A Study of Oscillations in Solar Active Regions

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by

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Under the Supervision of

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UDAIPUR

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DECLARATION

I hereby declare that the work incorporated in the present thesis entitled ***"A Study of Oscillations in Solar Active Regions"*** *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.*

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CERTIFICATE

I feel great pleasure in certifying that the thesis entitled ***"A Study of Oscillations in Solar Active Regions"*** *embodies a record of the results of investigation carried out by* ***Mr. Ram Ajor Maurya*** *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 the rules.

I recommend the submission of thesis.

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Countersigned by
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To my parents

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Ram Ajor Maurya

Abstract

Solar active regions (ARs) are three-dimensional magnetic structures extending from deep sub-photosphere to coronal heights. These ARs are responsible for producing most of the energetic transients, such as flares and Coronal Mass Ejections (CMEs), due to a complex interplay of their magnetic and velocity fields. Therefore, accurate high spatial and temporal measurements of solar magnetic and velocity fields are essential ingredients for the understanding of the evolution and energetic activities of ARs. However, availability of these measurements is limited only to the photosphere and to some extent, to the chromosphere. The energetic charged particles released during these transients may also affect the measurements of magnetic and Doppler velocity fields. In addition, the energetic transients are expected to excite p-mode oscillations in ARs by imparting a mechanical impulse associated with their thermal expansion on the photosphere.

While studying the magnetic and velocity fields in AR NOAA 10486, we detected some puzzling moving transient features during the X17/4B and the X10/2B flares of 28 and 29 October 2003, respectively. Both these flares were extremely energetic white-light events. The transient features appeared during impulsive phases of the flares and moved with speeds ranging from 30 to 50 km s^{-1}. These features were located near the previously reported compact acoustic (Donea and Lindsey, 2005) and seismic sources (Zharkova and Zharkov, 2007). We have examined the origin of these features and their relationship with various other aspects of the flares, *viz.*, hard X-ray emission sources and flare kernels observed at different layers - *i)* photosphere (white-light continuum), *ii)* chromosphere (Hα 6563Å), *iii)* temperature minimum region (UV 1600Å), and *iv)* transition region (UV 284Å).

We have determined the characteristic properties of local oscillation modes by applying the ring diagram technique to 3-D power spectra of NOAA 10486. Strong evidence of substantial increase in mode amplitude and systematic variations in sub-surface flows are found from comparison of the pre- to the post-flare phases of the energetic X17/4B flare of 28 October 2003. Furthermore, we have found statistically significant association between the mode energy and flare energy from

the study of several ARs of Solar Cycle 23.

Our study has revealed the prevalence of strongly twisted flows in the interior of ARs having complex magnetic fields. Using the Doppler data obtained by the Global Oscillation Network Group (GONG) project for a sample of 74 ARs, we have discovered the presence of steep gradients in meridional velocity at depths ranging from 1.5 to 5 Mm in flare productive ARs. The gradients showed an interesting hemispheric trend of negative (positive) sign in the northern (southern) hemispheres.

We have discovered presence of three sheared layers in the depth range of 0–10 Mm in many flare productive ARs, providing an evidence of their complex flow structures as compared to the dormant or less productive ARs. An important inference derived from our analysis is that the location of the deepest zero vertical vorticity is correlated with the remaining lifetime of ARs. These new findings may be employed as important tool for predicting the life expectancy of an AR and space weather predictions.

Finally, we have studied the kinetic helicity in sub-photospheric flows and magnetic helicity in photospheric magnetic fields of 91 ARs of solar cycle 23. We have investigated the hemispheric trend in the kinetic helicity of sub-photospheric flows averaged over depths 2.5-12 Mm. This has been examined with magnetic helicity parameter obtained for the ARs by using photospheric vector magnetic fields. However, any significant association between the twists of sub-photospheric flows and photospheric magnetic fields is not found.