Line-intensity Cross-correlations

Ishika Bangari

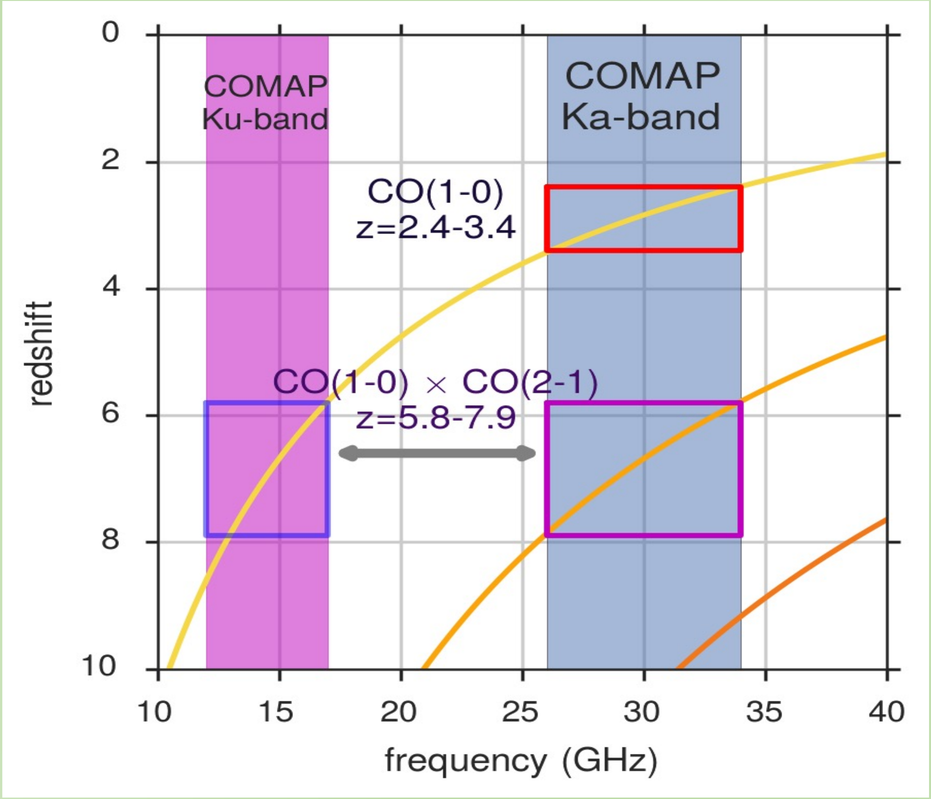
Supervisor: Dongwoo Chung, Collaborator: Patrick C. Breysse

Introduction

- Line intensity mapping (LIM) is a technique that measures the total emission of spectral lines from galaxies and the intergalactic medium (IGM) over large volumes
- Carbon Monoxide (CO) Mapping Array Project (COMAP) is a CO LIM experiment at high red-shift which is a part of a program that aims to trace the spatial distribution of star-forming galaxies at the Epoch of Reionization (EoR)
- Cross-correlating the two frequency bands used in COMAP will give us information about CO emission at z~7 and give constraints on galaxies at the EoR

Research goal

My goal is to pull out the common z~7 signals from under the brighter z~3 interloper. For this, I use a statistic termed Conditional Voxel Intensity Distribution (CVID)



Credit: Dongwoo Chung

CVID statistic

Convolution Theorem

For independent random variables T1,T2	In Fourier space,
$P_{1+2}(T) = (P_1 \circ P_2)(T)$	$\tilde{P}_{1+2}(\mathcal{T}) = \tilde{P}_1(\mathcal{T})\tilde{P}_2(\mathcal{T})$

Defining the R_{ij} estimator

- If we have two data sets with correlated signals and different noise, the signal PDF is $P_S^{2D}(T_i, T_j) = P_S(T_i)\delta_{ij}$ and the noise PDF is $P_N^{2D}(T_i, T_j) = P_N(T_i)P_N(T_j)$
- In Fourier space, we get these 2D PDFs become

$$\widetilde{P_S^{2D}}(\tilde{T}_i, \tilde{T}_j) = \tilde{P}_S(T_i + T_j) \text{ and}$$
$$\widetilde{P_N^{2D}}(\tilde{T}_i, \tilde{T}_j) = \tilde{P}_N(\tilde{T}_i)\tilde{P}_N(\tilde{T}_j)$$

- By convolution theorem, the full 2D PDF in Fourier space is

$$\widetilde{P^{2D}}(\tilde{T}_i, \tilde{T}_j) = \widetilde{P_S^{2D}}(\tilde{T}_i, \tilde{T}_j)\widetilde{P_N^{2D}}(\tilde{T}_i, \tilde{T}_j)$$

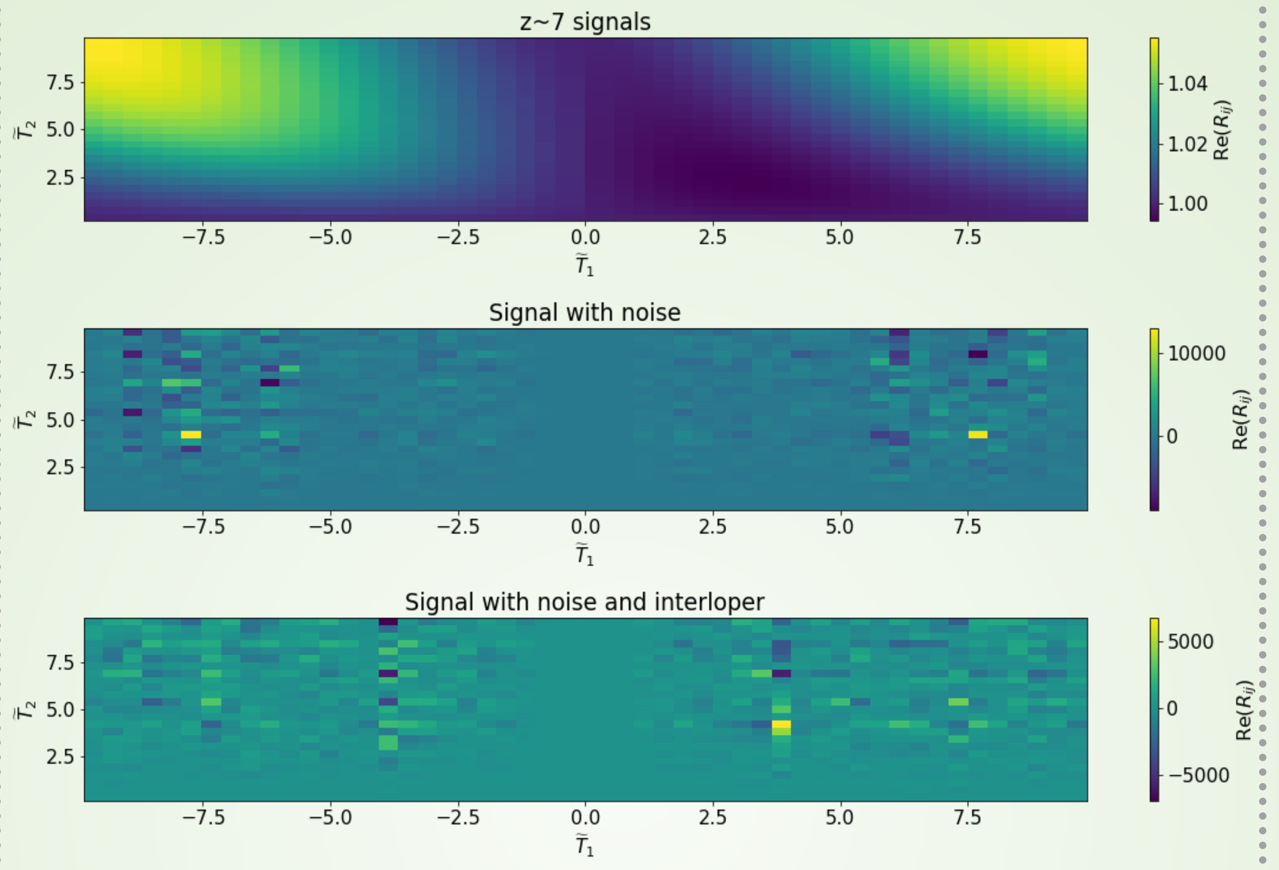
- We define the following estimator called R_{ij} whose expectation value only depends on the signals,

$$R_{ij} \equiv N_{vox}\frac{\tilde{B}_{ij}}{\tilde{B}_i\tilde{B}_j}$$

$$< R_{ij} > \approx \frac{\tilde{P}_S(T_i + T_j)}{\tilde{P}_S(\tilde{T}_i)\tilde{P}_S(\tilde{T}_j)}$$

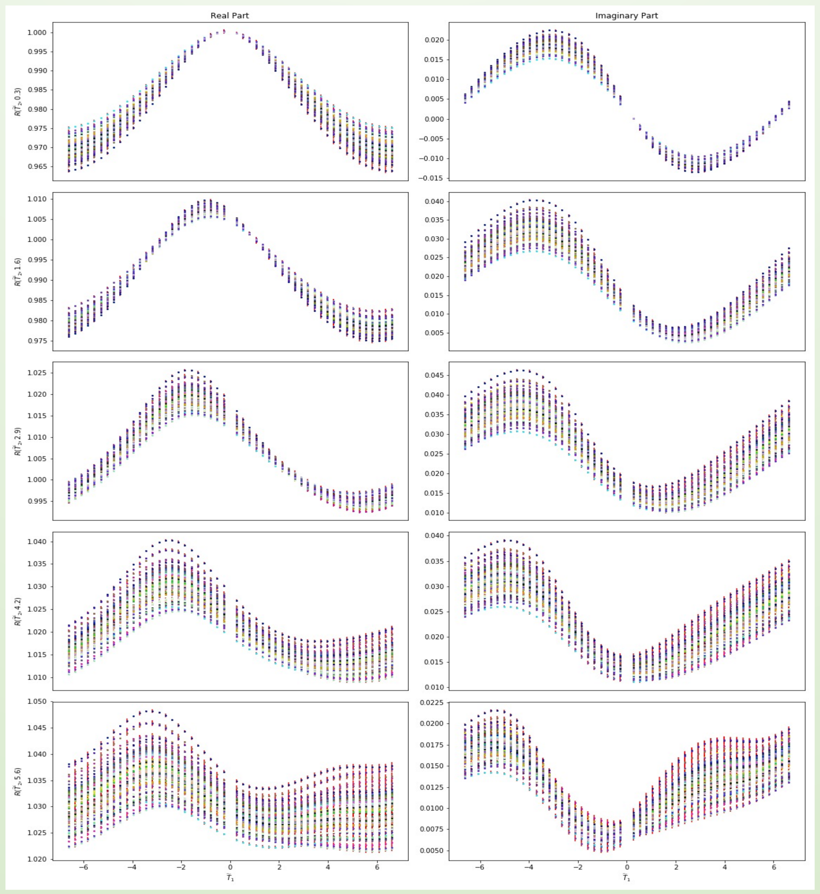
Testing CVID on CO simulations

For a single map

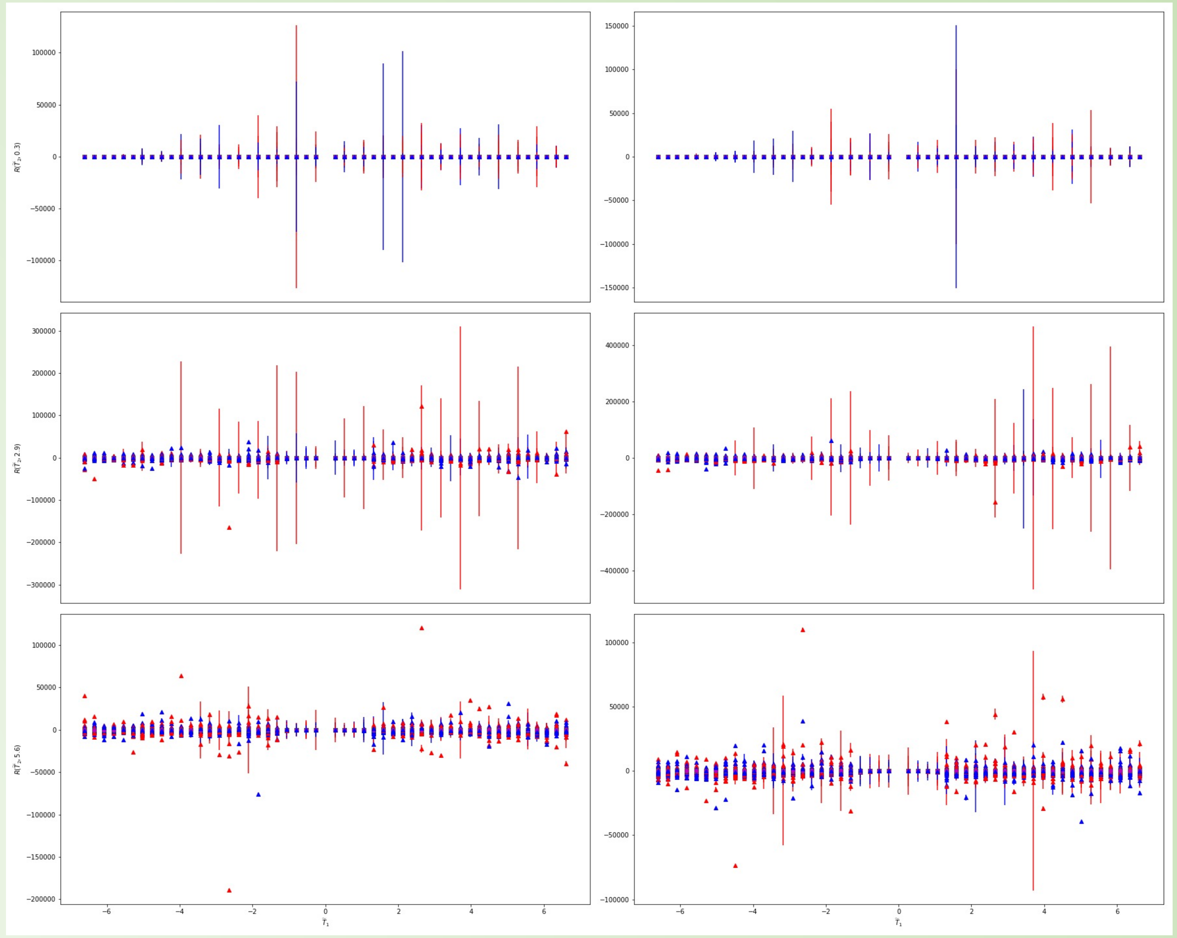


Color map showing real part of R_{ij} for a single realization with only z~7 signals present, signal with noise, signal with noise and z~3 interloper

For 80 maps

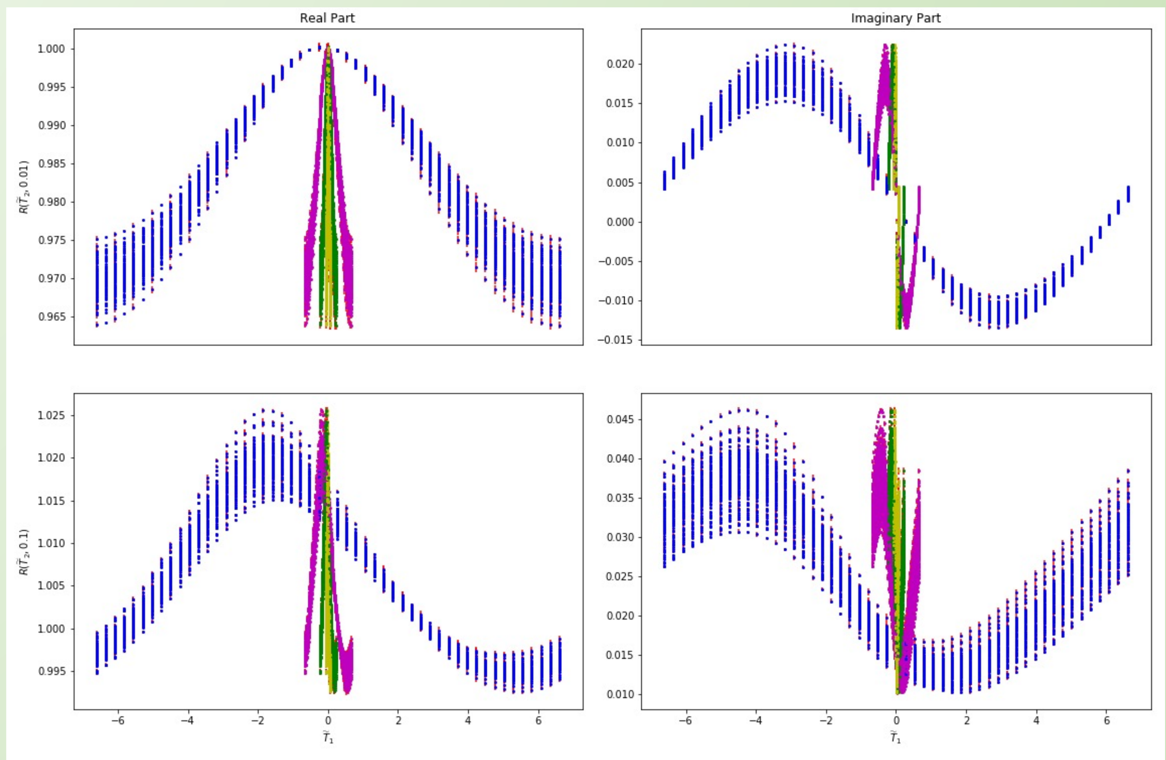


Real and imaginary parts of R_{ij} for 80 realizations with only signal present. R_{ij} is plotted at different $\tilde{T}_2$ slices.



Real and imaginary parts of R_{ij} for 80 realizations. Red points include signal and noise and blue points include signal, noise and the interloper at z~3.

Collecting CVID data for 80 maps with scaled signals



Real and imaginary parts of R_{ij} for 80 realizations with only signal present plotted at different $\tilde{T}_2$ slices. Blue data represents the unscaled z~7 signals, the magenta represents those signals scaled by a factor of 10, the green is for a factor of 30 and yellow is for 100.

Conclusion + Next steps

- The R_{ij} plots with noise and interloper show that the CVID statistic is robust to noise for low $\tilde{T}_1$ values
- The signal-only plots show that for higher $\tilde{T}_2$ values, R_{ij} values vary more
- Next steps include understanding how CVID behaves for realizations where z~7 signals are scaled up by some factor and plotting 5 and 95 percentiles of Rij distributions for each case (signal only, signal and noise, signal, noise and interloper) at each $\tilde{T}_1$ to better visualize the data

References

CVID Notes by Patrick C. Breysse (private communication)