Experimentation and numerical simulation of meteoroid ablation

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Abstract

When a meteoroid enters into Earth's atmosphere, it ablates and forms plasma that is deposited both behind and immediately around the meteoroid. The properties of this plasma are determined by the meteoroid's size, velocity and composition. These plasmas can be used to determine fundamental meteoroid properties, as well as understanding the impact of meteoroids on the upper atmosphere [1, 2].

In order to probe meteoroid properties, we investigate the ablation process by combining data from high-power large aperture radars and optical instruments with modeling. We developed a two dimensional numerical model taking into account pyrolysis, surface recession, and thermal non-equilibrium between the body and the surrounding flow. The surface energy balance condition is solved with a moving grid based on universal meshes [4] to calculate the shape change due to surface recession. The governing equations are discretized with a finite volume approximation in a body-fitted coordinate system.

Using our numerical model, we explore the effect of size and composition on time of flight of meteoroid events observed via radar and optical instruments during an experimental campaign in Alaska. From our analysis we can determine at what combination of size, shape and composition a multi dimensional characterization of the phenomenon matches the simple one dimensional ablation model.

Our results indicate that for fast moving meteors with apparent magnitude higher than 5 our numerical model and the 1-d single parameters are in agreement. As the apparent magnitude and velocity decreases, the size estimate - for a given composition - increasingly diverges, up to 40 % for metallic meteoroids. When considering rotating objects, whenever the model converged to a solution, the 1-d ablation case severely over-estimates the size (and hence masses) of the detected object. In addition our multi-composition concentric shell model seems to replicate the behaviour of meteoroids whose light curve/radar detection indicates the presence of differential ablation [3].

References

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