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The distributions of angular elements of new comets

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Abstract. We point out two important effects relevant to the information which can be obtained from the distributions of galactic angular elements of new comets. (i) The commonly used criterion for a selection of new comets from a catalog of long-period comets (reciprocal original semi-major axis $a < 1.0^{-4}\,\mathrm{AU}^{-1}$) is crude as already proved by Dybczyński in 2001. It is more relevant to regard as new the comets with previous perihelion distance $q > 15\,\mathrm{AU}$. (ii) The angular orbital elements of Oort-cloud comets referred to the galactic coordinate system undergo large changes at the observed (current) perihelion passage, therefore their values are chaotic enough. Thus the information contained in the distribution of angular elements is dimmed. We suggest constructing the distributions for the elements at other epoch, e.g. for those at the previous perihelion passage.

Keywords. comets: general, Oort Cloud

1. Introduction

The dynamically new comets are those comets in the zone of visibility (ZV), which were not significantly perturbed by planets at their previous perihelion passages. They are thus unique bodies carrying information about the Oort cloud (OC). Any model of the OC can be regarded as realistic only if we can predict, on its basis, all the characteristics of new comets.

For a long time, since Oort's era, the comets with $1/a < 10^{-4}\,\mathrm{AU}^{-1}$ were regarded as new. This criterion to select the new comets is, hereinafter, referred to as the *first criterion*.

In 2001, Dybczyński demonstrated that 41 of 85 comets, classified by the above criterion as new, were significantly perturbed by the planets at their previous perihelion passage. According his analysis, new comets are those of which the perihelion distance, q, at the previous perihelion passage is $q > 15\,\mathrm{AU}$, and current perihelion is situated in the ZV. This criterion is, hereinafter, referred to as the *q15 criterion*. Since there is no *previous* perihelion passage in the case of comets in hyperbolic orbits, these have to be ignored, when new comets are selected from a sample of orbits.

In this contribution, we show that the theoretically derived characteristics of new comets can be compared with their observed counterparts only if the comets to be considered new are correctly selected, that is, if the information is extracted from orbital parameters at an epoch different from the current perihelion passage.

2. Galactic angular elements of new comets

Due to observational selection, the observed distribution of q is too much biased to be used in a quantitative analysis. On the other hand, this problem is much less severe for the observed distribution of semi-major axis, a. In the following, we shall deal with the

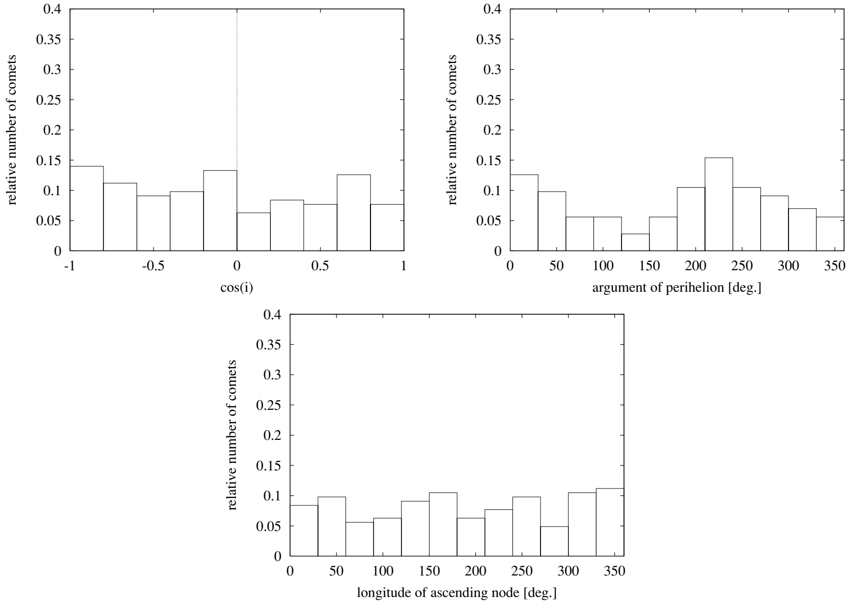

Figure 1. The distributions of dynamical galactic-coordinate-system $cos(i)$, ω, and Ω of new comets, selected from the catalog of the original orbits of long-period comets (Marsden & Williams 2003) by the $first$ ($1/a < 10^{-4}\,\mathrm{AU}^{-1}$) criterion, for the current perihelion passage.

distributions of the angular orbital elements of new comets, which appears to be a non trivial undertaking.

In Fig. 1, there are demonstrated the distributions of angular elements of new comets for the current perihelion passage. The new comets are selected from the catalog of precise original orbits of 383 long-period comets (Marsden & Williams 2003) by the first ($1/a < 10^{-4}\,\mathrm{AU}^{-1}$) criterion. (The set of precise original $1/a$ published in the catalog is completed including the original angular elements calculated by Dybczyński (private communication) utilizing the method described in (Dybczyński 2001).) 143 of total 383 long-period (LP) comets should be classified as dynamically new according to this criterion. (The catalog contains 386 original orbits of LP comets. Three of them are however suspected to be fragments of split nuclei and discarded from the used data. For more details see (Neslušan & Jakubík 2004)). We can see that the distributions of cosine of galactic inclination, $cos(i)$, and galactic ascending node, Ω, (the first and third plots) are nearly flat. No structural patterns are apparent. In the distribution of galactic argument of perihelion, ω, (the second plot), two shallow peaks, at $\omega \approx 15^o$ and $\omega \approx 225^o$, occur. Nevertheless, also this element spans through the entire possible interval of values.

Similarly, in Fig. 2, there are the distributions of $cos(i)$, ω, and Ω of new comets for the current perihelion passage, this time selected from the catalog by the $q15$ criterion. Since the comets on hyperbolic orbits have to be ignored in the case of this criterion, the set of orbits in the used data is reduced to 349 LP-comet orbits. 53 of the total 349 LP comets are classified as new according to the $q15$ criterion. Concerning the behaviors of the distributions, the same facts as for the *first* criterion can be stated: the distributions of $cos(i)$ and Ω (the first and third plots in Fig. 2) are flat with some fluctuations. The peaks at $\omega \approx 15^o$ and $\omega \approx 225^o$ (the second plot in Fig. 2) are slightly higher, but the element still ranges through the entire interval of values.

From these almost structureless distributions we can scarcely draw information. We would however like to point out that such behaviors are a consequence of the following

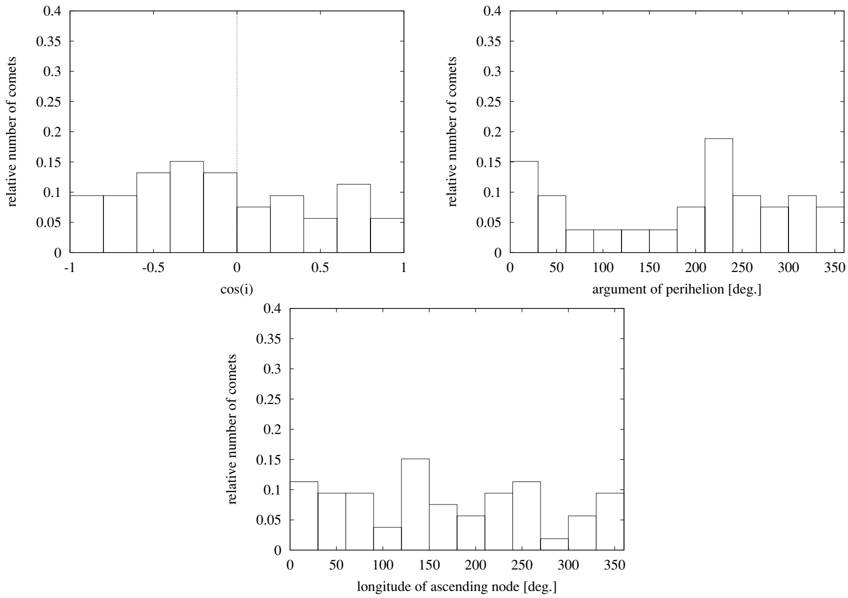

Figure 2. The distributions of dynamical galactic-coordinate-system $cos(i)$, ω, and Ω of new comets, selected from the catalog of the original orbits of long-period comets (Marsden & Williams 2003) by the $q15$ criterion, for the current perihelion passage.

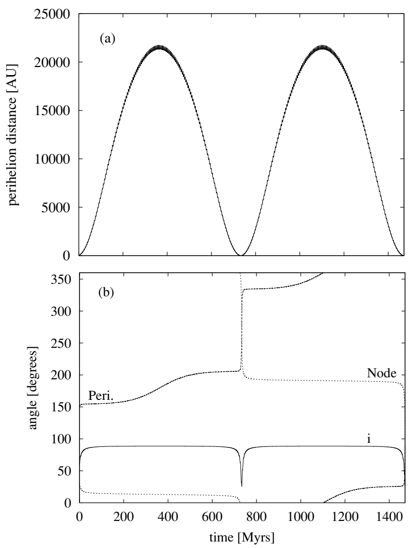

Figure 3. The evolution of perihelion distance (plot a) and dynamical-galactic-coordinate-system angular orbital elements (plot b) of a typical outer-Oort-cloud comet under an action of the Galactic tide during about two libration cycles of perihelion distance.

specific circumstance. In Fig. 3 the behaviors of perihelion distance (plot a) and angular elements (plot b) are shown for the orbit of a typical OC comet perturbed by the Galactic tide, which has been proved to be the dominant perturber reducing the cometary perihelia to the ZV (Heisler & Tremaine 1986; Morris & Muller 1986; Bailey 1986; Duncan, Quinn & Tremaine 1987; Heisler, Tremaine & Alcock 1987). The libration of q and libration/circulation of angular elements, displayed in Fig. 3, was found earlier by Heisler

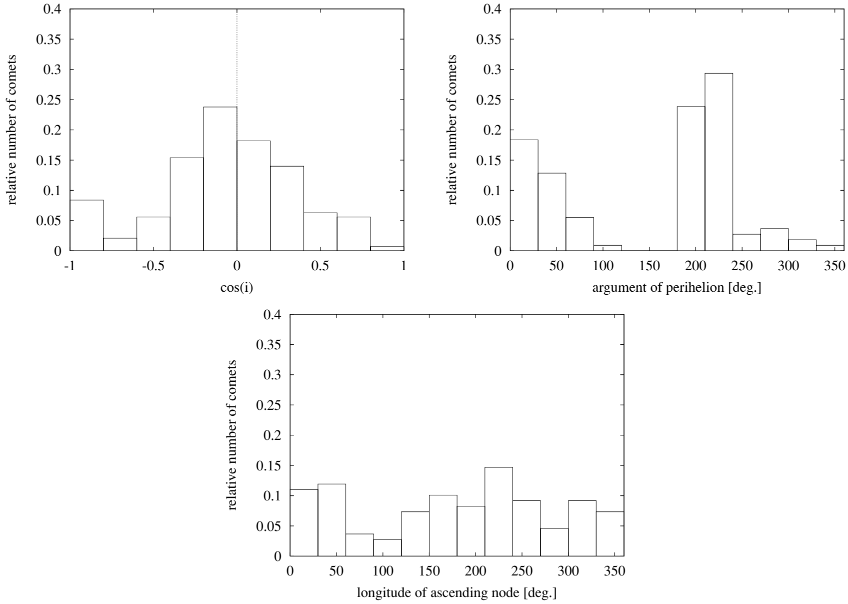

Figure 4. The distributions of dynamical galactic-coordinate-system $cos(i)$, ω, and Ω of new comets, selected from the catalog of the original orbits of long-period comets (Marsden & Williams 2003) by the $first$ criterion, for the previous perihelion passage.

& Tremaine (1986) (for a more detailed demonstration of the effect see, e.g., Pretka & Dybczyński 1994). We can see that the new comets come to the ZV in the phase of their libration cycle of q, when q is in minimum. In this phase, the angular elements are macroscopically changing and, consequently, their instantaneous distributions appear chaotic enough. A possible structure is, thus, dimmed.

Because of the bad defined values of the angular elements in the period of the current, i.e. observed perihelion passage, it is necessary to construct their distribution for some other time. Since we anyway have to compute the values of elements for the previous perihelion passage in the case of $q15$ criterion, we suggest constructing the distributions just for the previous perihelion passage.

In Fig. 4, we can see the distributions of angular elements of new comets, selected from the catalog of original orbits of LP-comet original orbits by the $first$ ($1/a < 10^{-4}\,\mathrm{AU}^{-1}$) criterion, for the previous perihelion passage. 109 of total 349 LP comets are classified as new according this criterion, by using the elliptical orbits at the previous perihelion passage. In the $cos(i)$ distribution (the first plot), a central peak, at $cos(i) \approx 0$, is apparent. A lower peak can be seen at $cos(i) \approx -0.9$: we can guess it is just a fluctuation. The peaks at $\omega \approx 15^o$ and $\omega \approx 225^o$ in the ω distribution (the second plot) are significantly higher than in the corresponding distributions for the current perihelion passage. There are only few comets having ω very different from these two values. The nearly flat behavior is conserved in the distribution of Ω, but the real behavior of this element is the least variable.

A single, high central peak also appears in the distribution of $cos(i)$ of the previous-perihelion-passage orbits constructed for new comets selected by the $q15$ criterion (the first plot in Fig. 5). In the distribution of ω (the second plot in Fig. 5), the cometary arguments of perihelia are clearly concentrated in the already noticed peaks at $\omega \approx 15^o$ and $\omega \approx 225^o$, when $q15$ criterion is applied. With one exception, there are no observed new comets having ω in the ranges from 90^o to 180^o and from 270^o to 360^o.

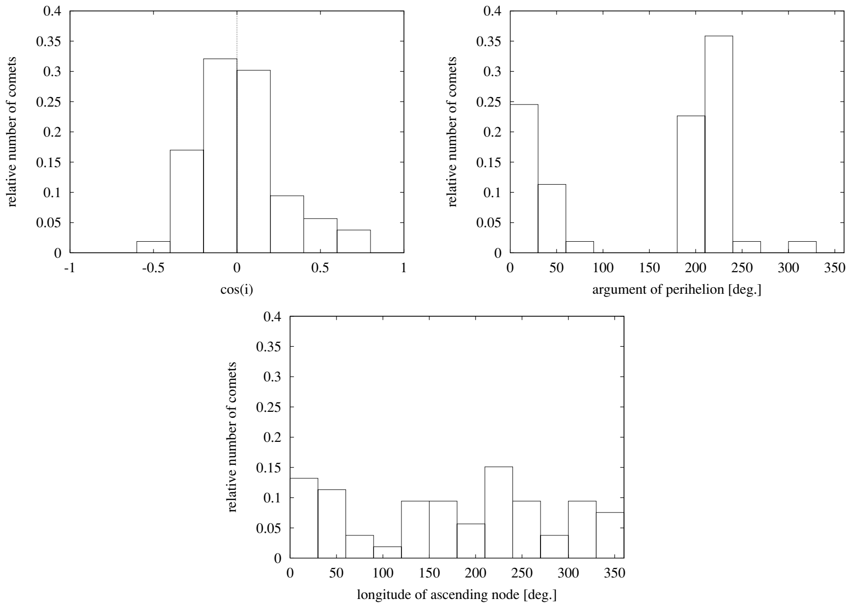

Figure 5. The distributions of dynamical galactic-coordinate-system $cos(i)$, ω, and Ω of new comets, selected from the catalog of the original orbits of long-period comets (Marsden & Williams 2003) by the $q15$ criterion, for the previous perihelion passage.

In conclusion, the measure and quality of information obtained from the distributions of angular elements of new comets depend on the particular choice of the criterion for a selection of new comets from a catalog of orbits of LP comets as well as on the choice of q-libration-cycle phase, in which the distributions are constructed. This is clearly documented by comparing the first plot in Fig. 1 with the first plot in Fig. 5 ($cos(i)$) and the second plot in Fig. 1 with the second plot in Fig. 5 (ω). In the case of Ω (the third plots in Figs. 1 and 5), the difference is small, obviously due to fact that the real distribution of this element is nearly flat.

It is necessary to note that our result has to be affected by the uncertainty of the original $1/a$. (The values of the other elements are not exact either, but their uncertainty is insignificant is the given context.) This is clearly indicated by the presence of hyperbolic $1/a$ in the used sample. The hyperbolicity has been interpreted as an error in the determination of $1/a$. As a result of the determination error, we may have classified, by the first criterion, some orbits with real $1/a \geqslant 10^{-4}\,\mathrm{AU}^{-1}$ as new. Similarly by using the $q15$ criterion, some comets in the ZV with the calculated previous $q > 15\,\mathrm{AU}$ could have their actual $1/a$ larger and, consequently, the actual current $q < 15\,\mathrm{AU}$. So, these comets could be classified as new, but they were not new in fact. To estimate a possible significance of this effect, we also repeated the construction of all distributions using only higher quality, class 1, orbits published in the used catalog (Marsden & Williams 2003). Though some small quantitative differences occurred, the same qualitative conclusions could be drawn from the corresponding series of graphs. (Unfortunately, the sample of class 1 orbits is less numerous than the entire sample, therefore a more reliable result is not warranted, despite of a higher quality.) The qualitative correctness, at least, of our conclusions is also supported by the appropriate shape of the $cos(i)$ and, especially, of ω distributions. The determination error is expected to cause some random fluctuations and, thus, a more dispersed behavior of whatever dependence. On contrary, we proceeded from the dispersed behaviors on Figs. 1ab and 2ab to much less dispersed behaviors on

Fig. 5ab. The absence of any comet in the intervals $\omega \in (90^o, 180^o)$ and $\omega \in (270^o, 360^o)$ (with one exception) in Fig. 5a can scarcely be any effect of the orbit determination error with its random character.

3. Summary

The best currently available criterion to choose new comets from a catalog is to require that their original-orbit perihelion distance q at the previous perihelion passage was $q > 15$ AU.

The distributions of angular elements of new comets can provide a usable information only if they are constructed for the elements at an epoch different from the current (observed) perihelion passage. We suggest to construct them for the previous perihelion passage (as the orbital elements for the previous perihelion passage must be computed anyway).

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