COMPARING THE EVOLUTION OF EARTH-LIKE EXOPLANETS ORBITING FGKM STARS: AN INFORMATION THEORY APPROACH

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Introduction: Signs of habitability and even signatures of life may be encoded in the atmospheres of planets. The presentation of these signs is sensitive to the evolutionary stage of the planet. In the past decade, limited information has been gleaned from exoplanet atmospheres due to both poor resolution data and signal-to-noise ratio, as well as limited understanding of the complexity of scenarios that support life [1,2]. The launch of the James Webb Space Telescope promises to accelerate the precision and abundance of exoplanetary spectra [3], motivating the need for an efficient and conjecture-free method of searching for habitable and even inhabited exoplanets. For this purpose, we present a novel method using a spectral measure derived from information theory [4] contrasting the information contained in exoplanetary and terrestrial spectra.

Methods: To quantify the information content of a life-supporting exoplanet, we use Kaltenegger et al. [5] to apply our method to simulated atmospheres of Earth-like planets at different geological times orbiting different star types. Using the Jensen-Shannon Divergence (D_{JS}), an extension of Shannon entropy [6,7], we compute the information entropy contrast between an Earth-like planet's atmosphere with modern Earth. The smaller D_{JS}, the more similar the planets. We use this as a proxy for more intensive and conjecture-heavy searches for habitability, such as identifying and exoplanet's habitable zone or isolating specific molecular biosignatures.

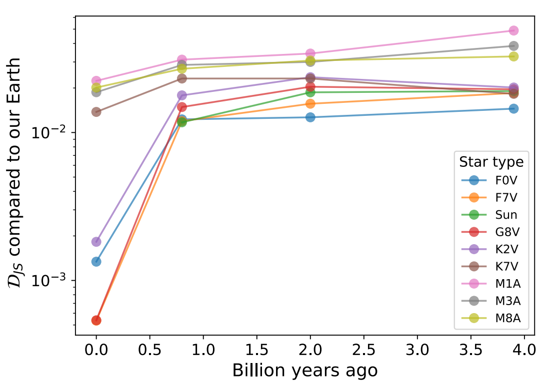

Figure 1: Information loss relative to modern Earth of exoplanets with varying age and host star

Results & Conclusions: The results of comparing modern Earth to both Earth at different geological stages (green line) and to an Earth clone orbiting different types of stars also at different geological stages are shown in (Figure 1). For all star-planet systems, the information contained in the planetary spectrum is most similar to that of Earth when they share Earth's age. The planetary atmospheres generally become less similar to modern Earth as they are evolved backwards in time. However, there is overlap in the information content of the systems. G-type and hotter stars, for example, are more similar to Earth 0.8 billion years ago than K7 and colder stars are to Earth today. F-type stars are more dissimilar to Earth than K-type and colder stars 2.0 billion years ago. We thus obtained a range for the information entropic content of an Earth-like exoplanet through different geological epochs orbiting different star types. These ranges can be further refined if the spectral type of the host star is known. These results provide an efficient and assumption-free method for identifying exoplanets whose current spectral imprints of habitability or even inhabitance resemble that of an evolving Earth.

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