

Title: Determination of Total C18O Column Density in Orion KL

Date: Jul 19, 2011 01:00 PM

URL: <http://pirsa.org/11070050>

Abstract: The large number of high-energy rotational lines of C18O, available via the Herschel Space Observatory, provides an unprecedented ability to model the total C18O column density in hot cores. Using the emission from all the observed lines (up to J=16-15) we use an automated algorithm to model all transitions simultaneously. Under Local Thermodynamic Equilibrium (LTE) assumptions and knowledge of source size, centroid velocity and line width, the model determines the values for total C18O column densities in 4 separate line-of-sight components of Orion KL known as the Extended Ridge, the Outflow/Plateau, the Compact Ridge, and the Hot Core. These values are determined to be:  $2.5 \times 10^{16}$ ,  $5.9 \times 10^{16}$ ,  $1.8 \times 10^{16}$ , and  $6.0 \times 10^{16} \text{ cm}^{-2}$  respectively. We also explain the difficulties in using the said algorithm to model optically thick molecules such as CO which require non-LTE modeling.

# DETERMINATION OF TOTAL $C^{18}O$ COLUMN DENSITY IN ORION KL



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# AGENDA

- Background & Motivation
- Observations
- Data modeling
- Results
- Conclusion









# STELLAR RECIPE



# STELLAR RECIPE

- Main ingredient: molecular hydrogen ( $H_2$ )
- Quantity:

# STELLAR RECIPE

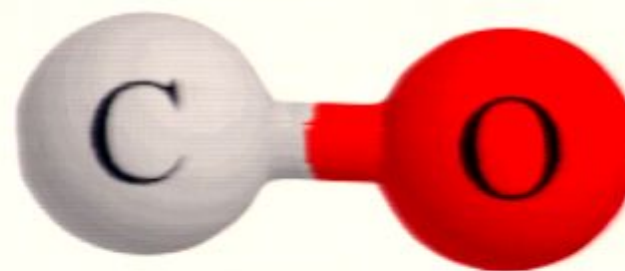
- Main ingredient: molecular hydrogen ( $H_2$ )
- Quantity:
  - 1 Cup?
  - 1 oz? lb?
  - 1 tbsp? tsp?

# HOW TO OBSERVE MOLECULES

- Light's electric field has an effect on certain molecules
  - If homonuclear (e.g.  $\text{H}_2$ ): no effect
  - If diatomic (e.g.  $\text{CO}$ ): a torque is applied due to molecule's permanent dipole moment and it acts like a linear rotor

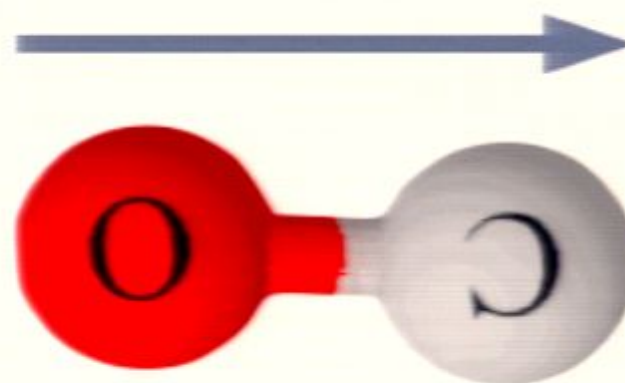
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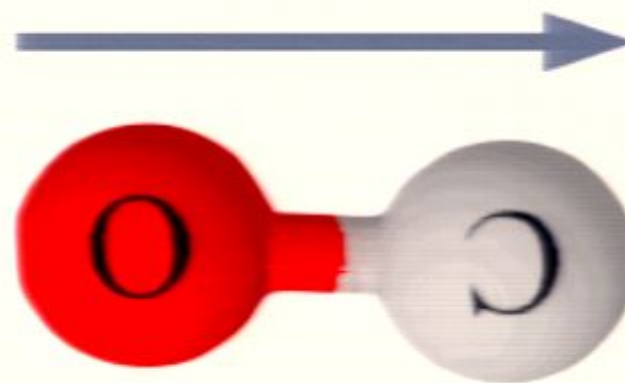
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- Such molecules emit light at submillimeter wavelengths through rotational transitions:  $\Delta J = -1$

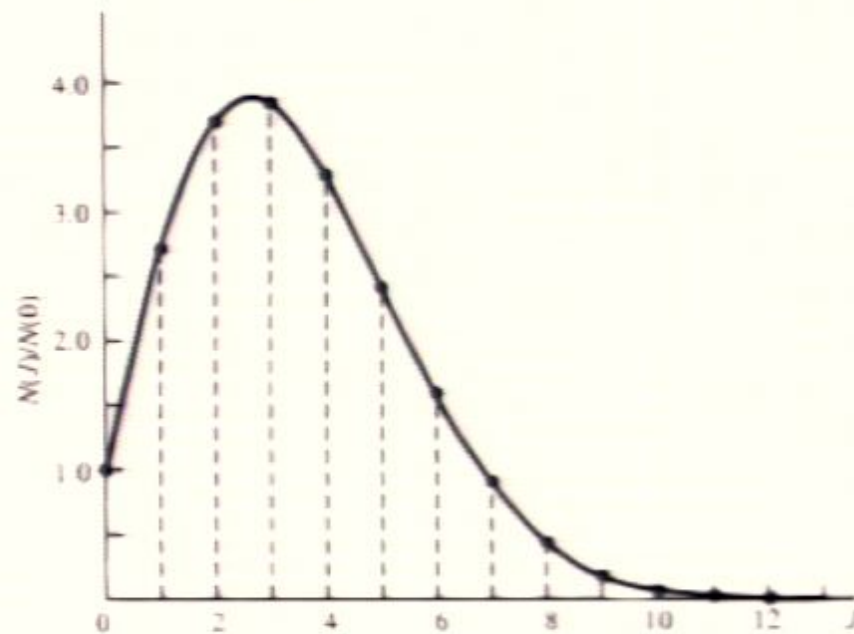


# ROTATIONAL SPECTROSCOPY

- Observe all rotational transitions
- Integrated intensity at each transition is linearly related to the column density in the upper state
- $N_{\text{tot}} = \sum N_u$

# ROTATIONAL SPECTROSCOPY

- Given density and temperature, rotational levels are populated by different amounts

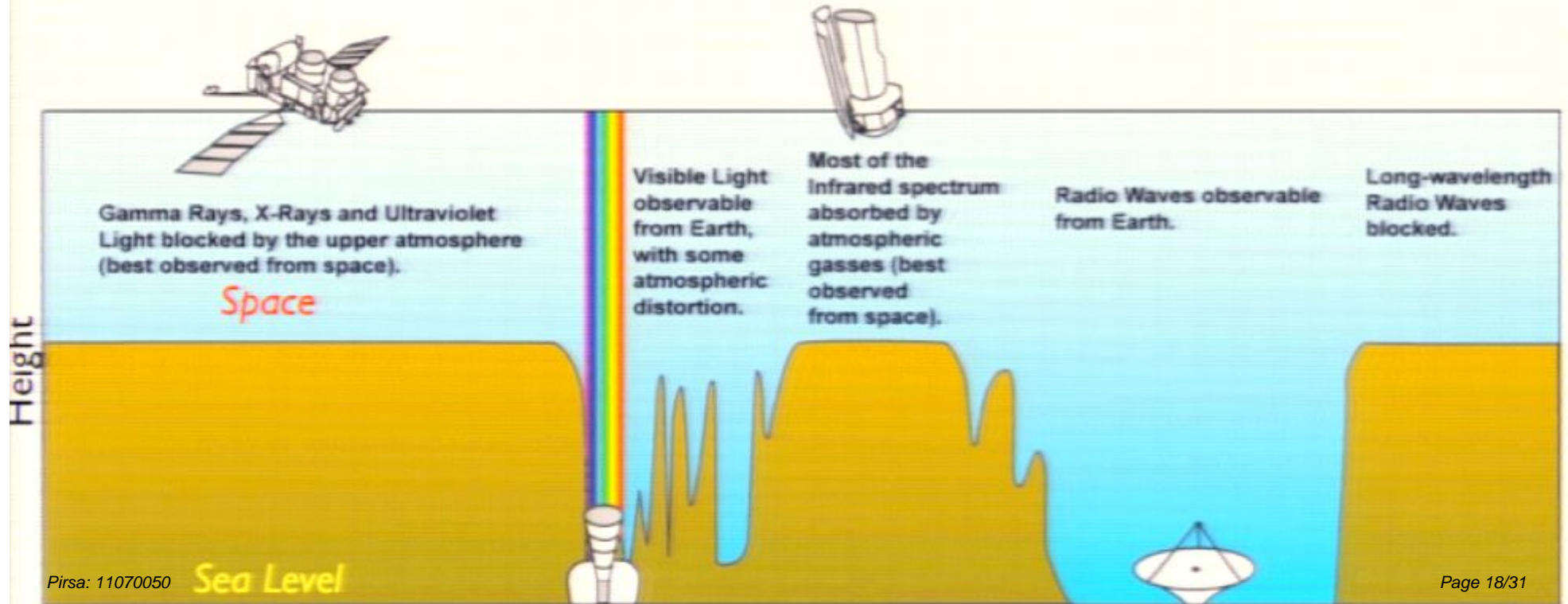
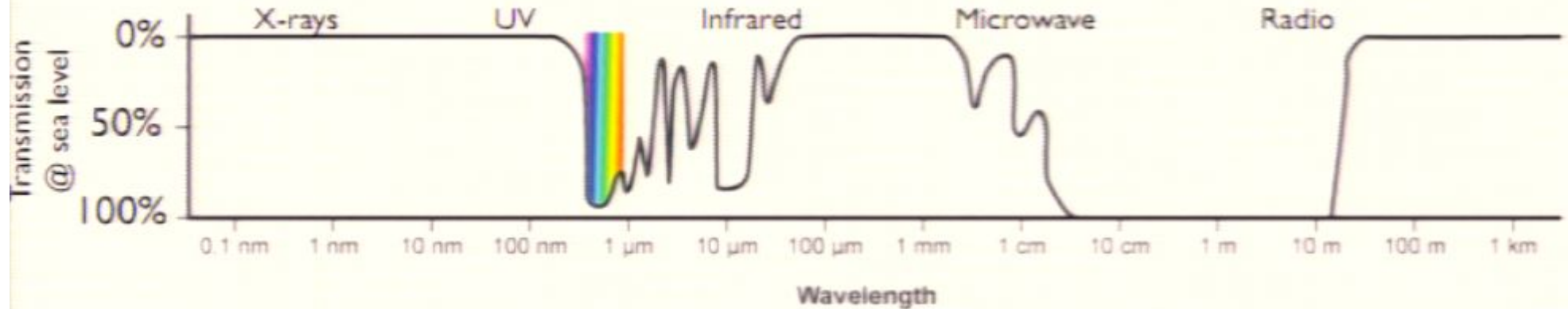




# WHAT KIND OF OBSERVATIONS DO WE NEED?

- Need observations of all possible transitions
- Higher transitions are more populated when dealing with higher temperatures
- Ground-based telescopes can only provide data for lower transitions

# ATMOSPHERIC OPACITY



# HERSCHEL SPACE OBSERVATORY

- Launched in May 2009 by the European Space Agency
- Observational capabilities in sub-mm and far-infrared
- Instrument used: Heterodyne Instrument for Far-Infrared (HIFI)
- Program: Herschel Observations of Extra Ordinary Sources (HEXOS)

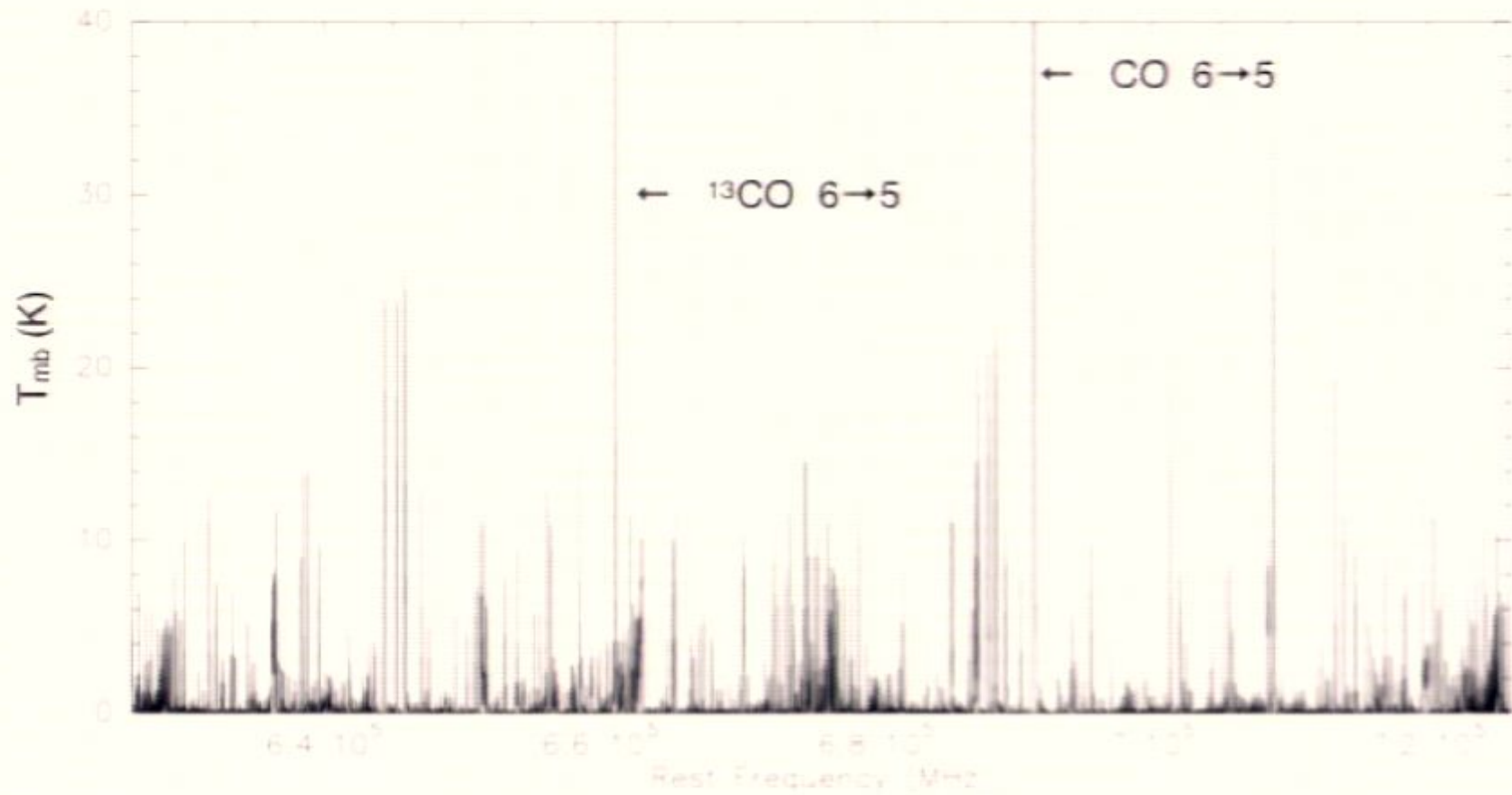


# ORION KL

- 500 pc away from the sun
- 4 primary line of sight components:

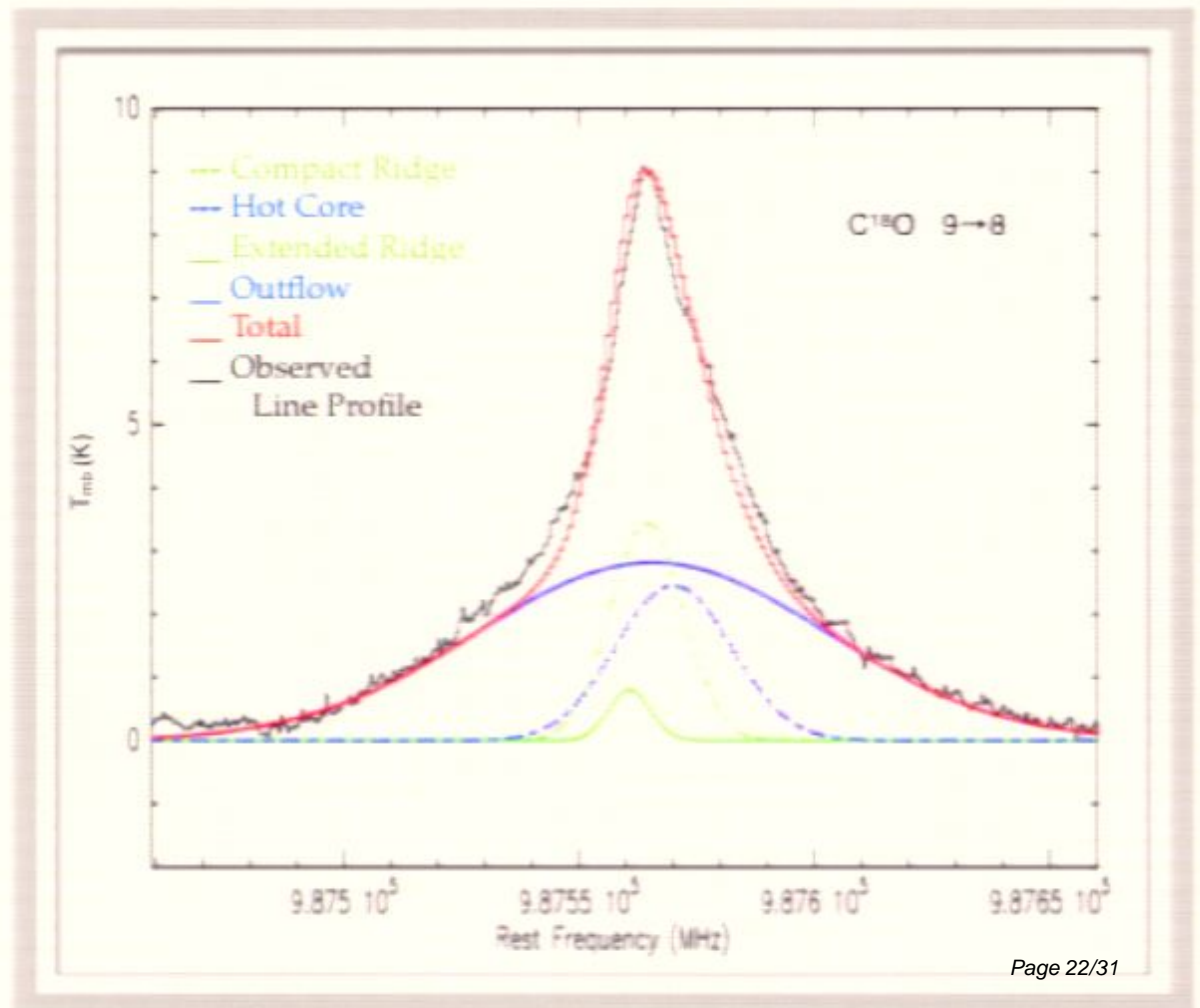
Component	Size (")	Temperature (K)
Extended Ridge	180	40
Outflow	60	100
Compact Ridge	25	125
Hot Core	10	150

# SAMPLE HIFI SPECTRUM



# AUTOMATED DATA MODELING

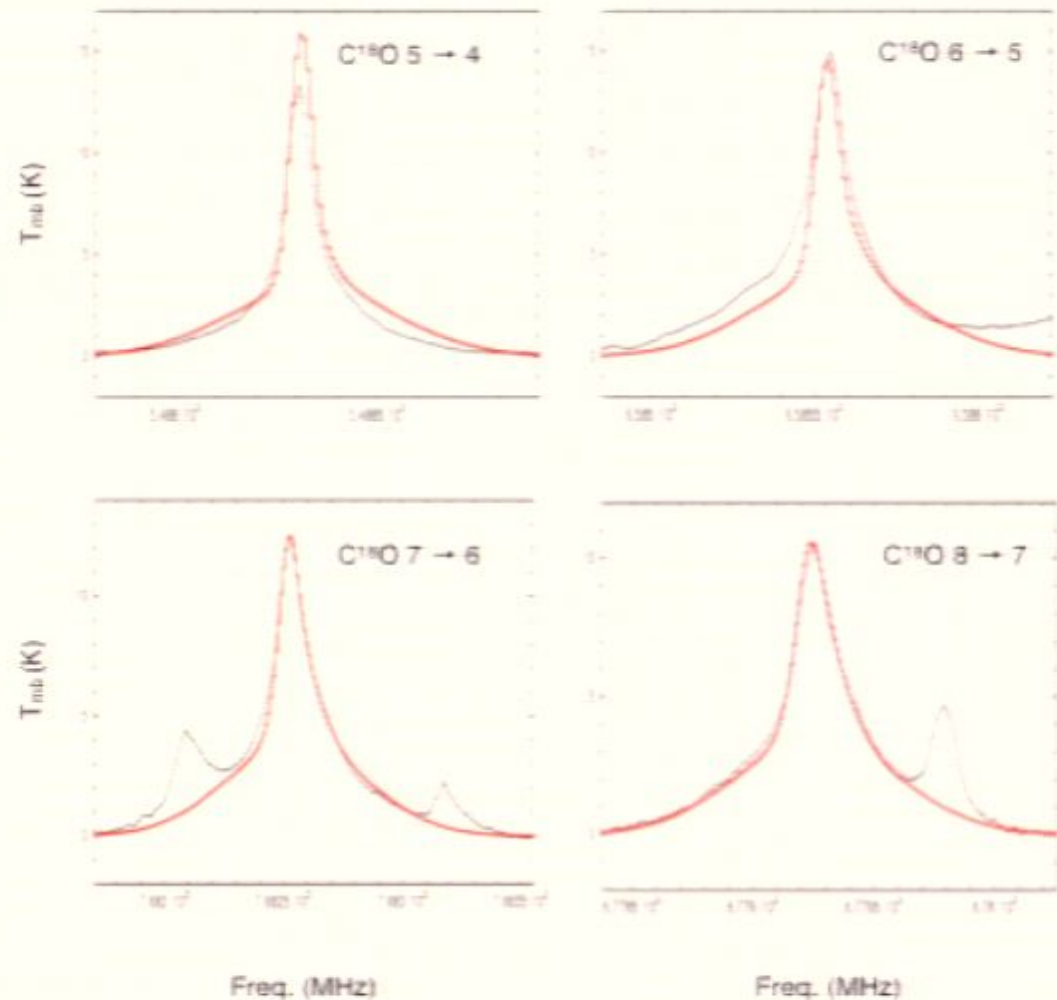
- Input initial guesses for:
  - source size
  - kinetic temperature
  - $N_{\text{tot}}$
  - line width (FWHM)
  - velocity offset



# RESULTS

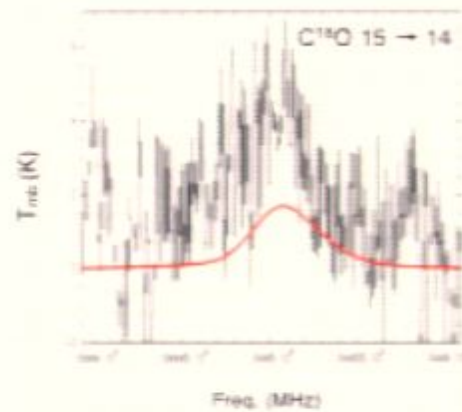
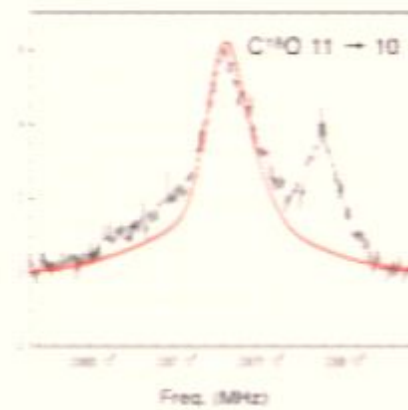
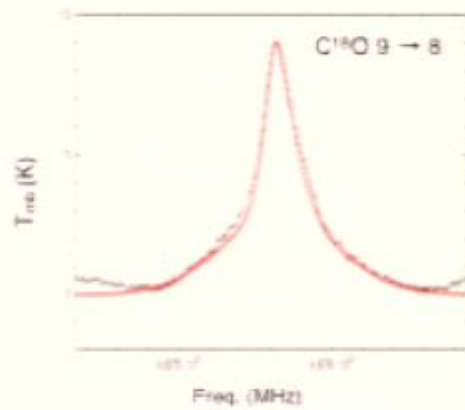
# RESULTS

- A best fit is not necessarily a good fit for all transitions
- Not very good fits for 5-4 and 6-5 transitions
- Good fits for 7-6 and 8-7 transitions





# RESULTS CONT'D



# RESULTS CONT'D

Component	$N_{\text{tot}} \text{C}^{18}\text{O}$ ( $\text{cm}^{-2}$ )	$N_{\text{tot}} \text{CO}$ ( $\text{cm}^{-2}$ )	$N_{\text{tot}} \text{H}_2$ ( $\text{cm}^{-2}$ )
Extended Ridge	$2.5 \times 10^{16}$	$1.3 \times 10^{19}$	$1.3 \times 10^{23}$
Outflow	$5.9 \times 10^{16}$	$3.0 \times 10^{19}$	$3.0 \times 10^{23}$
Compact Ridge	$1.8 \times 10^{16}$	$9.0 \times 10^{18}$	$9.0 \times 10^{22}$
Hot Core	$6.0 \times 10^{16}$	$3.0 \times 10^{19}$	$3.0 \times 10^{23}$

# CONCLUSION

- Direct measurements done by hand are of course more accurate, BUT for understanding physical evolution of a region, they are:
  - Time-consuming
  - unrealistic
- A method is needed that can efficiently model ALL molecules together
- This is why it is important to find and fix the flaws in programs such as the one used in this project in order to get better results

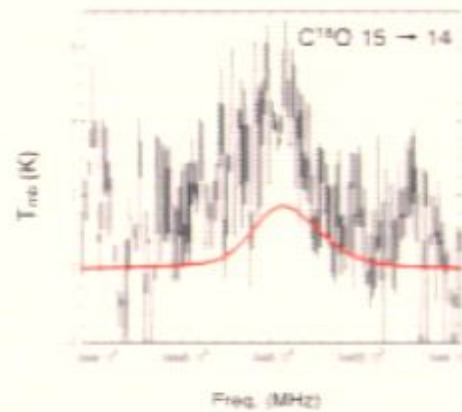
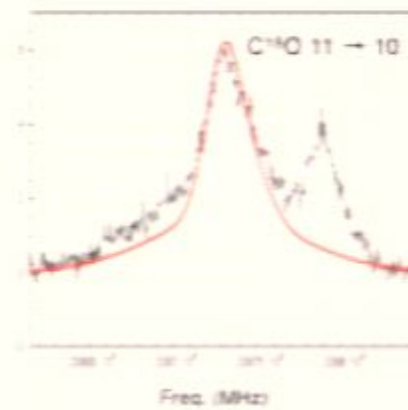
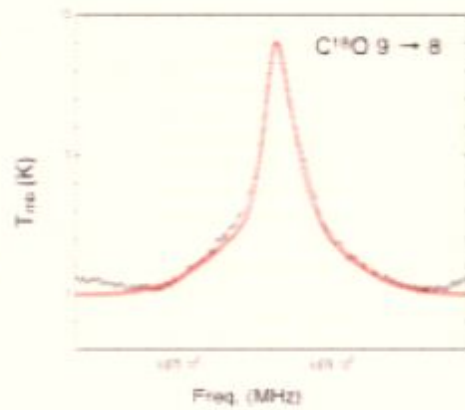
THANK YOU!

Questions?

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