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Habitable Zones in Binary Stars

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Abstract

Even though considerable efforts have been spent on investigating the extent of Habitable Zones (HZs) in single star systems ([1], [2] and references therein), regions where Earth-analogues could harbor liquid water on the surface in and around binaries have been treated mainly from a dynamical point of view (e.g. [3]). We present analytical estimates for a variable stellar radiation field and the extent of possible HZs in binary star systems as a function of the binaries' orbital elements, as well as numerical predictions on the actual amount of radiation arriving at an orbiting planet.

Introduction

The interaction of stellar radiation with the planetary atmosphere can be considered the dominating factor for habitability on terrestrial planets. Consequently, a good modeling of the amount and spectral distribution of incident radiation is paramount for determining whether liquid water can exist on the surface of an Earth-sized planet. For single star - single planet systems the amount of stellar radiation arriving at the planet's atmosphere (S) at time t is given by

$$S = \frac{L_\star/4\pi}{a^2\ [1 - e\ Cos(M + \sum_{n=1}^{\infty} J_n(n\ e)Sin(n\ M))]^2}$$

where $L_\star$ denotes the stellar luminosity, $a, e, M(t)$ the planet's semimajor axis, eccentricity and mean anomaly, and J_n are Bessel-functions of the first kind. For a given orbit, S is a function of time only and can be calculated to the required precision via series expansion in eccentricity. In order to include information on atmosphere models in the calculation of the HZ, Kasting et al. [1] introduced effective radiation coefficients (S_{eff}) for stellar spectral classes M0, G2 and F0, so that inner and outer borders of the HZ can be readily estimated once the incident radiation is known. In contrast, the lack of global integrability of the gravitational three body problem makes accurate predictions of the total amount of radiation a planet is perceiving a rather challenging task. From a dynamical point of view, the most likely binary - planet configurations are of *S-Type* where the planet orbits one star only, and *P-Type* where the binary revolves inside the planet's orbit.

Methods

For analytical estimates on the extent of the HZs we model the radiation field of the unperturbed binary as a function of spectral types, orbital parameters, as well as the relative orbital phase and calculate the RMS and Min-Max distances of the inner and outer borders of the HZs in *P-Type* and *S-Type* configurations [4]. In order to acquire the actual amount of radiation a terrestrial planet receives in a binary system, we apply high precision numerical integration methods such as Lie Series and Gauss Radau techniques [5] to determine the accurate orbits and relative distances of stars and planet. As toy-models for *S-Type* systems we chose tight binary configurations with a separation distance of $\simeq 20\ [AU]$ and eccentricities between $0.3 \leq e \leq 0.7$, since such systems seem to be promising candidates to host planets (e.g. Gliese 86, HD41004AB, HD196885AB & γ Cephei). Binary components usually have different spectral types, but for the sake of simplicity we used an equal-massed pair of G2 stars.

Results

Figure 1 shows the insolation on an Earth-like planet at the inner edge of the HZ initially circularly orbiting a G2 binary (*P-Type*). The radiation-amplitude naturally rises with higher eccentricities of the binary, and it exceeds the value assumed for a planet circularly orbiting a combined light source ($\frac{S_{eff}}{S_{eff\ Sol}} = 1$) in all cases. Also, the insolation variability throughout the planet's orbit is quite high. Such effects tend to be lower on the outer edge of the HZ. The short term radiative contribution of the second star in *S-Type* systems on the HZ

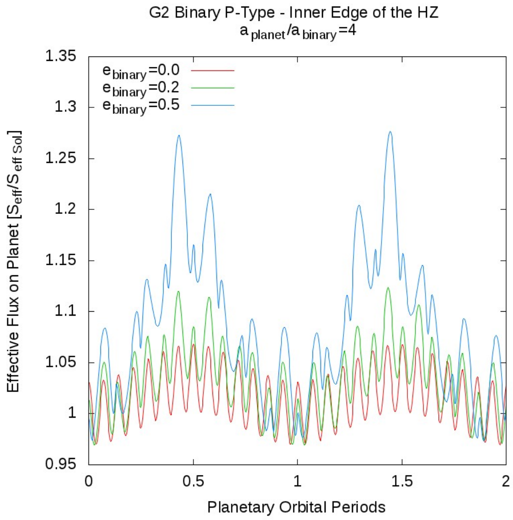

Figure 1: Insolation on a terrestrial planet in *P-Type* configuration for different eccentricities of the G2 binary. Flux values are given relative to the corresponding values in the Solar System [1].

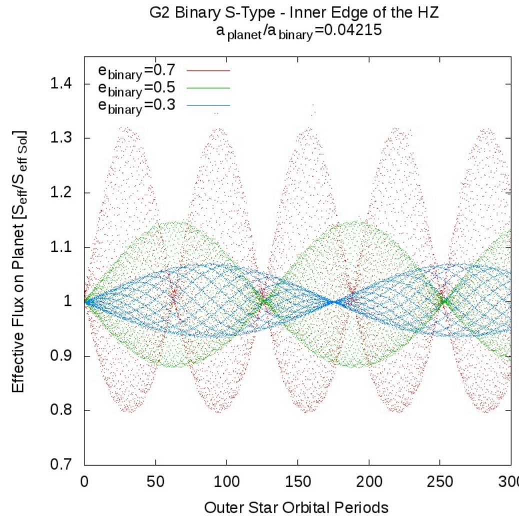

Figure 2: *S-Type* binary-planet configuration. The gravitational influence of the secondary causes long-term amplitude variation in planetary insolation. Flux values are defined as in Figure 1.

is comparatively non-essential. Yet, Figure 2 demonstrates, that such dynamical settings present considerable long-term variations in the amount of radiation arriving at the planet due to secular oscillations of the planet's eccentricity caused by the outer star.

Conclusions

S-Type HZ configurations tend to be gravitationally dominated, the radiative input due to the secondary star is negligible compared to its dynamical influence causing secular changes in the eccentricity of the planet. This alters the amount of incident radiation significantly. Therefore, assumptions on the continuous circularity of orbits and short period estimates can produce gravely inaccurate results. For rough radiation estimates in P-Type systems no long-term dynamical effects have to be taken into account. Nevertheless it is important to calculate the orbit of the outer planet with care in order to gain reliable insolation curves, as average values may not prove to be sufficient to capture effects caused by such strong variations.

Acknowledgments

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References

[1] Kasting, J.F., Whitmire, D.P., Reynolds, R.T.: 1993, "Habitable Zones around Main Sequence Stars", Icarus, 101, 108

[2] Kaltenegger, L., Sasselov, D.: 2011, "Exploring the Habitable Zone for Kepler planetary candidates", Astrophysical Journal Letters, accepted

[3] Haghighipour, N., Dvorak, R., Pilat-Lohinger, E.: 2010, "Planetary Dynamics and Habitable Planet Formation in Binary Star Systems", Planets in Binary Star Systems by Nader Haghighipour. Astrophysics and Space Sience Library, 366, Berlin: Springer, ISBN: 978-90-481-8686-0, 286

[4] Eggl, S., Pilat-Lohinger., E., Gyergyovits, M., Theis, Ch.: 2011, "On Habitable Zones in Binary Star Systems", in preparation

[5] Eggl, S., Dvorak, R.: 2010, "An Introduction to Common Numerical Integration Codes Used in Dynamical Astronomy", LNP 790, 431