Modeling non-linear clustering in Roman-Line Intensity Mapping cross-correlations

Shifting Landscapes in Astrophysics: New Frontiers to Explore with Roman

Rakshitha Thaman (NYU)

with Anthony Pullen (NYU), L.Y. Aaron Yung (STScI), Azadeh Moradinezhad Dizgah (LAPTh)

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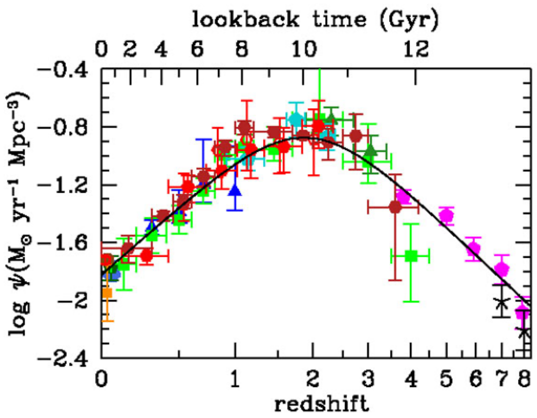
Introduction

- Roman's Wide Field Instrument (WFI) - will probe the universe wide and deep
- Study large scale structure (LSS) at high redshifts ~2 (peak of star formation)
- **Galaxy surveys** - biased samples, catalog only the brightest galaxies detected by telescopes
- **Line intensity mapping (LIM)** - maps total intensity of line emission like CII, HI, Hα, and CO over large areas of sky
- Accounts for emission from all galaxies along line of sight



Madau & Dickinson 2014

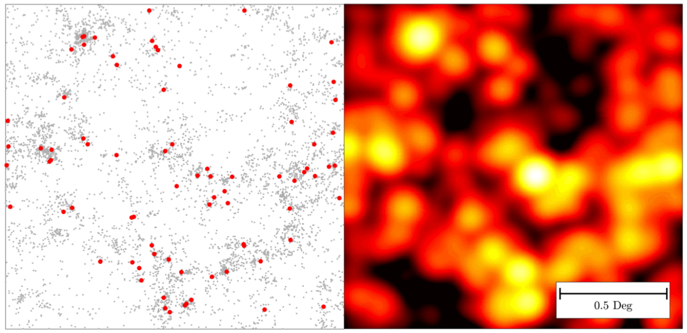
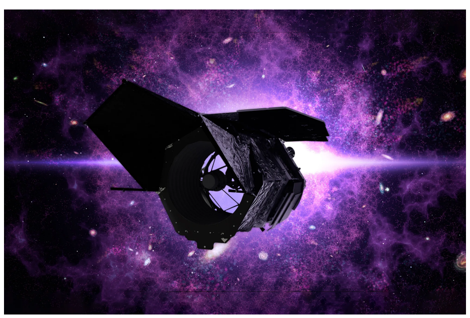


Figure 1. *A simulated 2.5 deg^2 field with galaxy positions (Left) and the corresponding CO intensity map (Right). Luminosities were drawn from a Schechter function model (Breysse et al. 2016). Sources bright enough to detect with 1hr of VLA time are marked in red (see Li et al. 2016). (Figure: Patrick Breysse)*

(From Line-Intensity Mapping: 2017 Status Report)

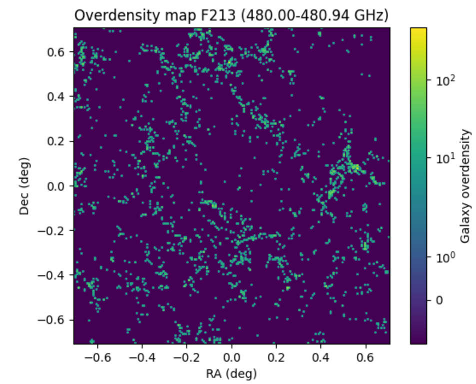
Introduction

- LIM X Roman : reduced shot noise => nonlinearities more prominent
- Cross-correlations will inform us about
    - galaxy formation and evolution - cosmic SFRD, line intensity and bias
    - cosmology - dark matter, dark energy, neutrino mass
- EXperiment for Cryogenic Large-Aperture Intensity Mapping (EXCLAIM) - map the CII line over z=2.5-3.5, trace SFR density over the cosmic noon



Simulations

- Semi-analytic models - computationally efficient, physically motivated
- 2 deg^2 light cone generated using Santa Cruz SAM for Roman - z=3



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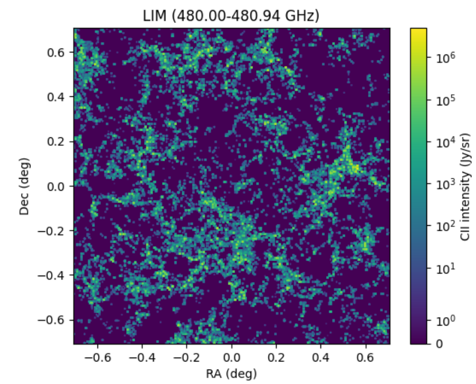
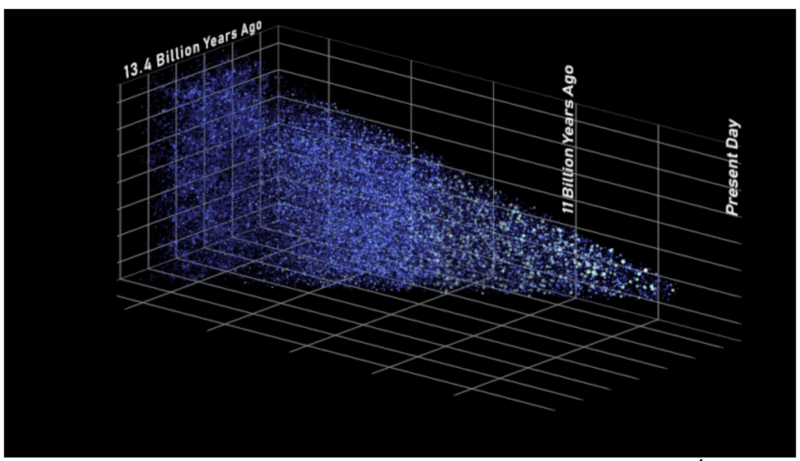
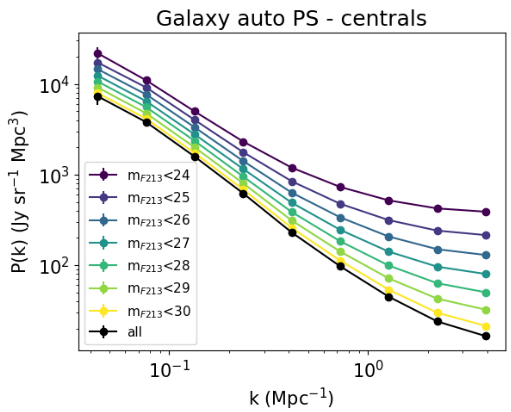
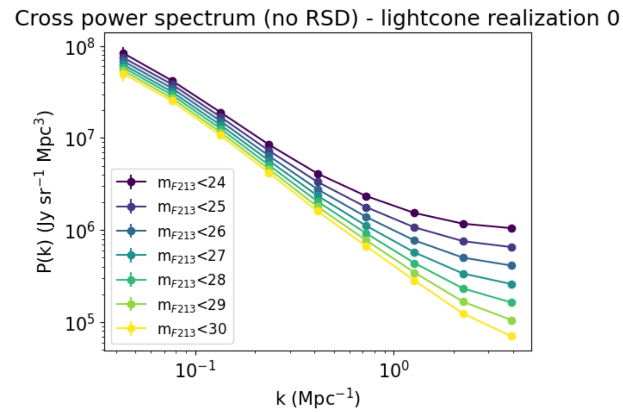


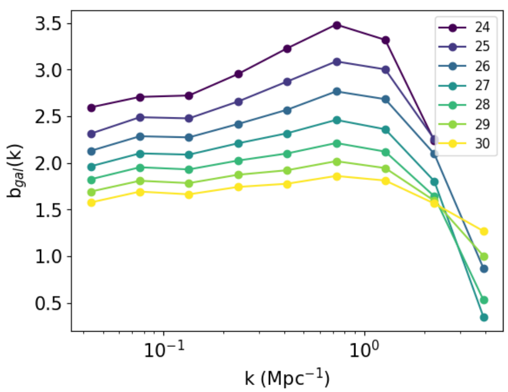


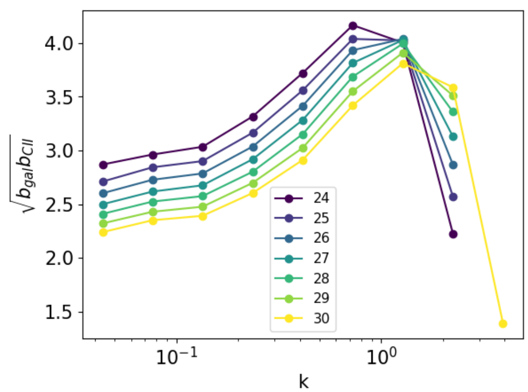
Credit: NASA's Goddard Space Flight Center and A. Yung

Power spectra from SAM









$$b_{gal} = \sqrt{(P(k) - P_{shot})/P_m(k)}$$

Non-linear model

Effective Field Theory of Large Scale Structure (EFTofLSS)

Diagrams for the two-point function or power spectrum up to one-loop.

Bernardeau et al 2001

$$\delta_h = b_1\delta + \frac{b_2}{2}\delta^2 + b_{\nabla^2\delta}\nabla^2\delta + b_{\mathcal{G}_2}\mathcal{G}_2 + b_{\Gamma_3}\Gamma_3$$

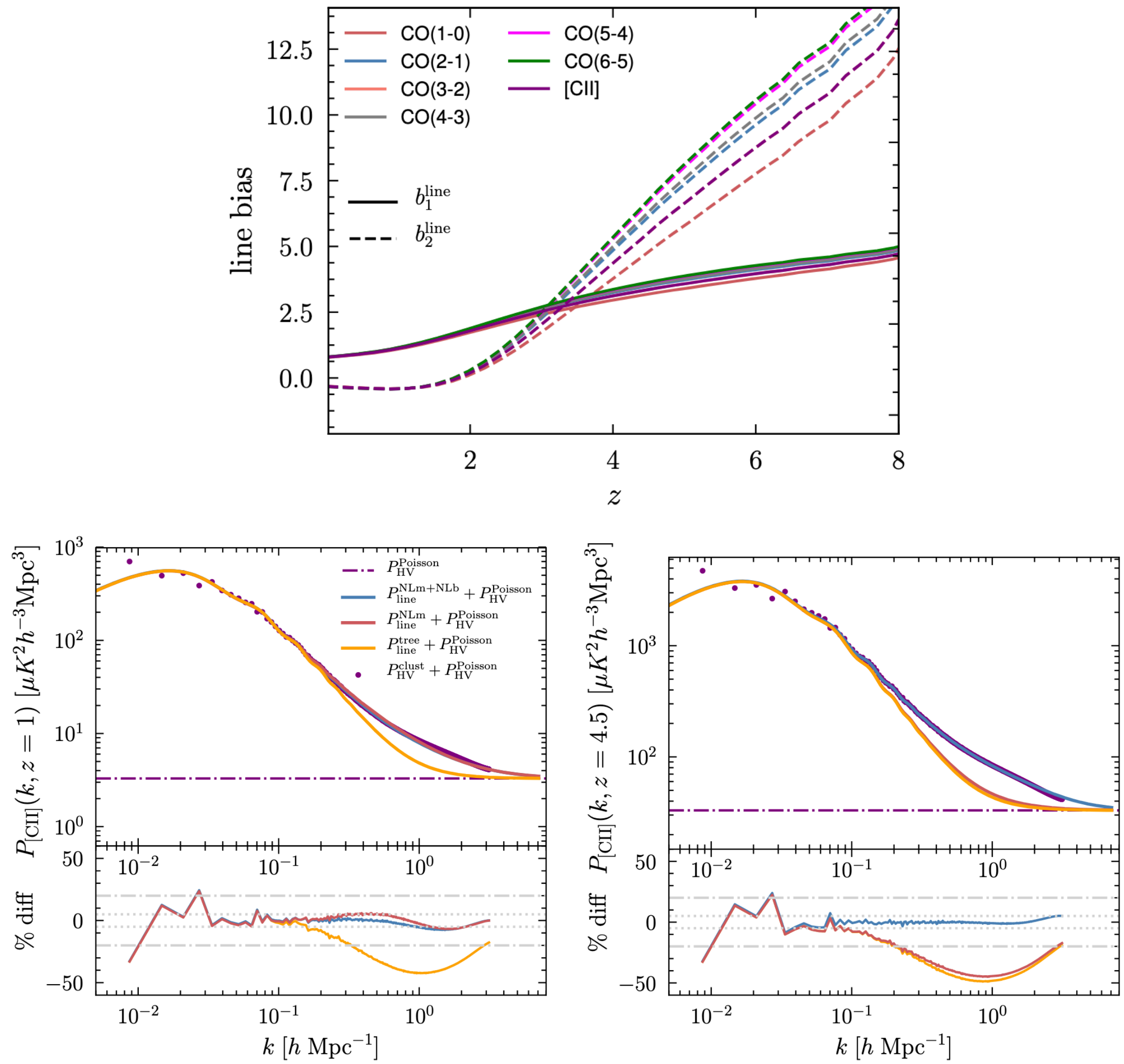
Density operators, non-local operators, tidal operators

$$P_g(k) = P_{tree}(k) + P_{1-loop}(k) + P_{ct}(k) + P_{shot}(k)$$

Linear theory, 1-loop PT, EFT counter term, stochastic term

Non-linear model

- EFTofLSS model - used for galaxy and LIM auto power spectra
- Cross-power spectrum - include higher order biases, EFT counter term, cross-shot noise
- MCMC forecasts - CosmoSIS_gClust



Moradinezhad Dizgah et al 2022

Non-linear model

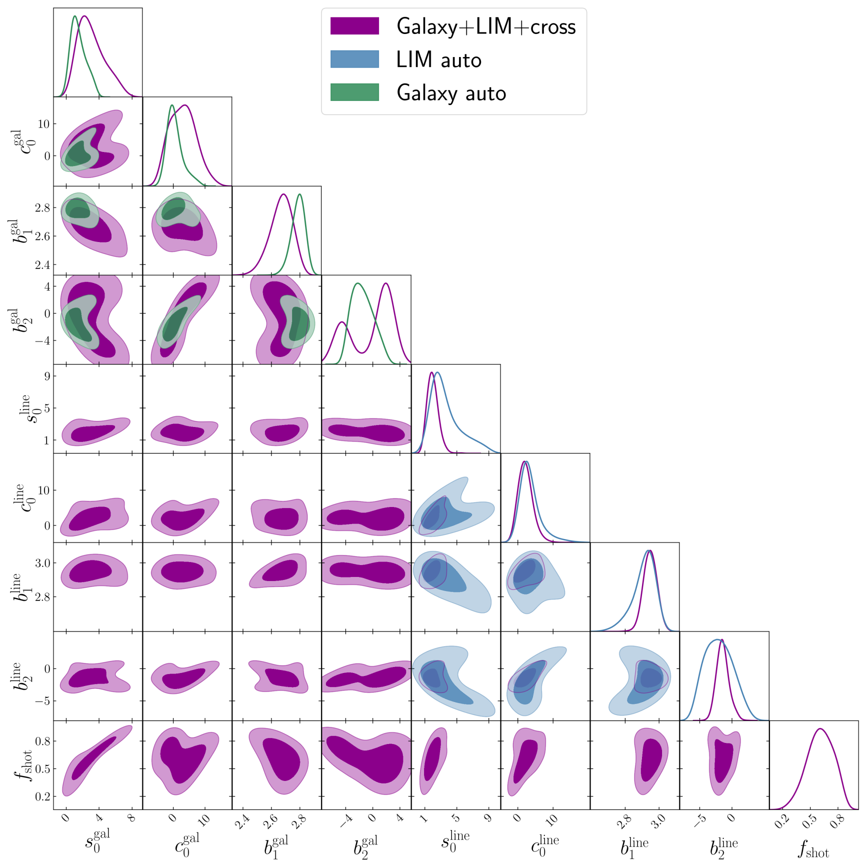
- We use co-evolution relations for $b_{\mathcal{G}_2}(b_1)$ and $b_{\Gamma_3}(b_1)$ to reduce the parameter space

$$b_{\mathcal{G}_2} = -\frac{2}{7}(b_1 - 1)\ ;\ b_{\Gamma_3} = \frac{23}{42}(b_1 - 1)$$

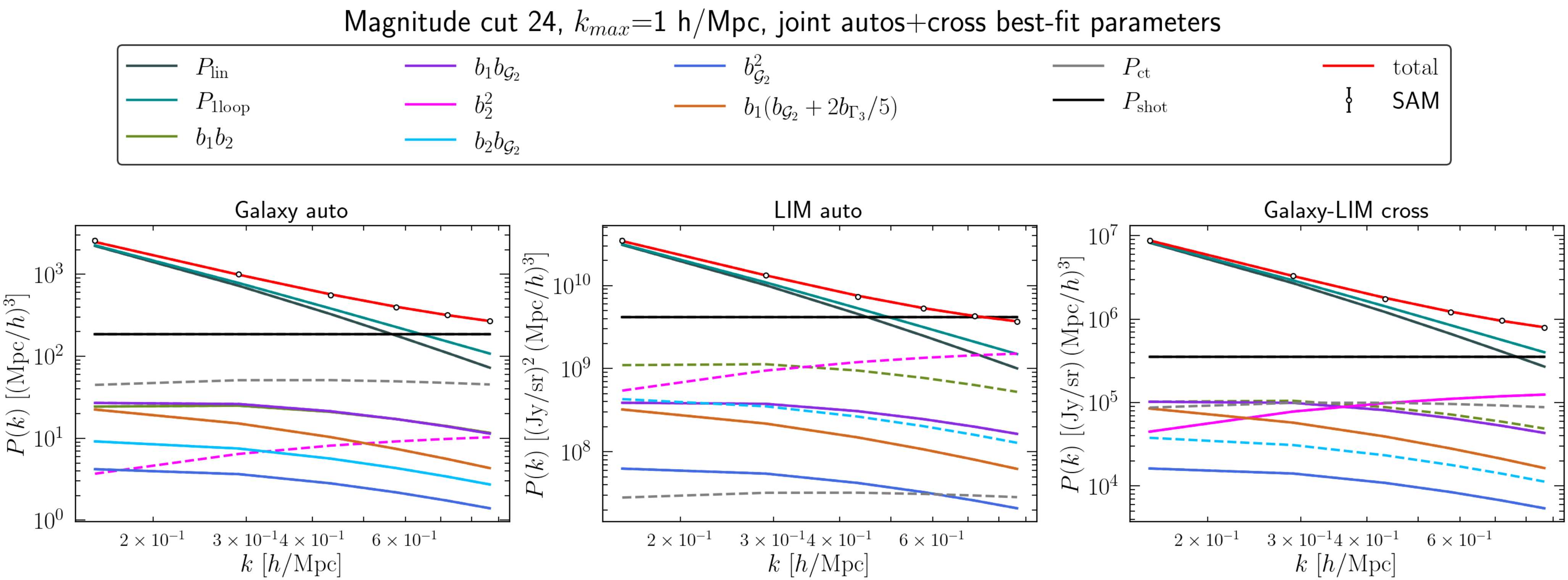
- Limitation: not valid at very small scales, need to compare to simulations to check validity and find the cutoff k_{max}

Joint constraints

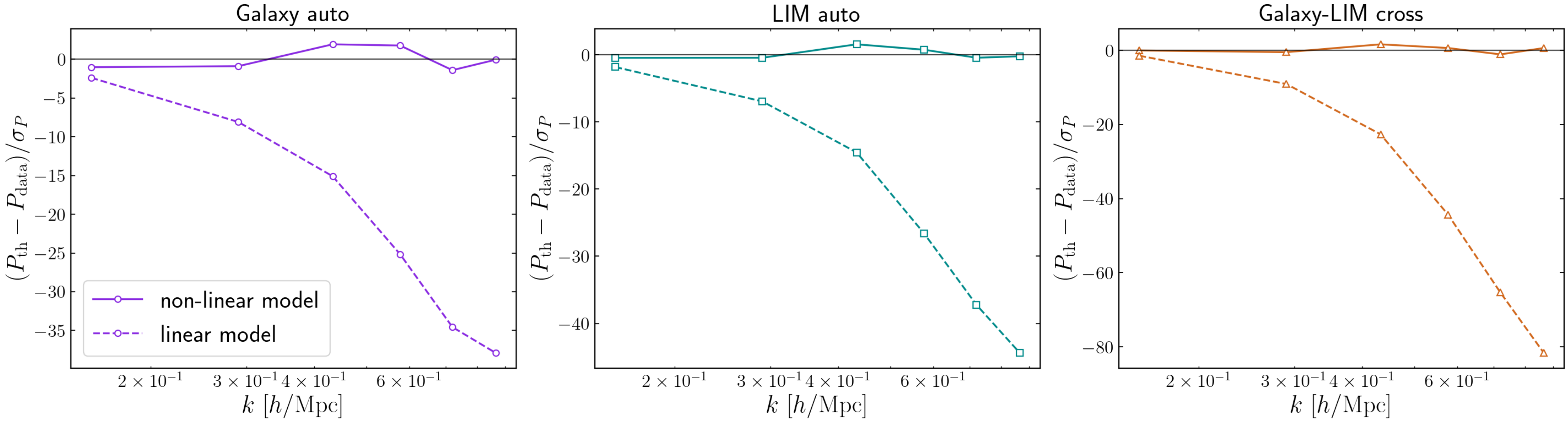
Joint constraints - Magnitude cut 24, $k_{\rm max} = 1\ h/{\rm Mpc}$



Best-fit power spectra



Best-fit power spectra



Conclusions

- Cross-correlations of Roman with line-intensity mapping surveys will be useful in constraining cosmology and star formation history at cosmic noon
- The deep observations from Roman will enable probing nonlinearities at smaller scales
- We need accurate nonlinear models to extract information from the full shape of the cross-power spectrum at small scales and high redshifts