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Pattern corotation radii from potential-density phase shifts

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The particular type of azimuthal potential-density phase shift distribution existing in spontaneously formed density wave modes provides a new approach for locating corotation resonance radii for density wave patterns in galaxies. This approach also sheds light on the validity of the modal view of the density wave perturbations in galactic disks.

Keywords: Galaxy structure; Galaxy evolution; Density wave theory; Collective effects

1 Introduction

The most important wave-particle resonance in disk galaxies is the corotation resonance (CR), where the pattern speed of the density wave equals the angular speed of the rotation of the stellar disk. We have previously shown [1] that CR for a wave mode may be located using an azimuthal potential-density phase shift distribution whose radial dependence is of a positive-hump followed by a negative-hump type of distribution with zero crossing occurring at CR, which is expected for any spontaneously-formed density wave mode possessing a bell-shaped radial angular momentum flux. This particular shape of the potential-density phase shift distribution is predicted both by Poisson's equation and by the equations of motion. Because these two types of calculation for a single galaxy need to give consistent predictions for the potential and density of a self-sustained density wave, infrared images alone can be used to locate phase shift-determined CR radii through solving the Poisson integral alone.

The Zhang–Buta (ZB) approach is based on the theory of Zhang [2], who, in contrast to Lynden-Bell & Kalnajs [3], showed that quasi-stationary density wave modes can induce significant secular evolution of the mass distribution of *both the stellar and gaseous content* in the basic state of the galactic disk. This process leads

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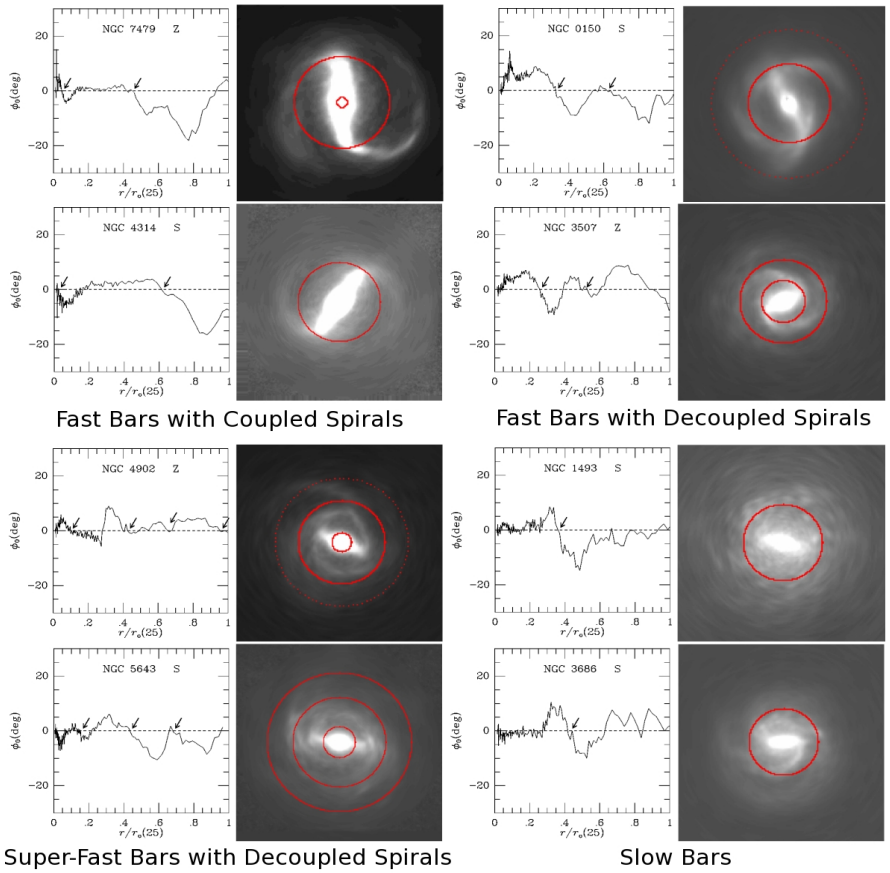


Figure 1 Montage showing examples of bars in different categories. Fast bars with coupled spirals are cases where the bar and spiral probably have the same pattern speed. Fast bars with decoupled spirals are cases where the bars extend to near their CR radius, but the spiral has a different CR radius. Super-fast bars with decoupled spirals are very unusual cases where the CR of the bar is likely to be well inside the ends of the bar. Slow bars are cases where the bar ends well inside CR. The deprojected images are due to [6].

to the growth of bulges and and the morphological evolution of galaxies along the Hubble sequence. To enable the participation of the otherwise adiabatic stars in the secular evolution process requires the presence of spontaneously-formed spiral and bar modes, because the azimuthal potential-density phase shift in such modes leads to a collective dissipation process that enables the exchange of angular momentum between the wave mode and the basic state, which slowly transforms a galaxy's morphology.

Near-infrared images can be used to measure the phase shifts because such images trace the stellar mass distribution better than do optical images, and may be used to calculate the gravitational potential. Buta & Zhang [4] have made such calculations for 153 OSUBGS galaxies, a statistically viable sample limited to $B_T < 12.0$ [5]. The basic assumptions are that the near-IR mass-to-light ratio is either constant or variable based on broadband colors, the vertical scale height is a type-dependent

fraction of the radial scale length, and that galaxies can be deprojected using the shapes of outer isophotes. As shown by [1], M/L assumptions have little impact on the results.

The basic rule for identifying a CR radius using the ZB method is that a region of positive phase shift (P) must be followed by a region of negative phase shift (N). CR is identified as the positive-to-negative (P/N) crossing. Figure 1 shows phase shift plots for eight galaxies belonging to different morphological and kinematic categories, with the CR locations (arrows) plotted as circles on H-band images. Full details are provided by [4].

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