A Heuristic Dual to Ordinary Matter Yielding Neutral Composite Flavored Self-interacting Dark Matter

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Abstract

A heuristic Dual to the Standard Model (SM) particles is proposed and outlined, by systematically step-by-step considering ways to modify the Dual properties to hide from ordinary SM matter, whilst preserving linkages and relationships to the SM, creating a spectrum of self-interacting flavored neutral dark matter that could be produced in the early epoch as a dual with the SM particles, and which stabilizes the Higgs. We assert it would be unusual that a dark sector from the early epoch, apparently a larger fraction of matter than the SM, would not be as varied in numbers and phenomenology as the SM. SM matter interacts via the forces associated with SU(3)xSU(2)$_{\mathbf{L}}$xU(1).We follow that group as a basis for a double-copy Dual, but make the forces between SM particles and Dual particles weak or vanishing for stable Dual particles, yet with self-interactions within the Dual. For each SM elementary particle (quarks, leptons, vector bosons, Higgs), there is a Dual (effectively dark) sector particle that preserves flavor and preserves masses at tree level up to field self-energy corrections. These 2 attributes make each particle unique - specify a flavor and mass is so specified for the Higgs field coupling, and vice-versa. The Dual systematically inverts the dynamical properties: e→g; chromoelectic→chromomagnetic,Left→Right; weak charge reversed; Spin reduced by 1/2 unit→ "squarks", "sleptons", Wino etc - SUSY-lite. This results in a remarkably large and varied spectrum of neutral *composite* flavored dark matter, including shatoms and smolecules, with an asymmetry between sleptonic matter and shadronic matter. Magnetic charges enable the early universe to make dark matter far more copiously that SM electric charge. We assert that it would be unusual for nature to have made only 1 or just a few quantums of dark matter. In this early stage simplistic description of a Dual, interaction terms and a Lagrangian are not yet proposed, and there is no manifest Lorentz nor gauge invariance, and no custodial group.

Overview

The work proposes a heuristic *Dual* sector to the Standard Model (SM) wherein, for every SM degree of freedom, there exists a partner with inverted dynamical attributes but preserved mass and flavor at tree level. Fermions ↔ (pseudo)scalars, vectors ↔ spinors ("SUSY-lite"), electric e maps to magnetic g according to the t'Hooft-Polyakov Dirac quantization g=$2e/\alpha$). To avoid 2/3e down quark sector ↔ non-integer 3/2g in the squark sector g→ 2g: sleptons, Wino $\pm 2g$; $\pm 3g$ up squarks, $\pm 6g$ down squarks to maintain integer quanta. SM chromoelectric charges map to chromomagnetic charges, and posit that the effective strength of chromomagnetic coupling in the chromomagnetic octet is analogous to the reciprocal relationship of electric<=>magnetic charges. The force strength by chromomagnetic spinor gluino exchanges between chromomagnetic particles is smaller than the chromo-electric forces between chromoelectric particles, i.e. we posit this scales as: $\alpha_m \simeq 1/\alpha_s$ like Dirac monopole charge as there is no triple-chromomagnetic gluino coupling. Left–right handedness is inverted $SU(2)_L \rightarrow SU(2)_R$. The weak charges are reversed,. The Dual is methodically designed so that interactions with ordinary matter are automatically suppressed or forbidden by conservation of electric/magnetic and chromo-electric/chromomagnetic charges, angular momentum, and the inverted handedness assignments. Composite, magnetically neutral, *stable* bound states ("smesons", "sbaryons", "shadrons", and more complex "shatoms/smolecules") emerge as natural dark-matter candidates with significant self-interactions yet feeble couplings to SM detectors except at very high (10-100 TeV) energies. The binding force and energy of the composite neutral dark particles is almost entirely by the enormous non-perturbative magnetic poles, for which both Abelian and Non-Abeian strong coupled electromagnetism exhibit confining phases in lattice QED. Magnetic γ_m with effective velocity-dependent cross-couplings ($\gamma_e : \beta g$, $\gamma_m : \beta e$). Strong, non-perturbative magnetic dynamics confine monopoles into magnetically neutral, flavor-preserving composites ("shadrons"), providing abundant, self-interacting, neutral dark-matter candidates and stabilizing the Higgs. We outline production, portals, and

cosmological implications.

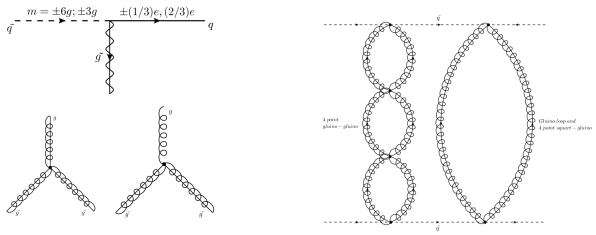

Figure 1: **Left: Forbidden Gluino Interactions:** (a) **Left Top:** Magnetic pseudoscalar squark quark cannot decay to an electric quark by gluino (or gluon) emission - magnetic and electric charges not conserved. (b) **Left Bottom**: Chromomagnetic, chromoelectric charges, angular momentum not conserved:thereby no g-g-$\tilde{g}$ nor $\tilde{g}$ -$\tilde{g}$-g vertex. *NOTE No triple spinor chromomagnetic $\tilde{g}$-$\tilde{g}$-$\tilde{g}$ vertices.*

Right: Di-gluino exchange A di-gluino loop can couple between 2 squarks or 2 scalar bound-systems of squarks . We posit that a chromomagnetic 2 gluino 4-point interaction can propagate as connected bubbles (chain of gluino-balls) between squarks. The gluino-ball propagates with 4-point self-interaction exchange with squarks in 2 dark matter shadrons with a Yukawa range $\approx$ 1/$m_{di-gluino-loop}$ or $1/m_{squark}$

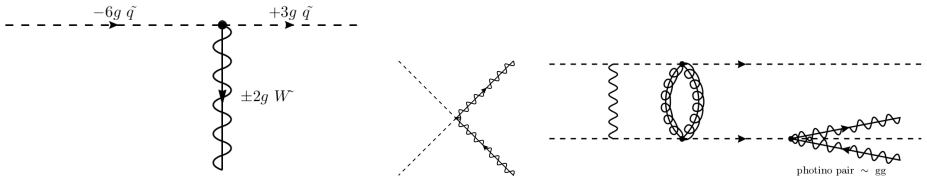

Figure 2: **LEFT:No squark flavor changing magnetic current in the Dual:** Wino weak magnetic charge 2g flavor changing current between 2 squark flavors is shut off by conservation of magnetic charge:-6g down-squark sector to +3g up-squark sector is forbidden. g=±2 Wino cannot conserve magnetic charge nor angular momentum. Similarly Zino spinor emission cannot conserve angular momentum, and SU(2)$_R$ handedness inversion: the Z cannot couple to all of the dark sector scalar fundamental particles. R-handedness inversion: the Z cannot couple almost all of the dark sector fundamental particles.: **M** Dual-Dual scalar $\rightarrow \tilde{\gamma}\ \tilde{\gamma}$. **R:** Dual scalar γ_m or digluino exchange, bremming $\tilde{\gamma}\ \tilde{\gamma}$

Magnetic and Chromomagnetic Structure

Magnetic duality. Electric charges map to magnetic monopole charges following a doubled Dirac-quantization heuristic so that scalar squarks carry $\{-6g, +3g\}$ and sleptons/Wino carry $\pm 2g$. Interactions between electric and magnetic sectors are with velocity-suppressed effective couplings: βg to g for a time-like photon from charge e; βe to e for a time-like photon from charge g, - β the CMS velocity. Electric photons γ_e from electric poles and "magnetic photons" γ_m from magnetic poles - that couple weakly to electric matter at low energies, resembling dark photons in practice. [***Fig 3***]. Photinos $\tilde{\gamma}$ are massless Majorana spinors produced only in Dual processes [**Fig 2 MR**]4-point scalar–$\tilde{\gamma}$ couplings. $\tilde{\gamma}$ evade any known limits. **Chromomagnetism.** [***Fig 1***] We posit that Chromomagnetic and Chromoelectric charges C_m x C_e = constant, a la Dirac. as angulat momentum is conserved, and that $\alpha_m \simeq 1/\alpha_s$, running more like e. Chromoelectric $\rightarrow$ chromomagnetic: the massless spinor gluino $\tilde{g}$ does not admit $\tilde{g}$-$\tilde{g}$-$\tilde{g}$ triple vertices, so chromocharge cannot propagate squark-to-squark as a string-like confinement among chromomagnetic scalars. Instead, semi-weak short-range interactions arise via di-gluino loops ("gluino-balls") exchanging between composite states with a Yukawa-like range set by the lightest squark masses. Separate conservation of electric/chromoelectric and magnetic/chromomagnetic charges prohibits $\tilde{g}$-mediated conversions between Dual and SM fundamentals. Relative motion between SM and Dual q and $\tilde{q}$ could generate small but significant forces but $\tilde{q}$ confinement is entirely from magnetic forces yielding confinement phases. The assignment of dual charge +2g or -2g (S or N) to e- is open - whether matter Dual partners correspond to matter or antimatter has consequences for cosmology.

Flavor, Mass, and Handedness

Flavor and mass preservation. Each Dual partner shares flavor and tree-level mass with its SM counterpart (modulo self-energy corrections), making flavor and mass jointly unique identifiers. This stabilizes the Higgs by scalar top and Higgsino duals *without requiring R-parity,* no mixed electric/magnetic diagrams are forbidden.
No flavor-changing magnetic currents for squarks. Charged-current flavor change is shut off in the squark sector: a $\pm 2g$ spinor Wino $\tilde{W}$ cannot convert a $-6g$ down-type squark into a $+3g$ up-type squark while conserving magnetic charge and angular momentum. Consequently, neutral smesons and sbaryons are *stable*. [*See Fig 2 LEFT*]
Inverted handedness. $SU(2)_R$ replaces $SU(2)_L$ for Dual weak interactions, eliminating problematic Z couplings such as $Z \to \tilde{\nu}\,\tilde{\nu}$ and forbidding $\tilde{Z}\tilde{Z}$/$\tilde{W}\tilde{W} \leftrightarrow Z$ vertices, while allowing channels like $\tilde{W}\tilde{W} \to \gamma_m$ that serve as Dual-sector portals.

Figure 3: (a) An electric photon γ_e coupling to a monopole as βg. (b) A magnetic photon γ_m coupling to an electric charge as βe.

Photon Sectors and Detection Implications

Two photon sectors: Photons are effectively partitioned by origin: γ_e from electric charges and γ_m from magnetic charges. The latter couple to electric charges with $\propto \beta$e, yielding suppressed interactions in typical detectors (long effective radiation lengths, anomalously dim signals, and isotropic inner bremsstrahlung with missing *total*—but not necessarily missing transverse—energy). Once γ_m converts (reflection, absorption, re-emission) in ordinary media, the outgoing quanta appear as standard γ_e, potentially giving rise to "dim" astrophysical sources and unusual calorimeter responses. High-energy γ_m with sizable β interact comparably to γ_e.

Composite Spectrum and Dark Matter

Magnetically bound Neutral Shadrons - sMesons and sBaryons *Neutral smesons*:Magnetically bound neutral stable smesons - analogs of the neutral mesons K^0, D^0, B^0 arise from $(-6g, +6g)$ or $(+3g, -3g)$ flavor pairs; $3 \times 2 = 6$ *neutral smesons* (plus anti-states) are stable against magnetic weak decay. K^o:[$\tilde{d}\tilde{\bar{s}}$], D^o [$\tilde{u}\tilde{\bar{c}}$], B^o:[$\tilde{b}\tilde{\bar{d}}$],$B^o{}_s$, [$\tilde{b}\tilde{\bar{s}}$],[$\tilde{u}\tilde{\bar{t}}$],[$\tilde{t}\tilde{\bar{c}}$] *Neutral sbaryons* made from $(+3g, +3g, -6g)$ configurations (27 flavor combinations) - such as the neutral "sproton" =($\tilde{u}\tilde{u}\tilde{d}$) - are likewise stable.
Multi-composite states. *Neutral di-smesons (*$\sim$ 18*)* [[$\tilde{\bar{u}}\tilde{d}\tilde{\bar{s}}\tilde{\bar{c}}$]; *di-sbaryons (*$\sim$ 36*)*[$\tilde{u}\tilde{u}\tilde{d}\tilde{\bar{c}}\tilde{\bar{c}}\tilde{\bar{s}}$] and tri-smesons ($\sim$ 36)enlarge the stable spectrum; long-range chromomagnetic di-gluino exchange provides additional binding among neutral composites.
Slepton sector and sleptonium. Charged $\pm 2g$ sleptons can interconvert via $\tilde{W}$ exchange, enabling neutral "sleptonium" bound states across flavors that may be stable or long-lived depending on binding energies vs neutrino masses, with potential cosmological consequences (e.g., apparent neutrino-flavor anomalies). **shAtoms and sMolecules.** Neu-

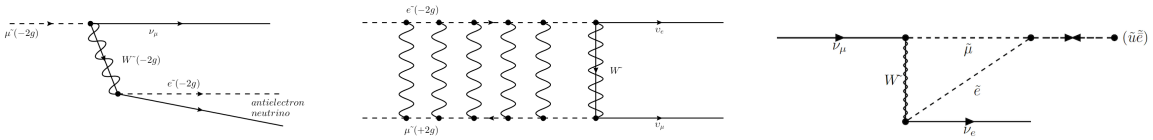

Figure 4: LEFT:$\tilde{\mu}$ (charge g=2) $\to\tilde{\nu}$ + $\tilde{W}$, which then decays to $\tilde{e}$ +$\tilde{\nu}$ MIDDLE: Di-slepton bound state exchanging non-perturbative γ_m and decays via exchange of g=2 $\tilde{W}$ to SM neutrinos *assuming bound state mass > mass ν if the binding energy>mass*. RIGHT Depending on masses, $\tilde{\nu} \to$ di-sleptonium+$\tilde{\nu}$ affecting ν oscillations

tral "atomic" and "molecular" bound states combining squarks and sleptons (e.g., $-6g$ squark with three $+2g$ selectrons) yield a vast neutral, self-interacting sector; exchange of γ_m and chromomagnetic $\tilde{g}$-loops mediates interactions reminiscent of van der Waals forces in condensed matter.

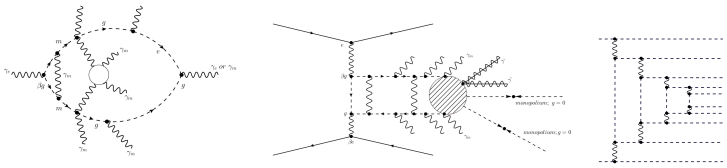

Figure 5: Flavored monopolium Production: **L:** If s-channel, γ_m bremss energy loss forces re-annihliation. **M:**If light-by-light non-perturbative γ_e - γ_m fusion to monopolium production - coupling chain: e-βg-g-βe, relatively weak -not shown are many γ_m binding or bremming away energy of escape leading to minimum 2 monopoliums and photino-pairs. **R:** Incident from left monopole pair produced by any SM process internally re-interact with each other via t-channel light-by-light, producing a new pair of poles, which then also can re-interact producing more pairs of poles which can either annihilate or pair up as flavored monopoliums that escape. The coupling is g-g-g-g; not shown are the many other γ_m binding or bremming. We call this a Nest or Telescope diagram.

Production and Confining Mechanisms [Figs 5]

s-channel suppression. Single time-like γ_e or Z couplings by SM annihalation to scalar monopole pairs are forbidden:
1. CP-forbidden:The coupling of an annihilation electric photon to N-S pair: P, T: does not change e ; P and T change the sign of the magnetic charge. P: monopole$\rightarrow$ antimonopole with the opposite momentum; CP symmetry absolutely forbids 1^{--} , 1^{++} states of the monopole-antimonopole system; true if P, C do not conserve separately, but CP does.
2. Time ordering: in the rest frame of the heavy vector(γ or Z) the poles are produced at $\beta \rightarrow 0$ at formation, reducing a βg-type coupling to zero, no matter size of g.
3. Dirac String*:* Accounting for the string scenarios: square of the amplitude not assured as positive definite, or vanish, Amplitudes do not take into account the huge non-perturbative strong-coupled contributions].

t-channel dominance, Dressing, Confinement. Peripheral $\gamma\gamma$ fusion preferentially deposits small fractions of total energy in light monopole pairs with large fractions remaining with the outgoing initial +/- electric poles. Unlike quark production producing low energy γ_e inner bremss, separating g-poles radiate nonperturbative γ_m removing escape energy faster than the confining force decreases with distance-time, spawning *light* Dual pairs ($\tilde{e}$, $\tilde{\mu}$, $\tilde{u}$,$\tilde{d}$,$\tilde{s}$,) decays of off-shell γ_m, (Schwinger-like processes, t-channel light-by-light), "dressing" into magnetically neutral bound states that *recombine or re-annihilate, hiding bare charges analogously to quark confinement in QCD.* **Numerical examples**

$$E_{\text{bind}} = \frac{g^2 \alpha \hbar c}{4\pi r}$$ **(GeV)at Multiple Formation Distances**

Particle	**Mass (MeV)**	r_0 **Compton (fm)**	E_{bind} **(Compton)**	E_{bind} $\mathbf{10^{-18}}$**m**	E_{bind} $\mathbf{10^{-21}}$**m**
$sElectron$	0.511	$3.86e+02$	$2.23e-02$	$8.60e+03$	$8.60e+06$
$sMuon$	105.7	$1.87e+00$	$4.61e+00$	$8.60e+03$	$8.60e+06$
$sTau$	1777	$1.11e-01$	$7.75e+01$	$8.60e+03$	$8.60e+06$
sUp	2.3	$8.58e+01$	$9.02e-01$	$7.74e+04$	$7.74e+07$
$sCharm$	1275	$1.55e-01$	$5.00e+02$	$7.74e+04$	$7.74e+07$
$sTop$	$1.73e+05$	$1.14e-03$	$6.79e+04$	$7.74e+04$	$7.74e+07$
$sDown$	4.8	$4.11e+01$	$4.71e-01$	$1.94e+04$	$1.94e+07$
$sStrange$	95	$2.08e+00$	$9.32e+00$	$1.94e+04$	$1.94e+07$
$sBottom$	4180	$4.72e-02$	$4.10e+02$	$1.94e+04$	$1.94e+07$
$sWboson$	$8.038e+04$	$2.45e-03$	$3.50e+03$	$8.60e+03$	$8.60e+06$

- e^+e^- at $\sqrt{s} = 10\,\text{GeV}$, $m = 10\,\text{MeV}$: $m/\sqrt{s} \sim 10^{-3}$. Expect $\sim 0.1\%$ of the total energy in $M\bar{M}$
- ILC-like $\sqrt{s} = 250\,\text{GeV}$, same m: $m/\sqrt{s} \sim 4 \times 10^{-5} \Rightarrow$ tens of ppm to the monopoles on average.
- LHC pp at $\sqrt{s} = 14\,\text{TeV}$, same m: $m/\sqrt{s} \sim 7 \times 10^{-7} \Rightarrow$ sub-ppm central energy fraction.

An r_0 of order few Fermi's creates binding of order few GeV, whereas 10^{-18} m has binding energies 10-20 TeV.

In the relativistic limit with $\gamma \approx$ constant over the range of r, and $v \approx c$, the energies of bremsstrahlung and escape scale as:

$$E_{\text{brems}} \sim \frac{g^6}{m^2 c r_0^3} \qquad E_{\text{escape}} = \frac{\mu_0 c^2 g^2}{4\pi r_0} \qquad \frac{E_{\text{brems}}}{E_{\text{escape}}} \propto \frac{g^4}{m^2 c r_0^2}$$

-*Confinement:* Bremsstralung overwhelms escape energy for the low mass squarks and sleptons.
-*Radius r_o:* Compton wavelength *or smaller* for each mass makes confinement more likely.
-*Monopolium Nested Pairs fig 5* - continuing nested light-by-light pair production removes energy of escape and adds multiple flavors to di-flavormonopoliums escaping.
-*Running of g and confinement*: Schwinger posited g runs the same as e; Coleman said they run oppositely, and recently reanalyzed as true. Hence g runs somewhat like α_s - ie confining. **SM-Dark Portals and Dark self-interaction summary.** Low-energy (<100's GeV) portals between the SM and the dual are limited: Higgs or di-Higgsino; γ_m exchange coupling is β_e suppressed to SM matter. Examples: A few eV γ_m interacting with an e in a camera has $\beta \approx$ Q/(Q+M) $\leq 10^-5$, interacting with a camera 100k less than γ_e; once aborbed by an electron (in camera/telescope materials), re-radiated as γ_e interact normally - but bright UV-IR energy γ_m sources from the cosmos or produced in accelerators would appear dim. Similarly,x-ray-gamma-ray γ_m interacting with high Z nuclei in calorimeter would appear to have radiation lengths 100's of times longer than γ_e, and could not be detected in current experiments. Neutral shadrons with chromomagnetic charges interact relatively weakly in hadron calorimeters. achromomagnetic di-gluino loops between composites. Very high momentum transfer is generally required to resolve the tightly bound constituent in shadrons; neutral composites have small effective couplings to SM detectors.

Cosmological and Phenomenological Notes and Consequences

Compatibility with existing data: **1. R ratio e+e** - SM production is t-channel;incoming e outgoes,thus not counted in the R-ratio. e+e- data should be looked at for outgoing +/-e's, many soft soft γ_m as they would appear anomalous in typical e-m calorimeters + missing energy from escaping monopoliums. Events with unusual excess photons appeared in LEP experiments at the Z-pole. **2. g-2:**γ_e from a μ couples weakly to magnetic scalar bubble:βg -vanishingly small- and non-perturbative. Lattice calculations are required whether a spinless g=0 blob of spinless magnetic particles can create a magnetic moment. Tightly bound small radius Dual matter has small dipole moments. Many other existing limits are inconsequential. A large spectrum of composite neutral Di-flavored particles with short range self-interactions comprise Dark Matter. Magnetic binding energy, inner bremsstralung during escape, and light-by-light generation of multiple squark pairs hide squarks as bound neutral pairs, creating dual-flavor neutral low mass monopoliums - i.e.squarks are hidden just as quarks are hidden. The flavored monopoliums - dark matter- self-interact by exchanging magnetic photons and di-gluino loops much like neutral SM atoms, molecules or n,p,nuclei; SM couplings are suppressed except at extreme energies where monopoles can be resolved at sizes less than 0.1F. This provides qualitatively viable composite self-interacting, mainly very light composite shadronic dark matter, with a huge spectrum, and asymmetric with the sleptonic components which can decay to each other and to ordinary matter. Notably because of the stable smesons, the baryonic component of SM matter is expanded to include 58 stable neutral smesons and 63 sbaryon, many shatoms, smolecules and snuclei. Massless Majorana Fermion photinos are continually injected into empty cosmos by $\gamma\gamma \rightarrow \tilde{\gamma}\tilde{\gamma}$ via $\tilde{e}$ loop, contribute nontrivially to cosmology - generating a Fermi pressure at universe scale wavelengths - *Dark Energy* - which decreases over time as the universe expands. Tightly bound neutral monopoliums evade CMB/GZK limits (100's of CR events evade, 10's exceed 10**20 eV); signatures indicate unusual cosmic-ray shower development. The Dual stabilizes the Higgs without R-parity - no magnetic diagrams that could mediate proton decay. Quantitative mass spectra, cross sections and binding energy require nonperturbative methods (e.g., strong-coupling QED/QCMD and lattice-inspired techniques) given $g \sim 2e/\alpha$ and the absence of small expansion parameters. Phenomenology of a cosmos consisting largely of sMesons, sBaryons, and sleptoniums is unusual. The anti/matter issue is modified by the asymmetry of slepton/shadron phenomena. Smatter dominated stars and galaxies UV-IR -would appear dim in telescopes as only about 1 per 100,000 of the γ_m would appear in telescopes. Eγ_m above 1 TeV interact full strength. Evidence to observe: places with no apparent objects.; magnetic-based neutral objects accelerated/formed at high energy (magnetars) appear as ν in large detectors. Cosmic emulsion data from 50 years ago detected several monopolium candidates. An extensive paper is nearly complete;this author is not qualified to add to arXiv - requests for a link welcomed. The author thanks Fairfield U and students for their support.