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Changing the non-gravitational accelerations of the comet Tempel 1 due a collision with impactor of Deep Impact space mission

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Abstract

Using positional observations of the comet Tempel 1 from 1967 to 2010 the non-gravitational acceleration and instantaneous change of the comet velocity due to collision with impactor of Deep Impact space mission were determined. Instantaneous change of velocity was compared with the perturbation, calculated on a basis of velocity and mass of the ejected matter. Comparison of these values showed that the comet obtained a much greater perturbation than it follows from the estimations of mass of ejected matter.

1. Introduction

Comet Tempel 1 was chosen as the object of a scientific Deep Impact space mission, whose purpose was to study the internal structure of cometary nuclei. Deep Impact spacecraft was launched on 12 January 2005. Approaching the comet at a minimum distance, the spacecraft was divided into two parts: the impactor and the main section. On 4 July 2005 impactor collided with comet nucleus with relative velocity of 10.3 km/sec. As a result of impact the large and bright cloud of dust was formed. This event was observed from the ground and space observatories. A large number of observations were made after collision. Our goal is to estimate the change of non-gravitational acceleration due to the collision with impactor of Deep Impact space mission.

2. Velocity and mass of the ejected matter

Two types of disturbances acted on the comet motion as a result of collision with the impactor. The first disturbance is the momentum from the massive impactor. The second disturbance is reactive force produced by ejection of cometary material. Collision of impactor with the comet occurred in the perihelion area with the relative velocity $|\Delta\bar{v}_{imp}|$=10.3 km/sec. Taking into account the mass of the comet M =7.5·10^{13} kg and the mass of the impactor m_{imp} =370 kg we have calculated the maximum increment of velocity that the impactor can provide to the comet $|\Delta\bar{V}_{imp}|$=5.1·10^{-8} m/sec. Observations showed that the ejection of comet material m_{jet}=4.1·10^{8} kg [1] occurred with the average speed of $|\Delta\bar{v}_{jet}|$=200 m/sec [2]. Hence, we can estimate the maximum change of velocity $|\Delta\bar{V}_{jet}|$ to be equal to 1.1·10^{-3} m/sec.

3. Changing the non-gravitational accelerations

We created a numerical theory of motion of the comet Tempel 1 on the interval from 1967 to 2010, assuming that the collision of the comet with the Deep Impact space mission impactor could lead to a change of non-gravitational parameters. Three components responsible for the change of non-gravitational accelerations [3] as a result of the collision were added to standard set of 9 elements, which is used to improve orbits of comets. The components of non-gravitational acceleration after the collision of the comet with the impactor on 4 July 2005 were as follows (in AU/day^2): A_1=0.0097·10^{-8}±0.58·10^{-10}; A_2=0.0002·10^{-8}±0.03·10^{-10}; A_3=0.0648·10^{-8}±0.62·10^{-10}. It should be noted that the values of these components before the collision were A_1=0.0199·10^{-8}±0.13·10^{-10}; A_2=0.0017·10^{-8}±0.00041·10^{-10}; A_3=–0.0129·10^{-8} ± 0.080·10^{-10}. The changing of the non-gravitational acceleration after the collision can be approximately represented as an instantaneous change of velocity $\Delta\bar{V}$ (see Table 1).

We have considered another model of the motion. In this model 12 parameters of the orbit were improved, including position, velocity and non-gravitational acceleration, as well as three components of instantaneous change of velocity $\bar{I}$, representing the impact. The values of the $\Delta\bar{V}$ components and the components of $\bar{I}$ are given in Table 1.

Table 1: *x*, *y*, *z* components of instantaneous change of velocity (in 10^8·AU/day)

	x	y	z
$\bar{I}$	0.692±0.14	–0.499±0.30	2.699±0.37
$\Delta\bar{V}$	0.917	–0.395	3.397

As can be seen from Table 1, the components of $\Delta\bar{V}$, obtained by non-gravitational acceleration, are close to the corresponding values of the components of instantaneous change of velocity $\bar{I}$ if we take into account the error of components.

4. Comparison of the results

We can now compare two values of velocity increment. The first value was obtained from the non-gravitational acceleration changing and the second – from the parameters of the ejected matter. Change of velocity at the moment of collision with the impactor 4 July 2005 is approximately $|\bar{I}(t_1)|=4.9\cdot10^{-2}$ m/sec, which is significantly greater than change of velocity of the comet due to ejection of cometary material $|\Delta\bar{V}_{jet}|=1.1\cdot10^{-3}$ m/sec and even more than momentum from the massive impactor $|\Delta\bar{V}_{imp}|=5.1\cdot10^{-8}$ m/sec.

5. Conclusions

Performed calculations allow us to conclude that there was a noticeable change in non-gravitational acceleration of the comet. This acceleration is much greater than it would be expected from the effects of the comet collision with impactor of Deep Impact space mission. Changing the rotation parameters of the cometary nucleus could be a possible explanation of these results.

References

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