H. NECKEL
Hamburg-Observatory, Germany

THE USE OF EARLY M-TYPE STARS FOR DETERMINING INTERSTELLAR ABSORPTION

Abstract. It is shown that the early-M-type stars are the most suitable objects for determining interstellar absorption by observations of the colors V and N (where N is Johnson's color at 10 micron).

I would like to talk about some special properties of M-type stars, not because their knowledge is important for the understanding of the internal structure, chemical composition, etc. of late type stars, but because it may be very important for the determination of interstellar absorption. Because my program involves photoelectric observations of about 1200 M-stars in the B, V-system and later on very probably also in the infrared at about 10 μ, it may be not worthless to talk in this colloquium about this program although it is just at the beginning.

In 1963 in Hamburg an observational program was started to determine the B and V magnitudes of about 1200 M 2 and M 3 stars brighter than the 10 magnitude and located between $+ 6^0$ and $- 6^0$ galactic latitude.

The aim of this program was at that time to derive from the color-excesses E_{B-V} of these stars the detailed distribution of interstellar absorption within about 500 pc from the sun.

The use of early M-type stars for this purpose seemed to me encouraging for the following reasons:

1) There exists a catalogue of uniform classification of all BD-M-type stars along the galactic equator. This classification was done by myself in 1957/58 at the Warner and Swasey Observatory in Cleveland (Neckel 1958).
2) Statistics show that about 95% of the M stars brighter than 10 magnitude are giants, that means, belong to luminosity class III, while the remaining 5% belong to luminosity class I and II. The portion of the M dwarfs can be neglected completely, only one dwarf is to be expected within 1000 M stars. Consequently, there is no urgent need for an accurate luminosity classification.
Figure 1 shows the distribution of absolute magnitudes for all M stars brighter than 6.5 magnitudes and north of $- 20^0$ declination according to the work of Adams, Joy and Humason (1926). Certainly, a zero-point-correction has to be applied to the absolute magnitude scale, but this is not important at this point.
3) Even if one restricts oneself to M 2 and M 3 stars only, the space density of these stars is much larger than of the O- and B-stars and one can hope to find details in the distribution of the absorbing matter in the vicinity of the sun. As mentioned earlier, there are about 1200 M 2 and M 3 stars within 500 pc and between $+ 6^0$ and $- 6^0$ galactic latitude.

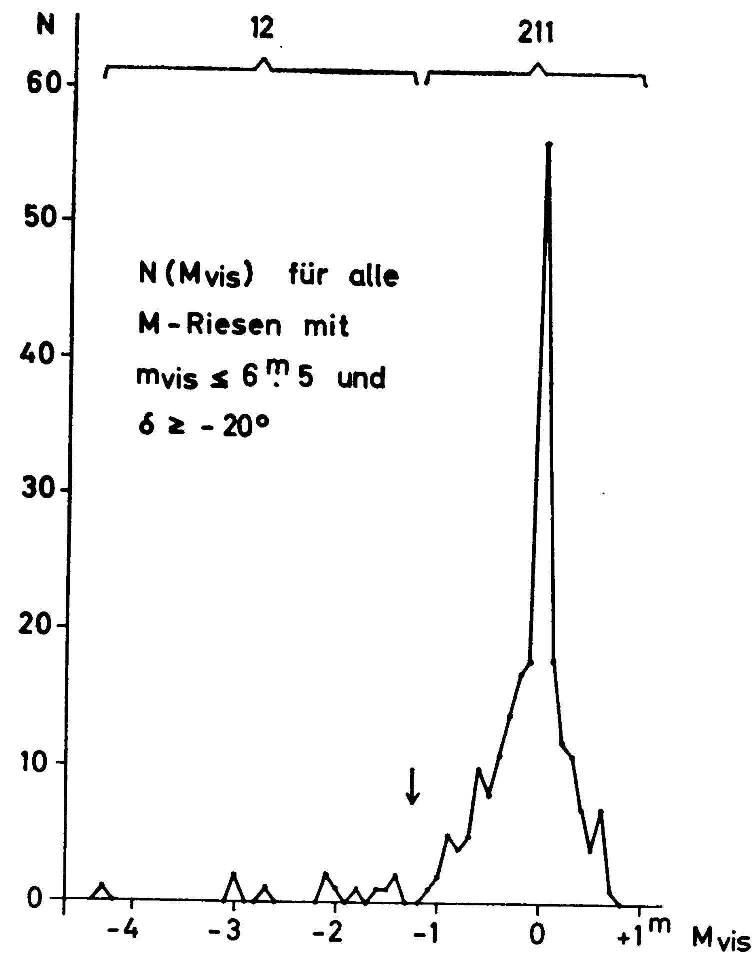

Figure 1

4) The intrinsic color $(B\text{-}V)_0$ of late type stars approximately does not change between K 5 and M 5 and consequently is not sensitive against errors in the classification of 1 or 2 subclasses. Also the scatter of the intrinsic color seems to be very small. The colors of 12 bright M-giants outside the Milky-Way are all between $1^m.52$ and $1^m.58$ with a mean value $1^m.56$. Knowing the spectral type (M 2 or M 3), one can determine the color excess E_{B-V} with fairly high accuracy.

5) The percentage of variables with large amplitudes ($A > 0^m.5$) is still rather small for the M 2 and M 3 giants (see *figure 2)* and the variability with small amplitudes is not very critical for the results to be derived if one considers the natural scattering of the absolute magnitudes.

Now, the progress of this program in the past was very small, due to the very poor weather conditions in Hamburg. Therefore, I am just now — in collaboration with Prof. Mavridis — preparing the installation of a 40 cm Cassegrain-Telescope in Greece, to carry out this program as soon and fast as possible.

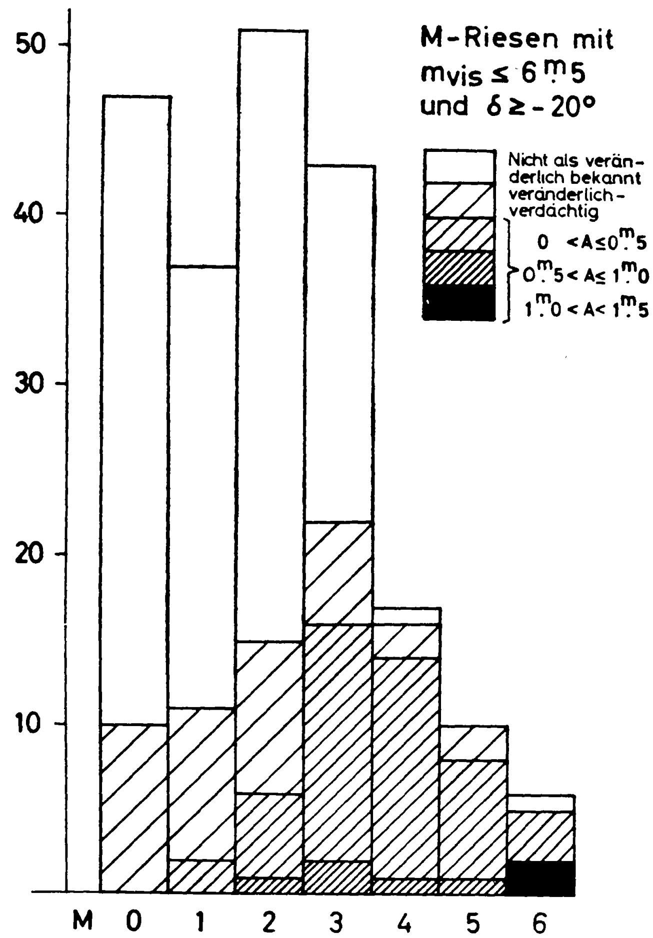

Figure 2

But, during the last years, things have changed and today we can not be sure any more that the ratio between total and selective absorption is constant within our galaxy.

As you may know, the first indications in this direction came from Baade and Minkowski (1937), who found an exceptional reddening law for the Orion-region. Their result was later confirmed by Stebbins and Whitford (1945) and Sharpless (1952).

Johnson and Morgan (1955) found differences in the reddening law between Perseus and Cygnus, and this result was also confirmed by Hiltner and Johnson (1956) and recently by Nandy (1965).

And all the more recent, and rather accurate work of Borgman (1961), Wampler (1962), Walker (1962), Johnson and Borgman (1963), Hallam (1965) and others seems to show that there exists not a uniform reddening law within our galaxy.

As a consequence of these results alone, the ratio R between total to selective absorption cannot be assumed to be constant. At least to me it seems unwise to *extrapolate* a relation observed at 2 or 3 points, if we cannot even *interpolate* between these points. And, if we look back today for really independent determinations before 1965, which are not based on Whitfords (1958) — averaged and more or less arbitrarily extrapolated — reddening law, only very few values remain, especially those of Hiltner and Johnson (1956) and Houck (1956), which were received by the variable extinction method and gave $R = 3$ for h and χ Persei and the I Crucis association.

The latest results in this point are those from Johnson (1965 a, b), who implied the variable extinction method systematically for many different regions, (in Per, Cyg, Cas, Cep, Aur, Gem, Ara, Mon, Ori) and finds for the ratio R values between 2.6 and 6.5. By observations made at 5 and 10 μ he also finds the main «key» to explain the difference against the so far adopted value of $R = 3$: It is *not* allowed to extrapolate the «normal» reddening law to infinite wavelengths, because the reddening law shows some kind of discontinuity at about 5 μ, which is more or less pronounced in different regions of the sky.

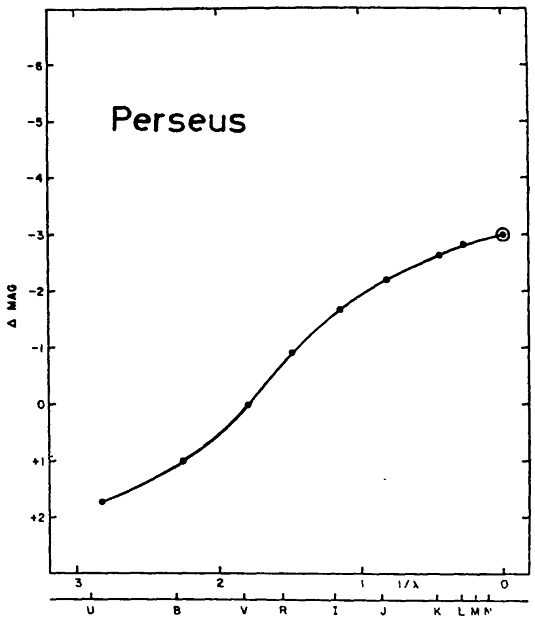

Figure 3

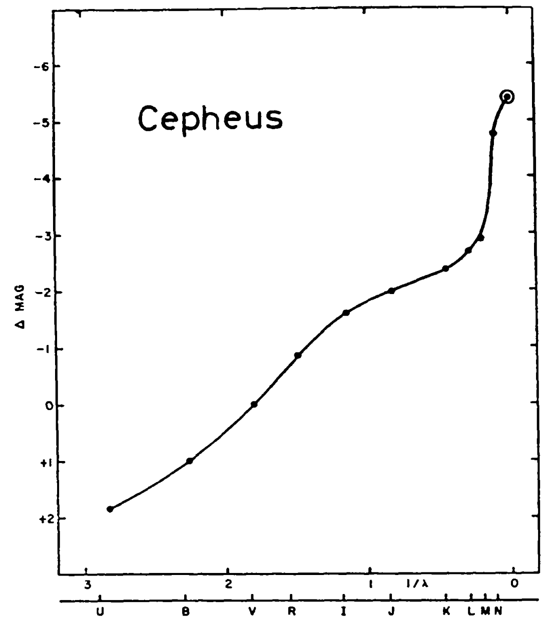

Figure 4

This behaviour may be explained by *figures 3* and *4* (Johnson, 1965a). Asking the question: How can we determine the absorption of single stars, we now return to the M-stars. Looking again to *figure 4*, we conclude immediately: For determining the visual absorption A_V, that is the difference of the ordinates at $1/\lambda = 0$ and 1.8, we should measure the difference of the ordinates at $1/\lambda = 0.1$ and 1.8 instead of the corresponding difference at $1/\lambda = 1.8$ and 2.2.

That means: Instead of determining color-excesses E_{B-V} we should try to measure color excesses E_{V-N}, where N is Johnson's color at 10 μ.

In *figure 5* I plotted a simplified H-R-diagram, which shows the dependency of the absolute magnitudes at 10 μ from spectral class for the different luminosity classes. Taking into account the small space density of supergiants as compared with giants, it becomes very obvious that the M giants are the most suitable objects for determining interstellar absorption by observations at the colors V and N.

If one considers the sensitivity of the infrared detectors developed by Low (1961), which are gallium-doped single crystal germanium, and the radiation flux of M stars at 10 μ, one can compute that M stars of 10 visual magnitude are just still observable with the large telescopes available today. But this means at the same time: It may be that the M-stars are the only objects through which we can get detailed information about the interstellar absorption within about 500 pc, and that 500 pc is about the limit within which we can get at all such a detailed information.

For determining color excesses E_{V-N}, we must know the intrinsic colors $(V\text{-}N)_0$ and their natural scatter.

The last *figure 6* shows the few values which are now available from Johnson's data.

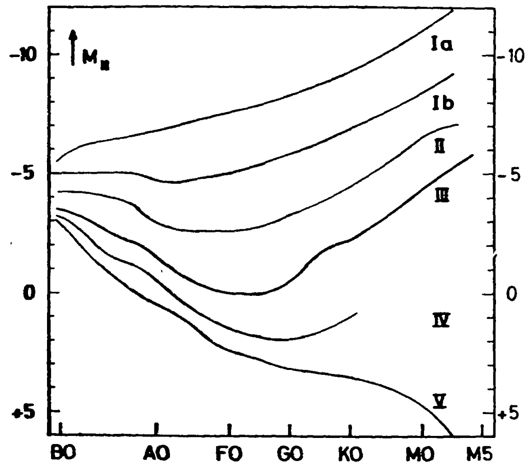

Figure 5

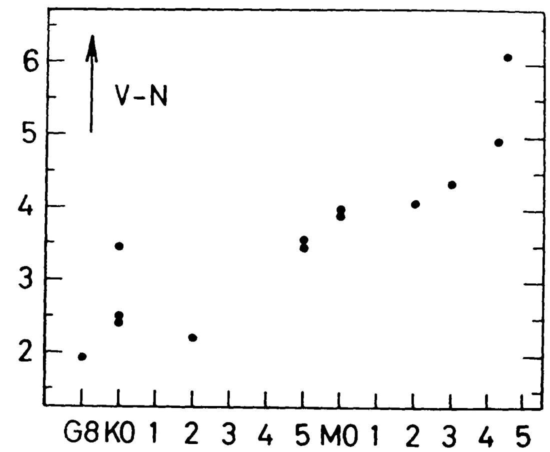

Figure 6

Final conclusions cannot be drawn yet by this diagram except the following one: One can still hope that the natural scatter of the intrinsic color $(V\text{-}N)_0$ is not too large to derive fairly accurate values for the color excesses E_{V-N} and from this the absorption A_V.

Photoelectric observations at 10 μ are a very difficult and complicated task and certainly one cannot observe all of the 1200 M stars at 10 μ. Therefore, we will carry out this program in two steps: At first a photoelectric B, V-photometry will be made of all M stars at our station in Greece. Than we will select those stars which seem to be most suitable for the infrared photometry with respect to the distribution in the sky, reddening, variability and so on. Thereafter, very probably, the infrared photometry of the selected stars will be carried out with Johnson's photometer in Arizona.

And, even if the conclusions drawn by Johnson and others should prove to be not very convincing, I think this program will at least add additional material to decide, wheter the interstellar material is uniform everywhere in the galaxy or not and also to improve our knowledge about absolute magnitudes, colors etc. of M stars.

REFERENCES

Adams, W. S., Joy, A. H. and Humason, M. L., 1926, Ap. J. *64*, 225
Baade, W. and Minkowski, R., 1937, Ap. J. *86*, 119
Borgman, J., 1961, BAN *16*, 99
Fernie, J. D. and Marlborough, J. M., 1963, Ap. J. *137*, 700
Hallam, K. L., 1965, IAU - Colloquium on Interstellar Grains, Troy - USA
Hiltner, W. A. and Johnson, H. L., 1956, Ap. J. *123*, 267
Houck, T. E., 1956, Thesis, University of Wisconsin
Johnson, H. L., 1965, Ap. J. *141*, 923
— — — 1965, Preprint from Stars and Stellar Systems Vol. *VII*
Johnson, H. L. and Borgman, J., 1963, BAN *17*, 115
Johnson, H. L. and Morgan, W. W., 1955, Ap. J. *122*, 429
Low, F. J., 1961, JOSA, *51*, 1300
Nandy, K., 1965, Publ. Royal Obs. Edinburgh *5*, 13
Sharpless, S., 1952, Ap. J. *116*, 251
Stebbins, J. and Whitford, A. E., 1945, Ap. J. *102*, 273
Walker, G. A. H., 1962, Obs. *82*, 52
Wampler, E. J., 1962, Ap. J. *136*, 100
Whitford, A. E., 1958, A. J. *63*, 201

DISCUSSION

PAGEL. I know that Prof. Becker has considered this business of variations of interstellar reddening. I think that the suggestion that he put forward to explain this curve, that you used just now, was that these stars might have an undetected very red companion.

NECKEL. I think, Prof. Becker's conclusions were based on Johnson's paper published in May 1965. But in the meantime Johnson (1965b) collected a lot of material which seems to show clearly, that the ratio $R = A_V/E_{B-V}$ is not constant. First, there are now much more observations at 10 μ, not only in Cepheus. Further, Johnson also considered the radii of galactic clusters, which were determined some years ago by Wallenquist. If one uses these diameters as a distance indicator, than one derives similar results. Furthermore Johnson applied the variable extinction method to much more clusters and associations. He gets a good agreement among the different methods: cluster diameters as distance indicators, photometry which goes up to 10 micron and the variable extinction method. Another indication is based on the different distance scales which one gets from the distances of Cepheids derived by geometric and photometric methods.

BUSCOMBE. I think it is very dangerous to use the linear diameters of clusters as a distance indicator because there is such a strong correlation between the linear diameter and the total luminosity; that is, the very faint clusters are much more compact.