Playful Thought Experiments About Breakthrough SpaceDrives

Marc G. Millis

2017 / Nov / 01

Today

- What I've Been Doing ① ② ③
- Playful What-Ifs

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Rebooting Tau Zero Foundation

Pioneering Interstellar Flight

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Rhonda


Jeff


Andy


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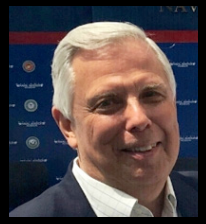
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Paul

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Tau Zero Foundation

Tau Zero Foundation

VISION: Lead the development of propulsion and power technologies to enable human interstellar travel

MISSION: While focused on breakthrough technologies, accomplish incrementally what can be done today by:

- [Near] Advancing propulsion and energy storage capabilities for near term space efforts
- [Far] Research and development of promising breakthrough propulsion physics
- {People] Encourage development of the technical skill base required to accelerate achievement of our vision

Tau Zero and Affiliate Activities

- Spreading News of Progress
  - Centauri Dreams news forum, Paul Gilster
  - *NEW STEM* - Janet Ivey-Duensing, *Janet's Planet*, PBS program
  - Web (tauzero.aero) & social media, Stevenson
  - Interstellar short course (Dresden, Purdue), Millis
- NASA Grant
  - Determining what to work on
  - Internet database for challenges and prospects
- Propulsion *Physics* Research
  - Anchoring book, *Frontiers of Propulsion Science,* 2009
  - "SpaceDrive" project, Dr. Martin Tajmar (TU Dresden)
  - Negative energy experiments for FTL, Davis & Hathaway

Tau Zero Future Interests

- Rebuilding Network of Subject Matter Experts
- Rebuilding Network of Affiliate Organizations
- Power & Propulsion *Technology* Research
  - Energy Generation and Storage
  - Propulsion Next-Step Advancement
- STEM / STEAM (guide future workforce)

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About that NASA Grant

"Breakthrough Propulsion Study"

- 3-Year Grant
- Interstellar Study
- Includes Propulsion Physics
- Creating a Ranking Process

— Grant's Goal —

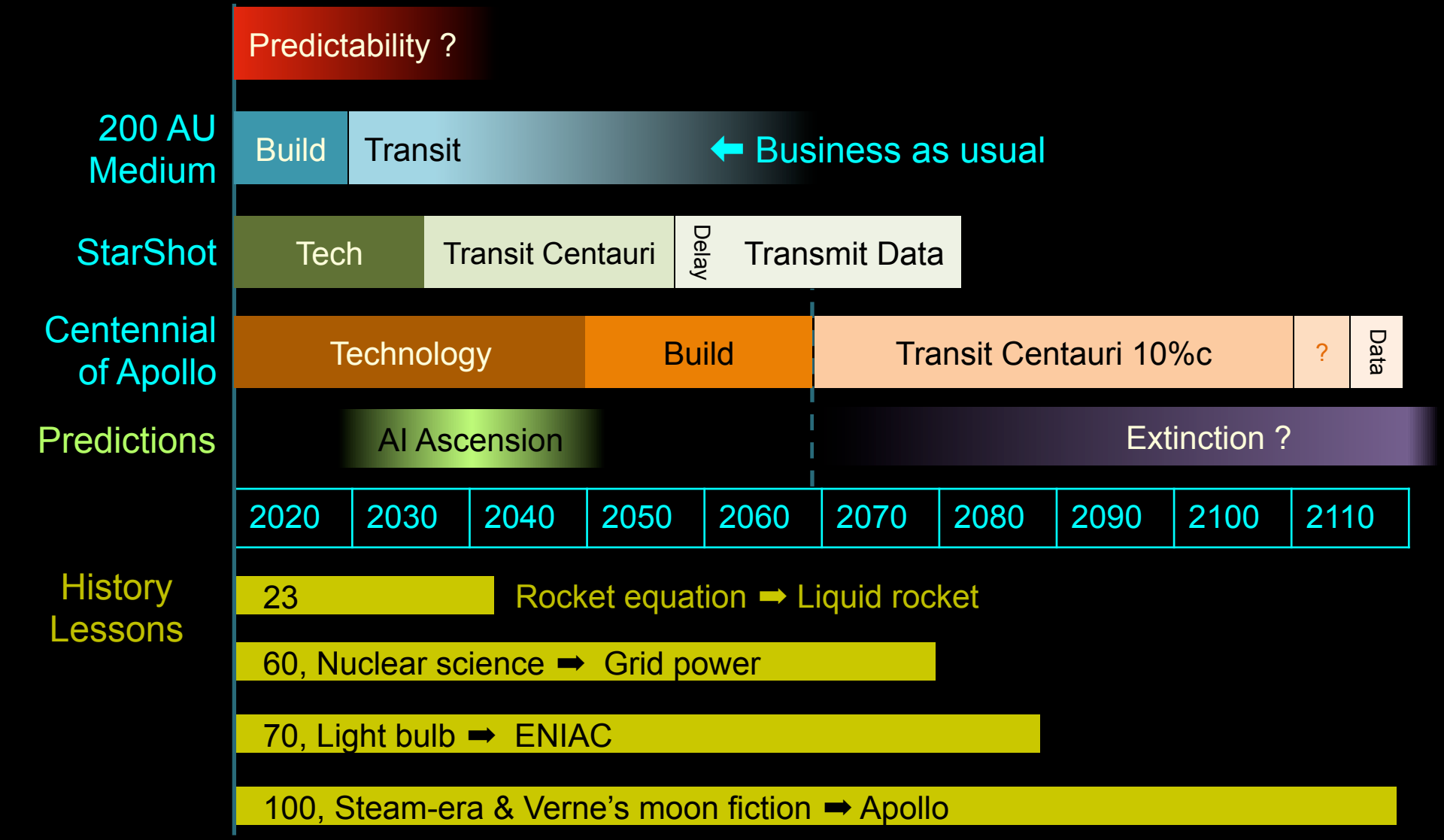
Create a process for comparing different interstellar mission architectures and their propulsion and power technologies…

To determine which research options have greatest leverage for improving NASA's ability to explore faster, farther, and with more flexibility.

Considering

- Span of motivations
- Common measures for disparate methods
- Infrastructure development
- History of long-scale revolutionary advancements
- Ancillary influences (Energy, AI, Life Extension…)

Timescale is Not Business as Usual



Grant 3-Year Work Plan

1. Define Challenges & Opportunities:
   Work Breakdown Structure (WBS) – the *right* questions
   - Challenges, top-down, mission driven
   - Prospects, bottom-up, tech & science
2. Populate WBS with accurate information
   - Online database
   - Begin creating comparative algorithms
3. Analysis & Recommendations

Grant - Process in Principle

Vary inputs to explore consequences

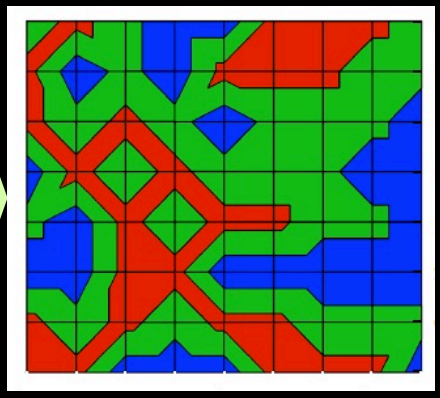
Choice-Driven Inputs

- Launch year (baselines)
- Destination
- Mission duration or speed
- Mission ambition
- Motive weighting factors
- Readiness thresholds
- Performance thresholds
- Scale of research support
- Scale of mission effort

Nature-Driven Challenges

- Distance, Energy = *f* (*m*, Δv), etc.
- Physics Performance Limits

META MEASURES ▸	Motive Sum	Payload Mass	Distance	Flight Duration
MISSION ARCHITECTURES		kg	AU	yrs
Act-1, Era of Precursors and Forays				
JPL TAU		1E+03	1E+03	30
Heliopause Probe		25	4E+02	30
StarShot		1E-03	3E+05	22
Act-2, Era of Infrastructure				
Beamed Energy Sails				
Rockets				
µEarth ships, World Ships			n/a	
Act-3, Undiscovered Future				
SpaceDrives				
FTL				



Prospects Now & Future

- Mission Architecture Options Specs
- Power & Propulsion Options Specs

Grant - Comparing Disparate Approaches

- Launch year sets common baselines
- Other performance parameters reduced to most fundamental measures: Mass, Time, Energy, Power
- Focus on lowest TRL part of the system for readiness assessment

Grant - Year 3 Recommendations

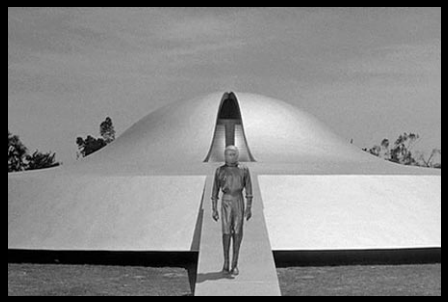
- Identify knowledge gaps and research needs for the most influential factors
- Recommend research solicitation strategy
  - Three year cycles of solicitations & tasks
  - Diverse suite of research approaches
  - Findings affect next cycle

Interstellar Short Course

- When / Where
  - Dresden, summer 2017…. again 2018 ?
  - Purdue, November 2017

- Content ≈ 10 hours
  - Interstellar challenges
  - 3 Era's of prospects
  - Emphasis on propulsion physics
    - SpaceDrives
    - Faster than light

Space Drives – Inspirations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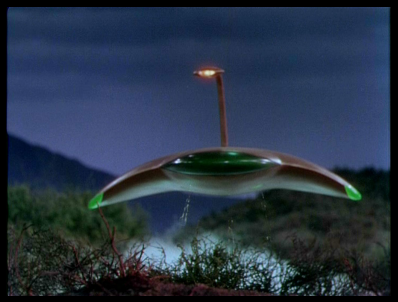
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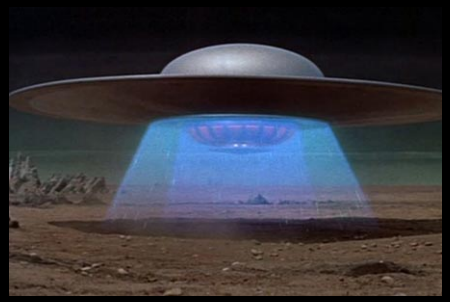
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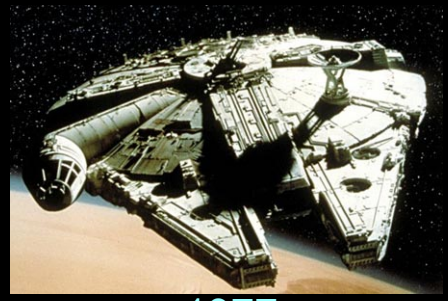
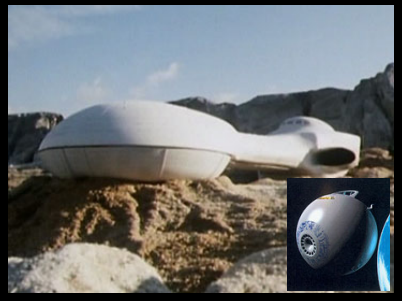
1964


1966

1966


1977


1977


1981, 2005

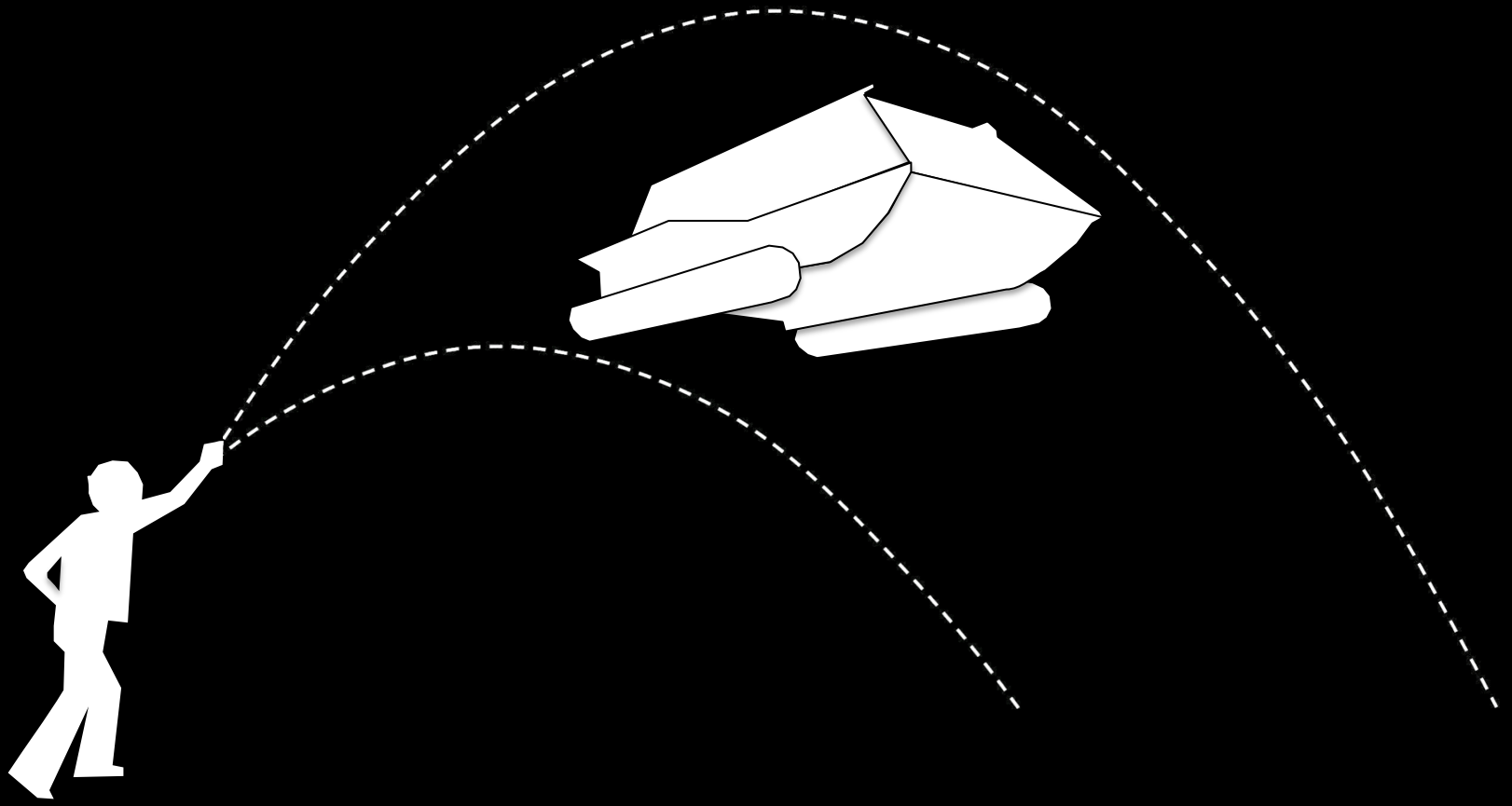

1984


1985

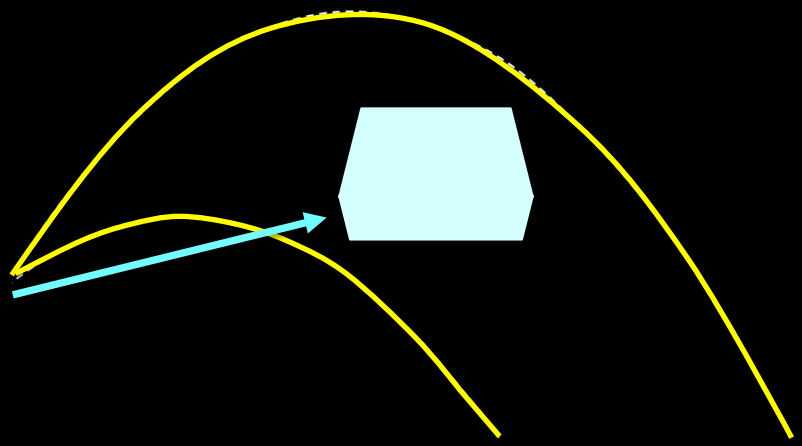

1986

Throwing Rocks and Poking it With a Stick

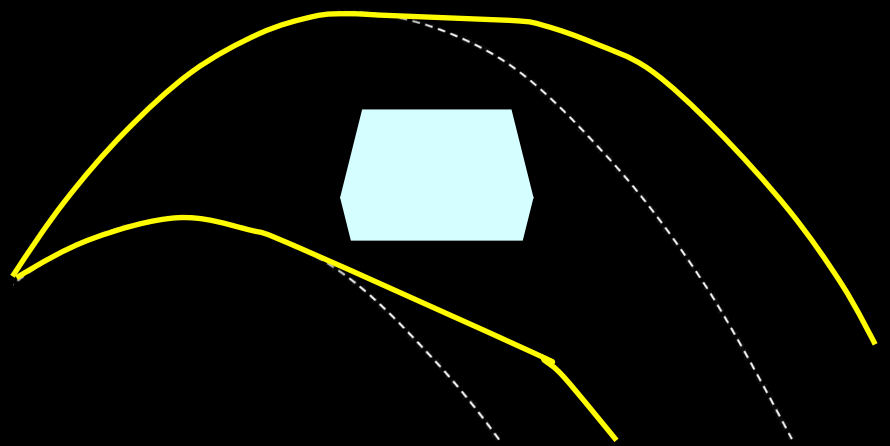
(10-14 yrs old)



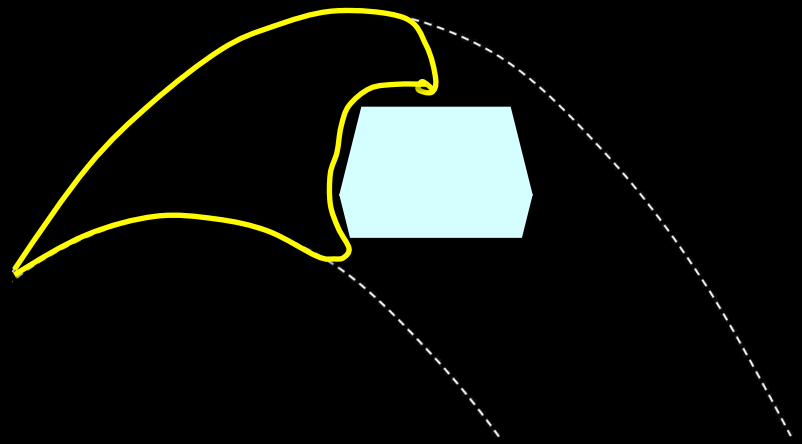
Throwing Rocks and Poking it With a Stick



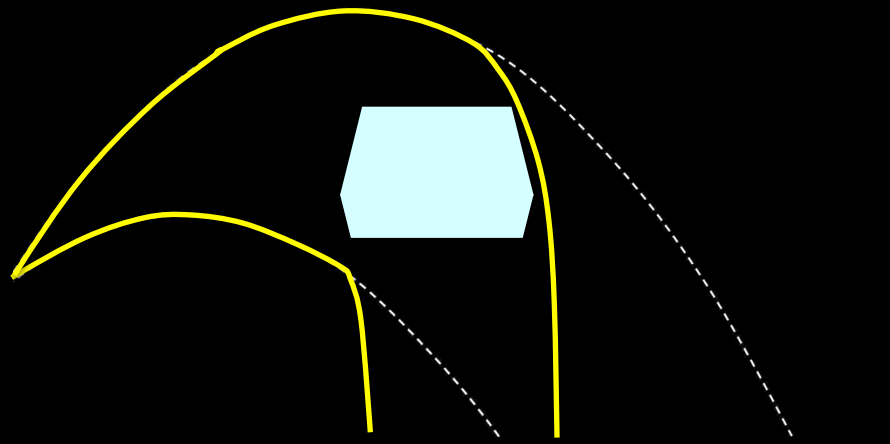
Vehicle Void of Gravitational Mass?



Gravitation Eliminated Around Vehicle?



Locally Inverted Field (Antigravity)?



Downward Force on Near Matter (Space?)

Also Wondered…

- What about the effect from the gravitational fields from the rest of mass in the universe?
  - Insignificant forces, but
  - Large number of other masses
  - Surrounding distribution leads to no net force

- How much energy or power would it take to levitate a mass?

Energy to Levitate by…
Negating Gravitational Potential Energy?

Difference in gravitational potential energy between Earth's surface and infinite distance (zero potential energy)

$$\frac{E}{m} = GM_E \int_{R_E}^{\infty} \frac{1}{r^2}\, dr = GM_E \frac{1}{R_E}$$

= 63 MJ/kg = 18 kWh/kg ≈ $2/kg (@12¢/kWh)

≈ ½ day/kg
Relative to ave house
2 yrs & $3k for a car

Power to Levitate by Thrusting on Air
Helicopter Analogy

How much power for a helicopter to hover?

$$P = \sqrt{\frac{m^3 g^3}{A\,2\rho}} \qquad P \propto m^{\frac{3}{2}} \qquad P \propto \frac{1}{\sqrt{A}} \qquad P \propto g^{\frac{3}{2}}$$

P = power, W

m = mass of vehicle, kg

g = gravitational acceleration, m/s^2

A = area of rotors, m^2

r = density of air, kg/m^3

≈ 20W for 1kg & $1m^2$

Those Led to This - Pondering Levitation

With analogies

Buoyancy

Reaction Force

Ground Effects

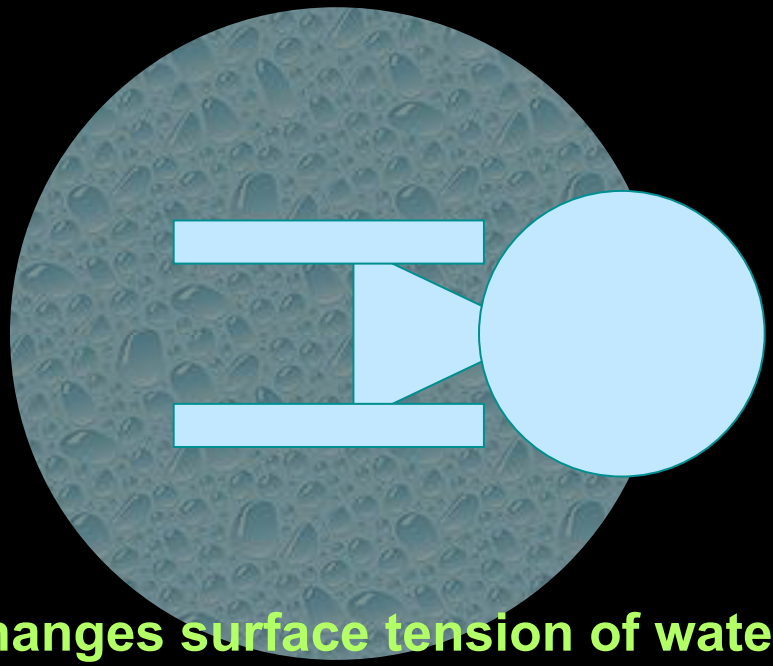
Apply Analogy to Gravitation

- Buoyancy
  - Zero-Out Gravity *of* the Vehicle?
  - Zero Surrounding Gravity ?
- Reaction Force
  - Antigravity? (opposing *g* force)
  - Force Fields on Air?
  - Force Fields on Space Itself?
- Ground Effects
  - Shield Gravity?
  - Ground Repulsed?

Consider the ‘What if” Implications

- Buoyancy
  - Zero-Out Gravity *of* the Vehicle? — Does its *inertia* also zero?
  - Zero Surrounding Gravity ? — How far does effect extend?
  - Antigravity? (opposing *g* force) — Would debris collect atop?
- Reaction Force
  - Force Fields on Air? — Does it affect other objects? How far does effect extend?
  - Force Fields on Spacetime? — What is the reaction mass?
- Ground Effects
  - Shield Gravity? — For everything above too?
  - Ground Repulsed? — What happens over water?

Analogy of the "Soap Boat"

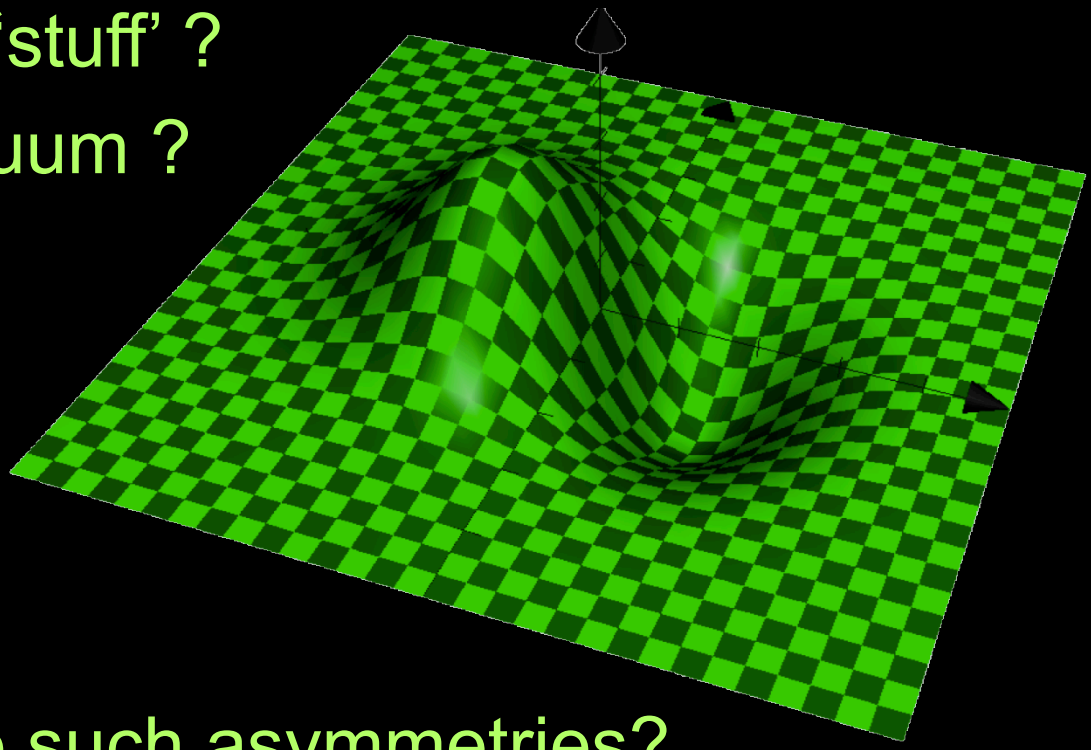


- Soap changes surface tension of water behind craft
- Asymmetric forces (fore/aft) push the craft
- Water is the reaction mass

- Water is analogous to spacetime (reaction mass?)
- Soap is analogous to a *local & asymmetric change* of spacetime (perhaps; Inertial Frames, *G*, F, *h*, *c*, *ZPE*, other?)

Thinking in Terms of Fields of…

- Gravitational scalar potential ?
- Inertial frame ‘stuff’ ?
- Quantum Vacuum ?



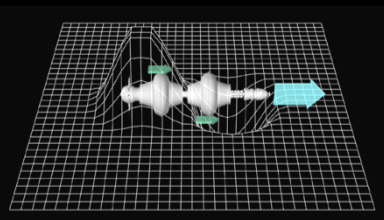
- How to induce such asymmetries?

Prior Conceptulizations

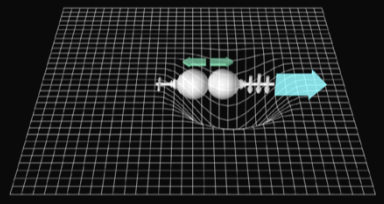
$$F = G\frac{mM}{r^2}$$

$$\Phi = -G\frac{M}{r}$$

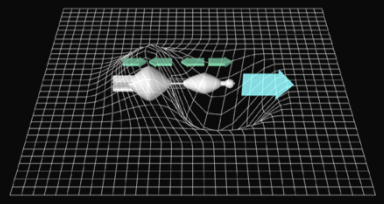
"Diametric Drive"
Change Sign of Mass?
(Negative Mass Propulsion)



"Disjunction Drive"
Split Mass Properties?
(Active, Passive, Inertial)



"Bias Drive"
Impose Asymmetry onto Newton's Constant, *G*?



Millis (2009) Prerequisites for Space Drive Science. In *Frontiers of Propulsion Science*. (Millis lead editor w/co-ed Eric Davis) AIAA. pp. 127- 174.

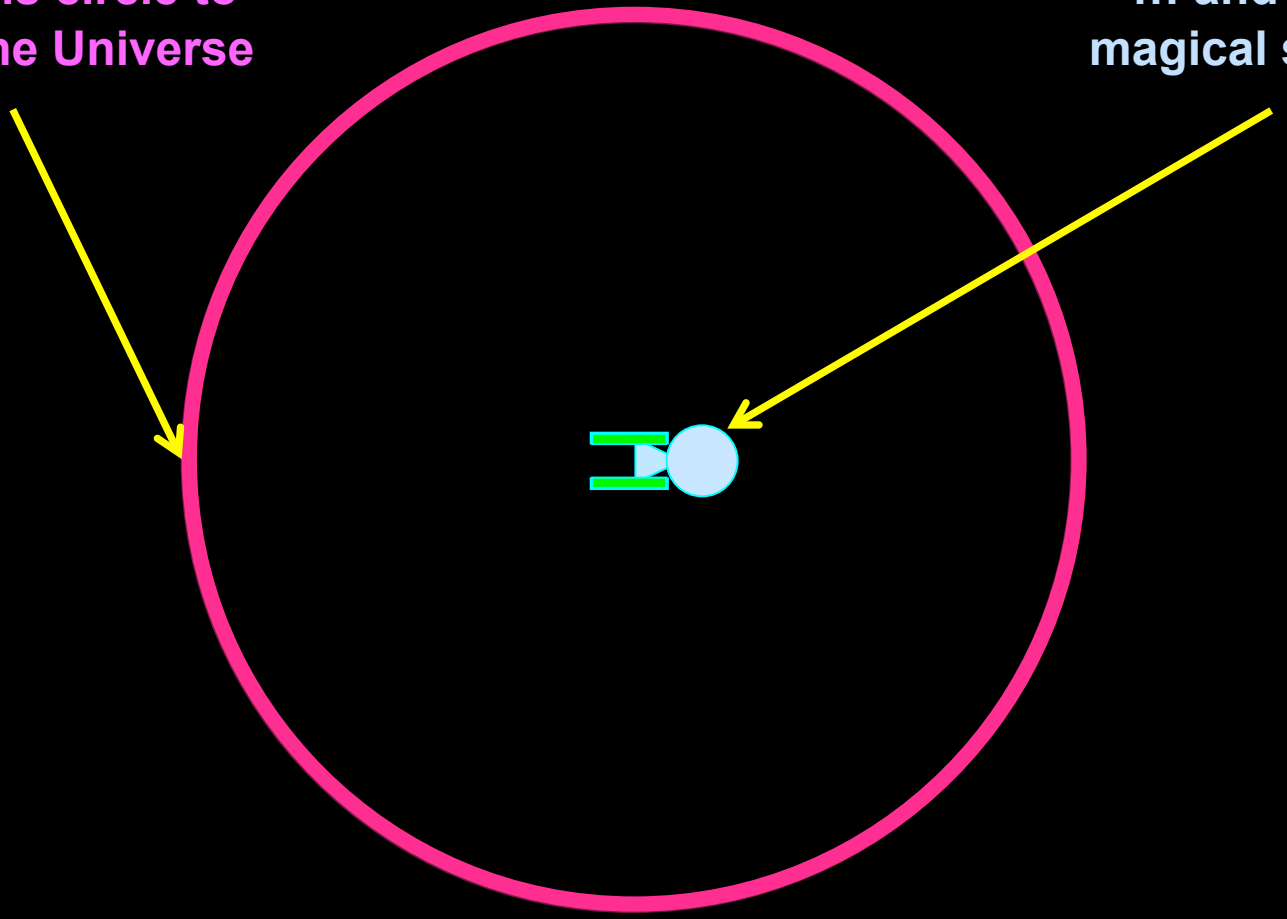
Thrusting Against a Machain Inertial Frame?

Disclaimer: Only intended to illustrate the inquiry

Engage Engines!

Consider this circle to represent the Universe

… and this is our magical spacecraft



Inertial Frame Thought Experiments

- Ingoing bias – Inertial frames ~ gravitational potential
- What I had hoped to have done….
  - Derive equations for how masses and charges (and their motions) affect the properties of inertial frames
  - Determine how the properties of an inertial frame affect mass and charge
  - Entertain the possibility of different propagation speeds for inertial frame effects and electromagnetism
- Hoping to find some sort of wave nature of inertial frames (Presuming they exist, undetected)
  - How to predict and measure such waves
  - How to induce waves for useful purposes

Inertial Frame Thought Experiments

Millis (2017) Inertial Frames and Breakthrough Propulsion Physics. *Acta Astronautica*, V.*138,* pp. 85-94.

Disclaimers:

Intended to illustrate a process

No definitive hypotheses yet posited.

Only a fraction of the variations shown

Wanting a SpaceDrive-Friendly Inertial Frame

- Machian - literally created by surrounding matter
  - Something to push against
  - Implies absolute reference frame (Euclidean)
  - Since Euclidean, Optical Mechanical Analogy (refractive index a function of gravitational scalar potential)

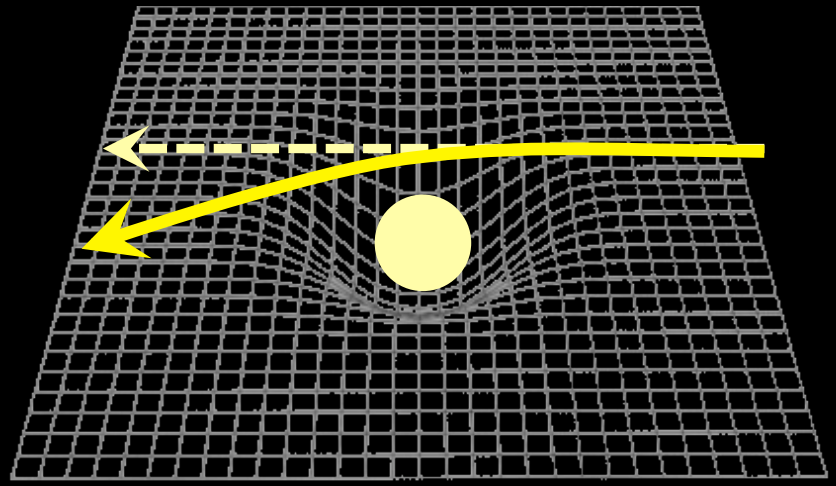
- Instead of "Inertia here because of matter there"
  1. Inertial *frame* created by surrounding matter
  2. Inertial frame affects *measured* inertia

Two Perspectives of Gravitational Lensing

Warped Spacetime

Riemannian Geometry

Light follows geodesic along curved spacetime



$$d = c\,t$$

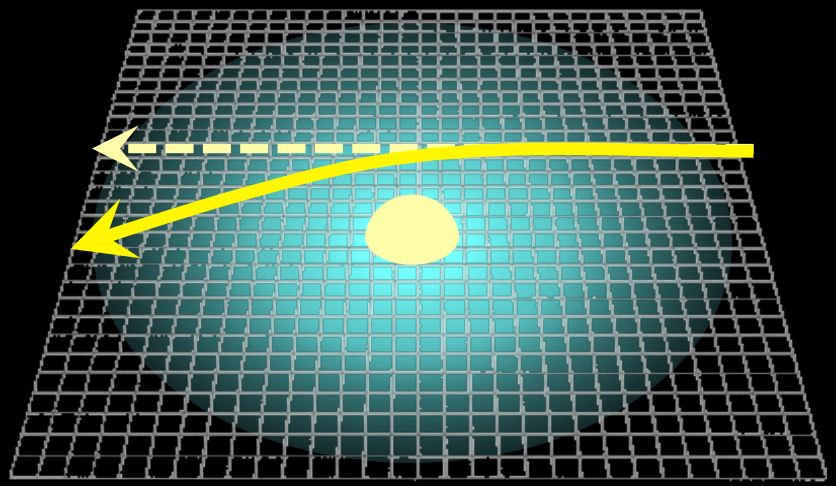
Reference Constant

vary as function to presence of Mass

Variable Refractive Index

Euclidean Geometry

"Optical Mechanical Analogy"



$$d = c\,t$$

Reference Constant

vary as function to presence of Mass

How to Envision Such an Inertial Frame?

- Need a description for frame's properties
  - Assumes multiple contributing sources
  - Assumes possible variation in position and *strength* of frame

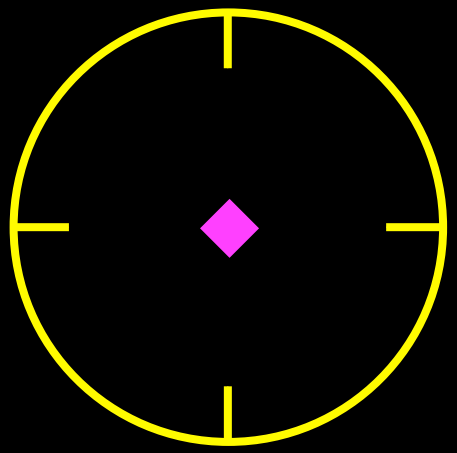
"*Strength* of Inertial Frame?"

"Intensity" "Magnitude"

- Need a description for how frame affects inertia
  - Motion of matter; F=ma, momentum, kinetic energy
  - Propagation of light (lightspeed, optical analogy)

Starting from Scratch

1. Start with an empty space that has *NO* inertial frame properties
2. Place an **inertial frame** into this void – presumed to have a source, and represented by the yellow reticule.
3. Place a **test mass (block)** at rest in this inertial frame
4. If we move or rotate the source of the frame (wrt an arbitrary non-physical reference), the mass remains fixed to the frame



Starting from Scratch Options

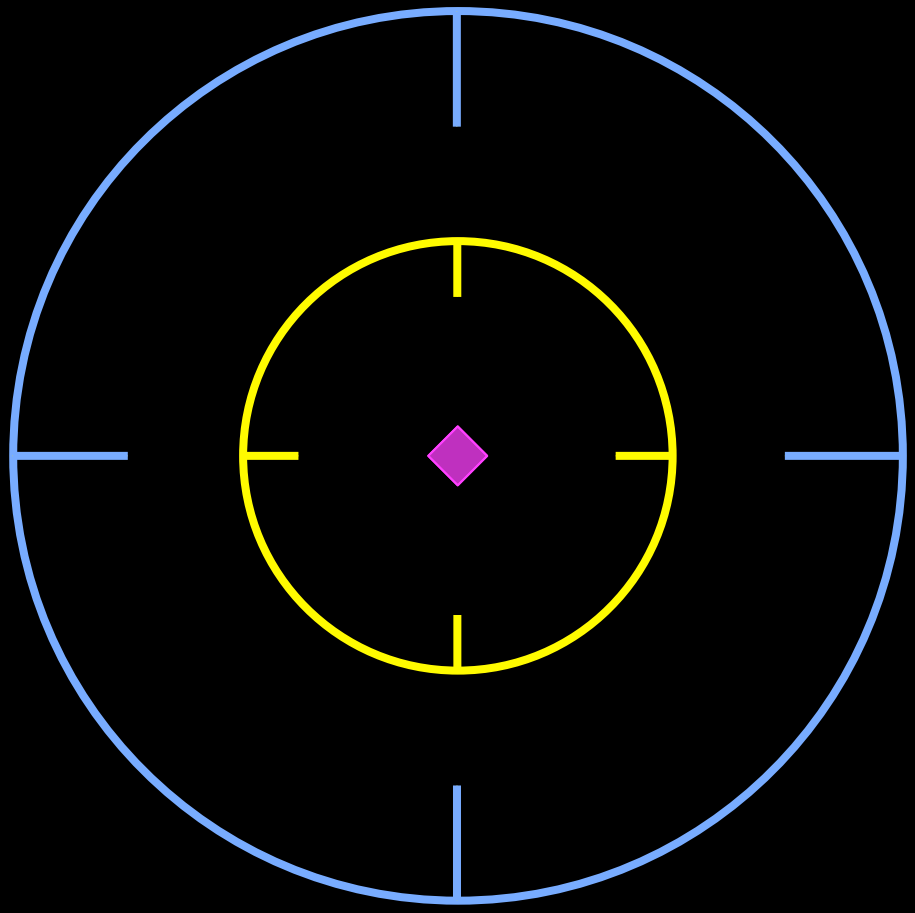
- 3D space + time? (additional dimensions?)
- What gives rise to inertial frame effects?
  - Mass?
  - Matter (energy)?
  - Charge?
  - Other or Combination (O/C)?

- Provisional (Spherical Shell) Representation

$$\Phi_f \propto \frac{S_f}{4\pi} \frac{M_f}{R}$$

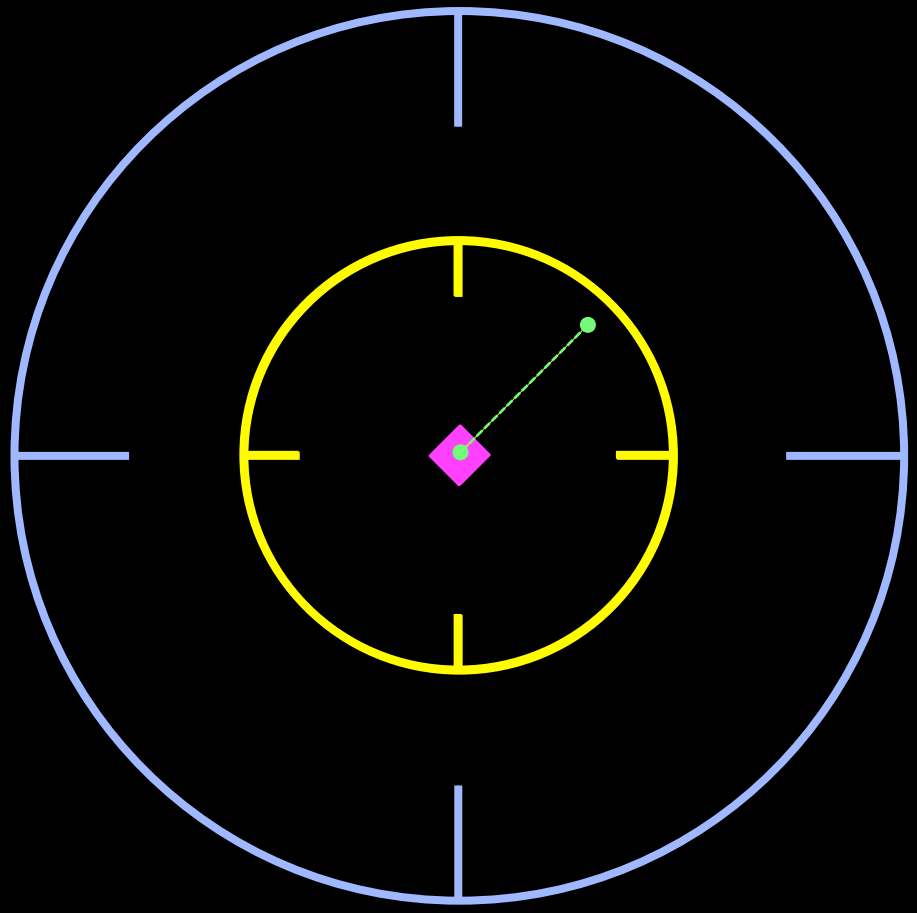
Add Another Inertial Frame

- Now place a second **inertial frame (reticule)** around the first
- Move the two frames and consider what happens to the test mass.



Proportionality of Sources

- What if only the Yellow Inertial Frame existed?
- What if only the Blue Inertial Frame existed?
- What if *both* frames contribute proportionally?

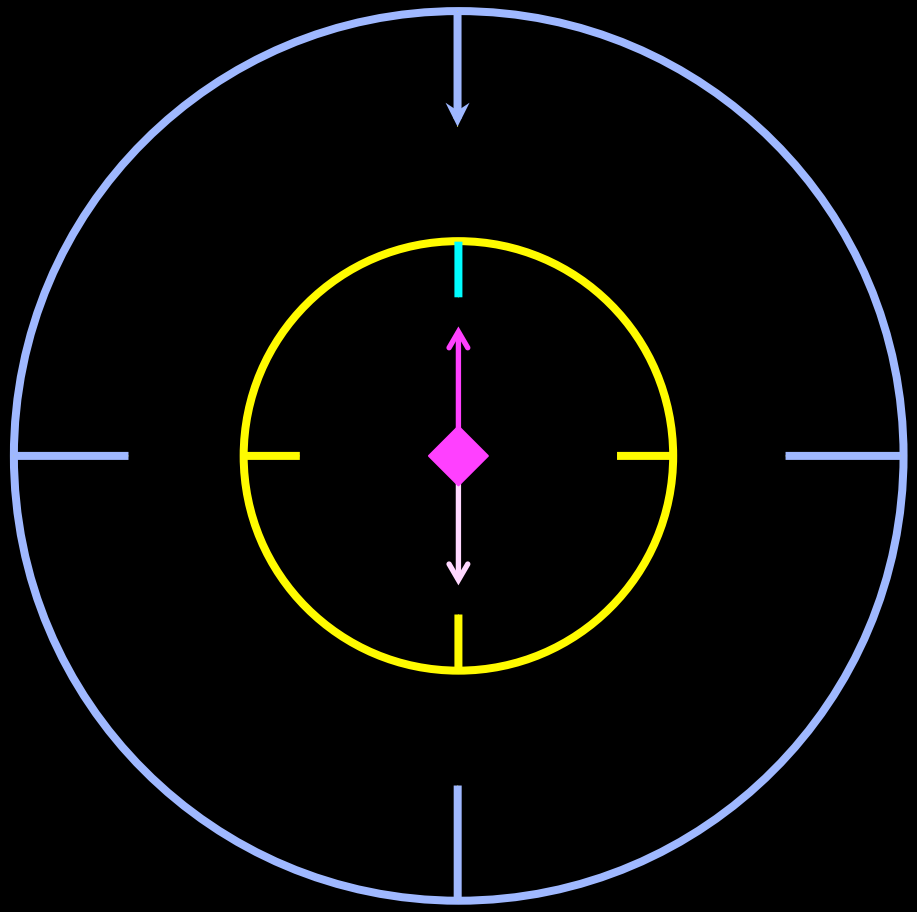


Inertial Frame Over Space - Options

- Distribution over 3D space and time?
  - Inverse square law
  - Waves
  - O/C?
- What supports [carries, transmits] the frame's effect?
  - Gravitational scalar potential and fields?
  - Electromagnetic quantum vacuum?
  - O/C?
- Summation of multiple frame contributions?
  - Linear superposition of scalar potential?
  - Linear superposition of vector properties?
  - Nonlinear?
  - O/C?

Comparative Inertial Frame Rotation

1. Without the outer frame, rotate the inner frame. By prior assertions, the test object will rotate in unison with the total frame (inner one only).
2. Bring back the outer frame, so that it contributes half to the total frame. The test object's rotation will be in between the two frames



Odd Correlation: Angular Momentum & Mass

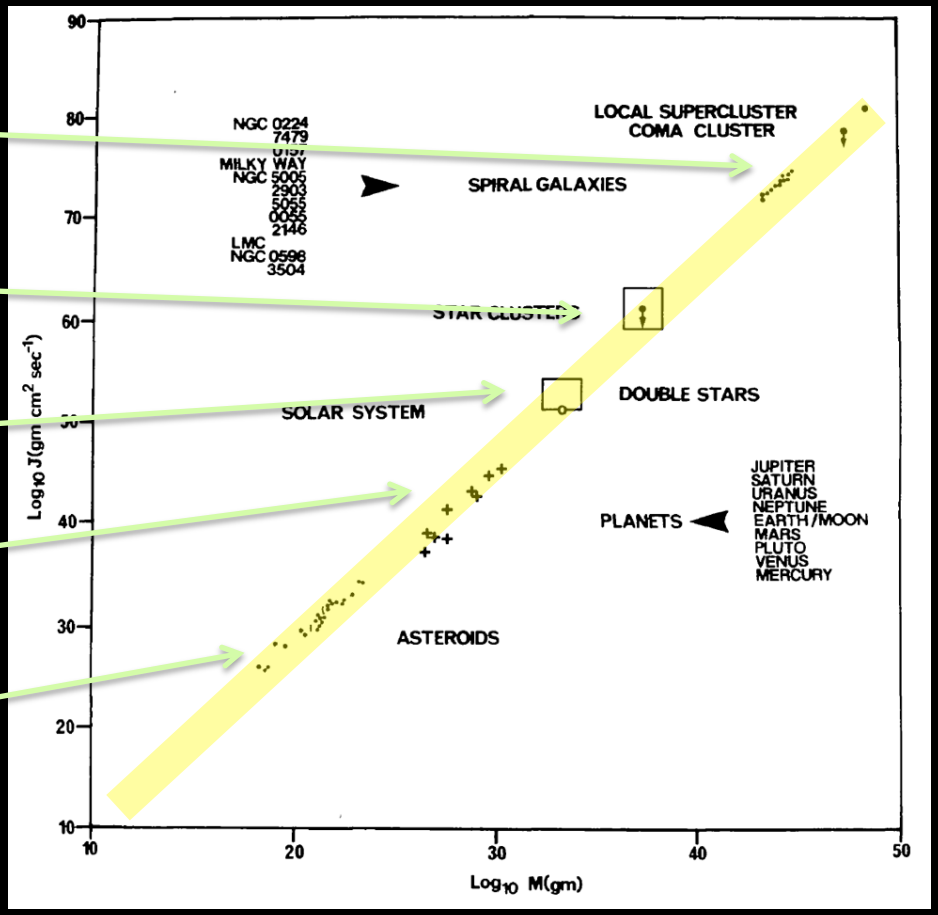
galaxies

star clusters

solar system

planets

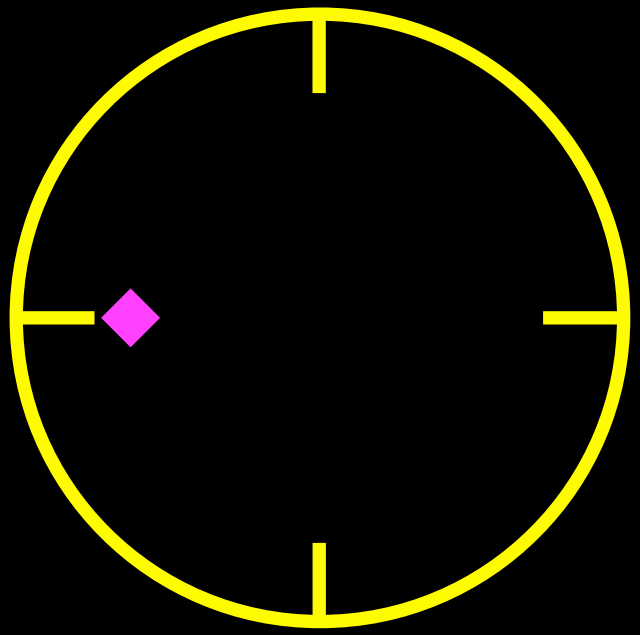
asteroids



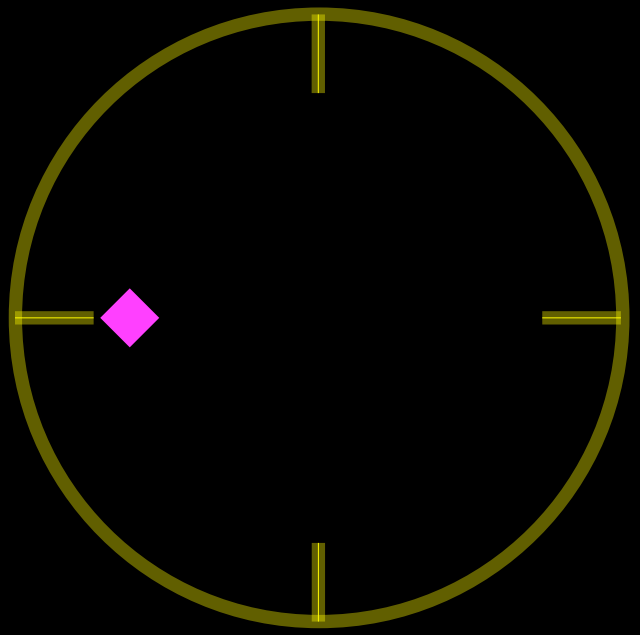
Wesson, P.S. 1979 Self-similarity and the Angular Momenta of Astronomical Systems, Astronomy and Astrophysics, 80, 296-300

How Does Inertial Frame Affect Inertia, Momentum, Kinetic Energy?

Greater Magnitude Inertial Frame



Lesser Magnitude Inertial Frame



- The same [force, momentum, energy] is applied to each test mass
- The resulting [acceleration, velocity] is less in the frame of greater magnitude… OR interpreted as a slowing of time

How Does Inertial Frame Affect Inertia, Momentum, Kinetic Energy?

$$F = f_i ma$$

$$P = f_i mv$$

$$E = \tfrac{1}{2} f_i mv^2$$

- Affects *apparent* inertial mass, *m*?
  - Requires a bare mass perspective?
  - Coefficient of inertial frame affect?
- Affects *apparent* rate of time?

Ever Notice This Exponential Expansion…?

Kinetic energy

Momentum

Inertia

Improper units

$$me^{v} = m + mv + \frac{1}{2}mv^{2} + \frac{1}{6}mv^{3} + \ldots$$

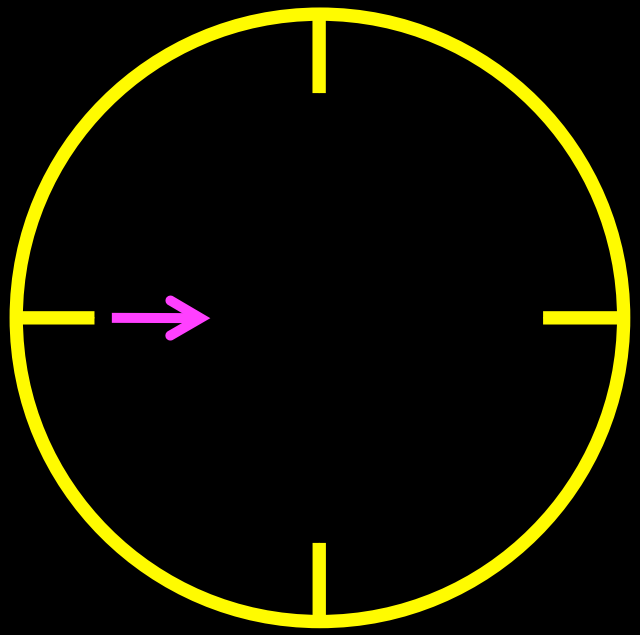
Proper units

$$me^{\frac{v}{c}} = m + m\frac{v}{c} + \frac{1}{2}m\left(\frac{v}{c}\right)^{2} + \frac{1}{6}m\left(\frac{v}{c}\right)^{3} + \ldots$$

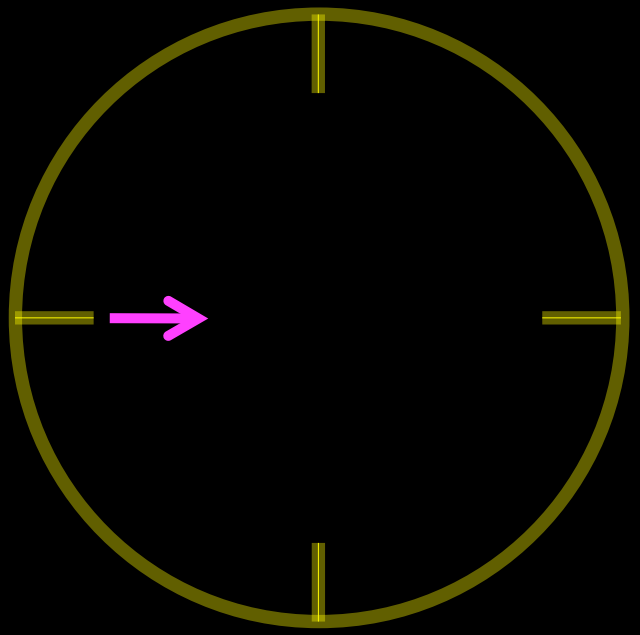
How Does Inertial Frame Affect Light Speed?

Akin to Optical Mechanical Analogy?

Greater Magnitude Inertial Frame



Lesser Magnitude Inertial Frame



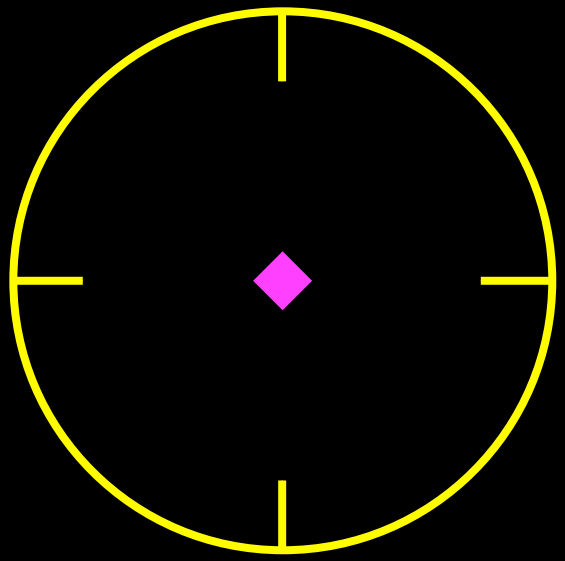
Laser bending in refraction gradient of settled sugar-water

Tau Zero Foundation

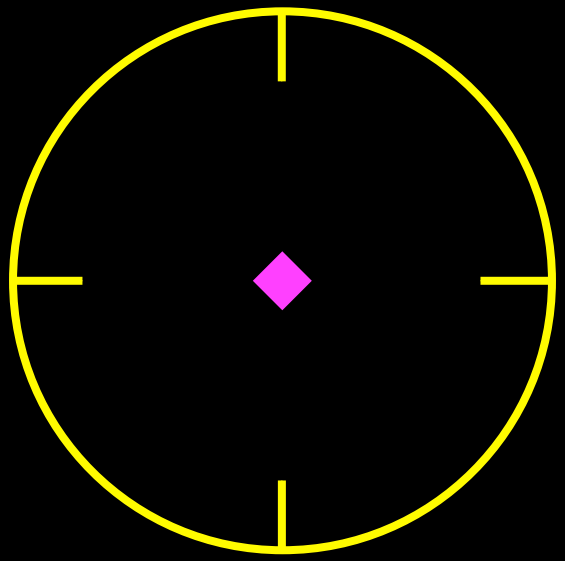
Propagation Delay ?

What if the inertial frame effect is something that propagates at finite speed?

If no delay



With finite delay



Frame Effect Propagation Rate Options

- Same as lightspeed, higher, or lower?
- Propagation Rate?
  - Constant relative to Null frame?
  - Constant relative to Inertial frame?
  - Variable - function of Inertial frame strength?
  - C/O?
- Waves?
  - Transverse or Longitudinal?
  - Dispersive media?

Which is "First," Gravitation or EM?

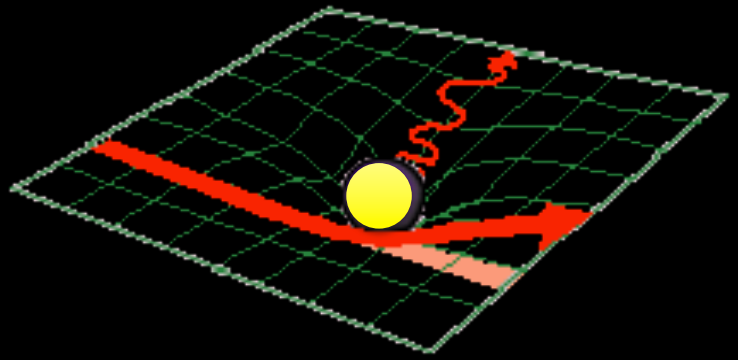
- Is *gravitation* a function of *electromagnetism*, or visa-versa?
- Is *mass* a consequence of *charge*, or visa-versa?
- For propulsion, it will be easier if $m = f(q)$

- **Electromagnetic Forces** [quantum]
  - Long-range (inverse square) forces between *charges*
  - Wave phenomena (light, transverse) → with $v = c$
  - Linked to the electroweak and nuclear forces
  - Does not affect mass (?)
- **Gravitational Forces** [fields or Riemannian geometry]
  - Long-range forces (inverse square) between *masses*
  - Wave phenomena → Quadrupole with $v = c$
  - Affects electromagnet propagation (general relativity)
  - Does mass affect charge?

Comparing Gravity to Electricity

- Gravitation affects electromagnetism
  - Light bends in a gravitational field (or in terms of curved spacetime)
  - Light redshifts when departing a gravitating body

- Photons have momentum, but no mass

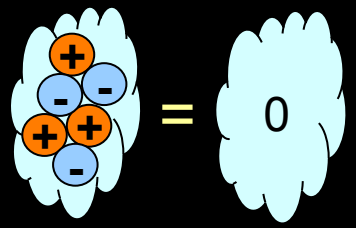


- Unknowns
  - Photon momentum in dielectric media is describable by two incompatible formalisms (Abraham–Minkowski controversy)
  - Presumed that speed of gravitation = lightspeed

Comparing Gravity to Electricity

- Gravitation much weaker than Electromagnetism –
  In Hydrogen, *gravitation* is smaller than *electric* by a factor of 10^{40}
  10,000,000,000,000,000,000,000,000,000,000,000,000,000

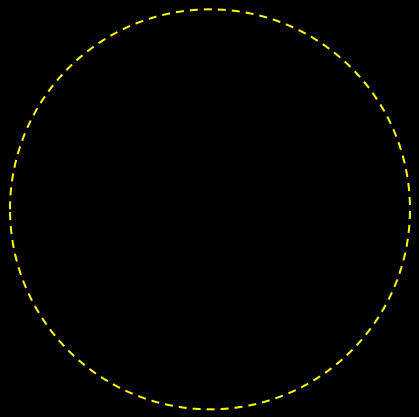
- Electric charge has two polarities (+) and (-)
  - Opposite charges can cancel = "off"
  - All charges have mass
  - Electrical fields can be affected by conductors and insulators



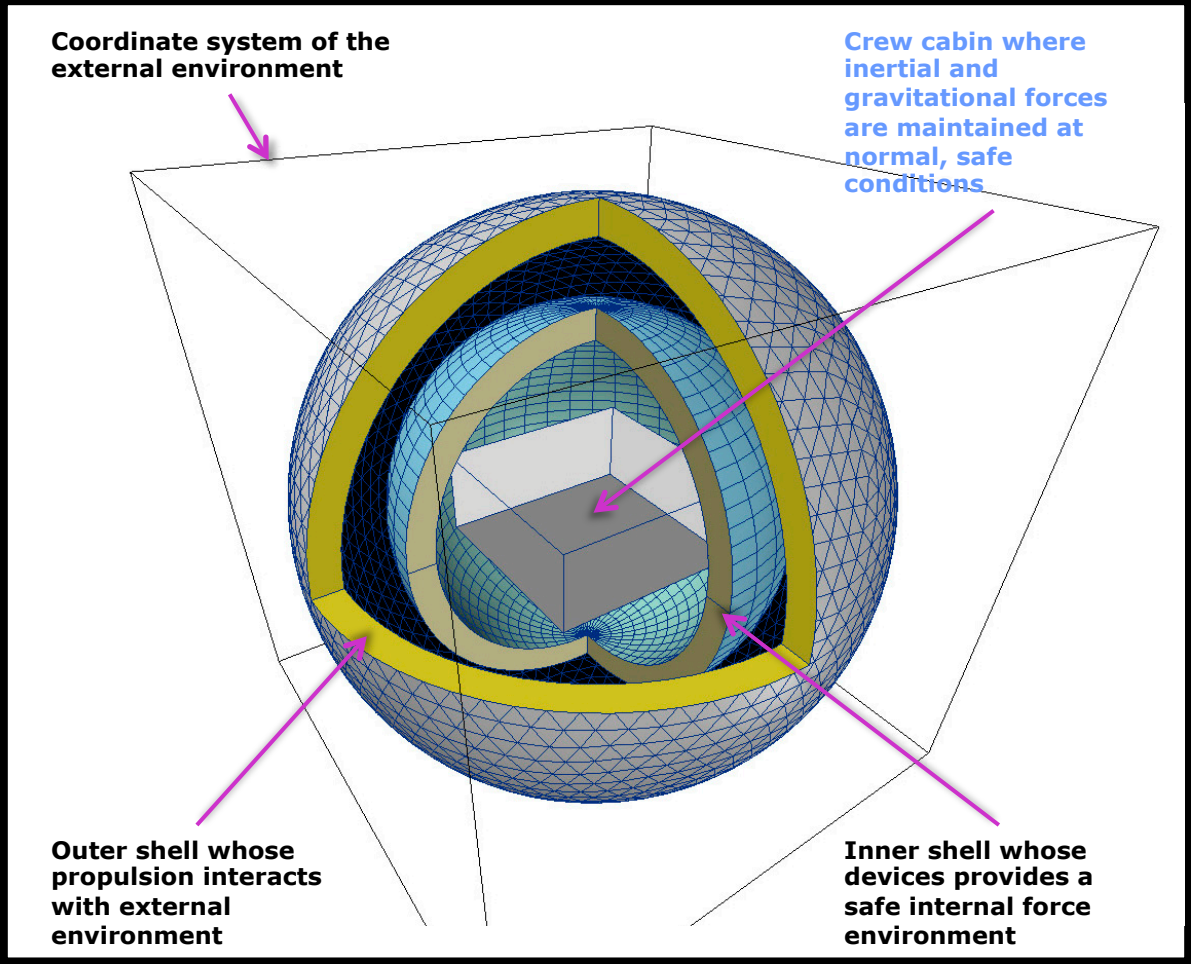
- Gravitational mass has one polarity (+) [maybe]
  - Gravity is always on
  - Not all masses have (net) charge
  - Gravity permeates everything – no gravitational insulators

What If's?

- Negative mass?
- Induce gravitational dipoles?
- Gravitational insulators?
- Gravitational 'lenses'?
- Analogies to a flux?



Another Ponderable Context:
Separation of Internal & External Inertial Frames



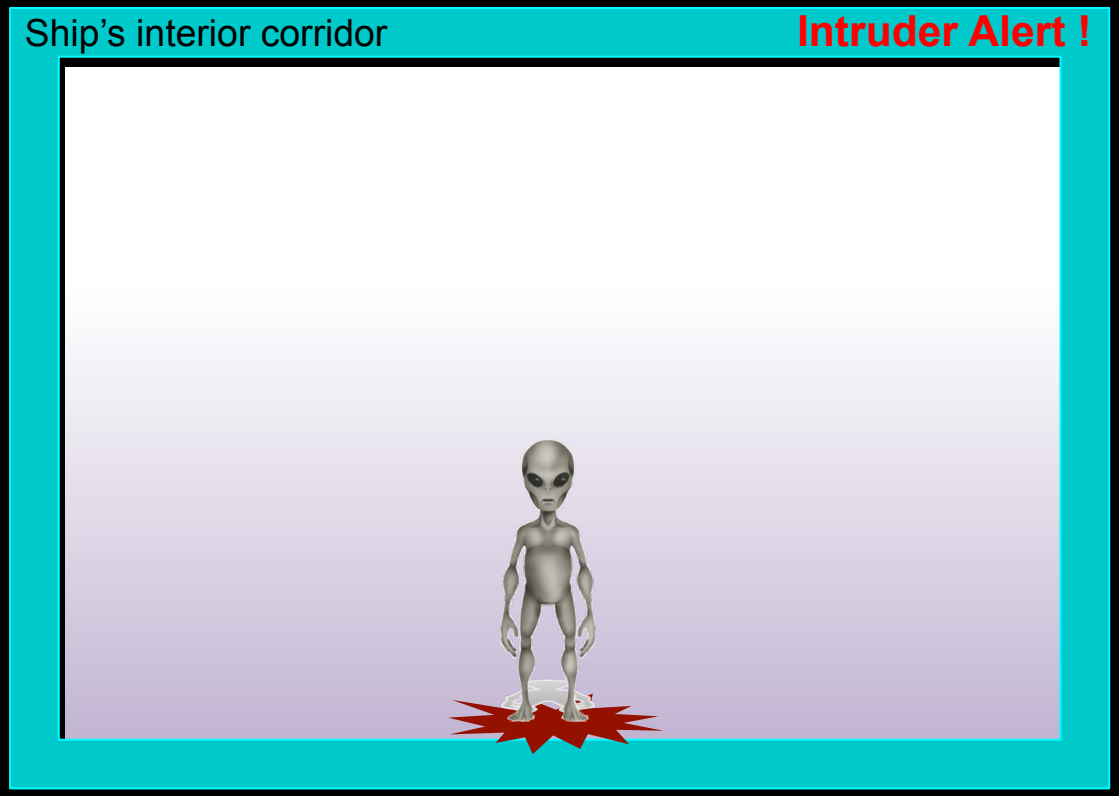
Millis (2013) Cockpit Considerations for Inertial-Affect and FTL Propulsion. *JBIS*, **66**, pp. 278-289.

“Just-In-Case” Charts Follow

Separate g's Inside & Out

- Needed for crew survival
  - High-g acceleration
  - Long duration spaceflight set to 1g
- Likely attribute and consequence of propulsion
- Loss of vestibular motion cues
- Loss of direct visual contact (no windows)

Pondering “Synthetic” Gravitation

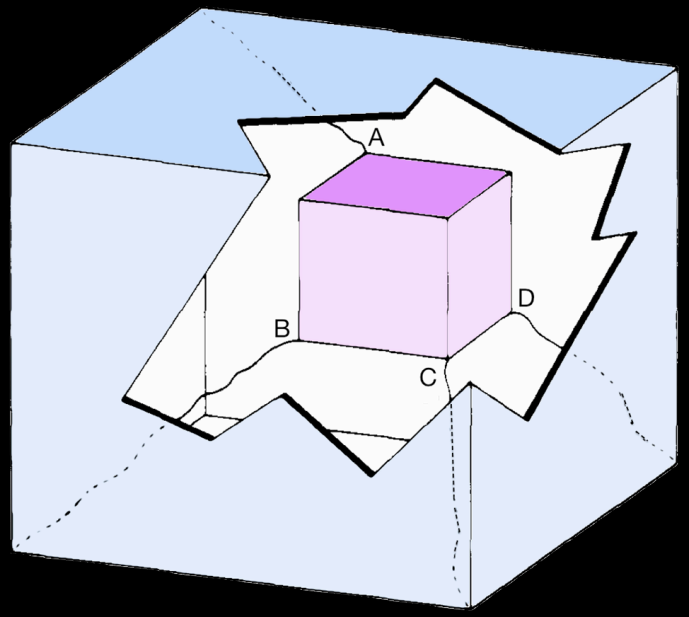


- What about increasing the intensity of the field?
- What about changing the direction of the field?
- What about oscillating the field?

Two Rotations to Return to Start

A consequence of 3D rotational transforms

- It's in the math
- It's physical



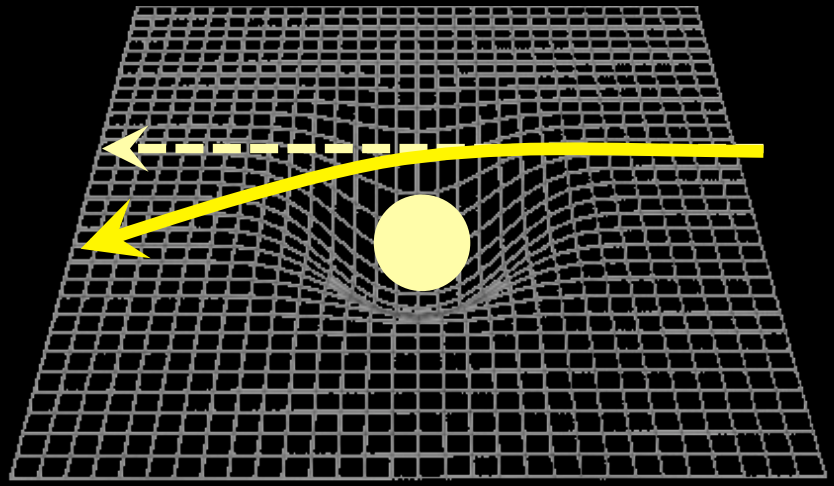
J. A. Wheeler *et al.*/1973

Two Perspectives of Gravitational Lensing

Warped Spacetime

Riemannian Geometry

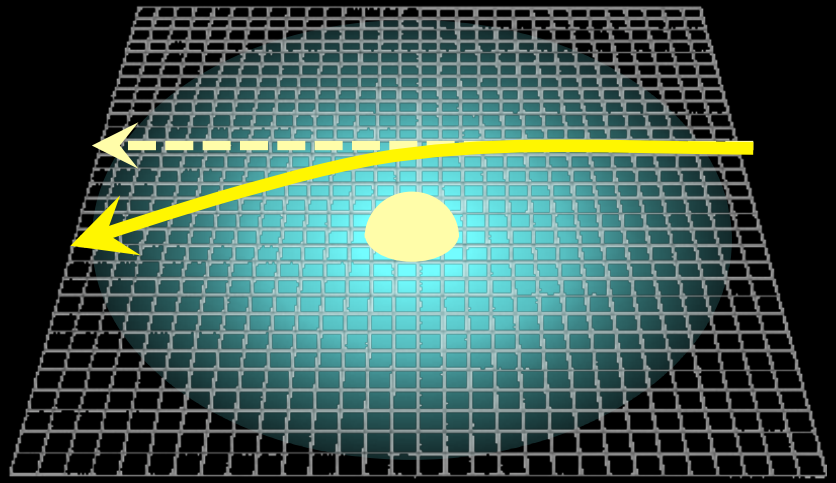
Light follows geodesic along curved spacetime



Variable Refractive Index

Euclidean Geometry

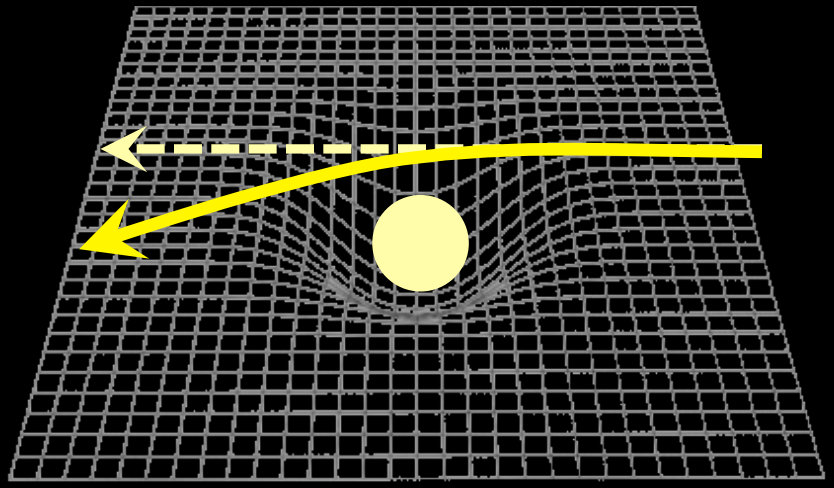
"Optical Mechanical Analogy"



Laser bending in refraction gradient of settled sugar-water

1919 Measurement of Gravitational Lensing

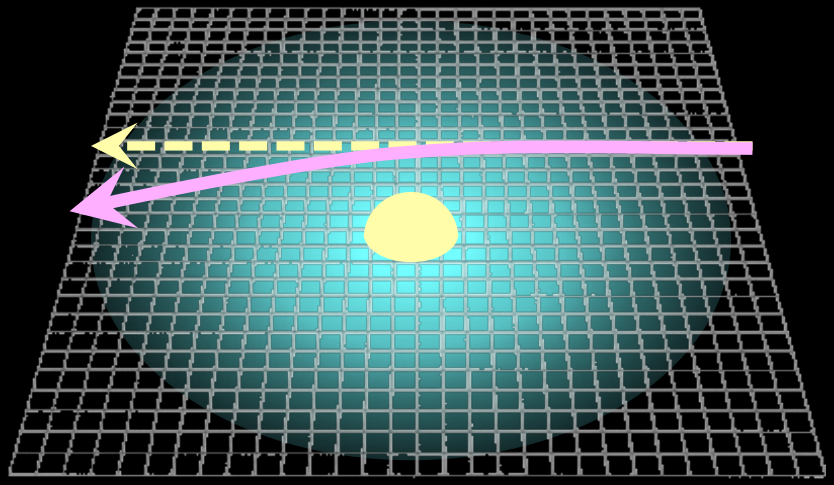
Warped Spacetime



$$(ds)^2 = \left[1 - 2G\frac{M}{rc^2}\right](cdt)^2 - \frac{(dr)^2}{\left[1 - 2G\frac{M}{rc^2}\right]} - r^2\left(d\theta^2 + \sin^2\theta(d\phi)^2\right)^2$$

$$\theta = 4G\frac{M}{rc^2}$$

Variable Refractive Index



$$n = n_0\left(1 + G\frac{M}{r}\right)$$

$$\theta = 2G\frac{M}{rc^2}$$

Revisions to Euclidian Formalism

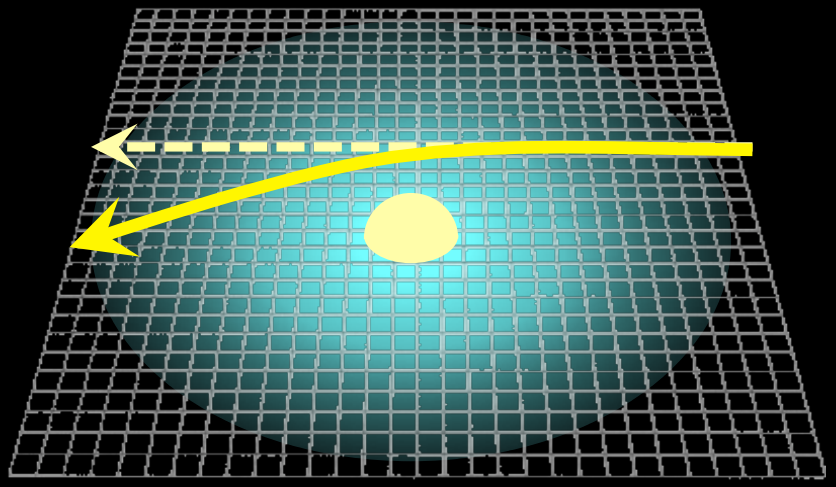
$$n = \frac{\left(1 + G\frac{M}{2rc^2}\right)^3}{\left(1 - G\frac{M}{2rc^2}\right)}$$

$$n = e^{\left(2G\frac{M}{rc^2}\right)} = 1 + 2G\frac{M}{rc^2} + \ldots$$

Where:

n = index of refraction of space, f(r,M)
c = light speed, 3 x 108 m/s
G = gravitational constant, 6.7 × 10-11 m3/kg s2
M = mass of gravitating body, kg
r = radius from center of gravitating body, m

Variable Refractive Index



Relevant to some inquires into "Mach's Principle" and the origin of inertial frames

Millis (2017). Inertial frames and breakthrough propulsion physics. *Acta Astronautica*.