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THE STUDY OF NON-GRAVITATIONAL EFFECTS IN THE COMET ENCKE MOTION

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Introduction

The 2P/Encke was the first comet in whose orbital motion non-gravitational effects were discovered back in 1821. They are of reactive nature and therefore associated with volatile mass loss. The first simplified simulation of volatile mass loss led to the conclusion on finite lifetime of non-gravitational effects [1]. In a series of works, we developed a more advanced model of volatile mass loss and analyzed a large number of new observations of the comet Encke up to 2010 [2]. The conclusions drawn by Sekanina [3] were fully confirmed by our new model. In contrast to the precession models in which radial, transversal, and normal components of non-gravitational acceleration are redistributed, the model of volatile mass loss implies simultaneous decrease in all the 3 components. The forecast date of the full termination of the comet Encke's non-gravitational effects is determined to be 2027.

Methods

The observed decrease in non-gravitational parameters of the comet Encke cannot be explained by heterogeneous nucleus sublimation at which all the surface matter is removed from the comet, since the ratio of effective volatility area to mass decreases. Such a non-regularity may be achieved in 2 fundamentally different ways: accumulation of significant amount of non-volatile mass or formation of a crust on the nuclear surface that reduces the effective area. It is clear enough that, actually, there is a combination of these options: non-volatile matter of any origin will constitute some additional mass and to some extent change the sublimation rate. Nevertheless, if the accumulated mass constituted a significant portion of the whole nucleus mass, then it may be concluded that during the accumulation process it almost did not confine the sublimation. If the crust reduces the sublimation rather quickly, then the large mass is not supposed to enter the composition. This is why these 2 cases were studied separately, which significantly reduced the number of free parameters. To combine observations of the comet appearances (taken during a large period of time with various accuracies) weights of observations were introduced and determined. Normally, the values inversely proportionate to the squared standard *a-priori* observational errors are accepted as weights.

Results

To process the observations using the developed algorithm a software complex was produced. Theoretical positions of the comet are determined by numerical integration of motion equations with taking into account the relativistic term and non-gravitational effects for the 2 options. It is also necessary to concretise the ratio of effective evaporating area to geometrical area (i.e. the extinction coefficient of sublimation) as a function of the crust thickness. There have been some attempts to find this important function in cometary astronomy both in theoretical and experimental ways. These studies produced completely different results. Moreover, the inversely proportional dependence results in an infinitely fast sublimation in the case of pure ice. In this paper, two elementary functions were considered: linear (equal to Shul'man's assumption that crust formation finishes when the volume, containing a coating area equal to nucleus area, evaporates), and exponentially decreasing. A model of volatile mass loss is built. A new solution provides non-gravitational parameters of the comet Encke and their uncertainties as follows: $A1 = -1.3 \times 10^{-11}$, $\sigma A1 = 1.6 \times 10^{-11}$, $A2 = -2.28 \times 10^{-12}$, $\sigma A2 = 9.9 \times 10^{-13}$, $A3 = 1.8 \times 10^{-9}$, $\sigma A3$ is not available. Non-gravitational effects occurred during IX and XX centuries in the modern age become statistically insignificant despite the increasing accuracy of astrometric observations. All the data obtained in the present paper confirmed the reliability of our model of volatile mass loss. The problem of constructing a theory of periodic comets motion combining all their appearances remains unsolved and this primarily refers to the comet Encke. The model proposed in this paper explains characteristic features of the change of the comet Encke's transversal non-gravitational parameter with time and allows producing a convergent solution by differential correction and using astrometric observations of all its appearances.

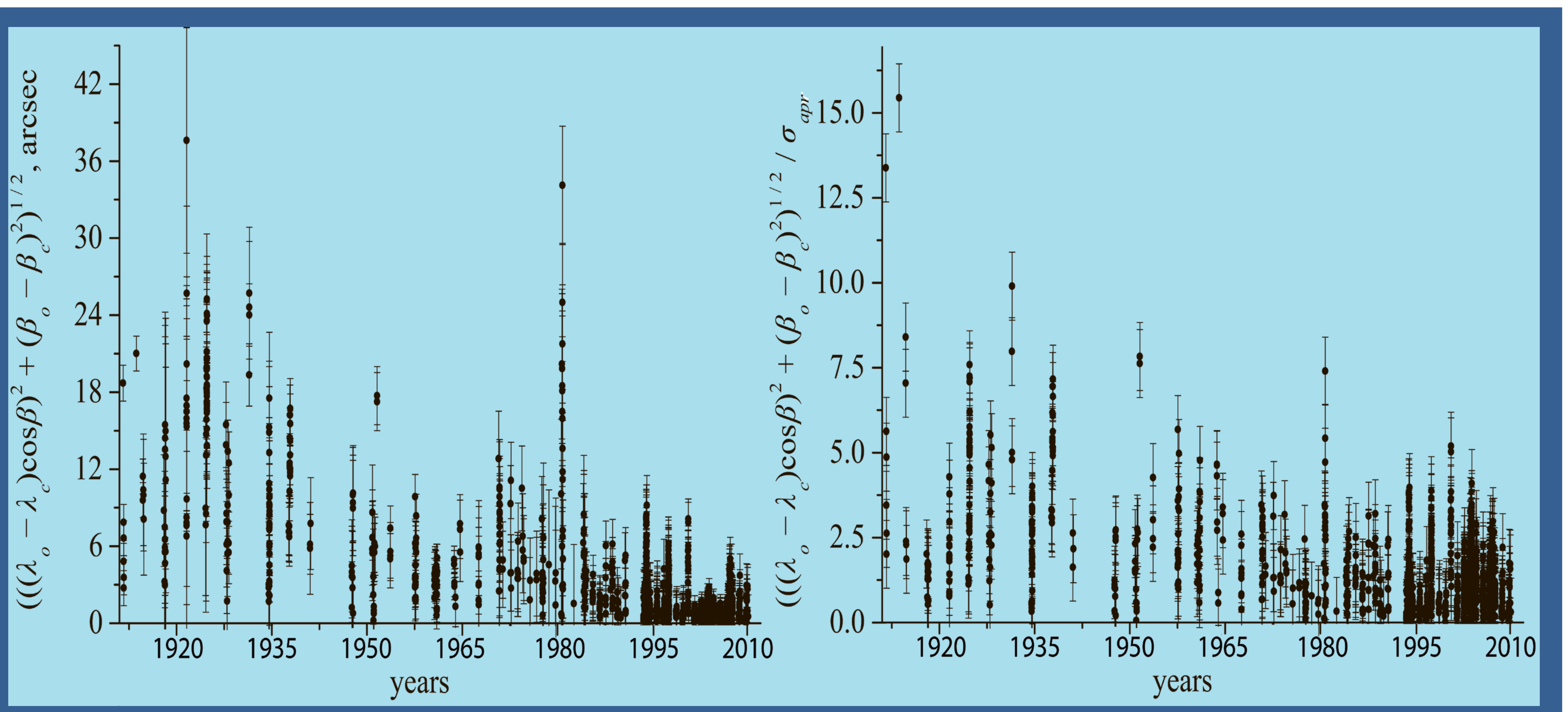

Fig.1 Residuals of the 2045 observed positions of comet Encke for 30 apparitions during the interval 1911–2010 (expressed in terms of angular ecliptic coordinates) from the positions calculated by the model based on Marsden's theory and our two additional nongravitational parameters [1]. The a posteriori root mean square residual was $\sigma_{apo} = 4.66''$, its ratio to a priori root mean square error was $\sigma_{apo} / \sigma_{apr} = 1.72$.

Conclusion

It is shown that in case of the comet Encke the erosion cannot be uniform. 2 scenarios are considered: accumulation of significant amount of non-volatile mass and formation of a surface crust. The formal solution of the introduced equations shows that the first scenario better explains characteristic features of transversal non-gravitational parameter of the comet Encke with time. It also predicts the upcoming termination of the comet activity. However, the second scenario cannot be eliminated either. We have found that in this case the sublimation weakening with the growing crust thickness may be closer to linear rather than exponential. In the future, our equations are going to be applied for simulation of the comet's dynamic positions.

Acknowledgements

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