

Physical and Logical Basis for Pauli Exclusion and
Spin-Statistics Connection
(Cosmic Gravity and the Quantum Spin)

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(Expts. on Gravity, Casimir force. BEC and ultra-cold atoms)

All our fundamental theories of the physics were completed well before we acquired ANY significant knowledge about the physical universe, its content and its long term evolution.

In particular, the theories of relativistic kinematics and dynamics as well as the theory of gravity were developed, starting with a theory of motion in EMPTY space, before we knew anything about the universe and its matter content.

– A reconsideration becomes essential.

Careful and rigorous examination of experimental evidence points to necessity to modify present theoretical framework that does not include the gravity of the universe in local physics.

An unavoidable logical point:

All our theories are constructed and TESTED in the background gravity of the entire matter in the universe. There are no experimental tests in the absence of this cosmic gravity, and there will not be any that can avoid it. Therefore, ALL theories have to incorporate this EVER-PRESENT gravitational background a priori. If not, these theories could be wrong or incomplete.

The present situation is that NO theory of physics incorporate this background a priori!

COSMIC RELATIVITY

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gr-qc//0406043

A well-known conflict between QFT and Cosmology

Energy density of QUANTUM VACUUM

Energy density

$$E/V \simeq \frac{4\pi}{hc^3} \int_0^{h\nu_c} E^3 dE$$

With Planck energy cut-off (10^{19} GeV) $> 10^{92}$ g/cm³

With a cut-off of 20 eV $> 10^{-14}$ g/cm³

Observations (cosmology, astrophysics):

Average cosmic density $< 10^{-29}$ g/cm³

COSMOLOGICAL CONSTANT PROBLEM

Quantum Field Theories are INCOMPLETE –
something seriously wrong at the foundations

There is very little, if any, energy density in the Vacuum of the
Quantum Fields

Most proofs of spin-statistics connection are related to the construction of an infinity-free field theory. Even if they are valid as consistency arguments, they do not give a **reason** for the connection, and certainly do not help in ‘understanding’ the connection.

The underlying theory is certainly inconsistent with cosmology

Any theory that assumes a Minkowski (empty) background metric and invariance under Lorentz transformation is inconsistent with cosmology, by direct observation.

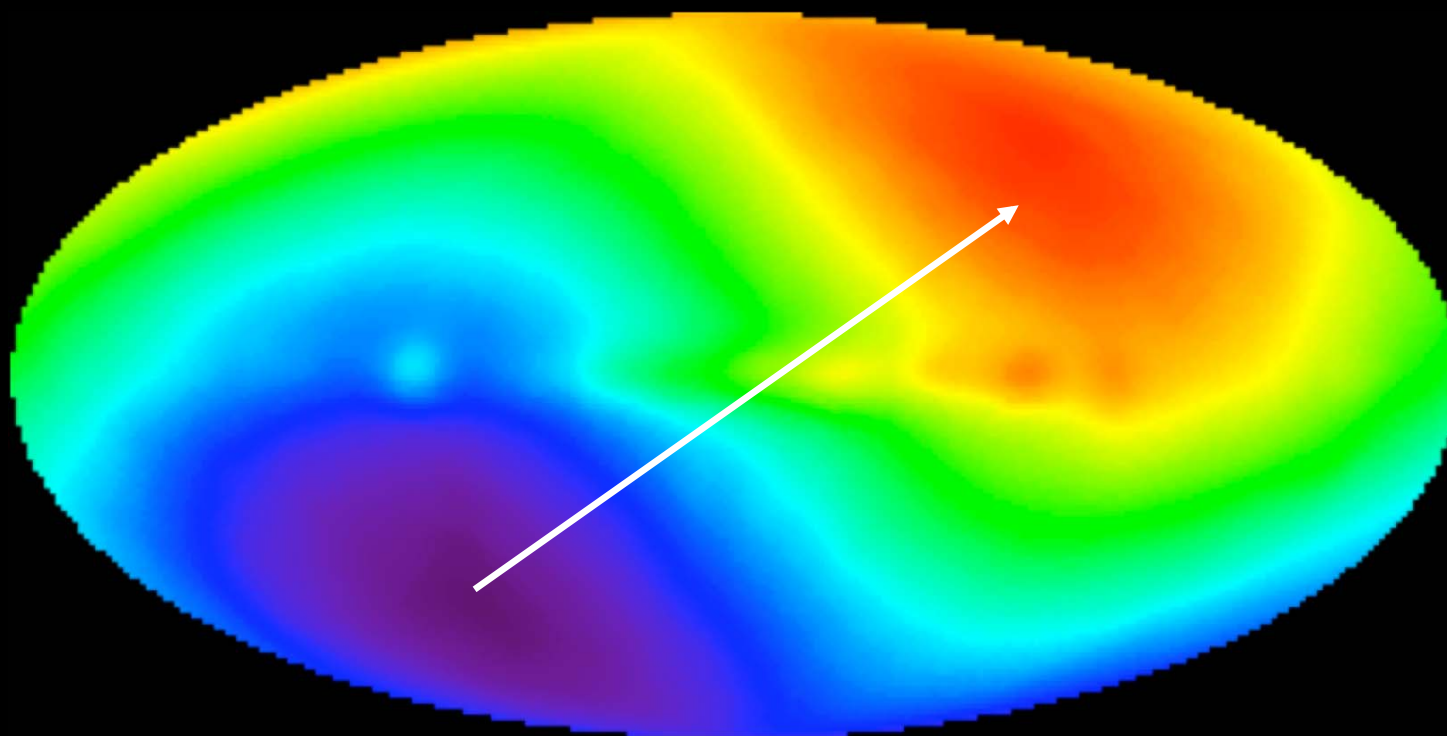
Also, without matter and distant stars, ‘rotation’ and ‘rotational invariance’ has no meaning in rigorous physics

Key aspects of my point of view and theory:

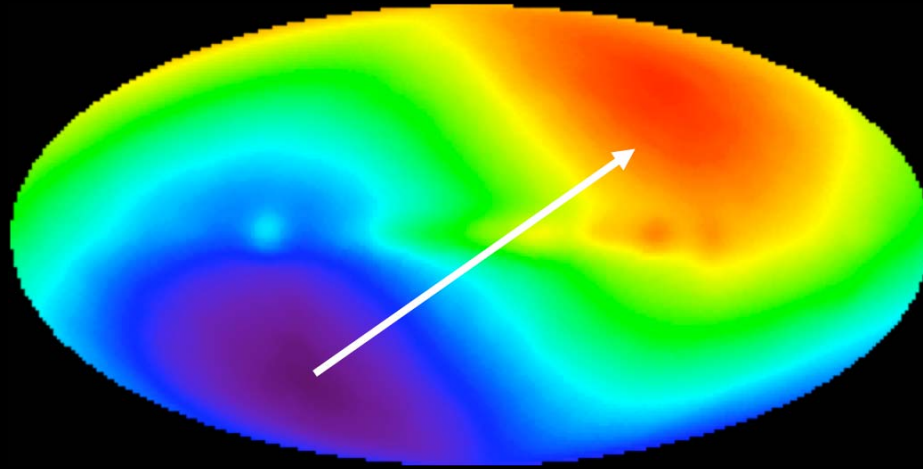
The physical origin of the Spin-Statistics Connection is in the gravitational interaction of the spin with the vast amount of matter in the Universe

- 1) Universal interaction of gravitomagnetic origin based on a cosmic scale generalization of well known effects in gravity, in a well characterized cosmos.
- 2) Try to understand phases acquired in rotation of particles with spin, geometric phases associated with rotational transformation on particles with spin, as well as the spin-statistics connection in the same gravitational framework.
- 3) Quantum mechanics enters the issue only for the quantization of the spin and for providing 'waves' or amplitudes that interfere (only) for identical particles – it is more about 'identical wavefunctions' than about identical particles.

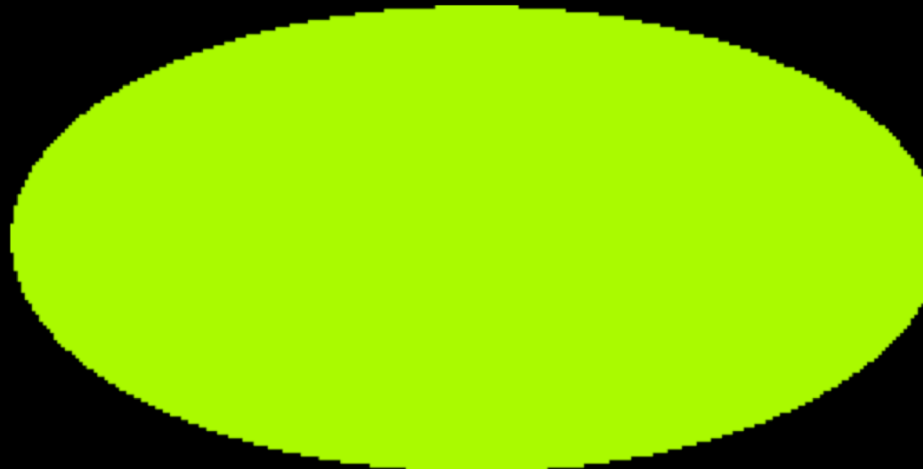
A well known anisotropy



Moving through the microwave background



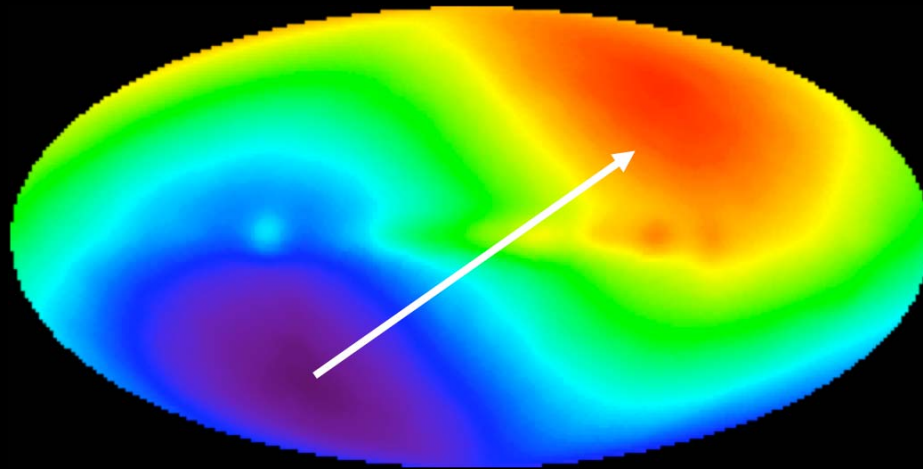
Absolute velocity



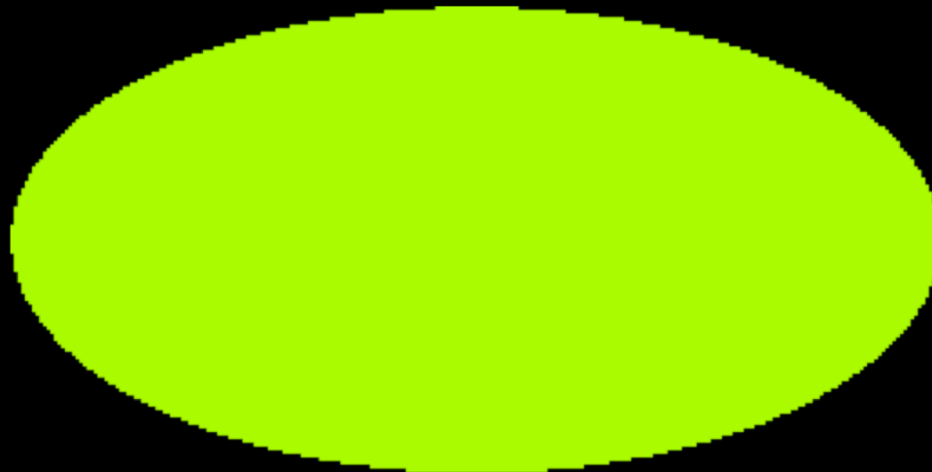
Absolute time
Same as average T

Every observer can decide whether he is moving or not, and all clocks in the universe can be synchronized identically to this temperature.

Moving through the microwave background



Absolute velocity



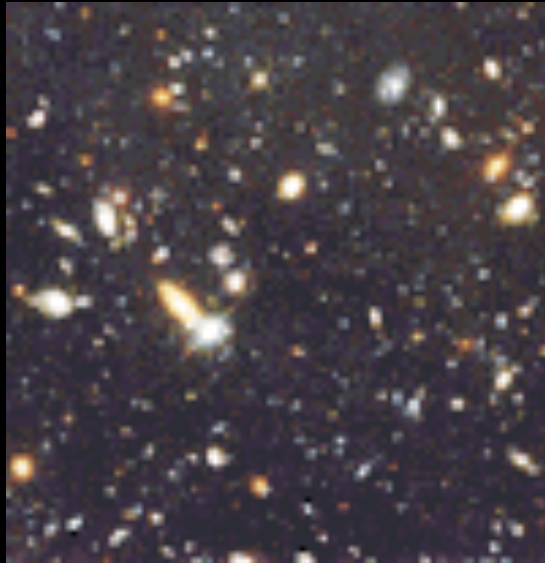
Absolute time
Same as average T

Every observer can decide whether he is moving or not, and all clocks in the universe can be synchronized identically to this temperature.

UNIVERSE IS NOT LORENTZ INVARIANT

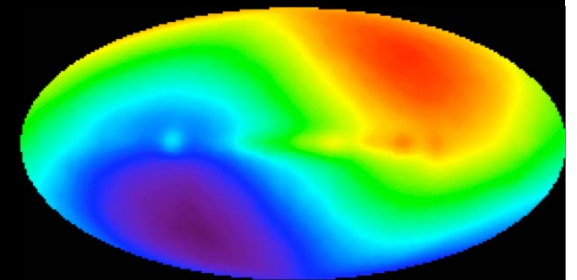
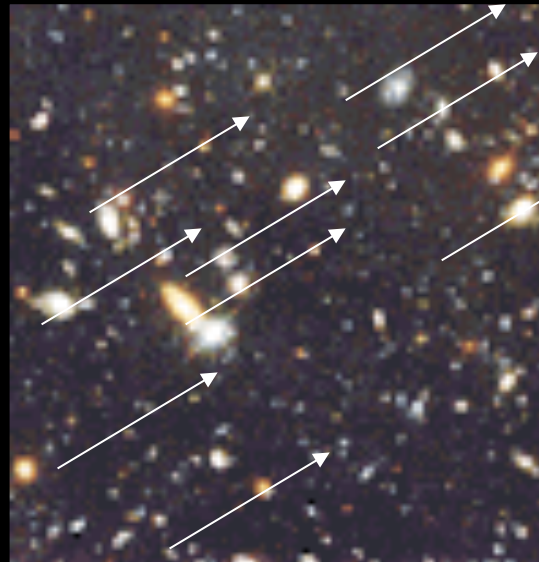
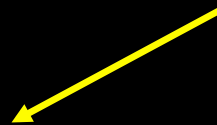
Massive Universe as a preferred frame

There is ONE special frame in which $V=0$



$$ds^2 = -dt^2 + a^2(t) \{ dx^2 + dy^2 + dz^2 \}$$

In all other frames,



SPACE is anisotropic in the frame of a moving observer.
There is a large current of matter (the charge of gravity)

$$ds^2 = -dt^2 + a^2(t) \{ dx^2 + dy^2 + dz^2 \}$$

$$a(t) \approx (1 + t/H + \dots) \approx 1 + 10^{-18}t$$

In a frame moving through this matter filled universe, there is a large matter-current and space is ANISOTROPIC

$$x' = x - Vt, \quad t' = t \rightarrow$$

$$\left[\begin{array}{cccc} g'_{00} = -(1 - v^2/c^2) & g'_{01} = v/c & 0 & 0 \\ g'_{10} = v/c & g'_{11} = 1 & 0 & 0 \\ 0 & g'_{21} = 0 & g'_{22} = 1 & 0 \\ 0 & 0 & 0 & g'_{33} = 1 \end{array} \right]$$

Galilean boost gives the physically reasonable metric

Time dilation and length contraction from cosmic gravity, directly from the gravitational metric

$$d\tau = \sqrt{-g'_{00}} dt' = (1 - V^2 / c^2)^{1/2} dt'$$

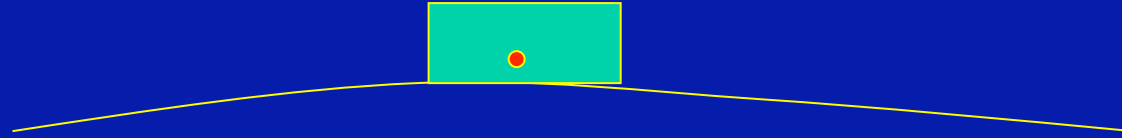
$$dl^2 = g'_{rr} dr'^2 - \frac{g'^2_{0r}}{g'_{00}} dr'^2 = dr'^2 + \frac{V^2 / c^2}{(1 - V^2 / c^2)} dr'^2 = \frac{dr'^2}{(1 - V^2 / c^2)}$$

Galilean transformation + gravity of matter filled Universe gives the correct relativistic effects on clocks and meter scales

All Lorentz factors depend on ABSOLUTE SPEED!

Unnikrishnan, Marcel Grossman meeting, Berlin, 06

What is the true gravitational potential “here”, in this room?

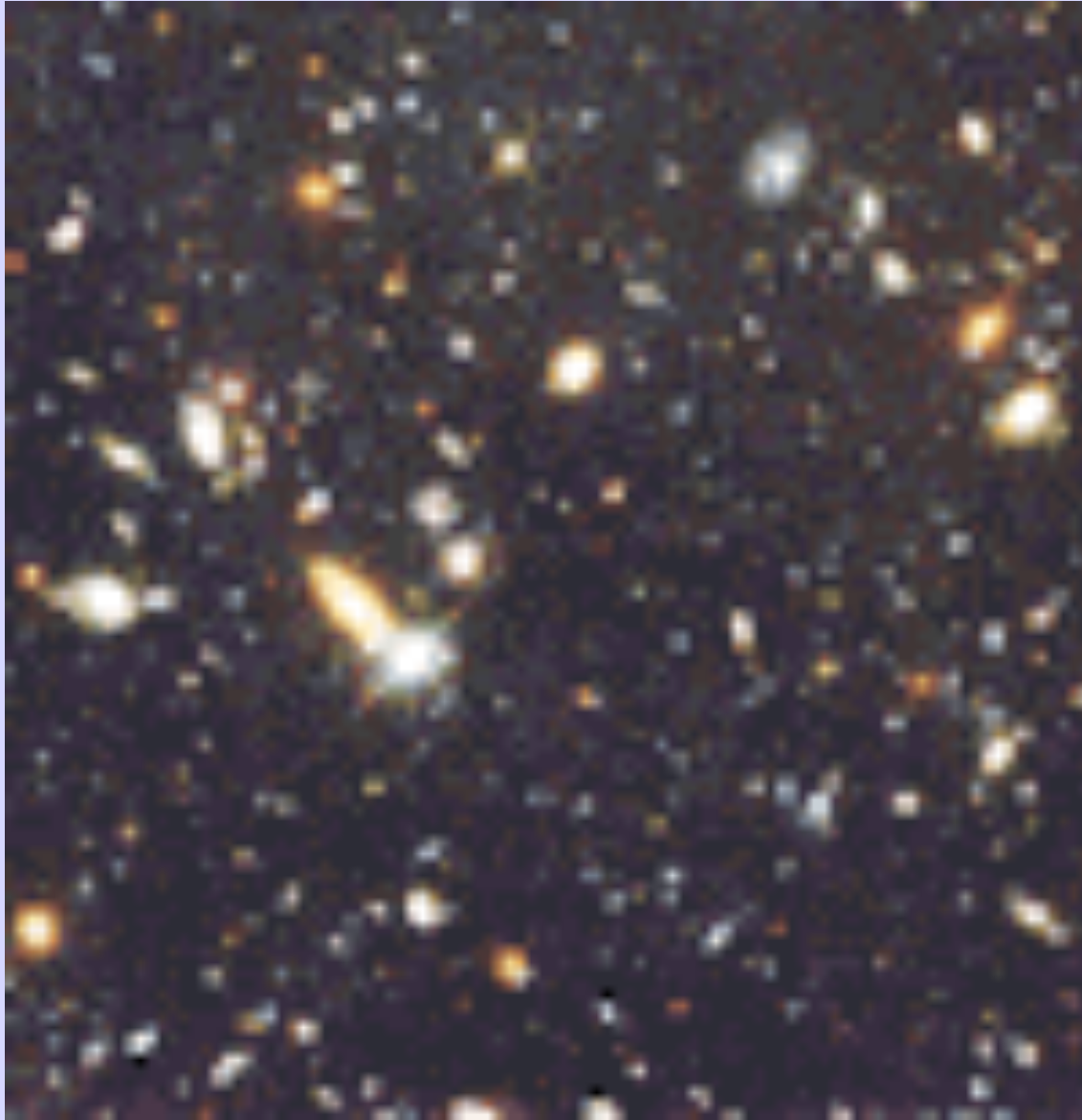


Earth: $\frac{GM_E}{c^2 R_E} < 10^{-9}$

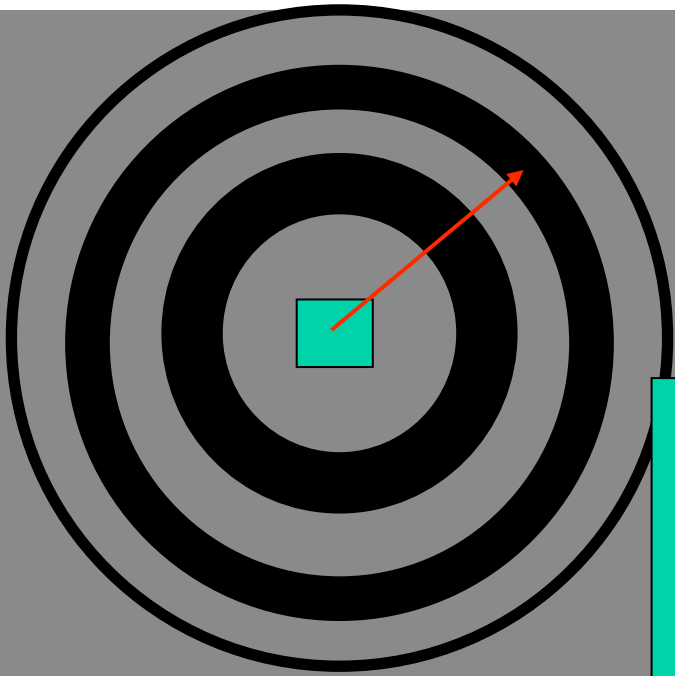
Sun: $\frac{GM_S}{c^2 R_S} \approx 10^{-8}$

Galaxy: 10^{-6}

Distant masses
dominate!



Billions and billions of galaxies, dark matter etc...extending to 10^{28} cm or more



$$\Phi_U \approx \int_{\text{Over all Galaxies}} G \cdot (4\pi\rho R^2 dR) / R$$
$$\approx 2\pi G\rho R_H^2 \approx 2\pi G\rho c^2 T_U^2 \approx c^2$$

$$\Phi_U \approx c^2$$

Our interaction energy with the matter in the Universe is billion time larger than our interaction energy with the Earth!!

$$\vec{A}_U \approx \left(\frac{\phi_U}{c^2} \right) \vec{v} / c$$

What can these large potentials do?

What are the observable LOCAL influences of the cosmic gravitational potentials?

$$\vec{A}_G = \frac{\vec{v}}{c} \phi_G$$

$$\vec{E}_G = -\frac{\partial \vec{A}_G}{\partial t} = -\phi_G \frac{\partial \vec{v}}{\partial t}$$

$$F_{reaction} = -\frac{m_g d\vec{A}}{cdt} = -m_g \frac{\Phi_U}{c^2} \vec{a} = m_i \vec{a}$$

NEWTON'S LAW FROM COSMIC GRAVITY!

(Newton's universal law of motion is gravitational, 'gravito-magnetic' and relativistic. It has an analog in electrodynamics – Lenz's law)

$$F_{reaction} = -\frac{m_g d\vec{A}}{cdt} = -m_g \frac{\Phi_U}{c^2} \vec{a} = m_i \vec{a}$$

$$m_i / m_g = -\Phi_U / c^2$$

EQUIVALENCE PRINCIPLE FROM COSMIC GRAVITY !

(Related to Mach's conjecture, proved directly from the known properties of the Universe)

Other predictions for

- a) Comparison of transported clocks {Proc. Marcel Grossman meeting 2006 (World Scientific 2008), Galileo symposium, Toulouse 2007)}
- b) Velocity of light relative to inertial observers {Proc. Marcel Grossman 2006, Proc. SPIE Photonics (2007)}

What are the observable influences of the massive Universe?



Universe in rotating frame

Currents of mass generates a vector potential

And its 'curl' is a magnetic gravitational force

$$\nabla \times \vec{A}_g = \frac{\Phi_U}{c^2} \nabla \times \vec{V} = 2\vec{\Omega}$$

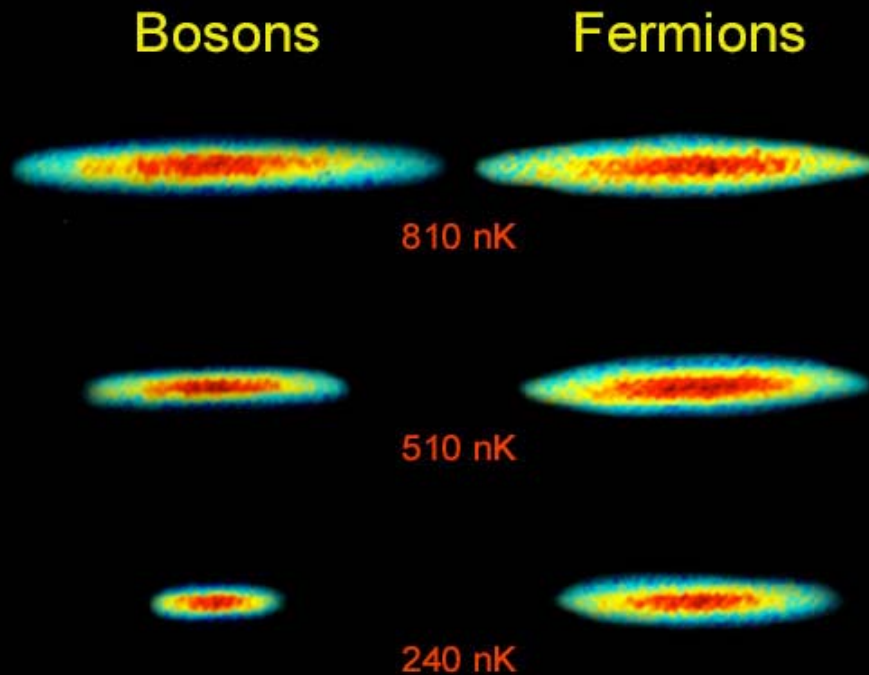
Gravitational Lorenz Force $m_g \vec{v} \times \vec{B}_g = 2m_g \vec{v} \times \vec{\Omega}$

CORIOLIS FORCE IS A COSMIC GRAVITO-MAGNETIC FORCE

1. There is no independent physical content in Inertial Mass; the only reality is that of gravitational mass (charge of gravity)
2. Spin is a current of matter – current of gravitational mass
3. Therefore, EVERY spin dependent phase in quantum mechanics is of gravitational origin, and the only gravitational field that can induce such large phases is the COSMIC gravitational field.

$$\vec{A}_U \approx \left(\frac{\phi_U}{c^2} \right) \vec{v} / c$$

Quantum Dynamics in the presence of the massive universe



The Thomas contribution to the fine structure can be interpreted as a gravitational effect using the equivalence principle

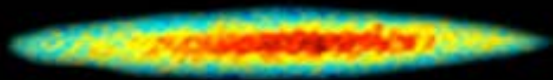
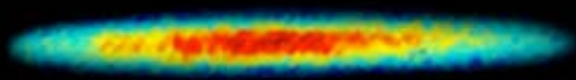
$$\frac{\vec{v} \times \vec{a}}{c} = -\frac{\vec{v} \times \vec{g}_e}{c} \rightarrow \vec{B}_g$$

$$\frac{d\vec{s}}{dt} = \frac{1}{2c} \vec{s} \times \vec{B}_g \rightarrow \omega_g = \frac{\vec{v} \times \vec{a}}{2c^2}$$

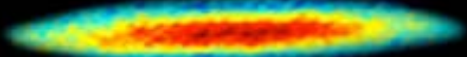
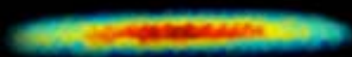
Mod. Phys. Lett. A **16**, 429, (2001)

Bosons

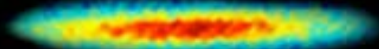
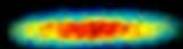
Fermions



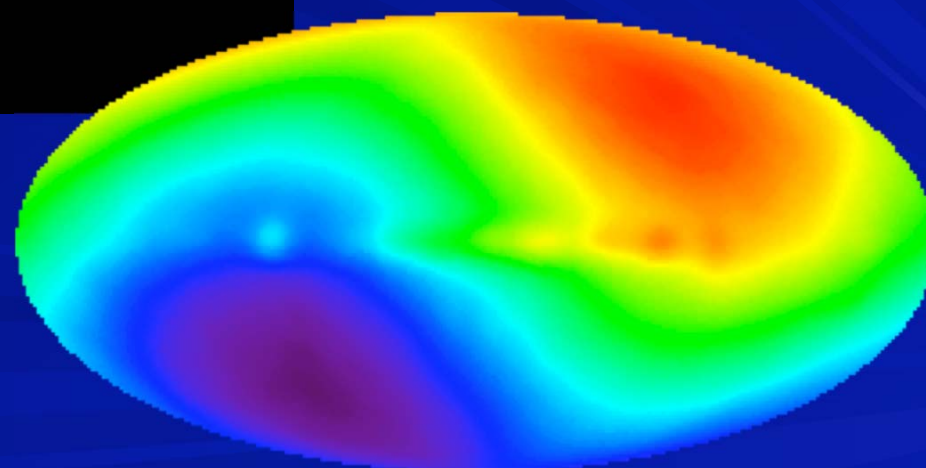
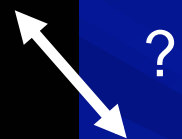
810 nK



510 nK



240 nK





Universe in rotating frame

Gravitomagnetism

$$B_g = \frac{\Phi_g}{c^2} \nabla \times \vec{v} = 2\Omega$$

Cosmic
Relativity
gr-qc/0406023

An assertion, supported by what we discussed so far:

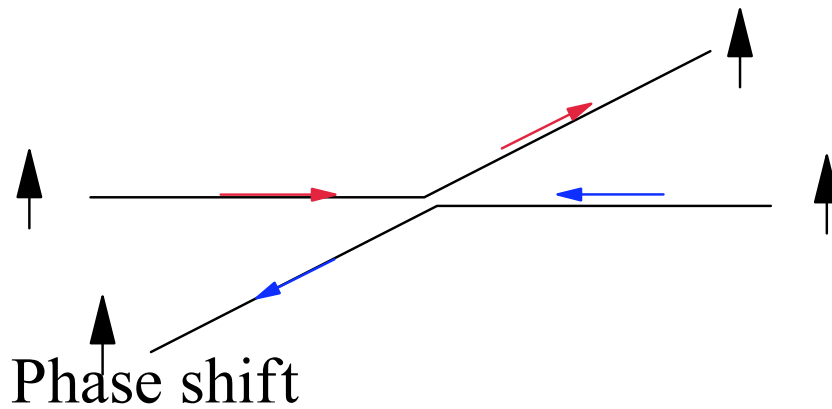
The physical laws in the massive critical universe is determined by cosmic gravitational interaction to be completely relativistic. In particular, rotating a physical system actively is equivalent in physical effects to the rotation of the entire universe by the same amount in the opposite rotational sense.

(This implies that a measurable physical effect is produced only by an active rotation of matter currents relative to the matter in the universe, and not by the rotation of a coordinate reference.)

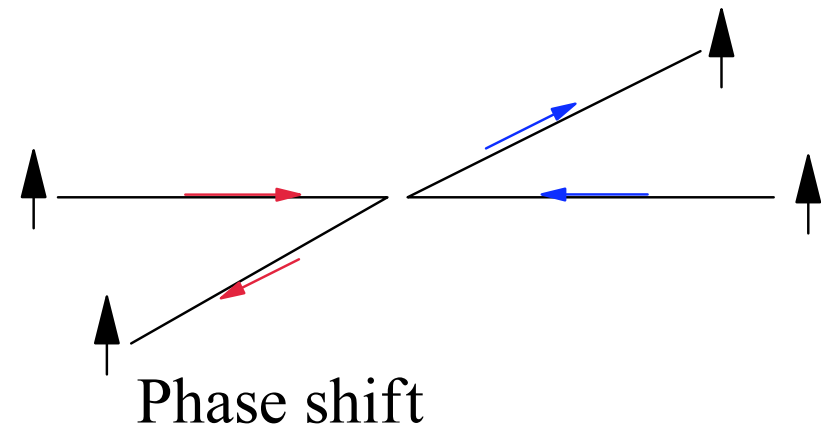
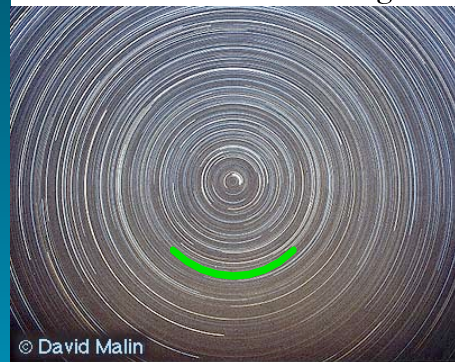
Newtonian matching condition: Coriolis force

$$\text{Phase: } \varphi = \int_{\gamma} p_{\mu} dx^{\mu} \rightarrow \int_{\gamma} s_g d\theta_*$$

The Origin of the Spin-Statistics Connection



$$\delta_1 = 2 \times \frac{1}{2} \vec{s} \cdot \vec{B}_g \delta t_1 = 2s\Omega t_1 = 2s\theta_1$$



$$\delta_2 = s \cdot B_g \delta t_2 = 2s\theta_2$$



Phase difference

$$2s(\theta_2 - \theta_1) = s \cdot 2\pi$$

There is most certainly a cosmic connection to the spin-statistics connection

The new paradigm:

Spin-Statistics connection has its origin in the only interaction possible for a pure spin with the rest of the matter in the universe – gravity.

Same proof for 2D problems: Spin-Statistics connection is valid

Photon is not left out, since its trajectory in the cosmic frame can be parametrized in terms of the absolute time.

Comments:

- 1) If true, this certainly is the simplest proof of spin-statistics connection.
- 2) This is the only attempt so far to connect Pauli-exclusion to a dynamical reason – the Machian nature of the deep principle represents the gravitational basis of laws of motion.
- 3) It clarifies the role of the spin, rotation, identicalness, and relativity in the structure of the ‘proof’.
- 4) In any case, without matter and distant stars, ‘rotation’ and ‘rotational invariance’ has no meaning in rigorous physics – and with these entities, gravity is unavoidable!
- 5) It satisfies our appetite for ‘feeling in the stomach’ that we understand the connection.

Issues to be settled:

- 1) Rigour of argument (stability of the phase against local gravitational perturbations)
- 2) A possible inconsistency with fine structure splitting (what is the exact fine structure splitting in this framework?)

Gravitational effects of the matter in the Universe

Particle in circular motion in the universe:

$$\vec{E}_g \sim -m_g \frac{\partial \vec{A}_g}{\partial t} \sim -m_g \phi_g v \frac{2\pi}{2\pi r / v} \simeq -m_g \phi_g \frac{v^2}{r}$$

Centrifugal force!