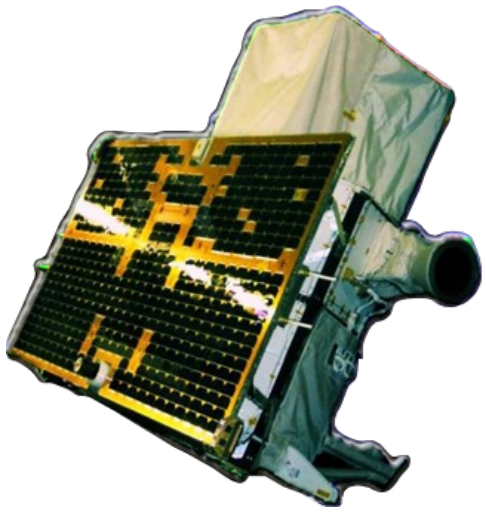


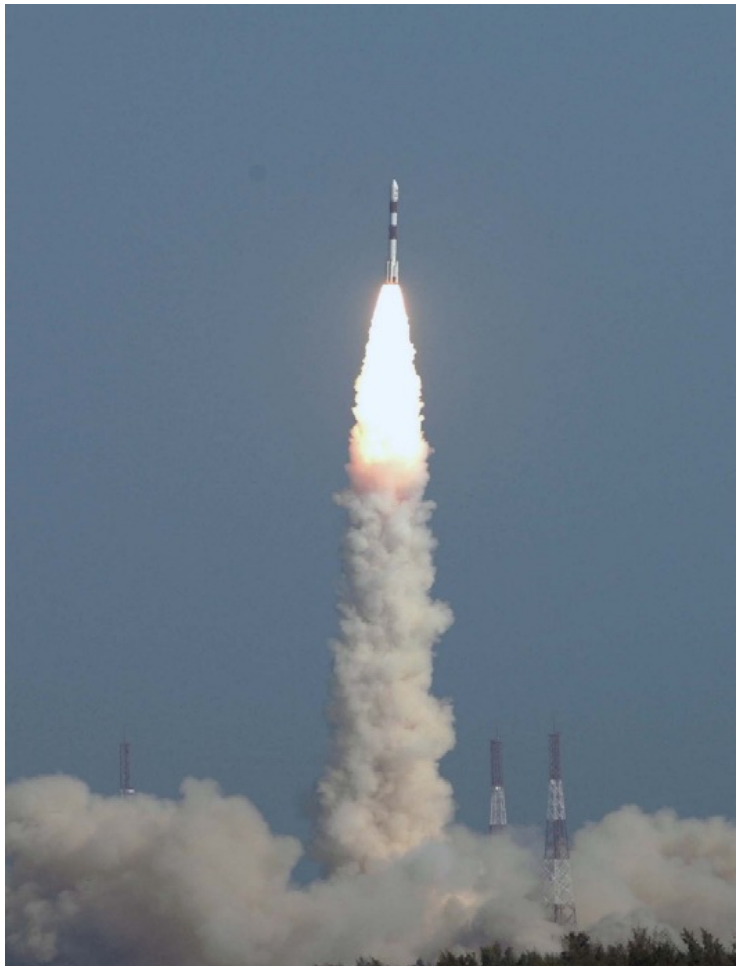
The AGILE experiment status and results

Carlotta Pittori (INAF-OAR and ASI-SSDC)
on behalf of the AGILE Team

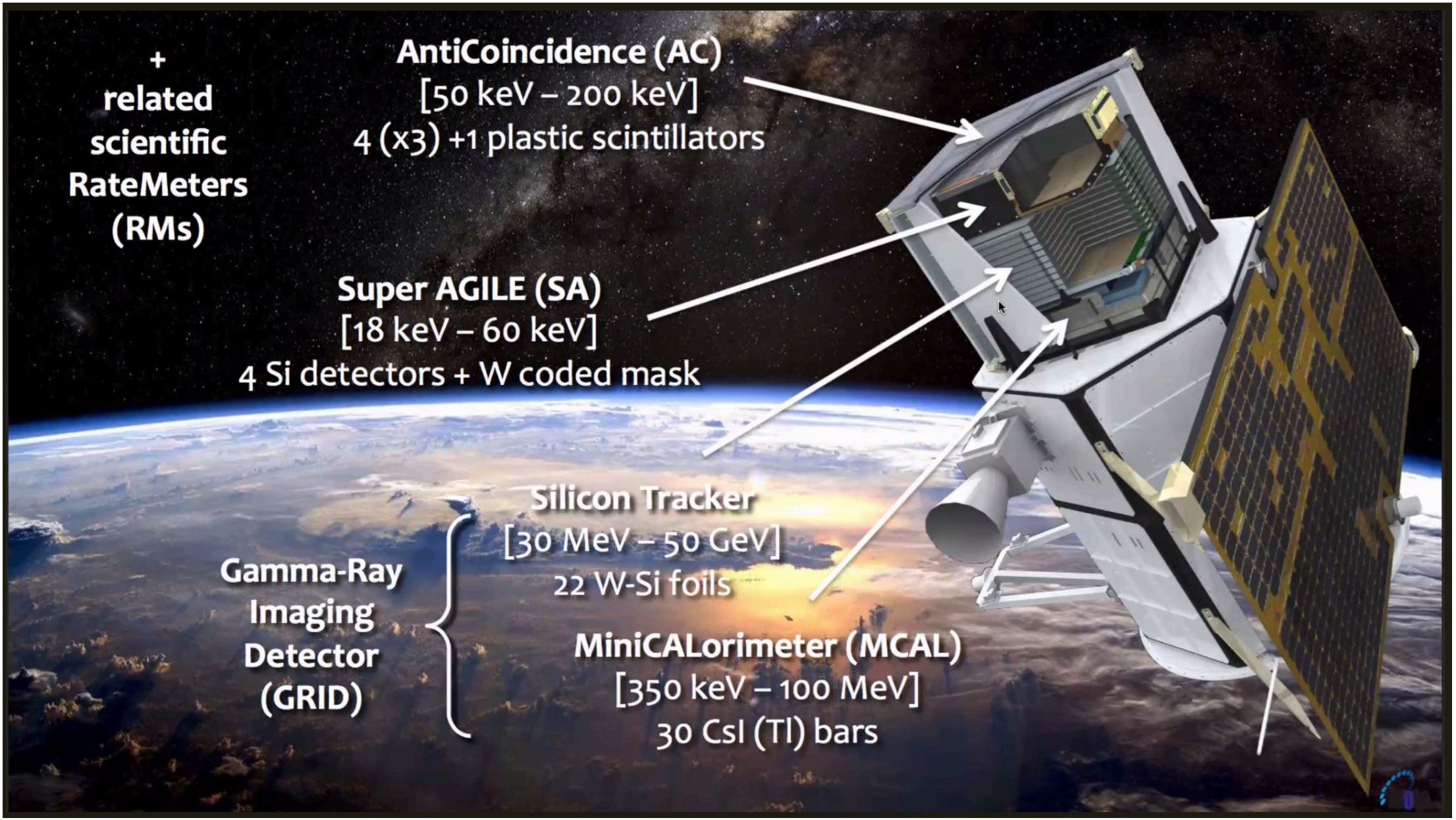
RICAP-22 September 9, 2022
Physics Department, University "La Sapienza", Roma, Italy

India April 23, 2007: AGILE satellite launch

Low Earth equatorial orbit: 550 Km and < 3 deg inclination angle



Italian Space Agency (ASI) Mission with INFN, INAF participation

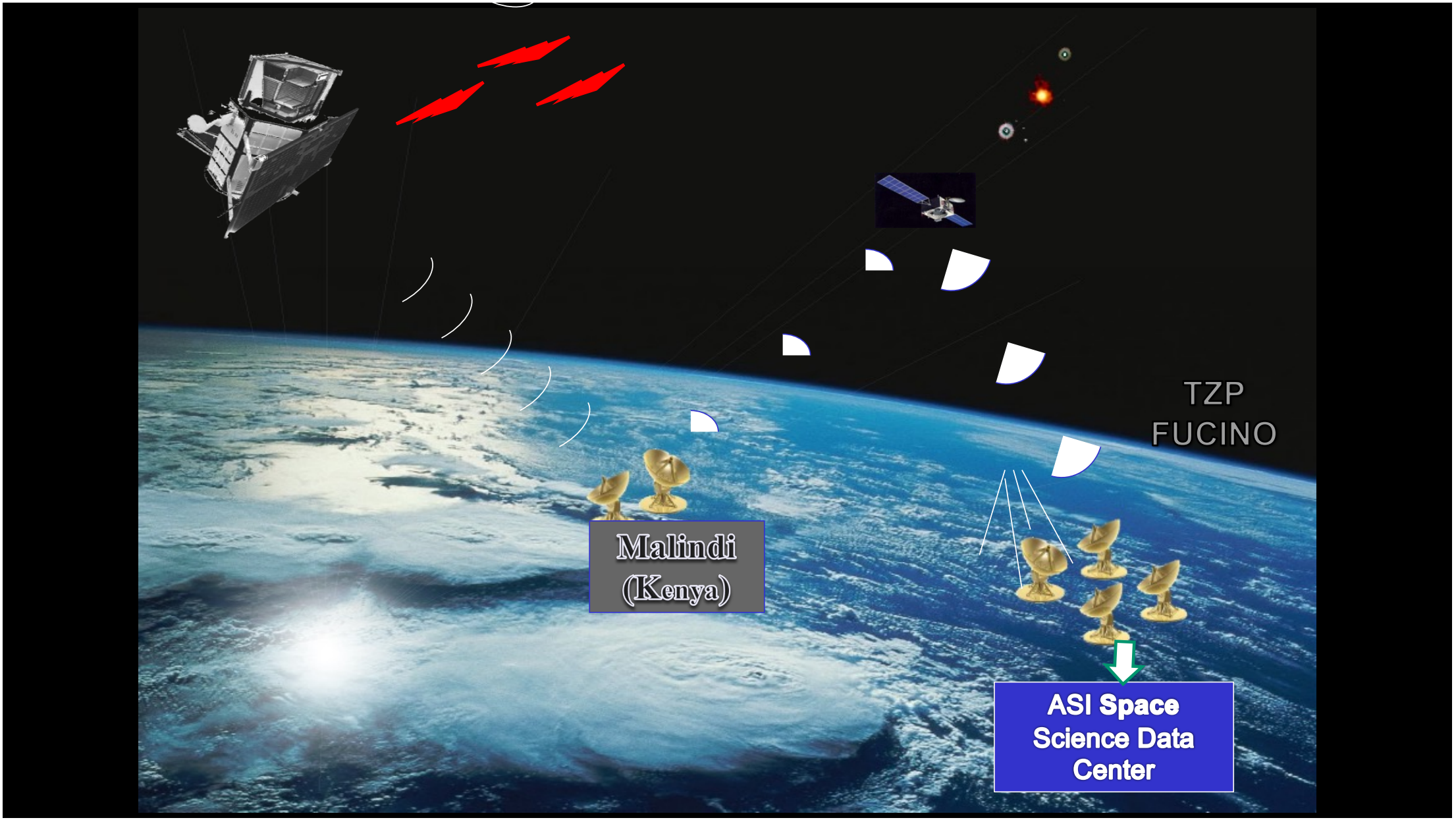

+
related
scientific
RateMeters
(RMs)
AntiCoincidence (AC)
[50 keV – 200 keV]
4 (x3) +1 plastic scintillators
Super AGILE (SA)
[18 keV – 60 keV]
4 Si detectors + W coded mask
Gamma-Ray
Imaging
Detector
(GRID)
Silicon Tracker
[30 MeV – 50 GeV]
22 W-Si foils
MiniCALorimeter (MCAL)
[350 keV – 100 MeV]
30 CsI (Tl) bars

AGILE in its 16-th year of operations in space

- Gamma-ray detector (GRID): 50 MeV - 1 GeV
- Minicalorimeter (MCAL): 400 keV-100 MeV
- Super-AGILE X-ray detector: 18-60 keV
- Anticoincidence System (AC): 80-200 keV

Fully operational, nominal status, and active in:

- gamma-ray astrophysics
- terrestrial atmosph. & magnetosph. physics
- search of GW counterparts, neutrinos, Fast Radio Bursts and other transients


TZP
FUCINO
Malindi
(Kenya)
ASI Space
Science Data
Center

Scientific status of AGILE

- **Nominal status.** AGILE was strongly affected by **limited ground operations at ASI-Malindi** due to the **COVID-19 pandemic**: **from March 2020 to May 2021** down to **3 passes/day** served for AGILE (instead of 14).

- **For more than one year AGILE has operated with the GRID in standby.** Only with **MCAL** and **ratemeters (RM)** on, due to the limited telemetry budged from Malindi.

- **On May 6, 2021,** Malindi has resumed serving ~ 7 passes/day to the AGILE mission, and the **GRID observations** could finally be **restarted**.

- **Since March 21, 2022 ~ 10 pass/day.** At least ~12-14 passes/day needed to have the Payload always in its "full GW" configuration (GRID and SA always in obs and MCAL at its full sensitivity).

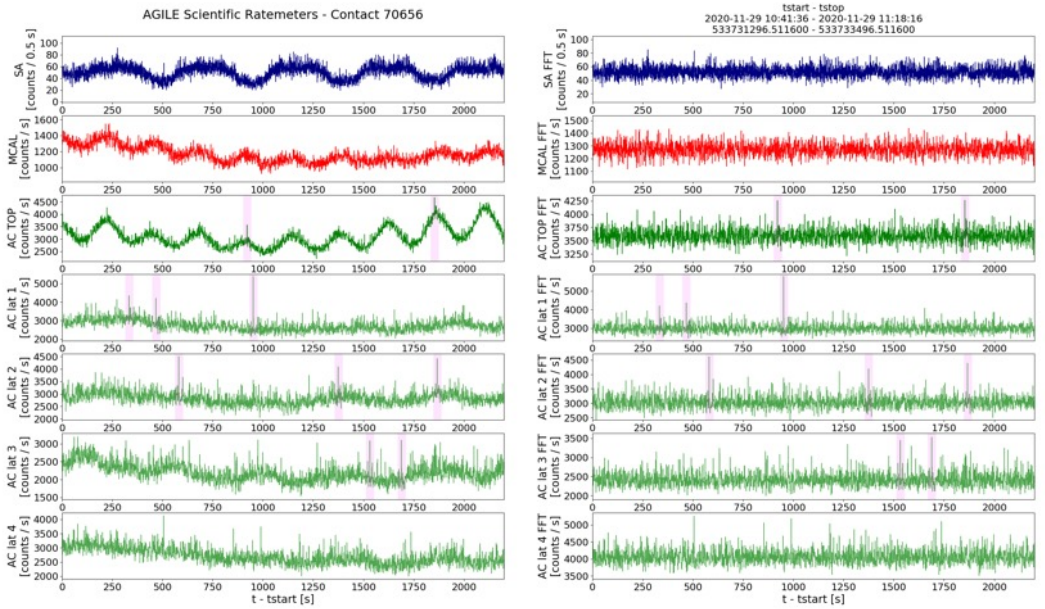
- However, during the limited TM period, **much improved RM analysis**, automatic processing and burst identification. The system was also updated for the follow-up of **Solar flares**.

Dedicated automatic pipeline for AGILE Ratemeters analysis

(Spinning detrending on the right)

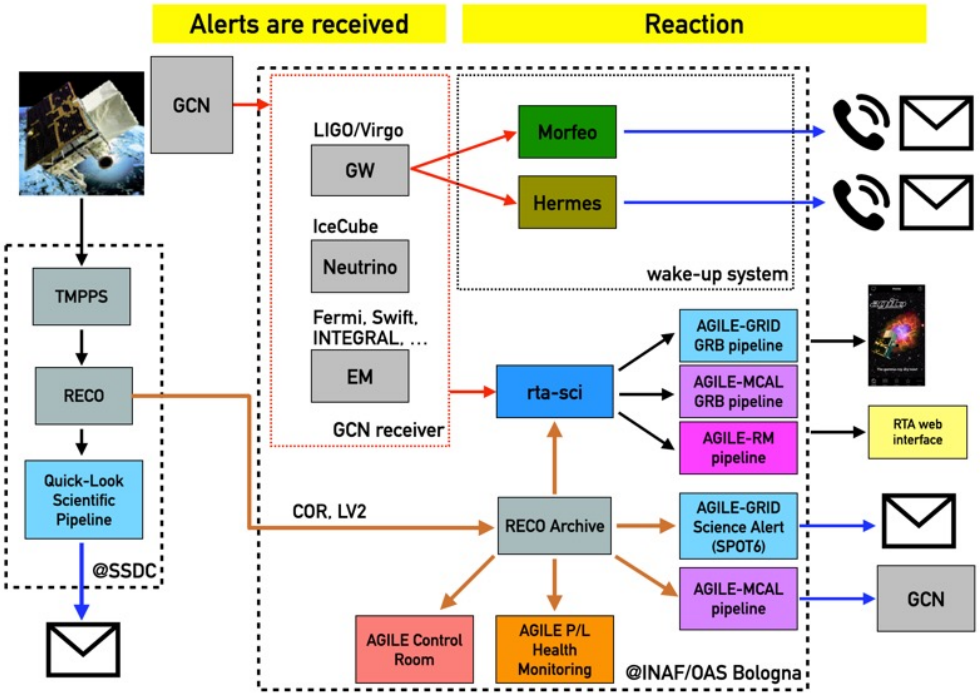
- RM SA
- RM MCAL
- RM AC top
- RM AC Lat 1, Lat 2, Lat 3 , Lat4.

(AC Lat4 always oriented towards the SUN)



- Daily Monitoring with 48-hour shifts
- MCAL automatic alerts published as Notices in the GCN Network
- ***New:*** Automatic solar flares alerts from AC Lat4 RM (internal emails)
- ***New:*** Automatic RM alerts (internal emails)

AGILE Fast Real-Time Analysis



- Distributed alert system between SSDC e INAF-OAS Bologna
- Automatic AGILE data analysis (GRID, MCAL, Ratemeters)
- Fast reaction to external alerts (GCN, e.g. GRB/GW)
- Internal automatic alert generation (via email, SMS) and direct connection with the GCN network for MCAL notices.
- Development of similar pipelines (starting from the AGILE heritage) for **new missions** such as CTA, COSI, Gamma-FLASH…

Nicolò Parmiggiani: PHD IN COMPUTER ENGINEERING AND SCIENCE
National award for research on big data and artificial intelligence 2021!

Parmiggiani, N. et. al. “The RTApipe framework for the gamma-ray real-time analysis software development”, Astronomy and Computing. Volume 39, 2022, doi.

AGILE main results
and work in progress

Summary of AGILE results in ~15 years of operations

- **Publications:** the scientific production of the AGILE Team consists of**> 790 bibliographic references in ADS, of which> 160 refereed articles.**
- The monitoring of the gamma sky with a rapid and efficient alert system led to the publication of **> 230 ATel** and **>110 GCN**. From May 2019, **> 80 MCAL GCN automatic notices** have been published.

- The Quick Look system developed by INAF-OAS, distributed between the data center at SSDC and INAF-OAS in Bologna, produces **scientific results within ~ 25 min** from the data downlink to the ASI Malindi ground station: an absolute record for gamma astrophysics. The Team has also developed an App to monitor and follow the observations of the AGILE satellite on mobile devices: **AGILEScience - App** on Google Play and App Store.

- **AGILE and the search for GW counterparts:** participation of Team members with shifts 24/7 during LIGO-VIRGO observational runs. AGILE follow-up of all GW events, with **96 GW-AGILE type GCNs published** and collected in a dedicated web page in SSDC**:** *https://agile.ssdc.asi.it/news_gw.html*

- AGILE contribution to **Fast Radio Bursts** science: **very important discovery** on April 28, 2020 published in **Nature, Tavani et al. 2021** (2021NatAs...5..401T)

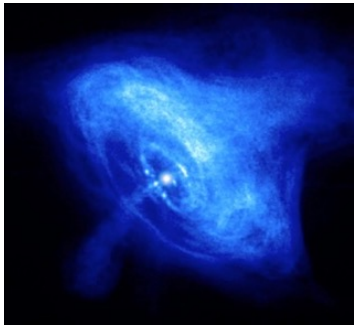
Main AGILE-led publications in descending order of citation in ADS

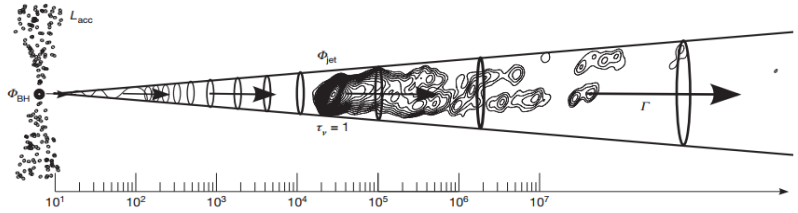
Therefore, neither important MW and MM publications nor the most recent ones are included in this list

#	DOI	Descrizione	
1	10.1051/0004-6361/200810527	Titolo: The AGILE Mission Autori:M. Tavani and G. Barbiellini and A. Argan and F. Boffelli and A. Bulgarelli and P. Caraveo and P. W .... Publisher:EDP Sciences Rivista: Astronomy \& Astrophysics Anno pubblicazione:2009	The AGILE Mission
2	10.1126/science.1200083	Titolo: Discovery of Powerful Gamma-Ray Flares from the Crab Nebula Autori:M. Tavani and A. Bulgarelli and V. Vittorini and A. Pellizzoni and E. Striani and P. Caraveo and M. .... Publisher:American Association for the Advancement of Science (AAAS) Rivista: Science Anno pubblicazione:2011	
3	10.1038/nature08578	Titolo: Extreme particle acceleration in the microquasar Cygnus\hspace0.167emX-3 Autori:M. Tavani and A. Bulgarelli and G. Piano and S. Sabatini and E. Striani and Y. Evangelista and A. T .... Publisher:Springer Science and Business Media LLC Rivista: Nature Anno pubblicazione:2009	Cyg X-3 mQSO flares, *Nature*
4	10.1088/2041-8205/742/2/L30	Titolo: NEUTRAL PION EMISSION FROM ACCELERATED PROTONS IN THE SUPERNOVA REMNANT W44 Autori:A. Giuliani and M. Cardillo and M. Tavani and Y. Fukui and S. Yoshiike and K. Torii and G. Dubner a .... Publisher:American Astronomical Society Rivista: The Astrophysical Journal Anno pubblicazione:2011	CR acceleration in SNR W44
5	10.1103/PhysRevLett.106.018501	Titolo: Terrestrial Gamma-Ray Flashes as Powerful Particle Accelerators Autori:M. Tavani and M. Marisaldi and C. Labanti and F. Fuschino and A. Argan and A. Trois and P. Giommi a .... Publisher:American Physical Society (APS) Rivista: Physical Review Letters Anno pubblicazione:2011	TGFs as powerful p.cle accelerators
6	10.1029/2009JA014502	Titolo: Detection of terrestrial gamma ray flashes up to 40 MeV by the AGILE satellite Autori:M. Marisaldi and F. Fuschino and C. Labanti and M. Galli and F. Longo and E. Del Monte and G. Barbi .... Publisher:American Geophysical Union (AGU) Rivista: Journal of Geophysical Research: Space Physics Anno pubblicazione:2010	HE TGFs seen by AGILE-MCAL
7	10.1016/j.nima.2007.07.147	Titolo: SuperAGILE: The hard X-ray imager for the AGILE space mission Autori:M. Feroci and E. Costa and P. Soffitta and E. Del Monte and G. Di Persio and I. Donnarumma and Y. E .... Publisher:Elsevier BV Rivista: Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment Anno pubblicazione:2007	SuperAGILE X-ray Imager on AGILE
8	10.1051/0004-6361/200911783	Titolo: First AGILE catalog of high-confidence gamma-ray sources Autori:C. Pittori and F. Verrecchia and A. W. Chen and A. Bulgarelli and A. Pellizzoni and A. Giuliani and .... Publisher:EDP Sciences Rivista: Astronomy \& Astrophysics Anno pubblicazione:2009	The 1AGL Catalog
9	10.1088/2041-8205/710/2/L151	Titolo: DIRECT EVIDENCE FOR HADRONIC COSMIC-RAY ACCELERATION IN THE SUPERNOVA REMNANT IC 443 Autori:M. Tavani and A. Giuliani and A. W. Chen and A. Argan and G. Barbiellini and A. Bulgarelli and P. C .... Publisher:American Astronomical Society Rivista: The Astrophysical Journal Anno pubblicazione:2010	CR acceleration in SNR IC443
10	10.1088/0004-637X/691/1/L13	Titolo: THE JUNE 2008 FLARE OF MARKARIAN 421 FROM OPTICAL TO TeV ENERGIES Autori:I. Donnarumma and V. Vittorini and S. Vercellone and E. Del Monte and M. Feroci and F. D\textquote .... Publisher:American Astronomical Society Rivista: The Astrophysical Journal Anno pubblicazione:2008	MWL analysis of flaring blazar Mrk 421

AGILE scientific lessons:

- Large Field of View (~ 60 deg) HE sky monitoring: fast and intense variability discovered at all scales.
- Extragalactic, Galactic and even Terrestrial physics
- New acceleration mechanisms
- Role of local magnetic field enhancements
- Plasma instabilities





Updates on AGILE and GRB

AGILE MCAL second GRB catalog

- Comprehensive catalog of all GRB detected by MCAL from 2007 to 2020 [*Ursi et al., ApJ, 2022*]

The Astrophysical Journal, 925:152 (16pp), 2022 February 1 https://doi.org/10.3847/1538-4357/ac3df7

The Second AGILE MCAL Gamma-Ray Burst Catalog: 13 yr of Observations

A. Ursi[1], M. Romani[2], F. Verrecchia[3,4], C. Pittori[3,4], M. Tavani[1,2], M. Marisaldi[5,6], M. Galli[6,7], C. Labanti[6], N. Parmiggiani[6], A. Bulgarelli[6], A. Addis[6], L. Baroncelli[6], M. Cardillo[1], C. Casentini[1,8], P. W. Cattaneo[9], A. Chen[10], A. Di Piano[6], F. Fuschino[6], F. Longo[11], F. Lucarelli[3,4], A. Morselli[8], G. Piano[1], and S. Vercellone[12]
[1] INAF/IAPS, via del Fosso del Cavaliere 100, I-00133 Roma (RM), Italy; alessandro.ursi@inaf.it
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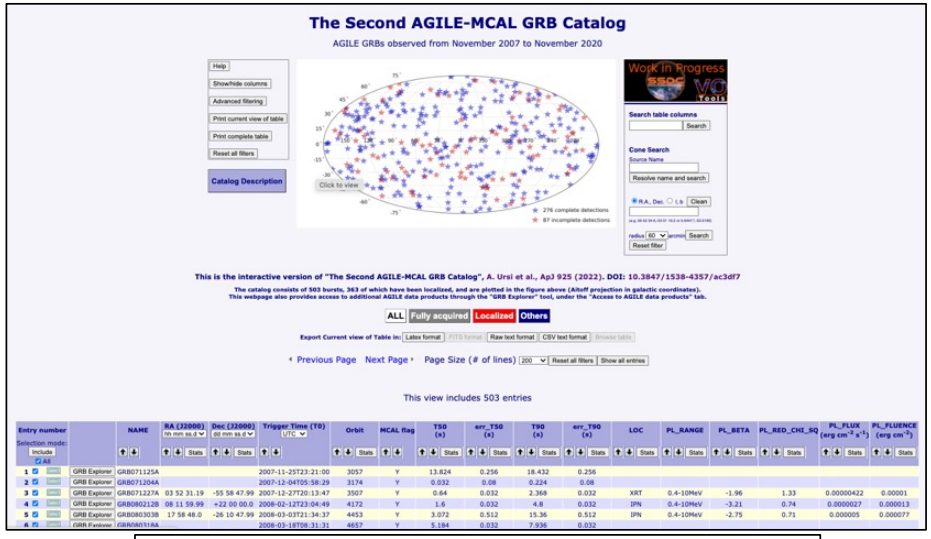
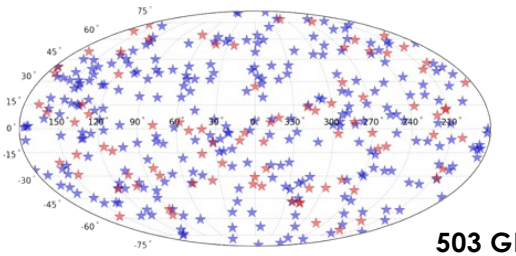
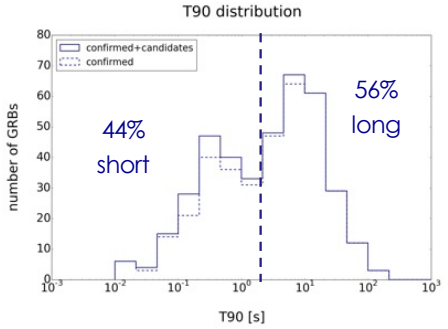
[11] Dipartimento di Fisica, Università di Trieste and INFN, via Valerio 2, I-34127 Trieste (TR), Italy
[12] INAF—Osservatorio Astronomico di Brera, via E. Bianchi 46, I-23807 Merate (LC), Italy
Received 2021 July 8; revised 2021 November 8; accepted 2021 November 24; published 2022 February 2

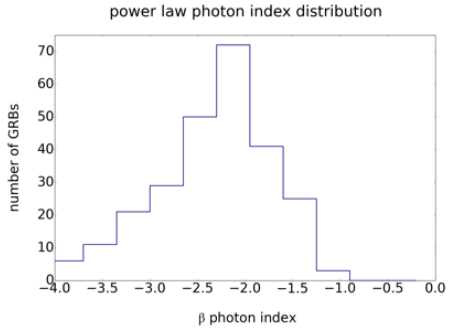


SSDC interactive web page
https://www.ssdc.asi.it/mcal2grbcat/



503 GRBs





Spectra mostly fittable with power-laws (high-energy tail of the spectra in MCAL band)

GRB 190114C

First GRB event detected at very high-energies by MAGIC

- participation to the multi-frequency paper [*MAGIC Collaboration, Nature, 2019*]
- dedicated analysis of the prompt phase with AGILE and Konus-Wind data [*Ursi et al., ApJ, 2020*]

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Article | Published: 20 November 2019

Observation of inverse Compton emission from a long γ-ray burst

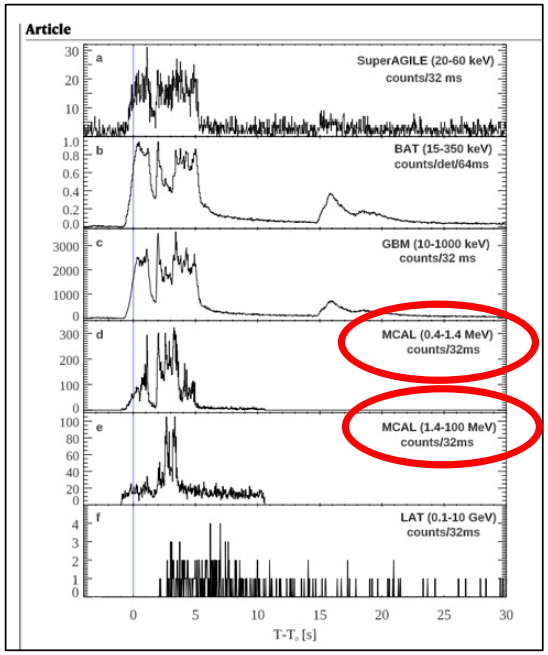
MAGIC Collaboration, P. Veres, ... D. R. Young + Show authors

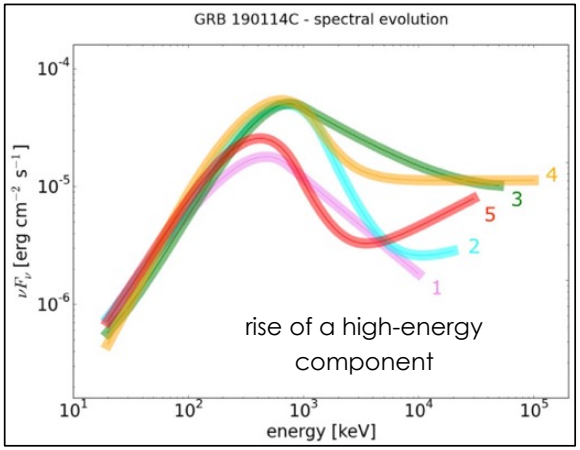
Nature **575**, 459–463 (2019) | Cite this article

10k Accesses | **91** Citations | **821** Altmetric | Metrics

Abstract

Long-duration γ-ray bursts (GRBs) originate from ultra-relativistic jets launched from the collapsing cores of dying massive stars. They are characterized by an initial phase of bright





The Astrophysical Journal, 904:133 (17pp), 2020 December 1 https://doi.org/10.3847/1538-4357/abc2d4

AGILE and Konus-Wind Observations of GRB 190114C: The Remarkable Prompt and Early Afterglow Phases

A. Ursi[1], M. Tavani[1,2], D. D. Frederiks[3], M. Romani[2], F. Verrecchia[4,5], M. Marisaldi[6,7], R. L. Aptekar[3], L. A. Antonelli[5], A. Argan[1], A. Bulgarelli[7], G. Barbiellini[8], P. Caraveo[9,10], M. Cardillo[1], C. Casentini[1], P. W. Cattaneo[10], A. Chen[11], E. Costa[1], I. Donnarumma[12], Y. Evangelista[1], M. Feroci[1], A. Ferrari[13], F. Fuschino[7], M. Galli[7,14], A. Giuliani[9], C. Labanti[7], F. Lazzarotto[15], F. Longo[8], F. Lucarelli[4,5], A. Morselli[16], F. Paoletti[1,17], N. Parmiggiani[7], G. Piano[1], M. Pilia[18], C. Pittori[4,5], D. S. Svinkin[3], A. Trois[18], A. E. Tsvetkova[3], S. Vercellone[19], and V. Vittorini[1]

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New Year's Burst GRB 220101A

event with the highest E_{iso} ever detected

- analysis of the prompt phase using AGILE ratemeters data [*Ursi et al., ApJ, 2022d*]

The Astrophysical Journal, 933:214 (12pp), 2022 July 10 https://doi.org/10.3847/1538-4357/ac746c

AGILE Observations of GRB 220101A: A "New Year's Burst" with an Exceptionally Huge Energy Release

https://orcid.org/0000-0002-9332-5319

A. Ursi[1], M. Romani[2], G. Piano[1], F. Verrecchia[3,4], F. Longo[5], C. Pittori[3,4], M. Tavani[1,6], A. Bulgarelli[7], M. Cardillo[1], C. Casentini[1,8], P. W. Cattaneo[9], E. Costa[1], M. Feroci[1], V. Fioretti[7], L. Foffano[1], F. Lucarelli[3,4], M. Marisaldi[7,10], A. Morselli[8], L. Pacciani[1], N. Parmiggiani[7], P. Tempesta[11], A. Trois[12], and S. Vercellone[13]

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TRA LE COSTELLAZIONI DI PEGASO E DI ANDROMEDA

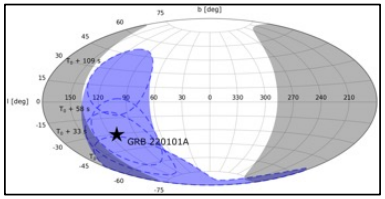
Capodanno col botto: visto un Grb da record

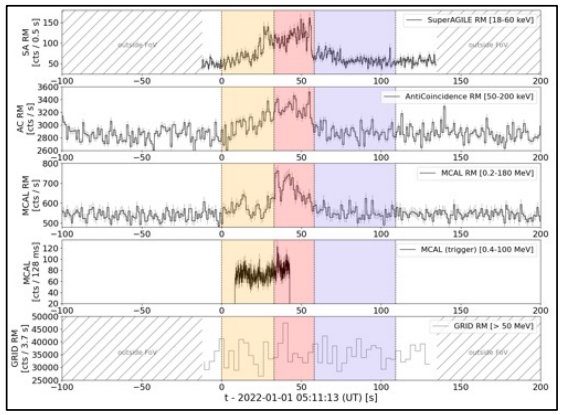
Ha viaggiato per oltre 12 miliardi di anni, è arrivato sulla Terra all'alba del primo gennaio ed è uno dei lampi di raggi gamma più potenti e lunghi mai registrati. Fra i primi strumenti al mondo a intercettarne e caratterizzarne il segnale, quelli a bordo del telescopio spaziale "made in Italy" Agile e quelli dei telescopi dell'Osservatorio di Asiago dell'Inaf di Padova. Na parliamo con due fra i protagonisti dell'osservazione, Alessandro Ursi e Lina Tomasella dell'Inaf

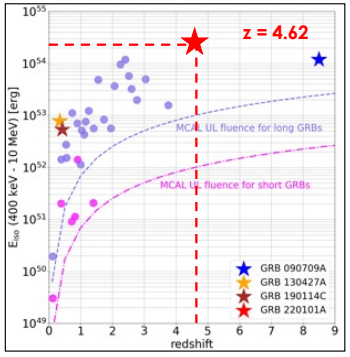
Marco Malaspina 03/01/2022 Tweet Condividi 1321

news on Media INAF

fully inside the AGILE FoV
for most of the duration
of the prompt phase







news on ASI website

Update on AGILE and GW

AGILE observations of GW events

• detailed analysis of AGILE MCAL and GRID data in correpondence of LIGO-Virgo GW events [*Ursi et al., ApJ, 2022*]

The Astrophysical Journal, 924:80 (15pp), 2022 January 10 https://doi.org/10.3847/1538-4357/ac332f

AGILE Observations of the LIGO-Virgo Gravitational-wave Events of the GWTC-1 Catalog

A. Ursi[1], F. Verrecchia[2,3], G. Piano[1], C. Casentini[1,4], M. Tavani[1,5], A. Bulgarelli[6], M. Cardillo[1], F. Longo[7], F. Lucarelli[2,3], A. Morselli[4], N. Parmiggiani[6], M. Pilia[8], C. Pittori[2,3], and A. Rappoldi[9]
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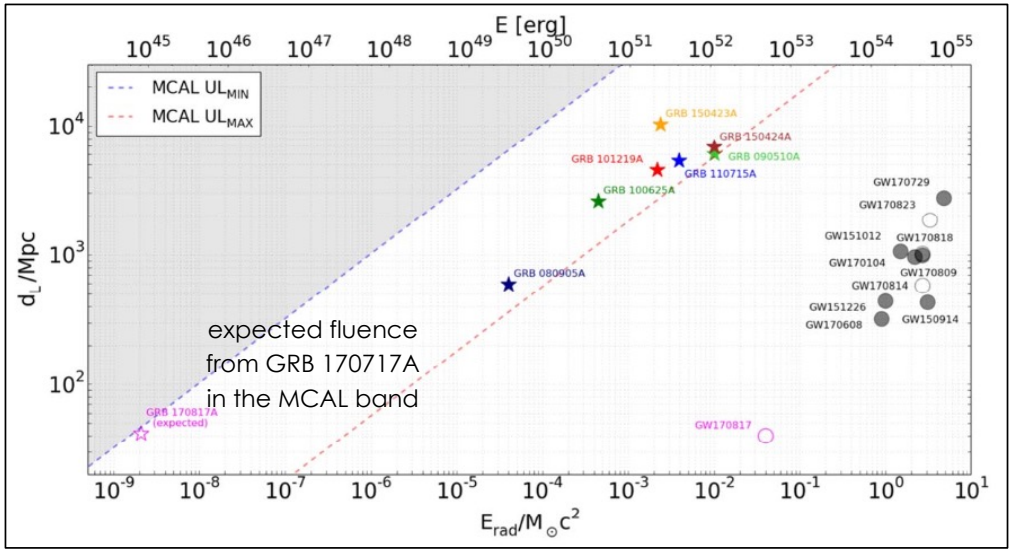
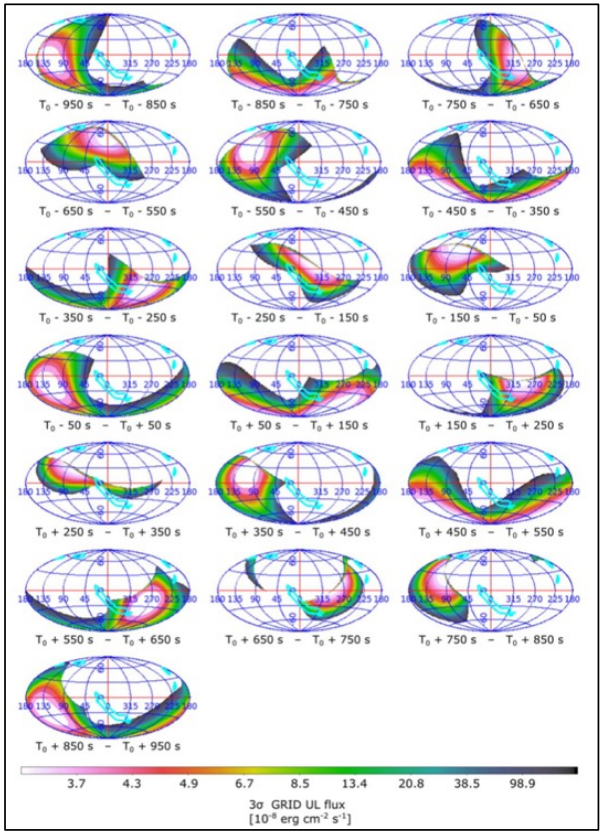
Received 2021 September 16; revised 2021 October 22; accepted 2021 October 24; published 2022 January 13

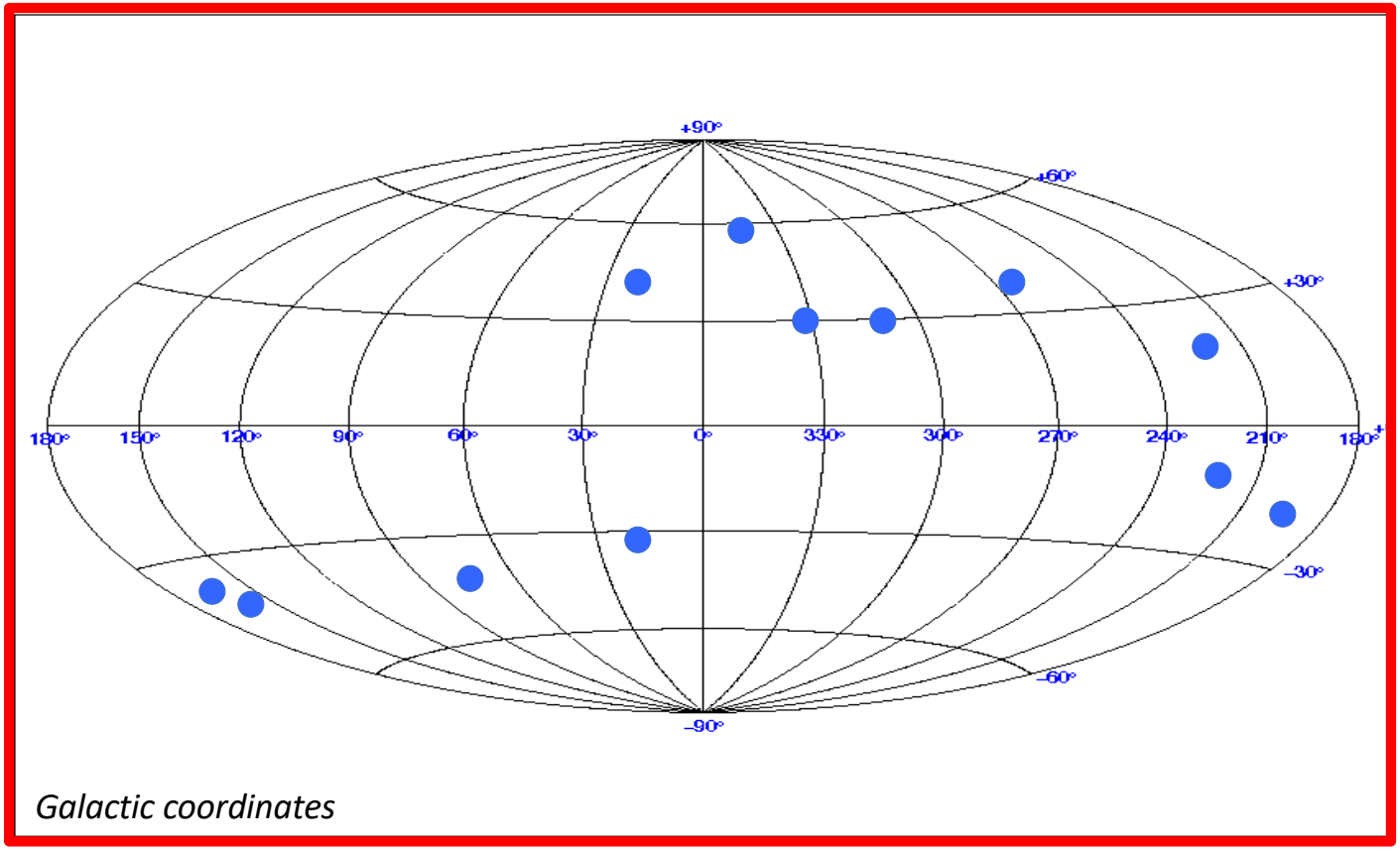




GRID exposure to error box of GW170729

Update on AGILE and Neutrinos

AGILE detections of IceCube neutrinos (2019)



Galactic coordinates

AGILE detections of IceCube neutrinos (2019)

Springer Link

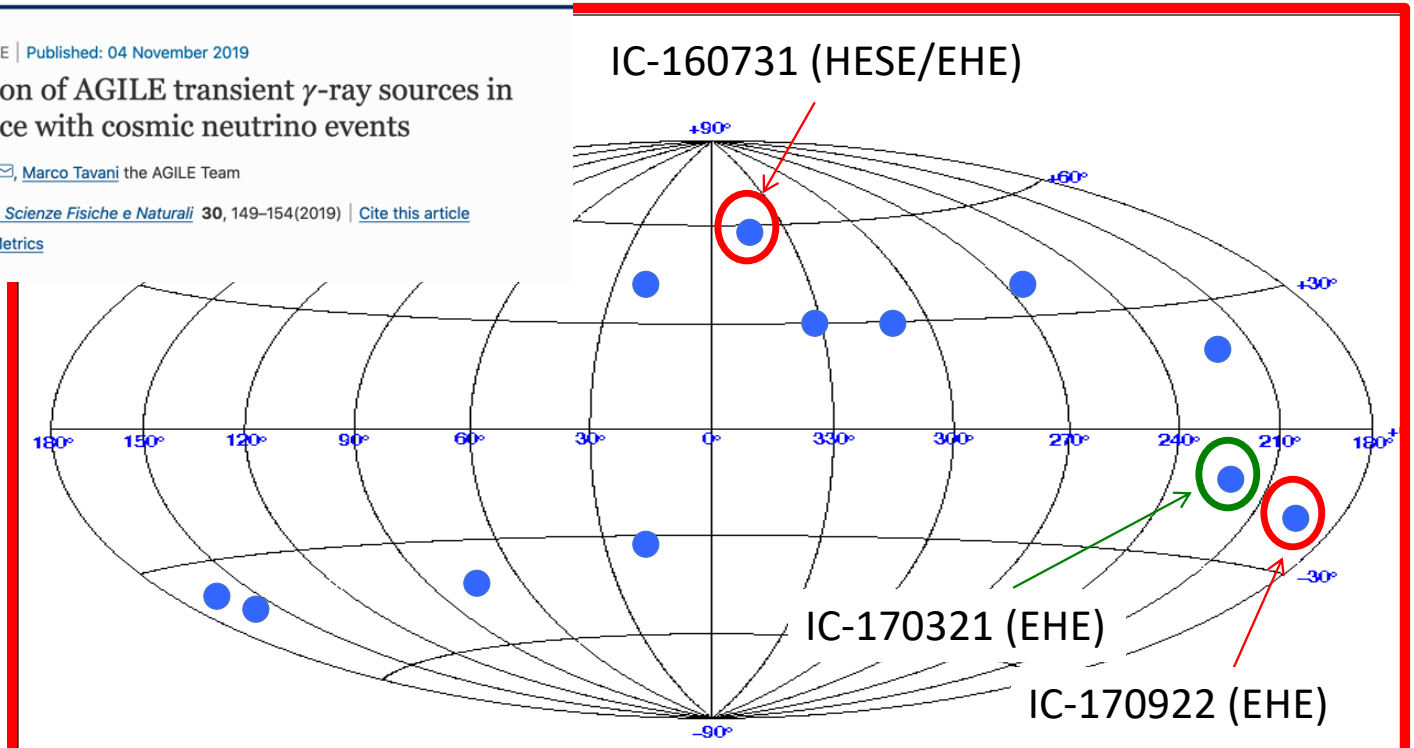
A Decade of AGILE | Published: 04 November 2019

Observation of AGILE transient γ-ray sources in coincidence with cosmic neutrino events

Fabrizio Lucarelli, Marco Tavani the AGILE Team

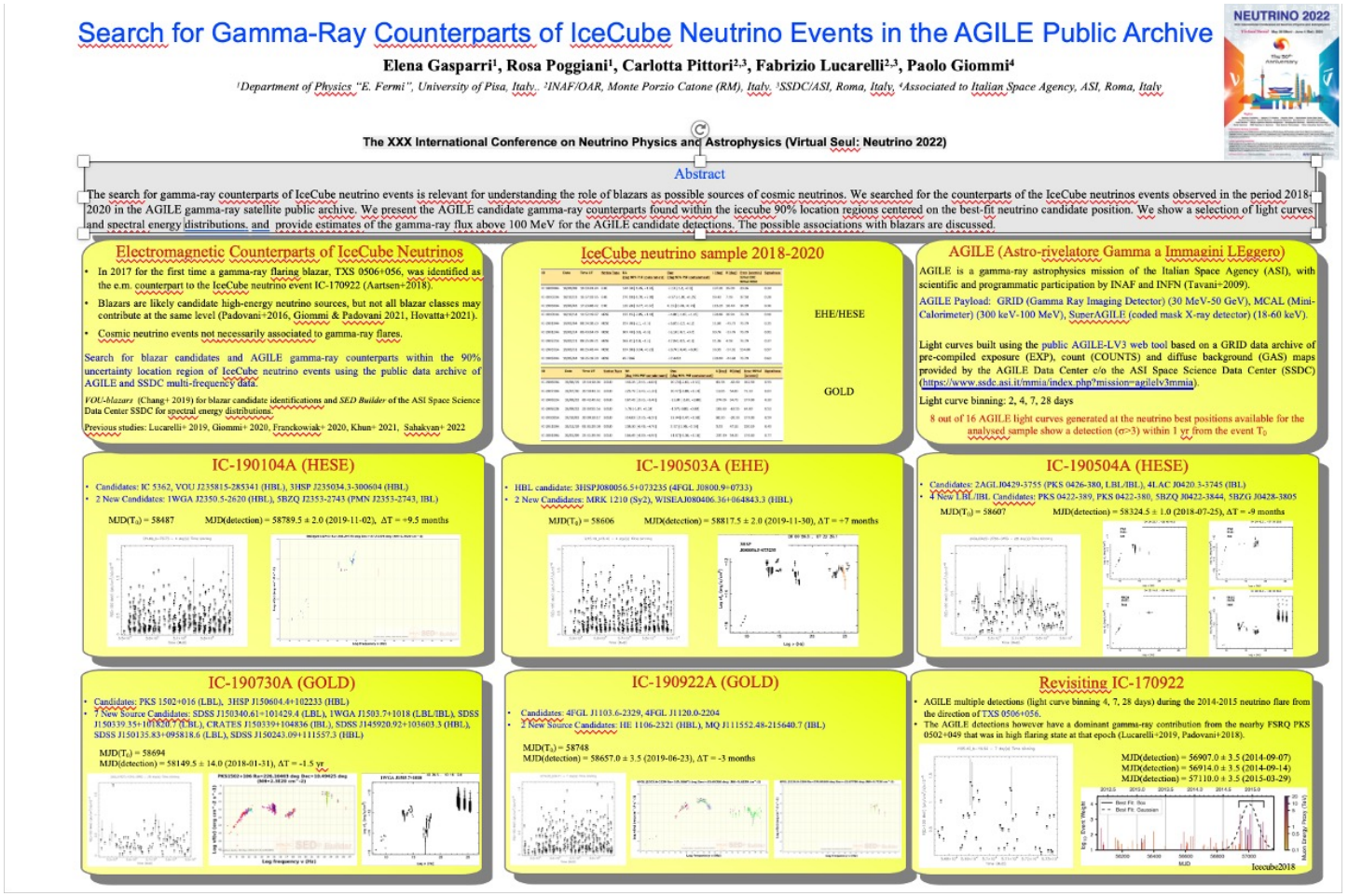
Rendiconti Lincei. Scienze Fisiche e Naturali **30**, 149–154(2019) | Cite this article

28 Accesses | Metrics



Three AGILE detections (~4σ each) from the automatic QL system consistent with time/position of 3 IC events out of 10 !

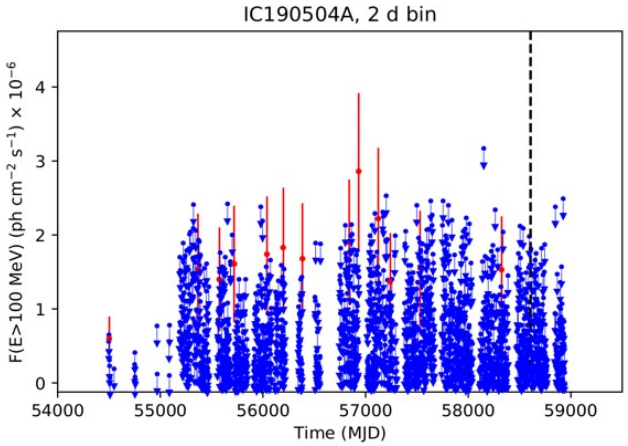
New study: Elena Gasparri Thesis (Laurea Magistrale)
Results presented as a Poster at Neutrino 2022

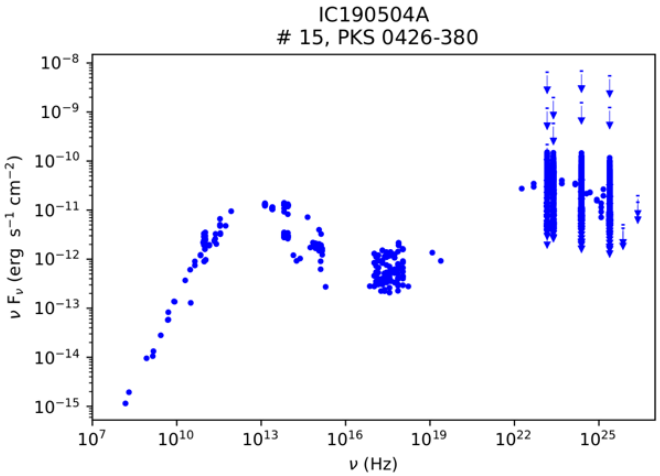


Search for Gamma-Ray counterparts of IceCube neutrino events in the AGILE public archive

(E. Gasparri, R. Poggiani, C. Pittori, F. Lucarelli, P. Giommi)

Paper in preparation

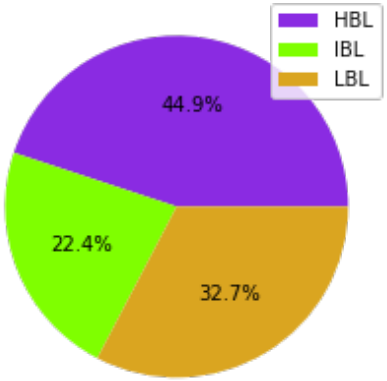




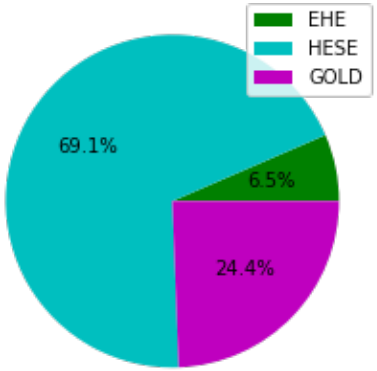
Blazars as possible cosmic neutrino sources: Padovani+ 2016, Lucarelli+ 2017, Krauss +2018, Lucarelli+ 2019, Giommi+ 2020, Franckowiak+ 2020, Garrappa+ 2021, Giommi+ 2021, Hovatta+ 2021, Kun+ 2021, Abbasi+ 2022, Sahakyan+ 2022, ...

Analysis of 16 IceCube neutrino events from September 2018 to March 2020

- Full-mission AGILE light curves using public data and AGILE-LV3
- SED of candidates identified with the VOU-Blazars Tool
- 8/16 light curves show significant detections ($\sqrt{TS} > 3$) within $T_0 \pm 1$ year:
  - 2/3 EHE neutrinos (IC-180908A e IC-190503A)
  - 3/6 HESE neutrinos (IC-190104A, IC-190221A, IC-190504A)
  - 3/7 GOLD neutrinos (IC-190619A, IC-190922A, IC-191001A)
  - 2/16 light curves with association to 2AGL catalog blazars



Classes of candidate blazars



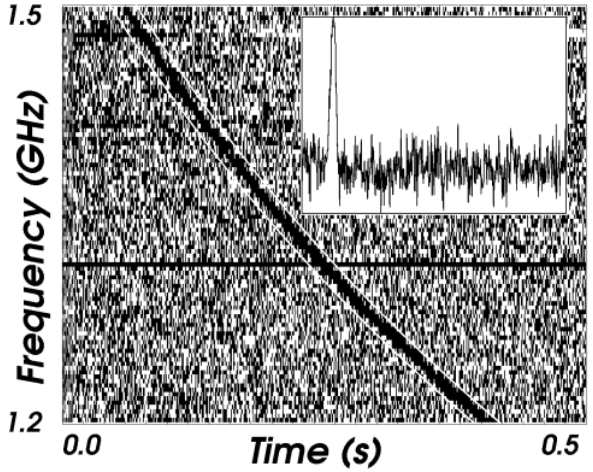
Candidate AGILE detections vs. neutrino event type

AGILE and FRB

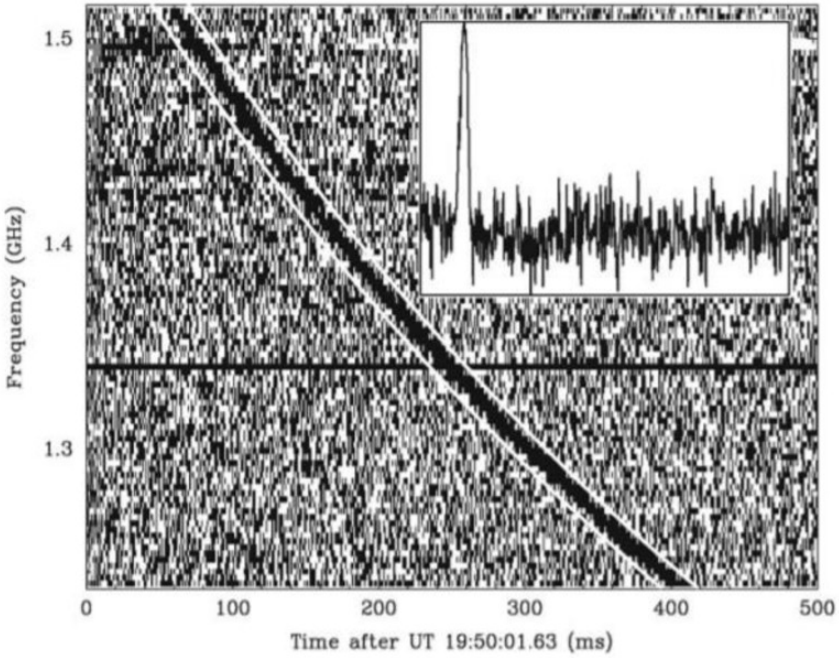
FRBs studies

- Fast Radio Bursts are transient radio events of unknown origin with
  - Duration: ***ms scale***;
  - Bandwidth: ***300 MHz – 2 GHz***;
  - Fluences: ***10^-2 – 400 Jy ms***
  - ***Population: 791 total sources, divided in «one-off» and «repeaters», which emitted more than a burst, currently 24 sources; 1 is periodic***

- The Dispersion Measure, **DM**, is a very important observable.
  It is the result of the sum of different components:
  - *Milky Way* (Galactic disk + Galactic halo);
  - *Host galaxy contribution* (Galactic disk + Galactic halo);
  - *Intergalactic medium* **(IGM)** that can give **indications about the source distance**.



Fast Radio Bursts (FRB)



FRBs are millisecond radio pulses originating from powerful enigmatic extragalactic sources. **Magnetars** (neutron stars with large magnetic fields) are considered as **possible** candidate sources powering the FRBs. **Important detection by AGILE** on April 28, 2020: an X-ray burst in temporal coincidence with a bright **FRB-like** radio burst from the **Galactic** magnetar SGR 1935+2154. Support to magnetar models.

FRB200428 from SGR 1935+2154

first correlation between an FRB-like radio burst and an X-ray flare from SGR

• analysis of the X-ray flare detected by the SuperAGILE ratemeters [*Tavani et al., Nature, 2020*]

nature astronomy

ARTICLES

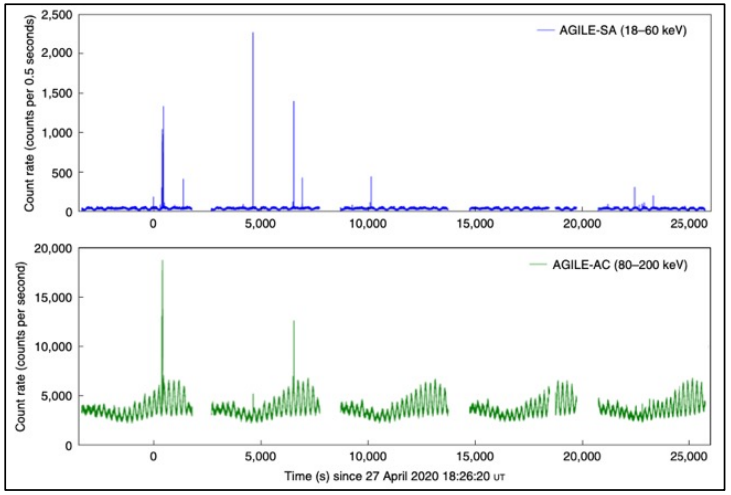
https://doi.org/10.1038/s41550-020-01276-x

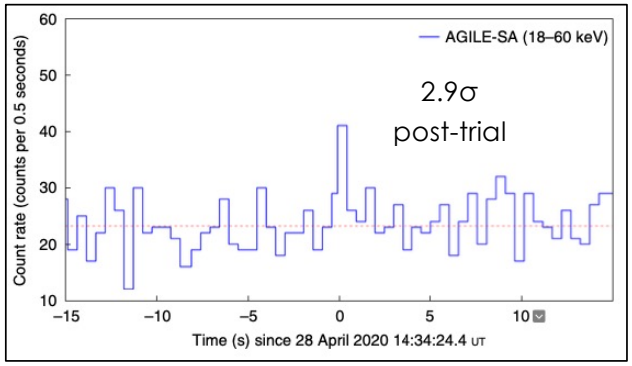
Check for updates

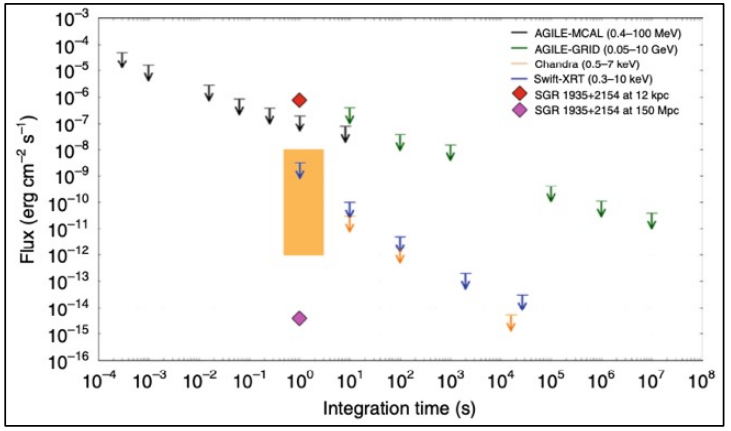
An X-ray burst from a magnetar enlightening the mechanism of fast radio bursts

M. Tavani[1,2], C. Casentini[1,3], A. Ursi[1], F. Verrecchia[4,5], A. Addis[6], L. A. Antonelli[5], A. Argan[1], G. Barbiellini[7,8], L. Baroncelli[6], G. Bernardi[9,10], G. Bianchi[9], A. Bulgarelli[6], P. Caraveo[11], M. Cardillo[1], P. W. Cattaneo[12], A. W. Chen[13], E. Costa[1], E. Del Monte[1], G. Di Cocco[6], G. Di Persio[1], I. Donnarumma[14], Y. Evangelista[1], M. Feroci[1], A. Ferrari[15,16], V. Fioretti[6], F. Fuschino[6], M. Galli[17], F. Gianotti[6], A. Giuliani[11], C. Labanti[6], F. Lazzarotto[1], P. Lipari[18,19], F. Longo[7,8], F. Lucarelli[4,5], A. Magro[20], M. Marisaldi[6,21], S. Mereghetti[11], E. Morelli[6], A. Morselli[3], G. Naldi[9], L. Pacciani[1], N. Parmiggiani[6], F. Paoletti[22], A. Pellizzoni[23], M. Perri[4,5], F. Perotti[11], G. Piano[1], P. Picozza[2,3], M. Pilia[23], C. Pittori[4,5], S. Puccetti[14], G. Pupillo[9], M. Rapisarda[11], A. Rappoldi[12], A. Rubini[1], G. Setti[9,24], P. Soffitta[1], M. Trifoglio[6], A. Trois[23], S. Vercellone[25], V. Vittorini[1], P. Giommi[4,26] and F. D'Amico[14]

Fast radio bursts (FRBs) are millisecond radio pulses originating from powerful enigmatic sources at extragalactic distances. Neutron stars with large magnetic fields (magnetars) have been considered as the sources powering the FRBs, but the connection requires further substantiation. Here we report the detection by the AGILE satellite on 28 April 2020 of an X-ray burst in temporal coincidence with a bright FRB-like radio burst from the Galactic magnetar SGR 1935+2154. The burst observed in the hard X-ray band (18–60 keV) lasted about 0.5 s, it is spectrally cut off above 80 keV and implies an isotropically emitted energy of about 10^{40} erg. This event demonstrates that a magnetar can produce X-ray bursts in coincidence with FRB-like radio bursts. It also suggests that FRBs associated with magnetars can emit X-ray bursts. We discuss SGR 1935+2154 in the context of FRBs with low–intermediate radio energies in the range 10^{38}–10^{40} erg. Magnetars with magnetic fields $B \approx 10^{15}$ G may power these FRBs, and new data on the search for X-ray emission from FRBs are presented. We constrain the bursting X-ray energy of the nearby FRB 180916 to be less than 10^{46} erg, smaller than that observed in giant flares from Galactic magnetars.







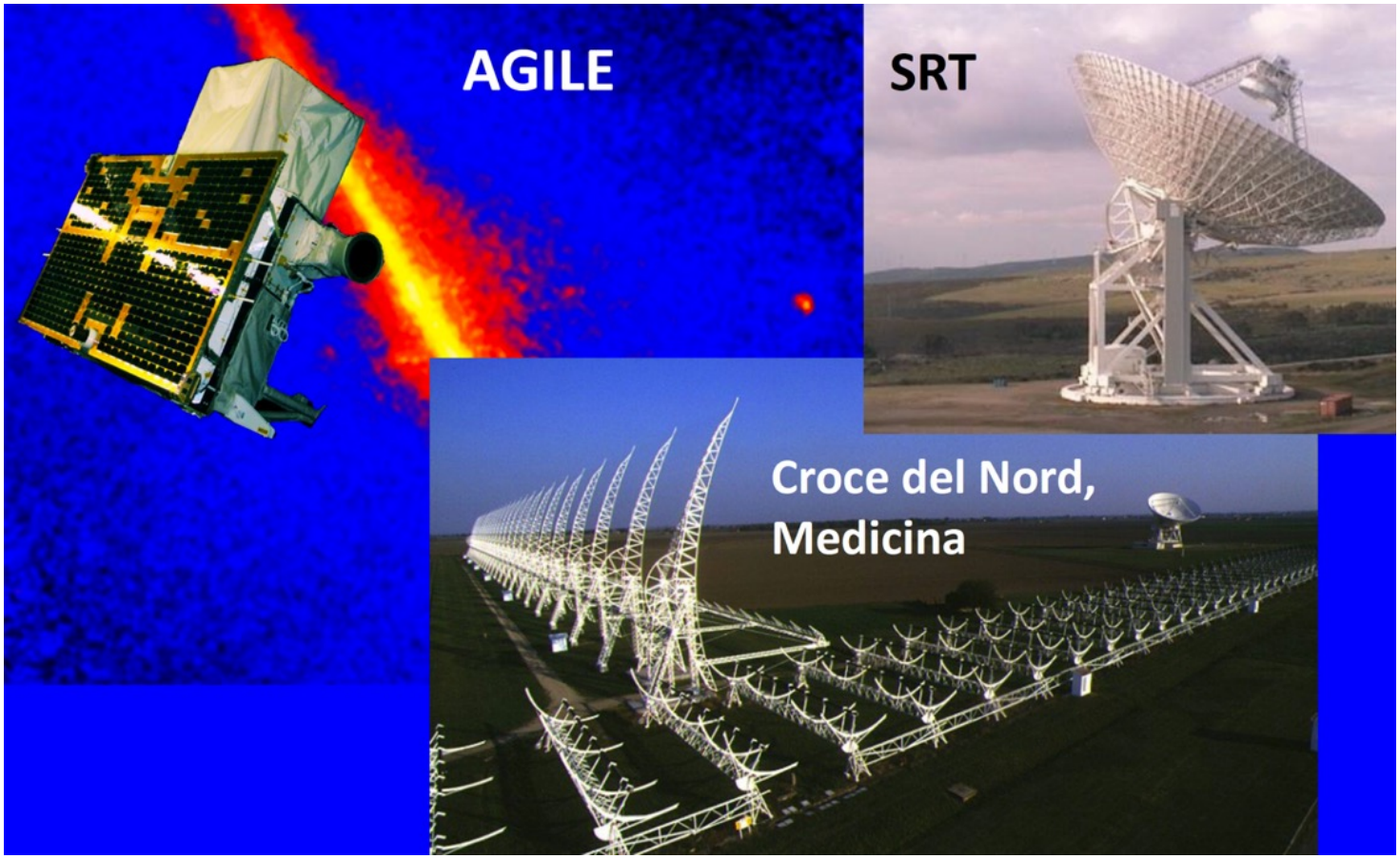
AGILE FRB studies

Paper	Production	Sign in	Sub.	Sub. to	Revision 1	Revision 2	Accepted for publication	Published
Casentini et al.	✓	✓	✓	*ApJL*	✓	✓	✓	✓
Tavani et al.	✓	✓	✓	*ApJL*	✓	✓	✓	✓
Pilia et al. (SRT coll. paper)	✓	✓	✓	*ApJL*	✓	✓	✓	✓
Tavani et al.	✓	✓	✓	*Nature astronomy*	✓	✓	✓	✓
Verrecchia et al.	✓	✓	✓	*ApJ*	✓	-	✓	-

5 published AGILE papers on FRB science:

1. Casentini et al., ApJL 2020: paper on two low IGM-DM repeaters, FRB180916.J0158+65 and FRB181030.J1054+73
2. Tavani et al., ApJL 2020: paper on the periodic R-FRBs: FRB20180916B. MW campaign with all AGILE detectors and Swift
3. Pilia et al., ApJL 2020, SRT Collaboration Paper on the periodic FRB 180916 : The Lowest-frequency Fast Radio Bursts at 328 MHz
4. **Nature Astronomy**: "**An X-ray burst from a magnetar enlightening the mechanism of fast radio bursts", Tavani et al.,** about SGR1935+2154 X-ray/radio flare
5. Verrecchia et al., ApJ 2021: paper on general search of HE counterpart in the AGILE data from sources in FRBCAT and TNS catalogues (89 sources included, 10 R-FRB)

Monitoring campaigns on specific FRB repeaters and SGRs in progress:

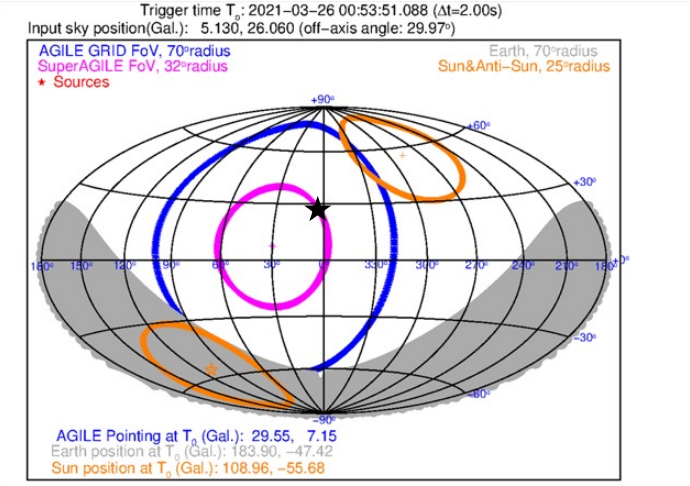


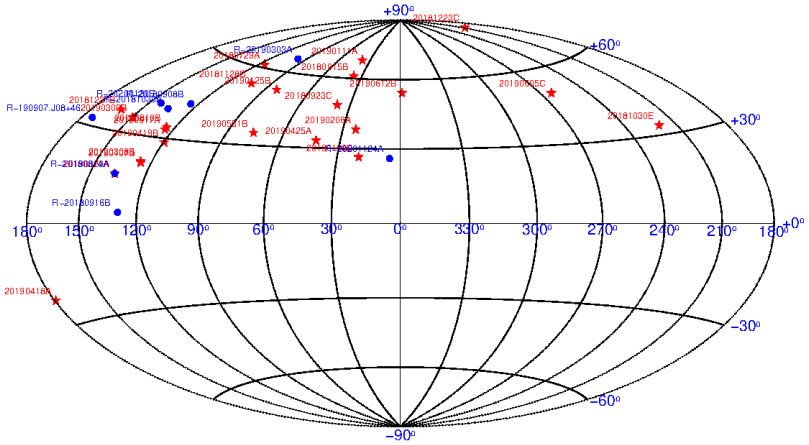
AGILE FRBs studies: complete search update

F. Verrecchia F., C. Casentini, A. Ursi, M. Tavani

After the pubblication of the 1° CHIME/FRB radio catalogue in 2021, a paper on the update of the general search for HE emission in the AGILE data is in preparation.

- **Casentini et al., in progress**: paper on updated general search of HE counterparts in the AGILE data from sources in TNS and CHIME/FRB updated catalogues, selecting only those having DM_IGM <= 200 pc cm^-3 => **31 sources included, 8 R-FRB**





AGILE and Solar flares

AGILE Solar activity monitoring

AGILE detection of C-class solar flares at the beginning of the new solar cycle 25

ATel #14172; A. Ursi (INAF/IAPS), C. Pittori (SSDC and INAF/OAR), P. Tempesta (Telespazio), M. Tavani (INAF/IAPS, and Univ. Roma Tor Vergata), F. Verrecchia (SSDC and INAF/OAR), M. Cardillo, C. Casentini, G. Piano (INAF/IAPS), A. Bulgarelli, V. Fioretti, N. Parmiggiani (INAF/IASF-Bo), F. Lucarelli (SSDC and INAF/OAR), I. Donnarumma (ASI), S. Vercellone (INAF/OA-Brera), F. Gianotti, M. Trifoglio (INAF/IASF-Bo), A. Giuliani, S. Mereghetti, P. Caraveo, F. Perotti (INAF/IASF-Mi), A. Chen (Wits University), A. Argan, E. Costa, E. Del Monte, Y. Evangelista, M. Feroci, F. Lazzarotto, I. Lapshov, L. Pacciani, P. Soffitta, V. Vittorini (INAF/IAPS), G. Di Cocco, F. Fuschino, M. Galli, C. Labanti (INAF/IASF-Bo), M. Marisaldi (INAF/OAS-Bologna, and Bergen University), A. Pellizzoni, M. Pilia, A. Trois (INAF/OA-Cagliari), G. Barbiellini, E. Vallazza (INFN Trieste), F. Longo (Univ. Trieste and INFN Trieste), A. Morselli, P. Picozza (INFN and Univ. Roma Tor Vergata), M. Prest (Univ. dell'Insubria), P. Lipari, D. Zanello (INFN and Univ. Roma Sapienza), P. W. Cattaneo, A. Rappoldi (INFN Pavia), A. Ferrari (Univ. Torino and CIFS), F. Paoletti (East Windsor RSD Hightstown and INAF/IAPS), L. A. Antonelli (INAF/OAR), P. Giommi, L. Salotti, G. Valentini, and F. D'Amico (ASI)

on ***13 Nov 2020; 20:27 UT***

Credential Certification: Fabrizio Lucarelli (fabrizio.lucarelli@ssdc.asi.it)

Subjects: X-ray, The Sun

The AGILE satellite is revealing bright solar activity, starting October 2020.

From October 27 to November 12, 2020 the AGILE Anti-Coincidence scientific ratemeters oriented toward the Sun (AC Lat4; 80-200 keV) detected about 45 intense X-ray emissions from C-class solar flares.

In particular, on October 27 and 29, 2020 and on November 5 and 8, 2020, AGILE clearly observed prominent X-ray emission from the solar flares emitted by the solar active regions AR 12778, AR 12779, and AR 12781, respectively, as reported by GOES satellites (https://www.goes.noaa.gov/).

In our preliminary analysis, using a dedicated Solar Flare event selection, solar activity is identified as X-ray emission with flux >=3 times higher than the typical flux of the Quiet Sun. We report information about the most intense X-ray bursts detected by AC Lat4, together with the class of the corresponding solar flare:

C4.3 | AR 12778 | UT 2020-10-27 06:14:30 | peak counts = 14859 | total counts = 1006398 | mean duration = 150 s

C4.3 | AR 12779 | UT 2020-10-29 11:44:03 | peak counts = 11688 | total counts = 4720341 | mean duration = 1485 s

C7.3 | AR 12781 | UT 2020-11-05 00:08:16 | peak counts = 24444 | total counts = 11149783 | mean duration = 1800 s

C1.4 | AR 12781 | UT 2020-11-05 02:50:12 | peak counts = 11694 | total counts = 396360 | mean duration = 115 s

C2.3 | AR 12781 | UT 2020-11-05 09:54:16 | peak counts = 27906 | total counts = 880041 | mean duration = 520 s

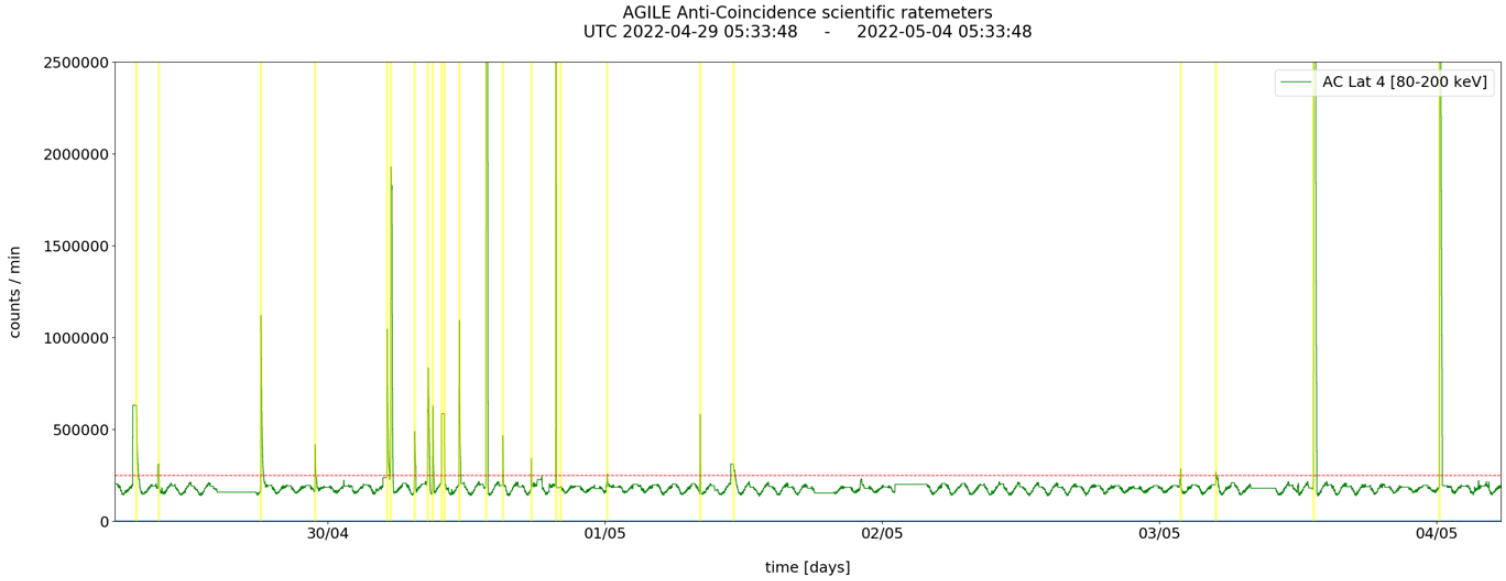
C5.7 | AR 12781 | UT 2020-11-08 05:16:43 | peak counts = 13680 | total counts = 221884 | mean duration = 60 s

The AGILE AC Lat4 ratemeter light curves can be found at http://www.agilescienceapp.it/notices/AGILE_SF_20201022-20201113.png .

Further analysis is still in progress. AGILE (Astrorivelatore Gamma a Immagini LEggero) is an X-ray and Gamma-ray astronomical satellite of the Italian Space Agency (ASI).

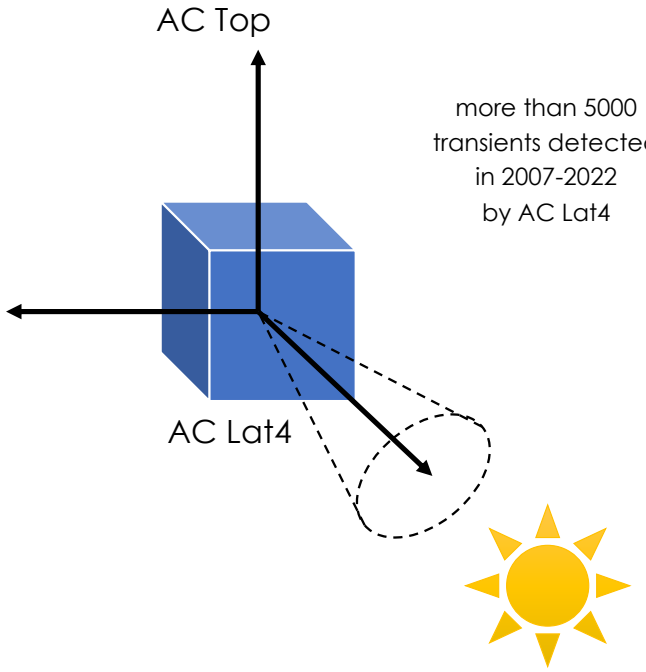
http://www.astronomerstelegram.org/?read=14172

Automatic AGILE Solar monitoring: 29 Apr-04 May 2022

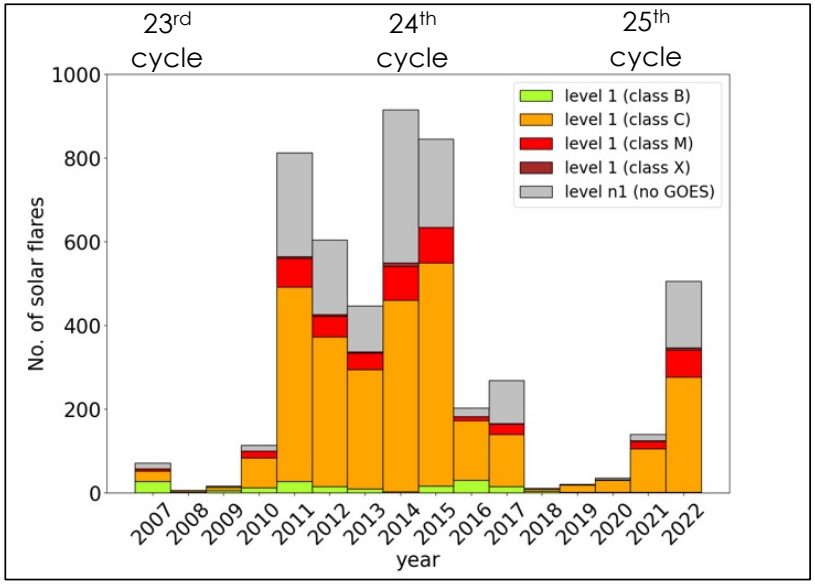


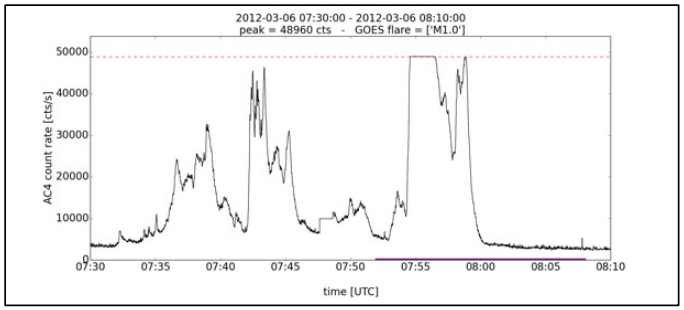
Solar flares

• comprehensive catalog of hard X-ray solar flares detected by AGILE AC since 2007 to 2022 [*Ursi et al., in preparation*]



more than 5000
transients detected
in 2007-2022
by AC Lat4



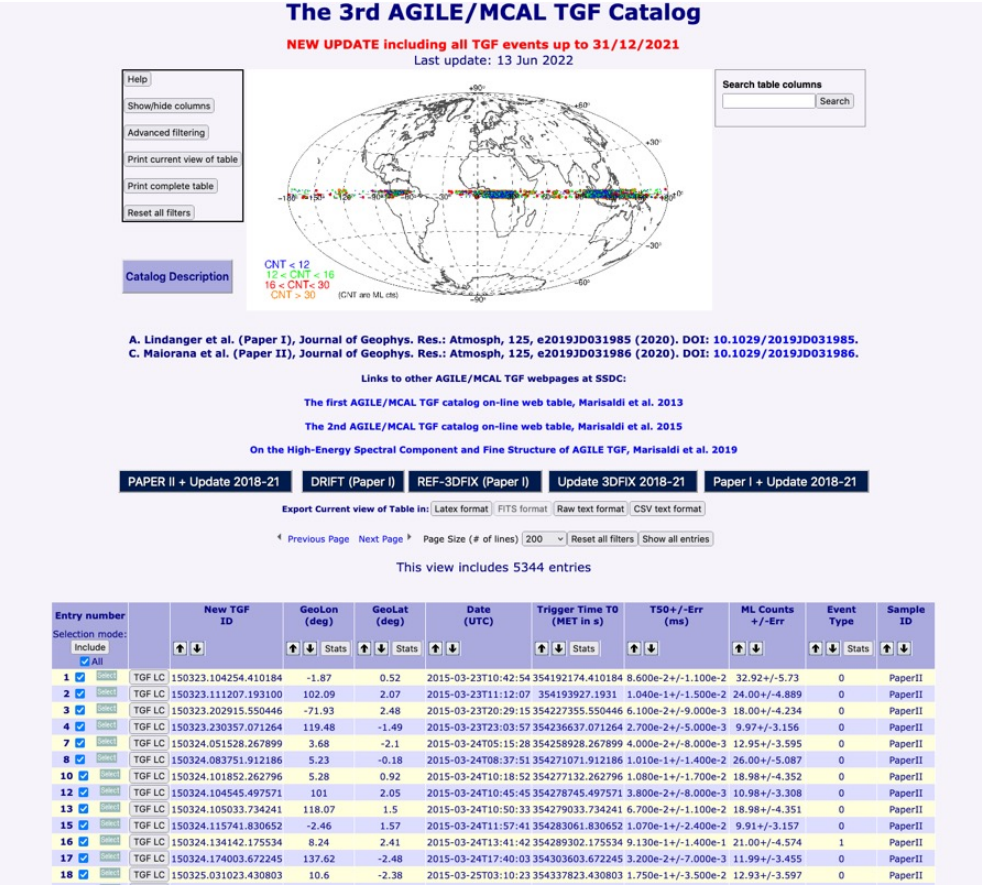


AGILE real-time pipeline

AGILE and Terrestrial Gamma-ray Flashes

3rd AGILE TGF Catalog and lightning associations. Interactive SSDC webpage

NEW recent update including TGFs with lightning spherics association up to Dec 2021



The 3rd AGILE/MCAL TGF Catalog

NEW UPDATE including all TGF events up to 31/12/2021

Last update: 13 Jun 2022

Help | Show/hide columns | Advanced filtering | Print current view of table | Print complete table | Reset all filters | Catalog Description

Search table columns: Search

CNT < 12
12 < CNT < 16
16 < CNT< 30
CNT > 30
(CNT are ML cts)

A. Lindanger et al. (Paper I), Journal of Geophys. Res.: Atmosph, 125, e2019JD031985 (2020). DOI: 10.1029/2019JD031985.
C. Maiorana et al. (Paper II), Journal of Geophys. Res.: Atmosph, 125, e2019JD031986 (2020). DOI: 10.1029/2019JD031986.

Links to other AGILE/MCAL TGF webpages at SSDC:

The first AGILE/MCAL TGF catalog on-line web table, Marisaldi et al. 2013

The 2nd AGILE/MCAL TGF catalog on-line web table, Marisaldi et al. 2015

On the High-Energy Spectral Component and Fine Structure of AGILE TGF, Marisaldi et al. 2019

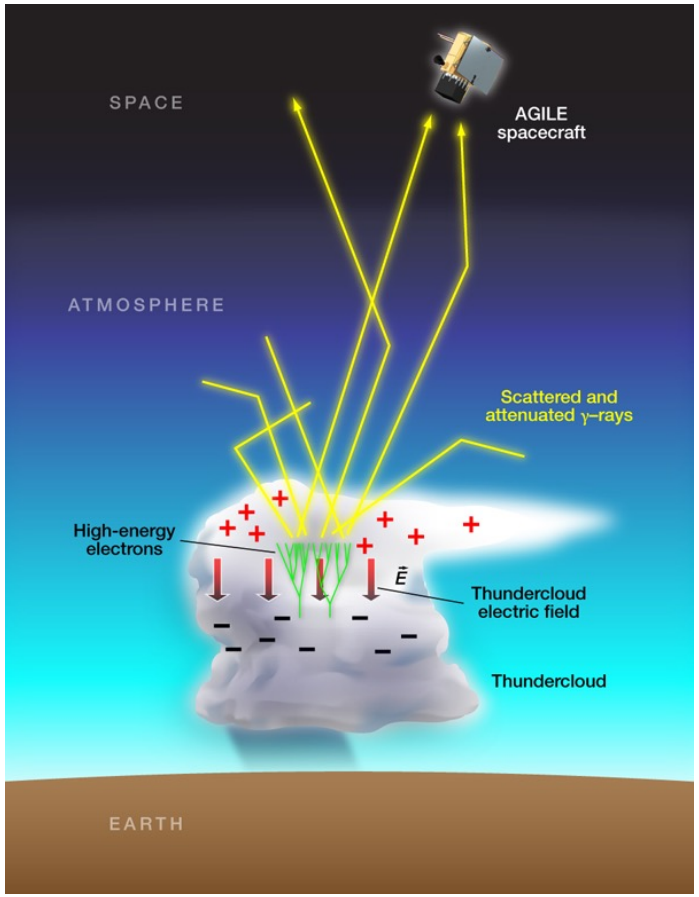
PAPER II + Update 2018-21 | DRIFT (Paper I) | REF-3DFIX (Paper I) | Update 3DFIX 2018-21 | Paper I + Update 2018-21

Export Current view of Table in: Latex format | FITS format | Raw text format | CSV text format

Previous Page | Next Page | Page Size (# of lines) 200 | Reset all filters | Show all entries

This view includes 5344 entries

Entry number		New TGF ID	GeoLon (deg)	GeoLat (deg)	Date (UTC)	Trigger Time T0 (MET in s)	T50+/-Err (ms)	ML Counts +/-Err	Event Type	Sample ID
1	TGF LC	150323.104254.410184	-1.87	0.52	2015-03-23T10:42:54	354192174.410184	8.600e-2+/-1.100e-2	32.92+/-5.73	0	PaperII
2	TGF LC	150323.111207.193100	102.09	2.07	2015-03-23T11:12:07	354193927.1931	1.040e-1+/-1.500e-2	24.00+/-4.889	0	PaperII
3	TGF LC	150323.202915.550446	-71.93	2.48	2015-03-23T20:29:15	354227355.550446	6.100e-2+/-9.000e-3	18.00+/-4.234	0	PaperII
4	TGF LC	150323.230357.071264	119.48	-1.49	2015-03-23T23:03:57	354236637.071264	2.700e-2+/-5.000e-3	9.97+/-3.156	0	PaperII
7	TGF LC	150324.051528.267899	3.68	-2.1	2015-03-24T05:15:28	354258928.267899	4.000e-2+/-8.000e-3	12.95+/-3.595	0	PaperII
8	TGF LC	150324.083751.912186	5.23	-0.18	2015-03-24T08:37:51	354271071.912186	1.010e-1+/-1.400e-2	26.00+/-5.087	0	PaperII
10	TGF LC	150324.101852.262796	5.28	0.92	2015-03-24T10:18:52	354277132.262796	1.080e-1+/-1.700e-2	18.98+/-4.352	0	PaperII
12	TGF LC	150324.104545.497571	101	2.05	2015-03-24T10:45:45	354278745.497571	3.800e-2+/-8.000e-3	10.98+/-3.308	0	PaperII
13	TGF LC	150324.105033.734241	118.07	1.5	2015-03-24T10:50:33	354279033.734241	6.700e-2+/-1.100e-2	18.98+/-4.351	0	PaperII
15	TGF LC	150324.115741.830652	-2.46	1.57	2015-03-24T11:57:41	354283061.830652	1.070e-1+/-2.400e-2	9.91+/-3.157	0	PaperII
16	TGF LC	150324.134142.175534	8.24	2.41	2015-03-24T13:41:42	354289302.175534	9.130e-1+/-1.400e-1	21.00+/-4.574	1	PaperII
17	TGF LC	150324.174003.672245	137.62	-2.48	2015-03-24T17:40:03	354303603.672245	3.200e-2+/-7.000e-3	11.99+/-3.455	0	PaperII
18	TGF LC	150325.031023.430803	10.6	-2.38	2015-03-25T03:10:23	354337823.430803	1.750e-1+/-3.500e-2	12.93+/-3.597	0	PaperII



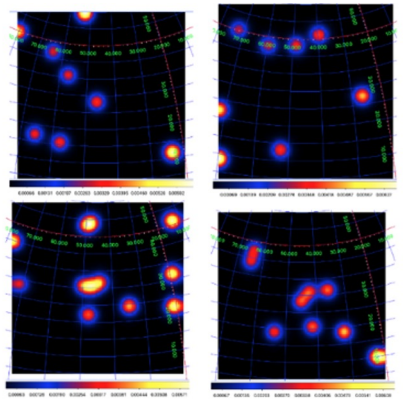
AGILE and deep learning technologies

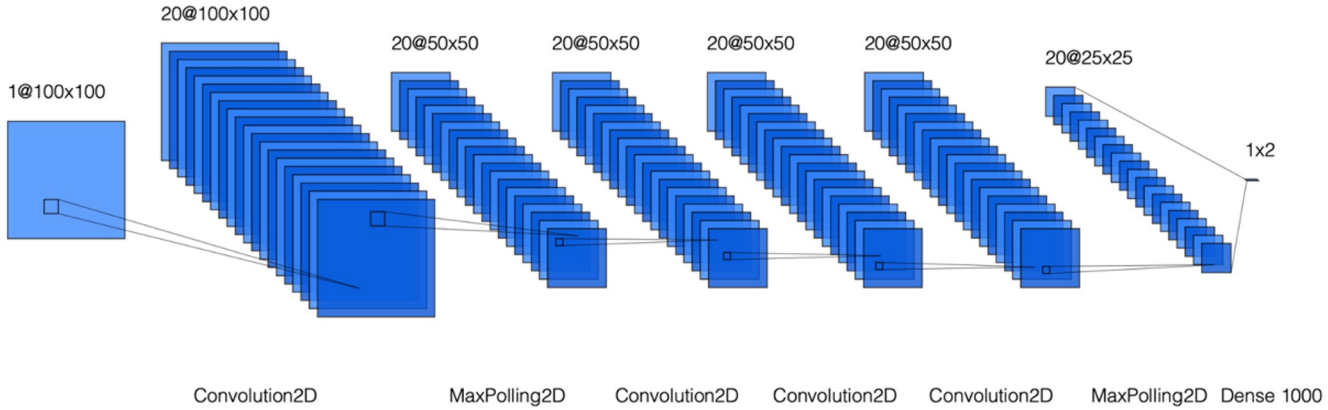
Deep Learning for GRB detection

INAF OAS BOLOGNA

- This research aims to apply Deep Learning technologies to detect GRBs in the data (time series and sky maps) acquired by the detectors on board the AGILE space missions.
- We developed a Convolutional Neural Network (CNN) to detect GRBs inside the AGILE Gamma-Ray Imaging Detector (GRID) counts maps when an external science alert is received.
- The CNN detected 21 GRBs in the AGILE/GRID data with a sigma > 3 from the list of GRBs obtained with Fermi and Swift catalogs outperforming the Li&Ma on the same list and with the same parameters.

Parmiggiani N., Bulgarelli A., Fioretti V. et al. “A Deep Learning Method for AGILE/GRID Gamma-ray Bursts detection”, Astrophysical Journal, Volume 914, Issue 1, id.67, 12 pp (2021)





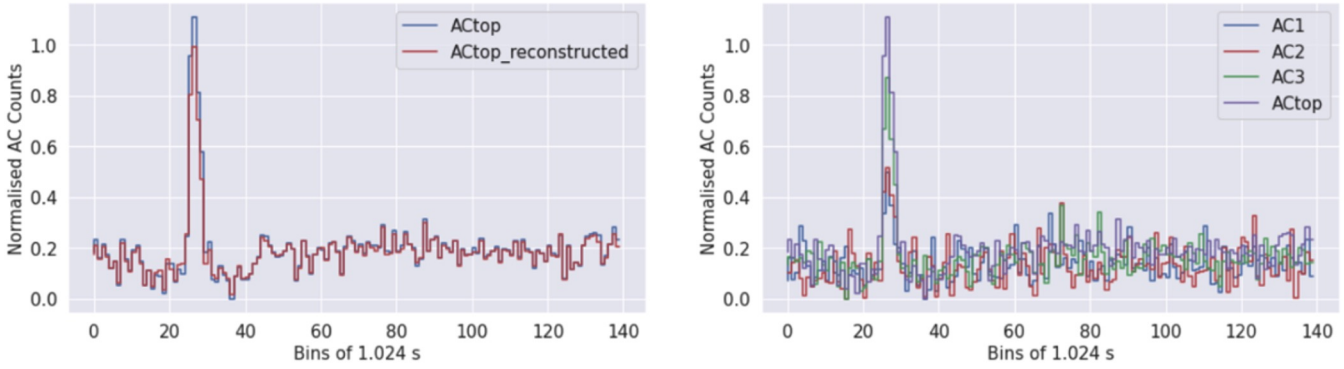
Deep Learning for time-series analysis

INAF OAS BOLOGNA

- We developed a Deep Learning anomaly detection model that exploits the auto-encoder architecture to detect GRBs in the AGILE Anticoincidence System (ACS) ratemeters in response to external science alerts that will be implemented inside the AGILE RTA pipeline.

- This model uses the ratemeters of the five panels of the ACS. The ACS was not originally designed to detect GRBs but to reject charged particles. However, it can detect X-rays (50-200 KeV).

- This model detects 73 GRBs into the AGILE/ACS time series with sigma > 3 starting from the GRBweb catalog.



Parmiggiani, N., A. Bulgarelli et al., “Preliminary Results of a Deep Learning Anomaly Detection Method to Identify Gamma-Ray Bursts in the AGILE Anticoincidence System” ADASS 2021.

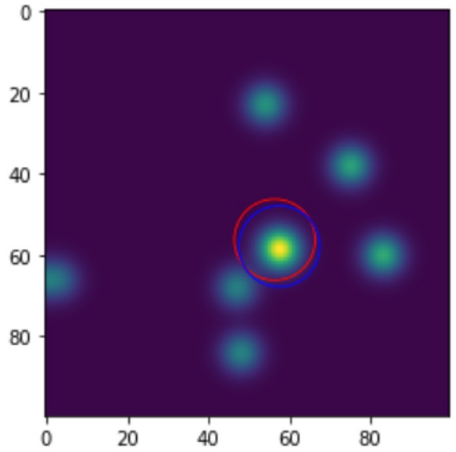
- A paper has been submitted to **ApJ** and we received the first review.

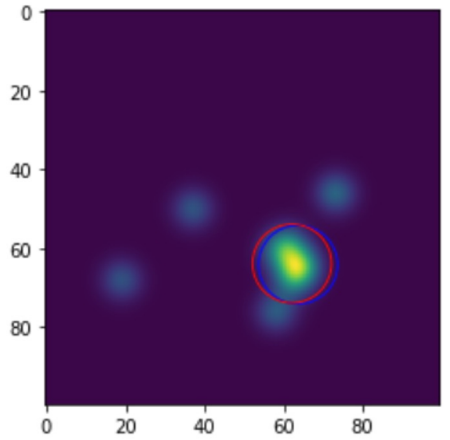
GRB detection localization in AGILE/GRID data

INAF OAS BOLOGNA

- We developed a new method for detecting and localizing GRB in the AGILE/GRID sky maps as a reaction to external science alerts.
- The science alerts can have error regions with different sizes depending on the instruments that detected the transient event. For this reason, we trained this method to detect GRBs in the AGILE sky maps located in a radius of 20 degrees from the map center; this radius is larger than 99.5 % of the error region present in the GRBWeb catalog.
- The method comprises **two Deep Learning models implemented with two Convolutional Neural Networks**. The first model detects if the sky map contains a GRB, and the second model localizes the GRB in the sky maps filtered from the first model.
- We trained and tested the models using simulated sky maps and GRBs. The detection model achieves an accuracy of 95.7 %, and the localization model has a mean error lower than 0.8 degrees.

A submission of this work to ADASS 2022 is in progress.





INAF OAS BOLOGNA

Deep Learning studies: summary

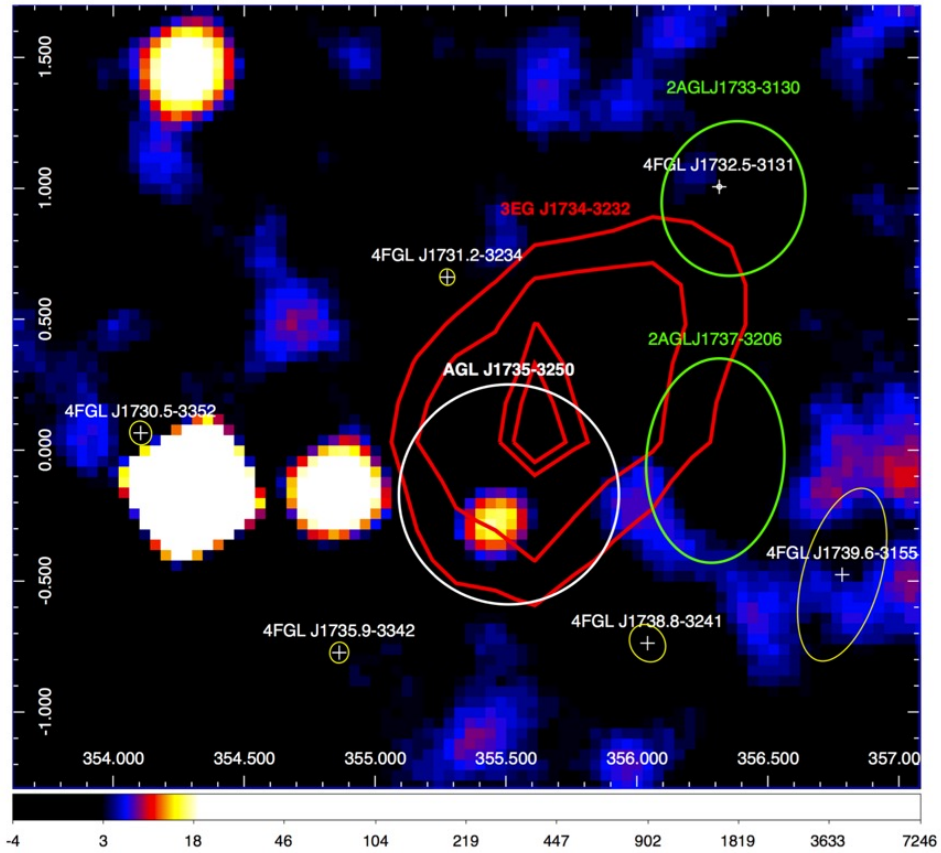
- We are developing Deep Learning models to detect GRBs in the time-series and counts maps generated with the data acquired by the instruments onboard the AGILE satellite.
- This study proves the capabilities of Deep Learning models to detect GRBs. We are implementing these detection models into the AGILE Real-Time analysis pipeline to follow up external science alerts.
- We think these methods can be used to develop models for detecting GRBs inside the data of other gamma-ray facilities such as the Cherenkov Telescope Array and the COSI space mission.

We won an INAF mini-grant to carry on these researches based on Deep Learning techniques.

AGILE: work in progress on two peculiar (1 Galactic and 1 extragalactic) sources and the AGILE-GRID Transient Catalog

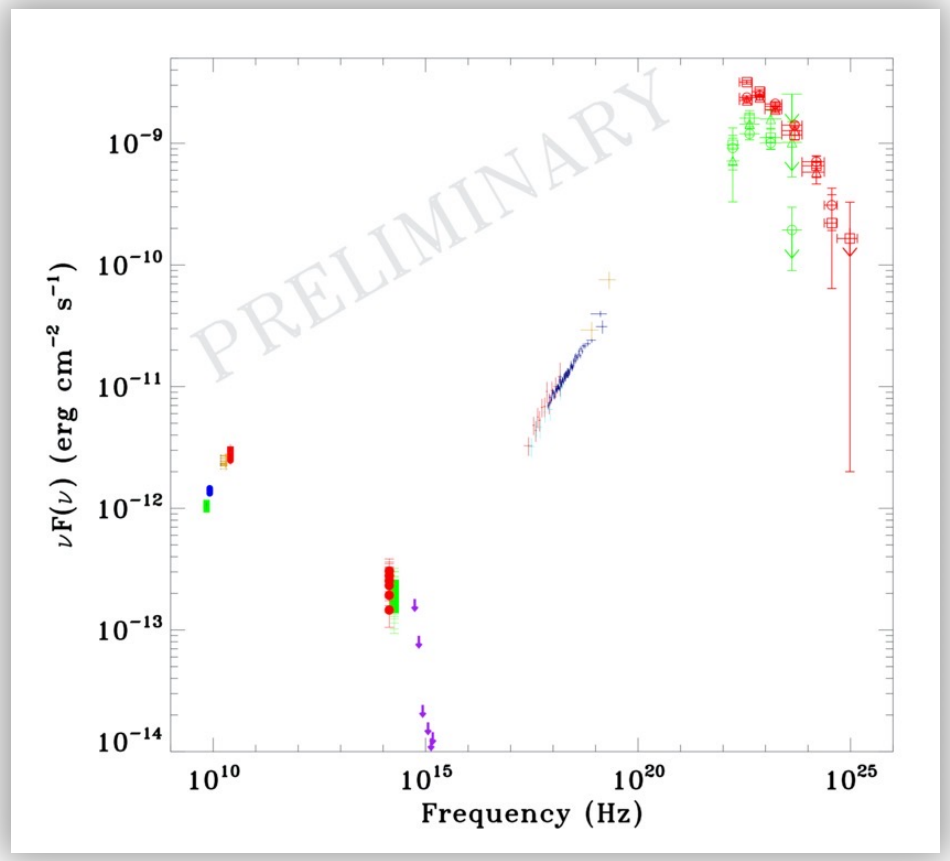
IGR J17354-3255 (Bulgarelli et al., in progress)

- On April 14, 2009 the AGILE satellite discovered a transient source named AGL J1734−3310. This prompted a Swift/XRT observation, that started about two days later and yielded a transient source positionally consistent with IGR 17354−3255.
- IGR 17354−3255 is a member of the subclass of **high-mass X-ray binaries (HMXBs)** called **Supergiant Fast X-ray Transients (SFXTs)**, with a massive OB supergiant star as a companion donor.
- We found a total of 14 events seen by AGILE compatible with the position of IGR17354−3255. The greatest part of these events also shows fast flares at 2, 4 or 6-hour time scale
- We calculated the phase of these events with the period of the binary system, and we found that half of the **γ-ray activity occurs around the apastron passage of the compact object** hosted in the binary system.
- We searched into the Fermi/LAT data to complement the γ-ray information provided by AGILE, finding coincidences.
- We also consider archival Swift and INTEGRAL observations to provide lower energy phase-folded light curves.



The INTEGRAL/IBIS mosaic significance map (18−60 keV) of the sky region surrounding IGR J17354-3255, with the refined positional uncertainty of AGLJ1734−3310 (white circle, 95% confidence) and the positions of the 2AGL sources (green circles) superimposed. Clearly, IGR J17354-3255 is the only hard X-ray source detected (18σ, 10 Ms on-source exposure time) and unambiguously located inside the error circle of AGL J1734−3310. γ-ray sources detected by Fermi/LAT are indicated with yellow ellipses (95% confidence).

AGILE and PKS 1830−211



PKS 1830−211 is a γ-ray, high-redshift (z = 2.507), **lensed flat-spectrum radio quasar**.

During the period mid-February to mid-April 2019, this source underwent a series a strong γ-ray flares that were detected by both AGILE and *Fermi*, reaching a maximum flux **of $F_{[E>100\ MeV]} \sim 2.3 \times 10^{-5}$ ph cm^{-2} s^{-1}.**

In **Vercellone et al**. (**A&A, to be submitted**) we present the results of the **MWL campaign** involving AGILE, Fermi, *Swift*, Chandra, NuSTAR, INTEGRAL, REM, SRT, Medicina and OVRO.

The AGILE-GRID Transient Catalog

Search for GRID transient detections over the whole sky and the whole *AGILE* lifetime using the LV3 Archive as input

The AGILE-LV3 "*post-look*" PIPELINE:

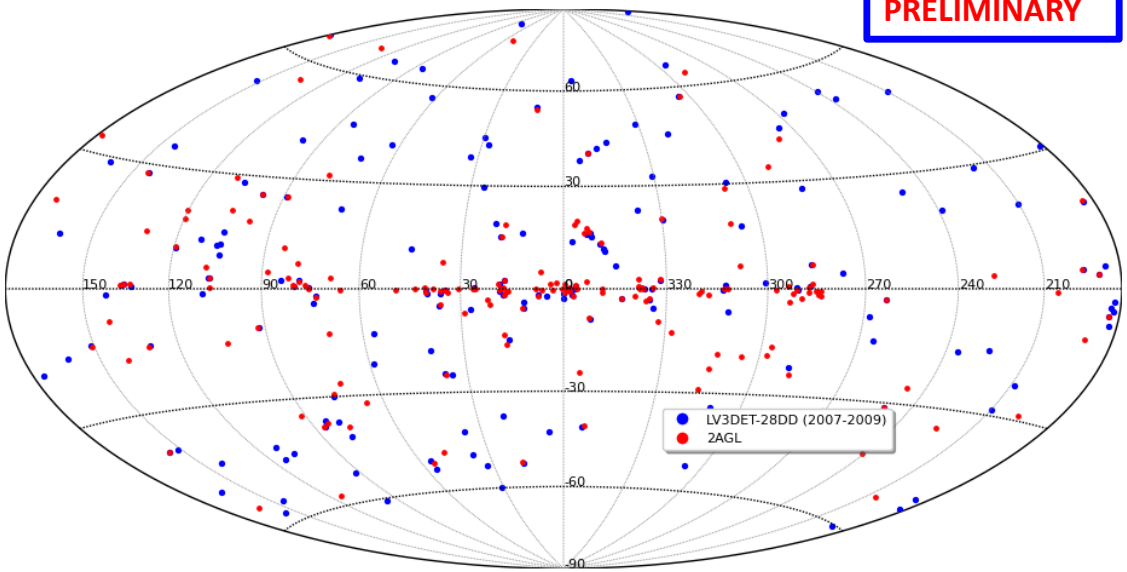
① Apply the XIMAGE *detect* task to blindly search for excesses on the LV3 merged maps, over the different time intervals 2-, 4-, 7-, and 28-days.

② Evaluate the *detect* excess positions found in the LV3 maps with the AGILE ML (**use 2AGL as reference catalogue**).

③ Save the ML output (ascii format) for each LV3 time interval, and apply "data mining" to extract the most significant detections.

F. Lucarelli, C. Pittori et al, in progress

PRELIMINARY

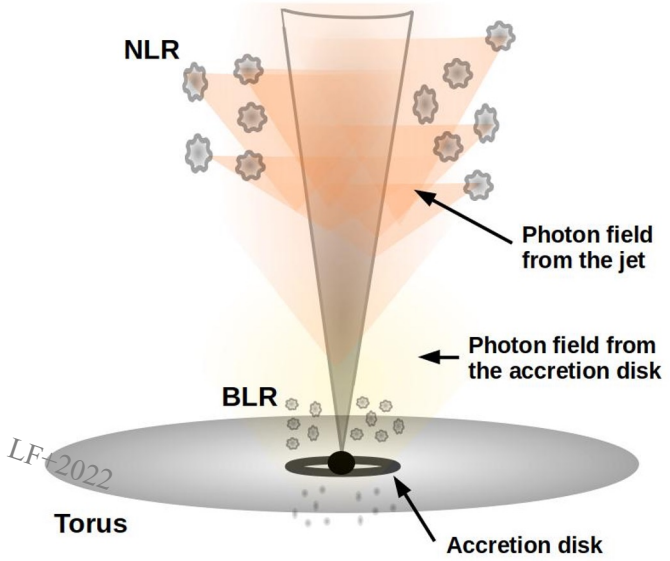


- **~200 automatic detections (σ>4) on the 28-day time-bins over the Pointing period.**
- **~50% not associated with the 2AGL Catalogue.**
- **Spinning Period and other time-bins (7, 4) in processing and evaluation.**

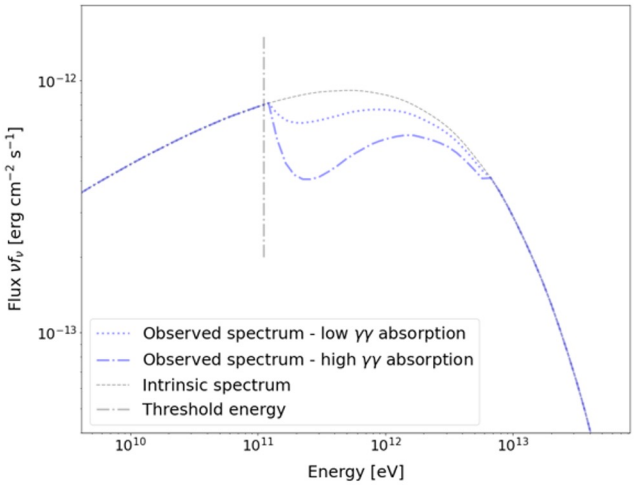
AGILE Theoretical Studies

Absorption features in gamma-ray spectra of BL Lac objects

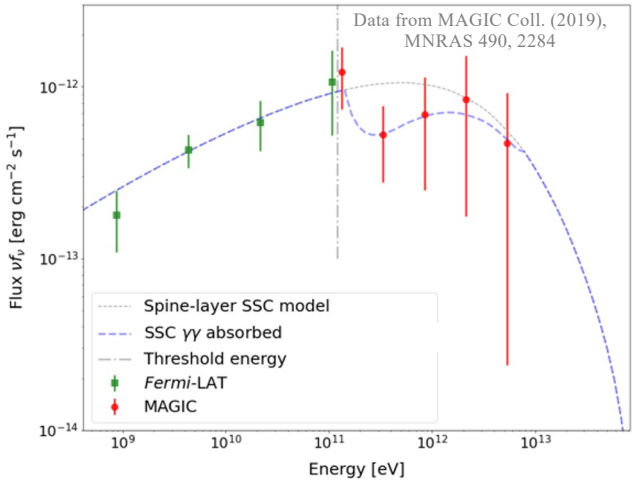
Foffano L., Vittorini V., Tavani M., Menegoni E., 2022, ApJ, 926, 95



Theoretical absorption feature



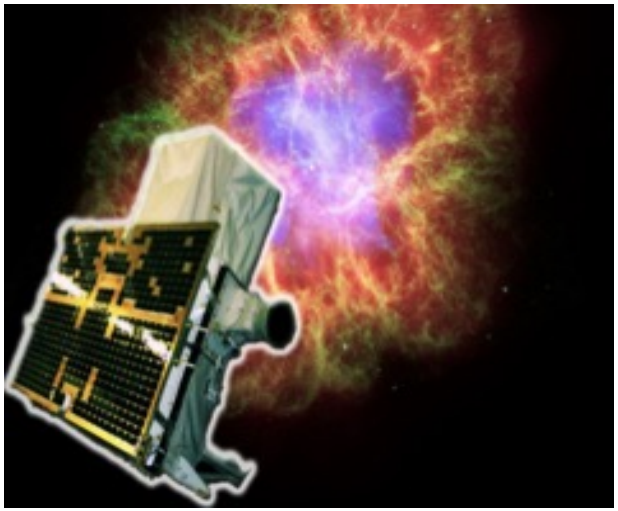
Real data of PGC 2402248



New **indirect method** to identify large-scale structures in BL Lac objects where these structures are not visible with the standard methods

Scientific Activities of AGILE Astrophysical Plasma Group

Team: **Valerio Vittorini, Eloisa Menegoni, Luca Foffano, Marco Tavani at IAPS Roma**.



- The AGILE discovery of fast variability of CRAB Nebula at energies around 300 MeV and beyond challenges the Burn-off limit for Synchrotron radiation, this process involves particle acceleration possibly out to PeV energies. Here **we study acceleration mechanisms of leptons in order to radiate beyond the 150 MeV limit from standard MHD**: the principal candidate is the **magnetic reconnection** that, in specific configurations, could locally annihilate magnetic field, producing coherent electric fields on length scale large enough to accelerate charges at extreme energies.

- We are developing **PIC codes** derived by Zeltron, in order to treat the magnetic reconnection and the dynamic of fields in **astrophysical plasma**. Our aim is to apply these techniques **to Blazar jets, PWN, and Galaxy (see FERMI Bubbles**) where the emitted photons cover the range from 50 MeV up to PeV that involve efficient acceleration in situ of particles out to **PeV energies**. We are able to model emission processes in these sources by also considering the effect of EBL absorption and γ-γ absorption in situ.

- We collaborate with **Proto-Sphera experiment at ENEA** in Frascati RM (F. Alladio, P. Buratti, A. Cardinali, S. Mannori, P. Micozzi) and Pisa University (F. Pegoraro)

In prep. - E.Menegoni, V. Vittorini, P. Buratti, L. Foffano, M. Tavani.

Conclusions: THE AGILE ALL SKY SCANNING GOES ON

- **Enhanced detection capabilities for transients: especially for GW and neutrino follow-up, short and long GRB detection, FRBs.**
- **Crucial need of 12-14 passes/day from Malindi to exploit the full AGILE potential (optimal MCAL configuration and SuperAGILE photon by photon observations)**
- **Fully integrated in a network of multi-frequency and multi-messenger observers from ground and space**
- **AGILE unique contribution for TGF. May play a role also on Solar related science**
- **Automatic pipelines plus human vetting: on-duty 7dd/7 - 24h/24 since the Ligo-Virgo GW run. Ready for next O4 GW run!!**

Thank you!

BACKUP SLIDES

- **AGILE unique features for transients:**
  - **> 100 useful passes/day over 80% of the sky of ~150 sec duration** (large FoV, spinning observation mode)
  - optimal PSF
  - optimal sensitivity above 30 MeV
  - **sensitivity ~ (1-2) 10^{-8} erg cm^{-2} s^{-1} in 100 sec.**
  - unique hard X/γ-ray coverage
  - **very fast processing and alert**
    (~25 min after the event if 100% of the **14 orbits/day** are transmitted)