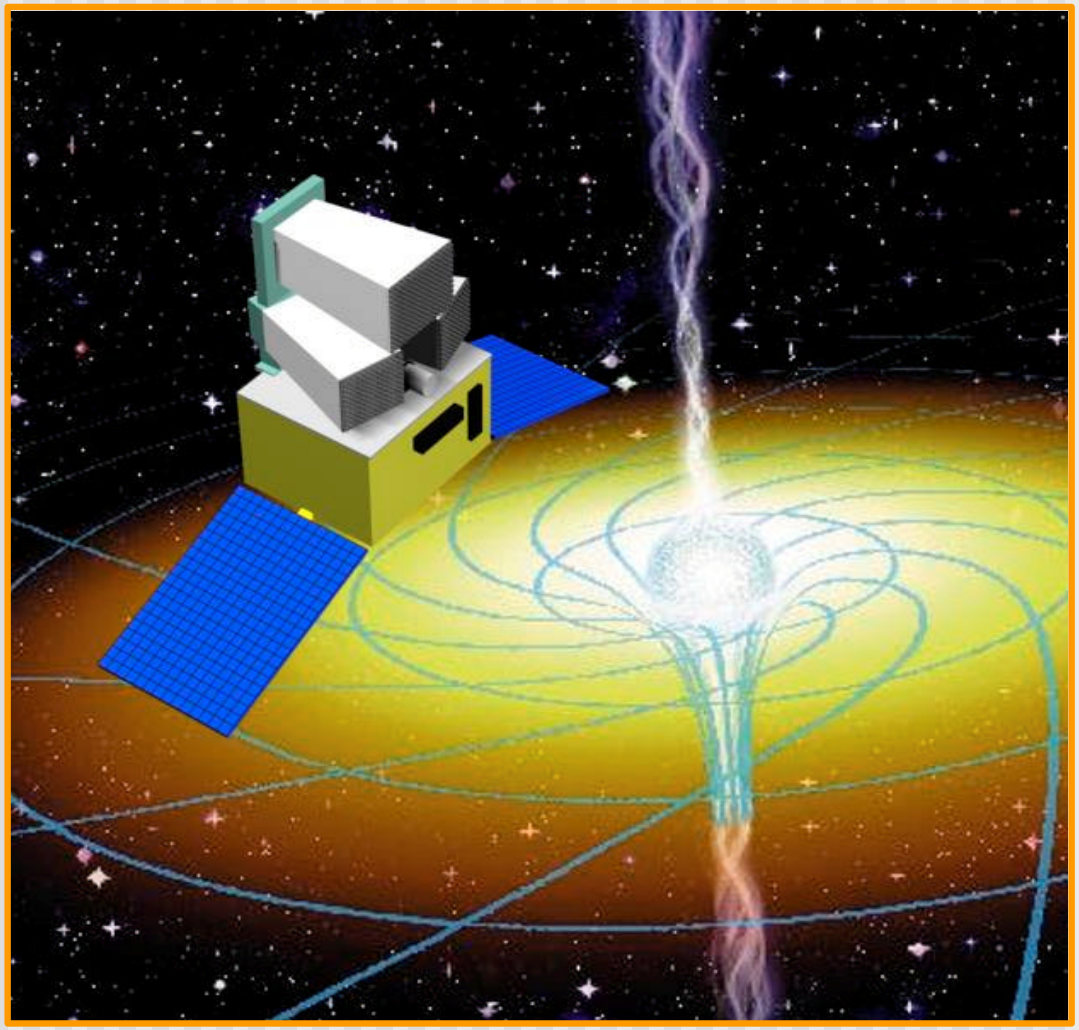
MIRAX and the Brazilian Space Program



João Braga

INPE

Brazil

Brazilian Space Program

- **1961** – "Comissão Nacional de Atividades Espaciais" (CNAE) established
- **1961** – first activities and research in space and atmospheric sciences
- **1965** – sounding rocket launches from Natal, with Brazilian payloads
- **1971** – INPE is established
- **1979** – "Missão Espacial Completa Brasileira" (MECB): development of
  - "data collecting" and remote sensing satellites (INPE)
  - satellite launch vehicle (IAE/CTA)
  - a launching site near the equator – Alcantara (IAE/CTA)

Brazilian Space Program

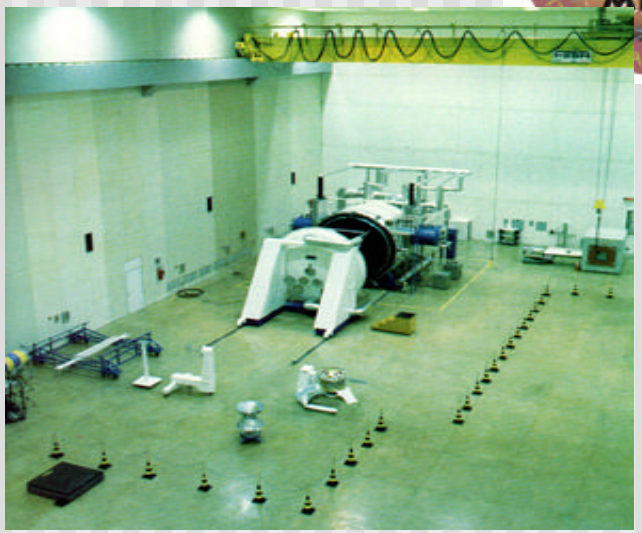
- **1982** – space infrastructure investments for MECB:

  LIT (1983-87) and CRC (1987-89)

LIT - Integration and Testing Laboratory

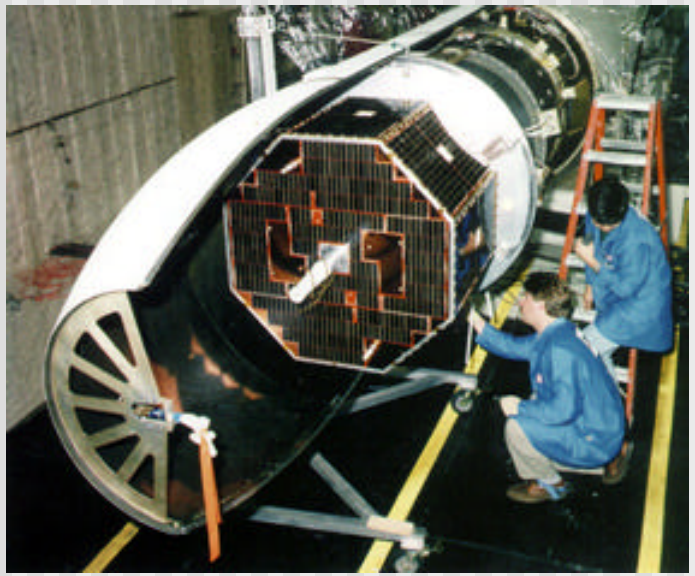
CRC - Satellite Control and Tracking Center

- **1988 –** Cooperation agreement with China (China-Brazil Earth Resources Satellites - CBERS)
- **1993** – launch of first “Satélite de Coleta de Dados” - SCD-1 by a Pegasus



LIT

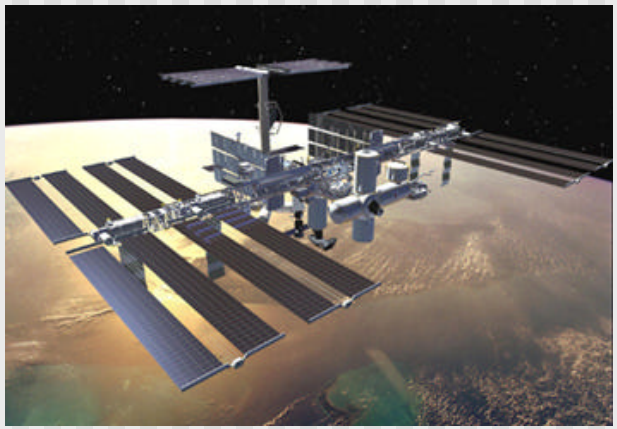
CRC



SCD-1

Brazilian Space Program

- **1994** – Agência Espacial Brasileira (AEB) is created with headquarters in Brasília
- **1997** – launch of “Satélite de Coleta de Dados” 2 - SCD-2 by a Pegasus
- **1997** – Brazilian participation in the ISS.
- **1999 –** launching of CBERS-1 from Shanxi (China) by Long March 4B launcher
- **~1997-2000** – two VLS launch attempts are unsuccessful
- **2003** – VLS disaster and launch of CBERS-2



Monitor e Imageador de Raios-X (MIRAX)

(www.cea.inpe.br/mirax)

MIRAX preliminary scientific team

João Braga, Flavio D'Amico, Chico Jablonski, Jorge Mejía[1]

Rick Rothschild, Biff Heindl, Jim Matteson[2]

John Heise, Jean in 't Zand[3]

Rüdiger Staubert, Jörn Wilms, Eckhard Kendziorra[4]

Ron Remillard[5], Erik Kuulkers[6]

1 INPE, 2 CASS/UCSD, 3 SRON, 4 IAA-A/Tübingen, 5 MIT, 6 ESA/ESTEC

MIRAX brief history

- Selected by INPE's Astrophysics Division on May 2000 to be part of INPE's microsatellite scientific program
- Collaboration with CASS/UCSD: CZT detectors
- Collaboration with IAA Tübingen: onboard computer and software development
- Collaboration with MIT: science and software for data archiving and distribution
- Presented at Brazilian Astronomical Society (SAB) meetings - open to community participation
- Collaboration with SRON: soft X-ray camera (WFC)

MIRAX summary

X-ray astronomy satellite mission

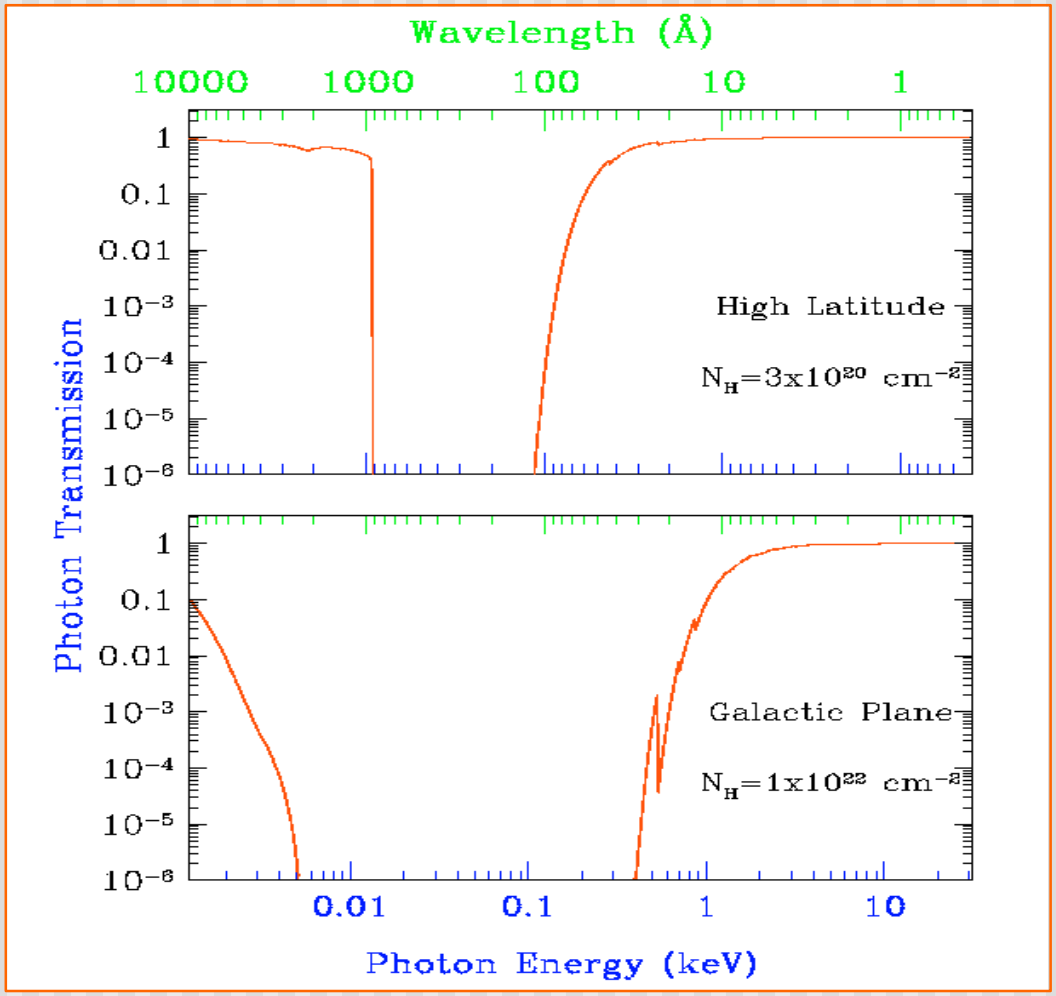
- small (~**200** kg, ~**240** W), low-cost (~**US$10M**)
- energy range: **2** to **200** keV
- angular resolution: **5'-7'30" (coded aperture imaging)**
- localization: **~ 1'** (10 σ)
- spectral resolution: **1.2** keV @ 6 keV, < **5** keV @ 60 keV
- time resolution: < **120 ms** (**10 ms** for the CXDs)
- field-of-view: **58° x 26°** FWHM along the Galactic Plane
- sensitivity **~10 x** ASM/RXTE, **~40 x** BATSE (Earth Occ.)
- inertial pointing (fixed at **central GP** for ~9 months)
- **equatorial** low orbit (~550 km)
- **S-band** telemetry (~1.5 Mbit/s) (1 or 2 stations)
- Launch in **~2008** by **Indian launcher** (possibly)

MIRAX mission

- First Brazilian astronomical satellite project
- High-energy astrophysics **observational window** for the Brazilian community
- International collaboration: **INPE, UCSD, SRON, Tübingen, MIT** ⇒ expertise in space missions and cost sharing
- Strong participation of Brazilian institutions and industry (IPEN etc.)
- 100% public data, NASA HEASARC archive

Window to High Energy Astrophysics

Photon transmission through the Galaxy



MIRAX SCIENCE

Continuous broadband imaging spectroscopy of a large source sample (~9 months/yr)

⇩

- Complete history of transient sources
- Study of the non-thermal universe (hard X-rays)
- Accretion torques on neutron stars

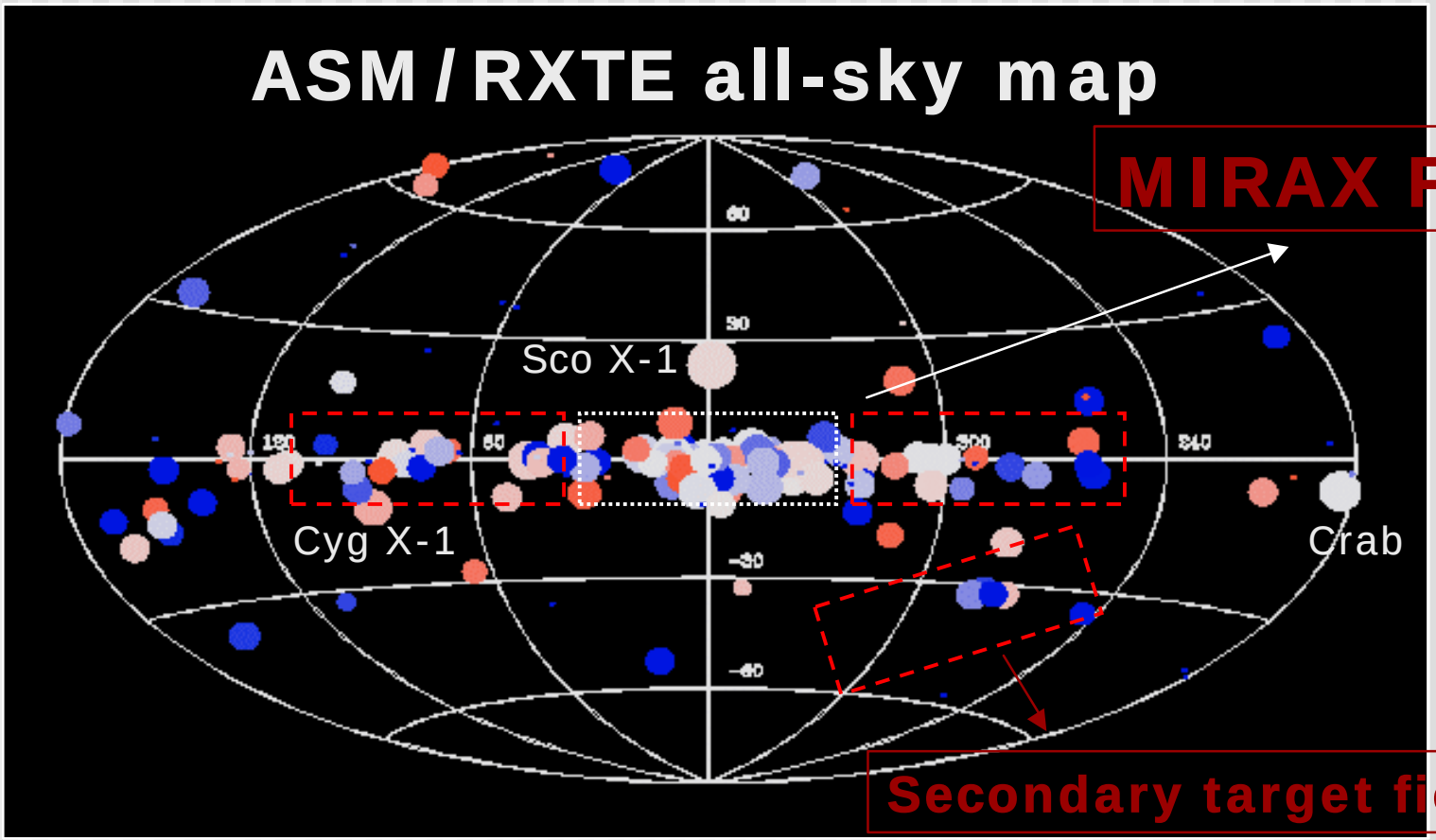
  ⇒ X-ray pulsars and burst oscillations, millisecond accretion pulsars
- Spectral state transitions and evolution on accreting black-holes
- Relativistic jets on microquasars

  ⇒ X-ray light curves during radio ejections
- Fast X-ray novae, X-ray bursts, SGRs
- Gamma-ray bursts (~1/month)
- AGN variability (obscured AGNs)

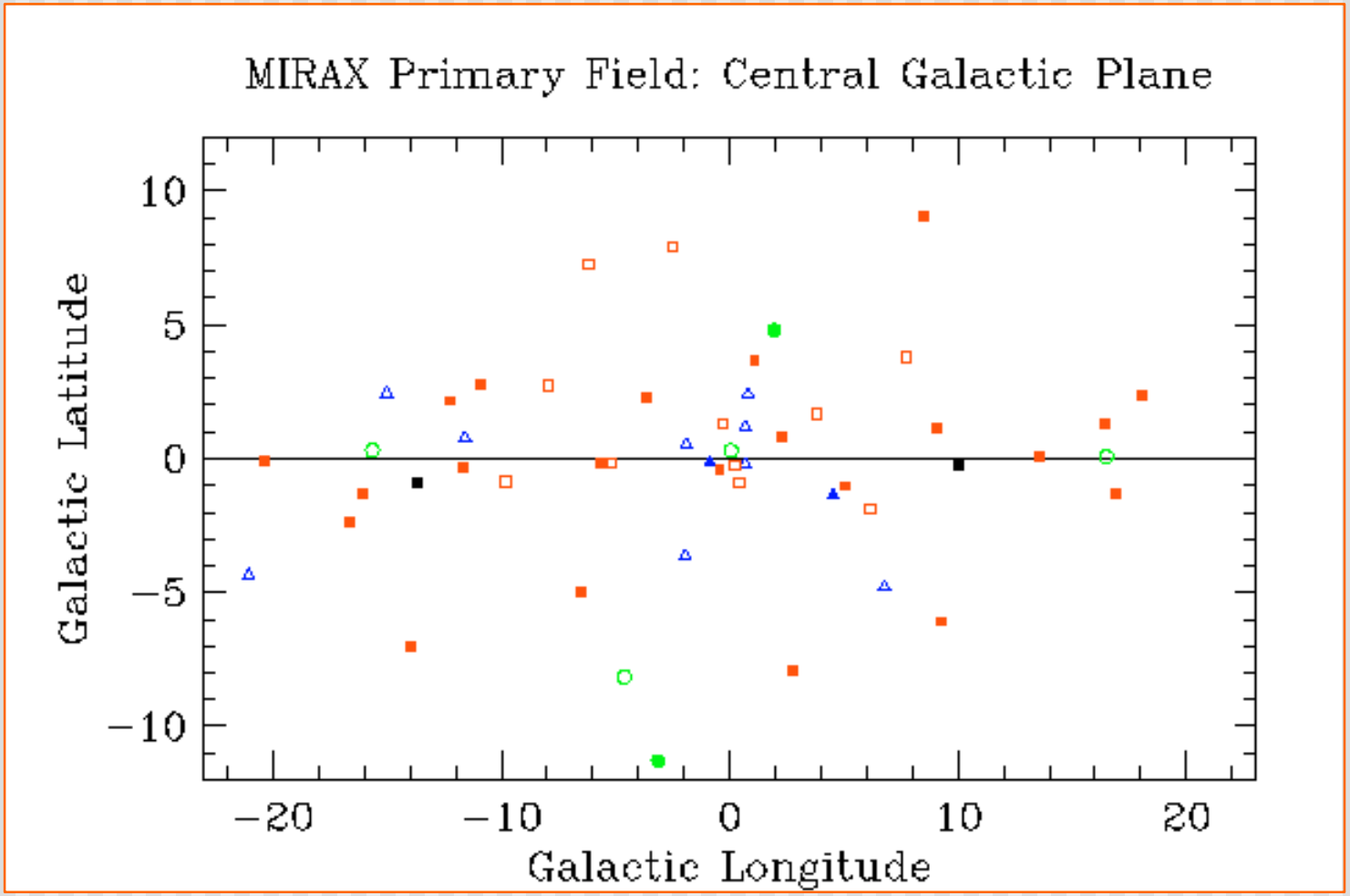
MIRAX Strategy

- Hard X-ray **survey** of central Galactic plane with GC continuous monitoring
- **Unique capability** to detect, localize, identify, and study short-lived, rare, and/or unpredictable phenomena, including X-ray transients and fast X-ray novae
- **Alert service** for astronomers on all λs; coordinated optical/IR and radio observations
- **Secondary target fields:** microquasars jets and Cygnus region; X-ray pulsars in Vela/Centaurus; Magellanic Clouds survey

MIRAX Strategy



MIRAX Primary Field



Symbol color: black hole binaries Δ;
(Neutron stars): pulsars, non-pulsing, peculiar
Symbol shape: open: transient solid: persistent

MIRAX strategy

Advantages over previous/existing missions:

- Detect, localize, identify, and study short-lived, unpredictable phenomena which last from minutes to days, and are very likely to be missed by traditional observing strategies;
- Observe longer-lived phenomena in great detail from 2 to 200 keV.

➢ Every object will be observed for 60 min of every 90 min orbit, 15 times a day, for 9 months

➢ Integral and Swift GC observations suffer from low duty cicles which make them unlikely to detect short-lived transients and unable to perform detailed studies of longer-lived phenomena

MIRAX instruments

2 hard X-ray imaging cameras (**10-200 keV**)
built by DAS/INPE in collaboration with CASS

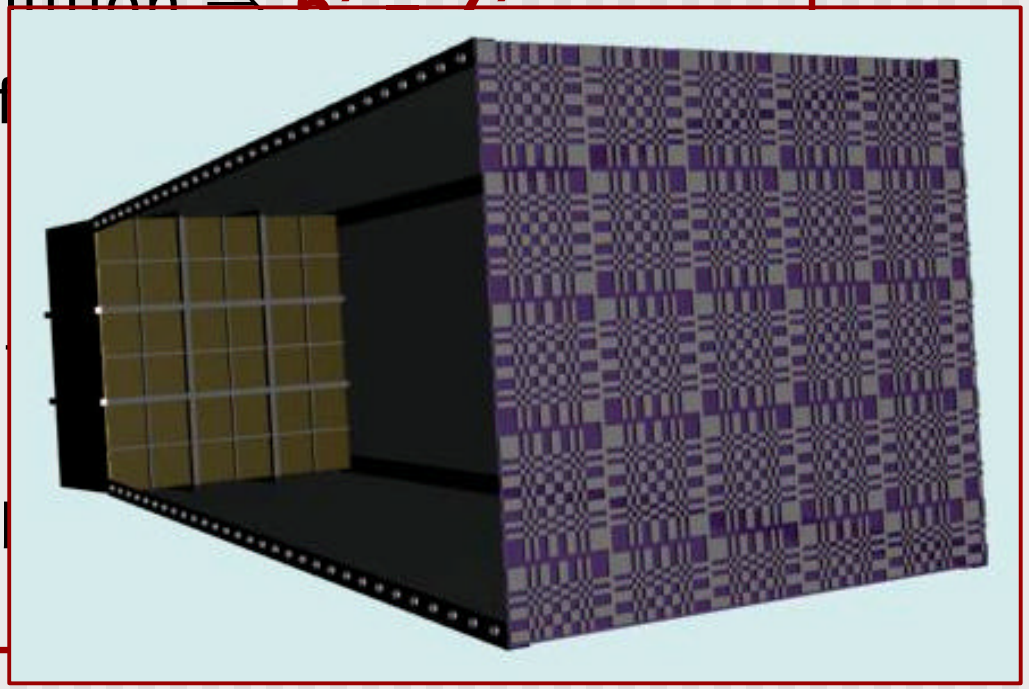
⇒ **Detectors developed at CASS/UCSD**

1 soft X-ray imaging camera (**1.8 – 28 keV**)
BeppoSAX WFC spare flight unit

Þ **provided by SRON (Holland)**

Câmeras de Raios-X Duros - CXD

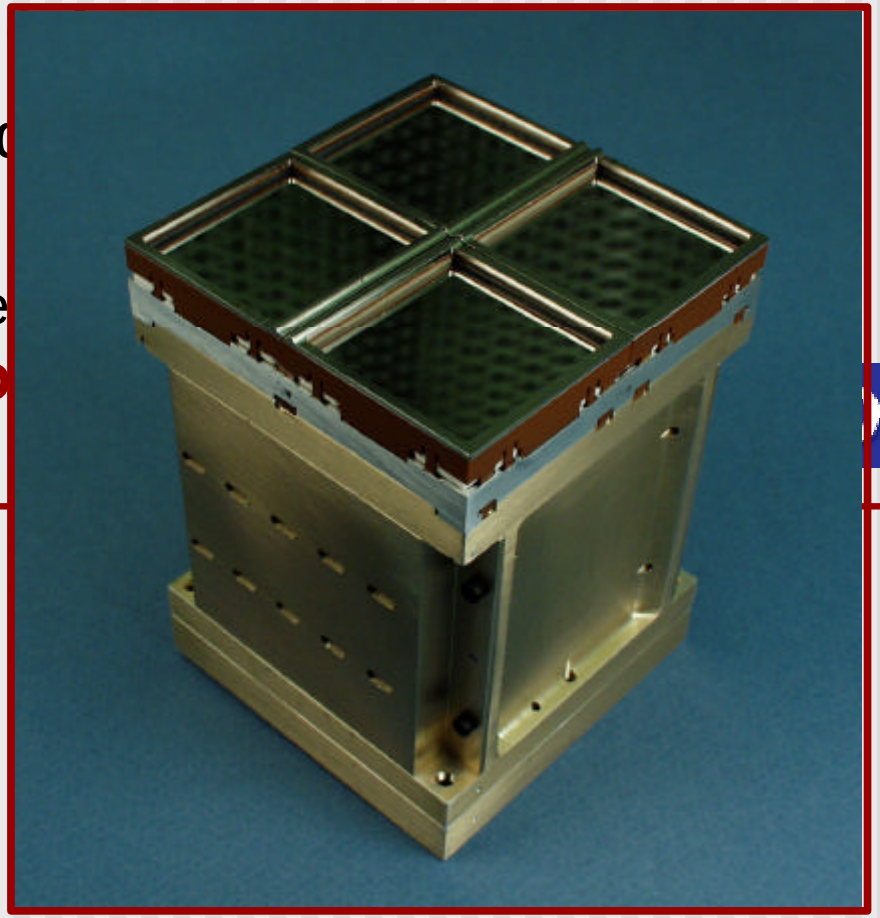
- wide field ⇒ **57.6º x 25.8º FWHM**
  39º x 6.2º uniform fully-coded FOV
  (combination of 2 CXDs offset by 29º)
- high angular resolution ⇒ **6' – 7'**
- localization: < **1'** f
- coded mask imag
- plastic scintillator
  (collaboration wi
- Pb-Sn-Cu graded
- ^{241}Am tagged cali



CZT detectors

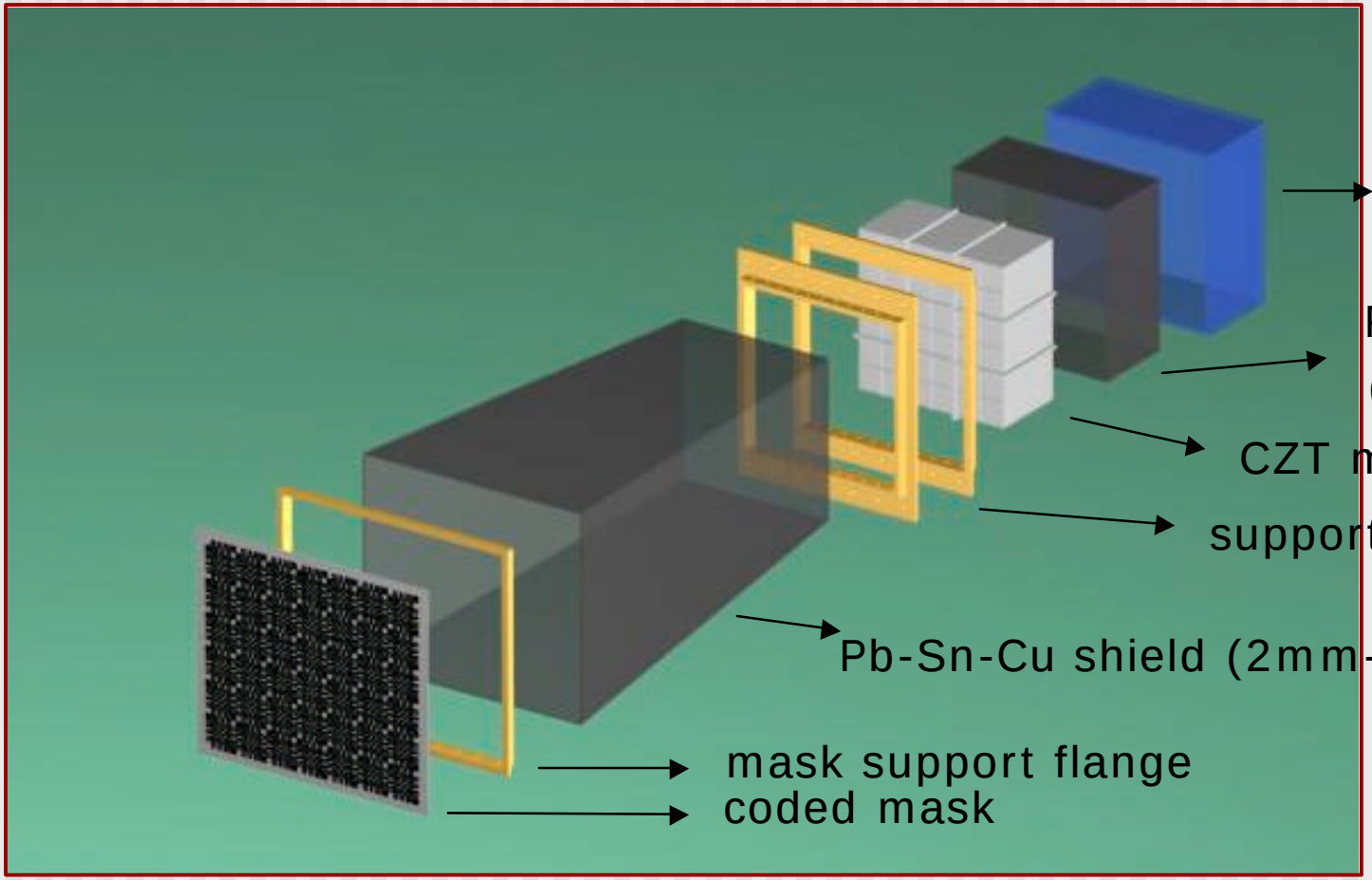
- **Energy range: 10-20**
- **Crossed-strip CZT** (Cd
  - 0.5-mm spatial resolutio
  - 3x3 modules of 2x2 dete

Provided by CASS/UCSD



7cm x 7cm x 10cm

CXD concept



drawing by L.A.Reitano

Câmera de Raios-X
Moles - CXM

- Spare flight unit of the **Wide Field Camera** on **Bepp**
- ⇒ provi
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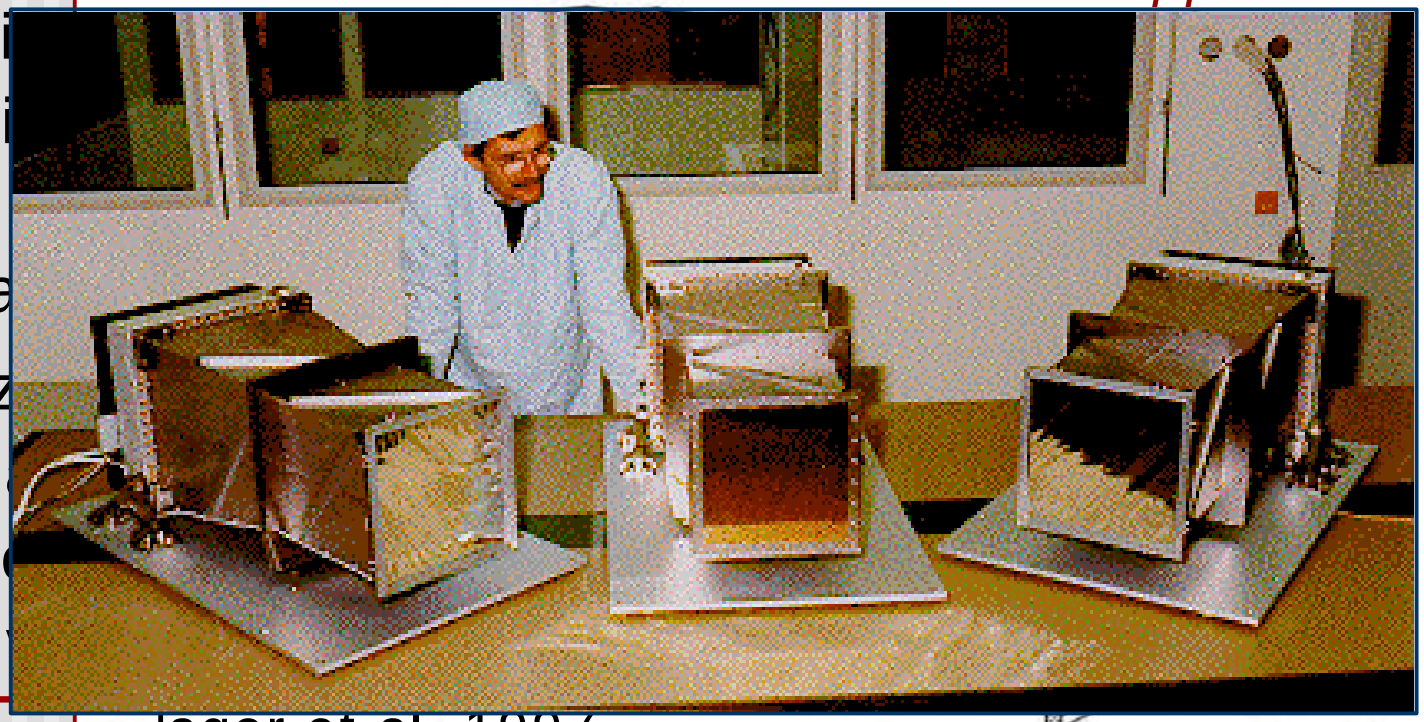
WFC/*BeppoSAX*



Jager et al. 1997

MIRAX sensitivity

- **CXDs:**
  - Background rejection: events on multiple, non-contiguous sites; low-energy deep interactions
  - Background: **~200** counts s^{-1} per imager (aperture flux dominates up to ~60 keV)
  - Sources in the central GP FOV: ~1 Crab ⇒ 120 counts s^{-1}

⇒ **< 2 x 10^{-5} photons/cm² s keV @ 100 keV (one day, 5 s)**

⇒ **2.6 mCrab/day, 10-100 keV**

(70% observing efficiency due to Earth occultation)

~40 times better than BATSE/CGRO (Earth occult. technique)

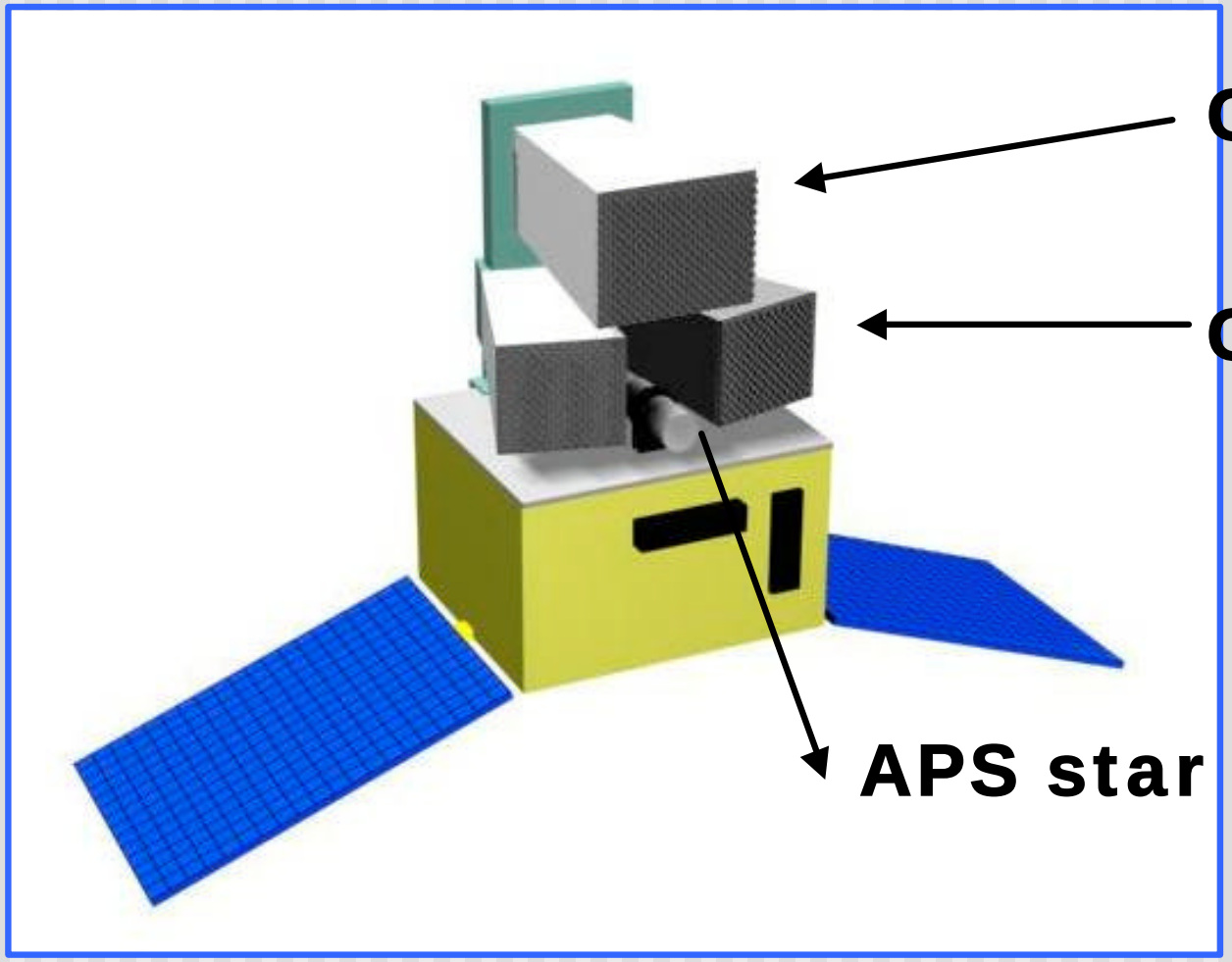
CXD one-year "survey" sensitivity (syst. limit of 0.1% of bkg):

Þ 10^{-11} ergs/cm² s (10-50 keV) (> 20 times better than HEAO-1 A4)

- **CXM: ~10** times better than ASM/*RXTE*

⇒ ~ **5 mCrab/day, 2-10 keV**

MIRAX concept
(preliminary)



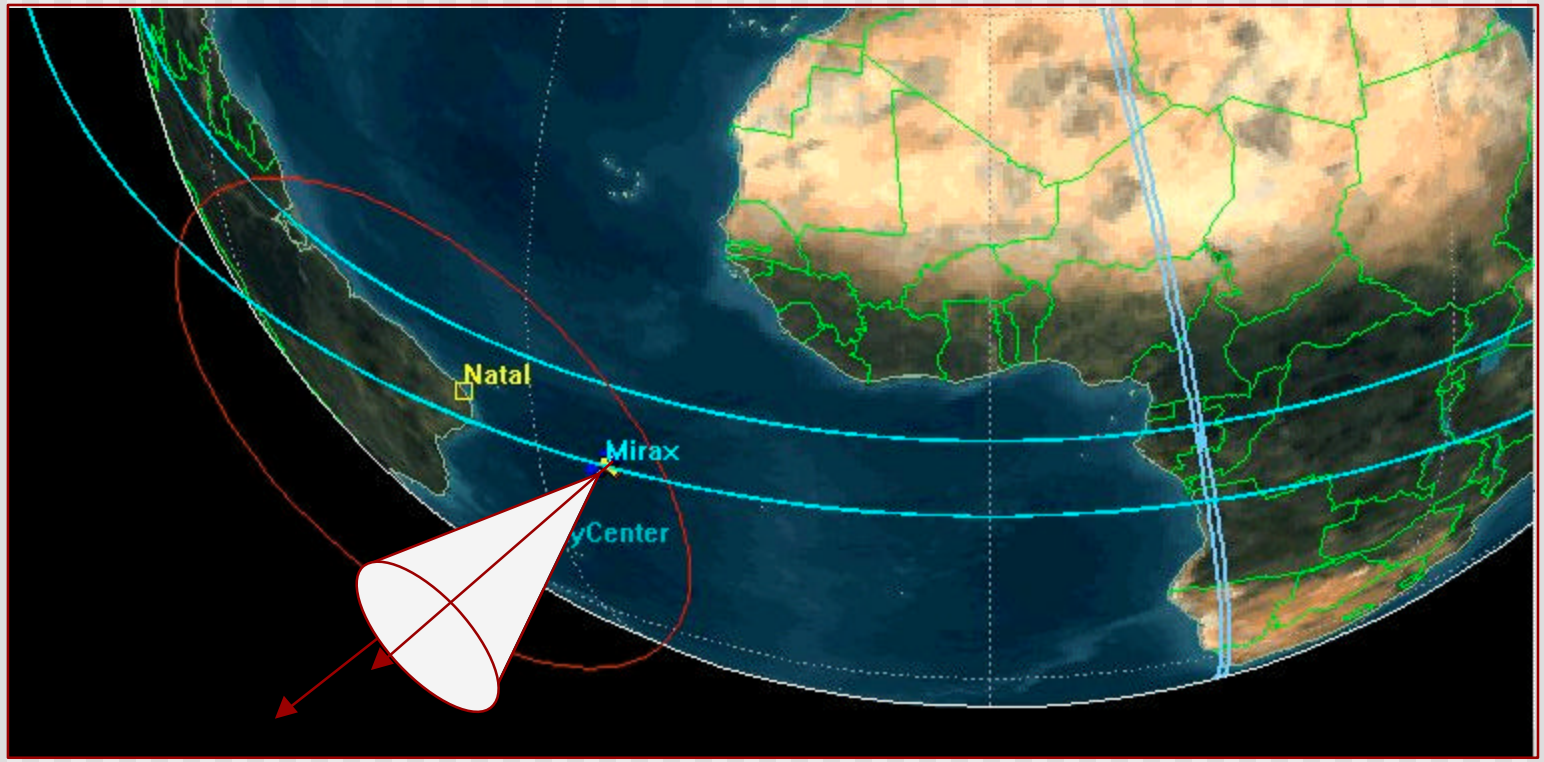
Coded aperture experiments on satellites

mission	Energy range (keV)	FOV	Angular resolution
WFC/BeppoSAX	2-28	2 x (20^o x 20^o) FWHM	5’
ASM/RXTE	2-10	“4π sr” (3 x 6^ox90^o FWHM)	12’
WXM/HETE	2-25	~1.6 sr FWZI	11’
JEM-X/INTEGRAL	5-35	4.8^o diam. FCFOV	3’
IBIS/INTEGRAL	15-10000	9^o x 9^o FCFOV	12’
BAT/SWIFT	15-150	2 sr PCFOV	17’
MIRAX	2-200	58^o x 26^o FWHM 39^o x $6^o12'$ FC	6’-7’

MIRAX satellite

- **simple and light**
  - based on an existing, tested platform (FBM)
  - payload has no moving parts
  - payload: 124.5 kg, 88-96 W, 1m diam. x 54cm
  - 2 10 A-hr 28 V batteries
- **3-axis attitude control system**
  - reaction wheels, torque rods, 2 start trackers, sun sensor, magnetometer
- **pointing requirements**
  - inertial pointing
  - 0.5º precision (goal: 0.1º º 6')
  - 0.01º(36")/hr (1/10 pixel) stability (jitter)
  - 0.01º(36") attitude knowledge (goal: 20")

Mission Geometry



mission data

- One or two ground stations
  - Brazil (Natal) and maybe in Kenya (Italian station - Malindi)
- 100% of data immediately available to the community
  - Database at mission centers and HEASARC (GSFC)
  - Specific web pages:
    - **Deep exposure webpage**
    - **Transient detection webpage**
    - **Flux history webpage**
    - **Pulsar period history webpage**
- Guest Observer program (mission center at INPE)

MIRAX
team contributions

hard X-ray cameras (CXDs)	DAS/INPE, CASS/UCSD
CZT detectors for CXDs	CASS/UCSD
soft X-ray camera (CXM)	SRON
payload structures	DAS/INPE
APS star camera	ETE/INPE
payload flight computer (CEU)	IAA Tübingen, CEA/INPE
spacecraft	ETE/INPE
assembly, integration & testing	LIT/INPE
launch	AEB
mission operations	ETE, CRC/INPE
software for data reduction and processing	IAAT, MIT
data storage and distribution	INPE, UCSD, MIT, IAAT
Guest Observer support	INPE, UCSD, MIT, IAAT

MIRAX
current status

- 2003 NASA proposal for CZT and HXI development at UCSD (SMEX - Mission of Opportunity) was not selected due to launch uncertainty, but received category 1 rating
- AEB launcher program not yet clearly defined – piggy-back launch on an Indian launcher being considered
- Possibility to fly a CXD prototype at FBM satellite
- Satellite development depends critically on MCT - AEB and INPE - budget for satellite programs
  - FAPESP funding being considered
  - “Fundo Setorial Espacial” is an option
- Partnership with IPEN being established for plastic scintillator active shield development
- Coded mask fabrication work being done at LAS/INPE