Tying knots to tubular geometry, DNA loops

Sailors and other knot users have a large repertoire from which to choose the right knot for any purpose, whether it's tying a shoelace, mooring a boat, or knotting together bedsheets to escape from an upper story of a building. Mathematicians also tangle with diverse knots, but they have traditionally concerned themselves with those tied in a one-dimensional string with no free ends, forming closed loops.

Like sailors and scouts, mathematicians are interested in identifying and classifying different knots (SN: 5/21/88, p. 328). Now, a team of researchers has proposed a novel method of characterizing knots, based on imagining them as tubes pulled tight into the configurations that give the highest possible ratio of volume to surface area. These tubular objects, in turn, serve as useful mathematical models of knotted DNA loops and polymer chains.

Structural biologist Andrzej Stasiak of the University of Lausanne, Switzerland, and his colleagues report their findings in the Nov. 14 NATURE.

"Such methods potentially offer a practical approach to [knot] classification," says mathematician Jonathan K. Simon of the University of Iowa in Iowa City. The methods may also "lead us to understand and predict how different knot types behave in real physical situations."

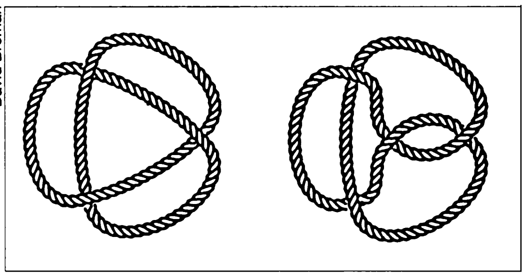
To tackle the problem of identifying and distinguishing knots, mathematicians have generally looked at the minimum number of times a given loop, laid on a flat surface, crosses over or under itself. The simplest possible knot is the trefoil knot, which is really just a loop that winds through itself once. In its plainest form, this knot has three crossings. Only one knot has four crossings, and two distinct knots have five crossings.

Over the years, mathematicians have worked out several different ways to use arrangements of crossings to generate the algebraic formulas that serve as labels for knots. Such a label, which stays the same no matter how a given knot may be deformed or twisted, is known as an invariant (SN: 10/26/85, p. 266). However, because two different knots may occasionally have the same formula, this scheme isn't foolproof.

Stasiak and his group approached the problem from a new perspective. They tied their knots not from imaginary one-dimensional strings, which have no width, but from tubes of a uniform diameter. They defined the ideal knot of a given type as that made from the shortest piece of tube.

The researchers used computer simulations to test their idea, starting with a narrow, knotted tube, then uniformly

David Broman



Simple knots with three (left) and four (right) crossings.

expanding the tube's diameter until there was contact between different portions of the tube.

"The modeled knots usually 'flowed' into their ideal geometrical representations, repeatedly adopting almost identical configurations [for a given knot]," the researchers report. Their method handled knots containing as many as 10 crossings.

The computer simulations revealed that these ideal knots have interesting mathematical properties. For example, the length-to-diameter ratio of a tubular knot is directly related to the average number of crossings, independent of a knot's actual shape.

Stasiak and his coworkers also demonstrated in their simulations that the average shape of loosely knotted DNA loops flopping around in a good solvent closely resembles the ideal configuration of the given knot. — *I. Peterson*

Speedy galactic aluminum vexes astronomers

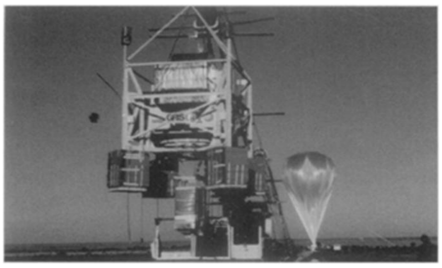
Astronomers rarely make discoveries that blast a hole in their understanding of the galaxy. Now though, explosive new findings are forcing them to rethink the structure of the Milky Way.

Using gamma-ray spectrometers mounted on high-flying balloons, some researchers have turned their attention to radioactive aluminum associated with clouds of gas near the center of the galaxy. Astronomers believe that this material was ejected by either a supernova or a giant star in the region.

Instead of seeing gamma rays with aluminum's characteristic energy, which would have indicated that the metal moves at the same speed as neighboring galactic material, they saw emissions with a broad distribution of energies around the expected value. This smearing indicated that the cloud of aluminum was expanding at 450 kilometers per second, three times faster than anticipated. The astronomers, from NASA's Goddard Space Flight Center in Greenbelt, Md., and the University of Maryland in College Park, report their findings in the Nov. 7 NATURE.

"This raises important questions about what our galaxy is made of," said Goddard's Jack Tueller, a study coauthor. Astronomers had thought that material ejected by supernovas or giant stars would come to rest after about 100,000 years, slowed down by shock waves and collisions with other interstellar material. Instead, they calculate from the size of the cloud and its rate of expansion that it has rocketed around for 750,000 years as if little stood in its way. "Don't worry," says Tueller. "It's nowhere near us."

Tueller



The researchers guess that the aluminum may be racing through an unusually low density pocket of the interstellar medium (SN: 4/20/96, p. 248). A region of space populated by many supernovas may have been blasted free of other gas by the explosions, leaving the way clear for an aluminum-containing cloud.

Alternatively, the metal may have precipitated out of its gaseous form. If the aluminum took the form of billions of tiny dust grains, "they would pass through space like little bullets," says Tueller. "Dust would shoot through shock waves set up by the gas around it with no braking." For this to be true, he adds, much more dust than predicted must be produced by decaying stars.

"These are very exciting observations," says astronomer Richard Lingenfelter of the University of California, San Diego, who believes the dust explanation best matches current knowledge. "It's a big candy store from the theoretical viewpoint," he says, pointing to recent studies suggesting that metallic particles accelerate cosmic rays.

If supernovas produce more dust than expected, according to Tueller, it could mean that the ratio of gas to dust in the galaxy has been miscalculated for decades. Some meteorites bear signs of dust impacts that may confirm this interpretation, he adds. "But if this explanation is right, it means we've underestimated how much of the galaxy is made of dust for a long time."

The spreading aluminum should interest astronomers for years, says Reuven Ramaty of Goddard. "The nuclear formation of material is central to astronomy—and to humanity. After all, we're all made of the ashes of stars." — *D. Vergano*

Balloons hoist gamma-ray spectrometers into the sky, above atmospheric interference.