Newsletter 21

30 JULY – 2013

The Gaia spacecraft (payload and service module), in the Astrium premises, being packed in its high-tech case in preparation to the shipping to Kourou in about a month. The deployable sunshield together with its umbrella-like mechanism will be dispatched in a separate shipment few days afterwards.

IN THIS ISSUE:

Editorial by DPAC chair, Anthony Brown

With the Mission Flight Acceptance Review successfully concluded Gaia is now ready for launch and has been assigned a launch window from November 17 to December 5 2013, with the Gaia Project Team aiming for a launch on the first day of the slot. Meanwhile Gaia has been `switched off' and packed and will be shipped to Kourou in early September in order to prepare for its launch. Ready to go at last!

The Ground Segment Readiness Review for DPAC was also successful, having demonstrated that the processing software that is needed for commissioning and early operations is ready and the people involved have been trained through the operations rehearsals. Thus everything is set on our side for the Gaia launch.

Over the next months DPAC will not sit still of course. The early mission processing software will be rounded off, the calibration teams will continue their preparations, the detailed planning for the longer term has started, and CU9 will start gearing up for the first data release. One more operations rehearsal is scheduled for early September in order to keep everyone ready for when the first data start arriving.

Everyone in DPAC should make sure to be well rested for the upcoming very exciting times, so I wish you all good summer holidays!

DPAC

Anthony Brown

In May the last major review of DPAC before the start of operations, the Ground Segment Readiness Review, took place. Overall the GSRR board and the external reviewer (V. Innocente from CERN) were positive about the status of DPAC and satisfied that the ground segment (DPAC, SOC, and MOC) is ready for Gaia launch and operations.

The one concern raised about DPAC was that the planning of the cyclic pipelines, which ultimately produce the science data products, was not as mature as for the systems involved in the early operations. This was subsequently addressed by making a much more detailed long term plan which takes the early data release scenario into account. This scenario is now publicly available on the Gaia web pages (http://www.rssd.esa.int/gaia). The Project Office worked out a plan which details when each cyclic software system needs to be tested, validated, and operational, in order to meet the goals of the data release scenario. The plan will be used to monitor the progress of the development of the cyclic pipelines in DPAC.

At the beginning of June a big test took place in which the Mission Operations Centre was in contact with the actual Gaia spacecraft in Toulouse. The calibration team from the Science Operations Centre was also involved and exercised the on-board activities to be carried out during the commissioning phase.

The first Gaia data generated from the actual spacecraft were received, and the commanding of the spacecraft was successfully exercised.

From August 28 to September 6 the fourth DPAC/SOC operations rehearsal will take place. This rehearsal will simulate nominal operations and will have a number of specific features needed for testing the daily processing pipelines. A high-volume day will be included (to validate the performance of the IDT/FL system) as well a stretch of data with a realistically simulated spacecraft attitude (based on the physical Dynamical Attitude Model). The rehearsal will serve also to keep everyone ready for the early operations and will be followed by an operations workshop, where the lessons learnt from the rehearsal can be discussed and the final details before the start of DPAC operations can be sorted out.

Finally, with the launch of Gaia approaching a range of outreach activities are being planned, coordinated by DPAC-CU9 and the ESA communications department. Apart from the ESA-led events around launch, several national and international initiatives are being pursued. For example at the University of Barcelona work is being completed on a Gaia smart-phone `app', and a relatively inexpensive 3D-printed model of Gaia has been developed. Very useful for explaining the mission to a general audience! The GREAT-ITN is coordinating the `GaiaLive in school' event in which children in schools across Europe will be taught about the Gaia mission and will be connected live to the MOC in Darmstadt, giving the kids the opportunity to see spacecraft operations and ask questions to the Gaia people in Darmstadt.

Coordination Unit 5

Floor van Leeuwen, CU5 manager

Although Gaia is primarily an astrometric mission, its overall success also depends on the photometric data associated with each source.

The Gaia photometry

The photometric data cover broad band photometry and dispersion spectra as obtained for each observed source. The photometric data are input to the variability analysis (CU7), classification (CU8) and chromaticity corrections in astrometry (CU3), and form a key element in the Gaia iterative reductions. Coordination Unit 5 (CU5) is responsible for the processing of those data, which covers the development and testing of the software, its execution at the Cambridge Data Processing Centre (DPCI), and the publication and documentation of these processes. Also the derivation of the fluxes from the measurements in the astrometric field, the implementation of which (in IDT and IDU) is a CU3 task, is a task CU5 has taken on.

Members of CU5 and a few guests at the CU5 plenary meeting held in Cambridge, 19-21 March 2013

The developments of software take place in 4 countries, Italy (Bologna, Rome, Teramo), Spain (Barcelona), The Netherlands (Leiden) and the UK (Cambridge, Edinburgh, Leicester and Rutherford Appleton Laboratory). The Bologna team, led by Carla Cacciari and Elena Pancino, work on aspects of the external calibration of the photometry, which involved amongst others the ground-based observations of a set of spectro-photometric standards, and methods to combine those data with the Gaia observations. The teams in Rome and Teramo, together with the team in Leiden, work on pre-processing of the dispersion spectra (led by Giorgia Busso, since 1 January 2013 in Cambridge), and the disentangling of blended spectra. The Barcelona team, led by Carme Jordi, work on the photometric calibration models and the definition and selection criteria for standard stars to be used in the calibrations.

The Leicester and Edinburgh teams, led by Duncan Fyfe and Nigel Hambly, work on the calibration of the LSF ((Line Spread Function) and PSF profiles, and the effects of the radiation damage on those profiles, the so-called charge-transfer inefficiency. They also provide the CCD health-check software for first-look. Cambridge activities cover the photometric calibrations, led by Dafydd Evans, the photometric science alerts, led by Simon Hodgkin, and the source environment analysis, led by Diana Harrison.

The photometric processing

The photometric data processing is carried out at the Cambridge data processing centre, led by Francesca De Angeli. The implementation of the processing algorithms on the Hadoop cluster is led by Marco Riello. Finally, Phil Richards at RAL takes care of the Quality/Assurance aspects of the software prepared by CU5. To coordinate these activities we have regular teleconferences of the management team and of various development groups. There are monthly written reports on the activities of the different groups, submitted to Livelink. Results from CU5 activities are expected to show up early in the mission through science alerts and the photometric data provided in early catalogue releases.

Words of Gaia: HEALPix

François Mignard

The analysis of continuous functions on spherical surfaces is an important topic in astronomy, cosmology, geophysics, to mention just a few. Although physical functions are normally continuous functions of position, the numerical processing and the mapmaking require a sampling at discrete points, referred to as pixels on the sphere. Moreover the access to spherical data can be by greatly accelerated with a storage on a data base mimicking a hierarchical sphere pixelisation. This is the interesting property for Gaia, allowing to manage the one billion sources on a computer.

The Hierarchical Equal-Area iso-Latitude Pixelisation (HEALPix) of a sphere allows to distribute $12n^2$ points on the surface of a unit sphere as regularly as possible, with the additional property that lines of latitude go through the centre of pixels, a feature of great value to optimise the computation of spherical functions.

Regular tiling

One dimensional data, like numbers or strings, can be (relatively) easily ordered and quickly accessed with binary search or direct access. In the case of 2D data with underlying plane topology, an ordering with an array does perfectly the job, keeping two nearby points of the initial plane into two nearby squares in the numerical image. A regular tiling can be obtained whatever the number of squares with a grid in which each square covers the same area in the space domain.

Astronomers, among others, have to deal with a less trivial problem with spherical distributions. There is no obvious way to order such a distribution to access quickly to a source defined by its two spherical coordinates or to the sources inside a certain simple domain (spherical square, triangle or disk). Big catalogues have been organised into zones of smaller size, so that the detailed search is restricted to a reasonable number of entries, such that nearby points on the sphere are also found in nearby branches in the structure of the data base.

Unlike a plane area, there is no natural way to tile the surface of a sphere into 2^k cells of similar shape and areas, preserving the rotational invariance. In fact outside the vertices of the five Platonic polyhedrons, one cannot distribute 'uniformly' n points on a sphere, such that the distribution looks the same when seen from any of the vertices. By central projection, each edge of the polyhedron draws on the sphere an arc of great circle, and eventually each face (square, triangle, pentagon) produces a similar spherical area. These areas are all equal for a given Platonic polyhedron. The largest number of cells produced by this process is just 20, the number of faces of the icosahedron. This is too small a number to be really useful to pixelise the sphere and access quickly to few sources among one billion.

Spherical polyhedrons

As each face of a polyhedron is plane, it is natural to think of subdividing these planes into cells of equal area and back projecting to the sphere as illustrated on Fig. 1 & 2, respectively for the cube and the icosahedron. Globally the symmetry of the polyhedron is preserved, but within a face between the inner cells this goes differently. While the cells drawn on the plane faces are identical in shape and areas, their spherical counterpart are not as can be seen on figure 1, near the edges and vertices of the cube or in Fig.2 for the icosahedron. A very desirable property (e.g. to compute integral or density from discrete sums) is lost

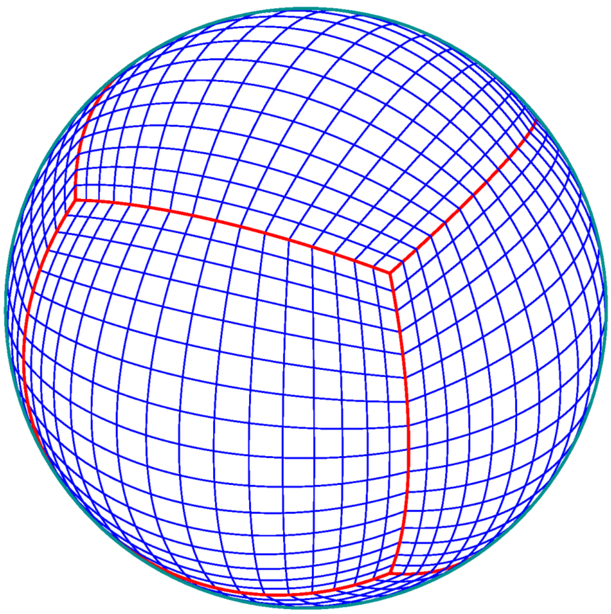


Fig. 1: A sphere tiling based on the central projection of a cube. The cube edges are projected as arc of great circles (red lines), while a regular tessellation of the faces produces spherical squares of variable areas (blue lines)

during the central projection. It is however possible to design for some polyhedrons a purposely contrived projection which preserves the symmetry by project-

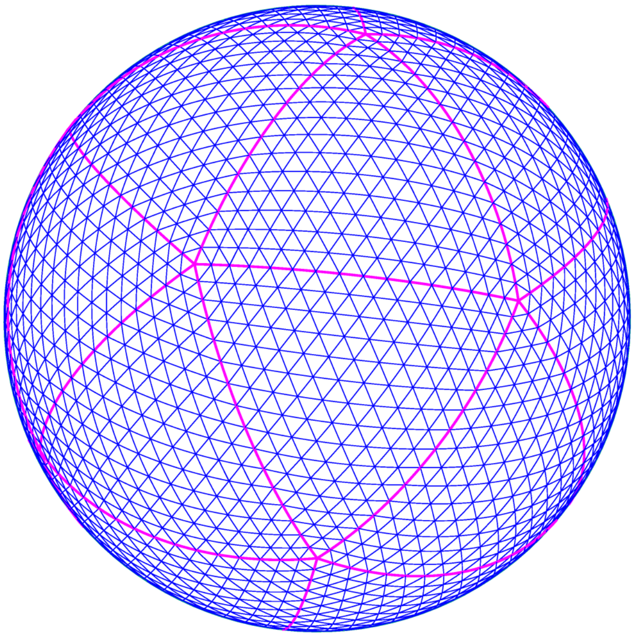


Fig. 2: Central projection of an icosahedron on the surface of sphere. The inner triangles of each faces are imaged on spherical triangles of variable areas.

ing the edges in the same way as the central projection, but altering slightly the projection of the boundaries of the inner cells so that the small spherical squares have all the same area equal to $4\pi/6/4^k$, where k is the order of the pixelisation. This is illustrated in Fig.3 for the cube. This solution adopted by COBE in 1975 was in fact rediscovered independently by M. Hénon and F. Mignard while searching for a hierarchical sphere pixelisation for Gaia before we eventually adopted HEALPix.

HEALPix for Gaia

HEALPix is the most evolved form of pixelisation of the sphere designed to ease computation of spherical functions in the spectral analysis of the CMB. It was adopted by WMAPS and PLANCK. It has given rise to a new family of spherical projections used in mapmaking. This is an equal area pixeling whose skeleton is not a regular polyhedron, but a rhombic dodecahedron (a Catalan polyhedron) with 12 faces (of rhombus shape) and 14 vertices. It offers the great advantage, and in fact was created for this purpose, to keep the axial symmetry in such a way that a latitude circle goes through the centres of a set of cells. This is this feature which saves computing time in the evaluation of spherical functions widely used for CMB analysis. The same feature, although not as critical, could be used by Gaia for the VSH (Vectorial Spherical Harmonics), though the main interest for Gaia resides in the efficient storage and information retrieval from the MDB.

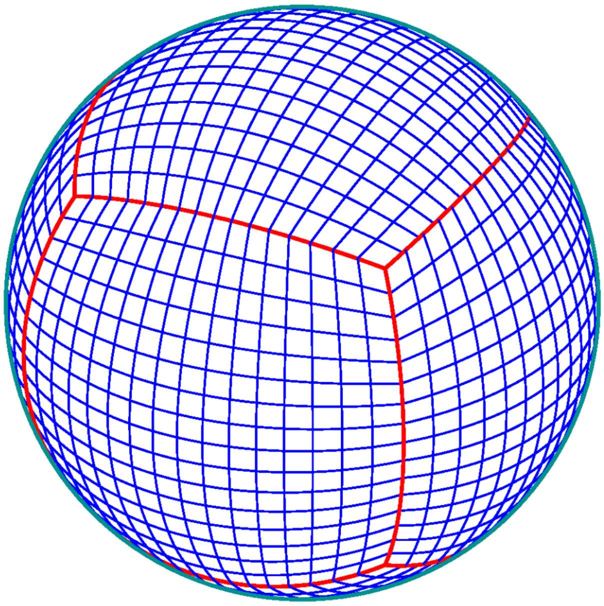


Fig. 3: Equal area projection of a cube where each face is projected with the same boundaries as in Fig. 1, but every inner spherical squares have all the same area and are imaged of uniform squares drawn on the faces of the circumscribed cube.

The Gaia Initial QSO Catalog

Alexandre Humberto Andrei on behalf of the CU3 GWP-S-335-13000

As a result of Gaia's scanning law and of the superposition of the images from its two telescopes, all compact objects, brighter than magnitude 20, can be observed at least once over the entire sky every few months. This forms a catalog of relative positions, proper motions, and hence parallaxes. To derive 'a non-rotating' Gaia catalog one needs a set of astrometrically 'still' objects, distributed in large numbers in nearly every direction. Quasi-stellar objects (QSO) form the only possible such set, since distant stars of negligible motion are few, faint, and only appearing in the galactic plane, while galaxies are too fuzzy and extended to allow for a precise centroid determination.

Recognition of QSOs

A frame formed by QSOs is fundamental for the interpretation of Gaia´s astrometry, photometry, and spectroscopy. From the beginning, ways have been worked out to detect QSOs using the satellite own measurements. This relies on templates of synthetic spectra from which QSOs can be located in color-color diagrams, well separated from the rest of the stellar population, including potential contaminants like red stars or white dwarfs. An Active Neural Network (ANN) developed for QSO recognition, working in tight mode, is currently able to deliver a sample at 98% of purity. This rate is sufficient to deliver the minimum number of QSOs needed to build the fundamental frame, reckoned at 10,000 objects. Such a set materialises the reference axes to sub-muas accuracy, and aligns the Gaia Celestial Reference Frame (GCRF) to the current International Celestial Reference Frame (ICRF) , as required to ensure metrological continuity.

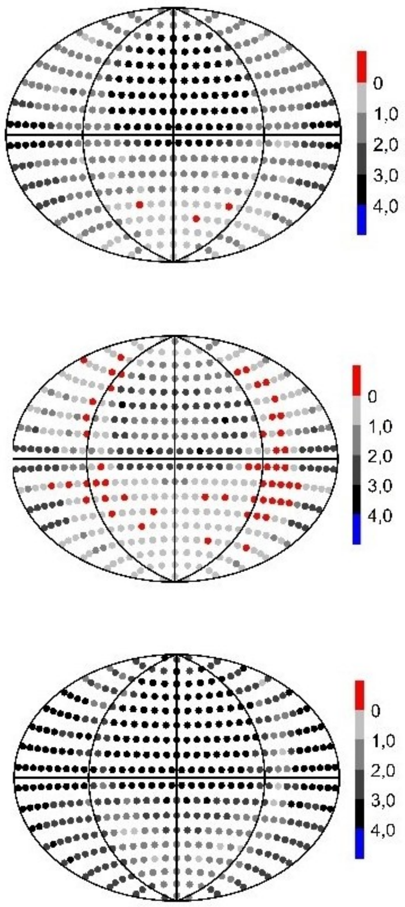
There are secondary methods used for the recognition, chiefly the absence of peculiar motion and the presence of the photometric variability peculiar to QSOs.

To improve the detection rate and validate the internal detection mode, an initial catalogue of known QSOs has been prepared in the CU3: the Gaia Initial QSO Catalog (GIQC). The GIQC was compiled from the existing QSO surveys, returning to individual observations when needed, and in all cases verifying their admissibility.

The work to construct the GIQC had three aims. First and foremost to furnish a clean sample, of at least 10,000 objects, all-sky distributed. Besides the clean sample, the GIQC also aims to reach completeness by registering all QSOs known from any other type of observations. With this not only can dubious cases of Gaia own detection be clarified, but the library of synthetic spectra is enriched and the AAN progressively better trained. Connected to this point, the last aim is to provide astrophysical characteristics of the catalogue entries, namely magnitude, redshift, morphology, and variability.

Status and content of the GIQC

The latest version of the GIQC contains 1,248,372 objects, of which 191,802 are marked as Defining ones, because of their observational history and spectroscopic redshifts. Objects with strong, calibrator-like radio emission are included in this category. The remaining objects aim to bring completeness to the GIQC at the time of its compilation. For the whole GIQC the average density is 30.3 sources per deg^2, practically all sources have an indication of magnitude and of morphological indexes, and 90% of the sources have an indication of redshift and of variability indexes. The GIQC is completed by two one-letter comments on the source origin and main feature. A recent account of the GIQC status can be found in SVN as GAIA-C3-TN-GPA-AA-003-01.



From top to bottom the sky density distribution of the defining, candidate, and other sources in the GIQC. Each point in the plots represents equal area cells of radius 10 deg, on equatorial coordinates and counts in logarithm scale

Identification of known Solar system objects observed by Gaia

Jérôme Berthier (for CU4/SSO/DU452 team)

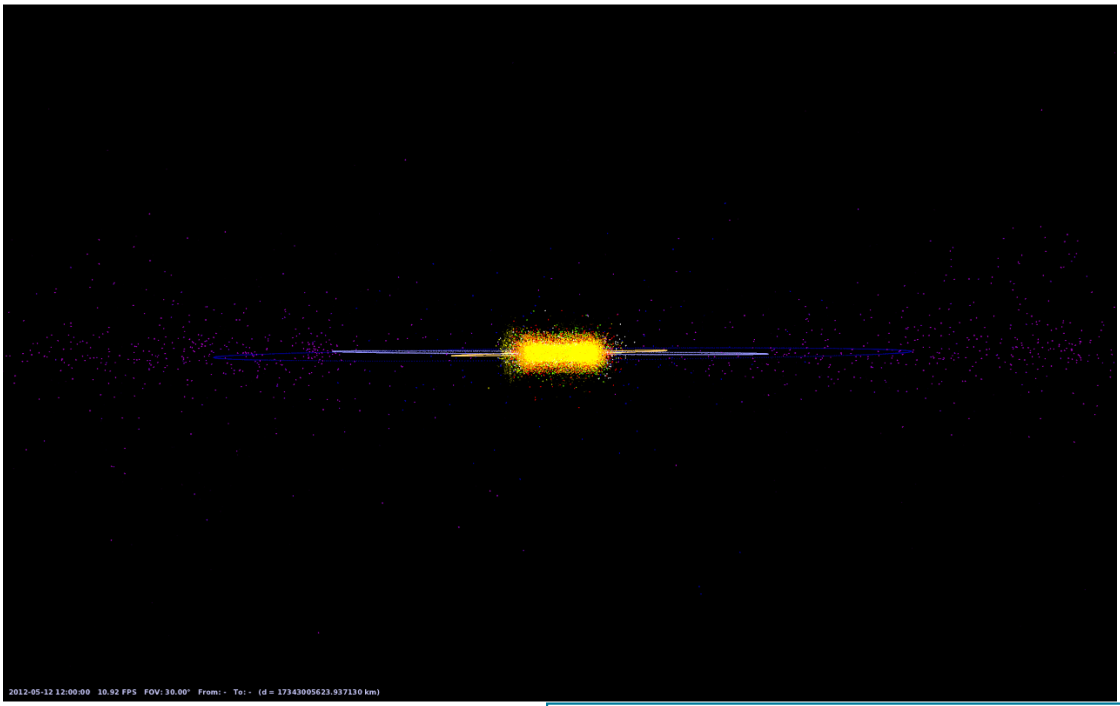
Among the billion of objects that will be observed and measured by Gaia, a handful of them will be Solar system objects. The Solar system zoo is composed of 8 planets, a little less than 200 natural satellites, a thousand of comets, and more than 600,000 asteroids. Gaia will capture primarily the latter, mainly main belt asteroids circling the Sun between the orbits of Mars and Jupiter. It is expected that Gaia will also detect several thousands Near-Earth objects (NEOs), which are of particular interest as they regularly graze the Earth (e.g. 2012 DA14 in Feb. 2013).

At the time Gaia flies, the vast majority of the small solar system objects, within reach by Gaia, will be known, characterized by their orbital elements and physical properties more or less accurate. Over the five years of the Gaia mission, the amount of data that will be collected will lead to the determination of orbits with an unprecedented precision, bringing new insights on their surface properties and composition. This will help refining the classification of the population of the small bodies in the solar system. More than one decade of scientific studies will begin.

Tagging known asteroids

Prior to that, each target observed by Gaia must be indexed, well-ordered among a large population, and insofar as possible identified. To accomplish this task, the CU4/SSO/DU452 team has constructed a dedicated algorithm, largely inherited from the IMCCE's SkyBoT service (http://vo.imcce.fr/webservices/skybot). In the framework of Gaia, the main requirement is the quality of identification combined with the performance issue: identify an observed source among a dataset of hundreds of thousands of moving objects. The whole system relies on a pre-computed database of ephemerides of all known solar system objects. This database represents a snapshot of the solar system at a given epoch (basically ten days), where each object is ordered in a subdivision of the Gaia Healpix celestial sphere in function of its position and its velocity at every moment. The identification process reduces then to a simple request: from the Healpix coordinate of the source, one extracts the subset of solar system objects which are in the Healpix cell (at the epoch of observation), computes their accurate ephemerides, then cross-matches the Gaia observation with each candidate by the mean of a Pearson's chi-squared test. The main benefit of such method is to reduce the search to only a few tens of solar system bodies.

The identification of known Solar system objects observed by Gaia is made possible by the existence of databases of orbits of these objects, such as ASTORB (Lowell observatory) and the Minor Planet Center for asteroids, COMETPRO (IMCCE) for comets. The success of this work is based on the contribution of the whole astronomical community, amateurs and professional, who share their observations and results.



Edge-on view of the Solar system from the ecliptic plane. Each colored dot represents an asteroid (TNOs in purple, Main belt in other colors). The colored lines show the orbits of Neptune, Uranus and Saturn.

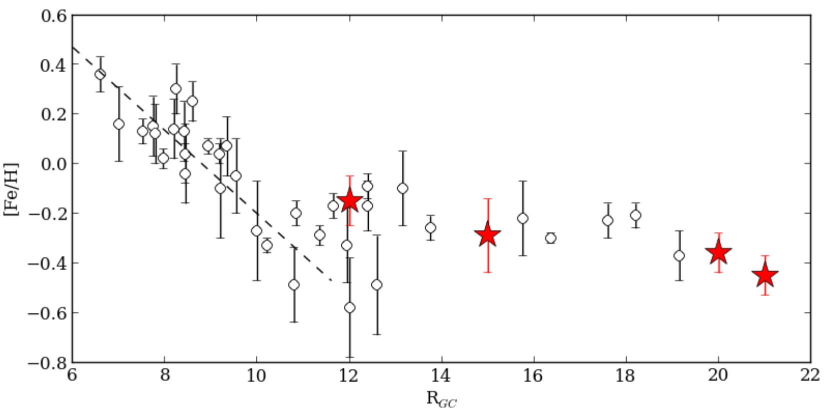
PhD Corner: Tristan Cantat-Gaudin, Observatory of Padua

Tristan Cantat-Gaudin is a Ph.D. student within the GREAT-ITN, working in the WP3: The Origin and History of the Milky Way, supervised by Antonella Vallenari. He works at the Astronomical Observatory of Padua, Italy.

His work focuses on open clusters in the Milky Way and what they can teach us about the formation and evolution of our Galaxy. Open clusters are homogeneous samples of stars that share a common age and chemical composition. They span a large range of masses and ages, and can be found all across the galactic disk, which makes them ideal tracers of the properties of the Milky Way. Open clusters, like other tracers, suggest that the metallicity in the outer disk is lower than in the inner disk, but the exact shape of the chemical gradient is not known.

Gaia will provide accurate distances and proper motions for the clusters, as well as better-defined cluster memberships. It will also enable to reconstruct the orbits, allowing us to track the clusters back to their birthplaces. When coupled with precise chemical abundances, this information will help to unravel the history of the evolution of the galactic disk.

Obtaining accurate chemical abundances from spectroscopy is fundamental to map the elemental distribution over the Milky Way and is one of main goal of the Gaia ESO Survey (GES) that will target 10^5 stars, and provide high-resolution spectra for 100 open clusters. Combining all this information will help discriminate between different scenarios for the formation of our Galaxy. Tristan is actively working on the GES data analysis. He has contributed to the automated pipeline for spectral analysis using equivalent width method. In addition to GES data, he has analysed in collaboration with Bologna Observatory several clusters of the external disk using archive spectra. The goal is to complement GES data using the same methods and abundance scale to build a coherent picture of the disk evolution.



The metallicity decreases steeply in the inner disk, while the distribution seems to be flat in the outer disk. Knowing how steep the gradient is and if clusters of different ages trace a different gradient is a key to understanding the formation and evolution of the Milky Way. Red symbols mark the objects recently analysed by TC.

DPAC meetings

Please note: Attendance at these meetings is restricted to members of the Gaia Coordination Units

Title Dates Links	Location	Convenor(s) / Local organiser(s)
DPAC/SOC Operations Rehearsal #4		
28 August - 6 September 13	several locations	A. Brown / others
CU1: Operations Workshop		
11 - 13 September 13	Fuerteventura	W. O'Mullane
http://www.rssd.esa.int/wikiSI/index.php?title=CU1:_System_Architecture:_Ops2013&instance=Gaia		
GST #43		
10 - 11 October 13	ESTEC	T. Prusti
CU4: Object Processing #16		
14 - 16 October 13	Royal Observatory, Belgium	D. Pourbaix / T. Pauwels

More information at http://www.rssd.esa.int/index.php?project=GAIA&page=Calendar_of_meetings