THEMIS: ITS CAPABILITIES AND KEY PROGRAMS

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ABSTRACT

THEMIS (Télescope Héliographique pour l’Etude du Magnétisme et des Instabilités de l’Atmosphère Solaire) is a french-italian, polarization-free telescope designed to obtain an accurate measurement of the vector magnetic field by Zeeman effect. It will be in operation in 1996 in Tenerife (Spain). Five basic modes of observation will be available: 1D spectroscopy, 2D spectroscopy (MSDP), Full Disk, high spectral resolution filter (UBFFP), images in wide spectral bands.

The key programs are listed as following: (i) Small scale structures and concentrated field (first priority), (ii) Instabilities and evolution of active region, (iii) Anisotropies, (iii) Systematic magnetograms. The fourth program will be a good support of SOHO, the second one will be a component of coordinated campaigns. Specific programs pointing out the interest of Themis + SOHO observations will be presented.

Keywords: solar physics, magnetograph.

1. Themis Organization

Themis is built by the Italy CNR and the France CNRS-INSU which have created a Joint Commission. The Project Engineering Group is directly related to this Commission.

Engineering Group

Scientific Responsibility: Caccin B.,
Landi E., Mein P., Rayrole
Technical Responsibility: Tournai A.
and Fasulo A.

Scientific Direction Chief Managers of the french component: Rayrole J., Mein P.

SCHEDULE

The Themis tower has begun to be built in May 1993. Italy will provide the dome. In Orsay optical and thermal tests are made through the summer 1994, using a polar siderostat. The instrument will be transported on the site (in April 1995) and will receive the first light by the end 1995. Themis is planned to be in operation in 1996.

The Themis data acquisition system has been completely changed in 1993 (VMS to UNIX). The new configuration is based on an ETHERNET network with a SUN spark 10 computer, a VME bus (see the scheme in Fig. 1). The acquisition allows to get 2.5 Mo/s. Using data storage 3.5 Mo/s may be possible.

WORKING GROUPS

WG 1 data processing
(Malherbe J.M.)

WG 2 First Observations
Leroy J.M. and Mein P.

WG 3 Radiative Transfer
Frisch H. and Mein N.

WG 4 Atomic Physics
Sahal S.

WG 5 MHD and extrapolation codes
Aly J.J. and Semel M.

WG 6 Stellar Observations
Foing B.

WG 7 Coordinated campaign of observations
Trottet G. and Vial J.C.

WG 8 Second Generation of Instruments
Müller R.

The chief managers of these 8 groups form the Scientific Committee of Themis with Baglin A. the responsible and Mein N. the editor of the Themis letter.

WORKSHOPS

Six workshops have been organized in France for French and Italian (the fifth only) Solar Physicists. The number of participants was between 16 to 50.

1 and 2 Radiative Transfer dec 1987 and February 1989
3 Polarization in Spectral line April 1990 (Lectures of Landi)
4 Plasma Physics May 1990
5 Magnetic Field Determination Methods January 1992
6 Magnetism in the Sun and the Stars May 1993

2. Themis Optical Scheme

Themis is a french-italian polarization-free telescope. It is a Ritchey Chretien telescope supported by an azimuthal mount. It is evacuated and closed by two windows. The entrance window L is made in BK7 and \( \phi = 1.1 \text{ m} \) (Fig. 2). Thermal gradient at the edge is controled by water circulation. The telescope consists of M1 (\( \phi = 0.9 \text{ m} \)) and M2 refrigerated by water circulation too. To avoid the effects of bad seeing (image motions) we will measure the 2 states


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of polarisation simultaneously. This may be achieved by a double beam setup or by high frequency modulator of the polarization (e.g. LEST). We have chosen the first solution. The polarizer is performed by the use of a quarter wave plate followed by a polarizing beam splitter (two cross calcite blocks). It will work in the 4500-10000 Å spectral range (the He line will be possible by changing the analyser) and will be quasi-aichromatic. It is mounted at the primary focus on a rotating wheel. The entrance beam will be split in two beams of different polarisations. The transfer optics includes a concave mirror M3, a 45° mirror and the tilting mirror which makes the correction of high frequencies motions, by taking into account the granulation tracker placed in F2. The principle used for the tracker is based on Fourier transforms (cross-correlation functions in 2 perpendicular directions).

The spectrographs are hanging vertically. The predisperser has 3 exchangeable gratings, one of them is an echelle grating which is used within the MSDP mode. The second spectrograph has also an echelle grating with a blaze angle = 63°26, and f/8. M in the focus is placed 20 CCD cameras 288x384 arrays. Two are already operating. More details are presented in Mein and Rayrole (1989). A special 1 D camera will be used for full disk observations.

3. Observing modes

The high spatial resolution of the instrument allows to observe with a pixel size as small as 0.16" (1" = 286 μ in the spectra). Different modes of observations will be proposed: SP spectra, MSDP Multichannel Subtractive Double Pass, FD full disk, UBFP Universal Birefringent Filter and Fabry-Perot, WL white light (see Table 1).

1. 1 D Spectroscopic SP

10 line observation is a winning card in the diagnostics of the magnetic field. By choosing a good sample of lines sensitive in different physical parameters (temperature, density, pressure) we could better interprete line profiles and determine with good accuracy the transverse magnetic field (Mein and Rayrole 1989). (TBD)

The expected accuracy is : B∥ = 5 G and B⊥ = 100 G. We may resolve subarcsecond spatial structure with a polarization signal of more than 10 % of the intensity and 1% noise level. On the other hand to to observe the Hanle effect we may prefer to reduce the noise to the level of 10⁻⁶ of the intensity, therefore choose long exposure time and accepted a resolution of the arc sec.

2. 2 D Spectroscopic MSDP

The MSDP (Multichannel Subtractive Double Pass) technique is already used in Meudon, at Pic du Midi, on the VTT in Tenerife and on the Wroclaw coronograph. In Themis optics the beams will not pass twice on the same grating because there are 2 spectrographs then the scattering light will be considerably reduced. The entrance window is 120°×10°. The 2 beams coming from the beam splitter (Mein 1989) will be used to increase the spectral resolution. 28 and 32 channels in 2 polarisations will be produced for 2 lines. After reconstruction of line profiles by computation, longitudinal magnetic field and perhaps transverse one, intensity and dopplershifts, in a 2 D array of the Sun will be accessible (Mein and Rayrole 1993).

3. Full Disk FD

The beams I+V and I-V are shifted by the analyser in the direction of the dispersion. Semel (1994) has
shown that the displacement difference between the profiles observed in opposite polarisations is proportional to the longitudinal magnetic field. We use the center of gravity to determine the position of the profile. By means of subtractive/additive spectroscopy using the 2 beams we obtain simultaneously the magnetic field/velocity field in the considered line (Na I for example) with a slit of 4' long. The full disk is covered by 10 overlapping strips in 25 minutes with a resolution of 0.5"/pixel. The scanning is obtained by diurnal motion (telescope stopped). Ion images are also available simultaneously. The software has begun to be developed yet.

4. UBFPP

The Universal Birefringent Filter and Fabry-Pérot, narrow band filter is built by the Italians in Arcetri and has the expected capabilities shown in Table 1. The detector is a CCD 1024 x 1024. It has the advantage to have a very high spatial resolution (0.08 arcsec) for monochromatic images, high scanning speed large field of view (50 arcsec) (Landi et al. 1993, Rayrole et al. 1994).

5. WL

The images in wide spectral bands will have a very high spatial and temporal resolution with a possibility of selection on-line.

<table>
<thead>
<tr>
<th>Table 1: Characteristics of the different observing modes</th>
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<tbody>
<tr>
<td>SP</td>
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<tr>
<td>---</td>
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<tr>
<td>N (simultaneous lines)</td>
</tr>
<tr>
<td><strong>Pixel 0.16 arcsec</strong></td>
</tr>
<tr>
<td>Spectr. res. at 5500Å (Å)</td>
</tr>
<tr>
<td>field of view (arcsec)</td>
</tr>
<tr>
<td>Spectral range / line (Å)</td>
</tr>
<tr>
<td>Scanning:</td>
</tr>
<tr>
<td>Time/arcmin² (s)</td>
</tr>
<tr>
<td>- full storage of pixels</td>
</tr>
<tr>
<td>- processing on-line</td>
</tr>
<tr>
<td><strong>Pixel 0.32 arcsec</strong></td>
</tr>
<tr>
<td>Spectr. res. at 5500Å (Å)</td>
</tr>
<tr>
<td>field of view (arcsec)</td>
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<tr>
<td>Spectral range / line (Å)</td>
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<td>- full storage of pixels</td>
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<td>- processing on-line</td>
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**FD**

<table>
<thead>
<tr>
<th>N lines</th>
<th>1 (+Hα)</th>
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<tbody>
<tr>
<td>Pixel 0.5 arcsec</td>
<td></td>
</tr>
<tr>
<td>field of view</td>
<td>240 arcsec</td>
</tr>
<tr>
<td>Scanning</td>
<td>1</td>
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<tr>
<td>Time/arcmin² (s)</td>
<td></td>
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</table>

**UBFPP**

| Pixel size | 0.08 arcsec |
| Spectral resolution at 5500Å | 0.021 Å |
| Field (diameter) | 50 arcsec |
| Useful wavelength range | 4600/6800 Å |
| Typical wavelength drift | 1 m/s/hour |
| Wavelength stability | ±1 m/s rms |
| Spectral homogeneity of the field | 10 m/s |

4. The Magnetic Field in the Solar Atmosphere

It is well accepted that the magnetic field strongly structures the solar atmosphere and controls all the solar activity. At low levels of the atmosphere (photosphere) the density of the plasma is high and convection motion is responsible of the observed pattern with concentration of magnetic field lines at the boundaries of the convection structures (granules, supergranules). The field lines are footpoints of small or large coronal loops. The convection motions induce deformations of the field lines with reconnection and disruption of the lines. This produces plasma instabilities, like flares, eruptions of filaments, CME, bright points and heating. Some of these phenomena are well displayed on coronal Yohkoh/SXT images (T ~ 2 x 10⁷ K).

Magnetographs provide the magnetic field value in cold plasma in the photosphere and the low chromosphere using the Zeeman effect when the thermal broadening of the lines are not too large and in prominences using the Hanle effect. By techniques of extrapolation assuming different hypothesis, coronal magnetic field can be obtained. Different problems have to be resolved to obtain the three components of B by using the Zeeman effect:

1. calibration
2. noise
3. ambiguity of 180 degrees

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THEMIS will provide a good calibration and will increase the ratio signal/noise because of its quality of being a polarization-free telescope and by the use of spectra of multi-lines.

The measurement of the coronal magnetic field can not be achieved directly except by using some other possibilities: radio or Hanle effect. Different methods exist to extrapolate magnetic field with advantages and disadvantages. First of all I want to mention the two different categories of extrapolation techniques according to the scale of the phenomenon: one is relevant of large scale structures, the other one is for small scale structures. In the large scale structures the magnetic field is supposed to be vertical, the currents are horizontal. Methods like this of Zhao and Hoeksema (1984) are relevant for streamers, plumes, solar wind. Themis will not be really useful to derive physical quantities in this frame. For the small scale which can be extended from 5 Mm (bright points) to 500 Mm (prominences), flare typical scale is around 50 Mm. Themis could provide the 4 Stokes parameters with a good accuracy. Different techniques of extrapolation can be used to get the coronal magnetic field. Some are rapid like the method based on the potential configuration (Green, Fouquet) but are not really relevant to study flares. The occurrence of flares are mainly due to electric currents which in the potential configuration are supposed to be minimum. Some methods are solving completely MHD equations but it is time consuming and work only with simple topology (Mikic et al.).

More generally we will be able to derive the magnetic topology in the atmosphere which supports the plasma, the magnetic energy storage which leads to instabilities. Coordinated observations with GB instruments and SOHO will provide the physical conditions of the plasma at different temperatures.

5. Key Programs

THEMIS key programs can be listed as following:

1. Convection and turbulence at small scale, concentrated field and propagation of waves (first priority)
   The high spatial resolution obtained with the active optics, the evacuated telescope and the good seeing are important points for this study. This program will require all the capabilities of the instrument with the use of 10 lines to derive the 3 components of B. The study of the physics of flux tubes and of sub-arcsecond structures is one of the main objective of scientists of Meudon and Bagneres.
   In these programs some scientists have already proposed some coordinated studies with SOHO oriented mainly to the study of the turbulence of the plasma and of the coronal heating (groups of IAS, ESTEC, Florence).

2. Instabilities and evolution of active region
   The conditions of flaring require the measurement of the 3 components and the extrapolation of B. The mode S is certainly the best one but for having accurate measurements of the entire phenomena versus time, the other modes MSDP, UB, BF will be nevertheless useful for fast viewing. In these latter cases only the longitudinal magnetic field will be derived.
   This program is devoted to study:

   • Exchange of energy in active region (T, V, B)
   • Flares, ejections and instabilities
   • Extrapolation of coronal magnetic field
   Many people of Meudon, ESTEC, IAS, OMP are interested in these programs. Some have already mentioned their willing to participate to coordinated campaigns.

3. Anisotropies
   In this program we can mention on the one hand the study of the weak magnetic field by Hanle effect requiring the treatment of 3 D radiative transfer of polarized radiation, and on the other hand the study of particle beams in flares.
   The measurement of the linear polarization can be done because the high quality of the Cassgrain telescope. However the sensitivity obtained with the first generation (10^-11) analyser seems not to be sufficient to allow such programs requested by the french community (DAMAP, IAS, OCA, OMP and few scientists of DASOP) and ESTEC. New instrumentations will be developed to obtain an accuracy of 10^-13.

4. Systematic magnetograms.
   These programs are good support for SOHO and coordinated campaigns. They benefit the speed of the mode FD. During the SOHO mission, a big effort will be done to obtain full disk magnetic maps (one component only). It will naturally depend on the program of the chief observer and on the quality of the seeing. If he gets time for program (1), magnetograms may be not done if the seeing has a high quality.
   Hopefully many people from DASOP, Bordeaux, ESTEC, IAP, IAS, OMP, Naples are interested for systematic magnetograms.

6. Some Specific programs for campaigns

6.1 Eruption of prominence
   A filament could be observed during its disk passage and its anchorage points well defined in the photosphere (THEMIS or GB observations). The destabilisation of a filament may be due to an emerging flux or other factors. The detection of the causes by THEMIS will be possible due to its high spatial resolution. The eruption could be observed by SOHO instruments. The heating of the plasma and its dynamics eruption could be quantified. If the event occurs near the limb, the coronagraphs could follow the arcade formed over and the magnetic field line evolution in the corona could be checked. CME could be detected.

6.2 Ejection of cool and hot plasma
   Emerging flux could lead to cool plasma ejection (Hα surge). Up to now two different classes of models exist, either the pressure gradient model- the plasma is ejected by a piston- or magnetic models with spring or release of magnetic energy. In the first one we expect a full loop of hot plasma, in the second class some reconnection process could favour some release of magnetic energy. Even in these latter models we could expect some heating of plasma at coronal or transition zone temperature. The simulation predicts the association of cool material (surges) with hot jets. The lack of observed jets associated to surges by Yohkoh may be due to its sensitivity limit for T and ρ. We could hope that with SOHO this discrepancy may be resolved.

6.3 Flares and electric currents
   The energy of flares comes from magnetic field. Twisting the magnetic field lines through the mass motions in the photosphere will produce electric currents and store...
the energy in the corona. The reconnection of opposite magnetic field lines releases the energy which accelerates particles and through different ways goes down to the low atmosphere and gives rise to chromospheric flares. Using observed magnetic field we could study the 3D topology of the field in AR. Combined with other instrumentation (SOHO), we can study the physical conditions of the plasma at the reconnection site, the current system.

Themis will resolve the problem of concentrated current in AR. SOHO will be of great interest for studying the energy transport through the atmosphere and for knowing which model is valid for flares.

7. Conclusion

THEMIS will have an international status. The observing time will be shared by a committee as following:

- 20% Spain
- 5% international time
- 75% for France (80%) and Italy (20%)

Through 1995 a data base center (CADOC) may be organized for french GB storage data (including future Themis data) at the OPMT (Bagnères de Bigorre) with possible interactions with Space Data Base Centers.

References


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