METEOR WITH INTERESTING CHARACTERISTICS FROM THE 2001 LEONIDS METEOR SHOWER.

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Some meteoroid intrusions into the Earth’s atmosphere show a rather unusual wake shape [3, 5]. We have processed the observation of one of such interesting intrusions from 2001 Leonids meteor shower [8] and present results of its study (https://astronomy.com/news/2020/12/do-meteor-showers-create-meteorites).

![Observations of meteors](image1)

Fig. 1. Observations of meteors.

![Contour images of the meteoroid](image2)

Fig. 2. Contour images of the meteoroid.

Using the "tuning technique" in conjunction with the simulated invasion model described below, we have estimated an initial meteoroid velocity of 28 km/s and its mass of 60 kg. The meteoroid intrusion occurred at an angle of 55 degrees. The contour image of the meteoroid in Fig. 2 show the brightness variations in the wake, as well as the ejections of matter in the transverse direction. It can be concluded that the ejections are moving at a speed comparable to that of a meteoroid. The scattering of fragments demonstrates the effect of a "sling" due to centrifugal destruction of meteoroid [9]. We showed that meteor completely burned up to zero mass at an altitude of about 32 km. The technique of fine tuning of invasion parameters [1] makes it possible to determine characteristics of meteoroid using data on frequencies of brightness fluctuations \( f \) and of wobling \( f_w \) [7]. Amplitude and frequency of wobling in meteor trail, as well as frequency of brightness fluctuations, which can be easily measured, provide estimates of size of meteoroid, its mass, distance to trail, and its height [10, 11]. Basic two-point observations of intrusion allow you to reliably determine height and speed of an invasion. “Tuning Technique” developed by us, in combination with a simulation model of invasion, makes it possible to determine characteristics of a meteor during “one-side” observations [3, 6]. In Fig. 3 shows graphs of brightness fluctuations and wobling in meteor wake (displacement of center of gravity of trajectory in transverse direction). Assuming the propagation length of the meteor trail to be equal to one second, it is possible to determine the periods of oscillations in interval 0.071-0.077 s, and we obtain values of frequencies \( f \) and \( f_w \) in the interval 13-14 Hz. It is noteworthy that in our case frequencies \( f \) and \( f_w \) coincide within error limits. Note also that in most real cases – frequencies are different. In this case, the frequency estimates were made by counting oscillation maxima over the observation interval. Accurate frequency estimation by Fourier analysis yields similar results. This is due to rather high signal-to-noise ratio (about 10, see Fig. 3). Essence of the "tuning technique" is to fine-tune initial parameters of intrusion simulation model until calculated and measured frequencies \( f \) and \( f_w \) match. We use the classical theory of ablation of meteors [1]. This model tracks changes in meteoroid speed, acceleration, mass, and visual radiation over time. By varying the relevant parameters of the model, such as initial mass and velocity, the characteristics of the meteoroid can be easily estimated.

![Graphs of fluctuations in wobling and brightness in the meteoroid track](image3)

Fig. 3. Graphs of fluctuations in wobling and brightness in the meteoroid track.

In Fig. 4 shows speed of a meteoroid as a function of altitude, rotation speed on surface and critical speed of dynamic destruction. It is easy to see that dynamic fracture limit [1] has not been reached. However, destruction of meteoroid by centrifugal forces was achieved when rotation speed reached a critical value of
about 3 km/s. Dynamic fracture was achieved at an ultimate strength of \(-10^7\) Pascal, which is characteristic of meteoroids of mineral composition [4].

Meteor began to collapse due to its rapid rotation at an altitude of \(-32\) km. Fig. 5 plays a decisive role in our work. The figure shows the values of the frequency ratio \(f_c/f_m\) depending on the height. By varying the initial parameters of the model, the primary mass and velocity of the meteoroid at the boundary of the Earth's atmosphere, we find the height at which the frequency ratio \(f_c/f_m\) coincides with the value found from the measurements. The time of flight of the meteoroid according to the simulation model using the Impact 4A program [2] was about 7.5 seconds (Fig. 6). At this moment, the meteoroid reached a critical value of the rotation speed on the surface and began to collapse.

In Fig. 7 it can be seen that the meteoroid ended its existence, having completely lost its original mass of 60 kg at an altitude of about 32 km, having a residual speed of about 10 km/s (Fig. 4) with an initial speed of 28 km/s. The above describes the characteristics of the meteoroid intrusion from the 2001 Leonids meteor shower into the Earth's atmosphere. Using a "tuning technique" in conjunction with a simulated invasion model, estimates were made for an initial meteor velocity of 28 km/s and with initial mass of 60 kg. The meteoroid reached its critical rotation speed at an altitude of about 32 km in about 7.5 seconds at zero residual mass and at residual speed of about 10 km/s.

At this moment, the meteoroid began to collapse by centrifugal forces, when its rotation speed reached a critical value of about 3 km/s. We have found that rotation plays an important role in the dynamics of meteors; in particular, they can explode due to centrifugal forces if they exceed the strength of the meteoroid material.