A Homogeneous Catalog of Kepler Solar-like Oscillators Observed in Short Cadence

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Introduction

NASA's *Kepler* mission[1,2] revolutionized the field of asteroseismology by enabling us to determine precise and accurate fundamental properties across the HR diagram[4,5,6,7,8,9,10,11,12,13]. The TESS mission is expected to yield an even higher number of solar-like oscillators including cool main-sequence stars[15,22]. *Kepler* benchmarks are highly complementary to TESS, and provide a powerful dataset for data analysis tools[16]. Furthermore, with continued coverage of the *Kepler* field, oscillations may be detectable in stars with both instruments[17] allowing us to study the dependence of oscillation amplitudes on wavelength. Therefore, it is essential to expand on the current asteroseismic sample for main-sequence stars.

Currently, there exist ~600 *Kepler* dwarfs and sub giants with detected solar-like oscillations, many analyzed with varying methods[18,19,20,21]. However, there exists no homogeneous analysis of all detections. Here, we use pySYD[22,23] to provide a homogeneous catalog for all solar-like oscillators observed by *Kepler* in short-cadence, including 56 new detections.

pySYD

GitHub Page — ReadTheDocs

pySYD

We use an automated pipeline pySYD[22,23] to extract global asteroseismic parameters. pySYD has been adapted from the IDL-based SYD pipeline[21], and consists of three primary steps:

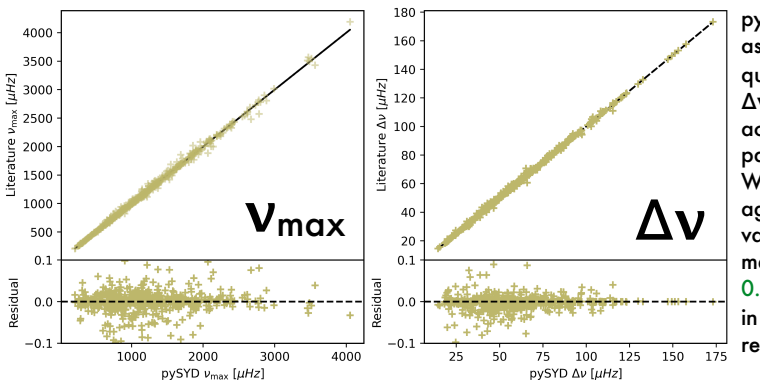
(a) estimate the position of the power excess in the spectrum
(b) correct for the background, and
(c) calculate the mean large frequency spacing, Δν, and the frequency of maximum power, ν_{max}.

Data Selection

We find 707 *Kepler* stars with detected solar oscillations obtained from the following sources. We find 56 new detections within *Kepler* short cadence data.

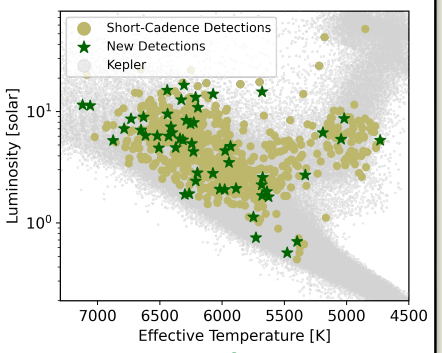
This Work	56
Chaplin (2014)[4]	4
Serenelli (2017)[24]	532
Balona (2020)[25]	62
Mathur (in prep)[26]	44
Literature[27]	10

Results - pySYD measurements compared to literature values



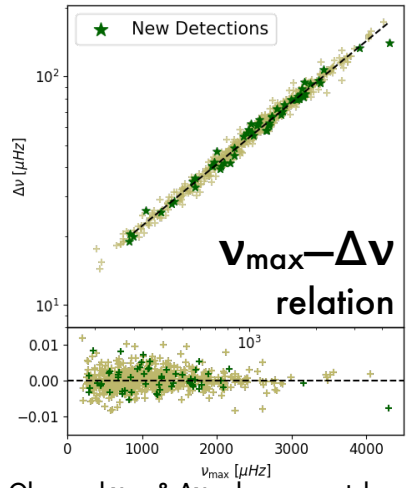
pySYD recovers asteroseismic quantities – ν_{max} & Δν – to high accuracy across parameter space. When tested against literature values, we find a median offset of 0.01% and 0.03% in ν_{max} & Δν, respectively.

New Detections



We find 56 new detections with solar-like oscillations. These new stars increase the number of *Kepler* short-cadence asteroseismic detections by 8.6%. These new detections span a similar parameter space as previously known solar-like oscillators, as seen in the H-R diagram above.

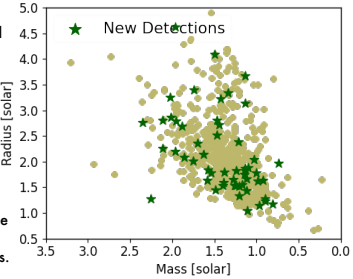
Accuracy of ν_{max} & Δν



Observed ν_{max} & Δν values accurately follow the ν_{max}-Δν power-law relation[6,30]. The median residual value (shown in bottom panel) is 0.03%. Outliers are still being investigated.

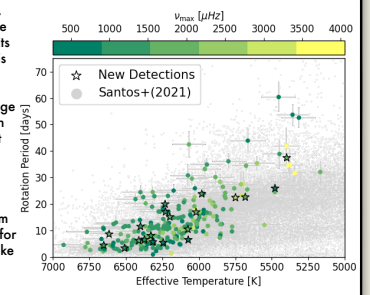
Fundamental Parameters

We calculated stellar mass and radius using asteroseismic scaling relations[14] and temperatures from Berger (2020)[28]. Our new detections span a similar parameter space as previously found detections.



Gyrochronology

Gyrochronology, used to determine stellar age from its rotation period, is a powerful technique to estimate stellar age for cool stars. On the right, we plot rotation periods from Santos (2021)[29] as a function of temperatures from Berger (2020)[28] for all *Kepler* solar-like oscillators within our sample, coloured by ν_{max}.



Takeaways

1. Our catalog provides homogeneous asteroseismic quantities and fundamental stellar parameters for 707 *Kepler* stars observed in short-cadence.
2. We find 56 new solar-like oscillators that span the H-R diagram, including main-sequence and subgiant stars.
3. Our seismic quantities agree well with literature values, with a median offset of ~0.02%.
4. The sample contains rotation periods for 267 stars, where 22 are new detections. The final catalog includes stars with long rotation periods, which are hard to measure with TESS. These can be used to determine stellar age through detailed modelling of oscillation modes.

References — [1] Borucki, W. J. et al. (2010), [2] Koch, D. G. et al. (2010), [3] Ricker, G. et al. (2014), [4] Chaplin, W. et al. (2014), [5] Hekker, S. et al. (2011a), [6] Huber, D. et al. (2011), [7] Huber, D. et al. (2013), [8], Huber, D. et al. (2014), [9] Mathur, S. et al. (2016), [10] Mathur, S. et al. (2017), [11] Stello, D. et al. (2013), [12] Yu et al. (2016), [13] Yu et al. (2018), [14] Kjeldsen, H. & Bedding, T. R. (1995), [15] Schofield, M. et al. (2019), [16] Sayeed, M. et al. (2021), [17] Stello, D. et al. (2021), [18] Mathur, S. et al. (2010), [19] Mosser & Appourchaux (2009), [20] Hekker, S. et al. (2010), [21] Huber, D. et al. (2009), [22] Chontos, A. et al. (in prep), [23] https://github.com/ashleychontos/pySYD, [24] Serenelli, A. et al. (2017), [25] Balona, L. A. (2020), [26] Mathur, S. et al. (in prep), [27] Creevey, O. L., et al. (2011), White, T. et al (2012), Pinsonneault, M. et al. (2018), [27] Li, Y. et al. (2020), [28] Berger, T. A. et al. (2020), [29] Santos, A. et al. (2021), [30] Stello, D. et al. (2009)

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