

Introduction

Observation of the solar spectrum and explanation of its appearance has been a major field of study for many years. Observational techniques have advanced to the point where accurate high wavelength resolution solar atlases are available, allowing individual spectral line profiles to be studied in detail. The basic principles of the formation of the spectrum are well understood, and it is possible to calculate the expected appearance of spectral lines, allowing comparison between theory and observation.

In this way, the solar spectrum has become a valuable tool for probing the sun. It yields information on the state of the solar atmosphere; it has allowed the chemical composition of the sun to be determined.

However, some physical processes in the photosphere have proved resistant to being investigated via the solar spectrum. It is difficult to obtain spectral measurements with high spatial and time resolution, so small-scale and transient phenomena are less well understood. One such phenomenon is the solar granulation. The granulation pattern is constantly changing, and its size is such that its features are at the limit of resolution. Granulation is also difficult to treat theoretically, as it is a particularly awkward problem in fluid dynamics.

While predicted spectral line shapes closely match observed line shapes, the agreement is not perfect. Where the processes giving rise to the features are well understood, the features of the line are accurately predicted. Where the features are strongly influenced by less well known factors, the agreement obtained is less close. The most important poorly known factors are damping and mass motions.

Damping is a difficult quantum mechanical and statistical problem to solve. Poor knowledge of damping has led to frequent avoidance of it, such as the use of very weak spectral lines for abundance determinations as their equivalent widths are relatively unaffected by damping. In some cases, damping can be accurately predicted, resulting in very good agreement between theory and observations.

Due to poor knowledge of photospheric mass motions, it is difficult to accurately model the profiles of spectral lines, even in the cases where the damping is known. Investigation of solar spectral lines shows that they are asymmetric. This asymmetry is small, and is usually ignored. The asymmetry of spectral lines offers an opportunity to study the processes that gives rise to it, namely photospheric motions, using readily available solar spectra.

This thesis thus consists of an investigation of photospheric mass motions and their effect on spectral line shapes and asymmetries. Knowledge of mass motions allows more accurate theoretical spectral line profiles to be calculated, with consequent improvement in results derived from comparisons between theoretical and observed spectra, such as observed damping constants and abundances. If the way the solar spectrum is influenced by mass motions is understood, mass motions on other stars can be investigated similarly. With better understanding of mass motions in the photosphere, the conditions in the photosphere, and how they are influenced by the solar interior can be better studied.

The problem of solar line asymmetries is discussed in Chapter 1: Solar Line Asymmetries. The asymmetry of lines in the solar spectrum is investigated. Past investigations of line asymmetries are discussed, and possible solutions to the problem are looked at. Asymmetries in the spectra of other stars are compared to solar lines.

Chapter 2: The Photosphere introduces the photosphere, and the overall structure thereof. The conditions within the photosphere are discussed, with emphasis on factors affecting spectral lines, such as level populations and ionisation fractions.

The basic theory of radiative transfer is presented in Chapter 3: The Formation of the Solar Spectrum, with emphasis on the formation of spectral lines in LTE (local thermodynamic equilibrium).

Chapter 4: Damping discusses damping in detail. The problem of damping is introduced, and the traditional approaches are discussed. The problems with these traditional treatments of damping are outlined, and more reliable methods, such as the Brueckner-O'Mara theory are discussed. As some damping processes will give rise to asymmetries in spectral lines, these processes are investigated. The usual treatment of such asymmetric quasi-static damping is incorrect; a correct theory is developed and presented here in order to verify that quasi-static damping does not significantly affect the asymmetry of solar spectral line profiles.

The calculation of spectral line profiles for plane-parallel LTE cases is discussed in Chapter 5: Spectral Synthesis. Most spectral synthesis is done in this manner. As spectral synthesis requires knowledge of the opacity of the photosphere, the calculation of such opacities is discussed in detail.

Granulation is discussed in Chapter 6: Granulation. Granulation is the main photospheric motion studied in this thesis, and its properties are presented here, along with the ways in which granular motions will affect the solar spectrum.

Chapter 7: Modelling Granulation investigates the structure of granules, and ways in which to feasibly model granules are studied. Both observations of granules and numerical simulation of granulation and the results which have been obtained by this means are compared to various granulation models. A simple parametric model of the photospheric granulation is developed.

Chapter 8: Synthesis of Asymmetric Spectral Lines investigates the success of using granular models to predict the asymmetry seen in solar spectral lines. Spectral synthesis using the adopted parametric granular model is discussed, and the resultant agreement between theoretical and observed spectra is investigated, and compared quantitatively with the agreement obtained using the standard model. An abundance analysis using the parametric granular model is carried out and compared to the results obtained using the standard plane-parallel model. The horizontal motions associated with the vertical motions in the disk centre model are determined, and are used to determine theoretical spectra for points away from (but close to) disk centre, which are compared to observations. Asymmetries in stellar spectra are also considered.

The Conclusion then summarises the results obtained in this work, and discusses the limits of such studies. Further extensions of this work are discussed.

Appendix A: Atomic Data - Measurement and Sources discusses the necessary data needed for accurate spectral synthesis. The availability of accurate data, and the means by which it can be obtained are discussed.

An experiment designed to obtain some of this data, namely accurate line strengths for weak lines of interest, is presented in Appendix B: An Automated Spectroscope. The design and operation of such experiments in general are discussed.

Appendix C: Data summarises the data used in this work.

