mass of ionized gas within a projected area of 230 x 60 kpc^2 is 3 x 10^{10} (<n>/n) $M_\odot$ where <n> is the average gas density of the order of 10^{-2} cm^{-3}. If the gas distribution is not homogeneous, the HII mass can be much smaller than 10^{10} $M_\odot$. The range of masses for giant HI halos is H_{HI} = 10^{10} – 10^{11} $M_\odot$, an extreme case being the spiral galaxy NGC 1961 with M_{HI} = 1.4 x 10^{11} $M_\odot$ (Rubin, Ford and Roberto 1979, *Astrophys. J.*, **230**, 35). The few known X-ray emitting groups (smaller than the well-known large X-ray clusters) have M (hot gas) = 10^{12} – 10^{13} $M_\odot$ (Schwartz et al, 1980, preprint). Although the mapping of the nebulosity around MR 2251–178 is incomplete, it seems that the mass of ionized gas falls in the range of masses of HI envelopes around spiral galaxies and this only if the gas is not clumpy.

The kinematics of the ionized gas are derived from the spectro-spatial observations of the [OIII] lines. A clear rotation pattern is detected within 15 kpc of the QSO. In the SW direction, 50 to 150 kpc away from the QSO, the rotation curve flattens. The total spread in velocity in the observed parts of the envelope is 300 km s^{-1}. This is much smaller than the spread in velocity of the galaxies in the nearby groups. The rotation pattern and the continuity in the velocity field over the whole HII envelope strongly favours an association with the QSO.

Stellar absorption lines are seen close to the QSO. The stellar and gas velocities are similar. However, these absorption lines are detected only at a few positions and we cannot derive the stellar velocity field.

It is worth noticing that the few nebulosities studied spectro-spatially up to now have different characteristics and no general scheme can be given. MR 2251–178 is a weak compact radio source and PKS 2158–380 is a strong extended radio source, yet both are surrounded by an ionized envelope in rotation around the nucleus. The weakness of disordered motions in MR 2251–178 contrasts strongly with the highly disordered velocity field around 3C120.

The envelope around MR 2251–178 appears similar to large HI halos around spiral galaxies. The neutral envelope around the Seyfert 2 Mark 348 and the ionized envelope around MR 2251–178 have comparable sizes and masses (if n ~ <n> in the HII envelope) and both show a clear rotation pattern. The difference in their ionization degree may only reflect their different X-ray power. The QSO MR 2251–178 is a very strong X-ray source with $L_x/L_{opt} \simeq 3$, but the Seyfert 2 Mark 348 is a weak X-ray emitter with L_x/L_{opt} = 1/100. The envelope around the QSO can easily be powered by the continuum hard energy source and the degree of ionization observed implies n $\lesssim 10^{-1}$ cm^{-2}.

The Dynamics of Elliptical Galaxies

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Introduction

Two epochs have to be recognized in the study of elliptical galaxies. Prior to 1975 it was believed that a globally correct description of the structural and dynamical properties of these objects had been achieved. It was thought that these galaxies were well understood, not only because their morphology appeared to be simple and they were considered to contain only *one* stellar population, but also, paradoxically, because of the lack of observational data. Then the observation of the first rotation curve called the validity of the currently admitted ideas in question.

These galaxies look more or less like ellipses whose brightness gradients increase towards the centre. They form a sequence ranging from the circular systems (E0) to the more elongated ones (E6) although a scarcely populated class E7 also exists. The parameter is a measure of the ellipticity of the observed image and may not be immediately related to the spatial shape.

A number of empirical laws, like that of de Vaucouleurs, or semi-empirical, like that of King, have been proposed to describe the brightness distribution of elliptical galaxies. De Vaucouleurs' law gives the surface brightness as a linear function of the fourth root of the distance to the centre. It contains two scale factors and has no free parameter. King's law, devised to describe the observed distribution in globular clusters, is based on the assumption of a quasi-isothermal dynamical model. This law, adapted to elliptical galaxies, makes use of two scale factors. One is the core radius of the galaxy which defines the distance along the bissectrice of the axes at which the projected stellar density, and therefore the brightness, become one half of the values at the centre. The other is the tidal radius, beyond which the brightness is zero. The ratio of these two scale factors is a free parameter in the model.

De Vaucouleurs' law is especially convenient to describe the surface brightness distribution of elliptical galaxies. It is easily compared with observations although it does not perfectly represent the light distribution in the central or peripheral regions of some galaxies like, for instance, M87 or NGC 3379.

Before 1972, the only direct access available to the dynamics of ellipticals was through the observation of the velocity dispersion in the centre which gave an estimate of the random motions of the stars. This quantity, derived by using absorption lines, is difficult to obtain even in the centre. Away from it, the spectrum is barely detectable since the brightness of the galaxy decreases rapidly. Other difficulties are due to the fact that these lines are broad and contaminated by the night sky, sometimes even by interstellar absorption lines. Moreover, the absorption spectrum of a galaxy is a blend of different stellar types and results from the integration along the line of sight. These difficulties explain why no observation of this type was done after the pioneering work of Minkowski (1954, in Carnegie Institution of Washington Year Book **53,** p. 26, 1962, in "Problems of Extragalactic Research", IAU Symp. No. 15, p. 112) and before modern detectors became available. In principle the rotation curve could have been obtained more easily using emission lines. However, not only very few ellipticals exhibit emission spectra, but also this kind of information does not tell us anything about the dynamics of the stars.

Making use of this rather poor observational background, models were built which gave the illusion that the morphology and dynamical properties of ellipticals were well understood. Simple models were proposed by Prendergast and Tomer (1970, *Astronomical Journal,* **75,** 674) and by Wilson (1975, *Astron, J.,* **80,** 175), following King's quasi-isothermal model. Other, more complex ones have been suggested. They start the description at the collapse phase of the system which ultimately will become a galaxy. Gott's model (e.g. 1975, *Astrophysical Journal,* **201,** 296) described the evolution of a cloud which condenses into stars without dissipation. The hydrodynamical models of Larson (e.g. 1975, *Monthly Notices of the Royal Astronomical Society,* **173,** 671) took into account the dissipation in the gas. In short, we can say that ellipticals were considered to be huge self-gravitating systems of high-velocity stars often flattened because of rotation. Consequently, they were supposed to be oblate spheroids.

We like to emphasize that the observational input to our knowledge of the dynamics of ellipticals was just the measurement of the velocity dispersion in the centres of a few objects. Other observations which now appear to be crucial for the understanding of the spatial configuration of these galaxies existed, by Evans in 1951 (*Mont. Not. Roy. Astron. Soc.,* **111,** 526) and Liller in 1960 and 1966 (*Ap. J.,* **132,** 306; *Ap. J.,* **146,** 28) showing that in some ellipticals the isophotes do not have the same orientation and/or eccentricity. But no attention was paid to these observations until the revision of our ideas on the dynamics of ellipticals took place and further work called new attention to this question. We shall see later how this phenomenon was interpreted in the light of the work, done for instance by Williams and Schwarzschild (1978, *Ap. J.,* **227,** 56) and Bertola and Galletta (1980, *Astronomy and Astrophysics,* **77,** 363).

Recent Observations

The first observations which cast a doubt on the description given above where those made in 1972 by Bertola (Proceedings of the 15th Meeting of the Italian Astronomical Society, p. 199), followed by Bertola and Capaccioli in 1975 (*Ap, J.,* **200,** 439), who published the first rotation curve of an elliptical galaxy, NGC 4697 classified E5. The measurements gave an unexpected result: although this galaxy has an appreciable flattening, its rotational velocity is only 65 km s^{-1}, a very low value indeed. This property has been confirmed for almost all the galaxies so far observed, the maximum velocity being almost always lower than 100 km s^{-1}. Velocity curves along the different axes have been published for about 30 galaxies, and velocity dispersions in the centres, with or without velocity profiles, have been obtained for more than 50 objects. These are basic measurements since kinematical observations are the key to the understanding of the dynamical properties.

Some results have been obtained, due to the improved observing methods, and especially to the use of very sensitive detectors and new reduction techniques. The photon-counting systems allowed to record spectra outside the nuclei of galaxies. The kinematical parameters could be extracted by numerical treatment of these spectra. This is done by correlating the spectrum of the observed galaxy with that of a template star having a spectral type close to that of the galaxy, making use of the Doppler broadening function. For any selected spectral range three quantities are simultaneously extracted at different positions perpendicularly to the dispersion: the redshift and the velocity dispersion and a parameter, usually called γ, which is the mean ratio of the galaxy absorption line strengths to the corresponding ones of the template star.

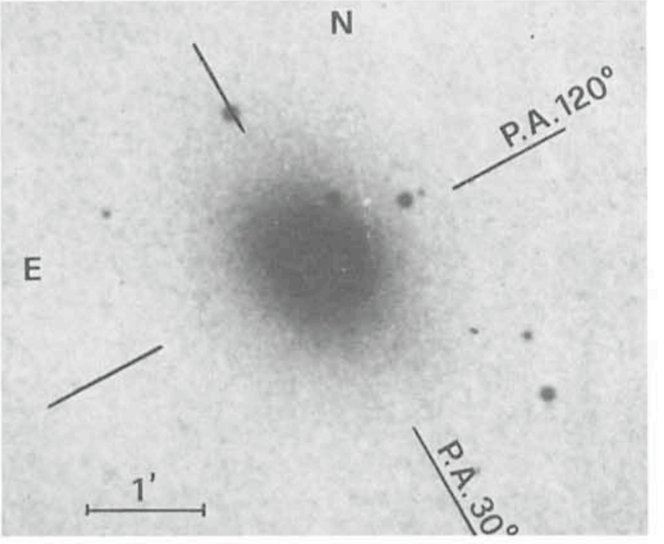

Fig. 1: *The elliptical galaxy NGC 596, reproduced from the Palomar Sky Survey. Despite its very common aspect it displays an unexpected phenomenon: stellar internal velocities along the minor axis, which have recently been confirmed by the authors with the ESO 3.6 m telescope. This result, together with the shape and twisting of the isophotes, suggests a triaxial ellipsoid model. The figure shows the position angles along which the observations have been done. They more or less coincide with the axes of the outer isophotes.*

New observations of this type have recently been made by the authors with the ESO 3.6 m telescope equipped with a Boller and Chivens spectrograph and an IDS (Image Dissector Scanner), which has proved to be satisfactory for this type of work. The four observed galaxies NGC 584, NGC 596, NGC 5128 and A0151–497 represent a sample of normal and peculiar galaxies.

The IDS has two channels for simultaneous observations of the object and the night sky which allow subsequent subtraction. In our observations both slits were used to observe the object. The exposure times were in the range of 30 minutes to two hours. Several spectra were secured during three nights. The subtraction of the night sky was done by using a separate integration.

Except for NGC 5128, the two slits were positioned either symmetrically with respect to the centre, or with one slit at the centre, with different position angles.

The reduction was done in two steps: the transformation of the spectra into absolute flux densities was made in Geneva, using the ESO image processing facilities (now located in Garching). The final analysis, based on the method of Fourier coefficients, using two template stars, was completed in Trieste. Three of the four observed galaxies have some especially interesting characteristics. The fourth one, NGC 584, was chosen because it has a large flattening. The results obtained in this latter case confirm that the rotation is too slow to account for the flattening. NGC 596 (Fig. 1) was known to show a peculiar phenomenon, radial stellar velocities along the minor axis. Our results confirm this observation which, together with the shape of the isophotes, is one of the best arguments in favour of the triaxial ellipsoid hypothesis.

The two other galaxies are good examples of the class of ellipticals with dust defined by Bertola and Galletta (1976, *Ap. J.* Lett., **226,** L 115). NGC 5128 (Fig. 2) is the prototype and A0151–497 a very good example in the southern sky. The location of the dust in these galaxies suggests that they are prolate spheroids. The observations of the type we have made can contribute to verify the hypotheses. A preliminary result is that in A0151–497 the velocity dispersion tends to show a minimum in the dust lane at a position which corresponds to the centre of the galaxy. A detailed account of these observations will be published by the authors in collaboration with D. Bettoni, G. Galletta, L. Rusconi, and G. Sedmak.

Interpretation

These results have led to discard the classical model in which flattening is due to rotation. It has been suggested for instance that elliptical galaxies are oblate spheroids but with a strong anisotropy of velocities, or prolate spheroids rotating about a minor axis. Fig. 3 from Binney gives the ratio of the maximum rotational velocity to the velocity dispersion at the centre versus the flattening. It clearly shows that the classical model should be discarded and that the new proposed models deserve attention. A third possible model is the slowly rotating triaxial ellipsoid. The assumption that elliptical galaxies are triaxial raises some important problems (see also Binney, 1978, *Comments on Astrophysics,* **8,** 27).

We may assume that elliptical galaxies are self-gravitating stellar systems without collisions. This means that every star moves in the smoothed potential of all the other stars. It may happen that the motions of two stars are perturbed because of a close approach. We say in this case that a close encounter or collision has taken place. However, owing to the relative distances and velocities of the stars in an elliptical, such collisions are rare events and can be neglected on a time scale of the order of the age of the galaxy.

Such a stellar system is described by a distribution function in phase space. This function gives us, for instance, the number of stars which are in a given small region of the configuration space with their velocities belonging to a small given region of the velocities space. If the system is in a steady state, this function does not explicitly depend on time. This assumption is usually made. We know from general dynamics that the motion of any given star in the gravitational field of this kind of galaxy is such that it conserves certain quantities, for instance the total energy, i.e. the sum of the potential and kinetic energy of the star. The total energy is said to be a first integral of the sixth order differential system of equations describing

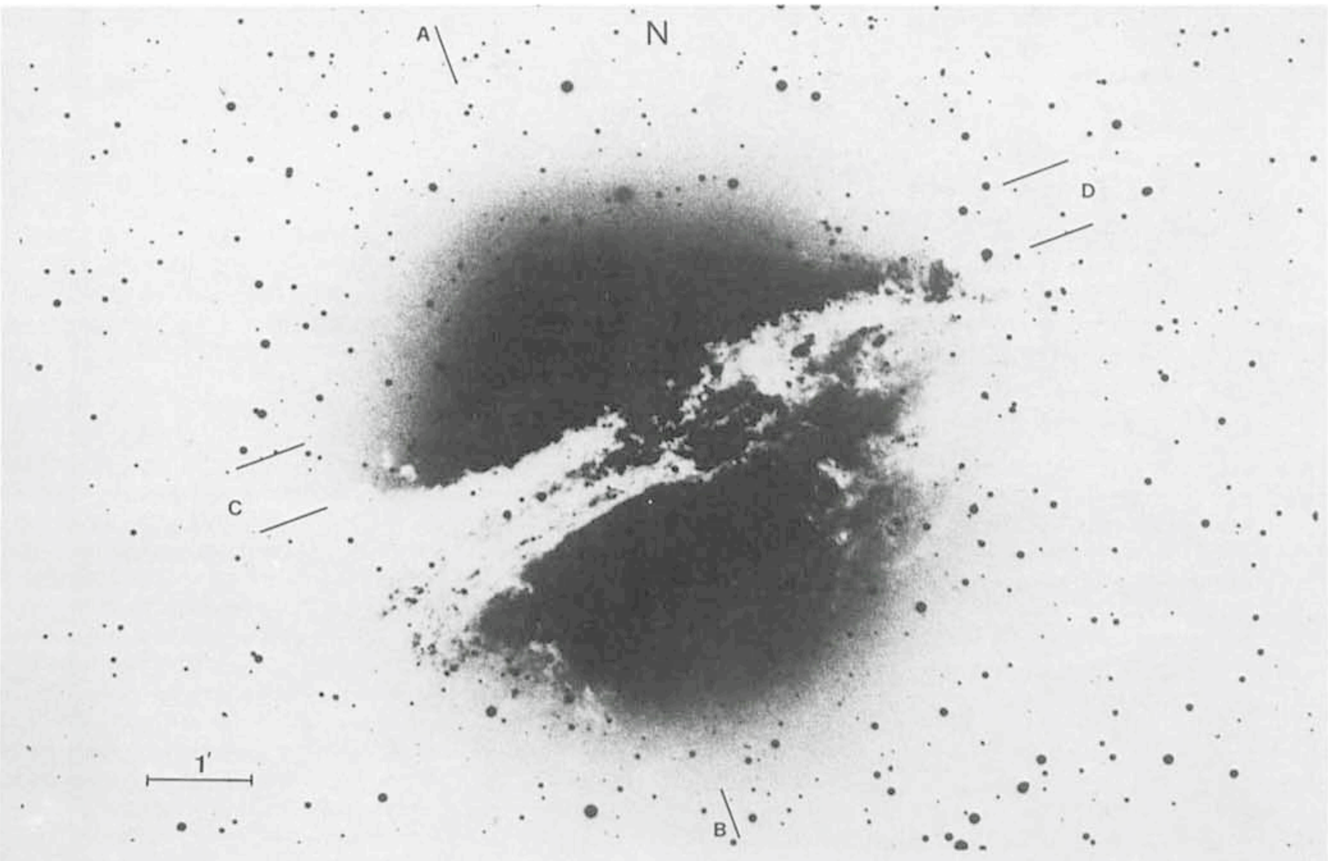

Fig. 2: *The well-known dusty galaxy NGC 5128 has recently been considered as the prototype of a class of galaxies for which the location of the dust suggests that they are prolate spheroids. It has been studied by the authors. The line AB on the photograph (ESO 3.6 m telescope) defines the direction of the two spectrograph slits, the positions of which are shown by the lines C and D. A preliminary inspection of the data indicates that the velocity dispersion near the dust line is about 100 km* s^{-1}.

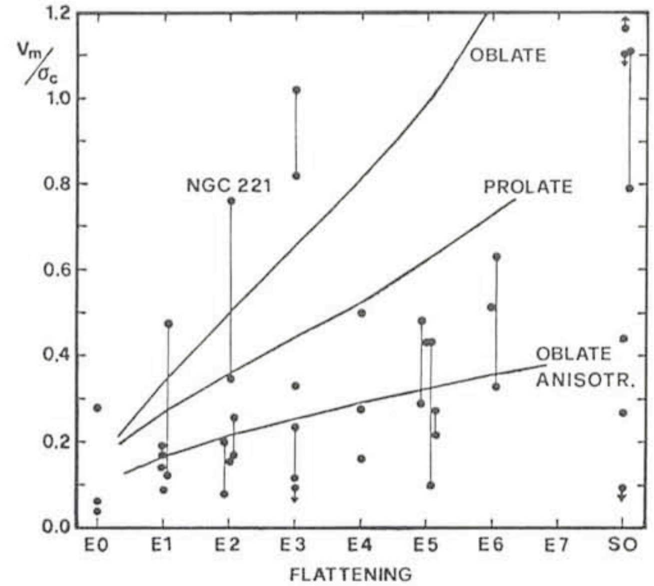

Fig. 3: *On the diagram, the ratio of the maximal observed radial velocity to the central velocity dispersion has been plotted versus the flattening. The curves correspond to different theoretical dynamical models (adapted by M. Capaccioli for* Photometry, Kinematics and Dynamics of Galaxies, *Austin 1979, from Binney 1978). It is seen that observations suggest to discard the isotropic oblate model.*

the motion of the star. More generally, an integral is a function of the variables which becomes a constant when one substitutes in it a solution of the above-mentioned system of equations. One can show that only five independent conservative integrals exist.

A theorem of Poincaré (but often referred to as Jeans theorem) says that the distribution function which is a solution of Liouville partial derivative equation, is an arbitrary function of conservative and isolating integrals of the equations of motion of a star. The mathematical definitions of isolating and non-isolating integrals are rather complicated (see for instance Contopoulos 1963, *Ap. J.,* **138,** 1298). We shall give here a simple geometrical representation of these integrals without any aim of being rigorous.

Phase space has 6 dimensions: 3 for space coordinates and 3 for velocity coordinates. Let I be a first integral. Then the equation $I = C$, where c is a constant, defines a region in phase space. I is said to be isolating in this region if the equation $I = c$ can be solved with respect to all the variables, giving a finite number of solutions. $I = c$ is then a "good" hypersurface. Classical integrals are of this kind. Non-isolating integrals are of two types: *ergodic* and *quasi-isolating.* An integral I is said to be ergodic if in the neighbourhood of any point in the above-mentioned region one can find some points where it can take values which are as different as we can think. It can also be said that the hypersurface $I = c$ goes as near as we want from any point in the region. The corresponding orbit in the 3-dimension configuration space is also called ergodic. An isolating integral brings restrictions to the motion in phase space and to the motion of the star in the 3-dimensional space as well. An ergodic integral does not so. An integral is said to be quasi-isolating if it is non-isolating in the above-defined region, but does not go through the neighbourhood of *all* its points. In fact the properties of quasi-isolating integrals make them similar to isolating ones. They can be arguments of the distribution function. Simple examples can be given of non-isolating integrals in well-known potentials, for instance the two-dimensional harmonic oscillator. Let us also mention that integrals can be stable, quasi-stable or unstable with respect to some type of perturbation of the potential.

The equations of motion of a star which moves in the field of a spheroid have two classical isolating integrals: energy and the projection of the star's angular momentum on the axis of symmetry. In general no other integral is known which can be given analytically. However, numerical investigation has shown that for some stars a third isolating integral exists. Sometimes the third integral is only quasi-isolating. It is well known for instance that the local distribution of velocities in the Galaxy is not, as one would expect, symmetrical with respect to the direction of the Sun's motion. It is thought that this effect is due to the existence of a third integral for some of the stars. (As the Galaxy is axisymmetric, the motion of a star has the classical two integrals. The last two integrals are non-isolating.)

In a similar way, it may be that the dynamics of elliptical galaxies depend on the distribution of the values of a third integral among the stars. In this case, flattened axisymmetric systems with a slow rotation but a strong velocity anisotropy could exist.

Let us assume now that for some stars of an elliptical galaxy two non-classical isolating integrals exist. This galaxy could then be triaxial. In this case, there is only one classical integral, namely the energy. We may then imagine that one of the non-classical isolating integrals would control the amplitude of the star's oscillations along the main axis. However, Vandervoort (*Ap. J.,* 1980, **240,** 478) has recently shown that triaxial systems in equilibrium may exist without any isolating integral except that of Jacobi, and he has drawn attention to the fact that Jeans theorem does not require that the distribution function should be a function of *all* the isolating integrals. But the models illustrating these results are not realistic for representing elliptical galaxies.

The work of Aarseth and Binney (1978, *Mont. Not. Roy. Astr. Soc.,* **185,** 227) and of Schwarzschild (1979, *Ap. J.,* **232,** 236) shows that satisfactory triaxial configurations seem possible and that they could last. The study of orbits in the field of a triaxial homogeneous ellipsoid shows that most of them are not ergodic and that there are two non-classical isolating integrals (Contopoulos 1963, *Astron. J.,* **68,** 1). The work of Schwarzschild suggests that self-coherent triaxial systems in dynamical equilibrium, which have density profiles like those of elliptical galaxies, may exist. Aarseth and Binney's work brings encouraging results on the fate of triaxial initial configurations which seem to keep their shape after the violent relaxation which could have proceeded the equilibrium state. On the other hand, Contopoulos (*Zf. f. Astrophys.,* 1956, **39,** 126) has shown that observations do not exclude the existence of triaxial structures: the observed shapes of the isophotes of elliptical galaxies could be the projection of spheroids as well as of triaxial ellipsoids. Finally *N-body* numerical experiments by Miller (1978, *Ap. J.,* **223,** 122) have produced such triaxial configurations.

Let us now recall the results on the twisting of the isophotes, which were described at the end of the introduction. This characteristic, shown by NGC 596, can be given two interpretations: either the galaxy has isodensity surfaces which are spheroids with axes of different orientations; or, more probably, these surfaces are triaxial ellipsoids which have the same orientation, but whose axes have different ratios. The twisting of the isophotes could then be considered as a projection effect. We see therefore that photometric studies bring a strong argument in favour of the triaxial ellipsoid hypothesis and that there are non-classical isolating integrals that may help elliptical galaxies to keep their shapes.

So there is no reason to suppose that elliptical galaxies are necessarily spheroids since the most general configurations are triaxial. As long as it was not realized that non-classical integrals exist that could shape lasting triaxial configurations, it was natural to believe that elliptical galaxies were spheroids. This is because an initial triaxial distribution could not be preserved after the dynamical mixing phase which lasts for less than 10^9 years. Now recent works seem to show that in order to produce a spheroidal rather than a triaxial galaxy one must start with peculiar initial conditions, that is from a configuration in which the isodensity surfaces have their same two main axes equal.

Let us mention a very recent work to be published by Miller and Smith. These authors suggest on the basis of numerical experiments that most elliptical galaxies have reached their present state in two steps. They may have taken first the shape of a bar (prolate spheroid) during a protogalactic collapse controlled by rotation. Then they would have been slowed down by tidal interaction with their neighbourhood to finally rotate as slowly as shown by observations.

Conclusion

The revolution in the field of elliptical galaxies is going on. But we are far from knowing for sure what are the actual shapes and the dynamics of these objects. Many questions remain unanswered. For instance:

If ellipticals are triaxial now, will they keep their shapes for a long time? We do not know how to write non-classical integrals and we are not sure whether they are isolating or non-isolating, stable, quasi-stable or unstable.

Are triaxial galaxies generally closer to oblate or to prolate spheroids? How are galaxies distributed among these varieties? What is the rotation of these systems as a whole?

Elliptical galaxies give rise not only to dynamical problems. We also would like to know about nuclei, interactions with the neighbourhood and resulting evolution, evolution of the stellar content, etc.

The least we can say is that, contrary to the idea which was prevailing not so long ago, elliptical galaxies are very complex systems.

The Pre-Main-Sequence Shell Star HR 5999 Unveiled

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The star HR 5999 is embedded in a dusty gaseous nebulosity and is surrounded by more than 10 faint T Tauri stars. From these facts and from studies so far made of the physical properties of HR 5999, we strongly believe that it is a very young pre-main-sequence object; it varies irregularly due most probably to changes in the properties of dust grains embedded in its circumstellar gas shell.

In 1978 a campaign of simultaneous observations of the variable pre-main-sequence shell star HR 5999 from several observatories in the world was organized. At approximately maximum brightness ($V = 7^{m}.0$) the star was observed in the ultraviolet with the IUE, in the visual with Walraven, Johnson and Strömgren photometers, in the red and the near infrared with photometers attached to the ESO 1 m telescope. Near infrared and visual measures were obtained at the South African Astronomical Observatory. Furthermore, polarimetric and spectroscopic observations were also made. A description of this international campaign was given in *Messenger* No. 16 (March 1979). In this article the first results of the study of the photometric data and preliminary notes on the spectroscopic material are described.

Interstellar and Circumstellar Extinction

HR 5999 (= V 856 Sco) is one of the brightest pre-main-sequence stars. We have been studying this star for several years now. Due to particularly favourable circumstances it is possible to penetrate deeply into the extended atmosphere of this irregular variable star. Before its light arrives on earth it has to go through circumstellar material and through foreground interstellar medium. The way this light is attenuated by the latter is well known, but the manner in which it is dimmed by circumstellar dust grains is often different. This, in general, entails the problem of separating both types of extinction. In the case of HR 5999 it is possible to estimate the amount of foreground extinction, because it has a common proper motion companion, HR 6000, separated at an angular distance of only 45″. The amount of foreground extinction suffered by the light of the companion is about the same as that by the light of HR 5999. Being located at a distance of approximately 270 pc only, the amounts of foreground colour excess and extinction are, actually, not excessively large: $E(B-V) = 0^{m}.06$ and $A_V = 0^{m}.19$.

The star HR 5999 varies in the visual often about 1 magnitude in brightness, simultaneously with its change in colour index, in the sense that the star becomes redder when its light weakens. In general, the determination of the extinction by circumstellar matter is difficult. In the case of HR 5999 there are, however, strong indications that it is this material which causes the star to vary in brightness irregularly, perhaps triggered by a phenomenon which occurs closer to the surface of the star. Additional evidence for such a phenomenon is provided by the observations of linear polarization made simultaneously with the photometric measurements. They indicate that the degree of polarization is varying in phase with the change in colour index.