Indeed, the work already offers a remarkably clear view of the stages of gene decay. As the *R. prowazekii* genome sequence shows, first genes are interrupted by a stop codon, a sequence of three nucleotides that tells the protein-synthesis machinery that it has reached the end of the gene and should stop. Occasionally, these interrupted genes continue to make incomplete proteins of their own. But as degradation progresses, genes lose the ability to produce proteins and eventually stop being copied into messenger RNA altogether, although they remain identifiable.

The decay is likely the combined result of random mutations and adaptation. Struck by a mutation that disables a gene, individual *Rickettsia* microbes either die or pass the altered genes on to their offspring. Raoult points out that some of the genes lost make enzymes needed to produce amino acids also generated by the host—meaning that the bug can abandon these genes without losing access to the amino acids. "If you don't have some positive benefit from that gene, you lose it," says Nancy Moran, an evolutionary biologist at the University of Arizona in Tucson.

Having painted the outline of *Rickettsia* evolution with broad brush strokes, scientists now hope to focus on the details of how gene inactivation occurs. Moran notes that many of the genes lost perform basic functions such as DNA repair. Thus, it's possible that the loss of, say, one specific DNA repair gene instead of another affects which mutations stick. By clarifying how genes lost may guide the bacterium's evolution, scientists can perhaps grasp how its existing design came to be. **–JENNIFER COUZIN**

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ASTROPHYSICS

## Orbiting Observatories Tally Dark Matter

**WASHINGTON, D.C.**—As galaxy clusters belch x-rays in all directions, they reveal the hidden mass in the universe. At a meeting here celebrating 2 years of observations with the Chandra X-ray Observatory,* astronomers claimed that Chandra observations, along with pictures from the Hubble Space Telescope, enabled them to calculate the amount of dark matter in the cosmos—and seriously damage one theory about its nature.

One of the biggest puzzles in astrophysics is the nature of dark matter, the invisible substance whose gravitational pull holds galaxies together. "It's been about 25 years since we appreciated that dark matter is the dominant form of matter in the universe," says Joel Bregman, an astrophysicist at the University of Michigan, Ann Arbor.

In the past few months, astronomers have measured the amount of dark matter by looking at wiggles in the cosmic background radiation (*Science*, 4 May, p. 823) and by analyzing the distribution of galaxies in space (*Science*, 13 April, p. 188). They've concluded that ordinary matter makes up only about 5% of the mass needed to give space the shape that cosmologists prefer, while dark matter makes up another 25% or so. (The mysterious "dark energy" or "quintessence" seems to make up the remainder.) At the symposium, Steven Allen, an astronomer at the Institute of Astronomy in Cambridge, U.K., presented new evidence that those figures are correct.

**Weighty matters.** Warped images of galaxies in cluster Abell 2390 helped reveal the mass in intervening space.

With the Chandra satellite, Allen and his colleagues observed the x-rays emitted by gas inside massive galaxy clusters. "For the very first time, we're able to accurately measure the temperature of this gas," Allen says. From the temperature profile and density of the gas, the team figured out how much mass is holding the cluster together. "It's very straightforward," he says.

Meanwhile, pictures from the Hubble Space Telescope and ground-based observatories gave an independent measurement, based on how much the extreme mass of the cluster bends light, a phenomenon called gravitational lensing. The more lensing, the more mass is concentrated in the cluster. Although the two methods are very different, their results agree. "With the optical data and the x-ray data, you get the same answer," says Allen. The values for the amounts of matter and dark matter in the universe match what the cosmic background and galaxy-distribution data imply. "It's the most accurate determination to date of the amount of dark matter in galaxy clusters," he says.

John Arabadjis of the Massachusetts Institute of Technology has used Chandra x-ray data to draw an even stronger conclusion about dark matter. Some theorists postulate that dark matter is self-interacting—that is, particles of it are fairly likely to collide with one another. In that case, the collisions should force the dark matter to spread out more than it would otherwise. This hypothesis seemed to explain the distribution of matter in the centers of dwarf galaxies, but according to Arabadjis, Chandra's x-ray measurements show that dark matter in galaxy clusters doesn't spread out as one would expect if the particles collided easily. Thus, the model that succeeds in dwarf galaxies seems to fail in larger structures. "We can more or less say that self-interacting dark matter is dead now," Bregman says.

Paul Steinhardt of Princeton University is less sure. "The model's been declared dead many times," he says. Steinhardt thinks the study's assumptions are too crude to give definitive answers yet. And even if Arabadjis is right, he says, "there's plenty of room left in the self-interacting picture. But the simplest version might be in trouble." **–CHARLES SEIFE**

* "Two Years of Science With Chandra," 5–7 September.

GEOLOGY

## Swiss Scientists Trace 645-Year-Old Quake

At dinnertime on 18 October 1356, residents of Basel, Switzerland, felt the jolt of an earthquake that toppled churches and castles 200 kilometers away and triggered weeklong fires. The ground seemed to slumber after that. Although a few obscure accounts tell of periodic tremors in the area up to 1721, the nature of the 1356 earthquake—the largest historical seismic event in central Europe—remained a mystery. Now, on page 2070, researchers re-

**Ravaged.** A 1544 woodcut shows the earthquake that leveled Basel 2 centuries earlier.

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