INAF
ISTITUTO NAZIONALE
DI ASTROFISICA
NATIONAL INSTITUTE
FOR ASTROPHYSICS

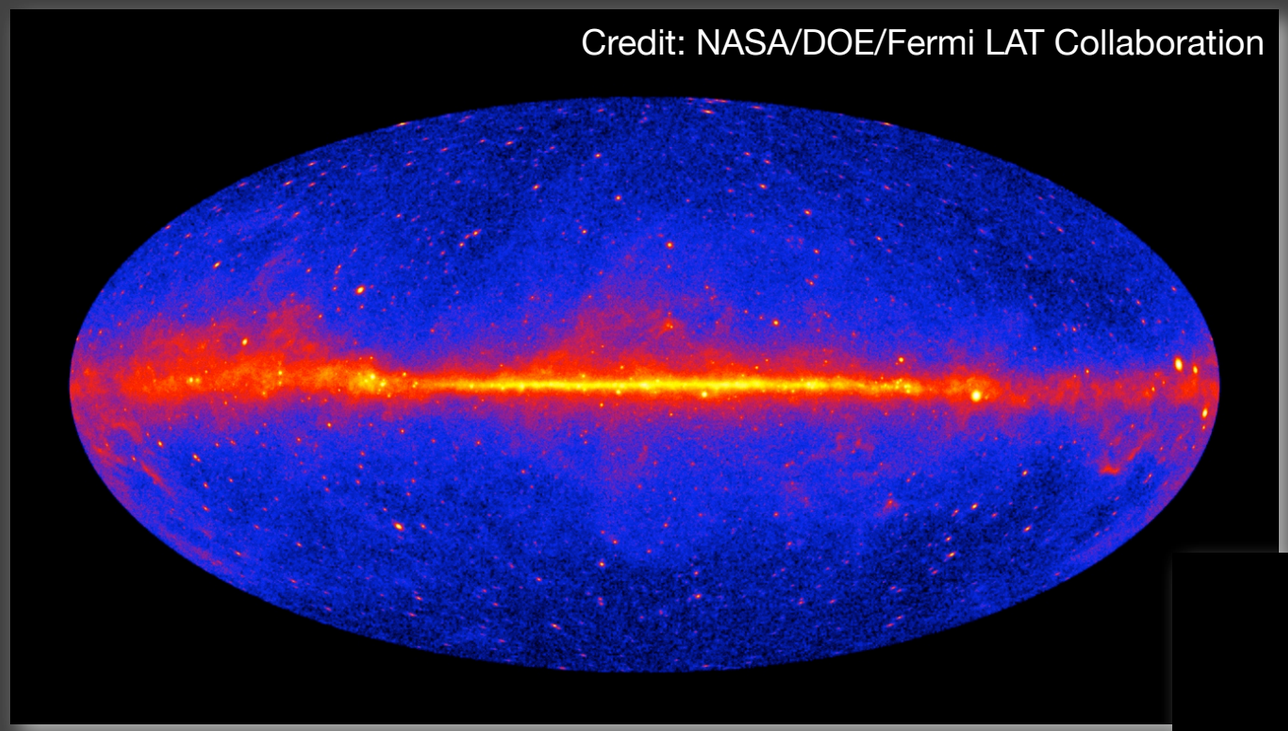
IASFPa

Astronomia gamma da terra e dallo spazio

Stefano Vercellone (INAF/IASF Palermo)

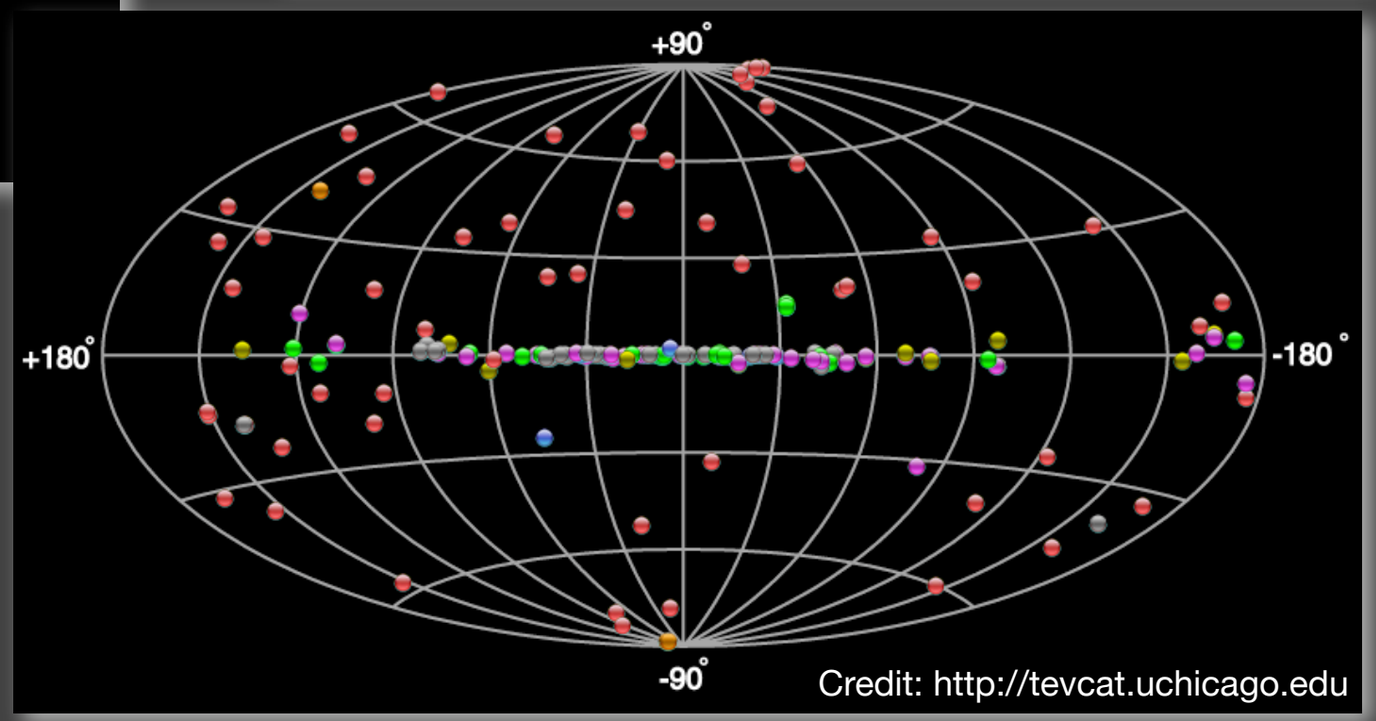
Introduction

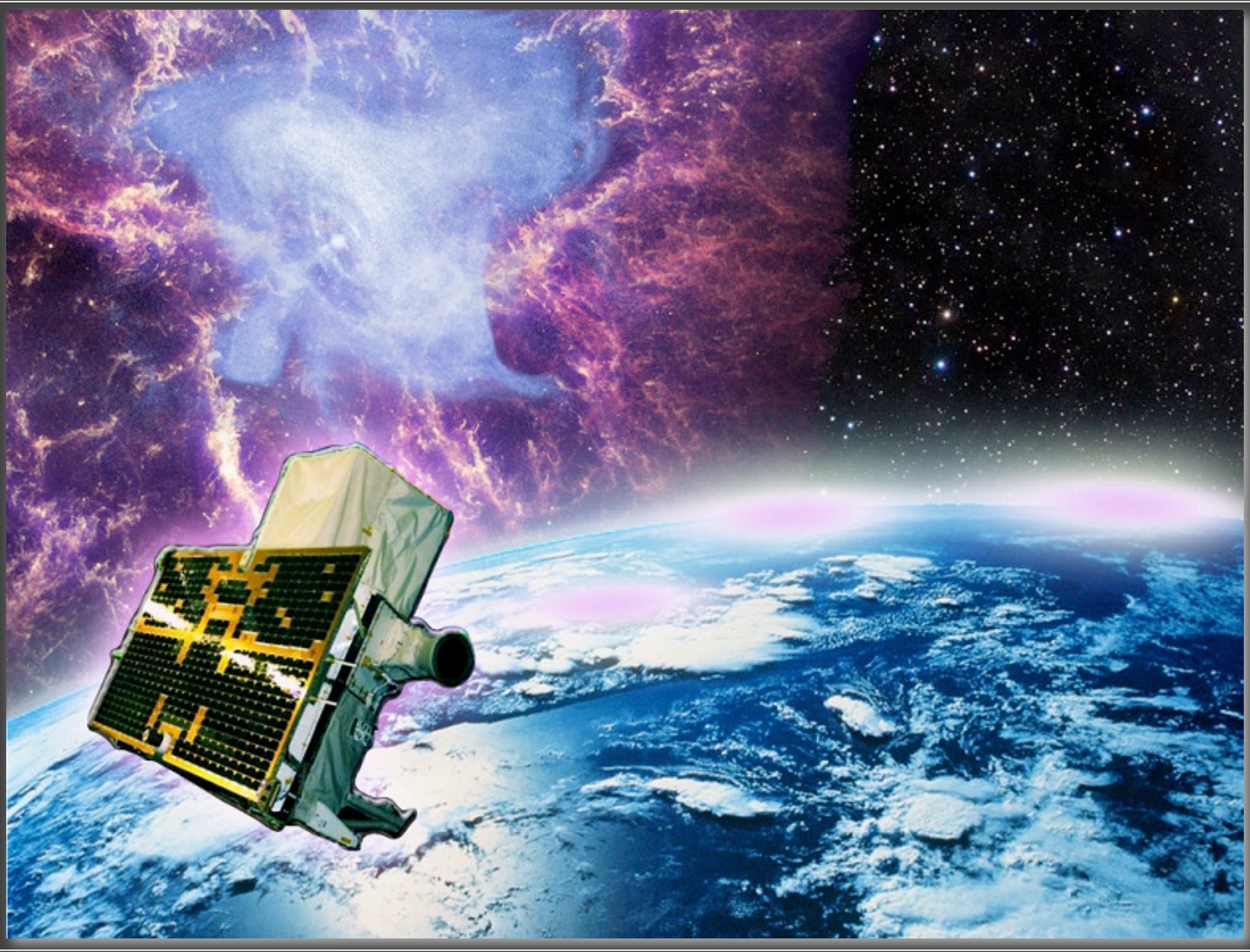
The γ-ray sky has been investigated by means of
Satellites (AGILE, *Fermi* - 30 MeV < E < 300 GeV)
Cherenkov telescopes (HESS, MAGIC & VERITAS - E > 100 GeV)



Fermi/LAT 60 months sky
(E > 1 GeV)

HESS, MAGIC & VERITAS
sources (E > 100 GeV)





The AGILE satellites is a joint ASI-INAF-INFN effort

Operative since 23 April 2007

It combines a γ-ray detector (GRID, 30 MeV - 30 GeV), a hard X-ray monitor (SA, 18 - 60 KeV), and a mini-calorimeter detector (MCAL, 350 keV - 100 MeV)

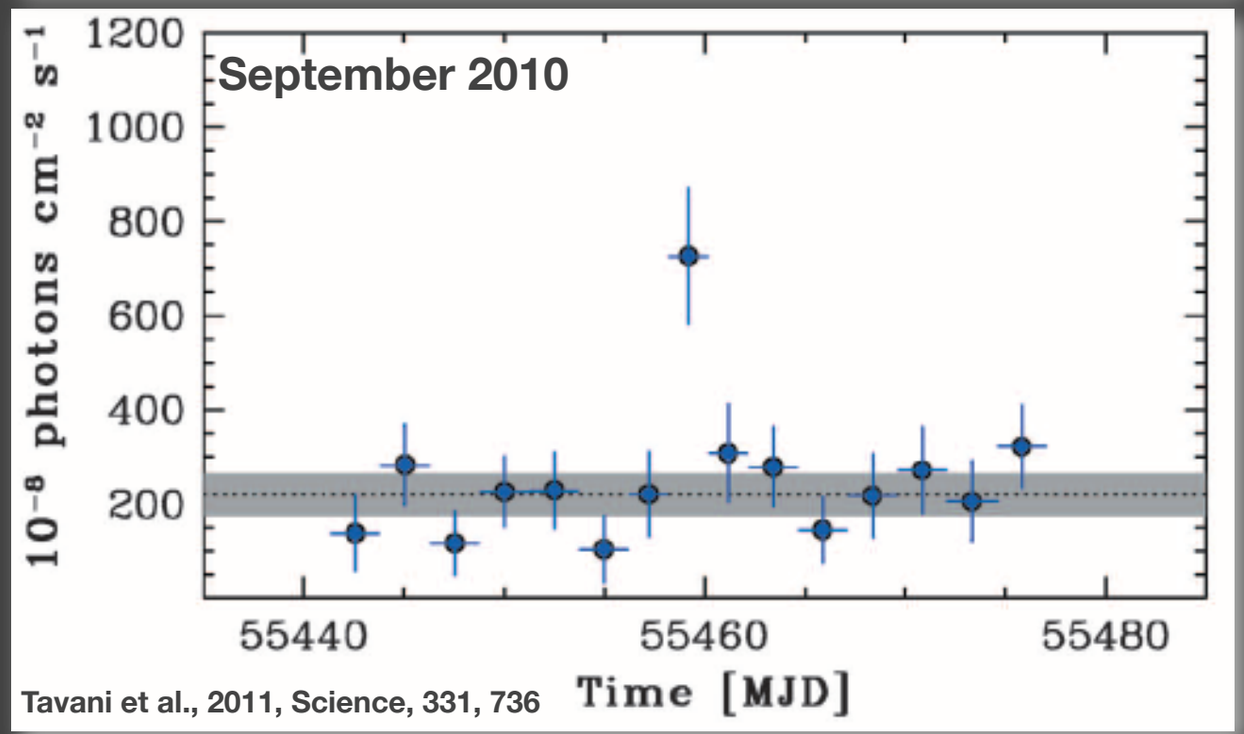
AGILE observes almost the whole sky, detecting hundreds of Galactic, extra-galactic and even terrestrial γ-ray events

Scientific data are collected, processed, and made public by the ASI Science Data Centre

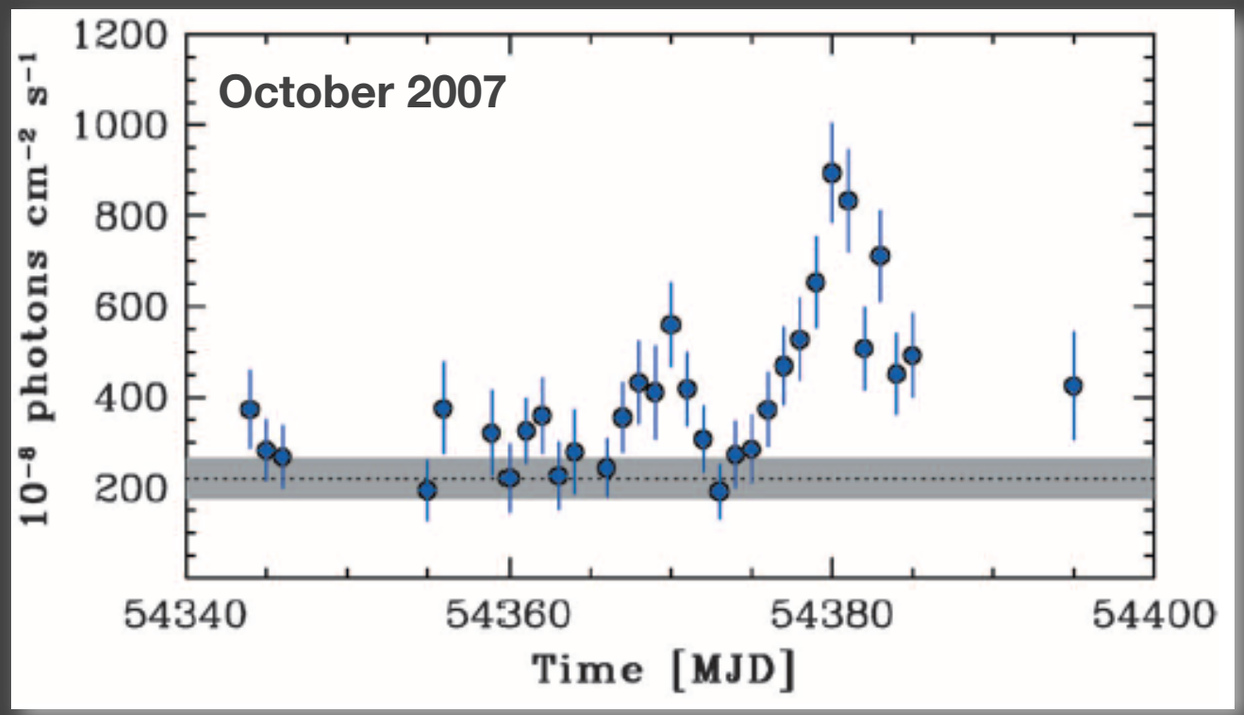
The AGILE Team provides the fastest γ-ray ground segment so far: less than 3 hours to issue an alert following the data telemetry download

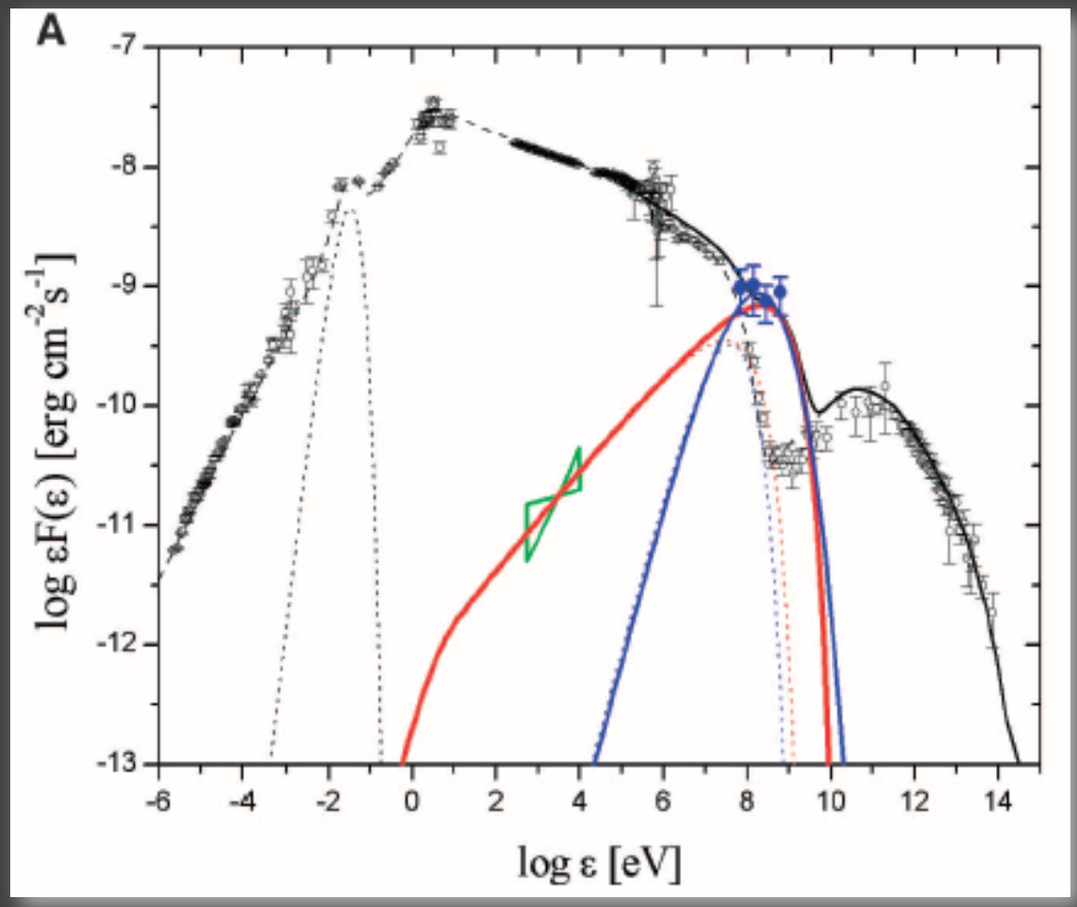
AGILE, the Crab Pulsar & the B. Rossi Prize

"... for the discovery of γ-ray flares from the Crab Nebula.



Tavani et al., 2011, Science, 331, 736

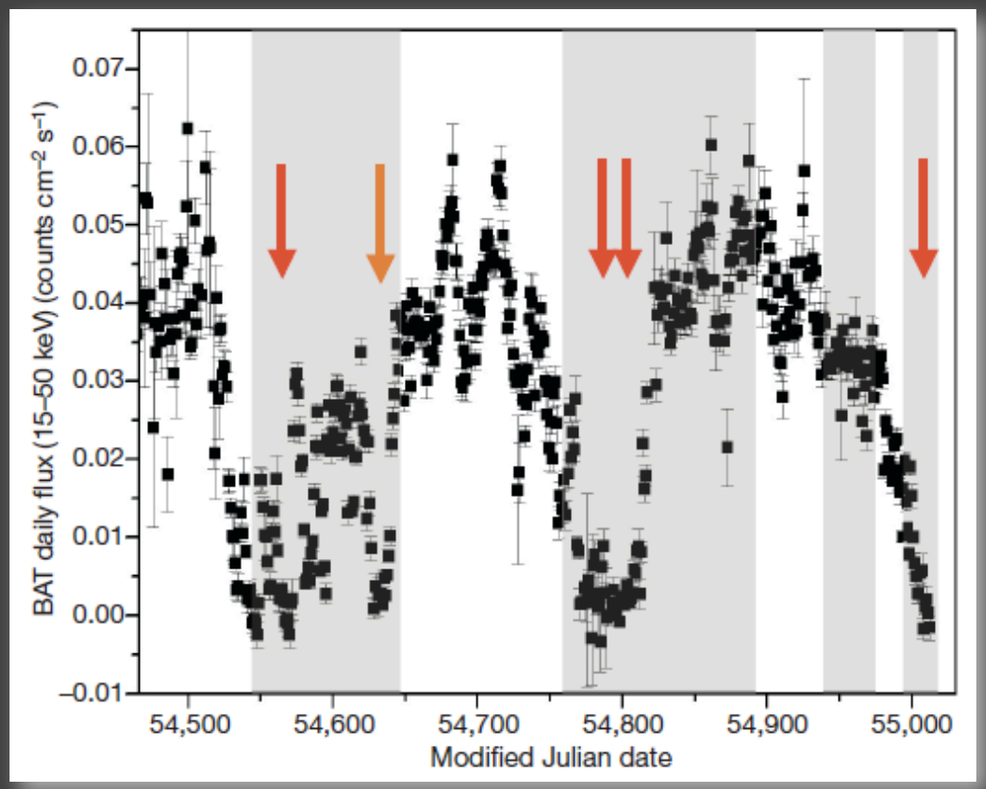




Crab nebula - the flare luminosity and short time scale favor an origin near the pulsar.
These observations challenge standard models of nebular emission and require power-law acceleration by shock-driven plasma wave turbulence within an approximately 1-day time scale.

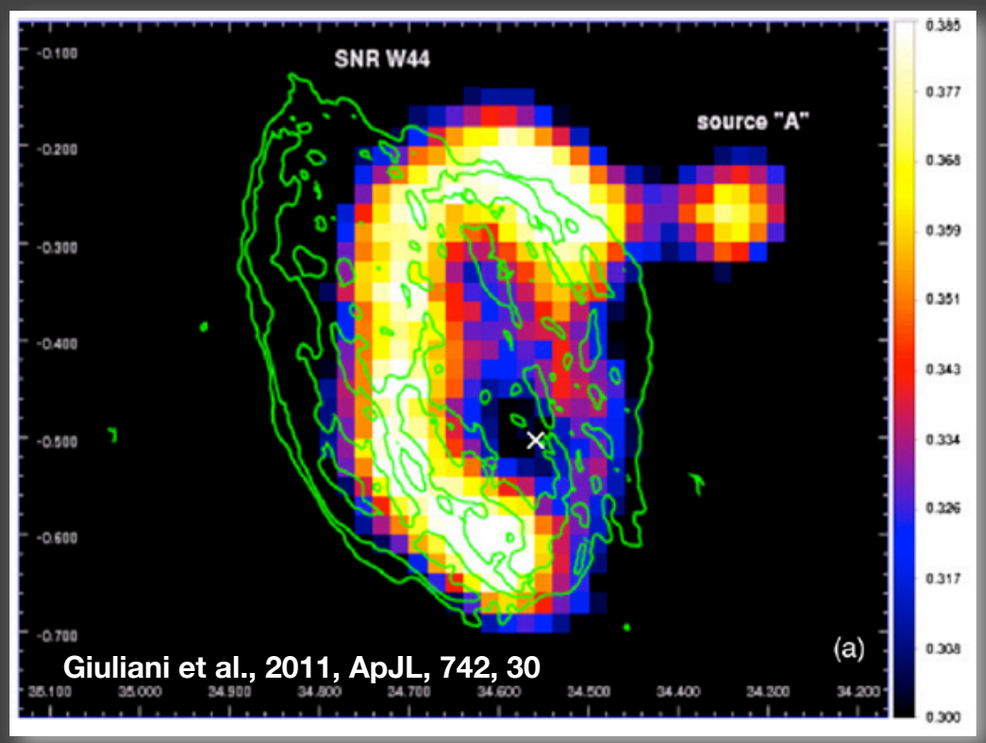
AGILE highlights & recent results

Tavani et al., 2009, Nature, 469, 620



Cygnus X-3 - discovery in this μ-quasar of a pattern of temporal correlations between the γ-ray flares and transitional spectral states of the radio-frequency and X-ray emission.

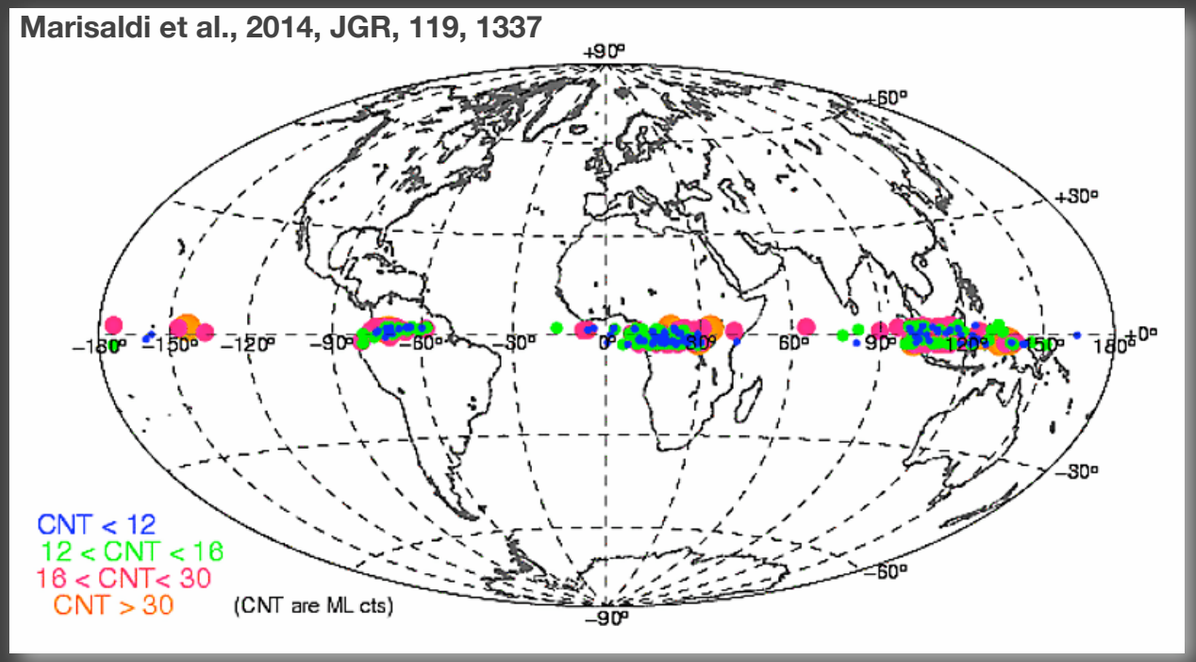
The process of jet formation implies the production of very energetic particles. In Cygnus X-3, particle energies during the flares can be thousands of times higher than during quiescent states.



W 44 - discovery of the direct evidence for pion emission in an SNR for the first time.

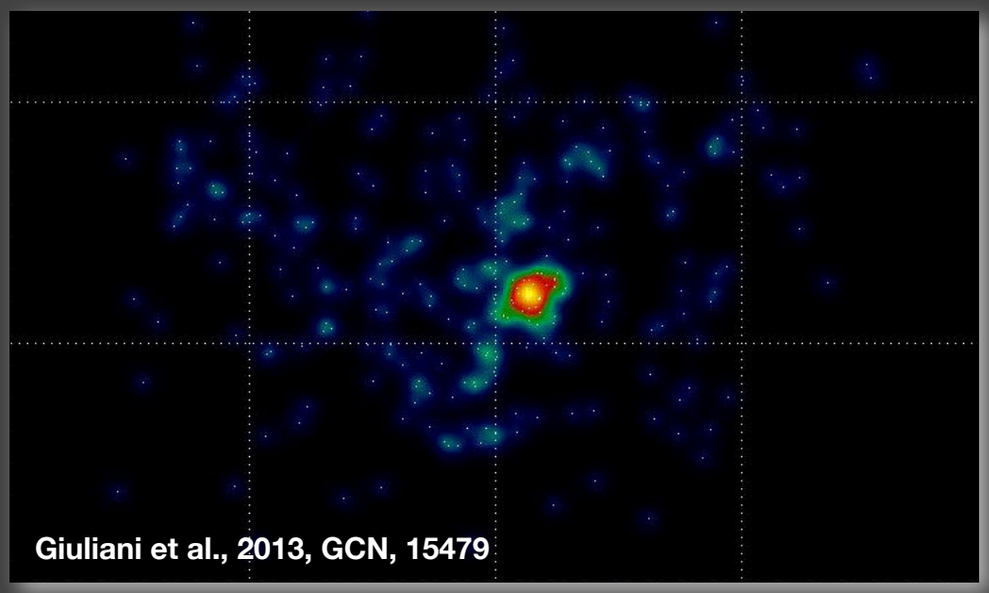
Hadron-dominated models are consistent with all W 44 multi-wavelength constraints derived from radio, optical, X-ray, and γ-ray observations, while ad hoc lepton-dominated models fail to explain simultaneous multi-wavelength data.

AGILE highlights & recent results

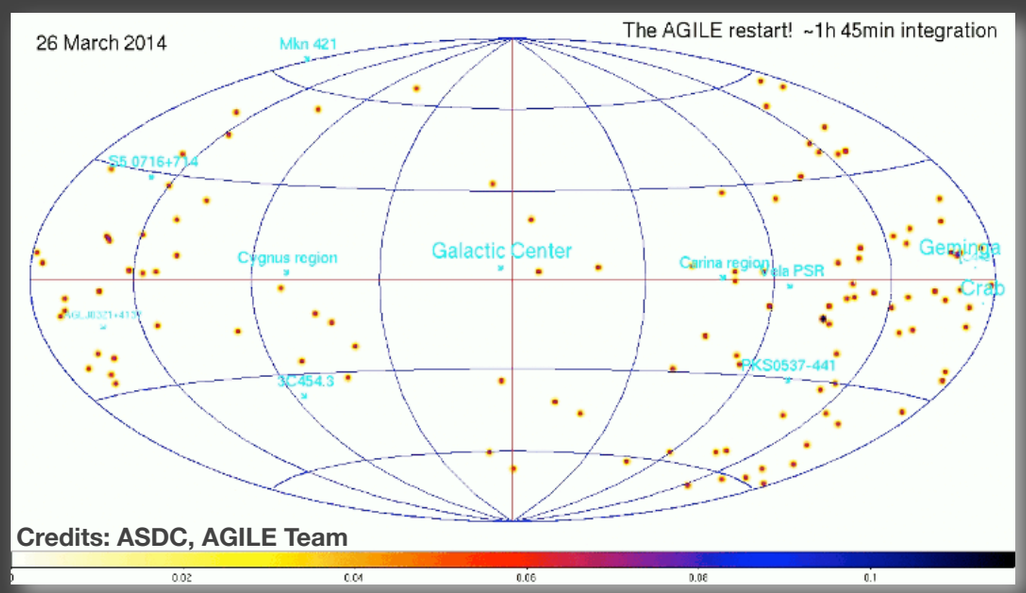


TGFs - Geographical distribution of the 308 Terrestrial Gamma-ray Flashes detected up to July 2012 (detection rate about 10 TGF/ month).

An online version of the AGILE TGF catalog below 30 MeV is accessible at `www.asdc.asi.it/mcaltgfcat/` as an interactive web table, including access to available TGF light curves



GRB 131108A, placed at z=2.4, is a γ-ray burst from ten billion years ago!



γ-ray events accumulating on 26 March 2014 after a 3-month stand-by

The *Fermi* satellite is a cooperation between NASA and DOE, with key contributions from France, Italy (ASI, INAF, INFN), Japan and Sweden.

Operative since 11 June 2008

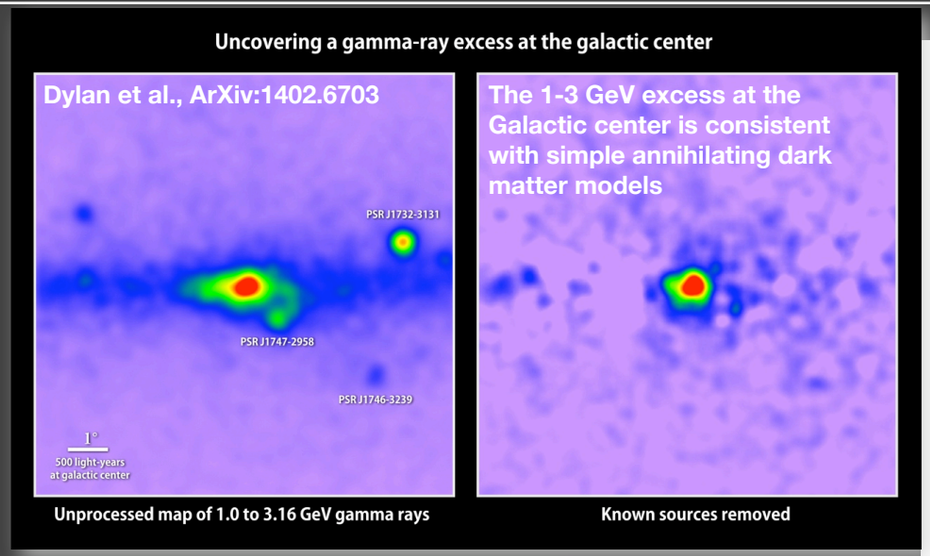
It combines a γ-ray detector (LAT, 30 MeV - 300 GeV) and γ-ray burst monitor (GBM, 10 keV - 30 MeV)

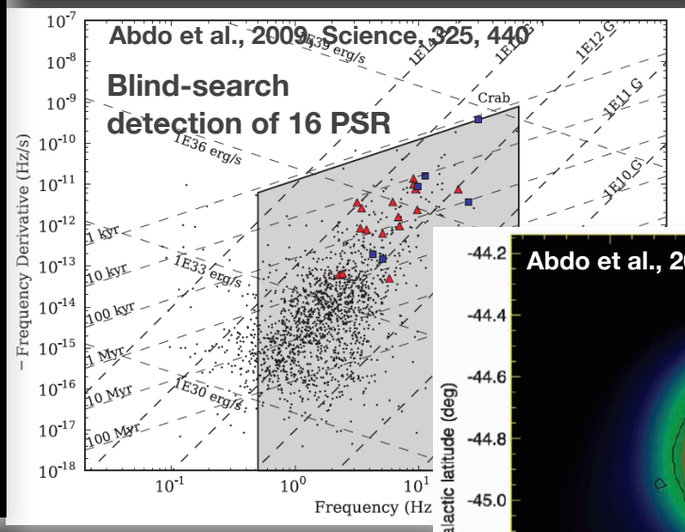
Fermi scans the entire sky every 3 hours and detected so far more than 1800 sources (both Galactic, extra-galactic, and the Sun).

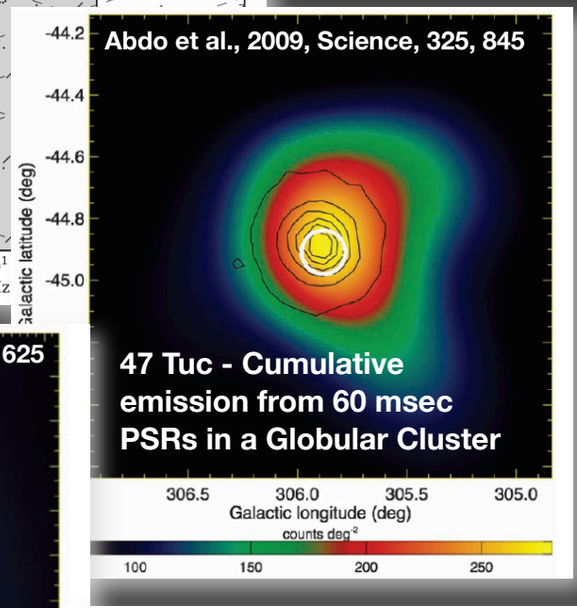
Scientific data are made public within one day and for more than 100 sources light-curves are provided for monitoring purposes

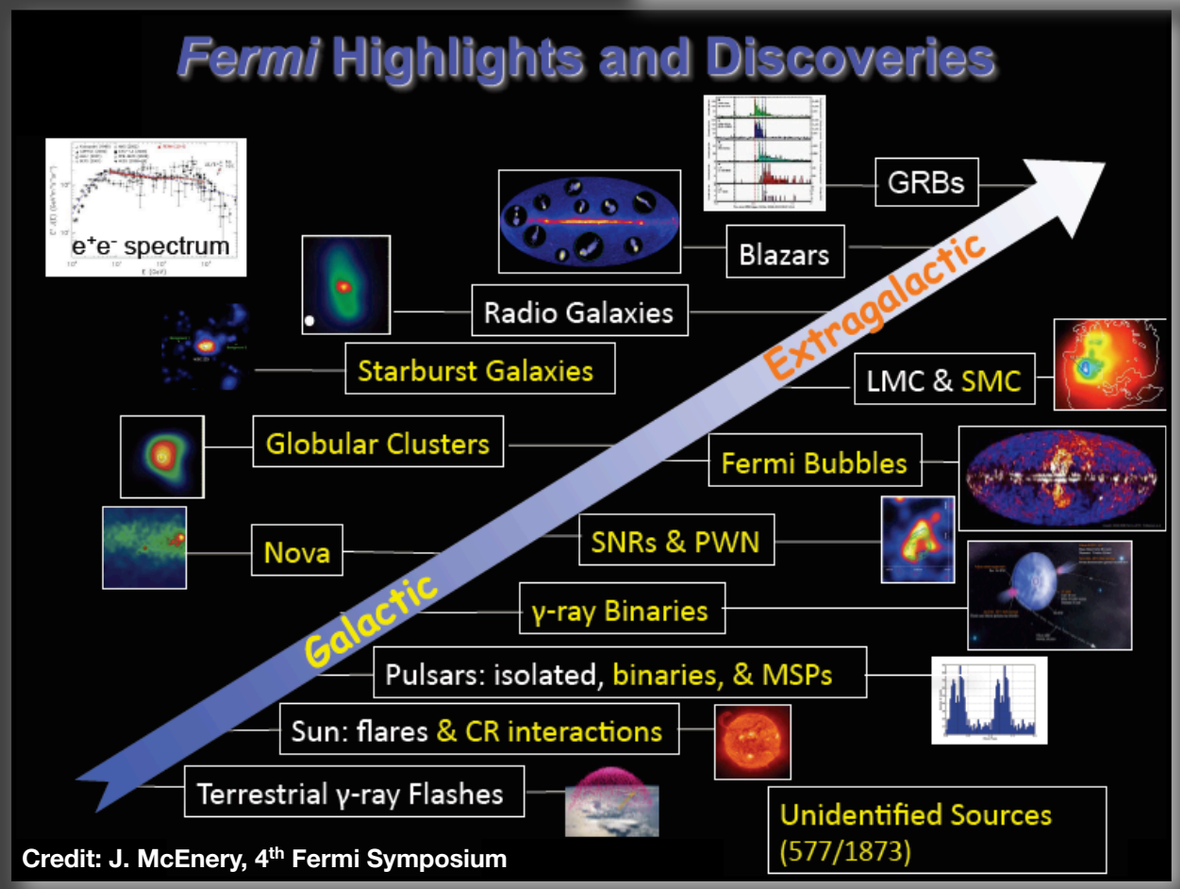
***Fermi* can operate both in scanning and in pointed mode, in order to follow any peculiar γ-ray event**

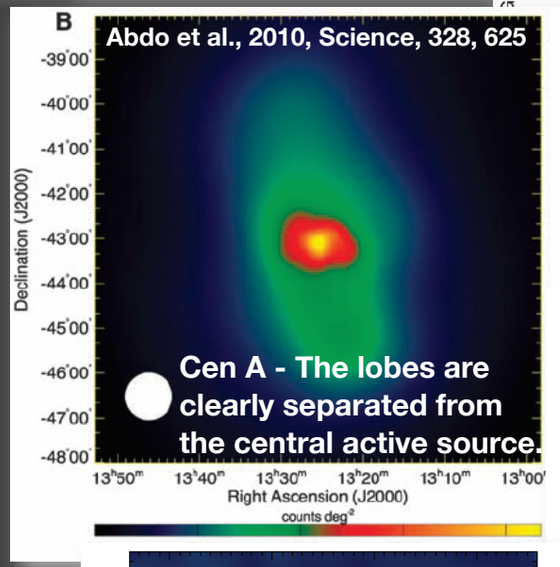
Fermi & the B. Rossi Prize

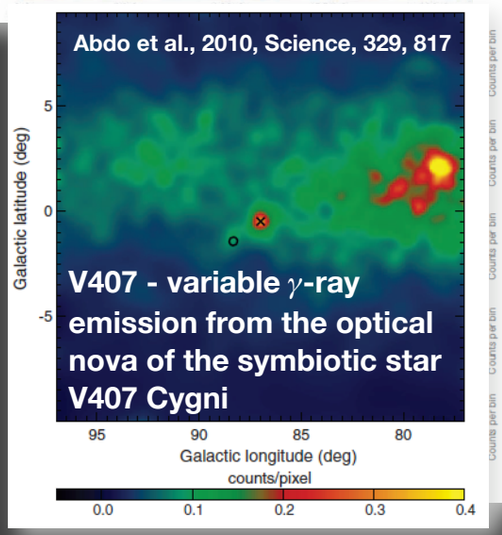


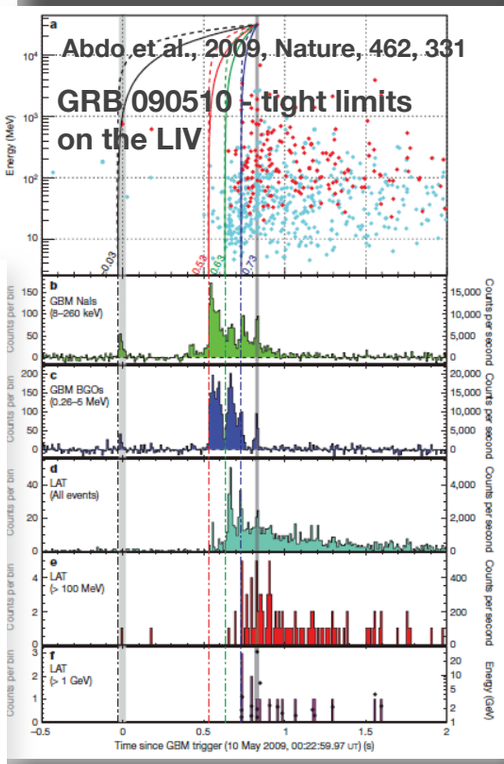






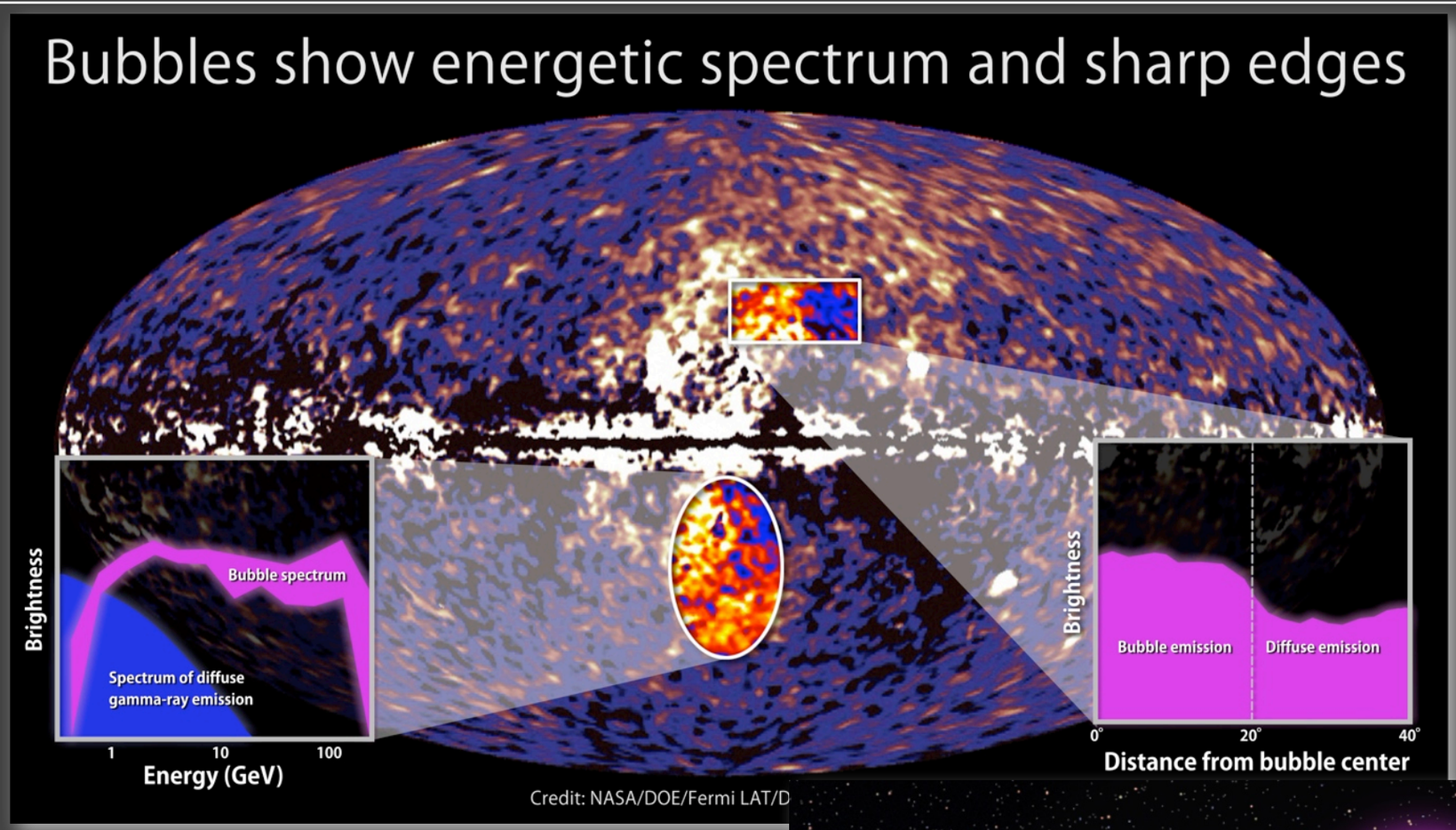




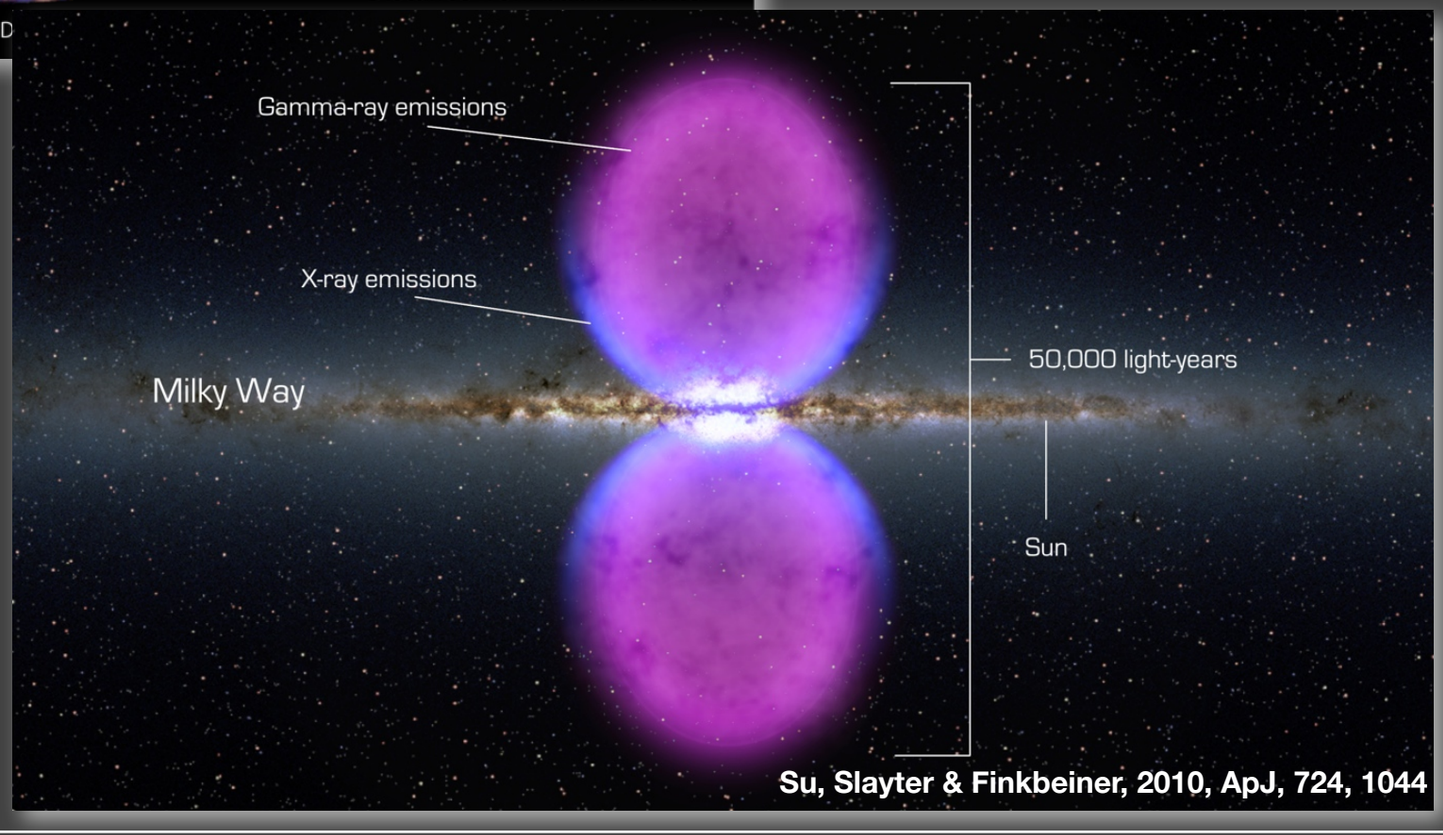


"...for enabling, through the development of the Large Area Telescope, new insights into neutron stars, SNRs, cosmic rays, binary systems, AGNs, and GRBs."

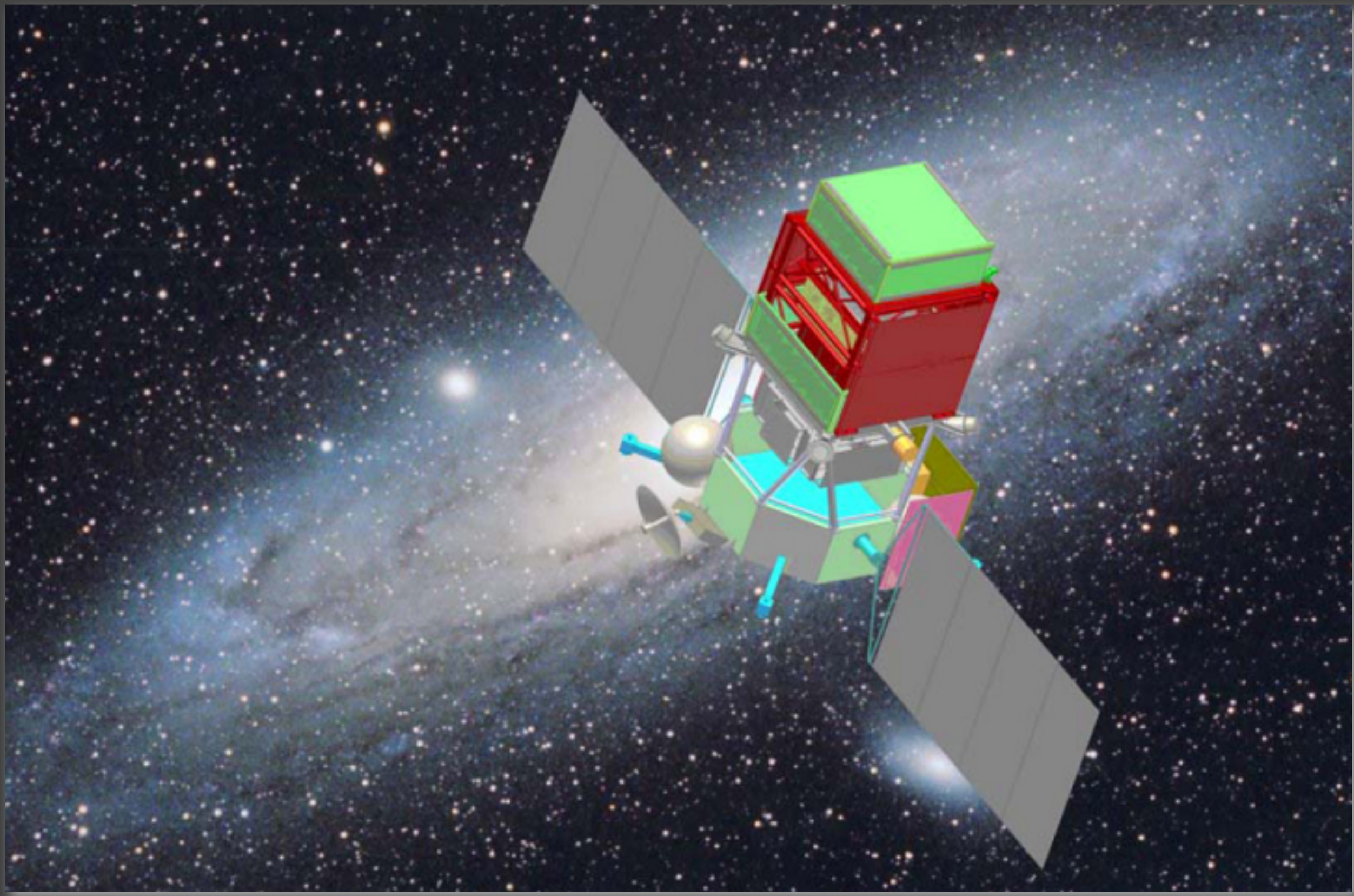
Fermi & the "*Fermi* Bubbles" B. Rossi Prize



"...for the discovery, in γ-rays, of the large Galactic structure now called the *Fermi Bubbles*.
From end to end, *Fermi bubbles* extend 50,000 light years, or roughly half of the Milky Way's diameter.
These structures may be the remnant of an eruption from a super-sized black hole at the center of our Galaxy."



Gamma-400



Gamma-400

Cooperation in the design and production of scientific equipment

Russian scientific organizations	Foreign scientific organizations
LPI RAS – Leading Institute	INFN (Italy) – Converter/Tracker and Calorimeter
NRNU MEPhI – TOF and A/C detectors	INAF (Italy) – Converter/Tracker
NIIEM — design, temperature control system	Taras Schevchenko National University (Ukraine) — Ukrainian main collaborator
NIISI RAS — electronics	CrAO (Ukraine) — ground-based observatio
Ioffe Institute — Konus-FG burst monitor	IKI (Ukraine) — magnetometer
IKI — star sensor	ISM (Ukraine) — scintillators
IHEP — calorimeters, scintillators	KTH (Sweden) — anticoincidence
TsNIIMASH — space qualification	

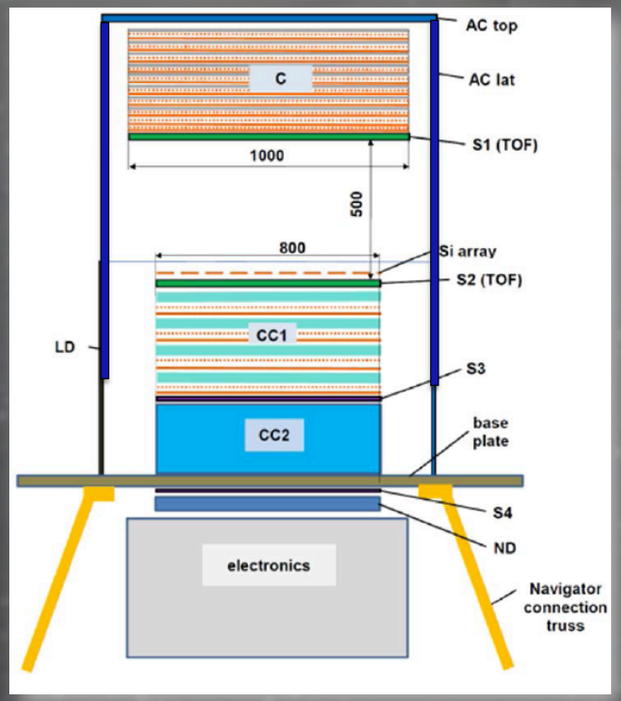
Gamma **A**stronomical **M**ultifunctional **M**odular **A**pparatus

Mission approved by ROSCOSMOS (launch currently scheduled by **November 2018**)

Scientific payload mass: 4100 kg
Power budget: 2000 W
Telemetry downlink: 100 GB/day
Lifetime: 10 years
Orbit: apogee 300.000 km, perigee 500 km, orbital period 7 days, inclination 51.8°

Standard mission concept.

Alternative mission concept is under investigation by INFN and INAF.



AC - anticoincidence detectors (AC top , AC lat)

C - Converter-Tracker - total 1 Xo
8 layers W 0.1 Xo +Si (x,y) (pitch 0.1mm)
2 Si(x,y) no W

S1, S2 - TOF detectors

S3, S4 calorimeter scintillator detectors

CC1 - imaging calorimeter (2Xo)
2 layers: CsI(Tl) 1Xo + Si(x,y) (pitch 0.5 mm)

CC2 - electromagnetic calorimeter
CsI(Tl) 23 Xo 3.6x3.6x3.6 cm^3 - 28x28x12=9408 crystals

LD - 4 lateral calorimeter detectors

ND - neutron detector

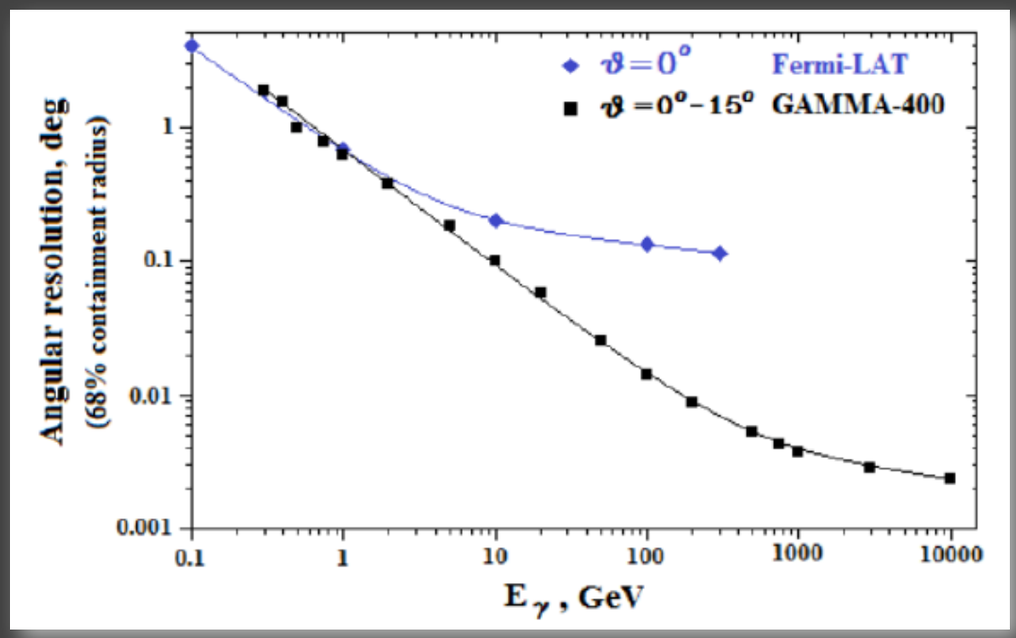
Courtesy: F. Longo, INFN-TS

Gamma-400

	space gamma-ray telescopes			ground gamma-ray telescopes		
	Fermi	**AMS-2**	**GAMMA-400**	**H.E.S.S.-II**	**MAGIC**	**CTA**
energy range [GeV]	0.02–300	10–1000	0.1–3000	> 30	> 50	> 20
acceptance [m² sr]	2.4	0.4	1.2	0.01	0.01	0.1
effective area [m²]	0.8	0.2	0.6	10^5	10^5	10^6
angular resolution (E_γ > 100 GeV)	0.2	1.0	< 0.02	0.07	0.05	0.06
energy resolution (E_γ > 100 GeV)	10%	3%	1–2%	15%	15%	10%

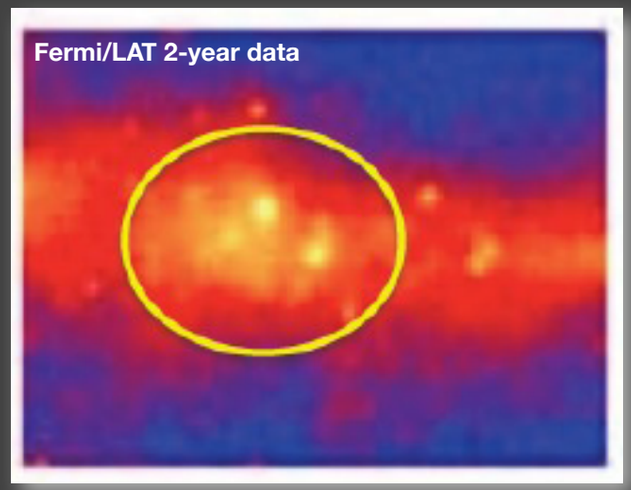
More information on the GAMMA-400 space mission can be found in

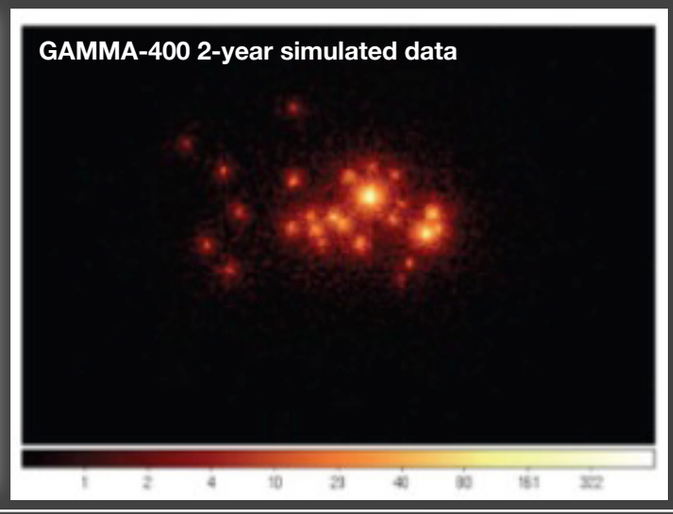
Galper et al., ICRC 2013, ArXiv:1306.6175



Physics objectives G-400

- cosmic-ray origin
  - leptonic vs. hadronic discrimination
  - spatially resolved spectra
  - propagation in the Galaxy
- Dark Matter & physics beyond the standard model
  - optimal angular & spectral resolution at the Galactic Center and plane
- Nature and variety of particle acceleration around black holes & compact objects
  - gamma-ray alerts
  - long continuous exposures
  - transient & fast emission
  - fundamental properties of acceleration





MAGIC is an international collaboration of 17 institutes in 8 countries.
INAF is involved with 10 full-member scientists since 2008.

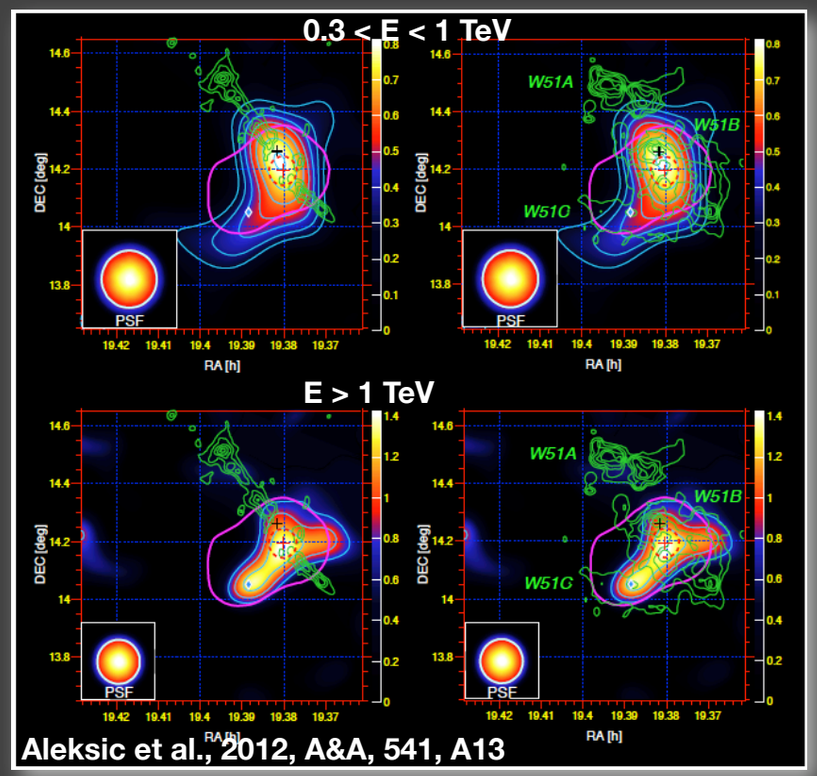
Array of two Cherenkov telescopes of 17 m diameter reflecting dish located at La Palma, Canary Islands “Roque de los Muchachos” Observatory active since 2004 (mono) and from 2009 in stereo.

New MAGIC-1 camera since 2012
New mirrors for MAGIC-1 from August 2014
At least 5 more years foreseen

Trigger threshold: ~ 50 GeV (25-30 GeV in “Sum Trigger” mode)
Energy resolution: ~20% @ 100 GeV, < 15% @ 1 TeV
Angular resolution ~0.1° @ 100 GeV, 0.05° @ 1 TeV

Sensitivity ~0.6% (at 200 GeV) of the Crab Nebula flux in 50 h

MAGIC highlights

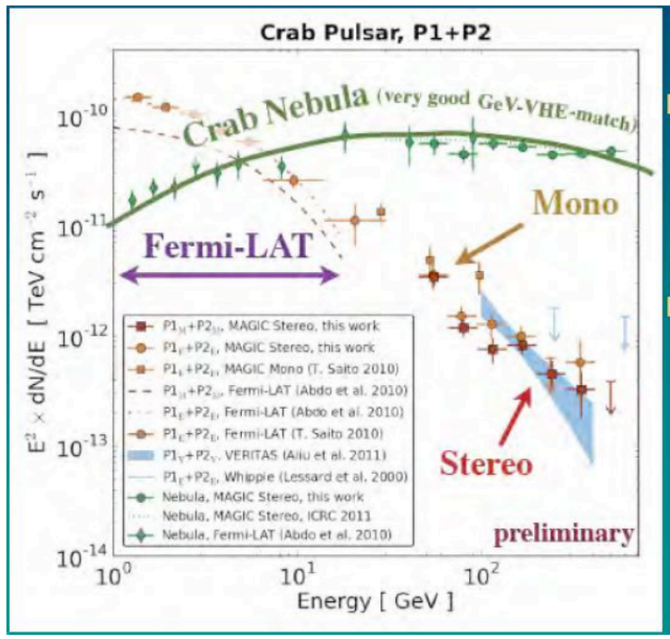


Aleksic et al., 2012, A&A, 541, A13

W 51 - is a SNR interacting with a molecular cloud. The MAGIC good angular resolution in the medium (few hundred GeV) to high (above 1 TeV) energies allowed to perform morphological studies.

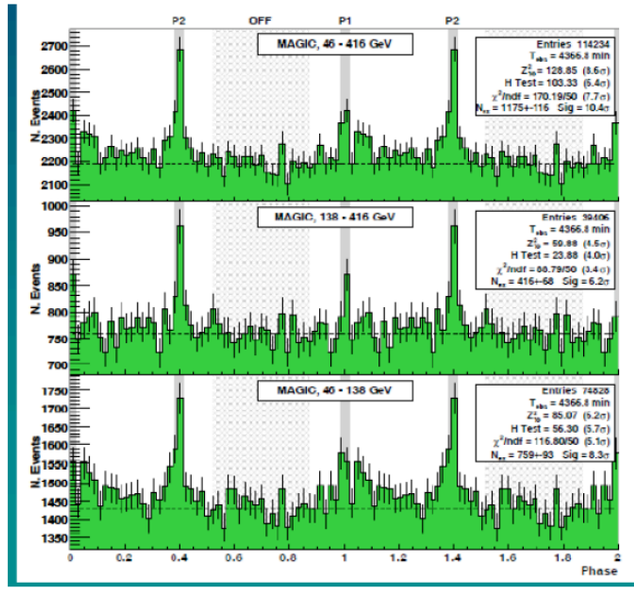
Extended emission of VHE gamma rays is detected with a significance of 11-σ. The broad-band SED can be explained with an hadronic model in which we observe ongoing acceleration of ions in the interaction zone between the SNR and the cloud.

VHE spectrum of the Crab Nebula and of the Pulsar



- *MAGIC Stereo provides spectra up to 400 GeV.*
- *Mono/stereo spectra agree… and go well beyond a cutoff at few GeV!*

73h stereo data, Oct.2009 – Feb.2011



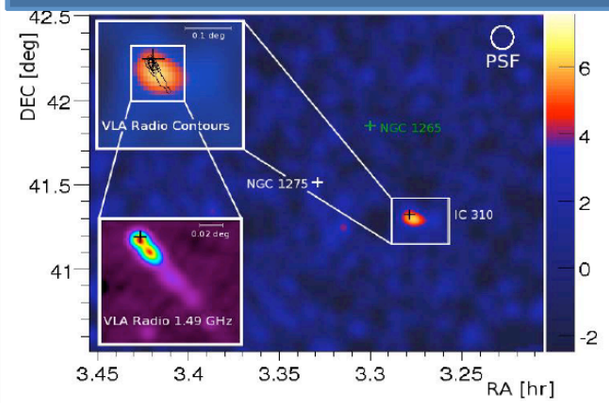
Pulsed emission detected up to 400 GeV !!!!!

- This data has already been published
- But the story is still continuing

MAGIC highlights

IC 310: Unexpected Discovery in the Perseus Cluster of Galaxies

IC 310: detected ≥ 30GeV by *Fermi*/LAT (Neronov et al. 2010) & ≥ 260GeV by MAGIC (Aleksic et al. 2010)



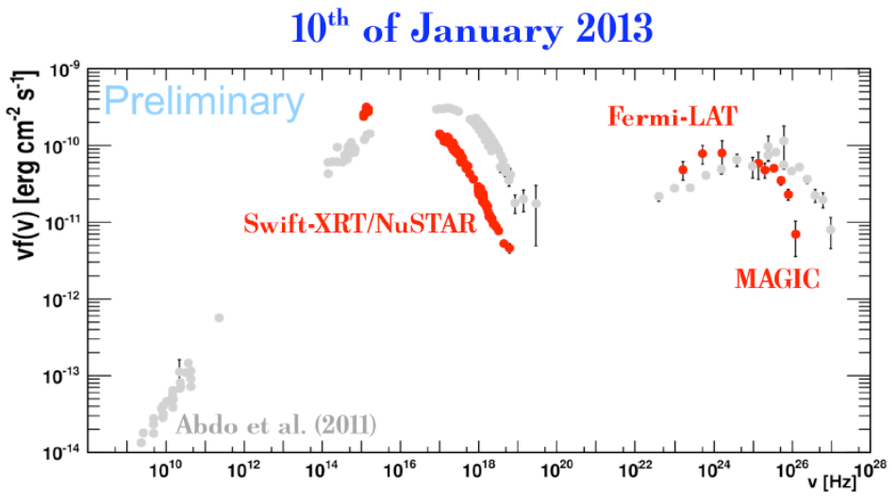
- Flux and spectral variability in X-ray
- Day-scale variability in VHE, no spectral variability
- Hard spectrum in HE and VHE → 2nd hump ≥ 1TeV
- Original head-tail classification not supported
- VLBI reports parsec-scale blazar-like structures; θ ≤ 38°

➢ MWL campaign in Nov. 2012 to Feb 2013

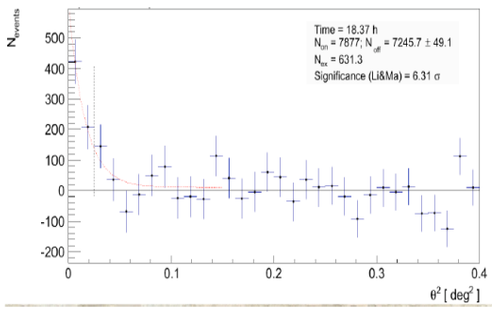
Aleksic et al., 2010, ApJL, 723, 207
Aleksic et al., 2014, A&A, 563A, 91

The very low X-ray and VHE activity of Mrk421

- Synchrotron and IC peaks shift to low energies by factor ~10
- NuSTAR exquisite characterization of the tail of the synch. bump

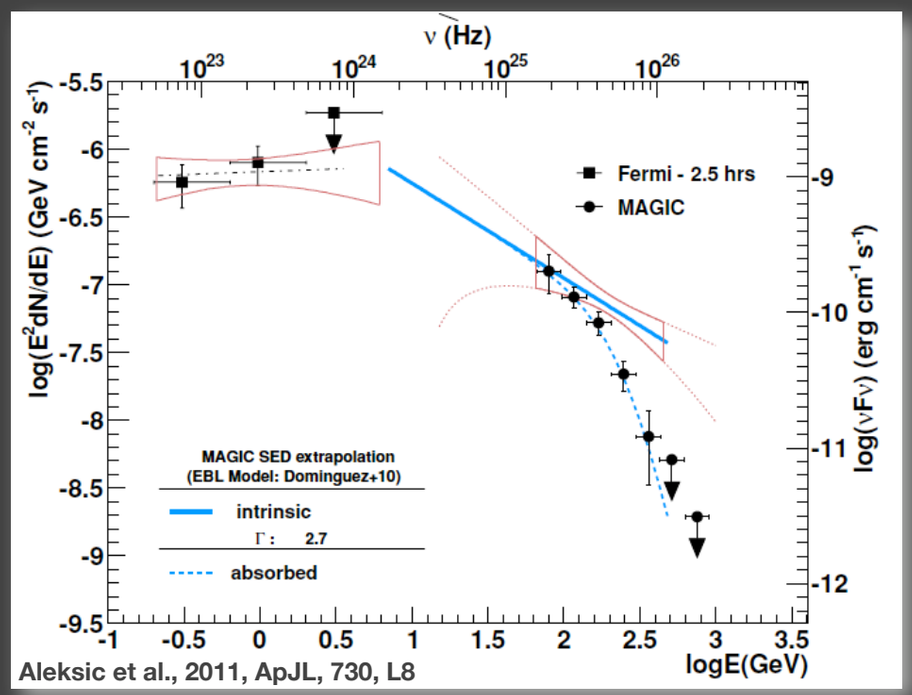


New Source: MS 1221.8+2452 discovered in May 2013



- Blazar
- z = 0.218
- Discovered in the night April 30th – May 1st
- 6.3σ in 4h
- High synchrotron peaked BL Lac
- XBL (X-ray selected BL Lac
- 2.3% Crab ≥ 100GeV

Cortina et al., 2013, ATel #5038



Aleksic et al., 2011, ApJL, 730, L8

PKS 1222+21 - MAGIC detected highly-variable emission (flux doubling time of about 10 minutes) from this blazar in 2010, constraining the size of the emitting region.

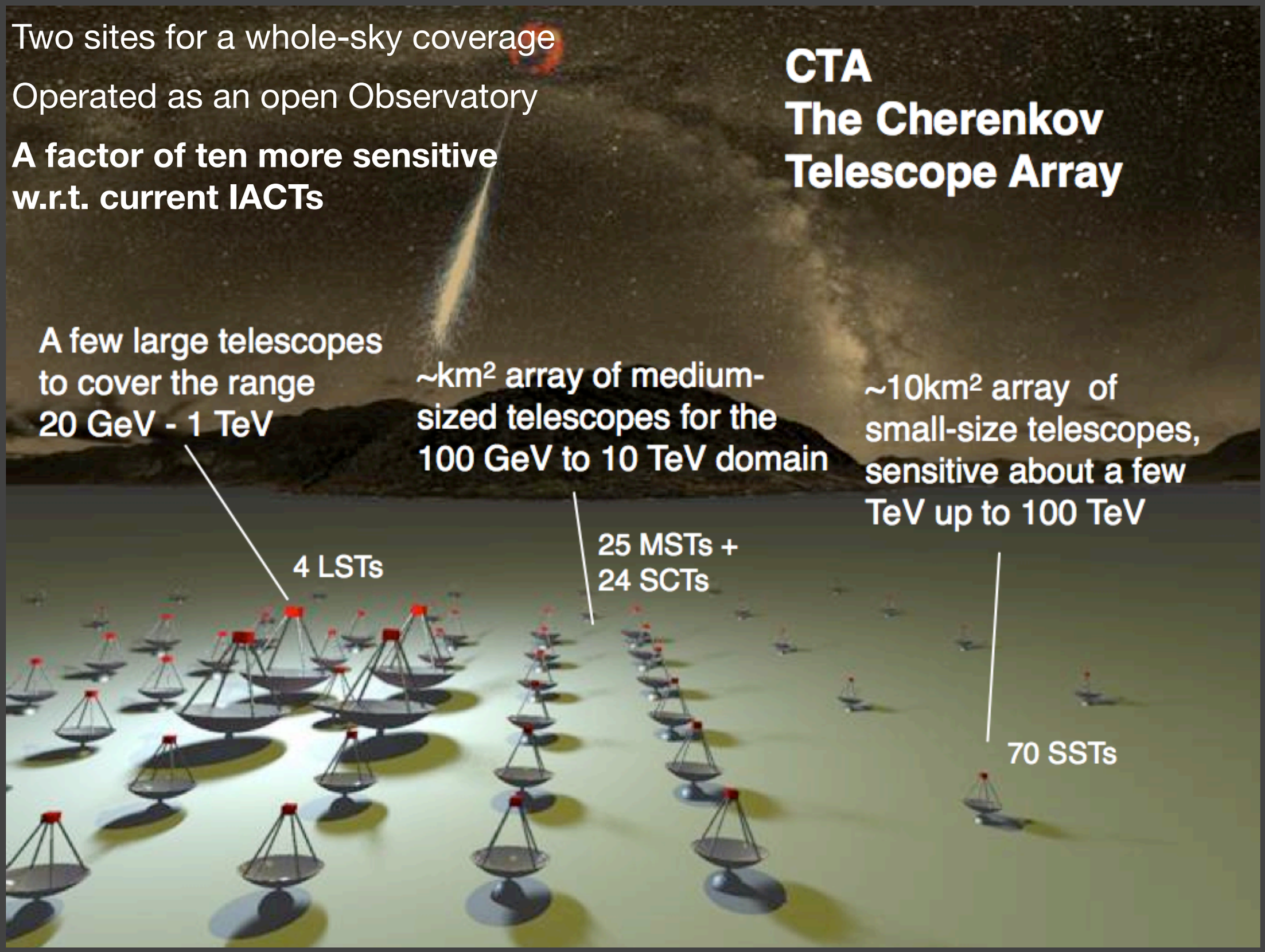
In order to avoid high-energy photons to be absorbed by the optical BLR photons, a compact region at large distances from the central BH and outside the BLR has to be invoked.

CTA & ASTRI

Two sites for a whole-sky coverage

Operated as an open Observatory

A factor of ten more sensitive w.r.t. current IACTs



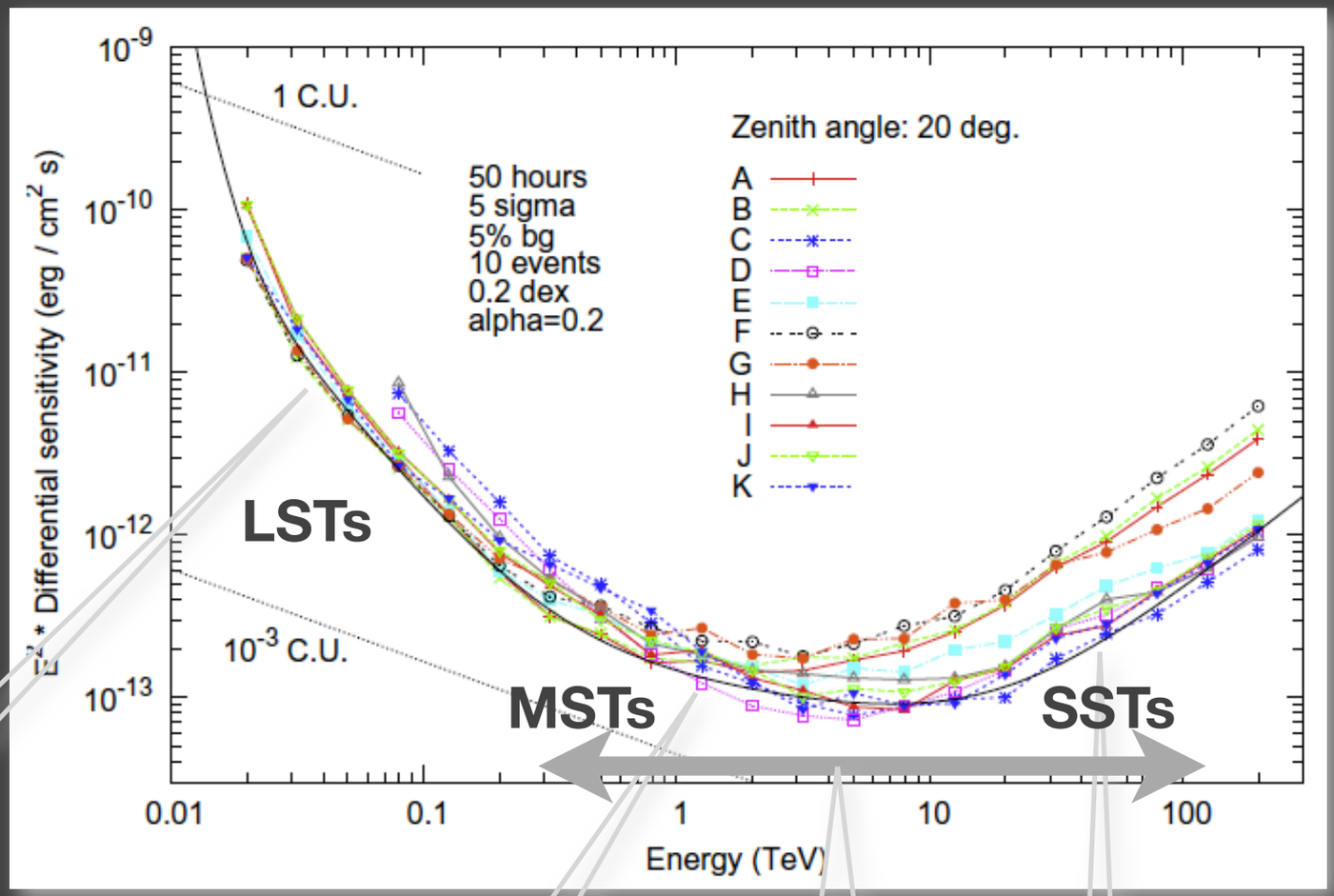
CTA & ASTRI

Improved angular resolution
Source id & morphology

Improved energy resolution
Cut-offs & spectral features

Large field of view (>5°-8°)
Extended sources, surveys

Multiple observation modes
Different scientific topics



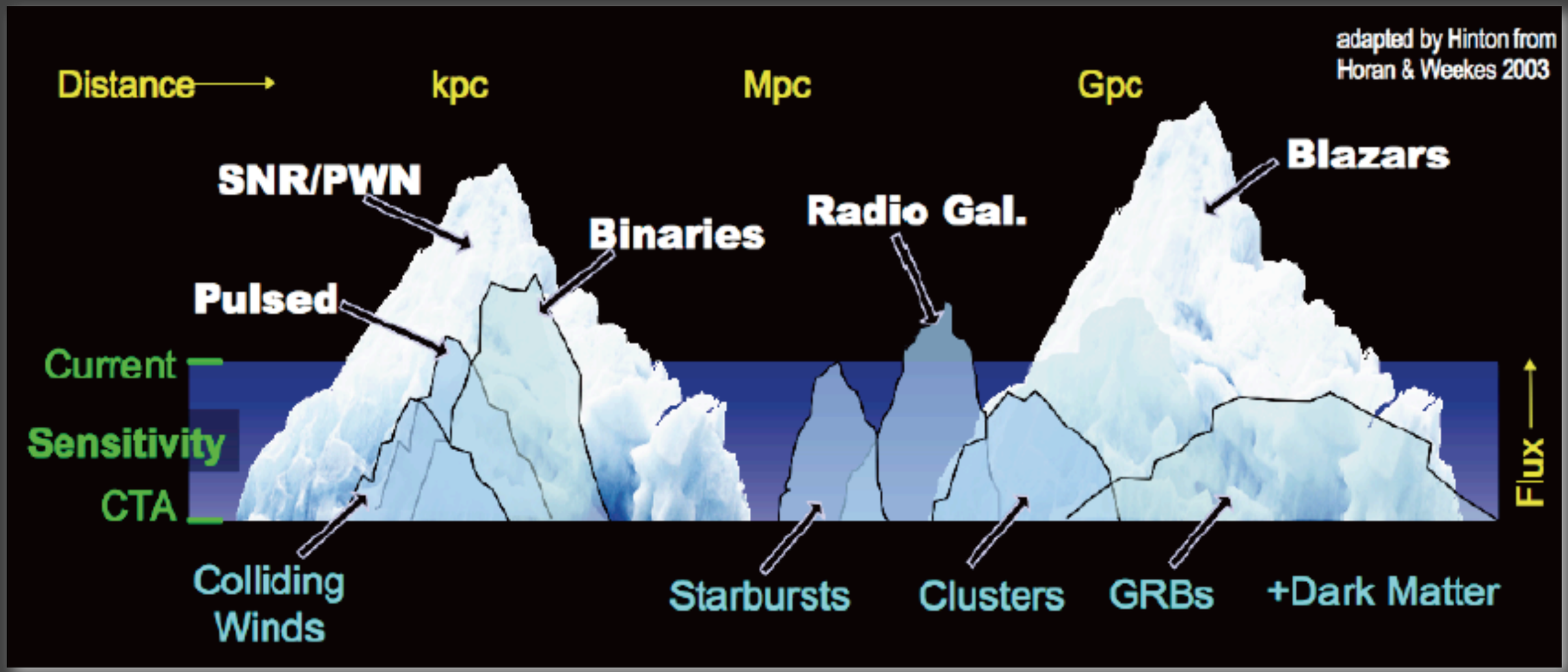
Hi-redshift AGNs
GRBs, PSRs,
Dark Matter

Population studies,
extended sources,
variability studies

1/4 of the sky blind survey above 200 GeV !

Exploring the cut-off regime of the cosmic accelerators

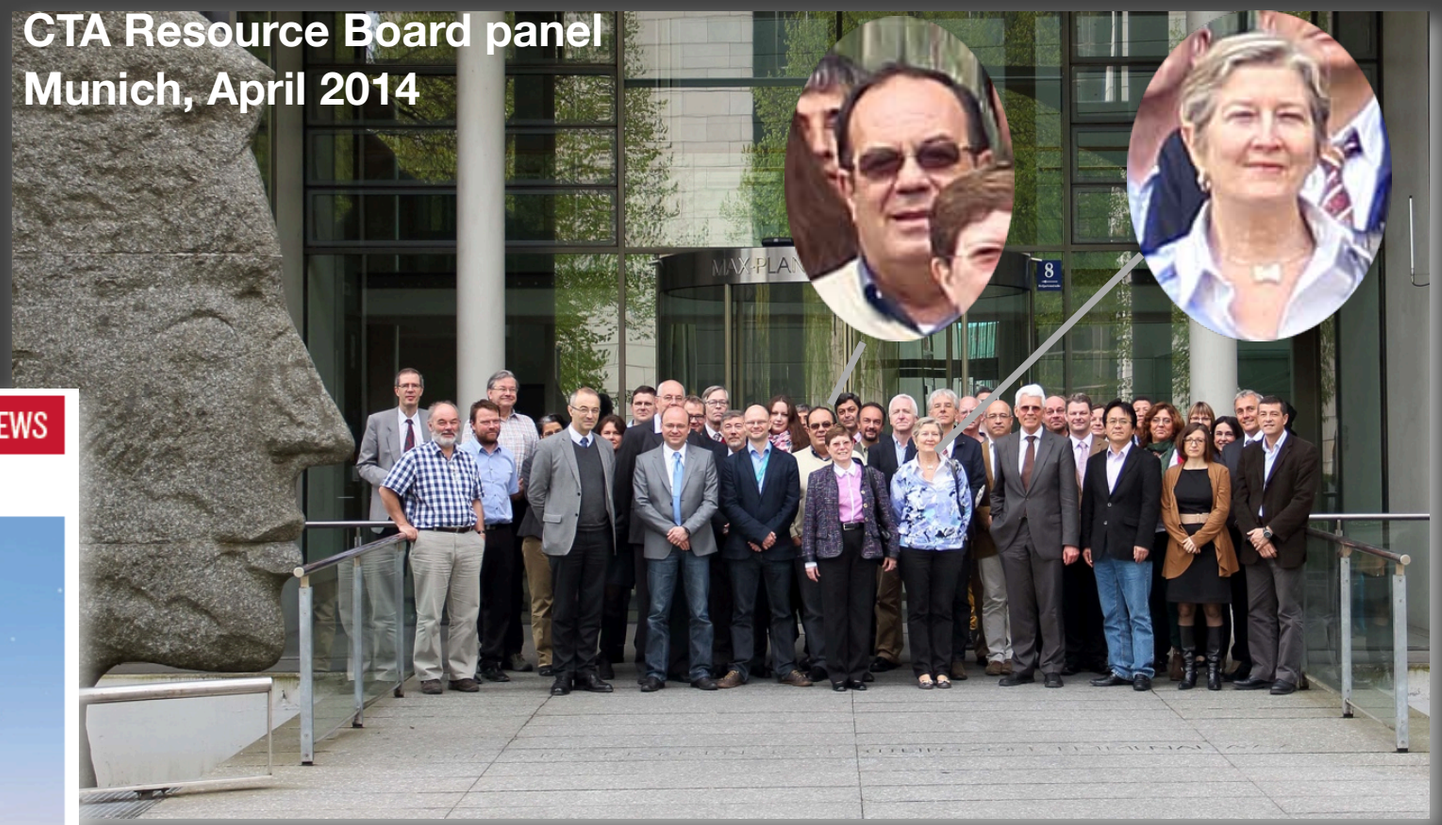
CTA & ASTRI



Current IACTs yield a “discovery sensitivity threshold”

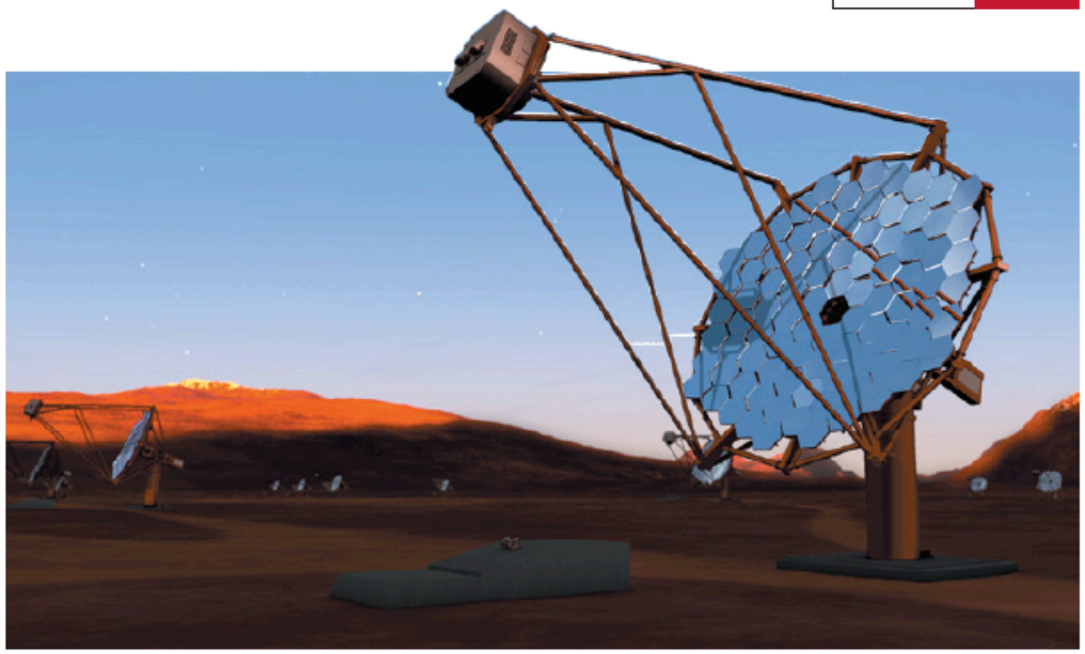
CTA will be able to explore “Vingt mille lieues sous les mers”

CTA & ASTRI



Gibney, 2014, Nature, 508, 297

IN FOCUS NEWS



The telescope array (artist's impression) will be split across the Northern and Southern hemispheres.

ASTRONOMY

Panel homes in on sites for γ-ray detector

Southern site: start the negotiations on the two sites, namely **Aar in Namibia** and **ESO in Chile**. After negotiations finally one site will be selected at the end of the year.

Northern site: candidate sites are located in Mexico, Spain and the USA - further considerations are necessary.

The INAF ASTRI Project

ASTRI is an Italian “Flagship Project” funded by the Ministry of Education, University and Research (MIUR) and led by the Italian National Institute for Astrophysics (INAF).

The main goals of the project are the design, development and deployment, within the CTA framework of:

an end-to-end prototype of the CTA small-size telescope in a dual-mirror configuration (ASTRI SST-2M) to be tested under field conditions at the INAF Obs. on the Mt. Etna (Sicily) at the end of **2014**;

a SST-2M mini-array to be placed at the chosen CTA Southern Site starting from in **2016**.

INAF is in charge of the design and production of the mirrors and the camera, the development of the end-to-end software, Monte Carlo simulations and other related activities.

Energy threshold

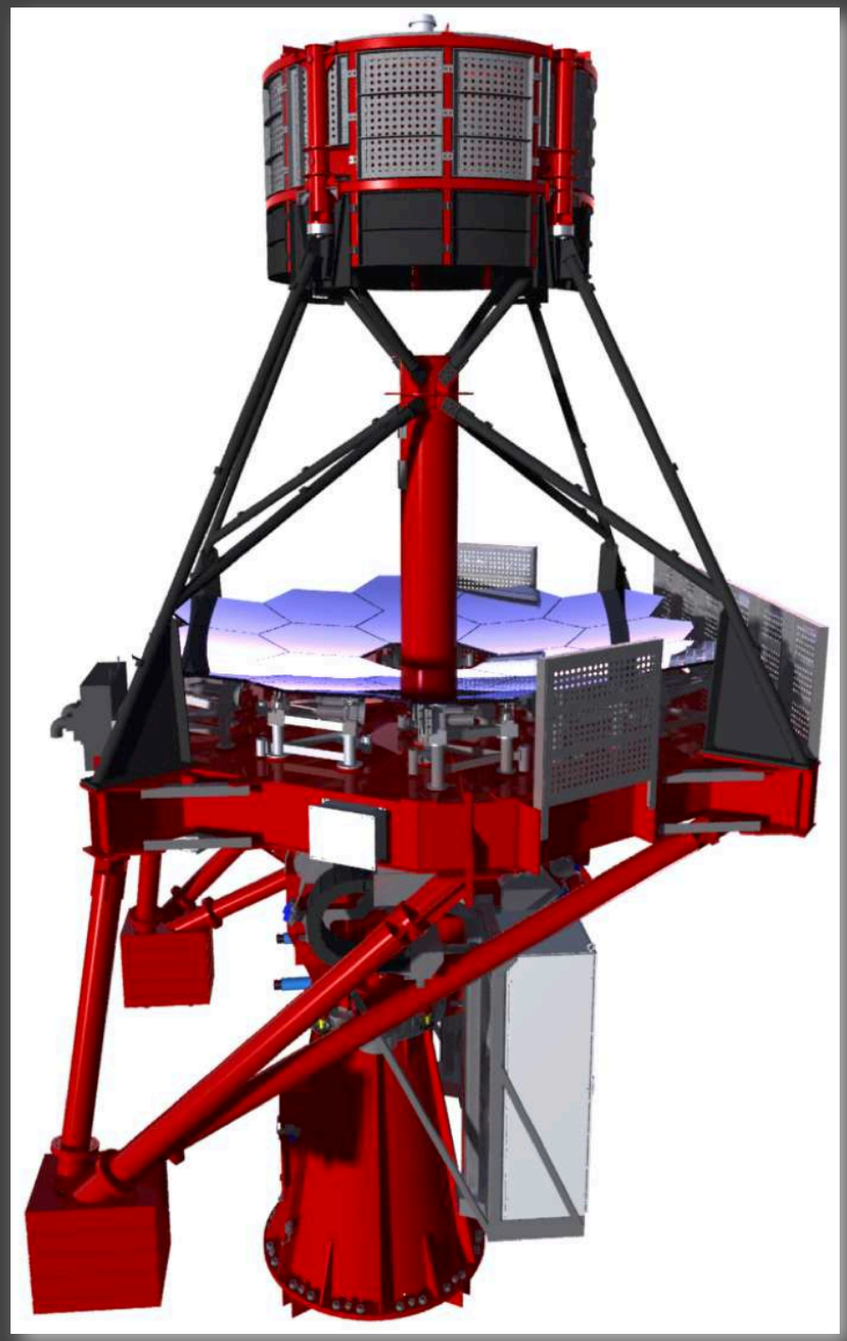
1 TeV

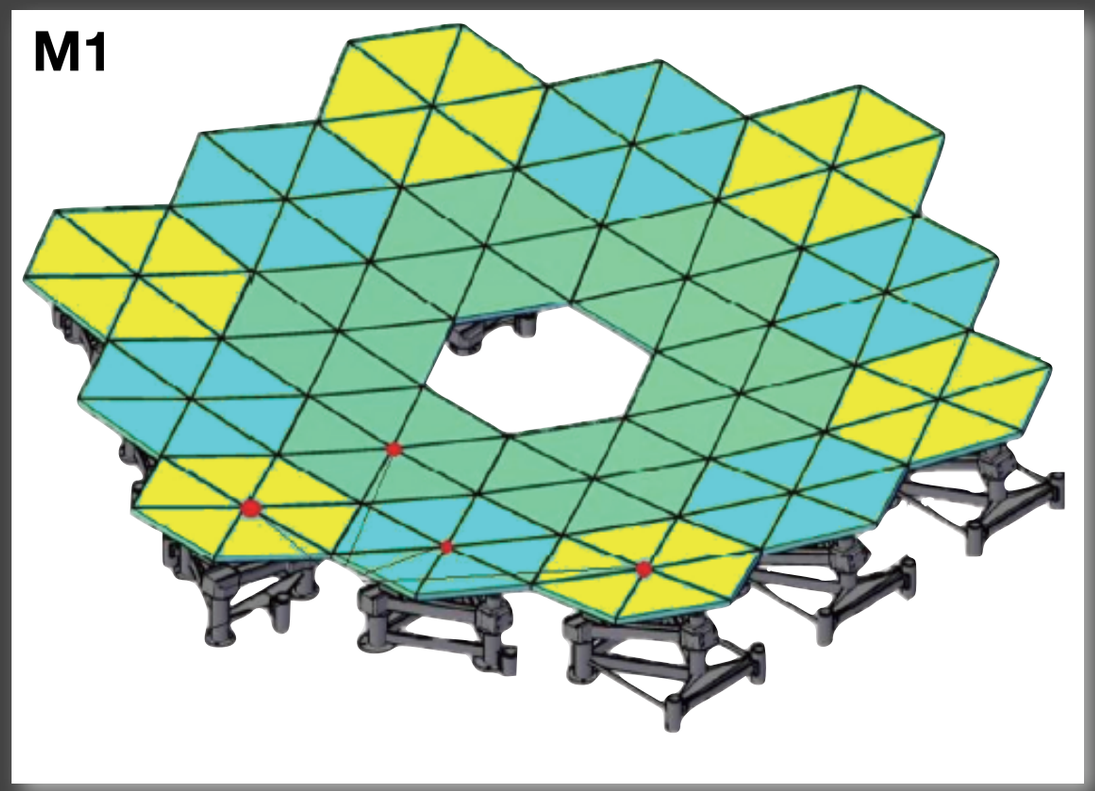
Telescope properties

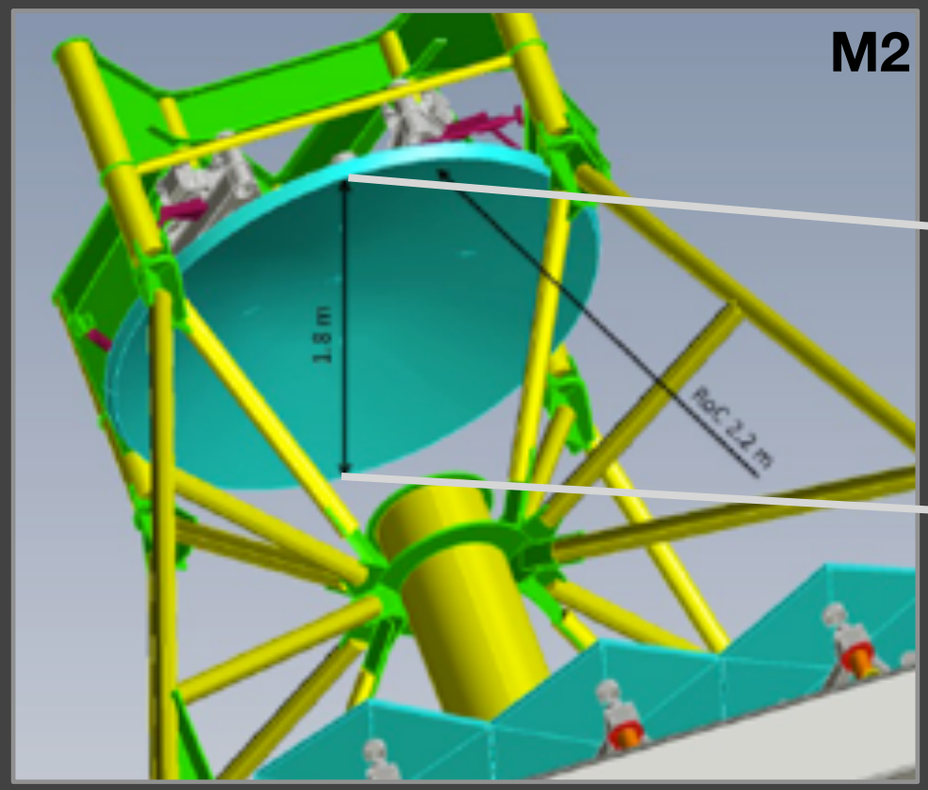
Primary mirror = 4.3m
Optical design = Schwarzchild-Couder
M1 type = Segmented (18, 3 concentric rings)
Secondary mirror = 1.8m (2.2m RoC)
M2 type = Monolithic
M1-M2 distance = 3m
Effective area = 6.5m2
F/D1 = 0.5, F = 2.15m

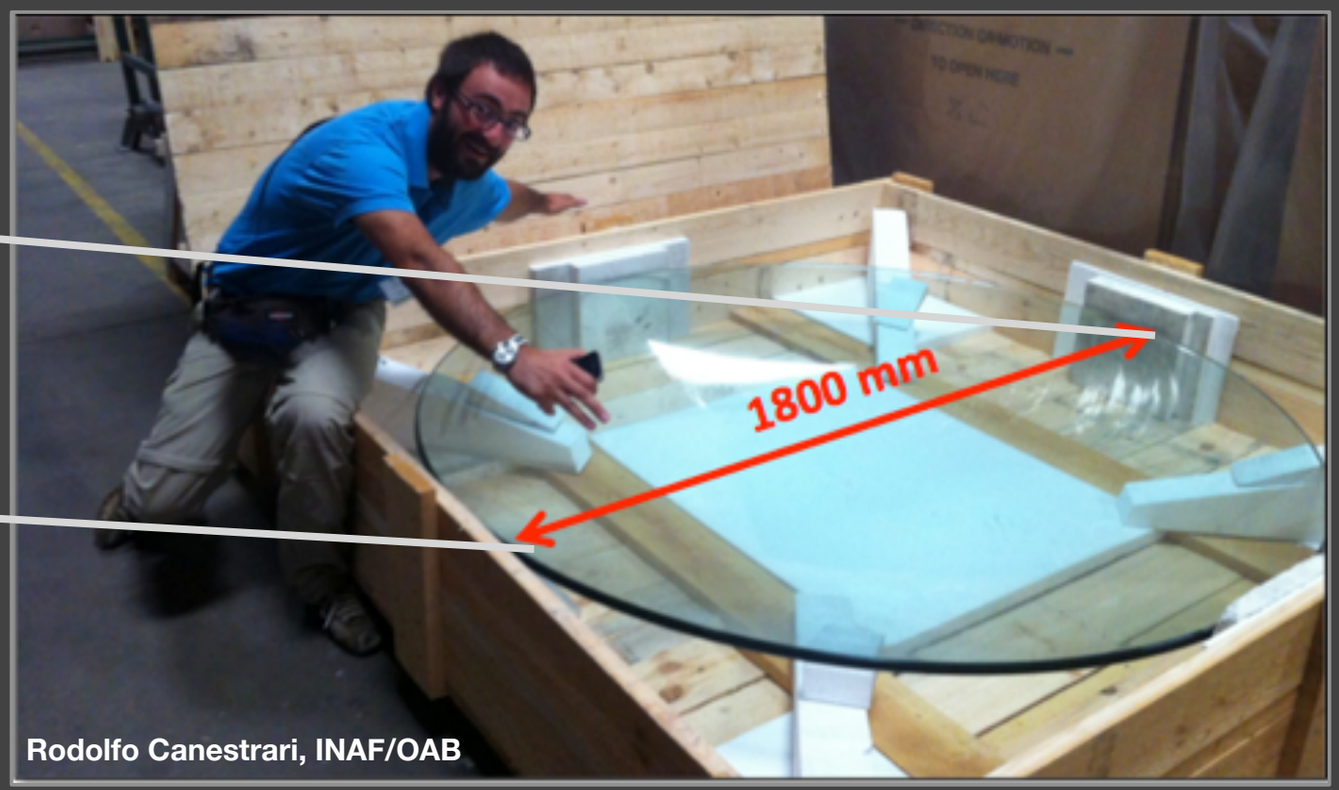
Camera properties

Number of logical pixels = 1984
Pixel size = 0.17° (plate scale = 37.5mm/°)
Field of View = 9.6°
Sensors type = SiPMs

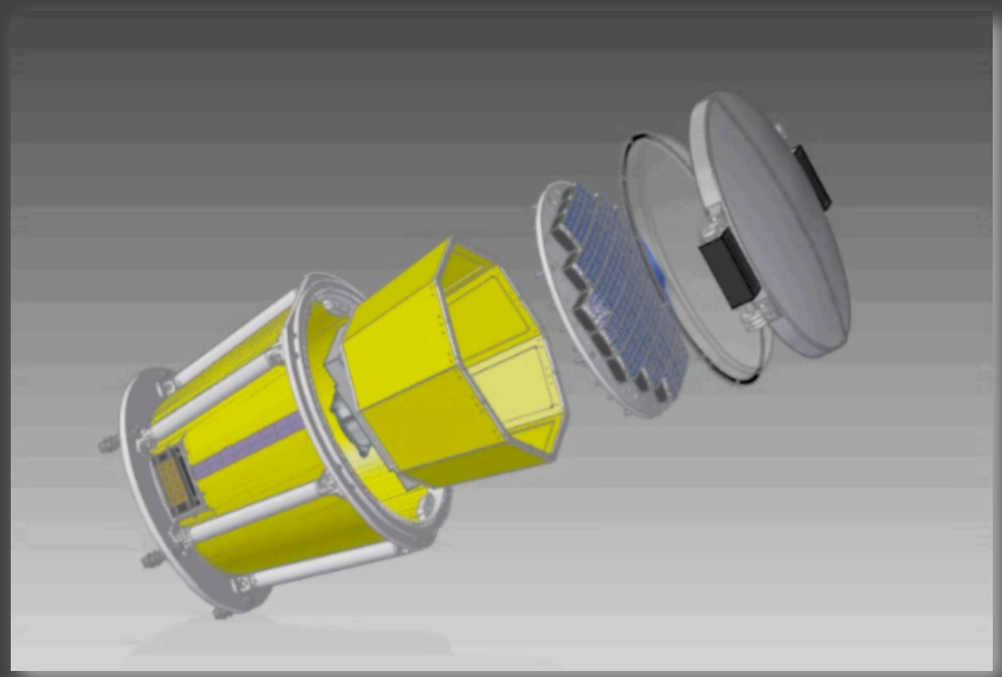



M1

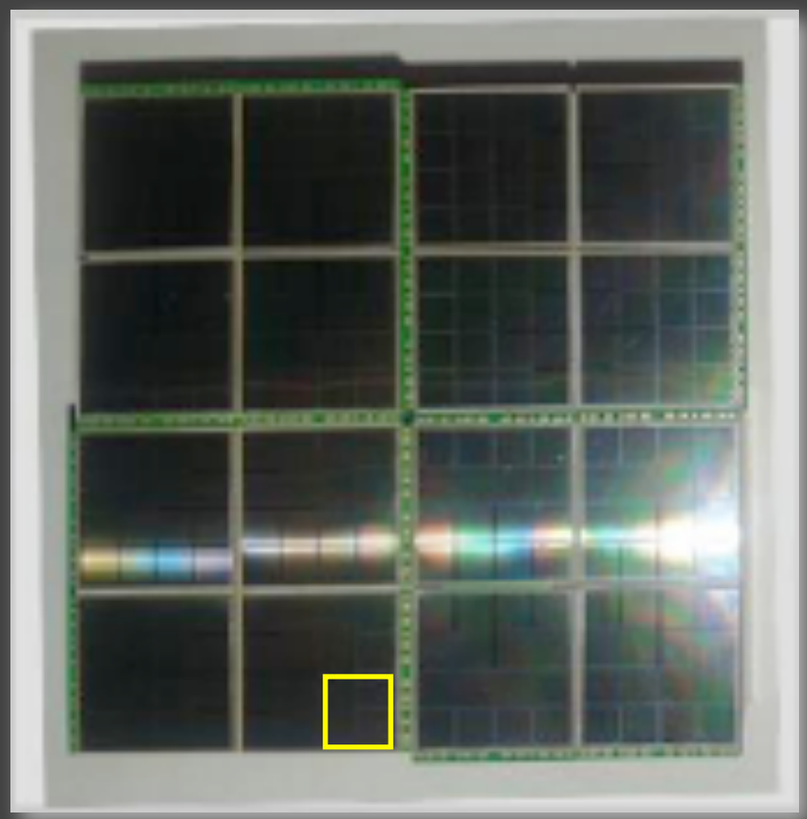

M2
1.8 m
RoC 2.2 m


1800 mm
Rodolfo Canestrari, INAF/OAB

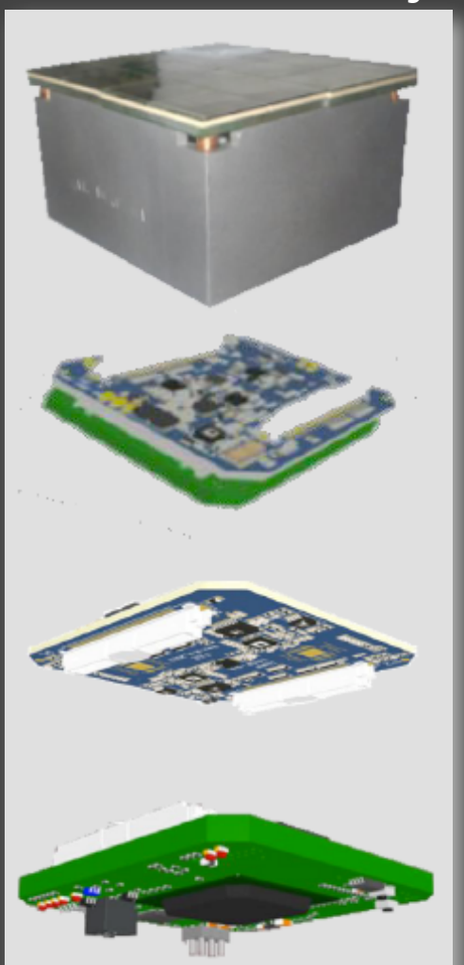
CTA & ASTRI



Photon Detection Module - PDM



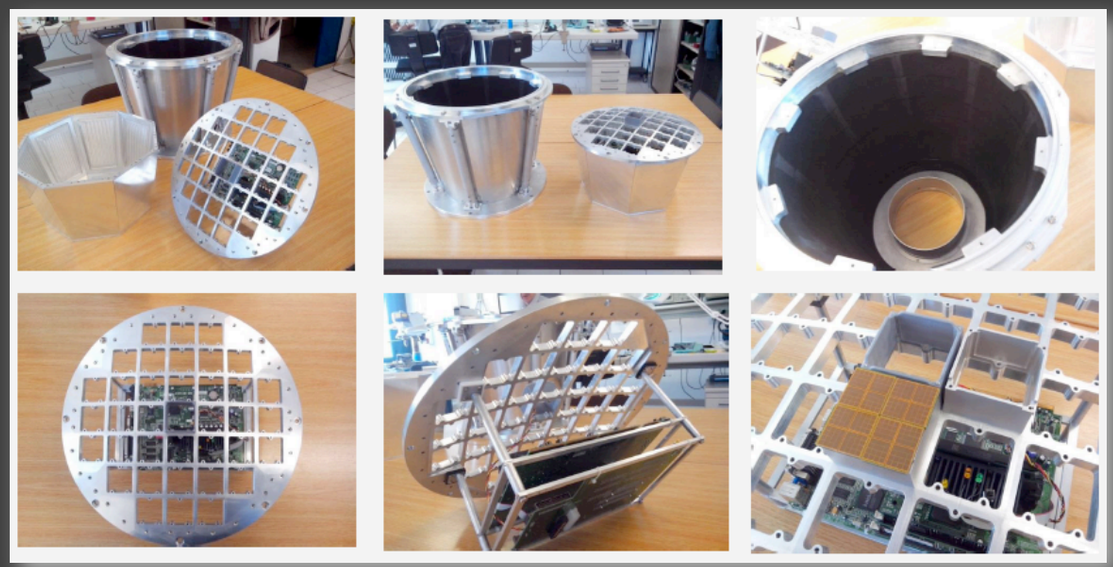
PDM assembly



Take away numbers

All parts fully integrated in the camera body
Logical pixel size = 6.2mm x 6.2mm
Number of pixels = 1984
Field of view = 9.6° (RoC = 1m)
Weight ~ 50kg
FFE ASIC = CITIROC [signal shaper]
Photo-sensors = SiPMs (S11828-3344M, other sensors under test for the ASTRI/CTA mini-array)

Camera Mechanics



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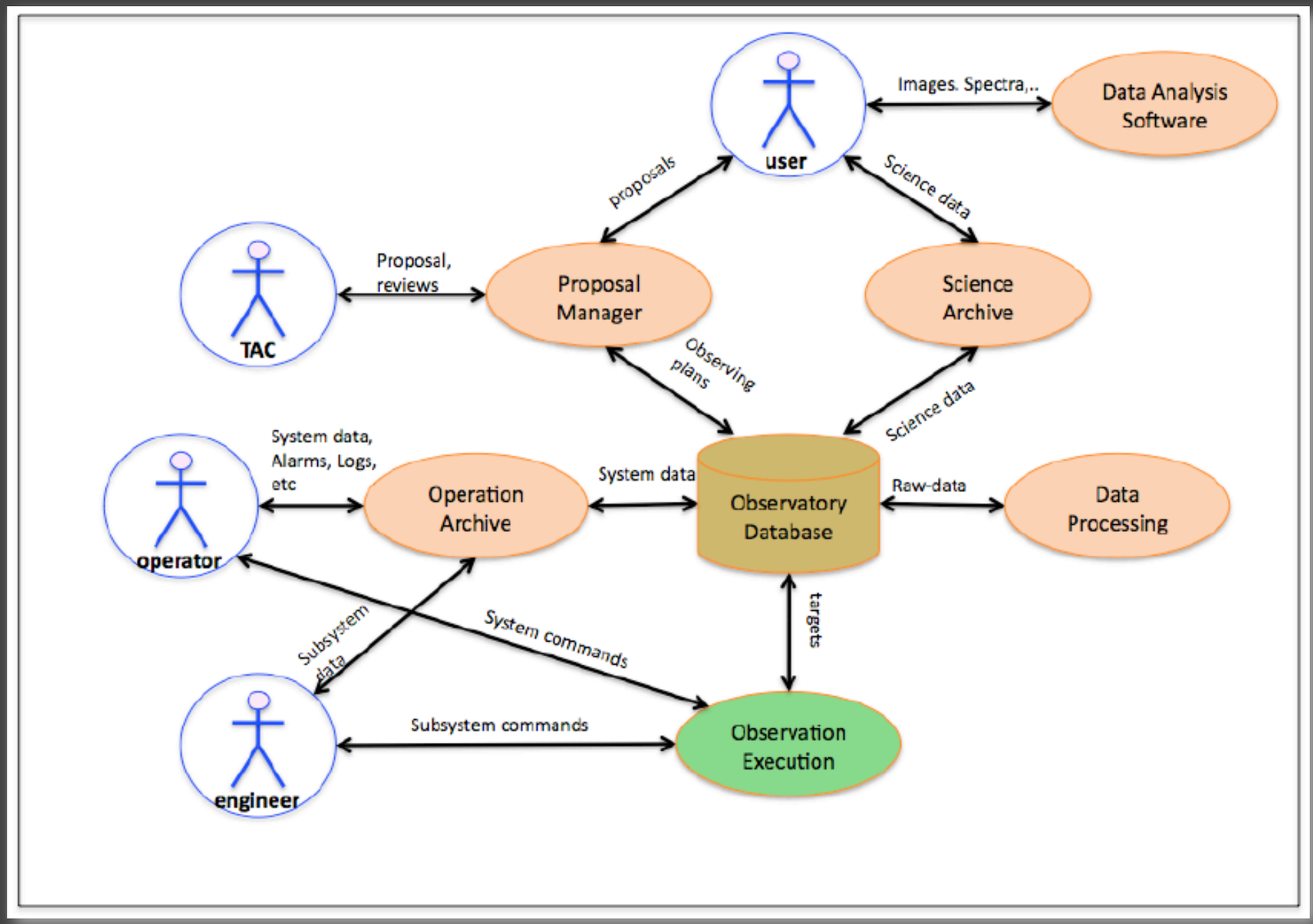
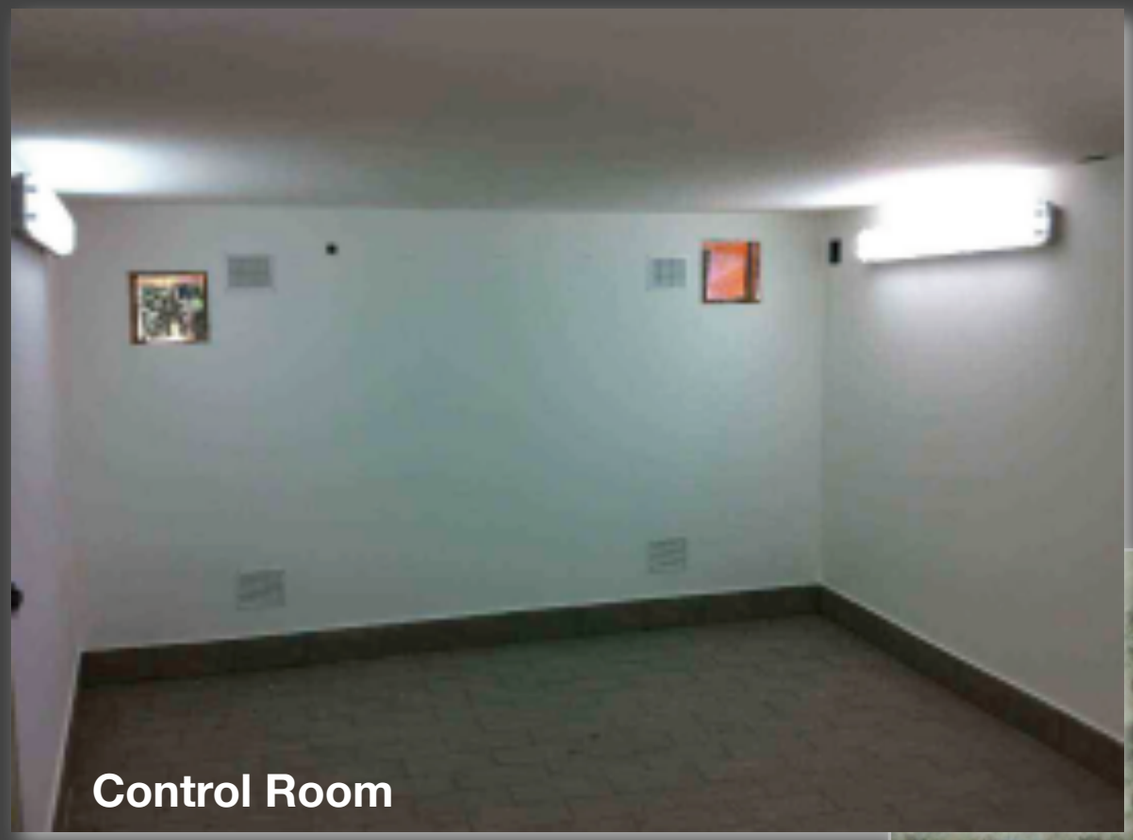


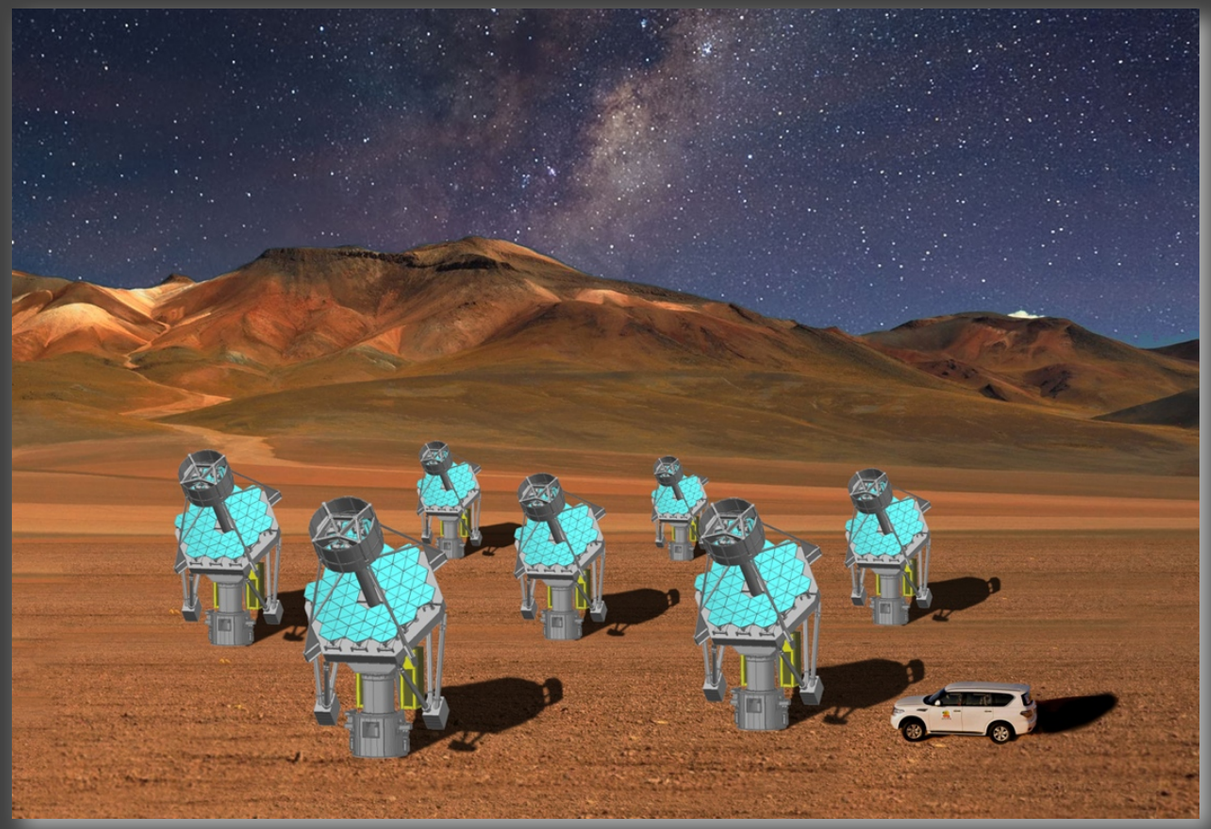
An end-to-end prototype requires a complete software chain, from the scheduling of the observations down to the data analysis and final data archiving. All the CTA standards (e.g., ACS, OPC-UA, FITS, DL0-DL4…) will be adopted.

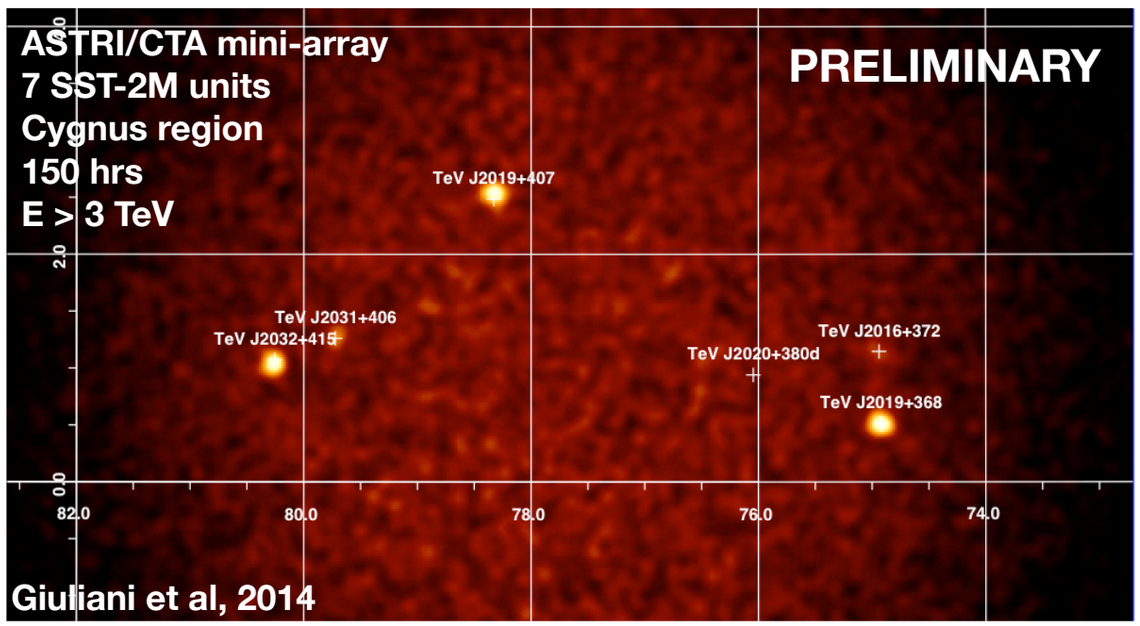
CTA & ASTRI


Control Room

The ASTRI SST-2M prototype will be installed at the INAF Facility on Mt. Etna (Sicily) at 1735m a.s.l.. The location altitude and the end-to-end approach will allow us to perform observations of the Crab, MKN 501 and MKN 421.

CTA & ASTRI





INAF and INFN proposed last year a joint "Progetto Premiale" **TECHE.it** (**TE**lescopi **CHE**renkov made in **IT**aly) to the Ministry of Research.

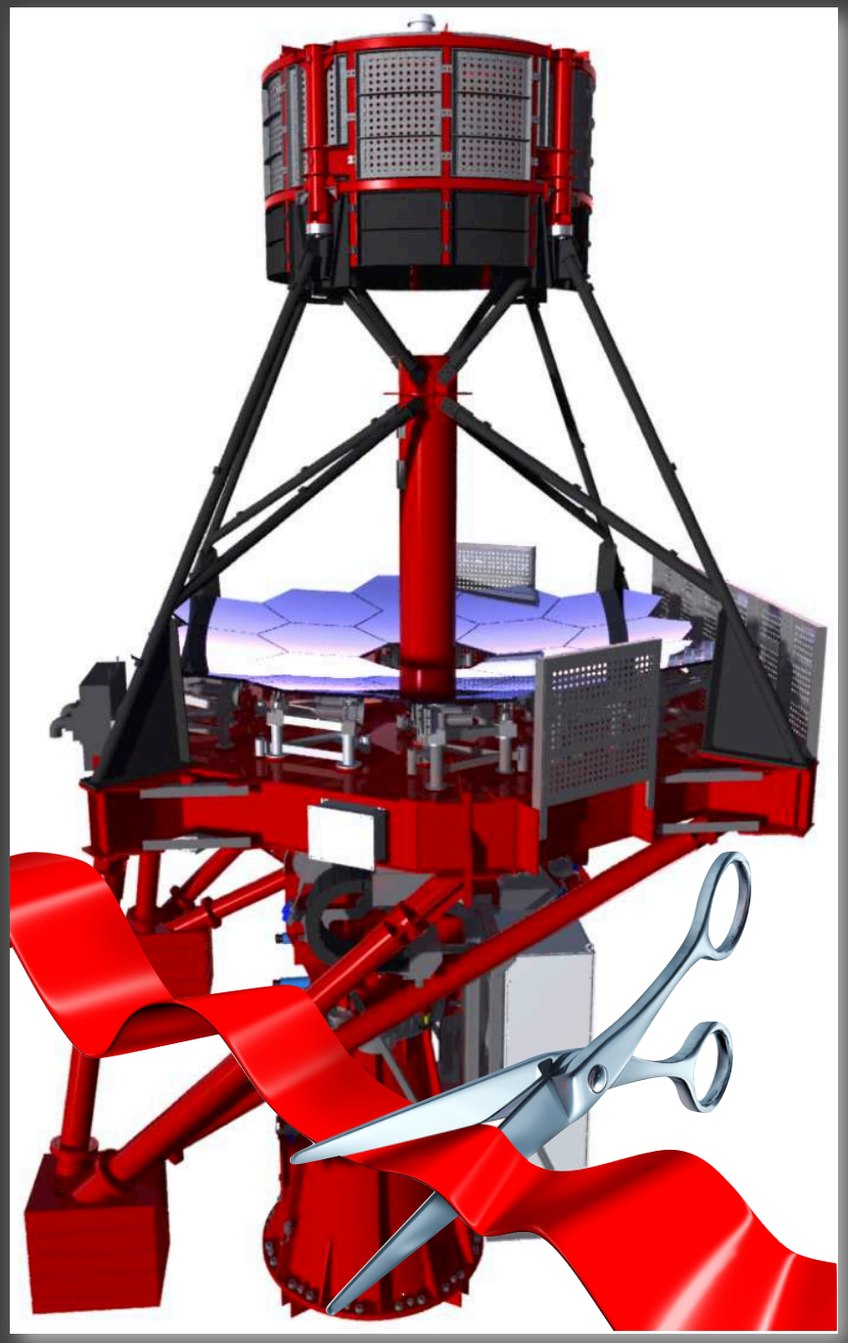
We made aware at the end of March that we obtained a total of about 3M€ (~2M€ INAF + ~1M€ INFN).

The INAF budget will be devoted to both technological and SW contributions.

Contribution from the North-West University, Potchefstroom, South Africa (~250k€).

Very likely contribution from the Universidade de São Paulo, Brasil (~1.5M€).

CTA & ASTRI



INAF/OACt will host the CTA Consortium Meeting on September 22-26 2014.

The official inauguration of the ASTRI SST-2M prototype will be held at the INAF Observing Station in Serra La Nave (Mt. Etna) during the Meeting.

Commissioning and science performance verification phases will start in October 2014 and continue up to mid 2015.

Scientific operations should start in Summer 2015.

The information obtained during the day-by-day scientific activities will be of paramount importance to tailor the re-assessment phase prior to the ASTRI/CTA mini-array development and deployment.

Current and future space- and ground-based key projects will ensure to the INAF γ-ray astrophysicists

- bright days...
- ...and hard work!