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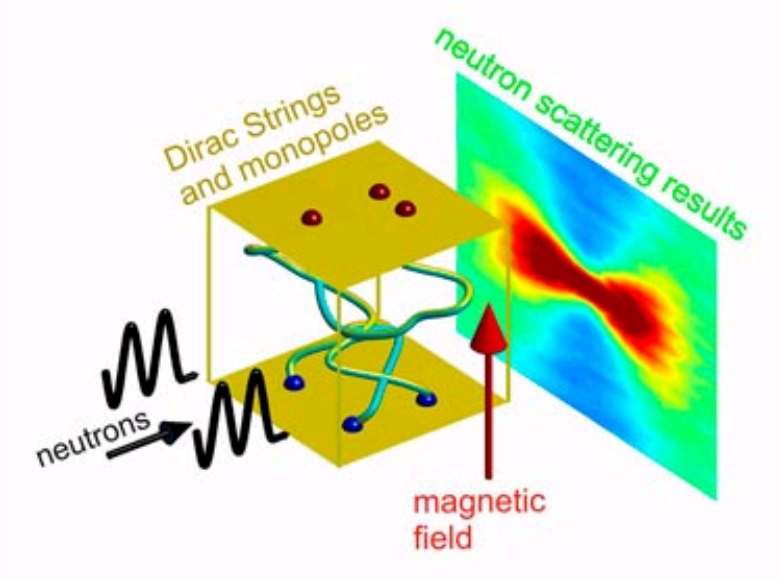
NEWS

Sep 3, 2009

Magnetic monopoles spotted in spin ices



Dirac strings and monopoles

Ever since magnetic monopoles were first predicted by Paul Dirac in 1931, physicists have looked in vain for these elusive entities in everything from particle accelerators to Moon rocks. Now, two independent research groups claim to have caught sight of monopoles – essentially magnets with only one pole – in magnetic materials called spin ices.

The spin-ice monopoles have very different origins from those predicted by Dirac's work on quantum electrodynamics and therefore their discovery is unlikely to help physicists develop grand unified theories of particle physics or string theories. But because the monopoles occur in magnetic materials, understanding their properties could help with the development of magnetic memories and other spintronic devices.

International collaborations

One team included Tom Fennell and colleagues at the Institute Laue-Langevin (ILL) in France along with physicists in the UK. The other included Jonathan Morris and colleagues at the Helmholtz Centre in Berlin (HZB) along with scientists in the UK, Argentina and Germany.

The Morris group studied the crystalline material $Dy_2Ti_2O_7$, which has a tetrahedral unit cell with two Dy spins pointing into the centre of the tetrahedron and two pointing out. It is called a spin ice because the arrangement of spins is similar to that of hydrogen atoms in frozen water.

The spins in a spin ice do not line up like those in a ferromagnet. Instead physicists believe that they join up to create magnetic flux lines within the material that resemble a knotted mess of strings. These are known as Dirac strings because they resemble the tubes of flux that should connect magnetic monopoles according to Dirac's calculations.

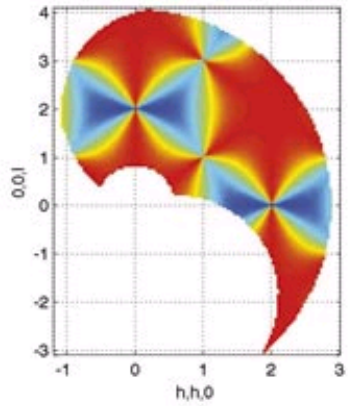
If the spin configuration of an individual tetrahedron is disrupted – say, by flipping a spin from "out" to "in" – a string is broken and the magnetic flux spills out in a manner resembling a monopole.

Morris and colleagues applied a magnetic field to their spin-ice sample and found that the stings began to break into finite sections that line up along specific directions in the material. This was revealed by firing a beam of neutrons at the sample and studying the interference pattern that results when the neutrons (which have magnetic moments) scatter from the strings.

Each finite string has a "north" and "south" end and physicists believe that under certain conditions the length of the string can change easily. As a result, the ends of the string will appear to behave as two individual "quasiparticles" – north and south monopoles.

While the Morris group was able to 'see' the Dirac strings with neutrons, they inferred the existence of monopoles by measuring the heat capacity of the spin ice. Physicists had calculated that at temperatures of around 1 K the heat capacity of a spin ice should resemble that of a gas of magnetic monopoles – which is exactly what Morris and team saw.

Pinch points to Coulomb phase



Pinch points

Meanwhile at the ILL, Fennell and colleagues used a beam of spin-polarized neutrons to study a similar spin ice – $Ho_2Ti_2O_7$. They were particularly interested in studying the ground states of the spin ice to establish if they can indeed support monopole excitations. At low temperatures and zero magnetic field, physicists had predicted that, in order to have monopoles, this knotty mess of a state must be a "magnetic coulomb phase" – which the team confirmed through the observation of "pinch points" in their neutron scattering data.

In the absence of finite strings and monopoles, the pinch points are very sharp. However at temperatures of around 1 K the thermal excitation of monopoles creates finite strings, which broaden the pinch points – which is what the researchers saw in their neutron diffraction data.

Fennell told *physicsworld.com* that the team is now trying to measure the width of the pinch point, which should give the length of the Dirac strings. Meanwhile, the Morris group is busy measuring the heat capacity of its spin ice as a function of applied magnetic field – which should provide further insight into the magnetic monopoles.

Oleg Tchernyshyov at Johns Hopkins University in the US said that the findings of both teams are in agreement with a theory (see "'Spin ice' could contain magnetic monopoles") that was unveiled last year by several of Morris's colleagues. However, he cautions that the theory and experiments are specific to spin ices, and are not likely to shed light on magnetic monopoles as predicted by Dirac.

One important general result of the research, according to Morris, is that the spin ice monopoles are one of the first examples of "fractionalization" – whereby a spin is split into two separate entities – in a 3D system. A familiar 2D example of fractionalization is the fractional quantum Hall effect, the discovery of which resulted in Robert Laughlin, Horst Störmer and Daniel Tsu winning the 1998 Nobel Prize for Physics. Because this and other properties of spin ices should be shared by similar magnetic materials, it could lead to the development of new materials for making spintronics devices, such as magnetic memories.

The research is published in *Science Express*.

About the author

Hamish Johnston is editor of *physicsworld.com*

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16 COMMENTS

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Oliver K. Manuel
Sep 3, 2009 10:56 PM
United States

MAGNETIC MONOPOLES DISCOVERED AGAIN! 1

As I recall, P. Buford Price discovered the elusive magnetic monopoles many years ago in cosmic rays.

With kind regards,
Oliver K. Manuel
www.omatumr.com...

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jmcaneney
Sep 3, 2009 11:04 PM
BANGOR, United Kingdom

2

Quote:

> Originally posted by Oliver K. Manuel
>
> As I recall, P. Buford Price discovered the elusive magnetic monopoles many years ago in cosmic rays.

Price withdrew his claim in 1978, after further analysis of his data showed that it did not possess the appropriate charge to be a monopole. See Physical Review D, 18 1382–1421 (1978) for the details.

Reply to this comment ▶ Offensive? Unsuitable? Notify Editor ▶

Oliver K. Manuel
Sep 4, 2009 4:34 AM
United States

MAGNETIC MONOPOLES IN COSMIC RAYS 3

You are right!

In 1975 Price et al. reported magnetic monopole in cosmic rays [Physical Review Letters 35 (1975) 487–489], the year he was elected to the National Academy of Sciences.

Buford Price, Robert Walker, and Robert Fleischer first became famous for chemically etching fission tracks and thus advancing the "fission track" dating method. As I recall, they were at GE Laboratories then.

Robert Walker moved to Washington University in St. Louis and Buford Price moved to UC-Berkeley.

With kind regards,
Oliver K. Manuel
www.omatumr.com...

Reply to this comment ▶ Offensive? Unsuitable? Notify Editor ▶

jmcaneney
Sep 4, 2009 10:21 AM

4

Quote:

> Originally posted by Oliver K. Manuel

BANGOR, United Kingdom

> You are right.
>
> In 1975 Price et al. reported magnetic monopole in cosmic rays [Physical Review Letters 35 (1975) 487–489], the year he was elected to the National Academy of Sciences.

As far as I am aware though, the alleged particle was never properly identified. So while not a monopole, maybe it was something as interesting (assuming it was a real signal).

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

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dl.robinson
Sep 4, 2009 4:09 PM
United States

5

Quote:

> Originally posted by jmcaneney
>
> Quote:
>
> > Originally posted by Oliver K. Manuel
> >
> > You are right.
> >
> > In 1975 Price et al. reported magnetic monopole in cosmic rays [Physical Review Letters 35 (1975) 487–489], the year he was elected to the National Academy of Sciences.
>
> As far as I am aware though, the alleged particle was never properly identified. So while not a monopole, maybe it was something as interesting (assuming it was a real signal).

I seem to remember the signal having been attributed to a high energy platinum nucleus. As I recall, the paper by Alvarez critiquing Price's work suggested that the signal didn't fit a monopole all that well, but fit a platinum nucleus very well, assuming certain deficiencies in the detector. Upon checking, the detector was indeed deficient in ways consistent with Alvarez' contention, and Price retracted his claim.

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

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jmcaneney
Sep 4, 2009 10:52 PM
BANGOR, United Kingdom

6

Quote:

> I seem to remember the signal having been attributed to a high energy platinum nucleus. As I recall, the paper by Alvarez critiquing Price's work suggested that the signal didn't fit a monopole all that well, but fit a platinum nucleus very well, assuming certain deficiencies in the detector. Upon checking, the detector was indeed deficient in ways consistent with Alvarez' contention, and Price retracted his claim.

Many Thanks for that.

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

Oliver K. Manuel
Sep 7, 2009 12:18 PM
United States

7

Quote:

> Originally posted by Oliver K. Manuel
>
> In 1975 Price et al. reported magnetic monopole in cosmic rays [Physical Review Letters 35 (1975) 487–489], the year he was elected to the National Academy of Sciences.

Here are a couple of real but overlooked findings between the 1975 and 2009 discoveries of magnetic monopoles:

1976 - The Sun gave birth to the solar system by ejecting the material that now orbits it.

2000 - Repulsive neutron-neutron interactions in the solar core trigger reactions that produce solar luminosity, solar neutrinos, and SW-Hydrogen in exactly the proportions observed.

With kind regards,
Oliver K. Manuel
www.omatumr.com...

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

jmcaneney
Sep 7, 2009 3:49 PM
BANGOR, United Kingdom

8

Quote:

> Originally posted by Oliver K. Manuel
>
> Here are a couple of real but overlooked findings between the 1975 and 2009 discoveries of magnetic monopoles:
>
> 1976 - The Sun gave birth to the solar system by ejecting the material that now orbits it.
>
> 2000 - Repulsive neutron-neutron interactions in the solar core trigger reactions that produce solar luminosity, solar neutrinos, and SW-Hydrogen in exactly the proportions observed.

With respect Oliver, you do try to twist every comment towards these ideas, which are ideas from your own research interests. These comment sections in PhysicsWorld are for discussions of the articles, not for platforms to piggyback your own research interests upon. there are other forums for that!

The origin of the solar system, and nuclear physics bares little relevancy upon the nature of monopoles in the solid state physics of spin ices, nor indeed with magnetic monopoles in general.

Most of your comments are deleted because you insist upon self promotion of your research, and because these

comments bare little relevancy to the discussion or article at hand.

Jonny

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

Oliver K. Manuel
Sep 7, 2009 11:00 PM
United States

9

Quote:
> Originally posted by jmcaneney
>
> With respect Oliver, you do try to twist every comment towards these ideas, which are ideas from your own research interests. These comment sections in PhysicsWorld are for discussions of the articles, not for platforms to piggyback your own research interests upon. there are other forums for that!

Thanks, Johnny. You are right. By this posting I request that the administrator delete my posting above.

Thanks,
Oliver

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

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g.preston3
Sep 4, 2009 8:03 AM
Austin, United States

10

Maxwell's equations do not have a mechanism for creation of a magnetic field for a radial oscillating electric field in a vacuum space. Neither is there a mechanism in Maxwell's equations for the charge to be created at the center point in that vacuum space, unless you allow the permittivity to be a variable as a function of the electric field, and in that case you could have a virtual charge created as a source, arising from the electric field interacting with a changing vacuum permittivity. If this were the case, and there were a radial oscillating electric field, then the rate of change in the electric field would need to transfer its energy into another type of field. Could it be that a radial oscillating permittivity field is also a magnetic field and that that radial oscillating magnetic field has a magnetic monopole source? What I am suggesting is a model for describing how the radial particles, electron, muon, and tau particles can be created as a result of nonlinear permittibity and use of Maxwell's equations. The radial oscillating permittivity would appear to be the source of the magnetic monopole as well as the source of the oscillating radial electric field. I would give it some serious consideration since there is no other good model for describing why these radial particles even exist.

Eugene Preston, PhD in electrical engineering
egpreston.com...

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eugenesittampalam
Sep 4, 2009 5:25 PM
Jaffna, Sri Lanka

11

Sorry to throw ice water here on our one-hand-clapping proponents and fans of the magnetic monopole persuasion (who can also, I suppose, breathe in and not out, or vice versa!). However, I would like you all to kindly check out the short section, 'The Magnetic Monopole – An Absolute Nonentity' in www.sittampalam.net/ThePulsar.htm.

We do not know what fundamentally causes magnetism. Therefore, it may be best to resolve this problem first ere venturing further any usefully on the research here. To make it all worthwhile, please see also the two-page letter: www.sittampalam.net/NobelResponse.pdf.
Thank you all and cheers – long live physics!

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

alreaud
Sep 5, 2009 1:39 AM
Fort Collins, United States

12

Quote:

> Originally posted by eugenesittampalam
>
> Sorry to throw ice water here on our one-hand-clapping proponents and fans of the magnetic monopole persuasion (who can also, I suppose, breathe in and not out, or vice versa!). However, I would like you all to kindly check out the short section, 'The Magnetic Monopole – An Absolute Nonentity' in www.sittampalam.net/ThePulsar.htm.
>
> We do not know what fundamentally causes magnetism. Therefore, it may be best to resolve this problem first ere venturing further any usefully on the research here. To make it all worthwhile, please see also the two-page letter: www.sittampalam.net/NobelResponse.pdf.
> Thank you all and cheers – long live physics!

We also don't know what gives fundamental particles their mass, but they have it nonetheless. Electron 'spin' alignment creates a magnetic field, but we also don't know what electron spin is, or what the electron actually is or what would happen if an electron didn't spin (which it can't). Those glaring lacks don't prevent valid research from occurring.

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

wisnij
Sep 4, 2009 6:56 PM

13

Leaving the crackpot websites aside for the moment... is this a "real" monopole, in the sense that there is some region where $\nabla \times B \neq 0$?

Reply to this comment ▸ Offensive? Unsuitable? Notify Editor ▸

alreaud
Sep 5, 2009 1:50 AM
Fort Collins, United States

14

Quote:

> Originally posted by wisnij
>
> Leaving the crackpot websites aside for the moment... is this a "real" monopole, in the sense that there is some region where $\nabla \times B \neq 0$?

That equation has for a long time been de facto proof of the

impossibility of magnetic monopoles. If they have been found then Maxwell's equations may have to be revisited.

We may find that the vector calculus simplifications to Maxwell's original equations, written in quaternions, have done us wrong in the long term. At the time that occurred, one must remember that quaternions would have been very hard to work with, and the use of vector calculus would have made Maxwell's equations manageable. That is no longer an issue due to computers and applications like Mathematica.

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nunoalex
Sep 4, 2009 11:34 PM
1, Portugal

15

Does this mean that we are one giant step closer to some new breakthrough propulsion system ?

Reply to this comment ▶ Offensive? Unsuitable? Notify Editor ▶

eugenesittampalam
Sep 5, 2009 12:33 PM
Jaffna, Sri Lanka

16

In kind response to “alreaud,” above.
Dear Sir/Madam, please be good enough to check out at least this one-page summary:
www.sittampalam.net/Summary.pdf

Our classical mechanical concepts of mass and energy are indeed strokes of genius. Moreover, it has also helped us now to show that the two concepts are not only equivalent but also – one and the same, fundamentally. There is now that casually used term, "mass-energy." I have salvaged this term for its greater purpose. Thus, the atom has mass-energy; and so does the photon. In this view, hardly anyone would disagree that the photon is the evaporated form of mass-energy (at speed c) and the atom the condensed state (at sub-c speeds) – as every single observation seems only to buttress the idea with nary an exception.

Now, from Plank’s amply verified equation, E = hf, it is easily shown that the per-cycle quantum of the photon energy is of the same constant value irrespective of the photon; and nothing smaller than this per-cycle energy is ever detectable by any of our instruments. (We rely on signals solely from photons to detect even the smallest and/or most elusive of particles in physics.) Hence, let us give this truly fundamental particle (in fact, it turns out it’s the ONLY fundamental particle required now) in physics the unit of one. If, for convenience, we name the per-cycle quantum as the RADIATON, then
The mass-energy of the radiaton = (dimensionless) 1.
And the mass-energy of the atom or photon would simply be its radiaton number.

Of course, we may continue to use the terms, "mass" and "energy," instead of "mass-energy," as we now use the phrases, "to the ends of the earth" and "to the four corners of the earth," from the flat-earth society (some of whom may still be around!), as long as we have the fundamentals in the right perspective.
Thank you and Cheers!

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