

THEMIS AND DOT JOINT OBSERVATIONS ON NOAA 9716

C. Briand^(1,2), M. Collados⁽³⁾, P. Sütterlin⁽⁴⁾

⁽¹⁾ THEMIS, C/O IAC, Via Lactea, E-38205 La Laguna, Tenerife, Spain, E-Mail: cbriand@themis.iac.es

⁽²⁾ LESIA, Observatoire de Meudon, F-92195 Meudon CEDEX, France

⁽³⁾ Instituto de Astrofísica de Canarias, Via Lactea, E-38205 La Laguna, Tenerife, Spain, E-Mail: mcv@ll.iac.es

⁽⁴⁾ Sterrenkundig Instituut Utrecht, Postbus 8000, NL-3507 TA Utrecht, The Netherlands, E-mail: P.Suetterlin@astro.uu.nl

ABSTRACT/RESUME

Ephemeral magnetic emergence has been detected in a decaying β region observed in December 2001 simultaneously with the DOT and THEMIS. We present here the main characteristics of this phenomenon.

Also the time evolution of a small group of pores is shown together with the time evolution of an horizontal magnetic field overlying them.

1. INTRODUCTION

We present here results on active region NOAA 9716 observed on December 2nd, 2001 during a joint campaign between the Dutch Open Telescope (DOT) and THEMIS telescope. Both telescopes are installed on the observatory sites of the Canary Islands (Roque de los Muchachos and Izaña respectively).

THEMIS data allow to deduce the magnetic field configuration of the region while the DOT images (G-Band) furnish a very useful complement to follow the rapid time evolution of the region.

2. OBSERVING CONDITIONS

2.1 THEMIS set-up

Three spectral lines were observed simultaneously: $\lambda 630.2$ FeI, $\lambda 656.3$ H α , $\lambda 854.2$ CaII with the spectropolarimetric mode named 2x1'. Slits co-spatiality accuracy was 0.1arcsec and the slits width was 1arcsec. The polarimetric modulation sequence was: $I+Q$, $I-Q$, $I+U$, $I+V$.

A region of 60arcsec x 85arcsec was scanned in 6m30s by steps of 1". The slit was oriented Solar North. Spatial sampling on the camera was 0.5arcsec/px

2.2 DOT set-up

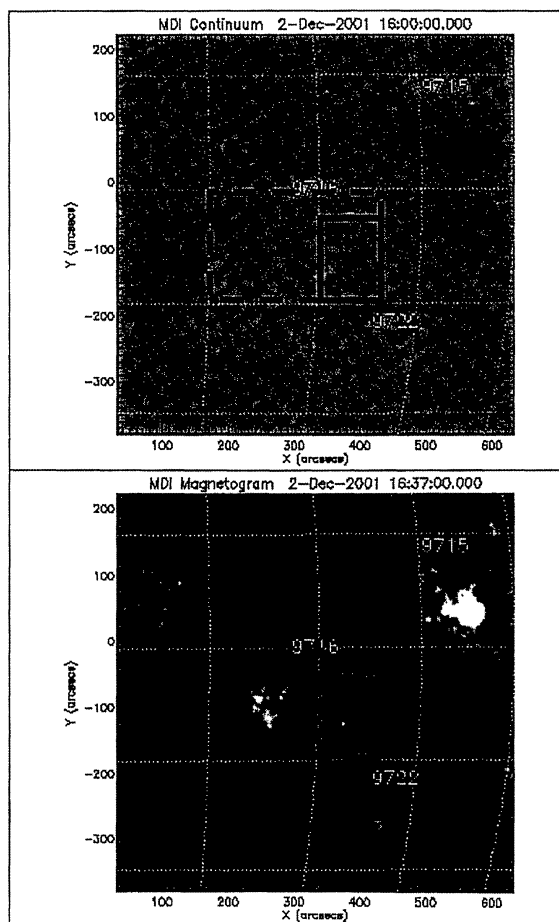
Imagery in G-Band (430.5 nm with a bandwidth of 1nm) over a field of view of 120 arcsecs. Burst of 100 images were taken (at a rate of 6 frames/sec) in order to perform speckle reconstruction.

A 10 bit camera (1296 x 1030 pixels) was used. The spatial scaling was 0.2 arcsec/px.

THEMIS observed between 9^h57^{mn} and 16^h45^{mn} (U.T.) while DOT follow the same region between 9^h35^{mn} and 11^h44^{mn} (U.T.).

3. ACTIVE REGION NOAA 9716

NOAA 9716 is a decaying β region. A small part of the complete region was observed. Figure 1 shows the selected area.



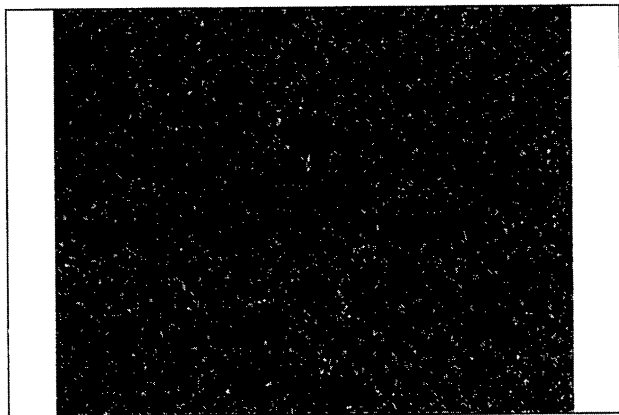


Fig. 1: Different pictures showing details of the active region observed. In each of them the full region is framed by a dot rectangle while the region scanned is framed with a full line rectangle. From top to bottom: MDI white light continuum; MDI magnetogram; G-Band DOT image (09h53 UT)

4. DATA REDUCTION

4.1 THEMIS data

The first step of the data reduction consists in "cosmetic correction". The goal of this step is to remove images defects (like dust and fringes) and dark current offset. It is based on the equation:

$$I^c = (I_r - \langle \text{Dark} \rangle) / (\langle \text{Flat} \rangle - \langle \text{Dark} \rangle)$$

where $\langle \text{Dark} \rangle$ represents the time average of individual dark images and $\langle \text{Flat} \rangle$ the mean average of the individual flat images. Flat images deserve a specific treatment in order to remove the spectral information still present (that is the line profiles). The flat correction to be applied on the data is obtained by dividing each row of the mean flat field image by the mean profile deduce from the mean flat image itself.

A demodulation matrix is applied to the data corrected for "cosmetic defects" to deduce the four Stokes parameters and correct for cross-talk between them. Seeing induced cross-talk is still not corrected after demodulation. However, the demodulation gives two images with opposite polarity but the same seeing effect. Subtraction of the two images allows to remove the seeing induced cross-talk. An example of final spectra is presented in Figure 2, and Stokes profiles are presented in Fig. 3.

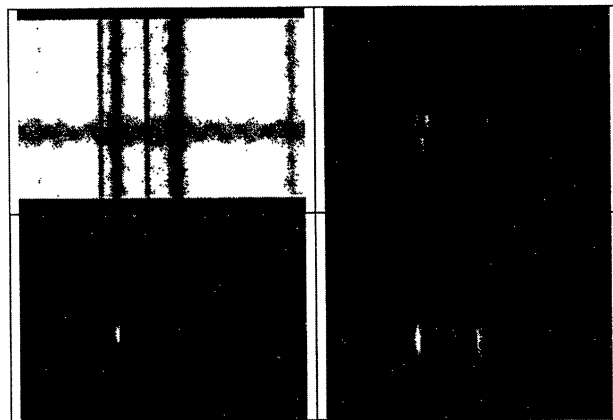


Fig. 2: Example of $\lambda 630.2$ spectra obtained after the full reduction. Accuracy of the measurement is $S/I_c = 10^{-3}$ with S being Q, U or V

4.2 DOT data

DOT images were submitted to speckle reconstruction. It consists in three main correction: 1) speckle masking (sampling the seeing, atmospheric model and correction by the theoretical telescope MTR); 2) Interference filtering; 3) Geometrical correction. For more details see [3].

4.3 Spectro-polarimetric data inversion

Polarimetric data were inverted with the code SIR [2]. For the inversion process, two atmospheric components are included: a magnetic one based on the HSRA atmospheric model [1] at which a magnetic field of 3000 Gauss has been added and a non magnetic "Quiet Sun" component to take into account diffused light (coming from terrestrial atmosphere or instrument) which is represented by the model atmosphere which best reproduced the average quiet Sun spectrum in our map. During the fitting process, the atmospheres have the following free parameters:

1. Magnetic component

- **B** (Inclination, Strength, Azimuth, Filling factor) but constant at all heights
- Macroturbulent and microturbulent velocities constant at all heights
- Height varying velocity and temperature

2. Quiet Sun component

- V_{qs} constant at all heights
- Filling factor free

In other words, the Stokes parameters are obtained through the following equation:

$$I = \alpha I^M + (1-\alpha) I^{QS}$$

where I^M stands for the intensity coming from the magnetic atmosphere, I^{QS} the one coming from the

Quiet Sun and α is a free parameter that represents the degree of combination between the two atmospheres for each given point of the map. Typically, $\alpha = 0.15$ in Quiet Sun region, $\alpha = 0.80$ in main spot.

The Reference coordinate system is relative to the observer. In the following maps, $\gamma = 0$ means a magnetic field directed towards the observer. The 180° ambiguity of the magnetic field azimuth is not resolved yet.

Only spectra for which $\max(Q/I_c)$ or $\max(U/I_c)$ or $\max(V/I_c) > 8.10^{-3}$ are inverted. This gives a limit for the magnetic field detection of $B_{\min} = 400$ Gauss. In the following maps, only points for which B is not equal to zero are meaningful, that is $\gamma = 0$ is a relevant value only if $B \neq 0$.

Figure 3 shows a comparison between observed and inverted profiles.

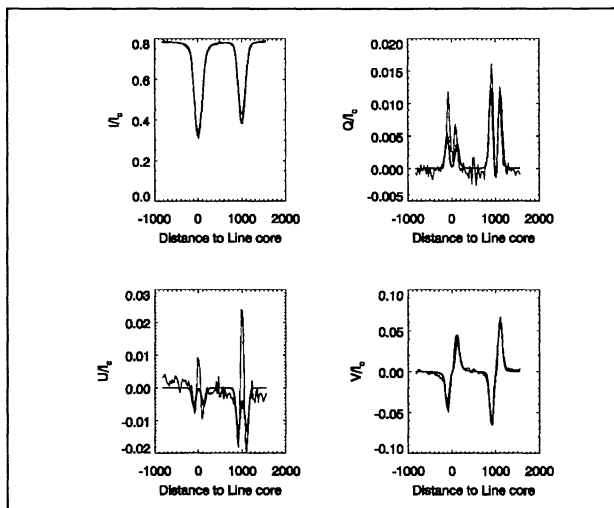


Fig. 3: Comparison between observed (thin lines) and inverted (thick line) Stokes profiles of $\lambda 630.2$ FeI. Note that the scale is different on each profile.

5. DATA ANALYSIS

5.1 Global morphology and general time evolution

The region is composed of two principal magnetic zones: a main pore (zone A) of magnetic intensity 2100 Gauss, and a magnetic region with small pore (zone B) with magnetic field intensity of 2000 Gauss, but opposite polarity compare to the main pore. An almost horizontal magnetic field is detected over the pores of zone B connecting the region of vertical but opposite magnetic field.

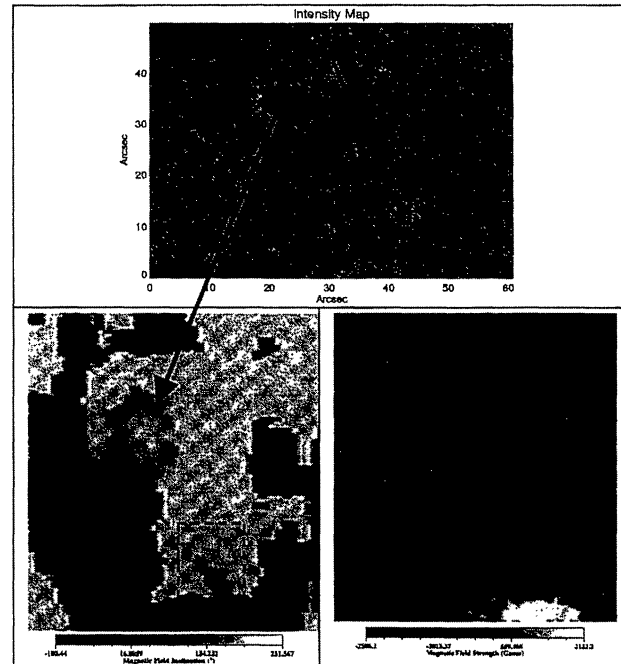


Fig. 4: Top: Intensity map obtained from the DOT; Bottom left: Magnetic field inclination; Bottom Right: Magnetic field intensity in the observer frame

Zone A doesn't exhibit any drastic changes all over the day, but bright points are recurrently noticed at the edge of the main pore. Zone B presents more evolution: the three small pores of the top part of the area disappeared and the small pore of the bottom part concentrate in a more regular form, without change in the total magnetic flux. It must be mentioned that a quite strong activity is present at chromospheric level over the zone B during all day.

The almost horizontal magnetic field present in the zone B seems to mimic the time evolution of the magnetic structures of this area. However, it is not clear if this horizontal magnetic field is related to the pores of region B or to the ephemeral magnetic field (see sect. 5.2). Detailed analysis of the spectropolarimetric data obtained in the afternoon should give us some answers about this important question.

5.2 Ephemeral emergence of magnetic field

Magnetic field time evolution shows the emergence of a small (5arcsecs) magnetic area of magnetic field oriented along the line of sight (the 400 Gauss detection limit can also explain the absence of horizontal field). The lifetime is 1 hour. No signature in G-Band (see Fig. 5) has been detected. These magnetic region reaches a maximum intensity of 1300 G.

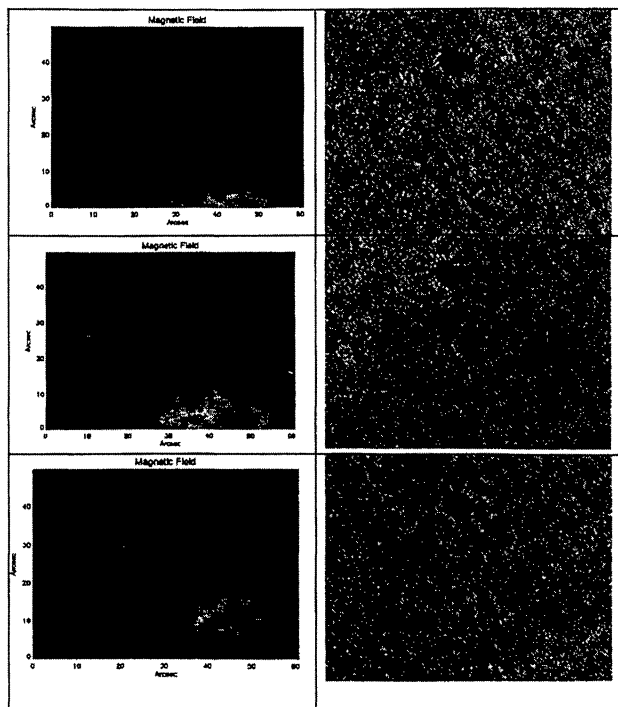


Fig 5: Left column: magnetic field intensity at 10h53, 11^h17^m and 11^h47^m. Yellow means towards the observer, blue means away from the observer, in red the region without inversion (compare also with Fig. 4). The black arrow indicates the zone of emergence of magnetic field mentioned in the text; Right column: G-Band images at the same time.

No specific feature are seen in the velocity maps deduced from the inversion. However, the temperature is much higher at $\tau_{500} = 1$ (8000K) in this peculiar feature compared to the other magnetic region (4000K) and even the surrounding region (6000K) - see Fig. 6.

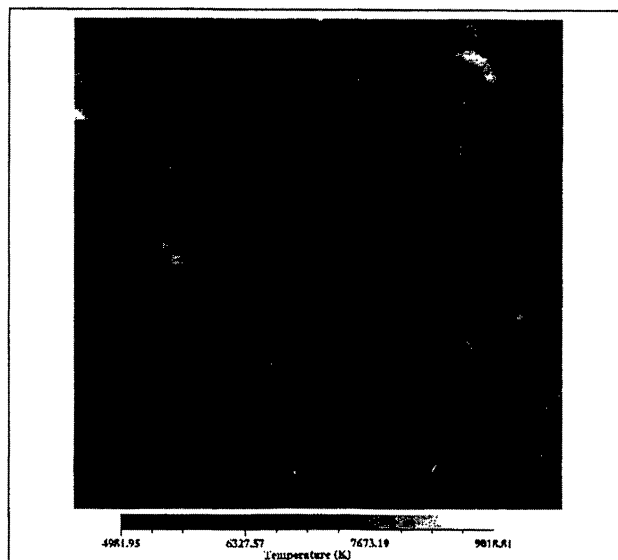


Fig. 6: Temperature map at $\tau_{500} = 1$ at 11^h11^m (UT) (i.e. at the maximum of the magnetic emergence). The

black arrow indicates the location of the ephemeral magnetic emergence. Temperature there is 8000 K.

6. CONCLUSIONS

We have presented here the first results concerning observations of a part of the active region NOA 9716 performed in December 2001 obtained during a joint campaign between the DOT and THEMIS telescopes. First we stress the very good complement of the two kinds of observation: high quality, large field of view images from the DOT and accurate multi-line polarimetric measurements with THEMIS. The data allow us to see very curious features in the decaying β region we were observing:

- The time evolution of a small group of pores: cancellation of some of them and concentration of others, chromospheric activity over this region
- The presence of an ephemeral magnetic field emergence: lifetime 1 hour, magnetic field along the line of sight

The magnetic field detection limit is 400 Gauss mainly due to the constraint to invert the four Stokes parameters simultaneously. New observational strategy must be found to increase the signal to noise ratio without loss of spatial and temporal resolution.

Also, new inversions with more free parameters will be performed especially to improve the fit quality between observed and inverted profiles. The 180° azimuth ambiguity must also be solved.

7. REFERENCES

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2. Ruiz Cobo, B., Del Toro Iniesta, J.C., 1992, *ApJ*, 398, 375
3. Sütterlin P., 2001, *A&A*, 374, L21-24