Dark matter: MACHOs in Milky Way's halo?

Two independent teams of astronomers report new evidence this week that dark matter resides at the outskirts of the Milky Way. Dark matter — invisible material thought to lie at the periphery of many galaxies — doesn't glow like ordinary matter, yet exerts a gravitational tug.

The studies, based on nightly scans of millions of stars in the nearby Large Magellanic Cloud (LMC) galaxy, suggest that the Milky Way's periphery contains dense pieces of dark matter called Massive Compact Halo Objects, or MACHOs. The new findings rely on the phenomenon of gravitational lensing, in which a massive foreground object bends and brightens light from an object that lies behind it.

After several years of searching, the astronomers report that three stars in the LMC have shown such telltale brightening. The researchers attribute all three increases to gravitational lensing by Milky Way MACHOs that happened to cross the line of sight between the stars and Earth. Each MACHO may have a mass roughly one-tenth that of the sun and a size about that of a small star.

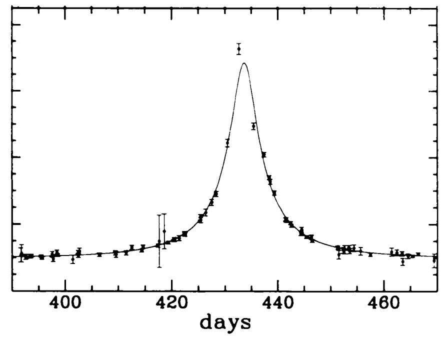
A U.S.-Australian team found evidence for a single MACHO, based on observations of an LMC star that suddenly increased its brightness nearly sevenfold. Another group, at the Centre d'Études de Saclay in Gif-sur-Yvette, France, found evidence for two MACHOs. This team bases its conclusions on separate observations of two LMC stars, each of which briefly appeared about three times as bright as usual. The two groups say the brightening is probably not caused by variations in the luminosity of the stars.

"For me, these three [observations] show that dark matter exists," says Sylvain Zylberajch of the Saclay group, which looks for MACHOs using two telescopes at the European Southern Observatory in La Serena, Chile. The two teams presented their data in Italy at the International Conference on the Cosmic Microwave Background Radiation in Capri and the Gran Sasso Conference on Underground Particle Physics.

The U.S.-Australian team, led by Charles Alcock of the Lawrence Livermore (Calif.) National Laboratory, has looked for MACHOs since 1992 using an elderly but refurbished 1.3-meter telescope at the Mount Stromlo Observatory near Canberra, Australia. Using a computer to analyze changes in light emission from 1.8 million stars in the LMC, the team discovered two weeks ago that one — perhaps a red giant — had brightened for 33 days early this year, says team member Kim Griest of the University of California, San Diego.

The symmetrical rise and fall in brightness suggested the handiwork of a gravitational lens, he says. In addition, the increase appeared the same in both red and blue light, another indication that the star had not suddenly boosted its own light output. Nonetheless, notes Griest, his group wasn't yet ready to go public with the finding. But after learning that the French team was about to announce its own recent discoveries, the researchers followed suit.

Contacted in Capri where he heard the U.S.-Australian report, Richard Saunders of the Mullard Radio Astronomy Observatory in Cambridge, England, said he was skeptical at first. "I thought, [the brightening] was just a background quasar. Then [the presenter] showed his light curve. . . . I was very impressed." — *R. Cowen*



Curve shows that a star in the Large Magellanic Cloud brightened for 33 days, possibly due to a MACHO.

A novel architecture for excluding photons

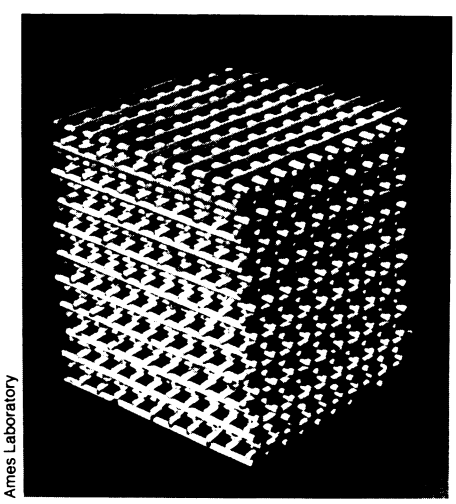
A stack of crisscrossed rods is the kind of structure one can readily imagine building out of pencils or soda straws. And that's precisely the point. It's easy to fabricate, even on a microscopic scale.

Discovered by C.M. Soukoulis and his collaborators at Iowa State University and the Energy Department's Ames Laboratory, this particular structure has just the right geometry to act as a photonic crystal. In other words, it prevents the absorption or emission of electromagnetic radiation at certain wavelengths that fall within an excluded range, or band gap.

This discovery suggests a promising route toward producing microscopic structures that exhibit band gaps at infrared or visible wavelengths. The fabrication of such photonic materials may one day lead to the development of highly efficient lasers and solar cells.

"We're very excited about this structure," Soukoulis says.

This research represents an outgrowth of earlier theoretical work done by Iowa State's Kai-Ming Ho and his colleagues. They predicted that an electrically insulating material having a repeating structural pattern resembling the arrangement of carbon atoms and bonds in diamonds would exhibit a photonic band gap.



This structure, made up of alumina rods 0.32 centimeter in diameter, 15.2 cm long, and 1.12 cm apart, exhibits a band gap at 13 gigahertz.

This prediction was confirmed when Eli Yablonovitch of Bell Communications Research in Red Bank, N.J., and his coworkers created one version of this geometry by drilling three sets of holes, slanted at specific angles, into the top of a solid slab (SN: 11/2/91, p.277). The resulting structure excluded certain wavelengths of microwave radiation.

But scaling this drilled structure down to smaller dimensions to get band gaps at visible wavelengths proved more difficult than expected. The Iowa State group decided to look for an alternative version of a diamond-like structure that would be easier to manufacture in a variety of sizes. They came up with a structure consisting of layers of parallel rods separated by a certain distance, with rods in adjacent layers at right angles to each other (see illustration).

The researchers then tested their idea by constructing this lattice out of rods of aluminum oxide (alumina). Measurements of microwave transmission through the model revealed a band gap at about 13 gigahertz. By scaling down the structure, they later produced band gaps at 24 gigahertz and 100 gigahertz.

"It's very robust," Soukoulis says. For example, varying the cross section of the rods from circular to elliptical or rectangular has little effect on the size of the band gap. "A graduate student could glue it together," he adds.

"I think it is a novel and interesting development," comments Fred M. Mueller of the Los Alamos (N.M.) National Laboratory, who has also worked on creating photonic materials. "It looks like it's going to have a lot of applications."

The Iowa State group and others are now exploring the possibility of crafting structures small enough to exhibit band gaps at visible wavelengths. — *I. Peterson*