Title: Quiet Quest for High Energy Frontiers: Exploring Nature at Short Distances with Low-Energy Precision Measurements

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Abstract:

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Guelph–PI

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2. P and CP violation. Search for Electric Dipole Moments
3. Lorentz violation and CPT, effective field theory approach
4. Supersymmetry and Lorentz violation
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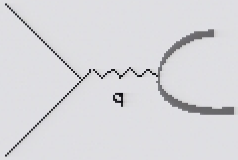
Two ways of probing UV physics

1. High-energy colliders

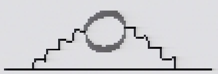


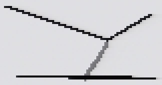
Probing

$$l \sim \frac{1}{q} \sim \frac{1}{E}$$

To probe/discover new physics at scale Λ_{NP} a typical energy of $E \sim \Lambda_{NP}$ is required.

Precision measurements at low energies





$$\Delta \text{Energy} \sim \frac{1}{\Lambda_{NP}^n},$$

where typically $n > 0$.

These two ways are complementary! As time scales and money needed to run collider programs increase, precision measurements become more popular.

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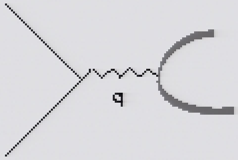

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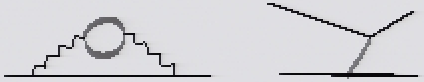

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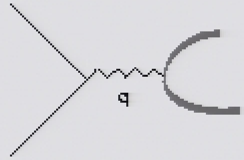

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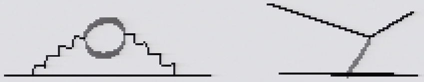

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What kind of experiments are informative?

What precision measurements can do and what they cannot... Particle Data Group book gives

$$m_p = 938.27200 \pm 0.00004\text{MeV}$$

(and even better accuracy for $m_n - m_p$) *Last digits ...7200 "know" about the contribution of weak interactions* to the proton mass ($\delta m_p^{\text{weak}} \sim G_F m_p^3 \sim 10^{-5} m_p$) but this information is lost under the contribution of strong and electromagnetic interactions. *To learn about weak interactions one should look at processes or observables that cannot be induced by strong or electromagnetic forces, e.g.* $n \to p + e + \bar{\nu}$.

Necessary condition for the success of any low energy measurement in providing information about short-distance scales: minimize/eliminate contributions of larger distance scales due to known physics or makes sure that they are calculable.

What you can study:

1. Properties of Z, Z' through parity violation in atoms
2. CP violation at a TeV scale and beyond by measuring EDMs (electric dipole moments)
3. extra Higgs bosons *if* they violate CP or flavour symmetry
4. Non-SM contributions to $g - 2$ of muon
5. Lorentz/CPT breaking effects (that may arise in variations of string theory and quantum gravity)
6. ......

What you cannot study:

Any short distance physics that respects flavour and CP and Lorentz inv., etc. For example, SM Higgs. You need a collider for that!

Parity non-conservation. Impact on HEP

1. The existence of neutrino is inferred (Pauli)
2. Effective interaction introduced by Fermi. It allows for a unified description of all β^+ and β^- effects

$$\mathcal{L}_{eff} = G_F(\bar{p}\gamma_\mu n)\,(\bar{e}\gamma_\mu\nu)$$

$\downarrow$ Lee and Yang

3. Discovery of Parity violation

$$\mathcal{L}_{eff} = G_F\bar{p}(a\gamma_\mu + b\gamma_\mu\gamma_5)n\,(\bar{e}\gamma_\mu\nu)$$

$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow$

4. Complete parametrization of all possible interactions of dimension 6: more than 10 different structures const $\times\,\bar{p}\Gamma_1 n\bar{e}\Gamma_2\nu$

$\downarrow$ experiment

5. $V - A$ structure of the theory

$$\frac{G_F}{\sqrt{2}}\bar{u}\gamma_\mu(1-\gamma_5)d\bar{e}\gamma_\mu(1-\gamma_5)\nu + \text{small corrections}$$

$\downarrow$

6. Chiral matter, W, Z are inferred. $SU(2)\times U(1)$ theory of electroweak interactions (Glashow, Salam, Weinberg)$\downarrow$
7. Experimental discovery of W and Z, precision measurements at LEP. Effective theory approach to TeV scale physics.

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Standard Model = effective field theory

Effective field theory is the modern *language* of particle physics.

New physics at the scale M
Experiment at low scales μ, $M \gg \mu$.
After identifying light degrees of freedom at scale μ, one can construct an effective action by *integrating out* frequencies higher than μ

$$S_{\text{eff}} = \int d^4x \sum_{\omega \leq \mu} (\mathcal{L} + \Delta\mathcal{L})$$

where $\Delta\mathcal{L}$ is the result of "integrating out" heavy modes between scales M and μ. $\Delta\mathcal{L}$ can be organized in terms of operators of increasing dimension,

$$\Delta\mathcal{L} = \sum_{i,n} c_i \frac{O_i^{(n+4)}}{M^n}$$

Operators $O_i^{(n+4)}$ have (mass) dimension $n+4$ and are built from fields with $\omega < \mu$ and their importance scales as μ^n/M^n. Wilson coefficients c_i/M^n contain information about details of dynamics at short distances.

Within Standard Model there are numerous examples how the effective field theory works, and works successfully as one crosses numerous energy thresholds. There are reasons to believe that Standard Model itself is an effective field theory.

Why EFT is so appealing?

1. It is very instrumental. Having e.g. Fermi interaction allows to describe muon decay, weak processes in stars, MSW effects in neutrino oscillations, ...
2. It is a complete description for all practical purposes, especially if the scale separation is large.
3. The rules of the game are well defined. All the machinery of field theory that gives renormalization of operators, their mixing etc. can be applied. Explicit cutoff $\Lambda_{UV} \sim M$ may be needed.
4. You can parametrize your ignorance. One can study known and ***unknown*** physics this way.
5. It is transparent and physical.
6. Problems that are usually encountered are ***naturalness problems***. (You expect certain coefficients to be large, but they turn out to be very small, i.e. cosmological constant, theta term, small Yukawa couplings). These are conceptual problems rather than problems that make theory nonexistent.

Electric Dipole Moments

Purcell and Ramsey (1949) ("How do we know that strong interactions conserve parity?" $\longrightarrow |d_n| < 3 \times 10^{-18} e\,\text{cm}$.)

$$H = -\mu \mathbf{B} \cdot \frac{\mathbf{S}}{S} - d\mathbf{E} \cdot \frac{\mathbf{S}}{S}$$

$d \neq 0$ means that both P and T are broken. If CPT holds then CP is broken as well.

Current most sensitive experimental limits:

$$|d_{\text{Tl}}| < 9 \times 10^{-25} e\,\text{cm} \quad (1)$$

$$|d_{\text{Hg}}| < 2 \times 10^{-28} e\,\text{cm} \quad (2)$$

$$|d_n| < 6 \times 10^{-26} e\,\text{cm}. \quad (3)$$

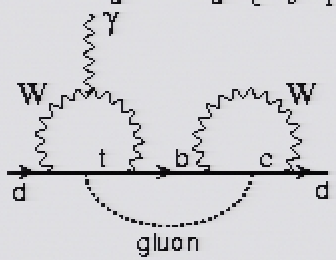
Method: Apply the moderate **B** and strong parallel **E**. Try to detect the precession frequency shift $\Delta\omega$ while reversing **E**.

Current sensistivity of the mercury EDM experiment. $\Delta\omega \sim 0.5$ nHz ($\sim 10^{-33}$GeV).

Last 5 years have seen sprawling of the EDM measurements: (Hg, U of Washington; PbO, Yale; YbF, IC UL; neutron, ILL, Grenoble; neutron, LANL-Oak Ridge; Rn, TRIUMF; electron EDM in solids, LANL; Ra, KVI, Netherlands; Ra, Argonne, Xe, Princeton;...)
New project with deuteron EDM at BNL.

Why bother? Importance of EDMs.

1. Known form of CP violation, Kobayashi-Maskawa phase, predicts extremely tiny EDMs, $|d_n| \leq 10^{-32}$ecm, $|d_e| \leq 10^{-38}$ecm. Therefore, *experiments have at least six orders of magnitude to explore before running into the CKM background!* $d_d \sim e m_d m_c^2 \alpha_s G_F^2 \mathrm{Im}(V_{tb}V_{td}^* V_{cd} V_{cb}^*)/(108\pi^5)$



2. Kobayashi-Maskawa phase (and θ_{QCD}) *cannot be a source of the dynamically generated baryon asymmetry*. New sources of CP violation are needed. Some scenarios of baryogenesis, e.g. electroweak baryogenesis, predict new source of CP violation at the weak scale, and measurable EDMs.

3. *EDMs are most easily induced in theories with additional scalars, like supersymmetric theories*. The search for scalars is one of the major goals of high-energy programme. EDM measurements are needed to complement collider information about new scalar particles.

CP or CPT ?

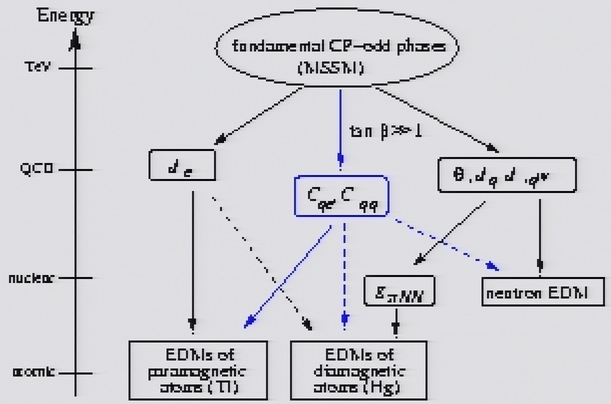
$$H_{\mathrm{T,P-odd}} = -d\mathbf{E}\cdot\frac{\mathbf{S}}{S} \to \begin{cases} \mathcal{L} = -d\frac{i}{2}\overline{\psi}\sigma^{\mu\nu}\gamma_5\psi F_{\mu\nu}, & \mathrm{CP}-,\ \mathrm{CPT}+ \\ \mathcal{L} = d\overline{\psi}\gamma^{\mu}\gamma_5\psi F_{\mu\nu}n^{\nu}, & \mathrm{CP}+,\ \mathrm{CPT}- \end{cases}.$$

where $n^\mu = (1,0,0,0)$ is the "preferred frame".

EDM d corresponds to a dimension 5 operator, and cannot be a fundamental quantity in field theory. A guess,
$d \sim e(\text{loop factor})^k \times \phi_{\mathrm{CP}}/M$.
High-precision measurement of an EDM translates into the sensitivity to ϕ_{CP}/M. If phase is of order 1, then $M \geq 1/(d_n^{\mathrm{exp}}/e) \sim 10^{13}$GeV. You could probe all the way to M_{Pl} before hitting the Kobayashi-Maskawa prediction!

Unfortunately, there are selection rule imposed by the $SU(2)\times U(1)$ invariance in the CP-odd, CPT-even case. The $SU(2)\times U(1)$-invariant generalization of $\overline{\psi}\sigma^{\mu\nu}\gamma_5\psi F_{\mu\nu}$ is necessarily an operator of dimension 6, involving the Higgs vev,
$\overline{\psi}_L\sigma^{\mu\nu}\gamma_5\psi_R H F_{\mu\nu}$.
Therefore, the scaling of d is $\sim$ (weak scale)$/M^2$, and "only" up to 10^8 GeV can be probed, with current sensitivity up to ten TeV.

From SUSY to an atomic/nuclear EDM



Appying EFT, one can classify *all CP-odd operators of dimension 4,5,6,...* at $\mu = 1$ GeV.

$$\mathcal{L}_{eff}^{1\text{GeV}} = \frac{g_s^2}{32\pi^2}\, \theta_{QCD} G_{\mu\nu}^a \tilde{G}^{\mu\nu,a}$$

$$-\frac{i}{2} \sum_{i=e,u,d,s} d_i\, \overline{\psi}_i (F\sigma)\gamma_5 \psi - \frac{i}{2} \sum_{i=u,d,s} \tilde{d}_i\, \overline{\psi}_i g_s (G\sigma)\gamma_5 \psi$$

$$+\frac{1}{3} w\; f^{abc} G_{\mu\nu}^a \tilde{G}^{\nu\beta b} G_\beta^{\mu c} + \sum_{i,j=e,d,s,b} C_{ij}\, (\bar{\psi}_i \psi_i)(\bar{\psi}_j i\gamma_5 \psi_j) + \cdots$$

The most complete to date calculations of EDMs in SUSY theories, from CP phases to the observables, can be found in D. Demir, O. Lebedev, K. Olive, M.P., A. Ritz, Nucl.Phys.B680 (2004) 339, with the bulk of QCD calculations done by M.P. and A. Ritz in 1999-2002.

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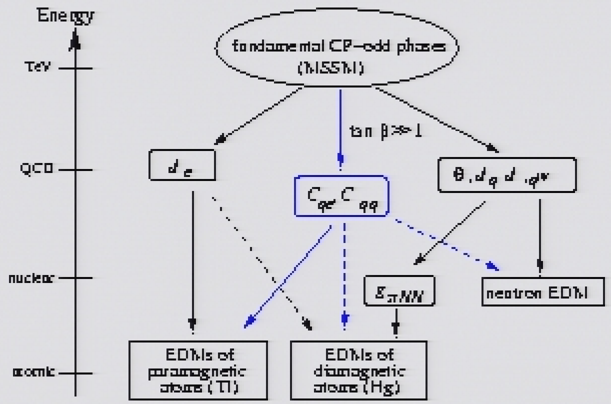

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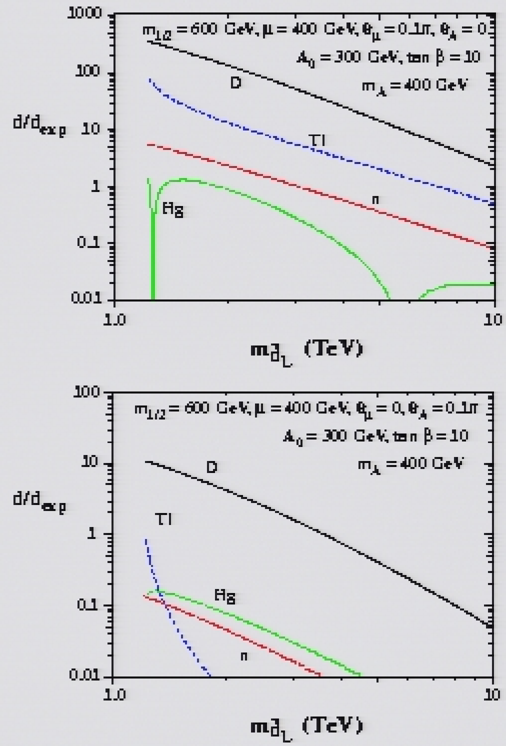
Future: deuteron EDM at 10^{-27} cm

Experiment: Deuteron EDM collaboration, (Semertzidis et al.), hep-ex/0308063; Theory: O. Lebedev, K. A. Olive, M.P. and A. Ritz, Phys. Rev. D70 (2004) 016003



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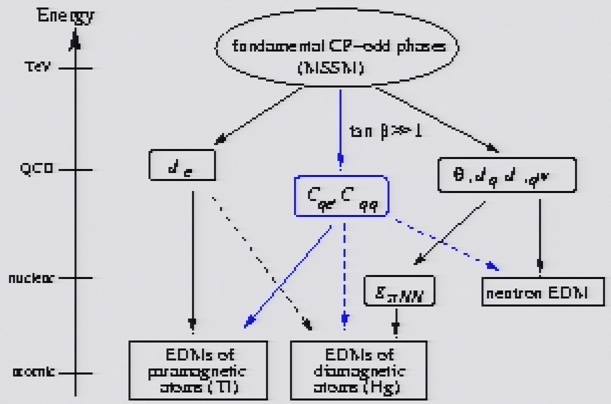

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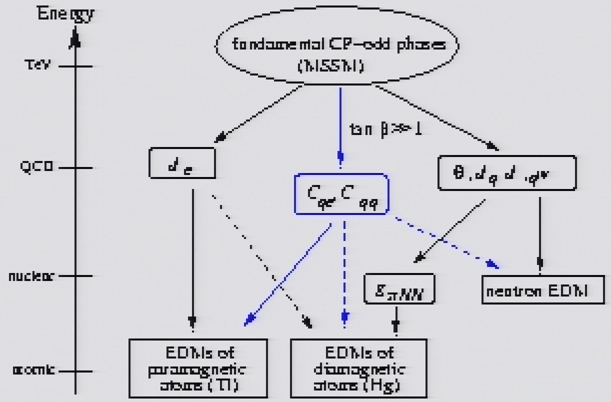
Type 3. ?

From SUSY to an atomic/nuclear EDM



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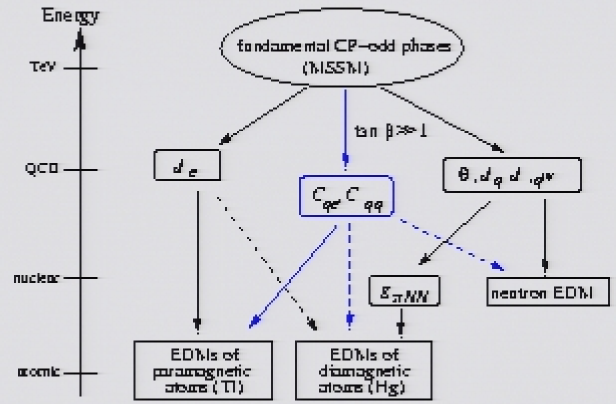

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CP or CPT ?

$$H_{\mathrm{T,P-odd}} = -d\mathbf{E}\cdot\frac{\mathbf{S}}{S} \rightarrow \begin{cases} \mathcal{L} = -d\frac{i}{2}\overline{\psi}\sigma^{\mu\nu}\gamma_5\psi F_{\mu\nu}, & \mathrm{CP}-,\ \mathrm{CPT}+ \\ \mathcal{L} = d\overline{\psi}\gamma^{\mu}\gamma_5\psi F_{\mu\nu}n^{\nu}, & \mathrm{CP}+,\ \mathrm{CPT}- \end{cases}.$$

where $n^{\mu} = (1,0,0,0)$ is the "preferred frame".

EDM d corresponds to a dimension 5 operator, and cannot be a fundamental quantity in field theory. A guess,
$d \sim e(\text{loop factor})^k \times \phi_{\mathrm{CP}}/M$.
High-precision measurement of an EDM translates into the sensitivity to ϕ_{CP}/M. If phase is of order 1, then $M \geq 1/(d_n^{\mathrm{exp}}/e) \sim 10^{13}$GeV. You could probe all the way to M_{Pl} before hitting the Kobayashi-Maskawa prediction!

Unfortunately, there are selection rule imposed by the $SU(2)\times U(1)$ invariance in the CP-odd, CPT-even case. The $SU(2)\times U(1)$-invariant generalization of $\overline{\psi}\sigma^{\mu\nu}\gamma_5\psi F_{\mu\nu}$ is necessarily an operator of dimension 6, involving the Higgs vev,
$\overline{\psi}_L\sigma^{\mu\nu}\gamma_5\psi_R H F_{\mu\nu}$.
Therefore, the scaling of d is $\sim$ (weak scale)$/M^2$, and "only" up to 10^8 GeV can be probed, with current sensitivity up to ten TeV.

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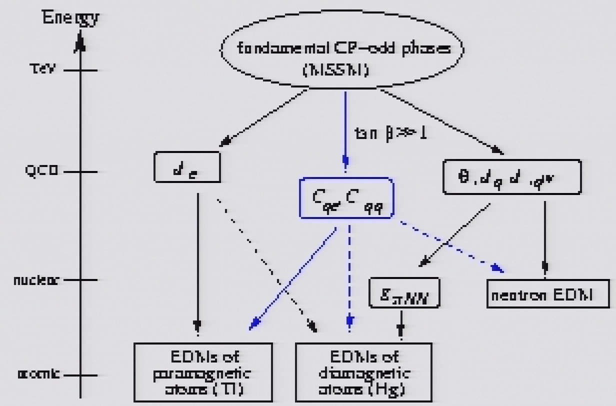

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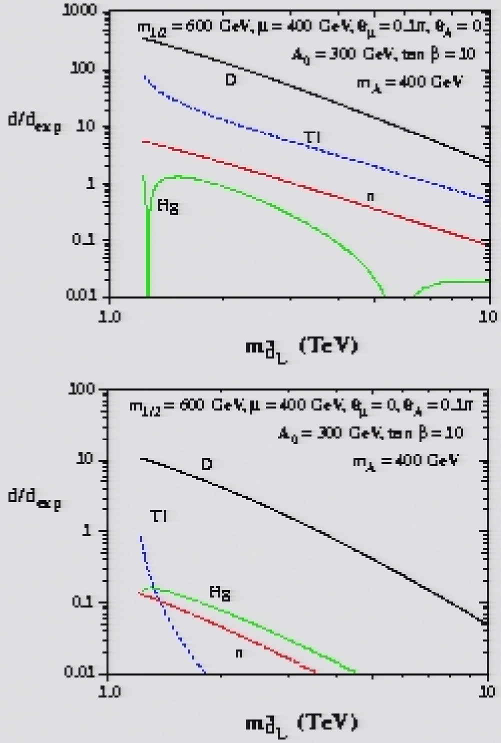
Future: deuteron EDM at 10^{-27} cm

Experiment: Deuteron EDM collaboration, (Semertzidis et al.), hep-ex/0308063; Theory: O. Lebedev, K. A. Olive, M.P. and A. Ritz, Phys. Rev. D70 (2004) 016003



EDM measurements are sensitive to CP violation at the multi-TeV scale. They must be continued. as they can lead to a discovery of new physics above the weak scale. and possibly above the reach of future colliders

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Type 2. UV physics violates fundamental symmetries such as Lorentz, CPT... In this case, much higher $M_{\rm QG}$ are accessible either through high-precision measurements or via astrophysical probes.
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Examples of "optimistic" outcomes

1. Noncommutative field theories.
For canonical ($[\hat{x}_\mu, \hat{x}_\nu] = i\theta_{\mu\nu}$) noncommutative field theory the sensitivity of "clock comparison" experiments is such that $\Lambda_{NC} > 5 \times 10^{14}$GeV (I. Mocioiu, M.P. and R. Roiban, Phys. Lett. B489 (2000) 390)

κ-Minkowski noncommutativity (?), $[\hat{x}_\mu, \hat{x}_\nu] = iC^\alpha_{\mu\nu}\hat{x}_\alpha$

2. Pure phenomenological approach. Let us modify the dispersion relations!

$$\mathbf{E^2 = p^2 + m^2 + c_1 \frac{E^3}{M_{Pl}} + c_2 \left(\frac{E^4}{M_{Pl}^2}\right) + ...}$$

(G. Amelino-Camelia, J. Ellis, N. Mavromatos, S. Sarkar, T. Jacobson, D. Mattingly, J. Alfaro, D. Sudarsky, L. Smolin, ...)
There are some attempts to derive such relation in LQG.

One can either study conditions such that $E^3/M_{Pl} \sim O(m^2)$ (astrophysical settings), or have the accuracy of laboratory measurements better than $m^2/M_{Pl} \sim 10^{-19}$GeV.

Both examples can be dealt with within the effective field theory framework.

Phenomenology of NC field theories

Mocioiu, Pospelov, Roiban

$[\hat{x}^\mu, \hat{x}^\nu] = i\theta^{\mu\nu}$. One can rewrite theory in normal coordinates in terms of the $*$-product,

$$(\phi * \psi)(x) = \exp\{\frac{i}{2}\theta^{\mu\nu}\partial_\mu(x)\partial_\nu(y)\}\phi(x)\psi(y)|_{x=y}$$

$\theta^{\mu\nu}$ has the dimension of inverse energy squared, that I call $1/\Lambda^2_{NC}$.

In the linear order in θ, there are corrections in terms of dimension 6 operators,

$$\mathcal{L}(*) = \mathcal{L} + \theta^{\mu\nu}\sum O_{\mu\nu}$$

For example, in NC QED,

$$\Delta\mathcal{L} = \frac{e}{8}\theta^{\mu\nu}F_{\mu\nu}F^{\alpha\beta}F_{\alpha\beta} - \frac{e}{2}\theta^{\mu\nu}F_{\mu\alpha}F^{\alpha\beta}F_{\beta\nu} + ...$$

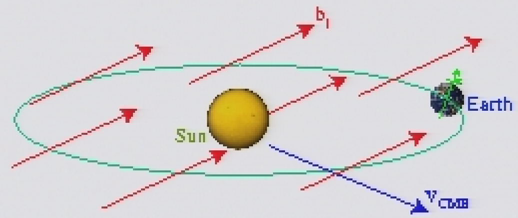
The "magnetic" part of $\theta_{\mu\nu}$, $\theta_{ij} \equiv \epsilon_{ijk}(\theta_B)_k$, couples to $(\theta_B \cdot \mathbf{B})(E^2 - B^2)$. In a bound state of charged constituents with a total spin $\mathbf{S}$ (nucleon, nuclei) this would lead to an effective coupling $\theta_B \cdot \mathbf{S}$,

$$\langle N|\mathcal{L}_{QCD}(*)|N\rangle \simeq d_\theta \theta^{\mu\nu}\bar{N}\sigma_{\mu\nu}N,$$

where $d_\theta \simeq 0.1(\text{GeV})^3$. Nucleon energy depends on the orientation of its spin relative to ther preferred frame given by $\theta_{\mu\nu}$.

Clock comparison experiments

As the Earth rotates, the effective angle between laboratory B and θ_B changes, leading to $24hr$ modulation of the precession frequency.



Best sensitivity measurements compare different spins in the magnetic field (co-magnetometers, or clocks). C. Berglund et al., (1995) compares ^{133}Cs and ^{199}Hg. θ_B affects mostly the nuclear spin, so that

$$\frac{\Delta\omega_{\rm Hg}}{\omega_{\rm Hg}} \gg \frac{\Delta\omega_{\rm Cs}}{\omega_{\rm Cs}}$$

The LV spin precession is not found with accuracy 100 nHz $\simeq 10^{-31}$GeV, so that

$$\frac{0.1({\rm GeV})^3}{\Lambda_{NC}^2} < 10^{-31}{\rm GeV} \rightarrow \Lambda_{NC} > 10^{15}\ {\rm GeV}$$

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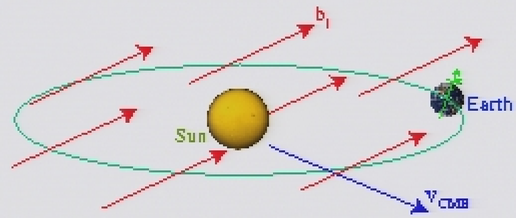

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EFT approach to quantum gravity

Does quantum gravity give me this?

$$E^2 = p^2 + m^2 + c_1 \frac{E^3}{M_{\rm Pl}}$$

I do not even know what quantum gravity is, but I can try to apply EFT to study its consequences. Large separation of scales, $M_{\rm Pl} \ggg E$ is guaranteed.

E^3 modification $\rightarrow$ dimension 5 operators
E^4 modifications $\rightarrow$ dimension 6 operators
...

We can built these operators using a slightly modified set of standard principles of EFT (Myers, Pospelov, Phys. Rev. Lett. 90 (2003) 211601). Dimension 5 operator should satisfy 7 creteria

1. Quadratic in the same field
2. One extra derivative relative to the standard kinetic term
3. Gauge invariant
4. Not reducible to lower dimension on equations of motion
5. Not a total derivative
6. Lorentz invariant, except for a "preferred frame" $n_\mu = (1,0,0,0)$
7. Should not contain coordinates x_μ explicitly

Selection rules and operators

Dimension 5 operators are severely constrained by these selection rules. The only possible operators that give E^3 modification of the dispersion relations are

Scalars:

$$\mathcal{L}_s = i\frac{\kappa}{M_{\rm Pl}}\bar{\Phi}(n \cdot \partial)^3 \Phi$$

Vectors:

$$\mathcal{L}_\gamma = \frac{\xi}{M_{\rm Pl}} n^a F_{ad} n \cdot \partial (n_b \tilde{F}^{bd})$$

Fermions:

$$\mathcal{L}_f = \frac{1}{M_{\rm Pl}}\bar{\Psi}\left(\eta_1 \not{n} + \eta_2 \not{n}\gamma_5\right)(n \cdot \partial)^2 \Psi$$

There are no modifications to disperison relation for a real scalar!

For photons, this modification is helicity dependent,

$$\left(E^2 - p^2 \pm \frac{2\xi}{M_{\rm Pl}} p^3\right)(\epsilon_x \pm i\epsilon_y) = 0$$

Only three constants are relevant for QED, $\eta_{1,2}$ and ξ.

Phenomenological constraints

Preferred frame → loss of isotropy due to Earth's motion relative to a "fixed" frame, $n_i \simeq v_i/c \sim 10^{-3}$.

A typical spin precession constraint is then

$$|(\eta_d - \eta_Q) - 0.5(\eta_u - \eta_Q) + 10^{-3}\xi| \leq 10^{-8}$$

(See also, Sudarsky, Urrutia, Vucetich, Phys. Rev. Lett.89:231301,2002)

The same operators are used to derive constraints from astrophysics (Jacobson et al.), and from the precession of polarization of light over cosmological distances (Gleiser, Kozameh). The limits are typically at $O(10^{-3} - 10^{-5})$ level.

Much stronger constraints from the mere existence of high-energy cosmic rays have been reported recently in Gagnon, Moore, hep-ph/0404196.

Astrophysics and low-energy tests provide constraints on different linear combinations of parameters

Using the evolution of operators over the scales, one can strengthen some limits due to the mixing of operators.

Naturalness problem

We assumed dimension 5 operators *without checking whether dimension 3 exist*. They do! See e.g. papers by A. Kostelecky. Again, for QED,

$$\mathcal{L}^{(3)}_{\rm QED} = -b_\mu \bar\psi \gamma^\mu \gamma_5 \psi - \frac{1}{2} H_{\mu\nu} \bar\psi \sigma^{\mu\nu} \psi - k_\mu \epsilon^{\mu\nu\alpha\beta} A_\nu \frac{\partial}{\partial x^\alpha} A_\beta,$$

Dimension three coefficients can be induced from dimension 5 via quantum loops with a predictable outcome,

$$b_\mu \sim ({\rm loop\ factor}) \times \xi \frac{\Lambda^2_{UV}}{M_{\rm Pl}}.$$

It is a disaster unless either fine-tuning happens, or Λ^2_{UV}-divergence is absent, or the cutoff scale is moderate to low.

Solution 1. Protection by a twist (Myers, Pospelov). Λ^2-divergence is absent if instead of $n_a n_b n_c$ we use absolutely symmetric irreducible tensor C_{abc} such that contraction $C^a_{ab} = 0$.

Solution 2. Operators that break SUSY are supersymmetric.

SUSY Lorentz violation

S. Groot Nibbelink, M. Pospelov, hep-ph/0404271; P. Bolokhov, S. Groot Nibbelink, M. Pospelov, in preparation.

Any LV operator respecting MSSM gauge invariance and exact SUSY has dimension five or higher and is therefore suppressed by at least one power of an ultraviolet scale M.

$$\int d^2\theta \left(\frac{1}{16e^2}W^2 + mE_+E_-\right) + \text{h.c.} + \int d^4\theta\, \bar{E}_\pm e^{\pm V} E_\pm$$

$$+\frac{1}{M}\int d^4\theta \left(iN^m_\pm \bar{E}_\pm e^{\pm V}\partial_m E_\pm - \frac{1}{2}N^m \bar{W}\bar{\sigma}_m W\right)$$

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It can be shown that these operators are reducible on the equations of motion, (e.g. $d^4\theta \bar{E}\partial_m E \to E^*\partial_m \partial^2 E$). Therefore, in SUSY theories a different modification of dispersion relation is possible:

$$\mathbf{E^2 = p^2 + m^2\left(1 + c_1\frac{E}{M_{Pl}} + c_2\frac{E^2}{M_{Pl}^2} + ...\right)}$$

These modifications are tiny. If SUSY is broken softly, then divergencies are under control. dim3 $\sim$ dim5$\times m^2_{\text{SUSY}}\times \log(\Lambda_{UV}/m_{\text{SUSY}})$.

A contradiction with LQG?

There are certain claims of LQG with regard to non-trivial LV phenomenology that the current form of the EFT approach cannot reproduce

1. Frame independence
2. Spatial isotropy
3. Modification of dispersion relations for a singlet scalar

It is good that there are contradictions. It gives us a chance to learn how quantum gravity merges with the rest of physics.

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Defficiency of the current EFT approach

1. Why $n_m = (1,0,0,0)$?
2. Gravity is ignored. All background tensors like n_m are going to become functions of coordinates, and eventually dynamical fields or their derivatives. Do we miss additional low-energy degrees of freedom?
3. When dinamics for n_m is put it, the way we classify operators may change as well.
4. Other constraints will neccessarily emerge once n_m is dynamical: cosmology, long-range forces, change of couplings...
5. Dynamical mechanisms to "condense" tensors are not sufficiently explored. See, however, J. W. Moffat, Int. J. Mod. Phys. D12 (2003) 1279 and "ghost-condensation" literature.
6. ....

Defficiency of the LQG claims

1. Do you really mean that below M_{Pl} Quantum Gravity *does not merge* with effective field theory? This is a good reason to be worried...
2. Don't you also have some new IR degrees of freedom?
3. If you convince us that EFT does not work, give us a formalism of *comparable usefullness*.
4. Should calculate not only phenomenology pertinent to cosmic rays and GKZ, but low energy effects, and spin dynamics in particular.
5. What are C,P,T properties of predicted modifications?
6. Effective field theory for κ-Minkowski space (M. Dimitrijevic, F. Meyer, L. Moller and J. Wess, Eur. Phys. J. C36 (2004) 117) contains explicit dependence on coordinates. How can it possibly be frame independent?
7. ...

Conclusions

1. Low energy precision searches of CP. CPT and Lorentz violation allow to probe short distance physics that is outside of reach of the existing collider experiments.

2. Effective field theory approach can be applied to to study effects of Lorentz violating backgrounds. Precision measurements. astrophysics and cosmology impose complementary and very restrictive bounds at better than $10^{-5}/M_{\rm Pl}$ level.

3. We classified Lorentz-noninvariant backgrounds in SUSY theories to show that only operators suppressed by at list one power of $M_{\rm Pl}$ are allowed and that there is no modification to dispersion relation.

4. Quantum gravity must merge with EFT at some point. The way it happens should be one of the focuses of theory community.