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A.S. GAIA: 2007-2011 AND PERSPECTIVES

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Abstract. The Action Spécifique Gaia (A.S. Gaia) has been created mid-2007 by the French National Institute for the Sciences of the Universe (INSU) with the aim of coordinating the French activities related to Gaia, the next ESA cornerstone mission, planned for launch by mid-2013. Various actions have been conducted in order to support 1) studies and ground-based observations mandatory for the calibration of Gaia instruments and for Gaia data analysis and 2) preparatory modelling and observations in view of enhancing the scientific return expected from Gaia data. Perspectives for the coming years are presented.

Keywords: Space observatory, Astrometry, Surveys, Galaxy: structure and evolution, Stars: fundamental parameters, ISM: 3-D structure, Minor planets and asteroids: orbits and fundamental parameters.

1 Introduction

Based on the experience gained with Hipparcos, the first space astrometry mission, launched by ESA in 1989 (Perryman et al. 1997), Gaia, the next ESA cornerstone mission, due for launch in 2013, continues the pioneering tradition of Europe space astrometry (Perryman et al. 2001). However, Gaia will surpass its predecessor by several orders of magnitude in terms of accuracy, limiting magnitude and volume of data. While Hipparcos had a predefined observing program, Gaia will systematically survey the sky, observing all objects brighter than magnitude 20, providing an unbiased view of the sky within a well-defined limit in flux. This combination of a complete census capability with an extreme astrometric accuracy and the simultaneous astrophysical characterisation of the observed objects by multi-epoch spectrophotometric and radial-velocity measurements makes Gaia a unique observatory with a very wide range of science goals. Detailed overviews of these science expectations and of the various questions raised by the huge mass of data expected from Gaia are available, among other references, in the proceedings of the Conference *Gaia at the Frontiers of Astrometry* (Turon et al. 2011).

Gaia is raising two types of challenge: the data processing (devoting one second per star would mean 30 years of data processing ...) and the data scientific exploitation: one billion objects will be repeatedly observed (about 74 observations per objects over the mission duration) with the astrometric, spectrophotometric and spectroscopic instruments on-board Gaia, with an extreme astrometric accuracy and an unprecedented homogeneity. While ESA is funding the satellite in its entirety - including the payload and operations - data reduction is mainly in charge of Member States, as is, of course, the data scientific exploitation. Since 2006, the Gaia Data Processing and Analysis Consortium (DPAC) has been appointed by ESA to process the raw data that will arrive from the Gaia satellite. It is a consortium of over 400 scientists all over Europe, chaired by François Mignard (Observatoire de la Côte d'Azur) and France is its first contributor with about 25 % of the members and manpower. In parallel, in many countries, national structures have been created to coordinate the national activities related to Gaia and prepare their respective astronomical communities for the exploitation of this unique and huge set of data. In France, the Action Spécifique Gaia (A.S. Gaia) has been created mid-2007 by the CNRS National Institute for the Sciences of the Universe (INSU). Also a European network, GREAT= Gaia Research for European Training, is being supported by ESF over the period 2010-2015.

The role of A.S. Gaia is multiple: to prepare the French astronomers, in strong co-operation with European and worldwide colleagues, to best exploit Gaia scientific data in their various domains of application (information about Gaia performance, support to related theory and modelling, support to complementary ground-based observations, including the design of new instrumentations); to support initiatives of dedicated workshops and international meetings; to support ground-based observations required by the Gaia data analysis and not otherwise funded; to represent the French Gaia community towards our National funding authorities and contribute to their roadmaps.

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2 Meetings and workshops

2.1 Plenary meetings

After a kick-off meeting in December 2007, the annual meetings of SF2A are the occasion either of plenary meetings of A.S. Gaia or of common workshops with other *Programmes Nationaux* and other European professional astronomical societies: A.S. Gaia and complementarity with optical surveys (2008); A.S. Gaia and complementarity with asteroseismology (2009); Common workshops 1) *Stellar populations and modelling of the Galaxy: now and after Gaia and complementary ground-based observations*, A.S. Gaia - PNCG, 2) *Resolved Stellar Populations*, SF2A - Società Astronomica Italiana - PNCG - PNPS - A.S. Gaia (2010); Common workshop *Stellar and Interstellar physics for the modelling of the Galaxy and its components*, A.S. Gaia - SF2A - Sociedad Española de Astronomía - PNPS - PNCG - PCMI * (2011). In addition, SF2A plenary meetings have been the occasion to present various domains of application of Gaia: *The Solar System seen by Gaia: new perspectives for asteroid science* by P. Tanga (2008), *Applications de Gaia à la métrologie, la relativité et la physique fondamentale* by F. Mignard (2009), *Gaia : promises and expectations in the field of galactic astronomy* by M. Haywood (2010), and *Stellar physics with Gaia* by B. Plez (2011).

2.2 Topical workshops

Many topical workshops have been organised with the support of A.S. Gaia, in the various fields of application of Gaia data, with the aim of presenting the performance of Gaia astrometry, photometry and spectroscopy. The goals are to make the community well aware of the enormous potential of the mission and to encourage and coordinate efforts in modelling and ground-based observations, including the design of new instruments (for example wide-field multiplex spectrographs) and the establishment of networks of Observatories (e.g. for tracking solar system objects, particularly near-Earth objects), in view of a fruitful scientific exploitation of Gaia data. Information on these workshops, their program and the presentations are available from the A.S. Gaia website (`http://wwwhip.obspm.fr/AS/`).

- 2008: *Reference systems and QSOs*, Bordeaux Observatory, P. Charlot & G. Bourda, 24/10/2008. *Earth-based support to Gaia Solar System science*, Beaulieu sur Mer, P. Tanga & W. Thuillot, 27-28/10/2008.
- 2009: *Multiplex spectroscopy in complement to Gaia*, Nice Observatory, A. Recio-Blanco & V. Hill, 19-20/02/2009. *The Milky Way*, Besançon Observatory, A. Robin, C. Reylé & M. Shulteis, 5-6/11/2009.
- 2010: *Extragalactic Science with Gaia*, Institut d'Astrophysique de Paris, E. Slezak & J. Souchay, 14-16/06/2010. *Milieu Interstellaire*, Paris Observatory, R. Lallement & D. Marshall, 25-26/11/2010. *Gaia Follow-Up Network for the Solar System Objects*, Paris Observatory, W. Thuillot, P. Tanga & D. Hestroffer, 29/11- 01/12/2010 (proceedings: Tanga & Thuillot 2011).
- 2011: *Alertes Gaia*, Institut d'Astrophysique de Paris, M. Dennefeld, 27/05/2011. *Orbiting couples: 'Pas de deux' in the Solar System and the Milky Way*, Paris Observatory, F. Arenou & D. Hestroffer, 10-12/10/2011. *Relevés spectroscopiques en accompagnement à Gaia*, Paris Observatory, P. Bonifacio & C. Babusiaux, 17-18/11/2011.

Beside these workshops and plenary meetings, A.S. Gaia provides some support to a few international conferences organised by French colleagues in France or elsewhere in Europe.

3 Support to ground-based observations

Two categories of ground-based observations, or projects for new instrumentations, are being supported by A.S. Gaia: observations necessary for the data analysis to ensure the precision and accuracy of the future Gaia data (in the context of DPAC) and observations expected to complement Gaia data, with the aim of enhancing the scientific return.

*PNCG = Programme National Cosmologie et Galaxies, PNPS = Programme National de Physique Stellaire, PCMI = Programme National de Physique et Chimie du Milieu Interstellaire

3.1 Ground-based observations in support to Gaia data analysis

A.S. Gaia is supporting two types of ground-based observations in this category: observations for the calibration of the RVS, the Radial Velocity Spectrometer aboard Gaia, and astrometric observations:

- There is no calibration source on board the RVS and the zero-point of radial velocities has to be defined using reference stars and asteroids. The radial velocity stability of these objects must be assured to within 300 m s^{-1} until the end of the mission. 1420 candidate stars were selected and observed in both hemispheres (Crifo et al. 2010). The Northern part (with the Sophie spectrograph at Observatoire de Haute Provence (OHP) and Narval at Observatoire du Pic du Midi) is supported by PNPS and PNCG. The Southern part (with Coralie on the Swiss telescope at La Silla) is supported by A.S. Gaia.
- Astrometric observations of WMAP are performed as a test of the possibility to obtain the position of Gaia on its orbit (also at L2 and with a very similar expected magnitude) with an uncertainty of 150 m in position and 2.5 mm/s in velocity (Taris et al. 2008). Observations of QSOs and compact extragalactic objects are made to enlarge the catalogue of radio sources to be used for aligning the International Celestial Reference System (ICRF) to the Gaia reference system: search for new suitable sources observed in VLBI and observations in the optical wavelengths to detect any variability (Charlot 2011). A.S. Gaia is supporting the observations made in OHP for these two programmes.

3.2 Ground-based observations in support to the preparation of Gaia data scientific exploitation

Most activity in this area is concentrated in two domains: high resolution spectroscopy for galactic archeology (support to observations with existing spectrographs and to the design of new multiplex wide-field spectroscopic instruments), and observations of minor bodies in the Solar System.

- *Galactic archeology.* With its unprecedented astrometric, photometric and spectroscopic survey of all stellar populations, Gaia will revolutionise our knowledge of Galactic and stellar evolution. However, *only* medium resolution spectroscopy ($R = 11\,500$) will be available from the RVS (Radial Velocity Spectrometer) on-board Gaia, and *only* for the brightest 10 million stars, leading to a huge but incomplete knowledge of the abundances and stellar atmospheric parameters. It has long been emphasised that high-resolution spectroscopy would be an essential complement to Gaia data and that Europe should consider the importance of large programmes of ground-based observations using existing instruments, and of designing wide angle high multiplex spectrograph(s) to be mounted on a dedicated ground-based telescope (de Zeeuw & Molster 2007; Turon et al. 2008). This resulted in the setting up of a Working Group on Galactic archeology within the GREAT ESF network, in the proposal of a Gaia-ESO public spectroscopic survey (accepted by ESO in June 2011), and in various projects for new dedicated instrumentations. A.S. Gaia is supporting the participation and contributions of French astronomers to all these actions.
- Observations of minor bodies in the Solar System. Gaia will detect and provide very precise astrometric and photometric measurements for a large number of asteroids. However, a ground-based follow-up is essential to confirm the new detections, to improve the determination of the orbits and to obtain a maximum of information about the physics of the objects observed by Gaia. A Gaia Follow Up Network of Solar System Objects (Gaia-FUN-SSO) is being established, involving observatories of very many countries around the globe (Tanga & Thuillot 2011). In this context, various astrometric, photometric, or spectroscopic observations are considered. This action is accompanied by a theoretical and modelling effort to interpret the results in term of Solar System formation and evolution.

4 Support to modelling and theoretical activities

As for ground-based observations, modelling activities are of two kinds: necessary for data analysis, in the context of DPAC, and in preparation for the exploitation of Gaia data.

4.1 Modelling and theoretical activities in support to Gaia data analysis

Gaia will observe all objects down to magnitude $V = 20$, i.e. a wide variety of stars, solar system bodies, and compact extragalactic objects. To be able to identify, classify and characterise them, it is essential to have a reliable modelling of how these objects will be seen through the Gaia optical system. With one billion objects,

all types of objects, even the rarest, will be observed in large quantity and classification algorithms should be extremely efficient and tested in advance for all possible cases. Many actions in this direction have already been supported by A.S. Gaia during the past four years and these efforts will continue in the coming years.

Among them: modelling of massive atmospheres of hot stars with emission lines with test and improvement of classification algorithms; simulation of globular clusters and multiple star systems and observability with Gaia; estimation of the performance of the RVS for the chemical analysis of giant stars (test on ground-based data); modelling of double stars and estimation of the uncertainties on the astrometric parameters; simulation of the detection and observation of binary asteroids; simulation of the observation of extended objects; development of a library of synthetic spectra of galaxies for the automatic classification of galaxies unresolved by Gaia; simulation and analysis of a catalogue of quasars and AGN for the definition of the Gaia reference system.

4.2 Modelling and theoretical activities in support to the preparation of Gaia data scientific exploitation

As already emphasised above, Gaia will observe in a systematic way all objects down to magnitude $V = 20$, thus achieving a complete census of stars in a large part of the Galaxy and of their stellar or planetary companions in the solar neighbourhood. It will provide an unbiased sampling of all stellar populations of the Galaxy, and of the brightest stars in galaxies of the Local Group. Optimum use of this mass of data requires new methods and models and A.S. Gaia has regularly allocated a high priority to such requests. This is also an effort that should be continued in order to obtain a scientific return at the level of the major investment made by France in Gaia preparations.

A list of the various studies supported within this framework is given here: kinematics and modelling of the Galactic bulge; kinematics and structure of the Galactic disk; 3D NETL modelling of stellar chromospheres in order to improve the determination of atmospheric parameters and abundances; calculation of collision rates for the NLTE modelling of stellar atmospheres; modelling of the observation of metal-poor giant stars and test with ground-based measurements; development of criteria for the taxonomic classification and the determination of the absolute magnitude and spectral characteristics of asteroids; modelling of the shape of asteroids from observations of stellar occultations by asteroids; prediction of close encounters of asteroids and determination of their masses; thermophysical modelling of asteroids; observability of comets with Gaia and modelling of the effect of non-gravitational forces on their orbits; preparation of the alignment of ICRF with the Gaia reference system; tests of relativity using Hipparcos, radar and Gaia data.

5 Perspectives

Since 2007, A.S. Gaia has played a strong role in the coordination of actions related to Gaia in France. During that period, the scientific and observational context has changed, with the increasing importance of systematic sky surveys (in photometry up to now) to detect and map halo streams, and of detailed spectroscopic analysis to better understand the evolution of all Galactic stellar populations. Also, the European astronomical community got organised to prepare for the scientific exploitation of Gaia data. The period 2011-2015 will cover the final preparations for the processing of Gaia data, hopefully the launch of the satellite, and the preparation for the first tests on real data. In addition to an increased support to programmes in preparation to Gaia data scientific exploitation, support to actions related to the preparation of the publication of the catalogue will become essential.

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