Pursuing the Limits of Failed Symmetry

Alan M. Schwartz

Abstract. Gravitation and quantum mechanics are separately accurately predictive to the limits of observation but together are utterly incompatible. No contemporary quantum gravitation theory offers testable predictions. It is shown that two founding postulates – vacuum isotropy and the Equivalence Principle – can be empirically falsified without contradicting prior observations in any venue at any scale, revealing more fertile pursuits of quantum gravitation theory.

I. Failure of theory

Galileo Galilei observed Aristotle was empirically wrong in his predictions. Isaac Newton modeled observation with geometry and mathematics, limited by facile postulates and a modest toolbox. A surge of mathematics enabled James Clerk Maxwell to provoke Albert Einstein in one corrective direction. Quantum mechanics pursued the other. Each is validated by nearly 100 years of observation but are mutually incompatible. Something postulated to be true is falsifiable.

Contemporary physics imagines a joint origin of gravitation and quantum mechanics in a maximally symmetric, hot and dense genesis that inflated, cooled, and differentiated. Beautiful mathematics shed symmetries through phase transitions and decays, pruning dimensions until the two incompatible models remained. Assumed residual global symmetries are amended case by case to be consistent with common observation.

The SI standard of mass is a physical artifact, Newton's G cannot be calculated, the Standard Model arrives massless. Supersymmetry's partners refuse to appear, protons do not decay, the Higgs mechanism does not reveal its vector boson. Supergravity, lattice and loop quantum gravity, and above all string and M-theory predict nothing. Physical theory also terrifically failed between Christmas 1956 and New Year's Day 1957.

Tsung Dao Lee and Chen Ning Yang forswore the fiat of Weak interaction beautiful symmetry. They exercised the heterodox temerity to look. Reality is a left foot. Generic weak interactions are sensitive to the difference between a pair of shoes. Physics had only considered socks - and it was incomplete (wrong). Reality was beautiful in a less simple way. Gravitation can be so tested in the massed sector.

II. Different in a different way

The Big Bang has a big problem. The visible universe is overwhelmingly matter essentially without antimatter. Its creation violated conservation of baryon number, conservation of lepton generation number, and other conserved properties arising from beautiful symmetries through Emily Noether's two profound theorems (that fail for discontinuous symmetry parity). The Weak interaction is strictly left-handed. All chiral (non-superposable mirror image) protein amino acids are L-configuration. Empirical reality fundamentally violates parity conservation but physical theory as derived does not.

Physical theory can be incomplete without contradiction. Add shoes to its socks when fitting a universal left foot. The vacuum, laboratory local or a billion lightyears' pathlength, is not refractive,

dispersive, dichroic, or gyrotropic toward photons to the limits of observation[1]. Massless photons do not configure. The massless sector provides unsuitable falsification tests.

Prevailing classical and quantum gravitation theories postulate or demand the (weak) Equivalence Principle (EP): All local centers of mass vacuum free fall along identical (parallel-displaced) minimum action trajectories. All atoms are anonymous unit masses in vacuum free fall, chemical bonding is invisible, all observables are differentially inert. No compositions of matter from beryllium marbles to PSR J1903+0327 pulsar (neutron star)-solar star binary[2] display EP[3] or General Relativity violation to the limits of experimental and observational error.

Gravitation physics does not discern chemically identical, self-similar, opposite geometric parity atomic mass distributions (e.g., Green's function). Physics does not know if opposite shoes vacuum free fall differently - a massed sector EP parity violation – perhaps because such metaphoric shoes when reduced to practice are chemistry. The limits to knowledge may be insular failures of vision.

III. Shopping for shoes

The Big Bang launched with an intense massed sector chiral pseudoscalar vacuum background. Its dilution powered cosmic inflation; matter dominated antimatter as broken symmetry forced baryon number and other conservation violations. The Weak interaction froze out left-handed. Biological homochirality was universally biased by residual chiral anisotropic vacuum background long thereafter. Quantized gravitation theories require supplementing Einstein-Hilbert action with a parity-violating Chern-Simons term[4].

Identical anonymous points (atoms) self-similarly, periodically array in 3-space as 230 crystallographic space groups. 65 Sohncke space groups contain chiral mass configurations. 11 pairs of Sohncke space groups are themselves enantiomorphic, forcing opposite geometric parity (chirality in all directions) independent of contents[5]. Three pairs of enantiomorphic Sohncke space groups contain no conflicting or racemic screw axes. They are our shoe boxes.

Space groups $P3_121$ and $P3_221$: The quartz group includes quartz[6], berlinite and analogues, cinnabar, tellurium, metallic selenium, others. Opposed solid single crystals of right- and left-handed quartz enable a parity-conserving Eötvös experiment sensitive to EP parity violation. Quartz' atoms are densely packed, 0.01256 nm^3/atom.

Benzil, C_6H_5-(C=O)-(C=O)-C_6H_5, is achiral when molten, gas phase, or dissolved. Solid state crystal lattice forces twist and stack benzil molecules into homochiral helices, space groups $P3_121$ or $P3_221$[7]. A parity-destroying calorimetry experiment measures divergent vacuum insertion energies plus EP parity violation as single crystals' divergent enthalpies of fusion, shoes fitted into the vacuum left foot then melted into identical socks. Benzil's atoms are densely packed, 0.01070 nm^3/atom.

See Figure 1, at end, or http://members.cox.net/xemist/benzil3.gif

Space groups $P3_112$ and $P3_212$: These lamellar solids (like pages in a book) grow large single crystals poorly and machine with difficulty. $CrCl_3$.

Space groups $P3_1$ and $P3_2$: Glycine gamma-polymorph[8], mesitylglyoxylic acid, 2,2-bis(hydroxymethyl)propionic acid, 1,2,4-thiadiazole-3,5-dicarbonitrile. Hydrogen atoms can have

large thermal ellipsoids in crystal lattices and thus uncertain positions. gamma-Glycine's atoms are very densely packed, 0.007869 nm^3/atom.

IV. Fitting shoes on feet

A chiral vacuum background appears in two independent ways. Right and left shoes fall through it differently. Right and left shoes insert into it with different energies. The former is a parity Eötvös experiment requiring exotic apparatus, 90 days, and PhD staff. Both together are a parity calorimetry experiment requiring two differential scanning calorimeters (DSCs), 2 days, and technicians.

EP violation as divergent rather than parallel trajectories disturbingly defines a privileged direction in space. EP violation as divergent acceleration magnitudes is unremarkable. Shine linearly polarized light through a chiral medium. The plane of polarization is the sum of its two propagating opposite chirality circularly polarized components. They have different refractive indices in a chiral medium. The propagation of one component is retarded versus the other, the medium being a foot divergently interacting with right and left shoes. The sum, the plane of polarization, progressively rotates.

V. Parity Eötvös experiment

An Eötvös torsion pendulum is a symmetric ~6 cm diameter rotor vertically suspended from a meter of ~20 micrometer diameter tungsten filament (a hair is 50 micrometers diameter) in an isolated ultra-high vacuum chamber. It carries two mass-balanced and moments of inertia-balanced sets of 180°-opposed test masses totaling ~40 grams. EP violation exerts nanoscopic periodic torque with interferometric rotation detection as the Earth gravitationally orbits the sun (m_g, gravitational test mass) and inertially rotates about its axis (m_i, inertial test mass). EP composition tests null to $2|m_g - m_i|/|m_g + m_i| = 5x10^{-14}$ difference/average sensitivity.

See Figure 2, at end, or http://members.cox.net/xemist/orbit.png

Geocenter orbital acceleration varies from 0.6133 cm/sec^2 03 January 2010 perihelion (day/month/year: 03/01/11, 05/01/12, 02/01/13) to 0.5737 cm/sec^2 06 July 2010 aphelion (04/07/11, 05/07/12, 05/07/13) averaging 0.5930 cm/sec^2 at one astronomical unit. Given World Geodetic System 1984, 44.95° latitude affords maximum 1.693 cm/sec^2 horizontal component of Earth's inertial spin at sea level. Sea level gravity there is 980.6 cm/sec^2 (differentially inactive in these experiments). Small imposed accelerations demand large contrasted property concentration and divergence for detectable EP violation of any kind.

An Eötvös experiment contrasts net active mass. Nuclear binding energy is the largest studied composition divergence but it is a very small fraction of total mass. Weighted for isotopic abundance,

p = 938.271998 MeV
n = 939.565330 MeV
Be = 6.462844 MeV/baryon binding energy
Mg = 8.265129 MeV/baryon binding energy
Ti = 8.714634 MeV/baryon binding energy

[Ti - Be]/[(30.9300n + 26p)/56.9300] = 0.002398
[Mg - Be]/[(17.3202n + 16p)/33.3202] = 0.001919

Atomic mass distribution in 3-space defines a geometric parity test mass. Ignoring electrons entirely, quartz is 0.99973 active mass. Parity Eötvös experiments are 400 to 500 times as sensitive as the best composition Eötvös experiments for the same test mass total loading.

If opposite geometric parity quartz single crystals fall through the vacuum differently, a time-varying Eötvös torsion balance net output will obtain as with a (never observed) successful composition experiment. Controls are each quartz geometric parity run against achiral amorphous fused silica test masses. Space group $P3_121$, a geometric right shoe, will display most of the EP parity violation. Space group $P3_221$, a geometric left shoe, will fall (approximately) unremarkably.

VI. Parity calorimetry experiment

A parity Eötvös experiment is geometric parity-conserving. A parity calorimetry experiment is geometric parity-destroying. It melts opposite shoes into identical achiral socks. A time-varying EP parity violation is summed with a constant differential chiral vacuum background insertion,

See Figure 3, at end, or http://members.cox.net/xemist/shoes2.png

All Eötvös experiments detect $2|m_g - m_i|/|m_g + m_i|$ divergence. Parity calorimetry experiments detect $|m_g - m_i|c^2$ plus chiral vacuum insertion difference. Benzil's ΔH_{fusion} (enthalpy of fusion) is 112 J/g. A $5x10^{-14}$ relative Eötvös signal is

$E = (5x10^{-17}\ kg)(299{,}792{,}458\ m/sec)^2$
$E = 4.49$ joules
4% relative $\Delta\Delta H_{fusion}$

DSC precision is 0.1%. A borderline detectable parity Eötvös experiment output is 40 times DSC baseline sensitivity. A parity EP experiment has 400 to 500 times the relative active mass of the best composition Eötvös experiment. State of the art composition Eötvös experiment sensitivity is $5x10^{-14}$ relative. Unremarkable parity calorimetry experiment sensitivity is 16,000 to 20,000 times better, $3x10^{-18}$ relative.

Two horizontally abutted DSCs' sample ports define a north-south line. Each holds a ~3 mm diameter ~17 mg benzil single crystal sphere with sample carriers crimped against sublimation. One sample port consistently contains one crystal in space group $P3_121$ and the other sample port one crystal in $P3_221$. ΔH_{fusion} are simultaneously run. New crystals run at half-hour intervals for 24 hours inclusive local time. If $\Delta\Delta H_{fusion} \neq 0$ within experimental error, repeat the run the next day with east-west alignment. $\Delta\Delta H_{fusion}$ will have a six hour phase shift on the second day. Calibration and controls are ΔH_{fusion} of finely powdered racemic benzil.

A parity calorimetry experiment in benzil has four possible outcomes:

1) No net signal. $\Delta\Delta H_{fusion} = 0$. Enantiomorphic single crystal ΔH_{fusion} are identical to that of powdered racemic benzil. Values do not change versus time of day and N-S or E-W geographic orientation.

2) $P3_121$ and $P3_221$ crystals consistently fit with different energies into chiral vacuum. The melts are achiral and identical. Opposite parities of chemically identical crystal melting to a common state must

display different enthalpies of fusion. At least one ΔH_{fusion} will be different from that of powdered racemic benzil, $\Delta\Delta H_{fusion} \neq 0$.

3) The angle between Earth's inertial spin and gravitational orbit rotates 360°/24 hours. This sources a composition Eötvös experiment signal. Add $P3_121$ and $P3_221$ benzil test masses aligned N-S and the coordinate frame cycles chiral, achiral, opposite chiral, achiral every 24 hours. A sinusoidal $\Delta\Delta H_{fusion} \neq 0$ will appear.

4) (2)+(3). Physics contains no alternative explanation for this observation.

VII. Conclusion

Quantum gravitation theories have been mathematically fertile and physically sterile, process without product. The Equivalence Principle in metric gravitation has an atomic mass distribution geometric parity flaw. BRST invariance in perturbational string theory, uniting the effects of a massive body and an accelerated inertial reference frame, has an atomic mass distribution geometric parity flaw. Noether's theorems have an atomic mass distribution geometric parity flaw.

The observed universe and its contents require fundamental odd-parity processes and structure, as do studied quantum gravitation theories. Two sensitive massed sector vacuum chiral background tests are proposed using existing equipment and commercial materials. The Equivalence Principle can fall to geometric parity violation through vacuum chiral anisotropy in the massed sector. Chemically identical, opposite parity atomic mass distributions in Einstein's elevator will misbehave. Quantum gravitation theory will then discard dead ends and proceed apace. Somebody should look.

[1] H. Mueller, et al., "Relativity tests by complementary rotating Michelson-Morley experiments", *Phys. Rev. Lett.* **99**, 050401(2007); http://arxiv.org/abs/0706.2031
[2] D. J. Champion, et al., "An Eccentric Binary Millisecond Pulsar in the Galactic Plane", http://arxiv.org/abs/0805.2396
[3] S. Schlamminger, K.-Y. Choi, T. A. Wagner, J. H. Gundlach, and E. G. Adelberger, "Test of the Equivalence Principle Using a Rotating Torsion Balance", *Phys. Rev. Lett.* **100**, 041101 (2008), http://www.npl.washington.edu/eotwash/publications/pdf/schlamminger08.pdf;
J.H. Gundlach,"Laboratory tests of gravity", *New J. Phys.* **7**, 205 (2005), http://www.iop.org/EJ/article/1367-2630/7/1/205/njp5_1_205.html
[4] N. Yunes, L. S. Finn, "Constraining effective quantum gravity with LISA", http://arxiv.org/abs/0811.0181
[5] H. D. Flack, "Chiral and achiral crystal structures", *Helv. Chim. Acta* **86**, 905 (2003), http://crystal.flack.ch/cacs.pdf
[6] K. Kihara, "An X-ray study of the temperature dependence of the quartz structure", *Eur. J. Mineralogy* **2**, 63 (1990); A. F. Wright and M. S. Lehmann,,"The structure of quartz at 25 and 590 degrees C determined by neutron diffraction", *J. Solid State Chem.* **36**, 371 (1981).
[7] M. More, G. Odou, J. Lefebvre, "Structure Determination of Benzil in its Two Phases", *Acta Cryst.* B**43**, 398 (1987).
[8] Å. Kvick, W. M. Canning, T. F. Koetzle and G. J. B. Williams, "An experimental study of the influence of temperature on a hydrogen-bonded system: the crystal structure of [gamma]-glycine at 83 K and 298 K by neutron diffraction", *Acta Crystallogr.* B**36**, 115 (1980).

Figure 1: Benzil configuration solid state and gas phase.
http://members.cox.net/xemist/benzil3.gif

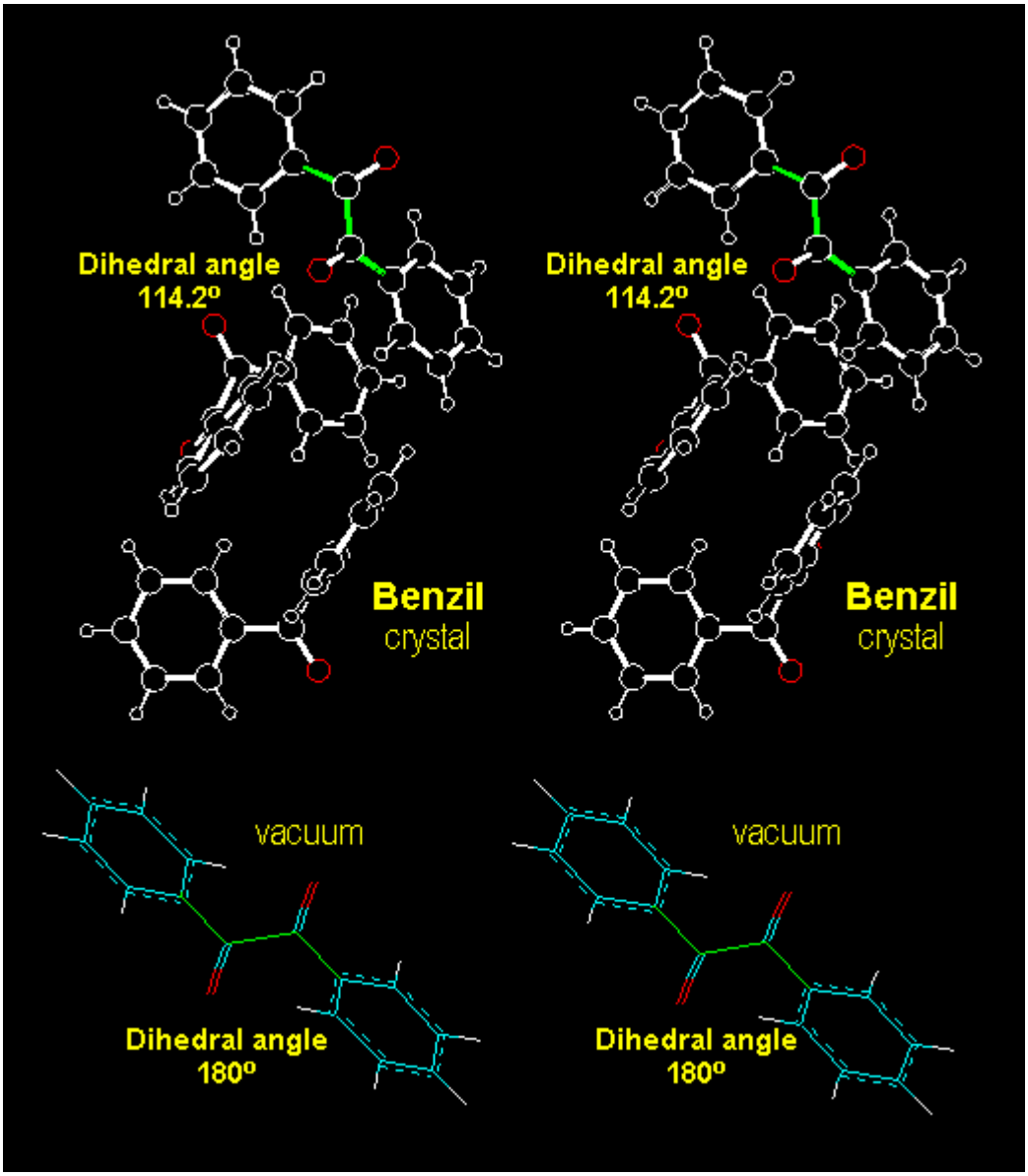

Figure 2: Earth's inertial spin and gravitational orbital accelerations.
http://members.cox.net/xemist/orbit.png

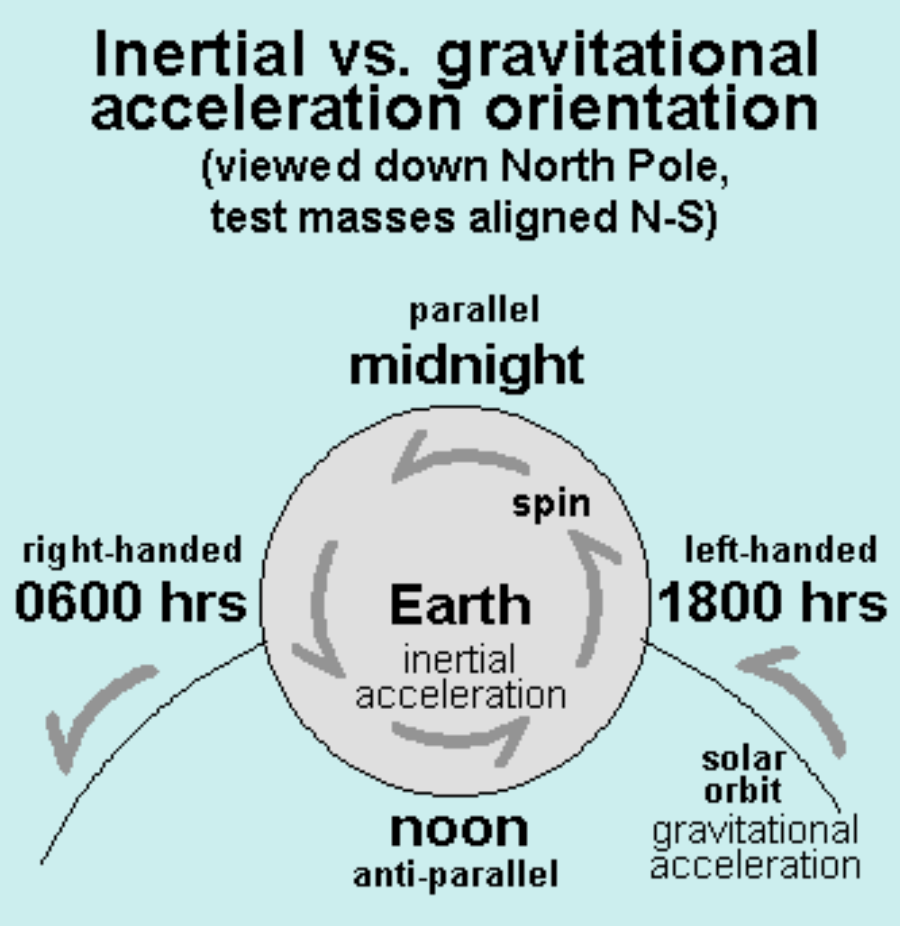

Figure 3: Chiral vacuum background detection by melting enantiomorphic single crystals of benzil. http://members.cox.net/xemist/shoes2.png