THREE WEAK-LINED T TAURI STARS IN ORION

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ABSTRACT

We have identified three new weak-lined T Tauri stars in Orion using the Double Spectrograph and 5-m telescope at Palomar Observatory. One of these is a candidate for the X-ray source RX0535-0633. Hα and Hβ line emission are detected and equivalent widths measured in all three stars, and in V942 On. We also searched without success for Hα line variability in V942 Ori. Assuming our identification of RX0535-0633 is correct, each of these stars is an X-ray source detected during imaging observations with the *ROSA 7* Observatory. The ratios of X-ray to optical luminosity for these stars is ≥ 10-3, similar to the larger sample of Orion T Tauri stars and larger than that seen in some other star formation regions.

Subject headings: stars: emission-line, Be--stars: flare--stars: pre-main sequence--X-rays: stars

1. INTRODUCTION

The majority of stars in the Orion star formation region can be characterized as pre-main sequence (PMS) emission-line, X-ray sources (e.g. Pravdo & Angelini 1995; PA95). They are also called T Tauri stars (TTS). Optical and X-ray studies of other star formation regions have found similar results (e.g. '1'aurus--Waltcr & Kuhi 1981; Cha 1 cloud--Feigelson et al. 1993), although the detailed characteristics of the stars, e.g., X-ray to optical luminosity ratios, are dependent upon global properties of the regions such as their ages. In this paper, we report observations which add to inventory of Orion PMS emission-line X-ray sources.

2. OBSERVATIONS AND RESULTS

We used the Double Spectrograph CC]> camera (Oke & Gunn 1982) mounted on the Palomar 5-m telescope to perform low resolution (≈2-3Å/pixel), broad-band (~5000Å) spectroscopy of stars that were known to be X-ray sources and/or emission-line stars (PA95). The observations were performed on the night of February 6, 1995. The seeing was estimated to be about 1,5 arcsec and we used a 1.0 arcsec slit. On a previous night we used the CCD-13 camera on the 5-m to obtain an image of the field near the star P1 792 (Figure 1).

We suggest that Star 1 in Figure 1 is the optical counterpart of RX053 5-0633. The optical position determined astrometrically from these data, R.A. *(2000)* = $05^h35^m26^s$, Decl = *-06°33'25"*, is offset 16" from the position of the X-ray source (PA95). However, the uncertain y in the X-ray position (David et al. 1994) for a far off-axis *ROSAT* High Resolution instrument observation (RX0535-0633 was detected almost 15' off-axis) makes Star 1 a viable candidate . The optical spectrum is typical of the X-ray sources in this region (PA95). This distinguishes it from the other candidate star P1 792, which while considerably brighter, V -9, is a non-emission line AO star (e.g. Strom et al. 1990). The relatively high X-ray luminosity of RX0535-0633 (see below), however, raises the question as to whether PI 792 makes a significant contribution.

Figure 2a-e show the spectra for the stars V942 Ori, WB41, WB57, and the candidate for RX0535-0633. WB41 and WB57 were first identified as emission-line stars by Wouterloot & Brand (1992; WB). PA95 identified V942 Ori as an emission-line PMS X-ray source. Figure 2 shows that the four stars including the three whose spectra are measured here for the first time, are of similar types. All exhibit Hα and Hβ line emission, Table 1 lists our inferred spectral types, V magnitudes, and emission-line equivalent widths and fluxes derived from these spectra. Our magnitudes are approximately 0.7 mag fainter than the original WB measurements. The X-ray luminosities derived from *ROSAT* (PA95) arc also given.

We performed two observations of V942 Ori separated in time by 0.5 hour to search for the Hα variability reported by PA95. There was no significant variability in these observations but the equivalent width (e.w.) measured here is about half the maximum measured by PA95.

3. DISCUSSION

"l'he four stars are PMS, weak-lined T Tauri stars (WTTS), based upon their optical spectra, probable location in Orion, and X-ray emission. Another possible diagnostic for this identification,

Li I (6707) absorption could not be detected with these observations. All the stars are near the 5-10 Å e.w. cutoff between classical (CTTS) and WTTS. Any significant distinction between the properties of CTTS and WTTS is unproven, and there may just be a continuum of TTS e.w.

A measurement of the Balmer decrement is given by the Hα/Hβ intensity ratio in Table 1. The intensity ratios are very similar to the Orion CTTS ratios measured by Cohen & Kuhi (1979). A distribution of ratios in the range 4-10 is indicative of collisional excitation and optical depth effects, perhaps from multiple emission regions.

Figure 3 shows the three newly identified WTTS added to the plot of X-ray (L_x) vs. stellar (L_*) bolometric luminosity for 19 TTS in this Orion field (PA95). The new stars are near the low end of the stellar luminosity distribution and they flatten the correlation from a slope of 0.7 to 0.5 (the line on the plot). This correlation maybe related to the proportionality between optical-emitting area and X-ray producing magnetic flux tubes on the stellar surfaces (e.g. Fleming et al. 1989). The L_x/L_* for the three stars is ≥ 10-3 which is common for the Orion region (PA95). This ratio is larger than that found in other star formation regions, for examples: p Ophiuchi - 10^{-4} (Casanova et al. 1995); Cha I - 1,6x 10-4 (Feigelson et al. 1993); 1.14951; -8.4 x 10-4 (Strom& Strom 1994). This higher ratio may indicate that the Orion stars are younger, $<10^6$ yr, than those in the compared regions.

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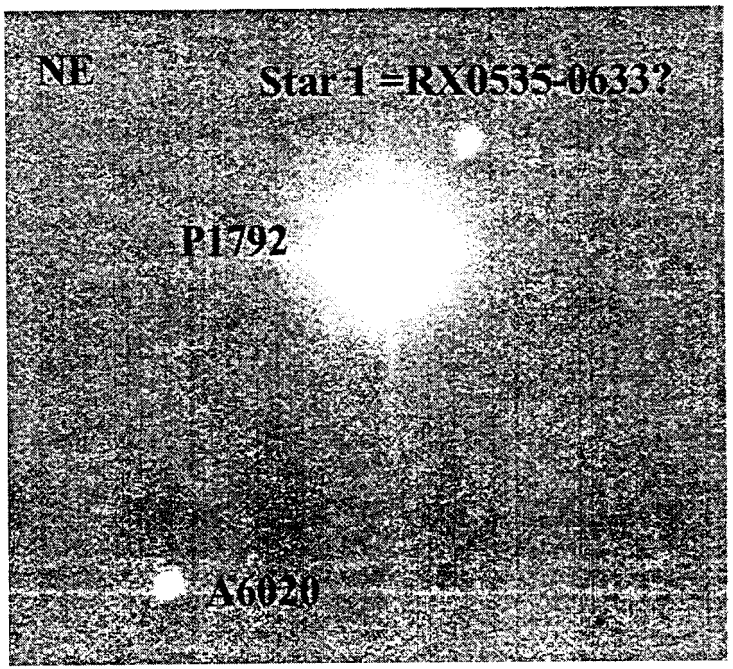
Wouterloot, J. G. A. & Brand, J. 1992, A&A, 265, 144 (WB)

FIGURE CAPTIONS

1. Optical image obtained with the Palomar 5-m/CCD-13 of the region in Orion containing the previously unidentified ROSAT X-ray source RX0535-0633.

2. Optical spectra obtained with Palomar 5-m/Double Spectrograph of the WTTS stars: (a) Star 1 (=RX0535-0633? - see text), (b) V942 Ori (observation 1), (c) V942 Ori (observation 2), (d) WB4 1, and (e) WB57.

3. The X-ray vs. Stellar bolometric luminosities for the identified WTTS stars in the L1641 region including the three stars identified in this paper,


NE
Star 1 =RX0535-0633?
P1792
A6020

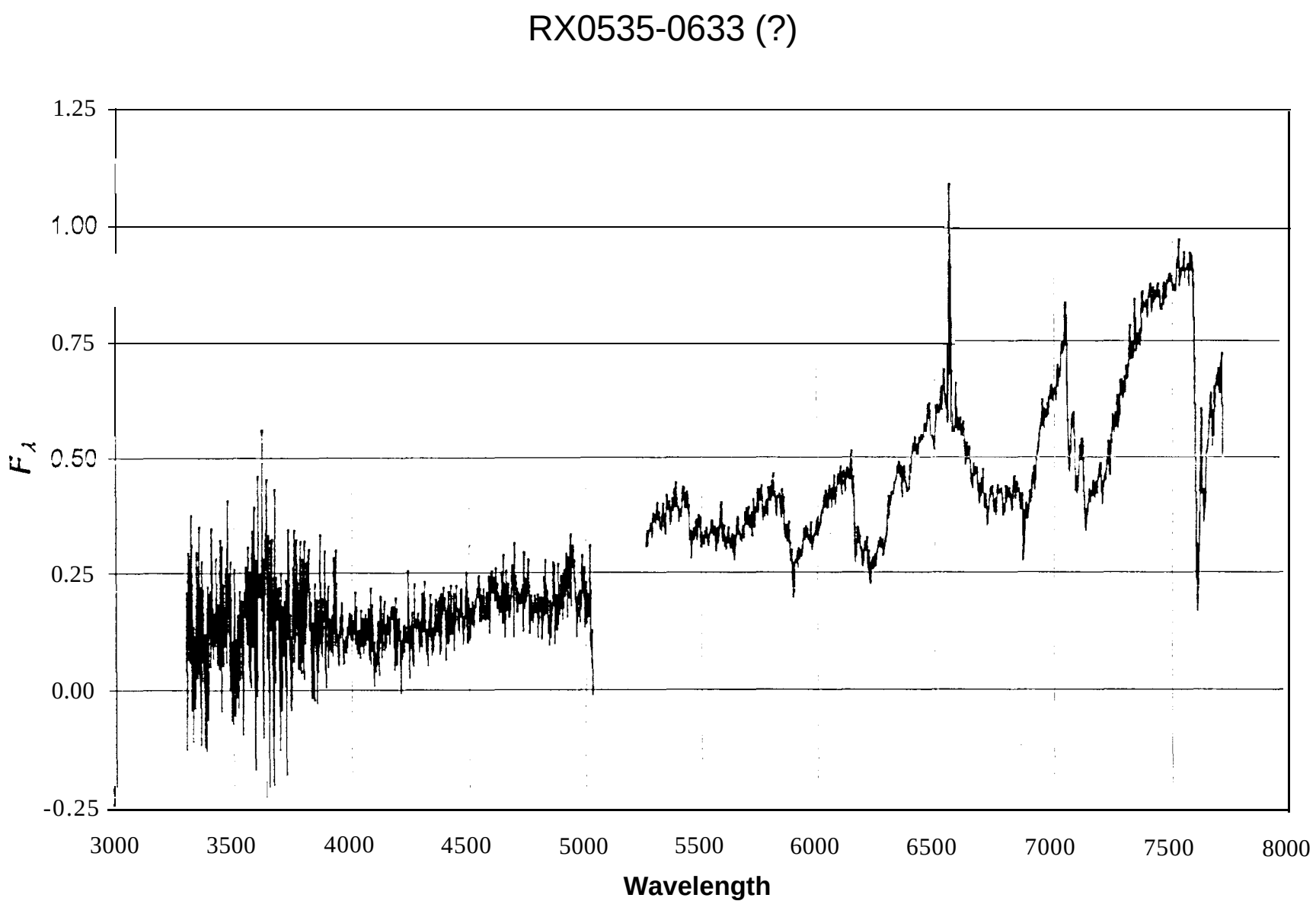

RX0535-0633 (?)
1.25
1.00
0.75
0.50
0.25
0.00
-0.25
F_λ
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Wavelength

Figure 2a

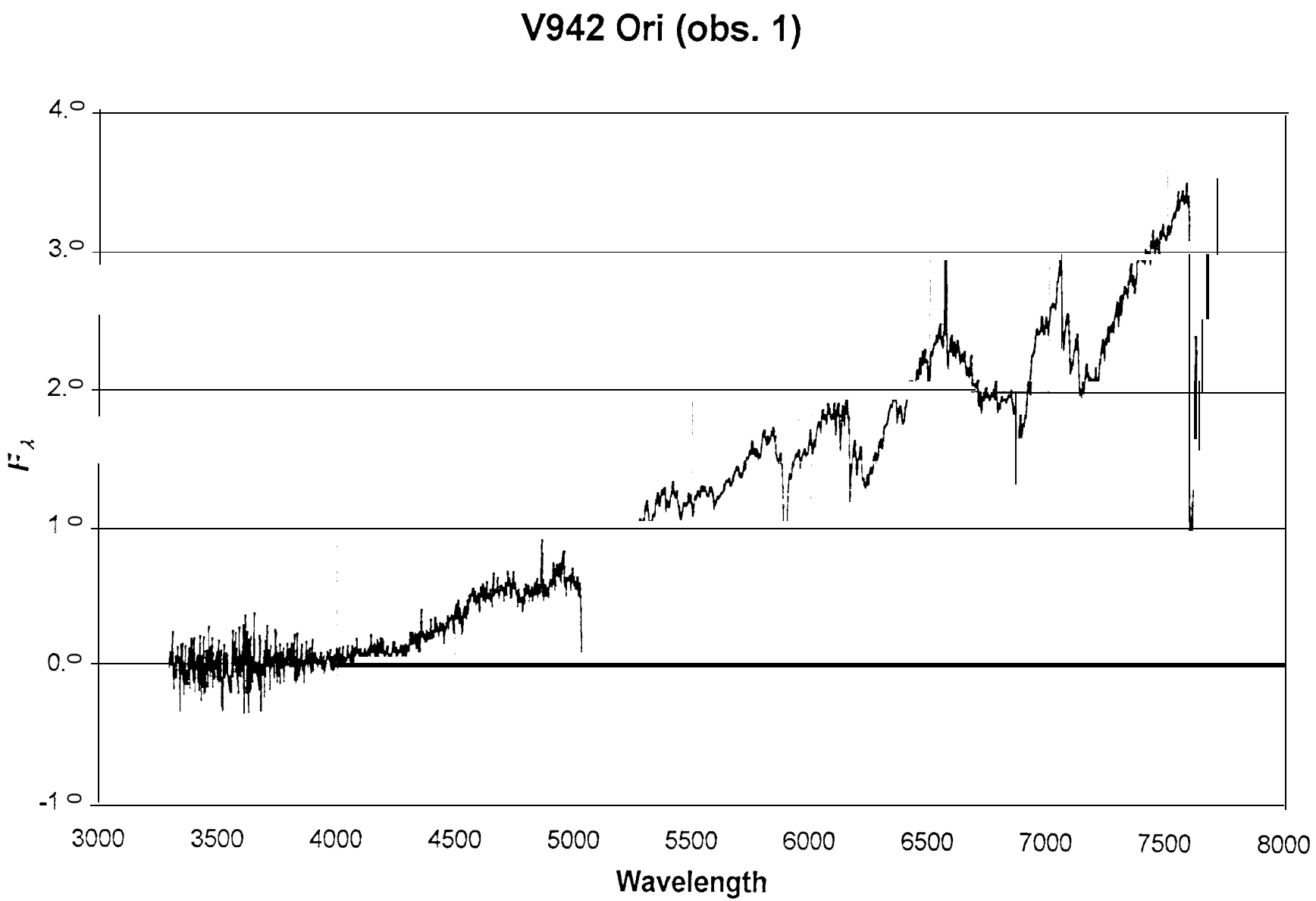

V942 Ori (obs. 1)
4.0
3.0
2.0
1.0
0.0
-1.0
F_λ
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Wavelength

Figure 2b

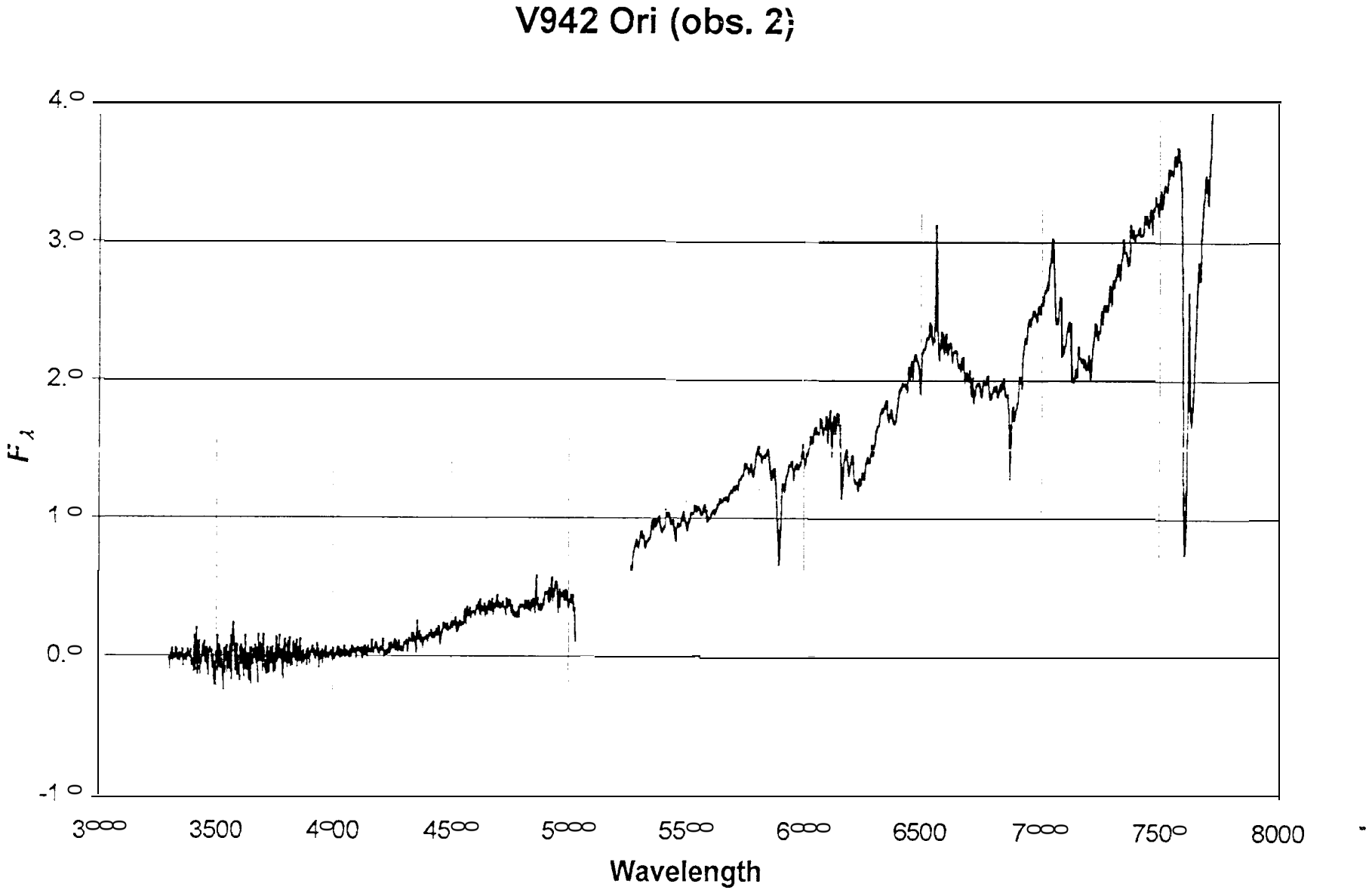

V942 Ori (obs. 2)
4.0
3.0
2.0
1.0
0.0
-1.0
F_λ
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Wavelength

Figure 2c

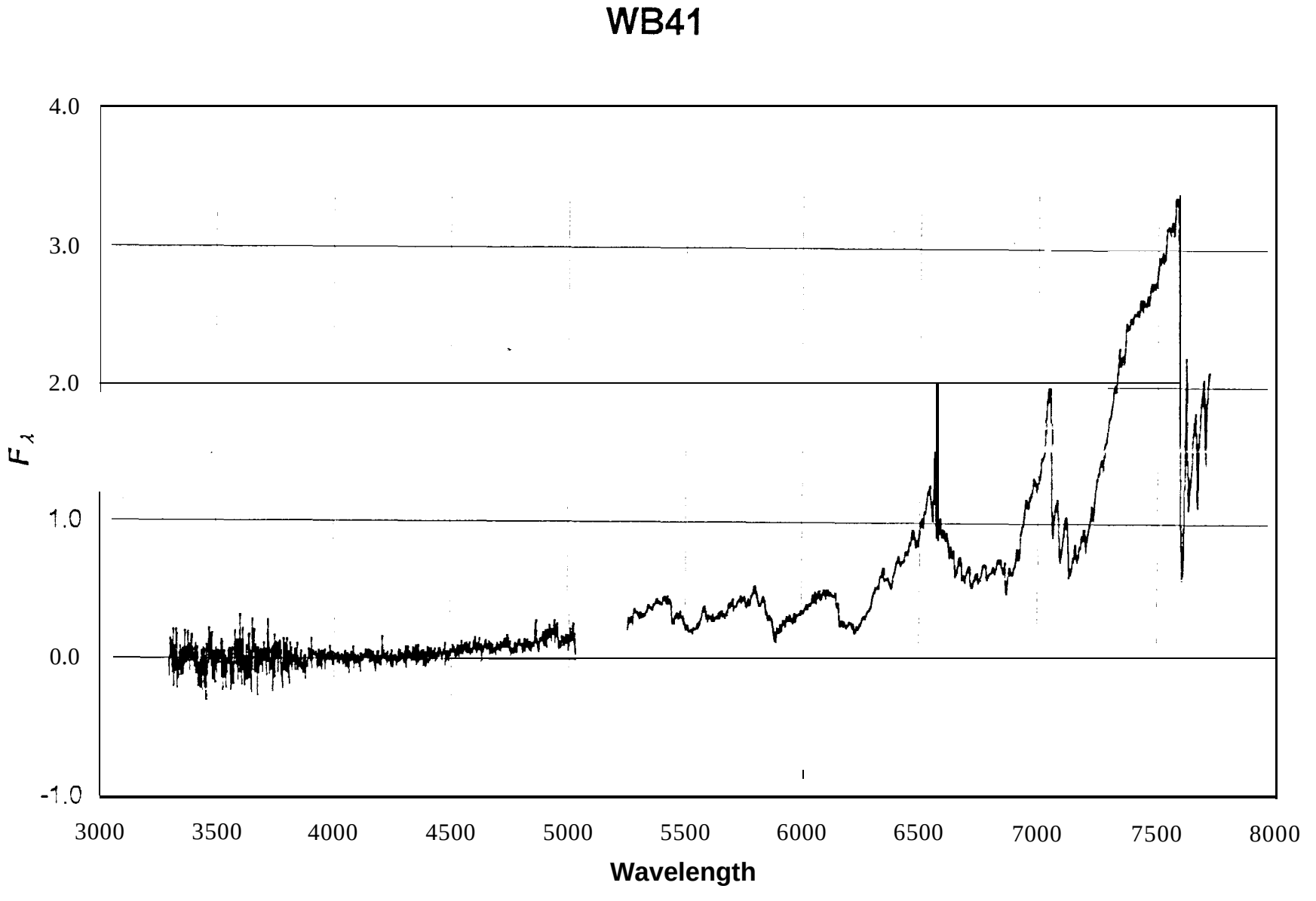

WB41
4.0
3.0
2.0
1.0
0.0
-1.0
F_λ
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Wavelength

Figure 2d

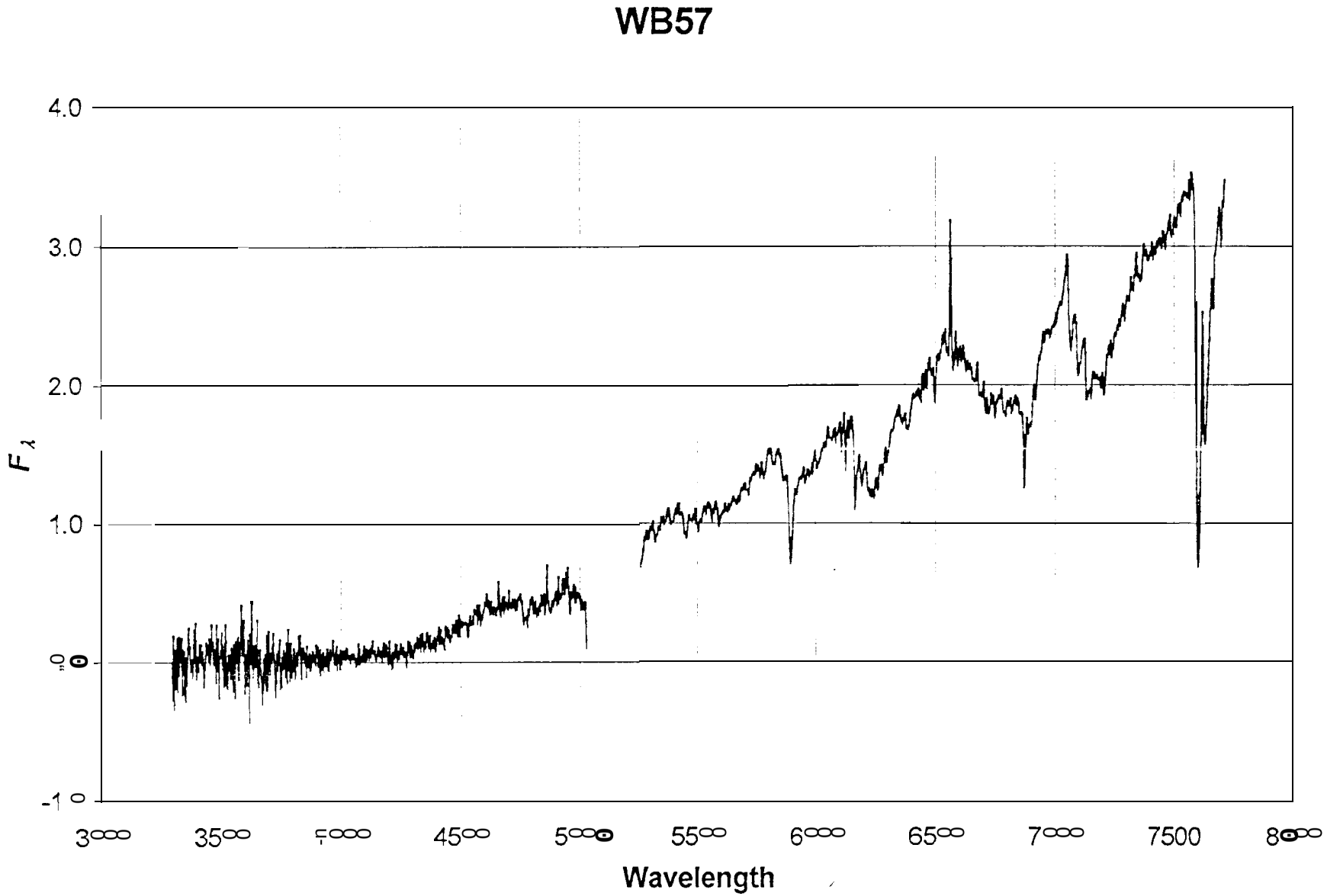

WB57
4.0
3.0
2.0
1.0
0.0
-1.0
F_λ
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
Wavelength

Figure 2e

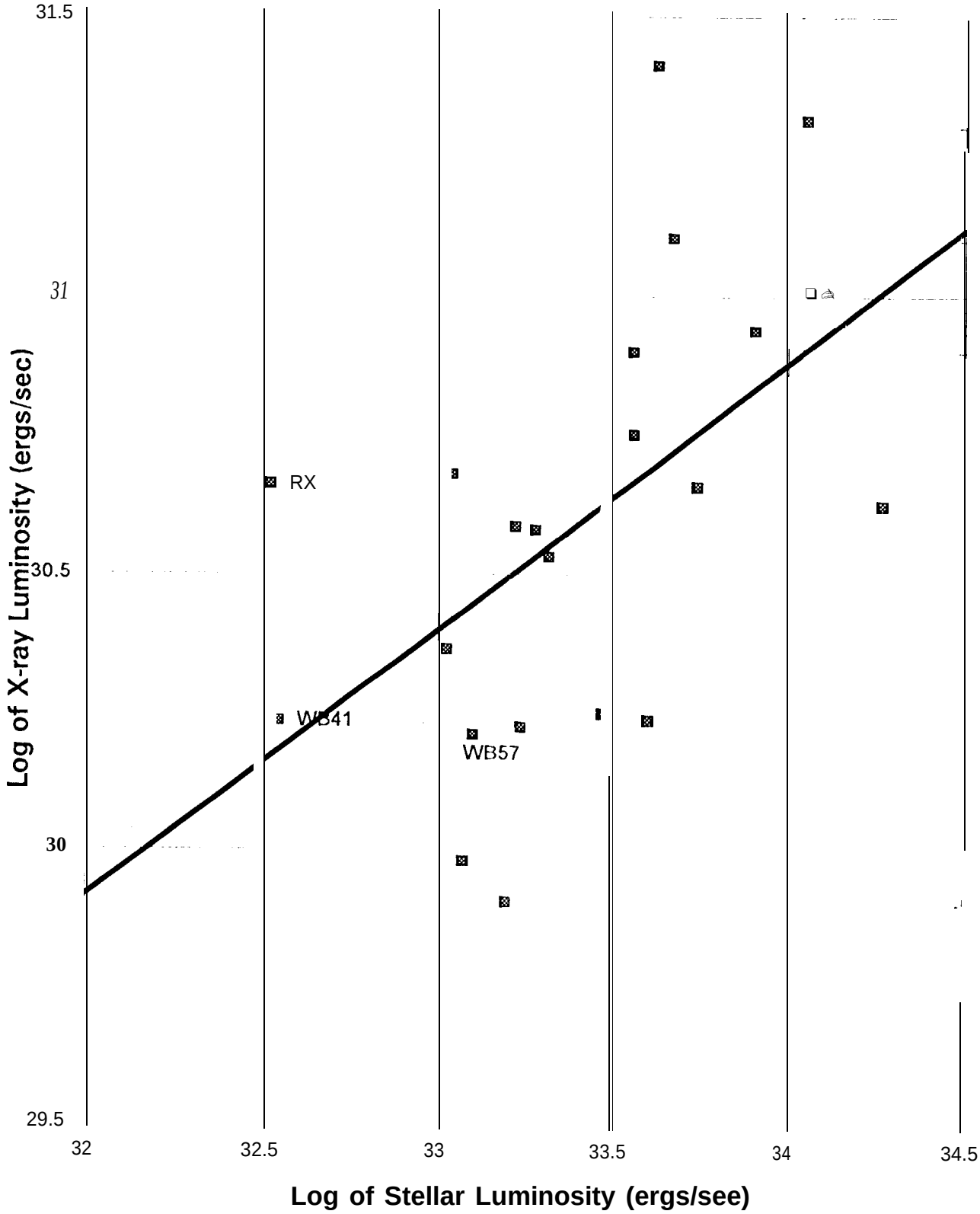


Figure 3. X-ray vs. Stellar Luminosity