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Note

The observing campaign on the deep-space debris WT1190F as a test case for short-warning NEO impacts

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A B S T R A C T

On 2015 November 13, the small artificial object designated WT1190F entered the Earth atmosphere above the Indian Ocean offshore Sri Lanka after being discovered as a possible new asteroid only a few weeks earlier. At ESA's SSA-NEO Coordination Centre we took advantage of this opportunity to organize a ground-based observational campaign, using WT1190F as a test case for a possible similar future event involving a natural asteroidal body.

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1. Introduction

The object known with the temporary observer-assigned designation of WT1190F was discovered by the Catalina Sky Survey on 2015 October 03 (Matheny et al., 2015), and quickly reported for confirmation as a possible new Near-Earth Object (NEO) to the Minor Planet Center. It was quickly realized to be in a geocentric orbit by the JPL Scout system (Farnocchia et al., 2015a, 2016), and after a few days of follow-up it was identified to also be on a collision trajectory with Earth, with a predicted impact on the morning of 2015 November 13, offshore the coastal region of Southern Sri Lanka (Jenniskens et al., 2016).

Even with a short arc of observations it quickly became clear that the object, just a few meters in diameter, was subject to significant non-gravitational perturbations due to the effects of radiation pressure (Gray, 2015). The magnitude of such effect implied an extremely low mean density, of the order of 100 kg/m^3, sufficient to exclude a truly asteroidal nature and suggesting a man-made origin, such as a hollow shell remnant of some unidentified spacecraft.

Although it was then clear that the object was not natural, and therefore not a real near-Earth asteroid, the team of ESA's SSA-NEO Coordination Centre decided to use this opportunity to organize an observational campaign in the shortest possible time, as a simulation and training for what kind of data would be possible to obtain in case of a future similar event involving a natural impactor.

The following is a report of this effort, focusing on the type of observations that were obtained, and which telescopes we were able to access during the available time. Our goal is to show that,

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through an effort of coordination of worldwide astronomical resources, it is possible to make the best possible use of available assets to obtain a complete set of observations that would be sufficient to fully characterize the event. For the actual scientific analysis of such data we redirect the reader to the exhaustive work of Buzzoni et al. (2017a, 2017b).

2. Observations

In the following sections we will quickly summarize the types of observations we were able to obtain, either directly or through collaborations, in the relatively short timespan between the discovery of WT1190F and its impact with Earth (much shorter than the typical cycle of telescope proposals).

It is important to note that, due to the unpredictable nature of these discoveries, none of these observations could have been planned in advance and requested to professional telescopes via the standard form of a regular telescope proposal. Most of them were obtained through collaborations with small and medium size observatories, which allow for the necessary flexibility and rapidity of response that were essential in this case. We are however pleased to report that even the more traditional channel of a Director's Discretionary Time (DDT) request for urgent observations at a large aperture telescope, like the ESO VLT at Cerro Paranal (Chile) was successful, showing that there is a possibility to obtain access to those highly competitive instruments (for small amounts of time) if the target is sufficiently urgent and unique.

2.1. Astrometric follow-up

The very first type of observation that is important to obtain shortly after the discovery of a new moving object is astrometric follow-up. The need for astrometric observations is even more urgent for an object in a collision path, because an accurate determination of its trajectory is essential to properly predict the impact point and time. More indirectly, for a small object like WT1190F, good astrometric coverage is essential to quickly ascertain the effects of solar radiation pressure on its dynamics, and determine the ratio between its cross sectional area and mass (the so called "Area to Mass Ratio", or AMR), which can in turn be converted into an estimate of its density, providing hints on its nature.

For this reason, in the few days after discovery we contacted collaborators in our network of observers to request images of the object, providing them with the most up-to-date station-specific ephemerides we generated internally with the software Find_Orb by Bill Gray[1] Over the few weeks between discovery and impact we were able to obtain images from various observatories, including those of Asiago and Loiano, both managed by the Italian Institute for Astrophysics (INAF), and ESA's own Optical Ground Station in Tenerife (Spain). We extracted high precision astrometry from each image set, using tools that can properly manage images where either the field stars, or the moving object (or both) are severely trailed (see Fig. 1 for an example of such images). For each telescope, we also carefully investigated with the observer the presence of possible time biases, which may have dramatic effects on the trajectory determination for objects moving at high plane-of-sky rates.

The astrometry resulting from these measurements was all submitted to the Minor Planet Center (MPC), and quickly published in their DASO (Distant Artificial Satellites Observation) circulars. However, for each position we also maintained record of our own positional and timing uncertainties, that cannot yet be included in the MPC astrometric format, but are nevertheless extremely valuable during the orbit determination process.

[1] The Find_Orb programme is publicly available at the URL: http://www.projectpluto.com/find_orb.htm.

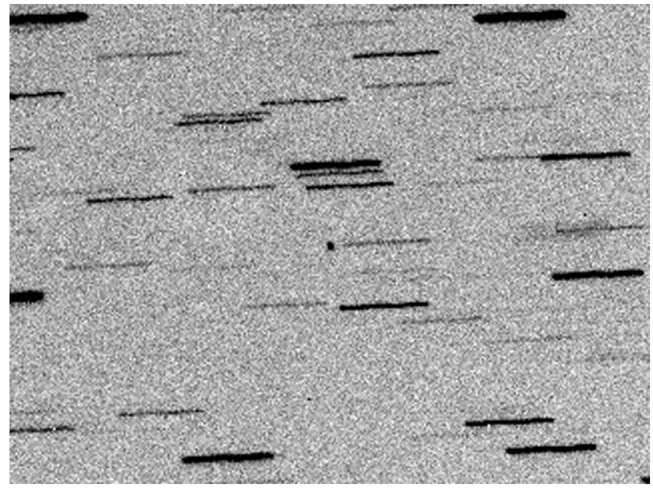

Fig. 1. An illustrative astrometric image, taken along the night of 2015 November 12, just a few hours before the WT1190F atmosphere entry, with the 1.52 m "Cassini" telescope of the Loiano Observatory (Italy). The telescope was tracking non-sidereally at the apparent angular motion of the target (which appears as a point source near the center of the field), therefore all astrometric reference stars in the frame are severely trailed (approximately 1′ in this example). A correct astrometric reduction of a frame like this requires to fit every reference star with a trailed model, to properly determine their centroid.

This dataset, together with the pre-impact data presented in Section 2.2 formed the basis of our trajectory and impact analysis, which is fully presented in Buzzoni et al. (2017b). This high precision orbit was also essential to guarantee that later observations, such as the slit spectroscopy discussed below in Section 2.4, could be properly carried out.

2.2. Pre-impact follow-up

In addition to the astrometric coverage obtained during the weeks between discovery and impact, in a case like WT1190F it is important to obtain observations during the last hours before the impact event. These observations are extremely useful for trajectory determination, because the reduced distance allows for a much better spatial accuracy for a given angular resolution. However, during the final phases of the approach, an object like WT1190F can become extremely fast, reaching an angular speed in excess of 1000′′/family min where the accuracy in the timing signals used to timetag the images becomes the leading source of error in the astrometric measurement. Furthermore, when the object is only a few thousands of kilometers away, even the accuracy in the geographical coordinates of the telescope becomes essential.

During the night between 2015 November 12 and 13 UT we tried to obtain the most complete possible coverage of the object. Our group directly used the 1.52 m reflector in Loiano (MPC code 598) and the 0.40 m reflector in Lumezzane (Italy, MPC code 130) to collect continuous observations and perform astrometric reductions in near real time. Additional astrometry was also provided by the Deimos team from its Mt. Niefla DeSS Observatory in Spain (MPC code Z66), through a couple of 0.40 m and 0.28 m reflectors, which further helped refine the trajectory. All these observations continued until less than an hour before impact, when the object set and twilight began to interfere with the observations.

In Table 1 we present a summary of the information that can be extracted from a selection of the astrometric datasets we obtained, analyzed with the Find_Orb software. When combined together, our ground-based astrometric observations allow for an extremely

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