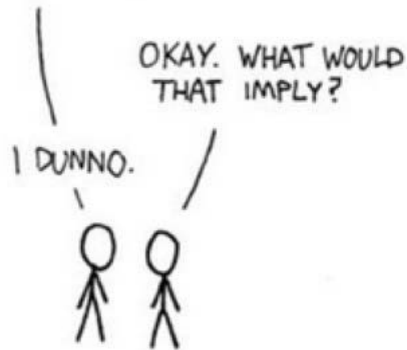


# Theories of Gravity

Sapan Karki

## STRING THEORY SUMMARIZED:

I JUST HAD AN AWESOME IDEA.  
SUPPOSE ALL MATTER AND ENERGY  
IS MADE OF TINY, VIBRATING "STRINGS."



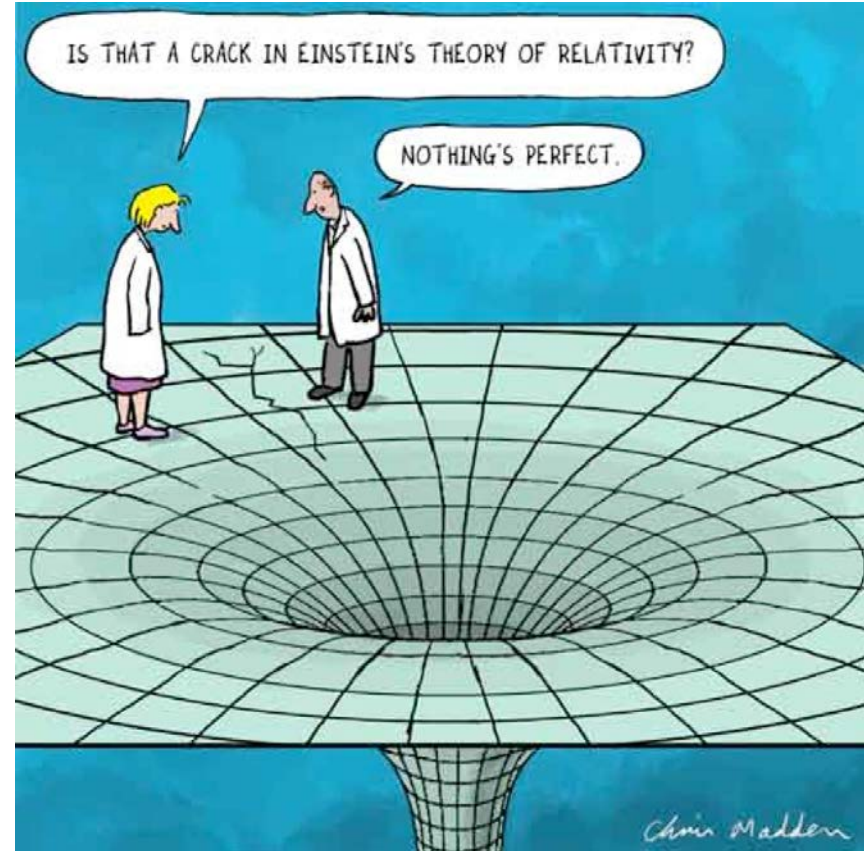
## Introduction:

- ▶ General Relativity is the most correct description of gravity till now.
- ▶ Two types of modification: Classical and Quantum
- ▶ The world is Quantum Mechanical - then why do Classical ?
- ▶ Is Quantum Mechanical Gravity possible ?

# Need for Modification

- ▶ General Relativity fails at high energies, so what about.....
- ▶ Black Holes, Singularities ?
- ▶ Beginning of the Universe ?
- ▶ Quantum Gravity ?
- ▶ and what about Dark Matter and Dark Energy?

All that from an apple falling to the ground ?

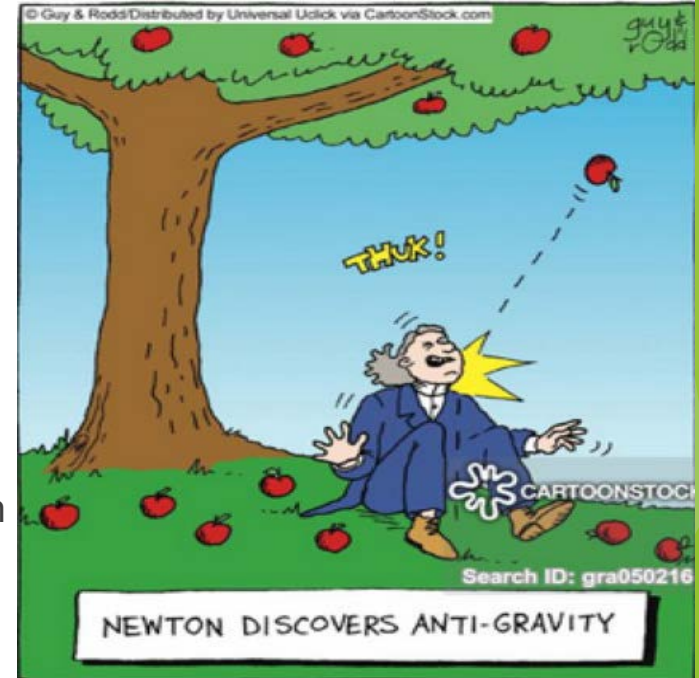


# God Said “Let Newton Be” and All was Light.....

- ▶ The first Law to actually unite Heavens and Earth:

$$F = G \frac{m_1 m_2}{r^2}$$

- ▶ Action at a Distance Force
- ▶ No gravitational waves, mercury perihelion and no explanation of gravity itself.



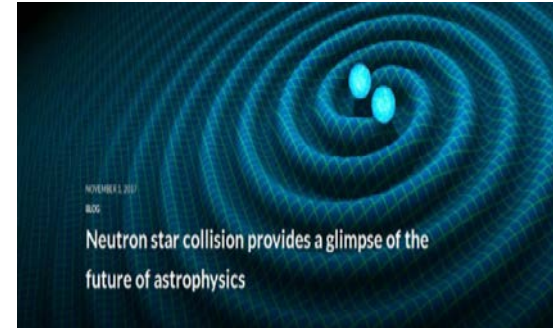
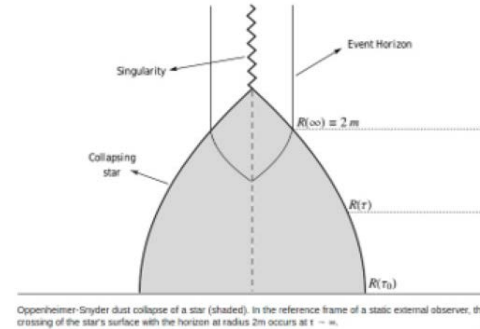
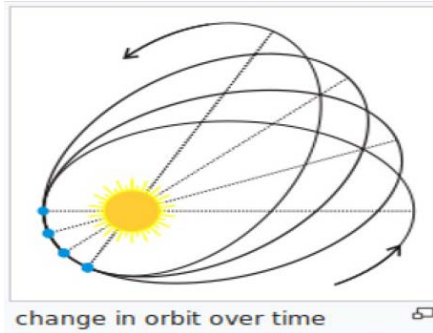
# General Relativity

- ▶ Matter tells space how to curve and space tells matter how to move.

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}$$

- ▶ This gives rise to the idea of “Gravitational Waves” which travel at the speed of light at far infinity.
- ▶ This also gives rise to the ideas in Cosmology like Big Bang, Black Holes, Singularities and all other weird stuff.

“Then I would feel sorry for the good Lord; the theory is correct.”



# Predictions made by General Relativity

# Brans-Dicke Theory of Gravity

- ▶ Brans-Dicke Theory of Gravity

$$\square\phi = \frac{8\pi}{3+2\omega} T$$

$$G_{\alpha\beta} = \frac{8\pi}{\phi^2} T_{\alpha\beta} + \frac{\omega}{\phi^2} \left( \partial_a\phi\partial_b\phi - \frac{1}{2} g_{\alpha\beta}\partial_c\phi\partial^c\phi \right) + \frac{1}{\phi} (\nabla_\alpha\nabla_\beta\phi - g_{\alpha\beta}\square\phi)$$

- ▶ The universal Gravitational Constant is a field.
- ▶ Field  $\phi$  tells how matter and curvature are related.

# Brans-Dicke Theory of Gravity

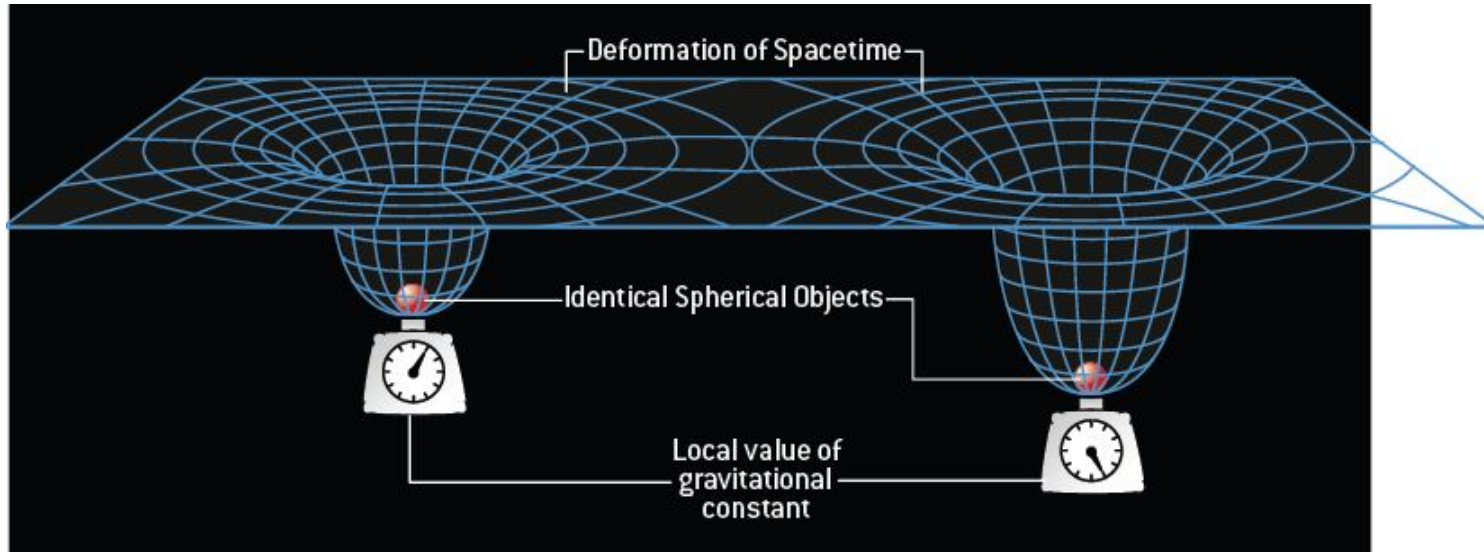


Image Credit: [https://physicsgg.files.wordpress.com/2012/09/brans\\_dicke.jpg](https://physicsgg.files.wordpress.com/2012/09/brans_dicke.jpg)



# f(R) Gravity Theory

- ▶ The Action in this theory is actually a function of Ricci rather than being the Ricci itself, usually a polynomial in R which acts as a correction:

$$S[g] = \int \frac{1}{2\kappa} R \sqrt{-g} d^4x$$
$$S[g] = \int \frac{1}{2\kappa} f(R) \sqrt{-g} d^4x$$

# f(R) Gravity Theory

- ▶ The Field Equation obtained from this Action is non-linear and contains a lot of complicated terms:

$$F(R)R_{\mu\nu} - \frac{1}{2}f(R)g_{\mu\nu} + [g_{\mu\nu}\square - \nabla_{\mu}\nabla_{\nu}]F(R) = \kappa T_{\mu\nu}$$

- ▶ This equation has very less exact solutions as compared to that for General Relativity.

# Kaluza-Klein Theory of Gravity



Image Credit: <http://www.thephysicsmill.com/2013/04/28/stuff-from-shape-kaluza-klein-theory/>

- ▶ Five dimensional gravity; a very special fifth dimension
- ▶ Light pops out of the fifth window miraculously
- ▶ This separates to four dimensional gravity and Maxwell's equations

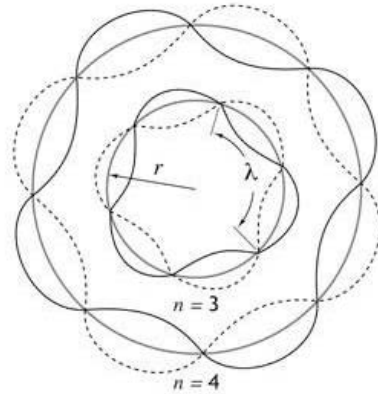
# Kaluza-Klein Theory of Gravity



## The De Broglie Wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv}$$

$\lambda$  = wavelength  
 $h$  = Planck's constant ( $6.63 \times 10^{-34}$  J · s)  
 $p$  = momentum  
 $m$  = mass  
 $v$  = speed



*De Broglie's extension of the concept of particle-wave duality from photons to include all forms of matter allowed the interpretation of electrons in the Bohr model as standing electron waves. De Broglie's work marked the start of the development of wave mechanics.*

Image Credit: <https://www.pinterest.com/pin/343962490275109785/>

- ▶ The motion in fifth dimension is constant
- ▶ This motion corresponds to the charge of the particle
- ▶ The motion and finally charge become quantized by Quantum Mechanics.

# Conclusion

A lot of work has been done to understand gravity.

Many different classical approaches have been made to take the quantum effect into account.

Not much progress, hopefully in the future.



*"Did you pay the gravity bill?"*

Thank  
You!!!!!!!!!!