THE SCIENTIFIC GOALS OF GAIA

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ABSTRACT

GAIA is a preliminary concept for an astrometric mission being considered in the context of ESA's 'Horizon 2000 Plus' long-term scientific programme. In its present form, the experiment is estimated to lead to positions, proper motions, and parallaxes of some 50 million objects, down to about $V = 15$ mag, with an accuracy of better than 10 microarcsec, along with multi-colour multi-epoch photometry of each object. The scientific case for such a mission is dramatic: basically, distances and kinematical motions for tens of millions of objects *throughout our Galaxy* would be obtained. As 'by-products', the global measurements would yield crucial information on the space-time metric (γ to a precision of about 1 part in 10^6, close to values which might distinguish currently competing theories of gravity), angular diameters of hundreds of stars, and a vast body of information on double and multiple systems. Perhaps the most dramatic of these subsidiary goals would arise from the screening of all 100 000 stars within 100 pc for periodic photocentric motions, which would provide the most powerful and systematic method of detecting possible planetary companions proposed to date.

Key words: space astrometry, Hipparcos, GAIA, interferometry, planetary detection, general relativity

1. INTRODUCTION

The Hipparcos project represented the first step in the acquisition of astrometric data from space. Positions, annual proper motions, and parallaxes have been determined with accuracies in the range 1–2 milliarcsec, and the concept of carrying out a global astrometric survey from space, resulting in a rigid positional reference frame, and providing *absolute* trigonometric parallaxes and proper motions, has been fully demonstrated.

The European Space Agency's 'Horizon 2000 Plus' scientific programme is now being formulated. Covering the period 2005–16, it contains three 'cornerstone' missions: one of these will be an interferometric observatory (Bonnet 1995). Assuming that an appropriate target accuracy can be demonstrated, the Survey Committee has recommended that such an interferometric mission be dedicated to astrometry, building on the results of the Hipparcos mission (Battrick 1994).

The parameter space of a future astrometry mission could be enhanced, with respect to Hipparcos, in the areas of accuracy, number of objects, and limiting magnitude. The GAIA concept (Lindegren & Perryman 1994, 1995) provides orders of magnitude improvement in *all* of these parameters, and thus *guarantees* its capability to provide the astrometric data that are needed after the exploitation of the Hipparcos results. In addition, consideration is being given to the parallel determination of the sixth astrometric parameter, the radial velocity. This possibility would greatly enhance kinematical studies, and improve the identification and understanding of binary of multiple systems, as well as allowing the effects of non-linear (orbital) photocentric motion to be decoupled from the effect of perspective acceleration (Favata & Perryman 1995).

The Hipparcos and Tycho photometric observations have demonstrated the power of an all sky-photometric survey conducted from space. Optimisation of the GAIA photometric system could lead not only to a further profound improvement in the study of stellar variability, but also to spectral classification through intermediate-band multi-colour observations at the instrument's focal surface. Improved determination of spectral type, luminosity class, metallicity, and spectral peculiarities may be feasible, and this would lead to GAIA performing the most dramatic census of the galactic stellar population contemplated to date.

The main measurement goals which would be achievable with such a mission are as follows:

- number of objects: > 50 million (120 000 for the main Hipparcos experiment, about 1 million for Tycho);
- limiting magnitude: $V > 15.5$ mag, compared with 12 mag for Hipparcos;
- completeness of catalogue: $V > 15.5$ mag, compared with 7.3–9 mag for Hipparcos;
- positional accuracy: 10 μas at $V = 15$ mag, compared with 1–2 mas at 10 mag for Hipparcos;
- parallax accuracy: 10 μas at $V = 15$ mag, i.e., 10% distance accuracy at 10 kpc, compared with 1–2 mas at 10 mag for Hipparcos;
- proper motion accuracy: 10 μas/year at $V = 15$ mag, i.e., 1 km s^{-1} at 20 kpc, compared with 1–2 mas/year at 10 mag for Hipparcos;
- multi-colour (e.g., 6-band, sufficient for spectral type and luminosity class classification), multi-epoch photometry (at each of several hundred epochs) throughout the five year mission.

The historical development of astrometric accuracies, and the role played by this future mission are summarised in Fig. 1.

Figure 1. The development of astrometric accuracies over the past two thousand years, illustrating the advance made by the Hipparcos mission, and the potential accuracies achievable by GAIA (courtesy of E. Høg, private communication).

Further details of the expected astrometric accuracies, for both the interferometric and incoherent imaging modes, are given in Lindegren & Perryman (1995), along with the assumptions entering into these accuracy estimates. Throughout this paper, we shall assume that accuracies of the order of 10 μas are achievable, although significantly better accuracies should be available for brighter objects, and the availability of improved photon-counting detectors would lead to a further increase in the astrometric performances and limiting magnitudes.

2. GENERAL SCIENTIFIC OBJECTIVES

Astrometric measurements provide model-independent estimates of basic geometrical and kinematical properties of astronomical sources. Traditionally the most important applications are the determination of stellar distances, motions and masses. GAIA will provide an immense quantity of extremely accurate astrometric and photometric data from which ultimately all branches of astrophysics will benefit. In the areas of the physics and evolution of individual stars and of the Galaxy as a whole the impact will be immediate and profound. On a much more modest scale this process will begin already with the availability of the Hipparcos results. However, while Hipparcos could probe less than 0.1% of the volume of the Galaxy by direct distance measurements, GAIA will encompass a large fraction of the Milky Way system within its parallax horizon, including much of the halo, and even touching on the nearest companion galaxies such as the Magellanic Clouds. Fig. 2 provides an overview of some objects and phenomena that can be studied by optical astrometry at various levels of accuracy and sensitivity.

Another goal of astrometry is the establishment of an accurate set of reference directions for dynamical interpretation of the motions of the Earth and other planets and of the Milky Way system, i.e., an optical reference system. The importance of having access to a dense and accurate inertial reference frame is easily overlooked in comparison with the more direct benefits of, say, parallaxes. However, the ability to establish small systematic deviations in the patterns of motions, whether it concerns the search for transneptunian planets or dark matter in our galaxy, crucially depends on the accuracy of the reference system. Through its global survey nature, GAIA is ideally suited to provide an extremely dense and accurate reference system. The limiting magnitude is sufficiently faint to allow a direct link with the extragalactic system by observation of quasars.

In the following scientific survey, emphasis is given to topics where the estimated astrometric accuracies lead to clearly identifiable applications. In addition to these, the multi-colour, multi-epoch, sub-millimagnitude photoelectric photometry will open up vast areas for study related to stellar stability over the entire Hertzsprung-Russell diagram. Other possible topics have not yet been carefully assessed, but appear highly promising—amongst these one may note the detection of MACHOs (Alcock et al. 1993; Aubourg et al. 1993), and the possible determination of the angular diameters of many hundreds of (nearby, giant) stars.

A 5-year mission has been baselined, not only because of its resulting improvement in the achievable astrometric accuracy, but also because of the importance of such a temporal baseline for the dynamical studies of asteroids, for the determination of the parameters (including orbital motion) of double and multiple stars, for the detection of possible planetary and brown dwarf companions, and for the photometric variability studies.

3. PHYSICS AND EVOLUTION OF STARS

Stellar luminosities: Luminosity estimates are based exclusively on determinations of stellar distances, themselves determined directly only from measurements of trigonometric parallaxes. With Hipparcos, direct distance measurements are limited to 100 pc with, say, 10% precision, a distance horizon insufficient to include rare but astrophysically important categories of stars such as O stars, Cepheids, and RR Lyrae variables. From ground-based observations, distance determinations and luminosity calibrations have been restricted to the main sequence, with indirect distance estimates, for example based on statistical calibrations, used to estimate stellar distances and luminosities for rarer spectral types. Parallaxes with a precision of 20 μas would reach to 5 kpc with 10% accuracy, or to 10 kpc with 20% accuracy. For the first time this would provide an extensive network of distance measurements throughout a significant fraction of our Galaxy, including the galactic centre, spiral arms, the halo, and the bulge.

Figure 2. Schematic overview of some objects and phenomena that can be studied by optical astrometry at various levels of accuracy and sensitivity. The region probed by Hipparcos (limited by 10^{-3} arcsec accuracy and magnitude 12.5) is indicated by the dashed curve at the upper left corner. The parameter region of interest for GAIA is also sketched. It includes direct (trigonometric) distances to all galactic supergiants and cepheids visible from the sun, RR Lyrae stars and bright halo stars within 10 kpc from the sun, as well as the brightest stars in the Magellanic Clouds (LMC+SMC). Jupiter-like planets can be detected from the photocentric motions of stars out to a few hundred parsecs.

Massive stars: Although only a small fraction of stars in the Galaxy are more massive than $20M_{\odot}$, such stars, which spend most of their short lives as H-burning O-type stars, play an important role in galactic structure and evolution. Thus, accurate knowledge of the luminosity of these stars is important for comparing masses derived from stellar evolutionary models with those derived from stellar atmosphere models, for determining initial mass functions, and for studying stellar evolution in the high luminosity/high mass region of the Hertzsprung-Russell Diagram. The absolute magnitudes of O stars are presently poorly determined (no O star is sufficiently close to the sun to have a trigonometric parallax accurately measured), the absolute visual magnitudes coming primarily from O stars in clusters and OB associations whose distances are themselves uncertain, but are typically around 1–2 kpc. Typical apparent magnitudes are $V = 4$–6 mag.

Novae and nova-like variables: Distance determinations to novae are required to interpret the energetics of the outburst, and to place these objects more securely within the context of evolutionary models. Distance estimates can be made through modelling of the shell expansion velocity, but such applications are restricted to particular periods after outburst, and also suffer from modelling uncertainties. Most galactic novae are brighter than $V = 12$ mag at maximum, although measurements to $V = 16$ mag or fainter would also allow the determination of distances to galactic novae observed over the last few decades. Related objects, such as dwarf novae, AM Her stars, symbiotic stars, and cataclysmic binaries could be studied, providing accurate luminosities needed to distinguish among alternate possible energy generation mechanisms. Many such nova-like variables would lie within the distance horizon and the magnitude limit (say, brighter than $V = 16$ mag) necessary to provide distances to better than 5%.

Planetary nebulae: Planetary nebulae appear to present a very narrow mass range for the remnant star, and thus provide the possibility of being good distance indicators. However, because of their rarity, and therefore their typical distances, no satisfactory method yet exists for the their distance estimation. Parallax measurements of the central stars would lead to significant advance in the understanding of the formation and evolution of the shells, the status of the central stars, and the role of these objects as standard candles. Many tens of planetary nebulae would be measurable down to $V = 16$ mag.

Cepheids and RR Lyrae stars: In addition to the importance of these stars to models of stellar structure and evolution, Cepheids and RR Lyrae form the cornerstone of the extragalactic distance scale. Some 55 Cepheids and 26 RR Lyrae stars are known to lie within about 1000 pc, and already contained with the Hipparcos observing programme, but most of these lie beyond about 300–400 pc. Parallaxes at the 20 μas level would yield distance estimates to better than 2% for these objects. In turn, the details of the period-luminosity-colour relationship for these objects would be significantly improved.

Stars in Open Clusters: Only two open clusters (Hyades and Coma Ber) lie within the 100 pc distance horizon yielding distances from Hipparcos (from individual objects within the clusters) to better than 10% accuracy. Cluster studies are important for numerous reasons, mostly related to the fact that they represent a coeval population of stars with well-defined initial chemical compositions. They can thus be used to follow the development of the formation of our Galaxy, and as a testbed for theories of stellar evolution. For example, they are amenable to studies of their dynamical behaviour, for the calibration of stellar luminosities and distances via properties such as the Wilson-Bappu effect and the mass-luminosity relation for binary stars, and for the calibration of the main sequence as a function of age and metallicity. Some 30 open clusters are considered to lie within about 500 pc, sufficient to provide individual distances to 1% accuracy with parallaxes measured at the 20 μas level.

Globular clusters: Little or no information will be provided by Hipparcos on the internal dynamics, and luminosity calibration, of stars within globular clusters, due to the faint magnitude and high central density of stars in these clusters. However, Hipparcos will provide a reference system with respect to which proper motions of cluster stars can be derived from ground-based observations acquired over long periods of time. Ages of globular clusters have indicated a possible discrepancy with the age of the Universe derived from present estimates of H_0 and Ω. Many observational effects and theoretical complications make interpretation of globular clusters properties far from straightforward; but cluster age determinations essentially require absolute magnitude calibrations of the main-sequence and, in particular, the turn-off point as a function of chemical composition. For absolute ages to be accurate to a billion years, essential for a resolution of the age conflict, the distance of the cluster must be determined with an accuracy of better than 3%. An observing programme reaching 15 mag and 20 μas accuracy on the parallaxes would include 20 or more globular clusters (such as 47 Tuc, ω Cen, M3, M5, and M15) lying between 5 and 10 kpc, and would yield *individual* distances accurate to better than 10–20%. Some 10 or more of the brightest stars per cluster would be observable, resulting in mean cluster distances at least a factor of three better than these individual accuracies.

Metal-poor stars and primordial nucleosynthesis: Recent determinations of boron abundances in the metal-poor star HD 140283 have raised important questions about the origin of this element: whether it originates from a high cosmic ray flux at the birth of the Galaxy, or primordial nucleosynthesis. If the former possibility is ruled out, it would seem to indicate that the standard Big Bang model is wrong, and that newer inhomogeneous models would be required. Cosmic ray spallation, in contrast, makes a specific prediction of the B/Be ratio, although the Be abundances turn out to be very sensitive to whether the star is a subgiant or a dwarf! A clear parallax determination (ground-based parallaxes are generally quite inadequate) would clarify this question. While the specific instance of HD 140283 should be resolved by the Hipparcos measurements, this example illustrates the importance of individual parallax determinations for astrophysical studies.

4. DYNAMICS OF STELLAR SYSTEMS

Visual and astrometric binaries: GAIA will be able to resolve binaries with an apparent separation exceeding 1–2 mas and a moderate magnitude difference. The astrometric and photometric characteristics of the components can be measured. For numerous systems with periods of a few years the absolute orbits can be determined and hence the individual component masses. Closer binaries, and systems with a faint companion, can in many cases still be detected from the non-linear motion of the photocentre. At the sensitivity level of GAIA some 25% of all stars may turn out to be non-single. This vast material on stellar duplicity will be essential for a correct interpretation of the astrometric and photometric parameters, as well as providing important constraints on theories of stellar formation.

Interacting binary systems: A rich variety of astrophysical problems related to interacting binary systems would become accessible with parallaxes in the 10–20 μas range. The evolutionary history of interacting binary systems, and the origin of Type I supernovae, millisecond pulsars, low mass x-ray binaries, and globular cluster x-ray sources is intimately bound up with the behavior of compact binaries with mass transfer and loss. Accurate knowledge of the stellar masses and orbital separation can be derived from astrometric measurements (yielding the orbital separation and the orbital inclination) combined with estimates of the mass function determined by radial velocity measurements. Many specific questions about accretion rates, precursors, mass distributions, and kinematic behaviour could be addressed with these data, including studies of the black hole candidates. Galactic black hole candidates have bright secondaries (9 mag in the case of Cyg X-1, and 12 mag or fainter in the case of V404 Cyg) and wide orbits (with orbital periods of about 6 days), which should yield definitive black hole masses by determining orbital separation and inclination.

Be Star X-ray Binaries: Be star x-ray binaries are believed to consist of a recently formed neutron star and a Be star companion. The orbit has not yet circularized, and the eccentric motion produces periodic eruptions at periastron as the compact star passes through the mass outflow from the Be star. Measurement of the orbital parameters would yield information on the anisotropy of the supernova mass ejection. It is important to relate this to the kinematics of isolated pulsars, and to the physics of the explosion.

Dynamics of globular clusters: Accurate proper motions of stars within globular clusters are required to yield information on the cluster's internal velocity dispersion, and thus constrain dynamical models of their formation and evolution. Within 47 Tuc, for example, proper motions of 20 μas/yr correspond to transverse velocities of 0.4 km/sec. In addition, spectroscopic binaries have been detected in globular clusters with amplitudes of tens of km/sec and periods of years, corresponding to separations of order 1 mas. Parallaxes and annual proper motions at the level of 50 μas or better would provide distances and orbital data necessary to clarify the formation and evolution of these binary systems, and their role in the formation of the milli-second pulsars now know to exist in the cores of globular clusters.

Galactic dynamics: The huge number, impressive accuracy, and faint limiting magnitude of the GAIA mission would totally revolutionise the dynamical studies of our Galaxy, which are now understood to be capable of providing considerable advances in our understanding of the structure and motions within the spiral arms, the disc and the outer halo. It is still unclear, for example, whether spiral arms are density wave enhancements in the background stellar distribution, or whether they are regions of enhanced star formation. If a density enhancement exists, it will affect the stellar motions in a characteristic way, and this could be tested on the relatively nearby Perseus arm (about 2 kpc distant). Stellar motions would be determined for stars near the arm, both foreground and background (distinguished by their parallaxes), with proper motion accuracy requirements of some 100 μas/yr, corresponding to about 1 km/sec in space velocity.

Dark matter within the disk: Two recent programs have attempted to determine the surface density of the Galactic disk in the solar neighborhood. One, led by Bahcall, finds evidence for dark matter in the disk, while the other (Gilmore & Kuijken) finds none. The issue is important because of the implications on the nature of dark matter—whether, if it exists, it admits matter in a baryonic or non-baryonic form. One source of uncertainty in the Bahcall result, based on the distribution of K giants perpendicular to the galactic disk, is the error in the distances to individual stars. These are relatively bright objects (apparent magnitudes 10 and brighter); their distance scale could be recalibrated and substantially improved by direct parallax measurements of K giants with a range of metallicities. Parallaxes at the level of 50 μas would be required.

Figure 3. Determinations of the post-Newtonian parameter γ, representing the deviation of the gravitational light-bending from Newtonian theory. According to general relativity, $\gamma = 1$. The figure illustrates the very preliminary determination of γ derived from the first 12 months of the Hipparcos data, $\gamma = 0.989 \pm 0.014$, along with other determinations. These include the original observations of Dyson, Eddington & Davidson (1920), and other optical determinations made at times of total solar eclipse, including the most recent published determinations of Jones (1976) based on the 1973 Mauritanian eclipse. All such metric determinations have been based on observations within a few $R_\odot$ of the solar limb. Other determinations based on VLBI observations and the Viking spacecraft (Shapiro) time-delay, also restricted to measurements made close to the solar limb, are also illustrated. The (non-Hipparcos) data are taken from Soffel (1989).

The mass of our Galaxy: The form of the rotation curve beyond the Sun, is very sensitive to the existence and amount of dark matter near to it. No very reliable determination of the rotation curve has yet been derived. In an extension of the programmes being undertaken with the Hipparcos data, measurements of the distances and motions of disk stars are required at a range of galactic longitudes, resulting in the rotation curve at distances out to 15 kpc determined from stars with $V < 12$ mag. Parallaxes at the level of 20 μas for an accuracy of 20% in individual distances, and annual proper motions of about 200 μas/yr (or 10 km/sec), would be required.

Proper motions of the Magellanic Clouds, and active galactic nuclei: Different explanations for the dynamical behaviour of the LMC/SMC, in particular whether these systems are gravitationally bound to our own galaxy, implies systematic proper motions of below about 1 mas/yr, very much at the limit of the Hipparcos capabilities. Large numbers of stars measured in the LMC/SMC at the level of 50 μas or better, would clarify their dynamical relationship with our own Galaxy. Further out, the nuclei of active galaxies are sufficiently pointlike that their absolute proper motions may be measurable. At a redshift of 0.03, a transverse velocity of 1000 km/sec corresponds to a proper motion of 3 μas/yr. Thus, transverse velocities of nearby galactic nuclei due, e.g., to galaxy cluster potentials, might be detectable.

The role of quasars: Future astrometric missions, at levels of accuracy very much better than 1 μas, could determine the transverse motions of external galaxies and quasars routinely, and determine their kinematic properties independently of a dynamical model of the Universe. In the meantime, an astrometric programme reaching 15–16 mag would include a number of quasars, and this in turn would allow a direct tie between the resulting reference system and an inertial reference frame, something which has not been possible (directly) in the case of Hipparcos. The considerable importance of this possibility is that the resulting proper motions of all the stars within the global observing programme would not be subject to arbitrary offsets in their proper motions, a fact critical for any dynamical interpretation of their motions.

5. DETECTION OF PLANETARY SYSTEMS AND BROWN DWARFS

The search for possible planetary systems beyond our own Solar System has received considerable attention in recent years, with ground-based searches based on accurate radial velocity measurements being undertaken (e.g., Kürster et al., 1994), and a variety of other ground- and space-based possibilities based on imaging in the optical or in the infra-red, or dedicated astrometric techniques being considered (e.g., Thronson 1995).

The Hipparcos mission, due to its limited astrometric accuracy and mission duration, is unlikely to make any serious contribution to the possible detection of sub-solar mass planetary companions around nearby stars. The essential idea, that of detection of non-linear photocentric motions in the paths of nearby stars due to such 'planetary' companions, has been extensively studied and simulated, for example as part of NASA's TOPS (Towards Other Planetary Systems) and later as part of the POINTS programme.

The probable size of the effect can be judged by considering the path of the Sun as seen from a distance of (say) 10 pc. The perturbation caused by Jupiter has an amplitude of 500 μas and a period of 5 years, while the effect of the Earth is a one-year period with 0.3 μas amplitude. With a mission length of 5 years and a target mission accuracy of 20 μas, GAIA should be able to provide annual normal points with an accuracy of 50 μas. This is sufficient to detect Jupiter-mass planets (at the 3σ level) out to 30 pc. This volume includes several thousand potential target stars, *all* of which can be monitored for possible companions. If the accuracy is instead 2 μas, which may be feasible for bright stars ($V < 10$ mag), then the detection horizon for Jupiter-mass planets is pushed beyond 100 pc and includes some 10^5 candidate stars. Screening all 50 million stars down to the survey limit of $V = 15$–16 mag for possible signatures of planetary and brown dwarf companions will provide a complete census of such bodies to well-defined detection limits.

6. GENERAL RELATIVITY

The reduction of the Hipparcos data has necessitated the inclusion of stellar aberration up to terms in $(v/c)^2$, and the general relativistic treatment of light bending due to the gravitational field of the Sun (and Earth). Light bending by the Sun amounts to 4 mas even at 90° (i.e., for light arriving perpendicular to the ecliptic). The astrometric residuals may be tested for any discrepancies with the prescriptions of general relativity; in principle this provides a constraint on the post-Newtonian light-bending term, γ, equal to unity in general relativity. Fig. 3 illustrates previous determinations of γ. These include the original observations of Dyson, Eddington & Davidson (1920), and other optical determinations made at times of total solar eclipse, including the most recent published determinations of Jones (1976) based on the 1973 Mauritanian eclipse. All such previous determinations have been based on observations within a few $R_\odot$ of the solar limb. Other determinations based on VLBI observations and the Viking spacecraft (Shapiro) time-delay, also restricted to measurements made close to the solar limb, are also illustrated (see Soffel 1989). The best available measurements to date are those from the Viking observations (Reasenberg et al. 1979), and provide a precision of about 10^{-3} in γ.

The GAIA measurements would provide a precision of about 1 part in 10^6 or better in the determination of γ due to the Sun, and will thus probe post-post-Newtonian effects. Interestingly, this expected precision is close to the values predicted by present theories which consider that the Universe started with a strong scalar component, and which is relaxing to the general relativistic value with time (e.g., Damour & Nordtvedt 1993). The importance of such theories is that they provide a possible route to the quantisation of gravity. For this reason, space experiments dedicated to the measurement of γ with a precision of about 1 part in 10^6 have been proposed, and are being considered for the ESA M4 round. We stress that GAIA would provide this precision as a simple by-product of its astrometric and photometric campaign.

Light deflection has also been observed, with various degrees of precision, on distance scales of $10^9 - 10^{21}$ m, and on mass scales from $1 - 10^{13} M_\odot$, the upper ranges determined from the gravitational lensing of quasars (Dar 1992). Light-bending by the Earth is at the level of $\sim 40\mu$as, and GAIA could therefore extend the domain of observations by two orders of magnitude in length-scale, and six orders of magnitude in mass. (The Pound-Rebka experiment verified the general relativistic prediction of a gravitational redshift for photons, an effect probing the time-time component of the metric tensor, while light deflection depends on both the time-space and space-space components). Light bending at the Jovian limb is predicted to amount to 17 mas.

At the level of accuracy expected from GAIA, even more subtle effects will start to become apparent, such as the quadrupole components of the gravitational fields of the Sun and the planets, and the 'frame-dragging' effects of their motions and rotations (see, e.g., Schutz 1982, Soffel 1989).

Light modulation effects due to gravitational lensing by MACHOs (Alcock et al. 1993; Aubourg et al. 1993) might also be detectable (Høg et al. 1995), and all of these possibilities will need to be studied in more detail.

The possible detection of gravity waves, as a result of the angular displacement of the apparent positions of stars has been considered by Fakir (1994). The speculative possibility that GAIA might achieve the first ever such detection, through the apparent motions of stars situated behind relatively nearby binary (giant) systems, has been briefly considered by Fakir (1995a,b).

7. CONCLUSIONS

As recommended for consideration by the ESA Horizon 2000+ Survey Committee, GAIA would employ a small optical interferometer in space, to conduct a global astrometric survey of some 50 million or more objects down to $V = 15$ mag or fainter. Based on the well-proven concepts of the Hipparcos mission, such a project would provide an enormous advance in the understanding of the evolution and dynamics of stars throughout our Galaxy, and a variety of remarkable by-products, including a large improvement in our experimental probing of the space-time metric, and the systematic scrutiny of tens of thousands of objects in the solar neighbourhood for possible planetary companions.

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