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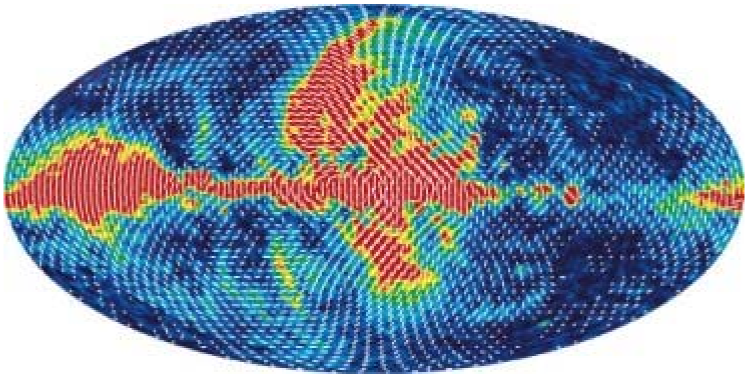
Dark matter may not be so dark



Polarization of the cosmic microwave background as seen by WMAP

Direct evidence for dark matter, the other worldy substance thought to make up 23% of the universe, could be staring cosmologists in the face. That's the conclusion of theoretical physicist Susan Gardner (http://www.pa.uky.edu/bios/Gardner.html) at the University of Kentucky in the US, who argues that if dark-matter particles had a tiny magnetic moment they would imprint a distinct polarization pattern in the radiation left over from the early universe.

For some researchers, this is a big if. The most widely studied dark-matter candidates, which arise naturally in supersymmetric extensions to the standard model of particle physics, do not have magnetic moments. But with few observational constraints, the difference between one dark-matter candidate and another is often a matter of theoretical preference.

Why should dark matter, which is much more abundant, be homogeneous in composition?

Susan Gardner, University of Kentucky

"Recently there has been a proliferation of novel candidates for dark matter," says Jonathan Feng (http://hep.ps.uci.edu/~jlf/) at the University of California at Irvine, who has come up with a few himself. "This one has a property that most others do not, but science is not a democracy — the most popular candidate doesn't necessarily win!"

Particles of the moment

Proposed in 1933 to explain why some galaxies rotate faster than would be possible if only visible matter was locally present, dark matter has gained plenty of indirect support in the last few decades. But apart from knowing that dark-matter particles interact gravitationally and must be electrically neutral (otherwise they would couple strongly to electromagetic radiation and would have been spotted), researchers do not know what dark matter actually is.

In fact, Gardner questions whether dark matter is made up of just one type of particle at all, as supersymmetric solutions suggest. "The world we know is made up of lots of different kinds of particles, many with magnetic moments," she says. "Why should dark matter, which is much more abundant, be homogeneous in composition?"

Provided the early universe contained a magnetic field, Gardner's dark-matter particles would line up like tiny bar magnets and produce a net magnetization (*Phys Rev Lett* **100** 041303 (http://link.aps.org/abstract/PRL/v100/e041303)). This would have a distinct effect on the polarization of photons in the cosmic microwave background (CMB), which was born 380,000 years after the big bang when the universe cooled enough for atoms to form. Dark matter is already vital when trying to explain the size of small fluctuations observed in the temperature of the CMB, since these come from density perturbations in the primordial plasma. Were photons to interact with magnetic dark-matter particles, however, their polarization vectors would be rotated via the Faraday effect.

Detecting such a polarization signature would not only rule out supersymmetric dark-matter candidates, but also show that dark matter is slightly less "dark" than originally thought.

Polarization modes

The problem is that there are many sources of polarization in the CMB photons. The most prominent comes from scattering by electrons that "see" non-uniform radiation due to surrounding density fluctuations. These are classed as "E-mode" polarization patterns, and recently have been measured in detail using the Wilkinson Microwave Anisotropy Probe (http://map.gsfc.nasa.gov/index.html) (WMAP) and other ground-based experiments. So far undetected are the much weaker "B-mode" patterns, which can arise due to gravitational waves that cause space to expand and contract.

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> Gary Hinshaw, NASA Goddard Flight Center

Crucially, the Faraday effect rotates the primordial E-mode polarization into B-mode polarization, producing a correlated *EB* signature. Furthermore, this signal would not depend on the frequency of light, providing a clear way to test Gardner's proposal. Indeed, in 2006 Bo Feng at the Chinese Academy of Sciences and co-workers, while searching for signs that nature violates a fundamental symmetry called CPT, hinted that such an *EB* signal already exists in the WMAP data (*Phys Rev*

Lett **96** 221302 (http://link.aps.org/abstract/PRL/v96/e221302)).

“The dark-matter proposal deserves further study, in particular to determine at which angular scales such effects would be evident,” says Gary Hinshaw at NASA’s Goddard Flight Center in Maryland. Hinshaw, who heads the data analysis for the WMAP science team, thinks the challenge will be to rule out a similar *EB* signal from synchrotron radiation produced in foreground galaxies, although he notes that this would have a strong frequency dependence.. “We are paying closer attention to our *EB* spectrum than ever because of these possible probes of new physics,” he adds.

About the author

Matthew Chalmers is a science journalist based in the UK