Using FRBs as cosmic flashlights

Two of the most mysterious problems in astrophysics and cosmology today are, "What generates Fast Radio Bursts (FRBs)?" and "How did the entire universe become reionized by the first generation of stars and galaxies?" While both questions have garnered the interest of many scientists, as cosmologists, we seek to address the latter.

During the early times in our universe's history, the cosmos was not the galaxy filled place it is today. When the universe was a mere tens of million years old, there were no stars or galaxies to be found, but instead neutral atoms populated all of space. Slowly but surely, due to gravitational collapse, these atoms got together to form the first generation of stars. Eventually young galaxies began to take shape and they drastically changed the environment around them. UV photons emitted from these galaxies, encountered the neutral hydrogen still floating in the intergalactic medium (IGM) ionizing this hydrogen and introducing a large number of free electrons into the IGM. This continued until the entire IGM was ionized. This process called reionization is something we cosmologists desperately want to understand, but also something that is notoriously difficult to study.

FRBs, on the other hand, are short, bright bursts of electromagnetic radiation, the source of which remains unknown. Despite uncertainties about the progenitor, we decided to explore whether FRBs can be used as tools for studying the ionization fraction in the IGM, and in particular, whether FRBs can help us distinguish between different reionization scenarios. This electromagnetic radiation gets dispersed on its way to us, meaning that every time a photon encounters an electron, the photon's travel time gets delayed. In this sense, FRBs are like cosmic flashlights because, through studying their dispersion measure, we can learn about the electron density between us and the source of the burst. Since the process of reionization introduces electrons into the IGM, FRBs that are emitted during reionization should be able to track this change, this reionization process, throughout cosmic history. It turns out that FRBs are indeed sensitive to different reionization models . We also find that with small samples of FRBs one is able to rule out certain reionization scenarios and with a very large sample, one is able to constrain the reionization scenario. We are only now entering the early days of FRB cosmology and we are excited about new cosmological discoveries that will result from advances in the detection of transients!

Two cosmology students studying transients?

Yes, we find it as surprising as you do, as did our supervisor, from whom we kept this project a secret for many months! In October 2020, Dr. Wenbin Lu gave a wonderful MSI seminar about FRB progenitor theories after which he mentioned that FRBs might be used to study reionization. The two of us took interest in this idea and after one short zoom call with Wenbin to discuss this in more detail, we were off on our first solo research journey!

Michael Pagano and Hannah Fronenberg are MSI graduate students under the supervision of Prof. Adrian Liu. Michael is working toward completing his PhD and is investigating the Epoch of Reionization (EoR) using various observational probes. Hannah is completing her MSc, studying how to use cross-correlations to study the EoR, and will continue as a PhD student at the MSI this fall. In their spare time they like to think about FRBs!

***Citation**: Pagano, M., & Fronenberg, H. (2021, March 04). Constraining the epoch of reionization with highly dispersed fast radio bursts. Retrieved April 13, 2021, from https://arxiv.org/abs/2103.03252*

***Below:** The middle panel shows the density field of the universe as a function of time where time runs from oldest at the top to today at the bottom. The two panels adjacent to it show the ionization field for two different reionization scenarios, and the two furthest panels from the centre show the resultant electron number density field.*