Low-Frequency Solar p Modes: Observations Obtained from m-Averaged Spectra

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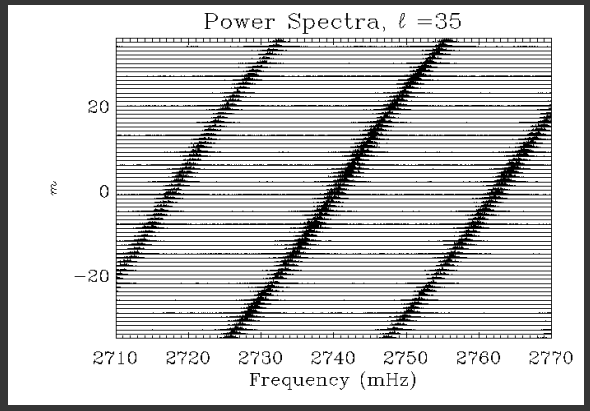
CEA/SAp

m-averaged spectrum:

average the (2l+1) m-components of an oscillation multiplet (n, l)

> Rotational and structural effects: degeneracy lift of mode frequency into (2l+1) m-multiplets.



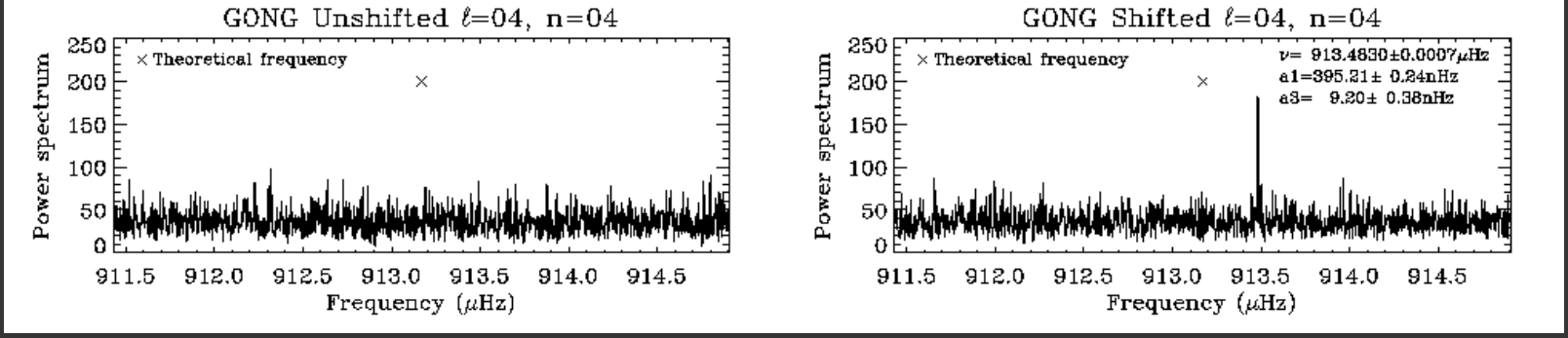
> The shifts (a-coefficients) are determined as we are searching for the low-frequency modes.

$$\nu_{n,l,m} = \nu_{n,l} + \sum_{k=1}^{k_{max}} a_k(n,l) P_k^{(l)}(m)$$

> Several way to find the best estimates of the a-coefficients:

- *minimum likelihood*,
- *narrowest peak in the m-averaged spectrum*,
- *smallest entropy*.

> Considerably improves SNR even when the m-components have too low SNR to be measured in the individual-m spectra.



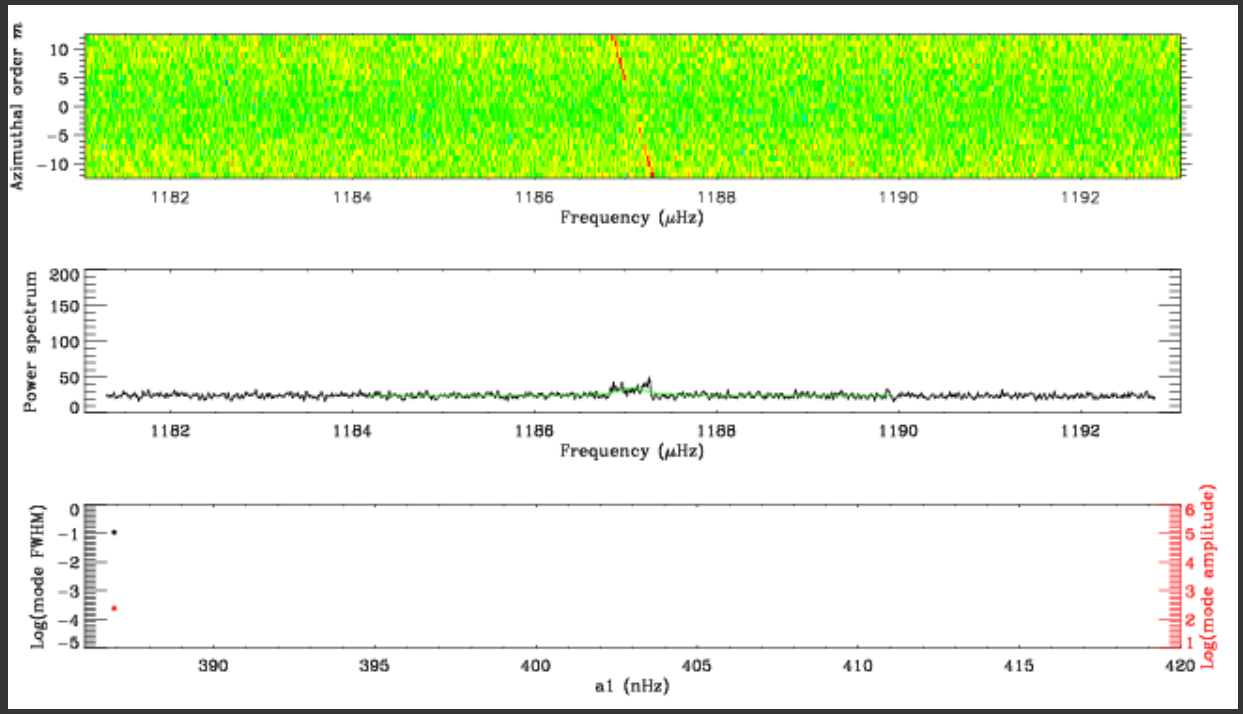
m-averaged spectrum technique

l = 12, n = 4 mode at ~ 1187 μHz

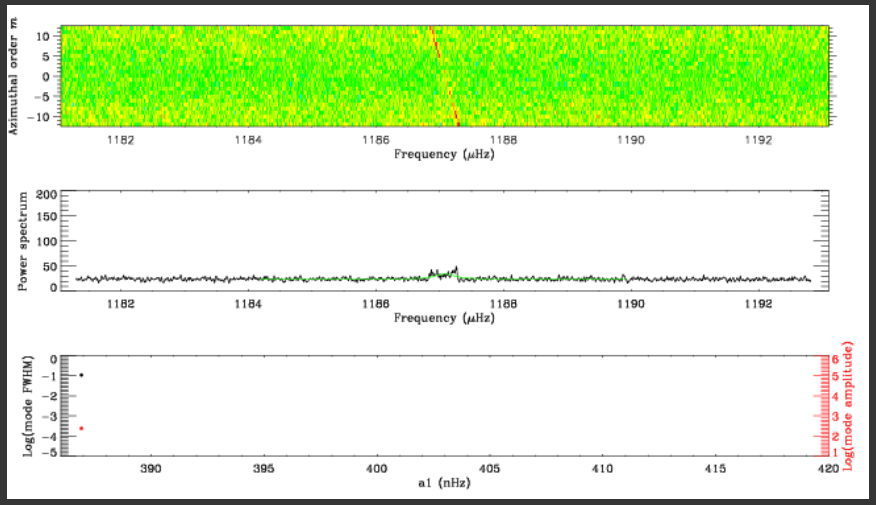
m-ν diagram

m-averaged spectrum

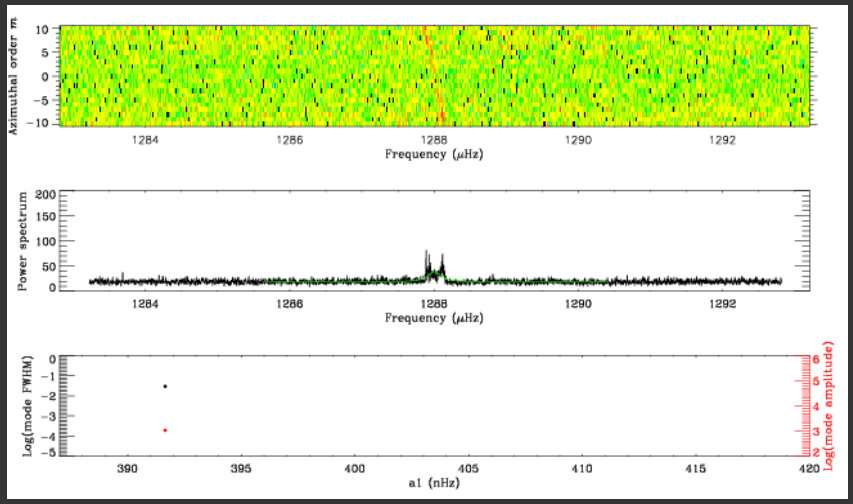
Figure-of-merit (a1)



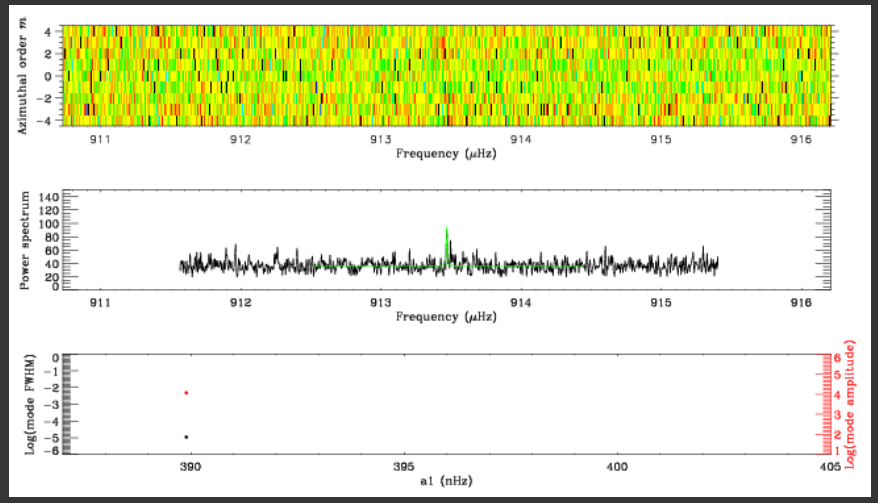
l = 12, n = 4 mode at ~ 1187 μHz



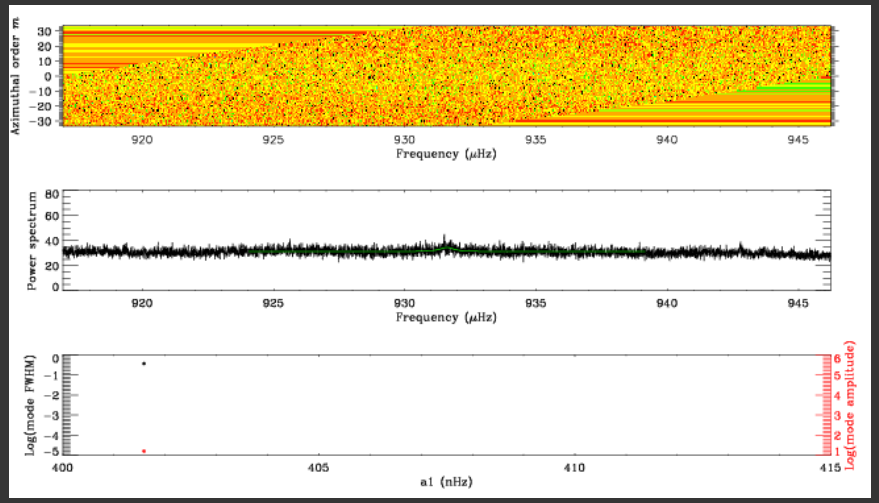
l = 10, n = 5 mode at ~ 1288 μHz



l = 4, n = 4 mode at ~ 913.5 μHz



l = 33, n = 1 mode at ~ 931 μHz



a1

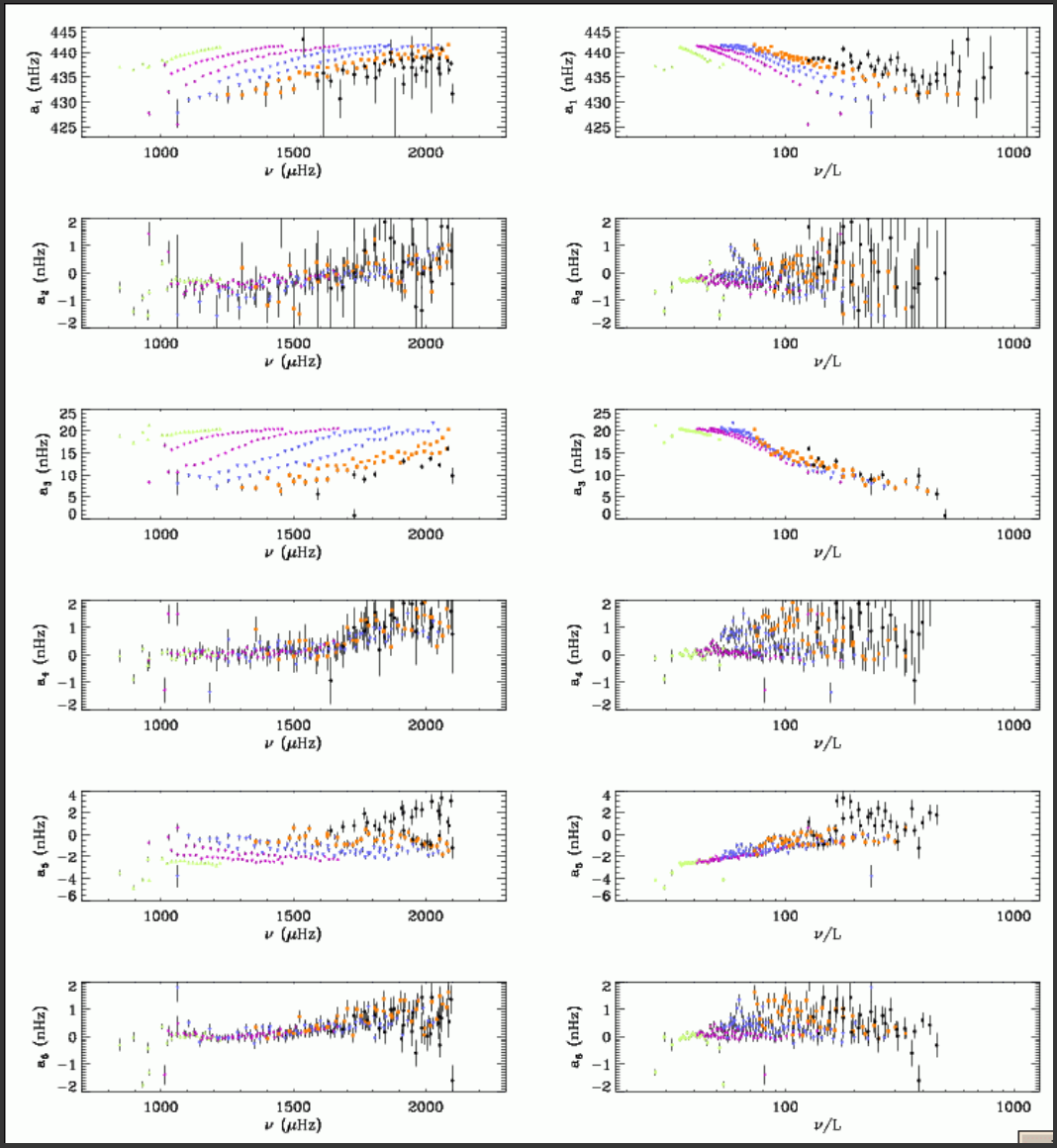
a2

a3

a4

a5

a6



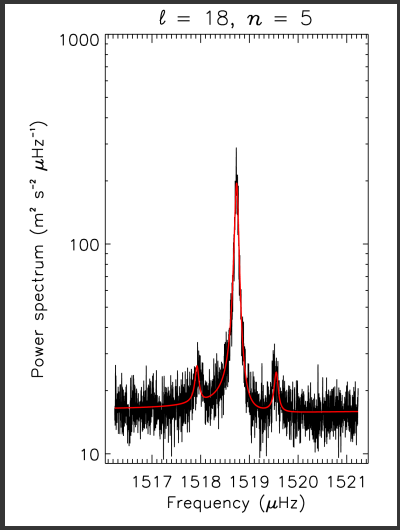
Frequency (ν)

ν / sqrt[l(l+1)]

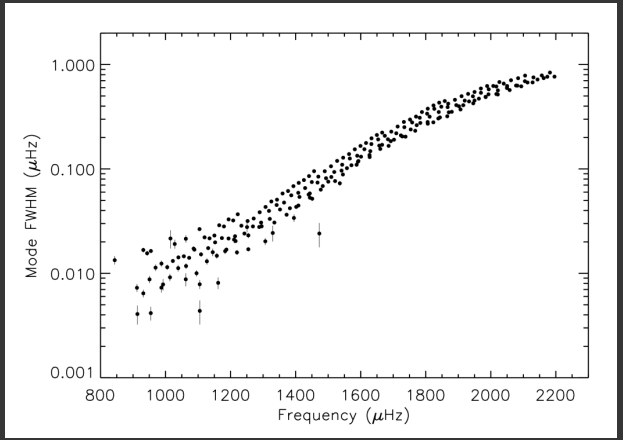
3960 days of GONG data

Six first a-coefficients estimated using the m-averaged spectrum technique of the low-frequency p modes ($1 \leq l \leq 35$)

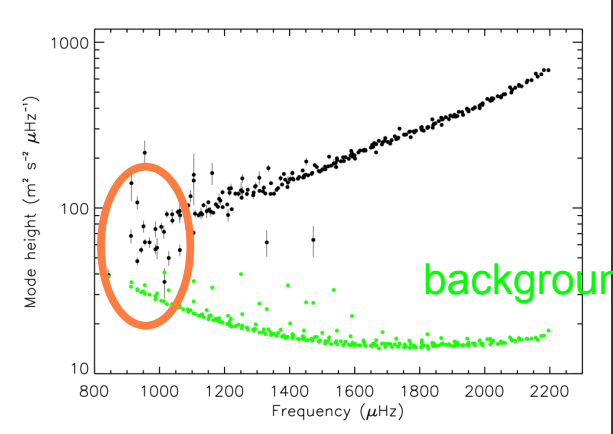
3960 days of GONG data
Fitted mode parameters



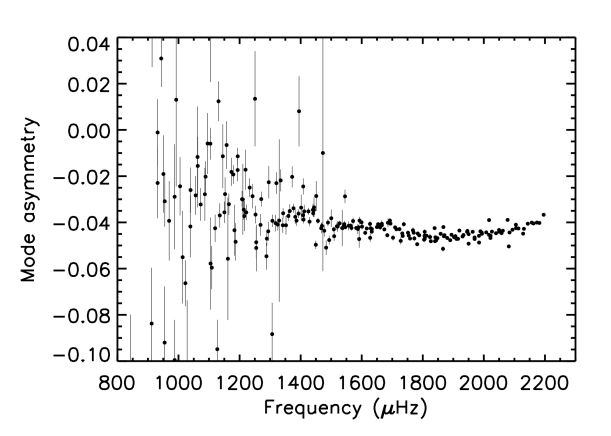
Mode linewidths (FWHMs)



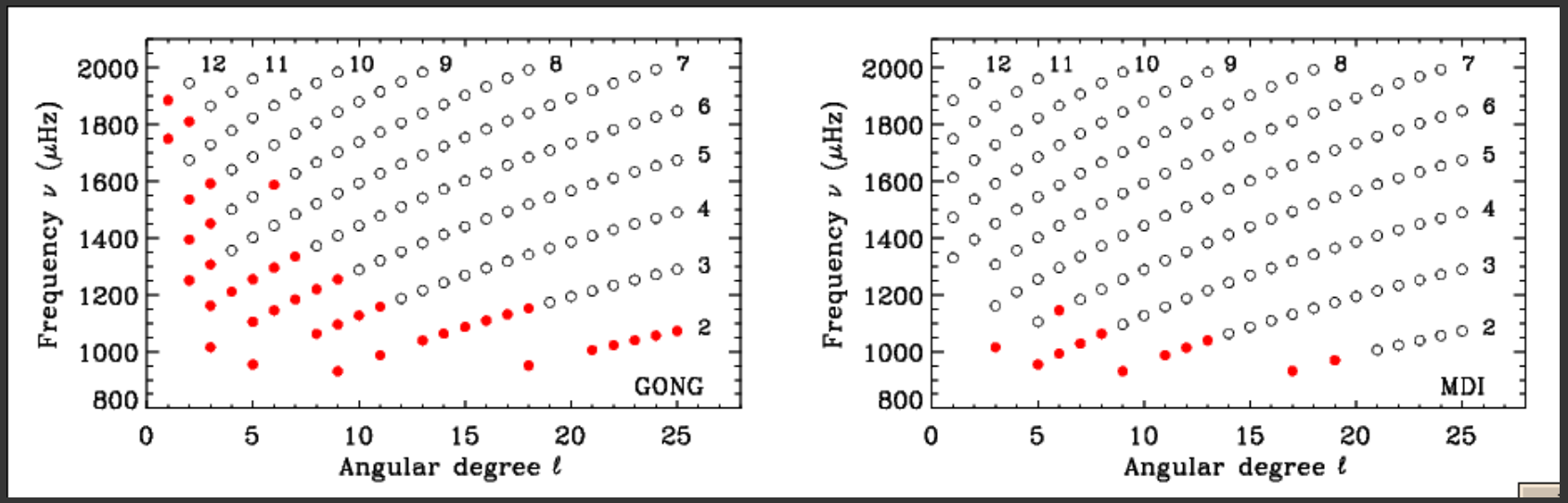
Mode amplitudes

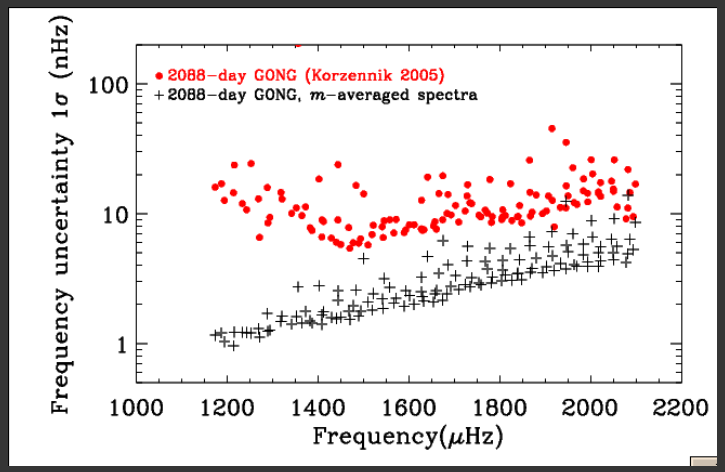


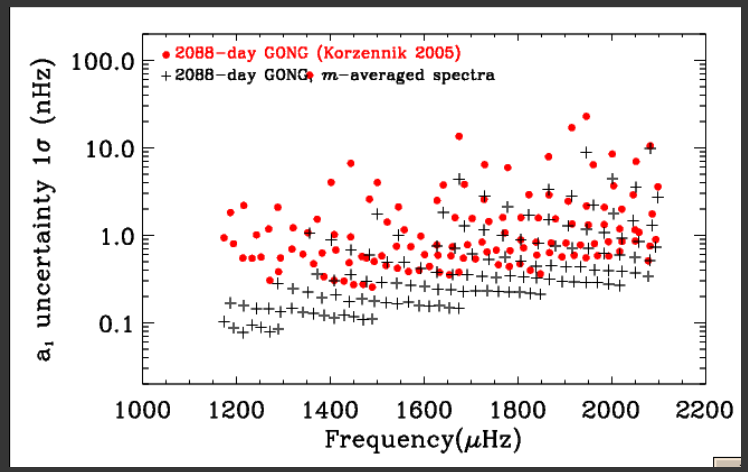
Mode asymmetries



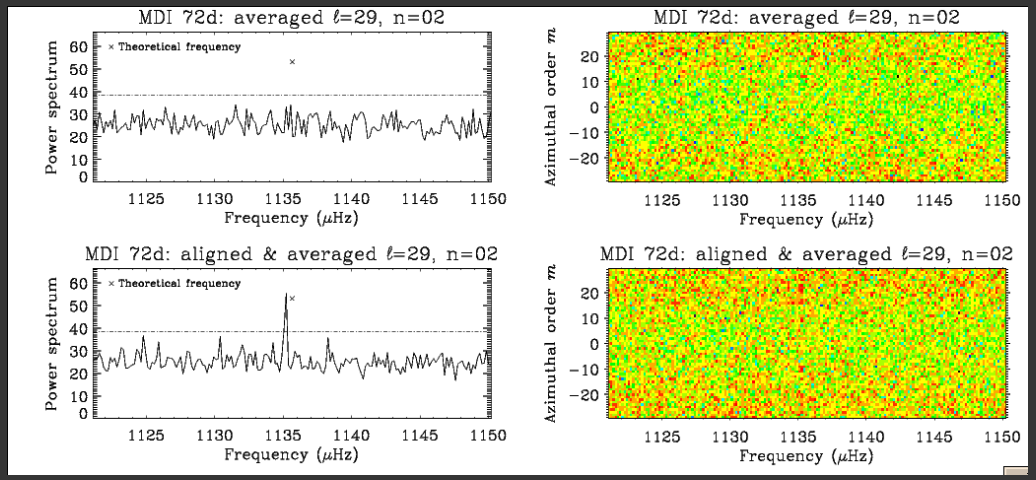
2088-day: comparison with other measurement (Korzennik 2005)





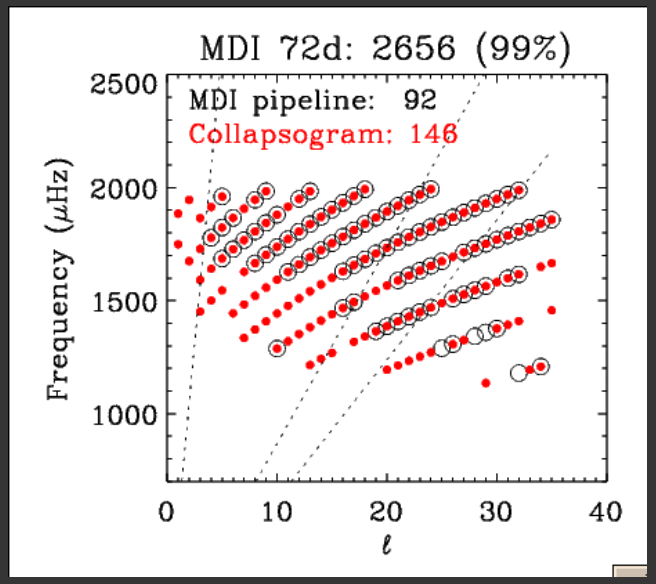


MDI 72-day & GONG 108-day time series

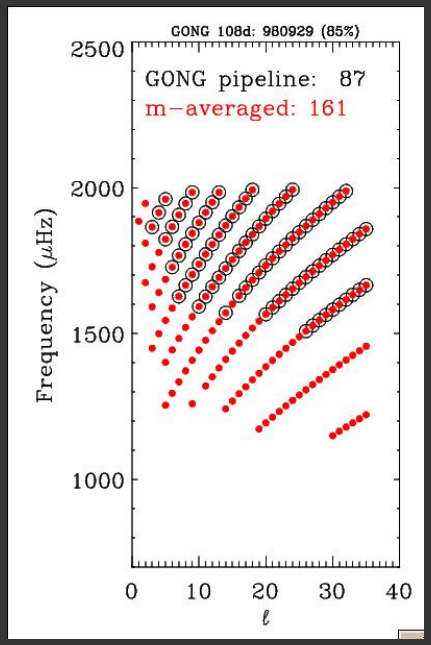


Example of a m-averaged spectrum with 72 days of MDI observations

MDI 72-day time series



GONG 108-day time series



Conclusions

> New method to measure and fit the low-frequency modes in spatially-resolved data

> Lower frequency where classic peak-fitting methods fail because low SNR

> Better precision of the fitted modes

> Rotation/Structure: deeper and better resolution throughout the Sun