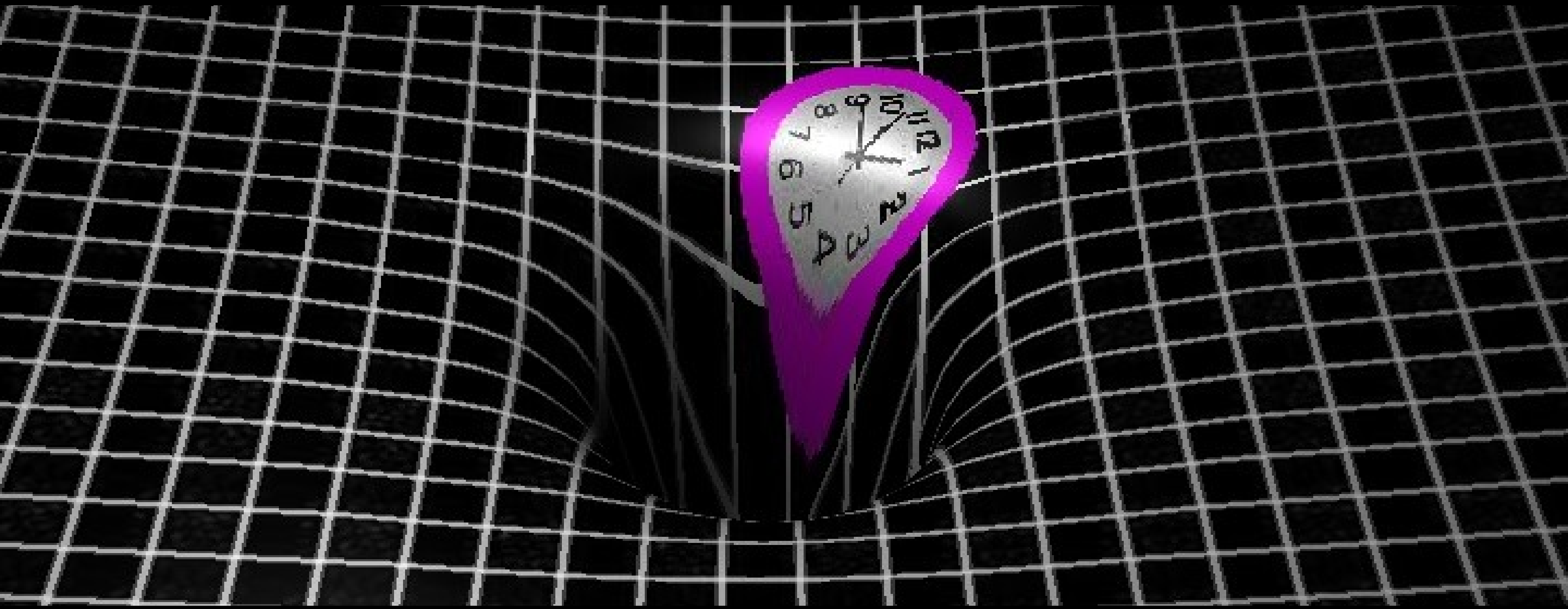
Tests of Lorentz Symmetry with STE-QUEST



Jay D. Tasson

Carleton College

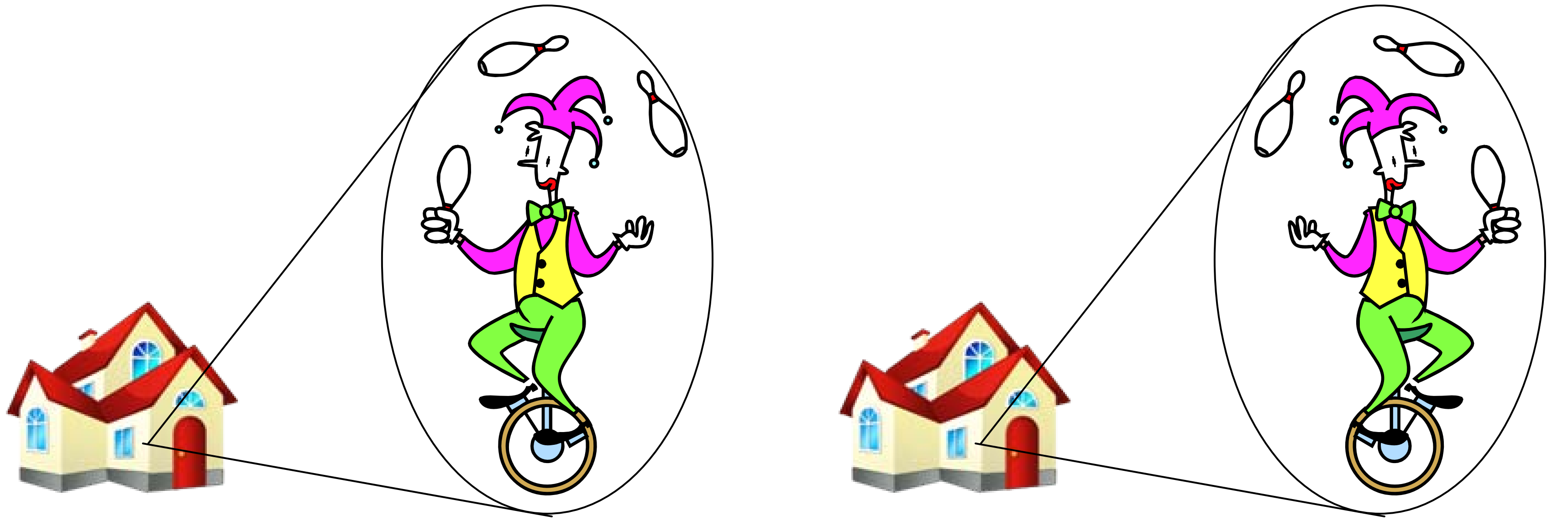
outline

- Lorentz invariance
  - meaning
  - violation
  - motivation for testing
  - test framework
- clock tests
  - theoretical analysis
  - STE-QUEST sensitivity
- WEP tests
  - theoretical analysis
  - STE-QUEST sensitivity

Based on STE-QUEST analysis
with Brett Altschul & Quentin Bailey

relativity

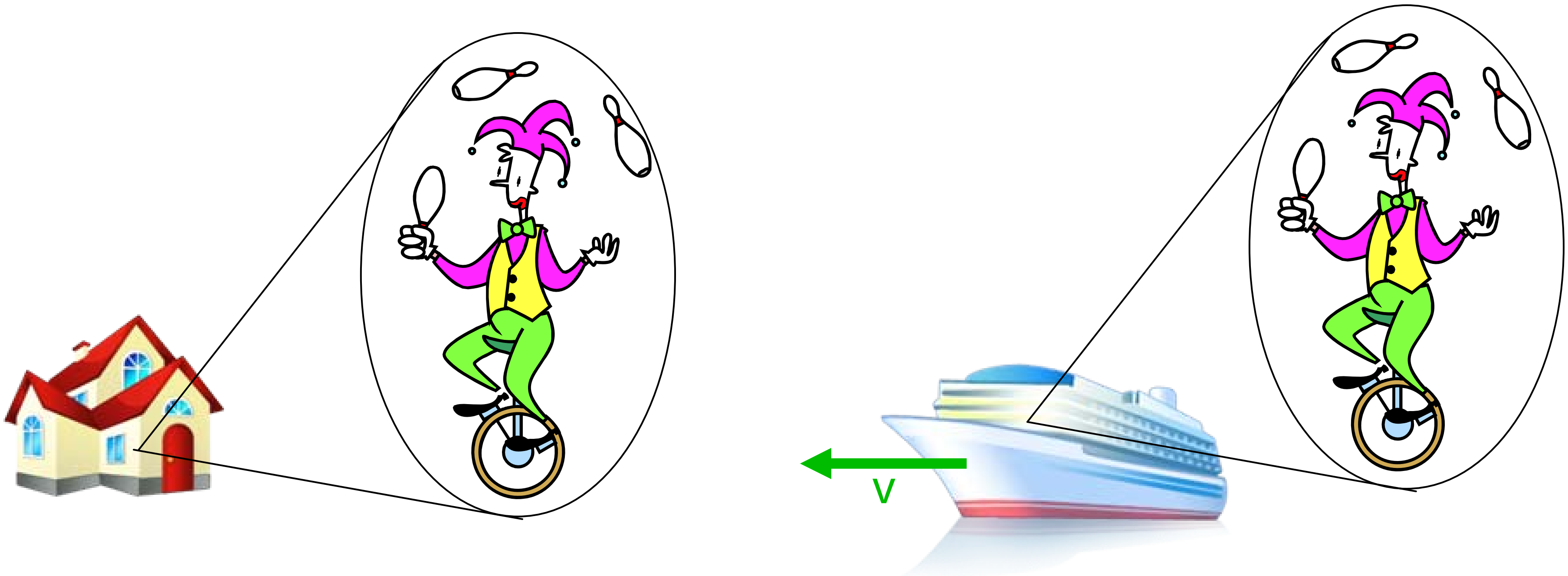
- physical results are independent of the velocity of the experiment and the ***direction*** it points



- juggling facing the other way still works
- rotation invariance – results are independent of the direction the experiment points

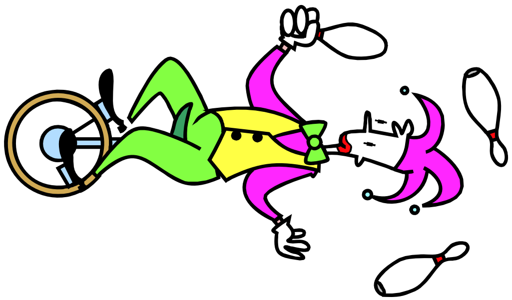
relativity

- physical results are independent of the ***velocity*** of the experiment and the direction it points



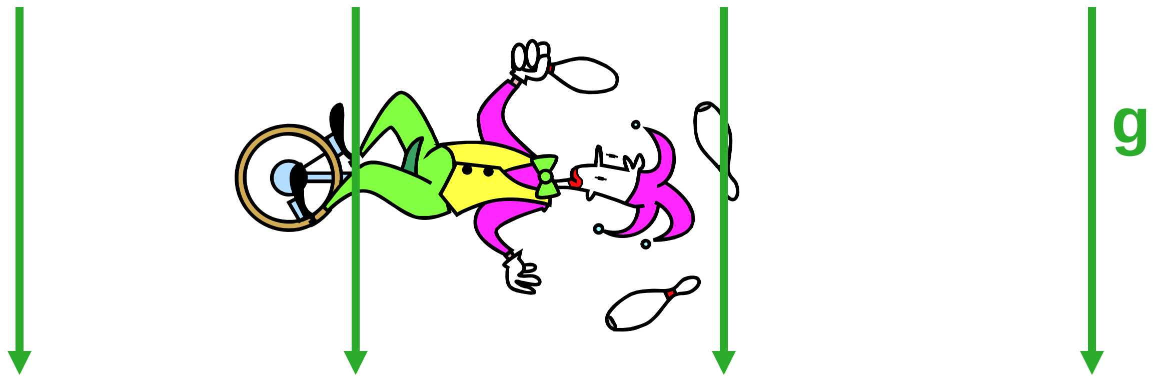
- juggling on ship moving at constant velocity without rocking still works
- boost invariance – results are independent of the constant velocity of the experiment

what does relativity violation look like?



- juggling while lying on your back is different

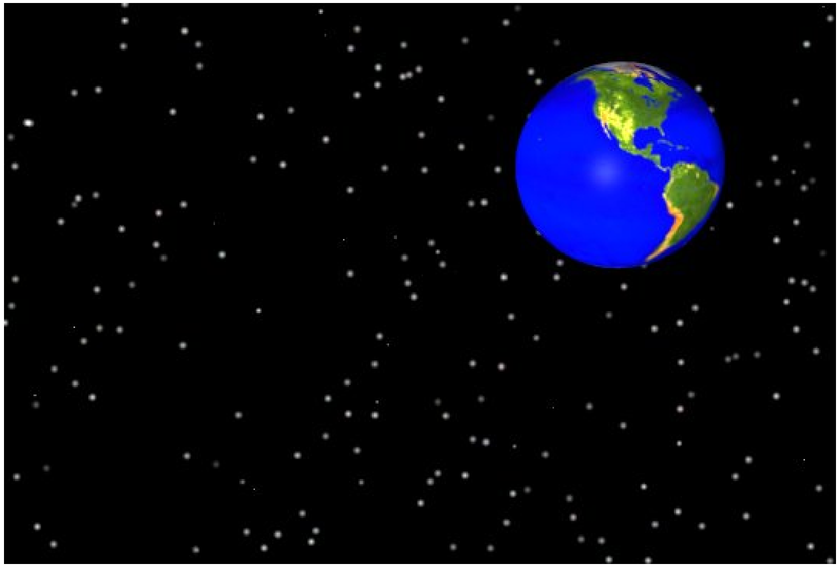
what does relativity violation look like?



- juggling while lying on your back is different
- apparent relativity violation
- resolution: Earth is part of experiment. It should be turned with the juggler.

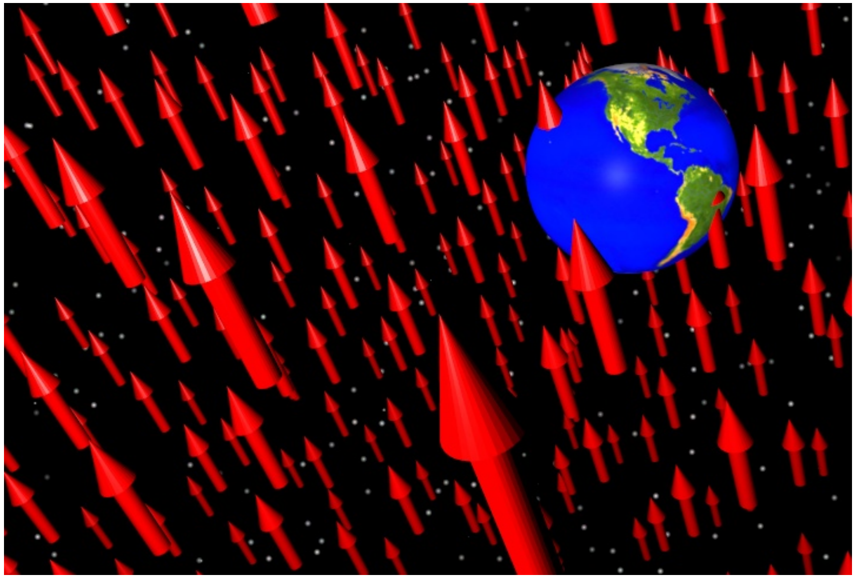
fundamental relativity violation

- relativity

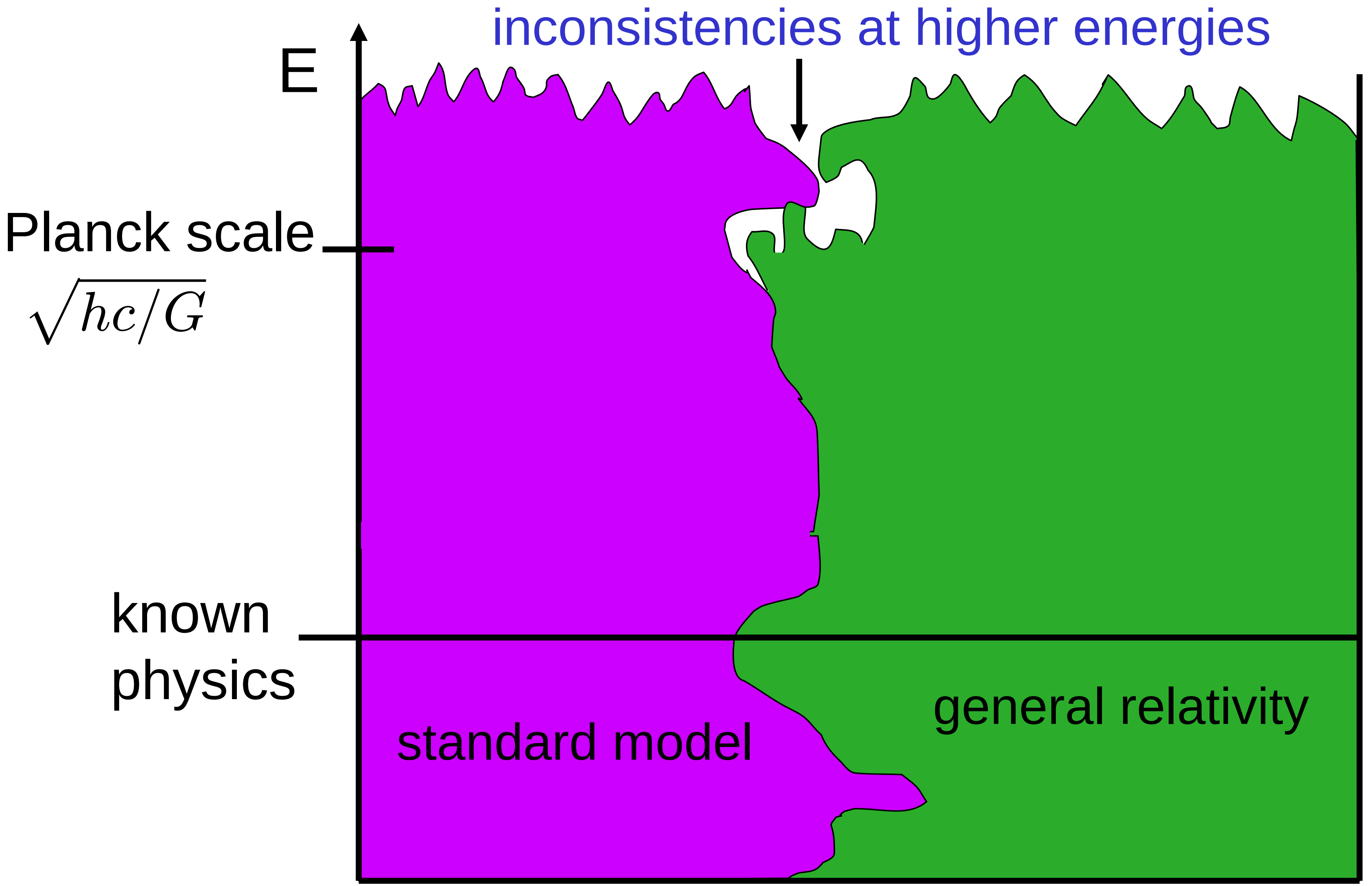


- relativity violation

(in general, there can be time components and higher rank tensors, but they're hard to draw)



motivation


inconsistencies at higher energies
E
Planck scale
$\sqrt{hc/G}$
known
physics
standard model
general relativity

underlying theory at Planck scale

options for probing experimentally

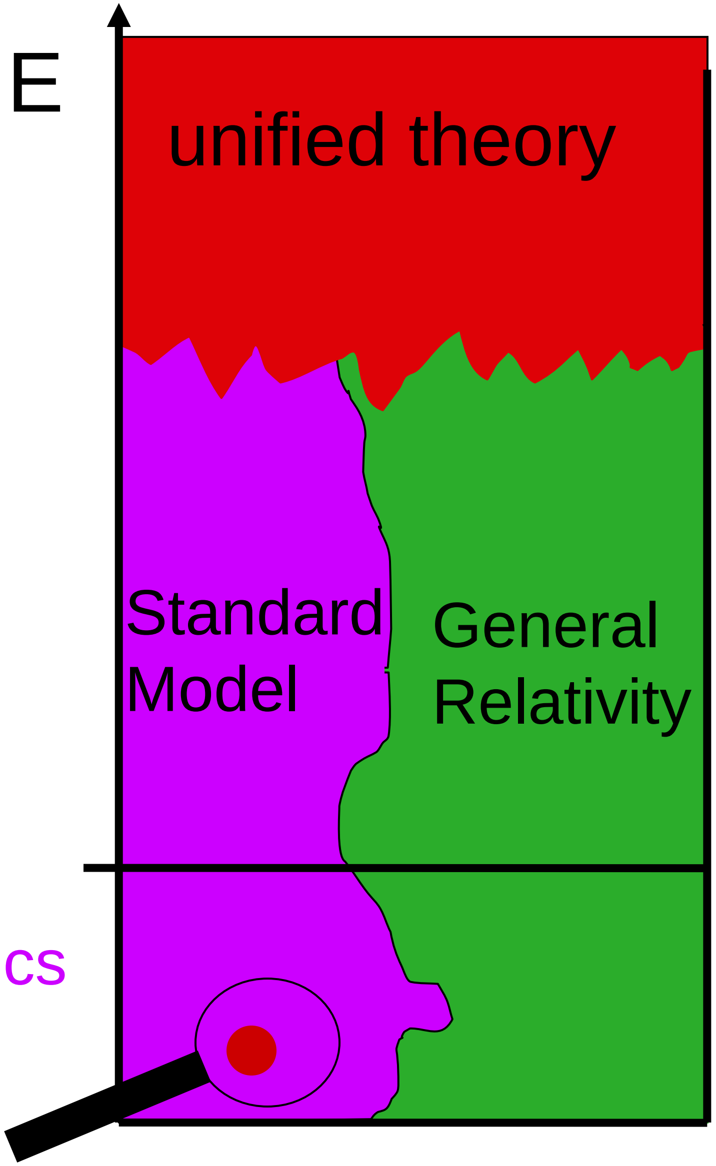
- galaxy-sized accelerator

- suppressed effects in sensitive experiments

Lorentz violation

- can arise in theories of new physics
- difficult to mimic with conventional effects

STE-Quest can probe Planck-scale physics!



general test framework

Gravitational Standard-Model Extension (SME):

effective theory which contains

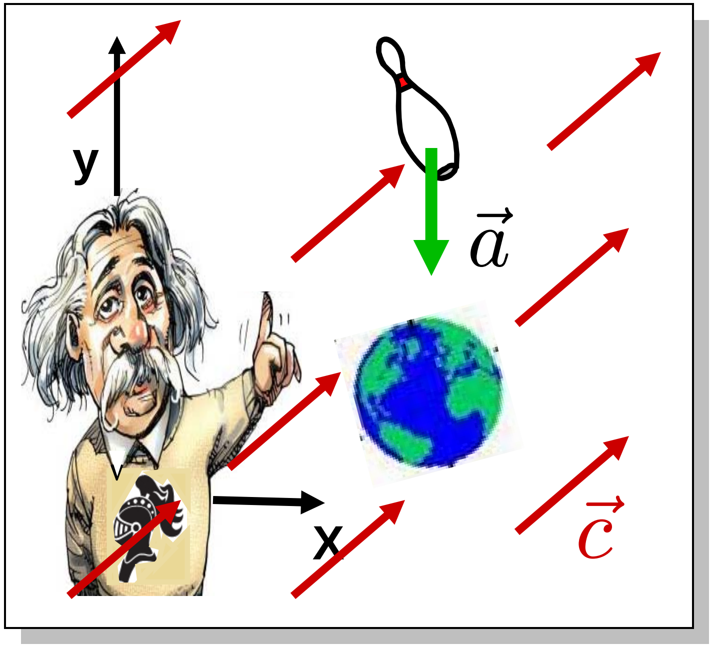
- General Relativity
- the Standard Model
- all Lorentz-violating terms
- broad search for LV

Lorentz-violating terms

- constructed from known physics (fields, particles, interactions)
- parameterized by coefficients
- sample

$$\vec{a} = \vec{g} + \vec{c}(\vec{c} \cdot \vec{g})$$

different for various particles



Colladay & Kostelecký PRD ’97, ’98   Kostelecký PRD ’04

gravitational SME

- effective field theory
- expansion of Lagrangian about known physics

$$L_{\mathrm{SME}} = \underbrace{L_{\mathrm{SM}} + L_{\mathrm{GR}}}_{\textbf{known physics}} + \underbrace{L_{\mathrm{LV}+L_{\mathrm{LV}}} + \ldots}_{\textbf{Lorentz violating corrections}}$$

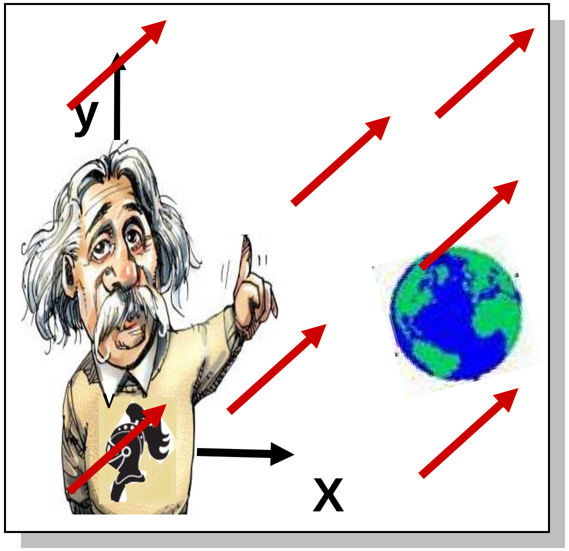
$$L_{\mathrm{LV}} = L_{\mathrm{fermion}} + L_{\mathrm{photon}} + L_{\mathrm{pure\,gravity}} + \cdots$$

- nongravitational minimal QED limit

$$L_{\mathrm{fermion}} = \tfrac{1}{2} i \overline{\psi} (\gamma^{\mu} - c^{\mu}{}_{\nu} \gamma^{\nu} - e^{\mu} \ldots) \overleftrightarrow{D_{\mu}} \psi$$
$$- \overline{\psi} (m + a_{\mu} \gamma^{\mu} + b_{\mu} \gamma_5 \gamma^{\mu} + \ldots) \psi$$

coefficients for Lorentz violation
- particle-species dependent
- to first approximation,

constant in Sun-centered frame



PPN vs. SME

framework	PPN	SME
parameterizes deviations from:	General Relativity (including some Lorentz violation)	exact Lorentz invariance (including some corrections to GR)
expansion about:	GR metric	GR + standard model Lagrangian
GR corrections?	Yes	Yes, different ones!
matter sector /standard model corrections?	No	Yes

tests

- compare experiments pointing in different directions

- compare experiments traveling at different velocities

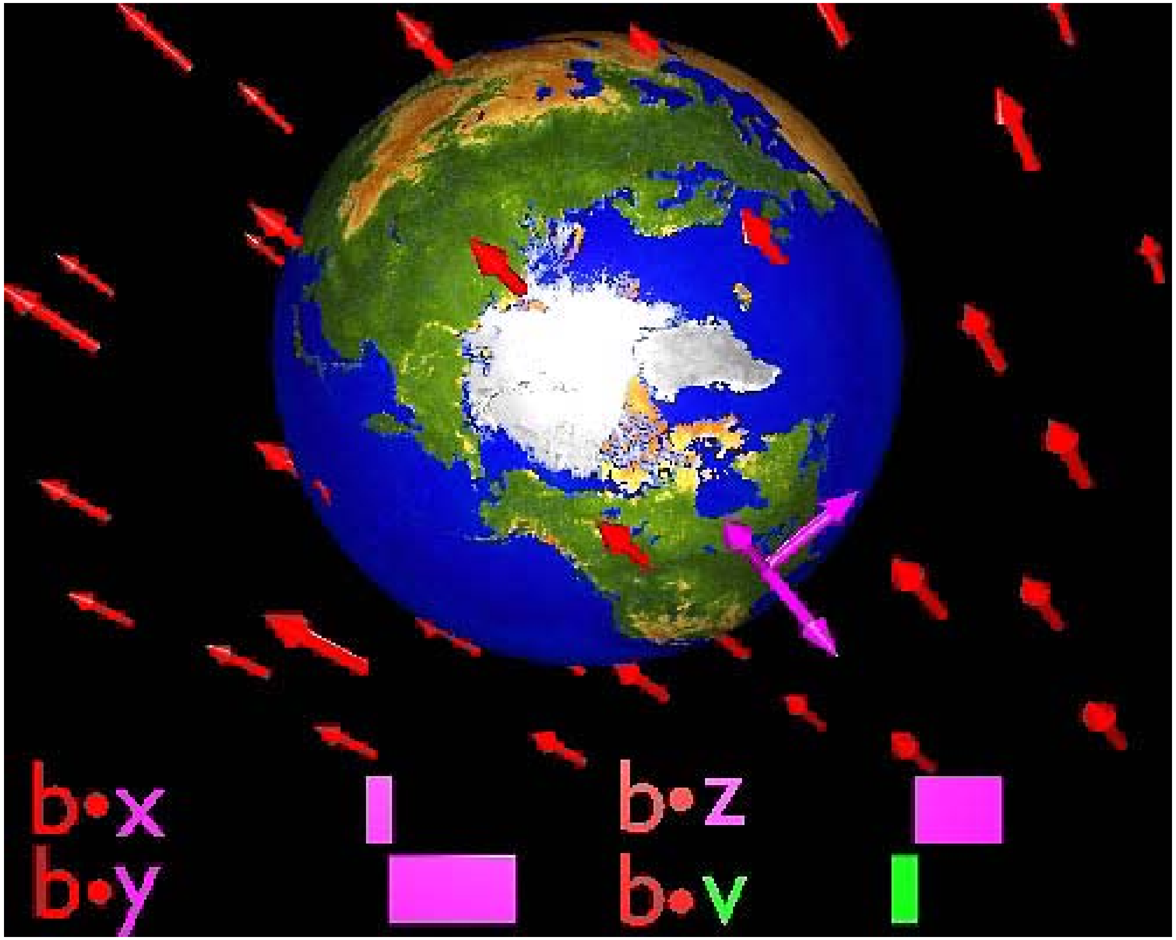
- SME
  - predictive
  - quantitative comparisons

- find
  - relativity violation
  - field of unknown origin eg. best existing bounds on spacetime torsion[1]

1) Kostelecký, Russell, Tasson PRL ’08

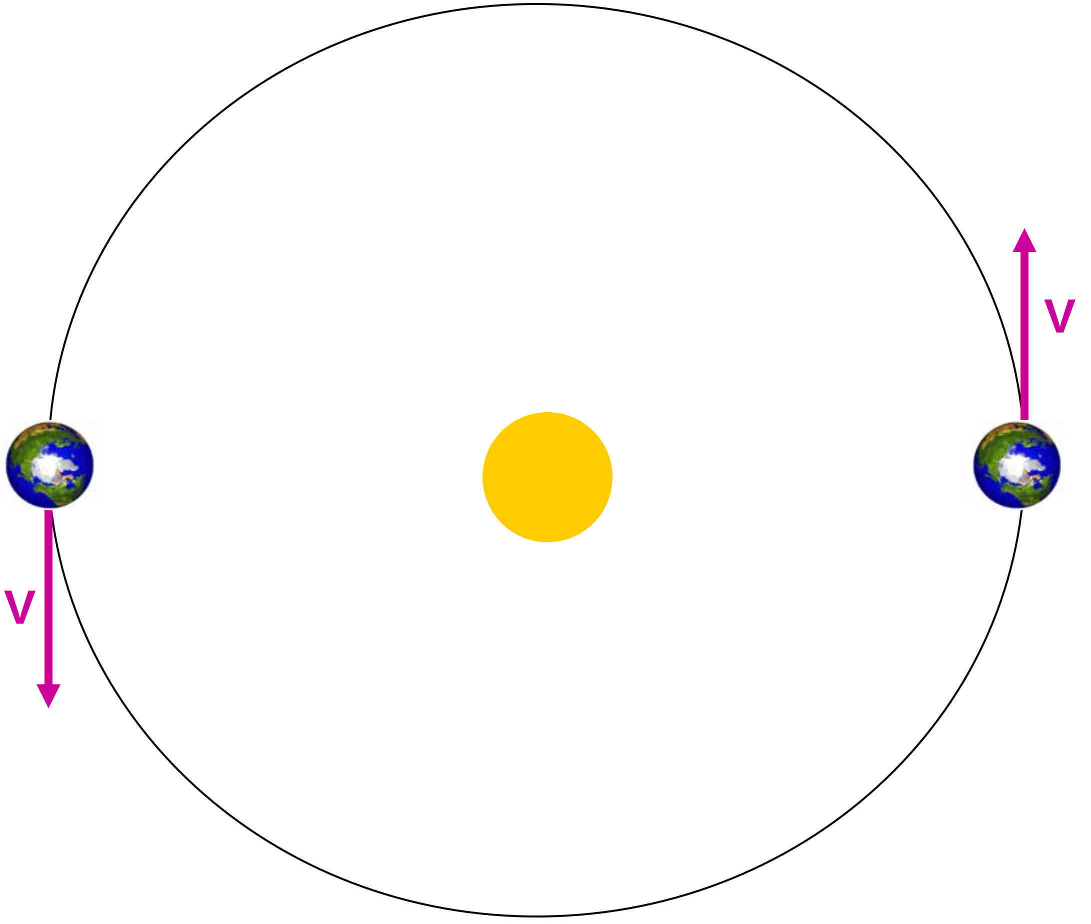
Earth rotation

- orientation & velocity of experiment constantly changes
- periodic at rotational (sidereal) period
- test relativity by comparing experimental results at an infinite number of orientations & velocities



Earth revolution

- velocity of experiment constantly changes
- annual periodicity
- test relativity by comparing experimental results at an infinite number of velocities

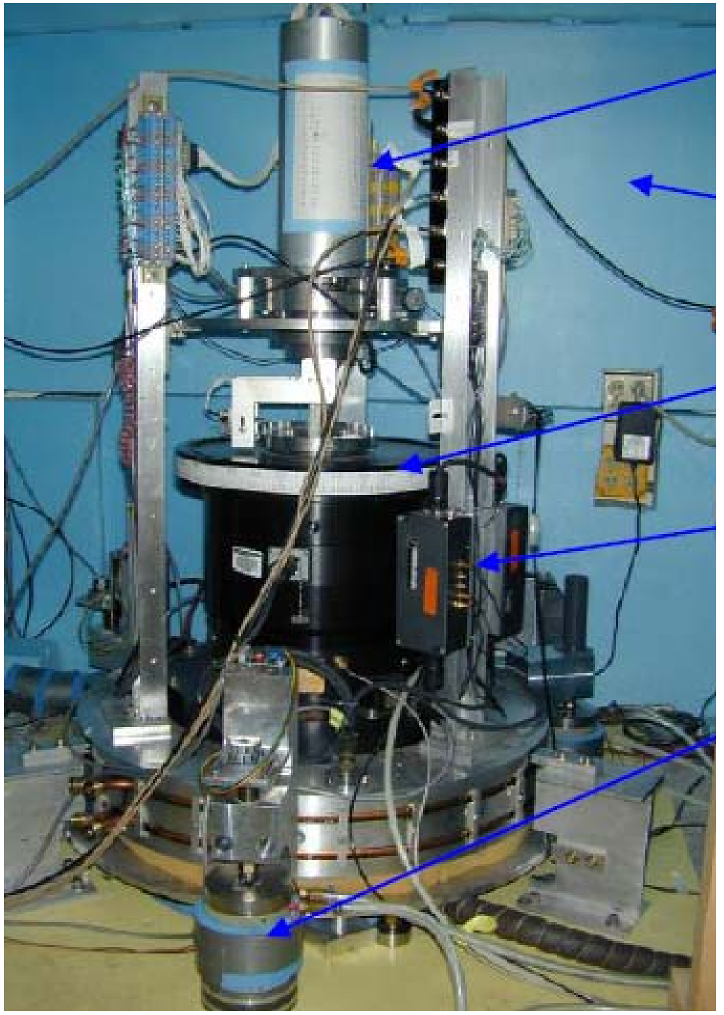


Turntable

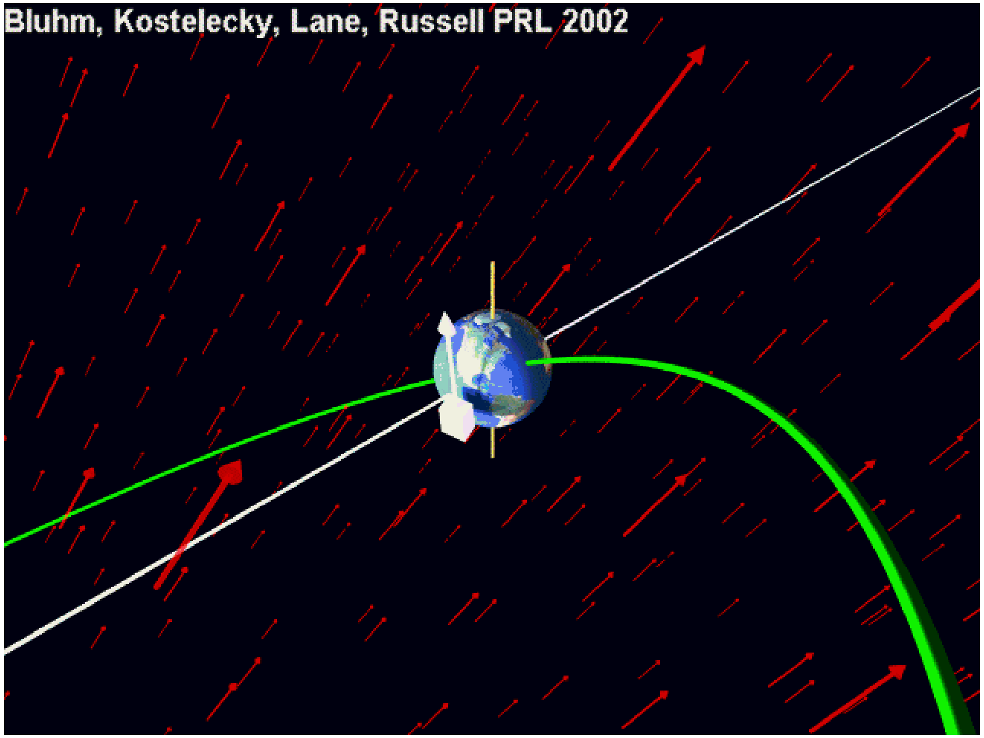
- variation in direction
  about an axis different from Earth

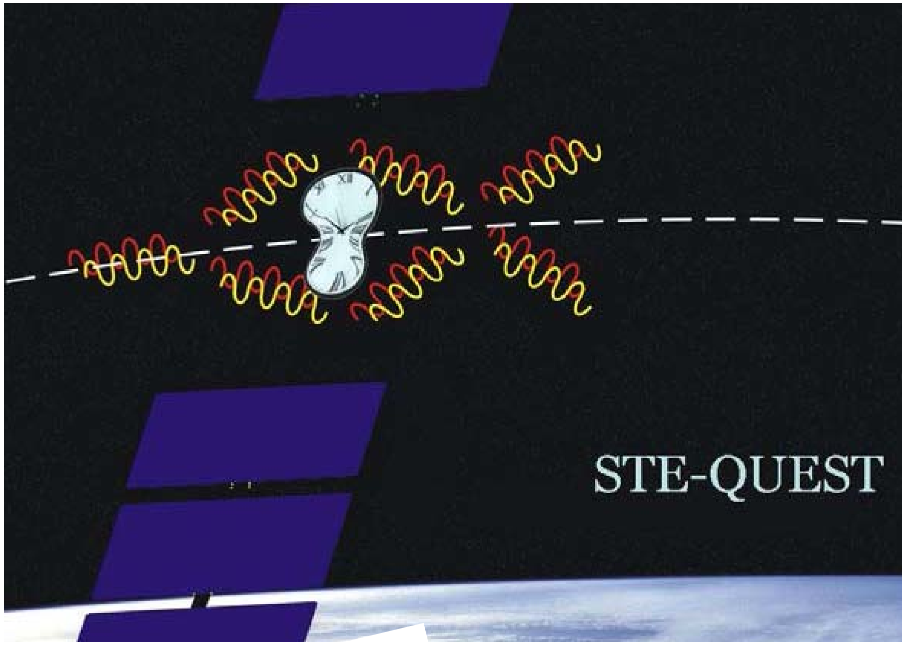
- additional sensitivities

- systematics



Satellite





- rapidly sample large space of Lorentz frames, higher boost, chosen directions
- STE-QUEST variable orbit – additional independent sensitivities
- additional advantages in the context of gravitational tests

clock comparisions

$$L_{\mathrm{LV}} = L_{\mathrm{fermion}} + L_{\mathrm{photon}} + L_{\mathrm{pure\,gravity}} + \ldots$$

tests:

- clock comparisons
- spin-polarized solids
- pulsar-timing observations
- particle traps
- neutrino oscillations
- muons

clock comparisions

$$L_{\mathrm{LV}} = L_{\mathrm{fermion}} + L$$

tests:

- clock comparisons
- spin-polarized solids
- pulsar-timing observ
- particle traps
- neutrino oscillations
- muons

Much experimental/observational work:

IceCube Collaboration, R. Abbasi et al., *Phys. Rev. D 82, 112003 (2010)* ; MiniBooNE Collaboration, T. Katori; MINOS Collaboration, P. Adamson et al., *Phys. Rev. Lett. 105, 151601 (2010)*; MINOS Collaboration, P. Adamson et al., *Phys. Rev. Lett. 101, 151601 (2008)*; LSND Collaboration, L.B. Auerbach et al., *Phys. Rev. D 72, 076004 (2005)* ; BNL *g-2* collaboration, G.W. Bennett et al., *Phys. Rev. Lett. 100, 091602 (2008);* V.W. Hughes et al., *Phys. Rev. Lett. 87, 111804 (2001);* BNL *g-2* collaboration, M. Deile et al.; H. Dehmelt et al., *Phys. Rev. Lett. 83, 4694 (1999)* ; R. Mittleman et al., *Phys. Rev. Lett. 83, 2166 (1999)*; G. Gabrielse et al., *Phys. Rev. Lett. 82, 3198 (1999).* ; B. Heckel et al., *Phys. Rev. D 78, 092006 (2008)* ; B. Heckel et al., *Phys. Rev. Lett. 97, 021603 (2006)* ; L.-S. Hou et al., *Phys. Rev. Lett. 90, 201101 (2003)* PRL server; B. Heckel et al., web manuscript. C. Gemmel et al., *Phys. Rev. D 82, 111901 (R) (2010)* ; K. Tullney et al., ; J.M. Brown et al., *Phys. Rev. Lett. 105, 151604 (2010)* ; I. Altarev et al., *Phys. Rev. Lett. 103, 081602 (2009)* ; T.W. Kornack, G. Vasilakis, and M. Romalis, in *CPT and Lorentz Symmetry IV, op. cit.*, p.206; P. Wolf et al., *Phys. Rev. Lett. 96, 060801 (2006)* ; P. Wolf et al., ; P. Wolf et al., ; F. Cane et al., *Phys. Rev. Lett. 93, 230801 (2004)* ; D.F. Phillips et al., *Phys. Rev. D 63, 111101 (2001)* ; M.A. Humphrey et al., *Phys. Rev. A 68, 063807 (2003)* ; D. Bear et al., *Phys. Rev. Lett. 85, 5038 (2000)* ; R. Walsworth et al., *AIP Conf. Proc. 539, 119 (2000)* ; L.R. Hunter et al., in *CPT*

sensitivities with ordinary matter

Coefficient	Electron	Proton	Neutron
$\tilde{b}_X$	10^{-31} GeV	10^{-31} GeV	10^{-32} GeV
$\tilde{b}_Y$	10^{-31} GeV	10^{-31} GeV	10^{-32} GeV
$\tilde{b}_Z$	10^{-29} GeV	–	–
$\tilde{b}_T$	10^{-26} GeV	–	10^{-26} GeV
$\tilde{b}^*_J$, $(J = X, Y, Z)$	10^{-22} GeV	–	–
$\tilde{c}_-$	10^{-18} GeV	10^{-24} GeV	10^{-28} GeV
$\tilde{c}_Q$	10^{-17} GeV	10^{-21} GeV	10^{-10} GeV
$\tilde{c}_X$	10^{-19} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{c}_Y$	10^{-19} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{c}_Z$	10^{-19} GeV	10^{-24} GeV	10^{-29} GeV
$\tilde{c}_{TX}$	10^{-18} GeV	10^{-20} GeV	–
$\tilde{c}_{TY}$	10^{-18} GeV	10^{-20} GeV	–
$\tilde{c}_{TZ}$	10^{-20} GeV	10^{-20} GeV	–
$\tilde{c}_{TT}$	10^{-18} GeV	10^{-11} GeV	10^{-11} GeV
$\tilde{d}_+$	10^{-27} GeV	–	10^{-27} GeV
$\tilde{d}_-$	10^{-26} GeV	–	10^{-26} GeV
$\tilde{d}_Q$	10^{-26} GeV	–	10^{-26} GeV
$\tilde{d}_{XY}$	10^{-26} GeV	–	10^{-27} GeV
$\tilde{d}_{YZ}$	10^{-26} GeV	–	10^{-26} GeV
$\tilde{d}_{ZX}$	10^{-26} GeV	–	–
$\tilde{d}_X$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{d}_Y$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{d}_Z$	10^{-19} GeV	–	–
$\tilde{H}_{XT}$	10^{-26} GeV	–	10^{-26} GeV
$\tilde{H}_{YT}$	10^{-26} GeV	–	10^{-26} GeV
$\tilde{H}_{ZT}$	10^{-26} GeV	–	10^{-27} GeV
$\tilde{g}_T$	10^{-27} GeV	–	10^{-27} GeV
$\tilde{g}_c$	10^{-26} GeV	–	10^{-27} GeV
$\tilde{g}_Q$	–	–	–
$\tilde{g}_-$	–	–	–
$\tilde{g}_{TJ}$, $(J = X, Y, Z)$	–	–	–
$\tilde{g}_{XY}$	10^{-17} GeV	–	–
$\tilde{g}_{YX}$	10^{-17} GeV	–	–
$\tilde{g}_{ZX}$	10^{-18} GeV	–	–
$\tilde{g}_{XZ}$	10^{-17} GeV	–	–
$\tilde{g}_{YZ}$	10^{-17} GeV	–	–
$\tilde{g}_{ZY}$	10^{-18} GeV	–	–
$\tilde{g}_{DX}$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{g}_{DY}$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{g}_{DZ}$	10^{-22} GeV	–	–

Data Tables for Lorentz and CPT violation
Kostelecký, Russell Rev. Mod. Phys '11
2013 edition arXiv:0801.0287v6

sensitivities with ordinary matter

Coefficient	Electron	Proton	Neutron
$\tilde{b}_X$	10^{-31} GeV	10^{-31} GeV	10^{-32} GeV
$\tilde{b}_Y$	10^{-31} GeV	10^{-31} GeV	10^{-32} GeV
$\tilde{b}_Z$	10^{-29} GeV		–
$\tilde{b}_T$	10^{-26} GeV		10^{-26} GeV
$\tilde{b}^*_J$, $(J = X, Y, Z)$	10^{-22} GeV	–	–
$\tilde{c}_{TZ}$	10^{-20} GeV	10^{-20} GeV	–
$\tilde{c}_{TT}$	10^{-18} GeV	10^{-11} GeV	10^{-11} GeV
$\tilde{d}_+$	10^{-27} GeV		10^{-27} GeV
$\tilde{d}_-$	10^{-26} GeV		10^{-26} GeV
$\tilde{d}_Q$	10^{-26} GeV		10^{-26} GeV
$\tilde{d}_{XY}$	10^{-26} GeV		10^{-27} GeV
$\tilde{d}_{YZ}$	10^{-26} GeV		10^{-26} GeV
$\tilde{d}_{ZX}$	10^{-26} GeV		–
$\tilde{d}_X$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{d}_Y$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{d}_Z$	10^{-19} GeV		–
$\tilde{H}_{XT}$	10^{-26} GeV		10^{-26} GeV
$\tilde{H}_{YT}$	10^{-26} GeV		10^{-26} GeV
$\tilde{H}_{ZT}$	10^{-26} GeV		10^{-27} GeV
$\tilde{g}_T$	10^{-27} GeV	–	10^{-27} GeV
$\tilde{g}_c$	10^{-26} GeV		10^{-27} GeV
$\tilde{g}_Q$	–	–	–
$\tilde{g}_-$	–	–	–
$(J = X, Y, Z)$	–	–	–
$\tilde{g}_{XY}$	10^{-17} GeV		–
$\tilde{g}_{YX}$	10^{-17} GeV		–
$\tilde{g}_{ZX}$	10^{-18} GeV		–
$\tilde{g}_{XZ}$	10^{-17} GeV		–
$\tilde{g}_{YZ}$	10^{-17} GeV		–
$\tilde{g}_{ZY}$	10^{-18} GeV		–
$\tilde{g}_{DX}$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{g}_{DY}$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{g}_{DZ}$	10^{-22} GeV		–

- **1^{st} – ever measurements possible in STE-QUEST clock test**
- **numerous other competitive measurements**
- **10^{-21} to 10^{-28} level sensitivities**

Data Tables for Lorentz and CPT violation
Kostelecký, Russell Rev. Mod. Phys '11
2013 edition arXiv:0801.0287v6

path to atomic experiment analysis

L_{fermion} expand to desired order in LV

↓ field redefinition

L'_{fermion}

↓ Euler-Lagrange eq.

$H_{\text{Relativistic}}$ ⟶ relativistic quantum experiments

↓ Foldy-Wouthuysen expansion

H_{NonRel} ⟶ non-relativistic quantum experiments

$$H_{\text{nonrel}} = \ldots + b_j \sigma^j + m(-c_{jk} - \tfrac{1}{2} c_{00} \delta_{jk}) \frac{p_j p_k}{m^2} + \ldots$$

spin

periodic energy level perturbations!

periodic energy level perturbations

$$< F, m_F | H_{\text{nonrel}} | F, m_F > = \ldots + \frac{m_F}{F} \sin\chi \sum_w \beta_w b_Y^w \sin\omega t + \ldots$$

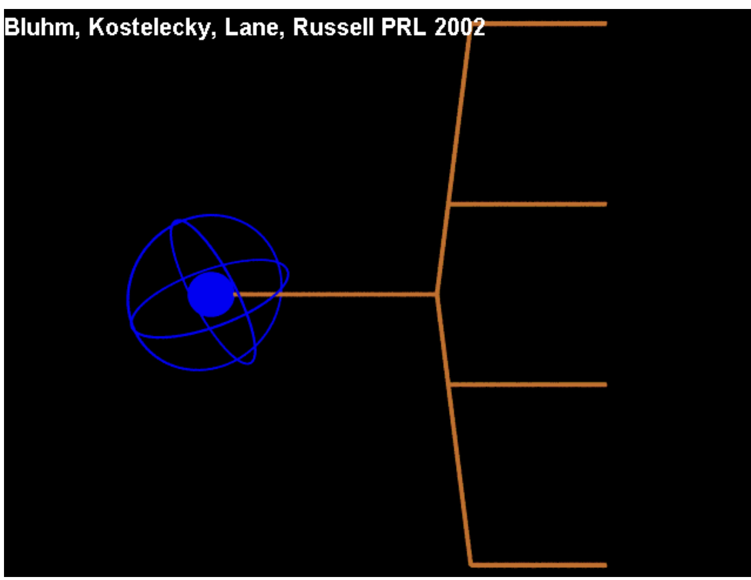
total angular momentum

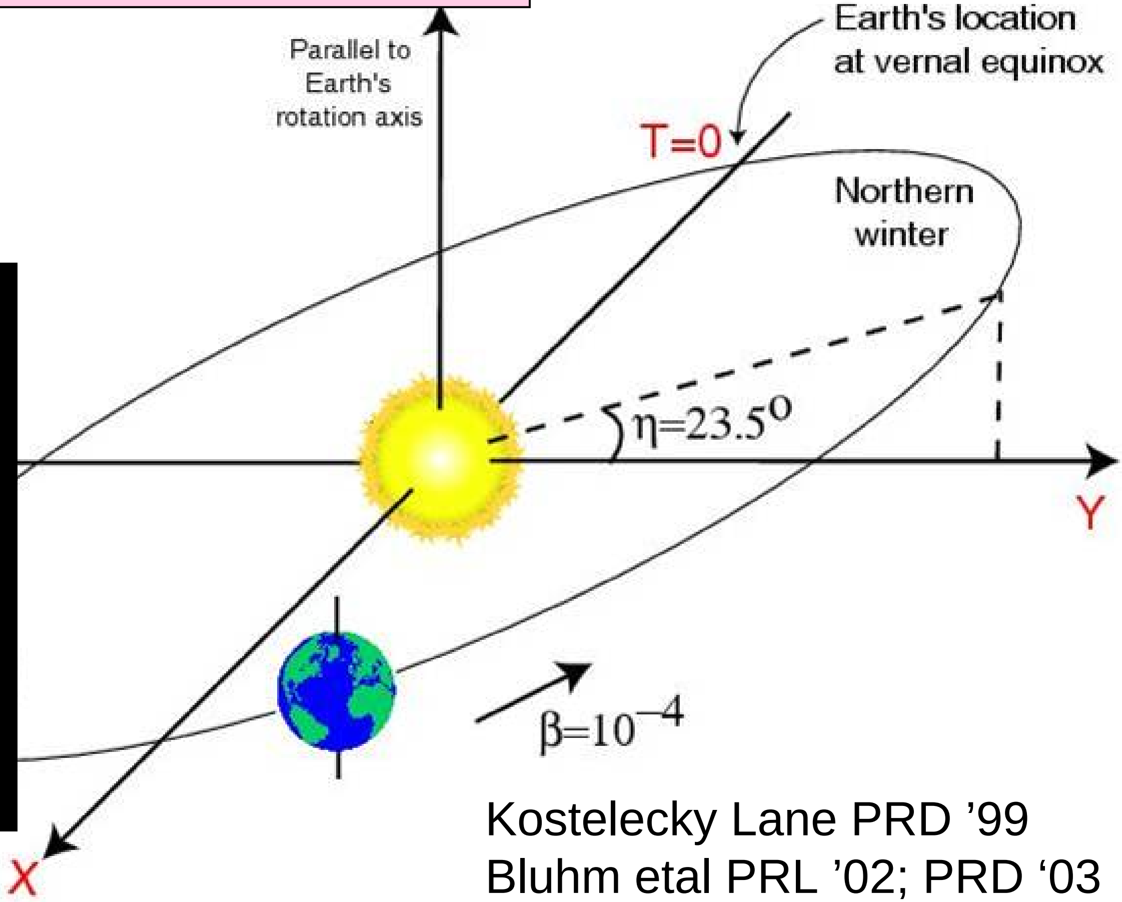
$$\beta_w := -\sum_{N=1}^{N_w} \langle [\sigma^3]_{w,N} \rangle$$

sum over N particles of species w

rotation frequency

Schmidt model:
primary proton secondary electron sensitivity





Kostelecky Lane PRD ’99
Bluhm etal PRL ’02; PRD ‘03

sensitivities with ordinary matter

Coefficient	Electron	Proton	Neutron
$\tilde{b}_X$	10^{-31} GeV	10^{-31} GeV	10^{-32} GeV
$\tilde{b}_Y$	10^{-31} GeV	10^{-31} GeV	10^{-32} GeV
$\tilde{b}_Z$	10^{-29} GeV		–
$\tilde{b}_T$	10^{-26} GeV		10^{-26} GeV
$\tilde{b}^*_J$, $(J = X, Y, Z)$	10^{-22} GeV	–	–
$\tilde{d}_+$	10^{-27} GeV		10^{-27} GeV
$\tilde{d}_-$	10^{-26} GeV		10^{-26} GeV
$\tilde{d}_Q$	10^{-26} GeV		10^{-26} GeV
$\tilde{d}_{XY}$	10^{-26} GeV		10^{-27} GeV
$\tilde{d}_{YZ}$	10^{-26} GeV		10^{-26} GeV
$\tilde{d}_{ZX}$	10^{-26} GeV		–
$\tilde{d}_X$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{d}_Y$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{d}_Z$	10^{-19} GeV		–
$\tilde{H}_{XT}$	10^{-26} GeV		10^{-26} GeV
$\tilde{H}_{YT}$	10^{-26} GeV		10^{-26} GeV
$\tilde{H}_{ZT}$	10^{-26} GeV		10^{-27} GeV
$\tilde{g}_T$	10^{-27} GeV	–	10^{-27} GeV
$\tilde{g}_c$	10^{-26} GeV		10^{-27} GeV
$\tilde{g}_Q$	–	–	–
$\tilde{g}_-$	–	–	–
$(J = X, Y, Z)$	–	–	–
$\tilde{g}_{XY}$	10^{-17} GeV		–
$\tilde{g}_{YX}$	10^{-17} GeV		–
$\tilde{g}_{ZX}$	10^{-18} GeV		–
$\tilde{g}_{XZ}$	10^{-17} GeV		–
$\tilde{g}_{YZ}$	10^{-17} GeV		–
$\tilde{g}_{ZY}$	10^{-18} GeV		–
$\tilde{g}_{DX}$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{g}_{DY}$	10^{-22} GeV	10^{-25} GeV	10^{-28} GeV
$\tilde{g}_{DZ}$	10^{-22} GeV		–

- **1^{st} – ever measurements possible in STE-QUEST clock test**
- **numerous other competitive measurements**
- **10^{-21} to 10^{-28} level sensitivities**
- **25 independent combinations**

Data Tables for Lorentz and CPT violation
Kostelecký, Russell Rev. Mod. Phys '11
2013 edition arXiv:0801.0287v6

WEP tests

$$L_{\mathrm{LV}} = L_{\mathrm{fermion}} + L_{\mathrm{photon}} + L_{\mathrm{pure\,gravity}} + \ldots$$

gravitational couplings

tests:

- lab tests
  - gravimeter
  - Weak Equivalence P. (WEP)
- space-based WEP
- exotic tests
  - charged matter
  - antimatter
  - higher-generation matter
- solar-system tests
  - laser ranging
  - perihelion precession
- light-travel/clock tests
  - time delay
  - Doppler shift
  - red shift
- ...

Kostelecky Tasson PRL ’09; PRD ‘11

WEP tests

place constraints on coefficients unobservable in flat spacetime

Coefficient	Electron	Proton	Neutron
$\alpha\bar{a}_T$	10^{-11} GeV	10^{-11} GeV	10^{-11} GeV
$\alpha\bar{a}_X$	10^{-6} GeV	10^{-6} GeV	10^{-5} GeV
$\alpha\bar{a}_Y$	10^{-5} GeV	10^{-5} GeV	10^{-4} GeV
$\alpha\bar{a}_Z$	10^{-5} GeV	10^{-5} GeV	10^{-4} GeV
$\alpha\bar{e}_T$	10^{-8}	10^{-11}	10^{-11}
$\alpha\bar{e}_X$	10^{-3}	10^{-6}	10^{-5}
$\alpha\bar{e}_Y$	10^{-2}	10^{-5}	10^{-4}
$\alpha\bar{e}_Z$	10^{-2}	10^{-5}	10^{-4}

* few independent constraints

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2013 edition arXiv:0801.0287v6

WEP tests

place constraints on coefficients unobservable in flat spacetime

Coefficient	Electron	Proton	Neutron
$\alpha\bar{a}_T$	10^{-11} GeV	10^{-11} GeV	10^{-11} GeV
$\alpha\bar{a}_X$	10^{-6} GeV	10^{-6} GeV	10^{-5} GeV
$\alpha\bar{a}_Y$	10^{-5} GeV	10^{-5} GeV	10^{-4} GeV
$\alpha\bar{a}_Z$	10^{-5} GeV	10^{-5} GeV	10^{-4} GeV
$\alpha\bar{e}_T$	10^{-8}	10^{-11}	10^{-11}
$\alpha\bar{e}_X$	10^{-3}	10^{-6}	10^{-5}
$\alpha\bar{e}_Y$	10^{-2}	10^{-5}	10^{-4}
$\alpha\bar{e}_Z$	10^{-2}	10^{-5}	10^{-4}

- extend range to 10^{-10} to 10^{-14}
- 3 – 5 order of magnitude improvement
- many more independent sensitivities

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Kostelecký, Russell Rev. Mod. Phys '11
2013 edition arXiv:0801.0287v6

path to experimental analysis

L_{fermion} expand to desired order in LV and gravity

$\downarrow$ field redefinition

L'_{fermion}

$\downarrow$ Euler-Lagrange eq.

$H_{\text{Relativistic}} \longrightarrow$ relativistic quantum experiments

$\downarrow$ Foldy-Wouthuysen expansion

$H_{\text{NonRel}} \longrightarrow$ non-relativistic quantum experiments

$\downarrow$ inspection

$L_{\text{Classical}}$

$\downarrow$ variation

non-relativistic quantum experiments
classical experiments

$\ddot{x}^{\mu}$

classical results

$$U = \frac{2Gm}{r}\left(1+\overline{c}^{\rm S}_{00}+\frac{2}{m}(\overline{a}^{\rm S}_{\rm eff})_0\right) + \ldots$$

$$\ddot{x}^j = -\tfrac{1}{2}\partial^j U+(\overline{c}^{\rm T})^j{}_k\partial^k U + \frac{1}{m^{\rm T}}\alpha(\overline{a}^{\rm T}_{\rm eff})_0\partial^j U + \ldots$$

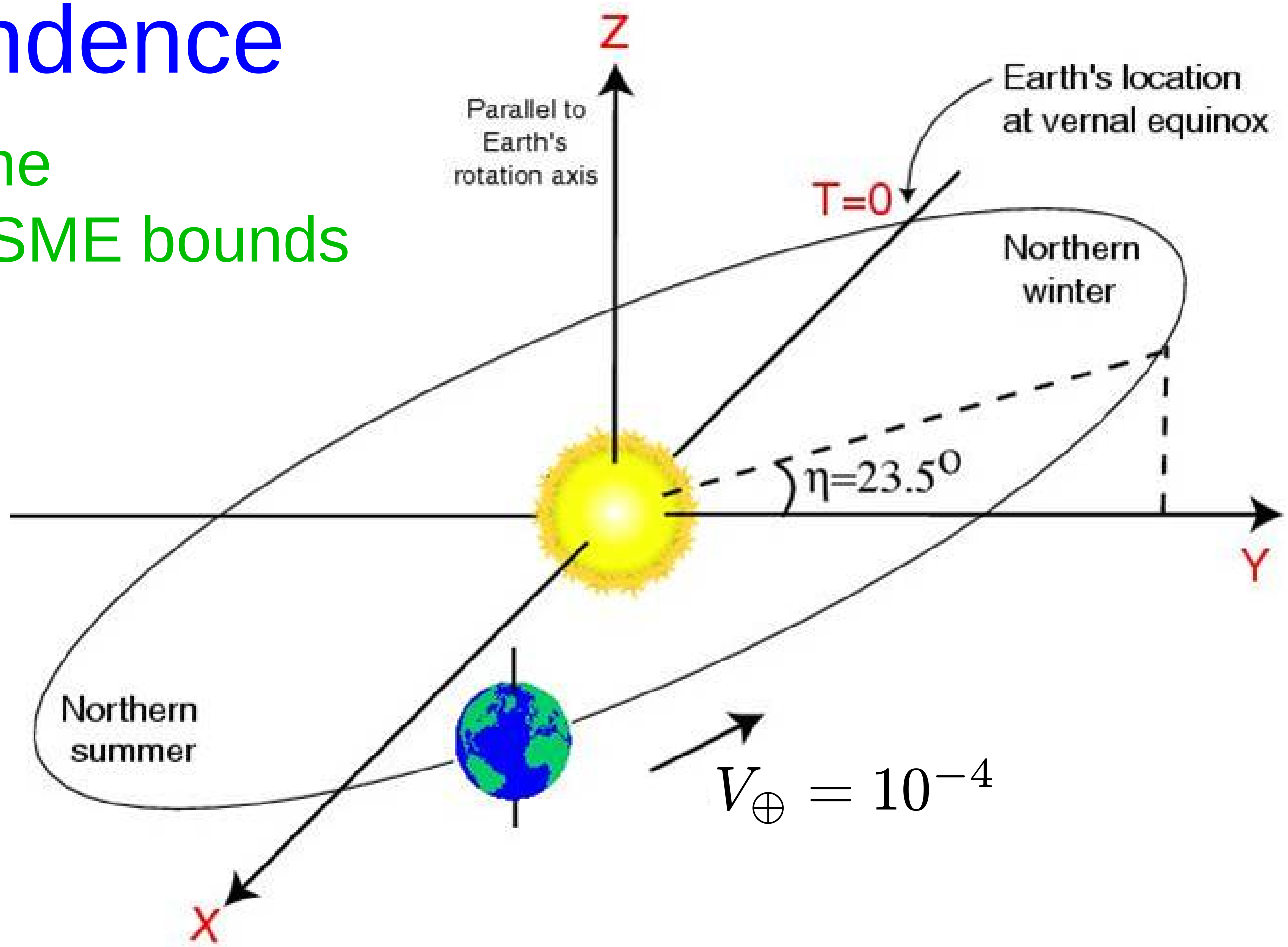
S and T denote
composite coefficients
for source and test respectively

$$\boxed{(a_{\rm eff})_\mu = a_\mu - m e_\mu}$$

- modified metric & particle equation of motion
- experimental hooks
  - particle-species dependence
  - time dependence

time dependence

- standard frame
  for reporting SME bounds



- boost and rotation of test $\longrightarrow$ annual & sidereal variations

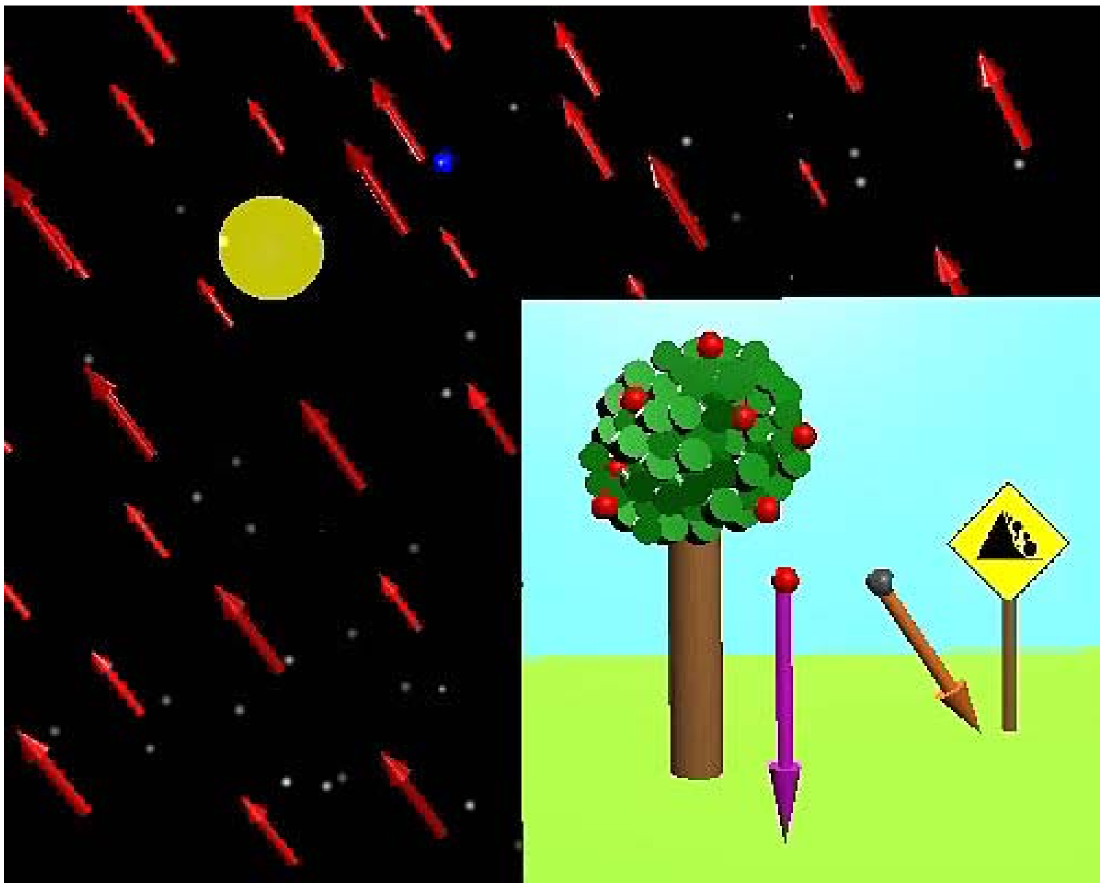
$$\ddot{\vec{x}} \supset -2g\ \alpha\bar{a}_T\hat{z} - 2gV_\oplus\ \alpha\bar{a}_X\sin(\Omega T)\hat{z}$$
$$-\tfrac{2}{5}gV_L\ \alpha\bar{a}_X\sin(\omega T+\psi)\hat{y}$$

lab tests

acceleration of a test particle T

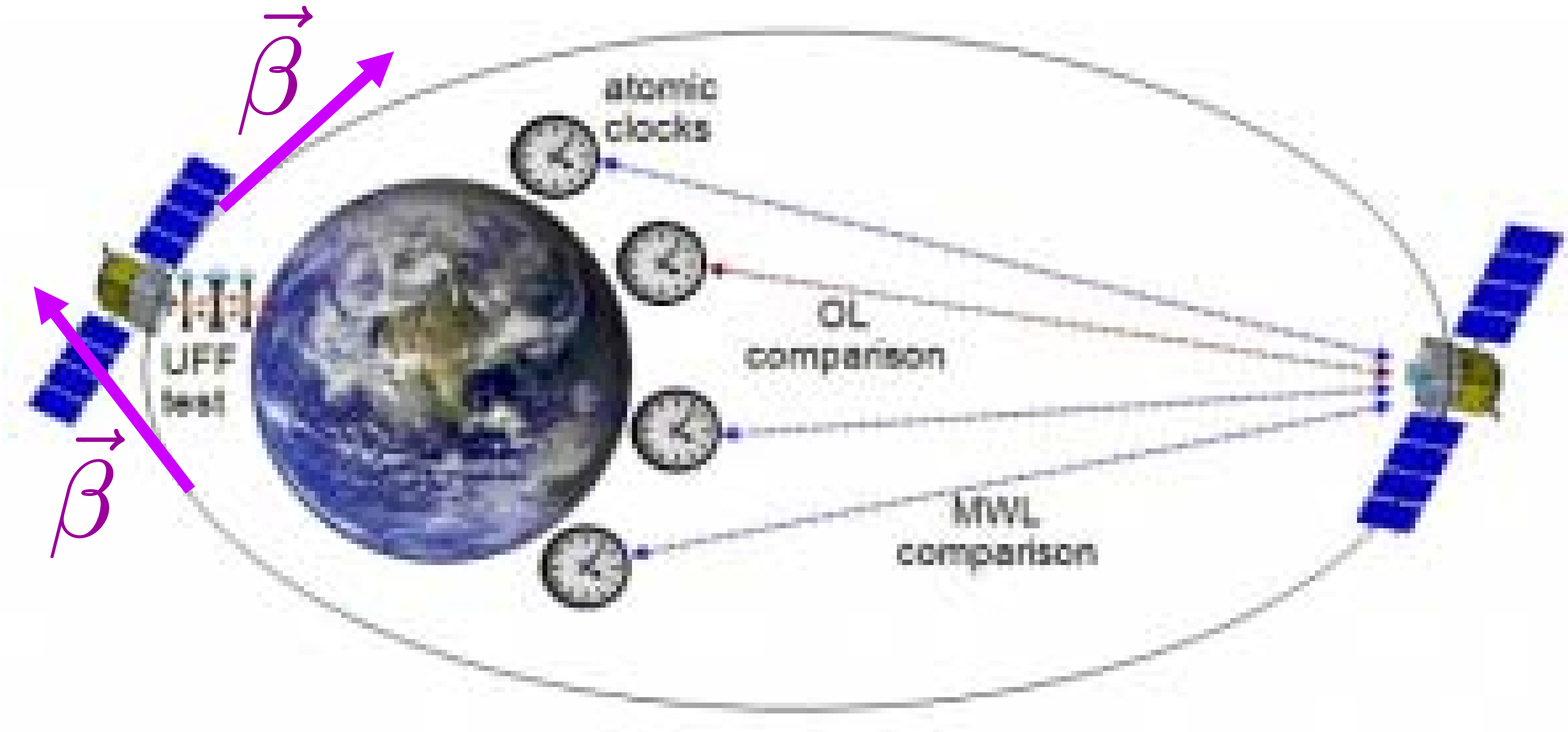
$$\ddot{\vec{x}} \supset -2\frac{1}{m} g V_{\oplus}\, \alpha(\overline{a}^{\mathrm{T}}_{\mathrm{eff}})_X \sin(\Omega T)\hat{z} + g V_{\oplus} (\overline{c}^{\mathrm{T}})_{TX} \sin 2\chi \sin(\Omega T)\hat{x}$$

boost variation frequency



- monitor acceleration of one particle over time $\longrightarrow$ gravimeter
- monitor relative behavior of particles $\longrightarrow$ WEP (Weak Equivalence Principle) test
- frequency and phase distinguish from other effects

STE-QUEST



- improved overall WEP sensitivity
- more independent measurements via sampling of many frames

WEP tests

place constraints on coefficients unobservable in flat spacetime

Coefficient	Electron	Proton	Neutron
$\alpha\bar{a}_T$	10^{-11} GeV	10^{-11} GeV	10^{-11} GeV
$\alpha\bar{a}_X$	10^{-6} GeV	10^{-6} GeV	10^{-5} GeV
$\alpha\bar{a}_Y$	10^{-5} GeV	10^{-5} GeV	10^{-4} GeV
$\alpha\bar{a}_Z$	10^{-5} GeV	10^{-5} GeV	10^{-4} GeV
$\alpha\bar{e}_T$	10^{-8}	10^{-11}	10^{-11}
$\alpha\bar{e}_X$	10^{-3}	10^{-6}	10^{-5}
$\alpha\bar{e}_Y$	10^{-2}	10^{-5}	10^{-4}
$\alpha\bar{e}_Z$	10^{-2}	10^{-5}	10^{-4}

- extend range to 10^{-10} to 10^{-14}
- 3 – 5 order of magnitude improvement
- many more independent sensitivities

Data Tables for Lorentz and CPT violation
Kostelecký, Russell Rev. Mod. Phys '11
2013 edition arXiv:0801.0287v6

additional possibilities

$$L_{\mathrm{LV}} = L_{\text{fermion}} + L_{\text{pure gravity}} + \ldots$$

gravitational couplings

- red-shift tests
- orbital tests

Kostelecky Bailey PRD '06
Bailey PRD '09
Kostelecky Tasson PRL '09; PRD '11

Gravitomagnetic effect on intrinsic spin

$$\vec{b} \leftrightarrow \frac{G}{r^3}\vec{J}_{\oplus}$$

Tasson PRD '12

$$L_{\mathrm{LV}} = L_{\text{minimal}} + \underbrace{L_5 + L_6 + L_7 + \ldots}_{\text{large space for new searches}}$$

existing tests

Kostelecky Mewes PRD '12

Summary

- STE-QUEST can probe Planck-scale physics via Lorentz symmetry tests

- sensitivities to large classes of presently uninvestigated coefficients can be attained

- significant sensitivities can be achieved via both clock-comparison tests and WEP tests that have qualitatively unique signatures

- sampling many Lorentz frames is an advantage of STE-QUEST in obtaining a maximum number of independent sensitivities to Lorentz violation