Multiple Lines of Attack at High Redshift: Simulating Line-intensity Cross-correlations

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Line intensity mapping (LIM) is a technique that measures the total emission of spectral lines along the line of sight from galaxies and the intergalactic medium over large cosmological volumes. One example of a LIM experiment is the Carbon Monoxide Mapping Array Project (COMAP) which is a program that aims to study the spatial distribution of star forming galaxies at the Epoch of Reionization (EoR) by detecting rotational carbon monoxide (CO) lines. COMAP explores two frequency bands: the Ku band (13-17 GHz) which is sensitive to CO(1-0) at redshift z∼7 and the Ka band (26-34 GHz) which is sensitive to CO(1-0) and CO(2-1) at redshift z∼3. Cross-correlating these two bands will allow us to get constraints on galaxies at the EoR. A challenge in LIM experiments is to obtain the desired signal from foreground emission and the Conditional Voxel Intensity Distribution (CVID) is a statistic that is able to reject the foreground by defining an unbiased estimator called R_{ij} that is a two-dimensional, complex function and only depends on the signal. For my project, I have used this statistic on CO signal simulations for COMAP to see how this estimator behaves in different cases.

I used a code written by Patrick C. Breysse which essentially takes in two data cubes or maps of the same size (so they both have the same number of voxels, or three-dimensional pixels) and computes R_{ij}. I did this for four different cases: first with a pair of maps with the redshift z∼7 signals in the Ku and Ka bands, second I subtracted the mean intensity value from each of these maps, third I added white noise to these signals with the mean subtracted and lastly I added the foreground at redshift z∼3 in the Ka band again with the mean subtracted. For each of these cases, I plotted the real and imaginary parts of R_{ij}. Initially, I did this only for one realization and later for 80 realizations to see how consistent this statistic is. I also scaled up the two redshift z∼7 signals by factors of 10, 30 and 100 to see how R_{ij} changes.

R_{ij} is a function of the Fourier conjugate of each map's voxel intensity, $\widetilde{T}_1$ and $\widetilde{T}_2$. For all my R_{ij} plots, I plotted R_{ij} at a fixed $\widetilde{T}_2$ value against $\widetilde{T}_1$. For the first and second cases with the 80 maps, R_{ij} values were more spread out for higher $\widetilde{T}_2$ values. I plotted all cases with 80 maps in one plot and found that this statistic varies very little for low values of $\widetilde{T}_1$ compared to larger values. To see how the scaled signals differ, I repeated this workflow and found that the x100 version gives comparable R_{ij} values for all cases. In doing this I encountered a systematic error for the third and fourth cases where the curves for the real part of R_{ij} follow a bell-shape rather than the expected bow-tie shape, so the next steps would include fixing this.

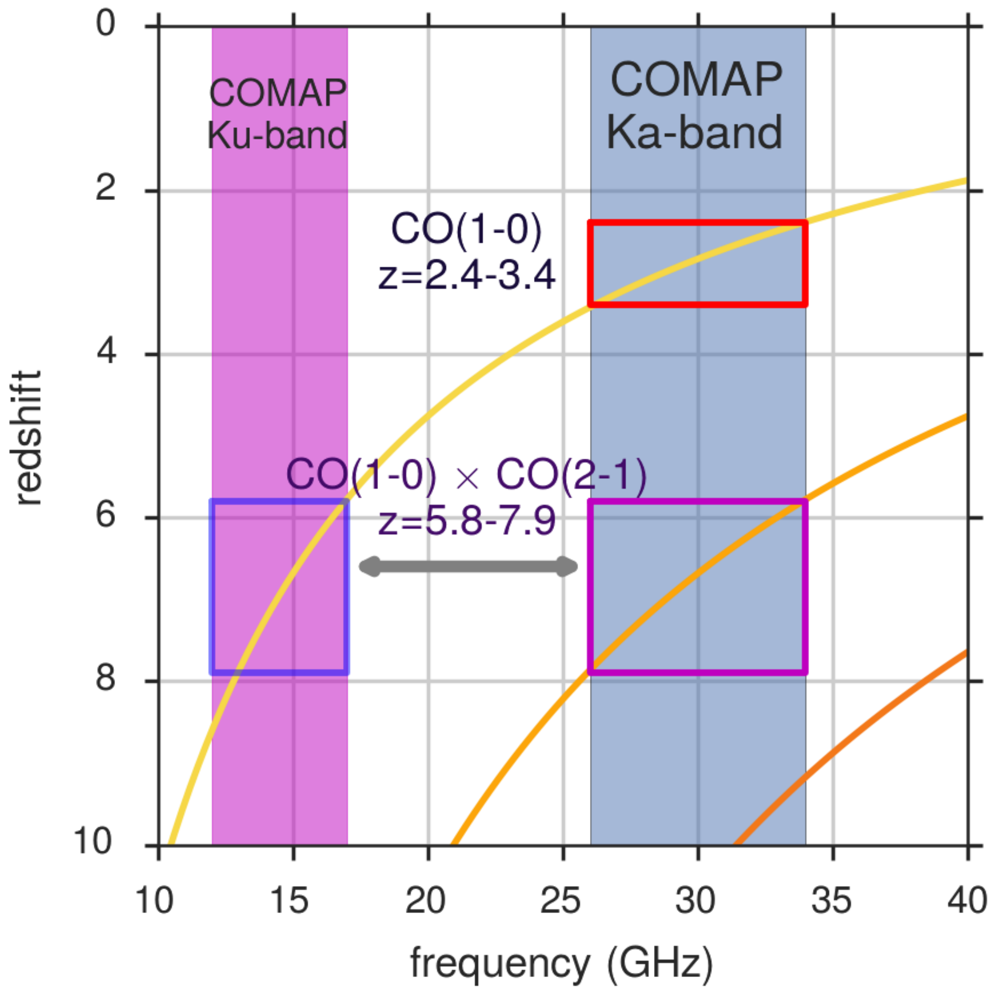

Figure 1: COMAP frequency bands sensitive to the CO lines shown
(Credit: Dongwoo Chung)