Gaia DPAC

Newsletter 11

gaia

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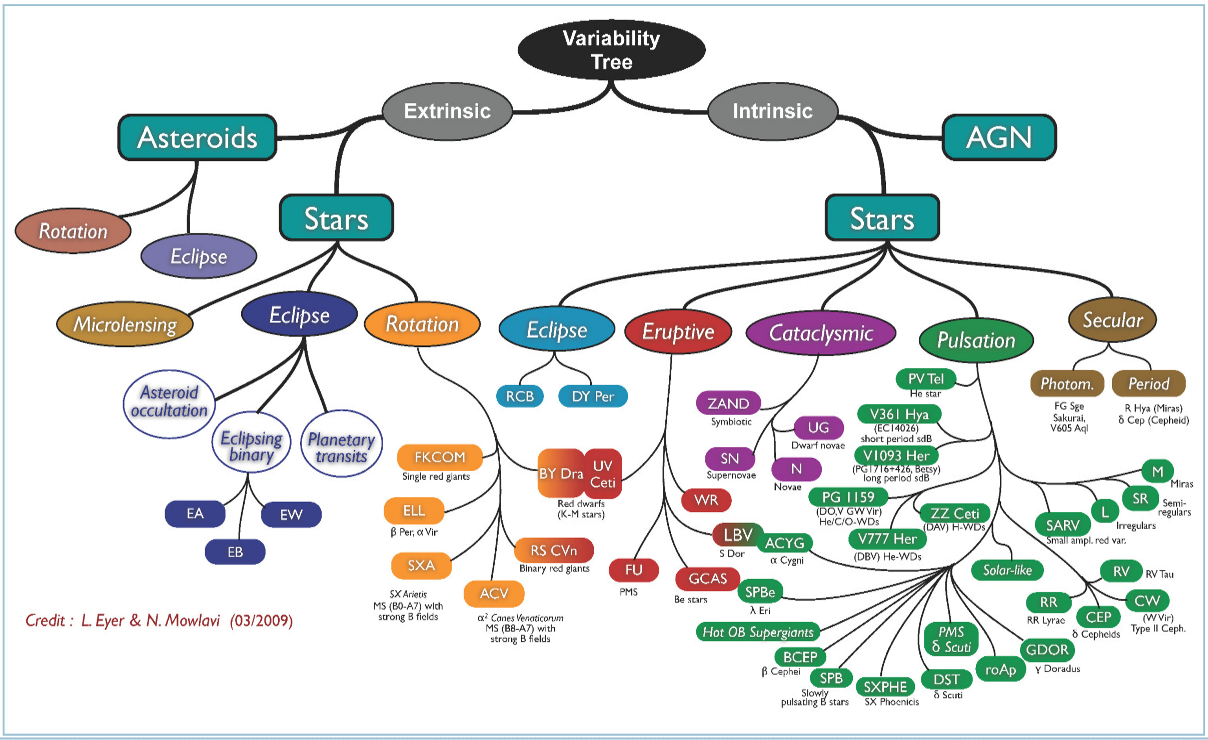


The Variability tree proposed by L. Eyer & N. Mowlavi in 2008. There are more than a hundred recognised types and subtypes of variable stars in the current catalogues. The tree is an attempt to generate some order, in a similar way as biological classifications, with a hierarchical series of nested classes according to the physical origin of variability. Here four divisions are introduced from top to bottom, starting with extrinsic and intrinsic variability. Most of the variability types shown on the figure will benefit from the Gaia mission, thanks to its sensitivity and its time sampling.

Editorial *by DPAC chair, François Mignard*

This winter issue of the NewsLetter, still offers me the opportunity to present to all our readers the Best Wishes for 2011 from the Editorial Board.

Many important developments are happening these days for Gaia, both on the Project and DPAC sides.

The testing and integrations of most of the Gaia subsystems are progressing normally and the unresolved critical points of the last few months, like the deployable sunshield mechanism or the validation of the micro propulsion system, are now behind us. All the Gaia qualified CCDs, 130 in total including the spares, are now delivered and the flight chips are being integrated and coupled to their video units. Quoting the own words of G. Sarri, the Gaia project manager, "today there are no unresolved technical issues remaining". However the schedule is still very tight, a feature deeply rooted in the genes of any complex undertaking, and Gaia is no exception to this rule.

The progress with Arianespace for the procurement of the Soyouz launcher is nominal and the newly built launch pad near Kourou is now scheduled for its maiden lift-off with a pre-Galileo test satellite, around summer. Few others launches will precede Gaia, whose launch date is now set in March 2013, not including a risk margin of six months.

Two particular DPAC key elements are presented in this issue, one related to the sky modelling and the other to the data handling. The Galaxy model is at the heart of the DPAC Universe model, from which the simulators extract all kind of sources, mirroring on a computer the real components found in the sky, from solar system objects to the most distant quasars. A. Robin, C. Reylé and D. Marshall describe its history and how its different parts have been combined into a single and versatile model. The second topic presented by C. Fabricius, from the Barcelona team, tells us how one will pair observations (what Gaia detects) and sources (what astronomers want to know), knowing that Gaia has no built-in catalogue to program its observations. The other usual columns are there with the presentation of two of the DPAC participating institutes and a larger-than-usual Word of Gaia.

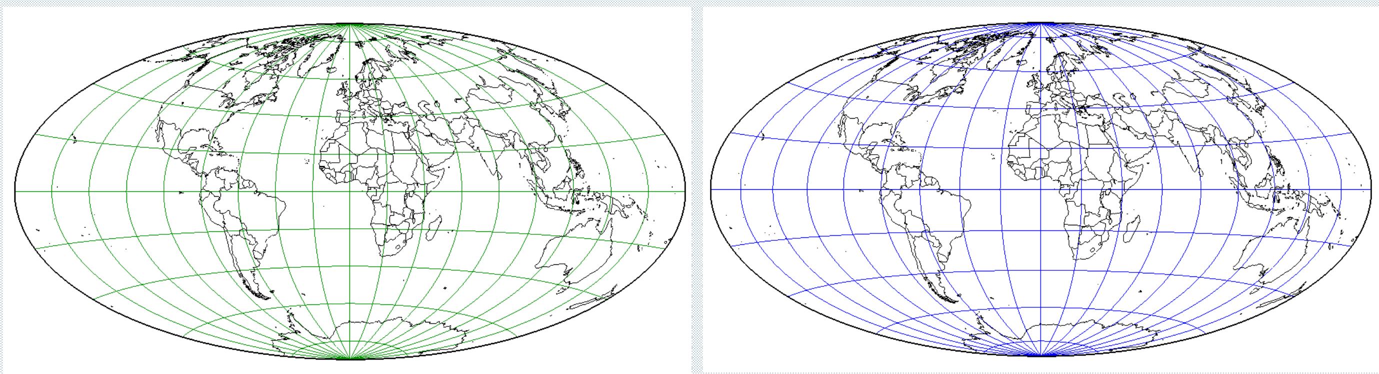
Enjoy the reading of this issue.

Hammer-Aitoff projection

In many of the whole sky representations of statistical distributions in the DPAC, one uses the so-called Hammer-Aitoff projection. It is widely used as a standard in AGIS to plot errors, number of observations or sources, but also more generally any time one wishes to show the distribution of a scalar quantity as a function of the astronomical coordinates, e.g. the scanning properties. There are several closely related map projections under the name of Aitoff, Hammer or Hammer-Aitoff. The latter has been preferred for Gaia and is actually implemented in the Gaia Tools for the following reason.

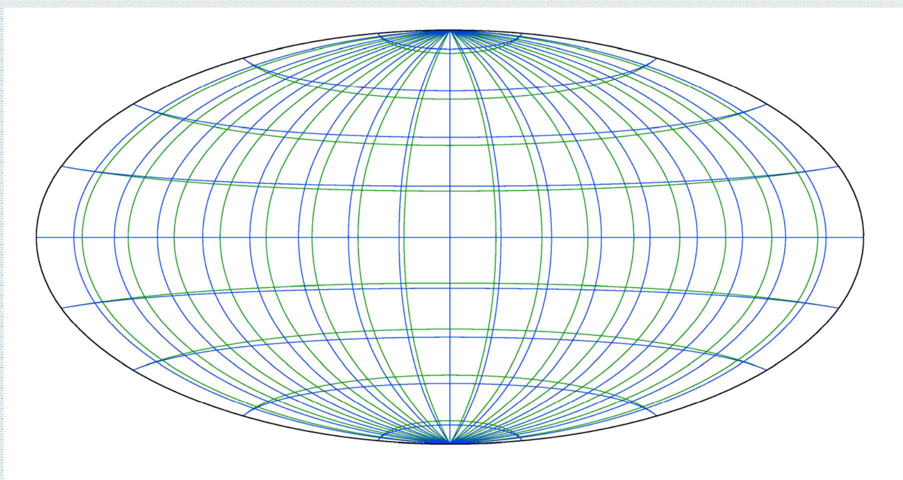
The Russian Cartographer David Aitoff invented in 1889 a nice trick to transform the azimuthal equidistant projection of one hemisphere by stretching the longitude horizontally by a factor two. Thus the world could be mapped entirely instead of just half of it. The new projection, shown below as Aitoff projection, is no longer equidistant, nor equal-area. However this trick inspired another geodesist, Ernst Hammer from Germany, to expand equatorially a Lambert azimuthal equal-area, to build in 1892 a world map looking much like Aitoff's, but preserving the areas. This is the very desirable feature, not shared by every projection, that makes it so valuable for Gaia.

This projection soon replaced Aitoff's and the name Hammer or Hammer-Aitoff has been used since then, although for a while the name Aitoff was incorrectly applied in the English literature until this was clarified in 1955 by H.J. Andrews and J.B. Leightly.



World maps with the Aitoff (green graticule) and Hammer (blue graticule) projections. Sky projections used in many Gaia applications are equal-area Hammer like, usually projected 'as seen', from inside the celestial sphere, with the right-ascension or longitude increasing right to left.

On a world map, they look very similar and the difference is not easy to spot, as illustrated in the two plots above with Aitoff projection on the left panel and Hammer on the right. However, by superimposing just the two graticules, the differences show up more clearly and are quite significant.



Comparison of the Aitoff (green) and Hammer (blue) graticules. Graticules of 20 degrees in both longitude and latitude.

Focus on partners

The CNES GAIA team in Toulouse, France, *by Xavier Passot*

CNES, the French space agency, has taken in Gaia the logical follow-up of its role in Hipparcos. Similarly as in this prestigious programme, CNES has the role of an integrator and operator of a processing centre, the DPCC. CNES is working for the data processing of CU4, CU6 and CU8, and is offering a computer platform and the engineering support for the GIBIS and GOG simulators since 2007.

The CNES team is located in Toulouse, nicknamed the "Pink City" for its colored brick architecture and roof tiles. Two people started on Gaia in 2005, growing now to about 20 engineers working on the project, from CNES or from software companies. We started working with CU1 on the DPAC system design, and on the methods and tools definition; training DPAC scientists to Java and to the software engineering rules has been the next step, before checking and integrating the scientific software modules in a framework called SAGA (System of Accommodation of the Gaia Algorithms) designed by the Thales company. SAGA and the scientific chains from CU4, CU6 and CU8 will run on the CNES computing facilities which comprise today more than 60 computers (for > 500 cores) and will be enhanced progressively to 200 computers for Gaia, when the maximum computing power will be required, typically 3 years after the launch.

The engineers have good reasons to enjoy their involvement with the Gaia groups: they interact closely with the creative European astronomical community and have the opportunity to participate in the software development in a cooperative environment offering up-to-date working methods. In addition handling a billion stars data base is an exciting and motivating challenge.

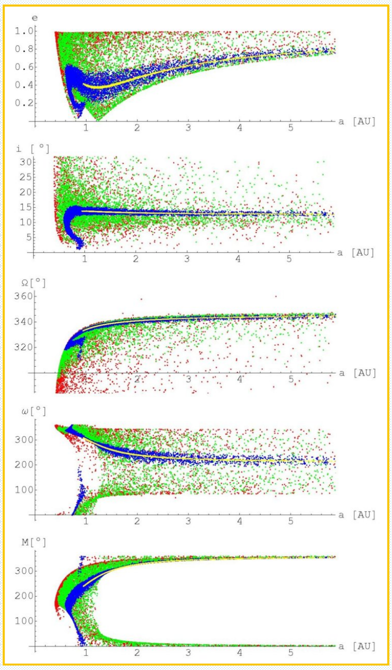
After the first system tests with ESAC, and the first integration of several scientific chains in the SAGA framework, the CNES team are very pleased with these recent successes, a first milestone along the way leading to the one billion star catalogue.

The CNES GAIA team in the Toulouse Space Center , December 2010 (photomontage X. Passot). More at *http://www.cnes.fr/*

Department of Physics at the University of Helsinki, Finland, *by Karri Muinonen*

Planetary astronomy within the Department of Physics at the University of Helsinki builds on the research on small solar-system bodies carried out at the Observatory before the merging of the Departments of Astronomy and Physics in the beginning of 2010.

Near-Earth objects (NEOs) constitute a population of solar-system objects of major interest to us due to their significance for understanding solar-system evolution and the impact hazard they entail. We work within CU4 of Gaia/DPAC, managing DU456 entitled "Orbital inversion" and contributing to DU458 entitled "Physical parameters" (managed by Alberto Cellino, INAF/ Osservatorio Astronomico di Torino). We develop for DU456 a statistical Markov-chain Monte-Carlo method (MCMC) for initial orbit determination. This aims at orbit of NEOs, as well as asteroids and comets, observed few times over a short interval of time. These methods derive from the statistical ranging principle, a robust orbital-inversion method developed at the Univ. Helsinki in late 1990's.



Collapse of the orbital-element distributions with improving observational accuracy for the NEO (1620) Geographos using three simulated Gaia observations of a single 0.25-day scan. The red, green, blue, and yellow colors correspond to the accuracies of 1.0, 0.1, 0.01, and 0.001 arcseconds, respectively.

Mapping of essentially all possible initial orbits, the key philosophy in our MCMC methods, is crucial for successful identification of objects and recovery efforts using ground based follow-up observations.

As to DU458, we contribute software for modelling of asteroid phase curves, that is, asteroid disk-integrated brightness as a function of phase angle, the angle between the Sun and Gaia as seen from the object. This modelling is important for the estimation of absolute magnitudes of asteroids to be observed by Gaia.

Our team is composed of K. Muinonen, T. Pieniluoma, D. Oszkiewicz (Lowell Observatory, working with asteroid phase-curve data base and returning in August 2011), and M. Granvik (Univ. Hawaii, working with Pan-STARRS and returning in March 2011). Our involvement in Gaia/DPAC is partially supported by the Academy of Finland. *More at: http://www.physics.helsinki.fi/*

Cross matching for Gaia *by Claus Fabricius (IEEC, Barcelona, Spain)*

One of the many tricky pieces of bookkeeping needed in the Gaia data processing is the Cross Match, i.e. the matching of observations with the Gaia catalogue. Gaia has no predefined list of sources to observe, but simply takes what enters the field of view while scanning the sky. When processing the data, we therefore need to establish which detections come from the same source, and if this is an already known source. At the end of mission, we must match 80 000 million detections to at least 1000 million sources. One can then imagine that the process is very demanding and must be designed with great care. The work is carried out in a collaboration between Turin Observatory, University of Barcelona, and Lund Observatory.

There is a bit of bootstrapping involved here. As a start, Star Trackers on board tell us roughly where Gaia is pointing using a set of very bright stars. Next, in the initial processing on ground, we use this crude pointing to identify bright observations in a star catalogue of about one million stars. We can then derive where Gaia was pointing at any time to an accuracy better than 0.05 arcsec, which is more than sufficient for the Cross Match.

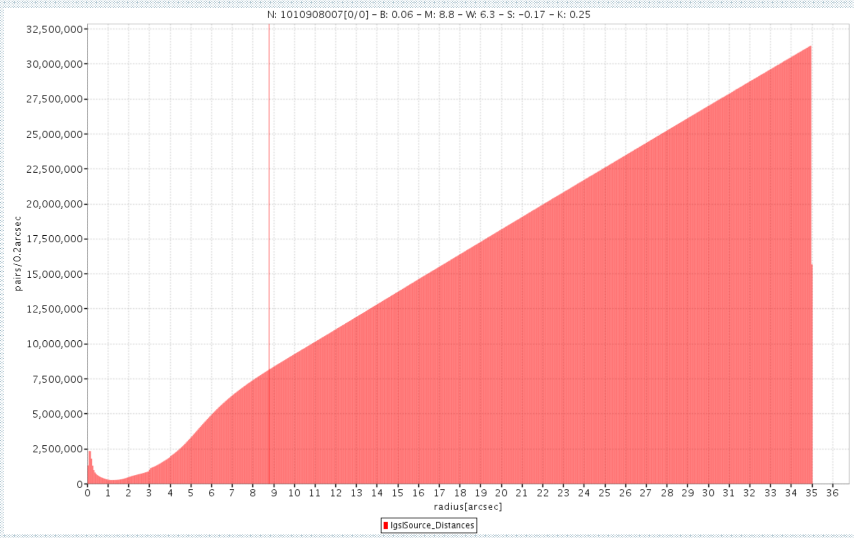
On board Gaia, a detection is boiled down to what is known as the reference pixel, corresponding to a pixel on one of the Gaia CCDs. This pixel is then used by all Gaia instruments for blindly centring their observations, and is therefore the natural starting point for the identification of the source in question. Knowing where Gaia is pointing, it is simple to calculate the position on the sky for the reference pixel. This position will be accurate to one or two pixels, or 0.1-0.3 arcsec, with the highest accuracy in the scan direction.

We primarily try to identify the detections with the sources in the current best Gaia catalogue: in the early phase of the mission, this will be the Initial Gaia Source List (IGSL), which will be gradually replaced by the Gaia results instead. We look for sources within some angle, 0.5-1.5 arcsec depending on the source, but with the condition that neighbouring detections are never matched to the same source. In case of ambiguity, it is important that the Cross Match does not restrict the downstream processes too much, but rather presents all options in a transparent way.

The IGSL is mainly extracted from GSC-II, based on photographic plates. It has an accuracy around 0.4 arcsec, a few times worse than our detections, and a modest spatial resolution. This latter point is illustrated in the figure which shows the distances from each source to its neighbours in the IGSL. In a uniform sky the number of neighbours will increase linearly with distance, but at distances below 5-7 arcsec there are too few neighbours. The real sky, however, has a huge peak at the small distances due to the ubiquitous double and multiple stars. Because of this resolution limit, many detections will have no match in IGSL, and we must then introduce new sources.

The Solar system group pays particular attention to the new sources, as they may instead be minor planets or comets.

As the mission progresses, we get a still better Gaia catalogue, with better spatial resolution, more accurate positions, proper motions, and parallaxes. In order to keep the identifications consistent, the cross match is therefore repeated from time to time throughout the mission. This also allows us to tidy up cases where e.g. a star with rapid motion has ended up with several entries in the source list.



Distribution of distances between the sources in the Initial Gaia Source List. The plot gives the number of neighbours in a ring of width 0.2 arcsec, as a function of its radius. The poor angular resolution of this ground based catalogue shows up as a dip below 7 arcsec and a very modest binary star population. These deficiencies will be a challenge for the cross match. (Courtesy Nadia Blagorodnova, Universitat de Barcelona)

The Besançon Galaxy model, a tool for preparing and analysing the Gaia mission

by Annie C. Robin, Céline Reylé, Doug Marshall (Observatoire de Besançon, France)

The preparation of the Gaia mission requires us to be able to simulate the number and characteristics of the astronomical sources which will be observed, or contribute to the background flux in the Gaia instruments. By and large, the main component of the observable sources will be the stars of the Milky Way galaxy. For simulation purposes a numerical model of the stellar content of the Galaxy has been used by CU2, in charge of the DPAC simulations, for predicting the stellar distribution on the sky together the star physical characteristics (temperature, mass, gravity, chemical composition and motions).

The Besançon Galaxy Model was developed originally by Michel Crézé in the Eighties, as a tool to test galactic evolution scenarios by comparing model simulations with real statistical data (Robin, Crézé 1986). It has been extensively tested and continuously improved since then, by comparisons with large scale surveys in the visible (Robin et al 2003) and the near-infrared (see figure).

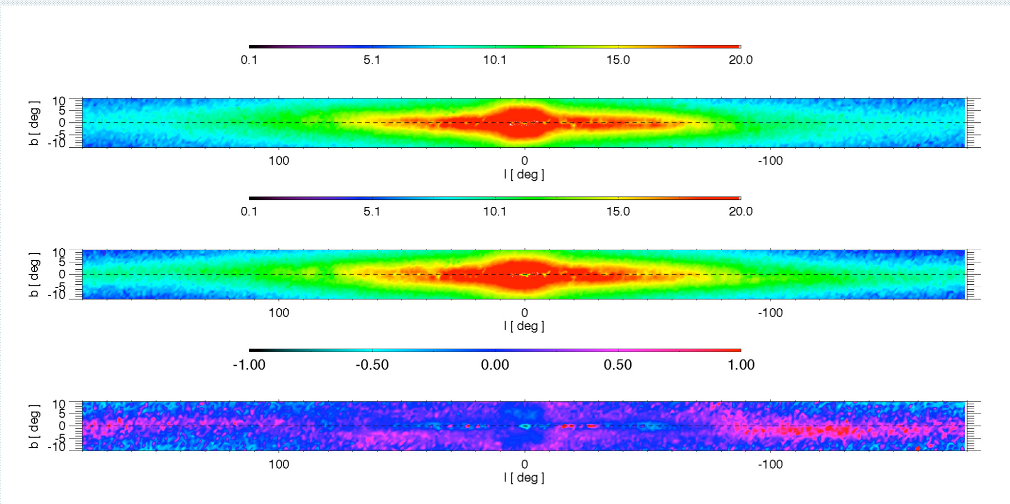
Complementary tests have also been done in X-rays (Guillout et al 1996) and UV (Ojha et al in prep). The Model provides a comprehensive description of the stellar components of the Galaxy with their physical characteristics (initial mass function, star formation rate, chemical abundances, spatial distribution, kinematics).

The dynamical self-consistency is provided locally using Boltzmann and Poisson equation (Bienaymé et al, 1987, Haywood et al, 1996). More recently a 3D extinction model has been derived and implemented for more accurate simulations in the Galactic plane (Marshall et al 2006). Hence, it was naturally that the BGM model has been chosen for simulating the Galaxy in the simulations for Gaia.

Inside the package GaiaSimu, the BGM has been first simply recoded in the available framework in Java. Then, a number of add-ons have been considered and implemented. One of these main improvements has been the simulation of double and multiple stars, which were not implemented in the original BGM. After several intermediate steps, the final implementation uses the core of the BGM model to create primary stars from the local luminosity function of the primaries, then double and multiples are added using realistic statistical distributions for the mass ratios and separations.

The second main addition was the stellar variability. Variable stars are introduced from specific regions of the HR diagram with their periods and amplitudes generated from templates or typical light curves. Data are provided by CU7. Extrinsec variabilities are also introduced, like gravitational microlensing. Eclipses result naturally from the binary simulations as well as the variability induced movers (VIMs).

In the future new improvements are planned, with the introduction of the most recent developments already in the revised version of the BGM, like the warp model, the spiral structure, and a better description of the bulge and bar. More detailed extinction modelling will also be implemented, to account for variations of the differential to selective extinction ratio along different lines of sight, and for small scale fluctuations of the total extinction.



A good test for the model is to compare star count predictions over a wide area of sky, in stars per deg². The figure presents the comparison between the star counts up to magnitude 12 from the 2MASS near infrared survey (top) with predicted star counts at the same scale (middle), from the most recent improvements of the model concerning the warp (Reylé et al 2010) and the bulge (Robin et al, submitted). The bottom plot gives the residuals in relative values.

A new scheme is also being developed to allow easy tests of the star formation rate and mass functions in different regions of the Galaxy (Czekaj et al, 2011 in prep).

After launch the BGM will be used for testing methods and for helping the analysis of the Gaia catalogue. In particular, we will produce simulations and statistics from different hypotheses concerning the Galactic potential, and Galactic components kinematical features, in order to be able to allow rapid and efficient tests to be applied on Gaia data.

ELSA: Luca Santoro, *University of Padova, University of Nice*

Luca Santoro is a Ph.D. student at the University of Padova and Nice. He was one of the ELSA fellows, and after two years at the Observatory of the Côte d'Azur in Nice, he is now at the observatory of Padova.

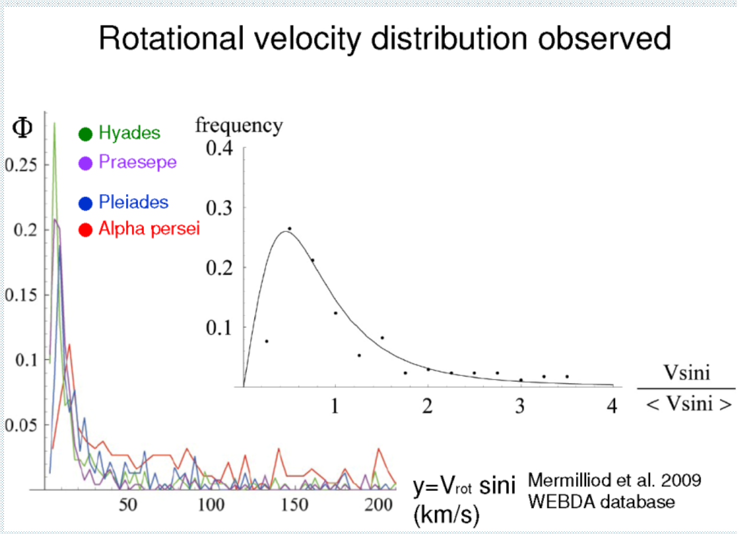
The general focus of his work is the impact of rotation on star evolution. This is investigated through a study of four open clusters, in order to quantify these rotational effects in the Gaia context.

This has important impact on HR diagram studies through the evolutionary tracks and extracted ages and masses of the stars, using the Cesam2k stellar 1D evolution code. Two approaches have been developed.

One is based on the random distribution of the inclination angle i of the axis of rotation on the line of sight, of stars in clusters, following the work of Chandrasekhar and Münch (1950) to estimate the true rotational velocity (V_{rot}) using the Tsallis distribution. Luca has used a statistical inversion method to obtain V_{rot} for each star.

The second approach consists of applying this procedure in particular for the Hyades because it is an ideal laboratory to test stellar modelling, thanks to well-known distance, chemical abundances, kinematics, etc.

The preliminary results that came out is to change by 15% the ages of the clusters (making them older when rotation is allowed without von Zeippel's effect) and in the case of the Hyades to change the helium content. In the Gaia context this means that for stars with masses above 1.3 Mo one cannot leave out this rotational velocity for the age and mass determination. Luca is working in the FLAME group activity of CU8, led by B. Pichon, also in the Gaia team in Nice.



Distribution of v.sini of stars in 4 young clusters with an example of fit of the Tsallis distribution used in the Chandrasekhar-Münch's theorem.

Calendar of next DPAC related meetings

Date	Place	Who	Type	Resp.
17-18/02	Leiden		In Orbit Calibration WS	A. Brown
01-02/03	Heidelberg		RTF#08	S. Jordan/ F. van Leeuwen
15-18/03	Geneva		CU1/PO	M. Beck / P.de Teodoro
07-08/04	Toulouse		GST #34	T. Prusti

Gaia and related science meetings

Date	Place	Title	Link
17-22/04	Le Grand Bornand, France	WS Milky Way Puzzle	http://mw2011.obs-besancon.fr/2011/index.php
03-06/05	Naples, Italy	Cosmic Distance Scale	http://www.oacn.inaf.it/ESFdistance/
May 4-6	Pisa, Italy	Solar System science before and after Gaia	http://www.oca.eu/workshop/Pise/
23-27/05	Granada, Spain	Stellar Clusters	http://sca.iaa.es/

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

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