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Titled "A Cosmic Ray Search for Fast Magnetic Charges"

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Abstract

The present outlook for monopoles is that they are either a)nonexistant, b)extremely rare or c)have unexpected properties. A Cerenkov counter telescope will soon be in operation to initially seek monopoles of catagory c. The instrumentation of this telescope is essentially as described in earlier proposals. It has been proposed that relativistic monopoles may produce straight lightning strokes. A detailed discussion of this is given in the preprint "Would Relativistic Monopoles Produce Straight Lightning Strokes?". Based on this (catagory b) a search is underway using Smithsonian Astrophysical night sky photography of lightning. Appendix A contains a press release and Science News report on a portion of this program.

Progress Report

It is curious that theoretical and some indirect experimental results lend ever more favor to the existance of monopoles while more or less direct experimental tests push the monopole flux limits to steadily smaller values. On the favorable side recent years have brought the advance of a consistent quantum electrodynamics with monopoles by Schwinger[1] and the observation of the lack of C.P. invariance[2] which has resulted in the construction of elementary particle models based on monopoles.[3, 4] On the stricter limits side we have the experimental results of Fleischer et al,[5, 6] Alvarez et al[7] and the recent primary monopole flux limits from Osborne's paper.[8] This narrows the situation down to three possible conclusions: (a)monopoles do not exist (a conclusion which is steadily losing ground among theoretical physicists), (b)monopoles' are extremely rare or (c)monopoles do not have all the properties we expect. We discuss the relavance of (b) and (c) to this experimental program.

If monopoles are as rare as present experimental limits indicate then geometry is a prime requisite for any cosmic ray method of searching for monopoles. To some extent this groups efforts have been based on Cerenkov counter methods and a dual Cerenkov counter telescope is just now nearing complete instrumentation. Unfortunately the experimental limits are now too small for Cerenkov counter methods to be effective for primary monopoles. One simply cannot achieve the required geometry. Realizing this the principal investigator sought and found two new large geometry methods.[9, 10] One of these methods would search for high altitude knock-on electron showers which would be characteristic of primary cosmic ray monopoles with a very large magnetic charge. This method is eclipsed by Osborne's very recent limits (subject to some uncertainty) on primary monopoles[8] unless the monopoles have a rest mass which is unbelievably large. The other method is to look for straight lightning strokes which would be characteristic of cosmic ray monopoles. This method applies to both primary and secondary monopoles of all allowed magnetic charge values. This method has an extremely large geometry which can, for large rest mass values, even compete with Osborne's limits. Also this method can set new monopole production cross-section limits. The Smithsonian Astrophysical Observatory has operated a system of sky photography stations for six years and is making four years of back film (as well as current lightning photographs) available for analysis. This film will either find monopoles or set new limits on both monopole production cross-sections and on the flux of massive primary monopoles.

If monopole properties are not what we expect then where is the error? Schwinger has argued that renormalization should be a universal property of the electromagnetic field and so is the same for monopoles as for electrons. This conclusion is consistent, in a simple way, with magnetic charge quantization conditions.

Except for this group's earlier experiment[11] no searches have been conducted for monopoles near minimum ionization (over-renormalized monopoles). The first use we will make of the Cerenkov counter telescope is to conduct a much more extensive search for such monopoles in cosmic rays.

Finally we note that many current experimental results depend strongly on the conservation of magnetic charge. No theoretical or experimental work has seriously questioned this property and we see no reason to do so. However it must be noted that Osborne's result as well as the trapping experiments require a magnetic charge lifetime of at least 10^5 years while the monopole track work of Fleischer et al[6] requires a lifetime of at least 10^{-4} sec (as also does the monopole lightning method). An extension of the Cerenkov counter method has been proposed[12] which would make it possible to identify monopoles with a lifetime as short as $10^{-14}/\gamma$ sec! No other method can approach this value although such work could only be done effectively with an accelerator beam. This method also makes it possible to search for monopole production in very thick targets. A modest effort using underground cosmic rays could investigate a cross-section of 10^{-27} cm^2 per year of data for the production of monopoles by muons above 10^3 BeV. This would not set new cross-section limits and so is not a planned experiment.

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Appendix A

The paper of D. R. Tompkins, Bull Am. Phys. Soc. 15, 39 (1970); was selected for a press release by the American Institute of Physics. Subsequently a brief report appeared in Science News 97, 151 (1970). A copy of the press release and a page copy from Science News are presented in this appendix.

NEWS FROM THE AMERICAN INSTITUTE OF PHYSICS
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Private Dining Rooms 7 & 8
Palmer House, Chicago, Illinois
Telephone: (312) RA 6-7500
Meeting Date: 26-29 January 1970

RELEASED FOR TUESDAY MORNING, JANUARY 27, 1969

Author's Popular Version of Paper: BE-8

"WOULD RELATIVISTIC MONOPOLES PRODUCE STRAIGHT LIGHTNING STROKES?"

Presented by: D. R. Tompkins
University of Georgia
Athens, Georgia

BE-8

Would Cosmic Ray M les ce Straight L ing Strokes?†

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It is wel own t cutting a net in f does not result in "half agnet ut rather two magr . If we really could i t on nd of a ma we woul ve a magnetic monopole (an i ed r etic charg The poss lity of the existance of n ame l particle ing an iso d magnetic charge (a mo e) i e of the n interestin cets of physics toda We kr that monop could only st as multiples o an elem ry unit of netic charg A fast monopole would in er very stron with matter and leave an intense trail of ions (electrical harged atoms obtained by knocking away atomic electrons). monopoles can exist then they must surely be present among the ticles of cosmic rays. Here it is shown that a trail of ions n a fast, heavy, multiply charged, cosmic ray monopole may ult in a very straight lightning stroke.

The bright stroke observed as ordinary lightning is actually preceeded by a dark stroke called a step leader. The step leader advances from the cloud toward the ground in a series of steps separated by pauses. This leader is found to change direction at

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each step and this causes the crooked shape of the resulting return stroke. The bright return stroke follows the path of the step leader and goes upward from ground to cloud. Multiple strokes are common and if these occur within no more than one tenth of a second then they occur in the previous return stroke channel. Such subsequent return strokes are immediately preceeded by a dart rather than stepped leader. The dart leader is dark and is only as straight as the return stroke ion channel which it follows. If the previous return stroke channel is "old" the dart leader may change into a stepped leader as it nears ground level.

In order for a monopole to penetrate the whole atmosphere and yet remain fast it must have a large initial energy and be at least several hundred times more massive than any elementary particle now known. Such a monopole (with multiple units of magnetic charge) may leave a trail of ionization whose density is comparable to that present in an "old" return stroke channel immediately prior to a dart leader. Unlike a return stroke channel this ionization trail would be quite straight. Because the ionization trail of a fast monopole would be comparable to an "old" rather than "young" return stroke channel we should expect a straight dart leader to often change into a stepped leader near ground level. Thus straight lightning may often appear as ordinary lightning with a long straight upper segment. Before we can have lightning we must have a sufficiently high voltage between cloud and ground. Do thunderclouds maintain high voltages over significant areas for appreciable lengths of time? An affirmative answer is provided by the occasional observation of lightning artifically induced by water plumes from depth charge explosions.

Finally we must ask if there are other possible causes of straight lightning? Very high energy cosmic rays generate a cascade of particle collisions in the atmosphere. In the resulting "shower" the total number of particles reaching the earth may exceed a billion and be spread out over an area of square kilometers. The "core" of such a shower is narrow and contains the greatest particle density. It turns out that in even the largest showers the particle density in the core does not approach that believed necessary for a dart leader. Thus air shower cores are not a likely source of straight lightning.

Because of uncertainties in quantitative properties of lightning itself we cannot draw negative conclusions about monopoles from failure to observe straight lightning. However we can hope to gain a hint about monopoles by actually seeing or photographing such strokes.

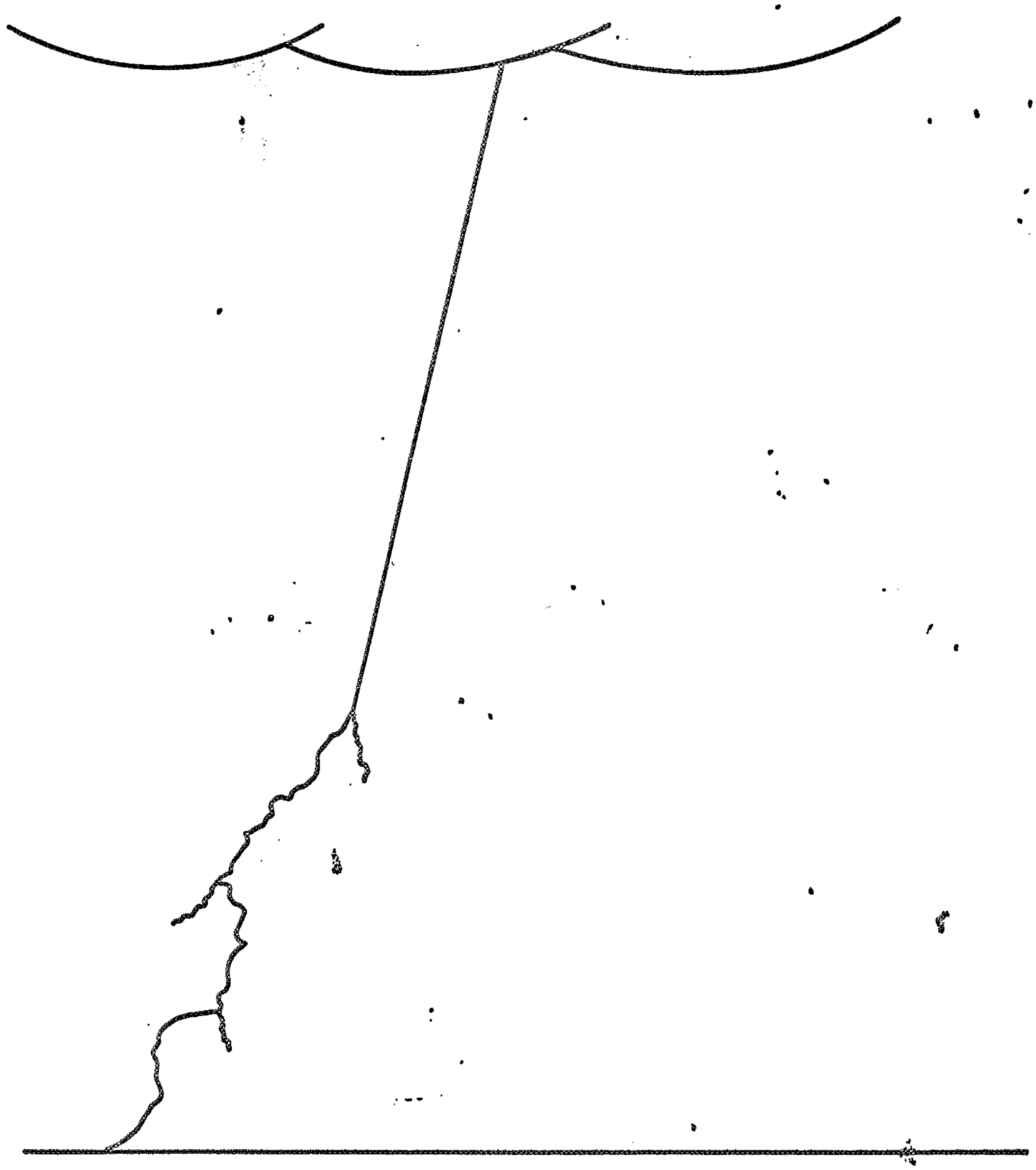

Fig. 1. . Likely Appearance of Straight Lightning

Science News

Gathered at the 1970 annual meeting of the American Physical Society in Chicago last week

ATOMIC PHYSICS

Measuring the magnetic moment

Much of the great success physicists have had in understanding the workings of atoms has come by measuring the strengths, or energies, of various interactions that take place within them. One of the most important is the interaction between spinning charged particles.

A spinning ball of charge acts like a tiny electromagnet, the strength of which is known as its magnetic moment.

Four scientists from the Massachusetts Institute of Technology, Drs. P. F. Winkler, F. G. Walther, M. T. Myint and D. Kleppner, report that they have measured the ratio of the electron and proton magnetic moments more precisely than has been done before—to an accuracy of one part in 100 million. The figure they obtained for the ratio is 658.210705 ± .000006.

Their precise measurement of one of nature's fundamental constants may increase knowledge of other ones, say the scientists, like a crossword puzzle in which filling in the letters of one word can help complete the spaces for other words.

ASTRONOMY

Another look at gamma source

Last year astronomers discovered the first point source of gamma rays, in the constellation Sagittarius (SN: 9/27, p. 277). There had been speculation for a decade that certain stars or nebulae might emit this extremely energetic radiation.

The source was located with equipment flown in balloons from Parkes, New South Wales. The source is directly overhead in the sky in Australia.

One of the members of the team that made the discovery, Dr. Glenn M. Frye Jr. of Case Western Reserve University, reports that additional balloon flights are planned to locate the position of the source more precisely. A clock accurate to one part in 100 million will be carried along to see if the source is winking on and off like the pulsars.

PARTICLES

Vector meson dominance

A comprehensive theory of subatomic particles will have to provide a unified explanation of the different classes of forces they respond to. In the hope of getting to such a theory physicists study examples of connections between different forces such as the behavior of photons when th[illegible] strike atomic nuclei.

Photons are carriers of the electromagnetic force, yet when they strike nuclei, they behave like vector mesons, carriers of the strong nuclear force.

In explanation of this, a theory called vector meson dominance has grown up, which says that, on approching the nucleus, the photon turns into a vector meson. If such a transformation does in fact happen, it would be a key to a theory uniting the strong and electromagnetic forces, could explain the structure of neutrons and protons and help solve the puzzles of nuclear structure.

Recently the theory has been under fire from experimenters who found results at odds with its predictions (SN: 8/30, p. 164), but Dr. Bernard Margolis of McGill University reports that accurate calculation of the latest experiments supports the theory. The shadows of various nuclei that a photon beam casts come out correctly, he says, if one assumes that photons turn to vector mesons as they interact with nuclei and then turn back to photons.

LOW TEMPERATURE PHYSICS

Helium molecules in the superfluid

When liquid helium is cooled to temperatures less than four degrees above absolute zero it becomes a superfluid. That is, it flows without friction, can go through holes too small for ordinary fluids, and in certain conditions can be induced to flow uphill.

The key to understanding this behavior lies in the microscopic structure of the superfluid. Drs. W. A. Fitzsimmons, J. W. Keto, M. Stockton and L. J. Smith of the University of Wisconsin propose a new experimental tool for this study.

Optical experiments show, they say, that neutral helium molecules, two atoms bound together, the usual constituents of helium gas, also form part of the substructure of superfluid helium. Ordinarily much more dramatic changes could be expected with a change of state, and they suggest that following them the apparently normal bound atoms around in the abnormal state will be a useful way of studying the structure of the superfluid.

PARTICLES

Magnetic monopoles and lightning

A magnetic monopole would be an object that had only one pole of magnetic charge instead of the two possessed by ordinary magnets. Monopoles have never been seen, but their hypothetical existence is important to basic physical theories, and they have been searched for in almost every conceivable place.

Dr. D. R. Tompkins of the University of Georgia suggests another: looking for them in lightning strokes. A lightning stroke consists of two movements, a leader stroke from the cloud to the earth and a return stroke from earth to the cloud. The leader, which is not visible, generally follows a stepwise path. It leaves a trail of ionized gas behind, and the bright return stroke runs back up this path to the cloud.

Dr. Tompkins points out that a magnetic monopole passing through the atmosphere would also leave an ionized path behind, but it would be straight instead of zigzag. Under proper conditions, he thinks, a return lightning stroke might follow such a path. This would be a clue to the existence of monopoles, he says.