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A Study on the Water World Regime around Extrasolar Planetary Systems and Planetary Environments

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Habitable zone (HZ) is defined as an orbital range around a main sequence star where planets could have liquid water on the surface (e.g., Kasting et al., 1993). It is, however, noted that, liquid water cannot exist on the surface of a planet without sufficient greenhouse effects of the atmosphere due to some greenhouse gasses, such as CO_2 and CH_4, even if the planet is orbiting within HZ (Tajika, 2008) In this sense, HZ is not a sufficient condition but just a necessary condition for the planets with liquid water.

There should be, however, an orbital condition for the planets which are close enough to their central stars to warm the climate to have liquid water without any other greenhouse gasses except water vapor in the atmospheres (Tajika, 2008). Such a condition is named here 'Water World Regime' (WWR).

In this study, the condition for WWR is estimated using a one dimensional (1-D) energy balance climate model with a radiation model for steam atmosphere. The 1-D radiative-convective equilibrium model of Nakajima et al. (1992) is adopted for outgoing infrared flux from the planet.

The orbital range of WWR is found to be approximated by an annual mean insolation from 243.4 to 293.9 W/m2. When the central star is the sun and orbital eccentricity is 0, the inner and outer boundaries correspond to 0.84 AU and to 0.94 AU, respectively. This range is very narrow compared with the traditional HZ (0.84 to $>$1.37 AU). This is because WWR is defined here as the condition for the planets without greenhouse gas in the atmosphere except for water vapor in contrast to the traditional HZ which implicitly assumes strong greenhouse effects of the atmosphere. Among the extrasolar planets discovered so far, there are 12 candidates for the planets which satisfy the WWR condition.

Keywords: extrasolar planet