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2A 0526−328: AN X-RAY-EMITTING CATACLYSMIC VARIABLE

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ABSTRACT

We identify the weak hard X-ray source 2A 0526−328 with a previously unknown cataclysmic variable on the basis of its optical emission-line spectrum and a precise X-ray location. This $V \sim 14$ mag star has spectral properties similar to dwarf novae at minimum light and AM Her, but shows no polarization. It is likely to be a Z Camelopardalis–type system in a very extended standstill (i.e., "nova-like" or UX Ursae Majoris–type) or a recurrent nova that has not erupted in recent times.
Subject headings: stars: emission-line — X-rays: sources

I. INTRODUCTION

Until the launch of the *HEAO 1* satellite the only suspected X-ray emitting cataclysmic variable (excluding AM Her) was SS Cyg, observed by Rappaport *et al.* (1974) when in optical outburst. Subsequently, Margon *et al.* (1978) detected SS Cyg as an ultrasoft source from *Apollo-Soyuz*, again during outburst, while *ANS* (Heise *et al.* 1978) observed soft and hard X-ray emission during an optically quiescent period. No other dwarf novae had been detected, in spite of several predictions (see, e.g., Warner 1974) of intense soft X-radiation and their noted similarity to "classical" X-ray binary systems.

With the advent of the *HEAO* era U Gem (Mason *et al.* 1978) and SS Cyg (Cordova, Garmire, and Tuohy 1978) were both detected as intense, ultrasoft X-ray sources during optical outbursts. In addition, Cordova and Garmire (1979) have observed a soft X-ray source consistent with the location of AY Lyr (although this source was not detected during an optical outburst); Bradt, Doxsey, and Jernigan (1979) have determined a precise ($\lesssim 1'$) position for 2A 1249−289 which they identify as the dwarf nova EX Hya; and Mason, Kahn, and Bowyer (1979) observed soft X-rays from the region of MV Lyr, a "nova-like" star. However, Cordova *et al.* (1979) also list ~25 dwarf novae that are not observed during outburst. Clearly, it is important to obtain as large a sample as possible of X-ray–emitting dwarf novae and related systems for the purposes of understanding the X-ray–emitting mechanism.

Here we discuss 2A 0526−328, a weak (2.4 *Uhuru* flux units; Cooke *et al.* 1978), high-latitude ($b = -31°$) X-ray source. Recently, Schwartz *et al.* (1979) determined a precise position for the source, using the scanning modulation collimator experiment on board the *HEAO 1* satellite. By combining their data with a line of position from the A-1 experiment, they were able to reduce the ambiguity of their measurement to four possible locations which lie within the 2A error box. They suggested an identification with a 19th mag galaxy in the southwestern error box. We shall now describe our observations of this region and our discovery of a previously unknown variable, emission-line object which we identify with the X-ray source.

II. OBSERVATIONS

a) Optical

On 1978 October 26 UT we used the Lick Observatory 3 m Shane reflector and image-tube scanner (ITS; Robinson and Wampler 1972) to continue the search for an optical counterpart. Because of the large air mass, we chose a grating tilt covering a relatively long wavelength region, from 4500 to 7000 Å. As reported by Schwartz *et al.* (1979), the three bright stars around the southwestern box and the single bright star inside the southeastern box had been studied by Liller and found to have ordinary spectra. This latter star is labeled 8 in Figure 1 (Plate L5), which shows the revised *HEAO 1* southeastern box (R. Griffiths, private communication). We decided to concentrate on the four remaining bright stars (1, 2, 6, and 7) in or near this box because we felt that the A-1 line of position excluded the two northern boxes as possible locations.

Stars 1, 2, and 7 showed no unusual features, although the signal-to-noise ratio and the grating tilt used precluded accurate spectral classification. However, star 6 showed prominent emission lines and, on a variety of grounds, we propose this star to be the optical counterpart. Although the star does not lie within the 90% confidence box shown (which has dimensions $30'' \times 160''$), we note that it is only $30''$ outside the error region in the least certain direction, and hence cannot be excluded on positional grounds. The position of star 6 is $5^h27^m34^s.5$, $-32°51'20''$ (1950.0) to approximately $2''$ accuracy.

Table 1 gives the strongest spectral features we have

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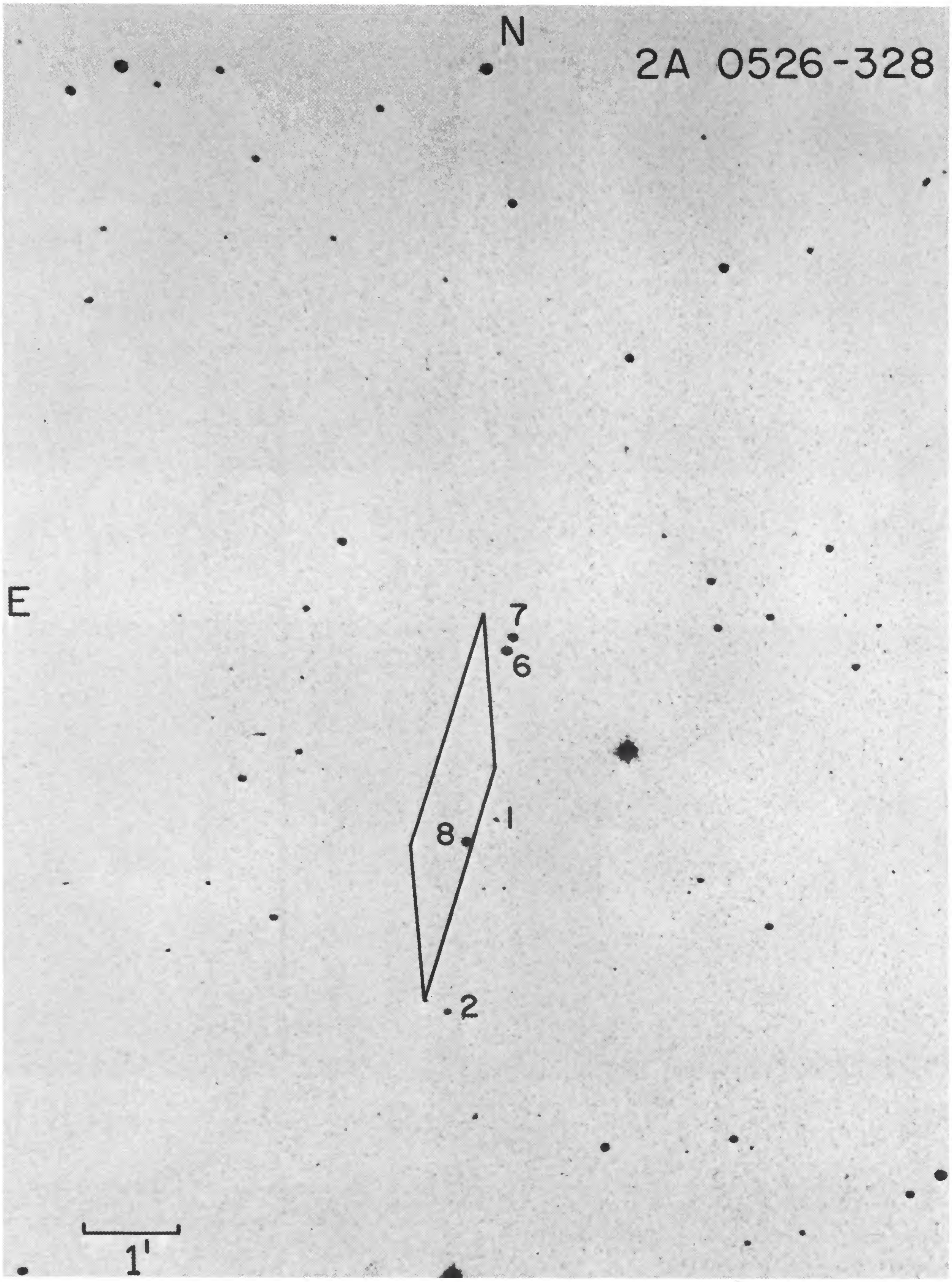

FIG. 1.—Finding chart for 2A 0526−328 showing the southeastern *HEAO 1* error box (from R. Griffiths, private communication) and the stars discussed in the text. Star 6 is the X-ray source. This chart is from a Crossley red plate (098-02 + RG 610).

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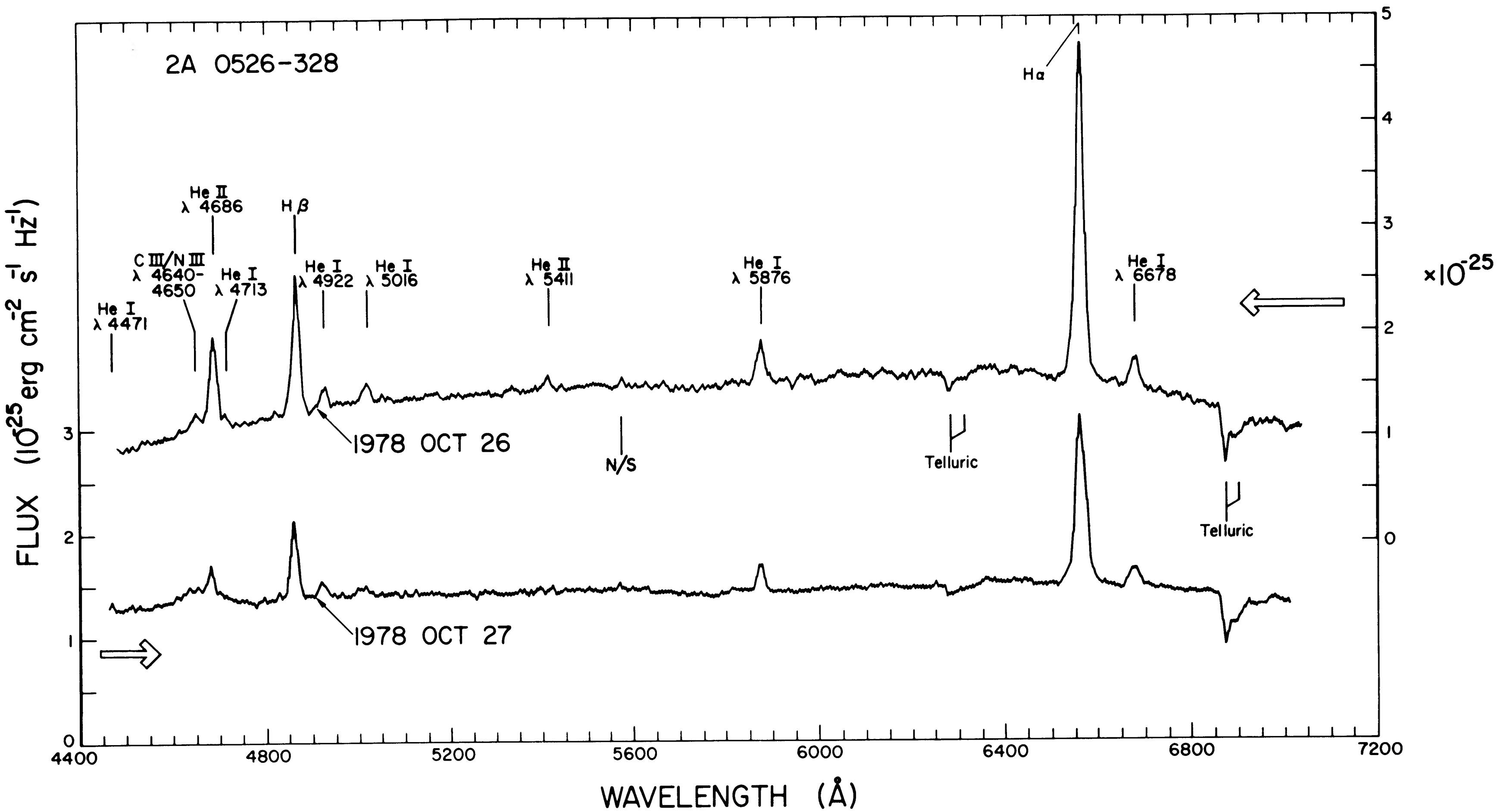

FIG. 2.—Spectra of the optical counterpart of 2A 0526—328 obtained with the Lick 3 m Shane reflector on 1978 October 26 (*upper*) and 27 (*lower*). Features marked N/S are due to imperfect subtraction of night-sky emission lines. The telluric absorption features at ~6300 Å and ~6900 Å are due to O_2.

TABLE 1

STRONG EMISSION FEATURES IN 2A 0526−328

Feature	Equivalent Widths (Å)		
	26.529*	26.540*	27.475*
Hα..............	41	44	31
Hβ..............	13	20	11
He I λ4922.......	3.3	2.8	1.7
He I λ5016†......	3.8	2.6	1.6
He I λ5876.......	4.2	5.1	3.7
He I λ6678.......	6.3	4.2	3.9
He II λ4686......	14.3	14.2	2.6
He II λ5411......	2.4	1.0	≪1
C III–N III λλ4640–4650...	≪4	2.7	(see text)
Integration time (minutes)....	4	8	152

* 1978 Oct UT date.

† Appears to be blended with a shorter-wavelength feature, possibly N II λ4994.

observed in the source and their equivalent widths during our various observations. Spectra from the two nights are displayed in Figure 2; absolute flux calibration is achieved through observations of standard stars from Oke (1974) and a reduction procedure similar to that described by Smith (1975). Several features of the results deserve comment. First, the spectrum is variable night to night and even on time scales as short as several minutes. Second, no absorption features are observed. In addition, comparison with night-sky features indicates that the lines are resolved even at ITS resolution (∼10 Å), having widths ∼500–700 km s^{-1}. On the second night, an unusual broad emission feature appeared under He II λ4686. It may result from Doppler broadening of λ4686 itself; but a more likely identification is a blend of N II λλ4607–4614, N II/Fe II λ4621, C III–N III λλ4637–4650, He II λ4686, O II λ4703, He I λ4713, and N II/Ne IV λ4719 with more modest Doppler widths.

During the October 27 ITS run we continuously monitored ITS total counting rates with a sampling interval of 40 ms, using the same instrumentation as in Middleditch and Nelson (1976). A search for strictly periodic modulation in the period range 0.1–100 s yielded typical upper limits of 0.5% for any such modulation. Figure 3 shows the low-frequency part of the noise-dominated power spectrum as a function of frequency. Some rapid variability was present in these data, on time scales $\gtrsim$ 1 minute, but the night was not entirely photometric, so this result must be interpreted cautiously. From our flux-calibrated spectrum we derive a V magnitude of 13.5 for this star at maximum light, but again the observing conditions suggest caution.

More reliable evidence of variability comes from 16 direct plates taken 1978 October 27, 28, and 29 UT with the 91 cm Crossley reflector at Lick. Most of these were taken in a red (Kodak 098-02 + RG610) passband, but some were broader band (Kodak 098-02 + GG385). Exposure times were typically 10 minutes.

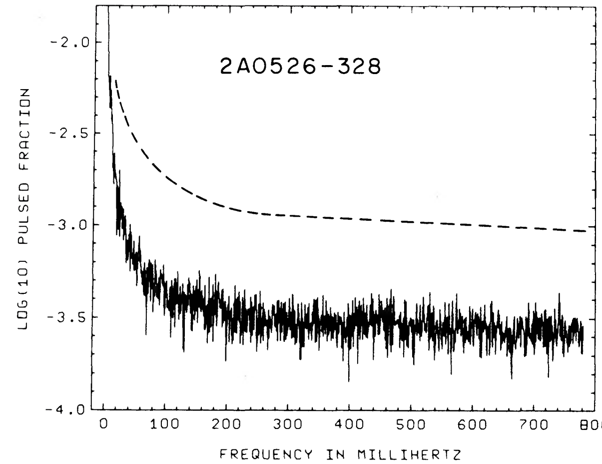

FIG. 3.—Pulsed fraction, averaged over eight points, as a function of frequency for our ITS photometric observation of 2A 0526−328 on 1978 October 27. The dashed curve represents a ∼5 σ upper limit to any periodic modulation.

Using the Berkeley Astronomy Department's iris astrophotometer, we measured our object and nine comparison stars on each plate. The star was approximately the same brightness for the first two nights, but ∼0.4 mag brighter on the third night. Since the scatter of the comparison stars indicates that a single plate provides ∼0.1 mag accuracy, and seven plates were used, this result has high statistical significance. We found no evidence for eclipses, and no strong evidence for variability within a given night. This star is not listed as a variable in the *General Catalog of Variable Stars* (Kukarkin *et al.* 1969).

b) X-Ray

This region of sky was scanned by the *HEAO 1* A-2 experiment[1] in 1977 September. The data from the low energy detectors (LEDs), which cover the energy range 0.1–3 keV, were processed and yielded a 2 σ upper limit of 3.2 counts s^{-1}, or $\sim 6 \times 10^{-3}$ photons cm^{-2} s^{-1} keV^{-1}. Assuming a Crab-like spectrum (given the detection at higher energies), this is equivalent to 1.1×10^{-11} ergs cm^{-2} s^{-1} keV^{-1}.

III. DISCUSSION

Despite its high latitude, this object is certainly a galactic star. The main spectral features are typical of a dwarf nova system near minimum light (see, e.g., Payne-Gaposchkin 1957). However, given the presence of the weak, hard X-ray source, it is also possible that this system could contain a magnetic white dwarf similar to the AM Her/4U 1809+50 system. The spectral features in AM Her are also broad (implying similar velocities) and vary in intensity on short time scales (Cowley and Crampton 1977; Stockman *et al.* 1978). The distinguishing factor for AM Her is princi-

[1] The A-2 experiment is a collaboration led by E. Boldt (GSFC) and G. Garmire (CIT) with collaborators at UCB, JPL, CIT, and GSFC.

pally the extremely high linear and circular polarization (Tapia 1977) that indicates the intense magnetic field.

Our optical counterpart of 2A 0526−328 was observed for polarization by Tapia (1978, private communication), who obtained a 2 σ upper limit of 0.5% (for linear and circular polarization) during observations in 1978 November. We therefore conclude that this star is not an AM Herculis–type system and is most likely a previously unidentified dwarf nova–type system. A comparison of the properties of this star with SS Cyg, AM Her, and U Gem is given in Table 2. The X-ray to optical luminosity ratios, assuming our star is in a quiescent phase, are comparable.

It is unlikely that the source undergoes quasi-periodic outbursts on a month-to-month time scale, as does a classical U Geminorum star, since it would almost certainly have been noticed. A number of other possibilities are attractive; in particular, it may be a Z Camelopardalis star in a very extended standstill (a "nova-like" or UX Ursae Majoris–type system; see Robinson 1976), or a recurrent nova that has not erupted in historical times. However, our optical spectrum is virtually identical to that of AM Her and that of the recently discovered AM Herculis–type system, 2A 0311−227, and does not have the weak, broad Balmer absorption typical of UX Ursae Majoris systems (Robinson 1976). In any case, it is almost certainly some form of cataclysmic variable and is the first to have been discovered on the basis of its X-ray emission.

We are particularly grateful to Santiago Tapia for observing this star to search for polarization and to Richard Griffiths for communicating the revised *HEAO 1* location for the source. Fred Walter helped with the optical observations, and we thank Keith Mason for useful discussions. Anne Charles programmed the analysis system now used for reducing Lick ITS data at the Space Sciences Lab. Stuart Bowyer acknowledges the support of a Miller Professorship. The optical work is supported by the NSF under grant AST 78-06873 and the LED X-ray analysis is supported by NASA under contract CIT 44 466866.

TABLE 2

COMPARISON OF PROPERTIES WITH OTHER X-RAY–EMITTING CATACLYSMIC VARIABLES

Parameter	2A 0526−328	SS Cygni		U Geminorum		EX Hydrae		AM Herculis	
		Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
V	13.5	8	12	9	14	11.5	13.7	12.5	15
Distance (pc)	100 (assumed)	50		100		100		100	
L_{opt} (10^{32} ergs s^{-1})	1.1	44	1.1	70	0.7	7	0.9	4[8]	0.28
F_x (10^{-11} ergs cm^{-2} s^{-1}):									
Soft*	<3.3	10[1]	0.4[2]	32[3]	<0.3[3]	...	<0.3[5]	50[13]	6.5[15]
Hard†	3.0[7]	<3	7[2]	3.8[4]	<0.8[4]	...	10[6]	26[14]	8[16,17]
L_x (10^{32} ergs s^{-1}):									
Soft	<0.4	0.28	0.011	3	<0.03	...	<0.03	100[13]	0.7
Hard	0.34	<0.08	0.2	0.43	<0.09	...	1.1	3	...
L_x/L_{opt}:									
Soft	<0.4	0.01	0.01	0.04	<0.04	...	<0.03	25	2.5
Hard	0.3	$<2.10^{-3}$	0.2	0.01	<0.1	...	1.2	0.75	...
Polarization	No[12]	No[11]		No		No		Yes[9,10]	

* Soft = <0.5 keV.

† Hard = >0.5 keV.

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