Tilt and Helicity of Solar Active Regions: theoretical mechanism and observational regularities

K. Kuzanyan; N. Kleeorin, I. Rogachevskii, D. Sokoloff, A. Tlatov, K. Tlatova

Abstract

The series of data on tilt of bipolar regions in the solar photosphere may be extended to nearly one century using Mount Wilson sunspot data for 1917-2016. The other data on bipolar groups involving magnetograms from ground-base and space-born instruments can also be used for more recent periods. The advantage of these series is its systematic properties and simplicity, and the main regularity revealed is the Joy's low indicating hemispheric bias in tilt angles.

In our studies we developed a simplest idea on the mechanism of formation of tilt connected with buoyancy of unstable magnetic flux tubes formed with the dynamo generated mean magnetic fields in the solar convection zone. During its rising phase the bipolar formations achieve some additional twist due to Coriolis force which is comparable my magnitude but for the most phases of the solar cycle is statistically opposite in sign to the original dynamo generated magnetic helicity. The interplay between these two effects determines the observed twist and helicity in the solar photosphere. Furthemore, the balance is dynamic with constant loss of helicity towards the solar corona and heliosphere with the solar wind. The latter can be estimated as the residual of the observed and theoretically calculated produced magnetic helicity. We have found that for the most of slammer bipolar groups there is no preferred bias in tilt and twist while for the larger bipolar formations it follows the hemispheric (Joy's) law. Therefore, we conclude that for the scales of larger active regions may reflect the conditions of the operation of solar dynamo while the smaller groups refer to the background fluctuation component. The proposed mechanism explains well some peculiarities of the observed variability of tilt in hemispheres with solar cycle.

Studies of Helicity Properties of Solar Vector Magnetic Field by Building Mosaic Maps

K. Kuzanyan; K. Otsuji, T. Sakurai, and N. Yokoi

Abstract

The advantage of high resolution in solar optical instrumentation is unfortunately diminished by their limited fields of view. Large active regions in the solar photosphere or even groups and clusters of smaller activity formations surrounded by plages and bright points cannot be covered by typical field of view of not only such highly precise instruments like Hinode SOT and BBSO NST but many other lower resolution telescopes. For achievement of high quality vector magnetic field data with such instruments, one may need to build a series of overlapped mosaic maps of the solar photosphere. Here we propose a method of construction such mosaics for Hinode SOT/SP large field of view raster magnetic field observations, with account of the time of data scanning and pointing procedures, as well as intrinsic variability of the solar turbulence pattern and the structure of the photospheric magnetic field. We have obtained very precise mosaic maps of longitudinal magnetic field as well as less precise (with some degrading of resolution) for transversal fields and electric currents. We compare our data with snapshots from lower resolution SDO HMI instrument. Furthermore, we study the distribution of electric current helicity in such large cumulative field of view, having resolved its spatial spectra and find some evidence of cascade of turbulent energy and helicity over it, such as known as the bottle-neck effect. The further implications of these results are yet to be investigated further. The method of building large-scale mosaic magnetograms can be used in the future at the newest high resolution instrumentation such as NST, DKIST and EST.