Target of opportunity JOP 119

VARIABILITY AND PHYSICAL PROPERTIES OF TRANSEQUATORIAL INTERCONNECTING LOOPS

František Fárník and Michal Varady,
Astronomical Institute of the Academy of Sciences of the Czech Republic, CZ-25165 Ondřejov

Zdeněk Švestka
Center for Astrophysics and Space Sciences, UCSD, La Jolla, CA 92093–0424, U.S.A.and SRON Utrecht, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands

Hugh Hudson
Solar Physics Research Corporation, 472 Calle Desecada, Tucson, AZ 85718, U.S.A.

Andrzej Fludra
Space Science Department, Rutherford Appleton Laboratory, Chilton, OX11 0QX, UK

Instruments: Yohkoh: SXT; SOHO: CDS, MDI, EIT; TRACE

Received 12 January 2000; Modified 17 February 2000

1 OBJECTIVES

We propose a joint observations of large–scale coronal structures — the transequatorial interconnecting loops (TILs) which connect active regions through the corona across the solar equator. The main aim is to get more information on the creation of the loops, on the relation between their variability and the variability of the connected active regions and to derive the physical parameters, temperature and density, along the loops.

2 SCIENTIFIC JUSTIFICATION

Our present knowledge about coronal loops that connect separate active regions ('interconnecting loops'), often across the solar equator, is rather poor, in spite of the importance of these coronal structures as large–scale magnetic field tracers, and one of the potential sources of coronal mass ejections (CMEs). The results about interconnecting loops published so far were based on data from Skylab (Chase et al. 1976, Švestka et al. 1977, Howard and Švestka, 1977, 1980, Švestka and Howard, 1979, 1981) and Yohkoh (Tsuneta, 1996, Fárník et al. 1999a, 1999b). Using Yohkoh SXT data, several systems of transequatorial interconnecting loops (TILs) were studied recently, starting with the episode of March/April 1992. TILs have now been shown to participate in CME formation (Khan and Hudson, 2000).

According to conventional ideas of solar magnetism, the TILs can only form as a result of magnetic reconnection in the corona, but we do not understand the circumstances of this process yet. It was shown that active regions of the new solar cycle, located at high latitudes, can be connected across the solar equator by TILs as long as 60 heliographic degrees. This length greatly exceeds the limit found for TILs on Skylab or in the early Yohkoh data, and implies that the length limit of TILs is simply due to the varying latitudes of active regions during the solar cycle. The result of Canfield, Pevtsov, and McClymont (1996) that TIL formation requires like chiralities in the two interconnected active regions was confirmed. The fact that we were unable to find any longitudinal (i.e., east-west) loops of comparably great length led us to suggest that an important component of the driving force for the reconnection of TILs may be the differential solar rotation.

Observations of several systems of TILS, including the recent system of long TILs observed in February 1999, were compared with force–free models of coronal magnetic field lines based on data from the Kitt Peak and SOHO/MDI magnetograms, using the method of Alissandrakis (1981) and Demoulin et al. (1997). The agreement between force–free models and Yohkoh images is substantially better for the TILs of February 1999 than for the earlier events, which might be due to the higher frequency and better quality of SOHO magnetograms which we could use in this case. Generally, however, it has appeared quite difficult to model all the magnetic interconnections seen in soft X-rays and get a perfect co-alignment. One reason is the limited spatial and temporal resolution of magnetic data, but mainly the very high sensitivity of the modeling to the selection of the starting points of modeled field lines (footpoints of the loops). Nevertheless, some computed lines correspond precisely to the loops seen in the SXT images and that result justifies the force–free modeling.

The determination of exact positions of footpoints often encounters the problem that X-ray emission of an interconnecting loop fades close to its footpoint, creating there a "brightness gap". This was also observed on Skylab and reasons for this gap are not yet clear. As an example, this is one of the problems which only close cooperation of high–temperature (Skylab) and lower–temperature (SOHO and TRACE) images can solve. If the gap is due to a temperature decrease, SOHO and TRACE might show the 'missing' portions of the loops in their images. And, generally, a comparison of data will provide information about the density and temperature distribution in the loops.

In spite of these problems with the exact location of many footpoints of TILs, we could confirm the earlier conclusion from Skylab data that interconnecting loops are mostly anchored in relatively weak fields at the periphery of active regions. However, this does not appear to be always true. In the March/April 1992 transequatorial loop system some active–region and interconnecting loops formed an "X-ray fountain", in the center of which was a big sunspot. Footpoints of some interconnecting loops were very close to the sunspot penumbra, hence in much stronger fields than in other cases.

Obviously, there are many questions to be answered, among others why we do not see direct signatures of the reconnection process in newly formed TILs, how the loop brightness variations correspond with the activity in each of the two interconnected active regions and with newly emerging flux in them, why do we observe the above mentioned gap in the loop brightness close to its footpoints, why the interconnecting loops prefer weak fields near their footpoints and why there are no X-ray TILS interconnecting strong fields in active regions (some connections may be indicated in TRACE images), how are temperature and density distributed along TILs, and how they vary with time in the loops.

Some these problems we are presently studying and others will be topics for further studies, thus justifying our proposal.

3 DESCRIPTION OF THE JOINT OBSERVATIONS

We propose simultaneous observations of TILs with CDS, MDI, TRACE and SXT. The observations should be carried out in times of different position of the TILs system relative to the limb and in both quiescent and dynamic stages of its evolution. The priorities are to obtain some observations near the center of the disk (with MDI magnetograms) and some limb observations. In these two cases the support of TRACE is most important.

The disk observations will be used to determine the flow speed at the footpoints of TILs in both quiescent and dynamic phase (CDS), the underlying photospheric magnetic field in the active regions where the loops are anchored (MDI) and the relative position of the footpoints to the magnetic field pattern (MDI, TRACE). The limb CDS data will be used to derive the temperature and electron density along the loop system. TRACE and SXT observations play an important role during the CDS observations. Because any interpretation of CDS rasters (with long scanning times) of highly dynamic events is extremely difficult, these instruments should guard the region observed by CDS and monitor the possible rapid evolution which could occur at the time periods when CDS is scanning the rasters. This data will help to disentangle the spatial and time changes in the CDS rasters. The images from TRACE will be used to trace the fine structure and its evolution during the CDS scanning period. The synoptic EIT data will be used together with the SXT observations to follow the large scale changes in the solar corona during the time period when this JOP is running.

3.1 TIME PLAN

The whole JOP should ideally last eight consecutive days, when the TILs passes from the disk center (eastern edge of the HR FOV of MDI) to the W limb of the Sun, with 6 hours of observations per day. We believe that this should give us enough time to catch the system in its different evolutionary stages. If this is too time expensive there can be a time gap between the central disk and limb observations.

3.2 CDS

All the CDS data will be obtained using the NIS detectors and 2×240 arcsec slit. The size of the raster in the E-W direction will be 240 arcsec or it can be reduced to the real size of the observed structure.

Disk observations: In each observational sequence on the disk (best near the disk center) we propose to cover the parts of both active regions where the footpoints of the TILs system are anchored. In case the TILs are too long to fit both footpoint regions into one raster, two rasters covering both footpoint regions plus a substantial part of the loops will be made in times as close as possible. This should be done in both quiescent and active stages of the TILs system.

Limb observations: We propose to cover the whole TILs system, when it is on the limb, by one or more rasters . In case the loop system does not fit into one raster we propose to cover the system with more rasters as close as possible in time. A crucial point is to obtain some limb data in the quiescent stage of TILs evolution.

Line selection: To meet the scientific objectives mentioned above we propose to observe the system in the following set of lines containing temperature and density sensitive line pairs and lines convenient for dynamic studies: O V 629.7 Å, Mg IX 368.1 Å, Mg X 624.9 Å, Si X 347.4 Å, Si X 356.0 Å, Fe XII 364.5 Å, Si XII 520.7 Å, Fe XIV 334.2 Å, Fe XIV 353.8 Å and Fe XVI 360.8 Å.

3.3 TRACE

The TRACE observations have to be carried out simultaneously with CDS (and MDI). This requirement has a very high priority especially for the limb and central disk observations. The observational sequences will be carried out in wavelengths 1550 Å and 1700 Å every 20 minutes. Wavelengths 1600 Å, 171 Å and 195 Å every 1 min 10 s. A mosaic of two fields of view can be made, if the loops are longer than a single 8'x8' field of view.

3.4 EIT

We would like to use the 6 hours EIT synoptic data obtained in the whole time period when this JOP is running.

3.5 MDI

MDI 96–minute magnetograms and continuum images are a minimum requirement for the JOP to be run. However, additional magnetogram data are highly desirable. If possible, MDI will provide high-cadence magnetograms, either in full-disk mode or in a mode such as cam_mag_movies2, which alternates two minutes of full-disk with 8 minutes of high-resolution magnetograms. This latter mode would be preferable when one of the TILs footpoints is in the MDI high-resolution field of view so that the whole system and a footpoint could be monitored at the same time. If full MDI support is not available, a few extra magnetograms (full-disk and high-res as appropriate) beyond the synoptic set, taken in coordination with the CDS observations, are highly desirable. Continuum images would assist in coregistration.

3.6 SXT

Full disk data will be used to monitor the evolution of the chosen TILs system both in the periods in between of the CDS, MDI and TRACE observations and during their observations. The real-time SXT data can be used to provide a warning of the E-limb arrival of a TILs system several days in advance of its entry into the MDI field of view. If possible we will obtain full-resolution SXT images, which can be used in connection with TRACE or other lower-temperature data to establish magnetic connectivity.

References:

Alissandrakis, C.E., 1981, A&A 100, 197
Canfield, R.C., Pevtsov, A.A., and McClymont, A.N. ,1996, ASP Conference Series 111, 341.
Chase, R.C., Krieger, A.S., Švestka, Z., and Vaiana, G.S., 1976, Space Res. XVI, 917.
Demoulin, P., Bagala, L.G., Mandrini, C.H., Henoux, J.C., and Rovira, M.G., 1997, A&A, 325, 305.
Fárník, F., Karlický, M. and Švestka, Z., 1999a, Solar Phys. 187, 33.
Fárník, F., Švestka, Z., Karlický, M. and Hudson, H.S., 1999b, SoHO-8 Workshop, Paris
Howard, R. and Švestka, Z., 1977, Solar Phys. 54, 65.
Howard, R. and Švestka, Z., 1980, Solar Phys. 71, 49.
Švestka, Z. and Howard, R., 1979, Solar Phys. 63, 297.
Švestka, Z. and Howard, R., 1981, Solar Phys. 71, 349.
Tsuneta, S., 1996, ApJ 456, L63.