Extra-galactic transient sources observed in the first year of the AGILE satellite in spinning mode

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Abstract

Since Nov. 2009, the AGILE satellite is observing a large portion of the sky in spinning mode. Thanks to the sophisticated "Quick Look" (QL) pipeline and AGILE Science Alert systems, a maximum likelihood analysis of possible gamma-ray transients (E>100 MeV) detected by the AGILE-GRID instrument onboard of the AGILE satellite is provided almost in real-time. In this contribution, we will present the refined analysis of some of the most significant high-galactic latitude (|b|>10) gamma-ray transients appeared in the QL alerts during the AGILE first year of observations in spinning mode.

The AGILE data-flow

The AGILE satellite raw data are received about every 100 minutes from the antenna of the ASI Malindi ground station (Kenya), then transmitted to the Mission Operations Center (MOC) in Italy. Within a few minutes, the scientific raw data are sent to the AGILE Data Center (ADC) hosted at the ASI Science Data Centre (ASDC) located in Frascati (Italy).

The AGILE-GRID telemetry packets received at ADC are pre-processed and transformed into the standard FITS format (Level-1 data) through the AGILE Pre-Processing System (TMPPS; [6]). Event filtering for the background subtraction and track reconstruction analysis with an AGILE specific Kalman Filter ([7]) is applied to the LV1 data in order to get a clean gamma-ray photons list. After a few hours from the telemetry reception, L2 data are ready to be analyzed with the official AGILE scientific software ([8]).

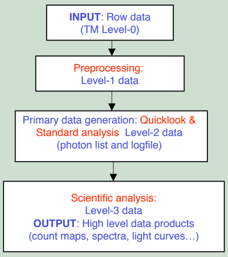

Figure 2: *The AGILE-GRID data-flow*

The AGILE spacecraft and its payload

Figure 1: *the AGILE payload. The gamma-ray imager GRID and, on top of it, the hard X-ray Super-AGILE detector.*

The AGILE (Astrorivelatore Gamma ad Immagini LEggero) ([1], [2]) satellite is an Italian Space Agency (ASI) mission dedicated to the observation of astrophysical sources of high energy gamma-rays. AGILE combines for the first time two sophisticated co-axial instruments: a Gamma-Ray Imaging Detector (GRID), sensitive to photons in the 30 MeV - 50 GeV energy range, and a hard X-ray detector (Super-AGILE) ([3]), sensitive to photons in the 18 - 60 keV energy range. AGILE-GRID is made by a 12 planes Silicon Tracker ([4], [5]), a Mini Calorimeter (MCAL) positioned at the bottom of the instrument (0.3-100 MeV) and an anti-coincidence shield.

AGILE was launched on April 23rd, 2007 and was inserted in an equatorial orbit with very low particle background contamination. Until October 2009, the AGILE spacecraft was operated in "fixed-pointing" mode, completing 101 pointings. Starting from Nov. 2009, the attitude control system had to be re-configured and the scientific operations changed into the "**spinning observation mode**". Nowadays, the instrument pointing direction scans the sky with an angular velocity of about 1deg/s, accessing about 70% of it each day.

The AGILE-GRID Quick Look monitoring systems

Thanks to the "very fast" Ground Segment, AGILE is well suited for the detection of galactic and extra-galactic gamma-ray transients. Various automatic detection algorithms of transient gamma-ray emissions have been developed by the AGILE Team and by the ASDC AGILE Team. The monitoring systems perform a first "Quick Look" (QL) analysis of the event files produced at the ADC within a few hours from the reception of telemetry packets. Automatic alerts are sent typically within just 2-2.5 hours from the astrophysical event, which is a record for a gamma-ray mission.

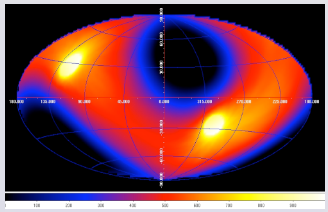

Figure 3: *Exposure map from 48 hours of data of AGILE-GRID in spinning mode (scale is in [cm^2 s sr]). The two regions around the Sun and anti-Sun directions (black areas in the map) are not accessible to the observations.*

The ADC Team has developed two QL monitoring systems: the "QL Variability" (QLV) system and the "Global Ximage" detection system. Both QL systems perform everyday a blind search for gamma-ray excesses on GRID data accumulated over the last 48 hours. The blind search for gamma-ray excesses is made using the 'detect' task available with the HEASOFT Ximage package ([9]). In the QLV pipeline, XIMAGE detect is applied on binned counts maps produced with the official AGILE software tasks ([8]), weighted by the exposure, while in the Global pipeline is ran over an event map produced directly from the event file. Finally, the estimate of source significance, gamma-ray flux and location for the excess positions found by XIMAGE is made applying a Maximum Likelihood (ML) analysis against the expected galactic and extra-galactic gamma-ray diffuse background ([10]). Two more QL systems search for transient gamma-ray emission in the GRID data: the AGILE Science Alert System ([11]) and the False Discovery Rate (FDR) detection method ([12]).

The GRID mean exposure on a 2-days integration in spinning mode is of the order of 500 cm^2 s sr, with a maximum exposure of the order of 1000 cm^2 s sr (see Fig.3). The expected AGILE-GRID sensitivity in spinning, on this time interval, is of the order of 2.0x10^-6 ph/cm^2/s (E>100MeV) for a detection at the level of 5σ.

Extra-galactic transients detected by the QL AGILE-GRID systems

The QL monitoring systems automatically send a report with the most significant GRID detections found during the last 48 hours. A refined analysis of the QL alerts is performed on the most significant automatic detection.

The refined analysis has a multi-fold purpose: check for the statistical robustness of the transient, search for the best integration period when the transient reach its maximum flux, optimize the input source list to the ML multi-source analysis and so on.

During the first year of observations in spinning mode, we have collected more than 40 high-latitude (|b|>10°) transients with a value of the ML test statistic TS>=20.25 after refined analysis. In what follows, we will present the updated analysis of some of these transients. For this analysis, the GRID data have been processed with the last available version of the reduction and scientific software.

AGL J0403-3608

This transient appeared in the QL alerts around middle of March, 2010. The automatic QL analysis founded a TS=17.6 and a flux F(E>100MeV) of 1.8x10^-6 ph/cm^2/s. The highest flux was found by a refined analysis on a 75 hours integration starting from 12:00 UT on March 13th, 2010 (MJD=55268.5) ([12]). The refined analysis performed in this work confirms the excess with a TS=24 on the same time interval. The estimated flux is F(E>100 MeV)=(1.8 +/- 0.6)x10^-6 ph/cm^2/s.

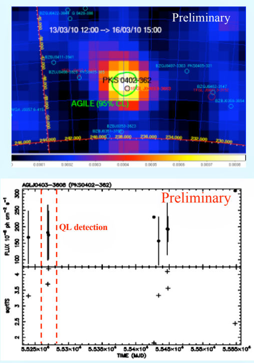

Figure 4: *Above: Intensity map ([ph/cm^2/s/sr]) in Galactic coordinates of the AGL J0403-3608 detection. Below: light curve showing all the automatic QL detections within 1° from the AGL J0403-3608 centroid.*

Fig.4 (above) shows the intensity map of this observation. The flat-spectrum radio quasar PKS0402-362[1] (BZQ J0403-3605 on the Blazar Catalogue ([13])) is well within the AGILE 95% C.L. error circle (rad=0.66°). This source has been already detected as gamma-ray source by the Fermi-LAT spacecraft (1FGL J0403.9-3603) with a mean flux of (81.4+/-8.4)x10^-9 for 100MeV<E<300MeV over 1 year ([14]). As seen in Fig. 4, below, some more automatic QL detections have appeared during the spinning observation mode within 1° from the AGL J0403-3608 centroid.

[1] This source was proposed for the observation in the 3rd AGILE Announcement of Opportunity (AO) by C. Pittori, co-author of this poster.

AGL J2142-7624

This transient appeared in the QL alerts (automatic ML analysis: TS=20.2, F(E>100MeV)=1.8x10^-6 ph/cm^2/s) around middle of April, 2010. The highest flux was found on a 57.5 hours integration starting from 11:30 UT on April 10th, 2010 (MJD=55296) ([15]). The refined ML multi-source analysis performed here found a TS=26 and a flux F(E>100 MeV)=(2.1+/-0.7)x10^-6 ph/cm^2/s. Fig. 5, left, shows the intensity map of this observation. The most plausible counterpart of the AGILE detection (95% CL error radius=0.52°) is the flat-spectrum radio quasar PKS 2142-75 (BZQ J2147-7536). The 1FGL gamma-ray source 1FGL J2152.4-7532 [14] (unassociated and with an UL of 3.02e-8 ph/cm^2/s in the 100-300 MeV energy band) lays just on the border of the AGILE contour.

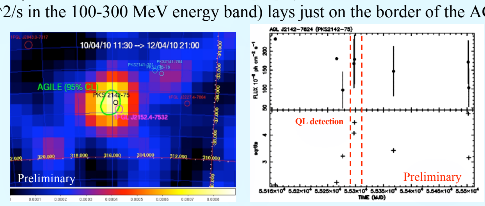

Figure 5: *Left: Intensity map ([ph/cm^2/s/sr]) of the AGL J2142-7624 detection. Below: light curve showing all the automatic QL detections within 1° from the AGL J2142-7624 centroid.*

AGL J1415+0730

Appeared in the QL alerts in July 2010 (automatic ML analysis TS=22, F(E>100MeV)=1.8x10^-6ph/cm^2/s). No ATel was addressed on this detection. The refined ML multi-source analysis finds a TS=25 and F(E>100 MeV)=(2.5+/-0.8)x10^-6 ph/cm^2/s on a 48 hours starting on MJD=55398. Fig. 6 shows the intensity map of this observation. No clear counterpart is found here. The FSRQ BZQJ1415+083 (2E1412.7+0846) is less than 1° from the AGILE centroid position. One further detection and two ULs are found in the database of the QL detections during the spinning period.

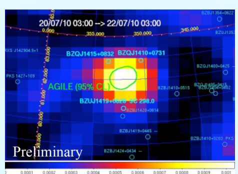

Figure 6: *Intensity map ([ph/cm^2/s/sr]) in Galactic coordinates of the AGL J1415+0730 detection. AGILE centroid: l,b=(352.1, 62.1) +/- 0.7 deg (95% C.L.)*

Conclusions

After the reconfiguration in spinning mode, AGILE has becoming an all-sky gamma-ray monitor. The fast Ground Segment along with the QL monitoring systems allow to efficiently monitor all the high-energy gamma-ray sky. In this work, we have presented three extra-galactic transients observed during the first year of observation in spinning mode. The complete list of the observed transients will be the subject of a dedicated paper in the next months.

References

[1] Tavani, M., et al. 2008, for the AGILE Collaboration, NIM A, 588, 52
[2] Tavani, M., et al. 2009a, for the AGILE Collaboration, A&A, 502, 1015
[3] Feroci, M., Costa, E., Soffitta, P., et al. 2007, NIM A, 581, 728
[4] Barbiellini, G., Bordignon, G., Fedel, G., et al. 2001, AIP Conf. Proc
[5] Prest, M., Barbiellini, G., Bordignon, G., et al. 2003, NIM A, 501, 280
[6] Trifoglio, M., Bulgarelli, A., Gianotti, F., et al. 2008, Proc. SPIE, 7011, 70113E
[7] Giuliani, A., et al., 2006, NIM A, 568, 692
[8] Chen A. et al. 2009, GRID Scientific Analysis User Manual, AGILE-IFC-OP-009
[9] Giommi, P., et al., A.S.P. Conference Series, Vol. 25, 1992
[10] Mattox, J. R., Bertsch, D. L., Chiang, J., et al. 1996, ApJ, 461, 396
[11] Trifoglio, M., et al., Procs. of the 7th AGILE Workshop
[12] Sabatini, S., A&A, submitted
[12] Striani, E., et al., Atel #2484
[13] Massaro, E., et al., 2009, A&A, 495, 681
[14] Abdo, A., et al., 2010 ApJS..188..405A
[15] Verrecchia, F., et al., Atel #2551