



The Teide Observatory Tenerife Asteroid Survey



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ABSTRACT

ESA's 1-m telescope on Tenerife, the Optical Ground Station (OGS), has been used for observing NEOs since 2009. Part of the observational activity is the demonstration and test of survey observation strategies. During the observations, a total of 11 near-Earth objects have been discovered in about 360 h of observing time from 2009 to 2014. The survey observations are performed by imaging the same area in the sky 3 or 4 times within a 15–20 min time interval. A software robot analyses the images, searching for moving objects. The survey strategies and related data processing algorithms are described in this paper.

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1. Introduction

Since 2010, the near-Earth object (NEO) segment of ESA's Space Situational Awareness programme has been regularly using a 1-m telescope on Tenerife (called Optical Ground Station, OGS) for asteroid observations. Additional one-week observing campaigns by one of us (MB) in 2009, 2010, and 2011, funded by ESA's Technical Directorate, are included in the analysis of this paper.

The telescope is used for both the follow-up of objects on the NEO Confirmation Page of the Minor Planet Center and of objects on the priority list of the Spaceguard Central Node, hosted by ESA and for demonstrating and testing strategies to search for NEOs. The second task is the one this paper will focus on.

The telescope is a 1-m Zeiss Ritchey–Chrétien telescope (IAU observatory code J04), called the Optical Ground Station (OGS). It is used with a field flattener/reducer at $f/4.4$. With a $4\text{ k} \times 4\text{ k}$ CCD camera it has a field of view with a diagonal of about 1° .

The search programme is called TOTAS (Teide Observatory Tenerife Asteroid Survey). It is based on software initially developed by one of us (MB) for the Starkenburg Observatory Heppenheim and later adapted to be able to control the OGS.

2. The telescope

The Optical Ground Station (OGS) was initially used for testing laser communication with satellites. Today, the telescope is used

not only for laser communications experiments, but also by ESA's Space Debris office for the observation of satellites and man-made debris, by the SSA-NEO programme for NEO observations, and for other scientific programmes. It is located at an altitude of 2400 m at longitude $16^\circ 30' 43''$ W and latitude $28^\circ 18' 04''$ N.

3. Survey observations

3.1. Overview

The sky area to be surveyed is selected by checking the Minor Planet Center's sky coverage page at <http://www.minorplanetcenter.net/iau/SkyCoverage.html>. An area which has not recently been surveyed is picked as a starting point. An automated planning tool produces a computer-readable file for commanding the telescope and the camera. After imaging and transferring the data, a processing pipeline searches for moving objects. Objects that are not found close to a catalogued position are presented to human operators via a web interface for confirmation.

We use the concept of survey 'regions'. These are areas of 5×5 images, corresponding to about $3.7^\circ \times 3.7^\circ$ in the sky. The whole sky is divided into regions, which are marked by a unique number. Each region is observed four times, with an exposure time of 30 s.

3.2. Observation planning

A software tool developed by one of us (MB) is used to generate an ASCII file called 'Short-Term Plan' (STP, Fuentes et al., 1999). Via this file, both the telescope and the camera are being commanded.

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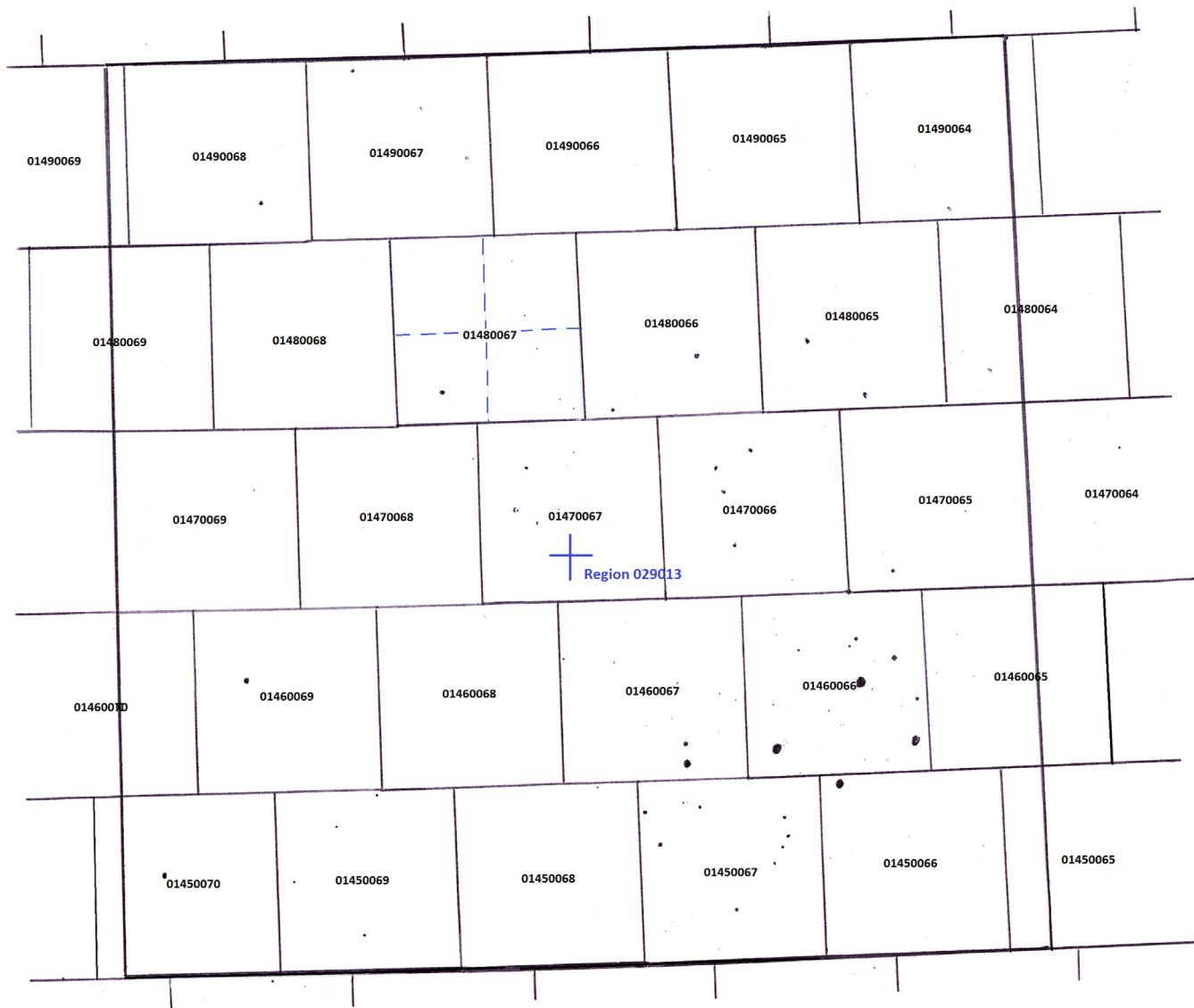


Fig. 1. Screenshot of the planning tool, showing the survey region 029013 and the 25 individual image frames that build it up. This survey region contains the open cluster M45, which can be seen just below the centre and gives an idea of the size of the region. Individual images are further split into 2×2 areas to reduce the image size, as indicated by the dashed lines in one image frame.

This tool needs as only input the number of the survey region. This survey region number is simply an area in the sky, described by its celestial coordinates.

The STP file will contain time-tagged commands to move the telescope to the correct pointing position, and to command the camera to take an image of the set exposure time (normally 30 s; see Fig. 1). The telescope is slewed from the lower right to the upper left image, then restarts at the lower right. In total, each pointing direction is re-visited four times. The scanning of one complete region lasts 68 min.

3.3. Data processing

At the end of the data acquisition of one survey region, the data is transferred via FTP to a central server and retrieved from there for data evaluation. This takes some time and for a future large survey the data processing should be done at the telescope.

An automated data processing pipeline searches the images for moving objects. Objects which are found close to the position of a catalogued asteroid ($< 40''$) are checked. If speed and direction of

motion match within certain limits, it is assumed to be this asteroid. Their position is measured and associated with the designation of this asteroid. For objects which are not close to a known one, thumbnails of a small area around the object are generated and posted on a web page. A team of (mainly amateur) astronomers visually inspects the images and discards possible false detections. The astrometric positions of those objects which survive the selection are written to the database of potential new discoveries. Their astrometric measurements are sent to the Minor Planet Center with a temporary 'OGS' designation.

The moving object detection is illustrated in Fig. 2. It works as follows:

- (1) Four images of the same sky area are analysed in one step. The astrometric engine 'PinPoint' (PinPoint, 2014) is used to find a plate solution. This means that PinPoint will find stars, compare them to the USNO-A2.0 star catalogue (Monet et al., 2003), and from that find the pointing direction and distortion coefficients of the images. – Note: we are aware of the fact that other star catalogues are better suited for astrometric

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