ISO-SWS calibration and the accurate modelling of cool-star atmospheres *

IV. G9 – M2 stars: APPENDIX

L. Decin1, B. Vandenbussche1, C. Waelkens1, G. Decin1, K. Eriksson2, B. Gustafsson2, B. Plez3, and A.J. Sauval4

1 Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200B, B-3001 Leuven, Belgium
2 Institute for Astronomy and Space Physics, Box 515, S-75120 Uppsala, Sweden
3 GRAAL - CC72, Université de Montpellier II, F-34095 Montpellier Cedex 5, France
4 Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180 Bruxelles, Belgium

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Abstract. A detailed spectroscopic study of 11 giants with spectral type from G9 to M2 is presented. The 2.38 – 4.08 µm wavelength-range of band 1 of ISO-SWS (Short-Wavelength Spectrometers on board of the Infrared Space Observatory) in which many different molecules — with their own dependence on each of the stellar parameters — are absorbing, enables us to estimate the effective temperature, the gravity, the microturbulence, the metallicity, the CNO-abundances, the $^{12}$C/$^{13}$C-ratio and the angular diameter from the ISO-SWS data. Using the Hipparcos’ parallax, the radius, luminosity and gravity-inferred mass are derived. The stellar parameters obtained are in good agreement with other published values, though also some discrepancies with values deduced by other authors are noted. For a few stars ($δ$ Dra, $ξ$ Dra, $α$ Boo, $α$ Tuc, $H$ Sco and $α$ Cet) some parameters — e.g. the CNO-abundances — are derived for the first time. By examining the correspondence between different ISO-SWS observations of the same object and between the ISO-SWS data and the corresponding synthetic spectrum, it is shown that the relative accuracy of ISO-SWS in band 1 (2.38 – 4.08 µm) is better than 2% for these high-flux sources. The high level of correspondence between observations and theoretical predictions, together with a confrontation of the estimated $T_{eff}$ (ISO) value with $T_{eff}$ values derived from colours — which demonstrates the consistency between $V – K$, $BC_K$, $T_{eff}$ and $θ_d$ derived from optical or IR data — proves that both the used MARCS models to derive the stellar quantities and the flux calibration of the ISO-SWS detectors have reached a high level of reliability.

Key words. Infrared: stars – Stars: atmospheres – Stars: late-type – Stars: fundamental parameters – Stars: individual: $δ$ Dra, $ξ$ Dra, $α$ Boo, $α$ Tuc, $β$ UMi, $γ$ Dra, $α$ Tau, $H$ Sco, $β$ And, $α$ Cet, $β$ Peg

Appendix A: Calibration accuracy and precision

In the following subsections, each of the 11 cool giants will be discussed individually. For each star, calibration details are specified. These, in conjunction with the general calibration specifications discussed in Paper II, gives us an idea on the calibration accuracy. If other AOT01 observations are available, they are compared with each other in order to assess the calibration precision of ISO-SWS. Note that when the ratio of two observations is shown, the observation with the highest speed number (= the highest resolving power) is rebinned to the resolution of the observation with the lowest speed number.

A.1. $δ$ Dra: AOT01, speed 4, revolution 206

A.1.1. Some specific calibration details

When looking to the spectrum, before it was multiplied with the factors given in Table 3 in Decin et al. (2002a), hereafter referred to as Paper II, one could notice that the subsequent sub-bands of band 1 lie always somewhat number. The observing data can be calculated from the revolution number which is the number of days after 17 November 1995.

Send offprint requests to: L. Decin, e-mail: Leen.Decin@ster.kuleuven.ac.be

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1 Each observation is determined uniquely by its observation number, in which the first three digits represent the revolution number. The observing data can be calculated from the revolution number which is the number of days after 17 November 1995.
lower than the previous one. The pointing offset in the z-direction is quite large ($dz = 1.48''$).

A.1.2. Comparison with other observations (Fig. A.1)

During revolution 072, $\delta$ Dra was observed with the AOT01 speed-4 option. Also for this observation, the subsequent sub-bands lie somewhat lower than the previous one. As for the other speed-4 observation, the pointing offset in the z-direction is $> 1''$. The data of the speed-4 observation, taken during revolution 072, have been divided by a factor 1.115.

An AOT01 speed-1 observation has been taken of $\xi$ Dra. Unfortunately, the pointing offset of this observation was approximately as large as for the speed-3 observation ($dy = -0.560''$, $dz = -1.403''$). The data of bands 1A and 1B were multiplied with a factor 1.04 and 1.03 respectively. The general correspondence between the two observations is not so good at the end of band 1E and around 2.8 $\mu$m, can one see a small difference in shape probably arising from the pointing difference. The absolute flux level differs by $\sim 11\%$, with observation 07201132 having the highest flux level.

A.2. $\xi$ Dra: AOT01, speed 3, revolution 314

A.2.1. Some specific calibration details

The AOT01 speed-3 observation of $\xi$ Dra was quite difficult to calibrate. The larger noise for a speed-3 observation (compared to a speed-4 observation) together with the large pointing offset result in a spectrum, after application of the standard calibration process, being more uncertain than for other observations. Therefore a speed-1 observation, in conjunction with a post-helium observation (see next paragraph) were used to obtain an optimally well calibrated spectrum.

A.2.2. Comparison with other observations (Fig. A.2)

An AOT01 speed-1 observation has been taken of $\xi$ Dra. Unfortunately, the pointing offset of this observation was approximately as large as for the speed-3 observation ($dy = -0.560''$, $dz = -1.403''$). The data of bands 1A and 1B were multiplied with a factor 1.04 and 1.03 respectively. The general correspondence between the two observations is not so good at the end of band 1A, in band 1B and band 1D. The flux of the speed-1 observation lies $\sim 9\%$ higher than the flux of the speed-4 observation (Fig. A.2).

Once ISO had run out off helium, the Short-Wavelength Spectrometer still has been operated during some 30 days. The observing programme aimed at obtaining 2.4 – 4 $\mu$m scans at the full grating resolution of stars spanning the whole MK spectral classification scheme, i.e. to extend this classification to the infrared.
ξ Dra was among the targets observed then. The pointing was far more better, being dy = 0.004′′ and dz = −0.073′′. Although the calibration still has not reached its final stage, these data are already very useful to study the strength of the spectral features at a resolving power of ∼ 1500. The overall spectrum lies ∼ 1% higher than the speed-3 observation. The data of bands 1A and 1B are shifted upwards by 5% and 4% respectively. The comparison between the speed-3 observation (revolution 314) and the post-He observation (revolution 887) of ξ Dra is shown in the middle and bottom panel of Fig. A.2. The same differences as seen in the comparison with the speed-1 observation can also be seen now. The confrontation with its synthetic spectrum (see next paragraph), with the speed-1 observation and with the post-He data indicates clearly that the final calibrated spectrum of ξ Dra of revolution 314 is still not so reliable.

A.3. α Boo: AOT01, speed 4, revolution 452

A.3.1. Some specific calibration details

The AOT01 speed-4 observation of α Boo was of very high quality. The shifts for the different sub-bands of band 1 show the same trend as most of the observations: the band-1B flux has to be multiplied by a factor ≤ 1.02 and the band-1E flux by a factor ≤ 1.01.

A.3.2. Comparison with other observations (Fig. A.3)

α Boo has been observed a few times with SWS. In revolution 056, 244, 275 and 641 a speed-1 observation was taken. In revolution 071, α Boo was observed with the AOT01 speed-4 option. Observation 2440266 and 64100101 were corrupted. The known pointing offsets of the two other speed-1 observations are dy = 0.703′′ and dz = 2.412′′ for observation 05601291, and dy = 0.667′′ and dz = −0.197′′ for observation 27503811. In the upper panel of Fig. A.3, the data of band 1A, 1B and 1E of observation 27503811 are multiplied by 0.965, 0.985 and 1.01 respectively. The data of the sub-bands 1A and 1B of observation 05601291 are multiplied by 0.98 and 1.005 respectively.

The speed-4 observation taken during revolution 071 displays a scan jump 3415 s after the start of the observation. The spectrum is therefore (more) suspicious around 3.05 μm. The pointing offset of this observation was dy = 0.269′′ and dz = 2.561′′. The data of band 1A and band 1B are multiplied by 0.95 and 0.97 respectively. The flux of the overall spectrum is ∼ 5% lower than for the observation taken during revolution 452.

The correspondence between the different observations is satisfactory taking into account the pointing offsets, the lower signal-to-noise of the speed-1 observations and the less accurate flux calibration at the band edges.

A.4. α Tuc: AOT01, speed 4, revolution 866

A.4.1. Some specific calibration details

Just as for α Boo, this speed-4 AOT01 observation was of very high quality. The data of band 1B were shifted upwards by 2% and the data of band 1E by 1%. The standard deviations after rebinning are similar to the ones given for α Tau in Fig. 6 in Paper I. Just as for α Cen A (Paper III), α Tuc belongs to a binary system. Its companion is however too far away to influence the ISO-SWS spectrum of α Tuc.

A.5. β UMi: AOT01, speed 4, revolution 182
A.5.1. Some specific calibration details

As for most of the stars in the sample, the data of both band 1B and band 1E are shifted upwards, by 1.5% and 1% respectively. The pointing offset is $>1''$ in the y-direction. No correction is made at this moment, since the beam profiles are still not available.

![Fig. A.4. Comparison between the AOT01 speed-4 observation of $\beta$ UMi (revolution 182) and the speed-2 observation (revolution 079). The data of the speed-2 observation are divided by a factor 1.065.](image)

A.5.2. Comparison with other observations (Fig. A.4)

$\beta$ UMi has also been observed with the speed-2 option during revolution 079. The pointing was not optimal, with offsets being $dy = 0.780''$ and $dz = -2.360''$. The band-1A and band-1B data are divided by 1.025 and 1.015 respectively, and the flux level of the overall spectrum is $\sim 6.5$% higher than for the speed-4 observation (Fig. A.4). Despite the low signal-to-noise of a speed-2 observation, the two observations agree quite well.

A.6. $\gamma$ Dra: AOT01, speed 4, revolution 377

A.6.1. Some specific calibration details

$\gamma$ Dra is one of the main calibration sources of the Short-Wavelength Spectrometer. The pointing of the AOT01 speed-4 observation was not optimal, being $dy = -0.304''$ and $dz = 0.181''$. The shifts of the different sub-bands of band 1 are all within 0.5%.

A.6.2. Comparison with other observations (Fig. A.5)

Several observations were taken of $\gamma$ Dra. During revolution 040 a speed-4 observation was taken, pointing offsets being $dy = -2.440''$ and $dz = -0.259''$. The data of band 1A and band 1B are multiplied by 1.015 and 1.01 respectively. Two speed-1 observations were taken during revolution 126 and revolution 496, the first one with a pointing offset of $dy = -0.586''$ and $dz = 1.320''$ and the latter one with $dy = 0.009''$ and $dz = 0.009''$. For observation 12601315 the band-1A and band-1B data are shifted down by 2% with the absolute flux level being 4% higher than for observation 37704637. The band-1A and band-1B data are
shifted upwards by 1\% and 1.5\% respectively for observation 49603004. This latter observation lies 5\% higher than observation 37704637.

Another (last) AOT01 observation of γ Dra was taken during revolution 811 with the speed-2 option. Pointing offsets were \(dy = 0.020''\) and \(dz = 0.019''\). The band-1A and band-1B data need however to be multiplied by quite a large factor: 1.05 and 1.065 respectively. The reason for this jump is maybe pointing jitter when moving from one aperture to another. The shape and the spectral features of the different observations are in good agreement.

A.7. α Tau: AOT01, speed 4, revolution 636

α Tau has been discussed in Decin et al. (2000).

A.8. H Sco: AOT01, speed 4, revolution 847

A.8.1. Some specific calibration details

Two remarks again have to be made for HD 149447. First, band 1B is shifted upwards by 1.5\%, secondly, no pointing errors were measured.

A.9. β And: AOT01, speed 4, revolution 795

A.9.1. Some specific calibration details

The speed-4 observation of β And was of very high quality. Only the data of band 1E had to be shifted upwards, by 0.5\%. No pointing offsets were measured in the y and z-direction.

A.9.2. Comparison with other observations

In conjunction with the speed-4 observation, there are also a speed-3 (revolution 440) and a speed-2 (revolution 423) observation available. For both observations, the pointing offset in the z-direction is smaller than in the y-direction. For observation 44004605, \(dy = -0.229''\) and \(dz = 0.096''\), while for observation 42301404 \(dy = 0.038''\) and \(dz = -0.15''\). For the speed-3 observation, the data of band 1A and band 1B are divided by 1.025 and 1.01 respectively, while the data of band 1E are multiplied by 1.015, with the total flux being 3\% lower than for the speed-4 observation. The flux of band 1A and band 1B of the speed-2 observation was, respectively, 3\% and 2\% higher than the flux of band 1D; band 1E is shifted upwards by 1\%. The total flux level of this speed-2 observation is 4\% lower than for the speed-4 observation. The shapes of the different sub-bands in band 1 for the three observations of β And do agree very well (Fig. A.6).

A.10. α Cet: AOT01, speed 4, revolution 797

A.10.1. Some specific calibration details

The speed-4 observation of α Cet, taken at the end of the nominal phase of ISO-SWS, did not suffer from a pointing offset. As for most of the other observations in the sample, the data of band 1E were shifted upwards by 0.5\%.

A.10.2. Comparison with other observations

A second speed-4 observation of α Cet was made by SWS only nine revolutions after the first observation. The same calibration remarks do also apply for the observation of revolution 806 (almost no pointing offset and the data of band 1E are multiplied by a factor 1.005). Since the same time-dependent calibration files are used for these two observations, they form a good test-vehicle for the stability during this calibration period and for the flux uncertainty. Good agreement is found. The ratio of the two spectra is shown in Fig. A.7. The strongest peaks in the lowest plot in Fig. A.7 correspond to the strongest CO-peaks in the uppermost plot. A (very) small difference in pointing causes this effect.
A.11. $\beta$ Peg: AOT01, speed 4, revolution 551

A.11.1. Some specific calibration details

$\beta$ Peg has been observed in almost optimal conditions. The pointing offset was $dy = 0.017''$ and $dz = 0.095''$. The band-1B data are multiplied by 1.015 and the band-1E data by 1.005.

A.11.2. Comparison with other observations

Two speed-1 observations and one speed-3 observation were also made from $\beta$ Peg. The speed-3 observation was taken during revolution 206 with pointing offset $dy = 0.35''$ and $dz = -0.76''$. No band shifts were applied and the overall flux level is 2\% higher than for the speed-4 observation. The two speed-1 observations were taken during revolution 206 and 056, with pointing offsets being $dy = 0.45''$ and $dz = -0.69''$ and $dy = 0.18''$ and $dz = 1.46''$ respectively. The larger pointing offset for this latter observation results in a shift upwards of the different sub-bands by 2\% for the data of band 1A and band 1B and by 1.5\% for band 1E. The speed-1 observation from revolution 206 (056) lies 2\% (4\%) higher than the speed-4 observation. The overall agreement between the different AOT01 observations is very good (Fig. A.8).

The two observations taken during revolution 206 are once more an indication for the flux calibration precision. The ratio of the speed-3 observation (rebinned to the resolution of a speed-1 observation) to the speed-1 observation is displayed in Fig. A.9 and proves a flux accuracy of $\sim 2\%$. 

Fig. A.7. Top: Comparison between the AOT01 speed-4 observation of $\alpha$ Cet (revolution 797) and the speed-4 observation (revolution 806). Bottom: The AOT01 speed-4 observation of $\alpha$ Cet taken during revolution 797 is divided by the AOT01 speed-4 observation of $\alpha$ Cet taken during revolution 806.

Fig. A.8. Top: Comparison between the AOT01 speed-4 observation of $\beta$ Peg (revolution 551) and the speed-3 observation (revolution 206). The data of the speed-3 observation are divided by 1.02. Middle: Comparison between the AOT01 speed-4 observation of $\beta$ Peg (revolution 551) and the speed-1 observation (revolution 206). The data of the speed-1 observation are divided by 1.02. Bottom: Comparison between the AOT01 speed-4 observation of $\beta$ Peg (revolution 551) and the speed-1 observation (revolution 056). The data of the speed-1 observation are divided by 1.04.

Fig. A.9. Ratio of a speed-3 observation of $\beta$ Peg to a speed-1 observation of $\beta$ Peg. Both observations were taken during revolution 206.
Appendix B: Comparison between the ISO-SWS and synthetic spectra (coloured plots)

In this section, Fig. ?? – Fig. ?? of the accompanying article are plotted in colour in order to better distinguish the ISO-SWS data and the synthetic spectra.

![Graph](image1)

**Fig. B.1.** Comparison between band 1 and band 2 of the ISO-SWS data of δ Dra (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4820$ K, $\log g = 2.70$, $M = 2.2 M_\odot$, $[\text{Fe/H}] = 0.00$, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 12, $\varepsilon$(C) = 8.15, $\varepsilon$(N) = 8.26, $\varepsilon$(O) = 8.93 and $\theta_d = 3.30$ mas.

![Graph](image2)

**Fig. B.2.** Comparison between band 1 of the ISO-SWS data (rev. 206) of δ Dra (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4820$ K, $\log g = 2.10$, $M = 2.8 M_\odot$, $[\text{Fe/H}] = 0.00$, $\xi_t = 1.7$ km s$^{-1}$, $^{12}$C/$^{13}$C = 12, $\varepsilon$(C) = 8.00, $\varepsilon$(N) = 8.26, $\varepsilon$(O) = 8.83 and $\theta_d = 3.31$ mas.

![Graph](image3)

**Fig. B.3.** Comparison between band 1 and band 2 of the ISO-SWS data (rev. 314) of ξ Dra (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4440$ K, $\log g = 2.40$, $M = 1.2 M_\odot$, $[\text{Fe/H}] = 0.10$, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 20, $\varepsilon$(C) = 8.00, $\varepsilon$(N) = 8.26, $\varepsilon$(O) = 8.93 and $\theta_d = 3.11$ mas.
Fig. B.4. Comparison between band 1 of the post-helium ISO-SWS data of ξ Dra (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4440\, \text{K}$, $\log g = 2.40$, $M = 1.2\, \text{M}_\odot$, $\text{[Fe/H]} = 0.10$, $\xi_t = 2.0\, \text{km s}^{-1}$, $^{12}\text{C}/^{13}\text{C} = 20$, $\varepsilon(\text{C}) = 8.00$, $\varepsilon(\text{N}) = 8.26$, $\varepsilon(\text{O}) = 8.93$ and $\theta_d = 3.125\, \text{mas}$.

Fig. B.5. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 452) of α Boo (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4320\, \text{K}$, $\log g = 1.50$, $M = 0.75\, \text{M}_\odot$, $\text{[Fe/H]} = -0.50$, $\xi_t = 1.7\, \text{km s}^{-1}$, $^{12}\text{C}/^{13}\text{C} = 7$, $\varepsilon(\text{C}) = 7.96$, $\varepsilon(\text{N}) = 7.61$, $\varepsilon(\text{O}) = 8.68$, $\varepsilon(\text{Mg}) = 7.33$, $\varepsilon(\text{Si}) = 7.20$ and $\theta_d = 20.72\, \text{mas}$.

Fig. B.6. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 866) of α Tuc (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4300\, \text{K}$, $\log g = 1.35$, $M = 1.3\, \text{M}_\odot$, $\text{[Fe/H]} = 0.00$, $\xi_t = 1.7\, \text{km s}^{-1}$, $^{12}\text{C}/^{13}\text{C} = 13$, $\varepsilon(\text{C}) = 8.30$, $\varepsilon(\text{N}) = 8.26$, $\varepsilon(\text{O}) = 8.93$ and $\theta_d = 6.02\, \text{mas}$.
**Fig. B.7.** Comparison between band 1 and band 2 of the ISO-SWS data (rev. 182) of $\beta$ UMi (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 4085$ K, $\log g = 1.60$, $M = 2.50$ M$_{\odot}$, [Fe/H] = $-0.15$, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 9, $\varepsilon$(C) = 8.25, $\varepsilon$(N) = 8.16, $\varepsilon$(O) = 8.83 and $\theta_d = 9.93$ mas.

**Fig. B.8.** Comparison between band 1 and band 2 of the ISO-SWS data (rev. 377) of $\gamma$ Dra (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 3960$ K, $\log g = 1.30$, $M = 1.7$ M$_{\odot}$, [Fe/H] = 0.00, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 10, $\varepsilon$(C) = 8.15, $\varepsilon$(N) = 8.26, $\varepsilon$(O) = 8.93 and $\theta_d = 9.98$ mas.

**Fig. B.9.** Comparison between band 1 and band 2 of the ISO-SWS data (rev. 847) of H Sco (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 3900$ K, $\log g = 1.30$, $M = 2.0$ M$_{\odot}$, [Fe/H] = 0.00, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 8, $\varepsilon$(C) = 8.20, $\varepsilon$(N) = 8.26, $\varepsilon$(O) = 8.83 and $\theta_d = 4.73$ mas.

**Appendix C: Temperatures derived from $V-K$ colours**

This section contains the coloured version of Fig. ?? of the accompanying paper.

**Appendix D: Literature study**

**D.1. Summary tables**

For each of the 11 cool stars in our sample, a summary table of the assumed and deduced stellar parameters retrieved from the various quoted references in the accompanying paper can be found in this subsection. The tables have been sorted by spectral type.
Fig. B.10. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 795) of $\beta$ And (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 3880$ K, $\log g = 0.95$, $M = 2.5 M_\odot$, $[\text{Fe/H}] = 0.00$, $\xi_t = 2.0$ km s$^{-1}$, $^{12}\text{C}/^{13}\text{C} = 9$, $\varepsilon(\text{C}) = 8.12$, $\varepsilon(\text{N}) = 8.37$, $\varepsilon(\text{O}) = 9.08$ and $\theta_d = 13.30$ mas.

Fig. B.11. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 797) of $\alpha$ Cet (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 3740$ K, $\log g = 0.95$, $M = 2.7 M_\odot$, $[\text{Fe/H}] = 0.00$, $\xi_t = 2.3$ km s$^{-1}$, $^{12}\text{C}/^{13}\text{C} = 10$, $\varepsilon(\text{C}) = 8.20$, $\varepsilon(\text{N}) = 8.26$, $\varepsilon(\text{O}) = 8.93$ and $\theta_d = 12.52$ mas.
Fig. B.12. Panel (A): Comparison between band 1 of the ISO-SWS data (rev. 551) of β Peg (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 3590$ K, log $g = 1.50$, $M = 1.7\ M_\odot$, [Fe/H] = 0.00, $\xi_t = 2.3$ km s$^{-1}$, $^{12}$C/$^{13}$C = 7, $\varepsilon(C) = 8.56$, $\varepsilon(N) = 8.24$, $\varepsilon(O) = 9.03$ and $\theta_d = 16.88$ mas. Panel (B): Comparison between band 1 of the ISO-SWS data (rev. 551) of β Peg (black) and the synthetic spectrum (red) with stellar parameters $T_{\text{eff}} = 3600$ K, log $g = 0.65$, $M = 2\ M_\odot$, [Fe/H] = 0.00, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 5, $\varepsilon(C) = 8.20$, $\varepsilon(N) = 8.18$, $\varepsilon(O) = 8.93$ and $\theta_d = 16.60$ mas. Panel (C): ISO-SWS observational data (rev. 551) of β Peg divided by the synthetic spectrum with the same parameters as in panel (B).

Fig. C.1. Comparison between $T_{\text{eff}}(V - K)$ derived from the relationship given by Ridgway et al. (1980), Beneditto (1993), Beneditto (1998) or Bessell et al. (1998), $T_{\text{eff}}(K_0, BC_K, \pi)$ and the effective temperature deduced from the ISO-SWS spectra.
Table D.1. Literature study of δ Dra, with the effective temperature $T_{\text{eff}}$ given in K, the mass M in $\text{M}_\odot$, the microturbulent velocity $\xi_t$ in km/s, the angular diameter $\theta_d$ in mas, the luminosity L in $\text{L}_\odot$ and the radius R in $\text{R}_\odot$. Angular diameters deduced from direct measurements (e.g. from interferometry) are written in italic, while others (e.g. from spectrophotometric comparisons) are written upright. Assumed or adopted values are given between parentheses. The results of this research are mentioned in the last line. A short description of the methods and/or data used by the several authors can be found in Sect. D.2.

| $T_{\text{eff}}$ | log g | M | $\xi_t/\text{km/s}$ | $[\text{Fe/H}]$ | $\epsilon$(C) | $\epsilon$(N) | $\epsilon$(O) | $^{12}\text{C}/^{13}\text{C}$ | $\theta_d$ | L | R | Ref. |
|-----------------|-------|----|----------------------|----------------|------------|------------|------------|------------------|----------|---|---|------|
| 4940            | 4.00  | 2.7 | 1.7                  | −0.09          | −0.08      | 8.26 ± 0.20 | 8.00 ± 0.30 | 8.74 ± 0.20     | 81       |    |    | 1. |
| 4940 ± 50       | 2.85  | 0.25 | 0.10                 | 8.47 ± 0.18    | 8.00 ± 0.30 | 81       |    |    | 1. |
| 4910            | 2.4   | 1.7 | (1.7)                | −0.08          | −0.07      | 8.55      | 8.36      | 8.70             | 13       |    |    | 1. |
| 4910 ± 60       | 2.10  | 0.15 | 2.4 ± 0.1            | −0.14          | −0.27 ± 0.12 | 3.8 ± 0.3  | 15 ± 4     | 13       |    |    | 1. |
| 4930 ± 120      | (2.10) | 2.9 | (2.4)                | −0.14          | −0.27 ± 0.12 | 3.8 ± 0.3  | 15 ± 4     | 13       |    |    | 1. |
| 4910 ± 200      | 2.98  | 0.27 | 2.0 ± 0.5            | 8.55 ± 0.25    | 8.26 ± 0.25 | 8.93 ± 0.25 | 12 ± 3     | 3.30 ± 0.20     | 58 ± 10  | 10.90 ± 0.68 | 14. |
| 4793 ± 50       | 2.70  | 0.20 | 2.18 ± 1.04          | 8.15 ± 0.25    | 8.26 ± 0.25 | 8.93 ± 0.25 | 12 ± 3     | 3.30 ± 0.20     | 58 ± 10  | 10.90 ± 0.68 | 14. |

1. van Paradijs (1973); 2. Gustafsson et al. (1974); 3. van Paradijs & Kester (1976); 4. Linsky & Ayers (1973); 5. Bonnell & Bell (1984); 6. Gratton et al. (1982); 7. Burnashev (1984); 8. Faucher et al. (1983); 9. Gratton (1984); 10. Brown et al. (1989); 11. McWilliam (1990); 12. Blackwell & Lynas-Gray (1998); 13. Taylor (1999); 14. present results

Table D.2. See caption of Table D.1 but now for ξ Dra.

| $T_{\text{eff}}$ | log g | M | $\xi_t/\text{km/s}$ | $[\text{Fe/H}]$ | $\epsilon$(C) | $\epsilon$(N) | $\epsilon$(O) | $^{12}\text{C}/^{13}\text{C}$ | $\theta_d$ | L | R | Ref. |
|-----------------|-------|----|----------------------|----------------|------------|------------|------------|------------------|----------|---|---|------|
| 4270 ± 150      | 2.5   | 0.3 | 1.5 ± 1.5            | 0.11 ± 0.12    | 20 ± 2     | 40         | 14         | 1. |
| 4470            | 2.42  | 0.15 | 2.3                   | −0.12 ± 0.14   | -0.36      | 3.076 ± 0.060 | 5. |
| 4510 ± 60       | 2.34  |    | (1)                   | +0.05          | 3.025 ± 0.060 | 7. |
| 4450 ± 45       | 2.61  | 0.30 | 1.9 ± 0.5             | −0.09 ± 0.09   | 20 ± 5     | 3.11 ± 0.22 | 46 ± 14     | 11. |
| 4420 ± 200      | 2.61  | 0.30 | 1.9 ± 0.5             | −0.09 ± 0.09   | 20 ± 5     | 3.11 ± 0.22 | 46 ± 14     | 11. |
| 4525 ± 30       | 2.40  | 0.25 | 1.20 ± 0.71           | −0.03 ± 0.036  | 8.00 ± 0.30 | 8.26 ± 0.40 | 8.93 ± 0.30 | 12 ± 3     | 3.30 ± 0.20     | 58 ± 10  | 10.90 ± 0.68 | 14. |
| 4495 ± 40       | 2.40  | 0.25 | 1.20 ± 0.71           | −0.03 ± 0.036  | 8.00 ± 0.30 | 8.26 ± 0.40 | 8.93 ± 0.30 | 12 ± 3     | 3.30 ± 0.20     | 58 ± 10  | 10.90 ± 0.68 | 14. |

1. Gustafsson et al. (1974); 2. Dearborn et al. (1975); 3. Gratton et al. (1982); 4. Gratton (1983); 5. Brown et al. (1989); 6. Blackwell et al. (1990); 7. McWilliam (1990); 8. Blackwell et al. (1991); 9. Blackwell & Lynas-Gray (1998); 10. Taylor (1999); 11. present results
Table D.3. See caption of Table D.1, but now for α Boo.

| T\(_{\text{eff}}\) | log g | M  | \(\xi_d\) | [Fe/H] | \(\epsilon(\text{C})\) | \(\epsilon(\text{N})\) | \(\epsilon(\text{O})\) | \(^{12}\text{C}/^{13}\text{C}\) | \(\theta_d\) | L  | R  | Ref |
|--------------|-----|----|------|------|----------------|----------------|----------------|----------------|-------|----|----|-----|
| 4350 ± 50    | 1.95 ± 0.27 | 0.1-0.6 | 1.8 | −0.5 | 7.81 ± 0.17 | 7.03 ± 0.15 | 8.23 ± 0.17 | (23) | 229 ± 100 | 28 ± 6 | 1.  |
| 4260 ± 50    | 1.90 ± 0.35 | 0.1-0.6 | 1.8 | −0.5 | 7.81 ± 0.17 | 7.03 ± 0.15 | 8.23 ± 0.17 | (23) | 229 ± 100 | 28 ± 6 | 2.  |
| 4410 ± 50    | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4240         | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4400 ± 50    | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4490 ± 50    | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4350         | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4205 ± 50    | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4375 ± 50    | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4490 ± 200   | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4375         | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |
| 4490 ± 200   | 2.01 ± 0.46 | (1.6) | 1.8 | −0.56 ± 0.07 | 8.07 ± 0.06 | 7.60 ± 0.07 | 8.76 ± 0.06 | (7) | 19.99 ± 0.40 | 7.  |

1. van Paradijs & Meurs (1974): 2. Mackle et al. (1975): 3. Blackwell & Shallis (1977): 4. Linsky & Ayres (1978): 5. Scargle & Strecker (1979): 6. Blackwell et al. (1980): 7. Lambert et al. (1981): 8. Lambert & Ries (1981): 9. Manduca et al. (1981): 10. Tsuji (1981): 11. Frisk et al. (1982): 12. Kjærgaard et al. (1983): 13. Burnashev (1983): 14. Harris & Lambert (1984): 15. Bell et al. (1985): 16. Gratton (1986): 17. Moon (1986): 18. Judge (1986): 19. Kyröläinen et al. (1986): 20. Tsuji (1986): 21. Altas (1987): 22. H. Benedetto & Rabbia (1987): 23. Edvardsson (1988): 24. Harris et al. (1988): 25. Bell & Gustafsson (1989): 26. Brown et al. (1989): 27. Volk & Cohen (1989): 28. Fernández-Villacanas et al. (1990): 29. McWilliam (1990): 30. Blackwell et al. (1991): 31. Judge & Stencel (1991): 32. Tsuji (1991): 33. Engelke (1992): 34. Bonnell & Bell (1993): 35. Peterson et al. (1993): 36. Gadun (1994): 37. Cohen et al. (1996): 38. Quirrenbach et al. (1996): 39. Aoki & Tsuji (1997): 40. Pilachowski et al. (1997): 41. H. Benedetto (1998): 42. Dyck et al. (1998): 43. Hammer et al. (1998): 44. Perrin et al. (1998): 45. Taylor (1999): 46. present results
Table D.4. See caption of Table D.1 but now for α Tuc.

| $T_{\text{eff}}$ | log g  | M    | $\xi_t$ | [Fe/H] | $\epsilon$(C) | $\epsilon$(N) | $\epsilon$(O) | $^{12}$C/$^{13}$C | $\theta_d$ | L  | R  | Ref |
|-----------------|--------|------|---------|--------|---------------|---------------|---------------|----------------|----------|-----|-----|-----|
| 4040            | 6.45   | 1.1  | 0.50    | 3.7    | 0.36          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4040 ± 70       | 3.7    | 6.45 | 0.50    | 3.7    | 0.36          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 3920 ± 250      | 1.10   | 1.15 | 0.35    | 1.10   | 1.15          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4300 ± 140      | 1.35   | 1.27 | 0.48    | 1.35   | 1.27          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |

Table D.5. See caption of Table D.1 but now for β UMi.

| $T_{\text{eff}}$ | log g  | M    | $\xi_t$ | [Fe/H] | $\epsilon$(C) | $\epsilon$(N) | $\epsilon$(O) | $^{12}$C/$^{13}$C | $\theta_d$ | L  | R  | Ref |
|-----------------|--------|------|---------|--------|---------------|---------------|---------------|----------------|----------|-----|-----|-----|
| 4000            | 1.2    | 1.2  | 1.2     | 1.2    | 1.2           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 3970            | 2.40   | 2.40 | 2.40    | 2.40   | 2.40          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4340 ± 100      | 1.86   | 2.00 | 0.25    | 1.86   | 2.00          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4220 ± 300      | 1.5    | 2.0  | 0.14    | 1.5    | 2.0           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4340 (4000)     | 1.6    | 2.4  | 0.30    | 1.6    | 2.4           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4030 ± 200      | 1.83   | 2.4  | 0.5     | 1.83   | 2.4           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4065 ± 80       | 1.6    | 1.5  | 0.5     | 1.6    | 1.5           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4060 ± 200      | 2.0    | 2.0  | 0.2     | 2.0    | 2.0           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4086 ± 225      | 2.0    | 2.0  | 0.2     | 2.0    | 2.0           |               | 6.1           |               | 4.52     | 4   | 1   | 1   |
| 4085 ± 140      | 1.60   | 2.49 | 0.92    | 1.60   | 2.49          |               | 6.1           |               | 4.52     | 4   | 1   | 1   |

1. Basri & Linsky (1973); 2. Stencel et al. (1980); 3. Glebocki & Stawickowski (1988); 4. Flynn & Mermilliod (1991); 5. Pasquini & Brocato (1992); 6. present results

1. Tomkin et al. (1976); 2. Linsky & Ayres (1978); 3. Lambert et al. (1980); 4. Stencel et al. (1980); 5. Lambert & Ries (1981); 6. Burnashev (1984); 7. Faucher et al. (1985); 8. Harris et al. (1985); 9. Bell & Gustafsson (1985); 10. Brown et al. (1985); 11. McWilliam (1990); 12. Judge & Stencel (1991); 13. Cornide et al. (1992); 14. Morossi et al. (1993); 15. Dyck et al. (1998); 16. Taylor (1999); 17. present results
Table D.6. See caption of Table D.4, but now for \( \gamma \) Dra.

| \( T_{\text{eff}} \) | \( \log g \) | \( M \) | \( \xi_t \) | \( \sqrt{V/V}\) [Fe/H] | \( \xi(C) \) | \( \xi(N) \) | \( \xi(O) \) | \( ^{12}\text{C}/^{13}\text{C} \) | \( \theta_d \) | \( L \) | \( R \) | \( \text{Ref.} \) |
|-----------------|----------|-----|---------|----------------------|---------|---------|---------|-----------------------|--------|------|------|------|
| 3780            | 1.5      | 1.3 ± 0.5 |         |                      | 13 ± 2  |         |         | 10.2 ± 0.43           | 263    |      |      | 1.   |
| 3820            | 1.6      | 2.2     | 0.33    | 0.69                 |         |         |         |                       |        |      |      | 2.   |
| 3950            | 0.4      | 2.2     | 0.12    |                      |         |         |         |                       |        |      |      | 4a.  |
| (3780)          | 1.8      |         |         |                      |         |         |         |                       |        |      |      | 4b.  |
| 4280 ± 100      | 1.55 ± 0.46 | 2.00 ± 0.25 | -0.23 ± 0.18 | 8.29 ± 0.15 | 8.06 ± 0.18 | 8.81 ± 0.18 | (13) | 8.7 ± 0.8 | 316 |      |      | 5.   |
| 4300 ± 200      | (1.87)   | 5       | (2.0)   | 8.42                 |         |         |         |                       |        |      |      | 6.   |
| (3980)          |         |         |         |                      |         |         |         |                       |        |      |      | 6.   |
| 3950 ± 100      | 1.35     | 2.0 [0.9] |         |                     | (13)    | 10.2 ± 0.3 | 900 ± 650 | 64 ± 23               | 8.     |      |      | 7.   |
| 3955            | (1.55)   |         |         |                     |         |         |         | 10.45                 |        |      |      | 10.  |
| 3940            | 1.3      | (1.7)   | 0.06    |                      |         |         |         | 10.2 ± 0.3            | (9.997)|      |      | 8.   |
| 3986            | 1.6 ± 0.2 | (1.87)  | (3.0)   | 0.00 ± 0.25          |         |         |         |                      |        |      |      | 14.  |
| 3930 ± 200      | 1.55 ± 0.30 | 2.2 ± 0.5 | -0.14 ± 0.16 |                      |         |         |         |                      |        |      |      | 15.  |
| 3960            | 1.20 ± 0.41 | 3.3     | 2.0 ± 0.5 | 0.00 ± 0.30          |         |         |         |                      |        |      |      | 16a. |
| 3950            | 1.15 [1.20] | 1.5 [2.0] | 0.00    |                      | 8.86 [8.85] |         |         | 10.17 ± 0.10 |        |      |      | 16b. |
| 3930 ± 200      |          |         |         |                      |         |         |         | 10.17 [10.17] |        |      |      | 16c. |
| 3950            | 1.15 [1.20] | 1.5 [2.0] | 0.00    |                      | 8.86 [8.85] |         |         | 10.16 ± 0.20 |        |      |      | 16d. |
| 3950            | 0.82 [0.85] | 1.5 [2.0] | -0.5    |                      | 8.51 [8.50] |         |         | 10.16 ± 0.20 |        |      |      | 16d. |
| 3944 ± 200      | 1.6 ± 0.2 | (1.87)  | (3.0)   | 0.00 ± 0.25          |         |         |         | 16.4 ± 0.02 |        |      |      | 17.  |
| (3980)          |         |         |         |                      | 13       |         |         | 16.4 ± 0.02 |        |      |      | 18.  |
| 3960 ± 100      | 1.3 ± 0.30 | 2.0 ± 0.5 | 0.00 ± 0.20 | 8.15 ± 0.25 | 8.26 ± 0.25 | 8.93 ± 0.20 | (9.17) | 16.4 ± 0.02 | 523 ± 101 | 48.53 ± 3.24 | 25.  |

1. Tomkin et al. (1975); 2. Blackwell & Shallis (1977); 3. Oinas (1977); 4. Lambert et al. (1980); 5. Lambert & Ries (1981); 6. Faucherre et al. (1983); 7. Harris & Lambert (1984); 8. Leggett et al. (1986); 9. di Benedetto & Rabbia (1987); 10. Harris et al. (1988); 11. Bell & Gustafsson (1989); 12. Brown et al. (1989); 13. Hutter et al. (1989); 14. Volk & Cohen (1989); 15. McWilliam (1990); 16. Bonnell & Bell (1993); 17. Morossi et al. (1993); 18. El Eid (1994); 19. Cohen et al. (1996); 20. di Benedetto (1998); 21. Dyck et al. (1998); 22. Perrin et al. (1998); 23. Robinson et al. (1998); 24. Taylor (1999); 25. present results
Table D.7. See caption of Table D.1 but now for β And.

| $T_{\text{eff}}$ | log g | M | $\xi_t$ | [Fe/H] | $\varepsilon$ (C) | $\varepsilon$ (N) | $\varepsilon$ (O) | $^{12}$C/$^{13}$C | $\theta_d$ | L | R | Ref. |
|-----------------|-------|---|---------|--------|----------------|----------------|----------------|----------------|--------|---|---|-----|
| 3660            |       |   | 1.6 ± 0.5 |        |                 |                |                | 11 ± 1.5 |        |   |   | 1.  |
| 3640            |       |   |         |        |                 |                |                |          |        |   |   | 2.  |
| 3520 ± 150      | 1.0 ± 0.7 | (1) |         |        |                 |                |                | 14.6 ± 1.3 | 13.5 ± 0.7 | 4.  |
| 3850 ± 400      |       |   |         |        |                 |                |                |          |        |   |   | 5.  |
| 3675            |       |   |         |        |                 |                |                | 10 ± 1.6 | 9 ± 0.5 | 6.  |
| 3820 ± 280 (3726) | 1.84 | (2) | (1.6) | 8.37 | (11) |                |                | 15.2 ± 1.7 | 33 ± 8 | 7.  |
| 3800 ± 100      | 1.6 ± 0.3 | 2.5 | 2.1 | (−0.10) | 8.53 ± 0.08 | 8.37 ± 0.08 | 8.84 ± 0.06 | 12 | 14.35 ± 0.19 | 19.9 ± 0.2 | 8.  |
| 3770 ± 64 (3800) | (1.6) | (2.5) | (2.1) | (−0.09) | 8.48 ± 0.12 | 8.32 ± 0.09 | 8.82 ± 0.06 | 11 ± 3 | 13.219 |        | 9.  |
| 3839 ± 10       | 1.6 ± 0.3 | 1.8 | (2.5) | 8.42 ± 0.30 | (10 ± 3) |                |                |          |        |   |   | 10. |
| 3895            | 1.63 ± 0.30 | (1.5) |        |        |                 |                |                |          |        |   |   | 11. |
| 4062 ± 175      | 0.95 ± 0.25 | 2.49 ± 1.48 | 2.0 ± 0.5 | 0.00 ± 0.20 | 8.12 ± 0.30 | 8.37 ± 0.40 | 9.08 ± 0.30 | 9 ± 2 | 13.30 ± 0.84 | 1561 ± 333 | 12. |
| 3840 ± 140      |       |   |         |        |                 |                |                |          |        |   |   | 13. |

1. Tomkin et al. (1997); 2. Linsky & Ayres (1973); 3. Clegg et al. (1979); 4. Sargle & Strecker (1979); 5. Manduca et al. (1981); 6. Tsuji (1981); 7. Faucherre et al. (1983); 8. Harris & Lambert (1984); 9. Koechlin & Rabbia (1985); 10. Smith & Lambert (1986); 11. Di Benedetto & Rabbia (1985); 12. Hutter et al. (1989); 13. Volk & Cohen (1989); 14. Smith & Lambert (1989); 15. Blackwell et al. (1991); 16. Judge & Stencel (1991); 17. Lazaro et al. (1991); 18. Mozurkewich et al. (1991); 19. Quirrenbach et al. (1993); 20. Dyck et al. (1998); 21. present results

Table D.8. See caption of Table D.1 but now for α Cet.

| $T_{\text{eff}}$ | log g | M | $\xi_t$ | [Fe/H] | $\varepsilon$ (C) | $\varepsilon$ (N) | $\varepsilon$ (O) | $^{12}$C/$^{13}$C | $\theta_d$ | L | R | Ref. |
|-----------------|-------|---|---------|--------|----------------|----------------|----------------|----------------|--------|---|---|-----|
| 3750            | 1.0 ± 0.7 | (1) |         |        |                 |                |                |          |        |   |   | 1.  |
| 3560 ± 150      |       |   |         |        |                 |                |                |          |        |   |   | 2.  |
| 3550            | 1.5 |        | +0.71 |        |                 |                |                |          |        |   |   | 3.  |
| 3680            | 1.8 |        | +0.26 |        |                 |                |                |          |        |   |   | 4a. |
| 3660            | 0.5 |        |        |        |                 |                |                |          |        |   |   | 4b. |
| (3905)          | (1.5) | (3) | 3.6 ± 0.3 |        | 8.06 ± 0.30 |                |                |          |        |   |   | 4c. |
| 3767 ± 100      | 0.4 ± 0.3 | 1.5 | (2.5) | 7.92 ± 0.30 | (10 ± 3) |                |                |          |        |   |   | 5.  |
| 3730            | 1.3 ± 0.3 | (1.5) |        |        |                 |                |                | 12.643 ± 0.25 | 13.6 | 2000 | 120 | 6.  |
| (3905)          | (1.5) | (3) | 3.3 ± 1.0 |        | 8.57 ± 0.04 |                |                |          |        |   |   | 7.  |
| (3905)          | (1.5) | (3) | 3.3 ± 1.0 |        | 8.50 ± 0.03 |                |                |          |        |   |   | 8.  |
| 3745 ± 40       | 1.3 |        | (3.0) | (8.57) | 7.84 ± 0.05 |                |                |          |        |   |   | 9.  |
| (3905)          | (1.5) |        |        |        |                 |                |                | 12.77 ± 0.25 | 10 ± 2 | 12. |
| 3869 ± 101      |       |   |         |        |                 |                |                | 12.77 ± 0.25 | 10 ± 2 | 12. |
| 3749 ± 140      | 0.95 ± 0.25 | 2.69 ± 1.61 | 2.3 ± 0.5 | 0.00 ± 0.20 | 8.20 ± 0.30 | 8.26 ± 0.40 | 8.93 ± 0.30 | 10 ± 2 | 12.52 ± 0.79 | 1455 ± 328 | 15. |

1. Clegg et al. (1974); 2. Sargle & Strecker (1979); 3. Tsuji (1981); 4. Burnashev (1984); 5. Tsuji (1986); 6. Blackwell et al. (1991); 7. Judge & Stencel (1991); 8. Lazaro et al. (1991); 9. Mozurkewich et al. (1991); 10. Tsuji (1991); 11. Quirrenbach et al. (1993); 12. Cohen et al. (1996); 13. Aoki & Tsuji (1997); 14. Dyck et al. (1998); 15. Ferrin et al. (1998); 16. present results
Table D.9. See caption of Table D.1 but now for \( \beta \) Peg.

| \( T_{\text{eff}} \) | log g | M | \( \xi_r \) | [Fe/H] | \( \varepsilon(C) \) | \( \varepsilon(N) \) | \( \varepsilon(O) \) | \( ^{12}C/^{13}C \) | \( \theta_d \) | L | R | Ref |
|-----------------|------|---|---------|------|-------------|-------------|-------------|----------------|-------|---|-----|
| 3650 ± 250 | 3467 | 3600 | 3280 | 3500 | 3530 ± 150 | 3600 | 3580 ± 150 | 3500 ± 200 | (3568) | 3600 ± 100 | (3580) | 3590 ± 44 | (3600) | 3547 ± 35 | (3600) | 3609 | 3600 ± 110 | (3580) | (3580) | 3600 | 3800 ± 74 | 3600 ± 300 | 0.65 ± 0.40 | 0.94 ± 0.27 | 2.00 | (0.00) | 8.20 ± 0.40 | (8.18) | (8.93) | 5 ± 3 | 16.60 ± 1.32 | 1800 ± 683 | 108.96 ± 9.90 | 32 |

1. Dyck et al. (1974); 2. Sanner (1976); 3. Blackwell & Shallis (1977); 4. Linsky & Ayres (1978); 5. Clegg et al. (1979); 6. Scargle & Stecker (1979); 7. Manduca et al. (1980); 8. Tsuji (1980); 9. Burnashev (1981); 10. Harris & Lambert (1984); 11. Smith & Lambert (1987); 12. Tsuji (1987); 13. di Benedetto & Rabbia (1988); 14. Lambert et al. (1987); 15. Harris et al. (1988); 16. Hutter et al. (1988); 17. Blackwell et al. (1990); 18. Smith & Lambert (1990); 19. Blackwell et al. (1991); 20. Judge & Stencel (1991); 21. Lazarro et al. (1991); 22. Mozerkewich et al. (1991); 23. Tsuji (1991); 24. Quirrenbach et al. (1994); 25. Worley (1994); 26. Cohen et al. (1994); 27. Aoki & Tsuji (1994); 28. Tsuji et al. (1994); 29. Abia & Wallerstein (1998); 30. Dyck et al. (1998); 31. Perrin et al. (1998); 32. present results
D.2. Comments on published stellar parameters

In this section of the appendix, a description of the results obtained by different authors using various methods is given in chronological order. One either can look to the quoted reference in the accompanying paper and then search the description in the chronological (and then alphabetical) listing below or one can use the cross-reference table (Table D.10) to find all the references for one specific star in this numbered listing.

1. van Paradijs (1973) has based his analysis on observations of line strengths on spectrograms of 1.6 and 6.5 Å/mm, in the wavelength region between 5000 Å and 6650 Å, and on calculations of weak-line strengths for a grid of model atmospheres. From the condition of minimum scatter in the curve of growth, effective temperatures are derived. The gravity of the stars has been obtained from the requirement that two ionisation states of one element should give the same abundance. With the effective temperature and gravity found, curves of growth have been made for different chemical elements.

2. Dyck et al. (1974) have derived complete energy distributions, photometric spectral types and total fluxes from narrow and broad-band photometry between 0.55 and 10.2 μm. For stars lacking infrared excesses, an intrinsic relation between the colour temperature and the spectral type and between the colour temperature and the effective temperature is found. The error in the effective temperature may be as large as ±7%. By comparing their effective temperature scale with the one of Johnson (1966), they find a good agreement in the mean relation, but the individual values of $T_{\text{eff}}$ do not always agree. Given the total flux and effective temperature, the angular diameter can be deduced.

3. Gustafsson et al. (1974) have measured the strength of a narrow group of weak metal lines. For more than half of the stars in their sample, the strength of another group with lines on the flat part of the curve of growth was also measured. The narrow-band indices, $A(48)$ and $A(58)$, were analyzed as a function of the fundamental atmospheric parameters by means of scaled solar model atmospheres. The temperature scale was established using a ($T$, $R - I$) calibration. The accelerations of gravity were estimated from absolute magnitudes and evolutionary tracks. The iron abundances and the microturbulence were calculated from an iterative process in which the observational quantities $R - I$, $M_V$, $A(48)$, $A(58)$ and the fundamental parameters $T_{\text{eff}}$, log g, [Fe/H] and $\xi$ are involved. From the errors in $R - I$, they estimate $\Delta T_{\text{eff}}$ to be 150 K. The accuracy of the other stellar parameters are $\Delta$[Fe/H] = 0.12, $\Delta$g = 0.2 km s$^{-1}$, $\Delta$ log g = 0.3.

4. van Paradijs & Meurs (1974) have adopted the angular diameter from Currie et al. (1974) and Gezari et al. (1973) for α Tau and α Boo respectively. To determine the effective temperature they used several continuum data, the curve of growth with the line strengths of Fe I lines and the surface brightness. Requiring that the neutral and ionised lines of Fe, Cr, V, Ti and Sc gave the same abundance, yielded the gravity. Gravity, parallax and angular diameter resulted in the mass, while the luminosity was determined from the effective temperature, the parallax and the angular diameter. van Paradijs & Meurs (1974) quoted that Wilson (1972) found [Fe/H] = −0.69 for α Tau.

5. Wavelength intervals around 8000 Å containing $^{12}$CN 2-0 and $^{13}$CN 2-0 lines, and around 6300 Å containing weak $^{12}$CN 4-0 lines were observed by Dearborn et al. (1973), with the McDonald 272 cm telescope and the Tull coudé scanner. The effective temperature and bolometric corrections were calculated from tables by Johnson (1966) and $UBVRI$ colours. The $^{12}$CN and $^{13}$CN curves of growth were then used to determine $^{12}$C/$^{13}$C.

6. Mackie et al. (1970) have analysed the Arcturus spectrum, using the observational material based on the Arcturus atlas of Griffin (1968). The effective temperature was determined from the wings of strong lines (Mgb, NaD, Ca II IR triplet) and different photometric observations, the gravity from requiring that the equivalent widths of the lines of neutral and ionised atoms yield the same abundance. The microturbulence was determined from the curve of growth and the mass from the gravity and the interferometric radius. The luminosity was deduced on the one hand from $T_{\text{eff}}$ and R and on the other hand from the observed parallax, apparent visual magnitude and the bolometric correction.

7. Tomkin et al. (1975) have obtained photoelectric spectral scans of lines belonging to the red CN system with the McDonald 2.7 m telescope and the Tull coudé scanner. Infrared colours were used to determine $T_{\text{eff}}$. This effective temperature together with the luminosity and masses - inferred from the locations of the stars in the H-R diagram - yielded the physical gravity. The microturbulence was obtained from a curve of growth technique. The CN lines yielded the isotopic ratio $^{12}$C/$^{13}$C.

8. The abundances of carbon, nitrogen and oxygen have been determined in the atmospheres of five G- and K-giants and one K-subgiant by van Paradijs & Kester (1976). Using the method described in van Paradijs (1973) $T_{\text{eff}}$, log g and [Fe/H] are determined. The abundance analysis is based on equivalent widths of the [O I] line at λ 6300 Å, of rotational lines in the violet bands of CN, of a red band of CN and of bands of CH.

9. Sanner (1976) has determined the absolute visual magnitude, bolometric correction and effective temperature from a spectral type calibration. The distance is deduced from the distance modulus and reddening correction. The radius is then obtained from measured angular diameters found in literature.

10. Tomkin et al. (1976) have used infrared colours to determine $T_{\text{eff}}$. The microturbulence was determined by fitting a theoretical curve of growth to the $^{12}$CN curve of growth ($^{12}$CN(2,0) around 8000 Å, weak $^{12}$CN(4,0)
lines around 6300 Å and weak $^{12}\text{C}/^{13}\text{C}$ lines around 8430 Å. Together with $^{12}\text{CN}$ lines around 8000 Å, the isotopic ratio $^{12}\text{C}/^{13}\text{C}$ was ascertained. The gravities were estimated from the effective temperature, the mass and the luminosity (but were not tabulated). The luminosity has been computed using different methods, e.g., trigonometric parallax, narrow-band photometry, K-line luminosity, ...

11. Blackwell & Shallis (1977) have described the Infrared Flux Method (IRFM) to determine the stellar angular diameters and effective temperatures from absolute infrared photometry. For 28 stars (including α Car, α Boo, α CMa, α Lyr, β Peg, α Cen A, α Tau and γ Dra) the angular diameters are deduced. Only for the first four stars the corresponding effective temperatures are computed.

12. Oinas (1977) has obtained observations with the 60-inch telescope on Mt. Wilson. Assuming a mass of 2.5 $M_\odot$ and taking the absolute K-line magnitude of Wilson (1977) in conjunction with the bolometric correction of Johnson (1966), the gravity was determined. The effective temperature was obtained from a fit of the model fluxes to the photoelectric scans, while a curve of growth technique was used to determine the abundances and the microturbulence. By using this ‘physical’ gravity a large discrepancy was found between the iron abundances from the Fe I and the Fe II lines of γ Dra. Therefore the surface gravity was lowered in order to force equality between the abundances derived from the neutral and ion lines. This yielded however a very low gravity-value of log $g = 0.4$ dex for γ Dra — instead of the physical gravity of log $g = 1.6$ dex.

13. By using a $T_{\text{eff}} - (V - I)$ transformation of Johnson (1966), Linsky & Ayres (1978) have determined the effective temperature.

14. Basri & Linsky (1979) have deduced the effective temperature from the $(T_{\text{eff}}, V - R)$-relation from Johnson (1966), while the angular diameter is computed by using a relation which links the colour $V - R$ to the apparent angular diameter.

15. Clegg et al. (1979) have derived both the stellar effective temperature from a $T_{\text{eff}}$-spectral type relation and a colour temperature. The surface gravities were derived on the assumption that all stars have a stellar mass of 1 $M_\odot$ and a luminosity estimated from a H-R diagram. In this way, the surface gravity may be uncertain by a factor 5.

16. Scargle & Strecker (1979) have compared the observed infrared flux curves of cool stars with theoretical predictions in order to assess the model atmospheres and to derive useful stellar parameters. This comparison yielded the effective temperature (determined from flux-curve shape alone) and the angular diameter (determined from the magnitudes of the fluxes). The overall uncertainty in $T_{\text{eff}}$ is probably about 150 K, which translates into about a 9% error in the angular diameter.

17. Blackwell et al. (1980) have determined the effective temperature and the angular diameter for 28 stars using the IRFM method.

18. Lambert et al. (1980) took model parameters from published papers which constrained the $^{12}\text{C}/^{13}\text{C}$ ratio, e.g. Tomkin et al. (1976) and Lambert (1976) to derive the lithium abundance for about 50 G and K giants.

19. Stencel et al. (1980) have taken $T_{\text{eff}}$, log $g$ and [Fe/H] from sources referenced by Linsky et al. (1979), Johnson (1966) and Gustafsson et al. (1973). The apparent stellar diameter is related with the $(V - R)$ photometric colour. Uncertainties in $T_{\text{eff}}$ and the bolometric correction can be significant in the determination of $\theta_d$. Especially the values given for α Tuc seems to be quite unreliable.

20. Lambert & Ries (1981) have used high-resolution low-noise spectra. The parameters were ascertained by demanding that the spectroscopic requirements (ionisation balance, independence of the abundance of an ion versus the excitation potential and equivalent width) should be fulfilled. The effective temperature was found from the Fe I excitation temperature and the model atmosphere calibration of the excitation temperature as a function of $T_{\text{eff}}$. As quoted by Ries (1981), Harris...
et al. (1988) and Luck & Challener (1995) their \( T_{\text{eff}} \) and \( \log g \) are too high and should be lowered by 240 K and 0.40 dex respectively. The isotopic ratio \( ^{12}\text{C}/^{13}\text{C} \) was taken from Tomkin et al. (1977), while the luminosity was estimated from the K-line visual magnitude \( M_V(K) \) given by Wilson (1976) and the bolometric correction BC by Gustafsson & Bell (1979). The abundances of carbon, nitrogen and oxygen were based on C2, [O I] and the red system CN lines respectively. Luck & Challener (1995) wondered whether the nitrogen abundance for \( \alpha \) Tau [N/Fe]=−0.20 reflects a typographic error and should rather be [N/Fe]=+0.20, resulting in \( \varepsilon(N)=7.86 \), which is more in agreement with being a red giant branch star.

Manduca et al. (1981) have compared absolute flux measurements in the 2.5 – 5.5 \( \mu \text{m} \) region with fluxes computed for model stellar atmospheres. The stellar angular diameters obtained from fitting the fluxes at 3.5 \( \mu \text{m} \) are in good agreement with observational values and with angular diameters deduced from the relation between visual surface brightness and \( (V-R) \) colour. The temperatures obtained from the shape of the flux curves are in satisfactory agreement with other temperature estimates. Since the average error is expected to be well within 10\%, the error for the angular diameter is estimated to be in the order of 5\%.

Tsuij (1981) has used the IRFM method to determine the effective temperature. A new calibration of effective temperatures against spectral type is given on the basis of direct analyses of several objects in each sub-class.

Burnashev (1983) has determined \( T_{\text{eff}} \) from narrow-band photometric colours in the visible part of the electromagnetic spectrum, obtained from different spectrophotometric catalogues.

Bonelli & Bell (1982) have used synthetic DDO photometric indices with precise DDO photometric observations of Population I G and K giants to determine carbon and nitrogen abundances and temperatures for these stars. The adopted gravity, metallicity and microturbulence were taken from Gustafsson et al. (1974). The obtained accuracy is \( \Delta T_{\text{eff}} = 170 \) K, \( \Delta \varepsilon(C) = 0.18 \) dex and \( \Delta \varepsilon(N) = 0.30 \) dex. To convert \([\text{C/Fe}]\) and \([\text{N/Fe}]\) to \( \varepsilon(C) \) and \( \varepsilon(N) \) we have used the solar abundances given by Anders & Grevesse (1989).

Frisk et al. (1982) have used photometry in the wavelength range from 0.4 – 2.2 \( \mu \text{m} \) in order to determine the effective temperature of Arcturus. A comparison with detailed model atmospheres (with \( \log g = 1.5 \), mixing-length parameter \( \ell/H_p = 1.5 \) and chemical composition \([\text{A/H}] = -0.5\)) leads to an effective temperature of 4375 K with an estimated maximum uncertainty of about 50 K.

Gratton et al. (1982) have analyzed blue-violet high-dispersion spectra of 26 K giants by a semi-automatic procedure for the determination of \( T_{\text{eff}} \), \( \xi_1 \), \( g \), \( \varepsilon(\text{Fe}) \) and \( \varepsilon(\text{Ti}) \). The procedure consists in a comparison of observed curves of growth with those obtained by model atmospheres. They mainly have used weak and medium strong lines. The standard errors of these stellar parameters are \( \Delta T_{\text{eff}} = 60 \) K, \( \Delta \xi_1 = 0.1 \text{ km s}^{-1} \) and \( \Delta \log g = 0.15 \) dex. Due to the uncertain excitation temperature of \( \xi_1 \) Dra, the temperature was estimated from a colour-temperature relation. The radius was derived from the visual surface brightness and was used to obtain the mass and the bolometric absolute magnitude. They found an average mass of the field K giants being \( 1.1 \pm 0.2 \text{M}_\odot \). The accuracy on the radius is \( \Delta \log R = 0.06 \), on the mass \( \Delta \log M = 0.19 \) and on the iron abundance \( \Delta \varepsilon(\text{Fe}) = 0.14 \).

Gratton et al. (1982) have derived the effective temperatures for the programme stars from observed \((R-I)\) and \((72-110)\) values and preliminary guesses for \( \log g \) and \([\text{Fe/H}]\). They noted that their effective temperature derived from this method could be systematically too high by about 50 K, due to the lack of an opacity source in the violet-ultraviolet spectral region of the used models. The gravity was assigned by using an empirical relation which relates the width of the Ca II line emission feature, the effective temperature, the metallicity and the gravity. The metal abundances were taken from Gustafsson et al. (1974) and a general value of \( \xi_1 = 1.7 \text{ km s}^{-1} \) was adopted for all the programme stars. The C, N and O abundances were then derived from high-resolution scans of the [O I] 6300 Å line and of the lines of the red CN (2,0) band and very narrow band index measurements of the C2 Swan (0,1) band head.

Burmashev (1988) has determined \( T_{\text{eff}} \), \( \log g \) and [Fe/H] from narrow-band photometric colours in the visible part of the electromagnetic spectrum.

Bonelli et al. (1981) have used the two-telescope stellar interferometer (I2T) at CERGA to measure angular diameters. The eleven colours of Johnson (1966) were used for the bolometric flux to yield the effective temperature.

Gratton (1983) has used an analogous method as in 1982, but now very strong iron lines are used. Therefore, he has first analysed the solar lines to derive a damping enhancement in order to match model atmosphere predictions and observational data. This yielded the quite low solar iron abundance \( \varepsilon(\text{Fe}) = 7.40 \). Using these damping enhancements, the stellar parameters are determined. This results in an iron abundance which is \( \sim 0.15 \) dex lower than the value deduced by Gratton et al. (1982) with an accuracy of \( \Delta \varepsilon(\text{Fe}) = 0.12 \). This lower iron abundance may be explained by observational uncertainties.

Harris & Lambert (1984) have taken \( T_{\text{eff}} \), \( \log g \) and \( \xi_1 \) determined by Dominy, Hinkle and Lambert (1984), a reference which we could not trace back. The isotopic ratio \( ^{12}\text{C}/^{13}\text{C} \) was adopted from Dominy, Hinkle and Lambert (1984). The carbon abundance was found by fitting weak \( ^{12}\text{C}^{16}\text{O} \) lines at 1.6 \( \mu \text{m} \), 2.3 \( \mu \text{m} \) and 5 \( \mu \text{m} \).

Bell et al. (1983) have estimated the surface gravity of Arcturus using the strengths of MgH features, strong metal lines and the Fe I – Fe II ionisation equilibrium. The MgH lines give \( \log g = 1.8 \pm 0.5 \), for an effective temperature of 4375 K (Frisk et al. 1982) and \( \xi_1 = 1.7 \text{ km s}^{-1} \). The uncertainty in \( T_{\text{eff}} \) leads to one of the
most important uncertainties of the gravity when estimated from MgH lines: a reduction of 50 K in temperature leads to log g = 1.6. Using the wings of pressure-broadened strong lines, a gravity log g = 1.6 ± 0.19 is obtained, while a gravity log g = 1.5 ± 0.5 is found from the Fe I - Fe II ionisation equilibrium. A reason for the discrepancy between this last result and the result of other determinations could be the departure from LTE for Fe I lines or could be situated in the ionisation equilibrium. Combining the results of these three methods yields log g = 1.6 ± 0.2, corresponding to an Arcturus mass of 0.42 M⊙ ≤ M ≤ 1.5 M⊙.

32. Gratton (1985) has derived C, N and O abundances by means of a model-atmosphere analysis of blends of the CN and C II bands and of literature data about the 6300 Å [O I] line. The atmospheric parameters (T_{\text{eff}}, \log g, \xi_t, [\text{Fe}/\text{H}]) were taken from Gratton et al. (1982). The stellar abundances were computed relative to the solar CNO abundances (which were not given). To convert [C/H], [N/H] and [O/H] to relative to the solar CNO abundances (which were not given). To convert [C/H], [N/H] and [O/H] to ε(C), ε(N) and ε(O) we have used the solar abundances given by Anders & Grevesse (1989).

33. Koefoed & Rabba (1985) have used the interferometer at CERGA (12T) to determine the angular diameter.

34. Moon (1985) has found a linear relation between the visual surface brightness parameter F_v and the (b−y)_0 colour index of uvbyβ photometry for spectral types later than G0. Using this relation, tables of intrinsic colours and indices, absolute magnitude and stellar radius are given for the ZAMS and luminosity classes Ia - V over a wide range of spectral types. Using this uvbyβ photometry, he found a radius of 23.4 R_⊙ for α Boo, which is in good agreement with the value 27.5 R_⊙ obtained from the parallax (97 mas) and the angular diameter (24.9 mas). The estimated accuracy of the radius is 1.1 R_⊙.

35. High-resolution spectra of OH (Δv = 2), CO (Δv = 3), CO (Δv = 2) and CN (Δv = 2) were obtained by Smith & Lambert (1985). They have used (V – K) colours and the calibration provided by Ridgway et al. (1980) to determine T_{\text{eff}}. Using the spectroscopic requirement that ε(Fe I) = ε(Fe II) yields, e.g., log g = 0.8 for α Tau, which is too low for a K5 III giant. They suggested that the reason for this low value is the over-ionisation of iron relative to the LTE situation. They then computed the surface gravity starting from a mass estimated from evolutionary tracks in the H-R diagram. The metallicity was taken from Kociécz (1983) and for the microturbulence they used Fe I, Ni I and Ti I lines, demanding that the abundances are independent of the equivalent width. Using the molecular lines, they determined ε(C), ε(N), ε(O) and 12C/13C.

36. Ayres et al. (1982) have determined T_{\text{eff}}, L and R from the distance, the angular diameter and the bolometric luminosity found in literature. These parameters were then used by Judge (1984) to determine the gravity and the mass. The metallicity was taken from Lambert & Ries (1981).

37. Kyrolainen et al. (1986) have observed α Boo with the 2.6m telescope of the Crimean Astrophysical Observatory during the years 1974 – 1980. The discussion of the results and methods used would be published later, which does not seem to be the case.

38. The IRFM method is used by Leggett et al. (1986) to determine the effective temperature and the angular diameter. The IRFM procedures true angular diameters, so that no limb darkening correction needs to be applied to these values. The parallax is combined with the angular diameter to give the linear radius and with the absolute integrated flux to give the luminosity.

39. The stellar parameters quoted by Tsuji (1986) were based on the results of Tsuji (1981), in which the temperature was determined by the IRFM method. Only for α Boo, the temperature determined by Frisk et al. (1982) was used. A mass of 3 M_⊙ was assumed to ascertain the gravity. Tsuji (1986) has used high-resolution FTS spectra of the CO first-overtone lines to determine ε(C) and ε(O) by assuming that the abundance should be independent of the equivalent width of the lines.

40. Aitas (1987) have done the analysis of α Boo on base of the Arcturus atlas of Griffin (1968). The atmospheric parameters were taken from different literature sources.

41. di Benedetto & Rabba (1987) used Michelson interferometry by the two-telescope baseline located at CERGA. Combining this angular diameter with the bolometric flux F_{\text{bol}} (resulting from a direct integration using the trapezoidal rule over the flux distribution curves, after taking interstellar absorption into account) they found the effective temperature, which was in good agreement with results obtained from the lunar occultation technique.

42. Lambert et al. (1987) have presented the first determinations of the Si isotopic ratios in M, MS and S stars. Therefore they have obtained observations with the KPNO m telescope and Fourier Transform Spectrometer. They however have used the not so accurate g_f-values of the SiO lines from a recipe of Tipping & Chackerian (1981) (see, e.g., Langhoff & Bauschlicher 1993; D’irita et al. 1997; Tsuji et al. 1994). The temperatures and gravities were taken from the analysis of Smith & Lambert (1985) and Smith et al. (1986). With the total equivalent width of the weak and strong lines, abundances were determined using the LTE spectrum synthesis program MOOG. Smith et al. (1974). The microturbulent velocity was set to the value which gave the same abundance of 28SiO for both weak and strong lines. This yielded a silicon abundance of 7.83 for β Peg. As Lambert et al. (1987) quoted, Smith & Lambert (1985) did not include Si, but the expected Si abundance may be estimated from their determinations of the iron and nickel abundance. This method yielded a silicon abundance of 7.40 for β Peg. The discrepancy between these two silicon abundances was attributed either to an inaccurate dissociation energy of SiO, a too high effective temperature, problems with the model atmosphere or with the
SiO $gf$-values. This latter possibility is likely to be one of the most important reasons: using the electric dipole moment function of [Langhoff & Bauschlicher (1993)] would increase the Einstein coefficient for the 2-0 overtone band by a factor of about two and consequently, the derived silicon abundance from the SiO lines should decrease by about 0.3 dex ([Tsuji et al. 1992]).

Edvardsson (1988) estimated logarithmic surface gravities from the analysis of pressure broadened wings of strong metal lines. Comparisons with trigonometrically determined surface gravities give support to the spectroscopic results. Surface gravities determined from the ionisation equilibria of Fe and Si are found to be systematically lower than the strong line gravities, which may be an effect of errors in the model atmospheres, or departures from LTE in the ionisation equilibria.

Glebocki & Stawikowski (1988) have obtained spectra of binaries from the IUE archive. The masses of the primaries, $M$, the mass ratios, $q$, and the inclinations of the orbits, $i$, have been evaluated from the radial velocity amplitude, from the mass-function and from the position of the primary on the evolutionary track calculations. The effective temperature of the primary is derived from infrared broad-band photometry, the error being smaller than 70 K. The radius $R$ is calculated from the bolometric magnitudes, with the error being $20 - 30 \%$. The error of the logarithm of the ratio of the tidal acceleration at surface to the surface gravity is estimate to be 0.5 dex.

Harris et al. (1988) have analysed 5 stars, containing $\beta$ Umi. They have taken $T_{\text{eff}}$ and log g-values from literature, slightly adjusted to give the best fit. Microturbulent velocity, $\varepsilon$(C) and $^{12}$C/$^{13}$C-ratio were obtained by requiring an optimal fit with the observed spectra. Different methods were used to estimate the stellar mass for 12 targets.

Bell & Gustafsson (1989) first determined the temperature from the Johnson K band at 2.2 $\mu$m using the IRFM method. By comparison with temperatures deduced from the colours Glass $J - H$, $H - K$, $K - L$ and $K$; Cohen, Frogel and Persson $J - H$, $H - K$, $K - L$ and $K$; Johnson $V - J$, $V - K$, $V - L$ and $K$; Cousins $V - R$, $R - I$; Johnson and Mitchell 13-colour and Wing's near-infrared eight-colour photometry they found that $T_{\text{eff}}$(IRFM) was $\sim$ 80K too high, by which they corrected the temperature. The gravity and [Fe/H] were adopted from literature values or were selected as being characteristic for the MK class in question (e.g. $\beta$ Umi).

Brown et al. (1989) have used two different methods to determine the effective temperature. In the first method published photometry was used. The observed DDO $C(45 - 48)$ and $C(42 - 45)$ indices were used together with a theoretical model-atmosphere DDO temperature calibration. In the second method, the $(R - I)$ colour index and a colour-temperature relation for giants was used. Equal weights were assigned to each of these temperature values. The gravity was ascertained by using the K-line absolute magnitude $M_V(K)$ of Wilson (1970) scaled to a Hyades distance modulus of 3.30, the effective temperature and an assumed stellar mass of $1 M_\odot$. A microturbulent velocity of 1.7 km s$^{-1}$ was adopted ([Gustafsson et al. 1974]). Using the observations from the 2.1 m reflector and coudé spectrograph at Mc Donald Observatory, together with up to four different literature sources, a mean iron abundance was determined.

Hutter et al. (1989) have presented stellar diameter measurements of 24 stars made with the MarkIII optical interferometer. This gives the uniform disk angular diameter, which was then corrected for limb darkening on the base of appropriate model atmospheres. Their obtained angular diameters are in good agreement with the angular diameters of stars in similar ranges of spectral type measured through lunar occultations for $\theta_d > 5$ mas.

Volk & Cohen (1989) determined the effective temperature directly from the literature values of angular diameter measurements and total-flux observations (also from literature). The distance was taken from the Catalog of Nearby Stars ([Gliese 1969]), or from the Bright Star Catalogue ([Hoffleit & Jaschek 1982]).

The effective temperature $T_{\text{eff}}$ and the angular diameter $\theta_d$ given by Blackwell et al. (1990) were determined by the infrared flux method (IRFM), a semi-empirical method which relies upon a theoretical calibration of infrared bolometric corrections with effective temperature. The infrared flux method uses a quantity $R$ which is the ratio of the total flux to the flux at an infrared wavelength. The temperature is obtained by comparing the observed value of $R$ to theoretical values, based on model atmosphere calculations. Since the infrared wavelength is in the Rayleigh-Jeans tail of the flux distribution, $R$ is proportional to the cube of the temperature. Thus, the temperature uncertainty is one third of the measured flux error. One expects that the IRFM should yield results better than 1% for the effective temperature and 2 – 3% for the angular diameter. The final effective temperature is a weighted mean of $T(J_n)$, $T(K_n)$ and $T(L_n)$, with $J_n$ at 1.2467 $\mu$m, $K_n$ at 2.2135 $\mu$m and $L_n$ at 3.7825 $\mu$m.

By taking the mean value of the different temperatures delivered by calibrations with photometric indices $(U - B$, $B - V$, $V - R$, $R - I$, $I - J$, $V - K$, $V - L)$, [Fernández-Villacanas et al. (1990)] have fixed the effective temperature. For the gravity, the DDO photometry indices $C(45 - 48)$ and $C(42 - 45)$ were used. The Fe I lines served for the determination of $\xi_t$.

McWilliam (1990) based his results on high-resolution spectroscopic observations with resolving power 40000. The effective temperature was determined from empirical and semi-empirical results found in the literature and from broad-band Johnson colours. The gravity was ascertained by using the well-known relation between $g$, $T_{\text{eff}}$, the mass $M$ and the luminosity $L$, where the mass was determined by locating the stars on theoretical evo-
lutionary tracks. So, the computed gravity is fairly insensitive to errors in the adopted L. High-excitation iron lines were used for the metallicity [Fe/H], in order that the results are less spoiled by non-LTE effects.

The author refrained from determining the gravity in a spectroscopic way (i.e. by requiring that the abundance of neutral and ionised species yields the same abundance) because ‘A gravity adopted by demanding that neutral and ionised lines give the same abundance, is known to yield temperatures which are ~ 200 K higher than found by other methods. This difference is thought to be due to non-LTE effects in Fe I lines.’ By requiring that the derived iron abundance, relative to the standard 72 Cyg, were independent of the equivalent width of the iron lines, the microturbulent velocity $\xi$ was found.

53. Smith & Lambert (1990) have determined the chemical composition of a sample of M, MS and S giants. The use of a slightly different set of lines for the molecular vibration-rotation lines of CO, OH and CN, along with improved gf-values for CN and NH, results in a small difference in the carbon, nitrogen and oxygen abundance with respect to the values deduced by Smith & Lambert (1985).

54. Blackwell et al. (1991) is a revision of Blackwell et al. (1990) where the H− opacity has been improved. They investigated the effect of the improved H− opacity on the IRFM temperature scale and derived angular diameters. Also here, the mean temperature is a weighted mean of the temperatures for $J_n$, $K_n$ and $L_n$. Relative to Blackwell et al. (1990) there was a change of temperature up to 1.4% and a decrease by 3.5% in $\theta_d$.

55. Flynn & Mermilliod (1991) have derived the metallicity from DDO photometry.

56. Judge & Stencel (1991) have used literature values for the effective temperatures of K stars. If these were not available the $(V−K)$ versus $T_{eff}$ calibration of Ridgway et al. (1988) was used. Direct measurements available in literature for $(V−R)$ versus visual surface flux corrections were used for $\theta_d$. In conjunction with the distance — obtained from the parallax — this yielded the radii. Stellar gravities from photospheric line studies, which should be reliable up to ~ 0.3 dex were used. Finally the mass was obtained from the surface gravity or from stellar masses for groups of stars. On the basis of initial mass function and time scales of evolution, Scalo & Miller (1978) argue that most O-rich giants must have masses around 1 M⊙.

57. Lazaro et al. (1991) have obtained intermediate-resolution ($\lambda$/$\Delta \lambda \approx 600$) scans of 70 bright late-type giants of luminosity class III (K5-M6) with a cooled grating spectrometer (CGS) at the Cassegrain focus of the 1.5m Infrared Flux Collector of the Observatorio del Teide. The wavelength range was at least 2.20 – 2.45 $\mu$m. Since the infrared scans have insufficient information to allow the determination of $T_{eff}$ and log g, the MK spectral types are used with the calibration of Ridgway et al. (1988) to determine $T_{eff}$. A physical gravity was deduced, with absolute magnitudes taken from Wilson (1970) and masses inferred from the H-R diagram. An advantage of using spectral types rather than a colour index such as $(V−K)$ to class the stars in temperature is that the former is independent of the (uncertain or unknown) reddening. Their use of the composite H-R diagram for red giants corresponds roughly to the adoption of a mean giant mass of 1.5 M⊙. This is in good accord with estimates for the mean mass of Scalo (Lazaro et al. 1991, and references therein). Lazaro denoted that the adoption by Tsuji (1980) of a mean mass of 3.0 M⊙ seems too high. Adopting a microturbulence velocity of 2.5 km s$^{-1}$ then yielded $\zeta(C)$ and $^{12}$C/$^{13}$C from the first-overtone lines of CO.

58. Mozurkewich et al. (1991) have used the MarkIII Optical Interferometer. The uniform disk angular diameter $\theta_{UD}$ has a residual of 1% for the 800 nm observations and less than 3% for the 450 nm observations. The limb darkened diameter was then obtained by multiplying the uniform disk angular diameter with a correction factor (using the quadratic limb darkening coefficient of Manduca 1975).

59. The stellar parameters quoted by Tsuji (1991) were based on the results of Tsuji (1981), in which the temperature was determined by the IRFM method. A mass of 3 M⊙ was assumed to ascertain the gravity. Tsuji (1991) used CO lines of the second overtone band. A standard analysis of these CO lines could, however, yield different results than a linear analysis of the weak lines.

60. Effective temperatures have been computed by Cornide et al. (1992) with the temperature calibration of Böhm-Vitense (1981).

61. Engelke (1992) has derived a two-parameter analytical expression approximating the long-wavelength (2 – 60 $\mu$m) infrared continuum of stellar calibration standards. This generalised result is written in the form of a Planck function with a brightness temperature that is a function of both observing wavelength and effective temperature. This function is then fitted to the best empirical flux data available, providing thus the effective temperature and the angular diameter.

62. Pasquini & Brocato (1992) have used the effective temperature given by Pasquini et al. (1992), who have used the spectral classification and the $(V−R)_0$ colour index to construct a colour-temperature relation. The accuracy on $T_{eff}$ is 250 K. Together with the bolometric magnitude and a mass inferred from the comparison with evolutionary tracks, they have deduced the gravity. Due to a raw division of the stellar masses into four sub-groups, their gravity is the parameter containing the major uncertainties.

63. Bonnell & Bell (1993) constructed a grid based on the effective temperature $T_{eff}$ of Manduca et al. (1981). They used ground-based high-resolution FTS spectra of OH and [O I] lines. The requirement that the oxygen abundances determined from the [O I] and OH line widths are in agreement amounts to finding the inter-
section of the loci of points defined by the measured widths in the ([O/H], log g) plane. The determination of \( \xi_t \) was based on OH-lines, but was hampered by a lack of weak lines from this radical for some stars. A least-square fit was then performed, which yielded \( \xi_t \). A lower \( \xi_t \) for the OH (\( \Delta v = 2 \)) lines than for the OH(\( \Delta v = 1 \)) lines was attributed to a greater average depth of formation for the OH (\( \Delta v = 2 \)) sequence lines.

64. Using the catalogue of Cayrel de Strobel et al. (1992), Morossi et al. (1993) have selected programme stars having a solar chemical composition. Effective temperature values have been derived from calibrations of broad-band Johnson colours, by adopting the polynomial relationships of McWilliam (1990). The surface gravity has been obtained from DDO photometry.

65. Using opacity distribution functions based on a newly expanded atomic and molecular line list, Peterson et al. (1993) have calculated a model atmosphere for Arcturus which reproduces the observed flux distribution of the Griffin atlas (Griffin 1968). Individual line parameters in the list were adjusted to match the solar spectrum. Using spectral lines for which the solar \( g_f \)-values are well determined in the region 5000 – 5500 Å, 6000 – 6500 Å and 7500 – 8875 Å, the effective temperature, surface gravity and microturbulence are determined.

66. Quirrenbach et al. (1993) have determined the uniform disk angular diameter in the strong TiO band at 712 nm and in a continuum band at 754 nm with the MarkIII stellar interferometer on Mount Wilson. Because limb darkening is expected to be substantially larger in the visible than in the infrared, the measured uniform disk diameters should be larger in the visible than in the infrared. This seems however not always to be the case. Using the same factor as Mozurkewich et al. (1991), we have converted their continuum uniform disk value for \( \beta \) And, \( \alpha \) Cet, \( \alpha \) Tau and \( \beta \) Peg into a limb darkened angular diameter, yielding a value of 15.23 mas, 13.62 mas, 22.73 mas and 18.11 mas respectively. There is a systematic uncertainty in the limb-darkened angular diameter of the order of 1% in addition to the measurement uncertainty of the uniform disk angular diameter (Davis 1998).

67. The effective temperature, surface gravity and mass of Harris & Lambert (1984) were used by El Eid (1994). He noted a correlation between the \( ^{16}\text{O}/\text{^{27}}\text{O} \) ratio and the stellar mass and the \( ^{12}\text{C}/^{13}\text{C} \) ratio and the stellar mass for evolved stars. Using this ratio in conjunction with evolutionary tracks, El Eid has determined the mass for \( \gamma \) Dra.

68. Gadun (1994) has used model parameters and equivalent widths of Fe I and Fe II lines for \( \alpha \) Cen, \( \alpha \) Boo and \( \alpha \) Car found in literature. It turned out that the Fe I lines were very sensitive to the temperature structure of the model and that iron was over-ionised relative to the LTE approximation due to the near-ultraviolet excess \( J_0 - B_0 \). Since the concentration of the Fe II ions is significantly higher than the concentration of the neutral iron atoms, the iron abundance was finally determined using these Fe II lines. It is demonstrated that there is a significant difference in behaviour of \( \xi_t \) from the Fe I lines for solar-type stars, giants and supergiants. The microturbulent velocity decreases in the upper photospheric layers of solar-type stars, in the photosphere of giants (like Arcturus) \( \xi_t \) has the tendency to increase and in Canopus, a supergiant, a drastic growth of \( \xi_t \) is seen. This is due to the combined effect of convective motions and waves which form the base of the small-scale velocity field. The velocity of convective motions decreases in the photospheric layers of dwarfs and giants, while the velocity of waves increases due to the decreasing density. In solar-type stars the convective motion penetrates in the line-forming region, while the behaviour of \( \xi_t \) in Canopus may be explained by the influence of gravity waves. The characteristics of the microturbulence determined from the Fe II lines differ from that found with Fe I lines. These results can be explained by 3D numerical modeling of the convective motions in stellar atmospheres, where it is shown that the effect of the lower gravity is noticeable in the growth of horizontal velocities above the stellar ‘surface’ (in the region of Fe I line formation). But in the Fe II line-forming layers the velocity fields are approximately equal in 3D model atmospheres with a different surface gravity and same \( \text{T}_{\text{eff}} \). Both values for \( \xi_t \) derived from the Fe I and Fe II lines are listed. If the microturbulence varies, the values of \( \xi_t \) are given going outward in the photosphere.

69. Worthey (1994) has used \( \text{T}_{\text{eff}}, \text{log g and [Fe/H]} \) from Worthey et al. (1994) for the construction of detailed models for intermediate and old stellar populations. Most temperatures come from a transformation of \( (V-K) \) colours. Worthey et al. (1994) have determined indices from 21 optical absorption features. These indices are summarised in fitting functions which give index strengths as function of stellar temperature, gravity and [Fe/H]. \( \beta \) Peg was, however, not mentioned in this project.

70. Cohen et al. (1996) have derived the effective temperature and angular diameter from the composite spectra of \( \alpha \) Boo, \( \gamma \) Dra, \( \alpha \) Cet and \( \gamma \) Cru using the Engelke (1992). Using a — not published — statistical relation between the spectral type and the gravity, the gravities of these stars were assigned. A gravity of 2.0 was adopted for \( \alpha \) Tau, though in Cohen et al. (1993), a value of 1.5 — taken from Smith & Lambert (1985) — was used.

71. The diameter of Arcturus has been measured by Quirrenbach et al. (1996) with the MarkIII interferometer at five wavelengths between 450 nm and 800 nm. By using the limb-darkening coefficient of Manduca (1979) and Manduca et al. (1981) they have computed the true limb-darkened diameter of Arcturus as being \( 21.0 \pm 0.2 \) mas. By combining this value with the bolometric flux, the effective temperature is determined, being \( 4303 \pm 47 \) K.
Abia & Wallerstein (1998) have derived the abundances of various elements from Sr to Eu relative to iron. Their quoted mass-value was computed from the adopted radius and gravity value. McWilliam (1990) did, however, not mention the target β Peg.

The IRFM method has been used by Blackwell & Lynas-Gray (1998) to obtain the effective temperature of a sample of stars selected for the flux calibration of ISO. The accuracy estimates are based on considerations concerning the accuracy of absolute fluxes, the agreement between temperatures derived using the various filters and on the relation between temperatures and various photometric indices. Because no account has been taken of uncertainties due to difficulties in theoretical modelling of stellar atmospheres, these accuracies are a useful indication of the relative accuracy of the determined stellar temperature by Blackwell & Lynas-Gray (1998).

di Benedetto & Rabbia (1987) calibrated the surface brightness-colour correlation using a set of high-precision angular diameters measured by modern interferometric techniques. The stellar sizes predicted by this correlation were then combined with bolometric-flux measurements, in order to determine one-dimensional (T, V − K) temperature scales of dwarfs and giants. Both measured and predicted values for the angular diameters are listed.

Dyck et al. (1998) have obtained observations at 2.2 μm at the Infrared Optical Telescope Array (IOTA) interferometer. Comparisons with lunar occultations at 1.65 and 2.2 μm, interferometry at 2.2 μm at CERGA and at IOTA with the FLUOR beam combination system can be seen to be good. Using broad-band photometry for the value of the bolometric flux, the effective temperature was determined.

Hammersley et al. (1998) have determined the stellar effective temperature using on the one hand the infrared flux method (IRFM) and on the other hand the (V − K) versus T eff relationship of di Benedetto (1993). The effective temperature of nine giant stars from diameter determinations at 2.2 μm with the FLUOR beam combiner on the IOTA interferometer. This yielded the uniform disk angular diameter of α Boo and α Tau. The averaging effect of a uniform model leads to an underestimation of the diameter of the star. Therefore, they have fitted their data with limb-darkened disk models published in the literature. The average result is a ratio between the uniform and the limb-darkened disk diameters of 1.035 with a dispersion of 0.01. This ratio could then also be used for the uniform disk angular diameters of γ Dra and β Peg, listed by di Benedetto & Rabbia (1987), and α Cet, which were based on a photometric estimate. Several photometric sources were used to determine the bolometric flux, which then, in conjunction with the limb-darkened diameter, yielded the effective temperature.

Robinson et al. (1998) have used different sources of scientific literature. Their quoted mass-value was computed from the adopted radius and gravity value.

Taylor (1999) prepared a catalogue of temperatures and [Fe/H] averages for evolved G and K giants. This catalogue is available at CDS via anonymous ftp to cdsarc.u-strasbg.fr.
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ISO-SWS calibration and the accurate modelling of cool-star atmospheres *

IV. G9 to M2 stars

L. Decin¹**, B. Vandenbussche¹, C. Waelkens¹, G. Decin¹, K. Eriksson², B. Gustafsson², B. Plez³, and A.J. Sauval⁴

¹ Institut voor Sterrenkunde, KULeuven, Celestijnenlaan 200B, B-3001 Leuven, Belgium
² Institute for Astronomy and Space Physics, Box 515, S-75120 Uppsala, Sweden
³ GRAAL - CC72, Université de Montpellier II, F-34095 Montpellier Cedex 5, France
⁴ Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180 Bruxelles, Belgium

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Abstract. A detailed spectroscopic study of 11 giants with spectral type from G9 to M2 is presented. The 2.38 – 4.08 µm wavelength-range of band 1 of ISO-SWS (Short-Wavelength Spectrometers on board of the Infrared Space Observatory) in which many different molecules — with their own dependence on each of the stellar parameters — are absorbing, enables us to estimate the effective temperature, the gravity, the microturbulence, the metallicity, the CNO-abundances, the \(^{12}\)C/\(^{13}\)C-ratio and the angular diameter from the ISO-SWS data. Using the Hipparcos’ parallax, the radius, luminosity and gravity-inferred mass are derived. The stellar parameters obtained are in good agreement with other published values, though also some discrepancies with values deduced by other authors are noted. For a few stars (δ Dra, ξ Dra, α Tuc, H Sco and α Cet) some parameters — e.g. the CNO-abundances — are derived for the first time. By examining the correspondence between different ISO-SWS observations of the same object and between the ISO-SWS data and the corresponding synthetic spectrum, it is shown that the relative accuracy of ISO-SWS in band 1 (2.38 – 4.08 µm) is better than 2% for these high-flux sources. The high level of correspondence between observations and theoretical predictions, together with a confrontation of the estimated \(T_{\text{eff}}\) (ISO) value with \(T_{\text{eff}}\) values derived from colours — which demonstrates the consistency between \(V-K\), \(BC_{K}\), \(T_{\text{eff}}\) and \(\theta_d\) derived from optical or IR data — proves that both the used MARCS models to derive the stellar quantities and the flux calibration of the ISO-SWS detectors have reached a high level of reliability.

Key words. Infrared: stars – Stars: atmospheres – Stars: late-type – Stars: fundamental parameters – Stars: individual: δ Dra, ξ Dra, α Boo, α Tuc, β UMi, γ Dra, α Tau, H Sco, β And, α Cet, β Peg

1. Introduction

In the fourth article of this series, we discuss the ISO-SWS (Short-Wavelength Spectrometers on board of the Infrared Space Observatory) spectra of 11 giants cooler than the Sun. These giants are part of a larger sample selected as stellar standard candles for the calibration of the detectors of ISO-SWS. In Decin et al. (2000) hereafter referred to as Paper I a method was developed to analyse the infrared data (2.38 – 12 µm) of cool stars: the specific dependence of the absorption pattern by the different molecules gives the possibility to estimate fundamental stellar parameters like the effective temperature (\(T_{\text{eff}}\)), the gravity (\(\log g\)), the microturbulence (\(\xi_t\)), the metallicity, the CNO-abundances, the \(^{12}\)C/\(^{13}\)C-ratio and the angular diameter (\(\theta_d\)). We now apply this method of analysis to the ISO-SWS data of these 11 giants. Keeping the general calibration problems and the accuracy of the theoretical models and synthetic spectra (based on the MARCS and Turbospectrum code (Gustafsson et al. 1975; Plez et al. 1992, 1993); version May 1998) in mind — as discussed in paper I, Decin et al. (2000) hereafter referred to as Paper II — the error bars on the different stellar parameters are determined and the resultant stellar parameters are confronted with other published parameters.

This paper is organised in the following way: in Sect. 1 a summary of the general discrepancies between the ISO-SWS spectra of the cool giants and the theoretical spectra,
as described in Paper II, is given. We will go more deeply into the determination of the different stellar parameters and their error bar in Sect. 3. After an overview of the deduced stellar parameters, each star is discussed in more detail. Not only are the accuracy and precision of the ISO-SWS data assessed, but the deduced stellar parameters are also evaluated with respect to other published values. A discussion on some of the stellar parameters obtained is held in Sect. 4, where we focus on (i) the effective temperature and (ii) the $^{12}$C/$^{13}$C ratio. The conclusions are given in Sect. 5.

The appendix of this article is published electronically. Most of the grey-scale plots in the article are printed in colour in the appendix, in order to better distinguish the different spectra or symbols.

2. Summary of general discrepancies (Paper II)

The origin(s) of different types of discrepancies seen in the spectra of the cool stars could be settled from a detailed comparison between ISO-SWS data and theoretical predictions. As far as the calibration is concerned, we demonstrated in Paper II that problems with the relative spectral response functions in band 1A (2.38 – 2.60 µm) and band 2 (4.08 – 12 µm), fringes at the end of band 1D and memory-effects in band 2 destroy the flux accuracy in this wavelength range. Problems with the CO lines underline that one needs to know the instrumental profile and resolution accurately. Concerning the modelling part, the main problems were situated in the incomplete knowledge of the atomic oscillator strengths in the infrared. The fact that the low-excitation first-overone CO lines were predicted as being too strong and the fundamental OH lines as being to weak, indicated that some of the assumptions the models are based on — e.g. hydrostatic equilibrium, homogeneity — are questionable for these cool stars.

3. Stellar parameters

As was demonstrated in Paper I, it is possible to estimate different stellar parameters for cool giants from their ISO-SWS spectrum and this due to the presence of many molecular absorbers in the 2.38 – 4.08 µm wavelength range. E.g. the slope of the continuum between 3.1 µm and 4.0 µm is indicative for the effective temperature ($T_{\text{eff}}$), while the slope in band 1B and band 1D makes it possible to pin down the gravity ($\log g$). The microturbulent velocity ($\xi$), the abundance of carbon, nitrogen and oxygen and the $^{12}$C/$^{13}$C-ratio can be deduced from the relative strength of the molecular features. For the determination of the metallicity ([Fe/H]), both the slope of the continuum and the strength of the features are required (see Fig. 2 in Paper I). Finally, the angular diameter ($\theta_d$) can be extracted directly from the absolute flux-level of the ISO-SWS data.

Although, these IR ISO-SWS data give us a lot of information concerning the stellar parameters, an inspection of a large grid with stellar parameters typical for these stars, learned us that there exists an actual danger to be trapped in a local minimum in this huge parameter space. Moreover, the preliminary results of a statistical study (Shkedy et al., in prep; Decin et al., in prep) indicate that the maximum error bar on the logarithm of the gravity (as determined from the ISO-SWS spectra) can be quite large ($\gtrsim 0.40$ dex) inducing significant error bars on e.g. the stellar abundances. Hence, we decided to determine first the effective temperature from $(V-K)$ colours (see Sect. 3.1). A first guess for the gravity was found from $K$-band photometry, the bolometric correction $BC_K$, the Hipparcos’ parallax $\pi$, $T_{\text{eff}}(V-K)$ and a mass $M_{\odot}$ estimated from evolutionary tracks (see Sect. 3.1). Using then the ISO-SWS spectra, the values of these two parameters were refined if necessary. In this way, the maximum error on $T_{\text{eff}}$, $\log g$, $\xi$, [Fe/H], $\varepsilon$(C), $\varepsilon$(N), $\varepsilon$(O) and $^{12}$C/$^{13}$C-ratio could be restricted to 200 K, 0.20 dex, 0.30 dex, 0.40 dex, 0.30 dex and 3 respectively. A mean error is then $\sim 2/3$ of this maximum error, depending on the quality of the observation. As will be discussed in Sect. 4.13, it was impossible to deduce $T_{\text{eff}}$, $\log g$, $\xi$, [Fe/H] and the CNO-abundances from the ISO-SWS spectrum of $\beta$ Peg. The error bars are estimated from a comparison with other quoted literature values.

3.1. First guess for $T_{\text{eff}}$ and $\log g$

One can calculate $T_{\text{eff}}$ directly from $V-K$ using (semi-)empirical ($T_{\text{eff}}, V-K$) temperature scales. Such a calibration is e.g. given by Bessell et al. (1998), who determined a polynomial fit between $T_{\text{eff}}$ and $V-K$ based on interferometer and IRFM data (Infrared Flux Method Blackwell & Shallis 1977) for giants. In Table 1, the $V$ and $K$ magnitude of Simbad are listed. For $\beta$ UMi, we list the $K$ magnitude of Fauchere et al. (1983) ; for $\alpha$ Tuc and H Sco the $K$ magnitudes found in the atlas of Gezari et al. (1999) are given. The $(V-K)$ colour has been corrected for interstellar extinction using $A_V = 0.8$ mag/kpc (Blackwell et al. 1990) and $E(V-K) = A_V/1.1$ (Mathis 1990), with the distance calculated from the Hipparcos’ parallax (see Table 3). The values for the effective temperature calculated from formula abed given in Table 7 in Bessell et al. (1998) are listed in Table 1. A comparison with other ($T_{\text{eff}}, V-K$) temperature scales will be given in Sect. 4.1. A typical error bar on the derived $T_{\text{eff}}((V-K)_{0})$ values is 50 K.

In order to determine the gravity, we need the radius $R$ and the mass. The first parameter is assessed from $K$, $BC_K$, $\pi$ (from Hipparcos) and $T_{\text{eff}}((V-K)_{0})$. We used

\footnote{This maximum error is not the error as obtained from varying one parameter at a time, since this only gives us an underestimate of the uncertainties. An error in one parameter may couple to the error in another parameter ‘constructively’. The effect of this coupling will be different for different type of stars. Considering here the G9 to M2 giants in our sample, a large grid with typical stellar parameters have been inspected in order to estimate this coupling and to determine the maximum error.}
Table 1. Magnitude measurements for the Johnson $V$ and $K$ pass-bands are tabulated. The effective temperature (in K) derived from the $(T_{\text{eff}}, (V-K)_0)$ relationship as given by Bessell et al. (1998) is listed in the last column.

| name   | HD-number  | $V$     | $K$     | $V - K$   | $(V-K)_0$ | $T_{\text{eff}}((V-K)_0)$ |
|--------|------------|---------|---------|-----------|-----------|---------------------------|
| δ Dra  | HD 180711  | 3.08$^a$| 0.80$^b$| 2.28      | 2.26      | 4828                      |
| ξ Dra  | HD 163588  | 3.75$^a$| 1.03$^b$| 2.72      | 2.70      | 4547                      |
| α Boo  | HD 124897  | −0.06$^a$| −2.95$^c$| 2.89      | 2.88      | 4331                      |
| α Tuc  | HD 211416  | 2.86$^a$| −0.09$^f$| 2.95      | 2.91      | 4312                      |
| β UMi  | HD 131873  | 2.06$^a$| −1.22$^d$| 3.28      | 3.25      | 4111                      |
| γ Dra  | HD 164058  | 2.23$^a$| −1.34$^b$| 3.57      | 3.54      | 3970                      |
| α Tau  | HD 29139   | 0.87$^a$| −2.81$^{b,c}$| 3.68      | 3.67      | 3915                      |
| H Sco  | HD 149447  | 4.16$^b$| 0.00$^b$| 4.16      | 4.08      | 3764                      |
| β And  | HD 6860    | 2.03$^a$| −1.83$^c$| 3.86      | 3.82      | 3856                      |
| α Cet  | HD 18884   | 2.49$^a$| −1.63$^e$| 4.12      | 4.07      | 3768                      |
| β Peg  | HD 217906  | 2.45$^a$| −2.20$^e$| 4.65      | 4.61      | 3615                      |

$^a$: Mermilliod (1986); $^b$: Johnson et al. (1966); $^c$: Lee (1970); $^d$: Faucherre et al. (1983); $^e$: Glass (1974); $^f$: Wamsteker (1981); $^g$: Nicolet (1978); $^h$: Price (1968)

$BC_K((V-K)_0) = m_{\text{bol}} - K$ from Bessell et al. (1998). The work of Bessell et al. (1998) is based on current SORSMARCS-models and synthetic colours, and ensures consistency between derived parameters and model spectra. The error on the bolometric correction is assumed to be 0.05; $m_{\text{bol},\odot}$ is assumed to be 4.74 (Bessell et al. 1998).

The radii derived in this way are tabulated in Table 2.

Mass values for the stars in our sample are estimated from evolutionary tracks with appropriate metallicity as calculated by Girardi et al. (2000), with the only exception being the more massive star α Car for which the evolutionary tracks of Lejeune & Schaerer (2001) have been used. The two sets of evolutionary tracks from the zero age main sequence (ZAMS) to the red giant branch (RGB) agree well with each other. Only Girardi et al. (2000) have given the evolutionary tracks from the zero age horizontal branch (ZAHB) to the thermally pulsating asymptotic giant branch (TP-AGB). By plotting $(L(M_{\text{bol}}) \pm \sigma(L(M_{\text{bol}})), T_{\text{eff}}((V-K)_0) \pm \sigma(T_{\text{eff}}((V-K)_0)))$ for each star on the HR-diagram the mass values $M_\star$ are obtained (see Table 2). Note that most of the giants lie above the horizontal branch and hence could burn hydrogen in a shell surrounding the helium core or could be post-He-flash stars. From our observations no diagnostic tools exist to decide upon the evolutionary status, with the only exception being β Peg, since its colours do not match any RGB evolutionary tracks. In Table 2 the mass values are given for a giant on the RGB (except for β Peg), with a typical error bar of $0.3 M_\odot$ when $M_{\text{hr}} \leq 2.5 M_\odot$. When a star would be on the AGB, this value should be lowered by $\sim 0.2 M_\odot$.

These radius- and mass values were then used to find first-guess values for the gravity (last column in Table 2). Also the mean error for all these parameters is listed.

3.2. Results

Using the ISO-SWS spectra, these first guesses were further refined and the [Fe/H], ε(C,N,O), $^{12}$C/$^{13}$C-ratio and $\theta_d$ were derived. The results from the detailed spectroscopic study and the final error bars are presented in Table 3. The distance $D$ (in pc) is calculated from the parallax measurements (in mas) of Hipparcos. $R(D, \theta_d)$ in combination with the gravity then yielded the gravity-inferred mass $M_\star$ (in $M_\odot$). The luminosity $L$ (in $L_\odot$), extracted from the radius $R(D, \theta_d)$ and $T_{\text{eff}}$(ISO), is the last quantity listed in this table. The objects have been sorted by spectral type, but since the spectral type does not necessarily provide a good indicator of the temperature (Tsuji 1984), this ordering is not always by decreasing effective temperature. The theoretical models and synthetic spectra for stars with spectral type earlier than K0 were calculated using a plane-parallel geometry, for the other ones a spherically symmetric geometry was assumed (see Fig. 1 in Decin et al. 1997). In order to judge upon the goodness-of-fit of the observed and theoretical data, the deviation estimating parameter $\beta$, derived from the Kolmogorov-Smirnov test (see Paper I), has been calculated (see Table 3). This parameter $\beta$ checks the global accordance between the two spectra. The lower the $\beta$-value, the better the accordance. The maximum acceptable $\beta$-values were derived from α Tau in Paper I. These $\beta_{\text{max}}$ values do not depend on the flux level of the observed target, since the $\beta$ parameter is a global goodness-of-fit parameter and these $\beta_{\text{max}}$ values may thus be used for all observations.

In the following subsections, each of the 11 cool giants will be discussed individually. For each star, calibration details can be found in the Appendix. These, in conjunction with the general calibration specifications discussed in Paper II, gives us an idea on the calibration accuracy. If other AOT01 observations are available, they...
Table 2. Magnitude measurements for the Johnson K band are tabulated. The absolute bolometric magnitude $M_{\text{bol}}$ and the luminosity $L($M$_{\text{bol}})$ (in L$_{\odot}$) are derived from the ($V - K$)$_0$ colour index, the bolometric correction $BC_K((V-K)_0)$ and the Hipparcos’ parallax $\pi$. The radius $R$ is calculated from $L($M$_{\text{bol}})$ and $T_{\text{eff}}((V-K)_0)$. Mass values estimated from evolutionary tracks are given in M$_{\odot}$ for all stars in our sample. A typical error bar for $M_{hr}$ is 0.3 M$_{\odot}$ when $M_{hr}$ ≤ 2.5 M$_{\odot}$. The gravity is derived from $R$ and $M_{hr}$. More details are given in the text.

| name  | $K_0$ | BC$_K$ | $m_{\text{bol}}$ | $M_{\text{bol}}(m_{\text{bol}}, \pi)$ | $L($M$_{\text{bol}})$ | $R($L$_{\text{bol}}, T_{\text{eff}}((V-K)_0))$ | $M_{hr}$ | log $g$ |
|-------|-------|--------|------------------|---------------------------------|---------------------|-----------------------------------------------|--------|---------|
| δ Dra | 0.80  | 1.94   | 2.74 ± 0.05      | 0.30 ± 0.06                      | 59 ± 3              | 11.01 ± 0.37                                  | 2.2    | 2.70 ± 0.07 |
| ξ Dra | 1.03  | 2.22   | 3.25 ± 0.05      | 0.58 ± 0.06                      | 46 ± 3              | 11.40 ± 0.41                                  | 1.1    | 2.36 ± 0.12 |
| α Boo | -2.95 | 2.31   | -0.64 ± 0.05     | -0.90 ± 0.05                     | 180 ± 9             | 23.81 ± 0.80                                  | 1.1    | 1.72 ± 0.12 |
| α Tuc | -0.10 | 2.33   | 2.23 ± 0.05      | -1.70 ± 0.05                     | 376 ± 32            | 34.72 ± 1.69                                  | 2.5    | 1.75 ± 0.07 |
| β UMi | -1.22 | 2.46   | 1.24 ± 0.05      | -1.71 ± 0.07                     | 379 ± 23            | 38.36 ± 1.50                                  | 2.2    | 1.61 ± 0.07 |
| γ Dra | -1.34 | 2.55   | 1.21 ± 0.05      | -2.07 ± 0.07                     | 530 ± 33            | 48.61 ± 1.94                                  | 1.80   | 1.31 ± 0.08 |
| α Tau | -2.81 | 2.59   | -0.22 ± 0.05     | -1.72 ± 0.06                     | 395 ± 23            | 42.62 ± 1.67                                  | 1.2    | 1.26 ± 0.11 |
| H Sco | -0.01 | 2.70   | 2.69 ± 0.05      | -2.40 ± 0.19                     | 716 ± 122           | 62.87 ± 5.61                                  | 1.4    | 0.99 ± 0.12 |
| β And | -1.84 | 2.63   | 0.79 ± 0.05      | -3.14 ± 0.11                     | 1415 ± 147          | 84.23 ± 4.88                                  | 2.2    | 0.93 ± 0.08 |
| α Cet | -1.64 | 2.70   | 1.06 ± 0.05      | -3.09 ± 0.13                     | 1356 ± 164          | 86.35 ± 5.71                                  | 2.5    | 0.96 ± 0.08 |
| β Peg | -2.21 | 2.80   | 0.59 ± 0.05      | -3.34 ± 0.11                     | 1702 ± 169          | 105.10 ± 5.97                                 | 1.85   | 0.66 ± 0.09 |

$a$: Johnson et al. (1966); $b$: Lee (1970); $c$: Faucherre et al. (1983); $d$: Glass (1977).

are compared with each other in the Appendix in order to assess the calibration precision of ISO-SWS. Knowing the accuracy and the precision of the observational data, several stellar parameters (and their error bar) are determined from the AOT01 observation and the agreement between observational and theoretical spectra is discussed. Furthermore, the deduced stellar parameters are evaluated with respect to published stellar parameters. Tables with a summary of the different published results, together with a short description of the used methods and/or data and of the assumed and deduced parameters by the different authors quoted in next sections, can be found in the Appendix.

3.3 δ Dra: AOT01, speed 4, revolution 206

3.3.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 1)

Some of the atomic features identified in Fig. 3 in [Paper I] can still be recognised in δ Dra, e.g. around 2.55 μm, 2.63 μm, 3.3 μm, 3.4 μm and 3.85 μm. The second most abundant molecule in nearly all cool stars is CO, because of its very high dissociation energy (11.09 eV), and because of the high cosmic abundance of carbon and oxygen. From δ Dra on, the first-overtone CO band dominates the spectrum till 2.8 μm. The problems with these CO lines are described in point 2 in [Paper I]. In band 1B, 1D and 1E the OH $\Delta v = 1$ lines become visible. Problems with memory effects in [Paper II] make it impossible to improve the data in band 2.

Fig. 1. Comparison between band 1 and band 2 of the ISO-SWS data of δ Dra (black) and the synthetic spectrum (grey) with stellar parameters $T_{\text{eff}} = 4820$ K, log $g = 2.70$, M = 2.2 M$_{\odot}$, [Fe/H] = 0.00, $\xi_t = 2.0$ km s$^{-1}$, $^{12}$C/$^{13}$C = 12, $\varepsilon$(C) = 8.15, $\varepsilon$(N) = 8.26, $\varepsilon$(O) = 8.93 and $\theta_d = 3.30$ mas. A coloured version of this plot is available in the Appendix as Fig. ??.

The carbon abundance is deduced from the CO lines in band 1A (where the standard deviation is larger than for revolution number. The observing data can be calculated from the revolution number which is the number of days after 17 November 1995.
Table 3. Final fundamental stellar parameters for the selected stars in the sample. The effective temperature $T_{\text{eff}}$ is given in K, the logarithm of the gravity in c.g.s. units, the microturbulent velocity $\xi_t$ in km \( s^{-1} \), the angular diameter in mas, the parallax $\pi$ in mas, the distance $D$ in parsec, the radius $R(D, \theta_d)$ in $R_\odot$, the gravity-inferred mass $M_g$ in $M_\odot$ and the luminosity $L$ in $L_\odot$.

| Sp. Type | $\delta$ Dra | $\xi$ Dra | $\alpha$ Boo | $\alpha$ Tuc | $\beta$ UMi | $\gamma$ Dra |
|----------|--------------|-----------|--------------|-------------|-------------|-------------|
| $T_{\text{eff}}$ | 4820 ± 140 | 4440 ± 300 | 4320 ± 140 | 4300 ± 140 | 4085 ± 140 | 3960 ± 140 |
| log g | 2.70 ± 0.20 | 2.40 ± 0.25 | 1.50 ± 0.15 | 1.35 ± 0.15 | 1.60 ± 0.15 | 1.30 ± 0.25 |
| $\xi_t$ | 2.0 ± 0.5 | 2.0 ± 1.0 | 1.7 ± 0.5 | 1.7 ± 0.5 | 2.0 ± 0.5 | 2.0 ± 0.5 |
| [Fe/H] | 0.00 ± 0.25 | 0.10 ± 0.30 | −0.50 ± 0.20 | 0.00 ± 0.20 | −0.15 ± 0.20 | 0.00 ± 0.20 |
| $\epsilon$(C) | 8.15 ± 0.25 | 8.00 ± 0.30 | 7.96 ± 0.20 | 8.30 ± 0.20 | 8.25 ± 0.20 | 8.15 ± 0.25 |
| $\epsilon$(N) | 8.26 ± 0.25 | 8.26 ± 0.40 | 7.61 ± 0.25 | 8.26 ± 0.25 | 8.16 ± 0.25 | 8.26 ± 0.25 |
| $\epsilon$(O) | 8.93 ± 0.25 | 8.93 ± 0.30 | 8.68 ± 0.20 | 8.93 ± 0.20 | 8.83 ± 0.20 | 8.93 ± 0.20 |
| $^{12}$C/$^{13}$C | 12 ± 3 | 20 ± 5 | 7 ± 2 | 13 ± 3 | 9 ± 2 | 10 ± 2 |
| $\theta_d$ | 3.30 ± 0.20 | 3.11 ± 0.22 | 20.72 ± 1.28 | 6.02 ± 0.37 | 9.93 ± 0.62 | 9.98 ± 0.63 |
| $R$ | 3.524 ± 0.46 | 29.26 ± 0.49 | 88.85 ± 0.74 | 16.42 ± 0.59 | 25.79 ± 0.52 | 22.10 ± 0.46 |
| $D$ | 30.73 ± 0.43 | 34.34 ± 0.57 | 11.26 ± 0.09 | 60.90 ± 2.19 | 38.78 ± 0.78 | 45.25 ± 0.94 |
| $M_g$ | 2.18 ± 1.04 | 1.20 ± 0.71 | 0.73 ± 0.27 | 1.27 ± 0.48 | 2.49 ± 0.92 | 1.72 ± 1.02 |
| $L$ | 58 ± 10 | 46 ± 14 | 197 ± 36 | 479 ± 93 | 430 ± 82 | 523 ± 101 |

The other sub-bands in band 1), the N-abundance from the CN lines which are almost invisible, and the O-abundance from OH lines which are also still very weak: the overall uncertainty on the abundance of carbon, nitrogen and oxygen is estimated to be 0.25 dex. Since the chemical equilibrium determines the shape of the synthetic spectrum, too inaccurate a nitrogen abundance would result in high $\beta$-values. So, although the CN and NH lines remain also very weak for the cooler giants, a wrong nitrogen abundance can be traced.

3.3.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

The temperatures given by the different authors quoted in Table ?? all agree quite well. Only the temperature given by Faucherre et al. (1983) and Gustafsson et al. (1974) are somewhat lower than the other values. Gustafsson et al. (1974) have established the temperature scale with the aid of a new theoretical calibration of $R-I$. This colour was computed from scaled solar model atmospheres, with the line blocking considered in a statistical way. The use of scaled solar model atmospheres led to underestimates of $T_{\text{eff}}$, an effect which is also noticeable for the $T_{\text{eff}}$-value of $\xi$ Dra in Table ??.

There is a rather large difference in published gravities, being either around 2.9 dex or around 2.1 dex. Only Gratton et al. (1983) and Gratton (1983) have tabulated a value of log g = 2.1, a result which was obtained from a curve of growth technique. Also the gravity value given by Burnashev (1983) — who has used narrow-band photometric colours in the visible part of the electromagnetic spectrum — is quite discrepant from the more common listed value of log g = 2.9. We note that also for other...
Table 4. The $\beta$-values from the Kolmogorov-Smirnov test are given not only for the different sub-bands, but also for the different molecular absorbers the $\beta$-values. In the second column, one can find the maximum acceptable $\beta$-value for that specific wavelength-range as estimated for a high-quality AOT01 speed-4 observation [Paper I].

|          | $\beta_{\text{max}}$ | $\delta$ Dra | $\xi$ Dra | $\alpha$ Boo | $\alpha$ Tuc | $\beta$ UMi | $\gamma$ Dra | $\alpha$ Tau | H Scorpius | $\beta$ And | $\alpha$ Ceti | $\beta$ Peg |
|----------|---------------------|--------------|----------|-------------|-------------|-------------|--------------|-------------|------------|-----------|------------|-----------|
| $\beta_{1A}$ | 0.06                 | 0.051        | 0.074    | 0.015       | 0.036       | 0.050       | 0.058        | 0.040       | 0.033       | 0.049     | 0.057      | 0.157     |
| $\beta_{1B}$ | 0.05                 | 0.046        | 0.072    | 0.041       | 0.013       | 0.029       | 0.048        | 0.034       | 0.026       | 0.046     | 0.041      | 0.150     |
| $\beta_{1D}$ | 0.04                 | 0.040        | 0.069    | 0.036       | 0.021       | 0.025       | 0.011        | 0.036       | 0.019       | 0.019     | 0.024      | 0.218     |
| $\beta_{1E}$ | 0.04                 | 0.051        | 0.022    | 0.043       | 0.035       | 0.040       | 0.014        | 0.027       | 0.033       | 0.044     | 0.044      | 0.084     |

Stars in our sample, quite some gravity values do not correspond with the ones given by Burnashev (1983). Possible reasons include inaccurate spectrophotometric data or inaccurate formulae to convert the colour indices to the stellar parameter values. Using a gravity of log $g = 2.10$, the best fit was obtained with a — low — carbon abundance of $\varepsilon(C) = 8.00$ (Fig. 3). The discrepancies are more pronounced than in Fig. 1, while the $\beta$-values are larger than for log $g = 2.70$ and $\varepsilon(C) = 8.15$.

Other indirect angular diameter determinations were not found. Gratton et al. (1982) have derived the radius from the visual surface brightness and the temperature, and so have obtained the mass $M_\odot$ of $\delta$ Dra. Faucherre et al. (1983) measured the angular diameter with the two-telescope stellar interferometer (I2T) at CERGA. By using $D = 36 \pm 8$ pc (Jenkins 1952), a radius $R = 15 \pm 4 R_\odot$ was obtained. Although different methods and/or data are used, the three values for the radius listed in Table ?? are in good agreement.

From the 10% absolute flux level accuracy, the uncertainty on the angular diameter ($\theta_d = 3.30$ mas) is estimated to be 0.20 mas. This yields a gravity-inferred mass of $M_\odot = 2.18 \pm 1.04 M_\odot$. This value for $M_\odot$ is higher than the gravity-inferred mass deduced by Gratton et al. (1982), due to their use of a lower gravity value.

3.4. $\xi$ Dra: AOT01, speed 3, revolution 314

3.4.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 3)

The larger pointing offset in the y-direction and the high noise level reduce the reliability of the shape of the sub-bands. Especially the shape of the data at the end of band 1A, in band 1B and in band 1D seems unreliable. As a result, the uncertainties on the fundamental stellar parameters are enhanced. Fortunately, the post-He spectrum does not display these problems. Using then both the speed-3 observation and the post-He data, the stellar parameters were estimated. Similar discrepancies as seen in Fig. 1 of $\delta$ Dra are also arising in the comparison between the observational data of $\xi$ Dra and its synthetic spectrum. Some examples caused by atomic transitions may be seen around 2.545 $\mu$m, 2.595 $\mu$m and 2.623 $\mu$m. The first-overtone CO lines are clearly visible around 2.4 $\mu$m. As described in Paper I, the strongest CO lines were predicted as some-
Fig. 3. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 314) of ξ Dra (black) and the synthetic spectrum (grey) with stellar parameters $T_{\text{eff}} = 4440$ K, log $g = 2.40$, $M = 1.2 M_\odot$, $[\text{Fe/H}] = 0$, $[\text{C/Fe}] = 20$, $\varepsilon(\text{C}) = 8.00$, $\varepsilon(\text{N}) = 8.26$, $\varepsilon(\text{O}) = 8.93$ and $\theta_d = 3.11\text{mas}$. A coloured version of this plot is available in the Appendix as Fig. ??.

Fig. 4. Comparison between band 1 of the post-helium ISO-SWS data of ξ Dra (black) and the synthetic spectrum (grey) with stellar parameters $T_{\text{eff}} = 4440$ K, log $g = 2.40$, $M = 1.2 M_\odot$, $[\text{Fe/H}] = 0$, $[\text{C/Fe}] = 20$, $\varepsilon(\text{C}) = 8.00$, $\varepsilon(\text{N}) = 8.26$, $\varepsilon(\text{O}) = 8.93$ and $\theta_d = 3.125\text{mas}$. A coloured version of this plot is available in the Appendix as Fig. ??.

4.005 µm, the 2-0 band head of the SiO first-overtone band emerges.

The post-helium observation is also compared with a synthetic spectrum generated with the same stellar parameters (but other $\theta_d$ due to the higher absolute flux in the post-He observation) as in Fig. 3 at an appropriate resolution (Fig. 4). The corresponding $\beta$-values are $\beta_{1A} = 0.089$, $\beta_{1B} = 0.105$, $\beta_{1D} = 0.087$ and $\beta_{1E} = 0.048$. The larger $\beta$-values are due to the very strong Mg-Si-Al-Fe feature around 2.55 µm in band 1A (see Fig. 3 in Paper II) and the still ongoing calibration of the post-He data. The spectrum resembles the spectrum of δ Dra.

3.4.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

As for δ Dra, the temperature given by Gustafsson et al. (1974) is lower than other published values (see the comment given in Sect. 3.3.2). The different values quoted for the logarithm of the gravity are in close agreement, with the maximum difference being 0.30 dex and our deduced gravity value being close to the mean. The lowest value was found by Brown et al. (1985) by using the K-line absolute magnitude $M_V(K)$ and the highest value was obtained by McWilliam (1990) by using the well-known relation between $g$, $T_{\text{eff}}$, $L$ and a mass value inferred from evolutionary tracks.

The angular diameter deduced from the speed-3 observation tallies very well with the IRFM angular diameter value given by Blackwell et al. (1991) — which is a revision of Blackwell et al. (1990). Also Gratton et al. (1982) deduced a gravity-inferred mass $M_g$, their value being somewhat higher than ours due to their use of a higher radius value.

For the first time, the abundances of C, N and O are determined. Since the spectroscopic analysis was done on the basis of a speed-3 observation and a post-He speed-4 observation, the error bar on the abundances is estimated to be ~ 0.30 dex.

3.5. α Boo: AOT01, speed 4, revolution 452

3.5.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. ?)
revealed that the Einstein coefficients based on the results of Tipping & Chackerian (1981) are about a factor two larger for the 2-0 overtone band than the currently accepted value. This explained the overestimate of the strength of the SiO lines. Presently, the more accurate SiO line list of Langhoff & Bauschlicher (1993) is used, resulting in a good agreement between observed and calculated spectra. The fundamental bands of SiO and CO are visible in band 2, although no quantitative statements can be made due to the problems with the memory effects. The memory effects in band 2 are quite strong due to the high flux level of α Boo in the infrared.

The high-quality data made it possible to pin down the atmospheric parameters (see Paper II). Where the first set of input parameters contained as gravity log $g = 1.75$, the ISO-SWS (and FTS-KP) spectra gave indications that this value could be refined to log $g = 1.50$.

3.5.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

The different temperature values deduced for α Boo vary around 4300 K, with the lowest value being 4060 K (Scargle & Strecker 1979) and the highest value 4628 K (Dyck et al. 1998). A quite often quoted value is the one of Frisk et al. (1982). $T_{\text{eff}} = 4375$ K, who used photometry in the 0.4 – 2.2 μm wavelength range in order to determine the effective temperature of Arcturus.

Concerning the gravity, one notices that some publications give quite a different gravity w.r.t. our deduced value (with a difference > 0.6 dex compared to log $g = 1.50$ deduced from the ISO-SWS and FTS-KP spectra). The large wavelength range of ISO-SWS, with the presence of many molecules, has proven to be very useful for the determination of the gravity for the cool giants. Our deduced value of log $g = 1.50$ is also corroborated by the excellent agreement between the FTS-KP-spectrum and the synthetic spectrum of α Boo discussed in Paper II. Using, e.g., a gravity of log $g = 1.75$, leads to a gravity-inferred mass of $M_\star = 1.30 M_\odot$. The evolutionary tracks of Bagot et al. (1994) give also support to a mass value around 0.8 $M_\odot$ (for $T_{\text{eff}} = 4300$ K and $L = 196 L_\odot$), suggesting the lower gravity value of log $g = 1.50$.

All obtained values for the metallicity mention [Fe/H] $\approx -0.50$. For the microturbulent velocity, a larger range occurs, with a minimum of 1.5 km s$^{-1}$ (Fernández Villacañas et al. 1990, Koki & Tsuji 1997) and a maximum of 2.5 km s$^{-1}$ (Gratton 1985). From studies on granulations, it is clear that the use of a single parameter to represent the non-thermal velocity field is highly phenomenological and thus, it is not surprising that large differences in deduced values for the microturbulence are obtained.

For the carbon abundance, most of the studies give [C/Fe] being solar or somewhat sub-solar ($\lesssim 0.005$), with the only exception being Altas (1987), who deduced an abnormal high carbon abundance using the Griffin atlas (Griffin 1968) and the model derived by Mäckle et al. (1975). Also for the nitrogen abundance, the value mentioned by Altas (1987) exceeds the other deduced values, although here the spread is higher than for the carbon abundance. We obtained $\varepsilon$(O) using OH-lines. Our de-

duced value agrees (within the error bar) with the ones obtained by Lambert & Ries (1981), Kjærgaard et al. (1982), Altas (1987) and Peterson et al. (1993). Only the value obtained by Mäckle et al. (1975) is substantially lower than our value. Within the error bars, our $^{12}$C/$^{13}$C ratio agrees with other published values.

Angular diameter, luminosity and radius values are in good agreement with other values found in the literature.

Quite a few authors have estimated the gravity-inferred mass, e.g., Mäckle et al. (1975), Gratton (1985), Harris et al. (1988), Judge & Stencel (1991), Peterson et al. (1993). Differences in assumed/adopted/deduced gravity, radius, angular diameter or parallax value explain the observed differences in $M_\star$.

In general, the atmospheric parameters we derived for α Boo agree with the ones found by Peterson et al. (1993). They have obtained the stellar parameters by computing a model atmosphere which reproduces the observed flux distribution of the Griffin atlas (Griffin 1968) of α Boo. Accurate model atmospheres, opacities, line lists, ... are

![Fig. 5. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 452) of α Boo (black) and the synthetic spectrum (grey) with stellar parameters $T_{\text{eff}}$ = 4320 K, log $g$ = 1.50, $\xi_t$ = 1.7 km s$^{-1}$, $v_t$ = 0.75 $v_\infty$, $\varepsilon$(O) = 7.96, $\varepsilon$(N) = 7.61, $\varepsilon$(C) = 7.33, $\varepsilon$(Si) = 7.20 and $\theta_d$ = 20.72 mas. A coloured version of this plot is available in the Appendix as Fig. ??..](image)
indispensable for a good assessment of the stellar parameters. Minor inaccuracies in photometric calibration formulae, in broadening parameters, in the assumptions made in the theoretical modelling computations, ... may lead to statistically relevant departures of the derived parameters. One should be careful when ascribing an atmospheric parameter based on the spectral type (like done by, e.g., Cohen et al. 1999). This is already obvious when comparing the parameters of α Boo and ξ Dra, which are both K2 giants.

3.6. α Tuc: AOT01, speed 4, revolution 866

3.6.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 3)

Fig. 6. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 866) of α Tuc (black) and the synthetic spectrum (grey) with stellar parameters $T_{\text{eff}} = 4300 K$, log $g = 1.35$, $M = 1.3 M_{\odot}$, [Fe/H] = 0.00, $\xi_t = 1.7$ km s$^{-1}$, $^{12}$C/$^{13}$C = 13, $\varepsilon(C) = 8.30$, $\varepsilon(N) = 8.26$, $\varepsilon(O) = 8.93$ and $\theta_d = 6.02$ mas. A coloured version of this plot is available in the Appendix as Fig. ??.

The somewhat higher $\beta$-value in band 1A is partially due to uncertainties in the temperature structure in the outer layers (Paper I) and partially due to the higher standard deviation in band 1A. The atomic features around 3.85 μm and 3.98 μm remain visible (see Fig. 3 in Paper I). The OH features are somewhat more pronounced than for α Boo. The SiO fundamental and first-overtone band, together with the CO fundamental band, arise in band 2.

3.6.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

Only a few published values for the different stellar parameters are available. The temperature derived from the ISO-SWS spectrum and the $V - K$ colour is somewhat higher than the effective temperature derived from the $(V - R)$ colour index (Basri & Linsky 1979; Pasquini & Brocato 1992) and from other broad-band photometry (Glebocki & Stawikowski 1988). Using the Johnson $B$, $V$, $R$ and $I$ colour measurements from Mendoza (1969) as listed by Simbad and the colour-temperature relations of McWilliam (1990), an effective temperature of 4080 K is obtained for α Tuc. The used $K$ magnitude of $-0.09$ mag listed by Wamsteker (1981) could not be checked against other literature values, since no other values were found.

There is however a large difference between the two listed gravities. Glebocki & Stawikowski (1988) have estimated the mass from the mass-function and the position of the primary on the evolutionary track calculations. The radius $R$ was estimated from the bolometric magnitude and the effective temperature deduced from infrared broad-band photometry. Pasquini & Brocato (1992) have not taken the binary character of α Tuc into account, but have deduced the gravity from $M_{\text{bol}}$ and a mass inferred from the comparison with evolutionary tracks. Due to a raw division of the stellar masses into four sub-groups, their gravity is the parameter containing the major uncertainties, which explains the difference with our first-guess value for log $g$, derived from the same $M_{\text{bol}}$ value, but using another $M_{\text{hr}}$ value. From the ISO-SWS spectrum and the corresponding $\beta$-values, we could draw the conclusion that a gravity of 1.90 is too high.

Our deduced angular diameter of $6.02 \pm 0.37$ mas corresponds with the value given by Basri & Linsky (1979), who have used a relation which links the colour $V - R$ to the angular diameter. These two values are higher than the value mentioned by Stencel et al. (1980). Both Basri & Linsky (1979) and Stencel et al. (1980) have used the scaling laws described by Barnes & Evans (1976) and Barnes et al. (1976) to convert fluxes observed on the Earth to fluxes at the stellar surface. Since this scaling law is based on the photometric colour $(V - R)$, an uncertainty in $(V - R)$ can induce a significant error. The photometric colour $(V - R)$ of α Tuc has been quoted as uncertain in both papers $(V - R) = 0.9$ in Stencel et al. (1980) and $(V - R) = 1.04$ in Basri & Linsky (1979), explaining the large difference in $\theta_d$.

The high-quality ISO-SWS spectra of α Tuc gave us the possibility to determine for the first time the C, N and O abundances and the $^{12}$C/$^{13}$C-ratio for this target.

3.7. β UMi: AOT01, speed 4, revolution 182
3.7.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 7)

Fig. 7. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 182) of β UMi (black) and the synthetic spectrum (grey) with stellar parameters \( T_{\text{eff}} = 4085 \) K, \( \log g = 1.60 \), \( M = 2.50 M_\odot \), \([\text{Fe/H}] = -0.15 \), \( \xi_t = 2.0 \text{ km s}^{-1} \), \( ^{12}\text{C}/^{13}\text{C} = 9 \), \( \varepsilon(\text{C}) = 8.25 \), \( \varepsilon(\text{N}) = 8.16 \), \( \varepsilon(\text{O}) = 8.83 \) and \( \theta_d = 9.93 \) mas. A coloured version of this plot is available in the Appendix as Fig. ??.

Band 1A has the largest \( \beta \)-value. For band 1A, the same reasons as for the previous stars can be quoted. The discrepancy between 3.91 and 3.97 \( \mu \)m causes the somewhat larger \( \beta_{1E} \)-value. One can notify an analogous discrepancy in Fig. ?? in the Appendix. The pointing offset (\(|\delta y| > 1''\)), together with a somewhat larger standard deviation after rebinning for the speed-4 observation in that wavelength range, render this discrepancy not significant. The OH spectral features dominate band 1D and band 1E, while the first-overtone band of SiO is clearly visible around 4 \( \mu \)m. The CO fundamental and SiO fundamental and first-overtone bands remain visible in band 2.

3.7.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

The published temperature values all agree very well, the only exception being the value derived by Lambert & Ries (1981) and used by some other authors. As quoted by Ries (1981), Harris et al. (1988) and Luck & Challener (1995), the effective temperature and gravity derived by Lambert & Ries (1981) are too high and should be lowered by \( \sim 240 \) K and \( \sim 0.40 \) dex respectively. Taking this remark into account and knowing that the gravity values quoted by Burnashev (1983) differ often with other values (see Sect. 3.3.2), our deduced gravity is in good agreement, although being at the lower end, with other deduced gravity values. The metallicity and microturbulent velocity agree with the other values listed in Table ??.

The \( ^{12}\text{C}/^{13}\text{C} \) ratio derived from the ISO-SWS spectrum is somewhat lower than other published values, but the difference is not significant due to the large standard deviation and the other problems discussed in Paper II for band 1A. The angular diameter from the SWS-spectrum lies in between the values quoted by Judge & Stencel (1991) and Stencel et al. (1980). Being somewhat larger than the value given by Judge & Stencel (1999), our deduced values of \( R \), \( M_g \) and \( L \) are also higher than those listed by Judge & Stencel (1991).

3.8. \( \gamma \) Dra: AOT01, speed 4, revolution 377

3.8.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 8)

Fig. 8. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 377) of \( \gamma \) Dra (black) and the synthetic spectrum (grey) with stellar parameters \( T_{\text{eff}} = 3960 \) K, \( \log g = 1.30 \), \( M = 1.7 M_\odot \), \([\text{Fe/H}] = 0.00 \), \( \xi_t = 2.0 \text{ km s}^{-1} \), \( ^{12}\text{C}/^{13}\text{C} = 10 \), \( \varepsilon(\text{C}) = 8.15 \), \( \varepsilon(\text{N}) = 8.26 \), \( \varepsilon(\text{O}) = 8.93 \) and \( \theta_d = 9.98 \) mas. A coloured version of this plot is available in the Appendix as Fig. ??.
It was difficult to decide between log g ≈ 1.20 and log g ≈ 1.55 for γ Dra, since the Kolmogorov-Smirnov test — applied in the region from 2.8 - 3.2 µm, where the synthetic spectrum is quite sensitive to the gravity — yields almost the same β-value. Since a gravity of log g = 1.30 was obtained from K, BC, π, T_eff (V – K) and M, this gravity was chosen to represent the ‘true’ gravity of the star. The small difference between the two β-values is reflected in the higher uncertainty of log g in Table 3. The other comments for γ Dra are similar to the ones for α Boo.

3.8.2. Comparison with other published stellar parameters

Different methods like IRFM, colour indices, interferometry, the Engelke function (Engelke 1992), ... almost all yield the same effective temperature for γ Dra. The value given by Tomkin et al. (1977) is quite low, which may be due to inaccurate colour indices or calibration. We note that Faucherre et al. (1983), who derived effective temperatures from interferometric measurements of angular diameters, underestimated the effective temperature of δ Dra compared to our value, but for γ Dra obtained a value slightly higher than ours. As for α Boo, the gravity deduced by Cohen et al. (1996) from the spectral type seems to be erroneous.

The reference quoted by Harris & Lambert (1984) for the determination of the atmospheric parameters could not be traced back. The only two other deduced values for the gravity listed in Table ?? are log g ≈ 1.55 and log g ≈ 1.20. As described in previous paragraph, the β-values from the Kolmogorov-Smirnov test for these two gravity values are quite alike.

Our deduced value for the angular diameter θ_d = 9.98 ± 0.63 mas is in close agreement with the values obtained by using the IRFM method (Blackwell & Shallis 1977; Leggett et al. 1980; Bell & Gustafsson 1989) or by using the Engelke function as was done by Cohen et al. (1996). While our results and the values adopted by Robinson et al. (1998) for the stellar radius are based on the Hipparcos’ parallax and the deduced (or adopted) angular diameter, Leggett et al. (1980) used the parallax value by Jenkins (1963) (π = 17 ± 6 mas). Consequently, their deduced radius (and luminosity) is higher than ours.

Only Harris et al. (1988) and Robinson et al. (1998) have estimated a gravity-inferred mass from adopted g and R values. The value of Robinson et al. (1998) is higher than our derived M_g value due to the use of a higher gravity, while the value obtained by Harris et al. (1988) (M = 0.9 M⊙) is much lower. This low value was discarded by Harris et al. (1988), who instead adopted M = 2.0 M⊙.

C, N and O abundances agree fairly well with the ones obtained by Lambert & Ries (1981).

3.9. α Tau: AOT01, speed 4, revolution 636

α Tau has been discussed in Paper I.

3.10. H Sco: AOT01, speed 4, revolution 847

3.10.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 9)

Fig. 9. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 847) of H Sco (black) and the synthetic spectrum (grey) with stellar parameters T_eff = 3900 K, log g = 1.30, M = 2.0 M⊙, [Fe/H] = 0.00, ξ_t = 2.0 km s⁻¹, 12C/13C = 8, ε(C) = 8.20, ε(N) = 8.26, ε(O) = 8.83 and θ_d = 4.73 mas. A coloured version of this plot is available in the Appendix as Fig. ??.

The use of the initial values for the effective temperature and gravity of T_eff = 3750 K and log g = 1.00 resulted in synthetic spectrum being very discrepant from the ISO-SWS spectrum. From the slope of the ISO-SWS data between 2.8 and 4.08 µm, the effective temperature was found to be higher by ~ 150 K. The logarithm of the gravity had to be increased with 0.3 dex. The used K magnitude to derive the initial values of T_eff and log g was quoted to be uncertain (Price 1968), which may result in initial values being quite off.

From H Sco on, the spectra are dominated by water lines. It has been calculated that at a temperature of about 3900 K the concentrations of water and OH are equal; below this temperature, water is the dominant oxygen-
containing molecule as well as the dominant opacity source (Wallace et al. 1995).

3.10.2. Comparison with other published stellar parameters

HD 149447 is classified by Simbad as a K6 III giant. Perrin et al. (1998) estimated the effective temperature for a K5 III giant (with \( V - K = 3.52 \)) as being \( T_{\text{eff}} = 3980 \) K and for an M0 III giant (with \( V - K = 3.78 \)) as \( T_{\text{eff}} = 3895 \) K. Gray (1992) has, however, listed somewhat lower temperatures, i.e. \( T_{\text{eff}} = 3915 \) K for a K5 III giant and \( T_{\text{eff}} = 3726 \) K for an M0 III giant. Using the Johnson \( B, V, R \) and \( I \) colour measurements listed by Johnson et al. (1966) and the colour-temperature relations of McWilliam (1990), we derived an effective temperature \( T_{\text{eff}} \approx 3900 \) K.

These \( T_{\text{eff}} \) values support our \( T_{\text{eff}} \) value estimated from the ISO-SWS spectrum of H Sco.

The quantities \( \log g, \) mass, \( \xi_t, [\text{Fe/H}], \) CNO-abundances, \( ^{12}\text{C}/^{13}\text{C} \)-ratio, \( \theta_d \), L and R are here derived for the first time for this stellar source.

3.11. \( \beta \) And: AOT01, speed 4, revolution 795

3.11.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 10)

Just like the K-giants, this ‘normal’ M-giant displays the molecular features and the discrepancies summarised in Paper I. However, \( \text{H}_2\text{O} \), rather than \( \text{OH} \), has now become the main absorber in the wavelength region from 2.8 \( \mu \text{m} \) to 4 \( \mu \text{m} \), although the OH lines remain very well visible.

3.11.2. Comparison with other published stellar parameters (see Table 10 in the Appendix)

As for \( \gamma \) Dra and \( \alpha \) Tau, the effective temperatures given by Tomkin et al. (1975); Leinsky & Ayres (1978); Scargle & Strecker (1979) are quite low compared to the other values derived from different methods. The interferometric value by Dyck et al. (1998) is the highest \( T_{\text{eff}} \) value in Table ??.

From \( K, BC_K, \pi, T_{\text{eff}}(V - K) \) and \( M_{\text{HR}} \) an initial input gravity of \( \log g = 0.95 \) was derived. Using this gravity value, \( T_{\text{eff}} = 3880 \) K, \( \xi_t = 2.0 \) km s\(^{-1} \), \( [\text{Fe/H}] = 0.00, \) \( \varepsilon(C) = 8.12, \varepsilon(N) = 8.37, \varepsilon(O) = 9.08 \) and \( ^{12}\text{C}/^{13}\text{C} = 9, \) a good agreement with the observed ISO-SWS spectrum was obtained. This gravity value of \( \log g = 0.95 \) is, however, much lower than most of the other quoted values in Table ??.

Examining the other gravity values, we see that

- Clegg et al. (1979) have derived \( \log g \) from an assumed mass of \( 1 \) \( \text{M}_\odot \), a \( T_{\text{eff}} \) value derived from spectral type and colours and has estimated a luminosity value using the HR diagram of Scalo (1976). Our deduced \( M_{\text{HR}} \) of 2.2 \( \text{M}_\odot \) would result in a higher luminosity and thus in a lower gravity.

- Both Smith & Lambert (1985) and Lazaro et al. (1991) have estimated the effective temperature from the \( V - K \) colour and the luminosity from \( M_V(K) \) obtained via the Wilson-Bappu effect and \( BC_K \). Comparing, however, these \( M_V(K) \) values from Wilson (1976) with \( M_V \) values obtained using the \( V \) colour given by Simbad and the Hipparcos’ parallax, we note that these \( M_V(K) \) are systematically higher than our derived \( M_V \) values (with a mean difference of 0.73 mag). Using another sample of cool giants, Tsuji (1981) compared the results from the Wilson-Bappu effect with those by Eggen (1973), showing that the results from the Wilson-Bappu effect are systematically \( \sim 0.5 \) mag fainter. Hence, Tsuji (1981) decided to use the mean of the two values. Using too high an \( M_{\text{bol}} \) value (by \( \sim 0.73 \) mag) results in too high a \( \log g \) value (by \( \sim 0.3 \) dex). Moreover, taking these questionable values for the luminosity into account, the mass values estimated by Smith & Lambert (1985) and Lazaro et al. (1991) using evolutionary tracks are meaningless. In addition, Lazaro et al. (1991) have estimated stellar parameters per spectral type, and so have adopted a mean mass of 1.5 \( \text{M}_\odot \). Although having the same spectral type, stellar objects may differ significantly in stellar parameters.

![Fig. 10.](image)
– Judge & Stencel (1991) have estimated the gravity from photospheric line studies, but these results could not be traced back.

Thus, we may conclude that the other quoted log $g$ values in Table ?? are either too high or are meaningless.

The derived angular diameter tallies with other indirectly determined angular diameters given in Table ??, The use of old parallax values by Faucherre et al. (1983); Volk & Cohen (1989); Judge & Stencel (1991) — which may be almost a factor 3 higher than the Hipparcos’ parallax — resulted, however, in a radius value much higher than any literature values. As a consequence, our deduced luminosity exceeds the other quoted values. Since our deduced gravity is at the lower end of the other quoted gravity values, our deduced C-abundance is also somewhat lower (see Paper I). The abundances of nitrogen and oxygen agree with other quoted values.

3.12. $\alpha$ Cet: AOT01, speed 4, revolution 797

3.12.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 11)

![Fig. 11. Comparison between band 1 and band 2 of the ISO-SWS data (rev. 797) of $\alpha$ Cet (black) and the synthetic spectrum (grey) with stellar parameters $T_{\text{eff}} = 3740\,\text{K}, \log g = 0.95, M = 2.7\,M_\odot, [\text{Fe/H}] = 0.00, \xi_t = 2.3\,\text{km s}^{-1}, ^{12}\text{C}/^{13}\text{C} = 10, \varepsilon(\text{C}) = 8.20, \varepsilon(\text{N}) = 8.26, \varepsilon(\text{O}) = 8.93$ and $\theta_d = 12.52\,\text{mas}$. A coloured version of this plot is available in the Appendix as Fig. ??.

For this cool giant, the spectrum resulting from the computations with a standard stellar model, i.e. without a stellar wind, shows a very good agreement with the ISO-SWS spectrum of $\alpha$ Cet. The discrepancies described in Paper I occur also for $\alpha$ Cet. The small atomic feature around 3.85 $\mu$m remains marginally visible.

3.12.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

Napiwotzki et al. (1993) quoted that the resulting IRFM temperatures are too low by 1.6 – 2.8 %, but the effective temperature found by Tsuji (1981) is $\sim 160$ K higher than the effective temperature deduced from the $V - K$ colour and confirmed by the ISO-SWS data. Using improved H$-$opacity, Blackwell et al. (1991) derived an effective temperature from the IRFM being 3745 K, which matches our derived temperature value.

Concerning the quoted gravity values in Table ??, the same comments can be given as for $\beta$ And. The use of too low a luminosity value results in too high a gravity value (Clegg et al. 1979; Lazaro et al. 1991; Tsuji 1986). Moreover, assuming a stellar mass (1 $M_\odot$ by Clegg et al. (1979), 3 $M_\odot$ by Tsuji (1986), 1.5 $M_\odot$ by Lazaro et al. (1991)) based on the spectral type, can introduce significant errors on the gravity. The obtained value by Judge & Stencel (1991) could not be traced back. Cohen et al. (1996) used a statistical relation between spectral type and gravity which may result in inaccurate gravity values taking into account the divergent stellar parameters for different targets having the same spectral type (cfr. e.g. $\alpha$ Cet and $\beta$ Peg). Burnashev (1983) has derived gravity values from narrow-band photometric colours. As can be seen from Table ??, the obtained values differ largely (see also the remarks given in Sect. 3.3.2 and 3.7.2). Hence, once more, we may conclude that the other quoted gravity values in Table ?? are not accurate.

Our angular diameter deduced from the ISO-SWS spectrum agrees quite well with other angular diameters deduced using indirect methods (e.g. Blackwell et al. 1991; Judge & Stencel 1991). Judge & Stencel (1991) used a somewhat lower parallax value quoted by Jenkins (1952) (which differs by a factor $\sim 1.2$ with the Hipparcos’ parallax), resulting in a higher radius and luminosity value than ours.

Our deduced carbon abundance differs somewhat from the values deduced by Tsuji (1991), who used second-overtone CO-lines. These values are higher than the values inferred from first-overtone CO-lines by Tsuji (1986) and Lazaro et al. (1991). Tsuji (1991) discussed this problem in conjunction with the smaller $\xi_t$, deduced from the second-overtone, than from the first-overtone CO lines. Probably, the origin of the discrepancy between the carbon abundances derived from the more or less saturated lines of the CO first-overtone and those from the less saturated second-overtone lines can, at least partly, be explained by an over-simplification of the treatment of the micro-
turbulent velocity, for which in classical models a depth-independent, isotropic Gaussian model is taken. Even in classical abundance analysis, an error of only 0.5 km s\(^{-1}\) in \(\xi_t\) produces an error as large as 0.3 dex in the derived abundances. Since line asymmetries in cool giant stars are as large as 0.5 km s\(^{-1}\), a poor modelling of the turbulence may also produce similar or even larger errors on the abundances derived from saturated lines. Our carbon abundance is, however, deduced from first-overtone lines. Its higher value w.r.t. the value given by Tsuji (1986) may be explained by our lower \(\xi_t\). Moreover, when using the parameter values as deduced by Tsuji (1981, 1986, 1991), a bad correspondence is seen between the observed and synthetic spectra: when using \(\varepsilon(C) = 8.06\) the CO (\(\Delta v = 2\)) lines are predicted as being far too weak, while they are predicted as being far too strong for \(\varepsilon(C) = 8.50\). It should also be noted that the agreement in band 1B was very bad.

3.13. \(\beta \) Peg: AOT01, speed 4, revolution 551

3.13.1. Comparison between the ISO-SWS spectrum and the synthetic spectrum (Fig. 12)

By using the classical models and synthetic spectra as calculated by the MARCS- and Turbospectrum codes, it turned out impossible to determine stellar parameters from the ISO-SWS data of \(\beta \) Peg: in the range 2.6 – 3.2 \(\mu\)m, certain lines were always predicted as far too weak (see, e.g., Fig. 12, where the synthetic spectra for 2 different sets of parameters are plotted).

Already from the early eighties, it was clear that the near-infrared absorption lines of CO and H\(_2\)O molecules yield insight into the structure of the inner parts of an expanding envelope (Tielens 1983). The picture emanating from these data was that three different regions are to be recognised:

(a) an extending pulsating photosphere terminated by
(b) a stationary layer which starts
(c) the cool expanding envelope.

In panel (C) in Fig. 12 — where the SWS observational data of \(\beta \) Peg are divided by the synthetic spectrum specified in panel (B) — a clear pattern is appearing. Comparing this pattern with typical molecular absorption patterns as displayed e.g. in Fig. 3.5 in Decin (2000) or in Fig. 4 in Decin et al. (2000), we see that — at least — H\(_2\)O is necessary to explain this excess absorption.

The discovery of such excess absorption/emission features visible in the ISO-SWS data was for the first time discussed by Tsuji et al. (1997). They concluded that these features could be interpreted as due to an excess absorption originating in a ‘warm molecular envelope’. These layers are clearly distinct from the much cooler circumstellar envelopes (CSE) already known from radio observations. At that time, it was however still not clear how such a molecular forming region could be developed.

A similar structure of features was found from ISO observations in quite some other stars (Fig. 13), among them \(\alpha\) Ori (Cami et al. 1997; Justtanont et al. 1998; de Jong 1999; Yamamura et al. 1999; Ryde et al. 1999). Together with \(\mu\) Cep, \(\alpha\) Ori is one of the two objects whose CSE kinetic temperature distribution has been analysed (Rodgers & Glassgold 1991). Indications were found by other methods and different authors that a hydrostatic model is not able to model these stars correctly (e.g. Hinkle et al. 1982; Aringer et al. 1999). Such discrepancies, found by both models developed by Tsuji and collaborators and models developed by the Uppsala group, may be too large to be relaxed by improving the model of the photosphere. Dynamical models for the outer layers of oxygen-rich AGB-stars reveal, on the other hand, a layered structure of the molecules and much higher column densities than predicted by hydrostatic models (Woitke et al. 1999; Höfner et al. 2002). This is a natural consequence of the shock waves occurring in these models. The
Fig. 13. \(\alpha\) Orionis and \(\beta\) Pegasi are compared in the wavelength region from 2.4 to 3.4 \(\mu\)m. The flux values of \(\beta\) Pegasi are multiplied by a factor 5. The 'problematic' \(\text{OH}/\text{H}_2\)O lines are indicated by the arrow.

The overall amount of levitated gas found in the models exceeds the lower density limits of \(\text{CO}, \text{H}_2\text{O}, \text{CO}_2\) and \(\text{SO}_2\) inferred from the ISO-SWS observations. Therefore, the levitation of the outer atmospheres of AGB-stars by pulsations seems to be a possible mechanism to form these 'warm molecular layers'. Other effects, such as dust formation and chemical non-equilibrium, are probably also involved.

Thus, it is an established fact that a better understanding of the complicated structure of cool stars — and more precisely their spectral features around 3 \(\mu\)m — will only be reached once dynamical modelling of stars, including good opacity calculations, NLTE and a CSE, are fully developed. One should therefore be very careful in the interpretation of results based on current modelling.

In order to determine \(\varepsilon(\text{C})\), the \(^{12}\text{C}/^{13}\text{C}\)-ratio, \(\theta_d\), \(L\), \(R\) and \(M_g\) we have adopted as \(T_{\text{eff}}\) and \(\log g\) the values obtained in Sect. 3.1. Furthermore, we adopted [Fe/H] = 0.00, \(\xi_t = 2.0\) km s\(^{-1}\), \(\varepsilon(\text{N}) = 8.18\) and \(\varepsilon(\text{O}) = 8.93\) assuming that \(\beta\) Pegasi has already gone through the first dredge-up. For the computation of the upper and lower limit of the stellar mass, \(\Delta \log g = 0.40\) dex was assumed.

3.13.2. Comparison with other published stellar parameters (see Table ?? in the Appendix)

As for \(\alpha\) Boo and \(\beta\) And, the highest effective temperature value for \(\beta\) Pegasi in Table ?? is given by the interferometric value of [Dyck et al. (1998)]. The other \(T_{\text{eff}}\) values do agree quite well.

A discussion on the other quoted gravity values in Table ?? can be found in the corresponding sections for \(\beta\) And and \(\alpha\) Ceti. As for \(\alpha\) Ceti, [Tsuji (1980)] has determined \(M_{\text{bol}}\) as being the mean of the value given by the Wilson-Bappu relation [Wilson (1976)] (\(M_{\text{bol}} = -1.9\)) and the result found by [Eggen (1973)] (\(M_{\text{bol}} = -3.2\)). Since this mean value is higher than our value for \(M_{\text{bol}}\) by 0.79 mag (see Table ??, \(M_{\text{bol}} = -3.34\)), the obtained value for \(\log g\) is higher by \(-0.3\) dex. [Tsuji (1991)] quoted, however, a lower gravity value, being \(\log g = 0.5\) dex, but the reason for this decrease is not mentioned.

The microturbulence was determined by various authors. They have used different kinds of spectral lines, such as the SiO first-overtone lines [Lambert et al. (1987)], the CO first-overtone lines [Tsuji (1984)], the CO second-overtone lines [Tsuji (1991)], CN lines [Aoki & Tsuji (1997)], Fe I, Ni I and Ti I lines [Smith & Lambert (1985)]. Unfortunately, these studies all yield different values.

Also for \(\beta\) Pegasi, a large difference is visible between the carbon abundance deduced from the CO (\(\Delta v = 2\)) lines and from the CO (\(\Delta v = 3\)) lines as obtained by [Tsuji (1980, 1991)]. Smith & Lambert (1991) have used both CO (\(\Delta v = 2\)) and CO (\(\Delta v = 3\)) lines. They are the only ones having deduced \(\varepsilon(\text{C}), \varepsilon(\text{N})\) and \(\varepsilon(\text{O})\) simultaneously based on high-resolution spectra of OH (\(\Delta v = 2\)), CO (\(\Delta v = 3\)), CO (\(\Delta v = 2\)) and CN (\(\Delta v = 2\)) lines. Using the assumed stellar parameters as described in previous section, \(\varepsilon(\text{C}), \theta_d, L, R, M_g\) and the \(^{12}\text{C}/^{13}\text{C}\)-ratio are deduced from the ISO-SWS spectrum of \(\beta\) Pegasi. We assigned a quite high error bar on the derived \(\varepsilon(\text{C})\) and \(^{12}\text{C}/^{13}\text{C}\)-ratio, since these ratios were deduced only from the first \(^{12}\text{CO}\) and \(^{13}\text{CO}\) features before 2.45 \(\mu\)m, where the spectrum is less disturbed by the excess absorption of \(\text{H}_2\text{O}\).

As for \(\alpha\) Ceti, the \(^{12}\text{C}/^{13}\text{C}\)-ratio obtained by [Lazaro et al. (1991)] is higher than the value deduced in this and other studies.

Our obtained angular diameter agrees well with the angular diameter obtained most recent by [Blackwell et al. (1999)] using IRFM. Also the luminosity and the radius correspond with other quoted values.

4. Discussion on the derived stellar parameters

4.1. Temperatures derived from \(V - K\) colours

It is instructive to compare the ISO-SWS \(T_{\text{eff}}\), mostly sensitive to the slope of the spectrum between 2.8 and 4 \(\mu\)m, to \(T_{\text{eff}}\) derived by other means. As already said in Sect. 3.1.1, one can calculate \(T_{\text{eff}}\) directly from \(V - K\) using (semi-) empirical \((T_{\text{eff}}, (V - K)_\odot)\) temperature scales. Such calibrations are e.g. given by [Ridgway et al. (1980)], [di Benedetto (1993, 1998)] and [Bessell et al. (1998)] (see Sect. 3.1.1). Ridgway et al. (1980) have established an empirical effective temperature calibration by using angular diameters from lunar occultation in combination with infrared photometry. More recently, Michelson interferometry has been producing much more precise radii for the K and M stars [di Benedetto (1993, 1998)].

\(T_{\text{eff}}\) may also be derived from \(M_{\text{bol}}\) and the angular diameter deduced from the ISO-spectra. It is easily shown that: \(\log(T_{\text{eff}}) = 2.720 - 0.5 \log(\theta_d/1000) - M_{\text{bol}}/10\), with \(\theta_d\) in mas and assuming that \(M_{\text{bol,}\odot} = 4.74\).
Table 5. Effective temperatures derived from the \((T_{\text{eff}}, V - K)\) relationship as given by Ridgway et al. (1980) (RJWW80), H. Benedicto (1993, 1998) (diBen9398) and Bessell et al. (1998) (BCP98) are tabulated in columns 3, 4, and 5 respectively. In column 6, \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) is listed and in the last column the effective temperature deduced from the ISO-SWS spectra is given.

| name | \((V - K)_0\) | \(T_{\text{eff}}(V - K)_0\) | \(T_{\text{eff}}(V - K)_0\) | \(T_{\text{eff}}((V - K)_0)\) | \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) | \(T_{\text{eff}}(ISO)\) |
|------|---------------|------------------|------------------|------------------|------------------|------------------|
| \(\delta\) Dra | 2.26 | 4846 | 4784 ± 48 | 4828 | 4858 ± 157 | 4820 ± 140 |
| \(\xi\) Dra | 2.70 | 4437 | 4412 ± 44 | 4457 | 4457 ± 166 | 4440 ± 300 |
| \(\alpha\) Boo | 2.88 | 4321 | 4280 ± 43 | 4331 | 4226 ± 139 | 4320 ± 140 |
| \(\alpha\) Tuc | 2.91 | 4302 | 4264 ± 43 | 4312 | 4052 ± 133 | 4300 ± 140 |
| \(\beta\) UMi | 3.25 | 4101 | 4061 ± 41 | 4111 | 3963 ± 132 | 4085 ± 140 |
| \(\gamma\) Dra | 3.54 | 3973 | 3926 ± 39 | 3970 | 3978 ± 134 | 3960 ± 140 |
| \(\alpha\) Tau | 3.67 | 3931 | 3874 ± 39 | 3915 | 3831 ± 129 | 3850 ± 140 |
| H Sco | 4.08 | 3793 | 3688 ± 98 | 3764 | 4112 ± 139 | 3900 ± 140 |
| \(\beta\) And | 3.82 | 3845 | 3722 ± 95 | 3856 | 3790 ± 127 | 3880 ± 140 |
| \(\alpha\) Cet | 4.07 | 3796 | 3689 ± 98 | 3768 | 3679 ± 124 | 3740 ± 140 |
| \(\beta\) Peg | 4.61 | 3648 | 3622 ± 102 | 3615 | 3554 ± 147 | (3600) |

From \(m_{\text{bol}}(K_0, BC_K((V - K)_0))\) in Table 2 and \(\theta_d\) from Table 3, \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) is calculated. This \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) is listed in column 6 in Table 3, together with \(T_{\text{eff}}\) derived from the three \(T_{\text{eff}}(V - K)\) calibrations discussed above. The comparison to \(T_{\text{eff}}(ISO)\) (Fig. 14) shows that these methods do agree within the \(\sim 5\%\) level, with the exception being H Sco (see further discussion)! Only for a few stars, \(T_{\text{eff}}(ISO)\) has been adjusted slightly w.r.t. the first guess value \(T_{\text{eff}}((V - K)_0)\) derived from Bessell et al. (1998). This good general agreement in \(T_{\text{eff}}\) proves that \(T_{\text{eff}}\) as derived from ISO-SWS spectra is compatible with \(T_{\text{eff}}\) derived from photometry. Since all the \(T_{\text{eff}}((V - K)_0)\) calibrations are based on almost the same principle, it is normal that all the \(T_{\text{eff}}((V - K)_0)\) values are clustered together w.r.t. \(T_{\text{eff}}(K_0, BC_K, \theta_d)\), as is seen in the lowermost plot of Fig. 14. For H Sco and \(\alpha\) Tuc, the derived \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) is quite discrepant w.r.t. the other \(T_{\text{eff}}\) values. Concentrating on the most discrepant star, H Sco, this too high a \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) value can be either due to too low an \(m_{\text{bol}}\) or \(\theta_d\) value. The used \(K\) magnitude of 0.00 mag is from Price (1968), who quoted this value as being uncertain. We note that an error of +0.4 mag in \(K\) (\(K = 0.4\) mag), inducing a 0.11 mag decrease in \(BC_K\) around 4000 K so that \(m_{\text{bol}} = 2.99\) mag, leads to an error in \(T_{\text{eff}}\) of −275 K (\(T_{\text{eff}}(K_0, BC_K, \theta_d) = 3837\) K; −367 K for the increase in \(K = +0.2\) K in the decrease in \(BC_K\)). Simultaneously, this increase in \(K\), through a decrease of \(V - K\) by 0.4 mag, induces an increase of about 75 K in the \(T_{\text{eff}}\) deduced from \(T_{\text{eff}}((V - K)_0)\) calibrations. Concerning the bolometric correction \(BC_K\) we have used the relation found by Bessell et al. (1998). As can be seen from Fig. 20 in Bessell et al. (1998), the \(BC_K\) values of Bessell & Wood (1984) are systematically somewhat higher in the region \(2.3 < V - K < 4.5\) mag, with a maximum difference around \(V - K = 3\) mag and being almost 0 for \(V - K \approx 4\). So, uncertainties in \(BC_K\) can not explain the observed differences. For H Sco, only 1 ISO-SWS observation is available. Inspecting the literature values for the angular diameter for the other cool stars in the sample, we see that \(\theta_d(ISO)\) is not systematically higher or lower than the other quoted values. Taking the worst-case scenario, in which the absolute-flux level of the ISO-SWS data is too low by 10 % (a value deduced from the comparison between the different observations of one target, as done in the Appendix) and using the same \(T_{\text{eff}}(ISO)\) value of 3900 K, the angular diameter of H Sco would increase from 4.73 mas to 4.96 mas inducing a decrease in \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) from 4112 K to 4016 K, still different by \(\sim 250\) K from the \(T_{\text{eff}}((V - K)_0)\) values. Moreover, as discussed in Sect. 3.1.3, we derive an effective temperature of \(T_{\text{eff}} = 3900\) K using the Johnson \(B, V, R\) and \(I\) colour measurements of Johnson et al. (1966) and the colour-temperature relation of McWilliam (1990). This value of 3900 K — being \(\sim 150\) K higher than the initial guess value based on \(K = 0.00\) mag — is supported by the slope of the ISO-SWS spectrum of H Sco. We may conclude that a least the (high) uncertainty in the \(K\) magnitude can explain the larger deviation of \(T_{\text{eff}}(K_0, BC_K, \theta_d)\) w.r.t. the other \(T_{\text{eff}}\) values.

Taking a (more typical) error of −0.1 mag in the \(K\) magnitude of \(\alpha\) Tuc, would also shift this target in within the 3 % level of correspondence in the lowermost plot of Fig. 14.

Taking all these remarks into account, we may conclude that uncertainties in the \(K\) magnitude or in \(\theta_d\) may cause H Sco and \(\alpha\) Tuc to deviate from the 3 % level of correspondence of the different obtained \(T_{\text{eff}}\) values. Moreover, this high level of correspondence proves the consistency between \(V - K, BC_K\), \(T_{\text{eff}}\) and \(\theta_d\) derived from IR and optical data.
Fig. 14. Comparison between $T_{\text{eff}}(V - K)$ derived from the relationship given by Ridgway et al. (1980), di Benedetto (1993), di Benedetto (1998) or Bessell et al. (1998), $T_{\text{eff}}(K_0, B_C K, \pi)$ and the effective temperature deduced from the ISO-SWS spectra. A coloured version of this plot is available in the Appendix as Fig. ??.

4.2. $^{12}\text{C}/^{13}\text{C}$ ratio

Classical models (i.e. those where stellar convective regions are instantly mixed, where no transport of matter occurs in the radiative regions and without rotation at any depth) predict that the carbon isotopic ratio $^{12}\text{C}/^{13}\text{C}$ in low-mass stars ($M \lesssim 2 M_\odot$) declines from 90 to about 20 – 30 along the red giant branch (e.g. Iben 1967; Dearborn et al. 1976; Charbonnel et al. 1998). This pattern is, however, not seen for our program stars (see Fig. 15). Observations of CNO elements in a large number of evolved stars (for an overview, see Sneden 1991) permitted already to confirm the qualitative occurrence of the first dredge-up, but quantitative disagreements appeared between the abundance pattern of real low-mass stars and of ‘model’ stars: in a large fraction of giants the observed $^{12}\text{C}/^{13}\text{C}$ and $^{12}\text{C}/^{14}\text{N}$ ratios appeared to be substantially lower than the predicted post-dredge-up ratios. Therefore, different processes involving an extra-mixing process have been proposed to explain the deviations from standard theoretical predictions (for an overview, see Charbonnel 1994; Charbonnel et al. 1998). Observational results of Charbonnel et al. (1998) confirmed that the extra-mixing process becomes efficient on the RGB only when the low-mass stars reach the so-called luminosity function bump, i.e. the evolutionary point where the hydrogen burning shell crosses the chemical discontinuity created by the convective envelope at its maximum extent, tending to indicate that the nature of this extra-mixing process on the RGB is related to rotation.

Fig. 15. The ratio of $^{12}\text{C}/^{13}\text{C}$ is plotted against the bolometric magnitude of the program stars. The absolute magnitudes are tabulated in Table 2. This figure should be compared with Fig. 1 in Charbonnel et al. (1998).

Our observational results are summarised in Fig. ?? where we show the observed dependence of the $^{12}\text{C}/^{13}\text{C}$ ratio on $M_{\text{bol}}$. The same conclusions can be drawn as by Charbonnel et al. (1998), namely (i) the least luminous star in our sample, $\xi$ Dra, shows a limit on the $^{12}\text{C}/^{13}\text{C}$ ratio in agreement with standard predictions, and (ii) for stars with $M_{\text{bol}} < 0.9$, the observed isotopic ratio drops to values between 7 and 13, well below the standard predicted post-dilution ratio. As quoted by Charbonnel et al. (1998), it is interesting to note that the RGB luminosity function bump of 47 Tuc (with $[\text{Fe}/\text{H}] \approx -0.65$) is at $M_{\text{bol}} = 1.05 \pm 0.20$, i.e. precisely where the disagreement between standard predictions and observed $^{12}\text{C}/^{13}\text{C}$ ratios appears. Our observational results, in which for the first time the $^{12}\text{C}/^{13}\text{C}$-ratio of $\delta$ Dra, $\alpha$ Tuc and H Sco are included, are thus a confirmation of the claims of Charbonnel et al. (1998).

Moreover it has to be noted that for more massive stars ($M \geq 1.7 – 2.3 M_\odot$, depending on the metallicity) the evolutionary scenario is different: the hydrogen-burning shell never reaches the region of constant molecular weight that has been homogenised by the convective envelope during the first dredge-up. Under these conditions, the extra-mixing process does not occur in these stars and their abundance pattern should resemble the pattern predicted by standard stellar theory. Taking into account the (large) error bars on the derived $M_g$ values or on the assumed $M_{\text{hr}}$ values, and assuming that the cool giants in our sample are still on the RGB — see also the discussion in the previous section — and that no other extra-mixing process occurs, the low values of the $^{12}\text{C}/^{13}\text{C}$ ratios are indicative...
for low-mass stars \((M \lesssim 2 M_\odot)\) in which this extra-mixing process occurs.

5. Conclusions

In this paper, the atmospheric parameters of 11 giants have been determined by using the method described in Paper I and Paper II. A confrontation with other published stellar parameters, other ISO-SWS data and the synthetic spectra always showed very ‘positive’ results both for the theoretical modelling and for the calibration of the ISO-SWS detectors. The very small discrepancies still remaining in band 1 are at the \(1 \sim 2\%\) level for the giants, proving not only that the calibration of the (high-

flux) sources in this band is better than \(\sim 2\%\), but also that the description of cool-star atmospheres and molecular linelists is already quite accurate at the ISO-SWS spectral resolution \((R \sim 1000)\).

In the discussion of the deduced parameters, we demonstrated that \(T_{\text{eff}}\) (ISO) is consistent with other \(T_{\text{eff}}(V-K)\) or \(T_{\text{eff}}(K_0, BC_K, \theta_d(ISO))\) values in within the few percent level, proving once more that the used MARCS-models to derive the quantities from the ISO-SWS spectra are very trustworthy and that the flux calibration of ISO-SWS is indeed reassuring.

The obtained \(^{12}\text{C}/^{13}\text{C}\) ratios are compatible with other sources (e.g. Charbonnel 1995).

Like already pointed out in Paper II, these synthetic spectra will now be used for the latest OLP10 calibration of ISO-SWS. Also other consortia constructing instruments for ground-based telescopes — i.e. MIDI (= the Mid-Infrared Interferometric instrument for the VLT with first observations foreseen in 2001) and new satellites — i.e. SIRTF, the Space InfraRed Telescope Facility, with launch foreseen in December 2001, and Herschel, a far-infrared submillimeter telescopes with launch foreseen in 2007 — will use this type of study and/or these SEDs for determining the required sensitivity of their instruments. A confrontation with existing SEDs, like the ones of M. Cohen, is therefore planned in a forthcoming paper of this series, in which also the new atomic linelist constructed by Sauval (Sauval 2002) will be implemented.

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