

RADIO SETI OBSERVATIONS OF THE ANOMALOUS STAR KIC 8462852

G. R. Harp¹, Jon Richards¹, Seth Shostak¹, J. C. Tarter¹, Douglas A. Vakoch^{1,2}, Chris Munson¹

¹Center for SETI Research, SETI Institute, 189 Bernardo Ave., Mountain View, CA, 94043

²SETI International, 100 Pine St., Ste. 1250, San Francisco, CA, 94111-5235

Abstract

We report on a search for the presence of signals from extraterrestrial intelligence in the direction of the star system KIC 8462852. Observations were made at radio frequencies between 1 – 10 GHz using the Allen Telescope Array. No narrowband radio signals were found at a level of 180 – 300 Jy in a 1 Hz channel, or wideband signals above 100 Jy in a 100 kHz channel.

Keywords: stars: individual (KIC 8462852), general, planets and satellites, SETI

Introduction

The unusual star KIC 8462852 (Boyajian et al. 2015) studied by the Kepler space telescope is a main-sequence F3 star at a distance of 454 pc that appears to have a large quantity of matter orbiting quickly about it. In transit, this material can obscure more than 20% of the light from that star. However, the dimming does not exhibit the periodicity expected of an accompanying exoplanet.

While the star has a rotation period of 0.88 days, the strong, aperiodic brightness dips can last from 5 – 80 days, and this is the first time that such behavior has been reported. Although natural explanations should be favored; e.g., a constellation of comets disrupted by a passing star (Boyajian et al. 2015), or gravitational darkening of an oblate star (Galasyn 2015), it is interesting to speculate that the occulting matter might signal the presence of massive astroengineering projects constructed in the vicinity of KIC 8462852 (Wright, Cartier et al. 2015).

Several motivations have been proposed for extraterrestrial civilizations to create megastructures orbiting their home stars. First, swarms of solar panels could serve to capture starlight as a source of sustainable energy (Dyson 1960). Such structures may be betrayed via re-radiated starlight at infrared wavelengths. Alternatively, large-scale structures might be built to serve as possible habitats (e.g., “ring worlds”) or as long-lived beacons to signal the existence of such civilizations to technologically advanced life in other star systems by occulting starlight in a manner not characteristic of natural orbiting bodies (Arnold 2013).

In view of the possibility that the occultations might have an engineered origin, we have undertaken observations of this star system to detect radio signals using the Allen Telescope Array (ATA). These observations comprise a search for narrowband signals ($\sim 0.01 - 100$ Hz) as well as moderately wide bandwidth signals (100 kHz – 100 MHz).

The ATA is an interferometer consisting of 42 antennas of 6.1 meter diameter, having a maximum baseline of about 300 m (Welch et al. 2009). For these observations, we used a subset of 20 antennas, and covered a frequency range from 1 – 10 GHz, spanning the terrestrial microwave window (Oliver and Billingham 1972).

Our searches are based on conceptually different scenarios for the putative alien transmitter. For the narrowband search, the archetypal transmitter is an intentional beacon directed toward the Earth with the specific goal of announcing an extraterrestrial presence. The second archetype is incidental radiation resulting from propulsion by powerful, beamed microwave transmitters (e.g., Marx 1966; Benford 2012). In this case, the suggestion is that if the matter occluding the star is actually due to extensive megastructures, then microwave-driven spacecraft to service these structures could inadvertently be revealed by a powerful, wide bandwidth signal.

Observations and Results

Observations with the ATA were conducted between October 15 and October 30, 2015 for approximately 12 hours a day, during which time other SETI observing was placed on hold.

Two types of radio instrumentation were used to examine the stellar system for signals. SonATA (SETI on the ATA) performed a fully automated, near-real-time spectral analysis of the star, following up immediately on detected candidate signals (see Tarter et al. 2011). SonATA was sensitive to narrowband emissions of widths between 0.01 and 100 Hz. Diurnal rotation and, to a lesser extent, orbital motion of the Earth introduce relative accelerations between any transmitters in the KIC 8462852 system and the ATA receivers that cause the frequency of detected narrowband signals to change with time. The maximum allowed fractional drift rate for the SonATA analysis is 1 Hz/sec.

The SonATA system uses three phased array beam formers to produce small (4 and 0.4 arcmin at 1 and 10 GHz, respectively) simultaneous, synthesized beams. For these observations, one beam was placed on KIC 8462852 and the other two were placed in locations at least 3 synthetic beamwidths away from the star. This ensures that the beams were nearly independent. Each beam placed an interference null at the positions of the other two beams (Barott et al. 2011) which improved their mutual independence by 7 dB. This three beam technique is an effective way to discriminate against local (human generated) interference. The same signal detected in more than one beam is presumed to be the result of radiation scattering into the sidelobes of the array.

The frequency range from 1 to 10 GHz was observed in 225 successive steps each of width 40 MHz. The full frequency range was swept twice to mitigate the effects of intermittent fading of signals due to the interstellar medium, especially at higher frequencies. Observations at each frequency lasted 92 seconds, and the detection threshold was set to 6.5 times the rms noise level. This resulted in a sensitivity of 180 and 300 Jy in a single 1 Hz channel at 1 and 10 GHz, respectively, corresponding to a narrowband transmitter with a minimum effective isotropic radiated power of 4×10^{15} W (and 7×10^{15} W) at the distance of KIC 8462852. No evidence of a persistent signal coming from the direction of KIC 8462852 was observed in this narrowband signal search.

A second set of radio observations used a spectral imaging correlator capable of measuring an instantaneous bandwidth of 80 MHz with 100 kHz resolution. Using the correlator output, frequency power spectra were obtained for the synthesized array beam in the direction of KIC 8462852 and then compared to the total spectral power arriving at the telescope. By comparing the flux from the narrow beam to the total power received by the array, one can judge if wideband radio energy is coming from the direction of the former.

This technique is demonstrated by Figure 1, produced from 10 minute observations of quasar 3C84 (with flux 23.4 Jy) and KIC 8462852. Here the blue points represent the measured power in a beam on the quasar relative to the total power entering the telescope. The scallops in the blue curve are artificial and arise because the array is calibrated perfectly only at two frequencies over the frequency range (4.42 and 4.46 GHz). The black points show the same response curve when the telescope is pointed at the star KIC 8462852. The lack of any wideband emission from the star is evident. Using the known true quasar flux as a function of frequency allows us to make a plot of maximum in-beam power received from the direction of the star.

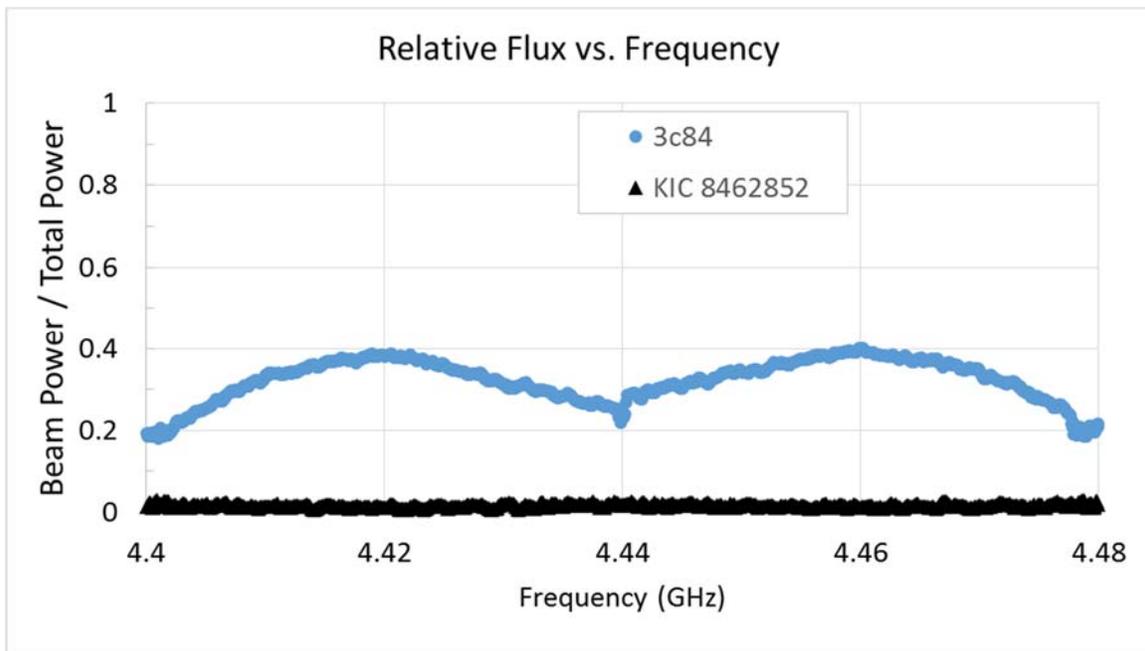


Figure 1: The total power received by the telescope is compared in correlator observations of quasar 3C84 and KIC 8462852. A graph like this is an easy way to determine whether any medium bandwidth radio energy is arriving from some particular direction on the sky.

A single sweep over the frequency range from 1 to 10 GHz was performed in 80 MHz steps with 10 minute observations on the star system followed by 10 minute observations on a bright quasar for calibration (quasars included 3C273, 3C380 and 3C84). The detected flux from KIC 8462852 is plotted in Figure 2.

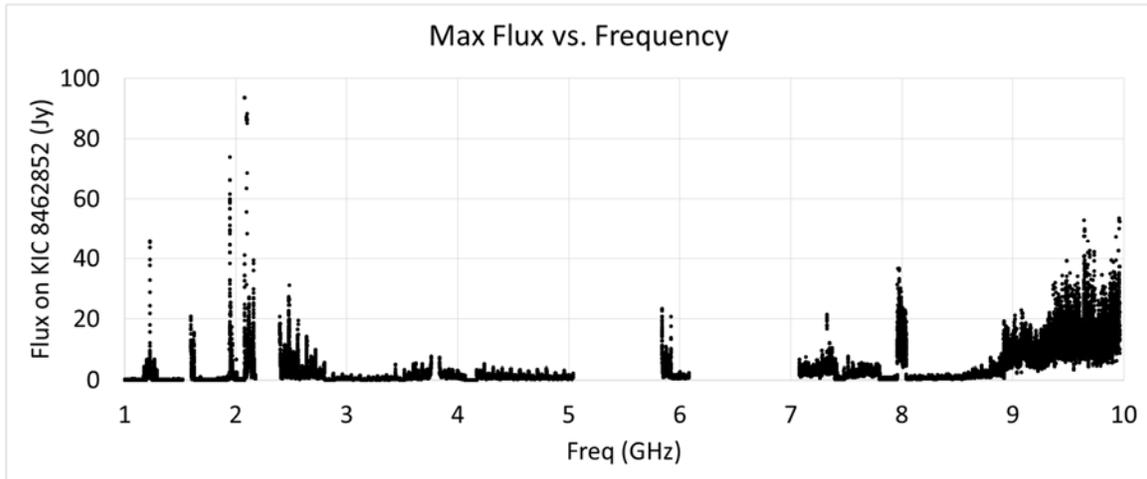


Figure 2: The maximum flux from KIC 8462852 in 100 kHz bins that is consistent with the observations.

In Figure 2, there are noticeable gaps in the observations that arise for one of two reasons. At frequencies below 2.5 GHz, the gaps represent regions where persistent strong radio frequency interference (RFI) prevents reliable measurements. At higher frequencies, the gaps correspond to frequencies where observations were incomplete. The scalloping in the calibrator flux of Figure 1 shows up in the form of regular peaks every 40 MHz in Figure 2. The gradual rise in the noise level above 9 GHz is due to a dropoff in the telescope sensitivity with increasing frequency. At all frequencies, the observed flux is below the estimated error in the measurement of the flux. To summarize these observations, we estimate an upper limit for anomalous flux from KIC 8462852 to be 100 Jy in a 100 kHz band over the frequencies displayed.

The results from the correlator observations are similar to those from the narrowband observations; no detectable moderate bandwidth (100 kHz or more) flux was observed from the direction of the star between 1- 10 GHz. At the distance of KIC 4862852, our sensitivity limit corresponds to a 100 kHz transmitter with an EIRP of $1 \cdot 10^{20}$ W.

Conclusions

We have made a radio reconnaissance of the star KIC 8462852 whose unusual light curves might possibly be due to planet-scale technology of an extraterrestrial civilization.

The observations presented here indicate no evidence for persistent technology-related signals in the microwave frequency range 1 – 10 GHz with threshold sensitivities of 180 – 300 Jy in a 1 Hz channel for signals with 0.01 – 100 Hz bandwidth, and 100 Jy in a 100 kHz channel from 0.1 – 100 MHz.

These limits correspond to isotropic radio transmitter powers of $4 - 7 \cdot 10^{15}$ W and 10^{20} W for the narrowband and moderate band observations. These can be compared with Earth's strongest transmitters, including the Arecibo Observatory's planetary radar ($2 \cdot 10^{13}$ W EIRP). Clearly, the energy demands for a detectable signal from KIC 8462852 are far higher than this terrestrial example (largely as a consequence of the distance of this star). On the other hand, these energy requirements could be very substantially reduced if the emissions were beamed in our direction. Additionally, it's worth noting that any society able to construct a Dyson swarm will have an abundant energy source, as the star furnishes energy at a level of $\sim 10^{27}$ watts.

This report represents a first survey placing upper limits on anomalous flux from KIC 8462852. We expect that this star will be the object of additional observations for years to come.

Acknowledgments

We thank Franklin Antonio for his generous support of this work, as well as for new instrumentation on the Allen Telescope Array.

References

- Arnold, L. 2014, arXiv:1303.1100
- Barott, W.C., Milgrome, O., Wright, M., MacMahon, D., Kilsdonk, T., Backus, P., and Dexter, M. 2011 *Radio Science*, **46**, RS1016
- Benford, J. 2012, [arXiv:1112.3016v2](https://arxiv.org/abs/1112.3016v2) [astro-ph.IM]
- Boyajian, T. 2015, *MNRAS* (in press)
- Dyson, F. 1960, *Science* **131**, 1667
- Galasyn, J. 2015 <http://www.desdemonadespair.net/2015/10/did-kepler-space-telescope-discover.html>
- Marx, G. 1966, *Nature* **211**, 22
- Oliver, B.M. and Billingham, J. eds. 1972, *Project Cyclops. A Design Study of a System*

for Detecting Extraterrestrial Life, NASA CR-114445

Tarter, J., Ackermann, R., Barott, W., Backus, P., Davis, M., Dreher, J., Harp, G., Jordan, Kilsdonk, T., Shostak, S. and Smolek, K. 2011, *Acta Astronautica* **68**, 340

Welch, Jack, Don Backer, Leo Blitz, Douglas Bock, Geoffrey C. Bower, Calvin Cheng, Steve Croft, et al. 2009. “The Allen Telescope Array: The First Widefield, Panchromatic, Snapshot Radio Camera for Radio Astronomy and SETI.” Proceedings of the IEEE 97 (Advances in Radio Telescopes): 1438–47. <http://arxiv.org/pdf/0904.0762>.

Wright, J., Cartier, K., et al. 2015, *Ap. J.* (in press)