A RAPID RESPONSE EXPERIMENT CARRIED OUT BY THE EU NEOROCKS PROJECT

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ABSTRACT

One of the ambitions of the EU funded NEOROCKS (NEO Rapid Observation, Characterization and Key Simulations) project is to perform a "rapid response" experiment. The purpose is to understand, relying on existing European assets and expertise in space surveillance and astronomical observations, how far and how fast we can go in stepping through the complete NEO risk assessment chain, from discovery to physical characterization. Highly automated astrometric observations of a sample of newly discovered NEOs were performed, rapidly disseminating the information to the consortium network of astronomical telescopes. Immediate follow-up observations of the targets' physical properties were successfully carried out. The experiment is described in detail and the outcome is discussed within the framework of the present and future NEO and Space Debris monitoring systems.

1 INTRODUCTION

NEOROCKS is a European project, funded by the UE Horizon 2020 programme [1]. Its aim is to increase our knowledge of the NEO physical characterization through observations and data dissemination. NEOROCKS is an international consortium, involving Italy, France, UK, Czech Republic, Spain, Romania and Poland, and coordinated by INAF, the Italian National Institute for Astrophysics.

The ambitions of the project are to optimize observational activities, enhance modelling and simulation tasks, foster international coordination and speed-up response times. All these issues concur in addressing the threat posed by the so-called "imminent impactors", i.e. objects in the 10-50 m range in route of collision with the Earth. Being able to discover and characterize these objects both from a dynamical and a physical point of view with sufficient warning time to undertake civil protection mitigation actions, is challenging [2]. Therefore. a "rapid response" experiment has been organized in which particular care has been given to reducing as much as possible human intervention by resorting to remote telescope tasking procedures and fast data dissemination techniques. The "rapid response system" eventually set up has greatly profited of the NEOROCKS consortium partners experience in NEO and Space Debris detection and data processing. In particular the DeSS (Deimos Sky Survey) telescopes [3] and the SpaceDys systems for NEOCP (NEO Confirmation Page) target selection have worked together in order to prepare and execute real-time astrometric follow-up observations, while the NEOROCKS telescope network coordinated by INAF was in charge of closing the loop by performing quick physical characterization. Two strategies were implemented: a "blind" experiment on known targets and a campaign devoted to newly discovered objects. In what follows the various elements of the experiment are presented and the main results obtained are summarized,

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highlighting the synergies between NEO and Space Debris monitoring. Finally, lessons learned for planetary defence when focussing on the imminent impactors problem are outlined.

2 TARGET SELECTION

The target selection process involved SpaceDyS, through the web tool NEOScan, available inside the NEODyS service [4], which has the commitment to scan just discovered NEO candidates appearing in the Minor Planet Center NEOCP to check for possible imminent impactors within the next month. The tool is polling the NEOCP on a time frequency of two minutes and the results are posted on the NEOScan Risk Page in case of possible impacts. Moreover, the NEOScan Priority List shows the list of all NEOCP targets, sorted according to the urgency, to be observed before they get eventually lost. NEOScan is also supporting the observers through services such as the observation prediction tool, which plots the uncertainty region on a star map at a specific time, or the ephemerides tool, which computes and displays the position of an object in the sky at different times.

The NEOROCKS rapid response experiment preparation considered the following caveats:

- the targets had to be visible starting a week before the new Moon. This implies that the orbits could be rapidly consolidated with DeSS observations, and this allowed the physical observers to perform the observations as soon as they could. In general, this is an ideal situation, while reality could be that the NEO candidate is detected/discovered much later. Nevertheless, the purpose of the experiment was to figure out the overall system efficiency and the possible bottle necks in the data provision;
- the targets had to be bright enough and geometrically favorable to allow the DeSS telescopes to perform follow-up observations. The DeSS telescopes primary mirrors are 40 cm aperture, therefore the experiment targets had to be brighter than magnitude 20.

The experiment time frame corresponded to the lunation between the 18th of March and the 16th of April 2022.

The first action consisted in preparing the proper HW and SW environment. We used an already available dev-server were an exact copy of the NEODyS data and services was replicated. The obvious reason is that we wanted to avoid to interfere with the NEODyS routine operations. In particular, the NEOScan Priority List clone was accessible through the internet at https://www.spacedys.com:8181/NEOScan/index_nspl.html. This page was intended to be read by Deimos system automatic scripts with the purpose to prepare as soon as possible the list of the targets to be followed during the night.

The second action was to prepare the list of possible targets which satisfied the requirements of visibility from the DeSS telescopes, as mentioned before. In this list, available in the corresponding clone NEOScan web page, were shown real NEO candidates, as grabbed from the NEOCP. Since we expected that several real targets could not satisfy the DeSS observability requirements, a different approach was also implemented in order to guarantee that the main goal of the experiment, i.e. put to test response times, could be reached. We took already known NEOs from the NEODyS database and which we knew were observable by the DeSS telescopes during the experiment lunation. Then, we created ad-hoc fake designations for the known objects, quite similar to those usually provided by the US surveys and included these objects in the targets list. The selected objects and their correspondences was the following:

2022DC5 C7DC5Z8
2022EA2 C78W2EA
2022EY P22sb5Y
2022DH1 C78d1H2
2022ER2 C0Ar22E
2011GD62 ST62gD8
2022CR3 A10c163
2022DM P11dZb2
2021SR41 C058945
2021VM25 P21vm2e

This information was known only to the SpaceDyS team, while the other partners were "blind" to it.

3 ASTROMETRIC FOLLOW-UP

DeSS is an advanced facility equipped with state-of-the-art technology for supporting space surveillance and tracking projects. The centre includes four telescopes and all the hardware and software systems that are needed for their on-site and remote operation. DeSS is built for autonomous operations capable to carry out remote robotic observations responding to a given schedule. This operational capability provides an essential element to the NEOROCKS rapid response experiment in order to shortcut the time lapse between the identification of an interesting NEO and the execution of the astrometric follow-up needed for orbit improvement, by directly tasking an available DeSS sensor.

A novel SW tool has been developed to this end. It monitored the NEOScan Priority List (clone) every 30 minutes, prioritizing the targets according to the best observing opportunity given the sensor capability, the estimated reachable magnitude, the angular speed and the elevation over the site. With the aim of shortening the reaction times when triggering the observations, the tool was also providing the necessary information for tasking the DeSS telescopes, by calculating the exposure times and the required number of frames according to the angular speed, magnitude and elevation (extracted from the NEOScan List). When the observation was successful, astrometric measurements were submitted to the NEOCP and to NEODyS.

In order to urge physical properties observations, the tool was also automatically emailing to the NEOROCKS observers network the obtained results, attaching the measurements if the observations were successful. The structure of the messages was the following:

TARGETING: Id and time starting observations
NOT DETECTED: Id and time after attempt
COMMENTS "if any" for alert to the observers network

- Diffuse appearance
- Variable magnitude
- Brighter magnitude
- Fainter magnitude

REPORTED TO MPC: Id and time

This allowed to increase the chances that quick physical follow-up observations could be actually carried out.

Fig. 1: The DeSS telescopes (Courtesy: Deimos Space).

4 PHYSICAL PROPERTIES FOLLOW-UP

In order to check the possibility to close the "detect-and-characterize" chain described in the previous sections, the NEOROCKS network of observers was alerted that during the lunation chosen for the experiment they could receive lists of NEO targets needing quick follow-up observations aimed at physical characterization. Yet the exact dates nor the specific objects (whether newly discovered or already catalogued, cf. Section 2) was known in advance. In this way we could test the responsiveness of the network in a realistic routine operational scenario. Several target lists were received from DeSS which included a grand total of 17 NEOs, out of which 8 came from the "blind" side of the experiment. The following reaction was recorded from the NEOROCKS observational network:

- INAF had no planned NEOROCKS observing runs during the experiment timeframe; however, on April 3rd 2022 upon receiving the DeSS list of targets, a DDT (Director Discretionary Time) request was immediately sent to the 3.6-m TNG (Telescopio Nazionale Galileo, Canary Islands), and observing time was granted to characterize 3 NEOs. Observations of asteroid 2022 GC1, a "real" NEOCP candidate, were successfully carried out in the night between April 5th and 6th (i.e., just 2 nights after the alert), and BVRI photometry successfully obtained (Fig. 2) [5]. Observations of asteroids 2022 DM and 2021SR41 were also planned, but failed due to bad weather conditions.

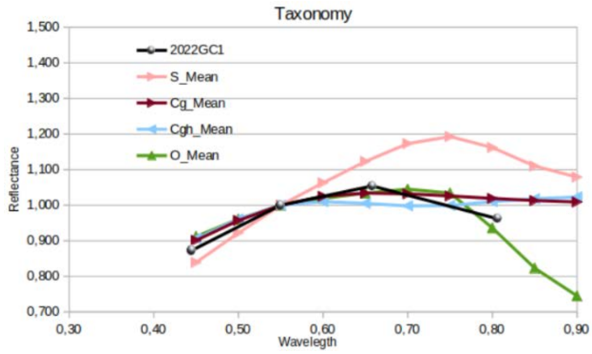

Fig. 2: Taxonomic classification of 2022 GC1 from BVRI photometry obtained with the LRS instrument at TNG

- IAC had NEOROCKS telescope time allocated during the experiment timeframe and obtained visible photometry of asteroid 2021 SR41 from TNG on the April 19th night, as well as a NIR spectrum of 2021 VM25 (Fig.3) also from TNG (April 23rd night). Visible photometry of 2021 VM25 was also obtained with the TCS 1.52-m TCS (Carlos Sánchez Telescope, Canary Islands) on April 1st.

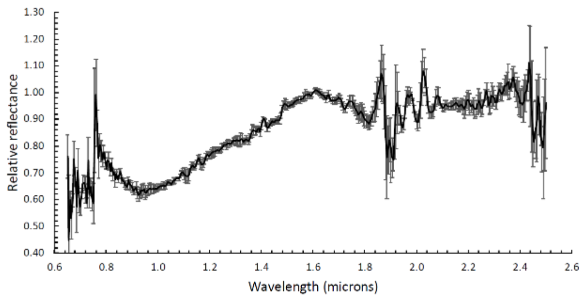

Fig. 3: NIR spectrum of 2021 VM25 obtained with the NICS instrument at TNG.

- The Observatory of Paris had NEOROCKS observing time during the experiment timeframe at the 1.2-m telescope of the Haute-Provence observatory (France). Visible photometry was obtained for the following targets, between April 4th and April 8th: 2021 SR41 (BVRI), 2021 VM25 (BVRI), 2022 DC5 (VRI), 2022 GC1 (VRI), 2022 GY2 (VR).

- The Astronomical Institute of the Czech Academy of

Science had NEOROCKS telescope time during the experiment timeframe, and used the 1.54-m Danish telescope (DK154) at the ESO La Silla station in Chile to obtain light-curve data of the following targets: 2022 DC5, 2022 GS, 2022 GC1, 2021 VM25, 2022 GJ2. All of them but 2022 GJ2 (limited data obtained during one night only) were observed on multiple nights (between March 27th and April 9th) and their rotational properties were retrieved.

5 DISCUSSION AND CONCLUSIONS

Being able to timely carry out the physical characterization of an imminent impactor is a key feature for developing a rapid response system for civil protection purposes. We have demonstrated that federating European existing assets through an EU funded initiative, it is possible to successfully perform an integrated imminent impactor rapid response experiment encompassing both, dynamical and physical characterization.

Thanks to the possibility of relying on the observing time devoted to the NEOROCKS project, many targets could be physically characterized, although the response times were depending on the specific asset. Nevertheless, in the case of 2022 GC1 it has been possible to close the loop in a matter of days from discovery, thus fulfilling a basic warning time requirement for undertaking civil protection actions.

Future work aiming to evolve the NEOROCKS experiment into a rapid response system prototype, should focus on:

- extending the network of telescopes that can be directly tasked for astrometry;
- automating as far as possible the tasking of large telescopes for physical characterization;
- obtaining priority tasking of telescopes through institutional empowerment (IAU, EU, UN).

To this end, a proper technical, institutional and funding scenario must be envisaged.

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