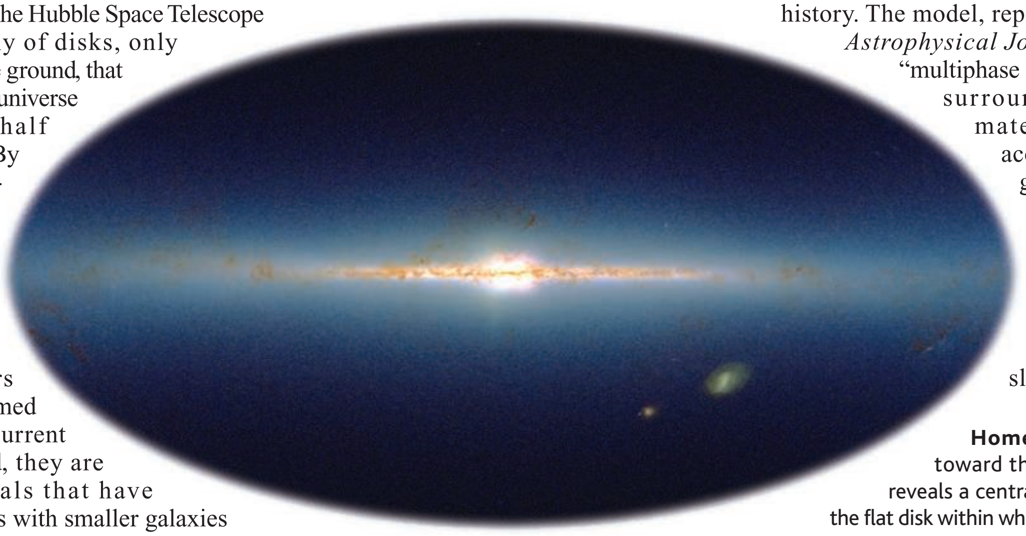
NEWS

# As the Galaxies Turn

**Spiral disk galaxies, serene icons of the universe, are hardy survivors of a battering cosmic history**

Gravity conspires to produce two dominant shapes in astronomy: spheres and disks. Both are on display in spiral galaxies, home to perhaps half the stars in the universe. Spherical central bulges of old yellow suns glow serenely, girdled by a disk consisting of curved arms of hot new stars and dark bands of dust. Such grand stellar disks, long the pinups of astronomy buffs, now play a starring role in studies of how galaxies have evolved.

Surveys with the Hubble Space Telescope reveal a panoply of disks, only hinted at from the ground, that existed when the universe was less than half its current age. By dating and classifying this huge population, astronomers are recognizing that spiral galaxies are not delicate flowers that have blossomed slowly to their current display. Instead, they are tough perennials that have survived mergers with smaller galaxies and—on occasion—crushing collisions with big ones throughout billions of years of cosmic time.



**Home.** An infrared view toward the Milky Way's core reveals a central bulge of stars and the flat disk within which we live.

CREDIT: IPAC/CALTECH/2MASS/NASA

In our edge-on view of the Milky Way's plane, we gaze upon just such a stalwart bisecting the night, one that undoubtedly consumed other galaxies. The Milky Way's disk provides clues to this history, but the sleuthing is tough because we're embedded within it. "We have an opportunity to understand it at a much deeper level than other galaxies, because we can measure the motions of individual stars," says astronomer Heidi Jo Newberg of Rensselaer Polytechnic Institute in Troy, New York. "But we're really just starting."

### It's all in the gas

The disks we see today took a long time to develop. "Almost all star formation was in clumps and chaotic structures" for roughly the first 4 billion years of cosmic history, says astronomer Sidney van den Bergh of the Dominion Astrophysical Observatory in Victoria, British Columbia. But during the next 1 billion to 2 billion years, recognizable features started to form under the inexorable pull of gravity.

Astronomers believe that a typical primitive galaxy was a bloated cloud, slowly rotating and rich in warm gas that had not yet coalesced into many stars. Energy escaped from the cloud as atoms and molecules collided and radiated light. Gravity pulled the cooling gas more tightly together, forcing more frequent collisions, but it would have kept its original angular momentum. As time marched on, the fledgling galaxy flattened and spun faster and faster.

"The final state of a runaway collapse is a thin disk where all particles go in exactly circular orbits," says astrophysicist Julio Navarro of the University of Victoria, British Columbia. But a galaxy isn't an idealized whorl of gas, he notes: "When the gas collects into tiny little packets of stars, you get a collection of bullets that never collide." Without energy-robbing collisions, a star-filled disk cannot settle down if it gets perturbed by another young galaxy plunging into it—a common event in the cosmic past. Instead, stars tend to scatter into spherical swarms, like a disturbed hive of bees.

This is exactly what happened when astronomers constructed computer simulations of evolving galaxies dominated by stars. "Disks are very fragile, dynamical entities. Mergers mess them up," Navarro says. But if mergers and collisions were so common in the early universe, why don't we see the sky full of formless elliptical galaxies?

The influence of gas is the key, Navarro and others now agree. Effervescent gas would have damped out the otherwise shattering effects of major mergers. Adolescent galaxies could have kept gas stirred up in plenty of ways: intense ultraviolet light from massive newborn stars, shock waves from supernova explosions, or outpourings of energy from vigorous cores.

Recent simulations have shown this damping effect of gas in action. For instance, a team led by graduate student Brant Robertson of Harvard University in Cambridge, Massachusetts, produced one of the first realistic disk galaxies in a simulation that spans cosmic history. The model, reported in the 1 May *Astrophysical Journal*, relies on a "multiphase gas" of cold clouds surrounded by hotter material, which more accurately captures a galaxy's interstellar environment. This hybrid recipe preserves gas during mergers and stabilizes the disk against external onslaughts, Robertson says. The approach works, but it's only a start: Just 1 of 20 simulated galaxies ended up with a flat pinwheel of stars and gas, compared with about half in the real universe. Improved models may need to churn up the gas even more with early bouts of star formation, other researchers believe.

And in new work submitted to *Astrophysical Journal Letters*, two of Robertson's co-authors demonstrate that a classic spiral galaxy can emerge even from the wreckage of a violent collision. Astrophysicists Volker Springel of the Max Planck Institute for Astrophysics in Garching, Germany, and Lars Hernquist of Harvard plowed two simulated gas-rich disks into each other. The concussive impact sparked a blaze of star birth, but enough gas remained to settle the merged object into a flat superdisk with clear spiral arms. "If disks can 'survive' even major mergers, they are probably less fragile than previously thought," the researchers write.

### Forty thousand personalities

Simulations are an alluring way to peer back to galactic youth, but nothing beats the real thing.