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We shall report on the scientific advances in Solar Physics in France in the past two years: 2002, 2003. The french Solar community (100 scientists) belongs to a National Programme on Solar Terrestrial relationship (PNST) and is largely split in different laboratories and Observatories. We do not propose an exhaustive report but report on specific groups working with THEMIS, Nançay instruments, RHESSI and SOHO/MEDOC. We report only on the French part of the activity of these instruments or missions. Next year we should report on other activities, i.e. the new polarimeter at Pic du Midi and long term solar activity.

1 THEMIS

The french part of the THEMIS observations concern mainly two modes using the long spectrographs: MTR (multi-line slit-spectroscopy) and MSDP (imaging spectroscopy). The french groups were involved in 10 of the 22 observations selected for the 2003 THEMIS campaign. The telescope was close for observations in August for repairing and painting the coupola. The THEMIS telescope has been open to observers since 1998, and the observing campaigns started on a regular schedule since 1999. Since then, 25 refereed publications directly resulted from THEMIS data obtained up to 2002, equally distributed over the three instruments: 6 papers and 3 letters for the MTR, 7 papers and 1 letter for the MSDP and 5 papers and 3 letters for the IPM. The results of the 2003 campaign are very encouraging but are not yet studied. On October 1 2003 a new director of THEMIS was appointed : Bernard Gelly.

We shall review briefly some results relevant to the main THEMIS performances:

- high accuracy polarimetry, spatial resolution,
- number of lines and/or stratification of the solar atmosphere,
- fast events in sunspots and ground-space coordinated campaigns.

We shall mention some advances in data base and software developments. No decisions are taken yet about adaptive optics or tilt tip.In 2003 til-tip development has been studied.

1.1 High accuracy polarimetry

THEMIS/MTR is able to produce high sensitivity measurements of Stokes parameters, up to 2.10^{-4} (Bommier and Rayrole, 2002).Interesting measurements of weak polarization were obtained at the limb, mostly by integrating the signal over long periods of time and/or along the spectrograph slit. In particular, the polarizability of some molecular lines (e.g. MgH, C2) have been measured with a sensitivity of Q/I$\sim 10^{-4}$, and have been related with polarized radiative transfer models (Faurobert and Arnaud, 2003). Observations of the so-called second solar spectrum (i.e. polarized spectrum at the limb), in particular in Sr I, Fe I and Na D1/D2, not only proved the potential of THEMIS for weak polarization, but also provided fine diagnostics which permit to deduce (possibly turbulent) magnetic fields at the limb of the order of 20-30 G (Faurobert et al., 2001, Bommier and Molodij, 2002), which is unfeasible with classical magnetography. However this type of diagnostic is very model dependant, so that THEMIS observations are now used to further constraint atomic physics models.

One of the only clear evidence of the return currents in solar flares that have long been predicted by theory has been obtained by the observation of polarization created by the impact onto the chromosphere of electron beams emitted from a diffusive layer higher up in the corona (Hénoux and Karlicky, 2003). The analysis of a flaring active region revealed the occurrence of a wide supersonic downflow in the photosphere, lasting a few hours before and after the flare (Meunier and Kosovichev, 2003). The role of this flow and its association with convective effects, for the gradual energy build-up to trigger the flare, is yet to be determined. A paradox for old measurements of magnetic field reversals with height has been naturally explained by the reversal of the shape $dI/d\lambda$ of chromospheric lines within their core, possibly due to radiative transfer effects even in the absence of a flare (Briand and Vecchio, 2003). This result has emphasized the importance of multi-line spectropolarimetry in the calculation of reliable chromospheric magnetograms.

1.2 Multi-line polarimetry

Interestingly, one of the very first and rare multi-line spectropolarimetric observation with the MTR provided in August 1999 a wealth of data of a unique quality (Molodij and Rayrole, in preparation) which has barely been reproduced. The quality of these observations permits to analyze the coupling between the thermodynamic parameters and the magnetic field, which seems to be crucial for the calibration of solar magnetic field measurements which are done throughout the world. These same observations permitted to deduce the vector magnetic

field in and around a sunspot at several altitudes in the photosphere, thus providing an estimate of the electric currents flowing in a high altitude filament that was located on the side of the sunspot. An measure of the vertical field gradient dB/dz within the photosphere was also estimated to be well consistent with the thin flux tube approximation (P+B2/(2μ)=cte) rather than with force-free models.

1.3 Stratification of the solar atmosphere

Another result concerns the expansion of the magnetic field with height above sunspots and pores in the magnetic transition layer where the plasma becomes force-free with height. MSDP measurements of the line-of-sight magnetic field at different depths in a line formed in the lower chromosphere revealed a super-expansion of the field with height in this layer, even though the magnetic plasma is there believed to be nearly force-free. Magnetohydrostatic models that take into account pressure and gravity failed to account for the observations. Therefore this observation suggested that the canopy effect around sunspots may be due to the presence of numerous unresolved magnetic flux elements, which tend to flatten the magnetic field in these area, thus leading to an over-expansion of the field with altitude (Eibe et al., 2002). This issue will have to be further addressed because, if it is true, it will change the budget of the coronal magnetic flux and may significantly reduce the energy flux toward the corona.

1.4 Fast events

Sunspot oscillations have been observed with the THEMIS/MSDP in the profile of CaII 8542 (Tziotziou et al., 2002). Power spectra, as well as relations between umbral flashes and penumbral waves have been investigated.

1.5 Ground and space coordinated campaigns

The dynamics of chromospheric plasma has been observed. Coordinated campaigns with SoHO permitted to reveal the unexpected occurrence of dark and wide channels of low opacity neutral plasma around prominences (Heinzel et al., 2001, Schmieder et al., 2003). Further modelling of these data provided the 3D geometry of these channels, and predicted the difficulty in distinguishing a filament from its channel using high opacity UV observations (Aulanier and Schmieder, 2002).

Another interesting result was obtained by combining THEMIS magnetograms with RHESSI data, which permitted to interpret the unexplained shape of the RHESSI soft X-ray emission by the flux asymmetry of an active region containing an emerging delta-spot observed in October 2002 (Berlicki et al., 2004).

The large flare of October 28 2003 (X 17) was observed by RHESSI and THEMIS and is under study.

1.6 Data base and software developments.

The BASS2000 data base is now storing the THEMIS data, with keywords allowing sorting and data processing. Some codes are available for THEMIS/MTR and THEMIS/MSDP. Works are in progress to allow systematic quick-look calculations. MSDP quicklook software is installed on the THEMIS computer in Izana.

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2 Nançay Radioheliograph observations and coordinated observations

In the metric wavelength range, quiescent filaments can be observed as brightness depression, due to the low electron density in the cavity, which surrounds the filament. Study of one event associated with a dark sigmoid filament which erupted and with a halo CME was performed. One of the interesting results of this study was to show the close association between the radio depression and a CME peculiar dark structure which had the same dynamical behavior. (Marqué et al. 2002).

Several studies on Coronal Mass Ejections were performed, using multi wavelength observations. Multifrequency radio imaging and spectral observations allow us to observe the initial steps of CMEs, below one solar radius, and to get information on the nature of the triggering mechanisms, on the CME lateral progression above the solar limb, as well as above the solar disk. A systematic radio survey, covering the period of the SOHO mission was established. This survey shows the space-time evolution of the emitting sources. (Pick et al., 2003).

Using imaging observations recorded by SOHO/LASCO-MDI, Yohkoh/SXT, the Meudon spectroheliograph and the Nançay Radio heliograph (NRH), and performing a linear force-free field extrapolation, the triggering and development of a complex eruptive/CME event in the chromosphere and in the corona was analyzed. The results show that the triggering and evolution of this event involve multiple magnetic flux system over a large coronal volume surrounding flare site, and that it resulted from the coupling of scales from narrow reconnection current sheets to very large interactive region magnetic connections. (Maia et al., 2003).

The solar origin of 40 interplanetary disturbances observed in the vicinity of the Earth was investigated; a search for associated coronal mass ejections was performed. Then, the solar source of these CMEs was performed using in particular a large set of solar observations, including EIT, NRH and H-Alpha images. Conclusions were drawn in particular on the location of solar sources of the interplanetary disturbances (Vilmer et al., 2003).

Joint observations of a prominence and a moving radio type IV bursts were used to probe the dynamics of ejecta and electron acceleration during a solar eruptive event. Mass and energy of the ejecta were estimated. The electrons were accelerated in the surrounding of the rising structure (Klein et Mouradian, 2002).

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3 Hard x-ray and gamma-ray observations of solar flares with RHESSI and coordinated observations (French participation)

After the successful launch of RHESSI (Ramaty High Energy Solar Spectroscopic Imager, PI R.P. Lin, UC Berkeley) in February 2002 which provides new observations of solar flares at X-ray/ gamma- ray wavelengths (3 keV-20 MeV), the group at Paris observatory has led several studies focussed on multi-wavelengths observations of flares.

1. A first comparison of RHESSI HXR images and of radio emission sites observed by the Nançay Radioheliograph was performed for several flares (Vilmer et al., 2002,2003). The comparison of HXR images and of radio emission sites shows for the analyzed events, simultaneous changes of the pattern of HXR sources above 25 keV and of the decimetric radio sources. This implies causal relationship between radio and HXR emitting sites which can be attributed to variation during the flare of the energy release and electron injection sites. This is the first time that direct comparisons between the evolution with time of >25 keV HXR and radio sources were performed.

2. The comparison of RHESSI HXR images and of the radio emission sites observed by the Nançay Radioheliograph at several frequencies also allows to study the link between the HXR producing electrons in the chromosphere and the energetic electrons injected in the high corona ($>1R_s$) towards interplanetary space. Several episodes of energy release and of electron acceleration are sometimes observed in a flare with variations of the conditions of the electron access to the high corona (Vilmer et al., 2003, Trottet, 2003)

3. Coronal hard X-ray sources (10" above the limb) in the 12-25 keV, 25-50 keV range were observed for a flare close to the limb (Vilmer, Koutroumpa, Kane, Hurford, 2003) . These HXR sources were observed above the hot magnetic structures seen with TRACE and the 25-50 keV sources were observed above the 12-25 keV ones. This is consistent with the previous

observations of "above the loop top sources" made with YOHKOH/HXT. However, the observations suggest that the coronal HXR sources show the production of energetic electrons at the sites of loop-loop interaction. Although radio gyrosynchrotron emission is observed during most of the HXR event, dm/m emission is observed only during a short duration, at the time of the appearance of a second coronal HXR source at 12-25 keV. A more detailed interpretation of these observations will be done in the future.

4. The gradual phase of a M1 flare observed during a coordinated observational campaign between ground-based observations (THEMIS and VTT) and space instruments (SOHO/CDS and MDI, TRACE and RHESSI) has been analyzed (Berlicki et al. 2003 in collaboration with N. Mein, P. Mein and P. Heinzel. The morphology and evolution of the flare during the gradual phase is studied, the objective is to understand the dynamics and energetics of the gradual phase and in particular the role of the different heating mechanisms. During the gradual phase, X-rays around 10 keV were observed above post-flare loops originating from trapped particles or continuous reconnection processes. No footpoints were observed. The thermal conduction could be responsible for the TRACE ribbons but not for the Ha flare emissions.

5. The observations of an intense (X4.8) g-ray line flare on 2002 July 23 by RHESSI led to many new results (Lin et al., 2003). The French contribution to the data analysis was focused on the first gamma-ray images of nuclear collisions of energetic ions in the solar atmosphere which were obtained with RHESSI. This showed that the centroid of the gamma-ray line image was displaced by 20"±6" from the centroid of the HXR image implying either a difference in acceleration and/or propagation between the accelerated electron and ion populations near the Sun.

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4 SOHO-French part / MEDOC

4.1 Observations

SOHO observations have been organized in the frame of four campaigns in 2002 and 2003, at MEDOC (Multi-Experiment Data and Operation Centre, http://www.medoc-ias.u-psud.fr, located at Institut d'Astrophysique Spatiale). A dedicated line between the Experiment Operation Facilities (EOF) at NASA and MEDOC allows the commanding of some SOHO instruments from MEDOC (SUMER, GOLF), during these campaigns, and allows the reception of data in real time continuously. MEDOC is the unique European center for SOHO operations.

MEDOC 9 from May 20th to June 2nd 2002,

MEDOC 10 from October 1st to November 3rd 2002,

MEDOC 11 from May 19 to June 1, 2003,

MEDOC 12 from from November 14 to November 30.

During these four campaigns, several Joint Observing Programmes (JOP) including several instruments on board SOHO, TRACE, RHESSI, ULYSSES, CORONAS and ground based observatories have been successfully coordinated:

- Ulysses-SOHO quadrature
- JOP157 Bright Points in Active Regions
- JOP131 Spectro-polarimetric diagnostics of prominences and filaments with SOHO and THEMIS

- JOP136 Default RHESSI collaboration
- JOP130 Doppler Dimming in polar coronal hole
- JOP158 The Fast Solar Wind from 1.05 to 4 Ro.
- JOP112 FIP effect in streamer
- JOP159 CME's in Lyman-alpha
- JOP163 Internetwork and Network oscillations
- Polar coronal hole SUMER/EIT/CORONAS
- Joint observations between SOHO/CORONAS/SuperDarn/WIND/EISCAT/ CLUSTER/EISCAT Solar-Terrestrial relationships
- JOP124 Eruptive prominence in Active
- JOP171 Solar Network Variability and Dynamics
- JOP170 Magnetic field temporal changes

4.2 Data Analysis and results using SUMER, CDS, EIT, UVCS, LASCO observations

In the frame of the MEDOC campaigns, results have been obtained in collaboration with scientists from several French and European institutes :

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4.3 Data analysis and results using GOLF

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4.4 Archive

MEDOC is one of the European Archiving Centers for SOHO approved by ESA. A copy of the SOHO archive is available from MEDOC, via a friendly web interface at : http://www.medoc-ias.u-psud.fr/archive where more than 1 million files are free to be analyzed.

4.5 Workshops

Workshops, with a high European participation, have been organized in the frame of MEDOC, on SOHO data analysis and results:

- October 28-29-30, 2003, "TOSTISP" workshop, on SUMER/CDS/EIT (SOHO) and TRACE, and RHESSI data analysis.
- November 13-15, 2002 on "Active region loops".