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OPTICAL SPECTROSCOPY AND PHOTOMETRY OF EX LUPI

EX Lupi (HD 325367 = HBC 253 = HV 11976) is an irregular variable star that falls into the class of pre-main sequence stars called EXors (Herbig 1989) or "eruptive" T Tauri stars. Eruptive T Tauri stars display outburst phenomena similar to that seen in the FU Orionis variables, but differ from that class in that the time spent at maximum light during an outburst is a only few hundred days and the change in brightness is only a few magnitudes in V . Historically, EX Lupi had at least five outbursts during the period 1893 to 1941 (McLaughlin 1946). A major event in 1955–1956 saw the star brighten to $V_{max} = 8.4$ from $V = 13.2$, the largest outburst ever recorded for this star (Bateson and Jones 1957, as cited by Herbig *et al.* 1992). Recently, EX Lupi went into outburst in early 1993, with $V_{max} = 11.4$ (Jones and Albrecht 1993). In early 1994, EX Lupi again brightened, reaching $V_{max} = 11.24$ (this paper). Presented here are optical photometry and spectroscopy taken during this latest outburst.

EX Lupi was observed with the Cassegrain Image Tube Spectrograph (the "2D-Frutti") and the Automated Single-Channel Aperture Photometer (PC-ASCAP) on the CTIO 1.0-m telescope during the period 1994 March 4 - 24.

The 2D-Frutti spectrograph was configured with grating #26 (600 lines/mm, 5000Å blaze) in first order to provide coverage in the range of 4200–7600Å with a spectral resolution of 3–4Å around H α (6563Å). Because the spectrograph was generally used on non-photometric nights, these spectra are not flux calibrated. Instead, an instrumental spectral response function was derived by comparing observations of A-type stars to the flux distribution of A-type spectrophotometric standard stars. Details of the individual spectroscopic observations and measured equivalent widths for the hydrogen Balmer lines are presented in Table 1. Figure 1 shows two spectra, one taken close to V_{max} for this latest outburst and, for comparison, one taken 19 nights later when the star had faded by about 1 magnitude in V .

Table 1
Spectroscopic Observations of EX Lupi

Julian Date (+2440000)	Exposure Time (sec)	H α	EW(Å) H β	H γ
9415.80	300	35	10	8
9418.87	480	45	12	7
9421.83	600	35	14	9
9422.82	600	32	11	10
9434.88	900	65	16	9

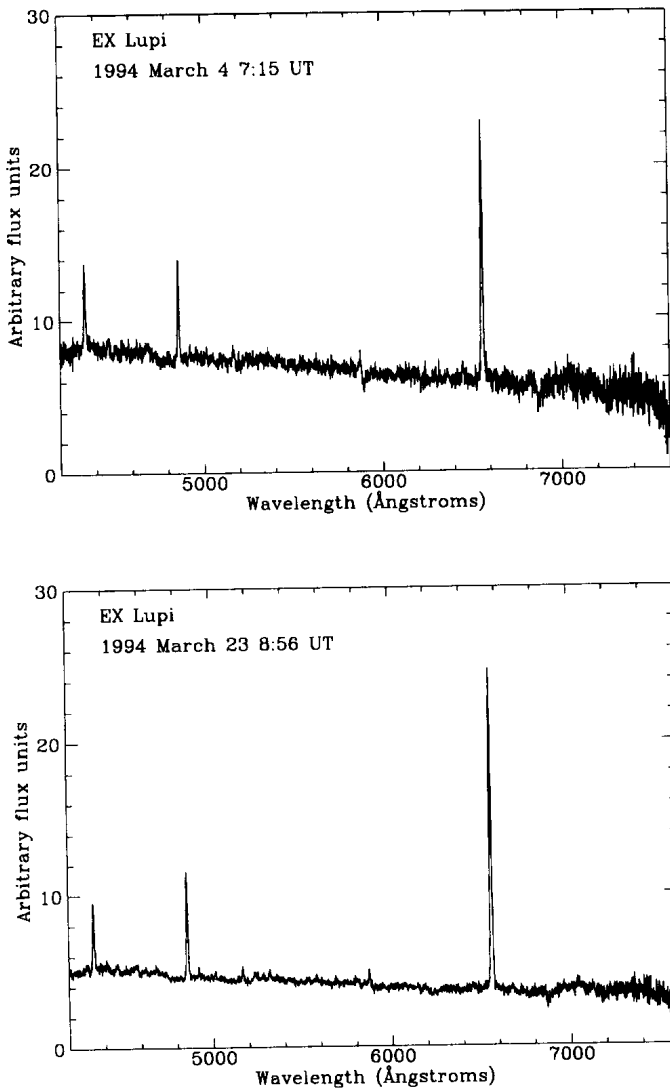


Figure 1: *Top*, EX Lupi on 4 March 1994 near maximum brightness in its latest outburst. The most prominent emission lines in this spectrum are the Balmer lines of hydrogen. *Bottom*, EX Lupi on 23 March 1994 after fading almost 1.0 magnitude in V from maximum brightness. These spectra *are not* flux calibrated.

Table 2
Photoelectric Observations of EX Lupi

Julian Date (+2440000)	$B - V$	$V - R_c$	$R - I_c$	V
9414.841	...	0.43	0.55	11.24
9424.831	...	0.48	0.63	11.84
9425.844	...	0.53	0.69	12.00
9426.844	...	0.57	0.73	12.11
9427.838	...	0.57	0.70	12.01
9428.847	0.60	0.62	0.72	12.12
9429.832	...	0.61	0.71	12.16
9429.868	...	0.64	0.72	12.22
9429.871	...	0.62	0.74	12.21
9429.879	...	0.61	0.74	12.21
9430.837	...	0.57	0.67	12.03
9430.880	...	0.58	0.68	12.04
9431.827	0.48	0.50	0.63	12.00
9431.864	0.48	0.49	0.64	12.00
9431.877	0.49	0.49	0.63	12.02
9432.828	...	0.52	0.59	11.81
9432.869	...	0.53	0.63	11.89
9432.882	...	0.53	0.62	11.91
9433.775	0.51	0.53	0.66	12.01
9433.815	0.46	0.54	0.65	11.98
9433.818	0.46	0.54	0.64	11.99
9433.820	0.45	0.54	0.64	11.98
9433.823	0.47	0.53	0.65	11.97
9433.862	0.47	0.53	0.64	11.96
9433.865	0.48	0.51	0.64	11.95
9433.870	0.43	0.54	0.63	11.96
9433.873	0.45	0.55	0.64	11.97
9433.876	0.45	0.53	0.64	11.96
9433.879	0.44	0.54	0.64	11.96
9433.881	0.46	0.52	0.65	11.95
9435.867	0.63	0.62	0.76	12.20
9435.874	0.60	0.64	0.77	12.22
9435.884	0.64	0.63	0.76	12.21

The PC-ASCAP system was configured with a *BVRI* filter set and a 19 arcsecond aperture. The data were reduced using standard methods and were placed on the *BVR_cI_c* system using observations of photometric standard stars (Graham 1982). The resulting magnitudes and colors are presented in Table 2. Photometric errors are about 1%, except for the *B - V* color, which has about 2% errors.

The spectra are dominated by Balmer emission lines and an early-type continuum devoid of absorption features. There are a few other emission lines in the spectra, such as those of He I(4471Å and 5876Å) and Fe II(4924Å), but they are generally weak, with equivalent widths $< 3\text{Å}$. The equivalent widths measured by Appenzeller *et. al* (1983), when EX Lupi was at $V = 13.7$, are comparable to those measured for this outburst. During the 1993 outburst Herbig (1994) measured $\text{EW}(\text{H}\beta) = 24.0$ and 20.2Å and $\text{EW}(\text{H}\gamma) = 18.0$ and 18.1Å for $V \approx 12.4$ on April 27 of that year. Although all these observations together span ~ 2.5 magnitudes in *V*, the Balmer line equivalent widths do not appear to change much between the outburst and quiescent phases.

The peak brightness of our *V* photometry ($V_{max} = 11.24$) is a little brighter than that recorded for the 1993 May outburst, however since this monitoring campaign began with EX Lupi apparently on the decline, the true maximum may have been brighter still. Over the 21 nights of observation in which photometry was recorded, the star was highly variable with a magnitude range of 11.24–12.22 in *V*. Repeated observations on March 21 and March 22 (JD 2449432 and 2449433) show that the star is active on time scales of minutes, with a few percent change in magnitude and colors.

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