effect of the whirling motion.

However, the storm also generates an outward pressure; this force expels the gas but has little influence on the movement of the solid dust particles. Thus, argue Adams and Watkins, some types of vortices can rapidly separate the raw materials for a Jupiter or a Saturn into a rocky core and a gas-rich exterior.

"If you have just gravity acting, there's no way to segregate heavy elements — the rocks — from the gas," says Adams. "You need a further mechanism...and we suggest vortices can do just that."

Adams notes that even those vortices that fail to produce a planet may play a leading role in the evolution of the star at the disk's center. When vortices take shape, the friction created as neighboring layers of the rotating disk rub against each other robs the disk of angular momentum. This slows the disk's rotation, hastening its gravitational capture by the young, sunlike star at the center. The vortex motion may thus explain why disks around young stars don't survive for very long, Adams says.

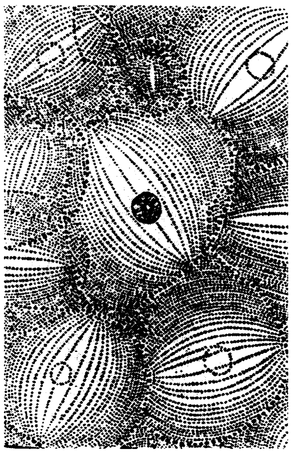
Douglas N.C. Lin of the University of California, Santa Cruz, says he finds the study intriguing but notes several caveats. "It's interesting work, but it's not yet fully developed," he cautions.

Lin observes that the kind of vortex Adams and Watkins propose has orderly internal motion, like a well-behaved merry-go-round. In fact, he says, the typical storm system, like the Great Red Spot, contains all kinds of tiny whirlpools and eddies. In such a complex, real-life system, dust may not migrate to the center of the vortex, a key aspect of the planet-forming theory.

He adds that the standard picture of the formation of the solar system explains neatly why the inner planets are mostly rock and many of the outer planets have massive atmospheres. The outer planets presumably formed in the more distant, chillier parts of the solar disk, where gas pressure is lower. The lower pressure allows the gravitational pull of a rocky core to capture more gas at the outskirts of the solar disk than it could closer to the center.

In contrast, the vortices envisioned by Adams and Watkins would occur at random, with equal probability everywhere in the disk, Lin says. Thus, their model can't explain why the gas giants formed only in the outer part of the solar system.

Adams responds that although vortices can indeed be generated anywhere in the solar system, they may form more readily and grow larger in the outer reaches. He notes that planet formation may require a combination of vortices and the standard method of accumulating gas and dust into planetesimals.



Heavenly bodies emerge from celestial vortices in this drawing by Gabriel Daniel, an interpreter of the ideas of Descartes. Vortex pattern is from Daniel's 1692 book, A Voyage to the World of Cartesius.

In an independent study, Adams and Willy Benz of the University of Arizona in Tucson consider the earliest stage of star formation, when the amount of material in the disk is comparable to the mass of the fledgling star. During this era, they note in their unpublished work, density variations in the disk can create knots of gas that orbit the immature star.

An orbiting knot typically contains about 1 percent of the mass in the disk. If this tiny companion grabs an appreciable share of the matter that has yet to rain down on the embryonic star, it might evolve into a giant planet — or even become a star in its own right. Adams and Benz note that many stars seem to be born in pairs. Their model, they say, offers an explanation of how a single star and its disk could fragment into two. □

Continued from p.243

Second, the inconsistencies between studies that see the association between symmetry and fitness (heterozygosity) versus those that don't often relate to whether or not the individuals developed under stressful conditions. The greater the stress, the greater the differences in symmetry between individuals with high or low levels of heterozygosity.

Michael C. Grant
Jeffery B. Mitton
Professors, Department of Environmental, Population, and Organismic Biology
University of Colorado
Boulder, Colo.

I recently bumped my nose, apparently bending it slightly. My wife suggested that, being slightly more asymmetrical, I must therefore be a slightly less desirable mate. While I immediately rejoined that the articles indicate asymmetrical males invest more energy in their primary relationships, I'd like to see more evidence before recommending that my male students wear two earrings instead of one — or before I start parting my hair in the middle.

Daniel Berleant
Fayetteville, Ark.

Quantum Musings

The problem of keeping the integrity of a quantum state ("Quantum Bits," SN: 1/14/95, p.30) has a possible solution: Use solitons.

As the energy state of a quantum system is changed to indicate a computational result, a soliton can be generated to represent that state. Solitons are remarkably robust, and the "memory" function can be implemented in a number of ways, including the use of what are referred to as "soliton mirrors."

While the soliton is considered a rather exotic phenomenon, it will take many *seemingly* exotic solutions to allow a quantum computer to be built.

Michael B. Shepperd
Livermore, Calif.

What gives a quantum computation its advantage over a classical computation is its ability to make use of quantum superpositions. However, all classical error-correcting methods will force some observation of the state of the computing device that, if done on a quantum computer, will collapse the superpositions.

Our scheme was specifically designed to get around this problem. We stabilize a quantum computation without destroying the superpositions. Thus the statement that our scheme is "nearly wiping out any advantages quantum computation may have" is incorrect.

Furthermore, our scheme is not "inefficient." The results we presented at the Dallas Workshop on Physics and Computation showed that, at least in a simple case, when it was possible to use either a classical majority vote or our scheme followed by a final majority vote, the latter offered significantly better error-correcting capability.

Implementing our scheme may be difficult, but from the theoretical point of view, it shows that quantum error correction is possible and thus opens the way for finding better (and more easily implemented) methods.

André Berthiaume
Informatique et Recherche Opérationnelle
University of Montreal
Montreal, Quebec

Quantum corrals are calculation devices in this sense: The height of the central wave peak in a quantum corral represents an analog sum of the iron atoms in the periphery.

Mathematically, this sum is calculated by first estimating the chances (amplitudes, actually) of the electron reflecting off each of the iron atoms — that is, by using Feynman's sum of all histories. There is no clear upper limit to how complex and dynamic "corralled electron" calculation devices could become, with a bit of ingenuity.

I would also note that ordinary waves provide the same advantage. Tap the side of a cup of coffee and you'll see waves focusing at the center of the surface with an amplitude that (as for quantum corrals) is proportional to the "completeness" of the surrounding cup — which hopefully is 100 percent!

This analogy is related to how Feynman's sum of histories translates into an ordinary wave equation whenever a problem extends over appreciable times or distances.

Thus the real question in quantum computing is whether computers based on quantum waves would provide any significant cost or speed advantages over easier-to-build wave computers based on light, electricity, sound, or even ordinary water.

Terry B. Bollinger
Flower Mound, Texas

Address communications to:
Editor, Science News
1719 N Street, N.W.
Washington, D.C. 20036
All letters subject to editing.