Measurement of the meridional flux transport in the solar photosphere

Michal Švanda[1,2], Alexander G. Kosovichev[3], Junwei Zhao[3]

[1] Astronomical Institute, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic
[2] Astronomical Institute of Academy of Sciences (v. v. i.), Ondřejov Observatory, Czech Republic
[3] W. W. Hansen Experimental Physics Laboratory, Stanford University, Palo Alto, USA

Introduction

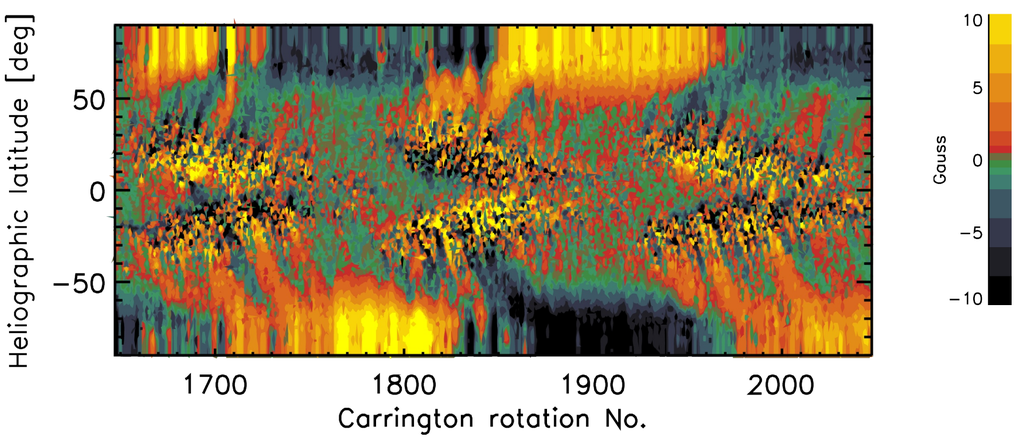
The largest-scale velocity field in the photosphere of the Sun consists of differential rotation and meridional circulation. The meridional circulation is calculated as integral of meridional component of velocity field, usually plotted over latitude. The meridional flow transports the magnetic flux towards the solar poles, taking the place in the process of recyclation of local magnetic fields to global field.

The meridional flux transport seems to be essential property influencing the length, strength and other properties of ongoing solar magnetic cycles. As the input in the flux-transport models, usually the meridional flow measured by local helioseismology is used. In this study we show that the meridional flow derived from the local helioseismology maps can be different from the direct measurement of the flux transport.

Data

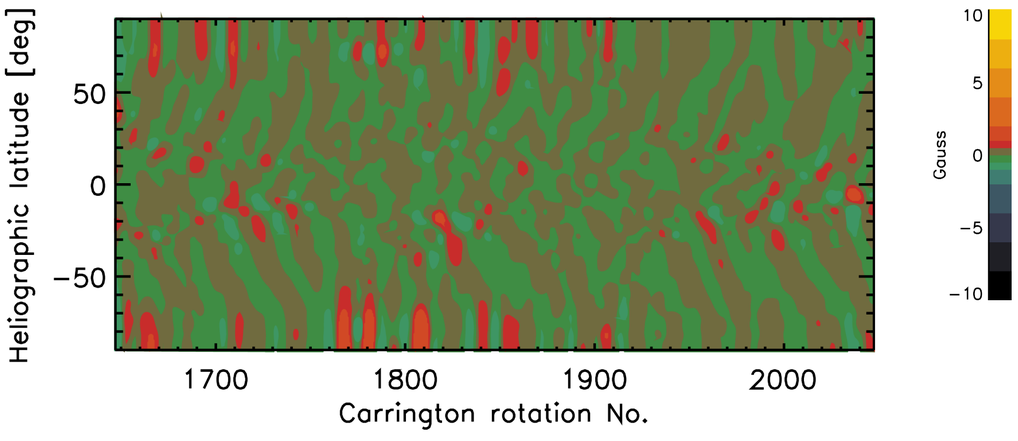
The meridional flux transportation speed is measured from the magnetic butterfly diagram, sketching the polarity of the surface magnetic field averaged over Carrington rotation in different latitudes and time. The original magnetic butterfly diagram is enhanced using unsharp-masking and magnitude compensation in order to make the “slopes” of the flux transport better detectable.

Measured magnetic butterfly diagram



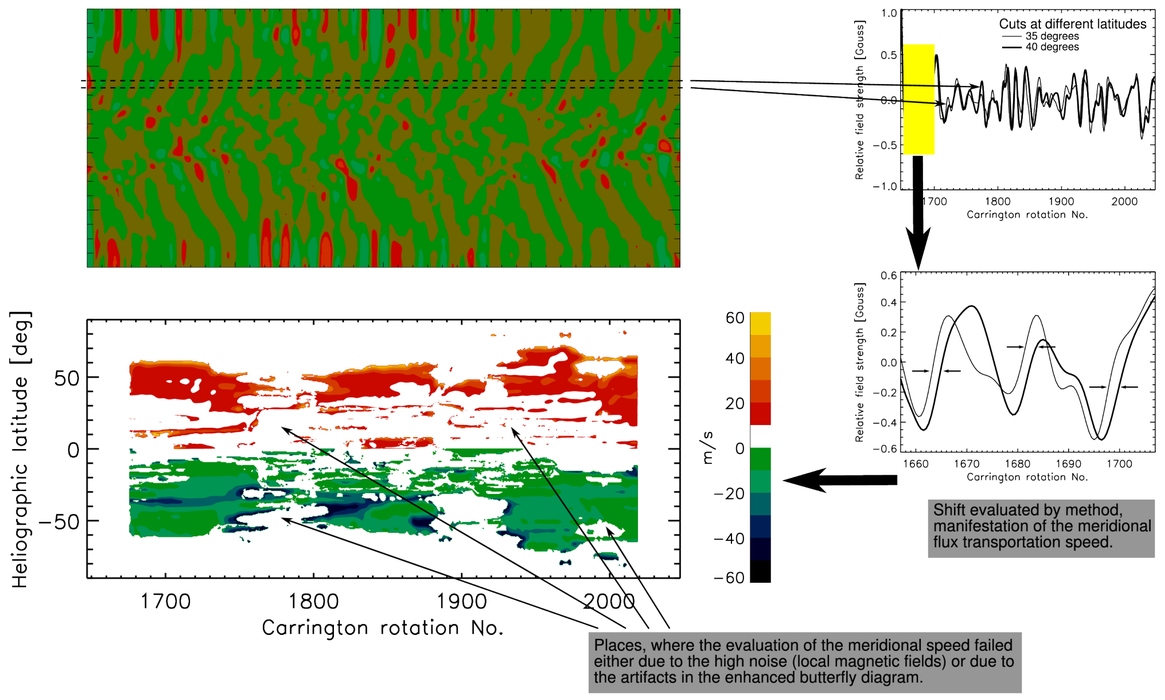
unsharp masking
+
magnitude compensation

Enhanced magnetic butterfly diagram



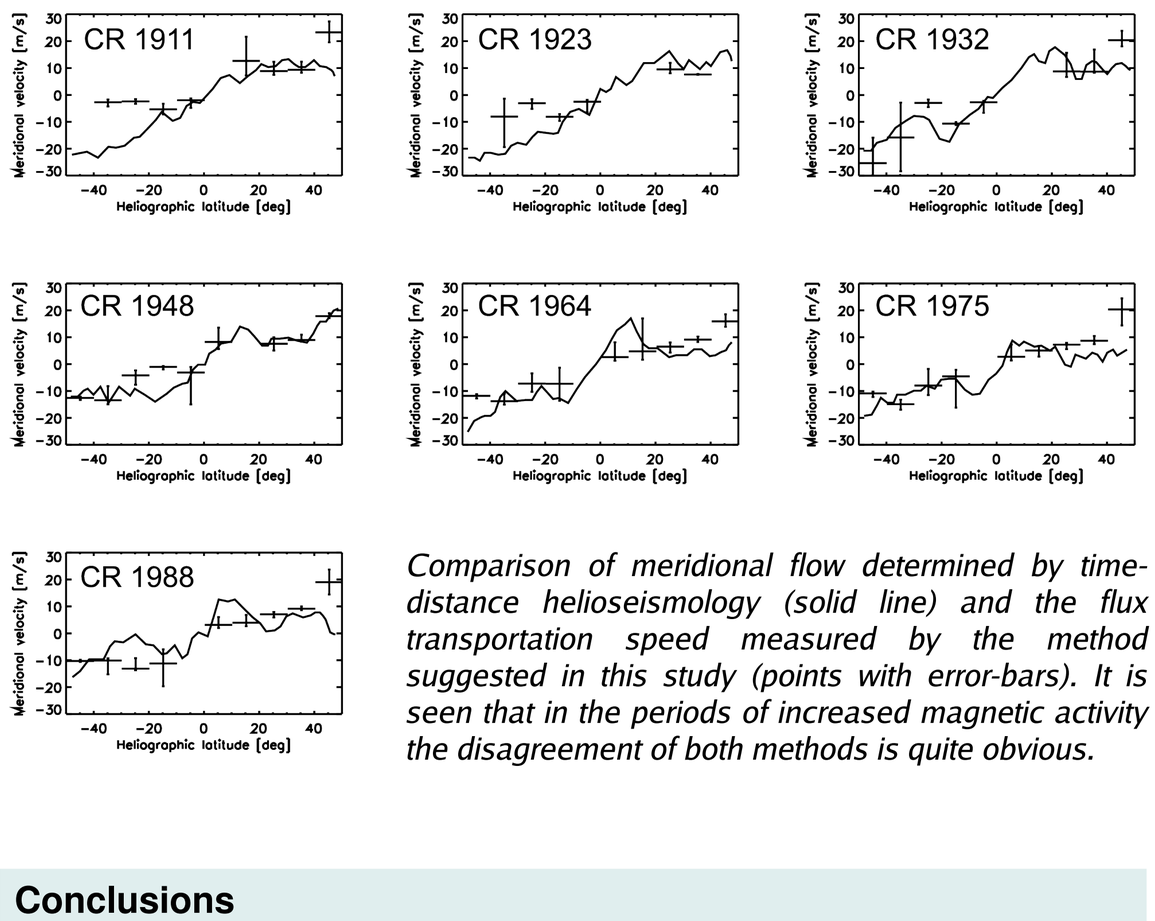
Processing method

The flux transport speed is evaluated from the detection of the slopes seen in the enhanced magnetic butterfy diagram. The displacement of the slopes position in cuts at different latitudes is determined using cross-correlation method.



Results

The measured flux transportation speed differs from the meridional flow determined from the time-distance helioseismology in regions occupied by strong local magnetic fields.



Comparison of meridional flow determined by time-distance helioseismology (solid line) and the flux transportation speed measured by the method suggested in this study (points with error-bars). It is seen that in the periods of increased magnetic activity the disagreement of both methods is quite obvious.

Conclusions

In this preliminary study we have found that it is possible to measure the flux transporation speed towards the solar poles from the magnetic butterfly diagram. Our results show that despite quite large error-bars the measured flux transport is different from the meridional flow determined by time-distance helioseismology in the areas occupied by the strong magnetic field. Therefore if in the dynamo model the time-distance meridional flow profile is used, the results of the calculations may be biased.

Next step in this study is to find the physical basics of this behaviour and estimate the influence of it on dynamo models.

5th Potsdam Thinkshop – “Meridional flow, differential rotation, solar and stellar activity”, June 24-29 2007, Potsdam, Germany