New Flare Stars in the Pleiades Region

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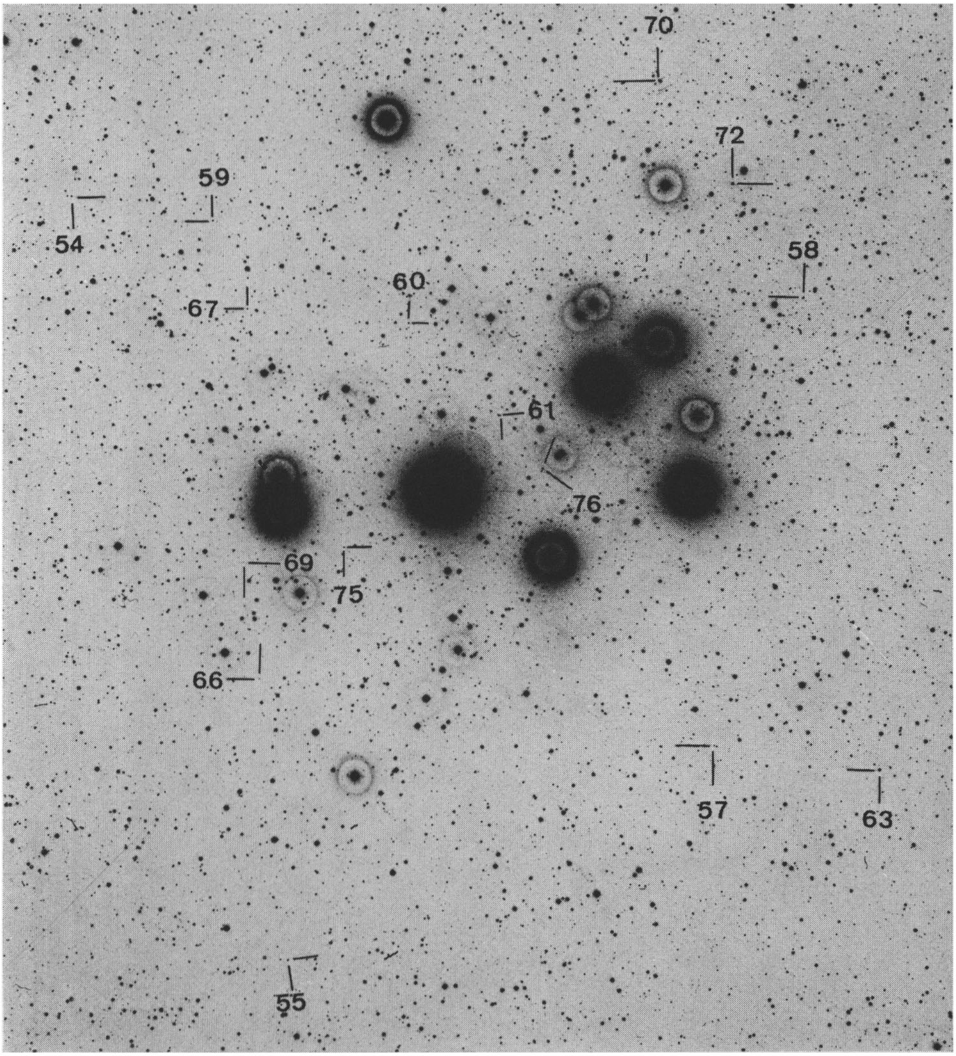
In a series of previous papers (ROSINO, 1966; ROSINO-PIGATTO, 1969; PIGATTO-ROSINO, 1971) we have given some results on the systematic search of flare stars in clusters and associations carried out at Asiago with the 90—67 cm Schmidt telescope. We have employed for the survey Kodak 103a—O or Oa—O plates without filter covering a field of 25 square degrees, the flares having been searched with the method of multiple exposures.

The present communication gives a list of new flares discovered in the Pleiades during the fall and winter 1970—71. The Pleiades cluster has been kept under control for a total time of 2778 minutes. Eighteen flares have been identified on this material, with a frequency of one flare every 2^h34^m which fairly agrees with the mean rate derived by previous investigations. Twelve of the flare-ups have been found in stars already known to display a flaring activity. The other six are new flare stars. It may be noticed, in this connection, that the proportion of stars in which repeated flares are found has reached now a significative value. The fact that 12 of 18 flares have occurred in stars which had priviously shown other flare-ups means that we are approaching the point when all of the flare stars in the Pleiades will be identified.

As we remarked in the previous papers, while the great majority of the flares in Pleiades stars have a relatively short duration, there are in the cluster some stars in which long-lasting flares (several hours) of large amplitude have been observed. These, however, are not „slow" flares according to the definition given by HARO (1968) and by HARO and PARSAMIAN (1969), since it is not proved that the rising is slow and, in one case at least (No. 22), it was fast. The long duration is due to large amplitude and slow decline, so that the normal minimum is reached after several hours. As a consequence of the slow decline it may happen that in such stars the magnitude variation recorded on a multiple exposure plate be relatively small (in comparison with fast flares) and therefore that flares of this type may escape detection. With this possibility in mind, we have re-examined the plates taken during the last years intercomparing photographs of different nights. The survey has brought to the discovery of eight other flares (Nos. 71—78), one of which was of the slow-decline type.

The new flares found in the Pleiades are listed in Table I. Column one gives the Asiago serial number; the other columns, respectively: coordinates 1900.0; photographic magnitudes at maximum and normal minimum; date; identification. Circumstances of the flares and other remarks are next reported. Identification charts and reproductions of some of the flare-ups are given in Figs. 1—5.

The mean photographic amplitude of the flares listed in Table I is 2.6. The maximum, in the frequency distribution of amplitudes, is found for flares with amplitude between 2 and 3. Only four flares have an amplitude larger than 4 pg magnitudes. The higher frequency of flare star is found in objects having pg magnitude between 17 and 18. However, it is obvious that selection effects act strongly. Flares in stars weaker than 18—19 pg can be discovered only when the amplitude is larger than 1—2 magnitudes. Moreover, the revision of the old material has shown that flares in relatively bright stars can also be missed, since the observer, during the searching of flares, has a tendency to look rather at weak than at bright images.



Figs. 1—4: Infrared photographs of the Pleiades field for identification of the flare stars 53—78. North is at the top.

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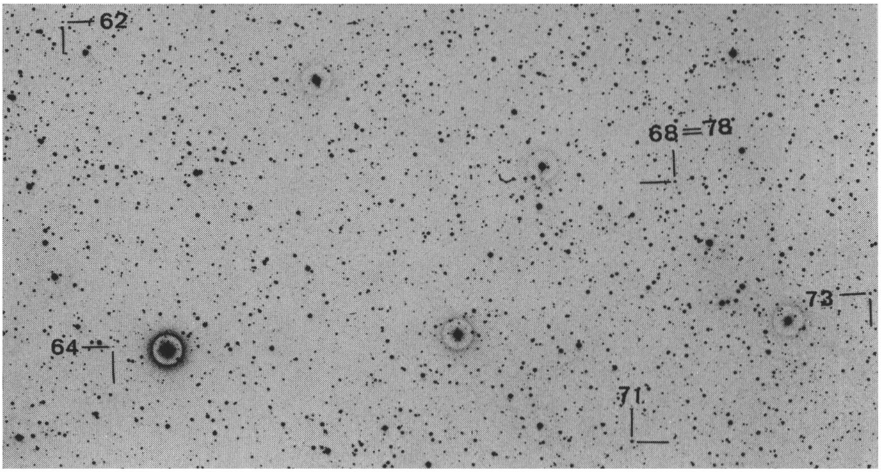

Fig. 2

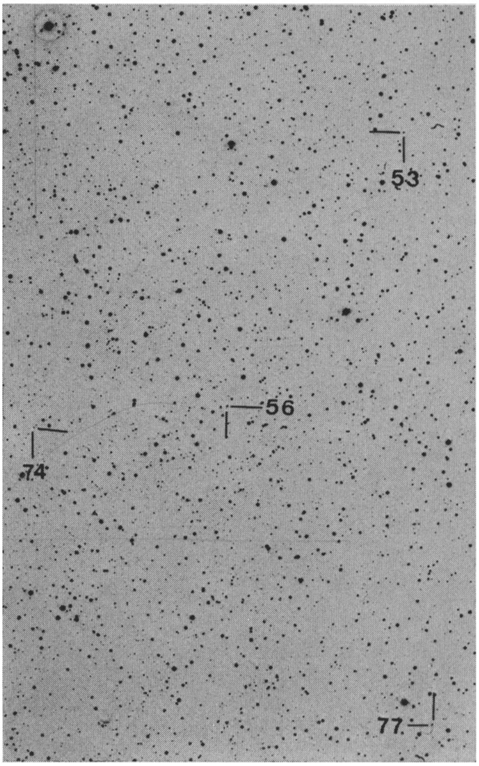

Fig. 3

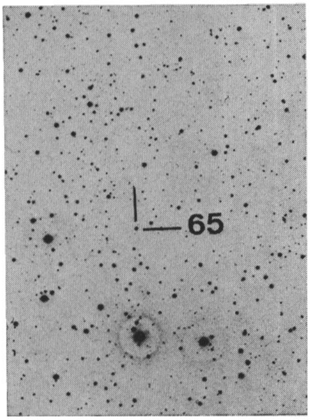

Fig. 4

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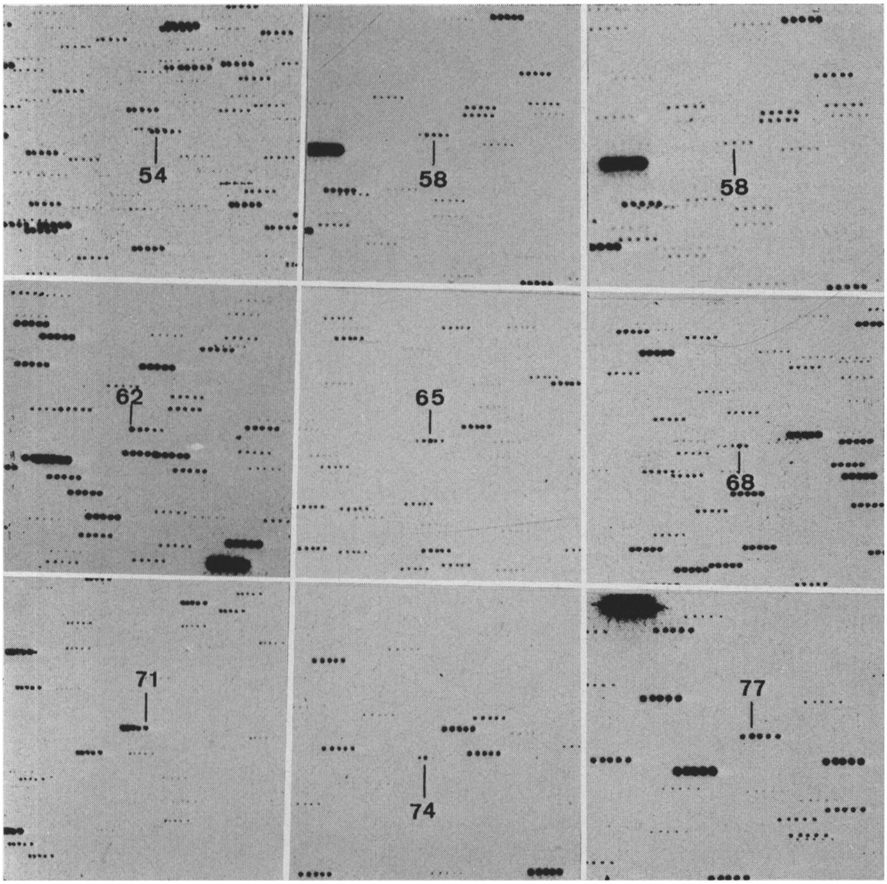

Fig. 5: Flare-ups in Pleiades stars.

Table I: New Flares in the Pleiades Cluster

N	RA 1900	D.	Magn. (pg)	Date	Ident.
				1970—71	
52	3^h 31^m 8^s	$+24°26'.7$	14.7 — 17.2	Oct. 4	RP 26
54	45 26	24 29.7	14.7 — 18:	„ 10	
55	43 6	22 40.3	15.2 — 16.6	„ 11	
56	33 12	23 41.1	16.5 — 17.6	„ 26	RP 22
57	38 43	23 11.7	16.3 — 17.8:	„ 26	RP 23
58	37 44	24 15.4	13.9 — 16.8	Nov. 23—24	H 41
59	43 57	24 26.3	14.8 — 17.4	„ 24	H 92
60	41 52	24 11.8	15.5 — 17.3	„ 24	
61	40 55	23 58.3	14.5 — 18:	„ 26	VM 16
62	45 32	26 7.9	13.6 — 16.8	„ 27—28	
63	36 57	23 7.7	15.1 — 16.2	„ 28	H 103
64	44 55	25 43.8	15.1 — 18:	„ 28	
65	48 6	23 3.0	13.8 — 15.5	Dec. 1	H 61
66	43 25	23 20.8	14.6 — 19:	„ 1	
67	43 34	24 13.3	14.4 — 19:	„ 25	H 90
68	38 25	25 43.8	14.7 — 16.5	Jan. 27	H 10
69	43 38	23 37.5	14.8 — 17.5	Feb. 21	R 3
70	39 15	24 46.5	13.4 — 15.4	„ 21	HII 566
				1968—69	
71	38 56	25 2.5	12.0 — 14.5	Oct. 20	
72	38 29	24 31.7	14.1 — 15.1	Jan. 17	HII 347
73	36 8	25 26.4	12.9 — 13.8	Oct. 12—13	
74	35 27	23 36.4	14.9 — 18.5	„ 13	
75	42 32	23 39.6	14.8 —(19	„ 13	
76	40 28	23 50.9	15.4 — 17.5	„ 16—17	R 2
77	30 47	22 49.9	13.7 — (19	„ 19	
78	38 25	25 43.8	15.1 — 16.5	Nov. 16	H 10

Notes to Table I:

1. *Flare No.* 53 — Plate No. 3688. Oct. 4, 1970.

UT 2^h19^m	17 pg	2^h34^m	16.6
24	17	39	14.7
29	17		

Magnitude at minimum about 17.2 pg. The star had also a flare on Jan. 19, 1969 (No. 26, see ROSINO-PIGATTO, 1969). At minimum the star seems to be weaker than in 1969.

2. *Flare No.* 54 — Plate No. 3724. Oct. 10, 1970.

UT 1^h52^m	15.2 pg	2^h07^m	15.5
57	14.8	12	15.8
2 02	15.2		

Weak, of about 18, at minimum.

3. *Flare No.* 55 — Plates No. 3727—3728. Oct. 11, 1970.

UT 1^h07^m	16.1 pg	1^h37^m	16.0
12	15.2	42	16.2
17	15.2	47	16.2
22	15.4	52	16.3
27	15.7	57	16.3

Magnitude at minimum about 16.6.

4. *Flare No. 56* — Plate No. 3795. Oct. 26, 1970.

UT 22^h45^m	17.5 pg	23^h00^m	16.5:
50	17.5	05	17:
55	17.5		

This star has shown a large amplitude flare (up to 13.3) on October 28, 1968 (Asiago serial number: 22).

5. *Flare No. 57* — Plate No. 3795. Oct. 26, 1970.

UT 22^h45^m	16.4 pg	23^h00^m	(17.5
50	16.4	05	(17.5
55	16.3		

The star coincides with Asiago No. 23 which showed a flare up to 14.5 on Oct. 28, 1968.

6. *Flare No. 58* — Plates No. 3895—96—97. Nov. 23—24, 1970.

UT 23^h40^m	16.0 pg	0^h18^m	15.4	0^h49^m	15.2
45	15.0	23	15.5	54	13.9
50	15.0	28	15.6	59	14.0
55	15.1	33	15.7	1 04	14.3
00 00	14.8	38	15.8	09	14.7
				1 23	14.8

The star coincides with Haro 41. Magnitude at minimum, about 16.8. Its light curve is represented in Fig. 6. We shall return later on this exceptional star.

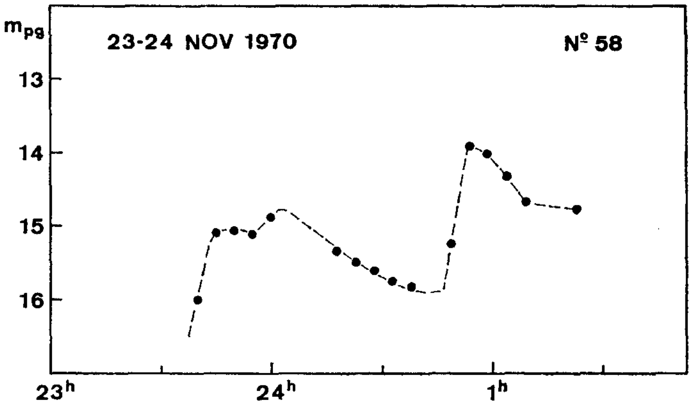

Fig. 6: Light curve of the double maximum flare No. 58.

7. *Flare No. 59* — Plates No. 3896—97. Nov. 24, 1970.

UT 0^h18^m	17.4: pg	0^h49^m	15.9
23	17.4	54	16.4
28	17.4	59	16.4
33	17.3	1 04	16.6:
38	14.8	09	16.6:

The star coincides with Haro 92. Magnitude at minimum, about 17.4:

8. *Flare No. 60* — Plates No. 3896—97. Nov. 24, 1970.

UT 0^h18^m	17.2 pg	0^h49^m	15.9
23	17.1	54	16.4
28	17.3	59	16.4
33	17.3	1 04	16.8
38	15.5	09	16.7

At minimum the star has magnitude 17.3.

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9. *Flare No. 61* — Plates No. 3930—31. Nov. 26, 1970.

UT 0^h51^m	15.2 pg	1^h22^m	16.1
56	14.5	27	16.3
1 01	15.3	32	16.5
06	15.5	37	16.5
11	15.8	42	16.6

The star is the well known van Maanen 16 (Haro 15) which has shown several flare-ups.

10. *Flare No. 62* — Plates No. 3961—62—63. Nov. 27—28, 1970.

UT 23^h29^m	16.8 pg	24^h00^m	13.6
34	16.8	0 05	14.1
39	16.8	10	14.6
44	16.8	15	15.1
49	13.7	20	15.6
		30	16.6

Beautiful flare in a star rather far from the centre. The flare is represented in Fig. 7. At minimum the star has a pg magnitude about 16.8.

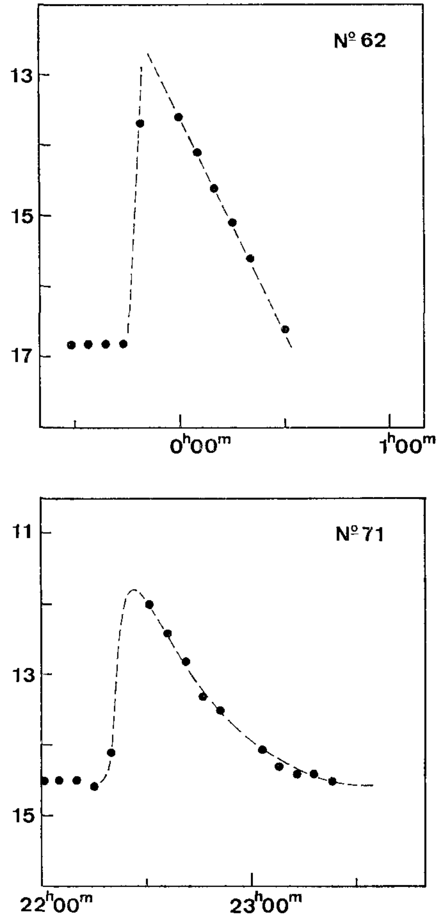

Fig. 7: Light curve of flares Nos. 62 and 71.

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11. *Flare No. 63* — Plate No. 3962. Nov. 28, 1970.

UT 0^h00^m	14.9 pg	0^h15^m	15.7
05	15.2	20	15.7
10	**15.5**		

The star coincides with Haro 103, which showed a flare on Dec. 16, 1968 (PARSAMIAN and CHAVIRA, 1969). The pg magn. at minimum is about 16.2.

12. *Flare No. 64* — Plate No. 3963. Nov. 28, 1970.

UT 0^h30^m	15.1 pg	0^h45^m	16.6
35	15.6	50	(17
40	16.1		

At minimum about 18 pg.

13. *Flare No. 65* — Plate No. 3988. Dec. 1, 1970.

UT 0^h32^m	15.5 pg	0^h47^m	15.1
37	15.0	52	15.3
42	13.8		

Is the flare star Haro 61. Pg magnitude at minimum: 15.5.

14. *Flare No. 66* — Plates No. 3989—90. Dec. 1, 1970.

UT 1^h02^m	(18 pg	1^h32^m	16.0
07	(18.	37	16.1
12	17.2	42	16.4
17	14.6	47	16.5
22	15.6	52	16.7:

The light curve is represented in Fig. 8. At minimum the star is barely visible, m_{pg} 19: .

15. *Flare No. 67* — Plates No. 4125—26. Dec. 25, 1970.

UT 22^h37^m	(17.5 pg	23^h17^m	14.9
44	(17.5	24	15.5
51	(17.5	31	16.0
58	16.3	38	16.2
23 05	14.4	45	(16.2

The star is barely visible at minimum. Magnitude about 19: pg. It coincides with Haro flare star No. 90 (HARO and CHAVIRA, 1969).

16. *Flare No. 68* — Plates No. 4167—68. Jan. 27, 1971.

UT 21^h12^m	16.1 pg	21^h43^m	15.7
17	16.0	48	15.7
22	15.6	53	15.8
27	14.7	58	15.8
32	15.3	22 03	16.1

This star is coincident with Haro 10. It shows a considerable flaring activity (see No. 78). The magnitude at minimum is estimated 16.5: pg.

17. *Flare No. 69* — Plate No. 4226. Feb. 21, 1971.

UT 20^h14^m	(17.2 pg
19	(17.2
24	14.8
29	15.4
34	15.8

This star coincides with our No. 3 (ROSINO, 1966) = Haro 54.

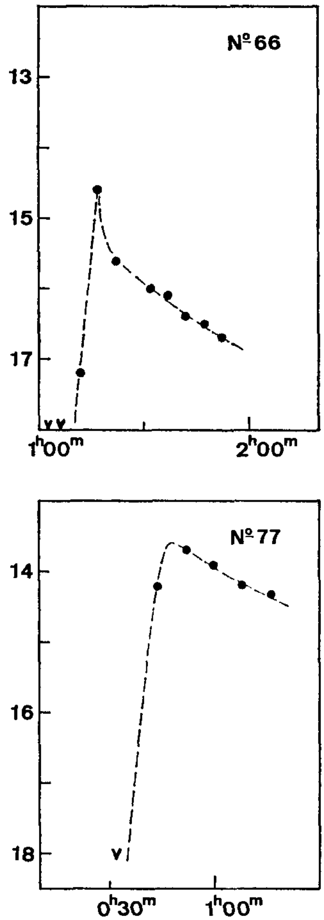

Fig. 8: Light curve of flares Nos. 66 and 77.

18. *Flare No. 70* — Plate No. 4227. Feb. 21, 1971.

UT 20^h44^m	14.7 pg	20^h59^m	14.0
49	13.4	21 04	14.3
54	13.8		

The star (HII 566) ist the north-east component of a close binary. The magnitudes are somewhat uncertain, because of the presence of the second component. The magnitude at minimum is about 15.4.

19. *Flare No. 71* — Plates No. 1865—66—67. Oct. 20, 1968.

UT 22^h00^m	14.5 pg	22^h31^m	12.0	23^h03^m	14.1
05	14.5	36	12.4	08	14.3
10	14.5	41	12.8	13	14.4
15	14.6	46	13.3	18	14.4
20	14.1	51	13.5	23	14.5

This flare, of a relatively bright star, has been found by a revision of old plates. At minimum the star has a magnitude 14.5 pg. Its light-curve is reproduced in Fig. 7.

20. *Flare No. 72* — Plate 2115. Jan. 17, 1969.

UT 20^h40^m	15.1 pg	20^h55^m	14.4
45	15.0	21 00	14.8
50	14.1		

The star coincides with HII 347. Magnitude at minimum: 15.1 pg.

21. *Flare No. 73* — Plate No. 2633. Oct. 12—13, 1969.

UT 23^h29^m	13.8 pg	23^h53^m	13.8
37	13.8	0 01	12.9
45	13.8		

22. *Flare No. 74* — Plate No. 2636. Oct. 13, 1969.

UT 1^h50^m	(17.2 pg	2^h14^m	14.9
58	(17.2	22	15.6
2 06	15.4		

Magnitude at minimum: about 18.5 pg.

23. *Flare No. 75* — Plate No. 2647. Oct. 13, 1969.

UT 22^h41^m	(17.2 pg	23^h05^m	14.8
49	17:	13	15.3
57	14.9		

24. *Flare No. 76* — Plate No. 2683. Oct. 16—17, 1969.

UT 23^h38^m	(17 pg	00^h02^m	15.4
46	16.3	10	16.2
54	16.1		

A flare-up of this star (van Maanen No. 6) was found by ROSINO (1966) on Sep. 9, 1964. The star has No. 47 in HARO's Catalogue (1968). Its magnitude at minimum is about 17.5 pg.

25. *Flare No. 77* — Plate No. 2699. Oct. 19, 1969.

UT 0^h44^m	14.2 pg	1^h08^m	14.2
52	13.7	16	14.3
1 00	13.9		

Slow-decline flare. At minimum the star is weaker than 19 pg, barely visible in infrared. Fig. 8 reproduces its light curve.

26. *Flare No. 78* — Plates No. 2783—84. Nov. 16, 1969.

UT 1^h04^m	15.1 pg	1^h49^m	16.4
12	15.4	57	16.5
20	15.7		
28	15.8		
36	15.9		

Haro No. 10. See No. 68.

The distribution of all the flare stars discovered at Asiago in the Pleiades field is shown in Fig. 9, which also represents the flare stars 1—112 of the HARO Catalogue (see HARO and CHAVIRA, 1969, pag. 32). It is confirmed that there is an increasing density of flare stars towards the centre of the cluster (Alcyone), except for the very central region, where, as noticed by MIRZOYAN and MNATSAKANIAN (1971) there seems to be a zone of avoidance. Some of the flare stars are found, in our plates, rather far from the centre and this may indicate that the extension of the cluster is larger than generally assumed.

Some light curves are reproduced in Figs. 6—8. Flares No. 62 and 66 are remarkable for their large amplitude. No. 77 shows a slow-decline flare. In fact, the star at its normal brightness is weaker than 19 pg, while in discovery plate it appears of mpg 14.2. The maximum, near 13.7, was attained a few minutes later, but the decline was slow, 0^m6 in 24 minutes, meaning that, if the rate of decline remained constant, the normal minimum was reached after 3—4 hours. We remember that the flare variables No. 22 (Haro 138) and 48 have displayed a similar behaviour.

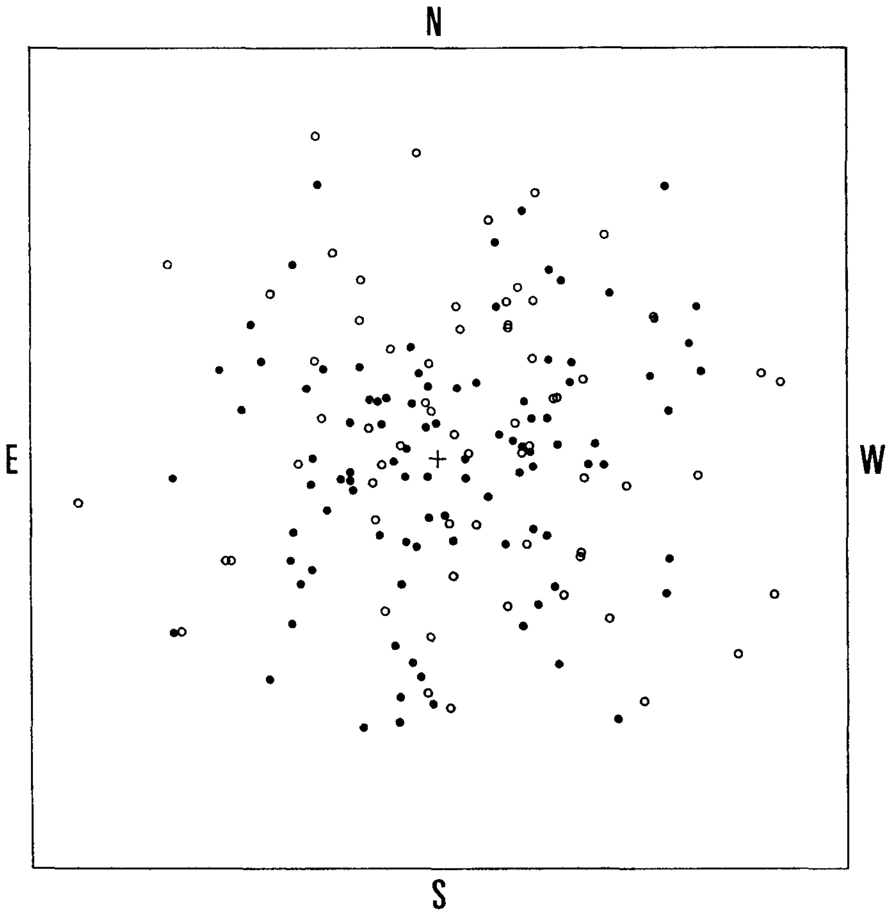

Fig. 9: Distribution of flare stars in the Pleiades cluster. Open circles indicate flares observed at Asiago.

Absolutely exceptional was the light curve of the flare star No. 58 (Haro 41). This star has shown a double maximum (Fig. 6), first rising to 14.9 and then, after a decline to about 15.8, rising again to 13.9. Complex flares, with two or more consecutive maxima, are not unfrequent in UV Ceti stars. Variable No. 58 proves that the Pleiades flare stars may share the same properties.. It is not unlikely that in some cases the complex structure of the Pleiades flares may be lost, because of the integration due to the length of the exposure time (5 to 8 minutes). Only when flares with complex structure last for hours, they can be caught through photographic observations. Photoelectric monitoring of some of the most active flare stars in Pleiades should be therefore highly desirable.

References:

HARO, G., 1968, Stars and Stellar Systems, Vol. III, Chapter 4, pag. 141. Chicago Univ. Press.
HARO, G., CHAVIRA, E., 1969, *Bol. Tonant.*, 5, 31, *pag.* 23.
HARO, G., PARSAMIAN, E., 1969, Bol. Tonant., 5, 31, pag. 45.
PARSAMIAN, E., CHAVIRA, E., 1969, Bol. Tonant., 5, 31, pag. 35.
PIGATTO, L., ROSINO, L., 1971, Mem. SAIt 41, 483.
ROSINO, L., 1966, Mem. SAIt, 37, 717.
ROSINO, L., PIGATTO, L., 1969, Mem. SAIt, 40, 447.
MIRZOYAN, L. V., MNATSAKANIAN, M. A., 1971, IBVS 528.