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On the missing interstellar comets

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Abstract : Comets are supposed to have been born in the outer part of the solar nebula and later thrown into their present location of the Oort cloud by the perturbation of the giant planets. This process was inefficient and a majority of the comets were totally lost into the interstellar medium, instead of being trapped in the Oort cloud. Assuming stars in the solar neighbourhood to have formed in the same way as the sun, one can find the number of interstellar comets and also estimate the expected number of detectable interstellar comets (McGlynn & Chapman 1989). In this work, using our present day knowledge of the local interstellar medium, we first calculate the population of interstellar comets. Then these calculations, combined with the detection probability and velocity distribution of the comets, as have been outlined by McGlynn & Chapman (1989), we show that the expected number of detectable interstellar comet per century is less than one. Thus the nondetection of interstellar comets within the past 150 years or so, is therefore nothing unusual and fully consistent with the existing models of the Oort cloud and solar system formation.

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1. Introduction

The subject of interstellar/ extrasolar comets, is drawing increasing attentions from the astronomers in recent days. After the pioneering work by Oort (1950), it was established that the new comets that visit the solar system are actually thrown from a spherical reservoir of comets (at a distance of 50,000 AU from sun), now known as the Oort cloud, by the perturbation of nearby passing stars. According to the current models, comets are born along with the outer planets in the outer solar nebulae. After their formation the comets were thrown into their present location of Oort cloud, by the perturbation of giant planets like Jupiter and Saturn. Different calculations and simmulation works, (Safronov 1972, Shoemaker & Wolfe 1984 ; Duncan et al. 1987; Bailey & Stagg 1988; Bailey et al 1990; Heisler 1990; Weissman 1990; Chakraborty 1992 etc.) show that the ejection processes were efficient only to an extent of a few percent to inject the comets into the Oort cloud. The majority of the comets were thrown into the interstellar medium. If we assume that the physical process, that led to the formation of sun as a star along with the planets, is a typical star formation process, the other stars are also expected to possess planets and comet like bodies. Those stars also had to lose majority of their pool of comets into the interstellar medium.

The net outcome will be a separate population of interstellar comets, around the sun, in addition to our own comets in the Oort cloud. The question naturally arises, can we detect such interstellar comets, when they pass through our solar system ? An interesting calculation by McGlynn & Chapman (1989), showed that over the last 150 years, we should have detected six interstellar comets, which can be distinguished by their hyperbolic orbits. But as we have not seen a single interstellar comet yet, according to them, it can give rise to several interesting questions, like , 'Solar system like ours is a typical or not ?'

Probably, the nondetection of interstellar comets till now has been established beyond doubt (Please see a recent work by KresáK 1992 and references therein). Whereas we feel problems related to the calculation of expected flux of interstellar comets, can be readdressed. In this work we attempt to calculate the expected flux of interstellar comets, mostly in the line of McGlynn & Chapman (1989). However, we feel since our knowledge on the local neighbourhood of sun, is getting clearer everyday it may be worth to readdress the above problem, with the latest part of the input data.

2 The expected number of interstellar comets

The comets after their formation in the outer solar nebula, were thrown in to their present location of Oort cloud, by the perturbation of large planets like Jupiter and Saturn. But as this process was inefficient, a majority of the comets escaped into the interstellar medium instead of being trapped in the Oort cloud. From a comparative study of the different models (Safronov 1972 ; Shoemaker & Wolfe 1984; Duncan et al. 1987), McGlynn & Chapman (1989), concluded that to every comet in the Oort cloud, there should be 30 -100 comets in the interstellar medium.

Oort cloud probably contains $2 * 10^{12}$cometary nuclei (Weissman 1983, 1985). Therefore the contribution of sun (or for that matter any star) will be 10^{14} comets in the interstellar medium.

Therefore density of comets $\rho_{comet} \sim 10^{14}\rho_{star}$.

Uptil now we were following the prescription laid by McGlynn & Chapman (1989). The problem lies now in finding out the density of stars in the solar neighbourhood. McGlynn and Chapman (1989), used a value of $0.1 M_{\odot} pc^{-3}$ for ρ_{star}.

We feel the above value of ρ_{star} is an overestimation, because of the following reasons discussed in the next section.

3. The matter distribution around the sun

The distribution of matter in the solar neighbourhood has been worked out by several authors (Bahcall 1986, Gould 1990, Kuijken & Gilmore 1991, Rana 1991, Basu & Rana 1992, Rana & Basu 1992). For consistency we stick to the most recent work by Rana & Basu (1992).

Their work shows, if we consider stars within the mass range $.09 - 100 M_{\odot}$, then we have in the local Galactic disk $41.1 M_{\odot} pc^{-2}$ mass in the form of stars. This corresponds to 117 individual stars in $p\bar{c}^2$ of galactic disk. Out of 100 stellar systems (including single star, binaries triple and quadruple system) containing 161 individual stars, there are only 51 single stars (Duquennoy 1988, see also Basu & Rana 1992). Now we argue that stars which are a part of binary, triple or quadruple systems, cannot have Oort cloud like our sun. We should consider only those stars which are single. Therefore, we get from the above,

the average mass for individual star $\frac{41.2}{117} = 0.35\ M_{\odot}$;

total number of single stars $117 * \frac{51}{161} \sim 37 p\bar{c}^2$;

mass contained in the total number of single stars $\sim 13.0 M_{\odot} p\bar{c}^3$

We approximated the actual model (Basu & Rana 1992, Rana & Basu 1992), for the vertical distribution of main sequence stars with an exponential law (corresponding to an isothermal disk approximation) having 480 pc as its vertical scale height. As a result we can find out, volume density of single stars $37/(2 * 480) \sim 0.039\ \ p\bar{c}^3$ near the mid-plane of the galaxy.

Therefore, total mass in the single stars $\sim 0.014 M_{\odot} p\bar{c}^3$

that is, $\rho_{star} \sim 0.014 M_{\odot} p\bar{c}^3$ (considering only single stars)

At this stage we make an assumption, that number of comets in the Oort cloud (and those thrown into the interstellar medium by a star) should be proportional to the mass of the star. Therefore, the density of the interstellar comets should be

$$\rho_{comet} = 10^{14} * \rho_{star} = 1.4 * 10^{12} \text{comets } p\bar{c}^3$$

4. The rate of encounter and detection

For the calculation on the rate of encounter of the interstellar comets, we adapt the procedure directly from McGlynn & Chapman (1989) :

intrinsically hyperbolic (interstellar) or not? These studies will surely open new windows into, the research on the formation of solar system and distribution of matter in the solar neighbourhood.

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