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HII 2411 A HYADES FLARE STAR

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RESUMEN

Proyectada sobre la región de las Pléyades, la estrella HII 2411, miembro del cúmulo de las Hiadas, con tipo espectral M4e, muestra una relativa gran incidencia en sus variaciones. En tanto y que en las más activas estrellas Ráfaga, miembros de las Pléyades, se han detectado como máximo siete diferentes explosiones, en HII 2411 se registraron, durante el mismo tiempo de observación, 46 distintas ráfagas con amplitudes en el ultravioleta ⩾ 0.5 magnitudes.

The object H_{II}2411 (Hertzsprung *et al.* (1947) has been recognized as a M4e star, member of the Hyades cluster (Herbig, 1962) projected on the Pleiades field not far from Alcyone. When we started at the Tonantzintla Observatory, in February 1963, our search for flare stars in the Pleiades region, it was precisely in this star in which we found the first outstanding outburst. Later on we realized that among all the Pleiades field flare stars, H_{II}2411 was one of the more active (Haro and Chavira, 1966, Haro, 1968).

The collection of the multiple exposure photographic material from February, 1963 up to January 1969 has largely confirmed our first observations. Up to this last date we have obtained 2,863 different blue and ultraviolet exposures during a total observing time of 551 hours.

The careful re-examination of all our available plates has given as a result the finding of 46 different outbursts with Δ mU ⩾ 0.5. The corresponding data are summarized in Table 1, in which we have added two additional flare-ups found by Rosino (Haro, 1968).

TABLE 1

H_{II} 2411 Different Flare-Ups

Nº	ΔmU	Flare Time U.T.	Duration of Flare	Date of Obs.	Nº	ΔmU	Flare Time U.T.	Duration of Flare	Date of Obs.
1	1^m5	4^h44^m— 5^h04^m	20^m	15 II 1963	25	0^m5	5^h31^m— 6^h01^m	30^m	10 XI 1966
2	0.6	3 23 — 3 33	10	26 II 1963	26	0.5	7 41 — 7 56	15	10 XI 1966
3	0.8	4 05 — 4 35	30	9 XI 1963	27	0.5	6 28 — 6 58	30	14 XI 1966
4	0.5	5 10 — 5 20	10	10 XI 1963	28	0.5	4 31 — 4 46	15	15 XI 1966
5	0.5	3 53 — 4 03	10	12 XI 1963	29	0.5	6 41 — 7 26	45	15 XI 1966
6	0.7	9 29 — 9 39	10	21 XI 1963	30	0.7	8 19 — 8 34	15	15 XI 1966
7	3.7	6 55 — 7 15	20	23 XI 1963	31	0.6	7 36 — 7 51	15	16 XI 1966
8	0.5	7 28 — 7 48	20	30 X 1964	32	0.5	6 55 — 7 10	15	8 XII 1966
9	0.8	7 14 — 7 34	20	2 XI 1964	33	0.6	3 02 — 3 47	45	5 I 1967
10	0.7	3 03 — 3 33	30	28 XI 1964	34	1.0	6 58 — 7 13	15	7 XI 1967
11	0.8	3 25 — 3 45	20	2 XII 1964	35	1.5	3 33 — 4 03	30	26 XI 1967
12	0.5	10 11 —10 21	10	2 XII 1964	36	2.5	2 56 — 3 26	30	27 XI 1967
13*	0.9	———	—	8 XII 1964	37	0.6	5 57 — 6 12	15	29 XII 1967
14*	1.3	———	—	9 XII 1964	38	0.5	6 37 — 7 22	45	29 XII 1967
15	0.5	4 54 — 5 39	45	17 XI 1965	39	0.6	3 01 — 3 16	15	20 XII 1968
16	0.5	4 15 — 5 00	45	18 XI 1965	40	1.5	6 39 — 6 54	15	20 XII 1968
17	0.6	6 35 — 7 05	30	19 XI 1965	41	0.7	2 07 — 2 37	30	21 XII 1968
18	0.6	2 03 — 2 23	20	21 XI 1965	42	1.4	2 44 — 4 38	114	21 XII 1968
19	0.5	3 43 — 3 58	15	21 XI 1965	43	0.8	6 19 — 7 04	50	12 I 1969
20	1.6	6 43 — 7 31	68	21 XI 1965	44	0.8	7 06 — 7 21	15	13 I 1969
21	0.5	4 06 — 4 21	15	23 XI 1965	45	0.6	3 17 — 3 32	15	15 I 1969
22	0.5	6 00 — 6 45	45	28 XI 1965	46	0.6	6 29 — 6 59	30	15 I 1969
23	0.5	4 05 — 4 50	45	29 XI 1965	47	0.6	6 38 — 7 08	30	17 I 1969
24	1.5	5^h35^m— 6^h20^m	45^m	8 XI 1966	48	3.7	4^h32^m— 6^h55^m	143^m	20 I 1969

* Rosino Obs. (Haro, 1968).

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It is important to say that although we have not included flashes with smaller amplitudes than 0.5 magnitudes, the star seems to vary very frequently — perhaps constantly as an irregular variable — within ranges from one to four tenths of a magnitude in the ultraviolet.

From the analysis of all our material on the Pleiades, we want to point out some of the more relevant observational data on $H_{II}2411$:

1. In our ultraviolet plates (U) the average minimum magnitude of $H_{II}2411$ is $\sim$16.8; in the blue (B) exposures (103 a 0 plates without an ultraviolet filter) the minima is $\sim$ 15.5.

2. As the limiting magnitude of our U plates is $\sim$17.3 and in B $\sim$18.3, the star is always under "constant" control.

3. All the flare-ups with amplitudes $\geqslant$ 0.5 have been detected in the U plates. The exposure time per image in this sytem was either of 10^m or 15^m.

4. Out of the 2,863 different exposures with 551 hours of effective observational time, only during 36 hours we made multiple different exposure series of 3^m, 5^m and 10^m, respectively, in the B system without finding in any of the blue series of images an outburst with Δ mB of more than $\sim$0.2 magnitudes. This can be explained either because, as is well known, the ultraviolet amplitude of a flare is always larger than the blue one or owing to the relatively stronger saturation of the blue images of $H_{II}2411$ in our plates, which makes the measurement of small amplitude variation more difficult — or due to both things. Notwithstanding, in certain cases it can be just guessed that there are some very small variations in the blue.

5. As all the detected flare-ups with Δ mU $\geqslant$0.5 magnitudes were only found in the ultraviolet multiple exposures, we computed the incidence of outbursts only in our U exposure system obtaining the value of one flare-up every 11.2 hours. Undoubtedly, this represents a minimum value for the incidence of outbursts in $H_{II}2411$.

6. Dividing all our observational material in to three different periods, we found; *a)* that in the period 1963-1964 — during 189 hours of effective observational time — there are 12 flare-ups, that is, one outburst every 15.75 hours; *b)* during the period comprised between 1965-1967 — with 215 hours of observation — we found 24 flare-ups, that is, one outburst every 9 hours; *c)* in the period 1968-1969 — with 111 hours of observation — there are 10 different flare-ups, that is, one outburst every 11 hours. We believe that right now it would be rather risky to interpret the incidence difference between periods *b)* and *c)*, with relation to the incidence of period *a)*, as a result of an intrinsic periodical or semi-periodical change in the frequency of flare-ups in $H_{II}2411$. Future observations will give more weight to our present results.

7. The time of the ultraviolet multiple exposures — either 10^m or 15^m each — in such a "fast" flare star necessarily has as a consequence the flattening of the light curves and, thus, the real Δ mU observed photographically or photoelectrically with considerably shorter integration time would show conspicuously greater values. The same can be said about the light rate time of increase from minimum to maximum. Regarding the total time of variation — from minimum to maximum and back to minimum — no doubt that our technique gives very large values, especially in the very short-time flares. Thus, for instance, if in a multiple exposure series of images — of 15^m or 10^m each — the flare-up starts in the last seconds or minutes of a given exposure and ends in the first seconds or minutes of the succeeding one, the observed photographic result would be an increment in the integrated magnitudes of the two contiguous stellar images and the total time of variation will be given by us as 30^m or 20^m, respectively — very possibly quite far from reality. Of course, this is a serious difficulty connected with our observing method and we have always been conscious of it. Anyway, for many other purposes and with all its obvious limitations, it has proved to be a very powerful and efficient technique.

8. Notwithstanding the aforementioned limitations in a good number of flare-ups in $H_{II}2411$ — and the same can be said in regard to many other flare stars — we can distinguish some outstanding differences in the light curves of these variables: the "fast" and "slow" rate of rising flares — the time from minimum to maximum — (Haro, 1968), and the relatively "fast" and "slow" declining flares — the time from maximum and back to minimum. In all observed instances $H_{II}2411$ can be classified as a "fast" rising flare, that is, the time of rising to maximum can be of the order of seconds or a few minutes, no more than 15^m if we take into account — very conservatively — our observational handicaps. But the decline of this star from maximum to minimum can be very fast — from very few minutes up to 10^m or 15^m — or relatively slow, let us say of the order of 2 hours or even more. Good examples of the above are the two flare-ups listed in Table 1, under Nos. 7 and 48: in both cases the Δ mU measured is of the same order, $\sim$3.7 magnitudes; the rise to maximum very rapid but the decline towards minimum in flare-up

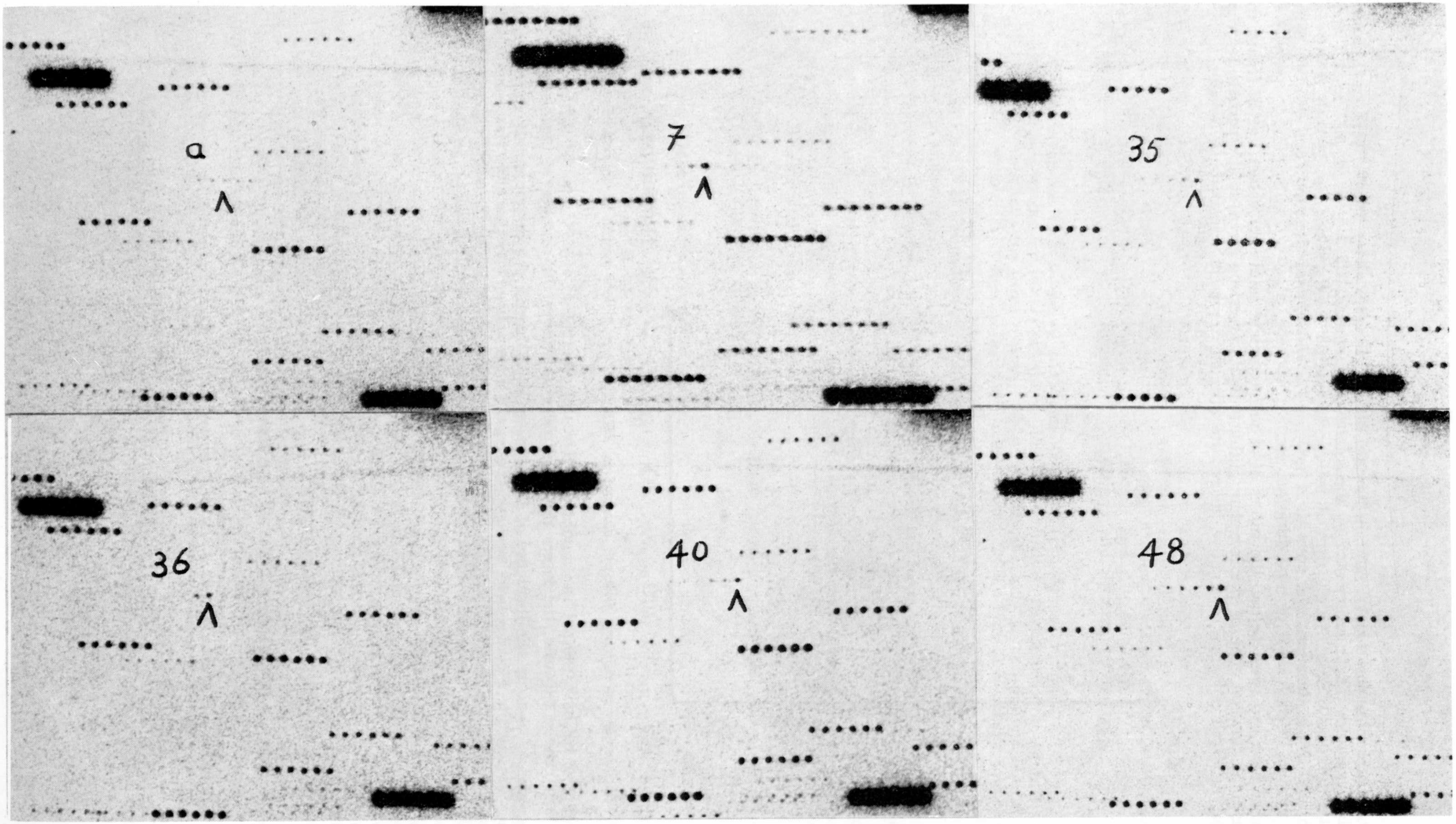

Fig. 1.—*Multiple-exposure plates showing some different flare-ups in HII 2411. The numbers correspond to the ones contained in Table 1. The arrow and letter* a *shows the flare star at its "normal" minimum. With the exception of flare-up Nº 7 in which the unit of exposure was 10 minutes in all the other cases, in this figure, each exposure was 15 minutes, with less than 1 second between exposures. The order of the exposures goes from right to left.*

No. 7 is equal or less than 20^m and, in flare-up No. 48, it takes about 2^h20^m (see Fig. 1). Some other examples can be represented by the following flare-ups: No. 1 with Δ mU = 1.5 and total duration of 20^m; No. 20 with Δ mU = 1.6 and 68^m of duration; No. 24 with Δ mU = 1.5 and 45^m of duration; No. 40 with Δ mU = 1.5 and 15^m of duration; and No. 42 with Δ mU = 1.4 and 114 ^{m} of total duration, etc.

As we have explained before, the values of Δ mU represent minimum values but in regard to the total duration time of the complete outburst light curves the given data, especially for the stars in which only two consecutive images are affected, represent a maximum possible value.

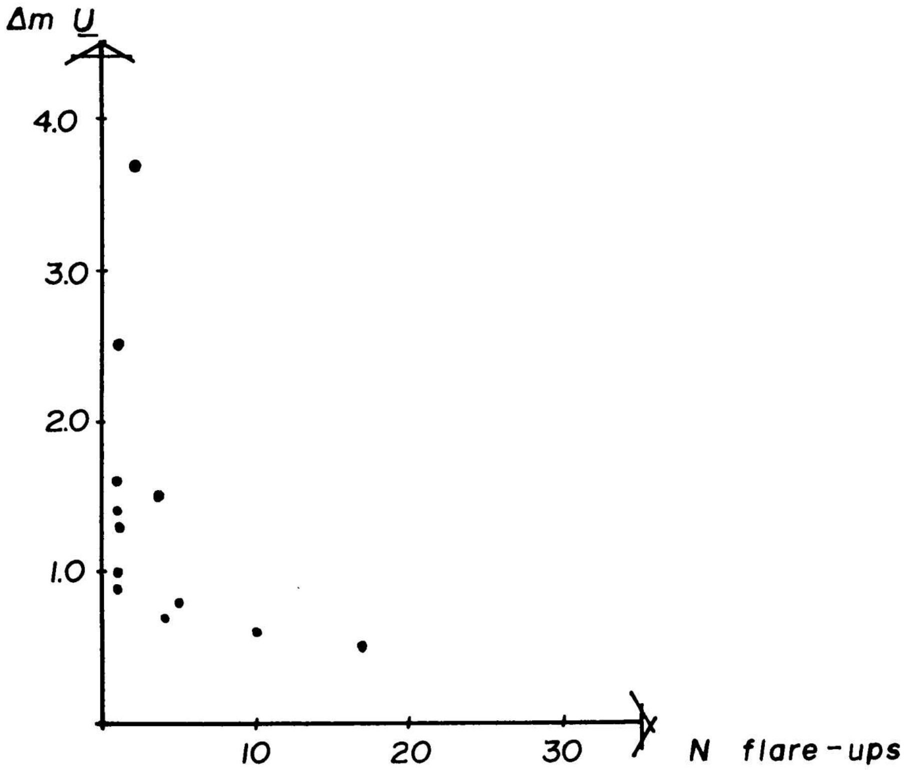

Fig. 2.—*The number of different flare-ups observed in HII 2411 are plotted against their respective* ΔmU.

In Fig. 2 we have plotted the number of flare-ups observed in H_{II}2411 against their respective Δ mU. As it can be expected, the larger the amplitudes, the fewer the number of outbursts.

In order to compare the incidence of flare-ups in H_{II}2411 with the corresponding incidence in some other stars in the Pleiades field we have chosen the more active cluster member flare stars which are at minima, brighter than mU = 17.3 and with Δ mU $\geqslant$0.5, that is the Pleiades field stars which due to their minimum apparent ultraviolet magnitudes appear — as well as H_{II}2411 — in all the plate material used. The result is the following:

H_{II}2411 — 46 flare-ups, spectral type M4*e* (Herbig, 1962).
H_{II}357 — 7 flare-ups, spectral type K6*Ve* (Kraft & Greenstein, 1969).
H_{II}906 — 6 flare-ups, spectral type K7-M0*Ve* (Kraft & Greenstein, 1969).
H_{II}1306 — 5 flare-ups, spectral type dK5 (*e*) (Herbig, 1962).
H_{II}1653 — 4 flare-ups, spectral type K4.5*Ve* (Kraft & Greenstein, 1969).

The difference cannot be more striking.

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