

*Sakura CLAW, Mar. 28, 2018*

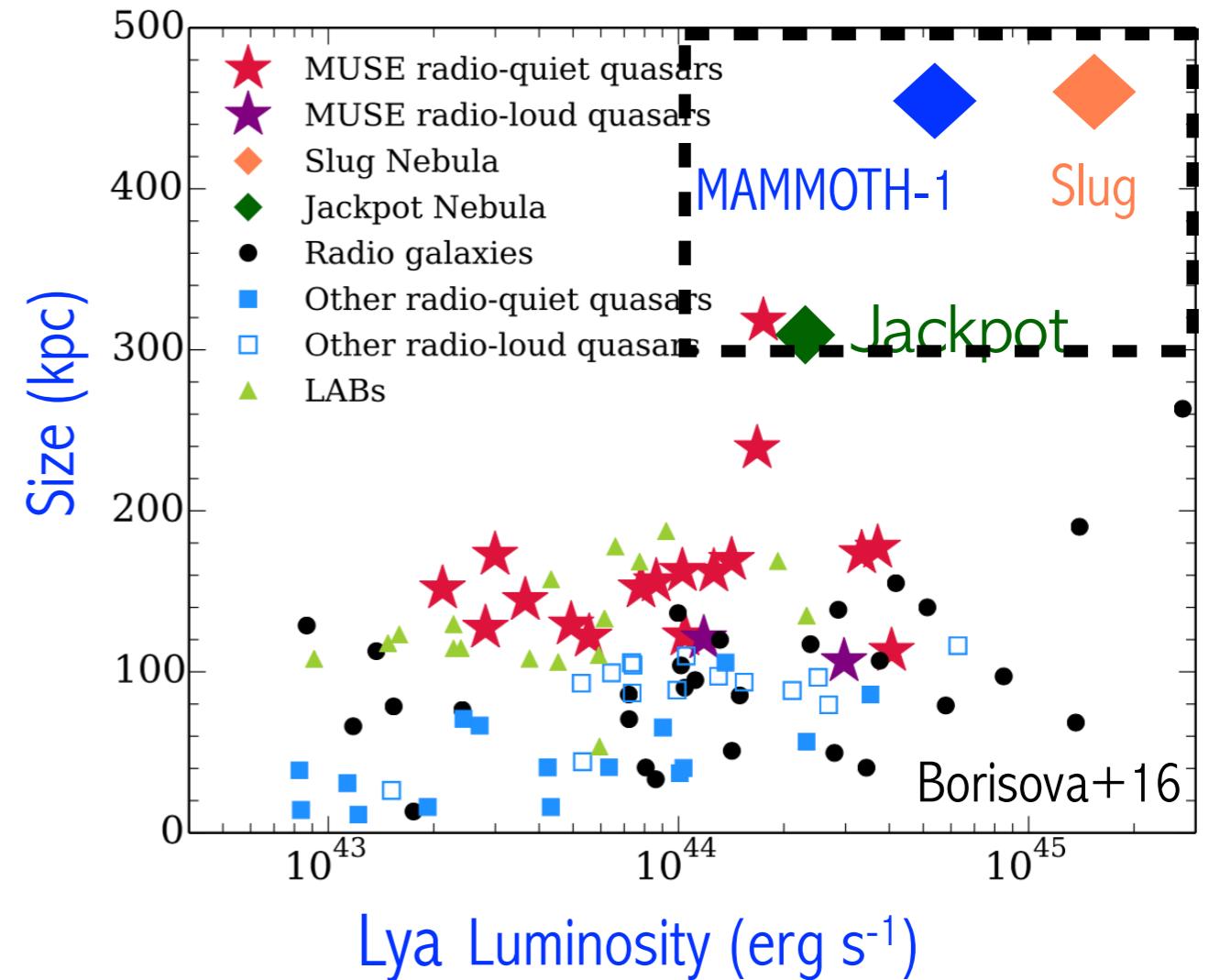
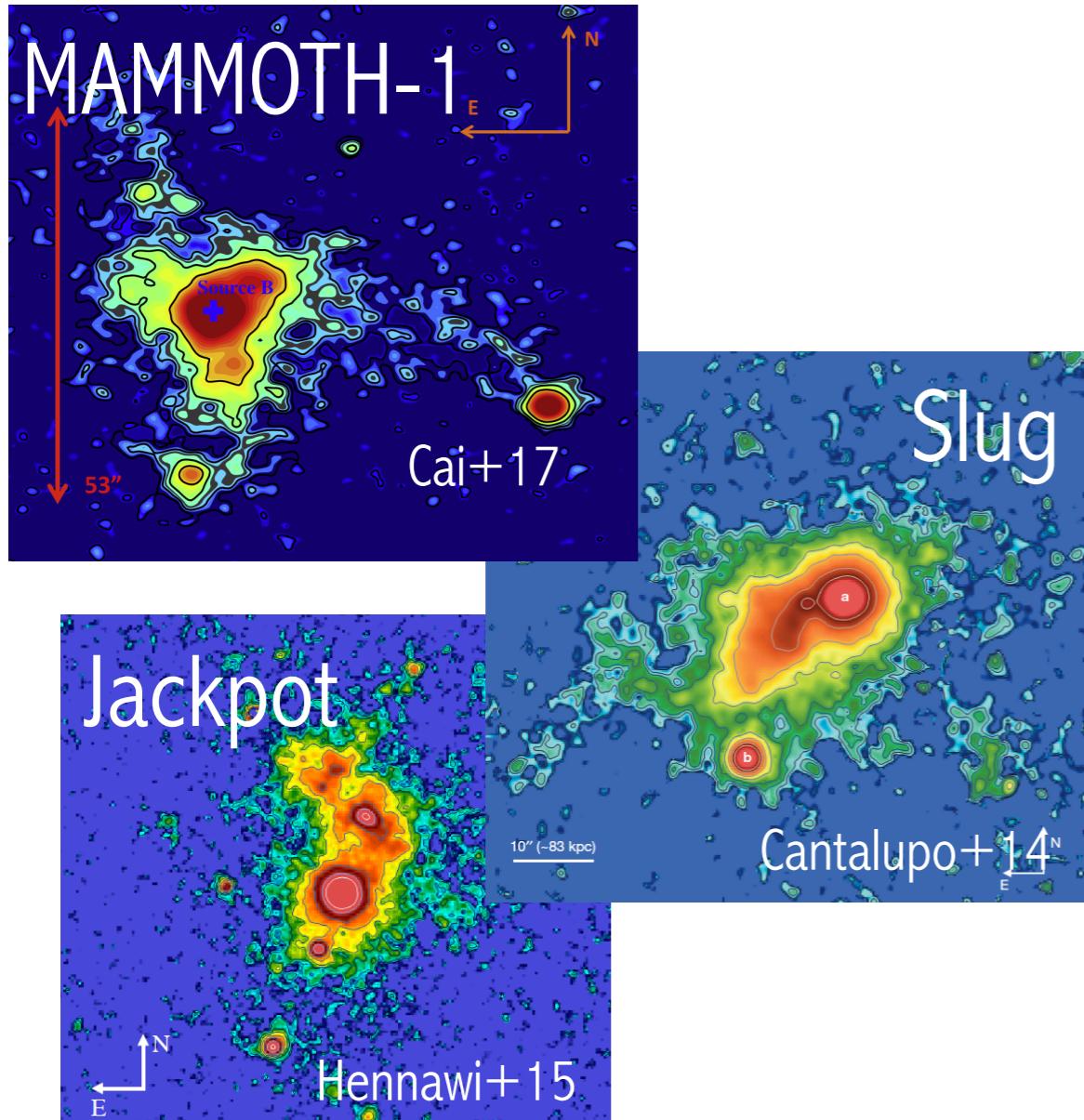
# Testing the physical origins of an Enormous Ly $\alpha$ Nebula at $z = 2.3$ by bright background galaxies

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in collaboration with...

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Kentaro Nagamine, Nao Suzuki, Suzuka Koyamada, Katsumi Fujita, John Silverman, and Yi-Kuan Chiang

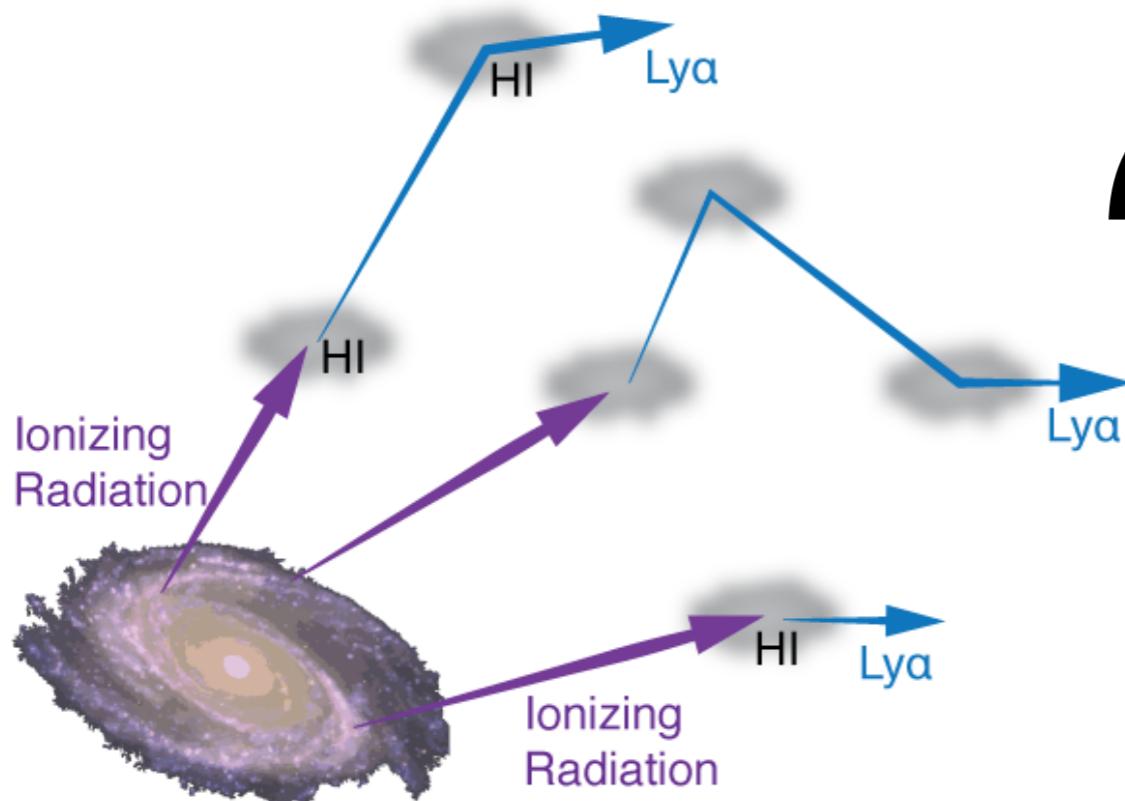
# Enormous Ly $\alpha$ Nebulae (ELANe)



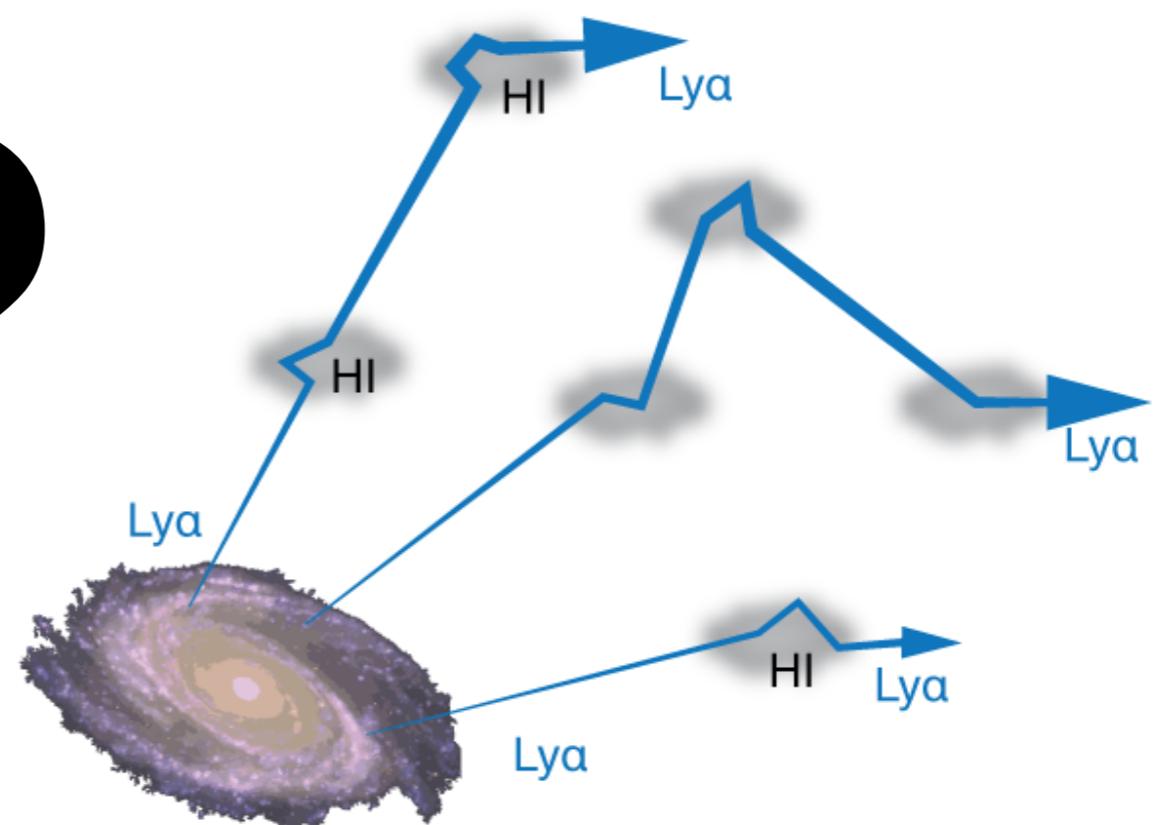
- **extremely luminous/extended Ly $\alpha$  sources w**  
 $L_{\text{Ly}\alpha} > 10^{44} \text{ erg s}^{-1}$   
Size  $> 300 \text{ pkpc}$
- beyond virial diameter (280 pkpc) of host qso → trace IGM filaments

# Physical origins

① Fluorescence



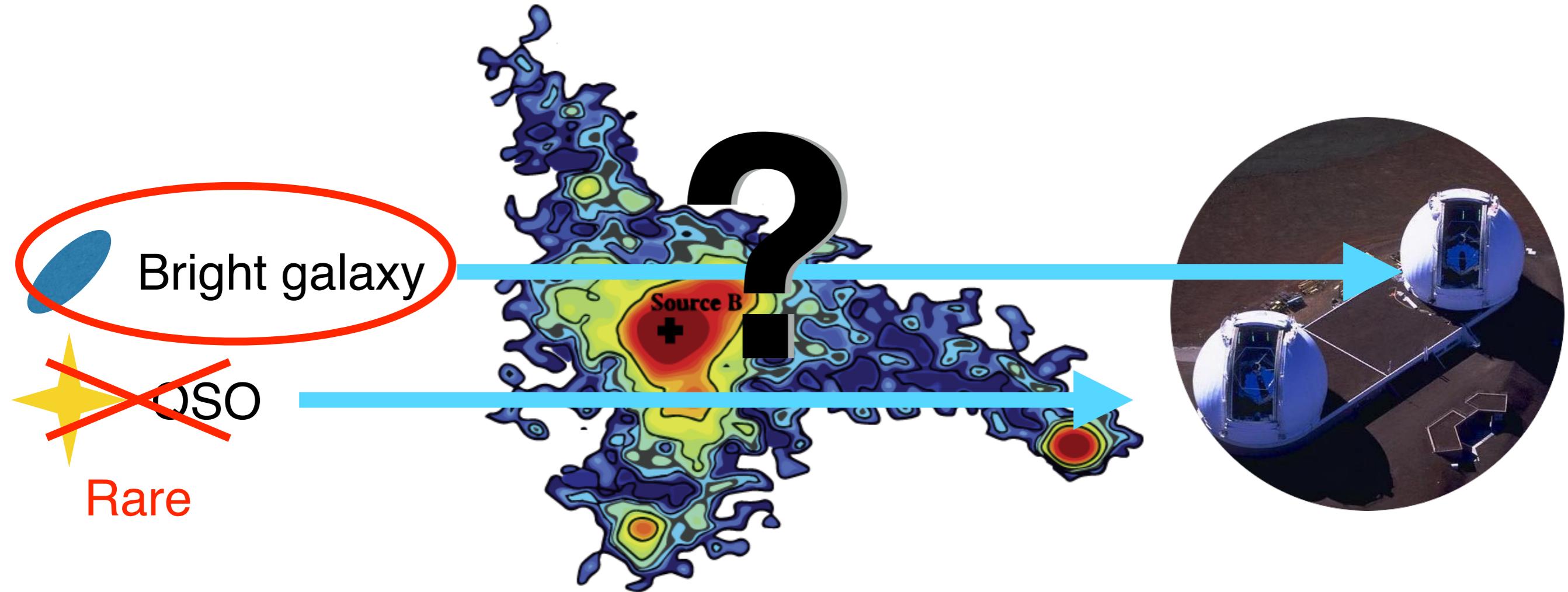
② Scattering



- no strong constraints on the physical origin
- HI property is still unknown → optically thin? thick?

**Key quantity: HI Optical depth of extended Lyα components**

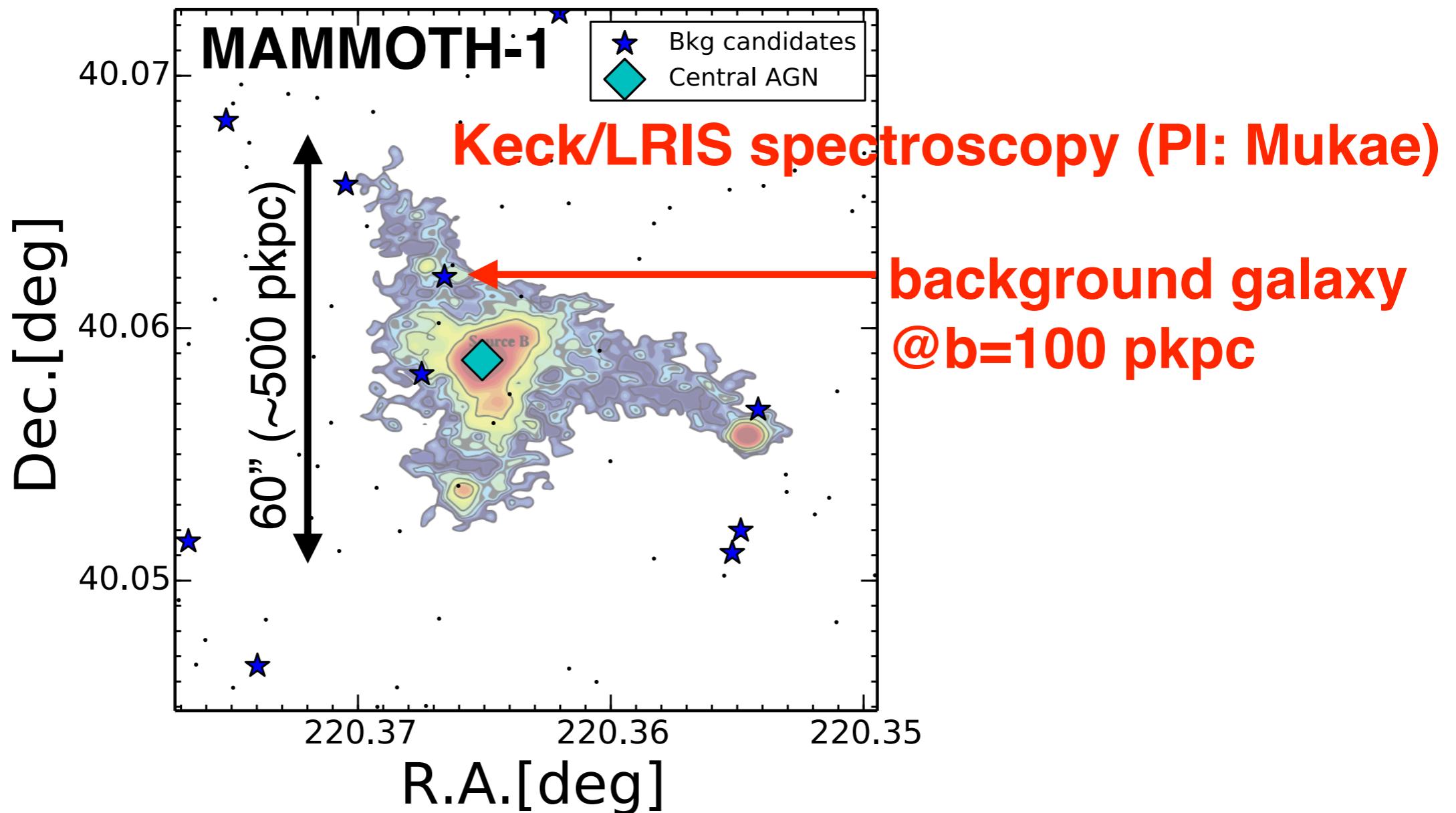
# Background sources



- to constrain HI optical depth of extended Ly $\alpha$  components,  
—> **HI absorptions** in background galaxy spectra

# Data and observations

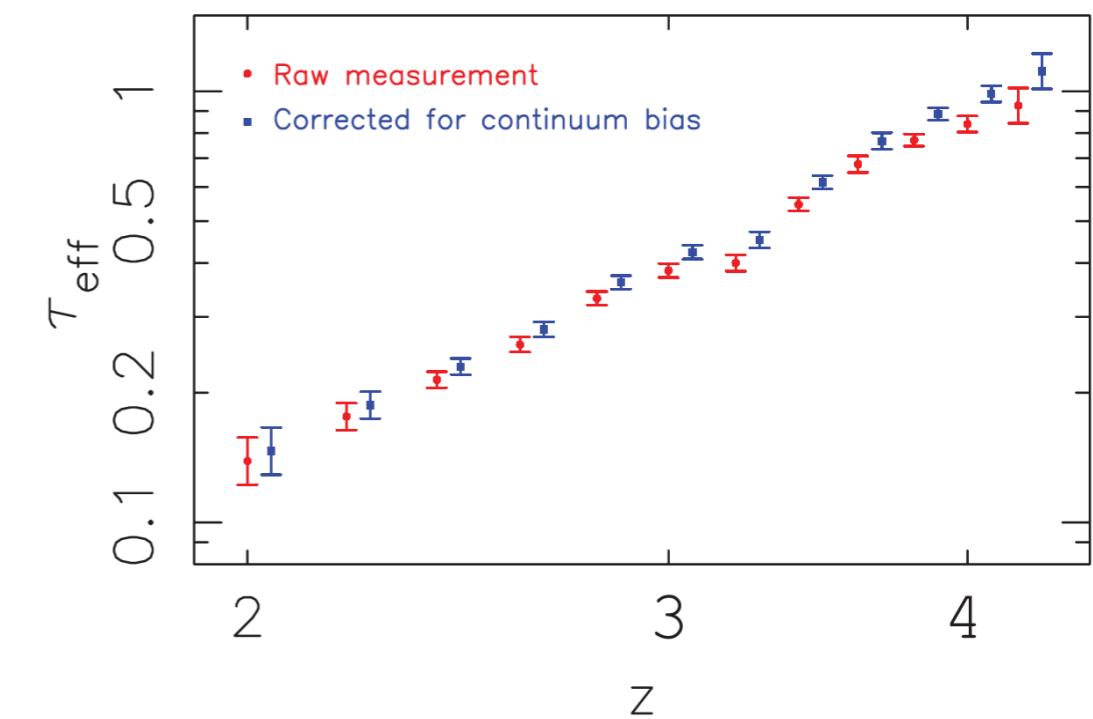
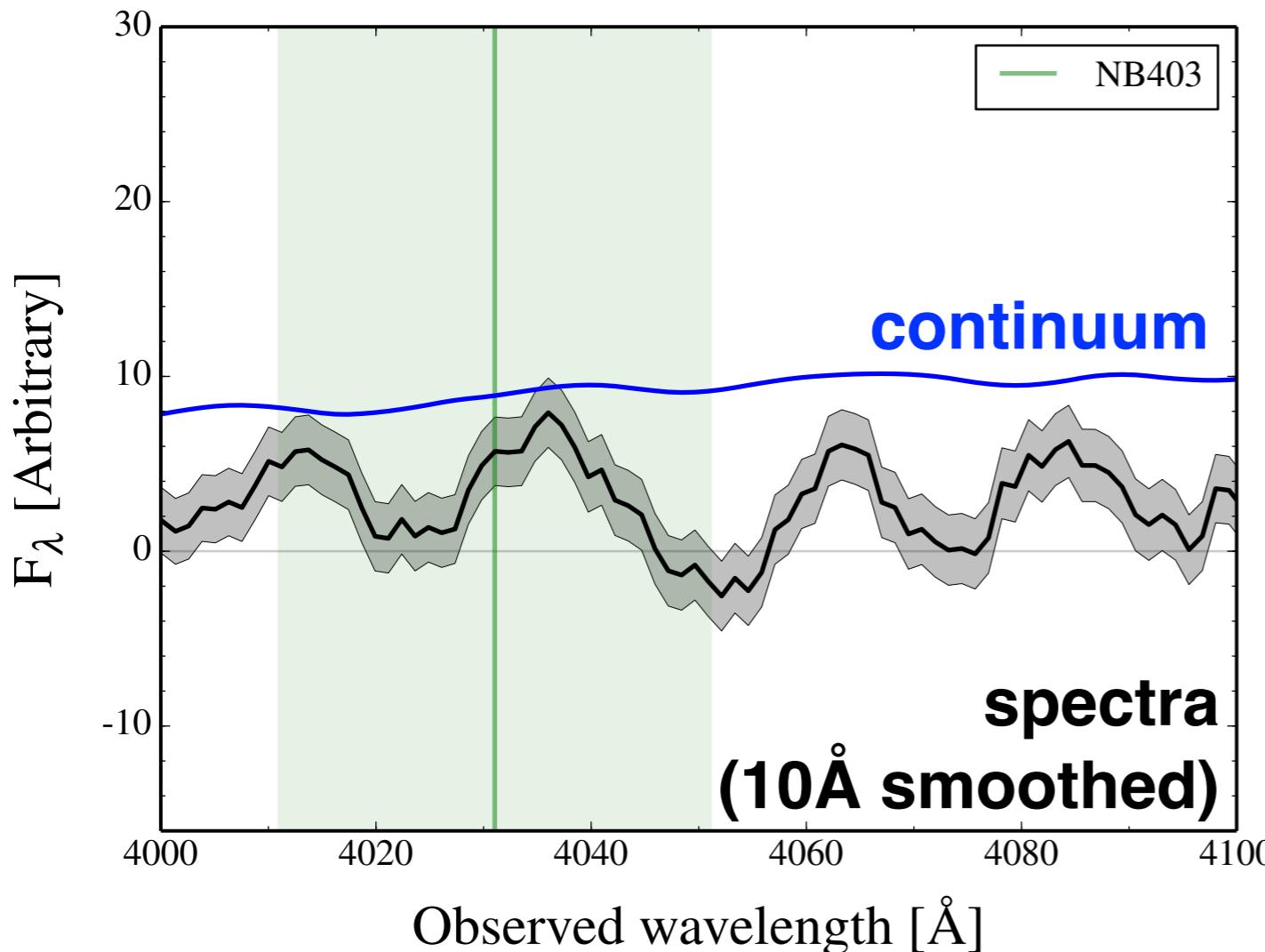
- ELAN: MAMMOTH-1 at  $z = 2.32$  (Cai+17)
- Background: star-forming galaxies ( $V_{AB}=23.8-24.6$ ) at  $z=2.4-2.8$
- BX selection (Steidel+04) + Photo-z (EAZY; Brammer+08)  
← imaging data: LBT/LBC (U, V, i) & UKIRT/WFCAM (J, H)



# Analysis—Background galaxy

## Background galaxy at $z = 2.52$ ( $V_{AB} = 24.5$ )

- inspected with Shapley+03 template (chi-square)
- Mean flux-regulated continuum fit with Berry+12 template (Lee+12)

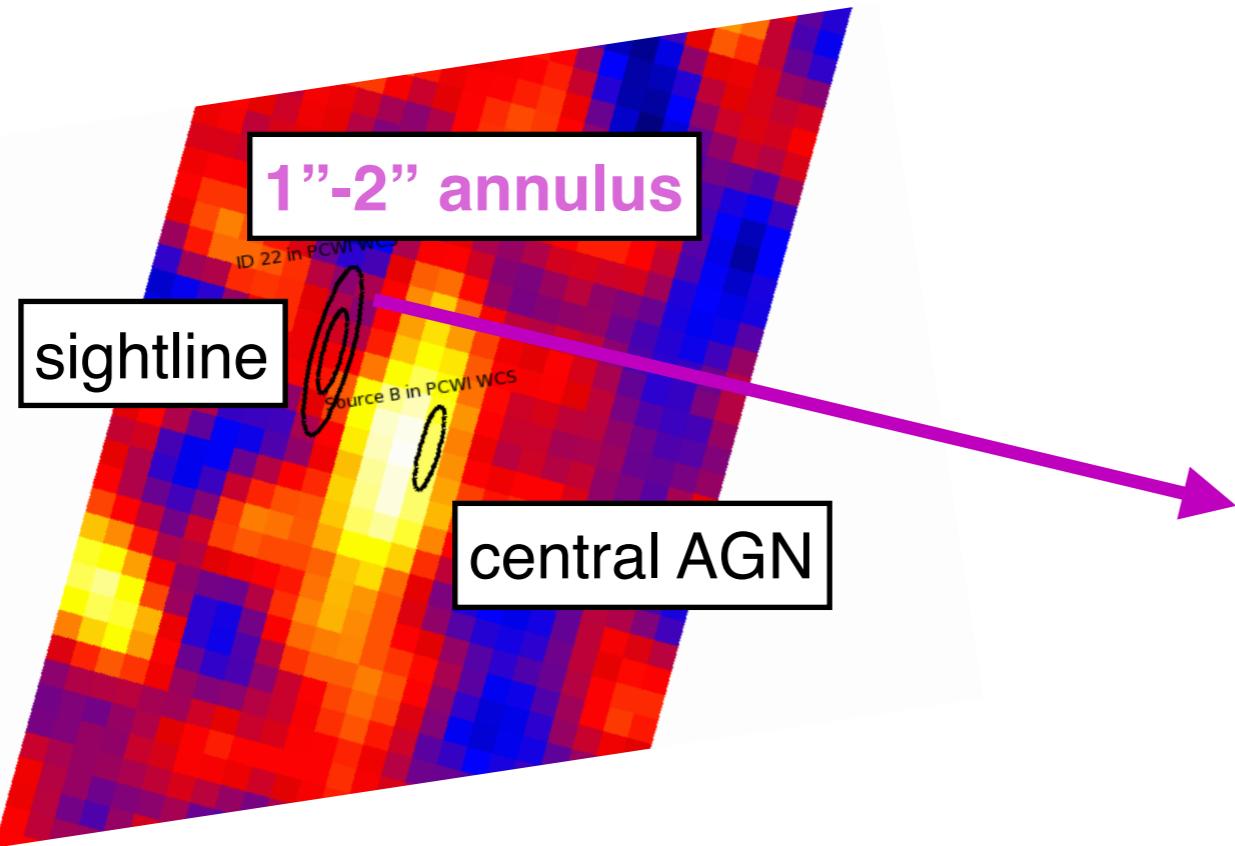


Cosmic mean flux  
(Faucher-Giguère+08)

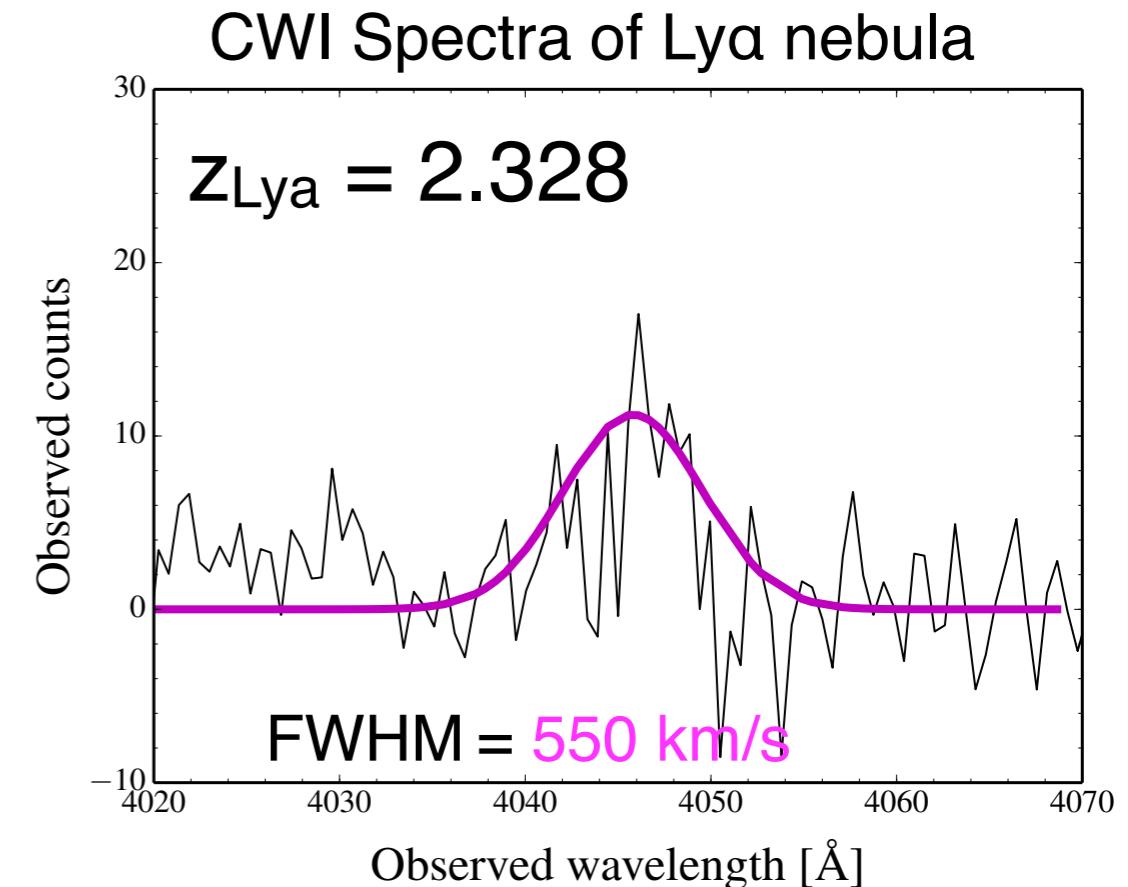
NB403 width is large ( $\pm 1500 \text{ km/s}$ ) —> Where is the Ly $\alpha$  nebula??

# Analysis—Ly $\alpha$ component

Ly $\alpha$  investigated with Palomar/CWI observations (PI: Zheng Cai)

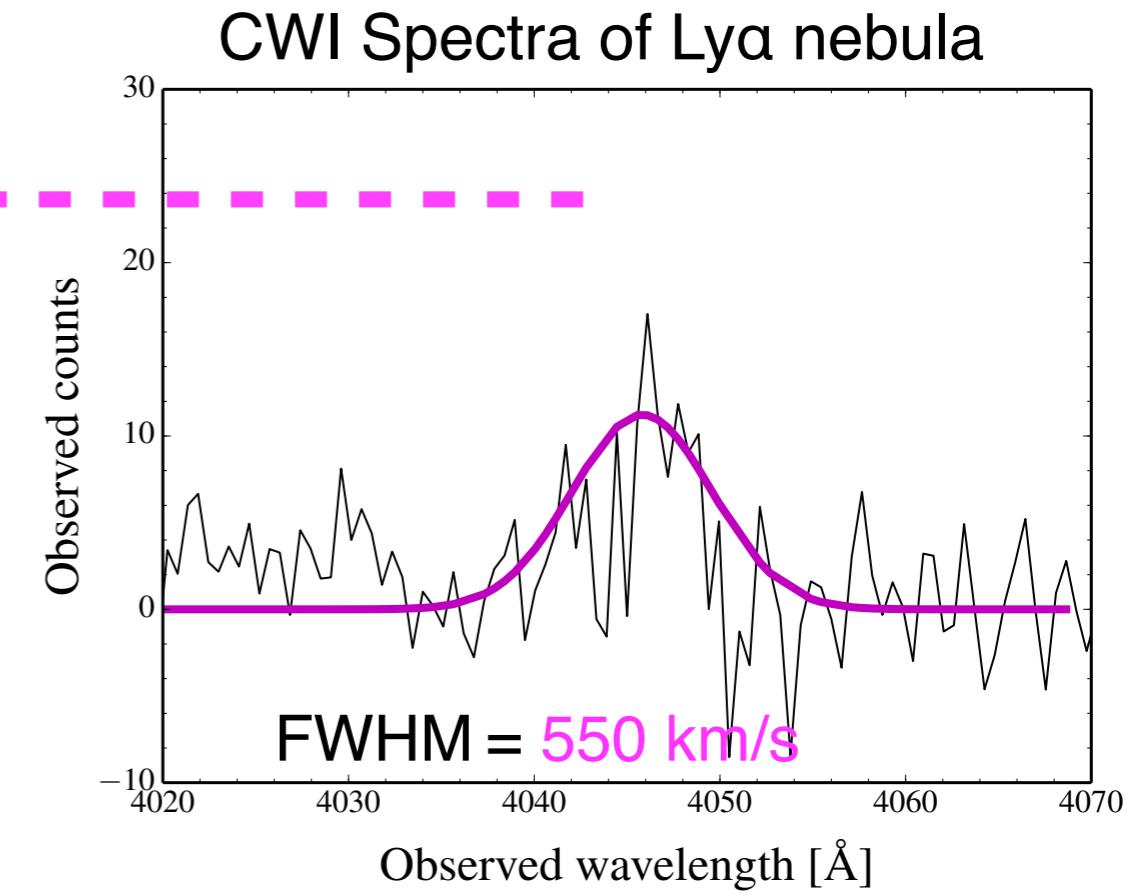
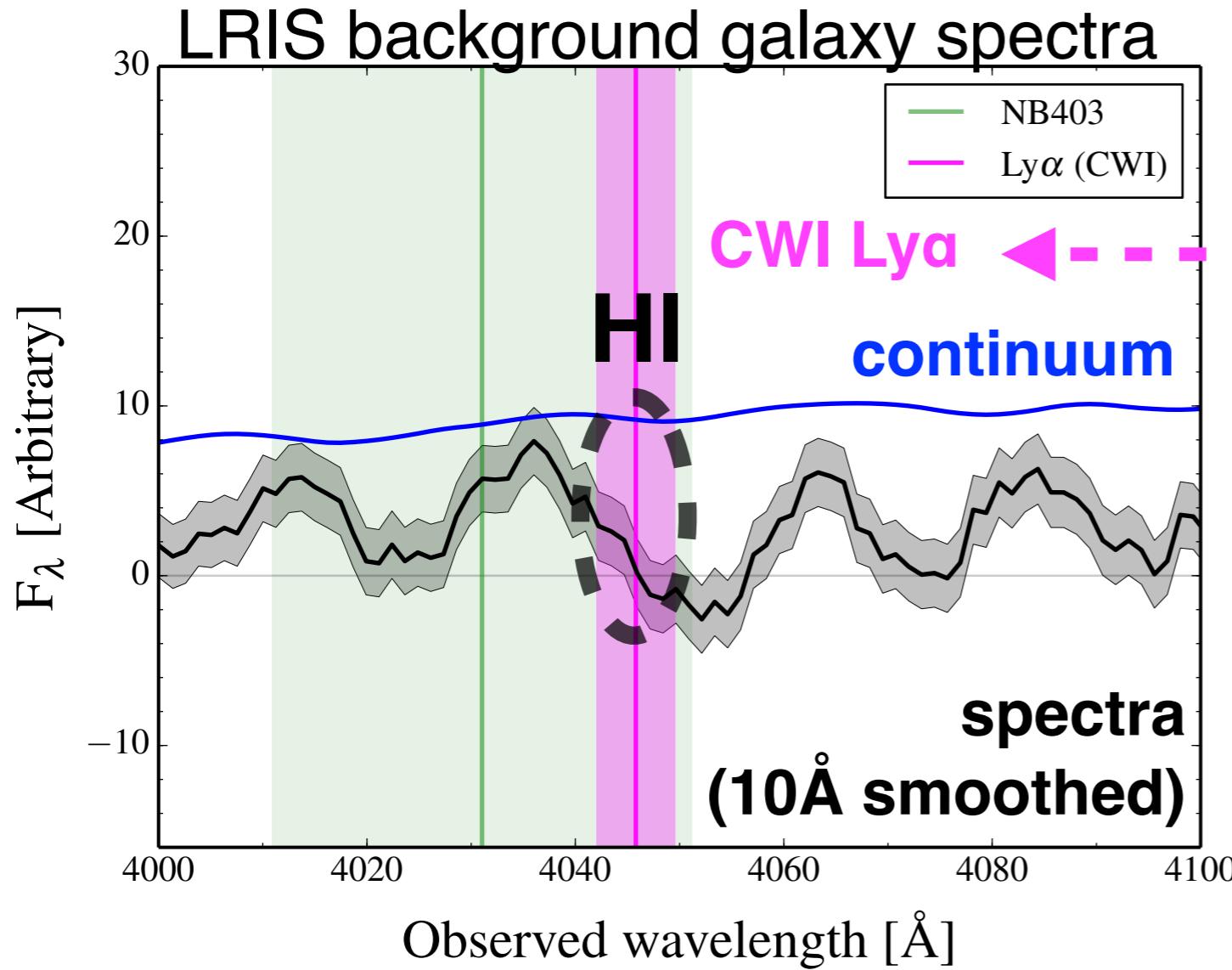


Datacube: 3800-4200Å (R~4000)



Ly $\alpha$  nebula emission **around 1-2 arcsec**  
→ measure the wavelength range of the Ly $\alpha$  emission

# Results – HI absorption



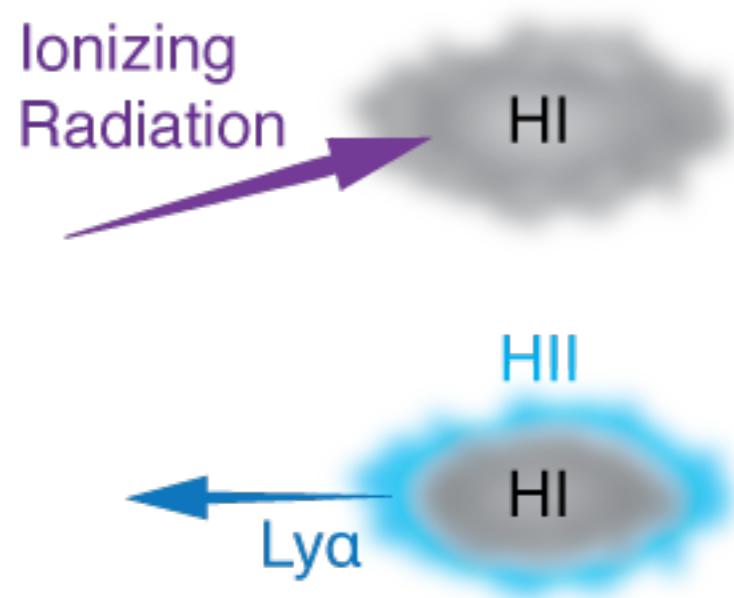
transmission  $0.09 \pm 0.01 \rightarrow \tau = 2.36^{+2.99}_{-0.67}$

$\rightarrow$  HI is optically thick @bright Ly $\alpha$  nebula components ( $b=100$  pkpc)

# Discussion1 – physical origins

The optical depth indicates that the HI gas is optically thick cloud whose ionized(neuetral) skin contributes to Fluorescence(Scattering)

① Optically thick Fluorescence



② Scattering

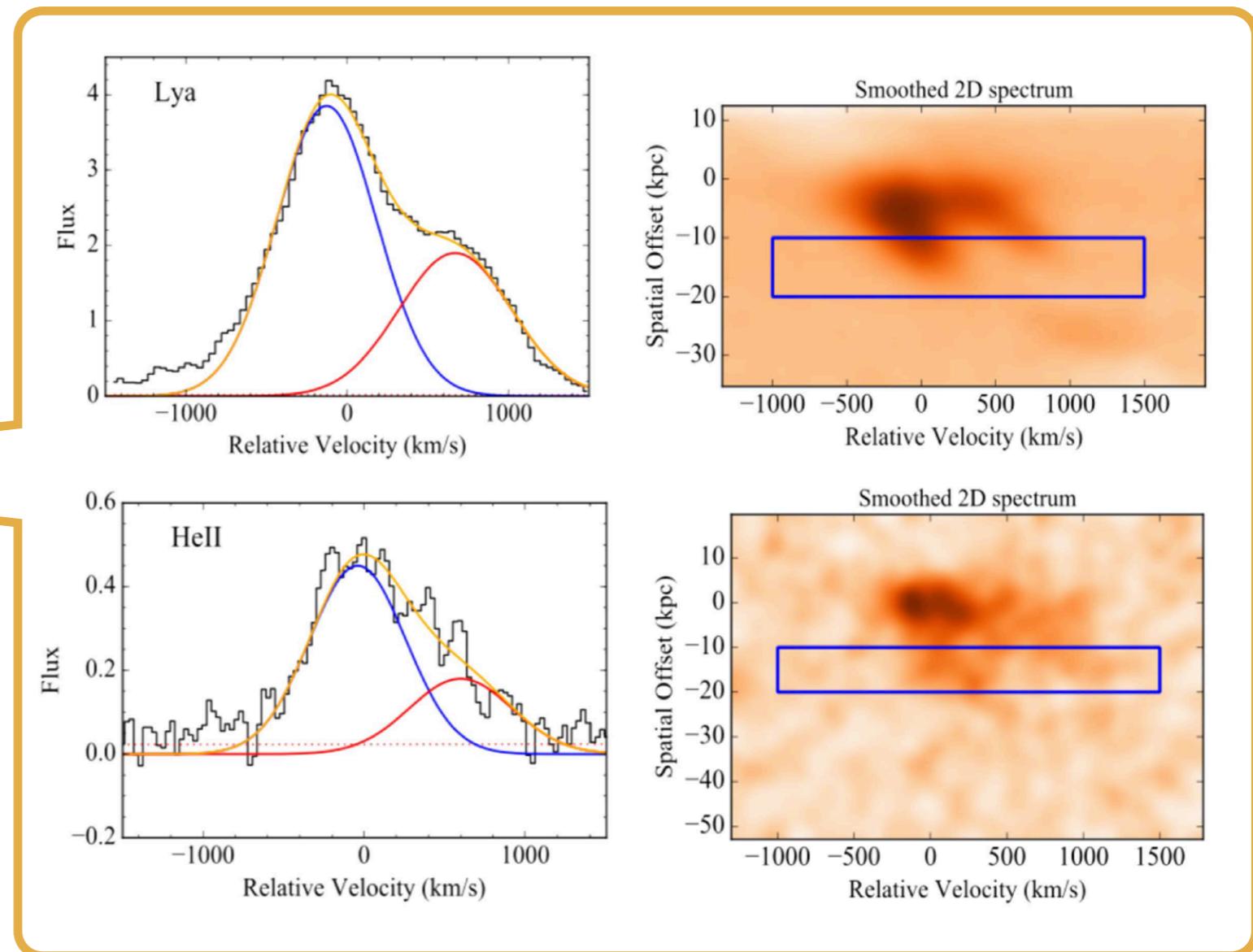
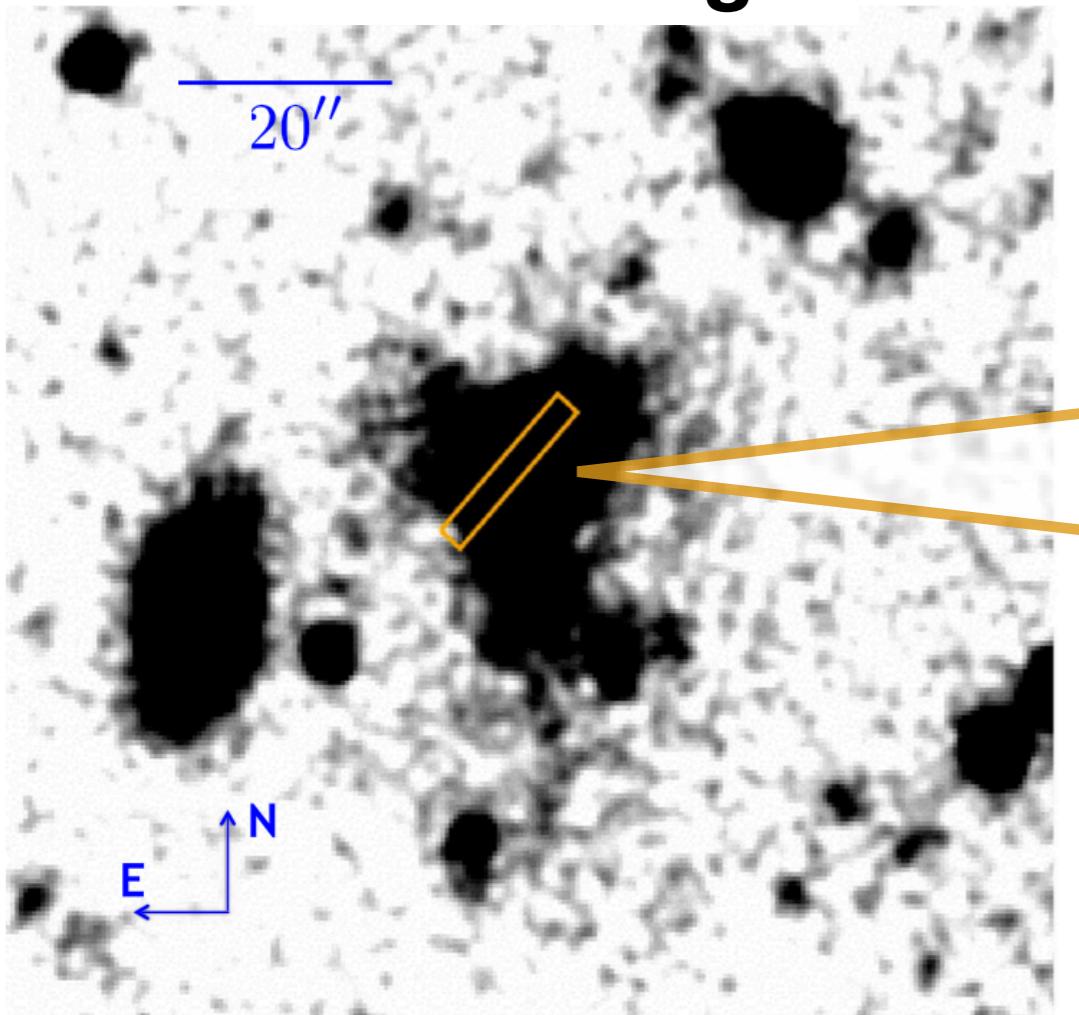


Key observation

Hell&CIV emissions@bright Lyα nebula component

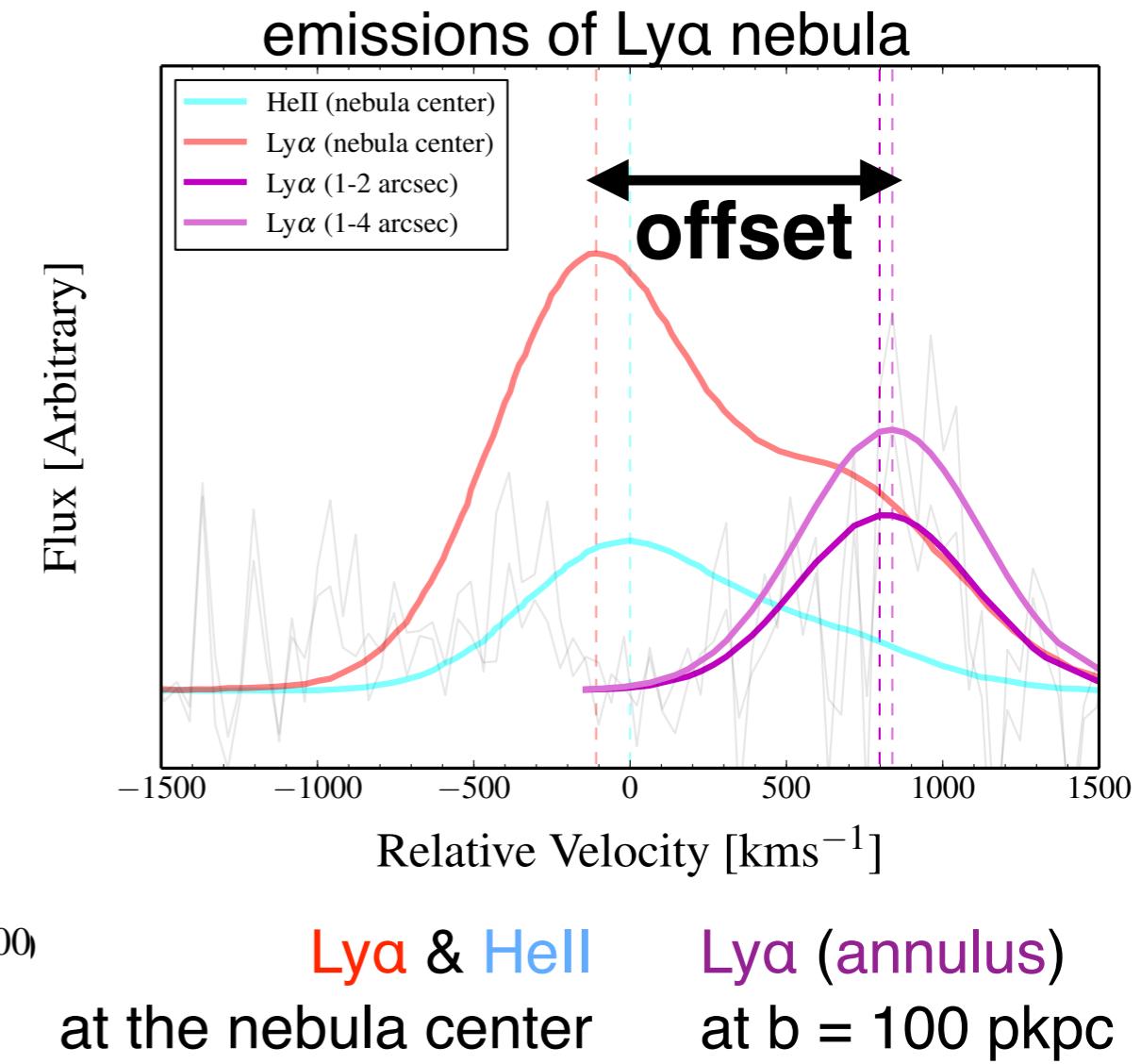
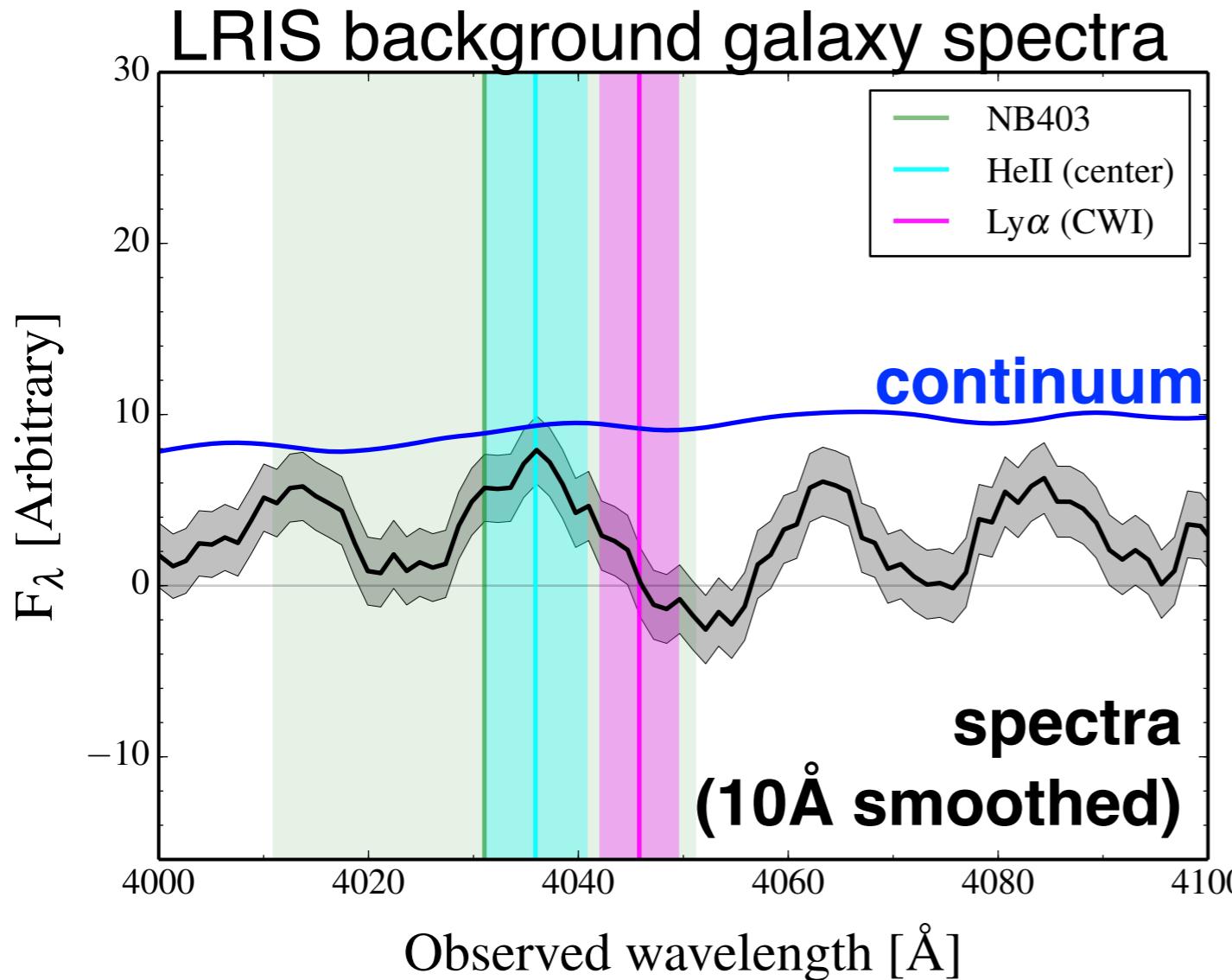
# Discussion 2 – AGN proximity

NB403 image



Extended HeII at the center of MAMMOTH-1 (HeII/Lya~0.1; Cai+17)  
→ assume  $z_{\text{HeII}}$  as the systemic redshift of MAMMOTH-1

# Discussion2 – AGN proximity



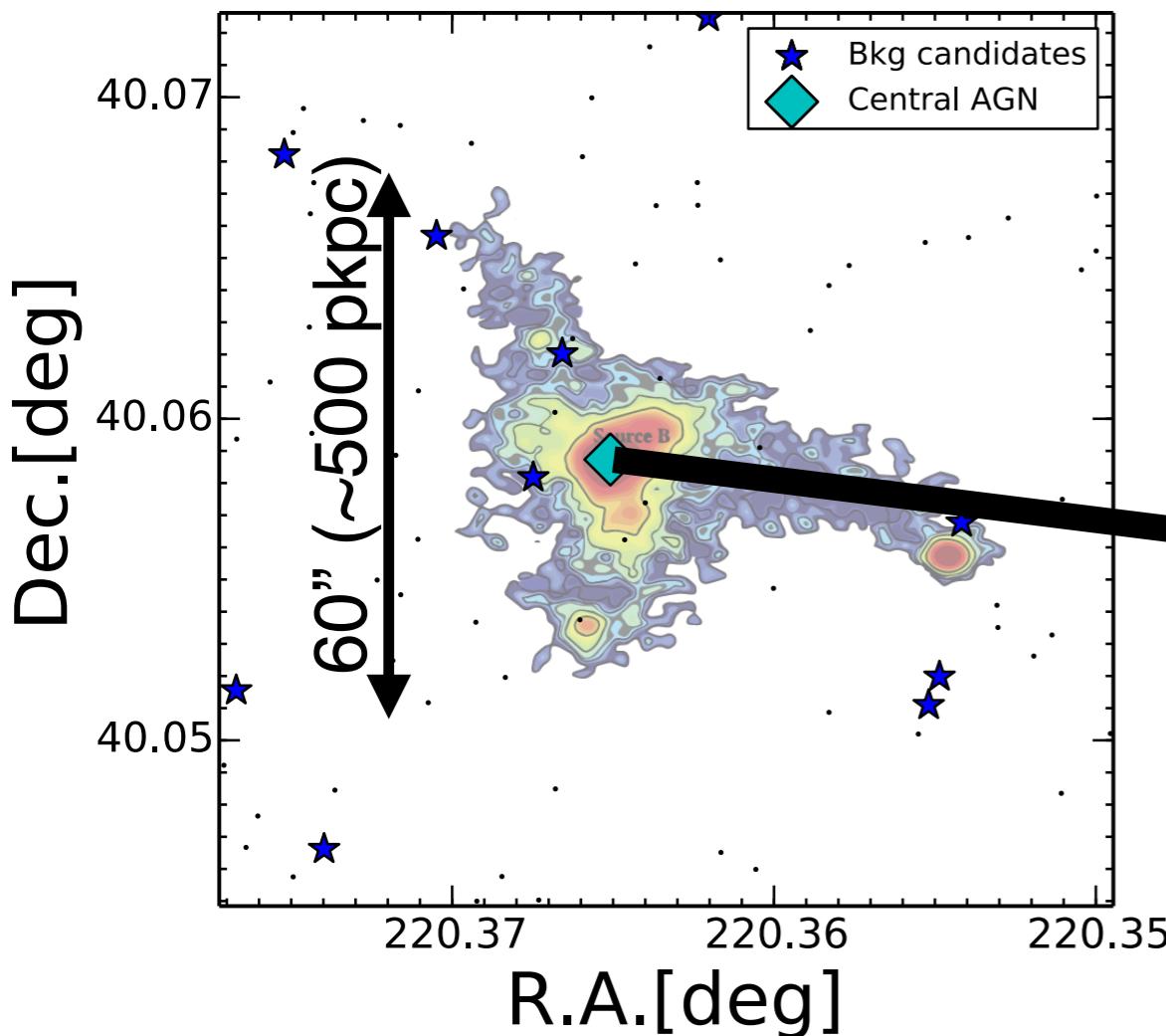
Bright Ly $\alpha$  nebula components@ $b=100\text{pkpc}$ : **spatially offset to the center**  
 → AGN proximity: transmission  $0.67 \pm 0.10$  →  $\tau = 0.40^{+0.16}_{-0.14}$   
 → **optically thin** (ionized/heated by the central AGN?)

Key observation

Hell emissions@bright Ly $\alpha$  component

# Conclusions

- We obtain deep LRIS spectra of background galaxies whose sightlines penetrate MAMMOTH-1 (one is  $b=100$  pkpc)
- HI absorption analysis combining with CWI spectra indicates...  
optically thick gas in the bright Ly $\alpha$  components
- physical origins?: fluorescence vs. scattering  
—> Key observations: H $\alpha$  & CIV



**KCWI:** emissions and absorptions  
+ IGM tomography of ELANe

