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Multi-instrument campaigns to observe the off-limb corona.

G. Del Zanna[1,6], V. Andretta[2], G. Poletto[3], L. Teriaca[4], Y.K. Ko[5], H.E.Mason[6], A. Vourdilas[5], A. Bemporad[7], M. Magri[2]

Abstract. We briefly describe two multi-instrument campaigns we coordinated to observe the off-limb corona in 2007, with some preliminary results. The first (Hinode HOP 7) was a SOHO/Hinode/TRACE/STEREO/Ulysses week-long campaign during the SOHO-Ulysses quadrature in May 2007. We could not achieve all of our goals, however we were very fortunate in that the 'Del Zanna' active region appeared on the Sun at the right longitude, and that a filament eruption and a CME was observed. Of particular significance is the finding of large (100 km/s) non-thermal broadenings in all coronal lines in the region where the filament was erupting observed by Hinode/EIS. The second campaign (Hinode HOP 44) involved SOHO (CDS, SUMER, UVCS), Hinode, TRACE to measure the physical parameters of plume/interplume regions in the polar coronal holes from the low corona to 1.7 solar radii, on 30/10 – 4/11. We obtained a good set of observations, however various instrumental constraints and the lack of fully developed plumes limited our goals.

1. Introduction

As an introduction we would like to stress the importance for science of long-term multi-instrument coronal observations. A single instrument/satellite normally provides only a limited set of information, and often interpretations based on observations from single instruments have turned out to be incorrect. It is also important to repeat similar set of observations, given the variability of the solar corona, along and across cycles. Coordinating multi-instrument observations with different satellites is still a time-consuming effort in need of much improvement. More coordinated observations must be needed, if none in the audience of the Hinode 2 meeting ever found a dataset containing all the information needed to solve a scientific problem.

[1]MSSL, University College London, Holmbury St. Mary, Dorking, Surrey RH5 6NT, UK

[2]INAF-Capodimonte Astronomical Obs., salita Moiariello 16, 80131 Napoli, Italy

[3]INAF-Arcetri Astrophysical Obs., L.go E. Fermi 5, 50125 Firenze, Italy

[4]MPS, 37191 Katlenburg-Lindau, Germany

[5]NRL, 4555 Overlook Ave. S.W., Washington, DC 20375

[6]DAMTP, Centre for Mathematical Sciences, Wilberforce road Cambridge CB3 0WA UK

[7]INAF-Torino Astronomical Obs., via Osservatorio 20, 10025 Pino Torinese (TO), Italy

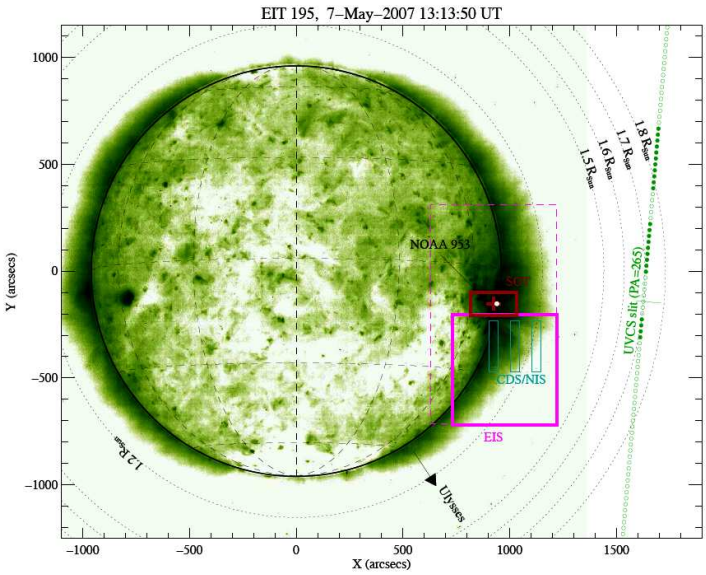

Figure 1. The instrument pointings during the May 7–10 campaign.

2. 2007 May 7-10 Ulysses quadrature: Hinode HOP 7

This campaign was coordinated by GDZ with the help of VA, GP, YKKo, HEM and AV. In May 2007 Ulysses was in quadrature with SOHO, at a latitude of 55 deg (south-west). Our main aim was to measure chemical abundances in an active region as a function of height using SOHO/CDS, Hinode/EIS, SOHO/UVCS, and link them with in-situ measurements by Ulysses. Our secondary aim was to measure electron temperatures T, densities N, and ionization state of the plasma as function of height from 1.0 to 1.7 solar radii using SOHO CDS, UVCS and Hinode/EIS. We obtained Hinode observing time during the period 7-10 May 2007. In order to achieve our goals we needed co-spatial and co-temporal off-limb observations from Hinode and SOHO, aswell as an active region at the right location!

Off-limb observations were not previously done and off-limb pointing of either the Hinode satellite or the EIS instrument was not agreed. We therefore designed an engeneering EIS 'study' to extract spectra from the bottom half of the slit. The drawback of using the bottom part of the CCDs was the lack of information about the instrumental characteristics. The EIS instrument was not characterisised during the first period of operation, but some observations to study the full extent of the 1" slit were obtained during March 2007. We (GDZ) have found that instrumental line widths were smallest and constant in the bottom 512" of the 1" slit. Preliminary studies of our off-limb observations suggest that the 2" slit has similar characteristcs.

The Sun was very quiet during March-April 2007, but was very cooperative to produce an active region at the right longitude (at the right time) such that it would be at the west limb during the planned campaign. The event is so remarkable that NOAA 953 has been called the 'Del Zanna' active region.

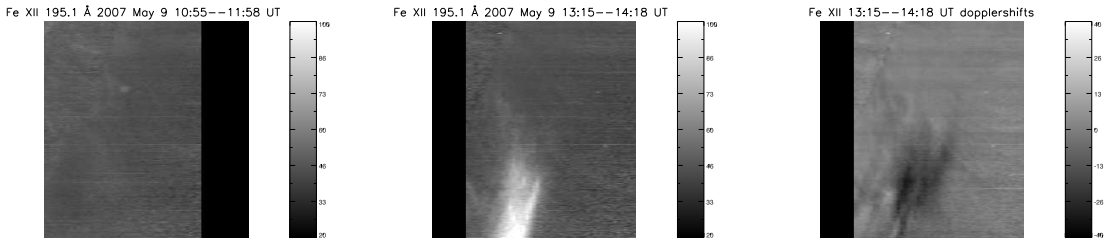

Figure 2. Non-thermal line broadening (km/s, from Fe XII) in the corona before (left) and during (centre) the the filament eruption of May 9 2007. Dopplershifts (km/s, from Fe XII) during the filament eruption (right).

One unfortunate occurrence was the low latitude of this AR, and the lack of co-spatiality between UVCS and EIS, which limited our science goals. Nevertheless, we obtained very good observations with all instruments. We were aswell very lucky in that one of the EIS observations caught part of a filament eruption, which had a Coronal Mass Ejection (CME) associated with. The event is described in Bemporad et al. (2009). Note that spectroscopic observations in the low corona of such events are extremely rare.

The filament was more clearly visible in the He II 256 Å line. We have found that this line is strongly blended with Si X, Fe XIII, Fe XII, Fe X and unidentified emission. We found significant (of the order of 100 km/s) non-thermal broadening in all coronal lines, in the region where the filament erupted. In the same region, we found enhanced dopplershifts, mostly towards the blue, suggesting large radial velocities of the coronal plasma. Further work is in progress.

3. Polar plume campaign Oct-Nov 2007 – HOP 44

This campaign was coordinated by GDZ with the help of VA, LT, GP and YKKo. The objective was to take the unique opportunity of multi-spacecraft observations during the current minimum to measure N, T, chemical abundances in polar coronal hole plumes. Also, to relate changes of the photospheric magnetic fields to their coronal response. All this required observations with Hinode EIS and SOT; SOHO CDS, SUMER, UVCS, and TRACE. A HOP (44) was approved to be run during Oct 30 – Nov 3 2007. We designed an EIS 'study' to scan an area of 300"x512" in about 1 hour. Planning problems within EIS limited observations only off-limb. During the Hinode operations, HOP 44 was mistaken for a SUMER campaign, which resulted in a limited set of EIS data. Good observations have been obtained from all instruments of the north polar coronal hole. The forbidden Fe X, XI, XII SUMER coronal lines were either saturated or very weak so temperature measurements from allowed EIS vs. forbidden SUMER lines were not available. With the assumption of isothermality and ionization equilibrium, we obtained a constant T=1 MK off-limb from the ratio of Fe XII / Fe X radiances measured by Hinode/EIS. An excellent direct T diagnostic involves a ratio of SUMER Mg IX lines. We obtained a variable (and lower) temperature in the off-limb region as shown in Fig. 3. Note the differences

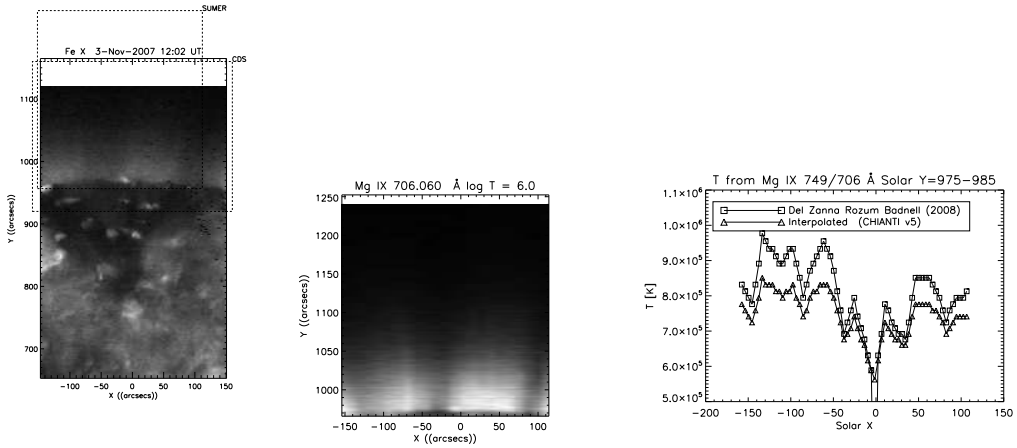

Figure 3. From left: EIS image in Fe X of the north polar hole, with the CDS and SUMER fields of view; SUMER image in Mg IX 706.06 Å; temperatures from the SUMER measurements across an off-limb area.

between the use of the new atomic data of Del Zanna et al. (2008), compared to the interpolated data of Keenan et al. (1986) available through CHIANTI v.5 (Landi et al. 2006). One major problem was the lack of clearly-defined plumes, which have only reappeared during 2008.

4. Conclusions

Despite various limitations and problems encountered in coordinating multi-wavelength campaigns involving the Hinode satellite, we have obtained good datasets for the study of the off-limb corona which we have only started to analyse in detail. We have found Hinode/EIS spectra to be very good for diagnostics of the active corona, but rather limited for coronal holes, as expected. The filament eruption of the 9th May is another example showing the importance of continuous observations for a long period of time with various instruments. There is clearly a potential for good science when combining Hinode, SOHO, TRACE and STEREO observations.

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