No. 29 – September 1982

The Users Committee – Where the Grassroots Talk

G. Lyngå, Lund Observatory, Chairman of the UC

Once a year, a sunny day in May, the Users Committee meets. Each national representative has from his colleagues at home brought a long list of complaints, suggestions and expressions of gratitude to ESO.

A number of ESO staff members devote the day listening and supplying information to them. The Director General, the Director in Chile, sometimes the head of the TRS, the head of the visiting astronomers office and several of the leading astronomers and engineers are present.

The agenda starts with a report by the Director General: Status of major telescope projects, future instrumentation and such matters. Then the Director in Chile and the head of the TRS describe the present condition of the instruments, the problems that have already appeared and those to be expected. These items are then open for discussion by the UC.

After this, the representatives of the various member countries present their points on different details of the La Silla activities, and also on the visitors facilities at Garching. Subjects debated concern calibration of equipment, information or lack of information about observing routines, logistics, etc. It is gratifying to note the good spirit in which reasonable criticism is accepted by the ESO staff. Often ESO can meet the demands, and at other times a compromise can be reached. If a certain point cannot be resolved, it is the task of the national representative to return that information to the colleague who raised the point. In all cases the airing of opinions is felt to be useful.

Sometimes the agenda contains special points which are of immediate concern. Last May we discussed the importance of astronomical staff on La Silla. Users and ESO representatives agreed about the essential function that is filled by staff astronomers who, for the benefit of their own research, take part in the development of state-of-the-art equipment. It was also pointed out that the staff astronomer is in a much better position than the visitor to detect the malfunctioning of instruments or telescopes.

The Users Committee is not only a safety valve for disgruntled visiting astronomers. It is also a fruitful collaborative effort where the ESO staff and the observers' representatives meet, talk and listen to one another.

Professor M. K. V. Bappu, 1927–1982

It is in the deepest sorrow that we have to announce the untimely death of Prof. M. K. V. Bappu, Director of the Indian Institute of Astrophysics, Bangalore, and President of the International Astronomical Union. He passed away in Munich, on August 19, 1982, during a visit to ESO, following complications after major heart surgery. An obituary will follow in the next issue of the *Messenger*.

The Metal Content of Magellanic Cloud Cepheids

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Introduction

Ever since 1912, when Miss Leavitt discovered the famous period-luminosity law for Cepheids in the Magellanic Clouds, the Clouds have played a central role in the study of these important and fascinating pulsating stars.

The reason for this is simple: the Magellanic Clouds are relatively small in comparison to their distances from us. When looking at one of the Clouds, we observe therefore stars which are all at approximately the same distance. A second advantage is that the extinction by interstellar dust in the Clouds is much less of a problem than in our own Galaxy, where it is a major obstacle for determinations of absolute magnitudes, distances, and intrinsic colours. Fortunately Cepheids occur frequently, both in the Large Cloud (LMC) and in the Small Cloud (SMC), and since they are supergiants they are still reasonably bright, even at a distance of 50 or 60 kiloparsecs. For an analysis of the relative differences between Cepheids of various periods the Clouds are therefore uniquely suited.

The relation between the most important observable properties of Cepheids is usually expressed by a refined version of Miss Leavitt's law, the period-luminosity-colour (P-L-C) relation. On the one hand, this relation describes the Cepheid region in the Hertzsprung-Russell (HR) diagram: it gives the period for a Cepheid of given luminosity and temperature (colour). On the other hand, it is fundamental for the use of Cepheids as distance indicators: for a Cepheid of a given period, colour, and apparent magnitude, it gives the absolute magnitude and the distance. Since long-period Cepheids are sufficiently bright to be seen in galaxies considerably more distant than the Magellanic Clouds, the P-L-C relation is an important tool in the calibration of extragalactic distances, and it is particularly this application that accounts for the fame of the relation.

Before we can apply it to derive distances, or to study the physical properties of Cepheids, the P-L-C relation has to be established accurately in the first place. This turns out to be a difficult problem, and even 70 years after Miss Leavitt's discovery, the work on improvements of the P-L-C relation is still continuing. From our earlier remarks it is clear that the slopes of the relations between P, L and C are most directly obtained by observing Cepheids in the LMC and SMC. Without independent information on the distance to the Clouds, we cannot determine absolute magnitudes, however, and the "zeropoint" of the P-L-C relation has to be found by other means. Usually this zeropoint is derived from a number of Cepheids which are members of galactic clusters, where distances can be determined from the cluster main-sequence stars. In principle it should be possible to calibrate the P-L-C relation entirely by means of these clusters, and to establish a relation that is based purely on galactic Cepheids, but unfortunately too few Cepheids in clusters are known, and they cover a too limited part of the whole range of periods.

There would be nothing against the combination of galactic and LMC/SMC Cepheid data, or against the determination of extragalactic distances from a P-L-C relation with a "galactic" zeropoint, if only we could trust that Cepheids are indeed the same in all galaxies. Especially for the Magellanic Cloud Cepheids the situation appears to be more complicated, however. There is convincing evidence for differences in average chemical composition between the Magellanic Clouds and the Galaxy, both for the interstellar medium and for the stars in these systems. These differences can be characterized as a decreasing abundance of the heavier elements along the sequence Galaxy-LMC-SMC. It turns out that composition differences can have noticeable effects on the P-L-C relation and on several other properties of Cepheids. Only very recently the first direct information on

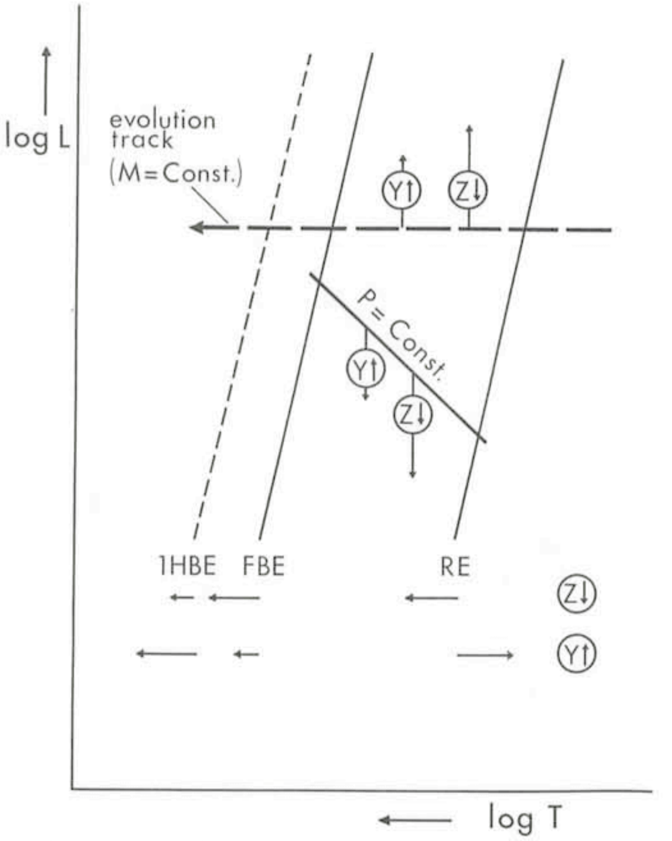

Fig. 1: *Sensitivity to helium (Y) and heavy-element (Z) abundances of the Cepheid strip in the theoretical HR-diagram. Arrows indicate schematically the effects of changes in Y and Z on the boundaries of the strip, and on the position of evolutionary tracks and constant-period lines. The blue edges for pulsation in the fundamental and first harmonic modes are indicated by FBE and 1HBE, the red edge by RE.*

the chemical composition of Magellanic Cloud Cepheids has become available, also indicating a deficiency in heavy elements as compared to Cepheids in the solar neighbourhood. In this paper I will discuss some of these new results, which have been obtained with the Dutch telescope on La Silla.

Composition Effects in Cepheids

At first sight it seems surprising that one should worry about chemical composition when dealing with Cepheids. Cepheids, at least the "classical" ones that we are discussing here, are young and massive population-I stars (10^7– 10^8 years, 4-12 $M_\odot$), all passing through the same evolutionary phase, and one expects that their composition is never very different from that of the Sun. Moreover, they all obey the same pulsation relation, which is very insensitive to composition. This relation is not the only law that governs Cepheids, however, and the composition effects enter otherwise.

The basic pulsation law gives the period of a Cepheid as a function of its mass and radius. It can also be written as a function of mass, luminosity, and temperature. This relation is nearly independent of composition, but it contains the mass, which usually cannot be determined directly. To arrive at the more "observable" P-L-C relation, we have to do two things: firstly to eliminate the mass by

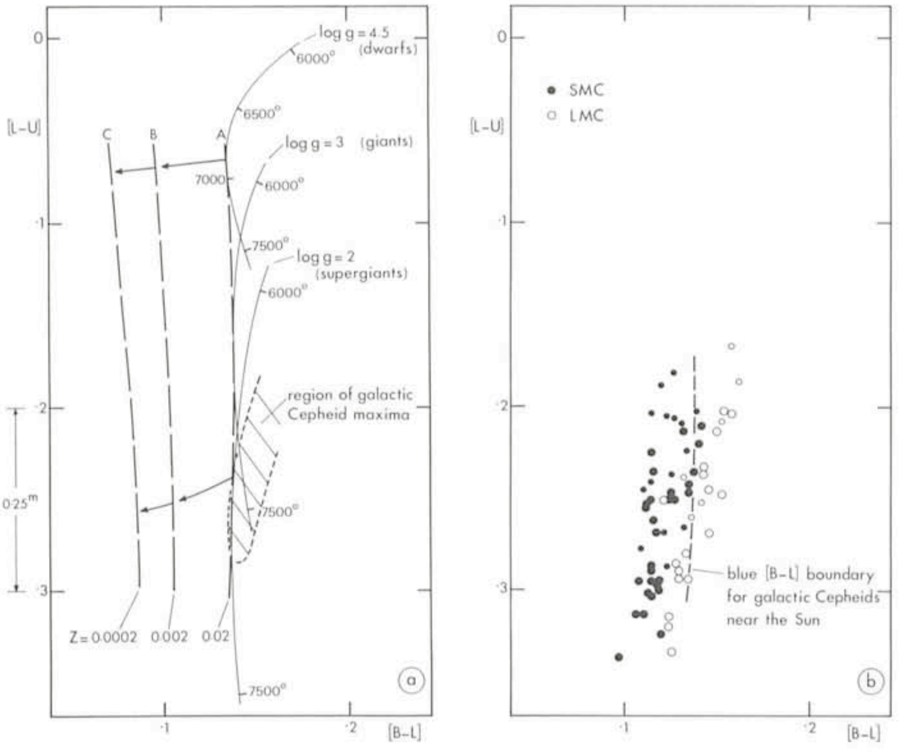

Fig. 2a and 2b: *Abundance effects in the [B-L] – [L-U] two-colour diagram. The scale is in log (intensity), so 0.1 scale unit is 0.25 mag. Fig. 2a gives the effects of temperature, pressure (log g) and heavy-element content Z, in the temperature range 6000–7500° (schematically). These theoretical colours are derived from the model atmospheres by R. L. Kurucz. For a given Z, the constant-temperature and constant-pressure lines form a sharp boundary at nearly constant [B-L]. Along this boundary [B-L] depends almost purely on Z. Line A gives this boundary for the solar value of Z (Z = 0.02). For lower Z the [B-L] boundary moves towards the left (lines B and C).*

Measurements near maximum light for 11 LMC and 14 SMC Cepheids are given in Fig. 2b. Smaller symbols denote observations further away from the maximum phase. The dashed line indicates the blue [B-L] boundary defined by maxima of Cepheids in the solar neighbourhood.

means of the mass-luminosity law for Cepheids, and secondly to relate the temperature to some observable colour via a colour-temperature relation. The problem is that both the M-L and the C-T relation are composition-sensitive, the first one because stars of the same mass but with different compositions evolve differently, the second one because, at the same temperature, stars with different chemical abundances have different spectra.

The pulsation law and the P-L-C relation predict the period of a Cepheid, but they do not tell us why it pulsates. In order to know which supergiants become Cepheids, and how the boundaries of the Cepheid instability-strip in the HR-diagram are determined, we need detailed knowledge about the physics of Cepheids. After thirty years of extensive theoretical work on the evolution and pulsation of Cepheids, the main features of Cepheid behaviour are now reasonably well understood. As a result of this theoretical effort a few more composition-sensitive factors have been discovered. Not only will a change in composition result in a different M-L law for Cepheids, which causes a shift of the lines of constant period in the HR-diagram, but it turns out that also the blue and red boundaries of the Cepheid strip in the HR-diagram are composition-sensitive, as well as the way in which the evolutionary tracks populate the strip. These composition effects on the width and position of the Cepheid strip are illustrated schematically in Fig. 1; the effects in the P-L-C relation are shown in Fig. 3, but I will return to this later.

New Results on the Composition of Magellanic Cloud Cepheids

Up to recently the evidence for chemical differences between the Galaxy and the Magellanic Clouds came almost exclusively from studies of the interstellar medium. Various differences between galactic and LMC/SMC Cepheids had been observed, and many authors had interpreted them as composition effects, but direct information on abundances in Magellanic Cloud stars was hardly available. This situation has now been improved by the work of H. C. Harris (*Astron. J.* **86,** 1192, 1981), and by the results obtained at La Silla by A. M. van Genderen, J. Lub, and the author (first results in *Astron. Astrophys.* **99,** L1, 1981). Both studies use a photometric technique to determine the metal content of Cepheids.

Harris observed a large number of galactic and SMC Cepheids in the Washington photometric system. This is a broadband system specifically designed to measure the strength of metal lines in the blue and near-ultraviolet part of the spectrum, and it provides two metal-sensitive indices which are independent of interstellar extinction. For the 45 SMC Cepheids in his programme Harris finds a mean metal abundance which is about a factor 3.5 lower than for galactic Cepheids near the Sun. An important aspect in the study by Harris is the possibility to detect gradients in metal content across the Galaxy and the SMC. Cepheids are particularly suited for this since they are visible over large and well-known distances, and since their spectra contain many metal lines. For this purpose Harris observed 102 galactic Cepheids, over a large range in galactocentric distances. The metal content of these stars shows an outward gradient of $-15\ \%\ kpc^{-1}$. No similar gradient is found in the SMC.

Let me try to describe in some more detail the programme of VBLUW photometry for Magellanic Cloud Cepheids by A. M. van Genderen, J. Lub, and myself. This started as one of the first programmes with the Dutch 90 cm telescope and the Walraven VBLUW photometer after the move to La Silla, as a follow-up of the large VBLUW project on galactic Cepheids and RR Lyrae stars carried out previously in South Africa. In fact Van Genderen had observed some SMC Cepheids with the Walraven photometer already, and he had found indications of a low metal content in these stars, but the South African summer was "bad season", and the poor seeing at Hartebeespoortdam made photometry in dense fields very difficult. It was decided to tackle the problem again from La Silla, making use of the excellent conditions there, of the improvements that the photometer had undergone in the meantime, and of a new promising method discovered during the analysis of the large VBLUW material on galactic pulsating stars.

The Walraven photometer measures simultaneously in five passbands of intermediate width (cf. J. Lub. *The Messenger* No. 19, 1979). This gives four independent colours, but since the W signals for Magellanic Cloud Cepheids are too faint (W lies at 3230 Å!), we are left here with only three. The composition effects that we want to determine have to be separated from at least three other factors: temperature and pressure in the stellar atmosphere, and interstellar reddening. This makes 3 observed quantities with 4 unknowns, but fortunately there occur "degeneracies" in certain colour combinations, where some of the unknowns cancel out. It is such a situation that we apply in our metal index [B-L].

The method is illustrated in Fig. 2. Since [B-L] and [L-U] are defined to be independent of interstellar reddening, this diagram is reddening-free, but [B-L] is very sensitive to the abundance of heavy elements (mainly Fe and other metals). Fig. 2a shows schematically the effects of temperature, pressure, and metal content around temperatures of 6500 K. In this temperature range the intrinsic lines for a fixed composition form a sharp vertical boundary. [B-L] at this boundary is almost purely sensitive to metal content. This range around 6500 K is reached by the maxima of large-amplitude Cepheids, and this allows us to determine the metal abundance in these stars in a temperature-, pressure- and reddening-insensitive way. The results obtained at La Silla for 14 SMC Cepheids and 11 LMC Cepheids are shown in Fig. 2b. After calibrating the diagram by means of the theoretical spectra by Kurucz, and by stars with spectroscopic abundance analyses, we find a mean metal deficiency of a factor 5 for the SMC Cepheids, and a factor 2 for the LMC Cepheids (compared to their galactic counterparts). Observations of non-variable F-type supergiants in the Clouds by Van Genderen confirm these numbers. These results agree within the uncertainties with the data of Harris for the SMC, and they are also consistent with spectroscopic calcium abundances for Magellanic Cloud supergiants by Smith (H. Smith, *Astron. J.* **85**, 848, 1980), who finds that calcium is low by a factor 4 in the SMC and a factor 1.6 in the LMC.

This new information on abundances in Magellanic Cloud stars is still very limited, but it fits well with the existing data on emission nebulae in the Clouds (cf. Pagel and Edmunds, *Ann. Rev. Astron. Astrophys.* **19**, 1981), and it is clear that we can no longer ignore composition differences between the Cepheids in SMC, LMC, and Galaxy, or between those in inner and outer regions of the Galaxy. One of the most far-reaching consequences of these differences is the effect that they have on the P-L-C relation, which is particularly sensitive to Z. We saw already in Fig. 1 that a decrease in Z shifts the constant-period lines towards lower L. At the same time the C-T relation changes, making the colour of a Cepheid at a given temperature bluer for lower Z. The result of both effects is (Fig. 3), that by applying a "solar" P-L-C relation to Cepheids with low Z, we overestimate their luminosities. If we assume that metals are representative for the overall heavy-element content, the SMC Cepheids have probably $Z \simeq 0.005$. In this case a P-L-C relation for $Z = 0.02$ would give 50 % too high luminosities, or distances that are 25 % too large.

This example, although schematic and incomplete (e.g. we did not yet discuss the effects of Y), demonstrates that abundance determinations are not only necessary for a better physical understanding of Cepheids, but also for improved accuracy of the Cepheid distance scale, which still remains one of the "steps towards the Hubble constant".

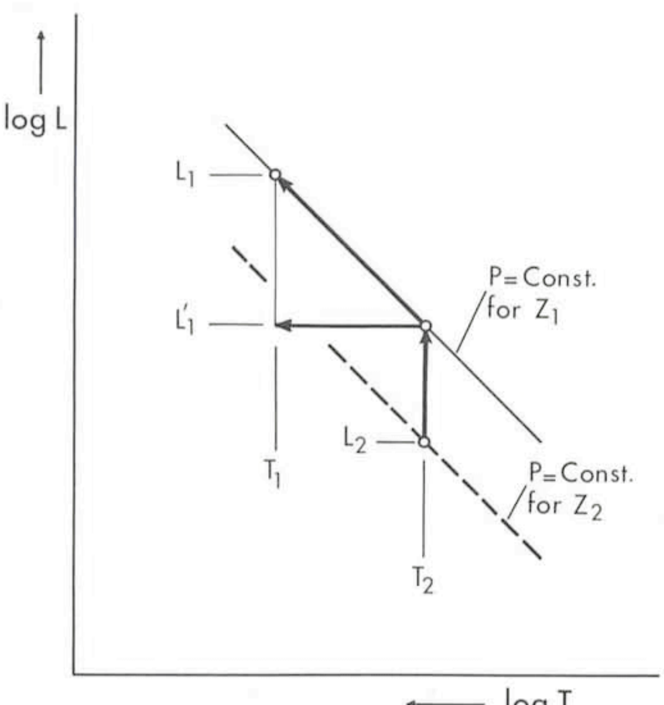

Fig. 3: *The sensitivity to Z of the P-L-C relation. T_2 and L_2 are the real temperature and luminosity of a Cepheid with period P, colour C, and $Z = Z_2$. When applying a P-L-C relation for $Z = Z_1$ ($Z_1 > Z_2$) to this star, we assign a higher temperature, T_1, to the same colour C, and also use a too luminous line of constant P. The result is that we put the star at (L_1, T_1), and overestimate the luminosity. For $Z_1 = 0.02$ and $Z_2 = 0.005$ the error is $L_1 - L_2 \simeq 0.5$ magnitude.*

List of Preprints Published at ESO Scientific Group

June – August 1982

201. H. PEDERSEN, J. VAN PARADIJS, C. MOTCH, L.COMINSKY, A. LAWRENCE, W. H. G. LEWIN, M. ODA, T. OHASHI and M. MATSUOKA: Optical Bursts from 4U/MXB 1636–53. *Astrophysical Journal.* June 1982.
202. H. PEDERSEN et al.: Simultaneous Optical and X-ray Bursts from 4U/MXB 1636-53. *Astrophysical Journal.* June 1982.
203. P. A. SHAVER, A. BOKSENBERG and J. G. ROBERTSON: Spectroscopy of the QSO Pair Q0028+003/Q0029+003. *Astrophysical Journal,* Letters. June 1982.
204. J. ROLAND, P. VÉRON, D. STANNARD and T. MUXLOW: MERLIN Observations of Compact Sources with Very Steep Radio Spectra. *Astronomy and Astrophysics.* June 1982.
205. A. F. M. MOORWOOD and I. S. GLASS: Infrared Emission and Star Formation in NGC 5253. *Astronomy and Astrophysics.* August 1982.
206. A. C. DANKS, M. DENNEFELD, W. WAMSTEKER and P. A. SHAVER: Near Infrared Spectroscopy and Infrared Photometry of a New WC9 Star. *Astronomy and Astrophysics.* August 1982.