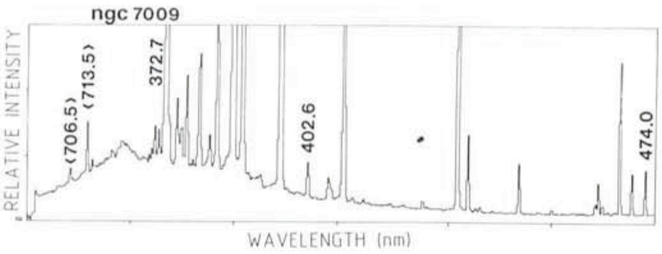

Fig. 5: *Spectrum of the nebulous parts of NGC 7009 in the range 350–475 nm. Other data as Fig. 3.*

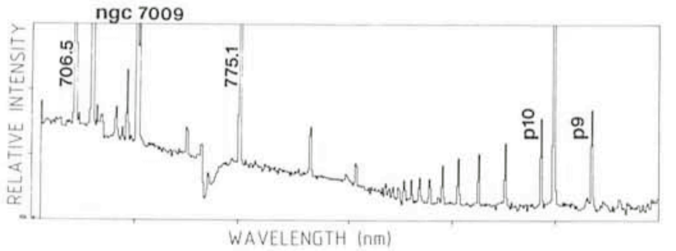

Fig. 6: *Spectrum of the nebulous parts of NGC 7009 in the range 693–950 nm. Other data as Fig. 4.*

Observing with the CCD

Although visiting astronomers are usually shown the telescope and how the CCD is mounted on it, there is no need for the observer ever to enter the dome. All acquisition and operation controls are carried out remotely from the control room. Faced with a couple of computer terminals and a colour monitor, the observer makes the decisions necessary for his or her programme. Almost all parameters are entered interactively on a terminal using a "form-filling" technique in which the observer is presented with a form showing the default parameters which can be left or modified at will. This permits newcommers to familiarize themselves with the equipment very quickly and to minimize mistakes without being too time-consuming or inconvenient for old-hands. The long waiting hours during integrations can be used to examine previous exposures, reduce and make prints of data. It has even been known for observers to sneak down to the midnight kitchen during such periods. This has been made easier of late by the provision of an automatic sequencing system that can be pre-programmed to execute a series of integrations with different exposure times and filters without observer intervention.

Data Reduction

It might appear from the preceding paragraphs that the CCD is completely without problems. This is certainly not so. As with any detector, a lot of care and patience is needed both during the observations, including the many calibration exposures necessary, and afterwards during the data reduction and interpretation. The main problems faced, that are intrinsic to the CCD, include interference effects, dead and "hot" pixels, non-linear columns at very low signal levels, charge transfer problems, and cosmic ray events. Some of these problems can be minimized by correct choice of operational and observational parameters. Others need to be corrected during data reduction. To assist with this there is a large and growing library of software routines available. We hope to return to these problems, and to give some more quantitative performance data in a later issue of the *Messenger.*

The Distance of the Magellanic Clouds

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Introduction

The Magellanic Clouds are very important for many problems of Astrophysics. At a distance of about one tenth of that of the Andromeda Nebula, they are the nearest extragalactic objets, and in many cases the individual stars can be studied in detail. On the other hand, the distance to each Cloud is quite large when compared to the linear dimensions. No distance effect greater than $\pm$ 0.15 mag is to be expected on the apparent magnitudes and, practically, all objects can be considered to be at the same distance. A great advantage of the Magellanic Clouds over other groups of stars is that their population, with radial velocities around + 275 km/s for the Large Cloud and + 160 km/s for the Small Cloud, can easily be separated from the Galactic foreground stars. In addition, very little interstellar absorption occurs along the line of sight, either in the Galaxy or in the Clouds. For all these reasons the Magellanic Clouds are a very efficient tool (c.f. the discovery of the period-luminosity relation in the SMC as early as 1904) and considerable efforts have been made to determine their distances.

The Distances to the Clouds During the Last Fifty Years

The distance to the Small Cloud could be estimated for the first time when the "period-luminosity" variables discovered in 1904 by Miss Leavitt were identified as Cepheids by E. Hertzsprung (1913). Cepheid variables are found in the solar vicinity and from their known proper motions and radial velocities, Shapley could determine their absolute magnitudes, the zero point of the "period-luminosity" relation and the distance to the Small Cloud. The first published data, around 1918, placed the Small Cloud definitely outside the Galaxy at a distance d = 19 kpc, changed six years later into 31 kpc after a revision of the apparent magnitude system (Fig. 1). The slow decrease with time of the distance between 1924 and 1951 is mainly due to the fact that interstellar absorption corrections were introduced. It is interesting to note that during the long period extending from 1918 to 1951 the zero point of the "period-luminosity" relation has been revised by several authors who all confirmed the first determinations of Shapley. Much more observational data on proper motions and radial velocities were at hand. The effects of galactic rotation on the motions as well as the effect of interstellar absorption on the magnitudes were included in the discussion. With the exception of an important increase in the absolute luminosity of the Cepheids proposed by H. Mineur in 1945, all the efforts which were made resulted only in insignificant changes of the zero point of the "period-luminosity" relation: the absolute magnitudes of the galactic Cepheids were apparently well established by the converging results obtained by different authors. However, at the same time more and more doubts arose upon the validity of these results, especially because no RR Lyr star could be observed at m = 17 or m = 18 as might be expected from their mean absolute magnitudes. When early in 1953 Thackeray and Wesselink found RR Lyr stars at m_{pg} = 18.7 in the Small Magellanic Cloud their result implied a correction factor of about 2 for the extragalactic distance scale. The old Cepheid zero point was abandoned and a set of several new and, as far as possible, independent distance indicators were used (novae, RR Lyr stars, integrated magnitudes of globular clusters, Cepheids in galactic clusters of known distance . . .).

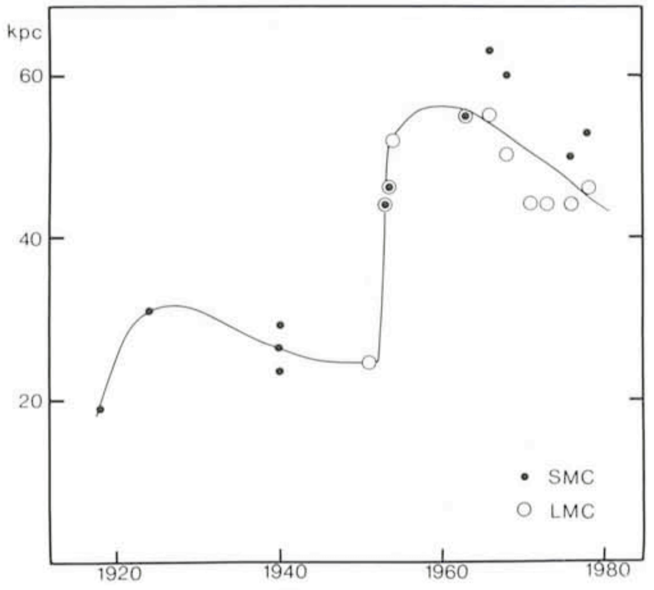

Fig. 1: *The distance to the Magellanic Clouds as a function of time. Note the great discontinuity around 1952, when it was finally recognized that the zero point of the period-luminosity relation for the Cepheids was unreliable. The new distances were derived from a set of several independent indicators.*

This is a very sound situation because if one of the indicators is viciated by an unrecognized parameter, there is a priori no reason why all the indicators should be viciated exactly in the same way. After the "great jump" of 1952–1953, the distance to the Magellanic Clouds did not undergo major changes and Fig. 1 shows only a slow decrease. However, this relatively stable distance is sometimes due to effects which cancel each other. For instance, we have seen that in 1953 Thackeray and Wesselink discovered the first RR Lyr variables in the Small Magellanic Cloud at the mean absolute magnitude m_{pg} = 18.7. At that time the adopted mean absolute magnitude was M_{pg} = 0 and the derived apparent modulus μ = 18.7. Ten years later, Tifft (*MNRAS*, **125,** 199) found the RR Lyr variables at the mean magnitude B = 19.7; fortunately the mean absolute magnitude adopted for the RR Lyr stars had also changed, from M_{pg} = 0 to M_B = 1,0 and the apparent distance modulus remained unchanged. . . . The magnitude scales are now well established but the reliability of the modulus still depends on the answers to the two questions:

(i) Given a certain type of stars in the Galaxy, are their counterparts in the Magellanic Clouds really identical?

(ii) Is it possible to determine accurately a mean absolute magnitude for this type of stars in the Galaxy?

None of these two questions can be answered favourably for any group of stars and the only chance of having some confidence in the distance moduli is to derive them from as many "good indicators" as possible. The population of the Clouds is very rich in groups of stars which have counterparts in the Galaxy and many distance indicators were used since the revision of 1952. Unfortunately most of them were difficult to handle and we are left with only three indicators, novae, Cepheids and RR Lyr stars, which have been re-examined many times. In 1970, considering the uncertainties still present in the distances to the Magellanic Clouds (and very happy at the idea of a first visit to La Silla) we initiated a series of observations at the ESO 150 cm telescope in order to derive the distance moduli of the Magellanic Clouds from a new indicator: the BCD parameters of moderately bright B and A supergiants.

The Large Magellanic Cloud Distance in the BCD System

In the BCD system, the first two parameters D and λ_1 are independent of the interstellar reddening. They are schematically described in Fig. 2. A third parameter is the energy distribution in the continuum, generally in the wavelength range 6200–3150 Å. The comparison between this observed energy distribution and the intrinsic energy distribution which can be deduced rom D and λ_1 gives the amount of interstellar reddening A_v for each star, and individual reddening corrections are made.

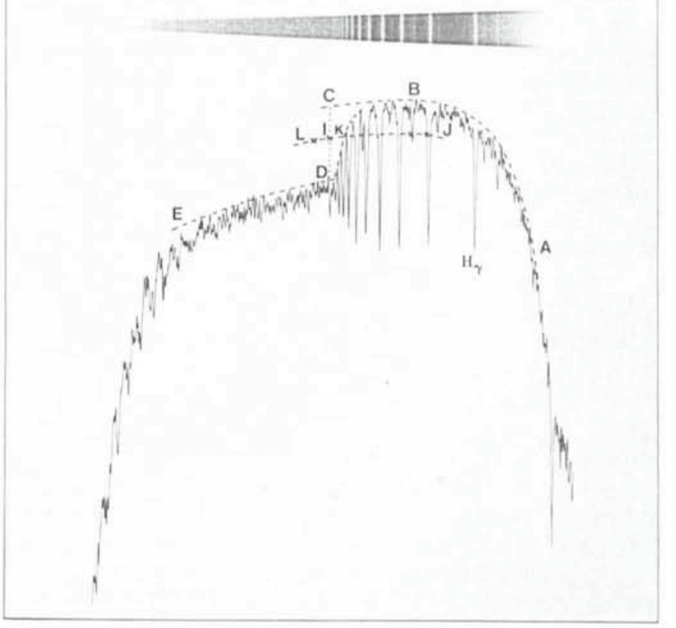

Fig. 2: *The parameters D and λ_1 of the BCD system represented on a microphotometer tracing.*
ABC: blue continuum; DE: ultraviolet continuum; CD: Balmer Jump (D, in dex); IJ: blue continuum – D/2; IL: ultraviolet continuum + D/2; K: intersection of IJ with a smooth curve joining the points of highest intensity between the Balmer lines. λ_1 is the wavelength corresponding to the point K. Let us note that the real determination of D has a sounder base than the "eye extrapolation" shown in the figure.

Twenty-three A and B supergiants have been measured in the Large Magellanic Cloud and ten of them are in regions of the λ_1D plane well calibrated in absolute magnitudes by a sufficiently dense population of measured galactic stars (Fig. 3). For these ten stars, M_v is obtained by interpolation between the curves of equal absolute magnitude. The mean value of the distance modulus ($V-A_v-M_v$) for these ten stars is found to be 18.1 which becomes 18.3 if we take into account the change of 0.2 mag in the distance modulus of the Hyades recommended by de Vaucouleurs (*Ap.J.* **223,** 351–363 and 730–733) in a very careful re-discussion of the galactic and extragalactic distance scales.

The same result (but based on quite a small number of spectra) was announced a few months after the first observing run at the IAU Symposium No. 50 and later, in 1972 (IAU Symposium No. 54) with some more results and a discussion of the underlying hypothesis.

Though derived from stars in a wide range of spectral types (B5–A3), the distance moduli are in very good agreement, with a dispersion $\sigma = 0.25$ and even only 0.17 if two deviating stars are not considered. No dependence of the modulus on the spectral type can be observed and the galactic calibration of the λ_1D plane in absolute magnitudes seems to fit quite well the LMC supergiants.

The two stars that deviate are probably interesting. The uncertainties in the BCD parameters (deduced from the results for stars that have two or more measurements) are too small to explain the difference between their distance moduli which are 18.6 for G233 (B6Ia) and 17.7 for G305 (B6Ia). As the two stars have the same spectral type, no change in the λ_1D plane calibration can help. The difference between their distance moduli must be due to the stars themselves: real difference in the distances, multiplicity, spectral anomalies. . . . However, these phenomena are marginal in the Large Cloud and would have been neglected if they did not occur at a much higher degree in the Small Cloud. In most cases the correlation between the position of a star in the λ_1D diagram and its apparent magnitude is very good even for the brightest supergiants and the calibration in absolute magnitudes can be extended to $M_v = -9$ or -9.5 with the results already at hand. It could easily be improved by observing some more stars and we would like to do it, especially in view of unexplained phenomena in the Small Cloud.

The Small Magellanic Cloud

Twelve stars have been measured in the Small Cloud. Only four of them are in the region of the λ_1D plane calibrated by galactic stars. The distance moduli have been derived and their mean is 18.4. This value is a little larger than for the Large Cloud in conformity with what is generally admitted, but the dispersion is abnormally high and the four moduli are spread over an interval of more than one magnitude. The eight other stars are in the region of the λ_1D plane which is calibrated only by LMC supergiants. As we have already said, this calibration is still provisional and should be improved. However, we used it to derive distance moduli for the eight brighter SMC stars. The mean modulus is 18.6, not very different from the first one and the dispersion is exactly the same, with a difference of 1.1 mag between the smallest and the largest modulus. If this dispersion reflected real differences in distance, the Small Cloud would have a depth about ten times larger than the linear dimensions projected on the sky. This result is for many reasons difficult to accept and we have verified that the individual interstellar absorptions A_v are all relatively small and have no correlation with the apparent distance.

The problem of the apparent depth of the Small Cloud has been investigated many times by different methods. All authors agree upon the existence of this apparent depth, but curiously,

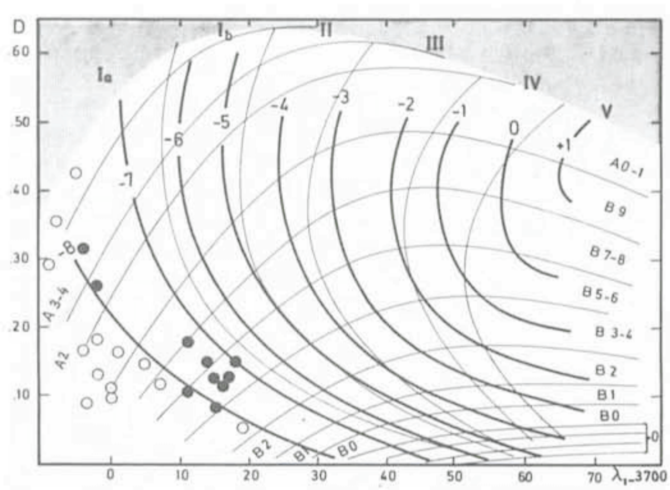

Fig. 3: *Position of 23 LMC supergiants in the λ_1D plane. The λ_1D plane has been calibrated in absolute magnitudes (thick continuous lines, M_v from +1 to −8) using stars situated in galactic clusters of known distances. All the LMC stars in this figure are brighter than $M_v = -7$. Ten of them (filled circles are in regions of the λ_1D plane well populated by galactic stars and for which the calibration in absolute magnitudes is reliable. For each of these stars a distance modulus can then be derived. The remaining stars (open circles) are brighter in apparent magnitudes and their higher luminosities (M_v between −8 and −9.5) are in very good agreement with their positions in the λ_1D plane.*

they completely desagree on which star is far and which star is near. The question is still open.

The Problem of Chemical Composition

It is now a general belief that our difficulties with the Magellanic Clouds are due to differences between the Galactic and Magellanic chemical compositions. These differences were first recognized in the interstellar medium. However, to detect eventual anomalies in their luminosities, stars themselves had to be analysed. This is a very difficult task because high-dispersion spectra and good model atmospheres are necessary. Both conditions cannot be fulfilled with the same star as only very intrinsically bright supergiants for which no good model exists have apparent magnitudes bright enough for a high-dispersion analysis. However, it is believed that the Large Cloud stars have a small metal deficiency and that a significantly larger one is present in the Small Cloud stars. These results could be in agreement with the fact that intrinsic luminosities seem to fit the galactic luminosities in the Large Cloud and not in the Small Cloud. They could also explain that the consistency between the MK and λ_1D spectral types is much better in the LMC than in the SMC.

The conclusion is that the distance to the Large Cloud is probably reasonably well determined. But in the case of the Small Cloud, even the mean distance modulus is questionable if the relation between the observed properties of the stars and their absolute luminosities is sensitive to relatively small changes in the chemical composition as suggested by J.W. Pel (*The Messenger* No. 29, Sept. 1982) in the case of Cepheids. For these stars J.W. Pel and collaborators claim that a decrease in luminosity as large as 0.5 mag occurs with a metal underabundance of a factor 4.

The effects of chemical composition on the other distance indicators are still to be investigated, but in the Small Cloud, unless very large differences in chemical composition from one star to another occur, the dispersion observed in the distance moduli for stars having the same BCD parametes, if confirmed, will remain unexplained.