No. 21—September 1980

The Canada-France-Hawaii Telescope

R. Cayrel

The 3.6 m telescope of the Canada-France-Hawaii Corporation on the summit of Mauna Kea, on one of the Hawaiian islands, was put into operation last March. This nice instrument, located on what seems to be one of the best possible sites in the world, is presented to the readers of the Messenger by Dr. Roger Cayrel, director of the Corporation.

Visiting astronomers have now used the Canada-France-Hawaii telescope for 4 months in the prime-focus configuration. It is then an appropriate time to give the first impressions gathered during these initial weeks of operation. Let us first present the telescope which, although fairly similar to the ESO 3.6 m telescope, has a few different features.

Sky Coverage

The most qualitative difference between the two telescopes is of course that they do not look at the same hemisphere of the sky. There is, though, a fairly large overlapping in particular because of the low latitude of Hawaii (+19°45′). The break-even point where an object is seen at the same zenithal distance from ESO and from Mauna Kea, when it crosses the meridian, is $\delta = -5°$. But taking into consideration also the difference in elevation between the observatories, the declination at which one has equal air mass is moved down to $\delta = -18°$. The extreme limit of observing from Mauna Kea is −60° (10° above horizon) but all programmes below −20° are most efficiently carried out from ESO. It is a fortuitous but agreeable circumstance that the ratio of sky coverage from ESO and from Mauna Kea is more or less in the proportion of the fraction of observing time that French astronomers get on these two facilities.

Optics

For an optically-minded astronomer (there are still a few) the main difference between the two instruments is that one is a Ritchey-Chretien telescope whereas the other one is not. As the CFHT telescope has been used only at the prime focus, it is not the best time to tell what difference it makes. However, it should be noted that the "naked" prime focus has not been requested very much (this use was the main reason for having a parabolic

Please Note!

During the month of August, the ESO administration, which was already in Garching, and the Scientific/Technical Group, which until then had been the guests of CERN in Geneva, moved into the just completed Headquarters building in Garching.

The new address for all ESO Services in Europe is now:

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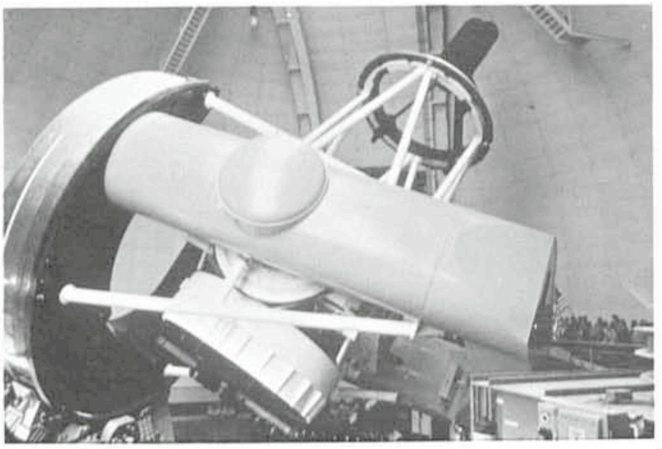

Fig. 1: *Canada-France-Hawaii Telescope, prime-focus configuration (picture taken in 1979).*

primary) whereas the wide-field corrector designed by C. G. Wynne has been very requested and very successful. The corrector gives almost one degree of field with a scale of 72 μm per arc second well suited for IIIa-J, IIIa-F plates or for L 4 electronographic emulsion. So both arguments, widely used during the discussions about classical versus Ritchey-Chretien, have been more or less defeated. One was that the naked prime focus was essential for limiting work, and the other that no good wide-field corrector could be designed for a parabolic primary!

Nothing can be said yet about the Richardson design of the coudé focus (high reflectance coated flats of small size) because it is not yet ready for use.

Control System and Mechanical Structure

The driving of the telescope at the horseshoe makes the response of the telescope as fast in hour-angle as in declination, even if the inertia involved is three times larger. Typically the response on both axes to a step function signal of amplitude *a* shows just a few strongly damped oscillations which are down to 5% of *a* after 1.6 second of time (so-called settling time). The tracking turned out to be very good. The automatic slewing to a position of given coordinates is not yet implemented.

None of the mechanical problems identified during the shop tests have reappeared on site: they have then been all successfully corrected at La Rochelle in France before shipping the telescope.

The pointing accuracy of the telescope has not been studied yet with full accuracy because one of the defining points of the primary mirror had a problem when we performed the pointing tests. The numbers collected show that after atmospheric refraction is corrected (this is done by the tracking software) there are ±1.'5 of residual corrections which are due to a variety of causes, including flexures of the structure, slight misalignment to the pole, etc. When good reproductible data will be obtained they will be tested by P. Wallace at the AAO for analysis of the causes of pointing errors.

Exchange of Upper Ends

Both the ESO and the CFH telescope have exchangeable upper ends. The exchange and the access to the prime-focus cage are done with the telescope horizontal at ESO and vertical at the Canada-France-Hawaii. The ride to the prime focus takes 5 minutes at CFHT and the primary mirror cover must be on in order to prevent possible damage resulting from accidental dropping of loose objects onto the main mirror. This is causing a delay which looks long to the observing astronomer, but from another side the telescope remains close to its average observing position, so it is difficult to find a great advantage in one or the other of the two approaches. The handling ring which carries the upper ends from the observing floor to the top of the tube and vice-versa is a fairly delicate equipment, which did have some problems initially.

Dome

The CFHT dome has no forced ventilation in the double skin but has a thick thermal insulation and, more important, a cooling floor, containing kilometres of pipes with circulating chilled glycol which allows to keep the temperature in the dome through the day a few degrees below the night outside temperature. This cooling floor appears to be a key element in preventing bad dome-seeing. Each time the cooling floor was off, we have observed a very poor seeing.

Operational Problems and Staffing

Technically the main problem we had was the insufficient size of the unit supposed to dry out the air supplied to the 18 axial supporting pads of the primary mirror. This air which is continuously flowing was condensing water in the system which subsequently was freezing in the pipes and obstructing them. The result was of course a malfunctioning of the supporting system, with excess load on the defining points.

Operationally, we have a very weak point with respect to ESO. Our total staff is sized for a single telescope observatory, so we do not have the possibility to draw people, as needed, from a larger pool as ESO or Kitt Peak can do. So we found very difficult to cope with the triple task of (1) properly supporting visiting astronomers who sometimes come with their own equipment and have needs which have not always been anticipated and tend to overload our logistic capabilities; (2) performing the maintenance of telescope and dome equipment (breakdowns are not rare and replacement of parts is much more difficult on an island than elsewhere); (3) preparing the installation of new foci and of new instruments, with the telescope available an always decreasing fraction of the time.

Our technical staff is made of 6 engineers supervising 14 technicians. This does not allow us to have two technicians on duty every night and we can afford a second technician by night only if the instrument has an unusual level of sophistication. We ask visiting astronomers using the prime focus direct photography to come with a colleague. In such a way that they can take turns in the prime-focus cage, in which it is not too pleasant to stay more than 4 hours in a row.

Effects of Altitude

The staff going frequently to the summit has a kind of permanent acclimatization and is not otherwise bothered by the elevation of Mauna Kea, except for the unavoidable loss of physical strength and a slight slowdown in the mental activity.

The score for visiting astronomers has been fairly satisfactory, only two visitors out of 21 having experienced serious discomfort. However, there was a kind of epidemy in the mid-level camp at that time, so it is not clear if the origin of the problem was not actually more flu or food-poisoning rather than hypoxia.

First Scientific Results

The very first scientific result obtained with the CFH telescope has been the resolution by Sidney van den Bergh of the spiral structure of NGC 3928 = Markarian 190 which was formerly classified S0 of E0. As this galaxy appears to be member of the Ursa Majoris cluster, it means that this galaxy is a miniature spiral, likely the smallest spiral ever identified.

New globular clusters habe been identified by Harris around elliptical galaxies (see Fig. 2).

Structures have been observed around QSOs of low redshifts by B. Campbell, one of our staff members.

The satellite of Pluton has been almost resolved in very good seeing by Bonneau and Foy performing speckle interferometry at the prime focus.

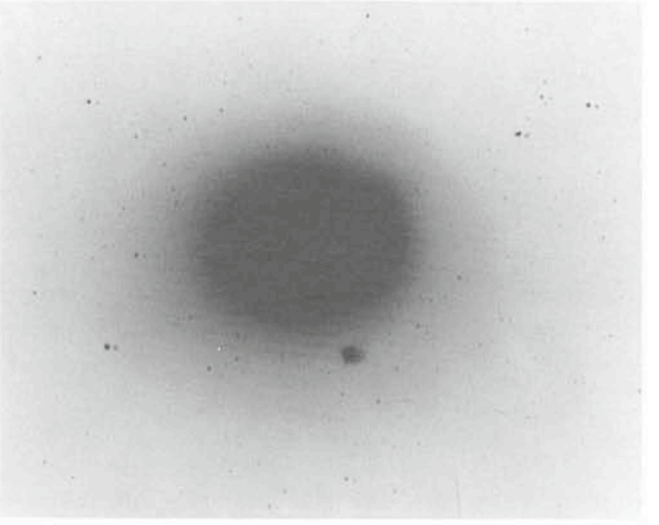

Fig. 2: *NGC 4472. 1-hour exposure on IIIa-J emulsion baked in forming gas. Note the swarm of globular clusters around this elliptical galaxy. The angular diameter of the first stellar images is between 0.7 and 0.9 arcsec.*

Work in Progress and Instrumentation Status

The telescope is expected to be kept in the prime-focus configuration until October 1980. Available are the photographic assembly, accommodating 160 × 160 mm and 10″ × 10″ plates, one wide-field corrector for the interval 340-800 nm (≃ 1° field), and one small field (20′) corrector for the UV and blue (300-500 nm). Grisms and a Racine Wedge are to come soon now.

The next focus to be put into operation is the coudé focus. It is scheduled for October 1980 with a coudé spectrograph equipped with 2 mosaic gratings (308 × 412 mm), one of them giving 2.8 Å/mm in the bue with the f/7.4 camera and two Richardson image-slicers. As the large spherical camera mirror is not yet available (such as Hindle sphere in testing the secondary f/8) we have replaced it by a small 60 cm mirror large enough for the field of high quantum efficiency modern detectors. The detector available in October will be a 1872-element reticon. Later, a one-piece holographic grating (300 × 450 mm^2) will be added.

The next focus to be implemented is likely the f/35 infrared Cassegrain (oscillating mirror). The two main instruments for this focus are already finished or nearly finished and are a photometer with a variable thickness filter (1 to 5 and 5 to 30 μm) and a Fourier transform spectrometer. The special IR upper end has been recently redesigned and should be available in the spring of 1981.

The availability of the f/8 optical Cassegrain focus depends upon the polishing of the secondary, which is still in progress at the Dominion Astrophysical Observatory in Victoria, B. C. Hopefully, this focus might be operational mid-1981.

Several instruments are planned for this f/8 Cassegrain focus, a faint-object spectrograph also built at D.A.O., a photometer for the visible built by Lyon Observatory and already delivered in Hawaii, a polarimeter built by the University of Toronto (delivery late 1980) according to a design made by Landstreet (University of Western Ontario), and an intermediate-resolution spectrograph built by the Institut d'Astronomie et de Géophysique according to a design made by Baranne (to be delivered in 1982).

In construction at the Laboratoire d'Astronomie Spatiale de Marseille is also an Image Photon Counting System which could be used at any focus of the telescope (delivery late 1980).

We should also mention that we have a Data-Acquisition and Instrumentation-Control System using CAMAC and HP21MX computers that we are upgrading to the F series, to be able to operate under RTE-IV instead of RTE-III.

Conclusion

The Canada-France-Hawaii telescope is now just starting its "scientific life". The first results obtained on the sky seem to justify the effort of having gone as far as the Mauna Kea in order to obtain optimal observing conditions. As far as we can tell, there is no design mistake in the telescope or in the dome which would cause a significant loss of these natural good conditions. Much work remains to be done to have the telescope equipped with all the instruments which have been planned for it, and the speed at which this work can be done depends critically on the staff power which will be there in the coming years.

Data Reduction Facilities at Garching

The ESO measuring machines and image-processing system (described in the December 1979 issue of the *Messenger*) are presently being installed in the new building, and will again be available for general use as of November 1, 1980.

IUE and La Silla Observations of Mass Loss in the Magellanic Clouds

F. Macchetto, ESA, ESTEC, Noordwijk

Introduction

The phenomenon of mass-loss in hot stars has been known for a good many years. The strong stellar winds which are the manifestation of this phenomenon are observed as broad emission lines in the spectra of hot stars. In a number of cases the emission is red-shifted from the laboratory wavelength and a blue shifted absorption component appears; this is the so-called "P-Cygni" line profile as it was first seen in the spectrum of the star P Cygni.

Although the mass-loss phenomenon was first discovered and studied from the ground, it was not until the advent of rockets and satellites, which allowed observations to be made in the ultraviolet, that its extent and importance were fully realized. The reason for this is easily understood if one remembers that most of the resonance lines of neutral and ionized ions of the most abundant elements such as H, He, C, N, O, Si, S, Fe and Mg all fall in the ultraviolet region of the spectrum. And it is precisely these lines that are the most sensitive indicators of the occurrence of mass-loss.

The first extensive sample of hot stars showing mass-loss was obtained with the Copernicus satellite. These observations were however limited to the brightest and therefore nearest stars. The launch of IUE in January 1978 has allowed these studies to be greatly extended. It has been possible, for example, to survey at high spectral resolution (~ 0.1 Å) a complete sample of galactic stars and to establish that significant mass-loss occurs only in those stars brighter than $M_{BOL} \simeq$ 5 or 6 (Lamers, de Jager, Macchetto, in press). Furthermore, the high efficiency of IUE in its low-resolution mode (~ 6 Å resolution) makes it possible to observe stars of magnitudes between 11 and 13 in reasonably short times. This magnitude interval is just what is required to study the early-type stars in the two nearest galaxies to our own, namely the Large and Small Magellanic Clouds.

With this possibility in mind, P. Benvenuti, S. D'Odorico, C. Chiosi and myself submitted a proposal to study such stars with IUE and at the same time submitted a proposal to carry out photometric and spectroscopic measurements of the same objects with the ESO telescopes. Needless to say both proposals were accepted (or I would not be writing this article today!)

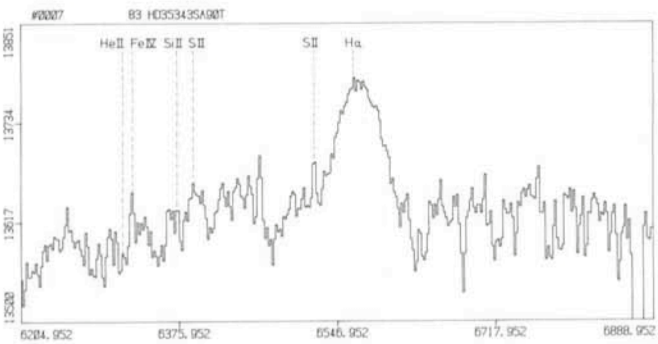

Fig. 1: *Red spectrum of the Bep star HD 35343 (SK 94) in the Large Magellanic Cloud. The most prominent emission line in this spectrum is Hα. The half-width at zero intensity of this line, measured towards the red wing, is 45 Å, corresponding to an expansion velocity of 2,057 km s⁻¹. (ESO 1.52 m telescope and Boller & Chivens spectrograph).*

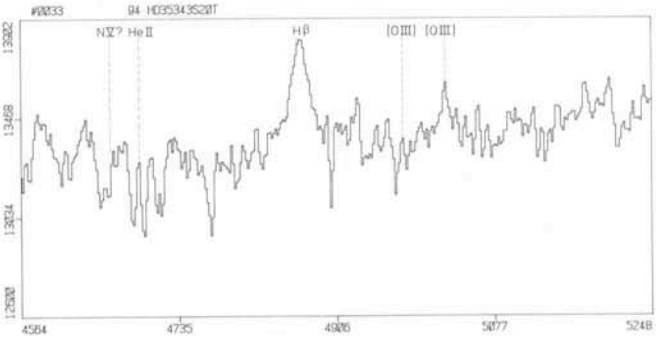

Fig. 2: *This spectrum of HD 35343 shows [O III] λλ4958, 5007 and He II λ4686 in emission, in addition to the strong and broad Hβ line (ESO 1.52 m telescope and Boller & Chivens spectrograph).*

Why do we want to study the mass-loss process occurring in stars of another galaxy? The reason is that we still do not understand how the mass-loss process works in detail. We know, or believe we know, fairly well what happens once the mass is ejected from the star and accelerated outwards. But we have little knowledge of why the mass-loss occurs, of what it is that pushes the matter out at velocities higher than the local sound speed or of what mechanism is responsible for accelerating the matter to the large terminal velocities (up to ~ 5,000 km/sec) observed in these stars.

We must therefore look for clues to solve those problems. One of the clues is the chemical composition. From theoretical models we expect the mass-loss to be dependent on the detailed chemical composition of the star. This is where the Magellanic Clouds can provide a unique test-bed. We know that the chemical composition of the Magellanic Cloud stars differs from that of stars in our own galaxy. We therefore expect to see direct evidence of this in the mass-loss characteristics of the hot stars in the Clouds. Of course by carrying out this study we will also extend our knowledge to the interplay of the different parameters such as temperature, luminosity, gravity, etc. that affect the mass-loss process.

Finally the effects that the mass-loss has on the evolution of hot stars can be studied, these observations serving as a test of the theoretical evolutionary models that exist.

The Observations

The strategy of observations was first to obtain U, B, V and Hβ photometric data, which in many cases were either poor or simply not available, then to carry out spectroscopy in the visible and a few months later to repeat and extend the spectroscopy in the visible and obtain simultaneous IUE observations in the ultraviolet. One reason for this was that observations separated by an interval of a few months would allow us to establish whether there was any spectroscopic variability. An additional consideration was that in the available IUE time we could not observe all the stars in our list and therefore a selection based on the visible data had to be made.

Photometric observations of 22 stars in the LMC and 7 in the SMC were carried out with the ESO 50 cm photometric telescope on La Silla, in September 1979. The diaphragm used was 15 arcsec in diameter. The U, B, V and Hβ photometric results are the average of three or four nights of observations. Night-to-night deviations were at most one or two tenths of a magnitude in V. The photometric standards used were taken from the E-region standards for U, B, V and for H_β from the photometric list of Crawford and Mander (1966, *Astron. J.* **71**, 114). Spectroscopic observations were carried out in September 1979 and January 1980 with the ESO 1.52 m telescope and the Boller & Chivens spectrograph. In September the dispersion used was 114 Å/mm. Recording was with a two-stage EMI intensifier tube and baked IIIa-J plates. In January the dispersion used was 60 Å/mm. Recording was with a three-stage EMI intensifier tube and baked IIIa-J plates.

Observations were carried out with IUE in January of those stars that had not already been studied by other investigators. These were obtained within hours of the ground-based observations from La Silla.

IUE observations of several other stars in our list had been made by other European and U.S. astronomers, and thanks to the IUE "six months" rule (i.e. the data become available to everyone six months after completion of the observation) we will soon be making use of it ourselves to enhance our statistical basis.

Some Early Results

We have not yet reached a point in our analysis where we can answer the many questions that arise, but we can give some general conclusions. (Preliminary results of this investigation have been published; F. Macchetto, P. Benvenuti, S. D'Odorico and N. Panagia, Proceedings of the Second European IUE Conference, Tübingen, 26-28 March 1980).

A significant fraction of the stars observed show mass-loss, as indicated for example by broad Hα emission or by P Cygni type profiles in the UV lines.

As an illustration of the results obtained, Figures 1, 2 and 3 show the spectrum of the star HD 35343 (SK 94). This star is classified as Bep in the Sanduleak catalogue and shows a large number of emission and absorption lines.

The most prominent emission lines in the visible are those of the Balmer series of Hydrogen of which Hα and Hβ are shown in Figures 1 and 2, respectively. The profiles of the lines appear to be asymmetric. It is not clear if this is due to the contamination by absorption lines of other atoms in the blue side of each of the lines or if these are real P Cygni-like profiles.

The half-width at zero intensity measured towards the red wing is 45 Å for Hα, corresponding to an expansion velocity for the wind of $V_{exp} \simeq$ 2,057 km/s. The equivalent values for Hβ are 24 Å corresponding to 1,580 km/s and for Hγ the width is 12 Å corresponding to 830 km/s. Other emission lines in the visible are those of SII 6521 and 6386, SiII 6371 and 5915, FeIII 6323, HeII 6310 (weak) 4686 (strong) and 4200 (strong), [OIII] 5006 and 4958, SiIII 4532 and 4567 and SIII 4478.

In the ultraviolet region the following lines are found in emission: NII 1758 and 1748, HeII 1640, CIV 1550 and 1549, SiIV 1394 and 1403 and NV 1239 and 1243. The

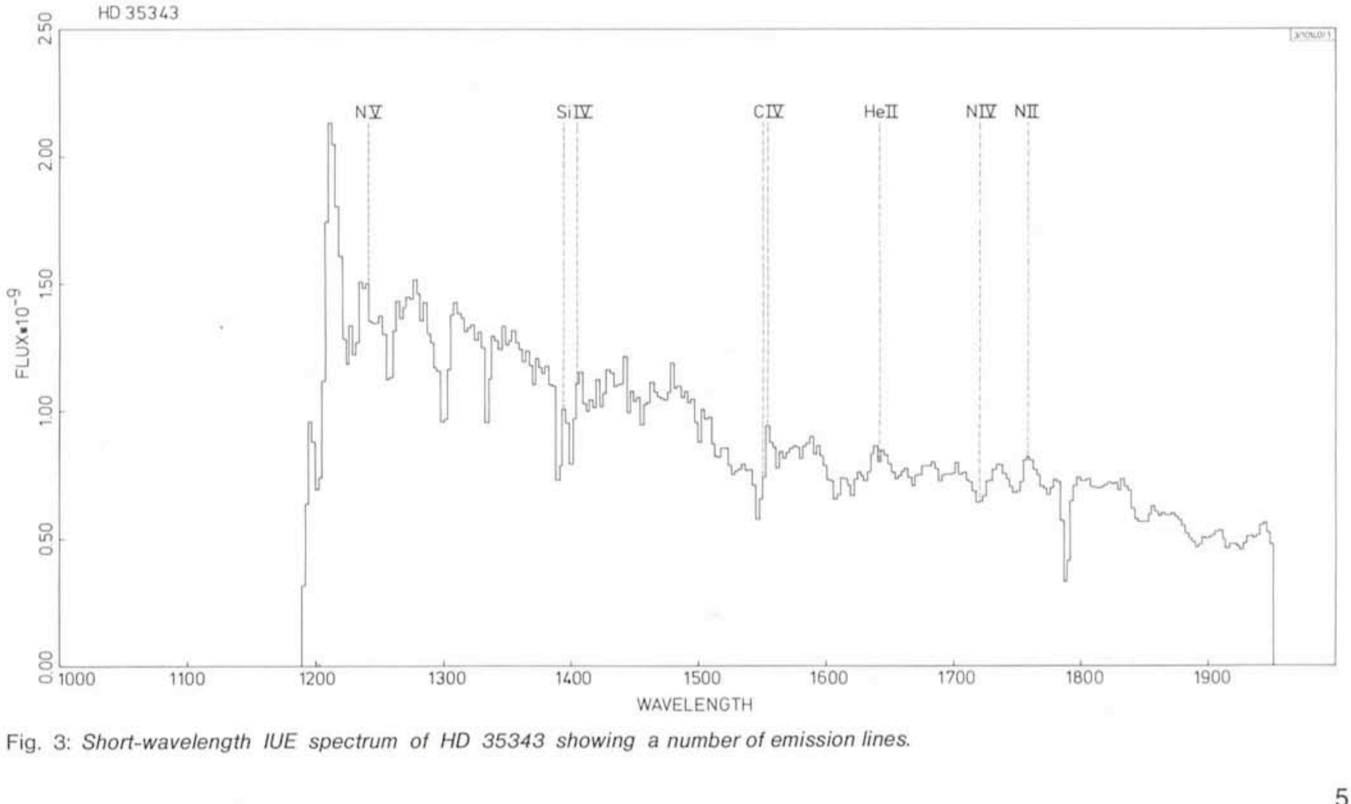

Fig. 3: *Short-wavelength IUE spectrum of HD 35343 showing a number of emission lines.*

wind velocity as measured from both the HeII and CIV profiles turns out to be 1,550 km/s which is significantly lower than that measured from Hα. This may be due to the depletion of hard ionizing photons which restrict the presence of CIV to regions closer to the star.

Discussion

It appears that in a broad sense the properties of the mass-loss process in the hot stars of the Magellanic Clouds and those of our own galaxy are very similar, although differences of detail, as already shown by Hutchins (*Ap.J.* April 1980, **237**, 285), can be seen and will be further investigated.

Of particular interest is the confirmation of a correlation found for galactic OB stars (Panagia and Macchetto, in preparation), between the terminal velocity and the effective temperature. A similar correlation between terminal velocity and excitation class has been found by Willis (Proceedings of the Second European IUE Conference), for WN stars. In both cases the higher the effective temperature the higher is the terminal velocity. In addition, for all high-temperature (or high-excitation) stars the momentum carried by the mass-loss ($\dot{M}V_\infty$) exceeds the momentum that the stellar radiation can release to the wind through *single* scatterings, by factors of between five and ten.

Clearly a more efficient mechanism for the wind acceleration is required. Such a mechanism has been proposed by Panagia and myself. It consists of the multiple scattering of hard ultraviolet photons in the approximate range 200 Å to 500 Å. In a qualitative way the mechanism can be described as follows. In the wavelength range 200 Å to 500 Å there are of the order of one hundred strong atomic and ionic lines. The average separation between lines is then of the order $c\,\Delta\lambda/\lambda = 1{,}000$ km/s.

A photon emitted by the star in this wavelength range will be absorbed by some layer of the envelope at some distance from the star. After undergoing a number of local scatterings, which do not contribute any net momentum to the wind, the photon will preferentially be scattered backwards to the opposite side of the envelope where it will be reabsorbed by a line shifted toward the red by $c\,\Delta\lambda/\lambda = 2V$ relative to the transition which had produced the first absorption. The process is then repeated. In each one of these scatterings the photon will contribute net momentum to the wind. Our calculations show that the process can be repeated a number of times (between 5 and 20), before the photon eventually escapes outwards or falls back on the star where it is thermalized. Therefore the momentum imparted to the wind by this mechanism can be several (e.g. 5 to 20) times the luminosity in the wavelength range 200 Å – 500 Å divided by the speed of light. This is just what is required to produce the observed velocities in the winds of the hot stars.

It has to be stressed that this mechanism is only useful in accelerating the wind but it presupposes the existence of the mass-loss. In other words we have not yet explained how the mass-loss itself is produced.

I am convinced that in the coming years a concerted attack based on ultraviolet, visible and infrared observations will produce the evidence required by the theoreticians to solve the problem of mass-loss.

Fig. 4: *The Large Magellanic Cloud.*

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Marie-Paule VERON, F, 1. 10. 1980

DEPARTURES

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Harald WALDTHAUSEN, USA, 1. 11. 1980
Hélène SOL, F, 1. 12. 1980
Joachim KRAUTTER, D, 1. 12. 1980

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Jeremy A. SELLWOOD, UK, 30. 9. 1980
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Hans R. DE RUITER, NL, 30. 9. 1980
Jean SURDEJ, B, 30. 9. 1980
Eduardus ZUIDERWIJK, NL, 30. 9. 1980

Optical and Radio Studies of Supernova Remnants in the Local Group Galaxy M33

I. J. Danziger and S. D'Odorico, ESO, and
W. M. Goss, Kapteyn Astronomical Institute, Groningen

The discovery of the first supernova remnants in M33 was made on material from a medium-size telescope but the subsequent detailed investigation involved the use of some of the largest optical and radio astronomy facilities in the world. Eventually, a complete study of these objects will improve our understanding of the stellar population and of the interstellar medium of that galaxy.

1. The Optical Search

At the present time about 130 extended galactic non-thermal sources have been classified as remnants of supernova explosions. Of these, only 30 have an identified optical counterpart, which, depending on the environment of the supernova and the age of the remnant, may consist in a few, faint filaments or in a nearly complete shell. The discrepancy between radio and optical identifications is due to galactic absorption and quite naturally has led optical astronomers interested in the subject to look in nearby extragalactic systems, where absorption conditions may not be so extreme. In the early seventies Mathewson and Clark pioneered this type of work by searching in the Magellanic Clouds. They started from a list of non-thermal radio sources, noting that in the shock ionized gas which is responsible for the optical emission, the strength of the [S II] emission lines at $\lambda\lambda 6717-6731$ is about equal to that of Hα, whereas in radiatively ionized nebulae they are one order of magnitude fainter. This effect is now understood from models of shocked radiating and cooling gas where temperature stratification can give rise to emission from a wide range of ions of differing ionization potential.

By observing at the position of the radio sources in Hα and [S II] light, Mathewson and Clark (*Ap. J.* **180**, 725, 1973) were able to identify 14 SNR on the basis of strong [S II] emission. In 1976 one of us, S. D., then working in the Asiago Observatory of the University of Padova in collaboration with Benvenuti and Sabbadin, started a similar search in the Local Group Sc galaxy M33 (Fig. 1). At the distance of 720 kpc, the Crab Nebula would appear stellar-like and an older remnant like IC443 measure a few arcseconds. High angular resolution was required to identify a shell structure when possible, to separate the remnants from nearby H II regions and to lower the background emission from the galaxy in order to observe faint features. For M33 there was no list of non-thermal radio sources to start with, but fortunately the angular extent of the galaxy is such that it can be covered with a reasonable number of plates. Additional attributes of M33 are the favourable orientation (close to face on), the high gas/mass ratio and the relatively large number of young, massive stars which eventually will explode as SN. The plates were obtained at the Cassegrain focus of the Ekar 1.82 m telescope (scale 12.5"/mm through Hα, [S II] and red continuum filters and a VARO image tube. The first set of plates centered on the main southern spiral arm were carefully compared and happily revealed three nebulae with the strong [SII] characteristic (*A&A* **63**, 63, 1978). One indeed appeared as a half completed shell

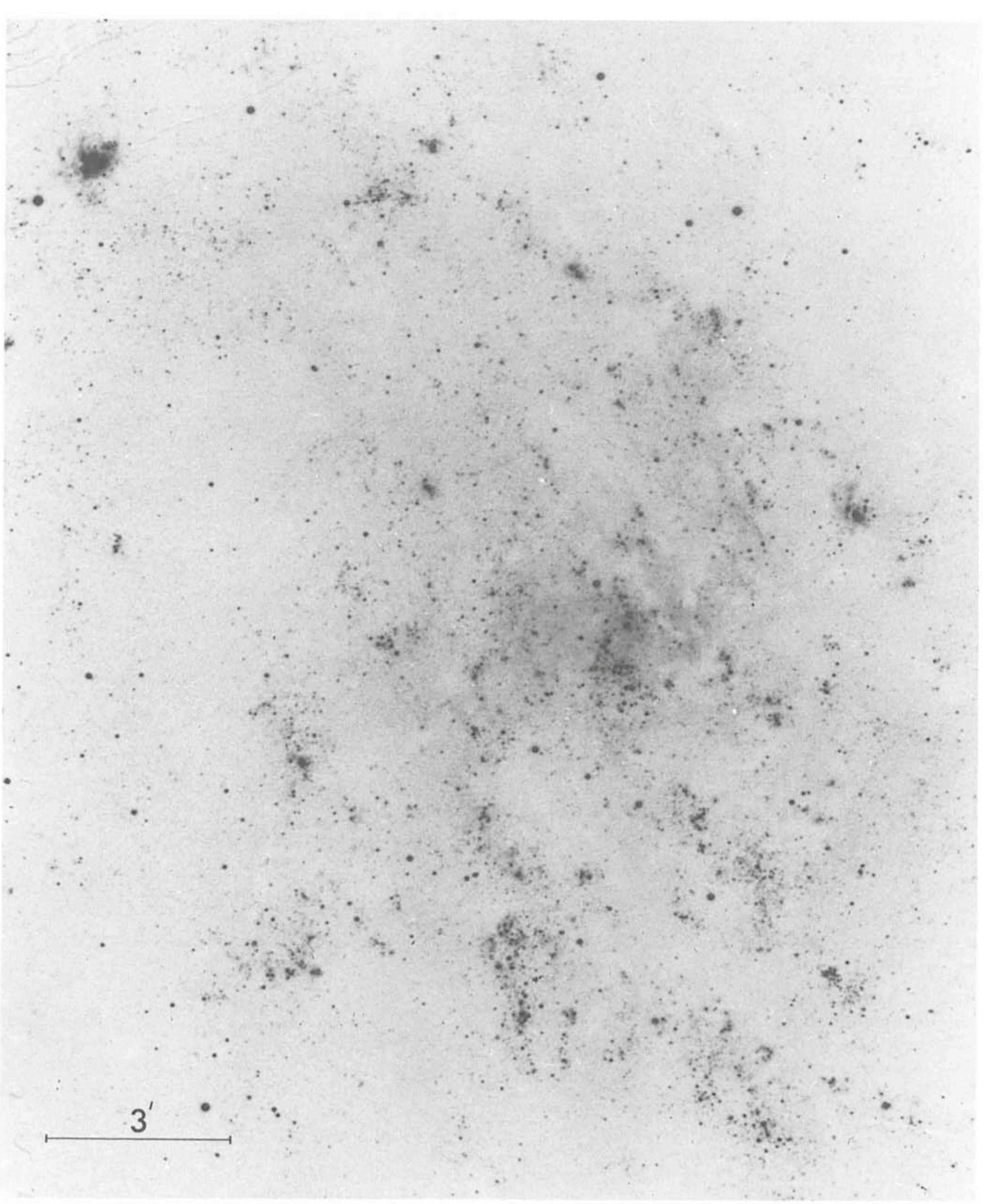

Fig. 1: *This ultraviolet photograph of the central part of M33 shows the spiral pattern as outlined by the OB associations. Asiago 1.82 m telescope, 103a-O plate + UG2 filter.*

probably caused by the interaction of the expanding shock with a nearby region of star formation (Fig. 2). The result was in a way expected, a natural follow-up of the Galactic and Magellanic Cloud work, but it was still rather exciting to find for the first time the place of a supernova explosion a thousand years after the event beyond the Magellanic Clouds.

Later on D'Odorico and Benvenuti joined Dopita, who had obtained observing time at the Palomar Schmidt on a similar programme to extend the survey to the whole galaxy. The Palomar plates complemented well the Asiago material because, with the wider field and fainter limiting surface brightness, they permitted the detection of large remnants in the periphery of the galaxy (*A&A Suppl. Ser.* **40**, 67, 1980). At present 20 SNR candidates are known in M33 with diameters from 6 (upper limit) to 60 parsecs.

2. The Optical Spectroscopy

The spectroscopic observations of the first 3 candidates in M33 were made with the UCL Image-Photon-Counting System attached to the RGO spectrograph at the Cassegrain focus of the 3.9 m Anglo-Australian Telescope in November 1977 by Danziger, Murdin, Clark and D'Odorico (*M.N.R.A.S.* **186**, 555, 1979). The system has several advantages for this type of work. There is the long slit mode allowing one to sample data from different regions of extended objects; there is the pulse-counting capability which allows one to make on-time assessments of the quality of the data particularly valuable for faint objects where accurate sky subtraction is essential; and there is the availability of a range of spectral resolutions which provide different types of spectral information. All of these capabilities proved useful as we shall see. At the AAT on the first night of the observations, as a result of the faintness of the objects and the large zenith distance ($>62°$) at which the northern galaxy M33 had to be observed, there was a mood of skepticism about the possibility of the undertaking. Ten minutes into the first integration on object (SNR 1) the mood suddenly changed to one of elation as it was realized that the on-line [SII]/Hα ratio clearly indicated a small SNR on a section of the slit. (In fact a partial first draft of the *M.N.* paper was written that night while other observations were proceeding.)

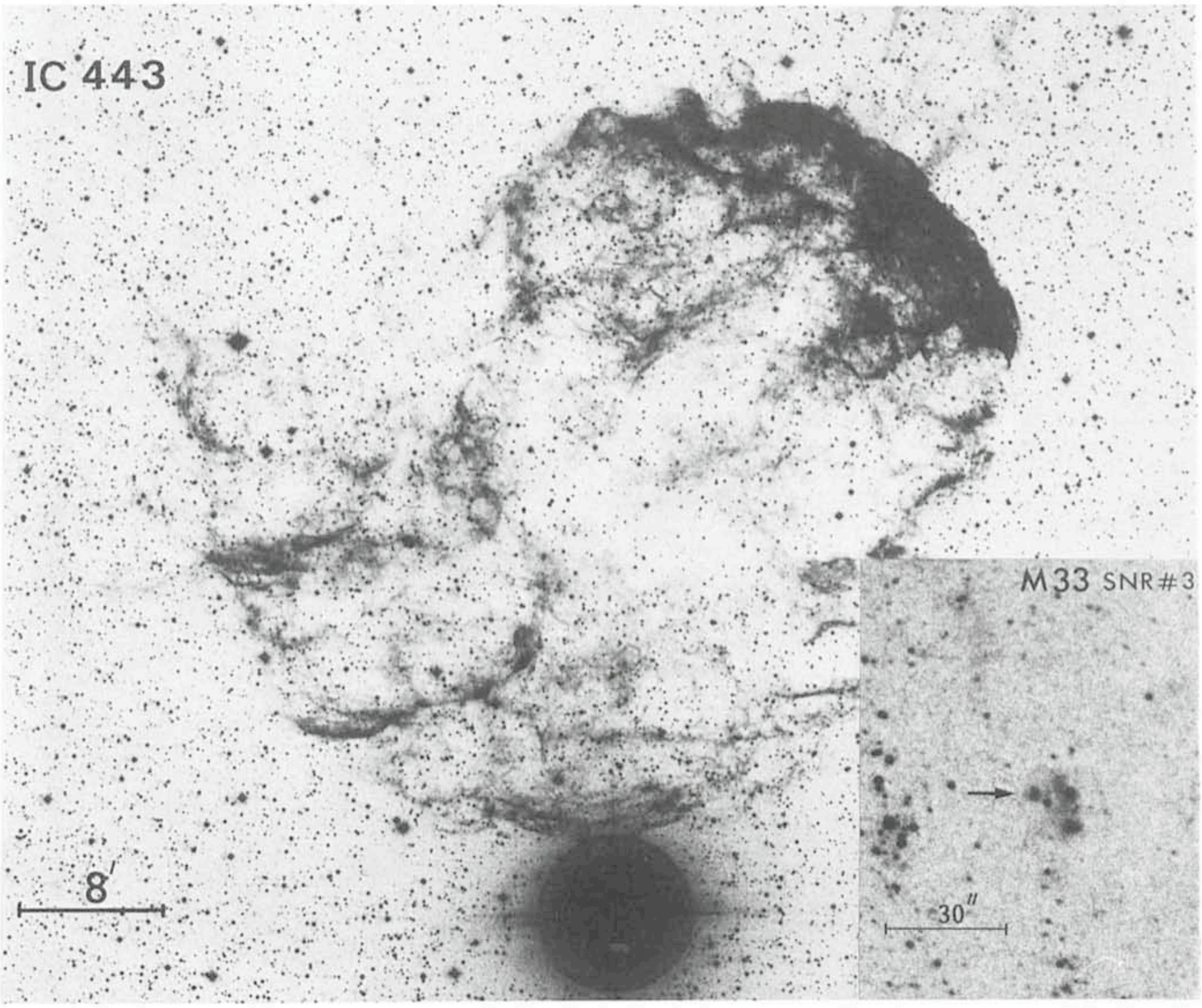

Fig. 2: *A typical galactic remnant, IC443 and SNR3 in M33 (insert). The objects have comparable linear dimension, but the extragalactic remnant is about 400 times more distant.*

A sample of a low-resolution spectrum of SNR2 is shown in Figure 3 where the great strength of the [SII] lines demonstrates the probability that this object is a supernova remnant. There are other pieces of evidence that suggest, but individually do not prove conclusively, that such objects are supernova remnants. Two of the objects have electron densities Ne $\sim 2 \times 10^3$ cm^{-3} (determined from [SII] doublet ratios), a value an order of magnitude higher than that observed in most HII regions.

The [OI] 6300 lines also tend to be stronger than observed in HII regions. Both of these effects are typical of supernova remnants in our Galaxy. A more compelling piece of information for SNR 1 is the presence of broad wings of low intensity (illustrated in Figure 4) on the profiles of the [OIII] 5007 emission line. This is the type of profile one might expect from a spherical shell of gas expanding outward from a central point. In the case of SNR 1 the velocity of expansion is > 375 km sec^{-1}, an order of magnitude higher than one ever observes in HII regions, but not uncommon in supernova remnants. This fairly high velocity and the small size of SNR 1, suggest that it is a relatively young object, not more than a few thousand years old.

The observations at the AAT with a long slit also demonstrated that these objects had a size greater than the seeing disk and had therefore an extent consistent with their being supernova remnants of young to intermediate age. One problem in this type of spectroscopy is the confusion of the SNR with nearby or intermixed HII regions. A high percentage of cases both in M33 and the Magellanic Clouds shows associated HII regions. This is one reason that care is required in using the spectra for interpretative purposes.

This spectroscopy allowed the above authors to discuss whether abundances obtained from these SNR spectra were consistent with abundances obtained from HII regions at similar positions by Smith (*Ap. J.* **199**, 591, 1975). No glaring discrepancies were found. A more extensive survey, detection and interpretation of SNR's in M33 have now been completed by Dopita, D'Odorico and Benvenuti (*Ap. J.* **236**, 628, 1980) using the Palomar 5 m telescope.

There have been occasional candidates from the direct observations which were not clear cut. It is reassuring to note that the spectroscopy and radio observations discussed below have been mutually supportive in helping to eliminate objects that are not SNR's.

3. The Radio Survey

In the initial Asiago Survey of the southern spiral arm of M33 the suggestion was made that several of the optical supernovae could be associated with radio sources. These sources had been found in a sensitive survey made in 1974 by Israel and van der Kruit (*A&A* **32**, p. 363) using the Westerbork Synthesis Radio Telescope (WSRT) at 21 cm. At the time of the Asiago Survey the radio continuum spectra and the positional agreement of the optical and radio objects was not known.

After the spectroscopic study at the AAT, we decided to extend the radio observations. These new observations are described in a paper in *Monthly Notices of the Royal Astronomical Society* (in press, 1980) by Goss, Ekers, Danziger and Israel. A new WSRT map at 21 cm has been made. The sensitivity is a factor of three improved in comparison to the 1974 map and the resolution is 25 × 49 arcsec. In addition we have used a 49 cm map

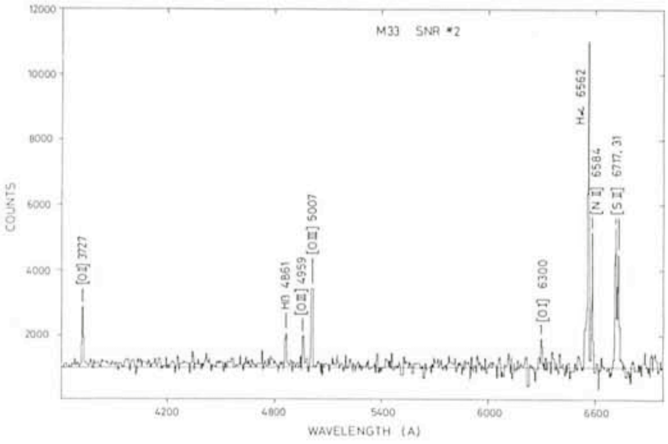

Fig. 3: *The λλ3500 – 7000 Å spectrum of SNR 2 in M33 obtained with the IPCS at the 3.9 m AAT. Spectral resolution 5 Å.*

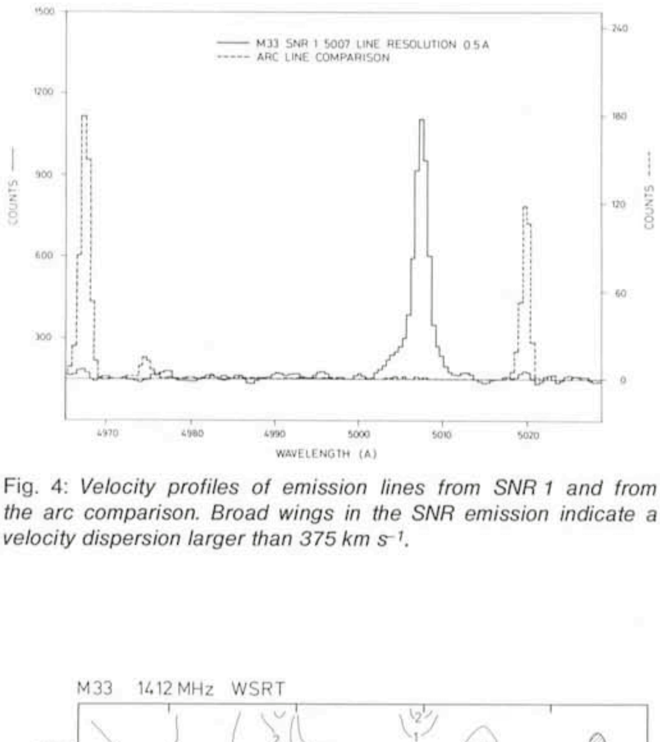

Fig. 4: *Velocity profiles of emission lines from SNR 1 and from the arc comparison. Broad wings in the SNR emission indicate a velocity dispersion larger than 375 km s⁻¹.*

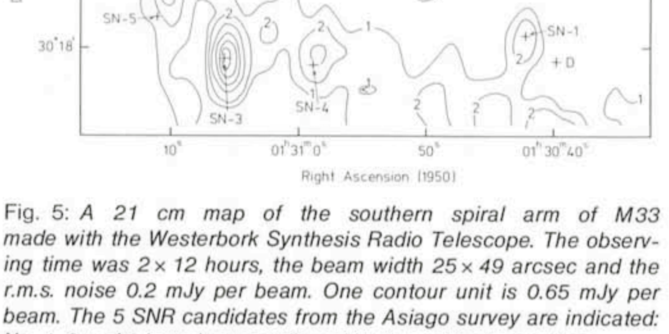

Fig. 5: *A 21 cm map of the southern spiral arm of M33 made with the Westerbork Synthesis Radio Telescope. The observing time was 2 × 12 hours, the beam width 25 × 49 arcsec and the r.m.s. noise 0.2 mJy per beam. One contour unit is 0.65 mJy per beam. The 5 SNR candidates from the Asiago survey are indicated: No. 1, 2 and 3 have been confirmed by the radio observations.*

made with the WSRT in 1975 in order to extend the radio spectra. The 21 cm map is shown in Figure 5; the five Asiago SNR candidates are shown. The SNR 1, 2 and 3 are the objects confirmed in the AAT study.

In 1978, we used the Very Large Array of the National Radio Astronomy Observatory in Socorro, New Mexico, to map SNR 1 and 2 at 6 cm. The goals were to determine the radio sizes with an angular resolution of 1.5 arcsec and to measure the flux densities at 6 cm.

The main results of the radio observations are:

(1) SNR 1, 2 and 3 have non-thermal radio spectra in the range 6 to 49 cm. The spectra are similar to galactic SNR.

(2) The radio positions agree precisely with the optical positions. There is little doubt of the correspondence of the two.

(3) Based on the measured angular sizes at 6 cm, the distance to M33 can be estimated. We assume the surface brightness (flux density/square of the angular size) diameter relationship for our Galaxy holds for M33. The determined distance is 860 ± 200 kpc. Although the error is large, the result is in good agreement with optically determined values.

We have also used the new 21 cm WSRT map to look for radio counterparts of the 20 new SNR candidates found at Palomar. In order to increase the reliability of the identifications, the optical positions have been measured to a precision of about 1 arcsec. Only two new positive identifications of weak radio sources and optical SNR can be made (two more are possible). It does appear that of the roughly 100 discrete radio sources in the WSRT map of M33 only very few can be unambiguously identified with optical SNR. The remainder of the radio sources are HII regions. Why is the rate of detections so low? This is simply a matter of sensitivity. Although we can detect a point source of 0.4 milli-Jansky throughout the disk of M33, this corresponds to a galactic SNR of ~200 Jy at a distance of 1 kpc. There are very few galactic SNR of such intensity. Thus with presently available radio techniques we can only detect the strongest SNR in M33.

4. How Complete is the SNR Sample in M 33?

From the above discussion, it is fair to remark that in the case of M33 the optical method of identification has still an edge with respect to the radio surveys. This is also true for the 0.5-4.5 keV imaging survey of M33 obtained with the Einstein Observatory. Only nine sources were detected in the galaxy field and no coincidences were found with the optical candidates.

This is not unexpected because, at the detection limit of the instrument, a source equivalent to the Cygnus Loop at the distance of M33 would not have been detected and very young remnants (possibly one or two) with strong X-ray emission could not have yet developed a significant optical counterpart.

There are two main reasons of interest in the SNR counts in M33. We can use them to check the SN frequency in a Sc galaxy (this time looking at all SN exploded in a single galaxy during the last few thousand years instead of looking at several galaxies over a few years interval). Second, we can pinpoint the location of the SN explosions and try to associate them with the stellar populations.

At present, we have no way to say whether an observed remnant is due to a type I or type II supernova. At this point one may wonder about the completeness of the sample of 20 SNR selected on the basis of the [SII]/Hα criterion.

Two confusion effects may play a role. First there is the problem of the large shells of ionized gas which originate as a consequence of supersonic stellar winds. It has been suggested by Lasker that the large loops seen in the Large Magellanic Cloud may have this origin (1977, *Ap.J.* **212**, 390) and by mimicking the line intensities and radio emission of SNR, contaminate their sample at large diameters. Several circular HII regions are present in M33 but their Hα/[SII] ratios do not appear as low as in the SNR candidates neither do we observe an excess of SNR with large diameters.

A second effect which will make our sample incomplete is the presence in the galaxy of SNR which do not obey the [SII]/Hα criterion either by the absence of [SII] lines, like the faint filaments in Tycho and the stationary knots in Cas A, or by being oxygen-rich with little H, N and S to give rise to the red emission lines (like G292.0 + 1.8 as reported by Goss et al. *M.N.R.A.S.* **188**, 357, 1979). These characteristics however are peculiar to a few, probably young SNR and should have little effect on the global statistics.

Observations of Radio Galaxies

R. A. E. Fosbury, Royal Greenwich Observatory (previously ESO)

It appears that only ellipticals become powerful radio galaxies. We believe this to be due to the depth of the gravitational potential well and the characteristic paucity of interstellar material in these galaxies. Aside from the particular interest of the nuclear activity associated with the radio galaxy phenomenon, these objects may, in two rather distinct ways, give us very useful information about the intergalactic medium in a range of different environments.

Firstly, there is growing evidence that the onset of nuclear activity and the subsequent generation of a powerful extended radio source may be triggered by a sudden increase in the gas content of the nuclear environment of an elliptical. This may be brought about by a close gravitational encounter with a neighbouring gas rich galaxy or even, perhaps, by the accretion of primordial intergalactic gas.

Secondly, once the extended radio source has formed, characteristically with a double-lobed morphology, its detailed properties can tell us something about the intergalactic medium with which it is interacting. The high-resolution, high-sensitivity radio maps now being made with the aperture-synthesis telescope show a very clear connection between the galactic nuclei and these sometimes

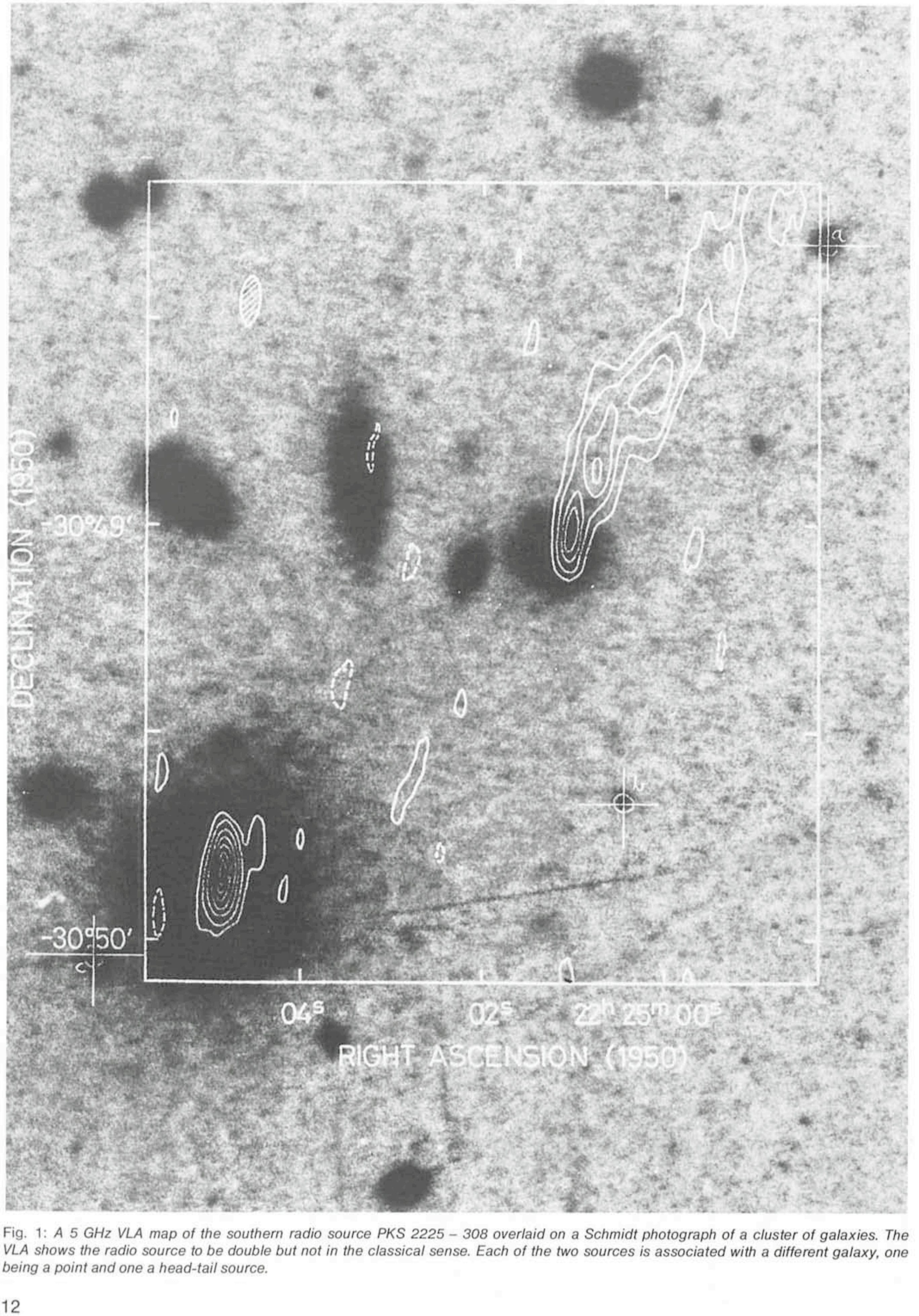

Fig. 1: *A 5 GHz VLA map of the southern radio source PKS 2225 – 308 overlaid on a Schmidt photograph of a cluster of galaxies. The VLA shows the radio source to be double but not in the classical sense. Each of the two sources is associated with a different galaxy, one being a point and one a head-tail source.*

very extended (several Mpc) outer regions. The sequence of aligned features and jets continue right down to the milliarsecond scale revealed using VLBI techniques.

A desire to study the interaction between a galaxy and its surroundings and, in particular, the role of the radio galaxy phenomenon in the evolution of ellipticals, has prompted a rather ambitious multi-wavelength survey of radio galaxies.

A collaboration consisting of John Danziger and Peter Shaver from ESO, Ron Ekers and Miller Goss from the University of Groningen, David Malin from the Anglo-Australian Observatory and Jasper Wall and myself from the Royal Greenwich Observatory has selected a sample of about a hundred galaxies from the Parkes 11 cm radio survey. Because of our interest in the optical morphology of the galaxies, our sample has been chosen to be within the area of the southern IIIa-J sky survey, that is with $\delta < -17^{o}$. So that we could study the radio morphology with the Very Large Array (VLA) in New Mexico, the southern declination had to be limited to -40^{o}. The observational material so fast accumulated includes: 5 GHz radio maps for all sources from the VLA (see Fig. 1), optical spectrophotometry for all sources from the ESO 3.6 m, the Anglo-Australian Telescope (AAT) and the Las Campanas 2.5 m, a large amount of new radio data from Molonglo, Culgoora, Fleurs and Parkes in Australia and access to many original plates from the UK Schmidt Telescope together with some short-exposure plates from the AAT. In addition, about a third of the galaxies have so far been observed in the infrared (H, K and L bands) by Pierro Salinari and Alan Morewood with the ESO 1 m and 3.6 m telescopes and the UK Infrared Telescope (UKIRT) in Hawaii. Not to be left out, the Danish 1.5 m telescope on La Silla has been taking some fine electronographs using the McMullan Camera. At least two of the galaxies have been observed with the IUE satellite and several more are scheduled for the Einstein satellite.

The sample has been chosen to be complete down to the radio flux density limit of the Parkes survey for all galaxies brighter than 17th magnitude. The observations are obviously yielding a wealth of statistical information but apart from that there are, of course, some objects of outstanding individual interest. It is to one of these that I wish to devote the rest of this article.

There have now been three spectroscopic observing runs on the 3.6 m telescope using the University College London Image Photon Counting System (IPCS). The first of these has already been described in the *Messenger* by Danziger and de Jonge (*Messenger* **15**, December 1978, p. 19). One of the observing programmes was to do spatially resolved spectroscopy of radio galaxies using a long spectrograph slit and the large digital memory now available with the IPCS.

It has long been known that some radio galaxies exhibit strong, high-excitation emission-line spectra not unlike those seen in the class 2 Seyfert galaxies. Unlike the spiral Seyferts known, however, we noticed that in the radio galaxies these high-excitation lines could come from a region of very large spatial extent, in one case over 100 kpc. One of the most spectacular of these objects, PKS 2158 – 380, had already been observed to have extended emission lines by Mike Disney a number of years ago at Mt. Stromlo. It has now become the subject of a detailed observational study using a range of different techniques and involving a corresponding range of investigators (R. A. E. Fosbury, A. Boksenberg, M. A. J. Snijders, I. J. Danziger, M. J. Disney, W. M. Goss, M. V. Penston, W. Wamsteker, K. Wellington and A. S. Wilson, to be submitted to *M.N.R.A.S.*).

Why should this phenomenon occur in some elliptical radio galaxies and not apparently in the spiral Seyferts? Does it stem from the differences in the nature and distribution of the interstellar material between these two types of galaxies or do they just have different ionization mechanisms operating? Perhaps more importantly, do the extended emission lines tell us anything about the origin of the radio galaxy phenomenon?

Fig. 2 shows a low-resolution, two-dimensional spectrum of P 2158 – 380 taken with the IPCS on La Silla. One thing it tells us immediately is that we are not seeing just a galaxy with an extended distribution of ordinary H II regions, photoionized by young hot stars. The level of excitation is far too high; even the He II λ 4686 line is strong over 10 kpc from the nucleus.

It seemed possible that the gas was being ionized by an intense source of hard ultraviolet radiation which, if it existed, was presumably located at the nucleus. Indeed, the optical continuum consists only of integrated starlight but, then, if the UV spectrum were hard enough, it could easily provide enough ionizing photons without significantly contaminating the optical spectrum. It would be difficult though for it to hide from the IUE satellite.

Objects as faint as this (15.3 mag. in the U band) are quite hard work for the 18 inch telescope of IUE. Nevertheless, in the short-wavelength region we could see that there is a point source of ultraviolet radiation which does indeed radiate enough flux to ionize all the gas we see emitting line radiation further out in the galaxy. It can only

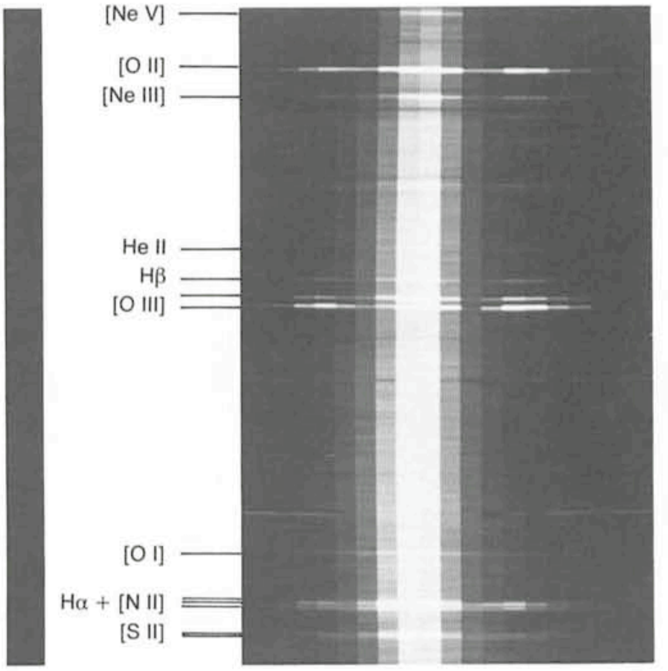

Fig. 2: *A two-dimensional spectrum of the galaxy associated with PKS 2158 – 380 obtained with the IPCS on the 3.6 m telescope on La Silla. This covers the whole optical spectrum from about 3400 – 7000 Å and each horizontal strip covers about 1.6 kpc at the galaxy. This spectrum photographed from a TV-monitor in Geneva, is fully calibrated. That means that the intensity in the picture represents the flux per unit wavelength from the galaxy. The continuum in the centre comes from the stars in the galaxy and several of the stellar absorption lines can be seen. The emission lines come from a region over 30 kpc in extent and the gas is in a high state of ionization throughout.*

do it, however, if a rather special condition on the distribution of the gas is fulfilled. Put simply, this is that a large fraction of the Lyman continuum radiation emitted by the nucleus must be intercepted by gas in the galaxy; but this cannot all happen close to the nucleus; a good fraction of it must be absorbed kiloparsecs away where we still see strong line radiation. This immediately rules out a simple geometry like a thin planar disk of gas which, to the nucleus, would cover only a very small fraction of the sky. It is possible to avoid this problem by assuming that the nucleus does not radiate its UV flux in an isotropic fashion and indeed, it may be that, given the high degree of anisotropy exhibited by the radio emitting material, the higher frequency radiation is beamed in some way.

A way out of this dilemma may be sought by appealing to observations of the dynamical state of the material in the galaxy, both stars and gas, and also, perhaps, by drawing analogies with objects closer to home (PKS 2158 – 380 is at 200 Mpc with $H_o = 50$ km s^{-1} Mpc). High spectro/spatial resolution observations of the [OIII] lines obtained with the IPCS on the AAT reveal the motion of the ionized gas in some detail. The velocity profile along the major axis of the emission line distribution does look rather like a normal galaxy rotation curve, but there are some peculiarities.

The change from positive to negative velocities happens at very small radii; within ± 2 kpc of the nucleus. Also, the emission line profile is broad at all radii with wings extending to over 300 km s^{-1} towards higher $|\Delta v|$. In contrast, the stars do not rotate at all about this axis ($<$ 15 km s^{-1} kpc^{-1}), so their motions are clearly quite decoupled from that of the gas. This lack of coupling strongly suggests that the gas is not native to the elliptical galaxy but has somehow recently been acquired. If the gas has been accreted, either from another galaxy in the small group of which PKS 2158 – 380 is a member, or directly from the intergalactic medium, then it is natural to expect any initially formed gaseous disk to be subject to perturbing forces. These could come either from the non-sperical symmetry of the ellipticals' gravitational potential or simply from the proximity of another galaxy. We propose that there is a rotating gaseous disk in PKS 2158 – 380 but that this disk has been severely warped by some such perturbation. The warp could look something like the photographs of a model shown in Fig. 3 which in turn shows a strong resemblance to deep photographs of the dust lane in the famous radio galaxy Centaurus A (NGC 5128). It can be seen in this picture that radiation from the nucleus can easily shine out to large distances before being absorbed by gas. Also, a good fraction of the nuclear sky can be covered by gas (about 40% in this illustration). Without going into detail, it is clear that the kinematical state of such a structure, deduced from slit spectroscopy, may appear quite complex; we believe that it is possible to interpret our "rotation curve" in this context.

While our interpretation of the observations may not be unique, it does perhaps give some clues about another radio galaxy puzzle. That is the question of the alignment of the radio axis (the line joining the components of the double) with the rotation axis of the galaxy.

Firstly there is the problem of defining this rotation axis when we know that the stars and gas can be decoupled.

Secondly, if we choose the gas as being the relevant component (after all the gas feeds the black hole which makes the radio source), we have the problem of defining the rotation axis of a highly non-planar disk. Our spectroscopic observations will indicate a rotation axis appropriate to the gas at some radius where the emission appears strongest and may tell us nothing about the conditions close to the nucleus. We can only say that in the two objects with extended emission lines which we have studied in detail, this and PKS 0349 – 27, there is no alignment between the radio and the apparent gaseous rotation axis. Although observations of other radio galaxies suggest that such an alignment does usually exist, this topic demands many more observations.

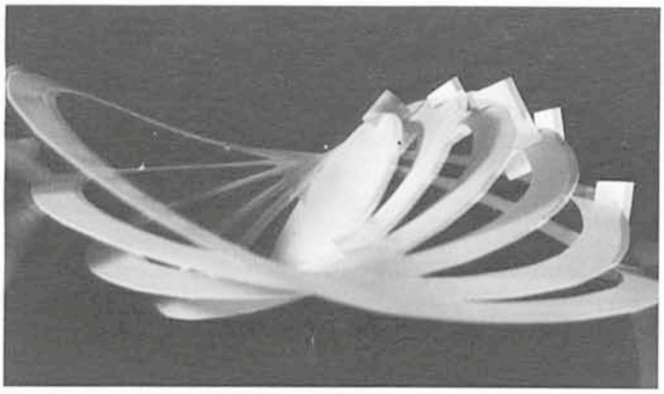

Fig. 3: *A cardboard model of a warped disk which we have used to represent the distribution of gas in PKS 2158 – 380. An important feature of this model is that, viewed from the centre (nucleus), a large fraction of the sky can be covered with gas.*

Our investigations of this galaxy have shown it to be an example of a situation where the dynamical state of the gas must be changing on a time scale which is very short compared to the evolutionary lifetime of the whole system. We believe that this rapid evolution of the gas content may be the cause of the nuclear activity and the extended radio source.

NEWS AND NOTES

The "Centre de Données Stellaires" at Strasbourg

The purpose of this note is to describe the assistance the "Centre de Données Stellaires" (CDS) can provide for either the preparation of an observing programme or for a discussion of results.

Let us state briefly that the "Centre de Données Stellaires" is an institution founded in 1972 by the French astronomical community with the aim of collecting all available stellar data in machine-readable form, in order to facilitate their use. The collection and analysis of the data is made by specialists in each field. Besides the staff of the CDS, several Institutes, namely:

Observatoire de Paris, Meudon
Observatoire de Marseille
Observatoire de Genève et Institut d'Astronomie de Lausanne
Rechen-Institut, Heidelberg
Zentralinstitut für Astrophysik, Potsdam

collaborate closely with the CDS and provide the coverage of certain areas. Furthermore, data exchanges exist with other institutes, like the:

Goddard Space Flight Center, NASA
Astronomical Council of the USSR Academy of Sciences
Computer Center, Kanazawa, Japan.

The data available at the CDS are at the disposal of all interested colleagues all over the world; in the last years the CDS received requests from colleagues of 27 different countries all over the world. The interested reader can learn further details about the CDS in *Vistas in Astronomy,* **21**, 311 (1977) and the CDS Bulletins which appear twice a year.

Let us now consider some of the uses a stellar astronomer can make of the existing data.

First of all, if one is interested in a certain type of data, for instance UBV photometry, one can ask for the latest catalogue in the field. This catalogue can be obtained either on tape or on microfiche (a microfiche has a size of a post-card and contains the equivalent of 200 book pages; it is readable with any magnifying device giving ×35). At this time the CDS has over 200 catalogues on tape and 50 on microfiches; the list of catalogues available is given in the CDS Bulletins.

If on the contrary one is interested only in data for a smaller number of objects, one can proceed differently, namely one can ask for all available data for the stars one is interested in. One gets then a listing containing:

the main identificators (Name, HD, BD)
equatorial coordinates for 1950 and 2000;
galactic coordinates
equatorial proper motion components
MK spectral classification
radial velocity
trigonometric parallax
UBV photometry
Strömgren photometry
UBVRIJKLM
Celescope colour indices
two micron sky survey
V sin i
Hγ
notes about variability and binarity

To complement this information, one can also ask for a listing providing the references to papers published from 1950 on, which refer to or discuss the star. For instance the star α Lyr is mentioned in 343 publications. Less "publicized" stars obviously are not mentioned that often – a "typical" object has about four references. For each paper the full reference and the authors are provided, as also the complete title, which permits to scan rapidly the most interesting papers.

It has been a common experience with the bibliographic service that everyone who uses it discovers that he has overlooked some reference which could have been useful for his own work.

The services mentioned do not cover however one essential aspect needed when one sets up an observing programme, namely to obtain a list of objects of a certain type.

We are also able to provide partial answers to this problem. One can create samples fulfilling certain conditions, like

list all HR objects south of +10° not having a radial velocity.

If one is interested in peculiar objects, one can ask for instance for lists of Ap, Am, Be, CH stars and so on – at present there exist about 30 different classes of peculiar objects. These lists are intended primarily for a first overview to be used together with the bibliographic service mentioned above.

A final point concerns observers of the Schmidt telescope or other large-aperture fields. Finding-charts exist for the Palomar and ESO/SRC Schmidt fields, providing a list of reference stars (which are also plotted on a chart), non-stellar objects and a coordinate grid. These "finding-charts" are provided on microfiche and are well suited for quick identifications.

We hope that this short description may encourage interested colleagues to request our services, or to inquire about more details. If so, please write or telex to the undersigned.

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Astronomical Analysis Software Workshop

A small workshop was held in Geneva on 2 and 3 July 1980 to discuss possible ways of co-ordinating developments in astronomy-related software.

Those attending were: R. Albrecht, Vienna; K. Banse, ESO; A. Bijaoui, CDCA Nice; M. Capaccioli, Padua; P. Crane, ESO; R. Fosbury, Starlink-RGO; U. Frisk, Stockholm; I. King, Berkeley; and F. D. Macchetto, ESA.

A major fraction of those groups involved in large-scale astronomy-related software developments in Europe was represented (I. King attended only as an observer). Broad agreement in several areas was reached. These included:

(a) mechanisms to further communications among and within groups and among individuals on what software they have or are developing;

(b) suggested guidelines for documenting and coding programmes that would increase programming efficiency, useability, and transportability; and

(c) the continuing need for an ad hoc working group which would keep these issues active.

The advantages of software co-ordination and sharing were obvious during the workshop as several participants discovered an interesting programme of another. One participant announced his intention to prepare a magnetic tape with about 500 astronomy-related application programmes. However, the main intent of the workshop was to discuss methods by which a wider community could benefit from co-ordination. To this end, the workshop produced a number of recommendations and conclusions.

The first recommendation was that the IAU Circular on astronomical Image Processing edited by R. Albrecht and M. Capaccioli be produced in a better physical format. Thus it was recommended that the circular have its own distinctive cover including a table of contents and that better methods of reproduction be found. The hope was that this would attract a wider audience and a broader range of contributions. Nevertheless, it was evident that the circular which is distributed free of charge and is not formally refereed would not fulfill all the needs for publication in this field. Therefore, the workshop participants drafted a letter that was sent to the editors of the five major astronomy journals in Europe and the US. This letter asked that these journals give more attention to papers which deal with data-reduction algorithms and computational software.

The second set of recommendations were of a more technical nature. The group endorsed the use of the FITS standard for the exchange of astronomical data (for a description of FITS see the paper by Wells and Greisen in "Imaging Processing in Astronomy" edited by Sedmak, Capaccioli and Allen, 1979, Osservatorio Astronomico di Trieste, or write to F. Middelburg, ESO-Garching). The group recognized the need for a FITS-based standard that extended to catalogue and list types of data. A tape format for the exchange of character data was adopted. This is: (a) 9 track, 800 bpi, unlabelled; (b) ASCII Character set; (c) 80 characters/line; and (d) 50 lines/record. This is essentially a card image format and, although it is not appropriate for very large data sets, it is simple and easy for most normal needs.

A subgroup of the workshop agreed to draw up a set of programming and documentation guidelines which would serve to aid people in developing and using their algorithms. These guidelines will probably be quite similar to those that will be recommended by NASA for the development of Space Telescope related scientific analysis software. The guidelines will be published in the IAU Astronomical Image Processing Circular.

The question of how to entice people to conform to any set of programming guidelines was another major topic of discussion. Clearly anyone who does not want his programmes seen or used by a colleague and who does not need to use his own programmes again 6 months later does not find any inducement to follow anybody else's guidelines. So why would anyone want guidelines? One major reason is that good programming practices help the author as much as anyone. Another benefit of following the simple guidelines will be that programmes of general interest written by others following these guidelines can be easily integrated. This opens up the possibility of sharing to a wide number of people. Perhaps the message from this workshop on following guidelines is: "Try it, you'll like." A corollary is: "So will your colleagues.".

Finally those present at this workshop felt that the success of these few days warranted continued meetings on this topic at roughly 6-month intervals. The group decided to baptize themselves as the "Working Group on Co-ordination of Astronomical Software", but did not consider drawing up any formal "terms of reference" to guide the further deliberations. Thus the future tasks of the Working Group are still to be defined. Suggestions are welcome.

P. Crane

Tentative Time-table of Council Sessions and Committee Meetings

The following dates and locations have been reserved for meetings of the ESO Council and Committees:

November 4	Scientific/Technical Committee, Garching
November 5	Finance Committee, Garching
November 6	Committee of Council, Garching
November 26-27	Council, Garching
December 2-4	Observing Programmes Committee, Garching

Cataclysmic Binaries – From the Point of View of Stellar Evolution

H. Ritter, Max Planck Institute for Physics and Astrophysics, Garching

Cataclysmic Binaries

Cataclysmic variables (CV's) is the common name of a subgroup of eruptive variables consisting of the classical novae, the dwarf novae, the recurrent novae and of the nova-like objects. Since Kraft's pioneering investigation about twenty years ago (Kraft, R. P.: 1973, *Adv. Astron. Astrophys.* **2**, 43) we know that probably all of the CV's are close binaries. However among the roughly 500 CV's known at present, only for about 50 objects has the binary nature been established by observations. Hereafter these objects will be referred to as cataclysmic binaries (CB's). From the histogram of their orbital periods, shown in Fig. 1, it is seen that CB's have extremely short orbital periods, typically only a few hours. Moreover the histogram shows a remarkable gap of orbital periods in the range between about 2 and 3 hours. This gap has been found to be statistically highly significant. Apparently CB's are divided into two subgroups, i. e. into the ultra-short-period CB's (hereafter USPCB's) with orbital periods $P \lesssim 2^h$ and into the longer-period CB's (hereafter LPCB's) with orbital periods $P \gtrsim 3^h$.

From the wealth of observational data gathered during the past twenty years (for details see the excellent review paper by B. Warner: 1976, IAU Symp. No. 73, p. 85) a standard model of CB's has been derived. Accordingly a CB consists of a white dwarf primary in orbit with a low-mass main-sequence secondary which fills its critical Roche volume (Fig. 2). Matter streaming from the secondary through the inner Lagrangian point L_1 falls into an accretion disk around the white dwarf. At the point where the matter coming from L_1 hits the disk a shock front is formed which is usually referred to as the hot spot (Fig. 2). The typical masses involved are roughly 1 $M_\odot$ for the white dwarf whereas the secondary's mass is approximately 0.1 $M_\odot$ times the orbital period in hours. The relation between the secondary's mass and the orbital period is a direct consequence of assuming the secondary to be a main-sequence star.

Are the Secondaries Evolved?

Knowing a CB's orbital period, the mass and the radius of the secondary can easily be computed if it is assumed to be a main-sequence star, i. e. that it is essentially unevolved. On the other hand deriving the secondary's mass and radius from observations without making this

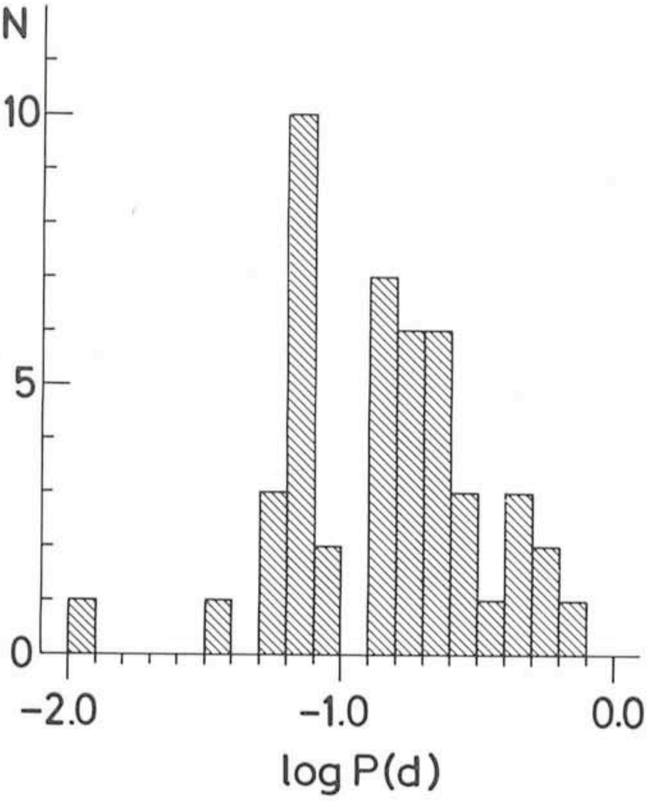


Fig. 1: *Histogram of the orbital periods of known cataclysmic binaries. Note the gap in orbital periods in the range $-1.0 \lesssim \log P$ (d) $\lesssim -0.9$, i. e. $2^h \lesssim P \lesssim 3^h$.*

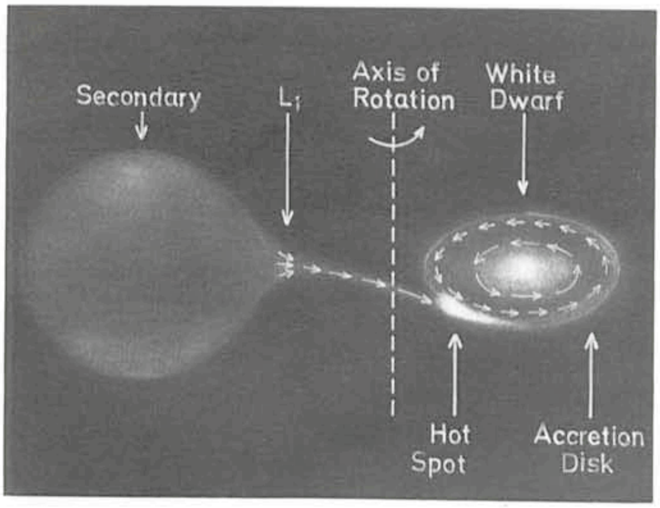


Fig. 2: *Model of a cataclysmic binary.*

assumption is very difficult. Nevertheless, it has been possible to make estimates in a few favourable cases, allowing a check of the main-sequence assumption to be made. For this, the secondary's position in the mass-radius diagram is compared with the theoretical mass-radius relation (M-R relation) of zero-age-main-sequence stars. This is shown in Fig. 3. Despite the considerable uncertainties in the observational data it is obvious that some of these secondaries lie significantly above the theoretical zero-age main sequence (ZAMS). This is usually interpreted as an evolutionary effect. Before starting to discuss whether this interpretation is correct it might be helpful to give first a short description of how CB's could have formed.

The Formation of CB's

In the framework of classical stellar evolution the formation of a massive white dwarf, as observed in CB's requires that the initial binary be a very wide system. This is because the primary needs a certain minimum volume in order to burn out a degenerate core of a given mass. Accordingly a typical progenitor of a CB would be a binary with an initial separation of $\sim 1{,}000\ R_\odot$, a total mass between $\sim 2\ M_\odot$ and $\sim 10\ M_\odot$ and an orbital period of a few years. By comparing the total mass and angular momentum of a typical progenitor with the corresponding values of a typical CB it becomes obvious that the progenitor has to lose almost all of its initial angular momentum and a substantial amount of mass during its evolution towards a CB. (Ritter, H.: 1976, *Monthly Notices Roy. Astron. Soc.*, **175**, 279). How does a binary achieve this? The current idea is that the Roche-overflow from the now red giant primary occurs on a very short time scale which in turn gives rise to the formation of a common envelope around the secondary and the primary's degenerate core. Due to its enormous moment of inertia that common envelope cannot maintain synchronous rotation with the binary inside it. As a consequence the binary transfers angular momentum via turbulent friction to the surrounding envelope. Thereby the binary speeds up faster than the envelope (Kepler's 3rd law!). Obviously such a situation is unstable. It forces the binary to spiral into the envelope by transferring most of its angular momentum to the outer shell in only a few thousand years (Meyer, F., Meyer-Hofmeister, E.: 1979, *Astron. Astrophys.*, **78**, 167).

Although details of how the binary manages to get out of such a desperate situation are not yet known, observations indicate that it does so by blowing off its common envelope. The result is an expanding shell which carries away some mass and almost all of the initial angular momentum. In its centre remains a very close binary consisting of the primary's degenerate core (to become a white dwarf) and of the secondary. To an observer the expanding shell would probably look very much like a Planetary nebula. In fact there are now two Planetary nebulae known (Abell 46 and Abell 63) in which the central stars have already many properties characteristic of CB's. Thus the above picture is strongly supported by observations of these two objects.

The Evolutionary Status of the Secondaries

(a) From a theoretical point of view: Some of the "evolved" secondaries in Fig. 3 are of very low mass, i. e. $M_2 \lesssim 0.5\ M_\odot$. If their present mass is still equal to their initial mass or if they have even accreted some mass during the common envelope phase, then these stars must be unevolved. This is because the evolutionary timescale for stars of such low masses exceeds the age of the universe. If on the other hand a secondary's initial mass was significantly higher than it is now and in addition was not too different from the primary's initial mass, say $1/2\ M_1 \lesssim M_2 \lesssim M_1$, then the secondary has already burnt a significant proportion of the hydrogen in its centre when the common envelope phase starts. Although such a secondary might still be very close to the main sequence before entering that phase, this will no longer be true if a considerable fraction of the star's hydrogen envelope is stripped off during the subsequent evolution. Removing

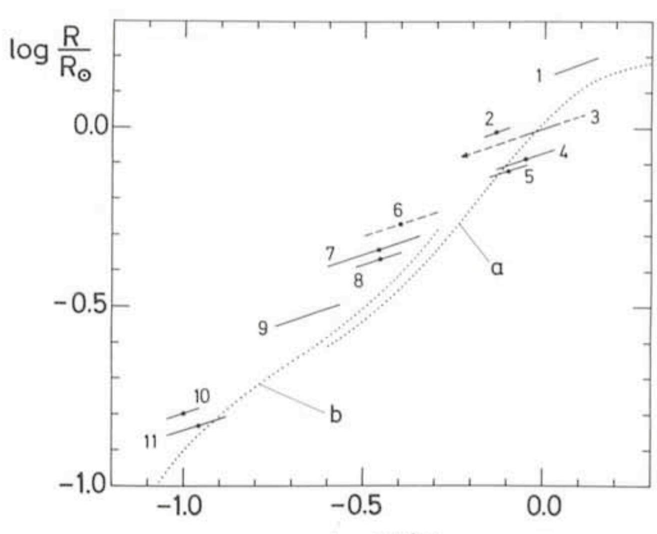


Fig. 3: *Mass-radius diagram of the secondary stars of selected cataclysmic binaries. The numbers refer to the following objects: 1 = BV Cen; 2 = AE Aqr; 3 = RU Peg; 4 = Em Cyg; 5 = SS Cyg; 6 = RW Tri; 7 = DQ Her; 8 = U Gem; 9 = AM Her; 10 = Z Cha, 11 = OY Car. For comparison two theoretical zero-age-main-sequence mass-radius relations are shown: (a) taken from Copeland, H., Jensen, J. O., Jorgensen, H. E.: 1970, Astron. Astrophys.,* **5**, *12; (b) taken from Grossmann, A. S., Hays, D., Graboske, H. C., Jr.: 1974, Astron. Astrophys.,* **30**, 95.

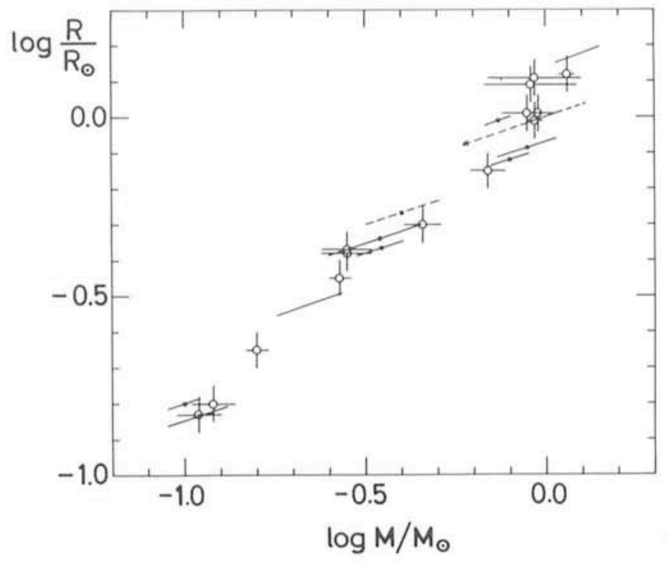


Fig. 4: *Comparison of the mass-radius diagram of the observed low-mass main sequence (open circles, data of visual binaries taken from Lacy, C. H.: 1977, Astrophys. J. Suppl.,* **34**, 479) with the mass-radius diagram of the secondary stars of cataclysmic binaries shown in Fig. 3.

all, or at least a substantial fraction, of the secondary's hydrogen envelope will result in a remnant which is considerably more evolved than a normally evolved star of the same mass and the same age. Depending on the exact chemical structure of such a remnant, the stripped star can stay either well above, or even below the main sequence. Since progenitors having secondaries of initially very low mass are less frequent than systems in which both stars are of comparable mass, the above suggested ablation of the secondary is likely to occur, at least in some cases. Thus a theoretician would not be much surprised if some of the secondaries of CB's were evolved.

(b) From the observer's point of view: In contrast to a theoretician, an observer would not compare the secondaries of CB's with theoretical computations but rather with other observations of stars which are known to be unevolved, e. g. with observations of visual binaries of low mass. The result of such a comparison is shown in Fig. 4. Obviously the secondaries of CB's and the observed low-mass main sequence, as defined by the visual binaries, match within the uncertainties. Thus the conclusion to be drawn from Fig. 4 is that the theoretical low-mass ZAMS is probably wrong rather than that the secondaries of CB's are evolved.

Consequences

As already mentioned above, the secondaries' masses can be determined from the orbital period by using a theoretical main sequence M-R relation. If, as has often been done, a M-R relation which is systematically incorrect is used, the resulting masses are also incorrect. The same holds for the masses of the white dwarfs, if they are derived from the secondaries' masses using an independently determined mass ratio. In fact, taking the observed rather than the theoretical M-R relation yields an interesting result in the case of the USPCB's. In contrast to previous results, it turns out that the corresponding white dwarfs are probably all of low mass, i. e. $M_1 \lesssim 0.5\ M_\odot$. This is interesting with regard to the physical significance of the observed period gap (Fig. 1).

The Period Gap

As just mentioned, the white dwarfs of USPCB's are probably all of low mass. On the other hand no low-mass white dwarfs have been found so far in any of the LPCB's. This gives rise to the speculation that the two subgroups of CB's may be distinguished in such a way that the USPCB's contain only (low-mass) helium white dwarfs ($M \lesssim 0.45\ M_\odot$) while the LPCB's contain only (massive) carbon-oxygen white dwarfs ($M \gtrsim 0.5...0.6\ M_\odot$). Thus the two groups would reflect two different modes of white dwarf formation. The USPCB's would accordingly have been formed in an evolution where the mass exchange started before the onset of the primary's central helium burning. On the other hand LPCB's would be the result of an evolution where mass exchange set in only after the central helium burning but still before the onset of central carbon burning (Ritter, H.: 1976, *Monthly Notices Roy. Astron. Soc.*, **175**, 279). The observed period gap would thus simply reflect the discontinuity in core masses connected with these two possibilities of mass exchange. However, the available observational data do not yet allow a reliable conclusion to be drawn.

Conclusions

The above discussion has shown the importance of reliable observational data of CB's for a better theoretical understanding of the history of these objects. New and better observations particularly aimed at determining the physical parameters of CB's, i. e. their masses and absolute dimensions, are urgently needed. It is with this end in view that the author, in cooperation with Dr. R. Schröder from the Hamburg Observatory, has started an observing programme on CB's. In a first step, two nights at the ESO 3.6 m telescope have been exclusively devoted to spectroscopy of the highly interesting CB Z Cha (see e. g. Ritter, H.: 1980, *Astron. Astrophys.*, **86**, 204). Thereby roughly 140 IDS-spectra have been obtained which are currently in the process of reduction. Results will be presented in a forthcoming communication.

NEWS AND NOTES

Micro-Workshop on Galactic Dynamics

Some members of the ESO Scientific Group and several distinguished guests participated in a "micro"-workshop on galactic dynamics at ESO Geneva, held on 5th and 6th May 1980.

The workshop concentrated on barred galaxies, and began with a lively discussion between Contopoulos and Lynden-Bell on the nature of stellar orbits in bars. They disagreed principally over the dynamical importance of highly elongated orbits in a weak bar. Sellwood presented results of several computer simulations in which bars formed due to instabilities in stellar disks, finding support in his models for some aspects of both theories. Lindblad had studied the response of stellar orbits to growing bars and found that spirals would result near the resonances of the pattern. Athanassoula reported an investigation of the global response of both stars and gas to forcing by a growing bar in which she demonstrated that the stellar component substantially affects the shape of the spiral arms formed in the gas. Kalnajs presented, amongst other things, a report of his students's (Schwarz) study of the role of dissipation in spiral formation in barred galaxies.

We also found time for a few other topics: Martinet was anxious to grapple with the complications of genuinely triaxial stellar systems. Wielen drew attention to the evidence for slow diffusion of stellar orbits which seems to be implied by the velocity dispersion of old stars in the solar neighbourhood.

The meeting was a great success. With fewer than ten participants, each contribution could be discussed quite informally, allowing everyone to gain much deeper understanding than is possible in larger gatherings, and several new ideas emerged for future study. *J. Sellwood*

New Technology Telescope

As an intermediate step towards a very large telescope (VLT), ESO intends to design and to build a New Technology Telescope (NTT) with a mirror of 3.5 m diameter. This telescope will help on the one hand to reduce the demand of the 3.6 m telescope on La Silla and will allow on the other hand to test some of the new ideas for telescope design in practice.

Until fairly recently, a telescope in the 3 to 4 m class was considered as the largest telescope for a big observatory. These telescopes were therefore built as very universal instruments with an important capital investment. It is only within the last few years that the first two telescopes which deviated remarkably from this trend came into operation. These were the Multi-mirror telescope (MMT) on Mount Hopkins and the British 3.8 m Infrared-telescope (UKIRT) in Hawaii. The new approach aims at achieving a large telescope at low cost. The NNT will follow the same approach.

The main guide-lines for large low-cost telescope are:

- minimum weight of primary mirror,
- minimum size of telescope-building,
- minimum number of focal positions.

Working on these guide-lines and from the information gathered at the Conference in Tucson [1] ESO astronomers and engineers defined in clear terms the requirements and the basic concept of the NTT.

From these discussions emerged the three main requirements for a modern telescope:

- high pointing accuracy of 1 arc sec,
- good dome seeing,
- large space inside the control room.

The combination of these requirements including low-cost guide-lines led to the following statements:

1. Alt-azimuth mounting occupies the smallest volume in the building and has the smallest deflections (best pointing accuracy) when compared to an equatorial or alt-alt mounting.

2. Cassegrain focus requires the smallest dome diameter and building volume when compared to a prime, Nasmyth and coudé focus.

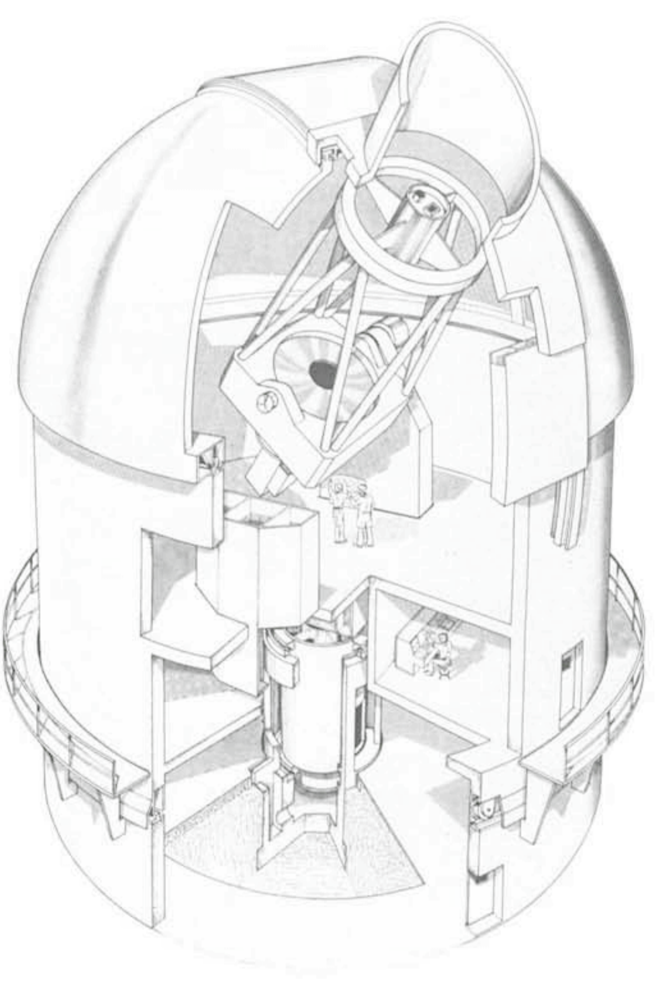
3. Main mirror with f/2.2 focal ratio is fast enough to obtain a small dome diameter and not too fast with respect to the increasing difficulties for the figuring of the mirror.

4. Rotating building increases the useful space inside the building and avoids difficult cable twists.

5. Control room beneath observing floor removes heat production from dome (which gives better seeing) and provides more space for the control room. This location of the control room without a direct view to the telescope is also a first step towards remote operation of the telescope.

Experience of telescope operation on La Silla revealed three facts which have been neglected in the design so far:

- space inside a telescope building is used efficiently only insofar as the work cannot be done elsewhere. It is therefore a bad capital investment to provide more than the barest minimum of space inside the building.
- a high building with a large dome and good climatization has a "dome seeing" which is worse than that of a very small building without heating and climatization.
- instrument changes on a telescope disturb the optical quality of the telescope and produce a considerable loss of observing time due to readjustments which are not properly carried out.



The outcome of the studies so far can be seen in the artist's view. The building has an outside diameter of 14 m and a total height of 20 m. There is no crane inside the building.

Assembly and major maintenance such as mirror aluminizing will be performed with an outside portal crane. No more than two instruments – one for optical observation during the new moon period and one for infrared observation during the full moon period – will be used with the telescope at any one time. It is envisaged however, that these instruments be changed after a year of service. The control room just underneath the observing floor has a surface of 100 m^2.

This description represents a very early stage in the project, and an invitation is extended to all future users of this telescope, and not only those astronomers from member states, to offer comments which will help to obtain the best final design. *W. Richter*

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[1] A. Hewitt: Optical and Infrared Telescopes for the 1990s. Proceedings KPNO-Conference, 7-12 Jan. 1980, Tucson, Arizona.

CO Observations in Galactic Clouds

A. R. Gillespie

During the last few years optical astronomers have been surprised to find radio astronomers using the larger optical telescopes with equipment that they have brought with them. The objects studied are usually molecular clouds and are observed using radio frequency transitions of carbon monoxide. In this article, Dr. A. R. Gillespie from the Max Planck Institute for Radio Astronomy in Bonn gives an outline of the astronomy that is produced as well as some of the results that have come from optical telescopes used in this way.

Introduction

Millimetre-wavelength spectral line astronomy is now one of the major areas of radio astronomy and tells us about the molecular clouds in the interstellar medium. Carbon monoxide (CO)* is one of the most important molecules studied, for reasons given below, and was first detected in the Orion nebula by Wilson et al. in 1970 (*Astrophys. J.*, **161**, L43) at a wavelength of 2.6 mm. Observations of CO, as with all radio-frequency transitions, are made with coherent detectors (heterodyne receivers) rather than the incoherent detectors used in optical and traditional infrared work and the telescope operates with a diffraction-limited beam. Since the radiation must be coherent at the telescope's focus the reflector's surface must be accurate to a small fraction of a wavelength. In the northern hemisphere a few radio telescopes are of sufficiently high quality and these have been used for extensive observations of CO during the last 10 years. Optical telescopes obviously have mirrors that are accurate enough for this work but, because their diameters are much smaller, they have larger beamwidths. In the south, however, only large optical telescopes are available for this work and both the ESO 3.6 m and the Anglo Australian Telescope have been used. The former by groups from the ESTEC division of the European Space Agency and the Max-Planck-Institut für Radioastronomie; the latter was used by a group from Queen Mary College, London. A 4 m radio telescope operated by CSIRO in Sidney, Australia, is now being commissioned and is beginning to produce data, but not yet at the frequencies of the CO lines.

This article will concentrate on the physics that the CO observations tell us and give examples of southern objects as these are probably of most interest to ESO users.

CO in the Interstellar Medium

CO shows the strongest observed line intensity for any molecule except the maser lines (H_2O, OH and SiO). The relevant transitions are those between the lower rotational levels of the molecule and these have frequencies of 115 GHz (J = 1-0), 230 GHz (J = 2-1) and 345 GHz (J = 3-2), etc. corresponding to wavelengths of 2.6, 1.3 and 0.9 mm for CO. The lifetime of the J = 1 level is about 10^7 secs which is much larger than for any other molecule and so with a relatively low excitation rate a large fraction of the molecules will be in this level. The long lifetime does mean that the strong line intensities observed are due to high CO abundances. The high thermal dissociation energy of 10 eV also ensures that the CO itself will be widespread, provided it is shielded from short wavelength radiation and this makes it a tracer of the interstellar medium that compares in importance with the HI observed by its 21 cm line. The necessity for at least a minimal shielding means that the CO emission will be stronger in regions of increased density where the HI is converted into molecular hydrogen and so complementary regions are observed using the two species.

As with all spectral line work, the data are obtained in the form of line shapes and intensities such as the spectrum shown in Fig. 1, usually for several positions in a source; the gas temperature and density in the emitting region must then be calculated from these. The intensity of the line is measured as degrees K of antenna temperature, a unit which comes from low-frequency radio astronomy and refers to the temperature of a source completely filling the telescope's beam. This intensity must then be corrected for atmospheric absorbtion, telescope efficiency and differences between the Rayleigh-Jeans approximation and Planck's law to give the brightness tempera-

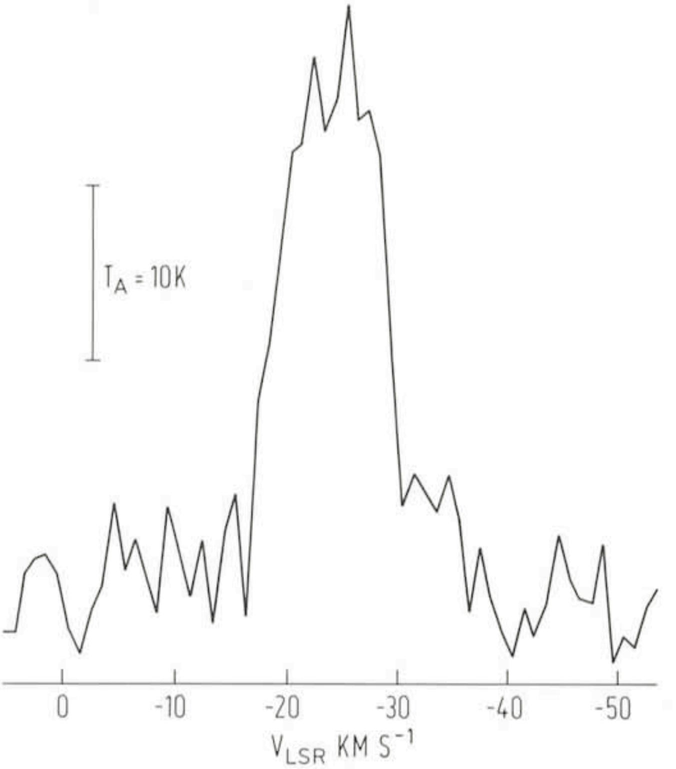

Fig. 1: *A CO (1-0) spectrum taken in the HII region RCW 57 with a velocity resolution of 2.6 cm sec^{-1}. The vertical line shows 10 K antenna temperature, corrected for telescope and atmospheric losses. A CO (2-1) spectrum taken at the same position gives a similar intensity and linewidth.*

* In this article, a widely used convention will be adopted. This is to use CO to refer to the main isotopic form of the molecule, i. e. $^{12}C^{16}O$. Superscripts are then only used to refer to molecules containing other isotopes, e. g. ^{13}CO and $C^{18}O$.

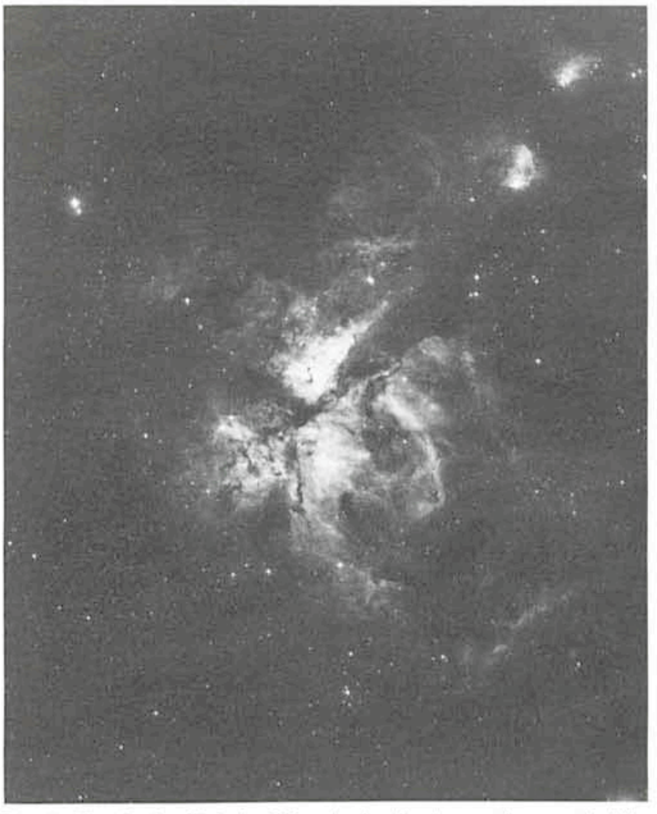

Fig. 2: *The Carina Nebula. CO emission is observed on most of the northern part of this photograph.*

ture (T_B) of the source. If the line is optically thick, and the source intensity is uniform across the telescope beamwidth, T_B is the kinetic temperature of the gas. CO is usually optically thick and gives kinetic temperatures in the range 5° for dark clouds to 70° for molecular clouds associated with HII regions. Since CO is mainly excited by collisions with H_2 molecules these temperatures then refer to the kinetic temperature of the H_2 which is the dominant component of the molecular clouds.

Unfortunately the CO's optical depth is so high that the observed lines are saturated and the CO or H_2 density cannot be calculated directly from these profiles. The density of the H_2 comes from observations of the lines due to the ^{13}CO and $C^{18}O$ isotopic variants which are optically thin and occur at frequencies relatively close to those of CO. The ^{13}CO is probably at the same excitation temperature as the CO and its optical depth can be calculated and then, taking a suitable value for the ratio $^{12}C/^{13}C$, the optical depth and density of the CO can be obtained. From this, the H_2 density can be calculated for particular models, the exact density obtained being dependent on assumptions about local thermodynamic equilibrium, radiation trapping, etc. A crude method of obtaining a mass estimate is to apply the Virial Theorem to the $^{12}C^{16}O$ line widths and neglect systematic internal notions. Clearly the CO data alone are not sufficient and usually the data are combined with those from other molecular lines and parts of the spectrum for a more detailed analysis.

Molecular Clouds

CO is so widespread that surveys have been made along the Galactic plane, showing weak emission with a similar distribution to the HII regions, but we shall restrict attention to particular molecular clouds rather than discuss the large-scale distribution of CO in our Galaxy and observations in external galaxies.

The molecular cloud associated with the Orion nebula region is one of the most extensively studied regions in the sky. CO observations have shown that there is a hot dense region associated with the Kleinmann-Low Nebula in the form of a ridge about 4′ by 9′ with a peak T_A^* of 70 K and a line width of 6 km sec^{-1}. Spectra taken at the centre of this ridge show a wider line width of 40 km s^{-1}, the plateau feature, from CO which may be optically thin and is due to very small turbulent clouds confined to an area less than 30 arc seconds diameter. There is, however, weaker CO emission extending over an area about 9° by 2° (63 pc by 14 pc) and comes from a giant molecular cloud located behind the optical nebula. The nebula is then due to recent star formation near the edge of the cloud (see, for example, Kutner et al. (*Astrophys. J.*, **215**, 521)). The spatial resolution of most observations is of the order of 1 arc minute and it is difficult to make maps of such large areas with complete angular sampling. When a smaller area is fully mapped, considerable structure is found (e.g. Gillespie and White, *Astron. Astrophys.* in press) and this can be interpreted as due to other sites of star formation or the effects of ionization/shock fronts moving through the cloud.

The Carina nebula shown in Fig. 2 is one of the brightest visible HII regions and is only accessible for observations from southern telescopes. The limited amount of CO data available shows that the CO covers an area at least 50 × 25 pc and is mainly related to the dust in the northern part of the nebula, although there is a hot-spot at the position of a radio continuum source associated with one of the regions of ionized gas. This area offers the possibility of detailed studies of the interaction of CO with dust and ionized gas when suitable facilities are available in the south.

One of the largest CO clouds in the southern sky is associated with the radio source complex G333.3 – 0.4. There are about seven radio peaks in an area 70′ by 15′, six of which lie in a line parallel with the Galactic plane. CO emission covers the whole area and the gas has considerable spatial structure and systematic velocity variations (see Fig. 3). The velocity of the CO puts the source at a distance of 4.2 kpc, well behind a visible region of HII emission (RCW 106) near G332.8 – 0.6, and the molecular cloud is about 100 pc by 35 pc. The radio and infrared data suggest that this cloud has several well developed HII regions in it.

In addition to the CO associated with the giant molecular clouds there are smaller dark regions of emission near HII regions such as that near RCW 38 shown in Fig. 4 and very small ones in dark clouds. Northern dark clouds from the Lynds catalogue have been studied by Dickman (1975, *Astrophys. J.*, **202**, 50) and a smaller globule by Martin and Barrett (1978, *Astrophys. J. Suppl.*, **36**, 1). CO emission was detected wherever dust was observed, even a small amount of dust being sufficient to protect the CO against photodissociation, and gave a kinetic temperature of 10 K for all positions in most of the clouds, and a total gas density of 10^4 cm^{-3}. The line widths and shapes of the profiles show that the clouds are gravitationally bound, but with internal motions, usually due to gravitational collapse and sometimes cloud rotation. In the southern sky the Coalsack is the most well known dark cloud complex and one of the globules in it has been ob-

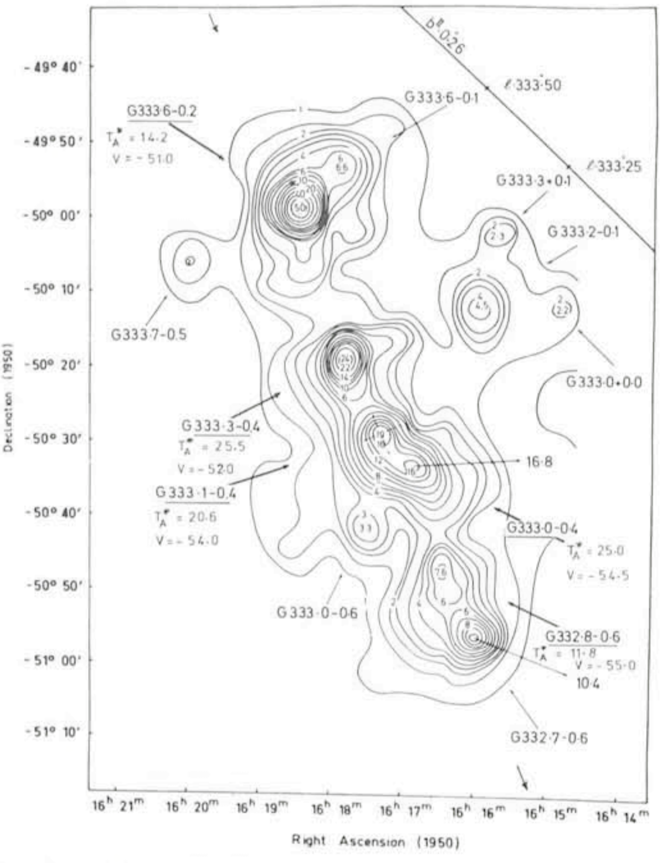

Fig. 3(a): *A radio continuum map of the G331.1 – 0.4 region with CO information added (taken from Gillespie et al 1977,* Astron. & Astrophys., **60**, *221).*

served and was found to be a typical example, with a mass of a few solar masses and a size of about 0.6 pc.

Future Observations

The above discussions have not elaborated on observations of several transitions of carbon monoxide which are now possible and becoming very important. All the CO observations made at La Silla, for example, were of

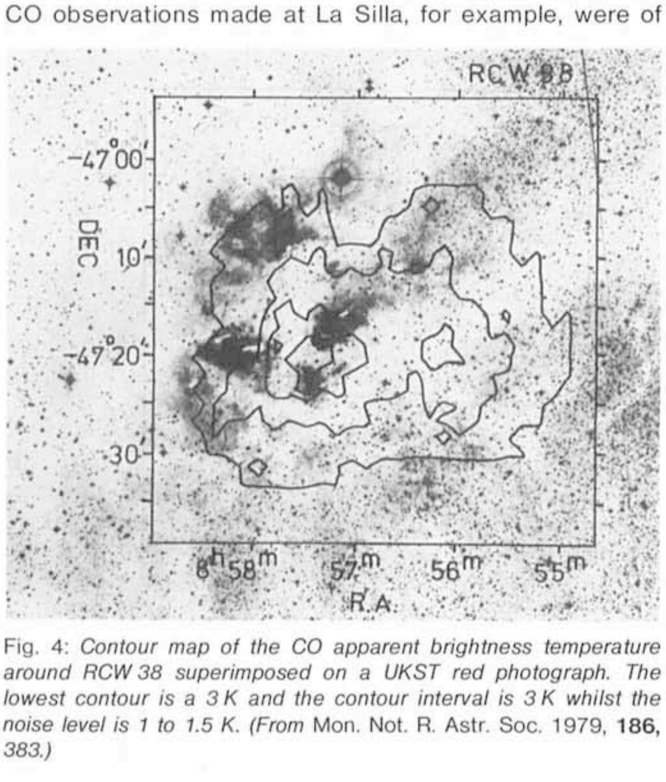

Fig. 4: *Contour map of the CO apparent brightness temperature around RCW 38 superimposed on a UKST red photograph. The lowest contour is a 3 K and the contour interval is 3 K whilst the noise level is 1 to 1.5 K. (From* Mon. Not. R. Astr. Soc. 1979, **186**, *383.)*

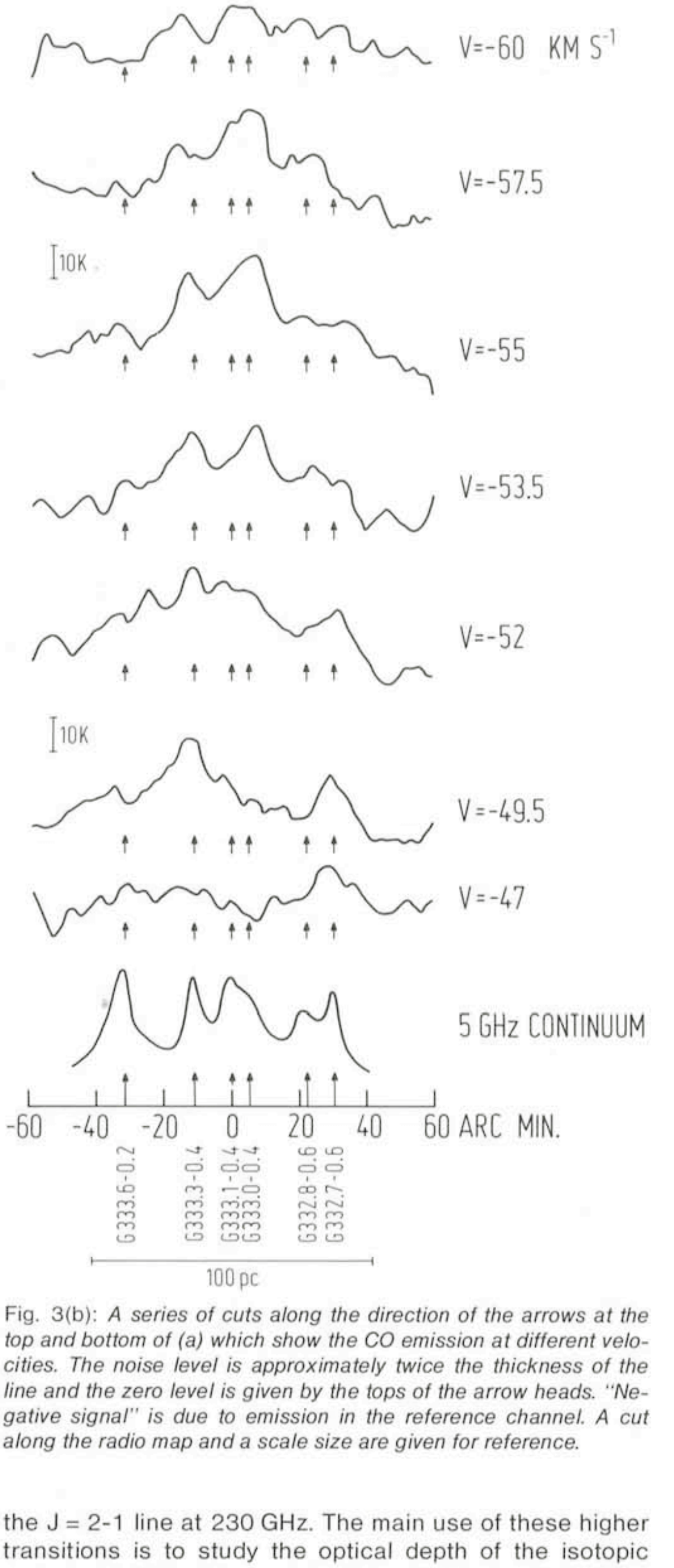

Fig. 3(b): *A series of cuts along the direction of the arrows at the top and bottom of (a) which show the CO emission at different velocities. The noise level is approximately twice the thickness of the line and the zero level is given by the tops of the arrow heads. "Negative signal" is due to emission in the reference channel. A cut along the radio map and a scale size are given for reference.*

the J = 2-1 line at 230 GHz. The main use of these higher transitions is to study the optical depth of the isotopic variants of CO and hence obtain more accurate values for the density of the molecular hydrogen and the masses of the molecular clouds. At the moment only a few northern radio telescopes are suitable for observations of the J = 2-1 transitions and one for the J = 3-2 transitions, which means that radio astronomers will be using optical and infrared telescopes for these observations until suitable radio telescopes are built. Because of this and an increasing awareness of the southern sky, radio astronomers are beginning to find themselves in the position of taking portable receivers to suitable telescopes in order to work in this rapidly expanding and exciting field.

Visiting Astronomers

(October 1, 1980 – April 1, 1981)

Observing time has now been allocated for period 26 (October 1, 1980 to April 1, 1981). As usual, the demand for telescope time was much greater than the time actually available.

The following list gives the names of the visiting astronomers, by telescope and in chronological order. The complete list, with dates, equipment and programme titles, is available from ESO/Garching.

3.6 m Telescope

Oct. 1980: D'Odorico, Swings/Surdej/Osmer, Tarenghi/Crane/Ellis/Kibblewhite/Peterson/Malin, Valentijn, Wlérick/Bouchet, Lequeux/West/Schuster/Laustsen, Lindblad/Athanassoula/Jörsäter, Thé/Alcaino, Alcaino, Moorwood/Salinari/Shaver, Danks/Wamsteker, Fricke/Kollatschny/Schleicher.

Nov. 1980: Fricke/Kollatschny/Schleicher, Pakull/Zuiderwijk, Westerlund/Lundgren/Richer, Lindblad/Athanassoula/Jörsäter, Möllenhoff, Westerlund/Lundgren/Richer, Thé/Alcaino, Alcaino, Dennefeld, Andrillat/Vreux, Andrillat/Swings, Campusano/Gilmore.

Dec. 1980: Campusano/Gilmore, Ardeberg/Linde/Lindgren/Lyngå, Eichendorf, de Ruiter/Lub, Hunger/Kudritzki/Simon/Méndez, Frandsen/Thomsen/West, Danziger, Kunth, Ardeberg/Linde/ Lindgren/Lyngå, Lépine/Abraham/Epchtein/Guibert, Seitter/Duerbeck.

Jan. 1981: Seitter/Duerbeck, Koester/Weidemann, Koester/Reimers, Shaver, Vigroux/Comte/Lequeux/Stasinska, Pettersson, Glass, Bensammar, Danziger/de Ruiter/Kunth/Lub/Griffith.

Feb. 1981: Danziger/de Ruiter/Kunth/Lub/Griffith, Péquignot/Ulrich, Ulrich, Chevalier/Ilovaisky/Motch, Nissen, Sibille/Léna/Perrier, Bensammar, Epchtein/Guibert/Q-Rieu/Turon/Lépine, Combes/Encrenaz/Vapillon/Berezné/Zeau/Arfouillaud, Miley/Heckmann.

March 1981: Miley/Heckmann, Melnick/Terlevich, Chevalier/Ilovaisky/Motch, Querci/Fort/Fauconnier/Lamy, van Paradijs/Hammerschlag-H./de Loore/v. Dessel, Moorwood/Salinari, Tanzi/Tarenghi, Sibille/Léna/Perrier, van Paradijs/Hammerschlag-H./de Loore/v. Dessel, Bergeron/Kunth.

1.52 m Spectrographic Telescope

Oct. 1980: Melnick/Quintana, Neckel, Ahlin/Sundman, Bouchet, Ardeberg/Gustafsson, Koornneef/Danks.

Nov. 1980: Koornneef/Danks, Fricke/Kollatschny/Schleicher, Danks/Dennefeld, Lachièze-Rey/Vigroux, Alloin/Jones B. & J., Condal, Houziaux/Nandy, Schoembs/Stolz.

Dec. 1980: Schoembs/Stolz, Hunger/Kudritzki/Simon/Méndez, Fehrenbach, de Vries, Appenzeller/Bertout/Wolf/Isobe/Walker.

Jan. 1981: Appenzeller/Bertout/Wolf/Isobe/Walker, Koornneef/Danks, Appenzeller/Wolf/Sterken, Spite, F. & M., Reimers, Barbier/Remijn/Thé, Ardeberg/Maurice, Koornneef/Maurice.

Feb. 1981: Koornneef/Maurice, Deharveng/Tenorio-Tagle, Ilovaisky/Chevalier, Andersen, Ardeberg/Maurice, Ferlet/Bouchet, Ilovaisky/Chevalier.

March 1981: Ilovaisky/Chevalier, Véron, M. P./Collin-Souffrin, Véron, P., Benvenuti, Simon/Kudritzki, Ahlin/Sundman, Ferlet/Bouchet, Gahm, de Loore/Burger/van den Heuvel/van Paradijs.

1 m Photometric Telescope

Oct. 1980: Azzopardi/Vigneau/Lequeux/Maeder, Wlérick/Bouchet, Thé/Alcaino, FitzGerald/Harris/Reed, Koornneef, Schmidt/Engels/Schultz, Bouchet, Chincarini.

Nov. 1980: Chincarini, Westerlund/Lundgren, Wlérick/Bouchet, Koornneef, Fridlund/Nordh/Olofsson, Sol.

Dec. 1980: Sol, Schoembs/Stolz, Schnur/Mattila, van Woerden/Danks, Bouchet, Groote/Kaufmann, Koester/Weidemann.

Jan. 1981: Koester/Weidemann, Wlérick/Bouchet, Pettersson, Geyer/Hänel/Nelles, Barbier/Remijn/Thé, Reipurth, FitzGerald/Harris/Reed, Dubois/Philip.

Feb. 1981: Dubois/Philip, Bastien, Bouchet, Epchtein/Guibert/Q-Rieu/Turon/Lépine, Ap-Workgroup, Melnick/Terlevich.

March 1981: Melnick/Terlevich, Ardeberg/Maurice, Véron, M. P., Gahm, Moorwood/Salinari, Mauder.

50 cm ESO Photometric Telescope

Oct. 1980: Surdej, A. & J, Ardeberg/Gustafsson Bouchet.

Nov. 1980: Bouchet, Lundin, Divan/Zorec.

Dec. 1980: Divan/Zorec, Schnur/Matilla, Bouchet, Barbier/Remijn/Thé, Wramdemark.

Jan. 1981: Wramdemark, Ap-Workgroup, Dubois/Philip, Bouchet.

Feb. 1981: Bouchet, Ardeberg/Gustafsson, Gieren, Ap-Workgroup.

March 1981: Ap-Workgroup, Debehogne, Drechsel/Rahe.

GPO 40 cm Astrograph

Oct. 1980: Azzopardi/Vignean/Lequeux/Maeder.

Nov. 1980: FitzGerald/Harris/Reed, Gieseking, Burnage.

Dec. 1980: Burnage, Büscher/Samson.

Jan. 1981: Büscher/Samson, Gieseking, Reipurth, FitzGerald/Harris/Reed.

Feb. 1981: FitzGerald/Harris/Reed, Gieseking, Schmidt-Kaler/Tüg, Debehogne.

March 1981: Debehogne, Mauder

1.5 m Danish Telescope

Nov. 1980: Strömgren/Ardeberg, Nieto, Schoembs/Stolz.

Dec. 1980: Schoembs/Stolz, Weigelt, Grosbøl, Valentijn/Pedersen, Grosbøl, Sterken.

Jan. 1981: Imbert/Prévot.

Feb. 1981: Imbert/Prévot, Nordström/Andersen, Ardeberg, Véron, P., Röser/Hawkins.

March 1981: Röser/Hawkins, Schnur, Schnur/Pedersen, Tarenghi.

50 m Danish Telescope

Nov. 1980: Ardeberg/Gustafsson.

Dec. 1980: Ardeberg/Gustafsson, Renson/Manfroid.

March 1981: Strömgren/Ardeberg, Ardeberg/Gustafsson.

90 cm Dutch Telescope

Oct. 1980: Kudritzki/Lub, Pakull/Zuiderwijk.

Nov. 1980: Greve/v. Genderen.

Dec. 1980: Greve/v. Genderen, de Ruiter/Lub.

Jan. 1981: Barbier/Remijn/Thé, Koornneef/Lub.

Feb. 1981: Koornneef/Lub, Pel.

March 1981: Darius/Barbier.

61 cm Bochum Telescope

Dec. 1980: FitzGerald/Harris/Reed.

Jan. 1981: FitzGerald/Harris/Reed, Celnik, Schober/Kristensen/Møller.

Feb. 1981: Schober/Kristensen/Møller.

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Smaller Galaxies

H. Arp

Dr. Halton Arp from Mt. Wilson and Las Campanas Observatory has spent a few months with the ESO Scientific Group in Geneva. He is well known for his unconventional ideas about the origin of the redshift of quasars; however, surprisingly, he has chosen to write on a "harmless" subject: dwarf galaxies.

A great deal of attention is given to giant galaxies in astronomy. These galaxies can be seen at the greatest distances in the Universe, they contain the largest masses of stars and some are in a stage of exploding outwards huge amounts of radio and luminous material. But around every giant galaxy there are usually smaller galaxies, and not so much attention has been paid to this class of galaxies.

Why are they important? First of all they must tell us something about how galaxies were created. The most obvious hypothesis is that when the large galaxies were formed there were parts of the condensing clouds left over which cooled into smaller, satellite galaxies much like planets around the sun. Quiescent, dwarf systems comprised of older stars like the companions around M31 (such as M32, NGC205, NGC185 and NGC147), would be possible examples of these kinds of primeval, residual condensations. Surprisingly, however, many companions are not quiescent at all, but have disturbed distorted shapes, and spectra that show emission lines and early stellar populations. The next large spiral that we encounter after our local group, M81, has two such companions. On one side of M81 is the irregular shaped, disturbed dwarf NGC3077. On the other side of M81 is the famous M82 with emission filaments radiating out along its minor axis from its nucleus. (An interesting note on M82 is that after the discovery of Lynds and Sandage of the filament system and redshift differences it was considered a prototype exploding galaxy. Then arguments by Morrison and Solinger about polarization convinced many astronomers that M82 was merely drifting through a cloud of dust. Now spectroscopic line splitting discovered in the filaments by the Isaac Newton telescope at Herstmonceux has revived the explosion interpretation.)

Most recently a systematic study of companion galaxies around dominant central galaxies has shown that these smaller galaxies are generally much more active than the larger galaxies. A three years spectroscopic study by Arp with the 100 inch reflector on Las Campanas has been reduced with the computer processing facilities at ESO. Those results show, among other things, that 65% of the small physical companions have emission lines. The existence of excited gas in these systems is supported by the generally disturbed shapes of these companion galaxies. An example is shown here in Fig. 1, drawn from this larger study, in which the companion galaxy is very much in the shape of an exclamation mark!

The meaning of all this is not very clear at the moment. The observations will undoubtedly be a challenge for theorists for many years to come. For example, one way present theory could be extended is to start with a cloud of companions all formed at the same epoch as the main galaxy. From time to time a companion could fall into a parabolic, near encounter with the main galaxy. The situation would be analogous to the cometary cloud around the sun which Oort postulated as supplying comets for the solar system. As the companion came near the main galaxy the gravitational perturbation could trigger star formation which would excite gaseous emission lines. Such encounters might distort the galaxies very much like those well-known computer models constructed by Alan and Juri Toomre and therefore account for the disturbed morphology of many of the companions. Also in the passage of the companion by the main galaxy material might be accreted onto the companion causing new star formation. Finally some companions might be slowed enough to be cannibalized by the main galaxy as Lynden-Bell has suggested might be happening with the Magellanic Clouds and our own Galaxy.

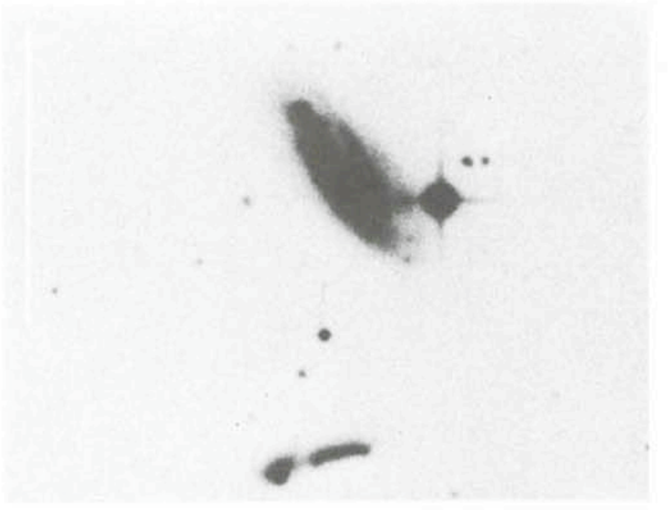

Fig. 1: *U. K. Schmidt photograph of galaxy at $00^h36^m55^s$-43°22' (1950). Companion to west of main galaxy is in shape of exclamation mark!*

Always there seem to be obstacles, however, in the most obvious interpretations. Here it is the fact that there seems to be no obvious cloud of quiescent companions around the main galaxy. That is, most of the companions seem to be presently in an active phase. Fig. 2 shows

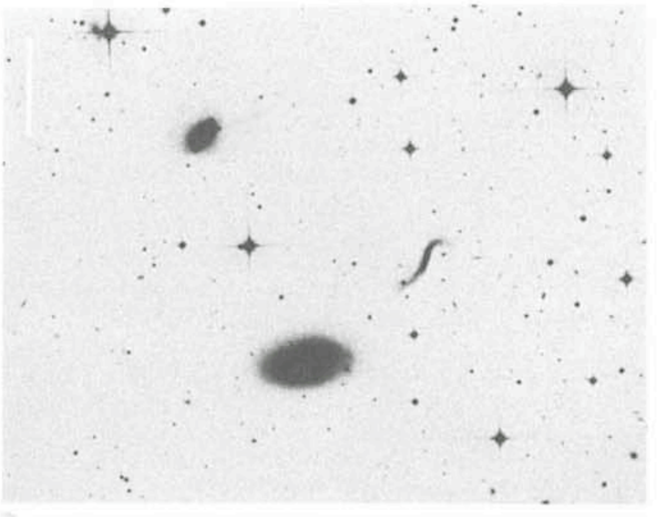

Fig. 2: *U. K. Schmidt photograph of NGC 434 with integral sign companion and companion NGC 440 to the east which has a faint jet emerging from it.*

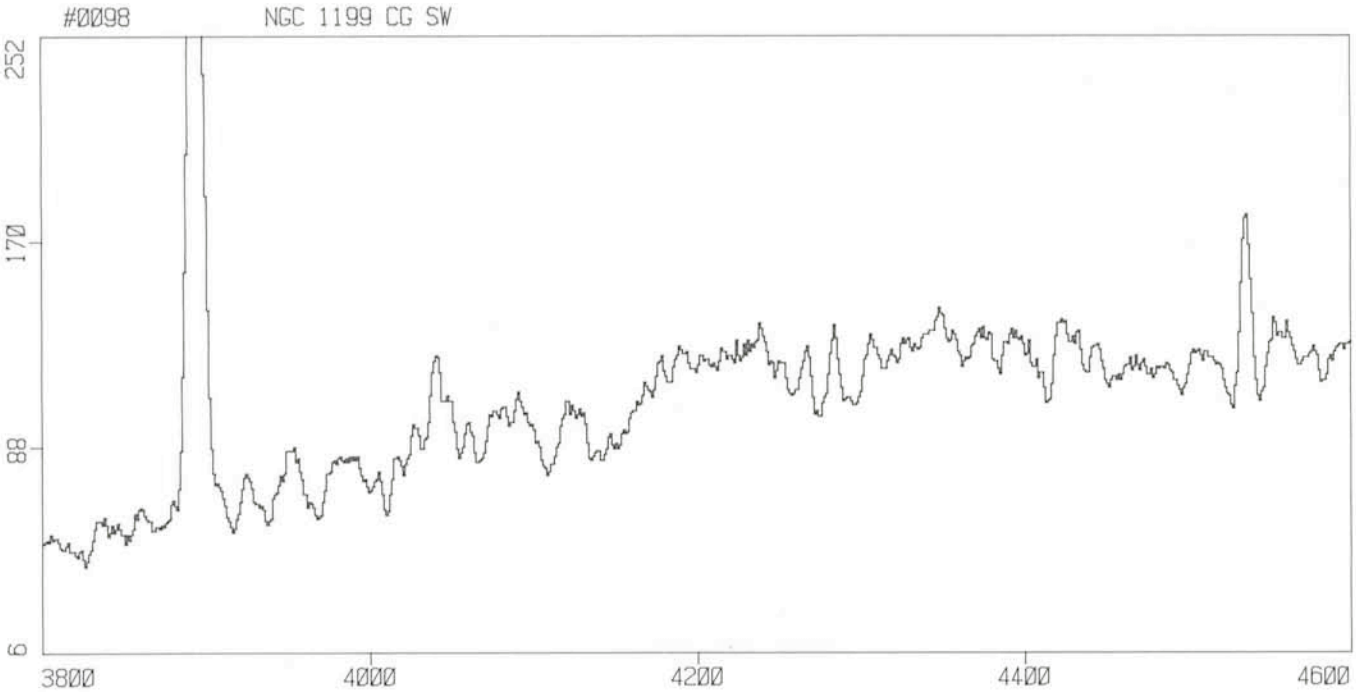

Fig. 3: *Spectrum of compact galaxy southwest of NGC 1199. This is a new spectrum taken with Shectman reticon detector on Las Campanas 100 inch reflector and shows strong O II emission at left end of spectrum plus the whole series of Balmer absorption lines down to H kappa.*

here one companion in an integral size shape and another with a faint jet emerging from it. Could they originate from within the large central body as fission or ejection products? Ambarzumian and Arp have pointed in the past to cases where luminous matter seems to be emerging from the centres of active galaxies.

The answers could come from the velocities of the smaller galaxies relative to the large central galaxies. Unfortunately at this time the answer there is also ambiguous. Many companions have small differential velocities as if they were in bound orbits around their central galaxies. But many others have velocities which are large and indicate the companions are escaping away from the gravitational neighbourhood of the central galaxy. To confuse matters further there seems to be a strong excess of positive redshift residuals for the companion which calls into question the usual interpretation of all the redshift as velocity.

So it seems these smaller galaxies are intimately connected with the origin of galaxies and many even have something to say about how galaxies evolve and even perhaps whether the physical laws operating at different times and distances in the universe are always the same.

But the smaller galaxies raise one final interesting question: Namely, is there any such thing as an isolated field galaxy? A spectrum is shown here in Fig. 3 of a nearly stellar appearing object in the outskirts of the large elliptical NGC1199. This object has a very peculiar spectrum, as is typical of the companion galaxies observed in the recent Arp study. The spectrum has strong emission lines and early stellar-type absorption lines which can be seen all the way down to H kappa! This turns out to be characteristic of galaxies which are companions to larger galaxies. Its redshift is considerably larger than the E galaxy it seems to be involved with (Arp, 1978) but if it is a background galaxy accidentally projected near the larger galaxy, does that mean it is all alone, isolated in empty space at a greater distance?

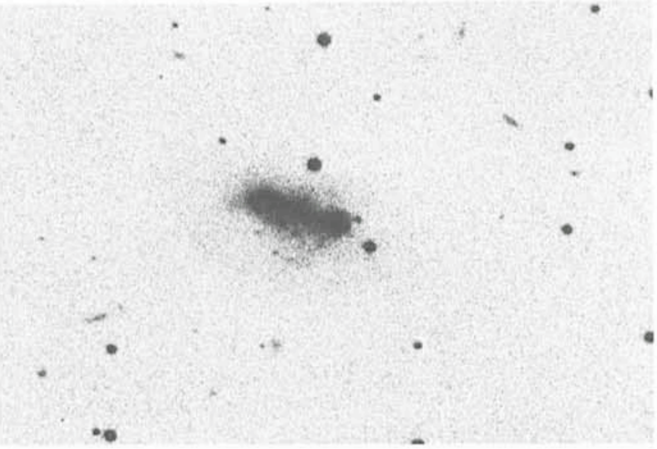

Fig. 4: *Photograph of small galaxy at $20^h33^m28^s$-50°18' (1950) with Las Campanas 100 inch reflector on 124-01 plate with no filter.*

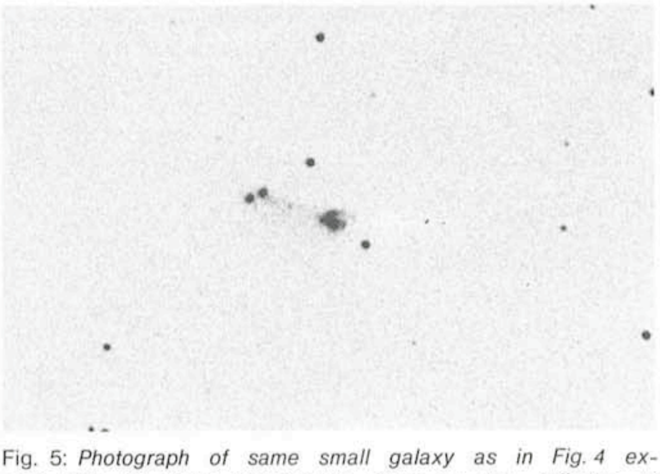

Fig. 5: *Photograph of same small galaxy as in Fig. 4 except with H alpha interference filter on 4 m reflector at CTIO. Since pictures are printed to same scale, the composition of the two end bulges can be seen as nearly stellar emission regions connected by a thin filament.*

Matter in the universe seems to occur in the aggregates of galaxies, clusters of galaxies and clusters of clusters. It seems strange to consider very peculiar objects sitting isolated away from everything else. Where did they come from?

An example of such a curious object at lower redshift, and thus presumably closer in space to us is shown in Fig. 4. What looks on the U. K. Schmidt prints to be three small lumps in a row, turns out spectroscopically to have spectra of high-excitation emission lines on each end of the line. A photograph through an interference filter in Fig. 5 shows that in the emission line of H alpha the image is comprised of only a double, stellar H II region on one end and a partially double H II region on the other end. The redshift of this object is around z = 2,600 km/sec. Is this a very small collection of H II regions isolated in space at about 2 1/2 times the distance of the Virgo cluster? Or are there other systems at the same distance which we have not discovered yet? Or is it associated in space with other systems more nearby to our own local group of galaxies?

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Why Aren't All Galaxies Barred?

J. Sellwood, ESO

We may be accustomed to believing that most problems confronting us in astronomy involve difficult and exotic physics. In this article, I would like to draw attention to a problem, as yet unsolved, posed by some of the simplest laws of physics known, viz: Newton's law of gravity and his laws of motion. To take a familiar example, we know that these laws give a pretty good description of the motion of the planets on their orbits about the sun; even though Einstein's refinements were required to account for some very minor discrepancies.

We also believe that the gravitational attraction of a galaxy will determine the orbits of the stars of that galaxy about its centre exactly as predicted by Newton's laws. But, surprisingly, it has turned out to be remarkably difficult to show how this can be true.

In some respects, the so-called disk galaxies (which include all spiral galaxies) resemble enormously scaled-up versions of the solar system. The name "disk galaxy" implies that the systems are highly flattened (see Fig. 1) and it has been known for many years that they rotate quite rapidly. We can measure the average speed of rotation of the stars and gas (the gas is actually much easier to measure); a typical "rotation curve" is sketched in Fig. 2. This figure shows that, moving outwards from the centre, the speed of the stars increases steadily at first but after a while remains fairly constant over a wide range of distances from the centre. This means that the galaxy is rotating differentially, since the stars near the centre take less time to complete one orbit about the centre than those further out. The typical average in the outer parts is 250 km/s, but even at this high speed a star's orbit takes somewhere between 50 and 500 million years.

The density of stars is highest in the bright bulge at the centre of all disk galaxies, clearly illustrated in Fig. 1.

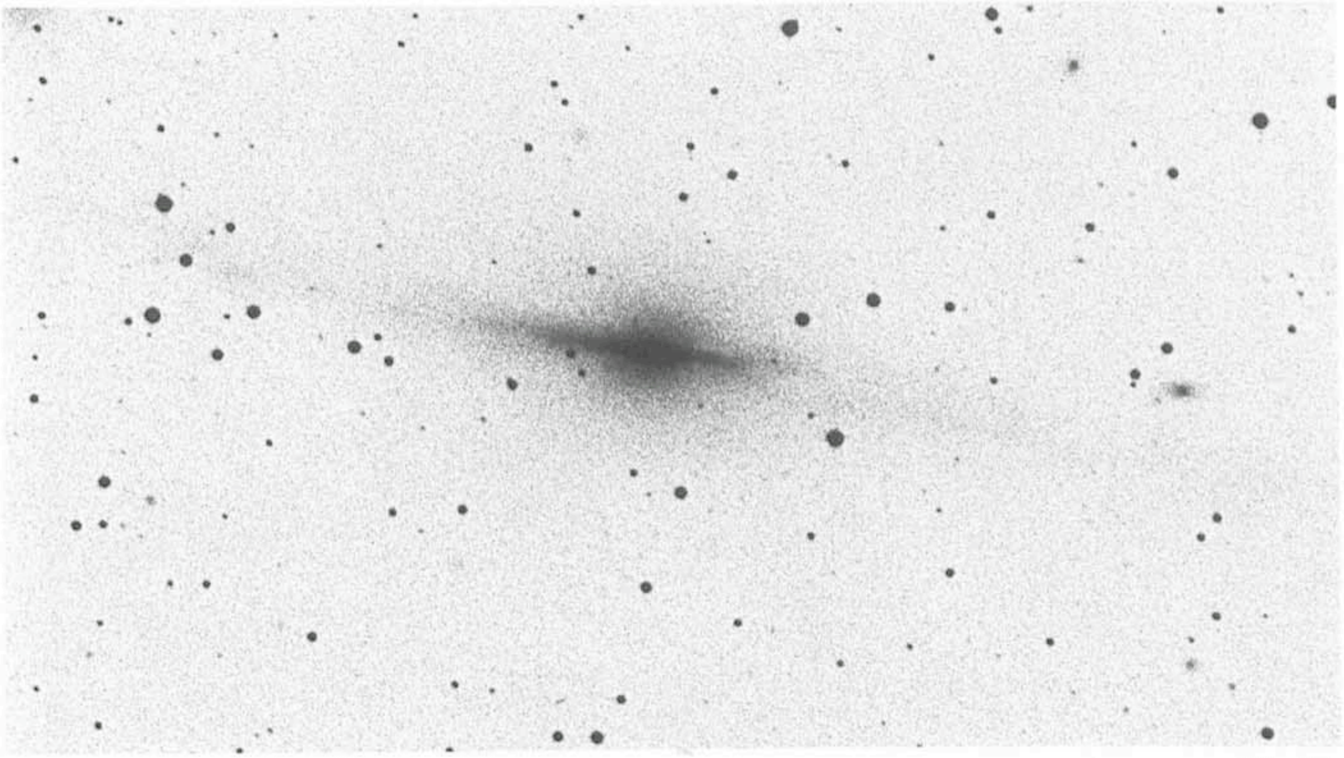

Fig. 1: *A negative print of the galaxy NGC 5084 taken during the sky survey on the ESO 1 m Schmidt telescope. This galaxy is very nearly "edge-on" and we can clearly see both the very flat disk and the central bulge.*

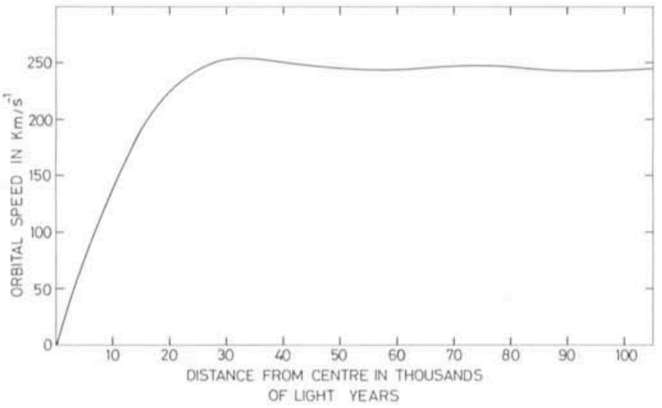

Fig. 2: *Sketch showing a typical rotation curve for a disk galaxy. The basic characteristics of a gentle rise and an extensive flat part are found for nearly all spiral galaxies.*

Here stars are found to be moving more or less at random, with little organized rotational motion.

In the case of the solar system, the sun is so much more massive than all the planets put together, that the orbit of each planet is dominated by the attraction of the sun, the attraction of the other planets being very weak in comparison. The situation in galaxies differs fundamentally from this, in that there is no single superstar dominating the gravitational field. The mass is divided fairly evenly amongst the one hundred billion stars that make up a typical galaxy. With so many stars in the system, the attraction of the few nearest neighbours is insignificant and the force on each star is still directed largely towards the dense concentration of stars at the centre. But prominent features such as spiral arms or a bar, apparent in most disk galaxies, contain enough stars to deflect the central attraction by an appreciable amount.

It is this aspect which makes calculation of the orbits of stars in a galaxy so much more complicated than those of the planets in the solar system, even though the relevant laws of physics are identical. One way, although not the only way, to study the behaviour of such galaxies, is to programme a computer to calculate how a given configuration of stars would develop over a long period of time. This is the approach I have followed at ESO using the CERN computers. Large, fast computers are essential, since we wish to calculate the force on each star caused by the attraction of all the others many hundreds of times. There are many short cuts and approximations which help to shorten the calculation, but such computations are still among the longest required in astronomy.

The calculation begins from a situation intended to be typical of the arrangement of stars in a disk galaxy, as illustrated in the first picture of Fig. 3. Here you can see a disk of stars viewed "face-on" in which all stars are moving in an anti-clockwise direction just fast enough to put them on nearly circular orbits. I have left out of the picture a second component of the computer model which represents the central bulge. This unseen component contains 25% of the total mass and is not rotating.

The other pictures in Fig. 3 show snapshots of the computed distribution of stars at later times, which are given in millions of years. These show clearly that the model galaxy develops a bar in a little over one billion years. This time is comparatively short on the astronomical scale, and in fact a star about halfway out in the disk of the computer model will have completed only four orbits about the centre during the entire calculation. We know that many non-barred galaxies in the sky are much older than this, so obviously they must differ from the computer model in some respect. The crux of the problem is: how can roughly half of all disk galaxies survive without forming a bar?

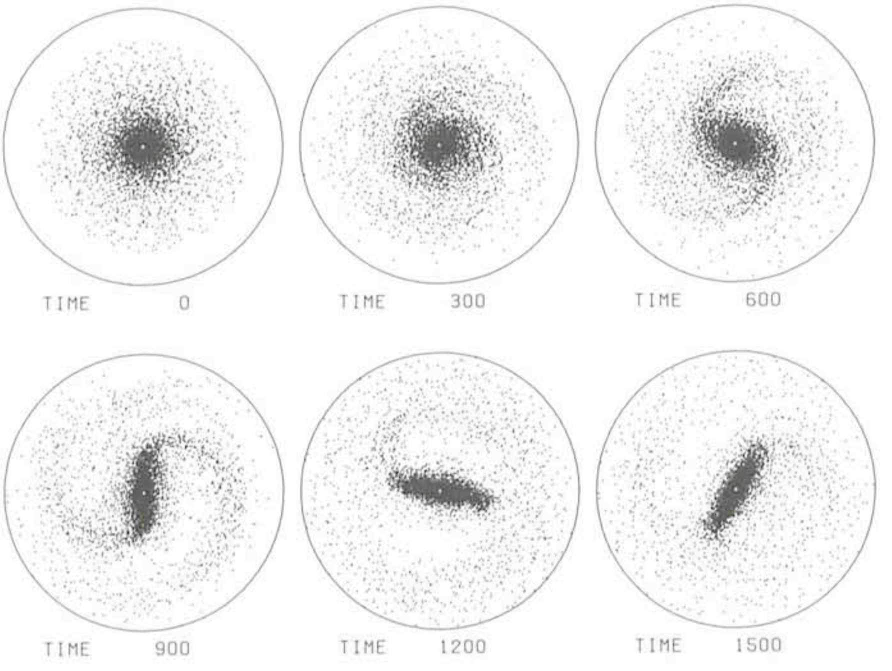

Fig. 3: *These pictures show how a computer model of a disk galaxy evolves. The arrangement of stars in the disk is viewed "face-on" in every case and the times are given in millions of years from the start of the run. The computer clearly predicts that this model galaxy will form a bar in a comparatively short time.*

Although the initial disk of stars in Fig. 3 was in equilibrium, the equilibrium is about as unstable as a pencil balanced on its point. Just as a tiny disturbance will cause the pencil to fall, so a slight clumping of stars will attract more, making the attraction stronger and so dragging in yet more stars. The result is a bar which forms in order to "redistribute angular momentum" among the stars: Each star's orbital motion prevents it from falling inwards towards the centre of attraction. If it could be "braked" in some way it could settle closer to the centre of attraction, but of course there is no friction in space. However, the beautiful S shape which appears during the bar-forming process is almost as effective. The stars near the centre of the S are pulled backwards by the high concentration of stars "behind" them and settle closer to the centre of attraction. This is at the expense of the outer stars which must move slightly further out to compensate, since they are accelerated by the extra density of stars in front of them. This is only a partial explanation; the full story would take too long to recount. Once the spirals, which provide the torque, fade away, no further changes occur and the bar simply rotates slowly.

There are only two ways known in which to prevent the formation of a bar. One is by increasing the amount of random motion in the disk, the other by invoking what is called a massive halo.

There is no random motion in a disk where all stars have exactly circular orbits. If the orbit of a star is not perfectly circular, then it moves alternately inwards and outwards, whilst sometimes gaining on other nearby stars and at other times dropping behind. When all stars behave in this way, we say that there is some random motion (or velocity dispersion) in addition to the orbital motion. The more eccentric the orbits of the individual stars, the greater the velocity dispersion in the galaxy.

The bar forms most readily when there is little random motion, since all stars respond similarly to any perturbation, quickly building up a big concentration. The more random motion there is at the start, the less coherent the response, hindering the growth of the disturbance. At some point there will be enough random motion to "dissolve" an arbitrary clump before sufficient nearby stars can reinforce it.

There is no simple formula to predict just how much random motion is needed to prevent the growth of a bar in all cases. In the few instances where it has been determined, it appears that the dispersion of velocities must be around 100 km/s. This is a larger value than one would expect and when compared with the 250 km/s of orbital motion, implies that most stars would have highly eccentric orbits. We have no direct measurements of the velocity dispersion of stars in the disk of other galaxies, although we do know that close to the sun in the Milky Way, the disk stars have a dispersion of only 35 to 40 km/s. Galaxies seen edge-on, as shown in Fig. 1, have very thin disks, indicating small velocities perpendicular to the plane, which suggests little random motion in the other directions too. Thus, although the case is far from watertight, it seems unlikely that random motion in galaxies is sufficient to prevent the formation of a bar.

We are also able to inhibit bar formation by assuming the mass of the bulge to be much greater than one would guess from its luminosity. As we increase the mass of the bulge component in the computer models, we reduce the growth rate of the bar. Eventually, when the bulge is roughly twice as massive as the entire disk, we find that the bar instability is totally suppressed.

However, this again is hard to reconcile with the observed facts. The bulge of a typical disk galaxy provides about 20% of the total light and it is unlikely to contain 70% of the mass. In fact, estimates of its mass from observed rotation curves support a lower value, closer to 20% than to 70%.

(There is mounting evidence for a large quantity of underluminous material in the outer parts of galaxies, which is usually called a "massive halo". It is clear that, if it is spherically distributed, this matter cannot affect the stability of the central parts of the disk, since the gravitational field inside a spherical shell of material is zero.)

Thus, we are faced with a severe problem, although the situation may not be desperate. The only two known methods which can prevent galaxies from forming a bar, taken separately, seem inconsistent with reality. But not all possible solutions have jet been explored. My work at ESO has shown that the bar-forming region is confined to the part of the disk where the rotation curve is rising. This is precisely where we are least certain that the velocity dispersion is small. We can construct models with more random motion near the centre than further out, and reasonable fractions of bulge mass, which will perhaps not form bars. Hopefully they would be consistent with our present knowledge of galaxies.

Observational astronomers can help with this problem too. Measurements of the velocity dispersion of stars in disk galaxies are just becoming possible with the latest observing techniques. Such measurements will provide more stringent tests for our theories.

Ring Galaxies

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Among the 338 exotic, intriguing and/or fascinating objects contained in Arp's catalogue of peculiar galaxies, two, Arp 146 and 147, are calling special attention as a presumably separate class of objects displaying closed rings with almost empty interior. It is difficult to find out when, historically speaking, attention was called first to this type of object as a peculiar class, but certainly galaxies with rings were widely found and recognized in the early sixties, under others by Vorontsov-Velyaminov (1960), Sandage (1961) in the Hubble Atlas or de Vaucouleurs (1964) in the first reference catalogue of galaxies. The most recent estimates by Arp and Madore (1977) from a search on about 200 Schmidt plates covering 7,000 square degrees give 3.6 per cent of ring galaxies among 2,784 peculiar galaxies found. However, despite the mythological perfection associated with a circle, some ordering is necessary before trying to understand the nature of such objects. This is particularly true

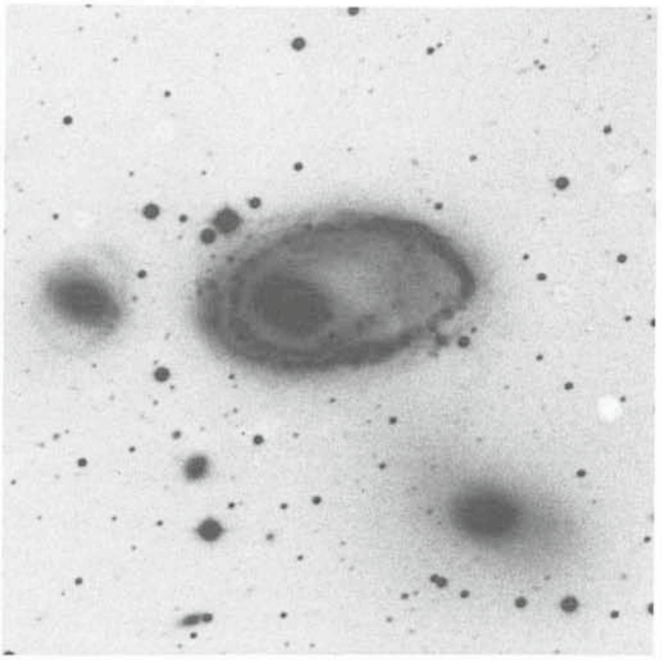

Fig. 1: *Graham's object classified RN4 by Theys and Spiegel (the number refers to the ellipticity). Note the two companions, one close to the minor axis at a distance of about three times this minor axis (ESO 3.6 m picture, IIIa-J + GG385).*

because a large fraction of those galaxies with rings are probably normal spiral galaxies of type RS or S(r) as defined by de Vaucouleurs, where the spiral arms are simply "closing the circle". A good example of such "ordinary" galaxy is NGC 3081 in the Hubble Atlas.

A classification of "ring galaxies" (meaning peculiar galaxies, excluding the ones with closing spiral arms) with strict selection criteria was set up by Theys and Spiegel (1976) who define three categories: RE (elliptical rings with empty interiors), RN (elliptical rings with an *off-centered* nucleus), RK (rings with a single knot on the ring itself). The classification is based on morphological criteria and immediately points to the importance of the scale of the photograph: particularly a ring which appears smooth on a Schmidt plate can often be resolved in several crisp filaments with knotty structure. But the emphasis is put on the off-centered position of the nucleus (or its absence). (An example is given in Fig. 1.) With such criteria, Theys and Spiegel had only nine first-class candidates and seven others probable! This number is likely to increase with objects from Arp and Madore's list. However, the new objects found are increasingly faint and small so that even with large telescope pictures (if we ever get them!) their classification will be difficult.

Two additional characteristics are important both for their selection and as clues to their interpretation. The first is that, appart from an eventual off-centered nucleus,

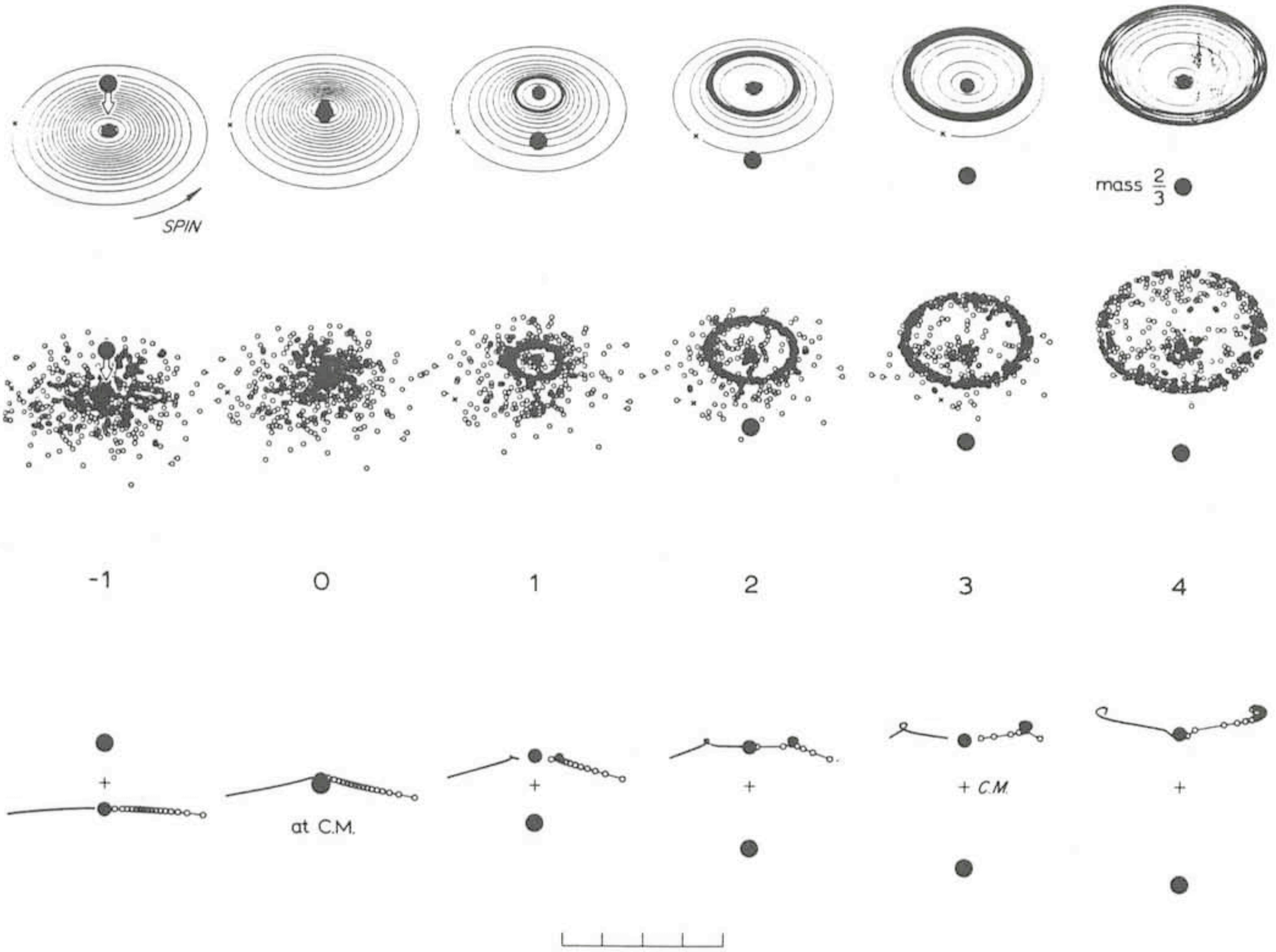

Fig. 2: *Results of an axial penetration of a Gaussian disk galaxy of mass M by another, more point-like mass 2.M/3; one-third of the former mass resides at the very centre of the disk. Time is reckoned in unit of $(r_o^3/GM)^{1/2}$ from the instant when the intruder reaches the centre of mass of the system (from Lynds and Toomre, 1976).*

the interiors of the rings are almost empty, showing neither a uniform stellar continuum nor pronounced condensations of the type found on the ring itself. This strongly suggests that we are dealing with flat objects rather than spherical ones. Second, Theys and Spiegel have found that in all cases, a companion galaxy was to be found closely, generally close to the minor axis of the ring, at a distance of 2 to 3 times this minor axis.

With the above description, one has now enough cards in hand to start to think about a strong interaction process as the formation mechanism (off-centered nucleus + empty ring + companion). Before the systematic presence of a companion had been recognized, Freeman and de Vaucouleurs (1974) had proposed an interaction between a disk galaxy and an intergalactic hydrogen cloud. The gas from the disk would have been compressed into a ring where eventually star formation could have started and excited the gas. However, the gas clouds required for this process should have several times 10^9 solar masses and sizes up to 15 kpc. Such intergalactic clouds are easy to detect in HI 21 cm line, but up to now, none has been found at any place in the sky and the general belief is now that if they exist, they could have only masses of the order of 10^8 $M_\odot$.

Fortunately, the presence of the companion provides an easy alternative, and numerical calculations by Lynds and Toomre (1976) and somewhat independently by Theys and Spiegel (1977) have shown that a fairly concentrated galaxy (like an elliptical one ...) falling nearly perpendicularly through a disk galaxy will provoke the right type of gravitational perturbation to produce a ring! (Fig. 2, taken from Lynds and Toomre, illustrates well this fact.) Again compression of the gas is likely to induce star formation and subsequent HII regions seen as knots on the ring. However, it is well known that such rings are unstable and the calculations have shown that a 10^{11} $M_\odot$ ring of a few kpc size would dissolve in a few 10^8 years. This timescale agrees very well with the observed distance of the companion (supposed to have been the intruder) assuming relative velocities of a few hundred km/sec, which are typically found in groups of galaxies. That the nucleus of the disk galaxy lies off-centered (i.e. displaced from its original position) after such a violent encounter seems very plausible (the contrary would be surprising ...). That such an encounter might really happen, is suggested by Fig. 3.

Such model, for attractive it looks, needs obviously a thorough comparison with observations. The few observations available directly to the authors of the models (essentially relative velocities of the galaxy and its companion and a few velocity points on the ring itself) were reasonably supporting their ideas, but clearly much more data were necessary. We therefore started an observing programme with several aspects. One has to deal with statistics: the encounters required are of such close a nature that the probability of encounter is rather low and therefore the number of expected ring galaxies must be small. It is therefore important to classify as many as possible of the Arp and Madore's candidates known only on small-scale photographs. An example is the so-called "Vela object" originally discovered by Sersic (1968) and which reveals a very complex structure on large-scale photographs (Dennefeld, Laustsen, Materne, 1979). It has an inner bar, an inner ring, an outer ring with complex filamentary and knotty structure, perhaps not even closing completely! The measured velocities are consistent with the model and an age of 10^8 years, but how could such a bar structure resist the interaction? Has it formed since then?

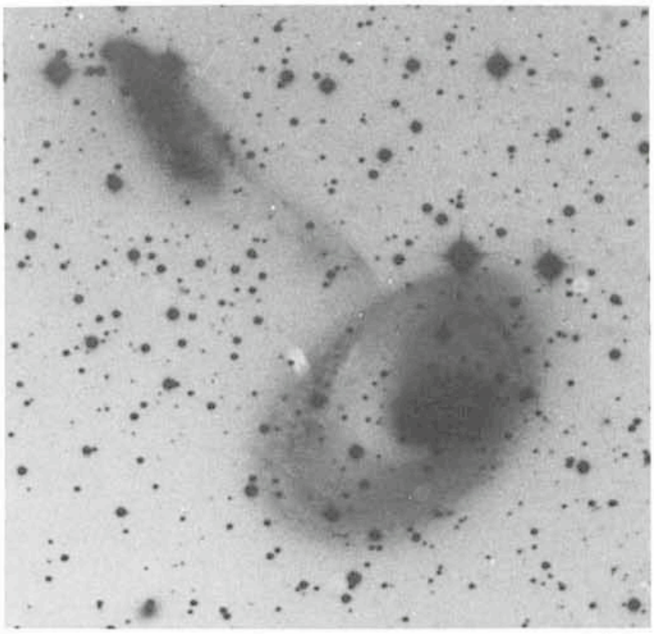

Fig. 3: *Ring galaxy with companion and jet suggesting an interaction. This object was first found on Schmidt plates and pointed out to us by H.-E. Schuster (ESO 3.6 m photograph, IIIa-J + GG385).*

One result of this programme, together with information from other authors, will probably lead to a simplified classification.

It is the author's increasing belief that the class RE does probably not exist. No additional cases have been found up to now! Furthermore, in the only three cases classified as RE, an off-centered nucleus can be seen on VII Zw 466, and Arp 146 and 147 have condensations on the ring which could be the nucleus itself (confirmed spectroscopically at least in one of the two). The same explanation holds for RK's.

The most important aspect of our study is of course a spectroscopic investigation of a few well selected cases. Only one case had been thoroughly studied before by Fosbury and Hawarden: the Cartwheel galaxy, where the ring was found in expansion with a timescale of 3×10^8 years in good agreement with the distance and velocity of the companion. The fascinating result was that the HII regions seen on the ring had proven to be metal poor, suggesting that the gas out of which the ring was formed did belong to a halo of unprocessed gas ... It is therefore important to find out if this is the general case with ring galaxies. Our spectroscopic programme was started in collaboration with A. Boksenberg, and his flying circus operating the Image Photon Counting System provides the most appropriate instrument for such a study: a two-dimensional detector with high sensitivity behind a two-minute slit spectrograph! Only preliminary reductions have been made, but some interesting results are already in hand. Generally, the nuclei and companions show the late-type stellar spectra expected from classical galaxies, but the same type of spectra is also often seen in the rings (projected nucleus? Stellar condensations?). The HII regions are often found of very low excitation, hardly compatible with a violent and recent burst of star formation in a metal-poor gas. Was the Cartwheel an exception? More observations are still necessary.

Finally, some efforts are also devoted over the world to the investigation of the properties of the "parent" galaxy compared to normal galaxies. This includes multi-colour photometry, continuum and HI radio-properties, study of the surrounding group ... All these investigations support the idea that the parent galaxy was a normal spiral galaxy ... It is fascinating to see that finally the most "exotic and peculiar" galaxies are "just" the result of normal galaxies simply in gravitational interaction. The mystery of the Niebelungen Ring (the southern ring galaxy known as Graham's object was called "Das Rheingold" by B. Madore) and power of the galaxies' Gods should not resist very long investigations by human astronomers.

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Un nuevo telescopio para ESO

Como ya se mencionó en "El Mensajero" No. 20, se espera que Italia y Suiza se integren a ESO como paises miembros a partir de 1981.

De acuerdo a la Convención de ESO, nuevos estados miembros deben pagar una contribución especial correspondiente a su parte de las inversiones efectuadas en el pasado. El Consejo de ESO ha decidido que este importe será utilizado para la construcción de un telescopio de 3,5 m.

Este telescopio representará un paso intermedio hacia la construcción de un telescopio muy grande y al mismo tiempo reducirá la demanda por el telescopio de 3,6 m en La Silla, y permitirá además, estudiar en la práctica algunas de las nuevas ideas para el diseño de telescopios del futuro.

Hasta recientemente un telescopio de 3 o 4 m era considerado como el telescopio de mayor dimensión en un gran observatorio. Por lo tanto, estos telescopios fueron construidos como instrumentos universales con un importante aporte de capital. Sin embargo, ésto tiende a cambiar actualmente y se está tratando de llegar a obtener grandes telescopios a bajo costo, y esta fórmula regirá para el nuevo telescopio de ESO.

Esto solamente podrá llevarse a efecto si el peso del espejo, el tamaño del edificio y el número de las posiciones focales son reducidos a un minimo. Estes restricciones, sin embargo, no deberán afectar la alta precisión para apuntar los objetos ni la calidad de las imágenes por perturbaciones dentro de la cúpula. Y deberá existir suficiente espacio dentro de la sala de control.

"Lord", el perro guardián de ESO durante más de 10 años, falleció en el mes de enero de 1980. La fotografía fue tomada en el año 1976.

El resultado de los primeros estudios para este proyecto, efectuado por el Dr. W. Richter del Grupo Técnico de ESO, se aprecia en el dibujo que aparece en la página 19.

El edificio presenta un diámetro externo de 14 m y una altura total de 20 m. Con el telescopio se usarán solamente dos instrumentos – uno para observaciones en infrarojo durante el periodo de luna llena. La sala de control ubicada debajo de la plataforma de observación tiene una superficie de 100 m^2.

For technical reasons the table of contents has exceptionally been omitted in this issue of the MESSENGER. *The editors*

ESO, the European Southern Observatory, was created in 1962 to...establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy ... It is supported by six countries: Belgium, Denmark, France, the Federal Republik of Germany, the Netherlands and Sweden. It now operates the La Silla observatory in the Atacama desert, 600 km north of Santiago de Chile, at 2,400 m altitude, where ten telescopes with apertures up to 3.6 m are presently in operation. The astronomical observations on La Silla are carried out by visiting astronomers – mainly from the member countries – and, to some extent, by ESO staff astronomers, often in collaboration with the former.
The ESO Headquarters in Europe are located in Garching, near Munich.
ESO has about 120 international staff members in Europe and Chile and about 150 local staff members in Santiago and on La Silla. In addition, there are a number of fellows and scientific associates.

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