Theories of Gravity

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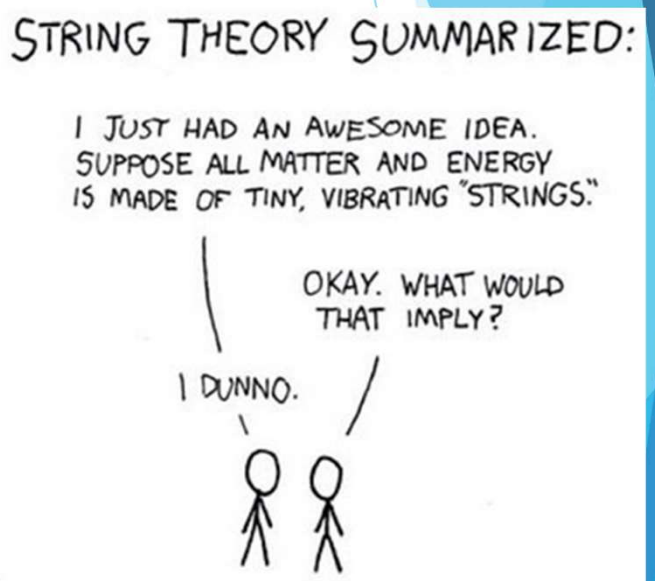
Introduction

- 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 not possible ?



Need for Modification

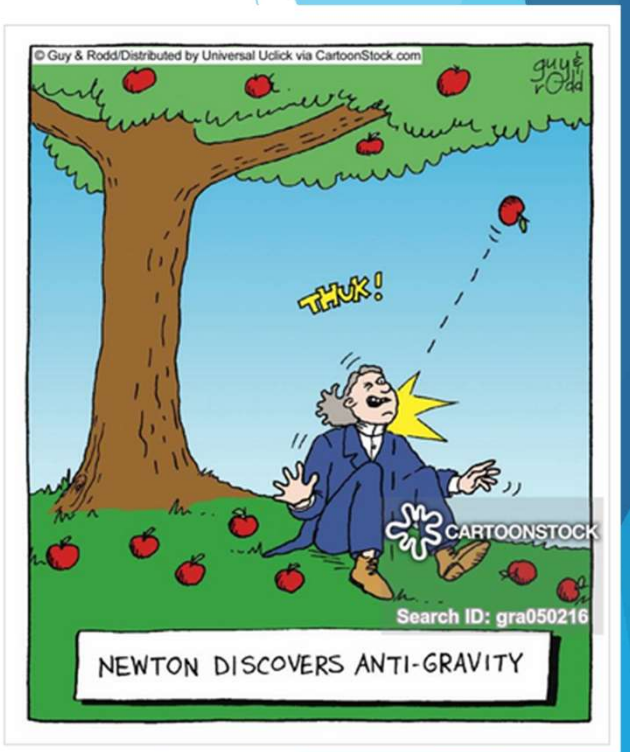
- Black Holes ,Singularities?
- Beginning of the Universe?
- Quantum Gravity?
- Possibly Dark Matter and Dark Energy?
-
- All that just from an apple falling to the ground

God said, "Let Newton be!" and all was light

- First law to accurately unite heavens and earth

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

- Action at a distance force
- No special Relativity



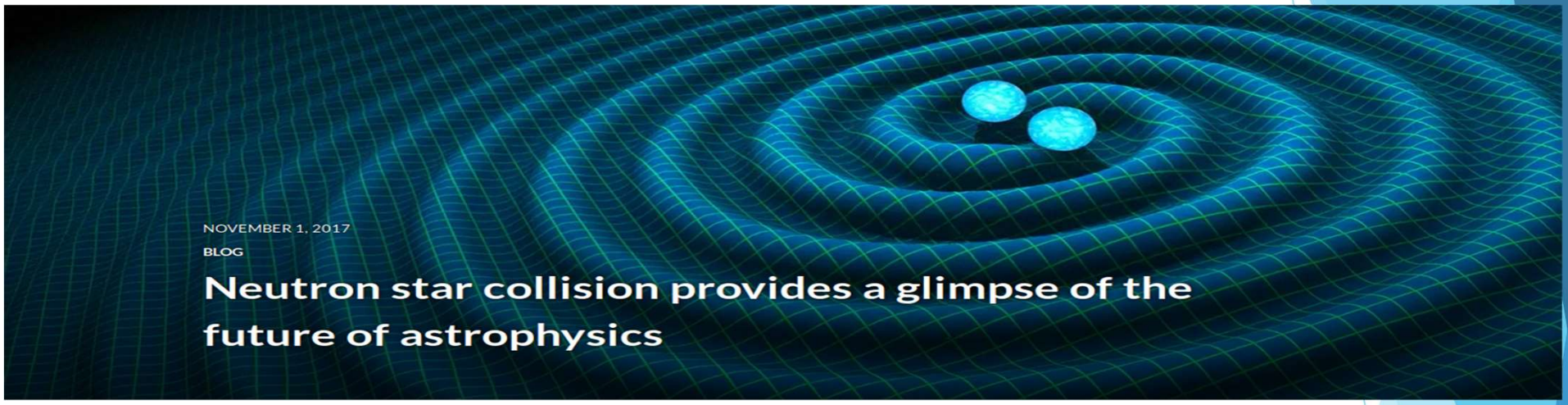
General Relativity

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

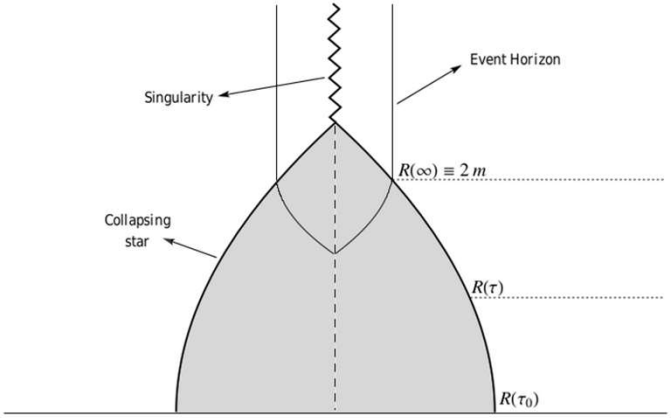
$$R_{\mu\nu} - \tfrac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}T_{\mu\nu}$$

- Gives rise to idea of gravitational waves which travel at speed of light at far
- infinity
- Gives rise to the idea of cosmology,big bang , black holes ,singularities and all the weird stuff

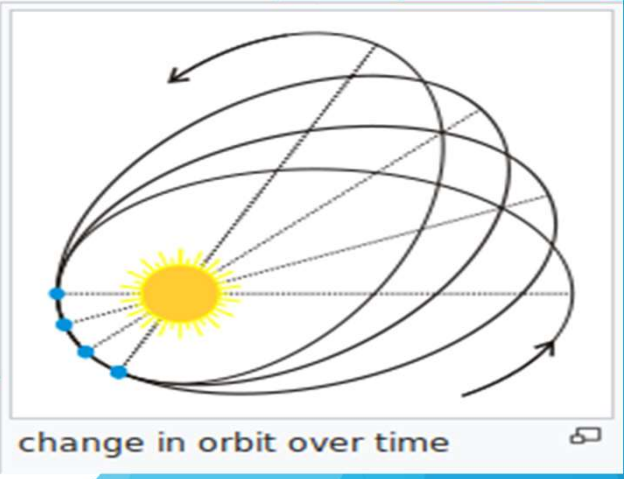
Predictions of General Relativity



One of Eddington's photographs of the 1919 solar eclipse experiment, presented in his 1920 paper announcing its success



Oppenheimer-Snyder dust collapse of a star (shaded). In the reference frame of a static external observer, the crossing of the star's surface with the horizon at radius 2m occurs at $\tau \to \infty$.



change in orbit over time

Some Classical Modified Theories

- Brans Dicke theory of gravity

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

$$G_{ab} = \frac{8\pi}{\phi}T_{ab} + \frac{\omega}{\phi^2}(\partial_a\phi\partial_b\phi - \frac{1}{2}g_{ab}\partial_c\phi\partial^c\phi) + \frac{1}{\phi}(\nabla_a\nabla_b\phi - g_{ab}\Box\phi),$$

- Holye Narlinkar cosmology
- Incorporates Machian principle , has failed a lot of test

- F(R) gravity Theories

Active field of research

F(R) Gravity Theory

- Natural extension to General relativity
- Higher order correction to General relativity
- Tries to act as Correction to General Relativity at high energy
- e.g. Starobinsky Gravity
- Massive gravitational waves
- Modified Newtons constant

F(R) Gravity Theory

- The action of this theory is a function of R , usually a polynomial in R , which acts like a correction

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

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

- The Field equation is a modification to that of Einstein's with addition of lot of complicated terms

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

- Very less amount of exact solutions , compared to that of General Relativity

Conclusion

- A lot of work has been done to understand gravity
- Different classical approaches for taking the quantum effect into account
- Not much progress ,Hopefully in the future

References

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