Study of Small Scale Processes on the Sun using High Resolution Techniques

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BY

Rohan Eugene Louis



Under the Supervision of

Professor P. Venkatakrishnan

SENIOR PROFESSOR

UDAIPUR SOLAR OBSERVATORY

PHYSICAL RESEARCH LABORATORY, UDAIPUR

MOHANLAL SUKHADIA UNIVERSITY UDAIPUR

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DECLARATION

I hereby declare that the work incorporated in the present thesis entitled "Study of Small Scale Processes on the Sun using High Resolution Techniques" is my own work and is original. This work (in part or in full) has not been submitted to any University for the award of a Degree or a Diploma.

Rohan Eugene Louis

CERTIFICATE

I feel great pleasure in certifying that the thesis entitled "Study of Small Scale Processes on the Sun using High Resolution Techniques" embodies a record of the results of investigations carried out by **Rohan Eugene Louis** under my guidance. I am satisfied with the analysis of data, interpretation of results and conclusions drawn.

He has completed the residential requirement as per rules.

I recommend the submission of thesis.

DATE:

Professor P. Venkatakrishnan

SUPERVISOR

To Mom, Dad, Julian & Mumu

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Abstract

Magnetic fields are ubiquitous on the Sun and are organized on a large range of spatial scales. The magnetic field is responsible for the solar activity and is manifest as different structures in the solar atmosphere. Sunspots, which are the largest and most conspicuous concentrations of magnetic fields on the Sun, are produced by a global dynamo that governs the 22 year periodicity of the solar magnetic field. While a sunspot is a highly stable and coherent object with typical lifetimes of the order of days, its global properties arise from the organization and evolution of the ensemble of small scale structures, which constitute a sunspot and evolve on much shorter time scales. Moreover, the interplay between convection and the orientation of magnetic fields within sunspots gives rise to different structures or processes whose diagnosis is crucial for understanding the formation, evolution and decay of sunspots. Understanding the global magnetic field on the Sun, thus requires investigation of sunspot fine structure at the highest spatial resolution. This can be facilitated through space based telescopes which can carry out observations in a 'seeing-free' environment as well as with instruments coupled to large ground based telescopes, equipped with on-line and off-line techniques to combat and correct image degradation introduced by atmospheric turbulence. The motivation of the thesis is to investigate the nature and evolution of small scale magnetic and velocity inhomogeneities in sunspot light bridges and the Evershed flow, while also assisting in developing the means to carry out such a study at high spatial resolution from Udaipur. The thesis is organized as follows.

Chapter 1 describes the physical, magnetic, thermal and dynamic properties of a sunspot which is followed by a similar description of sunspot fine structure. The importance of the small scale processes in sunspots in the context of a scalefree flux producing mechanism is established. Furthermore, the means of studying such processes from space as well as from ground is described. A brief chapterwise description of the thesis is presented.

The high resolution scientific data used extensively in the thesis comprises of filtergrams and Stokes spectra obtained from the Japanese space satellite *Hinode*. In Chapter 2, the spacecraft and the instruments are briefly described and the different data processing steps are illustrated. This chapter also details the inversion code SIR, that was employed to extract the thermal, magnetic and kinematic information from the *Hinode* spectropolarimetric data. The concept and importance of nodes while inverting actual data, is discussed.

In Chapter 3, high resolution photospheric and chromospheric filtergrams as well as spectropolarimetric observations of a set of four sunspot light bridges are utilized to investigate the association of velocity inhomogeneities in the photosphere to the chromospheric activity, if any, above light bridges. The physical properties and long term flows of the four light bridges are described and the dynamic nature of the brightness enhancements in the light bridges is presented.

Following the results of Chapter 3, the sunspot light bridge in NOAA AR 10953 was selected for a detailed investigation of its magnetic and kinematic properties and their possible role in the persistent and enhanced activity observed in the chromosphere. The rapid evolution of the photospheric magnetic field is described and the corresponding changes in the organization of velocity inhomogeneities is presented. The relationship between the photospheric magnetic and velocity sub-structures to the chromospheric phenomena is attempted. Furthermore, the impact of the evolution of the light bridge on the photometric throughput at the two heights in the solar atmosphere is established. The association of the light bridge to other structures such as penumbral filaments and umbral dots is discussed.

Chapter 5 highlights the penumbral fine structure in the context of the Evershed flow. The spatial and vertical distribution of the Evershed flow is obtained from the inversions assuming a spatially resolved magnetic structure. The existence of two distinct magnetic and thermal components in the penumbra and the presence of strong fields in the continuum layers is established. The spectral characteristics of the two penumbral components is presented. The temporal evolution of Evershed clouds and their perturbative effects on the intraspine channels is investigated. The coherence of the thermal and magnetic structure of the penumbra, over time scales much greater than that of the small scale features, is determined.

The developmental aspects of designing an Adaptive Optics system at Udaipur Solar Observatory are described in Chapter 6. A component wise study was conducted that included the estimation of the intrinsic and induced aberrations in the Deformable Mirror, determination of the influence matrix with real time correction of wave front errors induced by a second Deformable Mirror and determination of the optimal wave front sensor for the prototype Adaptive Optics system through computer simulations. The possibility of employing post-processing methods such as Phase Diversity on Adaptive Optics corrected images is also presented. First light observations with the prototype Adaptive Optics are highlighted and the improvement in image quality is discussed.

Chapter 7 presents a summary of the thesis work and conclusions drawn therein. Future scientific and instrumentation projects are briefly described.