Gaia DPAC Newsletter 9

N° 9 - July 23, 2010

EADS Astrium, Toulouse, 06 July 2010

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front: X. Luri, R. Drimmel, F. Thévenin, W. O'Mullane, U. Bastian

Picture: W. O'Mullane

During the last DPACE meeting held in CNES (Toulouse) a visit at EADS Astrium was organised for the participants. The picture shows members of the DPACE and a couple of other people before entering the white room where the Gaia payload is being integrated. Seeing the SIC torus and one of the primary mirrors in real size was truly impressive.

Editorial *by DPAC chair, François Mignard*

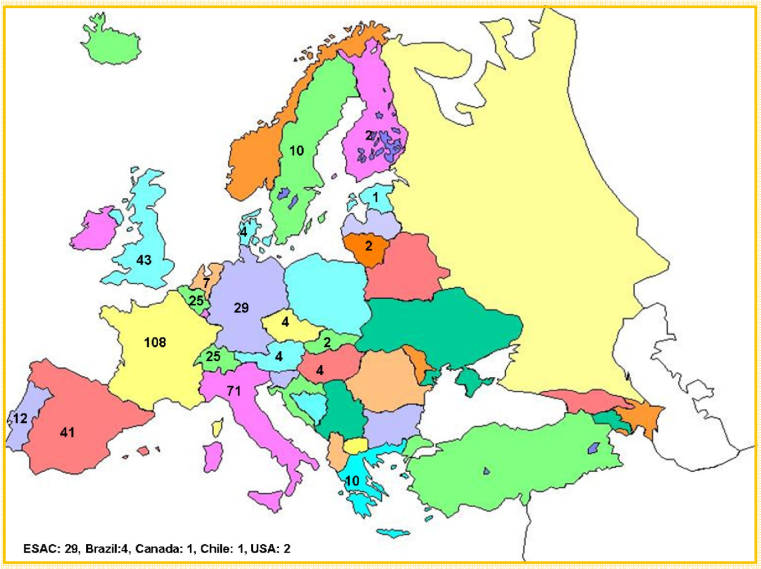
The last few months have witnessed a surge in the number of DPAC related meetings, with all CUs but CU8 holding a plenary or topical meeting to review their advancement and prepare the next development cycle. Beside these regular gathering there were also a meeting of the DPACE in early July, a Gaia Science Team meeting, the Steering Committee of the DPAC with the funding agencies, let alone the GREAT plenary and management meetings to decide on the second round of ESF calls.

Finally, several more science oriented meetings took place including the very successful final ESLA symposium organised in a wonderful setting in the immediate outskirts of Paris and two workshops, one dealing with the Gaia science alerts in Cambridge and the other one for the extragalactic science with Gaia, a topic which had so far retained little attention, but attracted a wide range of attendants not familiar with Gaia. Both demonstrated that a community much wider than the DPAC is truly in the making around Gaia with great expectation from the early or final mission products.

You will see in this summer issue of the NewsLetter, several references to these activities, together with the presentations of new technical issues like the time metrology required to meet the Gaia promises in astrometry or the windowing scheme applied on board to keep the telemetry flow manageable. Also a team from the Observatory of Bordeaux describe what they are doing to exploit the imaging capabilities of Gaia to classify galaxies, an objective that is very likely new for most of the DPAC member.

Good reading to all of you before a long awaited summer break.

DPAC news: Consortium statistics *(based on data from ESA - My Portal, May 2010)*



<u>Main figures:</u>

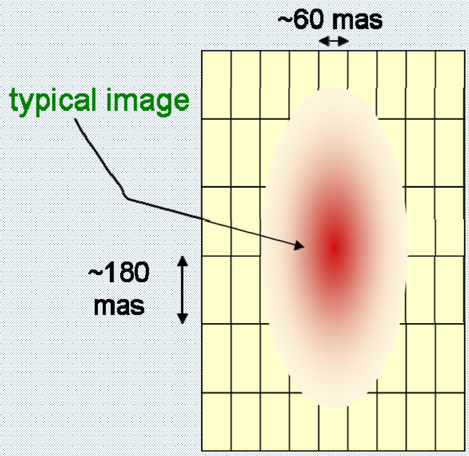
- 440 members *(inc. 21 that belongs only to DPCs)*
- 24 Funding agencies
- 85% in the 10 largest

Words of Gaia

Window

The word 'Window' is ubiquitous in the Gaia documentation dealing with the CCD acquisition or with the initial processing. The on-board software can handle pixel data in two ways: a full readout mode where all the pixels of a CCD are readout, or a windowing mode where only a subset of pixels is readout. Why should we bother with this on-board selection which looks like an unnecessary complication?

On the average, at any time, there are about 300 stars imaged on one CCD from the combination of the two fields of view. Each diffraction pattern covers approximately 6ALx6AC pixels, that is to say 36 pixels. There are 9 millions pixels in one CCD, meaning that about 1 pixel out of 1000 is harvesting photons from a celestial source. Therefore, downloading all the pixel data will essentially result in transmitting uninteresting noise and will explode the telemetry volume. Selecting interesting zones within a window solves the issue at the expense of a more complex on-board data handling.

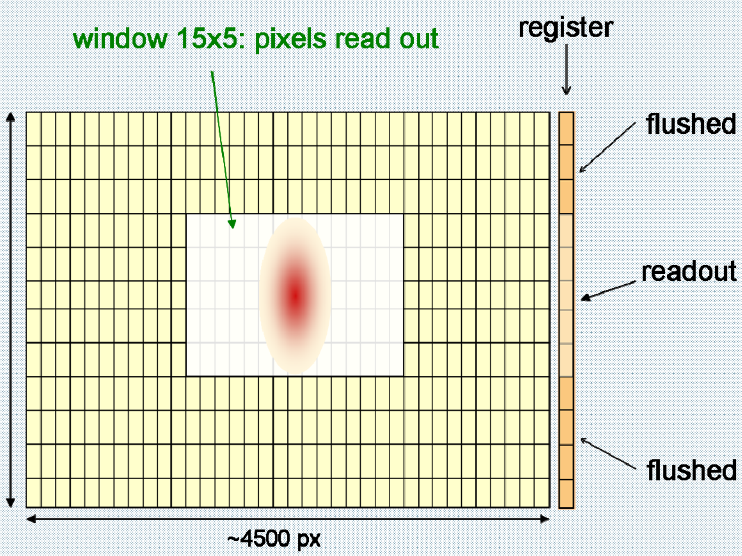


↑ *Illustration of typical diffraction pattern on the Gaia focal plane.*

But there is more and one can kill two birds with one stone: focus now on the CCD readout register after the images have crossed the CCD in the AL direction over 4.5 s. A line of ~ 2000 pixels must be transferred every TDI period of ~ 1 ms. What fraction of these pixels carries useful information? It is easy to show that the proportion is still 0.001, meaning that over one line of ~ 2000 units in the register, there are only 2 units with real data and 1998 with noise (this is an average over many TDIs). The faster one reads a pixel on the register, the larger is the noise created by the reading process itself. If one read the ~ 2000 pixels of a line in 1 ms (= 1 TDI), the readout frequency would be about 2 MHz, generating a lot of noise. Knowing that there are only few interesting pixels in one line, one can read them at low frequency, improving the noise performance, and flush out the useless pixels at high frequency, without damage.

This is the principle of Gaia windowing. Optimising the window sizes and shapes, has been a long process in which our Danish and retired colleague E. Hoeg brought many innovative ideas.

↓ *Windowing principle for an astro CCD. Only the useful pixels are read out, at low frequency.*



The Gaia team at the Astronomical Padova Observatory and Astronomical Department of Padova University *by A. Vallenari*

The Astronomical Observatory of Padova is one of the main structures of the Italian Istituto Nazionale di Astrofisica (INAF). About 30 people of scientific staff plus 20 post-docs and students are hosted there.

The Observatory, known also under the name "Specola", is located in the ancient part of the old medieval castle of Padova dated from the 13th century (see fig. below *courtesy of E. Giro*). The adjacent building accommodates the Astronomical Departments of the Padova University with about 70 people, including scientific staff, students and post-docs. The Institutes are very active in different fields such as stellar evolution, solar system, galaxies and high energy and relativistic astrophysics. A long standing tradition concerns technological activities in the optical and infra-red domain, both for ground-based and space observatories.

The Padova group has been involved in Gaia as early as 1999, when several researchers participated as members of the various working groups, in the definition of the scientific targets of the mission. Nowadays, the Gaia Team in Padova consists of 10 people of both Institutes collaborating on different topics.

The main contribution is in CU8. Our responsibility is to prepare the training data for classification algorithms. Our tasks include the preparation and the testing of synthetic spectral libraries, the modeling of unresolved galaxies in strong collaboration with other CU8 groups and with CU2. A considerable effort is devoted to the computation and delivery of large sets of up-to-date stellar isochrones and tracks. We are part of the CU8 GBOG activities to provide observed spectra. Our team participates also in the management and coordination of CU8 activities.

Finally, very recently, we got involved in the photometric science alert, for the detection and follow-up of supernovae.

All the Gaia activity at OAPD is currently funded by the Agenzia Spaziale Italiana and by INAF.

The Observatoire de la Côte d'Azur and the local Gaia team *by F. Mignard*

The Observatory of the Côte d'Azur is a French public research institute carrying out research in the area of the Science of Universe, basically astronomy and Earth science. It is associated to the University of Nice Sophia Antipolis and to the CNRS, the national organisation for basic research. Its four research labs are located in the Nice area and the Gaia team belongs to the Laboratory Cassiopée with all its staff stationed on the historical grounds of the Observatory, on top of a hill overlooking Nice and the Mediterranean coastline.

The local Gaia team comprises 10 permanent positions, 2 emeritus scientists and 5 PhD or postdocs involved at different levels in the DPAC or GREAT activities. Besides Gaia and DPAC, most of the scientists of the team develop their own research activities in galactic and stellar physics, physics and dynamics of small solar system bodies or fundamental astronomy.

Regarding the DPAC, one must single out the following activities:

- several responsibilities in the DPAC and CU top level coordination, with the current DPACE chair (F. Mignard) and his assistant (S. Rousset), and the deputy managers of the CU4 (P. Tanga) and CU8 (F. Thévenin); In particular the DPAC Newsletter content is defined by a local editorial board and realised by S. Rousset.

- Major software development for the processing of the solar system objects in CU4, including the photometric and taxonomic classification and the simulation of these particular sources for CU4 and CU2.

- Algorithmic and software development for the General Stellar Parametriser in Spectroscopy within the CU8, to provide an automatic determination of the astrophysical parameters of the stars, including chemical abundances, from the RVS data. Also in CU8, writing of a code to produce the best estimates of the luminosity, age and mass (WP FLAME) of the individual stars from the combination of the Gaia data.

- For CU6, generation of 3D stellar atmosphere models of late type stars to build up a grid of reference and help interpret the spectra.

- Production of synthetic spectra for FGK stars to help exploit the RVS data.

Finally, many DPAC and GREAT related meetings are organised locally and benefit from the support of the Observatory and the Gaia team.

From Left to Right: L. Bigot, M. Delbo, L. Santoro, A. Recio-Blanco, G. Kordopatis, F. Mignard, C. Ordenovic, V. Hill, B. Pichon, S. Rousset, S. Goletto, F. Guitton, A. Bijaoui, P. Tanga, T. Merle.
Missing: P. de Laverny, P. Morel, M. Mueller, E. Slezak, F. Thévenin, C. Worley

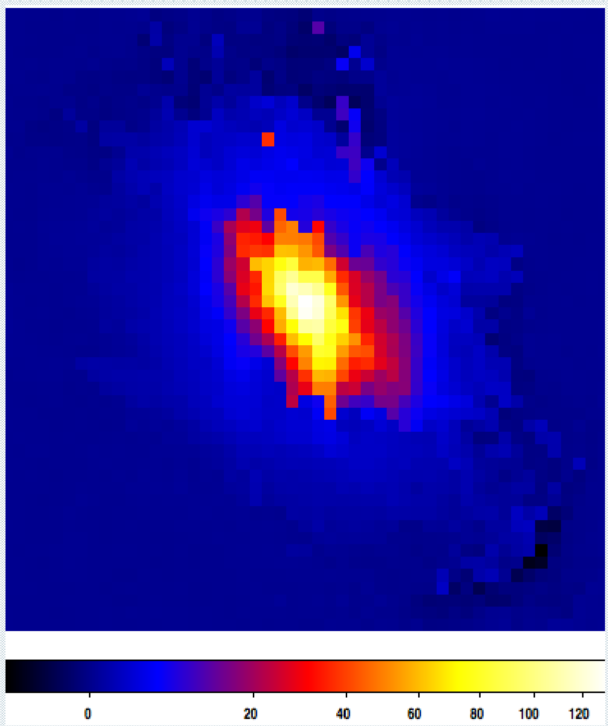
The morphology of millions of Galaxies that Gaia will observe

by C. Ducourant, A. Krone-Martins and R. Teixeira (Observatoire de Bordeaux)

Gaia's main goal is to study the composition, the structure, the formation and the evolution of our Galaxy and of its stellar content and to provide us with their highly accurate astrometric and photometric parameters. However the satellite will also survey many others objects. Gaia will observe a few millions galaxies and will offer us a unique opportunity to access to a whole sky survey of these objects that no ground-based survey has recorded. The high resolution of Gaia's observations, privilege of space astronomy, will allow the observation of small galaxies that could not be resolved from ground based surveys such as the Sloan Digital Sky Survey.

various transit angles, it is possible to numerically stack theses one-dimensional windows to produce a two dimensional map of their surrounding (thanks to D. Harrison from CU5 who developed the 2D image reconstruction code based on A. Bijaoui and C. Dollet algorithm).

To process simulated data from galaxies we developed a specific tool to introduce them into GIBIS: MAGIL (Manager of Gaia Images Library). The reconstructed images are rather small (~<2.5") and therefore limit the category of objects for which it will be possible to derive morphologic parameters.



2D reconstructed image (2.5"x2.5") of a bright spiral galaxy.

The spectrophotometry and astrometric solution derived for these objects will allow CU8 to classify a vast fraction of them and derive their astrophysical parameters. However, no information about their structure will directly be available. Nevertheless the information on the structure of these objects is present in Gaia's observations and can be retrieved. This is the objective of the "Extended Objects" DU470 of CU4 which has dedicated efforts to recover and analyse the spatial structure of the galaxies. This information may also be important for the classification of atypical extragalactic objects.

Gaia observations are very specific: the information from most windows is binned in the across scan direction of transit (for objects fainter than G=13) and the resulting information transmitted to earth is one-dimensional. Since objects will be recorded, on average, 70 times (depending on their position in the sky) in

Moreover, they contain artefacts which are consequence of the reconstruction method and of the specificity of the Gaia sampling of the scanning directions. These 2D maps are then measured to derive robust parameters that describe well their content: concentration of light, asymmetry, smoothness and momentum. Then, using these parameters, a morphologic classification is performed via a Support Vector Machine to answer the question: what is the object we are looking at, an elliptical, an irregular or a spiral galaxy?

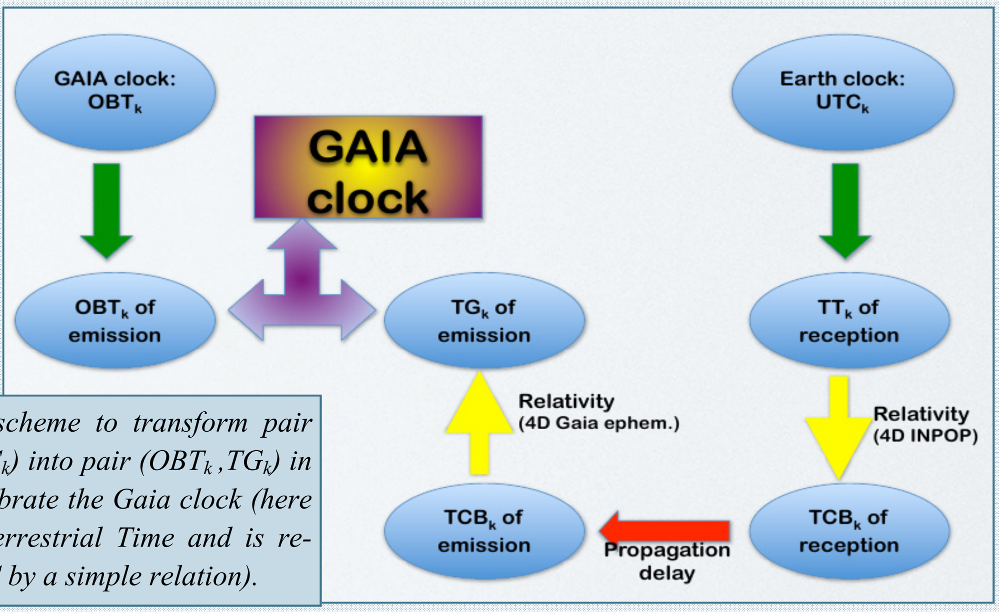
Once this is assessed, we perform a global analysis (based on Genetic Algorithms and Radon transforms) of the individual astro field and sky mapper observations to fit the appropriate bulb and disk profiles. We then derive the characteristic parameters such as size and "boxyness" of bulb and disk, axis ratio, position angle and relative surface brightness of each component of these small galaxies that Gaia will observe.

Calibration of the Gaia clock

by C. Le Poncin-Lafitte (Observatoire de Paris, SYRTE)

The Gaia rubidium clock plays a key role in the operations of Gaia and in the processing of the observations. On-board, the Gaia central clock will regulate the TDI clocking, provide a local time scale and be used to time stamp all observations. A careful monitoring of the clock is planned involving a full relativistic modelling of the time transfer between the ground and the spacecraft and an accurate model of the clock behaviour fitted to the synchronisation events generated on board.

The clock can be seen as a regular counter realising its own time scale referred to as OBT (On Board Time). However this clock is reset from time to time for technical reasons, and does not deliver a monotonously increasing scale; a modified version overriding those potential resets, has been defined by DPAC and called OBMT (On Board Mission Time). These two technical time scales must be related to the time scale used in the data processing, *i.e.* TCB (Temps Coordonnée Barycentrique) which is the time scale of the Barycentric Reference System defined by the International Astronomical Union.



Relativistic scheme to transform pair (OBT_k , UTC_k) into pair (OBT_k ,TG_k) in order to calibrate the Gaia clock (here TT is the Terrestrial Time and is related to UTC by a simple relation).

Specific requirements for the science products impose precise absolute timing and require that the OBT time scale be correlated to TCB with an accuracy of roughly one microsecond. However, if OBT can be viewed as a practical realization of the relativistic ideal Gaia proper time (TG for *Temps de Gaia*) along the worldline of the satellite, it suffers from the imperfections of the clock, meaning that in practice the OBT and TG time scales will be different.

Moreover because of the motion of Gaia and the non-zero gravitational potential at the spacecraft location around the Earth/Sun L_2 point, it is not straightforward to relate TG and TCB and a complete relativistic time transformation must be computed when the orbit of Gaia is known. The principles are well known and within reach of the DPAC experts in this field. The remaining issue is then to relate the ideal Gaia proper time (TG) and the generated time scales (OBT, OBMT): we call this task the *OBT-TG calibration*.

This is achieved by comparing the Gaia clock with Earth ground clocks. However, Gaia is observable from the ground only for about 8 hours per days, during the visibility above the ground station, during which time telemetry procedures are activated. The procedure consists in the interrogation of the Gaia clock to create a time tag *OBT_k of emission* stored by the onboard computer into a time telemetry packet, subsequently sent to the Earth.

After the flight time of the signal between the satellite and the Earth, the time telemetry package is received by the antenna of a ground station. A new time delay is then necessary to transfer the package from the antenna to a computer where a time tag *UTC_k of reception*, in Universal Coordinated Time, is created and stored. We finally obtain a pair *(OBT_k , UTC_k)* for each synchronisation event.

All these pairs constitute the initial data set that we use to deduce first a new set of pair *(OBT_k, TG_k)* by subtracting all station/on board delays and applying time scale transformations. Then for each pair *(OBT_k, TG_k)*, we will get a relation such that $OBT_k - TG_k = F(OBT_k)$. It remains to devise an expression of the function F and determine the free parameters with a least squares fitting on all pairs.

The final result is the *OBT-TG calibration* that will be used in the data processing chain to refer all measurements to a unique and well defined astronomical time scale.

About ELSA *by Lennart Lindegren (Lund Observatory)*

The ELSA contract comes to an end - but the work continues!

The Marie Curie research training network ELSA (European Leadership in Space Astrometry) comes to its formal end on 30 September 2010. Over the past years ELSA has employed 15 PhD students and postdocs to conduct original research in support of DPAC and the future scientific exploitation of Gaia (see previous Newsletters where several fellows have presented their work).

The culmination of the ELSA activities was the organization of the symposium "Gaia: at the frontiers of astrometry" on 7-11 June 2010, see http://ftphip.obspm.fr/gaia2010/. The symposium gathered some 120 participants at the Centre International d'Etudes Pédagogiques (CIEP) congenially located in the former Royal Porcelain Workshop at Sèvres, near Paris. The meeting gave an impressive account of the multifaceted work of the ELSA fellows, put in an international perspective through the broad participation of experts from many fields of Gaia science as well as projects such as the Japanese Nano-JASMINE satellite and the U.S. projects JMAPS and SIM Lite.

The end of the EU-supported project does not mean that the research programme is finished. Most of the PhD students have another year to obtain their doctoral degree and several postdocs continue work within DPAC. Most importantly, the extensive knowledge base and strong network of personal contacts built up during the project will continue to develop and help shaping the future Gaia community.

The ELSA conference, Sèvres, 7-11 June 2010 supported by Marie Curie Actions, L'Observatoire de Paris - GEPI, CNES, CNRS.

GREAT Update

The ESF RNP (Research Networking Programmes) Steering Committee awarded funding for several science workshops or conferences and exchange visits. Two conferences will be supported by the ESF funding, one on the Milky Way science to be held next spring in the French Alps, and the second on the Cosmic Distance Scale scheduled for early May next year in Naples. Similarly three workshops dealing with Gaia science have been selected on (i) QSO astrophysics and fundamental physics, (ii) the Chemo-Dynamical Survey with spectrophotometry and spectroscopy and (iii) asteroid science with and after Gaia. Meeting details and websites will be soon available on the Gaia meeting calendar webpage.

Calendar of next DPAC related meetings

Date	Place	Who	Type	Resp.
14-15/09	CNES	CU1	JAVA WS	W. O'Mullane
16/09	CNES	CU1	Plenary	W. O'Mullane
17/09	CNES	PO	Plenary	E. Mercier
29/09-01/10	Heidelberg	CU3	Management	U. Bastian
07-08/10	ESTEC	GST#32		T. Prusti

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

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