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RADIAL VELOCITY STUDY OF THE DWARF NOVAE KT PER AND TZ PER

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RESUMEN

Se presentan medidas de velocidad radial de las novas enanas KT Per y TZ Per, con las que se mejoran las estimaciones de sus parámetros orbitales. Para KT Per, encontramos un período orbital de 0.16265777±0.00000001 días y una semiamplitud $K_{em} = 136 \pm 6$ km s^{-1}, mientras que para TZ Per se encuentran valores del período de 0.2629062 ± 0.0000008 días y una semiamplitud $K_{em} = 107 \pm 3$ km s^{-1}.

ABSTRACT

We present radial velocity observations of the dwarf novae KT Per and TZ Per, that allow us to improve their orbital parameters. For KT Per we find an orbital period of 0.16265777±0.00000001 days and a semi-amplitude $K_{em} = 136 \pm 6$ km s^{-1}, while for TZ Per an orbital period of 0.2629062 ± 0.0000008 days and a semi-amplitude $K_{em} = 107 \pm 3$ km s^{-1} are found.

Key words: **BINARIES: CLOSE — STARS: INDIVIDUAL: KT PER, TZ PER — STARS: NOVAE, CATACLYSMIC VARIABLES**

1. INTRODUCTION

Dwarf Novae are a subclass of Cataclysmic Variables which have semidetached late-type secondary stars undergoing mass transfer onto a white-dwarf primary. Outbursts are frequent in these objects with timescales ranging from a few days to several weeks (see recent review by Warner 1995). The spectra of dwarf novae at minimum light or quiescence usually show strong, broad lines of H and He I in emission, while during outburst the same lines are seen in shallow absorption. In this paper we report low-resolution observations of the dwarf novae KT Per and TZ Per.

First reports of KT Per by Romano (1962) and Löchel (1965) indicated a Z Cam sub-type variable with an outburst periodicity of about 12d. Later studies by Szkody & Mattei (1984) indicate and outburst periodicity between 19 and 37d with a mean of 26d. Sherrington & Jameson (1983) (IR) and Echevarría (1983) (*UBV*) estimate an orbital period between 5.78 and 7.2h based on the photometric colours, but Szkody and Mattei argue in favour of a period around 0.47, 3.46 and 3.7h based on the outburst, rise and decline lengths, respectively. The first radial velocity study for this object, by Ratering, Bruch, & Diaz (1993) yield an orbital period around 3.9h. This is confirmed by Thorstensen & Ringwald (1997), who show that the period is more likely to be near 0.1627d, but with a possible period near 0.1618d.

TZ Per is a Z Cam sub-type dwarf nova early reported by Gaposschkin (1939) with an outburst periodicity of around 17d. Szkody & Mattei (1984) report an outburst interval between 4 and 27d with a mean of 17d. Echevarría (1983) predicts an orbital period between 6.33 and 7.9h, based on the *UBV* colours, while Szkody & Mattei (1984) estimate periods around 6.03, 6.03 and 3.70h based on the outburst, rise, and decline lengths, respectively. From a radial valocity study by Ringwald (1995) a period of 6.2520h is established.

2. OBSERVATIONS

The observations were obtained with the Boller & Chivens Spectrograph, attached to the 2.1-m Telescope at the Observatorio Astronómico Nacional at San Pedro Mártir.

We observed KT Per during November 6, 1991 and TZ Per during November 6 to 8, 1991. We used a 600 lines mm^{-1} grating near its blaze an-

TABLE 1

LOG OF OBSERVATIONS OF KT PER

Frame	Date (UT)	Exp. T. (s)	UT (h m s)	ST (h m s)	Frame	Date (UT)	Exp. T. (s)	UT (h m s)	ST (h m s)
kt001	08 Nov 91	600	05 47 50	01 14 30	kt010	08 Nov 91	600	07 56 40	03 23 43
kt002	08 Nov 91	600	05 58 05	01 24 47	kt011	08 Nov 91	600	08 08 40	03 35 45
kt003	08 Nov 91	600	06 09 20	01 36 04	kt012	08 Nov 91	600	08 19 05	03 46 22
kt004	08 Nov 91	600	06 40 25	02 07 14	kt013	08 Nov 91	600	08 31 05	03 58 14
kt005	08 Nov 91	600	06 50 50	02 17 41	kt014	08 Nov 91	600	08 41 10	04 08 21
kt006	08 Nov 91	600	07 01 45	02 28 38	kt015	08 Nov 91	600	08 53 10	04 20 23
kt007	08 Nov 91	600	07 12 45	02 39 43	kt016	08 Nov 91	600	09 03 30	04 30 45
kt008	08 Nov 91	600	07 34 45	03 01 45	kt017	08 Nov 91	600	09 14 02	04 41 17
kt009	08 Nov 91	600	07 45 20	03 12 20	...	...	...	...	...

TABLE 2

LOG OF OBSERVATIONS OF TZ PER

Frame	Date (UT)	Exp. T. (s)	UT (h m s)	ST (h m s)	Frame	Date (UT)	Exp. T. (s)	UT (h m s)	ST (h m s)
tz001	05 Nov 91	600	05 40 10	00 50 15	tz034	07 Nov 91	600	07 16 30	02 39 06
tz002	05 Nov 91	600	06 00 30	01 18 34	tz035	07 Nov 91	600	07 27 10	02 49 49
tz003	05 Nov 91	600	06 13 00	01 31 17	tz036	07 Nov 91	600	07 37 50	03 00 06
tz004	05 Nov 91	600	06 23 30	01 41 38	tz037	07 Nov 91	600	07 50 35	03 13 18
tz005	05 Nov 91	600	06 38 36	01 56 57	tz038	07 Nov 91	600	08 01 45	03 24 00
tz007	05 Nov 91	600	07 03 60	02 21 15	tz039	07 Nov 91	600	08 13 15	03 36 02
tz009	05 Nov 91	600	07 30 06	02 48 25	tz040	07 Nov 91	600	08 25 40	03 48 30
tz010	05 Nov 91	600	07 40 42	02 59 05	tz041	07 Nov 91	600	08 36 15	03 59 06
tz011	05 Nov 91	600	07 55 06	03 13 31	tz042	07 Nov 91	600	08 48 05	04 10 58
tz012	05 Nov 91	600	08 06 12	03 24 49	tz043	07 Nov 91	600	09 00 50	04 23 55
tz013	05 Nov 91	600	08 17 36	03 36 15	tz044	07 Nov 91	600	09 12 40	04 35 38
tz014	05 Nov 91	600	08 32 12	03 50 44	tz045	07 Nov 91	600	09 23 55	04 46 55
tz015	05 Nov 91	600	08 43 00	04 01 35	tz046	07 Nov 91	600	09 36 45	04 59 47
tz016	05 Nov 91	600	08 54 12	04 12 47	tz047	07 Nov 91	600	09 47 55	05 10 59
tz017	05 Nov 91	600	10 45 50	06 04 45	tz048	07 Nov 91	600	09 58 45	05 21 51
tz018	05 Nov 91	600	10 56 48	06 15 55	tz049	07 Nov 91	600	10 11 25	05 34 32
tz019	05 Nov 91	600	11 08 60	06 27 00	tz050	07 Nov 91	600	10 22 33	05 45 46
tz020	07 Nov 91	600	03 32 15	22 44 11	tz051	07 Nov 91	600	10 33 15	05 56 17
tz021	07 Nov 91	600	03 56 00	23 18 11	tz052	07 Nov 91	600	10 46 15	06 09 17
tz022	07 Nov 91	600	04 06 48	23 23 00	tz053	07 Nov 91	600	10 57 15	06 20 40
tz023	07 Nov 91	600	04 22 22	23 44 31	tz054	07 Nov 91	600	11 07 32	06 31 10
tz024	07 Nov 91	600	04 32 45	23 54 55	tz056	08 Nov 91	600	03 44 27	23 10 45
tz025	07 Nov 91	600	04 55 35	00 17 50	tz057	08 Nov 91	600	03 57 10	23 23 40
tz026	07 Nov 91	600	05 07 10	00 29 24	tz058	08 Nov 91	600	04 09 00	23 35 23
tz027	07 Nov 91	600	05 17 30	00 39 46	tz059	08 Nov 91	600	04 19 15	23 45 40
tz029	07 Nov 91	600	05 43 20	01 05 40	tz060	08 Nov 91	600	04 30 37	23 57 03
tz031	07 Nov 91	600	06 07 00	01 29 24	tz061	08 Nov 91	600	04 44 46	00 11 15
tz032	07 Nov 91	600	06 18 20	01 40 46	tz062	08 Nov 91	600	04 57 20	00 23 51
tz033	07 Nov 91	600	06 29 05	01 51 33	tz063	08 Nov 91	600	05 08 59	00 35 30

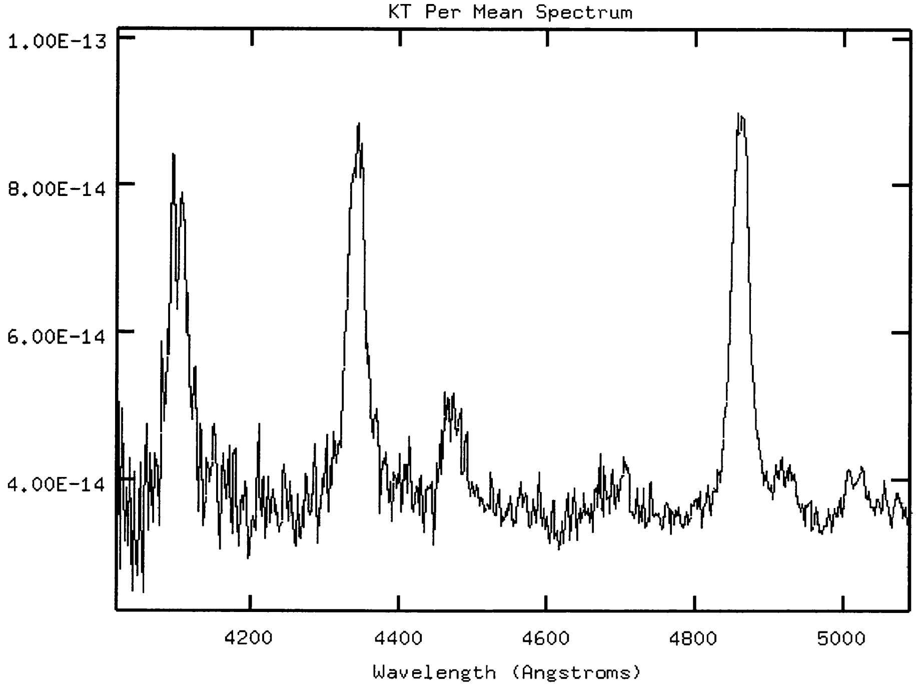

Fig. 1. The mean spectrum of KT Per.

gle of 8°.63 with a 384 × 576, 23 μm Thomson CCD to cover a spectral range from λ4040 to λ5100. We used a slit width of 120 μm corresponding to 1.6 arcsec. The spectral resolution is around 3.9 Å. The log of observations are shown in Tables 1 and 2, respectively. The spectrophotometric standard stars HD 17520, HD 192281, and HD 212948 were observed and used to calibrate the stellar fluxes. The late-type spectral standard star, HR 1588, was also observed. The weather was clear for all observations and the seeing at the telescope was around one arcsec.

3. DISCUSSION

3.1. *KT Per*

The mean spectra of KT Per, observed during a minimum, is shown in Figure 1. The object shows broad and strong Hβ, Hγ, and Hδ emission lines, plus weak He I lines (like λ4471, λ4922, λ5015) and He II λ4686 also in emission. The lines are in general double-peaked, but not always, with a dominant red peak present at several phases. We were unable to detect the absorption spectrum arising from the secondary star, and no cross-correlation with the K4III standard star produced any reasonable results.

We measured the Hβ and Hγ Balmer lines using the method of Schneider & Young (1980), in which a positive and negative Gaussians at fixed width and separation are convolved with the spectral line, with the zero of this convolution taken as the velocity. We followed the method described by Shafter (1983), to minimize the σ/K_{em} ratio. The *rvsao* IRAF package was used for this purpose. The radial velocity results are shown in Table 3. The quality of the results for Hβ is much better since this line is stronger and our detector more efficient at this wavelength. The separation and width of the two Gaussians gave best results for $a = 17$ Å and a width of 6 Å.

Ratering, Bruch, & Diaz (1993) (RBD93) and later Thorstensen & Ringwald (1997) (TR97), have measured the radial velocity of KT Per during quiescence and outburst. Our observations were obtained more than one year after the last published values, so an improved time baseline can be used to obtain better orbital parameters. A computer program to find the orbital parametrs of the binary was made. The program performs non-linear square fits with the Levenberg-Marquardt method, with a suitable iteration method to check for minimum internal χ and external σ values. The program makes a detailed search for possible solutions covering a wide range of orbital periods. As a test we reproduced the Cases 1, 2, and 3 discussed by TR97 with identical results. We paid special attention to these cases to try to discard one of the period aliases. As a first step we combined only the Hβ data with those by RBD93. We adjusted the individual observing runs to a common zero γ velocity. We found four possible periods: 0.161825,

TABLE 3

RADIAL VELOCITIES FOR KT PER[a]

$HJD_{\odot}$ (2440000+)	Hβ	Hγ	$HJD_{\odot}$ (2440000+)	Hβ	Hγ
8568.7496	− 3	161	8568.8390	−106	− 80
8568.7567	182	324	8568.8474	− 95	−188
8568.7645	179	189	8568.8629	− 95	7
8568.7933	191	196	8568.8699	−109	− 86
8568.8009	116	103	8568.8783	− 75	19
8568.8238	− 8	111	8568.8854	−147	54
8568.8311	−44	44	8568.8927	69	93

[a] In km s^{-1}.

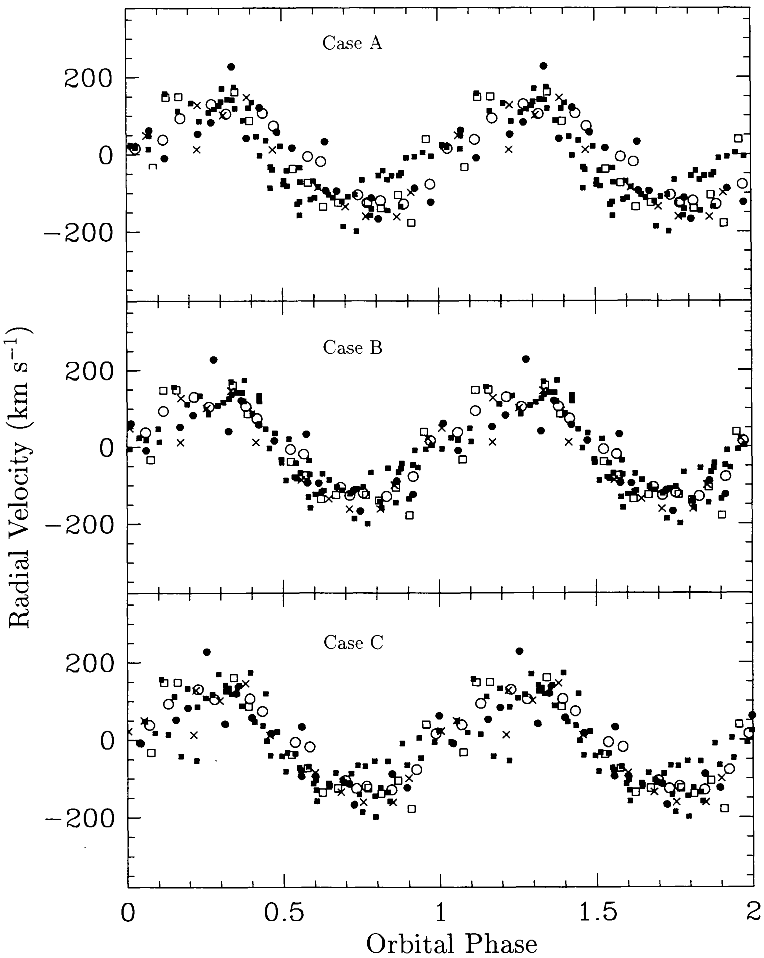

Fig. 2. Radial velocity curve of KT Per as a function of orbital phase for three different orbital periods, discussed in the text. Solid and open dots correspond to the Hβ data obtained by Ratering, Bruch, & Diaz (1993) on 1989, October 10 and 11, respectively. Crosses correspond to Hα observations by the same authors on 1989, October 12. Solid squares are Hα observations by Thorstensen & Ringwald (1997) obtained during several nights on 1989, November. Open squares correspond to our Hβ observations obtained on 1991, November 10.

TABLE 4

ORBITAL PARAMETERS OF KT PER

	γ (km s^{-1})	K_{em} (km s^{-1})	HJD$_\odot$ (2446643+)	P_{orb} (days)	σ
Case A	[−4.8] ± 4.7	128.6 ± 6.7	0.4867 ± 0.0001	0.16272927 ± 0.00000001	50.2
Case B	[−1.9] ± 4.0	136.0 ± 5.7	0.52042 ± 0.00001	0.16265777 ± 0.00000001	42.2
Case C	[−6.7] ± 4.5	127.0 ± 6.2	0.5802 ± 0.0001	0.16185958 ± 0.00000001	47.7

0.161859, 0.162657, and 0.162727 days with a similar sigma value of about 42.7. Thus, with this data only, we are unable to distinguish between the possible periods. As a second step, we combined the Hβ and Hα, of all authors. This includes the October 1989 results by RBD93 and the November 1989 results by TR97. The results are shown in Table 4 and in Fig. 2 for three different cases simliar to those of TR97.

We show in Figure 2 the radial velocity curve of KT Per, folded fcr three possible orbital periods. Case A (upper panel) has an orbital period similar to TR97 Case 1. The dispersion is higher than in the next two cases. In Case B (middle panel), we show the lowest dispersion solution. The period value is slightly different from the Case 2 in TR97. For Case C (lower panel) most of the data are reasonably fitted, except the two velocities obtained at JD 7852 and an observation obtained during the Hα October 1989 run (JD 7811.43151). However, this last point have neighbouring data which are well fitted; therefore, we consider this deviation due to observational errors. If we take out these three points the fit does not improve very much with respect to Case B (σ = 49.62). For these reasons, we believe that the best solution to the object is that for Case B with an orbital period of 0.16265777 ± 0.00000001 days. This value is close to TR97 Case 2.

The semi-amplitude of the radial velocity curve, K_{em} = 136 km s^{-1}, for our best solution is also similar to that obtained using the RBD93 October plus TR97 November observations with a period of

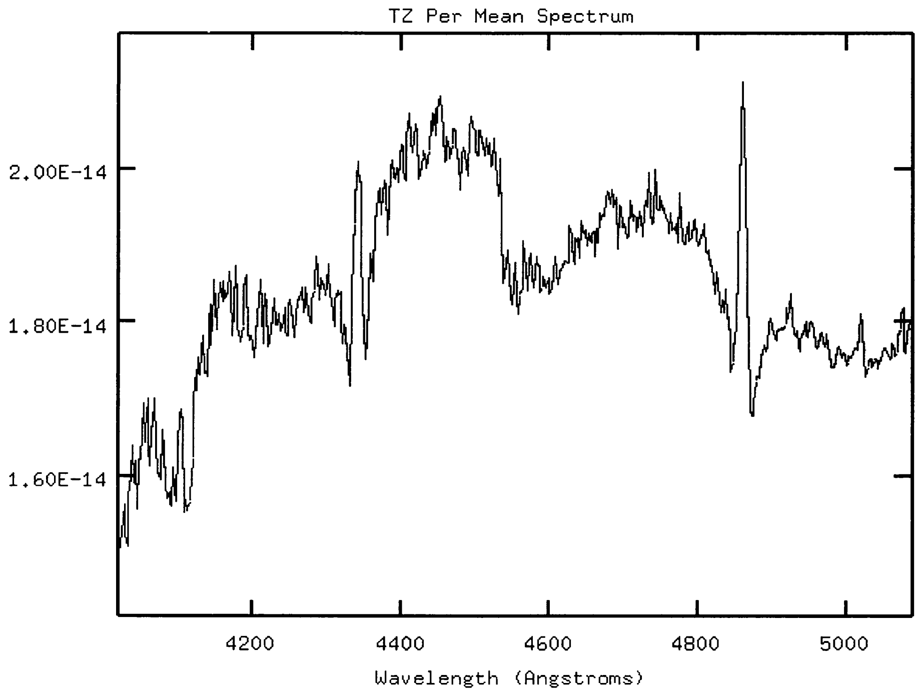

Fig. 3. The mean spectra of TZ Per for the three observing nights.

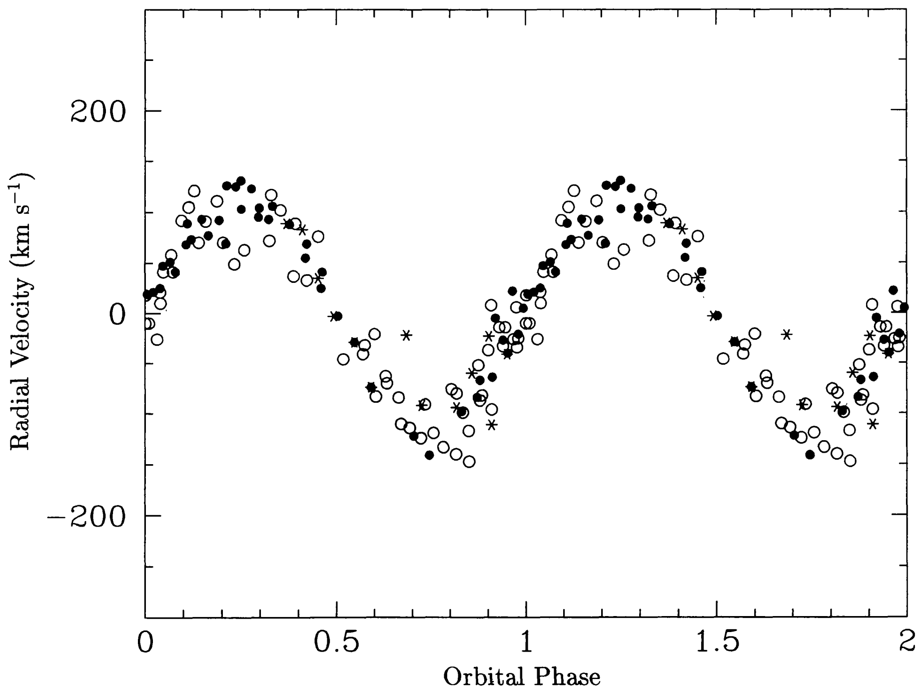

Fig. 4. The radial velocity curve of TZ Per. Open dots correspond to our observations during decline; stars, to data near maximum taken on October 16–20, 1991 by Ringwald (1995); and filled dots correspond to his observations near minimum light taken on October 26 and 27, 1991.

TABLE 5

RADIAL VELOCITIES FOR TZ PER[a]

HJD$_\odot$ (2440000+)	Hβ	HJD$_\odot$ (2440000+)	Hβ	HJD$_\odot$ (2440000+)	Hβ	HJD$_\odot$ (2440000+)	Hβ
8566.74389	− 67	8567.81080	− 53	8566.96378	81	8567.93277	0
8566.75801	− 62	8567.81821	− 42	8566.97156	16	8567.94000	37
8566.76669	−104	8567.82562	− 84	8567.65507	6	8567.94744	71
8566.77398	− 91	8567.83447	−105	8567.67156	20	8567.95646	100
8566.78447	−132	8567.84223	−135	8567.67906	20	8567.96410	70
8566.80141	−112	856785021	−145	8567.68987	84	8567.97124	90
8566.82023	− 97	8567.85883	−140	8567.69709	49	8568.66355	−101
8566.82760	−120	8567.86618	−154	8567.71294	49	8568.67239	−168
8566.83760	− 73	8567.87440	−161	8567.72099	28	8568.68060	−103
8566.84530	− 58	8567.88326	−138	8567.72816	42	8568.68772	−117
8566.85322	− 35	8567.89147	−108	8567.74610	96	8568.69561	− 55
8566.86336	− 47	8567.89929	− 13	8567.76254	68	8568.70544	− 55
8566.87086	− 31	8567.90820	− 35	8567.77041	12	8568.71417	− 31
8566.87864	− 47	8567.91584	− 15	8567.77787	55	8568.72226	− 11
8566.95616	51	8567.92348	− 3	...	...	...	...

[a] In km s^{-1}.

TABLE 6

ORBITAL PARAMETERS OF TZ PER

	γ (km s^{-1})	K_{em} (km s^{-1})	HJD$_{\odot}$ (2448545+)	P_{orb} (days)	σ
Hβ (this paper)	-20.86 ± 4.02	107.03 ± 5.34	0.199 ± 0.002	0.26424 ± 0.00001	26.4
Hβ (all data)	$[-1.7] \pm 2.47$	107.57 ± 3.49	0.31287 ± 0.00005	0.2629062 ± 0.0000008	24.4

0.16264 days (see TR97, Table 2), regardless of our inclusion of outburst observations or combining different emission lines.

3.2. *TZ Per*

Figure 3 shows the mean spectrum for the three observing nights. We observed broad H lines in absorption, with narrow and strong emission cores. There is a very conspicuous absorption band from λ4540 to λ4680. This band is also seen in the spectrum by Bruch & Schimpke (1992) and its origin is unknown. It is possible that it consists mainly of a series of Fe I lines.

Our observations of TZ Per were done during the outburst cycle following that observed by Ringwald (1995), only 10 days after his observations. According to the AAVSO light curve shown in Ringwald (1995), the system was observed between $V = 13.0$ and 13.5 mag. Minimum light occurred two days after our observations at $V = 13.8$. Since TZ Per was at the time undergoing frequent outbursts, it was not possible to observe the system at quiescence and to detect the secondary star.

We measured the narrow emission core for Hα in a similar way to that described in the previous section. Since the emission core line is narrow, the separation and width of the two Gaussians gave best results for $a = 7$ Å and a width of 6 Å. The separation of the fitted two Gaussians was best set around 3 Å. The results are shown in Table 5. Our data was tested first alone, with the results shown in Table 6. The data was then combined with that of Ringwald (1995) to improve the time baseline. As in the case of KT Per, this was done after adjusting all observations to a common $\gamma = 0$ velocity. The results are given also in Table 6 and Figure 4. The best orbital period, obtained with the combined data is 0.2629062 ± 0.0000008 days. This value is larger than that reported by Ringwald (1995): 0.2605 ± 0.0004 days. Although we have combined quiescence and outburst observations, our own observations alone yield a larger period. The semi-amplitude of the radial velocity curve is, within the errors, compatible with that obtained by Ringwald (1995).

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