continents, it indicates that mammals had an extensive evolutionary history in Gondwana at that time, he says.

Cifelli sees a third possibility: that *A. nyktos* may be an advanced member of the peramurans, an early group of mammals believed to have spawned placentals and marsupials. To him, the slender jawbone and molar structure also look reminiscent of monotremes, considered among the oldest and most primitive of all mammals. "This new thing appears to be intermediate between peramurans and monotremes, suggesting that monotremes share a much more recent ancestor with higher mammals than previously thought," he says. If so, monotremes would jump up the family tree by about 50 million years, making these odd egg-laying mammals closer cousins to placentals and marsupials.

Other paleontologists think the fossil is too fragmentary to start redrafting the family tree. Instead, says Rougier, it should spur paleontologists to sharpen all their thinking about the early evolution of mammals: "The discovery will force us to take another look at the evidence for an early origin of placentals and to evaluate what features diagnose the major groups of mammals."

As for Rich, he welcomes the discussion. "Science is a democracy," he says. He hopes to advance the debate by finding more bones. A complete skull would help, as would other parts of the skeleton. "Now we know there is one hole in all of Australia where this kind of fossil occurs," Rich says. "This is where Pat and I can spend the rest of our lives, God willing."

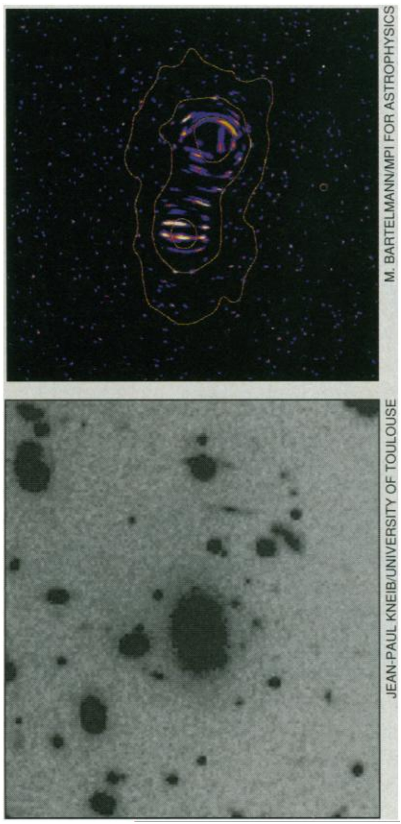
–Bernice Wuethrich

Bernice Wuethrich is an exhibit writer at the Smithsonian's National Museum of Natural History in Washington, D.C.

COSMOLOGY

Clusters Point to Never-Ending Universe

Until recently, the outlook for the expanding universe has varied with cosmological fashion. At times, the consensus view held that the universe contains enough mass for gravity to slow its expansion to a stop; at other times, cosmologists have doomed it to expanding forever. Lately, however, evidence ranging from galaxy clusters to distant supernovae has favored an ever-expanding, "open" universe. Now add another vote for an open universe, from the number of images from light-bending "gravitational lenses" in the sky.



Long lenses. Comparing simulated *(top)* and observed arcs puts focus on an open universe.

M. BARTELMANN/MPI FOR ASTROPHYSICS

JEAN-PAUL KNEIB/UNIVERSITY OF TOULOUSE

A team of German and British researchers has simulated how the vast clusters of galaxies that bend the light of objects behind them should evolve over time in universes containing different densities of matter. They then compared the results to the number of gravitational lens images actually seen in the sky. The verdict: The simulation that best matches the observed lensing images is one that assumes a low-density, open universe. "[This] work may be the strongest single piece of evidence [for an open universe] if it holds up," says Neil Turok of Cambridge University.

According to the general theory of relativity, light from a distant galaxy that passes close to a massive galaxy cluster on its way to Earth will be bent, with the cluster acting like a lens and producing an arc-shaped image of the distant galaxy. "In order for this process to be effective, you need the cluster—that is the gravitational lens—at roughly half the distance from us to the sources," says Matthias Bartelmann of the Max Planck Institute for Astrophysics near Munich, Germany, head of the modeling team. The clusters develop through the entire lifetime of the universe, at a rate that depends on the overall density of matter in the universe. So the number of dense clusters that have ended up in the right place at the right time to act as lenses is a powerful probe of the universe's overall mass density. "The lensing effect is very nonlinear—it reacts very strongly to changes in cluster evolution or in the compactness of the clusters," says Bartelmann.

In work that will be published in *Astronomy and Astrophysics*, he and Munich colleagues Andreas Huss and Jörg Colberg, along with Adrian Jenkins and Frazer Pearce of the University of Durham in the United Kingdom, began with two computer models that simulate the evolution of galaxy clusters. As input, the models required an estimate of the distribution of matter in the primordial universe, along with the universe's mean mass density and a parameter known as the cosmological constant—a hypothetical energy embedded in empty space, which may also influence the overall expansion of the universe. The researchers allowed the models to evolve until they reached the current age of the universe. The group then computed the lensing ability of the clusters that had emerged in each model and the number of arcs that would be seen from Earth.

Both simulations showed that a universe with just one-third of the mass density needed to stop its expansion—along with a small or zero value for the cosmological constant—would have dense clusters in the right numbers and places to produce about 2500 arcs across the sky. That number is a good match to the observed number of arcs, which is somewhere between 2300 and 2700. When the researchers wound up the cosmological constant, "the number of arcs goes down to about 250," says Bartelmann, "and when I then turn up the matter density ... the number of arcs reduces by another factor of 10 to about 25 on the whole sky." The dramatic differences in the outcome show, says Harvard University's Ramesh Narayan, that "this is quite a sensitive method to distinguish among models."

Narayan cautions that simulating cluster formation is "delicate." Bartelmann adds that the density distribution of the primordial universe is the largest uncertainty in the modeling, one that won't be dispelled until the cosmic microwave background—which records primordial density fluctuations—is mapped in detail by NASA's forthcoming Microwave Anisotropy Probe mission and the planned European Planck satellite.

Princeton University's Neta Bahcall notes, however, that Bartelmann's results on cosmic mass density are in "excellent agreement" with her own, based on direct counting of galaxy clusters. The findings are also in accord with direct measurements of how cosmic expansion has changed over time (*Science*, 31 October, p. 799). This forecast for the fate of the universe may be more than current fashion.

–Andrew Watson

Andrew Watson is a writer in Norwich, U.K.