Observed Magnetic Structure of X-Ray Bright Points from TRACE and MDI

D. S. Brown and C. Parnell
Dept of Mathematics, University of St Andrews, St Andrews, KY16 9SS, Scotland

E. DeLuca, R. McMullen and L. Golub
Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138, USA

Abstract. From 13th-17th June 1998, TRACE and MDI simultaneously observed the same quiet region of the Sun. From these observations the fascinating and complex structure of x-ray bright points, intense small scale brightenings that occur throughout the solar corona, can be seen in great detail.

For the first time, it has been possible to study bright points for their entire lifetime with a cadence of 2 minutes and a temporal resolution of 0.5 arcsec. One particular bright point which lasted two days exhibited dynamic structural behaviour which became increasingly complex and lead to its sudden eruptive demise.

With the use of MDI magnetograms, it is possible to extrapolate the magnetic structure using an analytical constant $\alpha$ force-free approximation. This has been used to help us to explain the topology and behaviour of the bright point.

By comparing two of TRACE’s Fe lines (FeIX and FeXII) the spatial and temporal temperature and density structure of the bright point has been investigated. This analysis indicates that this bright point is made up of a complex system of dense loops.

By understanding the magnetic, temperature and density structure of the bright point, it is hoped that the mechanism by which it is heated can be gained.

1. Introduction

Coronal bright points were discovered in the 1970’s (Vaiana et al 1970; Golub et al 1974, 1976a, 1976b). They were called points because they appeared as such in the early images, however with the tremendous improvements with coronal imaging telescopes both the temporal and spatial evolution of a bright point can now be studied. In the 1990’s NIXT for the first time observed complex loop structure in bright points (Parnell et al 1994) and then in 1998 TRACE enabled both high temporal and spatial evolution of the bright point to be made.
Figure 1. Evolution of the bright point in the TRACE Fe XII line from its beginning at around 20:00 on 13th June through to its eventual demise at around 5:00 on 15th June. Each image is 75 arcsecs by 50 arcsecs, with the time the image was taken underneath.
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Figure 2. Plot showing the change of the area of the bright point over the course of its lifetime.

The bright point extracted from the quiet Sun TRACE observation sequence is completely contained within the MDI high resolution field of view, passing approximately 60 arcsecs above disk centre. The region extracted is 75 arcsecs by 50 arcsecs and runs over a period of about 40 hours.

Image cubes from the FeIX, FeXII and Lyman-α lines of TRACE and from MDI high resolution magnetograms have been extracted and derotated to eliminate lateral movement, allowing a morphological study to be carried out.

2. Behaviour of the Bright Point

The bright point (figure 1) appears at around 20.00 on 13th June and continues to grow and brighten over the next 12 hours. At this point the bright point begins to twist forming a sigmoid shape, this lasts for the next 4 hours. This twist phase is followed by another 2.5 hour period in which the bright point is seen to have dramatically changed its structure to that of a π shape, before it disappears. It reappears again at 22.00 on the 14th. This reappearance is not as bright as before and fades away after about 7 hours.

The bright point can be defined as being made up of pixels which, statistically speaking, are higher than background intensity. The intensity range covered by the background intensity is well fitted by a Gaussian curve, with the bright point producing a skewed tail at the high end of the distribution.
Figure 3. Plots of how the peak (dashed line) and average (solid line) temperature of the bright point vary through its life cycle. The dotted line represents the average temperature of the region as a whole.

Using this definition, characteristics of the bright point are calculated. Figure 2 shows how the area of the bright point evolves over time. The bright point slowly grows over the course of about 20 hours to a peak associated with the π phase, after which it dramatically shrinks. A 5 hour period of calm then follows before the bright point re-emerges quite rapidly, before fading away to nothing.

Taking the ratio of the Fe XII observations with almost simultaneous Fe IX observations and applying a temperature scaling, gives a series of temperature maps of the bright point throughout its lifetime. Figure 3 shows how the peak (dashed) and average (solid) temperature of the bright point varies through its life cycle, with respect to the background temperature.

While the temperature of the bright point shows characteristics similar to that of the area of the bright point, the variation in temperature is not as pronounced as the variation in area. Further analysis (not shown here) shows that the density of the bright point has more influence on the behaviour than the temperature does.

3. Conclusions and Further Work

Due to the high spatial and temporal resolution of TRACE, the structure of the coronal bright point can be seen in great detail. Furthermore, the evolution of
the bright point is extremely clear and detailed. The bright point is obviously not a point, but a bundle of loops that gradually twist up over time and then completely reorder themselves. From the MDI data it is clear that the twisting is associated with shearing of the foot points and π shape configuration is due to reconnection between the original flux and newly emerged flux loops.

The interpretation of the results so far is just a tentative suggestion, further progress will be made using the MDI magnetograms. Magnetic fieldlines will be extrapolated using a constant α force free technique and matched with the loops in the TRACE observations. Comparison with the temperature and density maps can then provide temperature and density profiles along the loops. These can be compared with predictions by theoretical models to determine how the loops are heated and how the bright point evolves and why it behaves as it does.

From the temperature and density plots, it is believed that the heating mechanism in the pre-sigmoid, sigmoid and π phases are the same since the temperature of the region does not vary markedly through its entire life. However, this does not mean that the bright point is heated continuously; the temperature plot is not a straight line and variations along it are considerably larger than can be explained by errors. Impulsive heating is therefore likely. The impulses are neither evenly spread nor of the same intensity. Indeed, from careful study of the Fe IX and Fe XII images, it is clear that different regions of the bright point brighten at different times.

Furthermore, the density plot mirrors the area plot more closely than temperature, suggesting that the bright point loops are continuously heated, but that more and more plasma is injected along them until the heating slowly diminishes and the loop gradually drains out over about 2 hours.

References