Abstract

This thesis is aimed at developing both hardware and software required for obtaining high resolution images on a regular basis from ground-based telescopes using speckle and interferometric imaging techniques. A program (speckle code) for analysing the speckle data has been developed and used to analyze speckle data obtained from a few solar telescopes.

The first Chapter provides an introduction to the thesis. It starts with an overview of human endeavors to achieve high angular resolution in telescopic observations. It should be mentioned that no serious attempt has been made to present the developments in their chronological order. Another point to be noted is that only technical developments have been highlighted but the scientific achievements that these developments have led to have not been described, basically, to conform to the spirit of the title. These technical developments provide the foundation for the explorations presented in this thesis. The thesis itself finds its place under the the category of image restoration schemes mentioned towards the end of the overview. The next few sections have been devoted to explain the adverse effects of the atmospheric seeing, the importance of phases of an object's Fourier transform, and resolution as defined in Astronomy. Questions like Why is high resolution needed in Solar Physics ?, Why should special techniques be developed for ground based observations, while space telescopes have become the order of the day ?, and Why speckle and interferometric imaging techniques alone have been addressed in this thesis ? have been answered in the next few sections.

The second Chapter is concerned with the measurement of the atmospheric coherence diameter -the so-called ‘Fried’s parameter’. This parameter severely influences the quality of the recorded image in ground based observations; the larger its value, the better is the image quality. Estimation of this parameter is essential in solar speckle imaging. A few methods of estimating this parameter and their applicability to the nature of the data have been explored in this Chapter. The details of the speckle and interferometric imaging observations and the pre-processing methods that are essential for analysing the speckle data and have been adopted in our speckle code have been presented in this Chapter. The details of the back-end instrument developed at the institute for performing speckle observations at Kodaikanal Observatory (KO) have also been described.
In the third Chapter, practical methods used in our speckle code to reconstruct an image from a series of short exposure images have been described. In our speckle code, the Fourier amplitudes of an object are estimated by Labeyrie’s speckle interferometry method and the Fourier phases of the object are estimated using Weigelt’s speckle masking technique. The reconstructed images of a few sunspot and pore regions, observed with the tunnel telescope of KO show small scale features up to the diffraction limit of the telescope. The identification of these indicates the importance of speckle observations in achieving high spatial resolution. The reconstructed images of two sub-flare regions of the NOAA AR8898, observed with the 15 cm Coude telescope of the Udaipur Solar Observatory indicate that ‘frame selection’ can be one of the ways of improving the resolution. The high redundancy in the estimated phase of the Fourier transform of the object increases the signal-to-noise ratio of the reconstructions and implies that the reconstruction from a few selected ‘good’ frames can significantly improve the quality.

The fourth Chapter is concerned with the application of speckle imaging. The speckle imaging technique described in the previous Chapters was used to analyse near-simultaneous filtergrams obtained in the G-band ($\lambda=4305$ Å) and the K line of Ca II ($\lambda=3933$ Å) at a plage region, quiet Sun region and the NOAA AR8923. As the seeing conditions were poor, a reconstruction was obtained from three best images of the sequence of recorded images of each region in the G-band and the K line of Ca II. The G-band bright points (GBPs) were extracted from the corresponding reconstructed images using image segmentation techniques. Then the morphology of the GBPs and the Ca II K network bright points were studied in each region. The prime objective of this study was to see whether this data can offer a clue on the mechanism that leads to the preferential heating at the chromospheric level (network boundaries) while the source, if assumed to be the GBPs, is distributed everywhere. We suggest the possibility of having two classes of GBPs, those present at all locations and those swept by the supergranular horizontal motions to the network boundaries. While the former are perhaps generated continuously and observed at any given time, the latter may cause the preferential heating at the Ca II K network boundaries. The intra-network GBPs could be associated with the intra-network Ca II K bright points, not resolved in the present data.
In the fifth Chapter, the basic principle of the interferometric imaging observations has been described briefly. The possibility of having two kinds of transfer functions in such observations has been indicated. A laboratory experiment performed to understand the details of ‘closure phase imaging’ has been described. A program was developed to simulate phase screens. Specklegrams and interferograms were generated from the simulated phase screens and used for simulating fringes that could be formed by bright features residing inside pores. These fringes were then compared with those obtained from real observations at KO by placing a non-redundant mask at the re-imaged pupil plane of the telescope. Such observations can be useful, at least to resolve isolated bright points. The problem of “source confusion” can be minimised by restricting the field-of-view to about an arc second.

The last Chapter provides the summary of the thesis work. The speckle code developed by the authors is compared with that developed by others and the advantages are highlighted. This is followed by a brief description of the future plans of the authors.