# MASS ESTIMATION OF TWELVE K DWARFS

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**Abstract.** Detailed analyses giving the chemical composition have been carried out for twelve K dwarfs. Iron over hydrogen values have been found. Estimates of the masses of these stars are given.

## 1. Introduction

Because of the interest of the low-mass stars for galactic structure studies, we began, a few years ago, a study of chemical composition and atmospheric parameters of K dwarfs. Our aim was to correlate results from high-dispersion analyses with spectral classification work.

## 2. Detailed Analysis

We began this study by reanalyzing nine stars (Perrin *et al.*, 1975), already analyzed by other authors, Oinas (1974) and Strohbach (1970).

In the paper by Perrin *et al.* (1975), were discussed chiefly the strong differences found by Oinas (1974) between the abundance values derived from neutral lines and the abundance values derived from ionized lines of some elements such as Fe, Ti and Cr. The causes of these differences have been found. Indeed, as already said by Dr Bell, we could realize quite perfectly the ionization equilibrium for the nine stars using new oscillation strengths and a multi-branch curve of growth for the Sun (Foy, 1972).

A new paper will soon appear concerning a detailed analysis of three other K dwarfs. Two of these stars, 36 Oph A and 36 Oph B, belong to a visual triple system in which the third component, 36 Oph C (HD 156026), has been analyzed by Strohbach (1970) and by Perrin *et al.* (1975). The other star, HD 191408, is a high-velocity star whose photometry and kinematics have already been discussed by Eggen (1972). Following Eggen, HD 191408 is much older than the stars of the triple system which, according to their strong Ca II H and K emission and their very low space velocities, must belong to a much younger population. These stars, either HD 191408 or 36 Oph A and 36 Oph B, have very well-determined trigonometric parallaxes.

Table I contains some interesting data of the twelve stars studied until now. The heading of each column of this table is self-explanatory. Columns 9–12 contain the results from our detailed analyses.

From this table, we can see that none of the stars have abundance differences with

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respect to the Sun, $[Fe/H]^{*}_{\odot}$, exceeding the imposed error limit of ± 0.20 dex; not even the high-velocity star HD 191408.

This is an interesting result and confirms the results by Hearnshaw (1972), da Silva (1975) and Foy (1974) who found other high-velocity stars having normal metal abundances or having a much less metal deficiency than expected.

## 3. Mass Estimation

The last column of Table I contains the values of the masses which we have attributed to the stars.

These masses have been obtained by using a mean relation between masses of visual dwarf binaries vs $(R-I)$ indices (Figure 1). We found this mean relation using the data from Tables 13 and 15 of a paper by Eggen (1967).

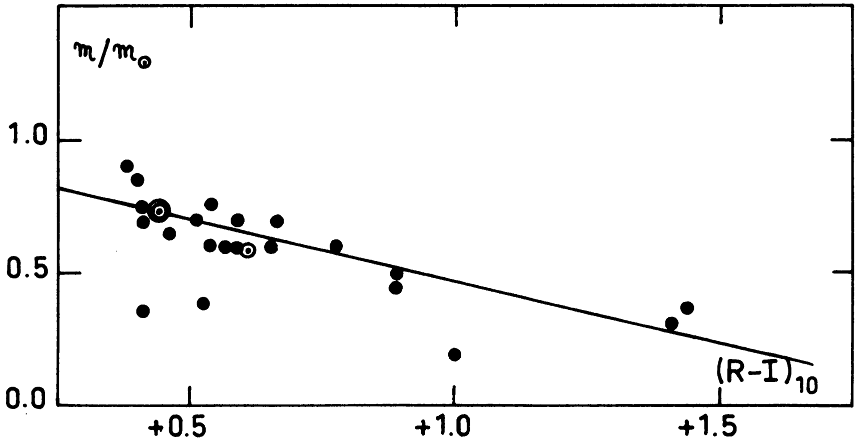


Fig. 1. Relation between mass and $(R-I)_{10}$ for Eggen's visual binaries. The double open dotted circle stands for 36 Oph A and B, the single open dotted circle for 36 Oph C.

There exists an astrometric mass determination by Brosche (1960) of 36 Oph A and B: $M_A + M_B = 1.46 M_{\odot}$. Since components $A$ and $B$ are very similar in spectrum and brightness, their masses are probably very close and we could attribute to them the same mass and the same $(R-I)$ index. It is interesting to see that the position of 36 Oph A and B (double open dotted circle) lies on the mean relation in Figure 1.

There exists also a mass estimation by Couteau (1975) for 36 Oph C (single open dotted circle in Figure 1).

The very good fitting for 36 Oph A and B on the mean relation and the rather good fitting for 36 Oph C encouraged us to trust our mass/$(R-I)$ relation and allowed us to estimate the masses of the other nine stars we have already analyzed.

TABLE I

| Star | Sp.T. | $m_V$ | $\pi_t$±p.e. (0.″001) | $(R-I)_{10}$ | $M_V$ | B.C. | $M_{bol}$ | log $g$ | $\theta_{eff}$ | log $T_{eff}$ | $[Fe/H]^*_\odot$ | $\mathcal{M}/\mathcal{M}_\odot$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 Oph A | K0 V | 5.1 (1) | 189±9 | 0.44 (2) | 6.48 | −0.23 | 6.25 | 4.6 | 0.99 | 3.707 | +0.10 | 0.73 |
| 36 Oph B | K1 V | | | | | | | 4.6 | 0.99 | 3.707 | −0.02 | |
| 36 Oph C | K5 V | 6.34 (1) | 178±8 | 0.61 (3) | 7.59 | −0.58 | 7.01 | 4.7 | 1.11 | 3.658 | +0.06 | 0.60 |
| HD 191408 | K3 V | 5.32 (2) | 177±8 | 0.49 (2) | 6.55 | −0.32 | 6.23 | 4.6 | 1.03 | 3.689 | −0.03 | 0.71 |
| HD 32147 | K3 V | 6.21 (2) | 109±4 | 0.49 (2) | 6.41 | −0.32 | 6.09 | 4.5 | 1.06 | 3.677 | +0.05 | 0.71 |
| HD 75732 | G8 V | 5.97 (1) | 74±7 | 0.40 (5) | 5.32 | −0.16 | 5.16 | 4.5 | 0.97 | 3.714 | +0.22 | 0.75 |
| HD 145675 | K1 V | 6.65 (1) | 63±7 | 0.40 (5) | 5.70 | −0.16 | 5.54 | 4.5 | 0.97 | 3.714 | +0.20 | 0.75 |
| HD 165341 | K0 V | 4.24 (4) | 195±5 | 0.38 (6) | 5.70 | −0.13 | 5.57 | 4.5 | 0.95 | 3.725 | −0.02 | 0.76 |
| HD 166620 | K2 V | 6.40 (2) | 93±5 | 0.49 (2) | 6.24 | −0.32 | 5.92 | 4.5 | 1.01 | 3.698 | −0.14 | 0.71 |
| HD 190404 | K1 V | 7.27 (1) | 51±11 | 0.45 (5) | 5.80 | −0.25 | 5.55 | 4.5 | 1.00 | 3.703 | −0.11 | 0.72 |
| HD 192310 | K0 V | 5.73 (2) | 120±10 | 0.45 (2) | 6.13 | −0.25 | 5.88 | 4.5 | 1.01 | 3.699 | −0.02 | 0.72 |
| HD 219134 | K3 V | 5.57 (2) | 147±4 | 0.53 (2) | 6.41 | −0.41 | 6.00 | 4.5 | 1.05 | 3.681 | +0.04 | 0.69 |

*Sources:* Spectral Type, $\pi$, $M_V$: Woolley *et al.* (1970)
Bolometric corrections: Johnson (1966) after a correction of −0.07
Photometry: (1) Woolley *et al.* (1970); (2) Johnson *et al.* (1966); (3) Gliese (1969); (4) Lutz (1971); (5) Dickow *et al.* (1970); (6) Oinas (1974).

### 4. Tentative Estimation of He-Abundance

Another contribution of this work on K dwarfs is related to a very important problem.

All the stars have good absolute magnitudes and carefully determined effective temperatures. They have been placed in a ($M_{bol}$–log $T_{eff}$) diagram.

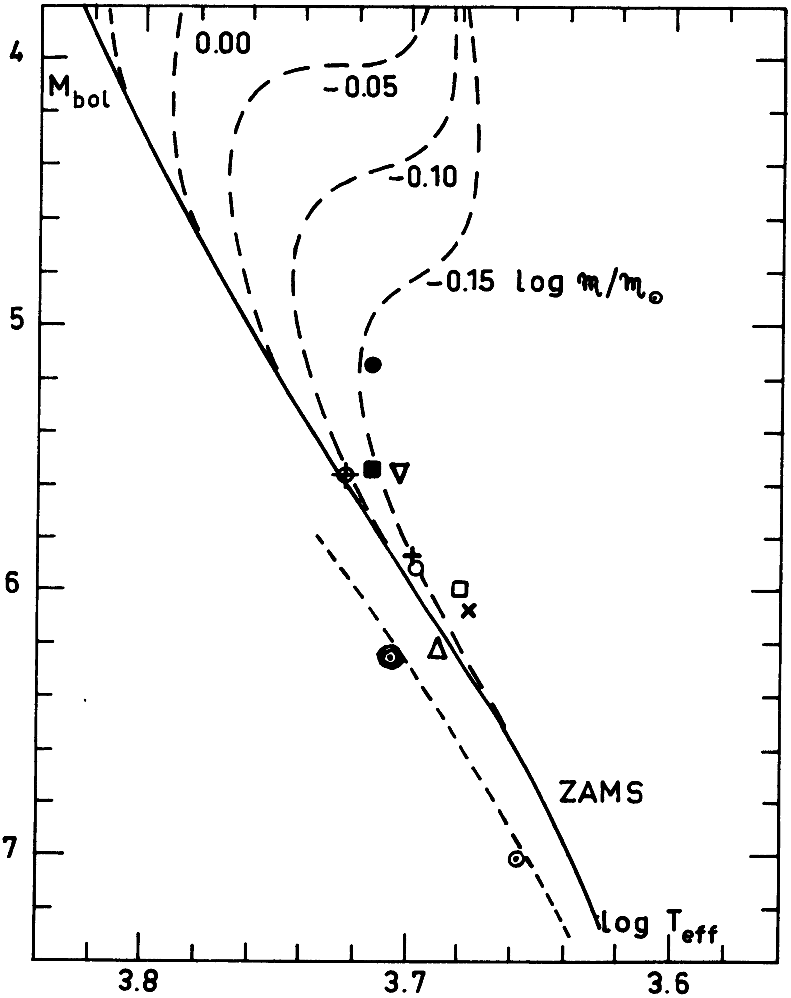


Fig. 2. The (log $T_{eff}$–$M_{bol}$) diagram, showing the zero age main sequence (ZAMS) and the evolutionary tracks computed by Hejlesen for $X = 0.70$, $Z = 0.02$ and $l/H_p = 2.0$, together with the positions of the twelve stars studied here, represented by the following symbols: • HD 75732, ■ 145675, ∇ HD 190404, ⊕ HD 165341, + HD 192310, ○ HD 166620, □ HD 219134, x HD 32147, △ HD 191408, ◎ 36 Oph A and B, ⊙ 36 Oph C; the lower dashed line represents the ZAMS computed by Hejlesen for $X = 0.60$, $Z = 0.02$ and same mixing length parameter.

The positions occupied by the stars have been compared with a theoretical zero-age main sequence (ZAMS) calculated by Hejlesen (1974) for normal solar helium and metal abundances ($X = 0.70$, $Z = 0.02$) and with a mixing-length parameter $l/H_p = 2.0$. In Figure 2, the continuous line represents this ZAMS, the broken line the evolutionary tracks and the different symbols the positions of the observed stars around this ZAMS. For the stars of the triple system the same symbols as in Figure 1 (double and single open dotted circle) have been used. Note that 36 Oph A and B fall together on the diagram because they have the same absolute magnitude and the same effective temperature as derived from detailed analyses.

It can be seen that the stars of the triple system lie below the normal He-abundance ZAMS.

On the contrary, they lie on the ZAMS (lower dashed line on Figure 2) computed by Hejlesen (1974) with higher He-abundance, in respect to the first ZAMS, same normal metal abundance ($X = 0.60$, $Z = 0.02$) and same mixing-length parameter.

We have seen that the metal abundances of the twelve stars are almost the same. If we believe that the position of the triple system on the HR diagram is exact and if we want to justify this position, the only way to do it is to attribute to the triple system a higher He-abundance than that of the other stars in the diagram.

Could this mean that the triple system was formed from interstellar matter enriched in helium? This is an open question and it requires more detailed analyses of low mass visual binaries to be settled.

## 5. Conclusion

We have seen how carefully determined atmospheric parameters combined with reliable distance parameters can be helpful in the determination of masses and in the estimation of He-content of some K dwarfs.

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## DISCUSSION

*Mendoza*: Your slide showed a small difference in the trigonometric parallax for 36 Oph A, B than from 36 Oph C. Why not use a single 'mean' value for the three components?

*Perrin*: Because the determination of parallax for 36 Oph A and 36 Oph B has been made simultaneously whereas 36 Oph C has an independent parallax determination. It is interesting to give this value in the table.

Of course, in the HR diagram I could have given a mean parallax for the three stars, but the position in $M_{\rm bol}$ of 36 Oph C would have been changed by an inappreciable amount.

*Maeder*: One has to be careful in the comparison of the theoretical zero-age sequence and observations. Firstly, because models with $l/H_{\rm p}=2$ use mixing-length theory in a case which is known to be not consistent. Secondly, because the opacities used in the quoted models are certainly insufficient for the low mass stars.

*Perrin:* Of course you are right that Hejlesen's models contain inconsistent $l/H_{\rm p}$ and poor opacities. But I used ($X$=0.70 $Z$=0.02) for evolutionary tracks calculated with normal He content and ($X$=0.60 $Z$=0.02) for evolutionary tracks calculated for high He content with the same $l/H_{\rm p}$ and the same opacities. All my stars fall on normal He content tracks except the three very young components of the visual system 36 Oph. These fall on the He-rich tracks.