Mem. S.A.It. Suppl. Vol. 9, 415

Memorie della
Supplementi

The foreseen Italian participation to Gaia

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Abstract. The ESA mission Gaia, aiming at a full-sky census of objects brighter than V = 20 mag, is getting close to implementation. We recall the mission concept and scientific goals, ranging from the structure and evolution of our Galaxy to fundamental physics, by means of astrometric, photometric and spectroscopic measurements in a full-sky magnitude limited survey of about one billion objects. The Italian community is assessing the desired participation, to identify scientific priorities, specific interests and possible contributions to critical tasks.

Key words. Astrometry, Instrumentation: high angular resolution, Space vehicles: instruments, Catalogs, Galaxy: general

1. Introduction

Gaia is approved by the European Space Agency (ESA) for launch before 2012. It aims at high accuracy *global* determination of position, proper motion and parallax of $\sim 1\%$ of the population of our Galaxy; the goal is 10 μas accuracy in absolute position, parallax, and annual proper motion for $V = 15$ *mag* targets, with survey completeness to $V \geq 18$ *mag* and limiting magnitude $V \geq 20$ *mag*. Gaia builds upon the Hipparcos concept, with the benefit of modern technology and deeper astrophysical understanding; for comparison, at 10% parallax precision, they have an horizon of respectively 10 kpc and 100 pc.

The astrometric survey is complemented by photometric and spectroscopic measurement, providing astrophysical as well as dynamical characterisation of each target. Gaia goes well beyond astrometry and will provide an unprecedented perspective on the composition, formation and evolution of our Galaxy, as described in Perryman et al. (2001), the mission World Wide Web page: *http://astro.estec.esa.nl/Gaia* and references therein.

The spectroscopic measurements were discussed in detail on September, 2002, in the conference "Gaia Spectroscopy: Science and Technology", Munari, Ed. (2003). The mission objectives and implementation, at the end of the definition phase, were reviewed on October, 2004, in the Symposium "The Three-Dimensional Universe with Gaia", Turon, O'Flaherty and Perryman, Eds. (2004).

The Gaia astrometric measurement concept is based on *global astrometry* to generate a three-dimensional map of a statistically significant fraction of our Galaxy. For a common reference frame, a single instrument observes the whole sky, on a space platform. Simultaneous observation at large *base angle* alleviates the

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attitude requirements. Finally, a spinning instrument does not require time to point repeatedly new fields, optimising the observing time usage. An appropriate combination of rotation, precession and orbital motion provides a nearly uniform *full sky* coverage. Accordingly to the Hipparcos concept, Gaia is a spinning satelite, observing on its equatorial plane along two lines of sight (LOS_1 and LOS_2) separated by the base angle $\alpha \simeq 99^\circ.4$. During each transit, each object is repeatedly measured, with comparable precision.

The composition of one-dimensional measurements is the basis of the "global sphere reconstruction", i.e. the determination of both angular coordinates of each target. The evolution of the apparent source position with time provides absolute parallax and proper motion. The five astrometric parameters (two angular positions, parallax, and the tangential proper motion) are deduced collectively, with an iterative process, from the complete data set. The desired parameters minimise the overall discrepancy with the elementary abscissæ. The reduction process also includes self-calibration of instrumental parameters.

The spectroscopic and photometric capabilities of Gaia complete the characterisation of the survey sample with radial velocity, medium resolution spectroscopy and multi-colour photometry. The photometric system includes five broad bands and 11 medium bands ($\sim 0''.1$ and $1''$ spatial resolution, respectively), sampling each object with 100 and 170 epoch measurements, on average. The spectroscopic instrument provides about 100 epoch measurements per object at resolution 11500 in the spectral range 8480-8740 Å, sampling about 100 million stars with spectra to $V = 15$ *mag* and radial velocity to $V = 17.5$ *mag*.

A set of science subjects were identified throughout the initial concept study of the mission (1995 - 1998). Dedicated working groups analysed the astrophysical impact of the payload, operation and data reduction (DR) concepts during the evolution of the detailed design, confirming the feasibility of most science goals.

The European participation to this study (1999-2004) included contributions from several countries. The Italian efforts were focused on astrometric payload design; photometric system definition; spectroscopic performance; data reduction and calibration; monitoring of the technology development impact on the science case. The key astrophysical issues include solar system objects, relativity, extra-solar planets, Galaxy and stellar astrophysics.

The planned schedule follows parallel tracks for the industrial and scientific development. ESA will support satellite and payload construction (call for tender issued in summer, 2005), launch and ground segment operation during the mission lifetime; however, the DR has to be supported by the European astrophysical community, funded by national agencies.

The computing requirements have been estimated in 10^{21} FLOPS on processing, and 200-500 Tbytes on data storage. The data structure is "tangled" in space and time, due to the measurement sequence and the variability of many sources. It is assumed that an iterative adjustment process is applied for estimation of the astrophysical and instrumental parameters from the measured data. This is implemented by "sphere reconstruction" on 100-200 million "well-behaved" stars (i.e. removing variables, binaries etc.). All sampled objects are then linked to the resulting reference system to deduce their astrometric and astrophysical parameters.

2. The Gaia data reduction scheme

Due to its complexity, it is mandatory that the data processing is implemented and validated before launch, to ensure timely delivery of *correct* results.

The goal of the Gaia Data Analysis Consortium (GDAC) is the generation of the primary astrometric catalogue of position, parallax and proper motion of the whole survey sample; of the catalogues of spectra, photometry and radial velocity data (possibly including some derived physical parameter, e.g. metallicity); of auxiliary catalogues on specific populations, e.g. asteroids, binaries, extra-solar planets, AGNs, etc. The astrometric and astrophotometric catalogues are strictly linked, due

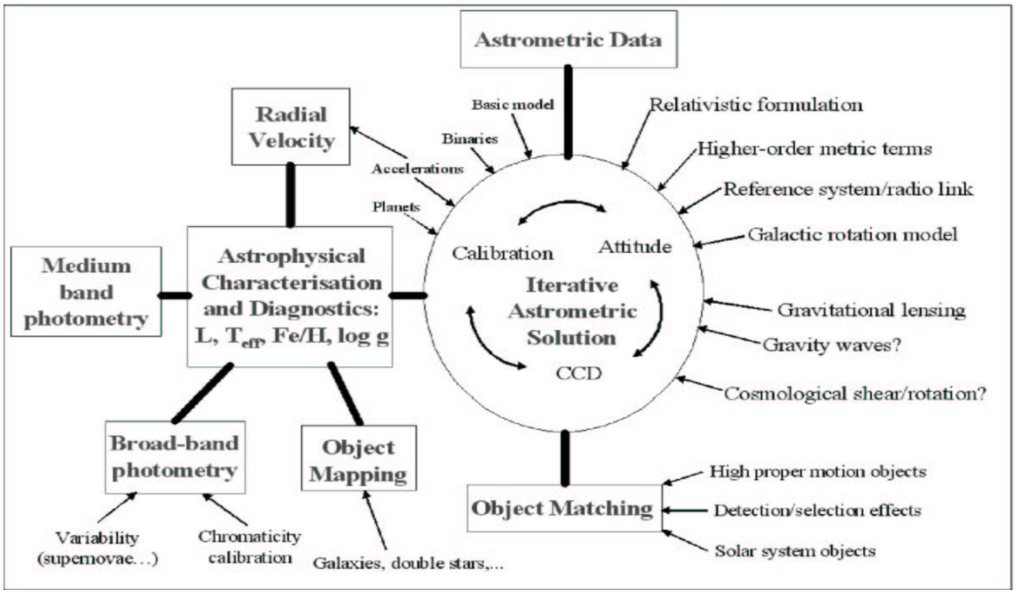

Fig. 1. Conceptual schematic of the Gaia data reduction scheme.

to the astrometric signature of the astrophysical parameters.

The GDAC effort is structured in a set of "core" and "shell" tasks; the former case includes all of the aspects necessary to the generation of the astrometric and spectrophotometric catalogues, whereas the latter refers mainly to the auxiliary catalogues. The mandatory task of GDAC is to cover the core tasks, ensuring that the main mission goals are fulfilled; in case some shell tasks are not implemented within the main processing, they may still be implemented outside the critical path of the mission (e.g. later on), as the raw data remain available. Many subjects affect both core and shell tasks: e.g., relativity affects core science (the deflection at 90° from the Sun is still a few mas!) and is a relevant scientific issue on its own, for the possibility of detecting with Gaia general relativity effects at the 10^{-6} level (Vecchiato et al. 2003).

The current concept of DR, from telemetry to astrophysical parameters, is based on a single data centre (ESAC, previously VILSPA, is proposed) and a single European reduction Consortium, jointly supported by the international community. The rationale is twofold: the cost of implementing more than one suitable data centre, and the limited number of available skilled scientists devoted to the Gaia issues. Besides, distributing science activity over Europe, it may be convenient to have secondary data centres in different countries, fulfilling the technical tasks of dataflow interface and of computing support to the local development on core and shell tasks. They are not intended to duplicate the central storage or computing power, but to facilitate the consortium work. ESTEC issued at the end of 2004 a request for Letters of Intent (LoI), in preparation of an Announcement of Opportunity (AO) for the Gaia DR, in 2006, to the Institutes interested in committing their resources to the reduction activity. After the AO, the current set of working groups will be replaced by the GDAC consortium, with the goal of developing, implementing and managing the DR system until catalogue delivery (~ 2019).

A DR study (GDAAS) has been run from 2001 to 2004, to assess the feasibility of the proposed approach, investigating aspects related to system architecture, hardware requirements, database management and software integration. The algorithms definition and testing is charged to the scientific community, through the core and shell tasks, and this efforts is compensated by timely access to the mission data thanks to the direct involvement.

3. The Italian participation: IGEA

In March, 2005, the President of INAF issued a LoI to ESA, after a verification of the astronomical community interest, allocating 16 Full Time Equivalent (FTE) per year to the Gaia GDAC activity.

For the AO, it will be necessary to define a formal engagement of the national Institutes / Agencies with detailed task definition and allocation of manpower and resources. The negotiation with the European partners must ensure that all core tasks are properly supported, and define the additional support to the shell tasks. The current activity is focused on detailed definition of the areas of interest with a possible high level Italian participation, and negotiation with other groups.

Expressions of interest have been issued from many INAF groups, and efficient coordination is necessary. The subjects cover most scientific and technical areas of Gaia: broad and medium band photometry, spectroscopy, astrometry (including sphere reconstruction), supercomputing and archiving infrastructure, and other topics.

The INAF LoI is focused on the critical activity of Quality Assurance and Validation (QA&V), as key contribution to the core astrometric processing, to ensure the consistency of the results. The short term (2005-2006) activity for coordination of the Italian groups, aimed at a qualified participation to the AO proposal, will produce a detailed work breakdown structure, including costs, resources and manpower. The management of this activity is assigned to the authors.

The long term objective, for the post-AO period (2007-2018), is the implementation of a national facility in support of the QA&V task, also providing data access services toward the main data centre for the Italian contributors to other core and shell tasks. The proposed name is Italian Gaia Exploitation Activity (IGEA).

4. Conclusions

We review the Gaia mission concept, with respect to the data reduction implementation concept, based on a single data centre and European reduction Consortium. The scientific community support is structured in a set of core and shell tasks, requiring significant efforts, compensated by timely access to the mission data thanks to the direct involvement. The proposed framework is a national centre for interface to the central data centre, for technical support to access by all Italian participants involved in science oriented tasks. The most critical core task proposed, instrumental in ensuring the goal measurement accuracy, is science data validation and calibration.

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