HELIOSEISMIC INVESTIGATIONS OF THE QUASI-BIENNIAL OSCILLATION

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1. Background

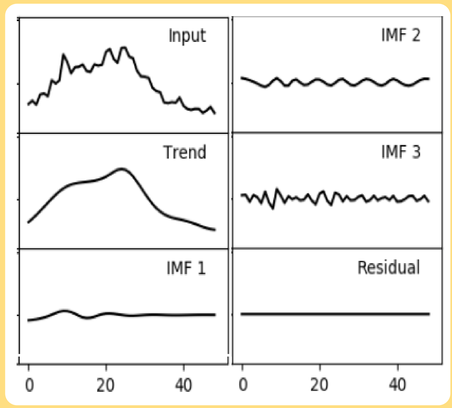
- Frequency shifts of p-modes can be seen to trace out oscillations with periods of ~11 years, aligning with the Schwabe cycle[1].
- Another oscillation, with lower amplitude and a period of ~ 2-3 years, has also been observed in p-mode shifts[2]. It is known as the quasi-biennial oscillation (QBO). **We don't know what creates the QBO** or how its linked to the Schwabe cycle.
- Frequency shifts of p-modes can be sorted according to the frequency and depth of the mode generating them. **So we can use frequency shifts to track where the magnetic field generating the QBO is located.**

2. Motivating questions

- Is the QBO constant over different cycles? And how does it change at different solar depths and mode frequencies.

3. Method

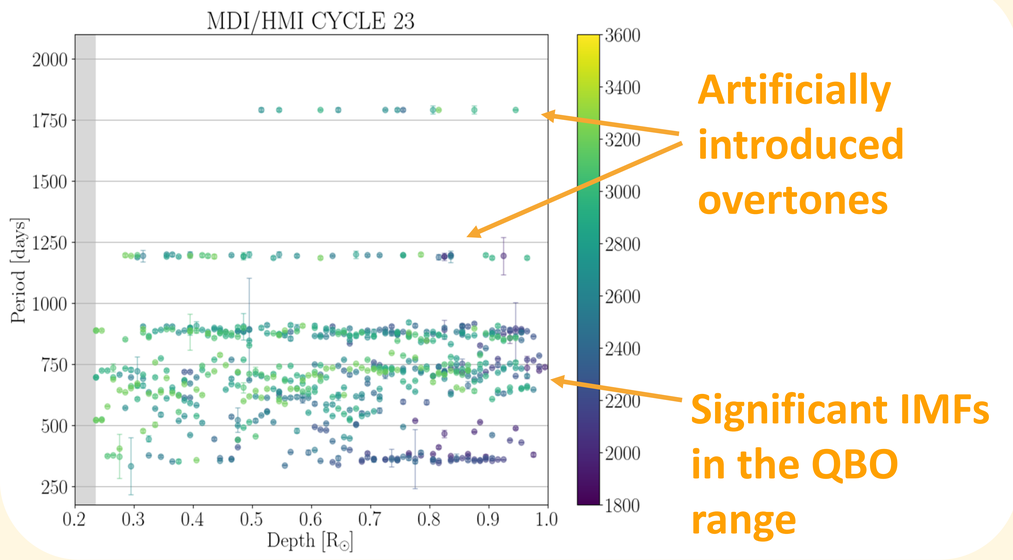
- Used observation data from MDI/HMI, GONG, and proxies 10.7 cm flux and Mg II index.
- We employed Automated Empirical Mode Decomposition **(ATEMD)**[3] which breaks up an input signal into child functions (IMFs), which are then assessed for their significance.



- The significant IMFs are assigned a value for their average period, and the depth and frequency of the p-mode the signal was obtained from.

4. Results

- IMFs falling in the QBO range are present over roughly **all depths** (from 0.2 – 1.0 $R_\odot$) and **all frequencies** (from 1600-4000 μHz).
- The approximate range over which the QBO exists (400-800 days) **is constant over solar cycles**, though its presence **was weaker in Cycle 24 than in Cycle 23.**
- ATEMD artificially introduces IMFs with periods of $\frac{P}{3}, \frac{P}{4}$ that can be statistically significant, where P is the input duration. These are known as overtones, and can be treated similarly to the spurious harmonics found by Fourier analysis.



5. Conclusions and further work

- As the QBO exists for modes across all depths, the magnetic field generating the QBO must be located in the near surface level
- The presence of the QBO is cycle dependent
- Additional work should be done on categorising the azimuthal dependence of the QBO.

References

[1] A.-M. Broomhall, Solar Physics, 292, 4, 67, (2017)
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[3] D. Kolotkov, A&A, 592, A153,(2016)

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