The Distribution of Interstellar Dust

Comparing the distribution of the observed Hα line intensity in Fig. 1 with the distribution of continuum emission across the Rosette nebula (Fig. 2, 3) it turns out that the features in the north-western region are very similar on both maps, but that strong differences are visible in the southern region. Fig. 4 shows the comparison of the observed and the expected Hα emission estimated from the 4750 MHz continuum emission quantitatively. Only points at which both the Hα and radio continuum intensities are greater than 2.5 times the rms noise were used. The mean value of interstellar extinction between the nebula and earth at 6563 Å is A(Hα)=(1.21±0.04)mag. This value results from UBV photometry data of NGC 2244 by Ogura and Ishida (1981, *Publ. Astron. Soc. Japan* **33,** 149) who obtained a reddening of E(B–V)=0.47 mag, and from the mean interstellar extinction law A(1/λ) reviewed by Schmidt-Kaler (1982, in: Landolt-Börnstein, Gr. VI, Bd. 2b, 449). After subtracting this value of the "interstellar" A(Hα) from the absorption map the remaining absorption must be "local", that is must occur in the direct neighbourhood of the H II gas in front of the Rosette nebula. Its mean value in Fig. 4 is (1.9±0.5) mag. In the north-western region A(Hα)=(1.3±0.1) mag is nearly constant down to the noise limit at the nebula edge. In southern condensations it increases up to (4.3±0.1) mag, but varies around a mean value of (2.5±0.2) mag. The mean error of a single value is 0.3 mag.

A Model of the Rosette Nebula and Its Neighbourhood

The measured radio continuum intensities of Fig. 2 and Fig. 3 integrated in rings of 1 and 4 arcmin width around the nebula centre could be reproduced by a spherical symmetrical radial distribution of electron density with a central cavity and a hole in the shell pointing approximately to the direction of the line of sight. The mean value of the electron density in the shell is $N_e=(15.0\pm1.5)\ cm^{-3}$. This model results in a total mass of ionized material in the nebula of $M_{ion}=(29{,}700\pm3{,}800)\ M_\odot$.

Interstellar dust clouds and molecular cloud complexes are frequently correlated. Blitz and Thaddeus (1980, *Ap. J.* **241,** 676) have observed CO molecules in the Mon OB2 molecular cloud complex in the Rosette nebula region with angular resolutions very similar to that of the A(Hα) map. Both the shape of CO cloud structures and their distribution correspond quite well to that of the absorption by interstellar dust. Using the assumption that all CO molecular clouds within the considered region contain dust grains, it is possible to distinguish between CO clouds lying in front of and those lying behind the H II region, because dust absorption is only visible from dust clouds in front of the nebula.

Indeed the CO clouds are distributed behind as well as in front of the nebula. This suggests that the H II region is embedded in the molecular cloud complex. The centre and the greatest part of the nebula are visible within a region of relative small dust absorption (Fig. 4). Thus we suppose that the H II region is lying at the border of the complex. A more detailed model of the complex (Celnik, 1982, thesis, Ruhr-Universität Bochum) could be established using the velocity field within the complex. Radial velocity information had been given by Fountain, Gary and O'Dell (1979, *Ap. J.* **229,** 971) and by Blitz and Thaddeus. Assuming a spherical shape of the complex we find for the total mass of the dust $M_d = 5{,}400\ M_\odot$. The total mass of the whole cloud complex consists of the masses of neutral hydrogen, molecules, stars, ionized matter and dust grains. Different authors have previously estimated the masses of neutral hydrogen ($1.5\cdot10^5\ M_\odot$, Raimond, 1964, thesis, Leiden), molecules ($1.3\cdot10^5\ M_\odot$, Blitz and Thaddeus) and stars ($5{,}000\ M_\odot$ for NGC 2244, Ogura and Ishida). For the total mass we derive $M_{tot} = 3.2\cdot10^5\ M_\odot$, which corresponds to a density of about $0.5\ M_\odot/pc^3$. 82% of the total mass is in the form of neutral hydrogen and molecules.

Conclusions

From the comparison of the photoelectrically measured distribution of the Hα emission line intensity across the Rosette nebula with the distribution of the radio continuum intensity it was possible to construct the distribution of interstellar dust in front of the nebula. The comparison of this dust distribution with measurements of molecular spectral lines from other authors resulted in a model of the molecular cloud complex Mon OB2 in three dimensions. The Rosette nebula is embedded in this complex near the border, on the side turned to the direction of the Sun. No evidence could be found that the Monoceros Loop has any connection to the Rosette nebula or the molecular cloud complex.

The Copenhagen Binary Project

J. V. Clausen, Copenhagen University Observatory

While this short contribution is written and the rain has been pouring down in Denmark, surely setting up new records, we strongly hope for an unbroken long series of clear, stable photometric nights at La Silla. The last long-term (40 nights) photometric observing run for our eclipsing binary project at the Danish 50 cm telescope began a few nights ago. Last – at least with the characteristically shaped, well-known *uvby* photometer mounted at the manually operated telescope, a combination which through the years has demonstrated its accuracy and reliability in a large number of projects in different fields of galactic research.

Besides these important features, we have benefitted from a remarkably stable photometric instrumental system (E. H. Olsen, 1977, *Astron. Astrophys.* **58,** 217). A discontinuity will now be introduced. A most welcome one, since much faster Strömgren photometers of the type known from the Danish 1.5 m telescope are now available. A year from now – according to the schedule – the observer will find a renovated microcomputer-controlled, fast-moving 50 cm telescope, equipped with a new efficient 6-channel *uvby-beta* photometer in the dome.

So it might be opportune to give a brief status report at this stage of the project even though more spectroscopic observations are still needed.

More Than 500 Nights

The first observations for the Copenhagen binary project were made at the Danish 50 cm telescope at La Silla in 1971. Since then more than 500 nights have been allocated, and well-covered and accurate *uvby* lightcurves have been obtained for about 40 relatively bright (approximately 4.5–9.5 mag) southern eclipsing binaries. Many astronomers contribute or have contributed to the project which was started by the late B. Grønbech, K. Gyldenkerne and H. E. Jørgensen. During the following years B. Nordström, Bo Reipurth, J. Andersen, B. E. Helt and I have been collaborating on the photometric observations and analyses and lately A. Giménez and L. P. Vaz have joined the group.

For many of the systems, high-quality radial velocity curves have also been established from high-dispersion coudé spectra observed with the ESO 1.5 m telescope. This indispensable part of the binary project is carried out by J. Andersen. In one case the radial velocities have been observed with the CORAVEL and the Danish 1.5 m telescope.

The majority of the candidates selected for the project are well *detached double-lined systems with main sequence components,* between which the interactions are rather week and the lightcurves thereby relatively uncomplicated. This selection is closely guided by the main scientific purpose – to contribute with a significant increase to the available information on *absolute stellar dimensions* and to use the precise binary data for *empirical tests of stellar evolution calculations.*

Until now about 40 papers on individual eclipsing binaries have been published and some 25 more lightcurves are finished. Those for which sufficient spectroscopic material is also available are presently under analysis. However, some of the important candidates are still lacking spectroscopy, and more observing time is needed.

But Why?

Well, more than 500 generally perfect La Silla nights is a considerable amount of observing time – why at all was such a large observing project started?

Undoubtedly the main source of inspiration was the IAU Colloquium No. 6 held in Denmark back in 1969 (eds. K. Gyldenkerne and R. M. West, published by Copenhagen University Observatory 1970). At this meeting D. M. Popper presented a review on the knowledge of masses and radii of eclipsing binaries and their accuracy. It clearly demonstrated first of all that only very few reliable dimensions were available, but also especially that more lightcurves were at that time strongly needed. Several systems had good spectroscopy but no photometry.

Furthermore, the review gave inspiration to an investigation which very nicely illustrated the potential of combining absolute dimensions from analyses of eclipsing binaries with theoretical stellar model calculations (D. M. Popper, H. E. Jørgensen, D. C. Morton and D. S. Leckrone, 1970, *Astrophys. J.*, **161**, L57). It presented a determination of the helium to hydrogen ratio for Population I stars on the basis of masses and luminosities for the presumably unevolved components of *seven* eclipsing binaries. Together with *six* more systems, which from their mass-radius relationship were found to be evolved, they made out the total and thus very insufficient empirical material available for B9–G2 main-sequence systems (approximately 1–3 solar masses) at that time.

Having ⅔ of the observing time at the Danish 50 cm telescope, newly installed at La Silla and equipped with a new *uvby* photometer for simultaneous observations in the four bands, it was therefore quite natural to include also lightcurve observations in the list of projects for that instrument. The more so because new extensive programmes on stellar model calculations were at that time carried out at the institute.

Besides the eclipsing binaries without lightcurves, mentioned above, several favourable southern systems were known (mainly listed by D. M. Popper) but lacked both accurate photometry and good spectroscopy. Since about 1973, when the spectroscopic part was started at the ESO 1.5 m telescope, most of these systems have been observed in the Copenhagen binary project together with new candidates, discovered mainly in the radial velocity programmes and in the extensive *uvby* field programmes carried out at La Silla by Danish astronomers.

Altogether I think it is fair to say that we have had the facilities and possibilities for a contribution of a size which only few other European groups could have made. The need for so many systems and so much observing time as mentioned above is probably best illustrated by shortly looking at the present situation with respect to reliable binary data.

Absolute Stellar Dimensions

That the situation has improved significantly since 1969 is clearly seen from the recent critical review on stellar masses by D. M. Popper (1980, *Ann. Rev. Astron. Astrophys.* **18,** 115) and from a glance to the empirical stellar mass – luminosity relation based on the data included there (see R. C. Smith, 1983, *Observatory* **103,** 29). Our project has contributed with accurate dimensions for 13 of the 48 eclipsing binaries, including – if the reader will please not accuse me for priding myself (I am doing photometry, not spectroscopy) – 3 of the only 4 real confident masses for stars earlier than B6 (approximately 4 solar masses).

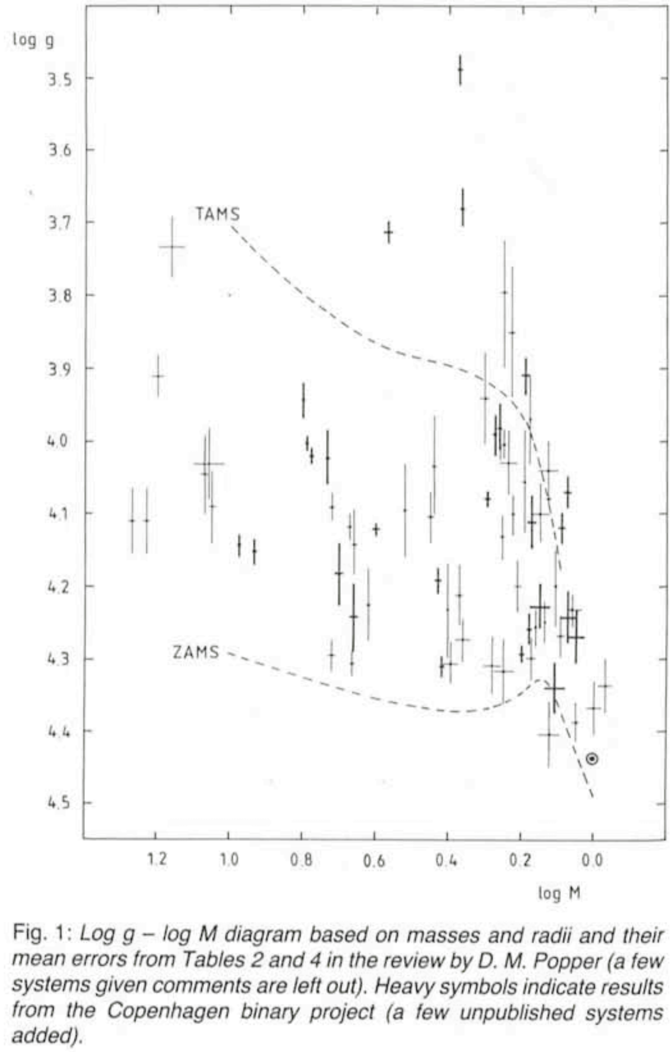

Fig. 1: *Log g – log M diagram based on masses and radii and their mean errors from Tables 2 and 4 in the review by D. M. Popper (a few systems given comments are left out). Heavy symbols indicate results from the Copenhagen binary project (a few unpublished systems added).*

Already this small number for the early type region indicates a need for still more data. And what if we want to trace evolutionary effects within the main-sequence band and want to make a critical empirical test of the available theory? Here the answer is not easily obtained from the mass-luminosity diagram which almost hides the dimension of evolution.

Let me give a short illustration of the present possibilities and limitations in a simplified frame where only the two most fundamental parameters – *mass and radius* – obtained from combined photometric and spectroscopic analyses of double-lined eclipsing binaries are used.

Fig. 1 presents a mass-surface gravity diagram where the data have again been taken from the review by D. M. Popper. Results from the Copenhagen binary project are indicated by heavy symbols. The two curves also shown represent the theoretical zero-age main-sequence (ZAMS) and the top of the main-sequence band (TAMS) for theoretical models where a chemical composition of (X, Z) = (0.70, 0.02) has been assumed (P. M. Hejlesen, 1980, *Astron. Astrophys. Suppl. Ser.* **39**, 347). For the most favourable systems and the most complete analyses the stellar dimensions are determined with an accuracy of 1–2 per cent, and as seen, this gives very good resolution and pinpoints a star (fixed mass) within about 1/20 of the main-sequence band. However, it also speaks for itself that this nice possibility of recognizing evolutionary effects within the core hydrogen burning phase of evolution is lost if the accuracy is not of this level. Even some of the data shown in Fig. 1 cannot be considered quite useful in this connection. The reader will also notice that a reliable empirical ZAMS is not defined by the too few systems at hand.

Here it should of course be mentioned that the position of the theoretical ZAMS depends on the chemical composition of the models. A change in the metal content parameter Z of ± 0.01 will e.g. shift the theoretical ZAMS by approximately ± 0.05 in log g, whereas the dependence on the hydrogen/helium content is much lower. Therefore, a detailed empirical test of theoretical model calculations cannot be based on radii and masses alone; less directly determined parameters for the binary components are also needed.

The theoretical frame can instead be effective temperature-surface gravity diagrams for a network of different chemical compositions, giving theoretical mass tracks and isochrones (see e.g. the paper by P. M. Hejlesen mentioned above). The *effective temperatures* for the components are derived from the colour indices and the calibration of the photometric system, and in some cases information on the metallicity can also be obtained in this way, e.g. for F-type systems through the m_1-index of the *uvby* system. Sufficient accuracy in the temperature determination is of course only obtained if accurate photometry in a well-calibrated multicolour system is available.

It is then interesting to investigate if, for a given chemical composition, the two components are located at the same isochrone (i.e. are of the same age) and simultaneously both lie at the theoretical evolutionary tracks for their mass. This determines, in principle and if correct theoretical models are assumed, the age and chemical composition of the binary. And more important, from a large number of carefully selected, well observed and critically analysed detached systems a detailed check of the *slope of the isochrones* is thereby obtained.

Such comparisons with theory have been published together with the absolute stellar dimensions for many of the individual systems in the Copenhagen binary project, and the reader is referred to our series of papers in *Astronomy and Astrophysics* for more details. Analyses for about 15 individual systems have been published until now. A brief presentation of the fundamental parameters for some of the systems and of the helium content derived from these data has been given by H. E. Jørgensen (1978, IAU Symp. No. 80, 433).

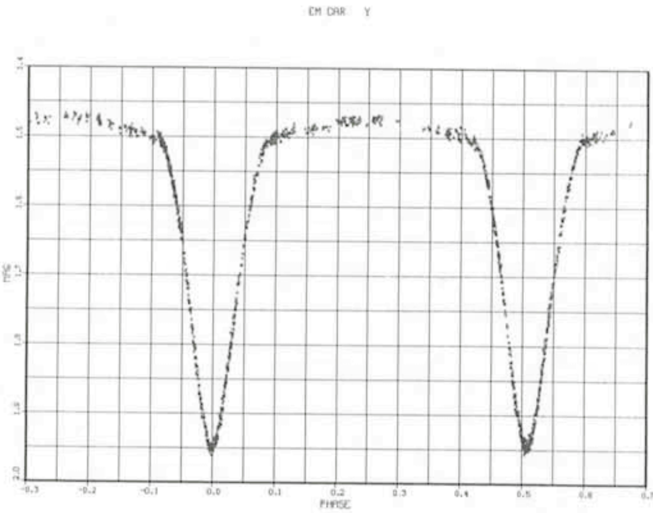

Fig. 2: *y lightcurve of the O-type system EM Car observed with the Danish 50 cm telescope at La Silla. Observations from February 1983 are not included, only the 1,175 points obtained before, mainly in 1982, are shown.*

The articles referred to above also describe in detail the methods of observation, reduction and analysis. Critical remarks on the determination of absolute dimensions can be found in J. Andersen, J. V. Clausen and B. Nordström, 1980 (IAU Symp. No. 88, 81), and I will not repeat all what can just as well be read there. On the other hand I would like to stress that routine work is not the route which leads to accurate stellar dimensions, and that reliable observations (accurate light-curves in several bands of a well calibrated intermediate band system, good high-dispersion spectra), use of a physically realistic binary model (we have widely used a modified version of that developed by D. B. Wood [WINK]), and *simultaneous analysis of photometry and spectroscopy* are essential. This, I think, is very clearly illustrated by our analysis of the interesting B2V system QX Car (in press).

More Data Still Needed

From the mass-luminosity diagram mentioned above and from Fig. 1 it is seen that the 1–3 solar mass range of the main sequence (i.e. A and F stars) is now reasonably well covered, but as already mentioned precise data for more massive early-type systems are still lacking. A large fraction of the yet unanalysed systems in the Copenhagen binary project belongs to this group, and especially interesting is the O-type binary EM Car for which the *y* lightcurve is shown in Fig. 2. Detached systems with such a nice uncomplicated lightcurve and well separated components are rare in this mass range (about 20 solar masses), and we expect EM Car to yield the most accurate absolute dimensions available for O-stars.

In the late-type end of the main sequence, below 1 solar mass, the situation also needs to be improved. Here new double-lined candidates can hopefully be discovered and also observed spectroscopically with the CORAVEL or similar instruments.

Without going into the situation for the more advanced evolutionary stages I will draw attention to one more candidate, namely TZ For. It is (to my knowledge) the only known double-lined eclipsing binary containing two normal giants. The period of TZ For is long – about 75 days – and the *uvby* lightcurves have been obtained at the Danish 50 cm telescope in a campaign including many observers. The highly accurate radial velocities have been observed with the CORAVEL.

With the photometric as well as spectroscopic observations of all the selected southern systems hopefully completed in the first half of 1984, the data base for accurate absolute dimensions will be significantly increased – although still quite incomplete in some mass regions – and we look forward to carrying through a comprehensive and detailed discussion based on all results obtained from this long-term observing programme at La Silla.

Some News About the Coudé Spectrograph of the ESO 1.52 m Telescope

P. Giordano and E. Maurice, ESO

The coudé spectrograph was installed at La Silla early in 1969; the first reference spectra were obtained in May 1969. Since the beginning of the routine observations, several thousands of spectra have been taken, 8,127 with camera 1 at 20.1 or 31.3 Å/mm^{-1}, 12,913 with camera 2 at 12.3 or 19.4 Å/mm^{-1} and 2,058 with camera 3 at 2.6, 3.3 or 5.1 Å/mm^{-1}. After 14 years of often heavy duty, it appeared necessary to do a careful overhaul of the spectrograph. Some significant improvements were done during this 14-year period, but some important components had not been touched during a very long time, for instance the two closed cameras 1 and 2. The overhaul was done between August 1982 and February 1983 under the supervision of P. Giordano and with the help of B. Buzzoni. A. Torrejón, E. Araya and J. Pérez actively participated in the focussing phase and P. Alvarez and J. Torres, from the workshop, in the mechanical phase.

Most of the work done will only be noticed by the observer from the improved quality of his spectra (mainly with camera 1). Other changes have been made in order to simplify the normal observation procedure and to allow some special operations such as, for instance, exposing several spectra on a single plate.

Among the more important optical adjustments done on the spectrograph we mention the following: the coudé has been realigned with the telescope polar axis. The spectrograph itself has undergone a thorough optical alignment with particular attention paid to cameras 1 and 2. The mirrors of these cameras have been realuminized. The slit assembly has been repolished and thereafter protected by a special coating.

Some mechanical improvements have also been done. The movable plate-holder supports have been renewed to insure a more exact positioning in the focal plane. A revision of the plate-holders themselves is also foreseen in order to improve the fit of the plates to the curved focal surface. Presently 3 plate-holders may be used for both cameras 1 and 3 (in both cases plate-holders Nos. 1, 2 and 3). In the case of camera 2 (Fig. 1) only plate-holder No. 3 is presently usable but other plate-holders are currently beeing modified.

Finally a complete electric re-cabling of the spectrograph was done.

A number of modifications and improvements which affect the use of the spectrograph have also been made. Following the light path, first, the comparison lamps device has been changed: instead of using only an integrating sphere as effective light-source, a plane diffuser and a flat mirror have been added. Changing from one of these systems to the other is instantaneous. This permits the use of the new iron hollow-cathode source with reasonable exposure times. Remember that the flat-mirror system is 3.3 times faster than the plane-diffuser which in turn is 3.3 times faster than the integrating sphere. Exact exposure times will be available at the spectrograph.

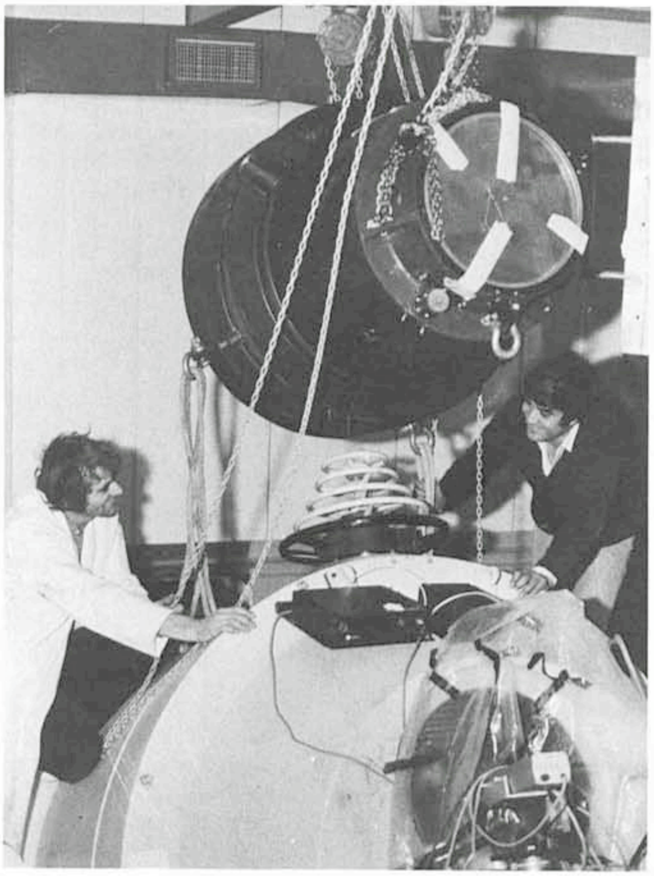

Fig. 1: *B. Buzzoni and P. Alvarez disassembling camera 2.*

Together with the new iron hollow-cathode lamp, the comparison lamps now in use are the following: the iron-arc, a mercury lamp, a neon lamp and a tungstene lamp for photometric calibration of plates in the coudé spectrograph itself. A colour filter to isolate the currently used grating order is now installed in the diaphragm of the source. Thus, it is no longer necessary to change these diaphragms if the comparison lamp is changed.

Following the light path, we now arrive at the decker immediately in front of the slit: the old prism-system is unchanged but new deckers (Fig. 2) will soon be installed. These will permit a better definition of the edges of the spectrogram and an easier guiding; some special deckers will also permit several (two at present) exposures on the same plate. Each of these deckers will also make it possible to insert a step-wedge, containing 8 neutral density levels, in front of the slit, for photometric calibration purposes. This will enable calibration plates to be