PARALLEL ACQUISITION OF RADIAL VELOCITIES AND METALLICITIES FOR A GAIA-TYPE INTERFEROMETRIC ASTROMETRY MISSION

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ABSTRACT We discuss some possible options for the parallel acquisition of non-astrometric data in the framework of an astrometric experiment such as the proposed GAIA mission. We concentrate on the acquisition of spectroscopic information, discussing the scientific rationale for the proposed measurements, in particular of precise (≈ 1 km/s) radial velocity and metallicity (≈ 0.1 dex) determination. We analyze the performance of a simple slitless scanning spectrograph system, discussing both space and ground-based options, showing that, even without careful optimization such a system could have a performance not too far away from that required to measure all the stars in the sky down to $V \approx 15$ in the lifetime of the proposed GAIA mission. Such an instrument would greatly enhance the scientific capabilities of an astrometric mission, allowing the determination of 3-d space motions as well of important physical parameters for an unprecedented sample of stars.

KEYWORDS: radial velocities; space astrometry; GAIA; spectral classification; abundances.

1. INTRODUCTION

The problem of parallel acquisition of non-astrometric data in the framework of an interferometric astrometry mission such as the proposed GAIA mission was first raised by Perlmann (1994) who drew attention to the importance of the question, and demonstrated that acquisition of 'auxiliary' data on the scale demanded by the GAIA mission would be a challenging issue. The possibility of acquiring the necessary spectral data through a dedicated ground-based multi-fibre spectroscopic facility was briefly considered. Here we consider an alternative approach, based on a scanning slit-less spectrograph, which could either be incorporated within the satellite payload, or considered as a separate ground-based instrument.

2. WHICH KIND OF DATA

What kind of auxiliary information would it be desirable to acquire in the framework of a mission such as GAIA? Assuming that medium-band (i.e., Strömgren-like) photometry will be acquired already on the focal plane of the interferometers (see Perlmann 1994) we have identified three main scientific parameters which would

FIGURE 1. The figure is intentionally empty.

be desirable to acquire for each of the stars for which GAIA will measure the astrometric parameters. Specifically, these are the radial velocity, the metallicity, and the MK spectral type. The rationale for each of the three measurements is described in the following sections.

2.1. Radial Velocity

An interferometric mission such as GAIA will measure both precise distances and proper motions. The third component of the space motion, i.e., the radial velocity, is however necessary to get a complete description of the space motions of the targets, and therefore to be able to carry out 3-d dynamical studies. The usefulness of radial velocity information in the context of an astrometric mission is demonstrated by the large number of ground-based radial velocity measurement programmes being carried out on Hipparcos targets, including two ESO key projects, see May (1989) and German (1989). While an ad hoc approach has been adopted in the case of Hipparcos (involving $\approx 100\,000$ stars), only a dedicated programme could be considered in the context of the 50 million or so stars which could be observed by GAIA.

To be maximally useful, the radial velocity measurements should match the precision of the astrometric measurements. The 10 μas/yr which is the GAIA goal translates, at 10 kpc, to about 0.5 km/s. A radial velocity acquisition programme should therefore aim for an accuracy of 1 km/s or better. Using current digital cross-correlation methods radial velocities can be extracted, at least for late-type stars with a spectrum rich in spectral lines, to a precision corresponding to about 1/10 of pixel (Batson 1985). Working in the red region of the spectrum (where the sensitivity of current digital detectors is greater) this translates into a spectral dispersion of about 10 km/s per pixel, or about R = 30,000, i.e., the typical resolution of an echelle spectrograph.

Working on Pop II stars Cowell et al. (1987) have shown that the digital cross-correlation technique is capable of extracting radial velocities to 1/10 of a pixel on spectra with S/N per pixel as low as 5, using only one echelle order (about 40 Å spectral coverage). This translates, in the space-based baseline design discussed here, into $\approx$ 700 m/s accuracy. Additionally, they showed that the same spectra could be used to determine the metallicity to about 0.12 dex. We have therefore considered as our goal an instrument which should be able to produce a spectrum with a S/N of 5 per pixel during the mission for the fainter of the GAIA target stars (which we have assumed to be V $\approx$ 15). Note that for high S/N spectra (such as the ones the instrument described here would produce for the brighter stars), radial velocities precise to 1/100 of a pixel can be extracted (Clark et al. 1988), i.e. a factor of 10 better than possible on the weaker objects (or $\approx$ 70 m/s accuracy in our space-based baseline design). Note that the motion of the Sun-Jupiter barycenter is about 12 m/s, i.e. lower than what it would be achievable at the type of spectral resolutions discussed here.

3. CONCLUSIONS

The limits of a space-based 1-m telescope, in the domain considered here, come out, even without careful optimisation, tantalisingly close to values of great astrophysical interest, with a magnitude limit comparable to that motivating the GAIA mission. One aspect that should be carefully considered is the satellite spin rate: for the astrometric rigidity a higher spin rate, detector considerations aside, is more desirable; in contrast, the limiting magnitude of the system considered here increases significantly with decreased spin rate.

The acquisition of these auxiliary data on ground versus their acquisition in space is bound to be a non-trivial question. On the one hand, focussing the goals of a future space mission exclusively on the astrometric data may be turning our backs on the true potential of such a mission. Considering the two as a single package may make the mission considerably more appealing to a broader scientific group. The experiment could be considered as institute-provided, being decoupled from the astrometric interferometers, and therefore of interest to instrument builders within Europe. The analysis of the resulting data would be an enormous challenge for software reduction, automated analysis and classification systems, and may therefore be of further scientific appeal. While such an option could not be allowed to jeopardize what is already likely to be a challenging project, enlarging the mission's vision should certainly be considered as an important part of a cornerstone mission definition. Proposing the project as a ground-based programme would create different but correspondingly significant problems: how would such an experiment be motivated, coordinated, funded, and exploited? On what time-scale could it be completed, etc?

Given the evident importance of the auxiliary data described here for any comprehensive exploitation of the astrometric data, we consider that further consideration of acquiring such data, in the same 'package' (either on ground or from space) is merited.

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