A Giant Step: from Milli- to Micro-arcsecond Astrometry
Proceedings IAU Symposium No. 248, 2007
W. J. Jin, I. Platais & M. A. C. Perryman, eds.

doi:10.1017/S1743921308019364

Gamma Astrometric Measurement Experiment: testing General Relativity with a small mission

A. Vecchiato, M. G. Lattanzi, M. Gai and R. Morbidelli

INAF- Astronomical Observatory of Torino,
via Osservatorio 20, I-10025, Pino Torinese (TO), Italy
email: `vecchiato@oato.inaf.it`

Abstract. GAME (Gamma Astrometric Measurement Experiment) is a concept for an experiment whose goal is to measure from space the γ parameter of the Parameterized Post-Newtonian formalism, by means of a satellite orbiting at 1 AU from the Sun and looking as close as possible to its limb. This technique resembles the one used during the solar eclipse of 1919, when Dyson, Eddington and collaborators measured for the first time the gravitational bending of light. Simple estimations suggest that, possibly within the budget of a small mission, one could reach the 10^{-6} level of accuracy with $\sim 10^6$ observations of relatively bright stars at about 2° apart from the Sun. Further simulations show that this result could be reached with only 20 days of measurements on stars of $V \leqslant 17$ uniformly distributed. A quick look at real star densities suggests that this result could be greatly improved by observing particularly crowded regions near the galactic center.

1. Introduction

The very first experiment devoted to the testing of General Relativity was based on measures of the bending of a light path due to the gravitational pull of massive bodies. This experiment was conducted during the solar eclipse of 1919, by Dyson, Eddington and collaborators and confirmed the predictions of GR within a 10% accuracy. In the PPN formalism, this is equivalent to say that the parameter γ is equal to 1 ± 0.1.

The same technique was used for several decades after 1919 but, despite the many further attempts, its accuracy could not be improved (Soffel, 1989), so modern experiments use different observing conditions or different kind of observables (Viking, VLBI, Cassini). The best measure of the PPN-γ parameter achieved so far was done using the Cassini data (10^{-5} level of accuracy) while, limiting ourselves to astrometric measurements, the most promising effort presently under development is represented by the Gaia mission (10^{-7} level by the end of the next decade (Vecchiato *et al.*, 2003)).

Modern technology can solve the technical difficulties which made impossible to pursue the solar eclipse tests, i.e. the short time available for the observations (limited by the eclipse duration) and the background noise due to the solar corona.

A dedicated satellite, possibly within the budget of a small mission, looking close to the Sun could compete with the present and future astrometric measurements of γ.

2. Preliminary mission constraints

After a preliminary assessment driven by the constraints of a small mission, we focused on the following measurement concept (more technological details in Loreggia *et al.* (2008)): a) observing at $\sim 2^\circ$ away from the Sun with a FoV of $\sim 7' \times 7'$; b) reconstructing

Table 1. Estimated mission performances from simulation results.

M_{max}	mean n. of obs.	$\sigma_{\gamma^*-\bar{\gamma}}$
14.5	203214	$3.95 \cdot 10^{-6}$
15.0	419309	$3.16 \cdot 10^{-6}$
16.0	964938	$2.85 \cdot 10^{-6}$
17.0	1835608	$2.61 \cdot 10^{-6}$

the attitude w.r.t. the Sun with a final accuracy $\lesssim 1''$; c) accuracy for the stellar positions at the level of the milli-arcsecond. This would suggest that $\sim 10^6$ single measurements of relatively bright stars could give a final result of $\Delta\gamma \sim 10^{-6}$. Estimates of the possible number of observations based on the star counts of the GSC-II catalog suggest that one could reach one million of observations in a reasonable amount of time.

3. First simulation results

We used the astrometric model developed in Vecchiato *et al.* (2003), which is based on a PPN Schwarzschild metric for the Sun and considers as observable the arc between two stars, to give a more reliable assessment of the mission capabilities for the measurement of γ.

The "Universe model" considers a sky with uniform spatial distribution and magnitude distribution compatible with the total GSC-II star counts, and the observation concept can be summarized as follows: a) the satellite observes simultaneously the stars in two Fields Of View (FoVs) with the Sun in between and with an exposure time of 100 s; b) the two FoVs are about 2° away from the Sun and have an amplitude of $7' \times 7'$; c) the observations are subsequently repeated, at intervals of 120 s, keeping the Sun between the FoVs, for about 20 days; d) the same FoVs are observed six months later (i.e. without the Sun in between).

As regards the data reduction scheme, the observables are arcs between two stars, and for each couple of FoVs, they are formed coupling each star in the upper FoV with the brightest star of the lower FoV, and vice versa.

The value of the PPN-γ parameter is estimated by the differences between the arcs measured with the Sun in between and six months later, and the results of a series of 50 Monte-Carlo runs with different magnitude limits indicate that after 20 days of measurements it seems possible to reach the 10^{-6} level of accuracy for $\delta\gamma$ (Tab. 1).

Simulations considered a uniform stellar density on the sky, but obviously that is not realistic. If we consider real star densities instead, it can be estimated that, choosing appropriate sky regions, the measurement of the γ parameter could be improved by an order of magnitude.

References

Loreggia, D., Gai, M., Lattanzi, M. G., & Vecchiato, A. 2008, *in this volume*, p.274

Soffel, M. 1989, *Relativity in Astrometry, Celestial Mechanics and Geodesy* (Springer-Verlag, Astronomy and Astrophysics Library series)

Vecchiato, A., Lattanzi, M. G., Bucciarelli, B., Crosta, M., de Felice, F. & Gai, M. 2003, *A&A*, 399, 337