Activity Team Report

The role of spectroscopic and imaging data in understanding coronal heating

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The team started its activity in February 2007 with the first 3 days meeting. A second meeting followed in October 2007, while the last meeting was organized in January 2009. This last meeting was specifically requested by the team for scientific reasons.

The work of the team was a great success. From the first meeting, the interaction among team members was excellent, and the scientific discussions were of very high level. The first meeting was mostly dedicated to reviewing all the topics related to stellar and solar coronal heating, from the theoretical, computational and observational point of views. The second part of the meeting was dedicated to discussing and organizing the follow up activities.

The result of this first discussion was a list of actions that we thought had priority for shedding light on certain open questions related to coronal heating. Among the issues that the team started to work on was the identification of the thermal structure, density and plasma dynamics of the non-flaring corona, including loops (the building blocks of active regions). The team has worked on different data both from SOHO, RHESSI, CORONAS-F, and the Hinode satellite, launched in September 2006.

The first set of results that came out from data analysis was quite challenging. New spectroscopic results from SUMER indicated that the active region plasma was dominated by a limited number of near-isothermal components with fixed temperature (for data limited to T < 5MK, Feldman & Landi, 2009; Landi & Feldman, 2008). This seems to be incompatible with the variation of the temperature from loop to loop and/or along the loop, as is expected if the loops were heated either by small impulsive events (*nanoflares*) or by a continuous steady process. These are the two main competing processes proposed. This study continued and the result was confirmed in the third meeting.

At the same time, the first results on Hinode/XRT data in active regions presented to the second team meeting showed, for the first time, a well defined fine thermal structure for plasma at temperature > 2MK (Reale et al. 2007). This was a first indication in the direction of a heating process acting over small scales.

The follow up of the work was to quantify the thermal distribution of plasma along the line of sight in the non-flaring active region and to look for the existence of a small and hot plasma component (> 5MK). To quantify the latter will add an element in favour to one or another of the different heating processes. The result of this part of the work was presented to the last meeting. The XRT data, indeed, showed the existence of a 10MK plasma component, which is very weak, only a few percent of the 2MK corona (Reale et al. 2009, Schmelz et al. 2008). It was also shown that such a component could be detected only under certain conditions, depending for example, on the instrument's temperature sensitivity. Such a hot component was also studied and detected on full Sun CORONAS-F/RESIK spectrometer data, during very low levels of activity. While Hinode/EIS detects a hot component only up to few MK (Patsourakos & Klimchuk, 2009). These pieces of work, whose results seems compatible with the nanoflare picture, are certainly the beginning of a new research phase addressed to further validate them and to find their theoretical explication. Furthermore, what is still missing is a unique picture enabling the interpretation of the results the team obtained for T<5MK from UV spectroscopic data and for T>2MK from X-ray data.

Important results were also obtained from spectroscopic analysis of active region with the new Hinode/EIS. Highly detailed maps of density and velocities in AR were provided which give important constraints to coronal modelling (Tripathi, Mason et al., 2008, 2009).

Another piece was added to the picture of coronal heating by the results obtained on the hard X-ray data analysis. The open question was to quantify the level of this emission in non-flaring AR and QS, and to establish how much of this emission has its origin from thermal and non-thermal electrons. The results showed that, contrary to active regions, no emission seems to be detected in QS, which may indicate that a different heating process is at work. However, this result may be biased by the instrument sensitivity, and the presence of very low emission is not excluded.

The coronal heating problem was approached also from the modelling/simulation point of view (Buchlin et al., 2007a,b; Patsourakos & Klimchuk, 2008). Addressing the small scale impulsive heating, a revised 0D multi-strand model (EBTEL) was developed (Klimchuk et al. 2008). This was used to investigate the observable parameters under different conditions. Other numerical simulations, using different models for nanoflares were made, addressing, for example the investigation of the rate of the impulsive heating or its statistical properties (Parenti & Young, 2008).

Effort has been made to include cross-physics coupling in the simulations. For example, a work still in progress is addressing how much the density variation, due to the heating injection inside loops, may affect the heating rate itself (Buchlin et al., 2009). Interesting discussions also addressed the difficult problem of coupling the corona and chromosphere.

The team has also worked intensively on the modelling of basic physics phenomena that may have an impact on coronal heating. Various effects that may become important in the high temperature and low density plasma (which is the expected plasma condition in the initial phase following the heating injection) were investigated: non-ionization equilibrium (Reale & Orlando, 2008), thermal non-equilibrium (Susino et al., 2009), non-thermal electron beams, non local thermal conduction (West et al., 2008), and deviation from Maxwellian velocity distributions for electrons (Feldman et al. 2007).

During the year 2007, several people in the team where involved in consortia for proposing instruments for the Solar Orbiter mission. As part of our goals, the team has discussed such instruments and the best configurations to address new and successful investigations in terms of coronal heating. Concerning small scales phenomena, the team discussed the problems of detection with the new instruments.

In conclusion, the success of this team was due to the extensive discussions held during the meetings, which has permitted individuals to analyse in detail certain physical aspects and problems using the different expertise of the whole team. Several of the published works were inspired by such discussions. The success of the team was also ensured by the excellence of the work environment. The team was highly satisfied by the support and help it received by ISSI.

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