THE DYNAMICS OF THE EJECTA PLUME FOLLOWING THE DART IMPACT. A. Rossi[1], F. Marzari[2], K. Langner[1,2], G. Zanotti[3], D.P. Deshapriya[4], P.H. Hasselmann[4], E. Dotto[4], E. Mazzotta Epifani[4], A. Zinzi[5], F. Ferrari[3], S. Raducan[6], M. Amoroso[7], J. Beccarelli[8], I. Bertini[9], J.R. Brucato[10], A. Capannolo[3,11], S. Caporali[10], M. Ceresoli[3], G. Cremonese[8], M. Dall'Ora[12], V. Della Corte[12], I. Gai[13], S. Ieva[4], G. Impresario[7], S.L. Ivanovski[14], R. Lasagni-Manghi[13], M., Lavagna[3], A. Lucchetti[8], D. Modenini[13], M. Pajola[8], P. Palumbo[15], D. Perna[4], S. Pirrotta[7], G. Poggiali[10,16], P. Tortora[13], M. Zannoni[13], E.G. Fahnestock[17], M. Hirabayashi[18] , and Li, Y.-J.[19]
1-*IFAC-CNR, Sesto Fiorentino, Italy. 2-Università di Padova, Padova, Italy 3-Politecnico di Milano, Dip. di Scienze e Tecnologie Aerospaziali, Milano, Italy. 4-INAF-Osservatorio Astronomico di Roma, Monte Porzio Catone, Italy.* 5-*Space Science Data Center, ASI, Rome, Italy. 6-Space Research and Planetary Sciences, University of Bern. 7-Agenzia Spaziale Italiana, Rome, Italy. 8-INAF- Osservatorio Astronomico di Padova, Padova, Italy. 9-Università degli Studi di Napoli "Parthenope", Naples, Italy. 10-INAF-Osservatorio Astrofisico di Arcetri, Florence, Italy.* 11-*ISAE-SUPAERO, Université de Toulouse, Toulouse, France.* 12-*INAF-Osservatorio Astronomico di Capodimonte, Naples, Italy.* 13-*Alma Mater Studiorum - Universita di Bologna, Dipartimento di Ingegneria Industriale, Forlì, Italy.* 14-*INAF-Osservatorio Astronomico di Trieste, Trieste, Italy. 15-INAF - Istituto di Astrofisica e Planetologia Spaziali 16-LESIA, Observatoire de Paris-Meudon, Meudon, France. 17-Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA.. 18. Auburn University, Auburn, AL, USA. 19- Planetary Science Institute, Tucson, AZ, USA.* ***Corresponding e-mail: a.rossi@ifac.cnr.it***

Introduction: On September 26, 2022, the impact of the DART probe against the asteroid Dimorphos, the small moon of the binary 65803 Didymos asteroid system [1], generated a large ejecta plume. The images taken by the small LICIACube cubesat [2], released by DART 15 days before the impact, revealed a complex plume with a cone-like structure, crammed with dust, clumps of objects, filaments and larger boulders [3][4]. The event and the resulting ejecta were also observed by several space and ground based observatories which allowed the characterization of the plume evolution and, in particular, the formation of a long lasting tail of debris, pushed by the solar radiation pressure, stretching for thousands of km [5]. The complex mechanisms responsible for the shape of the observed tail, its temporary "double" nature and its continuous presence after several months are related to the interaction of the ejecta particles with the binary system gravity and to secondary collision events of larger ejecta against the two asteroids [6][7][8].

The model: The LICEI (LICIACube Ejecta Integrator) model is used to study the dynamical evolution of the debris after its ejection from Dimorphos [8]. The model accounts for the irregular gravity field of both Dimorphos and Didymos and include the effects of radiation pressure and solar tide. The ejecta particle are treated as rotating ellipsoids with variable dimensions. The numerical integration of the fragments' orbits is performed in the IAU_DIMORPHOS rotating reference frame as given by NASA SPICE kernels. The accurate heliocentric orbit of the Didymos system and the binary orbital dynamics is derived from the SPICE kernels too, allowing an accurate matching with the LICIACube data. The model allows the integration of a large number of ejecta particles thus providing a global view of the plume evolution (e.g., see Fig. 1).

The study: The aim of this study is to characterize the first phases of the fragments evolution after the ejection from the crater. The full

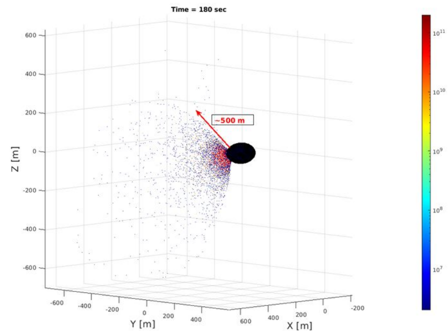

Figure 1: example of a simulation of the initial phases of the plume evolution with LICEI.

dynamics of the system is modelled up to several months after the impact to try to reproduce the LICIACube images details and to further study the tail evolution. In particular its relation with the re-impacting mechanisms able to generate further tail-feeding particles is investigated.

Different initial populations stemming from the DART impact, related to different possible physical properties of the Dimorphos asteroid [9], are generated [10] in order to find the best match with the LICIACube images. Moreover, as pointed out in [4], the actual observed cone is not circular (i.e., its base is elliptic and oriented roughly along the North-South direction on the surface of Dimorphos). The effect of different orientations of the non-circular cone on the initial evolution of the eject plume is explored considering also different cone aperture angles around the "nominal" one described in [3]. The relevance of these cone features for "immediate" re-impact of particles against Didymos is explored as well [11]. Finally, the effects of the ejecta particles complex evolution and of the simulated cone properties on the computation of the momentum enhancement factor, β, is analyzed.

Acknowledgments: This work was supported by the Italian Space Agency (ASI) within the LICIACube project (ASI-INAF agreement AC n. 2019-31-HH.0).

References:

[1] Cheng, A. F., Agrusa, H. F., Barbee, B. W., et al. (2023) *Nature*, 616, 457. [2] Dotto, E., Della Corte, V., Amoroso, M., et al. (2021) *Planetary and Space Science*, 199, 105185. [3] Dotto, E. & al. (2023) *Nature*, in press. [4] Deshapriya, J. D. P. & al. (2023) *Planetary Science J.*, in press. [5] Li, J.-Y., Hirabayashi, M., Farnham, T. L., et al. (2023) Nature, 616, 452 [6] Moreno, F., A. Campo Bagatin, G. Tancredi, Li, J.-Y., A. Rossi et al., (2023) *The Planetary Science Journal*, 4:138. [7] Ferrari F. et al. (2023) *submitted*, 2023. [8] Rossi, A., Marzari, F., Brucato, J. R., et al. (2022) *The Planetary Science Journal*, 3, 118. [9] Raducan et al. (2023), *Nature Astr.*, in press. [10] Zanotti, G. & Lavagna, M. (2020) in *71st International Astronautical Congress* (IAC 2020), 1–15 [11] Mazzota Epifani E. et al., (2023) ACM 2023.