Meteoroid mass determination using radar scattering simulations

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While meteors are readily observable with radar, it is not trivial to convert a radar observation to a mass estimate. As the mass of a meteor cannot be directly observed by a radar, it must be inferred by relating observable quantities like the radar cross section (RCS) to physical parameters. In general, this process requires multiple assumptions about the meteor's properties. This work presents a method for estimating meteor masses using single-frequency radar measurements by relating observable quantities to a density distribution, using simulation results. Marshall and Close [1] introduced a finite difference time domain (FDTD) model that simulates the scattering of a radar pulse as it encounters a meteor head plasma, and determines the RCS that would be observed by the radar. We improve these simulations by incorporating the head plasma model derived in Dimant and Oppenheim [2], which uniquely defines the meteor plasma distribution by its altitude, velocity, and the size of the meteoroid. The Dimant-Oppenheim distribution is derived from kinetic theory, and is defined by the meteors velocity and altitude, which are radar-observable quantities, as well as a size parameter. The FDTD model maps various possible head plasma distributions to an expected RCS. We can then invert this process using radar data to estimate the plasma distributions of the observed meteors, and thus calculate masses. By performing hundreds of simulations we use this model to construct tables that relate RCS values to the observed range of parameters for a set of coincident meteor observations from the MAARSY and EISCAT radars in Norway. We apply the mass determination technique to several hundred such observations, estimating the mass independently for each of the two radar observations and comparing the results. There is a strong linear correlation between the masses estimated using the MAARSY and EISCAT observations; however, the EISCAT estimates are consistently 1.3-1.5 times greater than the MAARSY estimates. We also present the estimated mass distributions for both radar. The results of this study will be used to validate the method, which can then be applied widely.

References

1. Marshall, R. A., and Close, S. (2015), An FDTD model of scattering from meteor head plasma, *J. Geophys. Res. Space Physics*, 120, 5931– 5942, doi:10.1002/2015JA021238.
2. Dimant, Y. S. and M. M. *Oppenheim*, Formation of plasma around a small meteoroid: 1. Kinetic theory, Journal of Geophysical Research: Space Physics, 10.1002/2017JA023960, 122, 4, (4669-4696), (*2017*).