THE X-RAY SPECTRUM OF THE CYGNUS LOOP WITH GSPC

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We observed the Cygnus Loop with Gas Scintillation Proportional Counter (GSPC) on board Tenma satellite. GSPC has an energy resolution two times better than that of a proportional counter (PC). Fig. 1 shows the spectrum with the crosses being the pulse height data with $\pm 1\sigma$ statistics. Superposed upon the data point is the best fit model spectra folded through the detector response. We found that two emission line features at 1.9 keV and 2.5keV, respectively corresponding to Si-Kα and S-Kα line blends, are needed to obtain an acceptable fit. The parameters for the emission lines are summarized in table 1. The abundances of these elements are consistent with those of cosmic values. The continuum spectrum in the energy range 1~3 keV can be represented with thermal bremsstrahlung spectrum with an electron temperature T_e of 7×10^6K.

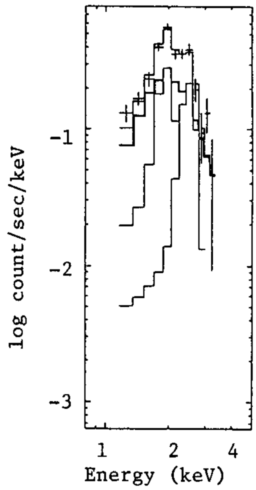

Fig. 1. X-ray spectrum observed with Tenma are shown with crosses.

Table 1. Emission line features in the Cygnus Loop

Element	Intensity (photonssec^{-1}cm^{-2})	Line energy (keV)
Si Kα	$8.4\pm2.3\times10^{-3}$	1.92 ± 0.04
S Kα	$2.7\pm1.0\times10^{-3}$	2.45 ± 0.06

Errors are 90% confidence level.

We performed a sounding rocket experiment in 1977 with GSPC (Inoue et al. 1979) and obtained the Loop spectrum in the energy range of 0.1~1.5keV. Combined the results with the sounding rocket flight shown in fig. 2 gave us a wide band of X-ray spectrum for the whole Cygnus Loop with the best energy resolution reported so far.

We fitted the combined data with model spectra based on the atomic data compiled by Raymond and Smith (1977). The model spectra employed here are both for collisional ionization equilibrium (CIE) and non-equilibrium ionization (NEI) models with cosmic abundances (Allen, 1977). Single T_e spectrum for both models can not fit the data. Two components of different T_e models can reproduce the data well for both models. The physical parameters obtained with CIE models are self inconsistent because the ionization parameter τ (the electron density n $\times$ the elapsed time t the after shock heating) is about 10^{11}cm^{-3}sec which is too short by an order of magnitude for the CIE condition to be reached.

Superposed upon the data point in fig. 2 is the best fit NEI model spectra.

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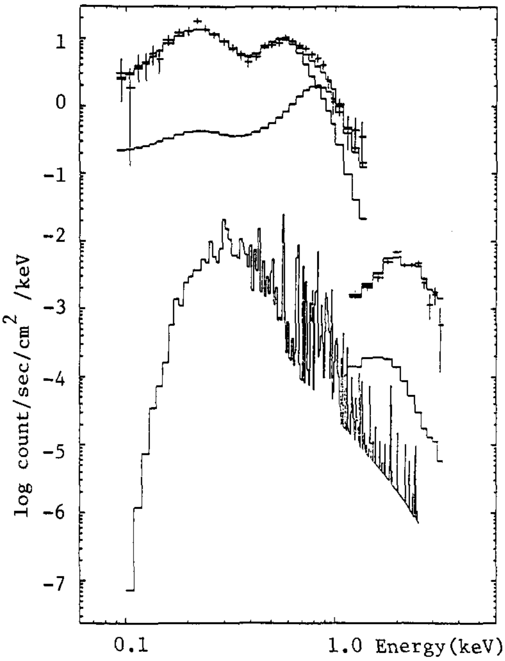

Fig. 2. Wide band X-ray spectrum for the whole Cygnus Loop with GSPC. Superposed the best fit NEI model spectra with two T_e components.

The model spectra contain two component of thin thermal spectra with different T_e and τ. The 90% confidence level contour in $\log\tau$-T_e plane are shown in fig. 3.

Previous observations so far with employing PC reported that the Cygnus Loop could be represented with a single T_e component of $2\sim4\times10^6$K (Gorenstein et al. 1971). The high spatial observation of the Loop with the Einstein Observatory (Charles et al.1985) found T_e in the limb to be lower than that of the interior. Vedder et al. (1986) observed a limited portion of the Loop with FPCS on the Einstein Observatory and found that the CIE condition has not been reached. Their results are shown in fig. 3 in dashed line.

From this context, we conclude that the low T_e component is from the shell region while the high T_e component from inside the Loop, since both of them are thermal in origin. If the width of the shell region is assumed to be R/12 from the strong shock theory, where R is the radius of the Loop, we found that n for low and high T_e plasma are $0.25\sim0.6$ cm^{-3} and $0.06\sim0.07$ cm^{-3}, respectively. The obtained range of τ restricts t as t $\geqq$ 2.5×10^4years.

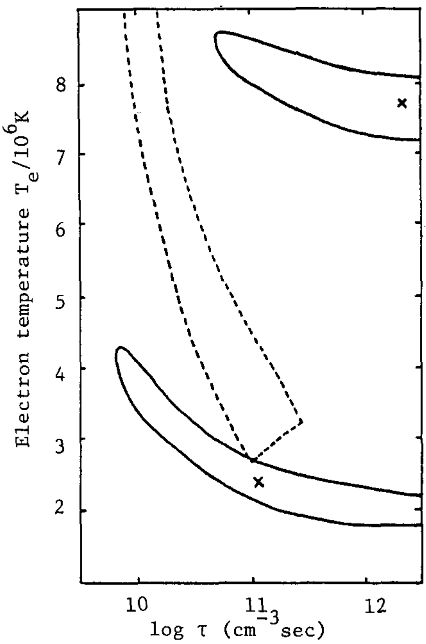

Fig. 3. Solid lines show 90% confidence level contour for the NEI model parameters. See text.

References

Allen, C. W. 1973, Astrophysical Quantities.
Charles, P. A., Kahn, S. M., and McKee, C.F. 1985, Ap. J., 295 456.
Gorenstein,P., et al. 1971,Science, 172 369.
Inoue, H., et al. 1979, X-ray Astronomy, (Oxford, Pergamon Press.) 309.
Raymond, J. C., and Smith, B. W., 1977 Ap. J., suppl., 35 419.
Vedder, P. W., et al. 1986, Ap. J., 307 269.