INSTITUTO DE ASTRONOMIA, GEOFÍSICA E CIÊNCIAS ATMOSFÉRICAS
USP
Universidade de São Paulo

LLAMA
Large Latin American Millimeter Array

Sulphur-Bearing and Complex Organics Molecules in an Infrared Cold Core

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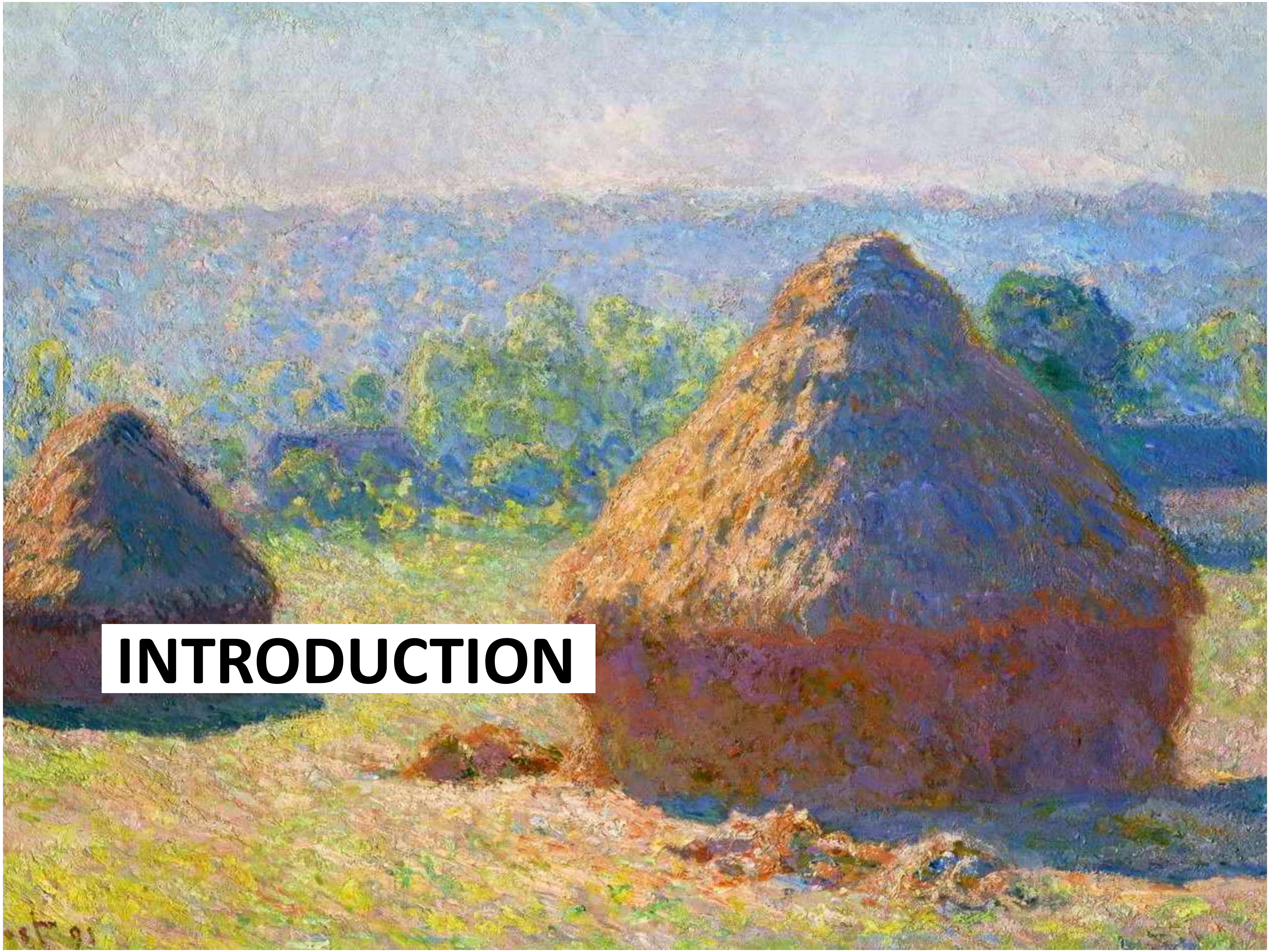
ALLAM2019
09/08/2019

ALLAM 2019
Astrochemistry LLAMA Meeting

Astrochemistry Group @ IAG-USP

http://www.astro.iag.usp.br/~astroquimica/

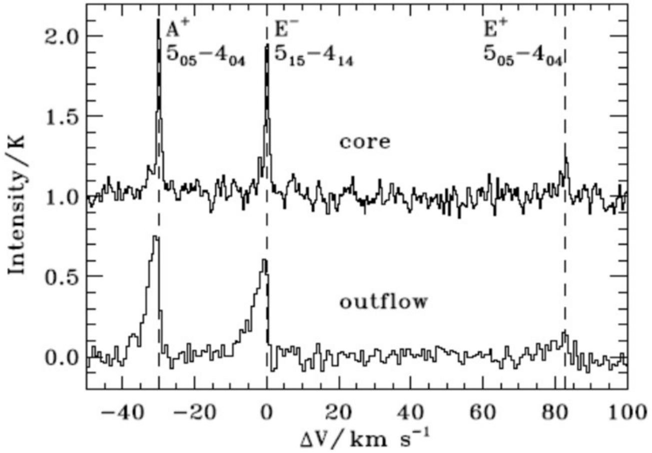
INTRODUCTION



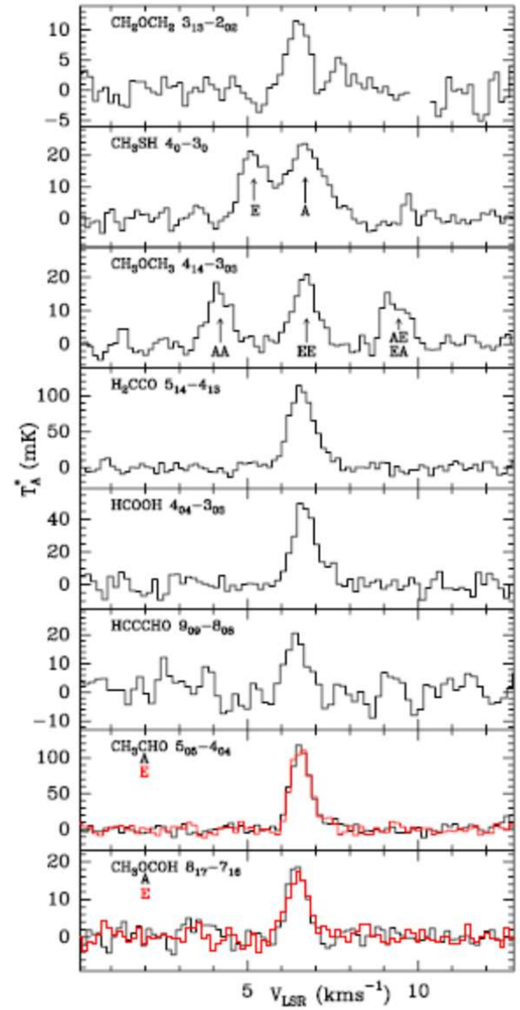
Chemistry on Cold Sources

Low Mass proto-Star B1-b

CH_3OH

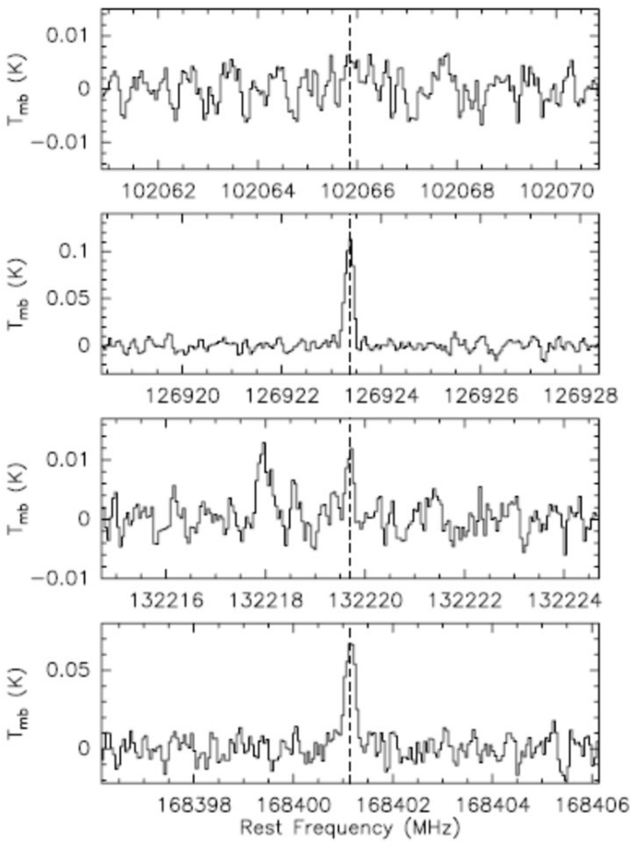


Oberg et al. 2010

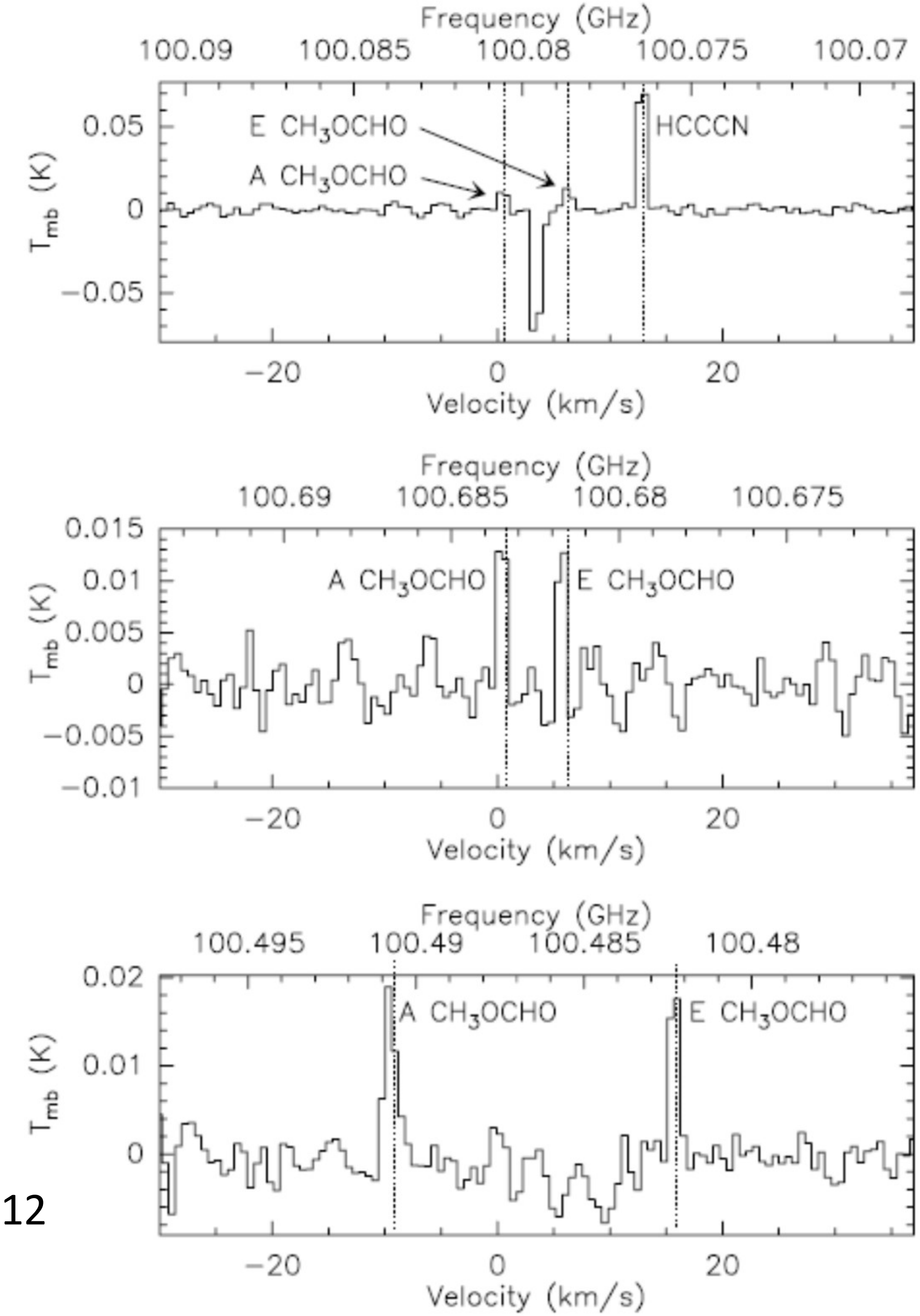


Cernicharo et al. 2012

L1689B



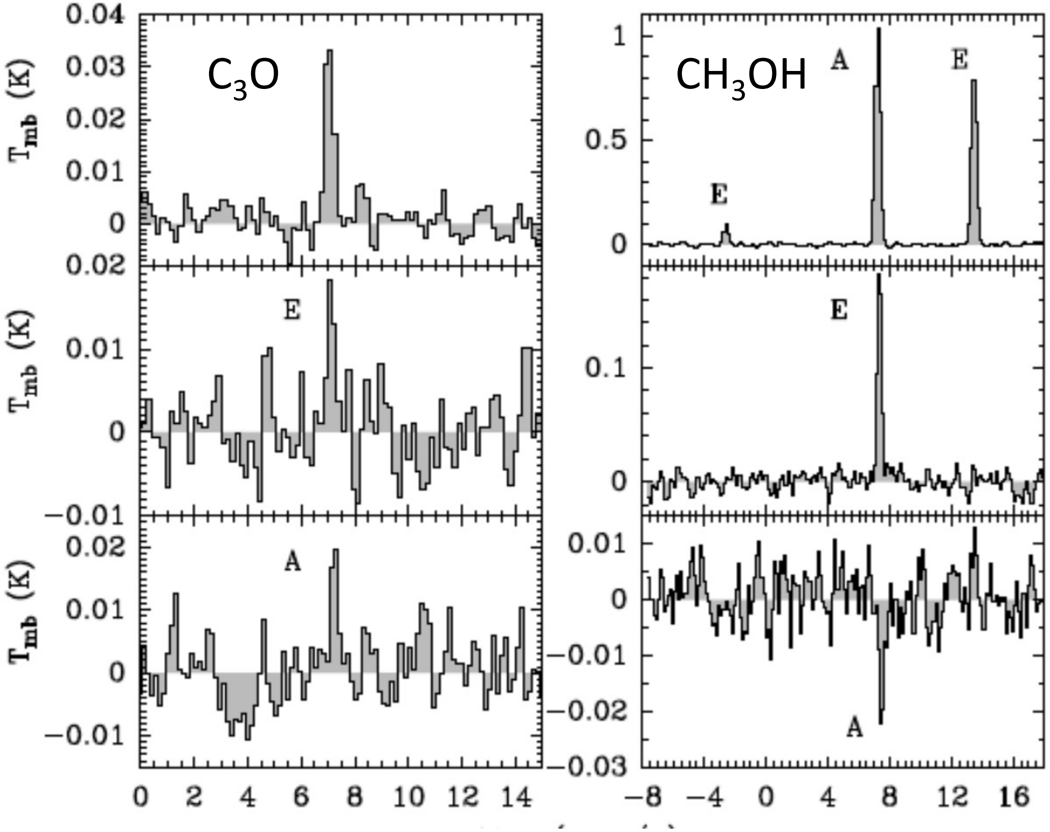
Bacmann et al. 2016
Transitions of H_2COH^+



Bacmann et al. 2012
pre-stellar core

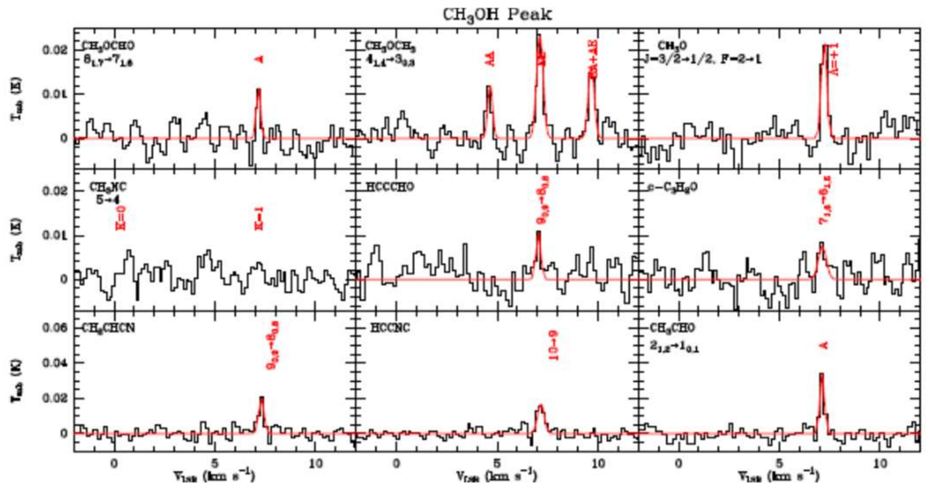
L1544

Pre-stellar core



Vestel et al. 2014

Jimenez-Serra et al. 2016



OBJECTIVES

Objectives

- Searching on the ALMA archive for Cold core data

↓

66 antennas

- Search for line of COMs

Atacama Large Millimeter Array

A HUNT FOR MASSIVE STARLESS CORES

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Draft version September 9, 2018

ABSTRACT

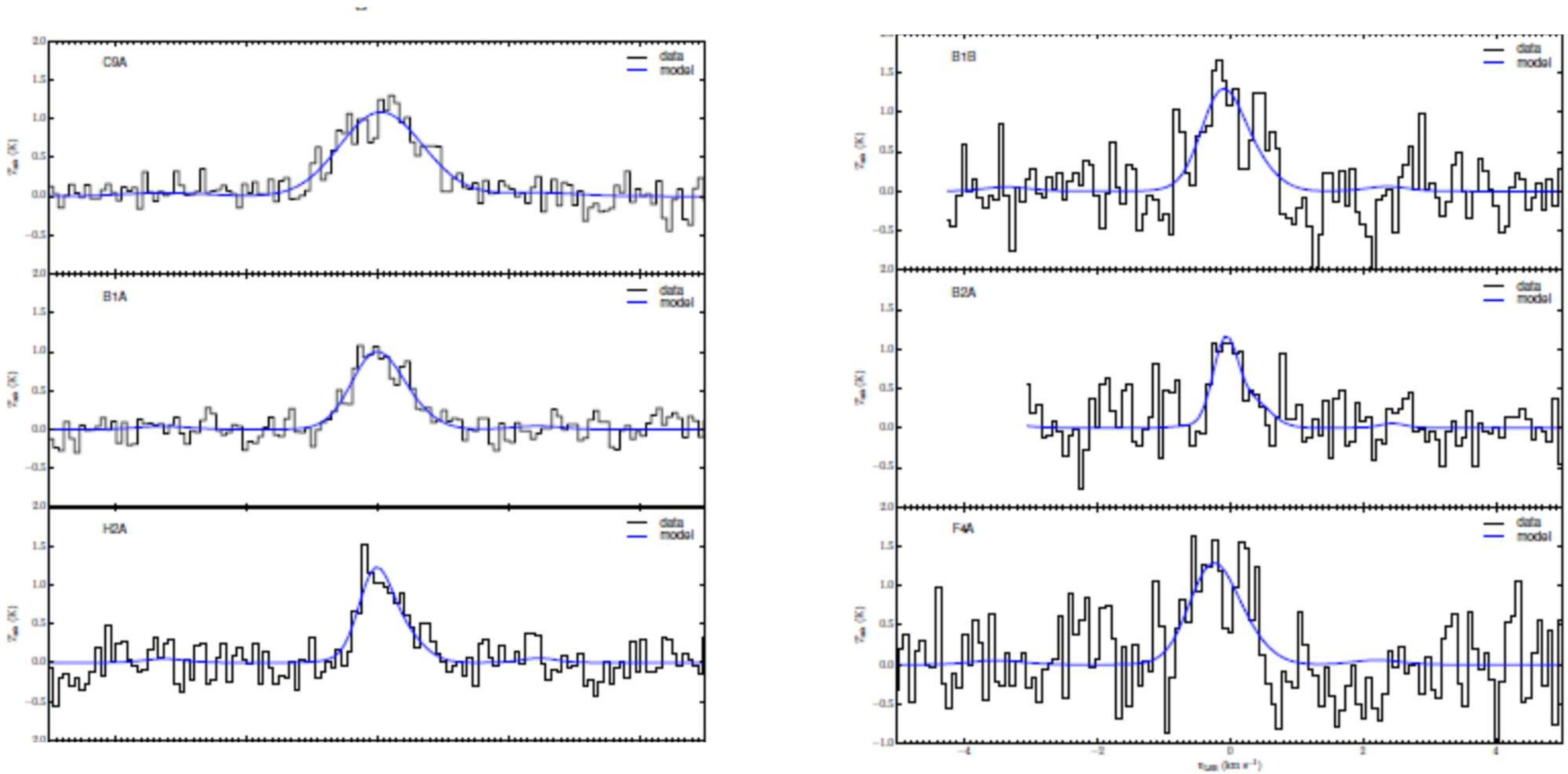
We carry out an ALMA N_2D^+(3-2) and 1.3 mm continuum survey towards 32 high mass surface density regions in seven Infrared Dark Clouds with the aim of finding massive starless cores, which may be the initial conditions for the formation of massive stars. Cores showing strong N_2D^+(3-2) emission are expected to be highly deuterated and indicative of early, potentially pre-stellar stages of star formation. We also present maps of these regions in ancillary line tracers, including $C^{18}O$(2-1), DCN(3-2) and DCO^+(3-2). Over 100 N_2D^+ cores are identified with our newly developed core-finding algorithm based on connected structures in position-velocity space. The most massive core has $\sim 70\,M_{\odot}$ (potentially $\sim 170\,M_{\odot}$) and so may be representative of the initial conditions or early stages of massive star formation. The existence and dynamical properties of such cores constrain massive star formation theories. We measure the line widths and thus velocity dispersion of six of the cores with strongest N_2D^+(3-2) line emission, finding results that are generally consistent with virial equilibrium of pressure confined cores.

32 Regions

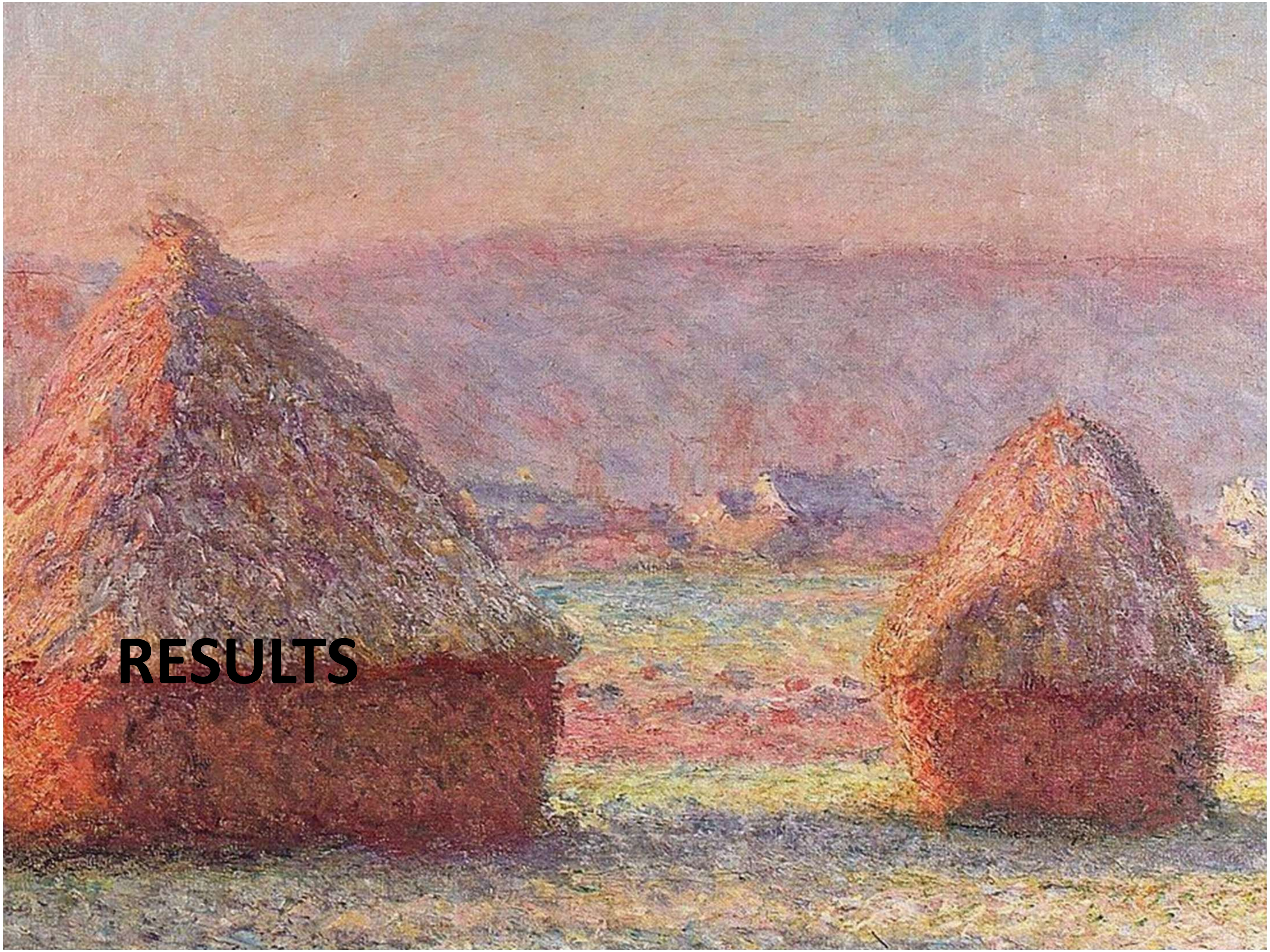
To Identify Cold Cores

Kong et al. 2017

6 Cores with N2D+ line clearly detected

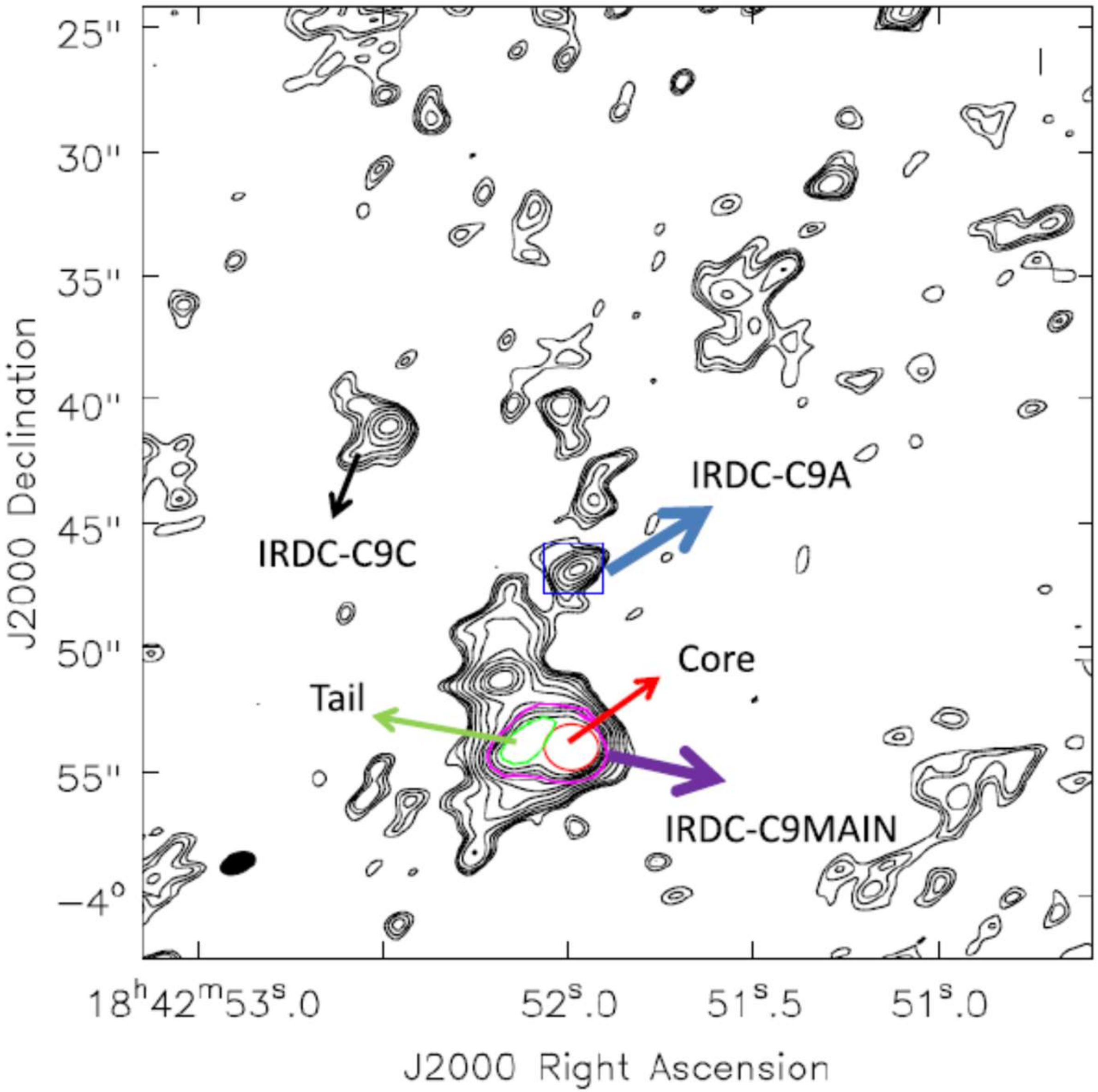


Kong et al. 2017

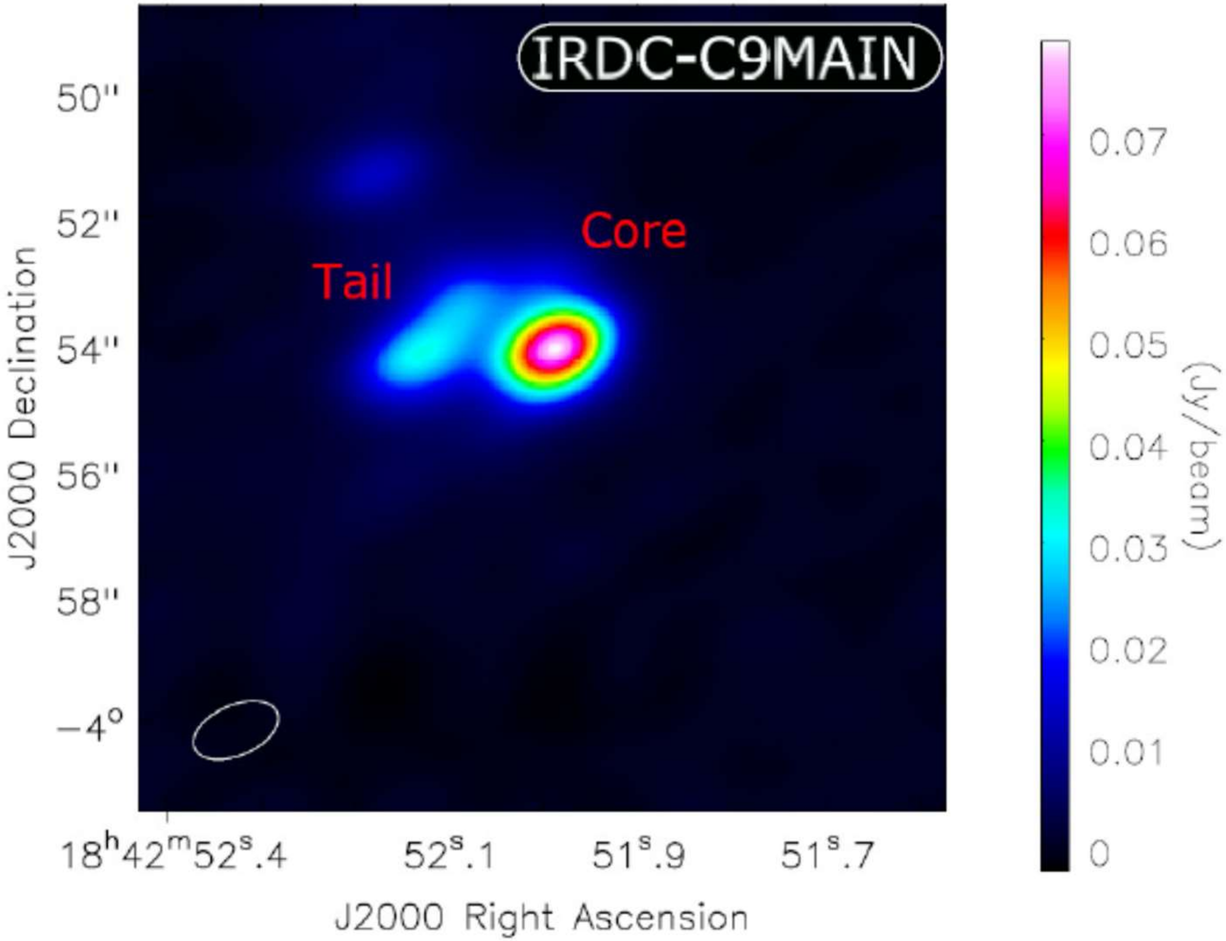

RESULTS

From 32 Cores

- Different morphology of continuous emission
- Most of them with any line
- Except one!
  - IRDC-C9

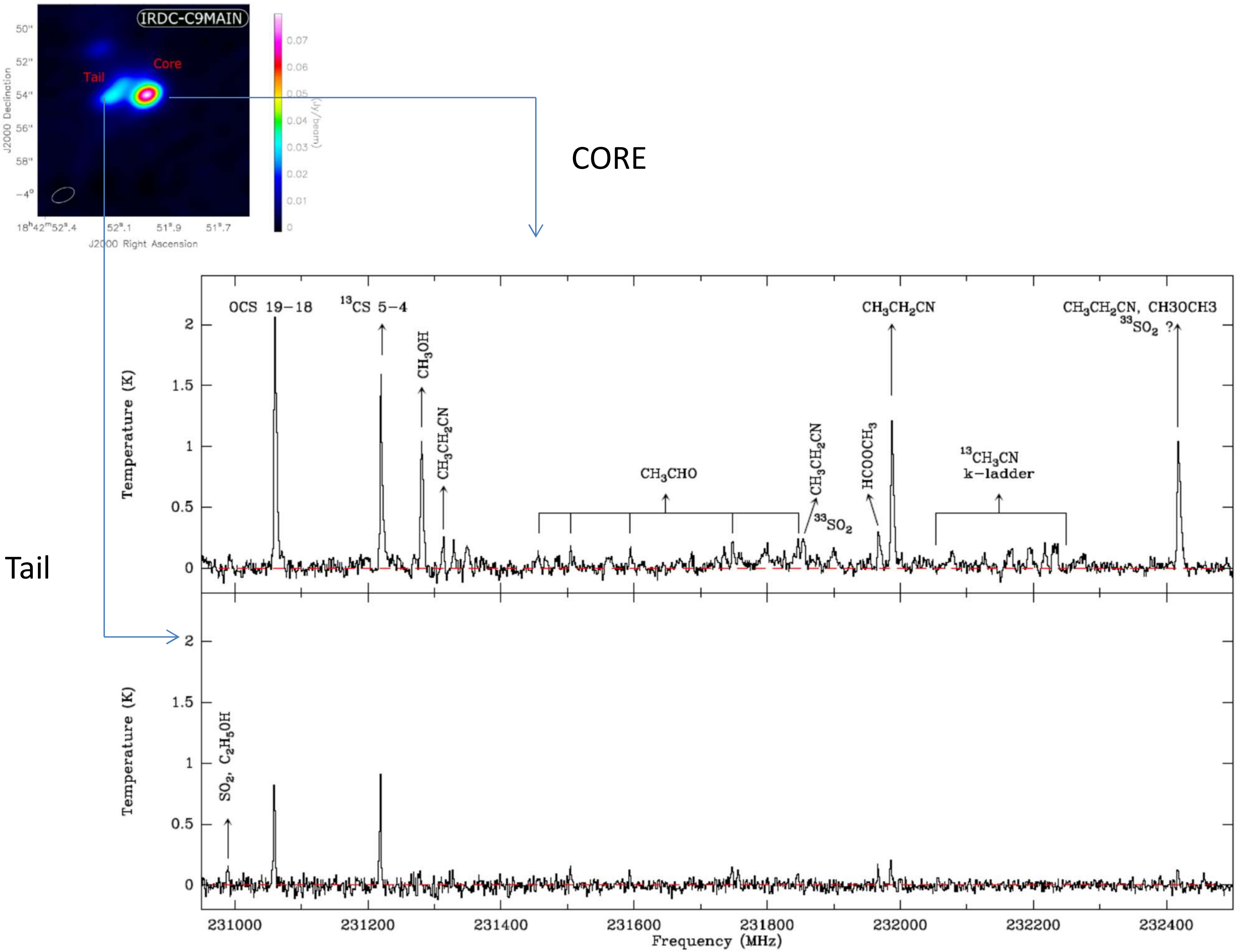


Beaklini et al. 2019 Submitted



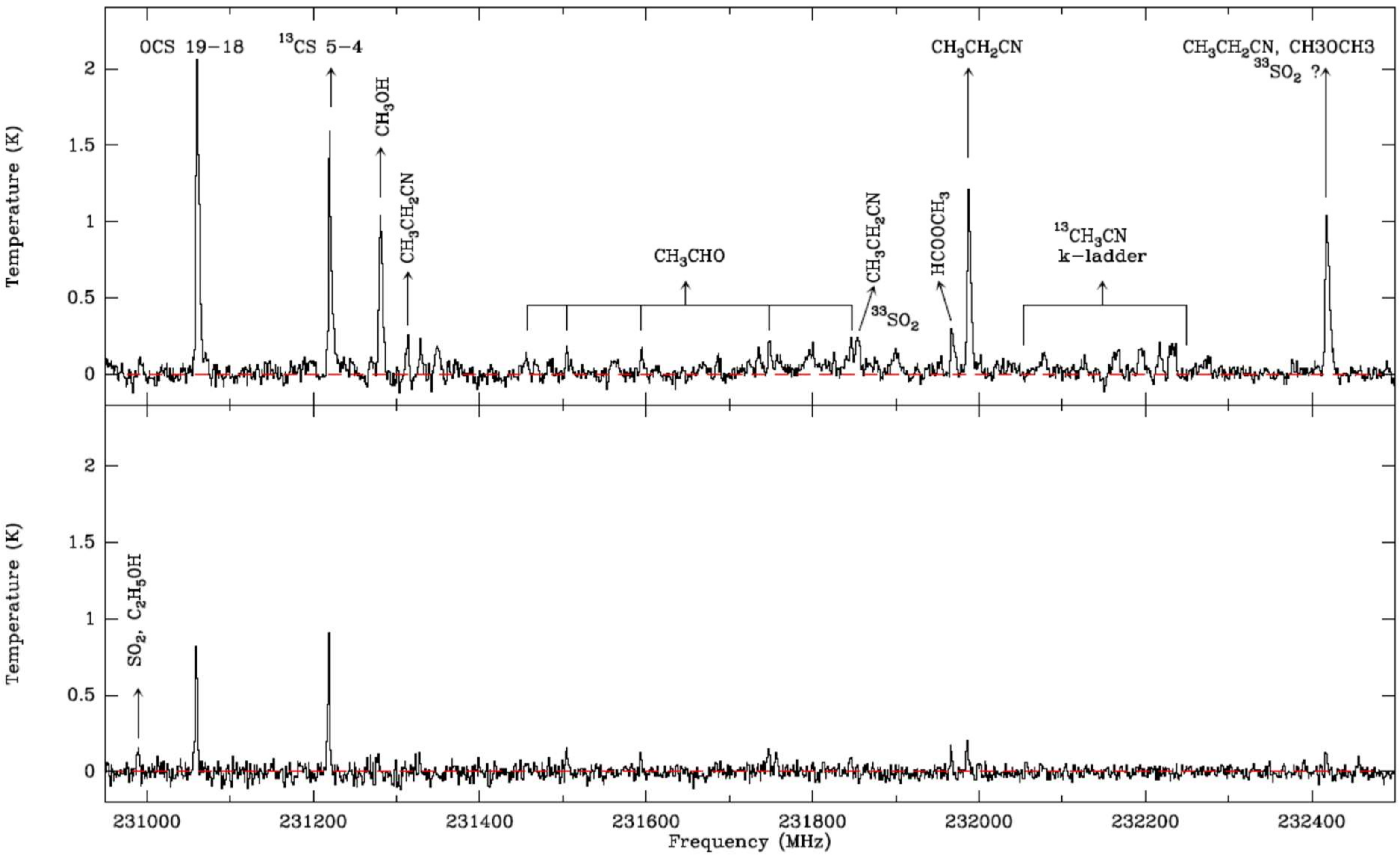
IRDC-C9MAIN
Core
Tail
50''
52''
54''
56''
58''
−4°
J2000 Declination
18h42m52s.4
52s.1
51s.9
51s.7
J2000 Right Ascension
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
(Jy/beam)

231GHz

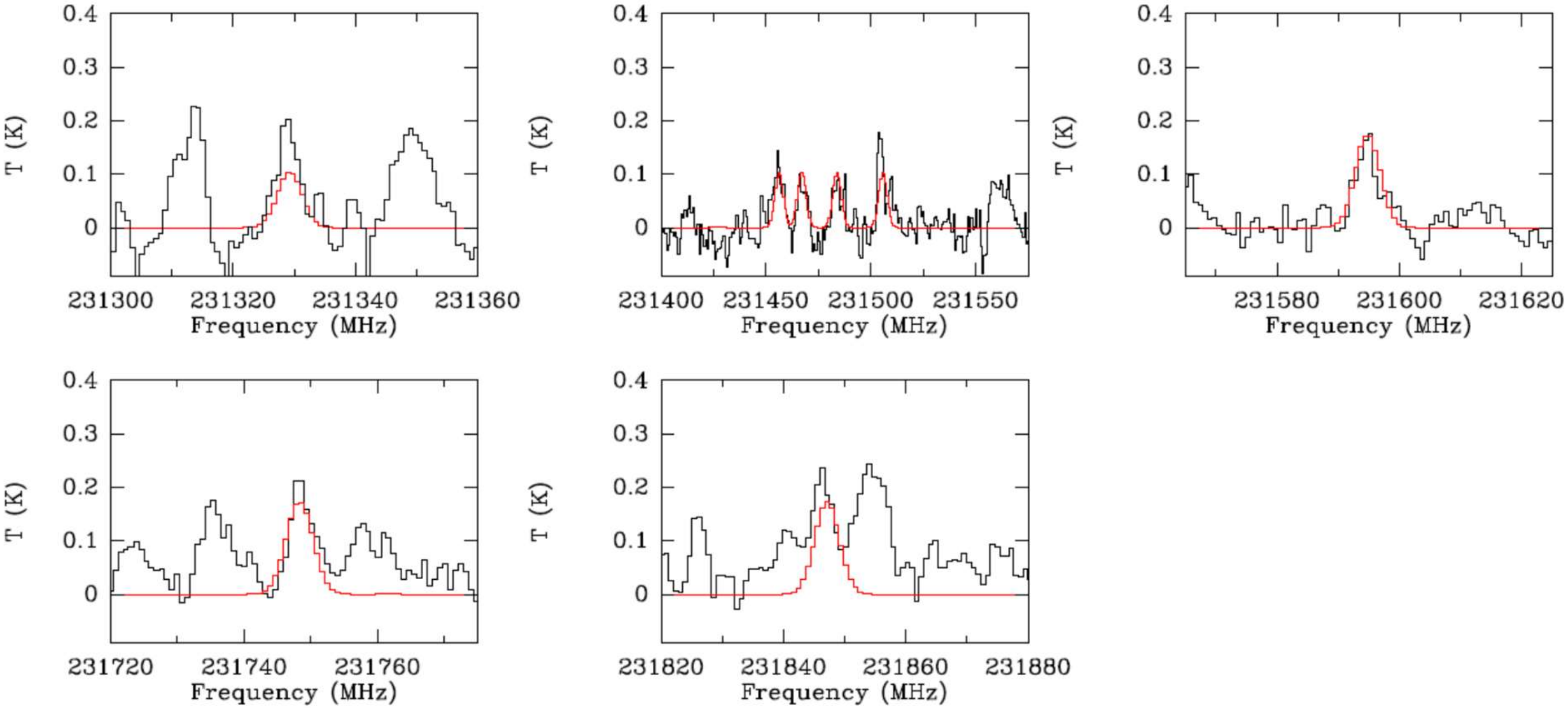

IRDC-C9MAIN
Core
Tail
J2000 Declination
J2000 Right Ascension
(Jy/beam)
CORE
Tail
OCS 19−18
^{13}CS 5−4
CH_3OH
CH_3CH_2CN
CH_3CHO
CH_3CH_2CN
$^{33}SO_2$
$HCOOCH_3$
CH_3CH_2CN
$^{13}CH_3CN$ k−ladder
CH_3CH_2CN, CH3OCH3 $^{33}SO_2$?
SO_2, C_2H_5OH
Temperature (K)
Frequency (MHz)

Sulphur Bearing

COMs

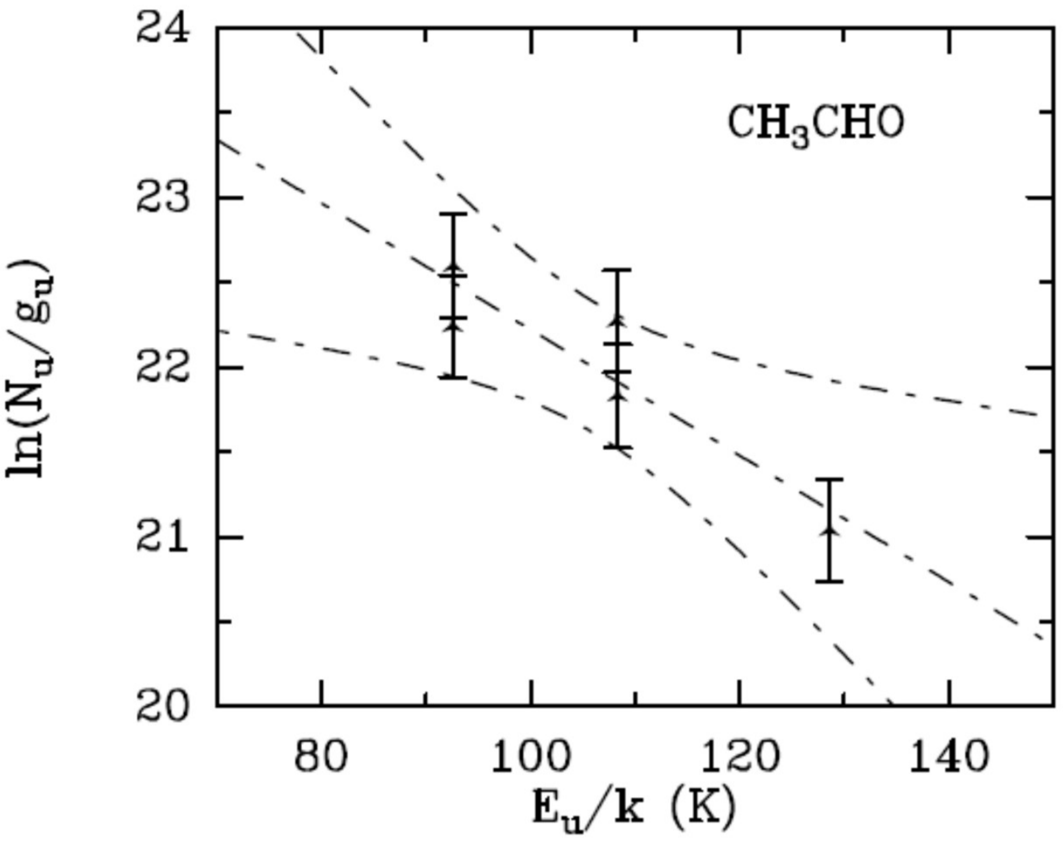


CH_3CHO



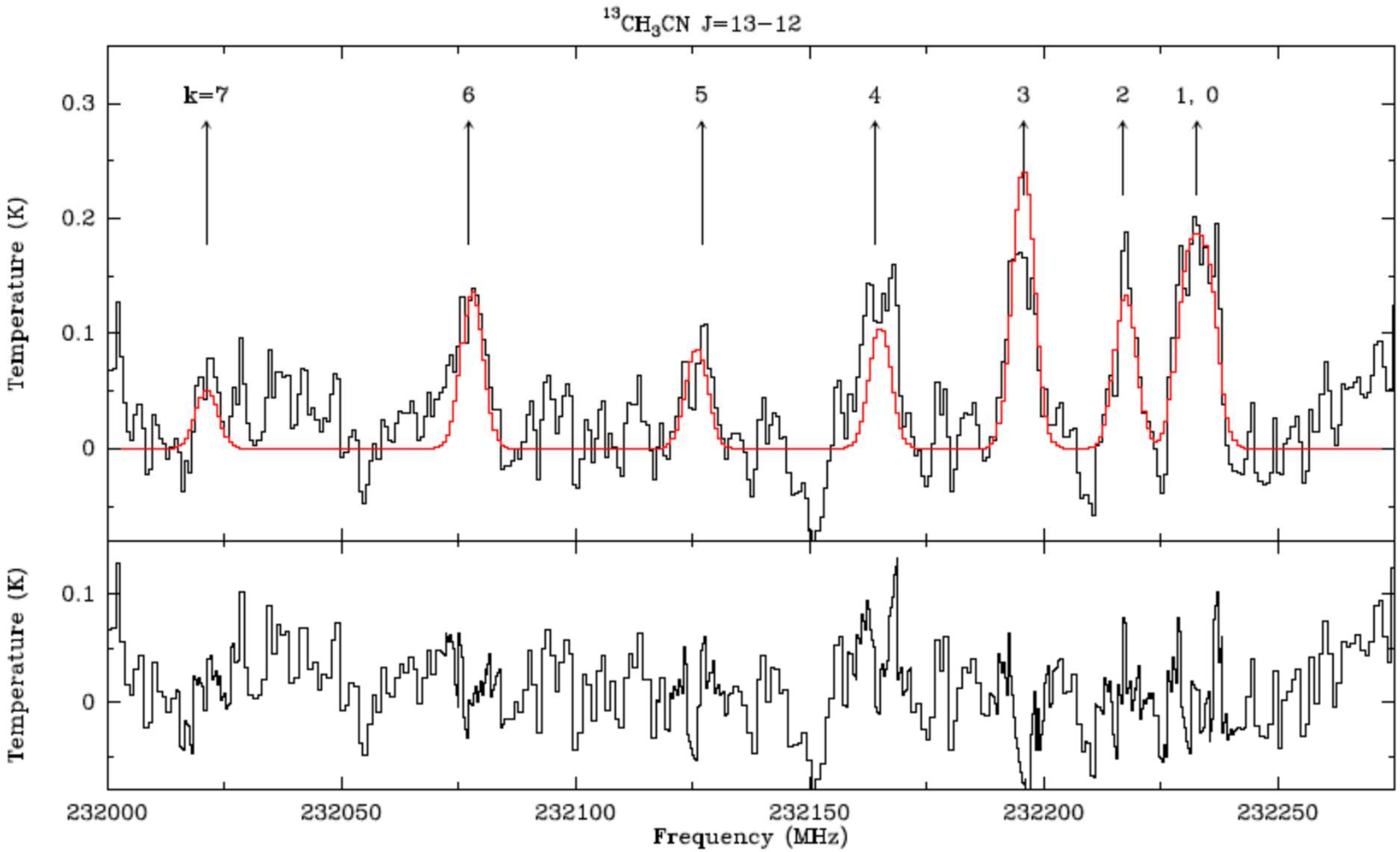
Red Line – Best Model for the LTE solution

Rotational Diagram

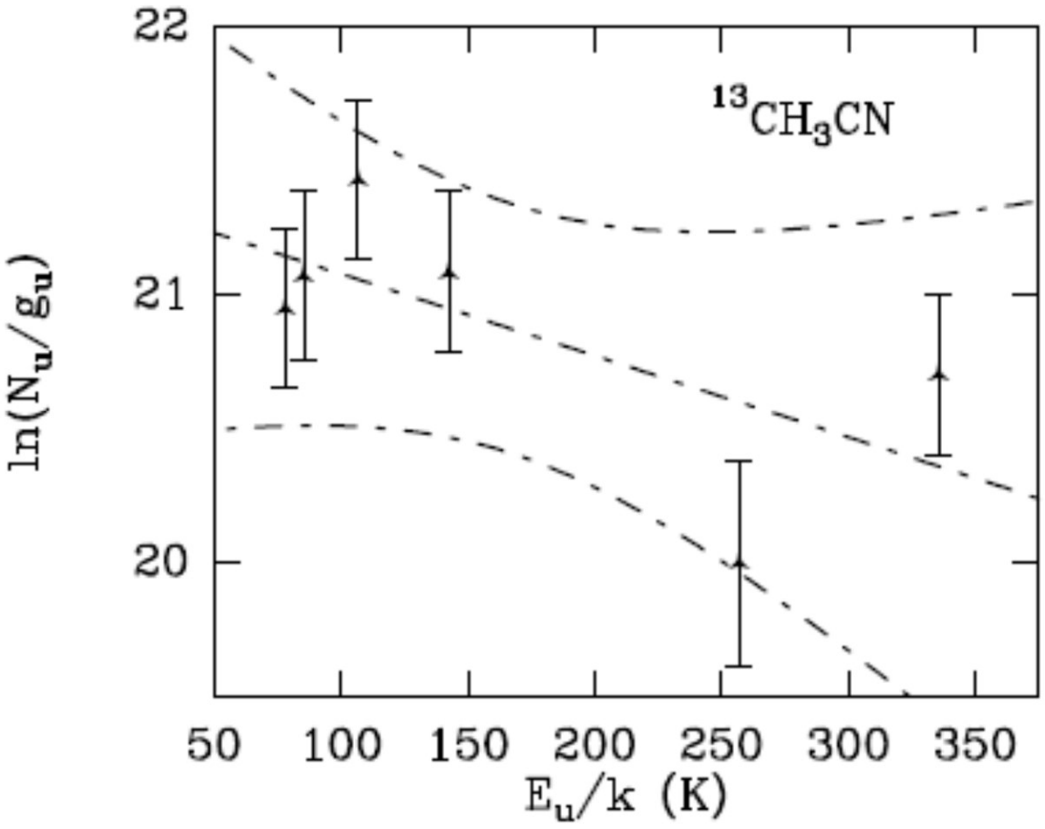


T = 27 ±5 K

$^{13}CH_3CN$ K-ladder



Rotational Diagram



T = 500 K

And Then?

- Cold Component

- Warm Component

Dust Emission

Gray Body

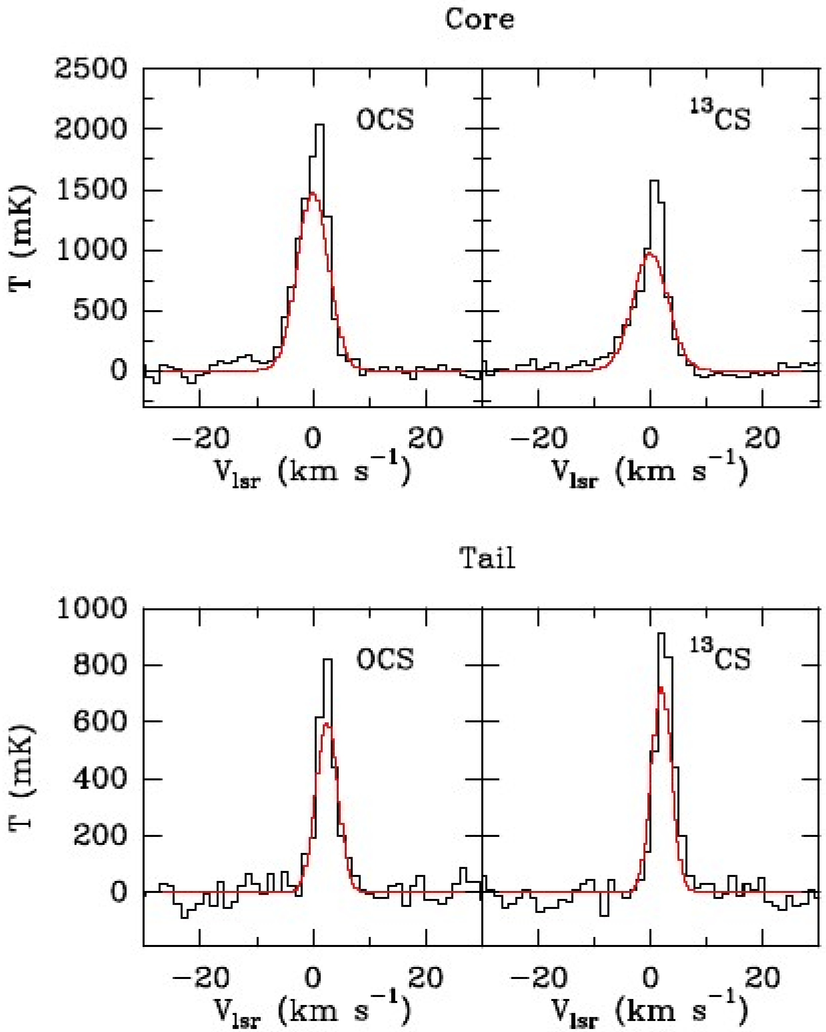
$$S_\nu = \frac{M\,\kappa_0}{d^2}\left(\frac{\nu}{\nu_0}\right)^{\beta} B_\nu(T)\ ,$$

Elia et al. 2010,2018
K = 0.005cm^{2}g^{-1}
B = 1

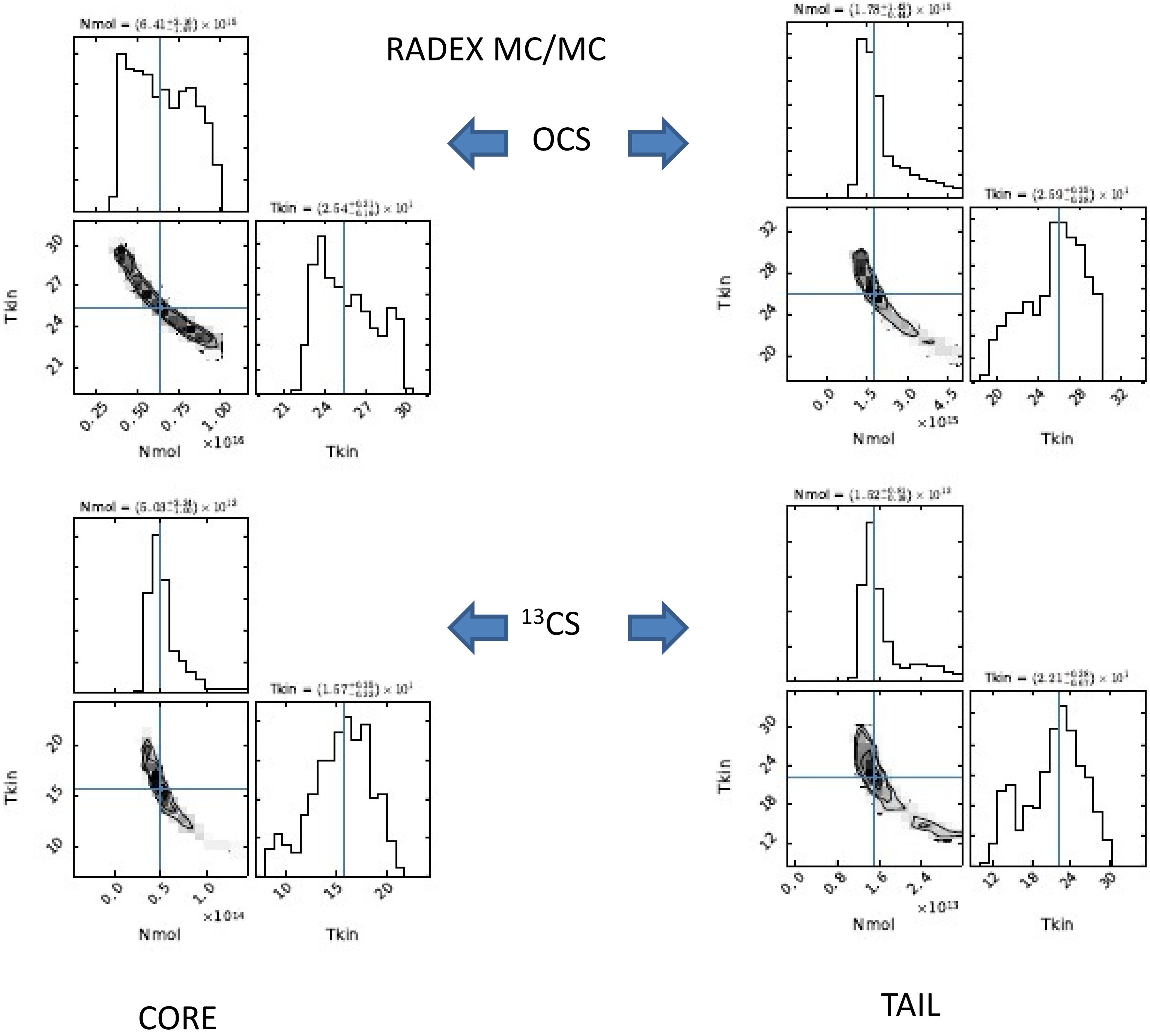
For a typical mass

T = 29K – Core
T = 16K – Tail

OCS and CS

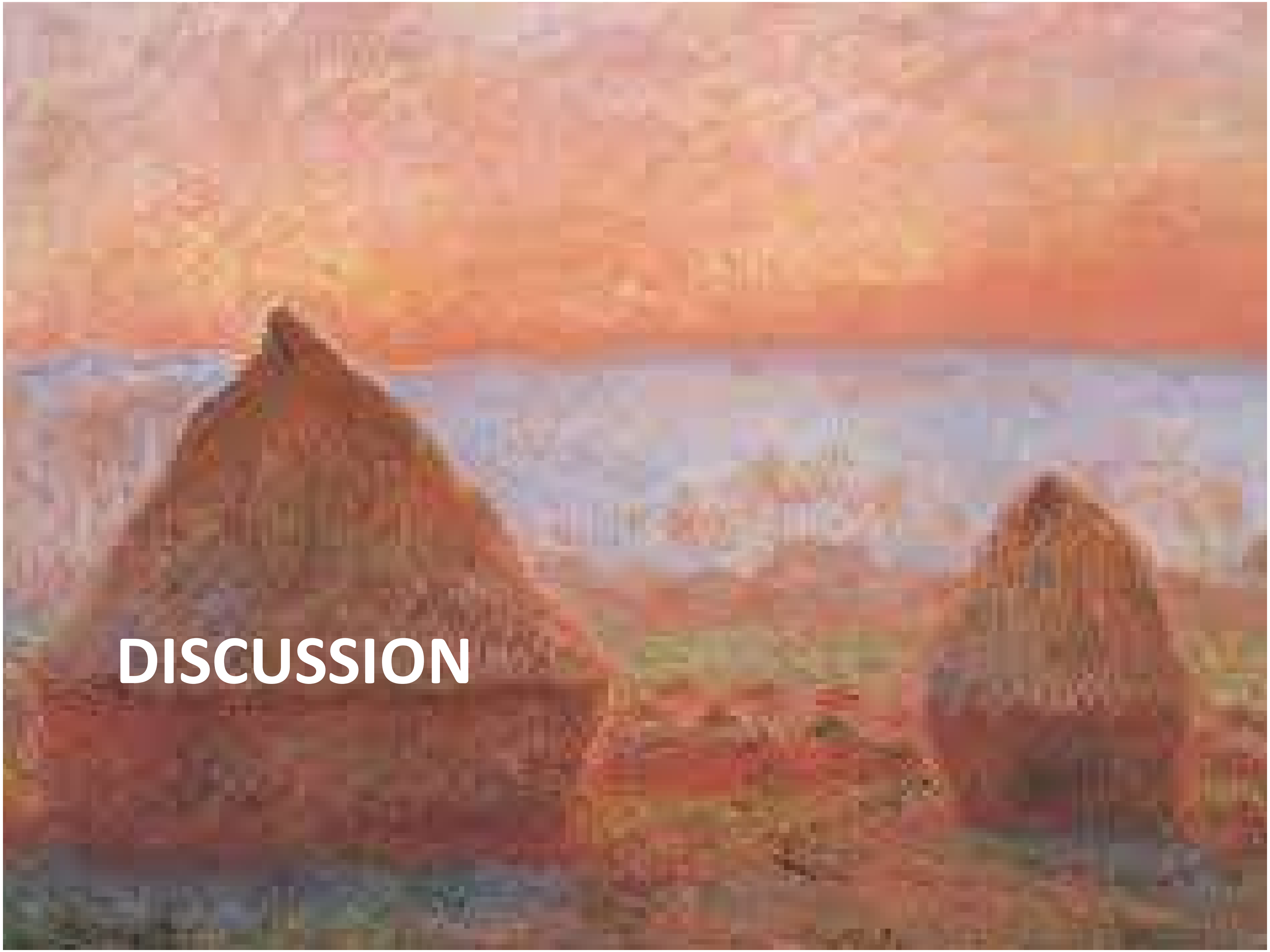


Core
2500
2000
1500
1000
500
0
T (mK)
OCS
^{13}CS
−20
0
20
V_{lsr} (km s^{-1})
Tail
1000
800
600
400
200
0
T (mK)
OCS
^{13}CS
−20
0
20
V_{lsr} (km s^{-1})


RADEX MC/MC
OCS
^{13}CS
CORE
TAIL
Nmol
Tkin

RADEX/MCMC

- Best solution
  - 25 K
- However, normally, OCS and ^{13}CS traces a warmer gas
- Temperature near 200K also seems to be a good fit
  - Are we looking a local minimum?


DISCUSSION

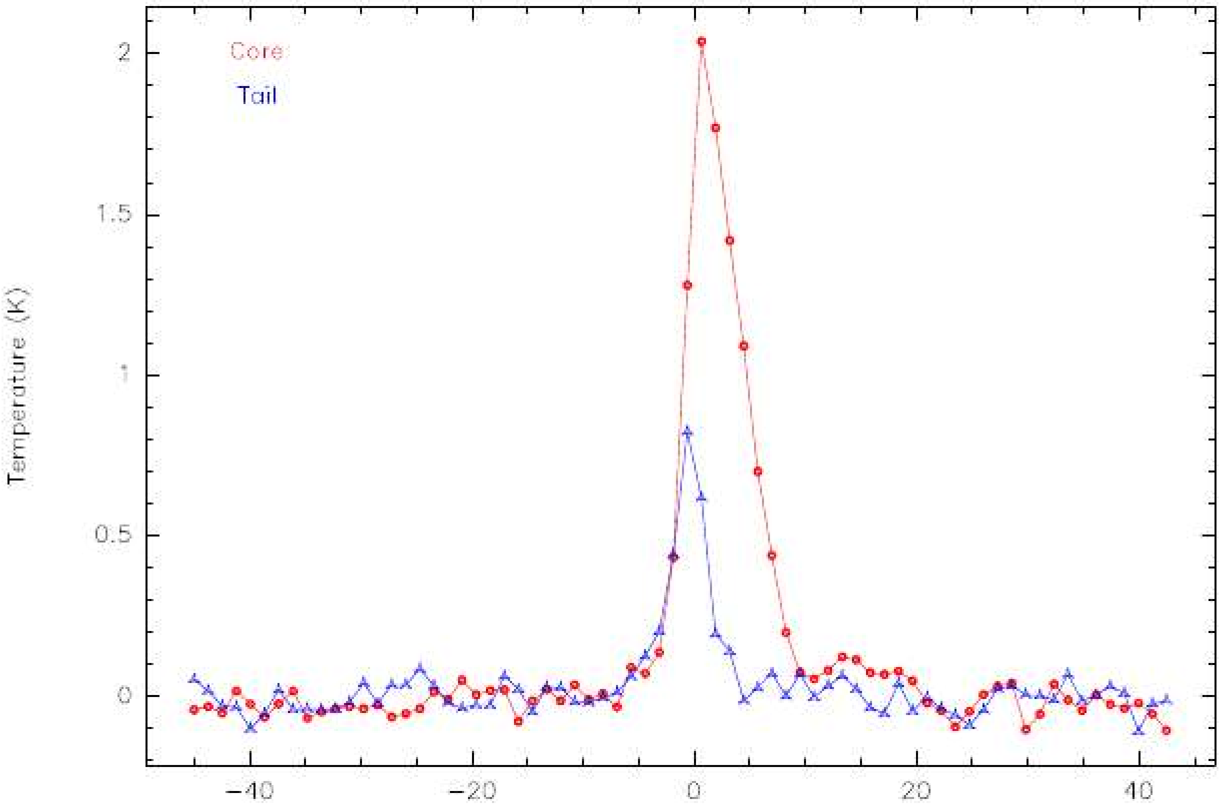
HOT/COLD

- IRDC-C9MAIN
  - It has cold and warm tracers.
- It is possible to have a proto-star borning inside (see Kong et al. 2017)
- It is a objecto to look carefully

CORE and TAIL

- What are the difference between them?
- Are they connected?

Same Velocity



OCS

Nautilus (Ruaud et al. 2015, 2016)

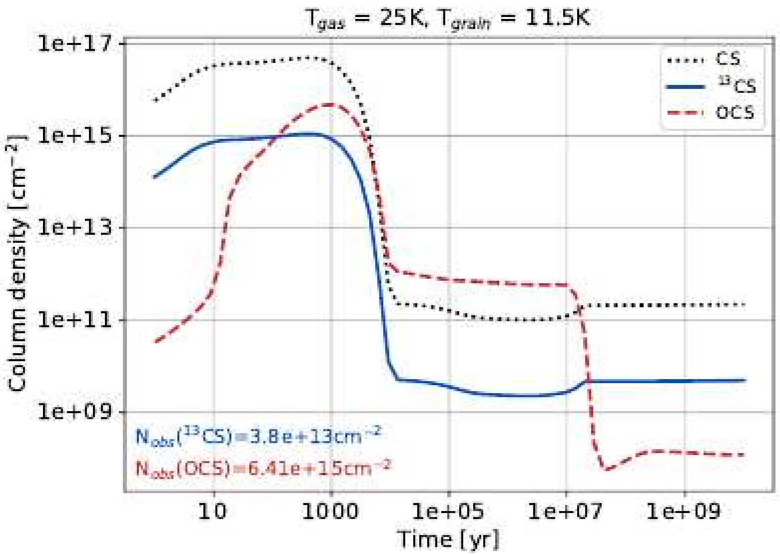
- a three-phase time-dependant simulation of the chemistry (gas + grain mantle + surface)
- includes chemical reactions in both gas and solid phases
- Our simulations are zero-dimensional
  * physical conditions are uniform
- No structure evolution

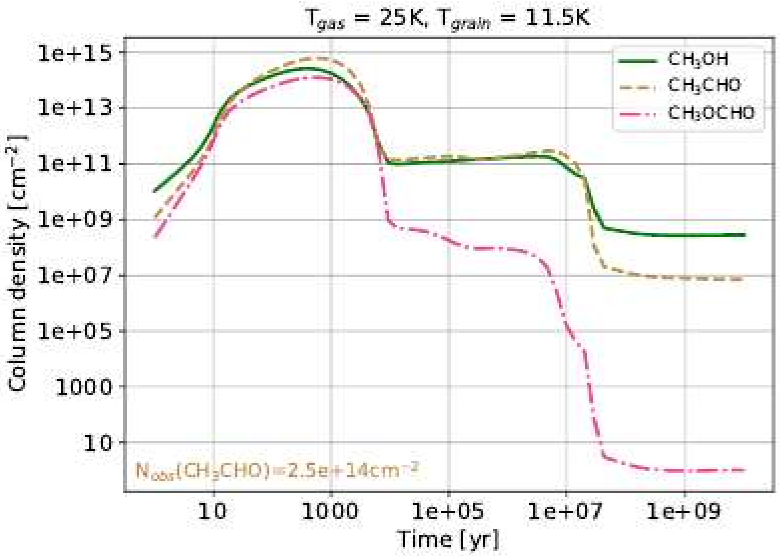
Cloud initial elemental abundances (Vidal & Wakelam 2018)

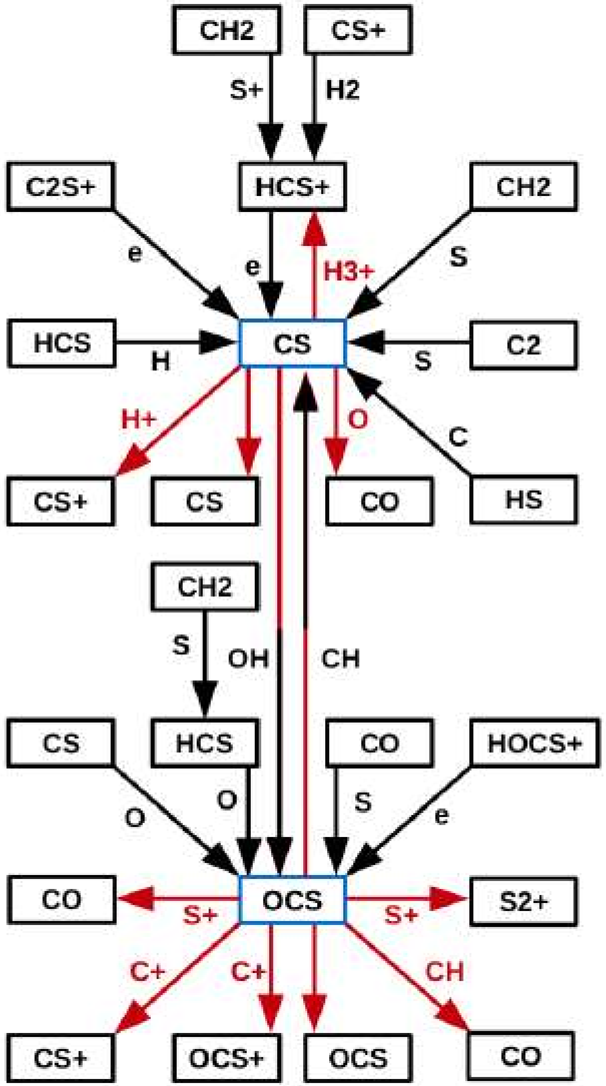
Elemento	**n_i/n_H[a]**	**Elemento**	**n_i/n_H[a]**
H_2	0.5	He	9.0(-2)
N	6.2(-5)	O	2.4(-4)
C+	1.7(-4)	S+	1.5(-5)
Fe+	3.0(-9)	Si+	8.0(-9)
Na+	2.0(-9)	Mg+	7.0(-9)
Cl+	1.0(-9)	P+	2.0(-10)
F	6.7(-9)		

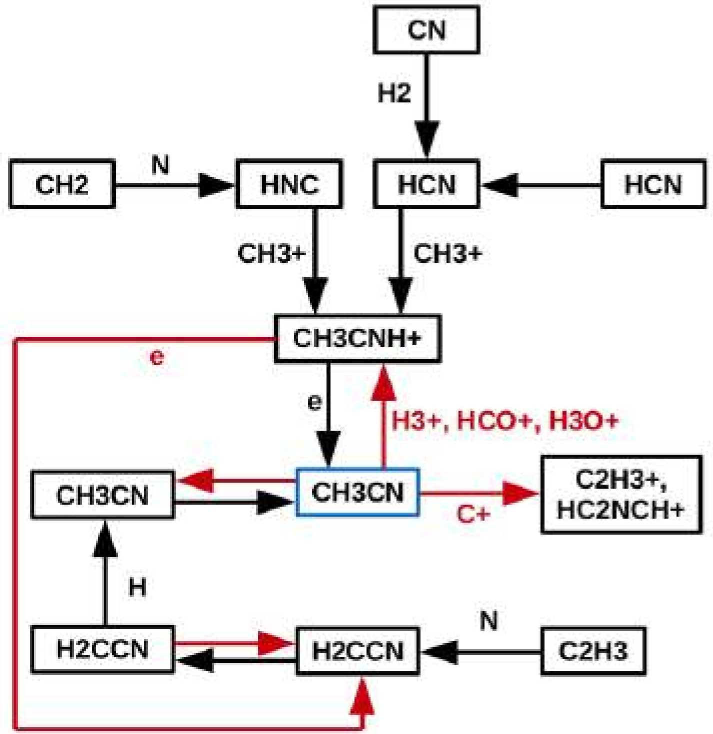
Nautilus Model

Ruaud et al. 2015

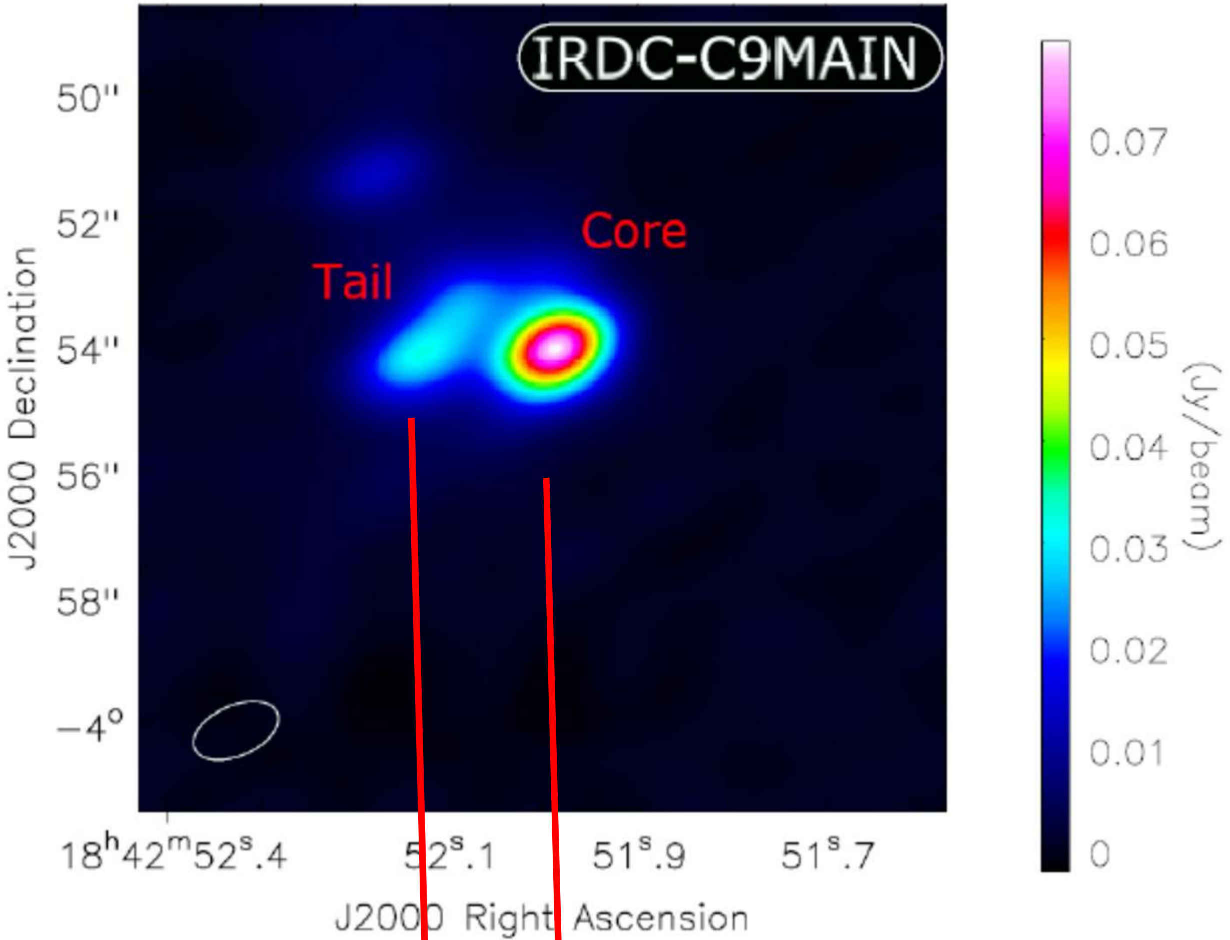





CH2
CS+
S+
H2
C2S+
HCS+
CH2
e
e
H3+
S
HCS
CS
C2
H
S
H+
O
C
CS+
CS
CO
HS
CH2
S
OH
CH
CS
HCS
CO
HOCS+
O
O
S
e
CO
OCS
S2+
S+
S+
C+
C+
CH
CS+
OCS+
OCS
CO


CN
H2
CH2
N
HNC
HCN
HCN
CH3+
CH3+
CH3CNH+
e
e
H3+, HCO+, H3O+
CH3CN
CH3CN
C2H3+,
HC2NCH+
C+
H
N
H2CCN
H2CCN
C2H3

Contraction



Earlier
Stage
0

Later Evolutionary
Stage0

CONCLUSION

- IRDC-C9 – Many Other sources
- IRDC-C9A – Starless core (Kong et al. 2017)
- IRDC-C9Main
  - Core (Cold and warm component)
  - Tail
- Core – later evolutionary stage