The details of this work, together with the role of $J$ in the growth of spiral modes, will be given in a forthcoming paper (Lau and Bertin, in prep.).

LIN: You might have added that for large values of $J$, one needs a higher value of $Q$ for stability.

W.W. ROBERTS: GALACTIC SHOCKS IN OPEN-ARMED NORMAL SPIRALS AND BARRED SPIRALS

In the steady state gas dynamical studies of the late 1960s (Fujimoto, 1968, I.A.U. Symp. No. 25, 435; Roberts, 1969, Ap.J. 158, 123) the dark dust lanes, which are observed along the inside edges of spiral arms, were identified as tracers of large-scale galactic shock waves which form in the gas. Thought also to be tracers of the shock phenomenon were the strikingly narrow and rather straight dust lanes often observed along the leading edges of the bar structures in barred spirals (see Lin, 1970, I.A.U. Symp. No. 38, 377). More recent two-dimensional, time dependent, numerical hydrodynamical calculations have been carried out by Sorensen et al. (1976, Ap.Sp.Sci. 43, 491), Sanders and Huntley (1976, Ap.J. 209, 53), and Huntley et al. (1977, in prep.) for the response of rotating disks of gas to bar-like perturbations in galactic gravitational fields. All of these time-evolutionary calculations evolve through a state in which the viscous, differentially-rotating disk of gas forms a central gas bar with two trailing spiral waves and exhibits features resembling shocks.

Here, in cooperation with J.M. Huntley and C.C. Lin, we discuss an approach in which we have been able to generalize the steady state gas dynamical studies for tightly-wound normal spirals to include normal spirals with open spiral arms and barred spirals with prominent bar structures in the inner parts. The response of the gas to a barred spiral-like perturbation, for example, is calculated by means of an analysis which enables the two-dimensional flow to be broken up into two physical regimes. In regime I where the gas flow is highly supersonic, the flow is determined through an asymptotic approximation that neglects secondary terms proportional to the square of the dispersion speed, such as the transverse gradient of pressure. In Regime II near and within the bar (and spiral arms) the flow is determined through an asymptotic approximation that neglects the small variation of the velocity, density, and pressure along a shock with respect to their variation normal to the shock. The composite picture for the steady state flow of gas is constructed by joining the two regimes of flow in the transition layer between regimes.

This composite picture is illustrated for one case, model A, in Figure 1. Arrows on two of the gas streamlines (left panel) indicate the clockwise sense of gas circulation about the disk and through the shocks (----) which form near the potential minimum (----) of the barred spiral perturbation. A photographic simulation (right panel) of the gas density distribution illustrates the strong compression of the shock on the inside edge of each gas arm.

Figure 2 illustrates the corresponding results for a second case, model B, in which the flow equations contain a "friction type" term
that simulates "gaseous friction" in the inner parts of the disk. The forward shift of the shock onto the leading edge of the bar in model B produces an offset similar in some respects to the offset exhibited by the dark dust lanes observed on the leading edges of bars.

ALLEN: Did I understand correctly that your model has a gas density contrast between the arms and the interarm regions of about 20?

W.W. ROBERTS: Yes, that is correct.