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Detection of gamma-ray bursts with the AGILE MCAL

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Abstract. The new AGILE MiniCalorimeter (MCAL)-Gravitational Waves (MCAL-GW) on-board trigger configuration enhanced the detector trigger capabilities for the detection of short duration high-energy transients, such as short duration Sub-Theshold Events (STEs), as well as short Gamma-Ray Bursts (GRBs). This change improved the satellite trigger logic, in order to make AGILE more competitive in the electromagnetic follow-up of gravitational waves detected by the LIGO/Virgo experiments and the possible detection of associated high-energy transients. The detection capabilities of MCAL have been substantially improved in the new MCAL-GW configuration, leading to the detection of 52 GRBs and more than $2 \cdot 10^4$ STEs in less than two years activity.

Key words. gamma-ray burst, sub-threshold events, high-energy

1. Introduction

1.1. Gamma-ray bursts

Gamma-Ray Bursts (GRBs) are gamma-ray emissions of extra-galactic origin (Klebesadel et al. 1973), representing the most energetic phenomenon observed in the universe, with released isotropic energies of more than 10^{51} erg. GRBs are classified in short GRBs and long GRBs, depending on their T_{90} time duration: long GRBs ($T_{90} > 2$ s), which are emitted by the collapse of Type Ic core-collapse supernovae (Galama et al. 1998), and short GRBs ($T_{90} < 2$ s), recently confirmed as the result of the merger of Binary Neutron Stars (BNS) (Abbott et al. 2017) and exhibiting rather harder spectra. High-energy astrophysics missions usually also detect Sub-Threshold Events (STEs), i.e., short duration transients usually not capable of triggering the on-board detection logic: such events should be carefully evaluated, as they can represent electromagnetic signatures of transients of astrophysical interests.

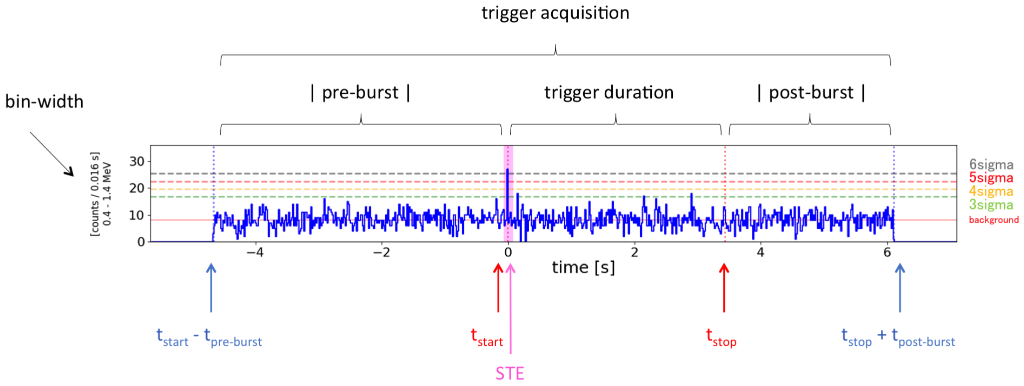

Fig. 1. A MCAL trigger acquisition of a sub-threshold transient (magenta line), identified offline by the search algorithm. The event has a 6.4σ significance over the background level (red line).

1.2. The MCAL-GW configuration

The AGILE satellite is an Italian satellite devoted to high-energy astrophysics, launched in 2007 and currently at its twelfth year operation in orbit (Tavani et al. 2008). The AGILE payload is composed of a Gamma-Ray Imaging Detector (GRID), sensitive in the 30 MeV – 30 GeV energy range, a coded mask detector (SuperAGILE), sensitive in the 20–60 keV energy range, a non-imaging Mini-CALorimeter detector (MCAL), sensitive in the 400 keV – 100 MeV energy range, and a surrounding plastic Anti-Coincidence system (AC), sensitive in the 50–200 keV energy range.

In August 2016, the AGILE MCAL was put in the so-called "MCAL-GW" configuration, constituted by a lowering of the on-board trigger thresholds. This configuration not only enhanced the MCAL trigger capabilities to detect short duration events, but also increased the detector exposure time, from about $1-5\%$ of the total orbit time to about 10% of the total orbit time, corresponding to > 540 s/orbit.

Fig.1 shows an example of a MCAL data acquisition is shown, triggered by a 6.4σ significance sub-threshold event at $t = 0$. The related background rate and the corresponding 3σ, 4σ, 5σ, and 6σ threshold levels are shown as well. The total data acquisition duration depends on the triggered logic timescale and consists of a central part, from $t = 0$ s to the stop condition at $t \sim 3.4$ s (red dashed vertical lines), and of two extra pre- and post-burst parts, aimed at the investigation of the previous and successive stages of the detection (blue dashed vertical lines).

2. Detection of gamma-ray bursts and sub-threshold events

MCAL triggers are routinely analyzed by an offline search algorithm to identify transients within the data stream. The algorithm performs a blind search for short duration events in the trigger light curves (at 32 ms and 64 ms timescales), looking for sharp variations or structured time profiles with respect to the background count rate. For what concerns the search for STEs, the algorithm searches for single bins with high independent significance ($\geq 6\sigma$) over the background rate: such search is performed on four different timescales (16 ms, 32 ms, 64 ms, and 128 ms), for each of which four time shifts are adopted. Fig.2 shows an example of short GRB 180204A detected by MCAL at UT 2018-02-04 02:26:17.06: the corresponding detection by the Fermi Gamma-ray Burst Monitor (GBM) at 2018-02-04 02:26:16.52 (i.e., 14 ms apart) is also shown.

At the moment, the search algorithm routinely runs whenever new MCAL data are available and delivered to ground. Everytime a GRB or a STE are identified, the corresponding analyzed data are promptly distributed to

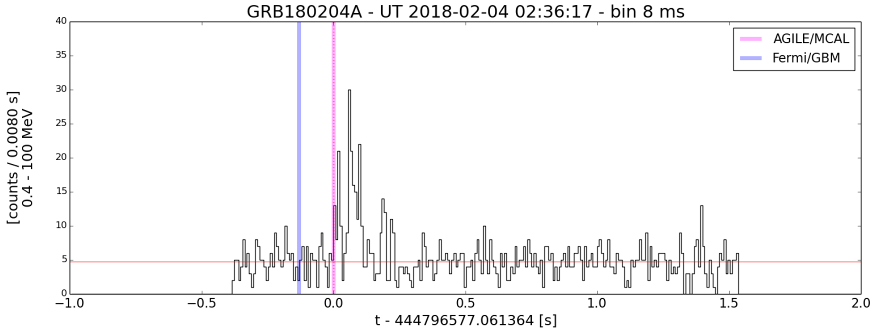

Fig. 2. GRB180204A triggered by MCAL on-board and identified on-ground by the offline search algorithm. The burst, revealed by MCAL at UT 2018-02-04 02:26:17.06 (magenta line), was also detected by the Fermi/GBM about 14 ms before (green line).

the members of the AGILE Team, in order to carry out the successive manual analyses.

In the 22 months running the MCAL-GW configuration, the MCAL detector acquired more than $3 \cdot 10^5$ triggers, collecting an exposure time of > 1 day. The search algorithm identified 52 GRB candidates and $> 26,000$ STEs. The cross-check with the burst database of the InterPlanetary Nework (Hurley et al. 2004) (IPN web page: *http://www.ssl.berkeley.edu/ipn3/*) found 40 events occurring within ± 10 s from our GRB candidates, confirming the astrophysical nature of these events. On the other hand, the remaining 12 unconfirmed bursts cannot be solidly confirmed as true short GRBs on the basis of stand-alone MCAL data. In the new MCAL-GW configuration, the AGILE calorimeter detected 10 short GRBs in 22 months, compatible with the 9 short GRBs detected in 2 years in the standard configuration (Galli et al. 2013). The improvement of the MCAL-GW configuration is represented by the enhanced trigger capabilities for the detection of short transients, and not by the number of overall detected bursts. In Fig.3, two short GRBs are shown, detected by MCAL running two different on-board trigger configurations: short GRB 171011B was detected in the new MCAL-GW configuration and was triggered on an anticipating peak episode (confirmed in the public light curves acquired by other space missions), whereas short GRB 090510A was detected in the previous configuration and was not triggered on the brief anticipating precursor (confirmed by Abdo et al. 2009), but on the main prompt phase on-set. This outlines the renewed trigger capabilities of MCAL for the detection of short duration gamma-ray transients.

3. Conclusions

The new AGILE "MCAL-GW" configuration, running since August 2016, made the detector more sensitive to short duration events, making AGILE more competitive in the follow-up of gravitational wave events detected by the LIGO/Virgo experiments and in the possible detection of correlated electromagnetic counterparts. MCAL data are routinely scanned and analyzed offline by a search algorithm that promptly searches for short GRB signatures and sub-threshold events as well. In the 22 months running the MCAL-GW configuration, MCAL detected 52 candidate GRBs: out of them, 40 have been confirmed as true GRBs by performing a cross-check with the IPN bursts. The enhanced trigger capabilities of MCAL to short duration events is confirmed by a number of short GRBs, detected in the MCAL-GW configuration, that were triggered on a brief anticipating peak episode and not on the on-set of the main prompt phase (as usually occurred in the previous less sensitive configuration, e.g. GRB 090510A).

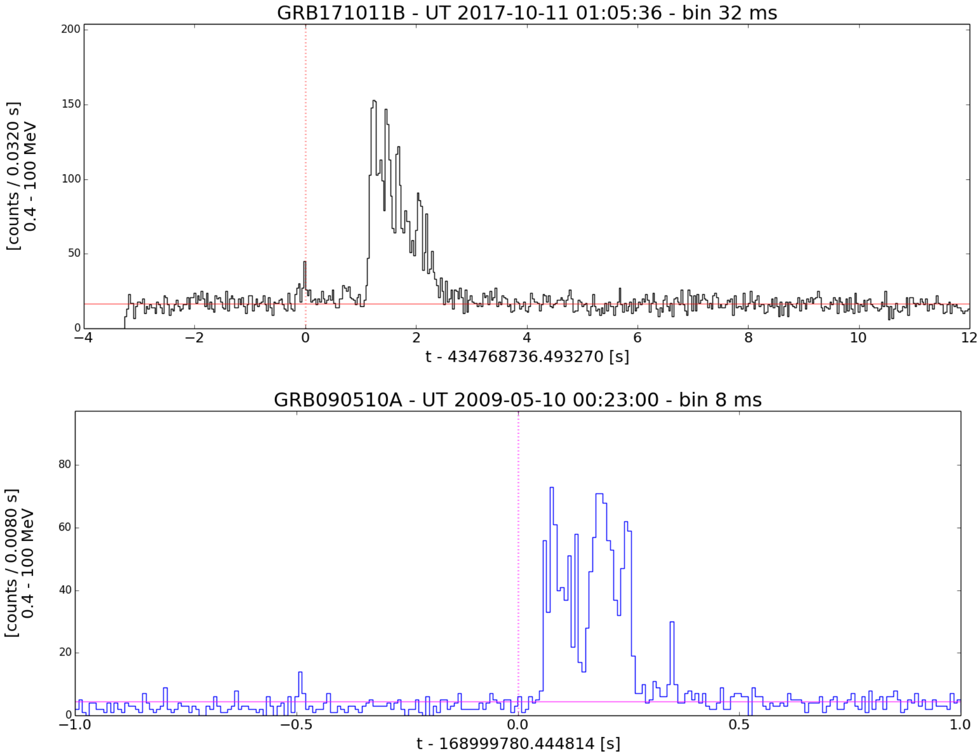

Fig. 3. (a) MCAL detection of short GRB 171011B, triggered on a low-significance anticipating peak in the new MCAL-GW configuration. (b) MCAL detection of short GRB 090510A, triggered on the prompt phase and not on the short precursor event in the previous standard MCAL configuration.

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References

Abbott, B. P., et al. 2017, Phys. Rev. Lett., 119, 161101

Abdo, A. A., et al. 2009, Nature, 462, 331

Galama, T. J., et al. 1998, Nature, 395, 670

Galli, M., et al. 2013, A&A, 553, A33

Hurley, K., and T. Cline 2004, in Gamma-Ray Bursts: 30 Years of Discovery, eds. E. E. Fenimore and M. Galassi (AIP Publ., Melville, NY), AIP Conf. Proc., 727, 613

Klebesadel, R. W., et al. 1973, ApJ, 182, L85

Tavani, M., et al. 2008, A&A, 502, 995