

Observational properties of high- z Galaxies and AGN during epoch of reionization

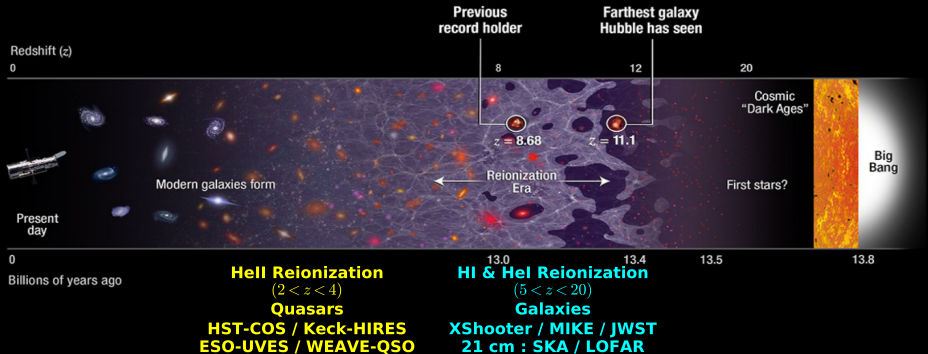
Prakash Gaikwad

Dec, 2023

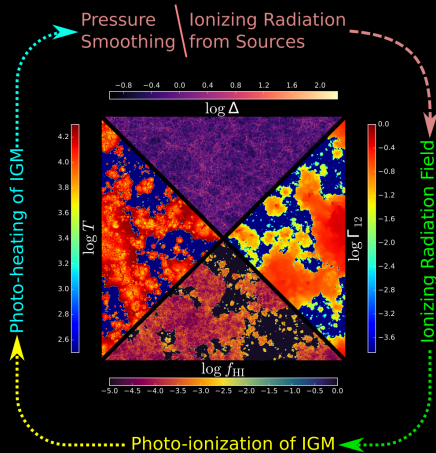


Introduction

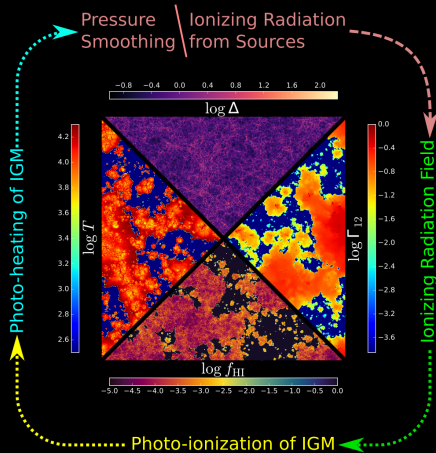
Image : NASA, ESA, P. Oesch, B. Robertson and A. Fei



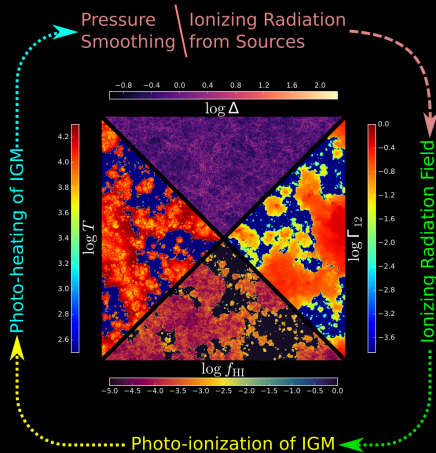
- 3 Important questions of reionization
- Timing of reionization? $\Rightarrow$ Early vs Late reionization
- Nature of reionization? $\Rightarrow$ Uniform vs Patchy
- Sources of reionization? $\Rightarrow$ Small or Large mass Galaxies, f_{esc} ?



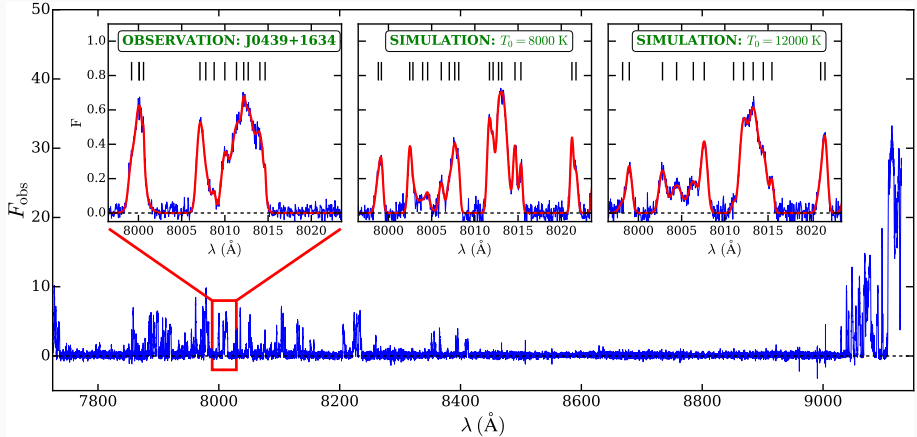
- 3 Important questions of reionization
- Timing of reionization?
- Nature of reionization?
- Sources of reionization?



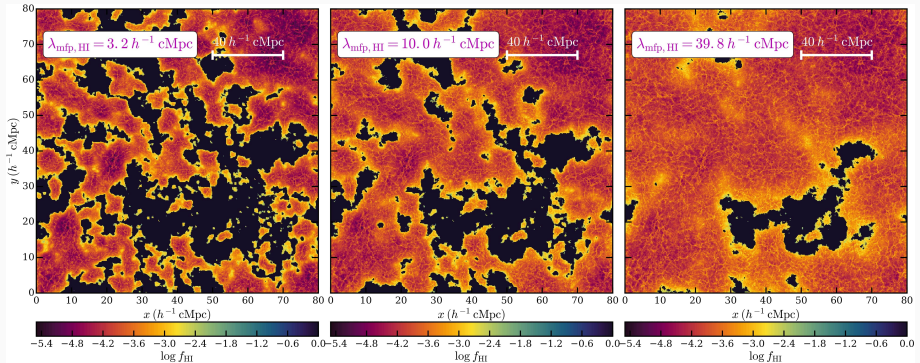
- Evolution of 3 IGM parameters to understand process of reionization
- Timing of reionization? $\Rightarrow$ Neutral Fraction, Photo-ionization Rate
- Nature of reionization? $\Rightarrow$ Mean Free Path of ionizing photons
- Sources of reionization? $\Rightarrow$ Temperature of IGM (SED of sources)



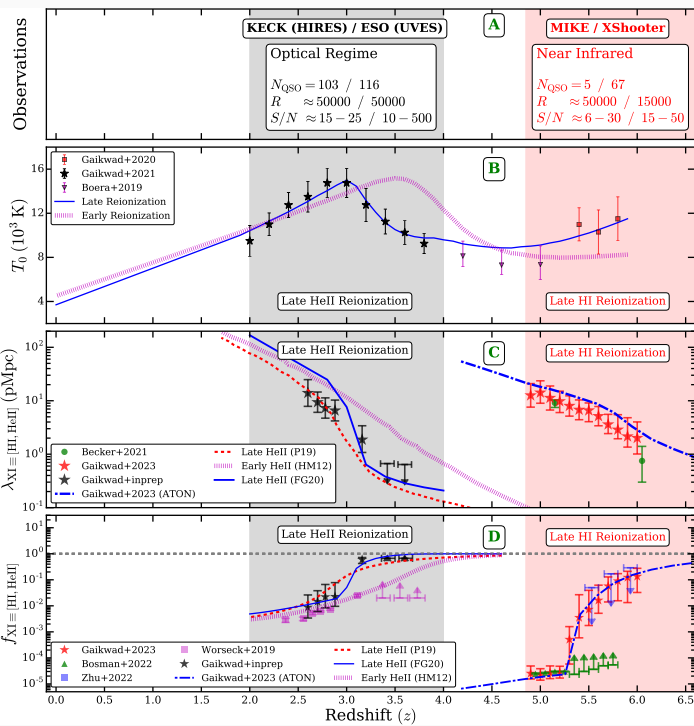
- Previous Research was focused on measuring evolution of Γ_{HI} , f_{HI} , λ_{mfp} , T_0
- Timing of reionization? $\Rightarrow$ Neutral Fraction, Photo-Ionization Rate
- Nature of reionization? $\Rightarrow$ Mean Free Path of ionizing photons
- Sources of reionization? $\Rightarrow$ Temperature of IGM (SED of sources)



- How can we measure / constrain f_{HI} , $\lambda_{\text{mfp,HI}}$ and T_0 ?
- Comparing properties of observations with simulations.
- **Observations: Quasar absorption spectra (Ly α forest)**
- **Simulations: Sherwood-Relics post-processed with EX-CITE or ATON**



- I have developed codes to analyze QSO absorption spectra in observations and simulations
- EX-CITE, GLASS, WEAVEIFY, VIPER, SPECRED, HEART (Available on Bitbucket)
- SPECRED $\Rightarrow$ To coadd spectra, fit continuum and mask metal lines (Gaikwad+2021)
- VIPER $\Rightarrow$ To decompse $\text{Ly}\alpha$ forest in multi-component Voigt profiles (Gaikwad+2017)
- EX-CITE $\Rightarrow$ To model patchy reionization (Gaikwad+2023)
- GLASS $\Rightarrow$ To generate QSO absorption spectra in simulations (Gaikwad+2018)
- WEAVEIFY $\Rightarrow$ To add instrumental resolution, noise and continuum to simulated spectra

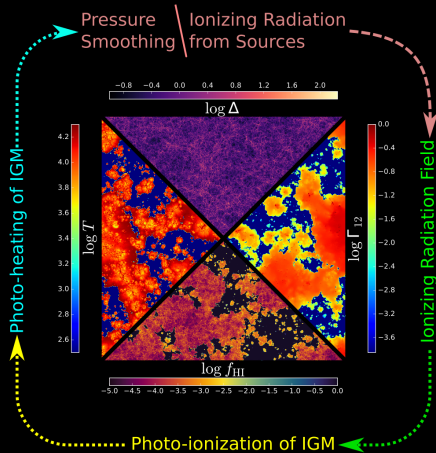


Previous Research

Parameters constrained from observations

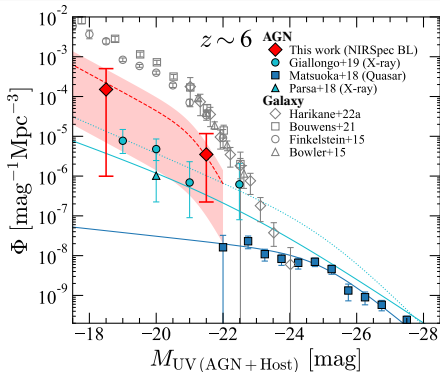
- Temperature
- Mean free path
- Neutral fraction

The evolution of parameters suggest “late” H I ($5 < z < 6$) and He II ($2 < z < 4$) reionization



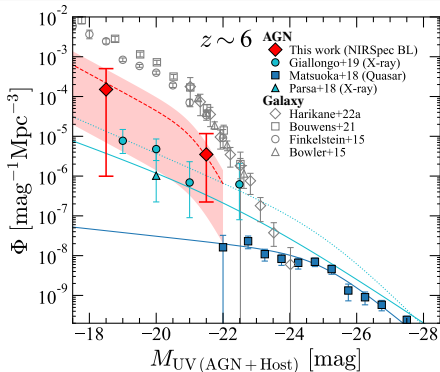
- Broad overview of Postdoc research plan
- Sources of reionization? $\Rightarrow$ Galaxy-QSO absorption cross-correlation, Role of faint AGN
- Timing of reionization? $\Rightarrow$ f_{HI} constraints at $z > 6$, Galaxy damping wing + Ly α forest
- Environment of Galaxies? $\Rightarrow$ Metal enrichment of IGM and CGM at $z > 5$
- Nature of reionization? $\Rightarrow$ Temperature Fluctuations and Pressure smoothing effects

Sources of Reionization?



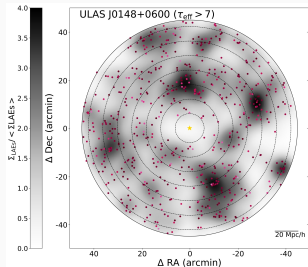
- JWST started to detect significant number of faint AGN (Harikane+2023)
- Their contribution is less uncertain due to low escape fraction
- However, their presence can not be neglected for modeling reionization
- Study the effect of such faint AGN on observations of high redshift QSO absorption spectra.

Sources of Reionization?

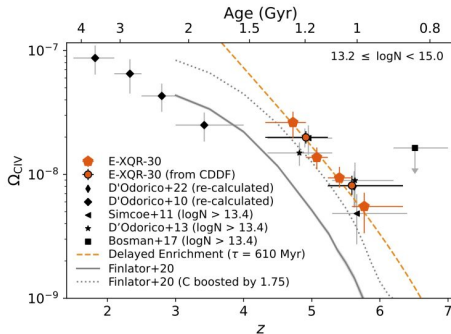
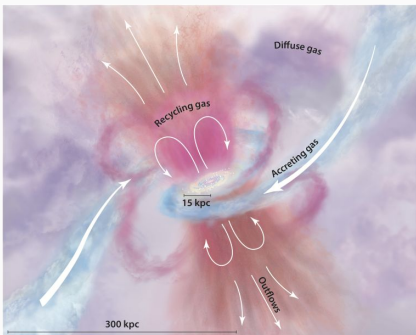


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- Overdensity of Galaxies around most opaque and most transparent QSO sightline is similar (Christensen+2023)
- Correlation of transmission spikes with Galaxy position in observations xQR-30 and simulations
- Potential Collaboration: Prof. A. Messinger and Prof. V. D'Odorico

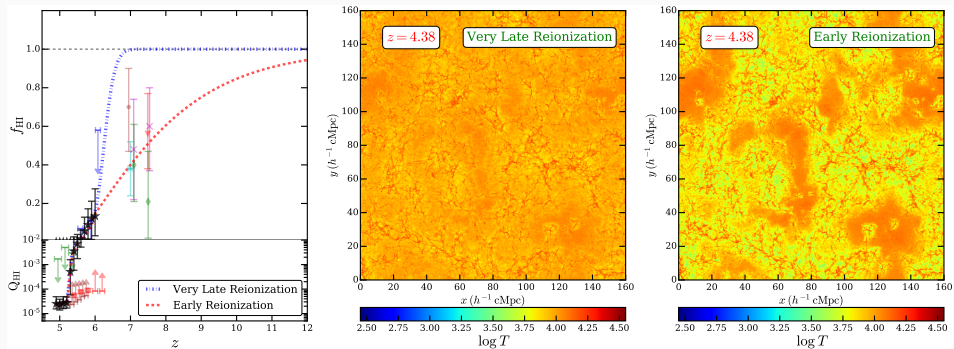


Environment of high redshift Galaxies



- The IGM is more metal enriched than that predicted by metals (Davies+2023)
- Modeling of the metal UVB in IGM using ray-tracing code EX-CITE (Gaikwad+2023)
- Models need to incorporate feedbacks from Galaxies in the form Winds.
- SNS experts: Prof. A. Pallottini and Prof. S. Carniani
- XQR-30 + MUSE program observations of high- z Galaxies (Col)
- Implication of metals in IGM and CGM to stellar synthesis models of high redshift Galaxies.
- SNS experts Prof. A. Ferrara

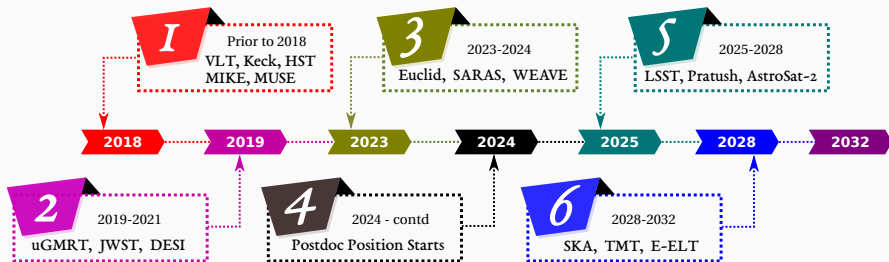
Timing and Nature of Reionization



- Important to extend the constraints on neutral fraction to higher redshifts
- Constraints on neutral fraction at $6 < z < 7$ from ASPIRE collaboration data
- Systematic study of Galaxy damping wing observed with JWST Collaboration with Prof. A. Messinger
- Imprints of temperature fluctuations on $\text{Ly}\alpha$ forest at $z < 5$
- Data from ESPRESSO large program can potentially constrain temperature fluctuations

Collaboration with Prof. V. D'Odorico

Summary



- My research interests aligned very well with the postdoc position
- Sources of reionization? $\Rightarrow$ Galaxy-QSO absorption cross-correlation, Role of faint AGN
- Timing of reionization? $\Rightarrow$ f_{HI} constraints at $z > 6$, Galaxy damping wing + $\text{Ly}\alpha$ forest
- Environment of Galaxies? $\Rightarrow$ Metal enrichment of IGM and CGM at $z > 5$
- Nature of reionization? $\Rightarrow$ Temperature Fluctuations and Pressure smoothing effects