

4.2.2.1 GAIA

Introduction

With the Hipparcos space astrometry mission completed, and the scientific impacts of this major European project just starting to enter the astronomical literature, the potential of extending spaceborne global astrometry into the microarcsec regime has been investigated in some detail. The foundations for this effort were laid in ESA SP-1180 (1995) *Horizon 2000 Plus: European Space Science in the 21st Century*. In that report, the Survey Committee recommended that ESA initiate a Cornerstone-level programme to perform astrometric observations at the 10 microarcsec level.

For those tempted to think that positional measurements at this level stretches credulity, it should be stressed at the outset that the recent GAIA studies have confirmed the possibility of undertaking such measurements for all objects down to 15 mag and at lower (but still sub-mas) accuracies for the hundreds of millions of objects complete to about $I=20$ mag. The relevance of this programme for our continued advance in understanding our Galaxy is enormous – parallaxes at 10 microarcsec imply a distance accuracy of 10% at distances of the Galactic centre (with distances to local group members also directly measurable), and transverse velocity determinations at the level of 1 km/s at a distance of 20 kpc. In short, the mission would supply a 3-dimensional picture of stars throughout our Galaxy in which everything would be seen moving, tracing out the distribution of matter as a result of its gravitational potential, and establishing motions, distances, luminosities and ages throughout the Galaxy.

A Workshop in Cambridge in 1995 (ESA SP-379) confirmed the substantial scientific interest in such a programme, and the enthusiasm and support of a wide community. Some of the critical aspects discussed during this workshop were included in a Technology and Research Programme contract awarded to Alenia Spazio. This study concentrates on an actively controlled option for the GAIA astrometric payload.

It was in this context that funding a Concept and Technology Study was approved in ESA early in 1997. A Scientific Advisory Group was established in mid-1997, and

Studies

Table 4.2.2.1. A comparison between the Hipparcos and GAIA observing capabilities.

	<i>Hipparcos</i>	<i>GAIA</i>
Magnitude limit	~12	20-21
Completeness	7.3-9.0	~20
Bright limit	–	~5-8
Number of objects	120 000	35 million ($V<15$) 350 million ($V<18$) 1.3 billion ($V<20$)
Accuracy	1-2 mas	~4 microarcsec ($V=10$) 10 microarcsec ($V=15$) 200 microarcsec ($V=20$)
Radial velocities	–	1-5 km/s ($V<16-17$)
Narrow-band photometry	–	6-colour ($V<16-17$)
Broad-band photometry	–	4-colour ($V<20$)
Observing list	needed	not needed

For further information on GAIA, see <http://astro.estec.esa.nl/GAIA>

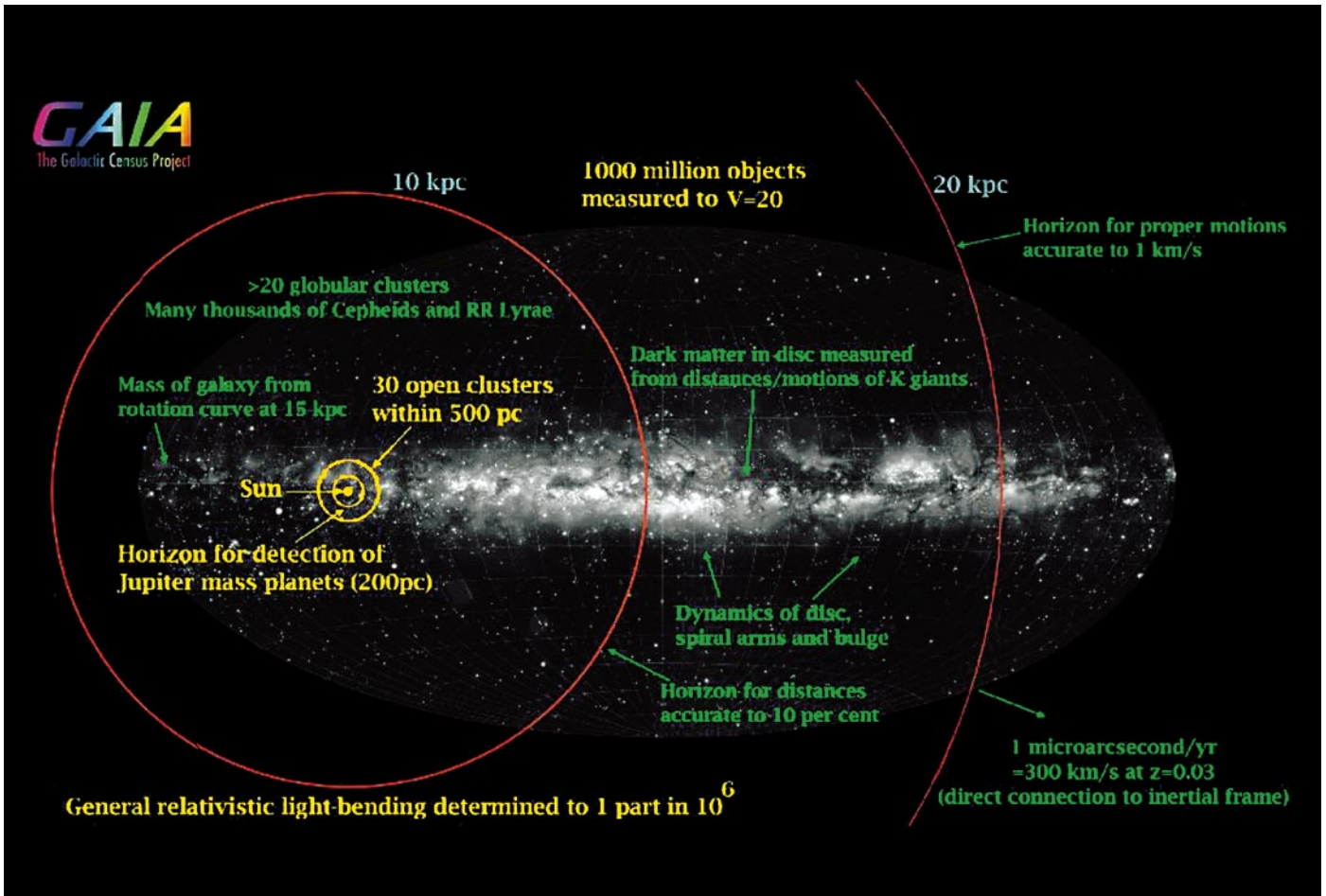


Figure 4.2.2.1.1. Distance and velocity measurement capabilities of GAIA in the context of various Galactic populations. A parallax accuracy of 10 microarcsec corresponds to 10% distance accuracy at 10 kpc. A proper motion accuracy of 10 microarcsec/year corresponds to 0.5 km/s at 10 kpc.

an industrial study started in September 1997 with Matra Marconi Space (Toulouse) competitively selected as the industrial contractor. This study will continue until the end of 1998, at which point a study report covering the scientific and technical aspects of a consolidated system design will be produced, forming the basis for a future decision on the inclusion of GAIA within the ESA scientific programme.

An earlier concept based on a first-level interferometric design (Lindgren & Perryman 1996, *A&ASS*, 116, 579, and references therein) suggested the feasibility of a mission able to measure all objects (some 50 million) down to 15 mag at the level of about 10 microarcsec. More mature designs have been proposed over the past two years, demonstrating the feasibility of the original idea.

The early meetings of the GAIA Scientific Advisory Group concentrated on optimising the detection possibilities, and the scientific relevance of measuring very large numbers of even fainter objects was emphasised. The motivation is not to construct an 'even bigger star catalogue', but emphasises (for example) the considerable importance of accessing primary kinematic tracers in the various Galactic populations, i.e. the halo, the bulge, the thin and thick disc populations, and the spiral arms. Relevant questions can be tackled only by highly accurate distance and proper motion measurements of very large numbers of objects much fainter than 15 mag and covering virtually every spectral type. The combination of high accuracy,

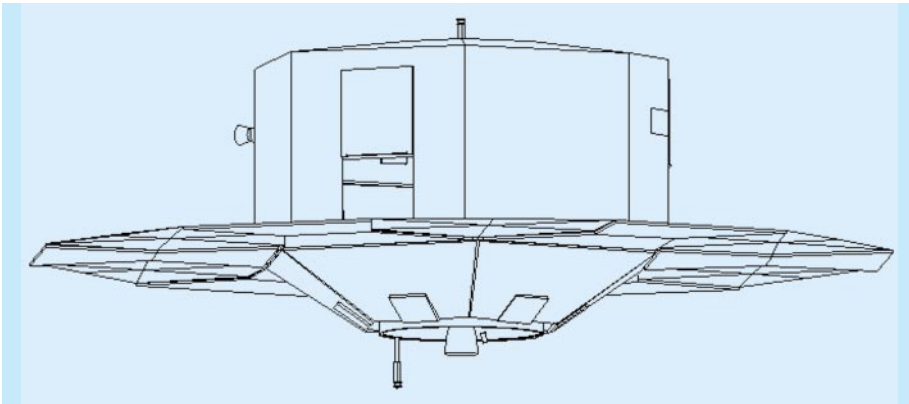


Figure 4.2.2.1.2. External schematic view of the GAIA satellite. The payload (at the top of the figure) is shielded from solar illumination by the deployed sun shield, which also carries the solar arrays. The conical extension of the service module to the bottom of the figure carries the phased arrays communicating between the satellite and the Earth.

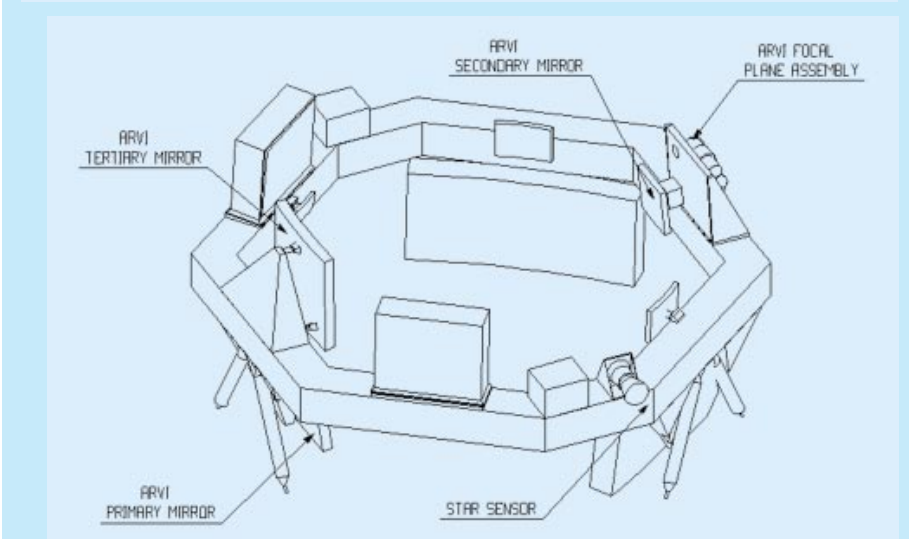


Figure 4.2.2.1.3. The GAIA payload consists of two primary mirror systems, below the central support structure, corresponding to the two viewing directions. The absolute radial velocity instrument, ARVI, views the sky region between the two primary viewing directions.

faint limiting magnitude and large numbers of stars will extend the relevance of astrometry from the (primarily) stellar astrophysics of Hipparcos into the (primarily) Galactic astrophysics regime. Thus GAIA aims at providing the Galactic phase-space distribution function equivalent to the HR diagram for studies of the formation and evolution of galaxies. To reflect a potentially substantial user community, the ongoing GAIA study is therefore also embracing the views of a much broader group of ESA member state scientists, through the organisation of a wider involvement of working groups devoted to the various aspects of GAIA. A well-attended ‘working group meeting’ was held in Leiden on 3 November 1997.

Matra Marconi Space presented its Phase 1 design to ESTEC and the GAIA Scientific Advisory Group on 14 January 1998. The remainder of the present study effort will be devoted to consolidating this present design, demonstrating its technical feasibility, and evaluating its cost and related implications. The emphasis is being placed on a design that can be realised strictly within the target Cornerstone mission envelope, and the Scientific Advisory Group has concentrated its efforts on reaching the scientific goals underlined by the Horizon 2000+ Survey Committee (i.e. 10 microarcsec) rather than on a specific instrumental configuration.

The results are highly encouraging, and a global mission concept has already been defined. The GAIA Scientific Advisory group currently considers that a mission

measuring all objects down to about $I=20$ mag, or more than 10^9 objects, is fully feasible, well within the target cost and adopted schedule (launch date 2009 and possibly earlier), and reaching the recommended target accuracy figures. In the baseline design, the satellite would be placed at the L2 Lagrangian point. The data rate to the ground would be about 3 Mbit/s.

The Scientific Advisory Group is acutely conscious of the enormous importance of measuring accurate colours, photometric variability and even radial velocities of a large fraction of the stars observed, and is drawing these elements into its overall mission design. If, as currently expected, the feasibility can be convincingly demonstrated by the end of 1998, GAIA would be poised to contribute a massive advance in our understanding of all aspects of Galactic structure and evolution, as well as providing substantial material related to such diverse fields as the space-time metric, the space motions of local group galaxies, and extrasolar planetary statistics (hundreds of thousands of stars would be rigorously screened for the presence of Jupiter-mass planets). Such interesting and intriguing 'by-products' will add substantially to the main goal of such a mission, which is to provide a vast body of kinematical and distance measurements to help unravel the details of the formation and subsequent evolution of our Galaxy.