Redshift Evolution of the Electron Density in the ISM at z ∼ 0 – 9 Uncovered with JWST/NIRSpec Spectra and Line-Spread Function Determinations

Yuki Isobe THE UNIVERSITY OF TOKYO

M.Ouchi[1,2,3], K.Nakajima[1], Y.Harikane[2], Y.Ono[2], Y.Xu[2], Y.Zhang[2], & H.Umeda[2]

1: NAOJ, 2: Tokyo, 3: Kavli IPMU

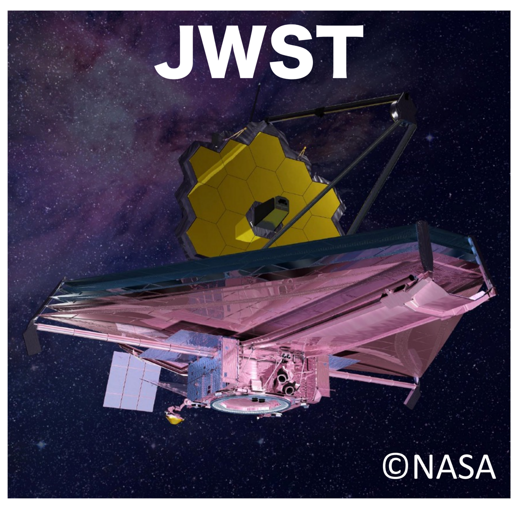
Isobe+23 arXiv: 2301.06811

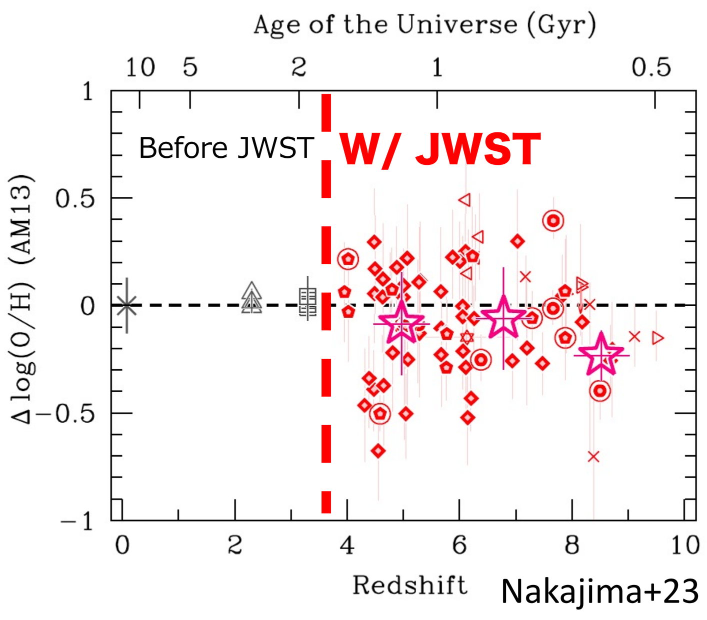
FY2022 ICRR Master and Doctor Thesis Workshop

Introduction

Data arriving from July 2022

James Webb Space Telescope (**JWST**) can directly observe high-redshift low-mass (stellar mass $M_* \sim 10^8\ M_\odot$) galaxies

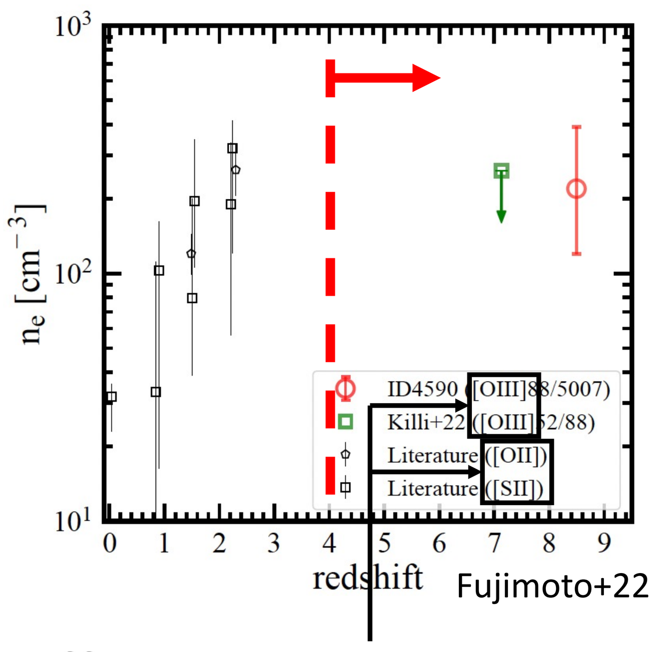


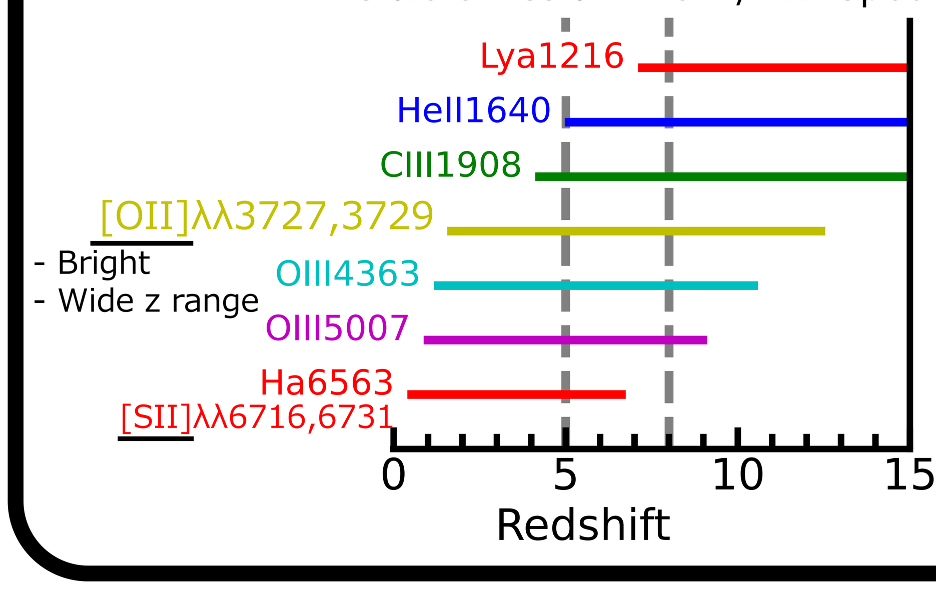


Near-infrared spectrograph

JWST/NIRSpec first explores precise high-z galaxy props, e.g.,
- Metallicity @ $4 \lesssim z \lesssim 10$
(e.g., Curti+23; Nakajima+23)

Only a few measurements of electron density (n_e) in the inter-stellar medium (ISM) at z > 4





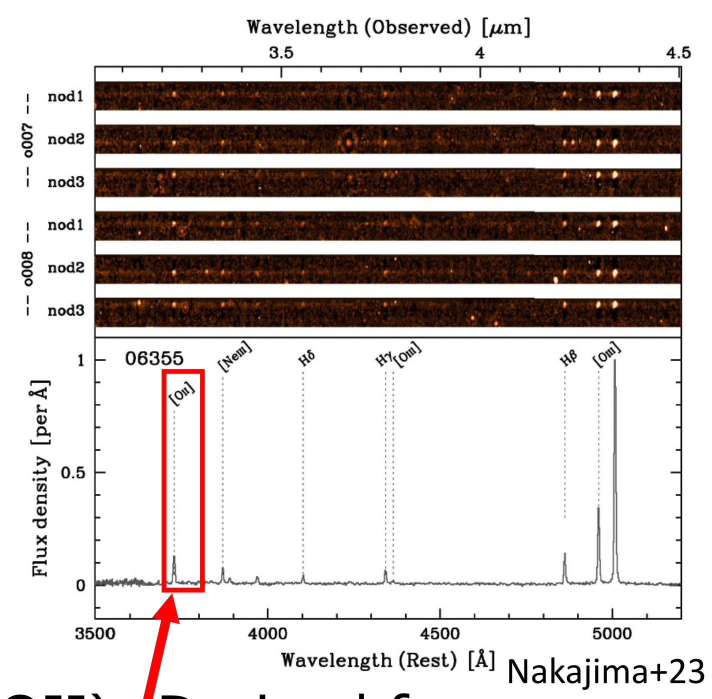
Different ionization regions
(i.e., different positions)

Goal:
n_e(OII) in the ISM at z > 4 using the NIRSpec data

Data & Analysis

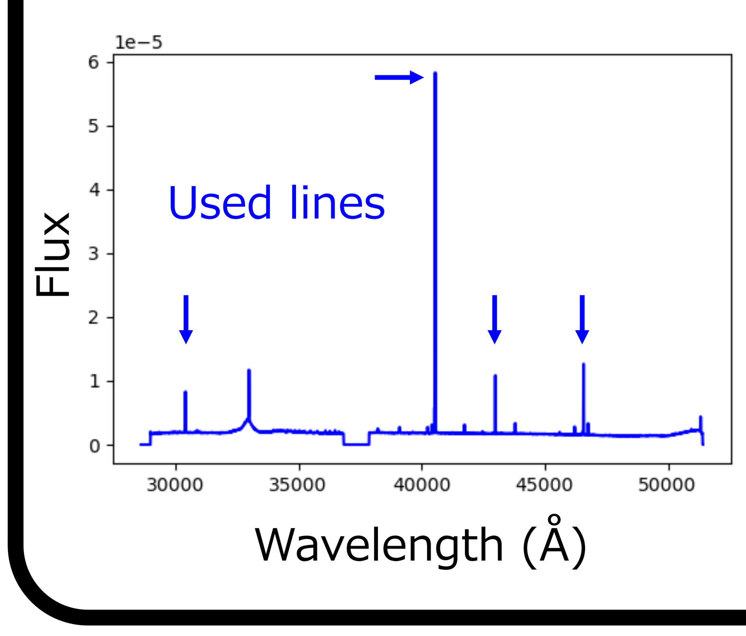
Public survey data of NIRSpec:
- GLASS (Treu+22)
  Spectral resolution R ∼ 2700
  λ_{obs} = 1.0–5.1 μm
- ERO (Pontopiddan+22)
  R ∼ 1000; λ_{obs} = 1.7–5.1 μm
- CEERS (Finkelstein+22)
  R ∼ 1000; λ_{obs} = 1.0–5.1 μm

Data reduction by our group
(Nakajima, Ouchi, YI+23)

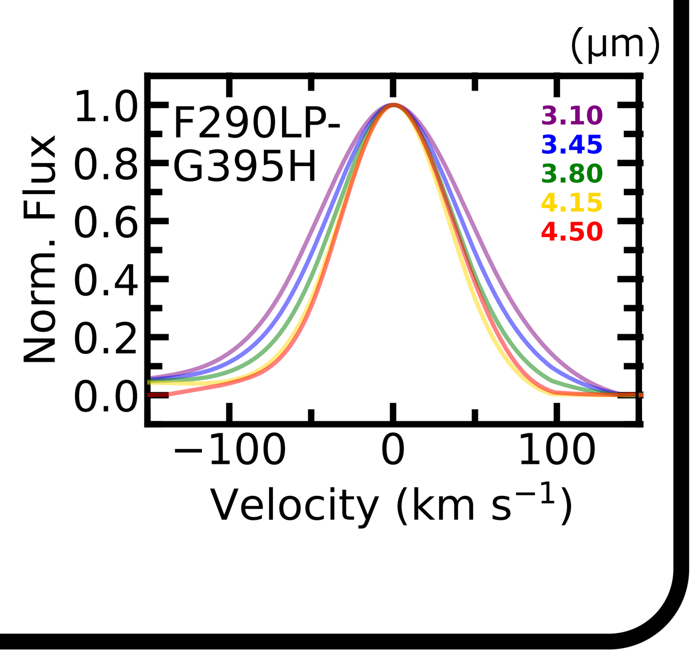


n_e(OII): Derived from [OII]λ3727/[OII]λ3729
Not fully deblended
→Careful deblending w/ line-spread function (**LSF**)

Deriving the LSFs from the spectra of a planetary nebula

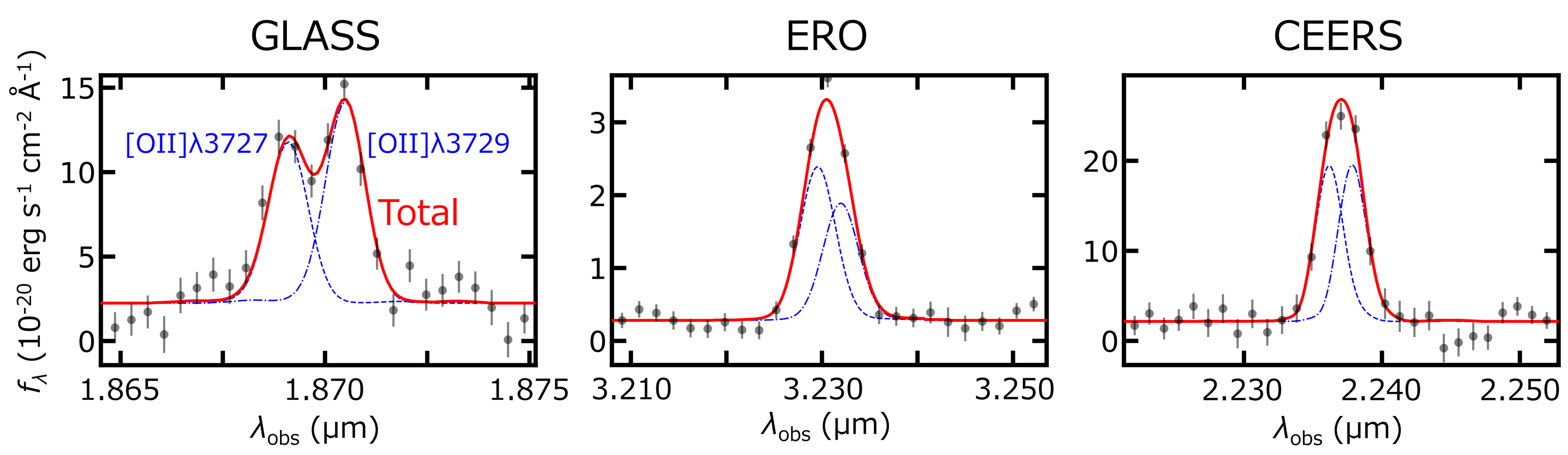


Interpolating line profiles →



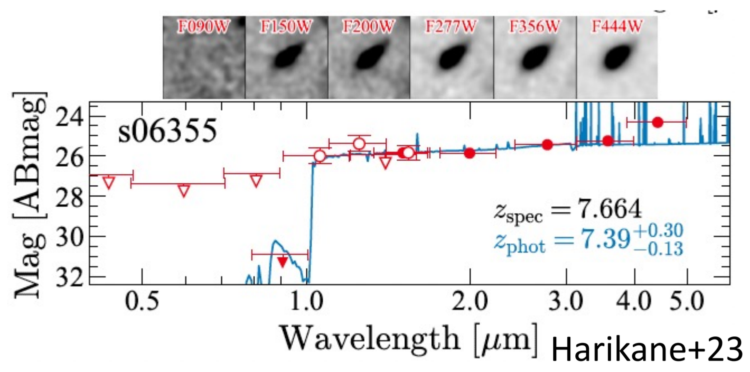
Analysis *(Continued)*

Fitting Gaussian conv. by the LSF to [OII]λλ3727,3729

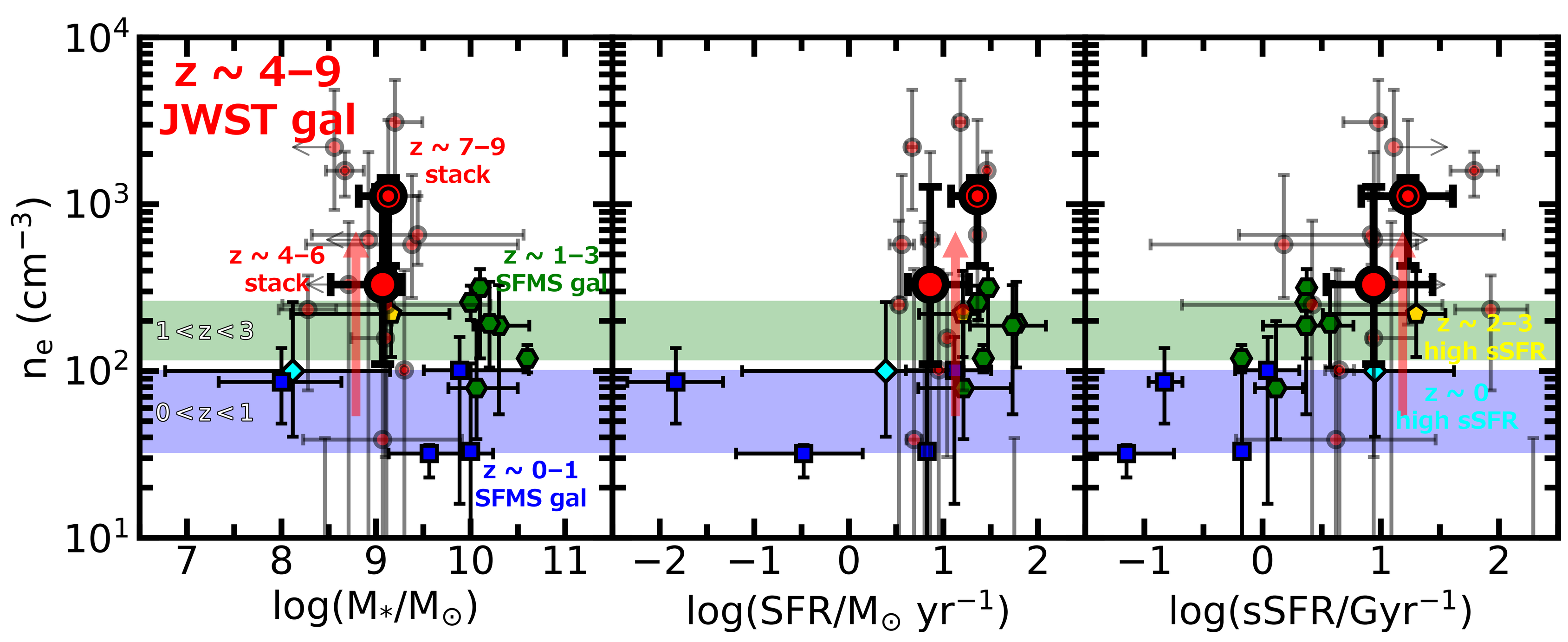


M_*: SED fitting
(Nakajima+23; cf. Harikane+23)

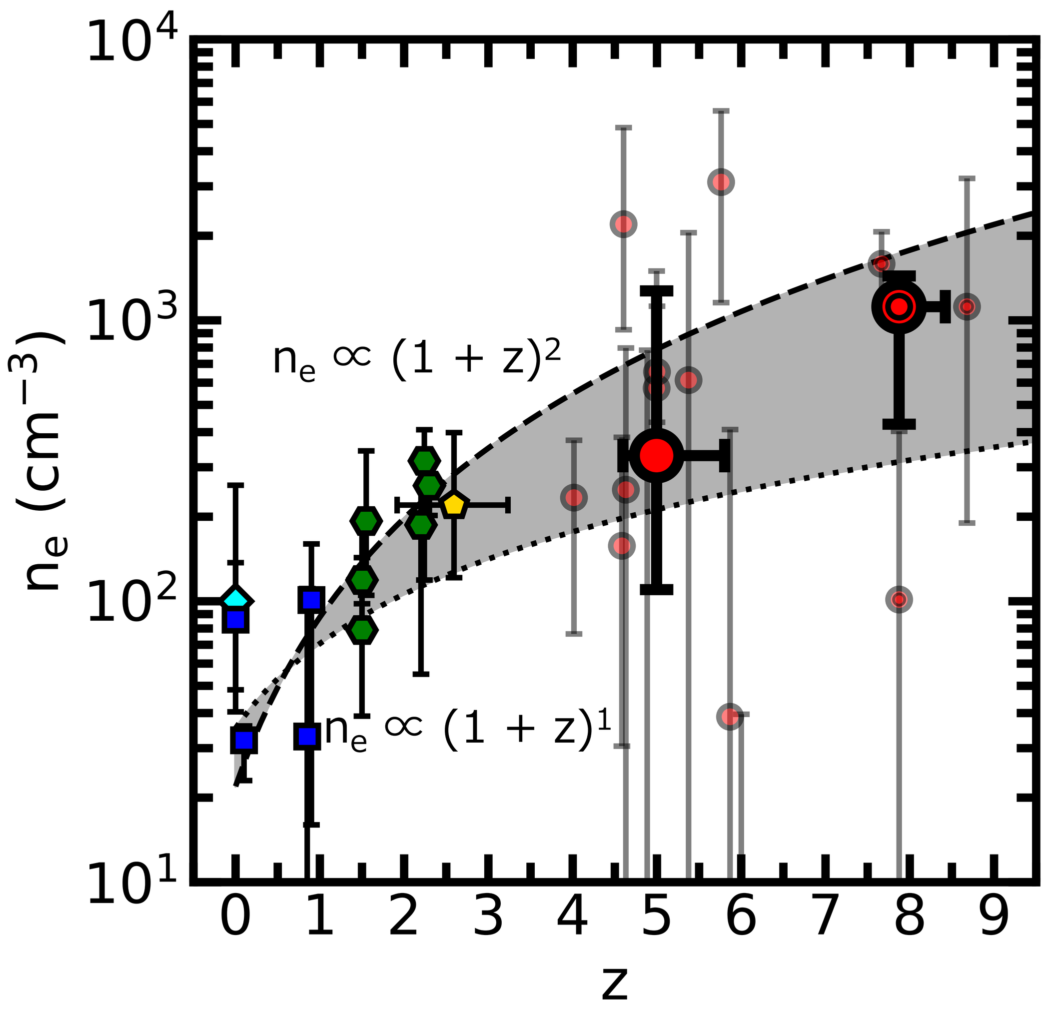
Star-formation rate (SFR):
From Hα (Kennicutt98)



Result & Discussion

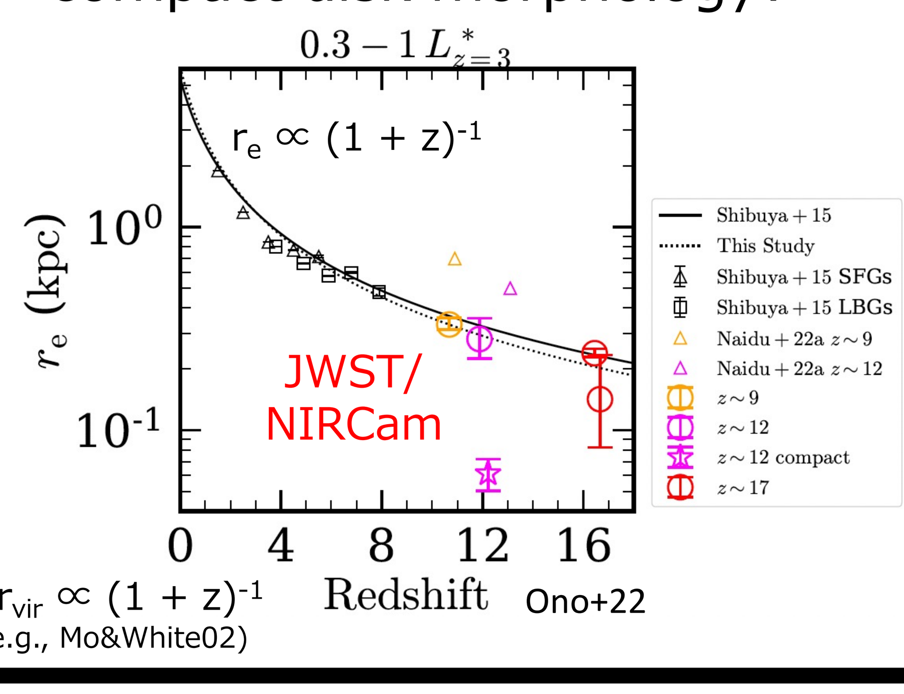


n_e increases with z at a given M_*, SFR, and sSFR



n_e increases with z
from z ∼ 0
to z ∼ 1–3
and z ∼ 4–9

$n_e \propto (1+z)^2$ relation can be explained by compact disk morphology?



* $r_{vir} \propto (1+z)^{-1}$
(e.g., Mo&White02)

n_e reduced by high electron temperature (T_e)?