Two Years of Global Analysis with HMI

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With HMI completing over two years of observations in May 2012, we have the opportunity to see the beginning of any trends in the global mode parameters and rotational inversions. In particular we can investigate whether the one-year periodicity seen in the f-mode frequencies measured by MDI is present in HMI. Furthermore, HMI gives us an opportunity to examine the helioseismic signals for a long span of time in observables contemporaneous with velocity, such as intensity and line depth, which MDI was unable to provide. The high resolution of the HMI instrument also gives us a chance to study in detail how the apodization of the images affects the inferred mode parameters, since our previous work has shown an as yet not understood systematic error relating to the apodization.

Annual Periodicity

In the MDI analysis, if one plots the fractional change in the f-mode frequency as a function of time, then superimposed on the solar cycle variation will be a periodicity of almost exactly one year (see figure 1). In our previous work we tried a number of corrections to the analysis, none of which significantly reduced the magnitude of this systematic error. We did see a reduction, however, when we corrected the f-mode frequencies for the doppler shift resulting from the spacecraft motion. For example, see figure 2 for the years 2003 and 2004, where we plot the fit of an annual sinusoid plus a function linear in time. For HMI, the observables have already been corrected for the effect of spacecraft motion, so perhaps it is gratifying that the fit of the same function to the first two years of HMI data does not seem much better than a straight line, but as it turns out, the last two years of MDI don't seem to have much of an annual component either (figure 3).

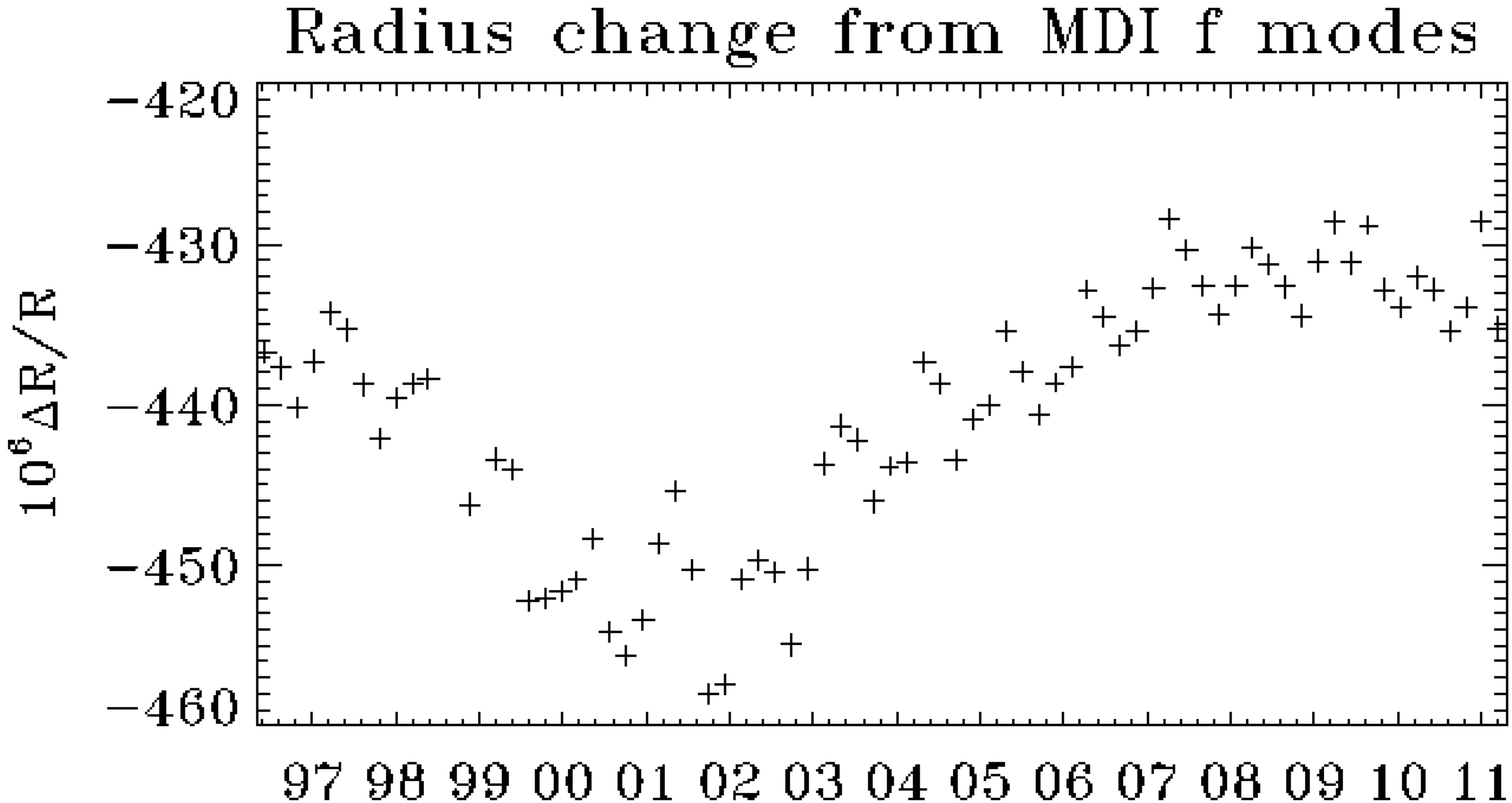

Figure 1. Fractional change in seismic radius, which is directly proportional to the fractional change in f-mode frequency, throughout the MDI mission.

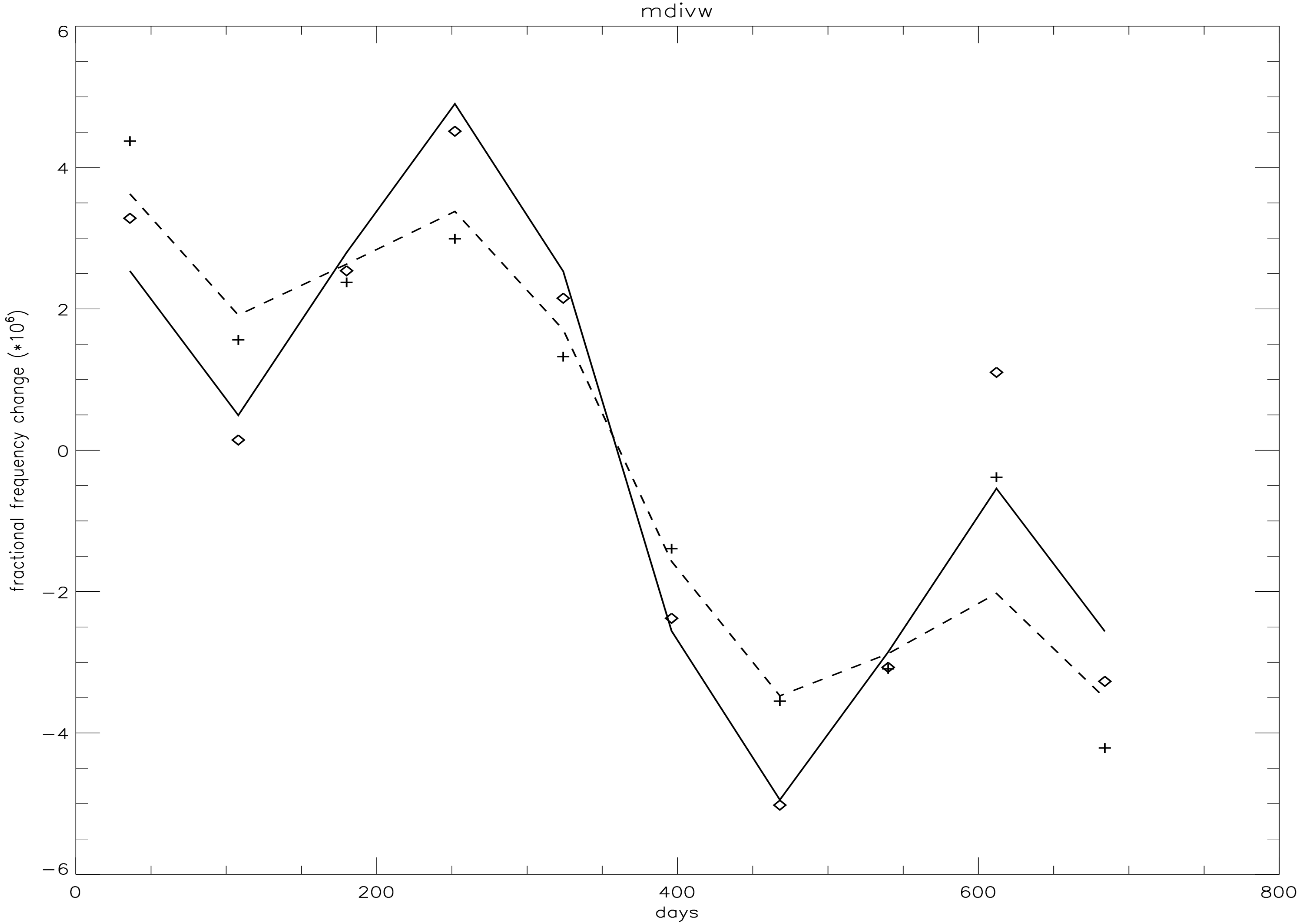

Figure 2: Plusses and dashed line are with doppler correction, diamonds and solid line are without. First time shown corresponds to 2003.01.13.

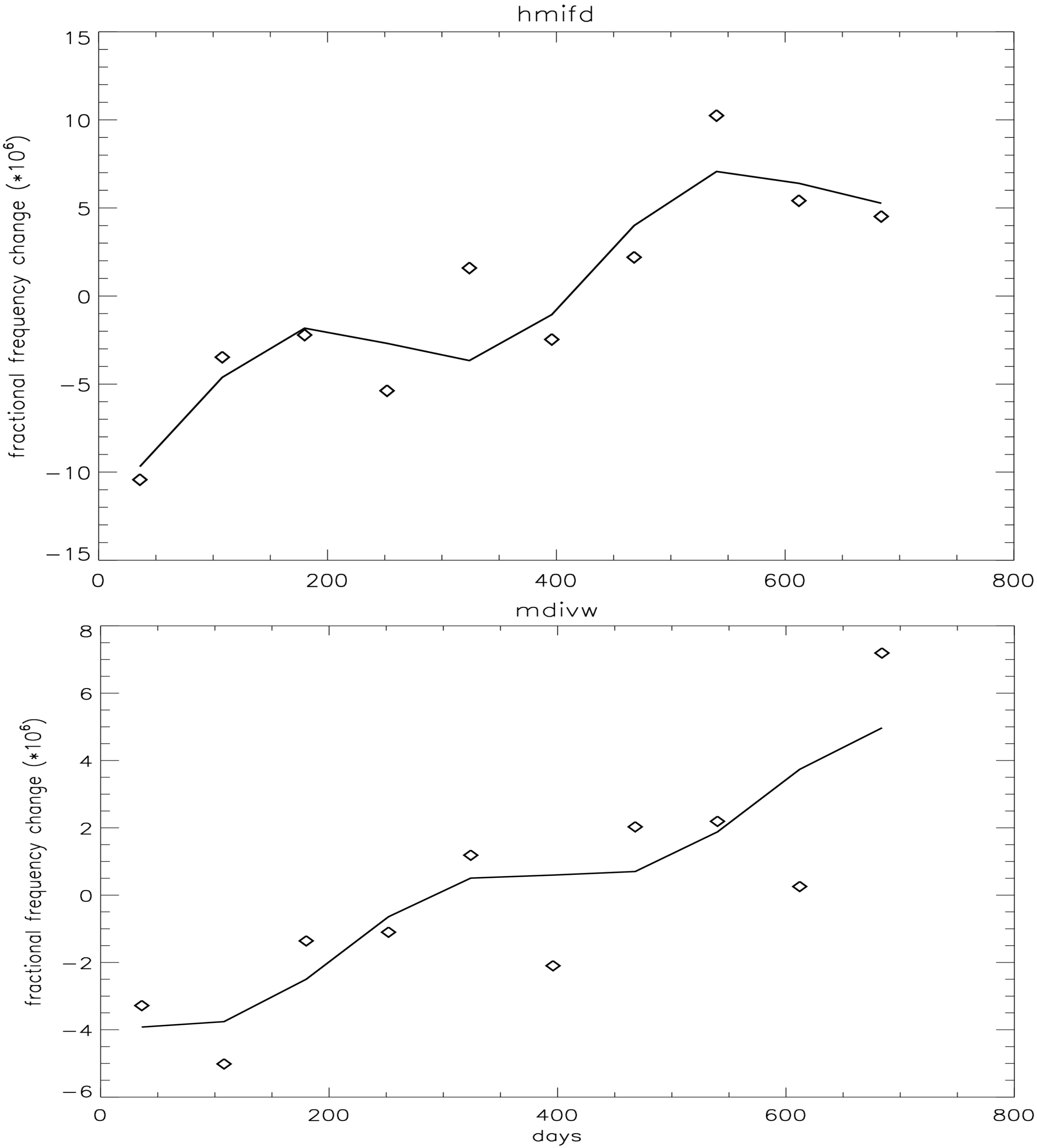

Figure 3. Top panel is first two years of HMI, bottom is last 2 years of MDI

Intensity Fitting

To study the feasibility of using observables other than velocity as the input to a global helioseismic analysis, we first tried to fit the first 72 days of continuum intensity from HMI. Unlike the velocity images, the intensity images do not suffer from the line-of-sight projection factor near the limb. To fit the intensity timeseries, a new leakage matrix was needed, which in turn required some model of limb darkening. For our first attempt we used a polynomial fit to an average of intensity images, which is already calculated for every 12 minutes of the mission. Also, whereas the velocity fitting uses a frequency interval around 7 mHz to calculate the covariance of the noise, for the intensity data we got much better fits using an interval near 1 mHz. Due to a low signal to noise ratio, we were unable to fit any modes for n=0 or 1. The following plots show the differences between the analysis of velocity and intensity images.

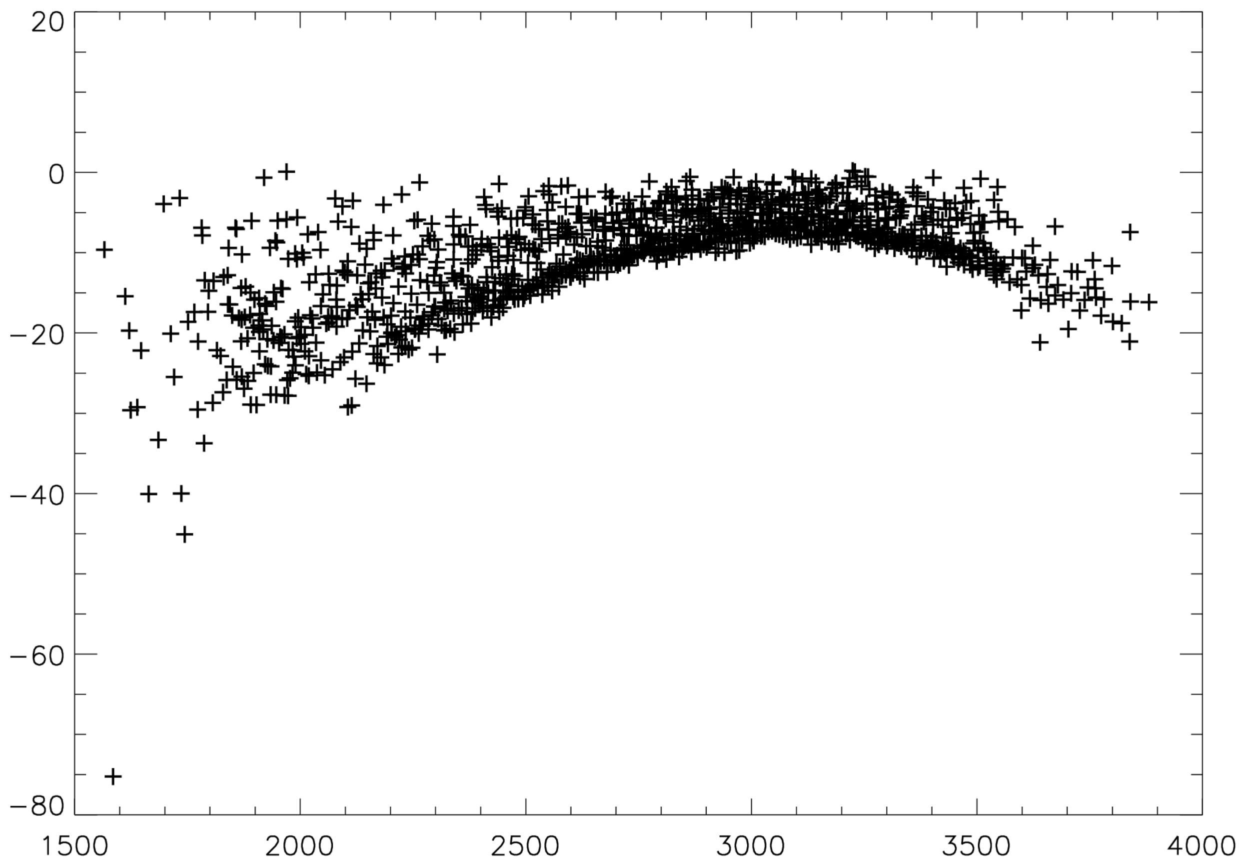

Figure 4. Frequency differences as a function of frequency in units of standard deviation. The differences have a systematic dependence on frequency, with the intensity analysis consistently giving a higher frequency.

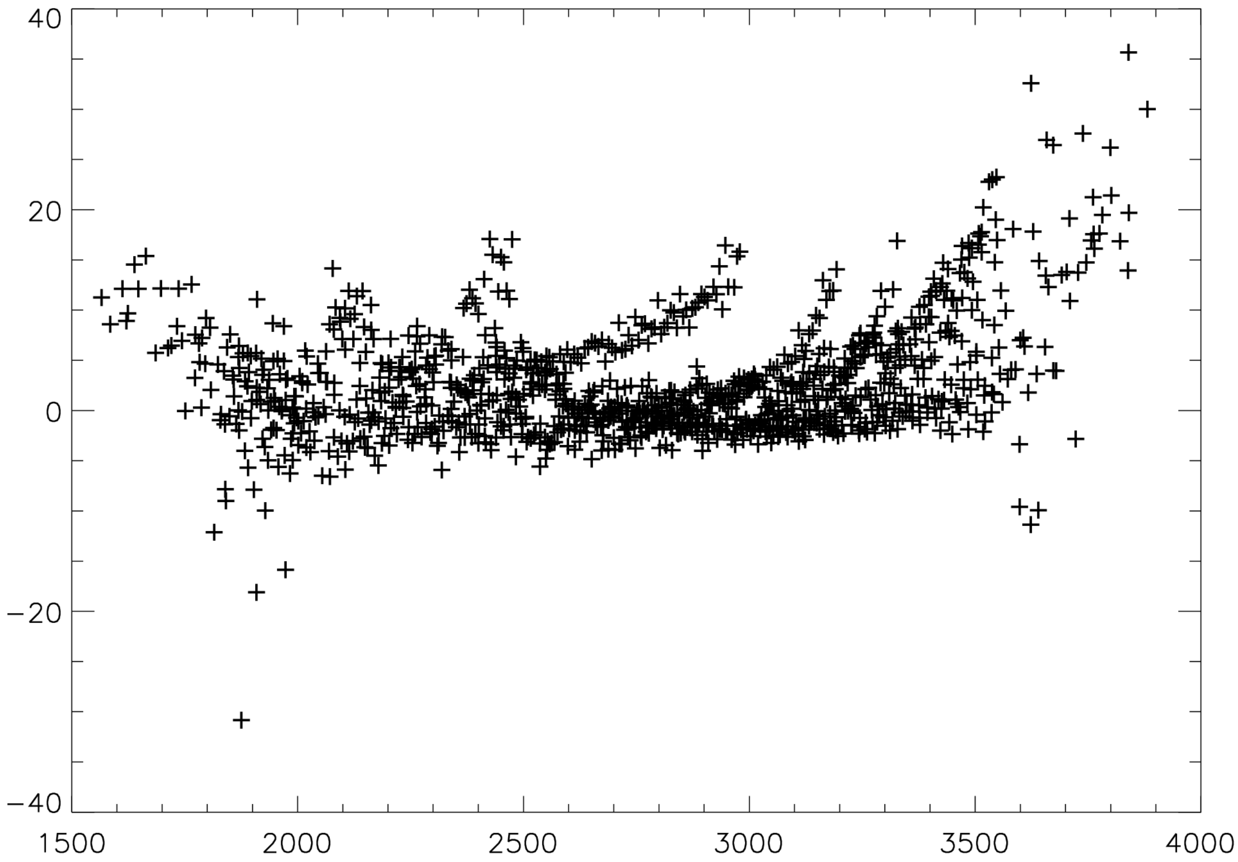

Figure 5. Differences in width in units of standard deviation as a function of frequency. The intensity analysis generally gave larger widths.

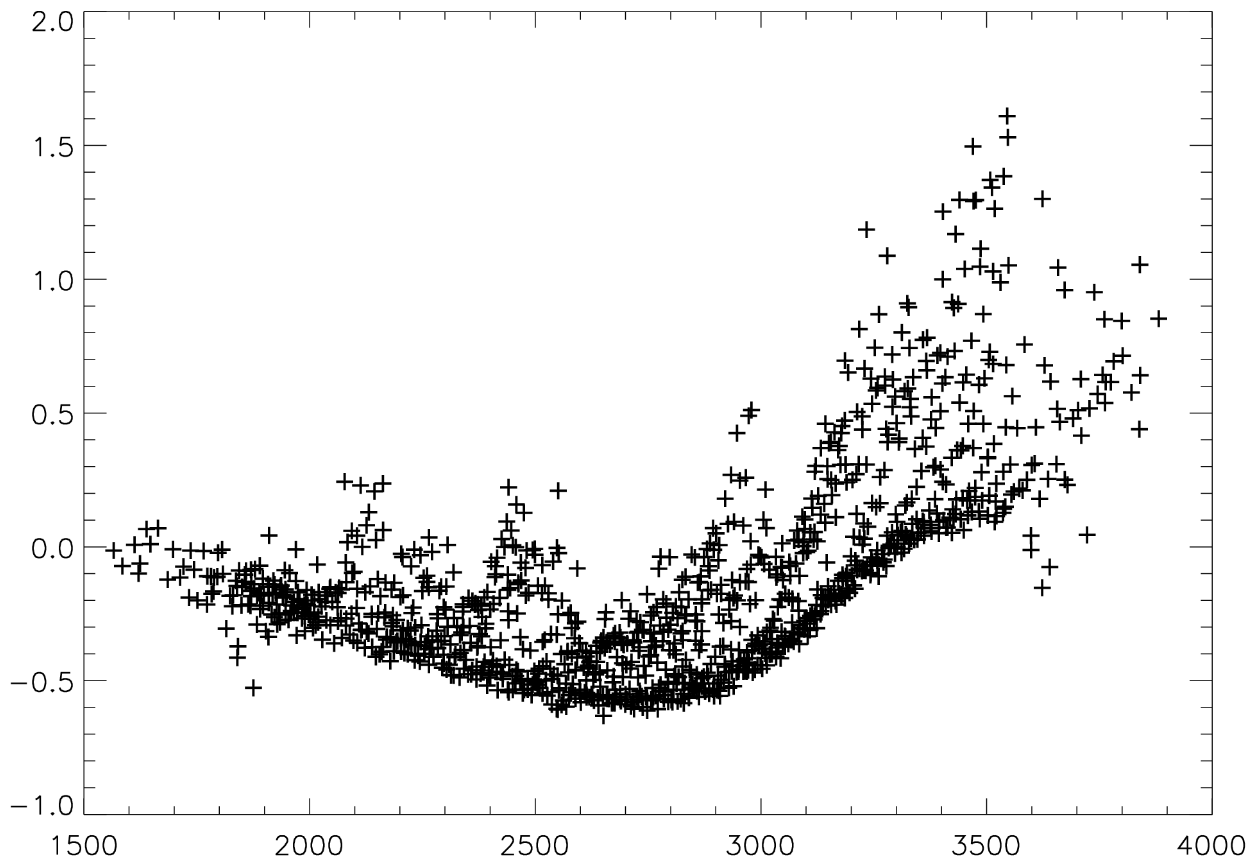

Figure 6. Differences in amplitude, unnormalized, as a function of frequency.

Apodization Studies

Inquiry into the discrepancy between MDI medium-l and full disk results led us to discover that the difference between them had mainly to do with the different apodization of the two datasets, rather than on their resolution or gausian smoothing. In particular, the bump in the normalized residuals of the odd a-coefficients following an inversion and a jet seen at high latitudes were both stronger for the more tightly apodized data (see figure XX). In this study we use the first 72 days of HMI data and apodize it in 6 different ways as listed in the following table.

	Inner Apodization Radius	Apodization Width
MDI Medium-l	0.83	0.04
	0.85	0.05
MDI Full Disk	0.90	0.05
	0.94	0.05
	0.94	0.01
	0.98	0.01

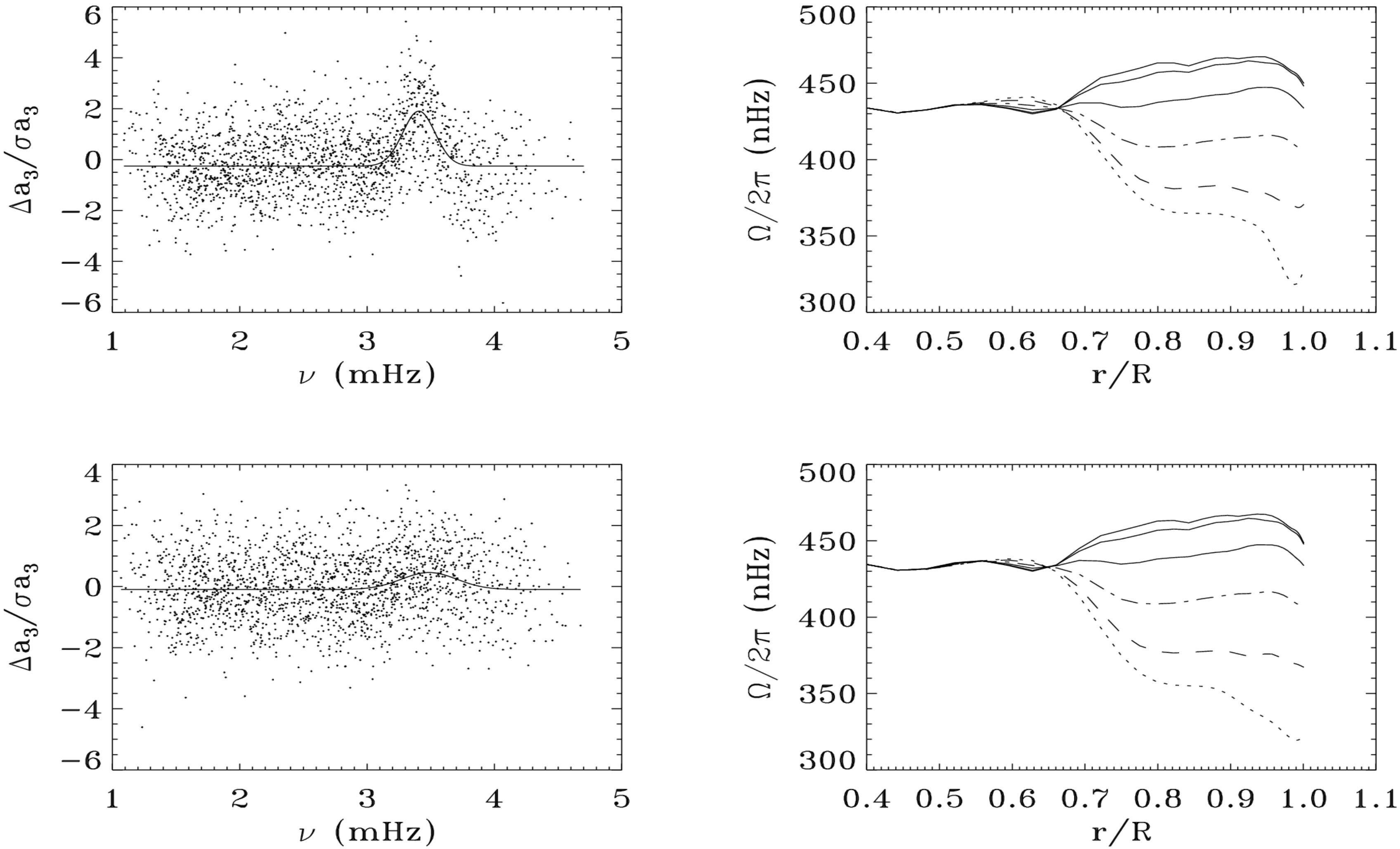

Figure 7. Left panels show normalized residual of a3 with a gaussian fit, right panels show internal rotation as a function of radius at 0,15,30,45,60, and 75 degrees latitude, from top to bottom. Top panels are the MDI medium-l apodization, bottom panels are the MDI full disk apodization.

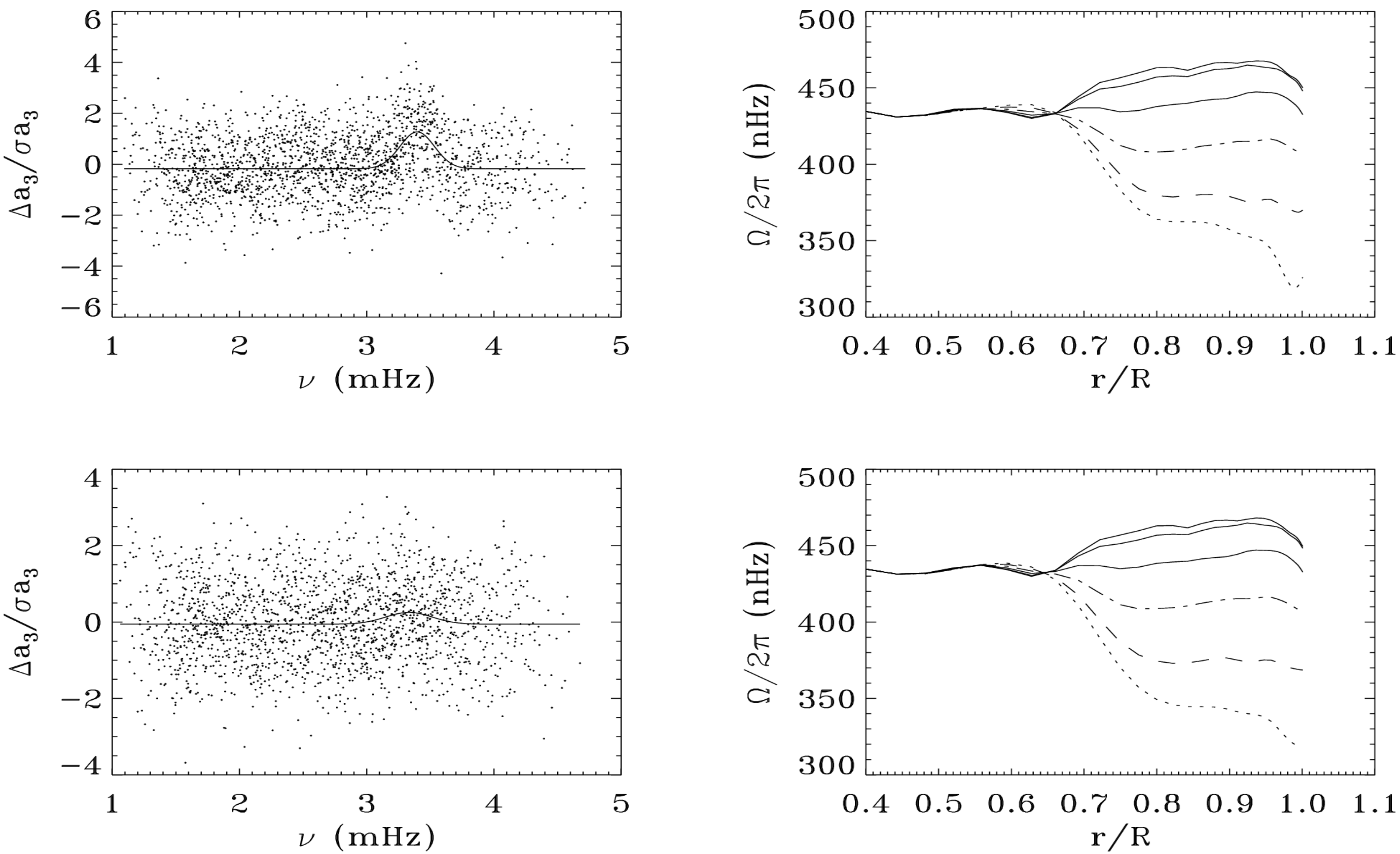

Figure 8. Top panels use an inner apodization radius of 0.85, bottom panels use 0.90. Both have an apodization width of 0.05.

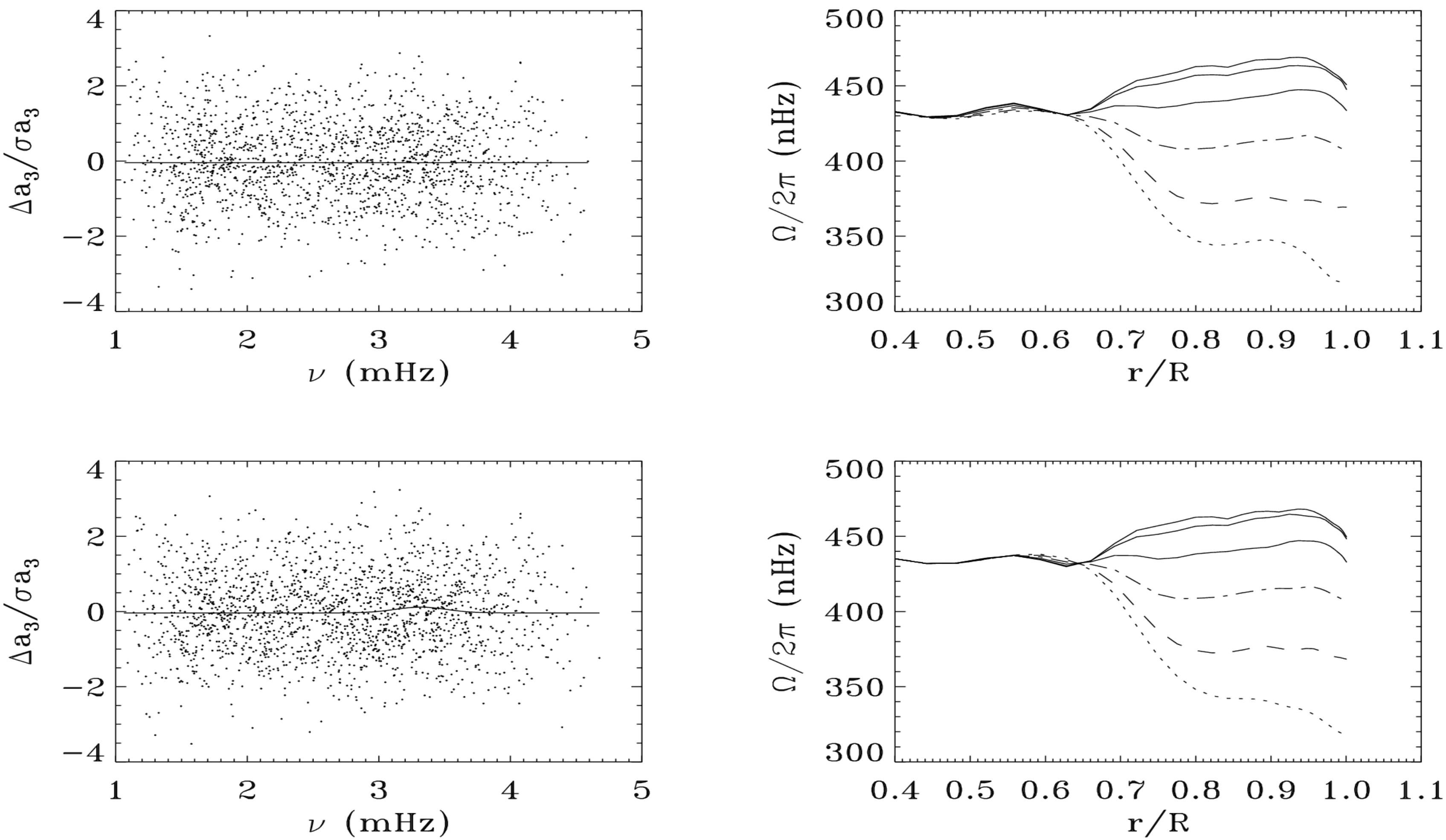

Figure 9. Top panels use an inner apodization radius of 0,94, bottom panels use 0.98. Both have an apodization width of 0.01.