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CHARACTERIZING THE NEAR-EARTH ASTEROID POPULATION IN THE FRAMEWORK OF THE NEOSHIELD PROJECT

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Extended Abstract—

Knowledge of the physical characteristics of near-Earth asteroids (NEAs) is fundamental to assessing the impact risk on our planet and designing efficient mitigation strategies.

In the framework of the NEOShield project, financed by the European Commission, the activity of Work Package 2 (January 2012 – July 2014) was aimed at improving our knowledge of NEA physical properties.

Frequency of mitigation-relevant properties in the NEA population

We made use of observational data catalogues (e.g. DLR EARN, NASA Planetary Data System Small Bodies Node, Minor Planet Center, JPL Small-Body Database, NEOWISE and Spitzer Space Telescope survey data), to investigate the distribution of mitigation-relevant physical properties of NEAs, such as size, albedo, composition, structure, etc.

One of our most interesting results (for more details see Harris & Drube 2014, ApJ 785, L4) is that there appears to be a systematic association of relatively high values of the Near-Earth Asteroid Thermal Model (NEATM) fitting parameter η (the so-called beaming parameter) with M-type asteroids and high radar albedos, suggesting that η is a potentially useful tracer of metal content in asteroids. The association appears to hold for both NEAs and main belt asteroids. Our results also imply that there are many metal-rich asteroids, possibly also in the NEA population, that have not yet been identified as such. The proportion of metal in an object is important for mitigation-relevant considerations of object density and robustness, and for identifying asteroids that may offer valuable resources for future ventures in the field of planetary materials exploitation.

Another very important consideration for mitigation purposes is that NEAs with diameters smaller than 300 m have a broad distribution of lightcurve amplitude and can have very high spin rates (up to around 1 revolution per minute). It would appear likely that small objects with high rotation rates and large lightcurve amplitudes (and therefore probably elongated shapes, with axial ratios of 4 or more) are structurally monolithic, though further observations and modelling are required to test this suggestion.

Requirements for dynamical and physical mitigation precursor reconnaissance

We assessed how the number and quality of observations are impacting orbit refinement and, hence, impact probability (including the importance of physical characterization for determining the influence of non-gravitational forces on a NEA's orbit). After the discovery of a potentially hazardous asteroid, the high priority parameters which have to be established in order to get a first estimate on the available timeframes are the NEA's orbital state vector and its absolute magnitude. The combination of these two parameters will not only allow for a rough placement of the discovered object on the Palermo hazard scale, it will also facilitate the prediction of

future observation opportunities. In case an impact cannot be ruled out, it is found that more observations spanning a data arc of at least 10 days are necessary: a statistical analysis of the current NEO observations shows that 10 days of data arc are generally insufficient to reduce the position uncertainty enough to allow for accurate impact risk predictions. This has an obvious impact in the case of a short warning time and emphasizes the opportunities that data mining provides in this respect, as pre-discovery records can strongly modify the preliminary orbit. Many of the newly discovered asteroids have been recorded but not identified during previous surveys or single frames intended to study other phenomena. If correctly identified and linked to current observations, such pre-discovery records can cause orbits of NEAs and risk assessments to be drastically modified. However we stress that a rendez-vous space mission would provide order-of-magnitude improvements in the positioning accuracy of a NEA with respect to tens of years of ground-based observations: in the case of a credible menace, a precursor reconnaissance spacecraft should be carried out whenever possible.

An orbital reconnaissance mission is also necessary to obtain the required information on an asteroid's physical characteristics needed for mitigation purposes. Moreover, a rendez-vous with the asteroid would facilitate the deployment of a lander on the surface, in order to obtain, for example, a much more detailed knowledge of its compositional, thermal, and mechanical properties. Such very detailed information would not be crucial for the basic design of a gravity tractor deflection mission, but would be relevant to the other two types of deflection methods mostly investigated within NEOShield, the kinetic impactor and the nuclear blast.

While rendez-vous orbiter missions offer the best prospects for NEA orbit refinement and physical characterization, they may not be able to be deployed in time if the threat turns out to be immediate. In these cases, flyby reconnaissance missions could be taken into account to acquire key physical parameters such as multiplicity, mass and spin with reasonable accuracy. However, flybys cannot achieve a positioning precision better than with radar observations, and cannot give a lot of information about the internal structure and the mechanical properties of the target.

Instrumentation for deflection space missions

Whether for a rendez-vous or a fly-by, we studied the possible scientific payload for a mitigation precursor mission to be launched in the case that an actual impact threat should arise. The current state of the art of the already developed instrumentation for planetary missions seems sufficient to achieve the required physical reconnaissance, and only minor modifications at most should be applied. Obviously, the design details could and should be optimized on a case by case basis.

We investigated in more detail which is the most suitable instrumentation for a mitigation demonstration mission and we identified two different scenarios: a 'basic' scenario where only a Radio Science Experiment (RSE) and one camera are considered for the payload of the explorer spacecraft. And an 'extended' scenario that foresees the presence onboard of further instrumentation, namely a LIDAR and/or a visible and NIR spectrometer. The LIDAR could be useful especially in view of a kinetic impactor demo mission including an optional gravity tractor experiment; the visible/NIR spectrometer will allow increasing the scientific outcome of the mission, and help to validate the impact experiment deriving more information on the underlying physical properties of the target. A thermal spectrometer seems redundant for a demo mission, provided that the wavelength range of the visible/NIR spectrometer extends to ~4-5 μm, where thermal emission of NEAs can be already investigated.

For the RSE, camera, spectrometer, it is found that the already developed European instrumentation fulfills the necessary requirements and could be applicable for the demo mission with no/minor modifications. More important modifications should be foreseen to adapt to our requirements BELA/BepiColombo or LIDAR/Hayabusa (through a possible agreement with JAXA), should a LIDAR be selected within the payload.

Requirements for modeling/simulation work and laboratory experiments

We specified high-level requirements and interfaces for modeling/simulation work and laboratory experiments to be performed in order to improve NEA characterization and investigate the response of an asteroid to external solicitation (e.g. a kinetic impactor, the deployment of a device on the surface, etc.) as a function of its physical/compositional properties.

Conclusions

A summary of our results will be presented and discussed. More information are available in Perna et al. (2013, A&A Rv 21, 65) and Eggl et al. (2013, SF2A-2013 proceedings, p. 169), and at the website http://www.neoshield.net/.