OBSERVATIONS OF DYNAMIC EVENTS IN He I λ10830

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Abstract. The characteristics of large-scale two-ribbon flares and dark points observed in He I λ10830 are summarized and compared with observations of these phenomena at other wavelengths and with the underlying magnetic field.

Key words: He I 10830 Å – infrared: stars – Sun: flares – Sun: magnetic fields

1. Introduction

Full-disk He I λ10830 spectroheliograms have been taken by the National Solar Observatory (NSO) since early 1974 on a daily basis using a 512-channel magnetograph at the Vacuum Telescope/Kitt Peak (Livingston *et al.*, 1976. Though the primary use the He I λ10830 spectroheliograms is for the identification of coronal holes, a variety of phenomena are being studied both in these data and in high time-resolution He I observations of a portion of the solar disk. This paper summarizes the characteristics of two types of events observed at this wavelength: (1) on a large scale, *Two-Ribbon Flare Events* and (2) on a small scale, *Dark Points.* Further details of these phenomena are described in Harvey, Sheeley, and Harvey (1987), Harvey (1985, 1991), and Harvey and Sheeley (1992).

2. Two-Ribbon Flare Events Observed in He I λ10830

Erupting quiescent filaments, termed *Disparition Brusque*, often are followed by two-ribbon flares or weak brightenings along the filament channel (see Švestka, 1976, and references therein). Such events also are seen, often more easily, in He I λ10830 spectroheliograms. A total of 90 two-ribbon events were identified in the daily NSO He I λ10830 full-disk spectroheliograms from early 1974 to June 1985. To determine the timing and history of these 90 events, additional data were examined. These include: (1) Hα filtergrams, from *Photographic Journal of the Sun, Osservatoire Astronomica di Roma*, *Solar Geophysical Data*, and flare patrol films from Sacramento Peak Observatory, Big Bear Solar Observatory (BBSO), and the SOON system, and (2) filament observations from *Pulkovo Solar Data Bulletin, Cartes Synoptiques de la Chromosphere Solaire et Catalogues des Filaments et des Centres d'Activité.*

2.1. Results

Most of the He I flare events identified occur outside active regions, such as the two-ribbon event of 27 October 1988 shown in Figure 1. In all events, the ribbons appear *dark* in He I λ10830 and straddle the magnetic inversion line previously occupied by the erupted filament. The two-ribbon event begins tens of minutes to a few hours after the onset of a filament eruption; the two ribbons separate with time at speeds of 0.1 to 2 km s^{-1}. Their spatial scale is 10^5 to 10^6 km; the largest extend over ~9% of the Sun's surface. The dark He I ribbons generally correspond to weak

D. M. Rabin et al. (eds.), Infrared Solar Physics, 71–76.

https://doi.org/10.1017/S0074180900124271 Published online by Cambridge University Press

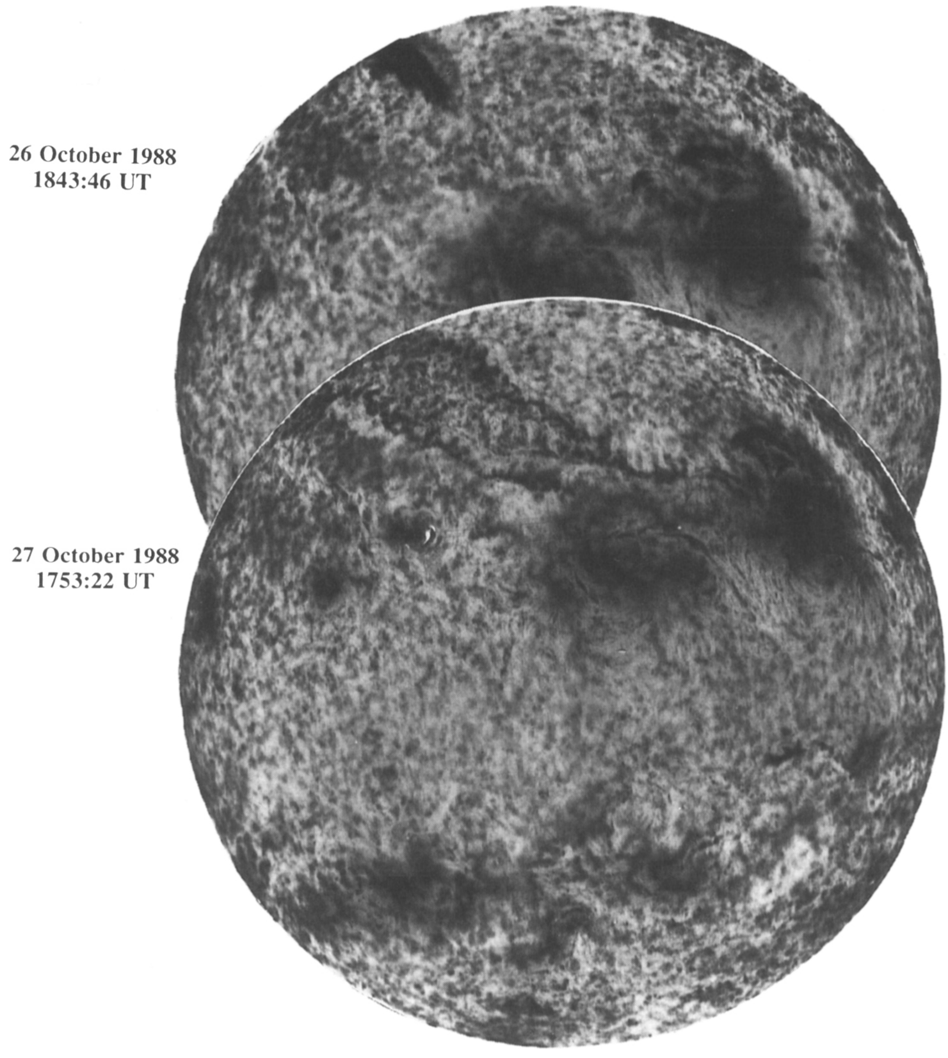

Fig. 1. NSO He I λ10830 spectroheliograms showing a filament near the north-east limb on 26 October 1988. This filament erupted on 27 October sometime between 1043 and 1346 UT and was followed by an extensive two-ribbon flare event and the expansion of the northern polar coronal hole down to the edge of the northmost ribbon. The *dark* He I ribbons (*arrows*) extended almost 10^6 km along the $H_{\|} = 0$ line. North is at the top and East is to the left.

https://doi.org/10.1017/S0074180900124271 Published online by Cambridge University Press

TABLE I
Association of Two-Ribbon Events with Other Solar Activity

Two-Ribbon Events Associated with:	%	Timing w/r Ribbon Onset
Coronal Mass Ejection	96%	1.9 hours *before*
Type I/Noise Storm	73%	0.8 hours *before*
Long-Duration 1-8Å X-ray Event	98%	0.4 hours *before*
GRF 10 cm-λ Radio Burst	87%	0.0 hours *after*
Type II Radio Burst	11%	0.6 hours *after*
Geomagnetic Storm	43%	2.5 days *after*

Hα brightenings; only 10 of the 90 events were reported as flares. The ribbons are first detected in He I λ10830 and then within minutes in Hα. The rise time of these events is on average 2.1 hours, ranging from 0.3 to 6.3 hours; their durations range from 3 to >64 hours, with 70% exceeding 20 hours. Their duration is longer in He I λ10830 than in Hα. With 64% of the two-ribbon events, coronal holes enlarge or form, these changes are transient, lasting from 1 to 6 days.

The association and timing of other solar activity with these two-ribbon events is summarized in Table 1.

The characteristics of these two-ribbon events are identical to those of major, more energetic, two-ribbon flares in active regions, though they are weaker, longer-lived, and larger. They are not a separate class of flares, but are at one end of a wide size-spectrum of two-ribbon flares. The comparatively low level of associated chromospheric activity indicates that these events may be primarily coronal.

It is concluded that the two-ribbon events are associated with a large-scale restructuring of the coronal magnetic fields that leads initially to the eruption of a filament and a coronal mass ejection. As the coronal mass ejection and filament move outward, the coronal magnetic fields stretch and open. Below this, the magnetic fields reconnect resulting in heating in the reforming coronal loops and enhancements at the loop footpoints. This picture is consistent with the formation of arcades of X-ray loops at the site of recently erupted filaments (Webb *et al.*, 1976; Kahler, 1977; Rust and Webb, 1977), and the enhancements at their footpoints seen in He I λ304 (Svestka, 1976; Harvey and Sheeley 1992), a line showing the same structures as in He I λ10830 (Harvey and Sheeley, 1977). The release of energy during a two-ribbon event, though at low levels, persists for extended periods (tens of hours) and over extensive areas of the Sun ($\leq$9% of its surface area).

3. Dark Points Observed in He I λ10830

Observations of the quiet sun in He I λ10830 reveal the presence of many small-scale dark structures of less than 30″. These structures are called dark points (Harvey, 1985) and, in many cases, are found to correspond to X-ray bright points (Harvey *et al.*, 1975).

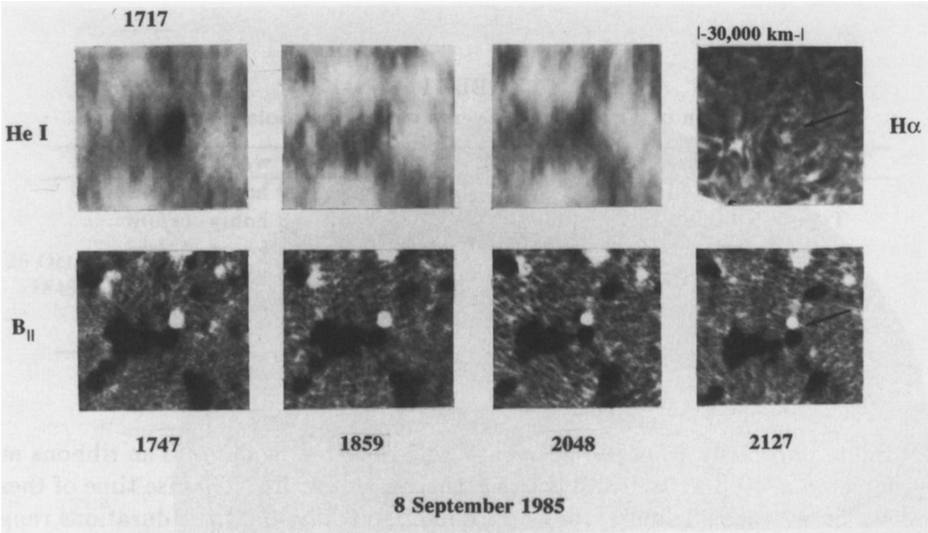

Fig. 2. Sequence of He I λ 10830 spectroheliograms and BBSO magnetograms on 8 September 1985 showing a dark point and the associated cancelling magnetic bipole. Fibrils connecting the opposite polarity magnetic elements of this magnetic bipole can be seen in the Hα filtergram at 2127 UT.

He I λ10830 dark points were studied in relation to the evolution of the photospheric longitudinal component of the magnetic field and chromospheric structures using simultaneous time-sequence images in He I λ10830 (NSO) and Hα lines (BBSO), 20 cm radio emission (Very Large Array), and of the magnetic field (BBSO) in selected areas of the quiet Sun. The cadence of these data are at least 3 min with a spatial resolution of 2–3″.

3.1. Results

The spatial scale of dark points observed in He I λ10830 are 8″ to 40″; their lifetimes range from a few minutes to hours. Rapid and strong intensity variations often occur in these structures, lasting from 9 to 40 minutes. These events are accompanied by brightenings in Hα (Harvey, 1991), C IV (Porter *et al.*, 1987), and in 20-cm radio emission (Habbal and Harvey, 1988). The characteristic flare-like intensity variations and their association with surges and eruptions of small filaments (Habbal and Harvey, 1988; Harvey, 1991) suggest that such events are flares, be it on a small scale. Almost all He I dark points are located at sites of magnetic bipoles. Two-thirds of these are cancelling magnetic bipoles, *i.e.*, where magnetic flux in the opposite polarity magnetic elements is decreasing (Fig. 2). One-third of the dark points are associated with the emergence of an ephemeral region. An investigation of simultaneous time-sequence He I, magnetic field, and Hα observations indicates that

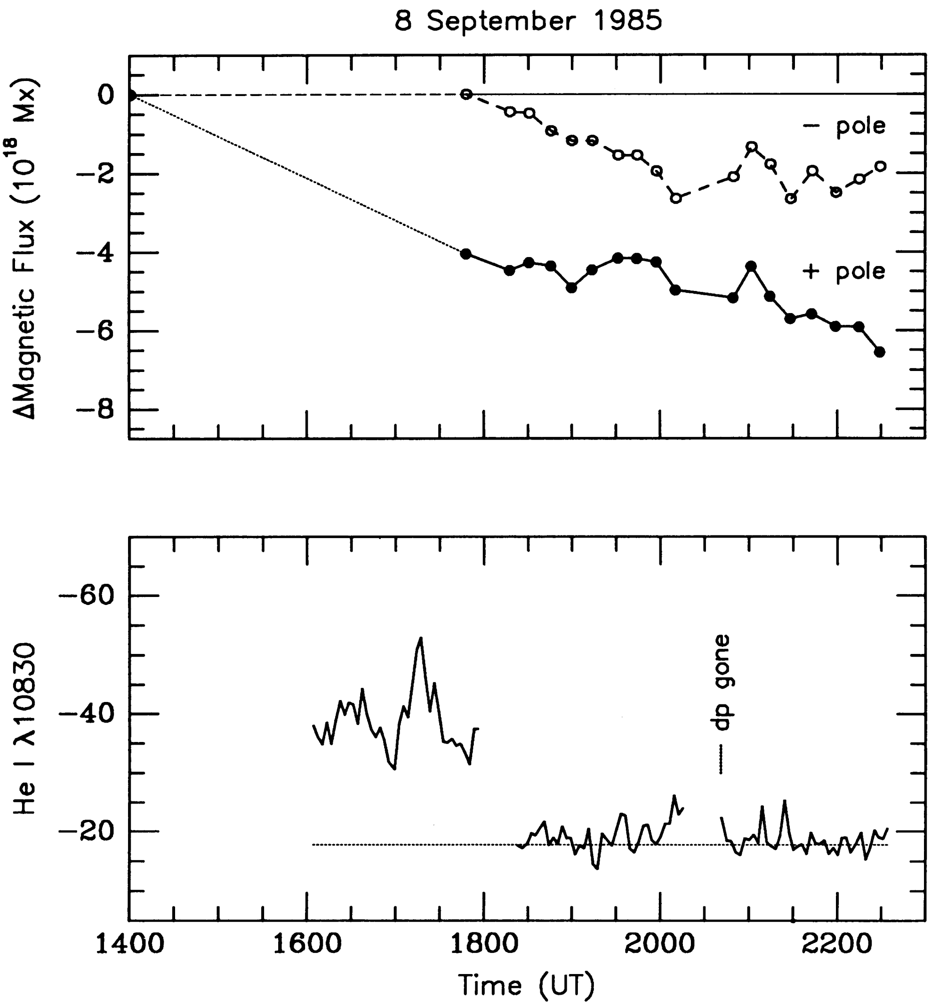

Fig. 3. Time variation of the He I λ10830 intensity (scale inverted) of the dark point in Figure 2 and the change in magnetic flux in the associated the cancelling bipole. The magnetic flux loss in this cancelling bipole is 8×10^{18} Mx over an 8.5 hr period, continuing hours after the associated He I dark point disappears.

https://doi.org/10.1017/S0074180900124271 Published online by Cambridge University Press

the cancellation or emergence of magnetic flux is not a sufficient condition for the occurrence of He I dark points. Many dark points are observed only during a fraction of the time of the magnetic field interaction, such as the event shown in Figure 2. Here, the opposite polarity network elements of the associated magnetic bipole continue to cancel several hours after the "end" of an identifiable dark point (Fig. 3). Such events suggest that their formation and evolution result from local magnetic field reconnection, rather than from the disappearance or emergence of magnetic bipoles. Further evidence of this comes from the observation (1) of the almost immediate reconnection with the nearby opposite polarity network of the magnetic fields of an ephemeral region as soon as it began emerging (Harvey, 1991), and (2) of Hα fibrils or filaments that connect the opposite polarity network elements in a cancelling bipole (Fig. 2). Once the fields have become completely reconnected, no further heating occurs and the dark point and flares cease.

Though there is a good correspondence between dark points observed He I λ10830 and X-ray bright points (Harvey *et al.*, 1975), the association found is not one-to-one (Golub *et al.*, 1989). However, this result must be viewed with caution as both He I dark points and X-ray bright points show rapid intensity variations on time scales of minutes, and there are very few simultaneous observations of these structures to reliably determine their detailed relation.

Acknowledgements

The analyses of the He I λ10830 observations was done while a Visitor at the National Solar Observatory, National Optical Astronomy Observatories (operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation). This work is supported in part through NSF Grant ATM-8319589 and under a contract with Lockheed Missiles and Space Company, Inc., through NASA Contract NAS8-37334. The NSO/Kitt Peak data used here are produced cooperatively by NSF/NOAO, NASA/GSFC, and NOAA/SEL.

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