Stretching the time to orbital catastrophe

The solar system has apparently survived in roughly its present configuration for more than 4 billion years. Yet computer simulations of the evolution of planetary orbits have revealed evidence of chaos.

Such uncertain behavior sharply restricts to a few tens of millions of years how far into the future one can predict the precise shape and orientation of a typical orbit, whether that of a planet or an asteroid (SN: 2/22/92, p.120). It leaves open the possibility that Mars, for example, could someday swing out of its present orbit and smash into Earth, or that Pluto may eventually escape the solar system.

Astronomers have now taken a step toward resolving the question of why chaos and unpredictability seem compatible with the solar system's apparent equanimity over billions of years. Using computer simulations of certain types of orbits, Myron Lecar, Fred Franklin and Marc Murison of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass., derived a numerical relationship linking the characteristic time over which an orbit remains predictable and the much longer time after which an orbit is likely to drastically change its shape or orientation in space.

For the solar system, the results imply that no catastrophe would likely occur for at least a trillion years. This represents "a long time, even by astronomical standards, but not infinitely long," Lecar says.

Is there a chance that the solar system might get into trouble much sooner? "Yes," Lecar says, "but it's very small."

The researchers studied more than 1,000 examples of three types of orbits. In one case, they computed sample orbits traced out by an asteroid gravitationally influenced only by the sun and Jupiter. In another scenario, they looked at orbits of hypothetical asteroids stationed between Jupiter and Saturn. The third situation involved tracking the orbit of a tiny body initially circling the smaller of two stars in a binary system.

For each situation, they computed a quantity known as the Lyapunov time, commonly used in the study of chaotic systems to characterize how rapidly two orbits starting at minutely different positions separate and go their own way. This number provides an estimate of how far into the future one can predict chaotic behavior.

The researchers then compared the computed Lyapunov time with the time it takes orbits to change sufficiently for an orbiting body to cross a planet's path or escape the system. They discovered that despite the great differences between the three types of orbits considered, all led to approximately the same numerical relationship between the Lyapunov time and the time for an orbit to make a sudden transition.

According to this relationship, the transition time is proportional to the Lyapunov time to the 1.8 power. "You always get this exponent, 1.8," Lecar says.

However, the researchers looked at only three special cases, involving gravitational interactions much less complicated and among fewer bodies than those in the solar system. Whether this analysis applies to real planets and other chaotic systems isn't clear.

"The correlation is interesting," says Scott Tremaine of the Canadian Institute for Theoretical Astrophysics at the University of Toronto. "But there's unlikely to be a single universal law that describes exactly what's going on. My general experience is that the details of what happens depend fairly strongly on the configuration."

Also missing is a convincing explanation of why the exponent in the cases studied happens to be 1.8. "I don't think anyone really understands the exact nature of the chaos [present]," says Martin Duncan of Queen's University in Kingston, Ontario, who has been computing the dynamical behavior of hypothetical asteroid orbits beyond Neptune. "This apparent stability in the face of unpredictability remains a puzzle." *— I. Peterson*

Where's the beef? In a meaty peptide

Meat-and-potatoes eaters may one day make tofu more appetizing for themselves by sprinkling it with the taste of steak.

As part of a long-term effort to learn why cooked meat soon develops a disappointing "warmed-over" flavor, physiologists have pinpointed a short peptide as the chemical responsible for beef's taste.

The peptide exists as a string of eight amino acids, and it probably forms as meat ages and enzymes within the meat break down specific proteins, U.S. Department of Agriculture researchers reported this week at the spring meeting of the American Chemical Society in San Francisco.

This meaty peptide might one day serve as a substitute for monosodium glutamate or make less expensive meat taste like prime cuts, says Arthur M. Spanier of the USDA's Southern Regional Research Center in New Orleans. It could also improve the flavor of precooked beef used in institutional and convenience foods, which account for 35 percent of the beef sold in the United States.

For several years Spanier, Peter B. Johnsen and their USDA colleagues have sought to get rid of the two processes that cause beef to develop its warmed-over flavor.

In one process, iron in the meat stimulates the breakdown during storage of fatty substances called lipids. The lipids combine with oxygen and become rancid, says Johnsen. Another process causes a decrease in the meaty, brothy taste of beef.

Two years ago, the USDA group succeeded in eliminating the rancid flavor by adding a derivative of a natural polymer called chitin to meat. The chitin binds to iron and slows the oxidation of fat (SN: 9/16/89, p.189). Over time, however, "there's still a decline in the desirable flavor," says Johnsen.

The USDA researchers now know that enzymes remain active as beef makes its way from slaughterhouse to oven to refrigerator and finally to the plate as leftovers. They isolated the beef-flavor peptide by analyzing the contents of pieces of top-round steak at these various stages.

Japanese researchers first discovered the peptide in 1978 among the residue of peptides and amino acids produced by "digesting" meat with a vegetable enzyme. But the USDA group is the first to prove that this peptide forms naturally in beef, Johnsen says.

"This is very significant," says Chi-Tang Ho, a food chemist at Rutgers University in New Brunswick, N.J.

By demonstrating that the peptide occurs naturally in substances generally eaten by people, the USDA researchers could make it easier for this substance to gain U.S. Food and Drug Administration approval as a food additive. However, Ho and Johnsen say it remains unclear how fast — or even whether — the new flavoring will make it to the dinner table.

The peptide seems to contribute to "umami," the little-known fifth taste sensation that some scientists think is perceived — along with salt, sweet, bitter and sour — by specific receptors in the mouth. The beef-taste peptide may evoke its savoriness by interacting with several types of these receptors. Japanese scientists have shown that small sections of the peptide do stimulate the four other tastes. In addition, enzymes may break up the peptide during storage so that its fragments cause sour or bitter sensations rather than beefy ones.

The USDA group plans to look for similar compounds in pork and poultry and to try to identify the enzymes and proteins involved in the formation and breakdown of the beef peptide.

— E. Pennisi