Asteroseismology of KIC 7107778: a binary comprising almost identical subgiants

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Introduction

Binary systems provide a good laboratory for studying stellar evolution due to their convenient constraints on metal abundance and age. Asteroseismology allows new ways to study binaries that previously could not due to being unresolved or non-eclipsing. The study of KIC 7107778 by Li and Bedding shows the power of asteroseismology in a very unique binary system.

Asteroseismology

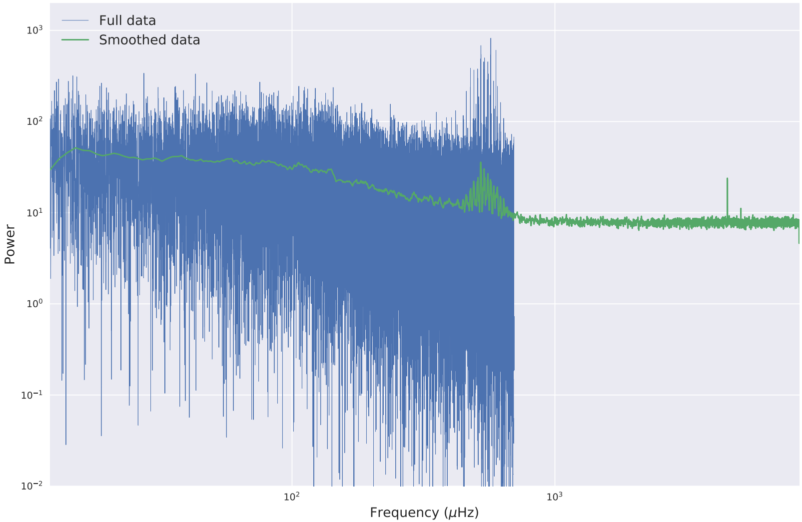
Asteroseismology is the study of how stars' brightness fluctuates. These fluctuations can be attributed to many different mechanics within stars. To analyze the periodicities we use Fourier transforms to view the data in frequency space.

KIC 7107778

Interesting features of this binary system

- Unresolved
- Widely separated
- Non-eclipsing
- Solar like oscillations from both components

Power Spectrum



Analysis Strategy

1. Model the Gaussian envelope
2. Analyze envelope and determine modes of interest
3. Model the oscillation modes

Envelope Model

$$P(\nu) = W + R(\nu)\left[\sum_{i=0}^{k} H_i(\nu) + \frac{H_0^2}{\sigma}\exp\left\{-\frac{(\nu-\nu_{max}^2)}{2\sigma^2}\right\}\right] \quad (1)$$

where

$$R(\nu) = \mathrm{sinc}^2\left(\frac{\pi\nu}{2\nu_{Nyq}}\right)$$

and

$$H_i(\nu) = \frac{2\sqrt{2}}{\pi}\frac{a_i^2/b_i}{1+(\nu/b_i)^4}$$

This is a flat noise plus response function modulating three Harvey power profiles and a Gaussian envelop.

Envelope priors

$$W \sim N(12, \sigma = 5)$$

$$a_i \sim N([59, 67, 76], \sigma = 20)$$

$$b_i \sim N([5, 150, 400], \sigma = [10, 50, 100])$$

$$H_0 \sim N(17, \sigma = 5)$$

$$\nu_{max} \sim N(568, \sigma = 5)$$

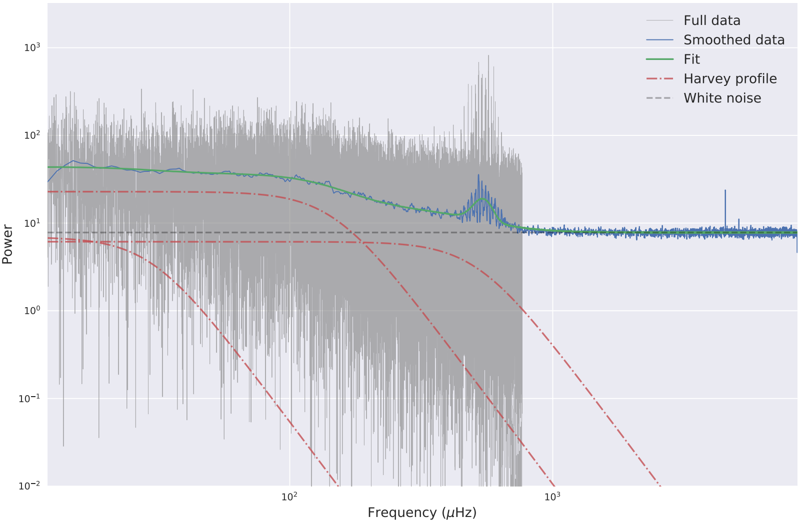
$$\sigma \sim Cauchy(55, 10)$$

Envelope posteriors

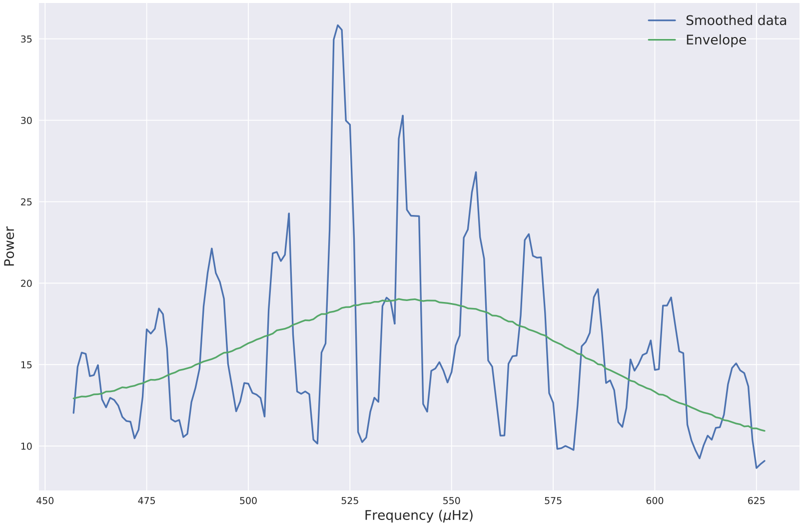
Table: Posterior Parameters

		mean	sd	2.5	97.5
a_0	$[ppm]$	15.15	0.4591	14.28	16.07
a_1	$[ppm]$	60.96	0.3549	60.29	61.66
a_2	$[ppm]$	59.23	0.4772	58.32	60.17
b_0	$[\mu Hz]$	29.76	1.641	26.61	33.00
b_1	$[\mu Hz]$	146.6	1.345	144.0	149.2
b_2	$[\mu Hz]$	514.7	9.656	495.9	533.8
σ	$[\mu Hz]$	42.57	0.9466	40.69	44.40
W	$[ppm^2/\mu Hz]$	7.808	0.01144	7.786	7.831
H_0	$[ppm/\mu Hz]$	29.82	0.3629	29.10	30.53
ν_{max}	$[\mu Hz]$	542.2	0.8259	540.5	543.8

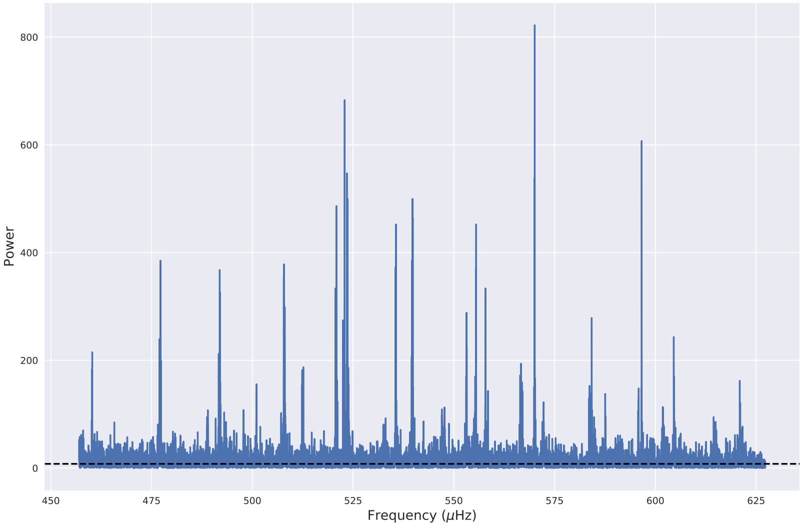
Envelope Fit



Envelope Fit



Envelope



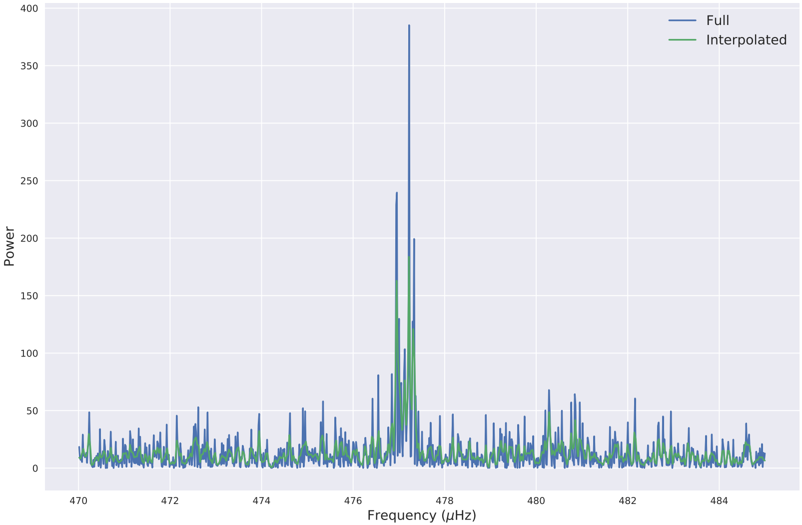
800
600
400
200
0
Power
450
475
500
525
550
575
600
625
Frequency (μHz)

Mode Model

$$P(\nu) = R(\nu) \left[\frac{A^2/\pi\Gamma}{1 + 4(\nu - \nu_0)^2/\Gamma^2} \right] \tag{2}$$

A Lorentzian modulated by the response function.

Mode Model



Full
Interpolated
Power
Frequency (μHz)
0
50
100
150
200
250
300
350
400
470
472
474
476
478
480
482
484

Mode Model

$$A \sim N(20, \sigma = 10)$$

$$\nu_0 \sim N(477, \sigma = 2)$$

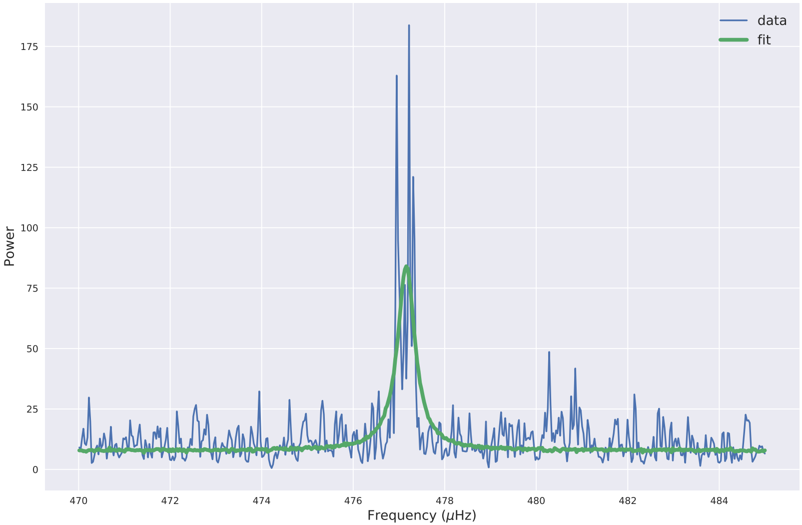
$$\Gamma \sim \text{half-Cauchy}(2)$$

Mode Model

Table: Posterior Parameters

		mean	sd	2.5	97.5
A	$[ppm/\mu Hz]$	7.480	0.2237	7.057	7.938
ν_0	$[\mu Hz]$	477.2	0.01817	477.1	477.2
Γ	$[\mu Hz]$	0.2320	0.01872	0.1948	0.2684

Mode Model



data
fit
Power
175
150
125
100
75
50
25
0
470
472
474
476
478
480
482
484
Frequency (μHz)

Remarks

1. It was a challenge to compute because of the high-dimensionality and multi-modality
2. Authors provided no information about their priors, so I had to come up with my own
3. Wish I could have done computations over full dataset without interpolation

Special thanks to Dr. Steve Kawaler, Dr. Alicia Carriquiry, and Nicholas Berry for their assistance in this analysis.