Helicity of the Solar Magnetic Field

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2009

DECLARATION

I hereby declare that the work incorporated in the present thesis entitled **"Helicity of the Solar Magnetic Field"** 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.

Date: 16 November 2009 Sanjiv Kumar Tiwari

CERTIFICATE

I feel great pleasure in certifying that the thesis entitled **"Helicity of the Solar Magnetic Field"** embodies a record of the results of investigations carried out by **Mr. Sanjiv Kumar Tiwari** under my supervision.

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 the thesis.

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To my family members

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Abstract

Magnetic helicity is a physical quantity that measures the degree of linkages and twistedness in the field lines. It is given by a volume integral over the scalar product of magnetic field **B** and its vector potential **A**. Direct computation of magnetic helicity in the solar atmosphere is not possible due to two reasons. First, we do not have the observations at different heights in the solar atmosphere to compute the volume integral. Second, the vector potential **A** is non-unique owing to gauge variance. Many researchers incorrectly inferred twist, a component of magnetic helicity, from the force-free parameter α. We clarified the physical meaning of α and its relation with the magnetic helicity. Also, a direct method is proposed for the computation of global α values of sunspots. An analytical bipole was generated to study the effect of polarimetric noise on the estimation of various magnetic parameters. We find that the effect of polarimetric noise, present in the recent vector magnetograms e.g., from *Hinode* (Solar Optical Telescope/Spectro-Polarimeter (SOT/SP)), on the magnetic parameters like α and magnetic energy, is negligible.

We examined the fine structures of local current and α in the sunspots. Local α patches of opposite signs are present in the umbra of each sunspot. The amplitude of the spatial variation of local α in the umbra is typically of the order of the global α of the sunspot. We find that the local α and current are distributed as alternately positive and negative filaments in the penumbra. The amplitude of azimuthal variation of the local α in the penumbra is approximately an order of magnitude larger than that in the umbra. The contributions of the local positive and negative currents and α in the penumbra cancel each other giving almost no contribution for their global values for whole sunspot.

We have introduced the concept of signed shear angle (SSA) for sunspots and

establish its importance for non force-free fields. The spatially averaged SSA (SASSA) gives the actual twist present in a sunspot irrespective of the force-free nature and the shape of the sunspot. We find that the sign of global α is well correlated with the SASSA of the sunspots but the magnitudes are not.

We find that there is no net current in the sunspots, although there is significant twist present in the photospheric magnetic field of the sunspots. The existence of a global twist for a sunspot even in the absence of a net current is consistent with the fibril-bundle structure of the sunspot magnetic fields. We also discovered the curly interlocking combed structure in the azimuthal component of sunspot magnetic field.

We studied the SASSA of sunspots to predict the flare activity of the associated active regions. We studied the evolution of vector magnetic fields using a large number of vector magnetograms of both, an eruptive and a non-eruptive sunspot. We arrive at a critical threshold value of the SASSA for each class of X-ray flare associated with these two sunspots. Thus, the SASSA holds promise to be very useful in predicting the probability of the occurrence of solar flares.

A good correlation is found between the sign of helicity in the sunspots at the photosphere and the chirality of the associated chromospheric and coronal features. This study will be very useful as a constraint while modeling the chromospheric and coronal features.

We find that a large number of sunspots observed in the declining phase of the solar cycle 23 follow the reverse hemispheric helicity rule. Most of the sunspots observed in the beginning of new solar cycle 24 follow the conventional hemispheric helicity rule. This indicates a long term behaviour of the helicity patterns in the solar atmosphere. However, this needs to be confirmed with the data sets spanning large number of years.