The European Space Agency *Gaia* mission: exploring the Galaxy

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Resum. La missió astromètrica *Gaia* és una de les dues properes missions punteres del programa científic de l'Agència Espacial Europea. Es va aprovar l'any 2000 i el llançament està previst per a l'agost del 2012. *Gaia* escombrarà el cel contínuament durant cinc anys, cosa que proporcionarà mesures de posicions i velocitats amb les precisions necessàries per a produir un cens estereoscòpic i cinemàtic d'aproximadament mil milions d'estrelles de tota la nostra galàxia i de més enllà; o sigui, aproximadament un 1 % de la població estel·lar galàctica. El principal objectiu científic de *Gaia* és quantificar la formació estel·lar en les primeres etapes i la subsegüent evolució dinàmica, química i de formació estel·lar en la nostra galàxia. Respondrà preguntes, com ara quan es van formar les estrelles a la Via Làctia, quan i com s'ha format la galàxia, i quina és la seva distribució de matèria fosca. La completesa de les observacions és fins a V = 20 mag, amb una precisió d'aproximadament 20 µas a magnitud 15. La informació astromètrica es complementa amb informació astrofísica, obtinguda a bord mitjançant espectrofotometria i espectroscòpia, fet que permetrà derivar la composició química i l'edat de les estrelles. A més, *Gaia* observarà desenes de milers de sistemes planetaris extrasolars, uns 10^5 - 10^6 cossos menors del nostre sistema solar, milions de galàxies a l'Univers proper, i 500.000 quàsars llunyans. Proporcionarà un seguit de nous testos estrictes a la relativitat general i la cosmologia. L'estimació és que, una vegada processades les dades adquirides per *Gaia*, el volum total de dades serà del voltant d'un *petabyte*. El repte del processament de dades és l'estreta relació que hi ha entre la informació astromètrica i l'astrofísica, que implica una solució global que millora la determinació dels paràmetres dels instruments, l'actitud del satèl·lit i les propietats dels objectes observats de manera iterativa. El Consorci per al Processament i l'Anàlisi de Dades és la col·laboració europea responsable de la preparació i l'execució del processament de dades.

Paraules clau: galàxia · astrometria · astronomia des de l'espai

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Abstract. The *Gaia* astrometric mission is one of the next two cornerstones of the European Space Agency's science program. It was approved in 2000 and the launch is foreseen by August 2012. *Gaia* will continuously scan the entire sky for five years, yielding positional and velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars throughout our Galaxy and beyond, i.e., about 1% of the galactic stellar population. *Gaia*'s main scientific goal is to quantify early formation and the subsequent dynamic and chemical evolution of the Milky Way and its history of star formation. It will provide insight into questions such as: When did the stars in our Galaxy form? When and how was it assembled? What is the distribution of dark matter? The stellar survey will have a completeness to V = 20 mag, with an accuracy of about 20 µas at 15 mag. The astrometric information will be combined with astrophysical data acquired through on-board spectrophotometry and spectroscopy, allowing the chemical composition and age of the stars to be derived. In addition, *Gaia* will observe tens of thousands of extra-solar planetary systems, some 10^5–10^6 minor bodies in our solar system, millions of galaxies in the nearby universe, and some 500,000 distant quasars. It will also provide a number of stringent new tests of general relativity and cosmology. Data acquired and processed as a result of the *Gaia* mission are estimated to amount to about 1 petabyte. The challenging problem is the close relationship between astrometric and astrophysical data, which involves a global iterative solution that updates instruments parameters, the attitude of the satellite, and the properties of the observed objects. The Data Processing and Analysis Consortium is a joint European effort in charge of preparation and execution of data processing.

Keywords: galaxy · astrometry · space astronomy

Introduction

The *Gaia* mission aims to study the origin, formation, and evolution of the Milky Way and its components. The Milky Way, the galaxy in which we live, is formed by a disk of about 50,000 light-years radius. It mainly contains stars of several types and ages, interstellar gas and dust, a spheroidal halo of some 100,000 light-years radius with very old stars, a bar and a bulge in the center, and the ubiquitous dark matter. The disk shows a spiral structure, with the arms being the preferred location of the star-forming regions. Although these general features are rather well known, much remains to be elucidated, including the detailed number and structure of the spiral arms, the disk warp, the detailed shape and rotation of the bulge, disk, and halo, the dynamics and the kinematics of the Galaxy, and the distribution of dark matter. Also, the process in which the Galaxy was assembled, presumably from small building blocks, and the history of star formation are not well understood.

To address these and many other questions, one needs a deep full-sky survey covering a significant volume of the Galaxy, providing positions and velocities at high accuracy and physical properties of the observed objects. This is what *Gaia* will do [2,7]. The goal of the mission is to create the largest and most precise three-dimensional survey of our Galaxy and beyond by providing unprecedented positional, proper motion, radial velocity, and spectroscopic data for about one billion stars in our Galaxy and throughout the Local Group. The *Gaia* launch is scheduled for August 2012 and the mission ends 5 years later. The detailed design and construction phase started in February 2006, with development and construction progressing as planned.

Gaia is a survey mission and the operating principle is that of its successful predecessor, the Hipparcos satellite of the European Space Agency (ESA) [4,6]. With two telescopes and two associated viewing directions separated by a highly stable basic angle of 106.5°, the satellite will continuously scan the sky. *Gaia* performs wide-angle astrometry, allowing the determination of absolute trigonometric parallaxes. The size of the primary mirrors and of the field of views and the use of CCD detectors in the focal plane mean an enormous step further than achieved with the Hipparcos mission. While Hipparcos yielded precisions of 1 mas at 9 mag and measured about 120,000 stars, *Gaia* will yield 20 µas at 15 mag and will survey a billion objects. Although Hipparcos seems, in retrospect, like a modest project, it was the first space astrometric mission and it revolutionized our view of the Galaxy, despite the reduced number of observed stars. *Gaia* builds on the experience acquired with the Hipparcos mission; it is an entirely European mission supported by a wide and motivated scientific and technological community distributed throughout Europe, which holds the leadership in the space astrometry domain.

This review discusses the scientific goals of the mission and the mission itself, with a description of its operating principle and instruments, as well as the organizational scheme with respect to its bodies and responsibilities. Finally, we describe the current involvement of the team at the University of Barcelona. A detailed presentation of the scientific case and mission design at the 2000 stage can be found in de Boer et al. [2] and a review of the mission at the 2004 stage in Turon et al. [8].

The scientific case

The scientific goals of Gaia have been extensively discussed [1,2,7], the main one being the production of a set of homogeneous and accurate data that can be used to carry out the deepest and most well grounded study thus far of the structure, origin, formation, and evolution of the Milky Way. To reach this goal, a large and unbiased sample of positional, kinematic, and astrophysical data of a statistically significant sample of the stellar content of the Galaxy is needed. Since *Gaia* is a survey mission, the observations will not be limited to the stars in the Galaxy, since any object in the fields of view will be detected and observed. Thus, *Gaia* will impact on all fields of astronomy and astrophysics as well as on fundamental physics [2,3] (Figs. 1,2).

Galactic structure, kinematics, and dynamics. The most conspicuous component of the Milky Way Galaxy is its flat disk, which contains nearly 10^{11} stars of all spectral types and ages orbiting the galactic center. The disk displays a spiral structure and is made up of interstellar material, predominantly atomic and molecular hydrogen, and a significant amount of dust. The disk of the Milky Way also includes numerous open clusters and associated super-clusters/moving groups as well as various manifestations of recent star-formation events. The inner kiloparsec of the disk features a bulge, which is less flattened, contains a bar, and consists mostly of moderately aged stars. At its center lies a supermassive black hole of ~$2.9 \cdot 10^6$ M_{sun}. The disk and bulge are surrounded by a halo of about 10^9 old and metal-poor stars as well as ~140 globular clusters and a small number of satellite dwarf galaxies. This entire system is embedded in a massive halo of dark material of unknown composition and poorly known spatial distribution. The distributions of stars in the Galaxy with respect to position and velocity are linked through gravitational forces, and through the star-formation rate as a function of position and time. The initial distributions are modified, perhaps substantially, by small- and large-

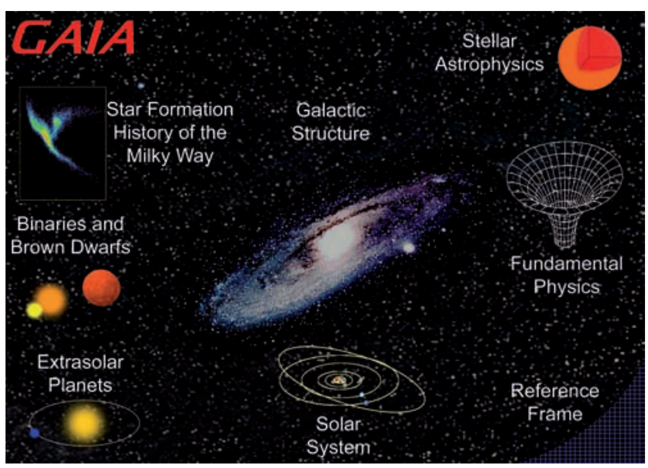

Fig. 1. Many areas of science will be addressed by the *Gaia* mission, as indicated in this schematic figure. (Courtesy of ESA).

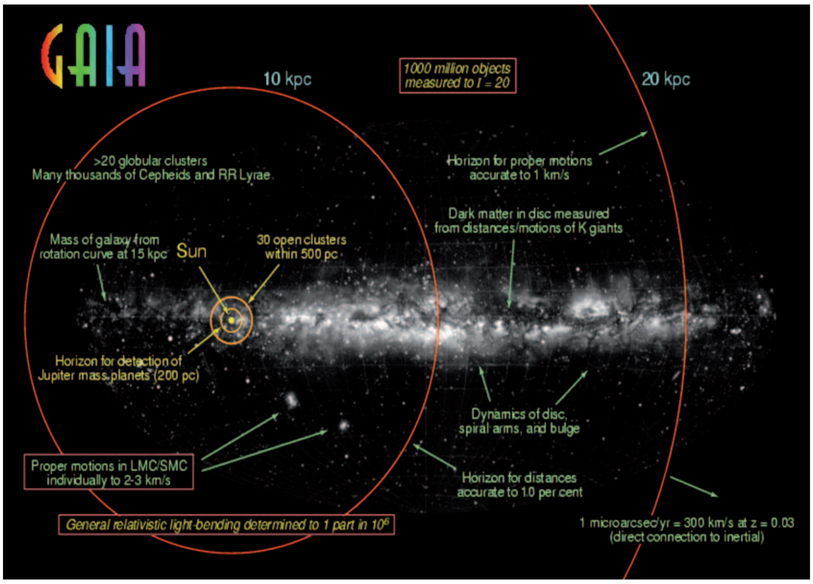

Fig. 2. Some of the capabilities of the *Gaia* mission. The horizon at 10 kpc of 20% precision of trigonometric parallaxes is shown. (Courtesy of ESA).

scale dynamic processes. These include instabilities that convey angular momentum (for instance, bars and warps) and mergers with other galaxies. The huge number of stars to be observed by *Gaia*, the impressive astrometric accuracy of the collected data, and the faint limiting magnitude will allow us to quantify the structure and motions of stars within the bulge, the spiral arms, the disk, and the outer halo, and will revolutionize dynamic studies of our Galaxy.

Star-formation history. A primary scientific goal of the *Gaia* mission is the determination of star-formation histories, as described by the temporal evolution of the star-formation rate and the cumulative numbers of stars formed, in the bulge, inner disk, solar neighborhood, outer disk, and halo of the Milky Way. In general, stellar age-metallicity-extinction degeneracy, combined with observational errors and uncertain stellar distances, have made current approaches to determine the star-formation history of a mixture of stellar populations unreliable and non-unique. The best available analyses involve comparison of an observed color-magnitude diagram with a model population; however, while powerful, such analyses can never be proven unique. The *Gaia* astrometric, photometric, and spectroscopic data, together with specifically developed, direct-inversion tools, will resolve this ambiguity and thereby make our Galaxy's full evolutionary history accessible. The star-formation history defines the luminosity evolution of the Galaxy directly. In combination with the relevant chemical abundance distributions, the accretion history of gas may be derived, while together with kinematics, the merger history of smaller stellar systems can be defined. The sum of these three processes comprises what is loosely known as "galaxy formation," and analysis of the *Gaia* mission's results will provide the first quantitative determination of the formation history of our Galaxy.

Stellar structure and evolution. The study of stellar structure and evolution provides fundamental information on the properties of matter under extreme physical conditions as well as on the evolution of galaxies and on cosmology. The accurate and homogeneous astrometric and photometric data provided by Hipparcos has allowed the precise characterization of individual stars and open clusters and the confirmation of certain aspects of internal-structure theory. Further progress in stellar modeling is required, for example, in atmospheric modeling, transport processes of matter, angular momentum and magnetic fields, and microscopic physics. On the observational side, more numerous samples of rare objects, including distant stars and stars undergoing rapid evolutionary phases, an increased number of common objects with high-quality data, and a census over all stellar populations are required. *Gaia* will return information about luminosities, surface temperatures, abundances, masses, and determinations of the interstellar extinction for all types of stars. This, in turn, will allow researchers to study the sizes of the convective cores of the massive stars, the internal diffusion of the chemical elements, and the outer convective zones and to solve the discrepancies among observations and stellar models.

Variability of stars. *Gaia* will provide multi-epoch, multi-color photometry for all sources brighter than 20-th magnitude. In addition, high-quality broad-band photometric measurements will be made in the astrometric field. These data will have the precision necessary to detect diverse variable phenomena and to describe nearly all types of variability, allowing a global description of stellar stability and variability across the Hertzsprung-Russell diagram. In addition, they will permit identification of the physical processes causing variability. Precise physical and orbital parameters of eclipsing binaries will be derived for about 10,000 systems. *Gaia*'s trigonometric parallaxes will complement data from dedicated asteroseismologic space missions (e.g., MOST, COROT, and Kepler).

Stellar ages and age of the universe. Precise stellar-age determinations are required for various galactic structural and evolutionary studies and for cosmological studies. The primary age-determination method relies on comparisons of stellar models or isochrones with the best available data–in particular luminosity, effective temperature, and abundances–for individual stars or stellar groups. The principle of the method is general, but its application to different types of stars requires specific considerations. Determination of the age of the oldest objects in the Galaxy provides a lower limit to the age of the universe, which in turn can be used to constrain cosmological models and parameters. Currently, the best estimate for the age of the oldest stars is based on the absolute magnitude of the main-sequence turn-off in globular clusters and is affected by the uncertainty in the cluster distances. *Gaia* will improve the age estimate of the oldest stars. The number of subdwarfs with accurate distances will considerably increase in each metallicity interval, allowing us to derive the distance of a greater number of globular clusters of various chemical compositions by main-sequence fitting. Furthermore, distances of a substantial number of field subgiants will be measured, improving the age determination of field halo stars.

Distance scale. Measures of trigonometric parallaxes will be unique. *Gaia* will have a major impact upon our knowledge of the distance scale in the universe by providing accurate distances and physical parameters for all types of observable primary distance indicators in the Milky Way and in the closest galaxies of the Local Group. It will generate a complete sampling of these indicators, allowing the corrections necessitated by metal, oxygen, or helium contents, color, population, age, etc. In particular, *Gaia* will extensively observe many galactic open and globular clusters and countless Cepheids and RR Lyrae, thus providing solid calibrations for cluster-sequence fitting and period-luminosity relations.

Binaries and multiple systems. One of *Gaia*'s unique features is the well-defined sampling and subsequent observations of tens of millions of binaries over the entire sky. Even though by the time *Gaia* will be operational large ground-based telescopes and interferometers may have greater resolutions and light-collecting areas, thus enabling detailed studies of individual binaries and multiples, relatively few objects will have been observed with such instruments. Moreover, the observed targets will have been primarily selected at random and thus do not form a complete sample in any sense. In looking at a nearby sample (<500 pc), many resolved binaries have periods short enough for orbit determination by *Gaia*. The study of binaries will facilitate the discovery of thousands of low-mass low-luminosity companions of stellar nature, brown dwarfs, or planets.

Planetary systems. The unprecedented precision of measured positions will allow us to detect the motion inferred by the presence of one or more planets surrounding a given star. The detection of 10,000–20,000 exoplanets and the determination of orbits for some 5000 of them is expected. The measurements will provide estimates of the actual planet masses, thus contributing to models that seek to determine whether dynamic interactions would permit an Earth-like planet to form and survive in the habitable zone of any given star. In addition, some 5000 planets can be discovered when transiting the disk of their hosting star.

Solar system. With its continuous scanning of the sky, *Gaia* will scrutinize our solar system. It is currently estimated that some 10^5–10^6 asteroids will be discovered (compared with the 65,000 known), plus some hundreds of Kuiper's belt objects. In particular, near-Earth objects will be observed, and their orbits known with a precision 30 times higher than what is possible today. Positional and photometric observations spanning the 5-year mission will provide masses, sizes, and composition, which can be analyzed as a function of distance to the Sun, thus improving our understanding of the history of the solar system's formation.

Gravitational light deflection. Given their µas-level accuracy in terms of position, the *Gaia* data must be treated in a general-relativistic context. For example, detected photons are bent during the last hours of their long journey across the solar system, under the influence of the gravitational fields of the Sun, planets, moons, asteroids, etc. The amount of this post-Newtonian light deflection depends on the mass of the perturbing object, its distance to the observer (*Gaia*), and the angular separation at which the photon passes the object. A well-known example is a light ray grazing the limb of the Sun: an observer on Earth will notice a deflection of 1.75 arcsec. The actual measurements of the blending of the light will constrain the various parameters of post-Newtonian theory.

Extragalactic astrophysics. *Gaia* will provide astrometric and photometric observations for about 500,000 quasars (QSOs) down to the 20-th magnitude over the whole sky; this is five times more than the number expected from the Sloan Digital Sky Survey. The *Gaia* data set will constitute the first all-sky survey of optically selected active galactic nuclei (AGN) and QSOs. The latter will be used to establish the inertial reference frame at an accuracy of ~0.4 µas/year. Galactocentric acceleration of the Sun will be derived at a precision of 0.2 nm/s^2. In addition, it is expected that some 100,000 supernovae will be discovered, and some 40×10^6 galaxies will be spectrophotometrically surveyed.

Gaia operations and instruments

Operating from a Lissajous orbit around the second Lagrange point of the Sun-Earth/Moon system (L2), the satellite will continuously scan the sky. During its 5 years of observations, *Gaia* will rotate, at a fixed speed of 60 arcsec/s, around a slowly precessing spin axis. As a result of this spin motion, objects continuously traverse the focal planes (Fig. 3). *Gaia* has two telescopes with two associated viewing directions. The primary mirrors are 1.45×0.5 m^2 in size each and telescope's focal length is 35 m. The two viewing angles are separated by a highly stable basic angle of 106.5°.

The telescopes' assembly consists of four mirrors for each line of sight and two common additional mirrors (Fig. 4). The two fields of view are combined into a single focal plane of 104 × 42 cm^2 (along scan × across scan) covered with 106 CCD detectors (Fig. 5). All the parts are mounted on a torus and all of

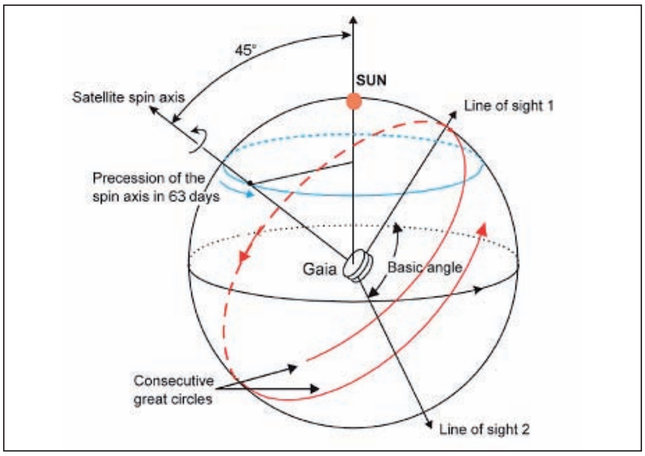

Fig. 3. *Gaia*'s two astrometric fields of view scan the sky according to a carefully prescribed revolving scanning law. The constant spin rate of 60 arcsec/s corresponds to 6-hour great-circle scans. The angle between the slowly precessing spin axis and the sun is maintained at 45°. The basic angle between the two lines of sight is 106.5°. (Courtesy of Karen O'Flaherty).

them are made of SiC, offering thermal and mechanical stability. The mirrors are silver coated.

Gaia's observations will be made using high-quality, large-format CCDs in the common focal plane (Fig. 5) . The CCDs are operated in time delay and integration mode. Charge images will be transported (clocked) in synchrony with optical images moving across the field due to the rotation of the satellite. The focal plane has four main sections:

a. Stars entering the combined field of view first pass across dedicated CCDs that act as a "sky mapper" (SM). Here, the objects are detected and the strategy of observations in the rest of the focal planes is established case by case (only windows of pixels around the objects are read and sent to the ground).
b. The astrometric field (AF) is sampled by an array of 62 CCDs. Astrometric observations are made with unfiltered light in order to minimize photon noise. The mirror coat-

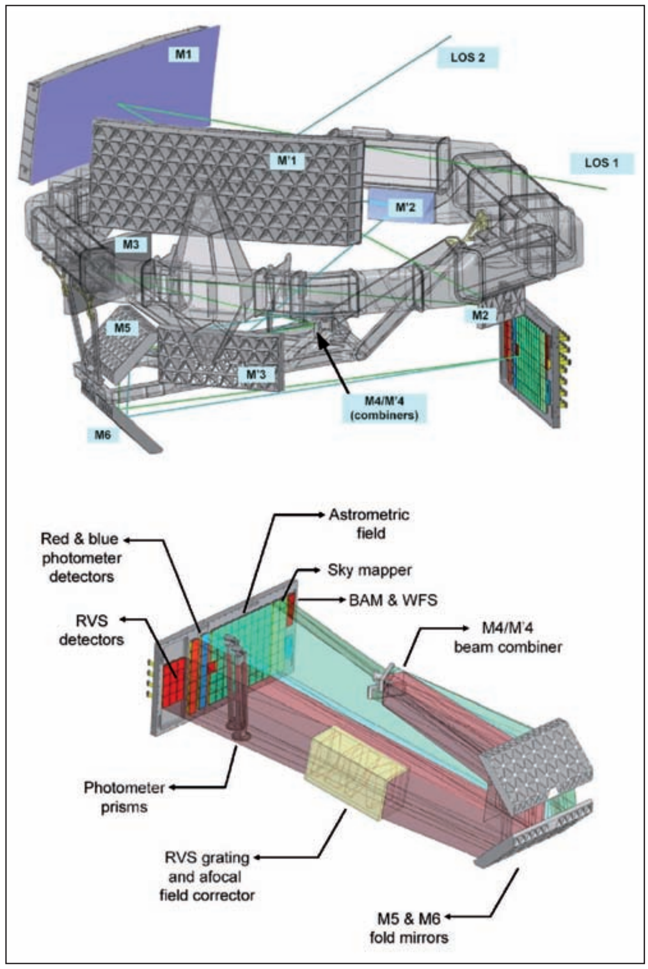

Fig. 4. (**Top**) *Gaia* payload and telescopes. LOS1&2 are the two lines of sight, M1&2 the two primary mirrors, and M2-6 the mirrors that drive the image to the combined focal plane (bottom right). The structure is made entirely of SiC. (**Bottom**) The configuration of the slitless spectrograph with the blue and red prisms and of the radial-velocity grating combined with the focal plane and the M4–6 mirrors of the telescopes. (Courtesy of EADS-Astrium).

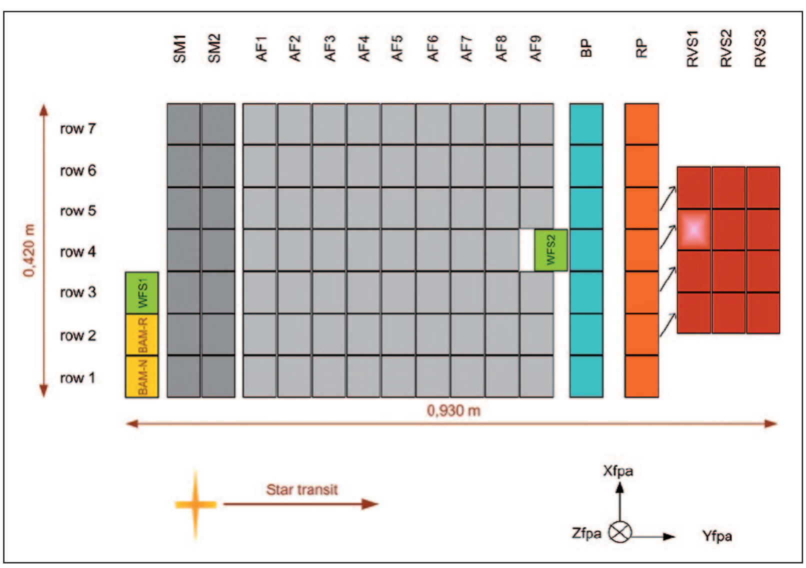

Fig. 5. Focal plane of Gaia containing 106 CCDs. SM1&2 will detect objects at field of view 1 and 2, respectively. AF1–9 are the CCDs collecting unfiltered light for astrometric measurements. BP & RP are the blue and red spectrophotometers, respectively. RVS1–3 are for spectroscopy. BAM and WFS are the basic-angle monitors and wave-front error sensors, respectively. Stars transit from left to right as the satellite scans the sky. (Courtesy of J. de Bruijne).

ings and the CCD QE effectively define a broad (white-light) passband covering the wavelength range of about 350–1000 nm, with the maximum energy transmission at ~715 nm and the full width at half-maximum of 408 nm.

c. The spectrophotometric CCDs record low-resolution spectra produced by two slitless spectrographs, BP (blue photometer) and RP (red photometer), covering the wavelength intervals 330–680 nm and 650–1050 nm, respectively. The goal is to provide astrophysical classification and parameterization of observed objects.
d. The radial velocity spectrometer (RVS) CCDs, combined with high-resolution integral field spectrograph (R = 11.500) in the range 847–874 nm on the IR calcium triplet, allows derivation of the radial velocities and chemical composition of the brightest stars.

By measuring the instantaneous image centroids from the data sent to ground, *Gaia* measures the relative separations of the thousands of stars simultaneously present in the combined fields. Scans in different directions during the 5-year mission allow the measurement of a given star in relation to many others in differently oriented great circles. At the end of the mission, this translates into a precision in angles measurements of about 20 μas at V = 15, that is, 20% precision in distance at 10 kpc, and equivalent to measuring a Euro coin at the Moon's distance. This kind of measurement also allows the separation of parallax-induced motion in the sky from the star's own motion, thus yielding the distance and the proper motion of the star with respect to the observer. In summary, the targeted numbers at the end of the mission are:

– One billion objects (0.34 × 10^6 to V = 10 mag; 26 × 10^6 to V = 15 mag; 250 × 10^6 to V = 18 mag)
– Positions and proper motions with precisions better than 20 μas and 20 μas/year at V = 15
– Parallax data with 20 μas at V = 15
– Stellar atmospheric parameters (temperature, gravity, chemical composition) for all stars up to V = 18
– Radial velocities of about 15 km/s precision at V = 17

Fig. 6. Members of the BOOSTEC and Astrium team just after the torus removal from the brazing furnace. The torus is made of SiC and consists of 16 different pieces independently manufactured. (Courtesy of ESA).

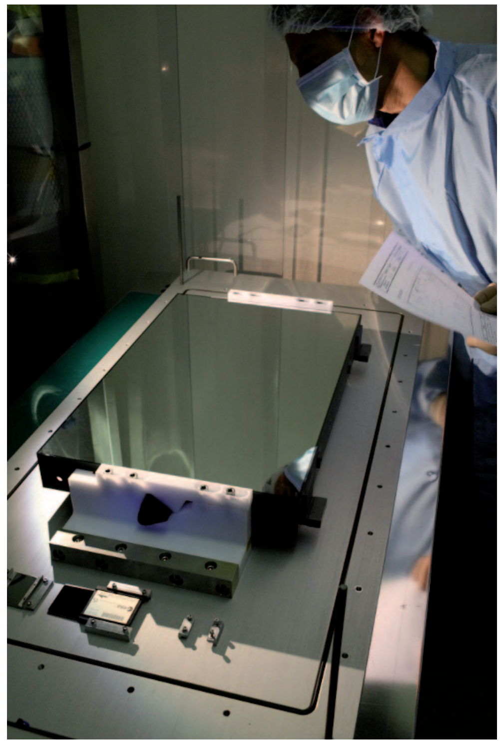

Fig. 7. The 540 × 336 mm M5 mirror undergoing inspection at the premises of Advanced Mechanical and Optical Systems (AMOS) in Liège, Belgium, in November 2009. The SiC structure was made by Boostec Tarbes, France; SiC vapor deposition on the surface was carried out by Schunk Kohlenstofftechnik at Heuchelheim, Germany. (Courtesy of ESA).

The total mass of the satellite including payload, service module, etc., amounts to 2100 kg, requiring a power of 1630 W that is to be provided by an assembly of solar panels. The spacecraft will be launched by a Soyuz-Fregat launcher from Kourou facilities. The ground-segment is provided by the 35-m antenna of ESA's Cebreros station, with a rate of 30 GB per day downlink. When *Gaia* is scanning the galactic plane, a second antenna, at the New Norcia station, will provide the necessary additional telemetry time.

The industrial consortium, selected in February 2006, for the *Gaia* spacecraft is spread over Europe, with EADS-Astrium at Toulouse acting as prime contractor. The design, building, and test phase is currently ongoing, with expected finalization in early 2012. The payload has passed the critical design review and the spacecraft critical design review is foreseen before summer 2010. The sixteen segments composing the torus structure were built and the torus has been successfully brazed (Fig. 6), one the main achievements of the building phase. The SiC substrate structure of the mirrors has been manufactured and polished. Testing and coating are ongoing for some of them, and some have already been coated, finalized, and delivered (Fig. 7). CCD production is also in progress, with 85% of the devices already finalized and tested.

One of the main critical items is the charge inefficiency that occurs when moving the charge under the operating conditions of radiation damage to the CCDs by proton particles from the solar wind. This charge inefficiency translates into delayed transport and a severe deformation of the diffraction images on

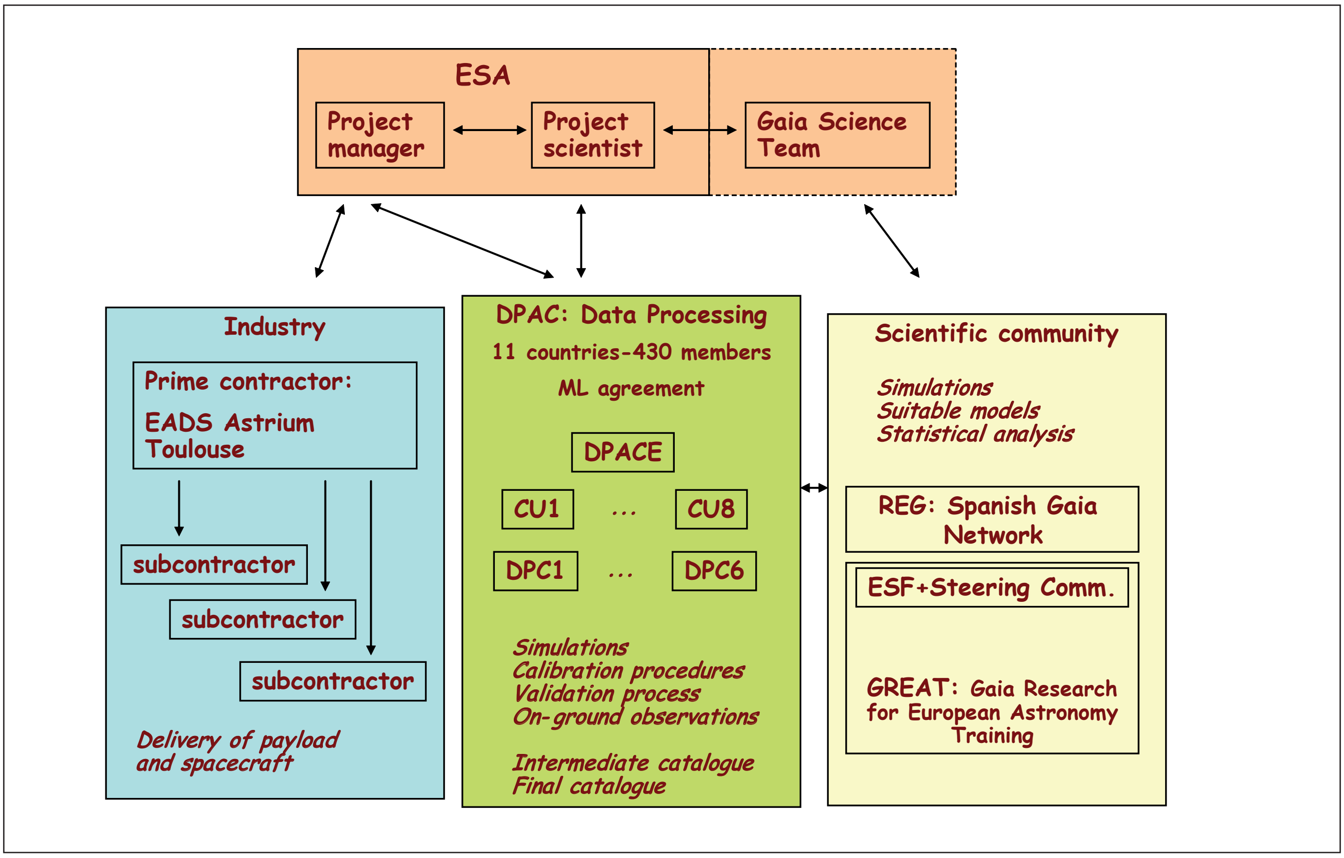

Fig. 8. Main bodies involved in *Gaia* development. The ESA is responsible for mission development and operations and is supported by the Gaia Science Team. The industrial sector is responsible for the actual manufacturing of the satellite, and the DPAC for data processing. The scientific community at large will exploit the acquired and processed data.

the focal plane. Tests are currently being conducted to characterize on ground the several dependencies of deformations. These dependencies wll be used as input knowledge to the a posteriori on-ground treatment of real *Gaia* data.

Organizational structure and responsibilities

The *Gaia* satellite and mission operation is fully funded by ESA. The *Gaia* management structure is summarized in Fig. 8 and includes a project manager and a project scientist. The project manager is in charge of supervising industrial development and ground segment management. The project scientist supervises the accomplishment of the scientific goals in the design phase and is assisted by a group of scientists external to ESA and representing the scientific community. Processing of the acquired data and production of the “Gaia catalogue” is the responsibility of the Data Processing and Analysis Consortium (DPAC [5]), comprising more than 430 members in 11 countries who are joining their efforts to overcome the challenging problem of managing the 1 petabyte of *Gaia* data. DPAC activities are supported by governments that have signed a multilateral agreement with ESA to ensure the stability of the scientific teams for the necessary period of time.

The work inside DPAC is presently organized in eight coordination units, with fields of competence and leaders. Members of the University of Barcelona have important responsibilities in CU2 (simulations), CU3 (core processing), and CU5 (photometry). Processing will be done on the premises of six Data Processing Centers (DPC) also made up of scientists and engineers from the countries who have signed the multilateral agreement. The CU2-led simulations are currently making use of both the Mare Nostrum computer in the Barcelona Supercomputing Center and the Supercomputing Center of Catalonia (CESCA). For example, cycle-7 of data simulation has generated some 6 TB of data and used about one million CPU hours. During missions operations and data treatment, it will be mandatory to continue using the Mare Nostrum facilities. Linked to DPAC, the University of Barcelona team also participates in an EU FP6 funded initiative, the European Leadership on Space Astrometry (ELSA). Its aim is the development and training of the next generation of experts in the field of astrometry.

Neither ESA nor DPAC has direct responsibility for *Gaia* data exploitation, which, instead, is to be conducted by the scientific community at large. It is up to this community to organize itself for the best use of *Gaia*’s products. Since the DPAC community has deep knowledge of the *Gaia* mission and extensive expertise in astrometry, synergy with the community at large is obvious and necessary for making use of the enormous legacy that *Gaia* will provide. To that end, several networks are currently in place, such as GREAT (Gaia Research for European Astronomy Training), founded by the European Science Foundation, and REG (*Red Española de Gaia*, Spanish Gaia Network) at the Spanish level. Both networks aim to strengthen the cooperation between teams, thereby joining expertise in observations, *Gaia* knowledge, theoretical analysis, model development and interpretation, and statistical treatment. Complementary observations on-ground covering the areas of science alerts, IR photometry, and high resolution spectroscopic surveys are being studied. Proposals for new instrumentation in 2- to 4-m class telescopes are being elaborated.

Table 1. Summary of the involvement of the University of Barcelona team in the *Gaia* project, scientific data exploitation, and managerial bodies

Group/Committee	Participation
Gaia Science Team	C. Jordi
DPAC executive committee	X. Luri
ELSA steering committee	J. Torra
GREAT steering committee	C. Jordi
REG PI	F. Figueras
CU1- Main data base	I. Serraller
CU2 -Simulations	X. Luri (manager), E. Masana, Y. Isasi, O. Martínez, E. Gallardo
CU3- Core processing	J. Torra (deputy manager), J. Portell, C. Fabricius, J. Castañeda, N. Blagorodnova, P. Vallés, A. Fries
CU5 - Photometry	C. Jordi, C. Fabricius, J.M. Carrasco, H. Voss, M. Gebran
Science data exploitation (galaxy)	F. Figueras, M. Romero, T. Antoja, M. Monguió, M. Czekaj, S. Roca
Science data exploitation (stars)	C. Jordi, L. Balaguer-Núñez, E. Masana, H. Voss, M. Gebran, E. Herrero, J.C. Morales
Management and tech support	L. Balaguer-Núñez, D. Molina

University of Barcelona involvement

The University of Barcelona ICC-IEEC group involved in *Gaia* is composed of scientists and engineers, some of them with experience in the prior Hipparcos mission and in the very early phases of *Gaia*'s definition and design. The members of the current team, participating either in data processing, science exploitation, or both are listed in Table 1.

Coda

The *Gaia* mission is one of the cornerstone missions within the cosmic vision of ESA's program. As outlined in Table 2, it is a challenging project from all points of view.

The development and manufacturing phase is well on track towards a scheduled launch in August 2012. Transfer to orbit around the L2 Lagrange point and commissioning will take up to 3 months, to be followed by the routine science operations phase. The science operations will last 5 years, with a possible extension of one year. Data processing will start as soon as data are received by the on-ground segment and will continue some 2–3 years after the mission's end. The final catalogue is expected around 2021, but with intermediate data releases produced during the operational phase.

A scientific and technical community of more than 400 members is currently involved in this project, which maintains European leadership in the space astrometry field. The scientific community is excited by *Gaia*'s goals and products and by the legacy that it will represent for future generations of astronomers. Doubtless, *Gaia* will revolutionize the concept of our Galaxy and beyond and the view of our solar system.

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Table 2. Main challenges of *Gaia*'s mission

Technological	– Mechanical and thermal stability of the whole assembly. – Stability of the basic angle (which could introduce biases in parallax determination). – Charge transfer clocked with the spin rate of the satellite. – Number of CCDs and quality of the mirrors. – Radiation damage to the CCDs.
Data processing	– Complex relationship among astrometric, spectrophotometric, and spectroscopic data. – Complex dependencies of the effects of radiation damage on image and serial register. – Global and iterative processing of the entire 5-year mission. – Volume of data ~1 petabyte, 1 billion stars.
Scientific	– Unprecedented accuracy in observations requires accurate theoretical models as counterpart. – Full-sky and deep coverage yielding one billion objects. – Need for a very accurate and realistic error model. – Evaluation of the biases in the final catalogue. – Rigorous statistical treatment.

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About the author

Carme Jordi has a Ph.D. in Physics from the University of Barcelona (UB), and is Professor at the Department of Astronomy and Meteorology of the same university. She is a member of the Institute for Science of the Cosmos and of the Institute of Space Studies of Catalonia. Her research is focused on the physical characterization of stars and star clusters, based on astrometric, photometric, and spectroscopic observations made from observatories in Catalonia, Spain, Chile, Mexico, France, Hawaii and from space. She has directed several doctoral theses and published numerous articles in international journals, among which those dedicated to the *Gaia* mission and the study of eclipsing binary stars as tools for the proof of stellar models and the determination of distances, stand out. She is coauthor of the first direct determination of the distance of Andromeda using these types of binary stars. She has participated in the Hipparcos Space Astrometry mission and currently participates in the *Gaia* mission of the European Space Agency (ESA), which brings together some 30 researchers from the UB and the Barcelona Supercomputing Center, in Catalonia. She is a member of the Gaia Science Team, which provides ESA with advice and guidance on the design, implementation, data analysis, and all other aspects related to the scientific performance and goals of *Gaia*. Her interest in communicating science to the general public had led her to participate for many years in educational programs and activities.