MUSE Characterization of DART-induced Dimorphos Ejecta. B. P. Murphy[1], C. Opitom[1], C. Snodgrass[1], S. Bagnulo[2], S. F. Green[3], M. M. Knight[4], J. de Léon[5,6], J.-Y. Li[7] and D. Gardener[1]. [1]Institute for Astronomy, Edinburgh University of Edinburgh, Royal Observatory, Edinburgh EH9 3HJ, UK (brian.murphy@ed.ac.uk), [2]Armagh Observatory & Planetarium, College Hill, Armagh, BT61 9DG, UK, [3]School of Physical Sciences, The Open University, Milton Keynes MK7 6AA, UK, [4]United States Naval Academy, Annapolis, MD, USA. [5]Instituto de Astrofísica de Canarias (IAC), C/Vía Láctea s/n, E-38205 La Laguna, Spain, [6]Department of Astrophysics, University of La Laguna, Tenerife, Spain, [7]Planetary Science Institute, Tucson, AZ, USA

Introduction: NASA's Planetary Defense Coordination Office commissioned the Double Asteroid Redirection Test (DART) mission to investigate the effectiveness of the kinetic impactor redirect technique, which could mitigate the chances that a future planetary impactor would strike Earth.[1] On 26 September 2022, at 23:14 UT, the DART spacecraft impacted the non-hazardous 170-m diameter asteroid Dimorphos, which orbits the larger 780-m diameter Didymos.[1-2] Ground-based observations from the Multi-Unit Spectrographic Explorer (MUSE) instrument at the Very Large Telescope UT4 (VLT) caught the ensuing ejecta cone at remarkable spatial, spectral, and temporal resolutions. These ground-based observations cover T-15 to T+680 hours post-impact and can be used to elucidate specific ejecta structures, spectral signatures, dust distribution and size, and overall morphological evolution of the Didymos system. Measurements from these data better inform kinetic impactor models, allow for further constraints on key asteroid properties (mass, density, porosity, shear modulus), and help secure the future success of planetary defense missions.[3]

Observations: The observations were taken using the MUSE integral field spectrometer's Narrow Field Mode (NFM, 8''x8'') with adaptive optics and Wide Field Mode (WFM, 60''x60'') without adaptive optics. A total of 34 and 67 centered NFM and WFM exposures were selected for analysis, supplemented by 75 off-centered exposures to capture the tail from October 3 through October 25.

Methodology: We focused our analysis on the 3D spectral data cubes and the 2D white-light field of view (FoV) images, which maintained the high spatial resolution of the original data cubes and plate scales of 0.2″/pix and 0.025″/pix for WFM and NFM, respectively. [4] We analyzed the ejecta morphology across the WFM and NFM images, specifically measuring the velocity of early clumps and structures in the ejecta plume. We also extracted position angle measurements of the primary tail, secondary tail, and ejecta cone in both NFM and WFM. We calculated the relative reflectance spectrum normalized at 600 nm for each spaxel in the 3D data cubes, and fitted a first order polynomial to the relative reflectance slope between 500 and 750 nm. We produced color maps that contained each spaxel's slope value for each exposure, and co-added the color maps to increase the signal-to-noise for all of our nights.[5]

Results: Initial estimates of averaged clump velocities on 27 Sep are $\bar{v} = 13.7 \pm 2\, m\, s^{-1}$, , which are consistent with ejection at time of DART impact (see Fig. 1). Position angles extracted from polar projections of the 2D images suggest a slightly curved primary tail, which complements similar measurements by the Hubble Space Telescope.[6] The relative reflectance spectrum color maps show that the initial ejecta was bluer, and that the later tail, northern, and southern ejecta cone edges were redder. This would imply that the initial ejecta cone and tail were dominated by smaller particles, while the later spirals and tail were comprised of larger particulate. Possible drivers of this phenomena could be that smaller particles were ejected from the system at higher speeds, therefore representing the majority of initial ejecta in the early images' FoV. Larger particles were ejected from the system at slower speeds, and remained in the FoV over longer timescales. Similarly, the tail was observed to become redder over time, possibly suggesting that small particles were more rapidly accelerated out of frame by the effects of solar radiation pressure, leaving large particles that reflect more red light. Further analysis of tail brightness, dust grain size distribution, and position angle are under way.

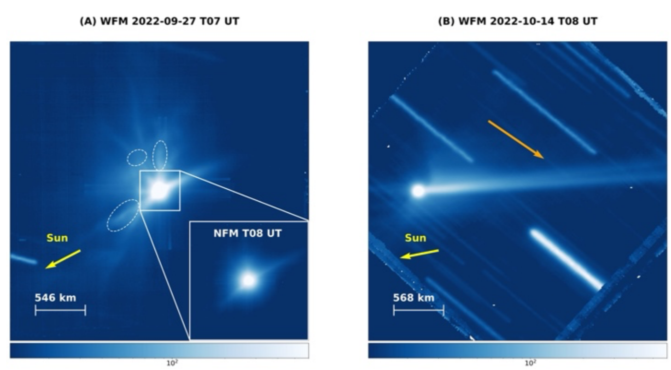

Fig 1. Initial ejecta cone with ellipses around clumps (left). Evolved primary tail with orange arrow highlighting secondary tail (right).

References: [1] R. T. Daly et al. (2023), *Nature, in press.* [2] A. F. Cheng et al. (2020) *Icarus* 352, p. 113989. [3] K. M. Kumamoto et al. (2022) *Planet. Sci. J.* 3, no. 10. [4] R. Bacon et al. (2010) *SPIE* 7735, no. 08. [5] C. Opitom et al. (2023), *A&A 671, L11.* [6] J.-Y. Li et al. (2023), *Nature, in press.*