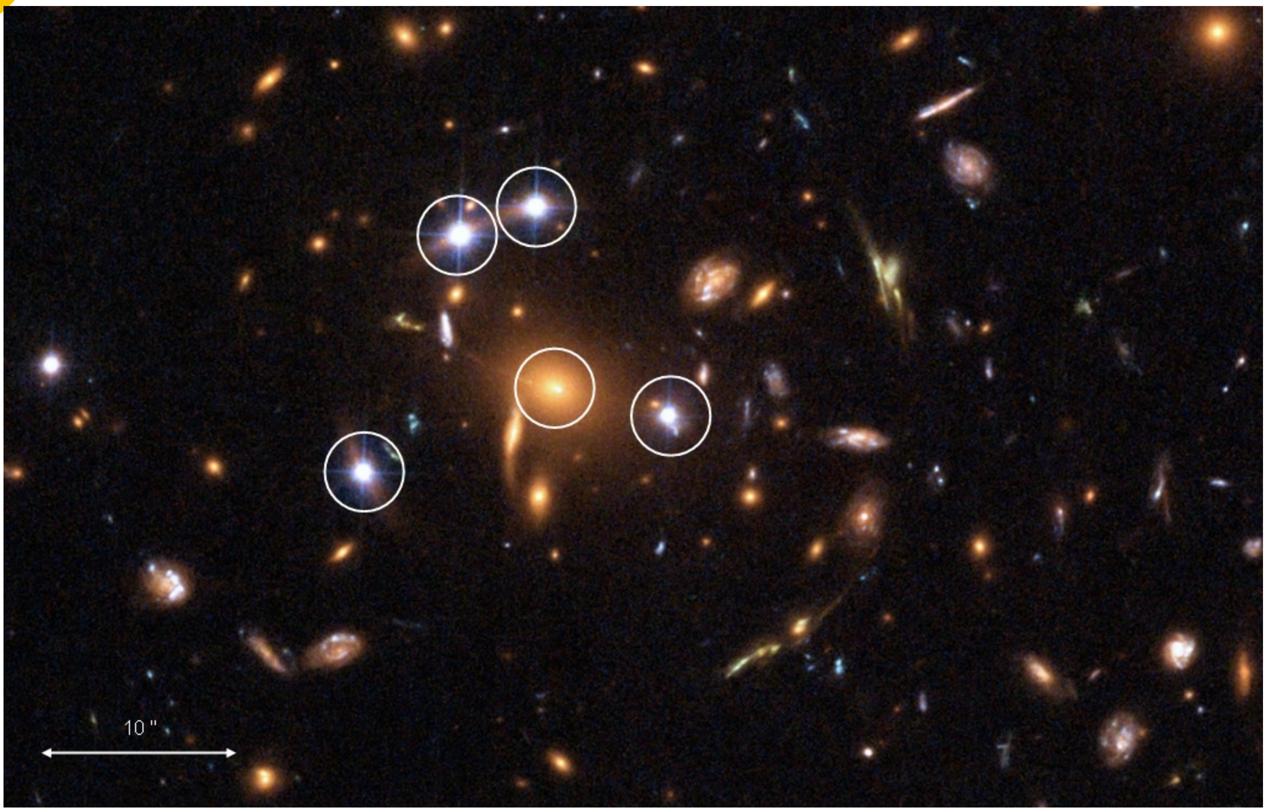
Gaia DPAC

Newsletter 13

N° 13 - July 25, 2011



A single quasar is shown in this Hubble photograph as five star-like points, as a result of gravitational lensing by an entire galactic cluster (SDSS J1004+4112) located in the foreground. The fact that there is a single source mapped five times has been confirmed by spectroscopy. The quasar is about 3.5 Gpc away, almost twice as more distant as the cluster.

During the Gaia processing, images of the immediate environment of quasars will be reconstructed (see NL #9) and searched for possible lensed copies within few arcsec. The rate of occurrence is strongly related to cosmological parameters. This is one of the interests of the Liège group presented in this issue.

Credit : ESA, NASA

Editorial *by DPAC chair, François Mignard*

Gaia spacecraft integration and testing is progressing nominally, both for the Service and Payload modules. All the CCDs have been delivered and are in place on the focal plane, giving Gaia a powerful eye of one billion pixels, nearly on its way to map the sky. An important event took place recently with the first full deployment of the sunshield assembly at the manufacturer site, fitted with the new opening mechanism replacing an earlier system that failed to pass deployment tests two years ago.

On the DPAC side, preparation of the Implementation Review is under way with many pieces of S/W already running at their respective DPCs to test how they meet the science and performances requirements. Test reports are being produced almost continuously by every CU and this will continue during the whole summer.

DPAC has now in hand a workable Operation Plan describing the detailed scenario of the processing, compatible with the cyclic and iterative nature of several of ours systems and the intricate dependencies between them. It took nearly two years to shape the current proposal, which will be presented in a forthcoming issue of the NewsLetter.

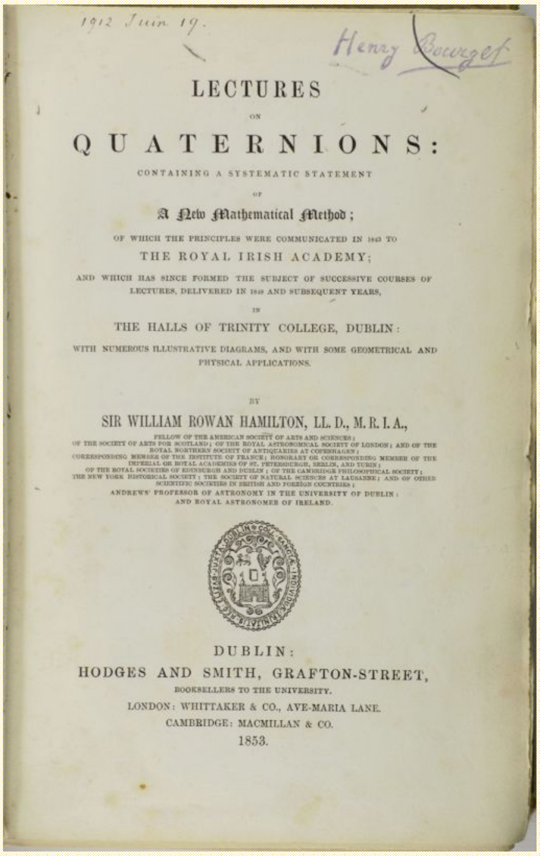
This summer issue brings in as usual the presentation of two DPAC participating institutes, one in Spain dealing with some aspects of the source classification, and the other in Belgium involved, in particular, in the processing of more than 500,000 quasars that Gaia will survey. On the technical columns you will learn about the brand new Solar system ephemeris (INPOP) to be used for both the data processing and the spacecraft navigation and will discover how epoch radial velocities are unfolded from the RVS calibrated spectra.

Good reading to all of you and a nice summer break.

Quaternions

At least in this column we have one non astronomically directly related word, since a quaternion is above all a mathematical object, first introduced by the Irish mathematician and physicist W. R. Hamilton in 1843. But he was also at that time the 3rd Royal Astronomer of Ireland and held the position of Professor of Astronomy at Trinity College, Dublin.

As a mathematical object, a quaternion is a quadruplet of real numbers endowed with particular internal composition rules for the sum and the product, such that if Q and Q' are quaternions then, under the product rule, Q*Q' is also a quaternion. Hamilton searched for years a generalisation of the complex numbers in the form of triplets T(t1,t2,t3) that could be multiplied together and given a norm N(T) (similarly to that of a complex number) satisfying the rule N(T*T') = N(T)N(T'), a constraint required to divide triplets. It is known today (Hurwitz's theorem) that there is no such solution in three dimensions and the next possibility, just above the complex numbers, needs four dimensions, as Hamilton realised on the 16 October 1843, while walking along the Royal Canal in Dublin.


1912 Juin 19.

Henry Bourget

LECTURES
ON
QUATERNIONS:
CONTAINING A SYSTEMATIC STATEMENT
OF
A New Mathematical Method;
OF WHICH THE PRINCIPLES WERE COMMUNICATED IN 1843 TO
THE ROYAL IRISH ACADEMY;
AND WHICH HAS SINCE FORMED THE SUBJECT OF SUCCESSIVE COURSES OF
LECTURES, DELIVERED IN 1848 AND SUBSEQUENT YEARS,
IN
THE HALLS OF TRINITY COLLEGE, DUBLIN:
WITH NUMEROUS ILLUSTRATIVE DIAGRAMS, AND WITH SOME GEOMETRICAL AND PHYSICAL APPLICATIONS.

BY

SIR WILLIAM ROWAN HAMILTON, LL. D., M. R. I. A.,
FELLOW OF THE AMERICAN SOCIETY OF ARTS AND SCIENCES;
OF THE SOCIETY OF ARTS FOR SCOTLAND; OF THE ROYAL ASTRONOMICAL SOCIETY OF LONDON; AND OF THE ROYAL NORTHERN SOCIETY OF ANTIQUARIES AT COPENHAGEN;
CORRESPONDING MEMBER OF THE INSTITUTE OF FRANCE; HONORARY OR CORRESPONDING MEMBER OF THE IMPERIAL OR ROYAL ACADEMIES OF ST. PETERSBURGH, BERLIN, AND TURIN;
OF THE ROYAL SOCIETIES OF EDINBURGH AND DUBLIN; OF THE CAMBRIDGE PHILOSOPHICAL SOCIETY;
THE NEW YORK HISTORICAL SOCIETY; THE SOCIETY OF NATURAL SCIENCES AT LAUSANNE; AND OF OTHER SCIENTIFIC SOCIETIES IN BRITISH AND FOREIGN COUNTRIES;
ANDREWS' PROFESSOR OF ASTRONOMY IN THE UNIVERSITY OF DUBLIN:
AND ROYAL ASTRONOMER OF IRELAND.

DUBLIN:
HODGES AND SMITH, GRAFTON-STREET,
BOOKSELLERS TO THE UNIVERSITY.
LONDON: WHITTAKER & CO., AVE-MARIA LANE.
CAMBRIDGE: MACMILLAN & CO.
1853.

Cover page of the first synthesis on the quaternions published by W.R. Hamilton in 1853. A 2-volume and more comprehensive treatise will appear posthumously.

DPAC scientists are using quaternions to represent the attitude of Gaia, that is to say its orientation as a solid body with respect to a fixed reference frame. Basically an orientation of a rigid body about its centre of mass is defined by an axis of rotation and an angle about this axis. Three independent parameters are then required, very often given in the form of three Euler angles. This is one among several ways to parametrise the continuous group of rotation. This representation, widely used in classical and quantum mechanics, is not uniformly good and has unavoidable singularity (a small rotation, meaning very close to the identity, may need two large Euler angles that almost cancel each other).

How quaternions, actually unit quaternions with N(Q) = 1, are related to the rotation group is not easy to grasp. For a mathematician this is just a matter of an algebraic association between two sets with the stability of the product rule in the correspondence. A more intuitive approach can be done with geometry. A quadruplet N(Q) =1, is naturally associated to a point on the surface of a 3D-sphere of unit radius (the outer boundary of a ball in the 4D Euclidean space). The product between two quaternions maps the two corresponding points to a third on this sphere, allowing to visualise the quaternion group on that sphere.

Now the rotations are defined by a unit vector (the direction of the axis of rotation) and a modulus (the angle of rotation), or three parameters. The direction could be a point on the surface of the usual sphere, and the radius of that sphere could be equal to the angle of rotation. Then, to cover all possible rotations, one fills a sphere until the largest radius stands for 360 degrees. This looks good, but the locus of the 360 degrees rotation, the identity rotation, would be a surface instead of a point. Very bad property! The correct geometry collapses the outer sphere into a point and leads to the geometry of a 3D-sphere, where the north and south poles are respectively the 0 and 360 rotation. The equator would be the 2D-sphere associated to the 180 degree rotation. The similarity with the quaternion is now almost perfect (although each rotation is mapped twice on this sphere) and can be proved correct.

For Gaia, unit quaternions are used to describe the attitude as a function of time and each of the four components is given in the form of a continuous and differentiable polynomial representation (a spline) going through preassigned nodes, typically on every 2 mn. Java tools are available to handle the algebra and the relationship with the Euler angles and the rotation matrices.

Focus on partners

The Gaia team at University of A Coruña, Spain *by Minia Manteiga*

The Interdisciplinary Laboratory of AI (Artificial Intelligence) Applications of the University of A Coruña is a multidisciplinary research group, comprising physicists, IT engineers and astrophysicists. Among the areas of interest of the group are the medical imaging, fisheries areas prediction, teledetection of marine pollution zones and the application of AI techniques to astronomical information retrieval. The group is based in the Informatics Faculty of The University of A Coruña, and is currently composed of 10 people, including university staff and students.

We joined the Gaia DPAC in 2006 with involvement in several CU8 software packages: General Spectra Parametrizer (GSP-Spec) for the extraction of physical parameters from calibrated RVS spectra, Object Cluster Analysis (OCA) that will perform unsupervised classification of all Gaia observations, and the full responsibility of the Outlier Analysis (OA), which must sort out everything which do not fit in the other CU8 classifiers.

Automatic information processing techniques are not flawless, and for some objects (hopefully not too many) it will be impossible to obtain a classification with an adequate degree of reliability. This is due to various reasons: because their nature is different from that of the known objects, because the objects (e.g. stars) are very distant, or simply because of an unusual kind of noise.

The objective of OA in CU8 is to reanalyse the data of these outliers by performing non-supervised cluster analysis, by statistical methods and AI techniques, in order to reveal the natural classes. Our algorithm is based on Self Organizing Maps (SOM) that segment the data in groups ordered in a hierarchical structure. The expectation is that their physical nature can be better disclosed under the hypothesis that there are several objects belonging to the same astronomical uncommon class of objects. A secondary objective of this WP is to identify the misclassified known objects and feed them back to the general classifier (DSC) in order to improve its performance.

All the Gaia activity at the University of A Coruña has been financed by funding received from the Spanish Ministry for Science, Innovation and Technology, in the framework of its Plan Nacional del Espacio, through projects ESP2006-13855-CO2-02 (2006-2008) and AYA2009-14648-C02-02 (2009-2011).

The Astrophysics Gaia team at the Liège University, Belgium *by Eric Gosset & Jean Surdej*

The Department of Astrophysics, Geophysics and Oceanography at the University of Liège (http://www.ago.ulg.ac.be) hosts a small team of astronomers, Java developers and DB specialists, all contributing to DPAC. The astrophysics group is further divided into several teams, among them one working on extragalactic physics, quasars and lensing, and the other more concerned with the stellar side, like massive stars and binaries systems. Our contribution to DPAC is within CU8, CU4 and CU6.

In CU8, Y. Damerdji, J. Poels and J. Surdej coordinate the QSO classifier activity, with three main goals:

- Producing the cleanest QSO sample, required to build the Gaia Celestial Reference Frame; this selection is based only on photometry.
- Delivering at mission completion the QSO survey based for the first time on three complementary data sets (BP/RP photometry, proper motion and variability).
- Determining the astrophysical parameters (APs) for each object classified as a QSO (such as its redshift and spectral characterisation).

The first two tasks are part of the DPAC Discrete Source Classifier (DSC) whereas the last one is specific to QSOs meant to fully exploit the Gaia capabilities on these sources, since no ground-based spectroscopic follow-up is foreseeable at this scale.

Regarding the CU4 activities, the group led by E. Gosset, includes Y. Damerdji, J. Poels and T. Morel, and contributes to the treatment of non-single stars. They manage the DU434 in charge of the final determination of the orbits of the spectroscopic binaries, from the radial velocities derived with the RVS.

This team is also responsible in CU6 of a work package included in DU650 (Single Transit Analysis), aiming to extract in RVS spectra that are exhibiting a composite nature, due to angularly unresolved objects or to true multiple stars, the two radial velocities.

From left to right: Thierry Morel, Eric Gosset, Yassine Damerdji, Jean Surdej.

Altogether, the members of the Liège DPAC team contribute some 3.5 full-time equivalent staff to the Gaia DPAC workforce. Funding for these Gaia groups is provided by the ESA PRODEX Programme «Gaia-DPAC», from the Belgian Federal Science Policy Office and by the Liège University.

Science and technical issues

INPOP, Planetary ephemerides for Gaia *by A. Fienga, J. Laskar, H. Manche, M. Gastineau*

INPOP (Intégration Numérique Planétaire de l'Observatoire de Paris) are the first European planetary ephemerides built independently from the US JPL DExxx ephemerides. Both the Gaia processing by the DPAC and the spacecraft tracking at ESOC will rely on INPOP as a primary source of solar system ephemeris.

The project began in 2003 and three versions of INPOP (INPOP06, INPOP08 and INPOP10a) are presently available for users through the website www.imcce.fr/inpop, in different formats: the JPL DExxx format, the INPOP specific format together with its library and soon in the SPICE format.

In using the INPOP format, users have access to positions and velocities of the major planets of our solar system and that of the moon as well. They also find the differences between the terrestrial time TT (the scale used for observation timing) and the barycentric times TDB or TCB (time scales used in the equations of motion). This difference, important for the Gaia timing procedure, is numerically computed in parallel with the planetary ephemerides, yielding a fully consistent solution for the motion and the correspondence between the time scales.

INPOP is a numerical integration of the equations of motion of the major planets of our solar system (including Pluto) and of the Sun about the solar system barycentre, as well as the motion and rotation of the Moon about the Earth. The modelling, developed in the relativistic PPN framework, includes the solar oblateness, the perturbations induced by more than 24000 asteroids as well as the tidal effects of the Earth and Moon. More than 136 000 planetary and lunar observations of various kinds (ranges, classical astrometry, ..) are used for the construction of INPOP. In the latest version, INPOP10a, up to 260 parameters are fitted to the data (Fienga et al. 2011). The internal accuracy reached by INPOP10a over 1 century is about 1 km for the inner planets, Jupiter and Saturn and more than 1000 km for the other outer planets. The Earth orbit is known with an accuracy of about 0.5 km over the same period.

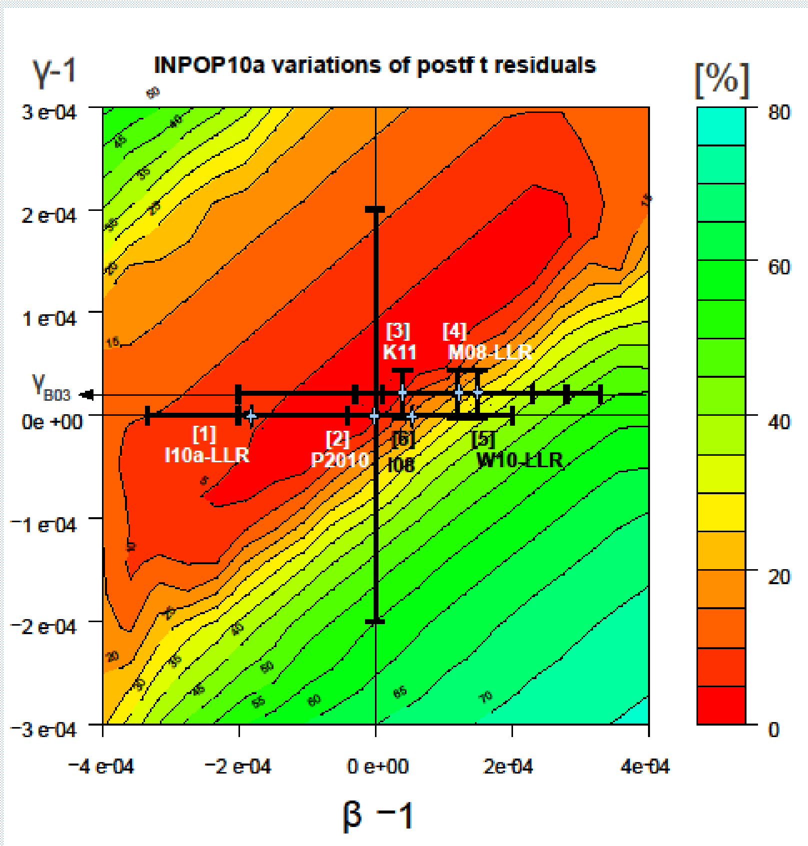
During the Gaia mission, the internal precision of the Earth orbit is estimated to be about 0.5 km and 0.05 mm/s, respectively for the barycentric position and velocity.

Besides asteroid mass determinations obtained with the construction of INPOP, tests of fundamental physics are made since INPOP08 (Fienga et al. 2010, Fienga et al. 2011). Estimations of acceptable intervals of non-zero values of PPN parameters β-1, γ-1, but also possible supplementary advances of perihelia and nodes of planet orbits, set new constraints for alternative gravitation theories.

The figure below illustrates the latest determinations obtained with INPOP10a and shows the constraints on a possible violation of general relativity at the scale of the solar system.

Finally, Gaia will also contribute its share to this field: thanks to its accurate star catalogue, it will be possible to correct earlier stellar catalogues from systematic effects that degrade the present analysis of the outer planet optical observations. Furthermore, the direct observations of the small satellites of these planets and of Pluto will also help improve the giant planet orbits.

Last but not least, the Gaia asteroid mass determinations will be used in INPOP for a better modelling of the inner planet orbits.



Variations of postfit residuals obtained for different values of PPN β (x-axis) and γ (y-axis). I10a-LLR stands for a PPN β value obtained by (Manche et al 2010) using LLR observations with γ=0, P2010 stands for Pitjeva (2010) by a global fit of EPM planetary ephemerides and I08 for the β value deduced from INPOP08 (Fienga et al. 2010). K11 refers to Konopliv et al. (2011) determinations based mainly on Mars data analysis. M08 is for Muller et al. (2008) and W10 for Williams et al. (2010) give values deduced from LLR for a fixed value of γ. γB03 line is the determination of γ by solar conjunction during the Cassini mission.

The RVS Single transit analysis *by the DU650 group*

The knowledge of the radial velocity of celestial objects (be they members of the solar system, stars or extra-galactic ones) is crucial in any study involving dynamics, but also for the determination of proper motions of nearby stars, the identification of members of clusters and moving groups or the flow patterns in the Milky way. For these reasons it was decided to include a Radial Velocity Spectrometer (RVS) in the Gaia mission so that radial velocities could be derived from the Doppler shift of the spectra.

The resolution of the RVS could not be very high because of its obvious impact on the telemetry volume; it was so selected as to deliver radial velocities with sufficient accuracy for the prime objects of the Gaia mission, in particular the study of galactic kinematics. While the original ambitions regarding accuracy of the RVS were thus relatively modest, it was realized that the exceptional observational opportunities offered by the Gaia mission made it imperative to get the very best possible results out of this instrument. This challenge is taken up by all the teams within CU6.

Although astronomers have devised several methods for deriving radial velocities from spectra, none of them conforms exactly to the peculiar nature of the data provided by the RVS. Moreover their response to observational errors, spectrum mismatch etc. may strongly differ, depending on the spectral type and the brightness of the object.

The DU650 group, responsible for developing “single transit analysis" (STA) software, therefore decided to implement not just one, but several of these methods and to compare their performance on a wide variety of spectra. Eventually for each object a “combined" radial velocity will be produced and stored in the Gaia database. However the results of these comparative studies will remain available, giving the user the possibility to make an informed choice between the individual solution and the combined result.

From left to right :
R. Blomme,
M. David,
Y. Viala,
C. Delle Luche,
Y. Frémat,
D. Katz,
G. Seabroke,
E. Gosset,
Y. Damerdji.

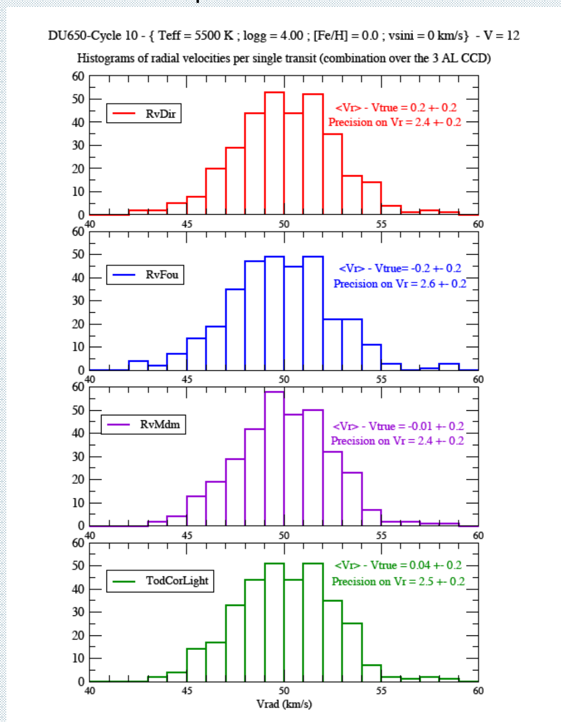
Missing :
P. di Matteo,
F. Royer

One of the methods applicable to single-star spectra is a classical cross-correlation technique using Fourier transforms (RvFou), while another uses the Pearson correlation coefficient as a measure of similarity between object and template (RvDir) and a third one resorts to a criterion of Minimum Distance, based on the maximum likelihood estimate of the radial velocity (RvMdm). In addition, the latter is implemented with different definitions for the distance, each suited to a particular type of noise distribution.

For multiple-star spectra we use essentially the TODCOR method from the literature, implemented with different level of refinements, compatible with source complexity and computational resources.

For each of the methods particular care is exercised to estimate the random error on the resulting Doppler-shift measurements, with classical or purposely developed methods. The reliability of these error estimates is being tested extensively using Monte-Carlo simulations.

To illustrate STA results, the histogram below shows the distributions of the results for the single transit radial velocities derived by each of the four modules for a G2V star of magnitude V = 12, using the same simulated dataset. All modules determine radial velocities with no bias and with a precision of 2.5 km/s, a factor 2 better than the scientific requirements.



Histograms of the radial velocities derived for a single transit (combination of the 3 AL CCD) by the 4 modules RvDir, RvFou, RvMdm and TodCorLight (see text). Each module applies to the same set of simulated input data: 333 spectra with different photon noise realisation of a G2V star at magnitude V = 12.

Besides radial velocities, the STA package will also supply hints on multiplicity or spectral variability in a broader sense, for the benefit of the DU's which focus specifically (using also photometric and astrometric information) on the analysis of objects with these characteristics. Transient phenomena (e.g. supernovae) will trigger Spectro Science Alerts that will be released within about one day of observation.

New!

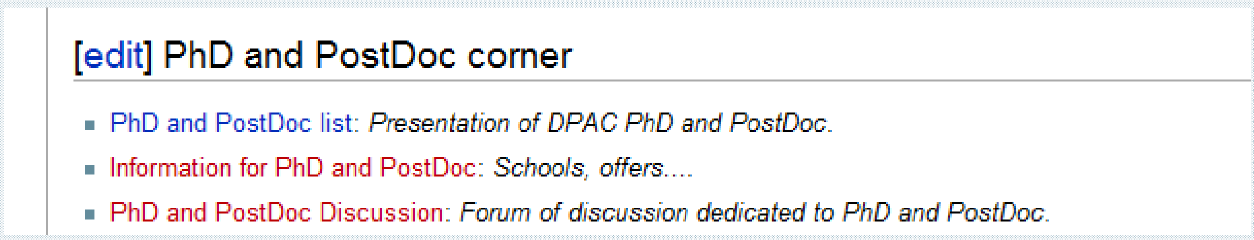
PhD and Post Doc corner on the DPAC wiki

We would like to invite all PhD and Post Doc researchers to complete a specific table that will allow DPAC management to know more about YOU! Information requested: First name, Name, Country, Institution, Starting Date, Status (PhD or Post Doc), Topic of research, email address.

Therefore, collected information will not only be used to know who is where within the DPAC but also to allow the Newsletter Editorial Board to invite you to present your work in future issues in the same spirit as this has been done for the ELSA fellows.

You will find in the 'PhD and Post Doc corner', a dedicated page to encourage discussion between all of you.

Should you have any specific needs or suggestion please contact nl_editorial_board@oca.eu .



[edit] PhD and PostDoc corner

- PhD and PostDoc list: *Presentation of DPAC PhD and PostDoc.*
- Information for PhD and PostDoc: *Schools, offers....*
- PhD and PostDoc Discussion: *Forum of discussion dedicated to PhD and PostDoc.*

Screenshot of the Front page of the DPAC wiki @ http://www.rssd.esa.int/wikiSI/index.php?instance=Gaia (restricted access)

Calendar of next DPAC related meetings

01-02/09	ESTEC	REMAT #9	CU3	J. de Bruijne / S. Klioner
06-07/09	Leiden Obs.	Radiation Task Force #9		A. Brown
22/09	Leiden Obs.	SC # 9	Steering	W. Boland
27-28/09	ESOC	IR Kick off		
03/10	ESAC	CU1: System Architecture		W. O'Mullane
04/10	ESAC	PO DPC meeting #3		E. Mercier
06-07/10	ESAC	GST # 36		T. Prusti
10-11/10	Barcelona	Calibration of BP/RP spectra	CU5	C. Jordi / F. van Leeuwen
20-21/10	ESAC	In Orbit Calibration		A. Brown

Gaia and related science meetings

05 - 09/09	Akdeniz University Technokent, Antalya, Turkey	**Summer School on Astrometry**	http://www.tug.tubitak.gov.tr/aass/
10 - 12/10	Paris Observatory, France	**Orbiting couples: "pas de deux" in the Solar System and the Milky Way**	http://wwwhip.obspm.fr/PasDeDeux/

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

This newsletter is published by DPAC Chair. To publish news or articles please contact: nl_editorial_board@oca.eu