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On the relationship between long-period comets and large trans-Neptunian planetary bodies

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Abstract. In the present work we investigate the possible relationship of long-period comets with five large and distant trans-Neptunian bodies (Sedna, Eris, 2007 OR_{10}, 2012 VP_{113} and 2008 ST_{291}) in order to determine the probability of the transfer of a part of these kind of comets to the inner of the Solar System. To identify such relationships, we studied the relative positions of the comet orbits and listed TNOs. Using numerical integration methods, we examined dynamical evolution of the comets and have found one encounter of comet C/1861J1 and Eris.

Keywords. TNO, LPC, close encounters

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1. Introduction

A significant number of trans-Neptunian planetary bodies (TNO), having diameters of 500 km and more have been discovered over recent years. Their quantity increases annually, also it cannot be excluded that astronomers will succeed in opening a body with a mass comparable to the masses of giant planets (Batygin & Brown 2016). Moving in a relatively dense environment – full of comet nuclei populations, these bodies can change their orbits considerably. Therefore, in the problem of comet origins, the role of these planetary bodies should not be ignored.

The present work is a logical development of the idea that part of the long-period comets (LPC) could be injected from the Kuiper belt and scattered disc via large trans-Neptunian planetary bodies. The existence of unknown bodies in those regions of the Solar System could be even predicted on the basis of regularities inherent to long-period comets. The point of the proposed comet transfer mechanism reducing to follows: there is a reservoir of comets in the trans-Neptunian region; there are a lot of large planetary bodies in that reservoir also; from time to time they are able “to throw” cometary nuclei into the region of visibility.

2. Problem formulation

If the comet is injected into the scope of a certain TNO movement zone, one of the nodes of its orbit should correspond to the zone. Hence, in this paper we investigate orbital parameters, particularly the orbit nodes of LPC regarding the orbits of the largest TNO: Sedna, Eris, 2007 OR_{10}, 2012 VP_{113} and 2008 ST_{291}. Selection of these objects conditioned by their quite big masses (diameters greater than 600 km) and long heliocentric distances that cover large intervals in the Kuiper belt and scattered disc.

In the selection of comets for our research we were guided by three main principles:

(a) Perihelion distance must be ($q > 0.1$ AU), since the interval ($q < 0.1$ AU) has a lot of "sungrazers". The origin of these comets is not a focus of our research.

(b) If the comet is fragmented into two or more parts, we consider only one of them, so removing the effects associated with the so-called "twin comets"

(c) Aphelion distances of comets must be limited below by the value of 30 AU, since only such comets could have possible encounters with TNO.

In the first phase we took orbital elements sample of 1190 LPC, satisfying the said conditions and observed prior to 2016. The relevant data are taken from the comets catalogue (Marsden 2008) and MPEC for 2008–2015. In this article, orbits of these comets are investigated regarding the plane of motion of each of listed TNO. During the calculations we select only those LPC which orbital nodes are in close proximity of the TNO orbit at relevant longitude.

On the second stage, after comets selection, their orbits are integrated backward in time by using extrapolation methods. The purpose of these computations is to determine the possible approaching of comet with TNO before their discovery.

3. Method and calculations

Applying standard methods of spherical astronomy, at the first stage we calculate orbital elements of comets relative to the plane of each TNO orbit. In so doing, the ascending node of certain planetary body's orbit stands as a reference point while calculating angular orbital elements (Guliyev 2017). Then we get heliocentric distances of near and distant nodes of cometary orbits by the formulas:

$$r_c = a_c \frac{1 - e_c^2}{1 \pm \cos \acute{\omega}} \tag{3.1}$$

where a_c and e_c – semi-major axis and eccentricity of the cometary orbit, $\acute{\omega}$ – argument of perihelion in the new reference system. Let the heliocentric distance of the cometary distant node as Λ_c.

Since we are interested only in distant nodes, we use the following formula to determine the planet's heliocentric distance at the relevant longitude:

$$r_p = a_p \frac{1 - e_p^2}{1 + e_p \cos(\omega_p + \acute{\Omega} + 180°)} \tag{3.2}$$

In equations (3.1) and (3.2) - a_p, e_p and ω_p – orbital elements of TNO, $\acute{\Omega}$ - angular value of comet's node in the plane of TNO's orbit. Let's commit variable Δ which is absolute value of difference between Λ_c and r_p: $\Delta = |\Lambda_c - r_p|$

Comets in this paper were selected on the basis of the Δ and integrated backwards. Note that minimum orbital intersection distance (MOID) Comet-TNO should not be greater than the value of Δ. For each TNO it is defined as 5% of body's average heliocentric distance. We should like to emphasize that such selection feature has purely conditional nature and not connected with any physical criteria. It is used only for narrowing the number of studied comets.

4. Integrations

To determine the dynamic link between testing TNO and LPC (in addition to kinematic link described above) we have performed a few test simulations of these objects to

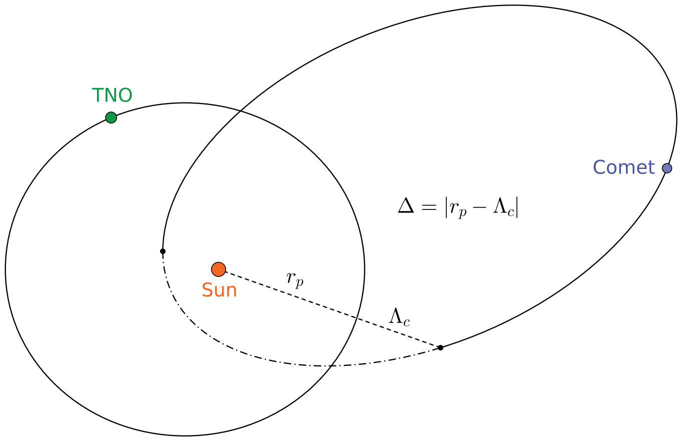

Figure 1. Schematic presentation of the orbits of comet and TNO. It also presents the values: r_p – heliocentric distance of planetary body towards a distant node, Λ_c – heliocentric distance of distant node, and also shown value of Δ.

explore their orbital evolution in the past. We faced some difficulties related to masses of TNOs. Therefore, on the basis of their dimensions, choosing some value of average density of these bodies ($2 < \rho < 3$), we were able to add them to the list of gravitating objects. Thus, our study of the orbital evolution acquiring a conditional nature.

As a result of the cometary orbits integration (Chambers 1999) on timescale of ~10000 years backwards, we found one encounter of comet C/1861J1 with Eris at the distance 0.0386 AU. This distance is comparable to the size of the TNO's influence sphere radius, which varies between 0.088 AU at perihelion and 0.198 AU at aphelion under the (Kislik 1964).

5. Discussion

Results of the calculations suggest that some part of LPC have dynamic connection with TNOs. This is primarily indicated by value of Δ. This supposition is reinforced by found real approach of comet C/1861J1 with Eris. As far as we know encounter of such kind was discovered for the first time. If we found one real encounter with TNO for selected 99 comets, this means that at least about two percent of the observed LPC could be dynamically connected with kuiper bodies. It is possible that by increasing accuracy of the initial data and applied integrator, these percentages can grow considerably. Hence, the idea about the possibility of comets transfer from the Kuiper belt and scattering disc into the visibility area via TNOs is very promising scientific challenge.

References

Batygin, K. & Brown, M. E. 2016, *AJ*, 151, 22
Marsden, B. G. & Williams, G. V. 2008, *Catal. of Comet. Orb.*, 17
Chambers, J. E. 1999, *MNRAS*, 304, 793
Kislik, M. D. 1964, *Cosm. Issl.*, 6, 853
Guliyev, A. S. 2017, *Kinem. and Phys. of Celes. Bodies.*, 33