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Constraints of habitability for the young Earth in a highly eccentric orbit

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Abstract. Thousands of planets outside the Solar system have been discovered, with exoplanets in different environments. Since we cannot expect to find an exoplanetary system fully resembling our Solar System, we consider a Solar System type configuration where the Earth moves in an eccentric orbit. We focus on young Earth 1 billion years ago, when the Sun's extreme UV (EUV) flux was about 5 times higher than the current radiation. In case of eccentric motion of Earth, strong variations of the EUV flux would influence the evolution of the planet's atmosphere (EUV radiation of 50 times the current EUV flux would be possible). Taking into account a certain amount of Nitrogen in the atmosphere of such a young Earth, we study the non-thermal loss of N2 over a long time interval. We therefore investigate to what extent eccentric motion will influence the conditions of habitability of a terrestrial planet.

Keywords. Young Earth, eccentric motion, EUV flux, Nitrogen loss

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1. Introduction

Pilat-Lohinger *et al.* (2008a) & (2008b) investigated the dynamical evolution of various solar system like configurations. These studies showed that the Sun's habitable zone (HZ) is mainly perturbed by the gravitational interaction of Jupiter and Saturn. Uranus and Neptune do not have a significant influence due to their lower masses. Consequently, it is possible to reduce the planetary system of Jupiter-Saturn like configurations. In Pilat-Lohinger *et al.* (2008a) it can be seen that not all Jupiter-Saturn pairs would lead to a nearly circular orbit for an Earth at 1 au. Contrariwise, it was found that strong variations in the orbital eccentricity could arise with a maximum eccentricity up to nearly 0.7 (see Pilat-Lohinger (2015)) which might change the conditions for habitability significantly. Especially, the evolution of the young Earth could be endangered when the young Sun is still more active, causing a higher extreme UV (EUV) flux which might spoil the planet's atmosphere.

2. EUV flux and Nitrogen loss for an Earth in eccentric motion

Tu *et al.* (2015) showed that the early Sun can follow different activity tracks which might influence the evolution of a planet since the planets form during this phase. If we consider an early time of the solar system (e.g. at 3.5 Gyrs) where the activity tracks of the Sun converged already and the atmosphere of Earth contained Nitrogen. Considering the case that strong gravitational perturbations cause eccentricity motion of the Earth

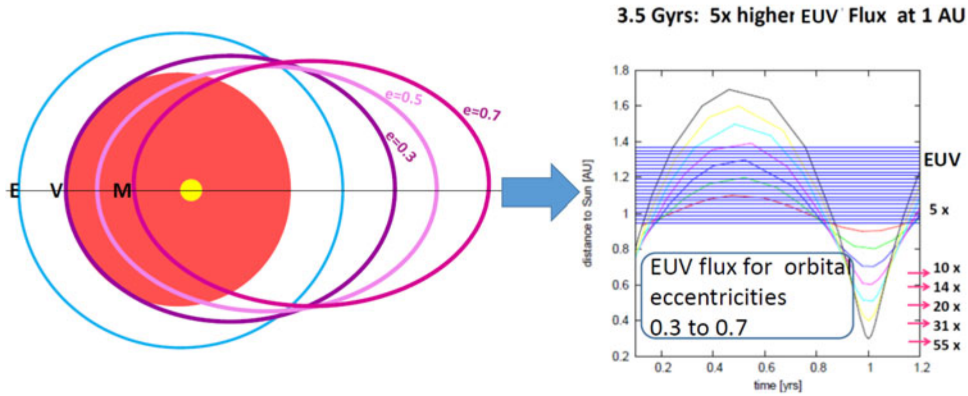

Figure 1. Eccentricity motion of an Earth-like planet at 1 au: left panel shows that the planet enters the "red" region with higher EUV flux when $e > 0.3$. Right panel shows the distance of the planet to the Sun over one orbital period for different eccentricities represented by different colours: 0.1 (red), 0.2 (green), 0.3 (blue), 0.4 (magenta), 0.5 (light blue), 0.6 (yellow) and 0.7 (black). The blue area lables the HZ (as defined by Kasting *et al.* (1993)). The EUV flux inside the red area (left panel) is indicated at the right side of this panel.

we studied the Nitrogen-loss due to the high EUV flux when the planet approaches the Sun. Simulations of exopheric clouds assuming a Nitrogen dominated atmosphere (Kislyakova *et al.* (2018)) based on the study by Tian *et al.* (2008) indicated the following features: (i) A higher EUV flux heats up the atmosphere efficiently, (ii) the lower atmosphere expands to high altitudes then consequently (iii) the exobase is located at very high altitudes. Consequently, high exobase altitudes lead to intense interactions between the stellar wind and the atmosphere so that severe consequences for the evolution of this planet can be expected. A detailed study thereto is in progress.

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References

Kasting, J. F., Whitmire, D. P., & Reynolds, R. T. 1993 *Icarus*, 101, 108

Kislyakova, K. G., Holmström M., Odert, P., Lammer, H., Erkaev, N. V., Dorfi, E., & Güdel, M. 2018 *A&A*, 2018 in prep.

Pilat-Lohinger, E., Süli, A., Robutel, P., & Freistetter, F. 2008, *ApJ*, 681, 1639

Pilat-Lohinger, E., Robutel, P., Süli, A., & Freistetter, F. 2008, *CeMDA*, 102, 83

Pilat-Lohinger 2015, *IJAsB*, 14, 145

Tian, F., Kasting, J. F., Liu, H.-L., & Roble, R. G. 2008, *Journal of Geophys. Research (Planets)*, 113, E05008

Tu, L., Johnstone, C. P., Güdel, M., & Lammer, H. 2015 *A&A*, 577, L3