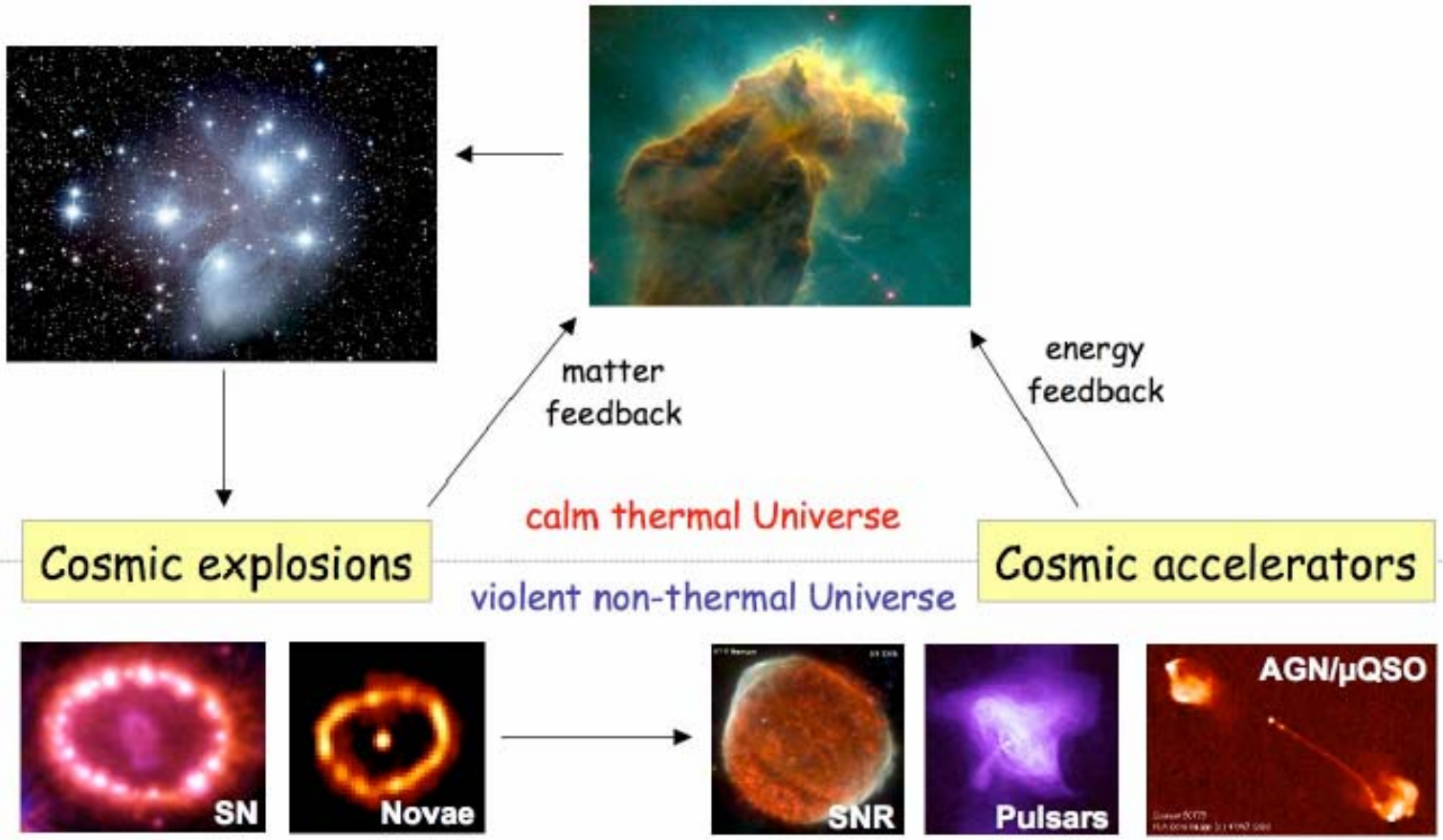


Figure 1. The calm and violent phases of the evolving Universe

ESA's INTEGRAL satellite: global overview of soft γ-ray sky.

But there's the need of

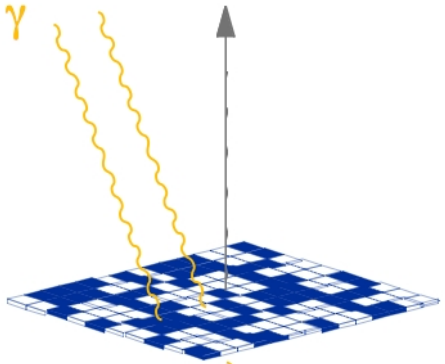
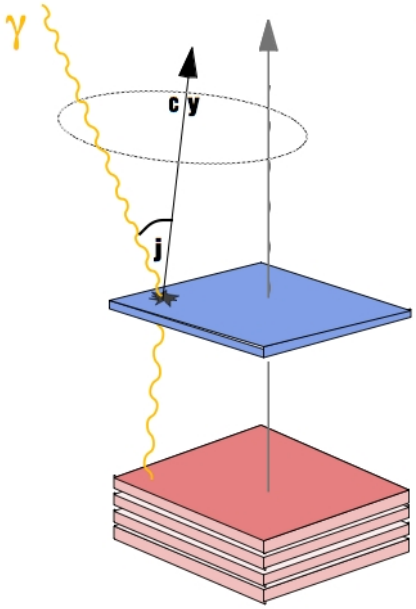
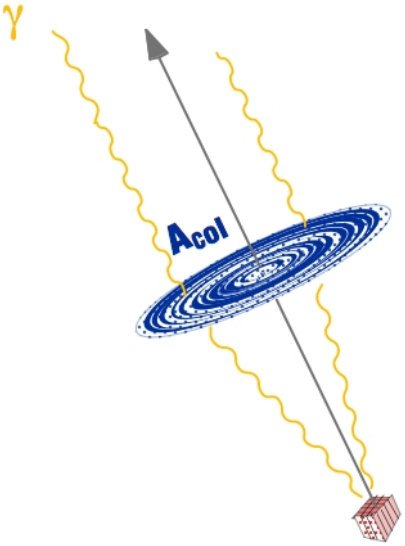
- deeper, more focused investigations of γ-ray sources
- some crucial γ-ray lines (nucleosynthesis in stellar explosions) not detected yet

SCIENCE DRIVERS OF THE GRI MISSION

- Understanding the physics of supernova explosions
- The origin of the soft γ-ray cosmic background radiation
- High-energy emission from compact binary systems
- Particle acceleration in extreme magnetic fields

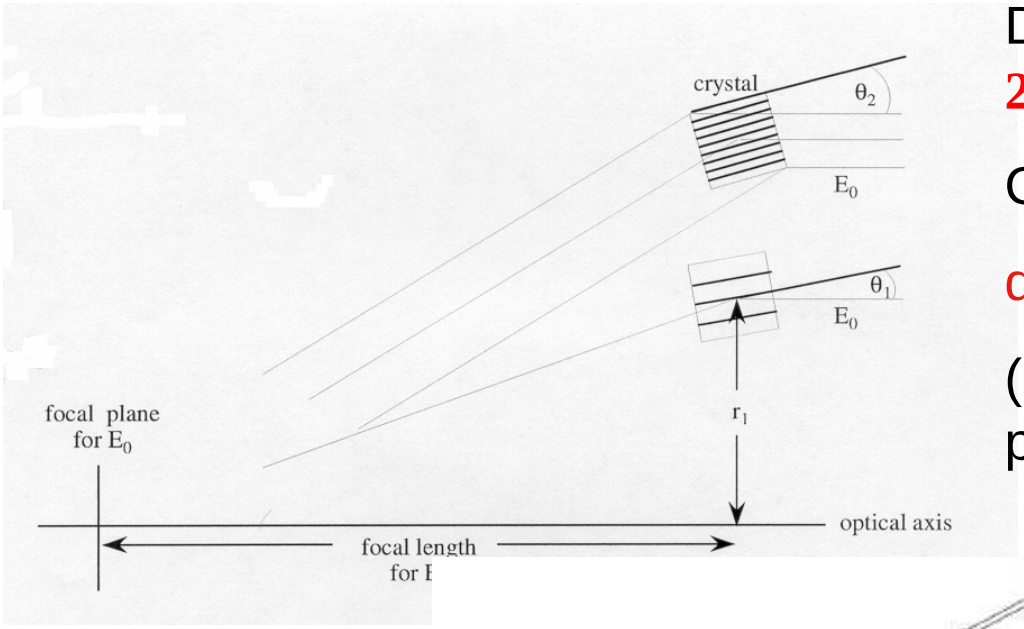
Taking the sensitivity leap

GRI

aperture / effect	modulating aperture systems geometric optics absorption	Compton telescopes quantum optics incoherent scattering	crystal lens telescopes wave optics coherent scattering
aperture system			
detector			
	$A_{det} = A_{col}$	$A_{det} = A_{col}$	A_{det}
signal S	~ A_{col}	A_{col}	A_{col}
background B	~ $V_{det} \sim A_{det} = A_{col}$	$V_{det} \sim A_{det} = A_{col}$	$V_{det} \sim A_{det} << A_{col}$
S/B	~ const (A)	const(A)	A_{col}/A_{det}

Courtesy: Peter von Ballmoos

How to focus γ-rays?



Diffraction; Bragg condition:

$2\,d\sin(\theta) = n\lambda = nhc/E$

Crystalline plane spacing:

$d = a/(h^2+k^2+l^2)^{1/2}$

(h,k,l:Miller indices of crystal planes)

$r_i = f \tan(2\theta) \approx f\, n\, \lambda/d_i$

d smaller for outer rings

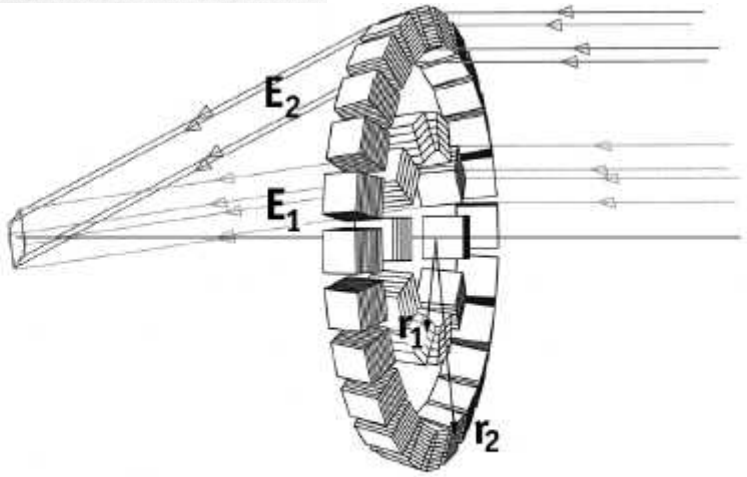


Figure 1 : The basic design of a crystal diffraction lens in Laue geometry

CLAIRE: A prototype of γ-ray lens for nuclear astrophysics

GRI

http://www.cesr.fr/~pvb/Claire/index.html

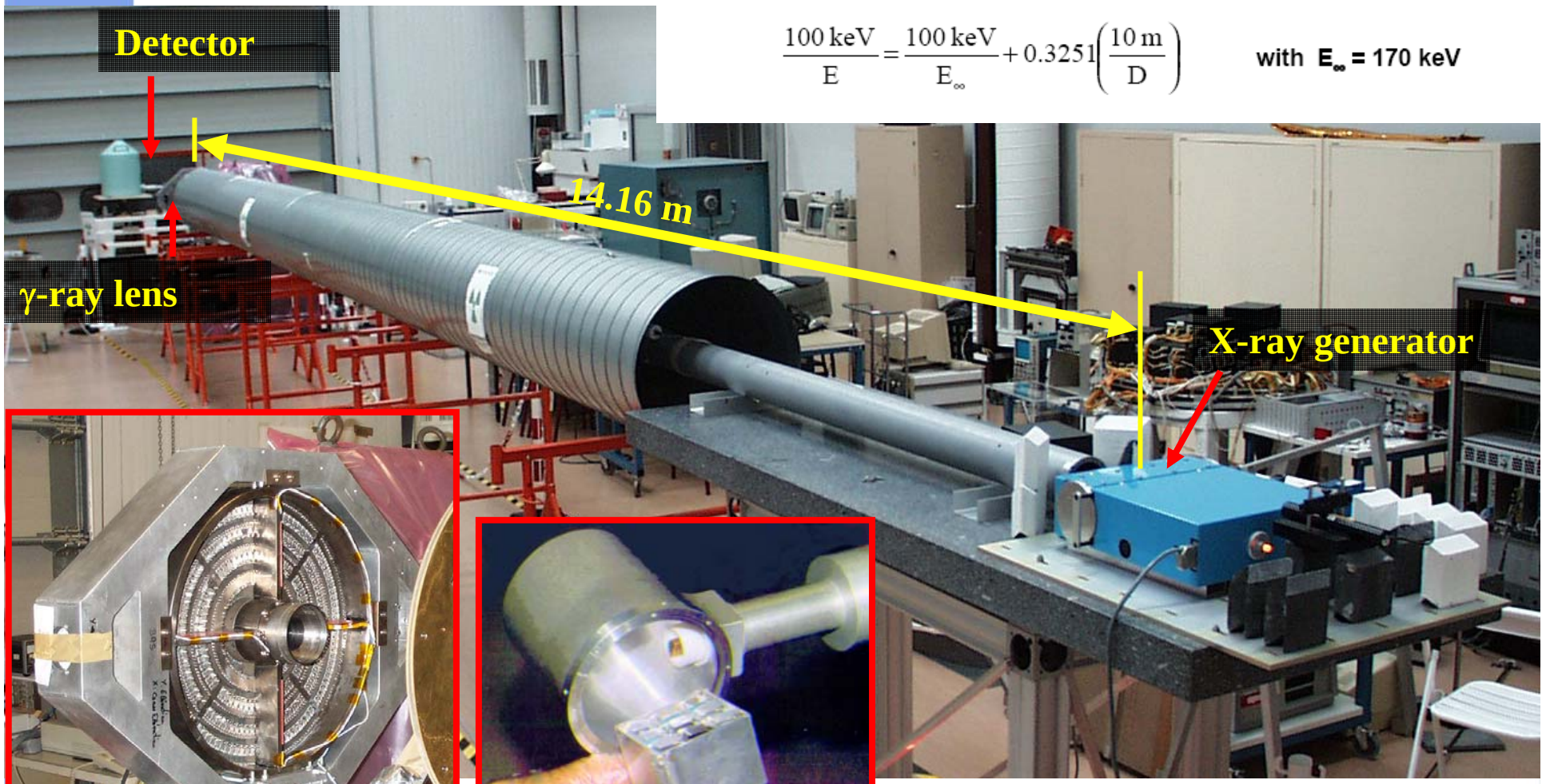
The gamma-ray bench at CESR

GRI

Relation between distance and diffracted energy

$$\frac{100\,\mathrm{keV}}{E} = \frac{100\,\mathrm{keV}}{E_\infty} + 0.3251\left(\frac{10\,\mathrm{m}}{D}\right)$$

with E_∞ = 170 keV

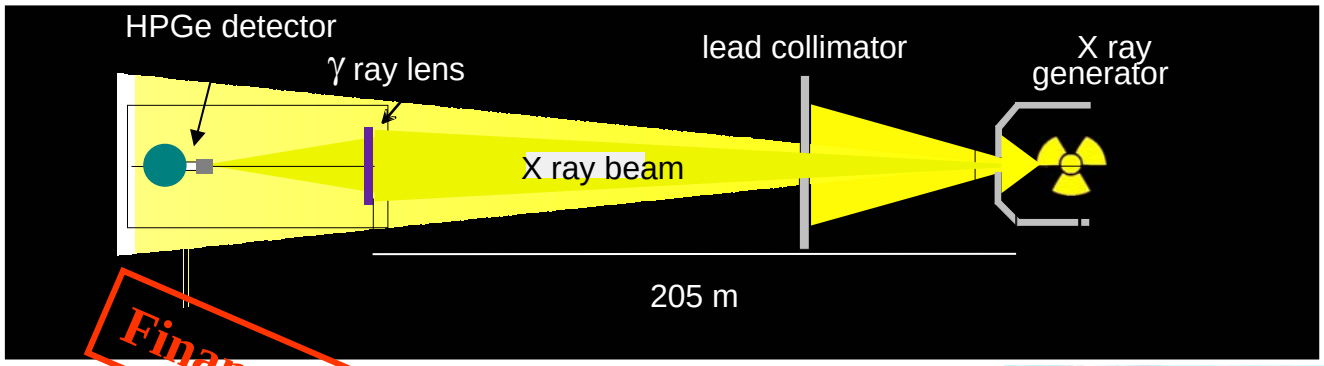


γ-ray lens

Detector

Dispositivo experimental del TGD ("Test a Gran Distancia")

GRI



Financiación : Acción Especial PNE

Aero Club de Ordis (Girona)

CLAIRE TGD: at 200m

GRI

TGD - Mozilla <2>

File Edit View Go Bookmarks Tools Window Help

http://www.ieec.fcr.es/hosted/claire/tgd.html

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IEEC

CLAIRE

CLAIRE
Long Distance Test in Ordis

CESR

CSIC

Financiación : Acción Especial PNE

- What is Claire-TGD?
- Setting of the TGD
- Arrival at Ordis
- Assembly in Ordis
- TGD measures
- X-ray generator tube
- Miscellaneous: Ordis May 2003

TGD Team (May 2003)

The experimental setup of the long distance test, along one of the tracks of the aero-club Ordis (May 2003)

Aero club ORDIS

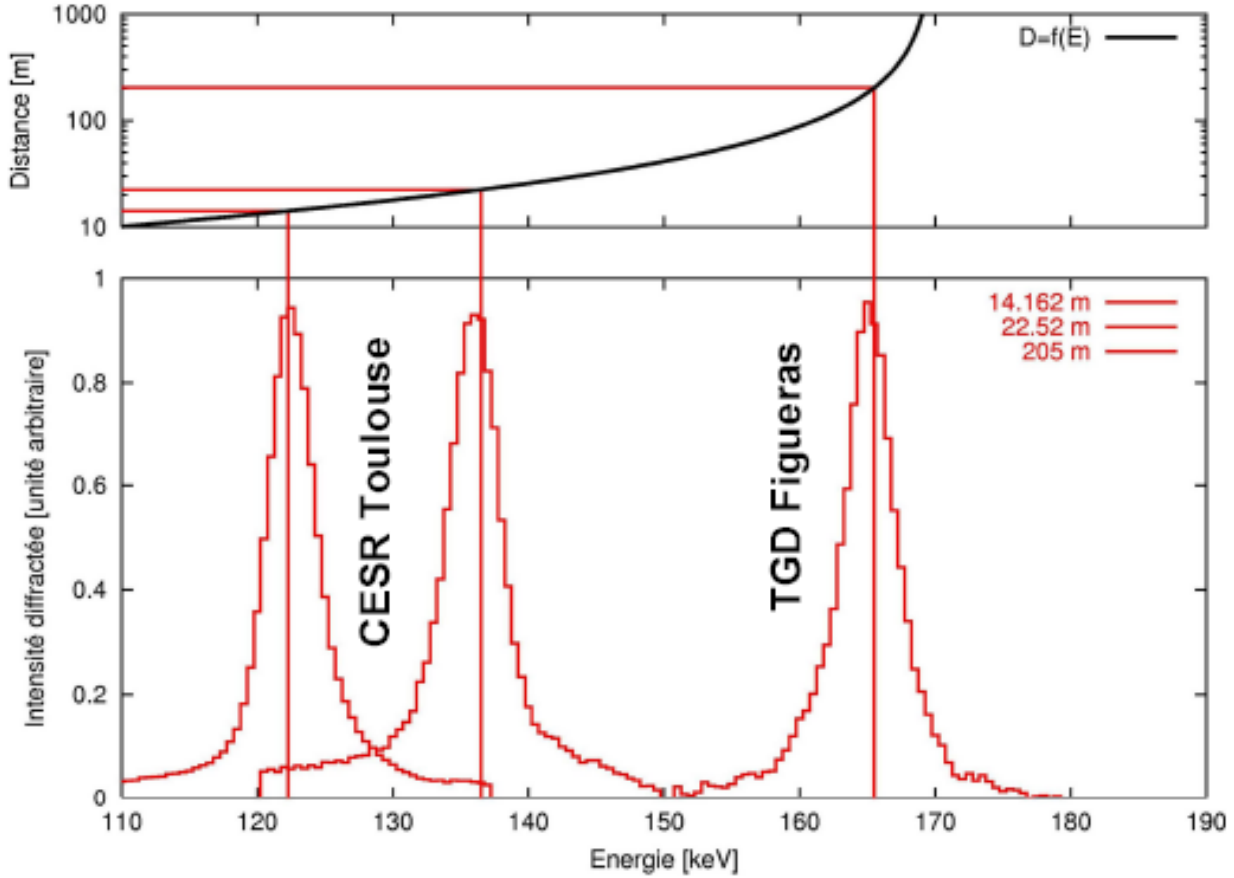
Web master

Done

Relation between distance and diffracted energy

$$\frac{100\,\mathrm{keV}}{E} = \frac{100\,\mathrm{keV}}{E_{\infty}} + 0.3251\left(\frac{10\,\mathrm{m}}{D}\right)$$

with E_{∞} = 170 keV



CLAIRE:balloon-borne γ-rays lens telescope

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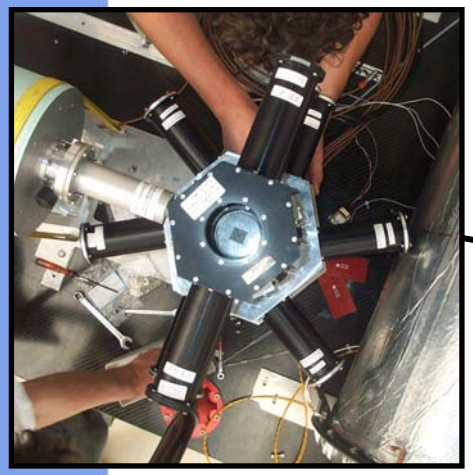
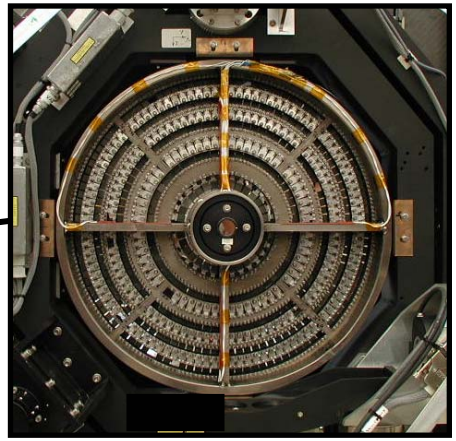
Detector

- 3x3 matrix
- high purity Ge
  1.5*1.5*4 cm

AC shield

- CsI
- BGO





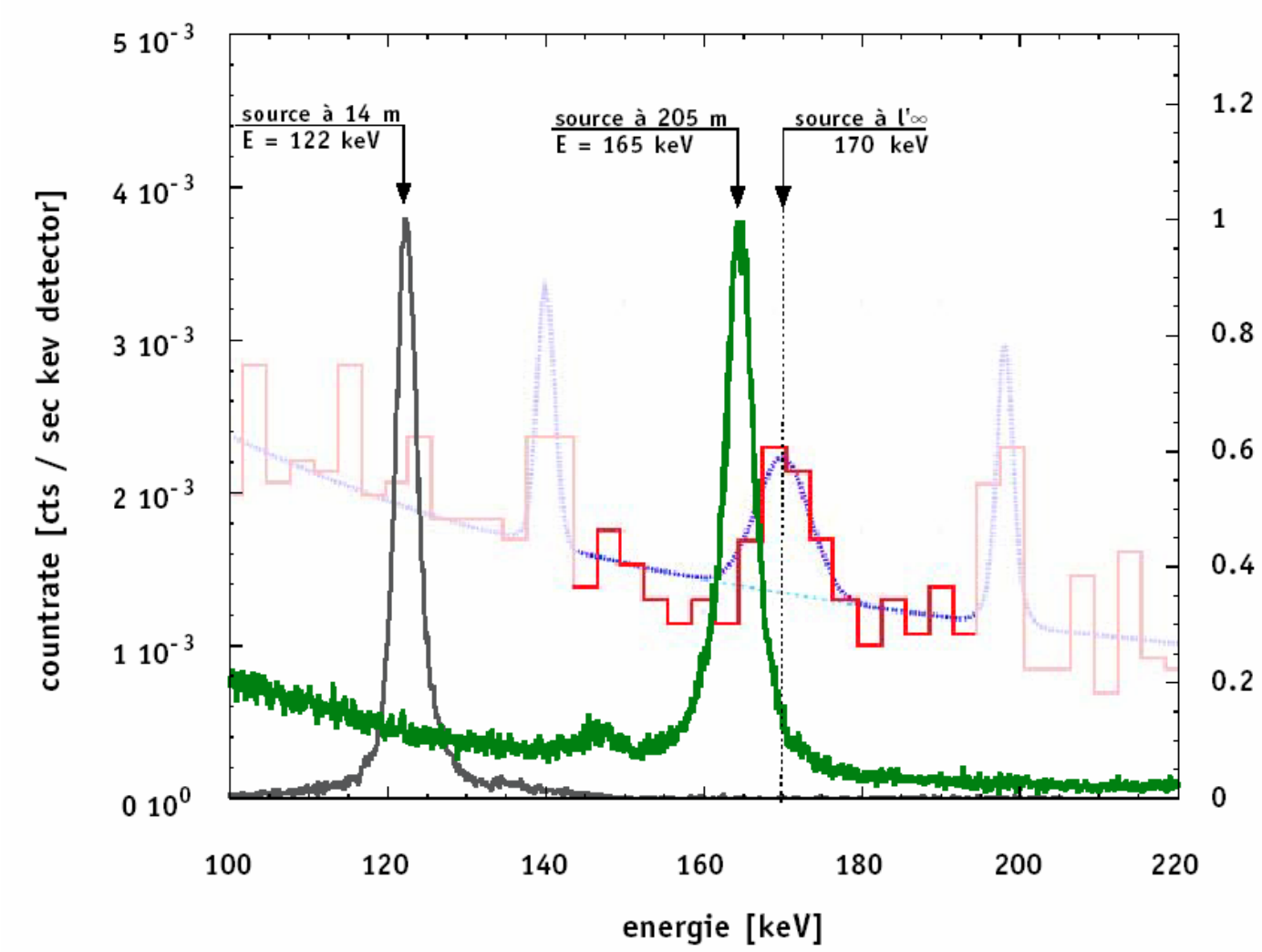
γ-ray lens

- 563 crystals
- E = 170 keV
- FWHM ~ 3 keV

http://www.cesr.fr/~pvb/Claire/index.html

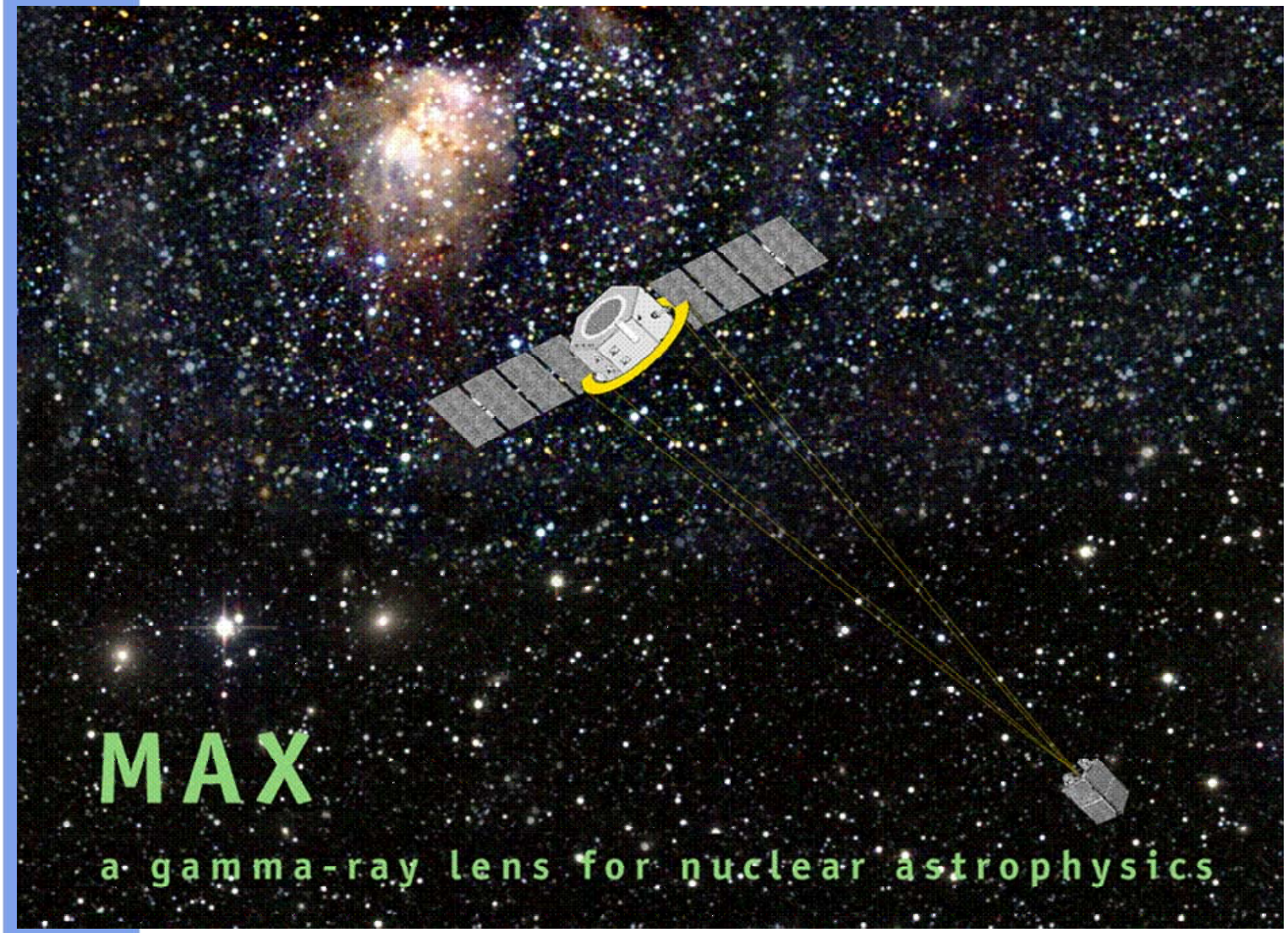
Is the lens performing as expected for sources at infinity?

GRI



LENS CONCEPT PROVEN

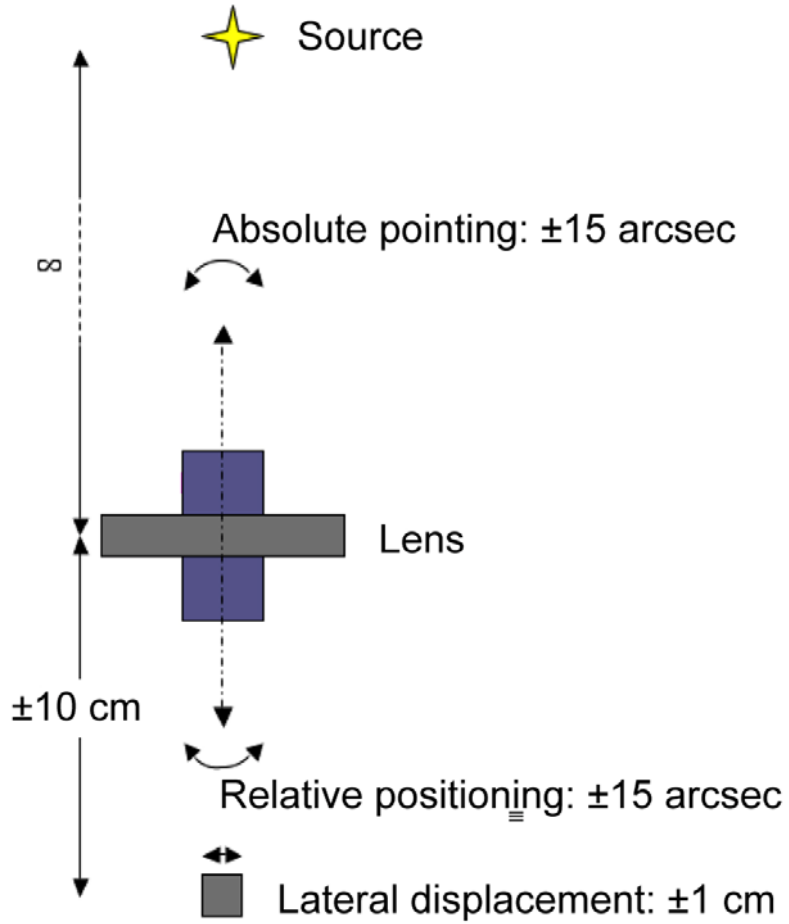
From CLAIRE to MAX (space mission)



proposal to CNES for technological flight to test formation flight → not approved (*crystal technology not mature yet*), but formation flight requirements OK

www.cesr.fr/~pvb/MAX/

Formation flight requirements



Formation Flight:

- R/F metrology for coarse formation control
- Optical metrology for fine formation control

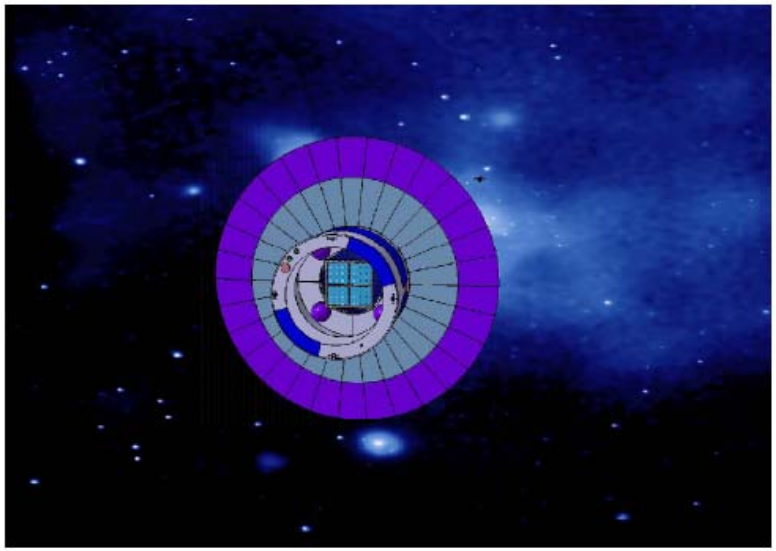
esa

Technology Reference Study

Final Report

GRL

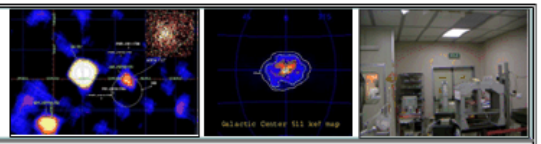
The Gamma Ray Lens



SCI-A/2005.058/GRL/CB
Craig Brown
July 2005

GRI

GRI Gamma Ray Imager



| Overview | Membership list | Publications | Events | Contacts | Links |

What's New on this site

Working version of simulation tools (named GRI Library) -->

4th GRI General Meeting. Presentations -->

Letter of intent in response to the call for proposals for the new Cosmic Vision 2015 - 2025 -->

GRI Project

- Overview
- Membership list
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- Links

Restricted area

- Login

ICE

Gamma-Ray Imager
5th Consortium Meeting

June 07 - 08, 2007
ICE, Barcelona

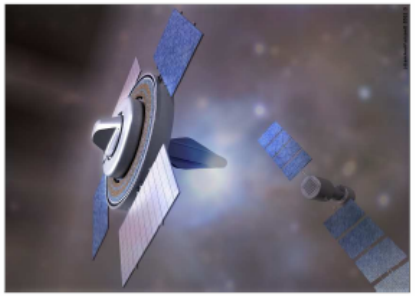
GRI Overview

Introduction

The Gamma-Ray Imager is an initiative of the European Gamma-Ray Community aiming in the definition of the next European Gamma-Ray mission within ESA's Cosmic Vision 2015-2025 program. The initiative has been started with a prospects seminar held in Rome (Italy) on March 18th, 2005. The conclusions of this seminar have been presented to ESA during the ESLAB Symposium, held at ESTEC from April 19-21th, 2005 in Noordwijk (Netherlands).

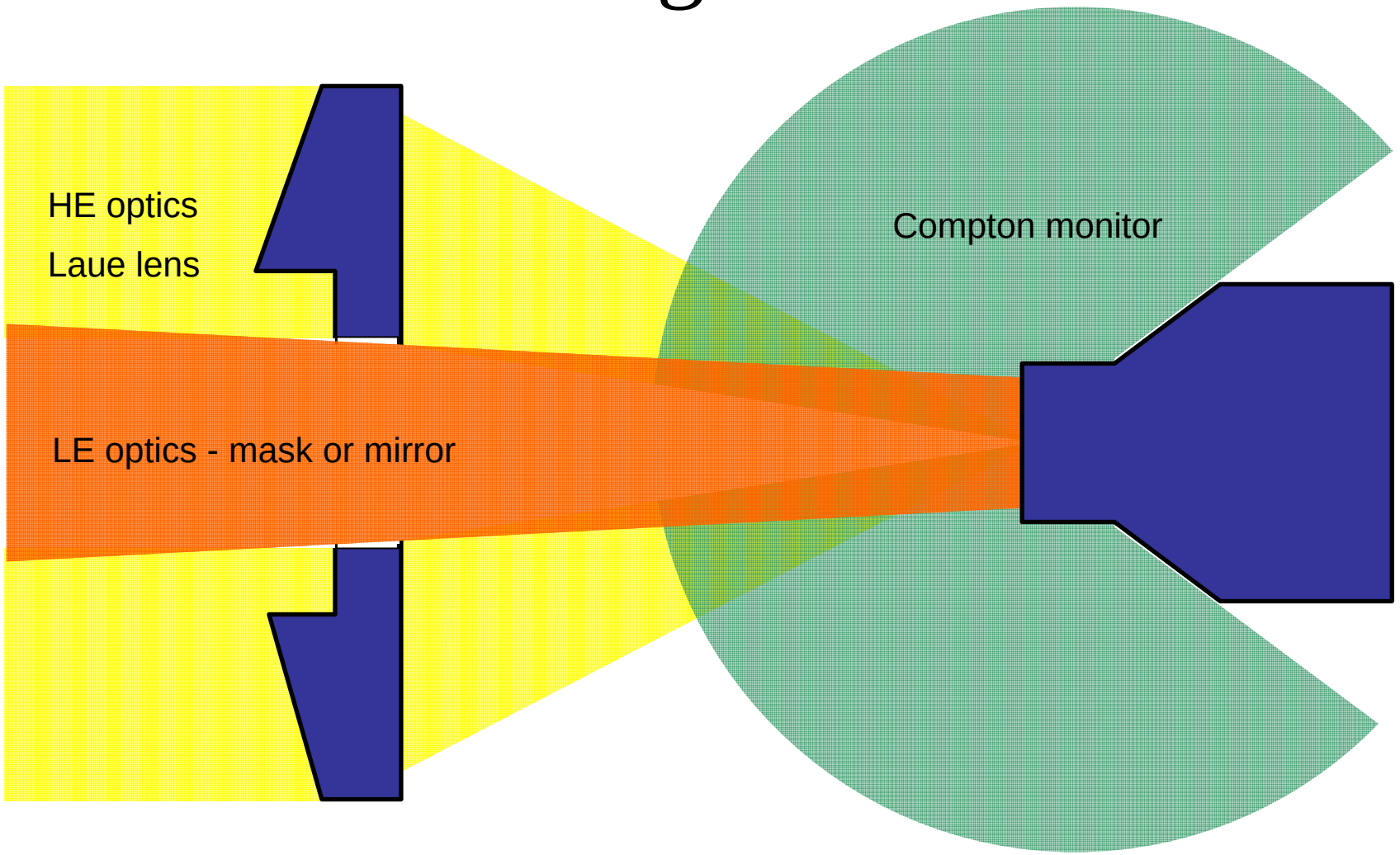
The declared goal of the initiative is to respond to the ESA call for missions for the Cosmic Vision 2015-2025 program with a well defined mission proposal. For this purpose, a Science Working Group has been set-up, which held its kick-off meeting in Toulouse (France) from June 6-7th, 2005. The Science Working Group is composed of Gamma-Ray Astronomers from all over Europe, and aims in the definition of the scientific objectives and the detailed mission design of the Gamma-Ray Imager.

Mission requirements



The major mission requirement for the future European gamma-ray mission is sensitivity. Many interesting scientific questions are in a domain where photons are rare (say 10-7 ph cm-2s-1), and therefore large collecting areas are needed to perform measurements in a reasonable amount of time. It is clear that a significant sensitivity leap is required, say 50–100 times more sensitive than current instruments, if the above listed scientific questions should be addressed.

GRI design iteration



Peter von Ballmoos, Nicolas Barriere and Julien Rousselle CESR

Optics (Optics spacecraft)

Laue Lens + single reflection multilayer mirror [see "HEFT" balloon-borne project from DNSC]

Global mass ≈ 1100 kg: includes structure, thermal, power, propulsion.. + 500 kg payload (300 kg of crystals + 200 kg structure ≈ 10 m^2) + 20% contingency

Detector spacecraft

Single detector module (based on CZT)

Similar global mass

TOTAL (HEO orbit) ≈ 2300 kg

GRI performance summary

GRI

Parameter	*Requirement*	*Goal*
Energy coverage (keV)	20 - 900	10 - 1300
Continuum sensitivity ($\Delta E/E=1/2$, 3σ, 100 ks)	10^{-7} ph cm^{-2} s^{-1} keV^{-1}	3×10^{-8} ph cm^{-2} s^{-1} keV^{-1}
Line sensitivity ($\Delta E/E=3\%$, 3σ, 100 ks)	3×10^{-6} ph cm^{-2} s^{-1}	10^{-6} ph cm^{-2} s^{-1}
Energy resolution (FWHM)	3%	0.5%
FoV (arcmin)	5 diameter	10 diameter
Angular resolution (arcsec)	60	30
Timing	100 μs	100 μs
Polarimetry (MDP, 3σ)	5% for 10 mCrab	1% for 10 mCrab
Observing constraints	ToO response < 1 day 50% sky coverage	ToO response < few hours; allsky coverage

Table 1. GRI mission requirements

Design and development of a Si/CdTe Compton camera prototype

GOAL: contribute to GRI's detector concept studies

Optimize the design through simulations with GEANT4.
Challenge: detect γ's with E up to 1-2 MeV

Fabrication and performance tests

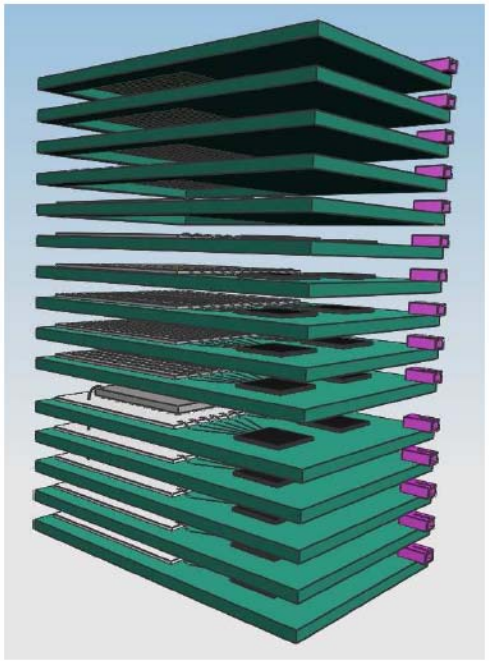
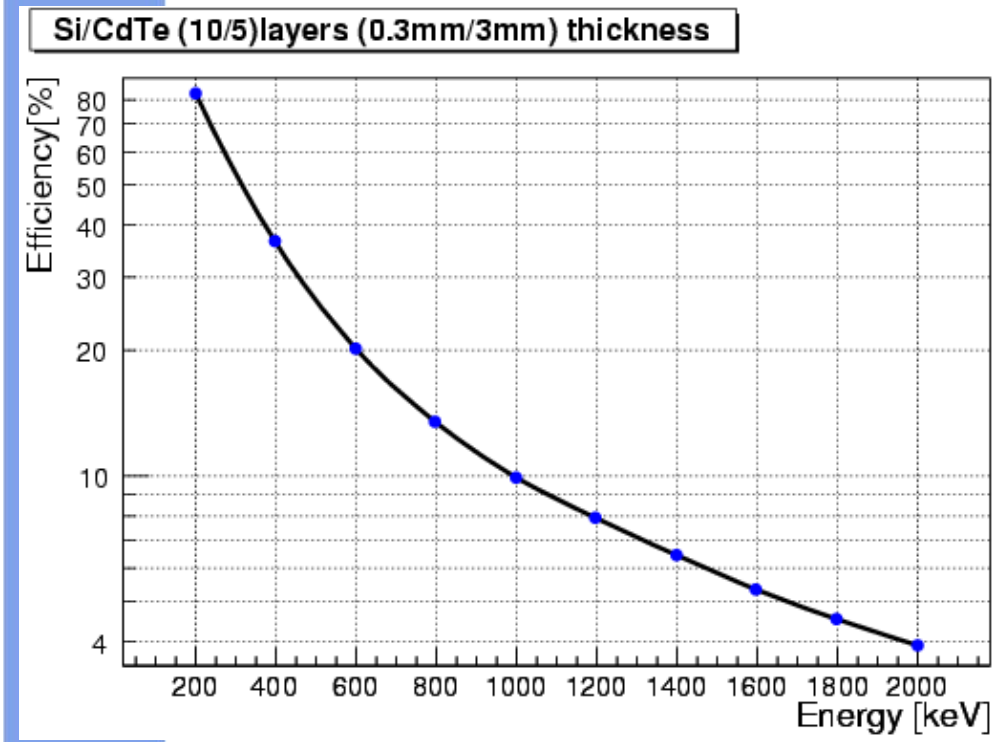


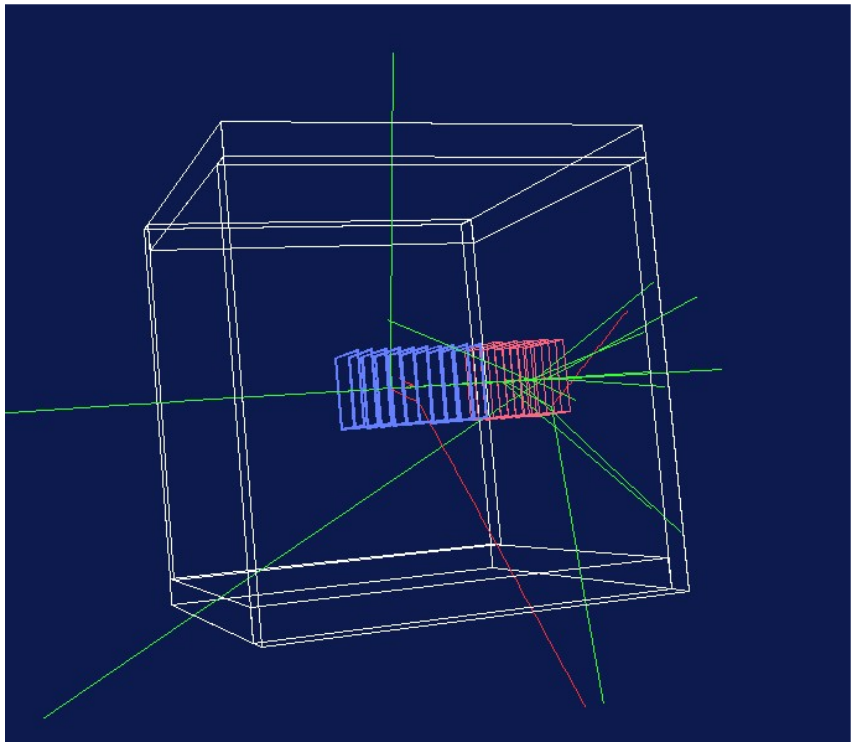
Figure 6. Schematic view of the global system, with the 15 sensing layers.

Simulations of performance in space background conditions, with the GRI lens beam

Photo peak detection efficiency: Si/CdTe stacked detector



Geant4 Geometry
10 layers of Si + 5 layers of CdTe



Technological implication

ICE/IFAE/CNM experience in radiation detectors

- Silicon detectors in LHC (CERN)
- CdTe detectors in mammography (DearMama european project)
- Radiation monitor for the LISA Pathfinder ESA's mission
- Detectors fabrication capabilities (CNM Clean Room)
- Electronic design
- Advanced packaging (Flip chip, bump bonding)