Penetration of Probes and Natural Cosmic Bodies into Planetary Atmospheres: Mathematical Interpretation of Observational Data

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The approximation of the actual data using theoretical models in general makes it possible to achieve additional estimates, which do not directly follow from the observations. For example, the correct mathematical modeling of meteor events in the atmosphere is necessary for further estimates of the key parameters, including the extra-atmospheric mass, the ablation coefficient, and the effective enthalpy of evaporation of entering bodies. In turn, this information is needed by some applications, namely, those aimed at studying the problems of asteroid and comet security, to develop measures of planetary defense, and to determine the bodies that can reach Earth's surface.

In the present report, an analytical model of the atmospheric entry is calculated using the altitude and rate of the body deceleration in the atmosphere from the data of actual observations. With this purpose the strict mathematical algorithm to find basic dynamic parameters of the theoretical relationship between the height and the velocity of the body that help to fit observations along the luminous part of the trajectories in the best way is suggested. The main difference from previous studies is that the given observations are approximated using the analytical solution of the fundamental differential equations of the hypersonic flight of the body.

The proposed general approach helps in understanding the extensive observational data of the deceleration of probes and natural cosmic bodies in the upper layers of the terrestrial atmosphere under conditions when the sizes, mass of a body and also aerodynamic flight regime are in advance unknown.

New model presented in the report was applied to well-known real impacts. These are several famous meteorite-producing fireballs and the STARDUST Sample Return Capsule (a hypersonic phase). The estimate of mass of SRC obtained using the data of actual observations is quite close to its real value of 45.8 kg.

On the basis of new mathematical interpretation of observational data in the report also it will be noted that the major part of the luminous segment of the trajectories of large bodies corresponds to continuous medium flow, while the condition of a free molecular flow holds outside this segment. The maximum brightness altitude is smaller than that at which a strong bow shock is formed. At a flow past body in a rate of the continuous medium, the basic contribution to luminescence gives radiation of heat atmospheric gas near the body. So,

luminosity of a body at its hypersonic flight in the atmosphere does not defined only by radiation of vapor of a body material, arising owing to evaporation of its surface. Therefore some of applied earlier methods for evaluating fireballs parameters from observational data are not correct.