CORONAL TRANSIENTS IN FE XIV 5303Å: FIRST TWO-DIMENSIONAL PHOTOELECTRIC GROUND-BASED OBSERVATIONS

Richard C. Altrock and Howard L. DeMastus
Air Force Geophysics Laboratory
Sacramento Peak Observatory
Sunspot, New Mexico 88349

ABSTRACT

An observational program has been undertaken at Sacramento Peak Observatory to photoelectrically detect coronal transients. Continuous observations are made in the Fe XIV 5303Å green line, utilizing the 40-cm coronagraph and the Photoelectric Coronal Photometer. Scans at three heights above the limb are combined to form a low-resolution picture of the green-line corona every 20 - 30 minutes. Difference pictures, relative to an initial scan, can be generated to search for sudden changes in the corona. The first few days of operation of this program have yielded three low-lying events (<1.55 solar radii) following minor chromospheric activity (a surge and eruptive prominences), which propagated up through the corona with velocities on the order of 100 km/s.

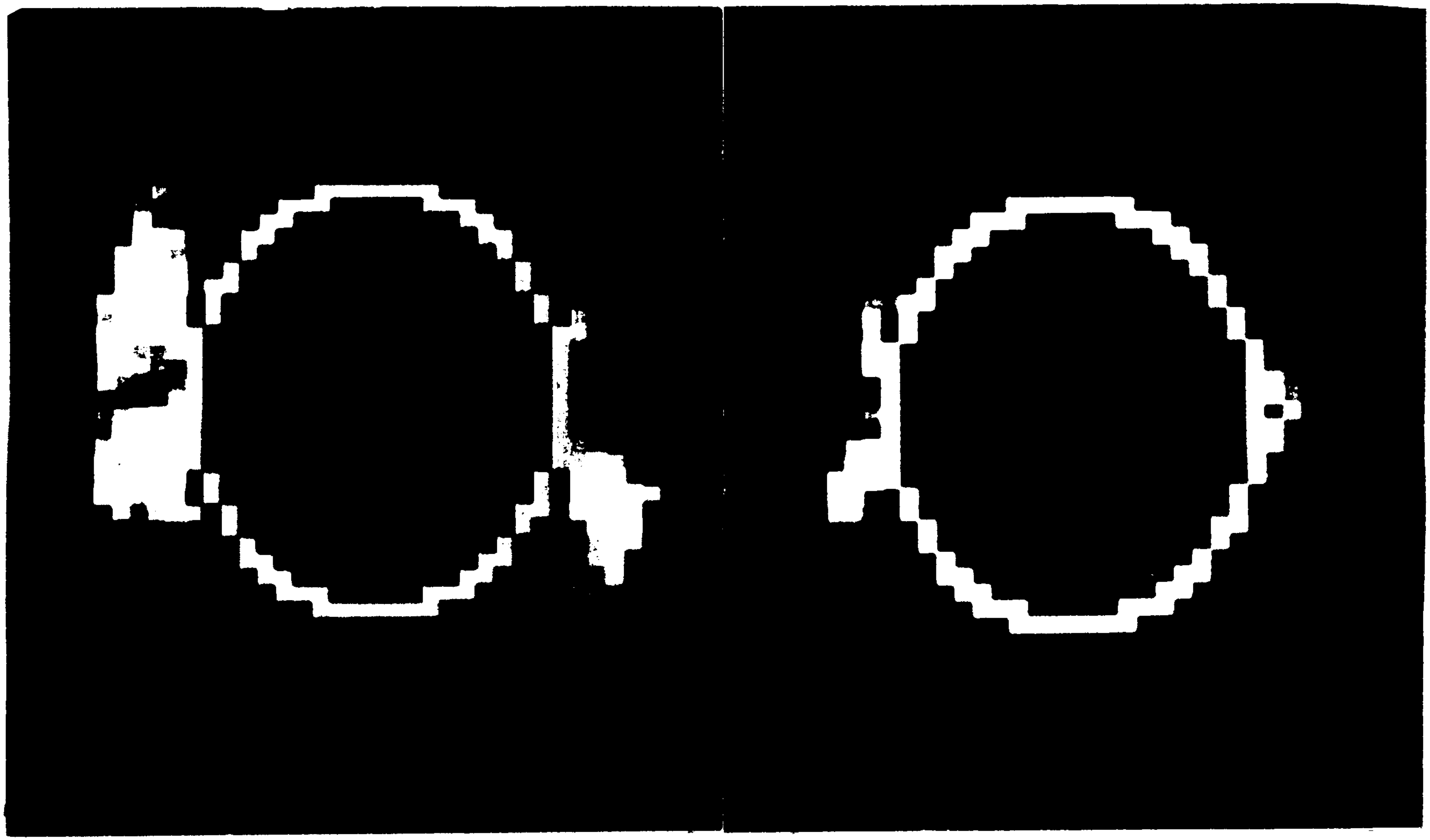
Introduction

Photoelectric observations of the corona have been made daily at Sacramento Peak Observatory (SPO) since 1975. The 40-cm-aperture coronagraph is used to form an occulted image of the corona, which passes through a narrow-band filter that spectrally chops at 100 kHz between the corona in the green line of Fe XIV 5303Å and an off-band wavelength. This technique allows the sky background contribution to be electronically subtracted. The output is sensed by a photomultiplier, digitized, and recorded. The entrance aperture of 1.1 arcmin is scanned around the limb at radius vectors of 1.15, 1.35 and 1.55 solar radii (R_o). Data points are recorded every three degrees in latitude. For further information on the instrument and the data, refer to Fisher (1973, 1974, 1978), Fisher and Musman (1975), Musman and Altrock (1978) and Altrock (1980, 1982).

The Coronal Transient Patrol

Since 1976, sporadic observations by Altrock (unpublished) and Fisher (1977) have shown that transient processes can be observed with the SPO coronal photometer. However, no systematic approach has been taken, due partially to slow data rates in the original instrument. Recent comprehensive improvements in computer control of this system have allowed much faster data acquisition rates, making systematic observations more attractive. On 15 Sep 1982 a program was started to patrol for green-line transients approximately one week each month. Every 20 to 30 minutes (depending on the time required for recentering, rezeroing, etc.) a set of scans is taken at the above three heights. From these scans, a "picture" of the corona can be generated, as in Figure 1a.

If an error in centering the image occurs prior to making a circular scan in the corona, the resultant intensity $I(\theta)$, where θ is the azimuth angle of the scan, contains additive errors $\Delta I(\theta)$ that may be expressed analytically. The only assumption required is that $I \propto R^{-a}$, where a is some positive constant and R is the radius vector. In addition to the radius errors, the analytic



(a) (b)

Figure 1. (a) A grey-scale picture of the solar green-line corona from 1.15 to 1.55 R_o taken from 14:49 to 15:10 UT on 19 Oct 1982. The bright inner circle represents the solar disk. Intensities have been scaled to yield a constant average intensity with height. Solar north is at the top and east is on the left. Note the two active regions on the east limb and one on the west limb. (b) A difference picture of the solar green-line corona, with the scan of (a) subtracted from one made from 22:02 to 22:25 on the same day. The transient discussed in the text is on the left, just below the equator (azimuth angle 105°). Two other transients are visible near azimuth angles 80° and 270°. The intensity scale is not the same as in (a).

expression can easily be modified to include changes in atmospheric and instrumental transmission from scan i to scan j. The resultant expression is

$$\Delta I_{i,j}(\theta)/I_i(\theta) = A_j + B_j \cos(\theta - \theta'_j),$$

where A_j, B_j, and θ'_j are constants to be determined by a least-squares fit to $\Delta I_{i,j}(\theta_k)$, $k = 1,\ldots,120$. Thus, each scan I_j during the day can be adjusted relative to a standard scan I_i, usually one near the beginning of the day. Figure 2 shows the result of applying this technique to all the scans on a given day.

The Transients of 19 Oct 1982

After applying the correction for image drifts and changes in instrument and sky transmission, difference pictures can be generated relative to the standard scan. Figure 1b shows such a picture for 19 Oct 1982. There was obviously at least one major change in the corona during that day, seen in the lower left hand corner of the image. In order to determine if this change could be considered a transient, as opposed to a gradual evolution or an effect of solar rotation, we first examined the SPO Hα patrol for that day.

At 17:48 UT a small bright surge on the disk occurred just inside the limb near an azimuth angle of 105° east of north. It propagated acrcss the limb to a maximum projected height of 55 Mm (1.08 R_o) with a projected radial velocity of 70 ± 10 km/s early in the event (through 18:00). In the green-line data, strong increases in intensity near azimuth angle 105° were seen at 1.15 and 1.35 R_o at 18:10 ± :24 and 18:16 ± :24, respectively (precursor activity, which will be discussed below, was seen prior to [illegible]). If we consider this main coronal intensity increase to be due to the chromospheric disturbance, the propagation velocities to 1.15 and 1.35 R_o are > 40 km/s and > 80 km/s, respectively. The inferred propagation velocity from 1.15 to 1.35 R_o is > 40 km/s. These coronal velocities are highly uncertain due to the long scan times and the difficulty of determining precisely when a "disturbance" starts at a given height.

Discussion

As the Hα surge rose above the east limb, it appeared to follow a loop-like trajectory, curving off to the south in the plane of the sky. The final configuration of the coronal event (Figure 1b) shows a nearly identical shape. Although it may not be apparent in this figure, there is evidence in the data for closure of the loop on the south side, with brightening at 1.15 R_o at 100° ± 5 and 120° ± 5 and at 1.35 R_o at 110° ± 5. In addition, there is marginal evidence for darkening in the center of the loop.

The vertical development of the main brightening appears to be consistent with a density perturbation (pressure pulse) travelling up with the surge. The surge velocity of 70 ± 10 km/s is consistent with velocities inferred from brightenings in the green-line corona (> 40 km/s). Preliminary data from the Mauna Loa Solar Observatory K-Coronameter (Fisher, 1982a) indicate enhancements up to 1.72 R_o, and perhaps higher, by 18:51, consistent with propagation velocities of 130 km/s (from the surface) to 70 < V(1.72 R_o) < 310 km/s (from 1.35 R_o).

The precursor activity referred to above was a brightening at R/R_o = 1.35 prior to 17:30 at a location directly above the site at which the surge occurred

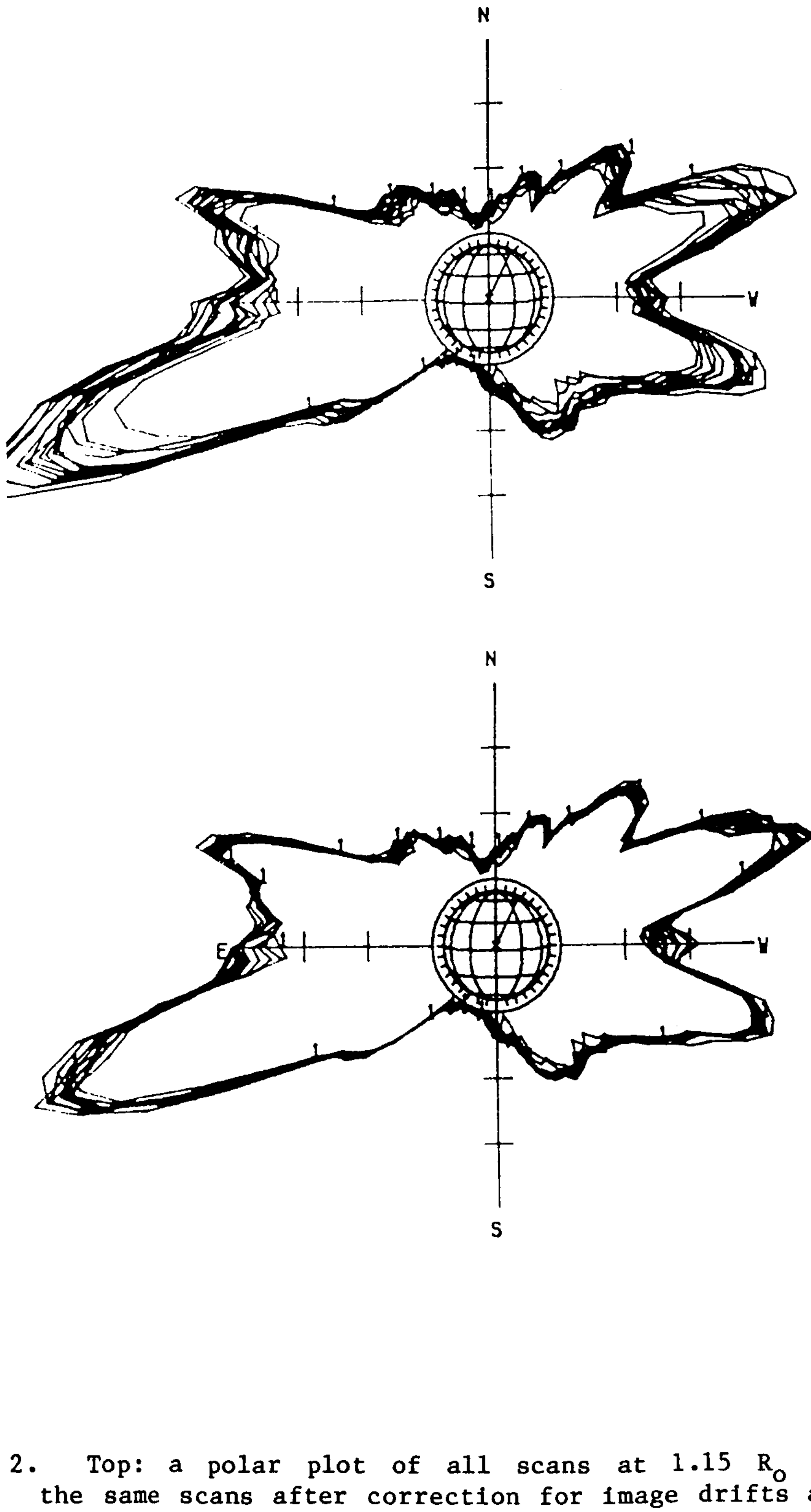


Figure 2. Top: a polar plot of all scans at 1.15 R_o taken on 18 Oct 1982. Bottom: the same scans after correction for image drifts and changes in sky and instrument transmission.

later. Similar observations by other investigators of precursors or forerunners prior to mass-ejection events appear to fit in the class of internal-energy events described by Fisher(1982b). Now, as we have seen, the main coronal intensity increase can be attributed to the mechanical effects of the rising surge. What then is the cause of the precursor brightening, which had no visible preceding Hα activity? One possibility is a density increase or heating in the corona due to magnetic activity prior to the surge. If such a physical connection does exist between the precursor and the surge, we may be seeing evidence for the first time of coronal magnetic-field activity as the cause of surges.

The qualitative model would then be: (i) Coronal magnetic-field activity causes a density increase or heating in the corona, which is reflected in green-line brightening; (ii) This same coronal magnetic-field activity creates an instability in the chromosphere that results in the expulsion of matter ("melon-seed" model?) into the corona (the surge); (iii) As the surge rises through the corona, the pressure pulse connected with it compresses the coronal material, causing the second, main brightening.

Finally, we note in passing that the two other brightenings of that day (cf. Figure 1b) on the west and northeast limbs also have associated Hα activity (eruptive prominences) and therefore also qualify as coronal transients. The coronal manifestations of these events at 1.15 R_o appear to have propagation velocities of < 140 km/s.

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