ASTROMETRY WITH GROUND BASED OPTICAL TELESCOPES

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ABSTRACT. Astrometry with ground based optical telescopes is a newly developed theme in the Paris Observatory SYRTE Department. It recovers some activities like: - the observation of the WMAP probe with optical telescopes for the future astrometric monitoring of GAIA, - the realization of an ecliptic catalog of quasars (using the CFHT images), - the link between radio and optical positions of quasars. In the case of WMAP we will detail more particularly the observations made with the ESO 2.2 m telescope and with the 105 cm telescope of the Pic du Midi. Our goal is to be able to obtain the position of GAIA on its orbit with an uncertainty of 150 m in position and 2.5 mm/s in velocity. We will give the first results for the astrometric reduction of the images of WMAP obtained with these two telescopes.

1. INTRODUCTION

In the domain of astrometry, SYRTE is involved in the realization of the International Celestial Reference Frame (ICRF) which is necessary to know with optimal precision the location of all the bodies in the Universe. One of the tasks consists in establishing the coordinates of quasars as accurately as possible. These quasars are assumed to provide fixed (quasi-inertial) directions in space, which make it possible to determine the coordinates of moving objects: stars in galactic rotation, planets and asteroids rotating around the Sun etc... Because of the increasing number of sources in the catalogues of quasars, it is necessary to make their intercomparison as well as the analysis of the extremely accurate observation data obtained by very long baseline interferometry (VLBI) in the radio domain, or by CCD images in the focal plan of large telescopes at optical wavelengths. Another research theme is the link between the International Celestial Reference System and the dynamical system represented by the trajectories of the mobile bodies in the solar system. At SYRTE, the analysis of lunar laser ranging data, of pulsar chronometry, and the use of optical observations lead to the determination of this link.

2. PREPARING THE GAIA MISSION

The requirements, due to astrometric reasons, about the position and velocity of the spacecraft on its orbit are very stringent. It has been shown (Perryman 2005, Mignard 2005) that the uncertainty must be, at most, 150 m (20 mas) and 2.5 mm/s (1 mas/h) respectively. To achieve that high level of requirements the Ground Based Optical Tracking (GBOT) must be used together with the classic Doppler and ranging techniques (these two last techniques can only deliver 6 km and 8 mm/s). GAIA's location roundabout the L2 Lagrange point is approximately 1.5 million km from the Earth, facing roughly opposite of the Sun. Its visual magnitude would be approximately 18 (this value can be off by a huge amounts, +/-1mag). In order to prepare the GBOT of GAIA, the Wilkinson Microwave Anisotropy Probe (WMAP) has been chosen. That probe is also located around the L2 Lagrange point and its magnitude (roughly 19) is very near from the expected magnitude of GAIA. WMAP is then a reasonable model for the brightness and observability of GAIA. The precise astrometric position of WMAP has been provided by Dale Fink, Navigator of WMAP Spacecraft Control Team at NASA.

3. ESO 2.2M + WFI

Sebastien Bouquillon (SYRTE-OP), Ricky Smart (INAF/OATo, Torino) and Alexandre Andrei (Observatorio Nacional, Rio de Janeiro) have used the 2.2 m telescope of the European Southern Observatory at La Silla, Chile, to take several images of NASA's WMAP satellite in its orbit. Sextractor (Terapix) or Daofind (IRAF) have been used to obtain the (x, y) positions of the sources on the CCD. The standard deviation of the difference between the computed and the observed positions of stars gives the best available information about the standard deviation of WMAP. Results obtained with three independent softwares are given here:

	Home made	TERAPIX	IRAF
Right asc. (α)	70.1 mas	70.5 mas	69.7 mas
Dec. (δ)	80.8 mas	77.0 mas	72.2 mas

Table 1: Results on astrometric reduction obtained with three independant softwares

4. T105 PIC DU MIDI (FRANCE)

The astrometric reduction has been done with the same three independent softwares that for the ESO CCD. A plate solution was determined with a second order polynomial in x and y leading to the following residuals:

Time of observ.	$\sigma(\alpha)$	$\sigma(\delta)$
23h05m33s	64 mas	48 mas
23h09m00s	65 mas	61 mas
23h12m25s	65 mas	57 mas

Table 2: Results on astrometric reduction obtained at the Pic du Midi

The results obtain were compared with the theoretical ephemeride. Moreover the brightness of WMAP has been calibrated with respect to the UCAC2 reference stars (UCAC2 stars are not photometric standards). The results are as follows:

Time of observ.	diff(α)	diff(δ)	mag($\pm - 1\sigma$)
23h05m33s	21.104"	3.234"	18.620(+/-0.249)
23h09m00s	21.297"	3.141"	18.661(+/-0.257)
23h12m25s	21.530"	3.231"	18.757(+/-0.251)

Table 3: Comparison between observed/theoretical coordinates and magnitude determination

The difference between the observed position and the ephemeride is relatively large but quite constant. This can be due to the ephemeride itself (constant offset), to the inaccuracy of the position of the telescope (10 m), to the time synchronisation of the Pic du Midi (0.1 s) or to other effects...

The fluctuation of the magnitude can be explained by the ambient conditions (clouds, bad seeing and Moon's age). The rapid changes in object brightness due to varying illumination of spacecraft must also be taken into account.

5. CONCLUSION

In the frame of the GBOT-GAIA, first observations of WMAP have been done with the 2.2 m ESO and 1.05 m Pic du Midi telescopes. Preliminary results show that it is possible to obtain the position of WMAP with the uncertainty of the UCAC2 stars. Hence when the GAIA early-catalogue will be accessible to the GBOT community the uncertainty about the GAIA position could be better than 20 mas. It will permit to reach the very stringent requirements of the GAIA mission.

6. REFERENCES

Mignard, F., 2005, Ephemeris requirements for GAIA, GAIA-FM-023

Perryman, M., 2005, Specifications for absolute time and orbital ephemeris for ESOC, GAIA-CA-TN-ESA-MP-012-2