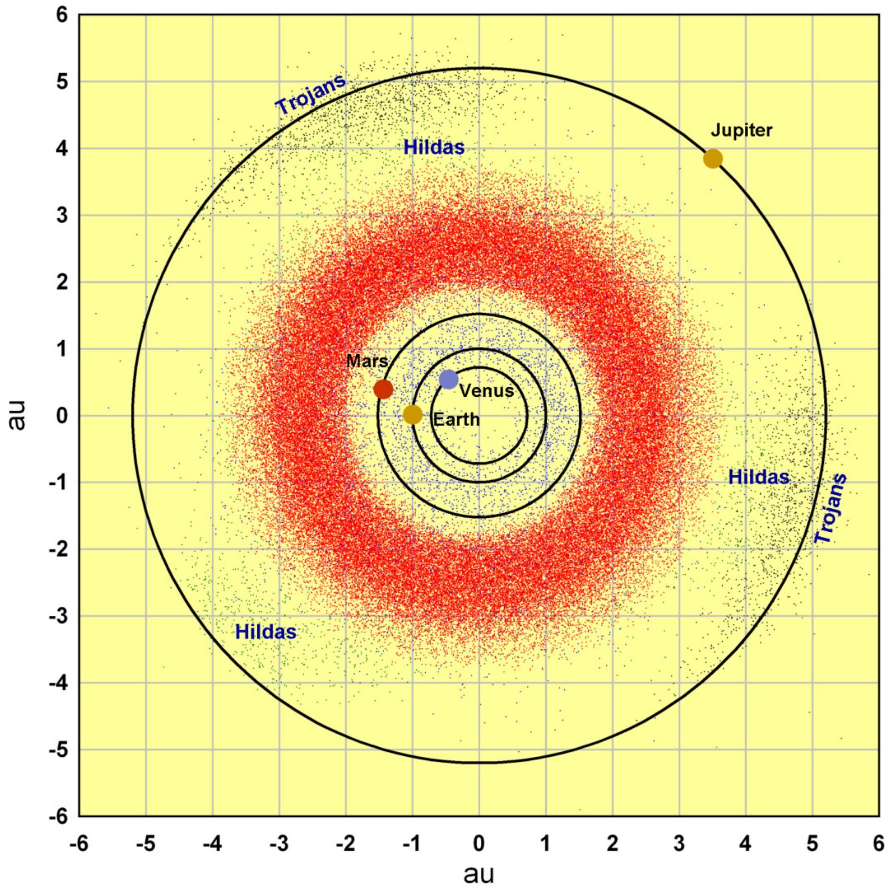
Gaia DPAC Newsletter

N° 5 — July 30, 2009

Inner solar system at the time of Gaia launch.



In addition to its core program in stellar and galactic physics, Gaia has a huge potential for Solar System science with the highly accurate astrometric and photometric repeated measurements.

The plot shows the position of the minor bodies projected on the ecliptic on the vernal equinox 2012, close to the nominal launch date of Gaia.

Main belt objects (limited to 100,000 here) appear in red between 2 to 4 au, then in blue come the NEA (Near Earth Asteroid) able to roam deeply into the inner solar system with perihelion distances below 1.3 au; the two Trojan clusters around Jupiter L4 and L5 are shown in black dots and finally in green the Hilda triangle in the 3:2 resonance with Jupiter with the concentration of aphelions opposite to Jupiter or at ±60 degrees.

Editorial *by DPAC chair, François Mignard*

Most of you have probably been informed that R. Schmidt, Gaia project manager, has moved to a new challenge in ESA and since July 1st, the position is filled by G. Sarri who was Payload Manager. On behalf of the DPAC, I wish to thank Rudi for all his achievements as PM and for having brought the mission in such a sastifactory state. I also express our pleasure to continue the work with Giuseppe for the next very exciting years that should culminate with the launch sometime in early 2012.

During the last week-end of June the very critical torus brazing took place in the premises of Boostec Industries, located near Tarbes in south-western France. The 17 parts were successfully brazed together into a single torus of SiC, 3.3 m in diameter, making the largest single piece of Gaia payload which itself, depends so much on its thermo-mechanical stability. This major event in Gaia life went on schedule and it is interesting to note that the power supply company has been asked to guarantee a stable power delivery during this critical operation.

Although critical for DPAC was the Design Review which ended up positively in June and put us on track to advance toward the early phases of the end-to-end testing scheduled in 2010. Much work ahead with a tight schedule.

Starting with this issue we have initiated a new column called 'the Words of Gaia' aiming to scrape on the meaning and history of words or expressions appearing frequently in the Gaia context. Suggestion or contributions are obviously welcome.

Critical Design Review *by François Mignard (OCA)*

During May and June 2009, the DPAC, together with the SOC (Science Operation Centre located at ESAC), has gone into its second overall review by ESA.

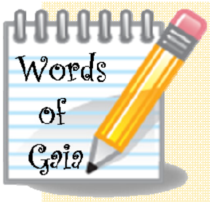
This Design Review was part of the Project C/D phase with the main objectives of (i) verifying that the DPAC/SOC design and status were compatible with the operational goals, (ii) ensuring that the verification, validation and testing procedures in place are adequate at this stage, (iii) checking the quality and adequacy of the management aspects with the project needs, (iv) identifying any problem areas that could impact on the DPAC activities.

The review was based on a large set of documents prepared by the SOC and DPAC with 80 documents in the review pack completed by about 140 supporting documents (not reviewed). This was a huge effort from each Coordination Units (CU) and Data Processing Centre (DPC) and from the DPAC overall management. This material was presented to the Review Panel on May 5th together with the development status of the Consortium. The reviewers communicated their remarks on the 22nd of May in the form of 149 structured comments, among them 40 were considered as major. DPAC and SOC provided an answer to each of them within two weeks and during the collocation meeting with the panel, the 149 RIDs were settled: 59 were closed with an answer and 90 were accepted with specific actions (109 actions in total, most to be completed by November 30, 2009). No issue was brought to the Review Board for resolution. During the Board meeting on June 23, the Board has concluded that the review has been successful.

The reviewers concentrated their examination on the Resource Management, Configuration Management, Verification and Control, Performance Profiling, the simulation and its validation, the external interfaces and made constructive remarks in all these areas. As for the System Review, ESA has asked also an external reviewer (V. Innocente from CERN) with expertise in large and collaborative data processing to assess the DPAC advancement and the adequacy of its general architecture to carry out safely the processing of the Gaia data. This generated nearly 30 recommendations on the management, the software validation, the testing, the security level, the execution framework and ended up with a very positive conclusion on the progress made.

As said earlier the review concluded positively for the DPAC and SOC and this was a very valuable exercise for the Consortium. One must now draw the best out of the remarks formulated by the Review Panel to improve our organisation and achieve the expected readiness level when the first data will enter the processing chains.

The next review will take place early 2011, when we have already started the end-to-end testing.



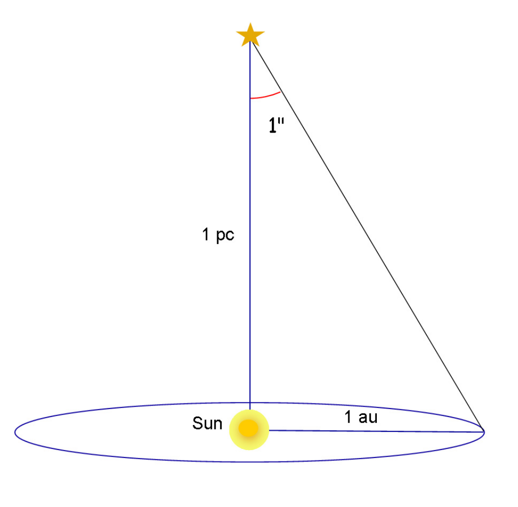
Parallax & Parsec:

Parallax is ubiquitous in astronomy and the term has been used for many centuries in relation with the distance of astronomical sources from the Moon to the most distant stars in our Galaxy.

Strictly speaking the word refers to the apparent change in the direction of an object, caused by a change in observational position yielding a new line of sight. This is exactly what astronomers probe with angular sights, from which the distance is derived as the inverse of the measured parallax.

For the stars, distances were initially given in light-years, totally unrelated to the measurement technique, until ***parsec*** was coined by the British astronomer H.H. Turner as the distance of a star having a parallax of 1". The name became standard after its adoption was proposed by F. W. Dyson, the then Astronomer Royal, in 1913 (MNRAS, LXXIII, 1913). At the same time the Swedish astronomer and statistician C. V. Charlier, who was director of the Observatory at the University of Lund, had suggested siriometer instead for the same quantity.

The word has not totally slid into oblivion and officially means one million of astronomical units (roughly 5 parsecs or about the distance of Sirius), although its use is probably restricted to a small circle of crossword wizards.



Definition of a stellar distance of one parsec

Focus on partners

Dept of Astrophysics, Astronomy and Mechanics of NKU of Athens *by Mary Kontizas*

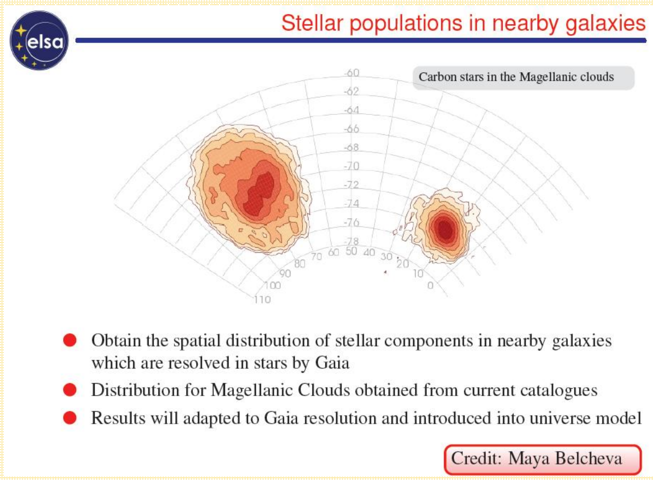
The Department of Astrophysics, Astronomy and Mechanics (*http://www.cc.uoa.gr/physics/sections/astrophysics/index.html*) of the National and Kapodistrian University of Athens hosts about 40 researchers, PhD students and support personnel. The main research areas are extragalactic astronomy (stellar populations in galaxies, galaxy evolution), variable and binary stars, theoretical astrophysics (AGNs, astrophysical jets), space astronomy, solar physics, gravitational waves, theoretical mechanics.

Our **NKUA Gaia** group includes four people from the University (Mary Kontizas, coordinator, Evdokia Livanou, Antonios Karampelas, Maya Belcheva), hosts three researchers from the National Observatory of Athens (Evangelos Kontizas, Ioannis Bellas-Velidis, Anastasios Dapergolas) and one researcher from the National Technical University of Athens (Romylos Korakitis). Our group is one of the 14 participants of "ELSA", (a Marie Curie RTN project).

In the DPAC we work both in CU8 and CU2.

1) For CU8, we are responsible for the TWP GWP-S-832 (Unresolved Galaxy classifier). The goal of this task is to classify unresolved galaxy spectra and estimate their astrophysical parameters. To achieve this we have produced libraries of synthetic galaxy spectra compiled with the code PÉGASE 2.0* .

2) For CU2, we work in the framework of the Universe model for the production of a library of synthetic galaxy spectra for various spectral types, inclinations and redshifts and the simulation of the spatial distribution of galaxies resolved in stars by Gaia.



Example of activities of the NKUA Gaia Group

*editor's note: PÉGASE is a code developed at the Institute of Astrophysics of Paris (IAP) to study the spectral evolution of galaxies from the evolutionary track of their stellar content, allowing for the gas and dust in the radiative transfer.

Lohrmann-Observatorium, TU Dresden *by Sergei Klioner*

Lohrmann-Observatorium (*http://astro.geo.tu-dresden.de/*) is a rather small astronomical institute belonging to the Dresden Technical University.

The core of the Observatory consists of four researchers and two technical and administrative staff. Besides the staff members, there are also four post-docs and a number of PhD students.

The Gaia group in Dresden (*http://astro.geo.tu-dresden.de/Gaia*) consists of five people: Lexey Butkevich, Sergei Klioner, Serge Mouret, Michael Soffel and Sven Zschocke.

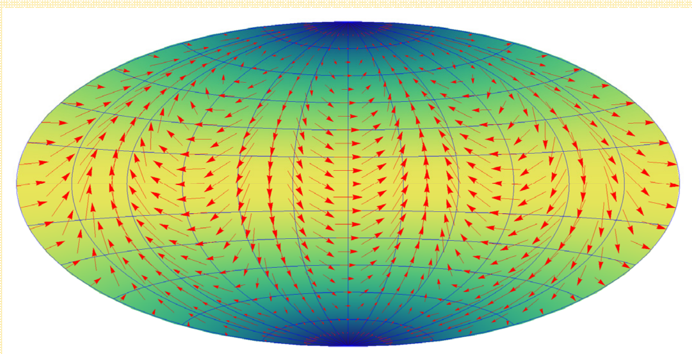
The main contributions of our group deal with the relativistic model and tests, reference frame and the techniques for the astrometric solution.

This Gaia work is primarily within the Core Processing in CU3 with the responsibility of the Relativistic Model and Test (REMAT). The group has also smaller contributions to CU2 and CU4.

We are responsible for the design, implementation and maintenance of the operational relativistic model GREM (Sergei Klioner, Sven Zschocke, and Michael Soffel).

Another activity area is related to the determination of Gaia velocity from Gaia's own astrometric data as a part the global astrometric solution (Alexey Butkevich and Sergei Klioner). Modelling of subtle effects in the motion of asteroids is the subject of Serge Mouret. We all are contributing to the formulation of a complete set of relativistic tests with Gaia data.

Our Gaia activity is supported by the German Space Agency (DLR) and the German Research Association (DFG).



Plot of the stream of 'proper motions' caused by a low frequency gravity wave propagating in the direction 90°. The use of Gaia as a gravity wave detector is under study.

Testing General Relativity with Gaia *by David Hobbs (Lund Observatory)*

The core data reduction for Gaia, known as the Astrometric Global Iterative Solution (AGIS), uses an astrometrically well-behaved subset of all observed objects called 'primary stars' which will number at least 100 million. The core solution simultaneously determines the astrometric parameters (positions, parallaxes and proper motions), the accurate spacecraft attitude and the geometric instrument calibration. In addition, a small number of global parameters will be estimated, one of these being the Parameterized Post Newtonian (PPN) parameter gamma (γ).

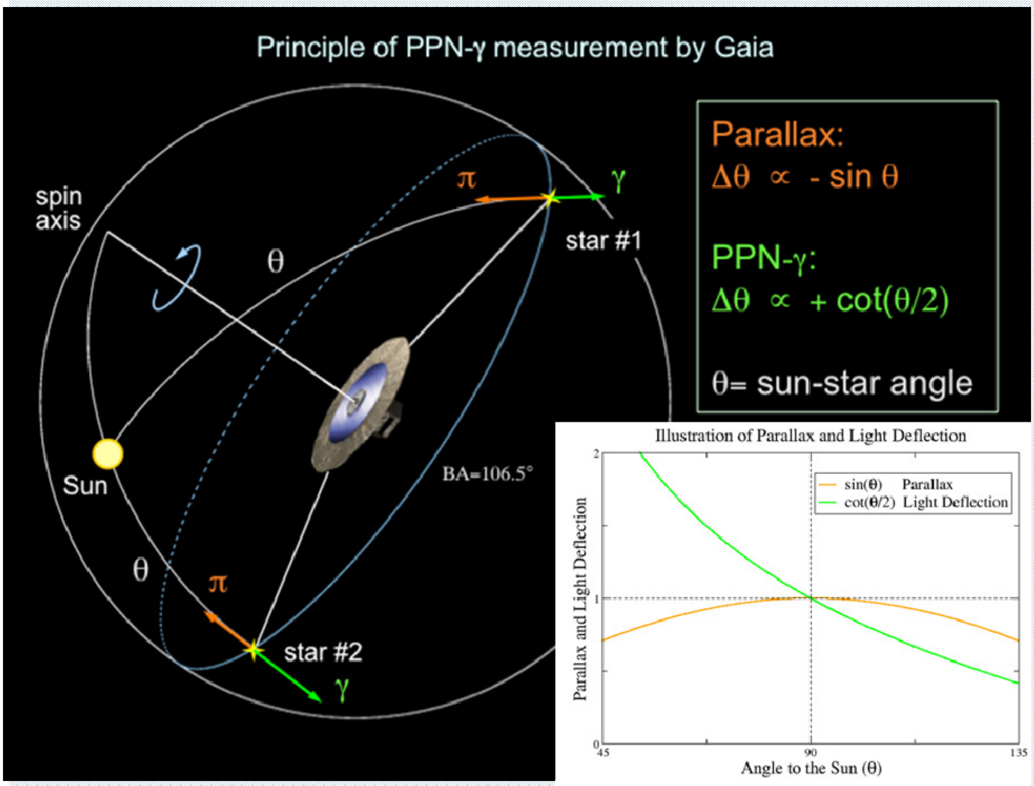


Illustration of the Gaia measurement principle for parallax and light deflection.

The PPN formalism was developed to make sense of the large number of alternative theories of gravitation, to elucidate their similarities and differences, and compare predictions with experimental results in a systematic way. The formalism characterizes the slow motion, weak field limit of gravitation by a set of 10 real-valued parameters, and is ideally suited to the analysis of solar system gravitational experiments. Measurements of PPN parameters can be compared with their values in Einstein's general theory and can place constraints on which, if any, alternative theory of gravity is correct.

Of the 10 parameters used in the formalism, Gaia is expected to provide useful constraints on β, measuring the degree of nonlinearity in the superposition law of gravity, and γ, measuring the curvature of space-time (and, hence, the degree of gravitational light deflection) due to rest mass. Of interest here is that some alternative theories of gravity predict deviations of these parameters from their values in general relativity ($\gamma = \beta = 1$). For PPN γ this deviation could be of the order of 10^{-5} to 10^{-8}. It is, therefore, highly interesting to estimate the accuracy by which this parameter could be determined from Gaia observations.

The direct measurement of large angles is fundamental to Gaia's ability to construct a globally consistent reference system as well as to determine stellar parallaxes and PPN γ. Gravitational light deflection by the Sun causes an apparent shift of a distant object, by a few milliarcseconds, in the direction away from the Sun (green arrows in the figure).

By contrast, stellar parallax causes an apparent shift towards the Sun (orange arrows in the figure). To first order, the two effects are highly correlated and difficult to distinguish.

This correlation slows down the convergence of the iterative solution, so an artificial parameter has been introduced to estimate and eliminate this correlation without changing the final solution for PPN γ in any way.

To estimate the accuracy of PPN γ large numbers of small-scale astrometric solutions are performed, taking into account the simultaneous determination of stellar astrometric parameters, the satellite attitude and PPN γ. Accurate determination of PPN γ requires that as many relatively bright ($G < 16$) stars as possible are used in the solution as these give the largest contribution due to lower observation noise. Extrapolating the results of these small-scale simulations to the full-scale solution for Gaia, assuming some 100 million primary stars, demonstrates that PPN γ could be obtained to $\sim 10^{-6}$ which is significantly better than today's best estimate from the Cassini mission with an accuracy of 2×10^{-5} and also within the range predicted for some alternative theories to deviate from general relativity. This also assumes that remaining minute instrumental or modelling effects are not significantly correlated with the γ-signature in the astrometric signal.

Monitoring the Gaia Basic Angle *By Daniele Gardiol (INAF-Osservatorio Astronomico di Torino)*

The Gaia optical configuration is based on two telescopes mapping two different fields of view (FOV) on the same Focal Plane (FP) and therefore superimposed onto a single image.

The angle between the two pointing directions is referred to as the Basic Angle (BA). Optically the BA can be defined as the angle formed by the lines of sight (LOS) of the two perfectly aligned telescopes. But it is also possible to give a definition that is more useful for practical purposes.

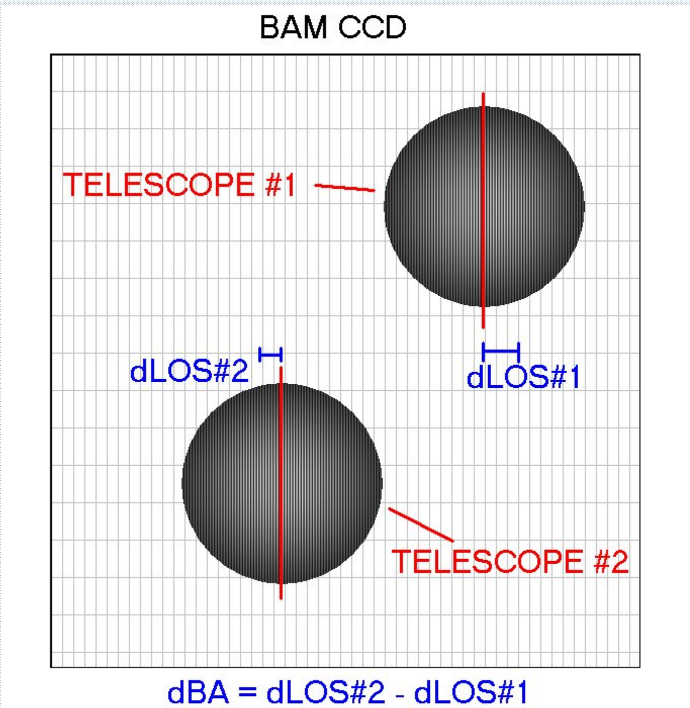
Consider two stars in the sky separated by exactly the BA, and two telescopes in their nominal configuration pointing at them. The position of the stars on the FP defines the BA value as the distance between the two star images, nominally zero. A variation of the BA can then be measured as a change in the stars position onto the FP.

But why is the BA so important?

In a very simple description, the equation that links the position of two objects (1,2) in the two FOVs is:

$$\xi_2 - \xi_1 + \varepsilon + \varepsilon_{BA} = s(y_2 - y_1) + BA$$

where ξ_i, y_i are the object position respectively in the sky along the scan circle and on the image (here we are concerned with the coordinates along the scan direction), ε_{BA} is the residual error due to BA variations, ε represents the other contributions to the final error, S is the CCD scale, and the subscripts identify the two objects.



Assuming stochastic error terms, the stars position can be expressed as

$$\xi_2 + \frac{1}{2}(\varepsilon + \varepsilon_{BA}) = s \cdot y_2 + \frac{1}{2} BA$$

$$\xi_1 - \frac{1}{2}(\varepsilon + \varepsilon_{BA}) = s \cdot y_1 - \frac{1}{2} BA$$

This tells us that the error associated to the measurements can be severely affected by a fluctuation of the BA of the same order of magnitude, and therefore adequate knowledge of the BA behaviour becomes a crucial issue. In addition, systematic changes in the BA at the spin period cannot be distinguished from a global parallax shift.

Low frequency BA variations, induced by mechanical distortions due to thermal fluctuations, will be recovered by the astrometric solution over a few spin periods. But this procedure fails at higher frequencies and to monitor the BA variation on shorter timescales, a dedicated instrument, the Basic Angle Monitoring device, has been added to the payload.

The BAM principle is based on the generation of two artificial stars by mean of a coherent monochromatic laser diode source. Each beam feeds one of the two telescopes, and is focused onto the same BAM dedicated CCD (see figure).

To improve the resolution in estimation of the star position an interference pattern is generated, obtained by splitting each of the original beams. A change in the BA due to small movements of the telescopes mirrors induces a differential fringe motion that can be detected and measured. The BA shall be monitored with accuracy better than 0.5 μas rms over 5 minutes; this variation corresponds to an optical path difference of 1.5 pm rms (equivalent to ~ 1.8 . 10^{-6} λ @ 850 nm).

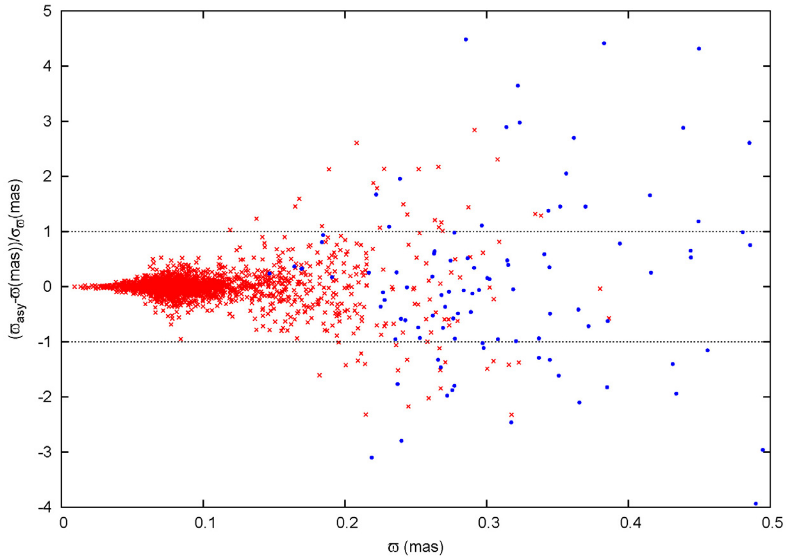
The Basic Angle variation is obtained from the relative shift between the fringes generated by Telescope #1 and Telescope #2 onto the BAM-CCD.

Focus on ELSA programme: Ester Pasquato, Brussels University

Ester Pasquato is a PhD student at Brussels University (ULB) and is working on "Effects of stellar surface inhomogeneities on Gaia astrometric accuracy". Since October 2007 she is working under the supervision of Alain Jorissen and Dimitri Pourbaix. Until now she has elaborated a model, based on 3D numerical simulations, of the star photo-centre motion due to the presence of brightness asymmetries. This model is being added to GOG (the Gaia Object Generator within the general simulator of CU2) and simulated data for asymmetric stars will be available soon.

By reducing simulated data for single stars through the standard Gaia pipeline, with or without the addition of the asymmetries, and by comparing the derived five astrometric parameters (position, parallax and proper motion) Ester is getting an estimation of the error induced on the parameters. On top of that, she is studying the behaviour of the goodness of fit parameter, which is crucial in the CU4 data processing flow as it is used to decide on the activation of the different branches of the pipeline.

Its modification due to the brightness asymmetries could cause the star being uselessly processed through all the steps of the CU4 pipeline.



Ratio between the error on the parallax induced by the brightness asymmetries and the error derived from the data reduction as a function of the parallax of the star for a sample of 2000 stars. Different colours correspond to different values of goodness of fit parameter (GoF); stars with GoF>3 (blue points) will enter the CU4 pipeline, stars with GoF<3 (red crosses) will not.

News & events

☞ **The Milky Way and the Local Group - Now and in the Gaia Era**

From August 31, 2009 to September 04, 2009.

Organisation: Centre for Astronomy of the University of Heidelberg, Germany.

Contact: Eva K. Grebel, Ulrich Bastian. **Website:** http://www.ari.uni-heidelberg.de/meetings/milkyway2009/

☞ **ELSA School on « the Techniques of Gaia »**,

From September 28, 2009 to October 02, 2009.

Organisation: Centre for Astronomy of the University of Heidelberg, Germany.

Contact: Stefan Jordan and Alex Bombrun. **Website (DPAC restricted): wiki DPAC / ELSA pages**

Calendar of next DPAC related meetings

Date	Place	Who	Type	Resp.
03 - 14/08	Rio de Janeiro	IAU GA		
10 - 11/09	Geneva	DPACE #09		F. Mignard / L. Eyer
17 - 18/09	ESTEC	GST #28		T. Prusti
22 - 23/09	Cambridge	CU1	Plenary	W. O'Mullane
28/09 - 02/10	Heidelberg	ELSA	Training WS	S. Jordan
15-16/10	Tenerife	CU1	Java WS	W. O'Mullane
12-13/11	Dresden	CU4	Plenary	D. Pourbaix / S. Klioner
16/11	Nice	GBOT		M. Altmann / S. Rousset
17-18/11	Nice	GBOG	Meeting #6	C. Soubiran / P. Bendjoya / S. Rousset
19-20/11	Nice	GREAT	Plenary	N. Walton / F. Mignard / S. Rousset
23-25/11	Nice	CU6	WorkShop	D. Katz / F. Thévenin / S.Rousset

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