Can Chemical Maps Indicate the Formation of Methyl Formate?
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Abstract:
Methyl formate (HCOOCH₃) is a well known molecule in the interstellar medium; however its formation is not clearly understood (Horn et al. 2004). It is presumed that methyl formate is formed in various processes such as, grain chemistry (Garrod and Herbst, 2006) and other gas-phase mechanisms (Horn et al. 2004). We propose that methyl formate is formed through a methyl transfer reaction leading to two different geometries of methyl formate, cis- and trans-. There are two consequences of this hypothesis; in the interstellar medium in regions where we find methyl formate, formic acid should be absent. The second consequence is that we should be able to find the cis- and trans- geometries of methyl formate in space. Liu et al. (2002) mapped the distribution of methyl formate and formic acid and showed that there is a clear difference in the locations of the peaks. These observations support the first consequence of our hypothesis. The cis- and trans- geometries have also been detected toward the Sagittarius B2N star forming region. Therefore, the next step was to detect these two geometries of methyl formate (cis- and trans-) in the Orion KL region and we attempted this detection using the GBT.

Experiment:
There are two consequences of this hypothesis; in the interstellar medium in regions where we find methyl formate, formic acid should be absent. As such, observed contour maps showing the distributions of methyl formate and formic acid should show a difference in the location of their peaks.

Problem:
The data collected from the Orion KL region detected chemical maps of methyl formate, formic acid, and methyl formate. There was also data of cis- and trans- geometries detections in the Sagittarius B2N region. The problem is being able to detect the cis- and trans- geometries in the Orion KL region.

Recent & Future Work:
New VLA observations show widespread distributions of methyl formate and methanol (see image below). GBT observations show a clear detection of methanol (top spectrum) but no detection of either geometry of methyl formate beyond the 1σ noise limit (~50 mK). More integration time is clearly necessary.

Hypothesis:
We propose that methyl formate is formed through a methyl transfer reaction (as seen in equation 1) leading to two different geometries of methyl formate, cis- and trans-. The cis- and trans- geometries of methyl formate refer to the orientation of the methyl group (CH₃) with respect to the other atoms in methyl formate. We can detect the difference in these geometries based on the spectroscopy of cis- and trans- as measured in the lab.

Methyl Transfer Reaction: [CH₃]OCH + HCOH → CH₃OH + CH₂O

With the increase in concentration of methyl formate and water there should be a decrease of formic acid and methanol. With formic acid being the limiting reagent in the reaction, there should be little to no formic acid with the presence of methyl formate. Methanol and water are already in high abundance in space, so their detection would not be a sufficient marker with the finding of methyl formate.

The formation of both cis- and trans- geometries are exothermic as the products are lowered in energy than the reactants. While the reaction barrier for cis- is 150K, the reaction the reaction barrier for trans- is essentially barrierless (70K). (See figure below).

References:

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