Chemical Structure of Barnard 68

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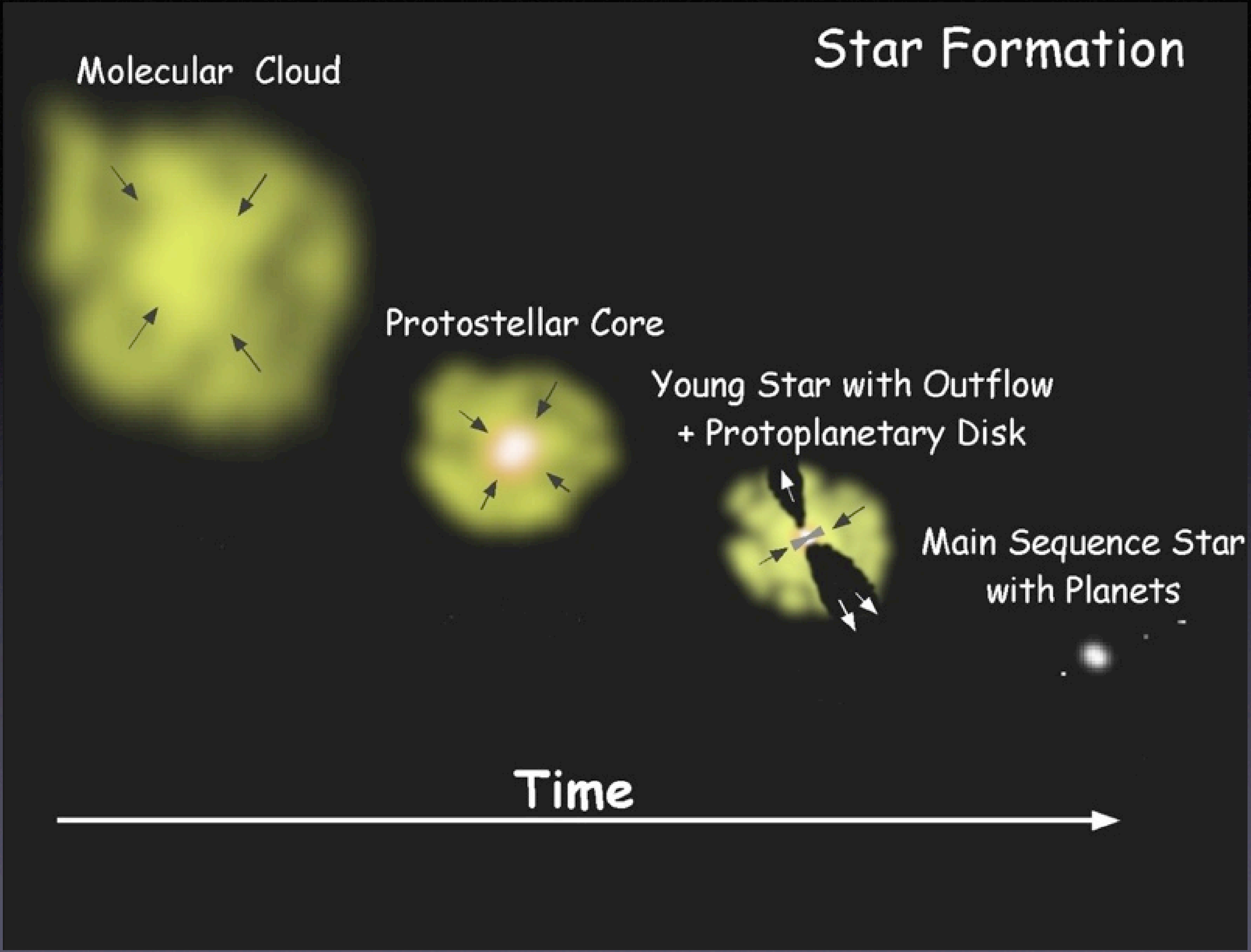
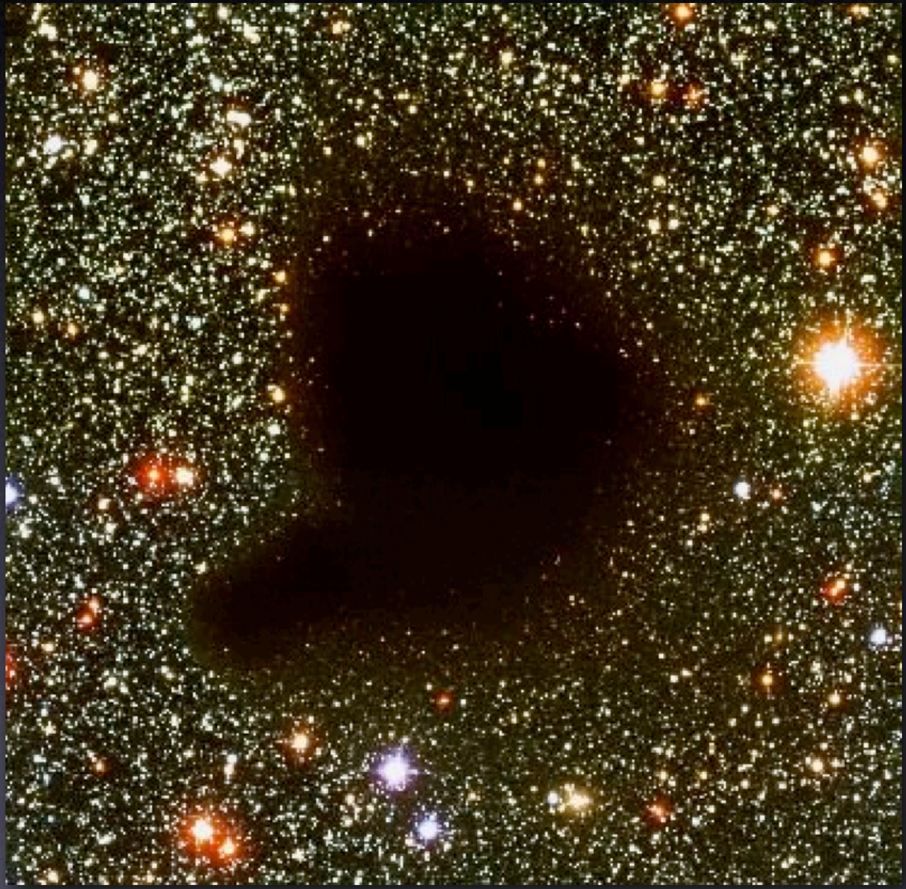

Star Formation
Molecular Cloud
Protostellar Core
Young Star with Outflow
+ Protoplanetary Disk
Main Sequence Star
with Planets
Time

B68: A Unique Interstellar Laboratory

- Pre-stellar core with a well defined physical structure
  - Density (Alves et al 2001)
  - Dust and gas temperature (Zucconi et al 2001, Bergin et al. 2006)
- On the verge to collapse: pristine material that will form a star

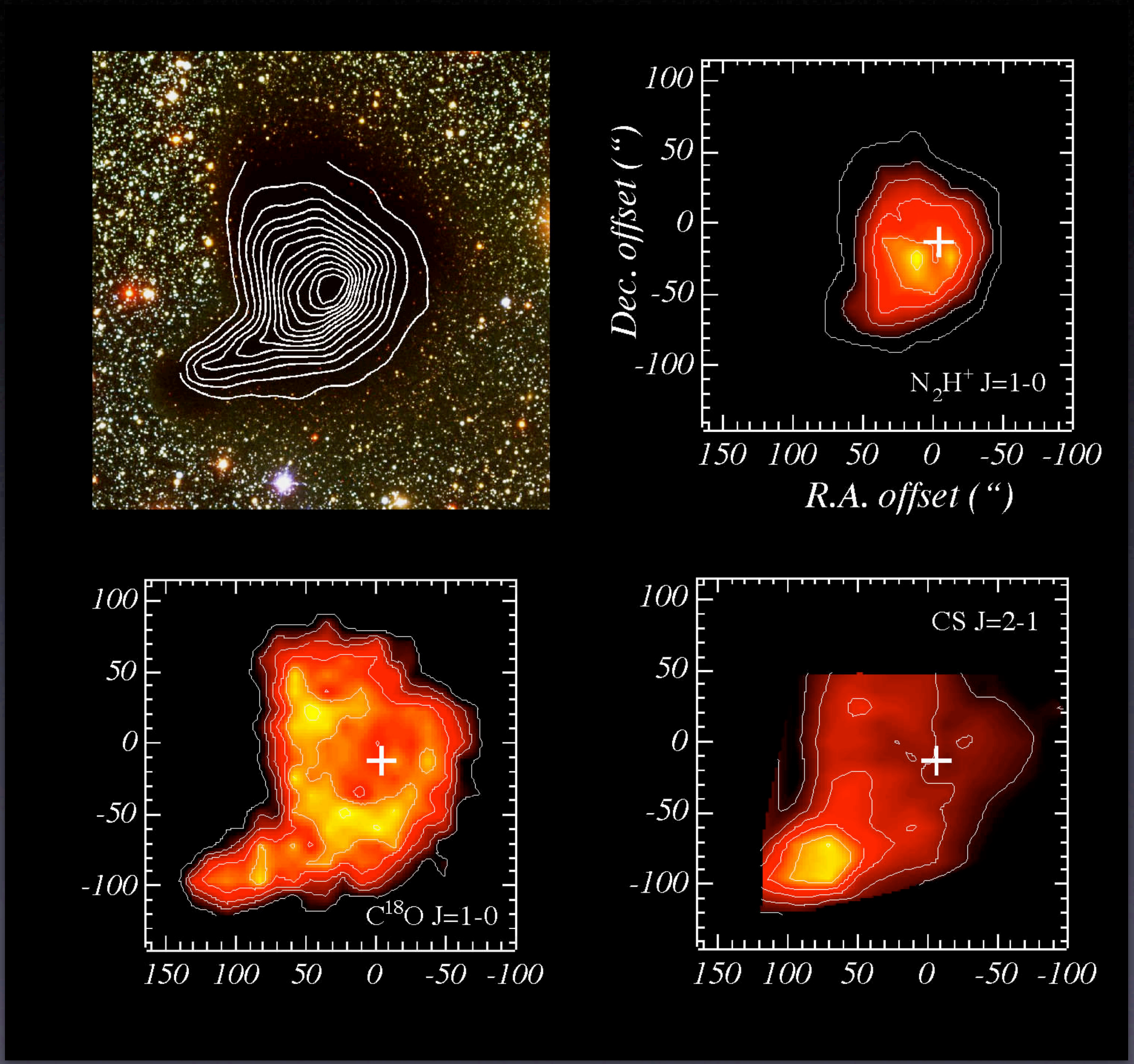


Optical VLT Image (Alves et al. 2001)

This talk...

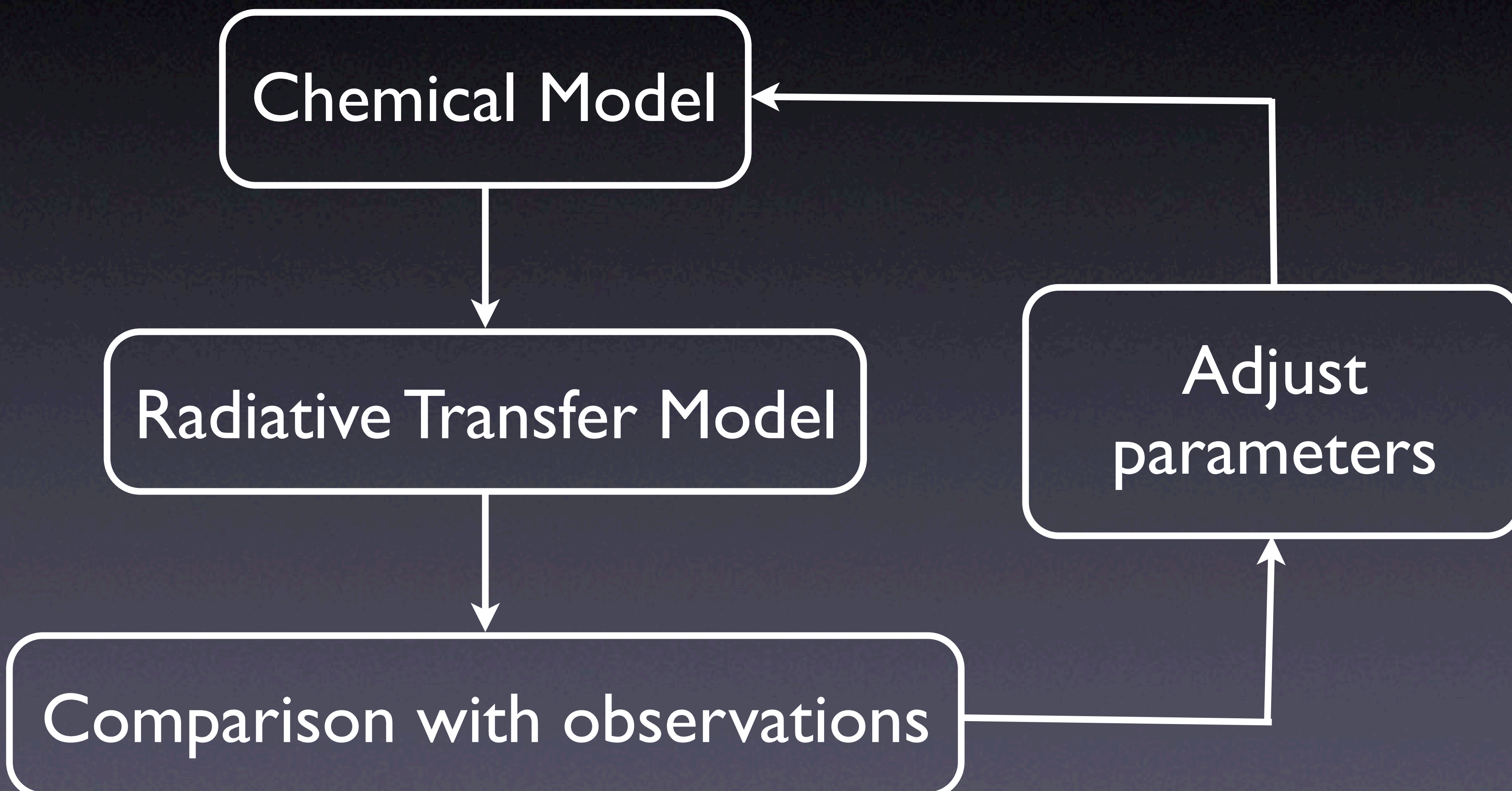
- We are going to examine the B68 dark cloud using molecular line observations (HCO^+, $H^{13}CO^+$, N_2H^+)
- For this we will match the observations with chemical models
- ... and we will show how this can put strong constraints on the chemical and dynamical structure of the core

B68: Line observations

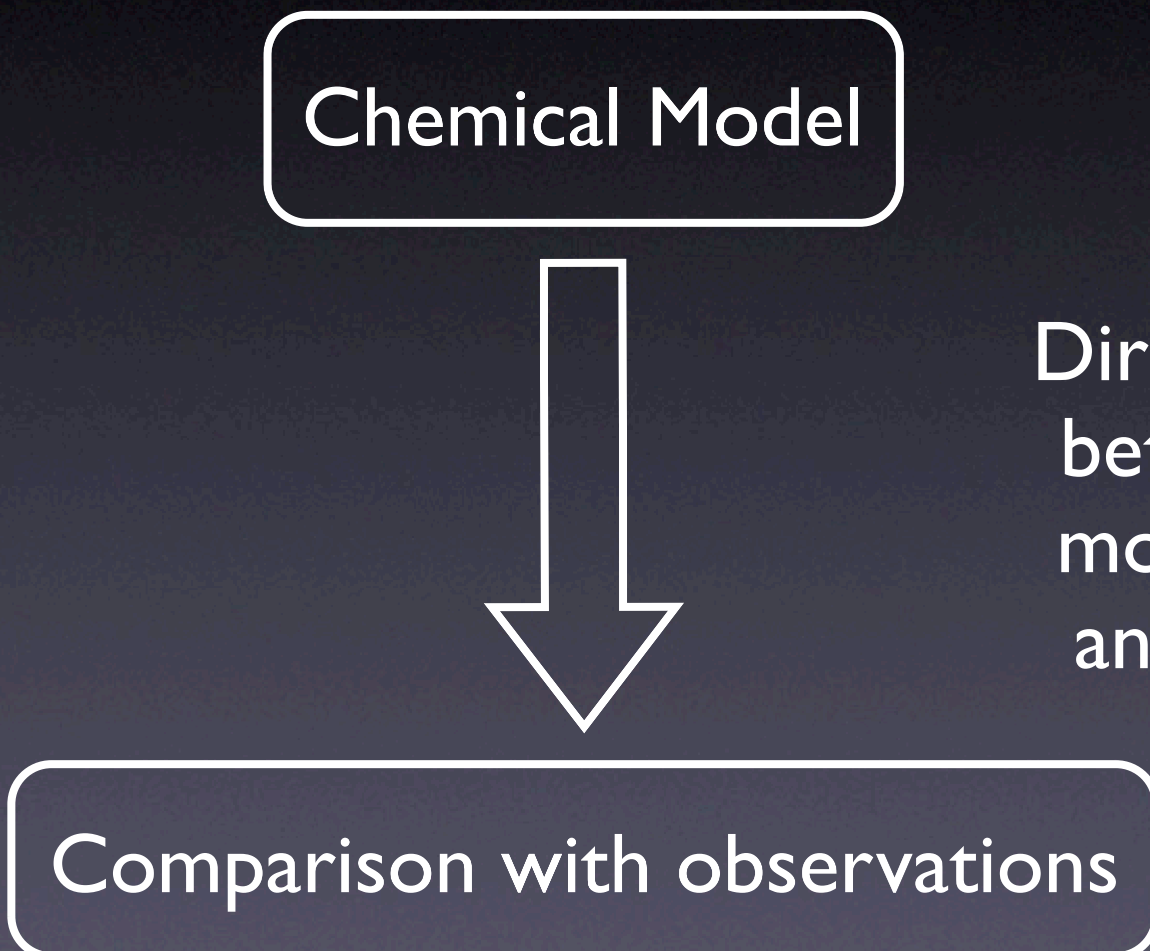


Bergin et al. 2002, Lada et al. 2003

Analysis


Chemical Model
Radiative Transfer Model
Comparison with observations
Adjust parameters

Analysis



Direct comparison between chemical model predictions and observations

$H^{13}CO^+$ analysis

Main formation route:

$$H_3^+ + {}^{13}CO \rightarrow H^{13}CO^+ + H_2$$

Main destruction route:

$$H^{13}CO^+ + e^- \rightarrow {}^{13}CO + H$$

Gives constraints on both electron abundance, and H_3^+ abundance

$H^{13}CO^+$ analysis

Main H_3^+ formation route:

$$\mathrm{H_2} + \text{cosmic ray}\,\gamma \rightarrow \mathrm{H_2^+} + e^-$$
$$\mathrm{H_2^+} + \mathrm{H_2} \rightarrow \mathrm{H_3^+} + \mathrm{H}$$

In turn, the $H^{13}CO^+$ analysis constrains the cosmic ionization rate ζ

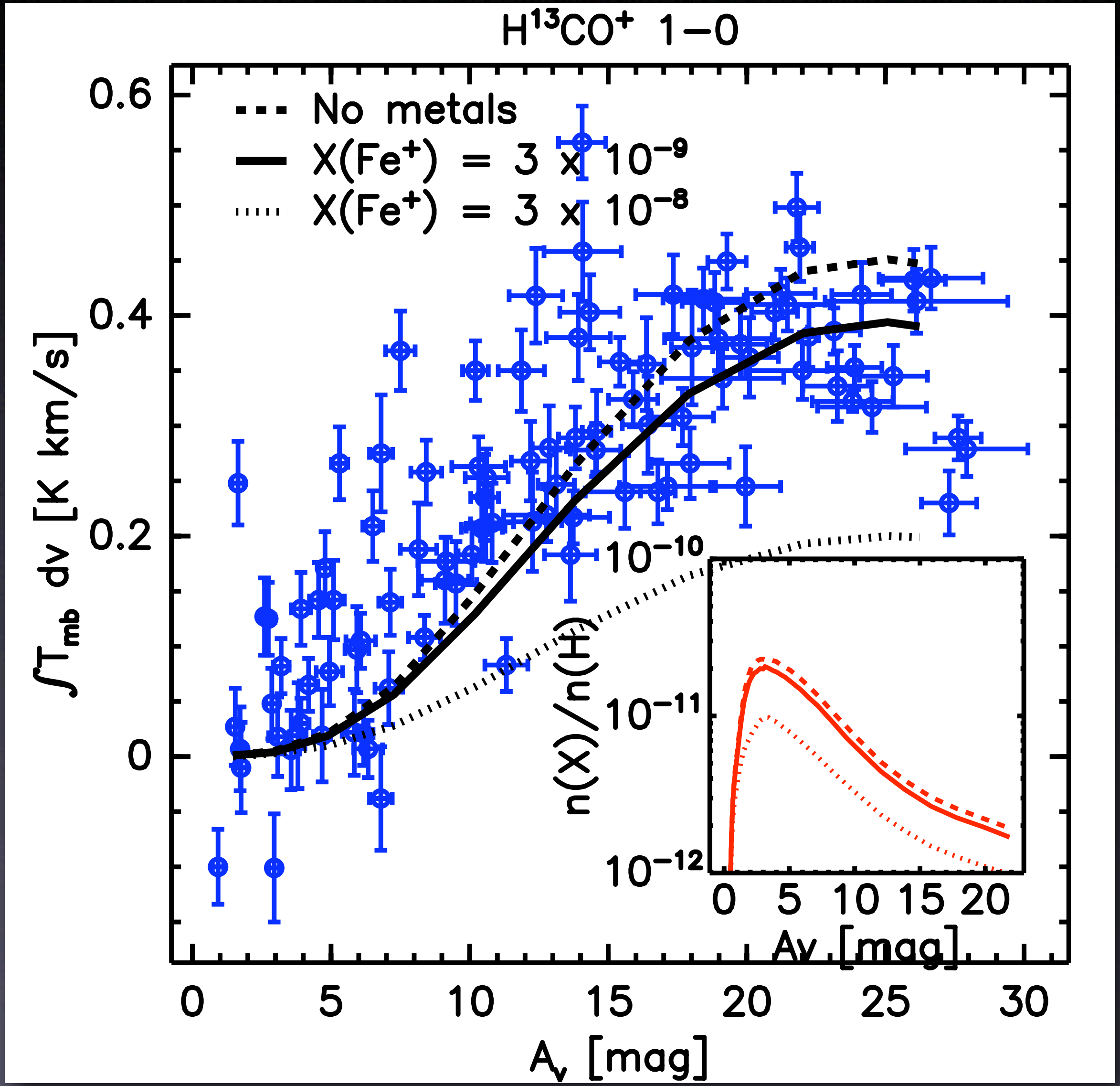
$H^{13}CO+$ analysis

Electron abundance is set by the metal abundance and cosmic ray ionization

No metals needed

$X(e^-) \sim 10^{-8}$

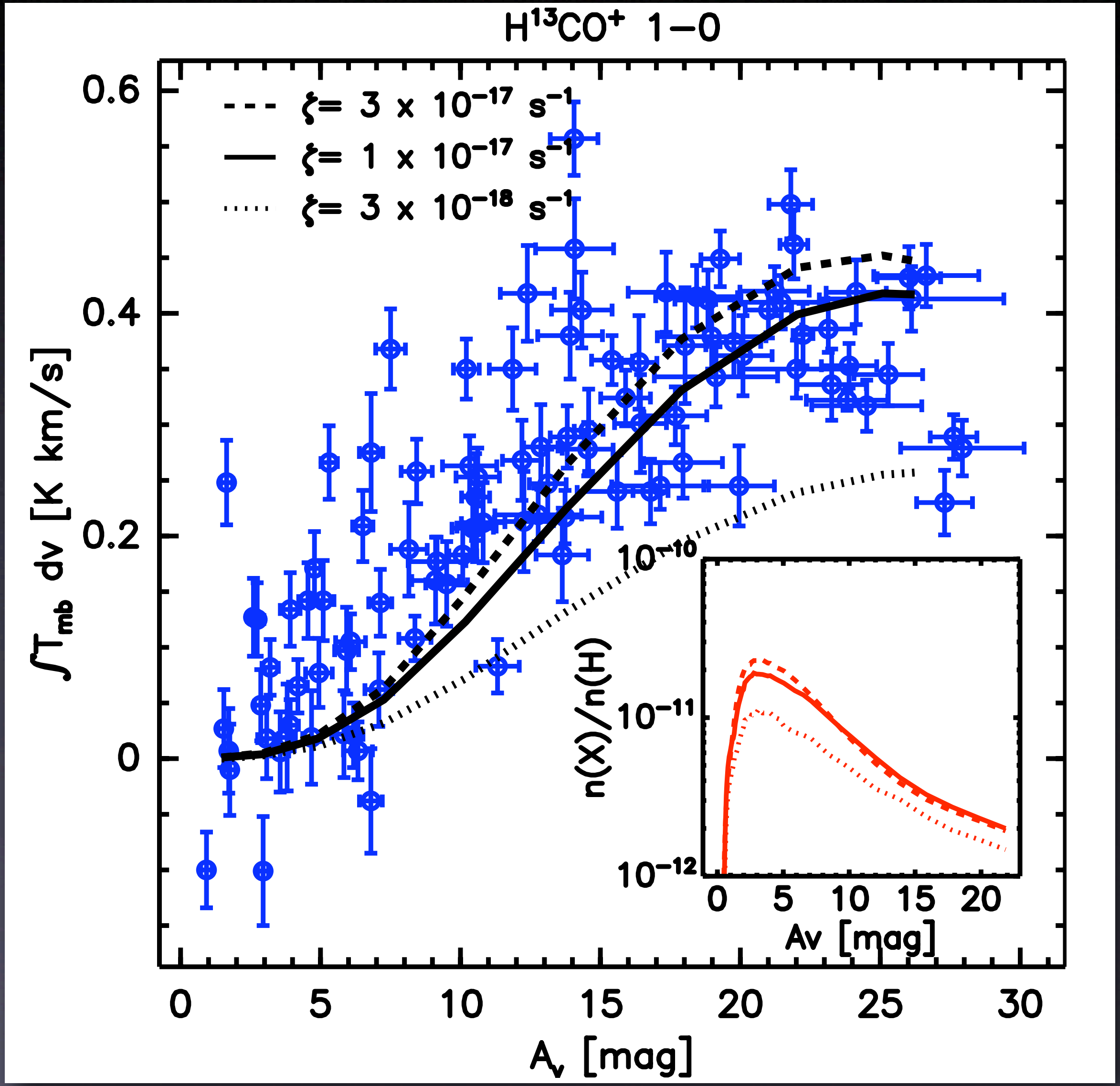
Maret et al., 2006



$H^{13}CO^+$ analysis

- The solution might be not unique...
- Complete depletion of metals: constraint on the cosmic ionization rate
- $\zeta > 3 \times 10^{-18}\,\mathrm{s}^{-1}$

Maret et al in prep.



N_2H^+ analysis

Main formation route:

$$H_3^+ + N_2 \rightarrow N_2H^+ + H_2$$

Main destruction route (Geppert et al. 2004):

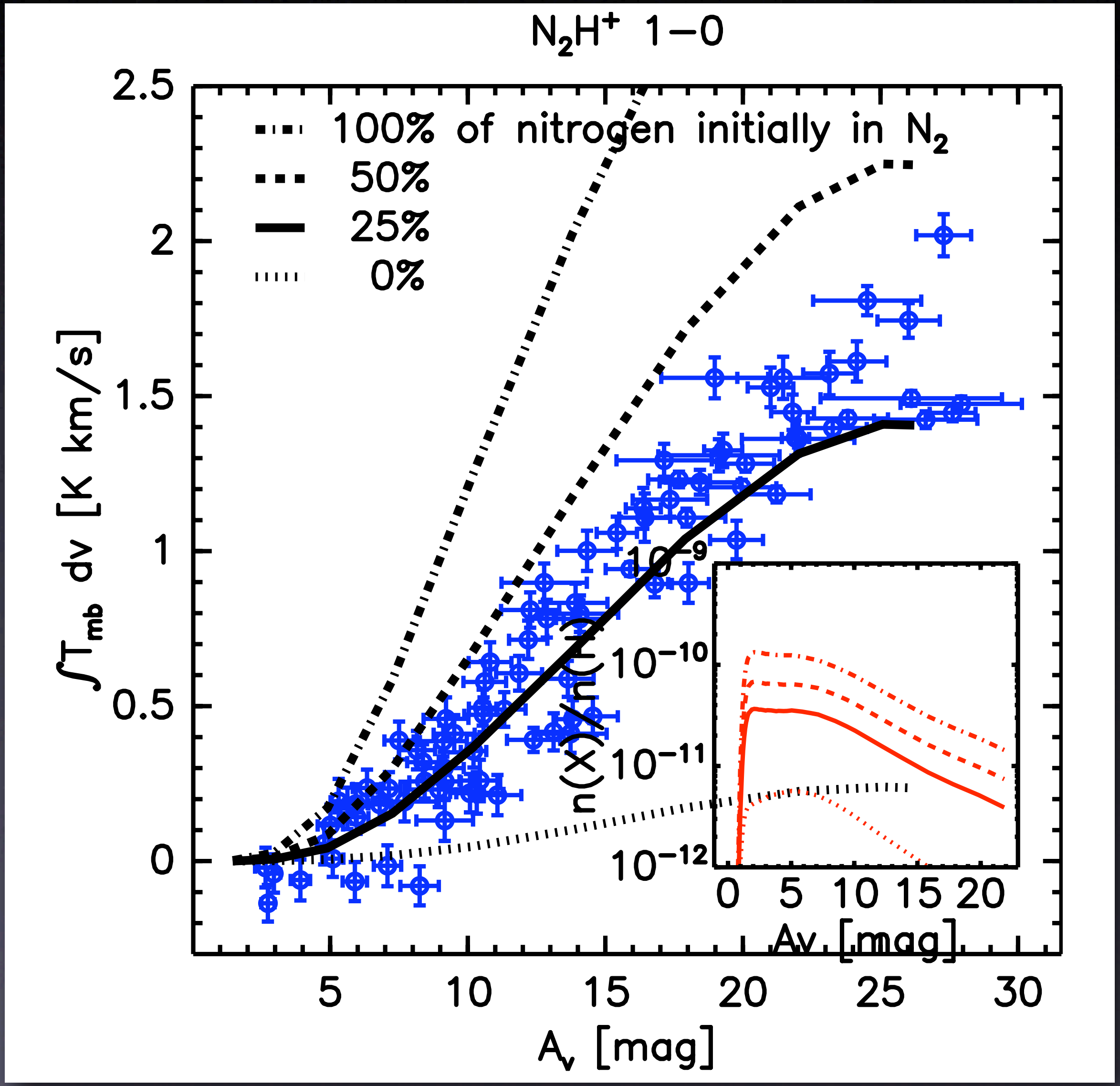
$$N_2H^+ + e^- \rightarrow N_2 + H \ (36\%)$$
$$\rightarrow NH + H \ (64\%)$$

Constrains on the N_2 abundance (previously assumed to be the main carrier of N)

N_2H^+ analysis

- Observations can not be matched if N is assumed to be in N_2
- Nitrogen is not mostly molecular (only 20-30 %), but is mostly atomic

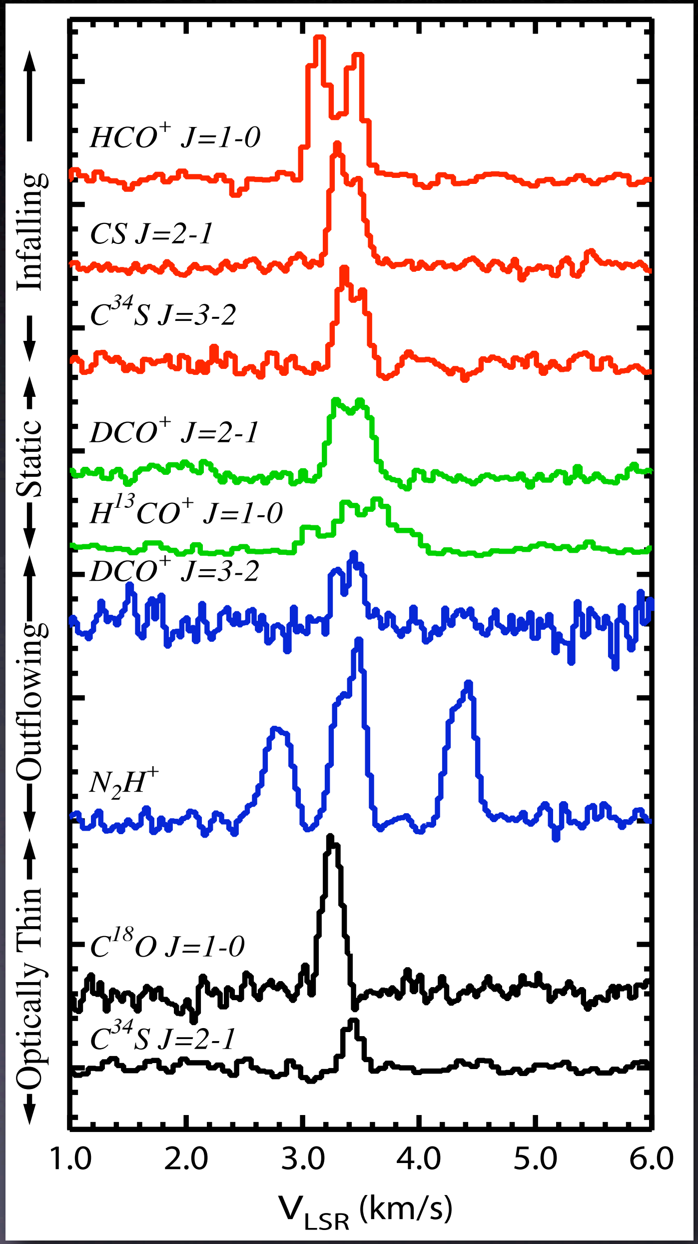
Maret et al., Nature, in press



Line profiles

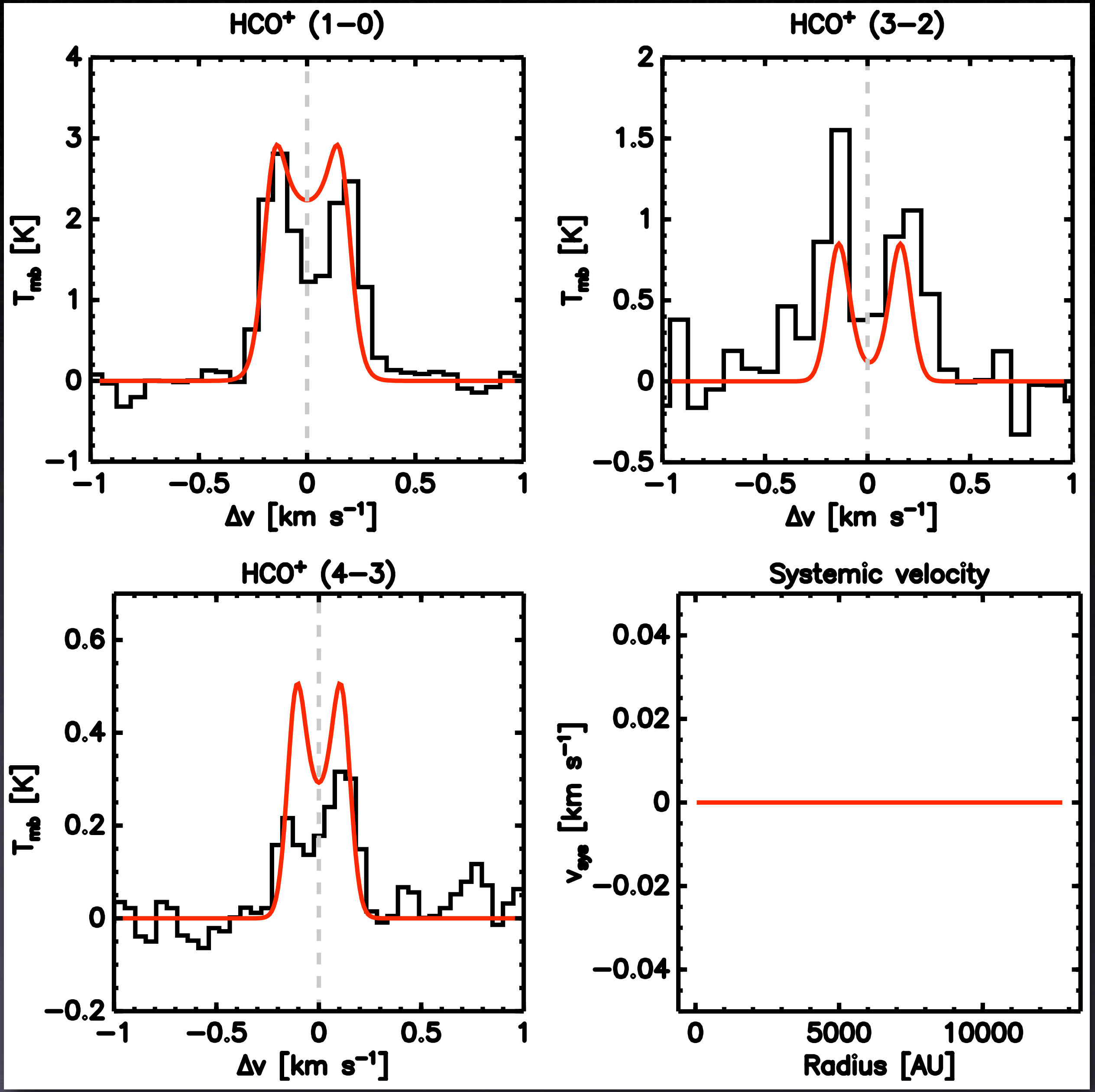
- Complex motions along the line of sight
- Chemistry is the key to understand the velocity structure

Maret et al., in prep.



Lines profiles

HCO^+ line profiles can not be reproduced by a static core model

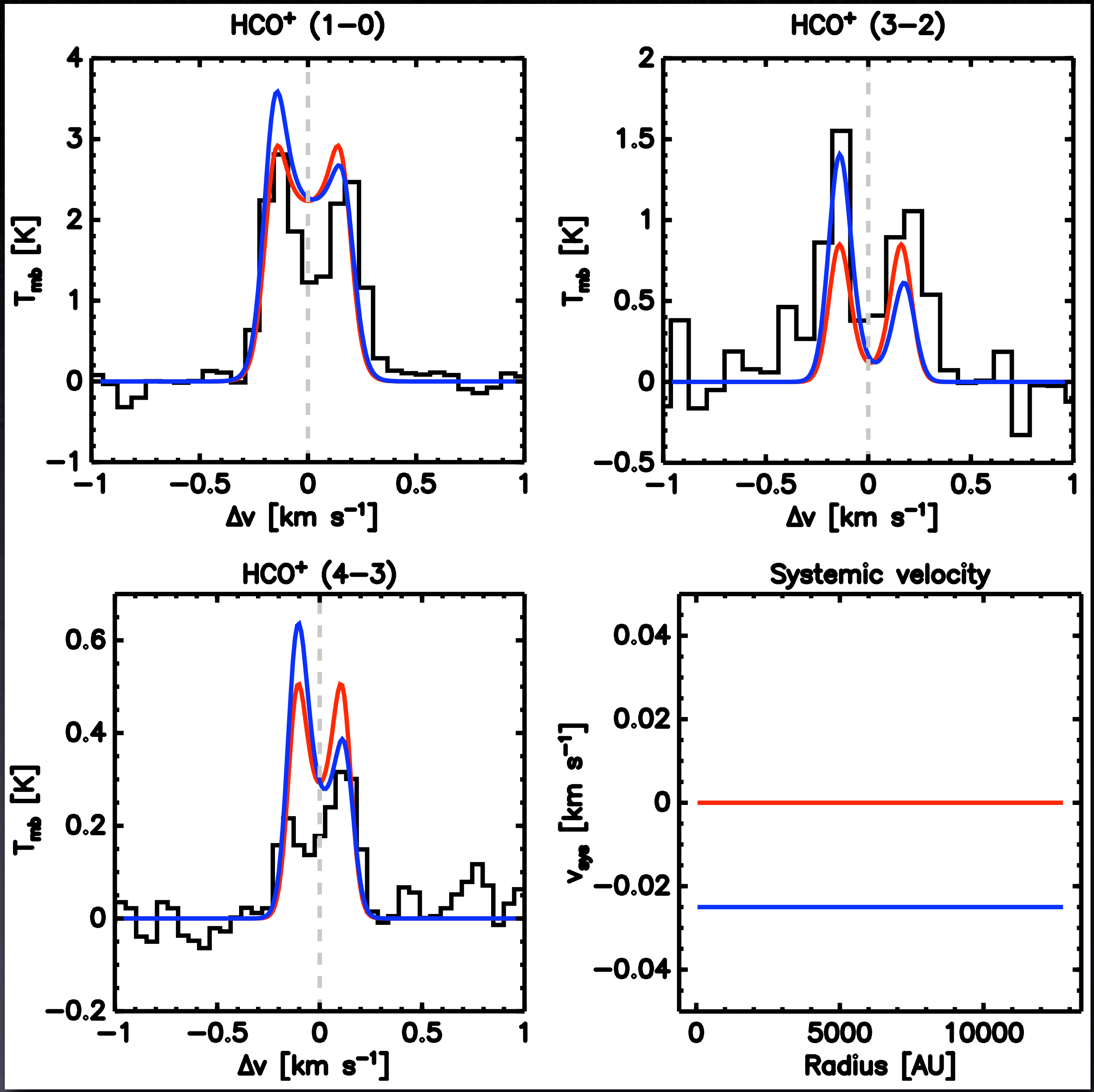


Maret et al., in prep.

Lines profiles

HCO^+ line profiles can not be reproduced by a static core model

An infalling core model fails to reproduce the HCO^+ (4-3) line profile



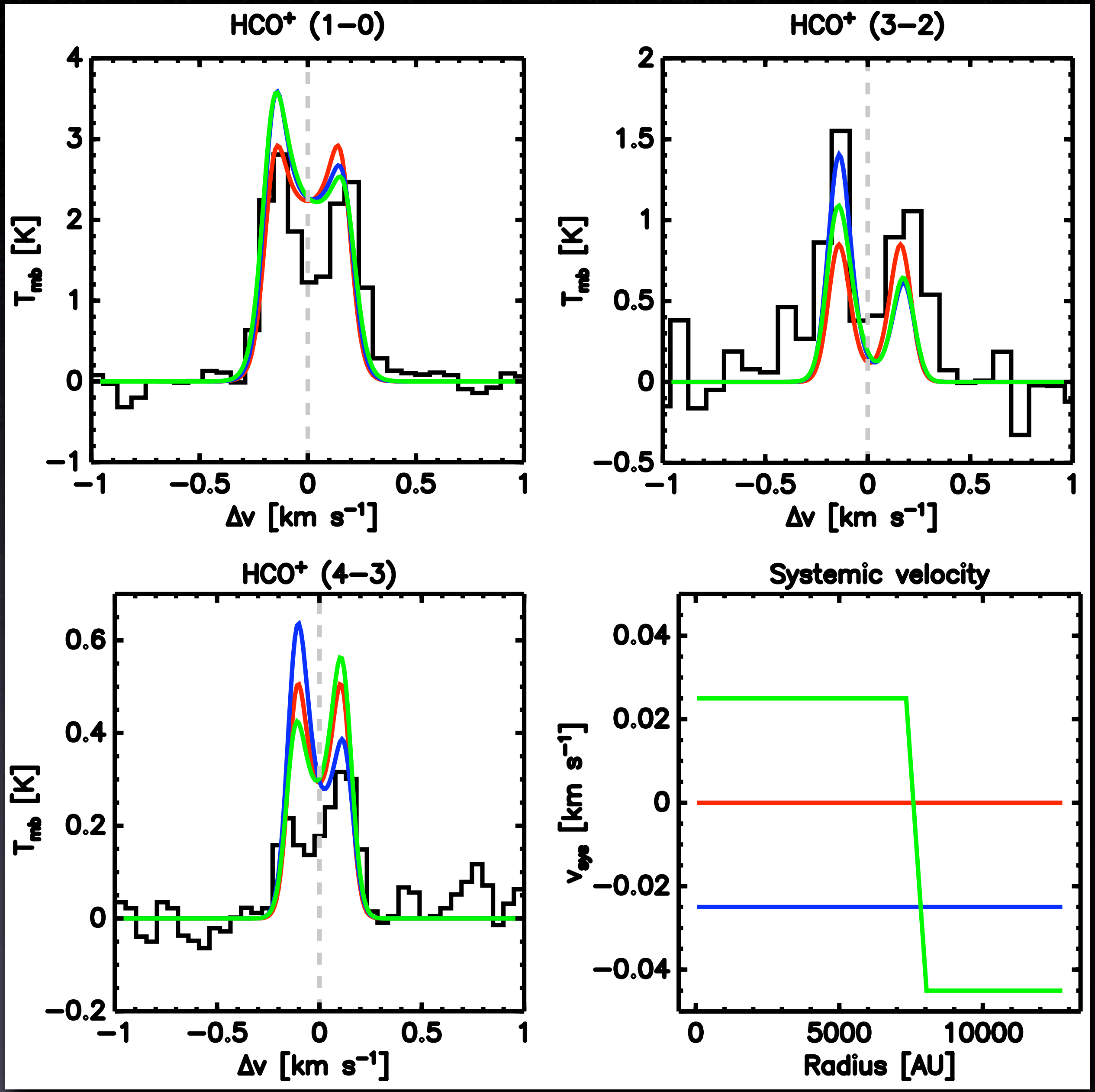
Maret et al., in prep.

Lines profiles

HCO$^+$ line profiles can not be reproduced by a static core model

An infalling core model fails to reproduce the HCO$^+$ (4-3) line profile

Outflowing gas at the center of the core ?



Maret et al., in prep.

Conclusions

- Chemical models are capable of matching line observations.
- Constraints on the electron abundance and cosmic ionization rate
- First evidence that N_2 is not the dominant N carrier in dense ISM.
- Chemistry is the key to understand the dynamics of star formation