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Comet Observations with Gaia

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Abstract

The European space mission Gaia [1] will provide a five-year repeated scanning of the full sky. Within this time it will provide photometric and high-precision astrometric observations of all objects in the sky with G−band magnitudes between about 6 and 20. Although designed for stellar observations, comets will also cross Gaia's fields of view while scanning the sky. We present a first assessment of the potential of Gaia in observing comets. This includes some statistics using realistic data about the number of Gaia transits for currently known comets and fictitious ones in order to have an insight into the Gaia ability to observe new comets. Furthermore, the on-board detection of comets as a requirement for transmitting observational data to ground is studied. According to the simulations, a rich data set of comet observations should be provided by Gaia.

1. Introduction

Gaia is a cornerstone mission of the European Space Agency (ESA) [1] [2], its launch is scheduled for August 2012. From its orbit around L2, Gaia will repeatedly scan the full sky within two fields of view, separated by a constant angle of 106.5°. The scanning follows a pre-defined law, resulting in a total of 70 observations on average for any region of the sky. For each field of view, a telescope with a rectangular 1.45m × 0.5m aperture is employed to image the sky on a focal plane. While the image of an object in the sky is moving over the focal plane due to the scanning motion of the spacecraft, it is first observed on a number of CCDs devoted to high-precision astrometry. Then, slit-less low-resolution spectra are obtained for photometry. For a subset of the objects, also medium-resolution spectrometry (R∼11500) for radial velocity determination is performed.

To be observed, an object has first to be detected by the on-board software. The detection depends on the brightness of the object (between about 6 mag and 20 mag), as well an on the object being sufficiently "point-like". A window of about one second of arc is then allocated to the object, and the signal inside this window is read out and later transmitted to ground. In order to assess the ability of Gaia for comet observations, we need to estimate the number of transits for known comets and fictitious ones in evaluating the Gaia capability of discovering new comets, and also to study the attitude of the on-board detection software with a comet signal. Both points are discussed in the following sections.

2. Comet transits in the Gaia fields of view

The future observation dates by Gaia for about 1,000 known comets (not including Sun-grazing comets) were derived from realistic simulations of the complex scanning law of Gaia and its orbit around the L2 point. The cometary orbits were numerically computed, including planetary perturbations and relativistic effects. The apparent magnitudes of the comets were estimated from standard empirical scaling laws with heliocentric and satellitocentric distances and used to apply the filter on the magnitude (see Sect. 1).

Huge artificial sets of comets were created for the three cometary families, Jupiter Family (JF), Halley-type (HT) and long-period (LP) comets. We then determined the number of fictitious comets observed by Gaia over a period of 5 years. Actually, a very large fraction of JF comets move across the Gaia fields of view, implying the ability to discover new JF comets with Gaia, and to estimate their number in the Solar System.

As to observations of known comets by Gaia, simulations are on-going based on software developed for asteroids [3] in order to estimate the precision in orbit determination and the detection of non-gravitational forces. Furthermore, investigations of Gaia's potential to derive asteroid masses by analysing their perturba-

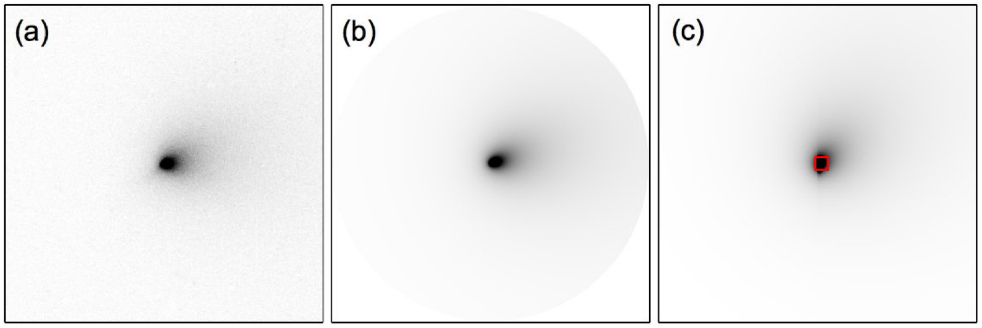

Figure 1: Panel (a): HST observation of a comet (47P/Ashbrook-Jackson with the WFPC2). Panel (b): Simulated brightness distribution for a comet. Panel (c): GIBIS simulation of the comet from (b) as it would be observed with Gaia. The red box indicates the window transmitted to ground. Each frame has a width of 18”.

tions on the motion of comets [4], and for tests of the theory of General Relativity, are ongoing.

3. On-board comet detections

3.1 Comet simulations

An individual observation for a comet with Gaia can be simulated using the Gaia Instrument and Basic Image Simulator (GIBIS, [5]). This tool allows for a detailed simulation of the signals on all the Gaia CCDs. The comet itself is modeled as a point-like nucleus with a given V-magnitude and a dust coma, characterized by an Afρ value. The brightness distribution in the coma is assumed to have a mean dependency according to $1/r$, if r is the projected distance to the nucleus position. The isophots of the coma are assumed elliptical, with an eccentricity ϵ ranging from 0 (spherically symmetric coma) to and excluding 1 (asymmetric coma). The orientation of the asymmetry with respect to the Gaia scanning direction, depending on the observing circumstances, can be taken into account in the simulations. Fig. 1 illustrates the assumed brightness distribution of a comet and how it would be observed with Gaia, together with an HST comet observation for comparison.

3.2 Comet detections

The prototype of the Gaia on-board software as developed by Astrium [2] is applied to comet observations simulated with GIBIS. Different values for the nuclear magnitude, Afρ, coma asymmetry, and apparent motion of the comets are studied. It turns out that cometary activity does not prevent the on-board software from detecting an object. Comets reaching the minimum brightness for detection are likely to be observed with Gaia. Only very active comets, as e.g. a new "Hale-Bopp", will not be detected by Gaia. As to the apparent motion of the comets, it is not problematic with respect to on-board detection.

4. Summary and Conclusions

Gaia can be expected to provide a significant number of observations over five years for a large number of comets. The on-board detection of comets is likely to be successful when their magnitude meet the Gaia limitations. Only an extraordinarily bright comet could not be observed. Thus, Gaia should provide a significant number of precise observations over 5 years for many known comets and allow an estimation of the number of short period comets in the Solar System. These observations will enable us to investigate non-gravitational forces on comets, as well as their photometric properties.

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