Tidal Deformabilities

August 12, 2020

1 Zhao 2019 [10]

This work focuses on constraining the tw degrees of freedom of scalar tensor theory (α_0, β_0). They combine pulsar timing data with GW170817. They take the mass and radius constraint from LIGO's publication. They do parameter estimation on α_0 and β_0 using mass and radius data points. They **do not** do their own PE of GW170817. They develop reduced order surrogate models to solve the modified TOV which are accurate and faster than solving the TOV directly.

2 Ganz 2019 [7]

This paper looks specifically at 'mimetic' gravity theories. These are new theories of gravity with an auxilary metric and scalar field. The scalar field can mimic dark matter in the absence of regular matter [3]. GW170817 provided a test of the speed of gravitational waves and confirmed that they move at very close to the speed of light ($|c_g^2/c^2 - 1| \leq 5 \times 10^{-16}$). Since some theories predict that gravitational waves do not propagate at the speed of light, it places limits on them.

3 Chagoya [4]

This paper, like the one above, uses the constraint of GW170817 on the speed of the propogation of gravitational waves. It derives from the assumption that the speed of gravitational waves is the speed of light a valid family of scalar tensor theories. This will be useful when I look at which equations to consider in PE.

4 Gong 2018 [8]

This paper appears to combine information from BBH mergers as well as GW170817. They actually look at Tensor Vector Scalar theories (also einstein aether theories) and not scalar tensor theories. They point out that BBH GWs suggest that tensor modes are favored over pure vector or pure scalar modes. They use the fact that GW170817 proves that GWs propagate at the speed of light.

5 Corda 2018 [5]

This paper looks at both f(r) and scalar tensor theories. It discusses the monopole and dipole radiation that occurs in these theories that differs from GR. These are lower order in (v/c) which means they are larger at early times in the binary inspiral. This force is discussed in [2]. However, in this paper they say th effect is small for bns systems because bns are roughly equal mass and the dipole radiation depends on 'gravitational dipole moment' which is a function of the mass and he effective newtonian constant. **Maybe we can actually use standard waveform? but have to demonstrate first that the difference is small?**. Scalar tensor theories have a third mode (in addition to the traditional plus and cross polarization modes). They derive detector response to massive and massless modes in addition to the standard h_+ anbd $h_\times$. They show that a massive tensor polarizations with gravioton mass $m_g \leq .7.7 \times 10^{-23} \frac{eV}{c^2}$ can still exist and still room for f(r) theories and scalar tensor theories.

6 Crisostomi 2018 [6]

Observations of GW170817 and GRB170817A prove that GWs move at the speed of light. Since certain scalar tensor theories predict that $v \neq c$ those can be discarded. This paper shows that the class of scalar tensor theories that are still viable are suitable dark energy candidates. These theories are a 'class of degenerate higher order gravity'. They also discuss possibilities for further testing these theories.

7 Langlois 2018 [9]

This paper also starts off using the fact that GW170817 andd GRB170817 show that GWs propagate at the speed of light. They present theories that are in the general category of 'degenerate higher-order scalar-tensor' theories that satisfy the $v_g = c$ condition. These include Horndesky theories. They look at mechanisms in the theories that suppress scalar interactions at small scales, particularly something called he 'Vainshtein Mechanism'. According to wiki this mechanism is important in suppressing scalar effects around solar system tests but allowing for large deviations to account for dark energy.

8 Baker 2017 [1]

Like any of the others they use the limits on the speed of gravitational wave propagation. They look at what theories are still valid.

9 Terms and Notes

- Conformally Invariant Theory: Conformal maps are functions that preserve angles but not necessarily lengths. Thus a conformally invariant theory remains unchanged when a conformal map is applied.
- Gauge Fixing (also called choosing a gauge) denotes a mathematical procedure for coping with redundant degrees of freedom in field variables
- Ghost Degree of Freedom: unphysical degree of freedom
- Horndeski Model: Horndeski's theory is the most general theory of relativity in 4 dimensions with a lagrangian including tensor and scalar field
- ΛCDM (lambda cold dark matter) model: the cosmological model where things are made up of three components: Λ- the cosmological constant which is related to dark energy, cold dark matter, and ordinary matter.
- Friedman-Lemaître-Robertson- Walker metric: an exact solution to GR hat describes a homogenous, isotropic, expanding (or contracting) universe. A "universe that is path-connected, but not necessarily simply connected". Path connected meaning a path can be drawn between any two points but that path might not be continuously transformable.
- Massive Gravity: a non GR theory of gravity with a massive graviton.

References

[1] T. Baker, E. Bellini, P. G. Ferreira, M. Lagos, J. Noller, and I. Sawicki. Strong constraints on cosmological gravity from gw170817 and grb 170817a. *Phys. Rev. Lett.*, 119:251301, Dec 2017.

[2] Enrico Barausse, Carlos Palenzuela, Marcelo Ponce, and Luis Lehner. Neutron-star mergers in scalar-tensor theories of gravity. *Physical Review D*, 87(8), Apr 2013.

[3] Roberto Caroli. *Cosmological Aspects of Mimetic Gravity*. PhD thesis, Ludwig Maximilians Universität München, October 2018.

[4] Javier Chagoya and Gianmassimo Tasinato. Compact objects in scalar-tensor theories after gw170817. *Journal of Cosmology and Astroparticle Physics*, 2018(08):006–006, Aug 2018.

[5] Christian Corda. The future of gravitational theories in the era of the gravitational wave astronomy. *International Journal of Modern Physics D*, 27(05):1850060, Apr 2018.

[6] Marco Crisostomi and Kazuya Koyama. Self-accelerating universe in scalar-tensor theories after gw170817. *Physical Review D*, 97(8), Apr 2018.

[7] Alexander Ganz, Nicola Bartolo, Purnendu Karmakar, and Sabino Matarrese. Gravity in mimetic scalar-tensor theories after gw170817. *Journal of Cosmology and Astroparticle Physics*, 2019(01):056–056, Jan 2019.

[8] Yungui Gong, Shaoqi Hou, Dicong Liang, and Eleftherios Papantonopoulos. Gravitational waves in einstein-æther and generalized teves theory after gw170817. *Physical Review D*, 97(8), Apr 2018.

[9] David Langlois, Ryo Saito, Daisuke Yamauchi, and Karim Noui. Scalar-tensor theories and modified gravity in the wake of gw170817. *Physical Review D*, 97(6), Mar 2018.

[10] Junjie Zhao, Lijing Shao, Zhoujian Cao, and Bo-Qiang Ma. Reduced-order surrogate models for scalar-tensor gravity in the strong field regime and applications to binary pulsars and gw170817. *Physical Review D*, 100(6), Sep 2019.