sample have secondaries later than K5. It will then be interesting to see if, and how, some of our estimators can be extrapolated in their direction.

Finally, this study may yield several important by-products, such as detailed abundance differences between the components of a system containing a dwarf and a giant, or age determination and tests of evolutionary sequences in the HR diagram.

A number of our spectra have now been digitized and reduced, and we have begun the analysis for some of the "simple" cases, such as 16 Cyg A and B. We are specially investigating some interesting indicators. It seems that ratios formed with Fe I lines around λ4872, λ4889 and λ4891 would provide sensitive temperature indicators. Another example is the line of Fe I at λ4404.8 which seems much more sensitive to changes in gravity than in effective temperature, as illustrated in Fig. 1. Combined with another fainter Fe I line of about the same excitation, in order to cancel the effects of chemical composition, it should give a good gravity estimator.

This programme will be rewarding only if it is carried through with the greatest care. But we think the questions at stake certainly deserve the effort.

Quasar Surface Densities

S. Cristiani, ESO

The story of the discovery of quasars has been told many times (see e.g. the 24th Liège International Astrophysical Colloquium 1983), nevertheless, it is always exciting to recall the first uncertain steps taken around 1960, when very little was known about this major component of the universe. In that period the identification of several radio sources, listed in the 3C catalogue, with more or less distant galaxies had been performed, but for many of them the optical counterpart was still unknown. In 1960 Matthews et al. (1) investigated with the 200″ telescope of Mt. Palomar the fields corresponding to the sources 3C48, 3C196 and 3C286. They could not find any trace of galaxies, the radio position indicating on the contrary three objects of stellar appearance. At that time no radio star was actually known besides the Sun, thus the discovery raised some questions, which became even more puzzling when spectroscopic observations revealed that each of these "stars" emitted a lot of ultraviolet and blue light with a few emission lines, different from case to case, which could not be plausibly identified with any known element. Many theoretical possibilities were opened, but, before any thorough examination could be performed, the nature of the problem was completely changed with the identification of the radio source 3C273, carried out by Hazard, MacKey and Shimmins in 1962 (2) with the 210 ft Parkes radio telescope. By means of several lunar occultations, the position of the source was measured with an uncertainty less than 1″ and its structure was shown to consist of two components separated by 19.5 arcsec. The relative accuracy of these measurements allowed an indisputable optical identification with a stellar object of about 13th V magnitude with an associated jet extending as far as 19.3 arcsec. Schmidt (3) took a spectrum of this object, which showed six broad emission lines which could be interpreted as being due to known elements assuming an unexpectedly large redshift of 0.158. It was possible to apply the same interpretation to 3C48, 3C196, and 3C286, when their spectra were reexamined, adopting respectively redshifts of 0.37, 0.87 and 0.85. At that time the radio galaxy 3C295 ($z = 0.46$) was already known, nevertheless the discovery was upsetting: if the redshift of 3C273 is cosmological, then its absolute magnitude is −27 (assuming a Hubble constant of 50 km/s/Mpc), that is about 40 times brighter than the brightest galaxies.

Since then many other amazing properties of these objects have been recognized: the ultraviolet excess, used as an aid for the identification of radio sources, led to the discovery of a few objects with similar colours far from any known radio source (the "interlopers" (4)), and finally a special survey for ultraviolet excess objects showed that radio quiet quasi stellar objects are not rare (5); variability, X-ray and gamma emission, the presence of absorption lines provided further information on the nature of these objects as well as new puzzling questions on the physical processes involved. The importance of complete surveys was soon felt, as stressed by Ryle and Sandage in the conclusion of their 1964 paper (at that time less than 10 QSOs were known): "The initial success of this survey suggests that many more objects of this type remain to be found. When a representative sample of these objects is available for study, such questions as the occurrence or non-occurrence of the objects in clusters of galaxies, the spatial distribution and the distribution over the plane of the sky, the presence or absence of light variations, the connection of the optical to the radio spectrum, the absolute luminosities and the dispersion about a mean, and the form of the redshift-apparent magnitude relation can be studied." Since then, in fact, a great effort has been made in order to establish complete samples of quasars down to fainter and fainter limiting magnitudes, up to higher and higher redshifts. In this subtle game astronomers have always had to face the presence of hidden selection effects, trying to disentangle the intrinsic properties of QSOs from instrumental biases. One of the most powerful tools available is the early-day UV excess method, which has now been refined in multicolour techniques.

A. Braccesi intended to take advantage of the quasar infrared excess and used an I plate, in addition to the same two-colour plate used in 1965 by Sandage and Véron, to construct a complete catalogue of candidates to a limiting magnitude of $B = 19.4$. The infrared excess was not entirely helpful at that stage due to the relatively large measurement errors; however the investigation was successful and led to the discovery of a number of new quasars (6), since most of the faint UV excess objects at high galactic latitude, as those selected in this survey, turn out to be quasars (of low redshift). This line of research was pursued and resulted in a sample of 175 UV excess objects down to $B = 19.4$ in the same field (7) and a sample of very faint ultraviolet objects down to $B = 20.1$ in a restricted 1.72 sq. deg. area of this field (8). These surveys constituted for many years the only ones with "sufficient size, completeness, and purity for proper analysis" (9) and are still, together with other samples selected by various authors (especially noteworthy is the survey of Schmidt and Green on 10,714 square degrees above galactic latitude 30° which is expected to be complete to $B = 16$), of extreme importance for the study of the change of the surface density of quasars with limiting magnitudes. Such observations are fundamental to

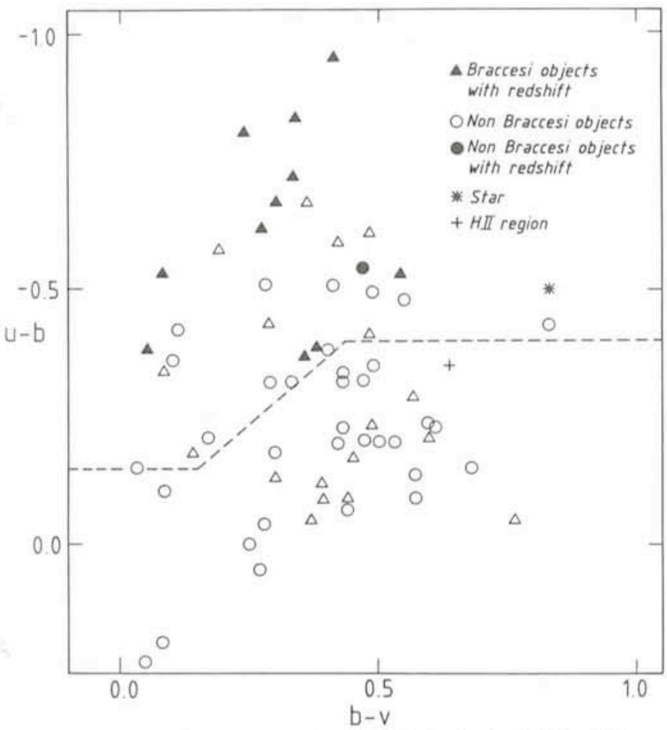

Fig. 1: *The two-colour diagram for the objects in the Cristiani, Véron and Véron survey.*

determine the quasar luminosity function at the various cosmic epochs, their evolutionary history as well as the physical conditions of the early universe.

To achieve this goal, detailed analyses are required and the completeness of the surveys on which the analyses rely must be carefully examined. Embarrassing large discrepancies in the quasar surface densities have been quoted by the various authors, revealing instrumental artifacts previously unsuspected. Even small effects can mask or alternatively simulate the evolutionary behaviour of quasars, heavily affecting any conclusion. As an example, the decrease of the quasar surface density beyond z = 2.2, claimed some years ago, was purely a selection effect, later recognized by means of new search techniques. The best way to get rid of such effects is to reobserve the same fields using other methods.

On account of these considerations several direct and grens plates were taken at the prime focus of the CFH 3.6 m telescope in Hawaii of a 0.46 sq. deg. area included in the Braccesi 1.72 sq. deg. field (10). The best IIIa-J grens plate has been searched for emission line and UV excess objects. The final selection was carried out by examining PDS tracings of these objects on IIIa-J and IIIa-F grens plates and provided a list of 185 objects whose U, B, and V magnitudes were measured on the original 48" Palomar Schmidt plates used by Formiggini et al. by means of PDS digitization and the standard IHAP reduction package. The low resolution slitless methods are known to be dependent on a number of parameters (such as seeing, resolution, etc.) which make it difficult to estimate the completeness. However, all the candidates found by Formiggini et al. in the field are also in our list which we believe to be complete down to B = 20.2. For the 75 objects contained in the unvignetted 0.46 sq. deg. part of the field and brighter than B = 20.1 the two-colour diagram (Fig. 1) allows the selection of 36 quasar candidates. The objects above the broken line, corresponding to an empirical but effective criterion stated by Braccesi et al. (11), are with all probability quarsars with redshift lower than 2.3. Furthermore, it is expected that all the quarsars with redshift lower than 2.3 are included in this group; it is easy to check that none should lie outside the above-mentioned region by drawing the two-colour diagram for all the quasars known in the literature with photoelectric measurements. As a result of this survey, the completeness of the Braccesi deep quasar survey is confirmed but only down to a B magnitude of about 19.8, with the incompleteness rising abruptly from this point (Fig. 2). Of the 36 quasar candidates one is known to be a star; if all the others turn out to be quasars, the surface density at B = 20.1 would be 76 QSO/sq. deg. However, this number cannot be directly compared with the values derived from other surveys which are usually restricted to quasars brighter than $M_B = -24$ and with redshift lower than 2.3. Spectroscopic follow-up is therefore greatly needed. Among the objects selected which lie under the broken line in Fig. 1, we believe to have found a few high redshift quasars (the IIIa-J emulsion is particularly effective to detect the Lyα emission for redshifts between 2

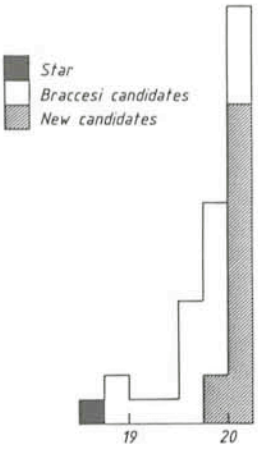

Fig. 2: *Histogram showing the magnitude distribution of the candidates in the Cristiani, Véron and Véron survey.*

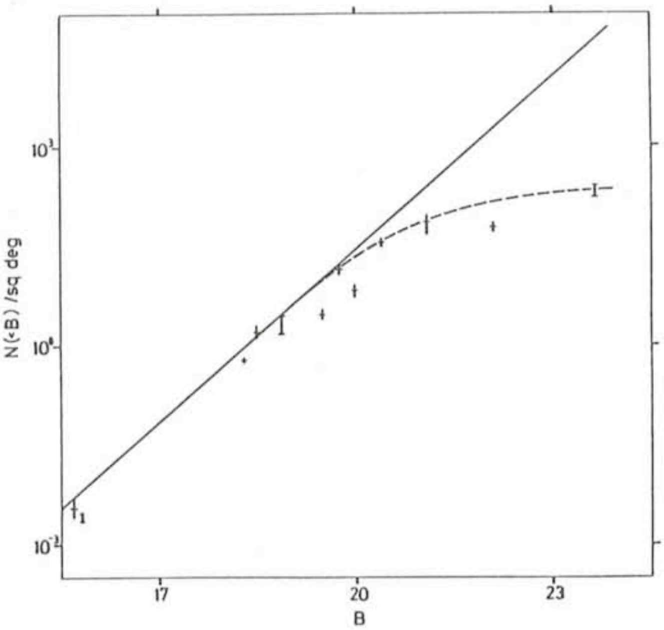

Fig. 3: *The number-magnitude diagram of quasars from Véron and Véron, 1982,* Astronomy and Astrophysics **105,** 405.

and 3.5). Higher dispersion spectroscopy of these objects and a detailed colorimetric study could provide a starting point for an investigation of the surface density of high redshift quasars, the present knowledge of which is greatly unsatisfactory. There is evidence of a decrease of the quasar space density beyond z = 3.5, but a detailed unbiased analysis is still lacking. This subject is of course of fundamental importance since it brings direct inferences on the evolutionary history of these objects and of the Universe itself.

Other independent methods can be applied to test and improve the completeness of the sample, and at present an automatic search for faint variable objects in the 6.5 x 6.5 sq. deg. field investigated by Braccesi et al. in 1970 is under way by Hawkins, M. R. S., Cristiani, S., Véron-Cetty, M. P., Véron, P., and Braccesi, A. This technique provides a powerful independent method of selecting quasar candidates which is particularly valuable in this case, since the completeness of the sample is checked and, at the same time, a statistically significant analysis of the quasar variability can be carried out, with remarkable consequences for the understanding of the physical processes involved in the quasar phenomenon.

Fig. 3 summarizes the present knowledge of the quasar surface density which is for astronomers a cause of dissatisfaction, for many questions are unanswered and a quantity of work still remains to be done, and at the same time a reason for pride, since properties of objects as far as several billion light-years have been determined.

References

1. Matthews, T. A., Bolton, J. G., Greenstein, J. L., Münch, G., and Sandage, A. R., 1961, Am. Astr. Soc. Meeting, N. Y., *Sky and Telescope* **21,** 148.
2. Hazard, C., Mackey, M. B., and Shimmins, A. T., 1963, *Nature* **197,** 1037.
3. Schmidt, M., 1963, *Nature* **197,** 1040.
4. Ryle, M., and Sandage, A. R., 1964, *Astrophysical Journal* **139,** 419.
5. Sandage, A. R., and Véron, P., 1965, *Astrophysical Journal* **142,** 412.
6. Braccesi, A., Lynds, R., and Sandage, A. R., 1968, *Astrophysical Journal* **152,** L105.
7. Braccesi, A., Formiggini, L., and Gandolfi, E., 1970, *Astronomy and Astrophysics* **5,** 264.
8. Formiggini, L., Zitelli, V., Bonoli, F., and Braccesi, A., 1980, *Astronomy and Astrophysics* Supplement Series **39,** 129.
9. Setti, G., and Woltjer, L., 1973, *Annals N. Y. Acad. Sciences* **224** 8.
10. Cristiani, S., Véron-Cetty, M. P., and Véron, P., 1983, ESO Preprint 303.
11. Braccesi et al. 1980, *Astronomy and Astrophysics* **85,** 80.

The Story of the Eclipsing, Double-lined Binary HD 224113

R. Haefner, Universitäts-Sternwarte München

For an observing astronomer it is always very exciting to record an unexpected event, even if this is "only" the detection of the optical variability of a spectroscopic binary. This happened to me in July 1978 when I performed a photometric programme at the ESO 50 cm telescope. Since the allotted observing time was a bit too late to follow my programme stars until the end of the night, I had prepared a list of about 20 radial velocity variables to check their photometric behaviour during the remaining hours. The first object I selected was HD 224113, a B6V star with a magnitude of V ~ 6.1. Suddenly, after some minutes of observation the brightness dropped off and faded away continuously until the rising sun prevented further measurements. The nature and range of the variation ($\triangle$ V ~ 0.2) indicated that an eclipse had been observed. Of course, for the nights to come, the hours before dawn were devoted to further observations of this star. However, no further variations were recognized, HD 224113 showed a constant brightness all the time.

Back at home I learned (a little disillusioned) that HD 224113 was known to be a single-lined spectroscopic binary with a period of about 2.5 days (Archer and Feast, 1958, *Monthly Notices of the Astronomical Society of Southern Africa* **17,** 9) and that it appeared in my list only because the radial velocity catalogue (Abt and Biggs, 1972) which I used as reference was incorrect: This star was marked only as variable in radial velocity and not as spectroscopic binary. A note in the paper by Archer and Feast that "a faint secondary spectrum is suspected on several of the spectrograms" was the stimulant to let things not rest. Eclipsing binaries showing in their spectra the lines of both components are the only sources for a precise determination of the system parameters in absolute units, including especially the masses. The knowledge of reliable empirical masses is essential for the theory of stellar structure and evolution. At that time system parameters of less than two dozen B-type main-sequence stars were known with high precision, among them only one B6V star. Since their masses and radii indicated a significant revision of the empirical mass and radius scale for B stars, a closer investigation of HD 224113 seemed to be worthwhile.

During the following years (1979, 1980, 1981) more than 2,700 uvby measurements were collected using the ESO 50 cm telescope. Descending and ascending part of the primary minimum as well as the whole secondary minimum could be covered several times allowing for a precise determination of the period. From the shape of the resulting light curves it is obvious that the interaction between the components is rather weak. The small displacement of the secondary minimum from midphase indicates a slight non-zero eccentricity of the orbit. For illustration the V light curve is presented in Fig. 1. In the course of two observing runs in 1979 and 1980, 36 high-dispersion spectra ranging from the blue to the infrared region could be obtained using the coudé spectrograph of the 1.5 m telescope. A careful inspection revealed that the only detectable lines of the secondary spectrum were those of Ca II-K and Mg II λ 4481, both very weak on the baked IIIa-J plates. The hydrogen lines cannot be seen distinctly double; there is only a variable asymmetry in the wings of the Balmer lines. A preliminary analysis (Haefner, 1981, *IBVS* No. 1996), based on radial velocities of the Ca II-K lines and on part of the photometry (Russell-Merrill nomogram method), yielded surprisingly good results for the system parameters when compared with the final solution.

In the meantime I learned that the optical variability had been detected independently by Balona (1977, *Mem. R. A. S.,* **84,** 101) and Burki and Rufener (1980, *Astronomy and Astrophysics* **39,** 121). The roughly 100 photometric measurements of Burki and Rufener which span the orbital period were analysed by Giurcin and Mardirossian (1981, *Astrophys.*