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The peculiar single giant HD 112989: rotation, activity and evolution*

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Abstract. A spectroscopic, photometric and evolutionary study is presented for HD 112989, an active peculiar giant star. The present spectroscopic observations show a significant CaII K&H emission core variability, whereas the UBV photometry shows that HD 112989 has a variable brightness. The rotational velocity for this star, 11.0 kms^{-1}, is about five times larger than the mean rotational velocity for giants with the same spectral type. In addition, we have found no sign of binarity for this star.

Key words: stars: activity – stars: chromospheres – stars: fundamental parameters – stars: individual: HD 112989 – stars: rotation

Table 1. The CaII spectra data of HD 112989.

Date	exposure time	S/N avrg.	S/N CaII K bottom	$W_0(K)$
8/9.4.1996	20+15^{min}	58	30	...
7/8.6.1996	2x15^{min}	74	37	2.21
30/31.7.1996	20+16^{min}	60	27	1.98
23/24.1.1997	2x15^{min}	79	36	1.95
24/25.1.1997	2x15^{min}	83	37	1.86
14/15.7.1997	2x20^{min}	43	21	...
5/6.6.1998	2x15^{min}	54	24	...
2/3.7.1998	2x20^{min}	48	29	1.95?

1. Introduction

HD 112989 = 37 Com, is a fifth-magnitude single giant star, with a spectral type G9III to G9III-II. Tomkin et al. (1976) have found an unusually low ^{12}C/^{13}C ratio of about 3.4, significantly lower than the solar value, indicating clearly that the composition of the atmosphere of this star was altered by material processed by the CNO cycle in its interior and subsequently dredged-up to the surface by an extensive convective envelope. Such finding shows that HD 112989 seems to be very probably a fairly evolved and well-mixed star. Brown et al. (1989) reported a normal content of Lithium for this star, in agreement with the standard predictions.

On the basis of a large set of differential UBV photometric observations Strassmeier & Hall (1988a) have found light variations which could presumably be due to spots on its surface, but have found no evidence of periodicity. The star's behavior in the Strömgren by filters was investigated by Lockwood et al. (1997) on a 10 year interval. They reported changes in the short–term variability rate and the presence of a long–term variability.

According to Maggio et al. (1990) HD 112989 is a normal X-ray emitter, presenting the same characteristic behavior of ordinary late G and early K giant stars. The ROSAT all–sky survey (Hunsch et al., 1998) also found that the star is a moderate X-ray emitter compared with the other single G and K giants from the catalogue. Reimers et al. (1996) have reported the absence of CS CaII H&K lines in the spectrum of such star.

In this work we present new spectroscopic and photometric observations for this unusual giant star, as well as a discussion on its evolutionary status.

2. Observational data

Spectroscopic observations in the CaII K&H region and differential UBV photometry were carried out from April 1996 to July 1998. CaII K&H spectra with 0.2 Å resolution were obtained by using a CCD camera mounted on the coude spectrograph of the 2m telescope at the Bulgarian National Astronomical Observatory–Rozhen. The processing of the spectra was done by using the programme package IPS (Smirnov et al., 1992). Eight such spectra are displayed in Fig. 1. A calculation of the full width of CaII K emission core $W_0(K)$ is presented in Table 1 with $W_0(K)$ = log(c$\Delta\lambda/\lambda$), where $\Delta\lambda$ is the wavelength difference of both edges of the emission core. No $W_0(K)$ calculation was carried out for the spectra obtained on April 8/9 1996, July 14/15 1997 and June 5/6 1998, because the emission core was absent or very weak.

UBV estimates and patrol monitoring in U-filter were obtained by using a computer–controlled single–channel electrophotometer attached to the 60cm Cassegrain telescope at the Belogradchik Observatory, Bulgaria. The equipment is described in Antov & Konstantinova–Antova (1995). The characteristic integration time was 1 sec. HD 113493 and HD 113494 were used as comparison and check star, respectively. The data

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* Based on observations collected at the Observatoire de Haute-Provence (France) and at the Bulgarian National Astronomical Observatory-Rozhen (Bulgaria)

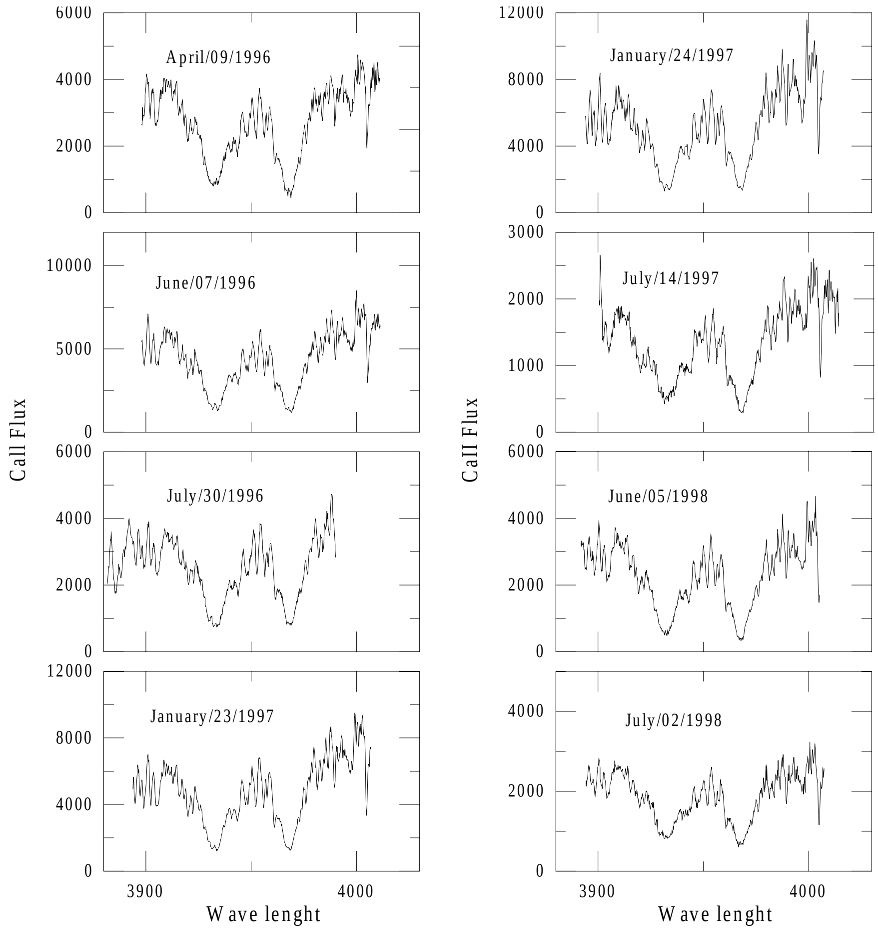

Fig. 1. Ca II K&H spectra of HD 112989

processing was made by using the programme package APR (Kirov et al., 1991). Our observations present a signal-to-noise $\geq$180 with a typical uncertainty of about 0.01 mag. The UBV data set with 44 new measurements in the visual magnitude V and the color indices $(B-V)$ and $(U-B)$ are presented in Table 2. The UBV measurement is a mean of at least 3 individual values, with a duration of 10 sec in each filter. The systematic shift of the star's brightness, observed since HJD 2450814 is due to the change of the preamplifier–discriminator module in the photometer and to the fact that the object is very bright and appeared in the non-linear part of the amplification curve.

The projected rotational velocity v sin i and radial velocity v_r were obtained from observations carried out with the CORAVEL spectrometer (Baranne et al., 1979), attached to the 1.0m Swiss telescope at the Haute-Provence Observatory. A precise projected rotational velocity v sin i of 11.0 ± 1.0 kms^{-1} was determined from the standard calibration by De Medeiros & Mayor (1999). The mean radial velocity from 20 CORAVEL observations is $v_r = -14.82 \pm 0.30$ kms^{-1}, with no sign of variability.

3. Results and discussion

The spectra presented in Fig. 1 indicate a CaII K&H emission core variability for HD 112989. Such a feature is also observed on the full width of the CaII K emission core $W_0(K)$ given in Table 1. By comparing the present result with the one reported by Wilson (1976), which indicates a moderately strong CaII K emission for this star, one can conclude that there is a significant change in the chromospheric heating rate for HD 112989. The analysis of the CaII K emission core asymmetry indicates macroscopic motions in the chromosphere of this giant. It seems also important to point out the variability of its structure, and especially the appearance and disappearance of the self–reversal emission core that might be interpreted as changes in the chromospheric transparency conditions. Let us recall that no sign of CS CaII K&H lines was found by Reimers et al. (1996), which is a strong evidence for the absence of mass loss phenomena in this star.

The present UBV photomectric observations show that HD 112989 has a variable brightness. Our photometric observations show dips of about 0.^{m}1 in V– and B–lights in February 1997, and in July, 1998. Such a brightness decrease could be due to the presence of spot areas on the surface of the star. In spite of the variability in brigthness, a periodogram study as well as normal Fourier analysis performed on the present UBV data have shown no real period for HD 112989.

From an inspection of Table 2 and Fig. 2, where the UBV measurements are shown, one can also find some brightenings of the star in the limits of one-two night observations with an

Table 2. The UBV photometry data of HD 112989

Date	J.D. 2440000+	V mag	$(B-V)$ mag	$(U-B)$ mag
15/16.6.1996	10250.370	5.26 ±0.01	0.98 ±0.01	0.77 ±0.01
18/19.6.1996	10253.369	5.27 ±0.02	0.99 ±0.01	0.76 ±0.01
19/20.6.1996	10254.393	5.10 ±0.03	1.00 ±0.02	0.83 ±0.02
13/14.7.1996	10278.334	5.24 ±0.02	0.99 ±0.01	0.83 ±0.02
27/28.7.1996	10292.329	5.28 ±0.01	0.97 ±0.03	0.83 ±0.01
1/2.8.1996	10297.326	5.15 ±0.01	1.02 ±0.01	0.94 ±0.01
2/3.8.1996	10298.312	5.19 ±0.02	1.01 ±0.01	0.91 ±0.02
7/8.2.1997	10486.591	5.25 ±0.01	1.02 ±0.01	0.82 ±0.01
9/10.2.1997	10488.537	5.25 ±0.01	1.03 ±0.01	0.74 ±0.01
10/11.2.1997	10489.511	5.29 ±0.01	1.02 ±0.01	0.78 ±0.02
11/12.2.1997	10490.476	5.35 ±0.01	1.00 ±0.01	0.74 ±0.01
18/19.3.1997	10526.393	5.31 ±0.01	1.01 ±0.01	0.81 ±0.02
8/9.4.1997	10547.373	5.32 ±0.01	1.00 ±0.01	0.82 ±0.01
9/10.4.1997	10548.285	5.33 ±0.01	1.01 ±0.01	0.78 ±0.02
14/15.4.1997	10553.342	5.33 ±0.01	1.00 ±0.01	0.80 ±0.01
1/2.5.1997	10570.346	5.22 ±0.01	1.01 ±0.01	0.86 ±0.01
9/10.6.1997	10609.379	5.33 ±0.01	1.01 ±0.01	0.77 ±0.01
10/11.6.1997	10610.381	5.37 ±0.01	1.02 ±0.01	0.74 ±0.01
12/13.6.1997	10612.364	5.38 ±0.01	1.02 ±0.01	0.72 ±0.01
14/15.6.1997	10614.370	5.32 ±0.01	1.01 ±0.01	0.74 ±0.01
28/29.6.1997	10628.340	5.28 ±0.01	0.99 ±0.01	0.78 ±0.01
29/30.6.1997	10629.322	5.25 ±0.01	1.04 ±0.01	0.81 ±0.01
1/2.7.1997	10631.333	5.39 ±0.01	1.01 ±0.01	0.77 ±0.01
11/12.7.1997	10641.375	5.25 ±0.01	1.05 ±0.01	0.87 ±0.01
14/15.7.1997	10644.353	5.27 ±0.01	1.04 ±0.01	0.87 ±0.01
17/18.7.1997	10647.375	5.24 ±0.01	1.06 ±0.01	0.93 ±0.01
31.12./1.1.1998	10814.570	4.91 ±0.02	1.15 ±0.02	1.02 ±0.02

Table 2. (continued)

Date	J.D. 2440000+	V mag	$(B-V)$ mag	$(U-B)$ mag
1/2.1.1998	10815.560	4.95 ±0.03	1.04 ±0.05	0.99 ±0.05
21/22.2.1998	10866.520	4.91 ±0.01	1.15 ±0.01	1.05 ±0.01
21/22.2.1998	10866.590	4.91 ±0.01	1.15 ±0.01	1.06 ±0.01
22/23.2.1998	10867.530	4.90 ±0.01	1.15 ±0.01	1.05 ±0.01
4/5.3.1998	10877.400	4.84 ±0.04	1.15 ±0.05	1.04 ±0.05
6/7.3.1998	10879.440	4.82 ±0.04	1.15 ±0.04	1.05 ±0.04
3/4.4.1998	10907.380	4.88 ±0.01	1.15 ±0.01	1.01 ±0.01
3/4.4.1998	10907.500	4.89 ±0.01	1.14 ±0.01	1.03 ±0.01
5/6.4.1998	10909.360	4.89 ±0.01	1.14 ±0.01	1.01 ±0.01
8/9.4.1998	10912.350	4.88 ±0.01	1.15 ±0.01	1.02 ±0.01
22/23.4.1998	10926.340	4.89 ±0.01	1.14 ±0.01	1.03 ±0.01
27/28.5.1998	10961.330	4.89 ±0.03	1.14 ±0.02	1.08 ±0.02
29/30.6.1998	10994.370	4.93 ±0.02	1.14 ±0.02	1.02 ±0.02
30.6./1.7.1998	10995.420	5.01 ±0.02	1.17 ±0.02	1.01 ±0.02
1/2.7.1998	10996.370	4.97 ±0.01	1.13 ±0.01	1.01 ±0.01
2/3.7.1998	10997.380	5.00 ±0.01	1.12 ±0.01	0.99 ±0.01
4/5.8.1998	11030.320	4.95 ±0.01	1.16 ±0.01	1.04 ±0.01

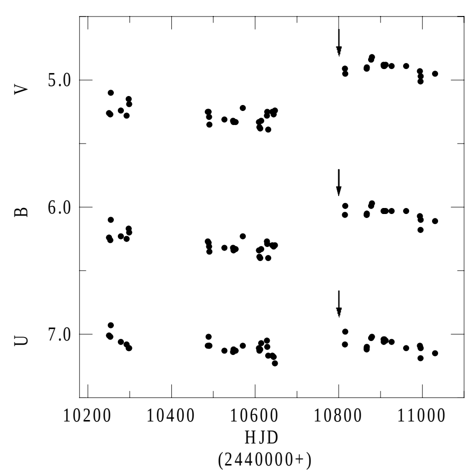

Fig. 2. UBV photometric observations for HD 112989. The systematic shift to the right of arrows, for HJD $>$ 2450814, is due to the change of the preamplifier-discriminator module in the photometer.

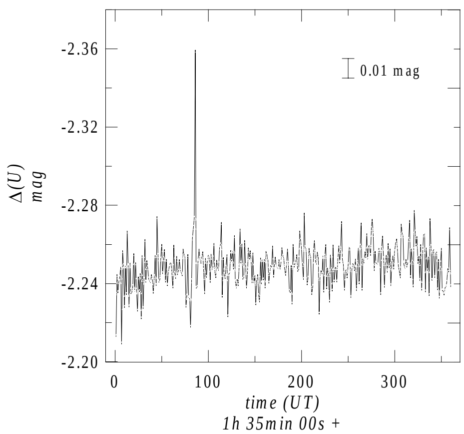

Fig. 3. The detected flare event on HD 112989. The error bar on the upper-right side indicates the rms of 0.01 mag for an individual observation.

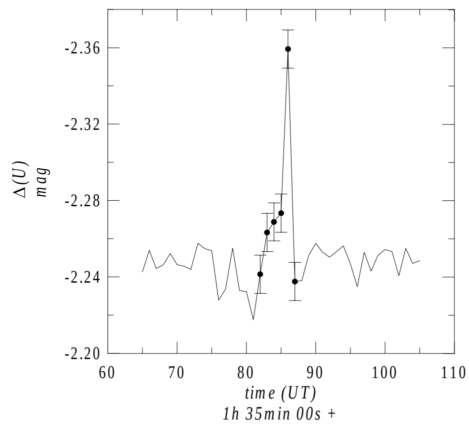

Fig. 4. Zoom of the region of the flare in Fig. 3, with some observational points indicated by dots. The uncertainty of $\pm$ 0.01 mag is indicated by the bars.

amplitude 0.1–0.15 magnitudes in V–light. This feature seems to indicate the presence of flare–like events, in spite of the fact that the classical rule $\Delta U > \Delta B > \Delta V$ is not fulfilled here. Similar brightenings have also been observed by different authors for the active single giants OP And and V390 Aur (Strassmeier & Hall, 1988b; Hooten & Hall, 1990; Konstantinova-Antova et al., 1995). The root cause for these events is not yet completely understood. However, by considering that the closest analogy to the single active late giants are the RS CVn binaries, these events might be similar to the long–duration flares on these stars.

A short–lived event, which seems to indicate a flare with a duration of 5 sec and an amplitude $0.^{m}12$ was detected at Belogradchik Observatory, on February 22, 1998 during an U-filter patrol monitoring. The total effective monitoring time in the U-filter was $11^{h}01^{m}07^{s}$, with a characteristic integration time of 1 sec. The event is represented in Fig. 3 where we show the U amplitude of HD 112989 relative to the U amplitude of the standard star HD 113493. The standard deviation of random noise fluctuation σ was $0.^{m}01$. Following Zhilyaev (1991) we found a probability of about 3.10^{-7} for such finding to be considered a random event. Neverthless, one should be cautious because this event is basically defined by four points and additional observations are certainly required to confirm the presence of flares in this star. An interesting feature in this short–lived event is that the rise time is greater than the decay time, what can be seen clearly from Fig. 4.

Henry & Newsom (1996) have carried out a search for flare events on the period Oct., 1983–Dec., 1987, with about 8^{h} total effective monitoring time in the three filters – U, B and V. By adopting $\Delta(U-V) \geq 3\sigma$ as a flare criterion, where σ is the standard deviation of the nightly $\Delta(U-V)$'s from the seasonal mean, these authors have detected no sign of flares for HD 112989.

A long–term light variability with a period of 13 years was reported by Donahue (1996), on the basis of photometric data from the long–term monitoring program by Lockwood et al. (1997), carried out from 1984 to 1995. This variation may be interpreted as analogous to solar activity cycle. An inspection of the light curve, presented by Donahue (1996) shows that HD 112989 seems to tend for its maximum activity level and, consequently, for its minimum in brigthness, around the middle 1999. Neverthless, we see no link between this situation and the fact that emission core was absent or very weak on some of the spectra presented here. Of course, one should be cautions with this later point because in the present work we have a limited set of eigth spectra and, in addition, the role of the rotational modulation should not be excluded. Two CaII K&H observations for HD 112989, carried out on July 14, 1997 and July 2, 1998 were supported with simultaneous UBV measurements. The first one (July 14, 1997) revealed an absence of CaII K&H emission core when the star was in a brighter state (V = $5.^{m}27$). This result is in agreement with the standard predictions of a "quiet" chromosphere above the spots free areas in the photosphere. In the second one (July 2, 1998) the star was observed in a lower brightness state, corresponding to the presence of a spot area on its surface. The relevant CaII K&H spectrum exhibited very weak emission core. This fact might be due to the drag effect of the magnetic loops in the star's atmosphere. The effect could occur in the old active regions after several rotational turnovers of the star.

The rotational velocity v sin i = 11.0 kms^{-1} is five time larger than the mean v sin i presented by giant stars located in the same G spectral region, indicating that this star appears to violate the general rule of low rotation for a late-type giant. As shown by De Medeiros et al. (1996) late G giants have a mean v sin i of about 2.1 kms^{-1}. Another interesting aspect related to the somewhat high rotation of HD 112989, comes from the radial velocity measurements, from which we have found no sign of variability, showing a single behavior for this star.

Indeed, such single status for HD 112989 represents an additional difficulty for the interpretation of the nature of this star because the evolutionary status of rapidly rotating single giants can be considered essentially unknown. However, the unusually low $^{12}C/^{13}C$ ratio of about 3.4 (Tomkin et al. 1976), indicating that this giant is very probably a fairly evolved well-mixed star, can perhaps represent a clue for the origin of its abnormal rota-

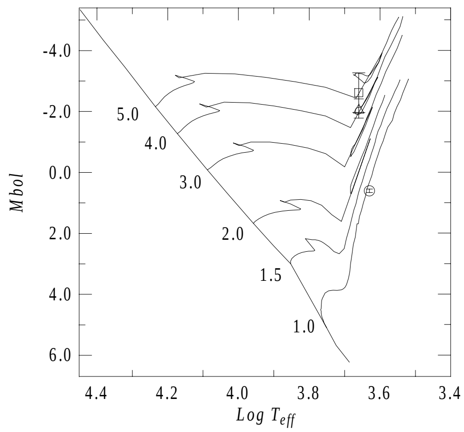

Fig. 5. The location of HD 112989 in the log(T_{eff})–M_{bol} diagram. The triangle stands for the estimation from the present work, the circle indicates the one on the basis of the data from Cayrel De Strobel et al. (1985) and the square is based on Hypparcos data

tion. As proposed by Simon & Drake (1989) the rapid rotation of giant stars evolving on their first crossing may be due to a sudden dredge-up of angular momentum from the interior as their convective zones advance upon more rapidly rotating regions in the radiative core of the star. By considering HD 112989 as a fairly evolved well-mixed star, one can certainly assume that such star has a well developed convective zone. In this context, a dredge-up of angular momentum from the interior is an interesting scenario to explain its high rotational velocity. But the question of how long single giants maintain their faster rotation still remains open. One should expect that they have to spin–down in a relatively short time scale because of the magnetic braking effect. It seems that HD 112989 maintains its faster rotation for a longer time.

A study of the star's evolutionary status was carried out with an indication of the location of HD 112989 on the H–R diagram. The evolutionary tracks by Schaller et al. (1992) for solar chemical composition were used. M_v was taken from Wilson's survey (Wilson, 1976), whereas T_{eff} and [Fe/H] were taken from Brown et al. (1989). The M_{bol} calculation was done by using the standard procedure given by Allen (1973). The star is situated near the 4 $M_\odot$ evolutionary track either in the He–burning region or on the red giant branch (RGB). For more clarification of its evolutionary status we used information for the $^{12}C/^{13}C$ ratio and CNO abundances from Tomkin et al. (1976), Sneden et al. (1978) and Lambert & Ries (1981). Clearly HD 112989 has peculiar surface chemical abundances. Its $^{12}C/^{13}C$ value is extremely low –3.4 and, in addition, this star is also nitrogen rich. Lambert & Ries supposed that HD 112989 was a weak G–band star, which indicates that the star either was formed from carbon–poor interstellar matter or has a rather special evolution. The present analysis shows that this giant seems to be evolved at least after the first dredge–up phase. These speculations are consistent with the star's motions reported by Eggen (1974), from which HD 112989 is a very young–disk field star.

We also examined the data for HD 112989 published by Cayrel De Strobel et al. (1985). Their M_{bol} and T_{eff} values, as well the [Fe/H] value differ significantly from the ones reported by the authors mentioned above. In the light of their results the object appear to be a moderately metal-deficient low-mass star. Using the evolutionary tracks for metal-poor stars, presented in Schaller et al. (1992) we found that this star is situated high on the RGB, approximately on the 1 $M_\odot$ evolutionary track. This result is inconsistent with the luminosity class reported by different authors as well as with the very young-disk population membership found by Eggen (1974).

Finally, by using the Hipparcos parallax for HD 112989 we have calculated a M_{bol} of -2.^{m}62 with a significant uncertainty of $\pm$0.^{m}65 due to the parallax standard error, indicating a location on the 5 $M_\odot$ evolutionary track, slightly after the base of the RGB. This scenario is consistent with our estimation of the evolutionary stage of HD 112989, in contrast with the one derived from Cayrel De Strobel et al. data. The results of this study are presented in Fig. 5.

In our opinion, HD 112989 is probably an intermediate-mass star, evolving after the base of the RGB, with a peculiar evolutionary history. There may exist a connection between the evolutionary history and the unusual fast rotation and activity observed in this fairly evolved single giant star.

4. Conclusions

The present spectroscopic study shows a CaII K&H emission core variability for HD 112989. In addition, the UBV photometric results confirm a variable brightness, showing also events which seems to indicate the existence of flares on this star. The somewhat high rotational velocity of about 11.0 kms^{-1} is unusual for its spectral type. The radial velocity spectroscopic measurements show no variability, indicating a single status for HD 112989. Finally, an analysis of its evolutionary behavior shows that this star is very probably an intermediate-mass giant evolving after the base of the RGB. This is in agreement with the well-mixed behavior inferred from the observed surface abundances.

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