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Coupling approaches used in atmospheric entry models

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Abstract

While a planet orbits the Sun, it is subject to impact by smaller objects, ranging from tiny dust particles and space debris to much larger asteroids and comets. Such collisions have taken place frequently over geological time and played an important role in the evolution of planets and the development of life on the Earth. Though the search for near-Earth objects addresses one of the main points of the Asteroid and Comet Hazard, one should not underestimate the useful information to be gleaned from smaller atmospheric encounters, known as meteors or fireballs. Not only do these events help determine the linkages between meteorites and their parent bodies; due to their relative regularity they provide a good statistical basis for analysis. For successful cases with found meteorites, the detailed atmospheric path record is an excellent tool to test and improve existing entry models assuring the robustness of their implementation. There are many more important scientific questions meteoroids help us to answer, among them:

Where do these objects come from, what are their origins, physical properties and chemical composition?

What are the shapes and bulk densities of the space objects which fully ablate in an atmosphere and do not reach the planetary surface? Which values are directly measured and which are initially assumed as input to various models?

How to couple both fragmentation and ablation effects in the model, taking real size distribution of fragments into account?

How to specify and speed up the recovery of a recently fallen meteorites, not letting weathering to affect samples too much?

How big is the pre-atmospheric projectile to terminal body ratio in terms of their mass/volume? Which exact parameters beside initial mass define this ratio?

More generally, how entering object affects Earth's atmosphere and (if applicable) Earth's surface? How to predict these impact consequences based on atmospheric trajectory data?

How to describe atmospheric entry features beforehand based on comprehensive telescopic survey?

1. Introduction

Hydrodynamic models describing air flow around the object are mainly useful in modeling a particular event (with certain pre-atmospheric velocity, entry angle, and given projectile properties) and thus are not generally effective [1]. Therefore this study aims to build up the model, which does not require any synthetic parameters as an input, and is focused mainly on comparison and coupling of different approaches describing the drag, ablation, rotation, fragmentation and meteor brightness in the atmosphere.

2. Technique

We convert observed photometric and dynamic measurements into information about the projectile, taking into account shape, velocity, and the mass history of the main body along the atmospheric trajectory. We start from the drag, mass loss, and the entry angle equations. Introducing basic dimensionless parameters, we derive analytical dependencies for the main body's mass, velocity and deceleration. The study is completed by considering the luminosity of an object, with an approach similar to that proposed in [2]. We then compare the results with the other studies and experimental results (see Figure 1 presented on the next page).

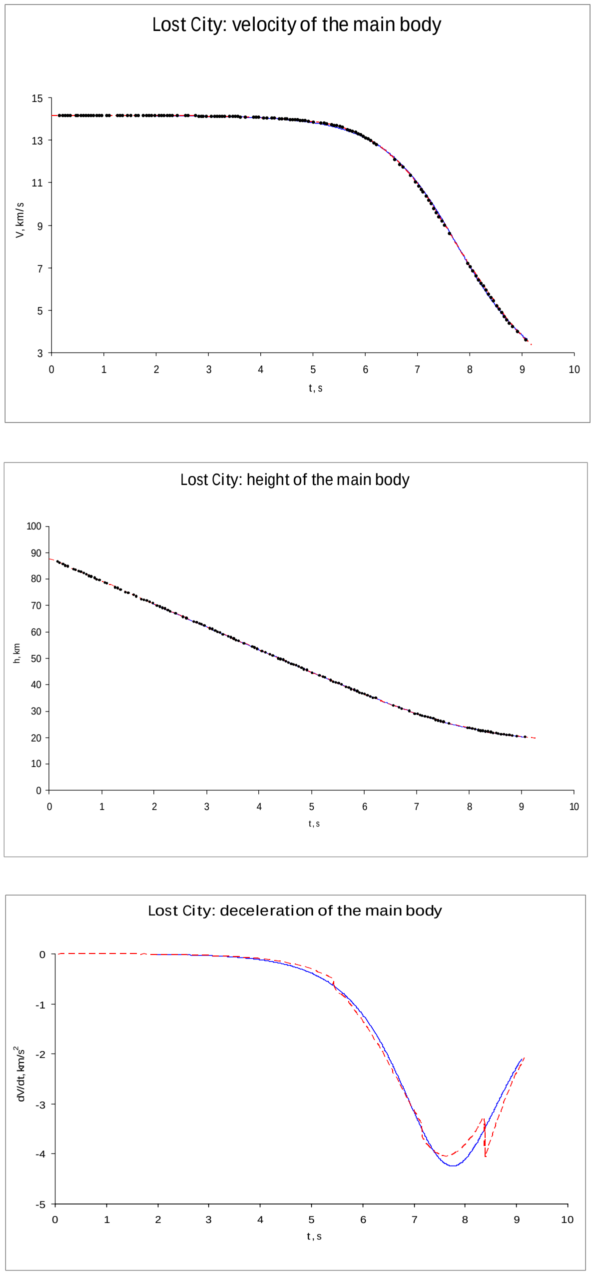

Figure 1: Reconstruction of the atmospheric entry for Lost City fireball: blue line corresponds to the model presented in this study, red line – numerical model by Ceplecha and ReVelle (2005), dots – observational results according to Ceplecha and ReVelle (2005).

3. Summary and Conclusions

The described model is competitive with other studies and helps us to better understand the processes following atmospheric entry and create better connection between the properties and structure of the entering bodies (asteroids/meteoroids) and recovered meteorites. Proper modelling allows better prediction of the fireball mass, which in turn increases the chances of successful meteorite recoveries in the future.

References

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