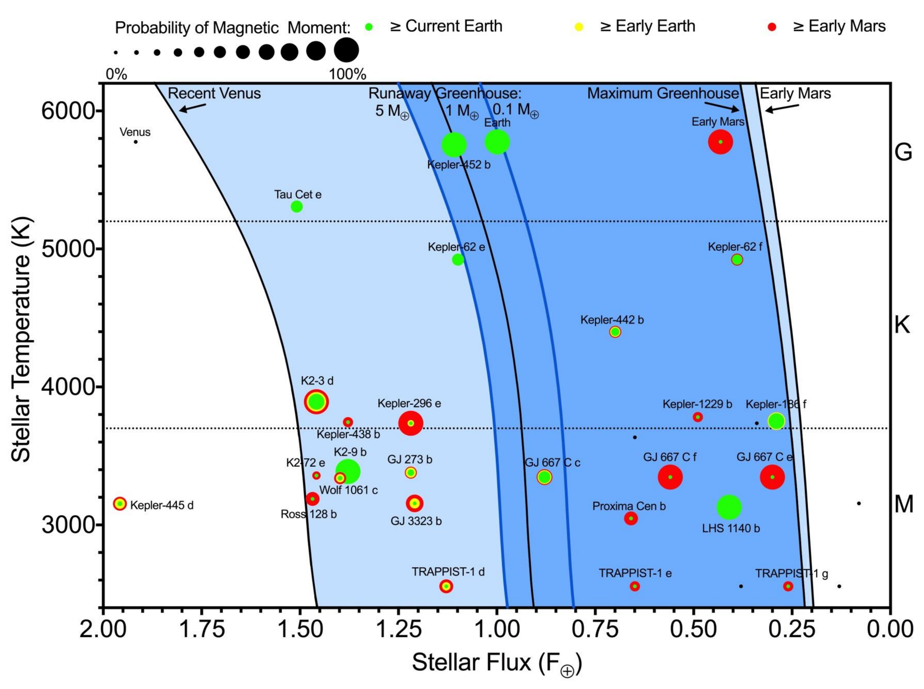
Multi-Parameter Approach to Exoplanet Habitability (M-PATH)

Moving beyond the one-dimensional habitable zone concept by examining, modelling and constraining how these additional factors interact on any given planetary body will enable us to generate a flexible framework for prioritisation that involves multiple observable characteristics and features that influence continuous planetary habitability. Based on the results, we will be able to provide a revised model of planetary habitability and suggest a suitable strategy for future spectroscopic observations of life in space.

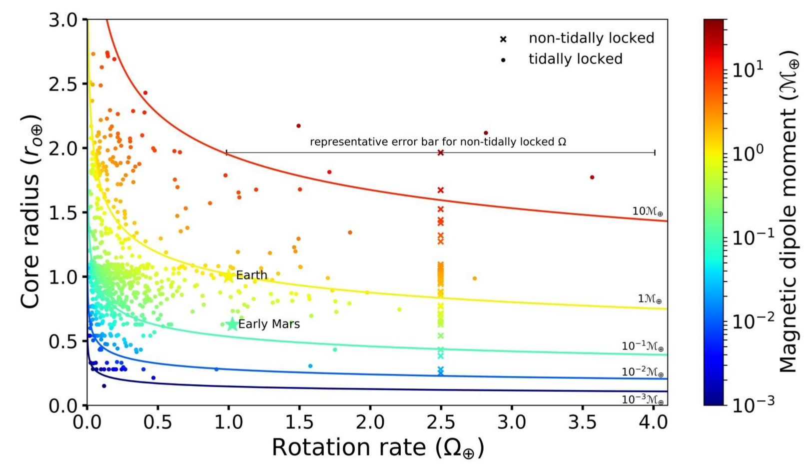


Magnetic Field

A lack of magnetic field has been connected with a loss of atmosphere, depletion of water supplies, and lack of plate tectonics. Our results show that even when modelled with best case scenario – modelling the maximum dipole moment, taking the upper uncertainty limit, comparing against the extinct Mars dynamo – there would still be 17% of exoplanets in the habitable zone that would not have sufficient protection to maintain the liquid water over prolonged timescales

Orbital Characteristics

The rotation rate, obliquity, or eccentricity of a planet's orbit has the potential to influence a number of other habitability factors, either by compensating for otherwise inhabitable circumstances, or by limiting the timespan of habitability. For example, planetary rotation effects the strength of the magnetic field, where planets that rotate slower are expected to have smaller magnetic fields, and are consequently more prone to atmospheric loss.



Atmospheric Features

A spectral biosignature can only be positively identified when we know both the probability of life forming it, and perhaps more crucially, the improbability of non-biological (abiotic) processes creating it. In advance of the next generation of telescopes, a thorough appraisal of potential biosignatures and the environmental factors and context that could create false positive abiosignatures, will increase our confidence in the spectroscopic detection of extraterrestrial life.

Mass

Planetary mass effects atmospheric composition by influencing both the degree to which a planet preserves its primordial atmosphere and the subsequent degassing of volatiles. This, in turn, determines the concentration of various greenhouse gases and whether they are sufficient to support liquid water on the surface of a planet. Determining the optimal mass to retain an atmosphere and surface liquid water will focus our targets for spectroscopic observation.

Stellar Type

The type of star influences the degree to which it effects its planetary companions, e.g. high amounts of stellar radiation directed towards a planet with insufficient magnetic protection could strip the atmosphere. The age of a star brings in another dimension – time. How long has a planet been habitable? Due to a highly volatile early stellar environment, has its atmosphere already been stripped? Answering questions like these could provide us with ideal stellar systems to target for optimal spectroscopic observation.

Plate Tectonics

Future atmospheric observations should target exoplanets with plate tectonics as this mechanism plays an integral role in planetary temperature regulation and is a critical component in sustaining conditions for long-term surface liquid water. By subducting rocks over large areas, plate tectonics provides a return pathway for CO_2 in the atmosphere that has been isolated in carbonate rocks (Cockell et al., 2016). The negative feedback inherent in this route results in the carbonate-silicate cycle regulating the surface temperature of a planet within the scope suitable for liquid water (Garrels, 1983; Walker et al., 1981).

Tidal Locking

Planets in the circumstellar habitable zones of M stars become tidally locked. This subset of planets will compose the majority of TESS habitable zone detections. While tidal locking could cause an atmospheric freeze-out on the planet's dark side, this can be averted if atmospheric circulation is sufficient. Additionally, high albedo cloud layers can moderate temperatures on the light side, theoretically resulting in a broader HZ for tidally locked planets and reducing the thermal contrast between the two sides of the planet (Yang et al., 2013).

Impact Events

Impact events are typically negatively associated with extinction events, however, the effects of impact events are not all negative – early impactors are hypothesised to be the vehicle for water to arrive on Earth. Furthermore, on interior liquid water worlds, planetary impactors could cause a complete geochemical turnover, or supply essential elements and redox couples. It is important to determine the optimal percentage of impactors per system to have adequate means for transporting water to rocky worlds, yet minimise the risk of a life-extinction collision.

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