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The "Memory" of the Oort cloud

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Abstract

Long term simulations of two proto-Oort clouds have been performed. The first shape was initially isotropic and fully thermalized and the second one was a disk-like shape. The aim of our study was to investigate how a memory of these initial shapes can be identified in the sample of observable long period comets. Our main result is that considering the orbital elements of the observable comets at the perihelion preceding the observable perihelion, some features are clearly related to a memory of the initial disk-like shape since they are no present for the isotropic case. Future works will be devoted to the extraction of these hidden informations from the sample of known long period comets.

1. Introduction

The formation of the Oort cloud is still an open question. Two main scenarios are proposed: a cloud formed by the stellar scattering while the Sun was still in the cluster where it was born (e.g. [3, 1, 5]), and a Oort cloud formed by planetary scattering (e.g., [7, 2]). The former kind of scenarios would preferentially built a proto-Oort cloud that is fully thermalized, whereas the second one built a proto-Oort cloud with a disk-like shape. Two such simplified proto-Oort clouds were thus considered for the present study.

In Sec. 2 a brief description of our simulations is made. Section 3 is devoted to our main results and the conclusions are made in Sec. 4.

2. Simulations

Our first proto-Oort (isotropic model) cloud has fully thermalized shape with semi-major axis between 500 and 50 000 au and perihelion distance greater than 15 au; and the second one (disk model) has a disk like shape with semi-major axis between 500 and 20 000 AU, perihelion distances between 3 and 45 au from the Sun and ecliptic inclinations between 0 and $20°$. In both cases the orbital energy and other distribution are uniform (except for q for the thermalized shape).

Each sample contains more than 10^7 comets. Each comet is propagated during a maximum time of 5 Gyr, or impact the Sun or a planet, goes at more than 400 000 au from the Sun or has a semi-major axis smaller than 100 au. The effect of galactic tides, passing stars and giant planets are taken into account.

Five final snapshots regularly spaced between 3.75 and 4.75 Gyr are made. After each snapshot a quiescent period of 30 Myr where we take care that no comets shower arises is performed. Then for each comet, the first perihelion passage after the quiescent period is considered. If this passage is made at less than 5 au from the Sun and the "original" semi-major axis, i.e. the barycentric semi-major axis at 200 au from the Sun before perihelion, is greater than 10^4 au, then the comet is counted as a "new" observable comets.

Four class of observable comets are considered: if the previous perihelion distance was beyond 10 au the the comet is a *Jumper*, otherwise it is a *creeper*. In addition, in the case where the original orbital energy $z = -1/a$ has increased for more than 10^{-5} au^{-1} from just before the previous perihelion passage, then the comet is also called a Kaib-Quinn comet (jumper or creeper) [6].

3. Results

Statistical results are shown on Tab 1. The main differences are: (i) the flux is four times greater for the disk model rather than for the isotropic model, (ii) the KQ-creeper are more numerous for the istropic model rahter than for the disk model, which is caused by the fact that such class of comet prefers retrograde orbit [4], and (iii), related to the previous point, the isotropic model produces more retrograde orbit than the disk model, mainly for the moderated original semi-major axis where KQ-creepers are creepers are coming from.

mod	set	p-f	ret (%)	$a_{0_{\rm min}}$	$a_{\rm med}$	$a_{0_{\rm max}}$
D	total	3.8	49.6	10.2	28.9	-235.6
	j	38,1	49.5	20.1	36.5	-235.6
	kqj	23.2	33.6	26.4	30.2	65.7
	c	11.3	67.9	10.2	18.5	46.6
	kqc	27.4	55.7	10.6	22.5	74.5
I	total	1.0	58.6	10.9	26.9	-144.0
	j	25.3	52.1	20.1	37.0	-144.0
	kqj	21.1	41.7	21.4	29.4	83.1
	c	9.7	71.6	10.9	15.7	35.3
	kqc	43.8	67.6	11.0	22.0	48.1

Table 1: Column “p-f" gives the flux per year considering a initial population of 10^{12} comets for the “total" line (given by the “set" column), otherwise it gives the proportion of the observable class (given by the “set" column) . Column “ret" gives the proportion (in percent) of retrograde orbits for each set. Columns $a_{0_{\rm min}}$, $a_{\rm med}$ and $a_{0_{\rm max}}$ gives respectively the minimal, median and maximal values of the original semi-major axis for each set of observable comets (unit is 1000 au).

On Fig. 1 an additional fundamental difference is observed on the distribution obtained from the KQ-jumpers. Indeed for the disk model this class of comets are concentrated toward the ecliptic plane (max. of $\cos i$ in 1 and max. of Ω close to $180°$) whereas such a concentration is not observed for the isotropic model. This is the class of comets for which the memory of the initial shape is stronger.

4. Conclusions

We have show that some characteristics of observable “new” long period comets are directly related to the initial shape of the Oort cloud. Future work will be devoted to the identification of such fingerprint in the sample of known long period comets.

Acknowledgements

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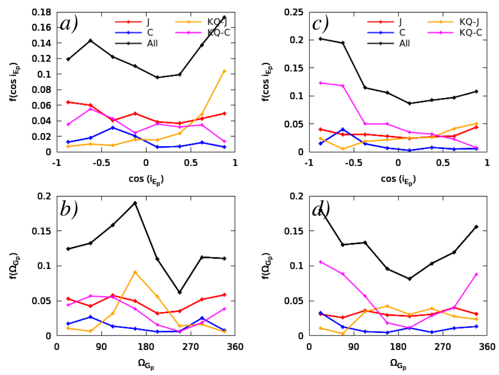

Figure 1: Distributions of $\cos i$ (where i is the ecliptic inclination) for the disk (panel a) and the isotropic (panel c) models and distributions of galactic longitude of the ascending node Ω for the disk (panel b) and the isotropic (panel d) models. All elements are original element for the perihelion preceeding the observable one. Black line is for all the comets, red, orange, blue and magenta are for jumpers, KQ-jumpers, creepers and KQ-creepers respectively.

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