Disentangling Galaxies during the Epoch of Reionization and Cosmic Noon using TIME & Roman

UNIVERSITY OF TORONTO

DUNLAP INSTITUTE *for* ASTRONOMY & ASTROPHYSICS

Baria Khan[1], Supervised by Jenna Freudenburg[2] & Abigail Crites[3]

1. Dunlap Institute for Astronomy & Astrophysics, University of Toronto, Canada
2. Canadian Institute for Theoretical Astrophysics, University of Toronto, Canada
3. Department of Physics, Cornell University, USA

Motivation

The period of the cosmic history known as the epoch of reionization (EoR), when light first emerged from the earliest stars and galaxies remains largely mysterious. Its specifics can be understood by **investigating the growth of molecular gas across cosmic time and the star formation history of our Universe**.

Cross-correlation analyses between **galaxy CO emission measured from line-intensity mapping experiments such as TIME**, and **infrared imaging** by upcoming state-of-the art observatories such as the **Roman Space Telescope** can **provide valuable insight into galaxy evolution and star-formation history**.

What are TIME & Roman?

TIME: Tomographic Ionized-carbon Mapping Experiment

- TIME is a mm-wavelength ionized carbon [CII] intensity mapping spectrometer, being built to study the EoR and earliest galaxies.
- **TIME will also measure CO fluctuations** that trace the role of molecular gas during the peak of star-formation at 'cosmic noon' (z ~ 2).

ROMAN: The Nancy Grace Roman Space Telescope

- Roman is a next-generation NASA space observatory, that will conduct Dark Energy Investigations, High-latitude surveys & Exoplanet science.
- **Roman's deep, infrared imaging survey** will image ~2200 deg^2 of sky in 4 broad NIR bands, capturing tens of millions of galaxies out to z ~ 2.

Galaxy Sample Selection

Emulating a Roman galaxy catalog using the Near-Infrared Deep **CANDELS-COSMOS HST/WFC3 & ACS Photometry Catalog** (2016) [1]:

Characteristics:

- **32721** H-band selected galaxies at $\mathbf{z_{phot} < 4.0}$ with good photometry**,** detected by the CANDELS Survey of the COSMOS sky field.
- Stellar mass range: $10^{4.0} < M_{stellar}\,[M_\odot] < 10^{11}$
- Sources flagged as 'stars' by SExtractor and HST/WFC3 H_{F160W} AB mag < 22 are excluded.

CO luminosities for these galaxies are modelled in this work, to later be compared with TIME's predicted CO power spectra.

Modelling IR-selected galaxies as CO proxies

i. **Selecting** actively star-forming galaxies (**SFGs**) and passively evolving galaxies (**PEGs**) through **Bzk** ≡ (z-K) - (B-z) and **VJL** ≡ (J-L) - (v-J) **colour-colour selections** [2,3]:

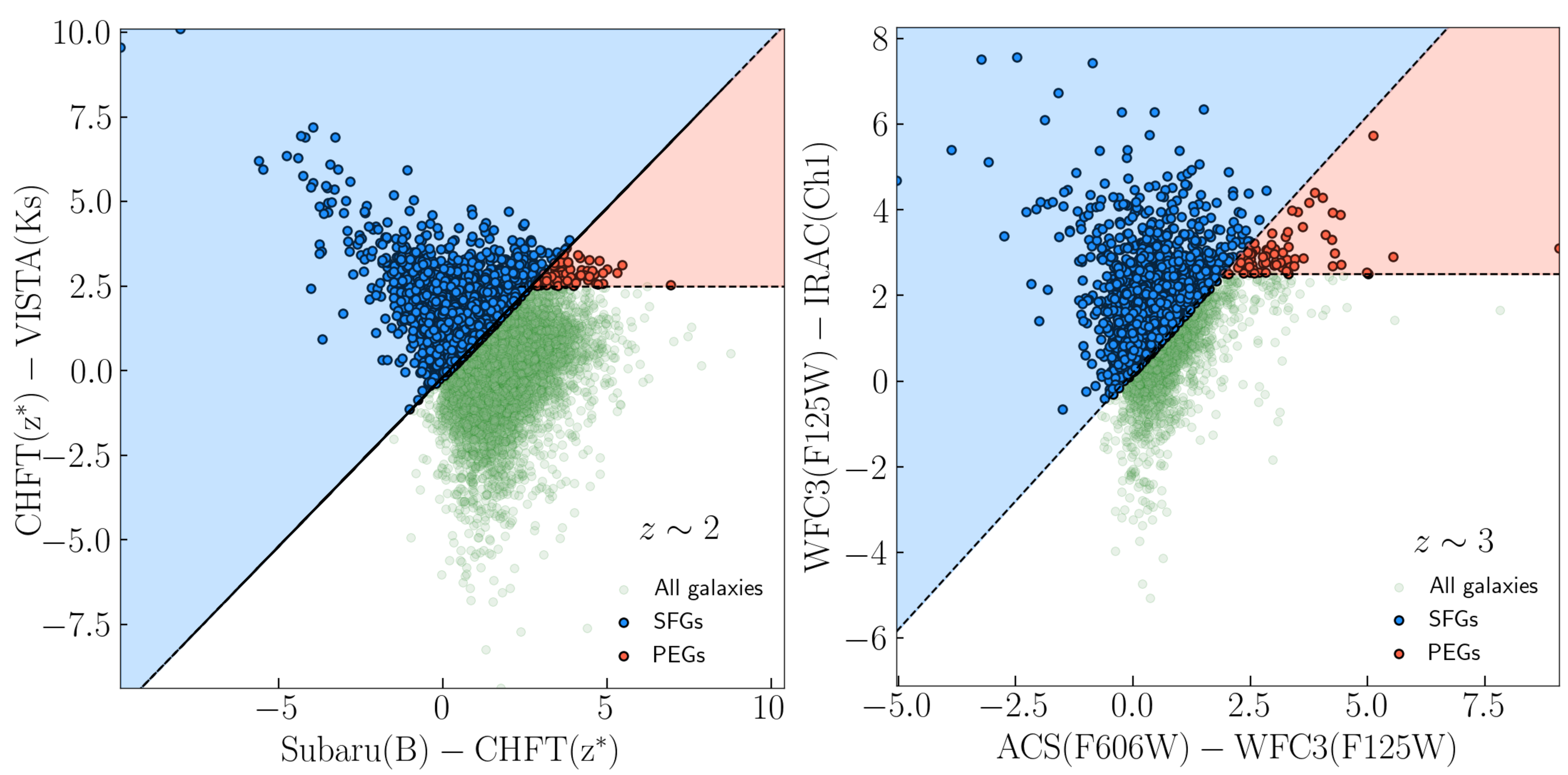


Figure 1: The BzK (left) and VJL (right) colour-colour plots showing the star-forming (blue) and passive galaxies (red) galaxies at z ~ 1.5 and z ~ 2.5, respectively.

ii. **Assigning total infrared luminosities** as a function of stellar mass and photometric redshifts, where n = 2 (1) for star-forming (quiescent) galaxies and $A_{p,q}$ are coefficient matrices from multilinear regression done by Viero et al. (2013) [4].

$$\log L_{IR}(M_*, z) = \sum_{n=0}^{n} \left\{ \left[\sum_{q=0}^{n} A_{p,q} (\log M_*)^q \right] z^p \right\}$$

iii. **Linearly correlating L_{IR} to L_{CO}**, where α and β are best-fit parameters obtained by Greve et al. (2014) [5,6].

$$\log \left[\frac{L'_{CO(J\to J-1)}}{\mathrm{K\,km\,s^{-1}\,pc^2}} \right] = \alpha^{-1} \left[\log \left(\frac{L_{IR}}{L_\odot} \right) - \beta \right]$$

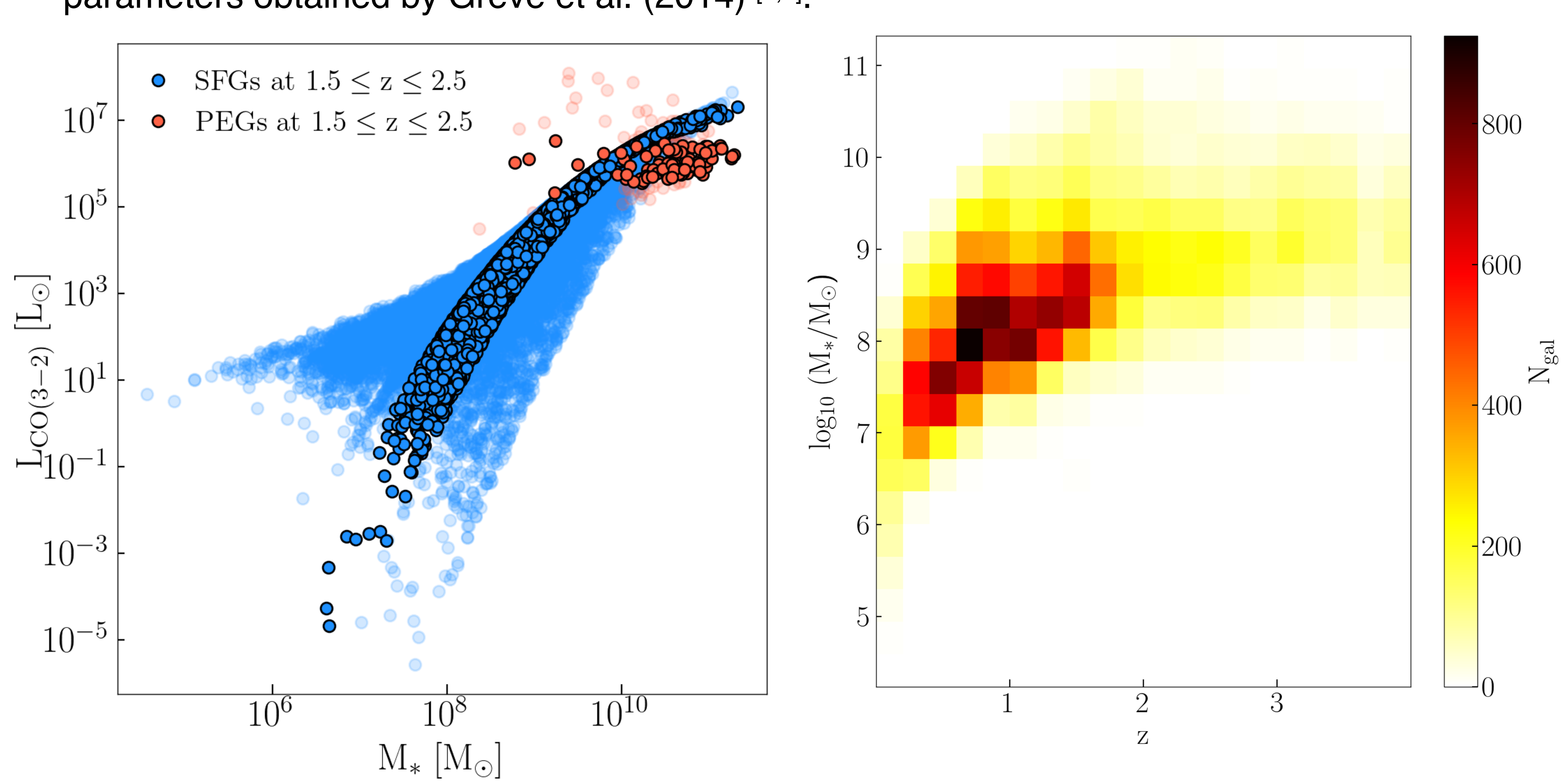


Figure 2: [Left] Modelled CO luminosities vs. stellar masses of classified SFGs and PEGs at 1.5 < z < 2.5. [Right] The distribution of stellar masses versus photometric redshifts of all catalogued sources.

Analytic Galaxy Power Spectra

The total analytic galaxy density power spectrum, for **TIME's cross-correlation analysis for the CO-foreground masking** can be compared to one measured from the available galaxy catalog.

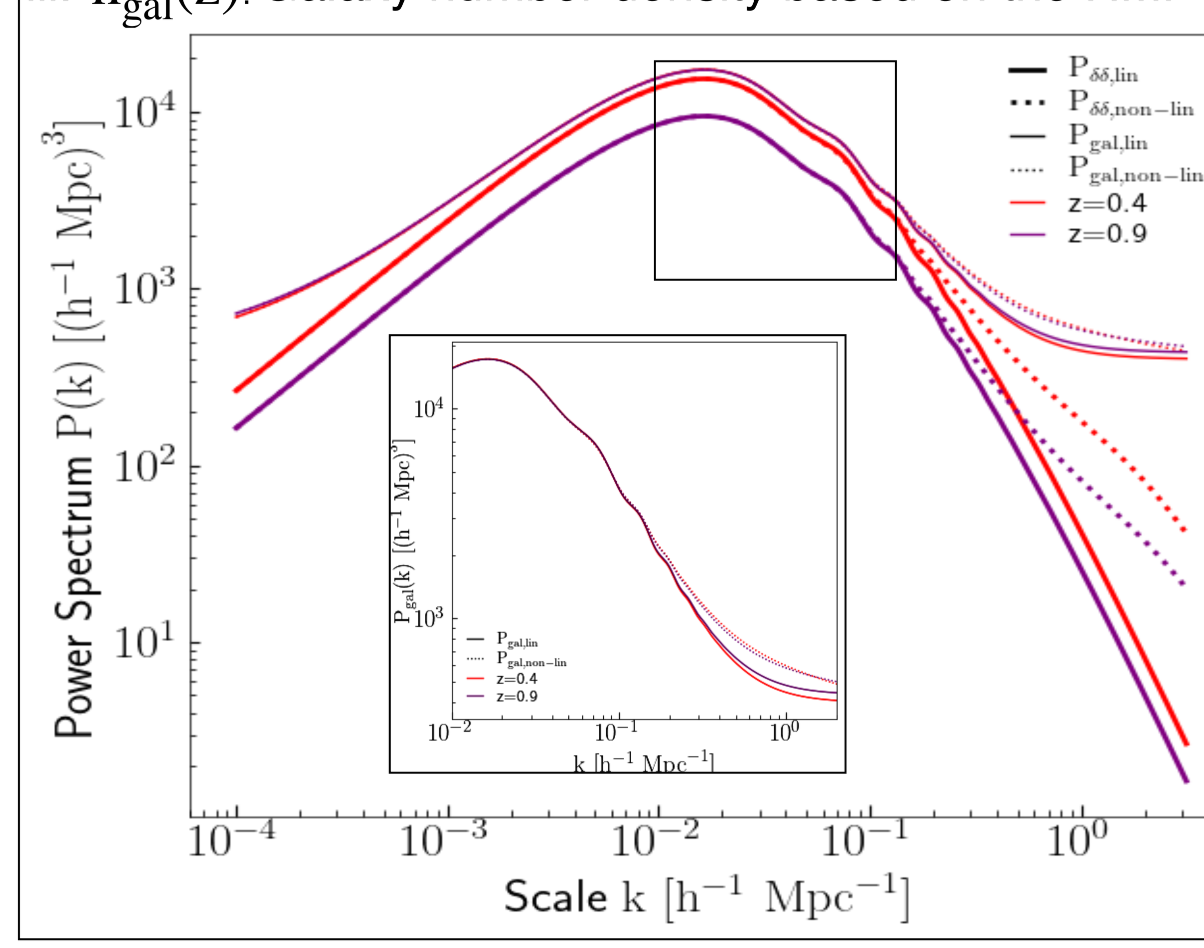
$$P_{gal}(k,z) = P^{clust}_{gal}(k,z) + P^{shot}_{gal}(z) = \bar{b}^2_{gal}(z) P_{\delta\delta}(k,z) + \frac{1}{n_{gal}}$$

The components of P_{gal}, include:

i. $\bar{b}_{gal}(z)$: Mean galaxy bias factor obtained using the bias and halo mass function (HMF)

ii. $P_{\delta\delta}(k, z)$: Power Spectrum of the underlying dark matter density fluctuations

iii. $n_{gal}(z)$: Galaxy number density based on the HMF



Conclusions & Next Steps

✓ After having **acquired a reasonable galaxy sample** and **investigated the nature, mass and photometric redshift distributions** of the galaxies, the **CO model will be improved by adopting optimal SF/QS, M* and z binning and considering scatter therein.**

↪ CO intensity distributions based on a halo model and catalogued galaxies will be used to **predict the CO-galaxy cross power spectrum that TIME will be able to measure.**

↪ The **galaxy power spectra modelled above will be compared to those of the current sample** to verify the criteria of galaxy selection adopted in this work.

References

[1] Nayyeri H., et al., 2017, ApJS, 228, 7
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[4] Viero, M. P., et al. 2013, ApJ, 779, 32
[5] Greve, Leonidaki., et al. 2014, ApJ, 794, 142
[6] Sun G., et al., 2021, ApJ, 915, 332