Title: Quantum Geometry Phenomenology: A Discrete Machian Model

Date: Oct 31, 2004 09:00 AM

URL: http://pirsa.org/04100044

Abstract:

Work in Progress

A Discrete Machian Model

Hypothesen sind Netze, nur der wird fangen der auswirft

-Novalis

Seth Major

Quantum Gravity in the Americas
Perimeter Institute
31 October 2004

A Discrete Machian Model

- Motivation:
  - Quantum Geometry Phenomenology, MDR
  - Discrete Spatial Geometry
- Assumptions
- Discrete Machian Model
- Constraining parameters with tests of LLI

Quantum Geometry Phenomenology

Can it be done?

- Modified dispersion relations (MDR) [Coleman,Glashow; Amelino-Camelia; Jacobson, Liberati, Mattingly; Alfaro, Morales-Tecotl, Urrutia; Myers,Pospelov; Konopka, SM, ...]

$$E_{\pm}^2 = p^2 + m^2 + \kappa_{\pm}\ell_P\, p^3$$

- Seperate parameters for photons, fermions, and hadrons.
- Particle threshold kinematics is highly sensitive to cubic terms.
- Current astrophysical observation severely constrain modifications.

Status of MDR 2004

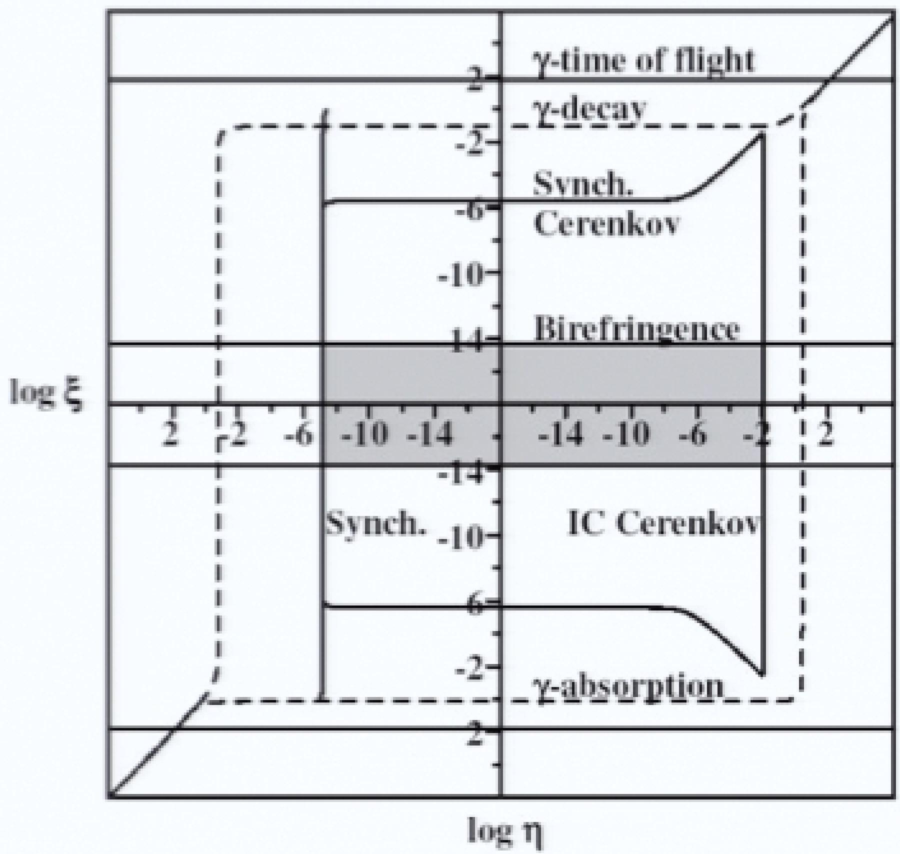
- Myers & Pospelov: Effective field theory framework → 3 parameters for QED - helicities independent

- Jacobson, Liberati, Mattingly, Stecker: Spectacular new constraints from synchotron radiation in SN remnants and polarization dependent dispersion from gamma ray burst GRB021206

- Collins, Perez, Sudarsky: A fine tuning problem → theoretical framework is sketchy

- Amelino-Camelia: Wait, wait! Should we be using *field theory at all* for QG phenomenology?

Status of MDR 2004

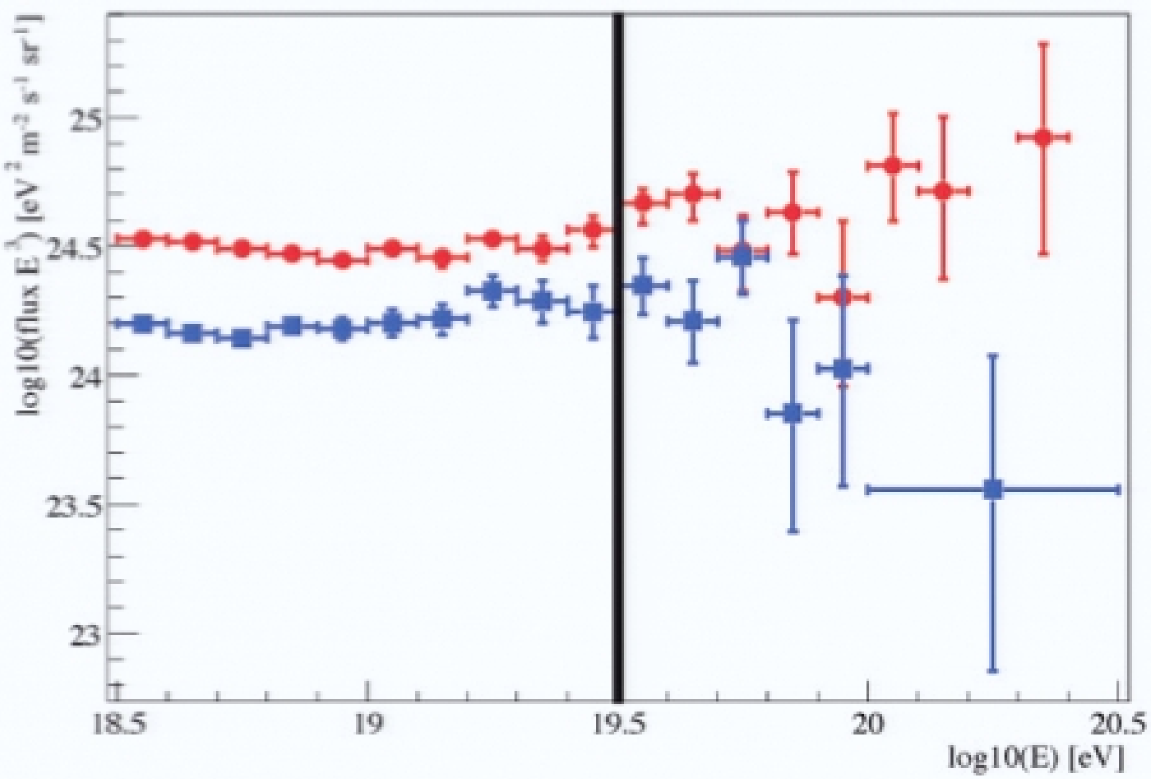


Allowed region is shaded

JLM arXiv:astro-ph/0309681

Is the GZK cutoff observed?

De Marco *et. al.* see no cutoff at a 2.5 σ level !



AGASA and HiRes Data

arXiv: astro-ph/0301497

Quantum Geometry Phenomenology

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6-a

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What about spatial geometry?

What about "breaking" rotational invariance?

No natural scale for onset of discreteness.

6-b

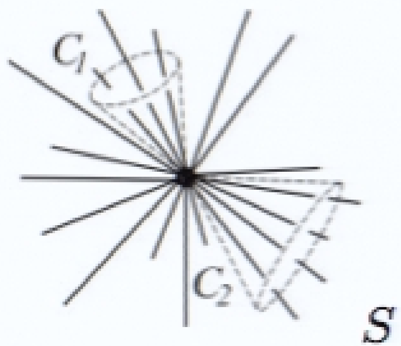
Discrete spectra for Geometry

Area*: $\hat{A}_S \mid s\rangle = a \mid s\rangle$

$$a = \ell_{eff}^2 \sum_{n=1}^{N} \sqrt{j_n(j_n+1)}$$

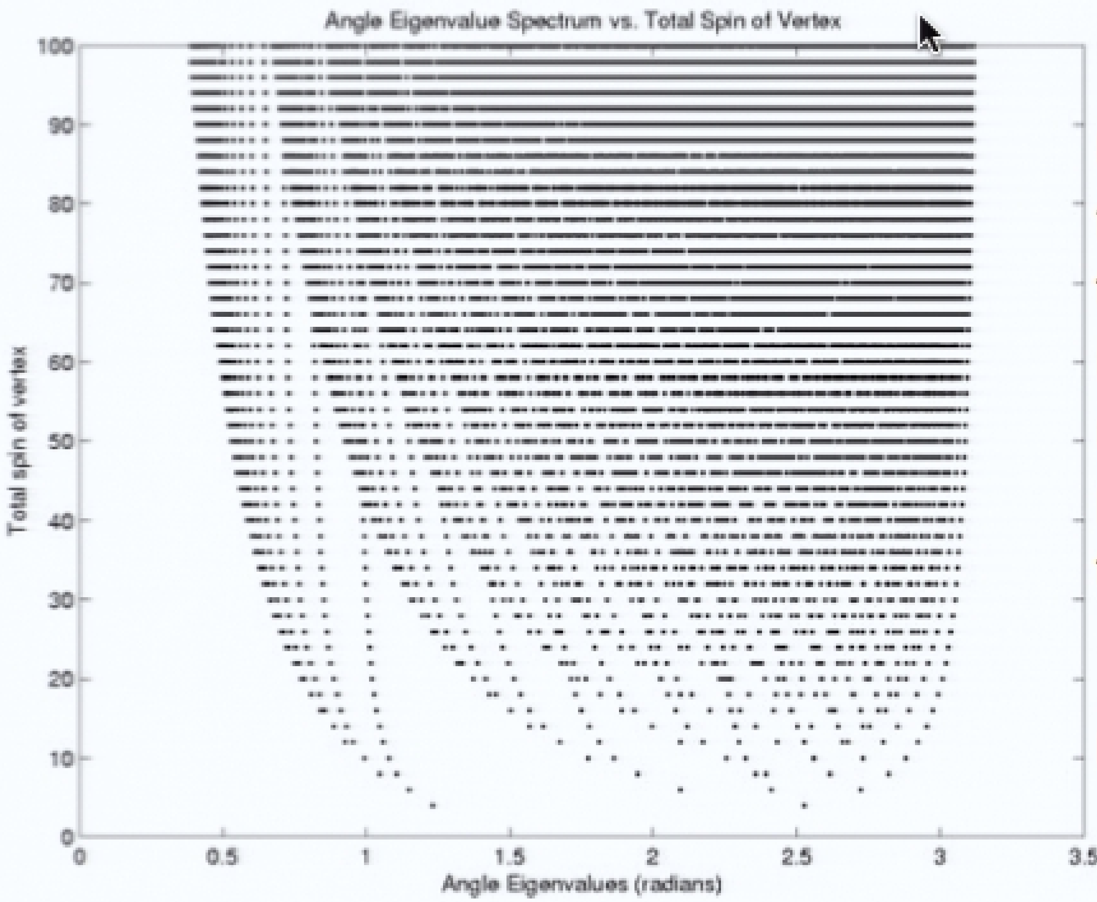
Angle†: $\hat{\theta} \mid s\rangle = \theta \mid s\rangle$

$$\theta = \arccos\left(\frac{j_r(j_r+1) - j_1(j_1+1) - j_2(j_2+1)}{2\left[j_1(j_1+1)\, j_2(j_2+1)\right]^{1/2}}\right)$$



*Rovelli,Smolin NPB **422** (1995) 593; Asktekar,Lewandowski CQG **14** (1997) A43

Discrete spectra for Geometry



Unless the graph is highly floculent, the angle spectrum is coarse. OV studies suggest that continuum angles are only approximated for total vertex spins of

$$j \sim 10^{20} \,!$$

[SM, Siefert CQG **19** (2002) 2211]

A Discrete Machian Model

Model based on two assumptions:

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9-a

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(ii) Inertial mass is determined by the total distribution of matter

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A Discrete Machian Model

Cocconi-Salpeter (1958): Non-uniformities in matter distribution lead to **anisotropy of mass** $m \mapsto m_{ij}$.

Quantitative form of Mach's principle:

$$m_{ij} \propto \frac{M(r)}{r^\nu}$$

$$m_{ij} \propto f(\theta)$$

θ between acceleration/velocity and preferred direction.

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Idea: As an experiment rotates with the Earth look for sidereal variations in the structure of Zeeman transitions. A short calculation shows

$$\Delta E = \frac{\Delta m}{m} \bar{T} \langle P_2(\cos\theta) \rangle$$

Not all transitions are affected, $\langle P_2 \rangle_{J=0} = 0$, so one transition can act as a reference.

A Discrete Machian Model

- Non-uniformities in matter variations cause deviations from isotropy

$\rightsquigarrow$ there is a local preferred direction

- Discrete random geometry cannot support a continuously changing angle
- If all deviations are equally likely, and the path does not depend on history, then "the preferred direction" performs a random walk

$\rightsquigarrow$ Diffusion on the space of directions

There is a local, stochastic preferred direction $\hat{n}(t)$.

A Discrete Machian Model

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Suggests looking for a generalized Dirac equation (Lämmerzahl CQG 15 (1998) 13). In the non-relativistic limit

$$H\varphi = -\frac{1}{2m}\left(\delta^{ij} + \frac{\delta m^{ij}(t)}{m} + \frac{\delta \bar{m}^{ij}_k(t)}{m}\sigma^k\right)\nabla_i\nabla_j\varphi - A^i_j\sigma^j\nabla_i\varphi$$
$$+\frac{e}{2m}F^{ij}\left(K^k\epsilon_{ijk} + K_{ijk}\sigma^k\right)\varphi$$

12-a

A Discrete Machian Model

Parameters of the model:

Scale of the anomalous mass tensor

$$\frac{\delta m_{ij}}{m} = \alpha \frac{M_{\text{non-uni}}}{r^{\nu}}$$

Diffusion constant:

$$\sigma = \frac{\delta^2}{4\Delta t}$$

δ is the angular scale and Δt is the time scale of the random walk

Can tests of local Lorentz invariance constrain the shape and scale of the discreteness?

Tests of LLI

- **Hughes-Drever Experiments**

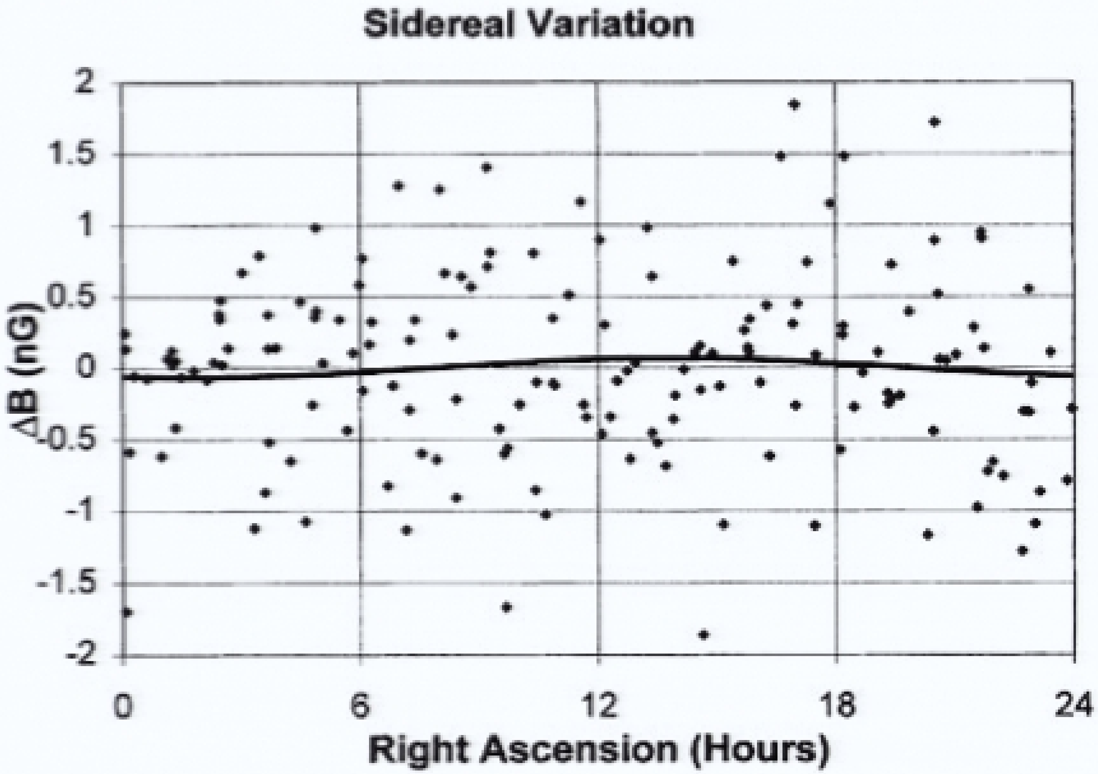
- Search for Lorentz-violating Zeeman frequency shifts
- Some of the most precise null experiments ever performed.
- No sidereal variation have been observed.

- Modern versions: co-located magnetometers track relative phases and Larmor frequencies. Recent results show

$$\frac{\delta m}{m} \leq 10^{-23}$$

Tests of LLI

Example data: Variation in **B** as function of sidereal day



From Berglund *et.al.* PRL 75 (1995) 1879.

Summary: A Discrete Machian Model

- Three parameters α, σ, ν
- Previous tests of LLI constrain parameters e.g. $\alpha \leq 10^{-23}$

To do:

- Relation to (generalized) Standard Model Extension (Kostelecky et. al.)
- Measurement schemes for discreteness scale, δ, and shape.
- ...