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

A THESIS

submitted for the Award of Ph.D. degree of

MOHANLAL SUKHADIA UNIVERSITY

in the

Faculty of Science

BY

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Year of Submission : 2010

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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Acknowledgements

It is said that the success of a movie is governed by the people behind the scenes, guiding and molding the actors to achieve the perfect shot. At this juncture, it gives me tremendous joy in thanking and acknowledging all the people who helped me in realizing this thesis. I am grateful to Prof. P. Venkatakrishnan for giving me this wonderful opportunity to work at the Udaipur Solar Observatory for my doctoral thesis. I could not have asked for a better place to do my research. He was magnanimous in providing the necessary infrastructure and encouraged me to think out-of-the-box and to develop a lateral independent approach to a problem. I also appreciate his interest in allowing me to pursue instrumentation and for involving me in the Adaptive Optics project. I thank Prof. J. N. Goswami, Director, PRL, for providing me the necessary funds to travel to Spain and Japan, thereby giving me an exposure to the international Solar Physics community. I am also grateful to the Academic Committee of PRL, whose suggestions allowed me to improve my thesis and work on two additional problems.

Dr. Shibu K. Mathew has been at the helm of developing instruments and I have learnt immensely from him. He was always eager to help and provided valuable suggestions whenever I was faced with uncertainty. I appreciate his efforts for helping me at various stages of my thesis including the many light-hearted moments that we shared. His never-rest just-do-it attitude is something that I have tried to imbue in my life. I am extremely grateful to Dr. Nandita Srivastava for her kind presence and words of advice. She has been a friend who always supported me and encouraged me during my troubled times. I enjoyed working with her and thank her for her patience and her timely anecdotes. Raja Bayanna, or 'Bava' as I fondly call him, has been an inspirational friend, counselor and teacher and whatever little Optics that I know, I owe to him. I will always remember the many wonderful and delicious meals both at his home as well as outside, when the fear of offending his wife Mahima was overwhelming. I shall always cherish their pleasant company.

I would like to express my sincere gratitude to the *Hinode* team for the high resolution data without which this thesis would not have been possible. *Hinode* is a Japanese mission developed and launched by ISAS/JAXA, collaborating with NAOJ as a domestic partner and NASA and STFC (UK) as international partners. Scientific operation of the *Hinode* mission is conducted by the *Hinode* science team organized at ISAS/JAXA. This team mainly consists of scientists from institutes in the partner countries. Support for the postlaunch operation is provided by JAXA and NAOJ (Japan), STFC (UK), NASA, ESA, and NSC (Norway).

I thank Prof. Ashok Ambastha for his inputs and suggestions during my thesis. If there is one person who patiently and surprisingly tolerated me the most, it is Mr. Raju Koshy, who put up with my antics on the badminton court as well with my dumb jokes. The friendly and hospitable staff at Udaipur Solar Observatory consisting of Mr. Sudhir Gupta, Mr. Naresh Jain, Mr. Rakesh Jaroli, Mr. Pinakin Shikari, Mr. Shankarlal Paliwal, Mr. Lakshmilal Suthar, Mr. Dalchand Purohit, Mr. Ramchander Carpenter and Mr. Jagdish Chauhan provided a very homely environment. I also thank Ram Ajor Maurya, Anand Joshi and Vema Reddy for their company and assistance. I extend my appreciation to Vikram, Maulik, Manish and Niraj for helping out with the AO acquisition software. I am also grateful to Mahima, Sanjukta, Hari Ram, Ratanlal, Husna Bano, Divya Mathew, Aaditya and Kuldeep for their pleasant company. I am grateful to Mr. Mukesh Saradava for speedily fabricating opto-mechanical mounts at the USO workshop. The security staff at USO was very friendly and always greeted me with a smile even in the wee hours of the morning. I wish to thank the staff at the USO canteen for providing good, hygienic and nutritious meals that enabled me to stay fit and healthy.

I wish to thank Dr. R. Sridharan for his meticulous efforts in preparing the Kolmogorov phase screens that were useful for my thesis. I acknowledge Dr. Ravindra who was extremely helpful in providing useful tips on Local Correlation Tracking.

Dr. Luis Bellot Rubio has been a proficient and patient teacher and gave me a lot of attention during my initial stint in understanding and executing the SIR code despite his extremely busy schedule. I thank him for his valuable inputs on Stokes polarimetry and on inversion codes. Dr. Horst Balthasar was very helpful during my stay at the VTT and explained the working of TIP in great detail. I also thank Prof. Dr. Carsten Denker and Torsten Waldmann for allowing me to work on the VTT AO system. I also thank Dr. Jürgen Rendtel and Thomas Hederer for assisting me during the observations. I am grateful to Prof. Oskar von der Lühe and Prof. Rolf Schlichenmaier for giving me the opportunity to visit the VTT. I acknowledge the KAOS team for an extremely user friendly interface which allowed me to operate the AO system with great ease.

Fr. Roger Lesser has been a spiritual advisor and a personal friend who lovingly and patiently guided me ever since I came to Udaipur. He has taught me to appreciate the many wonderful things beyond the purview of Science. I am deeply honoured to have lent my assistance during the preparation and publication of two of his books. I also thank Sheena for helping me in preparing the manuscript of his book. I acknowledge all the Reverend Fathers at St. Paul's for their kind and supportive company. A special word of appreciation to Ms. Celina Joy for graciously inviting me to several wonderful trips to her home at the Trident. I would like to express my gratitude to Varun Bhaiya and Joona Bhabhi for their love, support and encouragement and for making me feel at home with their warm hospitality.

My friends Sandeep Nanda, Pradeep Shankar, Srinivas Pradeep, Immanuel Anna and Lokesh Dewangan were always supportive of my research and chipped in with motivating words and lifted my spirits when I was feeling low. I am eternally grateful to Rev. Fr. Mudiappasamy Devadoss and Rev. Fr. Stephen Kulandaiswamy for giving me the educational support that enabled me to pursue research as a career. Rev. Fr. Stanislaus, Rev. Fr. Aloysius Xavier and the late Rev. Fr. Joseph always kept me in their prayers and I am truly thankful to them. My coming to PRL would have been impossible had it not been for the love, affection and care of Catherine Akka, Rajan Anna, Kulandaiswamy Uncle and Aunty, Victor Mama, Rosey Athai, Caro Akka, Thiru Anna, Pappy Athai and Uncle, Rev. Sr. Nirmala, my most loving grandmothers - Ammachi and Appai and my late grandfather.

The excellent LaTeX class file used for preparing this thesis document is based on Harish Bhanderi's PhD/MPhil template at Cambridge University. Parts of this template have been extended and corrected by Jakob Suckale to whom I am very grateful. I would like to acknowledge the thousands of individuals who have coded for the LaTeX project for free.

My parents, my brother Julian and my wife Soumita have stood by me through thick and thin and gave me all the love, moral support and motivation to carry out my research and work towards my PhD. The innumerable sacrifices that they made for me is beyond comprehension. It is thus only fitting that I dedicate my thesis to them for believing in me and my aspirations. I also acknowledge the support of Soumita's family who helped and encouraged me. The Almighty Lord has been most gracious with His abundant blessings and I thank Him for guiding me and protecting me at every step of the way.

Rohan Eugene Louis

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 scale-free 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.