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A Study of Shell Profiles

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Abstract. High signal to noise images have been obtained of a large sample of shell galaxies. We examine the photometric profiles of the shells of two galaxies from this sample at small and large radii in order to understand the dynamical history of the shells themselves. The shape of the profiles permit estimates of the cone angle of the shell thus enabling a three dimensional reconstruction of the shell feature to be made.

1. Introduction

Shells are giant arcs of stars which exist within and around the envelopes of many elliptical and lenticular galaxies (Malin & Carter 1983). Observed shell systems are diverse in appearance ranging from the spectacular, *e.g.* NGC 3923 (Prieur 1988) and NGC 474 (Figure 1), to the more common instances containing a few marked shells (Forbes & Thomson 1992). There is a strong connection between shells and kinematically distinct cores (KDC's): Forbes (1992) finds that all of the nine well established KDC's and a further 4 out of the 6 possible KDC's in his sample contain shells.

Merger models (Quinn 1984; Heisler & White 1990 and references therein) form shells from the phase and/or spatial wrapping of stars torn from a companion galaxy. They are also consistent with suggested explanations for the formation of KDC's (Balcells & Quinn 1990). Prieur (1990) and Carter (1998) have reviewed the merits of competing models of shell formation involving transient interactions (rather than mergers) and gas dynamical processes.

Previous work on shell profiles has focused on differentiating between shells formed from phase or spatially wrapped material (Prieur 1988). Simply put, for a razor-thin shell resulting from space wrapping, the shell surface brightness should decrease as $x^{-0.5}$ just interior to the projected shell edge (where x is a radial coordinate measured inward from the edge). In phase wrapping, the radial density distribution would increase asymptotically as $x^{-0.5}$ as the edge is approached leading to a *projected* plateau in surface brightness.

2. NGC 474 and NGC 7600

Here we briefly present work on the galaxies NGC 474 and NGC 7600. The morphology of these galaxies and their shell systems (including a discussion of the relative colors of the shells) is described in detail by Turnbull, Bridges & Carter (1999). Both were imaged on the Issac Newton Telescope, La Palma and

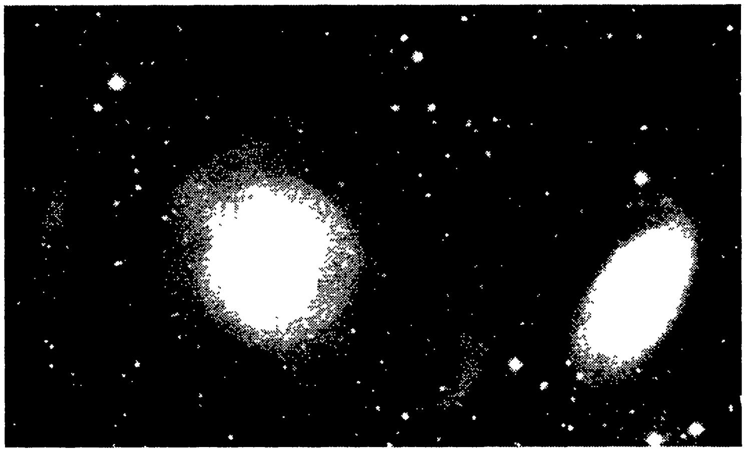

Figure 1. NGC 474 (left) and NGC 470. Note the rich shell system around NGC 474. North is up and east to the left. NGC 470 is located ~ 300 arcseconds west. For reference to Figure 3: shell e is located 100 arcseconds to the north east of the galaxy center, shell c is located 140 arcseconds to the south. (Image kindly supplied by Duncan Forbes.)

total integration times were 2700 seconds per galaxy in the R band with a chip scale of 0.59 arcseconds/pixel. The seeing was ~ 1.5 arcseconds.

After standard IRAF reduction procedures we took our combined frame and cleaned it of obvious features such as stars and globular clusters using PATCH in the Starlink image tool GAIA. We were careful to ensure this did not introduce artificial smoothness to the profiles. Using the package ELLIPSE we produced a model subtracted galaxy and obtained an accurate galaxy center. The profiles were produced by placing a curved bounding box around each shell, the angular size of which fixes the maximum number of independent profiles. Each profile can be examined individually and a mean profile produced. Observed profiles for NGC 474 and NGC 7600 can be viewed in Figures 3 and 4 respectively.

Figure 3 shows three representative shell profiles of NGC 474. Profiles 3a and 3b are suggestive of spatially wrapped shells. The shape may be compared with the model profile (Figure 2) allowing an estimate of the shell's angular extent out of the plane of the sky; in this case ~ 60 degrees. Profiles 3a and 3b are two ends of the same shell. On the counter side of the galaxy however, profile 3c has a plateau-like appearance. The shell system of NGC 474 is complex perhaps as a result of repeated interaction with NGC 470.

NGC 7600 has a regular interleaved shell system aligned along the apparent major axis of the galaxy. Two of the brighter shell profiles are shown in Figure 4. A small plateau is not ruled out based on the S/N of the observations, and based on the models for phase wrapped shells (Figure 2) it seems likely the shells are correspondingly narrow in the plane out of the sky.

3. Conclusions

Shell profiles are a useful diagnostic in uncovering galactic history. A more detailed treatment probing the release of stars in the (unsteady) potential of

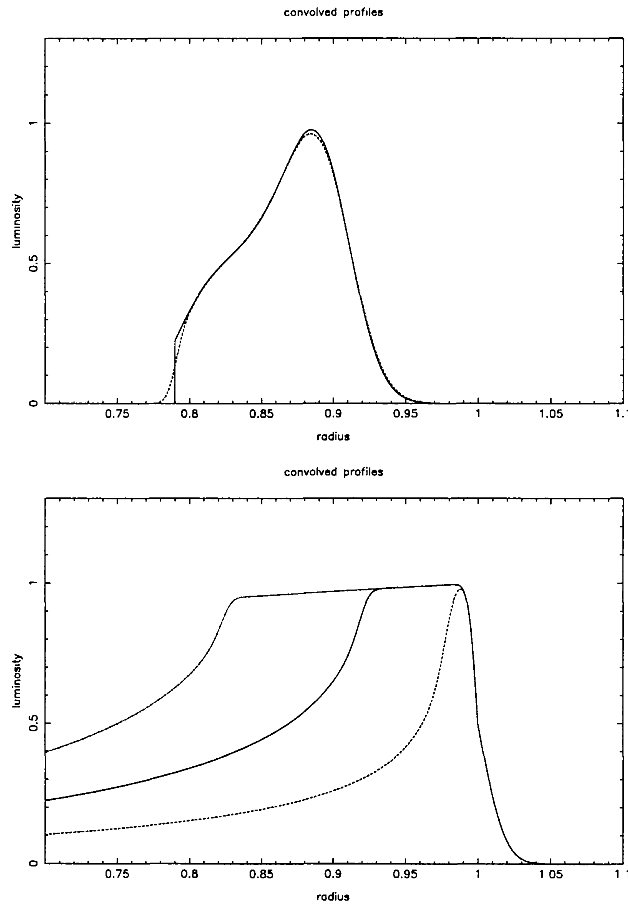

Figure 2. A model spatially wrapped shell consisting of a seeing-convolved Gaussian stream is illustrated in the top panel. The lower panel shows phase wrapped shells for a monoenergetic distribution of stars enclosed in a horn. The horn opening angles are 0.2, 0.4 and 0.6 radians. The radii are measured from center of the bounding arc.

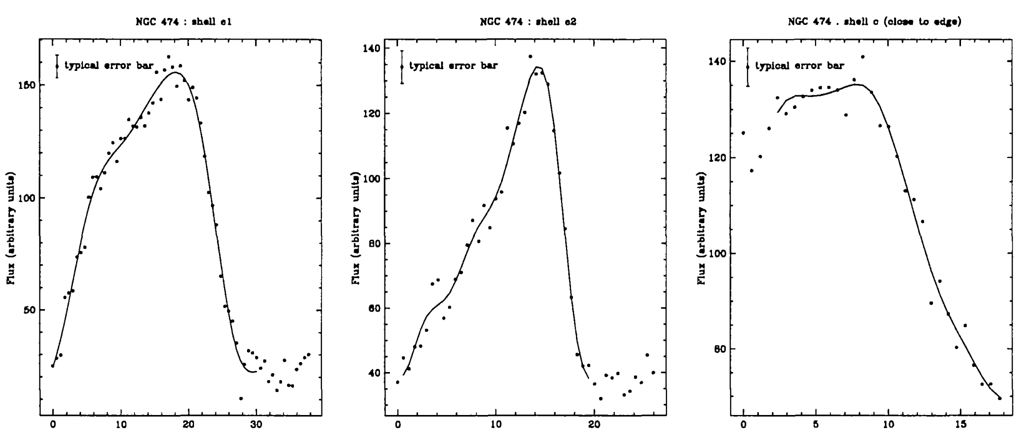

Figure 3. Three representative shell profiles from NGC 474 (3a,b,c from the left) obtained in the R band. The radii are measured in arcseconds across the width of each individual shell.

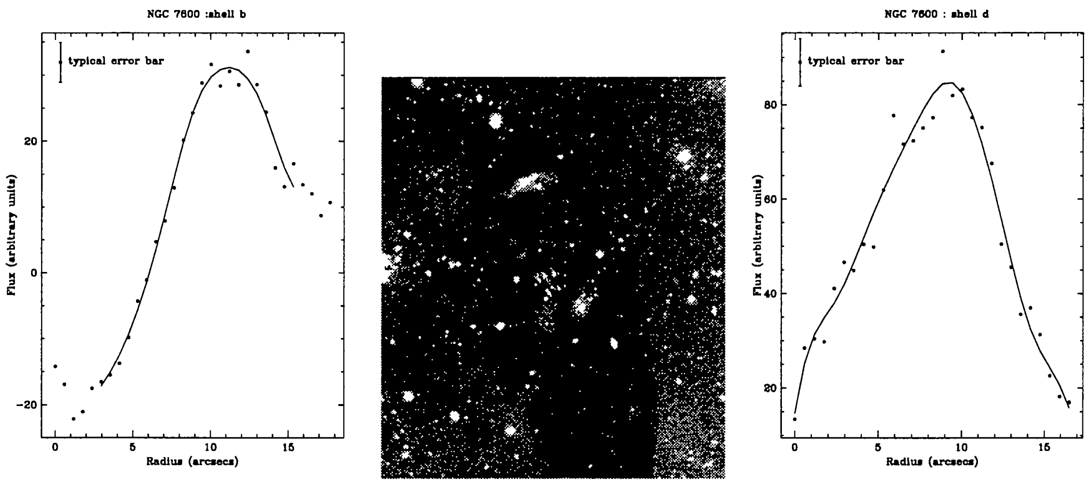

Figure 4. Two representative profiles from NGC 7600 together with a model subtracted image of the galaxy. Radii are measured in arcseconds across the width of each individual shell.

the primary and the subsequent evolution of the shells is contained in Collett & Turnbull (1999).

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