Green Bank 100 m Telescope Observations of Boyajian's Star from 1–27.5 GHz with the Breakthrough Listen Backend

J. T. Wright[1,2,3] A. P. V. Siemion[1], T. S. Boyajian[4], M. Lebofsky[1], D. MacMahon[1], D. Price[1]

[1]Berkeley SETI Research Center Breakthrough Listen Laboratory, UC Berkeley, CA [2]Center for Exoplanets and Habitable Worlds, Penn State, University Park, PA
[3]PI, NASA Nexus for Exoplanet System Science [4]Louisiana State University, Baton Rouge, LA 70803

http://sites.psu.edu/AstroWright astrowright@gmail.com @Astro_Wright

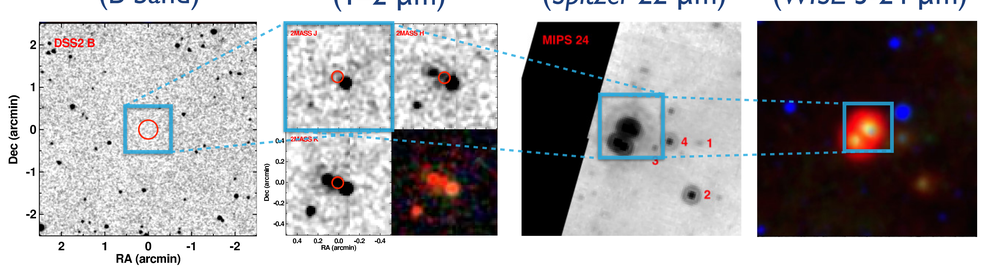
The Ĝ Survey

Glimpsing Heat from Alien Technologies (GHAT or Ĝ) is our survey to detect the heat of industry from very advanced civilizations.

Civilizations with energy supplies comparable to their stellar output (Kardashev type II civilizations) will have noticeable mid-infrared excess (MIR). Modern MIR surveys are sensitive to excesses of only a few percent.

Megastructures—planet-sized or larger artificial structures or swarms of structures in space—would be detectable both in the MIR and in transit (where they are distinguished from planets by their anomalous transit shapes, depths, timings, and chromatic properties.) *Kepler's* transit survey of 200,000 stars was effectively a search for megastructures.

Below we show an intriguing (but presumably natural) discovery from our MIR survey.



Search for Artificial Stellar Sources of Infrared Radiation (Dyson 1960 Science **131**, 1667)
Transit Light-Curve Signatures of Artificial Objects (Arnold 2005 ApJ **627**, 534)
The Ĝ Search for Extraterrestrial Civilizations with Large Energy Supplies:
Paper I : Background and Justification ApJ **792**, 26
Paper II : Framework, Strategy, and First Results ApJ **729**, 27
Paper III: The Reddest Extended Sources in WISE ApJS **217**, 35
Paper IV: The Signatures and Information Content of Transiting Megastructures ApJ ***816***,

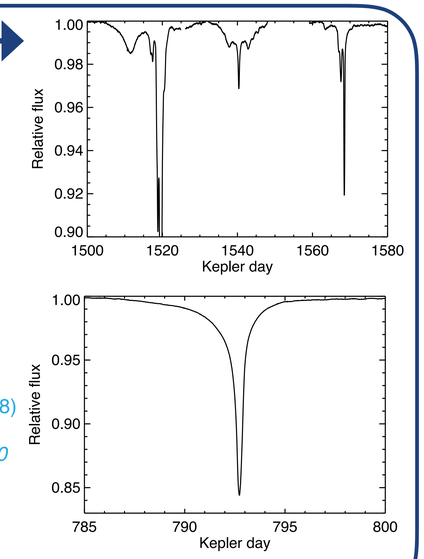
Links and popular descriptions

(Tabby) Boyajian's Star

The star KIC 842852 was discovered by *Kepler* to undergo unique, irregular, nonperiodic dimming events.

It also appears to have dimmed by 4% during the 4-year *Kepler* mission, and by over 15% over the past century. Both of these phenomena are unprecedented and extremely difficult to explain, given the star's otherwise ordinary status: it does not appear to be young or evolved and shows no evidence of a disk or radial velocity variations indicative of stellar-mass orbital companions. Its lack of near-infrared excess puts tight constraints on the amount of material that could be orbiting it.

Boyajian's Star is consistent with predictions of transits from orbiting megastructures. In parallel to our efforts to find a natural explanation for this intriguing star, we have begun a SETI campaign at the Green Bank Telescope to make an unprecedentedly deep and broad survey of the star's radio spectrum to search for potential transmissions from alien civilizations. Searches for laser emission are also underway.



Planet Hunters IX. KIC 8462852 - where's the flux? (Boyajian et al. 2016 MNRAS **457**, 3988)
KIC 8462852 Faded throughout the Kepler Mission (Montet & Simon 2016 ApJ **820**, 39
KIC 8462852 Faded at an Average Rate of 0.164±0.013 Magnitudes per Century from 1890 to 1989 (Schaefer 2016 ApJ **822**, 34
Families of Plausible Solutions to the Puzzle of Boyajian's Star ApJL **829**, L3
A Search for Laser Emission with Megawatt Thresholds from 5600 FGKM Stars (Tellis & Marcy) arXi:1704.02535

Links and popular descriptions

GBT Observations

- We were granted 25h of Green Bank 100m Telescope time through the NRAO Open Skies call. Our observations were spread over 4 days between 26 October 2016 and 31 January 2017.
- We used the L,S,C,X, and KFPA receivers to cover much of the spectrum between 1–27.5 GHz. We used the Breakthrough Listen backend to achieve an instantaneous bandwidth of up to 3.938 GHz.
- We covered the entire bandwidth afforded by the KPFA receiver with three intermediate frequency tunings of the down-conversion system.
- We nodded the telescope to produce on/off pairs of observations to enable robust RFI rejection.
- We observed flux and polarization standards in each configuration, and made observations of Mars in X band (to observe signals from its orbiters) and maser sources (including DR 21(OH)) as checks on our procedures.
- We all recorded data in "raw voltage" mode, and are transferring these data over the Internet to the PSU Advanced CyberInfrastructure high performance computing cluster. The total data volume is ~450 TB.
- Because the data were stored as raw voltages, we anticipate applying novel analysis methods, and invite suggestions for them.
- As with all Breakthrough Listen data, we intend to make the data public or publicly analyzable.
- These observations demonstrate the capabilities of the Breakthrough Listen backend and we hope will be emblematic of "gold standard," high bandwidth SETI observations for future observing campaigns of particularly promising SETI targets identified via artifact SETI.

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