Hipparcos Results for Solar Analogs

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Abstract

The combination of precise distances, detailed spectroscopic analyses, and internal structure calculations yields an evolutionary mass, a chemical composition, and state of evolution, hence age, of an observed sample of 52 photometric solar analogs of unprecedented accuracy.

1 Introduction

In this contribution we will approach the new results for stars like the Sun in three stages. First, we will review the reasons for the wide astronomical interest in studying stars resembling the Sun. Second, we will summarize the results of our spectroscopic search for solar analogs before the availability of parallaxes from the astrometric satellite Hipparcos. Finally, we will introduce the recent results from Hipparcos and show how they have affected our understanding of the relative ranking of solar analogs.

2 The purpose of studying solar analogs

The Sun is the only star for which almost all fundamental physical parameters are known with good accuracy, i.e.: mass, chemical composition, age, effective temperature, radius, luminosity, magnetohydrodynamic structure, atmospheric velocity fields, etc. Furthermore, the new data of solar seismology have led to a better knowledge of the Sun's internal structure and internal rotation. Because the Sun is an intermediate-low mass star on the main-sequence, its metal abundances can be interpreted as those which were produced by the supernovae of various types, which have enriched the interstellar medium from which this star was formed, about 4.6 Gyr ago. However, because of its proximity, the Sun is too bright to allow the direct comparison of its light to that coming from much fainter objects using identical observational techniques. Whence arises our interest in finding stars resembling the Sun.

3 Methods and observations in the search for solar analogs

Over the years, three primary methods have been used in the search for solar analogs. Photometric techniques were used by O.J. Eggen, M. Golay, H. Neckel, A.W. Cousins, among others. J. Hardorp and B. Taylor used methods of spectrophotometry in their very productive searches. And finally, spectroscopic techniques, both at low and high resolution have been utilized very successfully by D. Gray, D. Soderblom, B. Edvardsson, M. Mayor, G.F. Porto de Mello, and ourselves.

A large bibliography of these results is contained in Cayrel de Strobel (1996), but we would welcome e-mails warning us about any results we may have overlooked. In these searches for solar analogs, a recurring issue is the determination of the B−V index of the Sun. The most widely used effective temperature parameter in galactic and extragalactic research is the color index B−V and the most well-studied star is the Sun. But the B−V value of the Sun is still controversial. The large scatter between various determinations is visualized in Figure 1 from Gray (1992) which we find reproduced in the materials for this meeting. Gray's figure shows that, starting with the publication by Gallouet (1964), the B−V value of the Sun determined by various authors has ranged from 0.60 to 0.68. The color indices of the Sun in photometric systems other than UBV are not better known either.

The problem of finding actual solar twins, rather than the broader category of solar analogs, was raised by Hardorp in a series of 8 papers (1978-1983). Whether or not the spectral type of the Sun matches the spectral type of stars to which one attributed a G2V spectral type, other stars all have weaker UV absorption than the Sun when photoelectrically scanned in the wavelength interval 3650-4060 Å.

4 Spectroscopic search for solar analogs

Our spectroscopic search for solar analogs has been directed primarily toward the question of whether photometric solar analogs remain such when subjected to high resolution, high S/N spectroscopic detailed analyses and discussed with reference to internal structure models. In other words, is it possible to find, among the photometric solar analogs, stars with fundamental physical parameters – mass or effective temperature, age, luminosity, gravity, chemical composition, including lithium-content, atmospheric velocity fields, magnetic fields, chromospheric activity – very similar, if not identical to those of the Sun? Our spectroscopic work over the years has taken advantage of improved quality and signal-to-noise available in moving from photographic to digital detectors. Our analysis has followed common methods which have lent a uniformity and consistency to the results (Cayrel de Strobel and Bentolila 1989). And we have used a variety of independent spectral indicators to provide simultaneously the stellar temperature, metallicity, and level of chromospheric activity.

The profile in the wings of the Hα line is used to determine Teff with internal accuracy of typically 30K. The metallicity, [Fe/H], is determined from moderate and weak Fe I and II lines in the spectral region 6650 to 6780 Å. This region also contains the Li line at 6707 Å, and a variety of weak metallic lines, which are used as excellent metal abundance indicators. And, finally, the Ca II IR triplet provides an estimate of the level of chromospheric activity and consequently gives an estimation of the age of each object studied. Note that, although we start with stars selected on photometric criteria, photometric parameters in any system must be calibrated to the fundamental quantities of Teff, log g, and metallicity before being interpreted. In addition, because of the influence the stellar chemical composition has on the observed colors, accurate metallicity parameters can be determined only if an independent, non-photometric based determination of Teff has been made (in our case from the wings of the Hα line). At the beginning of the search, the stars selected as candidates had to satisfy 3 conditions: 1) their color index, B−V, must be contained in the interval of B−V between 0.59 and 0.69 mag., 2) they must possess a trigonometric parallax, 3) they must have undergone a high resolution detailed spectroscopic analysis.

5 Results and their interpretation by means of the observational (log Teff, Mbol) diagram

The results of the above selection of solar analogs, as of mid-1996, are presented in Cayrel de Strobel (1996), and yield a sample of 99 objects that were the basis of the discussion in that review article. We summarize the pre-Hipparcos situation for these stars in the H-R diagram of Figure 1. This figure represents the observational (log Teff, Mbol) diagram of 99 analogs with an overplot of a theoretical diagram computed by Lebreton (see, for instance, Lebreton et al. 1997) for a solar chemical composition (Y= 0.28, Z= 0.018, α = 1.7) and showing the ZAMS, the 1 solar mass evolutionary track, and 6 isochrones for 2, 4, 6, 8, 10, 12 Gyr. In Figure 1 the underluminosity for the stars lying below the solar composition ZAMS can come from incorrect parallax determinations, but also to a smaller extent it may derive from chemical composition effects. Indeed, in the sample considered here, a non-negligible number of stars have a metallicity significantly different from that of the Sun. Also, we see that a significant number of analogs are more evolved than the Sun; this conclusion is confirmed by the spectroscopic gravities determined from detailed analyses of these stars. It is striking that many of the supposedly solar analogs in the sample seem older than the Sun, falling on isochrones with ages of 6 to 12 Gyr.

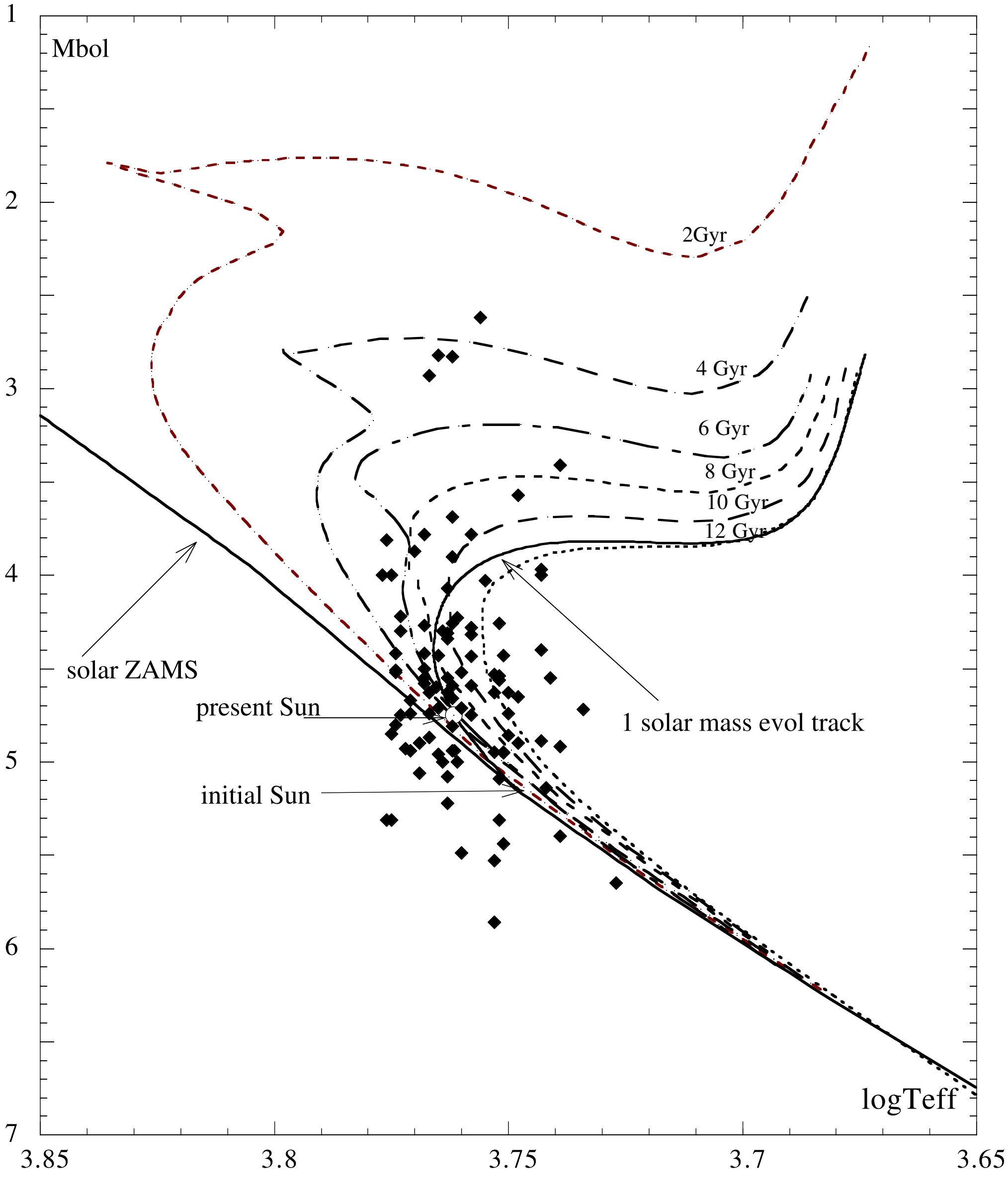

Figure 1: Observational (log Teff, Mbol) diagram of 99 solar analogs having ground-based parallaxes as the basis of their Mbol determination with an overplot of a theoretical diagram computed by Lebreton (1996) for a solar chemical composition (Y=0.28, Z=0.018), and for a mixing length parameter, $\alpha = 1.7$. Note that a significant number of stars are underluminous (lying below the ZAMS) and some other stars older than 12 Gyr (not compatible with their belonging to the disk population of the galaxy).

6 The Hipparcos parallaxes: discussion and interpretation

The Hipparcos (Hip) parallaxes as well as the ground based CCD parallaxes from the USNO have certainly increased by an order of magnitude the precision of stellar distances. A large number of Hipparcos parallaxes are now available for stars we have considered in our search for solar analogs.

Last May during the "Hipparcos, Venice '97" conference we have shown (Cayrel de Strobel et al. 1997) that the accuracy of the Hipparcos parallaxes combined with a precise determination of their effective temperature, chemical composition, and spectroscopic gravity has allowed us to locate the Hyades dwarfs on their appropriate ZAMS and consequently to determine their He abundance, Y$= 0.26 \pm 0.02$ (in mass).

How does Hipparcos change our understanding of the parameters and evolutionary status of our sample of 99 solar analogs discussed in Cayrel de Strobel (1996)? First, it reduces our sample size to only 52 objects, probably because the stars we have included in our initial list of solar analog candidates were unknown binary stars, or not apt to be observed by Hipparcos, and then because in this new list of solar analogs the most metal poor stars in Table 1 and Figure 1 of Cayrel de Strobel (1996) have been omitted. The basic data adopted for these 52 solar analogs are given in Table 1, which lists in the first three columns the HD number, common name, and the number used in the Hipparcos and Tycho Catalogues (ESA, June 1997, SP-1200), followed by the photometric parameters V and B$-$V, the spectral type, and the spectroscopic determinations of metallicity, [Fe/H], and temperature, as log Teff. The last 3 columns give the Hipparcos parallax, in milliarcseconds, and the determinations of bolometric magnitudes, the first from the ground based parallaxes, and the second those based on the Hipparcos parallaxes.

We show in Figure 2 the observational (log Teff, Mbol) diagram for these 52 stars using Hipparcos parallaxes as the basis for Mbol determinations. The theoretical tracks are from Lebreton et al (1997), as in Figure 1. These models show that the present Sun, with Mbol =4.75, has moved by Δ Mbol = -0.42 mag above its initial position and by Δ log Teff = $+0.0123$ (corresponding to Δ Teff = 166K) in effective temperature.

In Figure 1, we noted that a fair number of analogs are more evolved and older than the Sun. The evolutionary status and the old age of these objects is confirmed by Hipparcos. In "Hipparcos, Venice '97" we have heard that for many stars, (but not for all), Hip parallaxes tend to make them more luminous. This is also seen in our sample of 52 stars: their (log Teff, Mbol) diagram (Figure 2) has lost, except for two stars, the underluminous objects seen on the preceding H-R diagram. One can argue that, precisely, these underluminous stars have not been observed by Hipparcos, or rejected by us because of their high metal deficiency, but the comparison shown in Figure 3 between the same 52 stars having both ground based parallaxes (filled diamonds) and Hip parallaxes (crossed or filled squares), as the basis of their Mbol determinations, shows that some stars of the sample with ground-based parallaxes lie below the main sequence. Clearly seen in Figure 3 is the tendency for the use of Hip parallaxes to brighten the Mbol of stars. Note that in Figure 3 the abscissae have been kept strictly the same in the sample of 52 stars possessing either Mbol's from ground based parallaxes, or Mbol's from Hip parallaxes. Figure 2 shows that relatively few Hipparcos analogs are main-sequence stars.

A few notable objects can be seen in Figure 3, such as the three best known stars which are thought to have planetary companions: 51 Peg (Mayor and Queloz 1995), 70 Vir (Marcy and Butler 1996), and 47 UMa (Marcy and Butler 1996). The absolute bolometric magnitude of the star HD 193664 from its ground-based parallax is 0.49 mag. fainter than that from its Hip parallax. Similarly, that of ι Per is 0.47 mag fainter. On the contrary, good examples of stars becoming fainter as a result of using Hipparcos Mbols are μ Cnc and the planet star 70 Vir. The values of the Hip Mbol's of the well known components of the binary ζ^1 and ζ^2 Ret, together with the values of Teff and [Fe/H] from a careful detailed analysis by Del Peloso (1997), has permitted us to attribute to this couple of disk stars a very old age: both are lying nicely on the 12 Gyr isochrone.

What has happened to our best candidates for 'solar twins'? Figs. 4 and 5 show an expansion of the region in the H-R diagram around the Sun. Figure 5 shows only those stars in Figure 4 with approximately solar metallicity, i.e. those with a metal abundance defined as: [Fe/H] = 0.0 ± 0.10. Note that in these two figures the total span in abscissa is only Δ log Teff = 0.03, from Teff = 5625 to Teff = 6025 K, and in ordinates only 1 mag. The straight full line is the ZAMS for the chemical composition of the Sun. The straight dashed line is the ZAMS for the chemical composition of the Hyades. The full curved line is the evolutionary track of the Sun. VB 64, a Hyades effective temperature solar analog, is significantly more metal-rich than the Sun, and its position actually fits very nicely on the ZAMS at its appropriate metallicity. Other Hyades stars, VB 92 and VB 73, are shown in Figure 4 with vertical lines indicating the size of 1 σ error bars. Clearly the positions of these stars are also consistent with the Hyades ZAMS. The star 18 Sco, (probably the best solar analog), falls on the 1 solar mass evolutionary track and on the isochrone of 6 Gyr. Abrupt changes of slope of the very magnified isochrones reflect grid points of the models.

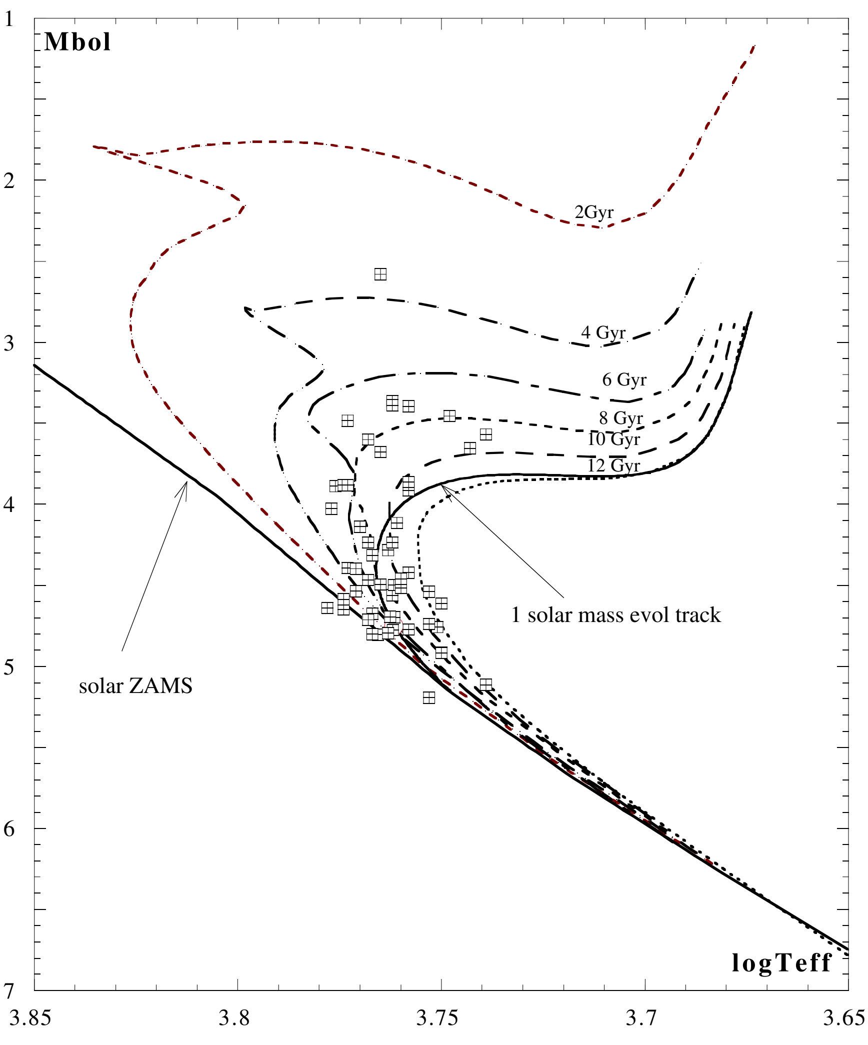

Figure 2: Observational (log Teff, Mbol) diagram of 52 solar analogs having Hipparcos (Hip) parallaxes as the basis of their Mbol determination with an overplot of the same theoretical diagram as in Figure 1. The sample size is reduced to only 52 objects because some of the stars included in the Cayrel de Strobel (1996) list were unknown binary stars and also because the most metal poor stars in the 1996 list have been omitted here. Please note that the underluminosity of certain stars has disappeared in this diagram.

Data for Solar Analogs with Hipparcos Parallaxes

HD	Name	Hip No.	V (mag)	B−V (mag)	Sp Type	[Fe/H]	log T_{eff}	π (mas)	M_{bol} (grd)	M_{bol} (Hip)
1461		1499	6.465	0.674	G0V	+0.30	3.762	42.67	4.940	4.560
1835		1803	6.385	0.659	G2.5V	+0.18	3.7619	49.05	4.810	4.775
2151		2021	2.810	0.618	G2IV	-0.17	3.762	133.7	3.690	3.365
10307		7918	4.960	0.619	G1.5V	+0.07	3.773	79.09	4.220	4.394
11397		8674	8.960	0.692	G6IV-V	+0.10	3.753	18.30	5.530	5.192
13974		10644	4.865	0.608	G0V	-0.33	3.750	92.20	4.740	4.612
14802		12186	5.195	0.604	G1.5V	0.00	3.773	45.60	4.750	3.482
16417		12186	5.780	0.652	G5IV	-0.10	3.765	39.16	4.430	3.675
19373		14632	4.050	0.595	G0V	+0.03	3.776	94.93	3.810	3.887
20630A		15457	4.845	0.681	G5V	+0.02	3.750	109.1	4.830	4.916
20766	ζ^1 Ret	15330	5.535	0.641	G2V	-0.22	3.739	82.51	5.396	5.115
20807	ζ^2 Ret	15371	5.235	0.600	G1V	-0.22	3.751	82.79	4.950	4.757
27685		20441	7.850	0.679	G4V	+0.03	3.750	26.96	4.630	4.917
27859	VB52	20577	7.795	0.599	G1.5V	+0.03	3.767	20.73	4.630	4.316
28099	VB64	20741	8.105	0.662	G2V	+0.16	3.7616	21.42	4.940	4.695
28344	VB73	20899	7.836	0.605	G1.5V	+0.14	3.771	21.0	4.670	4.396
28992	VB97	21317	7.905	0.685	G5V	+0.06	3.767	23.19	4.740	4.674
30495		22263	5.490	0.631	G2V	-0.02	3.7656	75.10	4.930	4.803
30562		22336	5.775	0.631	F8V	+0.13	3.768	37.73	3.780	3.602
30649A		22596	6.960	0.588	G1V-VI	-0.26	3.771	33.44	4.940	4.534
32923		23835	5.000	0.654	G4V	-0.20	3.758	63.02	3.780	3.914
34411		24813	4.700	0.630	G1IV-V	+0.10	3.770	79.08	3.870	4.136
39587		27913	4.395	0.592	G0V	-0.07	3.774	115.43	4.420	4.651
44594	Hardorp	30104	6.610	0.657	G3V	+0.15	3.7617	38.92	4.590	4.497
52711		34017	5.935	0.598	G4IV	-0.15	3.768	52.37	4.580	4.466
67228		39780	5.295	0.641	G2IV	+0.04	3.762	42.86	2.830	3.389
72905		42438	5.640	0.619	G1V	-0.11	3.767	70.07	4.870	4.801
76151		43726	6.010	0.656	G3V	+0.07	3.758	58.50	4.750	4.773
78418		44892	5.955	0.657	G5V-IV	-0.20	3.758	31.98	4.436	3.396
86728	20 LMi	49081	5.365	0.671	G1.5V	-0.05	3.758	67.14	4.320	4.423
89010	35 Leo	50319	5.962	0.662	G2IV	-0.03	3.748	32.94	3.570	3.457
90508AB		51248	6.430	0.605	G0V	-0.23	3.765	42.45	4.960	4.495
95128	47 UMa	53721	5.040	0.618	G0V	-0.02	3.768	71.04	4.270	4.236
105590A		59272	6.815	0.663j	G2V	-0.16	3.753	36.51	4.950	4.538
109358	β CVn	61317	4.255	0.589	G0V	-0.04	3.774	119.46	4.520	4.586
115043A		64532	6.825	0.602	G1V	-0.08	3.768	38.92	4.550	4.712
115383		64792	5.205	0.588	G0V	+0.04	3.774	55.71	4.510	3.883
117176A	70 Vir	65721	4.97	0.712	G5V	-0.11	3.739	55.22	3.160	3.570
128620	α Cen	71683	-0.01	0.70	G2V	+0.22	3.763	742.12	4.310	4.283
141004		77257	4.425	0.602	G0V	+0.03	3.777	85.08	4.000	4.026
142267A		77801	6.085	0.599	G1V	-0.28	3.763	57.27	4.070	4.796
143761		78459	5.400	0.606	G1V	-0.17	3.761	57.38	4.230	4.117
146233A	18 Sco	79672	5.495	0.651	G1V	0.00	3.7626	71.30	4.500	4.693
150680	ζ HerA	81693	2.81j	0.645	F9IV	+0.05	3.765	92.63	2.820	2.581
186408	16 Cyg A	96895	5.975	0.642	G1.5V	+0.06	3.762	46.25	4.260	4.234
186427	16 Cyg B	96901	6.240	0.661	G2.5V	+0.05	3.760	46.70	4.520	4.518
187923		97767	6.145	0.647	G0V	+0.06	3.758	36.15	4.590	3.863
189567		98959	6.080	0.644	G2V	-0.29	3.753	56.45	4.630	4.739
193664		100017	5.91	0.602	G3V	+0.06	3.778	56.92	5.022	4.640
212330A		110649	5.315	0.668	G3IV	-0.17	3.743	48.81	3.970	3.655
216437	ρ Ind	113137	6.05	0.660	G4IV-V	+0.10	3.773	37.71	4.300	3.881
217014	51 Peg	113357	5.46	0.666	G3.5V	+0.06	3.760	65.10	4.710	4.458

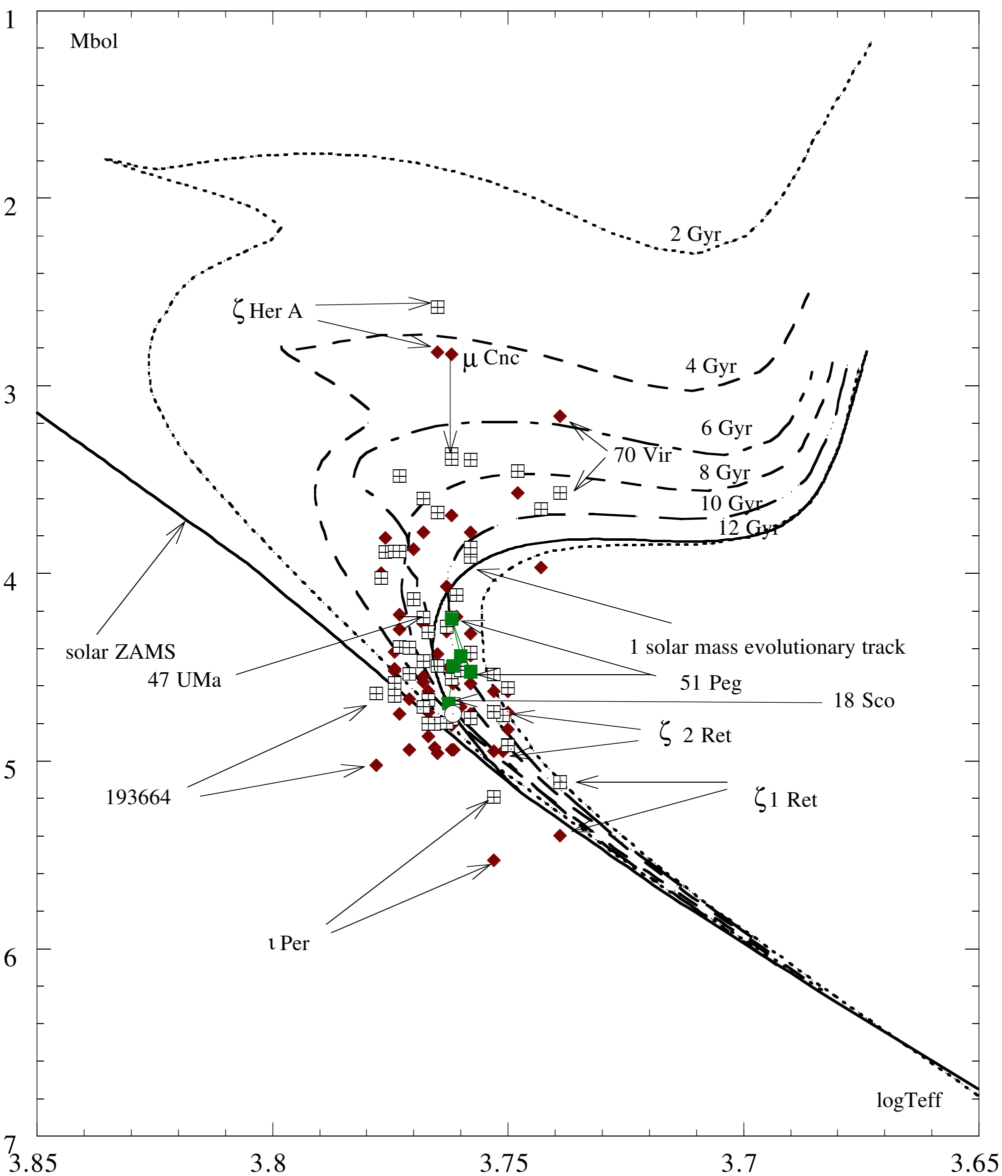

Figure 3: Comparison between observational (log Teff, Mbol) diagrams of 52 solar analogs using different sources for bolometric magnitudes, with an overplot of the same theoretical diagram as in Figure 1. Filled diamonds represent absolute bolometric magnitudes, Mbols, computed with ground-based parallaxes, and crossed and filled squares represent Mbols computed with Hip-parallaxes. Filled squares denote some of the past 'best' solar analogs. Here, clearly it is seen that the Hip Mbols of many objects brighten their positions in the H-R diagram with respect to the ground-based positions of the same stars.

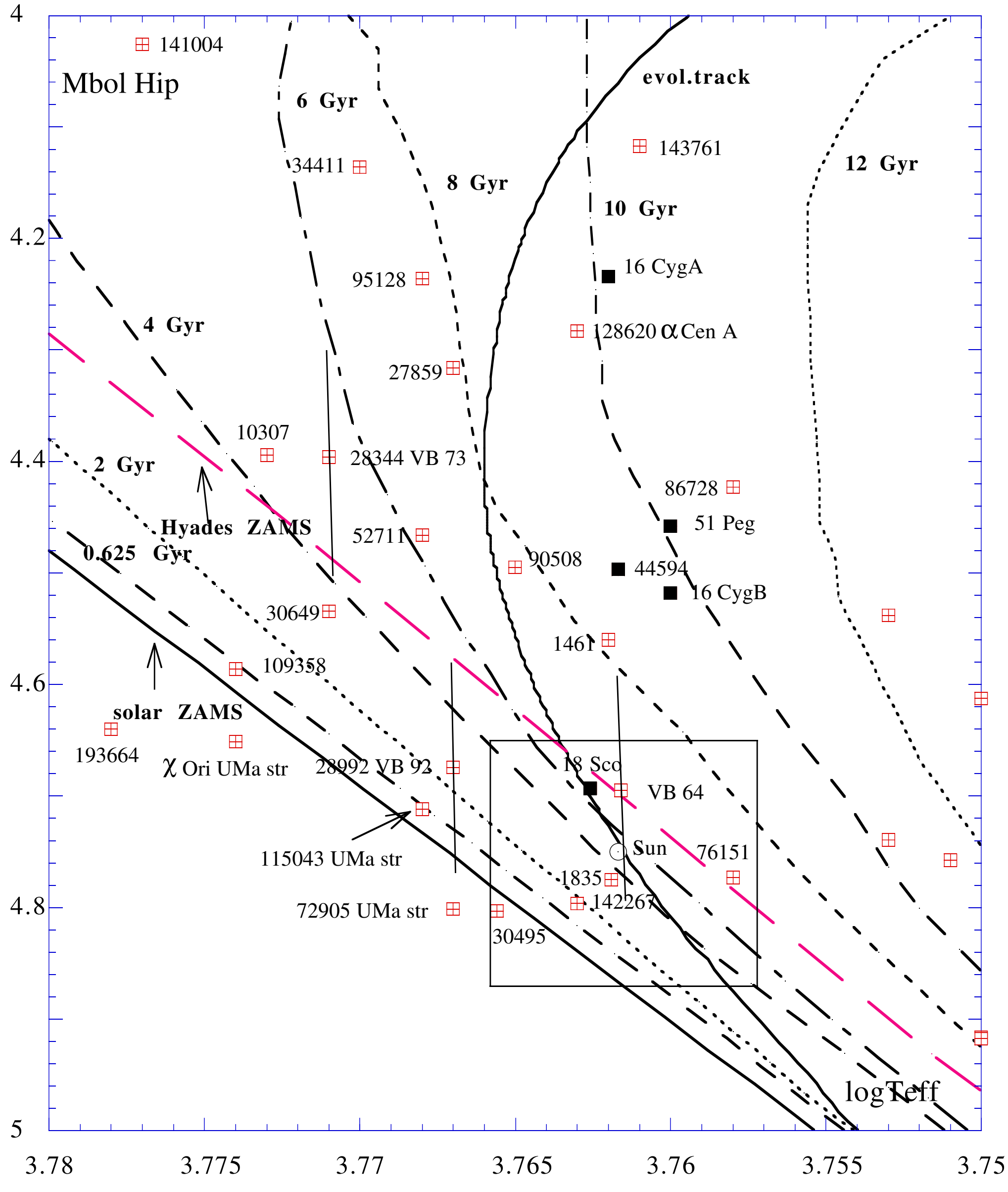

Figure 4: Zoom of the region in the previous H-R diagram (Figure 3) around the Sun. The straight full line is the ZAMS for the chemical composition of the Sun. The straight dashed line is the ZAMS for the chemical composition of the Hyades. The full curved line is the evolutionary track of the Sun. VB 64, a Hyades star, is significantly more metal-rich than the Sun, and its position actually fits very nicely on the ZAMS at the appropriate metallicity. The star 18 Sco, (probably the best solar analog), falls on the 1 solar mass evolutionary track and on the isochrone of 6 Gyr. Abrupt changes of slope in the isochrones reflect grid points of the models.

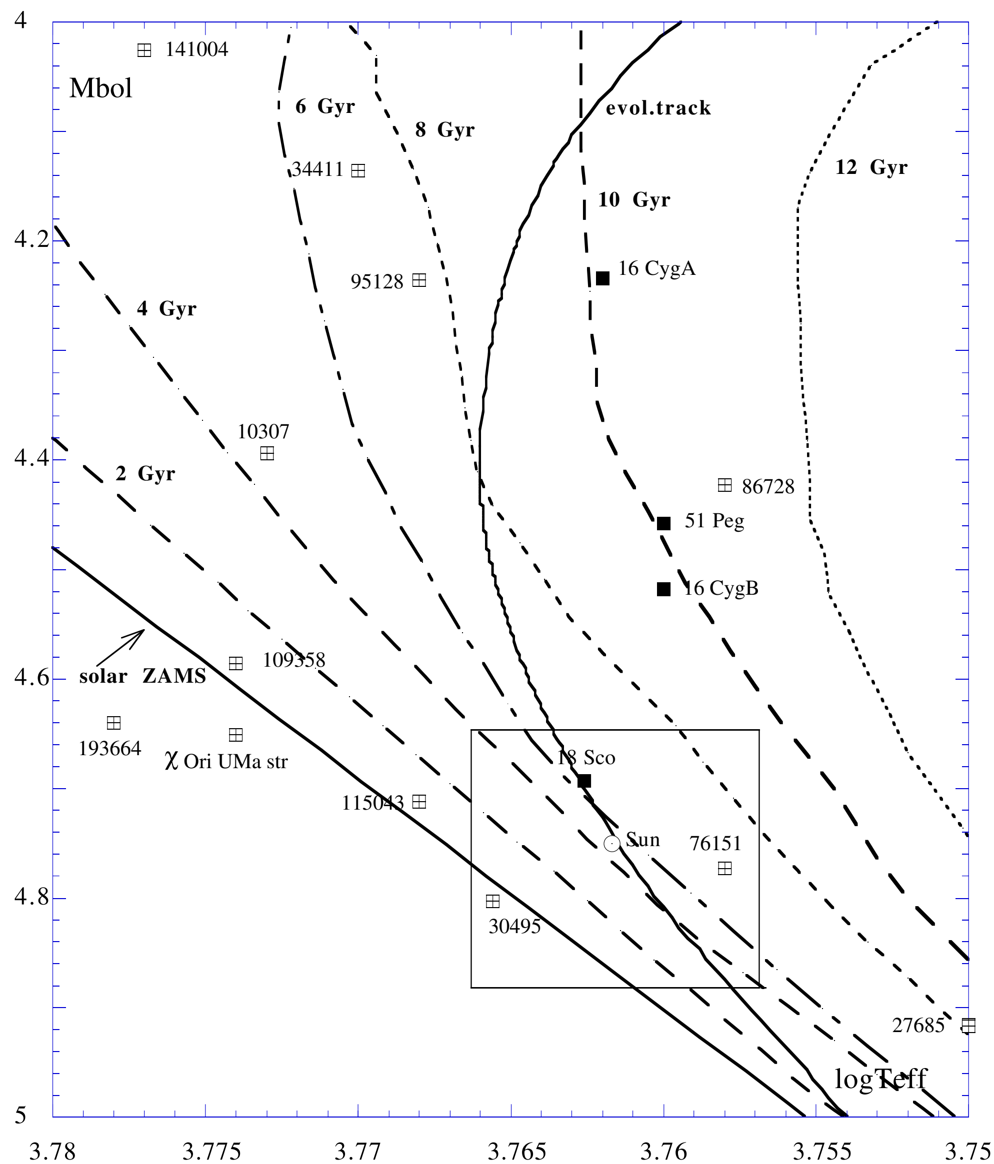

Figure 5: The same as Figure 4, but this (log Teff, Mbol) diagram contains only solar metal normal stars, having their metal abundance defined as: Δ [Fe/H] $= 0.00 \pm 0.10$. Note that in Figures 4 and 5 the total span in abscissa is only: Δ log Teff $= 0.03$, from Teff $= 5625$ to Teff $= 6025$ K, and in ordinates, 1 mag. Here, and in Figure 4, the box drawn around the Sun's position defines the region within 60 K and 0.1 mag of the Sun's effective temperature and bolometric magnitude. These are the mean error bars adopted for the stars with Hipparcos parallaxes.

The box drawn around the Sun's position in Figs. 4 and 5 defines the region within 60 K and 0.1 mag of the Sun's effective temperature and bolometric magnitude. By the way, these are also the mean error bars we have adopted for the stars with Hipparcos parallaxes. Very few stars now sit within this region of solar 'twinness' in Figure 4 and even less, in Figure 5. Notable in Figure 4 are : 18 Sco, VB 64, and HR 1835. Of these, we have heard a great deal about 18 Sco at this conference. HR 1835, we have heard, is much more chromospherically active, hence younger, than the Sun and 18 Sco is now our closest twin. The new parallaxes reinforce the conclusions (Friel et al 1993) that 16 Cyg A and B are both more evolved and older than the Sun, at 10 Gyr. Other solar analogs that are thought to have planetary companions, 51 Peg, 70 Vir and 47 UMa, are also more evolved and appreciably older than the Sun. Hardorp's (1978) best analog, HD 44594, is not contained in the H-R diagram of Figure 5 because it is appreciably more metal-rich than the Sun. The box drawn around the Sun in Figure 5 contains three stars : 18 Sco (Porto de Mello: in this workshop), HD76151 (Cayrel de Strobel and Bentolila 1989) and HD 30495 (Pasquini et al. 1994). Their detailed analyses have produced trustworthy atmospheric parameters: Teff, log g, and [Fe/H] and with their new Hip parallaxes these three stars certainly deserve to surround the Sun.

7 Final Comments

During this talk we have seen that the combination of detailed spectroscopic analyses, internal structure calculations, and precise distance determinations yields an evolutionary mass, a chemical composition, and state of evolution, hence age, of the observed sample of 52 photometric solar analogs of unprecedented accuracy. About our choice of the best solar analog, here in this workshop, we have to confess that the name of the best candidate has changed regularly in the 5 papers we have written on the subject in the last 16 years. Please note, though, that the principles for recognizing solar analogs have not changed in our group.

In 1981 no spectroscopic solar analog was chosen, because of poor spectroscopic results. In 1989 our choice went to Hardorp's spectrophotoelectric analog, HD 44594. In 1993 Friel et al. chose two stars ex equo as best solar analogs: the two components of the binary 16 Cyg. In the 1996 paper the planet star 51 Peg was elected best solar analog of the year. Today, I hope that you all will agree with me that 18 Sco is currently the best match to the Sun.

We shall finish in posing this interesting question: To know if there is a serious hope to find some other solar twins in the near future as good as 18 Sco? The answer is certainly "yes" if we agree to pay the price: i.e. to look for stars fainter than magnitude 8.0. However, the statistics are not very encouraging, because of the triple constraint on mass or effective temperature, on metallicity, and on age. If we are not wrong their number would not exceed 5 in a sample of 100,000 stars.

Acknowledgments

First of all our grateful thoughts go to the memory of Johannes Hardorp who was first in stimulating this research. And then our thanks go to Lodewijk Woltjer who has invited Giusa Cayrel to write a review on "Stars resembling the Sun" prior to the arrival of the Hipparcos results, to Conard Dahn who in the early stage of this project has sent us some precious USNO CCD parallaxes of stars belonging to our priority list of solar analog candidates, to Catherine Turon and to the members of the former Hipparcos Consortia, to Monique Spite for her help in solving problems in spectroscopic detailed analyses, to Yveline Lebreton who allowed us, in supplying an up-to-date grid of internal structure models, to determine the evolutionary status of our sample of solar analogs, and last but not least, to Jeff Hall who invited us to this Workshop. Special thanks go to Nora Knowles and Claire Bentolila who, since 1978, actively took part in this research, and to Danielle Morin for her prompt reply to all our questions concerning the utilized Hipparcos data.

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Discussion following Giusa Cayrel's talk

Radick: Well, as far as I'm concerned, that settles it [laughter], but maybe there a few dissenters...?

Garrison: With the kind of accuracy you're dealing with now with HIPPARCOS, it's a pity you're still using an extended source to compare with stellar sources. The Moon is *not* a good source; I wish you could use something else.

Cayrel: It is not a pity, because we have checked during several observing runs, at CFHT, ESO, and OHP, that the equivalent widths obtained from the Moon and from the asteroids Vesta and Ceres were undiscernable. As large-telescope time is very precious, and the time to get the desired S/N is at least a couple of hours, we are using moonlight.

de Mello: I have examined spectra of 18 Sco with those of Ganymede, at high signal-to-noise. All the spectra compare very well with one another. I have also examined the Moon and the sky, just a blue sky spectrum, at 30,000 resolution and again at very high signal-to-noise: they were the same, as far as I could tell.

Garrison: That depends on the spectrograph.

de Mello: Surely. It was a single-order spectrograph, well-behaved.

Cayrel: Because of this slight dependence of equivalent widths versus spectrograph (much reduced with solid state detectors in comparison with the old photographic spectra), we have always worked differentially, using the same spectrograph for program stars and comparison sunlight spectra.

Guinan: I just noticed that since 1980, the duration that you have a particular star "lover" decreases with time [laughter]. It's now just a year, or less.

Cayrel: You are certainly right. But this time, the time interval between the last but one (51 Peg) and the last best analog (18 Sco) was so short because of the Hipparcos event, which is responsible for this quick change of "lover." We are not done, and *you* [pointing at de Mello] are not now to think that you are sitting on yours [protracted laughter]!

Guinan: He has about six months [laughter].