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A POSSIBLE VARIABLE STAR RECLASSIFICATION FOR TX PISCIUM

From 1990 through 1995 the Lb (Kholopov, 1985) carbon star TX Piscium has been observed via photoelectric photometry as part of the AAVSO Small Amplitude Red Variable (SARV) program. The objective was to discover periodicity, if any, and refine existing measured amplitudes. Wasatonic (1993) reported the first evidence of semi-regularity in visual light with well defined amplitudes. This paper presents observations taken since 1992 to show further evidence of semi-regularity, which is used as the basis for variable star reclassification; no existing light curves have been found to back up the Lb classification.

A SIMBAD database search yielded 234 references of this highly observed star, most of them describing spectroscopic work. Various spectral types have been published: C6,2 (Judge and Stencel, 1991), N0 C7,2 (Barnbaum, 1992), or C5 II (Hoffleit, 1982) and (Richer, 1971). In general, carbon stars are peculiar red giants; their spectra are characterized by bands of carbon-containing molecules in contrast to normal K and M spectra, where oxides predominate (Faulkner et al., 1988). A more thorough discussion of carbon star spectral characteristics is beyond the scope of this paper and will not be addressed further.

All observations were made with a 8-inch f/10 Schmidt-Cassegrain and a silicon PIN photodiode SSP-3 photoelectric photometer using a Schott visual filter. Standard photometric observations and data reduction techniques were used, as described in the earlier paper by the author. The observations were made on 118 separate nights from JD 2448180 to JD 2449726. The maximum internal standard error calculated for each night was 15 millimags; the internal standard average error over all 118 nights was only 4.4 millimags.

It is proposed that the variable star classification for TX Piscium be changed from its current Lb type to that of a semi-regular variable of type SRa or SRb. The scientific justification of this reclassification is as follows:

- From SiO and H2O maser observations it is speculated that the circumstellar envelope surrounding the star is clumpy in nature, and is not confined to a region close to the star (Heske et al., 1989). This theory is supported to some degree by Judge and Stencel (1991) in which they state that TX Piscium, as an optically visible carbon star, is thought to be in a post-Mira evolutionary phase; in this phase there exists a circumstellar shell which has become "detached" from the star. Heske also states that since the detached circumstellar shell is irregular (clumpy), mass loss is asymmetric, which can be caused by pulsational properties of SR variables. Heske also states that TX Piscium is classified as an SR variable by referencing Kukarkin et al. (1969).

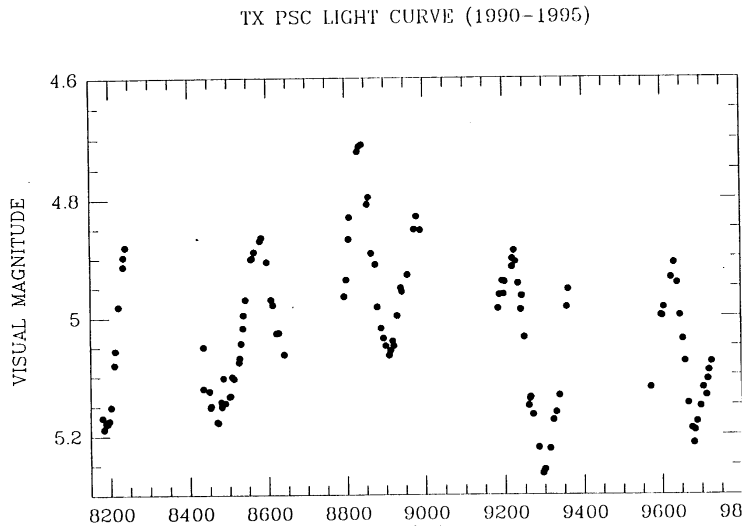

Figure 1

- Alksne et al. (1991) classify the spectrum as C7,2; according to this data distribution TX Piscium would be an Lb variable. However, most literature references classify the spectrum as either C6,2 or C5 II. This would indicate an SR type variability according to Alksne's data distribution, and again matches the proposed reclassification type.
- An examination of the light curve itself reveals semiregularity (see Figure 1). Table I lists the observed times of minima and the intervals between them. The last three intervals are actually times separated by two non-consecutive minima, as the missing minima are due to seasonal gaps. Hence the average time between all minima is about 222 ± 46 days.

Table I: TX Piscium Minima Data

Times of Minima	Intervals Between Minima (Days)
JD 2448190	
	290
JD 2448480	
	430
JD 2448910	
	390
JD 2449300	
	380
JD 2449680	

Table II: TX Piscium Maxima Data

Times of Maxima	Intervals Between Maxima (Days)
JD 2448580	
	260
JD 2448840	
	390
JD 2449230	
	410
JD 2449640	

Table III: TX Piscium Visual Light Curve Data

JD 244+	MAG	JD 244+	MAG	JD 244+	MAG	JD 244+	MAG
8180.547	5.17	8531.616	5.04	8909.564	5.06	9300.487	5.26
8184.536	5.19	8536.586	5.02	8913.558	5.06	9313.464	5.22
8189.514	5.18	8538.590	5.00	8918.529	5.04	9322.472	5.17
8191.563	5.18	8543.565	4.97	8921.525	5.05	9330.456	5.16
8193.550	5.18	8558.583	4.90	8930.521	5.00	9338.479	5.13
8197.539	5.17	8560.516	4.90	8940.484	4.95	9358.460	4.98
8202.495	5.15	8566.527	4.89	8943.484	4.96	9362.465	4.95
8211.506	5.08	8581.552	4.87	8957.483	4.93	9571.725	5.12
8213.533	5.06	8585.505	4.86	8975.528	4.85	9598.678	5.00
8222.473	4.98	8598.464	4.91	8981.478	4.83	9601.671	5.00
8234.461	4.91	8608.463	4.97	8990.482	4.85	9606.640	4.98
8235.471	4.90	8613.464	4.98	9185.840	4.99	9625.621	4.93
8240.475	4.88	8622.469	5.03	9189.496	4.96	9633.612	4.91
8434.860	5.12	8628.480	5.03	9196.756	4.94	9641.542	4.94
8435.817	5.05	8641.471	5.06	9199.824	4.96	9647.548	5.00
8449.816	5.12	8795.851	4.96	9202.740	4.94	9654.513	5.04
8452.810	5.15	8801.817	4.94	9221.830	4.92	9659.572	5.08
8454.813	5.15	8808.820	4.87	9222.759	4.90	9667.568	5.15
8469.804	5.18	8819.836	4.83	9226.708	4.89	9676.480	5.19
8471.756	5.18	8832.752	4.72	9229.664	4.91	9681.478	5.21
8479.750	5.14	8836.749	4.71	9236.641	4.94	9683.473	5.19
8481.806	5.15	8842.723	4.71	9242.627	4.99	9689.472	5.18
8485.724	5.10	8855.696	4.81	9245.628	4.96	9698.476	5.15
8490.733	5.14	8859.706	4.80	9250.636	5.03	9705.460	5.12
8501.683	5.13	8865.664	4.89	9261.620	5.15	9713.463	5.13
8503.690	5.13	8875.642	4.91	9264.604	5.14	9716.464	5.11
8508.667	5.10	8880.624	4.98	9265.598	5.14	9719.466	5.09
8512.641	5.10	8889.665	5.02	9271.566	5.17	9726.463	5.08
8526.595	5.08	8895.590	5.04	9285.625	5.22		
8527.611	5.07	8901.595	5.05	9295.595	5.26		

Table II lists the observed time of maxima and the intervals between them. Again, the last two intervals are actually times between two non-consecutive maxima, missing again due to seasonal gaps. Hence the average time between all maxima is about 220 $\pm$ 35 days, which nearly matches the minima interval. Therefore, one can deduce a semi-regular period averaging 221 $\pm$ 40 days.

Since SRa variables have relatively constant periods, smaller amplitudes than Miras ($<$ 2.5 mag), and strong cycle-to-cycle amplitude variations (Querci and Querci, 1988), it is apparent that the published light curve fits these characteristics to some degree. Hence these features lend credence to re-classifying TX Piscium as an SRa variable star.

- A distribution of semi-regular periods was done by Petit (1982), and for SRb stars of spectral type C and S there is a modal value at periods between 200 and 250 days; the apparent 221 day period falls within this range. Additionally the light curve asymmetry is 0.46, typical for SRa stars with possible extensions to SRb stars.

Hence, these features support a SRb classification.

- One can also see the superposition of a cycle on top of the 221 day principle cycle by noting the gradual rise and decline of each seasonal variation, with the peak occurring from JD 2448750 to JD 2449000. This second cycle is a characteristic feature of SRb stars (Petit, 1982). A preliminary cycle of 1490 days can be measured from the minimum at JD 2448190 to the minimum at JD 2449680. This is about 6.7 times the principle cycle but still less than the normal modulation of 8 to 15 years for SRb stars. Further observations are required to characterize this phenomenon.

In researching published amplitude ranges, Drake et al. (1991) and Judge and Stencel (1991) reported an amplitude range of 0.8 mag, somewhat more than the maximum observed amplitude of 0.55 mag. Mitton and MacRobert (1989) also reported a total amplitude of 0.50 mag. Because the total amplitude for the seasonal cycles averaged 0.33 mag, perhaps the Mitton and MacRobert amplitude is a feature of the superposition cycle. It now appears that the reported 0.8 mag amplitude is erroneous, and could be due mainly to scattered results.

Concluding, based on the visual light curve and supporting arguments, the classification of TX Piscium should be changed from an irregular Lb giant to an SRa or SRb giant. Due to the nature of red giants more observations could reveal a presumed resumption of irregularity; for this reason and to further define the superposition cycle observations will continue indefinitely. Nevertheless, in visual light TX Piscium is now pulsating with characteristics of a semi-regular star, and thus its classification should be made accordingly so.

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