DIFFERENTIAL IMAGING OF [Fe X] in IC 443

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Abstract: This paper presents images of two areas of the supernova remnant IC443 showing emission from the [Fe X] 6374Å red coronal line taken with an emission line differential imaging camera. The areas are in the vicinity of strong soft X-ray emission as observed with the Einstein Observatory. The [Fe X] emission is patchy on the scale of seconds of arc. For the highest emission regions we find an electron density of approximately 100 cm^{-3} and gas pressures of $10^8 cm^{-3} K$. No correlation is found between the X-ray and [Fe X] knots, and the results support a clumpy, multi-temperature region where the [Fe X] knots are balanced between collapse and evaporation.

Introduction

The middle-aged supernova remnant IC443 is interacting with a large dense interstellar cloudy region, as shown by optical, radio, infra-red and X-ray observations. The X-rays show a hot gas ($T \simeq 1.8 \times 10^7 K$) in the interior of the remnant, suggesting a blast wave when the gas was heated to 1100 km/s (Petre et al., 1987). The highest radial velocities observed for individual optical filaments is 220 km/s (Losinskaya, 1979). Evidence for intermediate temperature regions was obtained by detection of the [Fe X] 6374Å red coronal line (Woodgate et al., 1979) which requires a temperature of $1.2 \times 10^6 K$. We present observations in [Fe X] of the maximum soft X-ray region to investigate the relationship between the two temperature regions.

Observations

The two regions shown in Figure 1 were observed using the differential camera at the NASA/Goddard Space Flight Center 36-inch Telescope. On-band and off-band images through 6Å FWHM filters were observed using the 100x100 pixel photon-counting imager with an S-20 photocathode, and the difference image obtained. The fluxes obtained are shown in Table 1 for Region A. Figure 1 shows the positions of these knots detected in [Fe X] above 3σ compared to the Einstein Observatory HRI X-ray contours (shown in white). The field-of-view is 5 arcmin 50 arcsec. The 3σ surface brightness contour level is 1.5×10^{-6} erg $cm^{-2} s^{-1} sr^{-1}$.

For comparison with these [Fe X] observations, the Einstein HRI original data was remapped and binned to 10 arcsec to obtain

TABLE 1

Summary of Observed [Fe X] Data

Position RA sec	Position Dec "	Surface Brightness Max (10^{-6} ergs cm^{-2} s^{-1} sr^{-1})	Area# 3sd $arcsec^2$	Area# 2sd $arcsec^2$	Statistical Significance of Max(sd)
Region A 06:14:00	+22:50:00 [1950.0]				
E1 +8.0	+ 16	2.8 ±.5	221	453'	5.2
SE +5.2	- 47	2.6 ±.5	147	294	5.2
E2 +5.0	- 9	1.8 ±.5	122	221f	3.6
S" -1.1	-103	3.1 ±.6	49	147	5.0
W -3.1	+ 9	1.5 ±.5	208	281f	3.1
NW -3.6	+ 93	2.5 ±.4	282	355'	6.1
WS -7.4	- 16	1.8 ±.5	134	208	3.5
SW -8.7	-100	2.7 ±.5	98	172f	5.6
NWC -8.7	+114	2.9 ±.4	208	417'f	6.9
WN -9.7	+ 54	3.1 ±.5	245	380	5.9
Total positive values:		0.143±.024			
values above 3sd:		0.038±.013			

Notes: ' Source may extend further. f Filamentary.
" Probably not a source. x Extends around star.
Area covered by values above 3sd or 2sd.

TABLE 2

Summary of [Fe X] Calculations

Position	Surface Brightness Max(10^{-6}) (ergs cm^{-2} s^{-1} sr^{-1}) Obser.	Absor. Cor.'	Depth Pc" (±.02)	ne cm^{-3}	Pe (10^8) (cm^{-3} K)
Region A 06:14:00	+22:50:00 [1950.0]				
E1	2.8±.5	35.	0.13	83.	1.0
SE	2.6±.5	33.	0.10	89.	1.1
E2	1.9±.5	24.	0.09	82.	1.0
S	3.1±.6	39.	0.07	120.	1.4
W	1.6±.5	20.	0.11	67.	0.8
NW	2.5±.4	31.	0.12	80.	1.0
WS	1.9±.5	24.	0.09	81.	1.0
SW	2.7±.5	34.	0.08	100.	1.2
NWC	2.9±.4	36.	0.10	95.	1.1
WN	3.1±.5	39.	0.12	92.	1.1

Note: ' Corrected for interstellar absorption by factor 12.5
" Based on width at half of peak standard deviation.

accurate positions of the brightest points. No overlaps between the [Fe X] and X-ray bright points were found with a positional accuracy of 10 arcsec, although the [Fe X] knots are found in the region of generally high X-ray emission on the smoothed contour maps.

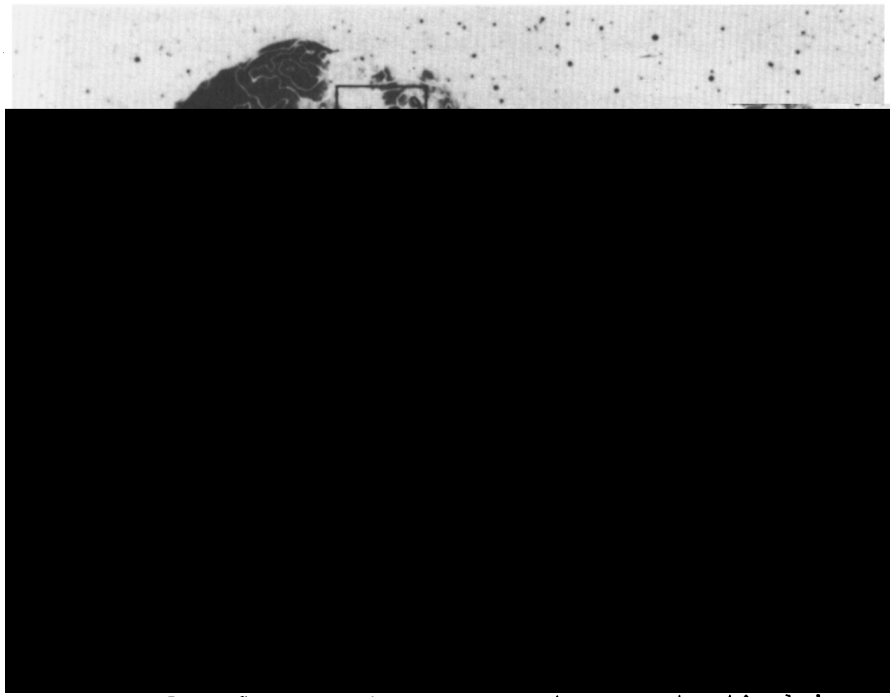

Figure 1. [Fe X] knots with X-ray contours and optical image.

Discussion

Petre et al. (1987) give N(H) = 6.5 x 10^{21}cm^{-2} for the interstellar gas absorption from the Einstein Solid State Spectrometer data. A normal gas to dust ratio would predict an absorption factor due to dust of a factor 12.5 for the [Fe X] line. Applying this correction, and assuming spherical knots, we estimate the diameters and electron densities in the knots. These are shown in Table 2.

We calculate the lifetime of these knots:

The lifetime against radiative cooling is given by

$$t_{cool} = 3kT/2E\ n_e$$

where the total emissivity E' = 1.5 x 10^{-22} erg cm^{3}s^{-1}.

For the average electron density in Table 2, t_{cool} = 600 yrs. If the knots are embedded in the less dense, hotter plasma as