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The Sun among the Stars

I. A Search for Solar Spectral Analogs*

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Summary. 77 solar type stars in parts of the northern and southern skies have been photoelectrically scanned with 20 Å resolution to find stars whose ultraviolet spectra (3640–4100 Å) match that of the sun. Down to $V=6\overset{\mathrm{m}}{.}6$ there seem to be only two: HR 7504 in the northern and HR 2290 in the southern hemisphere. No G2V star matches the sun, they all have weaker ultraviolet absorptions, most of them much weaker. Stars that do match have a B–V of $0\overset{\mathrm{m}}{.}66$.

The search shows that G type dwarfs are hotter than was thought before by many researchers, which has important consequences for metal abundances derived with respect to the sun. The program will eventually yield the colors of the sun in any photometric system and will enable planetary observers to derive albedos more accurately and on an absolute scale.

Key words: stars, solar type — abundances, stellar — albedo

I. Introduction

The sun is used as the fundamental standard in many astronomical calibrations. For example, the transformation of an observed $V/B-V$ diagram of a stellar cluster into the theoretically more useful luminosity/effective temperature diagram is fixed, for the cooler stars, by the effective temperature of the sun together with its $B-V$ color. Often this temperature-color relation is also used in abundance analyses, for example, in the work of Wallerstein (Parker et al., 1961) on the metal abundances of the Hyades, or by Hearnshaw (1974), who used $R-I$ to determine effective temperatures of solar type stars.

While the effective temperature of the sun is accurately known to about ±10 K, its colors are not so well known. Values of 0.62, 0.63, 0.64, 0.65, 0.66 and 0.68 are often used for the solar $B-V$. While the last value has been measured directly (Gallouët, 1964), most other values are derived indirectly, for example by folding the filter response function into the measured energy distribution of the sun. This way Labs and Neckel (1968) derived $(B-V)_{\odot}=0\overset{\mathrm{m}}{.}64$. The predicted color of the sun depends on the filter response functions and the absolute calibration of Vega, which has been improved since the work of Labs and Neckel (Oke and Schild, 1970; Hayes and Latham, 1975; Tüg et al., 1977). A better determination of the solar colors via the absolute calibration of the sun and Vega is therefore possible today and will be the subject of forthcoming papers in this series.

Another indirect approach to the solar $B-V$ has been taken by van den Bergh and Sackmann (1965) and by Alexander and Stansfield (1966). They found that the sun shows the same spectral features as stars of $B-V=0.670$ and 0.663, respectively. The last number was derived from the central intensities of two blue Fe I lines and Hδ, whereas van den Bergh and Sackmann compared central intensities of the G band and Hγ as well as the intensities in the continuum on either side of Hζ and of 4000 Å. Spite (1966), by a similar method, found $(B-V)_{\odot}=0.68$. Earlier determinations are summarized by van den Bergh (1965).

These are very important results as they directly affect metal-abundance determinations of solar type stars: With $(B-V)_{\odot}=0.63$ Parker et al. (1961) found $[\mathrm{Fe/H}]=0.11$ for the Hyades. This would turn into $[\mathrm{Fe/H}]=0.31$ with $(B-V)_{\odot}=0.666$ because, as the authors point out, an error of 0.025 in $B-V$ leads to an error of 0.14 in [Fe/H]. By assuming $(B-V)_{\odot}=0.666$, Nissen (1970) found indeed $[\mathrm{Fe/H}]=0.38\pm0.02$ for the Hyades, by a different method.

The indirect determinations of $(B-V)_{\odot}$ mentioned above have apparently not convinced everybody sufficiently, as is seen for example in Chaffee et al. (1971), who gave Hyades 63 = HD 28068 a temperature cooler than the sun, in spite of its $B-V=0.632$, and who therefore found no overabundance of iron for this star with respect to the sun. Hearnshaw (1974) likewise gave his solar type stars too low temperatures, in the light of

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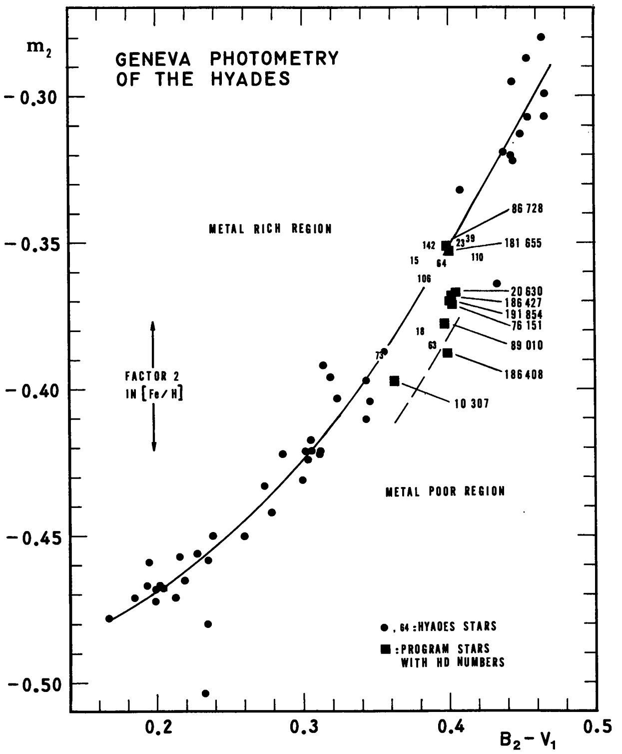

Fig. 1. Photometry of Hyades stars (filled circles) up to VB 121. Unresolved doubles and spectroscopic binaries are omitted. Cluster stars of particular interest are given by their VB numbers. According to Hauck (1973), a star's position in this diagram tells about its metallicity (see arrow), where m_2 is $(B_1-B_2)-0.457\,(B_2-V_1)$. The exact position of the sun is, however, unknown. If the (handdrawn) continuous curve is taken as the mean relation for the Hyades, then the sun, according to Hauck, should lie on the broken line

the $(B-V)_\odot$ mentioned above. Moreover, two later indirect determinations of the solar color yielded $(B-V)_\odot=0.63$: Fernie et al. (1971) used the strength of the Mgb triplet at 5157 Å, while Croft et al. (1972) compared intensities at Hδ, the K line and the G band. While the relation plotted by Fernie et al. can be fitted with $(B-V)_\odot=0.66$ just as well as with 0.63, this is not so in Croft et al.'s work, so here we have a real discrepancy to other indirect determinations of the solar color. Unfortunately, Croft et al. used a reflection from a gaseous surface (Uranus) to measure the solar spectrum.

These examples show that there is no generally accepted value for the solar color. A fresh attempt to determine the sun's place among the stars is therefore called for. From it we will learn that HD 28068 is indeed hotter than the sun (Section V).

It is well known that overall metal abundances can be determined from pure photometry. As an example the m_2 versus B_2-V_1 diagram of the Geneva photometry for the Hyades is shown in Figure 1, where a few of my program stars have been added for later discussion. The data are from Rufener (1976a, b), while the calibration in terms of [Fe/H] has been taken from Hauck (1973). However, this method is subject to the same criticism as that of model-atmosphere analyses: as long as the exact position of the sun in this diagram is unknown, one can determine abundances only relative to, say, the Hyades, but not relative to the sun. We will therefore never be able to find out whether the Galaxy has been enriched in metals since the birth of the sun, unless we know the sun's photometric properties with respect to the stars accurately.

My project has two aspects to it: in this paper I report on the results of a spectroscopic search for solar spectral twins, analogous to van den Bergh and Sackmann's approach, if somewhat more direct. This will be followed in later papers by the comparison of solar and stellar energy distributions, determined by comparing stars either directly to a black source, or to recently calibrated primary standard stars.

II. Observations

In the region 3640–4100 Å, spectra of solar type stars are very sensitive to small changes in temperature and/or element abundances. A search for solar spectral analogs can therefore effectively be done by scanning solar type stars in that spectral region photoelectrically with 20 Å resolution and dividing the result by the scan of an asteroid, a planetary satellite, the moon or the daytime sky, all of which distort the solar energy distribution but leave the spectroscopic features intact. For the observations from the southern hemisphere the scanner of the Astronomical Institute of Bochum University, attached to the 60 cm Bochum-telescope at the site of ESO, Chile, was used in November/December 1976.

The Bochum scanner is a rapid scanner, measuring while the grating is moving (for details see Haupt et al., 1976). This has the great advantage of being useful also in nonphotometric weather. Most of the spectra reported here have indeed been taken through clouds. One has to pay for this advantage by not being so flexible in the choice of the sensitivity profile and the central wavelengths. In my case this profile was a triangle with 20 Å halfwidth, centered on wavelengths from 3654 to 4064 Å. For the spectroscopic purpose dealt with in this paper the form of the profile is of no importance, but it will be when energy distributions are discussed in a later paper.

The northern observations were done in May/June 1977 at Mt. Hopkins Observatory, Arizona, with the scanner of the Smithsonian Astrophysical Observatory attached to the 150 cm SAO and 61 cm Stony Brook telescopes. In this case the profile was a rectangular band with 21 Å width, the central wavelengths were chosen such that no strong lines were near the edges of the band, to minimize errors due to bad tracking and missettings of the wavelength (with both scanners, the setting accuracy is about 1 Å). A few observations from former years done at Mt. Hopkins with 50 Å rectangular bands will be included in the discussion.

To compare the stellar spectra to the sun, scans were also taken of the satellite Jupiter III from Chile, as well as

TABLE 1. A SEARCH FOR SOLAR TWINS 3640 - 4100 Å

HR	HD/BD	name	m_V	B-V	n	hem.	SpT
1. Spectra indistinguishable from solar							
	28099	Hyades 64	8.09	0.657	1	S	G8 V
2290	44594		6.60	0.66	3	S	G0
7504	186427	16 Cyg B	6.20	0.66	8	N	G5 V
	191854		7.42	0.66	1	N	G5 V
2. Spectra potentially equal to solar (not enough scans yet)							
	120528		8.55	0.66	1	N	
	144873		8.54		2	N	
	15°3364		8.64		2	N	
3. Spectra very close to solar							
88	1835		6.44		1	S	dG2
996	20630	κ Cet	4.87	0.68	2	S	G5 V
3538	76151		6.01	0.68	3	S	G3 V
3626	78418	75 Cnc	5.96	0.65	2	S	G5 IV
3951	86728	20 Lmi	5.39	0.65	3	N	G4 V
4030	89010	35 Leo	5.97	0.65	4	S,N	G1 IV-V
5996	144585		6.31	0.66	2	N	G4 IV-V
6538	159222		6.54	0.64	2	N	G5 V
7345	181655		6.30	0.68	2	N	G8 V
4. Spectra similar to solar, some absorption features weaker							
448	9562		5.76	0.65	2	S	dG2
772	16417	λ^2 For	5.78	0.67	2	S	dG1
2208	42807		6.46	0.68	2	S	G8 V
6060	146233	18 Sco	5.49	0.66	1	N	dG1
	153344		7.10	0.67	2	N	G5 IV
7503	186408	16 Cyg A	5.96	0.64	3	N	G2 V
5. Spectra similar to solar, some absorption features stronger							
	124330		7.88		1	N	G4 IV
8701	216437	ρ Ind	6.04	0.66	2	S	G1 V
6. Some absorption features appreciably weaker than solar							
483	10307		4.94	0.63	2	N	G2 V
	28068	Hyades 63	8.05	0.632	1	S	G1 V
1536	30562		5.76	0.64	1	S	dG0
	31966		6.76		1	S	G5 V
2007	38885		5.98	0.64	1	S	dG4
2067	39881		6.60	0.65	1	S	dG0
2318	45184		6.24	0.62	1	S	G0
7896	196755	κ Del	5.09	0.70	2	N	G5 IV
8531A	212330		5.30	0.67	1	S	G4 V
7. Much weaker absorption features than solar							
77	1581	ζ Tuc	4.22	0.58	1	S	G2 V
98	2151	β Hyi	2.79	0.62	2	S	G2 IV
	4308		6.52	0.65	1	S	G3 V
512	10800		5.86	0.61	1	S	G2 V
660	13974	δ Tri	4.87	0.61	2	N	G0 V
695	14802	κ For	5.19	0.60	1	S	G1 V
	20619		7.05	0.65	1	S	
1006	20766	ζ^1 Ret	5.53	0.64	1	S	G2 V
1010	20807	ζ^2 Ret	5.23	0.60	2	S	G1 V
	28344	Hyades 73	7.85	0.609	1	N	G2 V
	30455		6.96	0.61	1	S	G2 V
1532	30495	58 Eri	5.51	0.64	2	S	dG1
1729	34411	λ Aur	4.74	0.62	4	N	G0 V
2667	53705		5.80	0.63	1	S	G3 V
2882	59967		6.64	0.63	1	S	G5
3138	65907		5.59	0.57	1	S	G2 V
3176	67228	μ Cnc	5.29	0.67	1	S	G2 IV
	20°2162	Praesepe 275	9.96	0.57	3	N	
3881	84737		5.11	0.62	4	N	G1 V
4523	102365		4.90	0.66	1	S	G5 V
	107583	Coma Tr 85	9.10	0.58	3	N	G1 V
4883	111812	31 Com	4.93	0.68	1	N	G0 III
	115043		6.85	0.60	4	N	G2 V
5235	121370	η Boo	2.69	0.58	2	N	G0 IV
5384	125932	51 Hya	6.27	0.64	6	N	dG3
5618	133640	ι Boo	4.76	0.65	1	N	dG1
5829	139777		6.58	0.67	1	N	G0 IV-V
5911	142267	39 Ser	6.10	0.60	2	N	G2 V
5968	143761	ρ CrB	5.40	0.60	3	N	G2 V
	154276		9.13	0.63	2	N	G2 V
6458	157214	72 Her	5.39	0.62	2	N	G2 V
7569	187923		6.16	0.65	2	N	G2 V
7644	189567		6.06	0.64	1	S	G2 V
7672	190406	15 Sge	5.80	0.61	2	N	G1 V
8042	200011		6.37	0.68	1	S	G3 IV
	202628		6.74	0.65	1	S	G5 V
8283	206301	42 Cap	5.13	0.65	2	S	G2 IV
8477	210918		6.22	0.64	1	S	G5 V
8700	216435		6.02	0.62	1	S	G3 IV
8. Much stronger absorption features than solar							
72	1461		6.45	0.68	1	S	G0
1008	20794	82 Eri	4.26	0.71	1	S	G5 V
1608	32008		5.69		1	S	dG4
2354	45701		6.45	0.66	1	S	G0
2668	53706		6.92	0.63	1	S	G3 V
8729	217014	51 Peg	5.53	0.68	2	N	G4 V

of the daytime sky from both sites. Because of better photon statistics, the scans of the sky were preferred as comparison spectrum. They were subjected to an arbitrary tilt, and all stellar scans were divided by the sky scans. No extinction correction was attempted, which would have been difficult anyhow for the cloudy nights (this explains the different slopes found in the figures).

The stars had been selected according to three different criteria. MK spectral types from the Bright Star Catalogue (BSC, Hoffleit, 1964) were originally used as the main criterion for candidacy. But MK types turned out to be a bad criterion (see Section III). Stars with $B-V$ between 0.65 and 0.67 stand a much better chance of showing the same absorption features as the sun in the ultraviolet than do G2 V stars. It then became clear in one of the earlier observing runs that the best criterion was obtained with the Geneva photometry (Rufener, 1971): stars with all six colors (where B is normalized to 0.0) similar to those of 16 Cyg B = HD 186427 were considered the most promising candidates for solar spectral twins. This criterion will be justified in Section IV by its success.

The stars chosen are thus 1) all G2V stars in the Bright Star Catalogue (BSC) in the regions searched (21^h to 11^h R.A. in the south and virtually the whole sky in the north); 2) all stars in the BSC with $0.65 \leqq B-V \leqq 0.67$ in the regions searched; 3) a number of fainter stars suggested by their Geneva-colors (Rufener, 1976a).

The ratio spectra star/sky of all 77 stars were plotted in magnitudes and grouped into 8 categories according to the outcome of the comparison. Table 1 gives the results. The spectral types listed in the last column are taken either from the BSC when available there, or from Jaschek et al. (1964). The types for HR 4030 and 3538 are from Keenan (1977). Column 6 gives the number of scans. A single scan means that between 10000 and 15000 photons were counted at 3830 Å, forward and backward scans summed together. With our GaAs photomultipliers, this took about 30 min for a star of $m_v = 6.6$ with either of the 60 cm telescopes. Column 7 indicates the site of observation.

III. The G2V Stars

16 Cyg B, the star singled out in the previous section, is an MK standard for the type G5V (Johnson and Morgan, 1953; Keenan and McNeil, 1976), while Morgan at one time had called it a G4.5V (Stebbins and Kron, 1957). How then do the G2V stars compare to the sun? They all

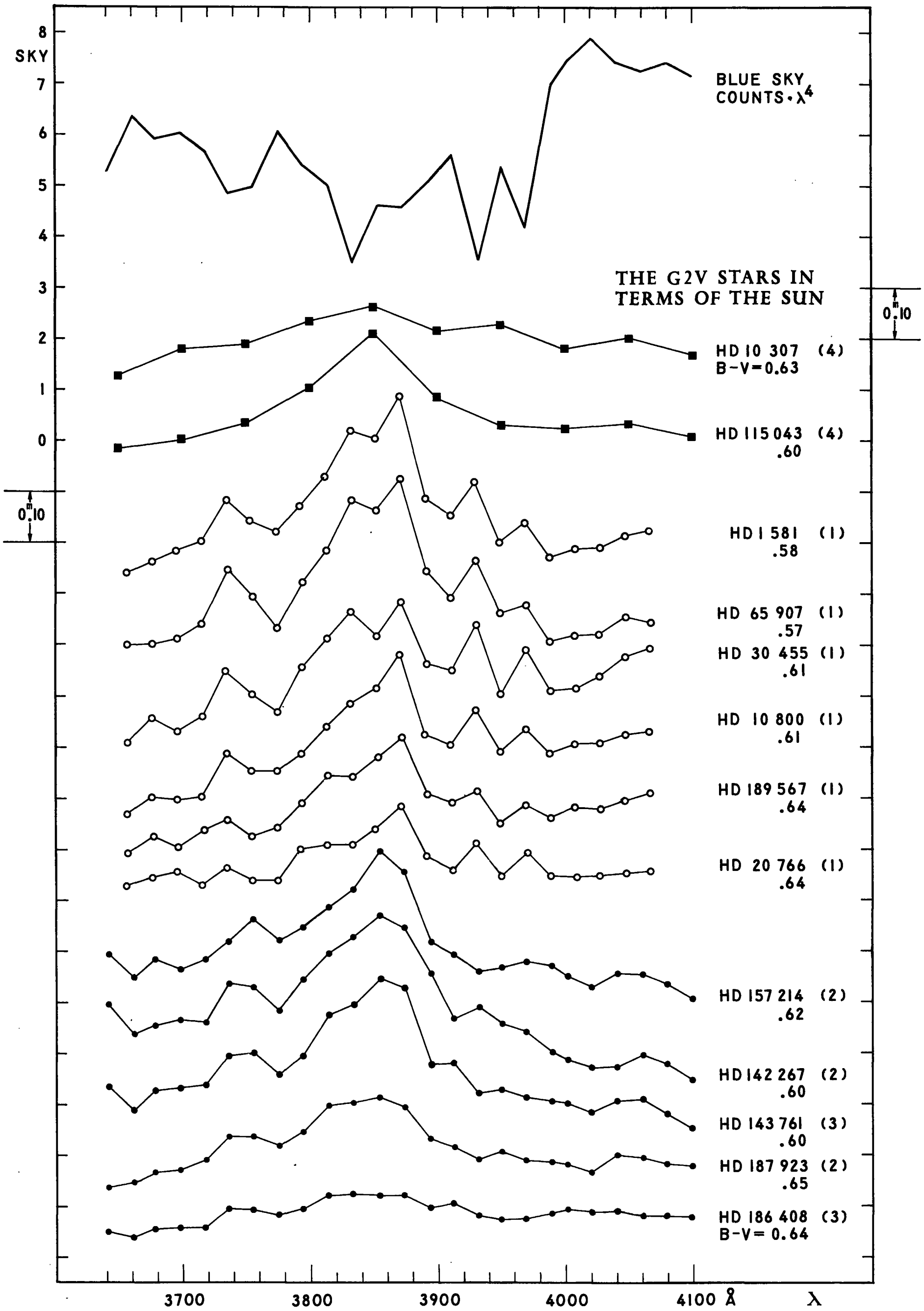

Fig. 2. Ultraviolet spectra of G2V stars, in magnitudes, in terms of the (tilted) spectrum of the blue sky, which is displayed on a linear scale on top of the figure. No extinction correction was attempted (in brackets number of scans). ■ Observed from northern hemisphere with 50 Å bandwidth. ● From northern hemisphere, 21 Å bandwidth. ○ From southern hemisphere, triangular bands with 20 Å halfwidth. It is seen that either the sun is not a G2V star, or more metal rich than any other G 2 V star

show weaker absorption features in the ultraviolet, most of them appreciably weaker. I have observed 12 stars which are designated G2V in the BSC. Their spectra are plotted in terms of the solar spectrum in Figure 2, together with HD 30455, whose type is taken from Jaschek et al. (1964). The ratio spectra should be looked at with the eye of a spectroscopist: only the spectral features matter, the slopes are influenced by extinction, which was not corrected for.

For a better orientation, the spectrum of the daytime sky is given on top of Figure 2 on a linear scale (while the ratio spectra are plotted in magnitudes). One recognizes the strong solar absorption features in most of the ratio spectra, but the largest change from star to star occurs in the CN band around 3870 Å, which is not one of the strongest absorptions in the solar spectrum. The G2V star most similar to the sun, HD 186408 or 16 Cyg A, used to be an MK standard for the type G2V (Johnson and

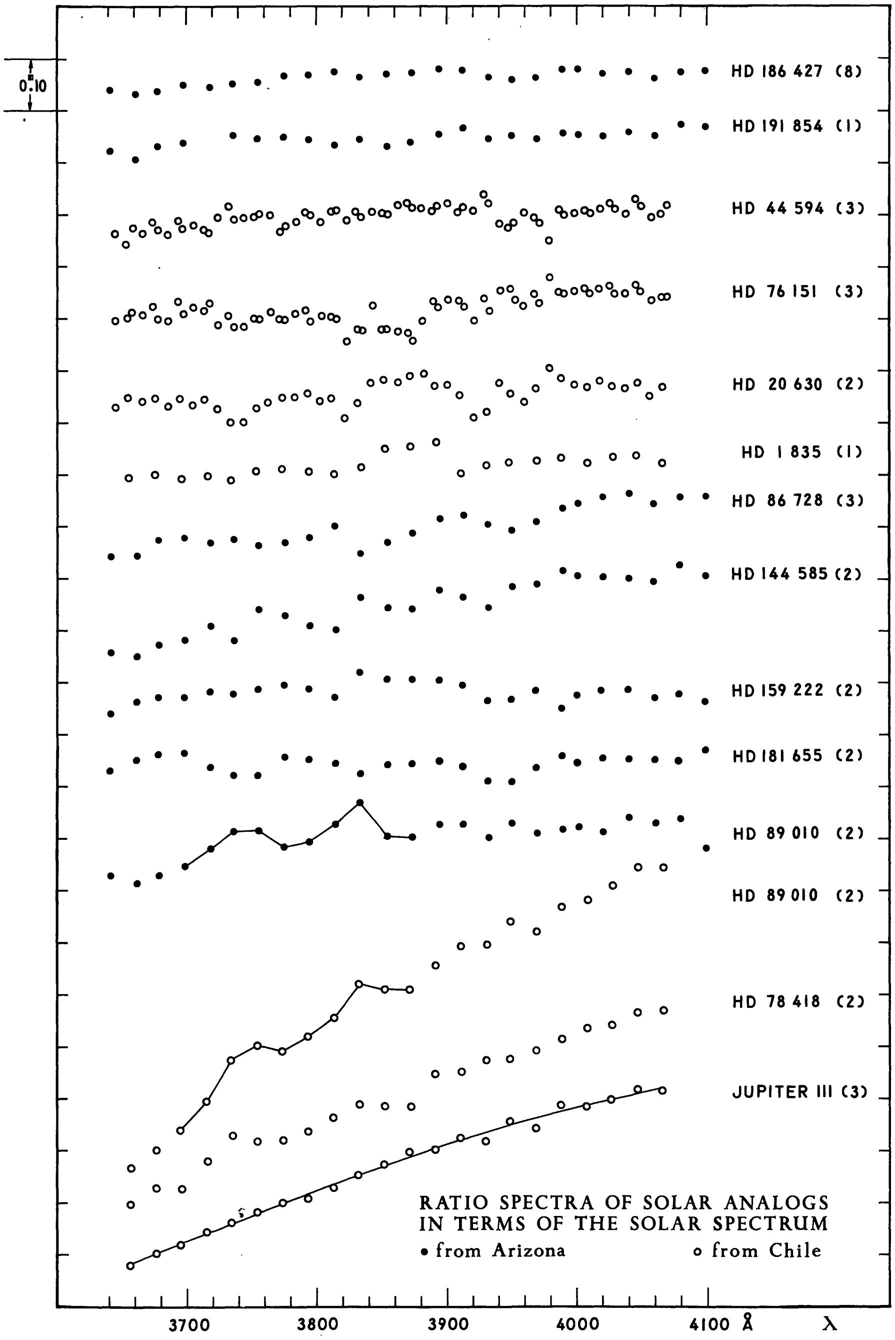

Fig. 3. Ratio spectra star/sky of stars found to be most similar to the sun (subgroups 1 and 3 of Table 1). Not corrected for extinction. Symbols as in Figure 2. The accuracy can be judged from the ratio Jupiter III/sky, which should be smooth in reality (in brackets number of scans)

Morgan, 1953), but has recently been redefined as a G3V standard by Keenan and McNeil (1976), who take the sun to define the class G2V. Clearly these types are not consistent with the line spectrum in the ultraviolet.

HD 20766 is the star for whose energy distribution above 4000 Å Labs and Neckel (1968) found agreement with that of the sun, comparing their solar measurements with those of Willstrop (1965). That agreement seems surprising in light of Figure 2 and would be worth checking. HD 10307, also one of the original MK standards for G2V (Johnson and Morgan, 1953), is the star claimed by Bell (1971) to best represent the sun. Although it is closer to the solar spectrum than most other G2V stars, I would still call it a wide miss in the ultraviolet.

We learn from Figure 2 that either the sun is not a G2V star or else more metal rich than any of them.

IV. Solar Spectral Analogs

It is probably not worthwhile to publish all ratio-spectra found. Instead, Table 1 groups all program stars according to the outcome of the comparison with the sun.

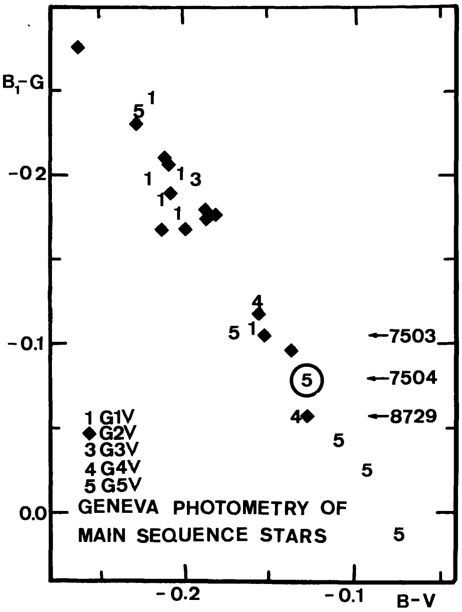

Fig. 4. All G1V to G5V stars in Rufener's (1971) catalog are combined in this 2 color diagram to show the lack of correlation between MK spectral types and energy distributions. The choice of the colors was arbitrary. Four-digit numbers refer to the BSC. The circle marks the most likely position of the sun, according to the results of Section IV

Readers with special interest in individual stars of that list can be provided with my results upon request. The stars of subgroups 1 and 3, with spectra very close to solar, are plotted in Figure 3, except for the Hyades star HD 28099 which is discussed separately in Section V. The accuracy of the spectroscopic comparison can be judged from the ratio Jupiter III/sky, also given in Figure 3, which should of course come out as a completely smooth curve, because Jupiter III has no atmosphere. From photon statistics alone one would expect an accuracy of about 1% for a single scan, or the size of the circles in Figures 2 and 3. This accuracy has not been achieved in the region of the very strong lines, because there we are not limited by photon statistics but by guiding errors, which shift the whole sensitivity profile in the wavelength scale. This is exactly the reason why people tend to avoid scanning solar type stars, and why filter photometry is usually more accurate.

It is obvious from Figure 3 that there are two prime candidates for solar spectral twins brighter than 7th magnitude: HD 186427 in the northern and HD 44594 in the southern hemisphere. Their absolute energy distributions from 3300 to 8500 Å will be compared to that of the sun in forthcoming papers. Among the fainter stars, there seem to be additional good candidates: HD 191854, and possibly also HD 120528 and HD 144873. The last two, however, have not yet been observed with sufficient accuracy, while HD 191854 is an unresolved double star. The star previously claimed by Wamstecker (1973) to have an energy-distribution like the sun, HD 89010 or 35 Leo, comes indeed very close to the solar spectrum, but it shows slightly weaker absorption-features at 3750 and 3830 Å, so it is not a prime candidate. To make this point more convincing, I have plotted this star's observations from the northern and southern hemispheres separately in Figure 3. Keenan (1977) has recently classified it as G1 IV–V while he assigned the type G3V to HD 76151. Both types seem consistent with my ratio spectra. HD 86728 or 20 LMi is interesting simply because it has been investigated by many observers. It appears on the lists of van den Bergh and Sackmann (1965), Alexander and Stansfield (1966), Hearnshaw (1974), Spite (1966) and others.

Table 1 confirms the results of van den Bergh and Sackmann and of Alexander and Stansfield: stars whose spectral features agree with those of the sun have a $B-V$ of 0.66. The table also justifies the selection of candidates by means of the Geneva photometry. Stars with all six colors similar to those of HD 186427 invariably turned out to also show nearly solar absorption spectra in the ultraviolet: they all made it into subgroups 1, 2 or 3 of Table 1. On the other hand, all stars of subgroups 1, 2 and 3, except for HD 159222, have Geneva colors similar to HD 186427, as far as they are known (none are known for HD 44594, 144585).

To quantify what is meant by "similar" I point to the fact that HD 76151 and 191854 fall into the (6 dimensional) "0.01 box" of HD 186427, that is, their 6 Geneva colors are identical with those of this star to within $0^{\mathrm{m}}01$ (or $0^{\mathrm{m}}02$ in the U color). The 0.02 box of HD 186427 contains the stars HD 20630, 28099, 31966, 78418, 89010, 120528 and 181655, in addition to the two stars mentioned above (Golay, 1976; Rufener, 1976b).

This close correlation between energy distributions (= Geneva colors) and line spectra at 20 Å resolution is remarkable because it was not found at all with classification resolution: stars in the same 0.01 box usually have a wide variety of MK types, while stars of the same MK type can show quite different energy distributions (Golay, et al., 1977). This is also illustrated in Figure 4, where stars with known spectral types have been combined in a two color plot.

V. The Hyades

Has the galaxy been enriched in metals since the birth of the sun? Even if we know the $B-V$ color of the sun can we not answer this question easily: While Nissen (1970) found [Fe/H] to be 0.38 for the Hyades, using $(B-V)_{\odot}=0.666$, Barry (1978) and Barry and Cromwell (1976) find solar and Hyades metallicities to be *identical* by comparing spectral features of stars of the same Balmer line strength and therefore presumably the same temperature. Incidentally, they also find $(B-V)_{\odot}=0.66$. Can my method of ratio spectra give any hints to the solution of this discrepancy?

Figure 5 shows the ratio-spectra of five cluster-dwarfs. The Coma- and Praesepe spectra are presented

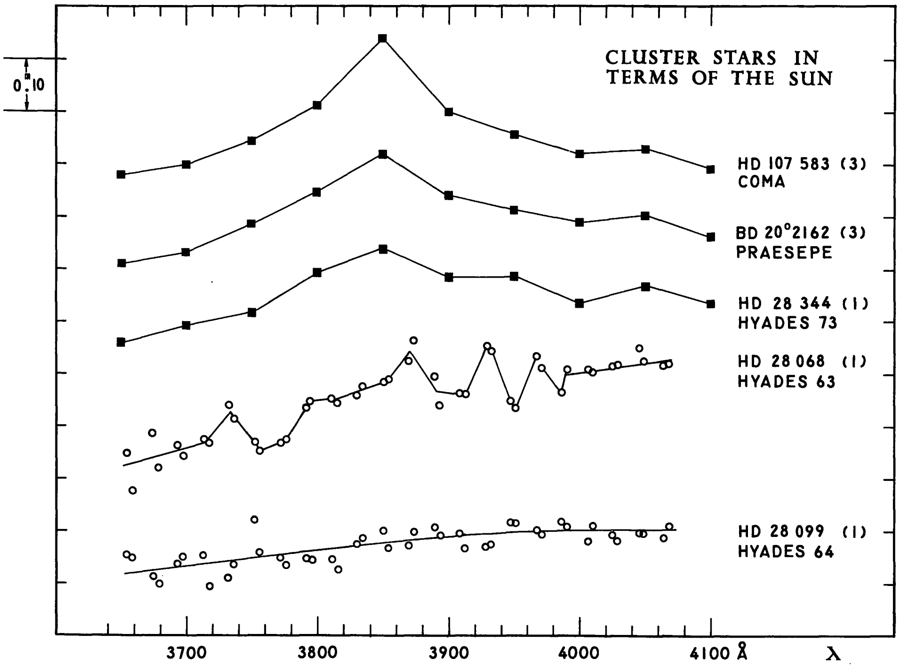

Fig. 5. Spectra of cluster dwarfs in terms of the sun, not corrected for extinction. Symbols as in Figure 2. HD 28344 and 28068 are definitely hotter than the sun, while HD 28099 could be of solar temperature, if it had solar abundances

only in order to show that solar analogs must be searched among fainter stars than done here. In contrast to Figures 2 and 3, values for the upward and downward scans have been plotted separately for the lower two Hyades stars. Figure 5 reiterates what was said in the introduction: unless one assumes that the Hyades have *less* metals than the sun, an assumption no one has ever made so far, we must conclude that HD 28068 is definitely hotter than the sun. Thus the results by Chaffee et al. (1971) must be corrected: the Hyades are more metal rich than they found.

Other determinations have likewise been deceived by a misjudgement of the temperature: Foy (1974) found [Fe/H] = 0.05 for HD 28344 by assuming $\theta_{\mathrm{eff}} = 0.86$, while Cayrel et al. (1970) found 0.02 for the same star using the temperature of the sun. Yet Figure 5 demonstrates that this star is appreciably hotter than the sun. The ultraviolet spectrum of HD 28099 seems to be identical to that of the sun, within the limited accuracy here.

From the information available in this first part of my investigation it is not possible to disentangle effects of metal abundance and temperature (nor of surface gravity, for that matter): HD 28099 could be hotter than the sun and more metal-rich, or it could be of solar temperature and metallicity. It is however interesting to note that Parker et al. (1961) found the excitation temperature of HD 28099 to be identical to that of the sun, while Cayrel et al. (1976), from a model-atmosphere analysis of a single high-dispersion spectrogram, tentatively said the same thing about the effective temperature. If the Hyades really had solar abundances, then HD 28099 would obviously have to show the solar energy distribution. If, on the other hand, HD 186427 were the perfect solar twin, then from its position in Figure 1 we would deduce [Fe/H] = 0.13 for the Hyades.

Obviously, with my method of ratio spectra the Hyades discrepancy cannot be resolved. I must therefore postpone further discussion of this problem to a later communication in which I hope to include information on the energy distribution from 3300 to 8500 Å.

VI. Planetary Albedos

On an absolute scale, albedos of solar system objects can presently be determined with an accuracy of at best ±5% only. The reason is that observers must divide planetary spectra by the solar spectral irradiance, which they cannot measure at nighttime. They can however measure a solar type star instead, if they knew one that matches the sun's energy distribution. With the exception of Wamsteker (1973), most observers have so far used unsuited solar type stars like η Boo for this purpose (see for example Savage and Caldwell, 1974).

I suggest that planetary observers who are interested in absolute albedos or in the run of albedos over wide wavelength-regions use HD 44594 or HD 186427 as their solar standards, because these stars not only promise to look like the sun, from the present investigation, but their energy distributions will become available on an absolute scale in forthcoming publications.

A few percent improvement on the absolute albedo can be essential for the input of solar energy to a planet in those cases where the Bond albedo is close to 1, because it is the difference to 1 that determines the input. On the other hand, relative albedos of one object compared to another or investigations of narrow spectral features in the reflection spectra of planets will not be affected by the work presented here.

VII. Conclusions

1) The spectral region around 3850 Å is very sensitive to changes of metallicity and/or temperature in solar type stars.

2) Either the sun is not a G2 V star or it is more metal rich than any G2 V star listed in the BSC.

3) Stars that match the solar spectrum at 20 Å resolution from 3640 to 4100 have $B-V=0.66$.

4) The Bright Star Catalogue contains two solar spectral analogs: HR 7504 in the northern and HR 2290 in the southern hemisphere. These stars are recommended as comparison stars for planetary photometry.

5) MK spectral types and energy distributions of stars are not well correlated.

6) Hyades 64 is a solar spectral analog.

7) The question of the metallicity of the Hyades with respect to the sun remains open.

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Note added in proof. Recent observations from the Northern hemisphere confirm and extend my preliminary results for the Hyades dwarfs: Hyades 64, 106, and 142 are solar analogues, while the 3870 Å absorption is weaker than solar in Hyades 63 and 18, stronger in 110. Differences to the solar spectrum tend to look less dramatic at 20 than at 50 Å resolution. Having seen HR 483 and 8729 with better resolution than before, I move them up to subgroups 4 and 5 of Table 1, respectively.