Student questions: SESE Students colloquium

Lucia Perez: Constraining Reionization with Void Probabilities

11/17/21

Does the Roman Space Telescope also show spectroscopic line profiles that are double peaked for Lyman Alpha Emission?

→ but I think yes unless the grism details change it! it is very very hard to confirm especially with low-z foreground emission line galaxies being good candidates, too–see Hu et al 2016, Matthee et al 2018 for double-peaked LyA features at z>6
James says: "Hard to be sure. They would be exceedingly rare but I reckon they remain possible within ionized bubbles provided the local ionizing UV intensity is really quite high."

Are there other constraining processes other than using powerful Telescope that could help resolve the double peaked spectroscopic line profile complexity from Lyman Alpha Emission?

→ hmmm there's been a lot of work studying lower redshift analogs of Lyman Alpha Emitters, like 'green peas' that lots of folks in our group have worked on over the years. Or just lower redshift LAEs–like Marchi et al 2019 that specifically focuses on the escape of LyA emission at z~3.5. And there's always big modeling efforts to try and understand it–I like the summary in Dijkstra 2014 for LAEs+EoR!

Of the three models introduced (Finkelstein et al., Yung et al., and Naidu et al.), is there one that has been demonstrated to be more accurate than the others, and if not is there one that you prefer to use?

→ Hmmm, the late ionization models–like Yung and Finkelstein–are currently favored from lots of constraints (e.g. LAGER's 4 field luminosity function from Wold et al 2021/in press likely predicts complete ionization by z=6.9), but Finkelstein isn't completely discounted yet. I don't know enough about the details of these models yet to have a preferred one!

Do the different models you mentioned have significantly different cosmological implications?

→ see my answer above–I will ask Aaron Yung in my group about this, who says: "Well indirectly.. because the galaxy physics is still playing a more dominant role in these models.. and all of these models assume the cosmological parameters are known :(
Btw when comparing to Naidu and Finkelstein, I sometimes say the Yung model predicted that the galaxies that contributed the most ionising photons have transitioned from low-mass to massive galaxies throughout the EoR. You can see that from fig.12 in Paper IV. It is really a combination of number density of galaxies and how many ionising photons each of them is contributing (which varies as a function of age and metallicity)."

What other scientific uses has the Void Probability Function been applied to, and how did this inspire the use of it in your research?

→ **Thank you for this question! The VPF has been used to:**

- **probe the hierarchical scaling of correlation functions (like, finding the underlying math of how all the scales of clustering tie together) for spectroscopically selected low-z galaxies (Conroy et al 2005, Croton et al 2004), since that's sort of how it was first proposed (White 1979).**
- **also, for a couple of years, for very small samples of LAEs (Palunas+2004, Kashikawa+2006, which promised a lot and inspired intrigue in my PhD advisor and that first initial question to start the journey; my team and I now know was maybe not the best way to apply it, e.g. Perez et al 2021a).**
- **to probe reionization, beyond just my work (first proposed in McQuinn+2007, recently also Gangolli+2021)**
- **and also for constraining halo occupation distribution (Berlind & Weinberg 2002, Tinker+2008 i think, Beltz-Mohrmann+2020, Walsh & Tinker 2019).**
- **I'm also using the VPF now in my research with the CCA and the CAMELS project to constrain cosmology with machine learning (google CAMELS-SAM and my name in the next few months to learn about that), so that's been fun so far!**

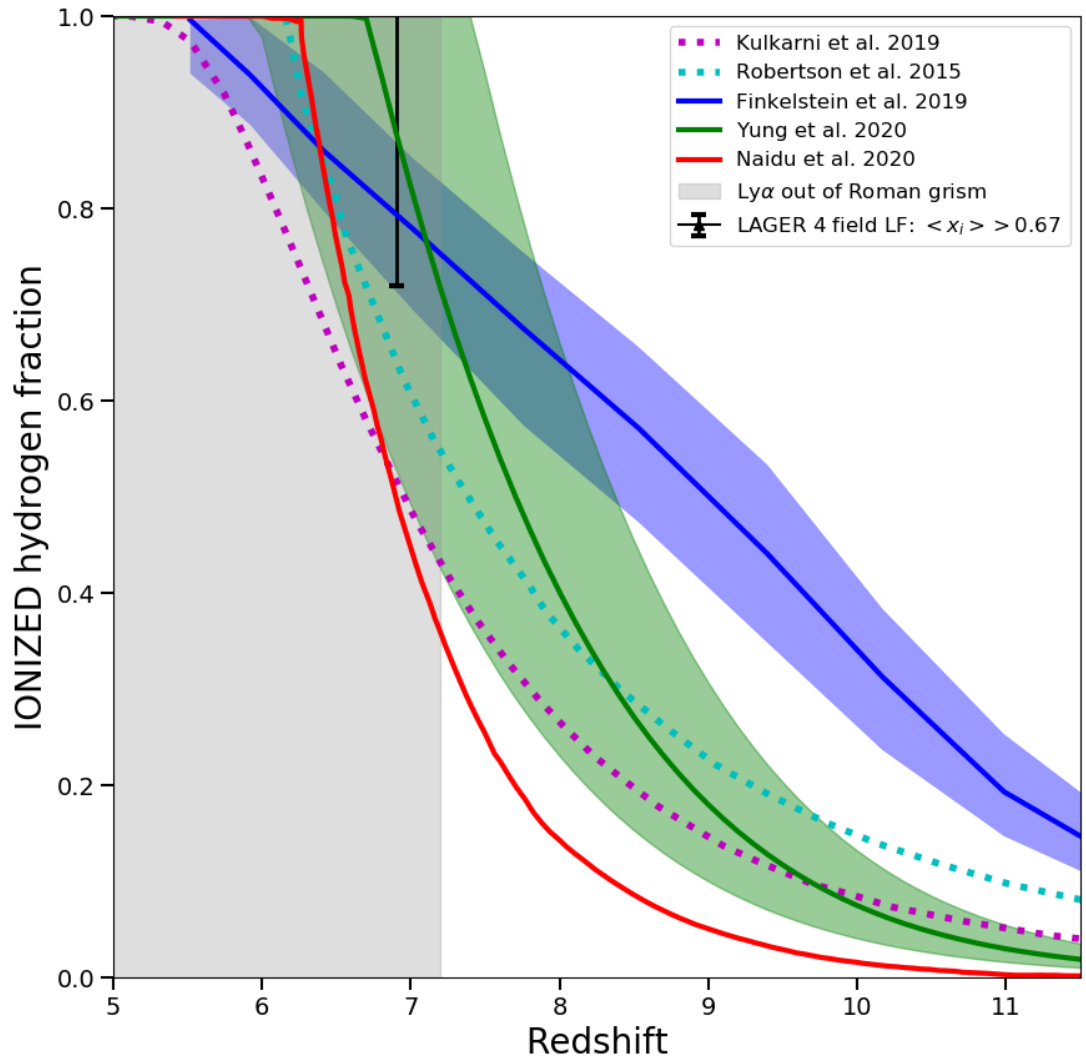
How does the distribution of the IGM affect your results?

→ **Thanks for this question, it made me dive deeper into the setup of the simulations I'm using. It sounds like this model assumes the IGM is mostly low density, is held at one single 10^4 K temperature, and they used the code IGMTransfer to simulate it for LyA. Again, wishing I knew more! Here's the closest bit from Jensen et al. 2013, from Section 2.3:** *"While the general problem of Lyα radiative transfer is complex and computationally demanding (e.g. Zheng et al. 2010), it can be greatly simplified in the low-density IGM far away from the galaxy where the radiation was emitted. In the high-density region close to the galaxy, photons are scattered in and out of the line of sight, undergoing frequency changes on the way. Simulating this process requires very high resolution and many assumptions regarding, for instance, dust content and star formation. However, as was shown radius of the galaxy, very few photons are scattered into the line in Laursen et al. (2011), after a distance of ∼ 1.5 times the virial of sight, and therefore it is justified to divide the radiative transfer into two regimes: a galaxy part where photons diffuse out of the optically thick gas around the halo (discussed in Sec. 2.4), and an IGM part where we consider only scatterings out of the line of sight (effectively absorption). We set the boundary between these two regimes to be at 1.5 rvir."*

I'm guessing there are more models for EoR than the 3 you showed, could your proposed 6ish Roman observations exclude other models?

→ **Somewhat, the other big ones (Robertson et al. 2015, Kulkarni et al. 2019) are sort of between Yung and Naidu's, and I would say those aren't distinguishable in a deep 4deg2 or ultra-deep 1deg2 field with Roman; perhaps with 16deg2, mayyyyybe, and sampled at various redshifts, but there's a good reason I picked those 3! One caveat that does hurt my study is that the Jensen simulations only exist at very particular ionization fractions, and there are redshifts where the models are quite distinct that I**

simply cannot create mocks for. E.g. Finkelstein v. Robertson v. Kulkarni are pretty far apart at z~10-10.5, but LAEs will be very few and between at those very neutral fractions, so perhaps other types of constraints will help there.



What do you think is the biggest problematic assumption when using models to study reionization?

→ **great question! I will tell you what Charlotte Mason of the Cosmic Dawn Center told me when I was telling her about this work: self-consistent modeling of galaxies in reionization! It's very hard/has only just started to be done to model both how galaxies are made, how the IGM gets where it is, AND what is doing the reionization all at once. Lots of the big simulations that are needed for truly large scales use the density fields to calculate where dark matter halos are, paint galaxies onto them, then take skewers to**

look at the IGM transmission; but the DM halos don't actually create the ionizing flux. Jensen improved on this, and the Astreus simulations recently, too. And Charlotte Mason and her group should be putting out very cool new simulations on this in the next few years!

In what ways, if any, can your research and simulations be extended to studying galaxy clusters?

→ **This sounds cool but I don't know. I will note lots of these simulations tend to be a little too low-resolution to really get the rich galaxy cluster physics that we observe.**

Do models with a higher neutral fraction show an increase in probability of finding holes in the LAE distribution?

→ **Yes, exactly! Though remember that throughout this type of analysis you're always asking: is this hole/void due to a neutral patch? Or a cosmic void in the dark matter web? Or just bad cosmic variance luck?**

If the universe is more neutral on average, then there are fewer ionized bubbles that the LAEs will be seen through. I will note that it's much easier to tell apart 30 vs. 50% ionized than 73% vs. 95% ionized for this reason, across many constraints.

What are the main science goals of the Nancy Grace Roman Space Telescope?

→ **It's a sort of catch-all for the type of infrared science that only space can do, plus the survey capabilities! Big goals include: dark energy,dark matter, and exoplanets. Dark matter will be through large-scale structure (here, much lower-z galaxies across much more of the sky), dark energy also with supernovae surveys, exoplanets with cadence and microlensing surveys, the high latitude spectroscopic survey to get TONS of higher-z galaxies (including LAEs!)**

https://roman.gsfc.nasa.gov/why_Roman_Space_Telescope.html