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Fresnel holography for radio characterization of meteoroid fragmentation

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Abstract:

It has been argued within the scientific community that meteoroids of all sizes fragment. Observations with the high-resolution optical network CAMO (Canadian Automated Meteor Observatory) have shown obvious fragments for 90% of meteoroids (Subasinghe et al., 2016). The remaining 10% may fragment as well, as Campbell-Brown et al. (2017) showed that even meteors with a very short wake cannot be fitted with a single body model.

Fragmentation is essential for a proper characterization of the structure and composition of meteoroids. In turn, the latter determine the dynamics of meteoroids in space, their ablation behavior when they enter the atmosphere and the potential damage that they cause to spacecraft. Ignoring fragmentation leads notably to an overestimation of ablation coefficients, an underestimation of meteoroid densities (Moorhead et al, 2017) and limit the accuracy in the determination of meteoroid orbits (Vida et al, 2018).

Direct measurements of fragmentation are particularly important for a better understanding of the underlying phenomenon and for improving the existing ablation models. Although high-resolution observations of meteor trails through optical means at mm-sizes have been done in the recent years (e.g., Campbell-Brown, 2017; Vida et al., 2021), there are few works performing fragmentation characterization through radio observations.

An approach that utilizes both the phase and amplitude associated to the radio echo of a meteor was developed by Elford (2001). This technique, called Fresnel Transform (FT), allows to study the structure of the ionized trail immediately behind the head of the meteor. Although it is highly effective for computing the variation of the electron line density along the trail and therefore characterizing fragmentation, to date the FT has been mainly used for the computation of meteoroid velocity (Baggaley & Grant, 2005; Campbell & Elford, 2006; Holdsworth et al., 2007; Roy et al., 2007).

We will present progress of a new Python software package which allows the computation of the FT applied to meteor echoes, with a specific aim of statistically examining the process of fragmentation at small meteoroid sizes.

With this software, we will apply the FT to meteor echoes detected by the Canadian Meteor Orbit Radar (CMOR) and compare the results with the high-resolution imagery furnished by CAMO as validation. This comparative analysis will validate both the accuracy of the Python tool and the physical interpretation of the scattering amplitudes produced by the FT.

This tool will be applicable in an automated mode to both backscatter and forward-scatter data, providing a versatile framework for meteoroid analysis. This project will, for the first time, enable us to examine fragmentation of small meteoroids in a self-contained manner.

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