How Sensitive are Helioseismic Mode Parameters and Subsurface Flows to Choice of the Spectral line?

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Motivation

We analyze simultaneous multi-spectral line observations to investigate how the results of helioseismology are affected by the spectral line used to observe the solar oscillations. This is important since the HMI instrument on SDO will use a spectral line different from SOHO/SOI and GONG. We carry out ring-diagram analysis, a local helioseismology technique, to study the relative changes in local mode parameters and subsurface velocity fields inferred from the different data sets.

Data and Methodology

- The data sets include simultaneous observations obtained with the **Ni I 676.8 nm** (from Global Oscillation Network Group - GONG), **K I 769.9 nm** (from Magneto Optical Filters at Two Heights - MOTH experiment at South Pole), **Na I D2 589.0 nm** (from MOTH experiment) and **Na I D1 589.6 nm + Na I D2 589.0 nm** (from Mount Wilson Observatory - MWO) lines during Austral summer of 2002-03. Here we discuss the data from Jan 17 to 20, 2003.
- The Ni and K lines are formed in the photosphere at heights of 200 km and 420 km respectively, and Na lines are in the lower chromosphere at a height of 780 km (D2) from base of the photosphere.
- The radius of the GONG solar image is 419.5 pixels, while that of MOTH and MWO are 178.4 and 441.33 pixels, respectively.
- The cadence of the GONG, MOTH and MWO images are 60s, 10s and 60s, respectively.
- The ring-diagram technique was used to calculate mode parameters and subsurface velocity fields. Prior to the analysis, the following procedures were applied to these data sets in order to minimize differences arising from the various image geometries;

(a) reduced the resolution of GONG and MWO images by a factor of 2 to approximate the MOTH resolution.

(b) changed the cadence of MOTH images to 60 seconds.

(c) calculated the angular correlation of MOTH and MWO images with that of GONG and accordingly changed the offset angle.

- A region of 30° x 30° at disk center was remapped and tracked for 1440 min.

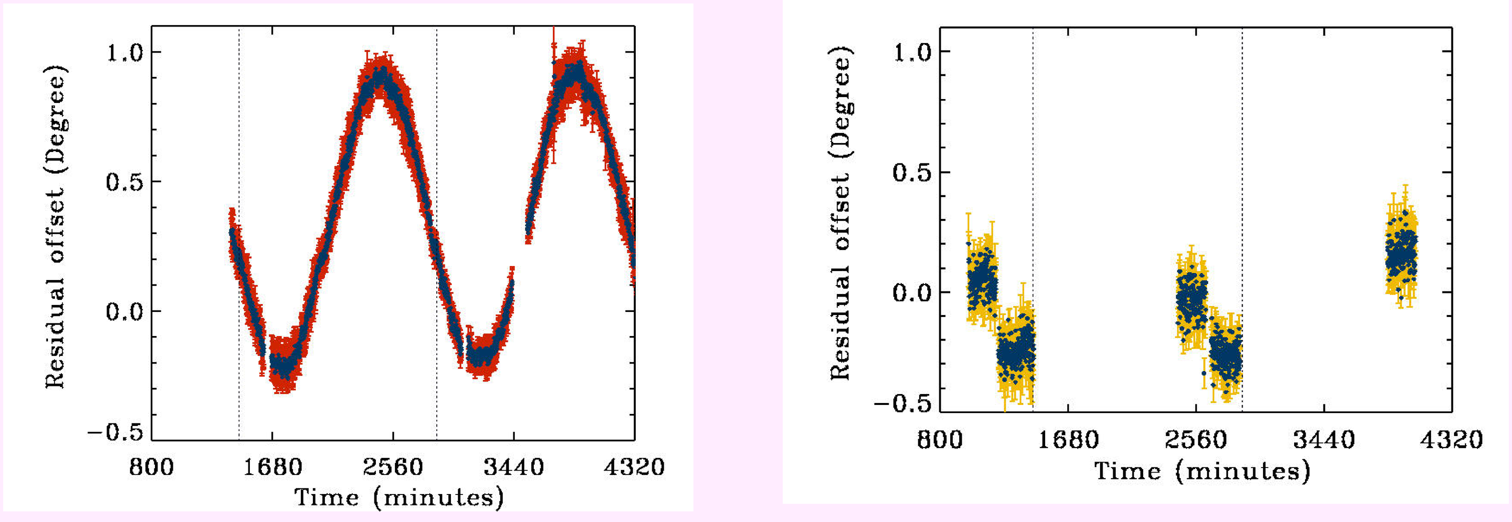

Figure 1: Calculated residual offset angle for MOTH - K (left) and MWO - Na (right) images with respect to standard GONG – Ni images. Blue represents the angle and red & yellow are for the estimated errors in K and Na images, respectively. Dotted vertical lines indicate the change of the day.

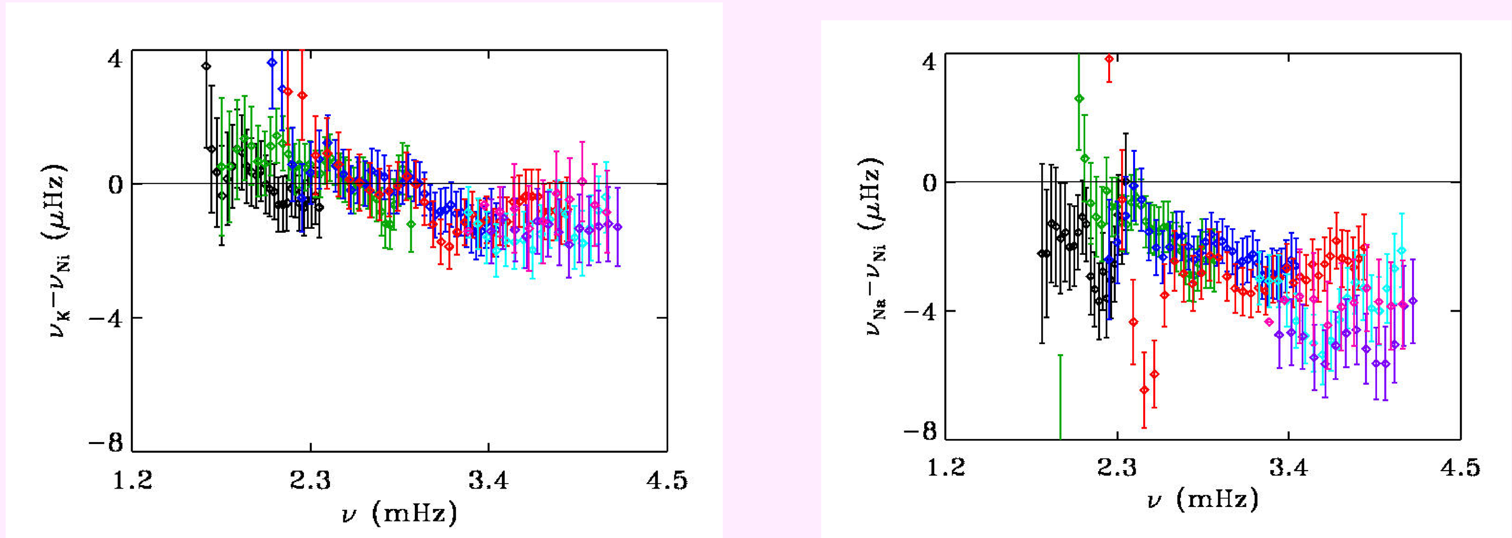

Figure 2: Difference in mode frequencies obtained from MOTH K (left) and Na (right) data with respect to those obtained from GONG Ni as a function of frequency. Different colors are for different n values (n = 0, 1, 2, 3, 4, 5, 6). Frequencies obtained with Ni and K lines are within 1σ, however, the difference increases with frequency for Na and Ni (~ 3σ).

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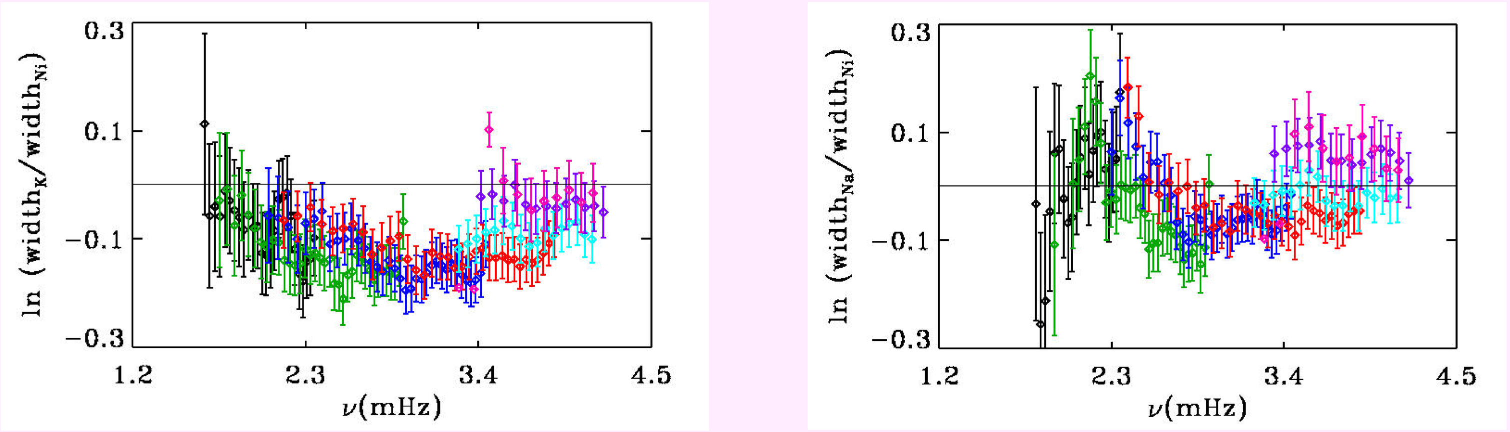

Figure 3: Comparison of line width of modes obtained by observing different spectral lines. Different colors are for different n values (n = 0, 1, 2, 3, 4, 5, 6).

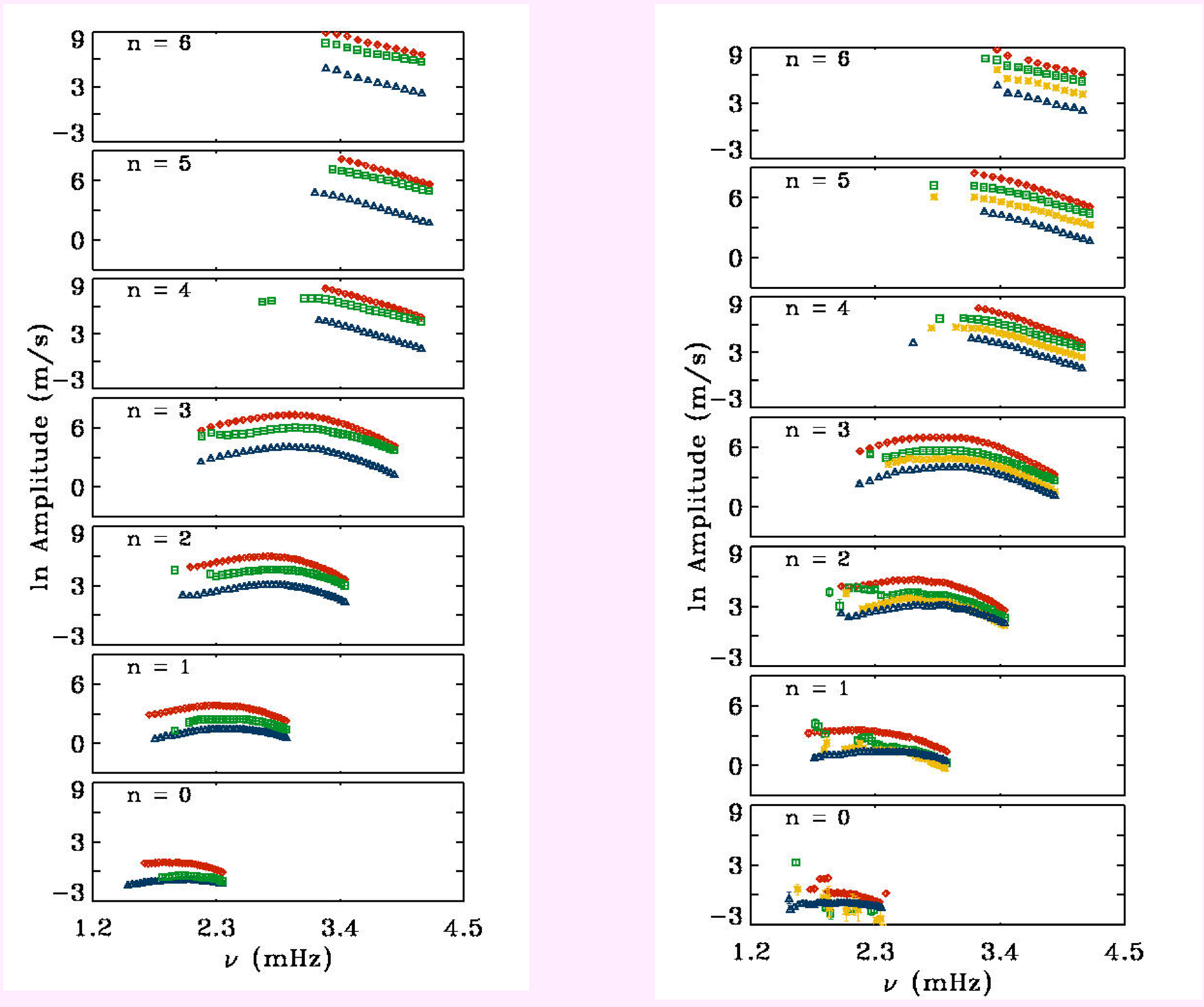

Figure 4: Mode amplitude at disk center as a function of frequency for different spectral lines: Ni, Na D2, K I and Na D1+D2 (right figure only). Modes were obtained by tracking a region for 1440 min (left) and 450 min (right). In the left figure, the amplitude of the modes for Na line is higher than Ni and lower than K for all n values. However, in the right figure, the amplitude for Na is lower than for Ni at higher frequency for low-n modes. It is clearly seen that mode amplitudes observed with K line are always higher than for Na.

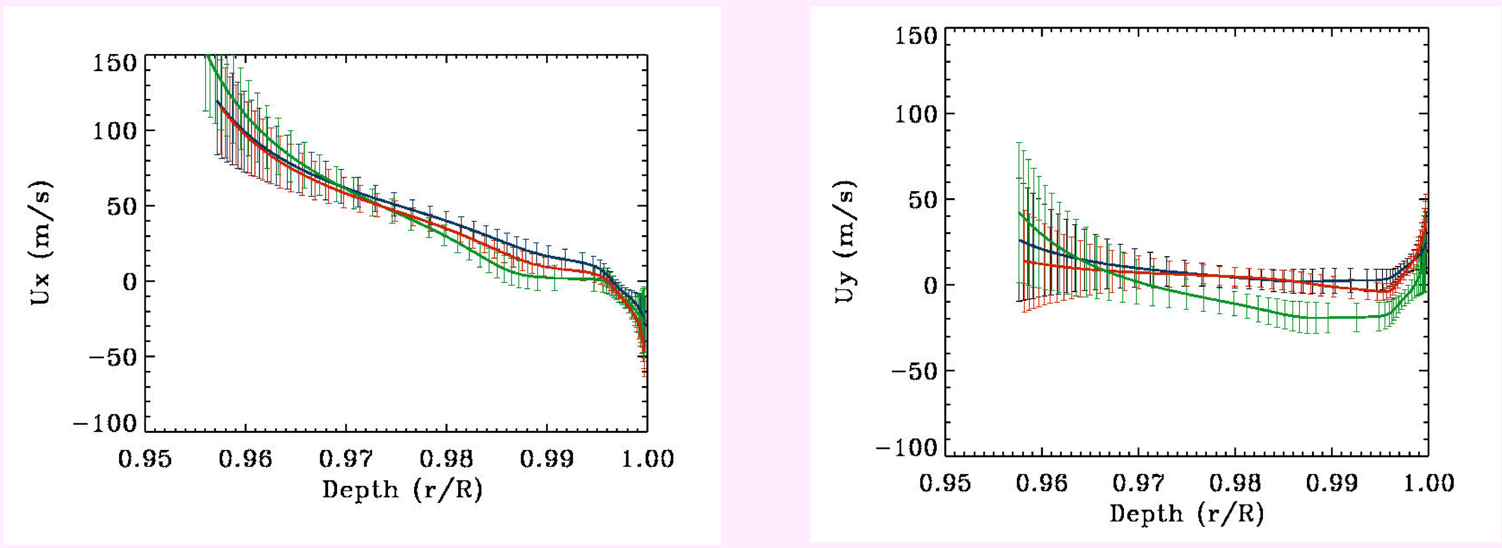

Figure 5: Zonal (left) and meridional flows at disk center as a function of depth for modes obtained with Ni, Na D2 and K I. Both zonal and meridional flows for Ni and K lines follow the same trend with depth, however, there are some differences for the Na line.

Summary

The analysis of simultaneous observations at different heights in solar atmosphere shows that

◆There are differences in mode frequencies obtained with different spectral lines. The frequencies obtained with Ni and K lines agree to within 1σ. However, frequencies obtained using Na line are lower than those with Ni and K. These differences are larger at higher frequencies (>3 mHz), and can reach 4 μHz.

◆The mode amplitudes obtained with K and Na lines are higher than those obtained with the Ni line. However, modes obtained with the K line have higher amplitude than Na, which is opposite to what is expected from solar models, i.e. the mode amplitude should increase with increasing height (decreasing density). The reason for this discrepancy is not understood.

◆We do not see any significant change in line width at the disk center. All differences are within 1σ.

◆Inferences of zonal and meridional flows do not change with the choice of spectral line.