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Probabilities of collisions of planetesimals with exoplanets in the Proxima Centauri planetary system

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Schwarz et al. [1] studied migration of exocomets in the Proxima Centauri system. Besides the exoplanet with a semi-major axis a_1=0.0485 AU located in a habitable zone, they also considered the second exoplanet with a semi-major axis a_2 from 0.06 to up to 0.3 AU (for test calculations up to 0.7 AU). Now it is considered [2,3] that the semi-major axis of the second planet equals to 1.489±0.049 AU.

In the first series of calculations, according to [2], I considered a star with a mass equal to 0.122 of the solar mass, and two exoplanets with the following semi-major axes and masses: a_1=0.0485 AU, a_2=1.489 AU, m_1=1.27m_E and m_2=12m_E, where m_E is the mass of the Earth. For the first exoplanet, the initial eccentricity e_1 and initial inclination i_1 were considered to be equal to 0, and the initial eccentricity e_2 of the second exoplanet was considered to be equal to 0 or to 0.1. The calculations were made for initial inclination of the second exoplanet $i_2=e_2/2$=0.05 rad and for $e_2=i_2$=0. For interest, I also considered i_2=152°, such calculations characterize the case when orbits of planetesimals were inclined to the orbit of the planet. In the second series of calculations, according to [3], I considered a_1=0.04857 AU, e_1=0.11, m_1=1.17m_E, a_2=1.489 AU, e_2=0.04, m_1=7m_E. I supposed $i_1=i_2$=0. In both series of calculations, the density of the first and second exoplanets were considered to be equal to densities of the Earth and Uranus, respectively.

In different calculation variants, initial semi-major axes a_b of planetesimals were in the range from a_{min} to $a_{max}=a_{min}$+0.1 AU, with a_{min} from 1.2 to 1.7 AU with a step of 0.1 AU. Initial eccentricities e_b of planetesimals were equal to 0 or to 0.15 for the first series of calculations, and e_b=0.02 for the second series of calculations. Initial inclinations i_b of the planetesimals equaled to $e_b/2$ rad. 250 planetesimals were considered in each calculation variant. The motion of planetesimals and exoplanets was calculated with the use of the symplectic code from [4]. Based on the obtained arrays of orbital elements of migrated planetesimals and exoplanets stored with a step of 100 yr, I calculated the probabilities of collisions of planetesimals with the exoplanets. The calculations were made similar to those in [5-7], which had been made for the planets of the solar system, but for different masses and radii of a star and exoplanets.

The probability p_1 of a collision of one planetesimal, initially located near the second exoplanet, with the first exoplanet was 0 in most calculations for both series. For the second series, p_1 about 0.01-0.02 at a_{min}=1.2 and a_{min}=1.3 AU. For the first series, only at $i_2=e_2/2$=0.05 rad and e_b=0.15 the values of p_1 were considerable and could exceed 0.1 at time T=10 Myr, i.e. they were much greater than the fraction (less than 10^{-5}) of planetesimals from the zone of the giant planets collided with the Earth [8].

For $i_2=e_2=0$ and $e_b=0.15$, the values of the probability p_2 of a collision of one planetesimal, initially located near the second exoplanet, with this exoplanet were about 0.06-0.1. For $i_2=e_2/2=0.05$ and $e_b=0.15$, p_2 was about 0.02-0.04, i.e. it was less than p_1. For the second series of calculations, p_2 was about 0.1-0.2 at T=5 Myr, exclusive for $p_2=0.5$ at $a_{min}=1.7$ AU and for $a_{min}=1.4$ AU when p_2 exceeded 1 already at T=1 Myr. The fraction of ejected planetesimals for the second series at T=5 Myr was between 0.6 and 0.8 at $1.5 \le a_{min} \le 1.6$ AU.

For both series of calculations, the ratio of planetesimals ejected into hyperbolic orbits usually exceeded the number of planetesimals collided with the planets by at least a factor of 4 if the number of planetesimals decreased by a factor of several. Only at $a_{min}=1.4$ AU this ratio was less than 1. In some calculations a few planetesimals could be left in elliptical orbits after 100 Myr. For $i_2=152^o$, $e_2=0$, and T=10 Myr, the values p_2 were about 0.02 at $e_b=0$ and about 0.02-0.05 (the range is for different values of a_{min}) at $e_b=0.15$. There was a small growth of p_2 after 10 Myr. For $i_2=152^o$, $e_2=0.1$, T=10 Myr, the values of p_2 were very small at $e_b=0$ and were about 0.01-0.05 (the range is for different values of a_{min}) at $e_b=0.15$.

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