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ScienceDirect
Planetary and Space Science 56 (2008) 1828–1831
Planetary and Space Science
www.elsevier.com/locate/pss

Contribution to the ground-based follow-up of the Gaia space mission

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Accepted 5 February 2008
Available online 14 August 2008

Abstract

The Gaia Space Mission [Mignard, F., 2005. The three-dimensional universe with Gaia. ESA/SP-576; Perryman, M., 2005. The three-dimensional universe with Gaia. ESA/SP-576] will observe several transient events as supernovae, microlensing, gamma ray bursts and new Solar System objects. The satellite, due to its scanning law, will detect these events but will not be able to monitor them. So, to take these events into consideration and to perform further studies it is necessary to follow them with Earth-based observations. These observations could be efficiently done by a ground-based network of well-equipped telescopes scattered in both hemispheres.

Here we focus our attention at the new Solar System objects to be discovered and observed by the Gaia satellite [Mignard, F., 2002. Observations of Solar System objects by Gaia I. Detection of NEOS. Astron. Astrophys. 393, 727] mainly asteroids, NEOs and comets. A dedicated ground-based network of telescopes as proposed by Thuillot [2005. The three-dimensional universe with Gaia. ESA/SP-576] will allow to monitor those events, to avoid losing them and to perform a quick characterization of some physical properties which will be important for the identification of these objects in further measurements by Gaia.

We present in this paper, the beginning of the organization of a Latin-American ground-based network of telescopes and observers joining several institutions in Argentina, Bolivia, Brazil and other Latin-American countries aiming to contribute to the follow-up of Gaia science alerts for Solar System objects.

Keywords: Astrometry; Gaia; Solar System; NEOs; Photometry

1. Introduction

The Gaia Space Mission will provide a revolutionary astrometric, photometric and spectroscopic database. More than one billion stars will be observed with unprecedented accuracy allowing to discuss many questions concerning the Solar System, the Milky Way and beyond in an extremely solid and never seen base (Mignard, 2005; Perryman, 2005).

An important task concerning the Gaia Mission, for the astronomical community, is the ground-based follow-up of science alerts, e.g., the observation from the ground of the large number of transients events to be detected by the satellite: supernovae, microlensing, gamma ray bursts and new Solar System objects. The follow-up of these events is essential to do a better astrophysical characterization and to keep them for further studies.

In the case of the Solar System, the transient events correspond to the detection by the satellite of a very large number of objects, among them probably more than 10^5 new asteroids (Mignard, 2002; Bayler-Jones, 2004; Thuillot, 2005).

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doi:10.1016/j.pss.2008.02.041

Efficient observations of these objects from the ground to supplement the Gaia Mission require a robust array of medium-size and small-size automatic telescopes, well equipped and scattered in the two hemispheres. For the Southern hemisphere the availability of adequate instruments is still a point of concern.

We present in this work a view of the available instruments at this moment for which the associated manpower answered the call to contribute to the development of this array in a positive way. This preliminary contact list contains, at this time, only some Latin-American institutions in Argentina, Bolivia and Brazil. Nonetheless, it will be extended in a near future. We have started to make contacts with Chilean and Venezuelan colleagues and we hope they will join this collaboration soon. On the other hand, in Argentina, Bolivia and Brazil it was possible to find some colleagues that answered this call in an enthusiastic way.

2. Available instruments

In this first contact with the goal to constitute a network of automatic telescopes in Latin-America, mainly to follow-up the Gaia Solar System objects, we could find a great interest to participate from two institutions in Argentina, one in Bolivia and three in Brazil. In all these cases we can figure on telescopes of small and medium size, adequately equipped and with sufficient manpower to significantly contribute with this Gaia task.

2.1. Argentina

In Argentina there are two contacted institutions that answered positively to the call to participate on this observational network. In the near future, it is possible that other institutions and colleagues come to join this list:

- *Estación Astronómica Dr. Cesco—El Leoncito*: This observatory is located at $\phi = -31°48'$, $\lambda = 69°20'$W, $h = 2437$ m and comes to participate in this network with a double astrograph regularly operating in a semi-automatic way with the following main characteristics in Table 1.

  In El Leoncito we also have the completely automatic San Fernando CCD Meridian Circle manufactured by GrubbParsons (Muiños et al., 2006). This instrument is operating regularly in a collaboration between the Real Instituto y Observatorio de la Armada (Spain) and Observatorio Astronómico Félix Aguilar. The CCD Meridian Circle observes in drift scan mode and although it can do only one observation per night, what is not ideal to follow an object, it can give an important contribution with very accurate positions for each observation night.

  The main characteristics of the San Fernando CCD Meridian Circle are summarized in Table 2.

- *Estación Astrofísica de Bosque Alegre—Córdoba*: The Bosque Alegre Observatory is located at $\phi = -31°36'$, $\lambda = 64°32'$W, $h = 1250$ m. Here we will be working with a semi-automatic telescope in very good conditions, but that is not operating at this moment due to re-aluminization of the primary mirror. The site has approximately 200 ± 30 clear nights each year, with an typical seeing of $2\,\text{in} \pm 0.5\,\text{in}$. The main characteristics of this instrument, that can be fully dedicated to the follow-up task, are shown in Table 3.

Table 1
El Leoncito telescope's characteristics

Objective	500 mm
Focal length	3750 mm
CCD1 detector	Pixel Vision $4k \times 4k$
Pixel size	15 μm
Field	54.0 arcmin × 54.0 arcmin
Scale	0.8 arcsec/pixel
CCD2 detector	AP-8 $1k \times 1k$
Pixel size	24 μm
Field	22.6 arcmin × 22.6 arcmin
Scale	1.3 arcsec/pixel

Table 2
San Fernando Meridian Circle's characteristics

Objective	176 mm
Focal length	2664 mm
CCD detector	KAF-1600 1536 × 1024
Pixel size	9 μm
Field	18.0 arcmin in Dec. × arbitrary in RA
Scale	0.7 arcsec/pixel

Table 3
Bosque Alegre telescope's characteristics

Objective	1540 mm
Focal length	7700 mm
CCD detector	Thomson 1024 × 1024
Pixel size	19 μm
Field (f/5)	9.2 arcmin × 9.2 arcmin
Scale	0.5 arcsec/pixel
Field (f/19)	3.3 arcmin × 3.3 arcmin
Scale	0.1 arcsec/pixel

2.2. Bolivia

At Bolivia we will have the participation of the *Observatorio Astronomico Nacional—Tarija* situated at $\phi = -21°36'$, $\lambda = 64°37'$W and $h = 1861$ m with two semi-automatic instruments.

The main characteristics of their astrograph are shown in Table 4.

The other available telescope at Tarija Observatory is a Zeiss reflector whose main characteristics are given in Table 5.

2.3. Brazil

In Brazil, there are three institutions from which we obtained a positive answer.

Table 4
Tarija astrograph's characteristics

Objective	230 mm
Focal length	2280 mm
CCD detector	IMG1001E 1024 × 1024
Pixel size	24 μm
Field	37.0 arcmin × 37.0 arcmin
Scale	2.2 arcsec/pixel

Table 5
Tarija telescope's characteristics

Objective	600 mm
Focal length	7360 mm
CCD detector	IMG1001E 1024 × 1024
Pixel size	24 μm
Field (f/5)	11.0 arcmin × 11.0 arcmin
Scale	0.6 arcsec/pixel

The main Brazilian Observatory, *Laboratório Nacional de Astrofísica—Brazópolis*, operates two telescopes at the Pico dos Dias site, one with 1600 mm and other with 600 mm, that are not fully available for using as automatic observing stations. It will be eventually possible to use them for observation in a coordinated opportunity target mode. Those instruments can be very important for the follow-up of the fastest and/or faintest objects.

Two other institutions answered positively to the call to participate with available instruments in the follow-up Gaia for Solar System objects:

- *Miniobservatorio—Instituto Nacional de Pesquisas Espaciais—São José dos Campos*: This Observatory is located at $\phi = -23°12'$, $\lambda = 45°52'$W and $h = 620$ m and can contribute with a completely automatic Celestron telescope with the following characteristics in Table 6.
- *Abrahão de Moraes Observatory da Universidade de São Paulo—Valinhos*: This Observatory is situated at $\phi = -23°00'$, $\lambda = 45°58'$W and $h = 850$ m and can participate in this network with three available fully automatic robotic instruments working regularly, in a site that has approximately 180 ± 20 clear nights each year.

  The first of those instruments is an MEADE telescope operating in a completely automatic way with the following main characteristics in Table 7.

  The other available instrument at Abrahão de Moraes Observatory is a completely automatic Celestron telescope whose main characteristics are shown in Table 8.

  Finally, we also have at the Abrahão de Moraes Observatory, one semi-automatic CCD Askania-Zeiss Meridian Circle (Teixeira et al., 2000). As the San Fernando Meridian Circle, this telescope works in drift scan mode and can observe an object only one time each night. Nonetheless, this instrument is capable of taking an arbitrary size image in RA, thus providing precise astrometry for the observation. The main characteristics of this telescope follows from Table 9.

Table 6
INPE telescope's characteristics

Objective	279 mm
Focal length	2794 mm
CCD detector	SBIG ST-7XE 765 × 510
Pixel size	9 μm
Field (f/10)	8.5 arcmin × 5.7 arcmin
Scale	0.7 arcsec/pixel
Field (focal reducer 0.63×, f/6.3)	12.1 arcmin × 8.1 arcmin
Scale	1.0 arcsec/pixel

Table 7
Valinhos telescope's characteristics

Objective	406 mm
Focal length	4060 mm
CCD detector	AP-10 2048 × 2048
Pixel size	14 μm
Field	24.3 arcmin × 24.3 arcmin
Scale	0.7 arcsec/pixel
Field (focal reducer)	38.5 arcmin × 38.5 arcmin
Scale	1.1 arcsec/pixel

Table 8
Valinhos telescope's characteristics

Objective	279 mm
Focal length	2790 mm
CCD detector	SBIG ST-7XE 765 × 510
Pixel size	9 μm
Field	8.5 arcmin × 5.7 arcmin
Scale	0.7 arcsec/pixel
Field (focal reducer)	17.0 arcmin × 11.3 arcmin
Scale	1.3 arcsec/pixel

Table 9
Valinhos Meridian Circle's characteristics

Objective	190 mm
Focal length	2590 mm
CCD detector	Thomson 512 × 512
Pixel size	19 μm
Field	13.0 arcmin in Dec. × arbitrary in RA
Scale	1.5 arcsec/pixel

3. Discussion

Undoubtedly the transient events that will be detected and observed by the Gaia satellite deserve a special attention concerning their monitoring from ground. For the Gaia science alerts related to the Solar System objects a ground-based network of instruments as proposed by Thuillot (2005) adequately equipped and scattered in the two hemispheres could provide the necessary support to

Fig. 1. Geographical distribution of the observatories.

ensure the highest possible scientific return. In addition, we can say that the establishing of a coordinated automatic network like this one can contribute as well for other important observational programs as those concerning the mutual events of planetary satellites.

Although the meridian circles are not the ideal instruments to a follow-up task due to some of their characteristics as the low limiting magnitude for example, they are able to provide a significative contribution thanks to their precise astrometric measurements, approximately 100 mas per individual observation. Also, the high availability in terms of observing time dedicated to the task makes the small-size telescopes a significant addition to the network.

An important point concerning our contribution is the range of magnitudes we are able to reach: from 15 to 21 magnitudes depending on the instrument. Concerning the astrometric precision attained in one single observation, the actual setup of the proposed network can reach between 100 and 200 mas.

In Fig. 1 we can see the distribution of the observatories included in the network up to this moment.

4. Conclusion

In this work we presented an initial organization of a follow-up network for Solar System object discoveries with the Gaia satellite. This network will surely expand, as Gaia's launch date approaches, and we encourage our Latin-American colleagues to join us in this contribution to this important astronomical space mission.

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