cil is constructing a ranking scheme that would place wet areas at the top of the list for protection and drier areas at the bottom. That system would "make no ecological sense whatsoever" in terms of the patch dynamics model, says Stan Gregory, associate professor of fisheries and wildlife at Oregon State University and principal author of the Willamette National Forest Riparian Management Guide.

Tolman, who told *Science* that he's never heard of patch dynamics, sees the situation differently. He and his colleagues are "aware that wetter is not always better," he says. Yet he argues that research on wetlands hasn't gone far enough to institute a more accurate ranking scheme. "The science isn't really in place to say which types of land are more valuable than others, and we need to have some scheme that will allow us to go forward with development in appropriate areas while protecting the nation's wetlands."

Tolman adds: "Until someone comes up with a better way of assessing the importance of different kinds of wetlands, we'll continue using this approach." One strategy his office is considering, he says, is a "mitigation bank" for each watershed area to which developers would pay a fee for filling in land according to its ranking. This money would then be used to acquire or construct wetlands somewhere else in the watershed. "The theory is that you would have a free market within that watershed ecosystem. Developers would obviously want to spend less money mitigating, so they would develop the less expensive land," explains Tolman.

Even if patch dynamics hasn't penetrated the White House, it has had an impact on the local level, as wildlife officials attempt to use the new ideas to better manage the lands under their purview. In Oregon's Willamette National Forest, to cite only one example, U.S. Forest Service managers are taking a patch dynamics approach to setting timber harvest procedures in such a way as to protect the area's rivers and surrounding riparian ecosystems. Oregon's Stan Gregory says the key to this plan is recognizing that a functional river depends as much on the forests that lie upland of the river—land that is rarely saturated at any time of the year—as it does on the lowlands more directly associated with the river. "The forest acts as a hydrological buffer, a seed bank, and a source of dead trees that reach the river and stabilize its banks. If you harvest the trees in the region, the river and adjoining land degrades significantly."

Whether approaches like Gregory's will ever be applied on a national scale depends, in part, on whether the divide between the White House and the ecology community can be bridged. Since at the moment they appear to be operating on the basis of two completely different paradigms, the prospects for accord would seem be remote.

–Joseph Alper

Physicists Rock the Standard Model in Dallas

The 1400 physicists who converged on Dallas 2 weeks ago for the International High Energy Physics meeting came from all over. Ask them about the state of their field, however, and you'll find a common dream–to go beyond the standard model of particles and forces. For physicists "searching for chinks in the model's armor," as several put it, the elusive, unobtrusive neutrino is a promising object of study. And while the meeting saw the possibility of a superheavy "17-keV" neutrino fade, cosmic ray-produced neutrinos gave new hints of physics in that over-the-rainbow region beyond the standard model.

Requiem for a Heavyweight

Early last year, after a long, dry decade without big discoveries, some particle physicists thought nature had finally offered up a surprise: a neutrino with 1000 times more mass than any existing theory predicted (*Science*, 22 March 1991, p. 1426). At the Dallas meeting, this inexplicable "17-keV neutrino" still topped the list of hot topics, but the biggest news was that the evidence is now stacking up against it.

The negative evidence, coming from three different research groups, was the fruit of an intensive effort to follow up on the early hints of the neutrino. Physicists admit that they got so excited about this elusive particle because they haven't had much else to be excited about. "Hundreds of millions of dollars are spent to find new physics," says Thomas Bowles of the Los Alamos National Laboratory, who is participating in several neutrino experiments. But "everything new and exciting has gone away."

> **"I think nature contrived to put artifacts in all these experiments to mimic a 17-keV neutrino."**
>
> **–Andrew Hime**

Before it looked like the heavy neutrino, too, was bound for oblivion, the physics community had been locked in a stalemate over whether it really exists. After all, the standard model of particle physics suggests that neutrinos have no mass at all. And though a few other theories did predict a trace of neutrino mass—perhaps a few electron volts—nobody expected anything like the 17,000 electron volt (17 keV) behemoth first sighted by John Simpson of the University of Guelph in 1985 in studies of radioactive nuclei.

Simpson was studying a process called beta decay, in which a decaying nucleus emits an electron and a neutrino. Ordinarily, the electron flies off with almost all of the energy of the reaction, but Simpson found that in some decays a chunk of energy—17 keV, to be exact—seemed to be missing from the electron. Simpson proposed that a heavyweight neutrino was carrying off the mass equivalent of the missing energy.

He gained allies in 1991, when a handful of experimenters found what looked like confirming evidence. But other physicists still saw grounds for doubt: All of the positive results, from Simpson on, came from solid-state detectors in which the electron energies were gauged by their ionizing effect on crystals of silicon or germanium. When other researchers tried to confirm these results by measuring the energy of emitted electrons in mass spectrometers rather than crystals, they saw nothing. And the physics community as a whole remained skeptical that either type of experiment had the sensitivity to settle the issue.

Until now. One result that especially impressed the physicists at the Dallas meeting came from Japanese researcher Takayoshi Oshima of the National Laboratory for High Energy Physics. He used a mass spectrometer, but one he says gives a more detailed picture of the energy region around 17 keV, where the effect should show up. The result: still no neutrino.

And even the solid-state detectors can't consistently find the beast, reported Eric Norman of the Lawrence Berkeley Laboratory, previously one of the biggest boosters of the 17-keV neutrino. He said he was getting a positive signal from the decay of carbon-14, but when he tried another experiment based on iron-55, he came up empty-handed. "If there were a 17-keV neutrino we would have seen it in the iron-55 [as well]," he said.

But the death blow, in the minds of many physicists, came from Stuart Freedman, also of Lawrence Berkeley. He also used a solid-state detector—and he boosted the credibility of his result by checking beforehand that his set-up was sensitive enough to detect the putative neutrino. He did so by mixing his electron source, radioactive sulfur, with a little carbon-14. Electrons from beta decay in carbon-14 are slightly less energetic than those from sulfur, creating an artificial energy deficit mimicking the 17-keV neutrino. The detector had no trouble picking up the artificial effect—but it didn't see any sign of a real 17-keV neutrino.

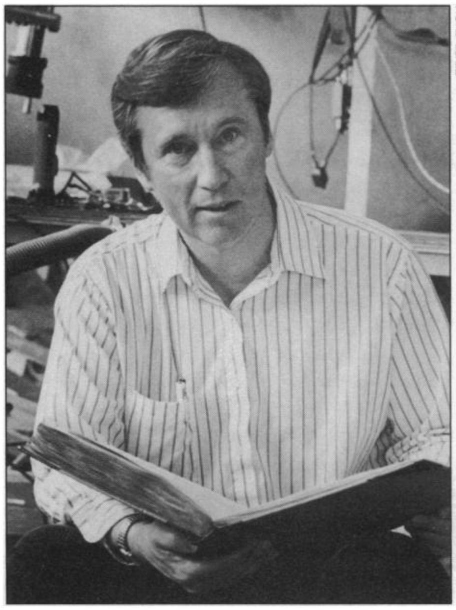
That result even shook up some of the strongest backers. "As far as I understand it, this is a pretty solid experiment," says Andrew Hime of Los Alamos, one of the original neutrino finders. "The situation is quite baffling," he says. His gut feeling now: "I think nature contrived to put artifacts in all these other experiments to mimic a 17-keV neutrino."

In a summary talk, Los Alamos researcher Hamish Robertson pronounced the superheavy neutrino officially dead. But, surprisingly, one of the neutrino slayers is reluctant to sign the death certificate. Freedman says he is still impressed that more than six different kinds of experiments have shown an effect, all right at the 17-keV mark. "It's very surprising that different experiments get the same values for these things," he says. "It's hard to believe that it's a bunch of random systematic errors." Sure, the negative evidence is weighing heavily, he admits, "but you don't do science by democracy."

Physicists Ponder a New Neutrino Problem

First there was the solar neutrino problem, which has dogged physicists for years: Huge underground detectors set up to capture neutrinos from the sun's nuclear reactions detect far fewer than theory predicts. Now get used to what you might call the cosmic-ray neutrino problem. At the meeting, University of Tokyo physicist Takaaki Kajita announced that the several kinds of neutrinos produced when cosmic rays collide with air molecules don't live up to theory either: They come in the wrong proportions.

For many physicists at the meeting, though, this new "problem" was welcome news. It adds another hint that the solution to the solar neutrino problem may require a fundamental change in physicists' picture of particles and forces. "It's a very exciting time," says neutrino physicist Hamish Robertson of Los Alamos National Laboratory. "People are starting to find there is something there." That "something" is the possibility that neutrinos can switch identity, "oscillating" from one of three neutrino varieties (electron, muon, and tau) into another—something they could do only if they have a trace of mass. In the standard model of particle physics, neutrinos are massless, so that any evidence of neutrino oscillations would open a gaping hole in the standard model, a prospect that theoretical physicists relish because it



Wary excitement. Hamish Robertson.

would finally give them a chance to improve this long-standing picture.

Physicists first raised the possibility of neutrino oscillations in an effort to explain what might be happening to the missing solar neutrinos. The measured deficit—as many as two-thirds of the predicted solar neutrinos are missing—might reflect some flaw in solar physicists' understanding of the sun's core. But, as physicist John Bahcall of the Institute for Advanced Study explains, no variation of the solar model can explain all the different solar neutrino results at once. Instead, many theorists suspect the problem lies in physicists' picture of neutrinos. Maybe the sun really is producing its quota of electron neutrinos, they say, but on their way out of the sun some of them are oscillating into muon or tau types, which today's detectors can't see.

Kajita and his colleagues think the same thing might be happening to neutrinos from cosmic rays. Their evidence comes from Japan's Kamiokande neutrino detector, which played a key role in confirming the solar neutrino problem. Even though the detector can't see any muon neutrinos from the sun, it can detect the much more energetic muon neutrinos produced by cosmic rays. About one cosmic ray neutrino hits each square centimeter of the detector each second, says Kajita's U.S. collaborator Alan Mann of the University of Pennsylvania, though all but about one a day pass through the detector's vast tank of water without being captured.

But the few that were captured were enough to convince the team that something was amiss. Compared to what physicists expected from standard physics, too few muon neutrinos appeared to be hitting the detector relative to electron neutrinos, explains Mann. According to Mann, another team conducting a nearly identical experiment in a salt mine near Cleveland has seen the same shortage of muon neutrinos. "The results are in such close agreement that it's remarkable," says Mann. "This leads to the tentative conclusion that there are oscillations," he says.

To explain both the shortage of solar electron neutrinos and atmospheric muon ones, theorist Thomas Gaisser of the University of Delaware points out, oscillation might have to be a two-way street. Perhaps, says Gaisser, electron and muon neutrinos tend toward some sort of equilibrium. The electron neutrinos from the sun would approach equilibrium by turning into muon types, while the mostly muon neutrinos from cosmic rays would do the reverse. The other possibility: The missing solar electron neutrinos and cosmic ray muon neutrinos are both eluding detection by changing into the third neutrino variety, tau neutrinos, which can't be detected even when they come from cosmic rays.

But many physicists aren't ready to embrace oscillations just yet. Says Los Alamos' Robertson: "The situation is not clear cut. There are other ways to interpret the results." For example, he says, physicists may simply be mistaken in their estimates of the proportion of muon neutrinos produced by cosmic rays in the upper atmosphere.

That explanation for the cosmic-ray neutrino problem would leave conventional physics intact. But there is another long-shot possibility, just as revolutionary as oscillations, which some researchers cautiously mention: The excess of electron neutrinos could come from the decay of protons in the detector's water molecules. Proton decay is the one main prediction of the "grand unified theory," popular about 10 years ago, that physicists hoped would eclipse the standard model. Indeed, Kamiokande and several other neutrino detectors were originally built to test this prediction, though they have yet to see a proton decay.

If the physics of neutrinos—rather than cosmic rays or protons—is to blame for this latest riddle, physicists should know for sure within the next 5 years. The key, agree Robertson and other physicists at the meeting, will be a neutrino project called the Sudbury Neutrino Observatory (SNO), run by collaborators in England, the United States, and Canada. That detector, to be built in Canada, will be sensitive to all three kinds of neutrinos from the sun. It should provide a straightforward test of the neutrino-oscillation hypothesis, says Los Alamos researcher Thomas Bowles: "If we see muon and tau neutrinos, there's no question—something is arriving at Earth which could not be produced at the sun." And if oscillating neutrinos can be caught in the act, the elusive particles will finally lift scientists up from their current plateau and on to bigger and better theories.

–**Faye Flam**