



Catching the Wave of a New Accelerator

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apart. They are virtually identical.”

To other ornithologists, Feduccia's gripping tale clinches the case. “Feduccia's paper establishes conclusively that the claws of *Archaeopteryx* have the morphology of a perching, climbing animal,” says Larry Martin, a paleo-ornithologist at the University of Kansas in Lawrence. “It was not running on the ground.”

Some paleontologists, however, think Feduccia is, well, out of his tree. Paul Sereno, an evolutionary biologist at the University of Chicago, disputes whether one can use a bird's claws to draw definitive conclusions about its overall behavior. “Many so called ground-birds, for example chickens, still spend some time in the trees,” he says. Sereno also questions Feduccia's claims for the wing, or hand, claws. “I think the hand claws are particu-

larly irrelevant because he makes no comparisons to dinosaurs. In fact, *Archaeopteryx*'s hand claws are very, very similar to those of theropods.” Gauthier adds, “If *Archaeopteryx* used its hand claws for climbing in trees, then all the related dinosaurs—theropods, *Velociraptor*, *T. rex*—all climbed in trees.” And if that's the case says Gauthier, “You've got a problem,” since *T. rex* was clearly a terrestrial creature.

But not all the clucks from paleontologists are those of disapproval. Ostrom, whom one might expect to be outraged, is preening instead. “I'm just having a ball,” he said with a chuckle. “It sounds to me as if Alan [Feduccia] has presented a very good argument; I'm not sure he's absolutely right, but I'm sure he's on solid ground.” Even though Ostrom acknowledges that Feduccia may be

right about the shape of the claws, Ostrom is far from giving up his own, hard-won ground. Like Sereno and Gauthier, he doesn't think the case can be closed before the claws of *Archaeopteryx* have been compared with those of the theropods.

In any case, says Ostrom, his ideas have been constructive in stimulating scholars to examine assumptions. “In the early 1970s, it was a given that birds learned to fly from the trees down,” Ostrom says. “I thought people hadn't looked closely enough at the evidence, so I deliberately wrote my paper to provoke people. And I'm laughing now because it has provoked people out of their hides. It's a great big controversy—which is what it should be.” And a controversy in which the world hasn't heard the final peep.

—Virginia Morell

PHYSICS

Catching the Wave of a New Accelerator

Even as heavy machinery cuts a tunnel under the Texas prairie for the Superconducting Super Collider's (SSC) 87-kilometer ring of concrete, metal, and equipment, a group of physicists and engineers at the University of California, Los Angeles, is developing a technology that has the potential of ending the era of ever more gargantuan accelerators. In a pinky-sized volume of gas heated by lasers, they created electric fields powerful enough to accelerate electrons at a rate that has physicists dreaming of doing the SSC's job in a setup only a few city blocks long.

“This is a significant step forward,” says accelerator physicist Andrew Sessler of the Lawrence Berkeley Laboratory. Adds physicist Chris Clayton, chief experimentalist in the eight-member group that did the work, “The success of this experiment has suddenly made future possibilities seem a lot more real.” Among those possibilities, Clayton, group leader Chan Joshi, and their colleagues suggest in the 4 January *Physical Review Letters* (PRL), are smaller, cheaper accelerators that could not only cut high-energy physics down to size but also open the way to compact x-ray sources for medical therapies, biological studies, and materials analysis.

Conventional accelerators grow like topsy because they rely on a gauntlet of strong electric fields to accelerate charged particles. The electric fields of the high-end accelerators have approached the limit of what materials can sustain before electrons tear themselves away from atoms in the accelerator constituents. As a result, the only way to boost the energy of conventional accelerators is to lengthen the gauntlet of accelerating fields.

Plasma wave accelerators work by a different principle and therefore aren't subject to the same limits. The fields are created temporarily by blasting hydrogen gas with a pair

of powerful laser beams. The result is a plasma—in this case a sea of positively charged hydrogen nuclei and negatively charged electrons. The laser beams, tuned to different wavelengths, interfere with each other, generating a pattern of light inten-



Little big accelerator. Tracks in a cloud chamber indicate paths of electrons accelerated in a plasma wave.

sities that segregate the plasma's charged constituents into alternating stripes. That creates a multitude of short, but extremely strong, electric fields between the stripes. And because the interfering beams also generate ocean-like waves in the plasma that travel at the speed of light, the charge-segregated disturbances race through the plasma. Like surfers gaining speed as they move down a wave, electrons can gain energy by catching and riding these lightning-fast plasma waves.

That principle was proposed almost 15 years ago by John Dawson of the University of California, Los Angeles, and Tajima Toshi of the University of Texas in Austin. But not until recently had the UCLA researchers and

other groups honed their understanding, machinery, and technical expertise enough to make plasma waves of sufficient quality for acceleration experiments. Now the UCLA group has gone on to harness the energy of those waves to accelerate electrons from an external source.

In the work reported in PRL, the group succeeded in boosting the energy of electrons injected into a laboratory plasma by at least 7 million electron volts. If the same acceleration rate could be maintained over just a few hundred meters (most likely through a series of shorter accelerating regions, within which high-quality plasmas would be easier to maintain), a plasma accelerator conceivably could match the 20 trillion electron volts of the SSC, says Dawson, who was not an author on the PRL paper.

Given that kind of payoff, it's not surprising that the UCLA group has company in the advanced accelerator business. Their recent work may have put them in the lead, concedes Jim Simpson, head of Argonne National Laboratory's accelerator R & D program, but researchers at Argonne and elsewhere have accelerated electrons in plasma waves generated by other methods. Notable among them is the “wake field” method, in which bunches of injected electrons plow through a plasma like a boat on a lake. The “wake” that results can accelerate electrons, but not yet at rates as high as the laser-based technique, says Simpson. Within the year, though, a testbed known as the Wake Field Accelerator should be up and running at Argonne. And that, Simpson adds, could inject additional energy into the “friendly competition” to shrink particle accelerators.

—Ivan Amato