the matrices have a lot of zeros—"sparse systems." These systems occur, for example, in weather forcasting and in the design of airplane wings. When a linear system is appropriately sparse, Reif and Pan's method uses far fewer processors than it does for more dense matrices. Now, says Reif, "In theory, you can get an answer at least an order of magnitude faster."

Yet, according to Reif, most parallel processors in use today have far fewer than 1000 processors and so the speed-up with the new method is currently less dramatic than it could be, although it is still substantial. But already there are a few systems with huge numbers of processors. For example, the Thinking Machine Inc.'s Connection Machine in Cambridge, Massachusetts, has 16,000 processors and the company is now developing a network with 64,000 processors. Several other companies, including IBM, claim that they intend to build networks with more than a thousand processors within the next few years. So, with the new parallel processors and the new algorithm, the process of finding solutions to huge linear systems should be much quicker. Weather forecasting equations, Reif notes, should be much easier to solve. In short, says Rivest, "the possibilities look very exciting."

—GINA KOLATA

Additional Reading

1. V. Pan and J. Reif, "Efficient parallel solution of linear systems," in *Proceedings of the 17th Annual ACM Symposium on the Theory of Computing*, Providence, R.I., May 1985, pp. 143–152.

Something Strange from Cygnus X-3

At least two proton decay experiments have now detected particle showers that seem to be triggered by emissions from the galactic x-ray source Cygnus X-3. However, the emissions are baffling: known elementary particles, such as photons or neutrinos, can be ruled out. Nor is there an obvious candidate among the supersymmetric and grand unified particles concocted by the theorists. If real, the Cygnus X-3 particle would have to be something new.

Cygnus X-3 itself is an x-ray binary system with a period of 4.79 hours, lying some 30,000 light-years from Earth. Essentially it consists of a compact object, probably a neutron star, pulling a stream of gas from a more or less normal companion star; in the process the gas is heated sufficiently to emit the x-rays observed. In fact, Cygnus X-3 is probably the most powerful source of high-energy photons in the galaxy. It is also well situated in the northern sky for observation by many of the proton decay experiments. The first indications came about 2 years ago, when showers of muons from the general direction of Cygnus X-3 were seen in a prototype detector operated in Minnesota's Soudan iron mine by physicists from the University of Minnesota and the Argonne National Laboratory.

As it happens, when the Soudan group submitted their results for publication, one of the reviewers was John Learned of the University of Hawaii, a member of the team that operates the giant Irvine-Michigan-Brookhaven (IMB) detector in the Morton Thiokol salt mine near Cleveland. Following Soudan's lead, Learned started analyzing the IMB muon events with particular attention to Cygnus X-3; by Christmastime 1984, he and his students had found suggestions of a signal that matched both the 4.79-hour periodicity of Cygnus X-3 and its proper phase.

Learned accordingly passed word back to the Soudan group and to the proton decay community at large. The Soudan physicists have now reanalyzed their data and confirmed the result: out of 874,000 muon events, 1200 come from the general direction of Cygnus, and an excess of 80 show the 4.79-hour periodicity (*1*). "It's like picking out a lighthouse," says Minnesota's Marvin L. Marshak. Similar results have also been reported from the European NUSEX detector in the Mont Blanc tunnel (*2*).

There remains the question of what is causing the muon tracks. Since muons are unstable and short-lived, they are presumably produced by some kind of primary particle from Cygnus X-3 interacting with the earth's atmosphere or with the rock around the detectors. (The detectors experience an enormous background flux of muons produced by cosmic rays in exactly this way.)

The fact that the periodicity is detectable over a distance of 30,000 light-years means that all the primary particles have to be moving at the same speed, the speed of light; otherwise some would lag behind the others and the signal would be washed out. The fact that the primaries still show some directionality means that they must be electrically neutral; otherwise the galactic magnetic field would have deflected and randomized them.

The only known particles that fit those two criteria are neutrinos, photons, and ultrahigh-energy neutrons. However, neutrons can be ruled out because they themselves are unstable, with a 15.3-minute half-life. To survive the trip they would need an energy in excess of 10^{18} electron volts. Yet the flux of all known cosmic rays above that energy would produce only about one event per year in the Soudan detector.

Neutrinos can be ruled out by the zenith angle effect: the signal tends to die away as Cygnus X-3 approaches the horizon, as if the primaries were being absorbed by the atmosphere or the surrounding rock. Neutrinos are perfectly capable of traversing the whole earth and would produce an isotropic distribution of muons.

And finally, photons can be ruled out because they simply do not produce enough muons. Barring some previously unsuspected interaction mechanism, calculations show that the known flux of high-energy photons from Cygnus X-3 fails to produce enough muon showers by a factor of 300.

"If the results are right, the deficiencies [with known particles] are *gross*," says Learned. "There's no way the theorists can wiggle out with a factor of 2 here or there. The only question is, Are the experiments correct?"

Indeed, there is ample reason to be cautious: the IMB collaboration in particular has been looking at additional data using two independent methods of analysis and has so far been unable to verify Learned's signal. As Learned himself paraphrases the group's official stance, "Whatever it is we do or don't see, it isn't neutrinos."

—M. MITCHELL WALDROP

References

1. M. L. Marshak *et al.*, *Phys. Rev. Lett.* **54**, 2079 (1985).
2. G. Battistoni *et al.*, submitted to *Phys. Lett. B*.