tively little except to ambush nearby prey; the other half were tree snakes, which depend on being svelte and swift so that they can slither up to their prey without breaking the slender twigs and leaves that support them. The scientific literature provided passage times for six more snake species.

The researchers found that passage times in the larger, ground-dwelling snakes were much longer than those of the arboreal snakes. One Gaboon viper, *Bitis gabonica*, had the longest time, eating multiple times over the course of a year but defecating only once, after 420 days. In contrast, its arboreal cousin, the sedge viper (*Atheris nitschei*), tended to produce a stool about once a week. A 145-day difference existed between the ground-dwelling and arboreal representatives of the family that includes boas and pythons. And the very slender arboreal *Uromacer oxyrhyncus* was the fastest, getting rid of waste in less than 2 days.

The "constipated" snakes retained the feces in the hindguts, thus putting 3% to 22% of added weight far to the rear. By anchoring the snakes' rear ends, the weight could be a boon for snakes that ambush relatively large animals, such as small antelope, says David Cundall, a functional morphologist at Lehigh University in Bethlehem, Pennsylvania. His own work shows, he says, that the sit-and-wait snakes do best when they are heavier: They can strike more quickly and get a better hold on prey. Indeed, he notes, the snakes that the Lillywhite group found to retain their feces longest are some of "the most effective and most rapid strikers."

Death struggle. This drawing from the 1800s illustrates why some snakes may need extra weight.

Retaining feces would be a far more efficient way of gaining ballast than, say, simply having a broader posterior, says Victor Hutchison, a physiological ecologist at the University of Oklahoma, Norman. "They don't have to maintain [any tissue], they just have to drag [the feces] around," he points out.

Hutchison and Cundall caution that there could be other possible explanations for the Lillywhite team's finding. Longer retention times in the gut may simply enable the body to absorb more water or nutrients from the feces. "The effect on ambush ability could be accidental," Cundall adds. Lillywhite himself has considered these possibilities, but says that holding onto feces for more than a few extra days, or even weeks, is a bit extreme unless it provides some adaptive advantage.

Over the next years, Lillywhite hopes to study more snakes to see whether the correlation between passage time and predation strategy holds up and whether the amount of feces does indeed affect prey capture. But, for the time being, his colleagues find the idea that constipation makes some snakes better hunters appealing, even though it is a little peculiar. Says Hutchison: "It makes pretty good sense."

–ELIZABETH PENNISI

ASTRONOMY

The Mystery of the Migrating Galaxy Clusters

Conflicting results have astronomers puzzled over whether there is a bulk motion of galaxies across a vast swath of sky

A mass migration of galaxies may be taking place, but astronomers can't agree on which way they are going. First reported 4 years ago by Marc Postman of the Space Telescope Science Institute in Baltimore and Tod Lauer of the National Optical Astronomy Observatories, the migration seemed to be taking place on a scale so huge—a swath of sky hundreds of millions of light-years across—that astronomers withheld judgment about whether it was real and what could be causing it until confirmation came in. Now three other groups have gone looking for the mass movement and have come back with results that only deepen the mystery.

Follow the crowd. Do nearby Abell clusters like this all move one way?

Two of the teams, one led by Michael Hudson of Canada's University of Victoria and the other by Jeffrey Willick of Stanford University in California, found "bulk motions" of galaxy clusters with very similar speeds, but at roughly 90 degrees to the earlier result. A third team, led by Riccardo Giovanelli of Cornell University in Ithaca, New York, found no bulk motion at all. "The field is pretty confused right now," says Michael Strauss of Princeton University, with astronomers wondering which, if any, of the varied techniques used can be trusted.

Astronomers have known since 1929 that, because of the expansion triggered by the big bang, all galaxies in the universe move away from us with a speed proportional to their distance. This velocity, detectable as a "redshift" in the galaxy's spectrum, is generally used as a yardstick for their distance. But galaxies have other "peculiar velocities," over and above the general cosmic expansion, which astronomers generally attribute to the gravitational pull of large concentrations of galaxies nearby. Using NASA's COBE spacecraft in 1993, astronomers got a fix on our own galaxy's peculiar velocity: We are moving at 600 kilometers per second (km/s) with respect to the uniform background glow left by the big bang, in a slightly different direction from that found by the Hudson and Willick teams.

To map cluster motions, astronomers have to work out how much their velocity—easy to determine from redshift—departs from the velocity that the overall cosmic expansion would give to an object at that dis-

CREDITS: (BOTTOM TO TOP) NASA; ILLUSTRATION: J. STEWART DEL, J. BISHOP SC/BLACKIE AND SON, GLASGOW, EDINBURGH & LONDON; PHOTO: H. B. LILLYWHITE tance. That means determining their distance without relying on redshift, a much tougher requirement. The usual strategy is to find some observable feature of galaxies that is thought to indicate their actual brightness or size, then compare it with the brightness or size observed from Earth to get distances.

In their 1994 study, Postman and Lauer simply picked the brightest galaxy in dense galaxy clusters and assumed that these galaxies had the same luminosity in each case. Parlaying those measurements into distance, they found that clusters out to a distance of 500 million light-years in every direction in the sky all appeared to be moving together at a velocity of 680 km/s in the direction of the constellation Virgo. It was a flow of an area 30 times larger than any seen before.

In trying to confirm it, Hudson's team, the Streaming Motions of Abell Clusters (SMAC) Collaboration, used a different distance measure. These researchers looked at elliptical galaxies and determined their absolute size by measuring the mean surface brightness in the central part of the galaxy and how fast stars are darting around within it—indicated by the broadening of spectral lines. They then compared these to similar known galaxies closer to home. "Once you have measured the velocity dispersion and the surface brightness, you know what the absolute radius of the galaxy should be," says Hudson. Willick's group also used the widening of spectral lines to estimate the rotation speed of about 250 spiral galaxies; comparisons to known galaxies gave their absolute size and brightness.

The two groups are in "remarkable agreement," says Willick. In next month's *Astrophysical Journal Letters*, the SMAC Collaboration reports that clusters of galaxies up to 400 million light-years from Earth are moving with a velocity of about 630 km/s in the direction of the constellation Vela. Willick's group, which has submitted its result to *Astrophysical Journal*, found that galaxy clusters in a slightly larger area flow with a speed of 720 km/s in roughly the same direction.

The problem is that direction is roughly at right angles to the direction originally measured by Postman. Worse, Giovanelli's group reported in the 1 January issue of *Astrophysical Journal* that it had studied several thousand galaxies but found no large bulk flow at all beyond a distance of 200 million light-years. Giovanelli and his colleagues used a method close to that of Willick to determine galaxy distances.

Many astronomers say the disagreement simply shows that all such distance indicators are unreliable, and the question of bulk flows is still open. But Hudson maintains that even though their distance indicators can be off target by as much as 20%, the large numbers of galaxies should cause random errors to be averaged out. "We use 700 galaxies, statistically we get a much stronger signal," says Hudson. Alan Dressler of the Carnegie Institutions in Washington, D.C., who investigated bulk flows in the 1980s using similar techniques, is not convinced. "Systematic errors tend to be big also when random errors are big … so I stopped working with these techniques," he says.

But if the bulk motions are real, astronomers will face the second puzzle: What could cause galaxies to stampede across the sky on such a large scale? One possible explanation is that some huge mass is pulling all these local clusters in one direction. Hudson mentions a couple of candidate superclusters: the Shapley Concentration and the Horologeum Reticulum, two very dense areas with a large number of clusters. "It is possible that they are pulling us in one direction, and there is a void on the other side [of the sky] that happens to push us," says Hudson. But such variations in mass density on such a large scale do not agree well with cosmologists' current model of mass distribution in the universe, says Willick. Dressler agrees: "The kind of mass concentrations necessary to make things move on big scales would make us a very rare part of the universe, much more uncommon than would be comfortable."

Before cosmologists embark on any large-scale revision of their models, the astronomers must get their results to agree. Says Willick, "We will have to try to understand why they are so different."

–ALEXANDER HELLEMANS

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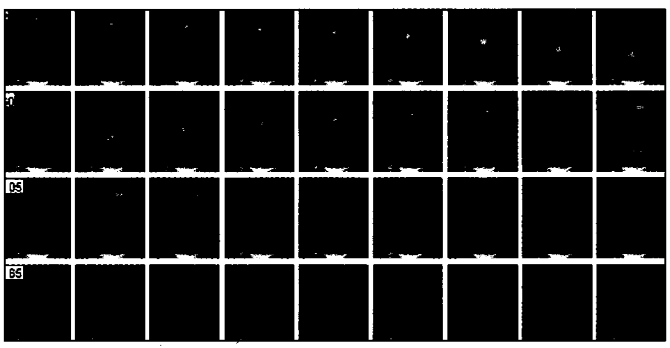
ATOM OPTICS

Videotape Brings Atoms To a Focus

With videotape, a cylinder, a lens, and some glue, researchers have made a focusing mirror that heralds a new age of atom optics

Physicists have known for decades that atoms can behave like light waves, and that they should be able to guide and focus them like beams of light. But researchers in the emerging field of atom optics have found this to be easier said than done: Creating an atom version of even simple optical elements, such as the humble mirror, has proven surprisingly challenging, and progress has been painstakingly slow. But in the 18 January issue of *Physical Review Letters*, a British team reports a major step forward with the first high-quality curved, focusing atom mirror. Such a mirror is likely to be an important ingredient in the creation of a controllable atom beam that could be used to create integrated circuits and other nanostructures many times smaller than those possible today.



Atom trampoline. The atom mirror is accurate enough to reassemble a cloud of atoms after two bounces.

The new mirror, developed by Ed Hinds and colleagues at the University of Sussex, near Brighton, U.K., deflects atoms using magnetic signals recorded onto commercial videotape. The tape is formed into a concave shape, giving a spherical mirror that can bring a beam of atoms to a sharp focus, a development Keith Burnett of Oxford University calls "a significant advance." The mirror is a "breakthrough," agrees Alain Aspect of the Institute of Optics in Orsay, Paris.

The problem with controlling atom beams is that atoms are electrically neutral, so they cannot be focused with electric fields as electrons and ions can, explains Peter Hannaford of Australia's CSIRO research agency in Melbourne. "Also, normally one cannot bounce neutral atoms from surfaces, as most atoms will stick to the surface," he adds. Over the past few years, researchers have devised ways around these problems to create mirrors, using light or magnets to repel atoms from a surface. For example, 4 years ago Hinds's group produced the first magnetic mirror by recording a sine wave audio signal on magnetic tape, producing an alternating magnet-

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