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SVO-ast: A citizen-science project to identify NEAs and Mars crossers using the Virtual Observatory

Enrique Solano (1,2), Carlos Rodrigo (1,2), Benoit Carry (3) and **Miriam Cortés-Contreras** (1,2)
(1) Departmento de Astrofísica, Centro de Astrobiología (CSIC-INTA), ESAC Campus, Camino Bajo del Castillo (esm, crb, mcortes@cab.inta-csic.es) (2) Spanish Virtual Observatory, Spain, (3) Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Lagrange, 06304, Nice, France (bcarry@oca.eu).

Abstract

We describe here a citizen-science project conducted by the Spanish Virtual Observatory to improve the orbits of near-Earth asteroids (NEAs) and Mars crossers (MCs) using data from astronomical archives. At the time of writing, almost 4000 registered users from 76 different countries have made more than 420 000 measurements which have improved the orbital elements of 613 NEAs and 508 MCs (3% and 4% of the total number of these types of asteroids, respectively). Even more remarkable is the fact that these results have been obtained at zero cost of telescope time as asteroids were serendipitously observed while the surveys were being carried out. This demonstrates the enormous scientific potential hidden in astronomical archives and the power of Virtual Observatory tools to mine them. The excellent reception of the project as well as the results obtained makes it a valuable initiative to improve the knowledge of near-Earth asteroids and Mars crossers.

1. Introduction

The discovery in the late 1980s of NEAs passing by the Earth at distances comparable to that of the Moon or the impact of the comet Shoemaker-Levy 9 to Jupiter in July 1994 led to an increased awareness of the potential threat of these objects.Therefore, many projects both from ground and space are presently devoted to discover new asteroids passing close to the Earth.

Nevertheless, discovery alone is not enough to quantify the threat level of a NEA. Above all, it is necessary to compute reliable orbits through accurate astrometric positions covering a period of time as long as possible. This can be achieved using two complementary approaches: performing follow-up observations after discovery or mining astronomical archives.

Together with discovery and orbit determination, the study of the asteroid composition is key in the design of a protection strategy: different compositions yield different densities and internal structure/cohesion [1], and an asteroid on an impact trajectory with Earth of a given size will require a different energy to be deflected or destroyed according to its nature.

Every single image taken by the most important ground and space-based astronomical observatories eventually end up in open archives, freely available on the Web. This represents an immensely data-rich field where the general public can significantly contribute, in particular in projects related to classification, pattern recognition and outlier identification where the visual inspection has proved exceptionally good. The Virtual Observatory[1] is an international initiative designed to provide the standards and tools necessary to enable the exploration of the digital, multiwavelength universe resident in the astronomical data archives in an efficient and seamless way for the users.

In this paper we describe SVO-ast[2], a citizen-science project designed by the Spanish Virtual Observatory[3] (SVO) to precover NEAs and MCs using images of the SDSS, UKIDSS, VISTA and VST surveys.

2. Methodology

People willing to participate in the project must register first. The new user is informed by e-mail when the authorization request is accepted, which allows him/her to start with the measurement process. The system, then provides the user with blocks of images that can be visualized using the Aladin VO tool [2] (Figure 1). NEAs and MCs are identified by visually comparing images of the same region of the sky taken at different moments. While the vast majority of the

[1] http://www.ivoa.net
[2] http://www.laeff.cab.inta-csic.es/projects/near/main/?&newlang=esp
[3] http://svo.cab.inta-csic.es

objects recorded in the images are stars and galaxies that will appear in the same position in all the images, NEAs and MCs are nearby objects with proper motions of several arcseconds per minute and they will appear in slightly different positions. To help users in the identification, the predicted position of the asteroid as given by NEODyS[4] is indicated (Figure 2) .

Once identified, the user must measure the position of the asteroid in the different images and include it in the RA/DEC column (Figure 1). After different quality control tests, the information is submitted to the Minor Planet Center[5] (MPC).

It is also important to stress that the system implements a rapid response capability for newly discovered asteroids of special interest needing a rapid identification in archives for a reliable characterization. Instead of waiting until the normal measurement process ends (typically of the order of weeks), these asteroids are prioritized to be looked for as soon as they are available in the MPC.

3. Results

- The top-five nations visiting the project are Spain (49%), France (10%), Argentina(4%), USA (3%) and Mexico (3%). The fact that the site is offered in Spanish, English and French helps to have this diversity of countries.

- A limiting magnitude of V:21-21.5 is reached, in good agreement with the nominal limiting magnitude of the surveys. This translates into a peak in H at $\sim$ 19-20 mag.

- Participants found asteroids prior to the first observation reported in the MPC (sometimes more than four thousand days), after the last observation given by MPC, and at new intermediate oppositions. New observations for single-opposition asteroids were also added. In all cases our astrometry significantly improved the orbital elements.

- Potential spacecraft targets: NEAs represent ideal targets for space exploration owing to their close distance from Earth. We have improved the orbits of more than 70 potential mission targets. Particularly remarkable are the cases of 2009 EK1 and 2006 KM103, whose arc lengths were dramatically increased thanks to our observations.

- The measurements made by the "citizens" have been the basis for "professional" papers: Carry et al. (2016) [3] determined the taxonomy of a large sample of NEAs and MCs, increasing 40% and 663% respectively the number of asteroids with known taxonomy in these populations.

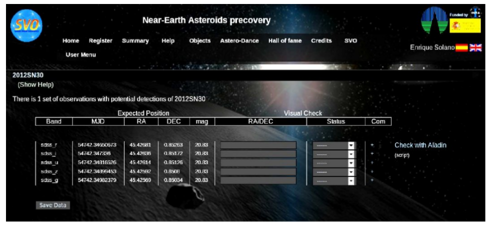

Figure 1: System's input window. The observing epoch of each image as well as the expected position and V magnitude as provided by NEODyS is given in columns 2-5. Participants measurements and the associated status can be included in columns 6-7. Images are displayed by clicking on "Check with Aladin (see Figure 2). The measurements are stored clicking on the "Save Data" button.

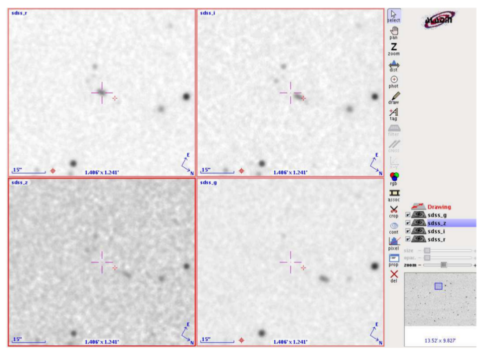

Figure 2: Asteroid identification. The asteroid 2007JZ20 is clearly seen moving in the sequence of SDSS images from South to North. The small red cross indicates the expected position as computed by NEODyS. The user must put the large magenta cross on the asteroid and paste the coordinates in the table shown in Figure 1.

[4] https://newton.dm.unipi.it/neodys/
[5] https://www.minorplanetcenter.net/

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