Indexing of exoplanets in search for potential habitability: application to Mars-like worlds

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Abstract: Earth Similarity Index (ESI) is defined as geometrical mean of radius, density, surface temperature and escape velocity of planets, that ranges from 1 (Earth) to 0 (dissimilar to Earth). Here we have established the calibration between surface and equilibrium temperatures of exoplanets. Also introduced a new approach called Mars Similarity Index (MSI) similar to ESI, to identify mars-like planets that may be habitable to the methane-specific life forms.

Introduction

Study on exoplanets is the holy grail of present research in planetary sciences and astrobiology. Analysis of huge planetary data from space missions such as CoRoT and Kepler is directed at ultimately finding a planet similar to Earth – the Earth's twin, and answering the question of potential exo-habitability. The challenges addressed here are: (i) To glance at the ESI scale (ii) Calibration technique between surface and equilibrium temperature. (iii) Introduction of MSI scale for Mars-like planets.

Data

The data of more than 3500 exoplanets are used for the present study from the data source: Habitable Exoplanets Catalog-University of Puerto Rico (www.phl.upr.edu)

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Mathematical formulation

$$ESI_x = \left(\left[1 - \left(\frac{x - x_0}{x + x_0} \right)^n \right]^{W_x} \right)$$

$$MSI_x = \left(\left[1 - \left(\frac{x - x_0}{x + x_0} \right)^n \right]^{W_x} \right)$$

Where, n is the free parameter, W_x is the weight exponent. x is physical quantity of the exoplanet, x_0 is the reference to Earth in ESI and Mars in MSI, respectively.

Graphical Interpretation

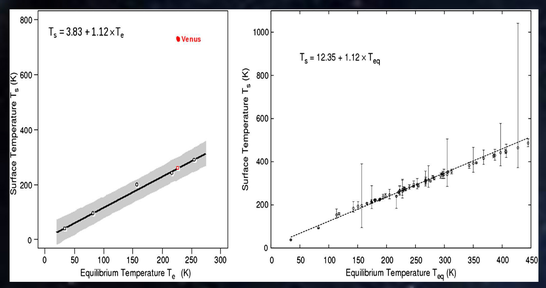

Fig. 1: Calibration of surface temperature. *Left*: Only Solar System objects with a linear fit. Venus was not used the fit due its very high surface temperature. *Grey colour* shows 95% prediction band for the model. The *red dot* on the fitting line is the predicted value for Venus. *Right*: of the exoplanets with temperature ranges

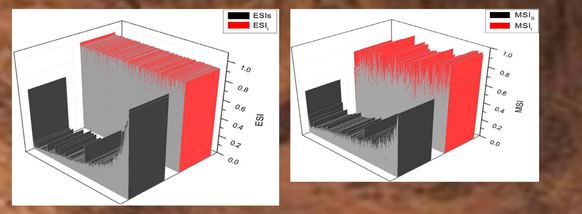

Fig. 2 Left: Interior and Surface ESI for 1650 rocky planets, right: Interior and Surface MSI for 1650 rocky planets

Fig. 3 Left: Plot of interior ESI versus surface ESI. *Blue dots* are the giant planets, *red dots* are the rocky planets, and *cyan circles* are the Solar System objects. The *dashed curves* are the isolines of constant global ESI, with values shown in the plot. However, the optimistic limit is ~0.67. Right Plot is for MSI with optimistic limit of ~ 0.63

Parametric Table

Planetary property	Ref. values for ESI	Weight exponents for ESI	Ref. values for MSI	Weight exponents for MSI
Mean radius (R)	1 EU	0.57	1 MU	0.86
Bulk density()	1 EU	1.07	1 MU	2.10
Escape velocity (V_e)	1 EU	0.70	1 MU	1.09
Surface temperature (T_s)	288 K	5.58	240 K	3.23

Discussion and Conclusion

We are interested in Earth-like and Mars-like planets to search for complex and extremophile life forms respectively. Extremophiles such as, the ones living in extreme environments on Earth; or example, methane atmosphere on Mars may be a requirement for the existence of a methane-specific extremophile life form. From our study, we found that 20 Earth-like exoplanets with ESI value above 0.8 are potentially habitable planets and 12 Mars-like planets with MSI value above 0.63. Using the known data for the Solar System objects, we established the calibration relation between surface and equilibrium temperatures to devise an effective way to estimate the value of the surface temperature of exoplanets.

References

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