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The Rotation of PZ Tel in the Far-UV

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Abstract. We observed the ultra-rapid rotator PZ Tel for one stellar rotation period starting 30 May 2003. The goals were to search for rotational modulation of the transition region lines, and to obtain good O VI line profiles, in order to measure the width of the broad underlying pedestal emission. We obtained optical photometry around the time of the FUSE observation. We detected the rotational modulation, in anti-phase with the optical modulation, as well as a small flare. The O VI line λ1032Å profile shows broad asymmetric wings.

1. Introduction

If the young Sun was normal for its mass and age, then it was highly magnetically active. This magnetic activity controls the flux of ionizing radiation, and directs the particle flux of these active stars. These are of interest, not only because they represent the extremes of stellar magnetic activity, but because it was in such an environment that the Earth formed. Clues to the nature of the magnetic activity and of the morphology of the magnetic field in such stars can be ascertained through study of the ultra-rapid rotators (URRs), zero-age main sequence stars that rotate with periods less than about one day. These represent stars at the peak of their pre-main-sequence spinup, prior to their subsequent spindown. The best known URR is AB Dor, with a 12.5 hour rotation period.

The URRs possess cool Hα prominences seen in absorption against the photosphere, rigidly rotating at heights of 2-5 stellar radii (Collier Cameron & Robinson 1989), confined in large magnetic loops. Brandt et al. (2001) showed that the UV line profiles of AB Dor, which consist of a broad pedestal underlying a narrower core, can be modelled as gas confined near or within the Keplerian co-rotation radius. Brandt et al. hypothesized that the prominences seen in absorption are the source of the pedestal emission when viewed off the stellar disk. In this case, the width of the pedestal emission should echo the orbital velocity at the Keplerian co-rotation radius, which scales as $P_{rot}^{-1/3}$.

To search for this effect, and to study the characteristics of extreme magnetic activity, we focussed on PZ Telescopii. This is a bright (V=8.4) 20 million year old K0V star with a rotation period of 0.95 days. The projected rotational velocity v sin i is 68 km s^{-1}, and the inclination i is about 60° (Barnes et al.

2000). It is a typical URR, with prominent dark spots and extended Hα prominences. With about twice the rotation period, we expect that its line pedestal widths should be about 15% narrower than those of AB Dor.

2. Observations, Analysis and Data

We observed PZ Tel for 1 day, or 1.06 stellar rotations, beginning at 11:59UT on 30 Mar 2003. The total exposure time was 55.8 ksec. We also obtained optical UBV photometry of the system on 12 occasions between 24 and 31 May 2003, using the ANDICAM dual channel photometer on the SMARTS 1.3m telescope atop Cerro Tololo. Two points were simultaneous with the FUSE observation.

As we were interested in the light curve as well as the line profiles, we waited for the release of CALFUSE 3.0 before reducing these data. We examined the 15 individual segments using CF_EDIT. The extraction software generally worked well, but in one case we adjusted the location of the slit width. For further analysis, we used customized IDL software that reads the IDF output files.

The strongest lines in the spectrum are C III λ977, O VI $\lambda\lambda$1032 (Figure 1L), 1038, and C III λ1175. Weak N I emission around 1150Å is also present. There is no appreciable stellar continuum. The O VI λ1038 line is asymmetric to the blue because of C II λ1036Å emission. There is no evidence for phase-related changes in the emission line profiles.

There is no significant continuum flux, so we summed the counts in the four strong lines and adjacent background independently for each detector. We determined the relative throughputs in each detector, and then summed the appropriately-scaled line counts to produce the final light curve.

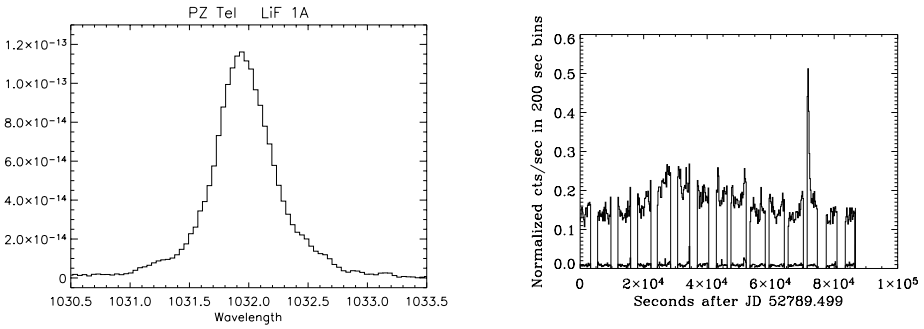

Figure 1. **Left:** The summed O VI λ1032Å line profile from the full 55 ksec exposure. The line has broad but asymmtric wings; further modelling will be needed to determine the width of the pedestal emission. **Right:** The light curve in the sum of the C III and O VI lines, in 200 second bins. The subtracted background is overplotted.

The summed light curve, constructed from the light of the four strong lines, is shown in Figure 1R. The light curves in the individual lines are similar. We see a smooth modulation of about 30% in the intensity. A short flare is also visible.

The folded light curve (Fig. 2L) shows that the light curve is continuous. With only 1.06 stellar rotations, it is not possible to definitively state that we see a rotational modulation, but the ∼sinusoidal variation on the rotation pe-

riod is appropriate for a star with an active hemisphere. The optical light curve is in anti-phase with the FUSE light curve. This suggests that a component of the far-UV emission arises from plage region associated with the dark photospheric spots. Some 70% of the far-UV emission is not modulated, and may arise from structures extended above the photosphere, from high latitudes, or from a relatively uniform distribution of active regions.

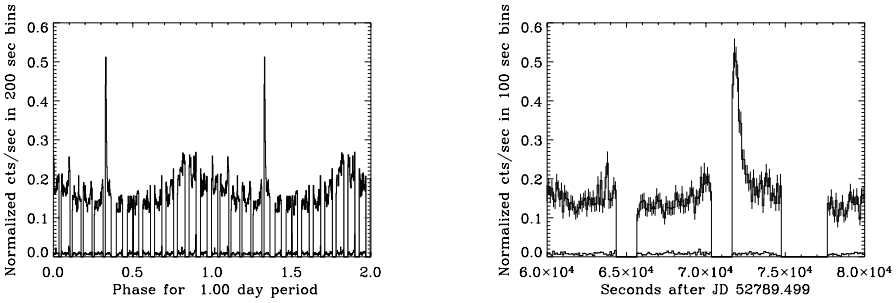

Figure 2. **Left:** The folded light curve in the sum of the C III and O VI lines. The binning is 200 seconds, The background has been subtracted, but is overplotted (the lower trace); there is no significant nighttime enhancement. The data are plotted twice. The phase overlap, near phase 0.6, is minimal. Zero phase is defined to be at JD 2452789.0. **Right:** The flaring light curve, eith error bars, in the sum of the C III and O VI lines. Background has been subtracted. The binning is 100 seconds. This is an expansion of the left panel.

The flare (Figure 2R), detected in all four lines, appears to have peaked about 100 sec after the start of this data segment. The decay is exponential with an e-folding time of 300 sec. We cannot tell whether in brightness increase at the end of the previous data segment is related to the flare. Note that the flare occurred while the inactive stellar hemisphere was in view. At peak, the peak flare is enhanced about a factor of three above the mean line intensity.

3. Summary

PZ Tel is an active star with bright far-UV emission lines of C III and O VI. The far-UV line fluxes show an apparent 30% rotational modulation. This modulation is out of phase with the optical V band modulation, as expected for emission from plage associated with the dark photospheric spotted regions. We detected one flare, with a 5 minute exponential decay time.

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References

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