Universidad de Salamanca

Álvaro de la Cruz-Dombriz, Ivan de Martino and M. Ángeles Pérez García
Universidad de Salamanca & SKA Collaboration

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(Some) Results in NR and GW in the context of Extended Theories of Gravity

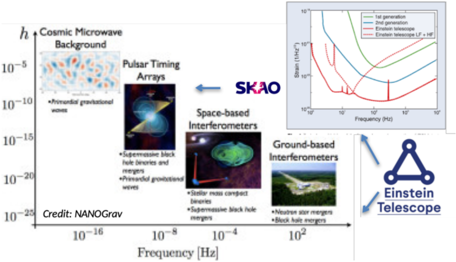
- **Establishing well-posedness**: Existence, uniqueness and continuous dependence on initial data;
- **Interpreting well/ill-posedness** in the context of effective field theory (EFT). IVP. Hyperbolicity?
  - Already in GR, hyperbolicity depends on the formalism [ADM weak vs. BSSD strong]
  - f(R): B. Mongwane, 1610.07224 ; Spherical symmetry scalar-tensor theories: Alcubierre et al., 1207.6142
- **Numerical challenges** associated with the above and with having extra fields
- **Parameterisations vs. Non-parameterisation** - Theory-agnostic or Specific Tests?

Theory-agnostic

- **PN Tests of GR Double Binary Pulsar** [Arun et al. (2006), Mishra et al. (2010)]
- **Parameterised post-Einsteinian Formalism**
  - PPE-modified Inspiral Waveform Phase [Yunes & Pretorius PRD80 122003 (2009)]
  - PPE Mapping to Specific theories [Yunes, Pretorius & Spergel PRD80 122003 (2010)]
- **Generalized IMRPhenom Waveform**
  - Inspiral-merger-ringdown Phenomonological D (IMRPhenomD) waveform in GR [Khan et al. (2015)]
  - Possible to model non-GR merger & ringdown (unknown mapping to specific theories)

Synergies between ET and SKA

ET will operate together with new observatories from radio to gamma rays (such as the Square Kilometer Array, the Vera Rubin Observatory, E-ELT, Athena, CTA)



- Pulsar-based timing arrays using radio telescopes SKA will be sensitive to periods of years. ET will shorten such time periods.
- Fast Radio Burst (SKA) and Gamma-Ray Burst (ET) sources would be complementary.

Gravitational collapse as an open issue in MG

Leit-motiv: The higher harmonics (in the ET-waveform) will reveal the nature of the space-time geometry in strong gravitational fields and will help us answer fundamental questions about the end-product of a gravitational collapse (bouncing? Inability of matching?).

In MG, gravitational collapse predictions and junction conditions differ significantly from GR

$f(R)$ - J.A.R. Cembranos, AdlCD, B. Montes, JCAP 04 (2012) 021 arXiv 1201.1289

$f(T)$ - P. K.S. Dunsby, AdlCD, D. Chillón Sáez-Gómez, JCAP 12 (2014) 048 arXiv 1406.2334

Stable torsion theories - AdlCD, F. J. Maldonado-Torralba, JCAP 03 (2019) 002 arXiv 1811.11021

Conclusions and Prospects

- TOV-like dynamical system in f(R) theories with **use of realistic neutron fluid EoS ready to be tested against ET data**
  - Physical mass assigned to each solution. Oscillations of the curvature scalar are damp enough to start retrieving Schwarzschild solution
  - Apparent masses larger than in GR and usually above observational values. R^2 **and Hu-Sawicki models**
  - Energy available for gravitational-wave emission as well as the total mass can well exceed what is assumed in Einsteinian gravity. **LIGO claims can be weakened Viable $f(R)$ theories may accommodate a $3-4M_{\odot}$ emission in the BNS merger**
- Dynamical strong-field gravity has little direct observational confirmation to date. Further insight may come from
  - **Ground-based detectors (ET)**, pulsar timing, the Event Horizon Telescope,
  - CMB polarization, surveys of the transient sky, **SKA (Fast Radio Bursts)**
- Gravitational collapse of NS->BH and the exterior spacetime may shed light on viable classes of MG.
- **GW emission from binary coalescence**: $f(R)$ models [De Laurentis and de Martino MNRAS 431, 741 (2013) & IJGMM 12, 1550040 (2015)];
- Cosmography in modfied gravity [de Martino, I.,et al. Phys. Rev. D 102, 063508. (2020)]
- Dark matter candidates (PBH, ULA) with **cross-correlation of GW-LSS data**