Forum della Ricerca Sperimentale e Tecnologica in INAF

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Electronics and Detectors at OAS-Bologna

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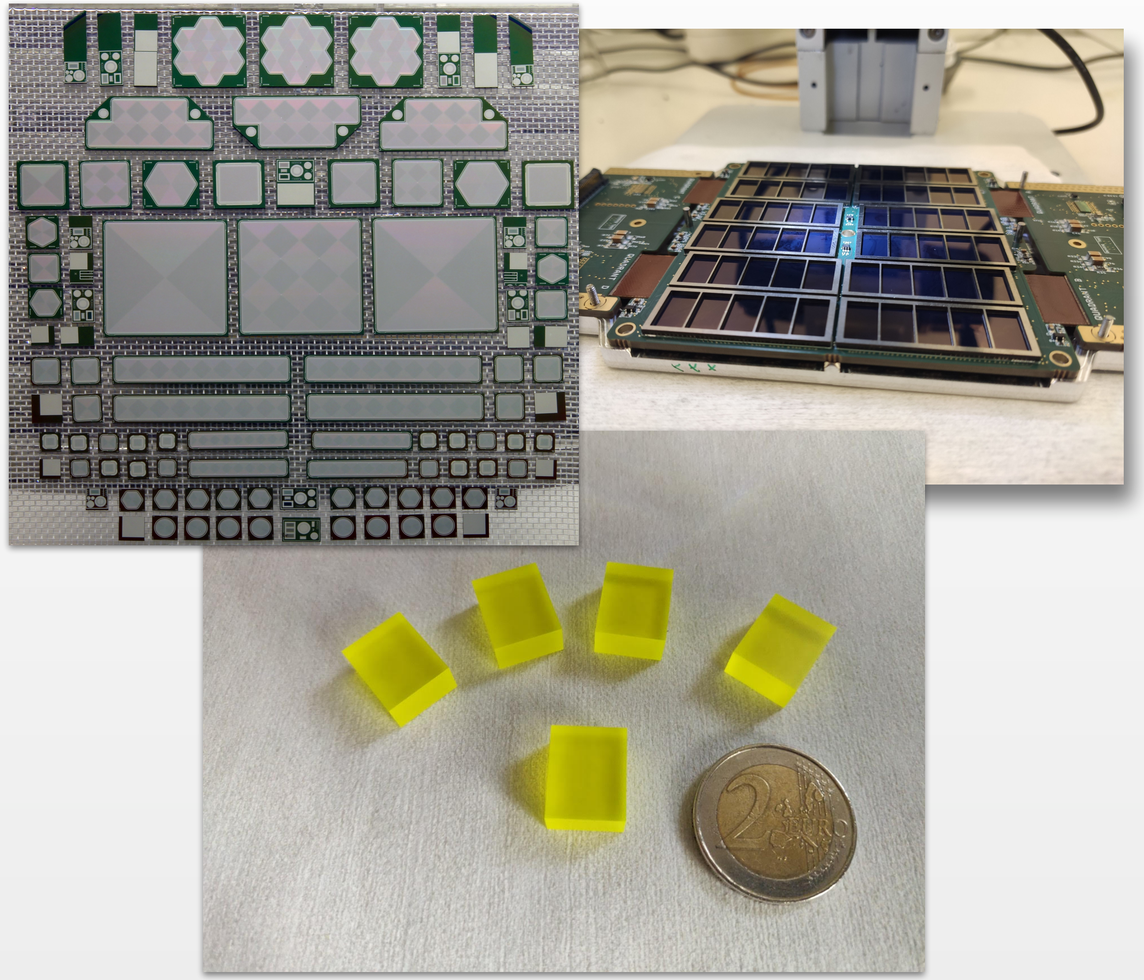
INNOVATIVE SPACE-BORNE X AND GAMMA-RAY DETECTORS

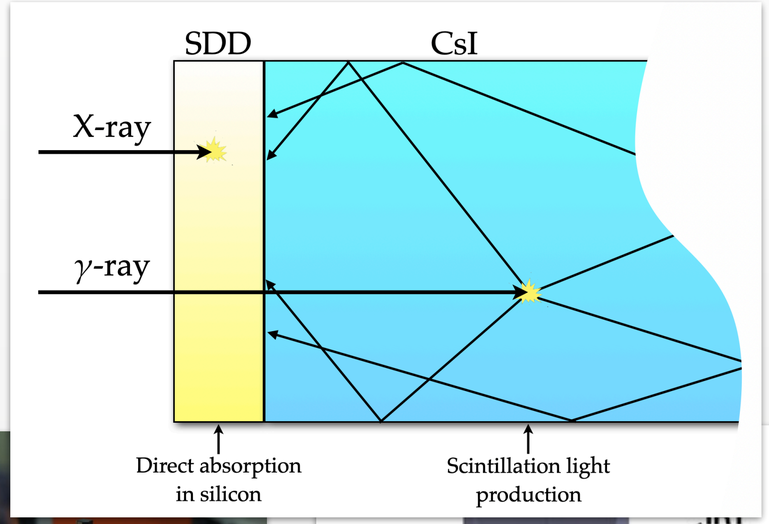
- **OAS Gamma-ray laboratory**: design and testing of **innovative detectors** for high-energy astrophysics experiments
- Integration, calibration, performance testing of detectors and prototypes
- Large **multidisciplinary collaborations** (e.g., INFN ReDSoX)
- **Solid-state** sensors (in particular, **Silicon Drift Detectors**, SDD) as **X-ray** detectors and/or as photodetectors for **scintillators**
- Testing of **low-noise** integrated **front-end** electronics (ASICs)

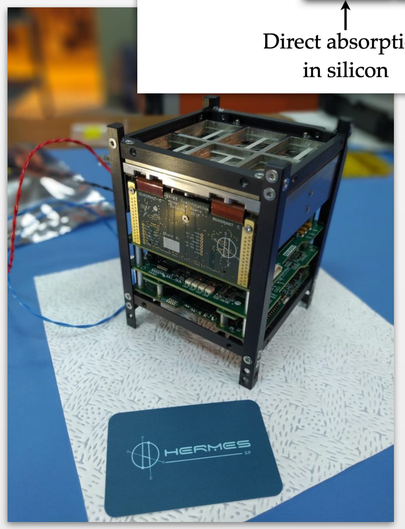


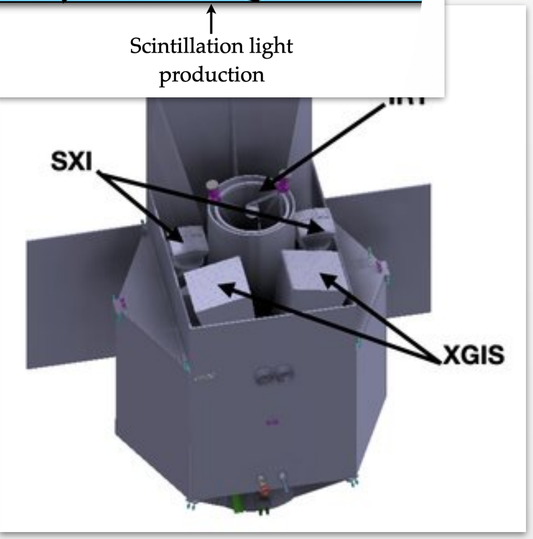
People involved: ***R. Campana, E. Virgilli, C. Labanti, E. Marchesini, F. Fuschino***

INNOVATIVE SPACE-BORNE X AND GAMMA-RAY DETECTORS

- The "Siswich" concept (SDD+scintillator) is the **basis architecture** for several current and proposed high-energy ASI/ESA/NASA astrophysics missions, e.g., HERMES, THESEUS
- Dual readout allows **unprecedented broadband energy coverage** ("X-mode" 2–30 keV, "S-mode" 20–10000 keV) in a **single, compact instrument**
- Also, 3-D kinematics reconstruction → background reduction, polarimetry





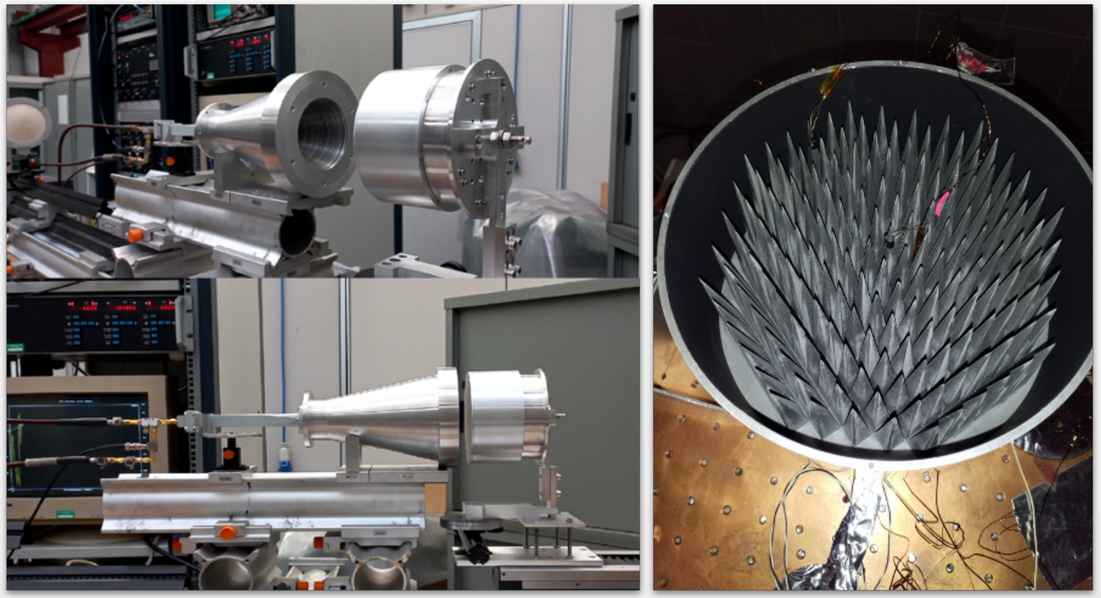


People involved: ***R. Campana, E. Virgilli, C. Labanti, E. Marchesini, F. Fuschino***

CRYOGENIC CALIBRATORS FOR RADIO AND MICROWAVE RECEIVERS

- Cryogenic reference sources ('quasi perfect' black bodies) are fundamental to **optimise and characterise receivers** from radio to THz. INAF-OAS has more than 20 years experience in design and verification of **'state of the art' cryogenic passive calibrators** for radiometric and bolometric receivers, for space, balloon, ground based instruments.
- Frequency coverage **from GHz to THz**: Alma B2 (ESO) 67–116 GHz, LSPE-Strip (ASI) 40–100 GHz, Tenerife Microwave Spectrometer (IAC-INAF), 10–20 GHz, Planck (30–900 GHz).

- Capabilities:
  - ✓ Electromagnetic modelling and RF verification.
  - ✓ Thermal modelling and cryogenic verification (to 3K)
  - ✓ Materials characterisation: RF, Cryo, Thermo-Mechanic
- Collaborations with CNR-SFTP Milano; IAC, Tenerife; ESA, ESO, ASI



People involved: ***F. Cuttaia*** *(RF design&verification),* ***L. Terenzi*** *(Cryogenic design&verification)*

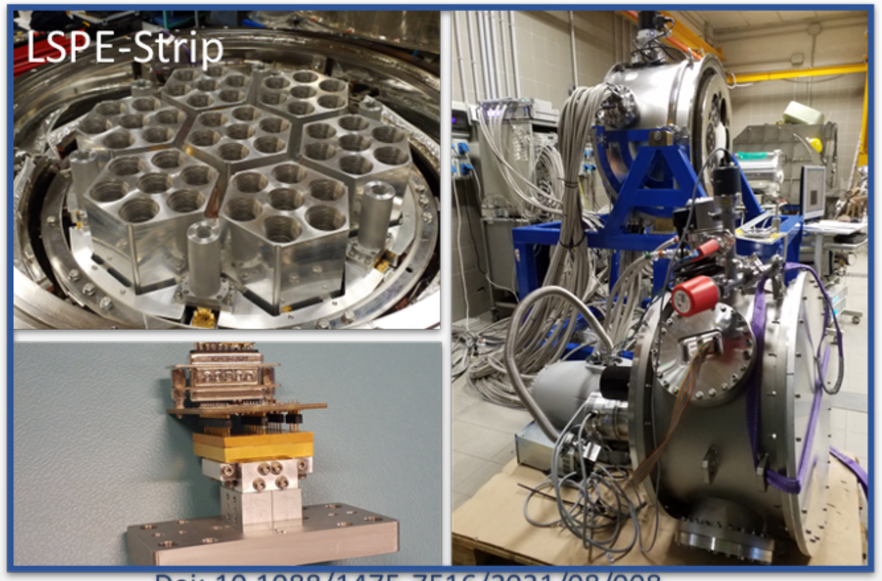
INTEGRATION, OPTIMISATION AND VERIFICATION OF MM/MW RECEIVERS

OAS has been strongly involved for long time (≥2002) in **AIV activities of cryogenic Low Noise Amplifiers** and 'microwave' receivers in general.

- ✓ developed dedicated methods & techniques to **verify, optimise** and fine-tune the performance and design for space and ground based receivers;
- ✓ is in charge of the V&V of **Alma B2** receivers [2015-2025];
- ✓ is in charge of and AIV&V of the 55 polarimeters aboard the **Strip-LSPE** instrument [2018-2023];
- ✓ is involved in the calibration of the **Tenerife Microwave Spectrometer** (TMS) [2018-2024];
- ✓ the **OAS Cryowaves laboratory** is equipped to integrate and verify state of the art performance microwave receivers at cryogenic temperatures down to 4K.
- ✓ The WP-5501 submitted to INAF PNRR proposal '**STILES**' is aimed at developing a **cryogenic multifrequency facility** to extensively characterise LNAs and receivers at frequencies and temperatures relevant for the INAF current and future astrophysical projects.

People involved: ***F. Cuttaia, G. Morgante, L. Terenzi, F. Villa***

INTEGRATION, OPTIMISATION AND VERIFICATION OF MM/MW RECEIVERS



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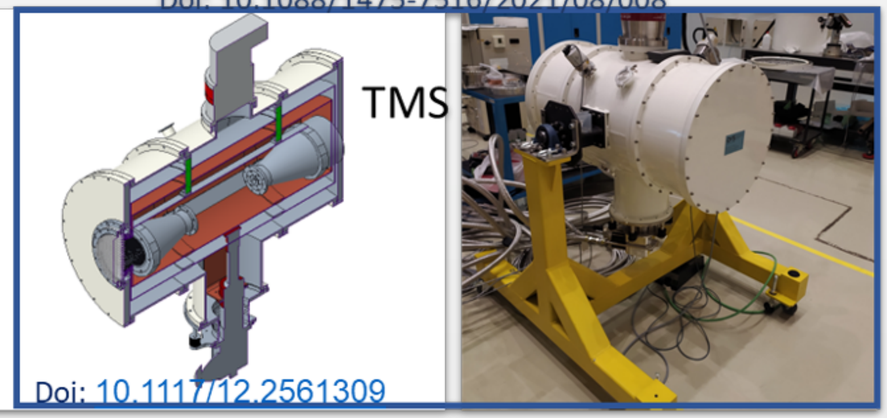

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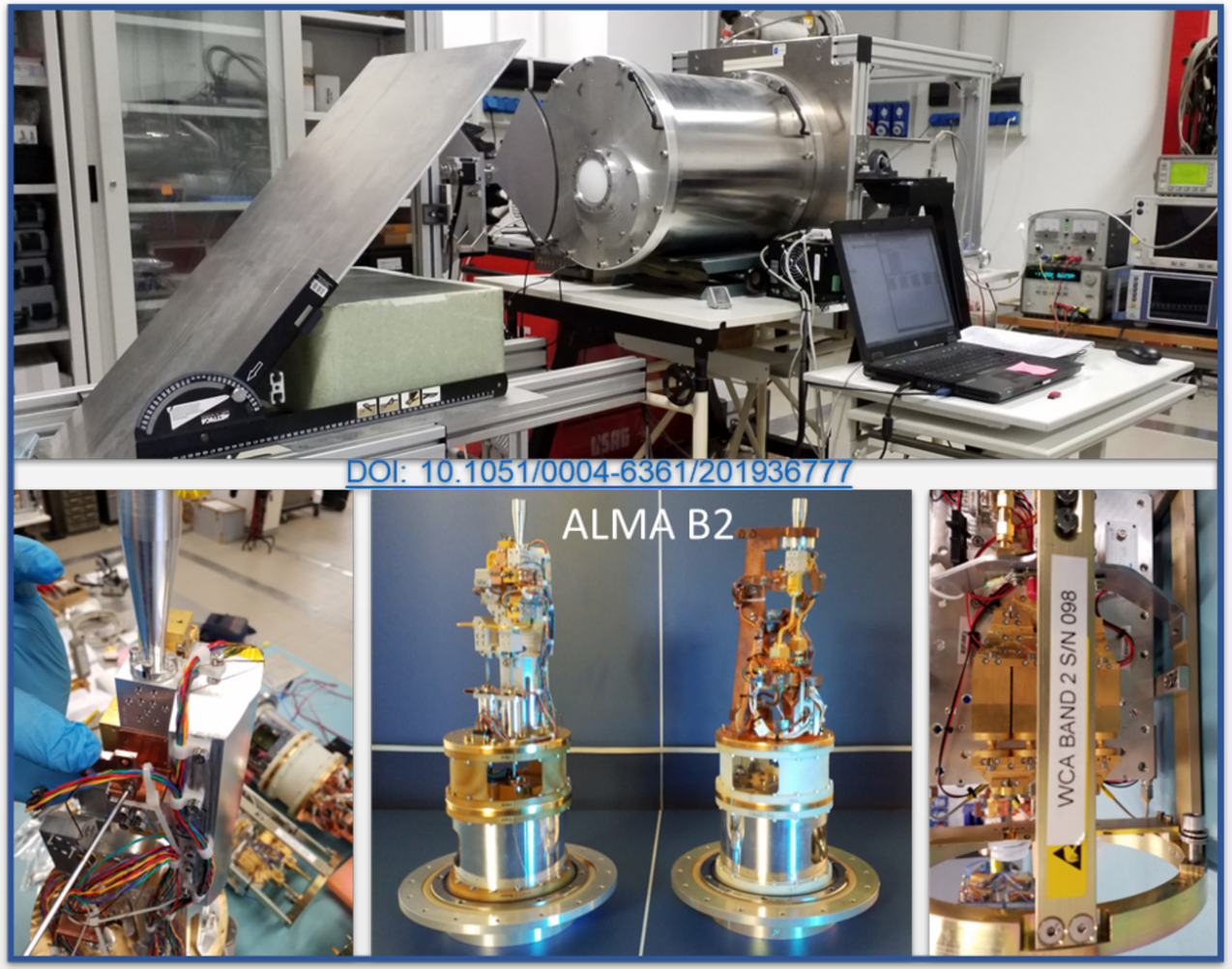

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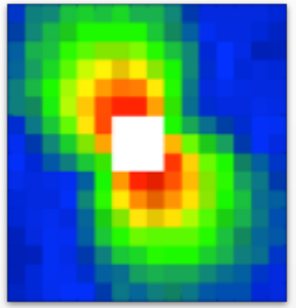
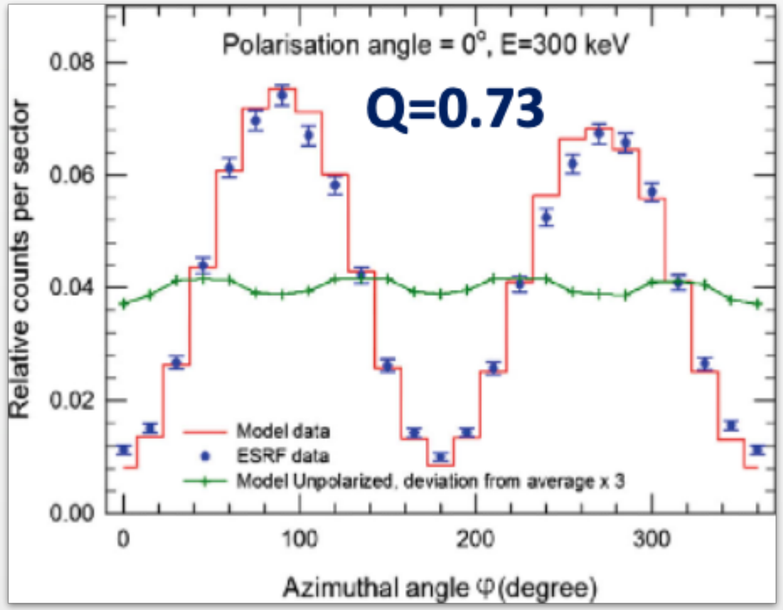
CdZnTe DETECTORS FOR SPECTROSCOPIC IMAGING AND POLARIMETRY IN HARD X AND SOFT γ-RAYS

Hard X- and soft **γ**-ray astronomy: what is the future?

- At least a **two–order of magnitude increase in sensitivity and angular resolution**, w.r.t. current instrumentation, in the energy band **up to several hundreds of keV** (600–700 keV) is required to be able to solve several hot scientific issues still open
- **Polarimetry** shall become a "standard" observational mode of cosmic ray sources in this energy regime to fully **understand the emission mechanism** of several source classes
- These requirements can be fulfilled only with **space telescopes implementing new high energy focusing systems**



Polarimetric capability of a highly segmented (0.6 mm) CZT spectro-imager with fine energy resolution (1% @ 511 keV)

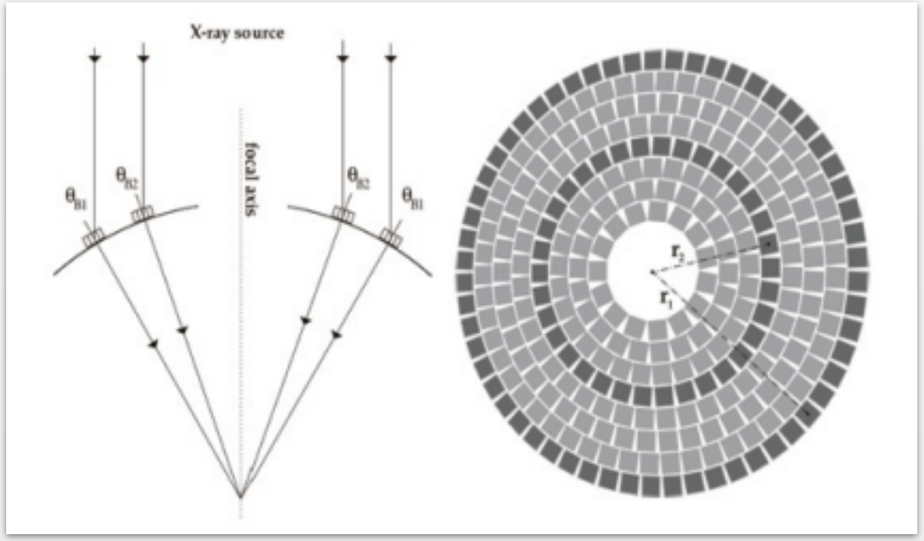


People involved: ***N. Auricchio, E. Caroli, E. Virgilli***

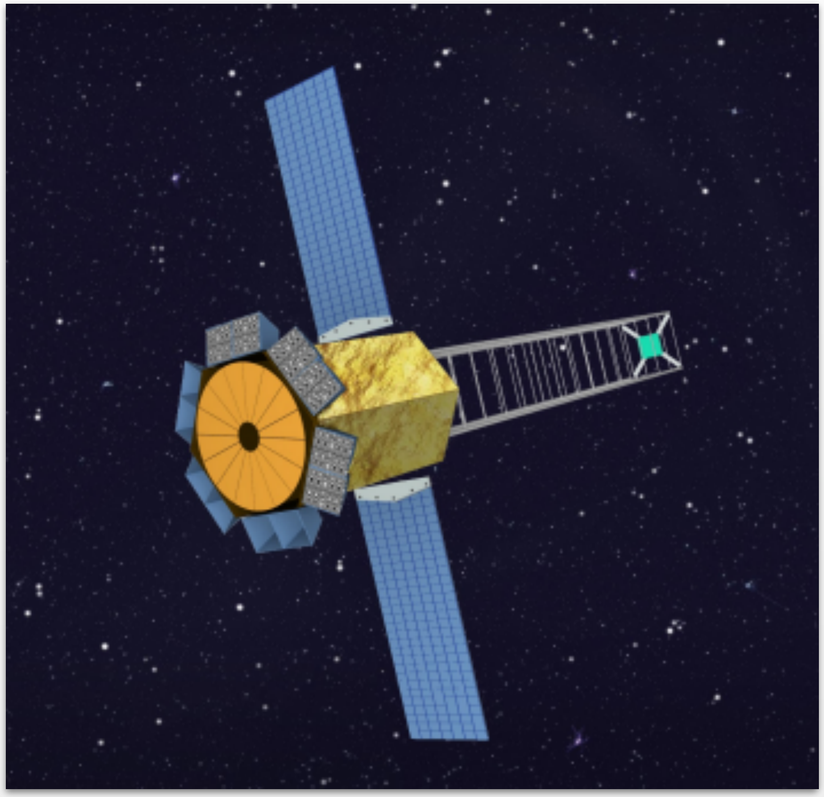
CdZnTe DETECTORS FOR SPECTROSCOPIC IMAGING AND POLARIMETRY IN HARD X AND SOFT γ-RAYS

Cutting-edge technologies able to meet the challenges of the next space missions for hard X and soft gamma ray astronomy

- **Broad band Laue lenses**
  - ✓ New optics based on bent crystals (GaAs, Ge, Si) operating in 30–700 keV;
  - ✓ Moderate focal length (15–20 m); low mass (60 kg including the support) for a 2 m diameter lens.



Laue lens concept: each ring of crystals focuses the same energy



ASTENA: A mission concept based on Laue lenses (orange circle)

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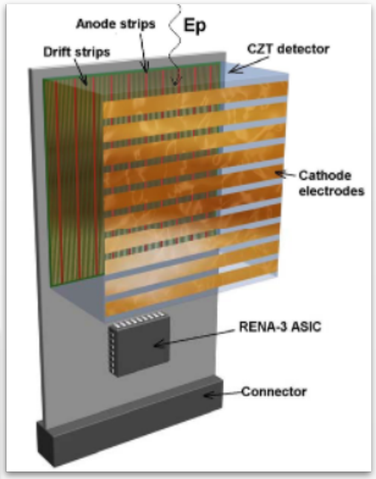
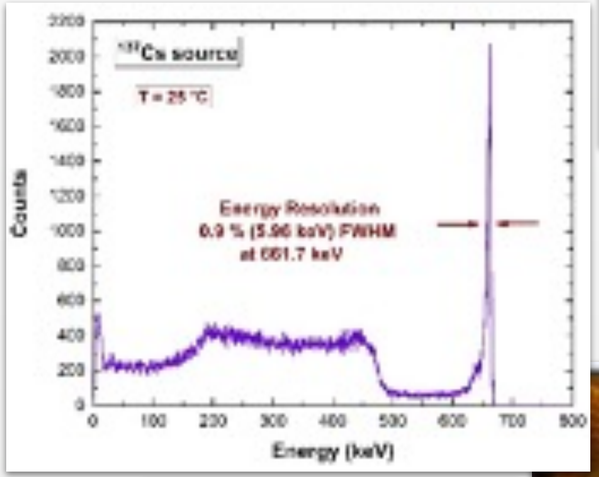
CdZnTe DETECTORS FOR SPECTROSCOPIC IMAGING AND POLARIMETRY IN HARD X AND SOFT γ-RAYS

Cutting-edge technologies able to meet the challenges of the next space missions for hard X and soft gamma ray astronomy

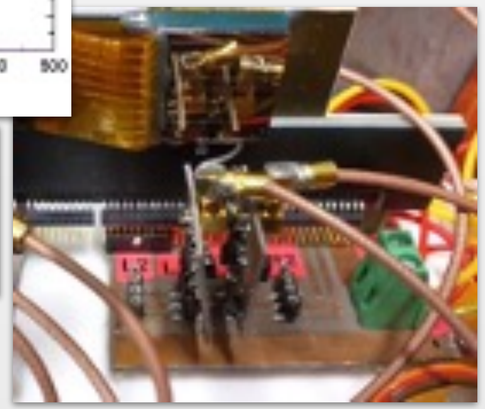
- **3D CZT spectro-imager as focal plane detector**
  - ✓ **High efficiency** using Compton in addition to photoelectric events; rejection of environmental and instrumental background, e.g. using Compton kinematics;
  - ✓ **Uniform response** achievable by means of signal compensation techniques;
  - ✓ Very low degradation of the PSF of the flux focused by a Laue lens or similar optics with energy by the identification of the photon interaction points for scattered events;
  - ✓ High efficiency **scattering polarimetry** above 100 keV;
  - ✓ **Fine spectroscopy** also for multiple events (small sensitive volumes, voxels).

Orthogonally segmented anode and cathode → **2D position (X;Y)**
Depth information (Z) from the ratio R=Qp/Qs, where Qp: electrode signal and Qs: anode strip signal → **3D detector (Z)**





3DCZT spectroscopy capabilities



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