G- AND K-DWARF STARS ARE THE BEST TARGETS FOR SETI. J. Haqq-Misra[1], R. K. Kopparapu[2], and E. T. Wolf[3], [1]Blue Marble Space Institute of Science (jacob@bmsis.org), [2]NASA Goddard/University of Maryland, [3]University of Colorado Boulder.

Summary: The liquid water habitable zone (HZ) describes the orbital distance at which a terrestrial planet can maintain above-freezing conditions on its surface. Calculations with one-dimensional climate models predict that the inner edge of the HZ is limited by water loss through either a moist or runaway greenhouse, while the outer edge of the HZ is bounded by the maximum greenhouse effect of carbon dioxide. This classic picture of the HZ continues to guide interpretation of exoplanet discoveries; however, recent calculations have shown that terrestrial planets near these inner and outer limits of the HZ may exhibit other behaviors, such as synchronous rotation for planets around cool stars, that affect their habitability. This suggests that the stellar spectral type and planetary rotation rate can constrain the likelihood of a planet supporting complex and intelligent life.

Here we discuss implications for SETI from a hierarchy of climate models, which allows us to understand the stellar environments most likely to support a habitable planet. We synthesize these results using a Bayesian analytic framework to reflect upon the implications of these HZ calculations for the prevalence of intelligent life over the history of the universe. We argue that planets orbiting mid G- to mid K-type stars should be prioritized as targets for SETI compared to planets around F- or M-type stars.

Habitability Models: Climate models of the HZ have provided theoretical constraints to guide exoplanet observations toward the most salient habitable real estate in a given star system. Target selection for SETI has already benefited from such efforts, which allows prioritization and extended observation of select objects.

One constraint on habitability comes from new insight on the behavior of glacial planets at the outer edge of the HZ. One-dimensional energy balance climate model calculations show the conditions under which planets in the outer regions of the HZ should oscillate between long, globally glaciated states and shorter periods of climatic warmth, known as 'limit cycles' [1,2]. Such conditions would be inimical to the development of complex land life, including intelligent life. The possibility that some planets near the outer edge of the HZ might reside in limit cycles makes F- and early G-dwarf stars less optimal candidates for hosting inhabited planets than later stellar types.

Planets around low-mass stars also experience other problems that could complicate the development of intelligent life. General circulation model (GCM) calculations provide a way to explore the climate of planets in synchronous rotation around low-mass stars, where the substellar hemisphere experiences perpetual daylight while the opposing antistellar hemisphere experiences perpetual darkness. In GCMs, as well as one-dimensional models, water loss near the inner edge of the HZ begins to occur as the stratosphere becomes saturated, and water is lost to space by photolysis, in advance of a traditional runaway greenhouse [3,4]. Planets around F- and early G-dwarf stars would lose all of their surface water within a relatively short time, but planets around some K- and M-dwarf stars could reside with habitable surface conditions in such a moist stratosphere state for several hundred million or even a few billion years.

Bayesian Reasoning: As a way of synthesizing these model calculations with observations to-date that indicate no evidence of extraterrestrial intelligence, we ask ourselves whether or not it is typical in a statistical sense for us to exist around a G-dwarf star, when K- and M-dwarf stars are much more numerous. Naively, we might expect that our existence around a G-dwarf star implies that G-dwarf stars are the best place for intelligent life to exist elsewhere, but such a conclusion is suspiciously Earth-centric and ignores the possibility that K-dwarfs or M-dwarfs could provide more numerous sites for life to develop, both now and in the future.

We analyze this problem through Bayesian inference to demonstrate that our occurrence around a G-dwarf might be a slight statistical anomaly, but only the sort of chance event that we expect to occur regularly [5]. Even if M-dwarfs provide more numerous habitable planets today and in the future, we still expect mid G- to early K-dwarfs stars to be the most likely place for observers like ourselves. This suggests that observers with similar cognitive capabilities as us are most likely to be found at the present time and place, rather than in the future or around a different stellar type.

References: [1] Haqq-Misra J. et al. (2016) *ApJ, 827,* 120. [2] Batalha N. E. et al. (2016) *Earth. Planet. Sci. Lett., 455,* 7–13. [3] Wolf E. T. (2015) *JGR, 120,* 5775–5794. [4] Kopparapu R. K. et al. (2016) *ApJ, 819,* 84. [5] Haqq-Misra et al. (2017) *IJA*, in review.