STRATOSPHERIC COLLECTION OF DUST FROM COMET 73P/SCHWASSMANN-WACHMANN 3.

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Introduction: Interplanetary dust particles (IDPs) collected in the stratosphere are unique materials that are compositionally distinct from meteorites. Astronomical observations and dynamical models indicate that both asteroids and short-period comets are significant sources of IDPs [1-4]. IDPs having fragile, porous structures, unequilibrated, anhydrous mineralogy, and high atmospheric entry velocities are thought to derive from comets, whereas asteroidal IDPs are identified by their compact structure, hydrated mineralogy and low atmospheric entry velocities [5,6].

Uncertainty remains in the classification of asteroidal and cometary IDPs owing to our limited sampling of comets and the asteroid belt and the complex dynamical histories of most IDPs in space. Most IDPs spend thousands of years in space prior to being accreted by the Earth [4]. During this time, dust particles undergo orbital evolution, including gradual reduction in their perihelion and eccentricity as a result of Poynting-Robertson drag [7]. Planetary encounters may also significantly change their orbital parameters. Consequently, it is generally not possible to identify the specific parent body of a given IDP.

However, it has been proposed that it is possible to identify dust from comets that have formed Earth-crossing dust trails [8]. In this case, the dust particles have been in space for such a short period of time (a few decades or less) that their orbits have not significantly changed. Furthermore, these 'fresh IDPs' could be identified in the laboratory from their short space-exposure histories (low solar noble gas abundance and lack of solar flare tracks). NASA flew several dedicated IDP collection missions attempting to collect dust from comet 26P/Grigg-Skjellerup, the best candidate identified by [8]. Remarkably, many particles from those collectors exhibit unusual properties, including low abundances of solar noble gases and high abundances of presolar grains [9,10]. These observations are consistent with the dust particles originating from comet Grigg-Skjellerup (hereafter G-S).

This Study: Here we consider the prospects for collection of dust from comet 73P/Schwassmann-Wachmann 3 (hereafter SW3). SW3 is a small (2 km diameter) Jupiter family comet whose perihelion is close to and just inside the Earth's orbit. The orbit of SW3 is suitable for producing a low-velocity Earth-crossing dust stream and is the likely parent of the τ Herculid meteor stream [11]. This study complements a previously published model of the SW3 meteor stream that predicted a very low level of activity for grains 100 μm – 100 mm in size [11].

SW3 has been historically a low activity comet. However, during its 1995 apparition, SW3 experienced a dramatic outburst. Over the course of several weeks, the dust and OH production increased at a rate of 20% per day, ultimately reaching a 10-20 fold increase in activity [12,13]. This heightened level of activity was sustained for a period of several months. Later observations confirmed that this major outburst was related to the disruption of SW3 into several large and dozens of smaller (tens of meter-sized) fragments [14]. Infrared imaging further revealed prominent dust/meteoroid trails formed during the breakup event having an enhanced abundance of 100-1000 μm grains [15] The subsequent returns of SW3 in 2001 and 2006 also showed an elevated (but diminishing) level of activity compared with the historical (pre-1995) average.

The dust trail created during the 1995 outburst and subsequent returns of the major fragments (B, C, and E) was modeled using the approach described in [8] using custom written software. The observed mass loss of the comet was used to estimate the production of dust particles in the 10-100 μm-size range. 600,000 test particles were generated using a power law size distribution and were given a size-dependent ejection velocity that increases with decreasing grain size (due to coupling with gas). The particles were released hemispherically with an axis directed toward the Sun. The orbits of the particles were evolved and the density of particles within 10^6 km of Earth was determined for each encounter (May 29 – June 3) through 2025.

The effects of planetary perturbations were not considered in this initial model. Jupiter is likely to have a significant effect on the orbits of dust particles over long time scales. However, over the very limited time frame considered here (30 years), planetary encounters are unlikely to have a major impact on the density and position of the node of the dust stream. It is important to note that similar models of meteor stream activity (such as [11]) are much more sensitive to these effects because larger grains are tightly focused in space. This accounts for the significant variability in the activity of meteor streams from year to year.

The orbits of dust particles differ from their parent comet due to the ejection velocity and radiation pressure. These effects tend to increase the eccentricity and orbital period of the dust grains. The radius of the nodal crossing is also increased, and in the case of SW3, radiation pressure causes the dust stream to intersect the orbit of the Earth. Within a decade, dust grains are distributed throughout the orbit, forming a coherent dust stream. However, the density of dust within the stream remains highly non-uniform for decades.

The first order finding is that the 1995 outburst and subsequent returns of SW3 have generated an Earth-crossing dust stream that is amenable for collection. The atmospheric entry velocities of these particles are quite low for cometary dust (15-16 km/s). The flux of dust encountered by the Earth will vary dramatically over the next 25 years (Fig. 1). The first opportunity for collection of SW3 dust from the 1995 outburst and subsequent returns will occur in 2012. The Earth will encounter this dust stream every year, but significant enhancements in SW3 dust flux are anticipated in 2017 and the 2023. The nodal crossing of the SW3 dust stream is well within the orbit of the Earth, and thus only the outer edge of the stream is encountered, consisting of particles in the 15-25 μm size range.

As discussed above, a shortcoming of this initial model is the neglect of planetary perturbations, which influence the orbits of Jupiter-crossing dust particles over long timescales. In future work we will study the effect of planetary perturbations on these dust stream evolution models. It is likely that some or many particles are scattered by encounters with Jupiter, but it is also conceivable that planetary perturbations could move the nodal crossing outward, ultimately enhancing the flux of dust accreted by the Earth. Future modeling efforts are also focused on more accurately modeling the dust production during the 1995 outburst and from each of the individual fragments to enable quantitative comparison with the previously published GS dust stream model [8].

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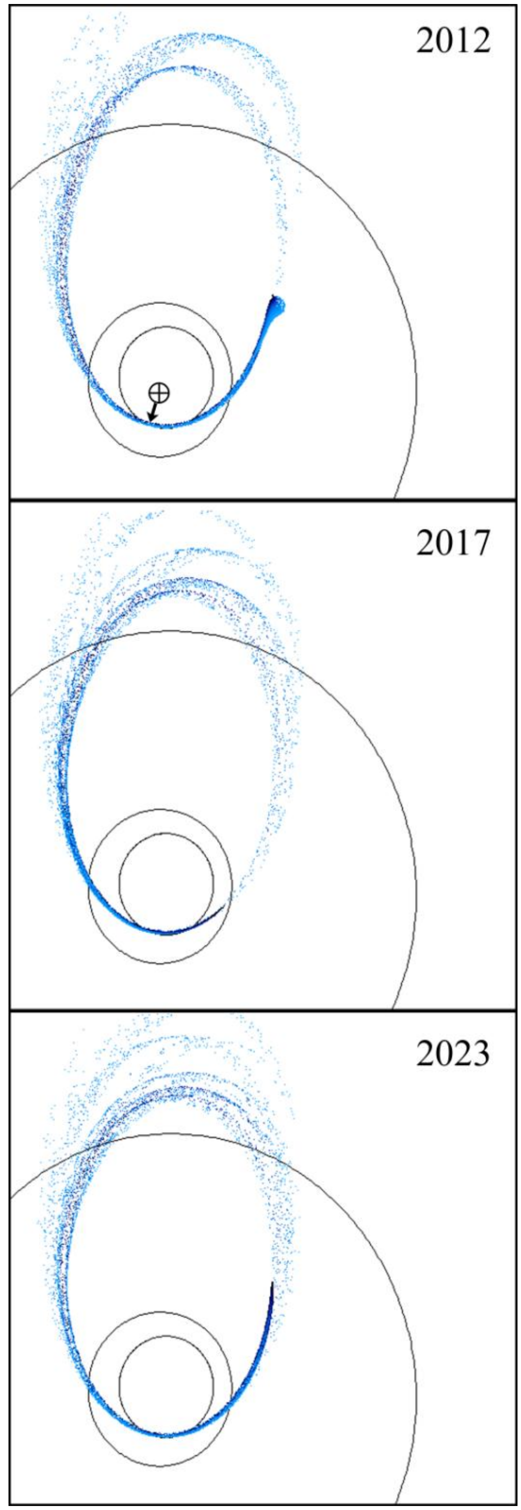

Figure 1: Modeled SW3 dust stream shown as of June 1 in 2012, 2017, and 2023. The position of the Earth at these dates is shown in the top figure. Variations in the distribution of grains around the orbit and concentrations at the nodal crossing are evident, but the dust trail trends toward uniform particle density over time.