ATMOSPHERIC RESEARCH

Stalking Flashy Beasts Above the Clouds

From the time of Benjamin Franklin on, thunderstorm researchers entranced by the commotion inside storm clouds have missed a quieter, more mysterious display taking place far above them. A few observers—mostly pilots—did spot strange flashes of light far above storm clouds, but they were never taken seriously by the research community. That neglect ended last summer when researchers turned highly sensitive cameras to the sky above the flood-gushing storms of the Midwest and recorded flashes by the hundreds, reaching tens of kilometers above the cloud tops (*Science*, 27 May, p. 1250). This summer, atmospheric scientists are back with more and better equipment, and they're finding there's even more to watch.

"There's more than one type of luminous phenomenon over clouds," says meteorologist Walter Lyons of Mission Research Corporation (MRC) in Fort Collins, Colorado, who recorded more than 600 flashes last summer. "There's a whole zoo of things running around." Two of the showiest members of the menagerie are red, carrot-shaped "sprites" and fountainlike blue jets. But although a four-institution project (involving the University of Alaska, MRC, Stanford University, and Pennsylvania State University) is studying the appearance and behavior of the flashes from the ground and from high-flying aircraft, the mystery has been slow to yield. "It's getting curiouser and curiouser," says Lyons.

Most curious of all are the blue jets, which "look for all the world like there was an explosion [in the cloud top] and out comes some stuff," says Eugene Wescott of the University of Alaska. He and his colleague Davis Sentman captured the first images of blue flashes when the researchers flew above Midwest storms early last month to make the first color video recordings of upper-atmosphere flashes. Wescott doesn't think anything is literally exploding out of cloud tops to produce these sprays of blue light, which stab upward at 300 times the speed of sound to altitudes of 25 kilometers above the cloud tops. Nor do the jets resemble topsy-turvy lightning bolts, which on rare occasions have been seen striking upward from cloud tops. So what are they? "I haven't a clue," admits Wescott.

Red sprites seem a bit more understandable. Sentman and Wescott's color video images of the sprites confirm Lyons' visual report of last year that sprites are usually red—salmon red to the human eye. The color suggests to atmospheric chemist Russell Armstrong of the Nashua, New Hampshire, office of MRC that the light comes from oxygen or nitrogen molecules excited by collisions with high-energy electrons—the same process that produces similar hues in the aurora. The presence of high-energy electrons, in turn, would support the idea that flashes are a long-distance effect of lightning within the clouds. In this scenario, the largest lightning strokes send an electromagnetic pulse into the thin upper atmosphere, where it rips electrons from air molecules and accelerates them to produce light.

The brightest part of such a flash, however, should appear above an altitude of 80 kilometers in the lower ionosphere, where the electrons no longer have to be torn from air molecules because they are already running free. And there's the rub: The sprites seen this summer are at their most intense 10 kilometers below that, notes Lyons. "There's something we don't understand." One more thing, that is.

UNIVERSITY OF ALASKA

Red sky at night. A so-called red sprite dances as high as 95 kilometers above a thunderstorm.

–Richard A. Kerr

COSMOLOGY

Spoiling a Universal 'Fudge Factor'

Even the most enthusiastic cosmologist will admit that current theories of the nature of the universe have some big holes. One such gap is that the universe seems to be younger than some of the objects contained within it. Another problem is that the observed universe just doesn't appear to have enough matter in it to explain the way it behaves now, nor the way theorists predict it will evolve.

To overcome these problems, many cosmologists have suggested that the equations of gravity should contain a number called the cosmological constant: a fudge factor that, if it has the right value, would make these bugbears disappear (*Science*, 5 November 1993, p. 846). But a new analysis of observations of gravitational lenses—galaxies whose gravity bends the light of more distant objects—shows that, if the constant does exist, it cannot be big enough to explain the anomalous age of the universe or the missing mass. "The lensing statistics really are becoming a problem for the cosmological constant models," admits cosmologist George Efstathiou of Oxford University.

D. BERRY/STSI

Cosmic optics. Light is bent by a galaxy to produce multiple images of a distant quasar.

Estimates of the age of the universe center on observations of distant galaxies: how far away they are and how fast they are receding as the universe expands. These data let cosmologists put a date on the Big Bang, and the current estimates put the beginning of time at around 8 billion years ago. But models of stellar evolution suggest that some star clusters are at least 5 billion years older than that, a discrepancy that is difficult to explain.

The emptiness of space is arguably an even tougher problem. According to the simplest current theories of the very early universe, there should be just enough matter in the cosmos to allow it to expand forever; any more matter and gravity will be strong enough to halt the expansion and pull the universe back into a cosmic crunch. Cosmologists express this theoretical prediction by saying that the value of "omega"—a measure of the density of matter in the universe—is precisely 1. Observations of the real universe tell a different story, however: omega values of just 0.2 are typical.

Many cosmologists felt that something quite fundamental needed to be done, so they proposed restoring the cosmological constant, originally suggested by Albert Einstein in 1918. In a universe with a cosmological constant, all of empty space would be endowed with extra energy, gently pushing distant galaxies away from each other. This would make the universe appear younger than it really is, because it boosts the speed at which galaxies recede from one another. The constant can also help with the value of omega: Because of the equivalence of mass and energy defined in relativity theory, the energy that accompanies the constant's antigravitational effect is equivalent to an increase in the apparent density of matter in the cosmos. Theory predicts that the cosmological constant could solve both the age and missing mass problems if it adds enough energy to produce the equivalent of an omega value of 0.8.

But gravitational lens expert Chris Kochanek of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, has now all but slammed the door on that possibility. When light from, say, a quasar passes by an intervening galaxy on its way to Earth, the galaxy's gravity bends the light like a lens, creating multiple images of the quasar. Astronomers have been scouring the sky for these strange objects and counting how many they see out to a specific distance. If the cosmological constant exists, its antigravitational influence has the effect of boosting the volume of space between two distant objects—and thus increasing the number of gravitational lenses caught by surveys that look out to a given distance. Unlike counting single objects, gravitational lens numbers reflect conditions at two locations—that of the quasar and of the galaxy—both affected by a cosmological constant.

For a cosmological constant equivalent to an omega of 0.8, Kochanek calculates that about 15 gravitational lenses should have been seen by current surveys. So far, only 6 have been found. With his current results, to be published later this year in the *Astrophysical Journal*, Kochanek can say with 90% certainty that the cosmological constant is less than 0.5 for current models of the universe. "A cosmological constant of 0.8 is more or less right out," he says.

Cosmologists have taken the news on the chin, but still cling to the hope that the result may be flawed. Princeton University cosmologist Jim Peebles, for instance, notes that the apparent dearth of lenses may be the result of their being obscured by dust. But Kochanek, unswayed, counters that dust does not explain other problems, such as the constant's failure to give the correct distance of individual gravitational lenses.

So what now? Once possibility is to introduce a cosmological constant that varies with time—an idea investigated by Peebles himself. With suitable tweaking, this might get around the current problems. But many cosmologists would find this disturbingly reminiscent of the attempts of medieval astronomers to patch up their Earth-centered view of the solar system by devising more complicated celestial machinery to propel the planets.

–Robert Matthews

Robert Matthews writes for the Sunday Telegraph *in London.*

ARCHAEOLOGY

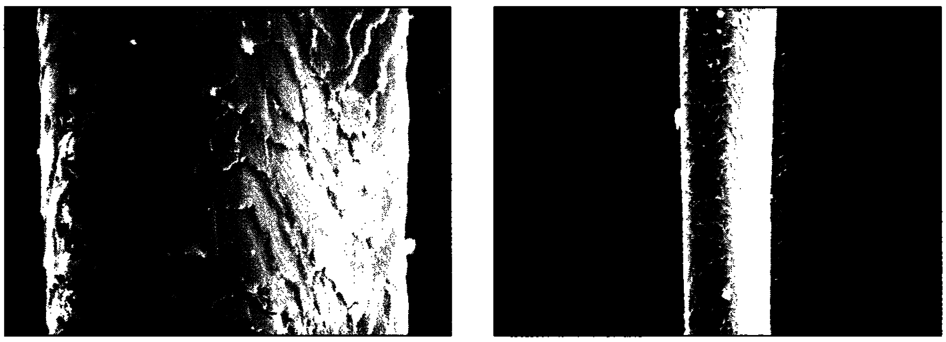
Pulling Hair From the Ground

Humans shed a lot of hair, hundreds of strands each day. And archaeologists are discovering that what was hair yesterday is here today as well: They are pulling it by the clump out of archaeological sites. "The hair has been there all the time, but we never saw it," explains Rob Bonnichsen, an archaeologist at Oregon State University (OSU), Corvallis, who has helped devise a technique for recovering ancient hair fragments. And researchers are finding hair and its immediate surroundings to be a hatful of information.

Bonnichsen and his colleagues have recently plucked hair from an archaeological site in western Montana dating from about 10,000 years ago, and last month they extracted DNA from some fragments—genetic information that could speak volumes about ancient populations should it turn out to be genuine and not a more modern contaminant. And other organic substances found in the soil around the hair, such as fish scales and bird feathers, could reveal important clues about the populations' diet and health.

By mixing the sediments with water and sodium hexametaphosphate, then running this slurry through a flotation tub and capturing the outflow in a mesh bag, Beatty was able to break down the clumps of earth, separating out any organic remains. A surprising amount turned up. "We've found a lot of little fragments of hair, both animal and human, plus bird feathers, a single fish scale, plant matter, beetles—things that we'd never found before because this [sediment] material is normally discarded," says Bonnichsen. The technique, he adds, is a little bit like "looking for a needle in a haystack—only there are a thousand needles to find."

If DNA is found in the hair, the molecule may provide clues about how many related groups occupied a given site. DNA may also help resolve disputes about the number of migrations into North America from Asia and from where in Asia these early peoples came. DNA linked to a specific archaeological site would also enable archaeologists to tie a particular culture to a particular people,



ROBSON BONNICHSEN

Hair-raising find. This hair from a 10,000-year-old site may reveal ancient population genetics.

George J. Armelagos, a physical anthropologist at Emory University in Atlanta, says that "any organic material that is recovered from an archaeological site is of immense interest. So finding a method to collect these hairs is a fantastic breakthrough."

Looking for hair seems obvious now, Bonnichsen says, but archaeologists usually go into a site with their eyes on bigger game, like bones or stone tools. In 1986, Bonnichsen got his first clue that hair could be found as well. While sieving the sediments at a 14,500-year-old cave in western Montana, his team noticed that hairs were often left behind on the water screens. Then, at the 10,000-year-old site, known for its Clovis artifacts, a team member found a single, long, black hair stuck in a clump of earth on the bottom of a stone. "That's when I realized there had to be more, but we were missing it," says Bonnichsen. He then turned to Marvin Beatty, a soil scientist from the University of Wisconsin, for aid.

something that is now nearly impossible to do. "We've often wondered who is Clovis," says Bonnichsen, referring to the earliest known culture in the Americas. "Some of us think of Clovis as a population group, others as a technology that spread across a group of populations." The DNA in hair samples associated with Clovis artifacts could conceivably lay this issue to rest.

But, says Walt Ream, the microbiologist at OSU who is pursuing the DNA in Bonnichsen's ancient hair, a lot of work must be done first. Ream's initial tests on 3- to 5-centimeter lengths of hair from Bonnichsen's 10,000-year-old site have given him a positive DNA signal, although he says a great deal of testing remains to be done before the DNA can be identified as coming from a past inhabitant. "It's premature to say we have viable old DNA," he says. Still, archaeology may yet become a field where splitting hairs is extremely significant.

–Virginia Morell