



La Fisica delle Astroparticelle a TS+UD

**Mirko Boezio**  
**INFN TS & IFPU**

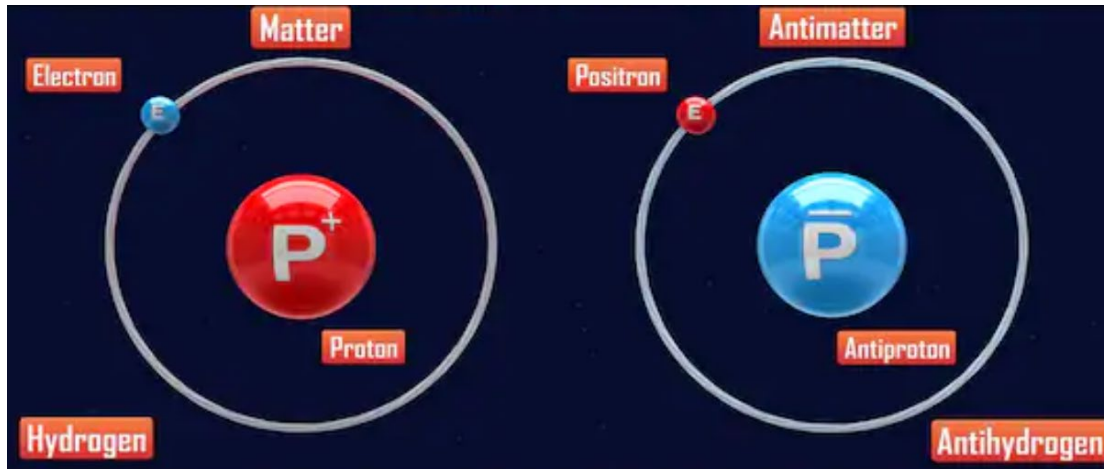




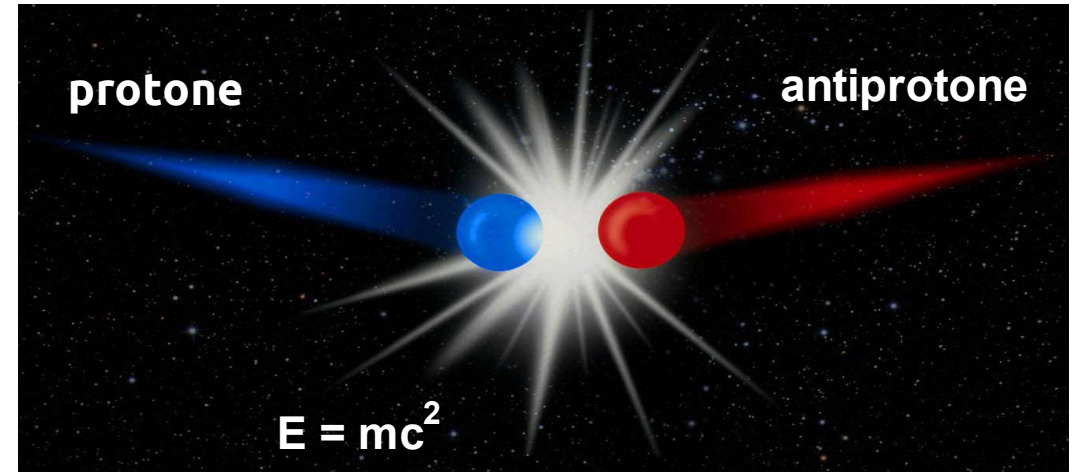
# GLI INIZI

# Antimateria

L'antimateria è del tutto simile alla materia ordinaria, ma con carica elettrica opposta.



Quando la materia e l'antimateria entrano in contatto si annichilano producendo energia.

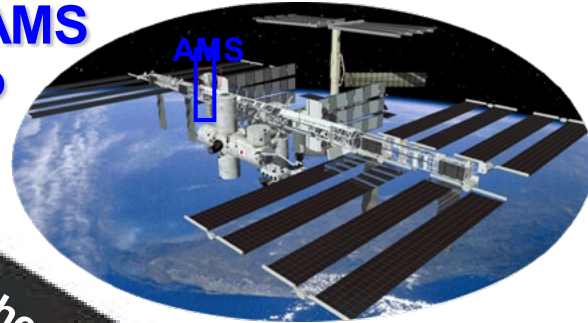


Il big bang ha prodotto un'eguale quantità di materia e antimateria. Perché l'universo è composto di materia?



# Il Mistero dell'Antimateria nell'Universo

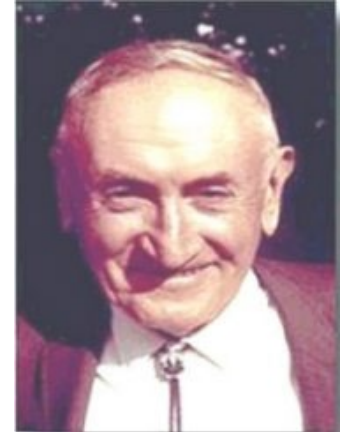
PAMELA e AMS  
nello Spazio



*L'origine dell'Universo con un Big Bang  
richiede che la materia e l'antimateria siano state  
nei primi istanti egualmente abbondanti*



# Il Mistero della Materia Oscura



Fritz Zwicky  
14/2/1898, Varna (Bulgaria)  
8/2/1974 Pasadena

Nel 1933 Zwicky, osservando il movimento delle galassie nell'ammasso Coma, dedusse la presenza di materia non visibile che teneva maggiormente unite le galassie tra loro.

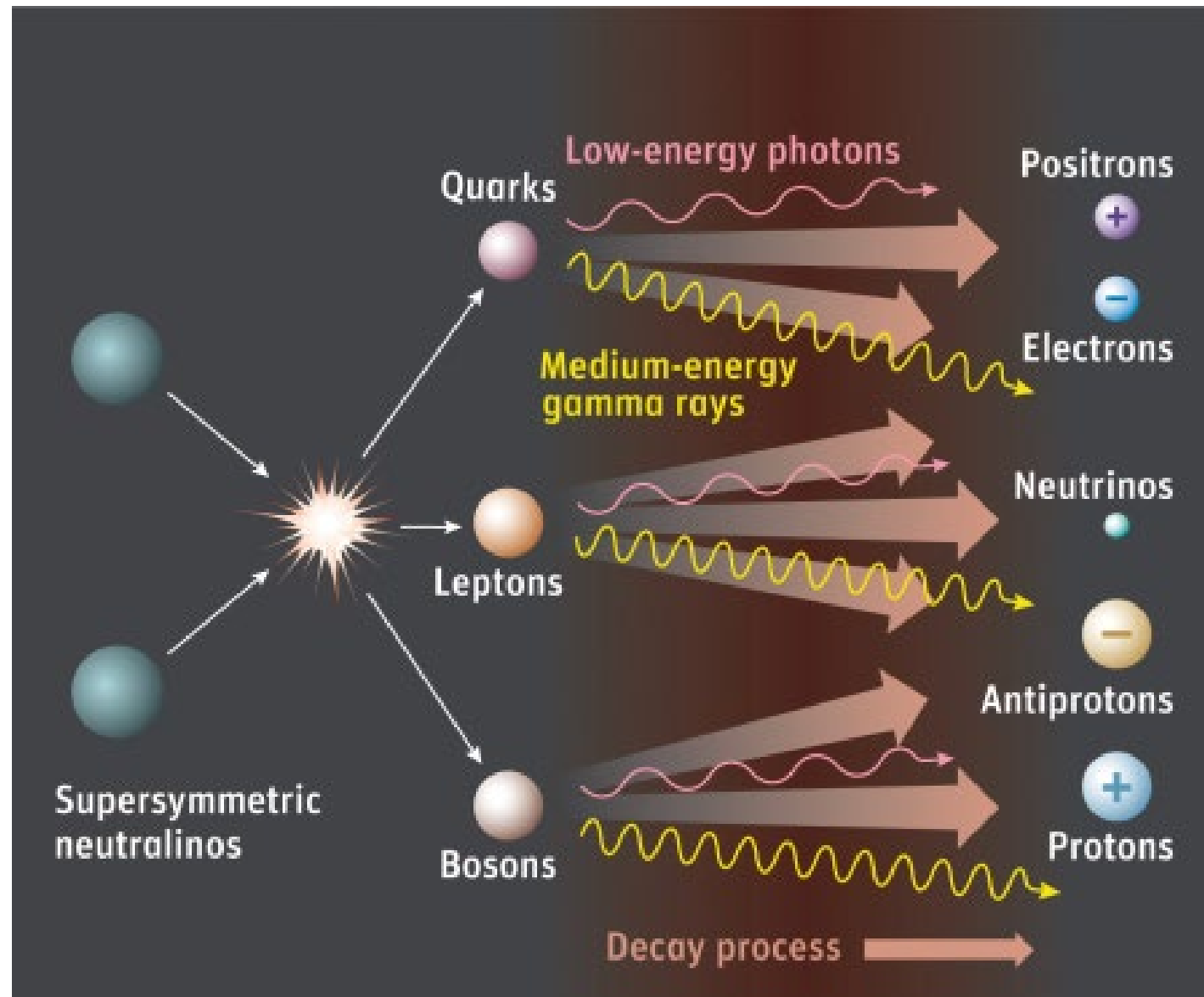
**...nessuno lo ascoltò per anni...**

**Eppur si muove!**



*Immagine a falsi colori: blu – visibile (Sloan Digital Sky Survey)  
Rosso e verde - Infrarosso (NASA's Spitzer Space Telescope)*

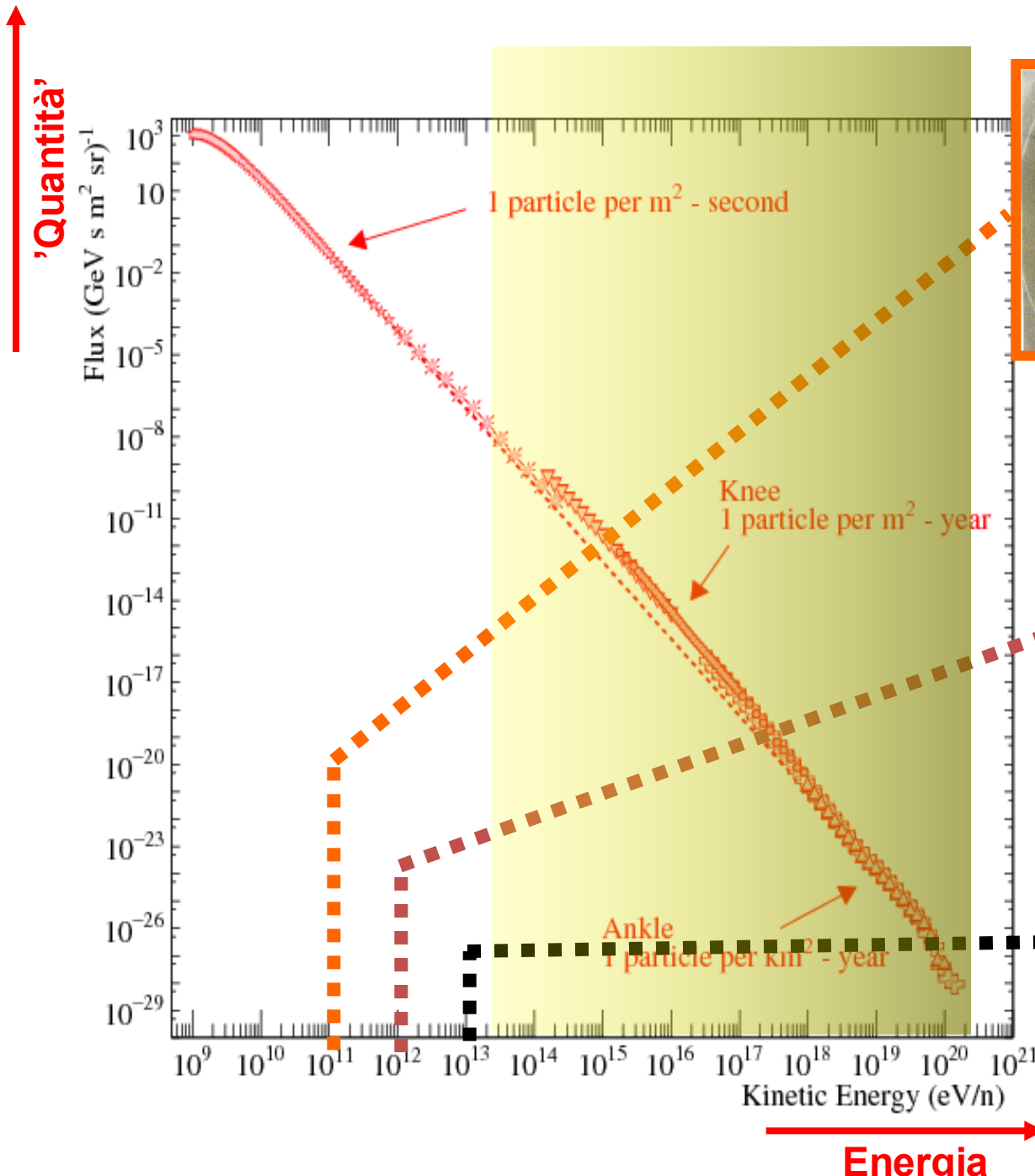
# Come scoprire la Materia Oscura?



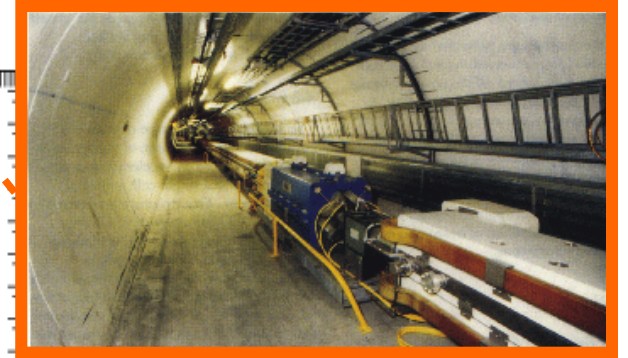


# I Raggi cosmici e le sorgenti di altissima energia

- Cosa sono i raggi cosmici?
- Quali sono le sorgenti?
- E quali quelle dei fotoni di alta energia?



[LEP / CERN]



[Tevatron / Fermilab]

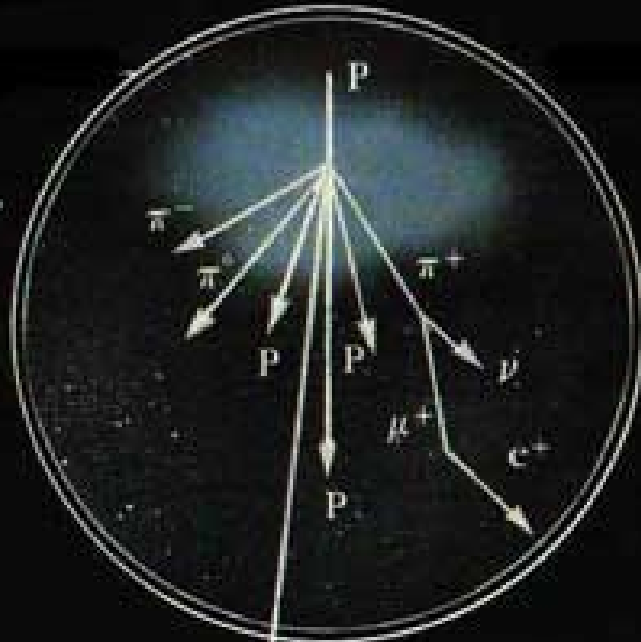


[LHC / CERN]

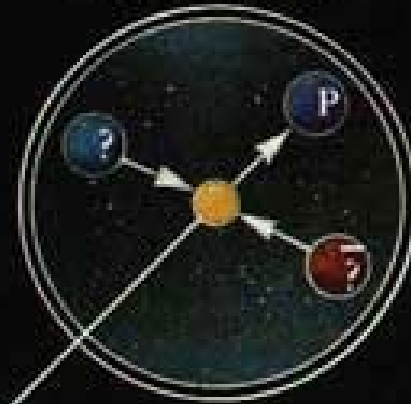


# ANTIMATERIA

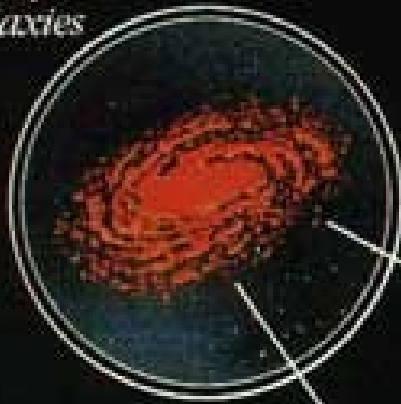
*Collisions of High Energy Cosmic Rays With the Interstellar Gas*



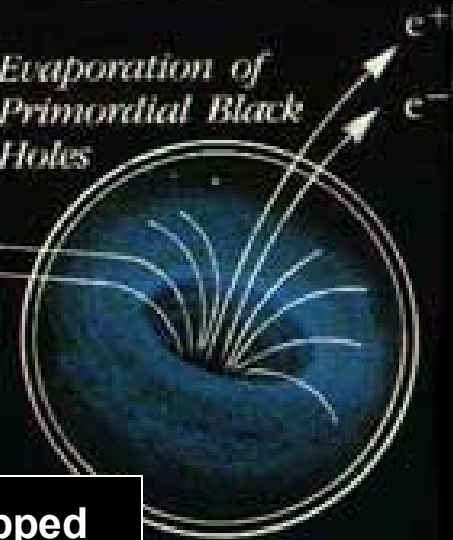
*Annihilation of Exotic Particles*



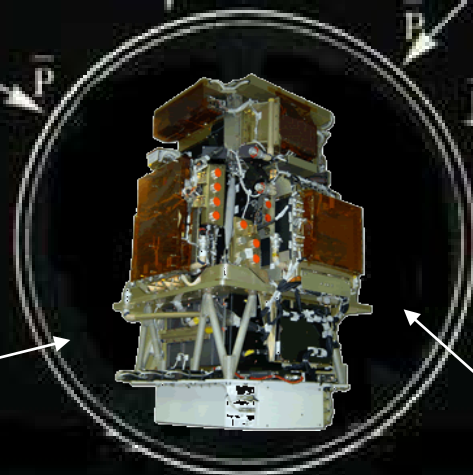
*Cosmic Rays Leaking Out of Antimatter Galaxies*



*Evaporation of Primordial Black Holes*



**Antimatter Lumps in our Galaxy**



**Trapped antiparticles**



# ASTROMAG - WIZARD

ASTROMAG: A SUPERCONDUCTING PARTICLE ASTROPHYSICS MAGNET FACILITY FOR THE SPACE STATION \*

M.A. Green, G.F. Smoot: Lawrence Berkeley Laboratory, Berkeley, CA 94720

R.L. Golden: New Mexico State University, Las Cruces, NM 88003

M. H. Israel: Washington University, St. Louis, MO 63130

R. Kephart, R. Niemann: Fermi National Accelerator Laboratory, Batavia, IL 60510

R.A. Mewalt: California Institute of Technology, Pasadena, CA 91125

J.F. Ormes: NASA Goddard Space Flight Center, Greenbelt, MD 20771

P. Spillantini: University di Firenze, I-50125 Firenze, Italy

M. E. Wiedenbeck: University of Chicago, Chicago, IL 60637

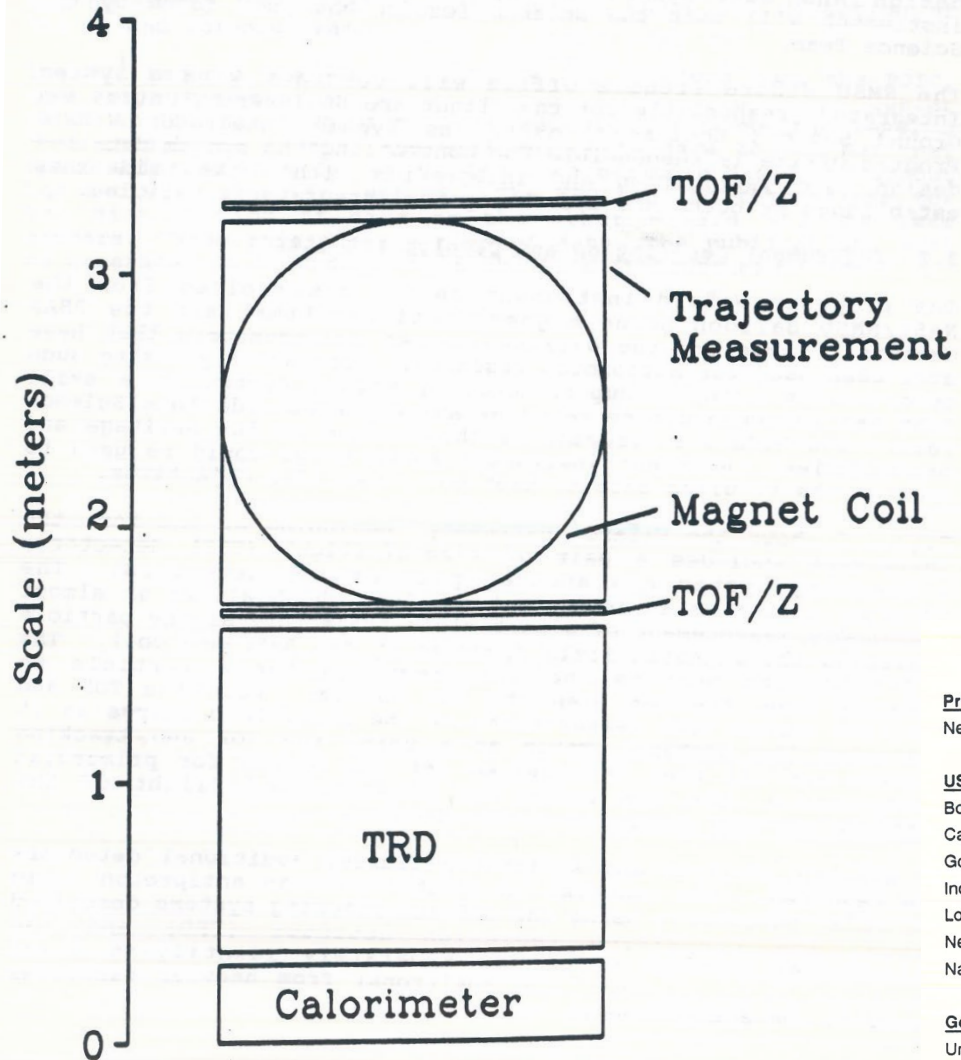


Figure 6. Wizard Instrument

THE WIZARD COLLABORATION

Principal Investigator:

New Mexico State University.....R. L. Golden

US Co-Investigators

- Boston University.....S. P. Ahlen, J. J. Beatty
- California, Univ. of.....H. J. Crawford, P. J. Lindstrom
- Goddard Space Flight Center.....J. F. Ormes, R. E. Streitmatter
- Indiana University.....C. R. Bower, R. M. Heinz, S. Mufson
- Louisiana State University.....T. G. Guzik, J. P. Wefel
- New Mexico State University.....S. A. Stephens
- Naval Research Laboratory.....J. H. Adams, K. E. Krombel, A. J. Tylka

German Co-Investigators

University of Siegen.....M. Simon, K. D. Mathis

Italian Co-Investigators

- Universita' di Bari.....C. De Marzo, B. Managelli
- Universita' di Firenze.....P. Spillantini, M. Bocciolini
- Laboratori Nazionali INFN.....G. Basini, M Ricci
- Universita' di Roma, Tor Vergata.....P. Picozza
- Universita' di Perugia.....A. Codino
- Laboratori Cosmogeofisica del CNR.....P. Calvetti
- Universita' di Trieste.....G. Barbiellini



MENU - ?

## Al Prof. Guido Barbiellini Amidei il Sigillo d'Argento della Provincia di Trieste

ne

Pubblicato il: 25/09/2015

Lunedì 28 settembre alle ore 11.00 verrà conferito il Sigillo d'Argento della Provincia di Trieste al Prof. Guido Barbiellini Amidei.

Il Prof. Barbiellini Amidei, professore ordinario di Fisica Generale presso il Dipartimento di Fisica dell'Università di Trieste, attualmente in quiescenza, vanta una lunga esperienza nel campo della Fisica delle Particelle elementari e nel campo dell'Astrofisica della radiazione cosmica di alta energia.

Ha lavorato per lunghi anni presso i laboratori dell'Istituto Nazionale di Fisica Nucleare di Frascati, poi ha proseguito la sua carriera al CERN di Ginevra dove è stato tra i responsabili dell'esperimento DELPHI, presso l'acceleratore LEP.

E' diventato professore ordinario all'Università di Trieste nel 1987 alla facoltà di Ingegneria, dove ha tenuto per molti anni il corso di Fisica Generale. E' stato successivamente direttore della sezione locale dell'Istituto Nazionale di Fisica Nucleare e membro del Consiglio di Amministrazione di ELETTRA.

Il Prof. Guido Barbiellini Amidei è attualmente co-principal investigator dell'esperimento AGILE dell'ASI ed è tra i membri fondatori dell'esperimento internazionale Fermi della NASA. Entrambi gli strumenti utilizzano i rivelatori al Silicio, proposti per un utilizzo spaziale proprio dal prof. Barbiellini Amidei nel 1987.



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-EP/88-57  
20 May 1988

### APPLICATION OF SILICON-DETECTOR TECHNOLOGY TO THE SPACE-LABORATORY EXPERIMENT ASTRO-MAG

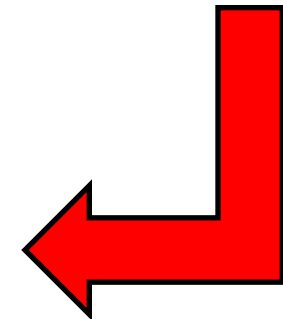
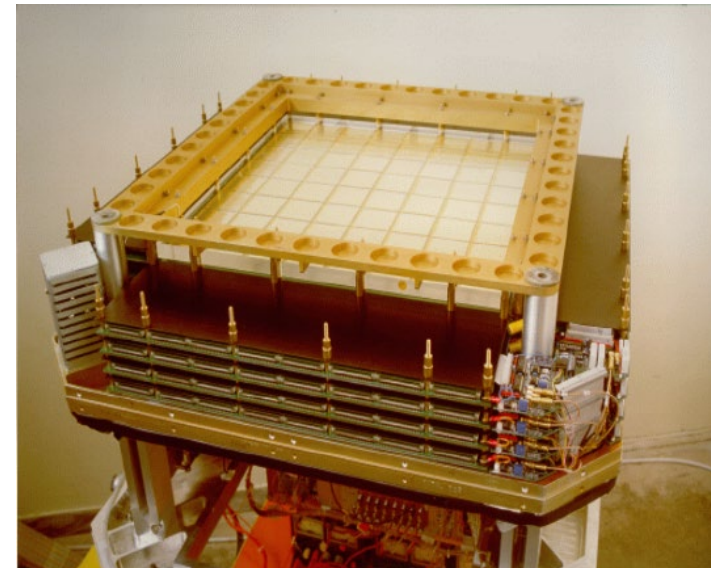
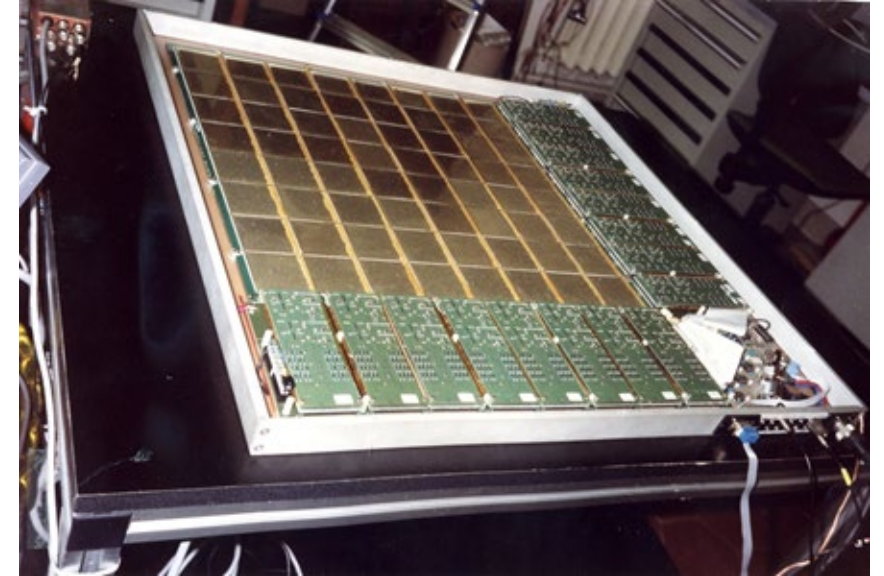
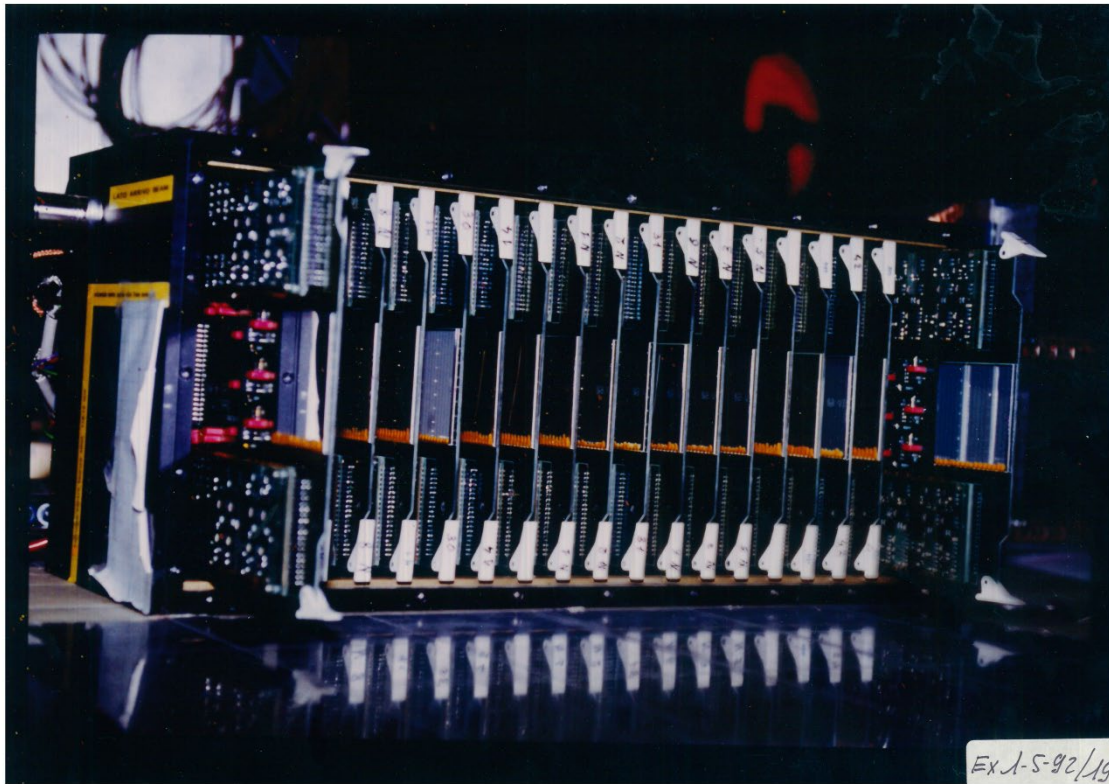
G. Barbiellini

INFN, Trieste, Italy  
and  
CERN, Geneva, Switzerland

Contributed paper to the  
First Meeting of the International Forum  
on Scientific Uses of the Space Station  
Venice, Italy - October 1987



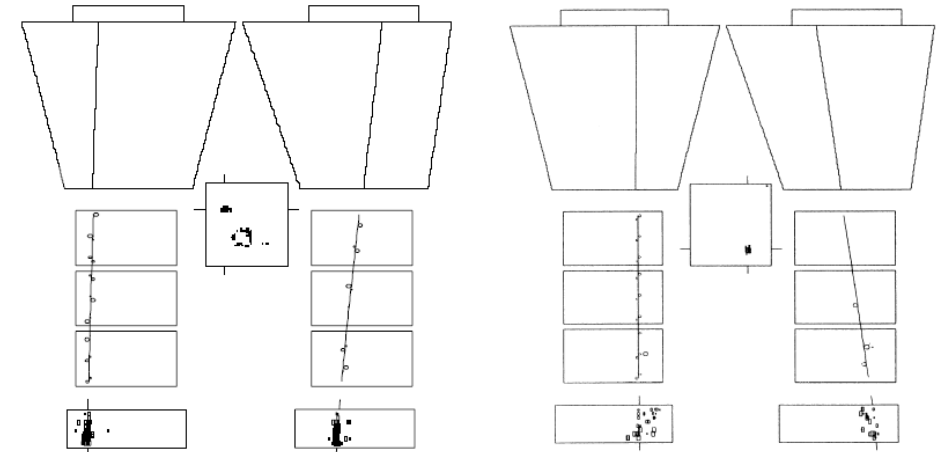
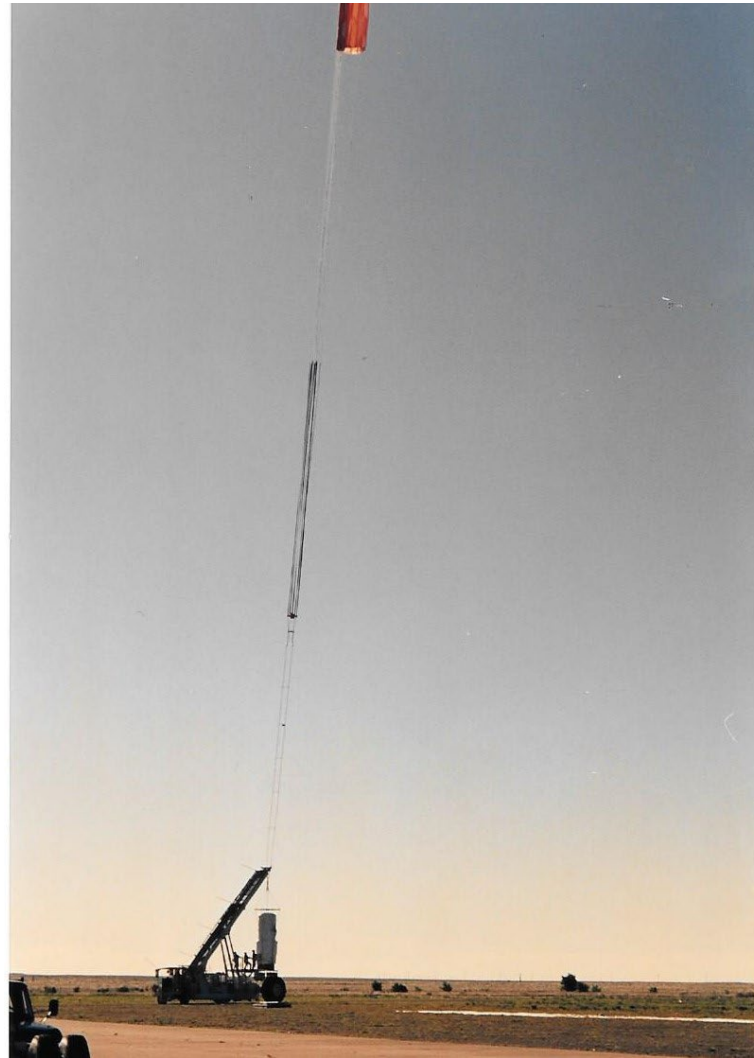
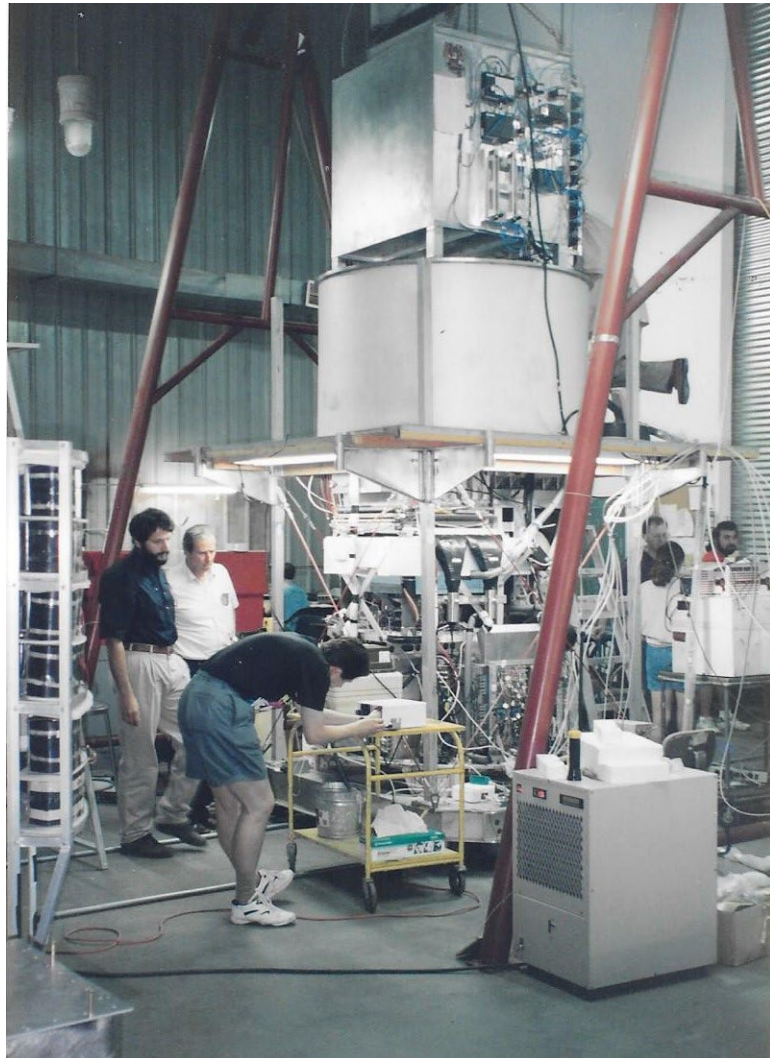
# Calorimetro Si-W: dai test alla realizzazione





# Esperimenti su pallone

MASS-89, 91, TS-93, CAPRICE  
94-97-98



THE ASTROPHYSICAL JOURNAL, 561:787-799, 2001 November 10  
© 2001. The American Astronomical Society. All rights reserved. Printed in U.S.A.

THE COSMIC-RAY ANTIPROTON FLUX BETWEEN 3 AND 49 GeV  
M. BOEZIO,<sup>1</sup> V. BONVICINI, P. SCHIAVON, A. VACCHI, AND N. ZAMPA  
Dipartimento di Fisica dell'Università and Sezione INFN di Trieste, Via A. Valerio 2, I-34147 Trieste, Italy

⋮



# The First Russian-Italian Meeting

## The first protocol

**PROTOCOL**  
of the discussions held in Moscow on May 24-26, 1993,  
between INFN and Moscow Engineering Physics Institute  
(MEPhI) on collaboration in Astroparticle Physics

Following the letter of the INFN President of May 19, 1993, (see Annex 1 to the present Protocol), an INFN Delegation visited from 24 to 26 May 1993 MEPhI in order to discuss a possible collaboration in the field of Astroparticle Physics.

The INFN Delegation, composed by Prof. P.G.Picozza, Vice-President of INFN, by Prof. P.Spillantini, Director of the INFN Section of Florence, and by Dr. M.Gigliarelli-Fiumi, Director for INFN International Affairs, met Prof. A.V. Shalnov, Rector of MEPhI and Prof. A.Galper, Head of C.Ph. Laboratory of MEPhI.

During these discussions the main lines of a joint research work on a large  $\gamma$ -ray telescope have been agreed and presented in Annex 2 to the present Protocol. Results of discussion have been included in Annex 3.

The two parties also took note of the offer made by the All-Russian Research Institute of Electromechanics (VNIIEM) of Moscow declaring their readiness to grant the installation of a silicon telescope to search for  $\gamma$ -ray sources in the energy range between 100 MeV and 100 GeV in their satellite which, according to their programs, is scheduled to be launched in 1996-97.

INFN and MEPhI agreed that a detailed feasibility study of all the scientific and technical aspects, in particular related to the installation of the silicon detector in the satellite, is needed.

Such a study, to be completed by 30 October, 1993, should be contracted by INFN to VNIIEM.

INFN and MEPhI, however, will follow in close co-operation with VNIIEM, the development of the above study.

Finally, INFN and MEPhI agreed that a specific "Memorandum of Understanding" between the two Institutions should be concluded in view of better implementing their scientific collaboration. It was also agreed the joint work program to be carried out before 30 October 1993 ( Annex 4)

Prof. P.G.Picozza - INFN



Prof. A.Galper - MEPhI



26.05.93



# Collaborazione RIM&PAMELA



Italy:



Bari



Florence



Frascati



Naples



Rome



Trieste



CNR, Florence



agenzia spaziale italiana



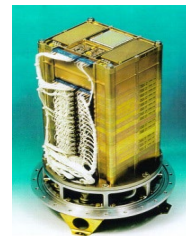
**SILEYE-1**  
1995



**SILEYE-2**  
1998



**ALTEINO:  
SILEYE-3**



**NINA 1**  
1998



**NINA 2**  
2000

Russia:



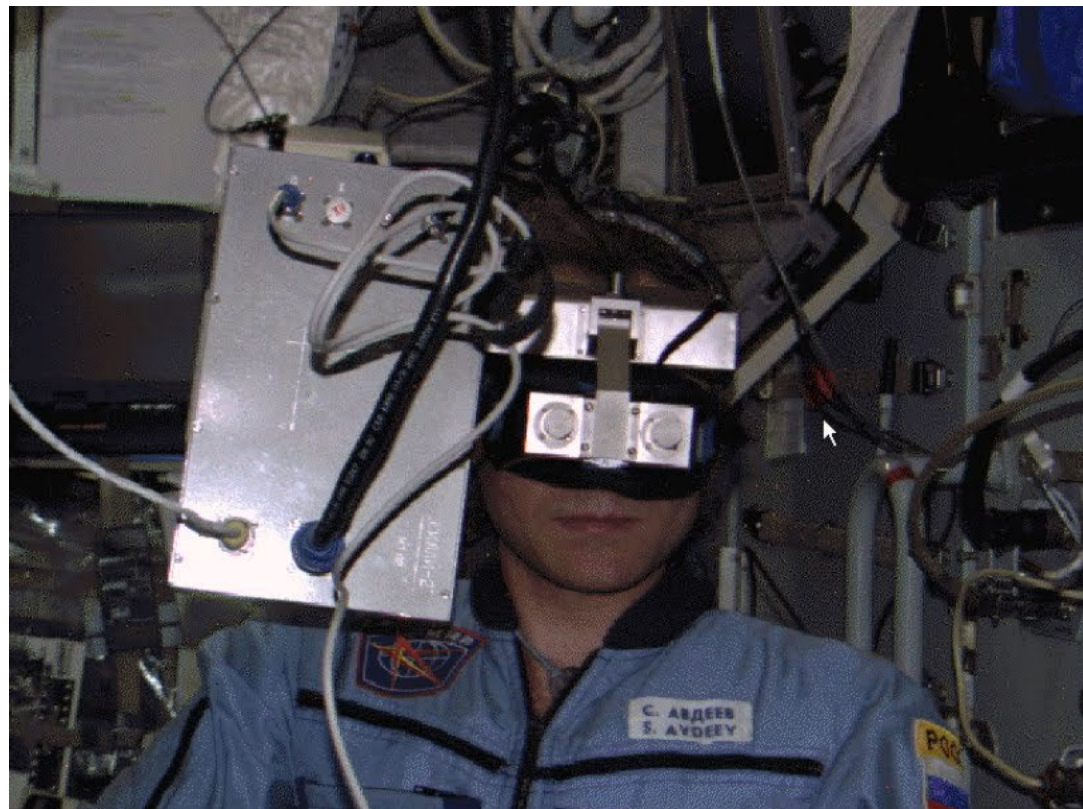
Moscow  
St. Petersburg

Germany:  Universität  
Gesamthochschule  
Siegen  
Siegen

Sweden:  KUNGL  
TEKNISKA  
HOGSKOLAN  
KTH, Stockholm



# Rivelatori di radiazione nello spazio

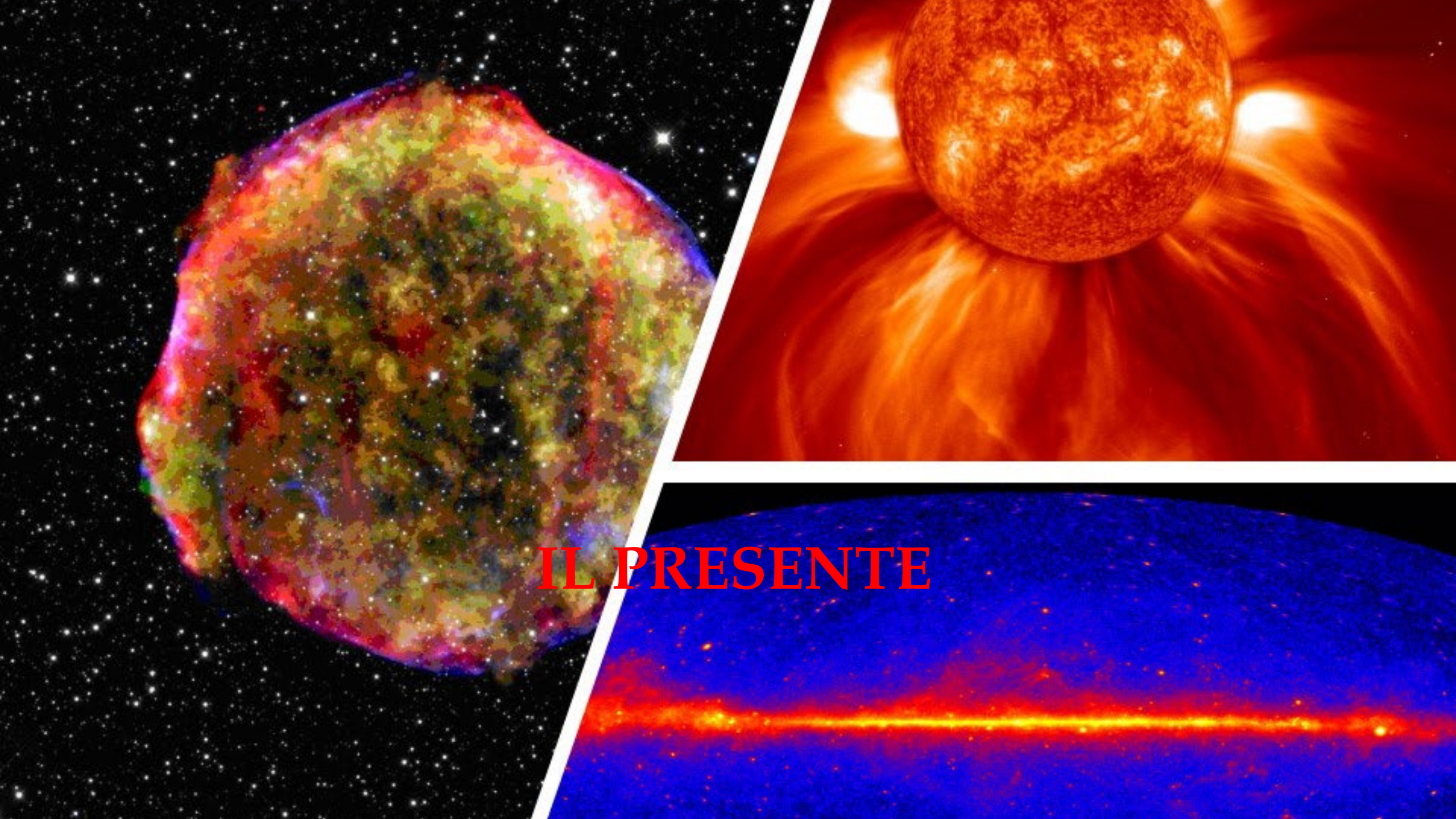


Cosmonaut Sergej Avdeev  
SILEYE-1 on MIR space station 1995



Astronauta Roberto Vittori  
Alteino sulla ISS 1995





**IL PRESENTE**



# L'Apparato PAMELA



Italy:



Bari



Florence



Frascati



Naples



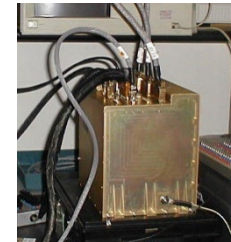
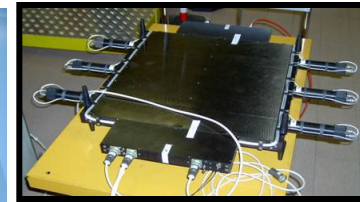
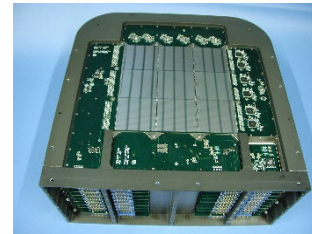
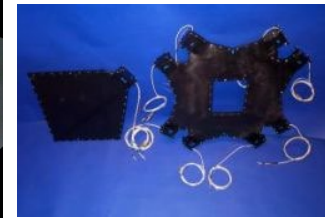
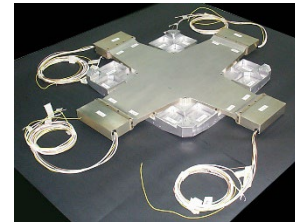
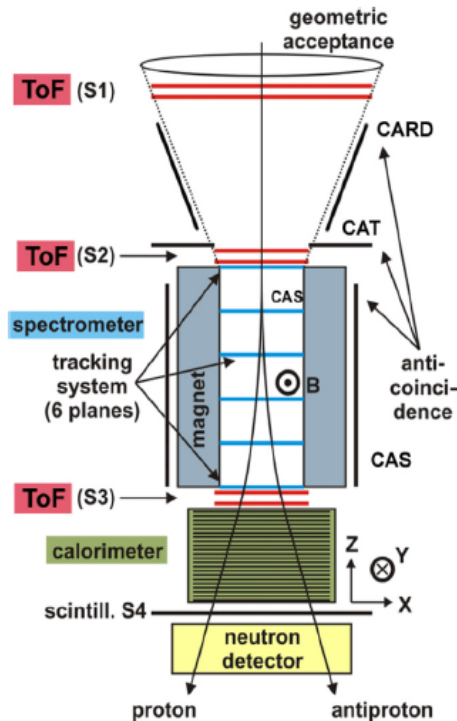
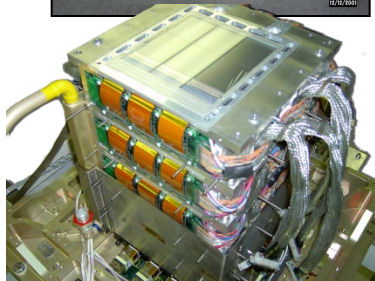
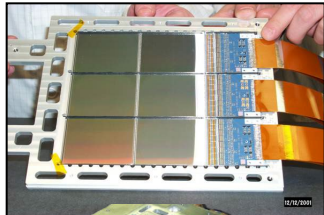
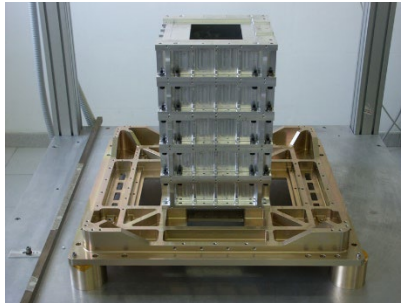
Rome



Trieste



CNR, Florence



Russia:



Moscow  
St. Petersburg

Germany:  Universität Gesamthochschule Siegen  
Siegen

Sweden:  KUNGL. TEKNISKA HÖGSKOLAN  
KTH, Stockholm

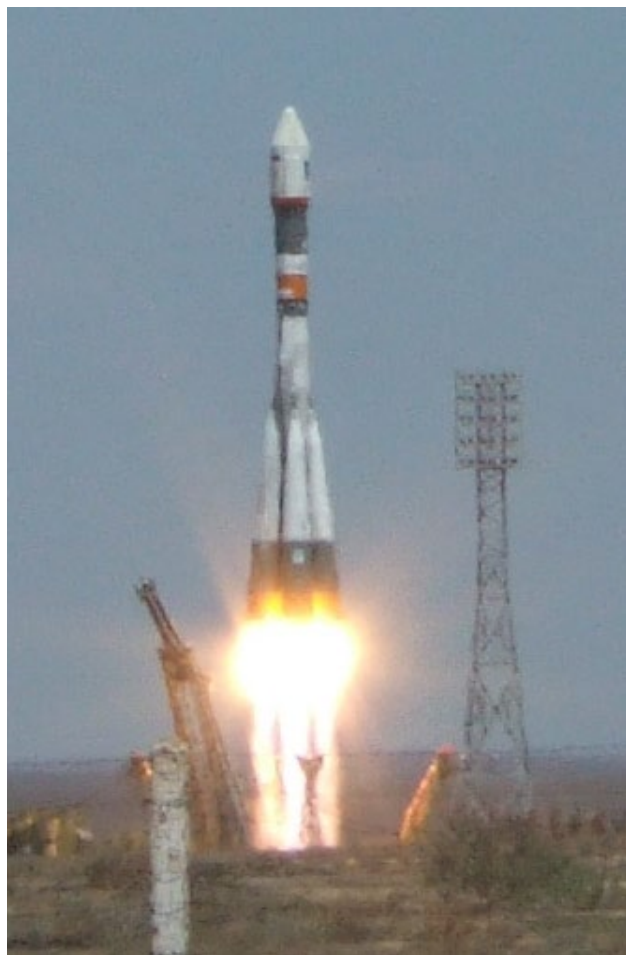


# Al sito di lancio: Baikonur.

14 giugno 2006



# Lancio - 15 giugno 2006



Home > News

## NEWS

Nature - 16 giugno 2006

Published online: 16 June 2006; | doi:10.1038/news060612-15

### PAMELA, or virtue rewarded

**After a decade's work, physicists are flying an antimatter observatory.**

Mark Peplow

The first satellite built to detect antimatter in space launched safely yesterday, boosting the chances of identifying the mysterious 'dark matter' that makes up more than 80% of the stuff in the Universe.

The PAMELA probe (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics) took off from the Baikonur Cosmodrome in Kazakhstan on 15 June, carrying instruments that will catch antiprotons and positrons, the mirror particles of protons and electrons.

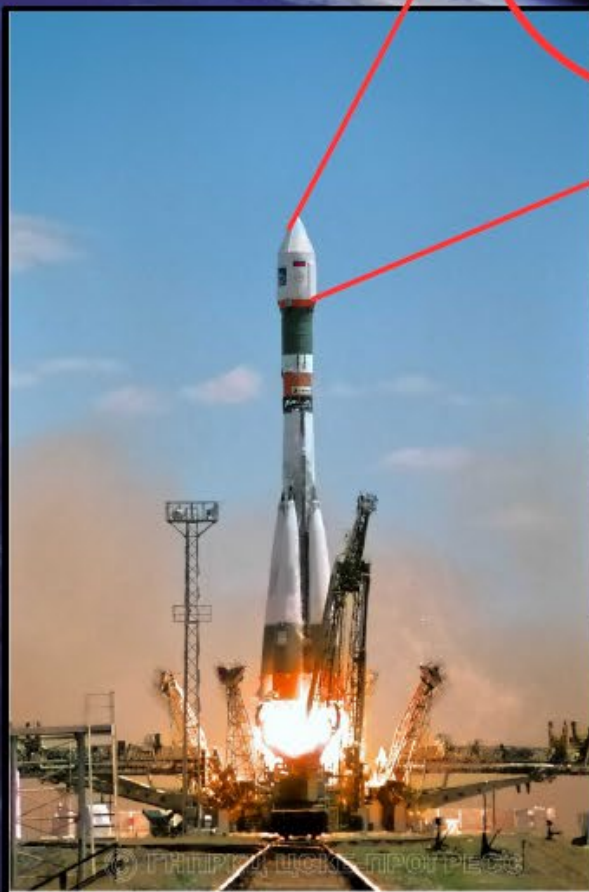


The PAMELA satellite: [click here](#) to see detailed diagram.

High-energy particles from elsewhere



# Launch: 15 June 2006 – Stopped in January 2016

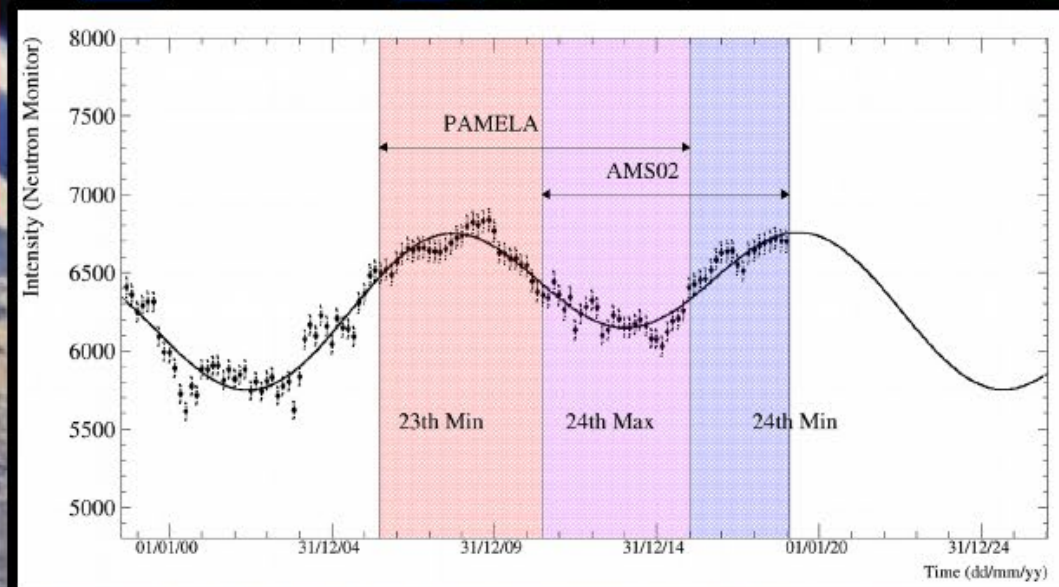
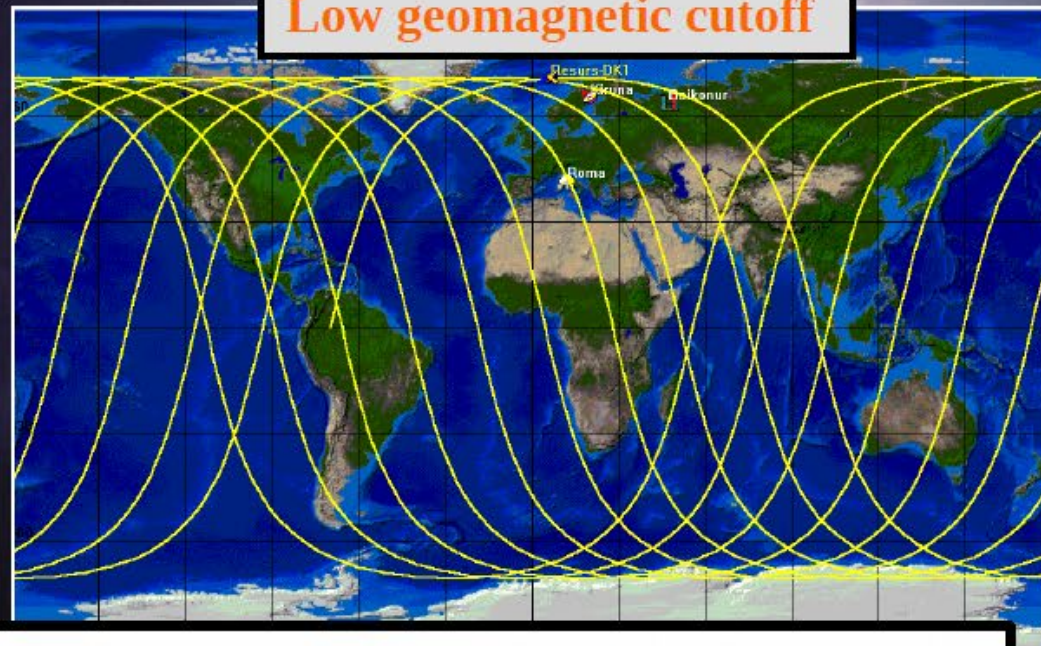


Пуск РН «Союз-У» с КА «Ресурс-ДК1». 15 июня 2006 год.

Quasi-polar elliptical orbit  
70 degree inclination  
350/610 km.  
Allows to measure low  
energy particles (70 MeV  
electrons)

Long flight duration: 10  
years of data  
Allows to test model  
over different period of  
solar activity

## Low geomagnetic cutoff



# A Worldwide Success

## Top 10, 2008

Vol 458 | 2 April 2009 | doi:10.1038/nature07942

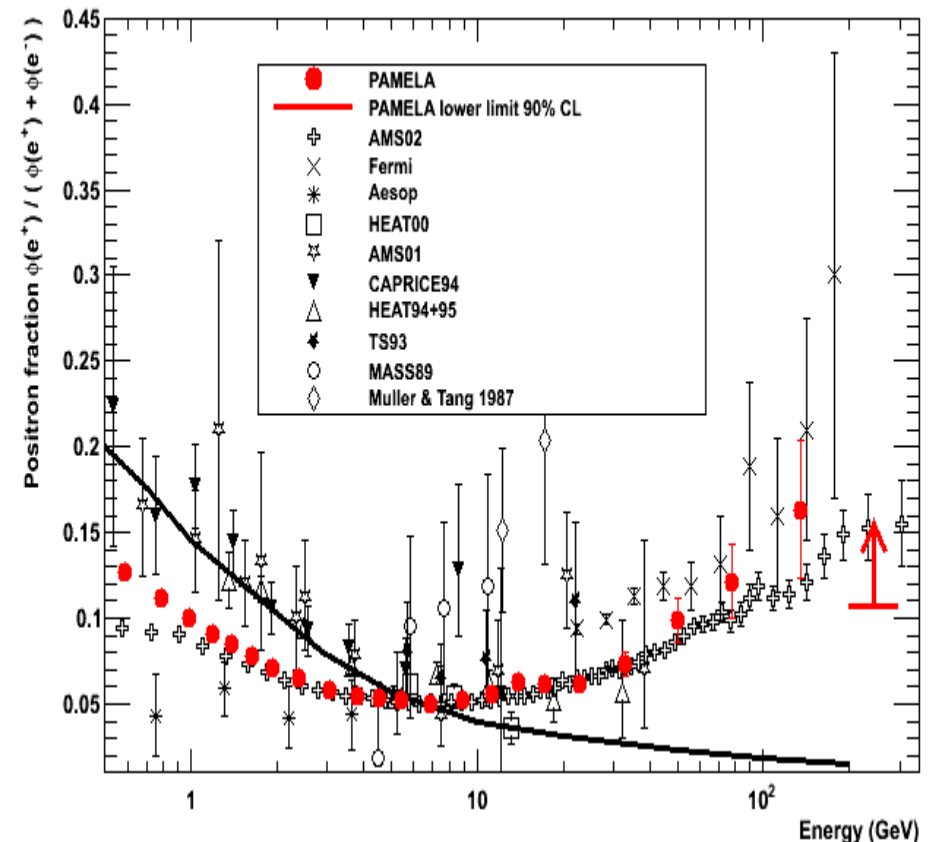
nature

LETTERS

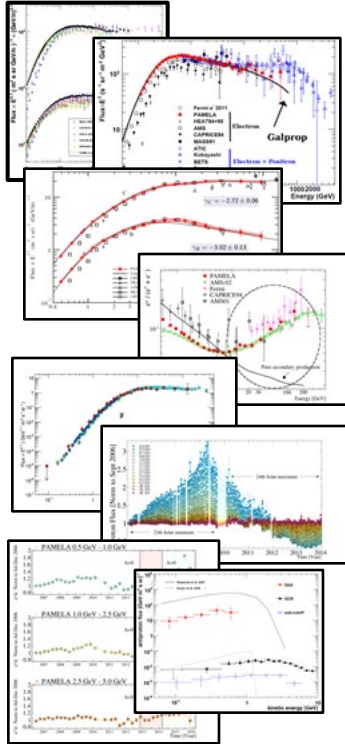
### An anomalous positron abundance in cosmic rays with energies 1.5–100 GeV

O. Adriani<sup>1,2</sup>, G. C. Barbarino<sup>3,4</sup>, G. A. Bazilevskaya<sup>5</sup>, R. Bellotti<sup>6,7</sup>, M. Boezio<sup>8</sup>, E. A. Bogomolov<sup>9</sup>, L. Bonechi<sup>1,2</sup>, M. Bongi<sup>2</sup>, V. Bonvicini<sup>8</sup>, S. Bottai<sup>2</sup>, A. Bruno<sup>6,7</sup>, F. Cafagna<sup>7</sup>, D. Campana<sup>4</sup>, P. Carlson<sup>10</sup>, M. Casolino<sup>11</sup>, G. Castellini<sup>12</sup>, M. P. De Pascale<sup>11,13</sup>, G. De Rosa<sup>4</sup>, N. De Simone<sup>11,13</sup>, V. Di Felice<sup>11,13</sup>, A. M. Galper<sup>14</sup>, L. Grishantseva<sup>14</sup>, P. Hofverberg<sup>10</sup>, S. V. Koldashov<sup>14</sup>, S. Y. Krutkov<sup>9</sup>, A. N. Kvashnin<sup>5</sup>, A. Leonov<sup>14</sup>, V. Malvezzi<sup>11</sup>, L. Marcelli<sup>11</sup>, W. Menn<sup>15</sup>, V. V. Mikhailov<sup>14</sup>, E. Mocchiutti<sup>8</sup>, S. Orsi<sup>10,11</sup>, G. Osteria<sup>4</sup>, P. Papini<sup>2</sup>, M. Pearce<sup>16</sup>, P. Picozza<sup>11,13</sup>, M. Ricci<sup>17</sup>, S. B. Ricciarini<sup>2</sup>, M. Simon<sup>15</sup>, R. Sparvoli<sup>11,13</sup>, P. Spillantini<sup>1,2</sup>, Y. I. Stozhkov<sup>5</sup>, A. Vacchi<sup>8</sup>, E. Vannuccini<sup>2</sup>, G. Vasilyev<sup>9</sup>, S. A. Voronov<sup>14</sup>, Y. T. Yurkin<sup>14</sup>, G. Zampa<sup>8</sup>, N. Zampa<sup>8</sup> & V. G. Zverev<sup>14</sup>

1921 citations and counting (source Scopus)



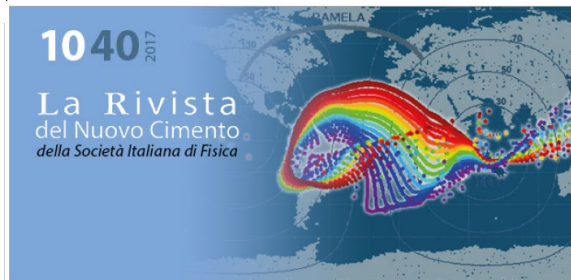




The PAMELA Mission: Heralding a new era in precision cosmic ray physics

O. Adriani<sup>ab</sup>, G.C. Barbarino<sup>cd</sup>, G.A. Bazilevskaya<sup>e</sup>, R. Bellotti<sup>f,g</sup>, M. Boezio<sup>h</sup>, E.A. Bogomolov<sup>i</sup>, M. Bongi<sup>ab</sup>, V. Bonvicini<sup>h</sup>, S. Bottai<sup>h</sup>, A. Bruno<sup>f,g</sup>, F. Cafagna<sup>g</sup>, D. Campana<sup>d</sup>, R. Carbone<sup>d,h</sup>, P. Carlson<sup>j,k</sup>, M. Casolino<sup>l</sup>, G. Castellini<sup>m</sup>, M.P. De Pascale<sup>ln,o</sup>, C. De Santis<sup>ln</sup>, N. De Simone<sup>l</sup>, V. Di Felice<sup>l</sup>, V. Formaro<sup>hp</sup>, A.M. Galper<sup>p</sup>, U. Giaccari<sup>q</sup>, A.V. Karelin<sup>r</sup>, M.D. Kheymits<sup>p</sup>, S.V. Koldashov<sup>p</sup>, S. Koldobskiy<sup>p</sup>, S.Yu. Krut'kov<sup>l</sup>, A.N. Kvashnin<sup>e</sup>, A. Leonov<sup>p</sup>, V. Malakhov<sup>p</sup>, L. Marcelli<sup>h</sup>, M. Martucci<sup>na</sup>, A.G. Mayorov<sup>p</sup>, W. Menn<sup>f</sup>, V.V. Mikhailov<sup>p</sup>, E. Mocchiutti<sup>h</sup>, A. Monaco<sup>f,g</sup>, N. Mori<sup>ab</sup>, R. Munini<sup>h,j,k,q</sup>, N. Nikonov<sup>ln</sup>, G. Osteria<sup>g</sup>, P. Papini<sup>h</sup>, M. Pearce<sup>jk</sup>, P. Piccozza<sup>ln,o</sup>, C. Pizzolotto<sup>h,ff</sup>, M. Ricci<sup>g</sup>, S.B. Ricciarini<sup>bp</sup>, L. Rosserio<sup>jk</sup>, R. Sarkar<sup>r</sup>, M. Simon<sup>f</sup>, R. Sparvoli<sup>ln</sup>, P. Spillantini<sup>ab</sup>, Y.I. Stozhkov<sup>e</sup>, A. Vacchi<sup>h</sup>, E. Vannuccini<sup>h</sup>, G.I. Vasilyev<sup>l</sup>, S.A. Voronov<sup>p</sup>, J. Wu<sup>jk,q</sup>, Y.T. Yurkin<sup>p</sup>, G. Zampa<sup>h</sup>, N. Zampa<sup>h</sup>, V.G. Zverev<sup>p</sup>

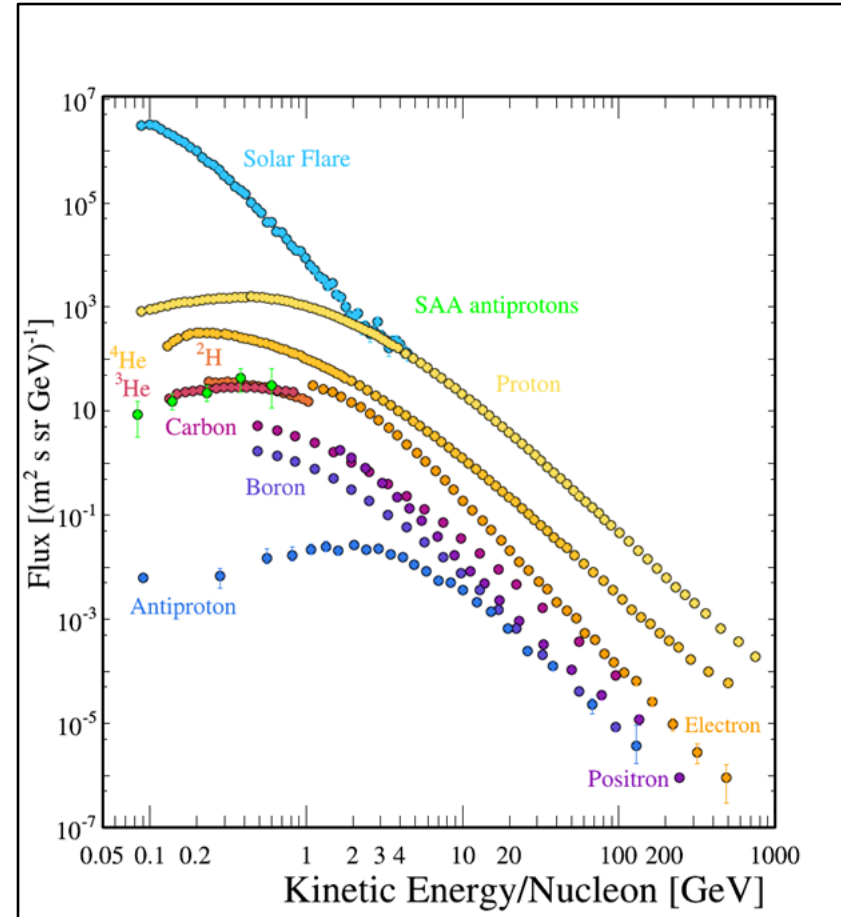
- <sup>a</sup> University of Florence, Department of Physics, I-50019 Sesto Fiorentino, Florence, Italy
- <sup>b</sup> INFN, Sezione di Ferrara, I-44019 Sesto Fiorentino, Florence, Italy
- <sup>c</sup> University of Naples "Federico II", Department of Physics, I-80126 Naples, Italy
- <sup>d</sup> INFN, Sezione di Napoli, I-80126 Naples, Italy
- <sup>e</sup> Lebedev Physical Institute, RU-119991 Moscow, Russia
- <sup>f</sup> University of Bari, Department of Physics, I-70126 Bari, Italy
- <sup>g</sup> INFN, Sezione di Bari, I-70126 Bari, Italy
- <sup>h</sup> INFN, Sezione di Trieste, I-34149 Trieste, Italy
- <sup>i</sup> Ioffe Physical Technical Institute, RU-194021 St. Petersburg, Russia
- <sup>j</sup> ICTP, King of Saudi Arabia, Department of Physics, AbdoNave University Center, SE-10031 Sodstrand, Sweden
- <sup>k</sup> The Oskar Klein Centre for Cosmoparticle Physics, AbdoNave University Center, SE-10031 Sodstrand, Sweden
- <sup>l</sup> INFN, Sezione di Roma "Tor Vergata", I-00133 Rome, Italy
- <sup>m</sup> INFN, Sezione di Roma "Tor Vergata", Department of Physics, I-00133 Rome, Italy
- <sup>n</sup> University of Trieste, Department of Physics, I-34147 Trieste, Italy
- <sup>o</sup> National Research Nuclear University MEPhI (Moscow Physics Engineering Institute), RU-115400 Moscow, Russia
- <sup>p</sup> INFN, Laboratori Nazionali di Frascati, I-00044 Frascati, Italy
- <sup>q</sup> Universität Siegen, Department of Physics, D-57068 Siegen, Germany
- <sup>r</sup> INFN, Sezione di Perugia, I-06123 Perugia, Italy
- <sup>s</sup> Agenzia Spaziale Italiana (ASI) Science Data Center, I-40014 Prato, Italy
- <sup>t</sup> School of Mathematics and Physics, China University of Geosciences, CN-430074 Wuhan, China



TEN YEARS OF COSMIC RAYS IN SPACE

A new issue of La Rivista del Nuovo Cimento on the role of a satellite-borne detector uncovering the mysteries of cosmic rays  
 La Rivista del Nuovo Cimento Vol. 40 N. 10: online in OPEN ACCESS for 30 days  
 Ten years of PAMELA in space  
 PAMELA Collaboration

# Dieci anni di dati di PAMELA



M. Boezio, V. Bonvicini, E. Mocchiutti, R. Munini, A. Vacchi, G. Zampa, N. Zampa,...

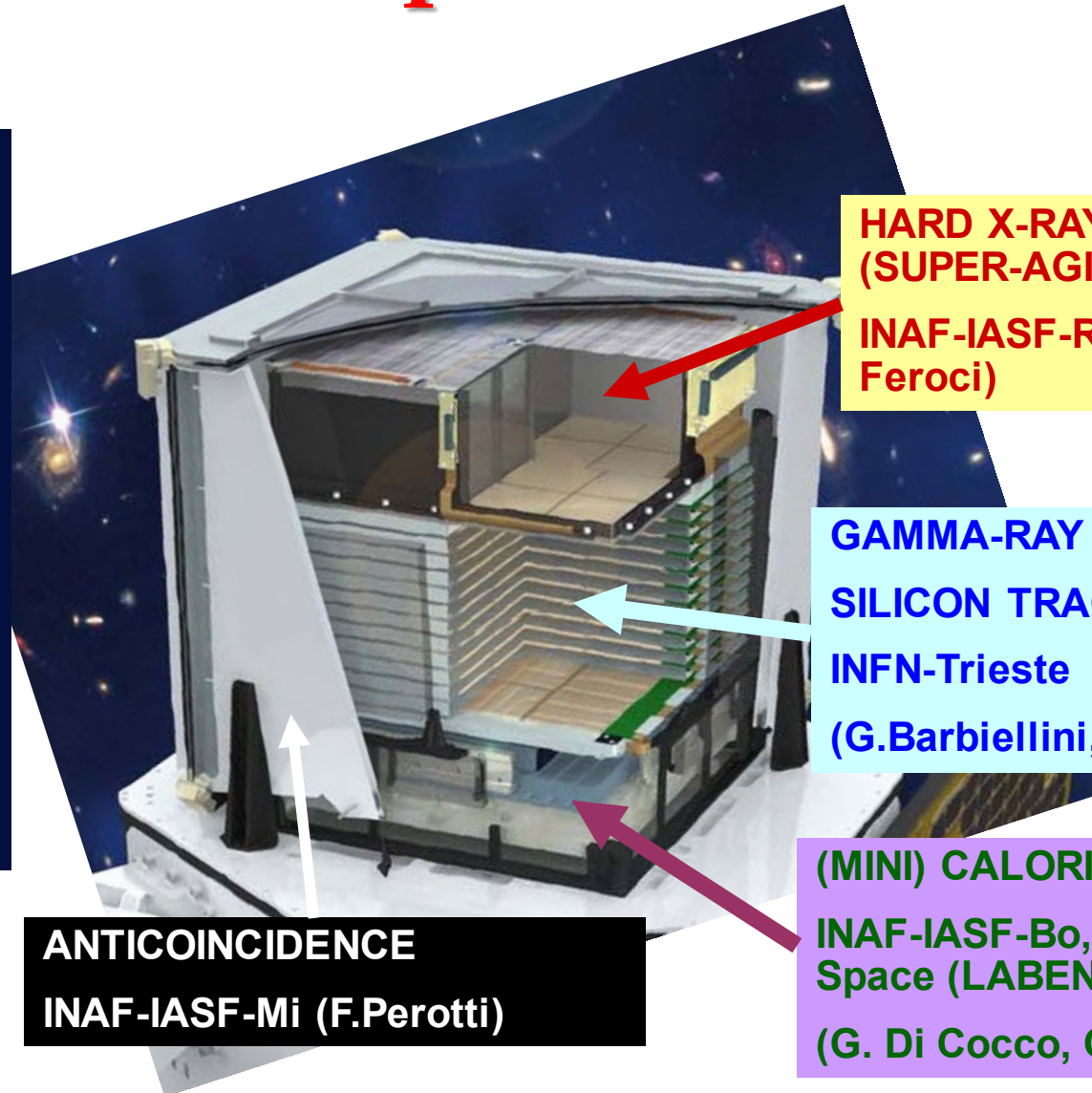


# Astrofisica Gamma - L'esperimento AGILE



The AGILE Payload:  
the most compact  
instrument for high-  
energy astrophysics

It combines for the first  
time a **gamma-ray imager** (30 MeV- 30 GeV)  
with a **hard X-ray imager** (18-60 keV) with  
large FOVs (1-2.5 sr) and  
optimal angular  
resolution



**HARD X-RAY IMAGER**  
(SUPER-AGILE)

INAF-IASF-Rm (E.Costa, M.  
Feroci)

**GAMMA-RAY IMAGER**

**SILICON TRACKER**

INFN-Trieste

(G.Barbiellini, M. Prest)

**(MINI) CALORIMETER**

INAF-IASF-Bo, Thales-Alenia  
Space (LABEN)

(G. Di Cocco, C. Labanti)

**ANTICOINCIDENCE**

INAF-IASF-Mi (F.Perotti)

G. Barbiellini, F. Longo, M. Prest, E. Vallazza...

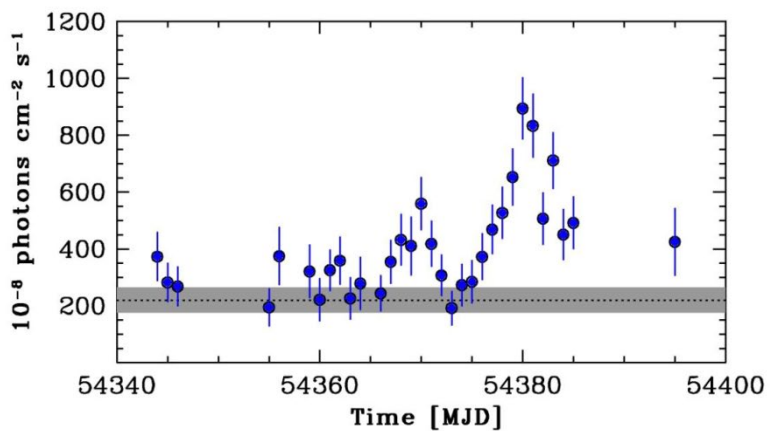
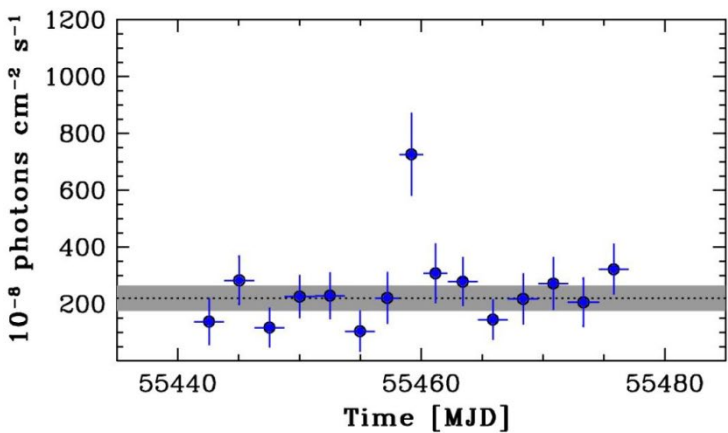


# Il Lancio di AGILE

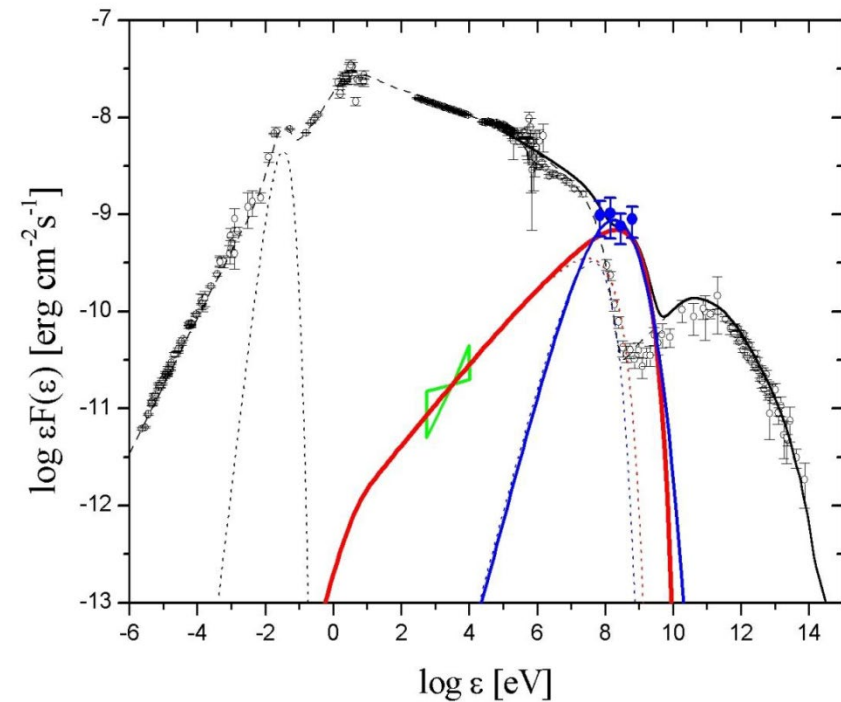


Sriharikota launch base (India)  
PSLV-C8 launch, April 23, 2007





M. Tavani et al., *Science*  
331 (2011) 736



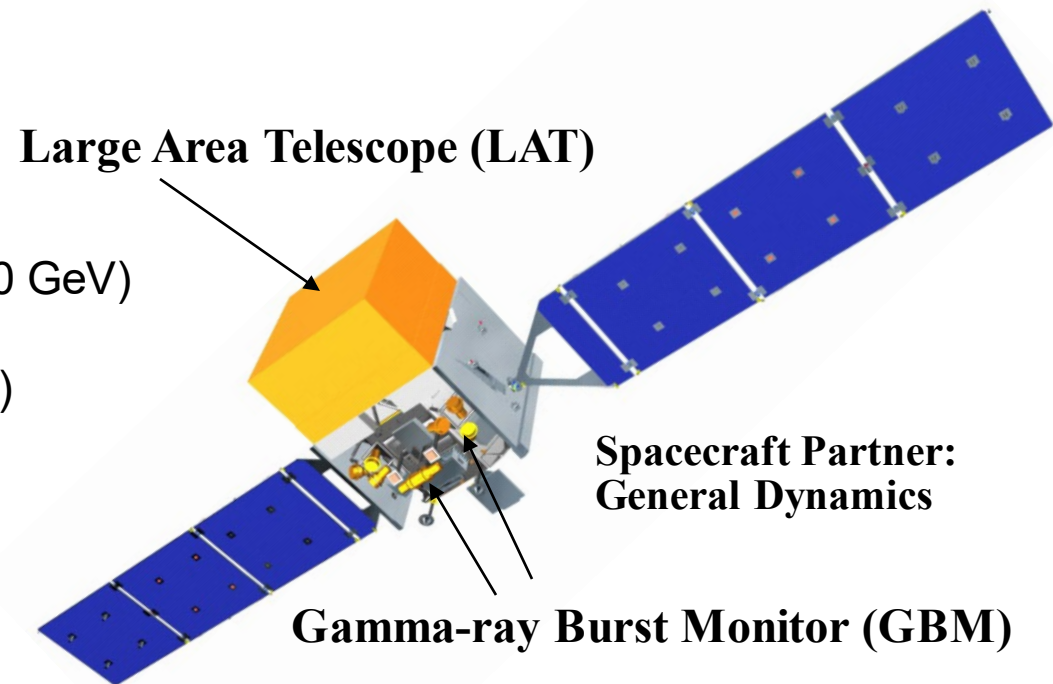
**The Bruno Rossi Prize in High Energy Astrophysics awarded by AAS to astrophysicist Marco Tavani and the AGILE Team for the discovery of gamma-ray flares from the Crab Nebula (January 10, 2012).**



# GLAST-Fermi

- Two instruments:

- LAT:
  - high energy (20 MeV – >300 GeV)
- GBM:
  - low energy (8 keV – 40 MeV)



- Huge field of view

- LAT: 20% of the sky at any instant; in sky survey mode, expose all parts of sky for ~30 minutes every 3 hours. GBM: whole unocculted sky at any time.

- Huge energy range, including largely unexplored band 10 GeV - 100 GeV

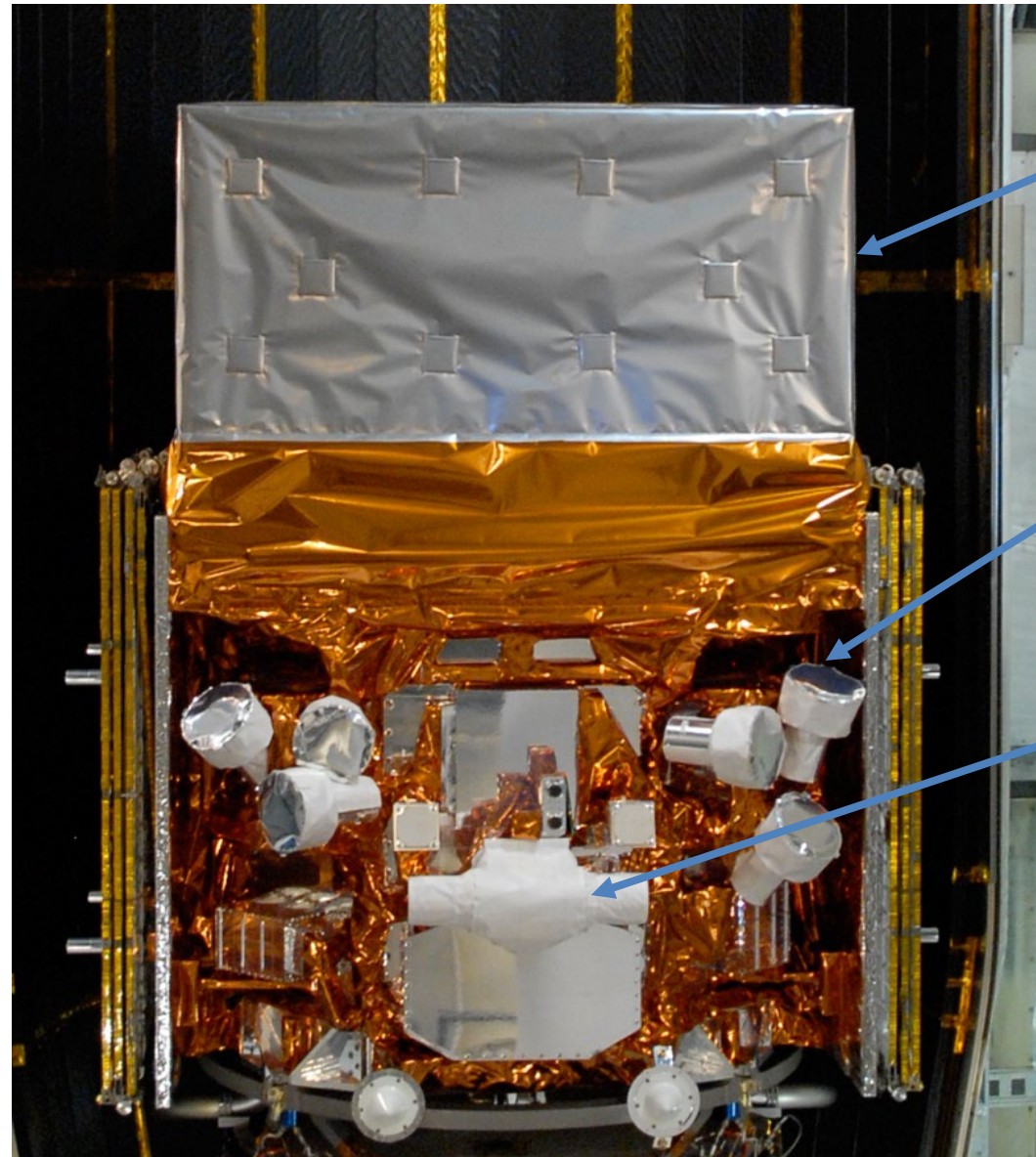
- Large leap in all key capabilities. Great discovery potential.

G. Barbiellini, F. Longo, E.Orlando, A.Celotti,  
L.Nava, E.Bissaldi,...

# Fermi



- Launch from Cape Canaveral Air Station 11 June 2008 at 12:05PM EDT
- Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination.



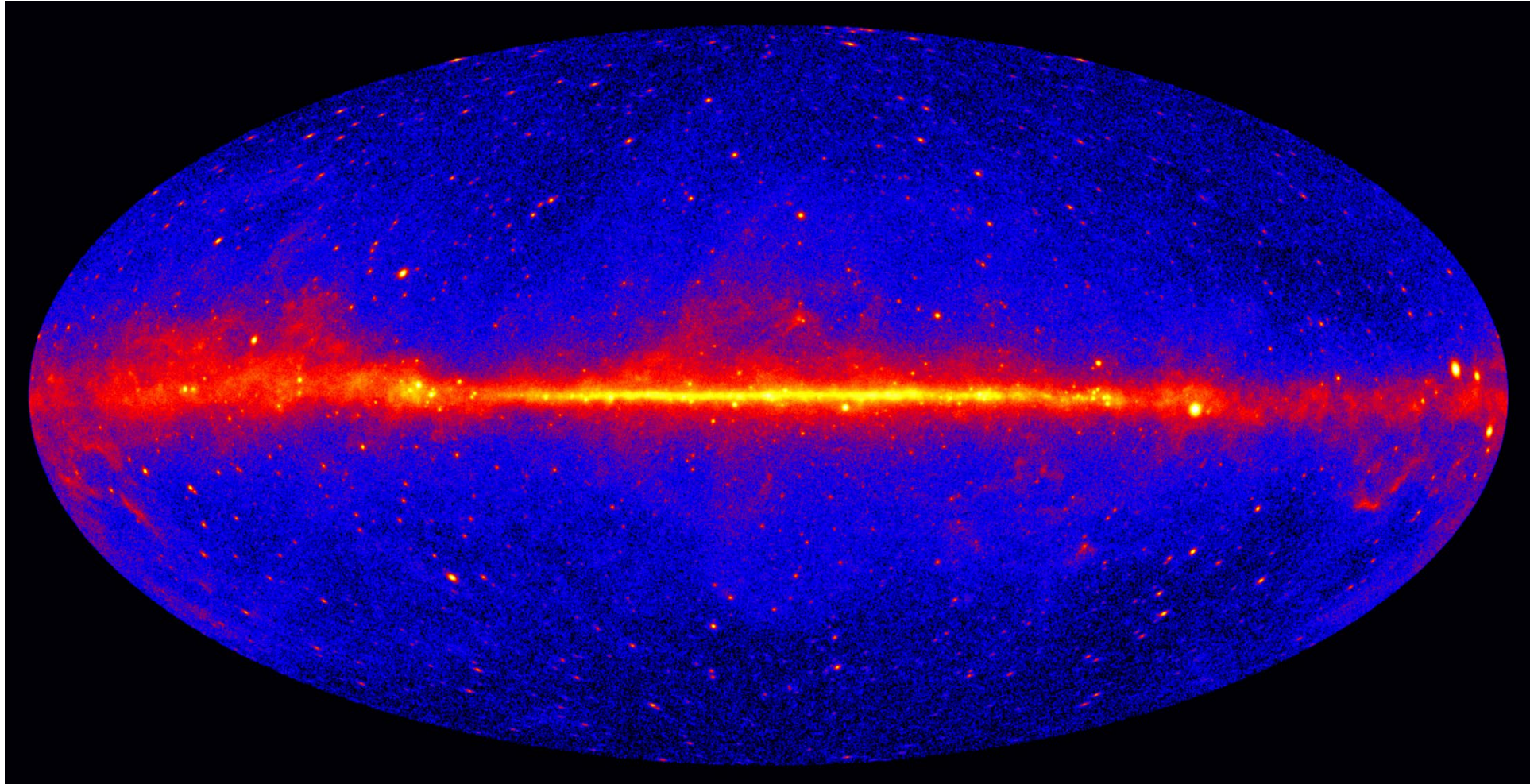
LAT

GBM  
NaI  
Detector

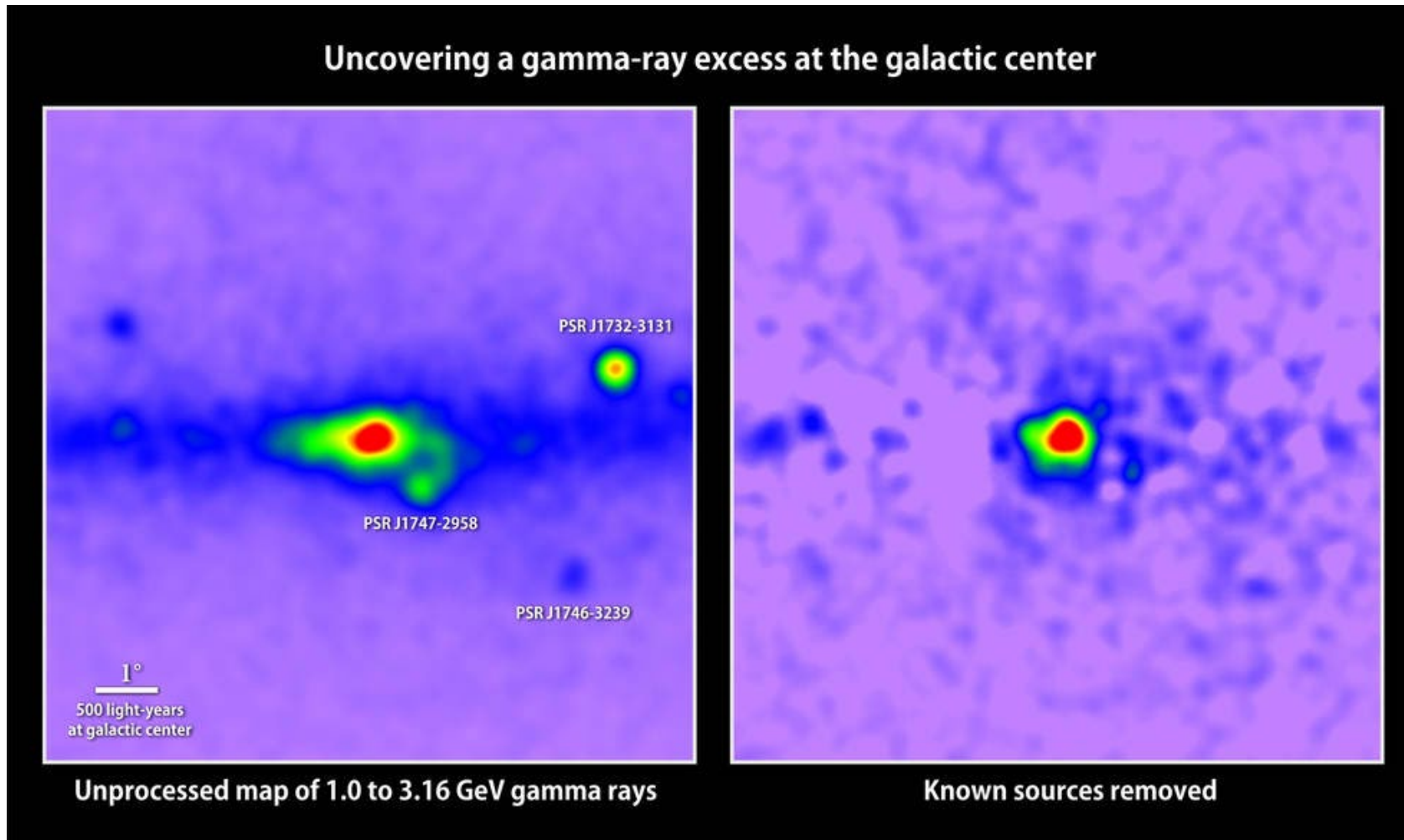
GBM  
BGO  
Detector



# The High Energy Gamma-ray Sky



# Alla ricerca della materia oscura

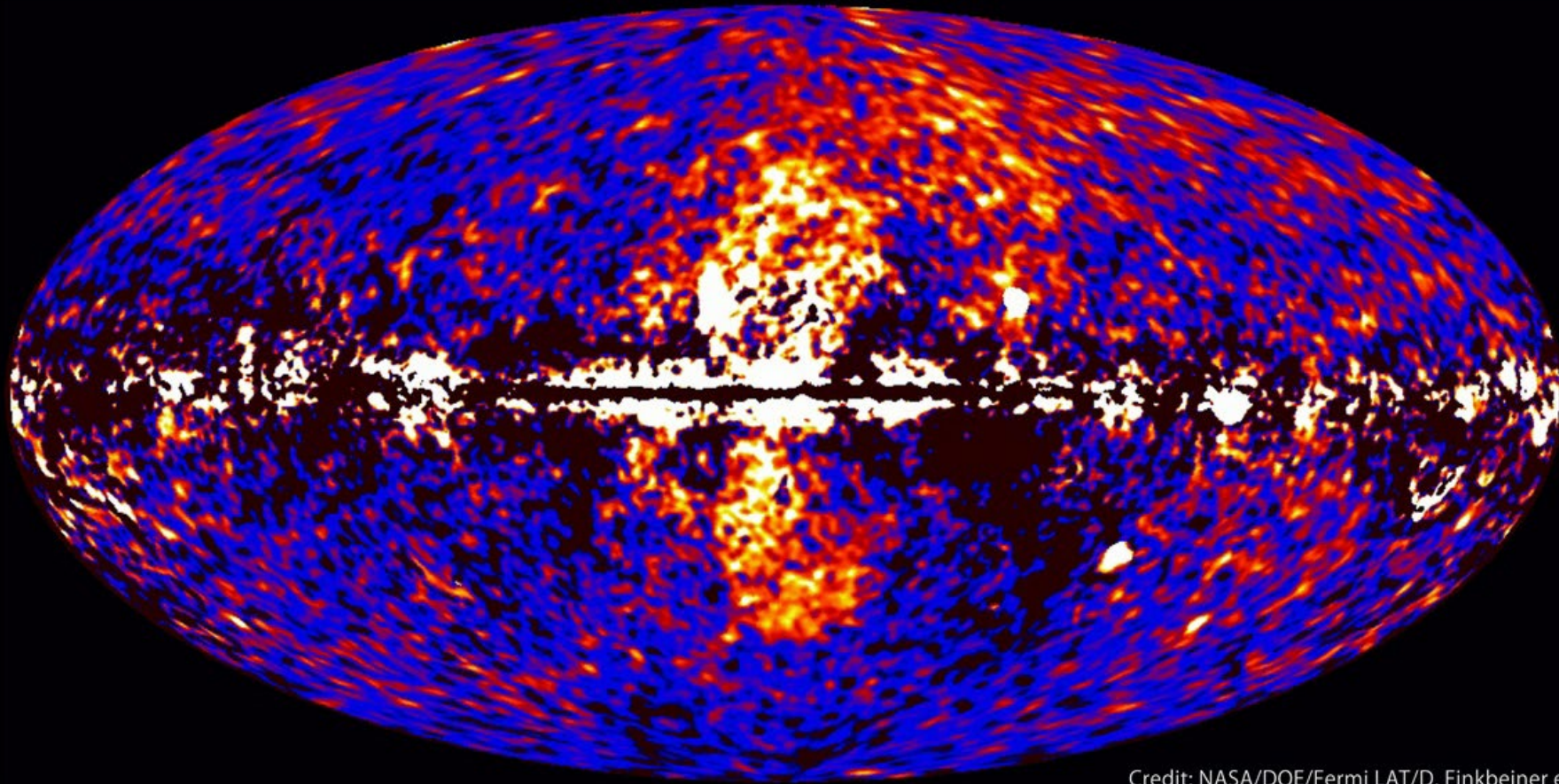


Credits: T. Linden, Stockholm University



# Sorpresa! The Fermi Bubbles

Fermi data reveal giant gamma-ray bubbles



Credit: NASA/DOE/Fermi LAT/D. Finkbeiner et al.



# MAGIC

## Major Atmospheric Gamma-ray Imaging Cherenkov telescopes

- Strumento pionieristico per l'esplorazione da terra della radiazione gamma da sorgenti cosmiche
- banda energetica:  $30 \text{ GeV} \lesssim E \gtrsim 100 \text{ TeV}$  - sotto 100 GeV prima considerata dominio satellitare



@ Osservatorio Astrofisico di Roque de los Muchachos, La Palma, Isole Canarie



# Contributo INFN - sezione di Trieste - gruppo collegato di Udine

- **Membro fondatore** (assieme alle sezioni di Pisa e Padova)  
attualmente la collaborazione conta 165 membri, 24 istituti, 12 paesi

## Ruoli di responsabilità INFN-TS:

- **CB chair**
- **Physics coordinator**
- **On line computing**
- **Responsabilità nazionale INFN**
- **Data quality check**
- **PhD training**

A. De Angelis, B. De Lotto, F. Longo, M. Persic, L. Nava,...



# Alcuni recenti risultati scientifici

## [Teraelectronvolt emission from the \$\gamma\$ -ray burst GRB](#)

[190114C](#) *Nature* 575 (2019)

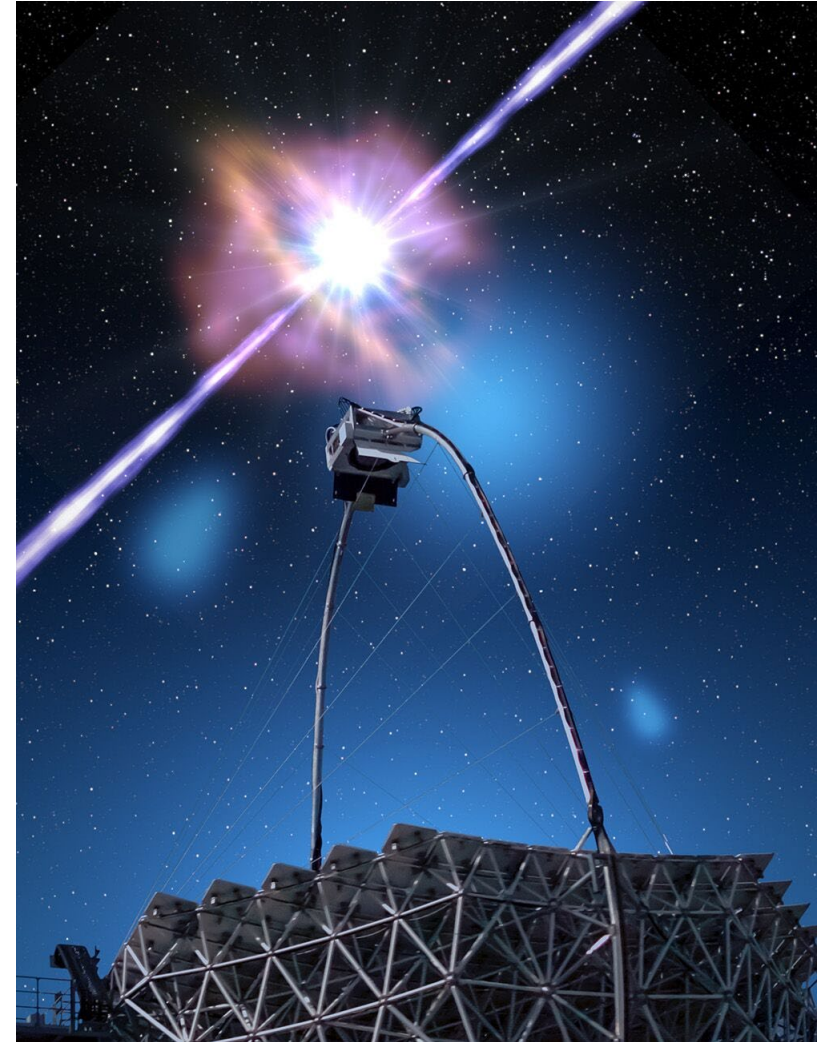
Per la prima volta rivelati fotoni di energia  $\sim$  TeV  
da un Gamma Ray Burst

Proton acceleration in thermonuclear nova  
explosions revealed by gamma [Nature](#)

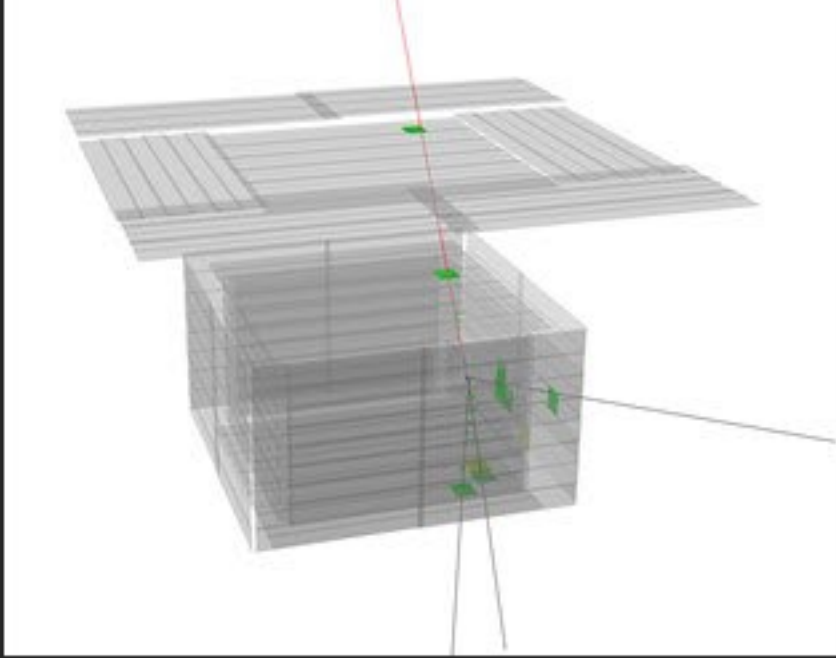
[Astronomy](#) (14 aprile 2022)

identificata nuova classe di sorgenti galattiche di raggi gamma  
di altissima energia originati dall'accelerazione di protoni,  
aperta nuova finestra sulla comprensione dell'[origine raggi](#)  
[cosmici](#)

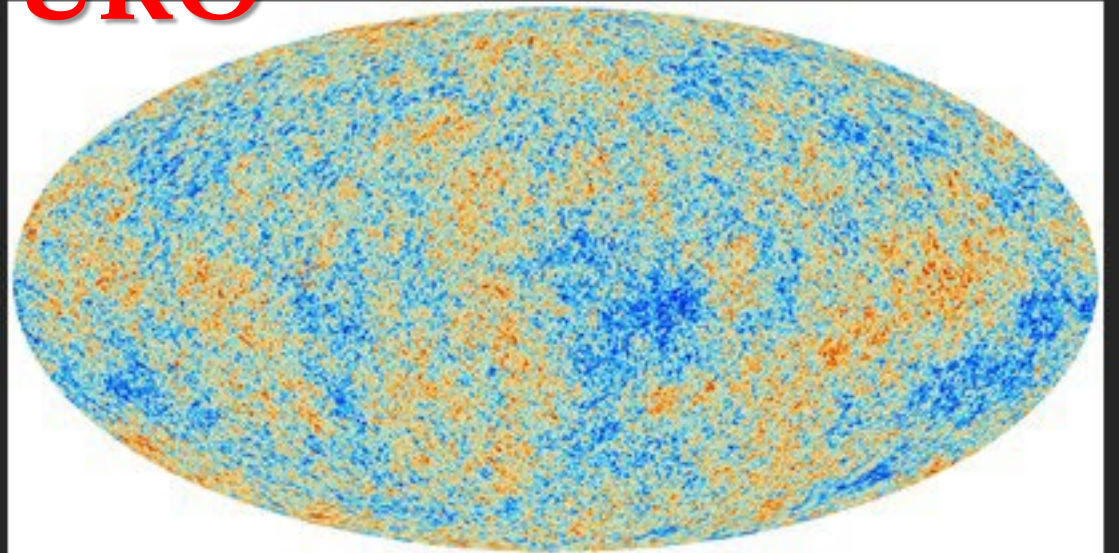
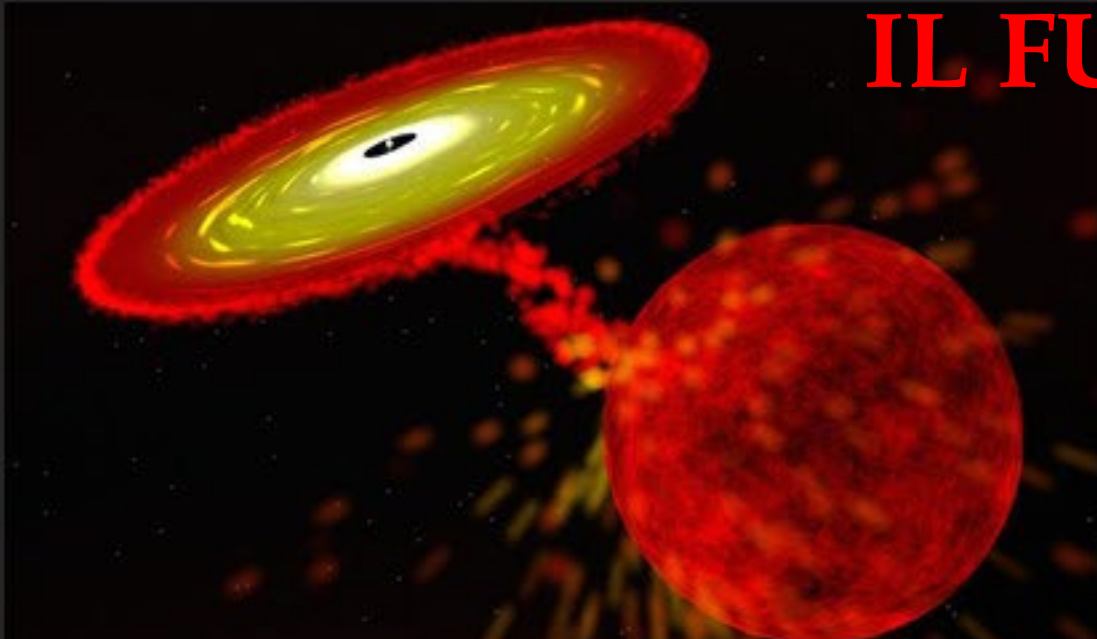
credit <https://superbossa.com> / MPP



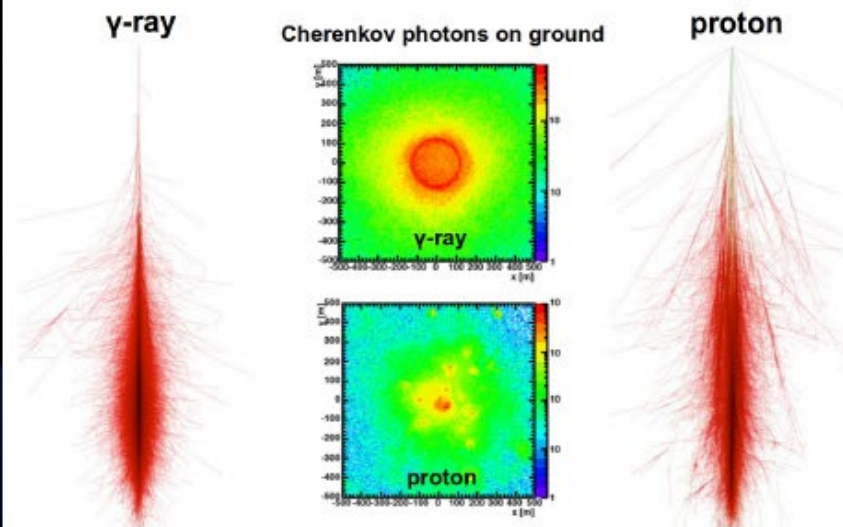
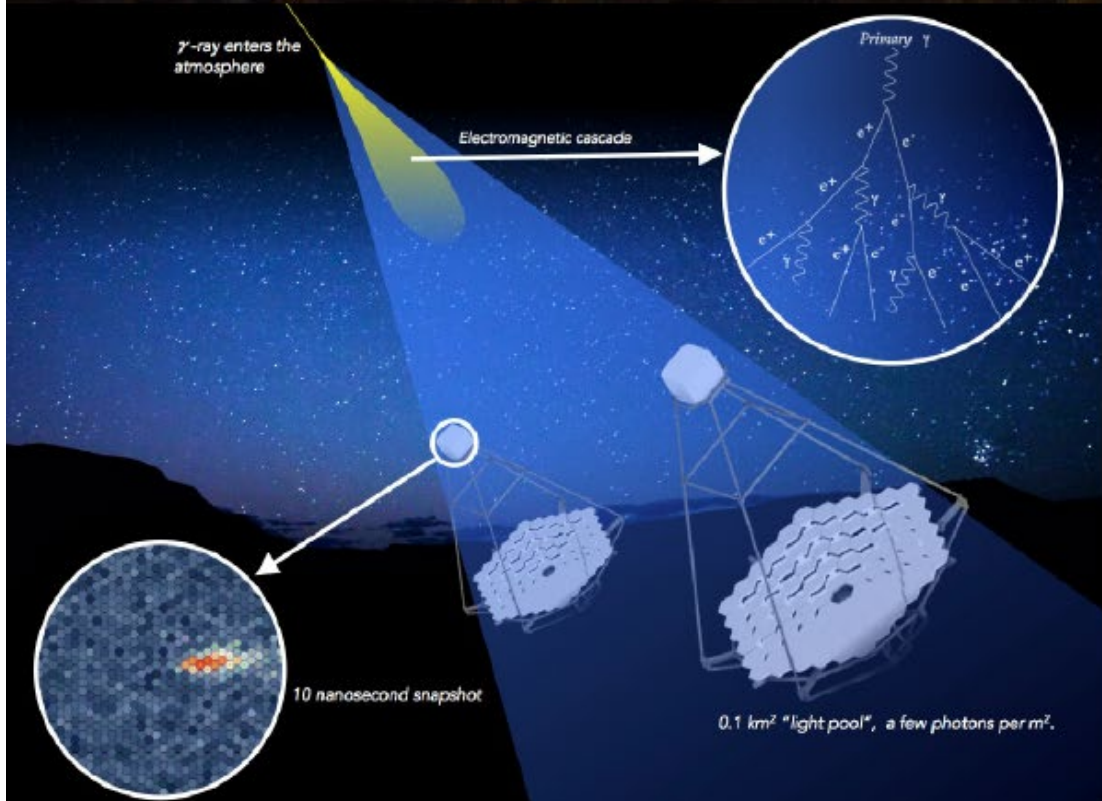




# IL FUTURO

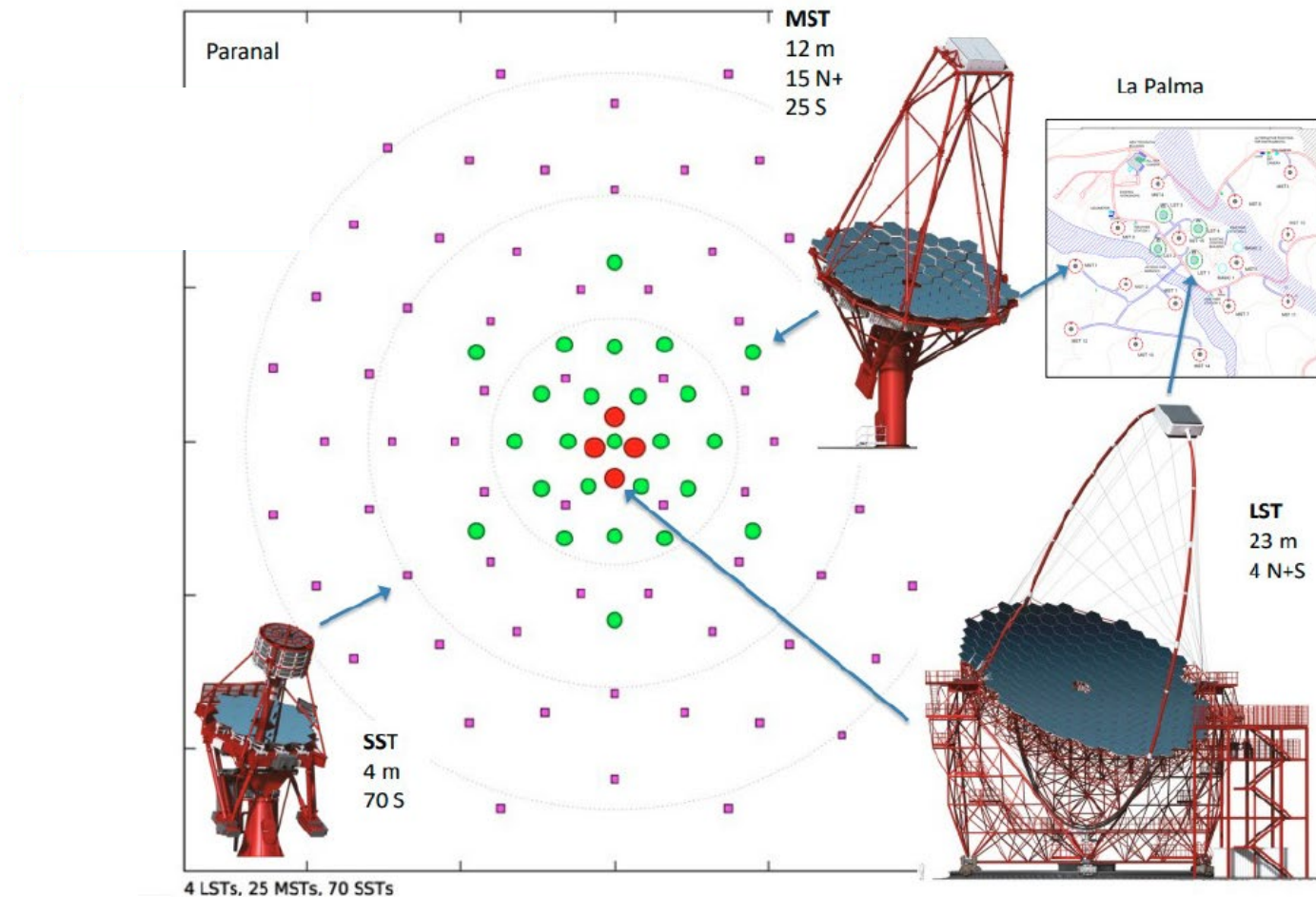


# Imaging Atmospheric Cherenkov Telescopes (IACT)





# Cherenkov Telescope Array (CTA)



A. De Angelis, C. Cauz, B. De Lotto, F. Longo, G. Pauletta, M. Persic, E. Orlando,...

# The GAPS experiment



International collaboration between US, Japanese, and Italian institutes



Istituto Nazionale di Fisica Nucleare

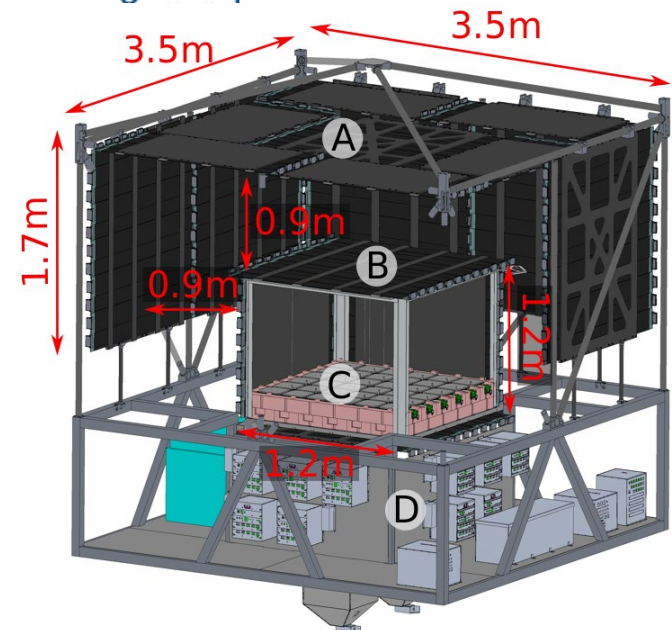


Alfred P. Sloan  
FOUNDATION



公益財団法人  
住友財団

公益財団法人 三菱財団  
THE MITSUBISHI FOUNDATION





# The GAPS experiment



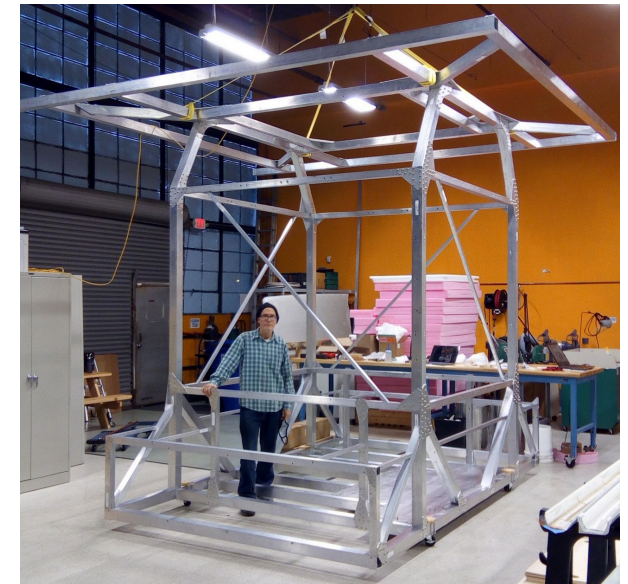
International collaboration between US, Japanese, and Italian institutes



Istituto Nazionale di Fisica Nucleare



Alfred P. Sloan  
FOUNDATION



# L'esperimento GAPS: il volo

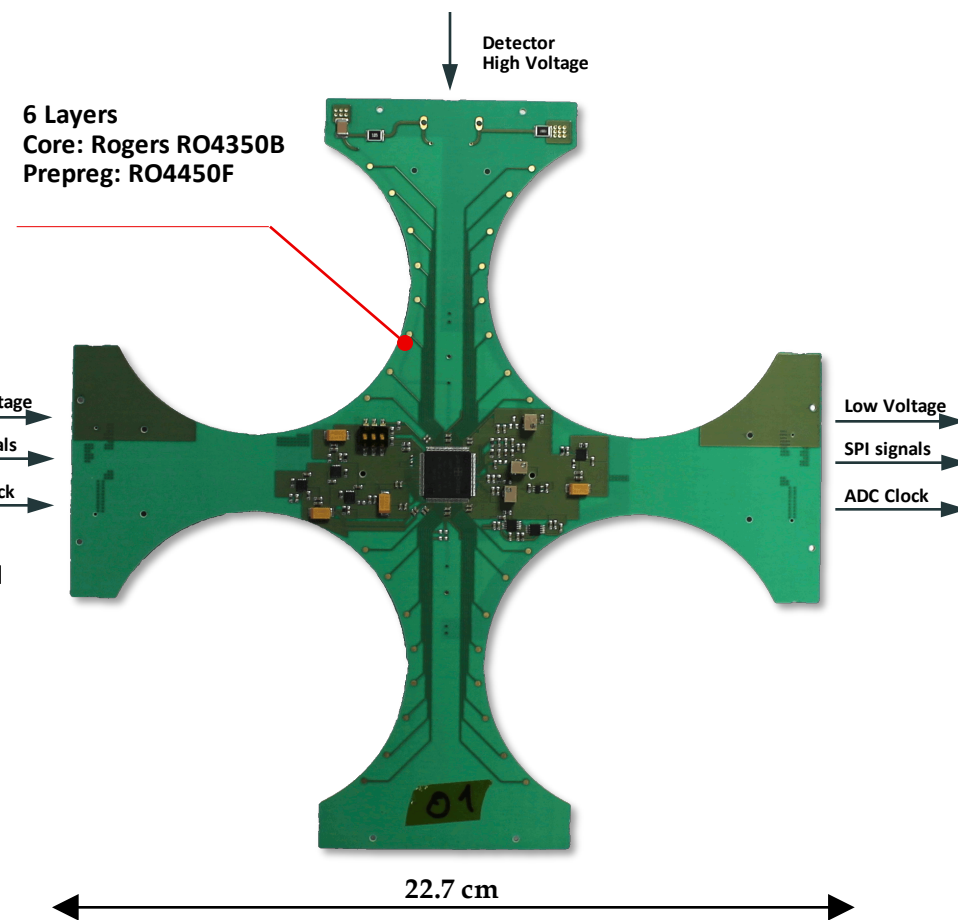
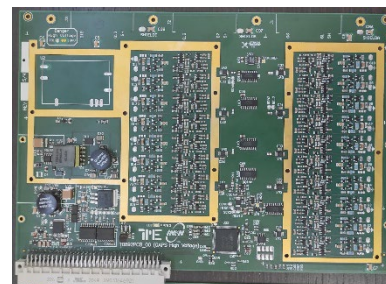
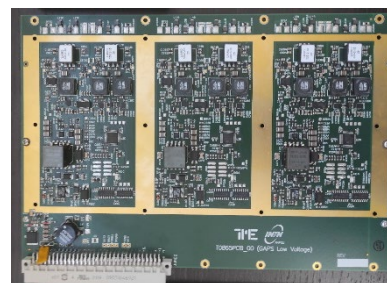
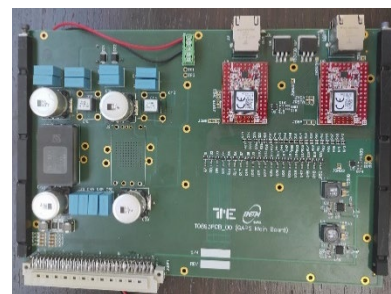
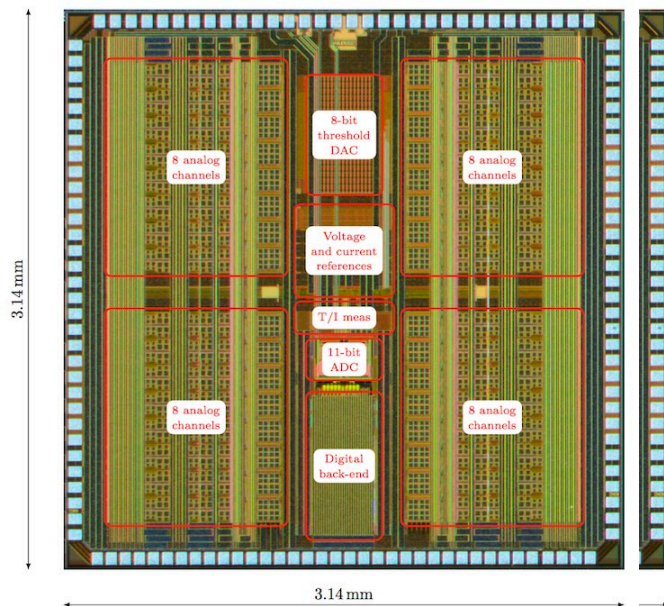


L'esperimento GAPS è un rivelatore di antinuclei nella radiazione cosmica.

Un esperimento NASA con la collaborazione italiana, anche dell'INFN di Trieste, e giapponese. Attualmente in costruzione, il lancio avverrà con un pallone aerostatico nel 2023 dall'Antartide. Il volo durerà circa 40 giorni dopodiché lo strumento verrà recuperato per futuri lanci.

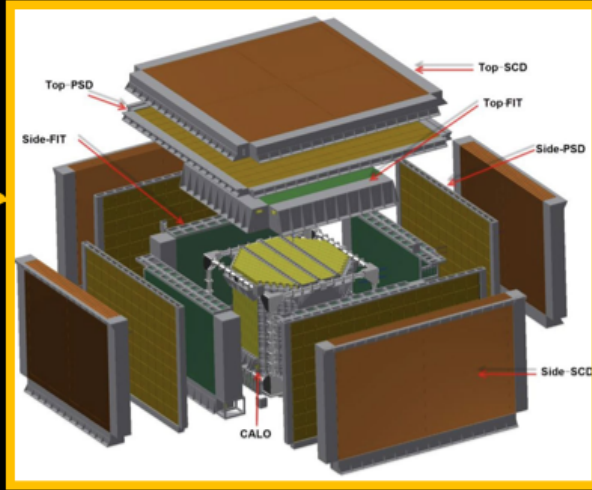
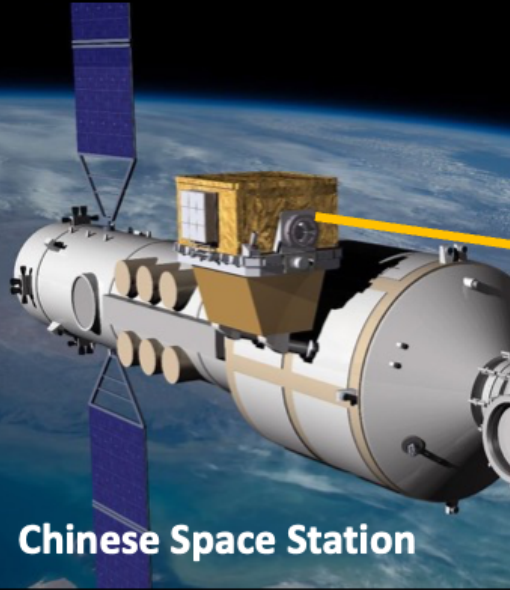


# L'esperimento GAPS: il contributo italiano



M. Boezio, V. Bonvicini,, E. Mocchiutti, R. Munini, G. Zampa,...

# Direct Measurement Towards the Knee: HERD

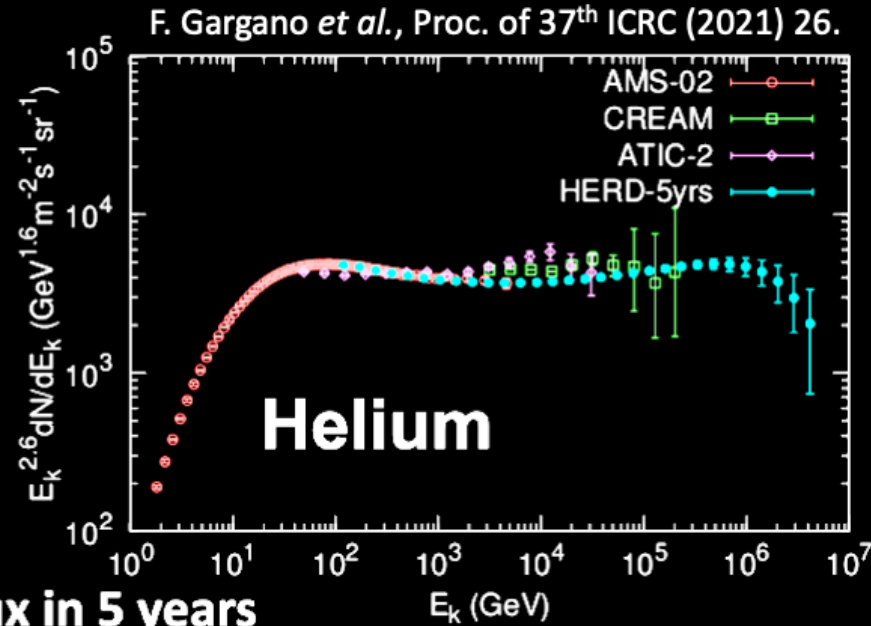
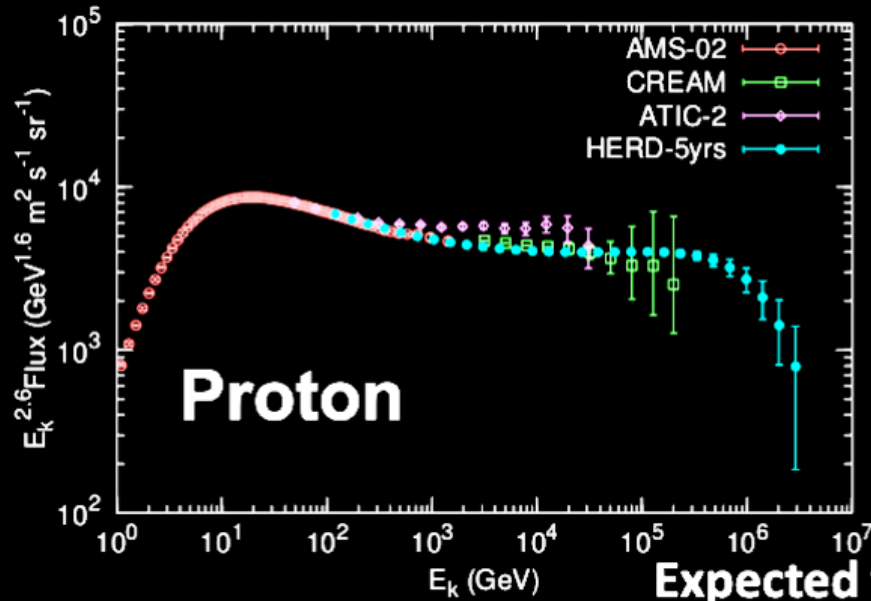


## High Energy Cosmic Radiation Detector (HERD)

Based on a 3D, homogeneous, finely-segmented calorimeter of  $55 X_0$  with a wide field of view ( $2\pi$ ). Complemented by other detectors for PID (charge, veto, tracking, ...).

Installation foreseen 2027.

- Measurement of cosmic-rays up to the knee.
- $\gamma$ -rays monitoring and full sky survey.
- Indirect dark matter search (all-electron,  $\gamma$ -ray)

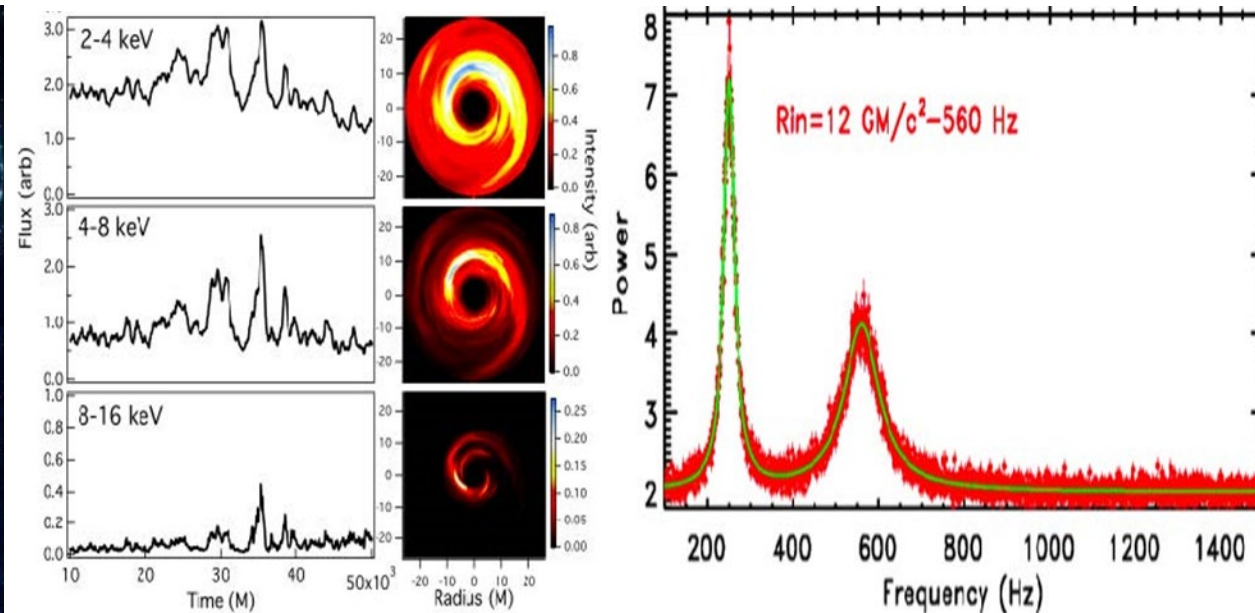


F. Gargano *et al.*, Proc. of 37<sup>th</sup> ICRC (2021) 26.

M. Antonelli,  
V. Bonvicini,  
S. Ciano,  
G. Orzan,  
C. Pizzolotto,  
G. Zampa,  
N. Zampa,...



# eXTP: enhanced X-ray Timing and Polarimetry mission



**Dense Matter:** which is the state of matter at supranuclear densities (i.e., in the neutron star's interior)? Exotic states of matter? Quark stars?

**Strong Gravity:** what are the properties of space-time under extreme gravity (i.e., in the vicinity of neutron stars and black holes)? Any deviations from Einstein's General Relativity theory?

**Strong Magnetism:** which is the behavior of light in the presence of ultra-strong magnetic fields (e.g., in magnetars)? Are the predictions of the QED theory verified?

Observatory science

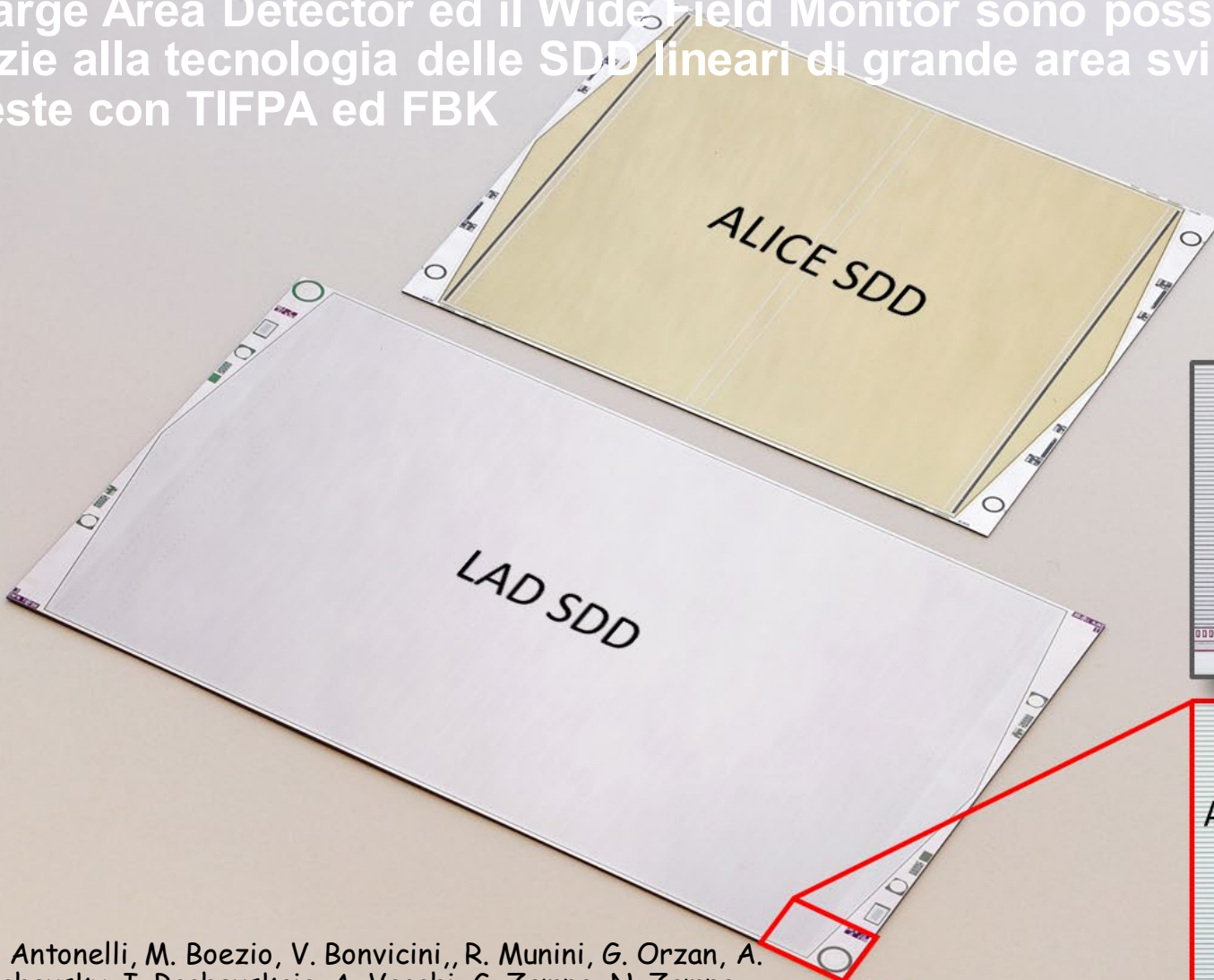
Parameter	Value
Orbit	550 km, inclination $\sim 0^\circ$
Pointing	3-axis stabilized, $< 0.01^\circ$ ( $3\sigma$ )
Launch	LM-7A/5, from Wenchang (19 deg N)
Launch mass	$\sim 5200$ kg
Telemetry	1.6 Tb/day (X-band)
Burst alert & real-time control	BeiDou Short Message, 30s to SOC (Up/down link: 400/500 bps); VHF transmitter (TBC);
Ground Stations	Colombo (China), Malindi (Italy)
Mission duration	5 years (goal 8 years)
Launch date	$\sim 2027$





# eXTP: enhanced X-ray Timing and Polarimetry mission

Il Large Area Detector ed il Wide Field Monitor sono possibili solo grazie alla tecnologia delle SDD lineari di grande area sviluppate a Trieste con TIFPA ed FBK

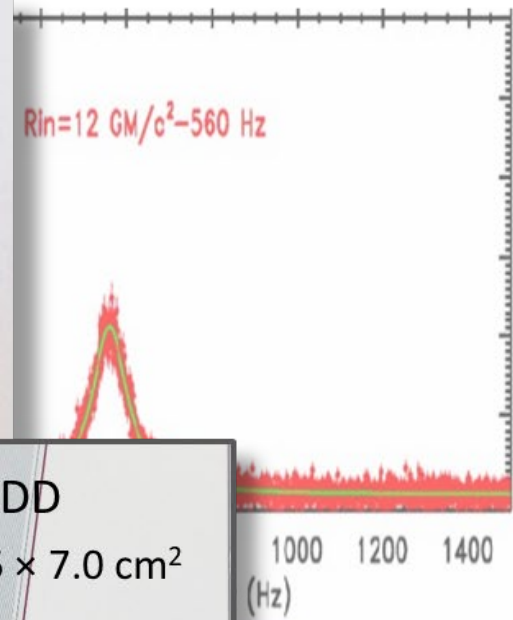


WFM SDD  
Area attiva:  $6.5 \times 7.0 \text{ cm}^2$

INFN TS  
FBK DOWN 2

Area attiva:  $10.86 \times 7.00 \text{ cm}^2$

INFN TS  
4 FBK

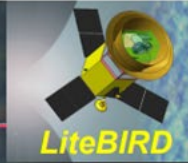


M. Antonelli, M. Boezio, V. Bonvicini,, R. Munini, G. Orzan, A. Rachevsky, I. Rachevskaia, A. Vacchi, G. Zampa, N. Zampa,...

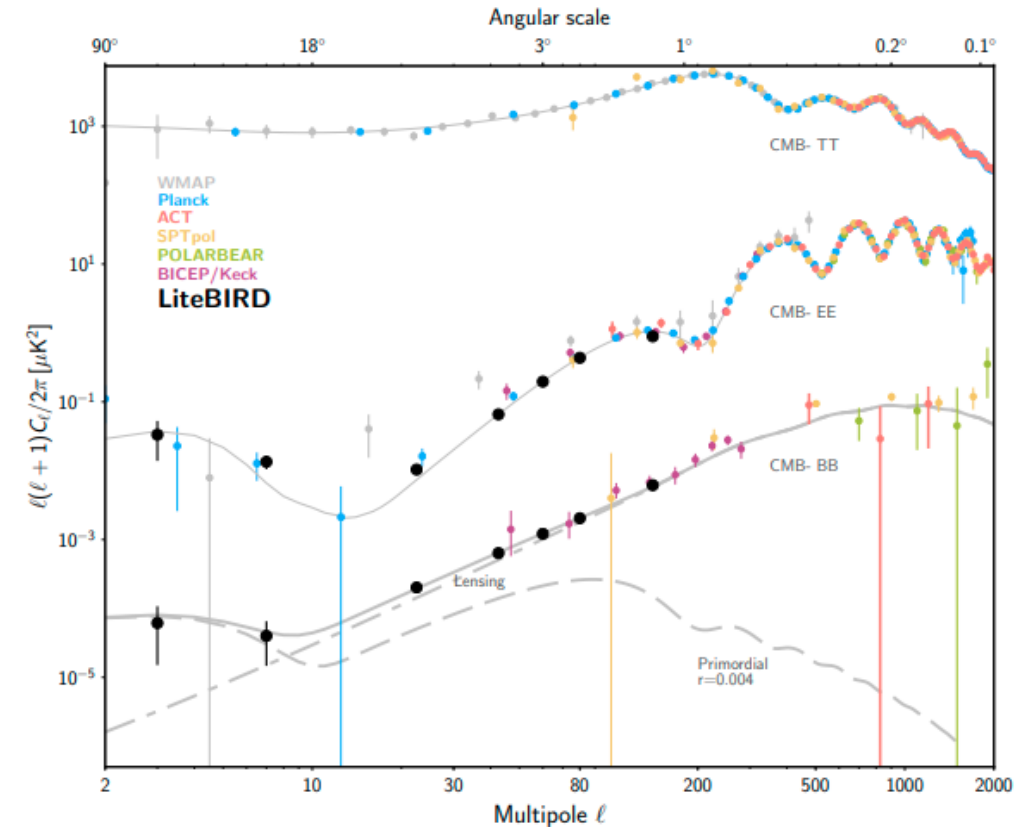


# LiteBIRD: the Ultimate Probe for Inflation

## LiteBIRD project overview



- JAXA L-class mission candidate with a solid basis in Japan
  - JAXA prefers a focused mission even for L-class
  - Test of inflation is one of the most important objectives in JAXA roadmap
  - MEXT (funding agency) chose LiteBIRD as one of 10 flag-ship future large projects among all areas of research
- Phase-A1 concept development at ISAS/JAXA (Sep.2016 – Aug. 2018) completed
  - The most advanced status among all CMB space mission proposals in the world
- Strong international contributions
  - US: Focal plane/cold readout technology development (NASA)
  - Canada: Science contribution studies and science maturity studies (CSA)
  - Europe:
    - Studies at Concurrent Design Facility (ESA) with the European consortium
    - Italy: Phase A commitment (ASI)
    - France: Phase A commitment (CNES)



[arxiv.org/abs/2202.02773](https://arxiv.org/abs/2202.02773)

C. Baccigalupi, N. Krachmalnicoff,...



A photograph of a rocket launch against a clear blue sky. The rocket is positioned vertically in the center, with a bright yellow and orange flame at its base. The word "GRAZIE!" is written in a bold, red, serif font across the middle of the image, partially overlapping the rocket's plume.

**GRAZIE!**