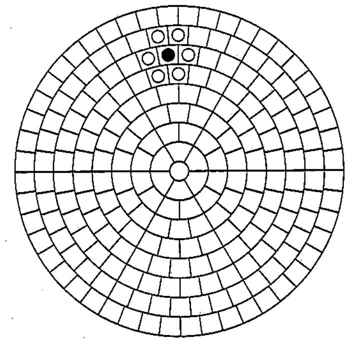

Figure 19.1 The nature of the polar grid used in `GalaxyApp`. Each cell has the same area and six nearest neighbors on the average. The filled circle denotes an active region of star formation. At the next time step, it can induce star formation in cells containing open circles. As time passes, the neighbors in adjacent rings change because of differential rotation.

theory of *self-propagating star formation* is based on the importance of this mechanism. Rather than determining which regions have the necessary conditions for star formation, we summarize all the uncertainty and variability in a single parameter p, the probability that a supernova explosion in one region gives rise to star formation in a neighboring region.

The other important observation we need to make about spiral galaxies is that galaxies do not rotate rigidly (with a constant angular velocity), but to a good approximation each region rotates with the same tangential velocity. The properties of random self-propagating star formation and constant tangential velocity are incorporated into `GalaxyApp` as follows. Imagine dividing a galaxy into concentric rings which are divided into cells of equal size (see Figure 19.1). Initially, a small number of cells are activated. Each cell corresponds to a region of space that is the size of a giant molecular cloud and moves with the same tangential velocity v. The angular velocity is given by $\omega = v/r$, where r is the distance of the ring from the center of the galaxy. At each time step, the active cells activate neighboring cells with probability p and then became inactive. Then the rings are rotated, and the process is repeated again in the next time step. At each time step, cells that have been active within the last 15 time steps are displayed as filled boxes, with the size of each box inversely proportional to the time since the cell became active. More details of the simulation are shown in Figure 19.1 and in the program. A typical galaxy generated by `GalaxyApp` is shown in Figure 19.2.

Our brief discussion of galaxies is not meant to convince you that the mechanism proposed by Schulman and Seiden is correct. Rather our purpose is to show how an alternative point of view can suggest new approaches in different fields. The images produced by computer simulations of the galaxy model show unanticipated features and have been the impetus for further studies by astrophysicists and astronomers.

19.3 ■ NUMBERS, PRETTY PICTURES, AND INSIGHT

The power of physics comes in part from its ability to give numerical agreement between theory and experiment. However, numerical agreement has little significance unless this agreement leads to insight into the phenomena of interest. For example, it is possible to

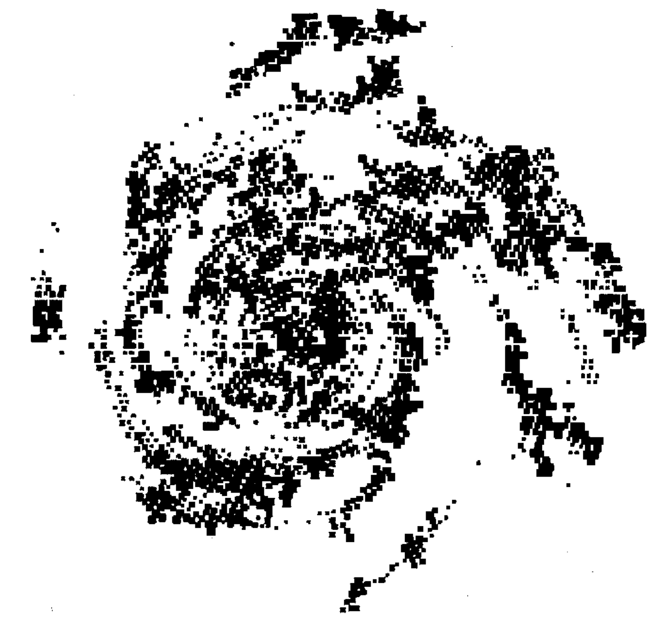

Figure 19.2 A typical structure generated by `GalaxyApp`. The parameters are the number of rings, `nring` $= 50$, the initial number of active cells, `nactive` $= 200$, the circular velocity $v = 1$ (200 km/s), the probability of induced star formation $p = 0.18$, and the time interval `dt` $= 10$ (10^7 years). The structure shown is at $t = 2720$ with 393 active star clusters. The diameter of the circle representing a star cluster is proportional to the remaining lifetime of the cluster.

design elaborate epicycle models of planetary motion that yield numerical results which are consistent with observations. Nevertheless, we prefer the Copernican approach, not for its impressive numerical success, but because it provided insight and lead to further advances by Kepler and Newton.

Computer simulations raise similar questions. The numbers produced by simulations, which are consistent with experimental observations, and the pictures that are suggestive of physical phenomena are not sufficient to establish the value of a simulation. As an example, let us briefly consider a simulation of river networks. You might have seen aerial photographs of the Earth's topography and the fractal-like drainage patterns formed by many rivers. A variety of random walk models can generate patterns that look remarkably like river networks and even share some of their statistical properties. In these models the path of a walker represents a river, and the branching and intersections of rivers are modeled by the intersection of the paths of many walkers. However, because models do not directly incorporate the important physical processes of erosion and sedimentation, they do not provide much insight.

Leheny has proposed a lattice model whose dynamics reflect actual physical processes. The model consists of first creating a terrain for the network and then defining the network on the terrain. The model can be summarized as follows:

1. The initial terrain is assumed to have a constant slope m. Each site of the lattice is given an initial height, $h(x, y) = my$.