THE HOURGLASS SHAPE OF THE DUST TRAIL OF COMET 17P/HOLMES

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Introduction: Is it possible to observe dust particles released by a comet, as small as ~ 0.1 mm, returning to the same region of space, revolution after the revolution, with a ground-based telescope? Eventually, the answer is yes if there are many of them since their dynamics obeys a physical law and the behavior of the trail that they form could be modelled and subsequently observed [1-2]. An illustrative example to this is the comet 17P/Holmes, which underwent an enormous and sudden increase in brightness during its recede from the Sun after the perihelion in 2007.

A vast amount of dust particles and gas that were ejected from the comet's coma during the outburst spread into elliptic orbits around the Sun. The evolving cloud of particles widened, apparently vanishing at first. Nevertheless, Lyytinen et al. [1] rediscovered this meteoroid stream, which converges again at the opposite side around the southern mutual node of the orbits. In one revolution the particles converge again at the original outburst site (the northen node). We studied dynamics of the particles ejected during the 2007 outburst from the coma of 17P/Holmes by developing the 'Dust Trail kit' model implemented in Orekit [2].

Methods: The following considerations were added compared to the earlier versions of the model:

1) Account for gravitational disturbances caused by Venus, Earth and Moon, Mars, Jupiter, and Saturn.
2) Inclusion of the particle's gravitational interaction with the parent comet.
3) Addition of the ejection speed section and 'particle feeding' as a one-particle-at-a-time algorithm using the Monte Carlo method.

The number of particles that can be considered in the model is arbitrary, with corresponding requirement for increased computational resourses. At present we use 3 particle populations ranging from particulate to fine dust and referred to as follows: big (or larger) particles with 0.1 - 1 mm radius, medium sized particles with 0.01 - 0.1 mm radius, and small particles with 0.001 - 0.01 mm radius. The distribution of the particles within each of these groups is uniform. Monte Carlo runs are accomplished with the Hipparchus add-in package to Orekit [2].

Observing campaigns: We validated the model using the telescopic observations obtained in 10 years time interval from 2013 to 2022. The observations were done in both common nodes of particles' orbits. The earlier observations are summarized in [2]. These observations were compared to the modeled position, position angle, width and brightness of the observed trail as well as the modeled trail particle's integrated distribution. In all cases, the predicted trail position showed a good match to the observations.

Main findings: We present the first set of direct observations showing the hourglass pattern formed by the particles in the trail of a comet. By using variations of the outburst model in our simulations we reproduce the hourglass pattern as well. We determine that the assumption of the spherical symmetry of the ejected particles leads to the scenario compatible with the observed hourglass pattern. Using these data, we provide predictions for the two-revolution dust trail behavior near the outburst point that should be visible with even modest telescopes in 2022. Observing the dust trail in 2022, or later, may aid in obtaining further information about (1) the symmetry conditions and exact mechanism of the 2007 outburst, (2) possible dispersion of the material in interplanetary space, (3) characterizing non-regular radiation pressure effects, such as seasonal type radiation effects to the particles, (4) particle size distribution evolution in the dust trail. We invite the community to join the effort of studying the dust trail of comet Holmes.

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References: [1] Lyytinen E. et al. 2013. *Journal of the International Meteor Organization* 41(3): 77–83. [2] Gritsevich M. et al. 2022. *Monthly Notices of the Royal Astronomical Society* 513(2): 2201–2214, *https://doi.org/10.1093/mnras/stac822*

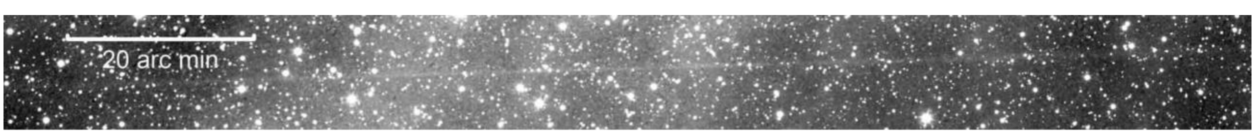

Figure 1. Observation of the dust trail of comet 17P/Holmes as seen on 15 Feb 2015. Without image subtraction.