CASPEN visitor exit report

Dates: May 5-19, 2019
Visitor: Christian Setzer, Ph.D. Student, Stockholm University
Host: Stephen M. Feeney

During my visit at the Flatiron Institute Center for Computational Astrophysics (CCA), hosted by Stephen Feeney, we discussed the problem of using gravitational wave (GW) and electromagnetic (EM) standard sirens to independently measure the local expansion rate of the Universe. Previous work that the host has undertaken looked at the details of using standard sirens to obtain an unbiased estimate of the local expansion rate. This assumed a that each source has clearly identified GW and EM signals. What we discussed is the scenario when the EM signal, specifically the optical to near-infrared kilonova (kN) signal, is the only identified signal from the source.

This allowed us to consider the possibility of using the knowledge of the identified counterpart kN signal to inform the detection procedure of the GW signal from the compact binary coalescence. Knowing the sky-position directly from the detection of the EM signal and a constraint on the time of merger either from the observation cadence of the EM observatory or a refined constraint assuming some model fit to the EM can reduce the volume of potential signals significantly. However, if model assumptions are incorporated coherently, knowledge of the EM signal can additionally inform the waveform shape that should be seen in GW. This reduces the number of templates that must be used and thus additionally reduces the false alarm rate (FAR).

This led to us extending the original Bayesian hierarchical model from the host's previous work to include the kNe signals into the inference of cosmological parameters and also define a separate, though very similar model, which would be used to modify the detection procedure to identify potential GW signals. We discussed at length approaches to solving this problem and the nuances to the detection process and how we can improve upon that, not only from the standpoint of incorporation of EM information, but also in choosing the appropriate detection statistic. This was something that I discussed at length with others at the CCA.

I was very fortunate that there were several visitors to the CCA from the LIGO science collaboration at the same time that I was there. I was able to meet and speak several times with Alan Weinstein about many aspects of LIGO, particularly focusing on the problem of detection as mentioned above. Additionally, I spoke with LIGO visitor Christopher Berry and CCA researcher Katerina Chatziioannou about the priors on the mass ranges for the LIGO template bank of compact binary mergers and specifically about using a population synthesis prior on the binary neutron star masses for simulation of detections. I also had several interesting discussions with another CCA visitor Mohammad Safarzadeh about using EM observations of kNe to constrain neutron star physics. This was from the work I have previously done predicting observations over the next decade with the Large Synoptic Survey Telescope. We discussed using the simulation tools I have developed to predict the number of observed kNe signals needed to discriminate between different neutron star material equations of state.

During my visit I also participated in the meetings of the GW and Cosmology X Data Science working groups, and I presented my previous work during one of these meetings. I found the atmosphere very engaging and I received many helpful questions. The further discussions, such as those mentioned above, revealed some very interesting ideas that may lead to new avenues of research and potentially future collaboration.

Currently I am building the tools for the precursor projects that will culminate in the analysis outlined above. Given the timeline for those projects, I suspect this work will lead to a publication which we hope to have on arXiv by the end of this year or early next year. Additionally, these tools may serve to facilitate investigating further the ideas I discussed with others while visiting the CCA to judge the viability of any potential collaboration.

This work was supported by collaborative visits funded by the Cosmology and Astroparticle Student and Postdoc Exchange Network (CASPEN).

Christian N. Setzer