fBLS

A fast folding algorithm to produce BLS periodograms in search for transiting planets

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- fBLS is a novel technique for detecting transiting planets, based on the fast-folding algorithm [1], extensively used in pulsar astronomy [2].
- fBLS is efficient and scalable. It can substantially reduce the computation time required to search for transiting planets. For example, when applied to the *Kepler* data, fBLS reduces the computation time by a factor of up to ~3000.
- We used fBLS to detect small rocky transiting planets with periods shorter than one day, a period range for which the computation is extensive [3]. We have discovered five new planet candidates (Shahaf et al., in prep.)
- fBLS is well suited to the analysis of PLATO lightcurves. We currently adapt fBLS and extend its operation to efficiently detect planets with varying transit duration and timing [4].

AFFILIATIONS

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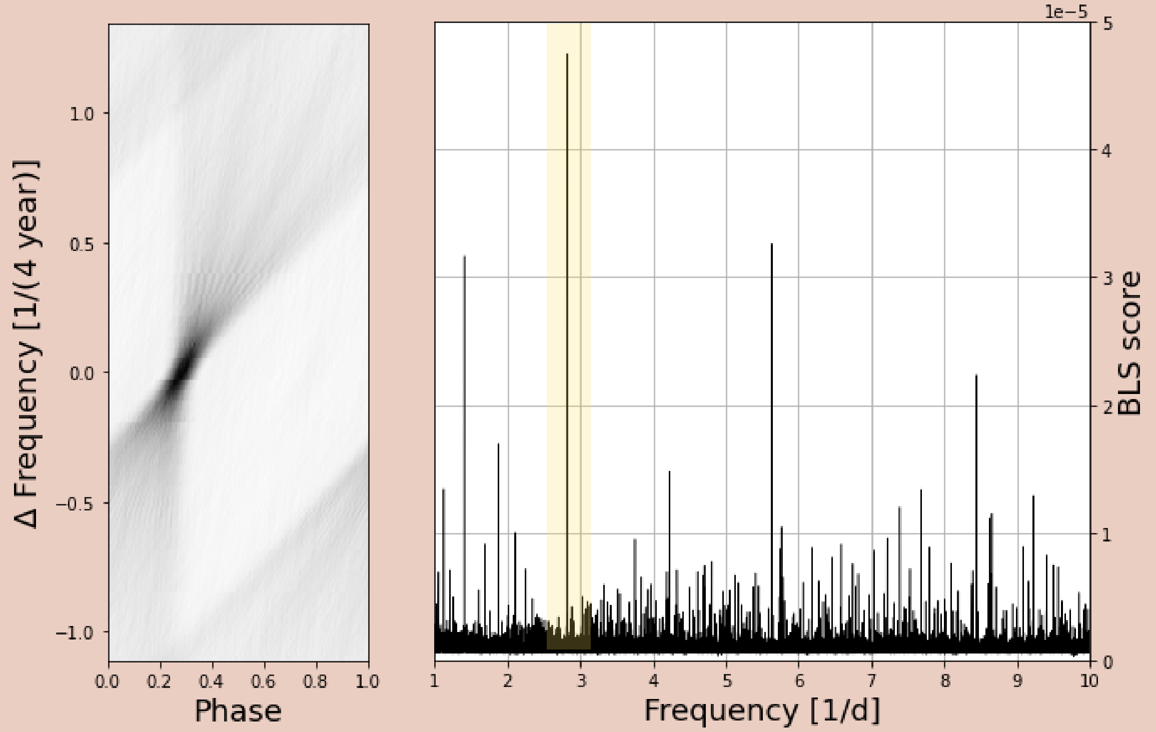
Hunting ultra-short period planets

Ultra-short period (USP) planets are exoplanets with orbital periods shorter than one day, which tend to be terrestrial. Studies of these extreme systems can shed light on planet formation, star-planet and planet-planet interaction, and orbital evolution.

Demonstration: *Kepler-78b*

Figure 1: fBLS periodogram of *Kepler*-78. The *left panel* is a grayscale diagram demonstrating the fast-folding algorithm output for a narrow frequency range centered around the periodogram peak. The fBLS periodogram appears on the *Right panel,* where the BLS scores were calculated for each of the fast-folded profiles. The central peak is highlighted in yellow. The required single-core computation time for the settings used in this example is ~10 sec.



How does fBLS work?

For a given lightcurve of N measurements, fBLS simultaneously produces binned and phase-folded lightcurves for an array of N_p 'sufficiently different' trial periods, with $\mathcal{O}(N_p \log N)$ arithmetic operations. This procedure is conceptually similar to FFT. For comparison, a standard BLS implementation requires $\mathcal{O}(N_p N)$ operations. For each folded lightcurve we compute the BLS statistic [5], producing a standard BLS periodogram.

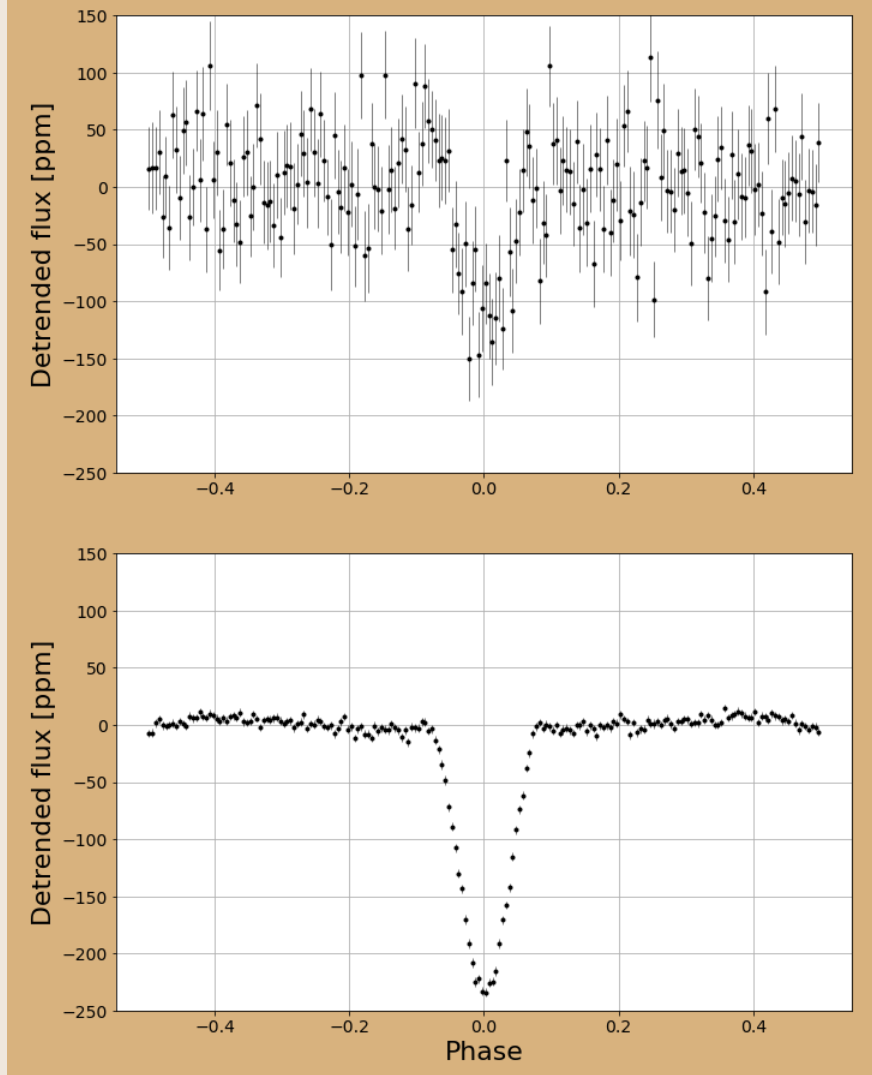


Figure 2: Two examples of phase folded USP planet lightcurves with the same number of bins. *Top*—a new USP candidate, detected by fBLS. *Bottom*—*Kepler*-78b, plotted for reference. Vertical axis range is identical. Despite the shallower signal and the significantly larger noise level, fBLS easily detects the transit, which could not have been detected before.

RELATED LITERATURE

[1] Staelin D. H., 1969, Proceedings of the IEEE, 57, 724
[2] Morello V., et al., 2020,MNRAS, 497, 4654
[3] Winn J. N., Sanchis-Ojeda R., Rappaport S., 2018, New Astron. Rev., 83, 37
[4] Shahaf S., Mazeh T., Zucker S., Fabrycky D., 2021, MNRAS, 505, 1293
[5] Kovács G., Zucker S., Mazeh T., 2002, A&A, 391, 369

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