DYNAMICAL MECHANISMS FOR DISCRETE UNSTABLE SPIRAL MODES IN GALAXIES

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Progress in understanding physical mechanisms for the excitation and maintenance of spiral structure has considerably benefited from investigations of tightly wound spiral density waves (e.g., see Bertin 1980). These studies have identified the existence of four basic kinds of density waves (trailing and leading waves, and in each case short and long waves) with different propagation properties. In addition, they have led to the conclusion that some realistic galaxy models can support self-excited global normal spiral modes. These owe their maintenance to the presence of trailing waves with opposite propagation properties and are excited mostly as a result of a WASER (superreflection) mechanism at corotation. In discussing the dynamics of spiral structure and in comparing theory with observations a number of important issues should be kept in mind (Lin and Bertin 1981). Here we just recall that the calculation of spiral modes is being pursued by many researchers, using different methods. In general the structure and the growth rates of the dominant modes are determined by the radial distributions of the active disk density, the differential rotation, and the dispersion speed through the dimensionless functions ε_o, j, and Q (Haass, Bertin and Lin 1982).

Analytical methods of investigation, based on certain asymptotic studies of properties of steady wave trains, prove to be very useful tools in understanding the physics of spiral modes. In the Figure we show propagation diagrams and density contours for two different regimes, one typical of normal spiral modes and the other characteristic of certain barred spiral modes. The difference in the regimes of the basic parameters is clearly reflected in the change of topology of the propagation diagrams. This in turn results in the different structure of the first two-armed mode. The relevant channels for wave reflection, wave refraction, and WASER are well illustrated in the diagrams (upper frames) which "diagnose" the numerically computed modes (lower frames). The main new result presented here is contained in the right frames, where we have tested an analytical model for barred modes. In the regime of higher Q and j considered, a new asymptotic analysis reveals the possibility of a WASER of type II (to be distinguished from

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the WASER of type I, found by Mark, which operates in the regime illustrated in the left frames). This mechanism is characterized by a leading wave impinging on corotation and producing an amplified trailing wave traveling back to the galactic center and a transmitted trailing wave which is eventually absorbed in the outer regions. The same asymptotic analysis reveals the possibility of a "reverse swing" close to the galactic center which completes the loop necessary for the maintenance of the barred spiral mode. For the case shown, there is quantitative agreement between the structure and the growth rate of the mode computed numerically and the predictions of our simplified analytical model based on a local dispersion relation. The equilibria investigated and the modes shown are part of an extensive exploration made by Haass (1982).

Clear results for extreme regimes, such as those presented above, encourage us to extend and apply concepts borrowed from asymptotic analysis to interpret more complicated transition cases. In this regard power spectra (Haass, Bertin and Lin 1982) and propagation diagrams are very useful and indicate that all different kinds of waves and loops participate in the structure of transition modes. Studies of this kind can form the basis for a dynamical approach to the classification of spiral galaxies.

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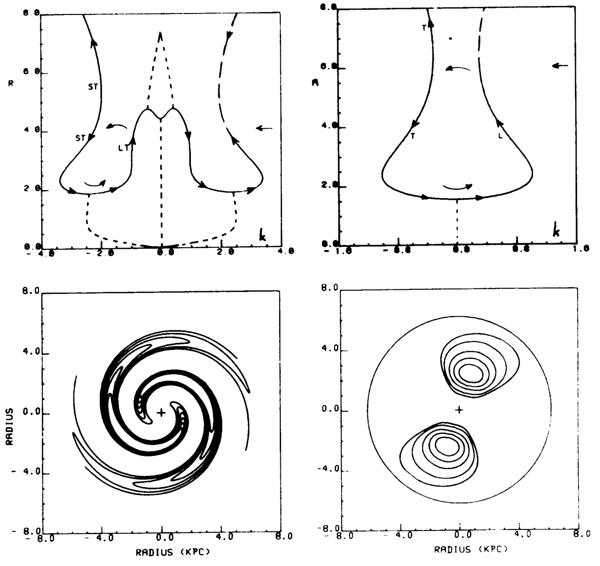

Propagation diagrams (upper frames) and density contours (lower frames) for a normal spiral mode (left) and a barred spiral mode (right).