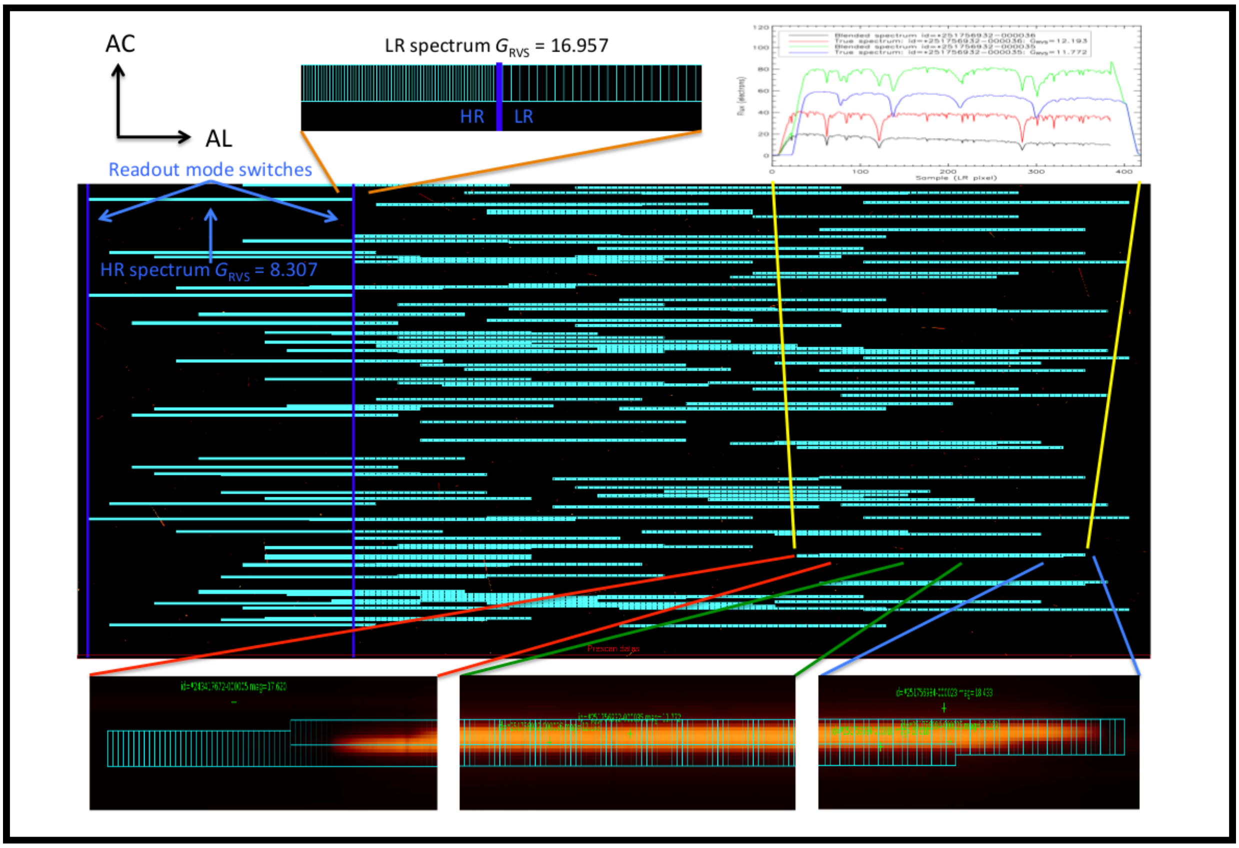
Gaia DPAC

Newsletter 15

N° 15 - January 30, 2012



Blended and unblended spectra from the RVS.
Centre: *GIBIS strip map raw image of a single RVS CCD. The cyan lines (produced by the GIBIS strip map visualisation java tool) delineate the RVS windowing scheme.* ***Bottom***: *Zoom in on the beginning, middle and end of two overlapping windows from the main image but with a different electron scale to show the signal in the windows. The cyan lines show the image is in pixels (i.e. before being read out) and that both windows are truncated in the AC direction. The central bottom image labels the positions and magnitudes of the two sources. The left and right images also label unwindowed sources adding signal to the windowed sources (see below p.5).* ***Top right***: *Extracted blended spectra from each of the highlighted two overlapping windows and the corresponding true (unblended) spectra. The calcium triplet lines of the fainter source contribute to the spectrum of the brighter source (comparison of green and blue lines).* ***Top left***: *A High Resolution (HR) spectrum (Grvs < 10, labelled in main image) has switched the readout mode of the whole CCD from Low Resolution (LR) to HR between the two vertical blue lines in the main image. The zoom in shows an LR spectrum (Grvs > 10) being partly read out in HR mode and partly read out in LR mode (mixed mode spectrum). Picture credit: compiled by G. Seabroke and K. Janssen using a GIBIS simulation and tool by P. Sartoretti, C. Babusiaux and N. Leclerc.*

Editorial *by DPAC chair, François Mignard*

This winter issue of the NewsLetter offers me the opportunity to present to all our readers the Best Wishes from the Editorial Board for 2012.

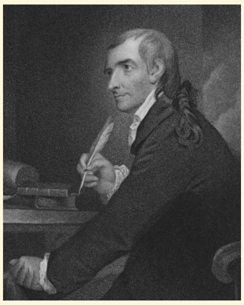
DPAC has been under scrutiny by ESA during the Ground Segment Implementation Review (GSIR), which came to an end recently with the conclusions of the Review Board, providing a set of recommendations and actions to improve the overall reliability of the system and a get a better control of the schedule.

On the spacecraft side, the integration and testing are progressing nominally and very few pieces of hardware are now missing and will be delivered in the coming months. All the mirrors are in place and optical alignments are being performed. The eye of Gaia, a giant mosaic of CCDs of nearly one square metre, is completed and fully coupled to the video and electronic chains. Launch date has slipped of just two months recently to August 2013, just 18 months ahead.

In this issue you will learn more about two of the DPAC participating institutes, including one from Slovenia, a small European country underway to become a full ESA member state. Also this issue includes our usual pair of technical topics that show how much attention is devoted by DPAC to reach the ultimate quality Gaia is designed for: one on how to get rid of the systematic shift in the RVS wavelength brought about by neighbouring point sources close to the target and the other about the final alignment of the Gaia self-realisation of the inertial frame to the radio ICRF, so that both have the same pole and origin.

Do you know who invented the diffraction “grating”? Fraunhofer, as if often said? No, this invention follows from an amazing experiment done by a non scientific person. Francis Hopkinson, an American author and one of the signers of the Declaration of Independence, had the strange idea to look at a point source through a silk handkerchief, experience repeated and transformed as a “grating” by David Rittenhouse, a renown American astronomer and surveyor of the second half of XVIIIth century.

Let's read pieces of the exchanged letters published in the Philadelphia Transaction in 1786.

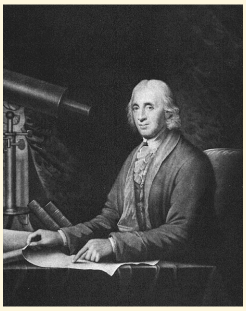


Dear Sir,

I take the liberty of requesting your attention on the following problem in optics. It is I believe entirely new, and the solution will afford amusement to you and to me. Setting at my door one evening last summer, I took a silk handkerchief out of my pocket, and stretching a portion of it tight between my hands, I held it up before my face and viewed, through the handkerchief, one of the street lamps which was one hundred yards distant; expecting to see the threads of the handkerchief much magnified. Agreeably to my expectation I observed the silk thread magnified to the size of very coarse wires; but was much surprized to find that, although I moved the handkerchief to the right and left before my eyes, the dark bars did not seem to move at all, but remained permanent before the eye... To account for this phenomenon exceeds my skill in optics. You will be so good as to try the experiment and if you find the case truly flatted, as I doubt not you will, I shall be much obliged by a solution on philosophical principals.

I am sir, with great sincerity, your most affectionate friend, a very humble servant, F. Hopkinson

At that point Hopkinson just saw the diffraction pattern of a pencil of light going through the narrow threads of a regular piece of fabric. Receiving this letter, Rittenhouse realised the experiment in a simpler way: not using a handkerchief but many parallel hairs held together with a constant and small spacing. In his experiment he used at most 190 parallel hairs (or similar) per inch. He described the observation as follows:



Dear Sir,

The experiment you mention, with a silk handkerchief and the distant flame of a lamp, is much more curious than one would at first imagine...

It appears then that a considerable portion of the beam light passed between the hairs, without being at all bent out of its first course; that another smaller portion was bent at a medium about 7' 45" each way; the red rays a little more, and the blue rays a little less; another still smaller portion 15' 30"; another 23' 15", and so on. But no light, or next to none, was bent in any angle less than 6', nor any light of any peculiar colour...

I was surprized to find that the red rays are more bent out of their direction, and the blue rays less; if as the hairs acted with more force on the red than on the blue rays, contrary to what happens by refraction, when light passes obliquely through the common surface of two different mediums. It is however, consonant to what Sir Isaac Newton observed with respect to the fringes that border the shadows of hairs and other bodies...

By pursuing these experiments it is probable that new and interesting discoveries may be made, respecting the properties of this wonderful substance, light, which animates all nature in the eyes of man, and perhaps above all things disposes him to acknowledge the creator's bounty. But want of leisure obliges me to quit the subject for the present.

I am, dear Sir, your affectionate friend, and a very humble servant, D. Rittenhouse.

Rittenhouse is considered by historians as the inventor of the “grating” that decomposes the light as the prism does. He recognized the similarity with the observation by Newton and Gregory of fringes of interference colouring the side of objects. He noticed and described the different orders produced by such disperser and he measured the angle between the order 0 and the followings.

Few decades later, Fraunhofer used such gratings made of wire to study the sunlight and it helped him to refine his earlier discovery of the so-called Fraunhofer lines. The great adventure of spectroscopy has started! By the end of the XIXth century spectrographs used in astronomy moved gradually from prisms to gratings. The advantages of grating on prism, among many, is the relatively constant power of resolution $\mathbf{R= \lambda / \Delta\lambda}$ of it and the capability today to produce high dispersion of high quality.

226 years after, one has finished to construct the RVS of Gaia. It is composed of such “grating” by transmission as the one of Rittenhouse, made with parallel lines engraved on a glass substrate to decompose the light of the source points observed in the field of view of Gaia. No doubt that we have to be respectful to Rittenhouse.

I had the idea to re-do his experiment by making myself a “grating” with hairs glued in parallel. I was able to glue an equivalent of 120 hairs on one inch, a little bit less hairs than Rittenhouse used. A laser used as light source was diffracted in several structures. Then a white light was tested. Two symmetric sources appeared on the side of the 0 order and as Rittenhouse the use of a microscope revealed a blue side and a red side at the first order.

But want of work for Gaia obliges me to quit the subject for the present.

I am, dear colleagues, your affectionate friend, and a very humble servant,

Frédéric Thévenin

Focus on partners

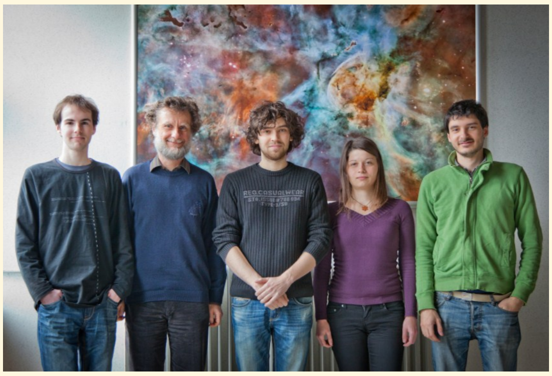
The Gaia team at the University of Ljubljana *by Tomaž Zwitter*

The Faculty of Mathematics and University of Ljubljana contributed to the initial Gaia's RVS studies in the early 2000s. These included some preliminary estimates of the RVS performance and its scientific requirements. Our efforts were in close collaboration with the Osservatorio Astronomico di Padova and with the RVS leading groups from Meudon, MSSL, Cambridge, and Nice.

Recent moves of Slovenia towards the full ESA membership and the associated PECS (Program for European Co-operating States) grant allowed us to rejuvenate our efforts. In particular we are pursuing two of the tasks within the single transit analysis of the RVS data flow. The first task is to implement measurement of the radial velocity and stellar rotation using an optimized binary mask, and the second to study noise-reduction techniques on single transit spectra. In both cases one can take advantage of the information drawn from previous Gaia observations. So one may optimize the binary mask's sequence of 0's and 1's using the best suited theoretical template for a given star. Similarly, noise could be reduced by wavelet techniques or by a suitable averaging of the most similar spectra obtained before.

The RVS effort in Ljubljana is the joint contribution of: Maruša Žerjal Janez Kos, Dr. Gal Matijevič and the undersigned and Tomaž Zwitter, the head of the group. A separate effort to contribute to the Gaia science alerts by detection and characterization of optical afterglows of gamma ray bursts is conducted by Dr. Andreja Gomboc and Jure Japelj. Both teams can draw from experience with similar datasets. RVS work profits from numerous test observations with the echelle spectrograph atop Cima Ekar in Asiago and from observations of the RAVE collaboration. Gamma ray burst studies build on ongoing collaborations with ARI, Liverpool John Moores University and INAF, Osservatorio astronomico di Brera, and are in close contact with the Gaia Photometric Science Alerts Working Group at IoA in Cambridge.

Want to know more about our activities? Come for the CU6 meeting in Ljubljana next June!



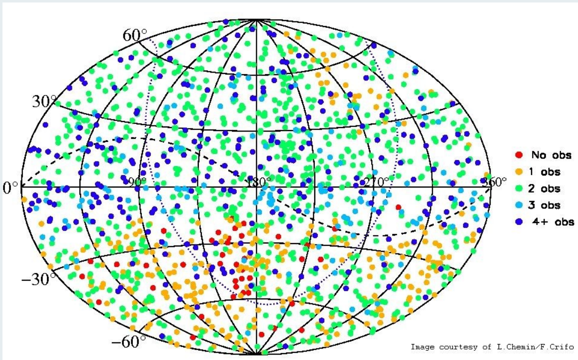
The Gaia team from Ljubljana: Jure Japelj, Tomaž Zwitter, Janez Kos, Maruša Žerjal, Gal Matijevič (from left), Andreja Gomboc is missing. Photo: G. Matijevič & D. Kopač.

The Gaia team at LUPM *by Gérard Jasniewicz*

The Laboratoire Univers & Particules de Montpellier (LUPM, http://web.lupm.univ-montp2.fr) was established in 2011. It results from the merging of the Groupe de Recherche en Astronomie & Astrophysique du Languedoc (GRAAL) and part of the Laboratoire de Physique Théorique & Astroparticules (LPTA). It is associated to the University of Montpellier 2 and to the french CNRS, and comprises three teams working on :

- stellar astrophysics
- experiments and modelling in astroparticle physics
- fundamental interactions, astroparticle physics and cosmology.

Three members of the LUPM (Gérard Jasniewicz, Claudia Lavalley & Claude Zurbach) are strongly involved in the preparation of Gaia, and three members of the POLLUX (database of stellar spectra) team are associated to the Gaia project.



Ground-based observations of the best star candidates to be validated as radial velocity standards for the RVS : number of observations per star on December 2011. The dashed (resp. dotted) line is the ecliptic (resp. galactic plane).

Within CU6, we are in charge of the DU640 related to the Radial Velocity Zero Point (RVZP) of the RVS (Gaia DPAC Newsletter 6, 2009 ; Picture of the week 09/23, 2008) that will be performed with the help of Radial Velocity (RV) standard stars and asteroids. DU640 is composed of four WP: “RV reference sources: Stars”, “RV reference sources: Asteroids”, “Auxiliary data: Database” and “Astrophysical Zero Point “(AZP). A full-sky list of RV standard stars candidates has been built and a ground-based campaign of RV observations has been initiated to eliminate unsuitable candidates. We should be able to control any harmful effect (especially the CCD radiation damage) on calibration and RVZP during the lifetime of the Gaia project.

The software AZP (Astrophysical Zero Point) will compute theoretical convective shifts of stars thanks to an interpolation algorithm from stellar atmosphere simulations. It will also use gravitational redshifts form CU8 in order to determine stellar kinematic radial velocities.

Our Gaia activities are supported by Université Montpellier 2, the CNES and the CNRS-funded "Action Spécifique" Gaia.

Towards an accurate alignment of the VLBI and Gaia frames *by Géraldine Bourda (Laboratoire d'Astrophysique de Bordeaux, France)*

During the past decade, the IAU fundamental celestial reference frame was the ICRF (International Celestial Reference Frame), composed of the VLBI (Very Long Baseline Interferometry) positions of 717 extragalactic radio sources. Since 1 January 2010, this first realisation has been superseded by the ICRF2, a new and more accurate realisation. It includes VLBI coordinates for 3414 extragalactic radio sources, with a floor in position accuracy of 60 µas. Later, Gaia will permit the realization of the extragalactic celestial reference frame directly in optical bands, based on the QSOs (Quasi Stellar Objects) that have the most accurate positions (~30000 objects), of the order of a few tens of µas at magnitude 15−18.

The alignment between the VLBI and Gaia frames will be important not only for guaranteeing a proper transition if the fundamental reference frame is moved from the radio to the optical domain, but also to record the radio and optical images of any celestial target with the highest accuracy. This data will allow one, for example, to pinpoint the relative location of the optical and radio emission in active galactic nuclei (AGN) to a few tens of µas, placing constraints on the overall AGN geometry. Estimates of this optical-radio core shift indicate that it may amount to ~100 µas on average at 8 GHz [1], significantly larger than Gaia and VLBI position accuracies. It should thus be directly measurable. Conversely, these shifts will also affect the accuracy of the link between the two frames. For this reason a large number of objects is desirable in order to average out such effects.

This alignment, to be determined with the highest accuracy, requires several hundreds of common sources, with uniform sky coverage and very accurate radio and optical positions. Obtaining such accurate positions implies that the link sources must be brighter than optical magnitude 18, and must not show extended VLBI structures in order to ensure the highest VLBI astrometric accuracy.

In a previous study, we investigated the potential of the ICRF for this alignment and found that only 70 sources are appropriate for this purpose [2]. With the determination of the ICRF2, which is based on the VLBI position of ~4−5 times as many sources, ~200 extragalactic radio sources were found suitable for aligning ICRF2 with the future Gaia frame. This highlights the need to identify additional suitable radio sources, which is the goal of a VLBI program that we initiated five years ago.

This program has been devised to observe 447 optically-bright extragalactic radio sources, on average 20 times weaker than the ICRF sources, selected from a dense catalogue of weak radio sources. A multi-step VLBI observing strategy has been specifically developed to detect, image, and measure accurate VLBI positions for these sources [3]. The first step, whose goal was to assess the VLBI detectability of the 447 targets, showed an excellent detection rate of 89%. In total 398 sources were detected. The second step was targeted at imaging the sources previously detected, in order to identify the most point-like sources and therefore the most suitable ones for the alignment. From the pilot imaging experiment, all sources were successfully imaged, and about half of them were found to be point-like [4]. Assuming similar statistics for the subsequent experiments, this would lead finally to a sample of about 200 additional sources suitable for the alignment of the frames. The third step dedicated to VLBI astrometry for the most compact sources will be engaged in 2012.

The 100-m diameter Effelsberg antenna (Germany), used during all the VLBI experiments to observe weak extragalactic radio sources for the alignment with the future Gaia frame. The large diameter is necessary to achieve the high sensitivity to detect such weak sources (Picture credit: Dr. Schorsch).

Finally, plans are being devised for VLBI observations of the link sources during the Gaia mission, in order to control source position stability and accuracy, as well as potential variations in VLBI structures. To this end, Gaia scanning law should allow us to carry out quasi-simultaneous VLBI and Gaia observations. This will be also of high interest for astrophysical purposes (e.g. near real time optical-radio comparisons for constraining AGN jets properties).

[1] Kovalev et al., 2008, A&A 483, 759

[2] Bourda et al., 2008, A&A 490, 403

[3] Bourda et al., 2010, A&A 520, A113

[4] Bourda et al., 2011, A&A 526, A102

Modelling the RVS Background Signal arising from Point Sources *by Katja Janssen (Astrophysikalisches Institut Potsdam, Germany)*

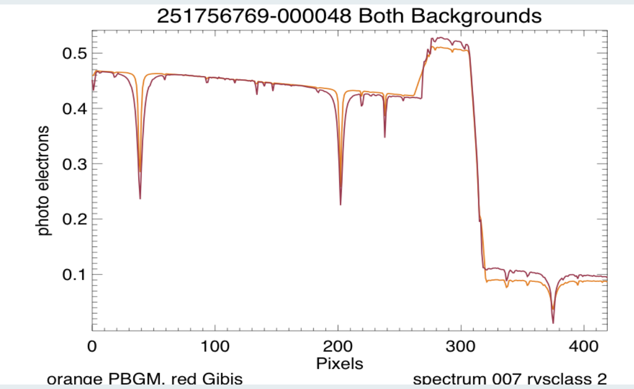
The Radial Velocity Spectrometer (RVS) is an integral field spectrograph, that displays simultaneously all sources in the instrument field of view as spectra on its detector. Like all Gaia instruments the RVS is operated in a windowing mode. Its readout windows contain 1260 x 10 pixels and include some pixels outside the RVS filter bandwidth to allow for an estimate of the diffuse sky background.

As a consequence of the integral field nature of the instrument, spectra of nearby point sources (nearby in across scan direction) may overlap. If this happens for two observed objects that both have a readout window, the spectra will be disentangled using the specific "Deblend" module (see cover picture). But in some cases one of the sources might not have a readout window. This happens for faint sources > 17 mag, or for bright sources in a very crowded field, in which the amount of available readout windows is exceeded. Especially in the latter case it is absolutely crucial for the interpretation of the data to correct the observed target spectrum from the disturbing point source (contaminant) spectrum.

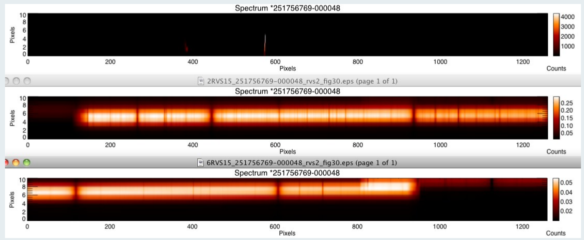
The "Point Background" module is designed to give an estimate of the contaminating flux for each pixel involved. As the contamination cannot be measured - and this is the whole point - it must be derived in a different way: The spectrum of the contaminant is simulated on the detector, then its spread into the target spectrum is calculated. In detail this is done as follows:

The position of the observed target spectrum on the detector is determined and through the target ID, observation time and a criterion for the field of view coordinates all nearby point sources that did not get a readout window are identified.

For each contaminant, we measure its distance from the target for later use. The eta distance will translate into a wavelength shift between contaminant and target, while the zeta distance accounts for the fraction of the signal spreading into the target window.



The modelled point source background signal (orange) in comparison to the "true" GIBIS background (red). We see contributions from two contaminants, one is shifted to the right and one is shifted to the left in respect to the target. Around pixel number 300 they overlap by about 40 pixels.



GIBIS Simulation of the above shown target window: GIBIS readout window containing target, background, noise and cosmics (top), GIBIS readout window containing target, background, no noise/ cosmics (middle), GIBIS readout window containing just the background with two overlapping contaminants (bottom).

Depending on the atmospheric parameters of the source we select the appropriate template spectrum from a library. We apply rotational and radial velocity if available, and apply the barycentric velocity correction that is set for the target.

We then scale the template:

1) apply the instrument response curve, limiting the template to the RVS wavelength range and continuum trend,
2) normalize the flux to the RVS zeropoint magnitude, defining the magnitude scale for the RVS,
3) scale the template flux to the contaminant's proper magnitude,
4) scale the flux by the fraction of the across scan line spread function, that reflects the length of a pixel at the earlier defined distance between target and contaminant in across scan direction.

The last step is repeated for each of the ten rows in the window (2D case), or for a ten pixel integral of the line spread function instead (1D case), depending on the target window geometry.

Once the flux scaling is done, the contaminant spectrum is interpolated to the wavelength positions relevant for the target window using the earlier measured eta shift between both sources.

In this way, the final background contribution of each contaminant is well defined for each pixel of the target window, regardless whether it is high or low resolution, 1D or 2D. It can now easily be summed up to form the final "Point Source Background Model", that is then subtracted from the target spectrum in the next step "Basic Cleaning".

First scientific validation of the model has been performed with simulated GIBIS data, the figure shows an example of a PointBGModel simulated background in comparison to the "true" background as simulated by GIBIS.

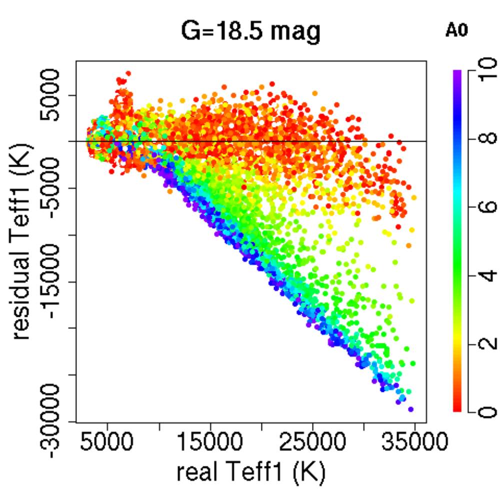
Note: The input properties for bright stars that were left out for telemetry constrains might be known from other transits for this field of view, but in case of absence of the atmospheric parameters, colour indices, radial velocity or rotational velocity, an appropriate degraded mode of this procedure will be applied.

PhD and Post Doc Corner

Paraskevi Tsalmantza, *MPIA Heidelberg, Germany*

Paraskevi Tsalmantza is a postdoctoral researcher at the Max Planck Institute for Astronomy and a member of CU8 within DPAC. Her work focuses on the estimation of the main astrophysical parameters of unresolved binary stars with Gaia BP/RP spectra. This problem is very interesting since most of the 1 billion stars that will be observed by Gaia will be binaries. For this purpose she is working on the development of the Multiple Star Classifier (MSC). The code, which will be part of the Gaia Astrophysical parameters processing chain (Apsis), is based on the Support Vector Machine (SVM) algorithm for regression. First tests on the performance of MSC on simulated Gaia spectra show that the parameter estimation for the binary system and the primary star is quite accurate. For the secondary star the results are also good for systems with a small brightness ratio between the two stars (i.e. $\Delta m < 1.7$). In order to improve the results for the secondary star she is currently working on developing and testing an additional method which is based on a probabilistic Bayesian approach.

Finally, as part of her work within CU8 she is also actively involved in the development of synthetic and semi-empirical spectral libraries which are used to train and test the various CU8 classification and parameterisation algorithms.



An example of the performance of MSC for simulated Gaia spectra of binary stars with magnitude G=18.5 mag. The residuals of the predicted effective temperature of the primary star vs. their real values. The dependence of the results on the extinction parameter is also presented. The poor performance at high extinction can be improved by estimating the extinction parameter at a first step and then the most significant parameters of the binary system.

Calendar of next DPAC related meetings

02/02	ESTEC	MLA Steering Committee meeting	T. Prusti
16-17/02	Barcelona	IIOC meeting #3	A. Brown
13-14/03	CNES	Java Workshop #12	W. O'Mullane
15/03	CNES	CU1: System Architecture #14	W. O'Mullane
16/03	CNES	PO DPC meeting #4	E. Mercier
20-21/03	Edinburgh	Radiation Task Force meeting #10	F. Van Leeuwen / N. Hambly
29-30/03	Nice	REMAT #10	S. Klioner / F. Mignard
17-19/04	Bologna	CU5: Photometric Processing #11	F. Van Leeuwen / C. Cacciari

Gaia and related science meetings

29/02 - 02/03	Barcelona, Spain	**Galaxy Modelling with a Gaia mock catalogue**	https://gaia.am.ub.es/Twiki/bin/view/WS2GaiaMock/WebHome
25 - 31/03	Villars-sur-Ollon, Switzerland	**Dynamics of Young Star Clusters and Associations**	http://www.astro.phys.ethz.ch/sf2012
16-19/04	Fermilab, Illinois USA	**Calibration and Standardization of Large Surveys and Missions in Astronomy & Astrophysics**	https://indico.fnal.gov/conferenceDisplay.py?ovw=True&confId=4958

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