trol: If they could displace susceptible worms in the environment, they could offer a potential natural control. Hedrick's laboratory also plans to investigate how resistant worms neutralize spores and whether resistant genes can be passed to susceptible worms.

Granath's studies point to another potential weak spot in the parasite's life cycle: At 15 degrees Celsius, huge amounts of TAMs are released from the worms into the water, but at 5 degrees, few are released. This laboratory finding parallels field observations that hatchling rainbows, but not stream-sharing brown trout, contract whirling disease. Fish biologist Dick Vincent of Montana Fish, Wildlife, and Parks in Bozeman found that young rainbows emerge in May, when waters are warm and filled with TAMs that bombard them. Young brown trout emerge in March, when waters are colder and contain few TAMs. One implication is that selective pressures may eventually favor rainbow trout that spawn earlier in colder waters.

All these recent discoveries have resulted from a tiny research investment. In 1996, federal grants to study whirling disease totaled just $360,000, the Whirling Disease Foundation awarded $73,000, and some chapters of Trout Unlimited gave up to $10,000. Colorado State's Ellis says it may be time for anglers to "put more money into research instead of flies."

–Carol Potera

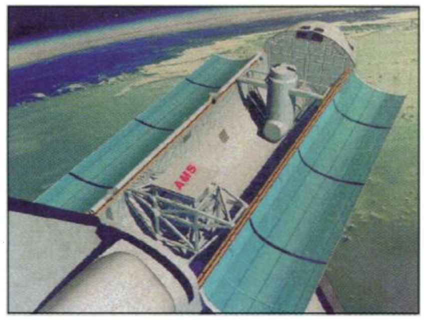
Carol Potera is a writer in Great Falls, Montana.

ASTROPHYSICS

Theorists Nix Distant Antimatter Galaxies

For those who yearn for an equal opportunity universe, half matter and half antimatter, the latest findings will be a disappointment: Matter dominates, and there are no antigalaxies, despite the dreams of science fiction fans everywhere. This is the conclusion of a trio of theorists after a lengthy analysis of the physics of matter-antimatter annihilation and the gamma-ray glow that pervades the sky. Their finding, to be reported in the *Astrophysical Journal* in February, may sound like a victory for conventional wisdom, but it underscores a long-standing mystery: why the big bang displayed such blatant favoritism toward matter.

The universe that sprang from the big bang should have contained equal parts of matter and antimatter. But cosmologists have long known that our cosmic neighborhood is all matter. Now physicists Andy Cohen of Boston University; Alvaro de Rújula of CERN, the European particle physics lab near Geneva; and Sheldon Glashow of Harvard University have confirmed that matter somehow dominated the rest of the visible universe as well. By rigorously calculating the energy that would have been emitted when matter and antimatter met and annihilated, then comparing the results with actual measurements of the gamma-ray background, they rule out the existence of large domains of antimatter. "It's probably the best job ever done of calculating the annihilation rates and the gamma-ray spectrum," says the University of Chicago's David Schramm.



AMS

Long shot? Artist's conception of the antimatter detector to fly on the space shuttle.

The favored explanation for the absence of antimatter in the nearby universe is that soon after the big bang a slight asymmetry developed between matter and antimatter. The asymmetry enabled a little extra matter to survive when the two annihilated, leaving a universe apparently devoid of antimatter. But that picture has been taken on faith more than data. The asymmetries in the relevant parameters of quantum physics—in particular, a phenomenon called CP violation—currently appear to be smaller than necessary.

The uncertainty opened the way for a second scenario: that the universe started off with equal amounts of matter and antimatter, segregated in nonoverlapping domains. When the newborn universe went through a spurt of exponential growth, called inflation, these domains grew so quickly that they never had time to annihilate completely. If so, the universe today would have huge domains of antimatter, on the scale of galaxy clusters or larger. These antigalaxies would look to us like the ordinary variety, but, says Cohen, there should be telltale signs of matter-antimatter annihilation at the boundaries between domains.

If the matter and antimatter domains are nearby in time and space, the high-energy gamma-rays from their boundaries would have been seen already, he says. But the signal from larger domains—at least the size of superclusters—could have been missed. Annihilation would have begun at their boundaries early in the history of the universe, says Cohen. "The gamma-rays would be smeared out, redshifted to lower energies by the expansion of the universe. Now, there is a diffuse gamma-ray background, and no one is exactly sure where it comes from. The suggestion that it comes from antimatter is an old one, going back several decades."

So he, de Rújula, and Glashow tested that idea by computing the spectrum of diffuse photons from matter-antimatter annihilation in the early universe. The process can be thought of as "the ultimate bomb," de Rújula says. A gas touching an antigas annihilates in an explosion of light, particles, and antiparticles, which in turn heats both the gas and antigas, causing them to annihilate faster, producing yet more annihilation and more heat and so on. … While calculating the energy from this chain reaction is "pretty difficult," says de Rújula, "it's just a case of laboriously applying our knowledge to a very complicated thermodynamic calculation."

The three physicists conclude that even in the most conservative analysis, matter-antimatter annihilation should produce a signal five times as large as the observable diffuse gamma-ray background. "It's an awfully big effect," says Glashow.

Cohen notes that there are still a few loopholes: For instance, if the universe consists of just two domains, one entirely matter and the other entirely antimatter, the analysis wouldn't hold. "If you looked in one direction, you might not see any gamma-rays at all," he says. "So we don't have anything to say about that case."

Schramm says the analysis definitely reinforces the "prior prejudices" of theorists that the antimatter isn't there. But the work wasn't done just for the enlightenment of theorists. In 1995, physicist Sam Ting of CERN and the Massachusetts Institute of Technology began work on a detector to fly on the space station that would search for antimatter cosmic rays, such as nuclei of anticarbon, coming from distant antigalaxies (*Science*, 12 January 1996, p. 142). Ting's experiment is scheduled to be tested on the space shuttle this May.

Ting says he promised to buy de Rújula, Glashow, and Cohen dinner if their analysis supported the possibility that his detector will see cosmic antinuclei. Now dinner is off, he says. But Ting, who is famous for knowing when to ignore the predictions of theorists and won a Nobel Prize by doing just that, isn't discouraged. "The most important thing is that no precision experiment has ever been done" to measure the composition of cosmic rays. Adds Glashow, "We're not exactly saying it's impossible for [Ting] to find antimatter. We're saying that from the context of current cosmology it's impossible. So if he finds it, he upsets the whole apple cart."

–Gary Taubes