Gaia DPAC Newsletter 8

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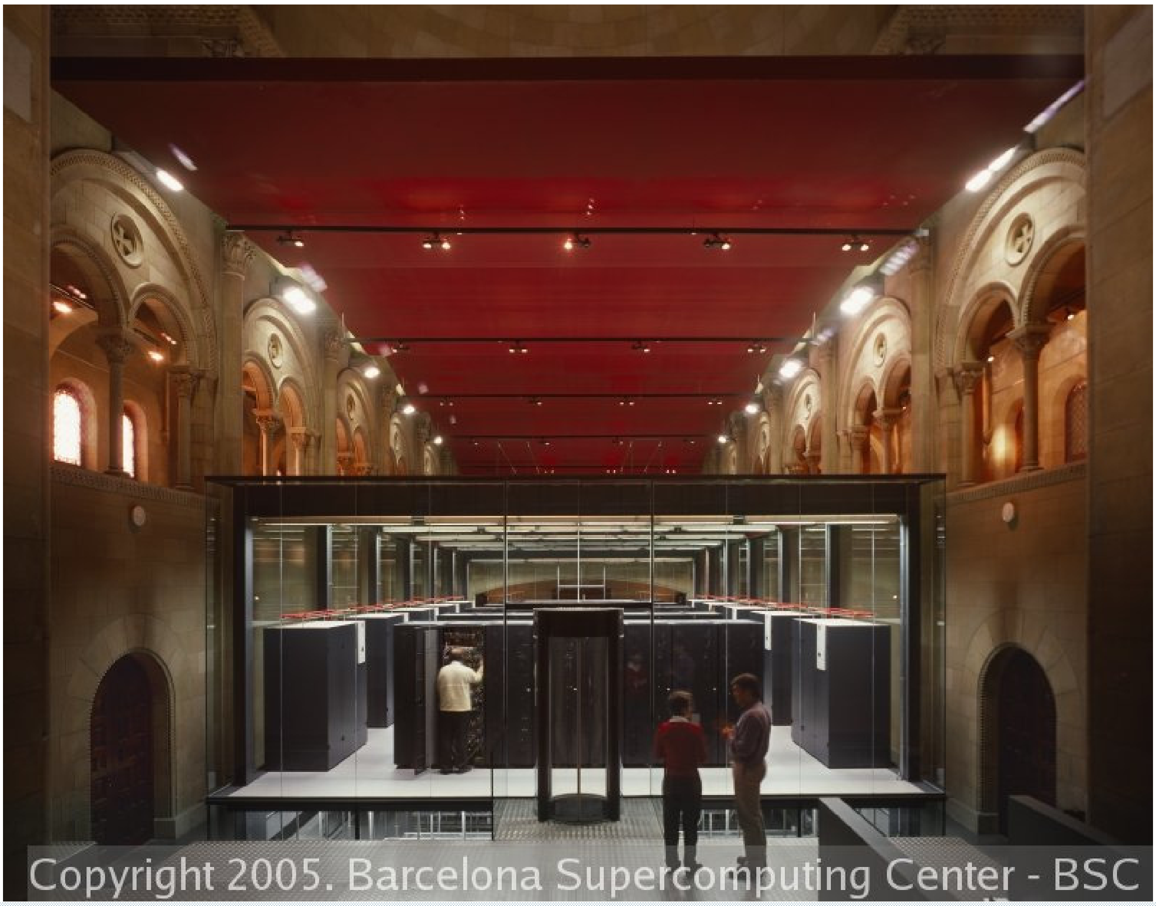


View of the MareNostrum Supercomputer housed in the decommissioned chapel Torre Girona at the Polytechnic University of Catalonia in Barcelona. This is one of the most powerful computer in Europe and is used by the DPAC to produce large volume of simulated data, and later will do number crunching for the processing of real data, primarily in the analysis of CCD images. *See detailed article in this issue.*

Editorial *by DPAC chair, François Mignard*

A major milestone for the mission took place over the last two months with the Critical Design Review (CDR) of the Payload Module (PLM). EADS Astrium, as main contractor, produced a datapack of about 100 different documents covering structures, optics, metrology, detectors and final performances. The goal was to show that the PLM as defined by the contractor meets the mission requirements and to assess the possible non-compliances. These highly technical documents were reviewed by a panel of experts who provided comments, suggestion and recommendations to the contractor. The Board finally declared the CDR successful.

At the same time, the deliveries and integrations of sub-systems continue, both for the PLM and the Service Module, the latter scheduled for a delivery in June. It is also expected that all mirrors should be available by this summer.

Another significant development around the mission is now clearly visible with the organisation of the Scientific Community to prepare the exploitation of the Gaia science results. Several topical workshops are being organised, with participation of scientists from outside the DPAC (science alerts, stellar modelling, extragalactic science, multiple systems, ..) and the European Science Foundation (ESF) has agreed to fund for five years a new science network around Gaia to address the scientific issues. This is a clear indication, that the community awareness and expectation is rising as the mission approaches.

In this issue you will find the usual columns about the DPAC groups and learn rather precisely the significant impact of that Gaia will have on the science of extrasolar planets and also how short period variable stars signal could be analysed with photometric data at the CCD time resolution.

DPAC news

In early February, DPAC and the Gaia Project at ESA signed and issued the Interface Control Document. This is an important document covering deliveries both for the development and operational phases dealing with the optical configuration and instrument parameters, the detectors properties, the spacecraft attitude, the on-board timing and the calibration support to be provided by DPAC. This document has been in the making for more than two years with contributions from DPAC,the Project team and the Project Scientist support team.

DPAC is actively preparing the Integration Testing whose stages have been described in a previous issue of this NewsLetter. A new schedule, integrating the updated launch date, has been proposed by the Project Office and approved by the DPACE. The scientific validation must proceed in parallel during the test campaigns.

The position of Project Management Officer for the DPAC Project Office at ESAC, funded by the Italian Space Agency (ASI) as part of its commitment to the Gaia mission, is in the process of being filled. Following the call issued few months ago, we received 46 applications that are being reviewed. Final selection is expected before summer with the expectation that the selected candidate can be in place in September. The applicant will be hired as temporary staff of INAF (Italian National Astrophysical Institute), which implements the position for ASI.

More anecdotical:

DPAC has not been spared by the ash transportation chaos following the eruption of the Eyjafjallajokull, since we had to cancel on very short notice an important meeting of the CU3 in Madrid. This has been a good test of our emergency decision procedure. Thanks to efficient on-line tools, within two hours of the cancellation notice by email, 49 or the 50 registered attendants had confirmed that had received the notification. CU3 management are exploring the best way to cope with this advancement meeting. Similarly the whole GST got trapped in Amsterdam and the four people based in Spain found not other solution than driving overnight over the near 1700 km !

Words of Gaia

Stellar classification

Stars are today associated to a letter representing a type in a surface temperature sequence, the so-called: ***OBAFGKM***. Why not ABC...? In the 1860s, the Italian astronomer P. A. Secchi was the first to exploit the fact that stars are not all the same, shine with various colours and different Fraunhofer spectral lines. He attempted to characterise many of them with a colorimetry matching a temperature sequence in four classes. Later H. Draper and then E. C. Pickering's group expanded Secchi's work, describing and ordering the stars according to the strength of the Hydrogen lines of their spectra, with letters A, B, C..., starting from A for those with the most prominent lines. However the sequence was fully artificial and did not link the classes to one or more physical parameter. A careful work done in this group around 1900 by Miss A.J. Cannon led her to re-introduce the Secchi's colorimetry classification with a temperature sequence, reducing the numerous letters into the ***OBAFGKM*** system. This related for the first time the amount of hydrogen to another physical property of the stars: their surface temperature.

She gave her system the well known mnemonic: "**O B**e **A** **F**ine **G**irl, **K**iss **M**e".

Miss Cannon was also a pioneer among women in Science. At this time, women were hired to do such work like stellar classification because they could be paid less than men for that boring job. Miss Cannon showed the American Astronomy Society that women are as competent as men in Astronomy, and deserved equal rights and opportunities.

Miss Annie Jump Cannon

The Royal Observatory of Belgium, *by the local Gaia team*

The Royal Observatory of Belgium (ROB) is a Belgian federal science institute with more than 100 scientists active in the fields of astrophysics, astrometry, planetology, geophysics, seismology, and solar physics, and strongly involved in space missions such as Mars Express, PROBA2, HERSCHEL, KEPLER, COROT … and Gaia.

The participation of the ROB in the preparation of Gaia started as early as 2003 in various working groups, and continued after DPAC definition in CU4, CU6, CU7, and CU8. The Gaia ROB team consists of 8 persons having different domains of expertise that encompass the physics and dynamics of intermediate mass to massive stars, of variable and multiple stars, and asteroids.

Our contributions imply work package management and software development.

- In CU8, we are dealing with the identification and classification of peculiar and emission-line stars. Our tasks include the computation and delivery of synthetic spectra based on different codes, the data mining in existing catalogues, the observation of peculiar stars and the subsequent data reduction as part of our GBOG activities.
- For CU7, our staff is working on variability characterisation and is designing algorithms enabling the search and determination of periods of variable signals. We are also involved in specific objects studies. As members of CU6, we are developing and proposing various approaches allowing the extraction of radial velocities and projected rotation velocities from single transit RVS data for single and multiple stars.
- Finally, in CU4, our team is taking care of the astrometric reduction of Solar system objects (SSOs).

Our efforts and participation to the Gaia DPAC are supported by the Belgian ESA PRODEX program.

The Gaia ROB team, from left to right with their respective CUs: R.Blomme (CU6, CU8), E.Van Hemelryck (CU4, CU6, CU7, CU8), Y.Frémat (CU6, CU8), J.Cuypers (CU7), A.Lobel (CU8), T.Pauwels (CU4), P.De Cat (CU7), M.Groenewegen (CU7).

The Gaia team at the Institute of Astronomy in Cambridge, *by Floor van Leeuwen*

It is against a background of theoretical astrophysics, cosmology and X-ray astronomy, more common to the Institute of Astronomy (IoA) in Cambridge, that a small group of some 12 developers and researchers is working on preparing software for the Gaia data processing.

The IoA Gaia team (+Ross Burgon), from left to right: Nic Walton, Marco Riello, Francesca De Angeli,Guy Rixon, Dafydd Evans, Chris Pelzer, Greg Holland, Floor van Leeuwen, Diana Harrison, Simon Hodgkin, Ross Burgon, Lukasz Wyrzykowski, Sue Cowell.

The Institute's involvement in this mission follows on from the UK participation in the Hipparcos data processing, a large part of which took place at the now no longer existing Royal Greenwich Observatory. The Gaia team at the IoA builds on that experience.

A major part of our responsibility is to prepare the Data Processing Center of the IoA for the DPAC (DPCI) for the photometric processing of the large data streams produced by the mission. The team participate also in the planning, management and coordination of the CU5 activities, with F. van Leeuwen as CU Leader and share tasks with other DPAC institutes in the instrument characterisation and the design of photometric calibration methods.

This involves considerable developments in signal modelling, reduction software and data handling, tasks that put high requirements on speed, accuracy and robustness.

We are further developing the photometric science alerts, source environment analysis and are involved in preparing the Gaia attitude model for the data simulations. The activities of the Cambridge team are closely linked and coordinated with our partners in CU5, but also with all other CUs. All Gaia activity at the IoA is currently funded by the UK Science and Technology Facilities Council.

The Gaia Astrometric Survey of Planetary Systems *by Alessandro Sozzetti (INAF – Torino)*

One of the relevant areas of astrophysics on which Gaia observations will have great impact is the science of planetary systems, in particular when seen as a complement to other direct and indirect techniques for planet detection and characterisation.

Gaia's useful horizon for planet detection (see Figure) extends as far as the nearest star-forming regions (e.g., Taurus at $d \approx 140$ pc) for systems with massive giant planets ($M_p \sim 2 - 3\ M_J$) on $1 < a < 4$ AU orbits around solar-type hosts, and out to $d \sim 30$ pc for Saturn- (and lower-) mass planets with similar orbital semi-major axes around late-type stars. Gaia will detect them by measuring a star's wobble in response to the gravitational pull of a planet, characterised by the astrometric signature $\alpha \sim (M_p / M_s)\times(a_p / d)$ (expressed in arcsec if a_p is in AU, and d in pc).

Using Galaxy models, our current knowledge of exoplanet frequencies, and Gaia's estimated single-measurement precision (σ~ 10-15 μas) on bright main-sequence targets ($6 < G < 13$, approximately 5×10^5 stars), one realises how Gaia's main strength will be its ability to measure astrometrically actual masses and orbital parameters for several thousands of giant planets, and to determine the degree of coplanarity in possibly hundreds of multiple-planet systems.

Thanks to the largest compilation of astrometric orbits of giant planets, unbiased across all spectral types screened with constant astrometric sensitivity up to $d \sim 200$ pc, Gaia will crucially contribute to several aspects of planetary systems astrophysics (formation theories, dynamical evolution), in combination with present-day and future extrasolar planet search programs. The Gaia data have the potential to:

a) significantly refine our understanding of the statistical properties of extrasolar planets: the predicted database of several thousand extrasolar planets with well-measured properties will allow for example to test the fine structure of giant planet parameters distributions and frequencies, and to investigate their possible changes as a function of stellar mass, metallicity, and age with unprecedented resolution;

b) help crucially test theoretical models of gas giant planet formation and migration: for example, specific predictions on formation time-scales and the role of varying metal content in the protoplanetary disk will be probed with unprecedented statistics thanks to the thousands of metal-poor stars and hundreds of young stars screened for giant planets out to a few AUs;

c) achieve key improvements in our comprehension of important aspects of the formation and dynamical evolution of multiple-planet systems: for example, the measurement of orbital parameters for hundreds of multiple-planet systems, including meaningful coplanarity tests will allow to discriminate between various proposed mechanisms for dynamical interaction;

d) aid in the understanding of direct detections of giant extrasolar planets: for example, actual mass estimates and full orbital geometry determination for suitable systems will inform direct imaging surveys about the epoch and location of maximum brightness, in order to estimate optimal visibility, and will help in the modelling and interpretation of giant planets' phase functions and light curves;

e) provide important supplementary data for the optimization of the target selection for future observatories aiming at the direct detection and spectral characterization of habitable terrestrial planets: for example, all F-G-K-M stars within the useful volume (~25 pc) will be screened for Jupiter- and Saturn-sized planets out to several AUs, and these data will help probing the long-term dynamical stability of their Habitable Zones, where terrestrial planets may have formed, and maybe found.

The problem of the correct determination of the astrometric orbits of planetary systems using Gaia data (highly non-linear orbital fitting procedures, with a large number of model parameters) will present many difficulties. Within the CU4 data analysis pipeline, DU 437 (Extrasolar Planets) is in charge of the modelling of the astrometric signals produced by planetary systems, using multiple robust procedures for astrometric orbit fitting (such as Markov Chain Monte Carlo and genetic algorithms) and for the determination of the degree of dynamical stability of multiple-component systems.

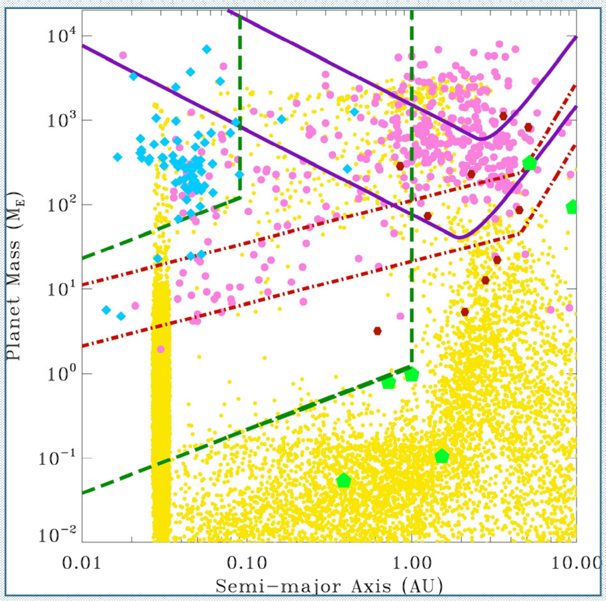


Fig. 1: Exoplanets discovery space for Gaia astrometry, Doppler, and transit techniques. Detectability curves are defined on the basis of a 3σ criterion for signal detection. The purple lines are for Gaia astrometry with $\sigma_A = 10$ μas, assuming a 1 M⊙ G dwarf primary at 200 pc and a 0.4 M⊙ M dwarf at 25 pc, respectively. The survey is set to 5 yr. The radial velocity curves (red lines) assume $\sigma_{RV} = 3$ m/s (upper curve) and $\sigma_{RV} = 1$ m/s (lower curve), $M_* = M_\odot$, and a 10-yr survey duration. For visible-light transit photometry (green curves), the assumptions are $\sigma_V = 5\times10^{-3}$ mag (upper curve) and $\sigma_V = 1\times10^{-5}$ mag (lower curve), *S/N* = 9, $M_* = M_\odot$, $R_* = R_\odot$, uniform and dense (>> 1000 datapoints) sampling. Pink dots indicate the inventory of Doppler-detected exoplanets as of April 2010. Transiting systems are shown as light-blue filled diamonds, while the red hexagons are planets detected by microlensing. Solar System planets are also shown, as green pentagons. The small yellow dots represent a theoretical distribution of masses and final orbital semi-major axes from Ida & Lin (2008).

A million of CPU hours for Gaia simulation *by Eduardo Masana & Xavier Luri (Dept. Astronomia i Meteorologia, Universitat de Barcelona)*

An important part of the DPAC task for the development of the data processing software for Gaia is the testing and validation of the software to ensure its functionality and scientific correctness. For this purpose the CU2 has been set up to generate simulated data allowing such testing and validation.

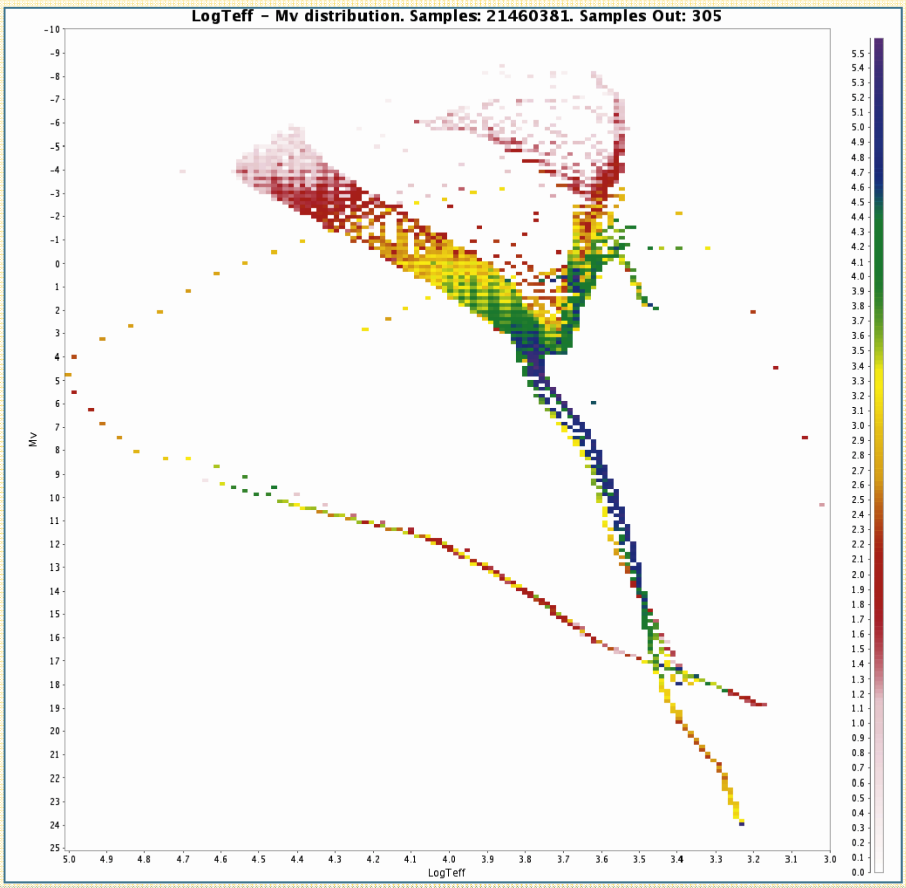
GASS is one of the CU2 data generators, in charge of producing Gaia-like telemetry data to be injected in the processing chain, from Initial Data Treatment (IDT) onwards.

GASS is run by the CU2 team at the University of Barcelona on the MareNostrum supercomputer, one of the most powerful supercomputers in Europe and the number 77 in the world, according to the last Top500 list. This machine is composed of 10,240 processors with a peak calculation capacity of 95 Teraflops.

The GASS simulations include several types of objects: single and multiple stars, solar system objects, QSOs, unresolved galaxies, which make up the Universe model of the simulator. On the other hand, the instrument model takes into account different effects, from the non-linearity of the CCDs to the charge transfer inefficiency or the variation of the quantum efficiency over the focal plane. Though some of those effects are introduced with simplifying assumptions, the complexity of the GASS code is very high, making GASS in need of a huge amount of computer resources.

From the beginning, GASS was designed to be easily run in a parallel way, just splitting the simulation interval in several smaller subintervals. In this way we have run simulations corresponding to the full mission (5 years) for up to 60 millions objects, ending up with more than 3 TB of compressed data (about 6TB uncompressed).

Now, in order to run the GASS simulations needed for the DPAC End to End (E2E) Integration Testing, a total of 1,100,000 CPU hours have been allocated by the *Red Española de Supercomputación* (RES, the Spanish Supercomputing Network) in MareNostrum for the next four months. This will allow the generation of 18 months of telemetry for a scaled-down version of the sky suitable for this E2E testing. This simulation is already running at the time of writing (April 2010) and we expect to deliver the data before the summer of 2010.



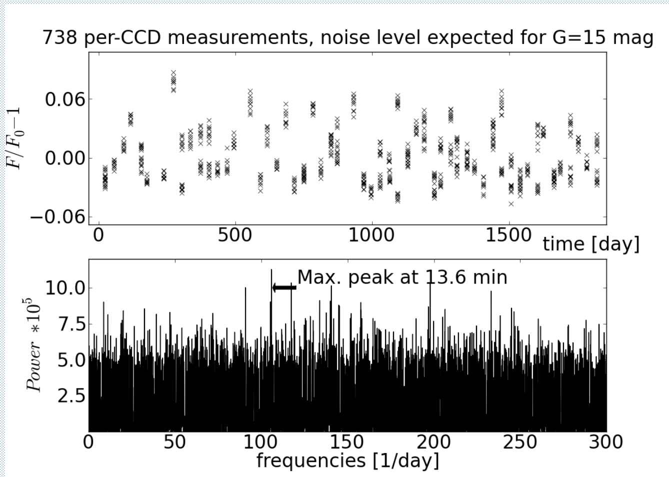
Plot of the Luminosity-Temperature diagram for the stellar sources included in the validation dataset of telemetry simulations being prepared for the Integration Testing phase of the DPAC. There are in total 6.2 million stars or star systems, and 15 million components, making up above 21 million stellar sources in this sample. The colour scale gives the log of the number of sources per bin of 0.2 in logT and 0.15 mag in luminosity. This reproduces fairly well the distribution expected in the Gaia survey.

ELSA: **Mihály Váradi** (Geneva Observatory)

Subdwarf and white dwarf variable stars, just like main sequence pulsator roAp stars, show multiperiodic light variations on a timescale as short as a few minutes. The detection of such short periodicity in the Gaia database requires first to have photometric data with the CCD time resolution, and then to explore a frequency space 5-10 times larger than the frequency space covered in the main stream CU7 variability processing. Such phenomena will be processed in the Special Variability Detection (SVD) work-package of CU7.

Mihály is responsible for maintaining the short time-scale and small amplitude work-packages in SVD; he develops, implements and tests methods that may efficiently detect these types of variability. For this, he builds a database of synthetic Gaia light-curves of short period variables, and uses the CU7 pipeline to obtain period recovery rates.

The figure here shows the synthetic light-curve (upper) and power spectrum (lower) of a multiperiodic white dwarf pulsator. The results were achieved using Gaia per-CCD time sampling and the expected photometric precision of Gaia. The highest peak of the spectrum in the figure shows the correct input frequency.



New on Gaia web portal *by Jos de Bruijne (ESA / ESTEC)*

On initiative of the Gaia Science Team, a new webpage has recently been released by the Project Scientist Support Team summarising the current prediction of the Gaia science performance. The webpage provides the expected accuracies of the astrometric parameters (positions, parallaxes, and proper motions) as function of magnitude, colour, and position in the sky. Links are provided to allow transformations between common/default and Gaia-specific photometric systems. In addition, the expected precision of astrophysical parameters extracted from the BP/RP photometric data, such as effective temperature, surface gravity, and metallicity, is summarised, together with the expected accuracies of the radial velocities as function of magnitude for a range of stars with various spectral types and luminosity classes.

The webpage will be maintained to reflect future developments, for instance when hardware is being delivered and performance can actually be measured in tests rather than predicted from theory or demonstrator models. The webpage will act as central repository for world-wide publication of Gaia's science-performance predictions. It can be accessed from the Gaia main portal http://www.rssd.esa.int/gaia by clicking on "Science performance" in the left-hand menu or directly by following the link:
http://www.rssd.esa.int/index.php?project=GAIA&page=Science_Performance.

Calendar of next DPAC related meetings

Date	Place	Who	Type	Resp.
03-05/05	Barcelona	CU2	Simul. Plans	X. Luri
18-20/05	Leiden	CU5	Plenary	A. Brown
19-21/05	Naples	CU7	Plenary	V. Ripepi
20-21/05	Dresden	CU3	AGIS #13	S. Klioner
26-28/05	Geneva	CU4	Plenary	D. Pourbaix
03-04/06	Torino	CU3	REMAT#07	S. Klioner
07-11/06	Paris	ELSA	Closing Symposium	C. Turon
14-16/06	Paris	CU6	Plenary	D. Katz
18/06	Paris	Steering	SC #06	T. Prusti
01-02/07	ESTEC		GST #31	T. Prusti
06-07/07	CNES		DPACE #11	F. Mignard

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

This newsletter is published by DPAC Chair
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