SPECTROSCOPIC OBSERVATIONS OF CORONAL EMISSION LINES AND THEIR RELATION TO SOFT X-RAY IMAGES

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Abstract

Spectroscopic observations of coronal emission lines were carried out to obtain the plasma distribution at different temperatures. Images in FeXIV5303Å(green), FeX6374Å(red) and CaXV5694Å(yellow) are compared with the soft X-ray images taken with the Soft X-ray Telescope on board Yohkoh. It is found that the distributions of green and red lines are quit different from that of the soft X-rays, while the yellow line shows quite similar distribution.

1. Introduction

One of the important initial finding of the Yohkoh Soft X-ray Telescope (SXT) is the existence of high temperature plasma of 5-6 million degrees in the active region corona without flares (Hara et.al 1992). After the launch of Yohkoh, the SXT revealed spectacular images of the solar corona with a variety of dynamic phenomena (Tsuneta 1993, see also the Yohkoh special issue of Publ.Astron.Soc.Japan, 44, 1992). The images obtained with SXT, however, may represent rather high temperature parts of the corona because of its instrumental characteristic of the X-ray sensitivity. On the other hand, ground based coronal emission lines. Spectroscopic observations of the emission lines also enable us to study the plasma motions associated with the coronal phenomena. Therefore the observations by coronagraphs in cooperation with Yohkoh are expected to provide valuable information for understanding the physical processes of the coronal phenomena found by SXT. In this paper we give an outline of a recent coronagraph observation at the Norikura Solar Observatory and describe an initial study of coronal temperature distribution by comparing the coronal images obtained with the coronagraph and the Yohkoh SXT.

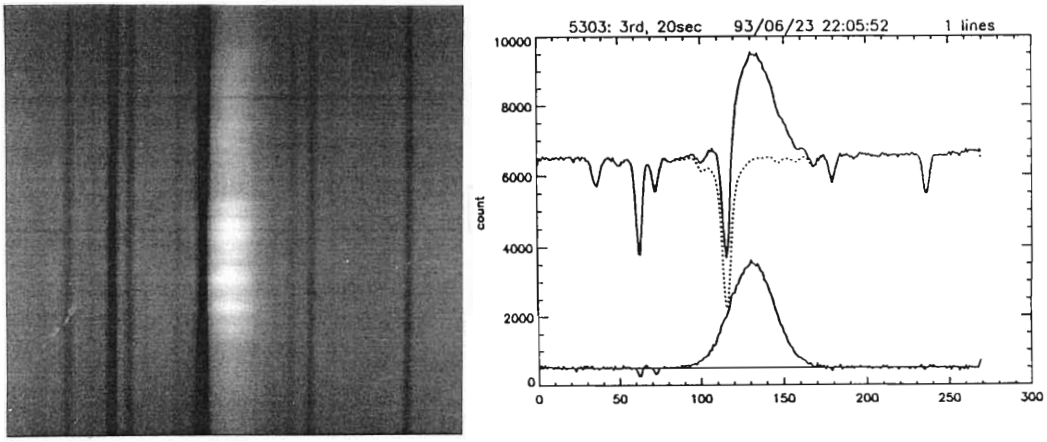

Fig. 1. a. An example of the green line spectrum. b. Profiles of the original spectrum (upper), the scattered light (dashed) and the emission (lower).

2. Coronagraph Observation and Data Reduction

Spectroscopic observations of the coronal emission lines were carried out at the Norikura Solar Observatory in June, 1993. Observation instruments consist of the 25-cm Coude type coronagraph, the Littrow type spectrograph and a low noise CCD camera. The CCD camera has 512×512 pixels and covers 500" along the entrance slit of the spectrograph and 7-15Åin wavelength, depending on the lines and the order of the used spectra. By changing the inclination of a glass block that is placed in front of the slit, successive spectra were obtained at different positions of the corona to get their two-dimensional distribution. Observed spectral lines are FeXIV 5303Å(green), FeX6374Å(red) and CaXV5694Å(yellow), which are sensitive to the coronal temperatures of 2MK, 1MK and 3.5MK respectively (Arnaud and Raymond, 1992). Figures 1a and 1b show an example of the green line spectrum. Typical exposure time is 10-20 sec. In figure 1b, the upper profile shows the original spectrum. After subtracting the sky component (dashed line) which is reproduced from a spectrum of the defocused solar disk image, we obtain the emission profile as shown by the lower curve in figure 1b. By fitting it with a gaussian, we can derive the peak intensity, central wavelength and the width of the emission line for each point of the corona. The spatial resolution is about 2×3 arc seconds. after 2 pixel-binning is applied in the slit direction. Red line heliograms are also obtained in the same way. In the case of the yellow line, however, only the integrated line intensity is determined because of its low signal level against the scattered light.

3. Results

Figure 2c Shows the distributions of the green line intensity obtained on June 23, 1993, and figure 2d shows its enhanced image by applying the unsharped masking method. Figure 2a and 2b show the corresponding soft X-ray image obtained with SXT using the A10.1μm filter and its enhanced image, respectively. It is obvious that the green line and the X-rays show quite different distributions. The green line shows that the corona is composed of many thin loops or streaks, while the X-ray corona shows more diffuse distribution. Some faint structures seem to correspond each other, but the distributions seem to be even exclusive in some parts.

In the same way, figures 3a-d give the X-ray and red line images obtained about 3 hours later than those of figure 2. Again we can notice quite different distributions between

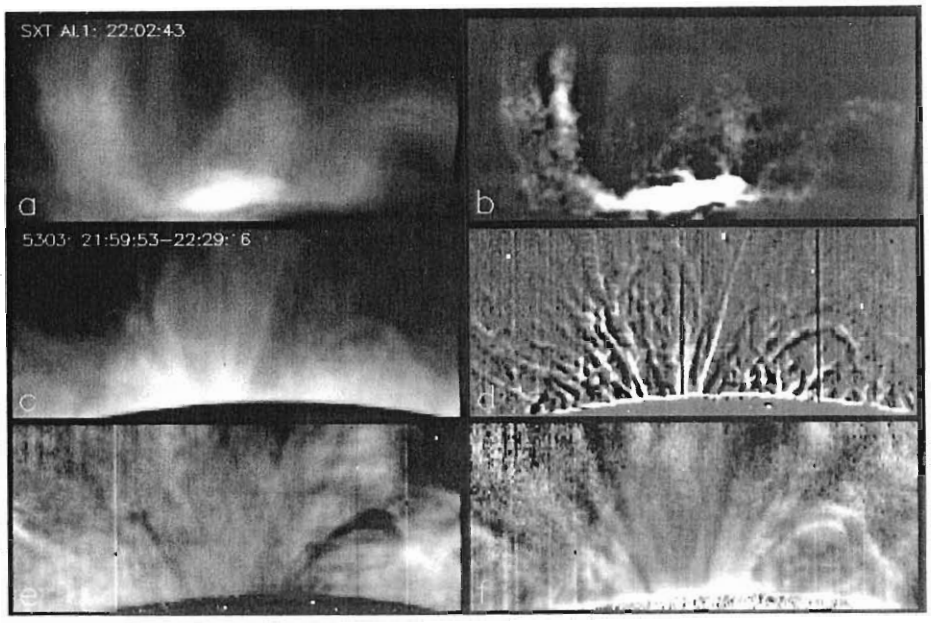

Fig. 2. Soft X-ray and green line images obtained on June 23, 1993. For detail, see the text.

them. The red line distribution is also different from that green line. Unfortunately, the following yellow line observation was interrupted by clouds, but we could notice from a partial image that the yellow line and the X-rays show quite similar distributions. A better example of the yellow line image was obtained on June 22. Figures 4a and 4b show the soft X-ray image and the corresponding yellow line image. We can confirm the good coincidence between their distributions. It may be worth to note here that, though the green and red lines show smaller structures than the X-rays, the X-ray source is more strongly concentrated in the center of the active region in a global sense.

Figures 2e and 2f and figure 3e and 3f give the distributions of the line of sight velocity and the line width obtained from the green and red lines, respectively. We can notice systematic motions in both of the velocity maps, especially in the loop-like structure in the right part. The amplitude is about 5km/s. In the map of the line width of the red line, we can also notice a concentrated region which shoes broad emission line profiles. The width corresponds to the thermal motion of the iron with the temperature of 3.5MK. Because the red line dose not emit effectively at this temperature, the broadening should be attributed to a turbulent motion of about 30km/s. At the same time, SXT observed a rapid loop expansion that may be the initiation of a coronal mass ejection (Hudson,1993 private communication). The plasma motion observed in green and red lines may be associated with this transient phenomena. Further investigations are required.

4. Discussions

We have described the initial study of the coronagraph images by comparing them with the Yohkoh soft X-ray images and have shown how the coronagraph data can provide valuable information to understand the physical processes in the corona. The most important result is that the high (~5MK) and low (1-2MK) temperature plasmas do coexist in the corona and the low temperature plasma shows a quite different distribution from that of the high temperature plasma. For active region corona, the SXT images effectively represent the high temperature corona as proved by their good correspondence with the yellow line images.

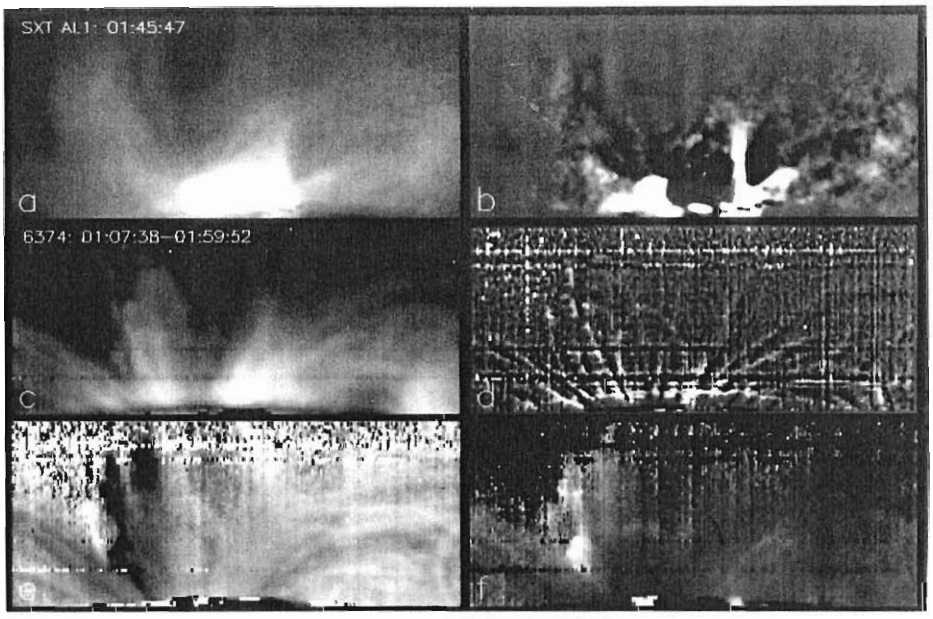

Fig. 3. Soft X-ray and red line images obtained at about 3 hours later than those in figure 2. For detail, see the text.

Fig. 4. Soft X-ray (a), yellow line (b) and green line (c) images obtained on June 22, 1993.

Further quantitative analysis and the coordinated observations are of vital importance to strengthen this conclusion. It should be mentioned, however, that the coronagraph images presented here were obtained with a spectrograph by scanning the corona and it took more than 30 minutes to complete one image. The time resolution should be improved in future observations by developing a new instrument. One possible solution is the use of the Fabry-Perot interferometer.

References

1. Arnaud, M. and Raymond, J., 1992, *Astrophys. J.* **398**, 394
2. Hara, H., Tsuneta, S., Acton, L.W., Lemen, J. R., and McTiernan, J. M., 1992, *Publ. Astron. Soc. Japan* **44**, L135
3. Tsuneta, S., 1993, in 'Proceedings of the Fourth International Conference on Plasma Physics and Controlled Nuclear Fusion', p. 75