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.

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

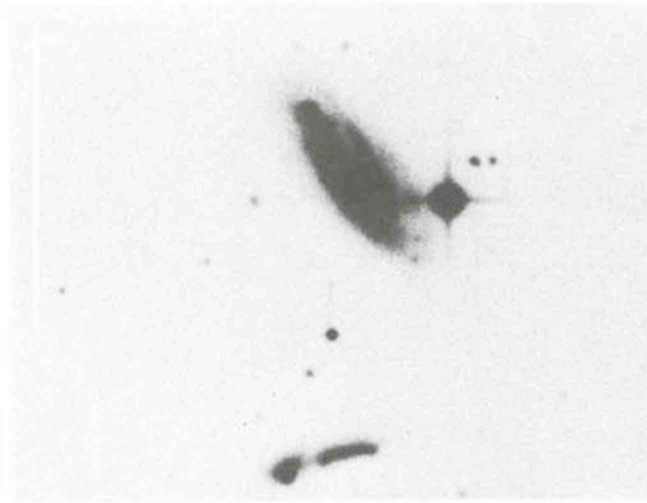

Fig. 1: *U. K. Schmidt photograph of galaxy at $00^h36^m55^s$ $-43°22'$ (1950). Companion to west of main galaxy is in shape of exclamation mark!*

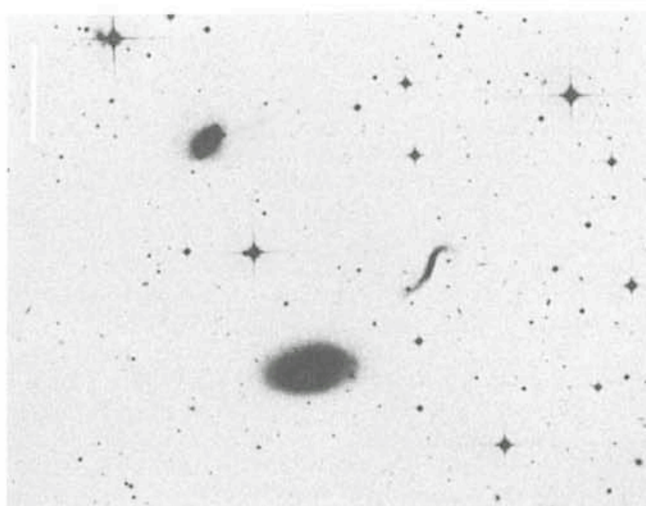

Fig. 2: *U. K. Schmidt photograph of NGC 434 with integral sign companion and companion NGC 440 to the east which has a faint jet emerging from it.*

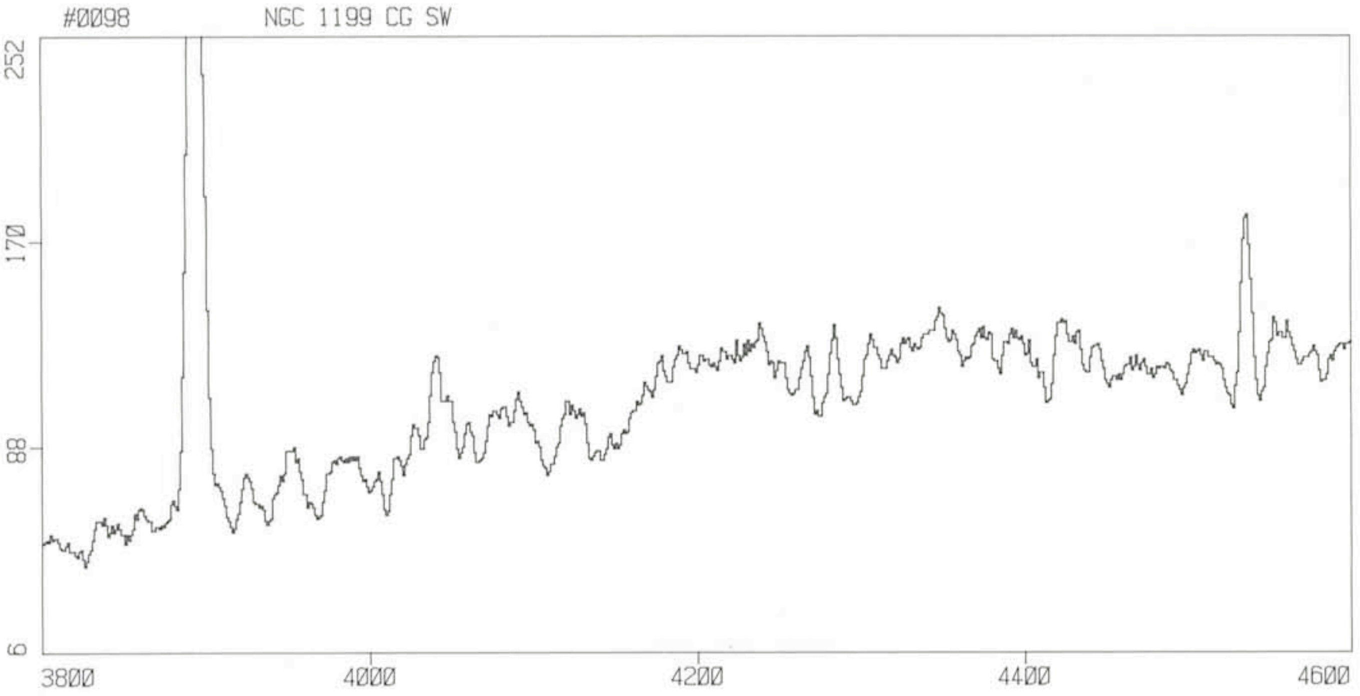

Fig. 3: *Spectrum of compact galaxy southwest of NGC 1199. This is a new spectrum taken with Shectman reticon detector on Las Campanas 100 inch reflector and shows strong O II emission at left end of spectrum plus the whole series of Balmer absorption lines down to H kappa.*

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?

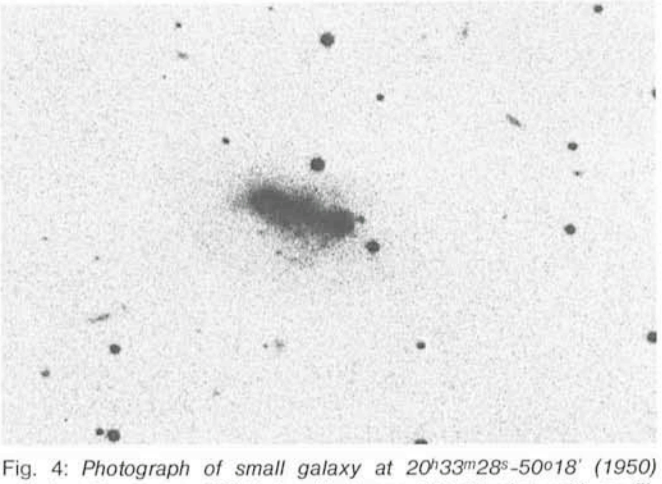

Fig. 4: *Photograph of small galaxy at $20^h33^m28^s$-50°18' (1950) with Las Campanas 100 inch reflector on 124-01 plate with no filter.*

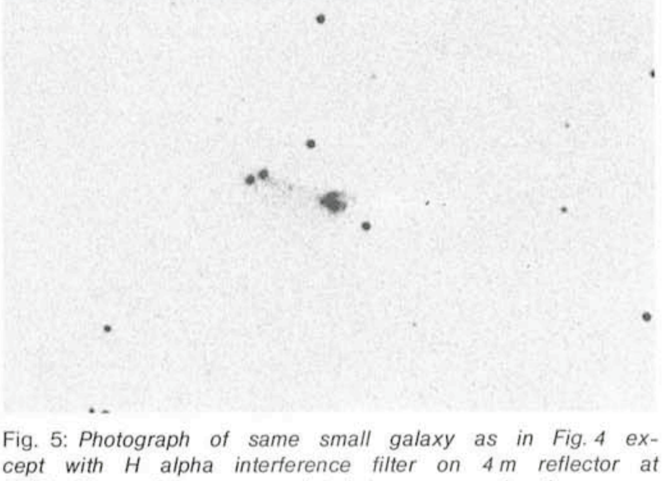

Fig. 5: *Photograph of same small galaxy as in Fig. 4 except with H alpha interference filter on 4 m reflector at CTIO. Since pictures are printed to same scale, the composition of the two end bulges can be seen as nearly stellar emission regions connected by a thin filament.*

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?

References

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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.

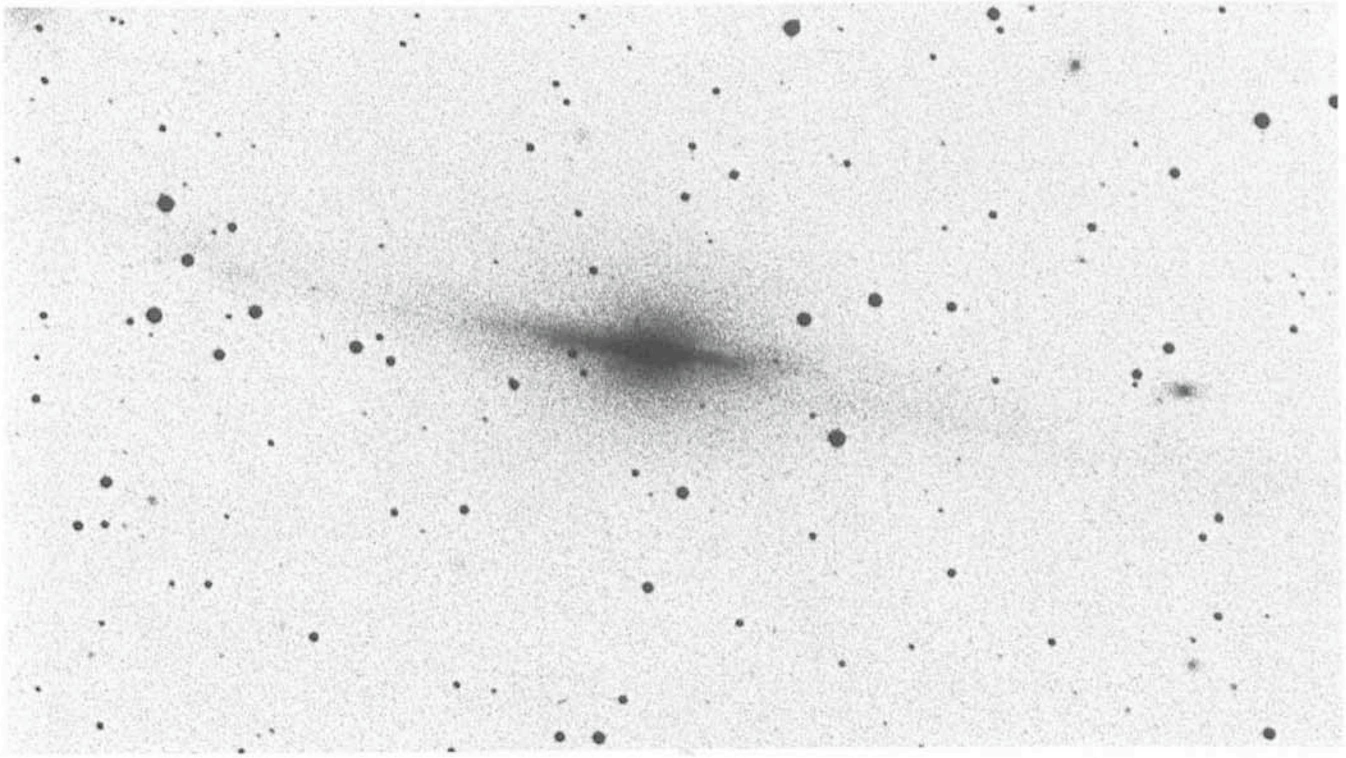

Fig. 1: *A negative print of the galaxy NGC 5084 taken during the sky survey on the ESO 1 m Schmidt telescope. This galaxy is very nearly "edge-on" and we can clearly see both the very flat disk and the central bulge.*