Gaia:
at the frontiers of astrometry

7-11 June 2010, Sèvres, France

book of Abstracts

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Chapter 1

Invited talks

Global Sphere Reconstruction in the Astrometric Verification Unit
Abbas U.
(INAF - Osservatorio Astronomico di Torino)
Gaia will estimate the astrometric and physical data of approximately one billion objects. The core of this process, the global sphere reconstruction, is represented by the reduction of a subset of these objects, which will constitute the largest and most precise catalogue of absolute astrometry in the history of Astronomy. General Relativity will be tested by estimating the PPN parameter γ to unprecedented accuracy. As the Hipparcos mission showed, and as it is natural for all kind of absolute measurements, possible errors in the data reduction can hardly be identified at the end of the processing, and can lead to systematic errors in subsequent analyses. In order to avoid such type of problems, a Verification Unit was established by the Gaia Data Processing and Analysis Consortium (DPAC). One of its jobs is to implement and perform an independent global sphere reconstruction (GSR), parallel to the baseline one, to compare the two results, and to report any significant difference. We will discuss the challenges, progress and results in the GSR pipeline.

Processing massive datasets in genomics
Artiguenave F.
(Genoscope / CEA)
Life science researches have been profoundly impacted by technological advances allowing faster and cheaper DNA sequencing. Opening a wide range of applications in medical and biology, the last generation sequencing platforms raised new challenges, in particular in processing, analysing and interpreting massive data. In this talk, the growing role of bioinformatics will be illustrated by providing some figures about genome sequencing and others applications aimed at unravelling biological mechanisms. Methods to gather insights from massive amount of data will be illustrated by the genome annotation process, by which genes are identified in the genome sequence.

Gaia: new perspectives in understanding the galactic bulge
Babusiaux C.
(GEPI, Observatoire de Paris-Meudon, France)
Although the Milky Way bulge is our closest opportunity to study in detail such a complex chemo-dynamical system, its formation and evolution is still poorly understood. The high extinction, the crowding, and the superposition of multiple structures along the line of sight make studies of the inner Galactic regions challenging. Two main scenarios have been invoked for the bulge formation: gravitational collapse or hierarchical merging of subclumps and secular evolution of the disc through a bar forming a pseudo-bulge. Recent results suggest that the Galactic bulge could be the result of both formation processes. Gaia will be limited by the extinction and the crowding but will still observe accurately more than 20 million bulge stars (Robin et al. 2005). The Gaia parallaxes and proper motions will probe the structure of the Galactic inner regions, will allow to obtain a clean bulge sample and will solve the different biases in distance currently present in the bulge surveys. Radial velocities will also be obtained for the brightest stars in the less crowded regions, providing 6D constrains to dynamical models. Completed by ground-based abundances, the Gaia bulge survey will provide unique constraints on the formation history of the Galactic inner regions.

Modelling stellar populations in galaxies resolved in stars by Gaia

Belcheva M. (1), Livanou E. (1), Kontizas M. (1), Kontizas E. (2) and Nikolov G. (3)
((1) Department of Astrophysics, Astronomy & Mechanics, Faculty of Physics, University of Athens, Athens, Greece; (2) IAA, National Observatory of Athens, Athens, Greece; (3) Department of Astronomy, Sofia University St. Kliment Ohridski, Sofia, Bulgaria)

Gaia is expected to resolve nearby galaxies in stars, improving greatly our knowledge of them. The main goal of our group is to obtain the spatial distribution of different stellar components in these galaxies and work towards producing a model of the Magellanic Clouds to be used, among others, in simulations by CU2 during the Gaia mission preparation. In this study the Magellanic Clouds are the main targets. The spatial distribution of various stellar populations in these galaxies is being investigated using isodensity maps and radial density profiles. We are now presenting the latest results from our work on modelling the Magellanic Clouds as seen by Gaia.

Gaia outreach features available to the scientific community

Blasco, C.
(ESA)

The already existing outreach resources available to the scientific community that have been updated (like the information sheets or the little books of Gaia) are shown. New features (vodcast in several languages, new posters and a science performance webpage) and short term projects (new and centralised image gallery and a rearranged Gaia webpage) are also presented.

Monitoring the quality of the astrometric global solution

Bombrun A.
(Astronomisches Rechen-Institut)

The astrometric global solution is a principal component of the final star catalogue. It is the solution of a relatively complex least-squares problem related to Gaia's design that can only be solved using an iterative process. Hopefully we found an efficient converging algorithm with a robust stopping criterion. Nonetheless the usage of an iterative algorithm imposes some limitations on our knowledge of the statistical properties of the solution such as the variance which need to be investigated further through simulation technics.

Concluding remarks

Brown A.
(Leiden Observatory)

I will attempt to summarise the conference and look ahead to the exciting time after the launch of Gaia launch.

Gaia spectro-photometry calibration and comparison to ground-based systems

Cacciari C.
(INAF, Osservatorio Astronomico Bologna)

The Gaia photometry consists of white-light G magnitudes obtained from unfiltered fluxes measured in the AF CCDs, and low resolution prism spectra measured in the CCDs dedicated to the blue (BP) and red (RP) parts of the energy distribution. The integrated flux of these BP and RP spectra will yield G(BP) and G(RP) magnitudes as two broad passbands. The internal flux calibration will correct for all possible instrumental effects and produce spectral energy distributions (SEDs) in a internally defined flux scale. The purpose of the absolute flux calibration is to tie this flux scale to physical units by means of spectro-photometric standard stars (SPSS) that relies ultimately on the absolute flux scale of Vega. In so doing, the external (absolute) calibration process will recover the correct shape and fix the zero point of the Gaia measured SEDs. The characteristics of the Gaia spectrophotometric system will be described, and the absolute calibration process will be outlined and compared with examples of ground-based systems.

QSO survey and reference frame with Gaia

Charlot P.
(Laboratoire d'Astrophysique de Bordeaux)

The Gaia space astrometric mission - unlike Hipparcos - will be able to build its own celestial reference frame based on thousands of QSO positions measured with an accuracy of a few tens of micro-arcseconds. It is anticipated that about 500 000 such QSOs should be detected with Gaia, of which 10000-20000 among the brightest ones may be used to define the frame. For consistency with the IAU fundamental frame - currently the ICRF2 (International Celestial Reference Frame, second realisation), comprising VLBI (Very Long Baseline Interferometry) positions for more than 3000 extragalactic radio sources - it is crucial that the two frames (VLBI and Gaia) be aligned with the highest possible accuracy. This requires a number of common objects with excellent optical and radio astrometric properties. Identifying such objects is not straightforward and requires developing VLBI programs concurrent with the Gaia mission. There may also be further complications because optical and radio positions are likely not to physically coincide at the 100 microarcsecond level due to nuclear opacity in the inner parts of these active galaxies. Conversely, direct measurement of such 'core shifts' by comparing optical and radio positions may provide information on actual physical conditions in these cores. The paper will review potential outcome in terms of AGN (Active Galactic Nuclei) physics that will result from comparing/combining ultra-accurate VLBI and Gaia QSO positions in the future.

The Gaia satellite: presentation & status of development

Charvet P.
(EADS Astrium)

Gaia is the sixth cornerstone of the ESA Scientific Programme. Beginning 2006, the programme implementation phase was kicked off at Astrium Satellites. At the time of the ELSA conference, all Critical Design Reviews of the modules have been passed successfully, which enables to give a good snapshot of the development progress. This presentation will summarise the history of the satellite programme and show the involvement of European companies. The status of the current development of the spacecraft will be presented with a focus of the main challenging equipment and a particular insight on the payload. The Payload Module developed by Astrium accommodates within a single architecture the 3 instruments necessary for astrometry, photometry and radial velocity spectrometry, but also accurate metrology subsystems. The Service Module accommodates also challenging subsystems as the large deployable sunshield, the phased array antenna and the micro-propulsion.

The chemical evolution of the Galactic thick and thin disks

Chiappini C.
(Geneva Observatory, Geneva University - Switzerland OATs - INAF - Italy)

Many are the proposed scenarios for the formation of the thick disk of the Milky Way, going from the merger with smaller galaxies to fast gas accretion. One way to get some hints on which is the scenario that best describes the formation of the thick disk is by comparing the chemical properties of bulge, thick and thin disk stars. Another way is by observing galaxies at high redshift. Both approaches will be briefly described. However, current data samples suffer from selection bias. A more clear picture will be obtained by models that can combine both chemistry and dynamics with data samples for which the stellar orbits are known. The last point will be provided by Gaia. By the same time we should be able to put in place more complex models involving both chemistry and dynamics. A work of this kind is underway in Geneva Observatory.

Pulsating variable stars, powerful tools for galactic structure and evolution

Clementini G.
(INAF-Osservatorio Astronomico Bologna, Italy)

Pulsating variable stars are powerful tools to study the galactic structure and evolution, offering several advantages with respect to normal stars. The light variation caused by the periodic expansion/contraction of the surface layers makes them much easier to recognise than normal stars. Their main parameter, the pulsation period, is measured at great precision, is unaffected by distance and reddening, and is directly related to stellar intrinsic parameters such as the star mass, radius, and luminosity. Among pulsating variables the Cepheids are one of the brightest stellar 'standard candle'. Their characteristic Period-Luminosity relation makes them primary distance indicators in establishing the cosmic distance scale. On the other hand, since pulsating variables of different types are in different evolutionary phases, they can be used to trace stellar components of different age in the host system. Their role can be crucial to disentangle different stellar generations in systems where stars of different age and metal abundance share the same region of the colour magnitude diagram. Among different types of pulsating variables the RR Lyrae and the SX Phoenicis stars, with ages comparable to the age of the Universe, were 'eyewitnesses' of the formation of their parent galaxy. Thus they can provide hints on the processes which led to the formation and early assembling of large galaxies such as the Milky Way and the Andromeda galaxy.
I will overview the role played by the pulsating variable stars in our understanding of galaxy structure and evolution in light of the promises of the scientific exploitation of the Gaia mission.

The Gaia spectroscopic instrument (RVS): a technical challenge

Cropper M. & Katz D.
(Mullard Space Science Laboratory, University College London; GEPI, Observatoire de Paris)

The lack of radial velocity data in the Hipparcos catalogue was considered a significant deficiency, so when Gaia was conceived, a spectrometer was a core constituent of its payload. The Gaia-RVS faced a number of design challenges, in particular set by the need to balance kinematic and astrophysical capability. We present an overview of the evolution of the instrument to its present form, identifying the competing technical, performance and programmatic factors which have shaped it.

Preparing the Besançon Galaxy Model for the comparison with Gaia data.

Czekaj M. (1), Robin A.C. (2), Figueras F. (1) and Luri X. (1)
(1 Departament d'Astronomia i Meteorologia, Barcelona, Spain 2 Observatoire de Besançon, Institut UTINAM, France)

The construction of a dynamical model of our galaxy is one of the primary goals of the Gaia mission. Kinematic and star count data, together with the physical parameters of the stars - ages and metallicities-, will allow to characterise our galaxy populations and, from that, the overall galactic gravitational potential. One of the promising procedures to reach such goal will be to optimise the present Population Synthesis models by fitting, through robust statistical techniques, the large and small scale structure and kinematics parameters that best will reproduce Gaia data. We present here the comparison between the data from the Tycho-2 catalogue and the Besançon Galaxy Model simulations.

The Variable Universe through Gaia's eyes

Eyer L., Suveges M., Mowlavi N. and Dubath P.
(Geneva Observatory, University of Geneva, Switzerland; ISDC, Geneva Observatory, University of Geneva, Switzerland)

When we think about the Universe, we are overwhelmed not only by its hugeness, but also by its diversity. One aspect of this diversity expresses itself in the time domain. Long thought to be immutable, many objects in the Cosmos show variabilities that are observable on a human time-scale. Indeed, the variability properties of observed light curves range from extremely regular pulsations like Cepheids to unique events such as supernovae explosions, cover time scales from the order of milliseconds for Gamma Ray Bursts to centuries for stellar secular evolution, and show amplitude variations from parts per million for solar-like oscillations to many orders of magnitudes for the most energetic phenomena in the universe like hyper-novae.
In the understanding of this broad range of variable phenomena, the ESA Gaia mission is unique thanks to its comprehensive approach that combines ultra-precise astrometric measurements to nearly simultaneous spectro-photometric and spectrometric measurements. As any multi-epoch survey, it has specific properties related, for example, to its sampling law and to its types of measurements that will be reviewed in this presentation. We will present the strengths of the Gaia mission, and its potential to better understand the properties of variable objects populating the universe from the analysis of their multi-band light curves. The objects that will be observed by Gaia include stars, active galactic nuclei and asteroids.

Prospects for wide field multi-object spectroscopic instrumentation

Freeman K.C.
(Research School of Astronomy & Astrophysics, The Australian National University)

I will concentrate on high resolution multi-object spectroscopic (HRMOS) instrumentation, because this provides a new class of opportunities for synergy between GAIA and ground based spectroscopy. It opens up the possibility to apply chemical tagging techniques to phase space substructures discovered by GAIA, and so determine whether these substructures are relics of star forming events or accreted galaxies on one hand, or the outcomes of dynamical resonances on the other. The combination of accurate phase space data from GAIA and accurate detailed element abundance data from HRMOS observations will help to identify stars which were born together with the Sun, and to determine the importance of accretion and radial mixing for the evolution of the Galaxy. I will use the HERMES instrument, under construction for the AAT, as an example.

Java-based communication in a High Performance Computing environment

Fries A.
(Dept Astronomia i Meteorologia, University of Barcelona)

Java is one of the most widely used computer programming languages, however its use in High Performance Computing (HPC) is very low. A typical HPC environment consists of a number of multi-core computing nodes, while a typical application running in such an environment contains CPU intensive code that can be executed in parallel. Such an application may require inter-node as well as intra-node communication. Message Passing Interface (MPI) is a language independent specification of an API to allow such communication. F-MPJ is a Java-based implementation of MPI, designed with efficiency as a main objective. DpcbTools is a set of tools designed to be used by the Gaia software running at the DPCB. It includes functionalities to allow for the launching, management and monitoring of applications, it can also act as a framework to distribute data amongst nodes in a HPC environment.

Testing instrument capabilities from simulations

Gardiol D.
(INAF - Osservatorio Astronomico di Torino)

Testing instrument capabilities is a crucial issue for Gaia, where high level performances are expected. This activity involves many aspects: simulation of the instrument through suitable modelling, comparison of the models with the actual instrument, as well as producing evaluation methods, which are strictly related to the way data will be processed and calibrated. In my talk I will discuss the interconnections among these aspects, and provide some example from the current testing activities.

New perspectives from the Galactic halo

Helmi A.
(Kapteyn Astronomical Institute)

I will review our current understanding of the spatial structure and the kinematics of halo stars in the Milky Way. In recent years, we have experienced a change in paradigm thanks to the discovery of large amounts of substructure, especially in the outer halo. I will discuss the implications of the currently available and future observational constraints and fold them into possible formation scenarios.

How I expect to access the GAIA catalogue

Hogg D.W.
(New York University)

Extremely complex data sets must support extremely sophisticated analysis methods for their full exploitation; the GAIA catalogue can be designed to permit these. The entries in the GAIA catalogue (fluxes, positions, parallaxes, and proper motions) will be something like the maximum-likelihood or maximum-a-posteriori parameters for a model that generates the raw data stream, or something approximating that, plus some uncertainty information. Users performing joint analyses on many stars will need to know more sophisticated things about the sensitivity of the likelihood function to multi-parameter changes to the catalogue than what will be straightforward to report. Although it is nearly technically impossible to deliver to the community the complete posterior probability distribution function over the few-billion parameters (catalogue entries), it is possible to deliver tools that make it possible for users to obtain the (relatively) small number of slices and integrals of this that they need to perform responsible probabilistic inference. A key component of this will be providing (limited) access to the raw (telemetered) data. I make some relevant recommendations.

Characterising the astrometric errors in the Gaia catalogue

Holl B., Lindegren L. and Hobbs D.
(Lund Observatory)

Accurate characterisation of the errors in the global astrometric solution for Gaia is essential for making optimal use of the catalogue data. We investigate the structure of the covariance between the estimated astrometric parameters by studying the properties of the astrometric least squares solution method. We find that astrometric errors can be separated in a source part and an attitude part, due to the estimation of the source and attitude parameters respectively. Hence the covariances can be separated in a source, an attitude and a cross term part. This is demonstrated using our scalable simulation tool AGISLab, with which we estimate the covariances statistically using Monte Carlo techniques.

The Depth of Heavens - Belief and Knowledge during 2500 Years (Dinner talk)

Høg E.
(Niels Bohr Institute, Copenhagen)

The lecture outlines the structure of the universe and the development of science during 5000 years, focusing on the distances in the universe and their dramatic change in the developing cultural environment from Babylon and ancient Greece to modern Europe. For Dante Alighieri (1265-1321) the spiritual cosmos contained the Heavens, Earth, and Hell, and it was compatible with the physical cosmos known from Aristotle (384-322 B.C.). Dante's many references in his Divine Comedy to physical and astronomical subjects show that he wanted to treat these issues absolutely correct. Tycho Brahe proves three hundred years later by his observations of the Stella Nova in 1572 and of comets that the spheres of heavens do not really exist. It has ever since become more and more difficult to reconcile the ancient ideas of a unified cosmos with the increasing knowledge about the physical universe. Ptolemy derived a radius of 20 000 Earth radii for the sphere of fixed stars. This radius of the visible cosmos at that time happens to be nearly equal to the true distance of the Sun, or 14 micro-light-years. Today the radius of the visible universe is a million billion (10 to the power 15) times larger than Ptolemy and Tycho Brahe believed.

Ground-based RVS standard stars

Jasniewicz G. (1), Crifo F. (2), Soubiran C. (3), Hestroffer D. (4), Katz D. (2), Siebert A. (5), Veltz L. (6) and Udry S. (7)
(1: GRAAL, Université Montpellier2 ; 2: GEPI, Observatoire de Paris ; 3: LAB, Université Bordeaux 1 ; 4: IMCCE, Observatoire de Paris ; 5: Observatoire de Strasbourg ; 6: IAS, Université Paris-Sud ; 7: Observatoire de Genève)

The Gaia-RVS is a integral-field spectrograph with no calibration device onboard. The instrument will be self-calibrated through the reduction procedure; but it needs a list of well-know objects to define the zero-point, to initiate the iterative reduction process, and to regularly check the behaviour of the instrument. Two categories of objects are envisioned for this purpose: bright asteroids with perfectly known kinematical properties, and a short full-sky list of about 1400 Radial Velocity Standard stars that will also be useful for many other astronomical projects.

Gaia photometry (G and BP/RP): methods, performance and problems

Jordi C. et al
(Dept Astronomia i Meteorologia, ICC-IEEC University of Barcelona)

The Gaia photometry is acquired by means of two low resolution dispersion optics located in the common path of the two telescopes: one for the blue wavelengths (BP) and another for the red wavelengths (RP). The goal of the BP/RP photometric instrument is to measure the spectral energy distribution of all observed objects and thus allow their classification by deriving the astrophysical properties, such as effective temperature, surface gravity and chemical composition, in case of stars. Once the astrophysical parameters are determined, ages and masses will be deduced allowing the study of chemical and dynamical evolution of the Galaxy over a wide range of distances. From the measurements of unfiltered (white) light, from about 350 to 1000 nm in the Astrometric Field, Gaia will yield G-magnitudes that will be monitored through the mission for variability analysis.

This talk will focus on the current view of the data processing of photometric data, based on a large set of internally defined reference sources and an iterative procedure that updates the solutions as new data come in. This way, all the particular circumstances of every transit (FoV, CCD strip and row, column, gate, time, etc.) are accounted for to refer all observations onto a unique Gaia system. An additional step uses ground based observations to tie the instrumental system to the real world and to physical units. Photometric performances and main difficulties will be discussed.

The Galaxy with Large Surveys: Successes and Future Analysis Challenges

Juric M.
(Harvard University)

The distributions of stars and their properties contain a treasure trove of information about the formation, evolution, and present day structure of the Milky Way. Large scale surveys now allow us to map and mine this rich resource across representative volumes of the Galaxy. As an example, the results from the Sloan Digital Sky Survey (SDSS) that I will discuss include measurements of Galactic structural parameters, mapping of stellar number density, metallicity, and kinematics, as well as ongoing discoveries of numerous streams and satellites. The imminent launch of GAIA, as well as the coming online of 2nd generation projects (e.g. SDSS-III, PanSTARRS, VISTA, SkyMapper, DES, and especially LSST) will increase our surveying capability by 10x-100x. It will also bring the challenge of optimally meshing and analysing these large datasets, as well as opportunities to develop strong synergies between them that should not be missed. If used to the fullest, these surveys together have the potential to make significant leaps in the theory of galaxy formation and near field cosmology in the next decade.

Gaia spectroscopy: methods, performances and scientific returns

Katz D., Cropper M., Meynadier F., Jean-Antoine A. and the CU6 coordination unit
(GEPI, Observatoire de Paris, CNRS, Université Paris Diderot)

During the five years of the mission, the Gaia spectrograph, the Radial Velocity Spectrometer (RVS) will repeatedly survey the celestial sphere down to magnitude V$\sim$17-18. This talk will present: (i) the system which is currently developed within the Gaia Data Processing and Analysis Consortium (DPAC) to reduce and calibrate the spectra and to derive the radial and rotational velocities and (ii) the RVS expected performances and scientific returns.

Next generation of light detectors in Astronomy

Kohley R.
(ESA/ESAC, Gaia Science Operation Centre, P.O. Box 78, 28691 Madrid)

The paper summarises the current status of light detectors in astronomy with focus on space science missions. Due to the effort and time needed for the necessary space qualifications, new technologies potentially interesting for space applications are commonly developed and tested for use at on-ground observatories and flown once the technology has matured. But the space environment also requires the development of special detectors for spectral ranges only detectable beyond earth's atmosphere or the development of features and technological enhancements, for example to mitigate space radiation effects. A broad overview of detector systems from X-ray to the far-infrared wavelength bands is given with emphasis on the visible to short wavelength infra-red (SWIR) technologies together with an outlook to the challenges of a next generation of light detectors in space.

The unresolved galaxies with Gaia

Kontizas M. (1), Rocca-Volmerange B. (2), Bellas-Velidis I. (3), Kontizas E. (3), Karampelas A. (1) and Livanou E. (1)
((1) Dpt of Astrophysics, Astronomy and Mechanics, Faculty of Physics, National and Kapodistrian University of Athens, Greece (2) Institut Astrophysique de Paris, France (3) Institute of Astrophysics and Astronomy, National Observatory of Athens, Greece)

We present the contribution of our team to DPAC/ CU8 concerning the classification and parametrisation of unresolved galaxies to be detected by GAIA.Considering that Gaia will observe more than 10^6 (unresolved) galaxies seen almost as point sources we need to provide the algorithm for classification and optimal estimates of their astrophysical parameters. Under this task: a) We are providing libraries of synthetic galaxy spectra (produced under the PEGASE.2 code) and a semi-empirical library using SDSS observations. b) We also develop an appropriate algorithm called Unresolved Galaxy Classifier (UGC). The algorithm is being developed implementing the Support Vector Machines (SVM), a supervised training technique. This algorithm utilises Gaia simulated BP/RP galaxy spectra of our synthetic galaxy library.

New perspectives in stellar physics: Gaia in the 2015 context.

Lebreton Y.
(GEPI, Observatoire de Paris, Section de Meudon)

In the decade to come major improvements are expected in the field of stellar physics coming from all sides: theory, laboratory and numerical experiments, and observation. We shall illustrate some aspects of the expected progress on the basis of a few examples concerning the input physics and parameters of the stellar models and the asteroseismic diagnostics.

ELSA and Gaia: Four years of fruitful European collaboration

Lindegren, L.
(Lund Observatory, Lund, Sweden)

ELSA (European Leadership in Astrometry) is a four-year, EU-funded Marie Curie Research Training Network that will come to its formal conclusion in September 2010. With a total budget of nearly 3 million Euros, the network has employed 10 postgraduate students and 5 postdocs for 2-3 years and financed a number of workshops, training events and topical meetings, culminating in the present symposium. As will be demonstrated by numerous contributions this week, ELSA has amply achieved its main goal: to train young scientists in the context of the Gaia project and Gaia data analysis activities. This talk gives a brief overview of the various ELSA activities and achievements.

The astrometric solution of Gaia: A hard problem

Lindegren, L.
(Lund Observatory, Lund, Sweden)

A core part of the Gaia data processing is the global astrometric solution, in which the positions, parallaxes and proper motions for at least 100 million stars are rigorously estimated simultaneously with the satellite attitude and a large number of instrument calibration parameters. The talk describes the assumptions underlying this solution, explains why it is and probably must be a difficult task, and outlines the practical reduction method known as the Astrometric Global Iterative Solution (AGIS).

Perspectives for determining stellar surface parameters

Ludwig H.-G.
(ZAH - Landessternwarte, Heidelberg, Germany)

We present ideas of GAIA's impact on the determination of the properties of stars primarily connected to the study of their atmospheres. This mainly relates to high-fidelity chemical abundances obtained by combining the GAIA measurements with ground-based spectroscopy for single objects to well-selected populations. We further discuss the impact of GAIA on the study of the atmospheric kinematics of stars.

Gaia data simulations: a powerful tool to prepare for scientific exploitation

Luri X. (1) & Babusiaux C. (2) on behalf of the DPAC CU2
((1) Dept. Astronomia, Universitat de Barcelona ICCUB/IEEC (2) GEPI - Observatoire de Paris, section Meudon)

For more than ten years, a collaboration of European scientists has been producing simulations of the Gaia mission. These simulations range from detailed realistic simulated CCD images to large volume simulations of the Gaia telemetry.

The data of this decade of simulations has been used for many purposes: instrument design, data processing software testing and validation, prediction of mission performances, etc. Today the launch date is getting closer and the task of the simulator in the mission preparation will be mostly wrapped up in a couple of years.

However, this is not the end of the story since the Gaia simulator can also be used for the preparation of the scientific exploitation of the Gaia data. In this talk we will present the simulator and its components, the data it can produce and the perspectives for the utilisation of this data during the mission, both for data evaluation and scientific exploitation.

Real-time classification of astronomical transients

Mahabal A.
(California Institute of Technology, Pasadena, USA)

The number of surveys and programs in a position to detect transients and variables has been on the increase and with it the realisation that quick follow-up and classification are crucial if one is to make use of these rich datasets. We have been working on many aspects of the entire process on various sky-surveys, most notably the Catalina Realtime Transient Survey. Often due to the scarcity of data on particular objects, novel methods have to be used and the classification process has to be iterative. We outline the accomplishments and challenges especially keeping GAIA in mind.

Gaia data analysis and mutual dependencies between the three data flows.

Mignard F.
(Observatoire de la Côte d'Azur)

The Gaia scientific data stream comprises basically three flows, with astrometric, photometric and spectroscopic data amounting to about 100 TB of raw telemetry data over a the five-year planned mission. A big pan-European organisation has been set up to face the challenge of the data processing, covering its overall and detailed design, testing and validation and finally its implementation, ending with the production of the Gaia Catalogue. I will describe the top-level structure of the data processing, and explain that beyond the first approximation where the three chains are developed independently, they are in fact quickly entangled with numerous mutual dependencies. I will show how the structure of the processing and its implementation have been designed to cope with this intricacy.

Inverse methods for asteroid orbit computation

Oszkiewicz D. A., Muinonen K., Virtanen J., and Granvik M.
(University of Helsinki, Finnish Geodetic Institute, Institute for Astronomy (Hawaii))

Statistical asteroid-orbit-computation methods have proven important in problems such as computing the collision probability, performing dynamical classification, identifying asteroids, and aiding the recovery of lost objects. These methods will be of major importance during the Gaia mission (to be launched in 2012). Here we present variants of those methods and some of its applications. As earlier, we examine the Bayesian a posteriori probability density of the orbital elements using Monte-Carlo methods that map the volume of solutions in the orbital-element phase space. In particular, we use the Markov-Chain Monte-Carlo (MCMC) method to map the phase space. Obtained orbital elements marginal distributions can then serve as a base for other problems as collision probability computation, dynamical classification and others.

Hardware and networks for Gaia data processing

O'Mullane W. (1), Beck M. (2), De Angeli F. (6), Hoar J. (1), Martino M. (3), Passot X. (4) and Portell J. (5)
(1. ESA / European Space Astronomy Centre 2. ISDC 3. ALTEC 4. CNES 5. CESCA/UB 6. IoA)

A considerable amount of computing power is needed for Gaia data processing during the mission. A pan European system of six data centres are working together to perform different parts of the processing and combine the results. Data processing estimates suggest around 10^{20} FLOP total processing is required. Data will be transferred daily around Europe and with a final raw data volume approaching 100 TB. With these needs in mind the centres are already gearing up for Gaia. We present the status and plans of the Gaia Data Processing Centres.

Limits in astrometric accuracy induced by surface brightness asymmetries

Pasquato E., Jorissen A. and Pourbaix D.
(Universite Libre de Bruxelles)

Surface brightness asymmetries are a very common characteristic of stars: the position of the light barycentre of such stars (the photocentre) is displaced with respect to the mass barycentre. Moreover, the photocentre position changes in time due to the evolution of those surface features. In some cases, like for supergiant stars or magnetic dwarfs, the induced photocentre motion can be a non-negligible fraction of the star radius. This effect can limit Gaia's astrometric precision being a source of noise that cannot be controlled.Our work focuses on the assessment of its impact on Gaia's astrometric solution and on the processing data flow.

Native and irradiated Charge Transfer Inefficiency characterisation

Pasquier J.-F.
(EADS-Astrium)

To fulfil its numerous science objectives, the Gaia mission needs to account for the impact of the radiations at CCD level. Through the defects generated in the silicon, the radiations will not only degrade the overall signal-to-noise ratio of the measurements, but also corrupt them with a bias to be corrected on ground. In order to characterise this effect, and help deriving a proper calibration strategy, an extensive radiation test campaign has been carried out in EADS Astrium since 2006, covering the different instruments and CCD variants. We present an overview of this radiation test bench, and the different investigations performed so far and associated findings.

Prospect for dynamical modelling of the Galaxy: Gaia in the 2015 context

Pfenniger D.
(Observatoire de Genève)

As data collection and computers expand their capabilities, modelling changes its characteristics. Not only the purpose of modelling becomes multiple, but thresholds are reached beyond which the best suited methods change. This talk will be a review of the modelling possibilities of the Milky Way and spiral galaxy dynamics over the next decade.

Radiation effects on Gaia CCDs

Prod'homme T.
(Leiden Observatory, Leiden university)

Gaia's launch in 2012 coincides with a peak in the sun's activity. Solar protons emitted during flares will continuously damage the CCDs during the 5-year mission lifetime. Protons colliding with silicon atoms create defects in the semiconductor lattice that capture the photo-electrons during their transfer and release them after a while. For all measurements of Gaia this will lead to large charge loss, which will cause a decrease in their precision. For the astrometric data in particular, while the expected residual centroiding error per CCD transit is ~ 0.6 milli-arcseconds for a 15th magnitude star, the radiation induced distortion of the PSF will lead to biases of up to 10 milli-arcseconds. The only way to mitigate these effects and reach the required scientific performance is to develop a detailed understanding of radiation damage effects through a combination of experimental results and physical modelling.

In this talk, I intend to give a brief introduction to radiation damage focusing on the physics, followed by a description of the Gaia community efforts, in particular my PhD research, to elaborate detailed physical models of radiation damage capable of reproducing experimental data, including the latest achievements on the understanding of the pixel electron density distribution and the radiation-induced trap physics.

General status of the Gaia mission and expected performance

Prusti T.
(ESA)

Gaia is an ESA mission performing astrometry, photometry and spectroscopy of about one billion objects in our Milky Way galaxy and beyond. The extent and content of the Gaia Catalogues will enable major progress to be made in many fields of galactic and stellar astronomy. The prime industrial contractor, EADS Astrium, Toulouse, is manufacturing the spacecraft and its payload for launch in 2012. Parallel to the space segment development the ground segment is getting ready as well. The Mission Operations Centre in Darmstadt, the Science Operations Centre in Madrid and the Gaia Data Processing and Analysis Consortium all over Europe are all tackling the challenges imposed by the high requirements of the mission. The presentation will outline the current overall Gaia status. With the approaching launch the expectations of the astronomer community are increasing. The state of the scientific performance estimates will be given and the scenario for the Gaia Catalogue (intermediate) releases will be discussed.

Hunting for stellar streams in the solar neighbourhood with the SDSS and GSC-II kinematic survey

Re Fiorentin P.
(INAF-Osservatorio Astronomico di Torino, Italy)

The growing awareness of the importance of the 'fossil record' in the Milky Way for constraining galaxy formation theory is reflected by the increasing number of new ground- and space-based surveys designed to unravel the formation history of the Galaxy.

Recently, a new kinematic survey has been produced by means of spectro-photometric data from the Sloan Digital Sky Survey (DR7) and high-quality proper motions derived from multi-epoch positions from the Guide Star Catalog II. In this framework, we assembled a sample of $\sim$ 30 000 FGK nearby metal-poor (sub)dwarfs for which selection and distance estimates take advantage of accurate stellar atmospheric parameters (effective temperature, surface gravity and metallicity) derived from SDSS spectra.

Here, as one of the most interesting applications of this (extremely accurate) catalogue, we consider the feasibility of probing fossil signatures of the formation of the Milky Way by selecting and analysing subsamples of stars as tracers of the seven-dimensional space distribution (full phase-space coordinates plus chemical abundance) of the Galactic halo population within a few kiloparsecs from the Sun. Preliminary results exhibit statistical evidence for discrete over-densities localised in kinematics and in the space of adiabatic invariants (angular momentum and energy). By examination of their intrinsic properties, we suggest that they may be possible fossil signatures of past mergers or other accretion events.

Modelling the attitude of the Gaia satellite

Risquez D.
(Leiden Observatory)

The Gaia Attitude Model is a simulation software package that is being developed to achieve a detailed understanding of the Gaia's attitude. It takes into account external physical effects and will consider internal hardware controlling the satellite. The main goal of Gaia is to obtain extremely accurate astrometry, and this implies to have a good knowledge of Gaia's behaviour as a spinning rigid solid body under the influence of various disturbances.

Synthetic And Observed Spectra Of Stars And Stellar Populations As Templates For Gaia

Saguner T. (1,2), Vallenari A. (1), Munari U. (1), Sordo R. (1)
((1) INAF-Osservatorio Astronomico di Padova, Padova, Italy (2) Astronomy Department, Padova University, Padova, Italy)

Abstract: Gaia will provide low resolution spectroscopy in the optical range for $\sim 10^9$ objects. Complete libraries of synthetic spectra for stars and stellar populations are needed to build algorithms that will automatically derive the classification and parametrisation from Gaia observations. Moreover, it is necessary to test those automatic parametrisation algorithms against observational data with precisely determined parameters. We present a homogenous catalogue of ~ 400 observed Red Clump stars having well determined parameters ($T_{\rm eff}$, $\log g$, [M/H]), radial velocities and its applications for Gaia.

Stellar rotation and the age of star determination

Santoro L.
(Observatoire de la Côte d'Azur, Nice)

The stellar rotation combined with 1D internal structure models is a hard problem which has been recently studied. Taking into account of this reality of stars in their modelisations has impact on the their evolutionary tracks in the HR diagrams and have direct consequences on their age determinations. We shall present in the first part of the talk the impact of rotation on the modelisation and position of star in HR diagram. In a second part we shall present how we propose to work on open cluster stars to evaluate the rotational velocity stars with the Chandrasekar-Munch statistic inversion and the use of these results with the CESAM. For that we shall discuss the rotational velocity distribution of stars for different open clusters like the Pleiades, Alpha Persei, Hyades, Praesepe and Blanco 1. We shall discuss the evolution of the rotational velocity of open cluster stars with time of evolution. This work presented is in the Gaia context and is related to the FLAME group activity for the data processing and age and mass determinations of single stars.

Astrometry and Exoplanets: the Gaia Era, and Beyond

Sozzetti A.
(INAF - Osservatorio Astronomico di Torino)

The wealth of information in the Gaia catalogue of exoplanets will constitute a fundamental contribution to several hot topics of the astrophysics of planetary systems. I will provide a brief overview of the potential impact of Gaia micro-arsec astrometry in several areas of exoplanet science, discuss what key follow-up observations might be required as a complement to Gaia data, and shed some light on the role of next generation astrometric facilities in the arena of planetary systems.

New perspectives in Solar System science: Gaia in the 2015 context

Tanga P. & Mignard F.
(Observatoire de la Côte d'Azur)

Gaia represents a major advance in Solar System observations, providing the opportunity of a dramatic improvement of our dynamical and physical understanding of the small body population. We will compare the expected Gaia contribution to other on-going and future surveys, for illustrating the forthcoming strong improvement of our knowledge concerning the Solar System. Gaia will be a unique complement to other observational efforts.

The Catalogue Gaia and the optical-IR interferometry of the future

Thévenin F.
(Observatoire de la Côte d'Azur)

The very accurate distance of bright stars mv<15 will open new stellar physics if the effective temperature is replaced by accurate radius measurement. The use of the top of HR diagram of globular clusters observed with km basis of interferometers will put stringent constraints on the variation of the mixing length along the AGB and more generally on the physics of stellar interior in giant phase of stars. Few examples are given and the best interferometer design is suggested combining long base and short wavelength. Are the main sequence of Open clusters observable with such interferometers? What would be the gain in stellar physics. Combined with asteroseismic space mission the Gaia catalogue of distances will offer a new deal on the ages of star determination. Few examples of the binary stars in Globular clusters are also presented in the age context.

Complementary ground-based observations for Solar System applications

Thuillot W. (1), Hestroffer D. (1) and Tanga P. (2)
(1) IMCCE-Paris Observatory (France) 2) OCA (France))

During its mission Gaia will give access to a so far never reached astrometric accuracy of a large number of Solar System objects. Nevertheless some of these Gaia observations could be efficiently completed by ground-based observations. This will allow us to get a better understanding of the dynamical and physical properties of these objects. We will present a general overview of these cases.

Modelling the attitude: lessons learn from Hipparcos

van Leeuwen F.
(Institute of Astronomy, Cambridge)

For the Hipparcos and Gaia satellites the attitude reconstruction defines the link between the timed transits in the focal plane and relative positions on the sky. Since its publication in 1997, some peculiarities have been identified in the motions of the Hipparcos satellite that affected the accuracy and noise characteristics of the reconstructed attitude as used in the original reductions. These peculiarities were identified and taken into account in a new attitude modelling approach, which led to an average factor five reduction in the noise level on the reconstructed attitude, and thus also reduced the noise on the final position measurements of stars. Most affected are the brighter stars, where parallax accuracies can now be as high as 0.1 mas. A new reduction of the Hipparcos data was performed, using the global iterative solution approach also planned for Gaia.

Study of short-period variables and small-amplitude periodic variables.

Varadi M. & Eyer L.
(Observatoire de Genève, Université de Genève, CH-1290 Sauverny, Switzerland,)

Our goal was to assess Gaia's performance on the detection of short period ($p < 2$ hours) and small amplitude variability. To reach this goal first we collected the properties of variable stars that fit the above requirements. Then we built a database of synthetic light-curves with short period and low amplitude variability with time sampling that follows the Gaia nominal scanning law and with noise level corresponding to the expected photometric precision of Gaia. After that, we investigated which variable star detection method is more effective by comparing period search and Chi square statistics with statistical hypothesis testing. Finally we performed period search on the synthetic light-curves to obtain period recovery statistics. We are going to present the results of this work.

Implementation of models for Charge Transfer Inefficiency (CTI) in the Gaia pixel-level data simulator

Weiler M. & Babusiaux C.
(Observatoire de Paris - Meudon)

The Gaia pixel-level data simulator GIBIS (Gaia Instrument and Basic Image Simulator) provides detailed data for all three instruments on-board the Gaia spacecraft. This data is used for the preparation of procedures required for the analysis of real Gaia data to come during the mission. Among the effects that strongly affect all Gaia data, that therefore have to be modelled with GIBIS, is charge transfer inefficiency (CTI). CTI, caused by radiation-induced microscopic defects in the CCD detectors, becomes manifest in a distortion of the line spread functions of observed objects, as well as in a loss of photo-generated charges inside the window allocated to each observed source. It affects the astrometric, photometric, and spectroscopic accuracy of the data. The CTI effects on a particular observation depend on observations done before, on CCD operations such as gate activity and charge injections, and on physical effects such as the sky background brightness and cosmic ray events in the detectors affect the CTI. In this talk different approaches for a simulation of CTI with GIBIS will be presented and the influence of the different effects will be discussed.

Nano-JASMINE: use of AGIS for the next astrometric satellite

Yamada Y.
(Kyoto University)

The core data reduction for the Nano JASMINE mission is planned to be done with Gaia's Astrometric Global Iterative Solution (AGIS). The collaboration started in 2007 prompted by Uwe Lammers' idea. In addition to similar design and operating principles of the two missions, this is possible thanks to the encapsulation of all Gaia-specific aspects of AGIS in a Parameter Database. Nano-JASMINE will be the test bench for GAIA AGIS software. We present this idea in detail and the necessary practical steps to make AGIS work with Nano JASMINE data. We also show the key mission parameters, goals, and status of the data reduction for the Nano JASMINE.

Chapter 2

Oral contributions

Can we use the nearby velocity distribution to constrain the properties of the bar and the spiral arms of the MW? Gaia capabilities

Antoja T., Figueras F., Valenzuela O., Pichardo B. and Moreno E.
(DAM and IEEC-UB, Institut de Ciencies del Cosmos de la Universitat de Barcelona, Instituto de Astronomia de la UNAM)

It has been shown that the effects of the bar and the spiral arms of the MW can induce kinematic groups in the local stellar velocity distribution. In this presentation we aim to explore to what extent we can use the kinematic imprints to constrain the large-scale structure of the MW and its recent evolution. We have performed test particle simulations in a flexible MW potential that is consistent with several observational constraints in order to explore the phase space available to the local stellar distribution. Our results show that the bar and the spiral arms create strong kinematic imprints on the velocity distributions. When the spiral arms and the bar act together, individual imprints of each component can be still identified in the final velocity distributions. The spiral arms crowd the kinematic region of Hercules and not only the bar, as traditionally believed. The arms also induce slightly tilted kinematic branches that resemble some of the observed ones. The low angular momentum moving groups such as Arcturus can have an origin related to the bar acting on a relatively hot stellar disc, which introduces a new perspective on the interpretation of its extragalactic origin. We find that the induced stellar kinematics groups depend on the structure and dynamics of the model and on the initial conditions of our experiments. We discuss several future perspectives in the field in order to definitively disentangle the origin of the different kinematic groups in the solar neighbourhood and finally constrain some properties of the MW and its evolution. We also evaluate the Gaia capabilities to provide new insights into the study of moving groups. We have calculated the accuracies in U, V, W velocities using the Gaia Universe Model Snapshot (GUMS), based on the Besançon Galaxy Model, and the current estimations of the Gaia errors. We have found, for instance, that even using the relatively inaccurate radial velocities offered by Gaia for stars up to $V = 16$ we may be able to perform robust statistical analysis of the disc velocity distribution (with accuracies better than $2\,\mathrm{km\,s^{-1}}$) up to $\sim 3\,\mathrm{kpc}$ from the Sun.

GYES, a multifibre spectrograph for the CFHT

Bonifacio P. et al.
(GEPI UMR 8111, Observatoire de Paris)

We have chosen the name of GYES, one of the mythological giants with 100 arms, offspring of Gaia and Uranus for our instrument study for a multifibre spectrograph for the prime focus of the Canada-France-Hawaii Telescope. Such an instrument could provide an excellent ground-based complement for the GAIA mission and a northern complement of the HERMES project on the AAT. The CFHT is well known for providing a stable prime focus environment which has hosted several imaging instruments, from the photographic plates, to the electronic camera of Lallemand and more recently MegaPrima-MegaCam and WIRCam, but has never hosted a multifibre spectrograph. Working upon the experience gained at GEPI with FLAMES-Giraffe we are investigating the feasibility of a high multiplex spectrograph (about 500 fibres) over a field of view of 1 degree diameter, or larger. We are investigating an instrument with resolution in the range 15000 to 30000, which should provide accurate chemical abundances for stars down to 15th magnitude and radial velocities, accurate to 1 km/s for fainter stars. The study is led by GEPI-Observatoire de Paris with a contribution from Oxford for the study of the positioner. The financing for the study comes from INSU CSAA and Observatoire de Paris. The study will be delivered by October 2010.

Long term analysis for the BAM device

Bonino D. & Gardiol D.
(INAF - Osservatorio Astronomico di Torino)

Algorithms aimed at the evaluation of critical quantities are based on models with many parameters, whose values are estimated from data. The knowledge, with high accuracy, of these values and the control of their temporal evolution are important features. In this work, we focused on the latter subject, and we show a proposed pipeline for the BAM (Basic Angle Monitoring) Long Term Analysis, aimed at the study of the calibration parameters of the BAM device and of the Basic Angle variation, searching for unwanted trends, or cyclic features, or other potential unexpected features.

Dynamical inference from a kinematic snapshot

Bovy J. & Hogg D.W.
(New York University)

One of the primary objectives of the Gaia mission is to achieve a coherent understanding of the structure and dynamics of the Galaxy. However, the problem of inferring the dynamics of the Galaxy from the Gaia data is fundamentally ill-posed: Gaia will only observe kinematics—positions and velocities—at a snapshot in time, but it is only the accelerations of the stars that are set by the gravitational potential. One basis for this non-trivial inference is the assumption that the potential is (close to) integrable and that (a large part of) the Galaxy is fully mixed. Under this assumption of mixed angles the inference becomes a standard exercise in probabilistic inference. We discuss this approach in the context of a toy-model: we infer the gravitational force law in the Solar System from the positions and velocities of the eight planets at a single moment in time. We show that an accurate inference is possible while making minimal assumptions about the distribution function. However, we find that a large fraction of the precision of the measurements is spent on inferring the (for our purposes) uninteresting distribution function, a situation that will not be different for Gaia.

The Joint Milli-Arcsecond Pathfinder Mission

Gaume R., Dorland B. and Johnston K.
(U.S. Naval Observatory)

JMAPS is a small, space-based, all-sky visible wavelength astrometric and photometric survey mission for 0th through 14th magnitude stars with a 2013 launch. The primary objective of the JMAPS mission is the generation of an astrometric star catalogue with better than 1 milliarcsecond positional accuracy and photometry to the 1 % accuracy level, or better at 1st to 12th mag. A 1-mas all-sky survey will impact on our current understanding of galactic and stellar astrophysics. JMAPS will improve our understanding of the origins of nearby young stars, provide insight into the dynamics of star formation regions and associations, investigate the dynamics and membership of nearby open clusters, and discover the smallest brown dwarfs at distances up to 5 pc after a 2-year mission, and Jupiter-like planets out to 3 pc after 4 years. JMAPS will provide critical milliarcsecond-level parallaxes of tens of millions of stars which when combined with stellar spectroscopy and relative radii determined from exoplanet transit surveys, allows a determination of stellar radii and exoplanet densities. In addition, the 20-year baseline between the groundbreaking Hipparcos mission and the JMAPS mission allows a combination of the JMAPS and Hipparcos catalogues to produce common proper motions on the order of 50-100 microarcseconds per year. Synergies between the JMAPS and Gaia missions will be explored.

News on Seeking Gaia's Astrometric Core Solution with AGIS

Lammers U. (1) & Lindegren L. (2)
((1): ESA/ESAC, Madrid, Spain (2): Lund Observatory, Lund, Sweden)

We report on recent new developments around the Astrometric Global Iterative Solution system. This includes the availability of an efficient Conjugate Gradient solver and the Generic Astrometric Calibration scheme that had been proposed a while ago. The number of primary stars to be included in the core solution is now believed to be significantly higher than the 100 Million that served as baseline until now. Cloud computing services are being studied as a possible cost-effective alternative to running AGIS on dedicated computing hardware at ESAC during the operational phase.

A New Mechanism for Galactic Disc Mixing: Implications to the Milky Way Evolution

Minchev I.
(Observatoire de Strasbourg)

We have identified a previously unknown radial migration mechanism resulting from the overlap of spiral and bar resonances in galactic discs. We have confirmed these results in fully self-consistent, Tree-SPH simulations, as well as high-resolution pure N-body simulations. I will show that, depending on the spiral and bar amplitudes, metallicity gradients in galactic discs can flatten in less than 1 Gyr, rendering mixing in barred galaxies up to an order of magnitude more efficient than previously thought. In addition, migration caused by resonance overlap can extend disc profiles to more than 10 scale-lengths in both massive and low-mass galaxies, such as NGC 300 and M 33. I will show that mixing in the Milky Way disc may be much more efficient than expected from previous studies not considering the effect of the Galactic bar. This new mechanism can account for both the observed age-velocity relation and the absence of age-metallicity relation in the solar neighbourhood.

The CNES role in the GAIA data processing

Passot X. & La Marle O.
(Xavier Passot CNES/DCT/PS Olivier La Marle CNES/DSP/EU)

As an introduction, we'll summarise the actions of the french space agency for the space astronomy, particularly for Hipparcos. Then, we'll describe the supporting role of CNES for the french astronomy laboratories, and the acting role in the DPAC consortium for the Gaia data processing. CNES is integrating the scientific chains of object processing (CU4), spectroscopic processing (CU6) and astrophysical parameters (CU8) in one processing center. It will be operated during the whole Gaia mission.

Space Interferometry Mission (SIM)-Lite Status

Shao M., Nemati B. and Zhai C.
(Jet Propulsion Laboratory, California Institute of Technology)

The SIM-Lite mission has finished its technology program and continues with an engineering risk reduction activity while waiting for the results of the 2010 decadal review. One of the last remaining activities is work on the SCDU testbed, which is designed to calibrate the spectral bias in interferometric astrometry to 0.1 microarcsec. This talk will provide a summary of engineering activities on building flight-like prototypes of the key interferometer subassemblies, as well as an overview of the types of problems one encounters when attempting to do astrometry below 1 microarcsec, as well as their solution.

Tests of MATISSE on large spectral datasets from the ESO archive

Worley C.C., de Laverny P., Recio-Blanco A., Hill V. and Bijou A.
(Observatoire de la Côte d'Azur)

The automated stellar classification algorithm, MATISSE, has been developed at the Observatoire de la Côte d'Azur (OCA) as a means of determining stellar temperatures, gravities and chemical abundances for large samples of stellar spectra. It has been selected by the Gaia DPAC as one of the key programmes to be used in the analysis of the spectra that will be obtained by the Radial Velocity Spectrometer (RVS) on the European Space Agency's (ESA) Gaia satellite. A key stage in the development of MATISSE is to test its performance on large spectral datasets in order to identify and address issues with analysing real spectra prior to the launch of Gaia in 2012. Under the GSP-Spectroscopy Work Package this testing is being carried out on large datasets of spectra from the ESO archive. Preliminary results regarding the analysis of the archived FEROS spectra will be presented

Chapter 3

Posters

Emission-line Stars and Early-type Stars with Gaia

Blomme R. (1), Fremat Y. (1), Lobel A. (1) and Martayan C. (2)
((1) Royal Observatory of Belgium (2) ESO, Chile)

Gaia will provide accurate parallaxes, spectrophotometry and spectroscopy for hundreds of thousands emission-line stars across the whole HR diagram. The presence of emission lines signifies that interesting physical processes are occurring in a star, such as stellar winds (Wolf-Rayet stars), discs (Be stars), magnetic fields (M stars), etc.

The Gaia data will lead to a better understanding of the physical mechanisms responsible for the emission lines. In preparation for the Gaia mission, we are developing algorithms to recognise and classify emission-line stars. A large collection of ground-based spectroscopic observations has been collected and will be used for testing and training the algorithms.

Gaia will also provide information on several millions of early-type stars. These stars are major contributors to galactic evolution. The Gaia data will allow us to study not only the early-type stars themselves, but also the dynamics of open clusters in which they are formed.

We discuss the detection and the parameter determination of early-type stars from Gaia data. We use synthetic spectra from model atmospheres to check the validity of our techniques.

Future radio reference frames and implications for the Gaia link

Bourda G. (1), Charlot P. (1) and Jacobs C.S. (2)
((1) Laboratoire d'Astrophysique de Bordeaux, France; (2) Jet Propulsion Laboratory, Caltech/NASA, USA)

Since January 1, 2010, the IAU (International Astronomical Union) fundamental celestial reference frame has been the ICRF2 (International Celestial Reference Frame), which is composed of VLBI (Very Long Baseline Interferometry) positions for more than 3000 extragalactic radio sources. This frame is constantly improving through joint efforts of the VLBI community. By surveying the whole sky up to magnitude 20, the European space astrometric mission Gaia will soon create its own celestial reference frame, directly in the optical domain and with many more sources. By 2015-2020, the two frames will thus cohabit and it will be important to align these to the highest accuracy for consistency between optical and radio positions. In this paper, we present the various observational approaches that are undertaken to improve the VLBI frame in the future. These include extension to weaker sources for densification, extension to higher radio frequencies to take advantage of the more compact morphology of the sources at these frequencies, and further observations in the southern hemisphere for homogeneous sky coverage. We also elaborate on how such future radio frames should contribute to highly-precise alignment between the VLBI and Gaia frames within the next decade.

The Photometric Gaia Processing

Busso G.
(Leiden Observatory)

An overview of the processing of the data of the Blue and Red Photometers, starting from the raw data to arrive to the final catalogue.

Membership Identification of Globular Clusters

Chen H.-C. & Ko C.-M.
(Institute of Astronomy, National Central University, Jhongli, Taiwan)

We have developed a method for obtaining membership probabilities by determining the 2-D radius-velocity relation based on our simulations. The spatial distribution and the proper motion data is taken from the UCAC3 catalog. The colour-magnitude diagram for clusters is also derived from the UCAC3, which combined the 2MASS data. We have identified the members of a few globular clusters simply by the separation of cluster members and the field stars in the $r-v$ relation (2-D).
Previous works usually identified the membership of clusters by the position of stars in spatial distribution (radius), velocity distribution (proper motion), and photometry (colour-magnitude diagram). Field star contamination might be severe and many high speed stars near the central region might be lost. More complete members, at least for higher velocity stars, could be identified and the mass of the cluster could be estimated better by our method.

The impact of minor mergers on the anisotropy of stellar orbits

Di Matteo P. (1), Qu Y. (1), Lehnert M.D. (1), van Driel W. (1) and Jog C. J. (2)
((1) GEPI, Observatoire de Paris, France (2) Indian Institute of Science, Bangalore, India)

By means of N-body simulations, we have investigated the impact of minor mergers on the angular momentum content and kinematical properties of a disk galaxy. Our simulations cover a range of initial orbital characteristics and the system consists of a massive galaxy with a bulge and disk merging with a much less massive (one-tenth or one-twentieth) gasless companion which has a variety of morphologies (disk- or elliptical-like) and central baryonic mass concentrations. Our results show that the specific angular momentum of the stellar component always decreases independent of the orbital parameters or morphology of the satellite, and that the decrease in the rotation velocity of the primary galaxy is accompanied by a change in the anisotropy of the orbits. The change in the anisotropy parameter is particularly large outside of the baryonic half-mass radius: in these regions, the stellar orbits, which before the interaction were dominated by tangential orbits, tend to become increasingly radially dominated as the merger advances.

Series of JASMINE missions

Gouda N. and JASMINE Working Group
(National Astronomical Observatory of Japan)

We will introduce the following series of JASMINE missions developed in Japan, which are complementary to the Gaia mission: (1) Nano-JASMINE mission: Nano-JASMINE project is planned to demonstrate the first space astrometry in Japan and to perform experiments for verifications of some technics and operation in JASMINE. Nano-JASMINE will make a whole-sky map of stars observed in Zw-band(central wavelength is about 0.8 micron). Nano-JASMINE uses a nano-satellite whose size and weight are about $50^3\,\mathrm{cm}^3$ and 35 kg, respectively. The targeted accuracy of parallaxes is about 3 mas at z = 7.5 mag. Moreover we can get proper motions with high accuracies(about 0.1 mas/year) combining Nano-JASMINE catalogue with the Hipparcos catalogue. It is determined that Nano-JASMINE will be launched by a Cyclone-4 rocket in August 2011 at a spaceport located in Brazil. (2) Small-JASMINE mission: Small-JASMINE is an astrometric mission that observes in an infrared band(Kw-band: central wavelength is 2.0 micron(from 1.5 micron to 2.5 micron)). Small-JASMINE will determine positions and parallaxes accurate to 10 micro-arc seconds for stars in the Galactic bulge, brighter than Kw=11 mag, and proper motion errors of 8 micro-arc seconds/yr. It will observe small areas of the Galactic bulge with a single beam telescope whose the diameter of the primary mirror is around 30 cm. A target launch date is around 2016. The main science objective of small-JASMINE is to clarify the formation history of the Galactic bulge and also determine the moderate model of the bulge structure formation and the co-evolution of the bulge and super massive black hole at the Galactic center. (3) JASMINE project: JASMINE is an extended mission of the small-JASMINE mission. It is designed to perform a survey towards the whole Galactic bulge region with a single-beam telescope whose the diameter of the primary mirror is around 80cm, determining positions and parallaxes accurate to 10 micro-arc seconds for stars brighter than Kw=11 mag, and proper motion errors of 4 micro-arc seconds/yr. A target launch date is around the first half of the 2020s.

Performance evaluation of Nano-JASMINE

Hatsutori Y., Kobayashi Y., Gouda N., Yano T., Murooka J., Niwa Y. and Yamada Y.
(National Astronomical Observatory of Japan, The University of Tokyo, Kyoto University)

We report the results of performance evaluation of the first Japanese astrometry satellite, Nano-JASMINE. It is a very small satellite and weighs only 35 kg. It aims to carry out astrometry measurement of nearby bright stars ($z < 7.5$mag) with an accuracy of 3 milli-arcseconds. Nano-JASMINE will be launched by Cyclone-4 rocket in August 2011 from Brazil. The current status is in the process of evaluating the performances. A series of performance tests and numerical analysis were conducted. As a result, the engineering model (EM) of the telescope was measured to be achieving a diffraction-limited performance and confirmed that it has an enough performance for scientific astrometry.

Nano-JASMINE: Simulation of Data Outputs

Kobayashi Y., Yano T., Hatsutori Y., Gouda N., Murooka J., Niwa Y. and Yamada Y.
(National Astronomical Observatory of Japan, The University of Tokyo, Kyoto University)

We simulated the data outputs of the first Japanese astrometry satellite Nano-JASMINE, which is scheduled to be launched by the Cyclone-4 rocket in August 2011. The simulations were carried out using existing stellar catalogues such as the Hipparcos catalogue, the Tycho catalogue, and the Guide Star catalog version 2.3. Several statics are shown such as the number of stars those will be measured distances using annual aberration observations. The method for determining the initial direction of the satellite's spin axis has also been discussed. In this case, the frequency of bright stars observed by the satellite is an important factor.

Properties of the thick disc far from the Solar neighbourhood

Kordopatis G., de Laverny P., Recio-Blanco A., Bijaoui A. and Ordenovic C.
(Observatoire de la Côte d'Azur)

Vertical gradients in kinematics, metallicities and spatial structure are crucial ingredients of Galaxy formation models. For that purpose, a spectroscopic survey of nearly 700 stars towards $l \sim 270$, $b \sim 47$ has been made, to detect and characterise possible stellar sub-populations in the Galactic Thick disc. MATISSE algorithm has been used to obtain the atmospherical parameters of the stars ($T_{\rm eff}$, $\log g$, [M/H]) and Y^2 isochrones to get the distances. We present here a comparison with Besançon's model of the Milky Way of the metallicities, distances and kinematics obtained for that sample.

Recognition of unresolved binaries on Gaia colour-indices diagrams.

Malkov O.Y., Mironov A.V. and Sichevskij S.G.
(Institute of Astronomy of the Russian Academy)

Detection of a composite flux in Gaia photometry can serve as an indication of a photometrically unresolved binarity and can allow us to contribute to the parameterisation of the components of binary systems. A main goal of the present study is to develop a method of automatic photometric detection, based on theoretical stellar spectral energy distributions and general understanding of binary evolution. The following procedure is applied to achieve the declared goal. One can compose possible pairs of components, based on evolution concept, and using theoretical binary evolutionary tracks. This can be done for all stages of binary evolution, excluding perhaps the most marginal and rapid stages. Theoretical spectrophotometric spectral energy distributions and response functions of Gaia photometric bands allows us to compute colour-indices of such pairs, when they are unresolved, as well as of single stars. Usage of an interstellar extinction law gives us theoretical colour-indices of reddened objects, both single stars and unresolved binaries. When plotted on a multidimensional Gaia colour space, they allow us to indicate areas, where unresolved binaries can be easily separated from single stars. The procedure also indicates Gaia colour indices, suitable to distinguish those pairs from single stars. As an output of the procedure, a Gaia list of detected photometrically unresolved binaries with physical parameters can be compiled.

Gaia: High contrast object detectability. Application to GAREQ

Mora A., Martin-Fleitas J.M., Raison F. and Kohley R.
(ESA-ESAC, Gaia SOC)

Some scientific cases proposed for Gaia critically depend on the ability to correctly detect and identify faint stars near bright astronomical objects, i.e. where there is a high brightness contrast between objects. One clear example is GAREQ, which aims to measure, for the first time, the quadrupole bending of star light near the Jupiter disk.

The large field of view of Gaia prevents downlinking full images of the sky. Instead, only small windows (samples) around each object of interest will be sent to ground. The Video Processing Units (VPUs) are responsible for identifying the astronomical objects, allocate resources and send the data to storage. The object detectability by the VPUs in fields with very high brightness contrast between objects is currently not well characterised. Object detectability is also a strong function of the optical aberrations and straylight.

The ESA-ESAC Gaia SOC calibration team has modelled and studied this effect. The GAREQ setup (moderately faint stars near Jupiter) has been selected as one of the most difficult scenarios. This talk presents the results obtained. First, the optical modelling of the aberrations and the code developed to produce synthetic images of Jupiter and stellar point sources will be explained. Second, the tool that generates artificial data to feed the VPU simulators will be introduced. Finally, the detectability analysis made via VPU simulator runs will be discussed.

Asteroid lightcurve inversion using Markov-Chain Monte-Carlo methods

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We present convex optimisation methods as well as a Markov-Chain Monte-Carlo inversion method for retrieving spins and shapes of asteroids from the forecoming Gaia photometry. The asteroid shape is modelled as a triangulated surface with or without smoothing using bicubic splines. We verify the methods with the help of simulated Gaia data for an ellipsoidal and a Gaussian-random-sphere sample asteroid.

Orbit Determination of Single-lined Spectroscopic Binaries

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The ultimate goal of binary orbit determination is to obtain the full orbital solution and the component masses. For a double-lined spectroscopic binary (SB2) with period smaller than 5 years and with known spectroscopic orbital elements and the component mass ratio, this goal can be achieved with very high precision by fitting the coming Gaia astrometric data. But this does not apply to a single-lined spectroscopic binary (SB1), because only the mass function can be obtained from spectroscopic observations. Recently, a new analysis technique is developed for separating spectroscopically the primary and the secondary components, and so, it is expected that some SB1s will be turned into SB2. We believe that this technique will become more efficient if an iteration process incorporating with full orbit determination is used. The basic idea is to use component radial velocities from the full orbital solution in optimising the outcome of the spectrum separation technique. As a starting point, we obtain the photocentric orbital solutions of 19 SB1s with main sequence component stars in the 9th Catalogue of Orbits of Spectroscopic Binaries by fitting the revised HIPPARCOS Intermediate Astrometric Data. For each of these systems, a preliminary full orbit solution together with component masses (or magnitudes) can then be obtained by virtue of colour-luminosity and mass-luminosity relations of main sequence stars. It should be mentioned that the component magnitude differences of three such systems are less than 3, meaning that they can already be turned into SB2 by the aforementioned spectrum separation technique. This promising result shows that Gaia mission would be helpful in binary full orbit determination of a lot more systems than what was thought to be.

Astrometric search for extrasolar planets in stellar multiple systems

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After more than 15 years of exoplanet search and more than 400 exoplanets found so far it is now time to characterise them in order to compare the observations with planet formation and evolution theories to understand (exo)planetary systems. Unfortunately, our observations today are strongly biased by selection and observational effects. For example, the radial velocity (RV) technique just yields the minimum-mass of an exoplanet and the transit method is mainly sensitive for very short periods and only possible for nearly edge on-orbits. The underrepresented region in the Mass-Orbit-Diagram of exoplanets (larger orbital radius and lower mass) can be filled by astrometric observations which are most sensitive to larger planetary periods and yield the full orbital information including the true mass of the exoplanet. The final aim should be unbiased observational data obtained by using and merging several observation methods with different sensitivity regions, like Transit, RV, Astrometry and Imaging (combining kinematic, photometric and spectroscopic information).
One if the selection effects is to exclude late-type stars and stellar multiple systems as targets and to concentrate exoplanet search programs mainly on single and sun-like stars. Thus, we search extrasolar planets with high precision ground based and single aperture astrometry in nearby stellar multiple systems, especially binaries with stellar low-mass components. Using a fast observation mode (so called cube mode) to obtain several thousand frames per target, a narrow band-filter located at the near infrared to suppress differential chromatic refraction and an old globular cluster to monitor the astrometric stability we achieve a final precision down to about 0.1 mas which enables us to find Jovian-like planets around sun-like stars and even less mass exoplanets around low-mass stars. In contrast to radial velocity, stellar activity is not a big issue for astrometry.
About the half of all stars are assumed to be a member of a stellar multiple system but only about 45 stellar systems are known harbouring at least one exoplanet detected so far, out of more than 360 exoplanetary systems in total. Is this just a selection and observational bias or is planet formation truncated by the multiplicity of stars? If so, is there a dependency between exoplanets and the properties of the host binaries? From the statistical point of view (2-Dim.-KS-TEST), there is no significant difference in the mass-orbit-relation, but there is one in the eccentricity-orbit-relation of exoplanets around single stars and in stellar multiple systems. Furthermore, there is a dependency between the exoplanet mass and the binary separation. In close binaries (rho $<$ 100 AU) the secondary seems to concentrate a protoplanetary disc, which favoured the formation of higher mass planets. For binaries with larger separation, there seems to be no difference relative to exoplanets around single stars. Another important question is the minimum separation of a binary where planet formation can still proceed. In our astrometric search program, we are able to observe nearby binaries with apparent separations down to a few astronomical units (AU), which is less than the expected minimum separation for planet formation which is assumed to be about 15 - 20 AU.
As a first result of our ongoing astrometric search program, we found a further component in the exoplanet host system HD19994 A & B. While searching the astrometric signal of the RV exoplanet around the A component, we detected a large astrometric signal (about 5 mas) which indicates the present of a high mass brown dwarf or a low mass star around HD19994B (depends on the flux-ratio). This astrometric detection was confirmed by speckle interferometry analysis of our data. Furthermore, spectroscopic follow-up observations are already done and were currently analysed.

Modelling Gaia CCD pixels with Silvaco 3D engineering software

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Gaia will only achieve its unprecedented measurement accuracy requirements with detailed calibration and correction for radiation damage. We present our Silvaco 3D engineering software model of the Gaia CCD pixel and its three applications for Gaia: (1) physically interpreting supplementary buried channel capacity measurements (pocket-pumping and first pixel response) in terms of e2v manufacturing doping alignment tolerances; (2) deriving electron densities within a charge packet as a function of the number of constituent electrons and 3D position within the charge packet as input to microscopic models being developed to simulate radiation damage; (3) deriving effective charge packet volumes as a function of the number of constituent electrons as input to macroscopic Charge Distortion Models being developed to correct for radiation damage in Gaia data processing chains.

Kinematic and chemical signatures of the formation processes of the galactic thick disk

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Thick disks have been observed in many disk galaxies and represent the frozen relics of the first phases of disk galaxy formation. Our Galaxy, the Milky Way, also presents a thick disk whose main spatial, kinematic, and chemical features of this population are well established. However, the origin of this ancient component is still unclear, in spite the many studies carried out and several formation scenarios proposed until now.
Recently, a new kinematic survey has been derived by assembling the astrometric positions extracted from the database used for the construction of the GSC-II with spectro-photometric data from the SDSS DR7. The resulting SDSS-GSC-II catalog contains positions, proper motions, classification, and ugriz photometry for 77 million sources down to $r = 20$, over 9000 square-degrees. There, we selected a subsample 27 000 FGK subdwarfs, for which photometric parallaxes have been estimated, and that we adopted as tracers of the 7D phase distribution (3D positions and velocities, plus [Fe/H]) of the thick disk and inner halo within a few kiloparsecs of the Sun. For the first time to our knowledge, we found evidence of a kinematics-metallicity correlation, of about 40-50 km/s per dex, amongst thick disk stars at $1\,\mathrm{kpc} < |z| < 3$ kpc and with abundance $-1 < [Fe/H] < -0.5$. This finding sets important constraints on the origin of the thick disk in the context of CDM hierarchical galaxy formation mechanisms and of secular evolutionary processes in galactic disks.
Here, further statistical analysis are presented and compared with the preliminary results derived from new N-body high numerical resolution simulations of stellar disks endowed with a bulge inside a dark matter NFW halo.

Binarity and cluster membership of classical Cepheids

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In view of the high incidence of binaries among Cepheids, photometric and physical companions exert adverse effects on the Cepheid related relationships. Possible physical effects of companions (phase jump in the pulsation, presence of slightly excited non-radial modes) and potential of Gaia to identify physical companions are also mentioned.
Cluster membership of Cepheids in our Galaxy and both Magellanic Clouds is also reviewed. Membership in clusters offers a calibration of the period-luminosity relationship independently of the pulsation.

Stellar energy flux modelling under gridified software SYNTSPEC

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We present a gridified stellar energy flux modeling tool SYNTSPEC for stellar spectra analysis. It is an example of data- and compute-intensive application running on the testbed of the EGEE GRID compatible infrastructure, which brings the new quality to the research in astrophysics. The multi job application is running within the Gridcom system - the user friendly interface that allows a common (virtual) work of a physically spread scientific group. Atomic and molecular structure of stellar photosphere redistributes the initial energy flux through the entire spectrum employing absorption, reemission, scattering processes and paints a unique shape of flux image of the specific star. SYNTSPEC software calculates the energy flux and normalised to the continuum stellar spectra that are applied for stellar classifications and determinations of e.g. chemical compositions, effective temperatures and surface gravities of stars. The SYNTSPEC application benefits from the usage of large computing resources, which makes possible the calculation of synthetic stellar spectra for significant wavelength ranges and numbers of stellar parameter combinations. The specific energy flux modelling is an important tool for analysis of data, which will be produced by the European Space Agency's GAIA space observatory.

Science brought by JASMINE data

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The planned astrometric space mission JASMINE will provide the exact positions, distances, and proper motions of the bulge stars. The data brought by JASMINE will certainly reveal the origin and evolution of the Galactic bulge. Here we present the major goals that we aim for.

Can Thick Disks Originate through Minor Mergers?

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By depositing energy into the star motions, minor mergers are a plausible mechanism to form a thick disk, with properties consistent with observations of the Milky Way and other nearby galaxies. Our N-body/SPH numerical simulated minor merger results show that the post-merger thick disk has an increasing disk scale height with radial distances and its vertical density profile poses an excess in outer regions above the disk plane. The presence of gas in the massive primary galaxy can affect the final properties of the thick disk, in particular its scale height, and that multiple mergers have basically the same effect as a single merger of the same total mass, i.e., the effect of multiple mergers does not saturate. Our results are in good agreement with the observed values for local galaxies.

Current Status of Astrometry Satellite missions in Japan: JASMINE project series

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We are developing the following series of astrometry satellite missions at National Astronomical Observatory of Japan. (1) Nano-JASMINE (an aperture size of 5 cm with a weight of 35 kg) (2) Small-JASMINE (an aperture size of about 30 cm) (3) JASMINE (an aperture size of about 80 cm) These three projects have common technological issues. (A) Astrometry satellites are required to measure the positions of stars with high accuracy from the huge amount of data during the observational period. (B) The high stabilisation of the thermal environment in the telescope is required. (C) The attitude-pointing stability of these satellites with sub-pixel accuracy is also required. Measurement of the positions of stars from a huge amount of data is the essence of astrometry. It is needed to exclude the systematic errors adequately for each image of stars in order to obtain the accurate positions. We have carried out a centroiding experiment for determining the positions of stars from about 10000 image data. The following two points are important issues for the mission system of JASMINE in order to achieve our aim. For the small-JASMINE, we require the thermal stabilisation of the telescope in order to obtain high astrometric accuracy of about 10 micro-arcsec. In order to accomplish a measurement of positions of stars with high accuracy, we must make a model of the distortion of the image on the focal plane with the accuracy of less than 0.1 nm. We have investigated numerically that the above requirement is achieved if the thermal variation is within about 0.4 deg / 0.3 h. We also require the accuracy of the attitude-pointing stability of about 280 mas / 3 sec. The utilisation of the Tip-tilt mirror will make it possible to achieve such a stable pointing. We will show the current status of small JASMINE.