Chapter 5

Conclusion

In this chapter I will briefly link the previous chapters together, summarize the various results obtained, and describe this work in a larger context.

When I started on this project, the intention was to invert the splittings from the Fourier Tachometer using some of the inversion methods described. Since it was expected that we would get good splittings up to say $l = 120$, this would have made it possible to infer the solar rotation rate as a function of radius and latitude in the outer part of the solar convection zone, which has been impossible using the previously published splittings, which only included modes up to $l = 60$.

Unfortunately, as has been described in considerable detail earlier, the infamous bump appeared, making any attempts at inverting the splittings somewhat suspect. An example of the results of doing an inversion was shown in the section on the bump, and although the rotation rate obtained is not physically impossible, it does appear rather extreme. Also, the fact that the bump appears in this particular place makes it highly suspect, as discussed earlier.

If only the modes with, say, $\nu/L \geq 50\mu Hz$ are used, that is modes above the bump in ν/L, as suggested in Bachmann, Schou, and Brown (1993), one obtains the inverted rotation rate shown in figure 5.1. The averaging kernels corresponding to the inversion using a_1 have also been shown in figure 5.1. Notice that the rotation rate is ill determined for $r/R < 0.4$ and $0.85 < r/R < 1$.

As can be seen from figure 5.1, the results are very similar to those obtained earlier (eg. Christensen-Dalsgaard and Schou 1988). It appears that the solar rotation rate is constant along radii in the solar convection zone and close to the surface values, and independent of radius and latitude in the radiative interior (see, however, Gough, et al. 1993). As with earlier observations, it is not possible to resolve the transition between the solid body rotation and the latitude dependent rotation, implying that the transition region is very narrow, probably less than a few % of the solar radius.

It also appears that the rotation rates for the two years are very similar. There are minor changes, but it is difficult to draw any conclusions from those, as they do not appear to be statistically significant (see, however, Goode and Dziembowski 1991).

Notice that while a_1 seems to be affected by systematic errors, the frequencies and the other a-coefficients seem to be largely unaffected, and thus usable for inversions etc.

Some mode parameters do appear to change from year to year due to solar effects, among those are the mode frequencies and the even a-coefficients. The change has been shown earlier in the section (3.8) comparing the results for the two years. As discussed in Libbrecht and Woodard (1990) and Woodard et al. (1991), it appears that the changes are correlated with the magnetic field close to the solar surface. Unfortunately, as we have reduced only these two years, we have not been able to follow the changes during a major fraction of a solar activity cycle. When the

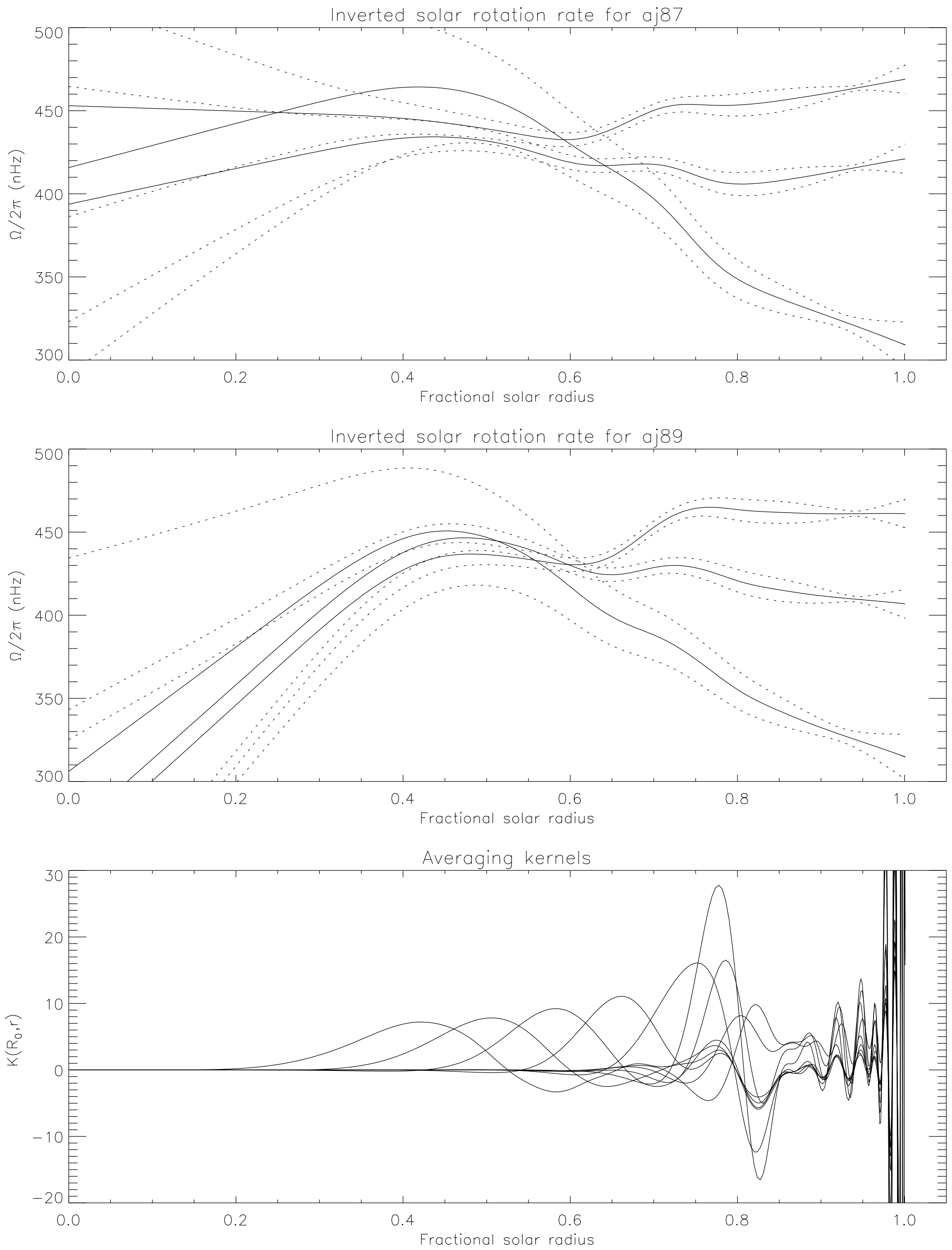

Figure 5.1: Results of inversions of the aj87 and aj89 splittings with $\nu/L \geq 50\mu Hz$. The 2 upper plots show the inverted rotation rates for the two years, with the dotted lines indicating the 1σ formal errors. The bottom plot shows selected averaging kernels for the inversion corresponding to a_1 for 1989, the kernels for 1987 being similar.

remaining years have been analyzed, it should be possible to get a better understanding of the physical reasons for these changes.

While there have been problems in eliminating systematic errors from the observed splittings, it is still the hope that the analysis method developed will be useful for the reduction of other sets of observations. In particular, we expect to have the remaining Fourier Tachometer datasets reduced fairly soon, provided that we do not run into more unpleasant surprises.

It is also the hope the the ideas presented will be useful for analysis of datasets other than those obtained with the Fourier Tachometer. Whether the method presented can be used for analysis of data obtained with the GONG or SOI/MDI instruments depends on the available computing power and whether the remaining systematic problems can be removed. The computing power is a problem because of the higher maximum l, but given the continued increase in computer speed, and the fact that the instruments will not operate for another few years, this problem is likely to be solved. The systematic problems will probably need some work, but are likely to be solvable too.

The analysis of artificial time-series obtained with the program described in Schou and Brown (1993) has proven extremely useful for testing the various analysis programs we have developed. While we have not been able to pinpoint the cause of the bump, we have been able to estimate the magnitude of various systematic errors. We are currently working on a comparison of the performance of our various analysis algorithms on artificial data. It is the hope that it will be possible to select among the different analysis methods and find the one that will be most suitable for the analysis of other datasets, both in terms of systematic/random errors and computational expense.

The various tests described in the chapter on the analysis of the Fourier Tachometer data have also been extremely useful in estimating the size of systematic errors caused by incorrect assumptions concerning the raw data. Performing these tests should help one understand which parameters for the real data must be well known, and which are of less importance. The use of the various diagnostics described should also be a considerable help in diagnosing various problems.

While there are currently no observations of mode frequencies for individual ms, which are needed to utilize fully the 2-dimensional inversion method described in Schou, Christensen-Dalsgaard and Thompson (1993), such observations may become available soon when the GONG and SOI/MDI instruments start observing. Since the transmission capacity from the SOHO satellite (on which the SOI/MDI instrument is going) is limited for most of the time, it will be necessary to select only certain modes for transmission or reduce the information transmitted in some other way. Using the inversion programs it should be possible to see what will be lost by using the various proposed schemes for reducing the amount of information transmitted, thereby allowing one to choose among the methods.

The use of 2-dimensional averaging kernels, as illustrated in Schou, Christensen-Dalsgaard and Thompson (1992, 1993, cf. App. 4, 5), should be extremely useful for estimating what can be learned from various mode sets. In particular, the 2-dimensional kernels for the 1.5-

dimensional case have shown what was meant by, for instance, the polar rotation rate, in the earlier 1.5-dimensional inversions for the latitude dependence of the solar rotation.