HABITABLE ZONES AND THE NUMBER OF HABITABLE PLANETS IN THE MILKY WAY

S.Franck, W.von Bloh, C.Bounama

Potsdam Institute for Climate Impact Research,
PF 601203, 14412 Potsdam, Germany

The discovery of a multitude of extra-solar planets and the discussions about the possibility of life outside the Earth has stimulated several investigations about the habitability of cosmic bodies. The habitable zone (HZ) around a given central star is defined as the region within which an Earth-like planet might enjoy surface conditions required for advanced life forms (Franck et al., 2000). Our approach for calculating the HZ is based on an integrated Earth system analysis that related the boundaries of the HZ to the limits of photosynthetic processes (Figure 1).

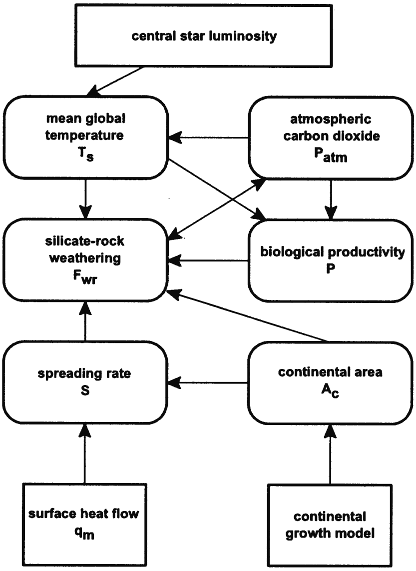

Fig.1 Integrated system box model. The arrows indicate the different forcings and feedback mechanisms (Franck et al., 2001).

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Within the latter approach, the evolution of the HZ for different central star masses (Figure 2) is calculated straightforwardly, and a convenient filter can be constructed that picks the candidates for photosynthesis-based life from extra-solar planets discovered by novel observational methods.

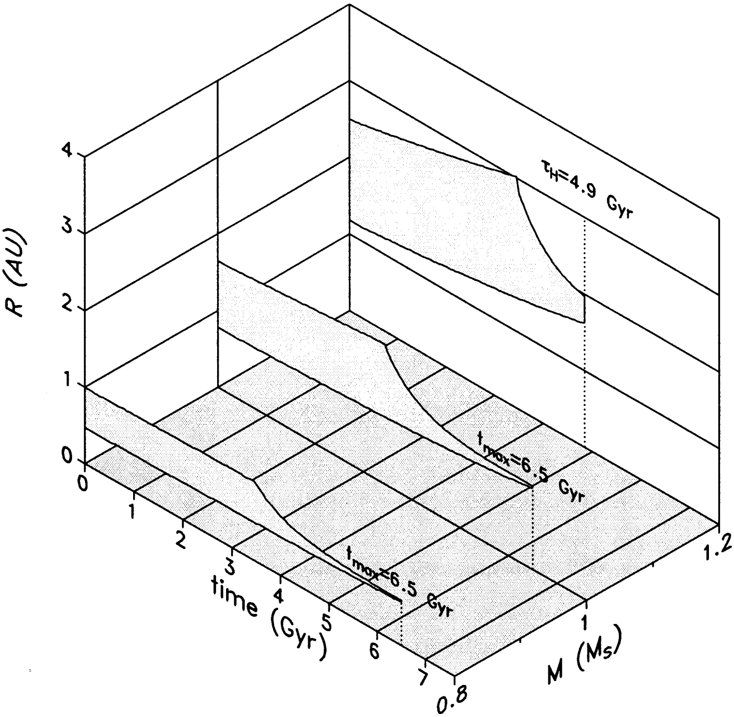

Fig.2 Graphs of the width and position of the HZ derived from the geodynamic model for three different stellar masses M (0.8, 1.0, 1.2 M_s); t_{max} is the maximum life span of the biosphere limited by geodynamic effects; τ_H indicates the hydrogen burning time on the main sequence limiting the lifespan of more massive starts (Franck et al. 2001).

These results can then be used to determine the average number of planets per planetary system that are within the HZ.

With the help of a segment of the Drake equation, the number of habitable planets is estimated. The Drake equation was first presented by Drake in 1961 to estimate the number of technological civilisations that might exists among the stars. From our view of Earth system analysis we will focus on an estimation for the contemporary number of habitable planets in the Milky Way $\mathbf{N}_{hab}$:

$$N_{hab} = N_{MW}\, f_p\, n_{CHZ} \quad (1)$$

where N_{MW} denotes the number of stars in the Milky Way. We use the value $N_{MW} = 4 \cdot 10^{11}$. The fraction of stars with planets is f_p. According to Lineweaver (2001) we use $f_p = 0.01$. The average number of planets per planetary system, which are suitable for the development of life, is n_{CHZ}. This number can be calculated directly from our results about the HZ (Franck et al., 2001). We find $n_{CHZ} = 0.012$, which means that only about 1% of all the extrasolar planets, are habitable. With the help of the numbers given above we arrive at

$$\mathbf{N}_{hab} \approx 4.8 \cdot 10^7 \qquad (2)$$

which is indeed a rather large number.

Nevertheless, there are a number of other important factors, which may significantly change $\boldsymbol{N}_{hab}$. Some of those are:

- the presence of a large moon,
- the presence of a giant planet to shield the habitable planet from comets and to scatter asteroids,
- the abundance of long-lived radioisotopes,
- extinction from gamma-ray bursts and so-called superflares.

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