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

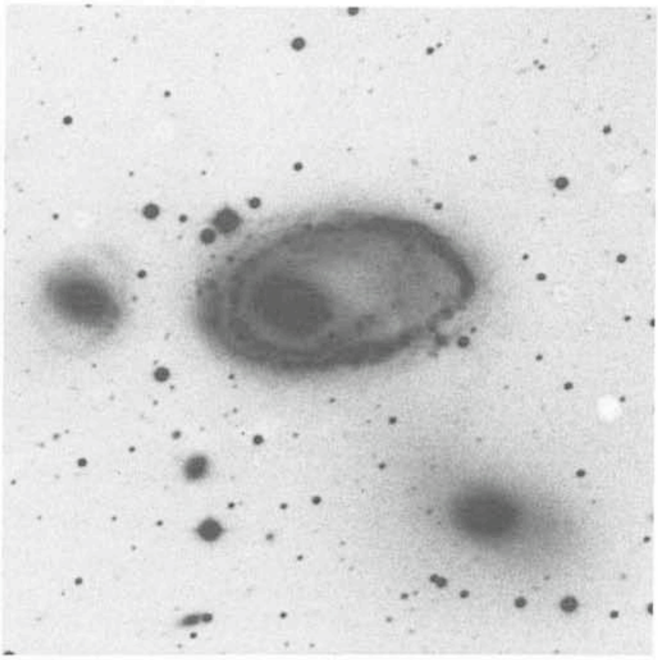

Fig. 1: *Graham's object classified RN4 by Theys and Spiegel (the number refers to the ellipticity). Note the two companions, one close to the minor axis at a distance of about three times this minor axis (ESO 3.6 m picture, IIIa-J + GG385).*

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,

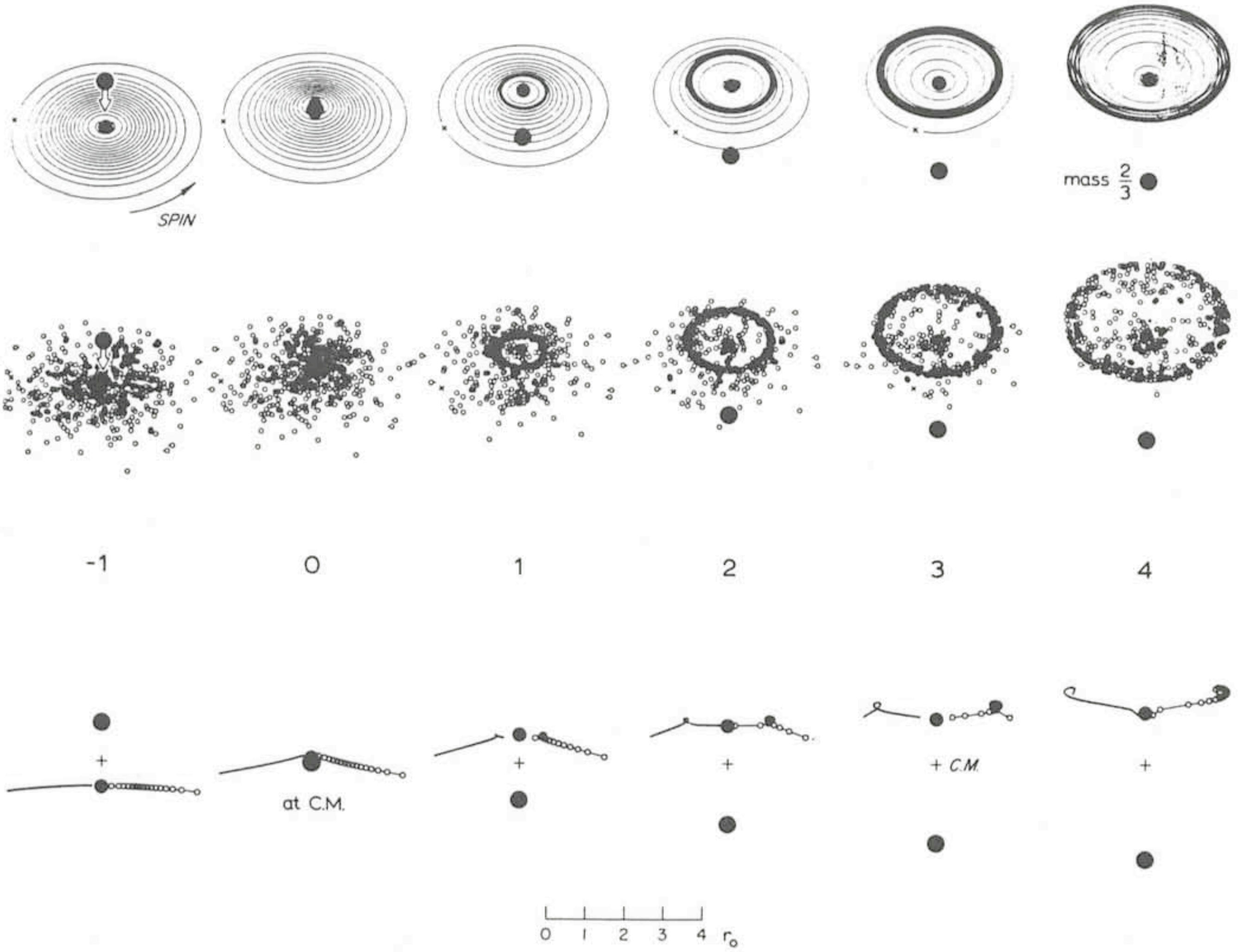

Fig. 2: *Results of an axial penetration of a Gaussian disk galaxy of mass M by another, more point-like mass 2.M/3; one-third of the former mass resides at the very centre of the disk. Time is reckoned in unit of $(r_o^3/GM)^{1/2}$ from the instant when the intruder reaches the centre of mass of the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

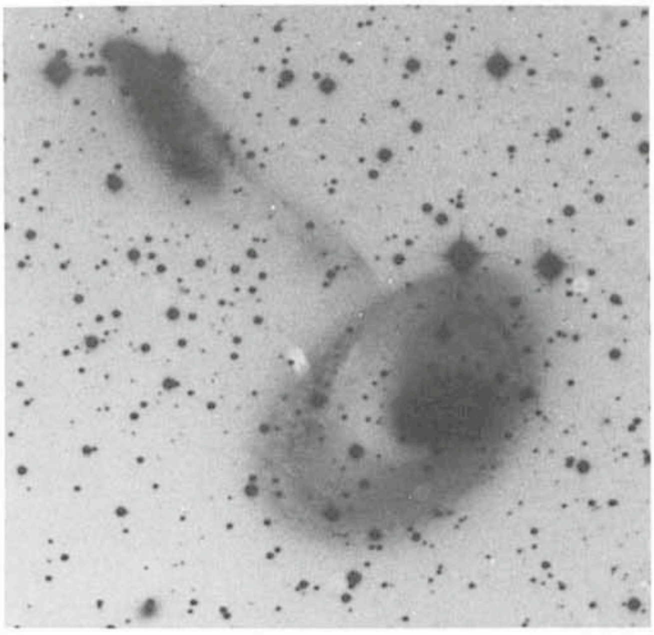

Fig. 3: *Ring galaxy with companion and jet suggesting an interaction. This object was first found on Schmidt plates and pointed out to us by H.-E. Schuster (ESO 3.6 m photograph, IIIa-J + GG385).*

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?

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 H II 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 H II 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.

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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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 países 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 mínimo. 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*