THE SPECTRAL VARIABILITY OF BP TAURI

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ABSTRACT We describe the results of a joint UV and optical monitoring program of the classical T Tauri star, BP Tau, carried out in January 1992. We find no evidence for cyclical variations in light, either on the 7.5 day photometric (rotation) period of the star or on the much shorter half-day timescale expected for the orbital period of an accretion disk boundary layer.

INTRODUCTION

BP Tauri is a mild T Tauri star that has shown signs of quasi-periodic photometric variability. In 1983 the optical brightness of BP Tau was found to vary with a 7.5 day period over a wide range of wavelengths from 3600 Å to 8000 Å (Vrba et al. 1986). These changes were interpreted as the effects of rotational modulation arising from a large, warm photospheric starspot. Similar variability was observed again in 1986 during a program of coordinated IUE spectroscopy and ground-based photometry (Simon et al. 1990). Dramatic changes were also observed in the UV spectrum of BP Tau, which appeared to be synchronized with the optical light variations: the 1500–3000 Å continuum of BP Tau brightened by about 1 magnitude at the time of visible light maximum, and the strengths of the high temperature UV emission lines also appeared enhanced in phase with these optical light changes.

Given the limited phase coverage of the UV observations, it was not possible to show that these changes in the UV spectrum of BP Tau were truly periodic on the 7.5-day rotation cycle of the star. In order to address this problem, a follow-up program was carried out with the IUE in January 1992 to provide a much better phase coverage. Our goal was to look for signs of any dominant timescale(s) for the photometric and spectroscopic changes, which might serve to constrain present-day models for the T Tauri star phenomenon. Among
them are the deep chromosphere model (Herbig 1970), the quasi-steady state accretion disk model (Bertout et al. 1988, Basri & Bertout 1989), and the magneto-dynamic accretion model (Uchida & Shibata 1985, Königl 1991). In the simplest non-magnetic accretion models, for instance, one might expect the light variations to occur on the 6–12 hour Keplerian orbital period of the boundary layer, whereas in the magnetic accretion models the UV and optical variability should be locked to the roughly 7-day rotational period of the star at the latitude where the magnetic accretion column is anchored.

OBSERVATIONS

We obtained low dispersion UV spectra of BP Tau with the SWP and LWP cameras of IUE on alternating days covering a 15 day interval, corresponding to two full (photometric) rotation cycles. Concurrently we obtained optical spectra of BP Tau from the Lick Observatory, using the Hamilton spectrograph on both the CAT and 3-m telescopes.

The UV spectra were reduced independently in two ways: line and continuum fluxes were measured first from the IUESIPS output by hand in the normal fashion, and then we used a state-of-the-art, automated reduction procedure to analyze the SWP spectra (Ayres 1993). Details concerning the photometric linearization scheme, the assignment of errors through a photometric noise model, the excision of cosmic ray hits, the removal of a spatially-filtered and heavily-smoothed off-spectrum background, and the extraction of line fluxes using an “optimally weighted” slit based on the local cross-dispersion profile of the spectral trace — these can all be found in Ayres (1993).

The line fluxes measured by the two methods are in very good agreement. Our quantitative estimates of the measurement errors in the fluxes (see Ayres 1993) are of the order 3–5%. For the Mg II lines we measure the net flux above the local “continuum”. We also measure the flux in several broad “continuum” bands 50–200 Å in width, for which IUE photometry is known to be reproducible at levels of a few percent.

RESULTS

Most of the UV lines appear to be brighter in 1992 than they were in 1986, with fluxes up to 50% larger in the strongest short-wavelength lines, e.g., C IV 1550 Å. However, the mean flux in Mg II is 10% weaker. No trend with the temperature of line formation is evident.

We observed significant variability in the strengths of all the UV lines and continuum bands at levels that far exceed the measurement errors. The variations are 10 times the estimated errors in C IV, 20 times larger in Mg II, and 30 times larger in the continuum. For most lines the difference in absolute flux between minimum and maximum brightness is the same in 1992 as in 1986.

At their faintest levels, the UV continuum fluxes in 1992 are similar to those observed in 1986, but the brightest flux levels are substantially weaker, so that the 1992 variability amplitudes are half those of 1986. The amplitudes amount to 0.8–1.0 mags in 1992, versus 1.0–1.3 mags in 1986, with the larger variations
occurring at the longer wavelengths. The visible FES magnitudes are similar in 1992 and 1986, with an amplitude of about 0.4 mags at both epochs.

None of the variations we observe in 1992 appear cyclic on the timescale of the 7.5-day rotation period, and a formal period search yields no definite periodicities. A sinusoid with an arbitrary 4-day period can be drawn through the UV and FES measurements, but the folded light curves exhibit a very large scatter at each phase, indicating either a fit of very low weight or intrinsic variability on a range of timescales. A photometric period as short as 4 days would be sensible if there are two spots present simultaneously on the surface of the star, separated by 180° in longitude (a circumstance which is not unusual for spotted stars).

The strengths of the optical lines, Hα and Ca II IR T 8542 Å, also vary but in a way that is distinct from the UV lines. The veiling-corrected EWs of these lines, which are derived by assuming a constant strength for the Li I 6707 Å feature, are at their peak brightness when the UV lines, UV continuum, and FES counts are at their faintest.

CONCLUSIONS

We observe significant variability in the UV and optical emission of BP Tau on both hourly and daily timescales, but find no evidence that these photometric changes are dominated by a single cycle (at least in January 1992). The starspot(s) thought to be responsible for these light variations must have a considerable range of lifetimes. In terms of the magnetic accretion model, the behavior we observe suggests that there may be multiple flux tubes connecting the star and its disk, which continually form, are disrupted, and then reform.

REFERENCES

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