

**Scientific Report on the GREAT ESF Workshop n. 4413:
“3rd Gaia Science Alerts Workshop - Classification and Follow-up of the Alerts”**

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1) Summary (1 page)

Gaia will discover large numbers of transient events. However without prompt and appropriate follow-up observations, much of the scientific potential of these new discoveries will be lost. It becomes crucial for transient astronomy that the new phenomena are rapidly observed with small and medium size telescopes and the data are analyzed quickly to share the knowledge.

The Gaia Photometric Science Alerts team, is responsible for generating alerts on transient and anomalous events detected in the data stream of the Gaia satellite - cornerstone ESA mission scheduled for launch in October 2013. The alerts will become public immediately, and to assure the complex data processing pipeline produces reliable and robust alerts, they need to be thoroughly tested and cross-matched with detections made by other surveys, both optical and in other wavelengths. Thorough and robust classification of transients requires a dedicated network of telescopes and a well-organised team. With the Gaia launch so close, there is need to organize teams, choose instruments and telescopes, construct observing proposals, and prepare the community for the influx of Gaia alerts.

One of the main issues related with the follow-up of transients is their robust and rapid classification at the survey level and then evolving classification with the additional follow-up data. Test observations are needed to develop the strategy for the ground-based verification of alerts during the early phases of the mission. A collaborative network has been established, charged with developing the strategy and preparing for the ground-based verification of alerts. Early-stage test observations were carried out over the year by four groups, including the INAF Observatories of Bologna, Padua, Catania, Naples, and Teramo, the LCOGT, the LivJM and Caltech. All these tests were based on alerts generated by the Catalina Real-Time Transient Survey (CRTS). The Workshop provided the opportunity to gather together and discuss the lessons learned and results of these first experiments. It also allowed to continue building and extending the network with new partners.

Present current techniques and methods of transient classification were presented by experts in the field and astronomers applying the techniques to their data.

2) Description of the scientific content of and discussion at the event (up to 4 pages)

The GREAT ESF Workshop “**3rd Gaia Science Alerts Workshop - Classification and Follow-up of the Alerts**” took place at INAF Osservatorio Astronomico di Bologna, Italy, over two days, starting on September 6, and ending on September 7, 2012.

With a number of early-stage test observations based on alerts generated by the Catalina Real-Time Transient Survey (CRTS), carried out from July to November 2011, this turned out to be a most proper time to gather together and discuss the lessons learned and results of these firsts experiments. Thirty-eight people attended the event. The participants’ list (available on the Workshop web page, see <http://www.ast.cam.ac.uk/iaa/wikis/gsaawiki/index.php/Workshop2012:registration>)

included speakers involved in a number of different networks, such as: W. Thuillot for the Gaia-FUN-SSO: a network for Solar System transient objects; A. Drake and A. Mahabal for the Catalina Real-Time Transient Survey (CRTS); V. Lipunov from the Global MASTER Net; J. Richards from the Palomar Transient Factory (PTF), just to mention a few of them.

A number of young scientists, students and post-docs also attended the Workshop.

Both photometric and spectroscopic Gaia science alerts were addressed.

The Workshop was open to all of the GREAT network, and was broad enough to be of general interest to a large number of potential participants, whilst remaining focused on the delivery of the best possible, science ready, alert stream from Gaia.

Three main issues were tackled during the Workshop:

1. Optimizing ground-based transient follow-up.

It can be shown that for any given transient, there exists a wide-range of follow-up observations that could be made, with differing degrees of effectiveness for improving classification. The general question was addressed of what should we do next, and it was investigated the dependence of the answer to this question on (i) the nature of the event, (ii) the availability and quality of measured data (photometry, astrometry, spectroscopy), (iii) the telescope and instrumentation available to the observer.

2. Machine learning approaches to the classification of transient data.

Classification of transients is a unique problem for computational astrophysics. During the workshop we discussed state-of-the-art techniques for transient classification, including: Gaussian Mixtures, Self-Organizing Maps, Random Forest, Neural Networks, naive Bayes and so on. A workshop session was focused on the application of these techniques to the CRTS data stream, and comparison to the Gaia data stream.

3. Expanding the follow-up community.

There are a large number of telescopes and observers around the globe, both suitable and interested in taking part in the follow-up of the Gaia alerts. The list includes professional astronomers, as well as skilled, hard-working, well-equipped and well-organized amateur astronomers who would love to work closely with the Gaia mission. The third goal of the meeting was to identify new potential partners for the alerts verification and discuss common practises for the verification process.

The Workshop included 30 talks, varying from 5 to 30 minutes in length, on the following main topics:

- Status of Gaia
- Follow-up strategies
- Machine learning approaches to the classification of transients
- Current/planned multi-wavelength transient surveys
- Reports from tests on transient follow-up
- Presentation of new partners
- Building training sets
- Supernovae, Microlensing, Novae, GRBs, TDEs, CVs
- Verification phase

Each day was concluded by a general discussion of about 1 hour. The Workshop was video recorded and all talks are available as pdf files on the meeting web page (see <http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/index.php/Workshop2010:agenda>).

The Workshop social dinner took place on September 6, 2012.

Reports on the Workshop were provided by G. Clementini during the GBOG Meeting held in Heidelberg on October 18-19, 2012 and during the Gaia CU7 Review Meeting held in Geneva on November 7-9, 2012.

3) Assessment of the results and impact of the event on the future direction of the field (up to 2 pages)

Gaia will discover large numbers of transient events. The new phenomena must be rapidly observed with small and medium size telescopes and the data must be analyzed quickly to share the knowledge. Without prompt and appropriate follow-up observations, much of the scientific potential of these new discoveries would be lost. On the other hand, participating members in the verification programme will benefit from their early involvement with the science aspirations of the Gaia Science Alerts project, their understanding of the contents of the alerts stream, and their preparedness for the rapid follow-up of transient events with well-matched resources in areas of their particular interest and expertise.

The Workshop main results can be summarized as follows:

1. the Workshop provided the opportunity to discuss the lessons learned from the first tests performed in 2011. New tests were planned to take place at the end of 2012/beginning of 2013;
3. current techniques and methods of transient classification were presented by experts in the field and astronomers applying the techniques to their data, thus allowing discussions and comparisons;
3. the Workshop provided also the opportunity for continue building and extending the network with new partners working in the field, thus fostering exchanges and collaborations
4. as an outcome of this an agreed version of the Memorandum of Understanding will be prepared, to be signed between the Gaia Science Alerts team and partners. This will cover all issues related with the data dissemination, processing and usage policy
5. an additional deliverable will be an evolving web site describing recommended follow-up procedures, providing detailed instructions on how to get involved, how to observe, how to share data, and instructing the astronomers how and who to credit.

4) Final programme of the meeting

The Workshop final program is attached below and is also available in pdf format along with the Abstract booklet for download from the Workshop web side (see <http://www.ast.cam.ac.uk/iaa/wikis/gsawgwiki/index.php/Workshop2012:agenda> and <http://www.ast.cam.ac.uk/iaa/wikis/gsawgwiki/images/9/91/AbstractBook2012-draft.pdf>).

| | title | name | time |
|-----------------|---|---|----------------|
| Thursday | | | with questions |
| 09:30 | Welcome | LW+STH+GC+MT | 5m |
| 09:35 | Gaia status | Timo Prusti | 25m |
| 10:00 | Gaia science alerts status and introduction to the verification phase | Simon Hodgkin | 25m |
| 10:25 | Gaia scanning law | Berry Hall | 15m |
| 10:40 | Gaia Spectro Science Alerts: first implementation plans | George Seabroke | 20m |
| 11:00 | Coffee | | 30m |
| 11:30 | Spectroscopic science alerts : possible triggers in the RVS domain | Paola Di Matteo | 20m |
| 11:50 | Gaia-FUN-SSO: a network for Solar System transient objects | William Thuillot | 20m |
| 12:10 | Open Transient Science and Future Prospects with CRTS. | Andrew Drake | 20m |
| 12:30 | Lunch | | 2h |
| 14:30 | Global MASTER-Net | Vladimir Lipunov | 20m |
| 14:50 | 4 Pi Sky of radio coverage: Transient discovery and response with next generation radio telescopes. | Tim Staley | 20m |
| 15:10 | Multi-messenger and multi-wavelength follow-up of LOFAR discovered transients | Peter Jonker | 20m |
| 15:30 | Locating Transients with the e-EVN | Zsolt Paragi | 20m |
| 15:50 | Coffee | | 30m |
| 16:20 | The TOROS project | Mario C. Diaz | 20m |
| 16:40 | Gravitational Wave research and their connection with EM observations | Gianluca M. Guidi | 30m |
| 17:10 | <i>Discussions on multi-messenger synergies</i> | | |
| 18:00 | <i>end of day 1</i> | | |
| 19:00 | Dinner | | |
| FRIDAY | | | |
| 09:30 | Transient discovery and classification for PTF and variable star classification. | Joseph Richards | 25m |
| 09:55 | Using field information to separate SNe and non-SNe | Ashish Mahabal | 30m |
| 10:25 | Classification of alerts within the Gaia pipeline | Lukasz Wyrzykowski | 15m |
| 10:40 | Analysis of outlying observations from Gaia CU8 classification pipeline | Minia Manteiga Outeiro | 20m |
| 11:00 | Coffee | | 30m |
| 11:30 | Responding to the Event Deluge with VOEventNet | Roy Williams | 25m |
| 11:55 | Cambridge Photometric Follow-up Calibration Server, report from tests and verification phase arrangements | Lukasz Wyrzykowski/ Giuseppe Altavilla | 30m |
| 12:25 | The 1.8m telescope at Cima Ekar and SN classification programme at Asiago | Massimo Turatto | 20m |
| 12:45 | Lunch | | 1h 30m |
| 14:15 | RTS2: advances in last two years | Petr Kubanek | 20m |
| 14:35 | Observational facilities at INAF OA-Catania | Giuseppe Leto | 15m |
| 14:50 | The Observing Facilities of the Vienna Observatory | Werner Zellinger | 15m |
| 15:05 | The PIRATE facility | Ulrich Kolb | 15m |
| 15:20 | Synergy of GAIA mission with the Devasthal Optical Telescopes for follow-up observations | Yogesh Chandra Joshi | 15m |
| 15:35 | Coffee | | 30m |
| 16:05 | <i>Discussions on verification details</i> | | 1h |
| 17:00 | <i>end of day 2</i> | | |