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Habitability of planets in the TRAPPIST-1 system: a potential role of planetesimals

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Abstract

This work examines possibility to deliver water from an asteroid-like planetesimal belt to the planets in TRAPPIST-1 system. We perform a set of numerical simulations of dynamical evolution of planetesimals in order to access efficiency of material transport from the belt to the planets. Our results suggest that significant amount of water could be efficiently delivered to the planets, primarily to Trappist-1b, Trappist-1g and Trappist-1h planets. The source region is however limited to a small chaotic part of the planetisimal belt, because the non-gravitational forces are generally inefficient in the TRAPPIST-1 system. For these reasons water delivery should happen in an early phase of the system.

1. Introduction

The TRAPPIST-1 system, with seven Earth-like planets, was discovered in 2016 using TRAnsiting Planets and PlanetesImals Small Telescope [4, 5]. The main question that arised at this point was is any of these planets habitable. In this respect, the key is a possible presence of water in the planets in TRAPPIST-1 system. Numerical simulation of transit timing variations [6] using newly determined masses and radii estimated composition of each planet. Grimm et al. found that planets Trappist-1c and Trappist-1e are almost completely rocky, while on Trappist-1b, d, f, g the existence of surface envelope is possible. Moreover, it was determined that three of seven planets - Trappist-1e, Trappist-1f and Trappist-1g - are placed in the Habitable Zone around Ultra cool dwarf star [11].

If the water is present on the planets in the TRAPPIST-1 system, how it could be delivered there?

Kilometer-size objects are residuals of planet formation [7], regardless of the mechanism of their creation. Transport of such objects through the Solar System was shown to be possible mechanism of water delivery to the inner of the Solar System [10]. The same idea could also work in other planetary systems. Similar possibility for the TRAPPIST-1 planetary system was tested by Kral et al. [8]. These authors found that volatile materials may be delivered to the planets by comet-like planetesimals from an hypothetical cold belt. Here we build upon the same idea, but we consider possible transport from an asteroid-like planetesimal belt.

2. Numerical simulations

We performed numerical simulations using „*Mercury*" software package [1]. Our model consists of seven planets of TRAPPIST-1 system and a planetesimal belt with 20000 massless objects, located at 0.07-0.20 AU from the host star. Inner border of the belt was selected to correspond approximately to the location of snow line, because objects of interest are planetesimals that contain some volatile materials. Although in the simulations there were only 20000 planetesimals, the final estimates are obtained using more realistic number of objects, determined based on the mass of protoplanetary disk, and assuming the size distribution of planetesimals is given by the exponential law:

$$N(>D) = N_{\rm t} D^{-\alpha}, \qquad (1)$$

with the exponent $\alpha = 1.43$ for $D < 100$ km and $\alpha = 2.5$ for $D > 100$ km [13].

Finally, for each planetesimal is assumed to be 5% made of water [3].

3. Results

Number of close approaches between planets and planetesimals is shown in Fig. 1). An exponential trend of decreasing a number of close approaches in time is clearly visible. This suggests the rapid emptying of the source region of potential impactors. Most of the object that had close approach with planets came from the narrow region of planetesimal belt, located close to its inner border (0.07 - 0.10 AU). Generally, only mean motion resonances 1:2 and 2:3 with planet Trappist-1h play an important role in dynamical evolution. Results for „Half-life" have shown that emptying of region of potential impactors should happen in a few Myr.

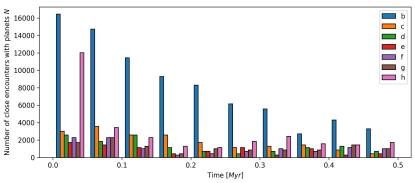

Figure 1: Histogram of number of close approaches between planetesimals and planets as a function of time.

In this model planets Trappist-1b, Trappist-1g and Trappist-1h have received significant amount of water, over 50% of current Earth's water volume. Since the planet Trappist-1g is in the habitable zone, it is expected that the water delivered to this planet might be in liquid state.

4. Conclusion

Efficient transport of water-bearing planetesimals from the belt, similar to the asteroid belt in our Solar System, is possible to the planets Trappist-1b, Trappist-1g and Trappist-1h. Other planets in the system which may get over 10% of Earth's water, are Trappist-1d and Trappist-1f. Only small amount of water may be delivered to planets Trappist-1c and Trappist-1e. Interestingly, study by Grimm et al [6] suggest that the latter are rocky planets without water.

Considering the insignificant role of the Yarkovsky effect in TRAPPIST-1 system, after the initial stages of system evolution, the water transport becomes inefficient, but at the same time the planets become safe from possible catastrophic impacts.

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