NASA-CR-199391

FINAL
IN-89-CR
OCIT-
67513
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A Deep PSPC Observation of the Cyg OB2 Association

FINAL REPORT

Submitted to:

Contracting Officer
Code 286
NASA/Goddard Space Flight Center
Greenbelt, MD 20771

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Contract No.: S-39746-Z (ARC #1282)

ARC Report #: R95-242

Date: September 27, 1995

CONTRACT: S-39746-Z (ARC # 1282)

TITLE: A Deep PSPC Observation of the Cyg OB2 Association

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SUBJECT: Final Report

START DATE: July 7, 1994

DELIVERY DATE: 18 Months from start of Contract

INTRODUCTION:

The Cyg OB2 Association contains six of the fifteen most luminous stars in the Galaxy (Humphreys 1978) as well as the most luminous and most heavily reddened Galactic star, Cyg OB2 #12. In addition, the association contains a number of Wolf-Rayet stars, at least one early-type binary (Cyg OB2 #5), and a trapezium-like system (Cyg OB2 #8). Though not physically associated with the association, the X-ray source Cyg X-3 lies within a half degree of the center of the association. The association is a known source of X-rays (Harnden et al. 1978). The X-ray emission from this region includes a contribution from Cyg X-3, as well as coronal emission from OB stars and hot diffuse gas. The region was extensively sampled by the HEAO-2 IPC (136 ks, which includes a single pointing of 57 ks on the central region of the association). A 3.6 ks PSPC observation of this region was obtained in the AO1 pointing phase. In addition, the four brightest OB stars (Cyg OB2 #5, #8A, #9, and #12) have been extensively monitored with the VLA. These stars show evidence of strong radio variability, and nonthermal radio emission characteristics (Bieging et al. 1989). Several of these radio observations were taken within about a month of an IPC observation, and the two PSPC observations.

SCIENCE OBJECTIVE:

We obtained a 19.5 ks exposure of the Cyg OB2 Association using the ROSAT PSPC instrument As primary CoI, my scientific tasks included:

(1) extracting the PSPC spectral distributions of the brightest OB stars (Cyg OB2 #5, #8A, #9, and #12);
(2) comparing the 19.5 ks spectral data with the 3.6 ks spectral data;
(3) investigating the long term X-ray variability (15 years), and;
(4) comparing the X-ray and radio variability.

(1) Data Extraction: The PSPC spectral distributions for the four stars were extracted following

the procedure as outlined at the GSFC ROSAT Guest Observer Facility. The observed PSPC spectra for PSPC image 900314P are shown in Figure 1 and the counting statistics are given in Table 1 for the two PSPC pointings. Although the results in Table 1 indicate that three of the four stars changed in intensity over the two year time span, the change is < 20%, consistent with the general finding that the X-ray emission from OB stars is relatively constant (Berghofer & Schmitt 1994). The exception being Cyg #8A were it is noted an increase of ~ 33% occurred.

(2) Spectral Fitting: All four Cyg OB2 OB stars suffer a very large ISM attenuation, with ISM column densities of order > 10^{22} cm^{-2}. We obtained ISM best fit models to both PSPC pointings. In a log T - log N_{ISM} fitting procedure, for Raymond-Smith emission models, the 90% and 99% confidence contours for the two pointings show substantial overlap in the log T - log N_{ISM} parameter space for all four stars. The observed N_{ISM} values lie within the overlapping regions suggesting that the two spectra for each star are consistent with a single fixed model. The exception was Cyg #8A were it was found that although the N_{ISM} (a value about a factor of 2 larger than the observed N_{ISM} was required) value was consistent for the two pointings, significant changes in T and emission measure (EM) were required (see Table 2). We also attempted to include the effects of stellar wind absorption as described in Waldron (1984). However, due to the large ISM column densities, we conclude that the wind column densities are constrained to be < $2x10^{22}$ cm^{-2}.

The best fit ISM models, consistent with both pointings, are given in Table 2 (the first entry is for image 200109P and the second is for 900314P). Comparison of the models with the observed spectra are shown in Figure 1. We have assumed a distance of 1.8 kpc and bolometric luminosities given by Bieging et al . (1989). The observed values of N_{ISM} are obtained using the relation $N_{ISM}/E(B-V) = 5.2x10^{21}$ (Shull & Van Steenberg 1985). The values of E(B-V) are from Abbott et al. (1984). We estimate that the errors in the observed N_{ISM} are of order of 50%. The EM is defined as the volume integral of n_e^2 (where n_e is the electron number density). The errors in the derived quantities are < 20%.

(3) X-Ray Variability: Our spectral analysis of the two PSPC pointings suggest that no significant long term variability over the two year span occurred except for Cyg OB2 #8A, where a decrease in T and an increase in EM was required, resulting in a ~ 20% increase in observed flux (see Table 2). We searched for short term variability (hours) and none was apparent in any of the four stars. We merged our PSPC observations with the earlier IPC data to obtain a 15 year baseline. The IPC data were collected from Harris et al. (1990). The IPC count rates were converted to flux units using the counts-to-flux conversion factor obtained by spectral fitting the long exposure (57 ks) IPC image #4221. It was found that the IPC best fits were also consistent with the PSPC fits. To ensure consistency, the observed fluxes were integrated over the same energy band pass (0.1 - 5.0 keV). The results are shown in Figure 2. This shows that, in general, the four stars have not varied by more than 20% over the past 15 years, consistent with the findings of Berghofer & Schmitt (1993) for other OB stars. The exception is Cyg OB2 #5 were a substantial flux increase (> 2) occurred in 2 IPC pointings. This is not too surprising since this is a known contact binary (Bohannan & Conti 1976) with a period of 6.6 days (Hall 1974).

(4) Comparison of X-ray and Radio Variability: All four of these stars have demonstrated

nonthermal radio emission characteristics (Bieging et al. 1989). We have included the observed 6 cm radio emission in Figure 2 for a time comparison with the X-ray emission. Unfortunately, both data sets are under sampled, but the results in Figure 2 suggest that the radio emission variability is significantly larger than the X-ray variability, and there is no hint of any correlative behavior. These results suggest that it would be highly advantageous to monitor both the radio and X-ray emission over a fixed time frame to determine whether the mechanism responsible for the nonthermal radio emission is related to the X-ray emission.

CONCLUSIONS:

(1) The PSPC spectra of the four brightest Cyg OB2 OB stars suggest the observed X-ray emission is consistent with an X-ray source at a log T ~ 7.0 attenuated by the observed ISM column density. The observed ratio of X-ray flux to bolometric flux ($\sim 10^{-7}$) is consistent with the general result for other OB stars.

(2) The X-ray emission has remained relatively constant (within 20%) for more than 15 years. The exception being the contact binary Cyg OB2 #5. There is no evidence of short term (hours) variability in any of these stars.

(3) The radio variability is substantially larger than the X-ray variability and the variability does not appear to be correlated.

The results of this study will be submitted to *The Astrophysical Journal* for publication within the next few months.

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TABLE 1. PSPC Counting Statistics for Cyg OB2 Association

Star	PSPC Image	Date	cnt/s	S/N
Cyg #5	200109P	4/21/91	0.1187±0.0061	19.8
	900314P	4/29/93	0.1141±0.0026	45.7
Cyg #8A	200109P	4/21/91	0.2025±0.0079	25.8
	900314P	4/29/93	0.2699±0.0038	71.4
Cyg #9	200109P	4/21/91	0.0404±0.0039	10.8
	900314P	4/29/93	0.0341±0.0016	23.3
Cyg #12	200109P	4/21/91	0.0708±0.0048	15.3
	900314P	4/29/93	0.0604±0.0019	32.6

TABLE 2. Best Fit ISM Models for the 4 Cyg OB2 OB Stars

Star	E(B-V)	observed log N_{ISM}	log L_{Bol}	log T	log EM	observed log L_x	corrected log L_x	reduced χ^2
Cyg#5	2.00	22.02	40.01	7.08	57.02	32.84	33.70	0.72
				7.08	57.02	32.85	33.70	1.00
Cyg#8A	1.60	22.22*	39.88	6.75	57.89	33.05	34.80	0.43
				6.66	58.20	33.15	35.05	0.77
Cyg#9	2.20	22.06	40.19	7.16	56.62	32.41	33.20	0.44
				7.12	56.56	32.35	33.20	0.75
Cyg#12	3.20	22.23	39.79	7.03	57.14	32.70	33.91	0.90
				7.08	57.13	32.72	33.81	0.33

*The observed log N_{ISM} is 21.92, but acceptable fits at this value could not be obtained.

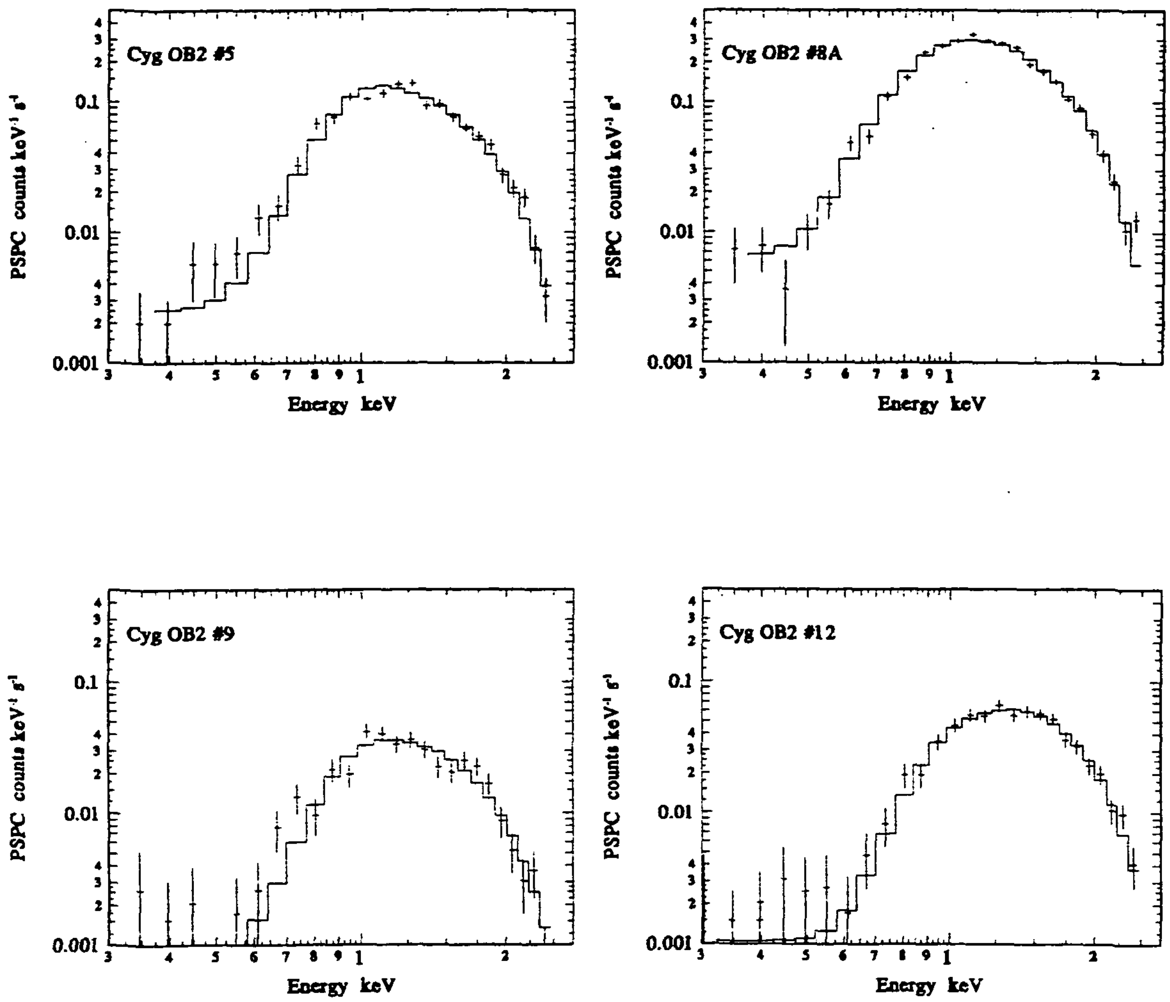

Figure 1. The extracted 900314P PSPC spectra for the four Cyg OB2 Association stars. The best fit ISM models are shown. The best fit parameters are given in Table 2.

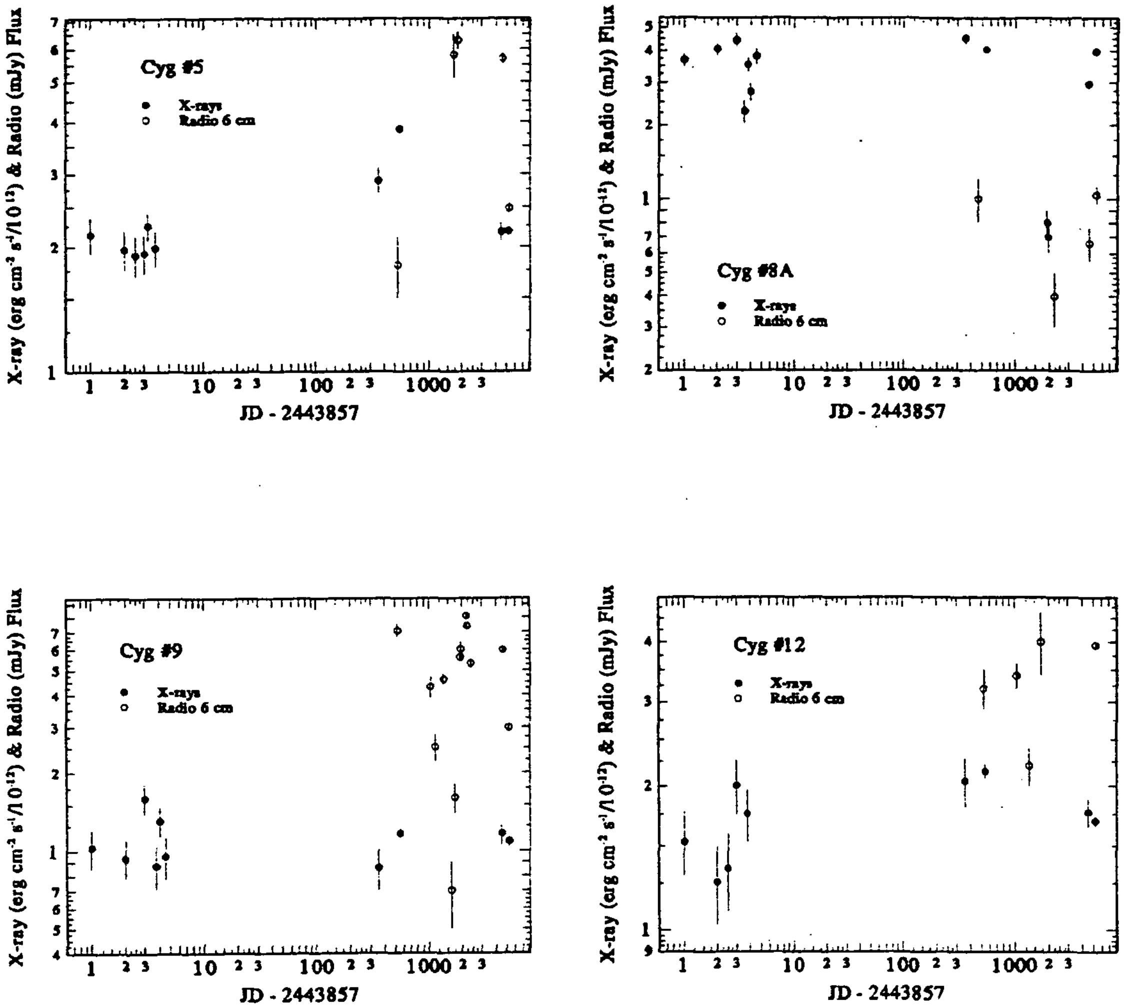

Figure 2. The time evolution of the observed X-ray flux (energy range 0.1-5.0 keV) and 6 cm radio emission for the Cyg OB2 stars (#5, #8A, #9, and #12), covering a time span of approximately 15 years. The last two points are the recent PSPC observations. The Julian Date (JD) is normalized from 14DEC1978. The X-ray flux is normalized by 10^{-12} and the radio emission is in mJy. This illustrates that although the radio emission shows significant variability, the X-ray emission has remained relatively stable, except Cyg #5.

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Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
A Deep PSPC Observation of the Cyg OB2 Association	September 27, 1995
	6. Performing Organization Code
7. Author(s) Wayne L. Waldron Mike F. Corcoran	8. Performing Organization Report No. R95-242
	10. Work Unit No.
9. Performing Organization Name and Address Applied Research Corporation Suite 1120 8201 Corporate Drive Landover, MD 20785	11. Contract or Grant No. S-39746-Z
	13. Type of Report and Period Covered Final Report 07/07/94-09/07/95
12. Sponsoring Agency Name and Address NASA/Goddard Space Flight Center Greenbelt MD 20771	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

We obtained a 19.5 Ks observation of the Cyg OB2 Association using the ROSAT PSPC. We extracted and analyzed the four brightest OB stars (Cyg OB2 #5, #8A, #9, and #12). These observations were compared with a previous ROSAT HO1 observation and the HEAO-2 IPC X-ray data to search for long term X-ray variability. It is found that for the past 15 years these stars have remained relatively constant in their X-ray emission.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
X-rays; Early-Type Stars; ROSAT	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
		7	

NASA FORM 1626 OCT 86