Towards a non-Gaussian Generative Model of large-scale Reionization Maps

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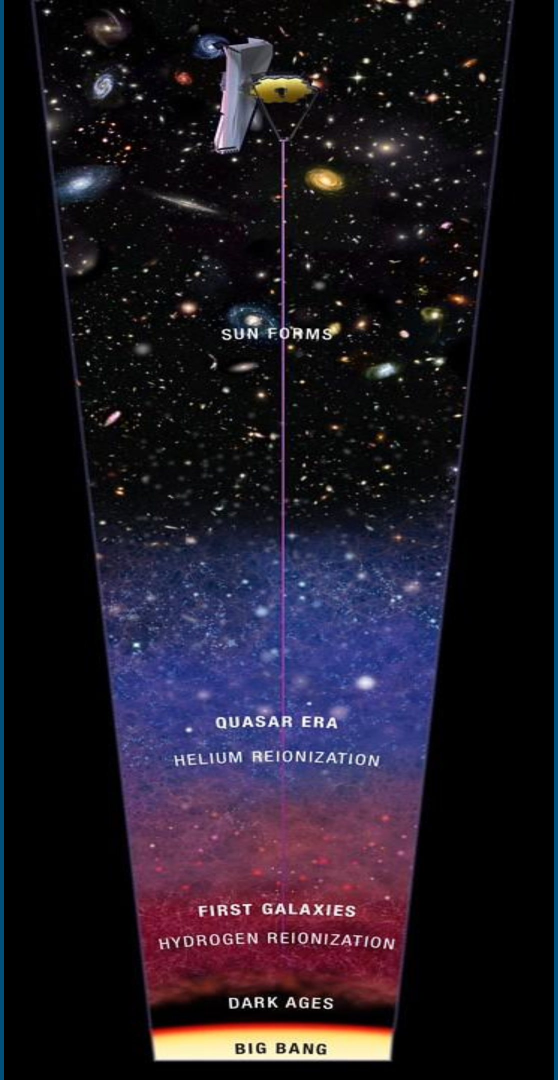
What is reionization?

- Ionization process in the early timeline of the universe
- Occured after the formation of the first galaxies
- Massive stars ionized the plasma that was located between those galaxies
- Data is modeled as intensity maps



Why study reionization?

- Necessary to study reionization since that gives insight into the formation of galaxies
- This is a peek into some of the earliest periods of the evolution of the universe
- Methods can be applied to other large scale ionization models like SKA and HERA

What are the complications of current models?

- Too expensive computationally
- Not possible to directly measure reionized galaxies
- Can be solved with more efficient sampling from summary statistics based off of a power spectrum

Steps of simulating cosmic reionization

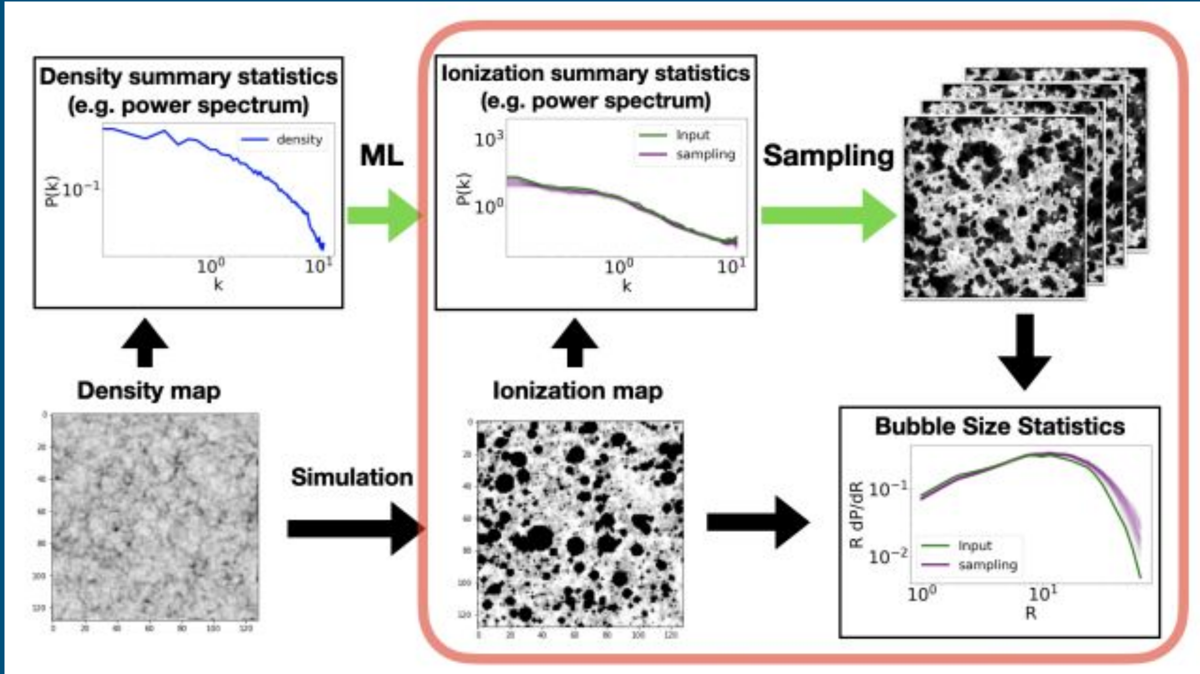
This creates an ionization field:

(1) Inclusion of initial density field
(2) Locating sources of ionization
(3) Calculating radiative transfer at different epochs

Proposed models aim to reduce computational load from steps (2) and (3)

The basis of the newly proposed models!

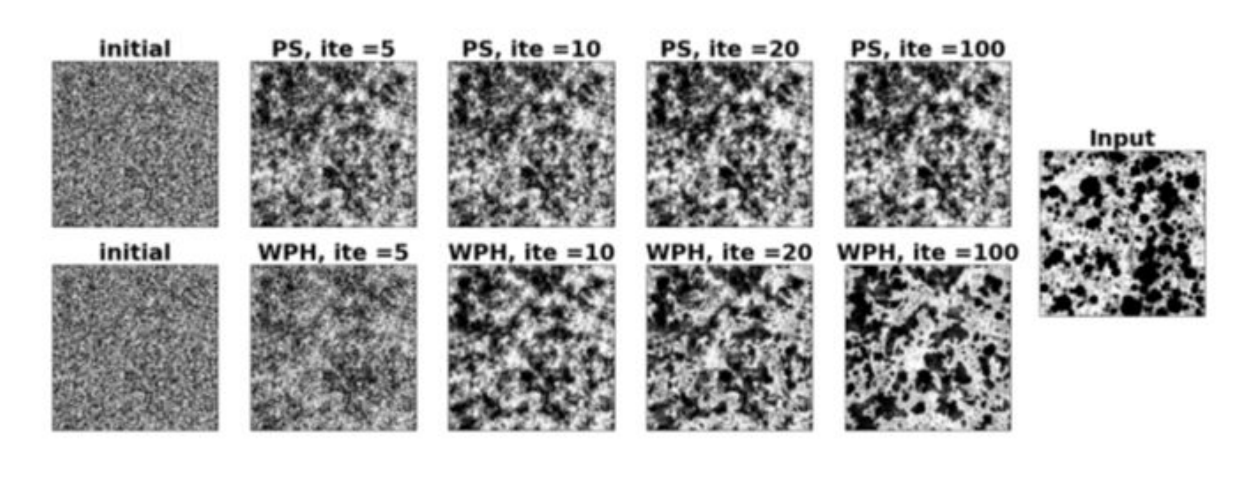
- Uses non-Gaussian generative model
- Based off of wavelet phase statistics
- Redesigning the ionization field off of the change in sampling
- These models are faster than the benchmark models



How the proposed models works

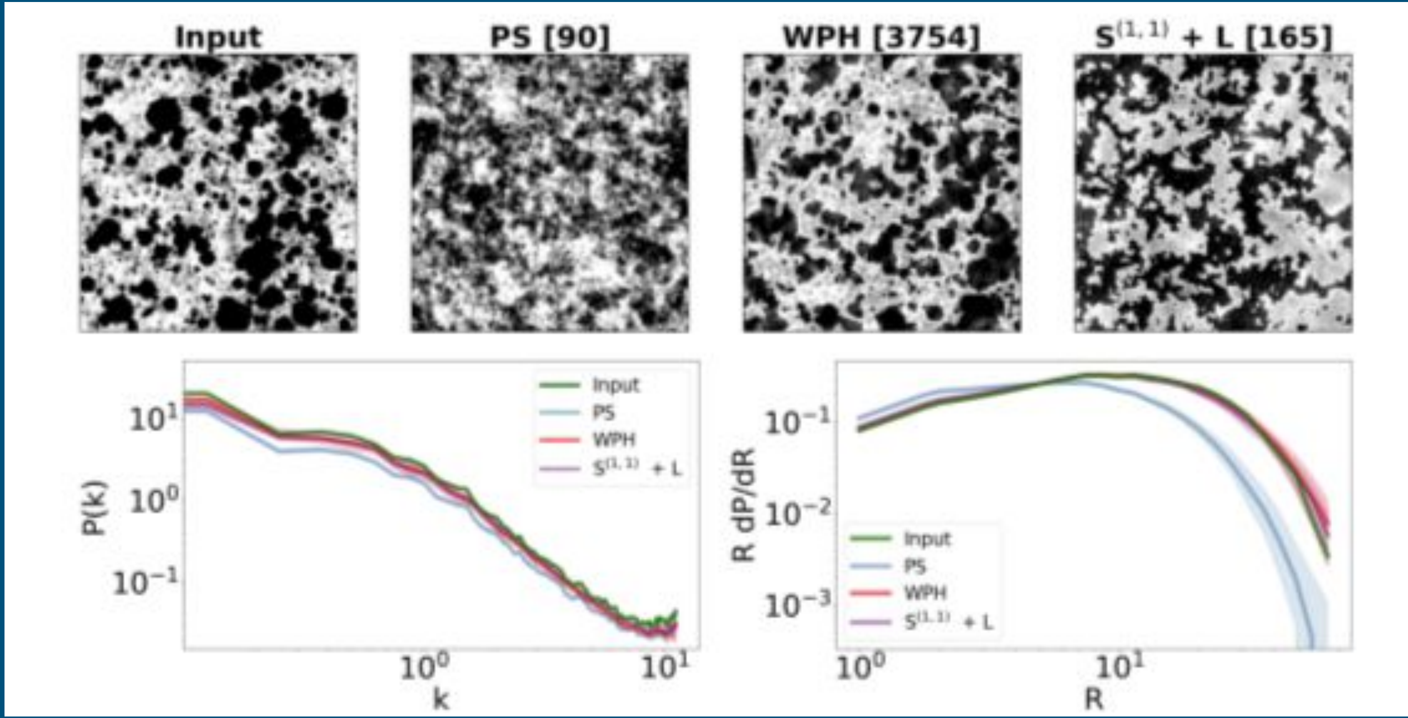
- Uses PyWPH to find the WPH statistics
- Then wavelet transforms gather data from convolution
- This is then integrated after applying the absolute magnitude operator

- A power spectrum model was added for comparison
- Both models iterated multiple times in order to reduce noise



How do the different models compare?

Above row: ionization maps with coefficients



Bottom right: bubble statistics

Bottom left: power spectrum

The analysis of the comparison

- (PS) model is fuzzy
- (WPH) model is very similar to the input map
- The WPH model has more realistic outputs compared to the PS model
- The S(1,1) + L model had a well separated map
- All models had very comparable power spectrum paths
- The WPH model performed better than the PS model on the bubble statistics graph

Summary

- Both proposed models are quick and decent at presenting ionizations maps
- The WPH model produces more realistic ionizations maps than the PS model
- These models are much faster than ones currently used
- Another model is being developed to include more advanced parameters

Sources

https://arxiv.org/abs/2210.14273

https://www.mwatelescope.org/science/epoch-of-reionization-eor#:~:text=Reionization%20was%20complete%20about%201,a%20redshift%20of%20about%206.5.

https://webb.nasa.gov/content/science/firstLight.html