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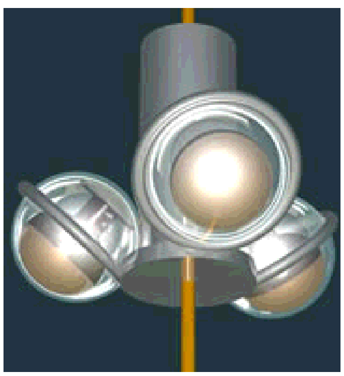
Hope for neutrino detection

Elusive energy-packed particles should give new view cosmos after all.
29 May 2002

PHILIP BALL



To be spotted, a neutrino has to interact with a nucleon.
ANTARES/F. Montanet/Univ.Mediterranee

Hundreds of millions of dollars are slated to be spent on detecting very energetic, almost ghostly particles called neutrinos as they stream through the Earth. Some astronomers and physicists hope these particles will open a new window on the Universe. Others doubt this window will reveal much at all.

Now, just as the US government has called for a spending review of its neutrino-detection programmes, two teams of scientists raise hopes that these programmes won't be futile after all. Their modelling studies show that if very-high-energy neutrinos are indeed out there, we should be able to see them.

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To be spotted, a cosmic neutrino has to collide and interact with nucleons, much heavier fundamental particles in the nuclei of atoms. Unfortunately, no one knows how strongly neutrinos and nucleons interact.

It doesn’t much matter, say Alexander Kusenko of the University of California at Los Angeles and Thomas Weiler of Vanderbilt University in Tennessee. There should be plenty of observable collisions no matter how strong the interaction is, their calculations show[1].

Meanwhile, a new way of detecting high-energy cosmic neutrinos should raise the chances of seeing them. It has been devised by Jonathan Feng of the Massachusetts Institute of Technology in Cambridge, Massachusetts, and co-workers[2].

Ice work

The Sun and other stars constantly spew out neutrinos which stream harmlessly through our bodies all the time. But some astrophysicists suspect there are also some neutrinos with such high energies that they are almost impossible to detect as they fly into and through our planet.

For example, some galaxies have furious centres, called active galactic nuclei (AGNs), possibly because they contain immense black holes. According to some theories, AGNs could be emitting hordes of very-high-energy neutrinos. If we could see these particles, we would have a better chance of understanding AGNs.

Like radio astronomy and X-ray astronomy, ultrahigh-energy neutrino astronomy could show us new, violent phenomena in the Universe. With this in mind, several detectors are being built.

As neutrinos

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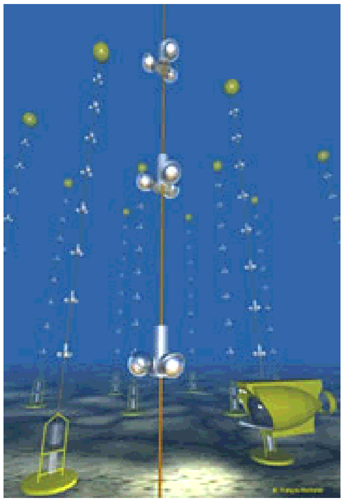

The Antares project aims to detect neutrinos from the sea bed.
ANTARES/F. Montanet/Univ.Mediterranee

As neutrinos barely interact with other particles at all, high-energy neutrino observatories plan to use the Earth itself as a detector. As the particles whizz through thousands of miles of rock in the deep Earth, some of them might collide with atoms in the rock to generate other, more easily detectable, particles.

To shield the observatories from the lower-energy neutrinos streaming down onto Earth , they are placed deep down below a layer of rock, ice or water. AMANDA (Antarctic Muon and Neutrino Detector Array) is searching for neutrinos in holes drilled deep into the Antarctic ice sheet, for example. The Antares project aims to detect neutrinos thousands of feet under the sea.

Leptons light up atmosphere

It should also be possible to detect ultrahigh-energy neutrinos that barely skim the Earth, colliding with nucleons just below the surface, say Feng and colleagues. These would produce particles called leptons, which can travel for dozens of kilometres through rock. When the leptons emerge from the Earth they should generate light in the atmosphere, which very sensitive light detectors could pick up.

Projects like AMANDA also search for leptons from neutrino collisions, but they look for the light the leptons produce as they travel through about a cubic kilometre of ice. In contrast, the Feng method has a vastly bigger detector volume: in essence, all of the atmosphere within 20 km or so of the light detectors.

The more detection techniques the merrier
Jonathan Feng, Massachusetts Institute of Technology

Only neutrinos with extremely high energies can stimulate light emission in the air. AMANDA can see lower-energy neutrinos too. So several detection techniques will complement each other. "The more the merrier," says Feng.

Kusenko and Weiler have calculated how well such a technique for detecting Earth-skimming neutrinos might fare for different strengths of neutrino-nucleon interaction. They find that interaction strength seems to matter little, provided a detector can also see leptons caused by collisions in the Earth's atmosphere.

The two processes seem to balance each other out. The weaker the interaction, the lower the number of atmospheric collisions - but the greater the number of collisions in the Earth, because neutrinos become detectable at bigger skimming angles.

References

1. Kusenko, A. & Weiler, T. J. Neutrino cross sections and future observations of ultrahigh-energy cosmic rays. *Physical Review Letters*, 88, 161101, (2002).
2. Feng, J. L., Fisher, P., Wilczek, F. & Yu, T. M. Observability of Earth-skimming ultrahigh energy neutrinos. *Physical Review Letters*, 88, 161102, (2002).