Surveillance and opportunities for observing Near-Earth Objects.

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More than 17,000 Near Earth Objects have been discovered so far. Their relatively small diameters, between 10 meters to kilometre-size, make them visible from groundbased observations only for their closest approach to Earth. On average this occurs only few times per century. Thus, it is vital to exploit such favourable geometries and to record as much as possible information concerning their dynamics and their physical properties. We will briefly present new results obtained using the 1meter telescope of Pic du Midi Observatory and s using the 0.4meter telescope in Bucharest recent results in photometry for Florence, 2012 TC4, and 2018 GE3. The presentation will include also the new spectrograph installed in Pic du Midi and devoted to NEOs, which will cover the spectral interval between 0.5 and 1.6 micron.

Recent observations of 3200 Phaethon and 1981 Midas

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We will review recent photometric observations of two asteroids – 3200 Phaethon and 1981 Midas. The first one was observed with a 0.61-m and a 1.3-m telescope at the Skalnaté Pleso Observatory in High Tatra Mountains (Slovakia), a 2-m Ritchey-Chretien-Coude Telescope at the Terskol Observatory (Russia), and a 1-m Zeiss at the Sanglok Observatory (Tajikistan). The second one at the Skalnaté Pleso Observatory only. Phaethon's data from October-December 2017 allows us to estimate color indices $B - V$ and $V - R$, absolute magnitude ~ 14.4 mag and diameter > 5.5 km. Previous diameter 5.1 km has been underestimated because the new radar observations from Arecibo tells about 6 km in size. Also spin axis orientation, the sense of rotation, and the shape model of Phaethon was determined. In the case of Midas we acquired BVR data from 5 nights in March 2018 before its closest approach to the Earth. All data showed a low amplitude ~ 0.1 mag which is in contrast with ~ 0.8 mag from previous works. We computed also color indices $B - V$ and $V - R$ and diameter slightly larger than 2 km.
Later we will say few words about two telescopes and the postfocal equipments at our Observatory.

Photometry of 2002 GZ32 and 2012 DR30

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Trans-Neptunian objects (TNOs) are sources of Centaurs and also of Near-Earth Objects: TNOs with a perihelion, q<34 au, can become Centaurs and evolve to the inner solar system. Some of them may be transitioning to become short-period comets, too. A few percent of both Centaurs and TNOs are known to host binary companions. It is important to know their physical characteristics in order to better classify them and connect them to some NEOs with semi-major axis smaller then 5.2 au. With this work, we aim to study and present new photometric data of one Centaur—2002 GZ32 and a very eccentric TNO, a scattering disk object (SDOs, are objects further out the Kuiper Belt, a region beyond Neptune, between 30 au and 52 au) very likely coming from the Oort cloud for its large semi-major axis or a former Kuiper Belt Object, scattered out after a close encounter with a giant planet (e.g. Neptune): 2012 DR30. Here we show very preliminary results of only the centaur. The observations are part of a programme focused on the study of Centaurs, TNOs, their physical characteristics and their possible cometary activity.

NEO Lightcurves from the Mission Accessible Near-Earth Object Survey (MANOS)

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Lightcurve photometry has been collected for several hundred NEOs as part of the NASA-funded Mission Accessible Near-Earth Object Survey (MANOS). MANOS employs a variety of 4-8m class telescopes to characterize newly discovered, low delta-v ($<$7 km/s), sub-km NEOs. The MANOS lightcurve sample provides interesting insights into the diversity of lightcurve properties, which can inform our understanding of physical properties such as internal cohesion and morphology. Our results suggest a wide range of NEO rotation states including the fastest rotators detected to date with periods less than 20 seconds. I will present on the distribution of rotational properties amongst the MANOS sample and use these results to derive the underlying distribution of shapes in the sub-km NEO population. This sample of objects provides an interesting comparison to the satellite of Didymos, which falls within a similar size regime.

Thermal inertia of binary near-Earth asteroids

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Binary asteroids represent ∼15% of the NEA population. Most primary bodies in NEA binaries have low bulk density (∼1-2 g cm^{-3}), high macro-porosity (∼40-60 %), rapid rotation (P∼2-4 h) and 'spinning-top' shapes, with secondary orbit characteristics consistent with models of formation through YORP-induced mass loss. Delbo et al. [Icarus 212, 138-148, 2011] used a distribution of 12 NEATM beaming parameters of 8 binary NEAs to infer a mean thermal inertia of 480±70 in SI units (J m^{-2} K^{-1} $s^{-0.5}$) more than double the mean value of 200±40 inferred in equivalent work for solitary NEAs [Delbo et al. Icarus 190, 236-249, 2007] and suggest that binary NEAs preferentially have large regolith grains on their surfaces. However, our previous work involving full thermophysical modelling for 3 binary NEAs, i.e. (1862) Apollo [Rozitis et al. AA 555, A20, 2013], (175706) 1996 FG3 [Wolters et al. MNRAS 418, 1246-1257, 2011], and (276049) 2002 CE26 [Rozitis et al. MNRAS 477, 1782-1802, 2018], found a much lower mean thermal inertia of ∼140. To resolve this apparent discrepancy, we determined the thermal inertia of an additional 4 binary NEAs ((3671) Dionysus, (66391) 1999 KW4, (153491) 2001 SN263, and (185851) 2000 DP107) using thermal-infrared observations from NEOWISE, Spitzer and VLT VISIR, a thermophysical model (ATPM: Rozitis & Green, MNRAS 415, 2042-2062, 2011) and previously published shape models and pole orientations. For these 7 binary NEAs we find an average thermal inertia of 150±50. This is at the lower end of the average of 385±225 determined for 12 solitary NEAs using thermophysical modelling [Delbo et al. Asteroids IV, University of Arizona Press, 107-128, 2015], and is significantly less than the value for binaries of 480±70 derived using NEATM analysis. Our results imply that fine-grained regolith is preferentially kept during the formation of binary asteroids by YORP spin-up.

Photometric observations of Didymos in 2003–2017, and outlook for observations in 2019 and beyond

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We will review the photometric observations of Didymos that we obtained from 9 stations in 2003, 2015 and 2017. The binary discovery observations taken from 2003-11-20 to -12-04 were of a high quality with the rms residual 0.008 mag, while the further data had rms residuals from 0.012 to 0.034 mag; the latter is a very marginal quality for that mutual events between the binary system components are only ~ 0.05 mag deep. We will present decompositions of the lightcurve data into the primary rotational and the orbital components. We will compare the primary rotational lightcurves with synthetic lightcurves from the preliminary primary shape model by Naidu&Benner, showing a sub-optimal match, and we will discuss possible reasons and implications. We will analyze what observations we will need to obtain in the next two (prior to DART) apparitions around the Didymos oppositions in March 2019 and February 2021. Particularly challenging will be a detection of the secondary's rotational lightcurve, which we need to derive P_s and estimate a_s/b_s, that will probably require high-quality data with errors < 0.008 mag while Didymos will be $V \sim 19.8$ and 18.9 in March 2019 and February 2021, respectively. Finally, we will analyze what we can obtain from photometric observations taken when "dust settles and fog clears" after the DART impact, say, from mid-October 2022 to April 2023, with only minimal constraints from the pre-DART system parameters. We will estimate with what accuracy we will be able to derive a new $P_{\rm orb}$ and P_p by April 2023, assuming only that the primary and orbit poles do not change by more than a couple degrees and that the mutual orbit eccentricity remains < 0.03. In particular, we will NOT assume that the primary's shape and surface albedo distribution remain unchanged after the DART impact; the new $P_{\rm orb}$ and P_p determination will be independent to a considerable degree to the pre-impact system parameters.

Determination of the orbit of Didymoon from past and future photometric observations

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We will present a current solution for the Didymoon's orbit derived from the photometric observations taken in 2003, 2015 and 2017. We will analyze how observations obtained around the next two oppositions 2019 and 2021 will improve the orbit solution and in particular what time distribution and quality of the data will be needed to predict the position of Didymoon with an uncertainty in mean anomaly $< 20°$ at the time of the DART impact in October 2022. We will present that, to reach the goal, it will be necessary to constrain a quadratic drift in mean anomaly due to the BYORP effect. We will show that it is likely not achievable with data taken in only one of the two upcoming apparitions; obtaining data in both will be needed. We will also analyze how potential additional observations (one event epoch) taken with the Hubble Space Telescope in August-September 2020 could improve the orbit solution and we will estimate whether they will be really needed, or if ground-based observations only will be sufficient to reach the goal of accurate prediction for the position of Didymoon at the time of the DART impact.

Ground-Based Radar Observations of 65803 Didymos

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Binary near-Earth asteroid 65803 Didymos is the target of the proposed Double Asteroid Redirection Test (DART) space mission. The mission would consist of a spacecraft that would impact the asteroid's satellite and the effect would be measured by space and ground-based observations.

We used radar observations obtained at Arecibo and Goldstone in 2003, and lightcurve data from Pravec et al. (2006) to model the shapes, sizes, and spin states of the components. The primary is top shaped and has an equatorial ridge similar to the one seen on 2000 DP107 (Naidu et al. 2015). A ∼300 m long flat region is also seen along the equator. The primary has an equivalent diameter of 780 m (+/- 10 %) and its extents along the principal axes are 826 m, 813 m, and 786 m (10 % uncertainties). It has a spin period of 2.2600 +/- 0.0001 h. A grid search for the spin pole resulted in the best fit at ecliptic (longitude, latitude) = (296, +71) degrees (+/- 15 degrees). This estimate is consistent with the spin pole being aligned to the binary orbit normal at (310, -84) degrees. Dividing the primary mass of 5.24e11 kg (Fang Margot 2012) by the model volume we estimate a bulk density of 2100 kg m^{-3} (+/- 30 %).

We estimated the motion of the satellite in successive images and used a shift-and-sum technique to boost its signal while mitigating smearing due to translational motion. This allowed us to obtain size and bandwidth estimates of the satellite. The visible range extent of the satellite is roughly 60-75 m at the 15 m resolution of the Arecibo images. Assuming that the true extent is twice the visible extent, we obtain a diameter estimate of 120-150 m. The bandwidth of the satellite suggests a spin period between 9-12 h that is consistent with the orbit period of 11.9 hours and with synchronous rotation.

We will present the physical characterization of the system and prospects for radar observations during the planned DART impact date.

Lessons learned from Gemini observations of Didymos mutual events in 2017

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The combination of a variety of proposal modes and queue observing with conditions constraints bins can make for a complex web of decisions to determine the best route to get the data we need from Gemini. In the context of solar system observations, I will compare and contrast the Gemini proposal routes and discuss strategies for dealing with a variety of rates of motion. Furthermore, I will provide concrete suggestions for future Didymos observations based on lessons learned from the 2017 Gemini observations.

The Thermal Response of Asteroid Surfaces: Results from ESO Large Programme

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The YORP effect [1] is a torque due to reflected and thermally re-emitted solar radiation. The YORP effect can: change rotation rates and spin-axis orientations over relatively short time-scales, modify orbits (semimajor axis drift from the related Yarkovsky effect depends on the obliquity) and thus plays a key role in replenishment of the near-Earth asteroid (NEA) population, cause regolith mobility and resurfacing, form binary asteroids through equatorial mass loss and re-aggregation, and cause catastrophic disruption. When we began our systematic monitoring programme in 2010, the YORP effect had only been detected for three asteroids [2-4]. That has now increased to six [5-7]. All detections so far are in the spin-up sense, and theoretical studies are making progress in explaining this observation [8]. However, a much larger statistical sample is required to robustly test this theory. We are conducting an observational programme of a sample of NEAs to detect YORP-induced rotational accelerations. For this we use optical photometry from a range of small to medium size telescopes, supplemented by thermal-IR observations and thermophysical modelling to ascertain expected YORP strengths for comparison with observations. For selected objects, we use radar data to determine shape models. We will present our latest results and progress on YORP detections/upper limits for a subset of NEAs from our programme, which include: (1917) Cuyo, (8567) 1996 HW1, (85990) 1999 JV6, (6053) 1993 BW3, and (29075) 1950 DA.

[1] Rubincam (2000). Icarus 148, 2.
[2] Lowry et al. (2007). Science 316, 272.
[3] Kaasalainen et al. (2007). Nature 446, 420.
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[5] Durech et al (2012). A&A 547, A10.
[6] Lowry et al. (2014). A&A 562, A48.
[7] Durech et al. (2018), A&A 609, A86.
[8] Golubov, et al. (2014). ApJ 794, 22.

Status and Predicted Performance of ESA's Flyeye Telescope

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ESA has recognised the threat that asteroids pose to our planet and in order to detect asteroids days to weeks before their potential impact it was decided to develop a telescope with a large field-of-view within ESA's Space Situational Awareness (SSA) Programme. The innovative idea is to split the incoming light into 16 different paths and place 16 cameras at the end of each optical path, a similar concept as the facets of the eye of a fly. The total field-of-view will be 6.7° x 6.7° or about 45 square degrees. This will allow imaging of about 50 % of a hemisphere three times per night (typical exposure time of 30 to 40 s). The limiting magnitude of this 1-m telescope at such exposure times is estimated to be about 21.5.

For the time being the funding for one Flyeye telescope is granted. To have good access during the development and commissioning phase it is planned to place the first telescope on Monte Mufara in Sicily. When the concept proves to be successful, a second telescope shall be deployed in La Silla, Chile providing coverage of the threat of asteroids approaching from the Southern hemisphere which is hardly monitored today. The long-term plan is to deploy 4 Flyeye telescopes (two in the Northern and two in the Southern hemisphere) to be less weather dependent.

OHB Italy is the prime contractor building this telescope for ESA. The CCD cameras are being built by OHB-I and CREOTECH (PL). Toptech (CZ) delivered the aspherical lenses and the test collimator. The optical system is already integrated and preliminary tests were performed. The Factory-Acceptance-Test is planned for June with two test cameras in Turate, Italy. The equatorial mount was integrated and preliminarily tested. A preliminary building permit was submitted for the site development work on Monte Mufara. The current goal is to have "first light" on the mountain before the end of 2019.

Status and Future of Arecibo Observatory

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I will present an update on the status and future of Arecibo Observatory and its planetary radar program. Over the last year, the observatory has been through equipment upgrades, a natural disaster, and a management change to the University of Central Florida, all while continuing to observe near-Earth asteroids when feasible. By the time of this workshop, a proposal to secure funding for the planetary radar program through 2023 will have been submitted to NASA. I can also present recent Arecibo radar results for triple asteroid 3122 Florence, DESTINY+ mission target 3200 Phaethon, 1981 Midas, or any of the binary asteroids observed by radar that could complement the presentations of Naidu et al. and others and aid in discussions about the Didymos system.

NEOexchange: A Target and Observation Manager For NEO Follow-up and Characterization

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We have developed web-based software called NEOexchange which automatically downloads and aggregates NEO candidates from the Minor Planet Center's NEO Confirmation Page, the Arecibo and Goldstone radar target lists and the NASA lists. NEOexchange allows the planning and scheduling of observations on the LCO Telescope Network and the tracking of the resulting blocks and generated data. We have extended the NEOexchange software to include automated scheduling and moving object detection, with the results presented to the user via the website. NEOexchange is an operating example of what are now being called Target and Observation Managers (TOMs). Several groups have developed similar project and science area-specific software for follow-up. However TOMs aim to provide generalized follow-up software that will scale to the size of the target lists produced by surveys like ZTF and LSST. In addition, they will provide scheduling, tracking and analysis facilities for the increasingly complex and more time-critical follow-up data on these targets. Recently, we have extended NEOexchange to include a generalized telescope and instrument model to estimate SNR, and applied this to the LCO 2-meter telescopes and FLOYDS low resolution spectrographs. This has enabled the planning and scheduling of spectroscopic observations of asteroids, along with flux standards and other calibration targets, on the LCO Network. We have also developed a characterization page that can analyze all the targets in the database, and provide an optimized target list for the current lunation. These targets can be scheduled on the LCO Network, and LCO is working to part automate the SOAR 4.1m telescope so it can be incorporated into a broader time-domain follow-up network. We are extending NEOexchange to allow co-ordination, planning, scheduling and data analysis of follow-up observations of all types of solar system objects across a wide range of telescopes.

The European Contribution to the Asteroid Impact And Deflection Assessment mission: Hera

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The European component of the AIDA mission has been redesigned and is called Hera hereafter. Hera is a small mission of opportunity built on the previous Asteroid Impact Mission (AIM) concept, whose objectives are to investigate a binary asteroid, to observe the outcome of a kinetic impactor test, and thus to provide extremely valuable information for asteroid impact threat mitigation validating models necessary to design a planetary defence mission. In its current formulation, Hera will be the first mission to carry, deploy, and communicate with an interplanetary 6U CubeSat in the vicinity of a small body, which will perform complementary in-situ spectral observations. The satellite and its CubeSat will also observe for the first time the outcome of a kinetic impact deflection test and drastically improve our understanding of the impact process at asteroid scale, which will serve for the extrapolation to other scenarios. Hera will demonstrate European capabilities to: (1) determine the momentum transfer by the hyper-velocity impact of DART and the resulting effects on Didymoon's surface; (2) carry, deploy and operate a CubeSat in interplanetary space, dedicated for the first time to the spectral characterization of a small body, with a second scientific investigation among radio science, seismology, gravimetry, and volatile detection; (3) perform close-proximity operations in the environment of a binary system and the smallest asteroid ever visited. The knowledge of Didymoon's surface/internal properties and the observation of the DART impact outcome are of high value to address fundamental scientific questions and to support the planning of potential surface activities related to mitigation, resources utilization, or sampling. The presentation will provide a detailed status update and overview of future related activities.

The Double Asteroid Redirection Test: Summary and Preliminary Observing Plans

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The Double Asteroid Redirection Test (DART) will be the first space experiment to demonstrate asteroid impact hazard mitigation by using a kinetic impactor. DART is entering the Final Design and Fabrication Phase ("Phase C"), and is part of the Asteroid Impact and Deflection Assessment (AIDA), a joint ESA-NASA cooperative project. The AIDA target is the near-Earth binary asteroid 65803 Didymos, an S-class system that will make a close approach to Earth in fall 2022. The DART spacecraft is designed to impact the secondary of the Didymos system (Didymos B) at 6 km/s and demonstrate the ability to modify its trajectory through momentum transfer. The primary goals of AIDA are: (1) perform a full-scale demonstration of the spacecraft kinetic impact technique for deflection of an asteroid; (2) measure the resulting asteroid deflection, by targeting the secondary member of a binary NEO and measuring the resulting changes of the binary orbit; and (3) study hypervelocity collision effects on an asteroid, validating models for momentum transfer in asteroid impacts.

We will provide an overview of the mission, with a focus on the observations necessary before and after the impact in order to meet our goals, current plans for making those observations, and our anticipated data management plan.

Planning for 2022: lessons learned from the Rosetta 67P observing campaign

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I will present an overview of the observing campaign that supported the ESA Rosetta mission between 2013 and 2016. This campaign included nearly all major observatories world-wide, and many smaller facilities, plus a related amateur astronomer effort. The campaign contained a total of 1300h of successful observations of the comet from more than 40 professional telescopes. I will discuss how this time was secured and how the campaign was coordinated, including what elements worked well and where lessons can be learned for future mission support campaigns, such as the Didymos observations around the DART impact in 2022.

Future Didymos Observing Strategy

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The binary near-Earth asteroid (65803) Didymos is the target for the Asteroid Impact and Deflection Assessment (AIDA) mission. The DART (Double Asteroid Redirection Test) mission is scheduled to impact the Didymos secondary during its apparition in 2022. One key scientific goal of AIDA is to measure and characterize the deflection caused by the impact. A combination of spacecraft and ground and space based optical and radar observations in 2022 will provide the required data for AIDA to meet its top-level mission goals. We will observe the Didymos system during the 2019 and 2020-2021 apparitions to further characterize the system by obtaining additional lightcurve observations and spectra. These planned observations would provide us with the opportunity to establish the state of the system before impact to a high level of precision. We will place additional constraints on the inclination of the satellite orbit, the long-term effects of Binary YORP (BYORP), and whether the satellite is in synchronous rotation with the primary. The Didymos apparitions in 2019 and 2020-2021 will be much fainter than that in 2022. We anticipate observations at a range of ground and space based facilities. We will discuss: (1) the timing of the two observing campaigns and our plans for each, (2) the improvements to system properties we expect following the two campaigns, and (3) the lessons learned from the 2017 campaign and how to improve for these next two apparitions.

Potential for thermal IR detection of dust plume from DART impact on Didymos

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Following the decision by ESA member states at the last ministerial not to fund AIM, the opportunity to observe the DART impact plume at thermal infrared wavelengths has been lost. The proposed inclusion of SelfieSat in the DART mission will obtain valuable close-up observations of the impact and subsequent plume development for several minutes after impact, at a range of solar phase angles as it flies past Didymos. However, these observations will only be made at visible wavelengths, and, with the demise of AIM, the possibility of observing thermal emission from the plume will reside with ground-based or space telescopes. The detectability of a dust plume from the Earth depends critically on the, generally well-defined, capabilities of the telescope and instrument used, and the less predictable properties of the dust plume produced by DART. We present a simple model of the initial dust plume and determine its detectability by ground-based telescopes immediately after the impact. We investigate the sensitivity of the results to uncertainties in the characteristics of the plume and to assumptions made in this simple model. Preliminary results indicate that thermal emission of the plume may be detectable with large ground-based facilities. We hope that this presentation will stimulate discussion on how more detailed impact models can be used to improve and constrain these predictions.

The Hayabusa2 Sample Return Mission and its Small Carry-on Impactor Experiment

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On December 3, 2014 the Hayabusa2 spacecraft was launched by JAXA to investigate and return samples from carbonaceous Asteroid (162173) Ryugu. The spacecraft's payload contains several remote sensing instruments that are designed to characterize the asteroid's surface and to help identify scientifically interesting locations from which samples can be obtained safely. The data collected by these instruments will also help place any obtained samples in context with respect to the global characteristics of Ryugu. In addition to the suite of remote sensing instruments and the sampling device, Hayabusa2 also includes a small carry-on impactor (SCI) payload experiment, which is designed to impact the surface of the asteroid and excavate fresh material for subsequent collection. The SCI consists of a 30 cm diameter 2 kg copper disk that is accelerated by an explosive charge into the surface of Ryugu at approximately 2 km/s. The resultant crater formed during this experiment is estimated to be approximately between 2 – 10 meters in diameter with an ejecta blanket extending to 10 − 100 meters on the asteroid. Hayabusa2 will not be able to observe the impact experiment directly due to considerations of spacecraft safety since there is some risk of collisions with debris from the explosion and ejecta from the crater. However, prior to moving safely away, the spacecraft will deploy a small imaging system called Deployable Camera 3 (DCAM3). DCAM3 will detach from Hayabusa2 just before the detonation of the SCI and will image the moment of impact, crater formation, and ejecta propagation. These data will be transmitted to Hayabusa2 and will help constrain the near-surface properties of Ryugu and also impact scaling laws for small bodies in low gravity environments. These data could also be useful for gaining insights into determining asteroid physical properties from higher velocity impact events (e.g., DART and HERA data of Didymos).

Asteroid Spectral Imaging Mission (ASPECT) CubeSat to characterize asteroid surfaces

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Asteroid Spectral Imaging Mission (ASPECT) is a scalable 3-6U CubeSat with a visible – near infrared (VIS-NIR) hyperspectral imager payload. The concept was developed for ESA-NASA AIDA (Asteroid Impact Deflection Assessment) project and is proposed as a payload for ESA Hera mission. ASPECT can be deployed on an asteroid orbit to characterize the composition of its surface with sub-meter spatial resolution. The prospecting objectives of ASPECT are based on the capabilities of the payload – the VIS-NIR imaging spectrometer. The payload allows for global compositional mapping and imaging of the target asteroid with sub-meter resolution. The spectral range of 500-2500 nm covers most common silicate mineral (olivine, pyroxene, and plagioclase) absorption bands related to Fe2+ ions in their structure. Additionally, ASPECT can also detect hydrated minerals as serpentine using 700 nm Fe3+ absorption features. Direct presence of -OH an H2O can be detected at 1400 and 1900 nm respectively. Additionally, observations at various phase angle allows for estimation of surface roughness. Currently, and extension of the hyperspectral imager to 4000 nm is being investigated. Such capability will allow for direct detection of water and organics.

TIRI: a multi-purpose Thermal InfraRed payload for asteroid observation

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TIRI is a multi-purpose Thermal InfraRed (TIR) Imager, initially designed for the Asteroid Impact Mission. It is conceived to pursue scientific goals such as retrieving temperature, thermal inertia, chemical composition and rock shape of the Didymos surface, and to aid the spacecraft navigation. A European consortium, formed by cosine measurement systems and GMV, has designed TIRI within the ESA General Studies Programme. TIRI takes advantage of the recent developments in TIR sensors, optical manufacturing, electronics and navigation algorithms. The result is a medium sized payload (ca. 11 kg mass and 18 litre volume). TIRI integrates two optical systems. The first is an imaging spectrometer, exhibiting a spatial resolution of few metres and a spectral resolution of tens of nanometres. It allows determining the asteroid surface temperature with an accuracy better than 5 K, to quantitatively evaluate its thermal inertia, and to sample its spectrum with more than 20 bands in the 8-14 micron range. The second TIRI optical head is NavIR, a miniaturised navigation camera (less than 1.5 litre volume), based on the HyperScout design, developed by cosine under an ESA GSTP contract. NavIR exhibits a fully reflective telescope with a large 2D field of view (up to 24x16 deg). The navigation system uses the NavIR images to determine the spacecraft position and velocity relative to the asteroid. A position error of tens of metres and a velocity error of centimetres per second are expected in the line-of-sight direction. Both optical instruments are integrated in the same mechanical structure and employ uncooled micro-bolometer arrays as detectors. The TIRI electronic system controls both detectors, it processes the acquired frames to enhance radiometric performance and it runs the navigation algorithms. Due to its high performance and versatility, TIRI can be effectively used in a wide range of small and medium size missions targeting near Earth small celestial bodies.