Age determinations of metal-poor field stars

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Abstract: To determine ages of individual (field) stars, composition, mass and distance should be known accurately, which is usually not the case. Even then, as we show, errors and misleading results are common. An alternative way is to use turn-off colours of field star populations. This method lead in the past to ages significantly higher than those of globular clusters of the same metallicity. We show that colour-based relative ages between the field and cluster population indicate that they have similar if not equal ages. Besides using data from Strömgren photometry, we also investigate the stellar objects of SDSS (DR2) which has the advantage of providing a huge database, and the disadvantage of lacking metallicities. First steps to metallicity estimations from SDSS spectra are shown.

To establish the evolution, in particular the chemical evolution of the Milky Way, we need accurate ages of the various subsystems. While there is now widespread agreement about the ages of Globular Clusters (see for example Salaris & Weiss 2002), the same cannot be said for field stars. If the star's mass, distance and composition is known, it can be put on an evolutionary track and its luminosity yields its age. This is done in Table 1 for stars analysed by Fuhrmann (1998), which probably have the best stellar parameter determinations available. Nevertheless, the assumed mass uncertainty of 5% results in a huge age range for such low-mass stars.

A warning: Without known mass, one is tempted to use colour or T_{eff} to select the evolutionary track, a method which results in completely meaningless ages for low-mass stars on the unevolved lower main sequence due to the uncertainty in T_{eff}!

Object	stellar parameters				age	
	[Fe/H]	M_{bol}	$M/M_\odot$	T_{eff}	age [Gyr]	age range
HD19445	-1.95	4.91	0.74	6016	13.4	9.9-18.0
HD45282	-1.52	1.98	0.90	5282	10.2	8.3-12.6
HD103095	-1.35	6.33	0.64	5110	9.7	<18.1
HD194598	-1.12	4.45	0.84	6058	11.1	7.7-15.0
HD201891	-1.05	4.46	0.81	5943	14.4	10.5-18.7

Table 1: Ages of nearby metal-poor field stars with accurate Hipparcos parallaxes. Stellar parameters from Fuhrmann (1998), ages from Weiss & Schlattl (2000). The "age range" results from the assumed mass uncertainty of 5%. Only an accuracy of 1% in mass would reduce this to 1 Gyr.

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A method related to the classical one for Globular Cluster ages consists in determining the turn-off colour or effective temperature of field stars of similar metallicity and to match this with theoretical isochrones of same composition. Although it is known that theoretical colours are prone to errors (stellar temperatures depending on convection theory; stellar colours on colour transformations), this may give reliable relative ages. Figure 1 shows such an attempt for stars with T_{eff} determined from Strömgren colours (Schuster & Nissen 1989), displaying for standard isochrones a severe age problem: metal-poor field stars appear to be 16-18 Gyr old! The inclusion of diffusion (sedimentation) changes the surface temperatures and leads to more reasonable ages.

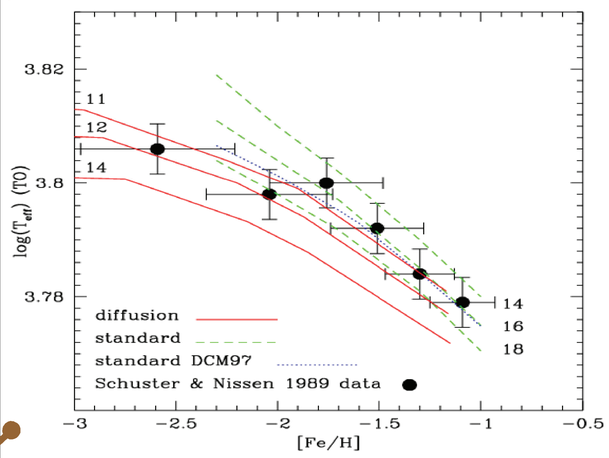

Fig. 1: Turn-off temperatures of stars from Schuster & Nissen (1989) in comparison with isochrones by Salaris & Weiss without (green) and with (red) diffusion. Ages are given next to the isochrones. For comparison, also one non-diffusive isochrone by D'Antona et al (1997) is shown (blue).

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Plotting colour vs. metallicity for a large sample of field stars allows an estimate of the TO-colour of the dominant population by comparing it with isochrones. As Unavane et al (1996) found, the field population appears to be 15 or more Gyr. Given the colour problems mentioned above, we have instead compared directly TO-colours of Globular Clusters with that of field star samples (below the recent one by Schuster et al. (2004). The cluster ages have been determined by Salaris & Weiss (2002) using the brightness difference between TO and horizontal branch. Field stars and clusters appear to be almost coevval. Only the more metal-rich field stars seem to be slightly older than the clusters.

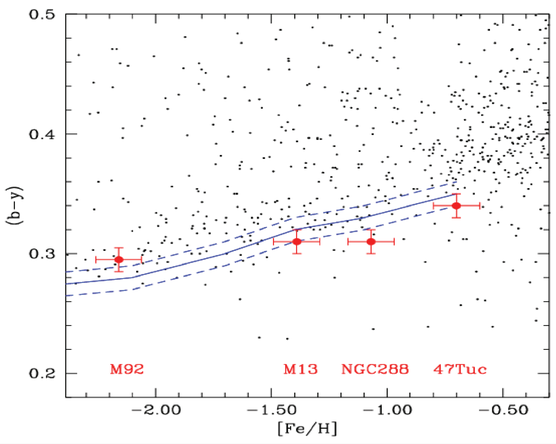

Fig. 2: Strömgren TO-colours of 4 representative GCs (Grundahl, priv. comm.) compared to the sample of 411 field stars by Schuster et al. (2004). The blue lines denote the drop in stellar density interpreted as the TO and its uncertainty. The clusters have ages of 11 to 12 Gyr (from 47 Tuc to M92).

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The next step: The Sloan Digital Sky Survey provides data about several hundred thousands of stars, without distance and metallicity information, however.

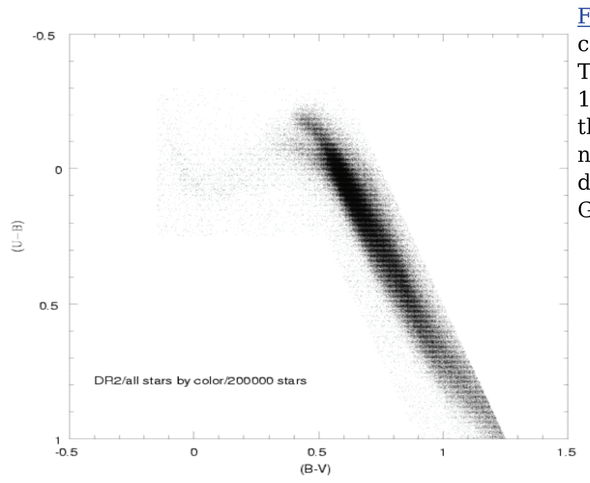
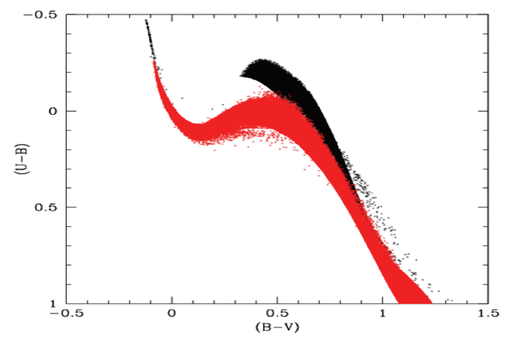
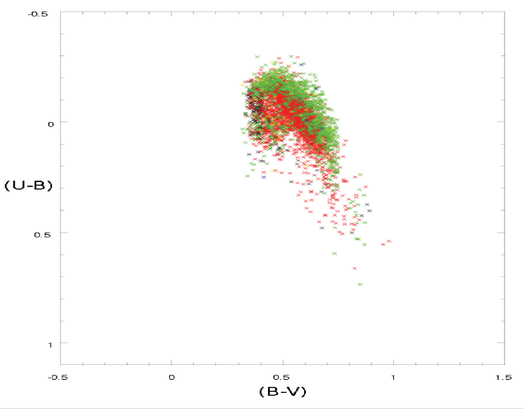


Fig. 3: SDSS stars from DR2 shown in a colour-colour diagram and selected by r-magnitude < 17. The number of stars with spectra is of order 10,000. Note the double TO structure and compare this to the simulated diagram below. Red: solar neighbourhood; black: halo stars with Gaussian distribution around [Fe/H]= -1.6 and ages of 12-13 Gyr.



Metallicities from SDSS spectra: We have determined Ca H+K equivalent widths from available spectra and used the method by Beers et al. (1990) to estimate [Fe/H]. The relations provided by Beers et al. do not cover the bluest TO-colors, so we do not have "SDSS-ages" so far. However, as

Fig. 4 shows, the colour-colour diagram nicely separates into metallicity bins (black, red, green, yellow, blue: from [Fe/H] = 0 to < -4 in steps of 1). Our method is very fast and reliable at an average level of ≈ 0.3 dex in [Fe/H].



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Conclusion. If straightforwardly compared with isochrones, metal-poor field stars appear to be older than GCs by several Gyr, although the effect of diffusion might resolve this problem. However, if compared to GCs with well-known ages, the field population seems to be coeval with them. SDSS potentially offers a huge sample of stars, allowing much better statistical determination of the TO and even to detect substructure. However, a metal determination for SDSS stars with spectra is still needed.

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References: Beers T.C., Preston G.W., Shectman S.A & Kage J.A., AJ 100, 849 (1990); Fuhrmann K., A&A 388, 161 (1998); Salaris M. & Weiss A., A&A 388, 492 (2002); Schuster W.J., Beers, T.C., Michel, R., et al., A&a 422, 527 (2004); Schuster W.J. & Nissen P.E., A&A 221, 65 (1989); Unavane M, Wyse, R.F.G. & Gilmore G., MNRAS 278, 727 (1996); Weiss A. & Schlattl H., A&A Suppl. 144, 487 (2000);