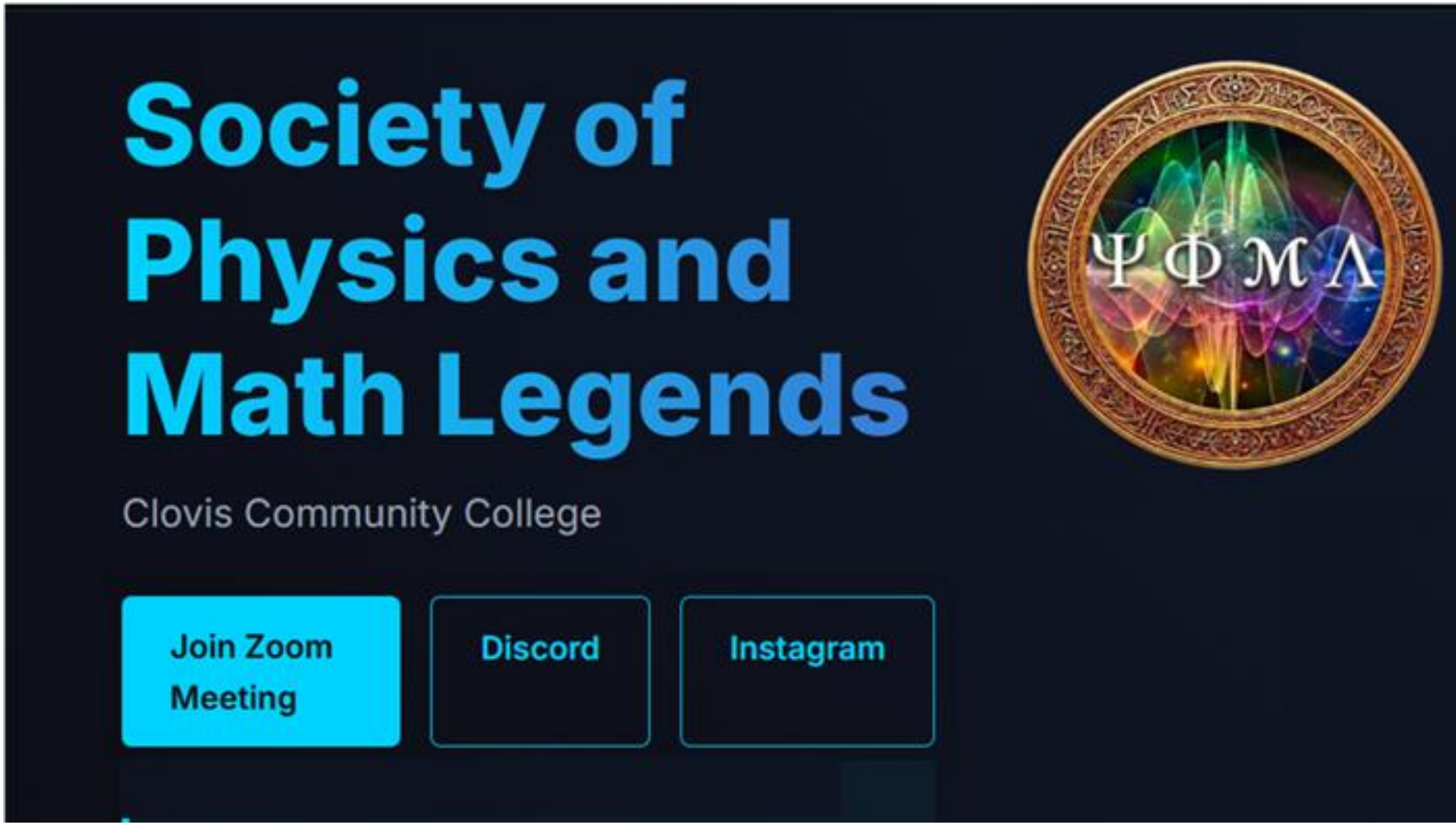
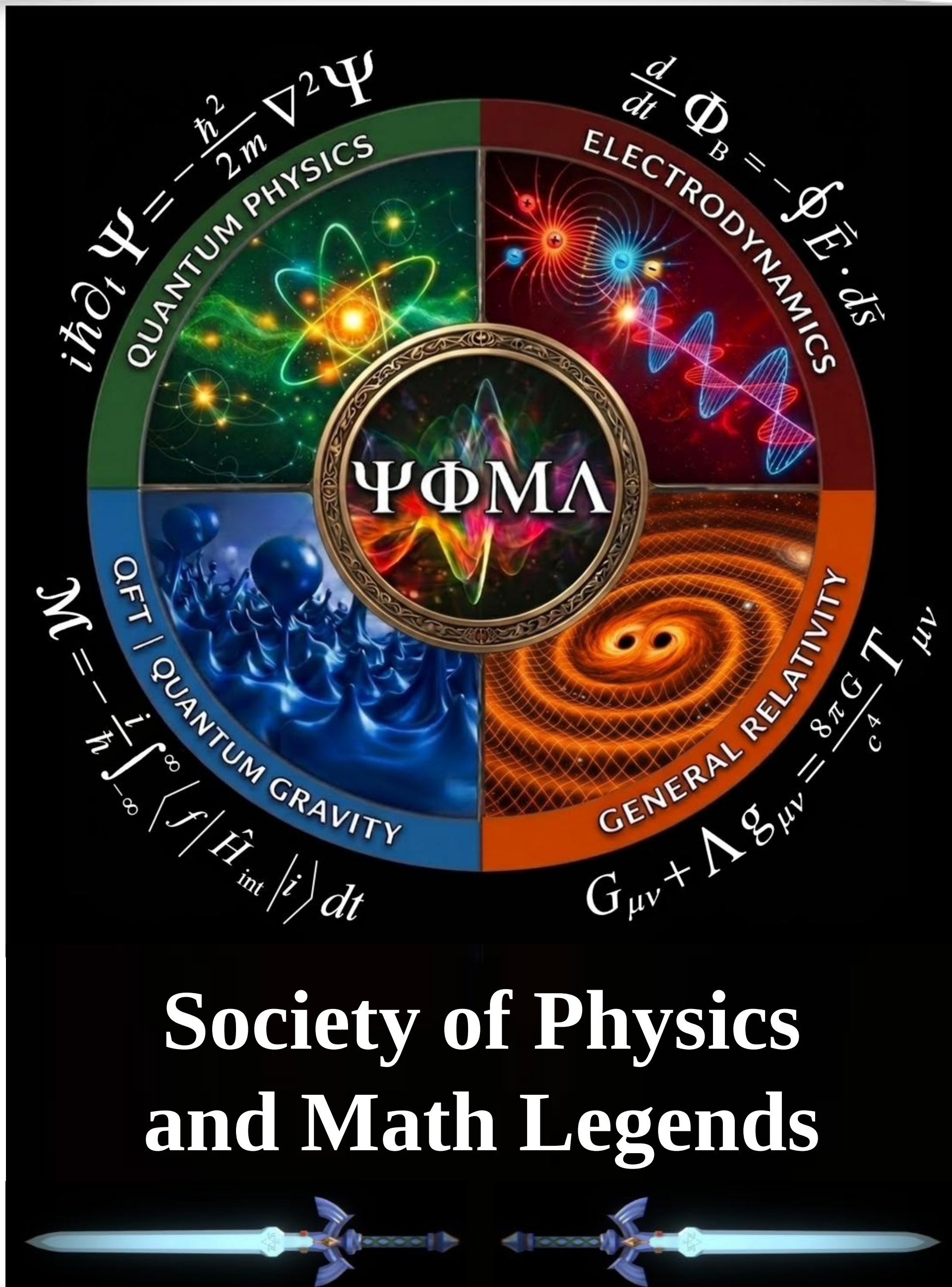


spml.netlify.app

ΨΦΜΛ

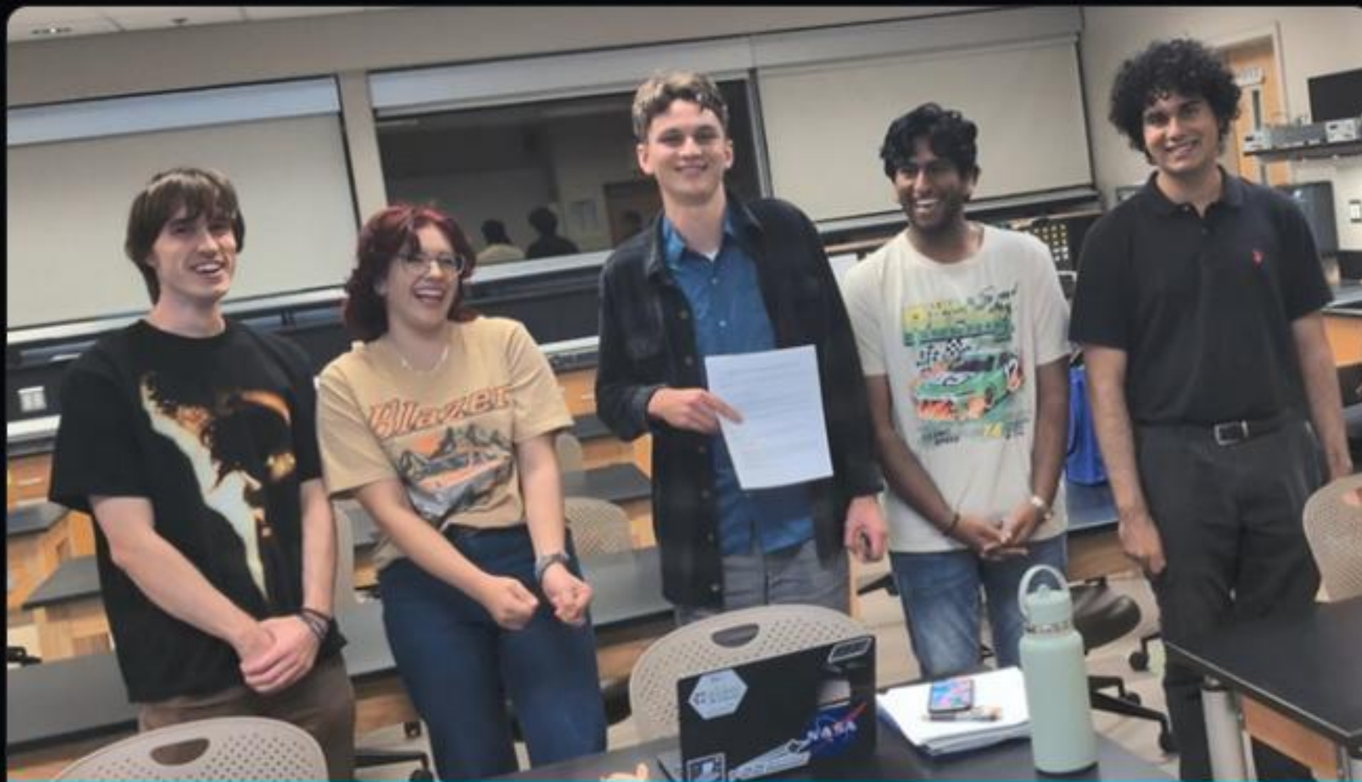


CLOVIS COMMUNITY COLLEGE

Members of the Society of Physics and Math Legends

- Jorel Abrantes
- Tyler Bridges
- Maximus Cappello
- Malika Castro-Neal
- Lucas Cox
- Efrain Cuellar
- EJ De Jesus
- Alan Erikson
- Antonio Estrada
- Rana Eyit
- Courtney Gainer
- Joseph Galarza
- Anureet Ghuman
- Mariah Gonzales
- Santino Gonzales
- Ethan Hall
- Lucia Hidalgo
- Jesse Holmes
- Dan Humphrey
- Erika Inan
- Sam Kann
- Gagik Khachatryan
- Gavin Kiggins
- Matthew Leeper
- Tyrell Lopez
- Mark Madla
- Muhammad Masood
- Rey Mendoza
- Mathew Oaks
- Joy Onyia
- Esteban Ornelas
- Rajdeep Pannu
- Priyanshu Patel
- Brandon Sayre
- Alexandra Scarano
- Julian Schmidt
- Maggie Schuler
- Chloe Sedehi
- Ella Nicole Siadto
- La Min Tun
- Carlos Vasquez
- Roxanne Vasquez
- Zach Watts
- Hayven Williams
- Mussie Yigzaw
- Samantha Young
- Zachary Zamudio
- Ivy Zheng

Club Officers (Legends!)



Zach G | President

Diego H | Vice President

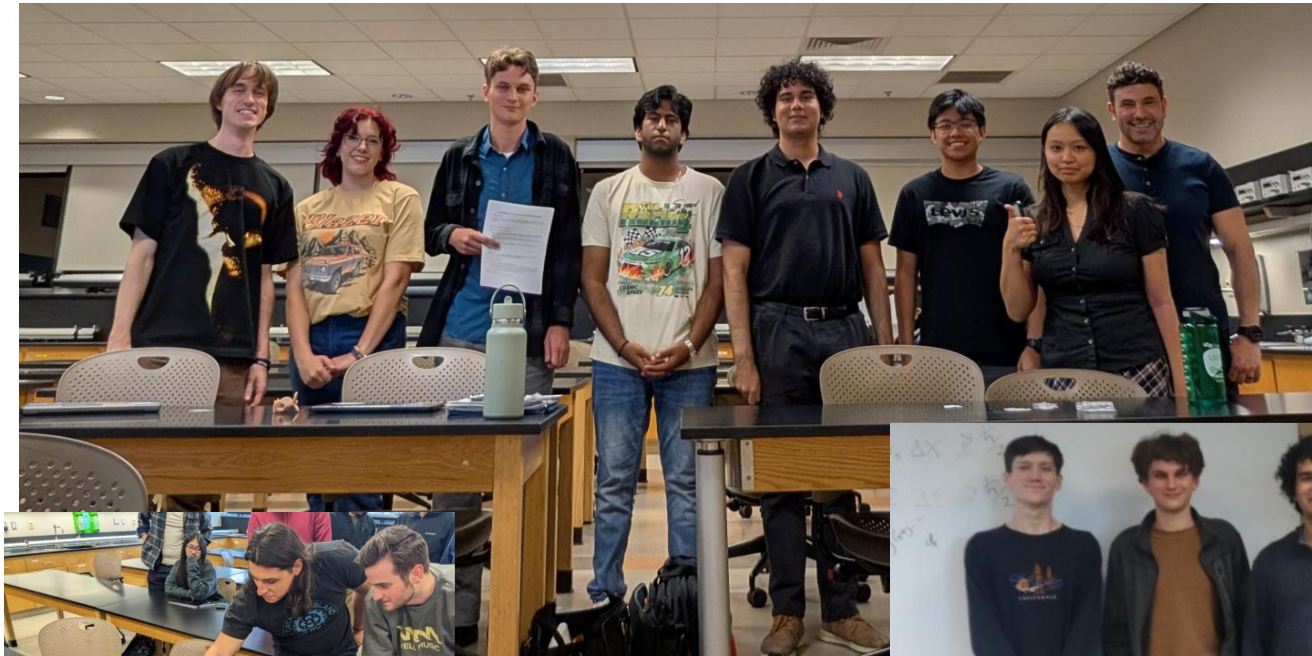
Ishan A | Treasurer

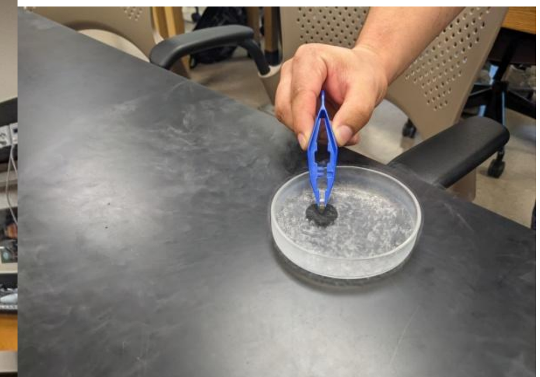
Rose Z | Secretary

Antonio N | Event Co-Coordinator

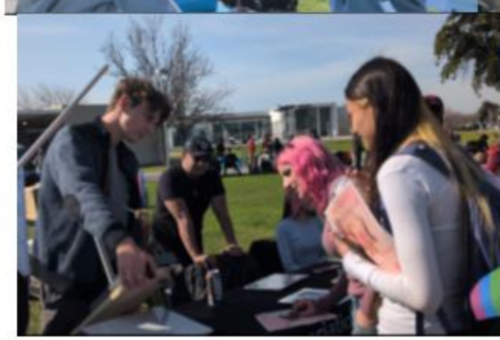
Mathew A | Event Co-Coordinator

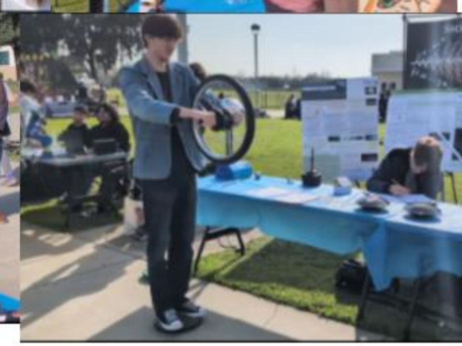
Club meetings and Outreach





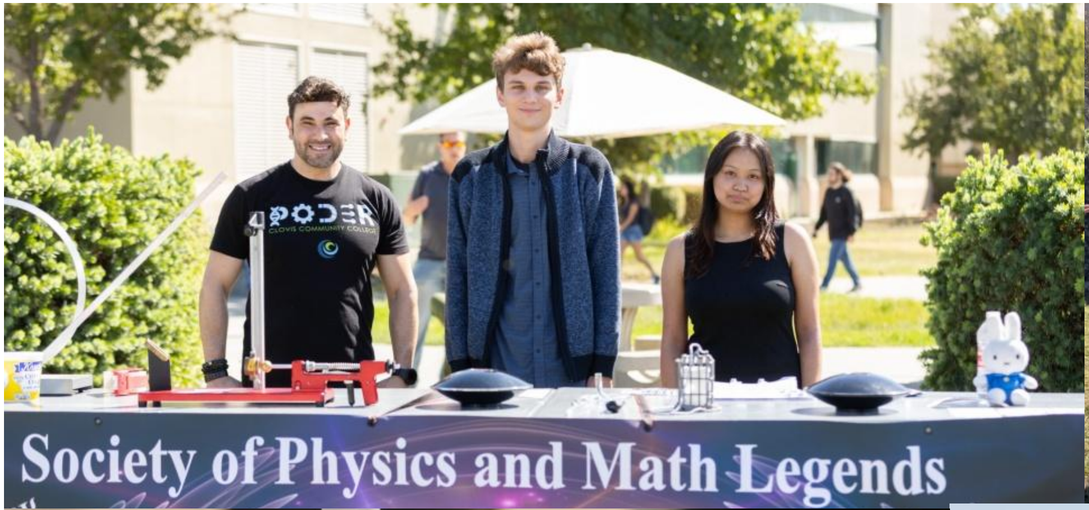
Club Rush (2026)

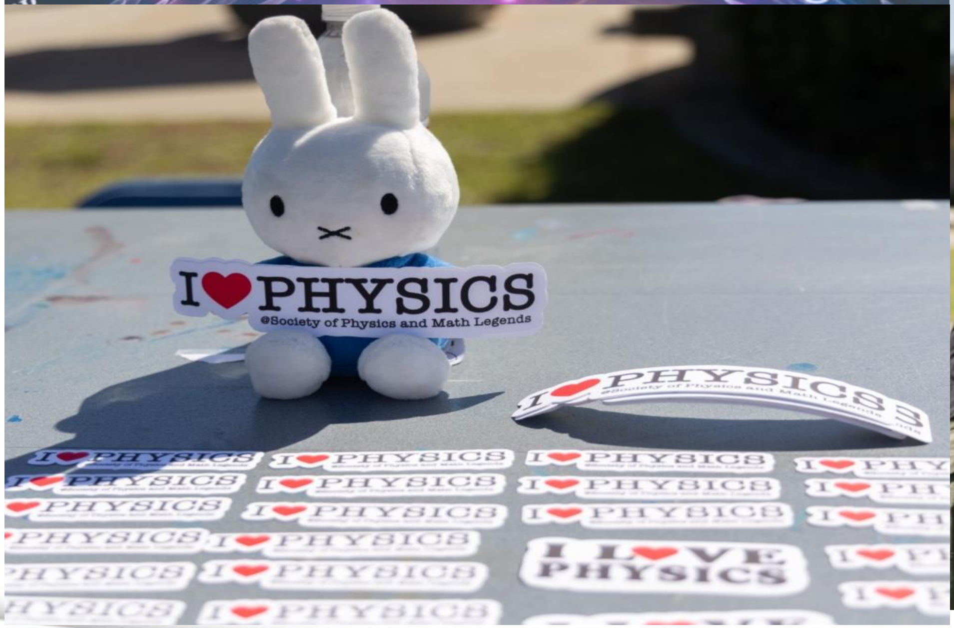




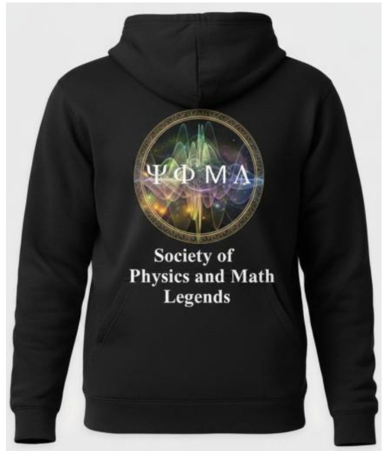
Spring Extravaganza (2026)

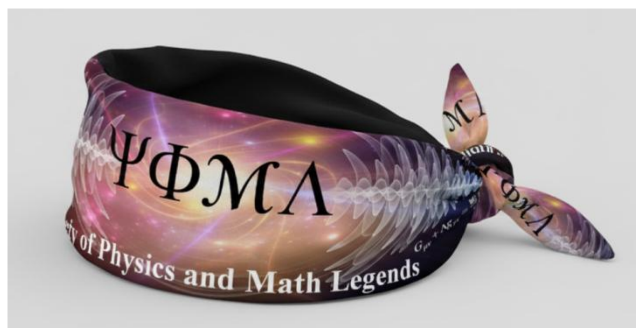
STEM Day (2025)



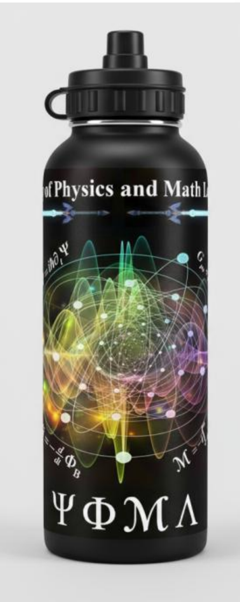


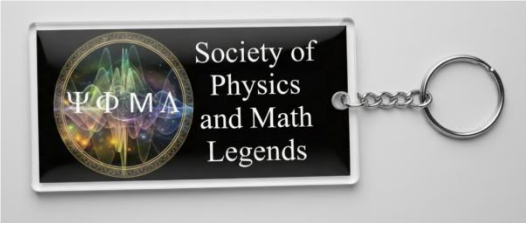
Check out our club merch!

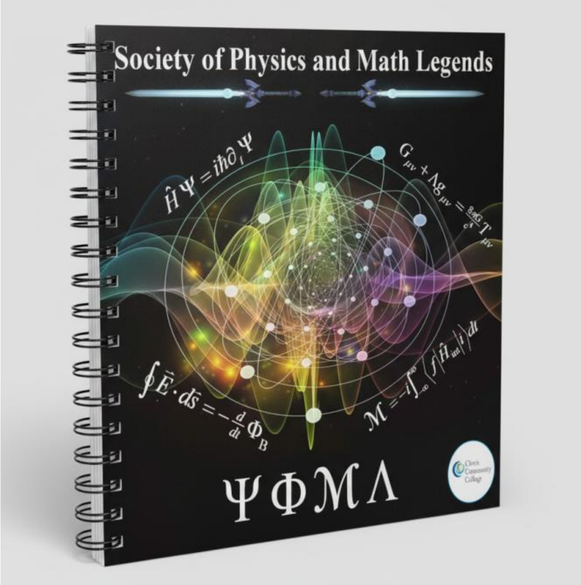




Check out our club merch!







Pacific Coast Gravity Meeting at UC Riverside (2026)

The 42nd Pacific Coast Gravity Meeting

Friday, February 27, 2026 -

Saturday, February 28, 2026

University of California, Riverside

Featuring introductory remarks by 2017 Nobel Laureate Barry Barish

Session VIII: Gravity Theory, HUB 302 North (map)

Zach Ghosoph, Clovis Community College

From Linearized GR to Quantum Gravity via Canonical Quantization

Diego Hidalgo, Clovis Community College

From Quantum Gravity to Linearized General Relativity via Bohr Correspondence

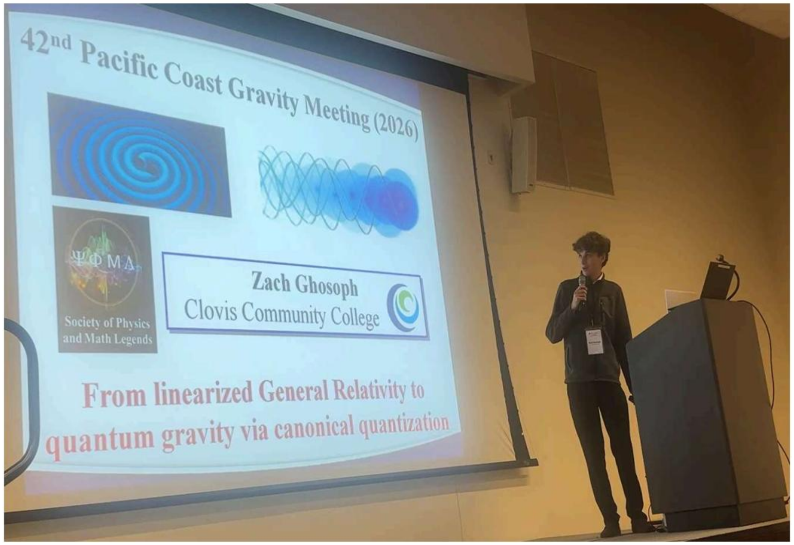
Rose Zanoni, Clovis Community College

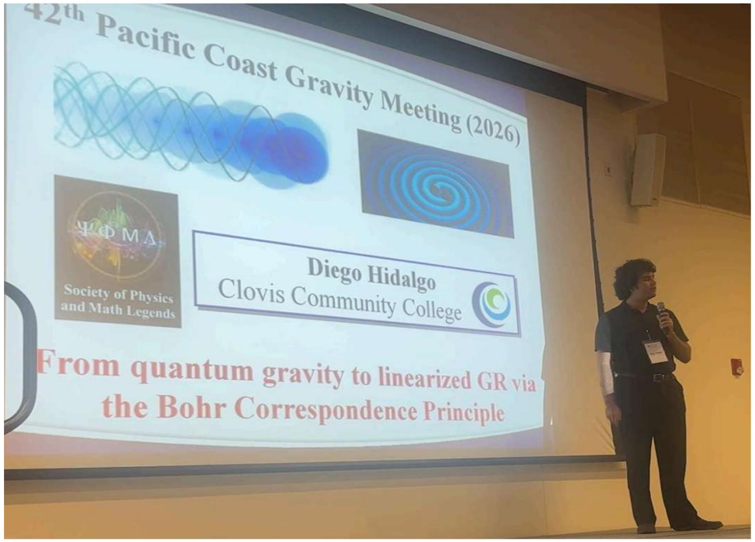
Resolving the Cosmological Constant Problem via quantum space-time uncertainty

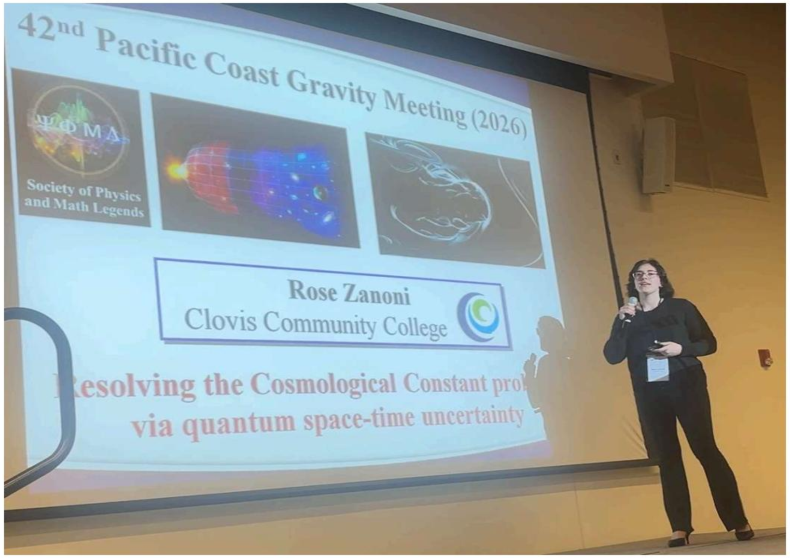
Nathan Inan, Clovis Community College

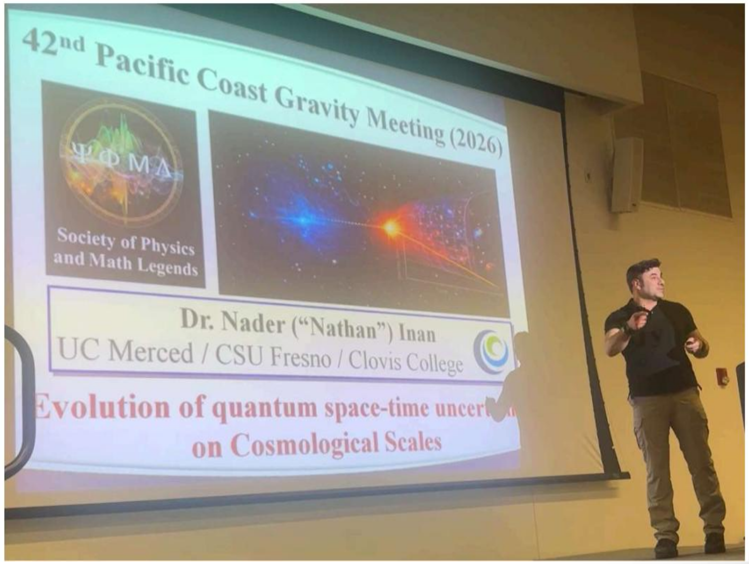
Evolution of Quantum Space-Time Uncertainty on Cosmological Scales

Pacific Coast Gravity Meeting at UC Riverside (2026)









APS Far West Section Meeting (2025)

Present your research at the

2025 American Physical Society
Far West Section Meeting

October 10-12, 2025

APS

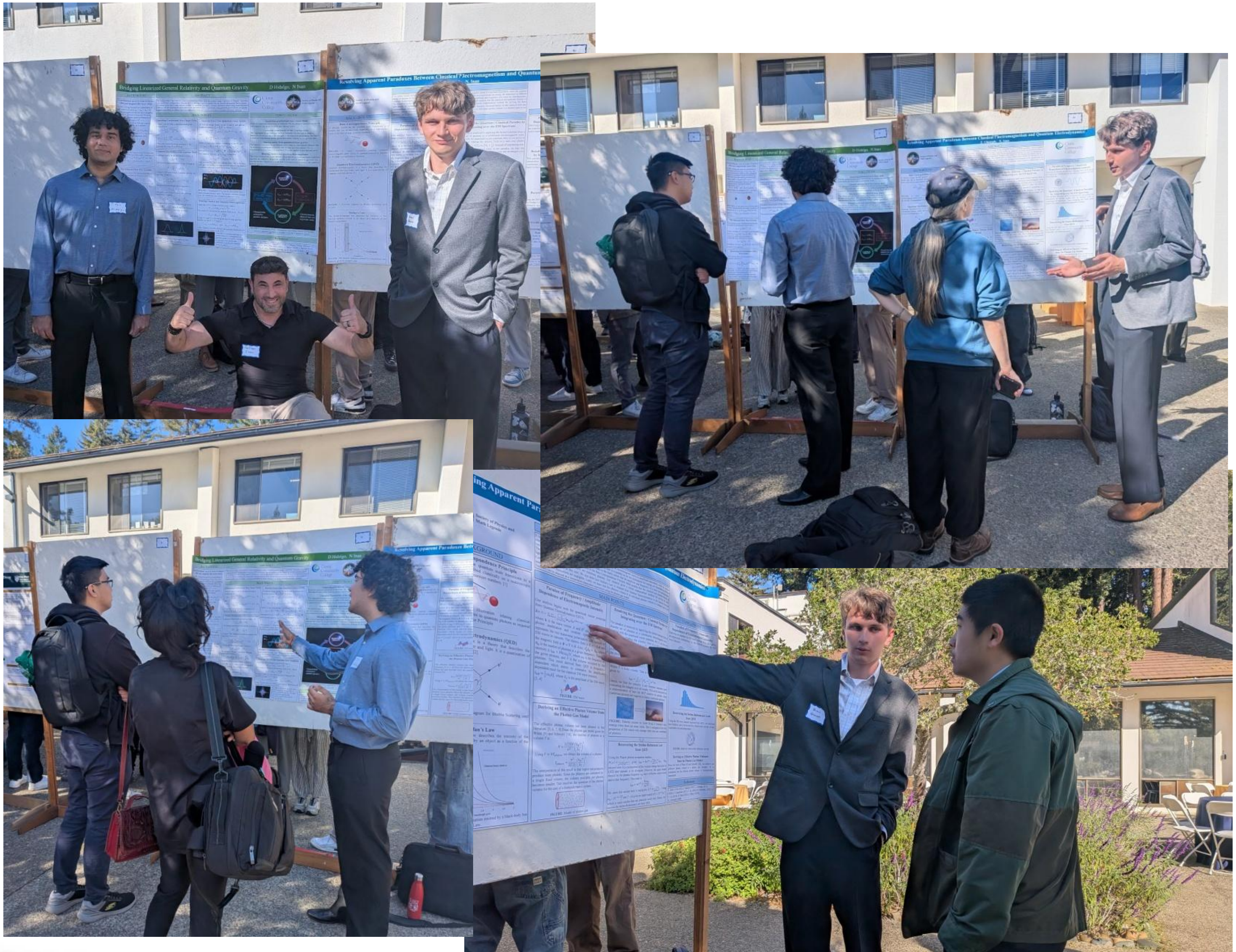
UC SANTA CRUZ | Science

Quantum Design
NORTH AMERICA

GENERAL ATOMICS

UC SANTA CRUZ

APS Far West Section Meeting (2025)



Resolving Apparent Paradoxes Between Classical Electromagnetism and Quantum Electrodynamics

Z. Ghosoph, N. Inan

ABSTRACT

It is widely known within the physics community that the classical energy of electromagnetic waves is amplitude-dependent, while the quantum energy of photons is frequency-dependent. This statement seems to lead to a paradox as the two expressions for energy are dependent on different variables. Furthermore, equating these two expressions leads to the faulty notion that the amplitude and frequency of a wave are interdependent. The resolution to this apparent paradox is found in the Bohr Correspondence Principle which predicts that the classical and quantum theories of light should be consistent when there are numerous photons. Our research gives a formal mathematical method for proving the Bohr Correspondence Principle in this case. We also show how Stefan's Law is obtained from Quantum Electrodynamics in the classical limit that quantum vacuum fluctuations are negligible. Lastly, we show that the effective volume of an individual photon (which is a debated topic in the literature) can be obtained as a temperature-dependent expression using the photon gas model.

BACKGROUND

Bohr Correspondence Principle

A physical system on the quantum scale transitions to a system that can be described classically on a macroscopic scale in the limit of large quantum numbers. [1]

FIGURE: A visual illustration relating classical electromagnetic waves to quantum photons as required by the Bohr Correspondence Principle

Quantum Electrodynamics (QED)

Quantum Electrodynamics is a theory that describes the interactions between matter and light. It is a quantization of classical electrodynamics. [2]

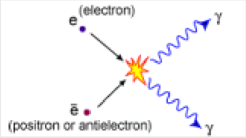


FIGURE: A Feynman Diagram for positron-electron annihilation used in QED

Stefan's Law

Stefan's law, also known as the Stefan-Boltzmann law, is a physical law describing the intensity of the thermal radiation emitted by an object as a function of the object's temperature.

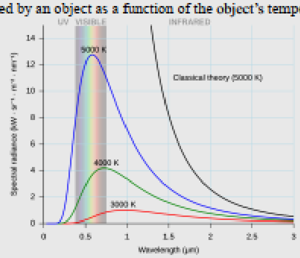


FIGURE: The thermal radiation emitted by a black-body has intensity given by Stefan's Law.

RESULTS

Paradox of Frequency / Amplitude Dependence of Electromagnetic Intensity

Our analysis begins with the quantized vector potential from Quantum Electrodynamics (QED):

$$A = \sum_{\mathbf{k}} \sum_{p=1}^{2} A_0(\omega_{\mathbf{k}}) \left[\mathbf{e}_{\mathbf{k},p} \hat{a}_{\mathbf{k}} e^{i(\mathbf{k}\cdot\mathbf{r}-\omega_{\mathbf{k}} t)} - \mathbf{e}^{*}_{\mathbf{k},p} \hat{a}^{\dagger}_{\mathbf{k}} e^{-i(\mathbf{k}\cdot\mathbf{r}-\omega_{\mathbf{k}} t)} \right],$$

where $A_0(\omega_{\mathbf{k}}) \equiv \sqrt{\frac{\hbar}{2\varepsilon_0 V \omega_{\mathbf{k}}}}$ is the quantum amplitude, $\mathbf{k}$ is the wave vector, $\hat{a}$ and $\hat{a}^{\dagger}$ are the respective photon annihilation and creation operators, and $\mathbf{e}_p$ represents the two transverse polarization unit vectors of EM waves in vacuum. The electric field is $E = -\partial_t A$ and the magnetic field is $B = \nabla \times A$. Also, $\hat{a}^{\dagger}_{\mathbf{k}} \hat{a}_{\mathbf{k}} = N_{\mathbf{k}}$, where $N_{\mathbf{k}}$ is the number of photons at a given frequency. Then the intensity is $I_{EM} = N\hbar c\omega_0/V$, where ω_0 is the frequency of the given photons, and V is the volume occupied by the photons. This result derived from QED is frequency-dependent which seems to contradict the amplitude-dependent result for the classical electromagnetic (EM) wave intensity, $I_{EM} = \frac{1}{2} c\varepsilon_0 E_0^2$, where E_0 is the amplitude of the EM wave. [3, 4]

Resolving the Quantum / Classical Paradox by Integrating over the EM Spectrum

The paradox is resolved by applying the formal transition from a discrete set of photons to a continuous electromagnetic wave. Starting with the quantized vector potential, $A(r,t)$, we arrive at the equation relating the electric field to a sum over photon modes: $\varepsilon_0 E^2 V = \hbar \sum \omega_k \left(N_k + \frac{1}{2} \right)$. Instead of considering only a single frequency which leads to the paradox, we take the classical limit by converting this summation into an integral over the photon wavenumber:

$$\sum_k f(k) \to \frac{2V}{(2\pi)^3} \int f(k)(4\pi k^2 dk).$$

Time averaging this expression leads to the intensity of the electromagnetic wave:

$$I_{\mathrm{EM}} = \frac{\hbar}{\pi^2 c^2} \int \left(N_\omega + \frac{1}{2} \right) \omega^3 d\omega .$$

Hence, we find the intensity is not frequency dependent once evaluating the integral over all modes. This can be interpreted as a demonstration of how the BCP resolves the paradox, since numerous photons are required to form a continuous spectrum.

FIGURE: Patterns created by birds flying in formation only emerge when there are many birds. This is analogous to how the properties of EM waves only emerge when there are a multitude of photons.

Deriving an Effective Photon Volume from the Photon Gas Model

The effective photon volume has been debated in the literature. [5, 6, 7, 8] From the photon gas model given by Wiese [9] and Schwabl [10], the number of photons in a volume V is

$$N = \frac{2\zeta(3)V}{\pi^2} \left(\frac{k_B T}{\hbar c} \right)^3$$

Using $V = NV_{photon}$, we obtain the volume of a photon:

$$V_{photon} = \frac{\pi^2}{2\zeta(3)} \left(\frac{k_B T}{\hbar c} \right)^3$$

The interpretation of this result is that higher temperatures produce more photons. Since the photons are contained by a single fixed volume, the volume available per photon becomes smaller. This resolves the question of the photon volume for the case of a thermodynamic system.

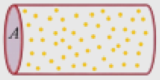


FIGURE: Model of a photon gas

Recovering Stefan's Law from QED

Using the Planck occupation number, $N(\omega) = \frac{1}{e^{\hbar\omega/(k_B T)}-1}$, gives $I_{\mathrm{EM}} = 4\sigma T^4 + \frac{\hbar c\omega_p}{2\pi^2 V} \int_0^{\infty} d\omega$, where $\sigma = \frac{\pi^2 k_B^4}{60 c^2 \hbar^3}$. The second term is a consequence of the vacuum energy that exists in QED and appears to be divergent. However, the upper bound of the integral should be the plasma frequency (ω_p) since reflection cannot occur above that frequency. This leads to

$$I_{\mathrm{EM}} = 4\sigma T^4 + \frac{\hbar c\omega_p}{2\pi^2 V}$$

The second term is negligible if $V \gg \frac{\hbar c\omega_p}{2\pi^2 4\sigma T^4}$. Using $\omega_p \sim 10^{-16} \frac{rad}{s}$ and $T \sim 1\mathrm{K}$ gives an upper bound of $V \sim 10^{-20} m^3$, which is vastly smaller than any practical cavity size. Hence, we recover the Stefan-Boltzmann Law from QED.

CONCLUSIONS

Paradox of Frequency / Amplitude Dependence of Electromagnetic Intensity

Deriving EM wave intensity from QED gives an expression that appears contradictory to the classical EM wave intensity.

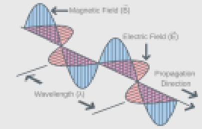
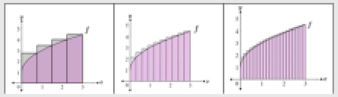


FIGURE: EM wave

Resolving the Quantum / Classical Paradox by Integrating over the EM Spectrum

The paradox above is resolved by turning the summation of discreet modes into an integral over a continuum of frequencies. This leads to the classical intensity equation.



Recovering the Stefan's Law from QED

Using the EM wave intensity derived from QED, we showed how Stefan's Law is recovered for a black body cavity.

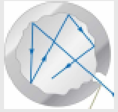


FIGURE: Model of a black-body radiation cavity

Effective Photon Volume

We derive a temperature dependent photon volume from the photon gas model.

References

Bohr (1918-1923); 2. Sakurai (1967); 3. Atonga, et al. (2024); 4. Goenawan (2021); 5. Xu (2021); 6. Huchin (2021); 7. Liu (2016); 8. Meis (2023); 9. Weise (2010);
10. Schwabl (2000)

Bridging Linearized General Relativity and Quantum Gravity

D Hidalgo, N Inan

Clovis Community College

PODER — CLOVIS COMMUNITY COLLEGE

Society of Physics and Math Legends

BACKGROUND

Gravitational waves in terms of electric-like and magnetic-like tensor fields

In GR, writing the metric using a perturbation to flat space-time gives $g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$. For gravitational waves in linearized GR, the propagating degrees of freedom are the transverse-traceless (TT) spatial perturbations, h_{ij}^{TT}, where $\partial_i h_{ij}^{TT} = 0$ and $\eta^{ij} h_{ij}^{TT} = 0$. [1] Electric-like and magnetic-like tensor fields can be defined, respectively, as [2]

$$E_{ij} \equiv -\partial_t h_{ij}^{TT} \quad \text{and} \quad B_{ij} \equiv \varepsilon_{ikl}\partial_k h_{lj}^{TT} \quad (1)$$

These fields are analogous to $\vec{E} = -\partial_t \vec{A}$ and $\vec{B} = \nabla \times \vec{A}$ in electromagnetism (EM).

FIGURE 1: A test particle in an EM field (left) versus a gravitational field (right). Equations of motion are $a^i = \frac{q}{m}\left(E^i + \varepsilon_{ijk} v^j B^k\right)$ for EM and $a^i = v^j E_{ij} + \frac{1}{4} v_j v_k \left(\varepsilon_{ijk} B_{lk} + 2\varepsilon_{ikl} B_{lj}\right)$ for linearized GR.

The Isaacson Power Flux Formula

The Isaacson power flux formula describes the intensity of gravitational waves in GR as

$$I_{GR} = \frac{1}{4c\kappa}\overline{\left(\dot{h}_{ij}^{TT}\right)^2} \quad (2)$$

where $\kappa \equiv 8\pi G/c^4$, and the overhead bar denotes spatial-averaging [3]. For unidirectional radiation, $I_{GR} = c\bar{u}_{GR}$, therefore using (1) and (2) gives

$$\bar{u}_{GR} = \frac{1}{8c^2\kappa}\left(\overline{E_{ij}^2} + c^2\overline{B_{ij}^2}\right) \quad (3)$$

analogous to $\bar{u}_{EM} = \frac{\varepsilon_0}{2}\left(\overline{E^2} + c^2\overline{B^2}\right)$ in EM, where ε_0 is the vacuum permittivity. Note that $\overline{E_{ij}^2} = \frac{1}{2}E_{ij,0}^2$, where $E_{ij,0}$ is the tensor amplitude of a sinusoidal field.

Quantizing the Gravitational Wave Perturbation

The classical metric perturbation can be promoted to a quantum operator as

$$\hat{h}_{ij}^{TT}(\mathbf{x},t) = \sum_{\mathbf{k}}\sum_{p=1}^{2}\sqrt{\frac{16\pi G\hbar}{c^2 V\omega_{\mathbf{k}}}}\left(\xi_{ij,\mathbf{k},p}\hat{b}_{\mathbf{k},p}e^{i(\mathbf{k}\cdot\mathbf{x}-\omega_k t)} + \text{h.c.}\right) \quad (4)$$

where V is the quantization volume, $\mathbf{k}$ is the wave vector, and ξ_{ij} are the two TT polarization tensors of a gravitational wave. Also, $\hat{b}$ and $\hat{b}^\dagger$ are graviton annihilation and creation operators, respectively [4, 5].

ABSTRACT

The classical energy of gravitational waves is amplitude dependent, while the quantum energy of gravitons is frequency dependent. Applying the Bohr Correspondence Principle (BCP) to the case of gravity predicts that the classical and quantum theories should be consistent in the limit of large quantum numbers (i.e. numerous gravitons). A formal treatment is shown using linearized General Relativity (GR) and assuming the quantization of the gravitational field. Furthermore, using quantized electric-like and magnetic-like tensor fields, we obtain a canonical quantization of the gravitational field and an associated uncertainty principle.

MAIN POINTS

Quantizing Gravitational Wave Tensor Fields

Using (1) and (4) leads to quantized fields given, respectively, as

$$\hat{E}_{ij}(\mathbf{x},t) = i\sum_{\mathbf{k}}\sum_{p=1}^{2}\sqrt{\frac{16\pi G\hbar\omega_{\mathbf{k}}}{c^2 V}}\left[\xi_{ij,\mathbf{k},p}\hat{b}_{\mathbf{k},p}e^{i(\mathbf{k}\cdot\mathbf{x}-\omega_k t)} - \text{h.c.}\right] \quad (5)$$

and

$$\hat{B}_{ij}(\mathbf{x},t) = i\sum_{\mathbf{k}}\sum_{p=1}^{2}\sqrt{\frac{16\pi G\hbar}{c^2 V\omega_{\mathbf{k}}}}\varepsilon_{ikl}k_l\left[\xi_{mj,\mathbf{k},p}\hat{b}_{\mathbf{k},p}e^{i(\mathbf{k}\cdot\mathbf{x}-\omega_k t)} - \text{h.c.}\right] \quad (6)$$

These newly defined fields are analogous to the quantized EM fields, $\hat{\boldsymbol{E}}$ and $\hat{\boldsymbol{B}}$ fields.

Canonical Quantization of the Graviton Field

Lagrangian density for the gravitational field is [6]

$$\mathcal{L} = \frac{1}{8c^2\kappa}\left(E_{ij}^2 - c^2 B_{ij}^2\right)$$

The canonical momentum tensor density is found as

$$\pi^{ij} = \frac{\partial\mathcal{L}}{\partial\dot{h}_{ij}^{TT}} = -\frac{1}{4c^2\kappa}E_{ij}$$

Promoting to a quantum operator and applying (5) leads to

$$\hat{\pi}_{ij}(\mathbf{x},t) = -i\sum_{\mathbf{k}}\sum_{p=1}^{2}\sqrt{\frac{c^2\hbar\omega_{\mathbf{k}}}{64\pi GV}}\left[\xi_{ij,\mathbf{k},p}\hat{b}_{\mathbf{k},p}e^{i(\mathbf{k}\cdot\mathbf{x}-\omega_k t)} - \text{h.c.}\right] \quad (7)$$

The associated Hamiltonian density operator is

$$\hat{\mathcal{H}} = \frac{1}{8c^2\kappa}\left(\hat{E}_{ij}^2 + c^2\hat{B}_{ij}^2\right)$$

The operators in (4) and (7) satisfy the following commutation relations.

$$\left[\hat{h}_{ij}^{TT}(\boldsymbol{x}), \hat{\pi}_{kl}(\boldsymbol{x}')\right] = i\hbar\delta_{ij,kl}^{TT}(\boldsymbol{x}-\boldsymbol{x}')$$

The generalized uncertainty principle is given by $\left(\frac{1}{2i}\langle[\hat{A},\hat{B}]\rangle\right)^2 \geq \left(\frac{\hbar}{2}\right)^2$, where $\hat{A}$ and $\hat{B}$ are canonical conjugate operators [7]. From this we obtain

$$\boxed{\Delta h_{ij}^{TT}(x)\Delta\pi_{kl}(x') \geq \frac{\hbar}{2}\left|\delta_{ij,kl}^{TT}(x-x')\right|}$$

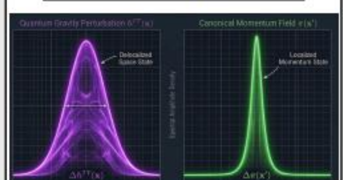


FIGURE 2: Example of distributions for the canonical conjugate pair: $\hat{h}_{ij}^{TT}$ and $\hat{\pi}_{kl}$.

Relating Classical and Quantum Field Amplitudes

The mode pre-factors for the quantum fields in (5) and (6) are

$$E_{ij,0,k} = cB_{ij,0,k} = \sqrt{\frac{16\pi G\hbar\omega_k}{c^2 V}}\xi_{ij,k}$$

Taking the expectation value of the operators acting on a coherent state leads to

$$\boxed{E_{ij,0}^{(\text{cl})} = 2\sqrt{\langle\hat{N}_k\rangle}\,E_{ij,0,k} \quad \text{and} \quad B_{ij,0}^{(\text{cl})} = 2\sqrt{\langle\hat{N}_k\rangle}\,B_{ij,0,k}}$$

where $\hat{N}$ is the graviton number operator, and (cl) refers to the classical wave amplitude. These relations between classical and quantum amplitudes are demonstrations of the BCP [8].

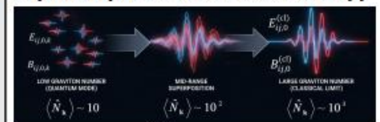


FIGURE 3: For large $\langle\hat{N}_k\rangle$, gravitons add coherently to produce the classical fields, $E_{ij,0}^{(\text{cl})}$ and $B_{ij,0}^{(\text{cl})}$.

Isaacson Energy from Quantized Linear GR

To find the energy density operator, we use (5) and (6), then take the modulus squared, $\hat{E}_{ij}^2 = \hat{E}_{ij}^*\hat{E}^{ij}$, to obtain

$$\overline{\hat{E}_{ij}^2} = \sum_{\mathbf{k}}\sum_{p=1}^{2}\hat{E}_{0,\mathbf{k}}^2\left(2\hat{N}_{\mathbf{k},p} + 1 - \hat{b}_{\mathbf{k},p}\hat{b}_{-\mathbf{k},p}e^{-2i\omega_k t} - \hat{b}_{\mathbf{k},p}^\dagger\hat{b}_{-\mathbf{k},p}^\dagger e^{2i\omega_k t}\right) \quad (8)$$

and

$$\overline{\hat{B}_{ij}^2} = \sum_{\mathbf{k}}\sum_{p=1}^{2}\hat{B}_{0,\mathbf{k}}^2\left(2\hat{N}_{\mathbf{k},p} + 1 + \hat{b}_{\mathbf{k},p}\hat{b}_{-\mathbf{k},p}e^{-2i\omega_k t} + \hat{b}_{\mathbf{k},p}^\dagger\hat{b}_{-\mathbf{k},p}^\dagger e^{2i\omega_k t}\right) \quad (9)$$

Combining (8) and (9) gives

$$\boxed{\hat{u}_{GR} = \frac{1}{8c^2\kappa}\left(\overline{\hat{E}_{ij}^2} + c^2\overline{\hat{B}_{ij}^2}\right) = \frac{\hbar}{V}\sum_{k}\sum_{p=1}^{2}\omega_{\mathbf{k},p}\left(\hat{N}_{\mathbf{k},p} + \frac{1}{2}\right)}$$

Taking the expectation value and the limit of large graviton number, $\langle\hat{N}_k\rangle \gg \frac{1}{2}$, make the vacuum energy negligible and recovers the classical Isaacson energy density in (3).

FIGURE 4: A localized gravitational wave packet formed by a superposition of quantum modes.

CONCLUSIONS

Quantizing Gravitational Wave Tensor Fields

From the quantized perturbation in linearized GR, we obtained quantized electric-like and magnetic-like tensor fields for gravitational waves.

Canonical Quantization of the Graviton Field

The Lagrangian for gravitational waves in linearized GR was used to obtain a canonical momentum that is conjugate to the quantized perturbation. This leads to a quantized Hamiltonian and a canonical uncertainty principle for quantized linear GR.

Relating Classical and Quantum Field Amplitudes

The classical amplitude of gravitational waves and the quantum mode pre-factor of the field operators are related by the expectation value of the graviton number operator. This demonstrates the BCP in the context of quantized linear GR.

Isaacson Energy from Quantized Linear GR

The classical expression for gravitational wave energy density was formally obtained from the quantized energy density in the limit of large graviton number. This is another demonstration of the BCP applied to gravitational waves.

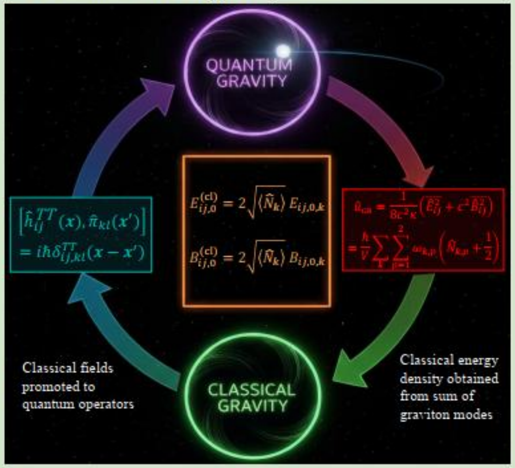
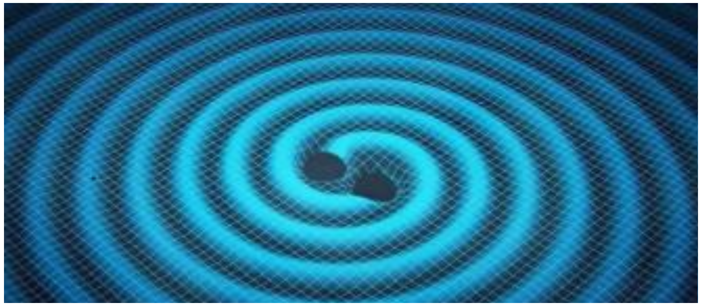


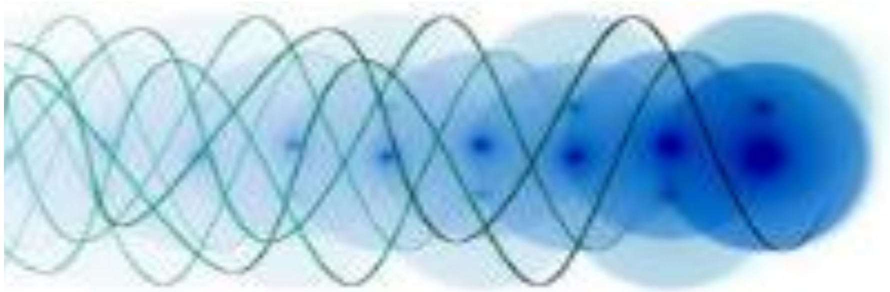
FIGURE 5: Visualization of key relationships connecting classical gravitational waves to quantum gravitons in a model of the BCP applied to linear GR.

References

1. Flanagan, Hughes (2005); 2. Inan (2016, 2018); 3. Misner, Thorne, Wheeler (1972); 4. Grishchuk (1974, 1976, 1992, 2001, 2005); 5. Carney (2024); 6. Barnett (2014); 7. Griffiths (1981); 8. Bohr (1918-1923); 9. Inan, Ghosoph, Hidalgo, et. al. (in prep)

APS Far West Meeting
(Oct, 2025)





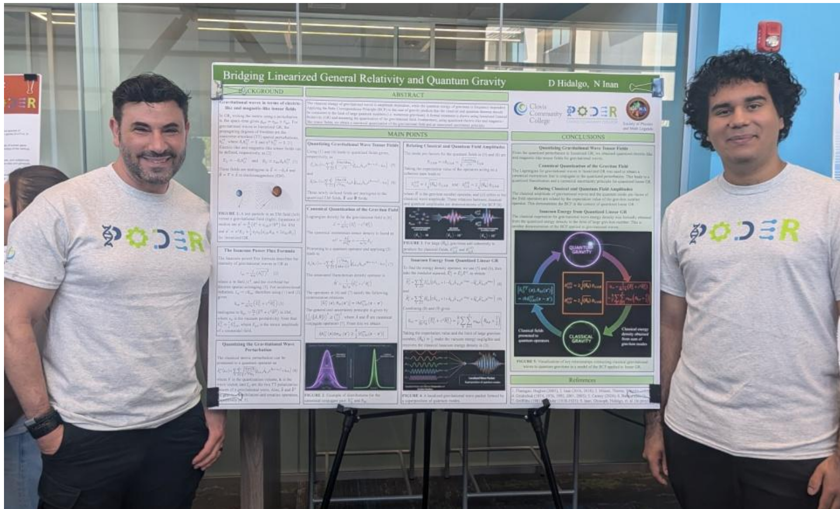
Dr. Nathan Inan

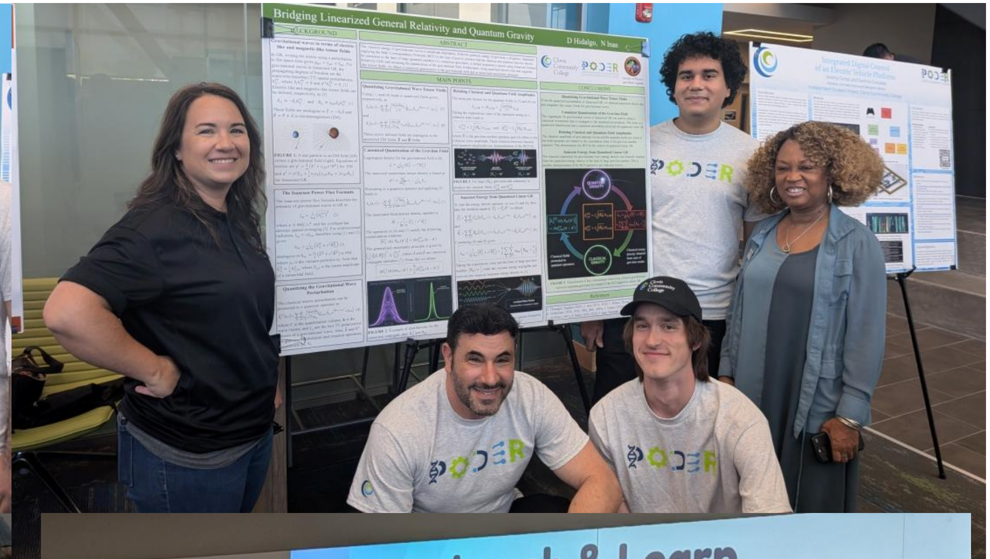
Zach Ghosoph, Diego Hidalgo, and other students from

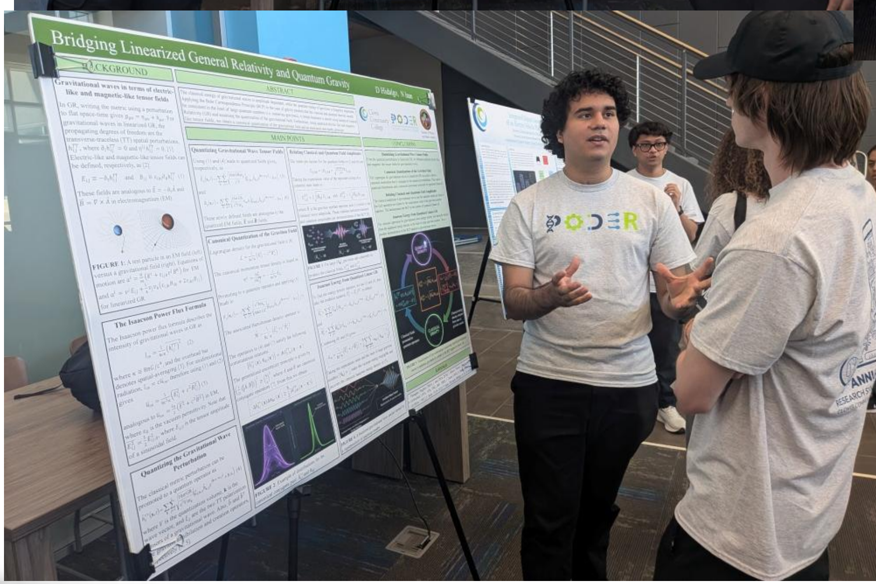
Clovis Community College

New Perspectives on Quantum Gravity:
Striking parallels between QED and quantized linear GR

STEM Research Symposium (2026)







Honors Symposium (2026)

One of our students (**Diego Hidalgo**) won third place in the 2026 district-wide Leon S. Peters Honors Program Symposium Competition. Now he's off to UCLA to study computer science and engineering!

STEM Research Symposium (2025)

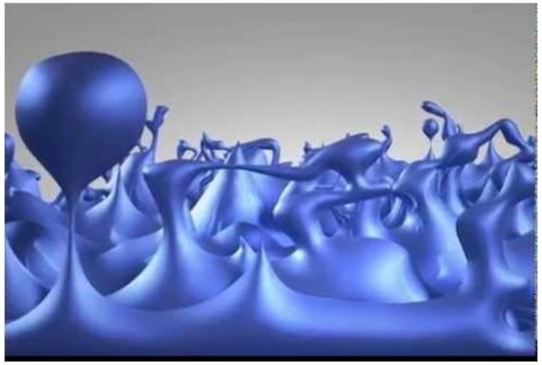
Interested in fundamental connections between Classical and Quantum Physics?

Join our team of **students** working on papers, posters, and talks given at public conferences and colloquia!

Title: Bridging the Classical and Quantum Realms –
the Correspondence Principle applied to Photons and Gravitons

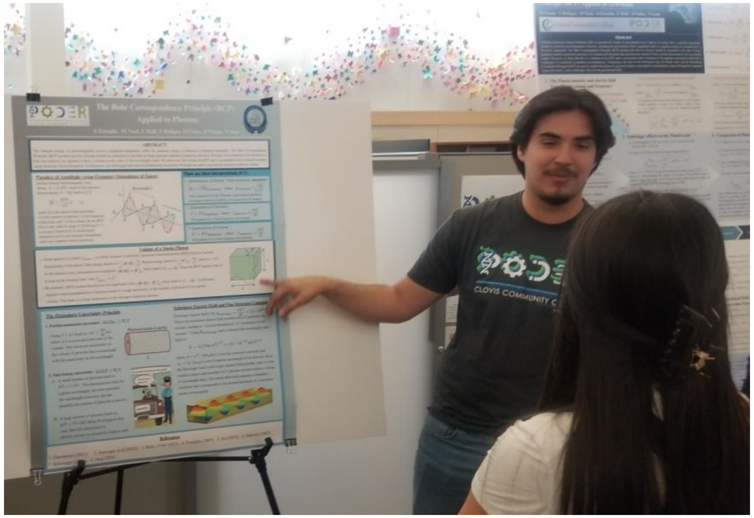
Topics studied in our paper:

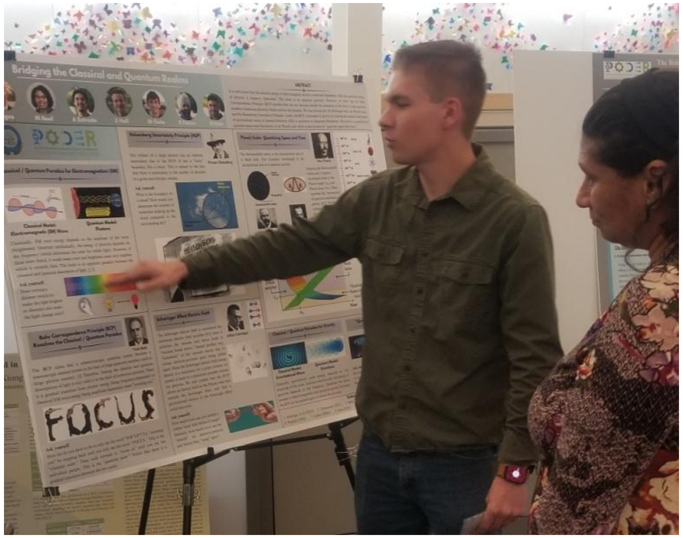
- Bohr correspondence principle
- Electromagnetic quantum vacuum fluctuations
- Gravitational vacuum fluctuations ("space-time foam")
- Schwinger effect (electromagnetic and gravitational)
- Planck scale physics



Interested in fundamental connections between Classical and Quantum Physics?

Presenting our research at the 2024 STEM poster symposium





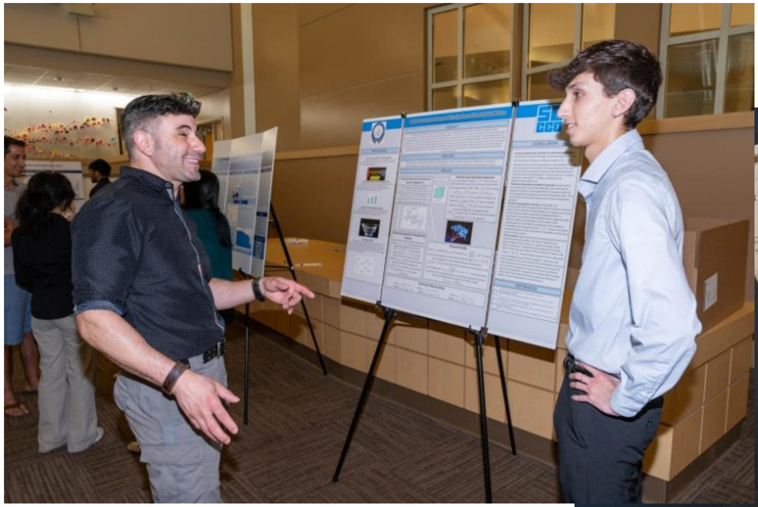
Antonio Estrada and **Tyler Bridges** were still in Physics 4A in Spring 2024 while presenting the content of our work.

STEM Research Symposium (2024)

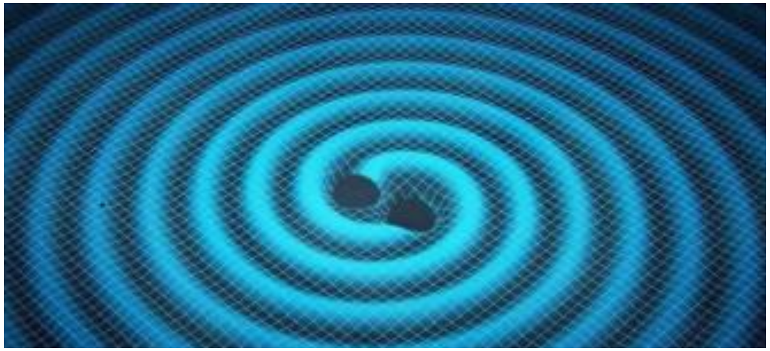
STEM Research Symposium (2023)
Ethan Hall

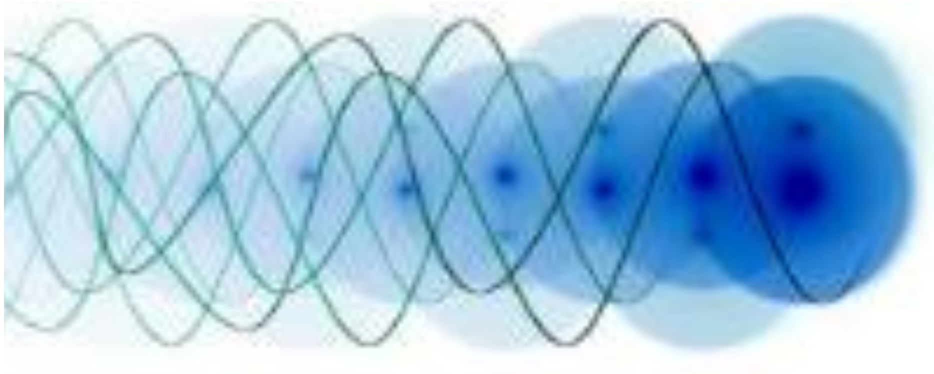
Honors Symposium (2024)

One of our students (**Mathew Oaks**) won <u>**first place**</u> in the 2024 district-wide Leon S. Peters Honors Program Symposium Competition. Currently he's off to UCSB to study quantum gravity! Ethan Hall is also at UC Berkeley now!



Fresno State Physics Colloquium





Dr. Nathan Inan and Antonio Estrada

Clovis Community College

Bridging the Classical and Quantum Realms –

the Correspondence Principle Applied to Photons and Gravitons

Group research papers

Bridging Classical Electromagnetism and Quantum Electrodynamics via the Bohr Correspondence Principle

N Inan,[1,2,3,*] T Bridges,[1] A Estrada,[1] Z Ghosoph,[1] E Hall,[4]
D Hidalgo,[1] M Neal,[1] M Oaks,[5] R Pannu,[1] and J Schmidt[1]

[1] *Clovis Community College, 10309 N. Willow, Fresno, CA 93730 USA*
[2] *Department of Physics, California State University Fresno, Fresno, CA 93740-8031, USA*
[3] *University of California, Merced, School of Natural Sciences, P.O. Box 2039, Merced, CA 95344, USA*
[4] *University of California, Berkeley, Department of Physics, 110 Sproul Hall, Berkeley, CA 94720, USA*
[5] *University of California, Santa Barbara, Department of Physics, Broida Hall, Santa Barbara, CA 93106, USA*

It is well known that the classical energy of electromagnetic waves is amplitude dependent, while the quantum energy of photons is frequency dependent. The Bohr Correspondence Principle (BCP) predicts that the two theories should be consistent in the limit of large quantum numbers (numerous photons). It is common in the literature to find that photons are claimed to have a volume on the order of the wavelength cubed. We show that this is a violation of the BCP and is inconsistent with a formal treatment using Quantum Electrodynamics. Lastly, the roles of the Schwinger limit and the Heisenberg Uncertainty Principle are used to explore the notion of a photon volume.

Group research papers

Bridging Linearized General Relativity and Quantum Gravity via the Bohr Correspondence Principle

N Inan,[1,2,3,*] T Bridges,[1] A Estrada,[1] Z Ghosoph,[1] E Hall,[4] D Hidalgo,[1] M Neal,[1] M Oaks,[5] R Pannu,[1] and J Schmidt[1]

[1] *Clovis Community College, 10309 N. Willow, Fresno, CA 93730 USA*
[2] *Department of Physics, California State University Fresno, Fresno, CA 93740-8031, USA*
[3] *University of California, Merced, School of Natural Sciences, P.O. Box 2039, Merced, CA 95344, USA*
[4] *University of California, Berkeley, Department of Physics, 110 Sproul Hall, Berkeley, CA 94720, USA*
[5] *University of California, Santa Barbara, Department of Physics, Broida Hall, Santa Barbara, CA 93106, USA*

It is well known that the classical energy of EM waves is amplitude dependent, while the quantum energy of photons is frequency dependent. The Bohr Correspondence Principle (BCP) predicts that the two theories should be consistent in the limit of large quantum numbers. When applied to the case of gravity, this would imply numerous gravitons. It is found in the literature to find that gravitons are claimed to have a volume on the order of the wavelength cubed. We show that this is a violation of the BCP and is inconsistent with a formal treatment using linearized General Relativity to describe the classical energy of gravitational waves, and by assuming the quantization of the gravitational field. Furthermore, the roles of the Schwinger limit and the Heisenberg Uncertainty Principle are used to explore the notion of a graviton volume. This results in a Correspondence Principle for gravitons and a Schwinger-like effect for the gravitational field.

Group research papers

Bridging Quantum and Classical Physics at the Planck Scale

N Inan,[1,2,3,*] I Arora,[1] Z Ghosoph,[1] D Hidalgo,[1] R Mendoza,[1] R Pannu,[1] S Young,[1] and R Zanoni[1]

[1] *Clovis Community College, 10309 N. Willow, Fresno, CA 93730 USA*
[2] *Department of Physics, California State University Fresno, Fresno, CA 93740-8031, USA*
[3] *University of California, Merced, School of Natural Sciences, P.O. Box 2039, Merced, CA 95344, USA*

We investigate the unifying role of Planck-scale physics across black holes, Hawking and Unruh radiation, quantum spacetime foam, cosmological models, and electromagnetic–gravitational analogs of the Casimir and Aharonov–Bohm effects. Multiple derivations of Planck units are compared and categorized as fundamental maxima, minima, or mesoscopic quantities, revealing geometric mean relationships and new physical limits. We introduce extended Planck-scale constructs—such as gravitational fine structure constants and Ricci invariants—and apply them to quantum field equations in curved spacetime. Through the Bohr correspondence principle and generalized uncertainty relations, we show how classical behavior emerges from quantum gravity, culminating in a framework where all forces and scales converge at the Planck regime.

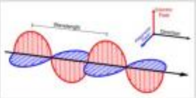
Bridging the Classical and Quantum Realms

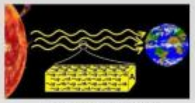
ABSTRACT

It is well known that the classical energy of electromagnetic waves is *amplitude* dependent, while the quantum energy of photons is *frequency* dependent. This leads to an apparent paradox. However, we show that the Bohr Correspondence Principle (BCP) predicts that the two theories should be consistent in the limit of large quantum numbers (numerous photons) which resolves the paradox. We also discuss the the Schwinger limit, the Planck scale, and the Heisenberg Uncertainty Principle. Lastly, the BCP is extended to gravity by relating the classical description of gravitational waves in General Relativity (GR) to gravitons in Quantum Mechanics. The result is a prediction of quantum space-time fluctuation at the Planck scale which is also known as "quantum space-time foam."

PODER
CLOVIS COMMUNITY COLLEGE

Classical / Quantum Paradox for Electromagnetism (EM)

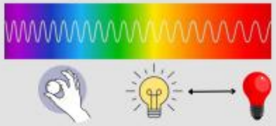




Classical Model: Electromagnetic (EM) Wave — **Quantum Model: Photons**

Classically, EM wave energy depends on the *amplitude* of the wave (brightness). Quantum mechanically, the energy of photons depends on the *frequency* (which determines the color for visible light). However, if these were linked, it would mean color and brightness must vary together which is certainly false. This leads to an apparent paradox between the classical and quantum description of light. [1,2]

Ask yourself:
Does turning a dimmer switch (to make the light brighter or dimmer) also make the light change color?



Bohr Correspondence Principle (BCP) Resolves the Classical / Quantum Paradox

Niels Bohr

The BCP states that a submicroscopic quantum system becomes a macroscopic classical system in the limit of large quantum numbers (such as large photon number). [3] Therefore, linking the classical and quantum descriptions of light is only valid to in the limit of numerous photons. There is a gradual transition from photon energy being frequency-dependent to classical EM wave energy being amplitude-dependent when "zooming out."

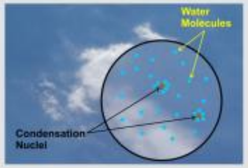
Ask yourself:
How far do you have to be to only see the word "FOCUS"? Try "zooming out" by stepping back until you only see the word "FOCUS." This is the "classical scale." Then walk forward to "zoom in" until you see the individual people. This is the "quantum scale." Notice that there is a gradual transition between the two scales.

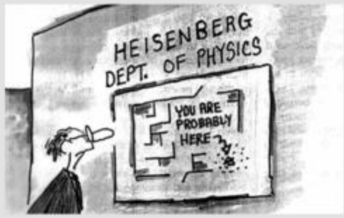
Heisenberg Uncertainty Principle (HUP)

Werner Heisenberg

The volume of a single photon has an inherent uncertainty due to the HUP. It has a "fuzzy" boundary like a cloud. This is related to the fact that there is uncertainty in the number of photons in a given macroscopic volume.

Ask yourself:
What is the boundary of a cloud? How would you determine the number of molecules making up the cloud compared to the surrounding sky?





Schwinger Effect Electric Field

Julian Schwinger

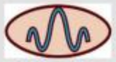
The Schwinger electric field is considered the maximum electric field possible [4,5] since it polarizes the vacuum and hence leads to "vacuum break down." Stated another way, "ionization" of the vacuum occurs due to virtual electron-positron pairs being pulled apart. Since the Schwinger electric field energy density is a maximum for a given volume, we predict it leads to a minimum possible volume for photons. We also predict that the HUP allows an electric field on the Planck scale that exceeds the Scwhinger limit, and that a gravitational version of the Schwinger effect could also exist.

Ask yourself:
How much force can you stretch a rubber band with before it snaps? Similarly, how much force can we "stretch" an electron-positron pair before they "snap" apart?

Planck Scale: Quantizing Space and Time

The Schwarzchild radius is the characteristic size of a black hole. The Compton wavelength is the characteristic size of a quantum particle.

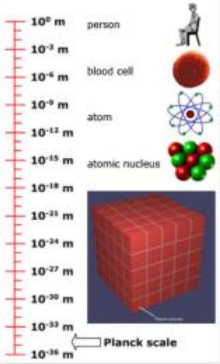
Max Planck



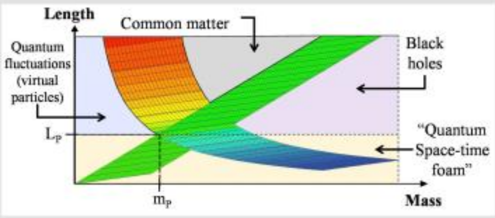
Karl Schwarzchild
$R = 2GM/c^2$

Arthur Compton
$\lambda = h/(mc)$

Equating the Schwarzchild radius and Compton wavelength leads to the Planck length, L_P, and Planck mass, m_P. These represent the "intersection" of quantum mechanics and gravity. [6,7] The Planck volume, $V_P = L_P^3$, can be thought of as the smallest "pixels" of space. The Planck time, $t_P = c/L_P$, can be thought of as giving a "frame rate" for time.

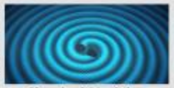


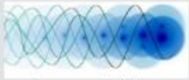
In the graph below, the green curve is the Compton wavelength while the multi-colored curve is the Schwarzschild radius. We show the scales associated with common matter, black holes, virtual particles, and "quantum space-time foam." The theories of General Relativity and Quantum and Mechanics are incompatible but both relevant at the Planck scale. [8]



Ask yourself:
What theory of physics do you use to describe an object compressed to a size equal to both its Schwarzchild radius and Compton wavelength? Do you use Quantum Mechanics or General Relativity (since you can't use both)?

Classical / Quantum Paradox for Gravity





Classical Model: Gravitational Wave — **Quantum Model: Gravitons**

Classically, gravitational wave energy depends on the amplitude of the wave. Quantum mechanically, the energy of gravitons depends on the frequency. Therefore the same paradox in electromagnetism also occurs for gravity. However, the BCP can be applied again to resolve the paradox.

"Quantum Space Time Foam"

If gravity is a quantum field, then the HUP predicts space-time is turbulent at the Planck scale. This has been called "quantum space-time foam."

Ask yourself:
Do you think the human mind can fathom the concept of space and time "bubbling" with uncertainty at the Planck scale? What analogy could you possibly use?

References

1. Antonga, et al (2023); 2. Goenawan (2021); 3. Bohr (1918–1923); 4. Schwinger (1951); 5. Ong (2020); 6. Planck (1899); 7. Lehto (2009); 8. Inan (2018)

The Bohr Correspondence Principle (BCP) Applied to Photons

A Estrada, M Neal, E Hall, T Bridges, M Oaks, R Pannu, N Inan

CLOVIS COMMUNITY COLLEGE

ABSTRACT

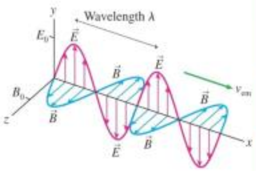
The classical energy of electromagnetic waves is amplitude-dependent, while the quantum energy of photons is frequency-dependent. The Bohr Correspondence Principle (BCP) predicts the two theories should be consistent in the limit of large quantum numbers (numerous photons). However, it is common in the literature to find that photons are claimed to have a volume on the order of the wavelength cubed. We show that this violates the BCP and is inconsistent with a formal treatment using Quantum Electrodynamics. Furthermore, the Schwinger limit and the Heisenberg Uncertainty Principle are used to explore the notion of a photon volume.

Paradox of Amplitude versus Frequency Dependence of Energy

Setting classical electromagnetic wave energy, $E=\frac{1}{2}\varepsilon_0 E_0^2 V$, equal to the quantum photon energy, $E=Nhf$, leads to [1,2]

$$E_0^2=\frac{2Nh}{\varepsilon_0 V}f \qquad (1)$$

where E_0 is the electric field amplitude, N is the number of photons, f is the frequency of photons, and V is the volume. By the BCP, this is only valid for large N. [3] Setting $N=1$ is an error found in [2]. It would mean frequency (color) and intensity (brightness) must vary together which is incorrect.



There are three interpretations of (1).

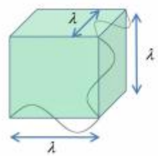
1. Quantization of Electric Field Amplitude (**incorrect**):
$$E_0=\sqrt{N}E_{0,\text{elementary}} \quad \text{where} \quad E_{0,\text{elementary}}\equiv\sqrt{\frac{2hf}{\varepsilon_0 V}}$$
This is claimed in [2,4]. However, quantization should be by integers (photon number), not square-root of integers.

2. Quantization of Intensity:
$$I=NI_{\text{elementary}} \quad \text{where} \quad I_{\text{elementary}}\equiv\frac{hcf}{2V}$$
This applies for a fixed frequency and volume.

3. Quantization of Volume:
$$V=NV_{\text{elementary}} \quad \text{where} \quad V_{\text{elementary}}\equiv\frac{hcf}{2I}$$
This applies for a fixed frequency and intensity.

Volume of a Single Photon

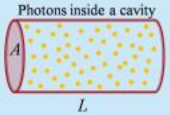
- Some papers [1,5] claim $V_{\text{photon}}=\lambda^3$ which we show is incorrect. Quantum Electrodynamics (QED) [6] gives vacuum fluctuations of the electric field energy density as $\frac{1}{\varepsilon_0}\langle 0|\hat{\mathbf{E}}\cdot\hat{\mathbf{E}}|0\rangle\sim\frac{hc}{\lambda^4}$. Photon energy density is $\frac{1}{\varepsilon_0}\langle\hat{\mathbf{E}}^2\rangle_{\text{avg}}\sim\frac{nhc}{\lambda}$, where $n=N/V$. In the classical limit, fluctuations are negligible, $\langle 0|\hat{\mathbf{E}}\cdot\hat{\mathbf{E}}|0\rangle<<\langle\hat{\mathbf{E}}^2\rangle_{\text{avg}}$ which leads to $V<<N\lambda^3$. Since the BCP requires that N is large in the classical limit, then $V_{\text{photon}}<<\lambda^3$
- By contrast, QED vacuum fluctuations are significant when $\langle 0|\hat{\mathbf{E}}\cdot\hat{\mathbf{E}}|0\rangle\sim\langle\hat{\mathbf{E}}^2\rangle_{\text{avg}}$ which leads to $V\sim N\lambda^3$. In this case, random creation/annihilation of photons leads to a large uncertainty in the number of photons (N) in a given volume. This leads to a large uncertainty in the average volume per photon.



The Heisenberg Uncertainty Principle

1. Position-momentum uncertainty: $\Delta x\Delta p_x\geq\hbar/2$

Using $V=AL$ leads to $\Delta V\geq\frac{3A}{4\pi}\Delta\lambda$ where A is a cross-sectional area of the volume. This shows an uncertainty in the volume of photons that is associated with the uncertainty in the wavelength.



2. Time-Energy uncertainty: $\Delta t\Delta E\geq\hbar/2$

A. A small number of photons leads to $\Delta N\leq\lambda/\Delta\lambda$. This demonstrates that for a given wavelength, the more precisely the wavelength is known, the less precisely the number of photons is known.

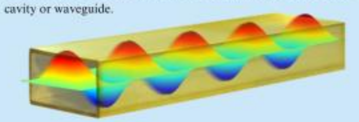
B. A large number of photons leads to $\Delta N\leq N\lambda/\Delta\lambda$. Since N is large in this case, then the uncertainty in photon number is necessarily large as well

Schwinger Electric Field and Fine Structure Constant

Schwinger electric field [7,8]: $E_{0,\text{Schwinger}}=\frac{m_e^2c^3}{e\hbar}\approx 1.3\times10^{18}$ V/m. This is the maximum electric field possible since it polarizes the vacuum, leading to "vacuum breakdown" or "ionization of the vacuum." Using $E_{0,\text{Schwinger}}$ and a volume with wavelength sides leads to

$$L=\lambda_C\left(N\alpha/\pi^2\right)^{1/4}\approx\left(4\times10^{-13}\,\text{m}\right)N^{1/4}$$

where $\alpha=e^2/(4\pi\varepsilon_0\hbar c)$ is the fine structure constant, and $\lambda_C=h/(m_e c)$ is the Compton wavelength of an electron. Since the Schwinger limit is the largest electric field possible, then L is the smallest length scale possible for N photons bound within a volume of wavelength sides. This result effectively assumes a boundary condition that corresponds to the second harmonic of a resonator cavity or waveguide.



References

1. Goenawan (2021); 2. Antonga, et al (2023); 3. Bohr (1918–1923); 4. Franklin (2005); 5. Xu (2021); 6. Sakurai (1967); 7. Schwinger (1951); 8. Ong (2020)

Planck Quantities and the Bohr Correspondence Principle (BCP) Applied to Gravitons

R Pannu, T Bridges, M Neal, A Estrada, E Hall, M Oaks, N Inan

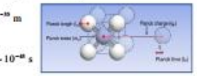
Clovis Community College

Abstract

Utilizing linearized General Relativity (GR) to describe the energy of gravitational waves leads to an energy that is *amplitude* dependent, similar to classical electromagnetism. However, assuming the gravitational field is quantized leads to a quantum energy for gravitons that is *frequency* dependent. The Bohr Correspondence Principle (BCP) predicts that the two theories should be consistent in the limit of large quantum numbers (numerous gravitons). It is found in the literature that gravitons are claimed to have a volume determined by the wavelength cubed. However, we show that this is a violation of the BCP and is inconsistent with a treatment of the quantum gravitational field that is analogous to a treatment in quantum electrodynamics. Furthermore, the roles of the Schwinger limit, the Planck scale, and the Heisenberg Uncertainty Principle (HUP) are used to explore the notion of a graviton volume, a description of gravitational vacuum fluctuations ("quantum space-time foam"), and a Schwinger effect for the gravitational field.

Planck quantities[1,2]

- Planck length: $l_{Pl}=\sqrt{\frac{\hbar G}{c^3}}\sim10^{-35}$ m
- Planck time: $t_{Pl}=\frac{l_{Pl}}{c}=\sqrt{\frac{\hbar G}{c^5}}\sim10^{-43}$ s
- Planck mass: $m_{Pl}=\frac{\hbar}{cl_{Pl}}=\sqrt{\frac{\hbar c}{G}}\sim10^{-8}$ kg
- Planck energy: $E_{Pl}=m_{Pl}c^2=\sqrt{\frac{\hbar c^5}{G}}\sim10^{9}$ J
- Planck frequency: $f_{Pl}=\frac{1}{t_{Pl}}=\sqrt{\frac{c^5}{\hbar G}}\sim10^{43}$ Hz



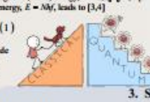
1. The Planck intensity and electric field from Planck volume and frequency

A. EQUATING CLASSICAL AND QUANTUM ENERGY

Setting classical electromagnetic (wave) energy, $E=\frac{1}{2}\varepsilon_0 E_0^2 V$, equal to the quantum (photon) energy, $E=Nhf$, leads to [3,4]

$$E_0^2=\frac{2Nhf}{\varepsilon_0 V} \qquad (1)$$

E_0 = electric field amplitude
N = number of photons
f = frequency of photons
V = volume



B. PLANCK QUANTIZATION OF INTENSITY

Use $I=\frac{1}{2}c\varepsilon_0E_0^2$ and V_{Pl} in (1) to obtain $I=NI_{\text{Planck elementary}}$ where $I_{\text{Planck elementary}}=\frac{hcf}{V_{Pl}}$. For a given frequency, $I_{\text{Planck elementary}}$ is a quantum of intensity that corresponds to the smallest volume possible in nature, the Planck volume. Using $V_{Pl}=l_{Pl}^3$ and $f_{Pl}=c/l_{Pl}$ gives the maximum possible intensity as

$$I_{\text{Planck (max)}}=\frac{hc^2}{l_{\text{Planck}}^4}=\frac{4\pi^2c^8}{\hbar G^2}\sim10^{123}\,\text{W/m}^2 \qquad (2)$$

C. PLANCK ELECTRIC FIELD AMPLITUDE

Using $I=\frac{1}{2}c\varepsilon_0E_0^2$ and (2) leads to

$$E_{0,Pl}=\frac{1}{l_{Pl}^2}\sqrt{\frac{\hbar c}{\varepsilon_0}}\sim10^{62}\,\text{V/m} \qquad (3)$$

which is the "Planck electric field." [5]
It is 44 orders of magnitude larger than the Schwinger electric field [6,7] which is

$$E_{0,\text{Schwinger}}=\frac{m_e^2c^3}{e\hbar}\approx1.3\times10^{18}\,\text{V/m}$$

Using (3) and a Coulomb electric field, $E_{0,Pl}=q_{Pl}/(4\pi\varepsilon_0 l_{Pl}^2)$, leads to a Planck charge given by $q_{Pl}=4\pi\sqrt{\hbar c\varepsilon_0}\approx104\,e\sim10^{-17}$ C.

2. Planck limits from HUP

A. CLASSICAL ELECTROMAGNETIC WAVE MODEL

Use $\Delta t_{\min}\Delta E_{\max}=\hbar/2$ with $E=\frac{1}{2}\varepsilon_0E_0^2V$, $\Delta t_{\min}=t_{Pl}$ and $V_{Pl}=l_{Pl}^3$ to obtain

$$E_{0,\max}=\frac{E_{0,Pl}}{\sqrt{\pi}}\approx0.56E_{0,Pl}$$

This is the maximum vacuum fluctuation of electric field within a Planck time scale.

B. QUANTUM PHOTON MODEL

Use $\Delta t_{\min}\Delta E_{\max}=\hbar/2$ with $E_{\max}=Nhf$, and $\Delta t_{\min}=t_{Pl}$ to obtain

$$f_{\max}=\frac{f_{Pl}}{\sqrt{2\pi}}\approx0.16f_{Pl}$$

This gives an upper bound on the frequency of a photon according to Planck scale physics.

3. Schwinger effects on the Planck-scale

A. COMPARISON OF PLANCK AND SCHWINGER ELECTRIC FIELDS

The ratio of the Planck and Schwinger electric fields is

$$\frac{E_{0,Pl}}{E_{0,\text{Schwinger}}}=\left(\frac{m_{Pl}}{m_e}\right)^2\sqrt{8\pi^2\alpha}\sim10^{44}$$

where $\alpha=e^2/(4\pi\varepsilon_0\hbar c)$ is the fine structure constant. Since $\sqrt{8\pi^2\alpha}\sim1$, then it is fundamentally the square of the ratio of the Planck mass to electron mass that leads to the Planck electric field being 44 orders of magnitude larger than the Schwinger electric field.

B. SCHWINGER EFFECT ON THE PLANCK SCALE

Within a time interval of t_{Pl}, a virtual electron-positron pair (moving apart at a speed ~c) would separate by ~l_{Pl}. The electric potential energy of the electron-positron pair in the presence of $E_{0,\max}$ would be

$$PE=eE_{0,\max}l_{Pl}=\sqrt{2\pi\alpha}\,E_{Pl}$$

Since $\sqrt{8\pi\alpha}<1$, then $PE<E_{pl}$ as expected since E_{pl} is assumed to be the largest energy possible in the context of Quantum Gravity.

4. Comparison of Planck and Gravitational forces

- A "Planck *electric* force" can be written as $F_{Pl(\text{Electric})}=eE_{0,Pl}\sim10^{43}$ N.
- A "Planck *mechanical* force" can be obtained from the Planck power, $P_{Pl(\text{Mech})}=cF_{Pl}$ where $P_{Pl(\text{Mech})}=E_{Pl}/t_{Pl}$. This gives $F_{Pl(\text{Mech})}=c^4/G\sim10^{44}$ N.
- Lastly, a characteristic *gravitational* force is obtained from GR using $F_{\text{Grav}}=1/\kappa$, where $\kappa=c^4/(8\pi G)$. This leads to $F_{\text{Grav}}=8\pi G/c^4\sim10^{42}$ N.

The results can be summarized by

$$F_{\underset{(\text{Electric})}{\text{Planck}}}=\sqrt{2\pi\alpha}\,F_{\underset{(\text{Mech})}{\text{Planck}}}=8\pi\sqrt{2\pi\alpha}\,F_{\text{Grav}}$$

These relationships are remarkable since F_{Grav} is derived from a purely *classical* theory of gravitation (GR), $F_{Pl\,(\text{Electric})}$ is derived from a combination of classical electromagnetism and the Planck volume and frequency, while $F_{Pl\,(\text{Mech})}$ is derived purely from Planck quantities (representing Quantum Gravity). Despite these diverse origins, these forces differ by only numeric factors involving π and α, falling within one or two orders of magnitude of each other. Hence these relationships between quantum and classical quantities offer a clue to bridging the classical and quantum realms.

5. Gravitational waves and gravitons

A. EQUATING CLASSICAL AND QUANTUM ENERGY

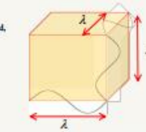
The metric in terms of a perturbation to flat space-time is $g_{\mu\nu}=\eta_{\mu\nu}+h_{\mu\nu}$. For weak gravitational fields, the propagating tensor field is h_{ij}^{TT}, where $\partial_i h_{ij}^{TT}=0$ and $\eta^{ij}h_{ij}^{TT}=0$. [8]
A gravitational electric-like tensor field is defined as $\mathcal{E}_{ij}\equiv-\partial_t h_{ij}^{TT}$.
The intensity is $I_{GR}=\frac{1}{4\pi\kappa}\mathcal{E}_{ij,0}^2$, and the energy density is $u_{GR}=\frac{1}{4c^2\kappa}\mathcal{E}_{ij0}^2$. [9] The gravitational analog to (1) is

$$\mathcal{E}_{ij,0}^2=4\kappa c^2\hbar Nf/V$$

where N is number of gravitons. The BCP [10] only permits this equality for large N. Setting $N=1$ (for a given volume) would be an error since it would mean frequency and intensity must vary together.

B. VOLUME OF A SINGLE GRAVITON

Some papers [11] claim $V_{\text{graviton}}=\lambda^3$ which we show is incorrect. If gravity is a quantized field, then a treatment similar to Quantum Electrodynamics [12] can be used to show that vacuum fluctuation of the gravitational field energy density are given by $\frac{1}{2c^2\kappa}\langle0|\mathcal{E}^{ij}\mathcal{E}_{ij}|0\rangle\sim\frac{\hbar c}{\lambda^4}$.
Graviton energy density would be $\frac{1}{2c^2\kappa}\langle\mathcal{E}_{ij}^2\rangle_{\text{avg}}\sim\frac{n\hbar c}{\lambda}$, where $n=N/V$. In the classical limit, fluctuations are negligible so $\langle0|\mathcal{E}^{ij}\mathcal{E}_{ij}|0\rangle<<\langle\mathcal{E}_{ij}^2\rangle_{\text{avg}}$ which leads to $V<<N\lambda^3$.
According to the BCP, N must be large in the classical limit. Therefore $V_{\text{graviton}}<<\lambda^3$

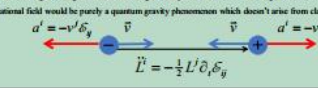


6. Gravitational Schwinger effect

The gravitational force on a test particle due to the electric-like tensor field (to lowest order in test mass velocity) is derived from the geodesic equation of motion in [9] as $a^i=-v^j\mathcal{E}_{ij}$, where v^j is the velocity of the test particle. The associated potential energy is $PE=mv^j\mathcal{E}_{ij}L^i$. The Schwinger field [6] is found from a heuristic argument [7] by letting the distance L be on the order of the Compton wavelength of virtual electrons/positrons: $L=\lambda_C=h/(m_e c)$. If the potential energy goes completely into creating electron-positron pairs, then the Schwinger gravitational field is

$$\mathcal{E}_{ij,0}=2c^2/(\lambda_C v)$$

An alternative approach is the use of the geodesic deviation equation. It is shown in [9] that the geodesic deviation between stationary test particles due to $\mathcal{E}_{ij}$ is $\ddot{L}^i=-\frac{1}{2}L^j\partial_t\mathcal{E}_{ij}$, where L^j is the separation vector between the two particles, as shown in the figure below. This leads to $\mathcal{E}_{ij,0}=4c^2/(\lambda_C^2\omega)$. Using $v=\lambda_C\omega$ leads to agreement with the boxed result above (up to a factor of 2). Also, using $\mathcal{E}_{ij,0}\sim\omega h_{ij,0}$ leads to $h_0\sim4c^2/(\lambda_C^2\omega^2)$. Remaining within linearized GR ($h_0<<1$), and permitting a minimum strain of $h_0=\Delta L/L\sim L_{Pl}/L_C\sim10^{-23}$, requires $10^{-23}\leq h_0<<1$. The corresponding angular frequency range is $10^{17}\,\text{rad/s}<<\omega\leq10^{32}\,\text{rad/s}$. Astrophysical sources produce strain fields within the given range for h_0 but with angular frequencies far below the range for ω. Therefore, a Schwinger gravitational field would be purely a quantum gravity phenomenon which doesn't arise from classical sources.



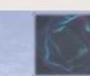
7. Planck scale gravitational field and "quantum space-time foam"

Using the Planck intensity (2) with $I_{GR}=\frac{1}{4\pi\kappa}\mathcal{E}_{ij,0}^2$ leads to a "Planck gravitational tensor amplitude."

$$\mathcal{E}_{ij,0,Pl}=\frac{1}{l_{Pl}^2}\sqrt{\frac{32\pi G\hbar}{c}}=8\pi f_{Pl}\sim10^{44}\,\text{s}^{-1}$$

This is related to quantum vacuum fluctuations predicted by the HUP. Using $\Delta t_{\min}\Delta E_{\max}=\hbar/2$ and $\Delta t_{\min}=t_{Pl}$ leads to $\mathcal{E}_{ij,0,\max}=\frac{\mathcal{E}_{ij,0,Pl}}{2\sqrt{\pi}}\approx0.28\mathcal{E}_{ij,0,Pl}$. Hence we find a maximum for "quantum space-time foam." However, using $\mathcal{E}_{ij,0}\sim\omega h_{ij,0}$ and an upper bound of ω_{Pl} leads to a lower bound of $h_0\sim1$ which violates linearized GR. Therefore, a formal treatment would require full non-linear GR.

References



1. Planck, "On Irreversible Radiation Processes" (1899).
2. Lehto, "On the Planck scale and properties of matter" (2009).
3. Goenawan, "The Relationship Between the Electromagnetic Field Amplitude and its Frequency in a Single Photon" (2021).
4. Antonga, et al, "Gravitational waves from high-power twisted light" (2023).
5. Haug, "Potential Simplification of Charge and the Coulomb Force without Affecting Predictions" (2022).
6. Schwinger, "On gauge invariance and vacuum polarization" (1951).
7. Ong, "Schwinger pair production and the extended uncertainty principle" (2020).
8. Flanagan, Hughes, "The basics of gravitational wave theory" (2005).
9. Inan, "Formulations of General Relativity and their Applications to Quantum Mechanical Systems" (2018).
10. Bohr (1918–1923), Collected Works, Volume 3, The Correspondence Principle (1976).
11. Tobar, et al, "Detecting single gravitons with quantum sensing" (2023).
12. Sakurai, *Advanced Quantum Mechanics* (1967).

Manifestations of the Bohr Correspondence Principle (BCP)

M Oaks, T Bridges, A Estrada, E Hall, M Neal, R Pannu, N Inan

Clovis Community College

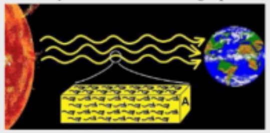
ABSTRACT

It is known that the classical energy of electromagnetic waves is amplitude dependent, while the quantum energy of photons is frequency dependent. The Bohr Correspondence Principle (BCP) predicts that the two theories should be consistent in the limit of large quantum numbers. However, it is common in the literature to find that photons are claimed to have a volume on the order of the wavelength cubed. We show that this is a violation of the BCP and is inconsistent with a formal treatment using Quantum Electrodynamics. Furthermore, the roles of the Schwinger limit, the Planck scale, and the Heisenberg Uncertainty Principle are used to explore the notion of a photon volume. Lastly, the analysis is extended to gravity by employing linearized General Relativity to describe the classical energy of gravitational waves, and by assuming the quantization of the gravitational field. This results in a Correspondence Principle for gravitons and a quantitative description of gravitational vacuum fluctuations.

BACKGROUND

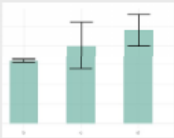
Bohr Correspondence Principal (BCP)

A submicroscopic quantum system becomes a macroscopic classical system in the limit of large quantum numbers [1].



Heisenberg Uncertainty Principal (HUP)

The volume of a photon has inherent uncertainty since there is uncertainty in the number of photons in a given volume. Consequently, there is uncertainty in the volume of a single photon. There is a fundamental minimum uncertainty inherent to all quantities in nature. This can be thought of as a minimum "error bar."



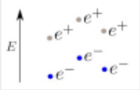
Quantum Electrodynamics (QED)

QED is a theory that explains the relationship between matter and light. It also states that in vacuum, there are random quantum fluctuations ("bubbling") of electromagnetic energy.

Schwinger Effect

The Schwinger Effect refers to the polarization of the vacuum. Under the influence of a strong electric field, electrons and positrons are pulled away from each other, subsequently creating a strong electric field between the positron and electron that will oppose the external electric field. This causes the external electric field to cancel out, and the interaction suggests a maximum electric field strength.

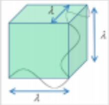
$E_{0,\text{Schwinger}} = \frac{m_e^2c^3}{e\hbar} \sim 10^{18}\ V/m$ [2, 3].



RESULTS

Classical/Quantum Paradox for Electromagnetism

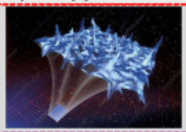
In Classical Physics, a light wave's energy depends on the amplitude of the wave (brightness), $E_{\text{classical}} = \frac{1}{2}\varepsilon_0 E_0^2 V$. In Quantum Mechanics, the energy of photons (particles of light) depends on their frequency, $E = Nhf$. Equating these (for monochromatic light) gives $E_0^2 = \frac{2Nh}{\varepsilon_0 V} f$ [4, 5]. The BCP only permits this equality for large values of N. Setting N= 1 leads to $E_0^2 \sim f$ which incorrectly implies a paradox that amplitude and frequency are interdependent [5].



Photon and Graviton Volume

Some papers incorrectly state $V_{\text{photon}} = \lambda^3$ for a single photon [5, 7]. QED states that vacuum fluctuations of the electric energy density is $\langle 0|\vec{E}\cdot\vec{E}|0\rangle \sim \hbar c/\lambda^4$. Photon energy density is $(\vec{E}^2)_{\text{avg}} \sim n\hbar c/\lambda$, where $n = N/V$. In the classical limit, fluctuations are negligible [8], so $(\vec{E}^2)_{\text{avg}} \gg \langle 0|\vec{E}\cdot\vec{E}|0\rangle$ which leads to $N \gg V/\lambda^3$. According to the BCP, N must be large in the classical limit. Therefore, $V_{\text{photon}} \neq \lambda^3$ but rather $V_{\text{photon}} \ll \lambda^3$.

Similarly, it has been incorrectly stated $V_{\text{graviton}} = \lambda^3$ for a single graviton [9]. However, we show that if gravity is a quantized tensor field, E_{ij}, then the classical limit again requires $(E_{ij}^2)_{\text{avg}} \gg \langle 0|E_{ij}E^{ij}|0\rangle$ where $\langle 0|E_{ij}E^{ij}|0\rangle \sim \hbar c/\lambda^4$ and , $(E_{ij}^2)_{\text{avg}} \sim n\hbar c/\lambda$. This also leads to $V_{\text{graviton}} \ll \lambda^3$.

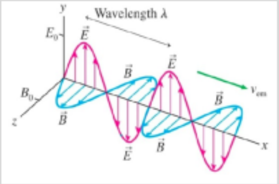


Planck and Schwinger Fields

Using $I = \frac{1}{2}c\varepsilon_0 E_0^2$, $V_{Pl} = l_{Pl}^3$ and $f_{Pl} = c/l_{Pl}$ leads $E_{0,Pl} = \sqrt{\frac{2\pi c^7}{\varepsilon_0 \hbar G^2}} \sim 10^{63}\frac{V}{m}$ which we call the "Planck electric field." It is 44 order of magnitude larger than the Schwinger limit but can only exist due to quantum vacuum fluctuations within a Planck time scale according to the HUP, $\Delta E\Delta t \geq \hbar/2$.

Similarly for gravity, $I_{GR} = \frac{c^3}{32\pi G}E_{ij,0}^2$. V_{Pl} and f_{Pl} lead to $E_{ij,0,Pl} = 8\pi f_{Pl} \sim 10^{44} s^{-1}$ which we call the "Planck gravito-electric tensor field." It is associated with "quantum space-time foam" since it can also be obtained from the HUP within a Plank time scale.

Lastly, a Schwinger gravito-electric tensor field is found to be $E_{ij,0,\text{Schwinger}} = \frac{4m_e^2c^4}{\hbar^2\omega}$. This expression would hold for angular frequencies between $10^{17}\ \text{rad}/s < \omega \ll 10^{32}\ \text{rad}/s$ which correspond to $10^{-23} < h_{ij,0} \ll 1$. Strain fields within this range exist in nature due to classical sources however not at the needed frequency range. Therefore, this effect would be purely a quantum gravity phenomenon which doesn't arise from classical sources.



Classical/Quantum Paradox for Gravity

To describe gravity in General Relativity, we use a metric with a perturbation to flat space-time: $g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$. For weak gravity, $|h_{\mu\nu}| \ll 1$, the propagating field h_{ij}^{TT} is transverse ($\partial_i h_{ij}^{TT} = 0$) and traceless ($\delta^{ij}h_{ij}^{TT} = 0$). A gravito-electric tensor field [6] can be defined as $E_{ij} = -\partial_t h_{ij}^{TT}$. Equating classical energy density, $\frac{c^2}{32\pi G}E_{ij,0}^2$, to graviton energy density, Nhf/V, leads to $E_{ij,0}^2 = \frac{32\pi G h N f}{c^2 V}$. The BCP only permits this equality for large N. Setting N=1 leads to $E_{ij,0}^2 \sim f$ which again incorrectly implies the amplitude and frequency are interdependent.

Common Planck (Pl) Units [10, 11]

Time: $t_{Pl} = \sqrt{\frac{\hbar G}{c^5}} \sim 10^{-44}\ s$ **Length**: $l_{Pl} = ct_{Pl} \sim 10^{-35}\ m$ **Mass**: $m_{Pl} = \sqrt{\frac{\hbar c}{G}} \sim 10^{-8}\ kg$

Frequency: $f_{Pl} = c/l_{Pl} \sim 10^{43}\ Hz$ **Energy**: $E_{Pl} = m_{Pl}c^2 \sim 10^9\ J$ **Charge**: $q_{Pl} = 4\pi\sqrt{\hbar c\varepsilon_0} \sim 10^{-17}\ C$

PODER — PROVIDING OPPORTUNITIES DESIGNED TO EDUCATE AND RECOGNIZE — CLOVIS COMMUNITY COLLEGE

CONCLUSIONS

Classical/Quantum Paradox for EM

Equating the classical energy of electromagnetic waves to the quantum energy of photons leads to $E_0^2 = \frac{2Nh}{\varepsilon_0 V}f$. We have shown that this equation is only valid for large N in accordance with the BCP. This resolves the apparent paradox that amplitude and frequency are interdependent.

Classical/Quantum Paradox for Gravity

Applying the same approach to linearized General Relativity also resolves an apparent paradox that the gravitational wave amplitude and the graviton frequency would be interdependent.

Photon and Graviton Volume

Using QED, we demonstrate that a single photon does not have a volume given by the cube of the wavelength as is falsely assumed in the literature. Assuming the gravitational field is quantized, we similarly demonstrate that a single graviton does not have a volume given by the cube of the wavelength as is also falsely assumed in the literature.

Planck and Schwinger Fields

Applying the HUP, we obtain a "Planck electric field" associated with quantum vacuum fluctuation that occur on the order of the Planck time. Using the same approach for gravity, we also obtain a "Planck gravito-electric tensor field" which is associated with the maximum for "quantum space-time foam." Also, We obtain a "Schwinger gravito-electric tensor field" and find that the associated strain fields could exist from classical source in nature, but the frequencies could not. Therefore, this effect would be purely a quantum gravity effect.

REFERENCES

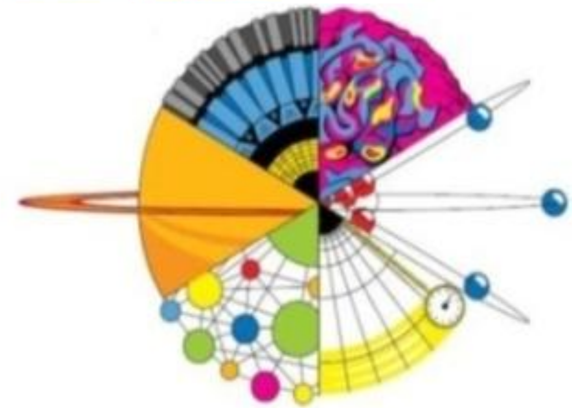
1. Bohr (1918-1923); 2. Schwinger (1951); 3. Ong (2020); 4. Antonga, et al (2023); 5. Goenawan (2021); 6. Inan (2018); 7. Xu (2021); 8. Sakurai (1967); 9. Tobar, et al (2023); 10. Planck (1889); 11. Lehto (2009)

Dr. Nader (Nathan) Inan

Affiliations: **Clovis College** / CSU Fresno / UC Merced

Home / Academic Resources / Pathways / Physics





Education

- B.S., Long Beach State
- M.S., Fresno State
- Ph.D., UC Merced

Research Interest:

Classical and Quantum Systems in Curved Space-time
(with emphasis on gravitational waves and superconductivity)

Clovis Community College

Athletics | Library | My Portal | Quick Links

About Us | Admissions & Aid | Academics | Campus Life | Student Services | APPLY NOW

Dr. Nader Inan - Physics

"If we knew what it is we were doing, it would not be called research. Would it?" – Albert Einstein

The truth is that research can be a bumpy ride with lots of mistakes along the way. But it can also be one of the most thrilling aspects of science! Discovering something new to the human race, and sharing that new found knowledge with the world, is a very satisfying experience. At Clovis Community College we aspire to help students have that experience by instilling the necessary skills to conduct effective research. We'd love for you to join our research and experience that thrill for yourself!

Interested in exotic physics like Dark Energy and Dark Matter?

Join me and colleagues from other parts of the US, Macedonia, and Egypt as we follow up on our recent publications. . . .

Journal of Cosmology and Astroparticle Physics
An IOP and SISSA journal

RECEIVED: *May 4, 2024*
ACCEPTED: *July 12, 2024*
PUBLISHED: *August 9, 2024*

Graviton mass due to dark energy as a superconducting medium-theoretical and phenomenological aspects

Nader Inan,[a,b,c,*] Ahmed Farag Ali,[d,e] Kimet Jusufi[f] and Abdelrahman Yasser[g]

[a]*Department of Physics, Clovis Community College,*
10309 N. Willow, Fresno, CA 93730, U.S.A.

Interested in exotic physics like Dark Energy and Dark Matter?

Join me and colleagues from other parts of the US, Macedonia, and Egypt as we follow up on our recent publications. . . .

ELSEVIER

Contents lists available at ScienceDirect

Annals of Physics

journal homepage: www.elsevier.com/locate/aop

Modified gravity/entropic gravity correspondence due to graviton mass

Kimet Jusufi [a], Ahmed Farag Ali [b,c], Abdelrahman Yasser [d,*], Nader Inan [e,f,g], A.Y. Ellithi [d]

[a] *Physics Department, University of Tetova, Ilinden Street nn, 1200, Tetovo, North Macedonia*
[b] *Essex County College, 303 University Ave, Newark, NJ 07102, USA*
[c] *Department of Physics, Faculty of Science, Benha University, Benha, 13518, Egypt*
[d] *Department of Physics, Faculty of Science, Cairo University, Giza 12613, Egypt*
[e] *Clovis Community College, 10309 N. Willow, Fresno, CA 93730, USA*
[f] *University of California, Merced, School of Natural Sciences, P.O. Box 2039, Merced, CA 95344, USA*
[g] *Department of Physics, California State University Fresno, Fresno, CA 93740-8031, USA*

Received 26 April 2024; Accepted 8 June 2024

Interested in exotic physics like Dark Energy and Dark Matter?

A LETTERS JOURNAL EXPLORING THE FRONTIERS OF PHYSICS

IOP Institute of Physics

Unraveling the mystery of the cosmological constant: Does spacetime uncertainty hold the key?[a]

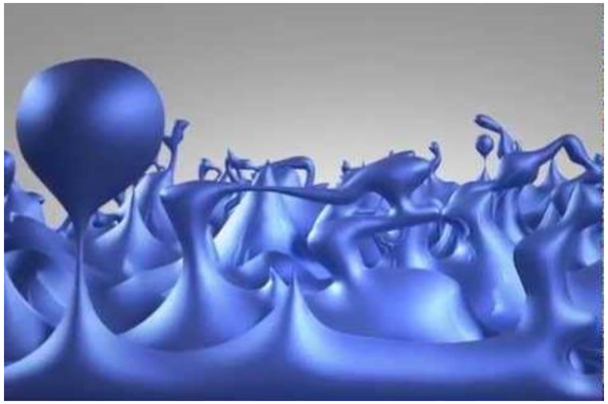
Ahmed Farag Ali[1,2] and Nader Inan[3,4,5]

Published 24 August 2023 • Copyright © 2023 EPLA

Europhysics Letters, Volume 143, Number 4

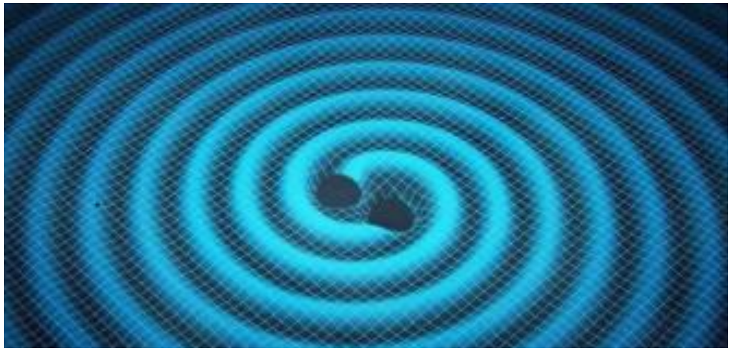
Citation Ahmed Farag Ali and Nader Inan 2023 *EPL* **143** 49001

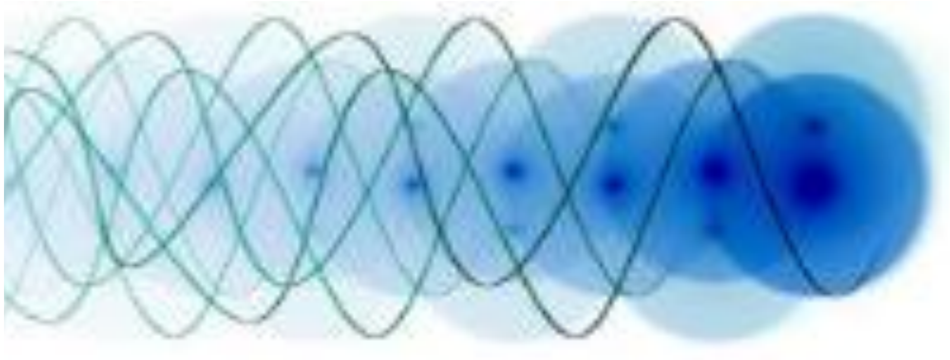
DOI 10.1209/0295-5075/acf0e5



Essay received honorable mention in the 2023 Gravity Research Foundation Competition.

Quantum Linearized GR
with Applications to Propulsion





Dr. Nader (Nathan) Inan

Clovis College / Fresno State / UC Merced

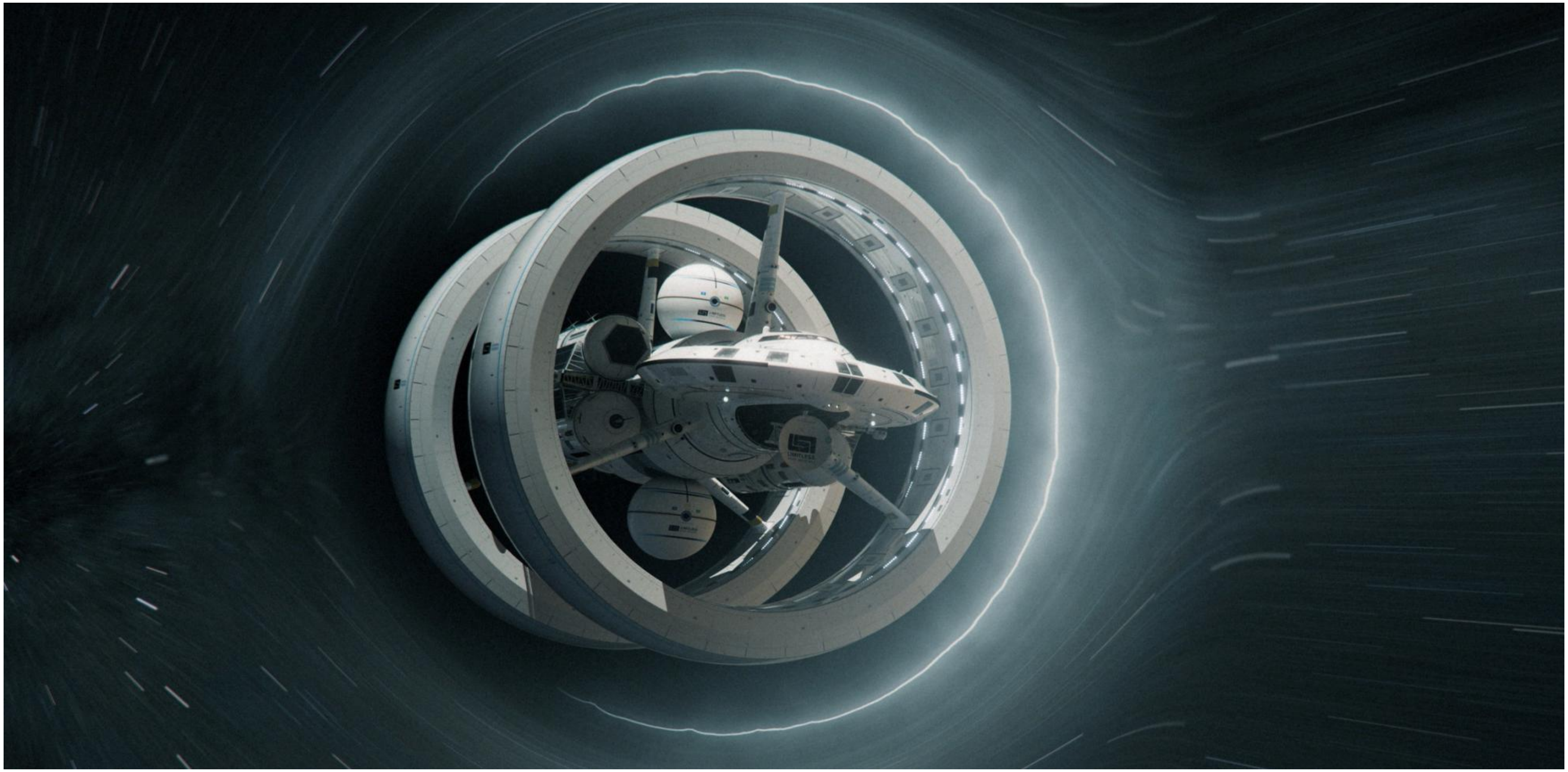
Texas Space

TEXAS SPACE

ALTERNATIVE PROPULSION ENGINEERING CONFERENCE

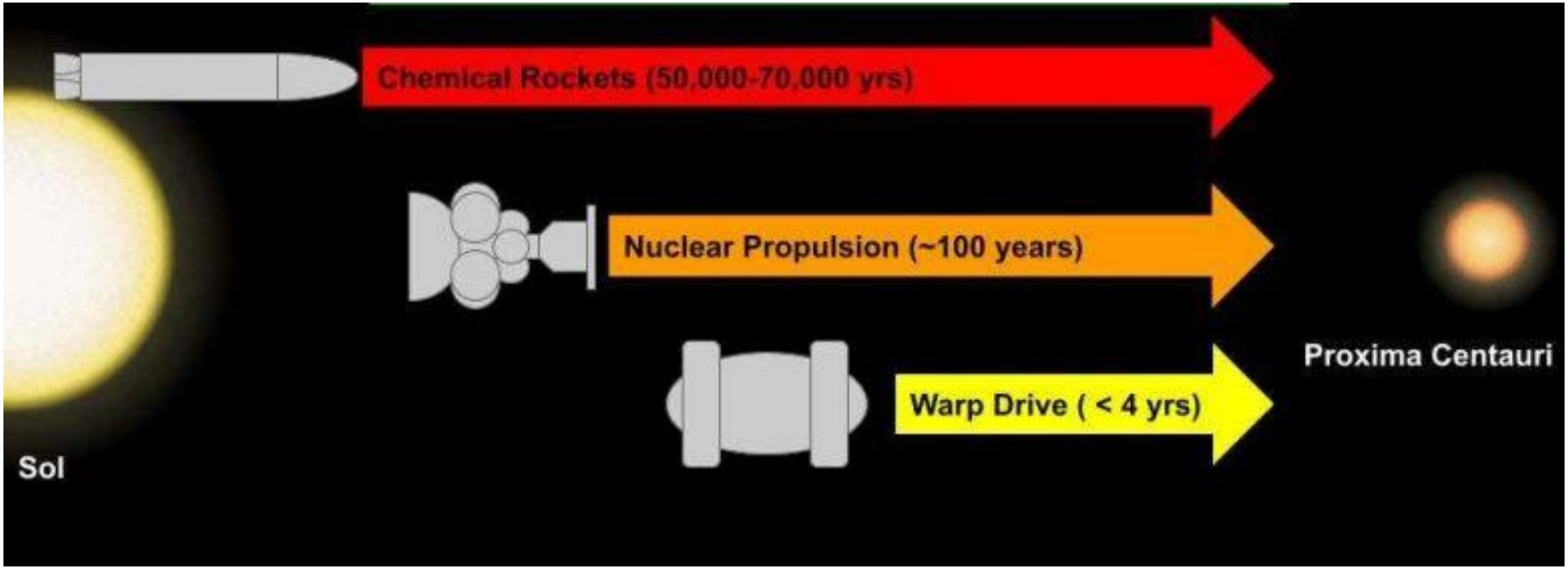
Dec 20th 2025

Speculative Applications of General Relativity: Warp drives



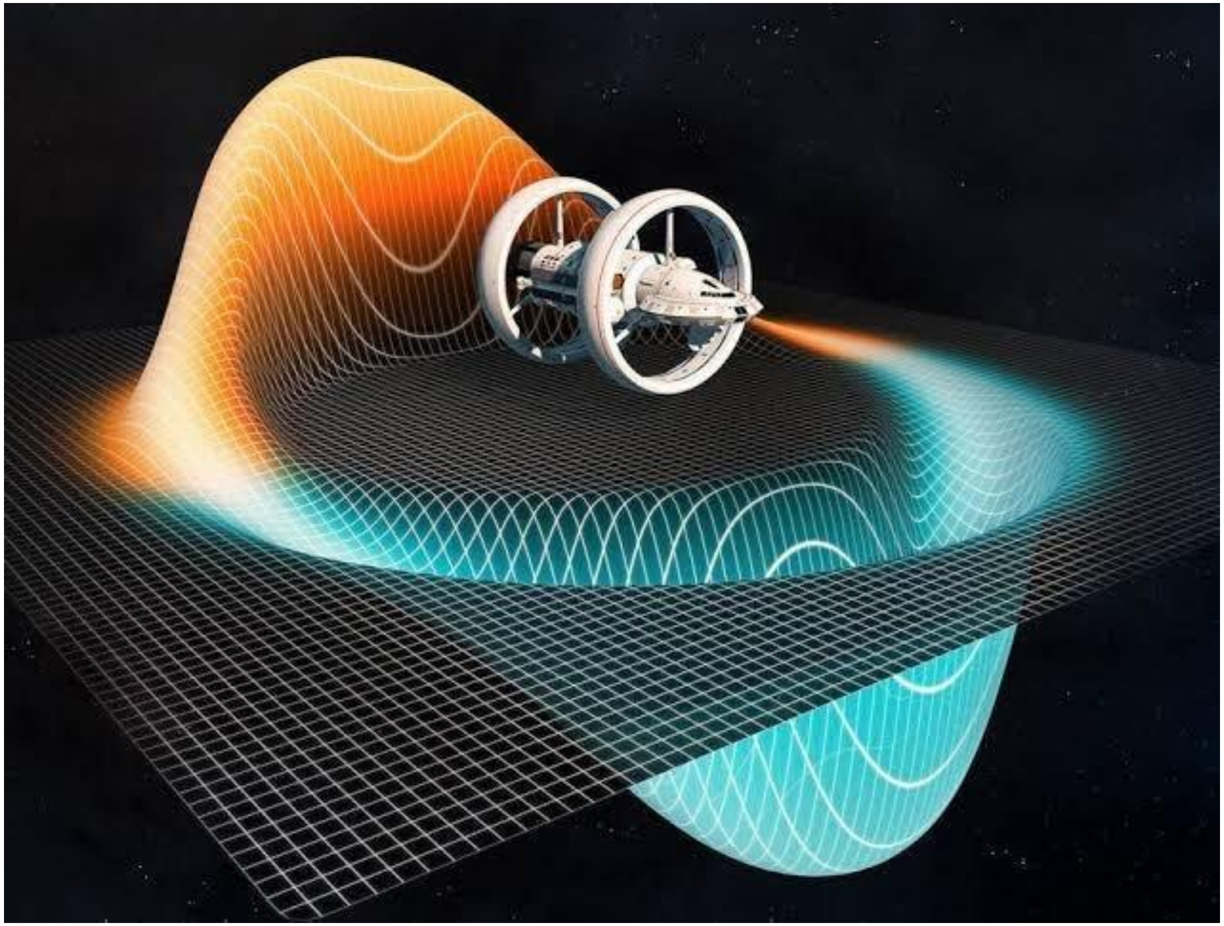
Can we "stretch" and "compress" space-time around a spaceship to produce propulsion?

Speculative Applications of General Relativity: Warp drives



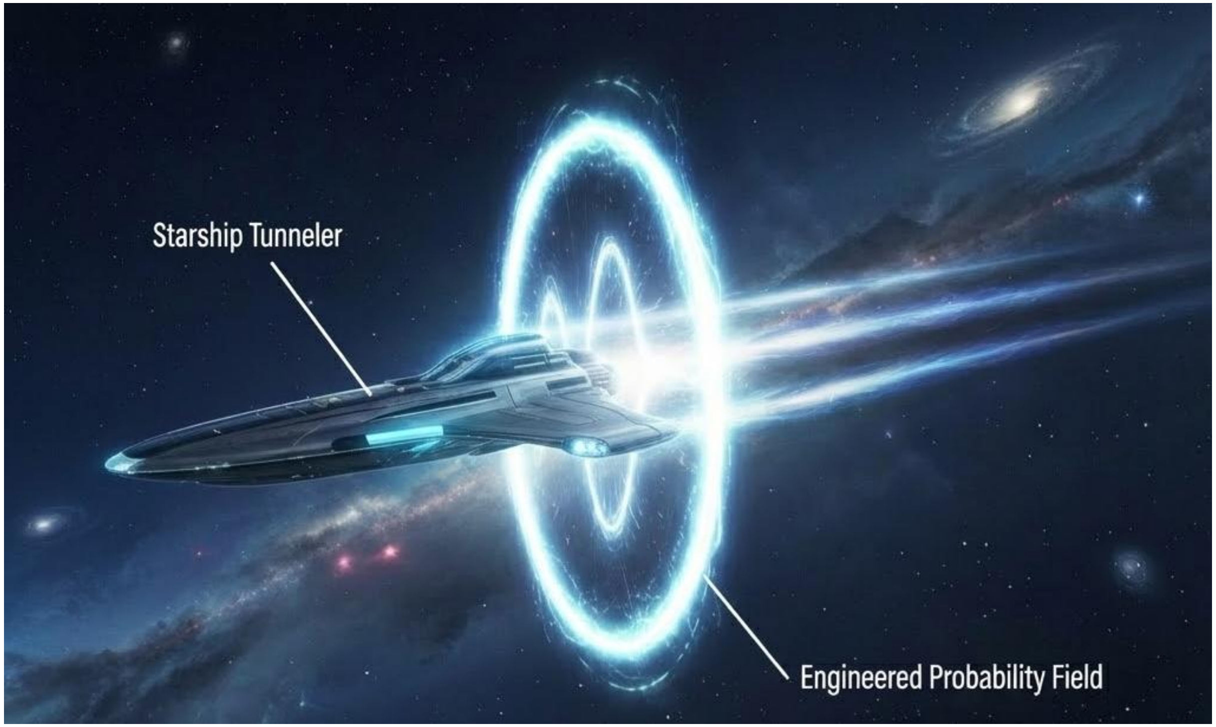
- **Chemical rockets** use combustion of fuel.
- **Nuclear propulsion** would use fission (nuclear detonation).
- **Warp drives** use space-time curvature for propulsion. There is no speed limit since GR does not put a limit on the speed of the "bubble."

Classical warp drive via metric engineering



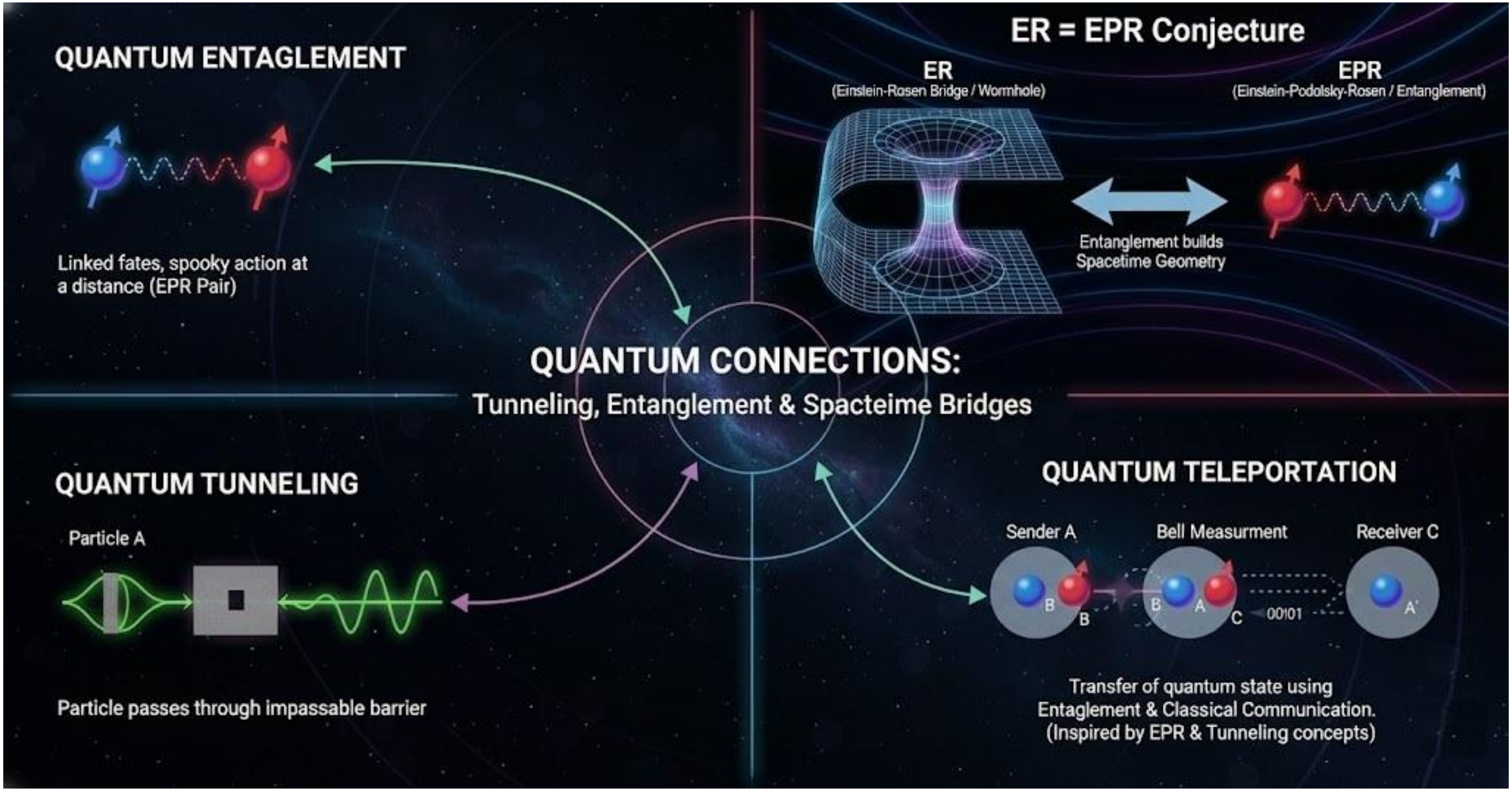
The classical warp drive is described in terms of warping space-time (metric engineering).

Quantum alternative: Warp drive via probability field engineering (gravitational quantum tunneling)



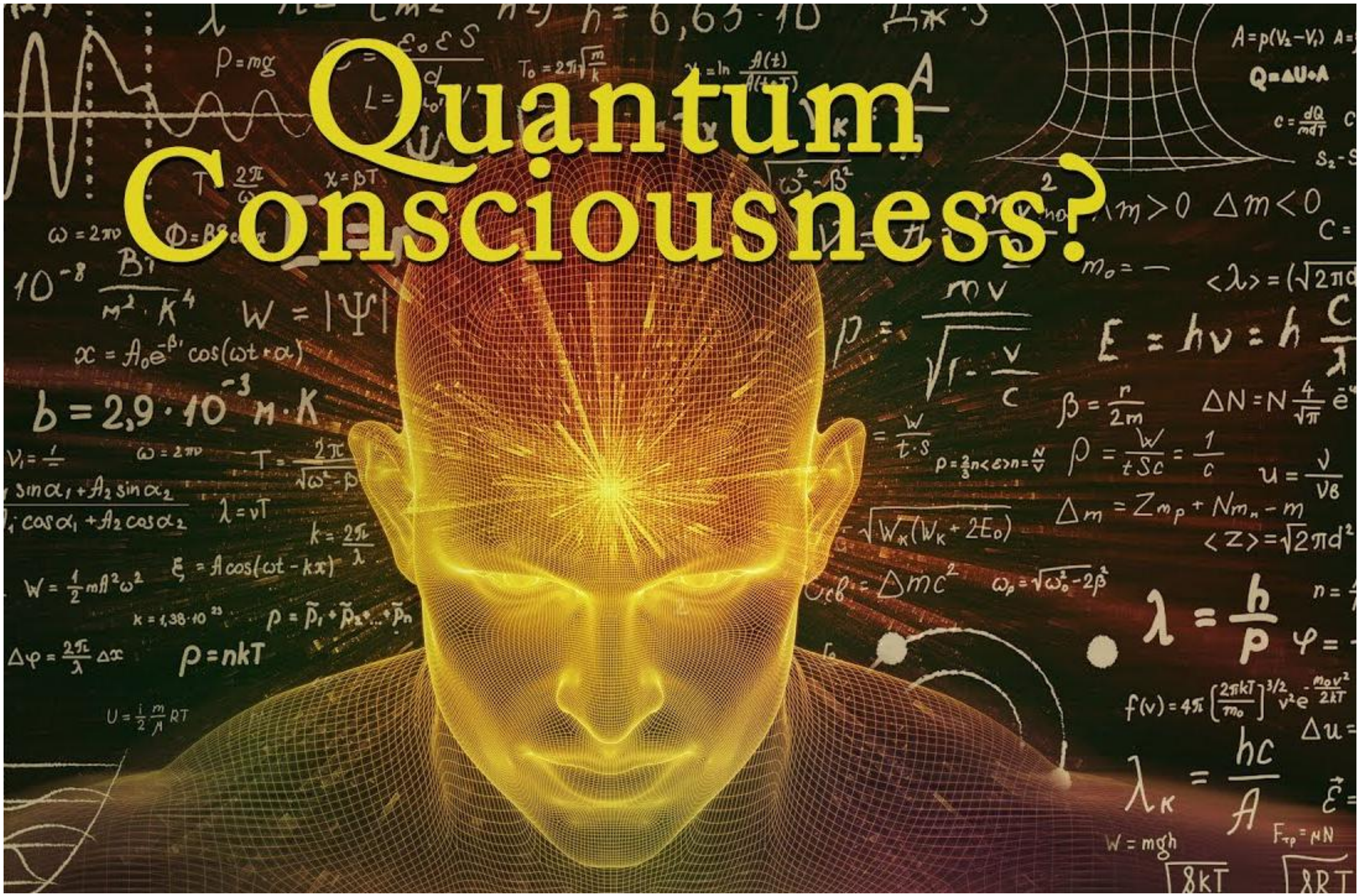
The quantized linear GR perturbation implies metric engineering is equivalent to probability field engineering. Could this make it possible to control quantum tunneling and use it as a type of warp drive? The idea requires engineering the quantum probability field to control quantum tunneling through the "space-time barrier" (a barrier similar to the vacuum gap between the tip and surface of an STM).

Relation to ER = EPR Conjecture



ER = EPR conjecture may be related to tunneling, entanglement, and teleportation because all involve non-locality ("spooky action at a distance")

Interested in exploring connections between Physics, Neuroscience, Metaphysics and Philosophy?



Interested in exploring connections between Physics, Neuroscience, Metaphysics and Philosophy?

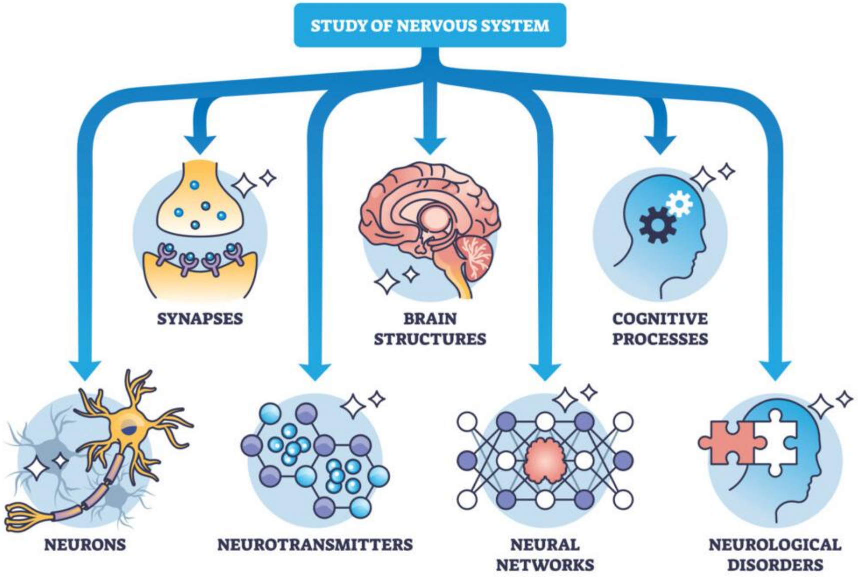
Join me and colleagues in exploring interdisciplinary topics . . .

Exploring Individual and Universal Consciousness using U(1) and SU(3) symmetry

Ahmed Farag Ali[△▽,*] Nader Inan[□⊕⊗,†] and Ruben E. Laukkonen[○‡]

Topics studied in this research:

- Bridging physics and neuroscience
- Quantifying states of consciousness



Interested in exploring connections between Physics, Neuroscience, Metaphysics and Philosophy?

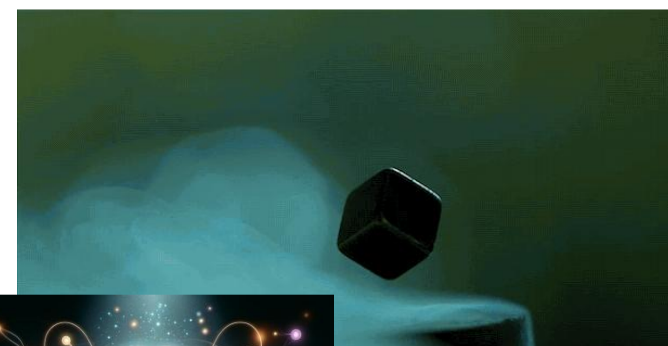
Join me and colleagues in exploring interdisciplinary topics . . .

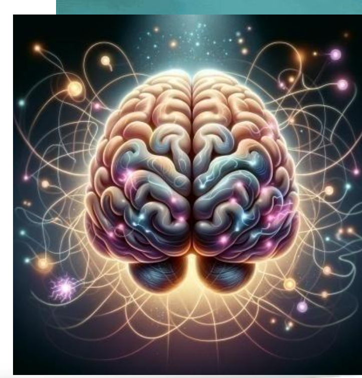
Exploring Individual and Universal Consciousness using U(1) and SU(3) symmetry

Ahmed Farag Ali[△▽,*] Nader Inan[□⊕⊗,†] and Ruben E. Laukkonen[○‡]

Topics studied in this research:

- Organic superconductivity of the brain
- Neurological quantum supercurrents
- Quantifiable features of meditative states
- The role of U(1) symmetry breaking
- **Patent idea**: Head device which induces meditative state





Interested in exploring connections between Physics, Neuroscience, Metaphysics and Philosophy?

Join me and colleagues in exploring interdisciplinary topics . . .

Exploring Individual and Universal Consciousness using U(1) and SU(3) symmetry

Ahmed Farag Ali[△▽,*] Nader Inan[□⊕⊗,†] and Ruben E. Laukkonen[○‡]

Topics studied in this research:

- Universal consciousness due to SU(3) symmetry which pervades the universe
- Unlock deepest conscious states
- Telepathy
- **Patent idea**: Telepathy device via SU(3) symmetry

Interested in developing cutting edge technology?

PHYSICS COLLOQUIUM:

Harnessing the potential of gravitational waves

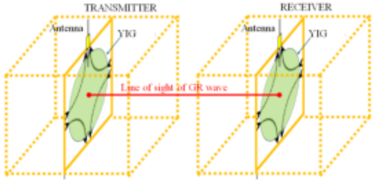
Juan Feria, Raymond Chiao, and Nader Inan
Physics
UC Merced and Texas Space LLC

About The Speaker:

Juan Feria is founder and CEO of Texas Space LLC, a quantum physics R&D company focused on groundbreaking innovations. Prior to that, he served nine years in the Marines and earned degrees in Technical Management and Homeland Security. He also worked as a senior executive managing $100 million in profit and loss before transitioning to the technology sector, excelling as an expert in large complex technology infrastructure, cyber, and engineering solutions.

Raymond Chiao is a professor emeritus jointly in the UC Merced schools of Natural Sciences and Engineering. Previously, he was a professor for 38 years at UC Berkeley, where he earned international acclaim (including the Willis E. Lamb Medal and the Einstein Prize for Laser Science) studying nonlinear and quantum optics. At UC Merced, he is pursuing a new line of groundbreaking research on gravitational radiation.

Nader (Nathan) Inan earned his PhD in Physics at UC Merced under the guidance of Professor Chiao. Nathan is a tenured physics instructor and has published numerous peer-reviewed papers, including papers that received honorable mention in the prestigious Gravity Research Foundation. His research focuses on formulations of General Relativity and their applications to quantum mechanical systems, with an emphasis on gravitational waves interacting with superconductors.



Date:
1/24/2025

Time:
10:30 AM – 11:50 AM

Location:
GRANITE PASS 135

Abstract:

For over a century, electromagnetic (EM) waves have been used for communication, imaging, radar, fiber optics, lasers, and an assortment of other technologies. However, EM waves have the critical limitation of being obstructed by various materials. This prevents their use in a variety of applications (such as communication with submarines, underground facilities, etc.). Furthermore, an elaborate network of satellites is needed for communication around the world since EM waves cannot pass through the earth. By contrast, gravitational (GR) waves were discovered only in the last decade and introduce a completely new way of overcoming all the obstacles associated with EM waves. In particular, because GR waves can pass through any material, they can be used for communication through any depth of the ocean, through any terrain, and even across the earth. This eliminates the need for satellite systems and revolutionizes communication technology. Further advancements could even lead to gravitational mirrors, lasers, fiber optics, imaging, and possibly even propulsion.

This was a colloquium at UC Merced where Dr. Inan spoke about gravitational wave (GW) communication.

We are partnering with researchers and tech companies (such as Texas Space) to produce patents for new communication and propulsion technology.

Learn how to get involved with tech companies!

Interested in developing cutting edge technology?

United States
Patent Application Publication
Texas Space LLC

COMMUNICATION SYSTEM USING GYROMAGNETIC TRANSDUCTION BETWEEN GRAVITATIONAL AND ELECTROMAGNETIC WAVES

Applicant: **Texas Space LLC**, Dallas, TX (US)

Inventors: **Raymond Chiao, Jay Sharping, Nader Inan**

Correspondence Address:
Texas Space LLC
300 N Akard St., #1617
Dallas, TX 75201-3459

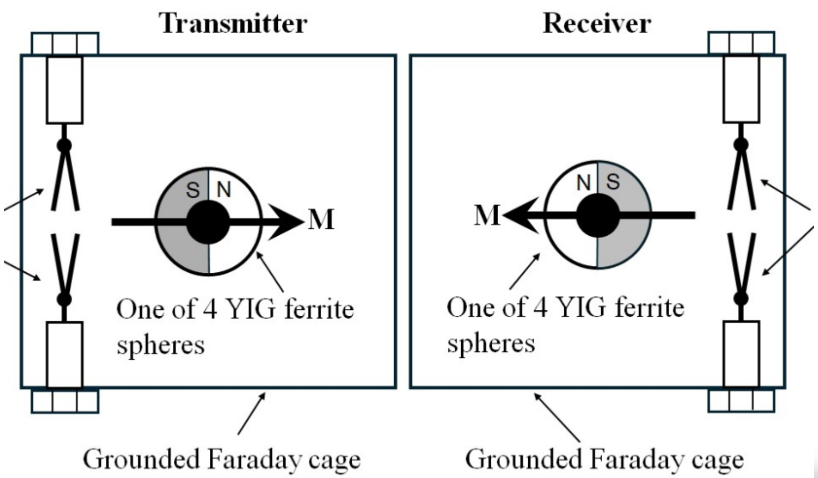
Appl. No: **xx/xxx,xxx**

Filed: [Month, day, 2024]

SUMMARY

The generation of HFGWs is proposed here via the coupling of GWs to the gyromagnetic moment of electron spin ("gravitational radio"). The gravitational radio enables communication by transduction between gravitational and electromagnetic radiation via coupling to the gyromagnetic moment of a coherent ensemble of electron spins in a magnetized material.

A gravitational radio transceiver



Benefit 1

Satellite Network Replacement

Because gravitational waves pass directly through the earth, there will no longer be a need to use space satellites for communication. This could revolutionize communication technology.

Benefit 2

Gravitational Wave Phone

Using gravitational waves would completely eliminate the interference and reception problems associated with traditional electromagnetic communication. Cell phones would be completely redesigned for gravitational wave communication, and the cell phone market would be entirely overturned.

Benefit 3

Underwater Communication

Because gravitational waves pass freely into the ocean, they can be used for underwater communication. This has obvious military use (such as for submarines) as well as civilian uses such as search and rescue, private sea expeditions, etc.

Benefit 4

Underground Communication

Because gravitational waves pass through rock, they can be used for underground communication. This has obvious military use (such as searching for enemy tunnels or communicating from deep bunkers) as well as other civilian uses such as cave exploration, geological research, etc.

Benefit 5

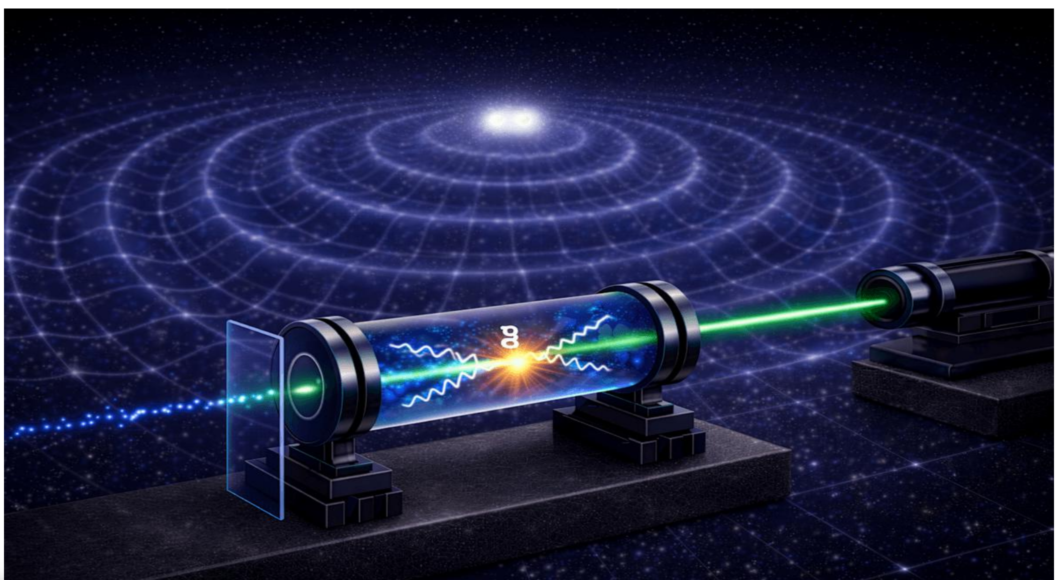
Secure Communication

If gravitational wave communication is only possible with this new technology involving gyromagnetic coupling, then this would provide a channel of communication that is completely private and secure. The fact that others do not have access to this technology would prevent them from eavesdropping on communication via gravitational waves

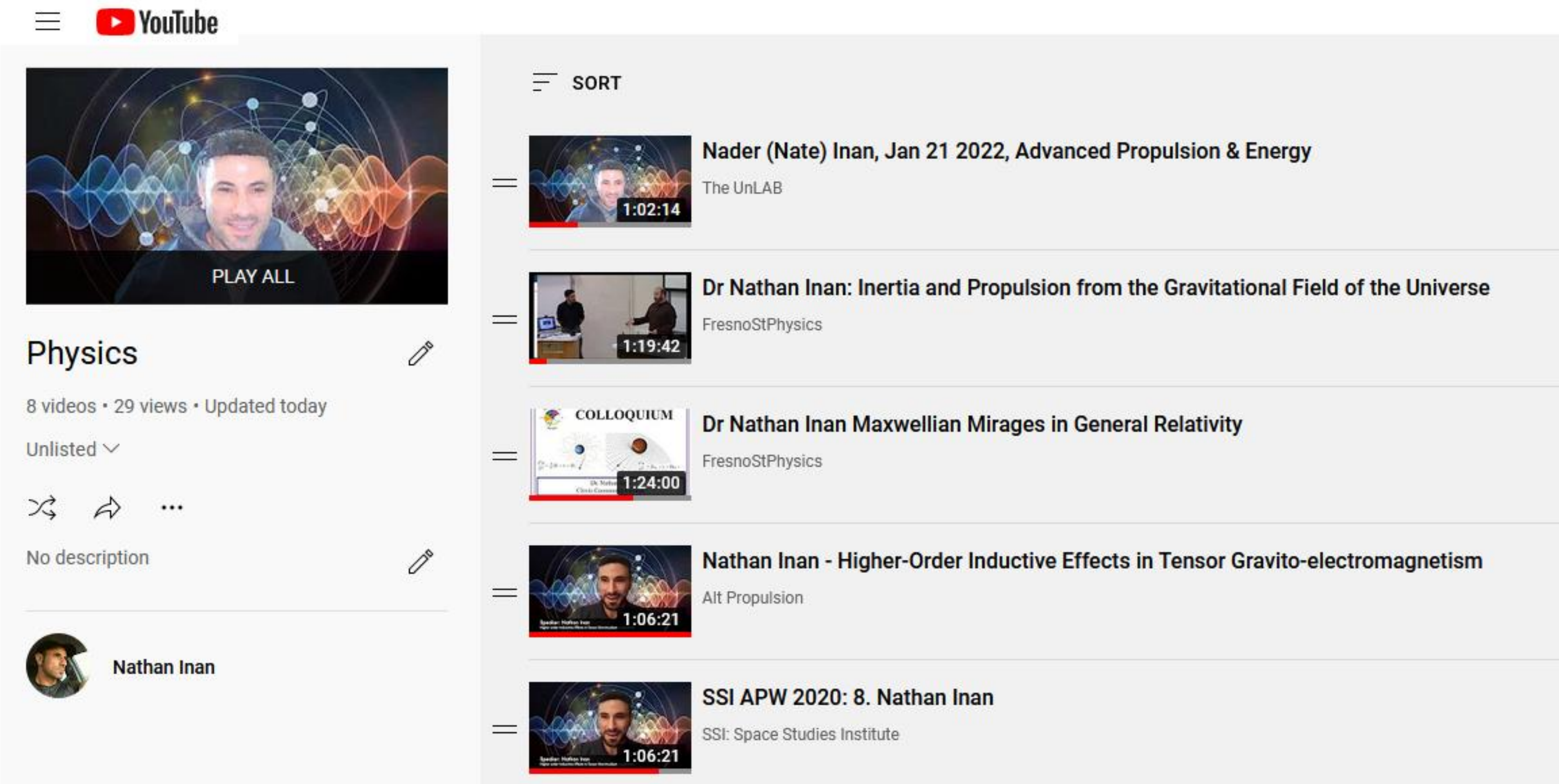
Benefit 6

Gravitational Lasers

If gravitational waves can be generated and amplified in a laboratory, there is a potential for creating a gravitational laser. All the physics of laser optics could then be applied to gravitational waves which might lead to new methods of research and applications yet to be discovered.



For more about our research, see YouTube . . .



https://www.youtube.com/channel/UCwH9igJckxl3hHNG2bl8fkw

Other topics actively researching . . .

- Gravito-electromagnetism
- Interaction of gravity and macroscopic quantum systems (superconductors, Bose-Einstein condensates, etc)
- Gravitational wave generation, detection, and reflection
- Casimir effects (electromagnetic and gravitational)
- Aharonov-Bohm effects (electromagnetic and gravitational)
- Cosmological Constant problem and vacuum energy
- Spontaneous symmetry breaking and mass generation
- Hawking / Unruh effects and Planck scale physics

Contact me if you're interested! ☺

Email: nader.inan@cloviscollege.edu