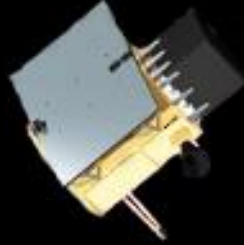


AGILE activity for GW γ -ray counterpart search

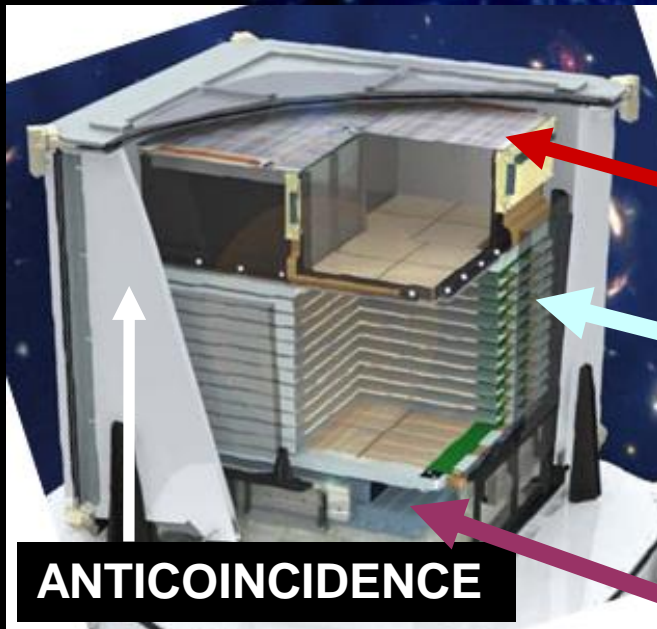
Sep. 24, 2024

*Verrecchia F. (INAF/OAR, ASI/SSDC), Casentini C. (INAF/IAPS),
on Behalf of the AGILE Team*



AGILE payload

Science Data Center



ANTICOINCIDENCE

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

Energy Range: 18–60 keV

SILICON TRACKER

GAMMA-RAY IMAGER (GRID)

Energy Range: 30 MeV – 30GeV

(MINI) CALORIMETER

Energy Range: 0.3–100 MeV

**AGILE had unique combination of X-ray and gamma-ray detectors for GW searches
two co-aligned detectors in hard X-rays (20-60 keV; super-A) and gamma (30 MeV-
10GeV; GRID) + MCAL (0.4-100 MeV) + Anticoincidence (80 – 200 keV)**

Operational from April 23rd, 2007 up to January 18th, 2024;

AGILE in spinning mode

- Very large field of view (~ 2.5 sr).
- Coverage of 70% -- 80% of the whole sky in about 7min.
- Very fast ground segment: first *Quick Look* analysis (on *contact* basis) available **~ 30 min** after telemetry download.

Very suitable instrument to perform all-sky searches

for short transient γ -ray sources and γ -ray counterparts to

multi-messenger transients (GW and neutrinos).

AGILE and GW astrophysics: summary

- Archival analysis for GW150914 (no MoU: [Tavani et al. 2016](#) , TEST case for development of GW dedicated procedures
- Preparation to O2 in 2016: developed first RTA pipeline
- Participation to O2 with MoU:
 - [GW170104: Verrecchia et al. 2017a](#)
 - [GW170817: Verrecchia et al. 2017b](#)
- Preparation to O3
 - New MCAL processing pipelines
- Participation to O3: public alerts
- Archival analysis: reanalysis of data for the GWTC-1 catalog → [Ursi et al. 2022a](#)
- MCAL processing pipelines results --> New GRB Catalog: [Ursi et al. 2022b](#)
- Preparation and participation to O4
- Work in progress: archival reanalysis for O3 & O4a events

AGILE activity for GW e.m. search: the beginning

Single revolution including T_0 of GW150914

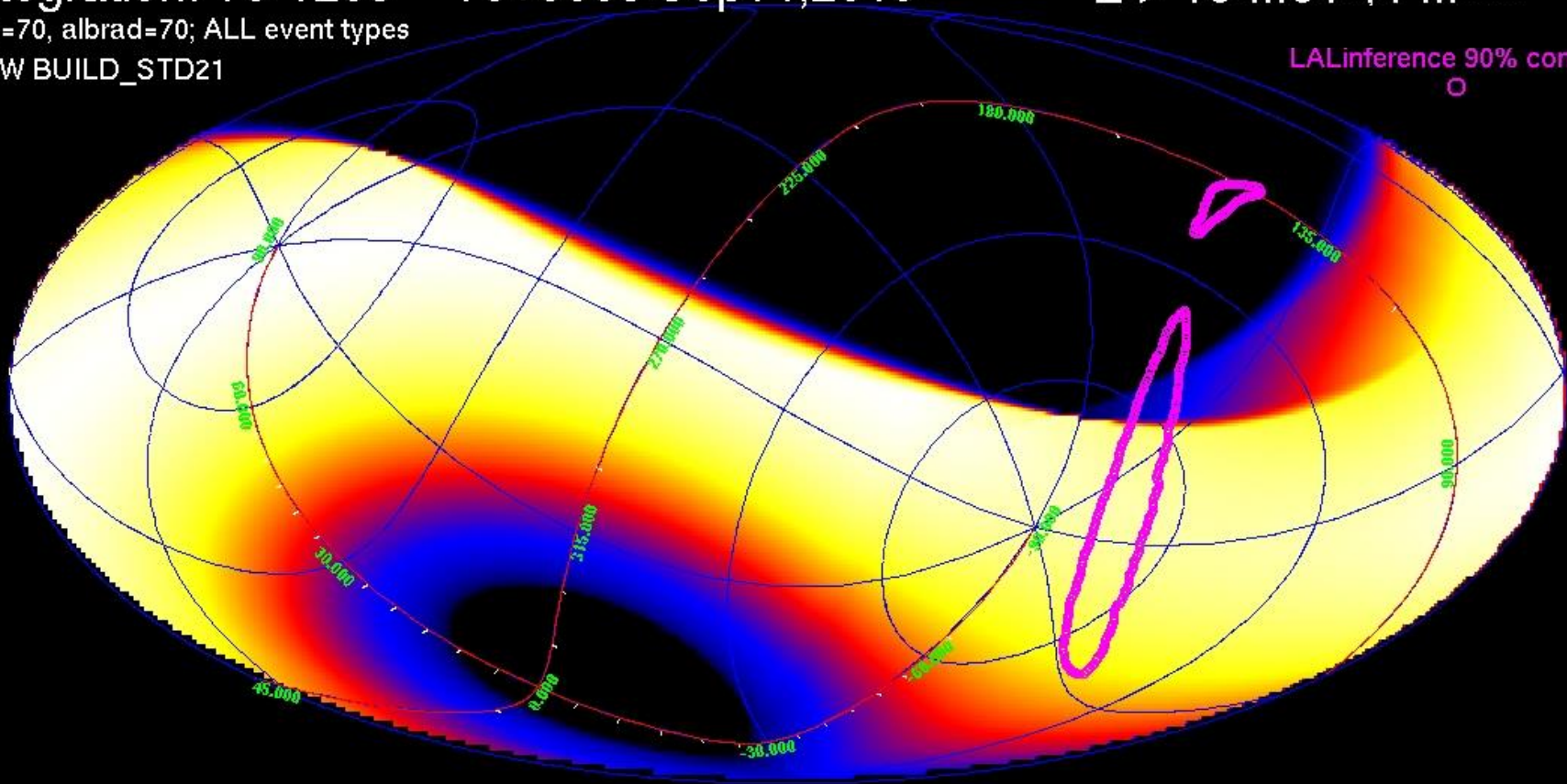
Integration: T_0-120s -- T_0+300s Sep14,2015

$E > 10$ MeV ; FM

fov=70, albrad=70; ALL event types

NEW BUILD_STD21

LALInference 90% contour



0.05

0.1

0.15

0.2

0.25

0.3

0.35

0.4

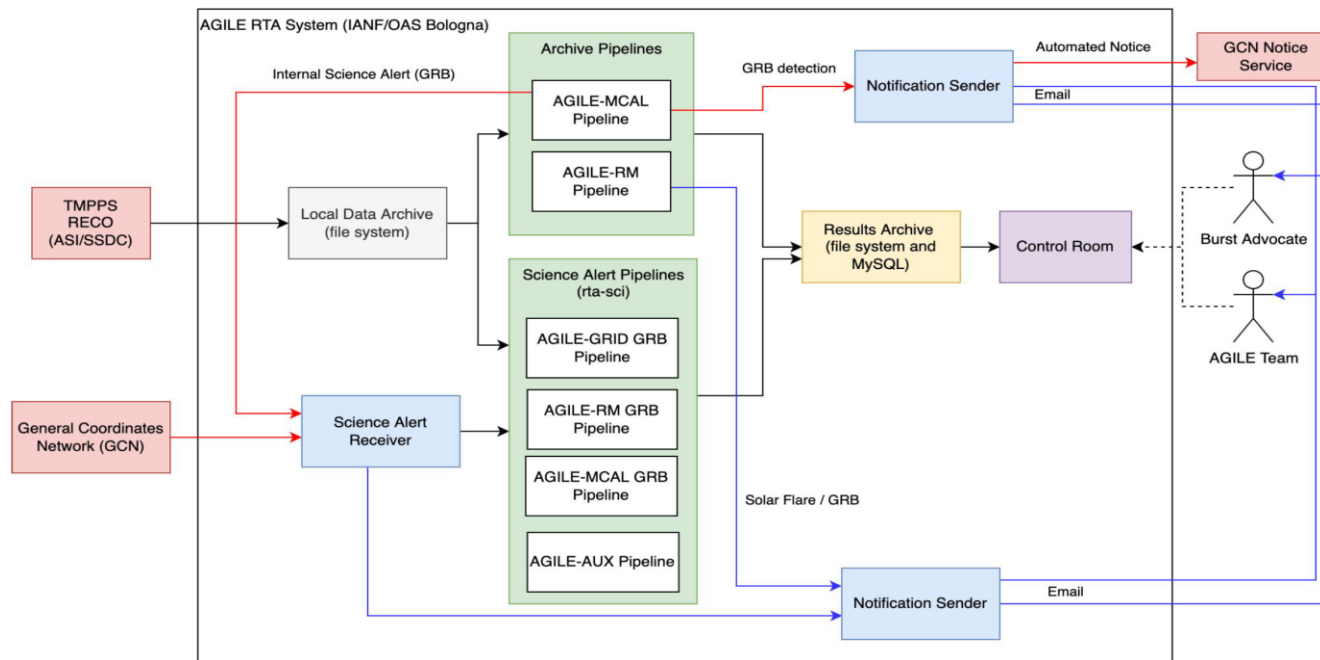
0.45

0.5

AGILE real-time analysis system

The Real-Time Analysis (RTA) pipeline developed by INAF/OAS and SSCDC, as a follow-up of the first GW data analysis and GRB previous analyses:

- Runs pipeline either on external trigger or to execute source blind search
- Distributed alerts system between OAS and SSCDC
- Fast reactions on transient alerts external notification
- UPDATED since 2016 various times!



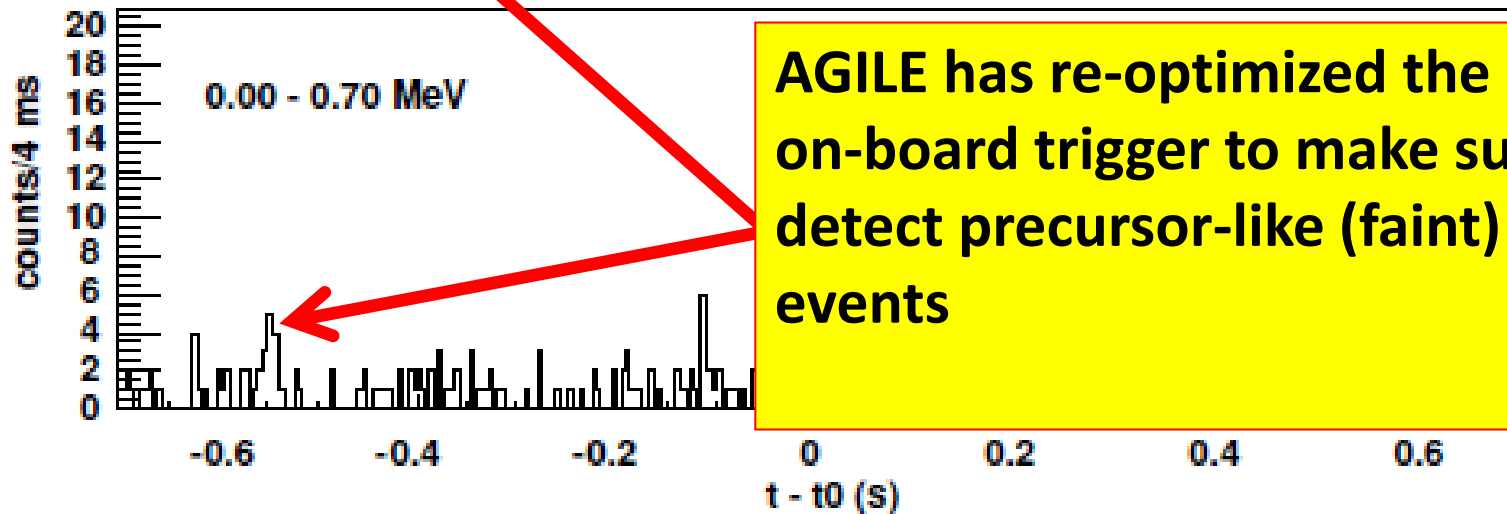
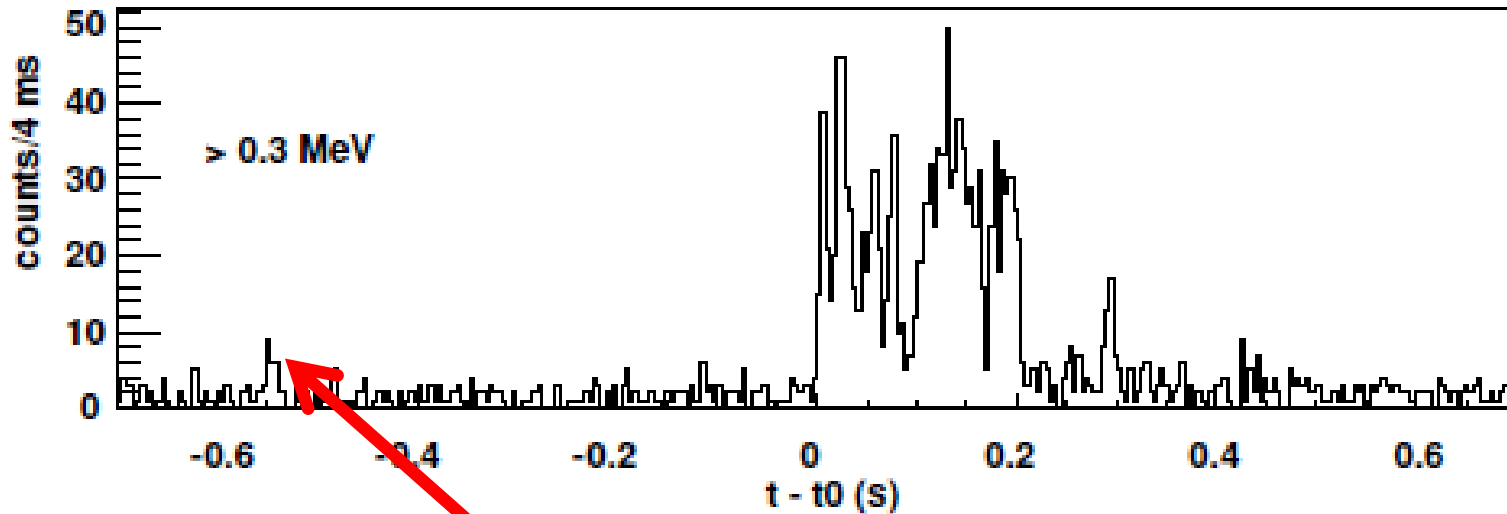
AGILE and GW astrophysics: O2

Preparation to O2:

- Setup improved performances for GW collaboration
- MCAL on board upgraded configuration
- very fast reaction to external GW trigger: AGILE real-time analysis «GW» pipeline @OAS Bologna and SSDC
- **MCAL processing pipelines for “sub-threshold events”**
→ automatic alerts
- great potential for fast discovery of gamma-ray transients associated with NS-NS, NS-BH
- **AGILE GW-Team monitoring shifts (24/7) during the O2, but also O3 and O4a GW LIGO-Virgo observing runs**
=>shift procedures REVISED at EACH run

O2 Preparation: AGILE-MCAL GRB090510 light curve

goal GRB090510 pre-cursor like bursts



AGILE has re-optimized the MCAL on-board trigger to make sure to detect precursor-like (faint) events

AGILE search for gamma-ray counterparts of GW events: in O1 and O2

GW ID	AGILE GCN #s	% coverage of 90% c.l. contour	NEAREST EXP.	Comments on Prompt and papers
150914	----	0 %	+330	Prompt just missed; Tavani et al. 2016
151226	----	30 %	0	Partially covered; ---
170104	20375, 20395	36 %	0	Partially covered GRID, covered by MCAL; Verrecchia et al.2017a
170608	21224, 21228	40 %	0	Partially covered GRID, covered by MCAL for a few tens of ms; ---
170729	----	0 %	+150	Prompt just missed;
170814	21477, 21482	0 %	+ 500	Not covered (1 st with Virgo data); ---
170817	21525,21526, 21562, 21785	0 %	+ 930	OT NOT covered; Verrecchia et al. 2017b

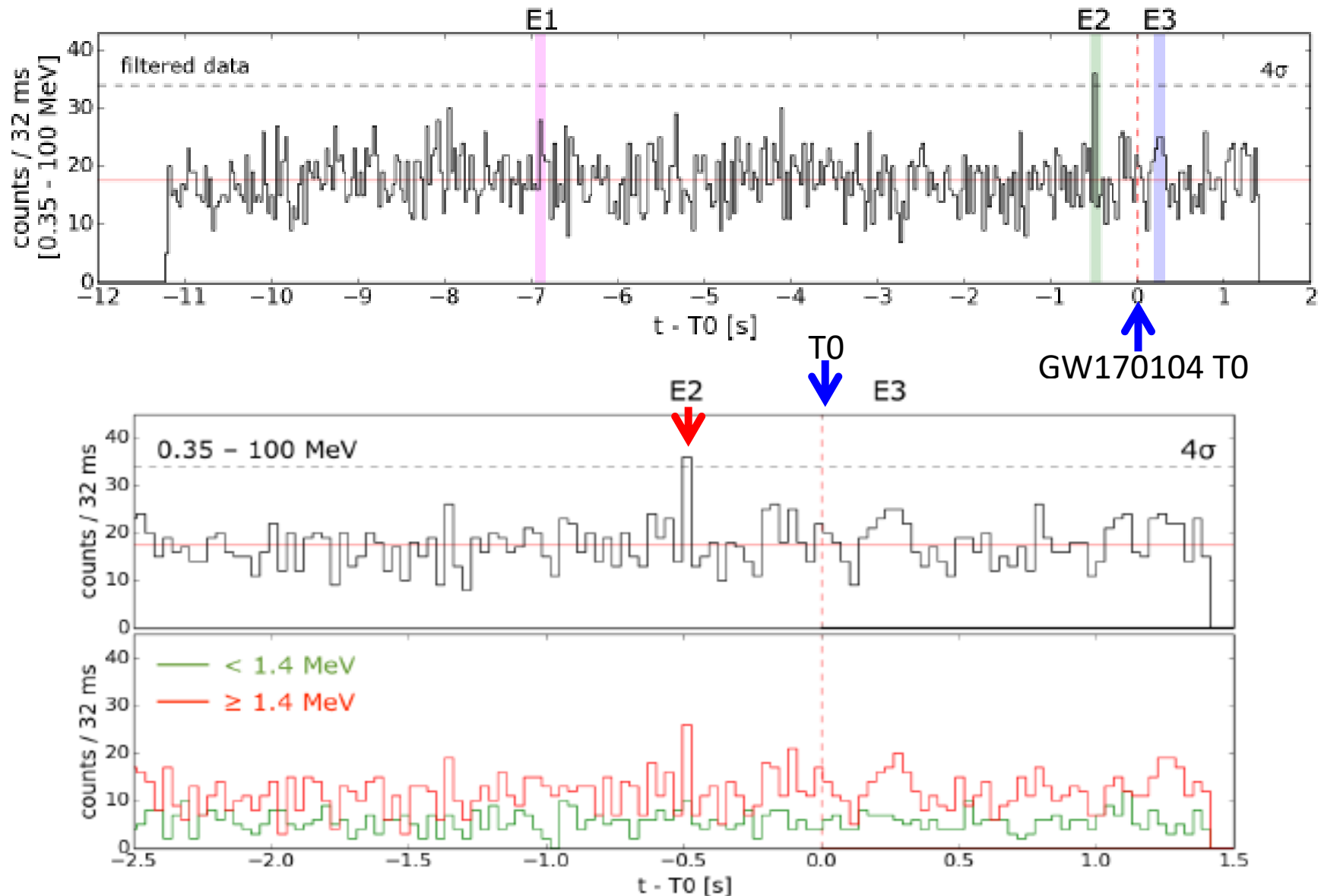
BLUE: Binary NS merger ; RED: prompt covered



O2 Summary:

- **AGILE in the MoU since Nov 2016: promptly reacted to all GW candidate events communicated by LIGO-Virgo in O2 **with reaction time of 2-3 hrs** (including manual refined validation)**
- **A possible AGILE-MCAL gamma-ray transient candidate found as counterpart of GW170104 (Verrecchia et al., ApJL 847, 2017)**
- **AGILE and GW170817: first γ -ray instrument with exposure on the localization region starting at $\sim T_0 + 930s$ (Verrecchia et al., ApJL 850,2017)**
- **AGILE observations provided the fastest response and among the most significant upper limits above 50 MeV **to all GW events detected in O2****

GW170104: an MCAL candidate event

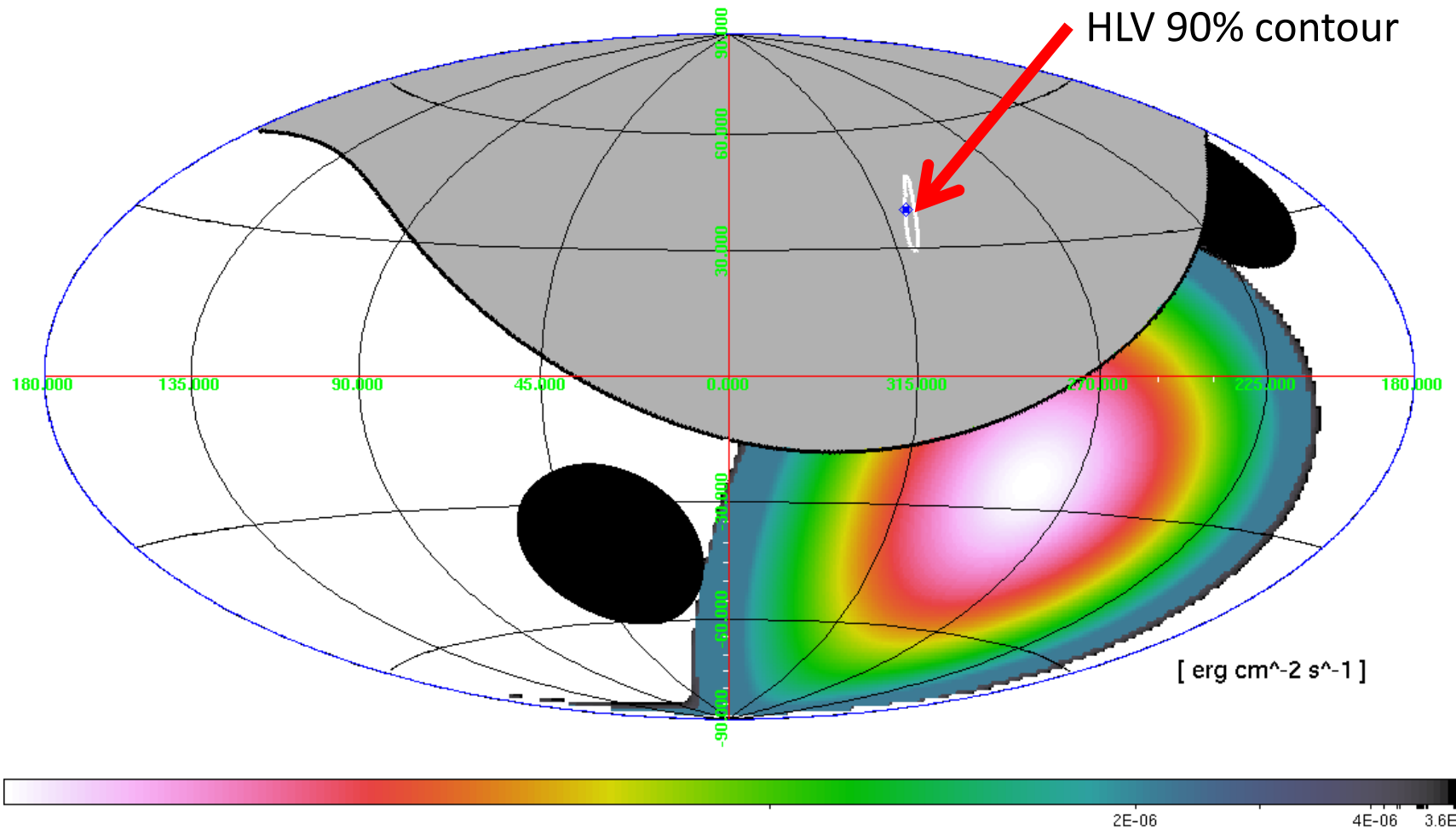


Careful FAR estimation, only E2 is a good candidate but post-trial Prob. resulted to be below 3σ

(Verrecchia et al. 2017a)

GW170817

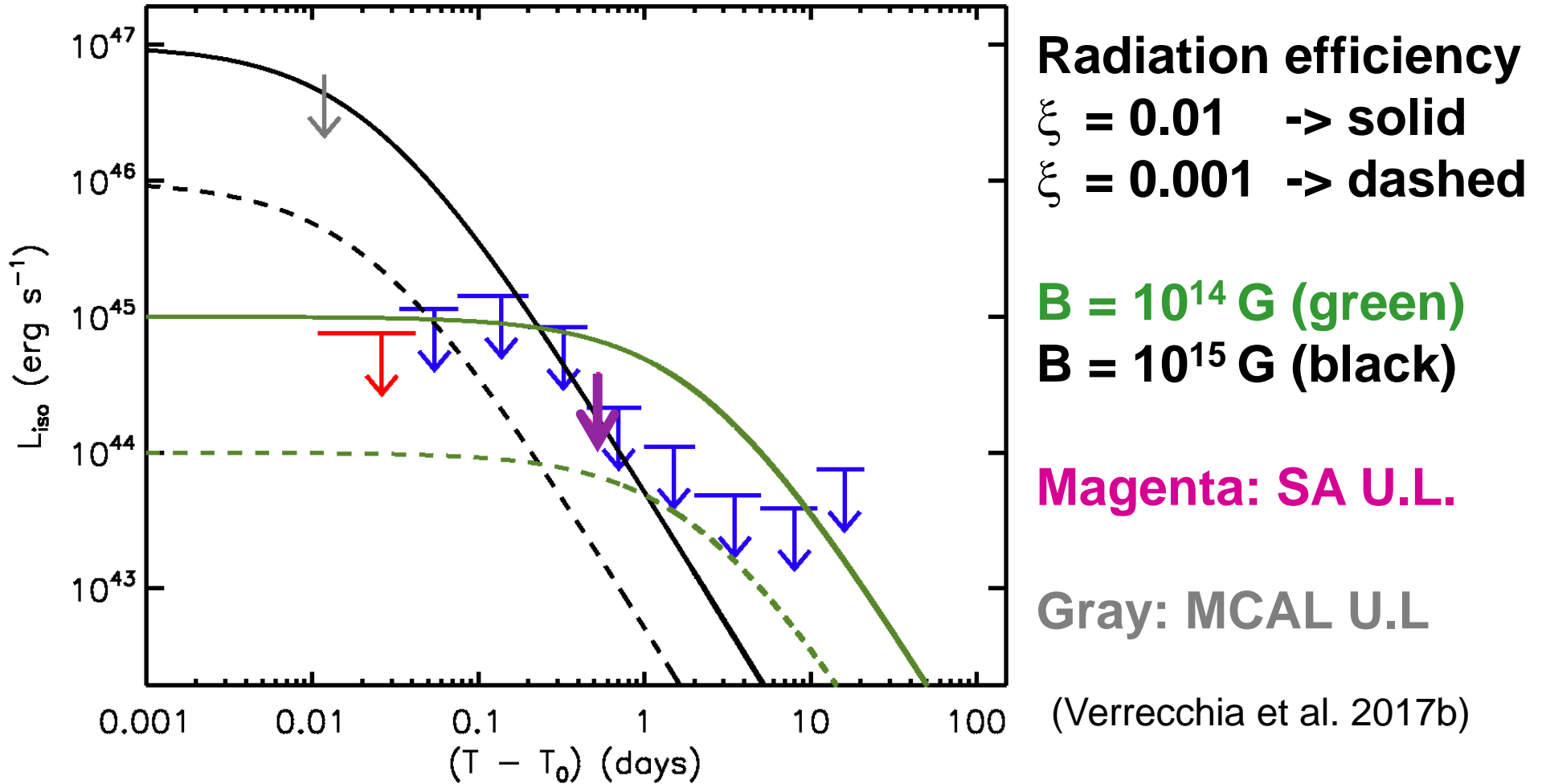
AGILE exposure at trigger time (-2 / +2 sec)



In E > 30 MeV energy band

GW170817: AGILE crucial limits on magnetar emission:

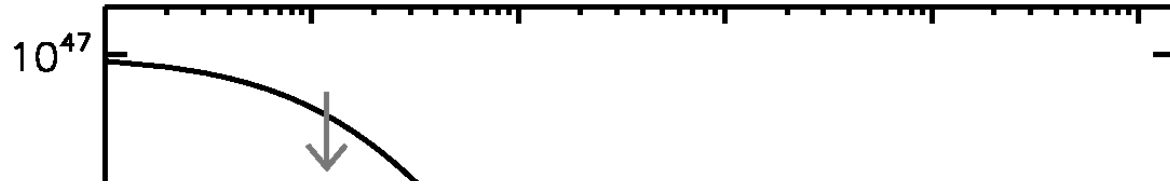
HE emission from a magnetar remnant left by NS-NS coalescence model:



(GBM GRB170817A spectrum cutoff **out** of MCAL band)

GW170817: AGILE crucial limits on magnetar emission:

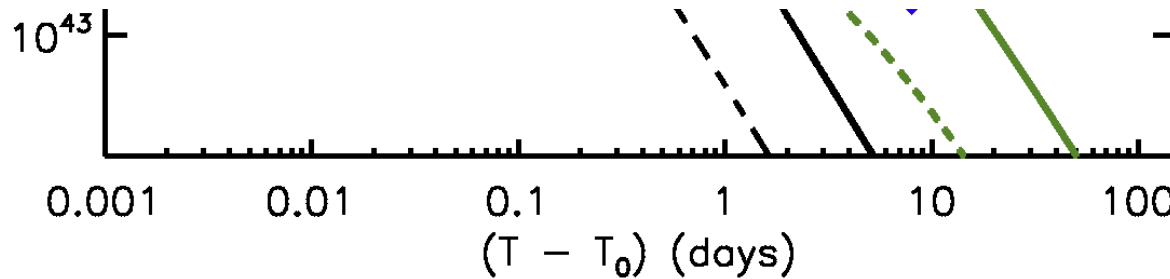
HE emission from a magnetar remnant left by NS-NS coalescence model:



Radiation efficiency $\xi = 0.01 \rightarrow$ solid

AGILE ULs set important constraints in the early phases, to exclude a highly magnetized magnetar for the remnant of GW170817- GRB170817A

(vertical text on the left side of the slide)



(GBM GRB170817A spectrum cutoff out of MCAL band)

Preparation of O3 GW run:

- **AGILE fast and unique hard X/ γ -ray coverage (good TM budget) - >IF possible!**
- **O3 LIGO-Virgo run: Public LV alerts! So need to increase speed in results publication**
- **Improved performance with NEW MCAL pipeline developed for “sub-threshold events” btw 5 \div 6 sigma pre-trial significance**
- **GW pipeline also upgraded: revised products/functionalities**
- **O3: reduced human vetting of detections: more use of automatic results and more automatic results!**
- **MCAL-GRB: automatic **detection** and notification to community with notices: operative (> May 2019)**

=>Contribution to LIGO-Virgo O3 run!

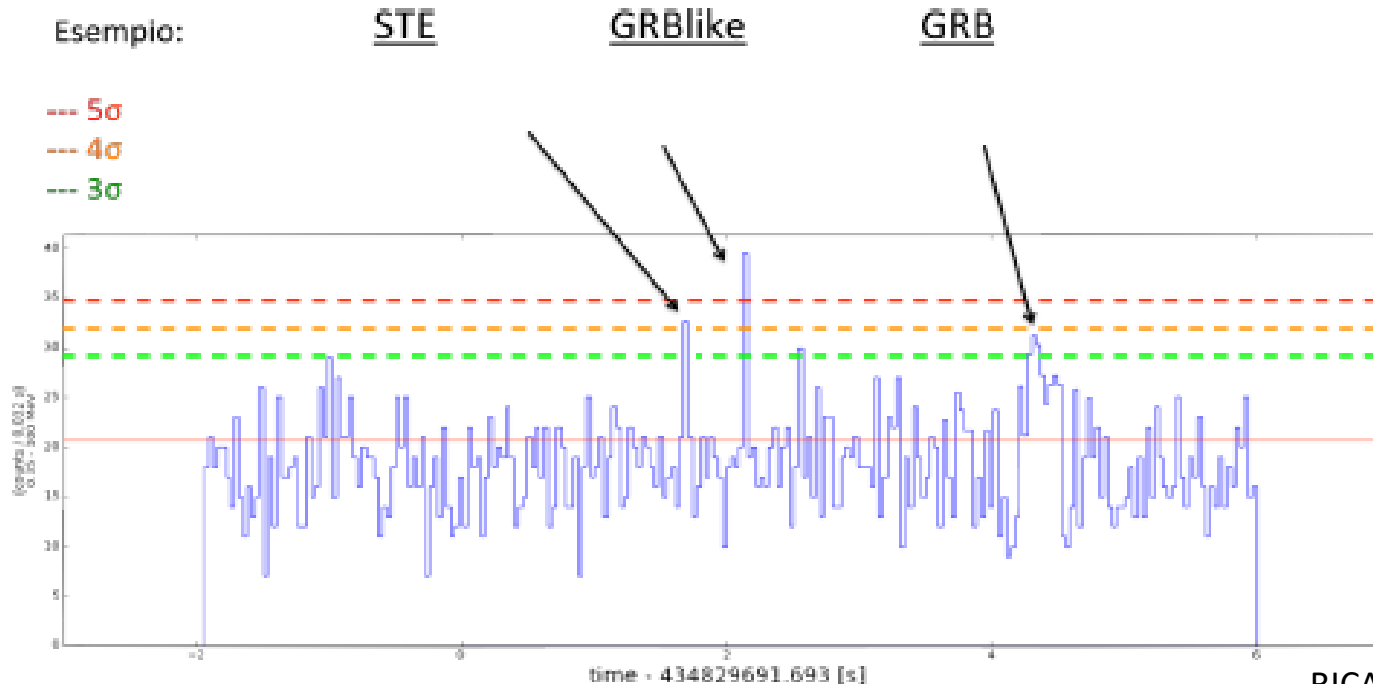
AGILE-MCAL, new detection pipeline

MCAL automatic detection pipeline: 4 binning timescales (16, 32, 64, 128 ms), 4 phase shifts.

Three event classes: **revised** (see archival analysis in Ursi et al. 2019)

- 1) standard GRBs (short & long),
- 2) GRB-like (single+S/N >6 σ),
- 3) Sub-Threshold Events (STEs, single+S/N >=5 σ).

differences among the three classes



(Ursi et al. 2019)

AGILE search for gamma-ray counterparts of GW events in O3

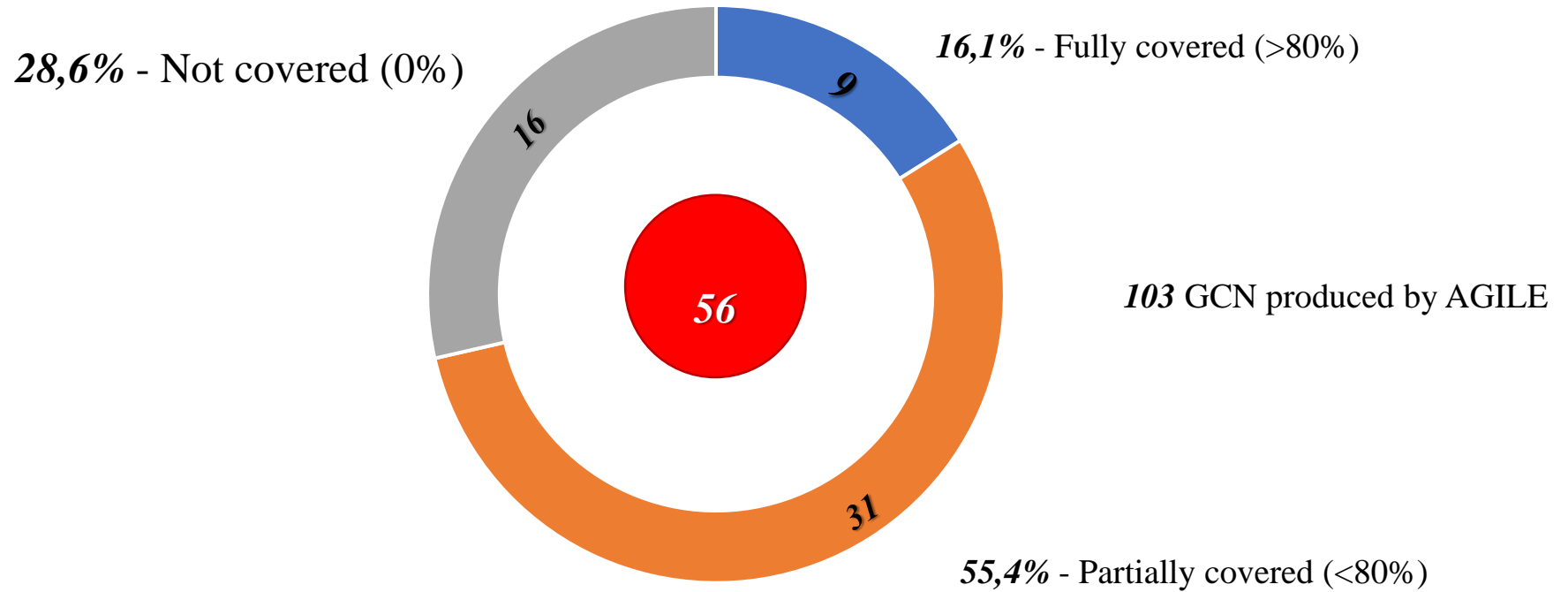
GW ID	AGILE GCN #	% coverage of 90% c.l. contour	NEAREST EXP.	Comments on Prompt
190408an	24063, 24071,24080	0 %	+100	Prompt just missed;
190412m	24100, 24110	0 %	-700	Occluded;
190421ar	24140, 24143	0 %	+450	Not covered, SAA;
190425z	24180, 24186	0 %	+100	Prompt just missed by GRID;
190426c	24245, 24246	70 %	0	Partially covered;
190503bf	24379,24382	4 %	0	Prompt partially covered, occultation;
190510g	24437,24457	60 %	0	Not covered;
190512at	24507, 24519	0%	+840	SAA+ occultation + Sun constraints;
190517h	24572, 24574	0 %	-100	Prompt just missed;
190519bj	24603, 24604	70 %	0	Partially covered;
190521g	24623, 24626	60 %	0	Partially covered;
190521r	24636, 24638	40 %	0	Partially covered;
....

AGILE search for gamma-ray counterparts of GW events in O3

AGILE RT Alert	Control Room	LIGO	Notices	Pipes	Science Alerts	Monitoring	GW Team	Help	2024-09-22T14:25:15 (UTC)	Mass Gap:	Alert Checked <input checked="" type="checkbox"/>
LIGO	2020-03-16T21:57:56.157	511480676.157206	2020-03-16T22:08:25	2003160210	1	ID: S200316bj	Sig:	<input type="button" value="Prompt Analysis"/> <input type="button" value="Full Analysis"/> <input type="button" value="Open Run"/> <input type="button" value="Open Results"/>	BNS/NSBH/BBH: 0/0/0 FAR: 7.1e-11 Has NS: 0 Has Remnant: 0 Mass Gap:	Alert Checked <input checked="" type="checkbox"/>	
LIGO	2020-03-16T21:57:56.157	511480676.157206	2020-03-16T22:01:50	2003160210	0	ID: S200316bj	Sig:	<input type="button" value="Prompt Analysis"/> <input type="button" value="Full Analysis"/> <input type="button" value="Open Run"/> <input type="button" value="Open Results"/>	BNS/NSBH/BBH: 0/0/0 FAR: 7.1e-11 Has NS: 0 Has Remnant: 0 Mass Gap:	Alert Checked <input type="checkbox"/>	
LIGO	2020-03-11T11:58:53.398	511012733.397786	2020-03-13T15:07:04	2003110207	3	ID: S200311bg	Sig:	<input type="button" value="Prompt Analysis"/> <input type="button" value="Full Analysis"/> <input type="button" value="Open Run"/> <input type="button" value="Open Results"/>	BNS/NSBH/BBH: 0/0/1 FAR: 8.9e-26 Has NS: 0 Has Remnant: 0 Mass Gap:	Alert Checked <input type="checkbox"/>	
LIGO	2020-03-11T11:58:53.398	511012733.397786	2020-03-11T12:16:20	2003110207	2	ID: S200311bg	Sig:	<input type="button" value="Prompt Analysis"/> <input type="button" value="Full Analysis"/> <input type="button" value="Open Run"/> <input type="button" value="Open Results"/>	BNS/NSBH/BBH: 0/0/1 FAR: 8.9e-26 Has NS: 0 Has Remnant: 0 Mass Gap:	Alert Checked <input type="checkbox"/>	
LIGO	2020-03-11T11:58:53.398	511012733.397786	2020-03-11T12:10:15	2003110207	1	ID: S200311bg	Sig:	<input type="button" value="Prompt Analysis"/> <input type="button" value="Full Analysis"/>	BNS/NSBH/BBH: 0/0/1		

LIGO-Virgo O3 run

What AGILE observed



NB: event sky coverage at T0

example: S190425z

$T_0 = 08:18:05$ UT, 25 April, 2019 Integration (+100 / +200 sec)

BNS

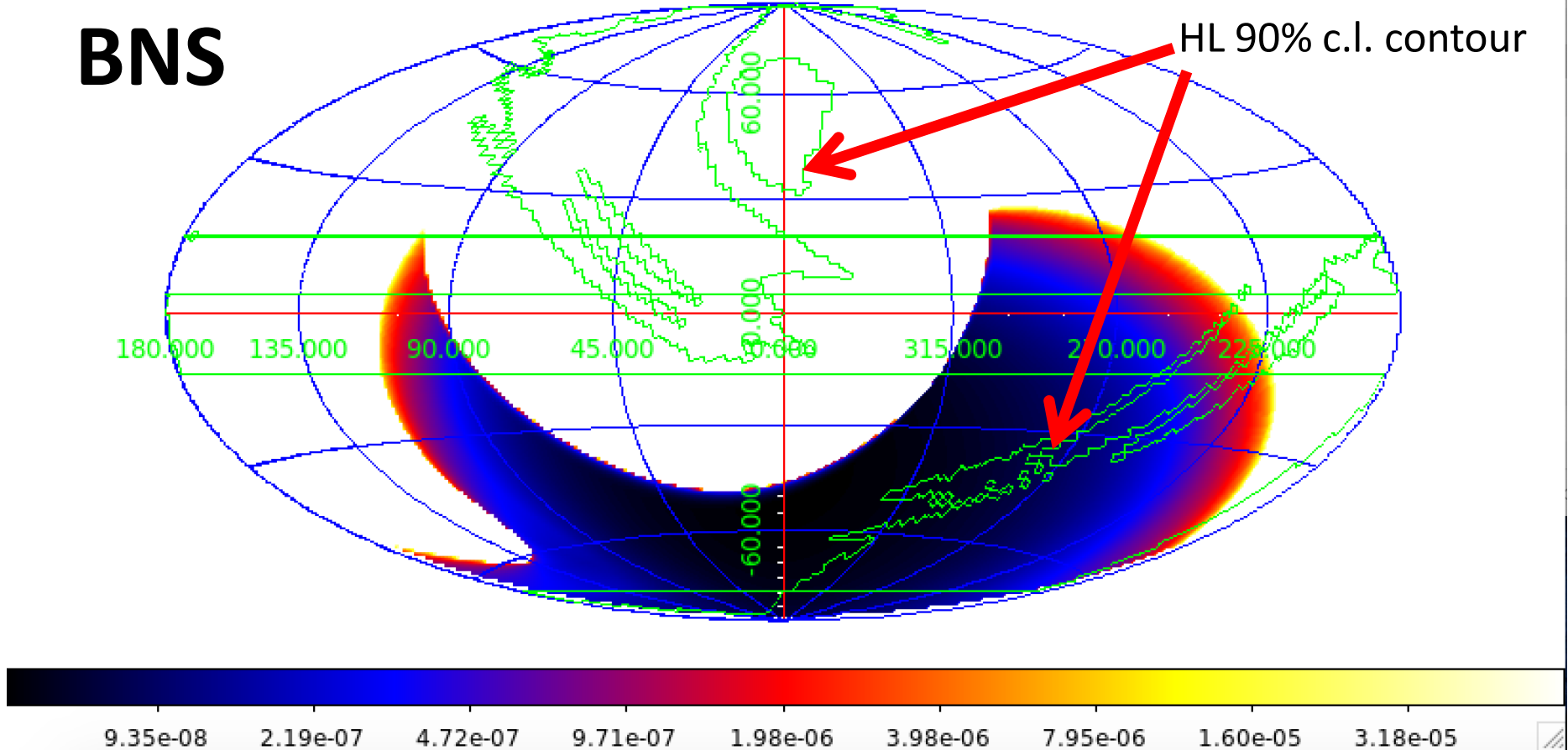
3-sigma upper limit ($E > 50$ MeV) $\sim 5.0 \times 10^{-8}$ erg cm⁻² s⁻¹

example: S190425z

$T_0 = 08:18:05$ UT, 25 April, 2019

Integration (+100 / +200 sec)

BNS



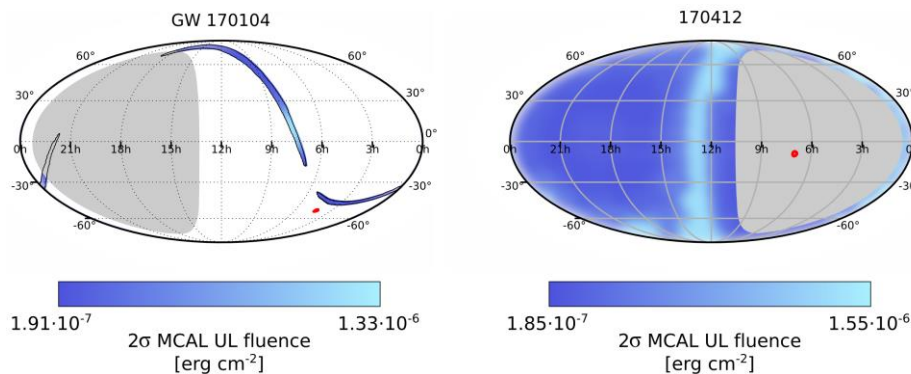
3-sigma upper limit ($E > 50$ MeV) $\sim 5.0 \times 10^{-8}$ erg cm $^{-2}$ s $^{-1}$

AGILE & GW: archival analyses

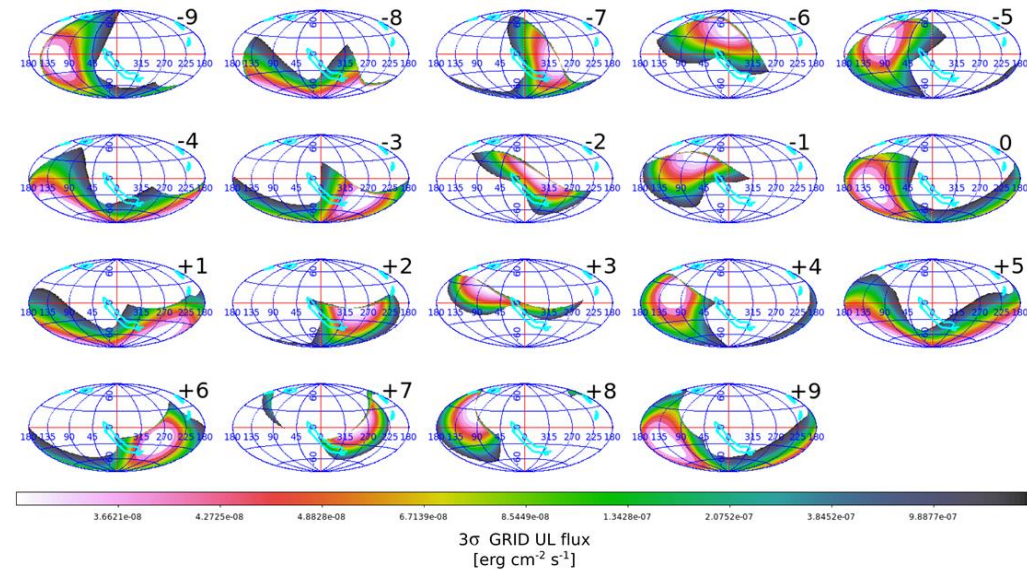
- AGILE activities on GW after O2: archival data re-analysis of previously published events, following the 1^o GW catalog (GWTC-1), with standard new processing on updated event parameters

=> paper on reanalysis of events included in GWTC-1, Ursi et al. 2022, published on ApJ:

- Reprocessing of all MCAL data within ± 100 s around event T0s



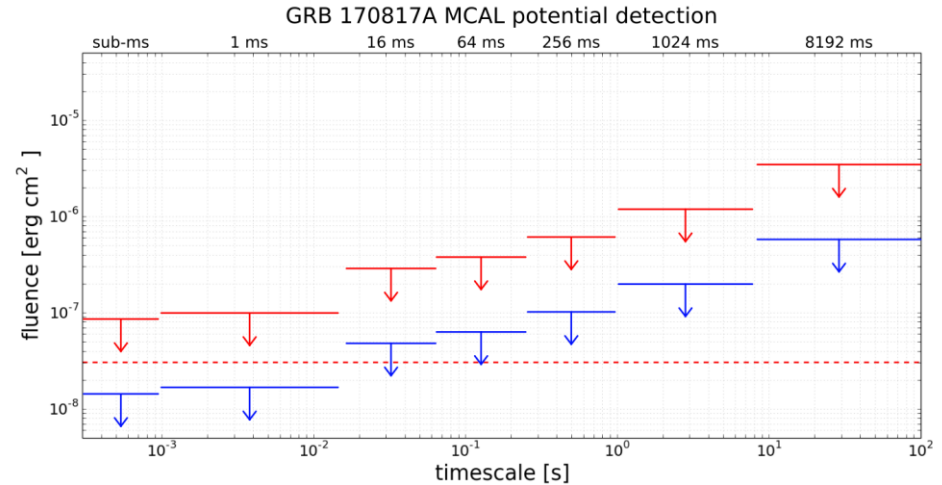
- No detection => extraction of fluence UL for each trigger logic timescale



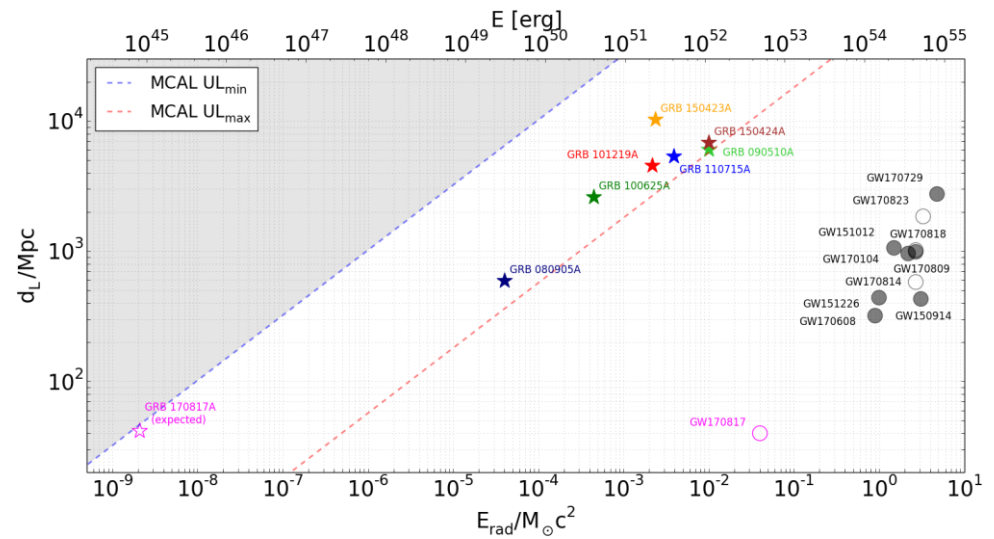
- GRID data check added: GRID coverage of the updated LV contours & UL evaluation

AGILE & GW: Ursi et al. 2022

- Check GRB170817 possible detection with MCAL data if not occulted by the Earth: minimum/maximum fluence UL



- Comparison of GW released energies and MCAL detected GRBs published in the recent new GRB catalog (Ursi et al. 2022, ApJ, 924, 80): distance vs energy



AGILE search for gamma-ray counterparts of GW events in O4

- O4a timeline: start on May 24th 2023 – end on January 18th, 2024

LVK status BEFORE start: good for a LIGO and Virgo: improved sensitivities, LIGO starting at 160 Mpc (140 end of O3), Virgo 80 (50) and further enhancement towards the end. KAGRA starting 1-3 Mpc (0.7?) but enhancement during O4 is uncertain.

Prospect for O4 were: NOT VERY different from O3, with expected improved number of events, but not very much in BNS

=>and it has been **CONFIRMED**: only 3 mergers including a NS in O4a

AGILE search for gamma-ray counterparts of GW events in O4

- O4a timeline: start on May 24th 2023 – end on January 18th, 2024

LVK status BEFORE start: good for a LIGO and Virgo: improved sensitivities, LIGO starting at 160 Mpc (140 end of O3), Virgo 80 (50) and further enhancement towards the end. KAGRA starting 1-3 Mpc (0.7?) but enhancement during O4 is uncertain.

Many BBH expected

=>Strategy: we decided not to publish ULs circular for BBH , check them but write a circular just in case of interesting signal

AGILE activity for LVK O4 run

AGILE GW Flare Advocate Team:

- **STRATEGY REVISION** based on GW event type: DISCARD BBH unless specific info available from EM community or interesting candidate in AGILE data
- Expert FAs exited the group, new personnel found and defined revised training based on simplified requirements

Cardillo M., Lucarelli, F. ->exited activity

Ciabattoni, A.; Cattaneo, P.; Panebianco, G.; Di Piano, A., Cutrona, F. (partial)

- **Add or REVIEW refined analysis tasks: develop updated tasks for FAs manual analysis (first released on 2022), more versatile and friendly**
- **REVIEW duty shifts: procedures and new staff training; manuals and documentation, video tutorial and training activities**
- **SSDC web reporting interactive tool for transients, GW/GRB and others: improved in O4**

AGILE activity for LVK O4 run

AGI



Agile Team

Version 1.3

verrecchia (Logout)

Insert New Doc

Show entries Type: Column visibility

Search:

Authors	Source	File	Notes	On Duty	Event StartDate (T0)	Event Type	FAR [Hz]	GCN	AGILE Pipeline	Primary Detector	MCAL T0 Coverage	GRID T0 Coverage
	S240109a		LVK O4, Sig=1, area=24219 deg^2; No data in MCAL, no data in GRID.	Casentini	2024-01-09 05:04:31.14	BBH (99%)	7.346E-9	Notices Circulars	HOST2 SSDC	MCAL	yes	yes
	S240109a		LVK O4, Sig=1, area=28048 deg^2; No data in MCAL, no data in GRID.	Casentini	2024-01-09 05:04:31.14	BBH (99%)	7.346E-9	Notices Circulars	HOST2 SSDC	MCAL	yes	yes
	S240107b		LVK O4, Sig=1, area=4143 deg^2; No data in MCAL, no exposure in GRID.	Longo	2024-01-07 01:32:15.59	BBH (97%), Terrestrial (3%)	5.834E-8	Notices Circulars	HOST2 SSDC	MCAL	yes	no
	S240104bl		LVK O4, Sig=1, area=24219 deg2. GRID=only a small fraction of GW area is inside GRID FoV. Earth is...	Panebianco	2024-01-04 16:49:32.170	BBH (99%)	3.6E-17	Notices Circulars	HOST2 SSDC	RM	no	yes
	S231231ag		LVK O4, Sig=1, area=27061 deg^2; MCAL No data. No valid GRID data.	Pilia	2023-12-31 15:40:16.20	BBH (>99%)	8.354E-15	Notices Circulars	HOST2 SSDC	MCAL	no	no
	S231226av		LVK O4, Sig=1, area=199 deg^2; No data in MCAL. Some exposure in GRID.	Foffano	2023-12-26 10:15:20.05	BBH (>99%)	0.0	Notices Circulars	HOST2 SSDC	MCAL	no	no
	S231224e		LVK O4, Sig=1, area=394 deg^2; No data in MCAL, no exposure in GRID.	Di Piano	2023-12-24 02:43:21.06	BBH (99%)	1.5E-9	Notices Circulars	HOST2 SSDC	GRID	no	no
	S231223j		LVK O4, Sig=1, area=3520 deg^2; No data in MCAL, no exposure in GRID.	Verrecchia	2023-12-23 03:28:36.69	BBH (>99%)	1.11E-9	Notices Circulars	HOST2 SSDC	MCAL	no	no
	S231213ap		LVK O4, Sig=1, area=1469 deg^2; MCAL No data. GRID no exposure	Pilia	2023-12-13 11:14:17.914	BBH (>99%)	6.335E-10	Notices Circulars	HOST2 SSDC	MCAL	yes	no
	S231206cc		LVK O4, Sig=1, area=342 deg^2; MCAL: no data (SAA?: no coverage within +/- 1000s), ULs; GRID: 0 %...	Verrecchia	2023-12-06 23:39:01.07	BBH (>99%)	1.932E-35	Notices Circulars	HOST2 SSDC	GRID	no	no
	S231206ca		LVK O4, Sig=1, area=2335 deg^2; data gap (No valid data) at T0, MCAL: no data (nearest trigger at...	Verrecchia	2023-12-06 23:31:34.02	BBH (>99%)	3.168E-10	Notices Circulars	HOST2 SSDC		no	no
	S231129ac		LVK O4, Sig=1, area= 3089 deg^2; MCAL: triggered data found a 4.5 sigma signal at T_mcal =...	cattaneo	2023-11-29 08:17:45.06	BBH (99%), Terrestrial (1%)	1.765E-8	Notices Circulars	HOST2 SSDC	MCAL	yes	no
	S231127cg		LVK O4, Sig=1, area=3413 deg^2; MCAL: triggered data found a 4.1 sigma signal at T0+6 , ULs; RM:...	Casentini	2023-11-27 16:53:00.87	BBH (>99%)	5.815E-9	Notices Circulars	HOST2 SSDC	GRID	no	yes
	S231123cg		LVK O4, Sig=1, area=2714 deg^2; MCAL: nearest trigger at - T0-800s, ULs; RM: no signif.peak.	Ciabattoni	2023-11-23 13:54:30	BBH (>99%)	3.168E-10	Notices Circulars	HOST2 SSDC	MCAL	no	no
	S231119u		LVK O4, Sig=1, area=5211 deg^2. AGILE in SAA	Pittori	2023-11-19 07:52:48.51	BBH (95%), Terrestrial (5%)	7.431E-8	Notices Circulars	HOST2 SSDC	MCAL	no	no
	S231118an		LVK O4, Sig=1, area=287 deg^2. AGILE in SAA	Piano	2023-11-18 09:06:02.31	BBH (74%), Terrestrial (24%), NSBH (1%)	7.476E-8	Notices Circulars	HOST2 SSDC	MCAL	no	no

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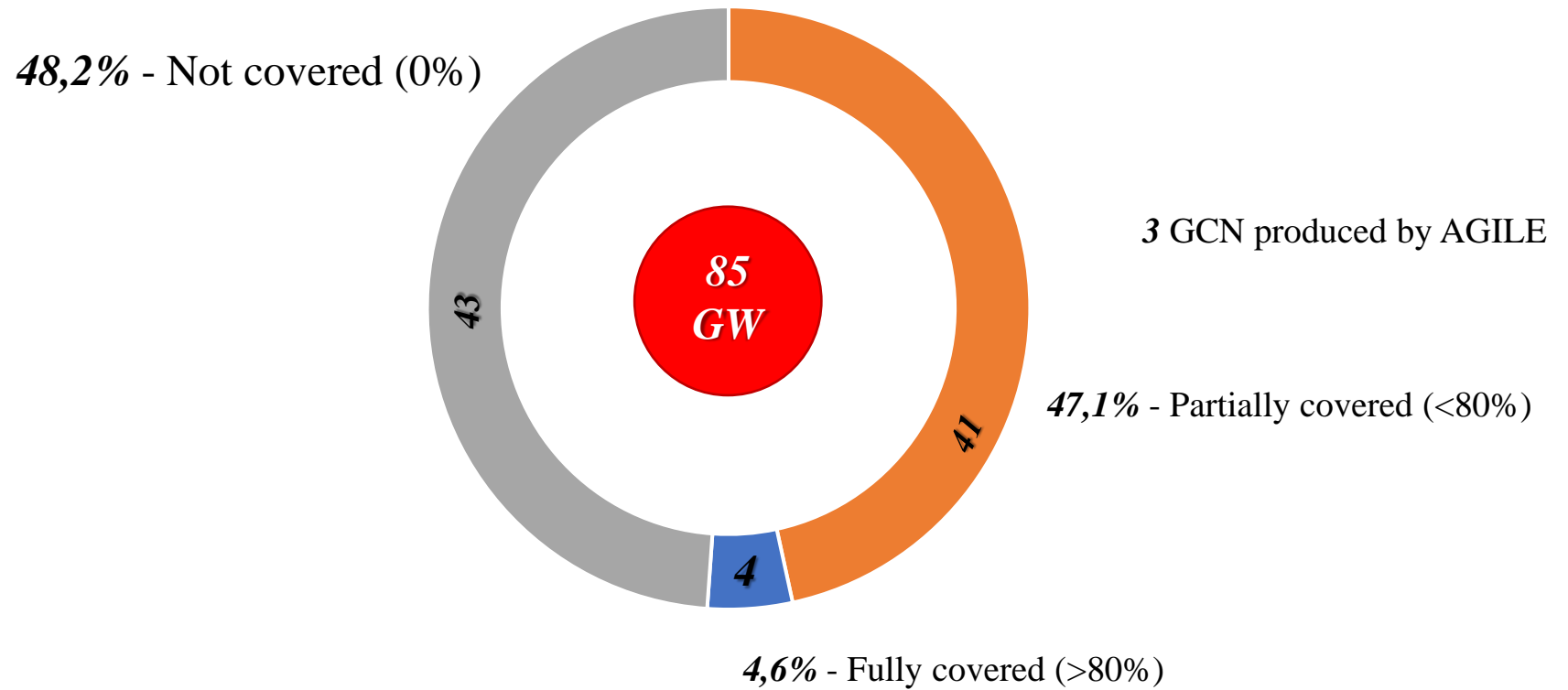
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LIGO-Virgo O4a run

What AGILE observed



NB: event sky coverage at T0

AGILE activity for LVK O4 run

AGILE GW/GRB pipelines (RTA):

-1) LIGO/Virgo Notices & Circulars:

=>AGILE-GW pipeline on LVC triggers: main updates on detection results revision

-2) Fermi, Swift, IceCube, FRB, Notices & Circulars:

=>AGILE-GW pipeline on GRB triggers

-3) AGILE/MCAL detection pipeline:

=>AGILE-MCAL GRB & Solar flares detection pipeline on AC Top

->notices on GRB (already in O3)

-4) AGILE/RM detection pipeline:

=>AGILE-RM short transients (GRB et al.) & Solar flares detection RMs pipeline ->applied in the First AGILE Catalog of solar flare (Ursi et al. 2023)

AGILE activity for LVK O4 run

AGILE

-1) LIGO

=>AG

-2) Fermi

=>AG

-3) AGILE

=>AG

->not

-4) AGILE

=>AG

Cat

AGILE RT Alert		Control Room	LIGO	Notices	Pipes	Science Alerts	Monitoring	GW Team	Help	2023-10-17T21:26:55 (UTC)
0/0/0.02										
FAR: 1.9e-5										
Has NS: 0.07091870744693507										
Has Remnant: 0.0										
Mass Gap: 0.24124385962027478										
Alert Checked <input type="checkbox"/>										
LIGO	2023-07-02T06:40:24.000	615364824	2023-07-02T19:13:05	23070217	2	ID: S230702aq	Sig: 0	Prompt Analysis		
BNS/NSBH/BBH: 0/0/0.02										
FAR: 1.9e-5										
Has NS: 0.07091870744693507										
Has Remnant: 0.0										
Mass Gap: 0.24124385962027478										
Alert Checked <input type="checkbox"/>										
LIGO	2023-07-02T06:40:24.000	615364824	2023-07-02T06:47:29	23070217	1	ID: S230702q	Sig: 0	Prompt Analysis		
BNS/NSBH/BBH: -1/-1/-1										
FAR: 1.5e-5										
Has NS: --										
Has Remnant: --										
Mass Gap: --										
Alert Checked <input type="checkbox"/>										
LIGO	2023-07-02T06:40:24.000	615364824	2023-07-02T06:42:55	23070217	0	ID: S230702q	Sig: 0	Prompt Analysis		
BNS/NSBH/BBH: -1/-1/-1										
FAR: 1.5e-5										
Has NS: --										
Has Remnant: --										
Mass Gap: --										
Alert Checked <input type="checkbox"/>										

rst AGILE

UPDATED WEB PAGE: MORE INFO AVAILABLE, Data Monitoring, COVERAGE, Solar Flares

AGILE activity for LVK O4 run

AGI

-1) LI

=>AG

-2) Fe

=>AG

-3) AC

=>AG

->not

-4) AC

=>AG

Cat

AGILE RT Alert Control Room **LIGO** Notices Pipes Science Alerts Monitoring GW Team Help 2023-10-17T21:26:55 (UTC)

0/0/0.02

FAR: 1.9e-5

Has NS: 0.07091870744693507

Has Remnant: 0.0

Mass Gap: 0.24124385962027478

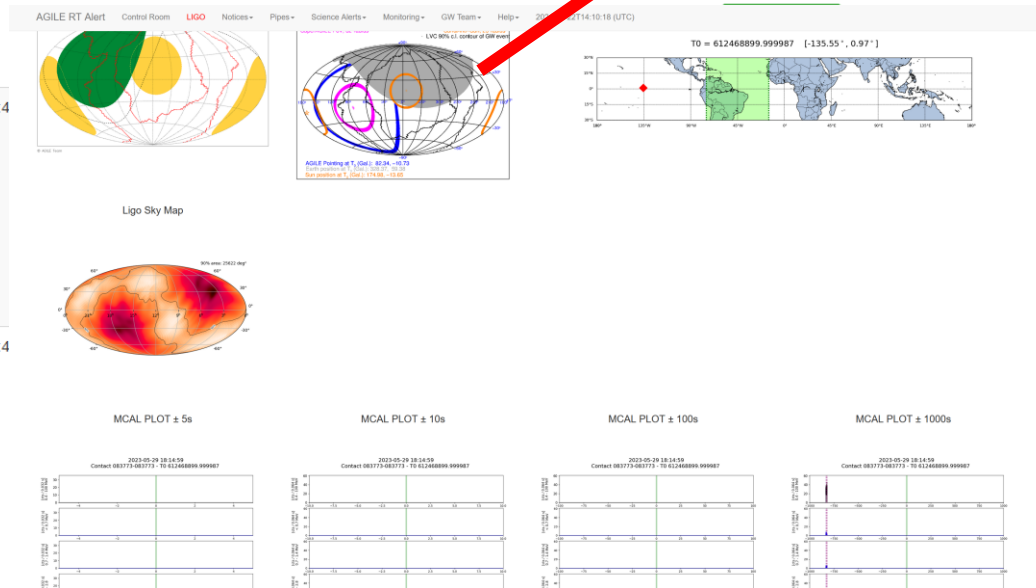
Full Analysis

Open Run

Open Results

Alert Checked

LIGO	2023-07-02T06:40:24.000	615364824	2023-07-02T19:13:05	23070217	2	ID: S230702aq	Sig: 0
BNS/NSBH/BBH: 0/0/0.02							Prompt Analysis
FAR: 1.9e-5							Full Analysis
							Open Run



UPDATED WEB PAGE: MORE INFO AVAILABLE, Data Monitoring, COVERAGE, Solar Flares

AGILE and GWs in O4:

- ER15: First event is one of the most interesting! May 18th, NSBH (86%),

All of these things happened in ER15 + O4

GraceDB Public Alerts Latest Search Alerts Pipelines Documentation Logout

Subscribed as Keith Kuwale

O4 Detection Candidates: 1 (1 Retraction)

URL: <https://gracedb.ligo.org/superevents/public/>

Sort: EVENT ID (A-Z)

Event ID	Possible Source (Probability)	UTC	GCN	Location	FAR	Comments
S230525c	BBH (72%), Terrestrial (28%)	May 24, 2023 02:38:17 UTC	GCN Circular Query Notices VDE		23.711 per year	Low Significance (= no human response)
S230524x	BNS (75%), Terrestrial (25%)	May 24, 2023 02:34:11 UTC	GCN Circular Query Notices VDE		2.2759 per year	Early Warning (Retracted)

ER15 Detection Candidates: 6 (0 Retractions)

Sort: EVENT ID (A-Z)

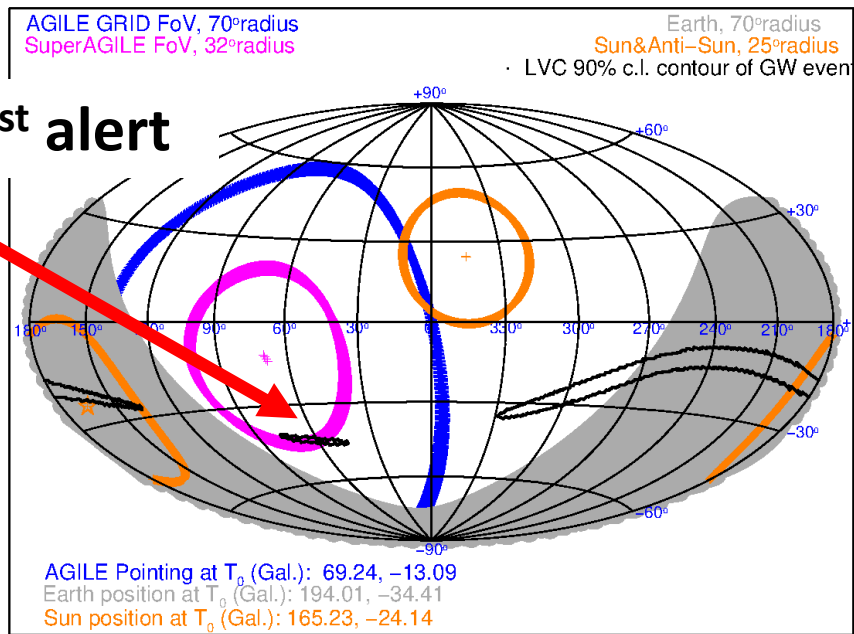
Event ID	Possible Source (Probability)	UTC	GCN	Location	FAR	Comments
S230524b	BBH (73%), Terrestrial (27%)	May 24, 2023 06:13:20 UTC	GCN Circular Query Notices VDE		26.052 per year	Low Significance (= no human response)
S230522h	BBH (99%)	May 22, 2023 09:38:03 UTC	GCN Circular Query Notices VDE		1 per 4.8906 years	No human response
S230522c	BBH (>99%)	May 22, 2023 09:38:05 UTC	GCN Circular Query Notices VDE		1 per 3.0614 years	No human response
S230521k	Terrestrial (80%), BNS (25%), NSBH (14%)	May 21, 2023 05:30:41 UTC	GCN Circular Query Notices VDE		76.393 per year	Low Significance (= no human response)
S230520de	BBH (>99%)	May 20, 2023 22:48:42 UTC	GCN Circular Query Notices VDE		1 per 10.354 years	RRT E2E Test
S230518h	NSBH (86%), BBH (10%), BBH (4%)	May 18, 2023 12:50:08 UTC	GCN Circular Query Notices VDE		1 per 96.462 years	Really interesting

AGILE and GWs in O4:

- ER15: First event is one of the most interesting! May 18th, NSBH (86%),

Trigger time T_0 : 2023-05-18 12:59:08.00000 ($\Delta t=4.00s$)

ER15 + O4



<https://gracedb.ligo.org/superevents/public/>

Location	FAR	Comments
	23.711 per year	
	2.2759 per year	RETRACTED
Location	FAR	Comments
	26.052 per year	
	1 per 4.8906 years	
	1 per 3.0614 years	
	76.393 per year	
	1 per 10.354 years	
	1 per 96.462 years	

0521k	Terrestrial (80%), ENS (25%), NSBH (14%)	Low Significance	May 21, 2023 05:30:41 UTC	GCN Circular Query Notices VDE		76.393 per year
S230520de	BBH (>99%)	RRT E2E Test	May 20, 2023 22:48:42 UTC	GCN Circular Query Notices VDE		1 per 10.354 years
S230518h	NSBH (86%), (10%), BBH (4%)	Really interesting	May 18, 2023 12:59:08 UTC	GCN Circular Query Notices VDE		1 per 96.462 years

AGILE and GWs in O4:

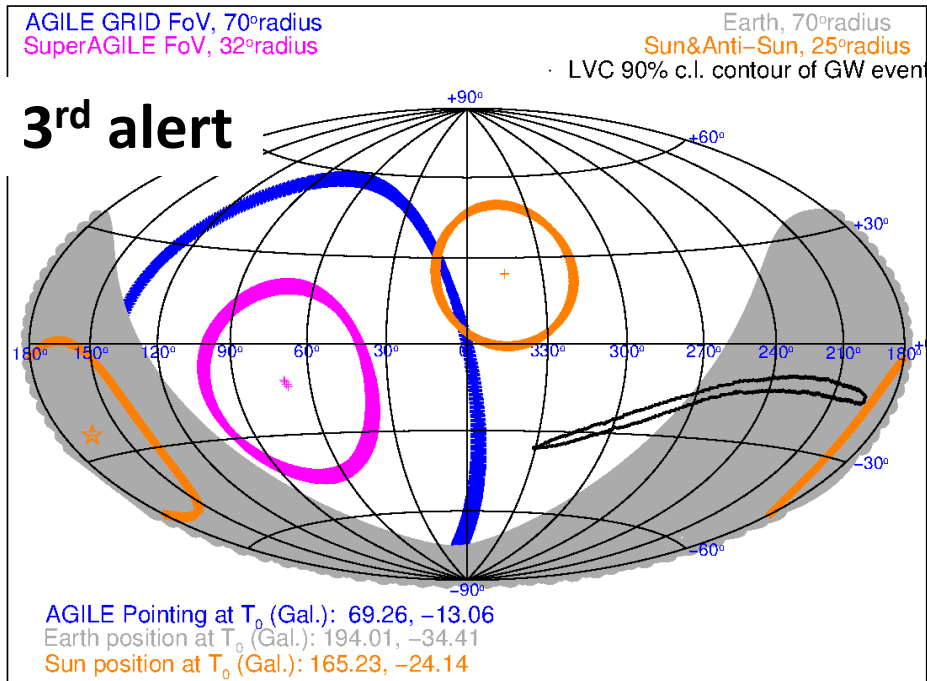
- ER15: First event is one of the most interesting! May 18th, NSBH (86%),

Trigger time T_0 : 2023-05-18 12:59:07.99998 ($\Delta t=4.00s$)

O4

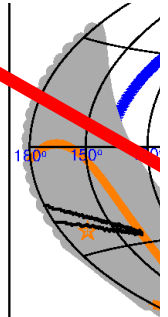
ligo.org/superevents/public/

FAR	Comments
23.711 per year	
2.2759 per year	RETRACTED
FAR	Comments
26052 per year	
1 per 4.8906 years	
1 per 3.0614 years	
76.393 per year	
1 per 10.354 years	
1 per 96.462 years	



AGILE GRID I
SuperAGILE F

1st alert



AGILE Point
Earth position
Sun position

S230520ce	NSBH (99%)	RRT E2E Test	May 20, 2023 22:48:42 UTC	GCN Circular Query Notices VDE		1 per 10.354 years
S230518h	NSBH (86%), (30%), DBH (4%)	Really interesting	May 18, 2023 12:59:08 UTC	GCN Circular Query Notices VDE		1 per 96.462 years

AGILE and GWs in O4:

- ER15: First event is one of the most interesting! May 18th



Trigger time T_0 : 2023-05-18 12:59:07.99998 ($\Delta t=4.00s$)

2023-05-18 12:59:07
Contact 083610-083610 - TO 611499547.999987

AGILE GRID I
SuperAGILE F

AGILE GRID FoV, 70°radius
SuperAGILE FoV, 32°radius

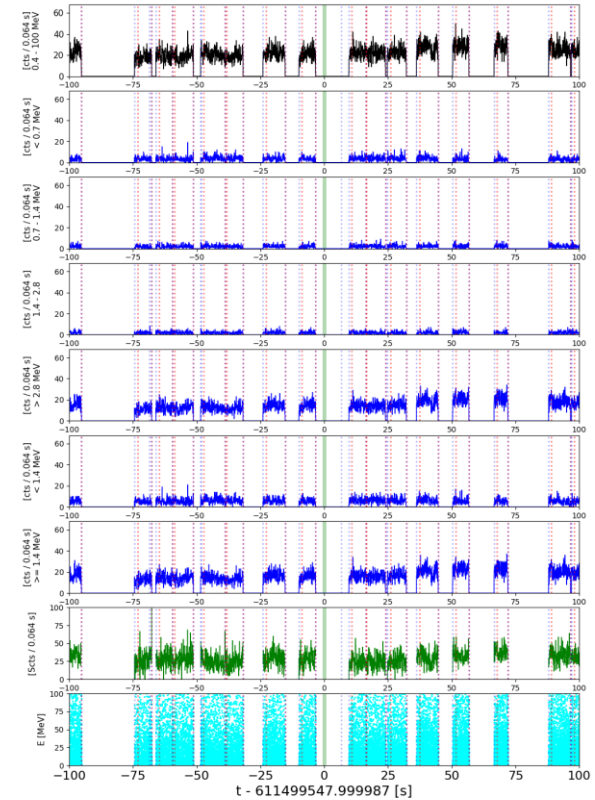
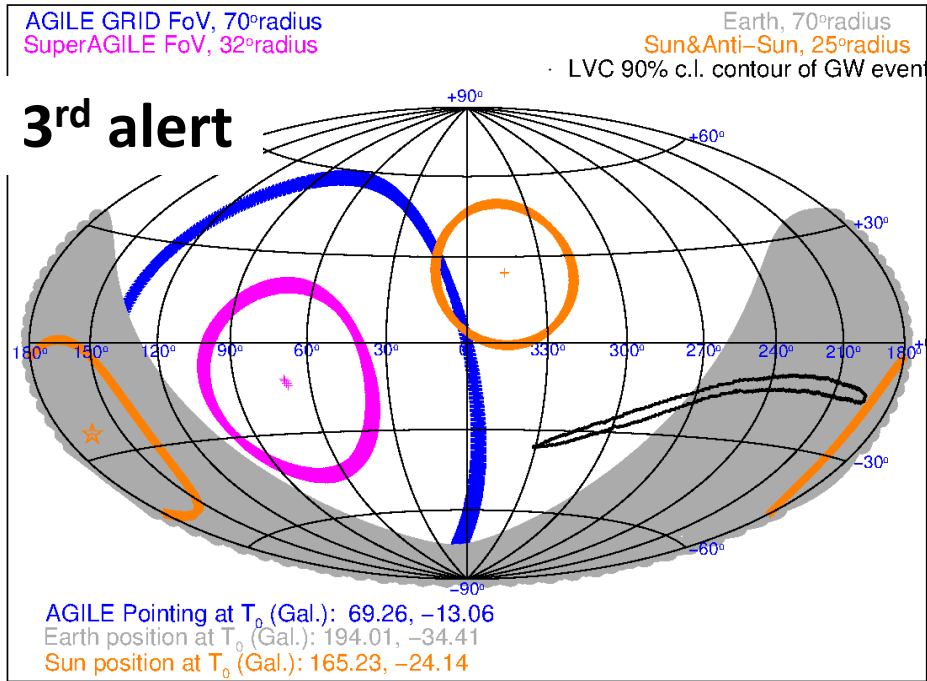
Earth, 70°radius

Sun&Anti-Sun, 25°radius

LVC 90% c.l. contour of GW event

1st alert

3rd alert



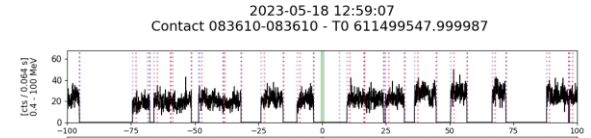
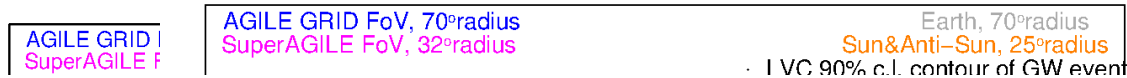
5230520ce	BSH (99%)	RRT E2E Test	May 20, 2023 22:48:42 UTC	GCN Circular Query Noticias VOE
5230518h	NSD-H (86%), (30%), DBH (4%)	Really interesting	May 18, 2023 12:56:08 UTC	GCN Circular Query Noticias VOE

AGILE and GWs in O4:

- ER15: First event is one of the most interesting! May 18th



Trigger time T_0 : 2023-05-18 12:59:07.99998 ($\Delta t=4.00$ s)



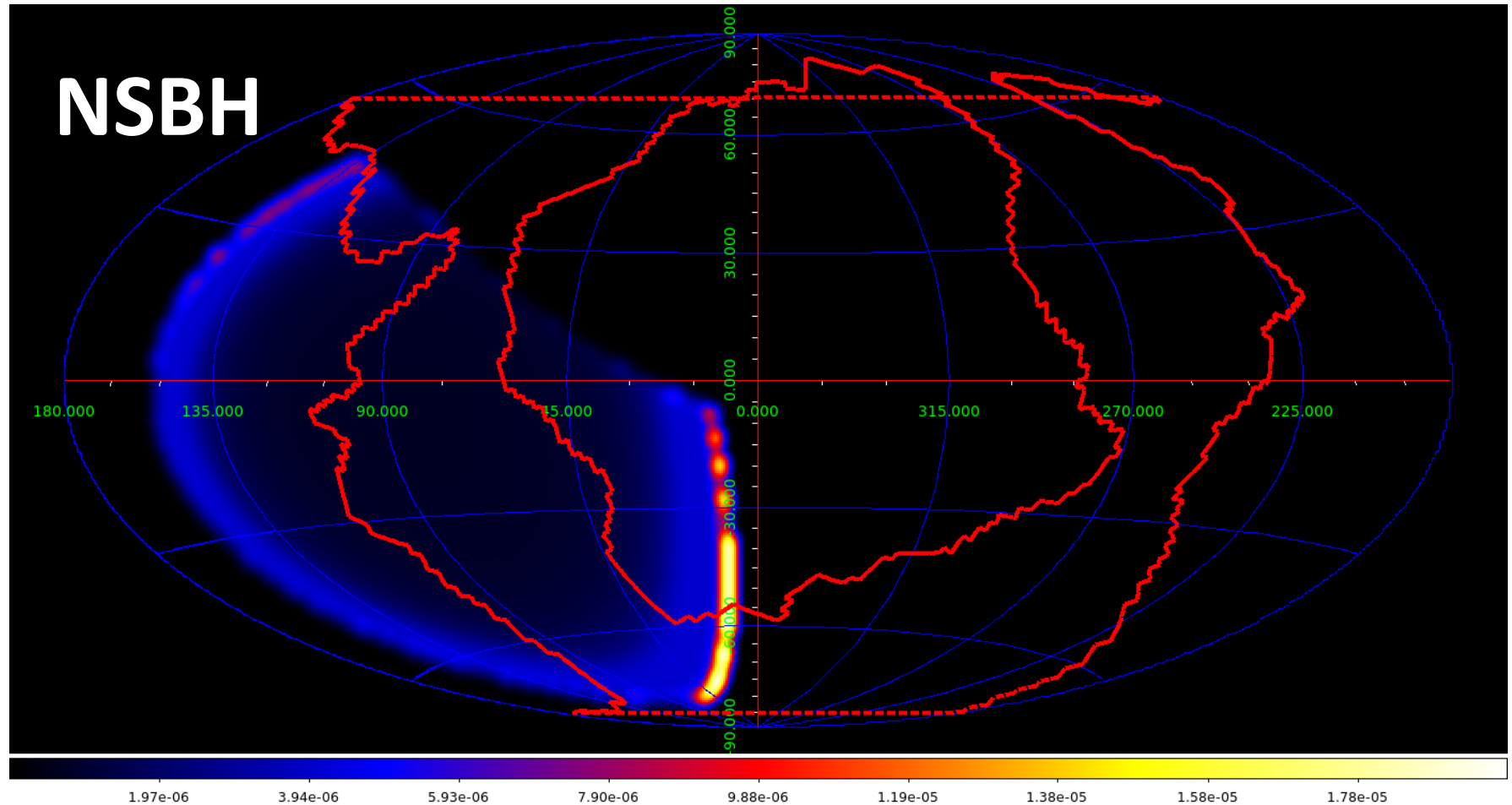
Candidate detections: need very careful False Alarm Rate (FAR)
and False Alarm Probability calculation (FAP)



example: S230529ay/GW230529

$T_0 = 18:15:16.75$ UT, 29 May, 2023

Integration (-2 / +2 sec)

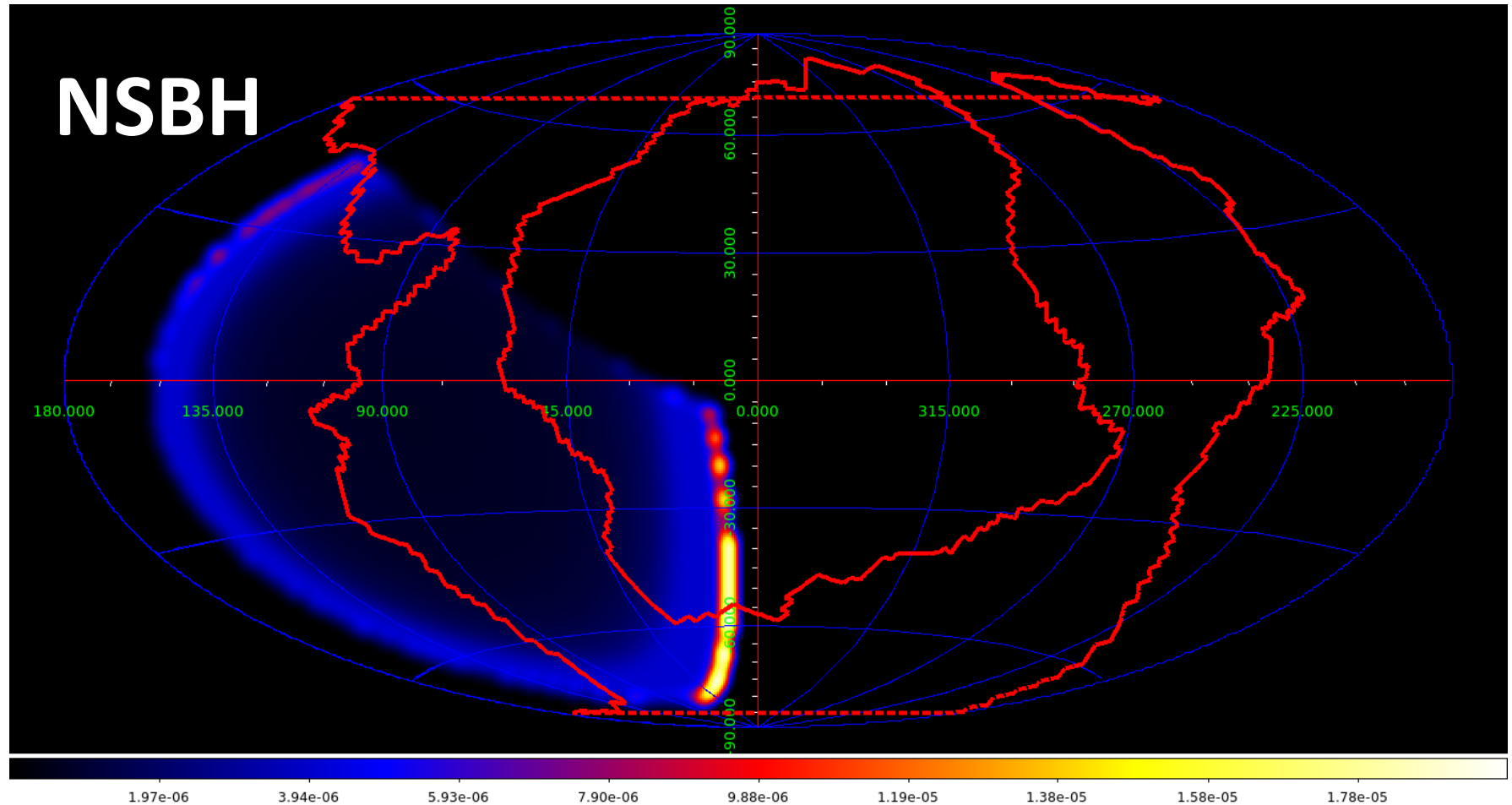


3-sigma upper limit ($E > 50$ MeV) $\sim 7.7 \times 10^{-6}$ erg cm $^{-2}$ s $^{-1}$

example: S230529ay/GW230529

$T_0 = 18:15:16.75$ UT, 29 May, 2023

Integration (0/ +100 sec)

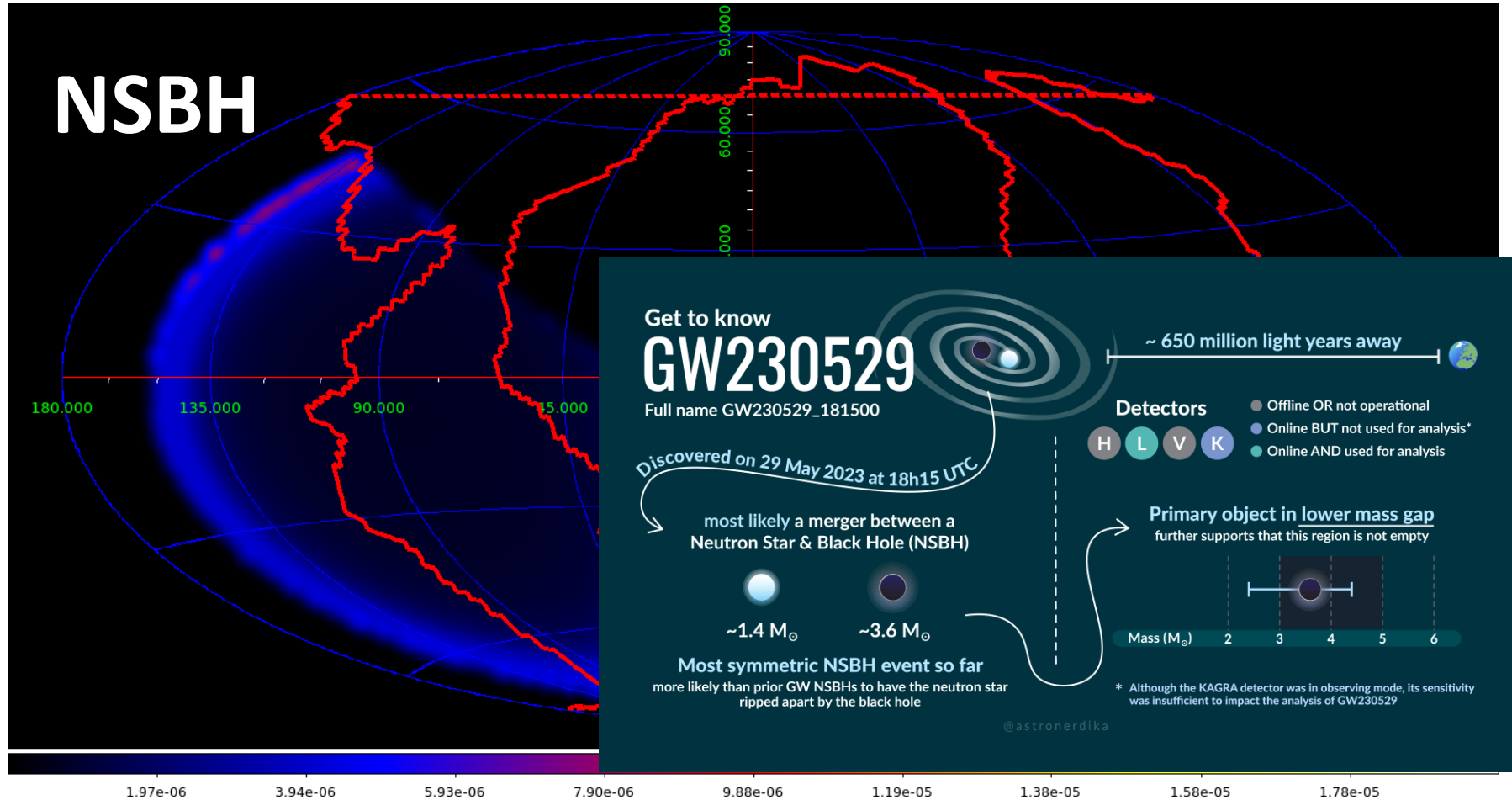


3-sigma upper limit ($E > 50$ MeV) $\sim 3.3 \times 10^{-8}$ erg cm $^{-2}$ s $^{-1}$

example: S230529ay/GW230529

$T_0 = 18:15:16.75$ UT, 29 May, 2023

Integration (0/ +100 sec)



3-sigma upper limit ($E > 50$ MeV) $\sim 3.3 \times 10^{-8}$ erg cm^{-2} s^{-1}

AGILE contribution to GW e.m. counterpart search

- **AGILE ended its journey... on Feb. 13rd, 2024**
- AGILE participation in GW EM counterpart search started in 2016: fully integrated in a network of multi-frequency observers from ground and space; with MoU and in public alerts context
- Enhanced detection capabilities of short (and long) transients, especially for GW events (and neutrinos), also GRB and FRB (**see Casentini's talk**)!
- RTA pipeline system
- Participation to O2, O3 and O4a: real time reaction; no detection but constraining U.L.s and some candidate published and other to be revised
- Archival works: first on 2022 on O1, O2 events; more under study on O3 and O4 events, on new GWTC-2.1 (O3a) and 3.0 (O3b) catalog events or further updates, dedicated to mergers including NS
- check also the AGILE APP ("AGILEScience") !

AGILE sky scanning

Bin central time: -1000s
Time bin: 410608468.6 -- 410608568.6

Trigger date: 2017-01-04

