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NEW FLARE STARS IN THE PLEIADES

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RESUMEN

Durante los meses de octubre, 1968 a enero, 1969, observamos fotográficamente la región de las Pléyades, obteniendo una serie de placas con exposiciones múltiples, tanto en la región espectral azul como en la ultravioleta. Como era de esperarse, el material ultravioleta resultó considerablemente más eficiente por lo que se refiere a la detección de ráfagas estelares. El análisis de las observaciones de las 112 estrellas Ráfaga conocidas en la región de las Pléyades, nos permite concluir, siguiendo la sugestión de Ambartsumian, que el número total de posibles estrellas Ráfaga en esta región de 16 grados cuadrados será aproximadamente igual a 400.

During the months October 1968-January 1969, we continued the observations of flare stars in the Pleiades field as part of a Tonantzintla and Biurakan Observatories' joint program. With the Tonantzintla Schmidt camera and centering in Alcyone we obtained multiple photographic exposures using 103aO Eastman Kodak plates with (U) and without (B) ultraviolet filter; the (U) plates covering an area of 16 square degrees and reaching limiting ultraviolet magnitude $\sim$17.3, and the (B) plates covering 25 square degrees and limiting photographic magnitude $\sim$18.3.

Table 1 gives the general data on the aforementioned material and the total number of flare stars found.

TABLE 1

Photographic Observations in the Pleiades Field

Spectral Region	*Number of Plates*	*Number of Exposures*	*Total Obs. Time (Hours)*	*Flare Stars Found*	*Different Flare-ups Observed*	*Flare-ups in H_{II} 2411**
U	84	488	111	17	31	10
B	50	332	27	1	1	0

* The Hyades flare star H_{II} 2411 is not included in Table 2.

From the inspection of Table 1 the eficciency of the ultraviolet observations (U) over the photographic ones (B) is obvious. This can be easily understood if we take into account that the amplitude of the flare stars is considerably larger in U than in B (Haro, 1968). Anyway, we try first the B system in order to shorten the exposure time and to avoid — up to a certain extent — the flattening of the corresponding light curves of the possible flares.

Table 2 summarizes our results. From the 17 flare stars found, 5 were previously discovered (Haro, 1968, Haro and Chavira paper in this same bulletin). Column one gives the Tonantzintla serial numbers, the ones in italics indicate that the outburst repeats in a given star. All the new flare stars with H_{II} numbers (Hertzsprung *et al.* 1947) in column two are proper motion "members". The spectral types, column seven, are taken from Kraft and Greenstein (1969), Herbig (1962), or are approximately determined by Haro (1969). In this Table star H_{II} 1881, which shows only one image with $\Delta mU = 0.8$, was not included because we doubt whether it is a real flare-up or just an emulsion defect; in any case, it is a proper motion "nonmember" of the cluster.

Since the duration time of the rise to maximum and the maximum itself can be considerably shorter than our U exposure time (10^m to 15^m) and even shorter than the B exposures (3^m to 5^m), the rate of rise, the estimated amplitudes and the corresponding general light curves by necessity must be smoothed down.

Figures 1 and 2 show, as good examples, some of the stars contained in Table 2 during their outbursts.

Gathering all the flare stars in the Pleiades field, listed in this bulletin by Haro and Chavira, and ourselves, we derive the corresponding luminosity function. The maximum number of flare stars appear in the interval $mU = 18.0\text{-}19.0$. Although many of these field stars could be considered as cluster members, it is quite probable that some of them are just projected stars from the solar vicinity.

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Figure 1

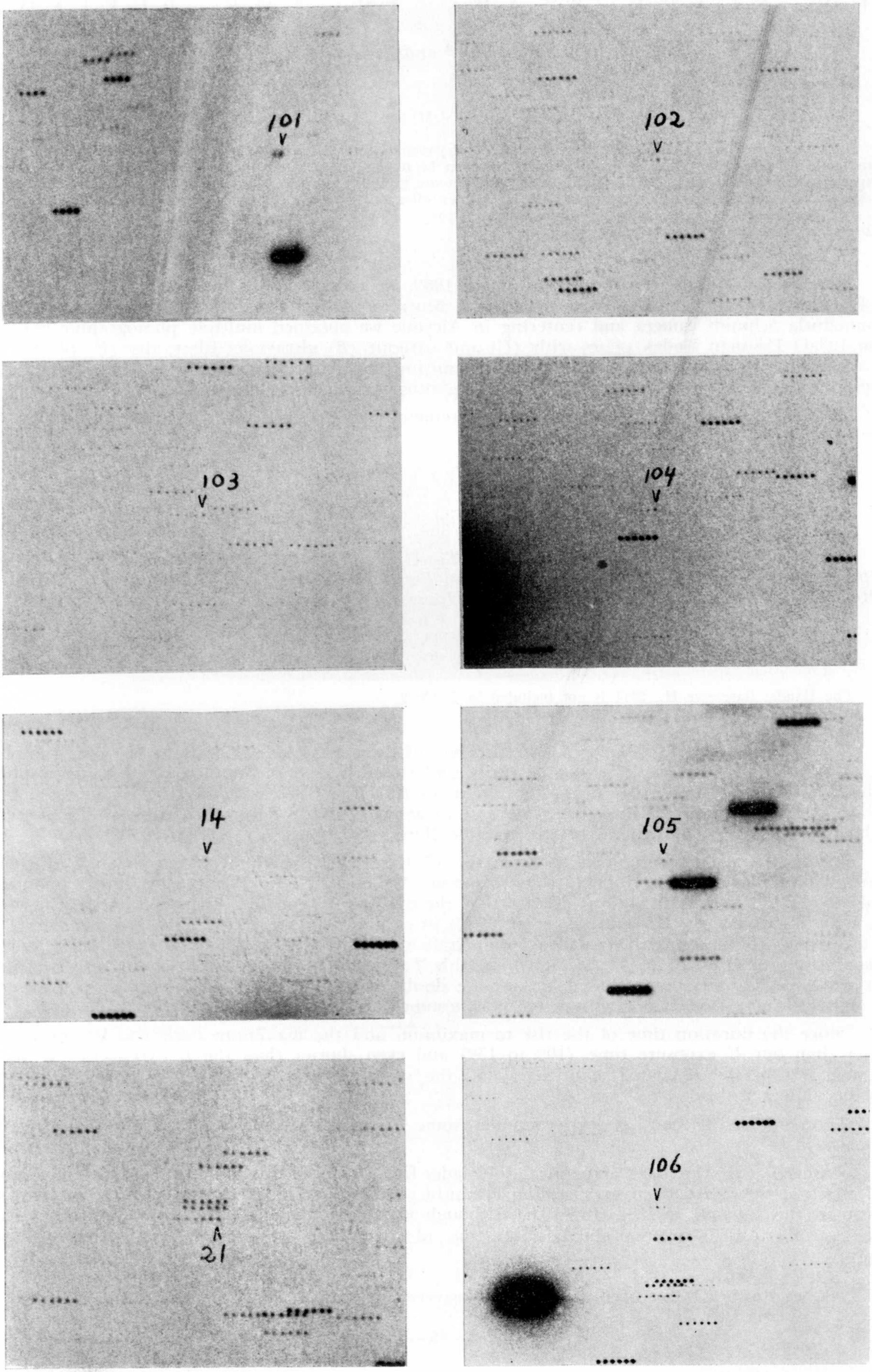

Figure 2

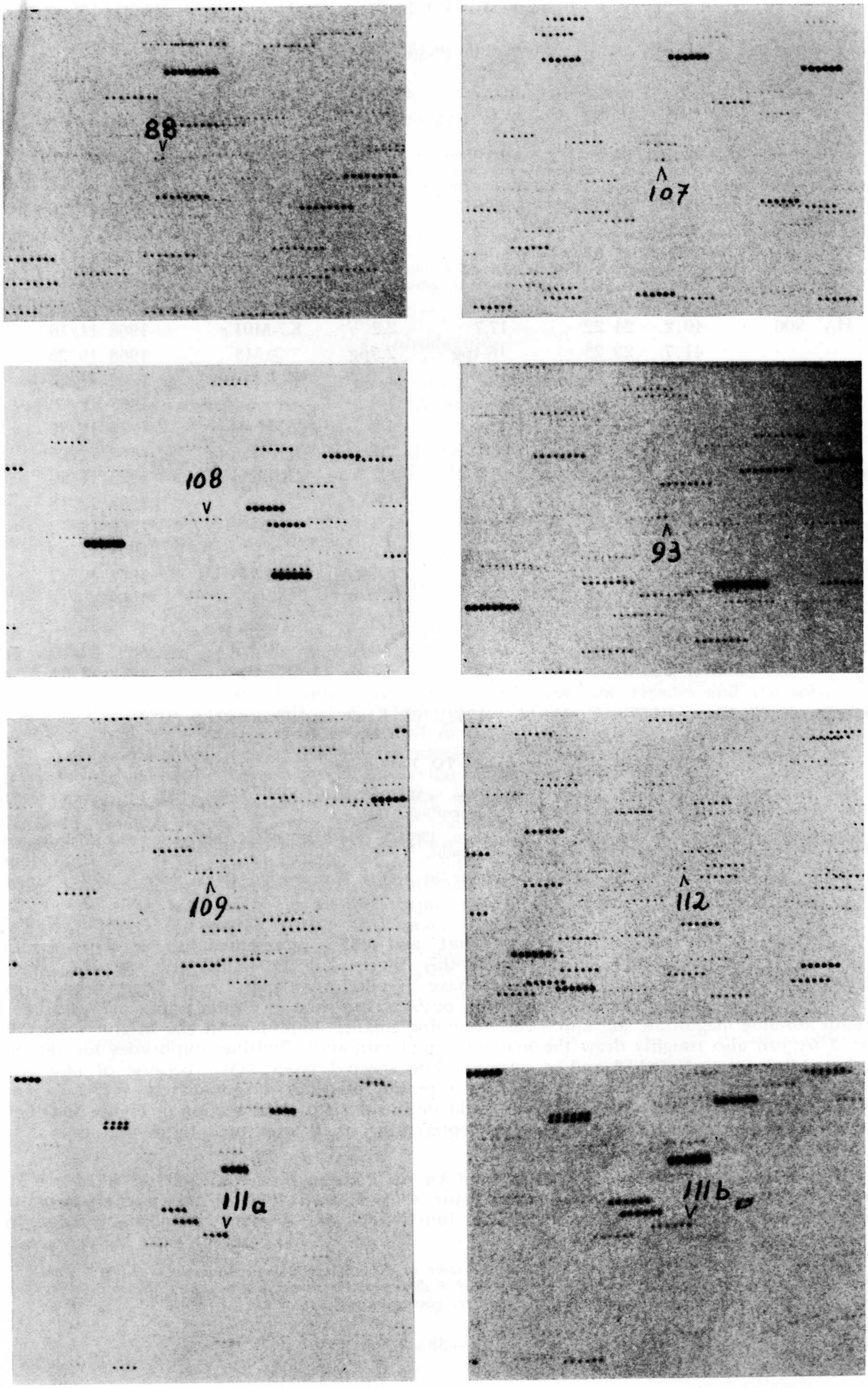

TABLE 2

Flare stars in the Pleiades

Nº	Star	R.A. (1900)	Dec. (1900)	mag. in U	ΔmU	Spectral Type	Date of Flare	Ref*
101		3^h33^m2	$+24°25'$	~19.5	6.5	≥M2	1968 12/23	1
101		”	”	”	4.8	”	1968 12/24	
102		34.8	24 50	~20.0	4.5		1968 11/26	
103		36.9	23 08	17.2	0.8	≥M3	1968 12/16	1
8	H_{II} 357	38.5	23 51	15.6	0.6	K5;K6*Ve*	1968 11/16	2,3
8	”	”	”	”	1.0	”	1968 11/16	
104		38.7	24 13	~20.0	5.1		1968 12/17	
14	H_{II} 906	40.2	24 22	17.7	2.2	K7-M0*Ve*	1968 11/16	3
105		41.7	23 23	16.4pg	2.5pg	≥M3	1968 10/26	1
21	H_{II} 1653	42.0	24 25	16.2	1.4	K7,K4.5*Ve*	1968 11/24	2,3
21	”	”	”	”	1.0		1968 12/20	
106		42.1	23 11	19.4	4.9	≥M4 (H_α)	1968 12/20	
88	H_{II} 2193	43.2	23 15	16.6	2.1	K6*Ve*	1968 12/26	3
107	H_{II} 2208	43.3	24 16	17.0	0.7	dK6,K6*Ve*	1968 11/16	2,3
107	”	”	”	”	1.8	”	1968 12/18	
108		43.9	25 06	15.8	1.3	M	1969 1/12	1
108		”	”	”	0.7	”	1969 1/20	
93	H_{II} 2602	44.2	23 41	18.2	3.1	M2.5*Ve*	1968 12/22	3
109	H_{II} 2927	45.1	24 26	16.2	1.7	K4*Ve*	1968 12/18	3
110	H_{II} 3019	45.4	23 47	15.6	1.0		1968 12/22	
111	H_{II} 3104	45.7	22 53	16.5	4.0	M0-M1	1968 11/26	1
112		3^h47^m8	$+24°07$	>19.2	4.0	≥M2	1969 1/13	1

* References: (1) Haro (1969), (2) Herbig (1962), (3) Kraft and Greenstein (1969).

NOTES TO TABLE 2

Star No. 101: This star (m*U* ~19.5, spectral type ≥M2) shows, during a period of 23 hours, two outstanding outbursts with amplitudes of the order of 6.5 and 4.8 magnitudes each.

Star No. 8: A well known flare star, H_{II}357 (Haro, 1968) — which is one of the more active Pleiades variable members — shows two flare-ups during an interval of 5 hours.

Star No. 106: This object is the only one of our list which, according to Haro, shows a rather strong Hα emission during minima; its spectral type is ≥ M4.

In Figure 3, the relationship between Δm*U* and m*U* is represented for the above mentioned lists of stars. It can immediately be noticed, in this figure, that the fainter the star, the larger the flare amplitude. In this last regard, we must have in mind that apart from observational selection the same amount of energy liberated during an outburst can produce a large apparent amplitude flare in a faint absolute magnitude star and a corresponding smaller amplitude in the brightest ones. From Figure 3 we can also roughly draw the maximum and minimum limiting amplitudes for the K4-M2 stars, but starting at m*U* ≥17.3 and at corresponding spectral types ≥M2, because of observational selection (the limit of our ultraviolet multiple exposure plates is approximately ~17.3) we would not detect in the faint stars flare-ups that could lie in the right lower section of Figure 3. Otherwise, this same section would be covered by points representing small amplitude flares that cannot be registered by our present telescope and technique.

The relation between the total number of known Pleiades flare stars and the incidence of outbursts in the same objects is represented in Figure 4. As Haro (1968) has shown, the observable incidence decreases, in general, quite rapidly as a function of the absolute luminosity increase in the

Figs. 1 and 2.—*Multiple-exposure showing flare-ups in some of the Pleiades stars contained in Table 2. Each exposure was of 10 minutes in the cases of the series of 8 different exposures, in the others the unit of exposure time was 15 minutes. The order of the exposures goes from right to left.*

stars. In the Pleiades, the flare stars with four or more flare-ups are comprised within the spectral interval K5-M0, but it seems that this is mainly the result of an observational selection.

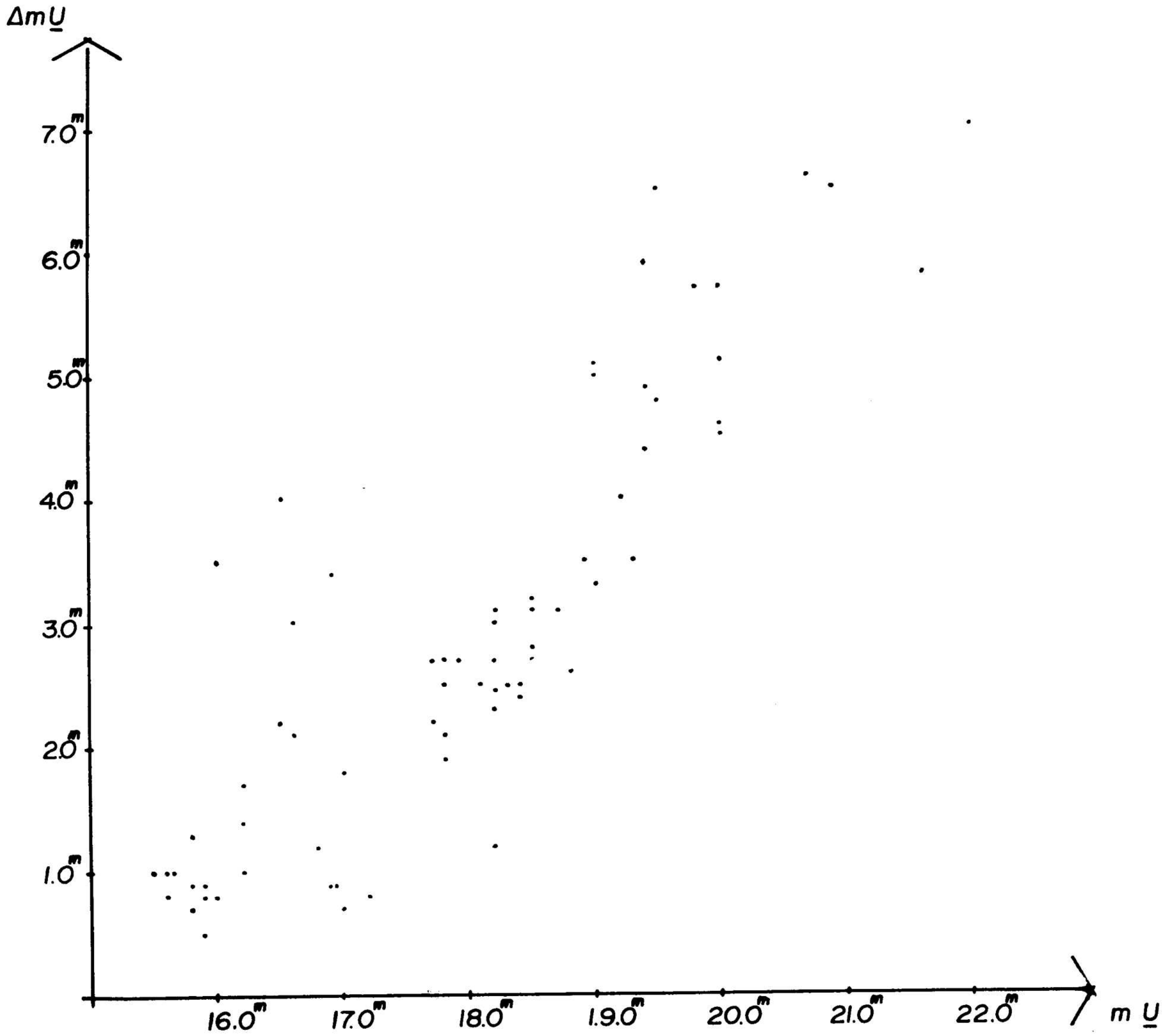

Fig. 3.—*The relation between* ΔmU *and* mU *for the flare stars listed in our Table 2 and in Table 1 of Haro and Chavira's paper in this same Bulletin.*

From the 112 Pleiades flare stars available data, it is possible to assume — following V. Ambartsumian (1968) — that the probability of flare stars appearance obeys the Poisson's law:

$$P_K = \frac{e^{-\nu t} (\nu t)^K}{K!}$$

being t the total time of observation, ν the frequency of flares, K the number of flare-ups during t, and using for mathematical expectation of the number of stars that flare K times, the following expression:

$$N_K = NP_K$$

With the data at hand, it is easy to conclude that the total number of expected flare stars in the Pleiades 16 square degree field is of the order of 400.

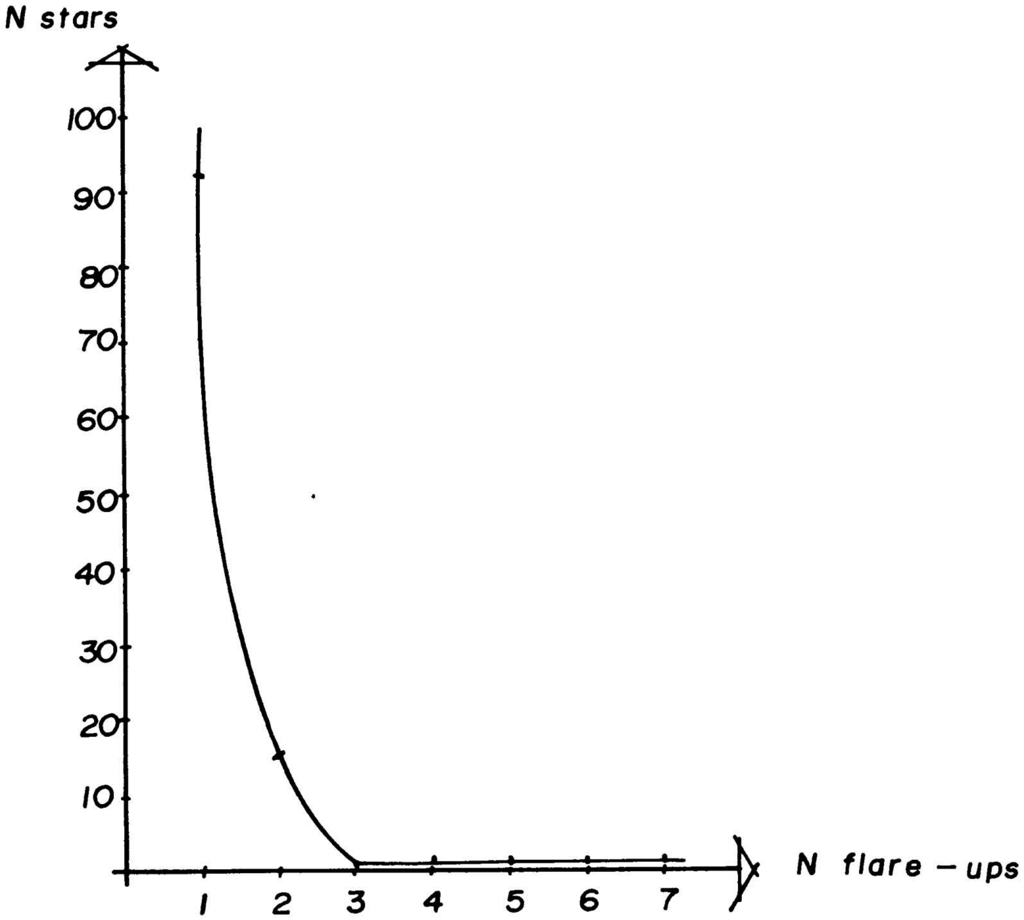

Fig. 4.—*Relation between the total number of known Pleiades flare stars (112) and the incidence of outburst in the same objects.*

Finally, we wish to express our gratitude to Dr. G. Haro for his advices and valuable discussions.

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