Newsletter 17

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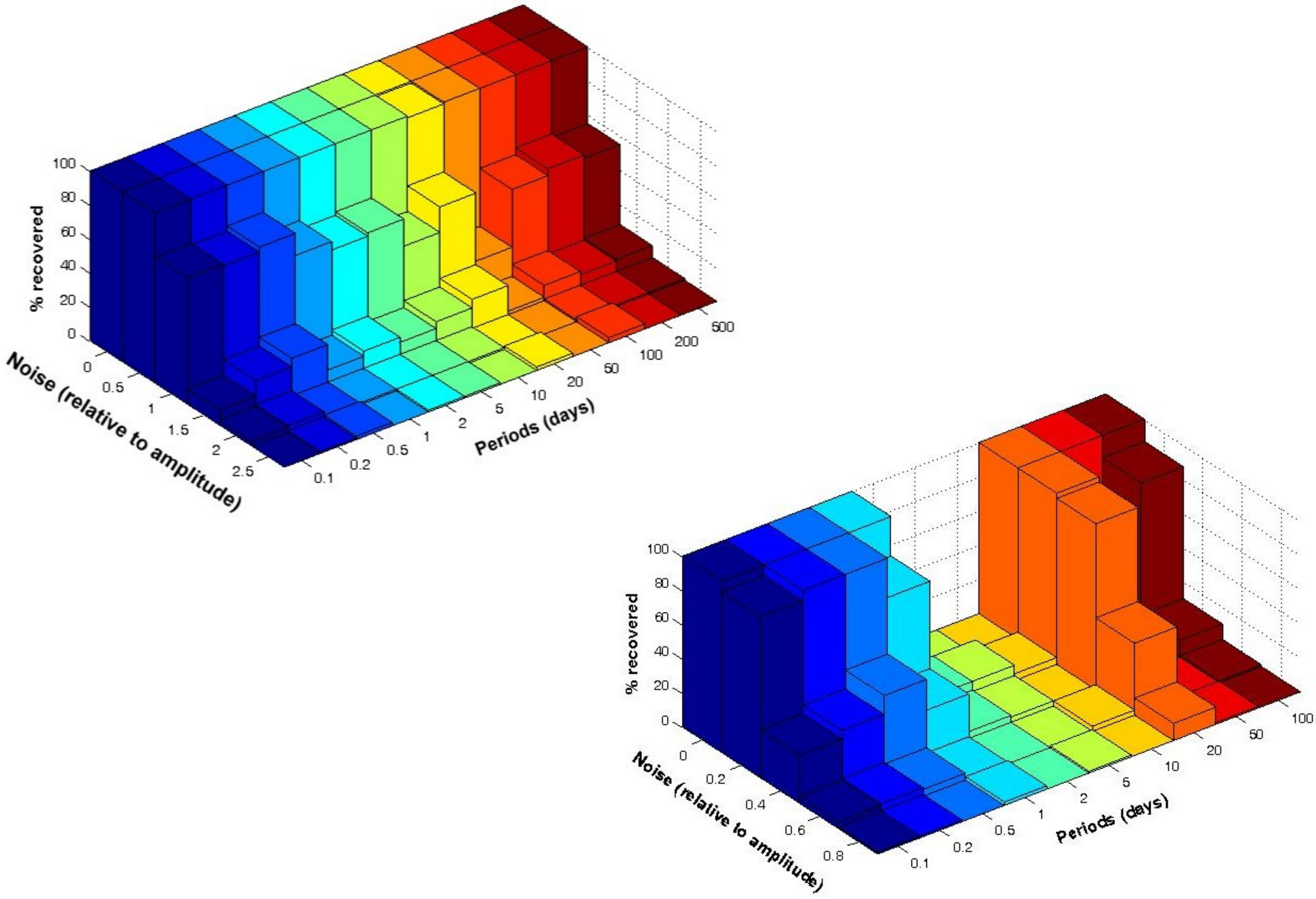


Period recovery efficiency from Gaia sampling with 76 observations generated by the nominal scanning law. Continuous sinusoidal variations can be easily recovered (upper left), even for large values of noise, close to SNR =1. The periods of eclipse-like variations (as in well detached binaries) are more difficult to recover, since for small values of the noise, some periods will never be found at a particular point in the sky (lower right: the same data points with an eclipse-like variation during 10% of the period). See a more complete coverage inside this issue.

Editorial *by DPAC chair, François Mignard*

A new testimony that launch is nearing. Gaia has an assigned launcher (being manufactured) and launch number: Sz-013. Integration of the Spacecraft is progressing nominally with a new set of mechanical tests scheduled for July and Service Module finalised for thermal/vacuum tests in August.

DPAC conducted its first Operational Rehearsal between 25th June and 4th of July. This was not a software test campaign, but an attempt to launch the daily systems and associated communication procedures as they should go during operations. Three full days of telemetry data had been prepared by CU2 for this purpose and used primarily by the IDT (initial treatment), FL (first look diagnostic) and PhotPipe (daily photometry). All DPCs (but Geneva) were involved to receive, ingest and possible process data in real time. DPAC drew fantastic lessons from this successful exercise on S/W, communication, recovery from anomalies and above all the building up of an operational spirit among the participants. A Second rehearsal is now scheduled in mid-December.

In this summer issue you will find our usual columns with an emphasis on the tricky task of period retrieval in a time series and the fascinating modelling of the astrometric binaries. Two DPAC partners from Italy and Germany present themselves on p.3 after our Word of Gaia dedicated to an illustrious Gaia forebear.

Enjoy the summer break and see you back in September.

Ptolemy's Catalogue of Fixed Stars

Seen with a long-term historical perspective, the Gaia astrometric Catalogue will appear as one of the numerous astronomical catalogues that have marked our discipline since the birth of the optical astrometry. Among the historical star catalogues, Ptolemy's stands out, at least in the Western world, as the first attempt to collate in a systematic and organised way the positions and brightness of all the stars accessible to naked eye from Alexandria or Rhodes (the question of whether there were others not bright enough to be seen was simply not discussed). Sky depiction and star lists have existed before in Ancient China with Shi Shen, Gan De and Wu Xian which resulted into an integrated Catalogue created by Chen Zhuo one century after Ptolemy with nearly 1500 stars. But nothing comparable to the Almagest has come down to us allowing to assess the astrometric accuracy of the measurements carried out by our Gaia Hellenistic predecessor.

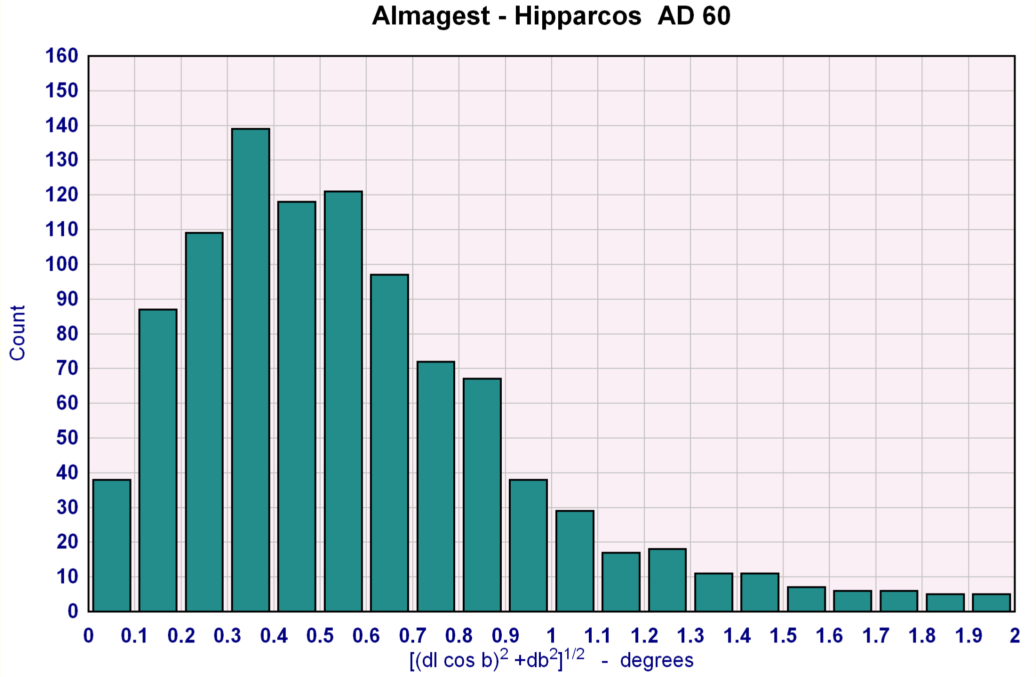
Ptolemy showed first in the Book VII of the Almagest, that between Hipparchus time (c. 130 BC) and his (AD 135) stars have not moved relatively to each others, since configurations and alignments noticed by Hipparchus have been preserved unchanged over the intervening 265 years. Taking the largest proper motions of about 1 arsec/yr, this indicates already that changes in alignments as large as 4 arcmin went unnoticed. Another clue for the accuracy is also provided by Ptolemy rounding off the coordinates to the nearest 10 arcmin in his Catalogue.

Now, using modern astrometric Catalogues with proper motions it is easy to propagate the star coordinates back to Ptolemy or Hipparchus time with an accuracy of few arcsecs, producing virtually an error-free position for the purpose of this comparison. But the hard part arises in relating the spherical coordinates 2000 years apart with the precession. The effect is much more important than the star true displacements.

If Ptolemy did observe himself the stars, one expects a mean epoch of about AD 135 for his catalogue. Surprisingly precessing modern positions to this epoch leaves a systematic difference in longitude of about 1.2 degree. This effect vanishes if one takes about AD 60 for the mean epoch, definitely not compatible with Ptolemy's time.

In fact Ptolemy has even (since Tycho Brahe, 1598) been accused by astronomers of fraud for stating *(Syntaxis, book 7, chapter 4)* that he observed all 1025 stars: "Hence again using the same instruments [as we did for the Moon] we observed as many stars as we could sight down the sixth magnitude" *(Almagest, Book VII, chap. 4, G.J. Toomer translation)*. Whether he observed himself no star at all, a fraction of its Catalogue or all of them is still debated and will be for years again. How many stars have just been precessed from Hipparchus will remain unanswered, since the Hipparchus data have not been preserved. Effectively taking the 190 years between Hipparchus and AD 60 the total precession amounts nearly to the shift of 2°40' that Ptolemy may have systematically applied from his own (erroneously) precession constant of 1° per century instead of 1.4°.

Regarding the Almagest Catalogue the truth is probably more complex, with some Hipparchus stars genuinely reobserved, some others precessed to Ptolemy's epoch and few others not found in Hipparchus and added by Ptolemy from his own observations. Noted historians range from scientific fraud (R. Newton) to the full trust of Ptolemy (O. Neugebauer).



Cross-match between Almagest's star Catalogue and Hipparcos, using modern proper motions and with a precession to AD 60, when the differences in ecliptic longitude have a zero-mean. Out of the 1027 stars, 21 have been removed because of ambiguous identification giving a distance larger than 2 degrees or twice assigned to the same Hipparcos star. The core of the distribution indicates that Ptolemy's (or more likely Hipparchus) accuracy was of the order of 0.5-0.6°.

Focus on partners

THE GAIA DPCT (Torino) TEAM

by Michele Martino

DPCT is the Italian DPC (Data Processing Centre) of Gaia, hosted at the ALTEC centre in Turin. ALTEC is a private-public company (www.altecspace.it) founded in 2003 (51% Thales Alenia Space, 29% ASI, 20% Icarus a local government organization) mainly involved in Operations, Engineering Support, Training, Logistics and utilization of the ISS, as well as in space exploration (ExoMars ROCC, STEPS) and other research projects (IXV, SMAT, GOCE).

ALTEC has started a deep collaboration with OATo (the Astronomical Observatory) in 2004, with the conceptual definition of the DPCT and its infrastructure, up to the build-up of a test facility for optical instruments (OPSys, used for the SCORE P/L and planned to be used for METIS) and to the definition of experiments to be flown on ISS or on stratospheric balloon.

The decision to place at ALTEC the DPCT was taken after a joint evaluation between OATo, ASI (the Italian Space Agency) and ALTEC. ALTEC centre has resulted as the best place for the DPCT site, providing the proper infrastructure for hosting the large HW platform and a good opportunity for a strong collaboration between science institution and local space industry, a real chance for team synergy and for expansion of the respective knowledge and experience.

In mid 2008 ALTEC officially started working with OATo (under ASI and INAF funding) in requirement and design activity of the center as part of the DPAC. ALTEC took the responsibility for the design, implementation, integration, validation and operations of the infrastructure (HW, SW framework, DB), including the roles of DPC Manager and PA/QA, while OATo maintained the responsibility for the design, implementation and operations of the scientific SW (Instrument modelling, basic angle monitoring, Sphere reconstruction etc) to be integrated in the DPCT.

Today the DPCT infrastructure development team is comprised of 8 ALTEC engineers and 1 OATo scientist, plus the ALTEC support staff of the technical experts on hardware, network, security, operating systems. At one year from launch, we are now working on building up the operations team, with the progressive integration of the scientists working on CU3 products, supporting integrated testing and finalizing the operational platform configuration.

The DPCT Team: : Novara, Sella, Uzzi, Pigozzi, Icardi, Trubian, Montironi, Solitro, Martino, Morbidelli, Marziani, Messineo, Mulone, Prati

Leibniz-Institute for Astrophysics Potsdam (AIP) *By Katja Janßen*

The key topics of the Leibniz Institute for Astrophysics (AIP, www.aip.de) are cosmic magnetic fields and extragalactic astrophysics. A considerable part of the institute's efforts aims at the development of research technology in the fields of spectroscopy, robotic telescopes, and e-science. The AIP is the successor of the Berlin Observatory founded in 1700 and of the Astrophysical Observatory of Potsdam founded in 1874, which was the world's first observatory to emphasize explicitly the research area of astrophysics (see DPAC NL #7 p.2). The AIP is a foundation according to civil law and is a member of the Leibniz Association. The Leibniz Association is a network of 86 independent research institutes and scientific service facilities, which strive for scientific solutions to major social challenges.

The Leibniz-Institute of Astrophysics Potsdam hosts a small group of two scientists that contribute to Gaia's data reduction software and data storage. The AIP joined the Gaia DPAC in September 2007, a change of personnel occurred for both positions though (J. Gerssen since 07/2009, K. Janssen since 10/2010), and just recently the team has been extended for our participation in the Gaia Archive Preparation by H. Enke.

The AIP is involved now in the Spectral Extraction software for the RVS (CU6), the Detailed First Look software (CU3/CU6), the Gaia reference star data archive (CU6/CU4) and the Gaia Archive Preparation (CU9):

The AIP CU6 contribution focuses on modelling the RVS background arising from sources that affect the measured spectra but are not included in the downlinked data (see DPAC NL #15).

For CU6/CU4 the AIP maintains the data archive for Gaia reference stars. The CU3/CU6 contribution concerns a software package that will run daily to monitor the status of the RVS based on results derived for individual spectra (e.g. wavelength dispersion per pixel) and comparison to long-term trends. And for the upcoming CU9 (Gaia archive access) we are exploring techniques to publicly access the Gaia data and work with the archive.

Our software development is carried out in close collaboration with the Mullard Space Science Lab in London, the Observatory in Heidelberg, the CNES in Toulouse and the Paris Observatory.

Eight ways to see double stars that seem single *by J.-L. Halbwachs & D. Pourbaix*

Gaia is expected to separate double star components as close as about 0.1 arcsecond, but its contribution to the field of astrometric binaries will concern systems with much smaller separations. Since Friedrich Bessel announced in 1844 that Sirius and Procyon had an unseen companion, it is well known that they can be detected through the wobble in the star proper motion. In fact, when the luminosities of the components are not very different, we do not observe the motion of the brightest star around the barycentre, but the motion of the photocentre, which is the luminosity centroid.

In the pipe-line of the CU4/DU 432, the binary nature of a star is inferred by fitting the astrometric measurements with one among 8 different models; for comparison, 4 models were used in the Hipparcos data reduction.

The most reliable way to detect an astrometric binary is to observe an elliptic orbit agreeing with Kepler's second law. This situation is illustrated on the first sketch in the figure below. The calculation is somewhat complex, but elements like the orientation of the orbit in space are derived. Moreover, when radial velocity measurements are also available (from Gaia or from ground-based observations), it is even possible to derive the masses and the luminosities of both components. Therefore, these binaries are real treasure-troves for stellar astrophysics.

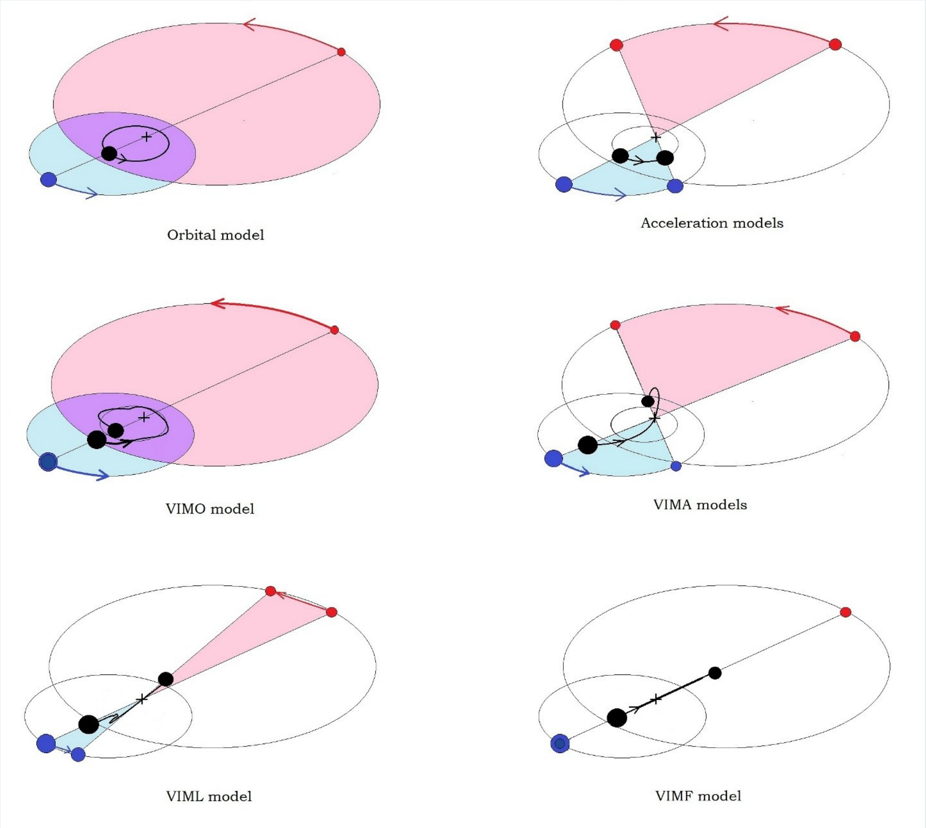
When the period of the orbit is longer than about twice the Gaia mission, it is not possible to infer the orbital parameters from the curved shape of the photocentric motion. However, the binary nature of the star may be established by the derivation of an acceleration solution. Two acceleration models are used from the expansion of the apparent coordinates of the photocentre in t^2 or t^3.

In the models above, it is assumed that the luminosities of the stars are invariable: therefore, the photocentre describes an orbit which has the same shape as that of the components (assuming there are only two). The motion of the photocentre is much more intricated when the stars are photometrically variable. When the luminosities of both components are variable in the same range, the problem is completely degenerate. However, in the course of the preparation of the Hipparcos mission, Roland Wielen has shown that relevant parameters may be derived when only one of the components is variable, since the motion of the photocentre is then related to the variation of the total luminosity. These models are called "Variability-Induced Movers", or VIM.

The VIM models illustrated in the middle of the figure are adaptations of the models used for constant stars. They include additional parameters derived from the wobble of the photocentre due to the variability of one component, such as the position and the velocity of the variable star with respect to the barycentre. As for the acceleration models seen above, two different "VIM + acceleration", or VIMA, models will be applied to the Gaia astrometric measurements.

The two last VIM models concern binaries which could not be detected if they were not photometrically variable. As a result of the variability, the photocentre oscillates between the components. The binarity of the system is then inferred from the calculation of the position, and possibly of the velocity, of the variable component with respect to an average photocentre.

A few fixed VIM, or VIMF ("VIM fixed") stars were discovered in the Hipparcos programme. The frequency of VIM objects, and particularly of VIMA and VIMO ("VIM + Orbital"), is expected to be rather small. However, due to the huge quantity of stars observed with Gaia, their numbers should not be negligible.



Orbital model

Acceleration models

VIMO model

VIMA models

VIML model

VIMF model

The six categories of models applicable to unresolved astrometric binaries. The blue filled circles (resp. red) show the positions of the primary (resp. secondary) component. The photocentres are shown with black filled circles, while the cross is located at the barycentre.

Period analysis of variable objects in Gaia *by J. Cuypers on behalf of CU7*

Because Gaia will observe its targets on average about 70 times and in some regions up to 200 times over five years, many kinds of variability will be detectable. Not only light variations in the G-band (and in RP and BP) will be seen, but also radial velocity changes will be available at the bright end.

An important part of the characterisation of these variable objects, a task mainly done within CU7 (Variability Processing), will be the detection of periodicity. The period (or its inverse: the frequency) is an essential parameter for the characterisation and classification of the variable objects. These objects will be mainly stars, but also asteroids and even some extragalactic objects will show periodic variations, so other Gaia CU's are involved as well.

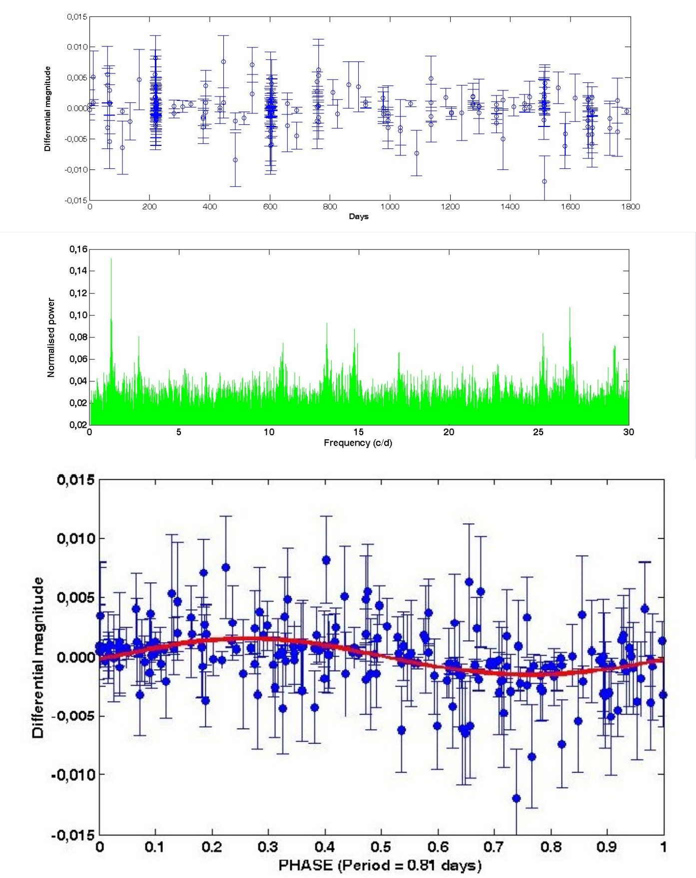
Because of the specific scanning law, the time sampling of Gaia observations will be very uneven with few packed observations over few hours followed by gaps of several weeks. In addition this exact distribution depends on the direction in the sky. Classical methods of (equidistant) time series analysis can therefore not be used, but luckily this feature is very familiar to many astronomers analysing ground-based data. As a consequence a wealth of methods to search for periods in sparse, un-evenly spaced observations is available in astronomical literature. A large number of these where implemented and tested within CU7.

An intensive study was also carried out in order quantify the reliability of each period found in the form of a 'False Alarm Probability' (FAP), e.g. the probability that an analysis of noise alone would result in this period for the given data set. Although this FAP is a very good indicator for the significance of a period, it is inevitable that a number of cases with very irregular variability will also have a small FAP and will mimic periodical variability. Because of the huge amount of expected variables to be processed (at least several millions), several of the more sophisticated methods cannot (yet?) be considered for the Gaia data, since they would take too much computing time.

Literature studies, tests on simulated Gaia data and analyses of other surveys indicated that Fourier-like methods, as the well-known Lomb-Scargle[1] method, are very efficient in finding periods in continuously varying data where the noise on a single data point is not (much) larger than the amplitude. In this case between 70 and 80% of the known or input periods are recovered with good computing efficiency. Methods based on fitting a sinusoidal signal to the data in the least squares sense[2] perform even better, especially when errors are unequal and appropriate weights are used. This takes some more computing resources, but this remains feasible if the fastest algorithms are used. The Deeming method[3], a sort of light version of the Lomb-Scargle method, performs significantly faster, but the number of correct recoveries drops below 70% in the same conditions.

For the large majority of pulsating, rotational and ellipsoidal variables a Lomb-Scargle or least squares method will give a reliable period. For well detached eclipsing binaries or pulse like variations it will be more difficult to extract the correct periods efficiently because the duty cycle is short and less amenable to a good representation on the basis of trigonometric functions.

The sparse sampling will limit the number of observations during eclipse and so the number of detections. Even is few observations are timed during eclipses, multiples or sub-multiples of the correct period will be often produced by an automated analysis. Period searches with other methods ("Phase Dispersion Minimization"[4]) or much slower methods ("String Length"[5]), triggered only if some parameters reach certain values, could remedy this, but nothing conclusive has been achieved yet for Gaia.



Example of time series analysis, with Gaia data (top), periodogram (middle) and folded light curve. A small amplitude sinusoidal variation can be fitted by a weighted period analysis method (here a least squares method) if the noise distribution is well known. In the periodogram the largest amplitude is found at frequency 1.23 cycle per day.

The period search as now done in the CU7 characterisation pipeline gives already very satisfactory results for many types of periodic variables and the fine-tuning as envisaged based on-going tests will still increase its efficiency.

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[1] *Lomb, N.R., 1976, APSS 39, 447 - Scargle, J.D., 1982, ApJ 263, 835*

[2] *Vaníček, P., 1971, APSS 12, 10 - Ferraz-Mello, S., 1981, AJ 86, 619 - Zechmeister, M., Kürster, M., 2009, A&A 496, 577*

[3] *Deeming, T.J., 1975, APSS 63, 137*

[4] *Jurkevich, I., 1971, APSS. 13, 154 - Stellingwerf, R.F., 1978, Ap. J. 224, 953*

[5] *Lafler, J., Kinman, T.D., 1965, ApJS. 11, 216 - Renson, P., 1978, A&A. 63, 125 - Dworetsky, M., 1983, MNRAS 203, 917*

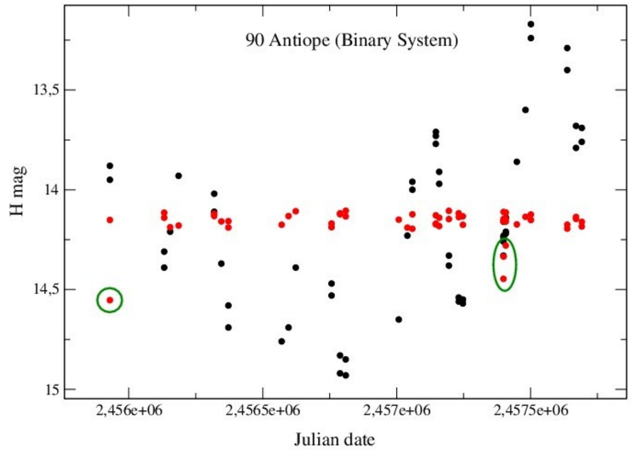
PhD and Post Doc Corner

Toni Santana i Ros, *Obserwatorium Astronomiczne UAM w Poznaniu, Poland*

Toni is a Ph.D. student within GREAT-ITN network, funded from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement no. 264895, working on WP5 package (Planetary Systems) under the supervision of Prof. Tadeusz Michałowski.

Despite the fact that Gaia is not explicitly designed for Solar System science, it is expected to collect a vast amount of valuable data that can turn into a small revolution on our understanding of the asteroids physical properties. Asteroids shape and spin axis modelling allow us, for example, to join them into families in order to study their common evolution, origin or composition. To do so one needs to obtain light curves during five to six oppositions (so it means about 5 long years of observations). That is one of the reason why only about 200 objects have been modelled so far.

Gaia will observe ~400.000 asteroids during the 5-year mission, giving us sparse photometric observations (around ~50-80 points for each asteroid on average), enough data to derive the basic parameters of many of them. Furthermore, when trying to fit the observations to our models, we expect to find very poor fittings as well, i.e. binary systems or tumbling asteroids. Actually, a software capable to detect such cases is being implemented, and it should became an important milestone in the student Ph.D. research (see image). Gaia thus will not only increase dramatically the asteroid population with known physical parameters, but also reveal the yet unknown history of many of them.



Gaia photometry simulation for the 90 Antiope binary system, using the ephemeris provided by the SSO Gaia Simulator (A. Cellino et al, 2009) and a tri-axial ellipsoid model for binary systems (the size ratio between the two bodies is 1/1) developed in UAM Poznań Observatory. Dark points represents the raw observations, while in red points distance and phase effects have been removed. The marked points shows clearly the event of an eclipse between the two bodies.

Calendar of next DPAC related meetings

27 - 28 September	Edinburgh	**Initial in-orbit calibration #4**	A. Brown / N. Hambly
1 - 2 October	ESAC	**CU1: System Architecture #15**	W. O'Mullane
2 - 3 October	ESAC	**PO DPC meeting #3**	E. Mercier
4 - 5 October	ESTEC	**GST meeting #39**	T. Prusti
9 - 10 October	Lund	**Radiation Task Force #11**	F. van Leeuwen / L. Lindegren
18 - 19 October	Heidelberg	**GBOG #12**	M. Altmann

Gaia and related science meetings

3 - 7 Sept	Tenerife	**IAC/GREAT - ITN school on "The art of observational campaigns"**	http://rialto.ll.iac.es/congreso/itn-gaia/
6 - 7 Sept	Bologna	**Gaia Science Alerts Workshop 2012**	http://www.ast.cam.ac.uk/ioa/wikis/gsawgwiki/index.php/Workshop2012:main
13-18 Sept	Redmond, WA & U. of Washington	**Astro-Visualisation School**	http://great.ast.cam.ac.uk/Greatwiki/GreatItn/VizSchoolSep2012
19 - 21 Sept	Paris Obs.	**Gaia-FUN-SSO-2**	http://www.imcce.fr/hosted_sites/gaiafun2012/index.php
19 - 21 Sept	Leuven, Belgium	**Asteroseismology with large time-resolved astronomical surveys**	http://fys.kuleuven.be/ster/conferences/GREATworkshop
1 - 5 October	St Petersburg,	**All-Russian Astrometry Conference "Pulkovo-2012"**	http://pulkovo-2012.gao.su/index.eng.html

More information on calendar of Gaia : http://www.rssd.esa.int/index.php?project=Gaia&page=Calendar_of_meetings

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