Characterizing the Orbital Periods of Transiting Planetary Debris around White Dwarfs

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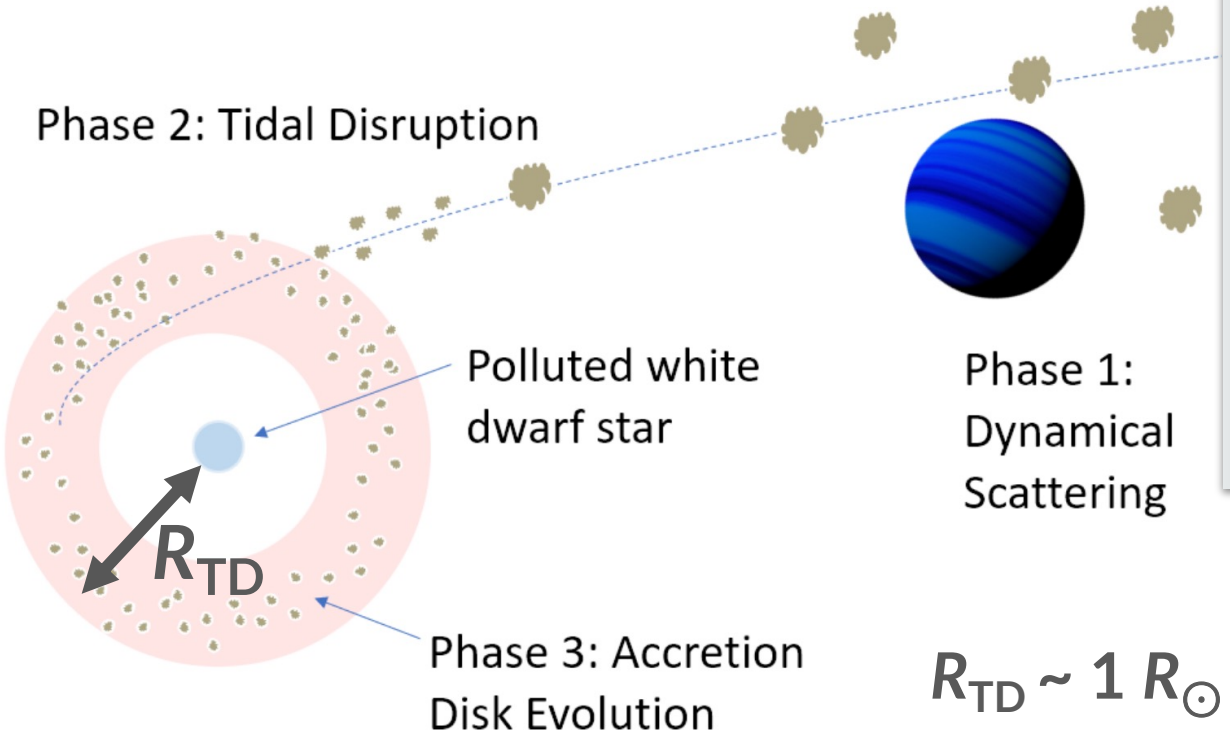
Image Credit: Mark A. Garlick

Recap: the tidal disruption model

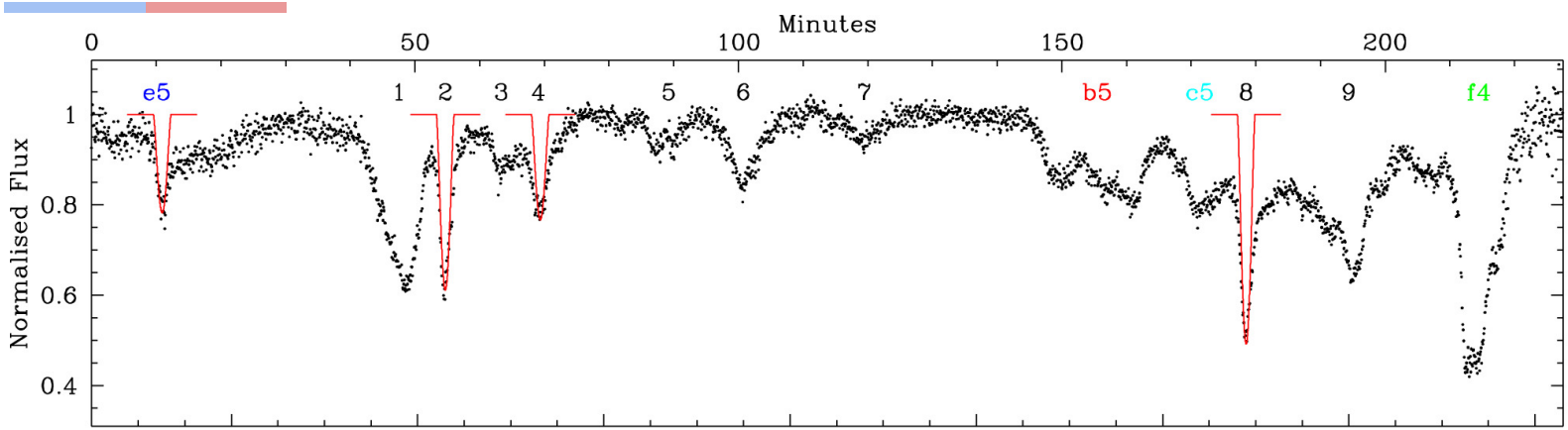


Surviving planetary systems explain white dwarf pollution

$R_{TD} \sim 1\ R_{\odot} \leftrightarrow$ ~4 hr orbit

Erik Dennihy's PhD Dissertation

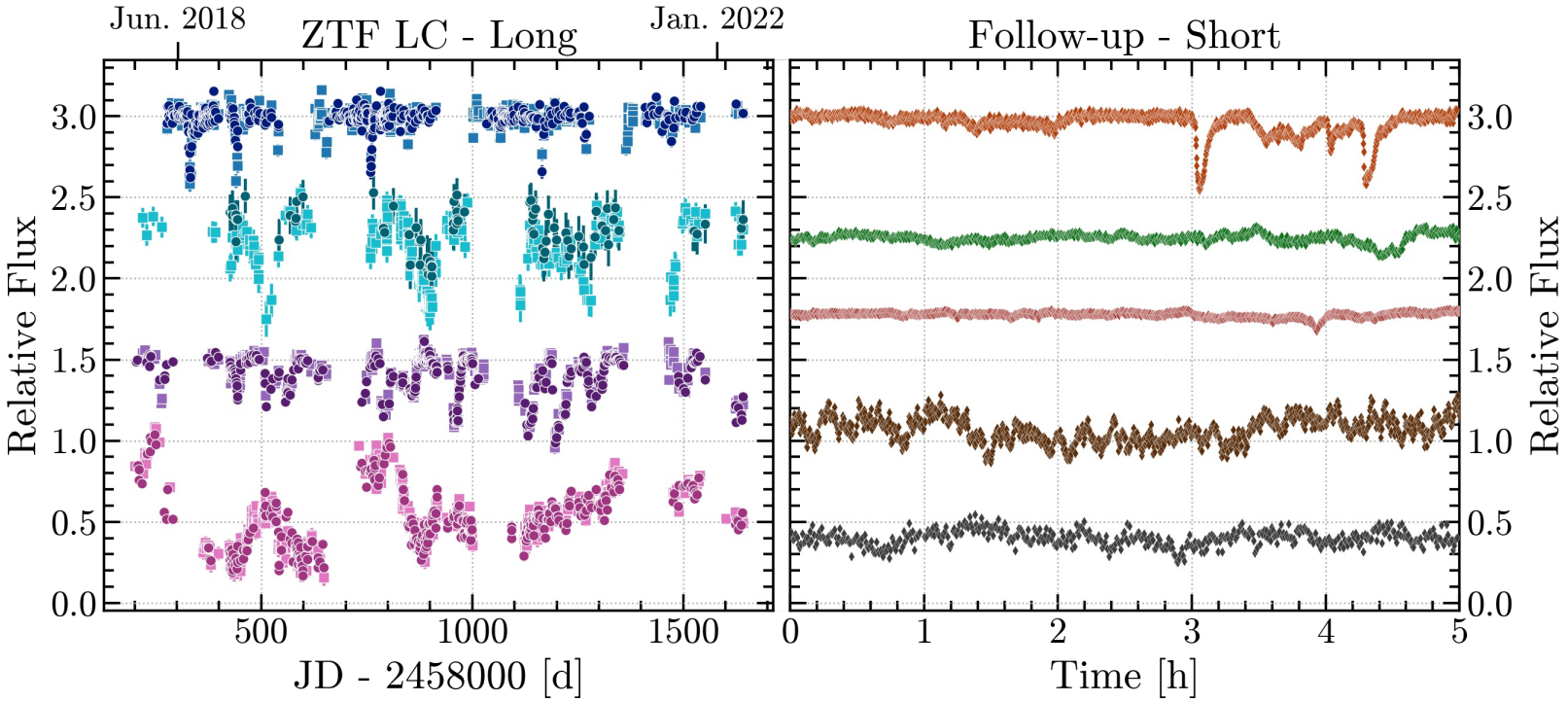
WD1145+017: Transits from planetary debris



WD1145 shows deep, irregular transits that repeat every 4.5 hours. Attributed to a disintegrating, tidally disrupted minor planetary body.

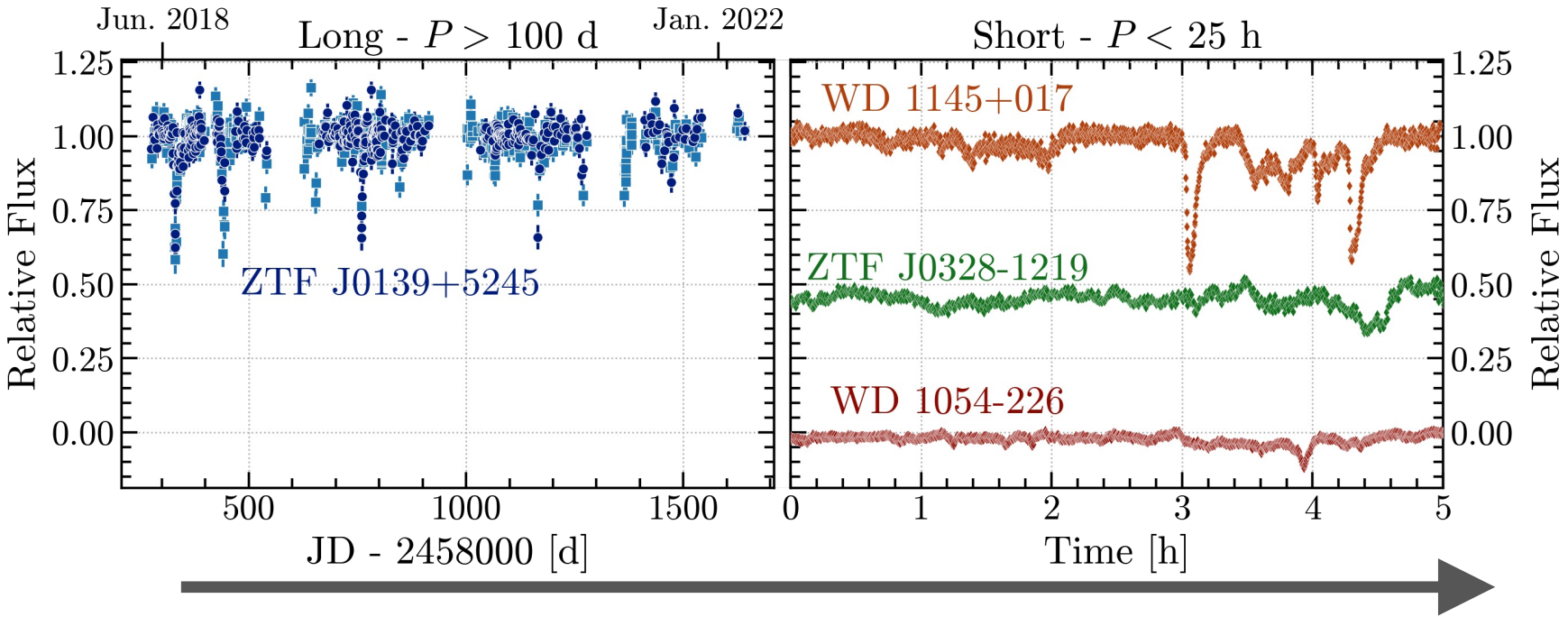
Vanderburg+ 2015; Gänsicke+ 2016
Image Credit: Mark A. Garlick

Transiting debris: zoo of light curve morphologies



Vanderburg+ 2015, Vanderbosch+ 2020, Guidry+ 2021, Vanderbosch+ 2021, Farihi+ 2022

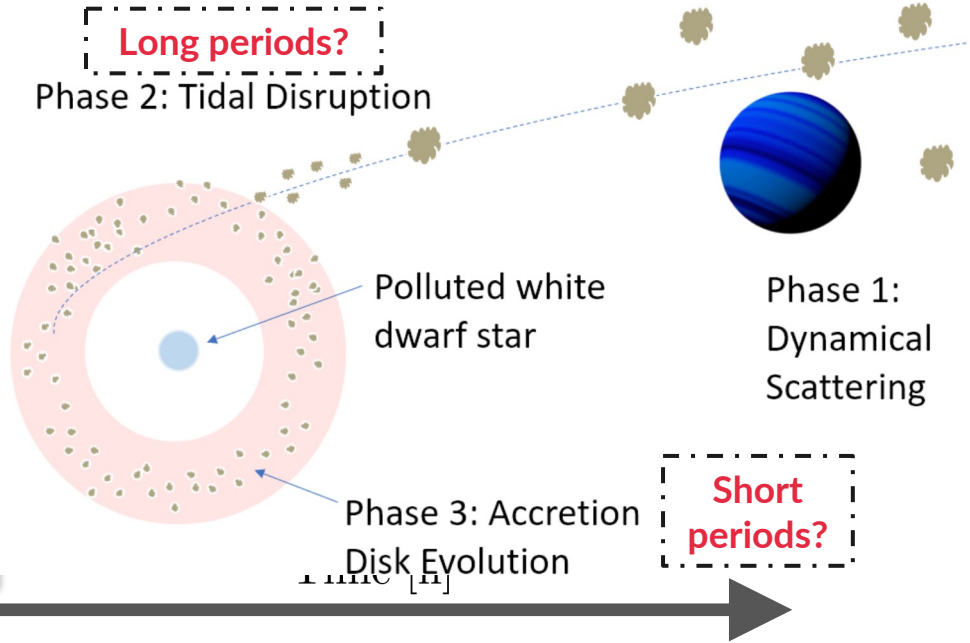
Only 4 systems have measured orbital periods



Eccentric, recently tidally disrupted debris? **Age?** **Older, less eccentric, more evolved debris?**

Orbital periods allow us to characterize transiting WDs

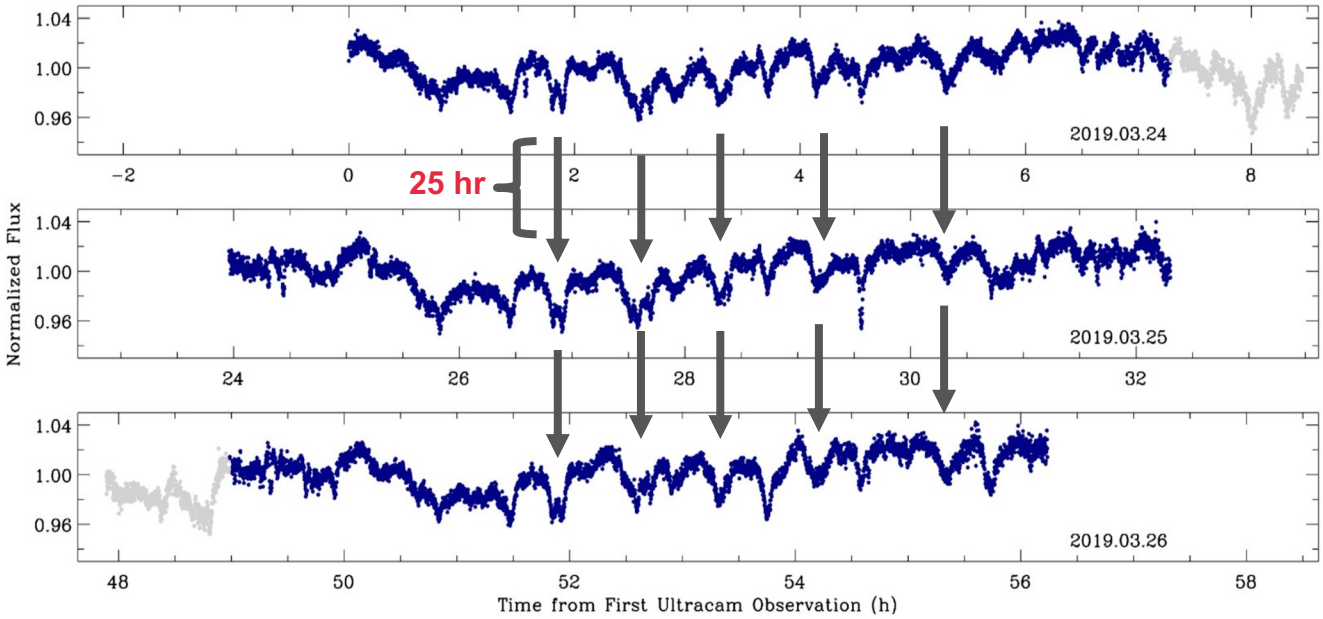
1) *Do transiting WDs show different properties as a function of orbital period or age?*
2) *What does that say about the role of collisions in the evolution of the debris?*



Eccentric, recently tidally disrupted debris? Age? Older, less eccentric, more evolved debris?

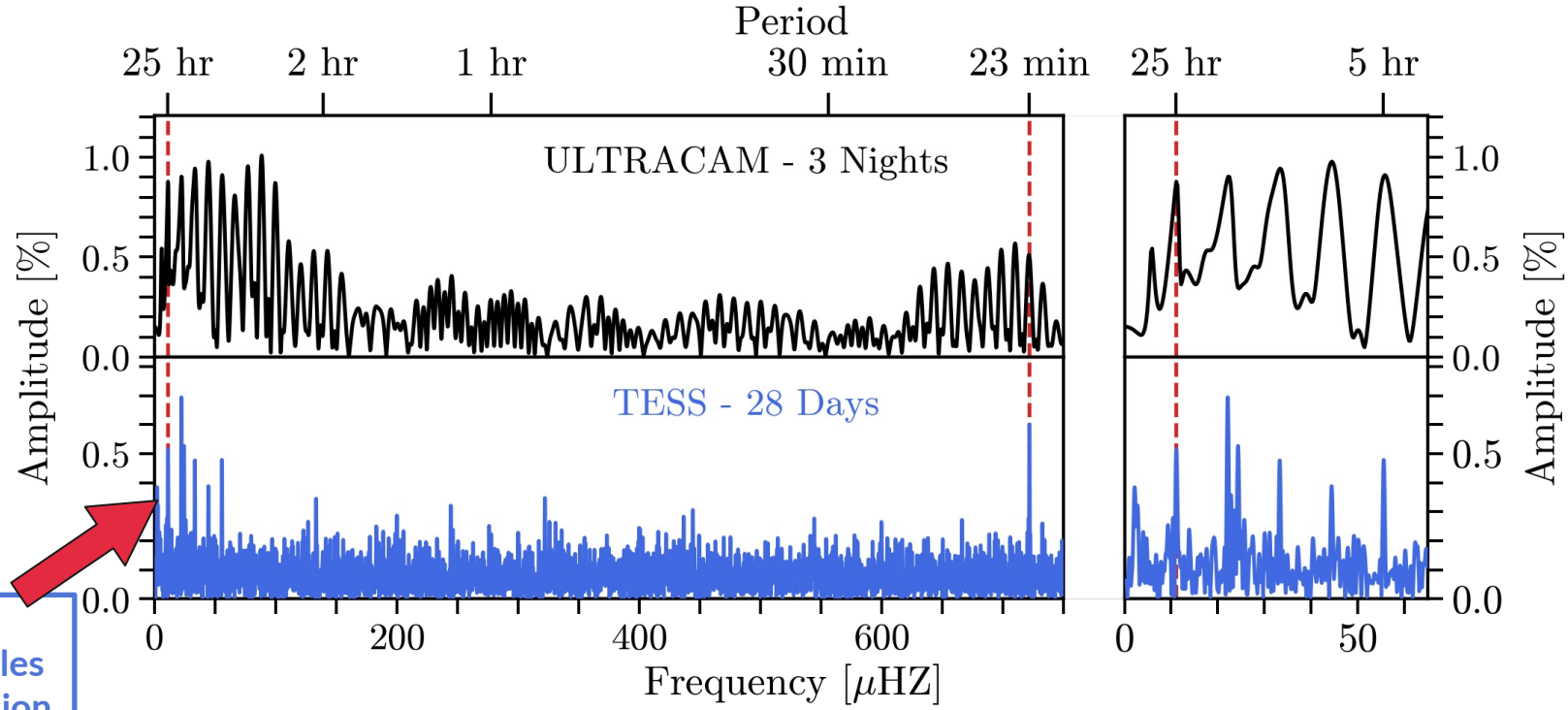
WD1054-226 – Repeating transits at 25.02 hr

- ➔ Continuous, non-stop transit events
- ➔ Transits phase together at **P = 25.02 hr**



Farihi+ 2022

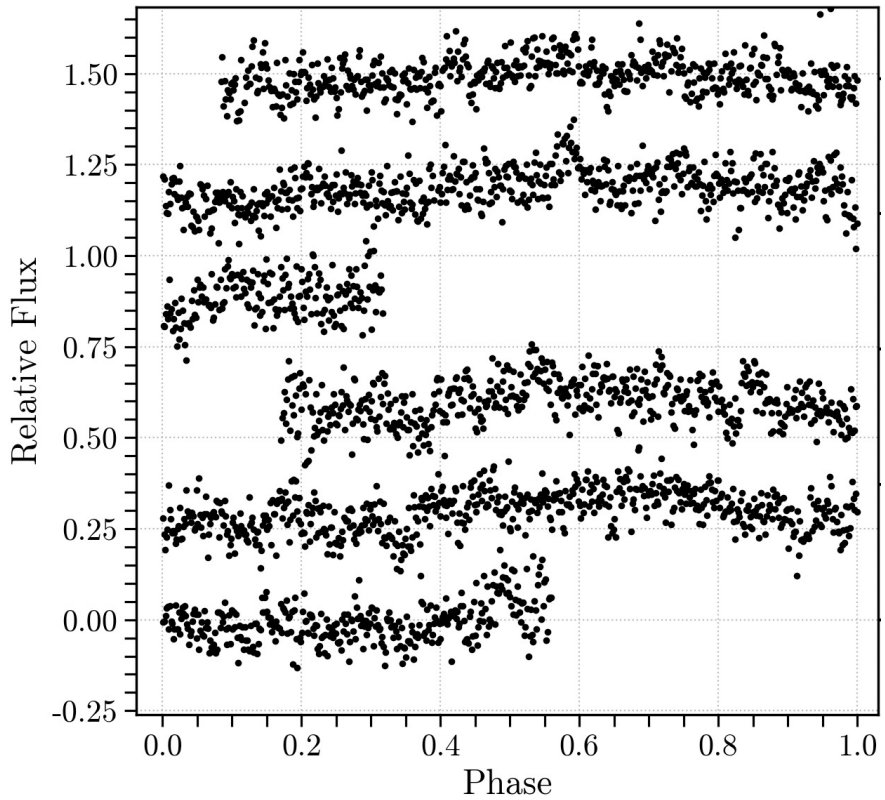
Periodograms revealed WD1054's period



Farihi+ 2022

TESS enables high-precision period determination

We can't always rely on TESS!



Is there an alternative period-finding tool that can compliment Fourier techniques?

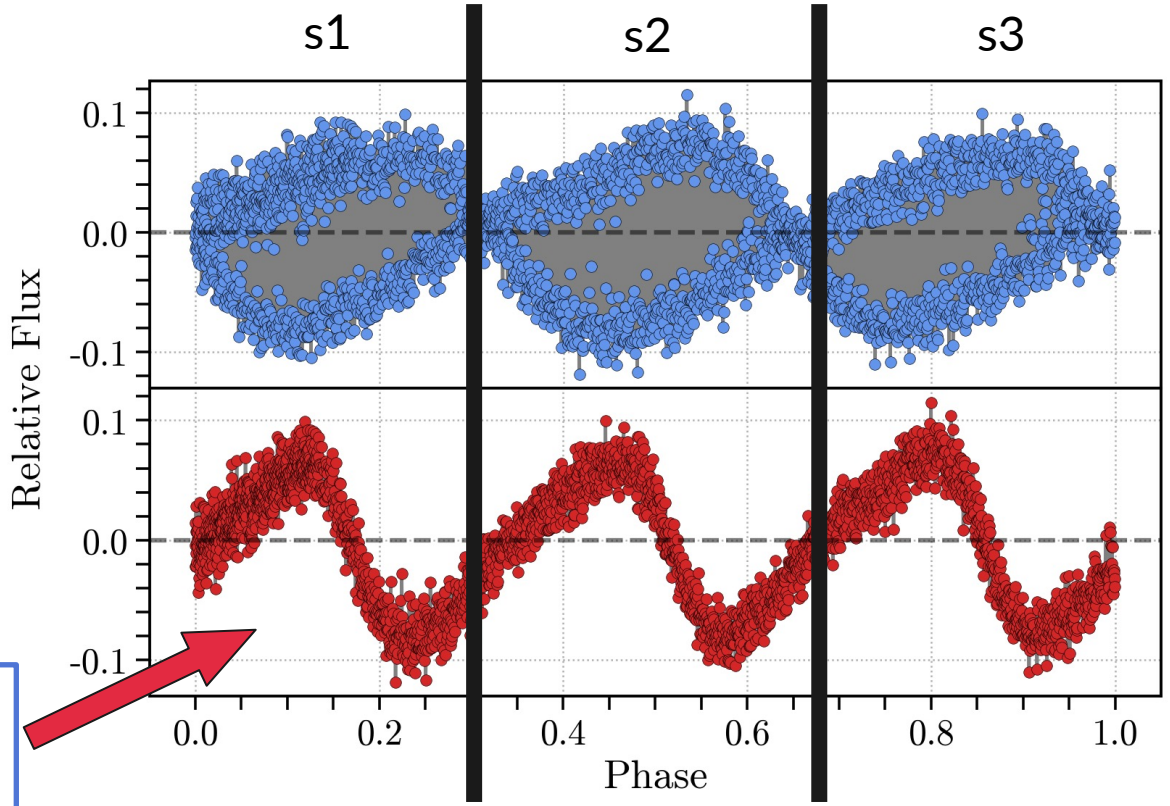
2.6 hr rotation period from LSP?
In line with measured WD rotation periods (Hermes+ 2017d)

Phase Dispersion Minimization

- Seeks the period that minimizes the path length of the light curve when folded over it (Stellingwerf 1978)

$$\Theta = s^2/\sigma^2$$

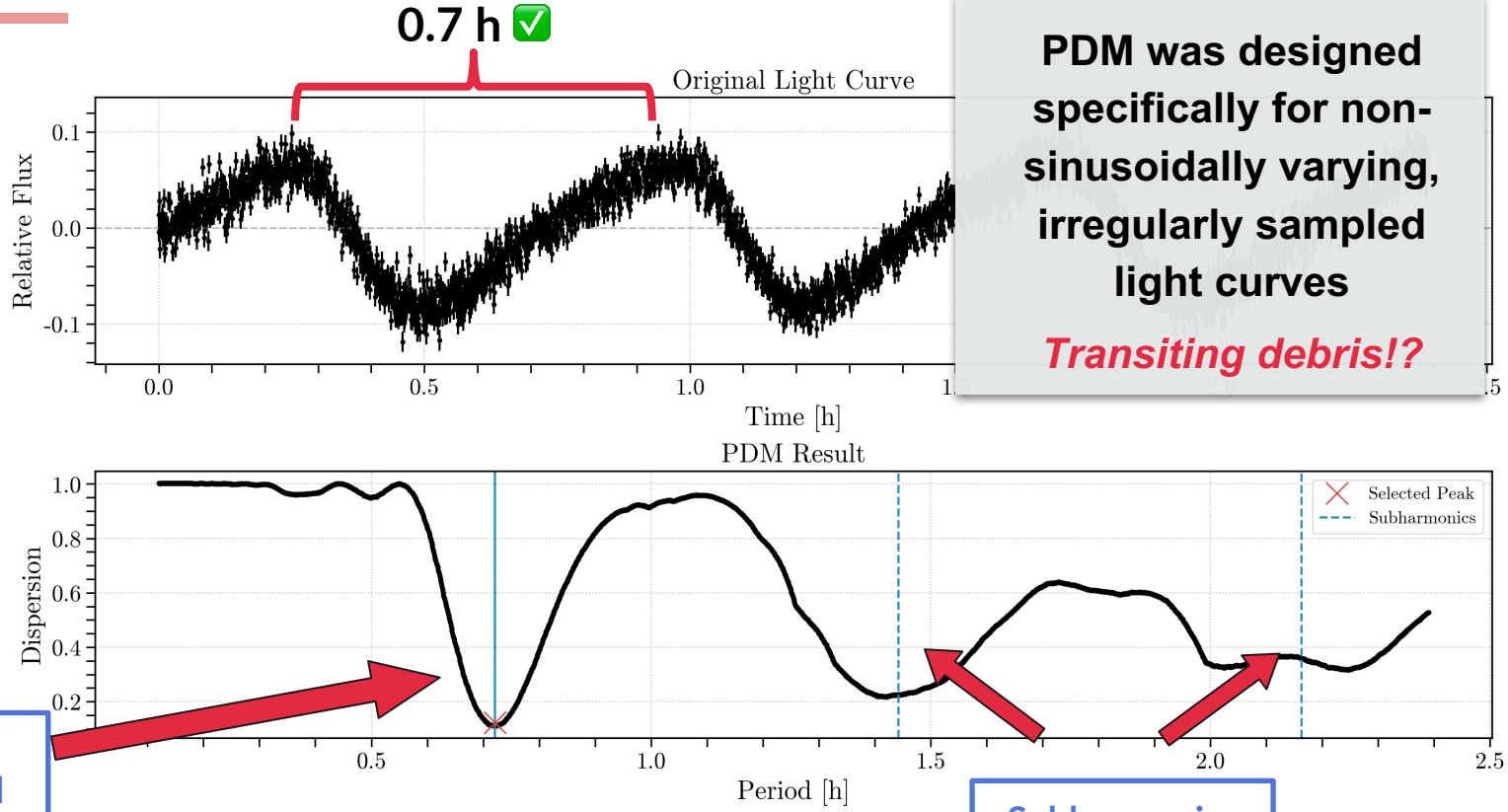
- s^2 is the weighted average of the path lengths s1, s2, s3
- σ^2 is the path length of the original light curve



Shorter path length, better period

Phase Dispersion Minimization

Using Ruth Angus' implementation of Stellingwerf (1978): **starspot**



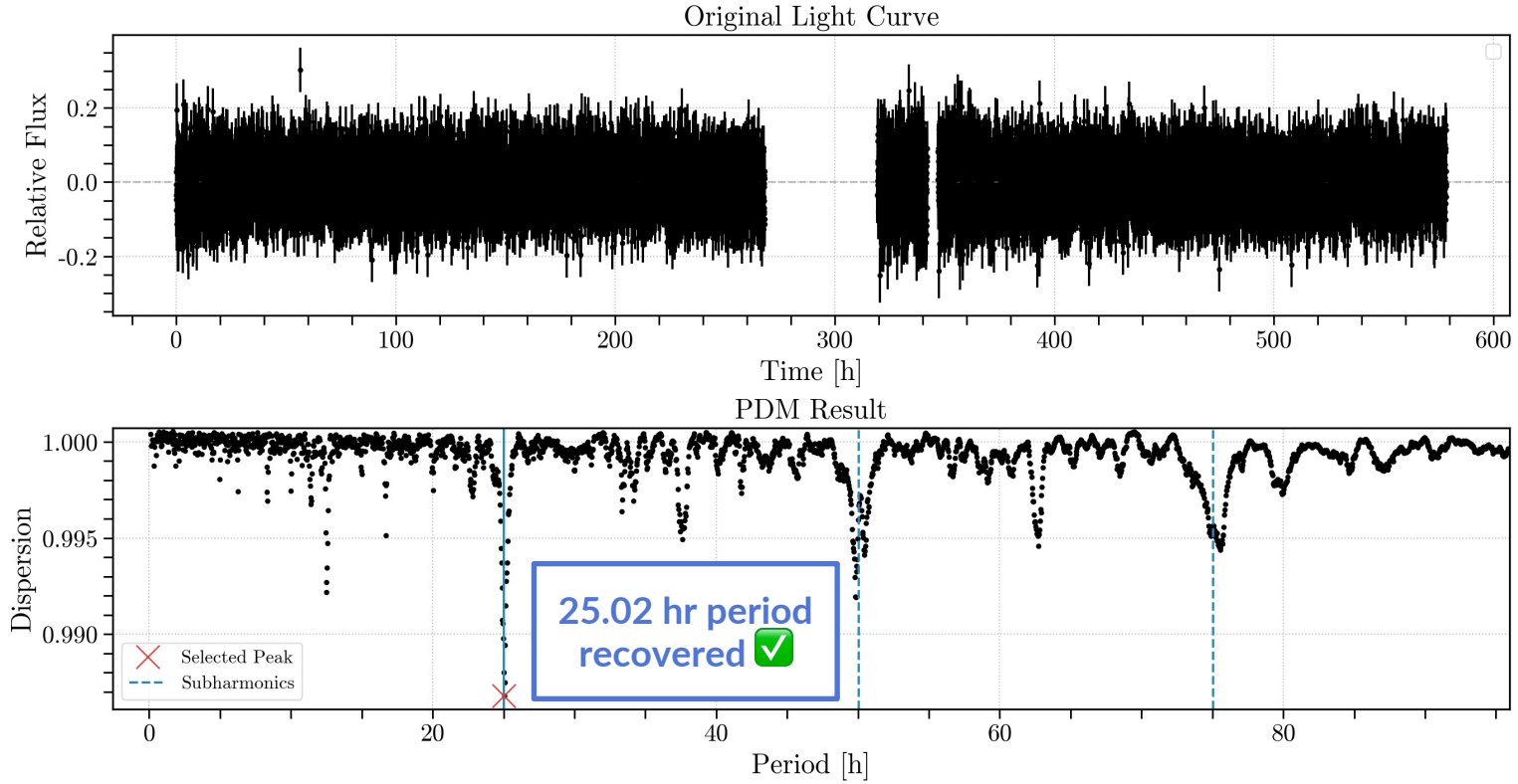
PDM was designed specifically for non-sinusoidally varying, irregularly sampled light curves

Transiting debris!?

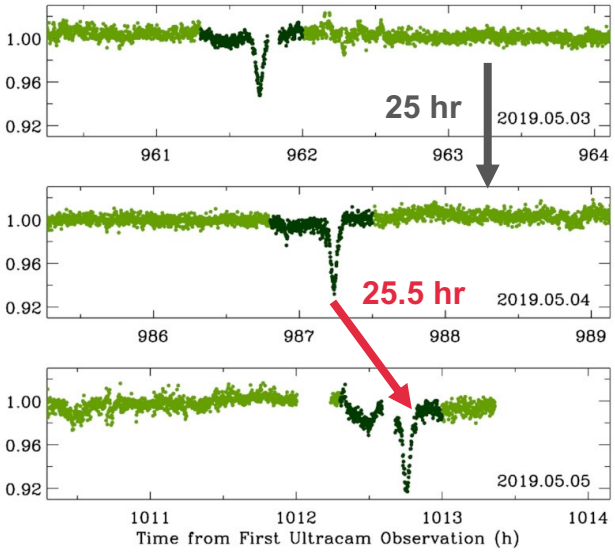
Theta is minimized at ~0.7 h

Subharmonics

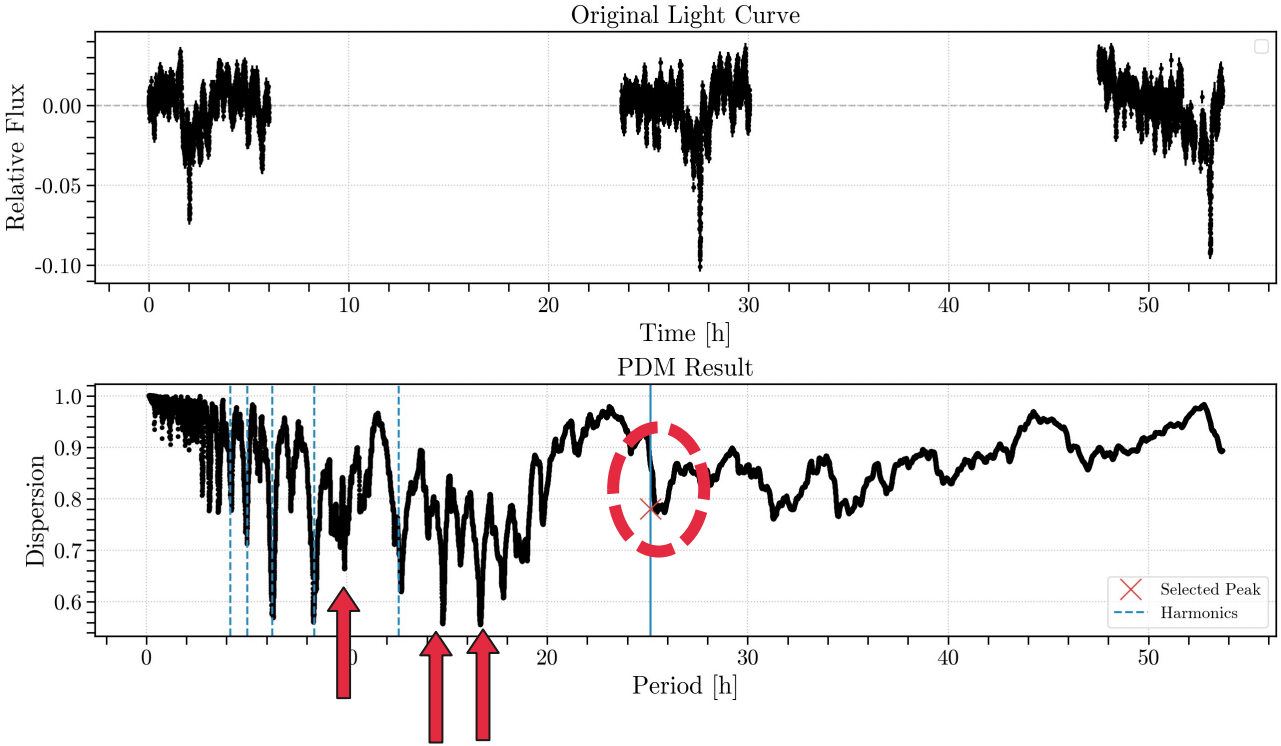
PDM of WD1054's TESS light curve



PDM of WD1054-226 follow-up

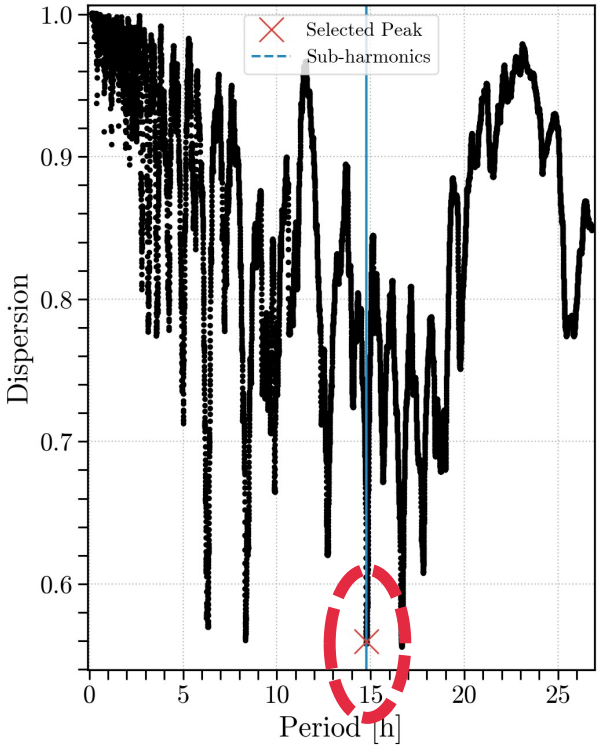


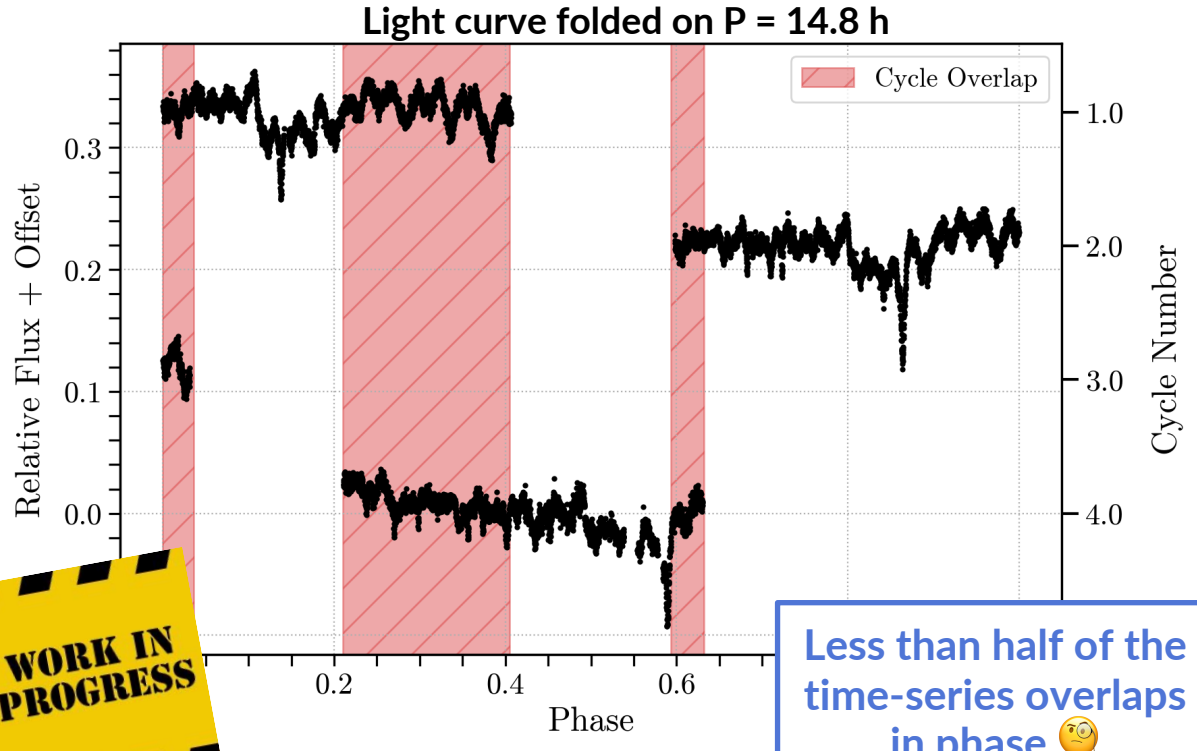
Farihi+ 2022



Are some minima drifters?!

But are all the minima “real”?





Less than half of the time-series overlaps in phase 🧐

Takeaways

1) White dwarfs showing **transits** from planetary debris are a **nascent class** of remnant planetary systems

2) Only **four** of these systems have measured orbital periods to date
   - ➔ There is a dichotomy of **short-** (~hours, less eccentric) and **long-** (~months, highly eccentric) periods

3) **Phase dispersion minimization** is a promising technique to measure new orbital periods that have eluded detection

Thank you!! 🙂

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