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SETI in the Spatial-Temporal Domain

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ABSTRACT

Traditional searches for extraterrestrial intelligence (SETI) focus on single stars to detect excess or transient emission from intelligent sources. However, the latest generation of synoptic time domain surveys enable a spatial-temporal SETI, where signals originate from spatially resolved sources or multiple stars. Here I propose one such SETI approach, which utilizes exoplanet-like transit signals coordinated around multiple stars to indicate the presence of an interstellar civilization. In this scenario, artificial occulting objects would act as beacons, being placed in orbit around stars surrounding the central home star system. The orbital period of each artificial satellite would be proportional to the distance from the beacon star to the home star system. If the orbital period versus beacon distance relationship was known, the exact location of the home system could be determined via triangulation (or trilateration) from a subset of the transiting beacons seen by an observer. Current and future exoplanet surveys would be able to detect such spatially coordinated transits around nearby low-mass stars. While contrived, this example highlights the need for SETI researchers to consider the spatial-temporal domain.

1. INTRODUCTION

In the search for extraterrestrial intelligence (SETI), most approaches focus on direct detection of photons originating from transmission or waste energy. These searches occur over a range of wavelength regimes, and assume an extraterrestrial civilization will produce sufficient radiation to be detected apart from their parent star. While this may be feasible at radio wavelengths where Sun-like stars have lower emission, it is much more difficult to outshine the star in the optical regime where many present-day time domain surveys operate.

Blocking a significant fraction of light from a star may instead be much easier than outshining it Arnold (2005a). This has led to recent searches for transit-like signatures that may have artificial origins. For example, PAPER demonstrated the observable impact of transits by non-spherical objects Arnold (2005b). on the impact

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of artificial structures on transits. also this work on that: Wright et al. (2016). recent data from *Kepler* (Borucki et al. 2010), has found weird transit-like signals Boyajian et al. (2015), which some have considered as SETI candidates. However, follow-up observations have yet to yield any confirming signatures, and instead this looks like a YSO w/ comets maybe (Lisse et al. 2015).

Previous work has suggested looking for SETI signals from interstellar "beacons" Benford et al. (2008) However, most such work has been focused on using lasers or other means to out-shine a parent star, often observed using spectroscopy Reines & Marcy (2002). This is a very expensive way to stand out, and a slow way to find it, and so far has no success in discovering ET laser emission Tellis & Marcy (2015) Arnold (2005a) note that objects could be placed at interesting spacing along the orbit to encode a pattern or simple message, demonstrating an intelligent origin. However, very little information can be effectively transmitted using eclipses, even with extreme precision in the recovery. Forgan (2017) show a galactic-scale communications network of using transits, but note links in the network are only stable for order 10^5 years as galactic orbital dynamics move things around

a review of Schelling points from Wright (2017) lighthouses (Zuluaga 2015) active and passive SETI in coordination (both temporal and spatial) with galactic events like supernovae (Lemarchand 1994) coordinated times/places, also known as Schelling or Focal points (Schelling 1960), are the key to finding people in unknown time/space. planets in Earth's transit zone Heller & Pudritz (2016) - maybe transits would be aligned for our viewing benefit?

THE POINT: in this new spatial-temporal domain, we should be looking for things that happen in space, such as over densities of events, or coordination of events like transits.

In this work we propose a new type of beacon system, which relies on ET transit signals from multiple stars to collectively "point" towards an ET civilization. This system has the advantage of being potentially detectable in the near future via exoplanet searches.

2. EXAMPLE: COORDINATED TRANSITS AS ET BEACONS

imagine a Type N civilization with the ability to both travel to nearby star systems, and to build large enough structures in orbit around other stars to produce a visible transit in our data.

give the detailed example i have thought up.

becons placed at distances

for clarity, this is what the ideal signal might look like on the sky

this type of beacon network is advantageous because it points directly back towards their home. only a few systems actually need to be transiting from any given line of sight.

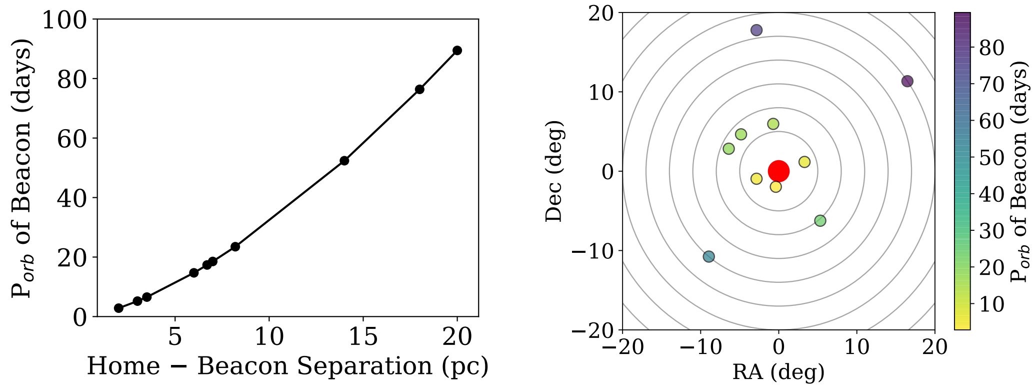

Figure 1. schematic figure of the signal to detect in 2 dimensions. ra,dec in arbitrary units. red circle in middle is the home system

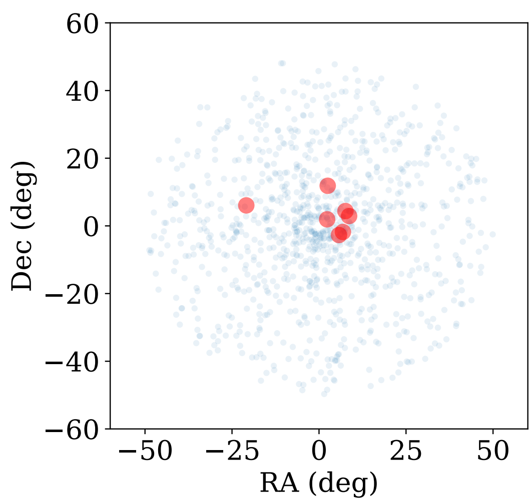

Figure 2. the model in 3 dimensions projected into the sky plane. 1000 simulated systems that span the galactic distance of 5-50 pc (blue) with 10 recovered transits highlighted (red). these would be hot Jupiters at the short P end.

NOW THE FULL SIMULATION... - computation to do: if had 100 beacons, each placed at random orbital alignment, in 3d sphere around home system. - assume G stars, - odds of observing transit of a fixed sized object versus orbital distance... goes down. need that plot to figure out probability. - assume ET places beacons with uniform RADIAL density in 3d space out to some maximum distance (even # of systems as function of radial distance) in bins of 10pc out to 100 pc (i.e. 10 beacons in each 10pc bin) - orbital period is exact for each system, no bins of period - do Monte Carlo sim with these parameters to figure out how many transiting systems we'd observe

—- make the plot for one MC realization of RA,Dec.... open circles for systems with no observed transits, colored for transits

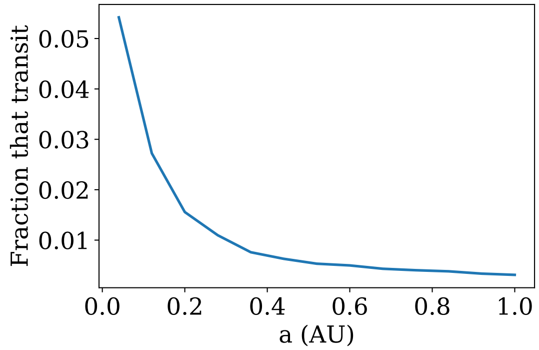

Figure 3. fraction of hot Jupiter-like systems recovered in 1000 realizations of our 1000-star simulation. This curve is dependent on the ratio of the occulter-to-star size, and the orbital period range sampled. The average from our model is 10 ± 3 systems recovered for these parameters.

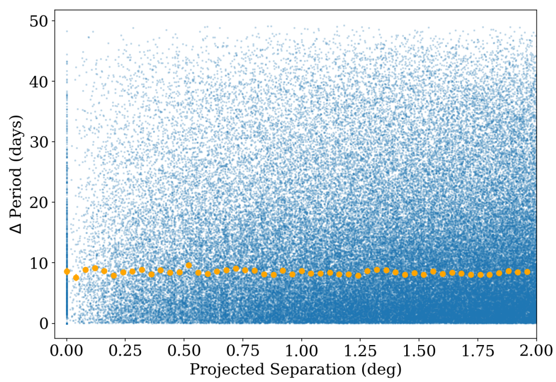

Figure 4. searching for correlation between transit periods and projected separations between all exoplanet systems out to 2deg in the Kepler data. median period differences are computed for bins of separation distance (orange points). there is no trend in these medians, indicating a distribution of orbital periods that are random on large scales.

3. SEARCHING FOR CORRELATED TRANSITS IN KEPLER

we compute the 2-point correlation between all transits in the Kepler sample in 2D space (radius)

we find there is no correlation. Thats OK, but at least we searched

4. PROSPECTS FOR FUTURE SURVEYS

to get accurate census you need a complete time domain survey at some transit depth sensitivity out to some orbital period. going off our simulation, TESS might work for very short period planets

TESS would be great for this in terms of spatial-temporal coverage.

LSST very good for finding SETI signals of this geometric style, but not ideal for events requiring such dedicating monitoring

5. DISCUSSION

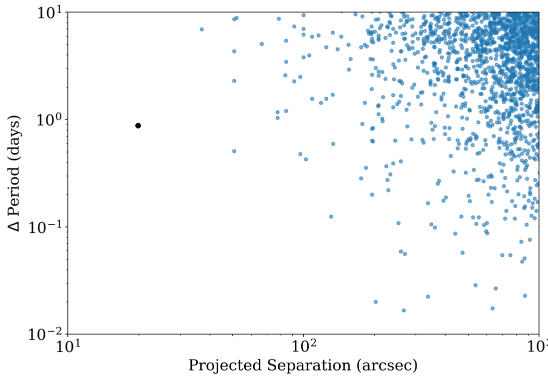

Figure 5. correlation between transit periods and projected separations, as in Figure 4, but emphasizing the smallest separations in both axes. One outlier was identified in the similarity of Kepler 1292b and Kepler 1235b (black circle). However, these two systems are more than 600 pc separated in distance.

this kind of distributed network could be very efficient at broadcasting the presence of a civilization. dust clouds could create sufficient "transit" signals, while not affecting orbital dynamics

IDEA: could improve the efficiency of these beacons if we consider a bit of galactic structure, aligning the median orbital inclinations of the beacon systems with the Galactic plane, and only allowing a smaller range of possible inclinations. How much more efficient would it be if we forced $i < 10°$, instead of $i < 90°$?

for a million system model w/ 90deg max, 0.46% total detection efficiency. by constraining the inclination to 10deg max, get 4.3% detection efficiency of planets. 30deg max gets 1.4%

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