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Parallax in "Pi of the Sky" project

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Abstract

The main goal of the "Pi of the Sky" project is search for optical transients (OTs) of astrophysical origin, in particular those related to gamma-ray bursts (GRBs). Since March 2011 the project has two running observatories: one in northern Chile and the other one in southern Spain. This allows for regular observations of a common sky fields, visible from both observatories which are scheduled usually 1–2 h per night. In such a case, the on-line flash recognition algorithm, looking for optical transients, can use parallax information to assure that events observed from both sites have parallax angle smaller than the error of astrometry. On the other hand, the remaining OT candidates can be verified against a hypothesis of being near-Earth objects. This paper presents algorithm using parallax information for identification of near-Earth objects, which might be satellites, or space debris elements. Preliminary results of the algorithm are also presented.

Keywords: Space debris; Satellite observations; Optical transients

1. Introduction

Parallax is the most direct method to determine distances to astronomical objects. There is no need for any assumptions here: one has to know line of sight directions to an object from two different observatories, the angle between them and the distance between these places (called the baseline). The only limitation for this method is an angular resolution, causing that it can be used only for relatively close objects. The parallax angle gets smaller and smaller quickly, when the distance increases. Thus, in order to measure the parallax of objects far away from the observer more powerful telescope or larger baseline is needed.

Nowadays a number of artificial satellites orbiting the Earth increases quickly. In consequence there are more

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and more space debris elements, which can be dangerous for working satellites, spaceships and astronauts in space in case of a collision. Quite a large number of these objects are easy to spot even with a naked eye. Moreover, some of orbiting objects (like ISS or Iridium Satellites), when passing above an observatory can become the brightest objects in the sky (sometimes they are even visible in the broad daylight!). Satellites sending short pulses of reflected sunlight (e.g. due to their rotation) can cause false triggers to observers looking for optical transients (OT), variable stars or other objects changing their brightness in short time scales. An amount of such events depends only on a limiting magnitude and a field of view of a given telescope.

There is a number of other objects, which are able to generate false triggers, like cosmic radiation, meteors, planes, etc., but they are relatively easy to reject. Satellites are much harder to recognize, because when they are in a huge distance from an observer, they look like stars. Thus, in order to reject them, one can consider using observations from a second observatory in some distance from the first one, depending on the angular resolution and field of view of a telescope.

Observations of artificial satellites become more and more important, mainly because geostationary orbit is more and more crowded, and possibility of a collision becomes significant. Different space programmes have to commit huge amount of money and time to finally launch a rocket with their satellite on board, so they have to know detailed orbit parameters for all objects orbiting the Earth or the Sun, which are potentially dangerous for such missions. Thus, several different programmes are being developed, like for instance Space Situational Awareness (SSA), which are designed for identification, tracking and warning about space debris elements before any potentially hazardous situation will occur. It is very important to continuously monitor the whole sky. "Pi of the Sky" project is designed for the same observation mode, meaning that it can be useful also for early identification and alerting about new space debris elements. In this paper, we would also like to demonstrate the advantages of large baseline parallax measurements in general.

2. The Pi of the Sky project

The "Pi of the Sky" project is a scientific cooperation of a few polish institutes, concentrating on a search and investigation of prompt optical counterparts of Gamma-Ray Bursts (GRB). Besides GRBs, we are also interested in other short timescales astronomical phenomena, particularly optical transients. "Pi of the Sky" started in 2004, when the first 2 cameras mounted on equatorial mount were installed in Las Campanas Observatory (LCO) in central Chile. The cameras observed the same part of the sky, which is helpful to reject background events due to cosmic rays hitting CCD chip, hotpixels and other sources of false alerts, which occur in only one camera. "Pi of the Sky" prototype detector worked in LCO until December 2009. The greatest success of the project was an observation of GRB080319B since the very beginning, when gamma-ray emission was still ongoing (Racusin et al., 2008). The burst was optically the brightest GRB ever observed (in its maximum it could had been observed even with the naked eye). "Pi of the Sky" cameras observed the burst position before, during and after the GRB, which allowed us to get limits on possible optical precursor (Piotrowski, 2012).

In December 2009 the telescope finished its operation in LCO and in March 2011 it was re-installed in a private observatory near San Pedro de Atacama (SPdA) in northern Chile. SPdA is located about 740 km north from LCO at $22°57'12''$S, $68°10'48'$W (Zaremba et al., 2011), thus from this location it is possible to observe a slightly bigger part of the sky.

In the meantime, in October 2010, we commissioned our new observatory in northern hemisphere, at Instituto National de Tecnica Aeroespacial (INTA), near Huelva in southern Spain at $37°6'14''$N, $6°44'3''$W. A new mount carrying 4 cameras was installed there. The cameras can observe the same or adjacent parts of the sky (Zaremba et al., 2011). In both observatories very similar CCD cameras are used. They carry Canon lenses f = 85 mm, f/d = 1.2, resulting in angular pixel size of $36''$ and sky coverage of $20° \times 20°$. In the future we consider to establishing another observatory in southern Spain, which will work in coincidence with the INTA system. The observatory could be located near Malaga in a distance of almost 240 km from INTA, allowing to use parallax to reject OTs from artificial satellites up to a distance of approximately 1.2 million km.

3. Parallax in Pi of the Sky

The two working observatories in INTA and SPdA allow to observe a parallax of all celestial bodies, which can be observed from both sites simultaneously and pass in proper distance from the Earth's centre. It can be used in order to distinguish not interesting OTs due to near-Earth object, mostly artificial satellites, from the real OTs coming from distant Universe.

The distance between observatories in Chile and Spain is almost 8500 km (along the Earth's chord) and the cameras' field of view spans for $20° \times 20°$ (a half of a diagonal is a bit more than 14°). Assuming, that both telescopes are pointing in the same direction this results in an observable parallax angle for objects, which are in a distance larger than 20,600 km from the centre of the Earth. In the case of closer objects, the parallax angle exceeds the image size, and they cannot be registered in pictures of the same part of the sky taken from both locations.

On the other hand, the smallest parallax which can be observed is $25''$ (a half of a diagonal of a pixel), resulting in a distance of almost 38.2 million km. The planet Mars can pass the Earth in a distance of almost 56 million km and Venus - in over 41 million km. So we could not observe the parallax of any planet, even during their maximum close-up to the Earth. But we should be able to measure