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Galaxies in Collision: The Formation of Rings and Arcs

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Ring galaxies offer a unique laboratory for the study of density-wave, shock-induced star formation. The passage of an intruder galaxy through the gaseous disk of the host galaxy, roughly perpendicular to the disk plane, produces an outwardly propagating density wave which, at its simplest, for passage almost through the center, takes the form of a ring. In this structure the density can be increased by a factor of ten and strong shocks are formed in the gas where expanding material from the inner disk collides with outer disk material which is still falling inwards in response to the passage of the intruder. When the impact parameter of the collision is approximately 25% of the radius of the disk or larger an expanding and rotating arc of high density is produced in the stars and gas. Both rings and arc structures have been observed in galaxies with nearby companions and they are often associated with regions of intense star formation. A detailed comparison between observations of such systems and numerical modes provides an opportunity to deduce the probable conditions and timescales for star formation in these galaxies, the chemical evolution resulting from the collision, and the detailed dynamics of the two galaxies involved.

We present some results from a series of numerical experiments in which we have produced combined stellar and gas dynamical computer models of colliding galaxies. Using a combined N-body/(SPH) hydrodynamics code we follow, through their first passage, the collision of a spherical, gas-free elliptical with a galaxy containing both a disk of gas and stars and a roughly spherical, live halo of stars and dark matter. Both galaxies are rotating. The three dimensional calculations performed with 50 000 N-body (star) particles and 20 000 SPH particles (representing the gas) on a Cray 2 computer show complicated structure in the direction perpendicular to the plane of the disk, and indicate that star formation may be triggered in two concentric rings in the case of nearly head-on collisions and near the tips of the high-density arcs in the case of off-center collisions. A detailed comparison of one of our models and the Arp 147 system which contains a galaxy with an incomplete ring in its disk (Gerber et al. , Ap. J. Lett. , 399, L51-54, 1992) indicates good agreement between model and observed properties, and allows an examination of some of the generic features of this type of collision.