ZVAR

(New capabilities in << 10 Years)

ZVAR = Zwicky Transient Facility Variability and Periodicity Project

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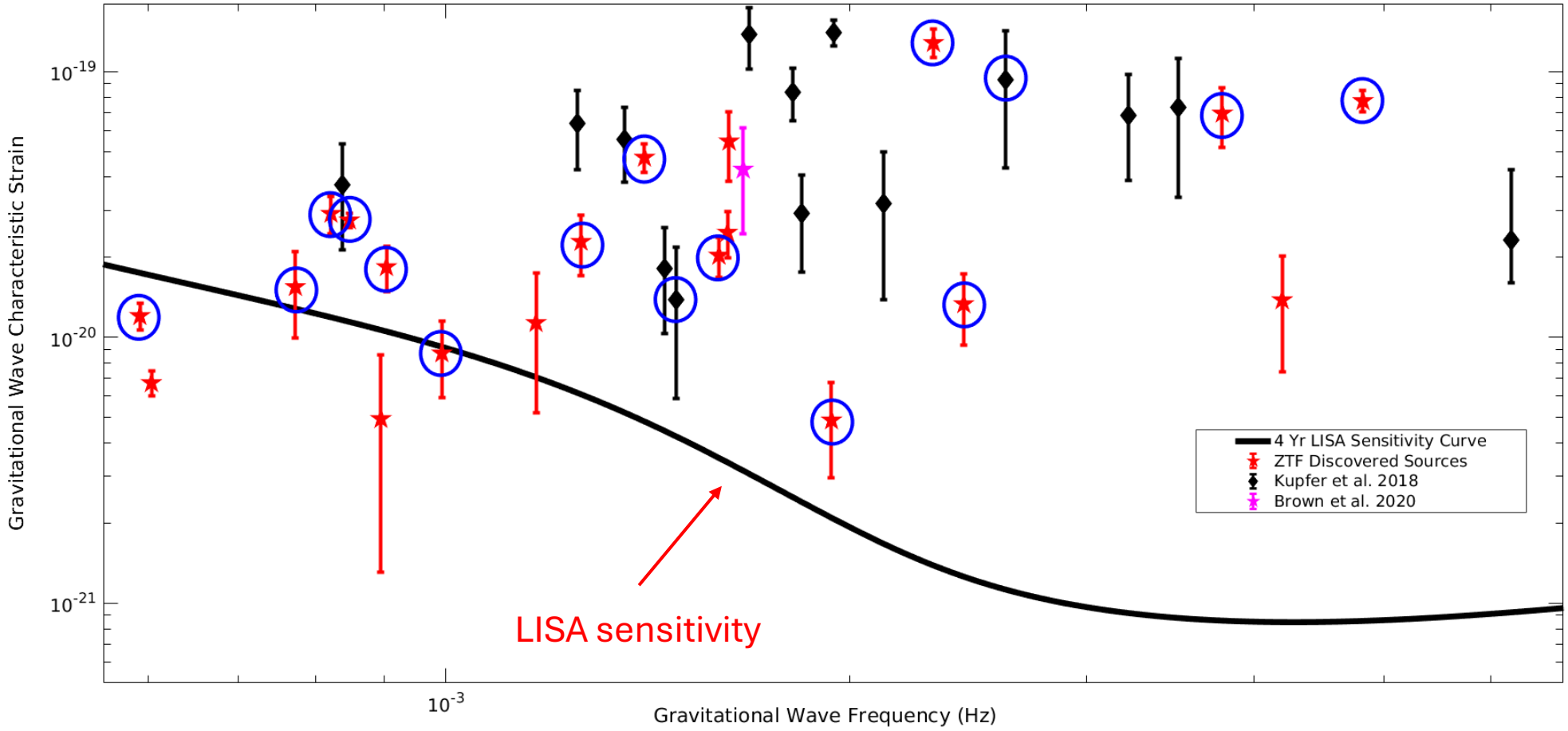
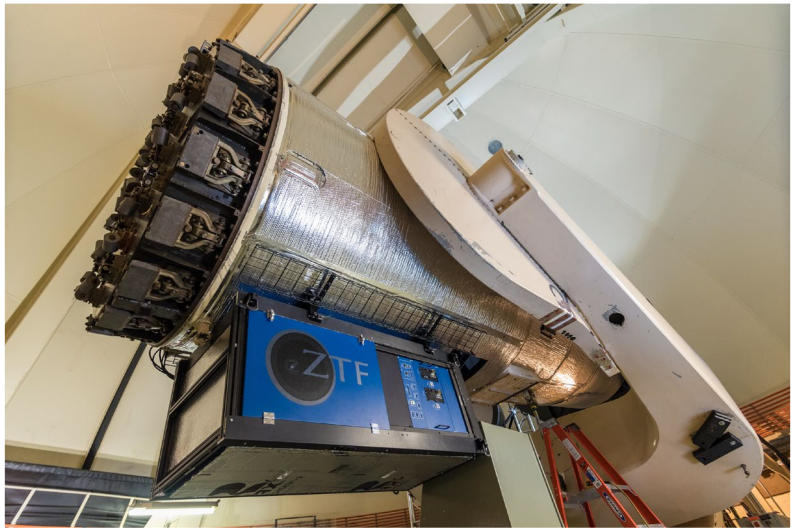
3 April 2025

[Non-spoiler alert: No discussion of new LISA-detectable sources in this talk]



(Red points show ZTF discovered ultracompacts)

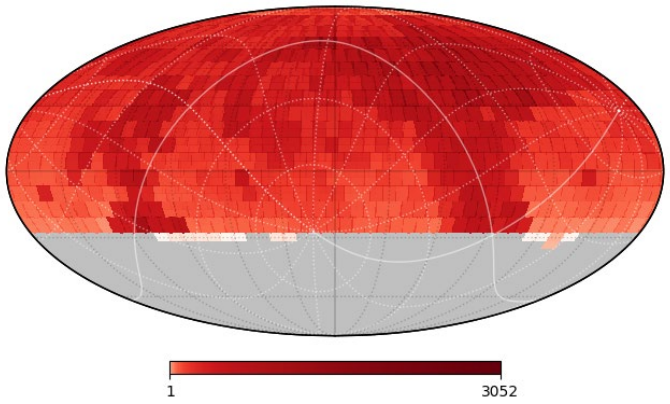
Low hanging fruit? Can we do significantly better?



Zwicky Transient Facility (ZTF)

ZTF Large Area Survey

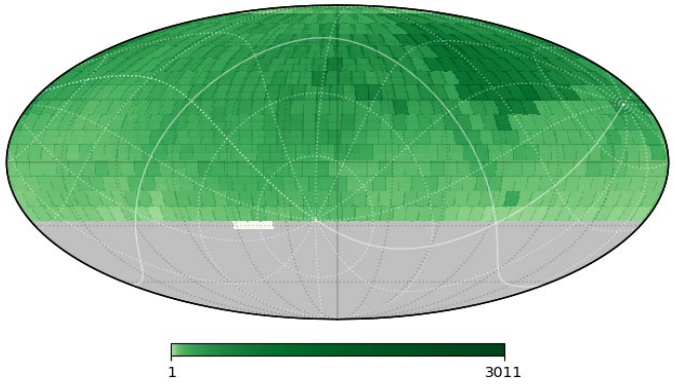
ZTF covers the visible sky every 2 nights
7 years of observing has produced a
data set containing a median of
~1750 observations/source for
about 1.5 billion sources



r-band

Coverage
> -30 deg
declination

Covers 2/3 of sky,
including significant
overlap with Rubin/LSST



g-band

ZVAR – ZTF Variability and Periodicity

Goal: Produce a definitive ZTF variability and periodicity data set open to the astronomical community

Transcends LISA (but will be very productive for LISA investigations)

- Besides ultracompact binariees
  - WD merger products, pulsators and rotators (from 5 minute to 30 day periods), CVs, low-mass binaries, certain types of exoplanets, …

In the sweet spot for follow-up with existing ground-based telescopes

- Follow-up is critical for LISA candidates
- Don’t have to wait for 30-meter class telescopes

ZVAR – a "Stone Soup" collaboration

The stone: LISA Preparatory Science Grant

ZVAR partnership now involves collaborators from 10 institutions:

- Caltech, Columbia, Harvard, IST (Austria), MIT, UMinnesota, Tata Institute (India), UToronto (Canada), VillanovaU, UWashington

First periodicity processing of data almost complete

(requires 10^{19} ops – periods down to 5 minutes - or less)

Includes periodicity summaries & tools for accessing and cross-matching
Significantly improved data sets to follow!

Funding requested to make data and tools public

Currently limited to partnership early-user access

But, room for additional partners *(who bring vegetables!)*

What Makes ZVAR Superior?

- New algorithm (FPW)
  - Previously mostly Lomb-Scargle. ZVAR: better for eclipses
- Proper motion corrected forced photometry
  - Previously, mostly PanSTARRS positions (>10 yrs old)
- Significantly better photometry
  - Previously, >10 mmag systematic errors. ZVAR: <5 mmag
- Better catalogs for forced-photometry positions
  - Previously, PanSTARRS. ZVAR adds Gaia & ZTFDeep (m~23)
- More observations (7 yrs), more deep drilling, better sampling in Rubin/LSST fields
- Tools: Cross-match with other surveys built-in

What Makes ZVAR Superior? [Eclipses!]

Previous analyses:

Mostly Lomb-Scargle

Not very sensitive to eclipses

ZVAR:

Uses new FPW algorithm

Sensitive to both sinusoidal and eclipsing sources

Finkbeiner+25

arXiv:2502.00243

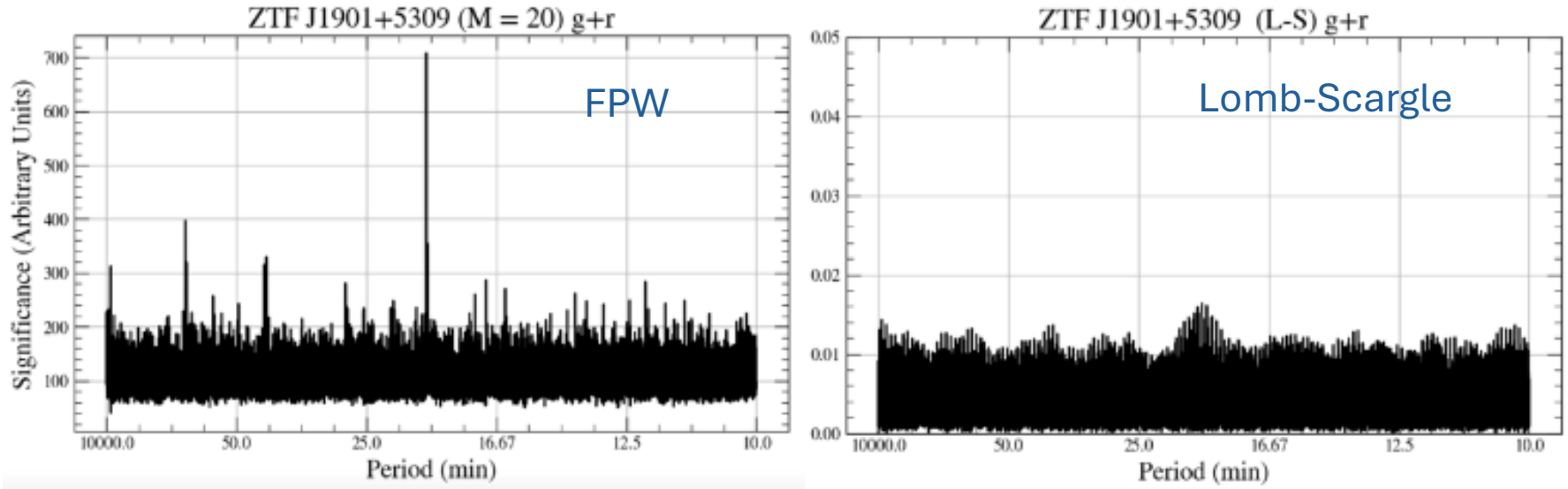


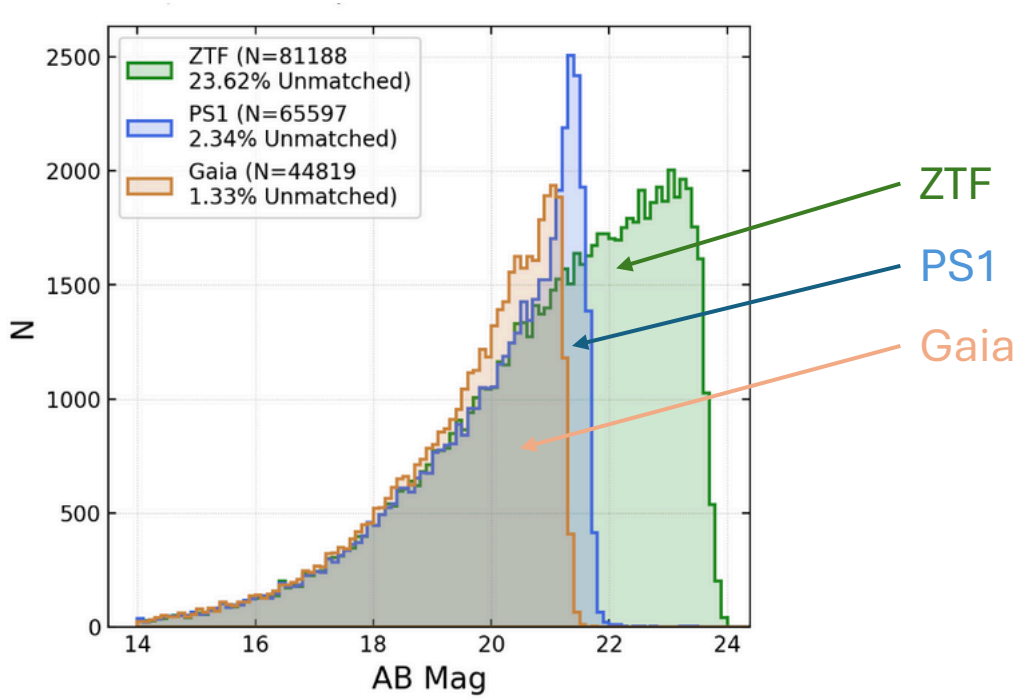
Figure 5. Analysis of the eclipsing source ZTF J1901+5309 (Burdge et al. 2020). Left: FPW analysis. The source exhibits narrow primary and secondary eclipses, leading to a strong detection at half the period, i.e., at 20.3 minutes. Right: Lomb-Scargle analysis of the same data set. A broad weak peak is seen at 20.3 minutes.

FPW = "Fast Periodicity Weighting", (or maybe "Finkbeiner, Prince, & Whitebook"?)

What Makes ZVAR Superior?
[Limiting sensitivity and number of sources

ZVAR

- m ~ 22-23 for periodicity
- More observations, better systematics, improved algorithm
- All sources in ZTFDeep catalog will be analyzed, down to m~23 or fainter
- What to do when we go fainter than Gaia? CMD? Proper motion?



[Example from one ZTF CCD]