Pros and Cons in Classification of Exoplanets: in Search for Right Habitability Metric

Margarita Safonova

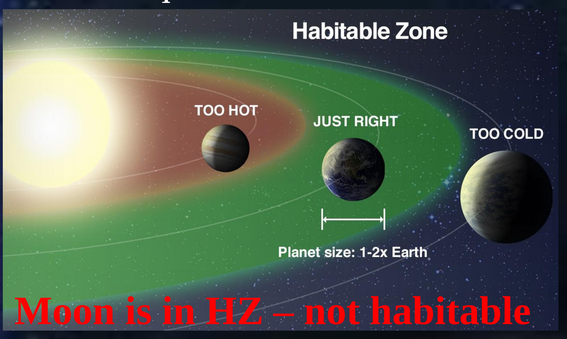
Snehanshu Saha, Jayant Murthy, Madhu Kashyap, Surbhi Agrawal, Suryoday Basak, Swati Routh, Kakoli Bora, Anand Narasimhamurthy

What is habitability? Can we quantify it? What do we mean under the term *habitable* or *potentially habitable planet*? With estimates of the number of planets in our Galaxy alone running into billions - number greater than the number of stars - it is a high time to start characterizing them, sorting them into classes/types just like stars, to better understand their formation paths, their properties and, ultimately, their ability to beget life. After all, we do have life thriving on one of these billions of planets, why not on others? Which planets are better suited for life and which ones are definitely not worth spending expensive telescope time on? We have to find sort of quick assessment score, a metric, using which we can make a list of promising planets and dedicate our efforts to them.

Classification Metrics

Habitable zone (HZ)

The range of orbital distances that allows liquid water on the surface



Moon is in HZ – not habitable

Best Case Scenario: 1 R, 1M planet at 1 AU from G2 star — is it?
G-type stars are only ~2% of all stars in Milky Way

***ESI* – Earth similarity index,**
based on R, D, T_s and V_e

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

n – number of parameters, w_x is weight exponent of x – physical quantity of the exoplanet, x_0 is the reference value (Earth here). Weights put ~ *ad hoc*

***ESI* of Mercury is 0.6 – not habitable**

***PHI* –Planetary Habitability Index**,
based on substrate *S*, available energy *E*, solvent *L*, chemistry *C*.

$$PHI_x = (S \cdot C \cdot E \cdot L)^{1/4}$$

***PHI* of Titan is 0.65 – not habitable for us**

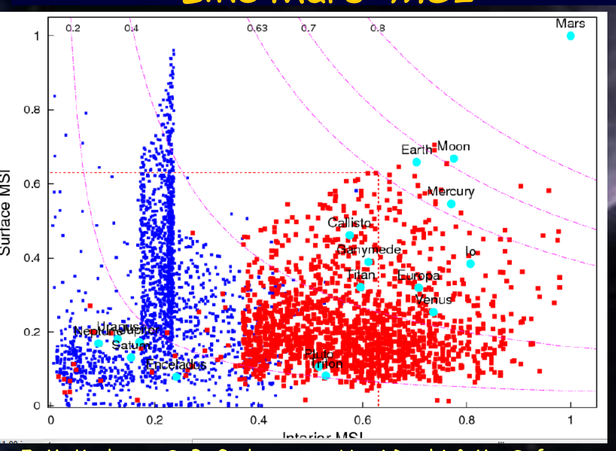
Nihilistic approaches

- No need to select special planets – we need to study all of them!
- Habitability poorly defined – habitable indices are misleading and harming the field in eyes of the general community, public & fund raisers.

Data Source:

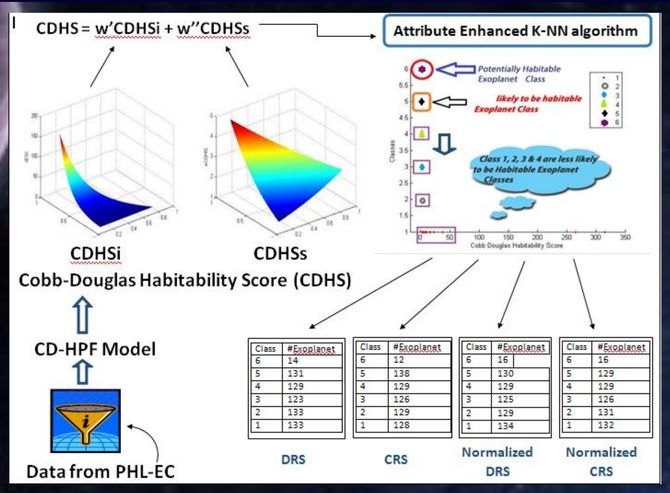
The data of more than 3000 exoplanets from Habitable Exoplanets Catalog of Planetary Habitability Laboratory (PHL) @University of Puerto Rico (www.phl.upr.edu)

Alternative approaches: extend ESI to small planets, suitable for extremophiles, for example? Like Mars: *MSI*



J. M. Kashyap, S. B. Gudennavar, Urmi Doshi & M. Safonova, *Similarity indexing of exoplanets in search for potential habitability: application to Mars-like worlds*, 2017, Astrophysics&Space Science 362:146

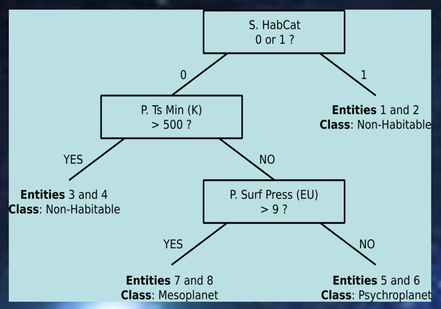
Inflexible: Introduce new index capable of accommodating other parameters and allow optimization: CDHS method



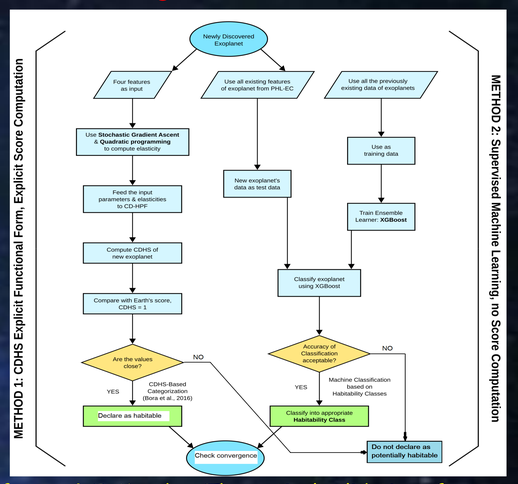
K. Bora, S. Saha, S. Agrawal, M. Safonova, S. Routh & A. Narasimhamurthy. *CD-HPF: new habitability score via data analytic modeling*, 2016, Astronomy&Computing, 17, 129-143.

Use full-scale Machine Learning approach, with other planets as training set. Answer questions: `*Is this new planet potentially habitable?*' and `*How potentially habitable is this new planet?*'

Example XGBoosted Tree for supervised Machine Learning



Convergence of two methods



S. Saha, K. Bora, S. Agrawal, S. Basak, P. Sarkar, M. Safonova & J. Murthy. *Theoretical validation of potential habitability via analytical and boosted-tree methods: An optimistic study on recently discovered exoplanets*, Astronomy&Computing, 2018, in review