Gaia Science Alerts Workshop 2011
White Book

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This document was created following the Gaia Science Alerts Workshop 2011, held in the Institute of Astronomy at the University of Cambridge on 29.June - 1.July 2011. The topic of the workshop was *Follow-up and Alerts Verification*.

Contents

[1] name pronunciation in English: *Woocash Vizikovsky*

1 Rationale of the workshop

The Gaia Science Alerts stream will be the first Gaia data released to the community, so it is extremely important to produce reliable and robust alerts. To ensure that the released alerts are accurately classified, low in contaminants and contain interesting transient events, the complex data processing pipeline has to be thoroughly tested. The first alerts will need to be verified with an extensive programme of dedicated follow-up observations. These comprise:

- imaging to confirm the presence and brightness of an alerting source,
- continuous photometric monitoring to obtain a detailed light-curve to help fine-tune the classification
- high/intermediate/low resolution spectroscopy to investigate the real nature of an event.

The verification programme is scheduled to take place in the first three months of operation of the Gaia Science Alert system. To classify as many alerts as possible requires a dedicated network of telescopes and a well-organised team. Now, with the Gaia launch so close (mid-2013), we are approaching a crucial point in time. We need to organise our teams, choose instruments and telescopes, construct observing proposals, and prepare the community for the influx of Gaia alerts. The goals of the workshop were:

- Familiarisation of potential observers and research groups with Gaia and its alerting system, and the specific requirements of verification.
- Preparation of a plan of the detailed scope of the alerts verification phase, including how long it should last
- Selection of likely telescopes and instruments
- Identification of key people who will assist with verification
- Confirmation of the scientific requirements for the follow-up of Gaia alerts, e.g. in the area of supernovae or cataclysmic variables
- Discussion of technical issues related with alert dissemination and follow-up feedback

2 Fact-sheet about Gaia Alerts

Please refer to the White Book of Workhop 2010 available from GSAWG wiki pages[2] for more details on Gaia and Gaia Alerts. Here we briefly outline the main characteristics of the alert processing, relevant for the follow-up and verification discussions.

- The Gaia mission is primarily an astrometric mission (successor of Hipparcos)
- Gaia Alerts will rely on photometric, astrometric and spectroscopic Gaia data available almost in real-time (subject to daily ground-station contacts, and IDT preprocessing).
- latency of the alerts: from a couple of hours up to 24h or even 48h, depending on the density of the sky observed, and the overheads in IDT preprocessing.

[2] http://www.ast.cam.ac.uk/ioa/research/gsawg/

- detection and classification methods: simple detection, sophisticated classification (combining photometry, astrometry and spectroscopy)
- each alert from Gaia will contain: position, current and all historic Gaia magnitudes, as well as low dispersion spectroscopy (roughly calibrated)
- the most suitable targets for Gaia: long transients and anomalies, longer than a few days.
- expected rates and types of Gaia alerts: hundreds to thousands alerts per day. Over 5 years of the mission we expect: e.g. 6000 SNe (2000 before the maximum), 1000 microlensing events.
- Gaia alerts will be disseminated mainly via *Skyalert.org* and a dedicated web-server
- verification of alerts will take place in first few months of the mission. The alerts will not be released to public at that stage.

3 Highlights from the workshop

In this section we summarise selected talks and major sessions/topics of the meeting. The notes were written after the meeting, using audio/video recordings made during the talks, and with reference to slides provided by the speakers.

3.1 What should we follow today? - *Ashish Mahabal*, Caltech

The numbers of transient detections are steadily increasing, and the follow-up facilities struggle to choose which targets to follow-up. With new surveys coming soon, the volume will be even higher. Follow-up data is crucial for proper and rapid classification of targets. Resources are limited hence prioritisation is crucial. With sparsely-sampled photometry most transients look very similar (e.g. examples from CRTS: flare star, dwarf nova, blazar).

Building a network is difficult as there are numerous differences between telescopes (e.g. apertures, locations, seeing, etc). The involvement of a telescope can be at different level: 100% of time, fraction of time, or just ToO. Also, scientific interests of people in charge of telescopes should be taken into account.

Characterisation of an object comes first, then comes classification. Characterisation can tell you quite a lot from a small amount of information. Can build priors, e.g based on delta-magnitudes, colours, image shape and so on. Example of dm *vs* dt plots - by examining pairs of data points to construct a jump histogram - and then feed it into a sparse decision tree. This works better than template matching for LCs with small numbers of data points.

Automating the optimal follow-up: what type of follow-up data has the greatest potential to discriminate object classification? In a Bayesian way, we can determine the best match between an alert and telescopes.

Follow-up observers will need a (semi-)automated pipeline for 2D processing, and to attach an astrometric and photometric calibration to their data, before it is fed back into the system.

3.2 *Skyalert.org* presentation - *Roy Williams*, Caltech

Skyalert.org is produced in Caltech and is used to visualise and store events released in VOEvent format: Who, What, WhereWhen, Why, Citation, IVORN. The system is used by e.g. AAVSO, CRTS, MOA, Swift, Fermi, LIGO, LOFAR, LSST, amateurs (also DC3.com), LAMOST.

Skyalert consists of: Streams (defined by an author to describe type of fields to be present in each event), Portfolios (events and associated data, including follow-up) and Alerts (what is interesting - users can define their own filters for alerts).

For details on how to use *Skyalert.org* please have a look at the recording of Roy's talk[3].

3.3 Scientific potential of Gaia Alerts

We have grouped together some of the main scientific topics discussed at the meeting. This is not a complete list.

Variable stars *Laurent Eyer*, 10-30% of stars expected to be variable; Cepheids (up to 9,000 expected in Gaia), Eclipsing binaries (3,000,000 expected with Gaia); main issue for Science Alerts will be these variable stars at the limit of detection popping up as "new" sources.

Supernovae *Massimo Turrato* considered the spectral and lightcurve evolution of SNe, and independently confirmed the SNe rate for Gaia (c.f. Hodgkin & Belokurov[4]) : 6300 (87% Ia), 1800 pre-maximum (95% Ia), 500 detected earlier than -5d (97% Ia); possibility of detection of a few shock break-out in CC-SNe (between subsequent FoVs). Early observations of SNe are crucial as the outermost layer of the exploding star is being observed. Data from the declining slope give information about the energy of the explosion. Reviewed major spectroscopic surveys. Ideal solution: XShooter-like instrument combined with imaging on a 4m-class telescope.

Microlensing *Svea Proft, Wyn Evans, Łukasz Wyrzykowski*, Gaia is not efficient at detecting photometric events. Astrometric microlensing events can be detected as a centroid shift of the source. Instantaneous astrometric precision after 2 years of the mission is good enough (order of few mas) to detect larger deviations. Gaia can alert on these astrometric microlensing deviations, but these need a detailed photometric coverage. Mass function could be retrieved - unique for Gaia. Black holes will give the largest deviations. Additionally, Gaia might detect astrometric signal from dark matter minihaloes substructures (dozens of micro-arcseconds). Fermi provides potential gamma sources.

GRBs *Jure Japelj, Andreja Gomboc* In 5 years Gaia might detect less than 10 on-axis afterglows. Gaia more suitable for detecting "orphan" afterglows (20-80, model depending) - these were never detected before.

3.4 Current and future transient surveys and follow-up facilities

The coordination of the Gaia Alerts verification will be organised with input from **GBOG** (Ground Based Observation for Gaia) - a working group within Gaia consortium, responsible mainly for gathering auxiliary data needed for photometric and spectroscopic calibrations of Gaia data. For the alerts validation, GBOG will provide help with coordinating the proposals, observations and data flow.

The central bulk of the workshop contained presentations of currently on-going transient surveys and individual observing facilities which could potentially be involved in the follow-up of Gaia alerts.

[3] http://www.ast.cam.ac.uk/~wyrzykow/GAIA/GSAW2011/Movies/Williams-Skyalert.mov
[4] http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/images/6/66/Supernovae_alerts.pdf

Geneva *Laurent Eyer*, 1.2m Euler Telescope (La Silla) and twin Mercator Telescope (La Palma)

SONG Danish world-wide network of 1m telescopes, build in progress, includes existing Danish 1.5m at La Silla. The primary driver is microlensing events follow-up with lucky-imaging cameras. Interested in following Gaia microlensing alerts (both photometric and astrometric)

Ondrejov Observatory *Rene Hudec*, 30cm and 50cm robotised telescopes, can obtain low disp. spectra, uses RTS2 control system (by Peter Kubanek)

Java Robotic Telescope *Jan Soldan*, home-built observing system, ready to accept alerts. 30 cm, robotised. BVRI standard filters; Wide field telephoto with resolution 10.3 arcsec (4x3 sq.deg fov).

Pi of the Sky survey *Marcin Sokołowski*, two robotised detectors (Chile and Spain) aiming at GRBs and other short optical transients over whole sky. Limiting magnitude down to 12 mag on 10s exposures using Canon f=85mm (20x20 sq. fov in Chile; 40x40 sq. fov in Spain). Potential cross-identification and follow-up of Gaia alerts (6-11 mag).

GLORIA network *Lech Mankiewicz*, Global Robotic Telescopes Intelligent Array for e-Science, coordinated by Universidad Politecnica de Madrid, with involvement from Warsaw University. 17 small diameter telescopes targeted to be robotised, and given to the general public. It will use RTS2 (Kubanek's). This can be used for Gaia alerts.

La Palma 0.5 Robotic Telescope *Stuart Littlefair*, build by Sheffield University, situated on La Palma. Projects include search for optical counterparts for LOFAR transients, LIGO/LISA GW triggers, follow-up of CRTS cataclysmic variables and Gaia alerts. UBVRI filters, can reach 19 mag in 10 sec exposure in V band (3σ). Will be fully robotised in Autumn 2011.

WASP *Peter Wheatley*, limiting magnitude $\sim$16 in 30s, aperture 0.11m, fov=62 sq.deg. Numerous M-flares discovered, novae, dwarf novae, supernovae.

LCOGT Network *Yiannis Tsapras*, LCOGT is the US privately funded institution building telescopes and instrumentation for time domain astronomy. Important educational component. Main research in microlensing and extragalactic transients. Few hours per night dedicated to schools. Fully robotised observatories. Plans for late 2013: 2x2m (Faulkes North and South), 15x1m, 24x0.4m all over the globe. Implementing Lucky Imaging.

Liverpool Telescope *Iain Steele*, 2m fully robotic telescope on La Palma, operating since 2004, funding available until 2014.

STILT *Neil Mawson*, 3 cameras attached to the Liverpool Telescope, all sky (6 mag), 20 deg (12 mag), 1 deg (18 mag) fov, white light; 2000 frames per night; detecting short-lived transients; possibility of cross-matching with Gaia alerts.

Iranian National Observatory *Habib Khosroshahi*, 3.4m telescope by 2015, interested in the follow-up of transients.

Catalina Realtime Transient Survey *Ashish Mahabal*, all sky survey, 3 telescopes (0.5, 0.7, 1.5m), limiting magnitude similar to Gaia (19, 19.5, 21.5 mag, resp.), coverage 30,000 sq. deg. Planning a release of all photometry data collected over many years - can be used as a reference for Gaia. 4 images separated by 10 min each are taken. Statistics: about 1 strong transient per million sources, other significant transients/variables about $10/10^6$. Detections of hyperluminous SNe in dwarf galaxies; slow type IIn SNe (400d to reach the peak), CVs and DNe (75% new), new FU Ori object, unsettled stars (suddenly disappearing, from 15-16 mag to 20-21mag); fast transients (dM flares); eclipsing WDs by planets? (periodic few magnitude deep eclipses); flaring blazars; mysterious events (e.g. SN from AGN disk?)

European and French spectroscopic facilities *Michel Dennefeld*, OPTICON gathers 2-4m European telescopes in order to facilitate access to them. Number of low-dispersion spectrographs is very low, not many telescopes with availability. Calar-Alto has 2.2m telescope with CAFOS - versatile LD spectrograph; NOT 2.5m at La Palma has ALFOSC, Haute-Provence Obs has 1.93m telescope with Carelec LD spectrograph (needs upgrade) and Sophie (HD); Asiago (Italy) has 1.22 and 1.82 with spectrometers in LD; Pic du Midi has 2m tel. with Narval: HR (50,000) down to 15 mag (spectropolarimetry). Emphasised the need for an official statement from Gaia Alerts community that these telescopes and instruments are necessary.

Italian facilities *Gisella Clementini*, These are willing to take part in GSA network: Asiago 1.82m (managed by Padova), Loiano 1.52m (Bologna), Teramo 0.72 (Teramo, remote), Sierra la Nave 0.8 (Catania, robotic), Toppo di Castegrande 1.54m (Naples), REM and TNG might join in future (located outside Italy). Italian community is offering self-organised, coordinated response to Gaia Alerts already at the verification stage.

Other facilities *Łukasz Wyrzykowski*, Other observatories which expressed interest in the Gaia Alerts follow-up: Wise Observatory (israel), Ostrowik (Poland), Austrian telescopes, Slovenian.

South African Astronomical Observatory *Patricia Whitelock*, 75% nights usable, SALT (11m) is the main facility, several partners from Europe which might be potentially interested in Gaia Alerts follow-up. Science: photometric monitoring of faint SNe, novae, AGNs, rapid variables (CVs, X-ray binaries). Good for ToO. Other instruments: 1.9m, 1.0m, 0.75m, 0.5m.

3.5 Other

Low dispersion spectra archives *Rene Hudec*, Digitised archives of spectra surveys with spectral range and magnitude limit similar to Gaia's BP/RP, e.g. Byurakan Survey (limiting magnitude 17.5) - these can be used for Gaia spectral classification preparations. Also, spectroscopic alerts on Hα line variability. Interesting bright object types: V407 Cyg energetic outbursts (7 mag in optical, weird low-disp. spectrum), GRB070610 with unusual afterglow.

Multi-wavelengths surveys and WDs *Danny Steghs* emphasised the need for coordinated work on combining multi-lambda data for classification of transients. Example: Monitor of All-sky X-ray Image (MAXI). Watchlist of interesting WDs. Eclipsing WDs - few hundred eclipses should be seen by Gaia (important for statistics of SNe progenitors).

Lucky Imaging Astrometric follow-up *Craig Mackay*, By 2014 there should be an instrument available on WHT using Adaptive Optics Lucky Imaging (AOLI), capable of astrometric precision of 1-2 mas. This could be used for astrometric alerts follow-up.

ESO Public Spectroscopic Survey of Transients *Stephen Smartt*, NTT survey (2012-2017) to follow-up Supernovae found mainly by PanSTARRS survey. Aiming at classification of 2000 SNe, with 150 of them with full spectroscopic coverage. Target range: 17-20.5 mag on EFOSC2 at 13 A resolution. Target range <17 mag on SOFI. Will produce a database for public. This survey might follow-up Gaia alerts if there are any interesting ones. Possible new SNe science with Gaia might be linked with the superb astrometry (e.g. centroid motions due to asymmetric explosions). Photometrically Gaia will have a tough competition with ground-based surveys (PanSTARRS, Skymapper, La Silla Quest).

Ground-based follow-up of Solar System objects , *William Thuillot*, Gaia will see about 300,000 asteroids, most of them will have 50-80 observations. A world-wide follow-up is needed in order to follow the asteroids candidates found by Gaia and derive their orbital parameters. A network of telescopes from 30cm to 2.5m was established with collaboration with ISON (International Scientific Optical Network) and Russian MASTER network. Expected rates of alerts on Near Earth Asteroids (NEA): 87/year, i.e. 1 alert every 4 days.

Outreach possibilities *Gerry Gilmore*, Gaia Alerts could be attractive for expert public (amateurs with resources) and educational systems (schools, universities).

3.6 Preliminary list of potential partners for GA verification

List and details on potential partner telescopes is available here:
http://tinyurl.com/telescopes-for-gaia

1. Geneva telecopes: La Silla and La Palma
2. 5 (+2?) Italian telescopes
3. Java Robotic Telescope, Ondrejov, Czech Rep.
4. pt5m (La Palma 0.5m Robotic Telescope)
5. LCOGT, whole globe
6. Liverpool Telescope, La Palma
7. SAAO

4 Towards the Gaia-FUN

We propose a creation of a Gaia Follow-Up Network (Gaia-FUN) to be composed of people and telescopes interested in extracting the science of alerts announced from the Gaia satellite.

4.1 Gaia-FUN-SSO

There already exists a Gaia-FUN-SSO network, dedicated to Solar System Objects (see William Thuillot's talk), which will take care of the follow-up of astrometric alerts released by CU4 unit (led from IAP, Paris). The astrometric alerts are related with asteroids and other Solar System bodies, which will naturally be detected by Gaia as new/moving sources. The follow-up of these alerts is needed in order to track these objects and derive their correct ephemeris.

The network is already formed[5] and it was suggested their members can also join the follow-up of photometric/spectroscopic alerts if they are interested.

4.2 GBOT

GBOT stands for Ground-based Optical Tracking and is the task of observing the Gaia satellite itself. It is necessary in order to get the position and velocity of the spacecraft and to achieve high level of precision in astrometric measurements. Because the requirements for the instrumentation and telescopes are overlapping with the regular follow-up, GBOT can also become a part of the Gaia-FUN. Its requirements are daily imaging for precise astrometry using 1-2m telescopes from both hemispheres. Gaia satellite is expected to have about 17-18 mag in R.

[5] http://www.imcce.fr/langues/en/publications/colloques/gaiafun/

4.3 Different follow-up strategies for different targets

- SNe, peculiar SNe and novae: high resolution spectroscopy, multi-band dense photometry - red-shift, light curve, type classification
- Microlensing events: photometry, spectroscopy, high-resolution astrometry (dense sky areas) - light curve, ruling out contaminants with spectroscopy (variable stars)
- CVs: spectroscopy for detailed studies at peculiar states, multi-band photometry for light curves
- Be, RCrB, YSO: spectroscopy for detailed studies at peculiar states, multi-band photometry for light curves
- GRBs: photometry, spectroscopy
- lensed SNe: deep high-resolution imaging for confirmation and lens modelling, slit spectroscopy if reachable
- asteroids: astrometry for ephemeris

4.4 How to get organized - notes from discussions

During the last hour-or-so of the meeting we had a wide ranging discussion covering the next steps. Some of the points made during the discussion are included below.

- We want to create a homogenous automatised response system for alerts
- A test of the system will be performed using Catalina Real-Time Transient Survey (CRTS) - a whole sky survey down to around 20 mag, alerts disseminated through *SkyAlert.org*
- The Catalina test will lead to a creation of superb dataset containing photometry and low dispersion spectroscopy, which will be then used as an input mock data stream to the Gaia alerts pipeline to fine-tune the system (Dennefeld).
- Follow-up at higher resolution may be helpful for developing RVS alerts (Seabroke)
- CRTS detects asteroids which could also be followed-up by Gaia-FUN-SSO
- Mankiewicz suggested creating a simulator of the alerts-telescopes system to develop and test the response system
- Eyer emphasised the need for scientific value of the Catalina test, as a "reward" for all people taking part in it.
- The CRTS follow-up data will be reduced, calibrated and put into SkyAlert with all logging information with observers names, etc. This will allow tracking who contributed to what in a given transient observations (Mahabal)
- We need a formalised network for Gaia Alerts Verification, but there is no need for formalisation for post-verification scientific exploitation.
- A formal list of requirements for verification needs to be documented and presented to ESA (soon).

- Formal letters of support from the Gaia Alerts community might be requested by the telescopes when communicating with their funding agencies at national levels (including non-European telescopes).
- It is worth astronomers/telescopes getting involved as early as possible in the verification of the alerts. While there is no advantage as regards over data access (after the verification phase all data will be public), there are very good reasons to start involvement now, e.g: (1) preparation and readiness of the observatory/people to carry out timely and well matched follow-up observations; (2) getting a better understanding of the Gaia alerts stream contents, and their foibles (indeed being involved in the fine tuning of the detection thresholds and classification strategies that will necessarily happen during verification); (3) an opportunity to prepare (observing time, working time, working teams) in advance, ready for scientific exploitation of the stream when it goes live.
- Standard stars should be observed as well as other stars in the target's field (requires at least few arcmin FoV). One of the ideas was to provide a list of standard stars to be observed along with each target (Clementini)
- In order to broaden participation to smaller facilities (including outreach and amateur telescopes), it was suggested that we could write specific experiments for a wide range of facilities. For example, what would be the best scientific use of a 50cm telescope based in Europe ?

4.5 Catalina Test Phase - summary

The plan, formed with the participation of a number of participating telescopes (Italian, LCOGT, LivJMT), will allow us to set up a response system for Gaia Alerts, based on the Catalina alert-stream, which uses *SkyAlert.org* (as we plan to do for Gaia). In order to get involved at this stage, one needs to obtain an account on *SkyAlert.org*, set up a stream related with given observatory/group and set up an alerting filter. The alerts will be then send via email and will contain information on selected targets, filtered according to, e.g. sky coordinates, magnitude, type of object. For example, a 0.5m telescope in Italy operated by people interested in blazars, may want to filter on only candidates of that type which are brighter than 16 mag and have Dec>0 to assure their visibility.

Once a filter is set up, the follow-up observations will be carried out by those participating astronomers/observatories. There are currently no strict requirements on what type of observations will be taken: e.g. photometry in one or multiple bands, low- or high-dispersion spectroscopy. We will rely on the experience of the scientists involved. The data will be processed at the site and any photometry or spectroscopy will be sent back to *SkyAlert.org* via the stream, quoting the event which was observed. In such way, all the follow-up data will show under a portfolio of a given event.

What is essential during this phase is to automatise the entire process as much as possible to allow for rapid response.

As an addendum, there is an idea being currently tested to create a centralised tool for photometric data calibration, which uses SDSS and USNO data and provides crudely but homogeneously calibrated data, which are then directly fed to *SkyAlert.org* and a light curve can be built (prepared by Sergey Koposov, IoA, Cambridge).

NB: Since the meeting a number of test observations of Catalina alerts have already been carried out by Giuseppe Altavilla at Loiano Observatory. Additionally telescope proposals have been submitted to LCOGT (PI: Tsapras) and LivJMT (PI: Steele). These will be uploaded to the wiki.

4.6 Gaia Alerts Verification Phase

This phase will probably start in early 2014 (3-6 months after launch) and will last for about 3 months. The Gaia alerts stream on *SkyAlert.org* will be visible only for Gaia-FUN members.

5 Future steps

- a formalised network has to be created for alerts verification, populated around a reasonably small number of motivated people/groups.
- define requirements which will be drafted ASAP and circulated around interested parties for comment.
- the proposals for telescope time should be submitted soon to assure time being allocated
- later prepare observing strategies/guidelines for observatories - generic for all kinds of alerts, but also specific for SNe only, microlensing only, etc.

6 Resources

1. Gaia Science Alerts Working Group wiki:
   http://www.ast.cam.ac.uk/ioa/research/gsawg
2. GSAW2010 meeting website with archived talks and White Book:
   http://www.ast.cam.ac.uk/ioa/research/gsawg/index.php/Workshop2010:agenda
3. GSAW2011 meeting website with archived talks:
   http://www.ast.cam.ac.uk/ioa/research/gsawg/index.php/Workshop2011:agenda

7 List of Participants

1. Giuseppe Altavilla, Bologna, Italy
2. Vasily Belokurov, IoA, Cambridge, UK
3. Ross Burgon, OU, UK
4. Gisella Clementini, Bologna, Italy
5. Michel Dennefeld, IAP, France
6. Paola Di Matteo, Paris, France
7. Martin Dominik, St. Andrews, UK
8. Wyn Evans, IoA, Cambridge, UK
9. Laurent Eyer, Geneva, Switzerland
10. Gerry Gilmore, IoA, Cambridge, UK
11. Andreja Gomboc, Univ. of Lubljana, Slovenia

12. Uffe Graae Jorgensen, Copenhagen, Denmark
13. Simon Hodgkin, IoA, Cambridge, UK
14. Rene Hudec, Ondrejov, Czech Republic
15. Jure Japelj, Univ. of Lubljana, Slovenia
16. Habib Khosroshahi, Tehran, Iran
17. Floor van Leeuven, IoA, Cambridge, UK
18. Stuart Littlefair, Sheffield, UK
19. Craig Mackay, IoA, Cambridge, UK
20. Ashish Mahabal, Caltech, USA
21. Lech Mankiewicz, Warsaw, Poland
22. Neil Mawson, Liverpool, UK
23. Svea Proft, Heidelberg, Germany
24. George Seabroke, MSSL, UK
25. Stephen Smartt, QUB, UK
26. Marcin Sokołowski, Warsaw, Poland
27. Jan Soldan, Ondrejov, Czech Republic
28. Danny Steeghs, Warwick, UK
29. Iain Steele, Liverpool, UK
30. Paolo Tanga, Nice, France
31. William Thuillot, Paris Observatory, France
32. Yiannis Tsapras, LCOGT London, UK
33. Massimo Turatto, Trieste, Italy
34. Nicholas Walton, IoA, Cambridge, UK
35. Peter Wheatley, Univ. of Warwick, UK
36. Patricia Whitelock, SAAO, South Africa
37. Roy Williams, Caltech, USA
38. Łukasz Wyrzykowski, IoA, Cambridge, UK