Magnetic Variability of an XRT Bright Point

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Abstract

Solar coronal bright points display complex internal structure when viewed at the high spatial resolutions provided by the instruments onboard Hinode. We study the magnetic evolution of a newly formed bright point on the 6th of April 2007, using high-resolution MDI magnetogram data as a basis for topological reconstruction of the 3D magnetic field in the corona. A dynamic network of magnetic connections exists both within the bright point itself and linking it with the surrounding magnetic features. When these changes in magnetic connectivity are compared with XRT observations of X-ray loops and brightenings, we can gain new insights into how changes in the coronal magnetic field configuration lead to brightenings of magnetic structures within the bright point, with possible implications for coronal heating.

Observations of the bright point

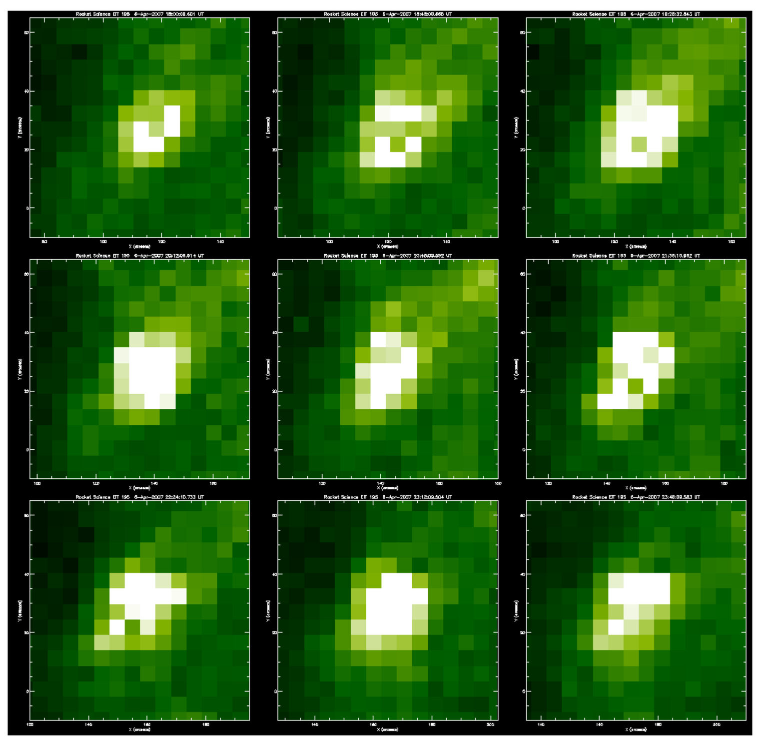

Fig. 1) EIT snapshots of the BP from 6pm to midnight

EIT (onboard SoHO) observed the bright point (BP) in the 195 Å passband with 12 minute cadence from its birth at 11:36 UT on 6 April 2007. It was about 20 arcseconds in diameter, and some structure could be seen, evolving on a timescale of several minutes.

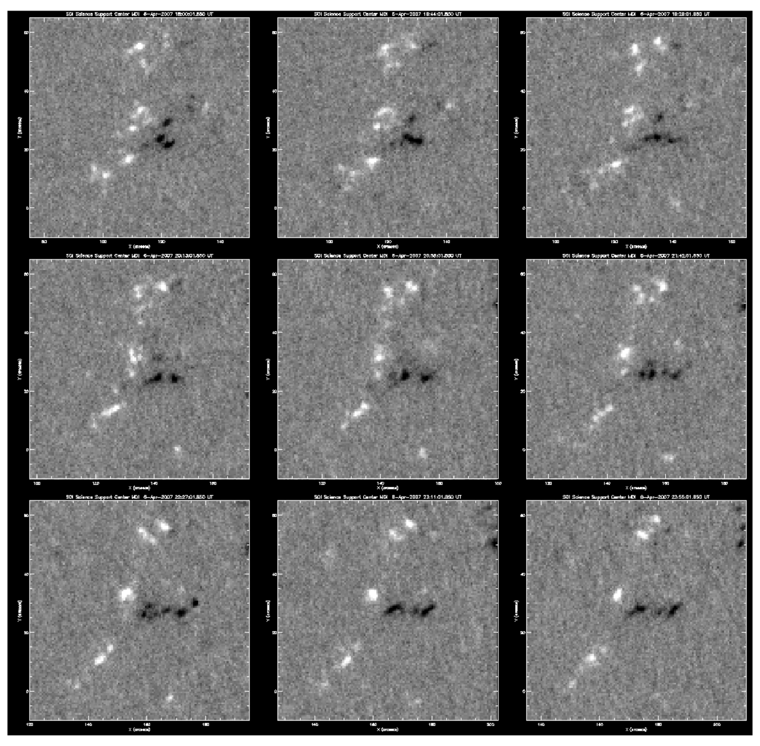

Fig. 2) MDI snapshots of the BP from 6pm to midnight

MDI (also on SoHO) observed the BP in high-resolution mode from 18:00:01 untill 23:59:01 the same day, with one minute cadence. At the start of the observations, the BP was magnetically quite compact with small-scale structure, but it expanded and its field simplified as time went on. This set of observations forms the basis for this study.

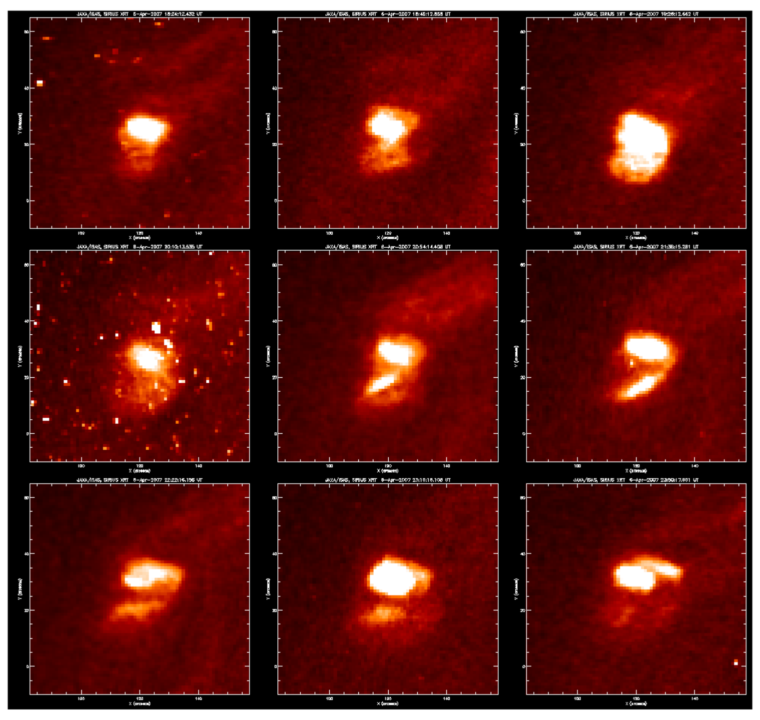

Fig. 3) XRT snapshots of the BP from 6pm to midnight

XRT on Hinode also observed the BP. We chose to work with a dataset taken with the aluminium polyimide filter, with 16 second exposure times and a 2 minute cadence. Observations were taken between 18:12:04 and 23:58:39. With the excellent spatial resolution of XRT, much more detail can be seen of the changing loop structures that make up the BP.

Topological modelling

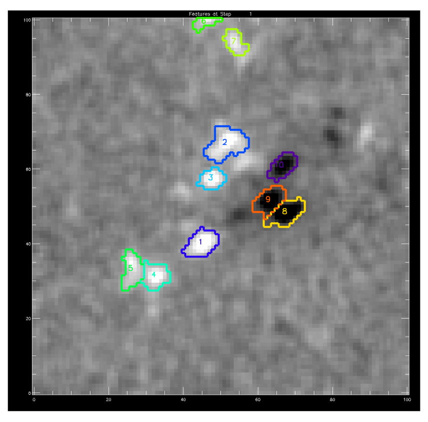

Fig. 4) Tracking the BP's magnetic features

To construct a model of the BP's 3D coronal magnetic field, we first picked out its strongest magnetic features from the MDI line-of-sight magnetogram data. A feature was defined as having a magnetic flux of over 20 Mx in a contiguous region of at least 10 pixels. These features were tracked over time as the BP's magnetic field evolved.

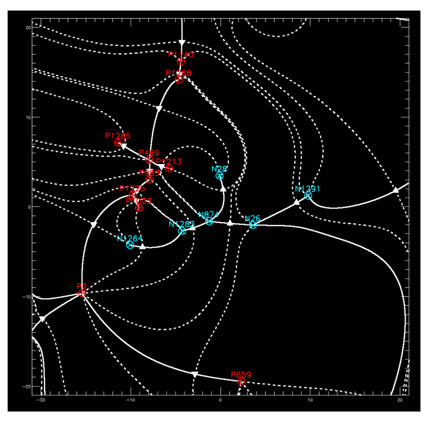

Fig. 5) Example photospheric topological footprint of the BP region

Each feature was then further reduced to a point magnetic source with magnetic field strength and location determined from its parent feature. Potential magnetic field reconstruction was carried out to determine the structure of the coronal magnetic field for each time frame in the six-hour observation period.

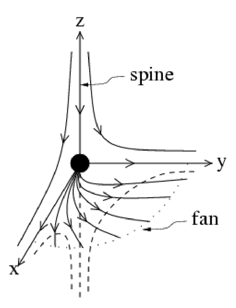

Fig. 6) 3D field structure near a generic potential magnetic null

The magnetic topology of the resulting 3D coronal magnetic field was analysed. By finding the magnetic null points in the field and their associated separatrix (fan) surfaces, the changing structure and connectivity of the field can be classified. Figure 5 shows an example of the photospheric footprint of the BP topology, consisting of positive (P) and negative (N) numbered magnetic sources, spine (solid) fieldlines and (dotted) fieldlines representing where separatrix surfaces intersect the photosphere.

Magnetic evolution

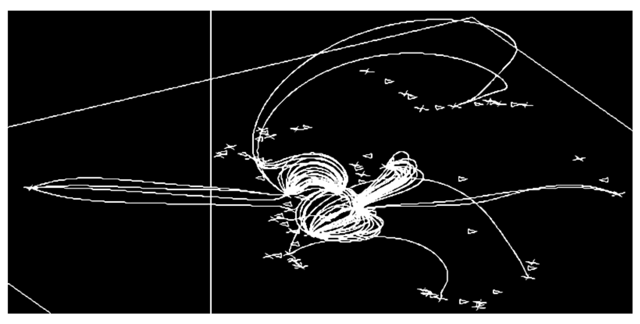

Fig. 7) 3D coronal magnetic fieldlines from the BP

On a large scale, the magnetic structure of the BP is two intersecting domes of magnetic flux (the two central small domes in Figure 7), one from the area of positive magnetic polarity, the other from the negative polarity. This structure becomes stretched out as the magnetic source regions move away from each other, but on a large scale it does not alter during the observation period. However, each polarity is made up of many smaller magnetic features, and their magnetic fluxes vary on a much shorter timescale, as shown in Figure 8, where each line represents an individual feature.

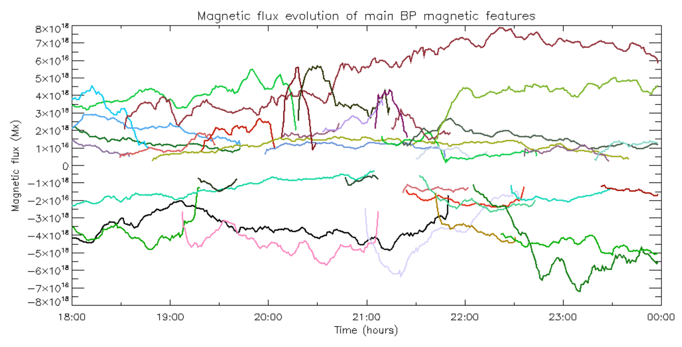

Fig. 8) Variation of magnetic flux of strongest BP features with time

So the constituent magnetic features of the BP can each last from several minutes to several hours, varying dramatically in magnetic flux over tens of minutes, yet the overall shape of the magnetic field is maintained to a good approximation over at least a six-hour period. Somehow the rate of flux emergence must regulate itself once a feature such as a BP (or a sunspot) is formed, to maintain the shape over a longer time than the lifetime of any individual element.

Magnetic connectivity

The BP's changing internal magnetic connectivity was studied. ***Flux domains*** are sets of magnetic fieldlines joining two sources, and they form, change in size and disappear due to topological bifurcations as the features in the underlying photospheric field change. Figure 9 shows the fluxes in several selected domains.

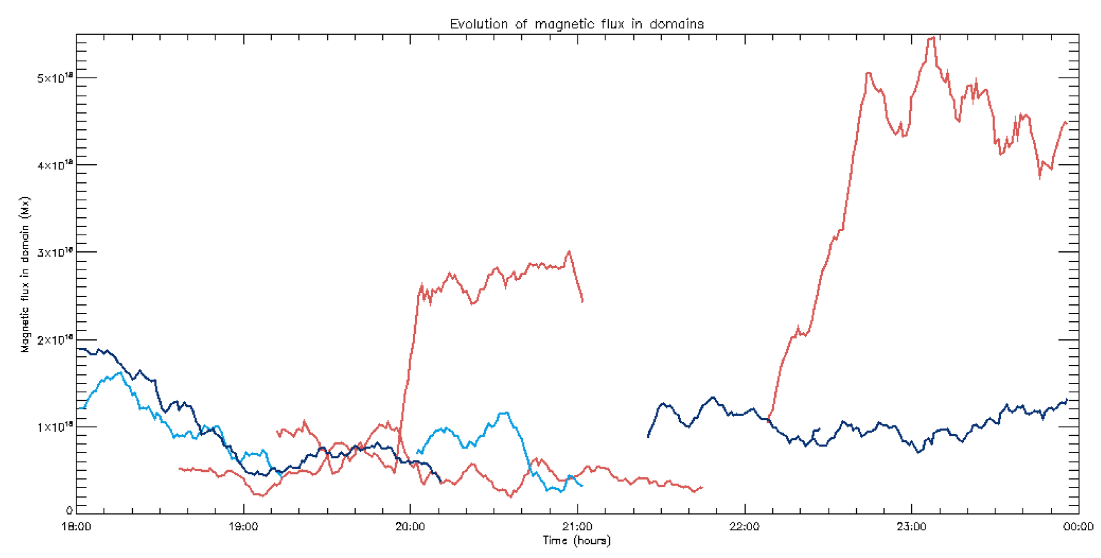

Fig. 9) Variation of magnetic flux of selected BP flux domains with time: dark blue lines are from domains representing the lower XRT loops; red lines the upper XRT loops; and light blue lines the mid XRT loops

From Figure 3, it can be seen that the main sets of X-ray coronal loops in the BP are one set to the south (lower) and two sets close together to the north (mid and upper). Each loop is a magnetic flux domain, or a set of such domains close together. The flux in the domains changes over a timescale of several minutes, and these changes may be related to X-ray brightenings (see next panel).

The sudden change in flux exhibited by the red line at 20:00 is caused by a global spine-fan bifurcation that greatly increases the volume of the flux domain P469–N874. In fact, many smaller bifurcations like this occur in the topology between each frame, but this one marks a major shift in the internal connectivity of the BP.

Correlation with XRT BP light curve

A correlation analysis was performed to discover any relationship between the XRT light curve (Figure 10) and the total positive and negative magnetic fluxes (Figure 11) of the BP. The linear Pearson correlation coefficients were 0.27 and 0.43 respectively, which are low values not indicating any definite correlation. Cross-correlation was also tried, but it was not possible to uniquely determine a best-fit time-lag due to the poor overall fit.

This BP is different from others we have previously studied, in that fieldlines from both source regions extend out to connect far away from it (*i.e.*, to at least several times the BP's own diameter). This can be seen in Figure 7, where the BP itself consists of the two small central domes of fieldlines, and several other connections can clearly be seen to relatively distant sources, meaning that distant magnetic features can strongly influence the BP's shape and brightness. In other BPs where one magnetic polarity is much stronger than the other and confines all of its fieldlines to a small volume inside the BP, there may be a simple relationship between the total flux of the weaker polarity and the X-ray light curve. An example of such a BP is presented in a related poster by D. Peréz Suárez *et al.*

Changes in XRT brightness may be due to changes in source fluxes, domain fluxes, or topology. For example, the jump in height of the red line in Figure 9 is conjectured to correspond to the spike in the XRT light curve just after 20:00. The bifurcation that is responsible for this jump injects (via magnetic reconnection) a large amount of magnetic flux into a domain in the upper XRT coronal loop, which may well respond by increasing its X-ray emission.

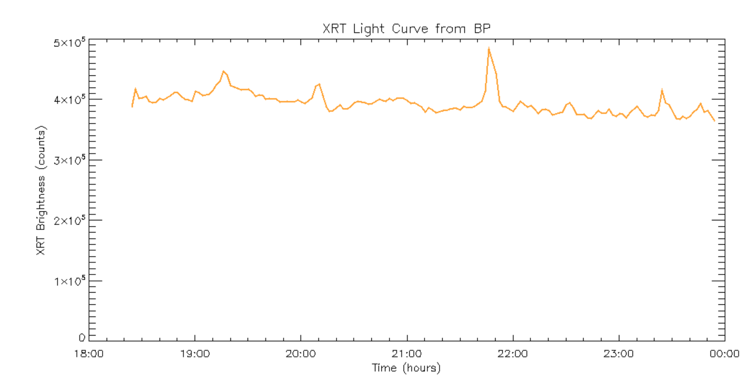

Fig. 10) XRT light curve (integrated over all pixels in BP)

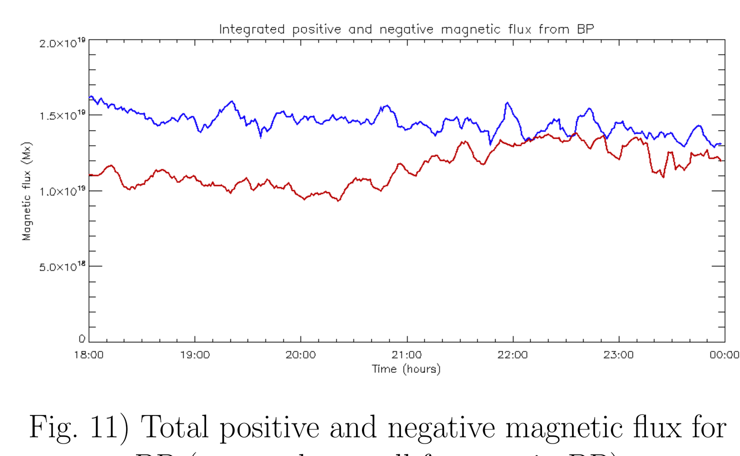

Fig. 11) Total positive and negative magnetic flux for BP (summed over all features in BP)

Conclusions

- High-resolution XRT data is providing new insights into the structure of magnetic bright points.
- A powerful approach is to combine this data with 3D topological reconstructions of the coronal magnetic field.
- Six hours of high-cadence observations from MDI and XRT were taken of a newly-formed BP on 6 April 2007.
- The BP's large-scale structure was two intersecting domes of magnetic flux, with fieldlines from both magnetic polarities extending out to connect to other sources far from the BP.
- The magnetic features constituting the BP studied here vary their magnetic field strength on short timescales of tens of minutes, yet the large-scale magnetic structure is preserved over longer timescales of several hours.
- No correlation was found between the XRT light curve and the total magnetic flux for this BP.
- However, it is possible that a change in a domain magnetic flux is responsible for a peak in the light curve, as the injected magnetic energy heats the loop.

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