

MITP Program Executive Summary

“The sound of space-time: The dawn of gravitational wave science”

Coordinators and organisers: Luis Lehner (Perimeter Institute, Waterloo, Canada), Rafael A. Porto (ICTP-SAIFR, São Paulo, Brazil), Riccardo Sturani (IIP, Natal, Brasil), Salvatore Vitale (MIT, Cambridge, USA).

Executive summary

The format of the meeting consisted of having a 2-3 long talks (1h each) in the mornings and 1 in the afternoons, followed by unrestrained discussions.

- Monday June 4th had talks by Haney and Krishnan. Haney presented the most recent LIGO/Virgo Gravitational Wave (GW) detection results with emphasis on the fundamental physics tests made possible by these observations. Krishna talked about testing General Relativity consistency in the signals from compact binary coalescence by comparing the inspiral phase in which the two initial compact objects are approaching each other to the ring-down phase in which the two initial objects have merged into a final black hole.

Discussion session has been about how much more accurate theoretical modelling one needs to interpret observational results.

- Tuesday 5th had talks by Carrasco, Foffa, Maia and Porto, all about the use of Effective Field Theory to model the two-body dynamics in gravity theory. Carrasco introduced new ideas for amplitude computations, Foffa gave an introductory talk about reducing the gravitational dynamics to computable scattering amplitudes. Maia showed her latest results on next-to-next-leading order in radiation reaction force of compact object with spin and Porto concluded with an overview of the effective field theory approach to General Relativistic 2-body dynamics.

Discussion continued from the previous day about the impact of theoretical computation on waveform modelling.

- Wednesday June 5th had talks by Korsakova, Vitale and Zaldarriaga. Korsakova gave an overview of the sources and data analysis issues foreseen for LISA, the space GW detector due to start its mission in the mid 30ies. Vitale presented a comprehensive study of the astrophysical implications obtained so far and possible in the near future of GW detections on stellar mass black astrophysical parameter distributions. Following on this line, Zaldarriaga told what are the binary formation mechanism favourite by present data and what can be expected from further LIGO/Virgo detections.

The discussion was centred on how GW detections can constrain the binary formation channels, with the conclusions that at present the common envelope model (object already in pairs before they become compact) seems favoured.

- Thursday had talks by Foffa and Exquiaga. The topic of the day was the use of the luminosity distance measured by GWs to test gravity in the weak curvature, long distance regime. Foffa showed how the current standard cosmological model can be challenged by other models with the same number of parameters and comparable evidence and how future GW observations by third generation detectors can enable choosing between one model and the other.

Exquiaga iterated on the topic by showing how dark energy or whatever is at the basis of the present cosmological acceleration can be probed by future GW detections in a model-independent way.

Discussion was about all possible ways, beyond standard sirens, cosmological information can be inferred from GW data.

- Friday June 8th had talks by Nichols, Horn Sheng, Krishnan and Calmet. All of the day was dedicated to exotic aspects of gravitational waves. Nichols talked about memory effects, which is an effect in standard General Relativity which however is far from having any detectable imprint on data. Horn Sheng explained the concept of super-radiance (amplification of GWs by a spinning black hole) and how it can be detected if it is further enhanced by

Krishnan gave a data analysis perspective of non standard source of GWs and the way to detect them. Calmet presented the results of his approach of adding higher curvature corrections inspired from quantum gravity to Einstein equations and check for detectable effects in both the conservative and dissipative sector of gravity.

Discussion went wild on possible exotic effects in GWs.

- Monday June 11th has talks by Krishnan, Pretorius and Gerakopoulos. Krishnan presented ongoing efforts to connect the GWs measured at infinity to assess the behaviour of horizons, such mapping would provide crucial insights on the nature of strong field gravity and trapped surfaces. Pretorius discussed opportunities and challenges in the context of eccentric mergers, reviewing the rich phenomenology such systems could display and the physics one can draw. Gerakopoulos, in turn, surveyed what is known on the possible existence of chaos in binary system of large mass ratio and its consequences, stressing however that further research is needed on this topic.

These talks were followed by a discussion on gravitational wave building blocks, specifically discussing the extent to which departures from General Relativity are considered currently and possible limitations in light of the limited theoretical knowledge.

- Tuesday 12th had talks by Lehner, Hinderer, Zimmerman and Lijing. Lehner summarised possible surprises with respect to current templates that compact binaries in General Relativity might display as well as an overview of what is known with respect to extensions of GR and alternative compact objects. Hinderer surveyed the know-how on semianalytical ways to encode the full waveform for both vacuum and non vacuum binaries. Zimmerman presented a detailed description of the analysis and physics drawn from GW170817 (binary neutron star coalescence) and Lijing gave an overview of results and opportunities to extract information of gravitational physics from pulsars.

Discussion was mostly on if and how currently used waveform models can catch appropriately non-dominant feature in the data.

- Wednesday had talks by O'Connell, Franchini and Saravanan.

O'Connell showed how to recover gravitational dynamical quantities like scattering amplitudes in gravity by appropriately squaring analogue computations in vector-gauge mediated processes. Franchini showed the result of his investigations on how strong field gravity like in neutron star interior can hide new physics which can be probed by GWs. Saravanan concluded the morning session by reviewing a new method to treat spin of compact objects in two body dynamics.

Discussion was mostly on the perspective that modern field theory techniques like double copy open for classical gravity phenomenological computations.

- Thursday 14th was dedicated to a Journal club discussion lead by Jose Exquiaga about papers appeared recently on the archive, namely arXiv:1801.00386 on dark matter (small) effects on GW

propagation and on arXiv:1806.04920 which showed how to derive the classical, non-relativistic limit of General Relativity from relativistic scattering amplitude of massive particle with graviton-mediated interactions.

- Friday 15th had talks by Zimmermann and Vitale. Zimmerman focused on Bayesian inference and model comparison, displaying the caveats that one has to keep in mind when looking for deviations from General Relativity in GW data, deviations which can not only be model dependent, but also dependent on the astrophysical system, loosening the strength of the tests which are currently being published by several groups, including the LIGO/Virgo collaboration.

Vitale concluded the program with an overlook of future generation GW detector and their foreseeable impact in astrophysical parameter estimations to constrains stellar mass black hole population and galactic evolution history.

Throughout the programme, a flexible schedule allowed and encouraged ample discussions which provided a forum where ideas and expertise were exchanged in a lively and cordial environment.