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X-RAY OBSERVATIONS OF H1908+050 (=SS433?)

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ABSTRACT

The X-ray source H1908+50 (=4U1908+05=A1909+04) was observed for three 6 day periods in 1977 and 1978 with the HEAO A-2 experiment+. Because of the positional error box and variability of the source, the unusual emission line object and variable radio source SS433 has been suggested as the optical counterpart. The X-ray luminosity of the source varied by a factor of $\sim$ 2 on a time scale of 6 months, and the spectrum of the object is consistent with either a power law of photon index, Γ, of 2.1 or with 14.3 keV thermal bremsstrahlung emission with a $\sim$ 575 eV equivalent width iron line. These X-ray characteristics argue against the source being extragalactic, but do not uniquely identify the type of source. The measurements are consistent with emission from a white dwarf with $\sim 10^8$ G magnetic field, but are also similar to the X-ray emission sometimes seen from Cir X-1. A search has been made for X-ray emission from similar radio sources, but no new X-ray sources were detected. A previously known source, A1850+00, is a possible counterpart for one of these radio sources.

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+The HEAO-A2 experiment is a collaborative effort led by E. Boldt of GSFC and G. Garmire of CIT, with collaborators at GSFC, CIT, JPL, and UCB.

I. INTRODUCTION

Recent optical observations of SS433 (Margon et al. 1979) show broad, intense Balmer lines which vary on a time scale of days. The most interesting features of the spectra are three broad intense lines which change apparently aperiodically in wavelength and intensity. Although no consistent explanation for these lines has been proposed, Margon et al. (1979) suggest the lines may be Zeeman splitting of Hα or plasma satellites of Hα and Hβ. Radio observations by Seaquist, Gregory, and Crane (1978) and Feldman et al. (1978) show SS433 to be a variable non-thermal radio source. Clark and Murdin (1978) suggest that SS433 is the correct identification for A1909+04, that SS433 is associated with SNR W50, and that SS433 may be similar to the Cir X-1 system. Ryle et al. (1978) suggest SS433 and Cir X-1 are members of a new class of radio stars which may be compact remnants of supernovae. The new HEAO-A2 observations provide contemporary X-ray measurements of SS433 and yield the first X-ray spectra of the object.

II. X-RAY OBSERVATIONS

The HEAO-A2 experiment (Rothschild et al. 1978) scanned across SS433 during 3 six day periods starting October 10, 1977; April 7, 1978; and October 10, 1978. Data presented here are mostly from the April 1978 observations since only preliminary data are available from October 1978 and the X-ray source was significantly weaker in October 1977.

The 90% confidence HEAO-A2 error box for a source designated H1908+050 was determined as discussed by Marshall et al. 1979, and is shown in Figure 1. Also shown are the boxes for A1909+04 (Seward et al. 1976) and 4U1908+05 (Forman et al. 1978). SS433 lies within 0.05 degrees of the 0.11 square degree HEAO-A2 box and a similar distance from the Ariel 5 and UHURU boxes. The clustering of the error boxes around SS433 strongly suggests that SS433 is the correct identification. Weak unresolved sources or short time-scale variability may cause small offsets in the position of the error boxes and account for the boxes not containing SS433. A much smaller error box is needed to secure the identification. The large X-ray error boxes contain many other stars, including 2 OB stars in the 4U box (Nassau and Stephenson 1973). None, however, are known as variables (Kukarkin et al. 1969,1971,1974). For the remainder of this paper, it will be assumed that SS433 is the correct identification for H1908+050.

Figure 2 shows the intensity of the X-ray source as seen by the Uhuru, Ariel 5 and HEAO satellites. For the combination of rates used, one HEAO-A2 count is $\sim 2.4 \times 10^{-11}$ ergs cm^{-2} sec^{-1} in the 2-10 keV band for Γ of 2.1. To compare results of the different experiments we have adopted conversions factors of 1 UHURU count to 1 A2 count, and 1 Ariel count to 3 A2 counts. The X-ray luminosity has varied by a factor of $\sim$ 5 during the last decade. Variability was first seen during the Ariel 5 observations (Seward et al. 1976). The different intensity seen in 1977 and 1978 with HEAO-A2 confirms variability on a six month scale which implies a size of $\lesssim$ 0.1 pc. There is some evidence for variation of $\lesssim$ 50% within the 6 day observations by HEAO-A2, but because of source confusion problems, it is not certain these variations are associated with H1908+050.

Clark and Murdin (1978) have suggested SS433 may be a remnant of the supernova W50. Consequently we have looked for short term periodic variability in the X-ray flux. No such variability was found for periods between 0.16 seconds and 5 seconds; the 90% confidence upper limit for sinusoidal modulation is $\sim$ 10%.

The spectrum of H1908+050 was obtained during the April 1978 observation using the xenon-filled HED3 detector. To reduce source confusion only the data from the smallest ($1\frac{1}{2}^{o}$ x 3^{o}) collimator have been used. No other known X-ray sources are included in the accumulated spectrum. The X-ray spectrum is shown in Fig. 3 with best fit parameters and 90% confidence error bars. Both a power law model with photon spectral index 2.1 and a 14.3 keV thermal bremsstrahlung model provide acceptable fits to the data with chi-squares of 11.3 and 15.6 respectively for 14 degrees of freedom. The 2-10 keV luminosity was 2.0×10^{35} ergs s^{-1} $(\frac{d}{3.5\ kpc})^{2}$. No low energy absorption is required for the fits, but the 90% confidence upper limit on n_H for either model is many times the amount in the direction of SS433 deduced by Margon et al. (1979).

The addition of an $\sim$ 575 eV equivalent width 6.8 keV line to either model reduces χ^2 by 11 for the addition of one parameter. The equivalent width of the line is consistent with that produced by collisional equilibrium of a 14 keV gas of solar abundances (Raymond and Smith 1977), and so suggests the thermal model may be more realistic than the power law model.

III. DISCUSSION

Since no physical system has yet been proposed which fully explains the observations of SS433, it is useful to use the X-ray observations to constrain possible models. Although its location near the supernova W50 at low galactic latitude suggests that SS433 is in our galaxy, there is no evidence requiring SS433 to be galactic. The association of SS433 with the supernova is uncertain (Velusamy and Kundu 1974; Margon et al. 1979). The lower limit on the distance to SS433 of 3.5 kpc is based on its being beyond most if not all of the galactic HI layer (Margon et al. 1979); the upper limit is that its redshift is $\lesssim$ 0.0006 (Margon et al. 1979). SS433 could, therefore, be a nearby galaxy whose nebulosity is obscurred by our galaxy. The broad Hα lines would suggest a Seyfert 1 galaxy. At a distance of 5 Mpc, M_V of SS433 is -18.9, comparable to a weak Seyfert 1 galaxy such as NGC4151. However, three X-ray characteristics argue against SS433 being a Seyfert galaxy. First, L_{opt}/L_x was $\sim$ 40 during April 1978. None of the X-ray Seyfert galaxies reviewed by Elvis et al. (1977) have L_{opt}/L_x as large as 6. Secondly, the spectrum of SS433 is softer than any of the 7 Seyfert 1 spectra measured with HEAO-A2 (Mushotzky et al. 1979). Finally, none of these Seyfert 1 galaxies have Fe line equivalent widths as large as seen in SS433. Hence, if extragalactic, SS433 is unlike previously observed X-ray sources.

There are several types of variable galactic sources from which X-ray spectra similar to that of SS433 have been observed. They include white dwarfs in dwarf novae systems, the bright galactic center sources, the pulsar X-Per, and the possibly massive binary Cir X-1. Thus similar spectra can arise for different types of compact objects and different types of binary systems at least under some conditions. We can compare the

X-ray, optical and radio data together, however, for a better idea of what the system is likely to be. We do not attempt to account for the 3 unidentified optical lines.

Margon et al. (1979) suggested the strong variable optical emission features of SS433 are formed in the strong (10^8 G) magnetic fields known to exist near the surface of some white dwarfs, although no consistent picture identifying the lines and explaining the lack of polarization has been achieved. AM Her is the only known white dwarf hard X-ray source for which there is good evidence for a 10^8 G magnetic field (Tapia 1977), but it has a much harder X-ray spectrum than does SS433 (Swank et al. 1979). However, two other white dwarfs, the dwarf novae SS Cygni and EX Hydrae, have thermal X-ray spectral with Fe line emission (Mason, Cordova, and Swank 1978; Mushotzky et al. 1978; Watson, Sherrington, and Jameson 1978) similar to SS433. While the highest X-ray luminosities of the known white dwarf X-ray sources are $\lesssim 10^{-3}$ that of SS433, current theories (Masters et al. 1977; Kylafis and Lamb 1979; Kylafis 1978; Masters 1978) indicate that for appropriate mass and accretion rate, a white dwarf of 10^8 G magnetic field would produce an X-ray spectrum and luminosity such as seen from SS433. For high magnetic fields there could be a large soft (¼ keV band) X-ray luminosity (10^{37} ergs sec^{-1}, of the order of the optical luminosity of SS433). The observed column density would account for such a flux not being detected (Riegler and Agrawal 1979) by the low energy detectors of the HEAO-A2 experiment. Detailed models are needed to determine if a white dwarf system could produce the optical luminosity seen from SS433.

The bright galactic center sources, as well as sources like Sco X-1, also have approximately thermal bremsstrahlung spectra with $kT \sim 5$-20 keV (Jones 1977; Parsignault and Grindlay 1978; Mason et al. 1977). Some are even associated with radio sources (Bradt, Doxsey and Jernigan 1979). While the X-ray luminosities of many of them are thought to exceed 5×10^{36} ergs s^{-1} and in the case of Sco X-1, at least, no narrow iron line emission is observed (see for example Long and Kestenbaum 1978), similar sources may exist which have lower X-ray luminosity and are optically thin. The optical luminosities of the identified counterparts, however, are < .01 of the X-ray luminosities (Margon 1979) so that the systems must be very different from that of SS433.

The X-ray binary pulsar X Per has a 12.2 ± 0.8 keV thermal bremsstrahlung spectrum (Becker et al. 1979). This spectrum is, however, unique among known X-ray pulsars which typically have hard spectra ($\Gamma \sim 1$) and high energy cutoffs. Becker et al. attribute the difference to the low luminosity (and hence low accretion rate) of the X Per system, which has only $\sim 10^{-4}$ of the typical pulsar luminosity of $\sim 5 \times 10^{37}$ ergs s^{-1}. No radio or Fe line emission have been seen for X Per, and no pulsar as luminous as SS433 is known with a similar spectrum. Therefore, it seems unlikely that SS433 is a neutron star with a 10^{12} G magnetic field, although a pulsar period $\gtrsim 5$ sec would not have been detected with HEAO-A2.

Clark and Murdin (1978) and Ryle et al. (1978) pointed out that the apparent association of SS433 with a variable X-ray source and with a supernova remnant was similar to the compact source associated with Cir X-1.

Clark and Murdin also noted the presence of strong Hα and He I lines in both SS433 and Cir X-1. Further, the unusually bright absolute magnitude of -3.5 given for SS433 by Margon et al. (1979) is similar to that of -4.5 for Cir X-1 (Whealan et al. 1977).

The X-ray source Cir X-1 is exceedingly variable on timescales from < 1 sec to months. Steep spectra unlike the spectrum of SS433 are observed when the source is strong. However, observations for 17 days with OSO-8 (Robinson-Saba et al. 1979) show extended periods of low luminosity ($L_x \sim 5 \times 10^{36}$ ergs s^{-1}) when the spectrum was well fit by $\sim$ 9 keV thermal bremsstrahlung with Fe line emission. Thus at least at times the radio, optical, and X-ray properties of Cir X-1 and SS433 are similar. The large outbursts ($L_x \sim 10^{38}$ ergs s^{-1}) of a softer component of Cir X-1, which have not been seen from SS433, may be due to the particular orbital elements of the Cir X-1 system.

Ryle et al. (1978) propose that Cir X-1 and SS433 are members of a new class of radio star and suggest 7 other radio sources as members. Production data from the 1st scan of the sky and ½ the 2nd scan of the sky by HEAO-1 have been searched for possible X-ray counterparts of these 7 radio sources. No new unresolved X-ray sources were found. Upper limits for possible X-ray intensities are presented in Table 1. Confusion with known sources and unresolved galactic emission cause the sensitivity of the survey to vary. Two sources would easily have been detected if their X-ray luminosities were comparable to that of SS433. We do suggest A1850+00 (Seward et al. 1976) as a possible counterpart to the radio source 1849+005.

IV. CONCLUSION

X-ray observations of SS433 with HEAO-A2 have produced the first X-ray spectra of the source and confirmed previous observations of X-ray variability. Both the spectrum and luminosity argue that the source is within our own galaxy. Comparison of the X-ray emission from SS433 to that from other galactic sources could not uniquely identify the type of object. White dwarfs with unusually high accretion rate or a system such as Cir X-1 have several characteristics in common with SS433. Although the observations strengthen the similarities to Cir X-1, a search of HEAO-A2 data did not find any resolved X-ray emission from 6 similar radio stars and ruled out an X-ray luminosity comparable to SS433 for two of them. A previously known source A1850+00 may be a counterpart for one of the radio sources.

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REFERENCES

Becker, R.H., Boldt, E.A., Holt, S.S., Pravdo, S.H., Robinson-Saba, J., Serlemitsos, P.J., and Swank, J.H. 1979, Ap. J. (Letters) 227, L21.

Bradt, H.V., Doxsey, R.E., and Jernigan, J.G. 1979, Proc. of the XXI COSPAR/IAU Symposium in X-Ray Astronomy, to be published in Advances in Space Exploration, Vol. 3.

Clark, D.H., and Murdin, P. 1978, Nature 276, 42.

Elvis, M., Maccacaro, T., Wilson, A.S., Ward, M.J., Penston, M.V., Fosbury, R.A.E., and Perola, G.C. 1978, MNRAS 183, 129.

Feldman, P.A., Purton, C.R., Stiff, T., and Kwok, S. 1978, IAU Circular No. 3258.

Forman, W., Jones, C., Cominsky, L., Julien, P., Murray, S., Peters, G., Tananbaum, H., and Giacconi, R. 1978, Ap. J. Suppl., in press.

Jones, C. 1977, Ap. J. 214, 856.

Kirshner, R.P., and Chevalier, R.A. 1979, Nature, in press.

Kukarkin, B.V., General Catalogue of Variable Stars, Sternberg State Astronomical Institute of the Moscow State University: Moscow, Vol. 1 (1969); First suppl. to Third Ed. (1971); second suppl. to Third Ed. (1974).

Kylafis, N.D. 1978, Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign.

Kylafis, N.D., and Lamb, D.A. 1979, Ap. J. (Letters), in press.

Long, K.S., and Kestenbaum, H.L. 1978, Ap. J. 226, 276.

Margon, B., Ford, H.C., Katz, J.I., Kwitter, K.B., Ulrich, R.K., Stone, R.P.S., and Klemola, A. 1979, submitted to Ap. J. (Letters).

Marshall, F.E., Boldt, E.A., Holt, S.S., Mushotzky, R.F., Pravdo, S.H., Rothschild, R.E., and Serlemitsos, P.J. 1979, Ap. J. Suppl., in press.

Mason, K.O., Cordova, F., and Swank, J.H. 1979, Proceedings of the XXI COSPAR/IAU Symposium in X-Ray Astronomy, to be published in Advances in Space Exploration, Vol. 3.

Masters, A.R. 1978, Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign.

Masters, A.R., Pringle, J.E., Fabian A.C., and Rees, M.J. 1977, MNRAS 178, 501.

Mushotzky, R.F., Serlemitsos, P.J., Smith, B., Boldt, E.A., and Holt, S.S. 1978, Ap. J. 225, 21.

Mushotzky, R.F., Boldt, E.A., Holt, S.S., Marshall, F.E., Pravdo, S., and Serlemitsos, P.J. 1979, to be submitted to Ap. J.

Nassau, J.J., and Stephenson, C.B. 1963, Luminous Stars in the Northern Milky Way IV, Hamburg-Bergedorf.

Parsignault, D.R., and Grindlay, J.E. 1978, Ap. J. 225, 970.

Raymond, J.C., and Smith, B.W. 1977, Ap. J. Suppl. 35, 419.

Riegler, G., and Agrawal, P. 1979, private communication.

Robinson-Saba, J., Swank, J.H., Boldt, E.A., Holt, S.S., Pravdo, S.H., and Serlemitsos, P.J. 1979, in preparation.

Rothschild, R.E., Boldt, E.A., Holt, S.S., Serlemitsos, P.J. Garmire, G., Agrawal, P., Riegler, G., Bowyer, S., and Lampton, M. 1978, submitted to Space Sci. Inst.

Ryle, M., Caswell, J.L., Hine, G., and Shakeshoft, J. 1978, Nature 276, 571.

Seaquist, E.A., Gregory, P.C., and Crane, P.C. 1978, IAU Circular No. 3256.

Seward, F.D., Page, C.G., Turner, M.J.L., and Pounds, K.A. 1976, MNRAS 175, 39.

Swank, J.H., Lampton, M., Boldt, E.A., Holt, S.S., and Serlemitsos, P.J. 1977, Ap. J. (Letters) 216, L71.

Tapia, S. 1977, Ap. J. (Letters) 212, L125.

Velusamy, T., and Kundu, M.R. 1974, Astro. and Astrophys. 32, 375.

Watson, M.G., Sherrington, M.R., and Jameson, R.F. 1978, MNRAS 184, 79.

Whelan, J.A.J., et al. 1977, MNRAS 181, 259.

TABLE 1

UPPER LIMITS FOR X-RAY EMISSION FROM RADIO STARS

90% Confidence Upper Limits

Radio Source	Distance* (kpc)	A2 cnts/sec	L_x (10^{35} ergs/sec)	Comments
0125+628**	5.4	2	1.5	near 4U0115+63
0503+46	1.8	1	0.08	
1347-61	8.1	5	8.2	between A1343-60 and A1354-64
1849+005	9.4	8	17	A1850+00(?)
1910+052	3.3	--	--	confused with SS433
2013+370	> 12	5	18***	near Cyg X-1
2048+312	1.2	1	0.04	

* estimated distance to supernova from Ryle et al. (1978)

** may be galaxy (Kirshner and Chevalier 1979).

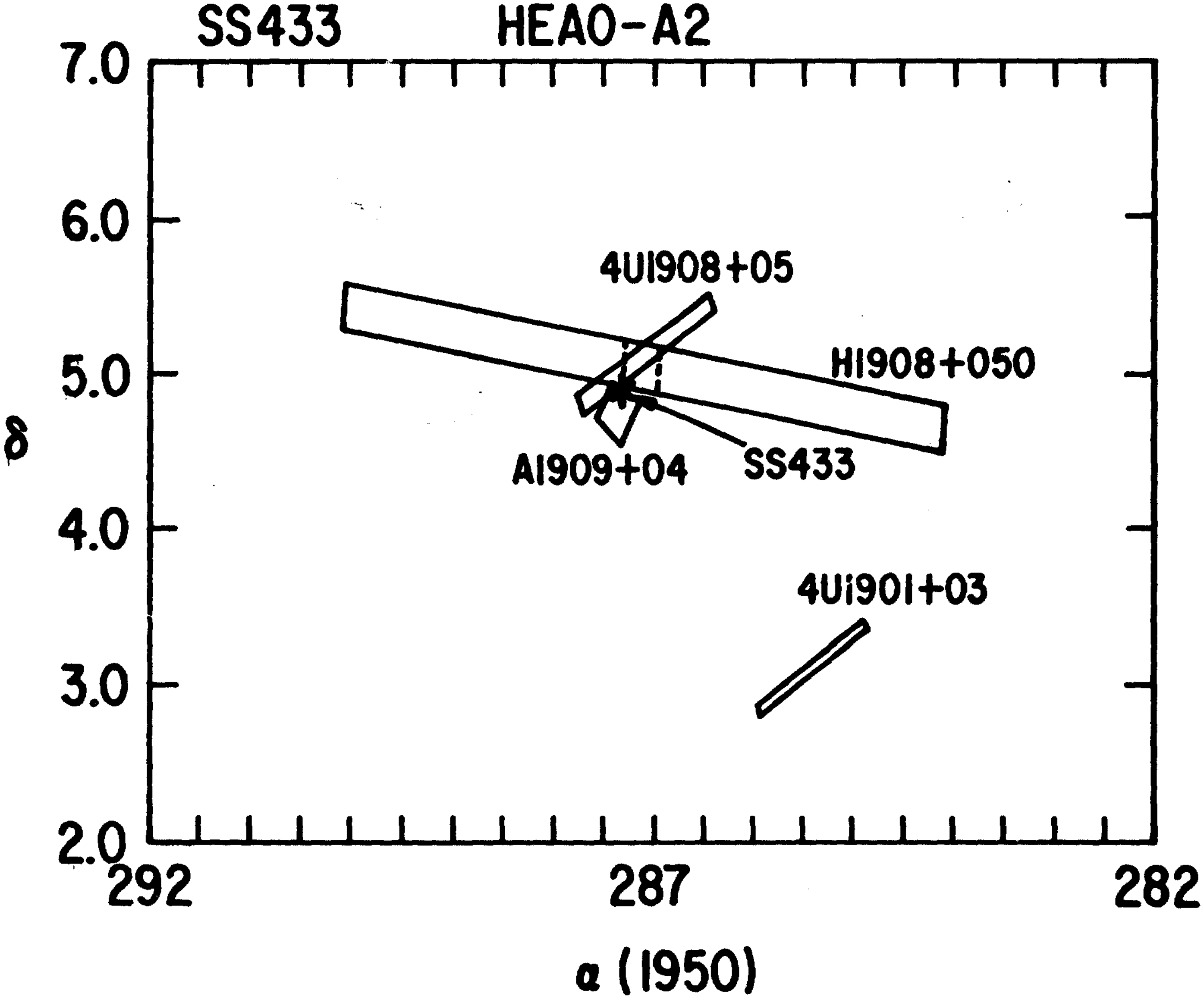
*** assumes 12 kpc

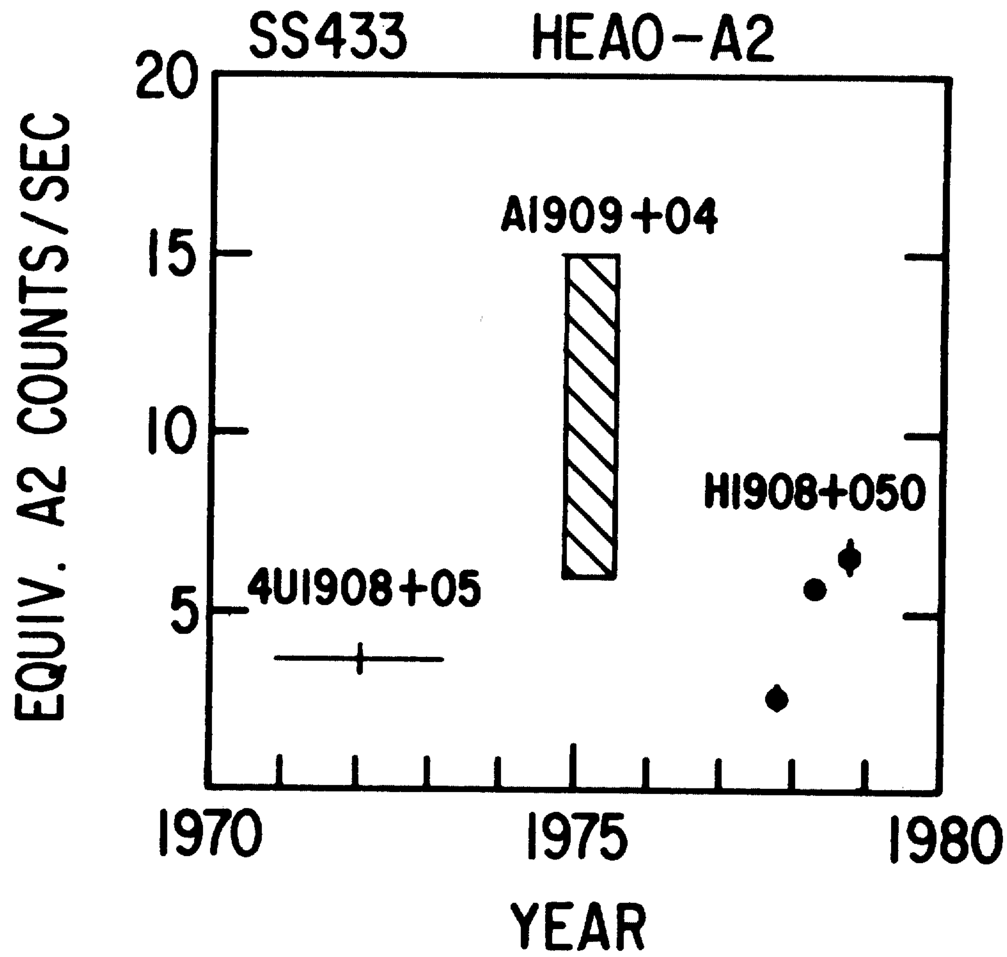
FIGURE CAPTIONS

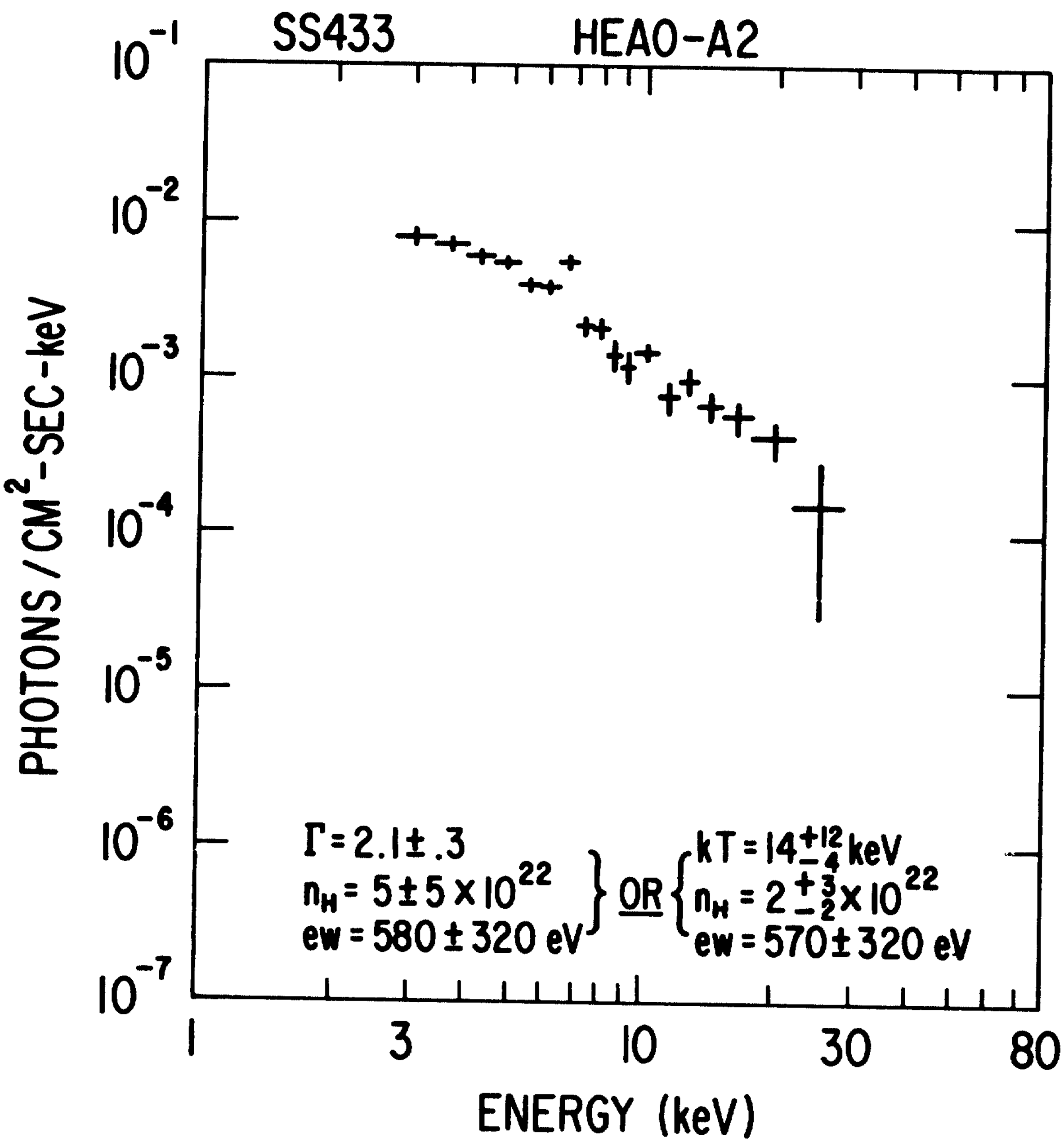
Figure 1 - HEAO-A2 90% confidence error box. The region inside the dashed lines is the 90% confidence box assuming the source does not vary on a time scale of days. Also shown are error boxes for A1909+04, 4U1908+05, and 4U1901+03.

Figure 2 - X-ray intensity of SS433 as observed with 3 satellites. One sigma errors are shown for the UHURU and HEAO-A2 observations, and the observed range of intensities is shown for Ariel 5 observations. The indicated times of UHURU and Ariel 5 observations are for large observing programs which included observations of SS433.

Figure 3 - X-ray spectrum of SS433 accumulated April 8-13, 1978. Best fit parameters and 90% confidence error bars are given for two acceptable models.


SS433
HEAO-A2
7.0
6.0
5.0
4.0
3.0
2.0
δ
292
287
282
α (1950)
4U1908+05
H1908+050
A1909+04
SS433
4U1901+03


SS433
HEAO-A2
20
15
10
5
EQUIV. A2 COUNTS/SEC
A1909+04
4U1908+05
H1908+050
1970
1975
1980
YEAR


SS433
HEAO-A2
PHOTONS / CM2-SEC-keV
10-1
10-2
10-3
10-4
10-5
10-6
10-7
Γ = 2.1 ± .3
nH = 5 ± 5 X 10^22
ew = 580 ± 320 eV
OR
kT = 14 +12 -4 keV
nH = 2 +3 -2 X 10^22
ew = 570 ± 320 eV
1
3
10
30
80
ENERGY (keV)