MAGNETIC MONOPOLES

A review of the literature with specific reference to MUFON Investigations

by
C.C. Paulson
(13110)

Magnetic Monopoles

All magnets so far found in nature are dipoles, having both a north and south pole. If a bar magnet is broken into two pieces, each piece become a new dipole. It has been speculated that a natural extension of Maxwell's equations indicates magnetic monopoles should be possible. Similar to an electric charge, a monopole would only be a north or south pole, with no accompanying opposite pole.

Although they do not seem to be a normal subject for MUFON investigators, every once in a while we do have a case where the possibility of monopole involvement exists. This paper has been written to provide some background to use in those instances. It should probably be noted at the outset, it would take a tremendous amount of evidence for this writer to ever state he had a case where he was sure magnetic monopoles were involved.

1.0 History

Throughout history scientists have noted the elegance and simplicity provided by mathematics in its description of the natural world. It is interesting that physicists are as impressed by this as mathematicians are. Most believe mathematical accidents do not just happen; they provide insights into the workings of nature.

The concept of a magnetic monopole is one such item which mathematics seems to predict but has never been found experimentally. This is an inevitable feature of the current trend toward unified theories. In essence, its absence destroys the symmetry of Maxwell's Equations. Without sources those equations in SIU (Standard International Units) exhibit a beautiful duality.

$$\nabla \bullet \mathbf{E} = \mathbf{0}; \quad \nabla \times \mathbf{E} = -(\partial \mathbf{B}/\partial t)/c \quad \text{and} \quad \nabla \bullet \mathbf{B} = 0; \quad \nabla \times \mathbf{B} = (\partial \mathbf{E}/\partial t)/c$$

Unfortunately the introduction of sources eliminates this symmetry.

$$\nabla \bullet \mathbf{E} = \mathbf{4\pi\rho_e}; \quad \nabla \times \mathbf{E} = -(\partial B/\partial t)/c \quad \text{and} \quad \nabla \bullet \mathbf{B} = 0; \quad \nabla \times \mathbf{B} = \{\partial E/\partial t + \mu_0 \mathbf{J}\}/c$$

Clearly electric charges and currents exist, but similar magnetic items have never been seen.

This situation existed unit 1931 when Paul Dirac published a paper[1] that attempted to explain the quantization of the electric charge. He found that it required postulating the existence of a magnetic monopole. In his paper he calculated the quantum of the magnetic charge to be

$$q_m = n\ 68.5\ e\ (n = 1, 2, ,,,) \qquad 1.$$

where e is the quantum of electric charge. Although not explicitly stated in his paper magnetic charge conservation implies these monopoles to be stable and produces in pairs. Mass was not discussed,

The next paper[2] of note concerning monopoles was by Julian Schwinger in 1962. That paper used a group theoretic approach employing rotational and gauge invariance and derived an integer relationship (twice that in equation 1) for q_m.

The final paper[3] to be included here was by Gerard t'Hooft. The paper produced the most general result. It assumed the electromagnetic group { U(1) }[(4)] is a subgroup of gauge symmetry[4] that was spontaneously broken by the Higgs mechanism. In this approach, magnetic monopoles arise naturally as solutions of the field equations and the mass is typically on the order of the Grand Unification scale[5] (~10^{17} GeV)..This level is not approached by present accelerators or any anticipated future machine of any type**.** Later authors have shown that the minimum energy required for a monopole can be dramatically lowered using additional dimensions. They have stated it may be to lowered into the tens of TeV[6] range. If so, we may in the future be able to create a monopole in an accelerator but to date there has been no indication of locating any magnetic monopole.

These required energy levels were however present during the first few instants of the universe. However, the cosmological model to use and the specific instant the symmetry was broken is open to conjecture. If the monopoles were created in the Grand Unified Theory (GUT) phase transition there should be many monopoles around today and they would have a mass of approximately 10^{15} GeV. However they haven't been seen and that lack of monopole evidence is referred to as the "monopole problem". Although no proof exists, it is assumed by many that the proposed inflation of the universe starting at approximately 10^{-32} sec (and lasting for approximately 10^{-36} sec) strongly diluted the monopole density and thus solved the problem. If monopoles were produced in later phase transitions in the early Universe their energies would be below ~10^{11} GeV and much larger fluxes of monopoles would be expected. As will be discussed later there have been recent searches for this monopole flux in cosmic radiation using neutrino telescopes without any indication of its existence.

Maxwell's equations with magnetic monopoles are actually quite easy to write down and discuss. Essentially the monopole equations mimic the well known electrical equations.

$$\nabla \bullet \mathbf{E} = 4\pi\rho_e; \quad \nabla \times \mathbf{E} = -(\partial \mathbf{B}/\partial t + 4\pi \mathbf{J}_m)/c \quad \& \quad \nabla \bullet \mathbf{B} = 4\pi\rho_m; \quad \nabla \times \mathbf{B} = (\partial \mathbf{E}/\partial t + 4\pi \mathbf{J}_e)/c$$

The magnetic monopole (ρ_m) is seen in the equation for the divergence of the magnetic field[7] (B) Figure 1 is a cartoon showing the fields for a positron (red) and a north pole magnetic monopole (green).

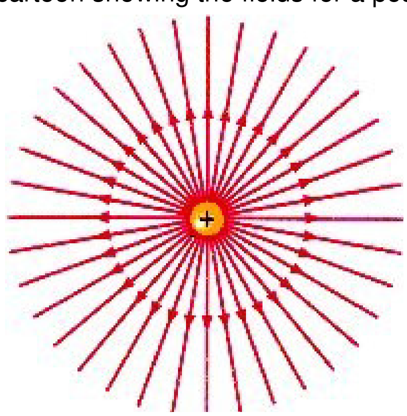
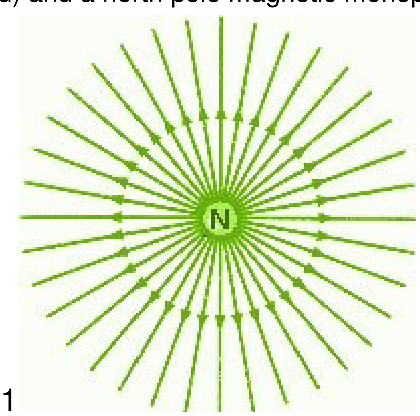


Figure 1



Positron Field North Mag. Monopole Field

Not surprisingly they are identical. Therefore similar to the electric field, the magnetic field due to the monopole field is radial and has an infinite range. In equation form, it is given by:

$$\mathbf{B}(\mathbf{r}) = k\, Q_{\mathbf{m}}\, \mathbf{r} / r^3. \qquad 2.$$

where k depends on the system of units used ($k = 1/4\pi$ in SIU). As was implied earlier. the existence of a magnetic monopole results in two continuity equations and two conserved charges[8]:

$$\partial\rho_E/\partial t = -\nabla \bullet \mathbf{J}_E \quad \text{and} \quad \partial\rho M/\partial t = -\nabla \bullet \mathbf{J}_M\ . \qquad 3.$$

For the MUFON investigator, a more useful result would probably be the magnetic Gausses Law obtained taking a closed surface integral of the divergence of B term in Maxwell's Equations. For a spherically symmetric magnetic mass this is:

$$\int_S \{ \nabla \bullet \mathbf{B} \}\, dA = Q_m\ . \qquad 4.$$

It will be shown later that measuring the field at any particular radius would allow the investigator to determine the total magnetic charge of the object.

2.0 Test Results

A number of experiments have been conducted in an attempt to locate a magnetic monopole. Subsets of these experiments are discussed in this section.

2.1 Accelerators

HERA

In 2005 a direct search for magnetic monopoles occurred at the HERA (Hadron Electron Ring Accelerator) collider at the DESY (Deutsches Elektronen-SYnchrotron) laboratory in Hamburg (Germany). Hera is a positron-proton collider "No monopole signal was observed". This placed a lower mass limit of 140 GeV for a magnetic monopole.

Tevetron

The MoEDAL (monopole trapping test array) detector system was deployed for direct searches for monopoles on the Fermilab Tevetron in 2012. The principle used was to expose passive detectors (thin plastic foils) to collision products near the collision point. It was designed to locate both in-flight (with a track-etch technique) monopoles and trapped (with an induction technique) monopoles. Trapping was accomplished via exposing the collision remnants an 8 TeV proton-proton beam (0.75 pb^{-1}[9]) to a magnetic monopole trapping (MMT) test array. As in HERA "no monopoles were found in any of the samples". These results placed the lower mass limits at:

285 GeV for n=1 monopoles;

355 GeV for n=2 monopoles;

225 GeV for n=3 monopoles;

420 GeV for n=6 monopoles.

The CDF (Collider Detector at Fermilab) and DØ detectors have analyzed data from up to 400 pb^{-1} of proton-antiproton collisions. In the CDF particles from collisions are collected and passed through the cryogenic detector. The active components are 2 superconducting loops connected to a Superconducting QUantum Interference Device (SQUID). The passage of a monopole would induce a change in the loops supercurrent. No events were found giving a mass limit of 350 GeV.

In all Fermi has searched for magnetic charges in the range from 1/30 to 24 times the Dirac magnetic charge and have seemed to have ruled out monopoles with mass less than 850 GeV, however a specific reference for this statement of this could not be found.

LHC

The Large Hadron Collider is presently extending the search using an MMT sub-detector (aluminum absorber). The full-scale MMT array will be more than 4 times larger than the previous test array. It is scheduled for deployment in 2014 – 2015 on the LHC VELO vessel below the interaction point. This experiment is expected produce the first monopole search results in the 14 TeV collision range.

The LHC also has proposals for a search using the ATLAS detector and CMS beryllium beam pipes. It is believed that these would be very sensitive to high magnetic charges (n > 4).

While no monopoles were discovered in any accelerator facility, there is one item of information that stands out sharply. If a monopole exists it is exceptionally heavy. In fact, it is heavier than the heaviest nuclei presently known. This is not the weight in terms of pound sitting on a scale that is important; it is weight in terms of energy. Specifically, it will require a tremendous amount of **focused energy** to create even 1 magnetic monopole particle. This thought will be repeated in the conclusion along with some additional comments on it.

2.2 Monopoles in Matter

As was stated in Section 1, the energy needed to create monopoles is known to have existed during the first instants of the universe. Additionally it is expected that magnetic monopoles should bind strongly with matter. That would seem to indicate that they should exist uniformly in presently existing matter.

These statement have lead to experiments looking in earthly materials and in cosmic debris. There was a Physical Review Paper[10] in 1995 that discussed a search in these materials using a superconducting induction coil connected to a SQUID. The authors stated they searched a total of 331 kg of meteorites, ferromanganese nodules, iron ores, and other materials with 112 kg being meteorites. They " found no monopole and concluded the overall monopole/nucleon ratio in the samples is $<1.2\times10^{-29}$ with a 90% confidence level".

In essence, they have stated there is no magnetic monopoles in the Earths crust. One explanation that has been offered for this uses the extreme heaviness discussed the previous section. It is thought that due to the age of the Earth and the monopoles have al sunk to the Earth's interior. If this is so, it should be expected that the abundance of monopoles trapped inside the Earth would be enhanced in the mantle beneath the geomagnetic poles. Therefore it is expected that the best possible source of monopoles would be polar volcanic rock.

That search has been done[11]. Similar to the above PRL paper, this search passed igneous rock samples through a SQUID (Superconducting QUantum Interference Device) based magnetometer. A total of 24.6 kg of rocks from various selected sites (23.4 kg from mantle-derived rocks from the Arctic and Antarctic areas), was analyzed. No monopoles were found. They quoted an upper limit for the monopole of 9.8×10^{-5}/gram with a 90% confidence level.

2.2 Monopoles in Cosmic Radiation

As was stated in Section 1, the energy needed to create monopoles is known to have existed during the first instants of the universe. However it was also indicated that we do not know exactly when it occurred; nor how many monopoles should we expect to see; nor what their mass may be.

As in searching for all high energy particles, the particles are not seen directly. In neutrino telescopes, what is seen is Cherenkov radiation. It is known that charged particles (electric and magnetic) produce electromagnetic radiation (Cherenkov radiation) when passing through a dielectric medium at a velocity higher than the speed of light in that medium. Although neutrino telescopes react similarly to muons as they are expected to react to monopoles, the photons expected to be emitted in the monopole case is 8550 times higher than the muon case. That is an easily detectable difference.

It should be noted that the data provided by some of these telescopes goes back years. Teams of investigators are presently going back through the data from multiple neutrino telescopes looking for magnetic monopoles indicators. As with the other methodologies, the published results to date have not found any monopoles but they have produced maximum monopole flux densities consistent with present results.

In-flight Induction: Superconducting Arrays

$$F < 10^{-12} \{ \text{monopoles} \} \text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$$ (12)

Ionization Array MACRO[13] (underground)

$$F < 10^{-16} \{ \text{monopoles} \} \text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$$

SLIM[14] (high altitude)

$$F < 10^{-15} \{ \text{monopoles} \} \text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$$

Relativistic Cherenkov Radiation (Relativistic): Antares[15] / Icecube[16]

$$F < 2\text{x}10^{-17} \{ \text{particles} \} \text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$$

Relativistic Cherenkov Radiation (Ultra-Relativistic): RICE[17]

$$F < 10^{-18} \{ \text{monopoles} \} \text{cm}^{-2} \text{sec}^{-1} \text{sr}^{-1}$$

Since we should be accepting all of these results, we have to say the minimum monopole flux density is the most stringent one. Therefore we can expect that the monopole flux is less than 10^{-18} monopoles per square cm per sec per steradian. Even if this were an equality rather than the "less than" it is, this is an exceptionally small number of particles in cosmic radiation. Therefore unless there is a "cloud" of monopoles somewhere in the cosmos, it is unlikely any large number can be collected for any reason.

3.0 Magnetic Monopole Matter

Although the search for individual magnetic monopole particles discussed in the previous section is important, that is not what a MUFON investigator is likely to encounter. Any case MUFON has that involves monopoles will, of necessity, be one of multiple monopoles embedded in normal matter. That situation is the subject of the remainder of this document.

As indicated earlier, although a magnetic monopole is a magnetic, it is also similar to an electric charge. That is an interesting dichotomy that would allow a world of new properties and uses. Some of those properties could be creating an electrical field when moving or providing a simpler method of containing electrical charges. However the most intriguing (and possibly the most important) is providing the possibility of a magnetic atom with exceptional properties due it's mass and denseness.

3.1 Anticipated Properties[18]

In analogy with electrical charges, there are at least 2 stable kinds of monopoles (north and south). Matter can therefore be created from them. Since in natural units the proton mass is approximately 1 GeV even using the lowest monopole result from the Tevetron, a monopole would be approximately 285 times more massive than a proton.

$$M_M = 2 \text{ x } 285 = 570 \text{ proton masses} \qquad 5.$$

A simple atom made from 2 monopoles of different magnetic charge would therefore have the mass of 570 protons (eq. 5). This is over twice as heavy as Ununoctium[19] which is claimed to be the heaviest element known. Additionally, as has been stated the minimum quantum of magnetic charge is 68.5 times stronger than the corresponding quantum of electric charge. Since a proton is about 1836 times more massive than an electron, a monopole is approximately 523,000 times more massive than the electron. Therefore a force balance shows the radius of the monopole atom would be the same 523,000 times smaller than a normal hydrogen atom.

It is well known that supplying the last electron required to any atom is basically the same as supplying the first to a hydrogen atom making all atoms approximately the same size. Therefore the density of a monopole atom will only depend on the arrangement of atoms and the mass of the atom (570 m_p)..In the simplest crystalline solid the volume occupied by a single atom would be the cube of the intermolecular distance. Therefore the density of a monopole atom referred to its electronic counterpart would be:

$$\rho_M \approx 570 \times (523{,}000)^3 \rho_E \approx 8 \times 10^{19} \rho_E \qquad 6.$$

The tensile strength of a solid is a function of the intermolecular force between molecules and since all intermolecular forces are electrostatic in nature each will have an inverse distance squared force law. The difference in forces seen in nature arises from the binding method (ionic, ion-dipole, dipole-dipole, etc.). It was determined above that these "atoms" are 523,000 times closer than their electronic counterparts. Therefore the binding strength between any 2 will be 523,000 squared times larger. A single atom will therefore see a binding strength stronger than its electrical counterpart due to size, which is 523,000 raised to the 4th power (4 neighbors). Additionally the binding strength will be 68.5 squared (both atoms) stronger due to the charge quanta involved. Therefore the tensile strength is approximately 3.5 x 10^{26} stronger than its electronic counterpart.

$$T_M \approx (523{,}000)^4 \times (68.5)^2 \approx 3.5 \times 10^{26}\ T_E \qquad 7.$$

This results in a strength to weight ratio of the monopole material that is almost a half-million times larger than its electronic counterpart

$$(S/W)_M \approx (3.5 \times 10^{26})/(8 \times 10^{19}) \approx 440{,}000\ (S/W)_E \qquad 8.$$

3.2 Possible Uses

As was stated the possibilities monopole material would provide are myriad. The following paragraphs list only a few.

Having spent approximately the first half of his career designing field coils for controlled nuclear fusion reactors, this author naturally thinks of the containment possibilities in that field first. Most of these reactors use large magnetic fields to heat, stabilize and contain plasmas where the fusion occurs. A monopole shell could be used to provide a natural pinch effect in Z-pinch, etc. reactors. In Tokamak type reactors the donut shape of the plasma could be heated and maintained via a monopole current. In essence, it may be possible to dramatically reduce the size of these reactors and make them economically viable.

Since the writer has also designed linear accelerators during the last half of his career, thoughts in that field also come naturally. At present these accelerators consist of a source to generate the particles (electrons, protons, deuterons, etc.) to be accelerated. That is followed by a low energy Radio-Frequency Quadrapole (RFQ) accelerator which bunches the particles into "bullets" and accelerate then to approximately 1 MeV (for protons). That is followed by a long Drift Tube Accelerator (DTL) section and later by a Couple Cavity Accelerator (CCL). Although these systems work very well they are huge and exceptionally expensive. Using a "bullet" made of monopole material in an electrical solenoid presents the possibility of building an accelerator capable of reaching the energy of the Large Hadron Collider (LHC) in a distance of less than a city block at minimal cost.

The results determined in the previous section would also transform the electronics and computing industries tremendously. The extreme density permits very small and very fast (about 10 million times as fast as conventional) monopole integrated circuits and computers. The RF frequencies involved would be in the gamma ray range.

Although not in the first thoughts of the writer, it is probable that the first use of monopole matter would be by the military. Since a moving monopole would produce a surrounding electric field (similar to the effect of a moving electrical charge), when fired, a bullet made of it would be surrounded by spiral arc of high voltage electricity. The most likely effect of that voltage would be to break down the surrounding air molecules producing a lightning bolt attached to and following the bullet; a la Zeus. The damage produced by this bullet would therefore be greatly enhanced against both human and electronic targets

It is also expected, the military would use the material to protect its soldiers. Applying a thin veneer of monopole matter over conventional material would protect the soldiers against almost every projectile except a bullet of the same material.

Returning to the accelerator discussion above, it is easily seen that monopole material would provide the military the possibility of constructing a rifle that would essentially be similar to a shoulder fired rail-gun..

The possibilities that would be presented by monopole matter are both exciting and frightening. Although it not known why it would be desired, a final possibility to consider with monopole material is the ability it presents to possibly construct a black hole. It will be left up to the reader to calculate the radius needed such that a monopole sphere would collapse in on itself in a manner that couldn't be stopped. Personally, this writer doesn't want to know the result. Perhaps its a good thing magnetic monopoles are so rare.

3.3 Monopoles and the MUFON Investigator

Since this document was written for MUFON the real question about magnetic monopoles should be what should be looked for; and is there any possibility it can be found? Unlike the Physics experiments discussed in Section 2, the MUFON investigator will not be looking for a single monopole particle; the investigator will be looking for multiple particles creating a gross measurable magnetic field. It obviously would not matter which pole is found, just that one is found.

It is a well known fact that for a spherical distribution of magnetic or electric monopolar charge, the resultant field will be totally radial and constant. It is also known that at a large enough radius, almost any charged monopolar field will look spherical. Therefore Gausses law (equation 4) can be re-written

$$\int_S \{ \nabla \bullet \mathbf{B} \} \, dA = \int_S \mathbf{B} \bullet \mathbf{n} = B4\pi r^2 = Q_m \, . \qquad 9.$$

Since the quantum of magnetism is given in equation 1 it is possible to determine the number (N) of (uncompensated for) monopoles needed to create this field.

$$N = B4\pi r^2 / (68.5ne) \qquad 10.$$

Equation 9 also allows a determination of the magnetic field of a single monopole particle of single charge.

$$B_{1,1} = 8.7 \times 10^{-19} \text{ Tesla} = 8.7 \times 10^{-23} \text{ Gauss} \qquad 11.$$

Since the Earth's magnetic field is approximately 0.312 G at the magnetic equator, it would require approximately 3.6×10^{13} monopole particles to create a magnetic field equal to that of the Earth. Therefore the **minimum** energy required to create a magnetic field equal to that of the Earth is:

$$W \approx (3.6 \times 10^{13})(285 \times 10^{9}) = 1.026 \times 10^{25} \text{ eV} \qquad 12.$$

The unit eV is actually a very small amount of energy. Specifically high energy physicists created the unit by dropping the electronic charge (1.6×10^{-19}) from the electromagnetic energy equation. Conversion of an energy quoted in eV back to the SIU unit requires multiplying it by that charge. Thus the above result is not as large as the exponent would have made it seem.

$$W(J) = e\,W(eV) = (1.6 \times 10^{-19})(1.026 \times 10^{25}) = 1.64 \times 10^{6} \qquad 13.$$

A reference was found discussing energy in terms of order of magnitudes. In that reference, the 1.64 MJ of energy is essentially equal to the "food energy" in a Snickers bar or half of a kW-hour.

It was stated above that the energy calculated was a minimum result. it is expected that the actual energy required to create a mass of monopolar material will be much higher. This is due to many factors.

1. Unless the charged material can be moved to a laboratory where very accurate measurements can be made, the investigator will require a field significantly higher than the earth's field to assure the field is radial.
2. The energy to create a single monopole is almost certainly higher than 285 GeV.
3. Theory presently does not indicate any difference in the creation method for north or south monopoles. If both are going to exist, the number of monopoles found above is the difference in the numbers of each.
4. The 285 eV energy used above is energy focused at a single point, not energy integrated over an area. Since the particles creating the field must all be the same polarity, they will repel each other. Therefore they cannot all be created in the same location and the energy has to be spread out over a relatively large area.
5. The 285 eV energy used above is energy focused at a single instant (high power), not energy integrated over time. Dumping a high amount of energy into a material in a very short period of time would have effects other than just creating the monopolar particles. The most dramatic of which would be an explosion.

It should be noted the above discussion does not state monopoles cannot be an indicator of a UFO presence. It does not even state the UFO cannot create the particles. It states it would be difficult for a UFO to create the monopoles from a distance. Since we have no idea as to what the UFO is trying to accomplish, this possibility cannot be discarded out of hand.

There is however a second manner for a UFO to leave a monopole signature; direct contact. That is not necessarily direct contact with the UFO itself. It may be contact with the volume surrounding and being transported to the scene by a low flying UFO. As stated in section 2.2 monopoles are expected to bind strongly with matter but they also tend to migrate downwards under the pull of gravity. That would allow the to migrate to the bottom of the UFO and then to the surrounding gas molecules. The additional weight of the monopole atom would reduce the buoyant force dropping those molecules down until they came in contact with other matter the monopole can transfer to.

The interesting possibility with the scenario is non-magnetic materials can become magnetized. Since the very existence of a magnetic field in these materials would indicate something very unusual has occurred. The difficulty with this is that the field produced will not be particularly strong. For low fields it will be impossible in the field to know the field exists let alone prove it is radial. These fields can only be determined in a laboratory.

There are many laboratory methods available to determine microscopic magnetic fields exist. Each has its strengths and its weakness. Among others these include:

- Magnetic Force Microscopy[20] allows the investigation of magnetic structures with a spatial resolution in the nano-meter range, but with low sensitivity.
- A Superconducting QUantum Interference Device(SQUID) Magnetometer[21] enables extremely sensitive magnetic-field measurements, but only with less resolution.
- The use of Scanning Magneto-Optical Kerr Microscopy[22] to determine changes of the perpendicular magnetization component.

This section is only a statement that techniques to measure extremely low magnetic fields. It is not suggesting any specific technique to use. That choice would probably be more dependent on availability and cost.

5.0 Conclusion

The lack of a unit of magnetic charge was one of the most fundamental properties of electromagnetism. Yet this paper has discussed theoretical arguments by 3 Nobel Prize winners[23] to expect their they should exist. In fact, the existence of magnetic monopoles is presently considered to be one of the safest bets one can make about physics that has not yet been seen[24]. Today, theorists believe that they are simply so rare that we have not detected them yes, and so massive that we have not been able to produce them. in particle accelerators. However, as has been stated many times, the basis of science is experience; not argument and since none have been found, the search continues.

From the published data we presently know:

1. The least energetic monopole has to be greater than 285 GeV. It has also been implied in some documents that this figure should be much closer to 1 TeV.
2. The monopole per nucleon density in the Earths crust must be less than 1.2 x10^{-29}. A similar study was also done in the arctic regions and found the density in those specific regions must be less than 9.8 x 10^{-5}.
3. Searches in cosmic radiation have indicated that their must be less than 10^{-18} monopole particles per cm2 per sec per steradian.

These are not particularly encouraging results but as already said, not totally discouraging either. Basically all they say is magnetic monopoles are very hard to make (very energetic) and at least in this portion of the cosmos they are very rare.

The document has also discusses the possibility of a monopole signature being left at the scene of a UFO sighting. It is understood by the author that both obtaining such a signature and proving its existence will be difficult. However it would be hard to overestimate the acceptance it would provide to both the investigator and MUFON in general. Of course that acceptance wouldn't be immediate. To this writer the most interesting possibility would be the possibility of magnetizing via direct contact. The effect does not require a specific action by the UFO; it is much easier to create; and finally the field required to prove the effect is much smaller.

References and Notes

1. Dirac, PAM; "Quantized Singularities in the Electromagnetic Field". Proc. Roy. Soc. **A 133**, 60 (1931); Phys. Rev **74**, 817 (1948) Equation 9: http://users.physik.fu-berlin.de/~kleinert/files/dirac1931.pdf

2. Schwinger, JS; "Magnetic charge and quantum field theory":; Phys. Rev. **144**, 1087-1093 (1966); Derived an integer relationship for monopole charge from a group theoretic quantization argument requiring rotational and gauge invariance.

3. t'Hooft, G.; Magnetic Monopoles in Unified Gauge Theories"; Nuc. Phy. **B79**, 274-284 (1974): http://www.staff.science.uu.nl/~hooft101/gthpub/magnetic_monopoles.pdf

4. In general groups are defined by the fact that an operation by a group operator on any object in the group results in a the same or another member of the group. The symmetry group U(1) is a general 1 dimensional rotation group. In electromagnetism, the U(1) symmetry group corresponds to electric charge. This group can be though of as the unit circle with multiplication of its points given by angle addition (a phase change).
   Normally the fields (gravitational etc.) that describe basic items in Physics cannot be measured directly. A gauge symmetry occurs when different fields produce the same observable (charge, mass etc.) quantity.

5. The reunification scale is the energy at which the symmetry had originally been broken The Grand Unification is approximately 1017 GeV.

6. GeV stands for Giga (billion) electron volts. TeV stands for Tera (trillion) electron Volts. The LHC is presently running at approximately 4.5 TeV. In terms of mass 1 eV is equivalent to 1.78 x 10-27 kg (approximately the mass of a proton) . {The energy unit eV can be converted to Joules (SIU unit of energy) by multiplying by the electron charge (1.6 x 10-19).}.

7. The Magnetic Field or Flux Density (B) is defined as the portion of the field generated by currents. When there is magnetic material to be considered, a second field (H) called the Magnetic Field Strength is defined. The relationship between these fields is given by: $B = \mu_0 (H + M) = \mu H$. The quantity M is called the Magnetization.

8. These equations are easily obtained from Maxwell's equation using the mathematical identity the divergence of a curl vanishes { $\nabla \bullet (\nabla \times \mathbf{V}) = 0$ }.

9. The "barn" is a unit of area. Its symbol is "b" ($b = 10^{-24}$ cm2). When "b" is preceded by a "p", it represents a pico (10^{-12}) barn.

10. Jeon, H.; Longo, MJ; "Search for Magnetic Monopoles Trapped in Matter"; Physics Review Letters **75** 1443 (1995)

11. Bendtz, K et.al.; " Search for magnetic monopoles in polar volcanic rocks"; arXiv:1301.6530, accepted in PRL (2013)

12. The symbol "sr" stands for steradian or squared radian. It is a unit of solid angle.

13. Laboratori Nazionali del Gran Sasso: A particle physics laboratory located near the Gran Sasso mountain in Italy.

14. The SLIM experiment is a large area array of nuclear track detectors administered by the Laboratorio de Fisica Cosmica de Chacaltaya in Bolivia and situated at It is installed at the high altitude Laboratory of Chacaltaya.. It is searching for intermediate mass (106 – 1010 GeV) magnetic monopoles.

15. Antares is a neutrino telescope located under the Mediterranean Sea off the coast of Toulon, France.

16. The IceCube Neutrino Observatory is a neutrino telescope administered by the University of Wisconsin at Madison and located under the ice at the Amundsen-Scott South Pole Station in Antarctica.

17. Radio Ice Cerenkov Experiment (RICE) is an experiment designed to detect the Cherenkov from the interaction of high energy neutrinos and highly-ionizing charged particles (monopoles) with the Antarctic ice cap. This experiment is co-located with the Amanda and Icecube detectors.

18. The genesis of the section on the properties of monopole material is an internet page the author once read on the internet. It is not referenced because the author cannot find it at present.

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22. Martin, Y.; Wickramasinghe, K,; "Magnetic Imaging by Force Microscopy With 1000 Å Resolution"; Appl. Phys. Lett. 50, 1455, 1987

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