# SNOWMASS LOI TF-08 -09 -11:

# A Suggestion for Dark Stable Monopolium Via Flavored Monopoles: Dark Matter from a Magnetic Dual to Ordinary Matter

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***Abstract:*** A study for a Dual to particle matter is proposed that transforms particle electric charges q to magnetic charges $g=n\alpha/2q$, chromoelectric charge to chromomagnetic charge such that $a_{s'}\sim 1/\alpha_s$, interchanges bosons-fermions, a superficial similarity to supersymmetry, interchanges left-right handed couplings, and conserves flavors of the electric sector in the dual sector. The masses of Dual partners are arbitrary but the bare masses could be similar up to field energy corrections. This Dual stabilizes the Higgs mass much like unbroken supersymmetry but without requiring R-parit (no diagrams for proton decay), provides a rich spectrum dark matter candidates such as stable neutral "smesons", yet remains largely hidden from ordinary matter. Constraints and consequences are discussed.

***Introduction:*** Magnetic Monopoles of magnetic charge $g = n(e/2\alpha)$ have not been found, despite many compelling reasons for them to exist . They have neither been observed nor their effects seen such as in hadronic light-by-light scattering or muon (g-2), with limits on their masses. We suspect that these calculations are incorrect, relying on unjustified use of the e-m dual. The calculations of monopoles affecting known phenomena require violating unitary or arbitrary cutoffs due to the strong coupling. The magnetic part of this dual is described by the electromagnetic tensors for electric charges and magnetic charges, respectively: $F^{\alpha\beta}$ is the electromagnetic tensor, $\tilde{F}^{\alpha\beta} = -\varepsilon^{\alpha\beta\gamma\delta}F_{\gamma\delta}$ is the dual electromagnetic tensor, and transform to each other through $\Lambda_{\upsilon}$ the Lorentz tensor.

We suggest a complex magnetic elementary particle spectrum that will result in stable complex magnetically neutral dark matter if the monopoles have flavor quantum numbers. For ease, we will refer to the Dual partners using SUSY-like nomenclature. In the Dirac formulation the magnetic charge is the reciprocal of the electric charge $g=n\alpha/2q$. If we follow Dirac's argument for quarks transformed to magnetic and chromomagnetic squarks $\tilde{q}$, with the $\tilde{q}$ magnetic charges are integer multiples of $-3g$ and $+3/2g$. Following arguments of Preskill the magnetic charges must be integer multiples of g. Therefore quark analogs spin 0 RH "squarks": partners of the down-like $\tilde{d}$=> $-n6g$; up-like squarks $\tilde{u}$ => +n3g. The spin 0, Right Handed particle analog of the charged leptons is like the selectron $\tilde{e}$ with magnetic charge = -n2g. The RH coupled $\tilde{W}$, *spin 1/2*, -2g, is the wino; the neutral spin ½ reverse handed sparticles are the Zino, photino and Higgsino. The rich magnetic monopole particle spectrum of this Dual ansatz is similar to that or even more complex than that of electrically charged matter seems more natural than if only a single type of spinor) monopole was the only magnetic charge created in nature. A main consequence is that Weak transformations of squarks are forbidden. The electric W does not couple to a pair of magnetic squarks: scalar $\tilde{u}$(+3g) cannot transform –> scalar $\tilde{d}$(–6g)+ spinor$\tilde{W}$(+3g) by both magnetic charge and angular momentum conservation. Thus a smeson $\tilde{u}$ +anti-c$^{\sim}$ is stable and neutral, with no weak hypercharge, and interacts with ordinary mainly by Higgs exchange. Smuon decay is $\tilde{\mu} \rightarrow \nu\mu + (\tilde{W} \rightarrow \tilde{e} + \nu e)$ is allowed, and creates an asymmetry between sleptons and squarks. Charged smesons, like $\tilde{u}$(+3) + anti-$\tilde{d}$(-6g), a g=-3 spion, could combine with 3 anti- $\tilde{e}$ creates a neutral "satom" or "shatom" the analog of Lithium. A neutronium of $\tilde{u}\tilde{u}\tilde{d}$ g=0 might be stable. The dark sector could be complex indeed. The inverted R-L coupling prevents, for example, the Z from decaying to sneutrinos which would make its width too large – and a possible solution to neutrino oscillation puzzles via scalar sneutrinos.

### *Issues/Items/Consequences to be worked:*

*Monopole pair production at accelerators:* Monopoles hide in monopoliums much like quarks hide in hadrons; isolated color is not seen and similarly isolated magnetic charges cannot be made in the present epoch. If a monopole pair is produced, it sheds energy proportional to $g^6$ via bremsstrahlung of magnetic photons, estimated to be about 50-100 magnetic photons. This leads to either re-annihilation or "monopolization" by massive magnetic photons creating monopole pairs which bind to the original N-S produced similarly to separating quarks' hadronization producing mesons. This means that contrary to present wisdom, *light monopoles* may make monopoles hidden – perhaps as light as the electron, as they are very readily produced from heavy

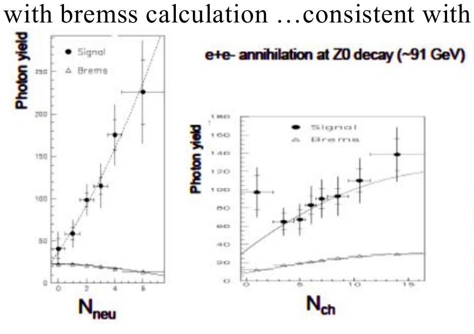
magnetic photons radiated from monopoles. The subsequent jet of monopoliums can be stable, neutral and very weakly interacting with ordinary matter if chromomagnetic charges interact weakly with hadronic matter. A brief review indicates that missing energy in hadronic reactions is consistent with the possibility of very light monopolium with low energy brems spectra.
- *Lattice strongly coupled QED* (abelian or non-abelian) has confining phases. The binding energy is proportional to $g^4$, leading to low mass monopoliums -
-*Electric-Magnetic Massive Photon Coupling:* Can a heavy virtual electric photon can couple to a monopole pair? Possibly problematic. In its rest frame, the monopole pairs being produced start with $\beta$~0 over the formation size. An effective coupling $\beta g$ between an electric and magnetic current is not justified in *relativistic* e-m; an effective magnetic charge $\beta g$ leads to formal calculations of *truncated* Drell-Yan(DY) or Photon Fusion(PF) production of monopoles, or of monopole loop corrections to QED phenomena – but such calculations remain non-perturbative i.e. *meaningless*. The magnetic photon may effectively a dark photon except between moving bare magnetic and bare electric charges. CP: the coupling of an off mass-shell electric to a (pseudo)scalar N-S pair is problematic. It can be argued[5] that it violates CP as the photon has $J^{PC} = 1^{--}$, whereas the N-S pair has $J^{PC} = 1^{+-}$, and the process of $e^+e^-$ or quark-antiquark annihilation into a single electric photon decaying to a pair of spinless monopoles is absolutely forbidden by CP.

***-Evidence for monopolium production and multiphoton decay?***

***1.*** This cosmic ray paper "M.Schein, D.M. Haskins, R.G.Glasser, Phys. Rev 99, 643 (1955)"[40] is discussed *by Malvin Ruderman and Daniel Zwanziger, Magnetic Poles and Energetic Photon Showers in Cosmic Rays, PRL 22, 146(1969) here quoted:*

*Multi-$\gamma$ events.* Five peculiar photon shower events were found in nuclear plates exposed to high-altitude cosmic rays [40]. The five events are characterized by a very energetic narrow cone of tens of photons, without any incident charged particle. The total energy in the photons is of the order of $10^{11}$ GeV. The radial spread of photons ($10^{-3} \div 10^{-4}$ rad) suggests a c.m. velocity corresponding to $\gamma > 10^3$. The energies of the photons in the overall c.m. system are very small, orders of magnitude too low to have $\pi^0$ decays as their source. One of the possible explanations of these events could be the following: a high-energy $\gamma$-ray, with energy larger than $10^{12}$eV, produces in the plate a pole-antipole pair, which then suffers bremsstrahlung and annihilation producing the final multi-$\gamma$ events.

***2.*** *Anomalous Production of soft photons* with low transverse momenta in high-energy hadron-hadron collisions and $e^+e^-$ annihilation are consistently produced in excess of what are predicted by electromagnetic bremsstrahlung when hadrons are produced, *but they agree with electromagnetic bremsstrahlung predictions in the absence of hadron production*. Associated production of soft photons with transverse momenta of many tens of MeV is consistently greater than what is predicted from the Low Theorem of electromagnetic bremsstrahlung. These excess soft photons are called anomalous soft photons. From "*Cheuk-Yin Wong, An Overview of the Anomalous Soft Photons in Hadron Production; arXiv:1404.0040v1 [hep-ph] 31 Mar 2014"*: "Anomalous soft photons in association with hadron production reveals either the presence of additional QED soft photon sources in QCD hadron production, ***or some anomalous hitherto undetected process***. Many different models have been proposed to explain the anomalous soft production, such as the oscillation of the color charge densities thereby accompanied by the oscillation of electric charge densities, but so far they seem to not work very well." Note the very large(100's) yield of unexplained soft photons of 10's MeV $k_T$, and peculiarly rising yield with the multiplicity of neutral hadrons. Inconsistent with bremss calculation …consistent with monopolium production?




| Experiment | Collision Energy | Photon $k_T$ | Photon/Brem Ratio |
|---|---|---|---|
| $K^+p$, CERN,WA27, BEBC (1984) | 70 GeV/c | $k_T$ < 60 MeV/c | 4.0 ±0.8 |
| $K^+p$, CERN,NA22, EHS (1993) | 250 GeV/c | $k_T$ < 40 MeV/c | 6.4 ±1.6 |
| $\pi^+p$, CERN,NA22, EHS (1997) | 250 GeV/c | $k_T$ < 40 MeV/c | 6.9 ±1.3 |
| $\pi^-p$, CERN,WA83,OMEGA (1997) | 280 GeV/c | $k_T$ < 10 MeV/c | 7.9 ±1.4 |
| $\pi^+p$, CERN,WA91,OMEGA (2002) | 280 GeV/c | $k_T$ <20 MeV/c | 5.3 ±0.9 |
| $pp$, CERN,WA102,OMEGA (2002) | 450 GeV/c | $k_T$ <20 MeV/c | 4.1 ±0.8 |

**3.** It remains difficult to explain cosmic rays with E>$10^{19}$ eV - isolated monopoles are naturally accelerated to >$10^{20}$ eV by the average galactic magnetic fields(~1 nT) – but such monopoles seem non-existent - Limits on *isolated* monopoles are excluded over a large mass range – *Auger data and LHC data* …. a back-of-the-envelop estimate of stable monopolium ($r_{Bohr}$ ~$10^{-14}$m) with a *very large magnetic dipole moment* accelerated by highly diverging magnetar dipole B fields (r~10km, B~$10^{11}$ T) might make it to those energies.