BOLETIN DE LOS OBSERVATORIOS DE TONANTZINTLA Y TACUBAYA, Nº 37, 6, 1971.

INFRARED PHOTOMETRY OF UV CETI STARS

Braulio Iriarte Erro

SUMARIO

Se efectuó fotometría infrarroja para veintisiete estrellas enanas de tipo espectral M, entre las cuales nueve son estrellas de tipo UV Ceti. El propósito de este estudio fue el tratar de encontrar excesos infrarrojos en las estrellas ráfaga. El resultado de las observaciones indica que estas estrellas no muestran exceso en el infrarrojo.

ABSTRACT

Infrared photometry is performed on twenty seven M-type dwarf stars, of which nine are stars of the UV Ceti type. The purpose of this study has been to search for infrared excesses in the flare stars. The result of the observations indicates that these stars do not show infrared excesses.

The existence of infrared excesses in T Tauri and related objects discovered by Mendoza (1966) and the suggestion by Haro (1968) that a nebulous envelope might be present around flare stars has led us to expect that it might be rewarding to attempt a search for infrared excess, which might be caused by circumstellar emission in flare stars of our neighborhood.

TABLE 1

Observed Magnitudes

Star	*V*	*U*	*B*	*R*	*I*	*J*	*H*	*K*	*L*	*n*
1538	9.63	12.32	11.12	8.34	7.39	6.68	6.08	5.93	5.81	3
1255	—	—	—	—	—	4.82	4.13	4.03	3.91	2
3079	—	—	—	—	—	6.02	5.31	5.10	5.06	2
3880	10.09	12.62	11.55	8.65	7.45	6.90	—	5.99	—	2
5012	8.58	11.25	10.04	7.20	6.14	—	—	—	—	—
49-1	8.08	10.88	9.63	6.67	5.50	4.86	4.43	4.06	3.87	5
2456	9.64	12.37	11.17	8.14	6.89	6.29	5.64	5.54	5.43	2
5563	8.68	11.40	10.18	7.24	6.10	5.41	4.78	4.58	4.38	4
5763	8.98	11.56	10.48	7.60	6.38	5.92	5.42	5.15	4.83	3
431	10.23	12.89	11.75	8.62	7.34	—	—	—	—	—
1609	10.01	12.83	11.60	8.38	6.96	—	—	—	—	—
4330	8.45	11.09	9.99	6.85	5.39	—	—	—	—	—
1305	11.48	14.41	13.15	9.67	8.01	7.18	6.64	6.42	6.11	2
2267	10.05	12.76	11.59	8.44	7.06	6.53	5.93	5.68	5.66	2
2524	11.66	14.50	13.34	9.84	8.17	7.31	6.77	6.53	6.25	2
2730	11.08	14.10	12.85	9.24	7.55	6.84	6.19	5.91	5.66	2
5546	10.10	12.80	11.68	8.37	6.76	5.97	5.26	5.11	4.73	2
1668	11.49	14.44	13.19	9.57	7.76	6.80	6.15	5.89	5.68	3
+55°1823	—	—	—	—	—	6.64	5.94	5.74	5.76	2
V371 Ori	11.45	14.00	13.01	—	—	7.74	7.10	6.90	6.65	3
Gr 34B-And	—	—	—	—	—	6.80	6.27	5.91	5.60	3
YZ CMi	—	—	—	—	—	6.51	5.93	5.72	5.53	2
DO Cep	9.59	12.50	11.24	7.86	6.31	5.50	5.08	4.71	4.46	4
EV Lac	10.09	12.28	11.45	8.37	6.97	6.18	5.97	5.29	5.06	3
EQ Peg	9.89	12.67	11.63	—	—	6.01	5.41	5.14	4.96	3
UV Ceti	12.03	—	13.90	9.61	7.52	6.79	6.25	5.71	5.55	2
Wolf 359	—	—	—	—	—	7.21	6.61	6.22	5.82	4

Twenty seven M dwarf stars were observed, nine of which are well known to be dMe flare stars: three are dMe stars that show H and K emission lines of Ca II and the rest are not known to be flare stars, nor do they show emission lines in their spectra. The observations were made by wideband photoelectric photometry in the *UBVRIJKL* system of Johnson, Mitchell, Iriarte and Wisniewski (1966); an additional filter, *H*, was used for the spectral region 1.6 μ. All observations were made with the 60″ photometric telescope at the Catalina Station of the Lunar and Planetary Laboratory of the University of Arizona.

The observational data are listed in Table 1. The first column gives the name or number of the star in the Yale Parallax Catalogue (Jenkins 1952). Columns second to tenth give the *UBVRIJHKL* magnitudes. Column eleventh gives the number of observation for each star in *JHKL*. The average probable errors of the infrared observations are listed in Table 2 for different magnitude intervals.

TABLE 2

Probable error of a single observation

Mag K	*K*	*J—K*	*K—L*
3-5 th	0.04	0.04	0.06
5-6 th	0.05	0.04	0.06
6-7 th	0.05	0.05	0.08

Our photometry from *U* (0.36 μ) to *L* (3.4 μ) could be compared with that of Johnson (1965) in his extensive work on M dwarf stars, since seven of the stars listed in Table 1, with Yale Nos. 49-1, 2456, 1305, 2267, 2524, 2730 and 1668, appear also in Johnson's lists. The agreement of the *UBVRI* photometry is good and particularly in *R* (0.70 μ) and *I* (0.88 μ) it is excellent. However, since our main interest concerns the longest wavelengths we have plotted in Figure 1 the differences of the observations, in the sense Iriarte minus Johnson, for color index *V—K*, which is designated by Δ (*V—K*), against $(V-I)_{Ir}$. Notwithstanding that the number of stars in the plot is small, it is noticeable that

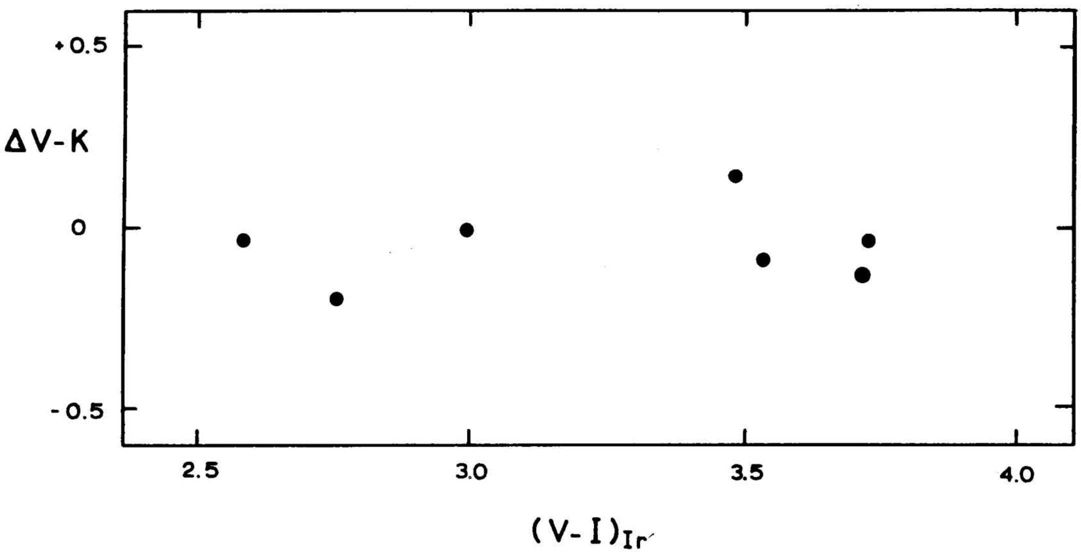


Fig. 1.—*The difference* Δ (V—K) *color as function of Iriarte's* (R—I). *The differences are taken Iriarte* minus *Johnson.*

Johnson's values, in general are larger and consequently his colors are redder than the ones presented in this work. Table 3 lists in the first column the name or number of the star in the Yale Parallax Catalogue (Jenkins 1952). Column second, the *V* magnitude. Columns third to tenth, the *U—V, B—V, V—R, V—I, V—J, V—H, V—K, V—L* colors respectively. Column eleventh, the spectral type by Kuiper (Jenkins 1952) for the stars not known to be flares. Joy's (1960) spectral types are given for the flare stars although, when available, types by Kuiper are also given in the notes. All additional data in Table 3 not contained in Table 1, are taken from Johnson's (1966) work and consist mainly in *UBVRI* photometry including also the data for two flare stars AD Leo and WX UMa.

TABLE 3

Color Indices

Star	*V*	*U−V*	*B−V*	*V−R*	*V−I*	*V−J*	*V−H*	*V−K*	*V−L*	*Sp*
1538	9.63	2.69	1.49	1.29	2.24	2.95	3.55	3.70	3.82	dM0
1255*	7.97	2.68	1.47	1.44	2.58	3.15	3.84	3.94	4.06	dM1
3079	9.06	2.71	1.49	1.45	2.54	3.04	3.75	3.96	4.00	dM1
3880	10.09	2.53	1.46	1.44	2.64	3.19	—	4.10	—	dM1
5012*	8.58	2.67	1.46	1.38	2.44	—	—	—	—	dM1
49-1*	8.08	2.80	1.55	1.41	2.58	3.22	3.65	4.02	4.21	dM2
2456	9.64	2.73	1.53	1.50	2.75	3.35	4.00	4.10	4.21	dM2
5563*	8.68	2.72	1.50	1.44	2.58	3.27	3.90	4.10	4.30	dM2
5763*	8.98	2.58	1.50	1.38	2.60	3.06	3.56	3.83	4.15	dM2
431	10.23	2.66	1.52	1.61	2.89	—	—	—	—	dM3
1609	10.01	2.82	1.59	1.63	3.05	—	—	—	—	dM3
4330*	8.45	2.64	1.54	1.60	3.06	—	—	—	—	dM4
1305*	11.48	2.93	1.67	1.81	3.47	4.30	4.84	5.06	5.37	dM5
2267*	10.05	2.71	1.54	1.61	2.99	3.52	4.12	4.37	4.39	dM5
2524	11.66	2.84	1.68	1.82	3.77	4.35	4.89	5.13	5.41	dM5
2730	11.08	3.02	1.77	1.84	3.53	4.24	—	5.17	5.42	dM5
5546	10.10	2.70	1.58	1.73	3.34	4.13	4.84	4.99	5.37	dM5
1668*	11.49	2.95	1.70	1.92	3.73	4.69	5.34	5.60	5.81	dM6
+55°1823	9.97	2.59	1.50	—	—	3.33	4.03	4.23	4.21	dM1.5e
V371 Ori*	11.45	2.55	1.56	—	—	3.71	4.35	4.55	4.80	dM3e
Gr 34B-And*	11.03	3.20	1.80	1.80	3.38	4.23	4.76	5.12	5.43	dM4e
AD Leo*	9.43	2.61	1.54	1.71	3.18	3.89	—	4.71	5.11	dM4e
YZ CMi*	11.20	2.62	1.61	1.83	3.62	4.69	5.27	5.48	5.67	dM4.5e
DO Cep*	9.59	2.91	1.65	1.73	3.28	4.09	4.51	4.88	5.13	dM4.5e
EV Lac*	10.09	2.19	1.36	1.72	3.12	3.91	4.12	4.80	5.03	dM4.5e
WX UMa*	14.53	—	—	2.30	4.35	5.56	—	6.53	—	dM5.5e
EQ Peg*	9.89	2.78	1.74	1.48	3.11	3.88	4.48	4.75	4.93	dM5.5e
UV Ceti*	12.03	—	1.87	2.42	4.51	5.24	5.78	6.32	6.48	dM5.5e
Wolf 359*	13.53	3.55	2.01	2.66	5.12	6.32	6.92	7.31	7.71	dM6e

NOTES TO TABLE 3

1255. H and K lines in emission; (Popper 1942).

5012. HD 199305. Moderately strong Ca II emission lines present on Mount Wilson spectrograms (Bidelman 1954).

49-1. ADS 246. Spectroscopic binary (Kron 1957).

5563. +15°4733. H and K lines in emission (Popper 1942). The radial velocity of this star was found to the variable (Joy 1947; Kron 1957).

5763. Very weak bright hydrogen lines present (Bidelman 1954).

4330. ADS 11632; *AB* sep. 17″. For *A:* Eggen $V = 8.90$, Iriarte $V = 8.45$.

1305. Subdwarf spectrum (Kron 1957).

2267. 0.6″, $\Delta m = 0.06$ $P = 5$ or 10 years (Eggen 1968).

1668. Ross 986. Sp. *B.* range 110 Km. sec.$^{-1}$, Eggen 1968). Hydrogen in emission (Bidelman 1954).

V371 Ori Spectroscopic binary. It has bright hydrogen and Ca II lines. The light variations of this star have been discussed by Hoffleit (1952).

Gr 34B-And. Y. P. 49B. dM5. Traditionally it has been classified as a subdwarf.

AD Leo. Y. P. 2420, dM5. It has bright Hα and HeI 5876, as well as emission cores in the Na I lines. Astrometric binary $P = 26$ yr (Eggen 1968).

YZ CMi. Y. P. 1827. It has the helium line 4471 bright at times. Both hydrogen and helium emission lines are variable in intensity (Bidelman 1954).

DO Cep. Y. P. 5438, dMe. A. D. S. 15972 *AB* semiaxis major 2.36″.

EV Lac. Y. P. 5520, dM5, double. *A* is the flare star. Sep. estimated at 5″; *B* may also be a close double.

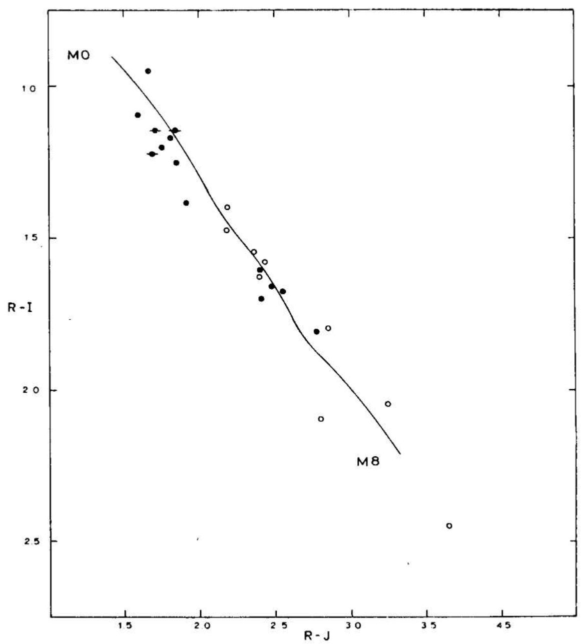
WX UMa. Double sep. 28″, Y. P. 2582B, dM8.

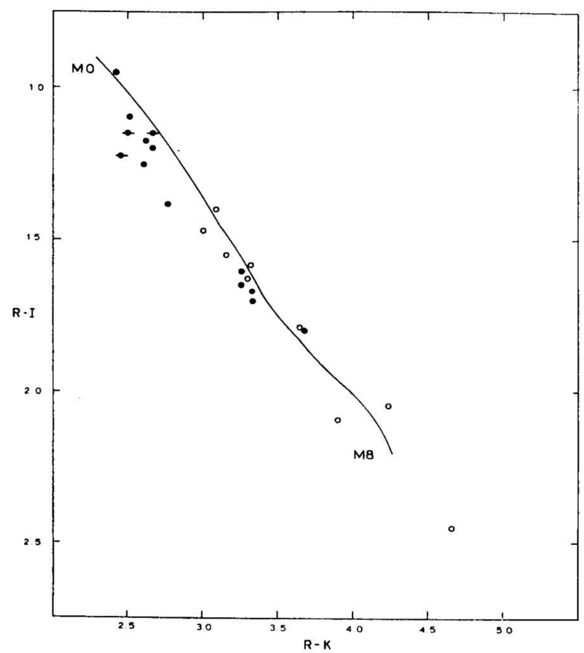
EQ Peg. Visual binary, sep. 3.5″.

UV Ceti. Binary, sep. 1.5″.

Wolf 359. Y. P. 2553, dM8. The spectrum shows the strongest titanium oxide bands yet observed among dwarf stars, the emission lines are very strong (Joy 1947).

The M dwarf stars in the solar vicinity are not an easy subject to deal with. Aside from the spectroscopic binaries and close binaries whose components cannot be observed separately, the spectral





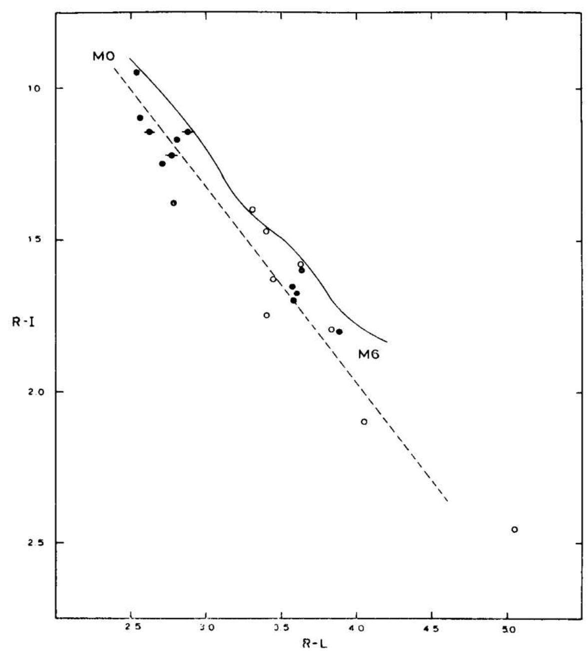


Fig. 2.—*The* (R—I, R—J) *diagrams for the observational data contained in Table 3. Filled circles represent dM stars; open circles UV Ceti stars; and filled circles crossed with horizontal lines, dMe stars not known to be flares. The solid line represents the interpolation of Johnson's normal colors for different spectral types*

Fig. 3.—*The* (R—I, R—K) *diagram for the observational data contained in Table 3. Symbols have been explained in Figure 2.*

Fig. 4.—*The* (R—I, R—L) *diagram for the observational data contained in Table 3. The broken line represents the line drawn to fit our observations. Symbols have been explained in Figure 2.*

types for the M dwarfs cannot be given in a single homogeneous system. Moreover, in this particular case the systematic differences between Johnson's colors and ours in the infrared shown in Figure 1, make it difficult to estimate the color excesses in the usual way; therefore, a series of diagrams was prepared. These are shown in Figures 2 to 4. Color index $R-I$, used as a measure of the temperature, is plotted against $R-J$, $R-K$ and $R-L$ respectively. The solid line represents in each plot the interpolation of Johnson's normal colors for different spectral types, the broken line in Figure 4 represents the line drawn to fit our observations.

The sample of stars plotted is not large, yet we can see from the diagrams that the deviations of our observational data from Johnson's normal colors increase with wavelength. In Figure 2, only the stars with $R-I < 1.4$ are shifted towards the blue; in Figure 3, the shift can be noticed starting from $R-I < 1.6$ and finally in Figure 4, the broken line representing the best fit to our observations is shifted to the blue side for all values of $R-I$. We can also notice from the plots that the stars with and without emission lines do not show any systematic difference in their colors; as a consequence, it appears safe to say that the observed flare stars, as well as the observed stars with emission lines in their spectra not known to be flare stars do not have infrared excesses.

For two flare stars, $+55°1823$ and V 371 Ori, R and I colors are not available, but from their remaining colors one can reasonably expect them not to be different from the rest of the group.

Seemingly, the presence of emission lines in the spectra of M-type dwarfs in the solar vicinity does not affect their position in the diagrams that have been discussed above. Therefore, it is plausible that emission line radiation in these stars is a superficial characteristic as it has been noticed before by Kron *et al* (1957).

A similar conclusion can be reached by a different approach: The light curves of flare stars of the UV Ceti type, according to Joy (1960), rise to maximum in a few seconds or minutes and decline to normal brightness in less than half an hour; this characteristic is in accordance with Haro and Parsamian's (1969) definition of a fast flare star. Now, following Ambartsumian's (1954, 1957) ideas, stressed by Haro (1964, 1968) and Haro *et al.* (1969) fast flares originate above the photospheric layers, mainly in the chromosphere. This provides further evidence of the superficial location of the regions where emission lines originate.

REFERENCES

Ambartsumian, V. A., 1954, *Comm. Biurakan Obs.*, No. 13.

———. 1957, *Non-Stable Stars, I.A.U. Symposium No. 3,* ed. G. H. Herbig (London: Cambridge University Press) p. 177.

Bidelman, W. P. 1954, *Ap. J. Suppl.*, **1**, 175.

Eggen, O. J. 1968, *Ap. J. Suppl.*, **16**, 97.

Haro, G., 1964, *I.A.U.-U.R.S.I. Symposium No. 20* eds. F. J. Kerr and A. W. Rodgers (Canberra: Australian Academy of Science) p. 30.

———. 1968, *Nebulae and Interstellar Matter,* ed. B. M. Middlehurst and L. H. Aller (Chicago: University of Chicago Press) p. 141.

Haro, G., and Parsamian, E. 1969, *Bol. Obs. Tonantzintla y Tacubaya*, **31**, 45.

Hoffleit, D. 1952, *Harvard Bull.*, **921**, 5.

Jenkins, L. F. 1952, *General Catalogue of Trigonometric Stellar Parallaxes* (New Haven, Conn.: Yale University Observatory).

Johnson, H. L., 1965, *Ap. J.*, **141**, 170.

Johnson, H. L., Mitchell, R. I., Iriarte, B., and Wisniewski W. Z. 1966 *Comm. Lunar and Planetary Lab.*, **4**, 99.

Joy, A. H. 1947, *Ap. J.*, **105**, 96.

———. 1960, *Stellar Atmospheres, Stars and Stellar Systems,* Vol. **6**, ed. J. L. Greenstein (Chicago: University of Chicago Press) p. 653.

Kron, G. P., Gascoigne, S. C. B., and White, H. S. 1957, *A. J.*, **62**, 205.

Mendoza, V., E. 1966, *Ap. J.*, **143**, 1010.

Popper, D. M. 1942, *Ap. J.*, **95**, 307.