

On the Temporal Changes of Helioseismic Properties Derived with Different Mode Fitting Techniques

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Introduction

- ▶ 3 methodologies, 2 data sets, 20 years of observations:

	NSO		SU		CfA	
	sym.	asym.	sym.	asym.	sym.	asym.
GONG	✓	*	✗	✗	✓	✓
MDI+HMI	✗	✗	✓	✓	✓	✓

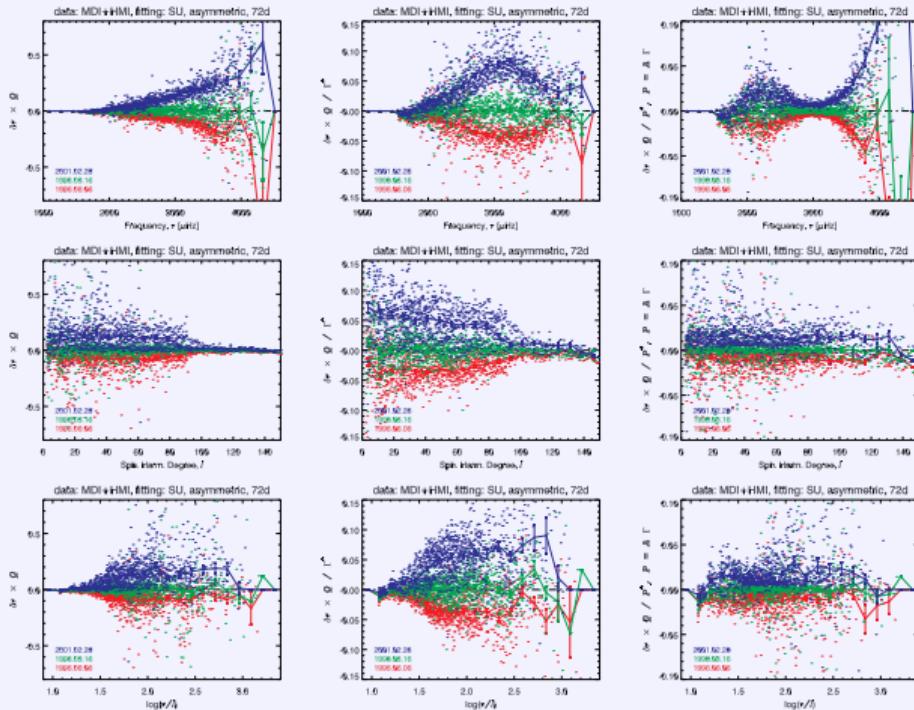
*: preliminary results, tables not available.

- ▶ Raw mode comparisons
 - ▶ Frequency
 - ▶ Scaling
 - ▶ Attrition
 - ▶ Singlets to multiplets reduction
 - ▶ Change of mean weighted frequency
 - ▶ Line-width, Asymmetry
- ▶ Rotation inversion comparison
- ▶ Conclusions

Frequency

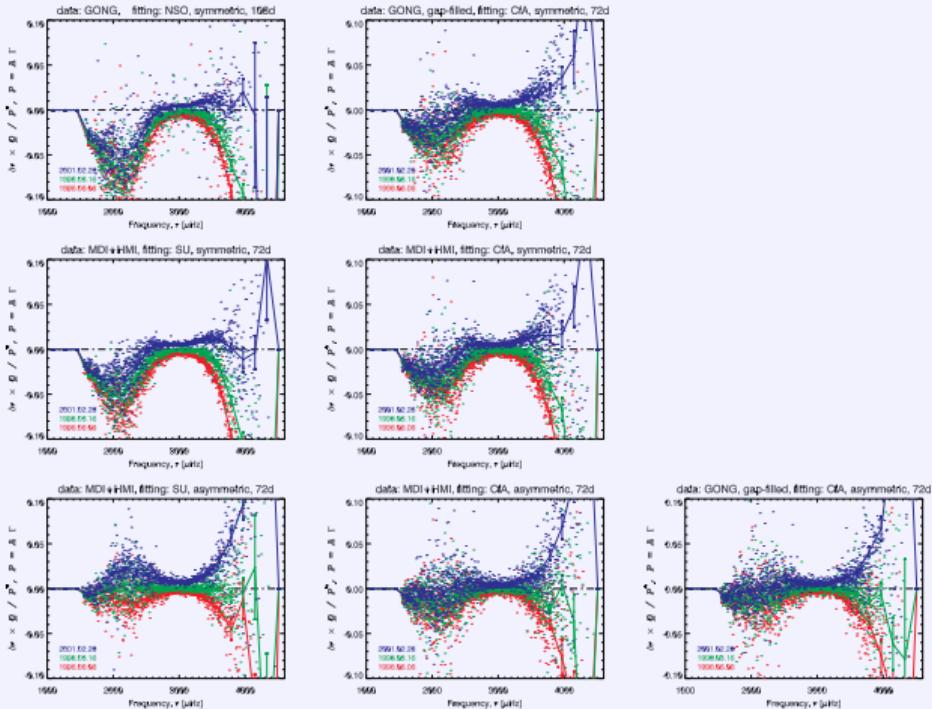
- ▶ $\delta\nu$: change wrt to time, hence activity;
- ▶ Raw $\langle\delta\nu\rangle$ sensitive to mode set, i.e.: $\{n, \ell\}$
- ▶ Weighted mean frequency shift:
 - ▶ relative mode mass ($Q_{n,\ell}$): mass of volume sampled;
 - ▶ by uncertainty (“tradition”), why?
 - ▶ More physical scaling: line-width (Γ) or power ($P = A\Gamma$)
- ▶ Weighting does not remove dependency on either ν , ℓ or $\log(\nu/L)$.
- ▶ Mode attrition complicates comparisons (need common mode set).

Frequency Scaling



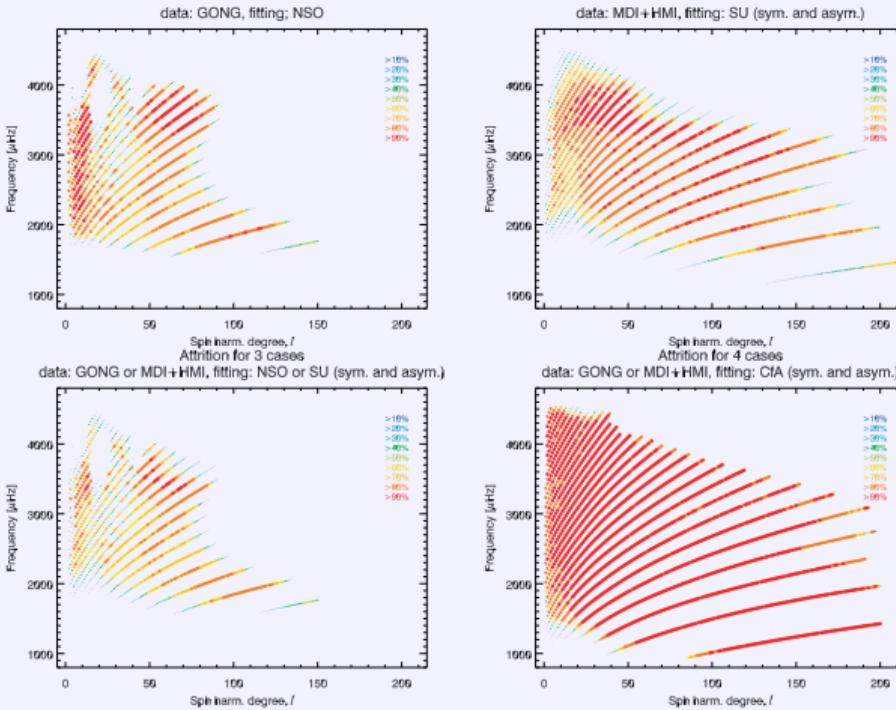
- Scaled frequency changes for 3 epochs and 3 weightings: Q , Q/Γ & Q/P

Frequency Comparison



- Scaled frequency changes, $(\delta\nu Q/P)$, as measured by 7 different fitting methods.

Attrition



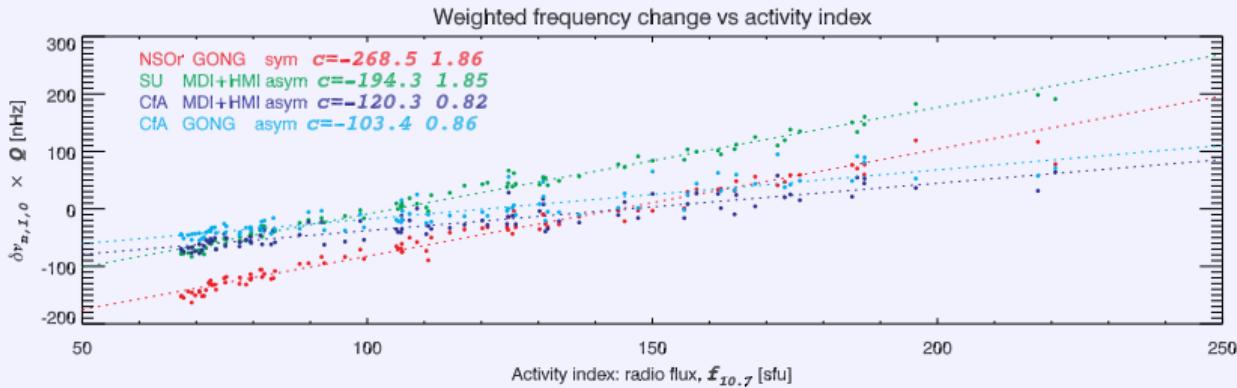
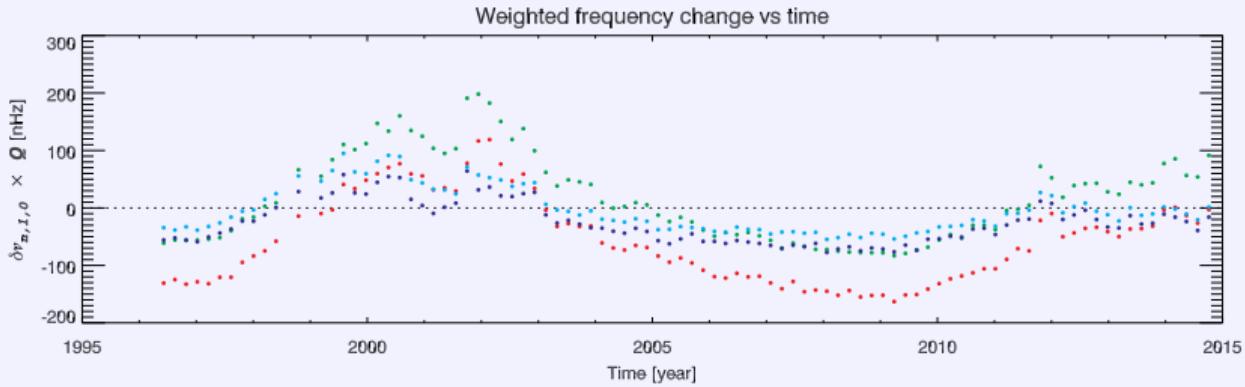
- Mode attrition for different fitting methodologies

Singlets to multiplets reduction

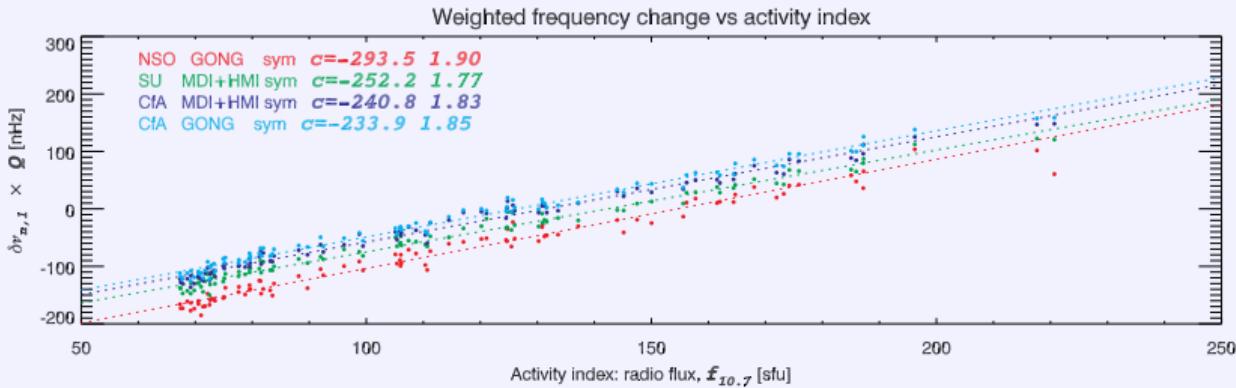
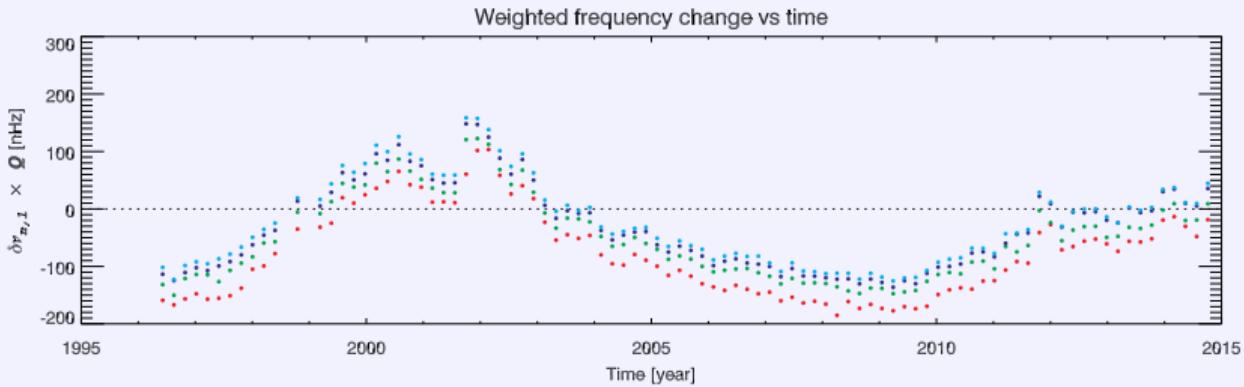
$$\nu_{n,\ell,m} = \sum_i c_i \beta_m^\ell(i) \rightarrow \begin{cases} \nu_{n,\ell} &= c_0 \beta_0^\ell(0) \\ \text{or} \\ \nu_{n,\ell,0} &= \sum_i c_i \beta_0^\ell(i) \end{cases}$$

- ▶ The quantity $\Delta_\nu^0 = \nu_{n,\ell} - \nu_{n,\ell,0}$ is a *strong* function of ν and solar activity.
- ▶ Explains *past* discrepancy between $\langle \delta\nu_{n,\ell,0} \rangle$ (CfA) and $\langle \delta\nu_{n,\ell} \rangle$ (NSO & SU).
- ▶ Adopted $\langle \delta\nu_{n,\ell} \rangle$ (which quantity means what?).

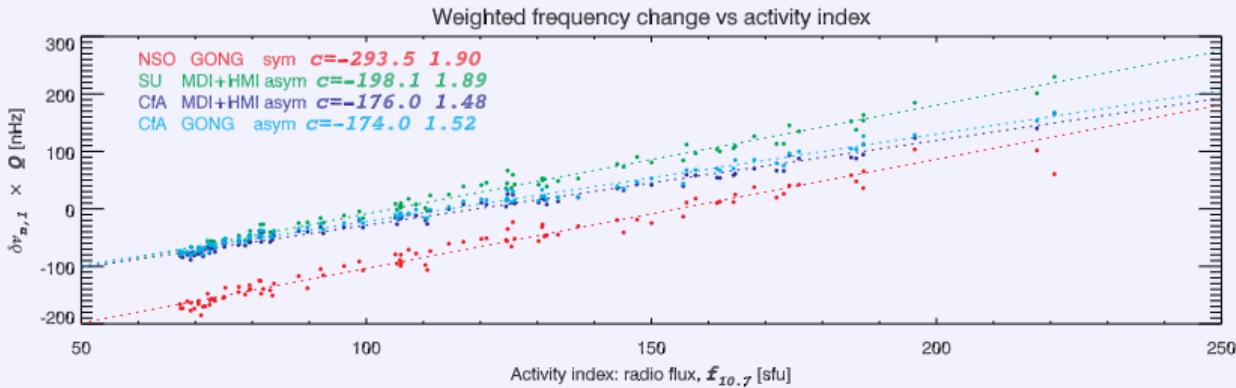
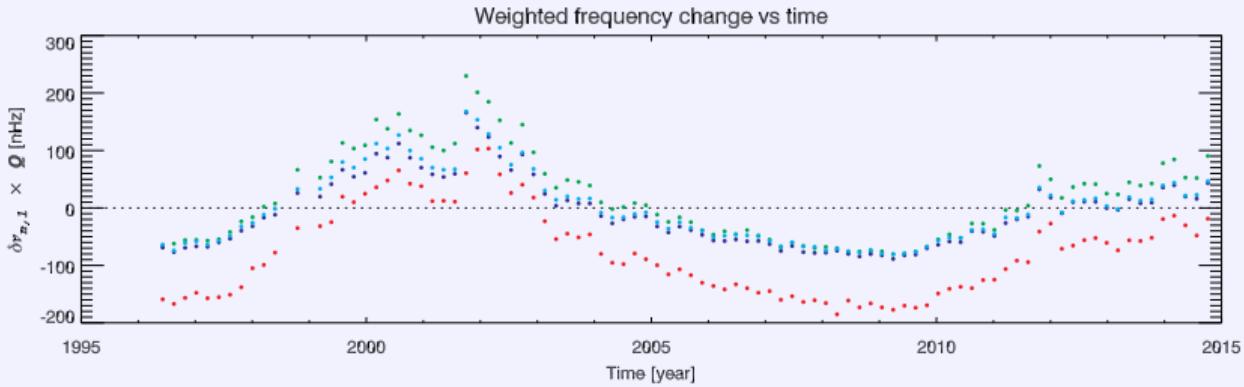
Change of frequency, $\delta\nu_{n,\ell,0}$



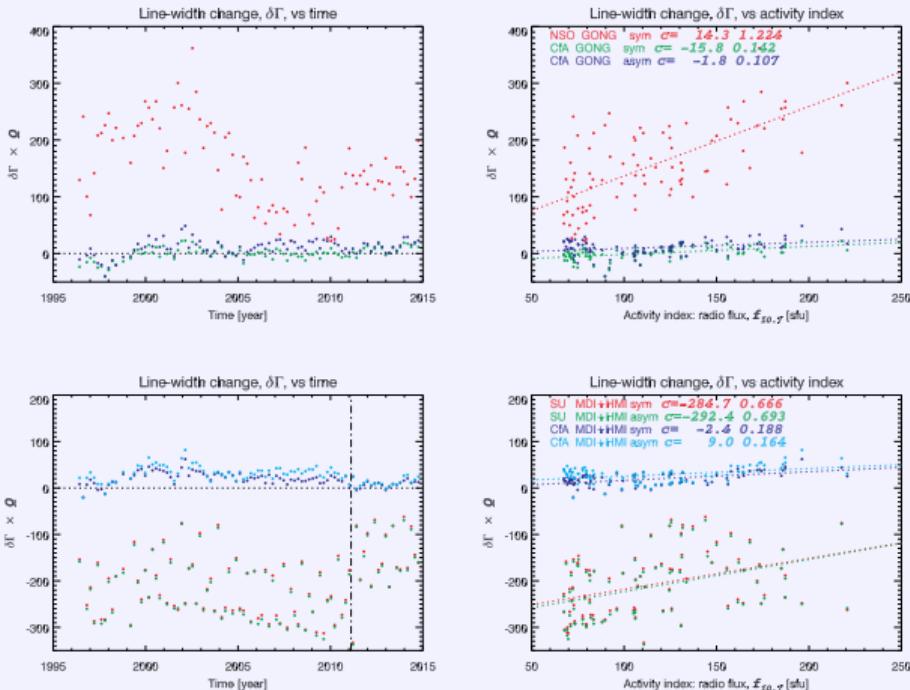
Change of frequency, $\delta\nu_{n,\ell}$, symmetric profiles



Change of frequency, $\delta\nu_{n,\ell}$, asymmetric profiles

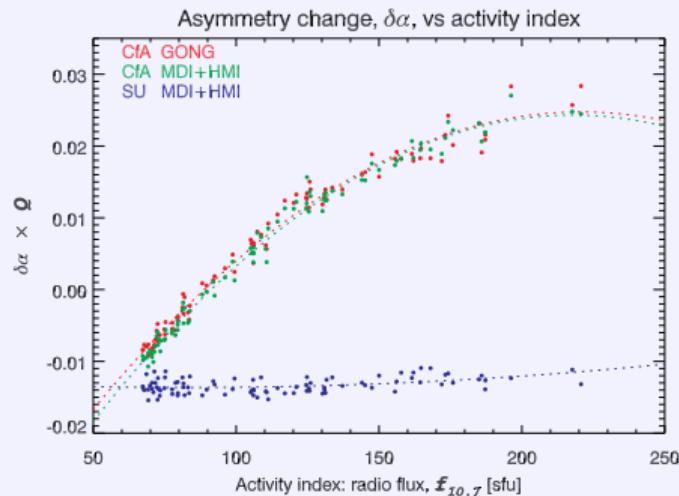
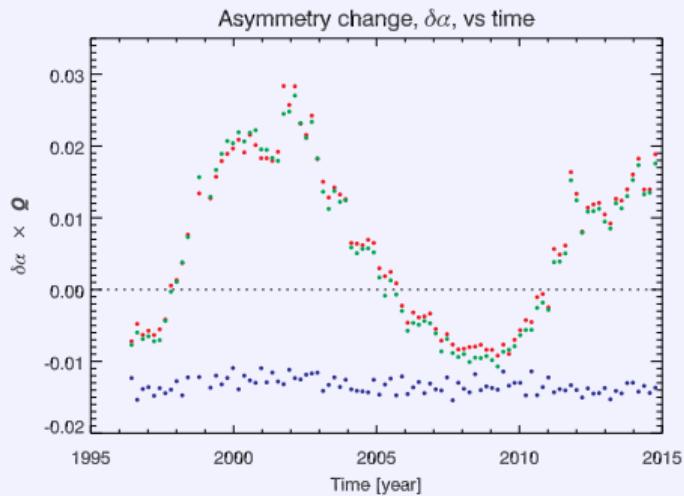


Line-width



- Top: GONG data (NSO & CfA), bottom: MDI+HMI data (SU & CfA)

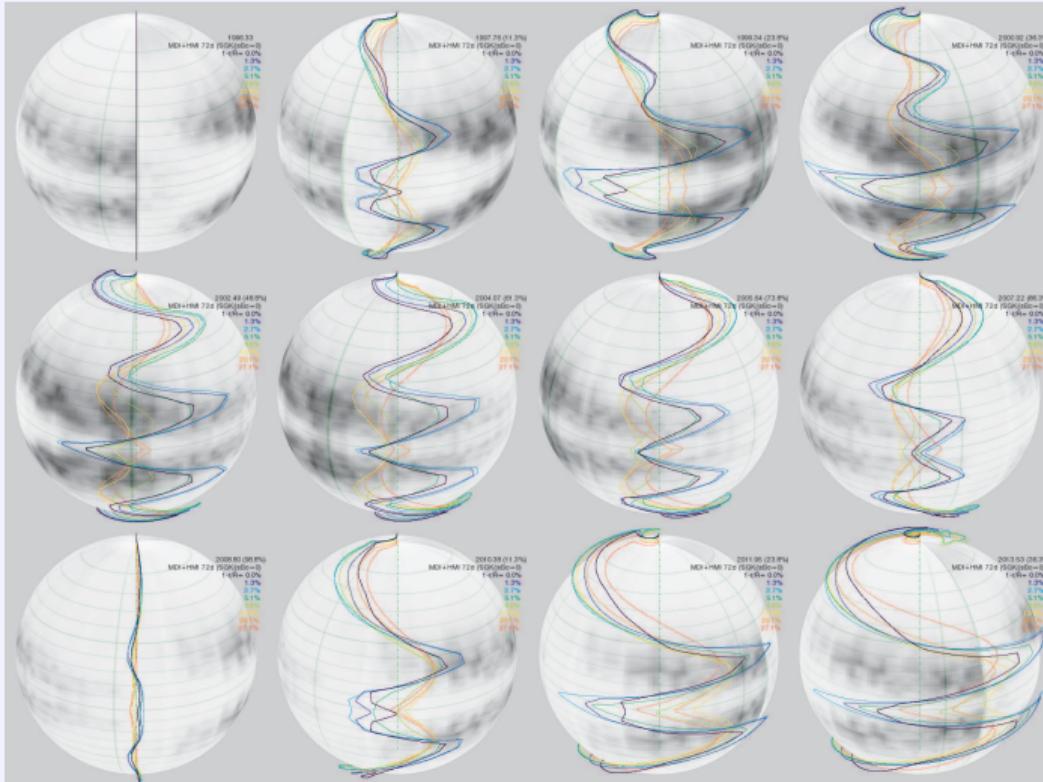
Asymmetry



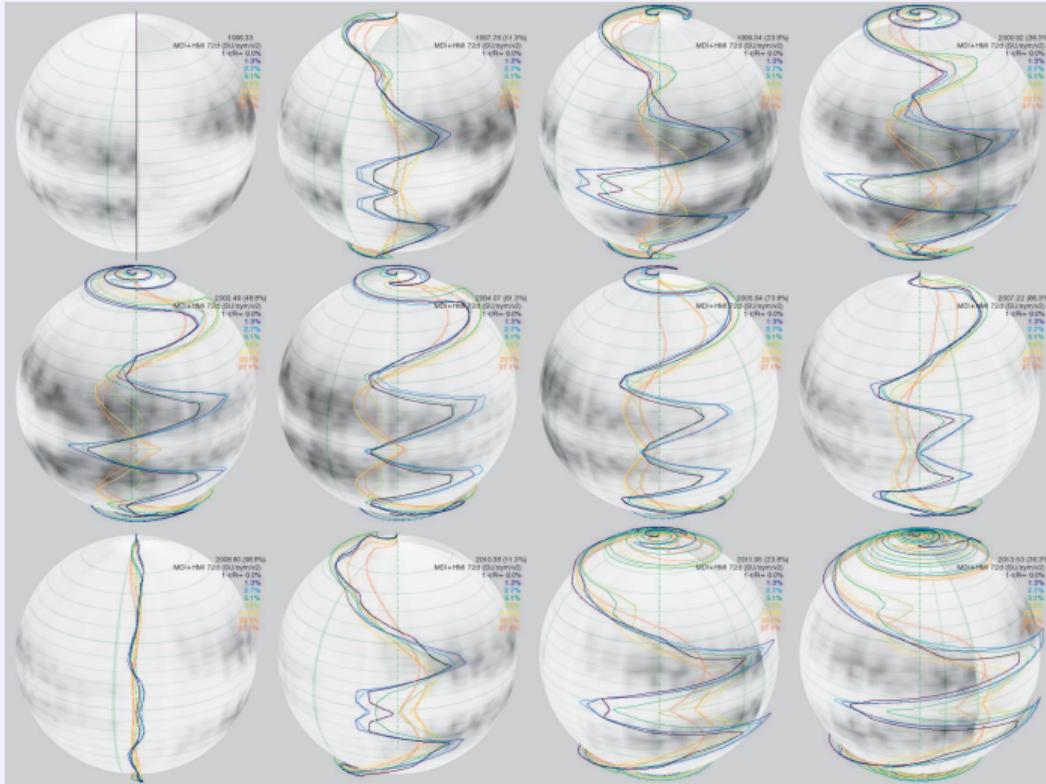
- ▶ Mean change of weighted asymmetry, $\delta\alpha Q$

Propagation Diagrams: my fitting to MDI+HMI

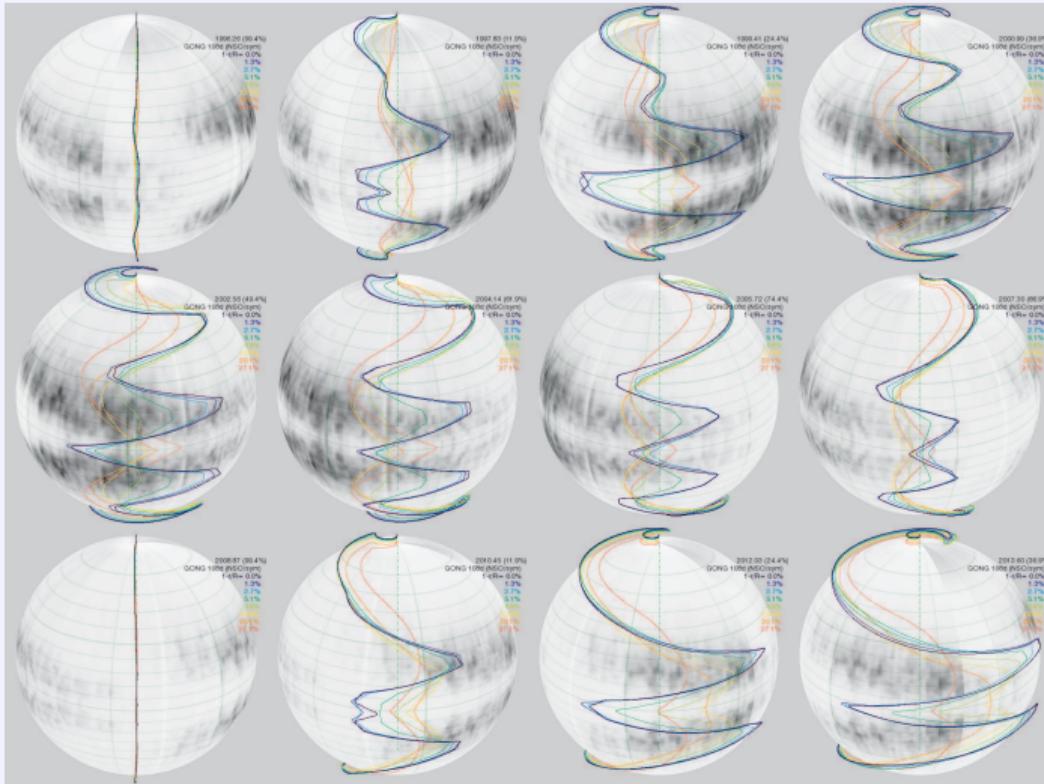
Collage: my fitting to MDI+HMI



Collage: SU's fitting to MDI+HMI



Collage: NSO's fitting to GONG



Conclusions

- ▶ Raw Frequencies, Line-width Asymmetry, Amplitudes & Background
 - ▶ Very different dependence of $\delta\nu$ on ν between symmetric and asymmetric fits.
 - ▶ Very different attrition patterns.
 - ▶ Much better agreement when using consistently $\langle\delta\nu_{n,\ell}\rangle$;
 - ▶ my symmetric fit matches NSO's and SU's magnitude;
 - ▶ my asymmetric fit leads to a small decrease in the magnitude of change.
 - ▶ Line-width: Inconsistent results between data and methods.
 - ▶ Asymmetry: inconsistent results between methods, consistent results between data (CfA)
 - ▶ A & B: inconsistent results.
- ▶ Rotation Inversions
 - ▶ Cycle 24 is different from Cycle 23;
 - ▶ un-physical twist at high latitudes when inverting SU's or NSO's results.

The End

<p>Introduction</p> <ul style="list-style-type: none"> 3 methodsologis, 2 data sets, 20 years of observational MDI+IMI = MDI + IMI + GONG MDI = Michelson Doppler Imager GONG = Global Oscillation Network Group Change of frequency Relative intensity measurements Conclusions 	<p>Frequency</p> <ul style="list-style-type: none"> Av. change with time, linear activity Power law sensitivity to noise level, $\propto (N, f)$ Weighted mean frequency shift Weighted mean frequency shift For planetary rotation, $f \propto R^2$, $f \propto R^3$ (for $R < R_c$) Weighting does not remove dependency on rotation, $\propto \log(f)$ Mode selection complicates comparisons (check coherence model) 	<p>Frequency Scaling</p>	<p>Frequency Comparison</p> <ul style="list-style-type: none"> Weighted frequency changes for 2 months and 10 months: GONG, MDI+IMI Weighted frequency changes, GONG, as measured by T different fitting methods 	<p>Atrition</p> <ul style="list-style-type: none"> Mode selection for different fitting methodologies
<p>Frequency Change</p> <p>Single to multiple reduction</p> $\text{new mode} = \text{old mode} - \text{old mode} / \text{new mode}$ <ul style="list-style-type: none"> The factor $\Delta f = \omega - \omega_0$ is the change of rotation rate and solar activity Estimated discrepancy between MDI+IMI (CM) and GONG (B, SO) Adopted velocity (kinematically means what?) 	<p>Change of frequency, Asymmetry</p>	<p>Change of frequency, Asymmetry, symmetric profiles</p>	<p>Change of frequency, Asymmetry, symmetric profiles</p>	<p>Line-width</p> <ul style="list-style-type: none"> Top: GONG data (SO & CM), bottom: MDI+IMI data (SO & CM)
<p>Asymmetry</p> <p>Linear fit to asymmetry</p> <ul style="list-style-type: none"> Linear change of weighted asymmetry, $\propto \Delta f$ 	<p>Propagation Diagram: my fitting to MDI+IMI</p>	<p>Collage: my fitting to MDI+IMI</p>	<p>Collage: SU's fitting to MDI+IMI</p>	<p>Collage: NSD's fitting to GONG</p>
<p>Conclusions</p> <ul style="list-style-type: none"> Raw Frequency, Line-width, Asymmetry, Asymmetry & Background Very different rotation rates, very different frequency measurements Very different rotation patterns Mode selection is very important Non-symmetric modes could work as a regularizer Weighted mean frequency shift is not a good measure of rotation change Line-width: heavier modes must have larger data, smaller mode Asymmetry: more modes between mode, smaller mode between mode (CM) All GONG mode Power law Cycle in rotation from Cycle 20 Individual mode might indicates what it is doing (SO or NSD results) 				