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OBSERVATIONAL ACTIVITIES AT ESA'S NEO COORDINATION CENTRE

Marco Micheli(1,2), **Detlef Koschny**(1,3,4), **Rüdiger Jehn**(1,5), **Juan L. Cano**(1,6), **Laura Faggioli**(1,2), **Marta Ceccaroni**(1,2), **and Javier Martín**(1,6)

(1)*ESA NEO Coordination Centre, Largo Galileo Galilei, 1, 00044 Frascati (RM), Italy,* neocc@ssa.esa.int
(2)*Rhea S.p.A., Via di Grotte Portella, 6/8, 00044 Frascati (RM), Italy*
(3)*ESA ESTEC, Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands*
(4) *LRT / TU Munich, Boltzmannstraße 15, Garching bei München 85748, Germany*
(5)*ESA ESOC, Robert-Bosch-Straße 5, 64293 Darmstadt, Germany*
(6) *Elecnor Deimos at ESRIN, Largo Galileo Galilei, 1, 00044 Frascati (RM), Italy*

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Extended Abstract—

ESA's NEO Coordination Centre (NEOCC), located in Frascati, Italy, is one of the key components of ESA's Planetary Defence activities. The center activities range from the collection and analysis of telescopic observations, to the computation of orbital information, to the dissemination of information about the NEO threat to scientists and the public at large.

The current observational activities are centered on the development of a network of observatories, telescopes and collaborators with the widest possible geographical distribution. Due to the typical short duration of the observability window of NEOs, especially for objects in an impact trajectory, the capability of quick reaction to an event can be achieved only if resources at different longitudes and latitudes can be activated within a timespan of a few hours at most.

In order to reach this global coverage, ESA is pursuing a variety of approaches.

First of all, we have access to some telescopes that are directly owned and controlled by ESA. Among these assets is ESA's Optical Ground Station (OGS), a 1 m telescope in Tenerife, Canary Island, and ESA's Test-Bed Telescopes (TBTs), two smaller wide-field telescopes to which we have continuous access, one of which is currently operational in mainland Spain, while the other is in the process of being installed on La Silla, Chile.

To supplement ESA's own telescopes, the Program actively finances and supports other observatories in Europe, by awarding contracts to the telescope operators in exchange for observational opportunities and data. With this mode of operation, we currently support the observational activities of telescopes in Spain, Czech Republic and Germany, with planned extensions to other ESA countries.

Additionally, we routinely obtain access to other telescopes worldwide via traditional scientific proposals, and/or direct agreements between ESA and other international agencies. An agreement with the European Southern Observatory (ESO) allows us to get access to ESO's VLT for deep imaging of faint NEOs, while approved proposals or established scientific collaborations with other telescopes worldwide give us additional coverage to longitude and latitude ranges outside direct European access.

A first example of our contribution to the worldwide observational efforts in the field of NEOs is the recovery of 2012 TC4 in July 2017, obtained as part of our long-term agreement with ESO for high-priority access to VLT. This object was the focus of an international campaign to test available detection and characterization assets on a small target having a close fly-by to Earth [1].

At the time the object was expected to become observable, its uncertainty was going to be significantly larger than the field of view of VLT's FORS2 imager. Therefore, our approach began with the remeasurement of a subset of the original discovery dataset from 2012, kindly made available by the original observers. The revised astrometry, computed with reference to the now-available Gaia catalog, resulted in a significant reduction of the object's positional uncertainty, simplifying the subsequent recovery attempt.

Because of this reduced ephemeris uncertainty, our ESA-ESO team was able to secure the recovery with a single field of VLT's FORS2 imager, exposed when the asteroid had magnitude V~27. This observation likely qualifies as the faintest NEO recovery achieved so far, and proves the excellent capabilities of VLT, and indirectly the astrometric value of the Gaia catalog.

In October 2017 we used ESA's own OGS telescope to obtain one of the earliest confirmation observation of the NEO candidate that then turned out to be 1I/'Oumuamua, the first discovered interstellar object. Our astrometry, when combined with the original observations from Pan-STARRS, provided us with the first evidence that the object was of interstellar origin. This information became the catalyst after which a

major international collaboration to fully investigate this fascinating object was established [2,3].

More recently, in June 2018, we attempted an immediate follow-up observation of the newly discovered impactor 2018 LA with a 0.6 m telescope in South Korea, in the context of an established collaboration with the Korea Astronomy and Space Science Institute. The observation was unsuccessful due to the large ephemeris uncertainty of the target, but it highlighted that quick access to telescopes in East Asia is essential to cover an existing longitudinal gap in the worldwide follow-up capabilities.

In order to better address these needs for immediate follow-up at longitudes between the US and Europe, we are now setting up a formal collaboration with a 0.6 m telescope at the Observatoire des Makes, on the French island of La Réunion. Another collaboration is being investigated to get access to the observational capabilities of the ISON network, which also has significant coverage in Central and East Asia. Both these collaborations will ensure we have access to adequate observational resources at the appropriate location to respond to future urgent needs for observations of imminent impactors, even within a short timescale of just a few hours as was required for the case of 2018 LA.

In order to test a similar challenging scenario, in this case involving an extreme Southern target, in March 2016 we successfully assembled a network of observers in the Southern Hemisphere to observe the outgoing trajectory of the ExoMars spacecraft in the hours just after launch.

Due to the geometry of the flight path and the launch sequence and its scheduled burns, the exact outgoing trajectory was not fully known in advance. However, it was clear that the spacecraft and the launch hardware would be observable as a bright but extremely fast moving object at high Southern declinations, with a positional uncertainty of at least a few degrees in the hours before radio acquisition and tracking could be achieved.

This scenario presented interesting analogies with the immediate follow-up of an imminent impactor, and could therefore be used as a test of the worldwide observational capabilities on a challenging fast-moving target.

Despite the (purposefully) short advance time we gave ourselves for the preparations, the campaign was successful, and resulted in a large number of observations from multiple countries, both during the last Earth-bound orbits and the early phase of the outgoing interplanetary trajectory.

Of particular note were observations of the launcher upper stage and associated hardware, obtained by our collaborators at Observatório Nacional in Rio de Janeiro using the 1 m OASI telescope. The images revealed the existence of small fragments of comoving material in the vicinity of the main stage, surrounded by a halo of dust and/or gas. The phenomenon was likely due to the passivation of the spent stage after delivery of the spacecraft to its intended orbit.

During the last few months we also became involved in the upcoming IAWN-organized campaign to observe and characterize binary asteroid (66391) 1999 KW4 during its Earth fly-by at the end of May 2019. We will use as many as possible of the observational resources at our disposal to collect physical observations in support of the campaign.

Furthermore, we are collaborating with ESO to attempt a challenging observation of the target with adaptive optics during close approach, with the goal of resolving the binary and possibly characterizing the two components separately.

In addition to these more challenging campaigns, our Centre also routinely uses our observational assets to follow-up and recover high-priority NEOs, with a particular focus on those having non-zero impact probability with Earth. Approximately 300 possible impactors were observed in the past five years, leading to the removal of all impact solutions in almost 100 cases. This list includes extremely faint objects observed with VLT down to a magnitude of approximately 27, a unique faintness regime not routinely covered by any other project.

We complement the direct observations with focused precovery efforts, attempting to locate unrecognized prediscovery detections of high-priority targets in various astronomical archives.

As an example of those observations, we recently achieved an interesting chain of observations that led to the recovery of 2017 RH16, the highest-rated impactor for the next century at the time of the observations. The sequence involved the identification of past precovery opportunities, the successful detection of the object in the corresponding images kindly provided by the original observers, and the use of this information to significantly refine the orbit, allowing the acquisition of additional confirmatory observations during the current apparition of the object. The entire dataset, when properly analyzed by the impact monitoring systems, resulted in the removal of all chances of impact for the object over the next century.

Our team also recently developed tools to perform “negative precoveries” of objects in a possible impacting trajectory [5]. We tested this technique on a high-rated virtual impactor of asteroid 2017 XO2, in collaboration with the Pan-STARRS team. We were able to locate archival images clearly showing the area of the sky where the object would have been visible if it had been in the actual impact trajectory, and prove that no detection was present at the location. This allowed us to indirectly exclude the impactor and retire the risk [5].

[1] Reddy V., et al.; Icarus 326:133 (2019)
[2] Meech K.J., et al.; Nature 552:378 (2017)
[3] Micheli M., et al.; Nature 559:223 (2018)
[4] Milani A., et al.; Icarus 145:12 (2000)
[5] Micheli M., et al.; Icarus 317:39 (2019)