

## Indexing of exoplanets in search for potential habitability: application to Mars-like worlds (Poster Flash Talk)

**Abstract:** Earth Similarity Index (ESI) ranges from 1 (Earth) to 0 (dissimilar to Earth). We established the calibration between surface and equilibrium temperatures of exoplanets. New approach called Mars Similarity Index (MSI) similar to ESI, to identify planets that may be habitable to the methane-specific forms of life.

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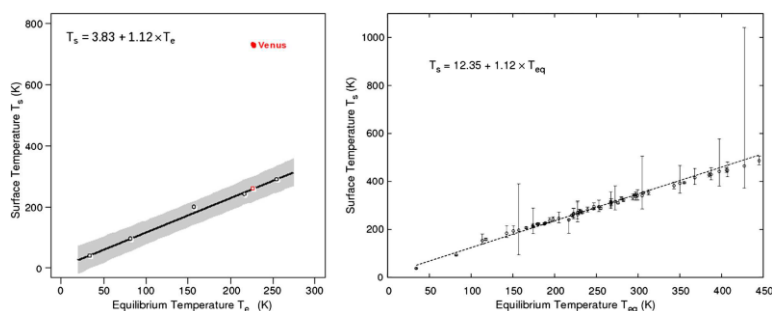
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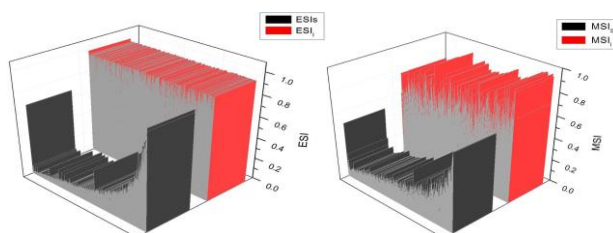
### Introduction

Study of exoplanets is one of the main goals of present research in planetary sciences and astrobiology. Analysis of huge amount of planetary data from space missions such as CoRoT and Kepler is directed ultimately at finding a planet similar to Earth. The Earth Similarity Index (ESI) is a first step in this quest, where the range from 1 (Earth) to 0 (totally dissimilar to Earth). It was defined for four physical parameters of a planet: radius, density, escape velocity and surface temperature. The ESI is further sub-divided into interior ESI (geometrical mean of radius and density) and surface ESI (geometrical mean of escape velocity and surface temperature) (Schulze-Makuch et al. 2011). The challenge here is to determine which exoplanet parameter(s) is important in finding this similarity; how exactly the individual parameters entering the interior ESI and surface ESI are contributing to the global ESI. Since the surface temperature entering surface ESI is a non-observable quantity, it is difficult to determine its value. 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. ESI is a first step in determining potential exo-habitability, which may not be similar to a terrestrial life. Thus, we introduced a new approach, called Mars Similarity Index (MSI), to identify planets that may be habitable to the extreme forms of life. MSI is defined in the range between 1 (present Mars) and 0 (dissimilar to present Mars) and uses the same physical parameters as ESI. We are interested in Mars-like planets to search for planets that may host the extreme life forms, such as the ones living in extreme environments on Earth; for example, methane on Mars may be a product of the methane-specific extremophile life form metabolism (Webster et al).

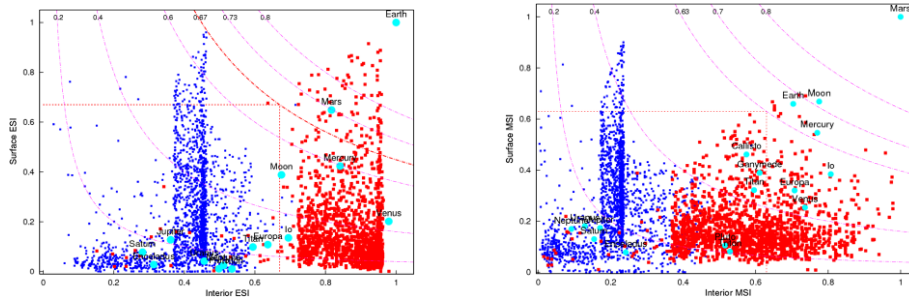
### Figures



**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, 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  $\sim 0.67$ . Right Plot is for MSI with optimistic limit of  $\sim 0.63$ .

### Tables

Table 1: The parameters for ESI and MSI scale

Planetary property	Reference values for ESI	Weight exponents for ESI	Reference values for MSI	Weight exponents for MSI
Mean radius (R)	1 EU	0.57	1 MU	0.86
Bulk density( $\rho$ )	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

### Equations

The ESI and MSI are mathematically expressed as:

$$ESI_x = \left\{ 1 - \left| \frac{x - x_0}{x + x_0} \right| \right\}^{w_x}$$

$$MSI_x = \left\{ 1 - \left| \frac{x - x_0}{x + x_0} \right| \right\}^{w_x}$$

Where,  $x$  is the physical property of the exoplanet (for example, radius or density), and  $x_0$  is the reference to Earth in ESI, and to Mars in MSI,  $w_x$  is the weight exponents as mentioned in Table 1. The full dataset of ESI and MSI is available online (Kashyap et al. 2017).

### Summary

In this investigation, we have collected the data of 3566 exoplanets available online as archives and analyzed it for Earth Similarity Index (ESI) using the work of Schulze-Makuch et al. 2011, Mars Similarity Index (MSI). We have studied how exactly the individual parameters entering the interior ESI (geometrical mean of radius and density) and surface ESI (geometrical mean of surface temperature and escape velocity), are contributing to the global ESI using graphical analysis. The mean surface temperature parameter entering into the surface ESI is non-observable quantity. In the PHL-EC data, maintained by the PHL, this parameter is obtained by adding a correction factor of 30 K based on the Earth's greenhouse effect. The main limitation of this method is that it is not consistent with all the given exoplanet. Hence the calibration of surface temperature is introduced and analyzed. 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 above 0.63.

### References

- 1) Schulze-Makuch, D., Mndez, A., Fairn, A. D., et al., "A Two-Tiered Approach to Assessing the Habitability of Exoplanets", *Astrobiology*, **11**, 1041, 2011.
- 2) Kashyap J. M., Safonova M. and Gudennavar S. B., "ESI and MSI data sets2", *Mendeley*, 2017. <http://dx.doi.org/10.17632/c37bvvp3z.6>
- 3) Webster C. R. et al., "Mars methane detection and variability at Gale crater", *Science*, **347**, 415, 2015.

## **Short Summary**

Earth Similarity Index (ESI) ranges from 1 (Earth) to 0 (dissimilar to Earth). We established the calibration between surface and equilibrium temperatures of exoplanets. New approach called Mars Similarity Index (MSI) similar to ESI, to identify planets that may be habitable to the methane-specific forms of life.