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FLARE STARS IN THE PLEIADES REGION (1971-1972). III

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SUMARIO

Durante los meses de octubre, noviembre y diciembre, 1971 y enero, 1972, obtuvimos con la cámara Schmidt del Observatorio de Tonantzintla 115 placas con exposiciones múltiples en el ultravioleta, utilizando como centro a la estrella Alcyone en las Pléyades. El número de diferentes exposiciones fue de 725 y el tiempo total de observación efectiva 135h45m. En este material encontramos 22 nuevas estrellas Ráfaga y algunas repeticiones en estrellas Ráfaga conocidas con anterioridad.

ABSTRACT

During the months of October, November and December, 1971 and January, 1972 we obtained 115 ultraviolet multiple exposure plates centered in Alcyone and covering an area of approximately 16 square degrees. There were 725 different exposures with a total time of effective observation of 135h45m. In this material we found 22 objects that can provisionally be considered as "new" Flare stars and 50 outburst repetitions in previously known Flare stars.

I. Introduction

Following the search for Flare stars in the Pleiades region previously reported (Haro 1968; Haro and Chavira 1969 — Paper I; Parsamian and Chavira 1969; and Haro and Chavira 1970 — Paper II) we have continued, at the Tonantzintla Observatory, the collection and analysis of multiple exposure photographic material in the mentioned region during the months of October, November and December, 1971 and January, 1972. We obtained 115 ultraviolet multiple exposure plates centered in Alcyone and covering an area of approximately 16 square degrees. There were 725 different exposures with a total time of effective observation of 135h45m. Besides the new Flare stars found, several outburst repetitions were detected in previously known Flare stars discovered at the Tonantzintla, Byurakan, Asiago and Konkoly Observatories. In general, all our former conclusions are confirmed.

TABLE I

New Flare Stars in the Pleiades Region (1971-1972)

No.	*Star*	*R. A. (1900)*	*Dec. (1900)*	*Mag. in U*	*ΔmU*	*Date of Flare-up*
13b		3h36m2	+21°57′	19.3	3.5	14 Nov. 1971
14b		3 36.8	23 02	19.5	3.5	20 Nov. 1971
15b		3 37.3	23 15	20.5	6.3	15 Dec. 1971
16b		3 37.9	24 44	20.0	5.1	15 Jan. 1972
17b		3 38.1	23 55	21.0	5.7	12 Nov. 1971
18b		3 38.4	24 17	20.7	5.5	12 Nov. 1971
19b		3 38.5	25 03	20.0	3.8	22 Nov. 1971
20b		3 39.3	23 48	18.3	2.0	10 Dec. 1971
21b		3 39.5	24 44	21.0	5.7	22 Nov. 1971
22b	HII 628	3 39.5	24 25	16.0	0.8	17 Oct. 1971
23b		3 40.4	23 43	20.5	7.2	17 Dec. 1971
24b	HII 1039	3 40.5	24 09	17.5	1.0	12 Dec. 1971
25b		3 40.8	25 09	19.0	3.2	23 Nov. 1971
26b		3 40.9	22 46	18.8	2.7	12 Dec. 1971
27b	HII 1280	3 41.1	23 51	16.8	0.9	15 Nov. 1971
28b	HII 1321	3 41.2	23 26	17.6	1.3	18 Nov. 1971
29b		3 41.4	23 25	20.0	5.0	16 Nov. 1971
30b		3 41.4	21 56	17.5	2.0	12 Dec. 1971
31b		3 43.2	22 48	19.8	6.2	22 Nov. 1971
32b		3 43.4	25 31	16.3	1.8	12 Nov. 1971
33b		3 46.7	24 27	15.4	2.2	12 Dec. 1971
34b		3h49m6	+23°29′	16.0	0.7	14 Dec. 1971

II. New Flare Stars in the Pleiades Region

The new Flare stars found are listed in Table 1. The first column shows the new serial numbering used by Haro and González (1972), making a total of 22 Flare stars of which Nos. 14b, 26b and 27b have two different outbursts. In column two the Hertzsprung (1947) number is indicated; the third and fourth columns give the approximate right ascension and declination; column five, the approximate apparent ultraviolet magnitude at minimum; column six, the ΔmU and, the last column, the date of the flare-up.

III. Flare-up Repetitions in Previously Known Flare Stars

Table 2 contains the Flare stars that have been found and published previously by the Asiago, Byurakan, Konkoly and Tonantzintla Observatories. In column one we give the original serial number with which the Flare stars were first published either by the Asiago, Byurakan, Konkoly or Tonantzintla Observatories. In this Table the data contained in each column are ordered as in Table 2 of the preceding paper by Haro and González (1972). In both papers we have assumed that in Ambartsumian *et al.* (1972), besides collecting all the published observations of various Observatories, the Asiago ones have been included up to star No. 78 and that stars Nos. 79 through 107 of Pigatto and Rosino (1972) have not been considered. For this reason we are adding at the end of our Table 2 the 1971-1972 Asiago Flare stars that have shown more than one outburst. Of the 83 Flare stars with 2 or more outbursts contained in Table 3 of Ambartsumian *et al.* (1972), 48 appear with new repetitions in Tables 2 of the present articles. Sixty-six additional Flare stars with 2 or more repetitions, not listed by Ambartsumian *et al.* (1972) are included in the two Tables mentioned before. This means that at least 149 known Flare stars in the Pleiades region have shown 2 or more outbursts.

TABLE 2

Repeated flare-ups observed during 1971-1972

Original Number	*Star*	*ΔmU*	*Date of Flare-up*	*Other Numbers or Designations*	*Total No. of Flare-ups Observed**	*Notes*
T2		3.7	1971, XII-22		2 + 1 = 3	
T12		3.3	1971, XII-12		T = 3	
T13	H_{II}686	0.5	1971, XI-17		T = 2	
T15	vM16	3.0	1971, XII-21	A13-24-61	4 + 2 = 6	
T17	H_{II}1306	0.8	1971, XI-22		6 + 1 = 7	
T18		0.6	1971, X-26	A106	16 + 15 = 31	
T27		6.0	1971, XII-21		2 + 1 = 3	
T35		2.0	1971, XII-22		2 + 2 = 4	
T36		4.6	1971, XI-14		4 + 4 = 8	1
T42	H_{II}230	0.8	1971, XI-20		T = 2	
T55	H_{II}2411	0.5	1971, XI-14	A11-12-41-51	72 + 6 = 78	
,,	,,	0.9	1971, XI-20	,,		
,,	,,	0.4	1971, XI-22	,,		
,,	,,	0.4	1971, XII-16	,,		
,,	,,	0.5	1971, XII-21	,,		
T55	H_{II}2411	3.0	1972, I-15	A11-12-41-51		
T61		0.5	1971, X-25	A65	2 + 3 = 5	
,,		0.4	1971, XII-12	,,		
T61		0.6	1971, XII-14	A65		
T68	H_{II}134	1.0	1971, XI-17		4 + 2 = 6	
T68	H_{II}134	2.0	1971, XII-14			
T71		1.0	1971, XII-16		T = 2	
T72		3.0	1972. I-18		T = 2	
T77		4.2	1971, XII-17		T = 2	
T81	H_{II}1173	2.2	1971, XI-20		T = 3	
T86		2.0	1971, XII-12	A85	2 + 2 = 4	
T87		0.5	1971, XI-18		T = 2	
T95		2.7	1971, XI-17		T = 3	

TABLE 2 (cont.)

Original number	*Star*	*ΔmU*	*Date of Flare-up*	*Other numbers or designations*	*Total No.* of Flare-ups observed*	*Notes*
T99		1.8	1971, XII-10	A46-B190	3 + 4 = 7	
T99		1.6	1971, XII-16			
T101		4.2	1971, XI-18		9 + 1 = 10	
T103		0.5	1971, XII-10	A63	5 + 10 = 15	
T106		5.9	1971, X-21		T = 3	2
T151	$H_{II}1103$	1.0	1971, XI-14		T = 3	
T155		6.8	1971, XI-20		T = 2	3
T158		6.0	1971, XI-16	B169	2 + 4 = 6	
T160	$H_{II}347$	0.6	1971, XII-14	A72	3 + 3 = 6	
A2	vM6	3.5	1971, X-23	T47	2 + 1 = 3	
A28		3.6	1971, XI-15	B143	A + T = 2	
A54		2.6	1971, XI-23	B238	A + T = 3	4
B115		0.5	1971, XII-12	T159-A95	2 + 8 = 10	
B115		1.5	1971, XII-18			
B180		1.7	1971, XI-23	B221	2 + 4 = 6	
B203		2.0	1971, XI-16		5 + 2 = 7	
B212	$H_{II}1029$	0.5	1971, XI-20		B + T = 2	
B216		4.5	1971, XI-12		B + T = 3	
T6b		3.8	1971, XI-14		T = 3	
T14b		5.5	1971, XI-21		T = 3	
T26b		2.9	1971, XII-20		T = 2	
T27b	$H_{II}1280$	0.6	1971, XII-11		T = 3	
T8	$H_{II}357$	2.2	1972, I-10	A97	8 + 1 = 9	5
T18		5.7pg.	1971, X-16	A106	16 + 15 = 31	5
T23		3.6:	1971, XII-17	A93	2 + 2 = 4	5
T25		1.5	1971, XI-21	A87	2 + 1 = 3	5
T39		1.4pg.	1971, XI-17	A103	2 + 1 = 3	5
T83		3.5:	1971, IX-23	A79	5 + 4 = 9	5
T86		3.5pg.	1971, X-26	A85	2 + 2 = 4	5
T156	vM46	4.0:	1971, XI-21	A88	A + T = 2	5
T165	$T_{II}2588$	1.1	1971, XII-16	A92	A + T = 2	5
T11b		2.8	1971, X-24	A83-B279	B + A + T = 3	5
A23-57		4.1:	1971, XI-16	A86 (B139)	3 + 1 = 4	5
A32		4.2:pg.	1971, X-16	A102 (B172)	A + A = 2	5
B115-T159		2.3	1971, XII-22	A95	2 + 8 = 10	5
B121-T152		>5.0	1972, I-10	A96	2 + 1 = 3	5
B196		4.4:	1971, X-25	A84	A + B = 2	5
B249		2.6pg.	1971, X-25	A107	A + B = 2	5
B271	$H_{II}1485$	1.3pg.	1971, XII-15	A104	A + B = 2	5
B286		>3.1	1972, I-14	A98	A + B = 2	5

* The total number of flare-ups observed for a given star is the same as in column six, Table 2, of Haro and González (1972).

Notes to Table 2

1. The rising toward maximum starts in the second exposure of a series of six exposures, reaching the maximum in the fourth exposure (see Fig. 1). The total time of rising toward maximum was from 20 to 30 minutes. It can be considered as a "semi-slow" Flare.

2. Very bright at maximum. A single image. The last exposure of a series of six (see Fig. 2).

3. Very bright at maximum. It rises rapidly to maximum in the fifth exposure and rapidly declines in the sixth one (see Fig. 2).

4. The U magnitude at maximum is equal to 16.4.

5. For these particular stars we are giving the Δm, the date of the flare-up and the Asiago number, privately communicated to us by Pigatto and Rosino (1972).

It is interesting to point out that in the list of Flare stars in the Pleiades region observed by Pigatto and Rosino (1972) during the fall and winter 1971-1972, out of the twenty-nine stars caught in the phase of flaring apparently only ten correspond to "new" Flare stars. In the case of the

present survey, out of the 72 flare-ups detected only 22 (Table 1) can provisionally be considered as "new" Flare stars. It should be stressed that undoubtedly there are some repetitions among the "new" Flare stars listed by the Byurakan Observatory and in the Tonantzintla numbering. In the general catalogue which is under preparation a very careful checking of these possible repetitions will be made.

In Table 3 we list all the Flare stars in the Pleiades region that have shown, up to now, 5 or more outbursts. As can be noticed, with the exception of T8 ($H_{II}357$), the Flare stars in which the incidence of outbursts is equal or larger than 8 are of spectral type M.

TABLE 3

Flare Stars with five or more Outbursts

No.	*Star*	*Total Number of Flare-ups observed*	*Spectral Type*
T 55	HII 2411	78	dM4e
T 18		31	M3-4e
T 103		15	$\geq$ M3
T 101		10	$\geq$ M2
B 115-T 159		10	M:
T 83		9	M3-4e
T 8	HII 357	9	K6Ve
T 36		8	M
T 14	HII 906	7	(K-M0Ve)dM2e
T 17	HII 1306	7	dK5e
T 99		7	M:
T 157	HII 2144	7	——
B 203		7	M
T 15	vM 16	6	dM1e-M2e
T 68	HII 134	6	K7Ve
T 158-B 169		6	Me
T 111	HII 3104	6	——
T 160	HII 347	6	(K7Ve)dM1
B 180		6	M3-4
T 40		5	——
T 61		5	M
A 50		5	M

Figures 1 and 2 show photographic reproductions of some of the new Flare stars during the outburst and a few of the flare-up repetitions.

IV Preliminary Conclusions

For the moment we can anticipate some of our conclusions:

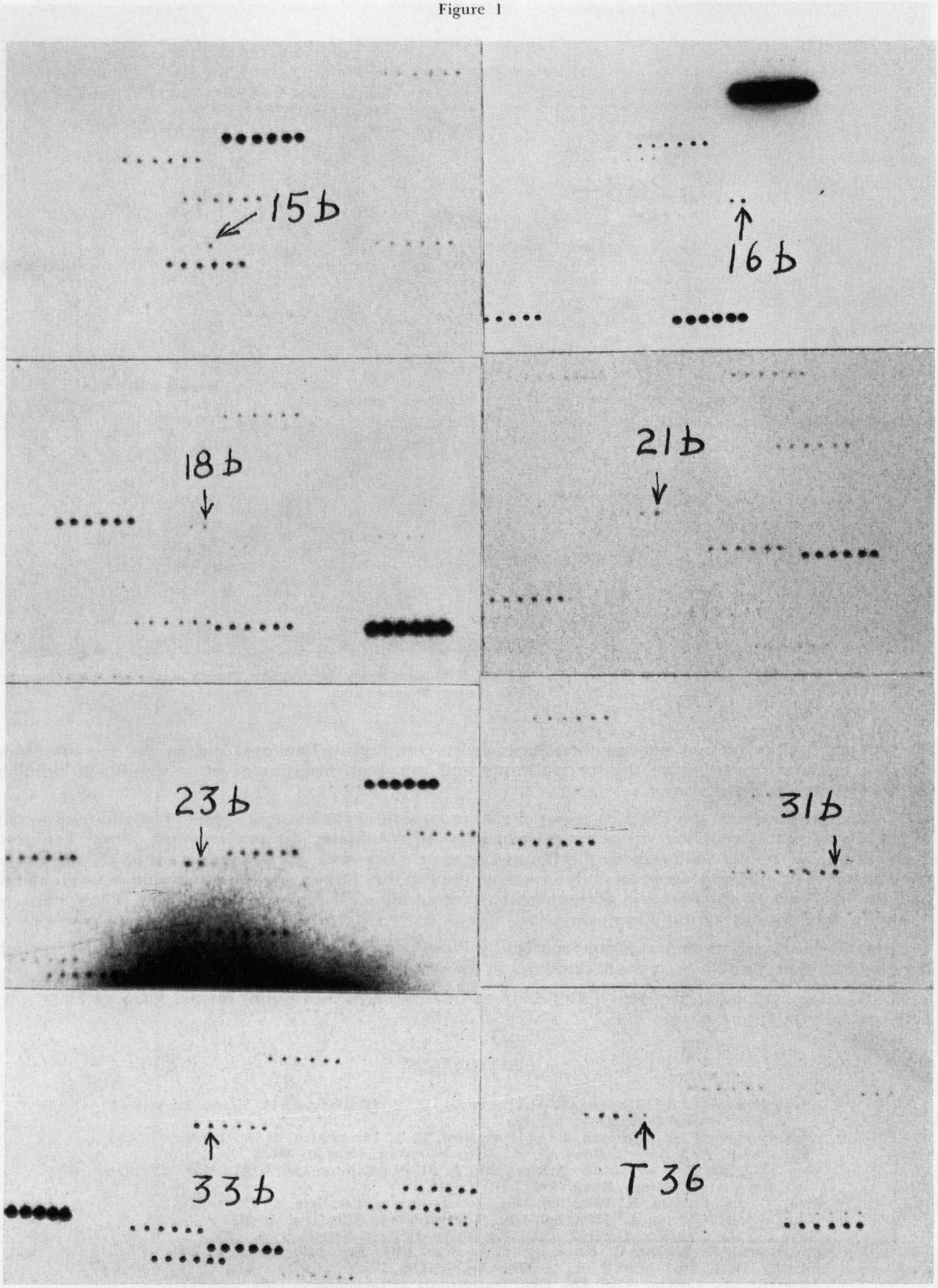
1st.—The brightest Flare star, a member of the Pleiades aggregate, is $H_{II}2034$ which at minimum has an apparent visual magnitude equal to 12.57. Flare stars $H_{II}2588$ and $H_{II}2908$, according to Johnson and Mitchell's photographic data (1958), have visual magnitudes during minima equal to 13.10 and 13.03, respectively. Thus, the very sharp magnitude limit (V = 13.3) for the Flare and non-Flare stars in the Pleiades region stressed by Ambartsumian *et al.* (1969) is not strictly valid.

2nd.—There is no doubt that the later the spectral type of the Flare stars in the Pleiades region, the larger the incidence of outbursts.

3rd.—Undoubtedly, the largest apparent amplitude of the variation corresponds to stars fainter than ultraviolet magnitude 17.5 at minimum. From our results it is obvious that in some cases the very faint stars, *if members of the Pleiades aggregate,* liberate more energy —at least during the peak of the outburst— than the brightest stars that have shown flare-ups. The absolute energy radiated by the stars during outbursts is, therefore, not necessarily larger for intrinsically brighter stars.

4th.—It seems that a significant percentage of the Flare stars found in the Pleiades region under study are not members of the Pleiades cluster. This statement is based on the facts that some of the

Figure 1



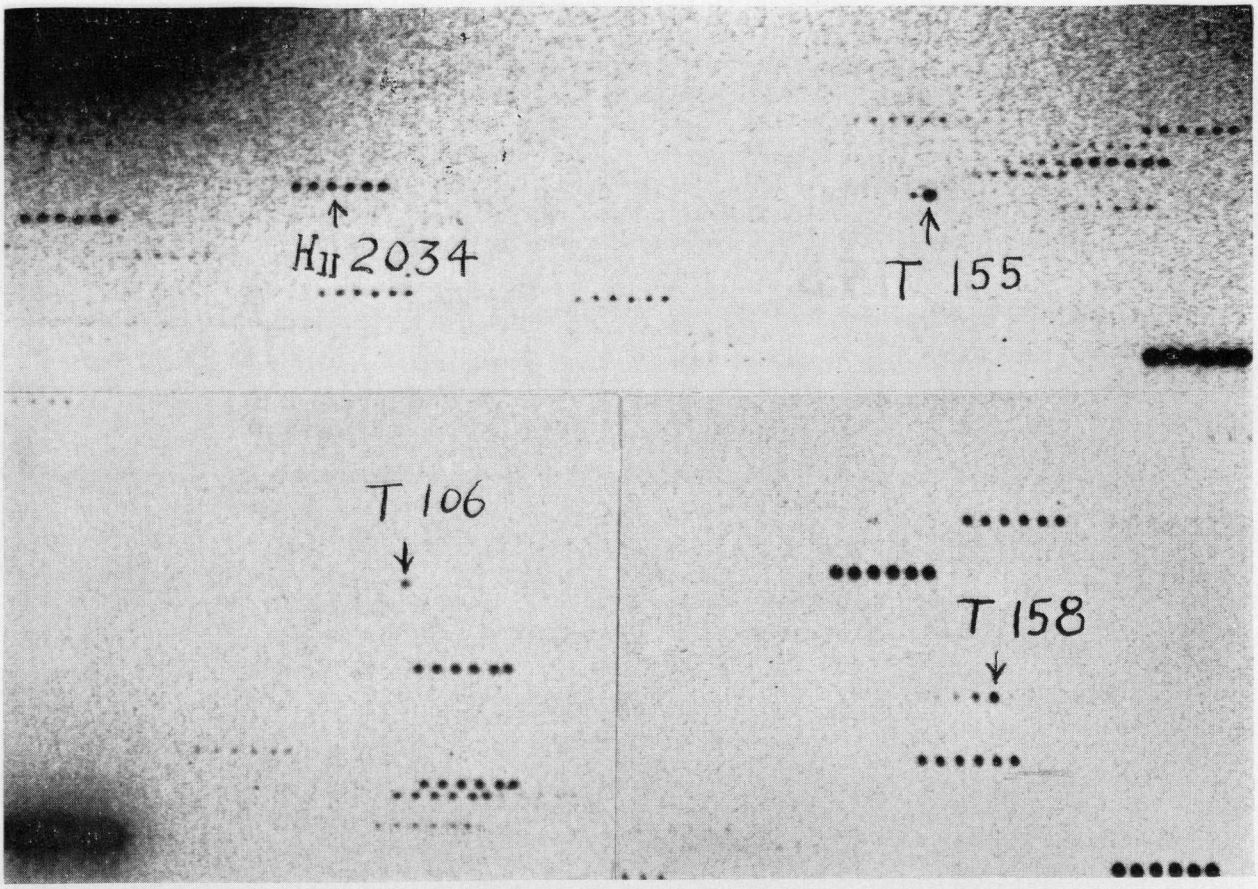


Fig. 2.—*Flare stars T106, T155 and T158 are a sample of faint stars which are brighter during maximum than Flare star T9b ($H_{II}2034$) during its maximum.*

Hertzsprung proper motion non-members have shown conspicuous flare-ups, and on the non-consistent distance modulus derived from the spectral types and apparent magnitudes of a significant number of Pleiades region Flare stars.

5th.—Although in the Pleiades region we have not found the extreme "slow" Flare stars observed in the Orion aggregate, there are some intermediate "slow" Flares as, per example, Nos. T36 and T103. From our results dealing with the Orion aggregate Flare stars (a re-examination of all our Orion plate material is under process) and the study of the Pleiades Flare stars, the conclusion is unavoidable that the incidence of the outburst phenomenon is conspicuously larger for the Pleiades Flare stars, as a whole, than for the Orion Flare stars.

6th.—There are numerous Flare stars in the Pleiades region that decline very slowly notwithstanding the fact that they show a rapid increase in brightness.

A more comprehensive analysis of our observations and conclusions on the Pleiades Flare stars will appear in a future paper.

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