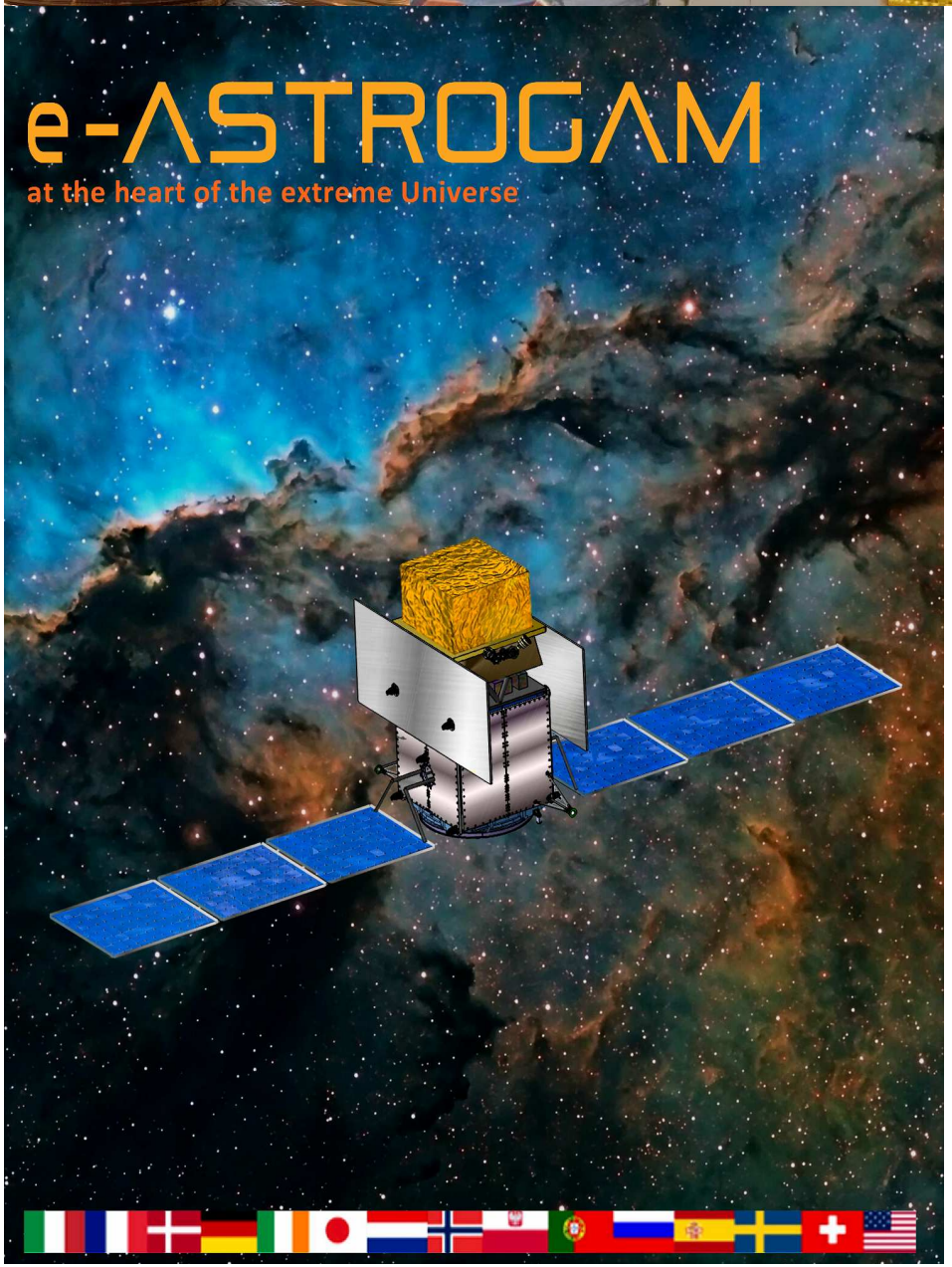


Communicating e-ASTROGAM: some speculations

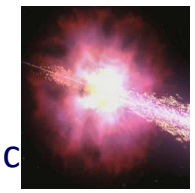
Stefano Ciprini[1,2]

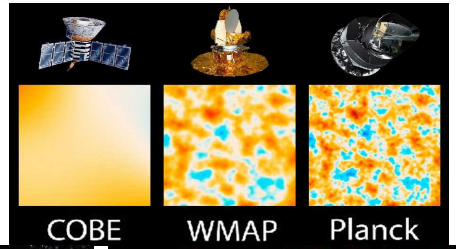
1. Italian Space Agency Space Science Data Center (SSDC), Roma, Italy
2. National Institute for Nuclear Physics (INFN), Perugia Section, Italy

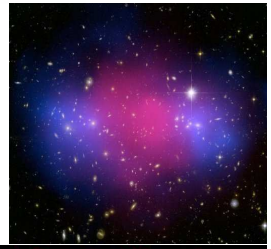
1st e-ASTROGAM workshop: the extreme Universe
28 February - 02 March 2017, Padova, Italy

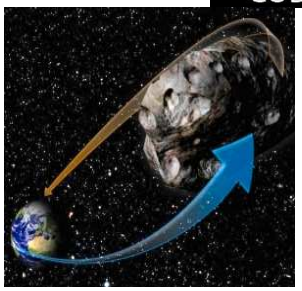
About challenges

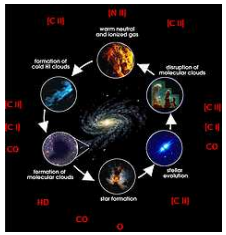
- Note: here there are only, very personal, opinions and ideas. These do not represent any team, group, or Institution.
- I tried to add a couple of inputs. Possible ideas about communication with the public, rather than full scientific topics. They are tentatively different from the science topics presented in this conference, although some comments are fairly obvious.
- e-ASTROGAM has a big challenge: it follows the success of Fermi and the promise of CTA
- e-ASTROGAM has a big challenge: it is in competition with compelling (inspiring for the large public) topics:
  - exoplanets (earth-size exoplanets in particular), water , organics and basic life) in our Solar System (Enceladus, Europa, Titan, Triton, Ganimede, etc.)
  - multiple flybys (beautiful pictures); asteroid/comets flybys and returns, atmosph. probes/ surface penetrators,
  - GRBs/transient explorers, aurora obs., fund. phys probes,
  - dark energy mystery,
  - obscured Universe,
  - cosmology, CMB, dark ages.

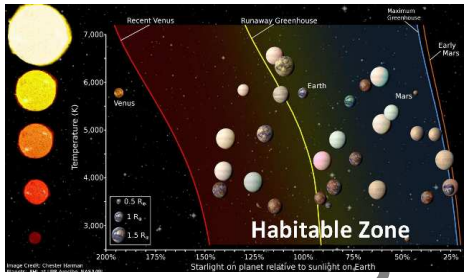


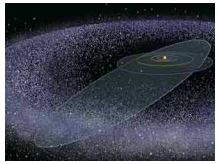












About challenges

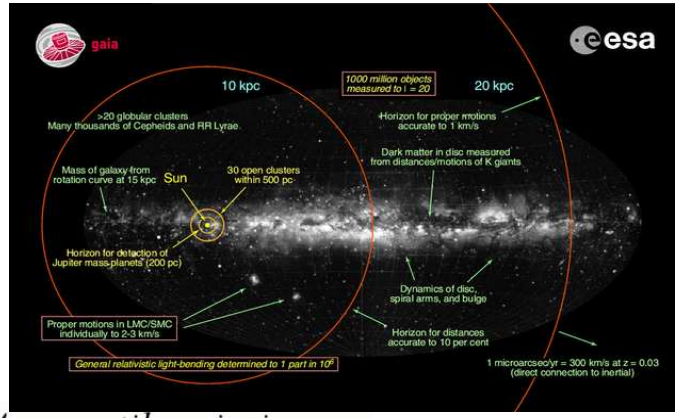
- The science case as a single/small-list of major, focused, science objectives is the optimal choice (a long list may give impression there is no single very-important scientific question to be answered).

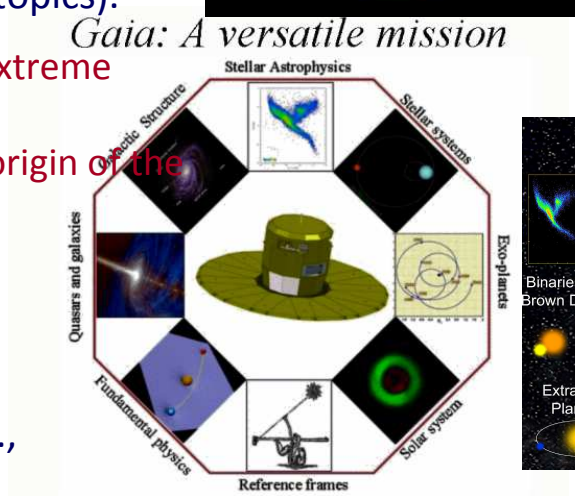
- On the other hand the list of supplementary ("ancillary"/"legacy"), accessory/secondary/bonus topics can be also large. (→ versatility)
(Example: the long list of "accessory science" for the ESA GAIA mission: space astrometry (motto "surveying a billion stars"), but data products supply information also for exoplanets, stellar astrophysics, star formation history of the Galaxy, Galactic structure, galactic star binaries, nearby brown dwarfs discovery, asteroids/comets/neo discovery, AGN flux/photocenter variability, fundamental phys., reference frame, solar system…).
→ objections based on the need for a single & focused science topic seems not valid for GAIA (4 official objectives, >5 science topics).

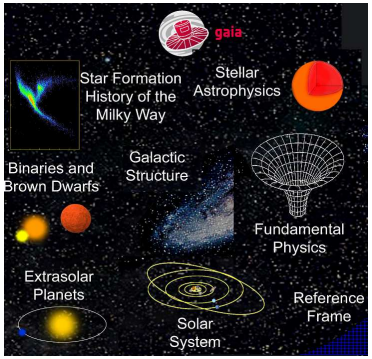
- 3 core objectives of e-ASTROGAM: 1) processes of the extreme Universe; 2) Galaxy evolution from cosmic rays to antimatter 3) nucleosynthesis (cosmochemistry, our radioactive Galaxy/origin of the elements).

- A 2/3fold character too? Collect data for two different (previously rather separated ?) science communities:
1) stellar thermal/nuclear astron./astroph.
and 2) extreme HE/VHE non-thermal gamma-ray astroph., particle-astroph., fundamental-physics.

GAIA: ambitious mission with at least 5 topics (3D map of our Galaxy and Galactic structure, stellar astroph. Solar system, asteroids, exoplanets). The mission core objectives are 4 (as reported in the ESA website).



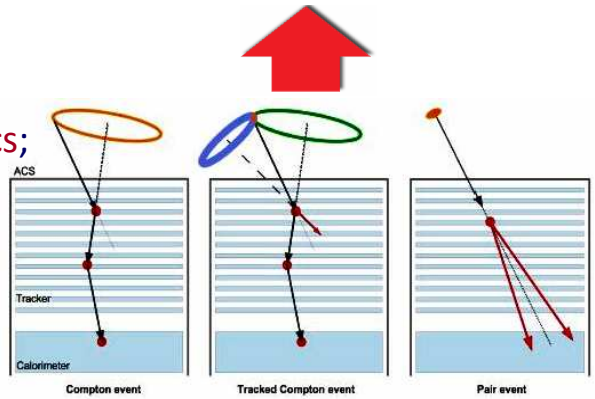




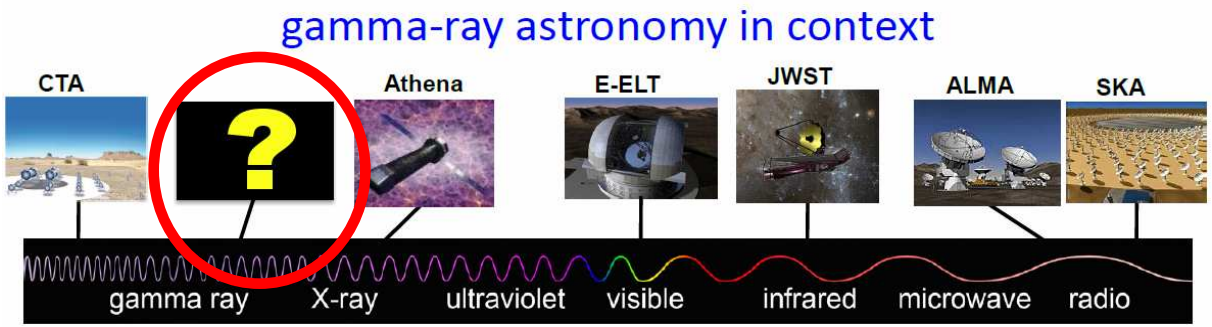
Three core topics …and three-fold duty(?)

❑ **THE MISSING PIECE** (of the puzzle) **:** need for a sensitive, wide-field of view, wide-energy band, good angular resolution, MeV-GeV gamma-ray space observatory operating in the same years as missions/exp./facil. as SKA, ALMA, extd.-JWST, LSST, Athena, CTA, LIGO/Virgo/Kagra/eLISA(?) Icecuce/KM3NeT, (…a big "?")

❑ **PROVIDING DATA TO A LARGE COMMUNITY:** need for gamma-ray space telescope in the MeV region: 1) still a rather unexplored region (improved sensitivity→ discoveries); 2) large menu of astrophysical sources / science topics; 3) serving different and large communities (stellar/nuclear astroph., & non-therm. HE astroph., fundamental/particle/DM/multimess. physicists/astrophysicists) → expected large number of discoveries, publications and products (scientific productivity evaluation).



❑ **PUSHING/EXPLOIT ESTABLISHED TECHNOLOGY:** put in orbit a conventional and successful (Fermi/AGILE) particle-physics detector technology based on Si strip detectors, now improving and pushing it forward to its extremes (two-side Si strip detectors, two-process Compton scatter. and pair-creation events).



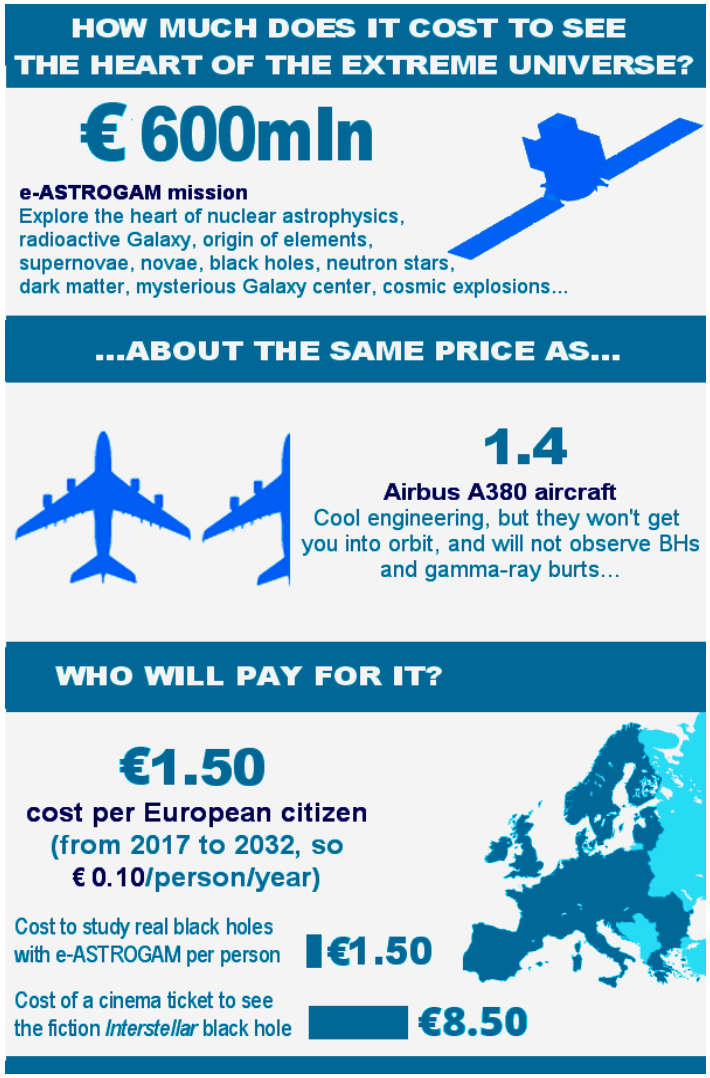
Full exploit of Si strip detectors in space with e-ASTROGAM. An exciting goal for Europe (that hosts and funds the CERN). The estimated total cost of finding the Higgs boson, partially also a Si-strip detector based discovery, is about $13.3 billions.

Further comments

- Can some tentative science visualizations, persuasive inspiring EPO graphics/pictures (to let better know e-ASTROGAM in the scientific community and large public) be useful at this early stage of the proposal evaluation ? (one example here →)

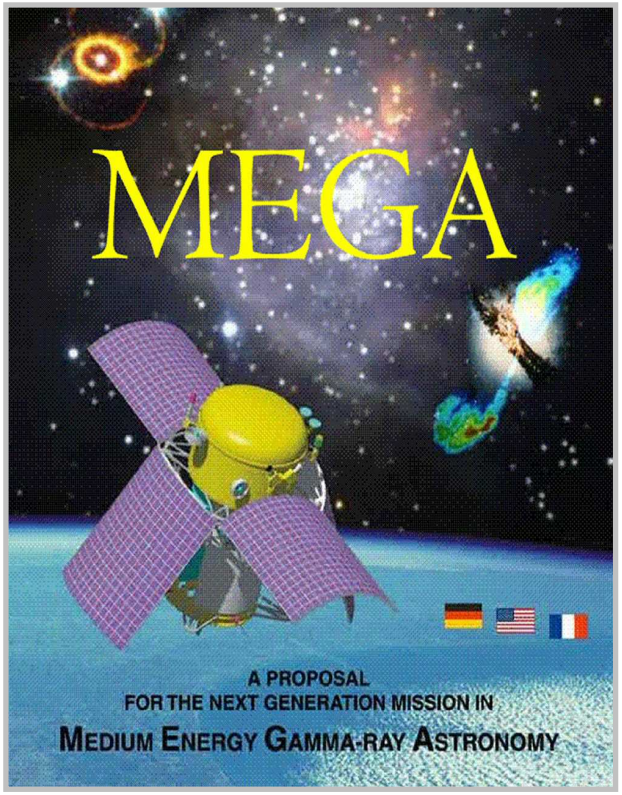
- 22 member Countries in ESA.
14 European countries in the e-ASTROGAM collaboration (proposal). Can be useful to add, if possible, two or three more flags to e-ASTROGAM ? (some ideas:).

- Is it possible to play a little in the same science field of the exciting exoplanet missions with e-ASTROGAM ?
(one curious example in the following slides, mostly related to communication with the large public, rather than science).

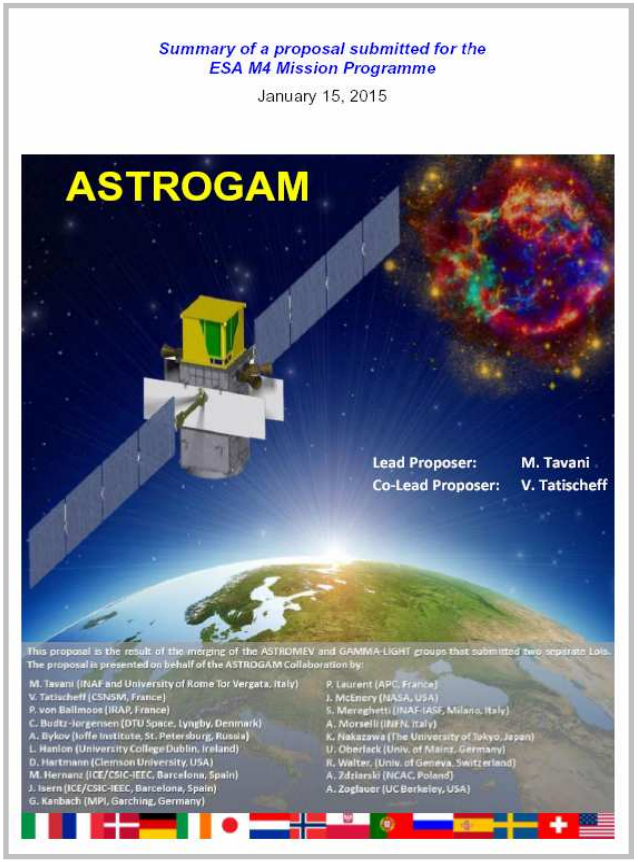


Evolution of proposal covers

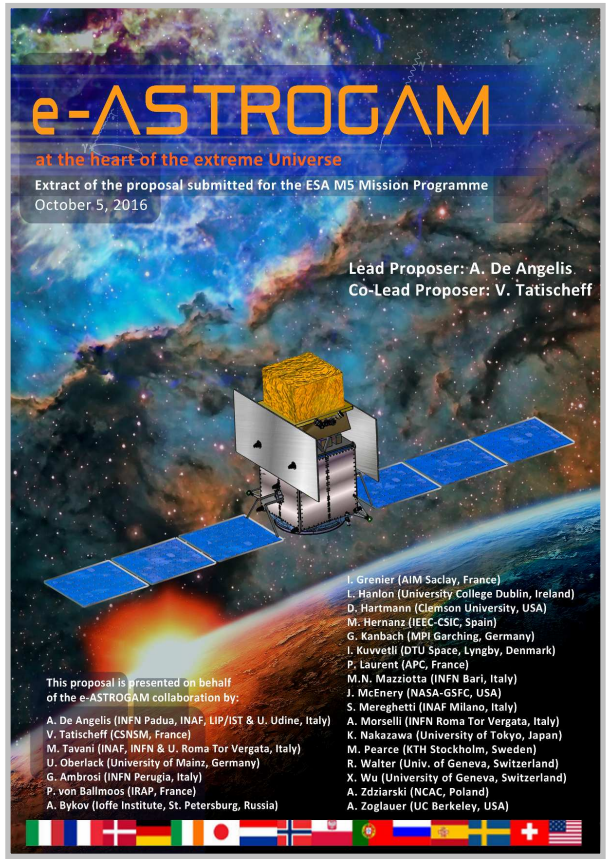
e-ASTROGAM cover: in the footsteps of the previous MEGA and ASTROGAM covers/posters:
same basic elements, the spacecraft, the earth, the sunrise on earth limb, the sky with some gaseous feature (radiogalaxy, SNR …or whatever).



~ 2000s

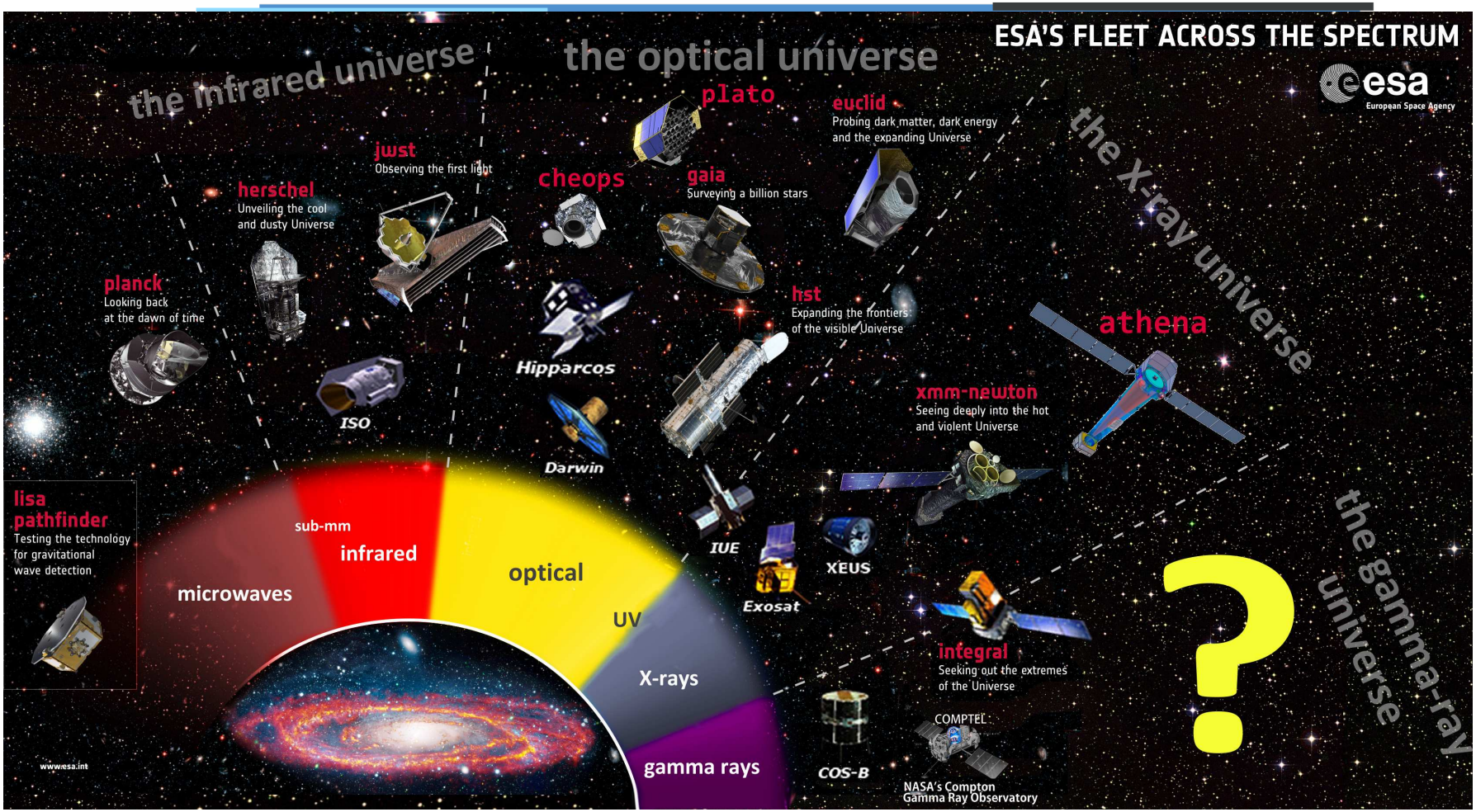


January 2015



October 2016

ESA's fleet across the EM spectrum



❑ The ESA's missions for the observation of the Universe : history and next approved missions (example of a pictorial representation elaborated from the official ESA wallpaper release)

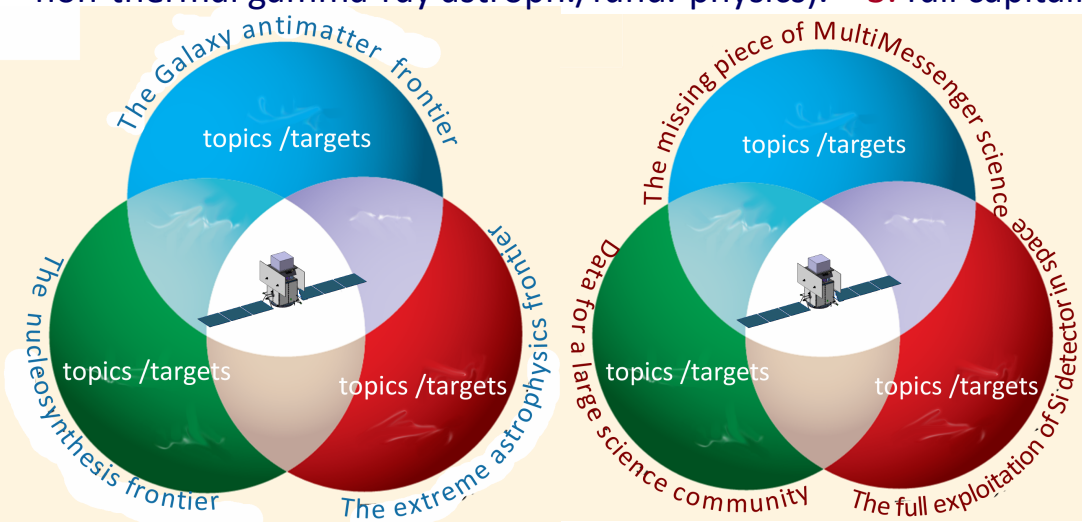
❑ A rather consistent (crowded) ESA fleet at optical bands. Only 2 gamma-ray missions (Cos-B, INTEGRAL) + 1 instrument (COMPTEL on the CGRO). A big question mark in this, gamma-ray, sector of the picture can be visually impressive.

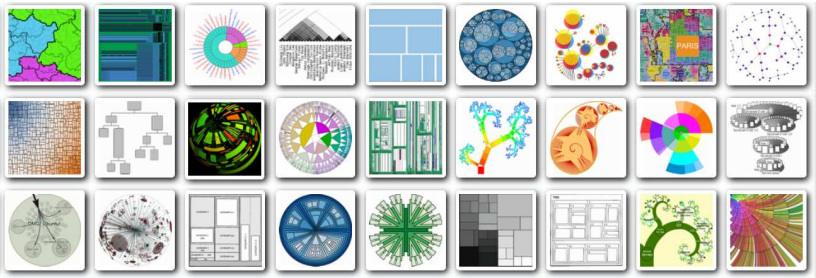
Visual concepts of core science topics and mission

❑ Other preliminary examples of possible graphical communication and concepts, addressed to summarize e-ASTROGAM science topic and mission/instrumental characteristics (work in progress).

❑ 3 core objectives of e-ASTROGAM: 1. processes of the extreme Universe + 2. Galaxy evolution from cosmic rays to antimatter + 3. nucleosynthesis (our radioactive Galaxy, the origin of the elements).

❑ A 3-fold function/character of the mission too? 1. the missing piece of the next/future generation of multi-frequency multi-messenger experiments/observatories + 2. collect data for (and unify) two different (previously rather separated ?) science communities (2a stellar thermal/nuclear astron./astroph. and 2b HE/VHE GeV/TeV non-thermal gamma-ray astroph./fund.-physics). + 3. full capitalization of Si-detector technology in space.





In the era of the social web, concise/fast communication, and the incoming era of citizen science, visualization can be important in science concept design and in summarization of objectives, both addressed to the science community and the citizens (a.k.a. large public, taxpayers funding public science).

❑ Different disciplines/views (stellar therm./nontherm. astroph. vs non-therm. GRB/PSR/AGN/HE astroph.) can make synergy, beyond mere incremental science.

(The core science case can also be a small list, not single, of objectives, with a further non-short list of ancillary science, see the example of the GAIA astrometric/survey mission).

e-ASTROGAM communication web portal

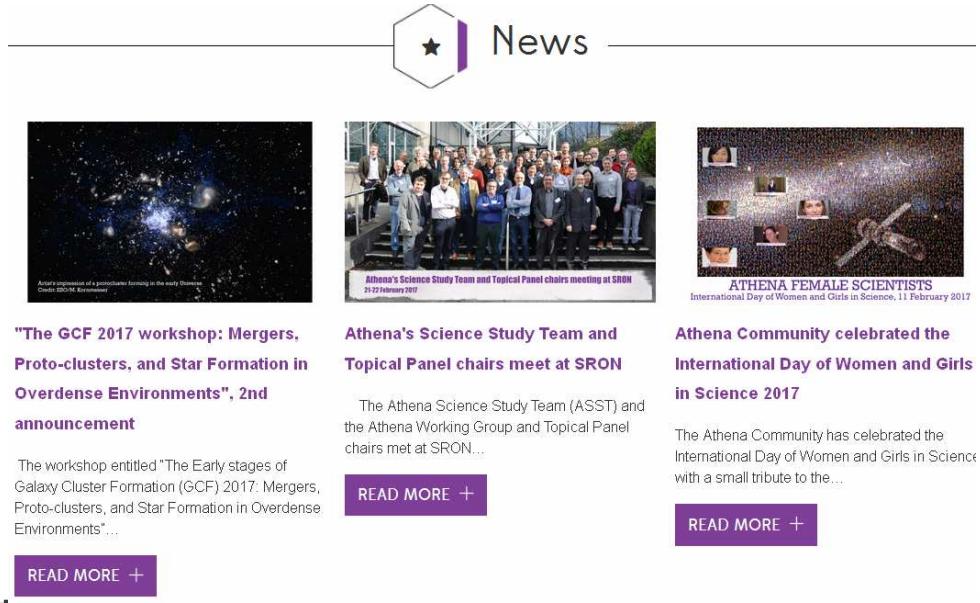
- The centralized standard mission web site related to the proposal is ok.

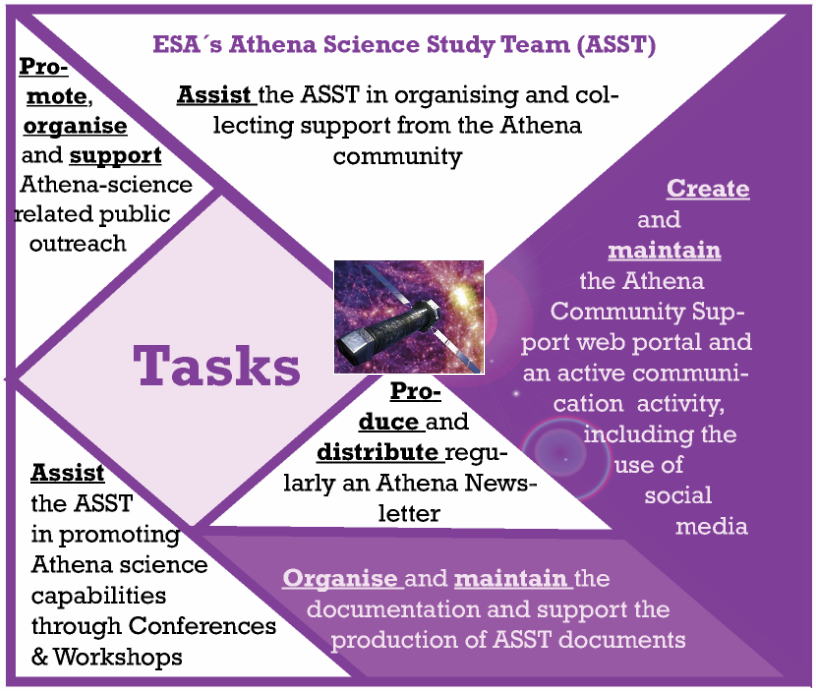
But do we need something more and also different ? Potential Wikipedia, Facebook pages, newsletter… In particular a possible web blog / site dedicated to communication addressed to both broad non-gamma-ray expert scientists community and the large public (E&PO) ? A sort of community support portal (?).

- The funding budget is much more consistent and the mission is already approved, but one example can be represented by the Athena mission Community Office, established by ESA's Athena Science Study Team to support its role as

"focal point for the interests of the broad scientific community".

[www.the-athena-x-ray-observatory.eu].



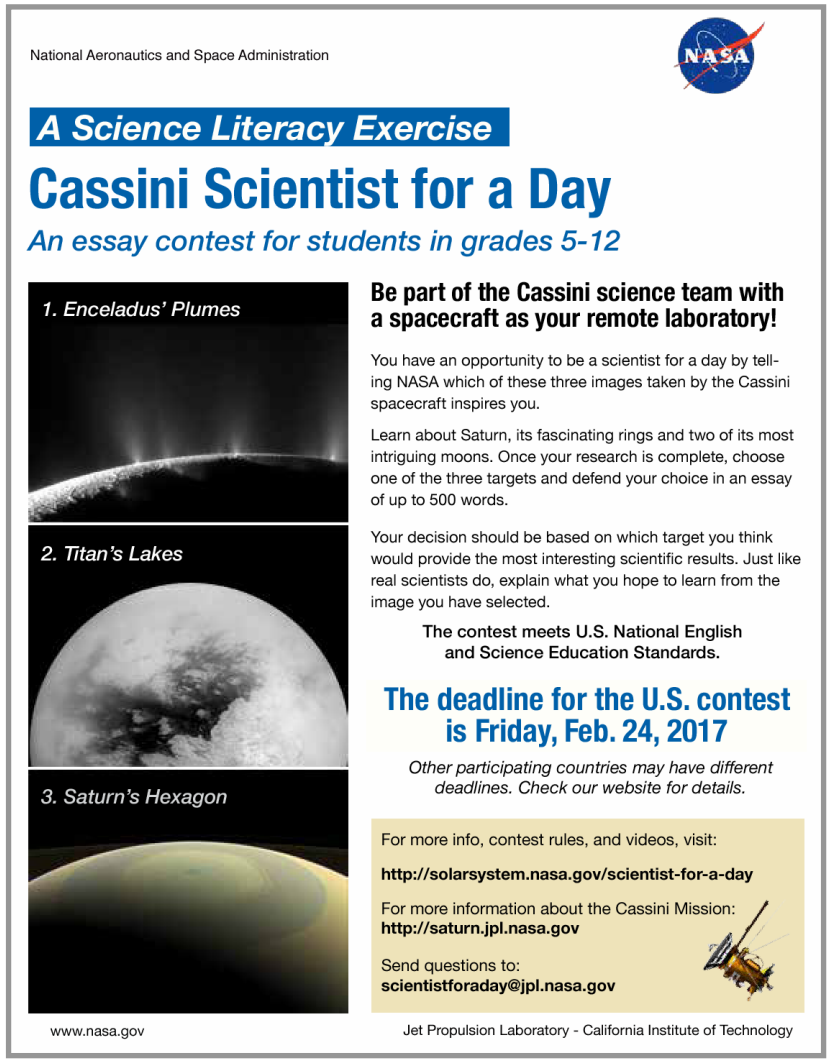


e-ASTROGAM scientist for a day

- Possible idea to establish an international contest, every year, for students (grade tbd) to become e-ASTROGAM scientists for a day selecting and studying e-ASTROGAM topic or target with a pointed space telescope observation. A list of three/fours pre-selected targets/topics to be chosen is another option.

- Thinking something similar also in these possible next >10 years of e-ASTROGAM mission study, simulations, implementation, construction, and pre-launch phases ?

- A successful example: "The Cassini Scientist for a Day" international contest. This challenges students to become NASA scientists studying Saturn system. Participants examine three possible observations taken (or to be taken) by the Cassini spacecraft and are tasked to choose the one they think will yield the best scientific results. This choice must then be supported in a 500-word essay.



National Aeronautics and Space Administration

A Science Literacy Exercise

Cassini Scientist for a Day

An essay contest for students in grades 5-12

1. Enceladus' Plumes

2. Titan's Lakes

3. Saturn's Hexagon

Be part of the Cassini science team with a spacecraft as your remote laboratory!

You have an opportunity to be a scientist for a day by telling NASA which of these three images taken by the Cassini spacecraft inspires you.

Learn about Saturn, its fascinating rings and two of its most intriguing moons. Once your research is complete, choose one of the three targets and defend your choice in an essay of up to 500 words.

Your decision should be based on which target you think would provide the most interesting scientific results. Just like real scientists do, explain what you hope to learn from the image you have selected.

The contest meets U.S. National English and Science Education Standards.

The deadline for the U.S. contest is Friday, Feb. 24, 2017

Other participating countries may have different deadlines. Check our website for details.

For more info, contest rules, and videos, visit:

http://solarsystem.nasa.gov/scientist-for-a-day

For more information about the Cassini Mission:
http://saturn.jpl.nasa.gov

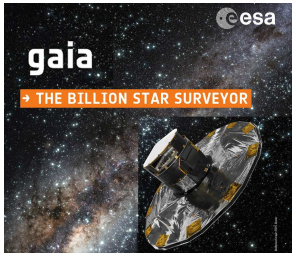
Send questions to:
scientistforaday@jpl.nasa.gov

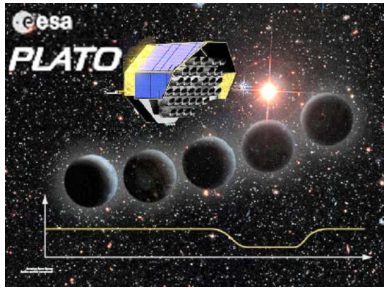
www.nasa.gov

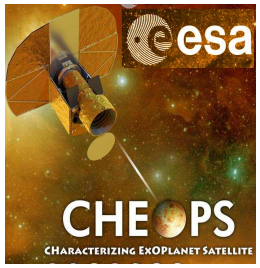
Jet Propulsion Laboratory - California Institute of Technology

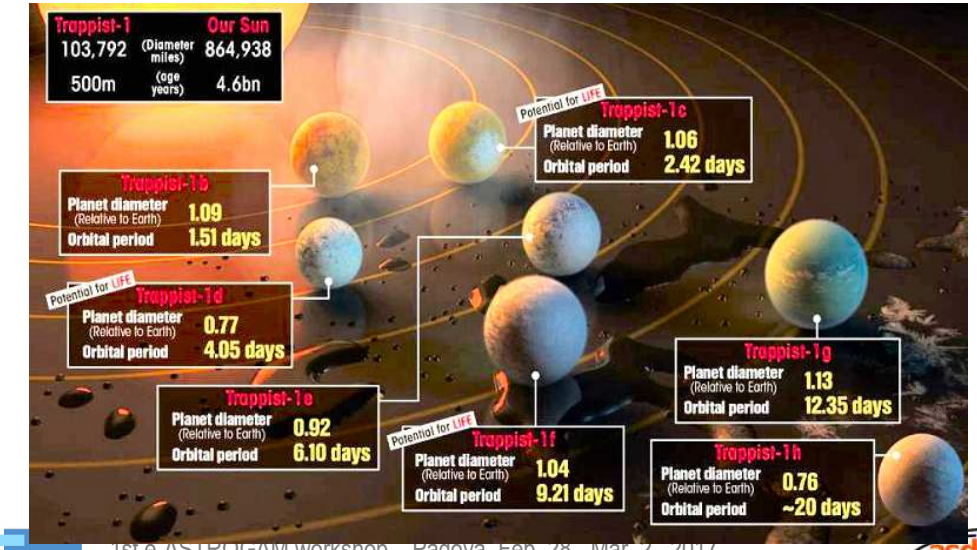
e-ASTROGAM versus exoplanets

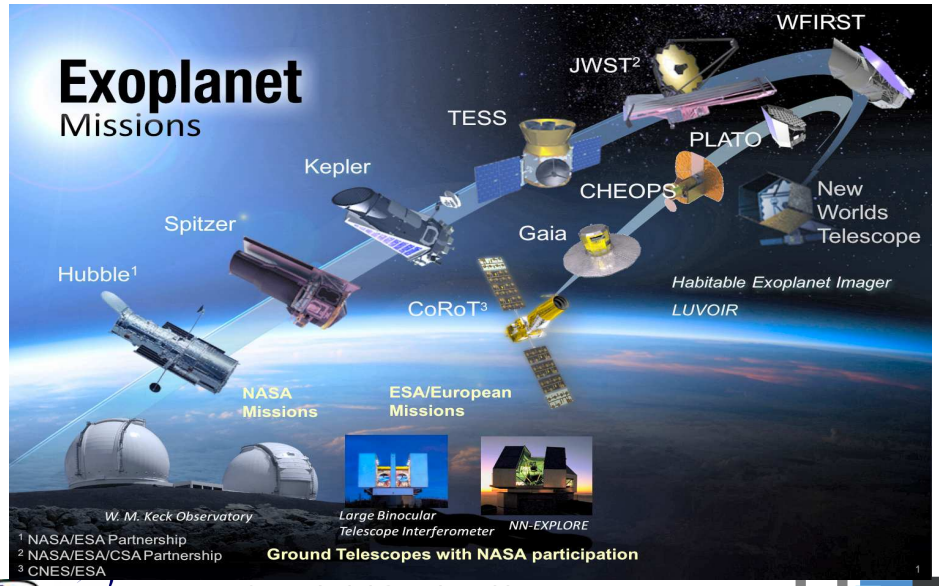
- Exoplanets is not the only compelling topic (example: CMB-related obs. for dark-matter/-energy, solar sys. explor.for water/organics, new FIR mission).
- Exoplanets anyway is very appealing for the large public and can lead to breaking news and some media hype.
- See the very recent discovery of the first known system of seven Earth-size planets around the single brown dwarf star 2MASS J23062928-0502285 at 40 ly (TRAPPIST-1) discovered by the Spitzer space telescope andd the ground-based TRAnsiting Planets and PlanetesImals Small Tel.-south).











Kepler discovery of misterious behavior in KIC 8462852

- KIC 8462852 (TYC 3162-665-1, Tabby's star) is a F3 main-sequence V star at 391 pc in Cygnus region (Boyajian+16).
- Inexplicable series of day-long brightness dips up to 20% observed by the Kepler Space Telescope.
- Infrared flux behavior is equally not explained and no evidence for close interacting companion.
- Weird behavior might originate from a family of large comets, close-in stellar renmants (Bodman & Quillen 2016), or potentially non-astrophysical artifacts like signs of a Dyson sphere (Wright et al. 2016), i.e. very advanced alien civilization.

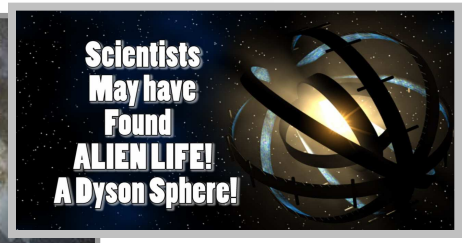
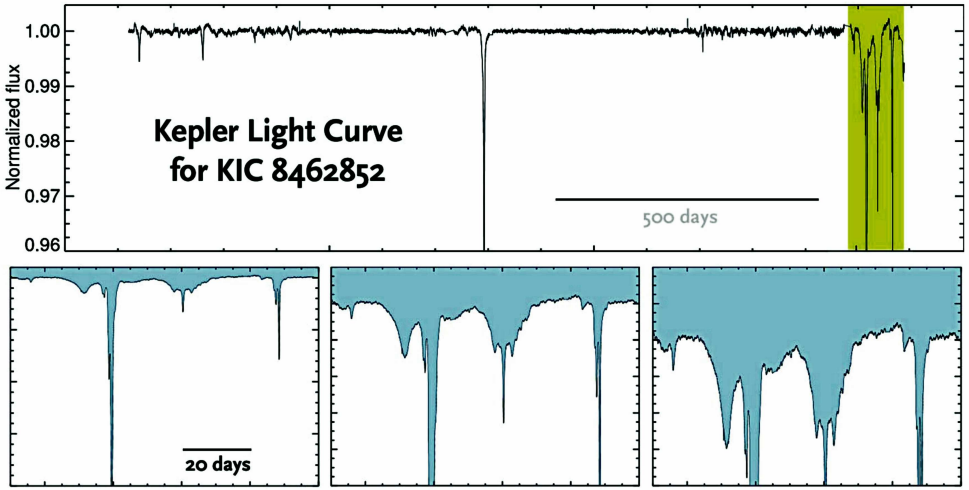


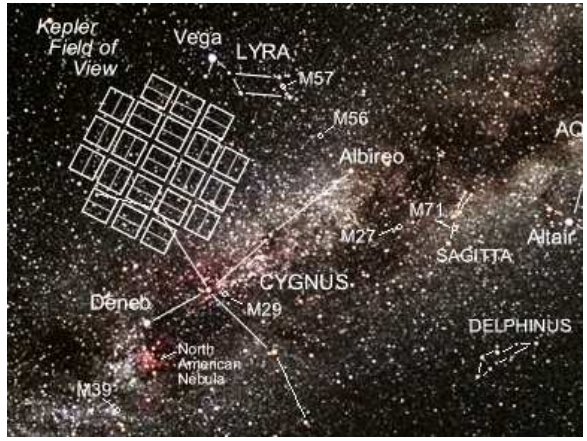
Table 1. Gaia data DR1

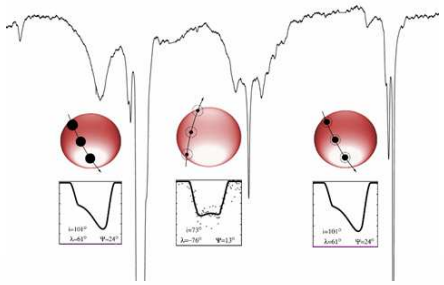
Parameter	Value
Identifier	TYC 3162-665-1
Source ID	2081900940499099136
G mag	11.685 ($n = 140$)
Parallax	2.555 ± 0.311mas ($n = 109$)
Distance	$391.4^{+53.6}_{-42.0}$pc only random uncertainty
	$391.4^{+122.1}_{-75.2}$pc incl. systematic uncertainty

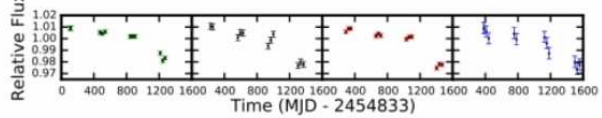


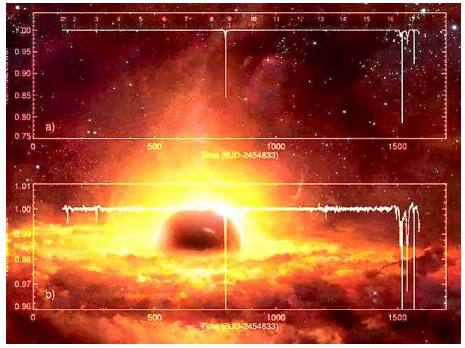
Kepler discovery of misterious behavior in KIC 8462852

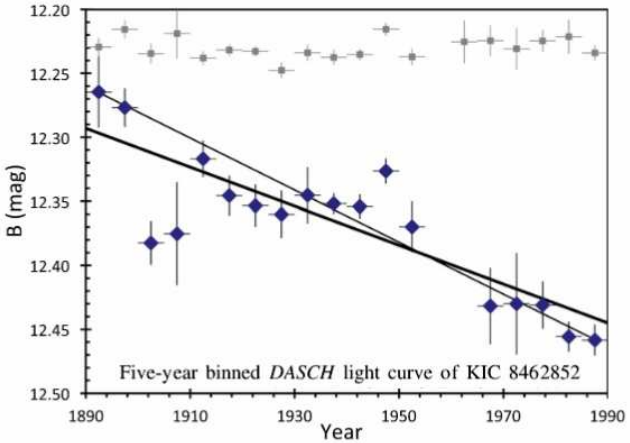
- Overall flux decline over a 4 years baseline from about-monthly Kepler fullframe monitoring observationons.
- Initial 0.34% per year drop, then a rapid dip in optical flux:
  → overall ~2% in 4 years (0.1 Lsun)
- Other longer-term studies have found a potential 0.15% per year drop over about last century using data from DASCH (Digital Access to a Sky Century at Harvard) (Schaefer 2016), disputed by Hippke et al. (2016), Lund et al. (2016).
- No X-rays in Swift (45 ksec) and not expected for a >100 pc F-star.

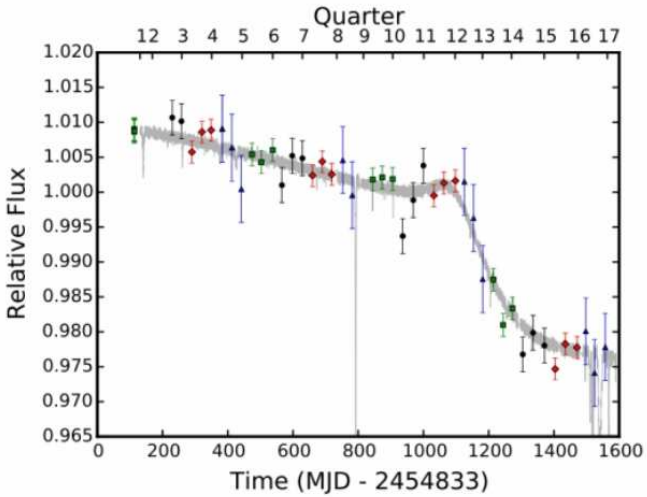






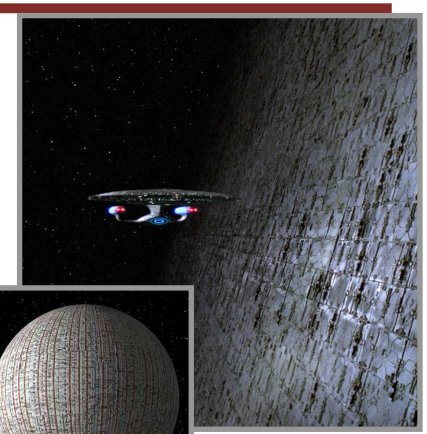


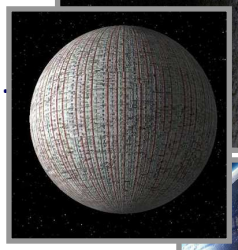


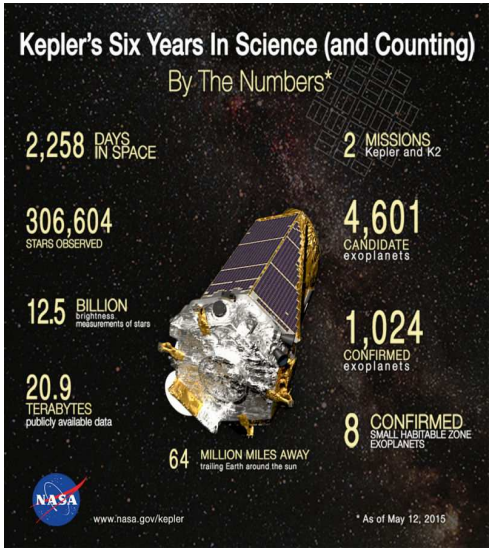


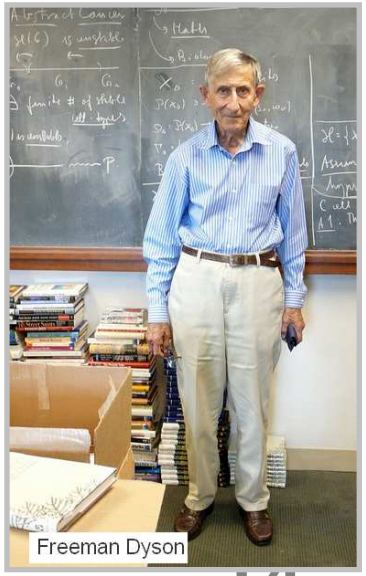
KIC 8462852: a Dyson sphere/array ?

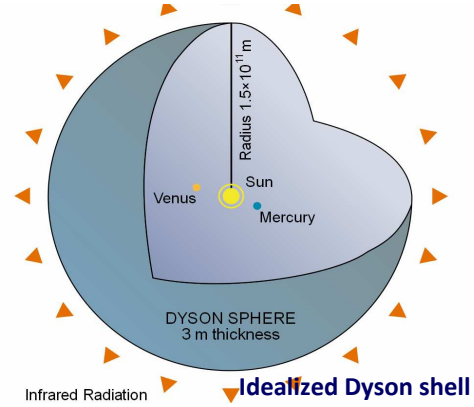
- In 1960, Freeman Dyson hypothesized spheres or swarms constructed to harness and harvest the energy of a parent star (Kardashev-scale Type II civilization). Very popular in science-fiction (space opera):
  - Dyson ring: simplest form of the Dyson swarm (orbit at 1 AU, collectors are 10^7 km in diameter spaced 3 degrees from center to center around the orbital circle. Multiple Dyson rings to form a more complex Dyson swarm.
  - Dyson bubble: an arrangement of statites around a star, in a non-orbital pattern.
  - Idealized Dyson shell: a variant on Dyson's original concept, with a radius of 1 AU.
- Dyson spheres may mean also shields constructed to protect very advanced civilization against nearby deadly cosmic explosions (SN, GRBs)

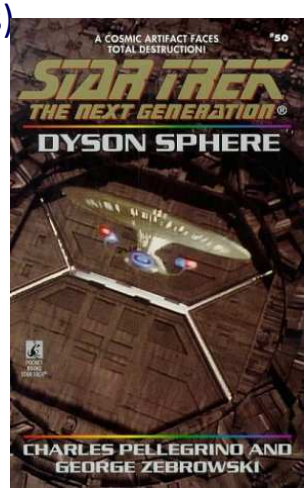


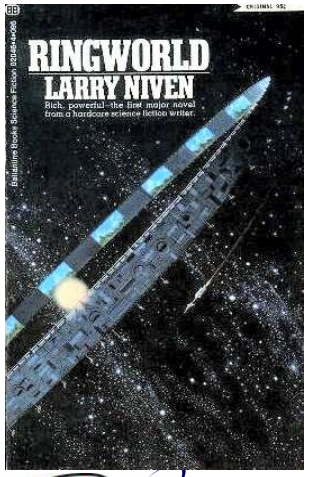


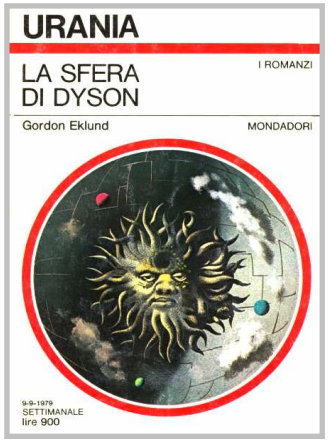




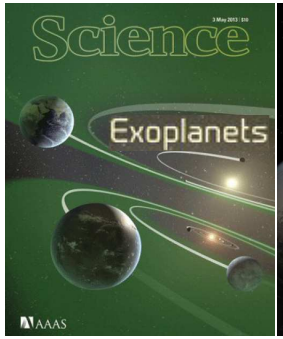




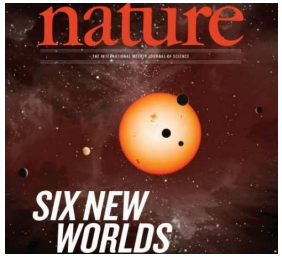




Exoplanets → exolife → alien civilizations (?)



- We can summarize as three the very recent and relevant discoveries related to exoplanets (extra-solar planets) leading to a strong impact on the large public and some media hype:
  - flux dips and flux dimming discovered by Kepler space telescope in star KIC 8462852 (Tabby star);
  - Earth-like planet in Proxima Centauri at 4.2ly (discovered at ESO La Silla 3.6m tel., HARPS spectrograph);
  - First known system of seven Earth-size planets TRAPPIST-1 at about 40ly.



- Is it possible for e-ASTROGAM to play a little bit in the same science field of the exoplanet-dedicated space missions (Kepler, GAIA, Plato, CHEOPS, COROT, TESS, NWM/NWT) and the other optical/IR space missions having exoplanets as one of the target science objectives (Gaia, Spitzer, JWST, WFIRST, LUVOIR..)?

KIC 8462852

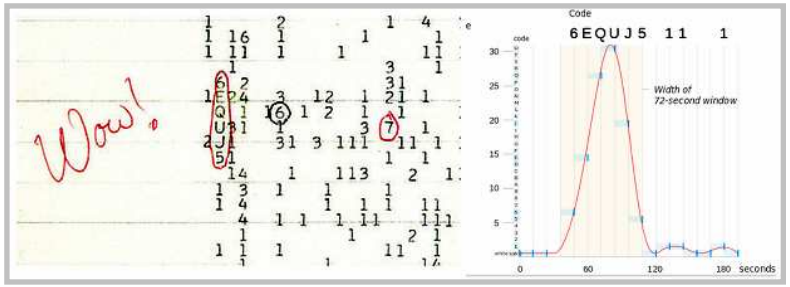
Proxima Centauri b

TRAPPIST-1

e-ASTROGAM & Gamma-ray SETI (?)

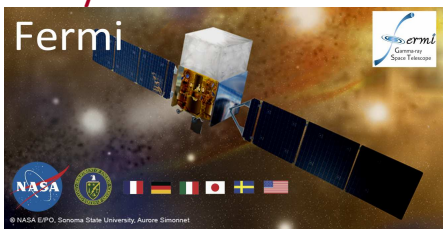
- The search for extraterrestrial intelligence (SETI) is a collective term for scientific searches for intelligent extraterrestrial life, monitoring e.m. radiation for signs/transmissions from civilizations on other worlds.

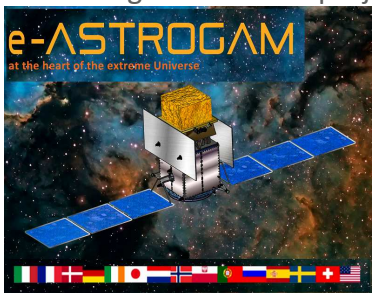
- Historically SETI omitted gamma ray frequencies. This now may change: we can start to think on how to approach to a sort of gamma-ray SETI search (already suggested within the Fermi LAT collaboration) →the future e-ASTROGAM MeV Galactic survey might be of some interest for gamma-ray SETI (with possible inspiring E&PO communication and stories to be built within the exoplanets and SETI fields). The search for technological/artificial signals.

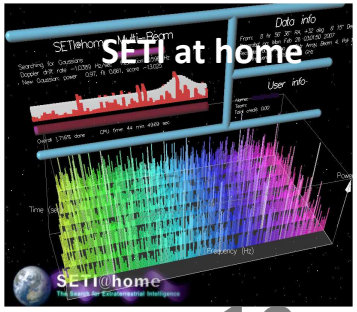


WOW SIGNAL (Aug.15,1977): a strong narrowband radio signal was received by The Ohio State University's Big Ear radiotelescope ('60s O+letter radiosource catalog, example blazars OJ 287, OQ 530, ON 231... were discovered by this radiotelescope) from a direction in the constellation of Sagittarius .
This peculiar unexplained radio signal was then assigned to a SETI project.

Gamma-ray SETI ?



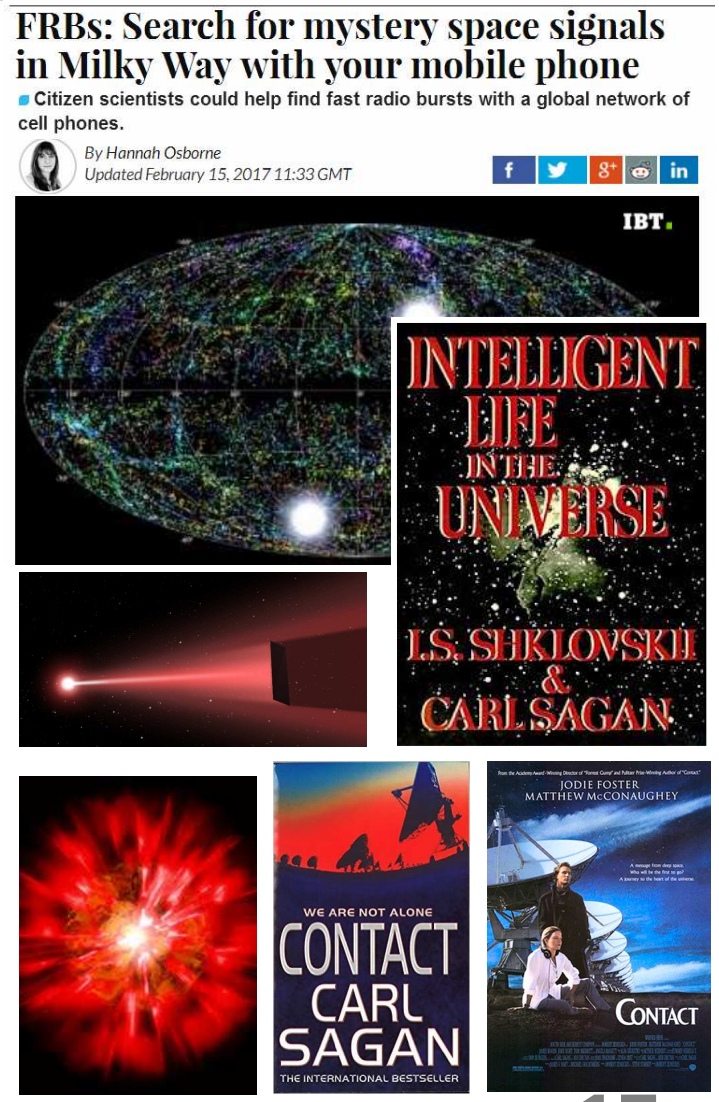




Gamma-ray SETI

Possible case for gamma-ray SETI (E&PO and, of course, SCIENCE FICTION). "Any search for distant intelligent life must also be a search for distant technology" (F. Drake):

- ❑ signals from directed power beaming accelerating spacecrafts
- ❑ signals in nearby stars for potential protective blast shields against nearby merging neutron stars, gamma-ray bursts, SN explosions;
- ❑ artificial objects in transiting orbits,
- ❑ inexplicable temporal signals in gamma-ray light curves and spectral features in gamma-ray SEDs (very high spectral resolution needed);
- ❑ huge space colonies, with large-scale industrial structures, which might operate furnaces for antimatter (again unusual gamma-ray signatures).
- ❑ self annihilation of civilizations by global thermonuclear wars.
- ❑ Type II civilization signals produced by manipulation of their own central star and mining star material:
  - Zwicky, Shkadov: theories to move stars (their planetary systems) with fuel pellets or huge mirrors (radiation pressure feedback) to new locations (because of interstellar dangers).
  - Burbidge, Shklovskii: concentrated gamma-ray flux (10^9 erg/cm2/s) should cause exceedingly high temperatures in outer layers of a star → a sort of SN → copious radiative energy to be collected and Fe/metal-rich expanding gas cloud to be stored. Shklovskii "mining graser" can also be used to turn stars off. Sweepships collecting and store unburned stellar H, then the 1% hot Jovian remaining may be disassembled.



Gamma-ray SETI

- To send notice signals over the Galaxy is convenient to choose energy bands where the background is low. Kardashev Type III civilization can control energy on the scale of its quadrant or entire host galaxy.
- Isotropic gamma-ray background is low, little stellar gamma-ray output.
  - Civilizations bathed in optical light. Absorption/reddening of optical/UV light along the Galactic plane.
  - Terrestrial and Solar interference at radio bands.
- MeV-GeV gamma rays represents a wide-energy band for transmission.
- Fermi LAT continuous all-sky survey, Integral survey of the Galactic plane → e-ASTROGAM deep MeV survey of the Galactic plane.
- Advanced civilizations (Type>II) may have reached a technological singularity enabling them to transmit a two-millisecond pulse encoding 10^18 bits of information.

Kardashev Scale	Barrow Scale
K I – energy consumption at ~ 4 x 10^{19} erg s^{-1}	BI – manipulates objects of its own scale ~ 1 m
K II – energy consumption at ~ 4 x 10^{33} erg s^{-1}	BII – manipulates genes ~ 10^{-7} m
K III – energy consumption at ~ 4 x 10^{44} erg s^{-1}	BIII – manipulates molecules ~ 10^{-9} m
	BIV – manipulates individual atoms ~ 10^{-11} m
	BV – manipulates atomic nuclei ~ 10^{-15} m
	BVI – manipulates elementary particles ~ 10^{-18} m
	BΩ – manipulates space-time's structure ~ 10^{-35} m

Energetic and Inward civilization development

A historical curio about CTA 102

❑ The gamma-ray loud blazar CTA 102 (OY 150, 4C +11.69, PKS 2230+11, DA 582), i.e. Caltech Radio Survey, List A object #102 (Harris & Roberts 1960) is one of the two great false alarms in the history of SETI, (the other being the discovery of pulsars, specifically PSR B1919+21):
-- 1963: N. Kardashev proposed that the then-unidentified radio source could be evidence of a Type II or III extraterrestrial civilization on the Kardashev scale.
-- 1965: G. Sholomitskii find variability in the radio emission of CTA 102.
A public announcement of these results caused a worldwide sensation. The idea that the emission was caused by a civilization was rejected when the radio source was later identified as one of the many varieties of a quasar.
-- 1967: the American folk rock band The Byrds whimsically reflected the original view that CTA 102 was a sign of extraterrestrial intelligence in their song "C.T.A.-102" from their album "Younger Than Yesterday".

❑ Curiosity: on Nov.2016-Feb.2017 an extraordinary GeV gamma-ray emission (>10^-5 ph/cm2/s-1) was observed in CTA 102 by gamma-ray space observatories (we know well now it is NOT related to SETI topic ☺).

PUBLICATIONS OF THE
ASTRONOMICAL SOCIETY OF THE PACIFIC

Vol. 72 August 1960 No. 427

RADIO SOURCE MEASUREMENTS AT 960 MC/S

D. E. Harris and J. A. Roberts

California Institute of Technology Radio Observatory
Owens Valley, California

99	3C 444	22 11 33 ± 8	+3.26	−17 13.7± 3	+0.29
100	3C 445	22 21 17 ±12	+3.10	−02 27 ± 4	+0.30
101	3C 446	22 23 03 ±10	+3.13	−05 14.6± 3	+0.30
102	N.P.C.	22 29 53 ± 6	+2.97	+11 28.2± 2	+0.31
103	3C 452	22 43 33 ±10	+2.71	+39 25 ± 3	+0.32
104	3C 459	23 13 57 ± 6	+3.05	+03 49 ± 3	+0.33
105	Cassiopeia A	23 21 11.4	+2.71	+58 31.9	+0.33

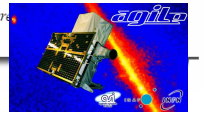
n.p.c.: not in previous (ex: 3C) catalogs

```
C T A 102
(Roger McGuinn/R.J.Hippard)

     G       C    G
1. C.T.A. 102
F                        C
year over year receiving you
G                   C          G
Signals tell us that you're there
F                        C            Dsus     D
We can hear them loud and clear

2. We just want to let you know
that we're ready for to go
Out into the universe
we don't care who's been there first

3. On a radio telescope
science tells us that there's hope
Life on other planets might exist
```

AGILE detection of intense gamma-ray emission from the FSRQ CTA102

ATel #9863; *A. Bulgarelli (INAF/IASF-Bo), M. Tavani (INAF/IAPS, and Univ. Roma Tor Vergata), F. Verrecchia, C. Pittori, F. Lucarelli (ASDC and INAF/OAR), P. Munar-Adrover*
on 14 Dec 2016; 23:03 UT
Credential Certification: Andrea Bulgarelli (bulgar

Subjects: Gamma Ray, >GeV, AGN, Blazar



Fermi LAT observation of renewed and strong GeV gamma-ray activity from blazar CTA 102

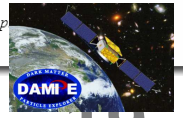
ATel #9869; *Stefano Ciprini (ASI ASDC Rome & INFN Perugia, Italy), on behalf of the Fermi Large Area Telescope Collaboration*
on 16 Dec 2016; 20:52 UT
Credential Certification: Stefano Ciprini (stef

Subjects: Gamma Ray, >GeV, Request for Observations, AGN

DAMPE detection of variable GeV gamma-ray emission from blazar CTA 102

ATel #9901; *Zun-Lei Xu (PMO), Micaela Caragiulo (Bari), Jin Chang (PMO), Kai-Kai Duan (PMO), Yi-Zhong Fan (PMO), Fabio Gargano (Bari), Shi-Jun Lei (PMO), Xiang Li (PMO), Yun-Feng Liang (PMO), M. Nicola Mazziotta (Bari), Zhao-Qiang Shen (PMO), Meng Su*
on 27 Dec 2016; 01:02 UT
Credential Certification: Zun-Lei Xu (xuzl@p

Subjects: Gamma Ray, >GeV, AGN, Blazar, Quasar

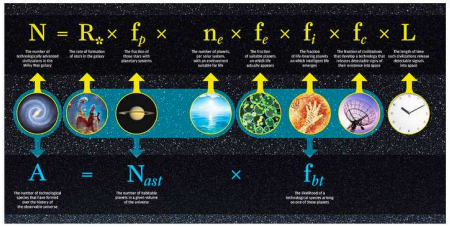


FRBs & MGFs

❑ Fast-radio-bursts (FRBs) first discovered in 2007. About 20 detected by big radiotelescopes (Parkes, Arecibo). They are inferred to originate from distant galaxies.

❑ FRBs could consist of multiple source populations. Even if FRBs may occur in different source populations, theremay be a common mechanism for coherent radio emission, in principle. Some FRBs could show the coincidence of a short gamma-ray spike a bit after the FRB pulse.

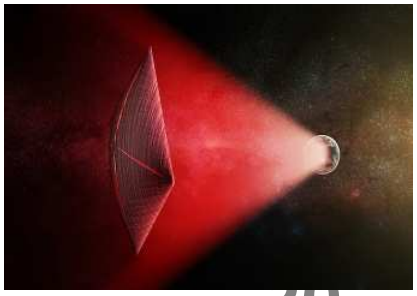
❑ Some photon pair search with search windows 1,2,5,10 millisec within 2 deg already done to search for FRB prompt gamma-ray counterparts in Fermi LAT data (search for millisecond-duration gamma-ray flashes, MGFs, Yamasaki et al. 2016). A disadvantage for gamma-ray SETI is the large power output requirements to emit gamma-rays.



What to search using per-photon MeV-GeV data and MGFs:

❑ unusual spectral signatures with possibly very high spectral resolution average SEDs (posible single energy bin detection). Photon pairs or multiplets (in energy and/or time) similar to blind LAT data searches for FRB counterpart, or primordial, intermediate mass, BH searches;

❑ unusual light curve signatures with dips or other features, possible periodicities (next optical periodic flux dip in KIC 8462852 in 2017, period 750 days), and even bursts (single GRBs, mini-GRBs (?)) with strange shapes, possible repeating bursts (?).



Very recent study on the possibility that FRBs originate from the activity of extragalactic civilizations. Radio beam emitter parameters estimated through energetic and engineering constraints. Beams used for powering large (two-earth size) light sails (propulsion for interstellar alien spaceships, Lingam & Loeb 2017)

Conclusions

In this light end-of-the-day (and pre-social dinner) talk I tried to introduce further two inputs than may be of possible interest for the e-ASTROGAM (possibly not already presented at this Workshop).

❑ Some simple questions and preliminary ideas about communication

• Data visualization, education and public outreach, communication, social digital technologies and platforms, open and increased usability of space science data to citizens, citizen science, etc. are all things that have an increasing interest and pressure for science and space missions.

❑ Some possible interest for what is being called gamma-ray SETI (or gamma-SETI). Again this input is mostly related to communication/promotion aspects rather than to expected possible scientific results.

• We could search in e-ASTROGAM data, and develop methods, that aim to detect anything would be unusual astrophysically in MeV-GeV band.

• It is an inspiring topic (at the border of sci-fi) for the large public (and remember SETI at home and citizen science in general), with direct competition in the exoplanets science but pushing forward:

→ exoplanet missions: earth-size planets / earth-like water/atmospheres searches (i.e. signs of life) .

→ e-ASTROGAM/current gamma-ray mission might directly search for very advanced civilizations (also based on gamma-ray signals).

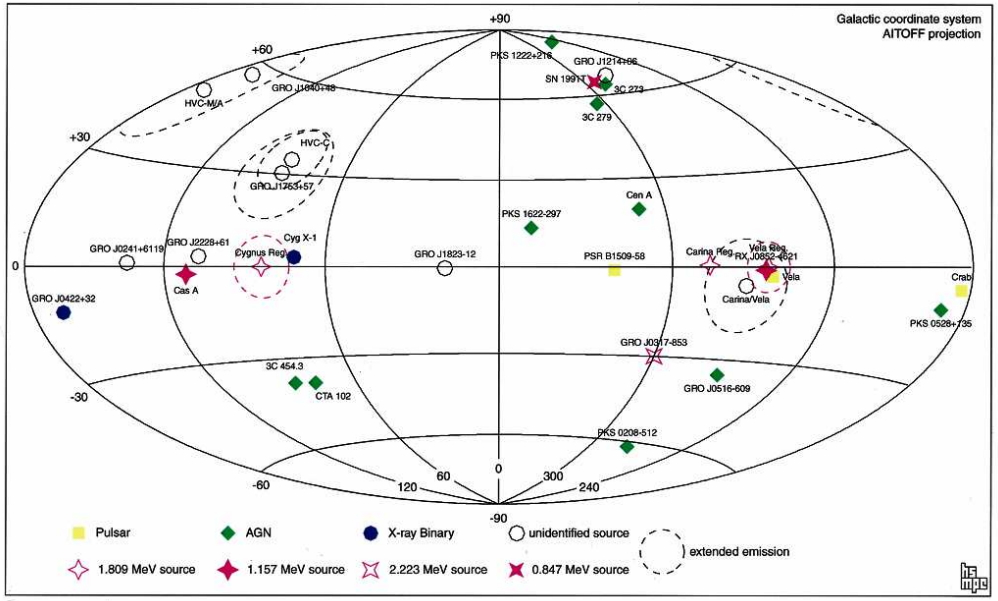
❑ Extra-note (this is science): a possible third input is the consideration of non-explosive nucleosynthesis, radioactives, by low/intermediate mass stars, AGB/super-AGB stars, circumstellar envelopes, enrichment of primordial solar nebula, infrared-MeV connection in late stages of stellar evolution for low/intermediate mass stars.

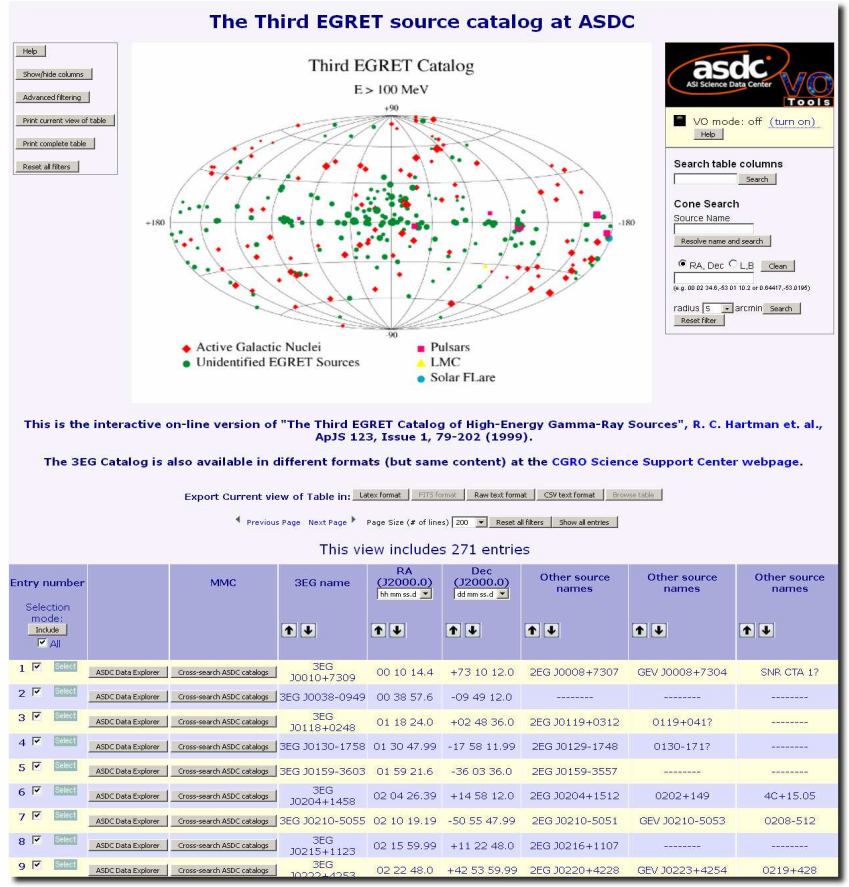
The European way to the extreme gamma-ray Universe

Backup slides

Interactive version of the 1st COMPTEL catalog ?

- We are thinking on how to implement the 1st COMPTEL catalog at the ASI SSDC as an interactive table and interface (many Fermi Catalogs, also the 3rd EGRET Catalog, are already implemented as interactive tables and web pages by the Fermi Team at the ASI SSDC).
- The 1st COMPTEL catalog has a dozen of tables with different format and content. Thinking how to best report this in a single web table.

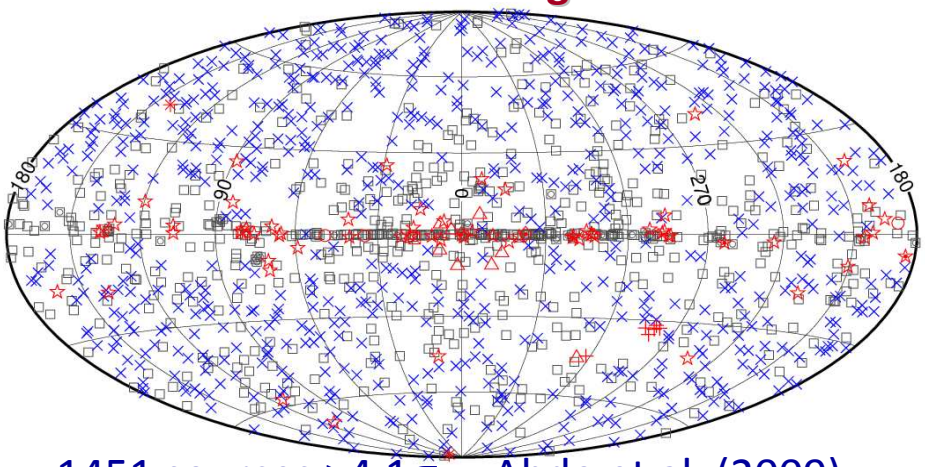




Fermi LAT general catalogs (1/2/3FGL)

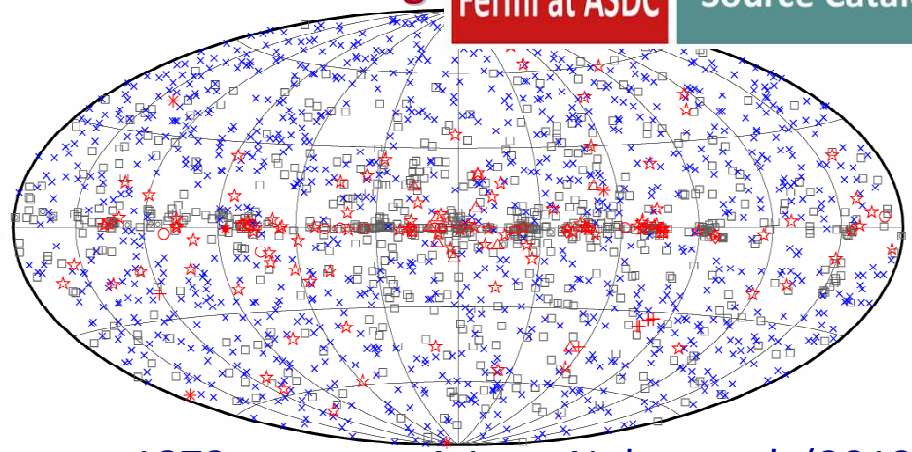
Fermi at ASDC | Source Catalogs

1FGL Catalog



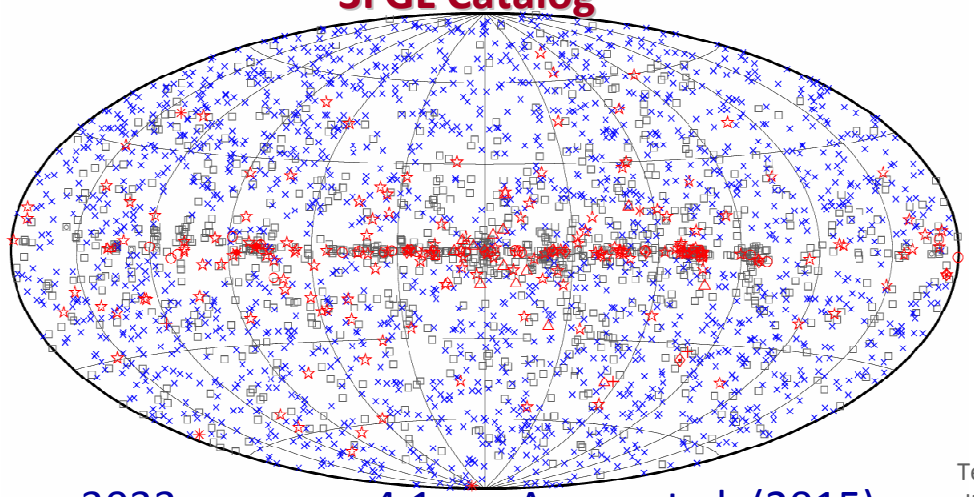
1451 sources >4.1σ Abdo et al. (2009)

2FGL Catalog



1873 sources >4.1σ Nolan et al. (2012)

3FGL Catalog



3033 sources >4.1σ Acero et al. (2015)

LAT catalogs:

- To know what the LAT has detected
- Approach for finding new gamma-ray source classes
- Population studies
- Systematic analysis of the sky
- Standard model-fitting LAT source analysis → the catalog is initial guess for detailed study of any source

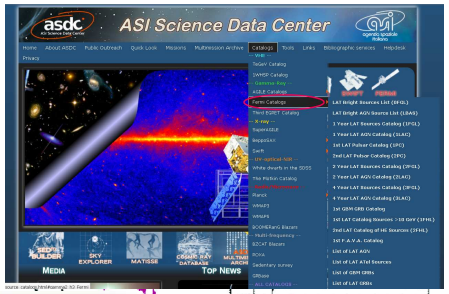
No association	Possible association with SNR or PWN		AGN
Pulsar	Globular cluster	Starburst Galaxy	PWN
Binary	Galaxy	SNR	Nova
Star−forming region			

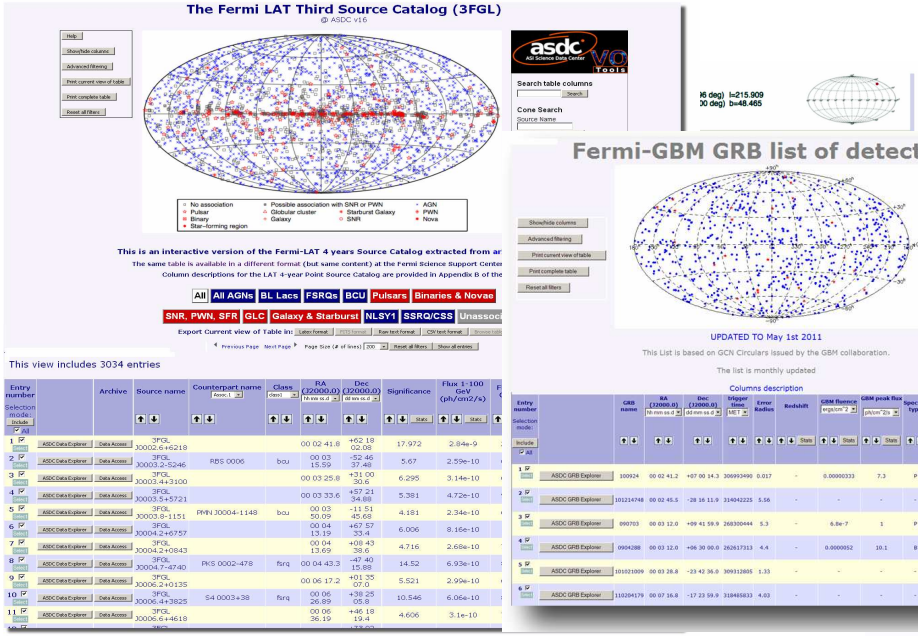
Test statistics TS>25 corresponds to a significance >4.1σ evaluated from the chi^2 distribution (4 degrees of freedom position, spectral parameters, Mattox et al. 1996).

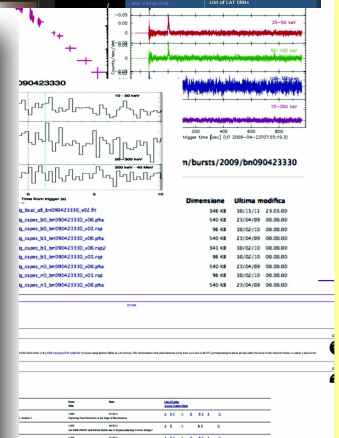
Fermi Source Catalogs/Lists at ASI SSDC

Fermi at ASDC | **Source Catalogs**

- Fermi official catalogs with dedicated web page tables, interactive interfaces, and products (stastics, plots, interfaces for multifrequency archives for each source, data query).
- Fermi incremental lists (built here) with dedicated web page tables, interactive interfaces, and products.

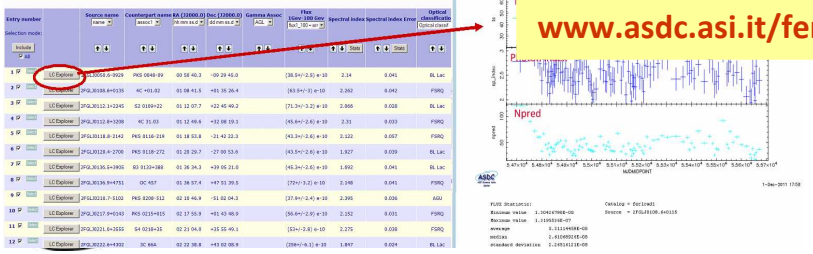




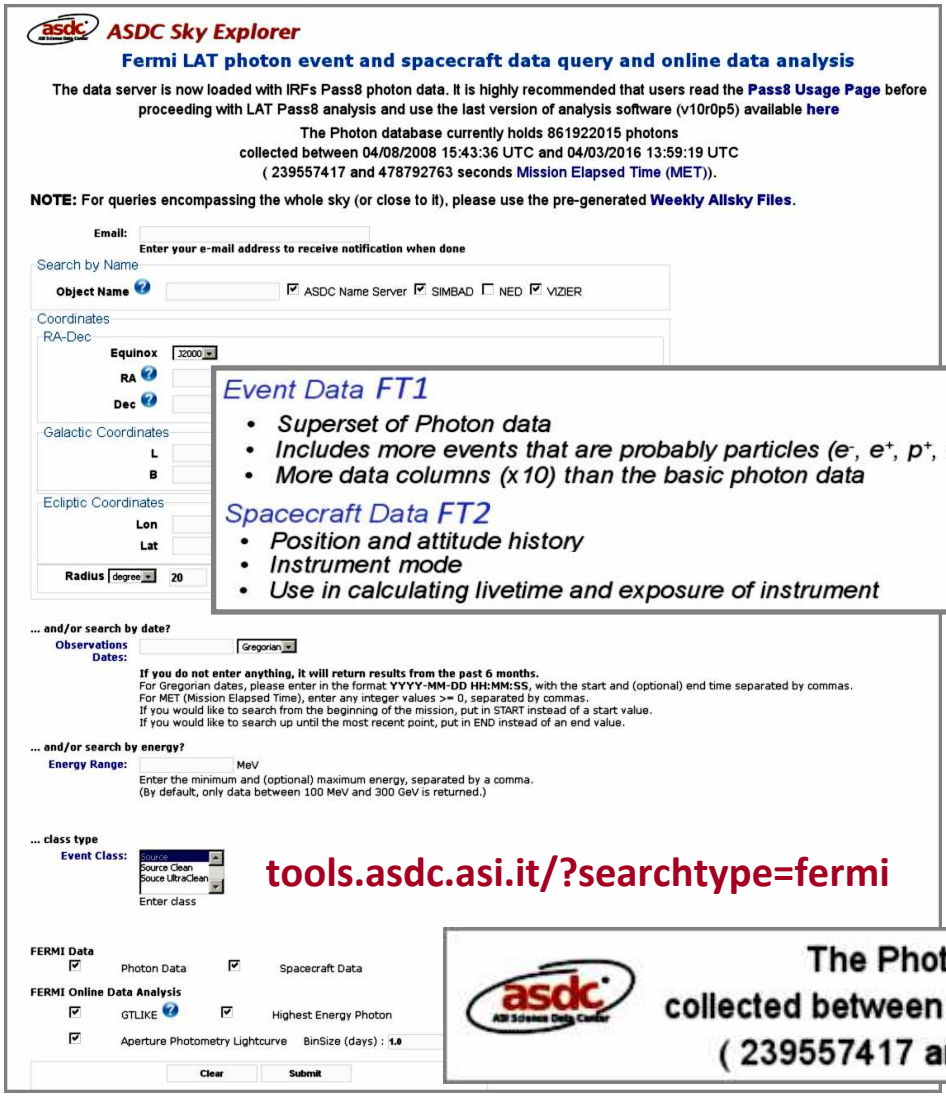


www.asdc.asi.it/fermibsl/
www.asdc.asi.it/fermilbas/
www.asdc.asi.it/fermi1fgl/
www.asdc.asi.it/fermi2fgl/
www.asdc.asi.it/fermi3fgl/
www.asdc.asi.it/fermi1lac/
www.asdc.asi.it/fermi2lac/
www.asdc.asi.it/fermi3lac/
www.asdc.asi.it/fermi1fhl/
www.asdc.asi.it/fermi2fhl/
www.asdc.asi.it/feratel/
www.asdc.asi.it/fava/
www.asdc.asi.it/gbmcatalog/
www.asdc.asi.it/gbmsolar/
www.asdc.asi.it/grbgbm/
www.asdc.asi.it/grblat/
www.asdc.asi.it/fermipsr/
www.asdc.asi.it/ferbrlc2/
www.asdc.asi.it/fermiagn/

- 3FGL Catalog: 4 years, P7REP_SOURCE_V15, improved PSF.
- Front/Back handled separately (different isotropic, Earth limb).
- Energy range 100 MeV - 300 GeV.
- 3033 sources (2192 at |b|>10°) >4.1 σ.
- Blazars and pulsars dominate. 1/3 unassociated sources.



Fermi LAT Public Data Archive at ASI SSDC



Event Data FT1

- *Superset of Photon data*
- *Includes more events that are probably particles (e^-, e^+, p^+, etc.)*
- *More data columns (x 10) than the basic photon data*

Spacecraft Data FT2

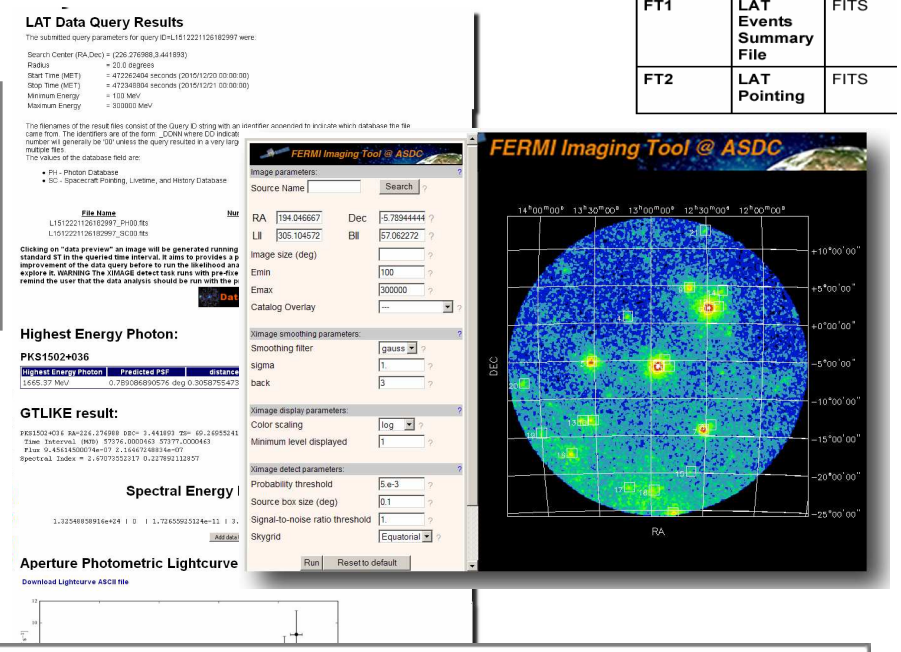
- *Position and attitude history*
- *Instrument mode*
- *Use in calculating livetime and exposure of instrument*

tools.asdc.asi.it/?searchtype=fermi

Fermi at ASDC | LAT Data Archive

- Mirror database of the LAT high level public science data (FITS format FT1/FT2 event/spacecraft) at ASDC.
- Photon Data Rate: coming in at about a rate of 4.4 Hz → 120 million photons per year
- New data available every 2, 3 hours.

File Name	File type	Format
FT1	LAT Events Summary File	FITS
FT2	LAT Pointing	FITS



The Photon database currently holds 861922015 photons
collected between 04/08/2008 15:43:36 UTC and 04/03/2016 13:59:19 UTC
(239557417 and 478792763 seconds Mission Elapsed Time (MET)).

Fermi team at the ASI SSDC

- 1) Fermi public data archive at the ASI SSDC is an official copy archive (MoU) of the standard FT1/FT2 fits files distributed through the official NASA Goddard FSSC web site. All the data are immediately public.
- 2) Two primary tasks and science topics of modern astrophysics and astroparticle physics: multifrequency/multimessenger astronomy and survey/time-domain astronomy (transients, variability monitor, HE extreme-physics, cosmic accelerators, increasing sensitivity for new physics and dark matter search, CR production sites,… and serendipity!). ASI SSDC team involved science groups like AGN, Catalogs, MW analysis.
- 3) Building and distribution of gamma-ray source catalogs.
- 4) Development of data visualization and exploration interactive tools through the web, quicklook analysis in short time intervals, development of scientific software, simulations, analysis.
- 5) Gamma-ray and multifrequency data analysis and scientific researches about extragalactic sources (AGN/blazars), one of the historically main topics of the, formerly ASDC, Center.
- 6) Contribution to analysis, duties, coordination within the LAT Instrument International Collaboration. Relations with other Data Centers like ISOC-SLAC (Stanford) and the FSSC-GSFC (NASA).