ENCOUNTERS OF THE SUN WITH NEARBY STARS IN THE PAST AND FUTURE

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Abstract. The relative space motions of the Sun and nearby stars are considered. The coordinates and velocities of the stars are taken from the Catalogue of Nearby Stars by Gliese and Jahreiss (1991). The minimum space separation between the Sun and every star as well as the corresponding moment of time are calculated by two ways. Firstly, the straight line motions are considered. Secondly, the effect of the Galaxy potential is taken into account. The Galaxy model proposed by Kutuzov and Ossipkov (1989) is used. Twenty five stars approaching the Sun closer than two parsecs are selected. The effects of the uncertainties in the observational data are studied. The influence of the encounters to the Oort cloud is discussed.

Key words: Solar neighbourhood, Oort comet cloud

1. Introduction

The large sudden changes of the terrestrial climate could bear evidence of some possible cosmic catastrophes encountered by the Earth. One of the hypothetical reasons for such events is a close passage of a nearby star by the solar system. The encounters could initiate a shower of comets with small perihelia. A collision of the Earth with such a comet may lead to the catastrophic transformation of the climate. The cometary shower forming after a star’s passage acts during $\sim 10^6$ years of the passage of the star. Thus it is of interest to trace the mutual trajectories of the nearby stars and the Sun during a short time (e.g. about $10^8$ years) to the past and to the future.

2. Observational Data and Results

We consider the nearby stars from the Preliminary Version of the Third Catalogue of the Nearby Stars by Glicse and Jahreiss (1991). The stars with known heliocentric space velocities $U$, $V$, $W$ are taken into account (1946 stars). Here the vector $U$ is directed to the galactic center, $V$ in the direction

of the galactic rotation, and $W$ to the Northern Galactic Pole. The coordinates and velocities of the stars have been calculated in the galactocentric reference frame.

Firstly, we consider the straight line motions of every star with respect to the Sun. We found the shortest distance $r_{\text{min}}$ from the Sun to this line and the corresponding moment of time $t_{\text{min}}$. The stars with $r_{\text{min}} < 2$ pc have been selected. The results for these 25 stars are presented in Table I. The values of $r_{\text{min}}$ are given in $10^3$ astronomical units; the times $t_{\text{min}}$ are in $10^3$ years. The Sun may have had encounters with three of these stars in the past and can have encounters with another 22 stars in the future.

A similar study was carried out by Revina (1988) who used the data from the previous version of the Catalogue of Nearby Stars (Gliese 1969). She found 25 stars (6 for the past and 19 for the future) having the close (less than 2 pc) encounters with the Sun. Ten stars from her list are the members of our sample. These stars are marked by an asterisk in Table I. Some of the disagreements of values $r_{\text{min}}$ and $t_{\text{min}}$ could be explained because the data is more precise in the new Catalogue. A similar study was also recently carried out by Matthews (1994). He has considered the stars from the solar neighbourhood with radius 5 pc. For a few stars he used slightly different initial conditions. Our results are in agreement with his results for the same stars.

We have taken into account the effect of the errors in the velocities $U$, $V$, $W$ and in the parallaxes $\pi$ to the values of $r_{\text{min}}$ and $t_{\text{min}}$. A Monte Carlo method was applied to estimate the expectations and r.m.s. deviations of $r_{\text{min}}$ and $t_{\text{min}}$ for 25 stars mentioned above. We varied the additions to the input values $U$, $V$, $W$, and $\pi$ by a Gaussian distribution with expectation equal to zero and dispersion $\sigma = 3$ km/s for the velocities and corresponding errors from the Catalogue for the parallaxes. The values of the expectations $\langle r_{\text{min}} \rangle$ and $\langle t_{\text{min}} \rangle$ as well as r.m.s. deviations $\sigma_r$ and $\sigma_t$ are also given in Table I.

Secondly, we consider the movements of the stars in the model Galaxy by Kutuzov and Ossipkov (1989). The distance of the Sun from the galactic center is adopted $R_0 = 8.23$ kpc and the height of the Sun upwards the galactic plane is $z_0 = 0.015$ kpc. The circular velocity at the solar distance $R_0$ is assumed $V_0 = 226$ km/s. The components of the solar motion are $U_0 = +8$, $V_0 = +12$, $W_0 = +7$ km/s. We have integrated the equations of the motion of the Sun and of each star from 1946 stars with known space velocities during $10^8$ years forwards and to the past. We neglected the interaction between the stars and the Sun, as well as the influence of the irregular forces. Corresponding values of $r_{\text{min}}$ and $t_{\text{min}}$ are presented in Table I too.

The two methods are in a good qualitative agreement: the same stars were selected by each of the methods. Also the less is the error of the parallax the