

Search for impact polarization in H α flares

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Abstract. Polarimetric filter observations of solar flares in H α have been carried out with ZIMPOL at IRSOL. The aim was to search for impact polarization with high polarimetric accuracy and a time resolution of a few seconds. Against expectations we could not detect polarization signatures above 0.15 % for any of the 23 flares that were observed except one with 0.4 %. However, even this 0.4 % signal is unlikely to be of solar origin. This indicates that the large majority of flares do not exhibit any impact polarization.

1. Introduction

In 1999 we decided that IRSOL (Istituto Ricerche Solari Locarno) would contribute to the RHESSI project by performing ground based observations of impact polarization in solar flares with ZIMPOL. The reasons for this choice are the unique capabilities of the ZIMPOL system when combined with the IRSOL telescope. ZIMPOL is a fast single-beam system that is free from seeing-induced polarization noise or gain-table effects and therefore allows higher polarimetric precision than alternative systems. The Gregory Coudé Telescope of IRSOL has low instrumental polarization that is independent of hour angle. Abundant observing time could be allocated to optimize the project.

Observations of H α impact polarization at the Meudon Observatory have been reported by Henoux & Chambe (1990) and Henoux et al. (1990). These observations however needed minutes of integration time to detect signals in the range of percents. Our set-up constitutes a significant improvement on this.

Solar flares are characterized by fast intensity variations that give rise to spatial and temporal intensity gradients, which can easily be the source of spurious polarization produced by image motion, too slow modulation, differential optical aberrations, and/or gain-table effects. With the ZIMPOL system these problems are eliminated, since the modulation frequency (42 kHz for circular,

84 kHz for linear polarization) is well above the characteristic seeing frequencies, and the different polarization states are recorded by the same pixels (Povel 1995).

In July and August 2002 we recorded 23 events for which the $H\alpha$ images showed significant intensity enhancements. Table 1 gives the date, time of maximum X-ray emission, and the maximum linear polarization signals seen.

Table 1. List of recorded events

Date	Time of max (UT)	max pol. (%)	Date	Time of max (UT)	max pol. (%)
July 4	10:47	0	July 4	13:28	0.05
July 4	14:57	0.03	July 5	13:32	0.1
July 7	13:03	0.05	July 11	07:12	0
July 11	ca 09:40	0.05	July 11	11:21	0.08
July 11	ca 12:00	0.06	July 11	12:08	0.05
July 11	ca 13:07	0.08	July 11	ca 15:25	0.03
July 11	14:19	0.08	July 11	14:48	0.4
July 12	10:35	0.1	July 18	07:44	0.05
July 18	11:57	0.15	July 20	10:46	0.1
July 22	ca 10:10	0.1	July 29	07:51	0.06
August 2	10:51	0.08	August 4	07:20	0
August 4	09:55	0			

2. Instrumentation and observational procedure

We used the following optical set-up, which is directly mounted on an optical bench along the hour axis at the exit of the telescope. First comes the polarization modulation package, which contains a piezoelectric modulator (PEM) and a Glan polarizer. Second comes the 0.6 \AA $H\alpha$ filter. Third, an image derotator compensates for the image rotation of the Gregory Coudé telescope. Fourth, a beam splitter allows the ZIMPOL CCD camera and the flare detector system, built by Fachhochschule (FHS) Wiesbaden, to be fed simultaneously.

The present ZIMPOL configuration (with one PEM) allows the simultaneous recording of one linear (Stokes Q) and the circular (Stokes V) polarization components. The field of view of the telescope is 200 arcsec. The image is magnified by a telecentric system to match the image scale with the CCD pixels to 1 arcsec per pixel.

The flare detection system developed at FHS Wiesbaden (Küveler et al. 2002) stores 14 8-bit intensity images per second, records the GPS time, and detects intensity enhancements.

The ZIMPOL and FHS systems use separate buffers to store data recorded in an active region in advance of the occurrence of any flare with a frame rate of one set of Stokes images I , Q/I , and V/I per second. After a specified time interval the data are overwritten. Should an $H\alpha$ enhancement be detected, the

buffered data are transferred to permanent storage, together with the subsequent data recorded during the flare event itself. Dark and calibration images were obtained before or after the flare recordings.

The use of ZIMPOL together with an $H\alpha$ filter is similar to previous ZIMPOL observations with the Universal Birefringent Filter at NSO/Sac Peak (Stenflo et al. 2002) and the night-time observations of Jupiter and Saturn with interference filters at NSO/Kitt Peak (Gisler & Schmid 2003). The flare observations were preferentially done in active regions close to the limb, where the largest impact polarization signals would be expected for geometrical reasons. The particle beams are believed to be directed in the direction normal to the solar surface on the average, and impact polarization should be maximum for transverse beams. The analyser was oriented such that the Stokes Q direction was aligned with the limb in order to have a well defined polarization basis, and because the impact polarization for symmetry reasons should be larger in Stokes Q than in Stokes U . Care was taken to set the integration time such that the CCD would not saturate during a flare. An optimum orientation of the active region on the CCD was obtained with the help of the image derotator. The automatic guiding system (Küveler et al. 1998) keeps the observed region on the sensor with a positional stability of a few arcsec. The flare detection system was set to recognize intensity enhancements above a specified threshold. If this would happen, then a signal is transmitted to the ZIMPOL system, and both systems store the data as described above.

Just before the end of several of the flare sequences a linear polarizer was briefly inserted in front of the analyser and aligned parallel and perpendicular to the limb. A tilted glass plate was also inserted on a few occasions to introduce a known small amount of linear polarization. These operations were done to verify that the instrument was working correctly and recording polarization as it should. Another test we did consisted in recording the Zeeman-effect circular polarization in active regions by tuning the filter to the line wings. The change of polarity of the V/I image and the linear polarization signals with the tilt plate confirmed the proper functioning of the system.

3. Results

As shown in Table 1 the observations were carried out in the period July – August 2002, during which 23 events were detected, although none of the flares was very large. For each event data were stored for periods of 10–30 minutes. Figure 1 illustrates one case of the 18 July 2002 flare, which had its maximum X-ray emission ($1\text{--}8\text{ \AA}$, 0.056 W/m^2) at 7:44 UT and was located at N19 W30. The top row shows the time sequence of the usual intensity images. The linear polarization (Q/I) images are given in the second row, while the third row gives the V/I images. The three bottom rows represent a continuation of the time sequence of the top rows. The displayed area has the size $120 \times 120\text{ arcsec}^2$.

This flare recording started in the last part of the impulsive phase. The system was set to produce one image each 4 s. Each image in Fig. 1 is an average of 10 such images. The time increment between successive images is therefore 40 s. For this flare the initial enhancement in $H\alpha$ was quite intense, so that several pixels were saturated during the first few minutes in spite of the

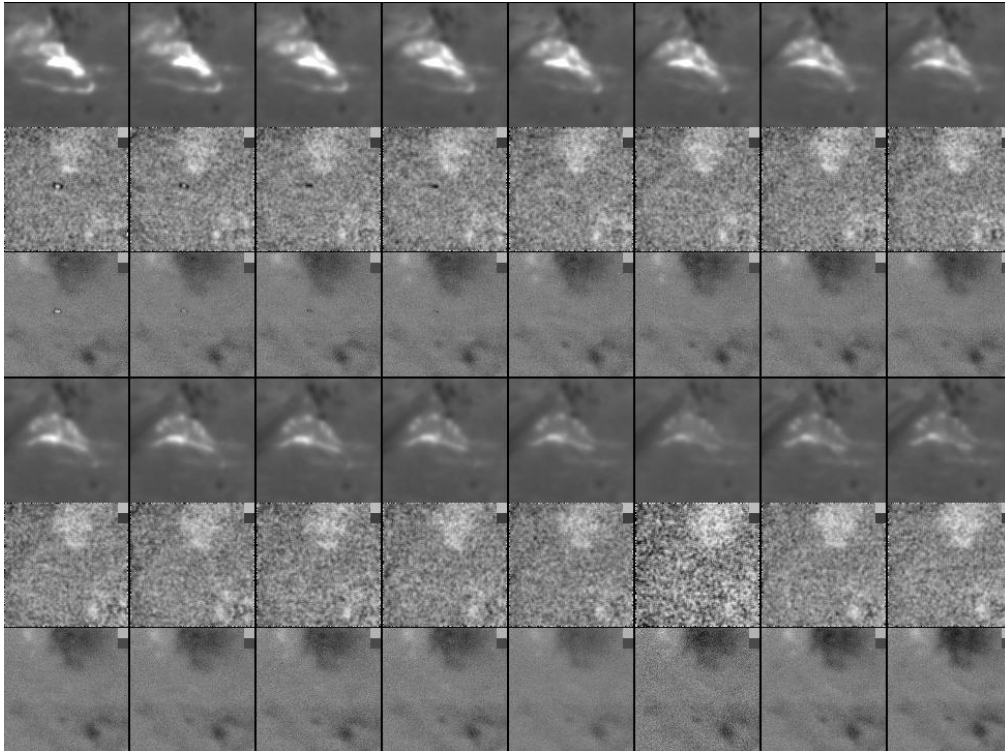


Figure 1. Flare of 18 July 2002, time sequence with 40 s between the set of intensity, Q/I , and V/I images, each having a field of view of $120 \times 120 \text{ arcsec}^2$. See text for details.

conservative choice of exposure time. In the right top corner of the Q/I images two small squares are over-plotted. The bright square corresponds to 0.1% polarization perpendicular to the limb, and the dark square to 0.1% polarization parallel to the limb. Mere visual inspection allows us to exclude the existence of strong polarizations signals for this event. In the V/I images we have similarly in the top right corner overplotted two squares, corresponding to +0.5 and -0.5%. The signals seen in V/I are due to the longitudinal Zeeman effect. The filter pass band was slightly shifted from the $H\alpha$ line center. The same features are noticed in the Q/I images (with opposite sign), and are due to telescope cross talk.

Spatial profiles are shown in the left panels of Fig. 2. The top panel gives Q/I along a row located 5 arcsec down from the top of a single Q/I image. The middle panel gives the values in the same row but after the averaging of 10 images. The third panel gives V/I in the same row for a 10 image average.

To determine the upper limit of a possible signal, we inspect the movies of the time sequences to identify the location where the largest Q/I variations seem to occur. There we place a small rectangle and determine the averaged value in the rectangular area for each image. The right panels of Fig. 2 show the resulting sequence obtained with such a rectangular area of $11 \times 11 \text{ arcsec}^2$ to the right of the brightest point, chosen to avoid the saturated pixel area. The

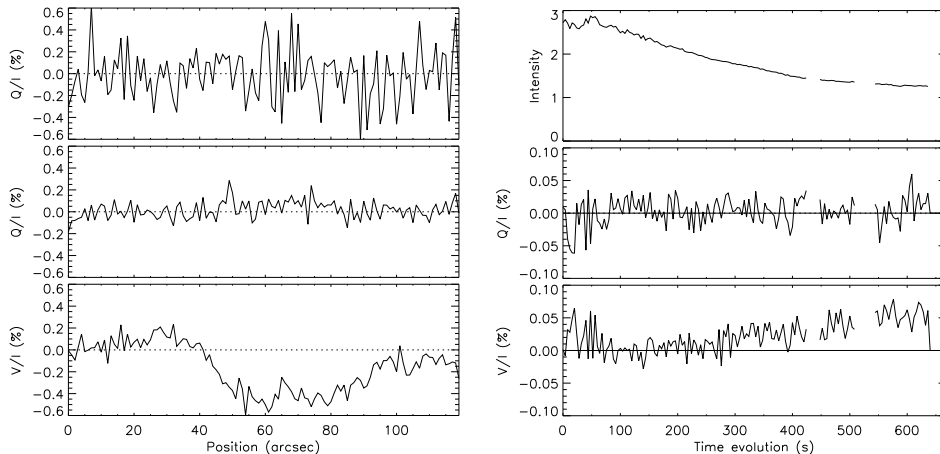


Figure 2. Left panels: Spatial profiles from single (top) and averaged frames. Right panels: Time evolution of the values averaged over a small area to the right of the brightest point. See text for details.

top panel gives the evolution of the brightness in time steps of 4 s with respect to a quiet area (data gaps are caused by calibration and by the transit of a small cloud). The evolution of the averaged Q/I and V/I values are given in the middle and bottom panels, respectively.

All the other events have been reduced in this way, and the maximum polarization values found are given in Table 1. In one event a polarization signal as large as 0.4% is found, but its spatial morphology is highly correlated with that of the intensity gradients, and the orientation of the plane of polarization is parallel to the limb instead of radial as one would expect. Problems related to the recording of the dark current are a possible explanation of the observed signal. It is therefore doubtful whether the detected signal is of solar origin.

4. Conclusion

We do not find any significant impact polarization in any of the 23 flares that we have observed, although our observing system has considerably higher sensitivity than previous instruments used to study this effect. This null result can hardly be explained in terms of observational errors, since weak polarization introduced artificially with a tilting glass plate shows that the system is capable of detecting weak signals without problems. We are therefore led to the conclusion that no impact polarization above a few promille was present in any of the flares. It should however be noted that our observations did not include any major flare event.

According to the observations of Kashapova (2003), only some but not all flares show impact polarization. On the contrary our results suggest that impact polarization must be a quite rare phenomenon. Based on our limited sample of 23 flares we however cannot conclude that impact polarization does not occur at all. To clarify this point it would be important to perform coordinated observations of the same flares with different instruments and compare the results.

References

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Discussion

SEMEL: Let us remember that polarization is not a scalar. In the Henoux observations the orientation of the polarization mainly directed to the limb is a crucial information.

KELLER: I suggest to put a quarter wave plate with its fast axis at 0° in front of the modulator to convert Stokes U to V so that you get Q and U simultaneously and therefore also the linear polarization direction.

ZHARKOVA: What makes you think that this is impact polarization? Is it not linear polarization that is more likely caused by the external radiation?

BIANDA: We do not think that anything that we see is impact polarization. On the contrary ours is a null result: the absence of impact polarization for our sample of flares.

HENOUX: The $H\alpha$ emission you observed on August 4 was coming from the top of a loop. The plasma there may be just thermal plasma coming from chromospheric evaporation and cooling down. In that case you don't expect $H\alpha$ to be polarized by impact.

GANDORFER: In polarimetry of flares one encounters very difficult challenges, which are due to the very steep intensity contrasts, in both the spatial and temporal regimes. We can clearly state that a fast single beam polarimeter like ZIMPOL is free from spurious effects down to the noise levels in the presented observations. However, slow polarization modulation will definitely be affected by (apart from seeing) infiltration of the increasing intensity during flare evolution. Therefore the detected polarization signal will be proportional to the temporal derivative of the flare intensity! On the other hand, a dual beam polarimeter will be limited by the *spatial* derivative of the intensity structures, due to differential aberrations in the two beams. The only way to get out of this dilemma is to use the beam-exchange technique.

HENOUX: Beam exchange makes the measurements of Stokes parameters dependent on image motion and flare intensity time evolution. It introduces cross talk in intensity.