Measurement of the evolution of the magnetic field of the quiet photosphere during a solar cycle

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Abstract. The solar photosphere is filled by a magnetic field which is tangled on scales much smaller than the resolution capability of solar telescopes. This hidden magnetic field can be investigated via the Hanle effect. In 2007 we started a synoptic program to explore if the magnetic flux of the quiet photosphere varies with the solar cycle. For this purpose we applied a differential Hanle effect technique based on observations of scattering polarization in C2 molecular lines around 514.0 nm, taken generally every month. Our results now span almost one complete solar cycle.

1. Introduction

The solar photosphere is seething with a vast amount of magnetic flux tangled on scales much smaller than the resolution that can be achieved by solar telescopes. Observing techniques based on the Zeeman effect are in practice blind to such magnetic flux due to signal cancellation effects generated by mixed polarity fields present in a single resolution element. This hidden magnetism can be however investigated considering the Hanle effect observed with high precision spectropolarimetric measurements.

In 2007, when the minimum of the solar cycle was approaching, we started a synoptic program (Kleint et al. 2011, 2010) to explore possible variations with the solar cycle of this tangled magnetic flux. The observations consist in the measurement of the scattering polarization of C2 molecular lines in the spectral region around 514.0 nm in the quiet Sun. The magnetic flux is then inferred applying a differential Hanle effect technique as described by Stenflo et al. (1998).

2. The observations

The observations are generally carried out with the cadence of about one month at the Gregory-Coudé telescope in Locarno. With the ZIMPOL polarimeter (Ramelli et al. 2010; Gandorfer et al. 2004) we achieve a polarimetric resolution of the order of 10−5, thanks to a fast piezo-elastic modulator (42 kHZ) and a synchronous demodulation, done with a special dedicated CCD-camera. As a result of the fast modulation, see-
ing induced effects are avoided. The scattering polarization measurements are obtained with the spectrograph slit set parallel to the solar limb at a distance of about 5-10 arcsec from it (i.e., $\mu = \cos \theta = 0.1-0.15$) and subtends about 180 arcsec. A set of five observations is usually carried out in five heliographic positions: North Pole (N), North-West at $+45^\circ$ latitude (NW), West equator (W), South-West at $-45^\circ$ latitude (SW) and South Pole (S). Including all calibrations (polarimetric, dark, flat-field), this set of observations takes about half a day.

Since beginning of this synoptic program, several improvements were applied to the instrumentation, such as the deployment of the version III of the ZIMPOL system in 2010 (Ramelli et al. 2010) or a new silver coating of the mirrors. Thanks to them it was possible to increase the observing efficiency. A limb tracking system and other automatic systems allowed to fully automatize the observing procedure.

3. Results

An example of the linear polarization profile (Q/I) obtained in a typical observation, is shown in Figure 1. The zero level of polarization has been shifted here in order to correspond to the average polarization measured in the continuum. The four marked peaks represent the R1, R2, R3 and P spectral lines of two different C$_2$ triplets considered in this synoptic program.

![Figure 1](image_url)

Figure 1. Typical linear scattering polarization observation (Stokes Q/I) of C$_2$ spectral lines obtained near the solar limb. (This observation example has been taken on 11th January 2012 at the West limb).

The temporal evolution of the observed ratios between the Q/I signal amplitudes of different C$_2$ lines with respect to the continuum are reported in Figure 2 for the whole data set. The observing period from 2007 to 2016 includes both the minimum (2009) and the maximum (2014) of the present solar cycle. From the temporal evolution it is difficult to see significant variations.
Measurement of the evolution of the magnetic field

In order to better analyze the correlation between the solar cycle and the observed ratios through a more careful analysis we report in Figure 3 scatter plots of the measured ratios towards the smoothed International Sunspot Number (SSN)\(^1\), which is an index directly related with the amount of solar activity. In order to reduce the scattering of the points we average for each observing day the ratios obtained at the different limb positions. We report one point on the scatter plots for each day during which we obtained at least three complete observations at different limb positions. Thus the statistics include 87 observing days. The smoothing of the SSN has been obtained considering the running average over a period of 30 days.

4. Conclusion

It is not easy to appreciate long term variations of the measured ratios among the polarization signals observed in C\(_2\) lines. The available data do not show a very clear correlation with solar activity, that could lead us to think that the turbulent unresolved magnetic field strength varies with the solar cycle. A more detailed and careful interpretation and analysis of the results are in progress. The observing program will continue and provide more statistics. The data will soon cover a complete solar cycle.

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\(^1\)Source: WDC-SILSO, Royal Observatory of Belgium, Brussels
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