

# ASI Science Programme: Current and Future Space Missions

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*Head of Exploration and Observation of the Universe Department*

**Vulcano Workshop 2016 – Frontier Objects in Astrophysics and Particle Physics**



Activities of ASI's Department for the Exploration and Observation of the Universe (EOS) are organized into three main lines:

- **Exploration of the Solar System** (heliophysics, planetology of the Solar System and exo-planets)
- **Cosmology and Fundamental Physics** (general relativity, theory of gravitation, universe on a large scale and early universe)
- **High Energy Astrophysics** (astrophysics and astroparticles)

Scientific activities are carried out in collaboration with the National Institute for Astrophysics (INAF), the National Institute for Nuclear Physics (INFN), the National Research Council (CNR) and a number of Universities.

ASI has launched national scientific satellites and participated in major missions by ESA, NASA and other agencies (JAXA, Roscosmos, etc.)

ASI involvement in space programs can be grouped as follows:

- **ESA Scientific Programme:**

- Cosmic Vision 2015-2025 (mandatory Science Programme):
- Not mandatory programme: ExoMars Programme:
  - ExoMars 2016 (launch: 16 March 2016)
  - ExoMars 2018 (launch: 2020)

- **Programs in cooperation with other agencies (NASA, JAXA, Roscosmos, etc ...)**

- **Missions In Operation (Planetary, Astrophysics, Astroparticles)**

- **National scientific satellites in orbit: AGILE and LARES**

## COSMIC VISION 2015-2025

1. Large missions, L
2. Medium missions, M
3. Small missions, S
4. Opportunity missions, O (previously known as cooperative)
5. Missions in operation
6. Basic activities
  - a. Preparation for the future
  - b. Technology development

- Horizon 2000+ Cornerstone: **GAIA**, advanced astrometry, adopted: 2000; launched Dec. 2013.
- Cosmic Vision: **BEPI-COLOMBO**, mission to Mercury, approved in 2007; target launch: Mar. 2017.
- M1: **SOLAR ORBITER**, adopted: Oct. 2011; launch Oct. 2018.
- M2: **EUCLID**, adopted: June 2012; target launch: Dec. 2020.
- M3: **PLATO** extrasolar planet search, selected Feb. 2014; target launch: 2024.
- M4: **ARIEL, THOR, XIPE**, selection June of 2017
- S1: **CHEOPS** Exoplanets, adopted: Jun. 2014; launch Jul. 2018
- M5: call issued April 29, 2016

- L1: **JUICE**, JUpiter Icy moon Explorer, selected: May 2012, target launch: 2022.
- L2: **ATHENA**, Advanced Telescope for High-Energy Astrophysics, selected: June 2014, target launch: 2028.
- L3: **gravitational wave observatory**



# Some major steps in ASI Science Programme



1997 Cassini-Huygens



1992 Lageos2



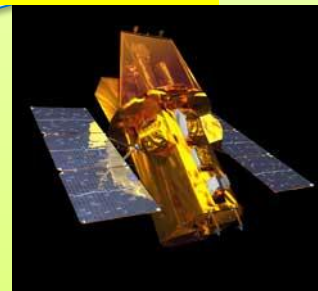
2003 Mars Express



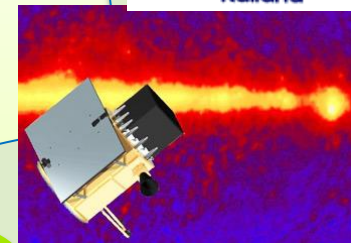
2004 ROSETTA



2005 MRO



2004 SWIFT



2007 Agile



2007 DAWN

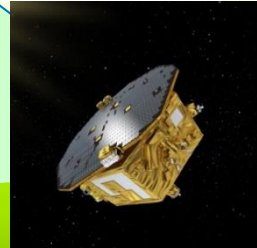
# Some major steps in ASI Science Programme



2011  
Juno  
AMS



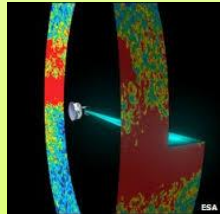
2013 GAIA



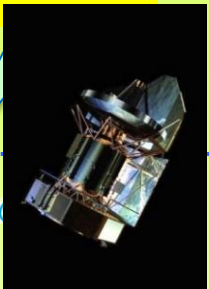
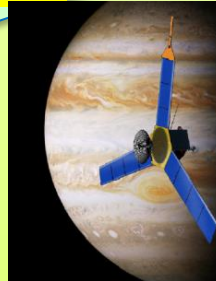
2015 Lisa-  
PF

2012  
Lares on Vega  
NUStar

2008  
Fermi



Herschel  
Planck





# Remote sensing Payloads

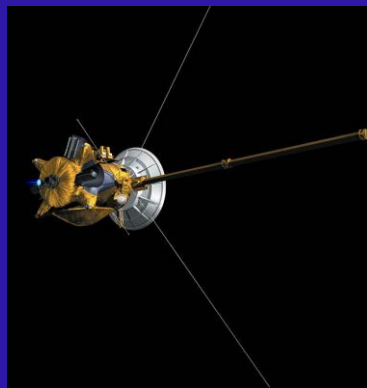


Agenzia Spaziale Italiana



## Sounding radar

Mars Express  
MRO



## SAR Radar

Cassini

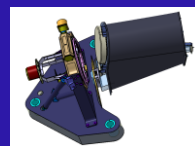


## Radio science

Cassini  
Juno  
Bepicolombo

## Cameras

Exomars  
Rosetta



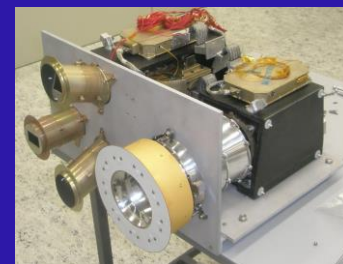
## Imaging Spectrometer

Cassini  
Dawn  
Rosetta  
Juno  
Venus Express



## Optical suite

BepiColombo



Radio

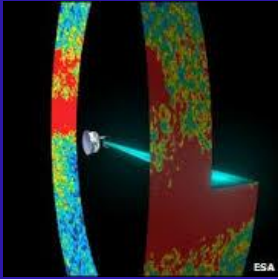
Microwaves

Radar

Infrared  
(IR)



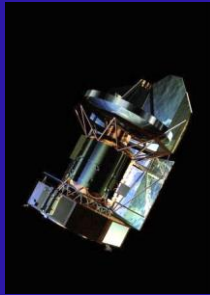
# Astrophysics and Cosmology missions



Planck



Herschel



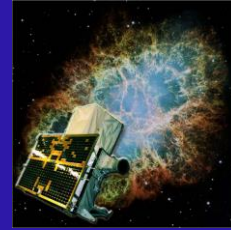
XMM  
Integral  
Fermi



Nu-Star



AGILE



Pamela



AMS-2

Microwaves

Infrared  
(IR)



Ultraviolet  
(UV)

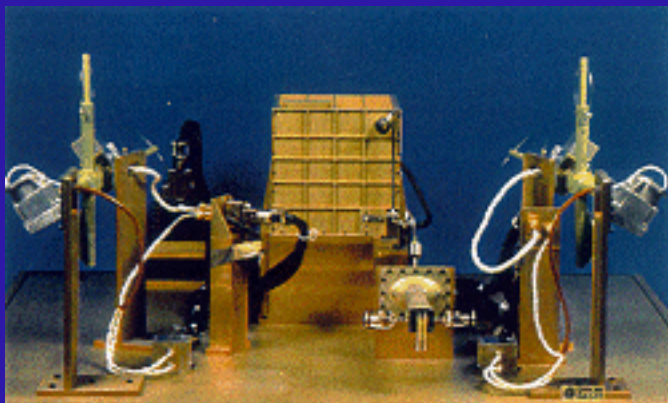
X-rays

Gamma  
rays

Cosmic  
rays



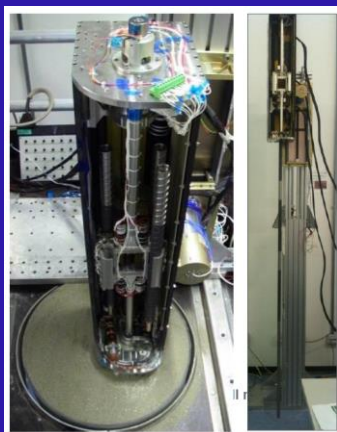
# In situ instruments



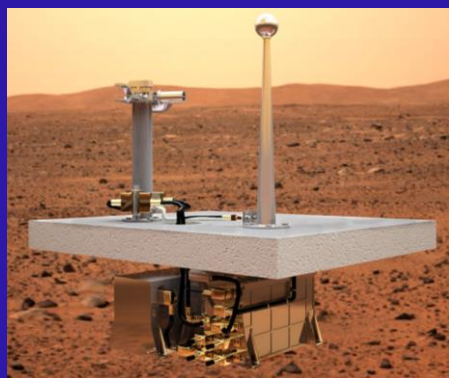
H-ASI



Philae



MA-MISS



DREAMS



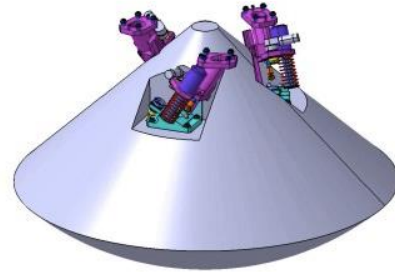
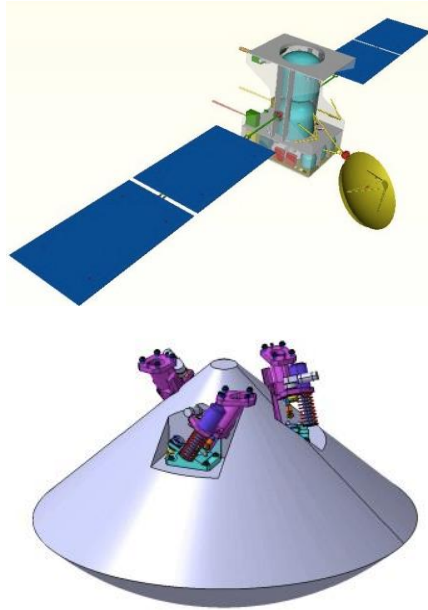
SD2





## 2016 Mission

### Trace Gas Orbiter (TGO)



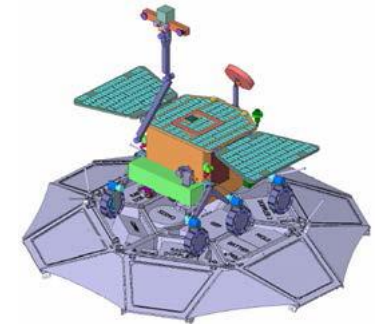
Proton

EDL Demonstrator Module



## 2020 Mission

### Carrier & Descent Module

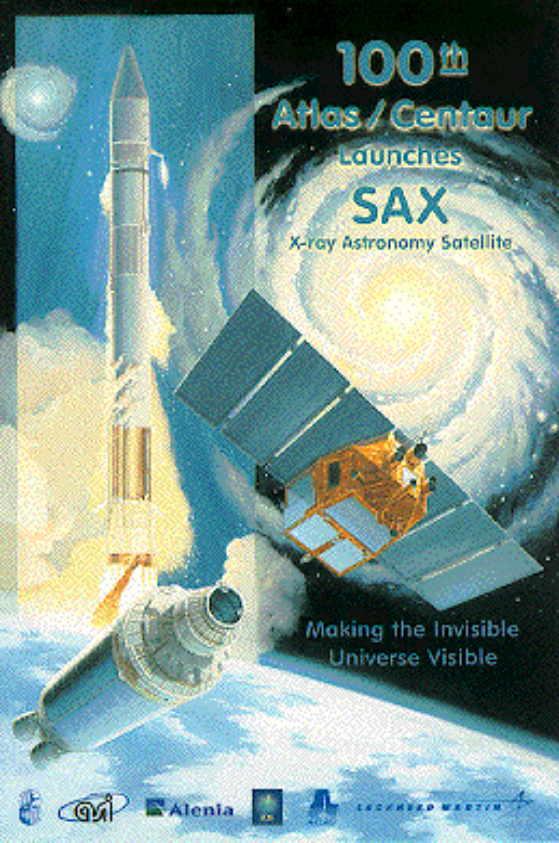


Proton

Rover + Landed Platform

**ExoMars Programme: *prima missione lanciata il 14 marzo 2016 arriverà a Marte il 19 ottobre 2016. La seconda missione sarà lanciata nel 2020.***

- La missione 2016 consiste del Trace Gas Orbiter (TGO) e del EDL Demonstrator Module (EDM)
- La missione 2020 consiste di un Rover accomodato dentro il Descent Module (DM) portato su Marte da un Carrier Module (CM)



## ASI BeppoSAX satellite

Launch date: 04:31, April 30, 1996

Rocket: Atlas-Centaur AC-78

Launch site: Cape Canaveral

Deactivated: 13:38, April 30, 2002

Decay date: 22:06, April 29, 2003



**GRB X-ray afterglow discovery**

**20 YEARS THIS YEAR!!**

## BeppoSAX Instruments

**LECS** Low Energy Concentrator Spectrometer (0.1-10 keV – 20 arcmin)

**MECS** Medium Energy Concentrator Spectrometer (1.3-10 keV – 30 arcmin)

**HPGSPC** High Pressure Gas Scintillation Proportional Counter (7-60 keV – 1 degree)

**PDS** Phoswich Detector System (15-300 keV – 1 degree)

**PDS SHIELDING** (100-600 keV – all sky)

**WFC 2** Wide Field Camera (2-30 keV - 40x40 degrees each - 90 degrees from all **NFI**)



**SWIFT - NuSTAR**

## SWIFT

Launched on November 20th 2004, is still operative and in very good health.

Bruno Rossi Prize, 2007

**ASI Science Data Center**, for both satellites, is responsible for the software which contributes to the decoding the data coming from the X-ray Telescopes and is one of the official mirrors for the data archiving and distribution.

The **heritage of BeppoSAX** has allowed ASI and ASI Science Data Center to be successfully involved in:

- the NASA's **Swift** satellite dedicated to the study of the **gamma-ray burst (GRB)** and more broadly X-ray galactic and extragalactic sources
- the NASA's **NuSTAR** satellite, dedicated to focus light in the **high energy X-ray (6 - 79 keV)** region of the electromagnetic spectrum.



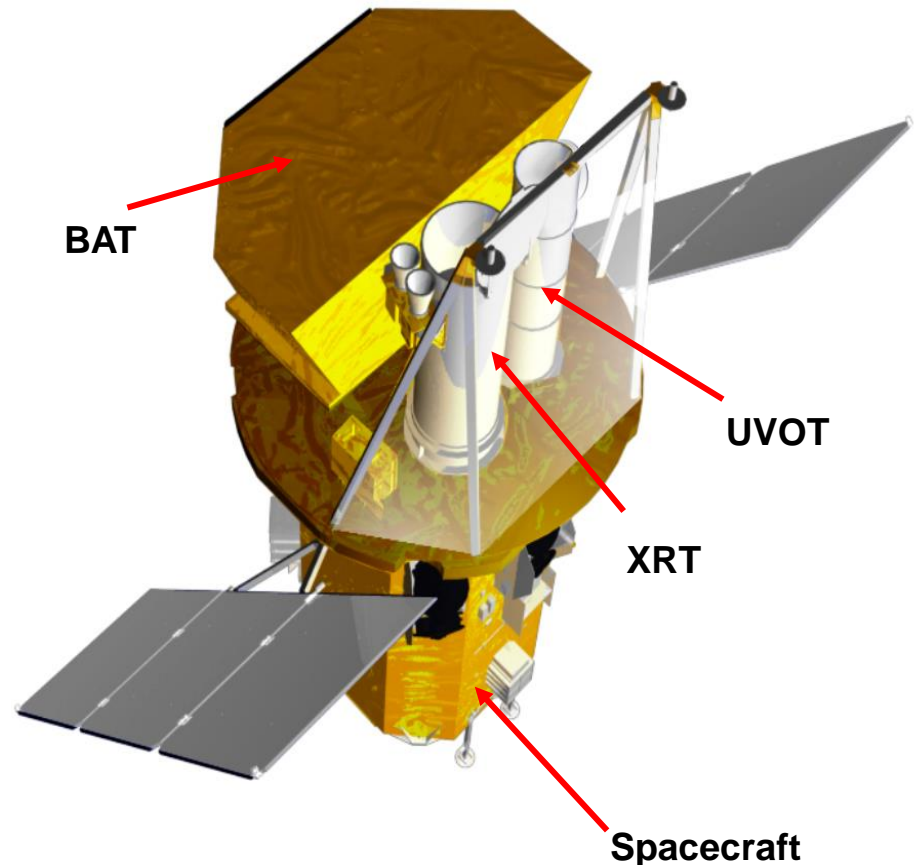
# Swift satellite

## Instruments

- Burst Alert Telescope (BAT)
  - New CdZnTe detectors
  - Detect >100 GRBs per year depending on logN-logS
  - Most sensitive gamma-ray imager ever
- X-Ray Telescope (XRT)
  - Arcsecond GRB positions
  - CCD spectroscopy
  - Photometry in the range  $10^{-7}$ - $10^{-15}$  erg cm<sup>-2</sup> s<sup>-1</sup>
- (UVOT) UV/Optical Telescope
  - Sub-arcsec imaging
  - Grism spectroscopy
  - 24<sup>th</sup> mag sensitivity (1000 sec)
  - Finding chart for other observers

## Spacecraft

- Autonomous re-pointing, 20 - 100 sec
- Onboard and ground triggers





# Swift: Italian Contribution

- Mirror Module of the XRT Telescope
  - Malindi Ground Station
  - XRT data Analysis software & mirror archive of the Swift data

**To date, Swift has detected more than 900 GRBs.**



Responsibility for the XRT calibration

XBS & BA responsibility 2 weeks every  
5 weeks (24 hours / 7 days)

One person at the MOC (PSU-USA)

From ASDC web site, it is possible to perform the on-line analysis of Swift and NuSTAR data (as for AGILE, Fermi, Herschel etc) to get also data ready to be published



### Standard Products

Show energy spectrum

- 0.3-10 keV lightcurve
- 0.3-2. keV lightcurve
- 2.0-10 keV lightcurve

### Download Data

- Spectrum (pha file)
- Anc. Resp. File (arf)
- Red. Matrix File (rmf)
- Exposure Map File
- Lightcurve (FITS file)

### Spectral analysis (with XSPEC)

NH (e.g. 3.e20) : default

default: NH=Galactic value  
(from Dickey & Lockman 1990)

Freeze NH? ☐ yes ☒ no

Xspec Model : power

photon index : 1

norm : 1

Energy range for spectral analysis

Emin 0.3 Emax 10.0

Energy range for Xspec flux estimate

Emin 2.0 Emax 10.0

Number of SED bins 8

Submit

### Timing analysis (with LCURVE)

Bin size (> 200) seconds 200

Plot type ☒ Linear ☐ Log

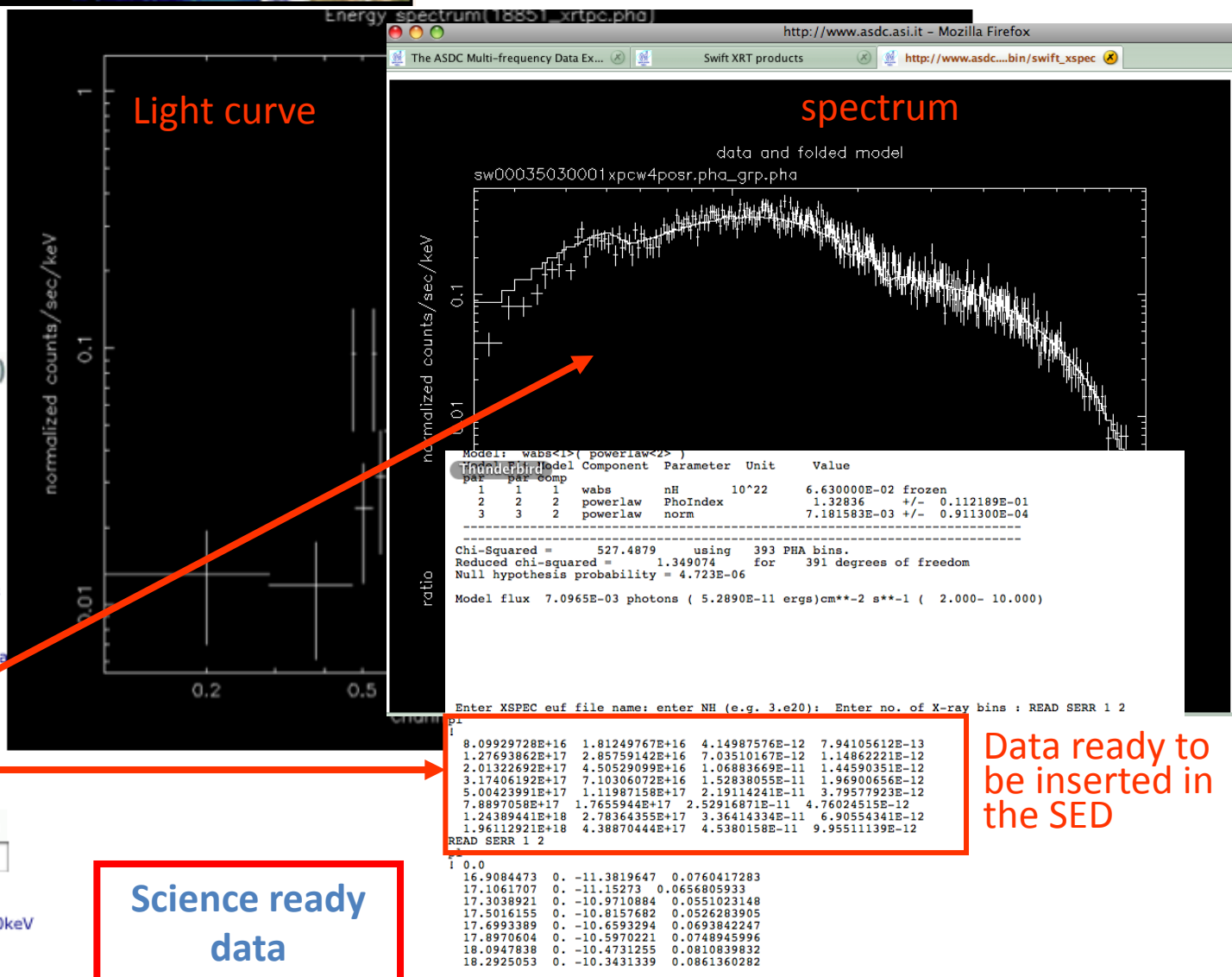
Energy range

☒ Full band ☐ 0.3-2.0keV ☐ 2-10keV

Hardness ratio? ☐ yes ☒ no

nframe 4

Submit





**AGILE**

AGILE (Astrorivelatore Gamma a Immagini Leggero)  
The fully Italian astrophysical mission after BeppoSAX,  
dedicated to the gamma-ray sky study

Launched on April 27th 2007  
Still operative and in very good health



**Bruno Rossi Prize, 2012**



AGILE is the **first of a new generation** of high-energy space missions based on solid-state silicon technology, **combining for the first time two sophisticated co-axial instruments: a gamma-ray detector**, sensitive to photons with energy in the range 30 MeV - 50 GeV, and a **hard X-ray detector**, sensitive in the range 18 - 60 keV. The instrument is completed by a **calorimeter** (energy range 250 keV - 100 MeV) and by an **anti-coincidence system**. Its optimum angular resolution, 0.1 - 0.2 degrees in gamma-rays and 1-2 arcminutes in X-rays, the very large field of view as well as its small dead time (100 microsec), makes AGILE a very good instrument to study persistent and transient gamma-ray sources.



INFN- TS

Si-Tracker 3/3



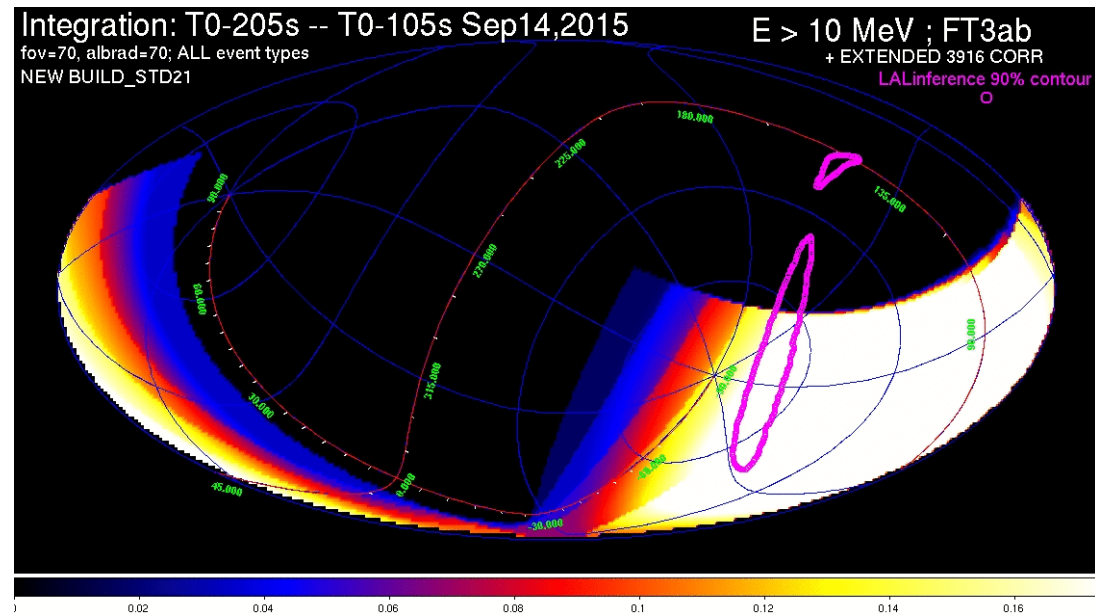
Figura 14 – Il Si-Tracker di AGILE: modello di volo completo.



The **AGILE Data Center**, located at the ASI Science Data Center, is in charge of all the scientific oriented activities related to the analysis and archiving of AGILE data and it is responsible to manage the Announcement of Opportunities of the mission Guest Observer Program.



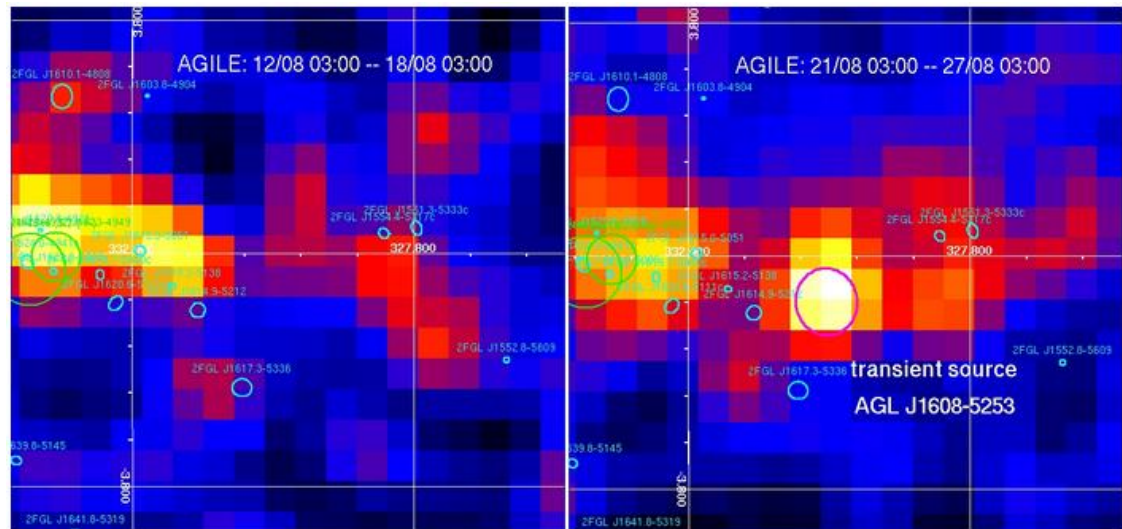
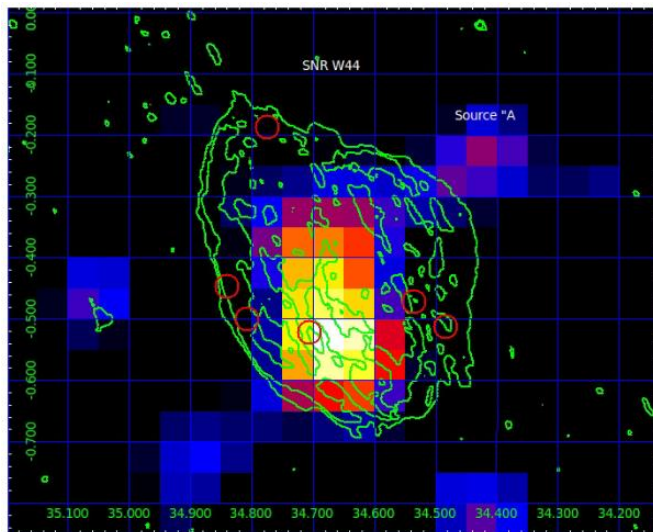
## AGILE contribution to gravitational wave's precursors



## Transient search capability

### Extended source study

SNR 44, Cardillo et al 2014



AGILE 6-day intensity map (E > 100 MeV) of the transient source region during the flare on August 21-27, 2014, and before it on August 12-18 2014 ([ATel #6427](#))

INTEGRAL - Fermi



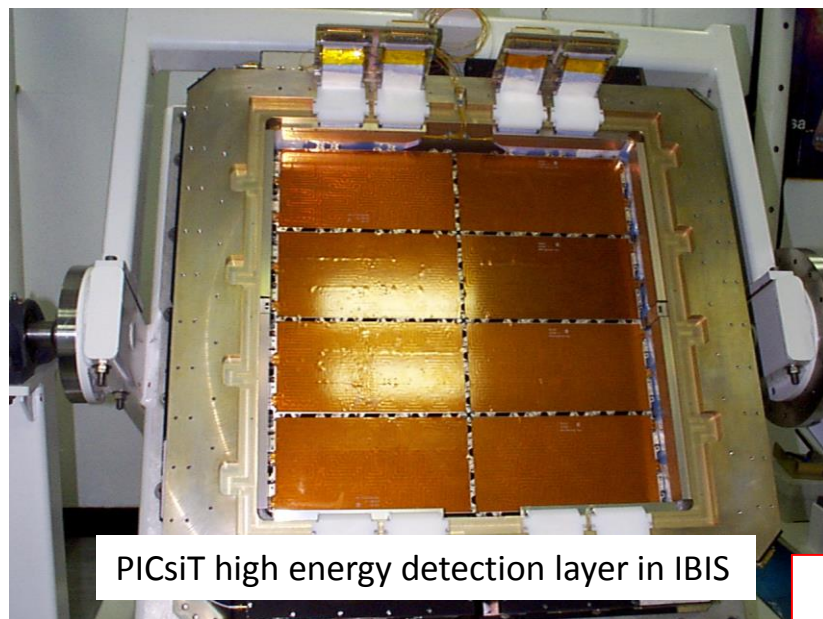


The heritage in building BeppoSAX instrumentation allowed Italy and ASI to participate to ESA' mission **INTEGRAL** (INTErnational Gamma-Ray Astrophysics Laboratory).

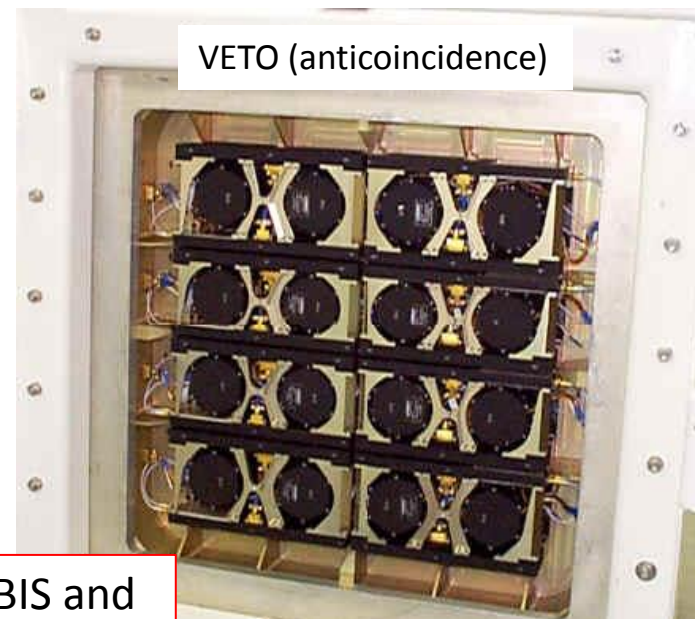
Launched on October 17th 2002, still operative and in good health

Italy contributed mainly with the telescope IBIS and other items.

The INTEGRAL satellite continuously observes the sky in the **X-ray and gamma-ray band**, reaching the inner parts of our own Galaxy, the Milky Way, and also much farther away sources, like gamma-ray bursts.



PICsiT high energy detection layer in IBIS

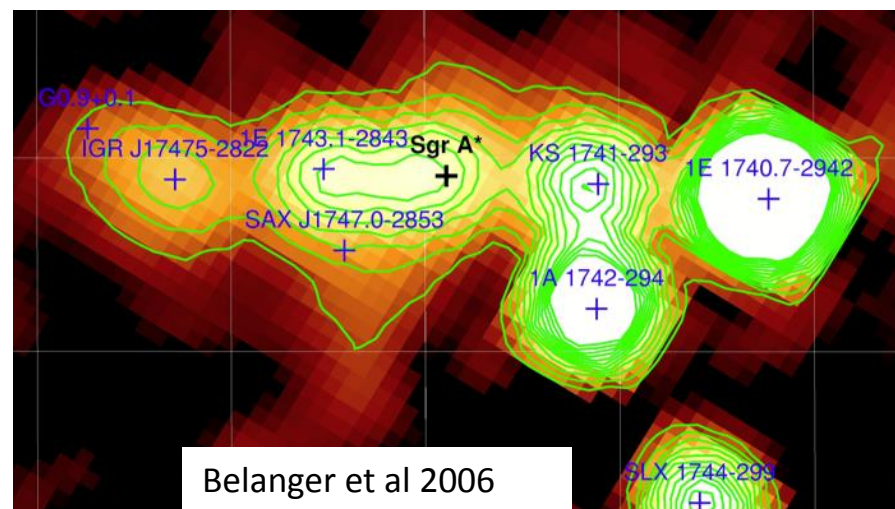
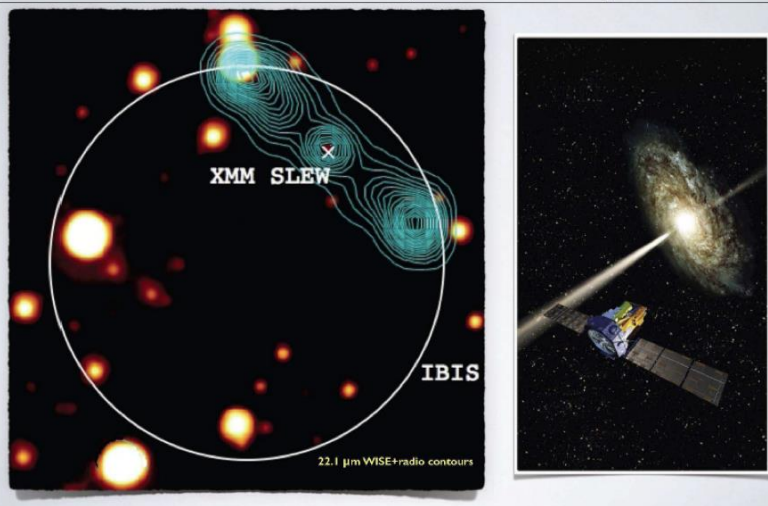


VETO (anticoincidence)

## Contribution to IBIS and scientific results

IGR J17488-2338

A Powerful Giant Radio Galaxy Discovered by INTEGRAL



Belanger et al 2006

The galactic centre emission is dominated by several X-ray binaries including black-holes or neutron stars and two apparently diffuse sources. One of them could be related to particles accelerated in Sgr A\*, the massive black-hole at the centre of our Galaxy. The other reflects radiation emitted by Sgr A\* about 300 years ago.



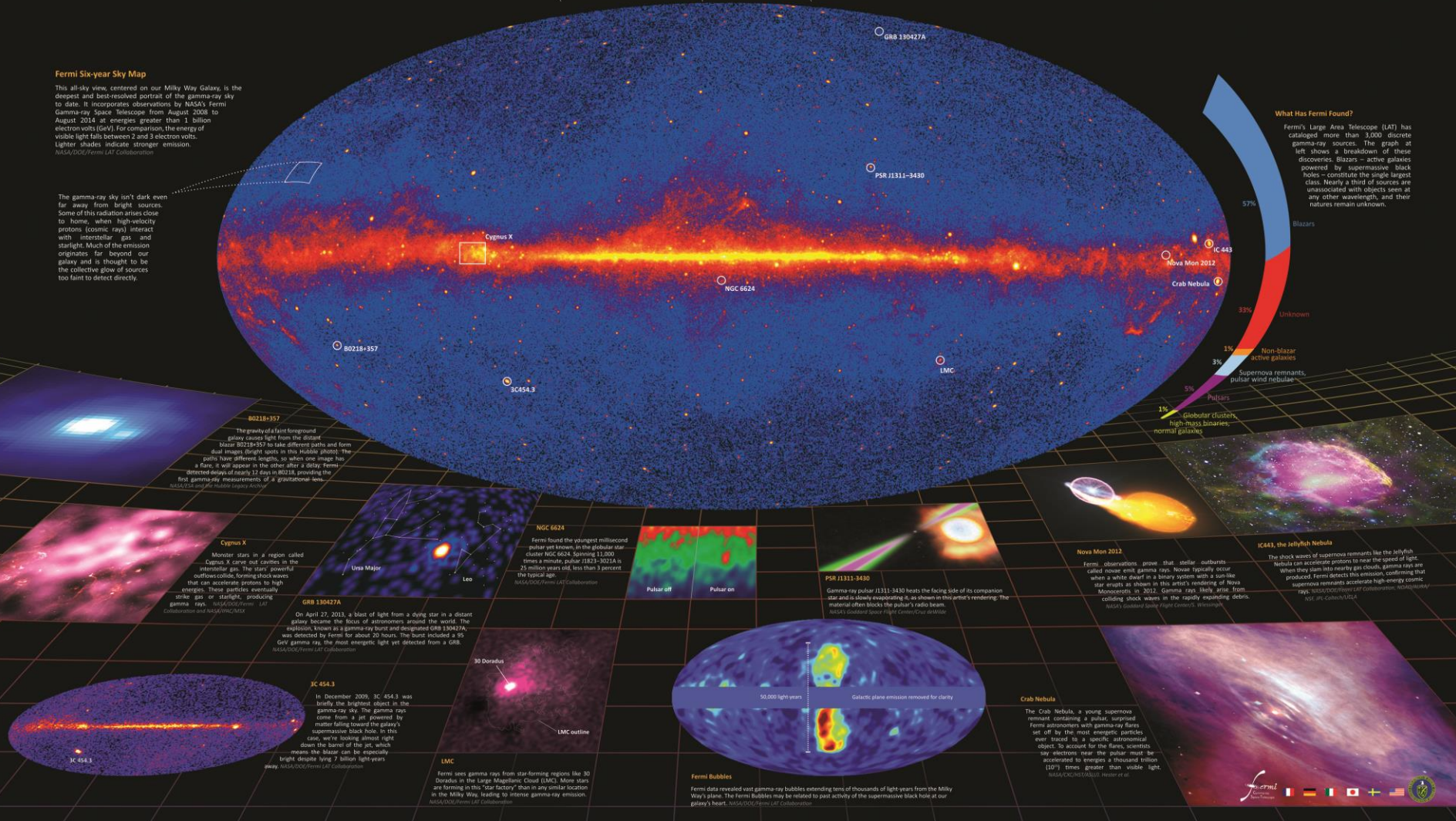
# FERMI'S GAMMA-RAY COSMOS

## Fermi Six-year Sky Map

This all-sky view, centered on our Milky Way Galaxy, is the deepest and best-resolved portrait of the gamma-ray sky to date. It incorporates observations by NASA's Fermi Gamma-ray Space Telescope from August 2008 to August 2014 at energies greater than 1 billion electronvolts (GeV). For comparison, the energy of visible light falls between 2 and 3 electron volts. Lighter shades indicate stronger emission.

NASA/DOE/Fermi LAT Collaboration

The gamma-ray sky isn't dark even far away from bright sources. Some of this radiation arises close to home, when high-velocity protons (cosmic rays) interact with interstellar gas and starlight. Much of the emission originates far beyond our galaxy and is thought to be the collective glow of sources too faint to detect directly.



NASA's mission Fermi Gamma-ray Space Telescope, launched on June 11th 2008 still operative and in good health

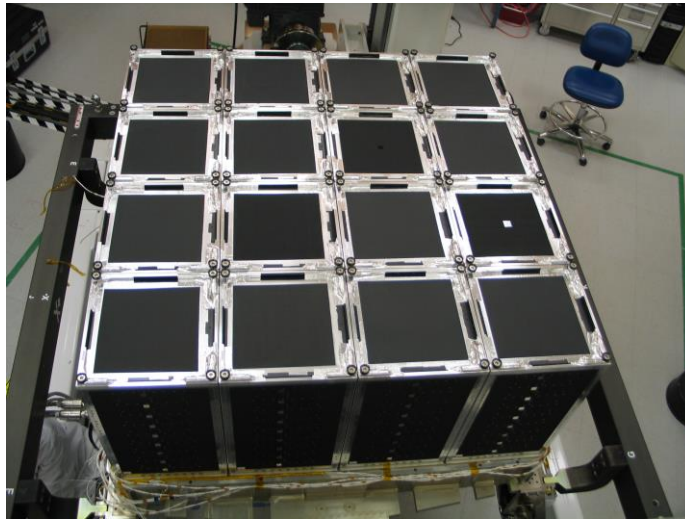
**Bruno Rossi Prize, 2011**



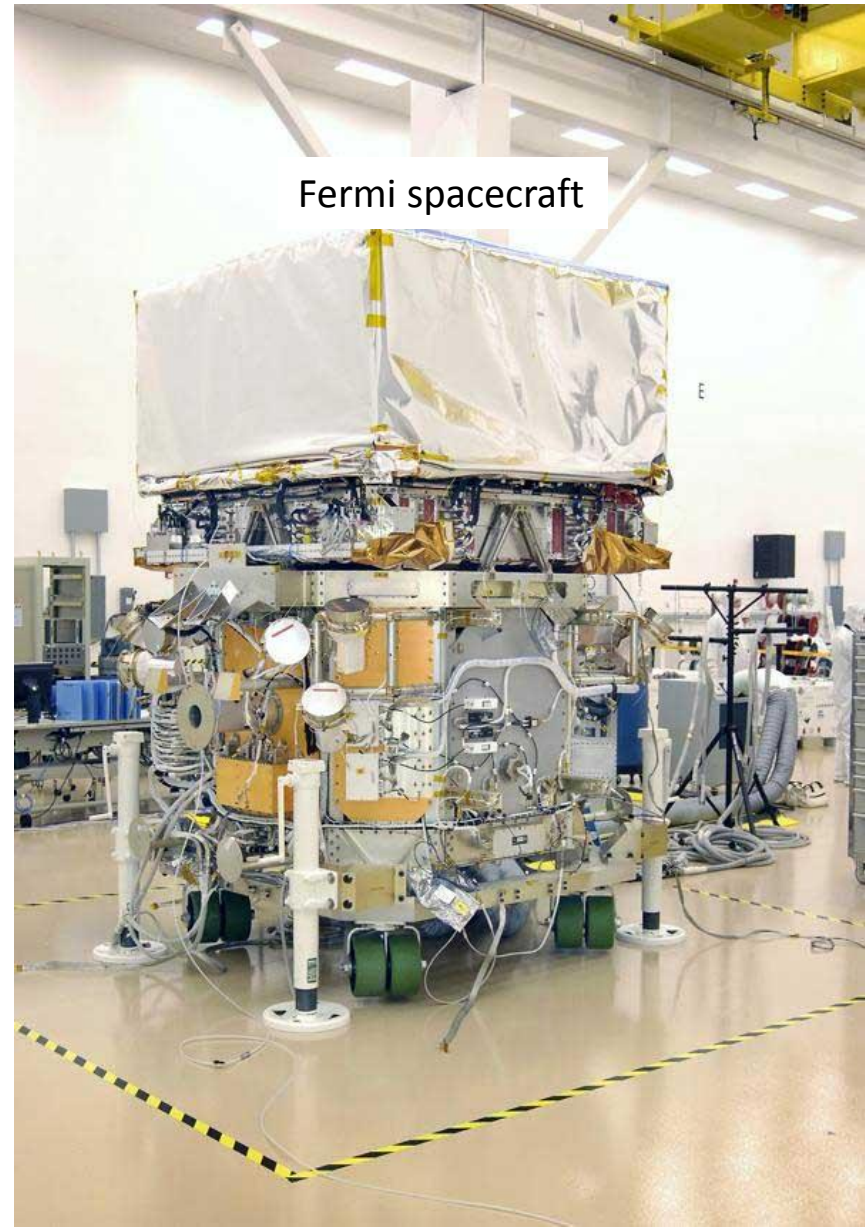
# Italy's contributions to the construction phase of Fermi concern mainly the silicon tracker of the Large Area Telescope (under responsibility of INFN)



Testing a silicon tower at Bari's TV facility

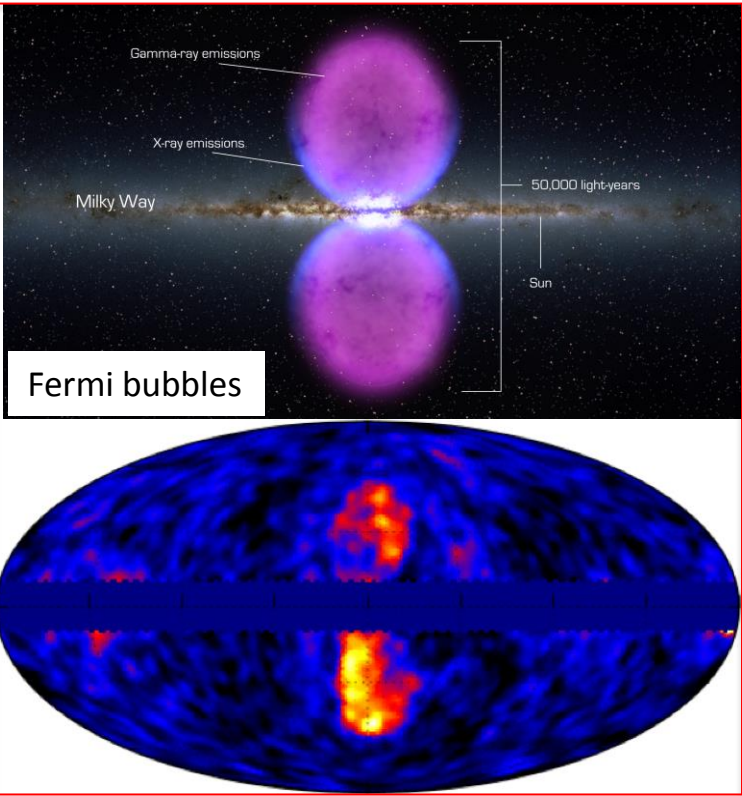
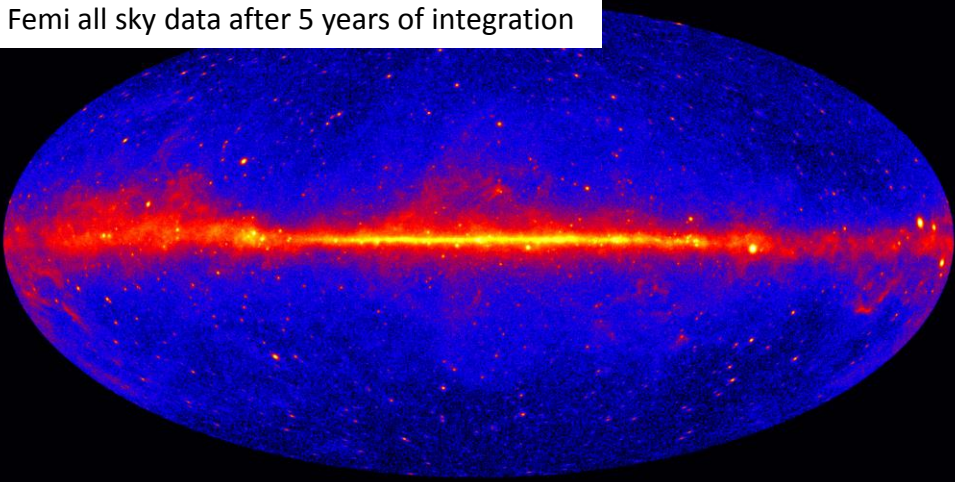


The LAT 16 silicon towers assembled



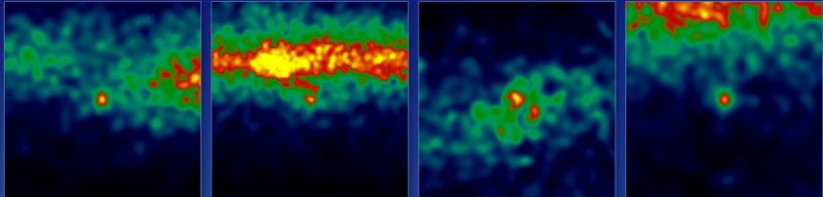
Fermi spacecraft

Fermi all sky data after 5 years of integration



Fermi bubbles

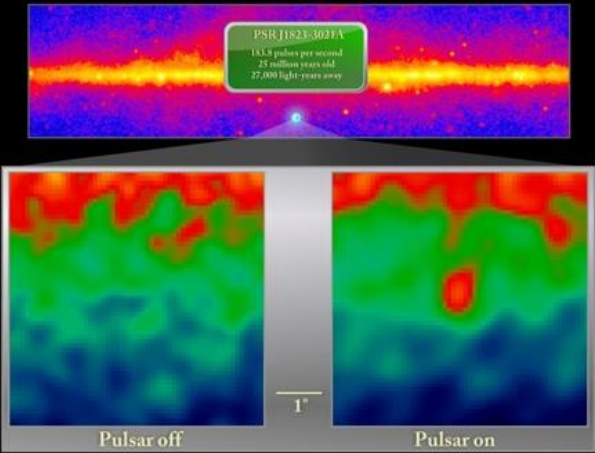
Fermi's Gamma-ray Novae



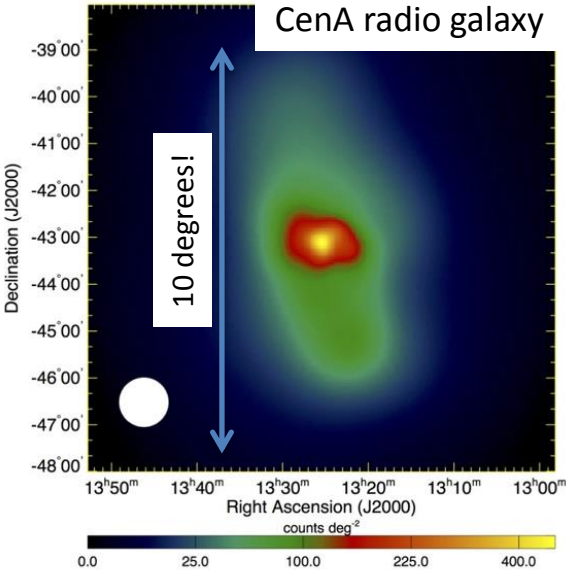
Nova Cygni 2010 (V407 Cyg) Nova Scorpii 2012 (V1324 Sco) Nova Monocerotis 2012 (V959 Mon) Nova Delphini 2013 (V339 Del)

Novae

The Youngest Millisecond Pulsar



CenA radio galaxy





PAMELA

# Payload for Antimatter Matter Exploration and Light Nuclei Astrophysics



Launched on June 15th 2006, still operative.

**10 YEARS THIS YEAR!!**

Italian contribution

- Science
- Mission Control
- Data taking from RESURS DK satellite
- Data analysis
- Public Outreach

Search for dark matter annihilation, antihelium (primordial antimatter), new Matter in the Universe (Strangelets?)

Study of cosmic-ray propagation, solar physics and solar modulation, terrestrial magnetosphere, high energy electron spectrum (local sources?)

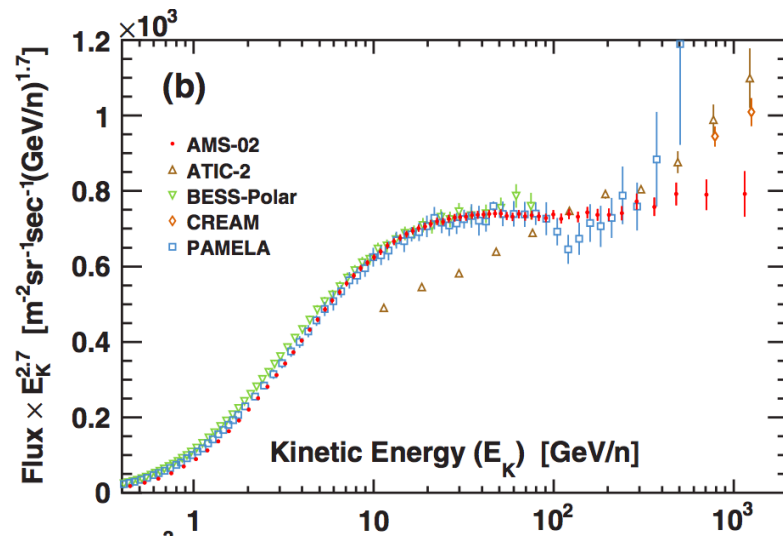
AMS



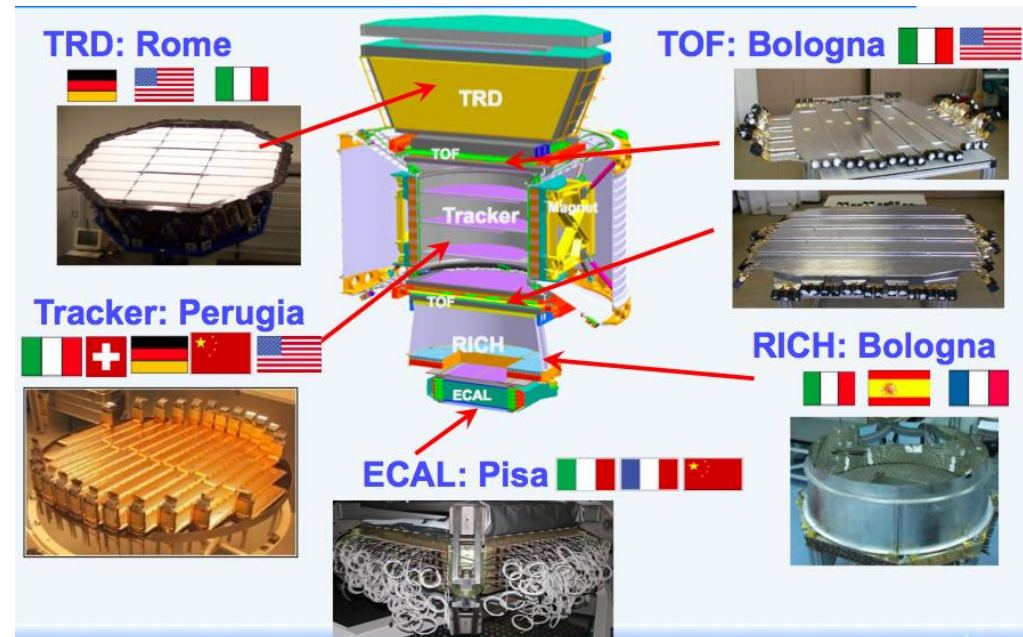
Installed on ISS on May 19th 2011.

Italy contributes currently to the data taking, analysis, on-orbit detector calibration, P/L monitoring.

## Italian contribution to hardware



The AMS helium flux, Aguilar, M. et al PRL 2015





CALET



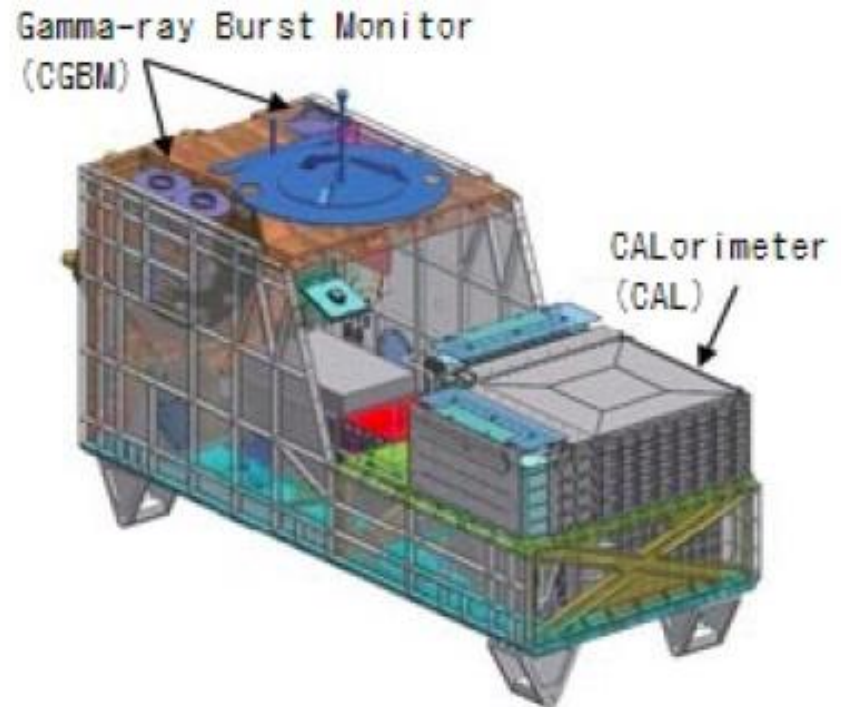
Installed on ISS in August 24th 2015.

**Italian contribution:**

- Science
- High Voltage Power Supply for CAL
- High Voltage Power Supply for CGBM

**CALET Science goals:**

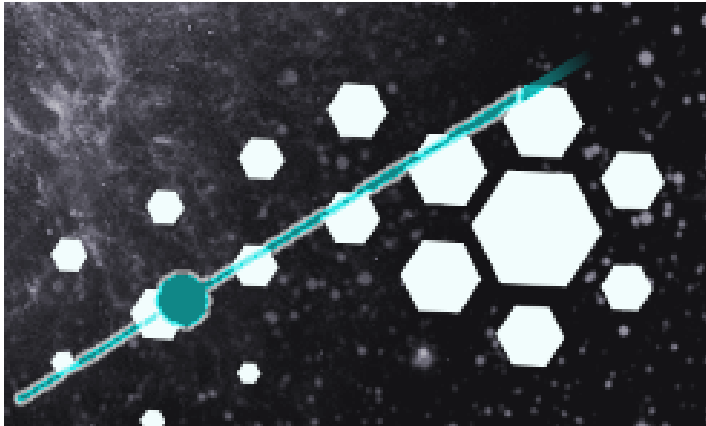
- Electron spectrum from 1 GeV to 20 TeV.
- Charged cosmic rays
- Dark Matter searches and gamma-ray astrophysics



CALorimetric Electron Telescope (CALET)

# Future missions

**Athena:** an X-ray observatory to study the Hot and Energetic Universe. L2 ESA mission, launch in 2028. Italian contribution: science, ground segment, anticoincidence system based on **microcalorimeters**. At the moment, ASI is funding the technological R&D Phase.



**XTP X-ray Timing and Polarization mission** (Chinese Academy of Sciences (CAS), launch in 2020): key science objectives in the areas of dense matter and strong field gravity to be attained using supermassive and stellar mass black holes (BH) and neutron stars (NS). Italian contribution: science, **SDD (Silicon Drift Detectors)**, **GPD polarimeter**.

**XIPE X-ray Imaging Polarimetry Explorer** (candidate M4 ESA mission, launch in 2026) and **IXPE** (candidate next NASA Small Explorer Mission, launch in 2020). Time-, spectrally-, spatially-resolved X-ray polarimetry. Italian contribution: science, ground segment, the **polarimeter (GPD-Gas Pixel Detector)**.

