

# The AGILE real-time analysis pipelines in the multi-messenger era.

**Authors:** N. Parmiggiani (presenter), A. Bulgarelli, A. Ursi, V. Fioretti, L. Baroncelli, A. Addis, A. Di Piano, C. Pittori, F. Verrecchia, F. Lucarelli, M. Tavani and D. Beneventano

AGILE (Astrorivelatore Gamma ad Immagini LEggero - Light Imager for Gamma-Ray Astrophysics) is a scientific mission of the Italian Space Agency (ASI) launched on 23rd Apr 2007. The AGILE payload consists of the Silicon Tracker (ST), the SuperAGILE X-ray detector, the CsI(Tl) Mini-Calorimeter (MCAL), and an AntiCoincidence System (ACS). The combination of ST, MCAL, and ACS form the Gamma-Ray Imaging Detector (GRID).

The raw telemetry data produced by the AGILE instruments are downlinked in the ASI ground station (Malindi, Kenya), and this may happen at each orbit (about every 90 minutes) or according to the ground station availability schedule. The contact packet contains the data of one or more satellite orbits. The data are immediately transferred to Italy via a dedicated ASINet network to Telespazio, Fucino (Italy), and then to the ASI Space Science Data Center (SSDC). The automatic pipeline system developed at SSCD performs the preprocessing (by the AGILE Preprocessing System), reducing, archiving, and distributing the data. The reconstructed data are then sent to the National Institute for Astrophysics (INAF/OAS) in Bologna (Italy) for further analysis, performed by the automated software described in this contribution.

This contribution describes the real-time analysis (RTA) software developed for the AGILE space mission in the context of multi-wavelength (MW) and multi-messenger (MM) astronomy. A science alert is a communication from/to the astrophysical community that a transient phenomenon occurs in the sky. In MW and MM astronomy, observatories share science alerts to study the same physical phenomena with different "messenger" signals (electromagnetic radiation, gravitational waves, and neutrinos) through communication networks such as the Gamma-Ray Coordinates Network (GCN) and The Astronomer's Telegram (ATel). Usually, the observatories develop pipelines to identify possible transient phenomena (e.g. GRBs), send science alerts to the astrophysical community, and speed up the reaction time to science alerts sent by other facilities.

The AGILE Team developed three RTA pipelines, one of which is a Science Alert Pipeline. It reacts to internal or external science alerts such as Gamma-ray Bursts (GRB) and Gravitational Waves (GW). The other two pipelines are Archive Pipelines that perform a blind search of transient events (mainly GRBs) into the AGILE/MCAL instruments' data and the ratemeters of all detectors onboard AGILE. The AGILE/MCAL pipeline automatically searches for GRBs and Terrestrial Gamma-ray Flashes (TGF) at each contact received by the satellite. When a GRB is detected, the pipeline sends a Notice to the GCN Network to notify the scientific community about this transient event. Since May 2019, the AGILE-MCAL pipeline sent more than 40 Notices to the GCN. The AGILE/RM pipeline analyses each instrument's ratemeters (RM) data contact-by-contact and can detect fast transients, GRBs, and solar flares.

The results of these pipelines are saved in a MySQL database and can be visualized by the AGILE Team using a password-protected web Graphical User Interface (GUI). The Astronomer on-duty is the AGILE Team member that is in charge of the follow-up of science alerts through the GUI. There are dedicated shifts for this activity. Several papers, ATels, GCN circulars and notices have been published by the AGILE Team using the support of the RTA pipelines. The fast follow-up of transient events could not be possible without an automated analysis system. The design and the solutions adopted for the AGILE RTA pipelines can be useful to other gamma-ray projects.