Coupling of Electromagnetism and Gravity:

Where *to search for a propulsion breakthrough*

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Two Facets of the Propulsion Problem

- The Fuel Problem
- The Time-Distance Problem

The Fuel Problem

- The need for propellant arises from conservation of momentum
- In empty space, the total momentum of ship plus expelled propellant must be zero for all time
- Amount of propellant carried is limited by the size of the ship
- Carried propellant requires propellant => an exponential problem
- Travel to the nearest star at 1g acceleration requires an astronomical amount of propellant, and an astronomical ship size

No propellant-based finite-size ship can reach the stars

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The Time-Distance Problem

- The limiting speed of light implies tens of thousands of years to cross the galaxy, as measured on earth
- No civilization lasts long enough to send a ship, or even a radio signal, hundreds or thousands of light years.
- If ships could be accelerated to the speed of light, the occupants could traverse the galaxy in their lifetime.
  - Time dilation effects would strand such explorers, Planet-of-the-Apes-like, in the far future.

No finite-time civilization can reach beyond a few light-years

Nature of the Propulsion Problem

- More propellant is required to escape the gravity of planets and stars, compared to accelerating in deep space
  - The Fuel Problem is, in part, a gravity problem
- Time dilation and the limiting speed of light arise from relativistic considerations, and gravity is intimately tied to relativity
  - The Time-Distance problem is a gravity problem

The Propulsion Problem is a Gravity Problem

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Who's Working on Gravity Problems?

- Fundamental research in gravity is quantum gravity
  - Quantum gravity research is mainly string theory
- There is no directed research into classical gravity
  - Classical gravity is presumed to be an approximation to a deeper theory, like classical EM is to QED
  - No progress on gravity is anticipated until we unlock quantum gravity, then we hope our gravity problems will evaporate
- We've been failing on quantum gravity for 100 years
  - we're waiting for someone smarter than Einstein or Dirac or Feynman or Pauli or Weinberg …

Have we waited long enough?
Should we give it another 100 years?

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What's in the Engineering Toolbox?

- There are 4 known forces in nature at our disposal for engineering
  - (And two mysterious forces: dark energy and dark matter)
- Two of the 4, the Strong and Weak forces, are purely quantum, operating only in the nucleus
  - We cannot do engineering with the Strong and Weak
  - We harness them in fission or fusion, but only to create heat
  - Weak force unified with electromagnetic force (QED) at quantum level
- The third is gravity
  - We cannot do engineering with gravity because astronomical masses are required – and we are puny.
  - Wormholes and Alcubierre metrics are here. Feasible? Yes. Possible? No.
- The fourth is electromagnetism

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Electromagnetism

The only known force accessible to human engineering

Power generation

Telecommunications

Metallurgy

Chemistry

Cell metabolism

The binding of atoms and molecules

Radio, X-rays, microwaves, visible light

We are an electromagnetic species.
Our civilization is electromagnetic.

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Constraints on Extensions/Modifications to the Theory of Gravity

- The Dicke framework was used to parameterize tests of GR
  - cf. C.M. Will, *Theory & Experiment in Gravitational Physics*, 1993
- Any proposed theory of physical law:
  - Must be covariant
  - Must obtain from a Lagrangian
  - Fields must transform as tensors
- Additionally:
  - Can't break existing theory and observation
  - Must provide a testable prediction

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Summary of Requirements for a Breakthrough in Propulsion

- Coupling between EM and gravity
- Covariant formulation
- Fields that transform as tensors
- Derivable from a Lagrangian
- No harm to existing theory
- No harm to existing experimental tests
- New, testable prediction => no free parameters

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The Kaluza theory has all these features!

(Except no testable prediction has been proposed)

The only successful unified field theory involving general relativity!

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Kaluza Theory* History

(*the most influential theory you've never heard of)

- Proposed by Theodor Kaluza in 1919, and sent first to Einstein
- Forwarded for publication by Einstein in 1921
  - Launched Einstein on his life-long, quixotic quest for a unified field theory
- All basic features and assumptions worked out by Kaluza
- Modified by Klein for quantum field theory in 1926
  - Launched multi-dimensional quantum field theory
- Field equations not properly attempted until 1940s, by independent groups (cf. Goenner)
  - Scherrer in Switzerland
  - Lichnerowicz and Thiry in France
  - Pascal Jordan group in Germany
    - Later, the Dicke group at Princeton
  - cf. the Wikipedia page on Kaluza-Klein, maintained by L.L. Williams
- Lagrangian and correct field equations discovered in 2014 by L.L. Williams
  - Using tensor algebra software

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Why Was It Abandoned?

- Investigated by giants of 20th century physics
- Abandoned by 1930
- Possible Explanations
  - It was not a quantum theory
  - The scalar field was unknown then, but we have scalar fields now in physics
    - Inflation, dark matter
  - The cylinder condition seemed arbitrary
  - Einstein sought to explain matter from fields
  - The correct equations for the scalar field were unknown in 1930

No good reason in 2019 to abandon the theory

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Kaluza Concept

- Write the Einstein field equations in 5 dimensions
- Identify the spacetime metric and EM vector potential as part of the 5D metric
  - A new scalar field is required in this approach
  - Recover standard theory when scalar field constant
- Ignore derivatives w.r.t. the 5th coordinate (“cylinder condition”)

$$\tilde{g}_{ab} \sim \left[\begin{array}{c|c} g_{\mu\nu} & k A_{\mu} \\ \hline k A_{\nu} & \phi \end{array}\right]$$

Kaluza Implications

- Mass-energy sources from 5D vacuum
  - "Kaluza miracle"
- Electric charge identified as momentum in the 5th dimension
  - Not a Lorentz scalar
  - Component of energy-momentum-charge 5-vector
- Scalar field a new force of nature unknown to physics
  - No identification with existing measurements
  - Couples gravity and EM
  - Implies a variable gravitational constant

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Kaluza Field Equations and Lagrangian

cf. Williams (2015) http://dx.doi.org/10.1155/2015/901870

$$L = g^{1/2}\left[\phi g^{\mu\nu} R_{\mu\nu} - \frac{1}{4} k^2 \phi^3 g^{\alpha\mu} g^{\beta\nu} F_{\alpha\beta} F_{\mu\nu}\right]$$

- Brans-Dicke "omega = 0" theory (when electromagnetic field vanishes)
- The constant k is fixed by identification with 4D theory => *no* free parameters

The theory identifies the scalar field as
a variable gravitational constant.
(a result only known since 2015)

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Equation for Scalar Field

In presence of electric charge

$$R - \frac{3}{4} k^2 \phi^2 F_{\mu\nu} F^{\mu\nu} \propto q^2$$

In vacuum

$$\frac{1}{4} k^2 \phi^3 F_{\mu\nu} F^{\mu\nu} = \nabla_\mu \nabla^\mu \phi$$

Electromagnetic fields are sources of the scalar field, but it also propagates in vacuum

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Nature of the 5th Dimension

- Electric charge is momentum in the 5th dimension
  - 5th component of energy-momentum-charge 5-vector

$$k\frac{dx^5}{d\tau}=\frac{q}{m}$$

- Classical results maintain the 5th dimension has a spacelike signature in the 5D metric
- Lagrangian analysis shows it has a timelike signature
  - Recent experiment by Martin Tajmar seems to confirm this

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The Scalar Force Field

$$\frac{dU^{\mu}}{d\tau}+\Gamma^{\mu}_{\alpha\beta}U^{\alpha}U^{\beta} = k^{2}\phi^{2}Q\,g^{\nu\beta}F_{\beta\alpha}U^{\alpha}+\frac{1}{2}Q^{2}g^{\nu\alpha}\partial_{\alpha}\phi^{2}-U^{\nu}\frac{d}{d\tau}\ln\left(f\left(\phi\right)\right)$$

$$Q \equiv U^{5}+kU^{\mu}A_{\mu} = \frac{q}{km}+kU^{\mu}A_{\mu}$$

Charged particles are subject to a force unknown to science

Summary of Implications

- The Kaluza theory is the only unified field theory that successfully includes general relativity
- Gravity and EM are recovered for constant scalar field
- The scalar field is identified with the gravitational constant, as in Brans-Dicke theory
- EM fields can alter the gravitational constant, and thereby the coupling of matter to gravity
- The scalar field can affect the motion of material bodies

The scalar field is a total mystery.
Is dark matter a candidate?

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Not a Path, but a Way

- Undertake experiments to detect electromagnetic control of gravity, guided by this theory
- Attempt to find an experiment to test the existence of the scalar field
- Understand the connection/coupling between the square of electric charge and the scalar field

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