portunities for paleontologists.

When it comes to research money, private support can make a huge difference, because agencies give only moderate support to paleontology. Last year, the National Science Foundation gave out about $1 million worth of new grants in vertebrate paleontology; almost half went to three dinosaur projects. The National Geographic Society handed out almost $316,000 to vertebrate paleontologists. But the *JVP* has received $500,000 in private donations in the past 4 years for supporting fossil preparators and paying publishing charges in *JVP*.

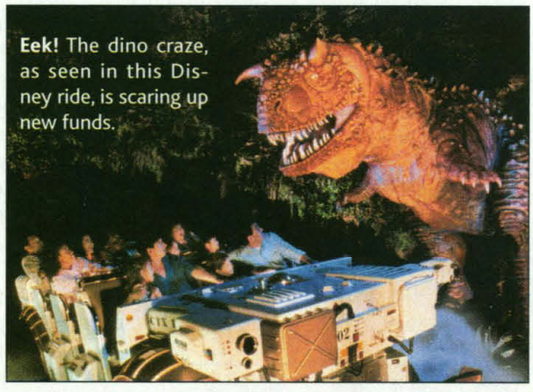
And more than 70 researchers got small grants from an organization called The Dinosaur Society, founded in 1991. Two years later, the society teamed up with Steven Spielberg and Universal Studios to put out a traveling exhibition based on *Jurassic Park*, showcasing casts of skeletons and eggs, as well as studio props and merchandise. Part of the proceeds went to the society, which began to give out peer-reviewed grants for dinosaur research, often supporting exploratory field trips that agencies won't fund. By 1997, when the exhibition was canceled, the society had handed out more than $980,000. "The Dinosaur Society was an experiment of science going into business, and it worked," says Steve Gittelman, president of a marketing firm who served as the society's second president. In addition, since May 1997, the Jurassic Foundation has amassed about $150,000 from *The Lost World* exhibit, which will be distributed as grants next year.

Other private foundations also dig deep for dinosaur research. Sereno has received substantial support from the Packard Foundation and Pritzker Foundation. Rowe thinks that dinosaur appeal helped him win a major grant from the Keck Foundation for a high-resolution computed tomography scanner.

A few enterprising paleontologists have managed to tap public interest in other ways. Lou Jacobs, a mammal paleontologist at Southern Methodist University in Dallas, wrote two general-interest books about Texas dinosaurs. In the early 1990s, a chain called Half Price Books, headquartered in Dallas, agreed to donate their profits on the books—about $50,000 so far—to paleontology.

Sometimes the fossils themselves are sources of funds. When the most expensive fossil in the world, a *Tyrannosaurus rex* named Sue, was bought at auction in 1997 for $8.4 million, the Field Museum of Natural History in Chicago enlisted the support of McDonald's, Disney, and the California State University system. The deal will support a prep lab, two staff positions, six preparators, and a postdoc.

Indeed, corporations hold the big money, and they're often willing to spend some in exchange for a tax break and cheap advertising.



Eek! The dino craze, as seen in this Disney ride, is scaring up new funds.

Mercedes Benz supplied field vehicles for the recent AMNH expeditions to the Gobi desert, and American Airlines flew 6 tons of African dinosaur fossils and some of Sereno's crew back to the United States in 1993. "The possibilities are unlimited," says May, who is now director for Policy and Environmental Issues at the Geological Society of America.

But paleontologists are often uneasy with corporate funding. Potential donors must be catered to, says Gittelman. "These things irritate the psychology of the scientist," he says, "and most of them won't do it." Partly it's the worry of a stigma. "Nontraditional sources are still almost like dirty money," says May, "because they may be—and often are—generated not on the scientific importance of the endeavor but on spin-off benefits like education or career training or goodwill value." And the visibility sometimes gives the mistaken impression that dinosaur research is richly funded, says Sereno. In fact, he says his work is "a hand-to-mouth operation."

Yet other paleontologists don't seem to begrudge the popularity of dinosaurs. "This rise fuels a lot of the rest of the science, so those of us who don't work in dinosaurs are perfectly delighted with these trends," says Cifelli. "Dinosaurs are a vehicle for highlighting other specimens," says mammal paleontologist John Flynn of the Field Museum. "People love those extinct things that represent a different world. Dinosaurs are just one heightened example of that."

–ERIK STOKSTAD

CREDIT: (TOP) THE WALT DISNEY CO.

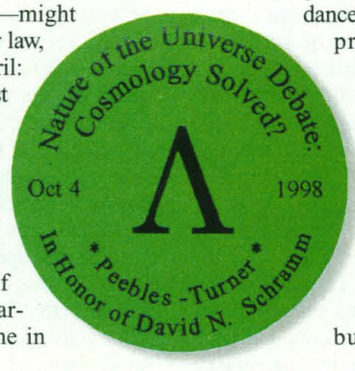
COSMOLOGY

Does Science Know the Vital Statistics of the Cosmos?

Cosmologists recently debated whether signs of a background energy in empty space point to a unified picture of the origins and makeup of the universe

Nelson Algren, the Chicago writer, said he lived by just three rules, two of which could be listed in polite company: Never play cards with any man named "Doc" and never eat at any place called "Mom's." Viewers of the face-off called "Great Debate III: Cosmology Solved?"—pitting the University of Chicago's Michael Turner against Princeton University's James Peebles in a crowded auditorium on 4 October—might have come up with another law, to be violated at great peril: Never debate a cosmologist whose viewgraphs are considered objets d'art.

The artful cosmologist is Turner, whose colorful creations were once the subject of a one-man exhibition. With the help of flamboyant graphics, he argued that for the first time in history, cosmologists have a credible handle on the origin, overall makeup, and ultimate fate of the universe.



Symbol of unity. The Greek letter lambda, representing the background energy called the cosmological constant, appeared on badges at the cosmologists' debate.

His case, made to an audience of several hundred astronomers, students, and interested nonspecialists at the National Museum of Natural History in Washington, D.C., drew heavily on this year's observations of distant, exploding stars called supernovae. In Turner's optimistic view, these cosmological beacons have helped bring previously conflicting evidence into an eerie concordance. As one of the viewgraphs proclaimed in fat letters, "Cosmology solved? Quite possibly!"

By showing that the universe is expanding at an accelerating rate rather than slowing from the force of gravity, the supernovae imply that the bulk of the universe consists not of matter but of a mysterious background energy called the cosmological constant. In Turner's picture, this energy acts as a cosmic deus ex

machina, rescuing the inflationary theory of cosmic origins. This favored theory had been threatened by astronomers' inability to discover as much matter in the universe as it predicted. But now that the universe is fleshed out with pure energy, said Turner, all the pieces fall into place.

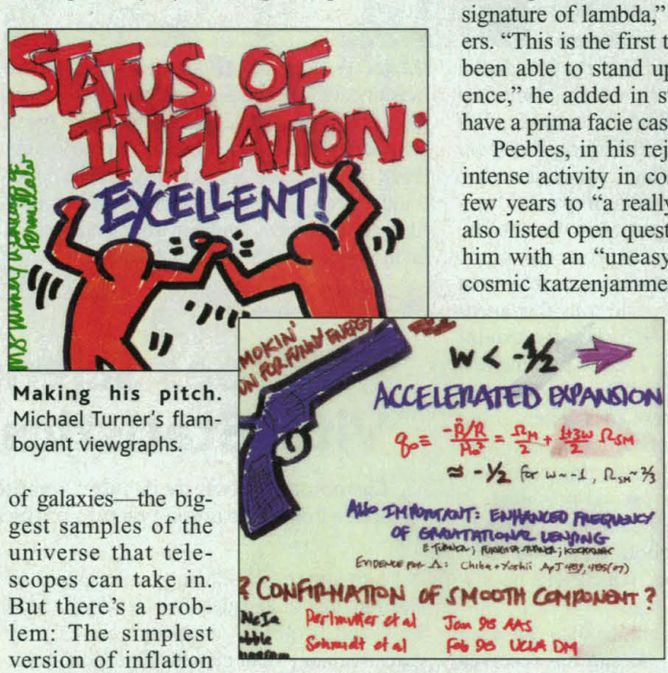
His opponent, Peebles, the reserved author of *Principles of Physical Cosmology*, a book that all but defines the field, argued for caution. Although the concordance is theoretically plausible, he said, the resulting universe is chock-full of stuff too bizarre to accept without serious reservations. "This was a 'good cop, bad cop' deal where [Peebles] was doing his best to be pessimistic," says Jerry Bonnell of the NASA Goddard Space Flight Center in Greenbelt, Maryland. But many astronomers are finding it hard to argue with Turner's infectious optimism. "At the moment there seems to be remarkable concordance and peace between the various observations," says Paul Steinhardt of Princeton. The question that nags at him and most of his colleagues, he says, is whether "everything will fall apart" with further observations.

The history of cosmology is enough to give even an ardent optimist pause. The face-off was the third commemorating a 1920 debate, held in the same auditorium, between the astronomers Harlow Shapley and Heber Curtis, who argued over the size of our galaxy and whether it comprises the entire universe or is only one island of stars among many. Much of their debate revolved around exploding and variable stars that, like the supernovae studied today, served as "standard candles"—objects thought to have a predictable brightness, so that their apparent brightness can be used as a measure of distance.

Both participants were partly right—often for the wrong reasons—and partly wrong. And both misinterpreted the evidence from standard candles, in part because they did not appreciate how interstellar dust could dim them. "It was 40 years before the dust settled on that debate," says Owen Gingerich, a historian of astronomy at the Harvard-Smithsonian Center for Astrophysics (CfA). The moral could be that present-day cosmology is not as solid as it appears. But for now, Gingerich concedes, "it all seems to be coming together very dramatically."

Turner, standing in for the late David Schramm, the equally irrepressible Chicago cosmologist who died in a plane crash last December, has been trying to stitch together a consistent picture of the universe ever since he, Steinhardt, Princeton's Jeremiah Ostriker, and a few others realized that they could connect the vast features seen in the sky today with an appealing theory of the universe's origin. According to inflationary theory, in the first fraction of a second of the big bang, the universe experienced an exponential growth surge. The newborn universe, smaller than a coconut, would have been crisscrossed by waves of quantum uncertainty, and theorists realized that inflation would have stretched those waves into the precursors of today's largest structures: the giant clusters and filaments of galaxies and the ripples on the microwave background radiation, the big bang's afterglow.

The match between the structures we see and the quantum fluctuations in the infant universe is best if the overall density of matter in the universe is low. And a low matter density is just what astronomers have been finding as they try to "weigh" large clusters of galaxies—the biggest samples of the universe that telescopes can take in. But there's a problem: The simplest version of inflation predicts that the universe contains enough matter to make it geometrically "flat" in the four-dimensional space described by Einstein's equations of relativity. That's far more matter than the observations suggest.



Making his pitch. Michael Turner's flamboyant viewgraphs.

A flat universe, Turner emphasized, isn't just theoretically desirable. It also meshes with sketchy observations of the temperature ripples in the microwave background. Cosmologists can predict how big the ripples should be for a particular amount of matter and energy in the universe, so their observed size serves as a cosmic probe. And the tentative results so far do seem to show that the strongest ripples have a size of about 1 degree on the sky—the marker of a flat universe. "There it is—the baby picture of the universe, at 300,000 years old," said Turner, showing a viewgraph with the data.

Turner and others thought they saw a way out of the conflict: a more refined version of inflation in which reservoirs of energy in empty space itself—equivalent to matter according to Einstein's equation $E = mc^2$—make up the matter deficit and flatten the universe. To make everything fit, however, the universe would need about twice as much energy in the cosmological constant, called lambda, as in matter. That energy would lend a "springiness" to the cosmos, counteracting gravity on large scales and causing the expansion of the universe to accelerate over billions of years. That possibility was so bizarre that few scientists could accept it.

Then, earlier this year (*Science*, 30 January, p. 651, and 27 February, p. 1298), two groups announced that they had detected signs of that speedup in observations of distant supernovae. "That's the smoking-gun signature of lambda," Turner told his listeners. "This is the first time a cosmologist has been able to stand up in front of an audience," he added in summary, "and say, 'I have a prima facie case for a flat universe.'"

Peebles, in his rejoinder, compared the intense activity in cosmology over the last few years to "a really good party." But he also listed open questions that, he said, left him with an "uneasy feeling"—a kind of cosmic katzenjammer—about whether the concordance will survive new and more precise tests. Invoking one lesson of the Curtis-Shapley debate, Peebles noted that despite astronomers' best efforts to account for dust and intrinsic differences in the supernovae (see p. 1249), something other than cosmic acceleration could still be skewing the most distant beacons. He also emphasized that no one really knows what the background energy or even the bulk of the matter in the universe could possibly be.

Astronomers in attendance agreed that there's plenty of room for doubt. "If you have a model in which most of the matter and energy are unknown, then it's not much of a model," said Margaret Geller of CfA. And it is a little too neat for some astronomers to swallow comfortably. "Mike Turner came close to saying that we expected" the supernova result, said Peter Garnavich of CfA, a member of one of the supernova teams. "Certainly I didn't."

But Garnavich, like many of his peers, acknowledges the power of Turner's picture. "It does fit," he says. And if it holds up, says Princeton's Steinhardt, that just means there will be "new and even deeper mysteries to address"—and grist for future debates.

–JAMES GLANZ

CREDITS: MICHAEL TURNER