LINEAR ANALYSIS OF INFRARED CO SPECTRA

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The first overtone band $v = 2 \leftarrow 0$ of CO at 2.35 μm is a powerful probe for studying interstellar gas in a variety of environments in the long sightlines toward the Galactic center (GC), in particular the intervening spiral arms and the Central Molecular Zone (CMZ). We have been observing this band of CO together with the fundamental band of H_3^+ at 3.5 - 4.0 μm since the two bands give comparable absorption depths but are sensitive to different environments. The overtone CO band is essentially only a probe of dense clouds, while H_3^+, which is present in both diffuse and dense clouds, allows one to distinguish diffuse clouds from dense clouds, when both species are observed at high resolution. The foreground spiral arms show both spectra intensely, indicating dense clouds, while the CMZ contains significant amounts of both dense and diffuse gas.[ab]

Last year we started to develop a linear program for quantitative analysis of the overtone CO spectra similar to our program for the H_3^+ spectrum.[c] The linearity is employed in two ways. First, since the transition dipole moment of the $v = 2 \leftarrow 0$ band is very small, μ_{2-0} = 0.00651 Debye, the optical depth of the transition is orders of magnitude lower than radio and ultraviolet spectra and column densities can be obtained linearly from observed equivalent widths (integrated intensities) without the complications caused by radiation trapping in the radio and saturation in the ultraviolet. Second, we assume linearity in thermalization; that is, we ignore the effects of radiation trapping. This is a more serious neglect, but it is justified to some extent for the analysis of the gas in the CMZ because of the low CO column densities in the cloud clumps and the high velocity dispersion. Conditions for the applicability of the linear analysis and corrections to the approximation using the Sobolev escape probability method will be discussed. The calculation should also be applicable to the infrared CO fundamental band and even to the radio under some limited conditions.

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[a]Oka, T., Geballe, T. R., Goto, M., Usuda, T., & McCall, B. J. 2005, ApJ, 632, 882
[b]Geballe, T. R., & Oka, T. 2010, ApJ, 709, L70
[c]Oka, T. & Epp, E. 2004, ApJ, 613, 349