ELLIPTICAL GALAXIES WITH SHELLS

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A considerable number of otherwise normal elliptical galaxies show sharp edged, low surface brightness concentric features, often at very large radii from the parent galaxy. Features like this are visible in some of the photographs presented by Arp (1966). More recently extensive lists of galaxies with such features have been prepared from searches of sky survey material by Malin and Carter (1980, 1983) and Schweizer (1983), and the implications of these features for models of ellipticals and for peoples ideas about their formation have been considered in detail.

THE PROPERTIES OF SHELL GALAXIES

Before considering what the shell forming process is it is important to define what the properties of shell galaxies are. The data base is the sample of 137 shell galaxies south of -17° found on the SRC IIIaJ survey by Malin and Carter (1983). These galaxies are galaxies at elliptical morphology in which Malin and I could see one or more sharp edged concentric features, these are the defining characteristics of the sample, but the sample also has the following properties:

1) In elongated galaxies the shells tend to lie along the major axis.
2) The shells are concentric but not complete.
3) In elongated galaxies the shells will alternate with radius, if the galaxy is elongated North South and the innermost shell lies on the northern semi axis, then the second shell will be to the south, the third to the north, the fourth to the south, and so on.
4) Shell galaxies tend not to occur in clusters or rich groups of 13 shell galaxies classified as T = -5 or -4 by the second reference catalogue (de Vaucouleurs et al. 1976, hereafter RC2) only one lies in what RC2 calls a group, whereas 40% of all ellipticals lie in rich groups or clusters. Of the 137 shell galaxies in our prime sample only five (including NGC1316 and

M. Capaccioli (ed.), Astronomy with Schmidt-Type Telescopes, 389–392.

IC4329, neither of which is classified as an elliptical by RC2) lie in clusters

5) Of the isolated ellipticals in RC2 we detect shells around 12 (16.5%).
6) Of the 137 galaxies in our prime sample only two, NGC1316 and NGC5128, are coincident with radio sources in the Parkes catalogue. This is a smaller number than would be expected of a similar sample of randomly chosen ellipticals. Shell galaxies are not radio sources.
7) Sensitive searches of a small sample of shell galaxies have revealed no strong emission lines, and, with one exception no neutral hydrogen. The exception is NGC2865 which does show a considerable quantity of H I.
8) BVRJH colours for the outer shell of NGC1344 (Carter, Allen and Malin 1982) look like those of stars of spectral types G to K, but there is evidence that the shells are bluer than the parent galaxy.

THE NATURE OF THE SHELLS

Two classes of model have been proposed to account for the observed properties of shells; models in which stars are formed in a galactic wind (Fabian, Nulsen and Stewart 1980); and models in which a small, dynamically cold galaxy falls in to the more massive parent elliptical. Although, as Fabian et al. have pointed out, the mass function of stars which would be formed in a galactic wind is essentially unknown, we feel that the colours of the outer shell of NGC1344, together with the detailed agreement of the dynamical models with the observed properties, favour these models over the stellar wind models. Accordingly I will discuss the dynamical models in more detail.

It is clearly a problem for a model of a collision to produce as many features as sharp edged as we see; in NGC3923 for example we can identify between 19 and 23 separate sharp edged shells. For the features to be sharp edged the galaxy which falls in must be very cold, any velocity dispersion will tend to smear out the features. Another problem encountered by the models is that the number of particles in an n body simulation is limited to maybe 1000 by the available computer time, and it is rather difficult to simulate 20 sharp edged features with only 1000 particles.

Two distinct processes have been suggested to account for shells. The first is due to A. Toomre, and is described by Schweizer (1983). In this process the disc galaxy falls in on a non radial orbit and wraps spatially around the centre of mass of the elliptical. The disc galaxy forms arcs when viewed from out of the orbit plane of the disc. The structures do not resemble the shells seen in galaxies such as NGC3923 and NGC1344, being confused and sometimes overlapping, but they may resemble the structure seen in NGC1316 and NGC5018 (Fig. 1).

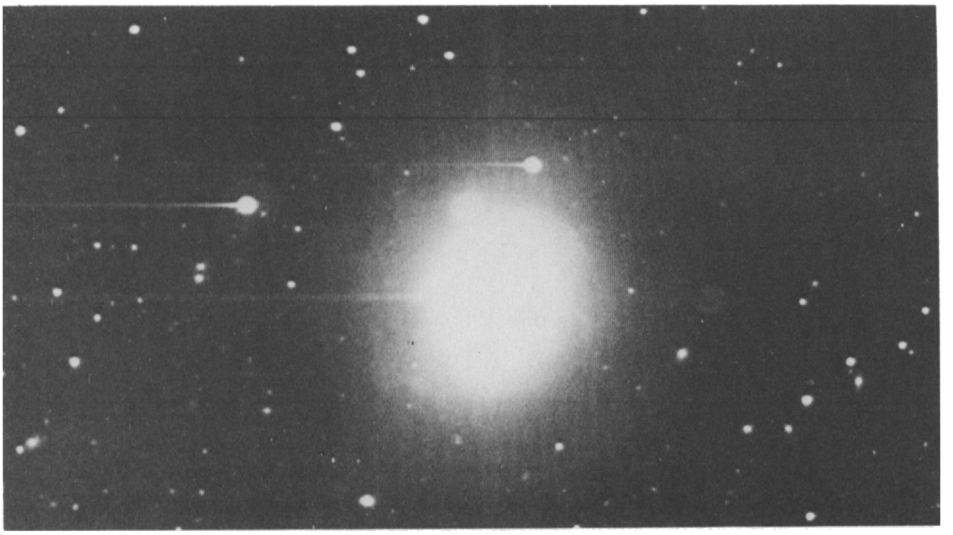

Fig. 1 NGC 5018. A galaxy with shells and dust. This is a CCD image at 5200 Å from the Canada-France-Hawaii Telescope.

The second process is due to Quinn (1982, 1983), who discusses radial encounters between disc galaxies and a potential well representing an elliptical. In Quinn's process wrapping takes place in phase space, which can be illustrated for a one dimensional system, and the maximum spatial excusion of each phase wrap at a particular time produces a sharply defined density maximum. The density maxima are radially propogating density waves, and the outer shells are the first to form. These models, although limited by the number of particles it is possible to reproduce many of the observed features of shells, specifically the density maxima are interleaved in the manner we observe in the elongated shell galaxies, such as NGC 3923 and NGC 1344

FURTHER WORK

With Dr. B. P. Fort of Toulouse Observatory I have begun a project to obtain much better colours for some shells, we obtained images in four passbands with a CCD on the Canada-France-Hawaii Telescope, an example is shown in Figure 1. The colours will tell us about the galaxy which has fallen in, and possibly about the merger process itself.

Quinn (1983) has pointed out that shells may well tell us about the potential of an elliptical. At present we are limited by the small size of the sample for which detailed observations are possible, but only a third of the sky has been surveyed to deep enough levels to uncover these features, and we hope that the SRC equatorial and Palomar

https://doi.org/10.1017/S0252921100106931 Published online by Cambridge University Press

northern surveys will increase our sample by a factor of three or so.

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DISCUSSION

T. SHANKS: If the dynamical model is correct, why do we see no residual gas from the disk galaxy?

D. CARTER: In some cases we see dust. The galaxy which is swallowed probably has to be of very low gas, so perhaps all of the gas is used up in a short time, whereas the shells last longer. NGC 2865 does have quite a lot of neutral hydrogen.

W.P. BIDELMAN: What is wrong with the simple-minded idea that your shells are just remnants of spiral (or circular) arms that the elliptical galaxy might have once possessed?

D. CARTER: Shells are concentric, also they have sharp outer edges which suggest a spherical structure seen in projection. Nevetheless there are galaxies with weak spiral arms, and at a distance it is difficult to tell them from shell galaxies, but we try to throw them out of our sample.

J.-L. NIETO: About the possible relations existing between outer parts and inner parts of galaxies, we have preferentially geometry changes in shell elliptical galaxies.

D. CARTER: The sample of shell galaxies for which we have data on the inner parts is very small, one shows a clear isophote twist and some have dust lanes, but the numbers are not statistically significant.