

Far Ultraviolet Spectral Images of the Cygnus Loop Observed with SPEAR/FIMS

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Abstract. We present far-ultraviolet spectral images of the entire Cygnus Loop, observed with the Spectroscopy of Plasma Evolution from Astrophysical Radiation (SPEAR) instrument, also known as FIMS, onboard the first Korean Science and Technology SATellite, STSAT-1. The emission line maps of C IV 1550Å, He II 1640Å, Si IV/O IV] 1400Å, and O III 1664Å were made by fitting the spectra in each pixel with Gaussian line spread functions and a constant background. The spectral maps were subsequently smoothed with an adaptive smoothing algorithm. The spatial distributions of FUV emissions generally correspond to a limb-brightened shell and are similar to optical, radio and X-ray images. The features found in the present work include a “carrot”, diffuse interior, and breakout features, which have not been seen in previous FUV studies. The images provide the first complete global morphology in FUV spectral line emissions of the remnant.

1. Introduction

The Cygnus Loop is one of the best-studied supernova remnants (SNRs) in our galaxy because of its large apparent angular size, its high surface brightness, and its low reddening. It is generally considered the prototypical “middle-aged” SNR. Global features of the Cygnus Loop have been studied in great detail at optical, X-ray, radio, and infrared wavelengths (Levenson et al. 1998; Aschenbach & Leahy 1999; Leahy, Roger & Ballantyne 1997; Arendt, Dwek & Leisawitz 1992). Observations of far-ultraviolet (FUV) emission have played an important role for the reliable estimation of shock speeds and elemental abundances.

We report the first FUV spectral line images of the entire Cygnus Loop. These images, with spatial resolution of 3' to 30', were obtained with *SPEAR* (The Spectroscopy of Plasma Emission from Astrophysical Radiation), also known as *FIMS* (Far-ultraviolet IMaging Spectrograph).

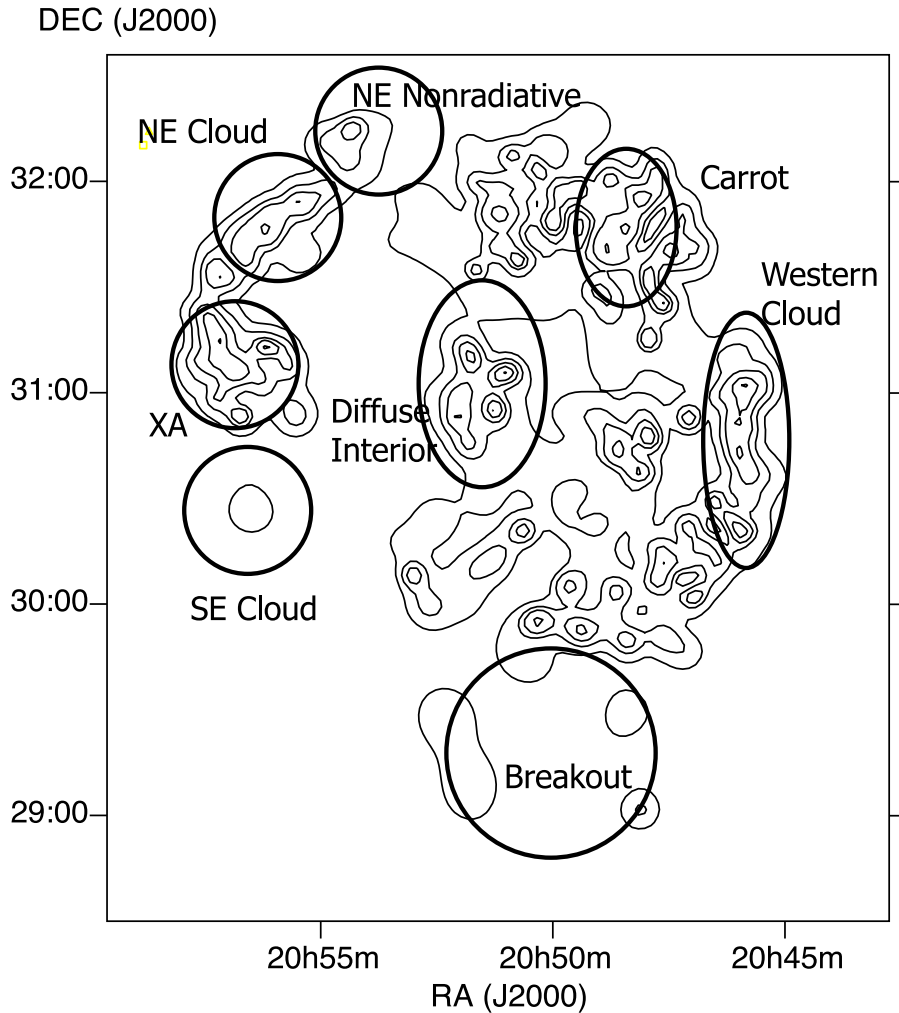


Figure 1. Contours of C IV ($\lambda \sim 1550\text{\AA}$) emission intensity of the Cygnus Loop. Thick solid lines identify characteristic features.

2. Observations and Results

SPEAR is a dual-channel FUV imaging spectrograph (Short channel ‘S’: 900–1150Å, Long channel ‘L’: 1330–1720Å, $\lambda/\Delta\lambda \sim 550$) with a large field of view (S channel: $4.0^\circ \times 4.6'$, L channel: $7.5^\circ \times 4.3'$), designed to observe diffuse FUV emission lines.

The Cygnus Loop was observed during 30 orbits between July 12 and July 22, 2004. Of these, we used 11 orbits that include reliable attitude knowledge of $\leq 30'$. All the photon events near the locations of the 11 brightest TD-1 stars were removed to avoid stellar contamination. To generate a net emission-line image, we fitted the spectrum in each pixel with a constant continuum plus a spectral resolution-width Gaussian function, fixed at the corresponding emission line center. To estimate the surface brightness distribution as well as possible, we

rebinned the images using a Gaussian function with a position-variable angular scale through an adaptive kernel method. The resulting C IV emission map is shown in Figure 1, together with the names of characteristic SNR features.

References

- Arendt, R., Dwek, E., & Leisawitz, D. 1992, *ApJ*, 400, 562
Aschenbach, B., & Leahy, D. A. 1999, *A&A*, 341, 602
Levenson, N. A., Graham, J. R., Keller, L. D., & Richter, M. J. 1998, *ApJS*, 118, 541
Leahy, D. A., Roger, R. S., & Ballantyne, D. 1997, *ApJS*, 118, 541