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Research Note

A note on infrared standard stars*,**

C. Jaschek[1] **and Y. Andrillat**[2]

[1] Observatoire de Strasbourg. URA 1280, CNRS. 11, rue de l'Université, F-67000 Strasbourg, France
[2] Laboratoire d'Astronomie Université de Montpellier 2. URA 1280 CNRS, Place Eugène Bataillon, F-34095 Montpellier- Cedex 5, France

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Abstract. During the preparation of the infrared spectral atlas for early type stars, a large number of MK standards was observed in the $\lambda\lambda$ 8400–8800 Å region. A list of eighteen standards is given which present some degree of inconsistency between the infrared and the MK type. It is suggested to modify the list of MK standards, excluding the PI's, so that the list can also be used for the infrared spectral region.

Key words: stars: early-type stars: fundamental parameters infrared: stars

In the course of the classification work in the near infrared region ($\lambda\lambda$ 8400–8800 Å) for the establishment of a spectral atlas, we have observed a large number of early type MK standard stars. In the introduction to the Atlas (Andrillat et al. 1995) it was stated "A close examination of these standards showed that they lead also in the infrared region to a consistent reference frame, if one excludes about ten percent of the standards". The purpose of the present Note is to examine in detail the standards which had to be eliminated for various reasons

1. Material

We refer to the previous paper (Andrillat et al. 1995) for the details of the instrumentation with which the spectra were obtained. We recall simply that the spectra cover, at a dispersion of 33 Å/mm, the wavelength region 8375–8770 Å, with a resolution of 1.2–1.5 Å. Equivalent widths were also measured. Often the stars were also observed at P 7 or in the 7000 Å region and in such cases the measures are also given.

2. The standards

We have used the MK standards listed by García (1989), which for early type stars is based upon Johnson & Morgan (1953), Morgan & Keenan (1973) and Morgan et al. (1978). With these standards we set up a reference frame for the infrared region, but, as remarked before this was only possible at the price of omitting some MK standards. In some cases the differences could have been artificially eliminated by attributing either a different spectral type or a different luminosity class than the one specified for the blue ($\lambda\lambda$ 3800–4800 Å) region. In other cases even this artificial procedure would not have been applicable since the equivalent widths do not fit an unique spectral type. We have therefore preferred not to change any classification, but to call all non-fitting stars "peculiar in the infrared" (PI).

In what follows we provide a list of PI's. When we quote equivalent widths, they are expressed in Angstroem units. Numbers quoted between parentheses provide the value the equivalent width should have according to the spectral classification of the star and the calibration curves given in the Atlas.

HD 3901 – B2 V. W(P14) = 2.80 (1.60), W(P7) = 5.88 (5.40). These values do not correspond to a dwarf. They would fit a B2III star.

HD 21071 – B7 V. W(P14) = 7.71 (9.0), W(P7) = 2.43 (2.75). Such values correspond to a B5 V object.

HD 26015 – F3 V. W(P14) = 0.98 (0.85). Whereas the Paschen lines are normal for the type, the O I line W(8446) = 0.90 (0.35) is much too strong and corresponds to luminosity class Ib.

HD 31647 – A0 V. W(P14) = 2.56 (3.15). The Paschen lines are too weak for the type.

HD 34503 – B5 III. W(P14) = 3.80 (3.50), W(P7) = 6.50 (5.80), W(He 7065) = 0.15 (0.45), W(He 6678) = 0.20 (0.55). We have therefore Paschen lines too strong and He I lines too weak for a

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Send offprint requests to: Y. Andrillat, 27 ter, rue Adam de Craponne F-34000 Montpellier, France

* This research was completed before the untimely death of Mercedes Jaschek, who should have figured as the principal author.

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B5 III object. The star could be a new He-weak object. We notice however that the measures were not made simultaneously.

HD 36861 – O8 III(f). W(He 7065) = 0.67 (0.80), W(He 6678) = 0.60 (0.80). He I lines are either too weak for class III or they correspond to a class V object.

HD 47839 – O7 V. W(He 7065) = 0.42 (0.60), W(He 10123) = 1.24 (1.30). These values do not correspond to an O7 object.

HD 97603 – A4 V. W(P14) = 3.25 (2.65). This value corresponds to a more luminous star.

HD 97633 – A2 V. W(C I 10684) = 0.93 (1.10). The C I line and also 10691, 10707 and 10729, are weak in this star.

HD 102647 – A3 V. W(P 7) = 13.22 (11.40). This line is very strong whereas P(14) is normal for the type. The observations are however not simultaneous.

HD 115664 – F3 III. W(O I 8446) = 0.60 (0.58) and W(O I 7772) = 0.87 ((0.88). Whereas both O I lines are normal for a giant, the W(P14) = 2.97 (3.90) corresponds to a more luminous object.

HD 123299 – A0 III. W(P7) = 10.67 (8.6) is strong whereas W(P14) = 4.37 (4.20) is normal for the type. The observations are however not simultaneous.

HD 127762 – A7 III. W(P7) = 8.88 (7.4) is strong whereas W(P14) = 3.09 (3.20) is normal for the type. The observations are not simultaneous.

HD 160762 – B3 IV. W(P7) = 7.80 (5.50) is too strong for the type.

HD 163506 – F2 Ib. This star has several peculiarities discussed in the literature. In the infrared W(8446) = 0.92 (0.82) of O I corresponds to class Ib, whereas W(P14) = 2.20 (3.70) corresponds to class III. All Paschen lines are too weak for the type. The Ca II triplet shows emission on the red side, which are well visible in P13 and P16.

HD 176437 – B9 III. W(P14) = 5.76 (2.90) which is very strong. W(8446) = 0.75 (0.45) of O I corresponds to luminosity class Ib. N I lines are also very strong. The Paschen series is visible to at least n = 21. This is characteristic of a shell star.

HD 186832 – B9.5 III. W(P7) = 9.62 (8.2) is too strong for luminosity class III and corresponds better to class IV.

HD 222173 – B8 V. W(P14) = 4.5 (2.7) is anomalously strong for luminosity class V, whereas O I with W(8446) = 0.43 (0.46) agrees with class V.

3. Discussion

A perusal of the list shows that discrepancies occur at all spectral types we find 2 O-type stars, 7 of B-type, 6 of A type and 3 of F type. The total number of standard stars observed in each spectral type were: 27 of O type, 58 of B-type, 32 of A type and 31 of F-type. Given the small numbers, we find no accumulation of peculiarities at some special type. The same happens with luminosities-we find 9 stars of class V, one of class IV, 7 of class III and one of class Ib. It should be added that we did not observe many class IV stars, because class IV is not easily distinguishable in the infrared. As for the discrepancies themselves, we have only admitted cases in which the discrepancies between the observed and the expected equivalent widths are larger than 25%. This probably is overpessimistic, since measured equivalent widths are precise to $\pm 10\%$, but it permits the exclusion of a number of marginal cases in which the errors of the average curve and the measured values combine in the least favorable sense. We conclude thus that the differences are real.

As remarked, we found in a number of stars discrepancies between the equivalent widths of P14 and P7. Since our observations were not made simultaneously, it would be worthwhile to reobserve these stars, if possible at higher resolution, in order to find out if the differences are caused by weak emission features, line profile variations or binarity.

We recall two further stars from which we have no Paschen observations, which were found to have a peculiar spectral behavior in an earlier paper (M. Jaschek et al. 1994). These are HD 36371 and HD 83754. In the first, HD 36371 (B5 Iab), He I 6678 is very strong, whereas He I 10028 and 10128 are normal and H alpha very weak. In HD 83754 (B5 V) He I 6678 is very strong, whereas other He I lines (l 10028 and 10138) are weak or absent.

Let us recall also that the discrepant cases found in later spectral types (F5-M) were already discussed by Ginestet et al. (1994).

It is perhaps surprising that such a large number of discrepancies came up. Let us recall however that we observed some 150 stars, so that the percentage of discrepancies is $12 \pm 1\%$. We found earlier a similar percentage of inconsistencies when examining the ultraviolet region. (Jaschek & Jaschek 1984).

In view of the forthcoming paper by Jaschek and Gómez (1997) on the absolute magnitudes of the MK standards, it is worthwhile examining if the anomalies found in the infrared reflect in the absolute magnitudes. We have only a small number of stars common to both list, namely 21. Of these, 11 present no problems. Among the other ten, we have four cases in which the equivalent width of the P7 line does not agree with that of P14, but this is not reflected in the absolute magnitudes. One further star in which the C I lines are too weak, also does not reflect in the absolute magnitude. The remaining five cases are mentioned below.

HD 26015 (F3 V) in which we found the O I line to be too strong for luminosity class V, i.e. indicating higher luminosity class, has nevertheless an absolute magnitude corresponding to class V.

HD 97603 (A4 V) which we found in the infrared suggests a brighter class than V, has nevertheless a normal absolute magnitude.

HD 176347 (B9 III), which we found in the infrared to show characteristics of a shell star has a much too bright absolute magnitude.

HD 186882 (B9,5 III), which seems more luminous in the infrared, is also brighter as expected.

HD 222173 (B 8 V). We found above that the O I and H I lines disagree as far as luminosity is concerned. The absolute magnitude of the object is found to be too bright – it falls in an intermediate position between classes V and III.

In summary, we have three cases in which the absolute magnitude agrees with the infrared indications and two cases in which it does not agree. The numbers are too small to draw a general conclusion, except the obvious one that in the infrared as well as in the blue region the agreement between luminosity classes and absolute magnitude is not perfect, but rather statistical.

One can ask if it is worthwhile eliminating standards with infrared anomalies from the list of standards in the MK system. One can argue that the MK system was set up in the blue region ($\lambda\lambda$ 3800-4800), and that therefore there is no need that these standards be also standards in another region. The sobering fact however is that the set up of the MK system took some forty years, incorporating the experience obtained from the examination of several thousand spectra. In our opinion it is at least very doubtful if in other spectral regions, like the ultraviolet and/or the infrared, a similar effort will be made in a near future. What is much easier is to make a selection among the MK standards so that the standards in one region become also standards in the other regions. It is very fortunate that both Morgan and Keenan defined several standards for the different combinations of spectral type and luminosity class, so that a convenient selection of standards is an entirely feasible operation. If this is not done, we shall end up with the usual inconsistencies, namely that spectral types extrapolated from the visual to the ultraviolet and/or the infrared do not correspond to the MK type. This implies then that we shall run into the usual difficulties of defining what a "normal" star looks like in any of the new regions. It would be easy to point out various cases of ultraviolet or infrared observations in which the comparison star (supposed to be "normal") for a peculiar object, turned out to have a spectral peculiarity itself - despite the fact that in the blue region the spectrum was normal.

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