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Bulk densities of meteoroids and insight into their compositions

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Abstract

The study introduces available models of meteor atmospheric entry, meteoroid density evaluations and initial pre-entry mass estimates. We will describe new dynamic approach for meteoroid density calculations and present results on data from Canadian Fireball Network. The results will be further compared to empirically derived density ranges of known extraterrestrial materials. Finally, the limitations of the current model precision will be discussed.

1. Introduction

Techniques to determine the mass and bulk density of meteoroids have been long discussed in the literature dedicated to meteor studies. These data are of current importance because of their implications on the influx of the cosmic matter onto the Earth, on more reliable and rapid meteorite recovery, on the studies of cometary nuclei composition and structure, on the orbital evolution calculations and on the estimates of the atmospheric entry peak temperature. These applications are quite sensitive to the assumed meteoroid's mass and bulk density values and these estimates sometimes differ by more than an order of magnitude depending on the approach.

The empirical results on physical properties of collected extraterrestrial materials should not be ignored in the modelling. Thus, part of this study is a bulk density review for various extraterrestrial materials and bodies.

2. Methodology

The new technique of fireball atmospheric entry analysis is used to estimate an initial meteoroid's mass [1]. This method is further modified to provide meteoroid bulk density from its dynamic modelling while incorporating mass estimate from the photometric approach. The bulk density formula proposed in our study allow us to consider changes of the body's shape during its movement in an atmosphere and avoids use of deceleration values obtained by numerical differentiation what essentially differ our approach from previous studies. Our model makes possible to do density calculations from initial parameters only.

We covered the whole realistic range of drag coefficient c_d and initial shape factor A_e. Additionally we apply empirical margins on the bulk density range to match known meteoroid compositions.

3. Results

The approach was applied on the data from Canadian Camera Network (MORP). In some cases the calculations led to tighter final meteoroid bulk density range (Fig. 1 and 2).

For example bolides in Fig. 1 are within the range of loose porous, volatile rich material up to stony meteorite bulk densities and are not expected to be metal rich. The bolides in Fig. 2 have high bulk densities pointing out on their stony or possibly metal rich nature.

The empirical bulk density margins can be subsequently also used to reduce uncertainty in the photometric initial mass estimate.

References

[1] Gritsevich, M. I.: Determination of parameters of meteor bodies based on flight observational data, Advances in Space Research, Vol. 44, No. 3, pp. 323-334, 2009.

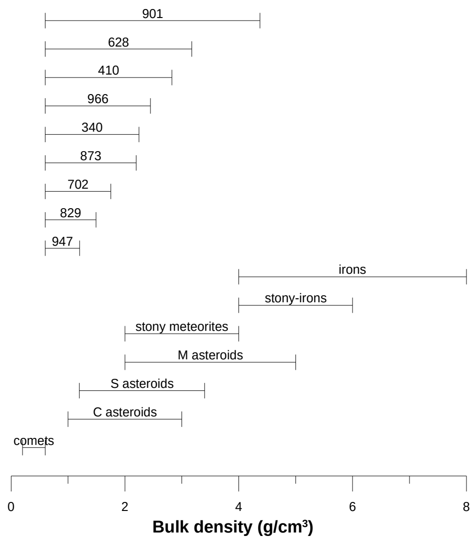

Figure 1: Low density meteoroids detected by Canadian Fireball Network.

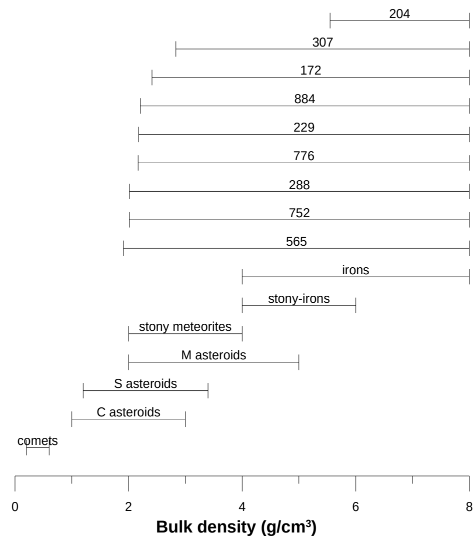

Figure 2: High density meteoroids detected by Canadian Fireball Network.