The Search for Planets Transiting White Dwarf Stars

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ZTF Team Meeting
October 19, 2020

White dwarfs as planet hosts

Facts:

1. Most main sequence stars host planets
2. Most main sequence stars become white dwarfs

→ Most white dwarf stars host planets

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→ Most white dwarf stars host planets

Additional evidence:

- ~27--50% of white dwarfs are currently accreting planetary debris (Koester, Gänsicke & Farihi, 2014, A&A, 566, A34)
- ~2% show IR emission from debris disks (Rebassa-Mansergas et al. 2019, MNRAS, 489, 3990)
- Detected planetesimal systems, e.g., WD 1145+017 (Vanderburg et al. 2015, Nature, 526, 54), ZTF J0139+5245 (Vanderbosch et al. 2020, ApJ, 897, 171)

The Astrophysical Journal, 897:171 (9pp), 2020 July 10 https://doi.org/10.3847/1538-4357/ab9649

A White Dwarf with Transiting Circumstellar Material Far outside the Roche Limit

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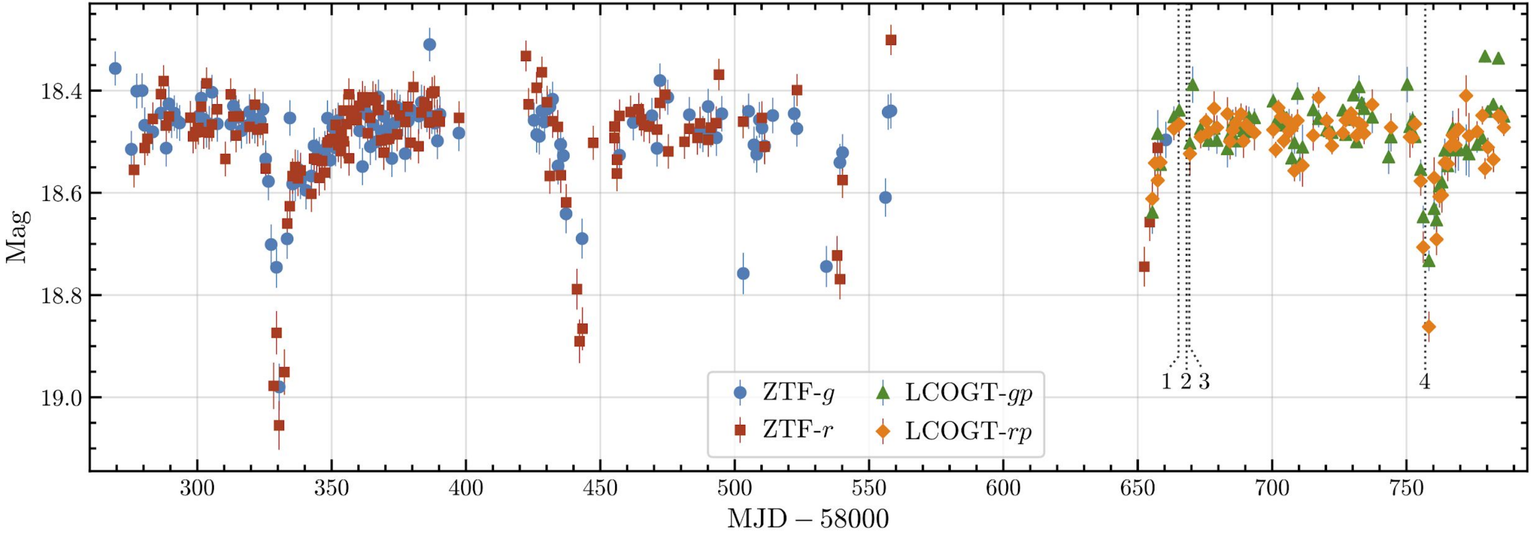

Article

A giant planet candidate transiting a white dwarf

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Check for updates

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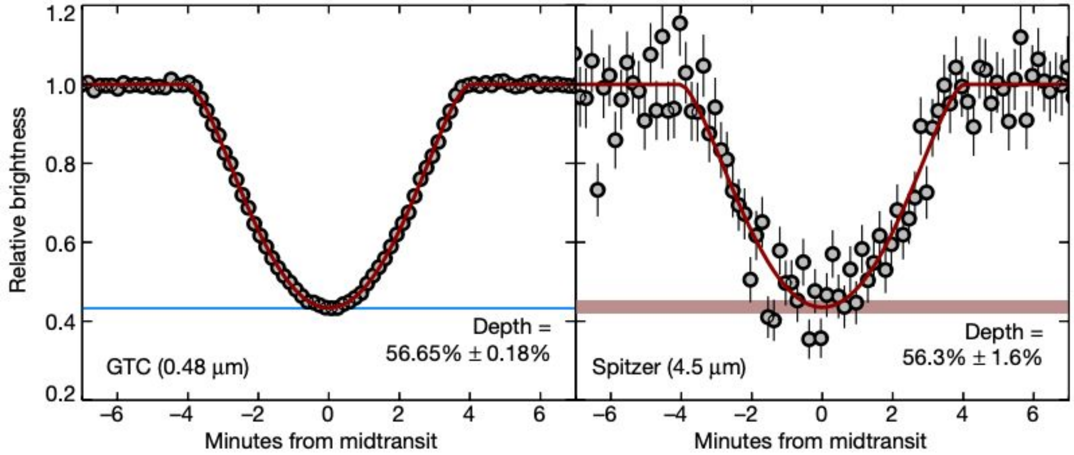
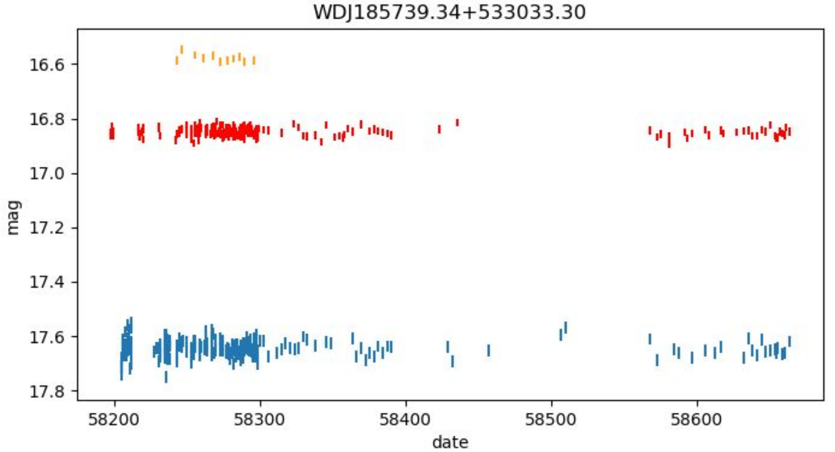
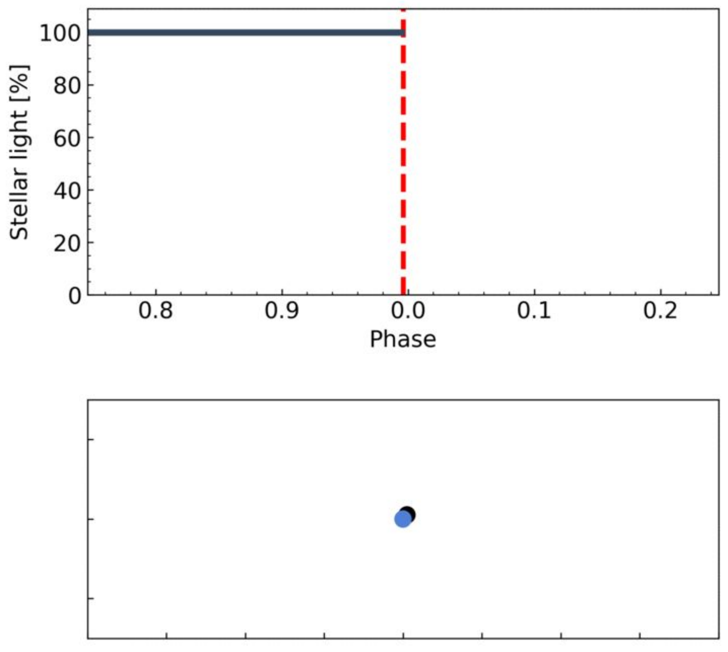


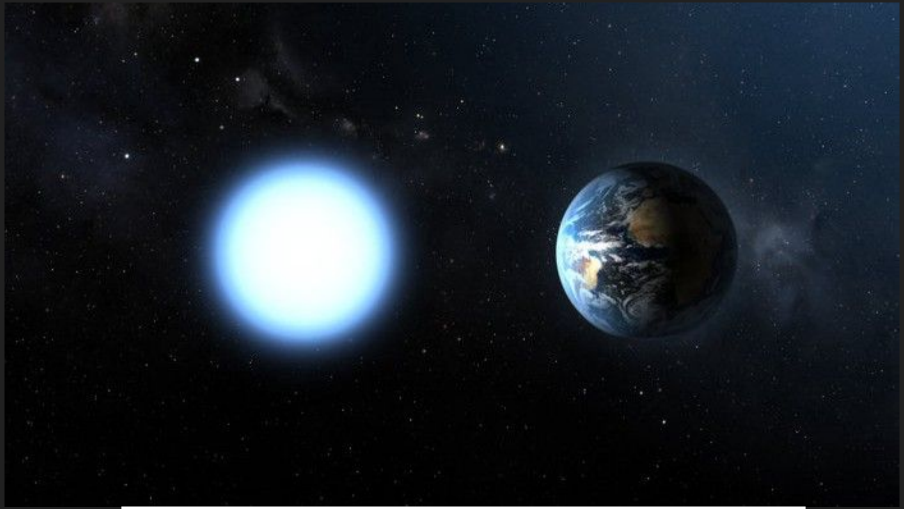


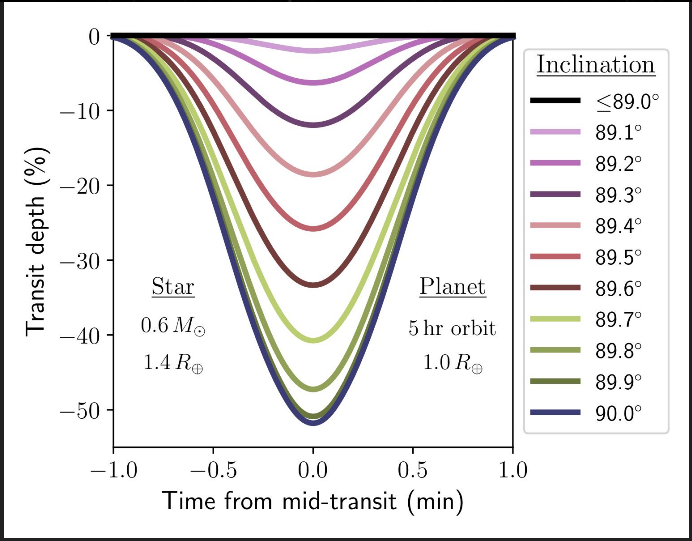
An observational challenge

White dwarfs are compact objects
~Earth size = small transit target



Animated with github.com/oscaribv/tango





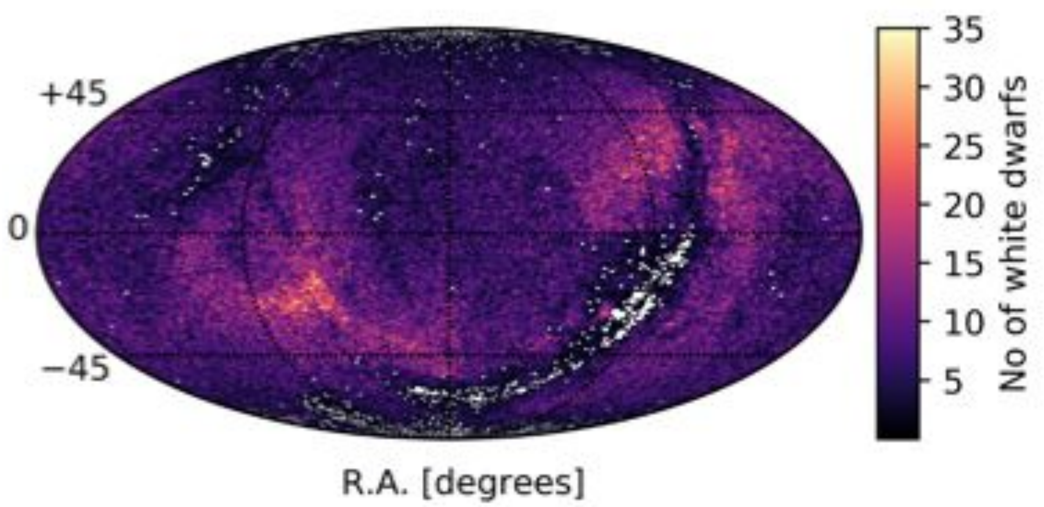
Expected yield of transiting planets

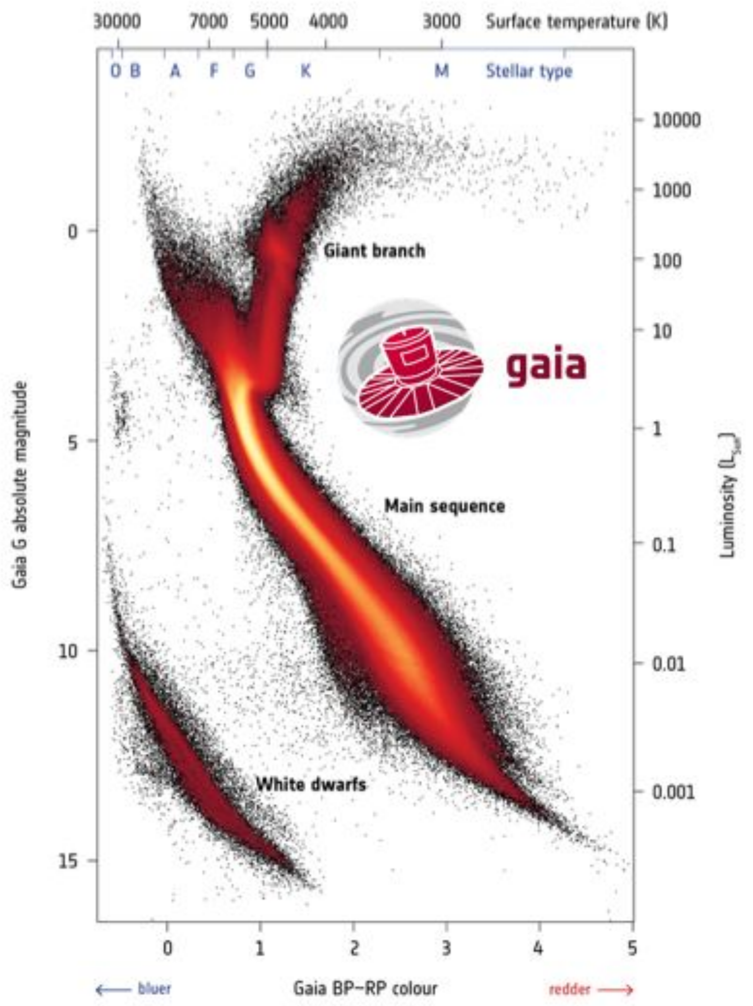
$$N_p = N_{WD} \times f_p \times f_t \times N_{obs}$$

where:

- N_p = number of transiting planets we expect to discover
- N_{WD} = the number of white dwarfs observed
- f_p = the fraction of white dwarfs with planets
- f_t = the fraction of time these planets are transiting
- N_{obs} = the number of observations of each white dwarf

Expected yield of transiting plar





Expected yield of transiting planets

$$N_p = N_{WD} \times f_p \times f_t \times N_{obs}$$

where:

- N_p = number of transiting planets we expect to discover
- N_{WD} = the number of white dwarfs observed ~200,000
- f_p = the fraction of white dwarfs with planets
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- N_{obs} = the number of observations of each white dwarf

Expected yield of transiting planets

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- N_{obs} = the number of observations of each white dwarf ~870

Expected yield of transiting planets

$$N_p = N_{WD} \times f_p \times f_t \times N_{obs}$$

where:

- N_p = number of transiting planets we expect to discover
- N_{WD} = the number of white dwarfs observed ~200,000
- f_p = the fraction of white dwarfs with planets
- f_t = the fraction of time these planets are transiting ~0.00001
- N_{obs} = the number of observations of each white dwarf ~870

Expected yield of transiting planets

$$N_p = N_{WD} \times f_p \times f_t \times N_{obs}$$

where:

- N_p = number of transiting planets we expect to discover
- N_{WD} = the number of white dwarfs observed ~200,000
- f_p = the fraction of white dwarfs with planets ~0.01?
- f_t = the fraction of time these planets are transiting ~0.00001
- N_{obs} = the number of observations of each white dwarf ~870

Expected yield of transiting planets

$$N_p = N_{WD} \times f_p \times f_t \times N_{obs}$$

where:

- N_p = ... ~17?
- N_{WD} ... ~200,000
- f_p = t... ~0.01?
- f_t = t... ~0.00001
- N_{obs} ... ~870

White Dwarfs as Probes of Fundamental Physics: Tracers of Planetary, Stellar and Galactic Evolution
Proceedings IAU Symposium No. 357, 2019
M. A. Barstow, S. J. Kleinman, J. L. Provencal & L. Ferrario, eds.
doi:10.1017/S1743921320000204

The search for planet and planetesimal transits of white dwarfs with the Zwicky Transient Facility

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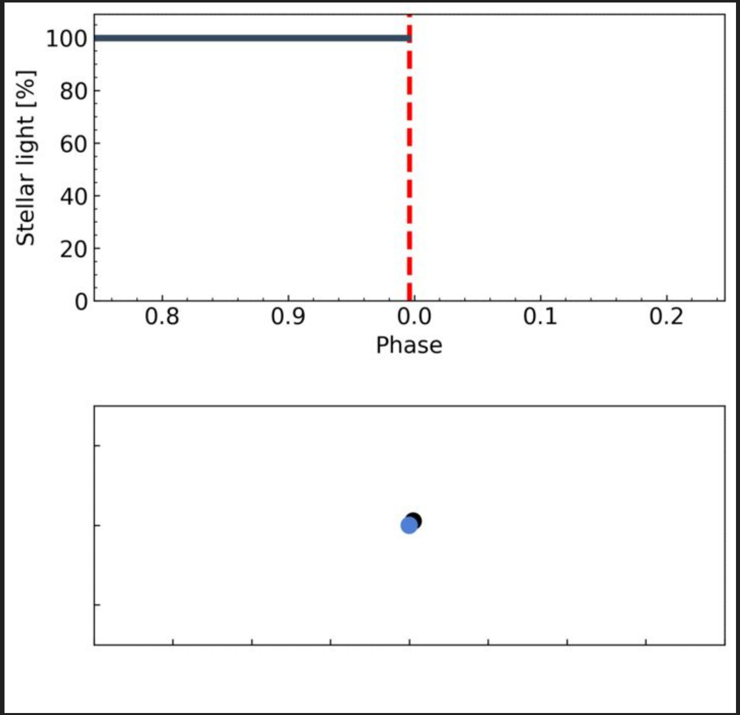
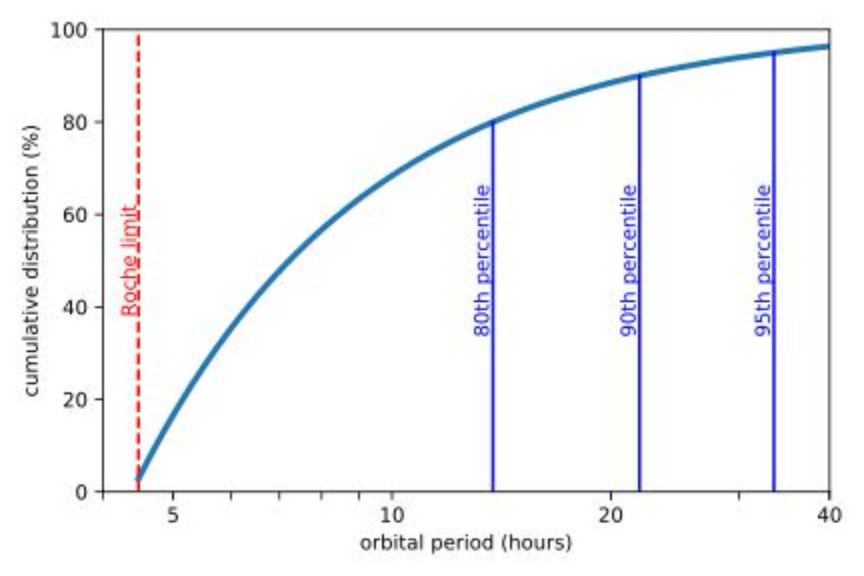
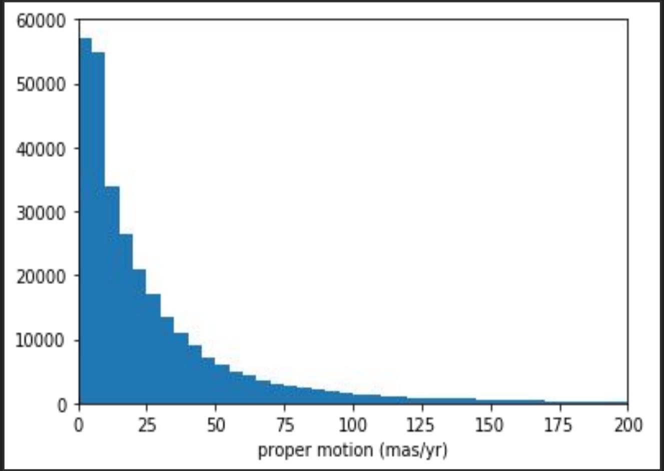
Silver lining: only short-period planets transit





Generating light curves

Using AXS for rapid analysis of large data set
(detections table)
Cross match to Gaia WD positions
(proper motion propagated)



THE ASTRONOMICAL JOURNAL, 158:37 (14pp), 2019 July
https://doi.org/10.3847/1538-3881/ab2384

CrossMark

AXS: A Framework for Fast Astronomical Data Processing Based on Apache Spark

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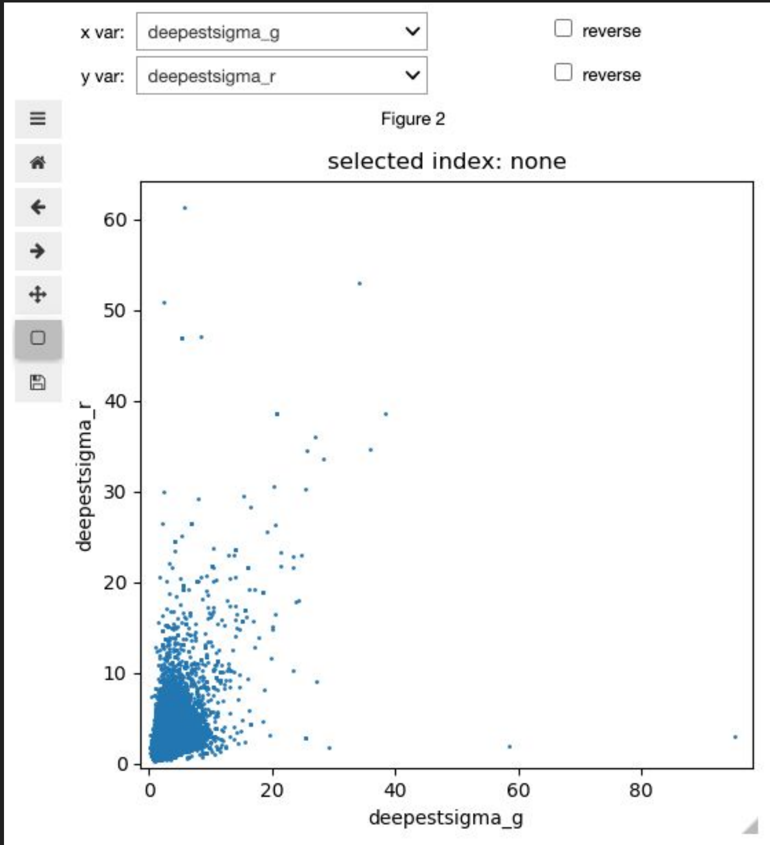
Searching for transit signatures

Calculate various statistics of interest in each band (highest-sigma dip, standard deviation flux, etc.)

Explore with dfbrowser:
github.com/keatonb/dfbrowser



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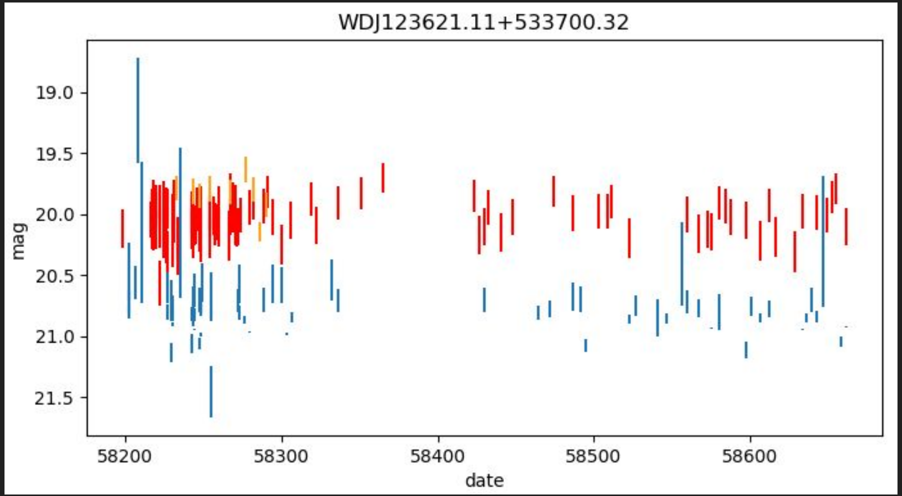

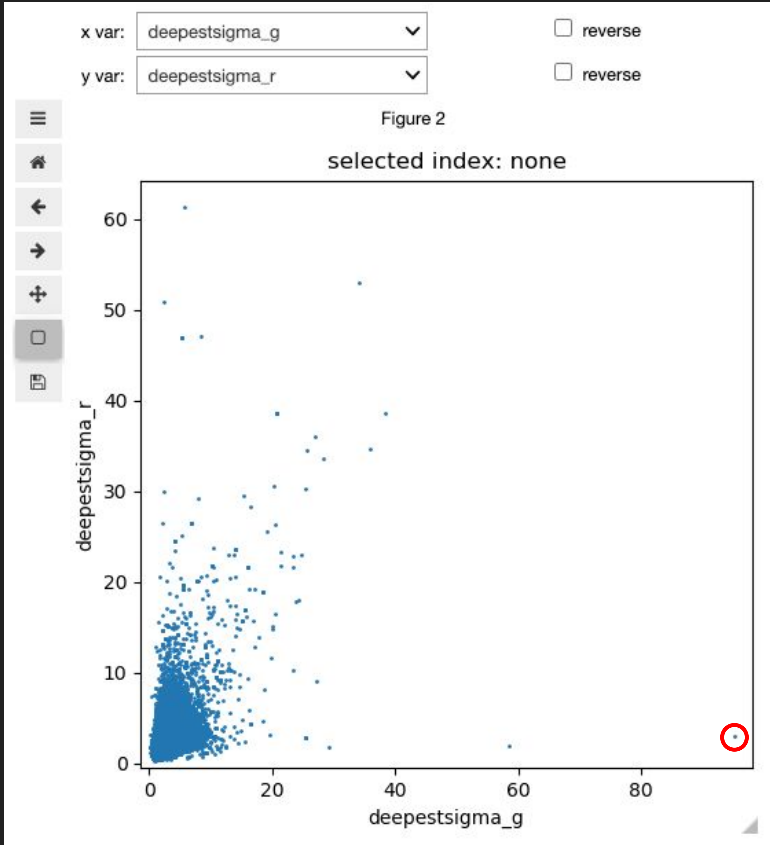

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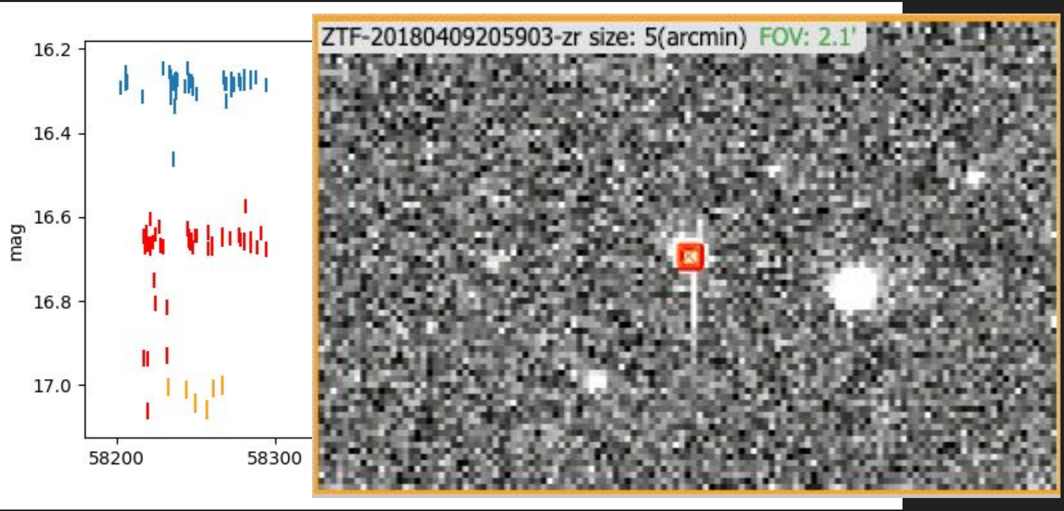

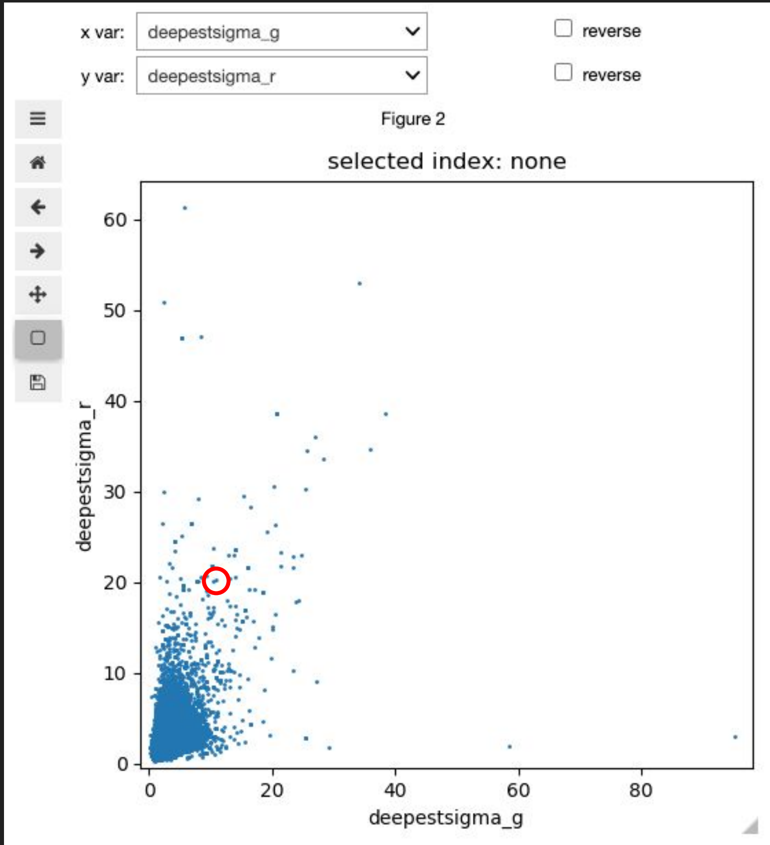

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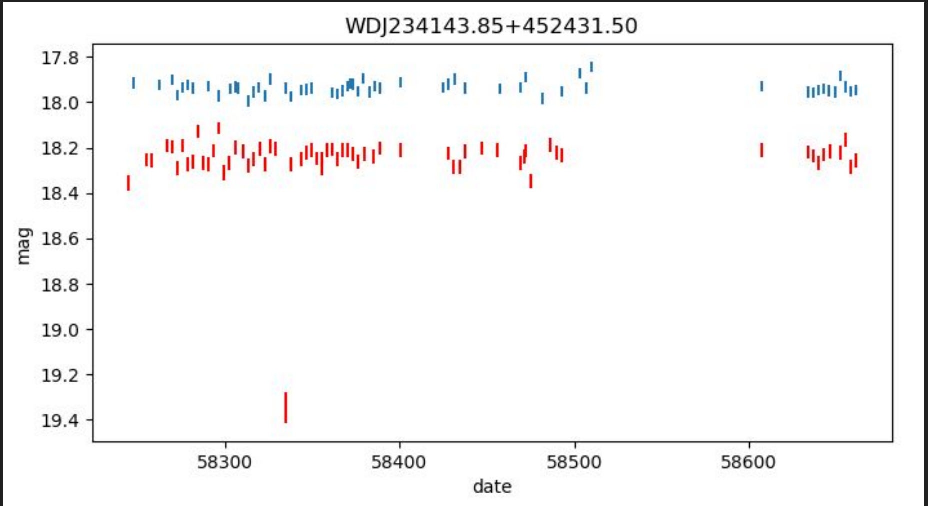

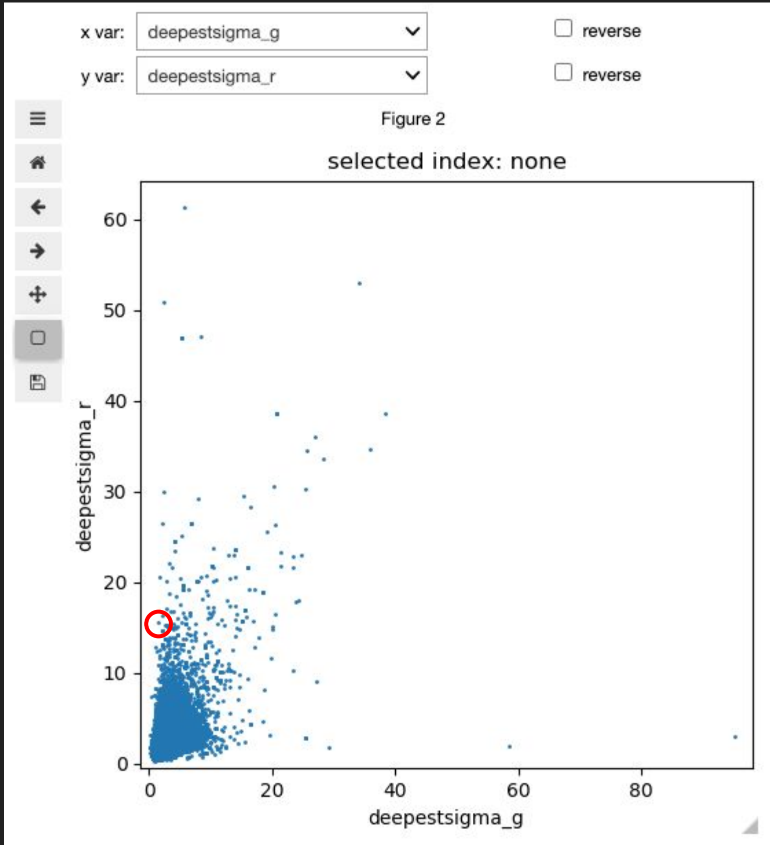

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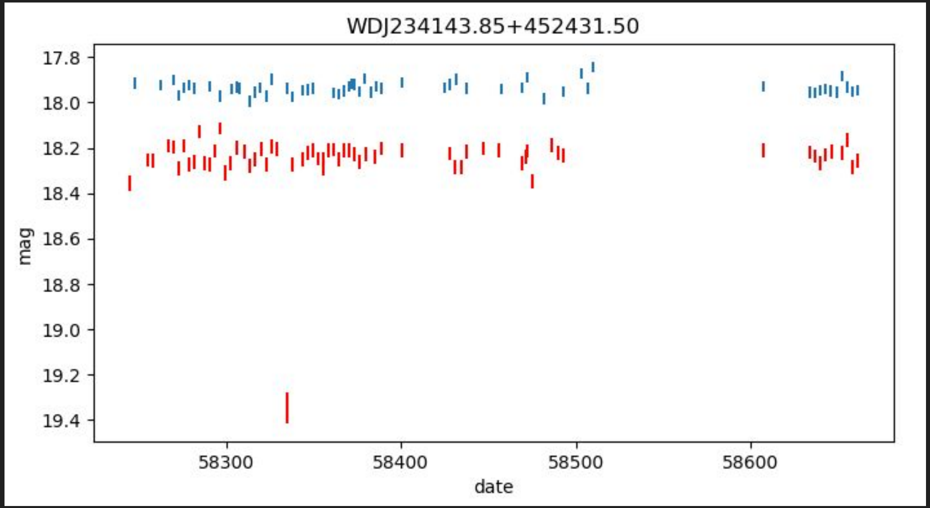

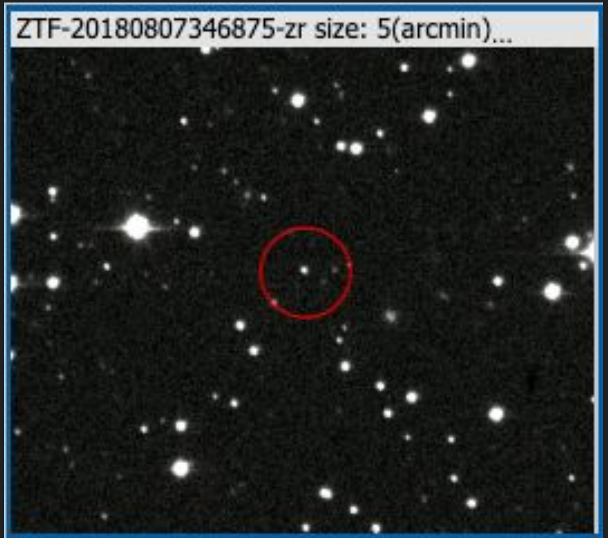

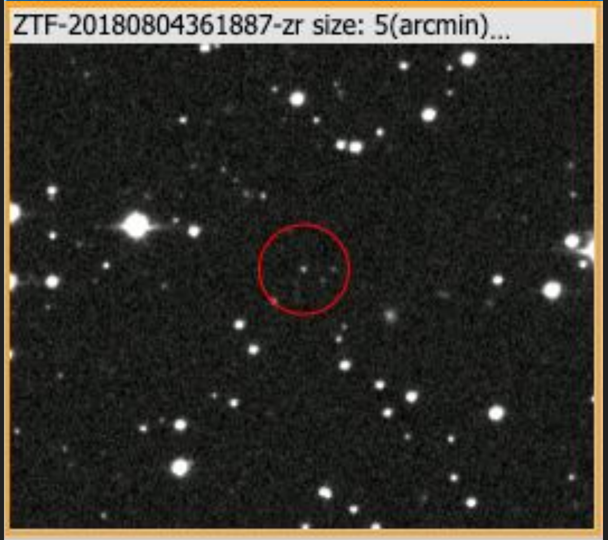

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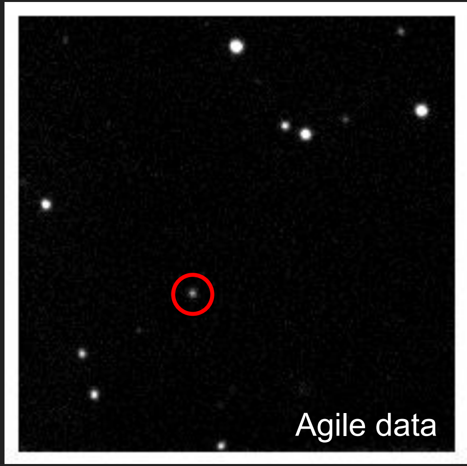

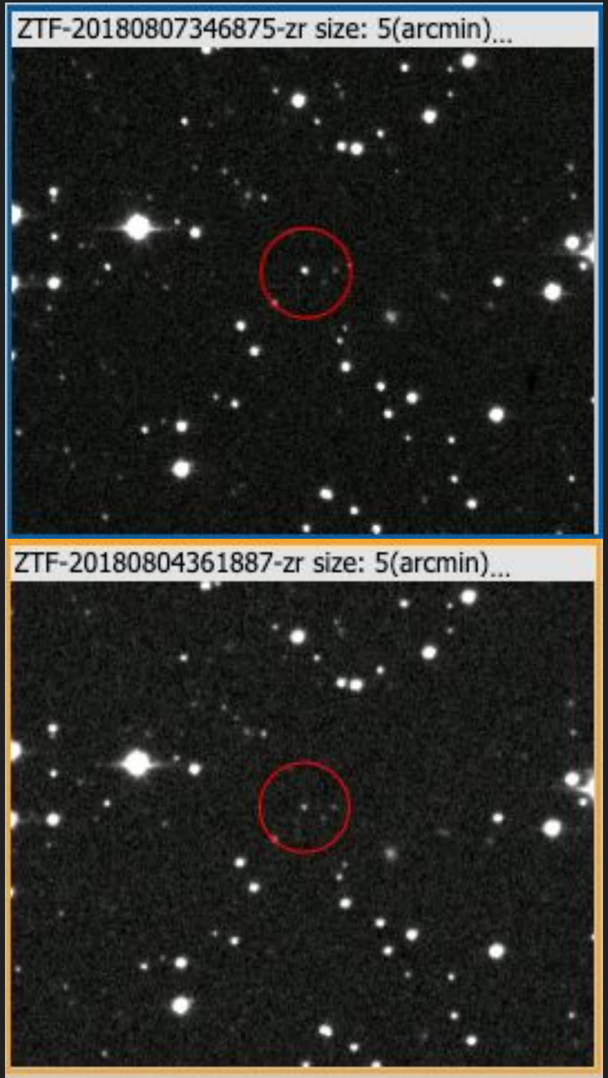

Improvements in progress:

Upper limits from non-detections

Compile and consider SEDs (check IR excess)

Now that candidates are quite robust, include an RV follow-up approach

ZTFQuery to replace manual IRSA search?