### **21-cm x Galaxies during the Epoch of Reionization** Prospect with Current Radio and Optical Surveys



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### 21-cm @ EoR



### 21-cm @ EoR



## 21-cm x Galaxies





Chowdhury+ (2020)

### **Cross-correlation @ EoR**

#### Galaxy Density Field



#### 21cm Field



### **Cross-correlation @ EoR**

#### Galaxy Density Field



#### 21cm Field



# **Cross-correlation** @ EoR

- Cross-spectra forecast has been extensively studied (e.g., Cox+ 2022, La Plante & Mirocha+ 2023, Gagnon-Hartman+ 2025)
- We focus on cross-correlation via stacking image cubes around Lyman-alpha Emitters (LAEs)
  - Theory template derived from radiative hydro sims
  - Case study using realistic
    HERA mapping pipeline to accurately model noise statistics





- Observed properties of Ly-alpha lines at EoR are highly dependent on surrounding IGM
- Consistent modeling of 21-cm lines of sight and Ly-alpha properties via full radiative transfer studies (Neyer+ in prep.)



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- Stacked 21-cm signal around **intrinsically** bright LAEs  $\delta T_{21} \approx T_0(z)(1+\delta_b)x_{\rm HI}\left(1-\frac{T_{\rm rad}}{T_{\rm S}}\right)\left(\frac{H}{dv_r/dr+H}\right)$



- Stacked 21-cm signal around **observed** bright LAEs.  $\delta T_{21} \approx T_0(z)(1+\delta_b)x_{\rm HI}\left(1-\frac{T_{\rm rad}}{T_{\rm S}}\right)\left(\frac{H}{dv_r/dr+H}\right)$



- Stacked 21-cm signal around **observed** bright LAEs.  $\delta T_{21} \approx T_0(z)(1+\delta_b)x_{\rm HI}\left(1-\frac{T_{\rm rad}}{T_{\rm S}}\right)\left(\frac{H}{dv_r/dr+H}\right)$



- Cross-correlation between HERA and LAEs in CDFS
- Ground-based narrow-band LAE surveys at z~6.9 and ~7.3 (LAGER and CIDER projects)
- 80 LAE candidates at z~6.9
- 9 spectroscopically confirmed
- Propose observational campaign to continue follow up



• 21-cm Images with an optimal mapping pipeline (Xu+ 2022)  $V_{\mathbf{b}}(\nu) = \int B(\hat{\mathbf{s}}) \delta T_b(\hat{\mathbf{s}}) \exp\left(-i\frac{2\pi\nu}{c}\mathbf{b}\cdot\hat{\mathbf{s}}\right) d\Omega$ 



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# **Preliminary Forecast**



# Summary and Outlook

- Cross-correlations are important validations
- A simple stacking could constrain reionization history
- ~100 LAEs with accurate redshift could be enough for crosscorrelating with current generation radio experiments
- Work in progress: Examine noise statistics in foregroundfiltered HERA images