



Optimal exploitation of different simultaneous/contemporaneous data sets

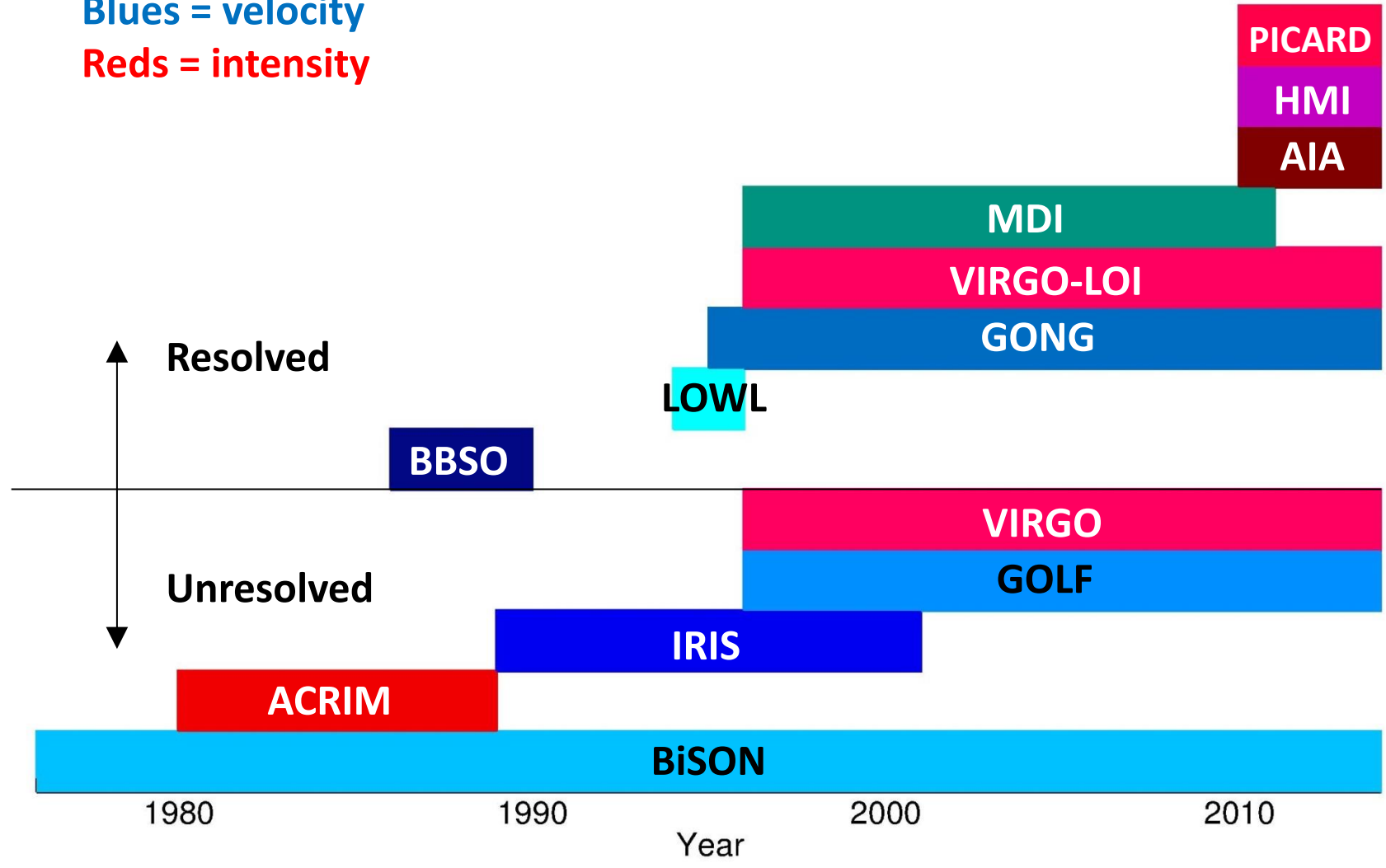
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Data available

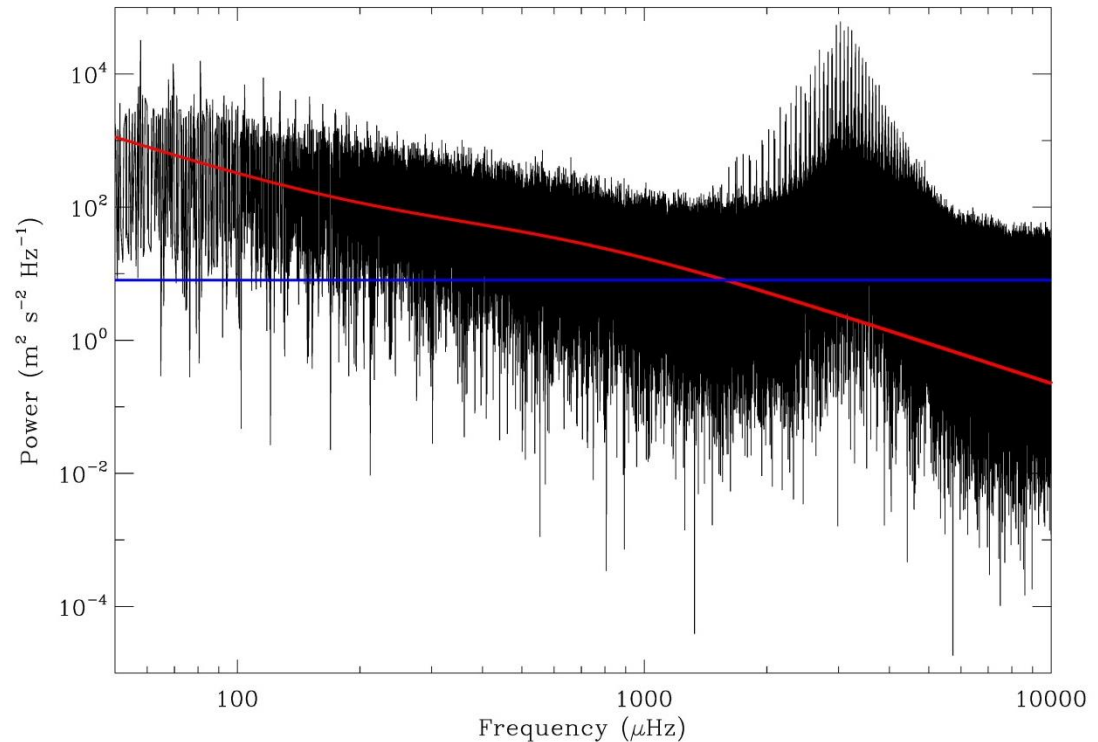
Blues = velocity
 Reds = intensity



Contemporaneous data

- Contemporaneous data has

- Coherent signal: oscillations.
- **Coherent noise: solar noise.**
- **Incoherent noise: instrument, atmospheric.**



- Main aim: Emphasise coherent signal.

Emphasising the coherent signal

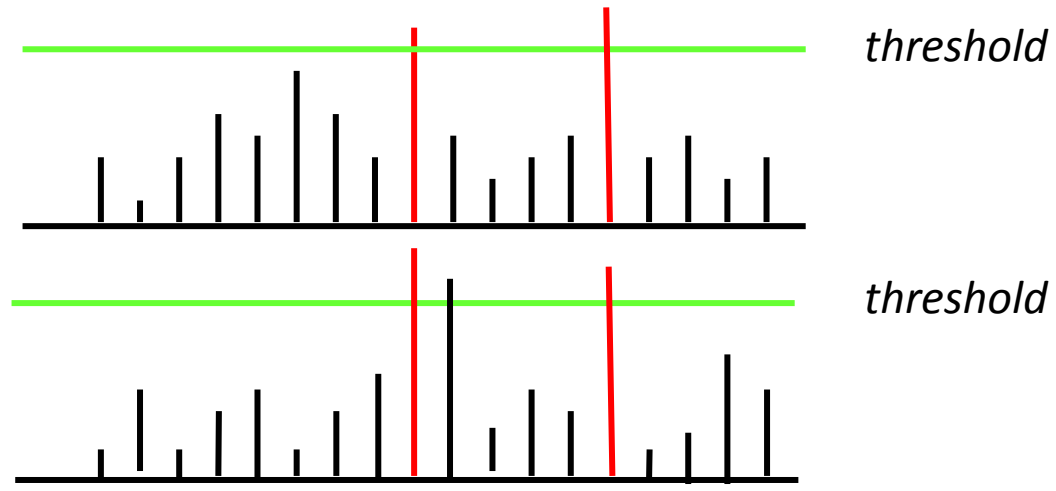
- Can take cross-spectra: $\text{Real}(A(\nu) \cdot B^*(\nu))$
 - Between different instruments (e.g. Elsworth et al. 1994).
 - Between photo-multipliers of GOLF (García et al. 1998).
- Multivariate spectral regression analysis (e.g. Appourchaux et al., 2000)
 - Determines extent to which variance in 1 time series is explainable in terms of variance of other time series.

Similar methods used to improve S/N in single data set

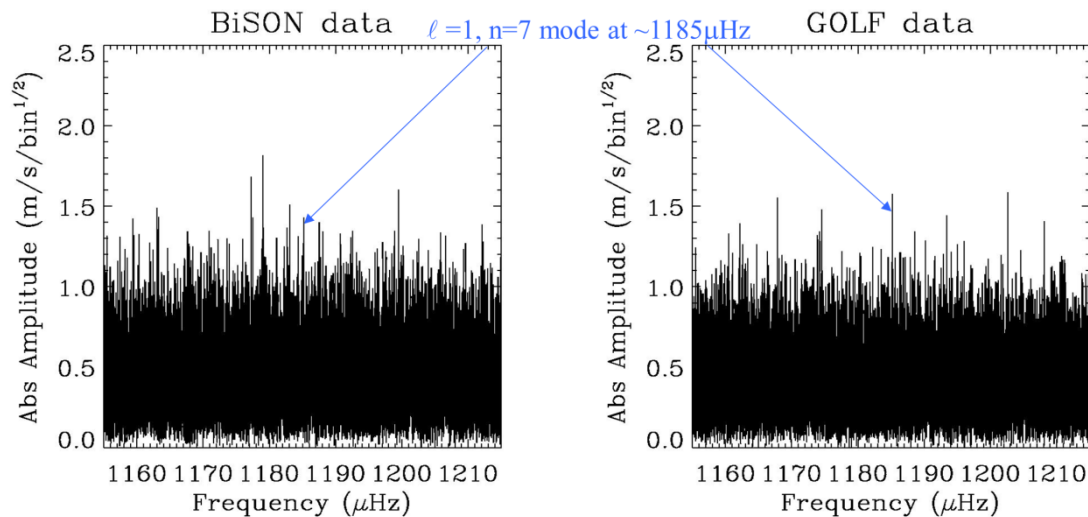
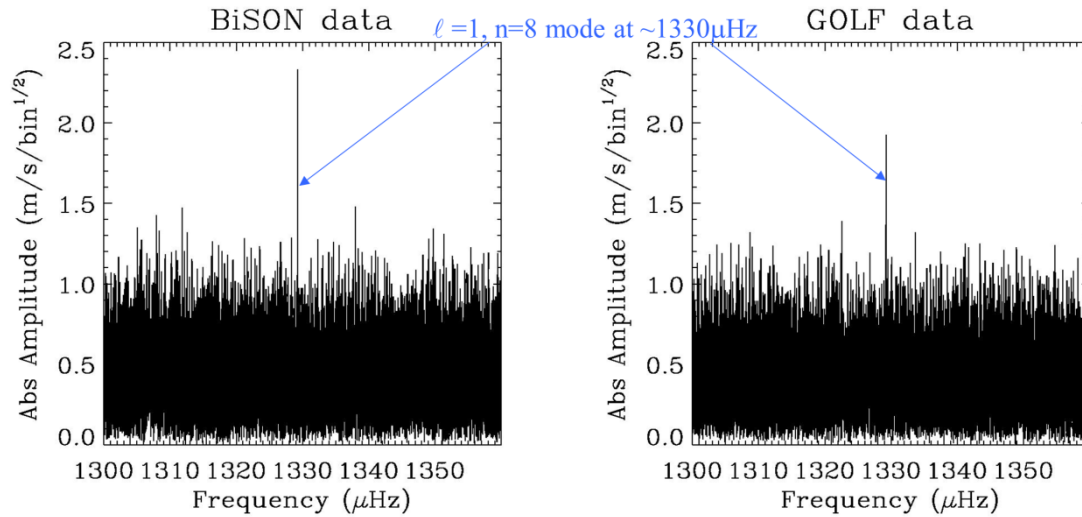
- Autocorrelation.
- *m*-averaged spectra / collapsogram
 - Constructed from *m* spectra at chosen *n, l*.
 - Detection limit scales approximately as $1/(2l+1)^{1/2}$.
- Inter-leaved-Shifted-Cross-Spectrum (García et al. 1999)
 - Split single time series in two by separating odd and even indexed points.

Joint probability

- Allows searches for coincidences in contemporaneous data.
- Calculate probability of observing these coincidences in noise.
- Search for concentrations of power that lie significantly above the background noise level.

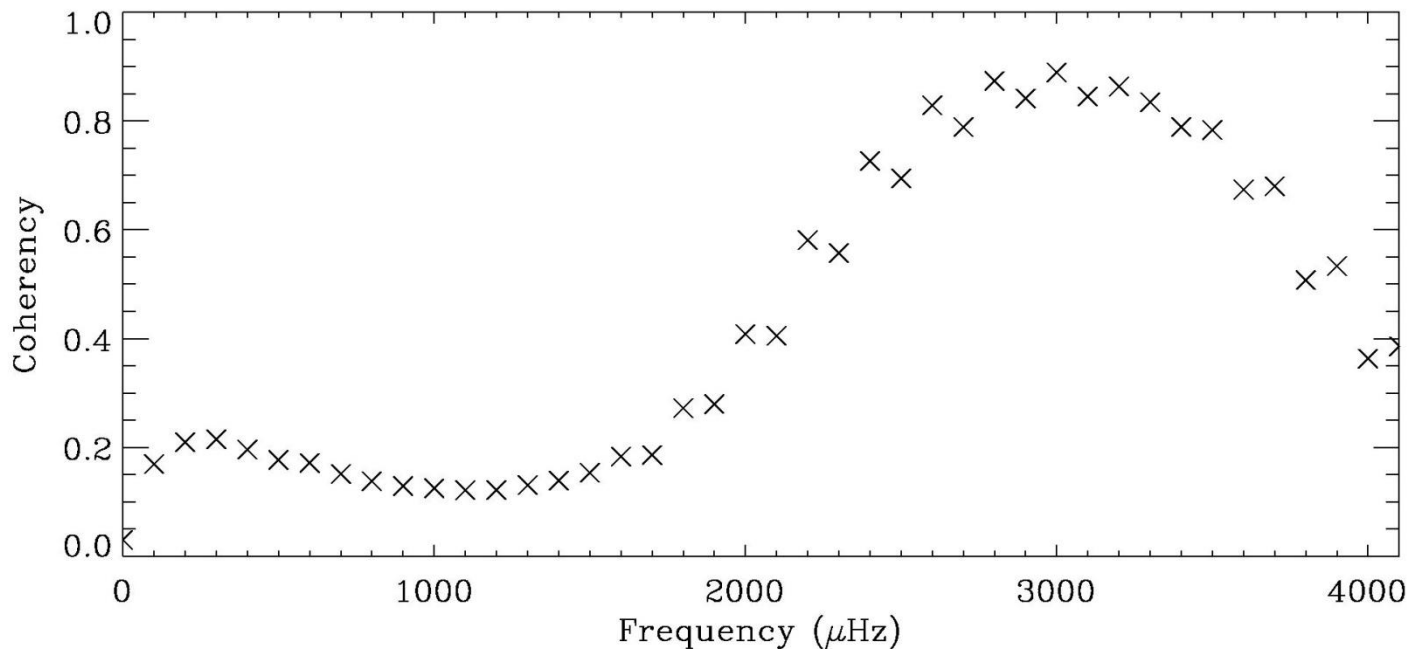


Examples from real data



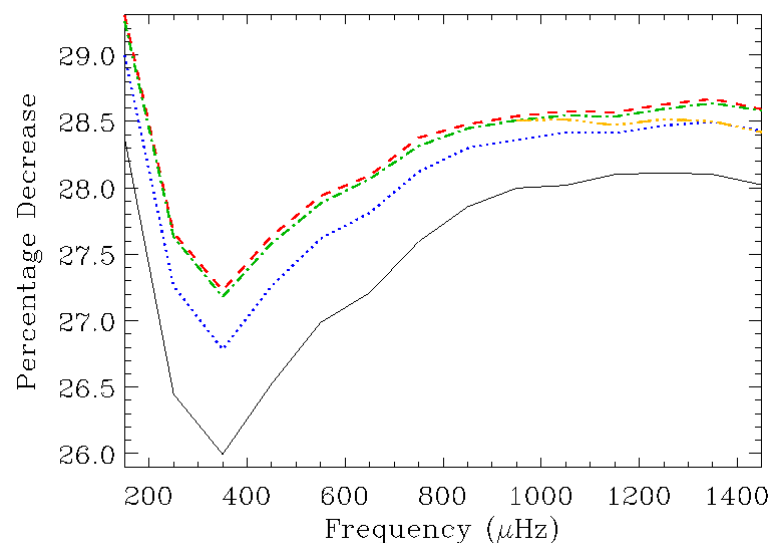
Common noise

- Solar noise will be common to data from two instruments.
- Proper allowance must be made for the level of noise common to the two sets of data.



Reduction in Thresholds

- Broomhall et al (2007): Joint probability for finding prominent peaks in contemporaneous BiSON and GOLF data.
- Comparing the two spectra allows the threshold levels to be reduced by $\sim 28\%$.



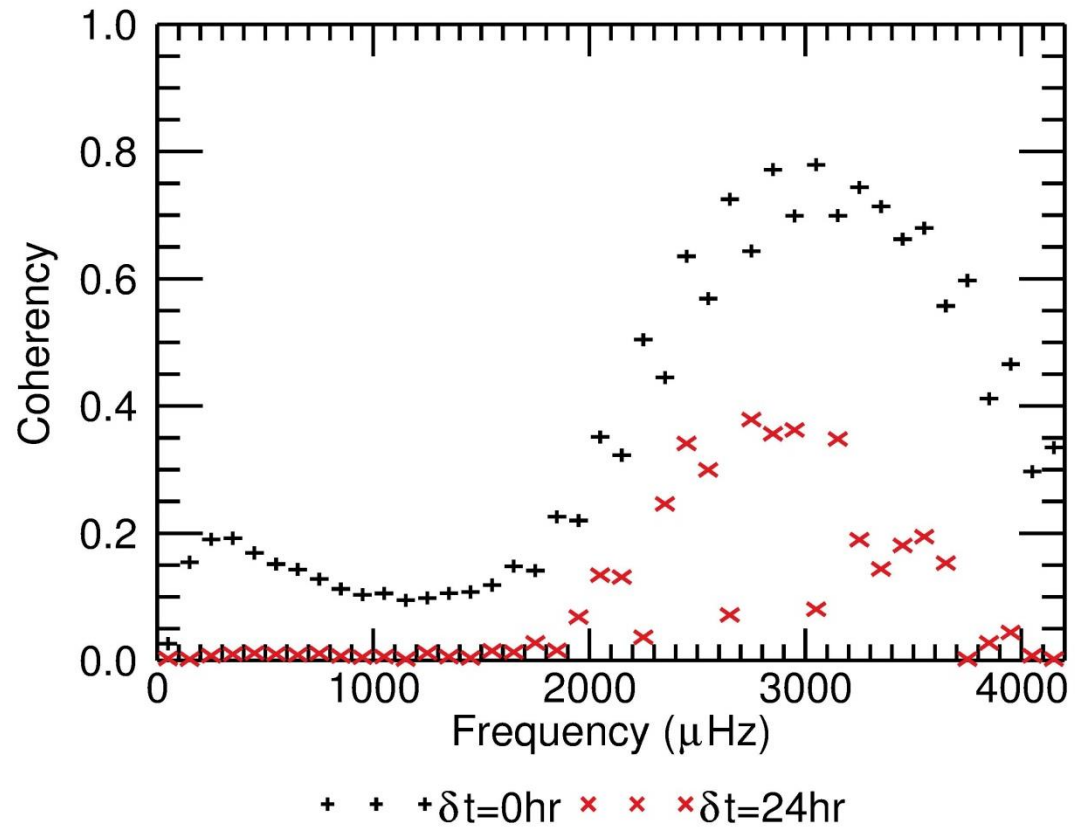
→ If coherency=0
reduced by $\sqrt{2}$

Single spike
2 consecutive spikes
2 or more spikes
2 rotationally split spikes
3 rotationally split spikes

% decrease in
amplitude detection
threshold levels

NEAR-contemporaneous data

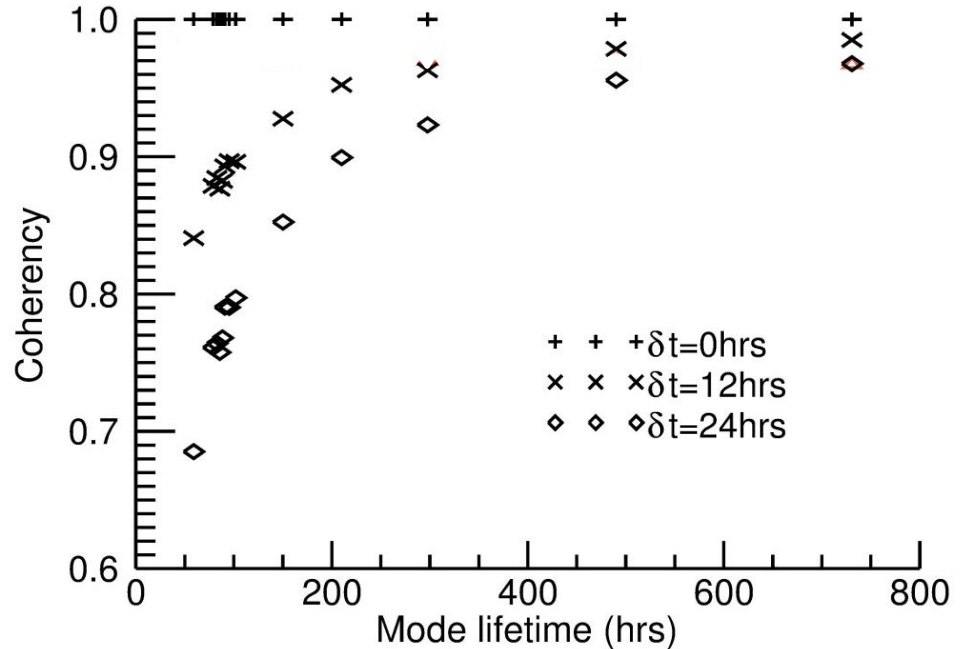
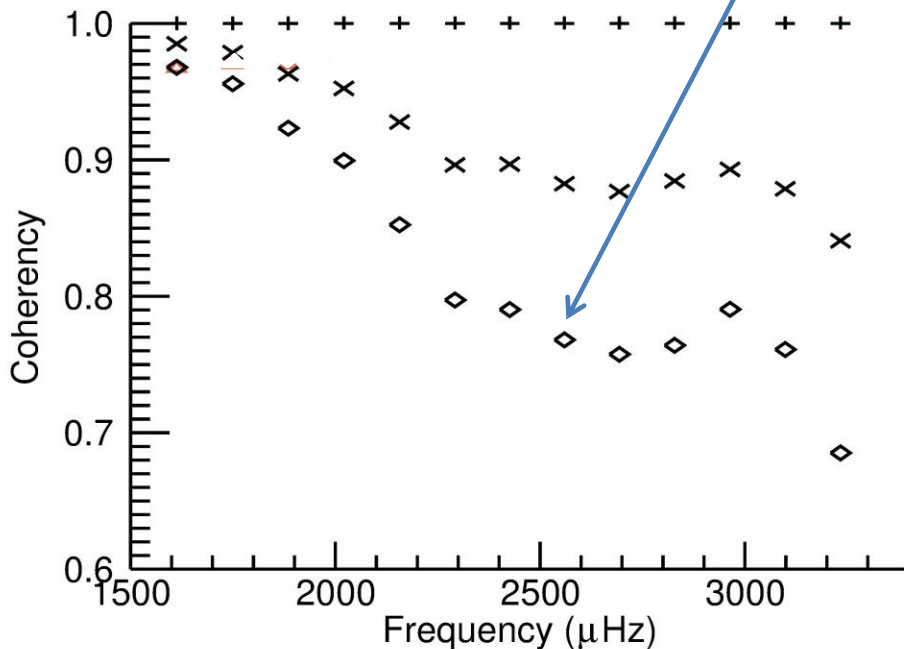
- Using data with start times that differ by 24hr can remove correlated noise.



But what does this do to the modes?

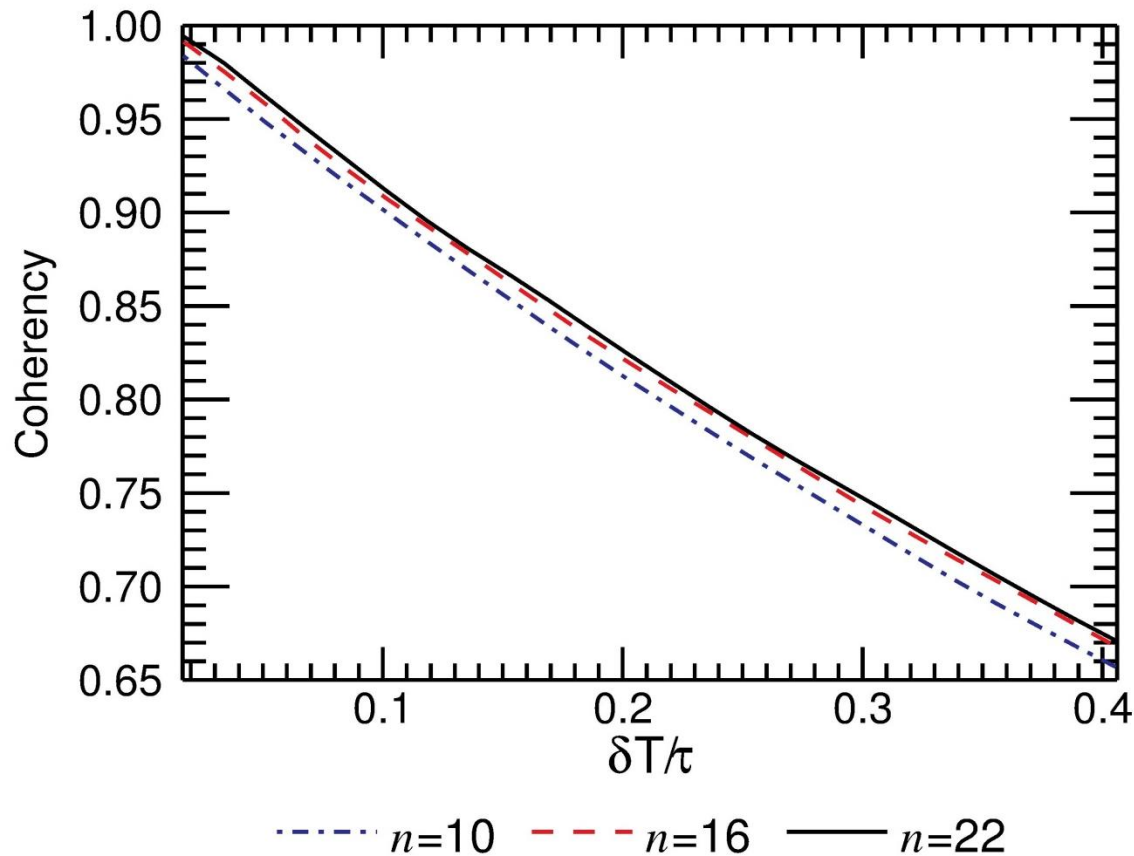
- Effect of separation is frequency dependent
- Or more precisely lifetime dependent.

Follows frequency dependence of lifetimes



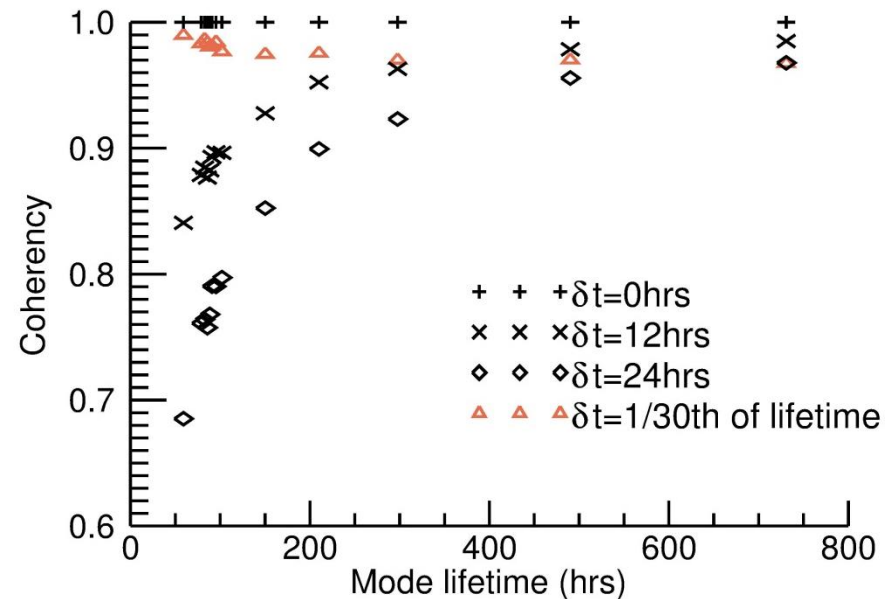
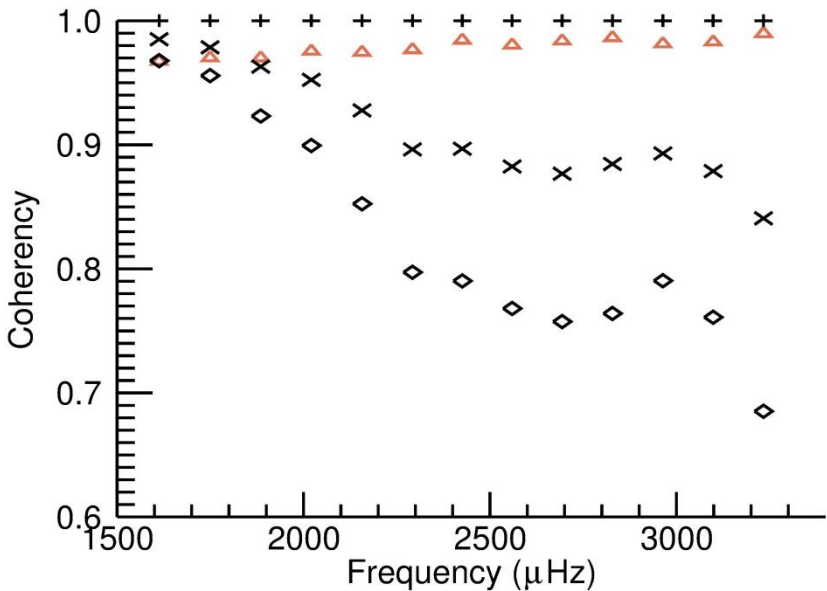
Lifetime dependence

- If $\delta T/\tau$ is small, decrease in coherency small.



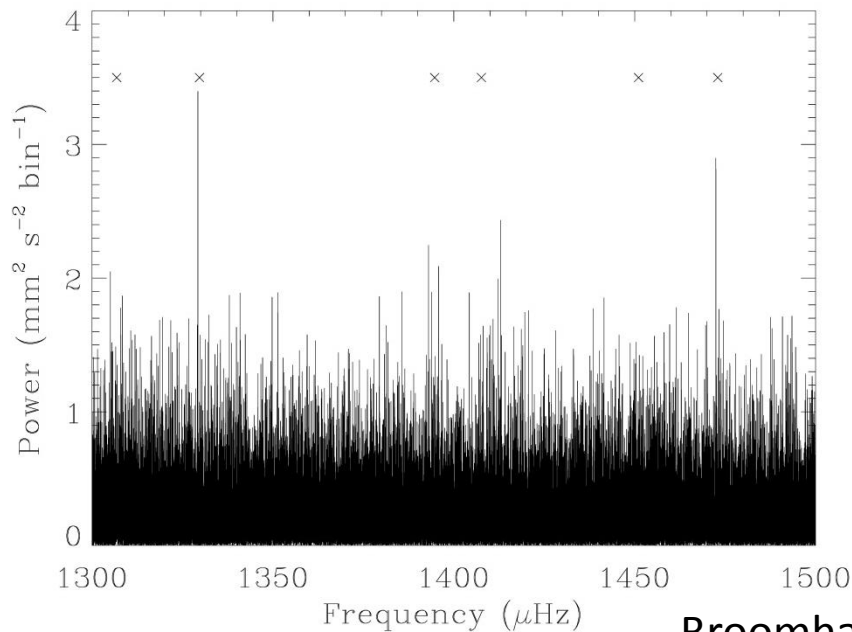
But what does this do to the modes?

- Effect of separation is frequency dependent
- Or more precisely lifetime dependent.
- If separate time series by e.g. $1/30^{\text{th}}$ lifetime decrease in coherency is small.

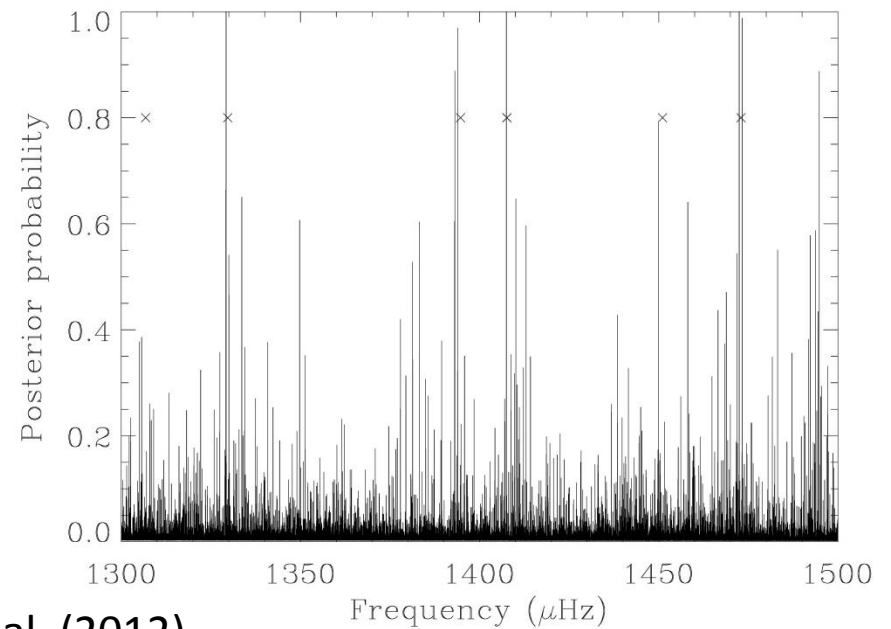


Advantages of using near-contemporaneous data

- No common noise:
 - Maximum reduction in threshold levels.
 - Statistics become much simpler.

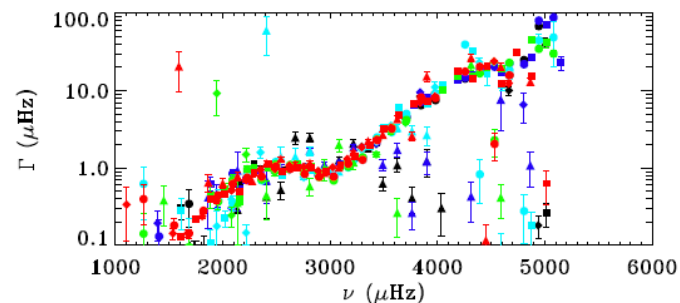
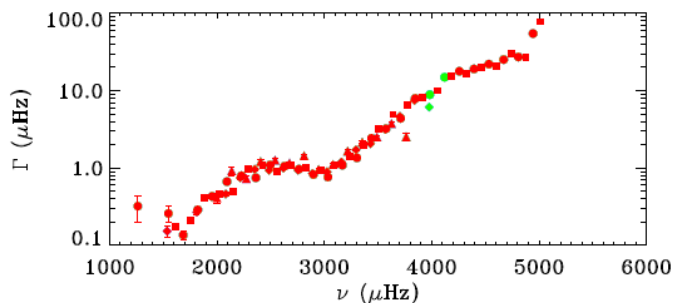
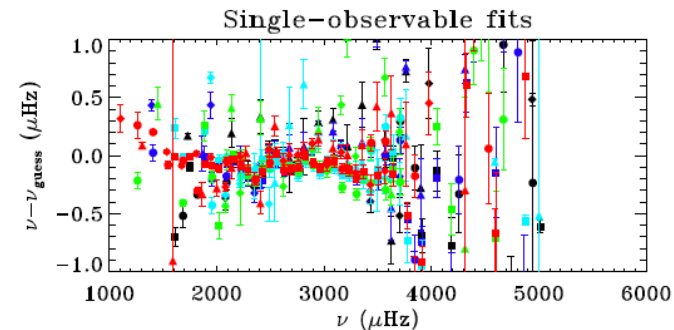
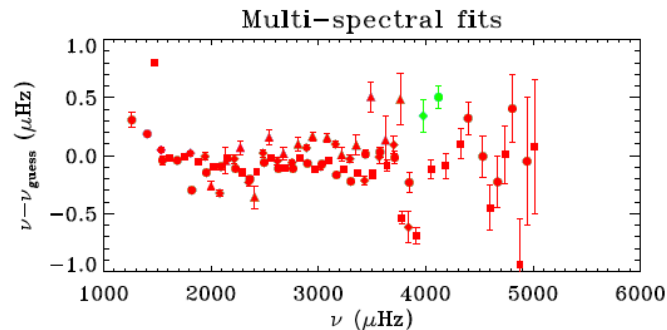


Broomhall et al. (2012)



Multi-spectral fitting

- Howe et al. (2013) simultaneously fitted AIA and HMI data.
 - Common frequency and linewidth.
 - Independent amplitude, asymmetry, background.



Summary

- Lots of contemporaneous helioseismic data is available.
- Many methods have been developed to take advantage of this.
 - Including multi-spectral fitting.
- Progress can be made with near-contemporaneous data.

Discuss

(and thank you for listening)