PHOTOGRAPHIC MAGNITUDES OF 201 STARS AT 2600 Å

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Résumé. Les magnitudes de 201 étoiles à 2600 Å (longueur de la bande passante: 1000 Å) ont été obtenues grâce à deux photographies de la Voie Lactée d'hiver données par une caméra à grand champ. Une estimation préliminaire du rougissement interstellaire a permis de tracer un diagramme couleur-type spectral. Il semble que les étoiles O sont plus brillantes que prévu à 2600 Å.

Abstract. The magnitudes of 201 stars at 2600 Å (1000 Å passband) were derived from two plates of the winter Milky Way obtained with a large field camera. A preliminary investigation of the interstellar reddening allowed us to plot a color-spectral type diagram. Stars of type O seem to be brighter than predicted.

1. Introduction

The preliminary results, presented here, are from the second flight of a sounding rocket programme.

These experiments were proposed by G. Courtès to the Centre National d'Etudes Spatiales (CNES). They are designed to photograph the sky in an ultraviolet passband, by night, at a high altitude (200–300 km), with different cameras having large fields (actually 5700 sq deg), a high luminosity ($f/1$) and a low angular resolution (about 10′). These parameters allow the use of poor pointing and guiding systems.

Because of the large field of these cameras, it is theoretically possible to cover the entire sky in 10 flights.

2. Description of the Experiment

The experiment was launched on April 4, 1967. Despite the difficult recovery, it gave the two expected photographs.

The optical system (Figure 1) is as follows: a hyperbolic convex mirror forms a large field image of the sky, which is refocussed by a Maksutoff-Brouwers camera. This very simple design is free of astigmatism and the convex curvature of the sky image given by the hyperbolic mirror has been calculated so that the Maksutoff-Brouwers camera gives a flat field. This field was 82° radius and was limited to a sector of about 120°.

The ultraviolet passband, which we call U', was produced by a multilayer coating on the spherical mirror of the Maksutoff-Brouwers camera. The transmission curve is shown in Figure 2.

The exposure times were successively 20 sec and 210 sec, with Kodak 103 a0-UV film.

3. Description of the Photographs

The shorter exposure (Figure 3) shows only about 50 stars but during this time the

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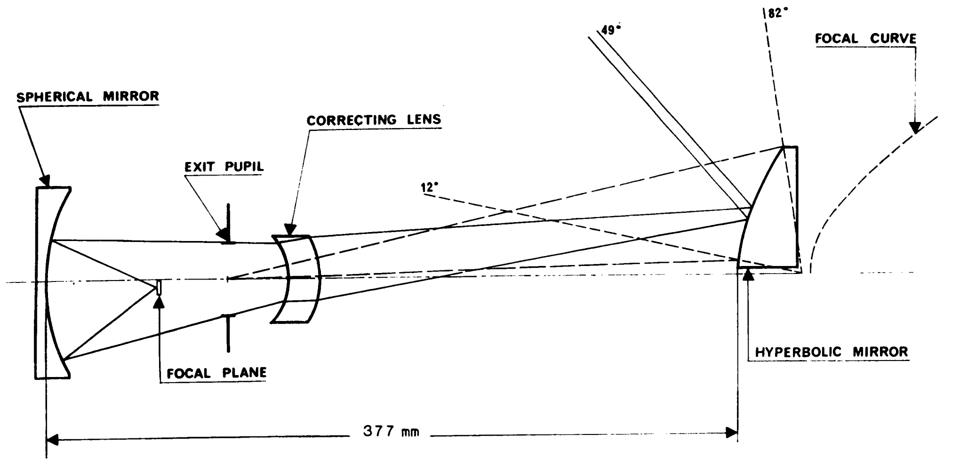

Fig. 1. The optical layout.

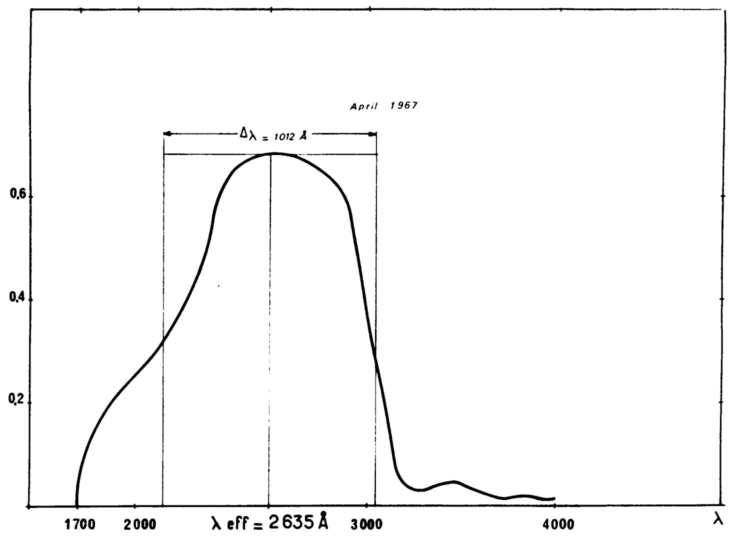

Fig. 2. Camera transmission for a flat energy spectrum.

guiding was very good and the optical resolution is reached. The brightest stars, particularly the Orion's Belt stars, are available for measurements. The individual stars of Pleiades are almost separated.

On the longer exposure (Figure 4), more than 700 stars were identified. The visual limit V-magnitude is about 8 for type O5 stars and about 6 for type F0 stars.

The thin distribution of population I stars in the Milky Way is to be seen and the Zodiacal Light (bottom right) is detectable up to the Milky Way (58° from the sun).

The high contrast of these two phenomena shows that the night UV brightness of the very high atmosphere (more than 200 km high) is not detectable in our instrument

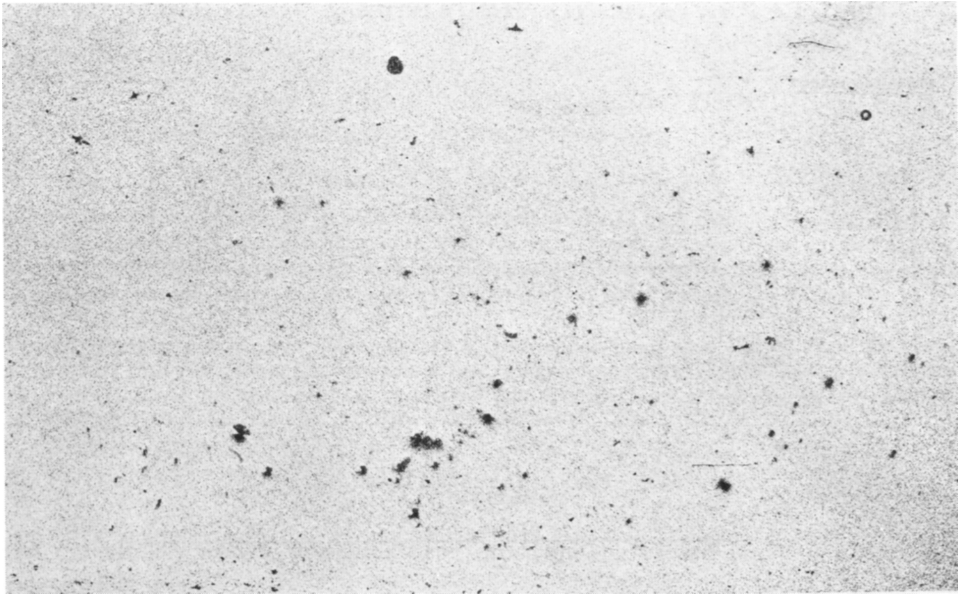

Fig. 3. 20 sec exposure photograph.

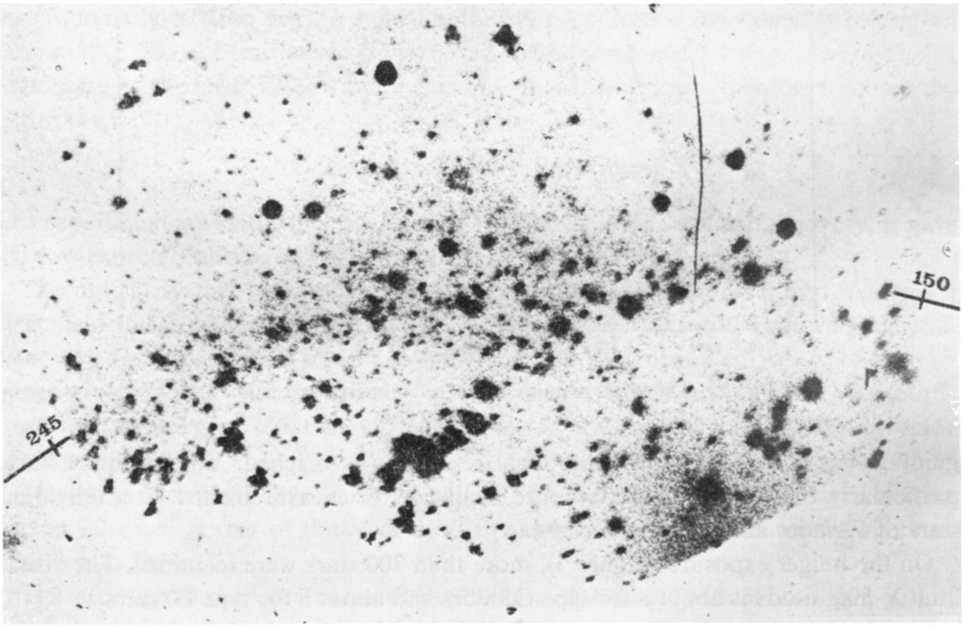

Fig. 4. 210 sec exposure photograph. Extreme galactic longitudes (l^{II} system) are given. Constellations of Orion (bottom center), Auriga (top right) and Canis Major (bottom left) are easy to identify. Among the Zodiacal Light (bottom right) are the Pleiades, much over-exposed, as for Jupiter (top center).

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TABLE I

HD	Chart No.	Name		Spectral Type		V	B-V	U-B	U′	Remarks
20995	3420			B9.5	V	5.62	−0.03	−0.16	5.31	
21856	3414			B1	V	5.88	−0.06	−0.86	3.69	
22091	2804	7	Tau	A3	V	5.90	+0.13		6.19	doub.
22951	3416	40	Per	B0,5	V	4.99	−0.02	−0.84	2.76	
23016	2806	13	Tau	B8	Ve	5.56	−0.01		5.07	
23793	2113	30	Tau	B3	V	6.00			2.99	doub. var.?
24155	2104			B9	II-III	6.16	−0.06	−0.48	5.66	
24398	3422	44 ζ	Per	B1	Ib	2.84	+0.12	−0.77	1.32	mult. var.?
24640	3413			B2	V	5.48	−0.03		3.19	var.?
24760	3408	45 ε	Per	B0.5	III-V	2.89	−0.18	−0.99	+0.53	
24912	3412	46 ξ	Per	O7	I	4.03	+0.01		2.05	var.?
25330	2112			B8		5.67	+0.02	−0.41	4.67	doub.
25204	2105	35 λ	Tau	B3	V	3.8			1.61	3.8–4.1 var.
25823	2701	41	Tau	Asi		5.21	−0.13	−0.48	4.10	
25940	3904	48	Per	B3	Vpe	4.03	−0.03	−0.55	2.79	var.?
27026	3302			B8	V	6.10	−0.08	−0.30	5.81	
27396	3808	53	Per	B6	III	4.86	−0.02	−0.54	3.62	var.?
27638	2704	59 χ	Tau	B9.5	V	5.38	−0.02		4.92	doub.
27742	2712			B9	V	5.90	+0.03	−0.26	4.86	
28217	2106			B7	III	5.83	+0.05		5.55	doub.
28929	3315			Ap		5.70	−0.05		5.00	doub.
29140	2107	88	Tau	Am		4.25	+0.18	+0.09	5.10	doub. var.?
29365	2710			B8	V	5.72	−0.05	−0.34	4.80	
29499	2108			dA9		5.39	+0.25	+0.12	6.16	
29646	3316			A2	V	5.58	−0.02		5.79	doub.
29722	3814	59	Per	A1	V	5.26	+0.01	+0.02	5.80	
29763	2706	94 τ	Tau	B3	V	4.31	−0.13	−0.56	2.25	
29866	3305			B7e		6.07	+0.10	−0.29	5.93	
30652	2009	1 π^3	Ori	F6	V	3.19	+0.45	−0.01	4.99	doub.
30739	2008	2 π^2	Ori	A0	V	4.34	+0.01	−0.01	4.08	
30780	2711	97	Tau	dA5		5.11	+0.21	+0.12	6.11	
30836	2017	3 π^4	Ori	B2	IV-III	3.69	−0.17	−0.81	1.42	var.?
30870	2004			A0-B5n		6.09	+0.08	−0.45	5.14	
31237	2025	8 π^5	Ori	B2	III	3.71	−0.19	−0.82	1.40	var. 0.05
31295	2003	7 π^1	Ori	A0p		4.68	+0.08	+0.09	4.66	
31331	2027			B5		5.92	−0.13	−0.55	4.83	
31373	2643			B8	III	5.71	−0.08	−0.46	4.54	
31592	2606	98	Tau	B9.5	V	5.54	0.00		5.79	doub.
31647	3308	4	Aur	A0	V	4.93	+0.02		5.28	doub.
32301	2619	102 ι	Tau	A7	V	4.65	+0.15	+0.14	6.05	
32549	2641	11	Ori	A0si		4.66	−0.07	−0.09	4.46	
32630	3816	10 η	Aur	B3	V	3.17	−0.18	−0.67	1.17	var.?
32977	2620	106	Tau	A3		5.17			6.44	
32990	2607	103	Tau	B2	V	5.41			4.06	doub.
32991	2618	105	Tau	B2	Vp	5.87	+0.20	−0.55	4.60	
33641	3306	11 μ	Aur	Am		4.80	+0.18	+0.10	5.10	
34029	3806	13 α	Aur	G8	III + F	0.09	+0.80		2.62	doub var.?
34203	2644	18	Ori	A0	III	5.48	−0.02	+0.05	5.60	
34656	3206			O7		6.71	+0.01		4.74	
34759	3711	20 ϱ	Aur	B5	V	5.09	−0.18		3.24	
34989	2005			B1	V	5.78	−0.13	−0.88	3.39	

(Table I, continued)

HD	Chart No.	Name	Spectral Type	V	B-V	U-B	U′	Remarks
35149	2016	23 Ori	B1 V	4.99	−0.16	−0.86	2.53	
35239	3224		B9 III	5.92	+0.04	−0.12	5.88	
35439	2020	25 Ori	B1.5 Vpe	4.94	−0.21	−0.91	2.33	var.?
35468	2010	24 γ Ori	B2 III	1.64	−0.24	−0.87	−0.26	var.?
35497	3234	112 β Tau	B7 III	1.66	−0.13	−0.49	0.50	
35671	2628	115 Tau	B5 V	5.30			3.67	doub.
35708	2608	114 Tau	B3 V	4.83			2.61	doub.
36351	2014	33 Ori	B1.5 V	5.44	−0.19	−0.81	2.85	doub.
36408	2627		B7 IV	5.42	−0.04		4.73	doub.
36486	2029[1]	34 δ Ori	O9.5 V-II	2.21	−0.21	−1.06	0.02	trip. var.
36576	2622	120 Tau	Bp	5.52			3.80	
36653	2636	35 Ori	B3	5.56			3.76	
36741	2022		B2 V	6.58	−0.20	−0.77	4.97	
36819	2603	121 Tau	B3 V	5.25	−0.06?		3.57	
37098	3232		B8 III	5.69	−0.05		4·92	doub.
37128	2029[2]	46 ε Ori	B0 Ia	1.69	−0.19	−1.04	−0.40	
37202	2609	123 ζ Tau	B2 IVp	2.99	−0.15	−0.68	0.91	var.?
37320	2006		B8	5.88	−0.08	−0.37	4.63	
37339	3202		B9?	6.89?			5.37	
37438	3231	125 Tau	B2 V	5.07	−0.16	−0.69	3.04	
37490	2012	47 ω Ori	B3 IIIe	4.52	−0.09	−0.78	2.80	
37519	3215		B7 V	6.01	+0.03	−0.20	5.57	
37711	2625	126 Tau	B3 IV	4.85			2.77	doub.
37742 / 37743	2029[3]	50 ζ Ori	O9.5 Ib / B3	1.75	−0.21	−1.06	−0.48	trip. var.?
38478	2624	129 Tau	B7 IIIp	5.90	−0.06	−0.44	5.10	
38622	2635	133 Tau	B2 V	5.15	−0.18		3.10	doub.
38670	2610		B7 V	5.92	−0.09		4.52	doub.
39317	2531	137 Tau	Ap	5.54	−0.04		5,20	
39357	3222	136 Tau	A0 III	4.52	−0.02		4,74	doub.
39698	2612	57 Ori	B2 V	5.86			3.51	
39777	1945		B2 V	6.55	−0.19	−0.80	4.80	
39970	2601		A0 Ia	6.02	+0.39		5.52	
39985	1906		B9	5.98	−0.06	−0.14	5.64	
40005	2524		B3?	6.91?			5.07	
40111	3229	139 Tau	B1 Ib	4.80	−0.07	−0.93	2.61	
40183	3706	34 β Aur	A2 V	1.90	+0.03		1.40	doub. var.
40312	3201	37 θ Aur	B9.5pv	2.69	−0.08		2.18	doub. var.?
40446	1936	60 Ori	A1	5.22	+0.01	+0.01	5.18	
40932	1905	61 μ Ori	Am	4.12	+0.15	+0.10	5.00	doub. var.?
40978	3704		B3	7.12	−0.06	−0.70	6.32	
41076	2539		B9.5 V	5.94	−0.04		6.37	
41335	1302		B2 IV-Vne	5.22	−0.08	−0.84	3.37	var.?
41692	1946		B5 IV	5.37	−0.15	−0.53	4.03	
41753	2530[2]	67 ν Ori	B3 V	4.42	−0.27		2.30	doub. spectro.
42509	2514	68 Ori	B9.5 V	5.67	−0.09		5.21	
42545	2525	69 Ori	B5 V	4.92	−0.15	−0.60	3.13	
42560	2530[1]	70 ξ Ori	B3 V	4.38	−0.20		2.25	
42657	1947		B9	6.17	−0.09	−0.36	5.22	
42690	1301		B2 V	5.06	−0.22	−0.77	2.86	
43112	2530[3]		B1 V	5.91	−0.24	−0.96	3.27	doub.

(Table I, continued)

HD	Chart No.	Name	Spectral Type	V	B-V	U-B	U′	Remarks
43153	2526	72 Ori	B7 V	5.24	−0.14	−0.46	3.86	
43247	2536	73 Ori	B9 II-III	5.34	−0.03		5.37	
43285	1916		B5e-B6 V	6.00	−0.12	−0.53	4.60	
43362	1306		B9	6.10	−0.08	−0.30	5.07	doub.
43819	2521		Ap	6.16	−0.08	−0.34	5.50	
44092	3107		A1 V	6.27	+0.06	+0.01	5.74	
44112	1305	7 Mon	B2 V	5.24	−0.20	−0.74	3.08	
44173	2541		B5n	6.40			5.48	
44700	1921		B3 IV	6.32	−0.16	−0.62	4.55	
44701	1943		B5?	6.58?			4.73	
44769	1920	8 Mon	A5 IV	4.48	+0.21	+0.09	5.20	doub.
44783	1902		A0	6.25	−0.08	−0.30	5.24	doub.
45542	2509	18 ν Gem	B7 IVe	4.15	−0.13		2.79	doub.
46052	3104	WW Aur	Am-A7 V	5.80			5.98	var.
46300	1907	13 Mon	A0 Ib	4.48	+0.01	−0.25	4.37	
46487	1939		B6 V	5.07	−0.14	−0.56	3.65	
46553	3110	49 Aur	B9.5 V	5·07	−0.03	−0.08	5.16	
46769	1934		B8 Ib	5.72	0.00	−0.46	4.81	
47054	1950		B8ne	5.51	−0.10	−0.39	4.57	
47100	3601	52 ψ³ Aur	B8 III	5.25	−0.07	−0.40	4.05	
47105	2522	24 γ Gem	A0 IV	1.93	0.00	+0.04	2.07	
47129	1914		O8 O9	6.04	+0.05	−0.90	3.02	var.?
47152	3111	53 Aur	A0p	5.53	−0.01	−0.08	5.81	
47395	3112	54 Aur	B6 III	5.86	−0.09		4.67	doub.
47432	1929		O9.5 II	6.18	+0.15	−0.85	4.42	
47839 }	2544	15 Mon	O7	4.65	−0.25	−1.06 }	1.66	doub. var.
47887 }			B2 III	7.02				
47964	1933		B8 III	5.78	−0.10	−0.35	4·85	
48099	1913		O6-O7	6.36	−0.05	−0.96	3.34	
48434	1919		B0 III	5.83	−0.02	−0.90	3.84	
48977	1901	16 Mon	B3 V	5.91	−0.18	−0.68	3.76	
49147	1218		A0 IV	5.65	−0.06	−0.10	5.68	
49567	1832		B3 II-III	6.14	−0.14	−0.67	4.32	
49606	2523	33 Gem	B8 III	5.71	−0.13	−0.52	4.75	
49643	1848		B8 V	5.70	−0.10	−0.46	4.65	doub.
49908	2501	36 Gem	A2 V	5.18	−0.02		5.72	doub.
50019	3101	34 θ Gem	A3 III-A2 I	3.59	+0.10	+0.13	3.98	doub.
50635	2417	38 Gem	F0 Vp	4.63			6.23	doub. var.?
50820	1847		B3 Ve + K2 II	6.22	+0.56	−0.36	4.70	
51104	2422		B7 V	5.88	−0.08	−0.35	4.88	
52266	1850		O9 V	7.23	−0.01	−0.90	5.47	
52312	1207		B9 III	5.84			4.97	doub.
52559	1817		B2s	6.52	−0.02	−0.64	5.35	
52721	1215		B3?	6.52?			4.66	doub.
52918	1846	19 Mon	B1 V	4.93	−0.21	−0.93	2.77	var.?
53205	1828		B9	6.52	+0.02	−0.05	6.61	
53244	1233	23 γ CMa	B8 II	4.10	−0.12	−0.48	3.08	
53257	3017	44 Gem	B9.5 V	5.89	−0.03	−0.08	6.05	
53744	3009		B9 V	6.22	−0.10	−0.26	5.77	
53755	1214		B0 V	6.48	−0.05		4.28	triple
53929	1815		B8	6.05	−0.14	−0.47	4.77	

(Table I, continued)

HD	Chart No.	Name		Spectral Type		V	B-V	U-B	U′	Remarks
53974	1216			B0.5	IV	5.38	+0.05		3.31	mult.
54662	1213			O6		6.21	+0.03	−0.94	4.50	
54801	3010	47	Gem	A4	V	5.58	+0.12		6.40	
55879	1212			B0	IV	6.00	−0.18		3.55	
56310	1231			B1	V	6.79			4.99	
56386	3004			B9.5	V	6.01	−0.04	−0.11	6.33	
56446	1804			B9		6.57	−0.12	−0.40	5.57	
56537	2407	45 λ	Gem	A3	V	3.58	+0.11	+0.09	3.94	doub. var.?
56986	3016	55 δ	Gem	F0	IV	3.52	+0.34		4.75	doub.
57539	1201					6.53	−0.10		5.29?	
57682	1210			O9	V	6.42	−0.20		3.59	
57744	3014	58	Gem	A1	V	5.96	−0.01		6.23	
58050	2406			B3	III	6.35	−0.13	−0.93	3.95	var.?
58187	2419	1	CMi	A4	III	5.30	+0.10	+0.13	6.27	
58343	1229			B3	Ve	5.29	−0.05	−0.60	4.10	
58580	1839			B9		6.75	−0.01	−0.11	6.45	
58599	2420			B6	IV	6.30	−0.13	−0.47	4.37	
58715	1801	3 β	CMi	B8	V	2.87	−0.10	−0.29	1.99	var.?
58923	1803	5 η	CMi	gF0		5.28	+0.22	+015	6.40	doub.
59037	3007	64	Gem	A6	V	5.01	+0.11	+0.12	5.91	
59059	2405			B9	V	6.05	−0.05	−0.11	5.88	
59211	1221					6.62?			5.63?	
60107	2404	68	Gem	A1	V	5.08	+0.05	+0.06	5.63	
60325	1226			B1	V	6.21	−0.04		4.05	
60357	1821	9	CMi	A0n		5.80	−0.02	−0.09	5.29	
61421	1810	10 α	CMi	F5	IV-V	0.35	+0.41	−0.01	1.46	doub var.?
61887	1820			A0n		5.92	−0.04	−0.08	6.03	var.?
62832	2309	11	CMi	A1	V	5.26	+0.01	−0.02	4.94	
63655	1108			B9		6.12	−0.09	−0.48	5.35	
63975	1711	13 ζ	CMi	B8		5.14	−0.13	−0.47	3.77	
64648	2902	85	Gem	B9.5	V	5.34	−0.04	−0.06	5.29	
65241	1703			B9		6.35	−0.04	−0.06	5.77	
65396	1706			B9?		6.78?			6.17?	doub.
65810	0606			A3	V	4.61	+0,08	+0.08	5.46	
65873	2302	5	Cnc	B9	V	5.89	−0,02	−0.02	5.73	
65875	1713			B3	Vp	6.48	−0,08	−0.83	4.55	
65900	1707			A0		5.64	0.00	+0.01	5.69	
66664	2303	8	Cnc	A0	IV	5.10	0.00	0.00	4.86	
66834	0605	14	Pup	B3	V	6.12	−0.17		4.58	
67159	1104			A0		6.00	−0.04		5.78	doub.
67797	0604	16	Pup	B5	V	4.40	−0.17	−0.59	2.73	
67880	1115			B3s		5.67	−0.18		3.58	doub.
68099	2306			B7	III	6.07	−0.11	−0.42	4.56	
69686	2305			B8?		7.02?			5.50	
72310	0601			A0		5.41	−0.06		5.00	doub.
72660	1608			A1		5.69	0.00	0.00	5.88	
73262	1604	4 δ	Hya	A0	V	4.15	0.00	0.00	3.22	
74280	1605	7 η	Hya	B3	V	4.30	−0.20	−0.74	1.42	
74988	1607			A2-A0n		5.26	+0.04	+0.08	5.87	
75333	1001	14	Hya	Ap		5.25	−0.09	−0.34	3.80	

between 2000 and 3000 Å. Neither is the sky brightness to be seen far away from the Milky Way (galactic latitude up than 40°). Isophotes and quantitative data will be published later.

4. Calibrations

Using a deuterium-lamp source, we made three series of calibrations with different backgrounds for the longer exposure and a single calibration with no background for the shorter one. Each series covered a range of five magnitudes for each of 13 field angles.

When comparing the different series, we found errors generally less than 0.1 magnitude.

For the flight photographs, we determined the accuracy of the magnitude measurements by comparing the stars common to both the exposures. We found a mean error of about 0.2 magnitude.

5. First Results

Among the 700 stars detected, only 201 were suitable for measurement. The remaining stars were either too faint or too badly defined or the background was too irregular or the part of the field was too vignetted for accurate correction.

Measurements were made with a Becker type iris photometer. The information in Table I is as follows:

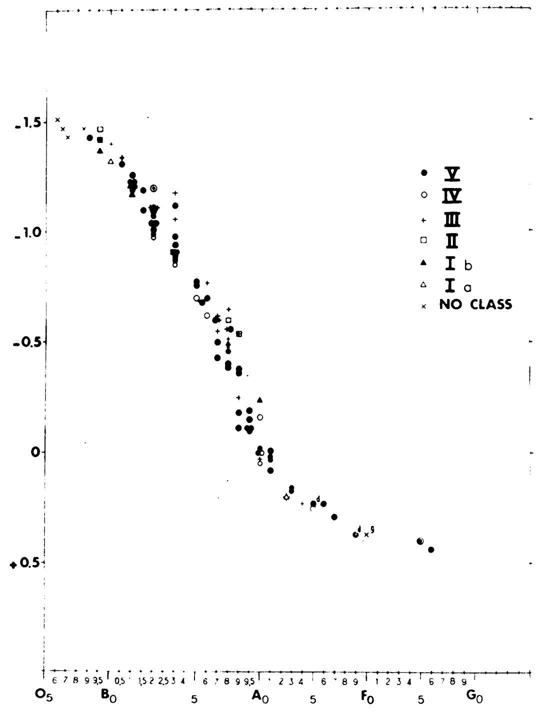

Fig. 5. $(U-V)_0$ color diagram for 100 stars.

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Column 1 – HD number
2 – Our code or 'Chart' number
3 – Star names or numbers
4–7 – Spectral type, luminosity classification of UBV data from the BSC or from Jaschek (1968) or from other sources
8 – Our U'
9 – Remarks, generally from the BSC.

The zero adjustment for U' magnitudes was defined such that $(U'-V)_0=0(\pm 0.1)$ for A0 V stars.

We tried first to determine the mean interstellar reddening by comparing stars of identical type. The preliminary results thus obtained seem to show that the color excess ratio $(E(U'-V))/(E(B-V))$ is slightly higher than those found by Stecher (1965), Boggess and Borgman (1964) and others at 2600 Å, e.g. about 4. But because of the large scatter for this ratio, it is probably not a real effect and we think that it is due to the actual lack of accuracy of UBV and spectral type data. Nevertheless, it is probable that there is some scatter in the reddening law itself.

For this first paper, we have adopted a color excess ratio of 4 and knowing the intrinsic colors, we were able to plot two color-spectral type diagrams.

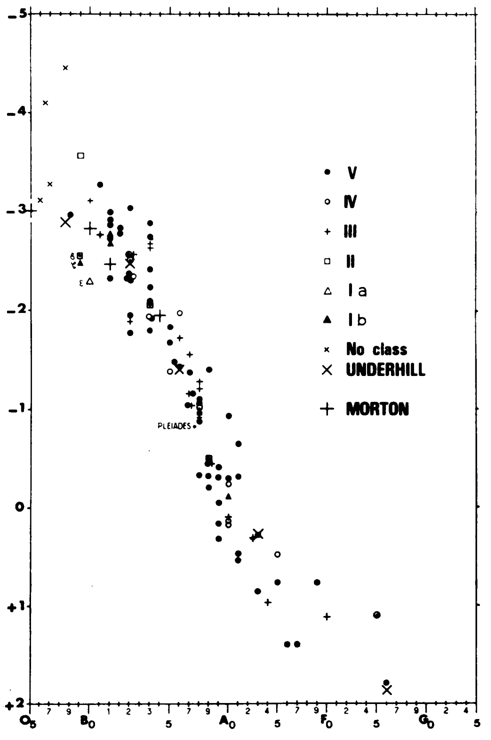

Fig. 6. $(U'-V)_0$ color diagram for 100 stars.

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The first one (Figure 5), a $(U-V)_0$ diagram, shows that the 100 stars for which U, B, V, and spectral types are well known, are quite normal.

The second one (Figure 6), a $(U'-V)_0$ diagram, shows the large scatter of O type stars and that they are brighter than theoretical models, the A type stars being fainter.

It can be seen that there is no significant difference between giant and main sequence stars. A recent rough study showed us that giant stars seem to be fainter by 0.2 or 0.3 magnitude. The Pleiades appear to be quite normal (integration in the V band was made for 13 component stars). The Orion's Belt stars (ζ, ε and δ) seem to be fainter than other O9–B0 stars, which is in agreement with a paper presented by Carruthers during the Symposium.

6. Conclusions

It is to be noted that we have arbitrarily adjusted the theoretical models in the linear and well-defined part of our diagram, e.g. for B4 (Morton's models) (Mihalas and Morton, 1965; Adams and Morton, 1968; Hickok and Morton, 1968), and B6 (Underhill's models) (Underhill, 1963), spectral types, because we have no absolute calibrations.

We are now trying to integrate Stecher's spectral energy measurements for ζ and ε Persei, given in a paper presented during the session, which will give us a better adjustment of theoretical models.

More complete reductions for the interstellar reddening, intrinsic colors and Milky Way and Zodiacal Light isophotes are now in progress and will be given in a further publication.

Our next experiment, 'JANUS' (which will be launched in one year's time) will give directly and simultaneously an accurate color index between two ultraviolet bands.

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Discussion

Morton: Why do you not see the nebulosity of the Barnard loop found in the ultraviolet by Henize and his colleagues from the Gemini photographs?

Viton: No, we have not detected the Barnard loop, despite of the high aperture ratio of our camera (*f*/1) probably because of the low angular resolution, too short exposure time, and wavelength range.