Thesis (Phase 2) Mid Term

presented by :

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Under the guidance of

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Spectroscopic Modelling of Cold ATLASGAL Dust Clumps

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Project

- ***AIM :*** To study *physical properties & kinematics* of dense clumps selected from ATLASGAL 870 µm survey.

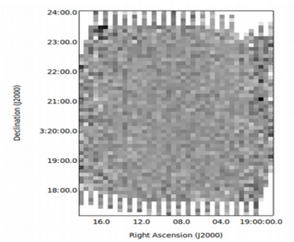
S.N	Name	α (J2000) (h,m,s)	δ (J2000) (º ' ")	V_{LSR} (km/s)
1	AG 36.826-00.039	18:58:41.31	03:26:49.60	60.2
2	AG 36.794-00.204	18:59:13.11	03:20:36.80	78.1
3	AG 36.899-00.409	19:00:08.48	03:20:35.70	80
4	AG 41.077-00.124	19:06:49.15	07:11:14.10	63.3
5	AG 41.049-00.247	19:07:12.48	07:06:19.30	66
6	AG 46.174-00.524	19:17:49.80	11:31:07.50	50.1
7	AG 46.426-00.237	19:17:16.48	11:52:30.50	52.3
8	AG 47.031-00.244	19:16:41.18	12:38:05.90	54.9
9	AG 47.051-00.251	19:16:42.03	12:39:20.70	56
10	AG49.253-00.41	19:23:21.22	14:17:22.10	66.1

- Sources were mapped in multiple molecules such as ^{12}CO, ^{13}CO, $C^{18}O$ & high gas tracers HCO^+, $H^{13}CO^+$, HCN, CH_3OH.

Schuller et al., 2009

Thesis Phase I

Low dense gas tracers : CO & it isotopologues



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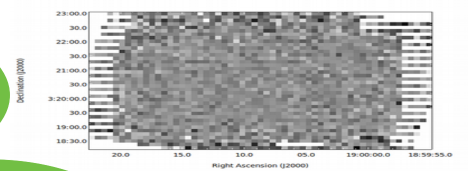
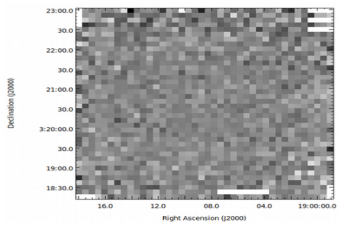
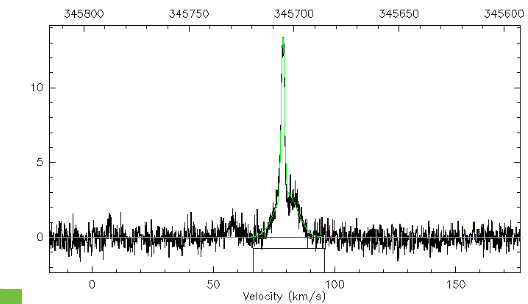
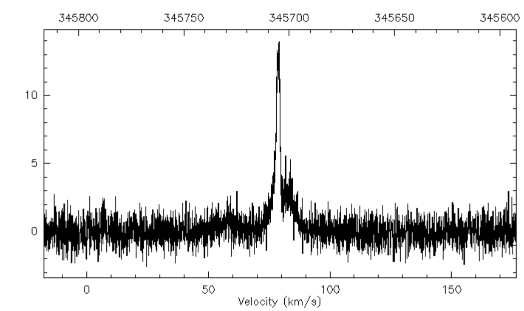
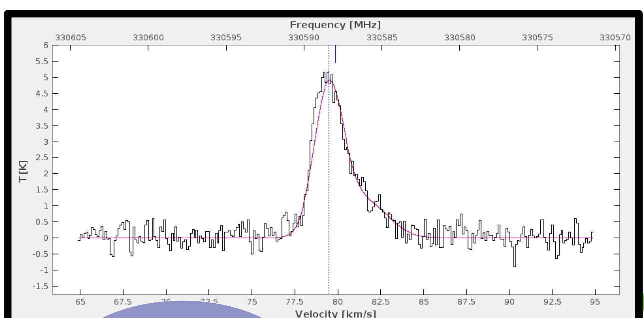






Smoothing & Fitting



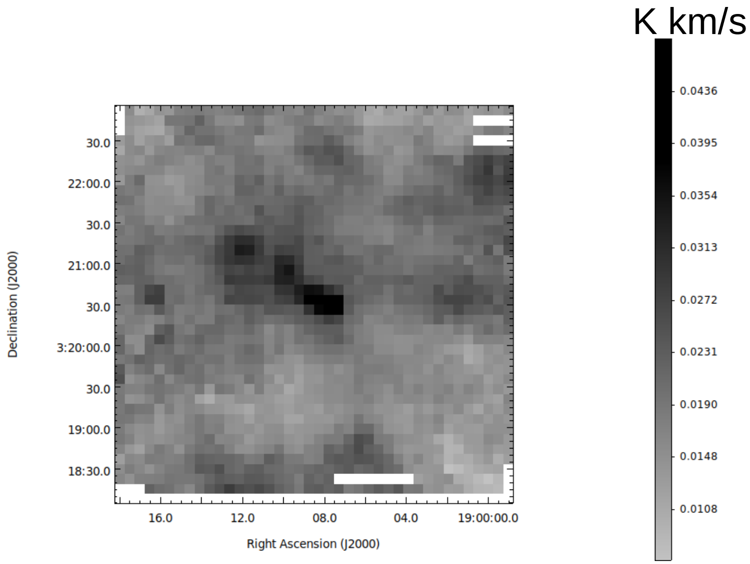


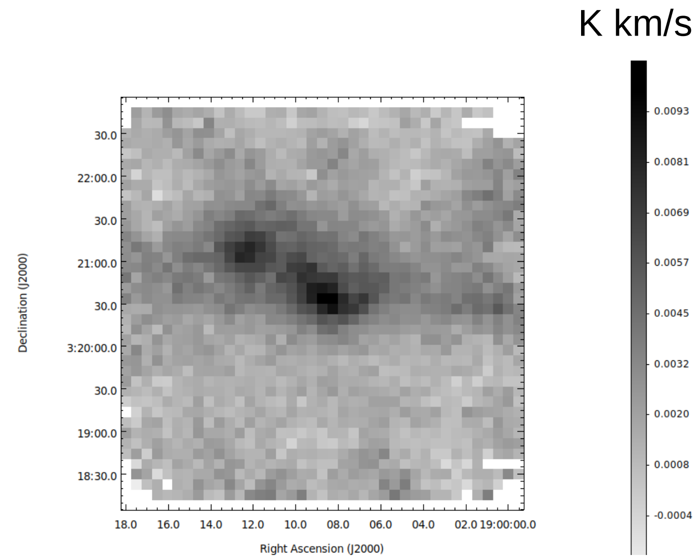
Modelling in CASSIS

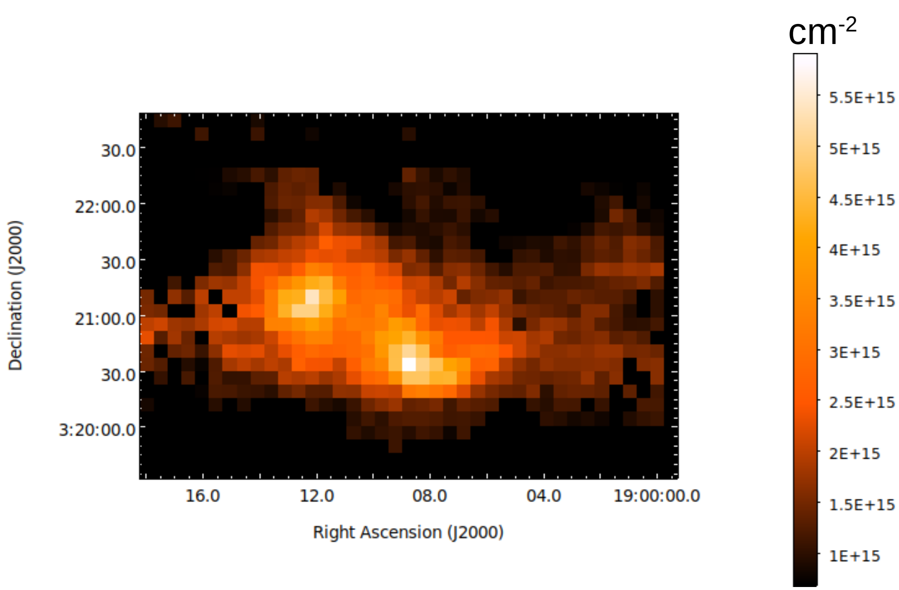
LTE & non-LTE

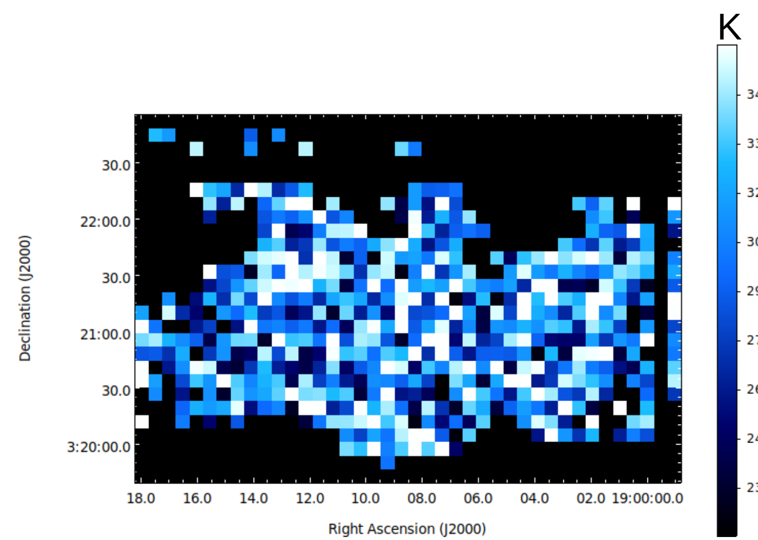
Thesis Phase I

Low dense gas tracers : CO & it isotopologues



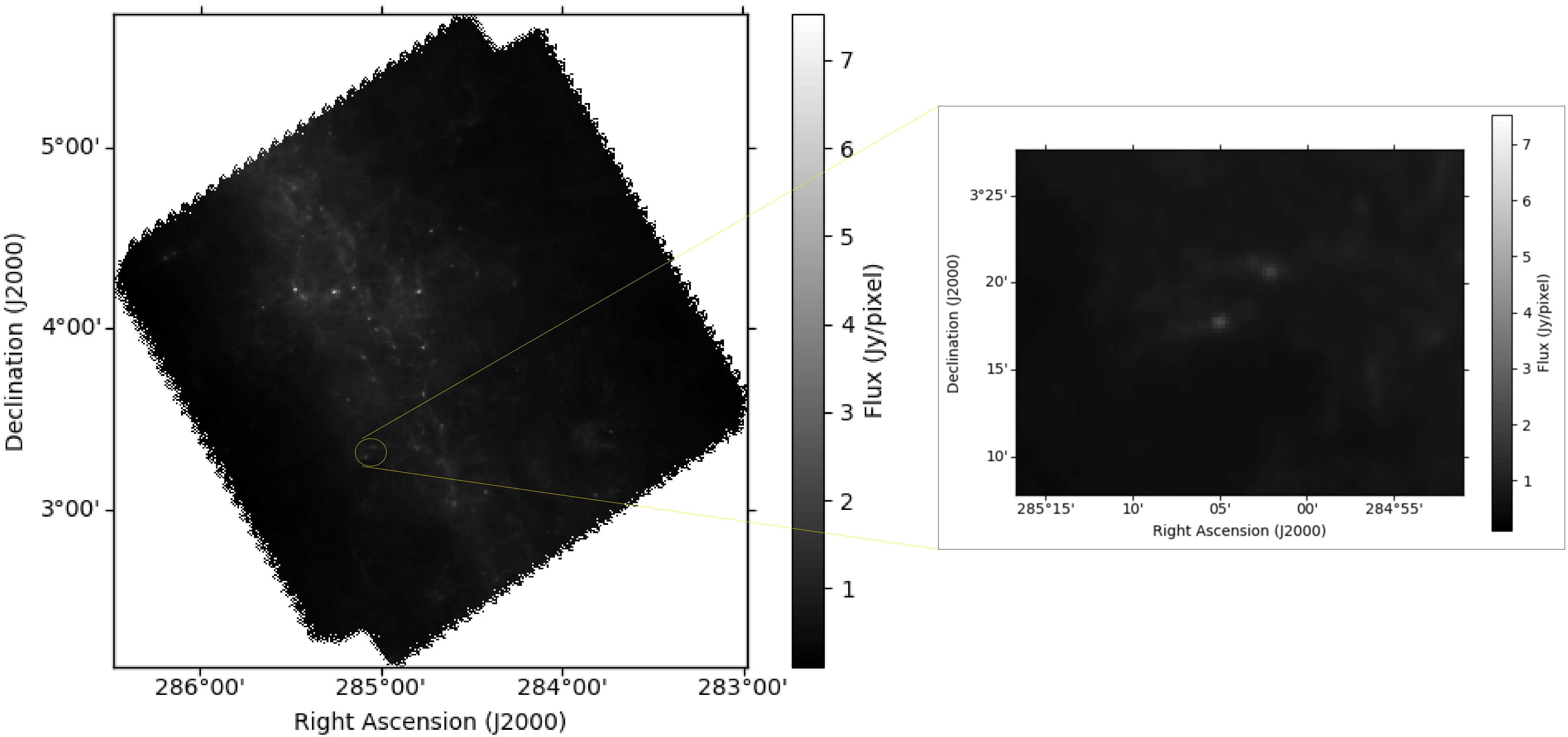






Characterization of Dust Emission

Analysis in HIPE

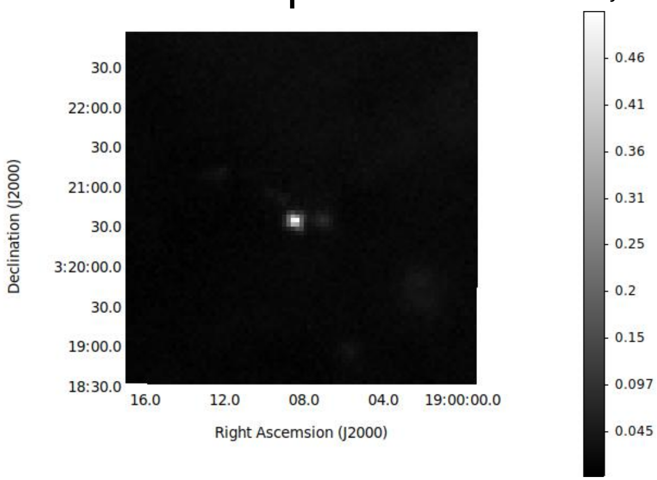


Molinari et al., 2010

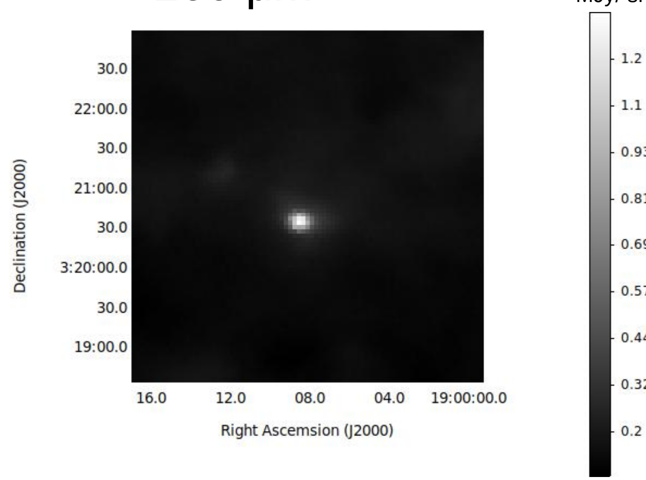
Characterization of Dust Emission

Analysis in HIPE

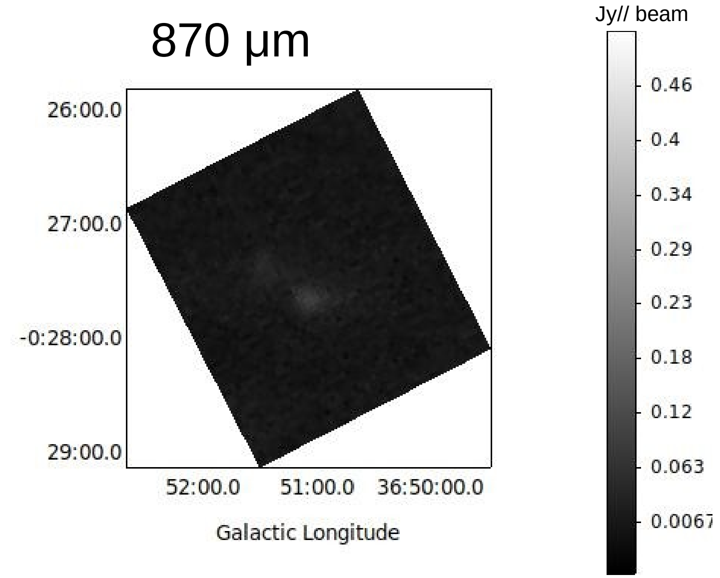
70 µm



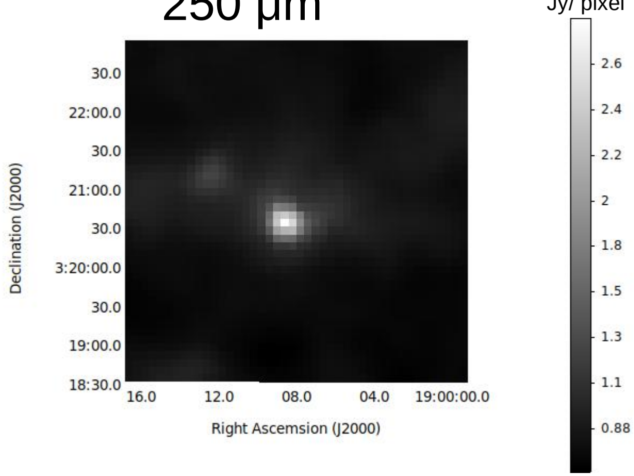
160 µm



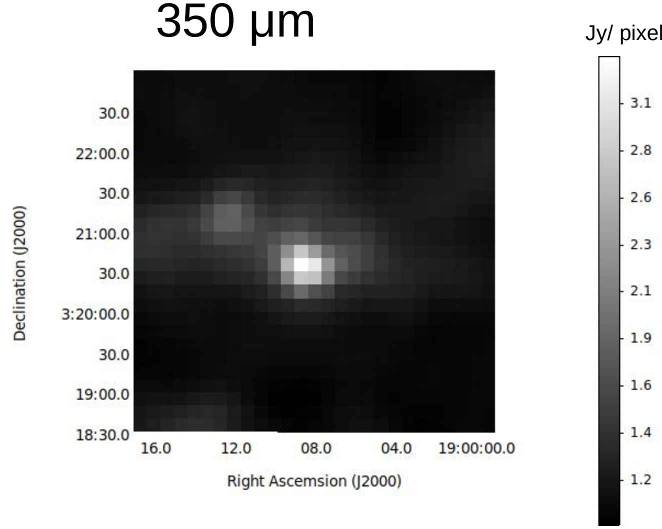
870 µm



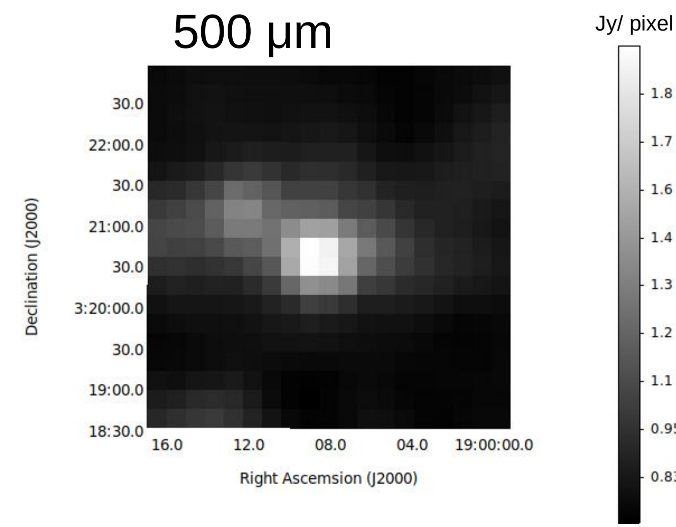
250 µm



350 µm



500 µm



Characterization of Dust Emission

Analysis in HIPE

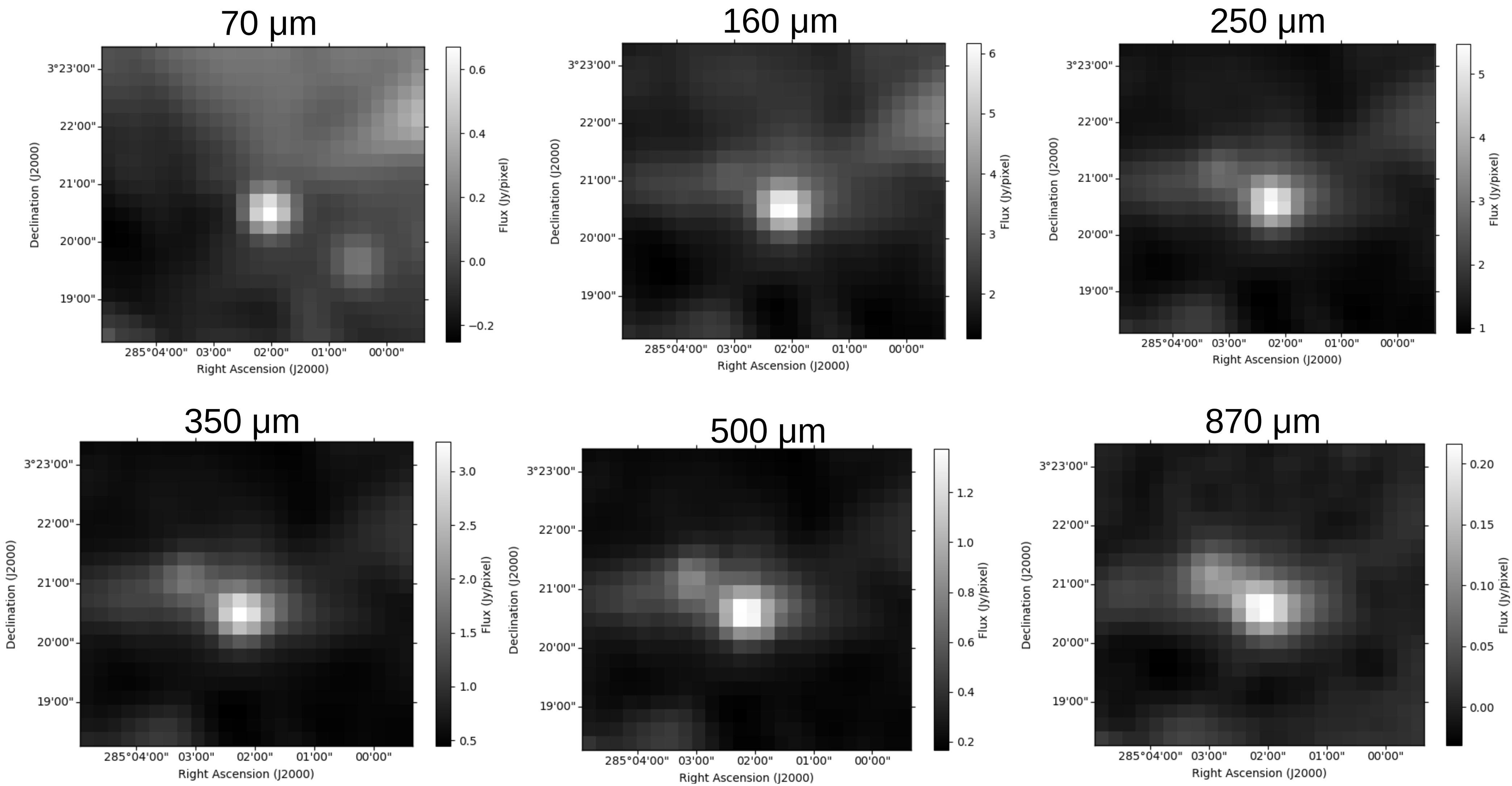
		Band (µm)	Resolution (")	Pixel Size (")	
HI-GAL	SPIRE	70	5.7	3.2	MJy/sr
		160	11.6	3.2	
		250	18.2	3	
	PACS	350	25.3	5	Jy/pixel
		500	36.9	7	
ATLASGAL		870	18.2	6	Jy/beam

Jy/pixel

Convolution
(500 µm)

Characterization of Dust Emission

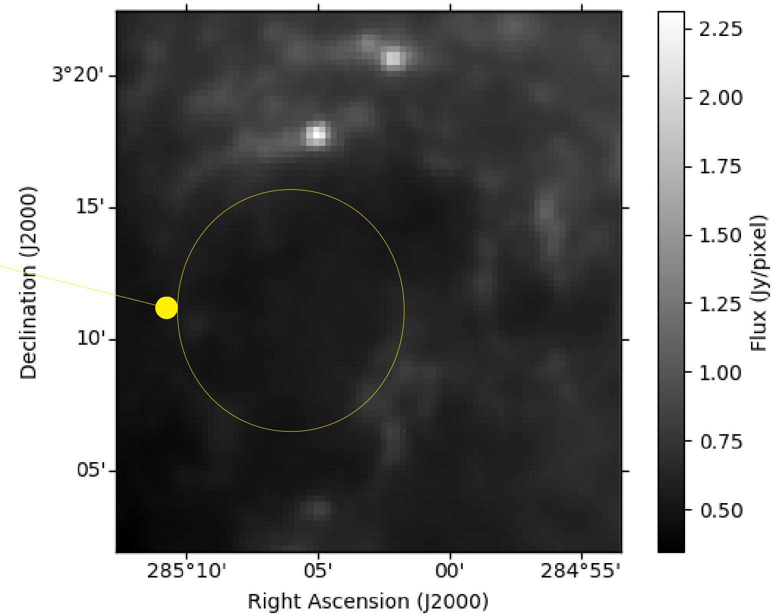
Analysis in HIPE



Characterization of Dust Emission

SED Model

- *Background Subtraction*



- *Modified Black body*

Ω	$(\pi\theta^2_{FWHM})$ /4log2
μ_{H2}	2.8
R	100
κ_0	5.04 cm^2/g
β	2
λ_0	500 µm

$$S(\nu) - I_{bkg}(\nu) = \Omega\, B(\nu, T_d)(1 - e^{-\tau})$$

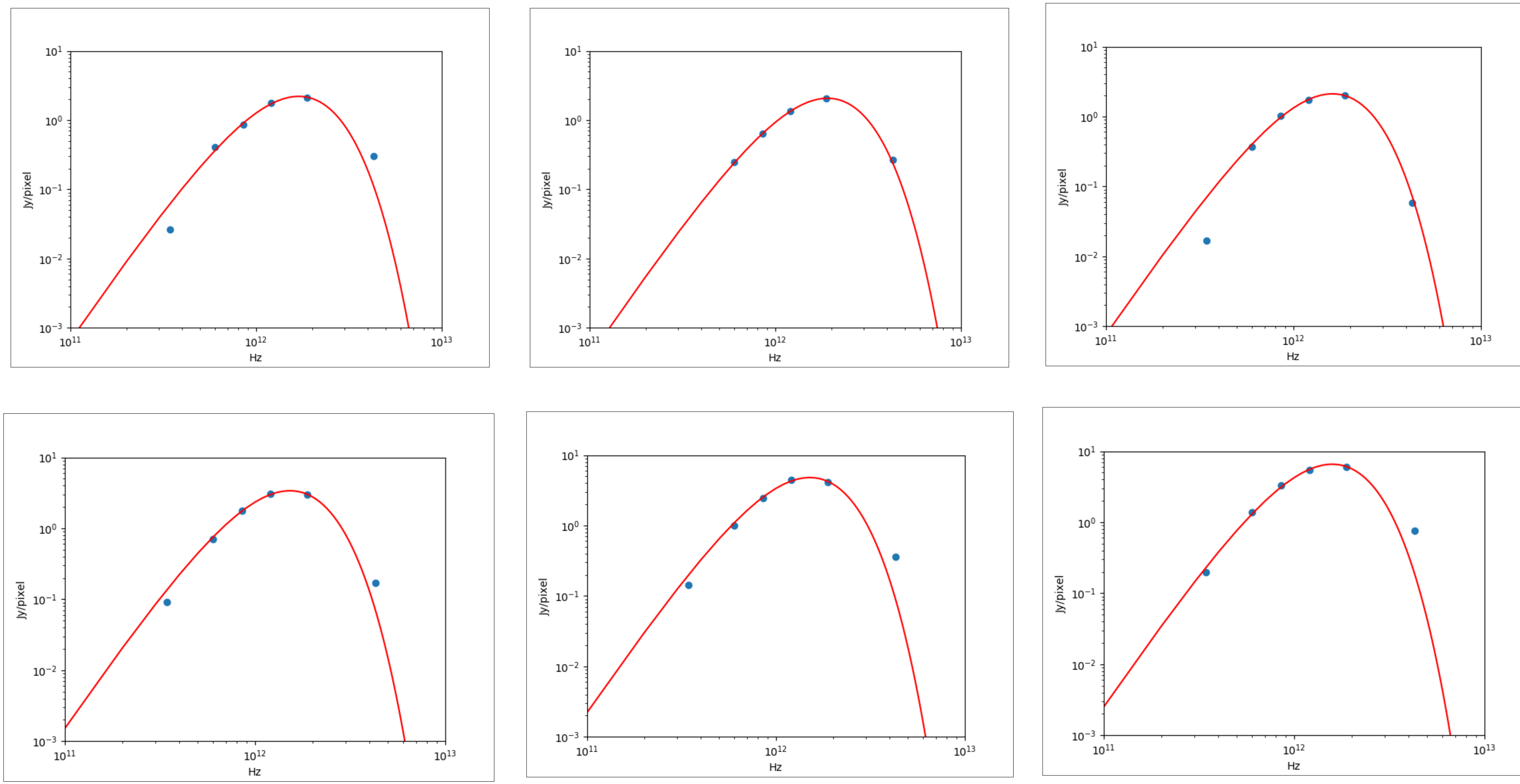
$$\tau_\nu = \mu_{H2}\, m_H\, \kappa_\nu\, N(H_2)/R$$

$$\kappa_\nu = \kappa_0\, (\nu/\, \nu_0)^\beta$$

Kauffmann et al., 2008 ; Ossenkopf and Henning, 1994 ; Hildebrand, 1983

Characterization of Dust Emission

SED Fitting

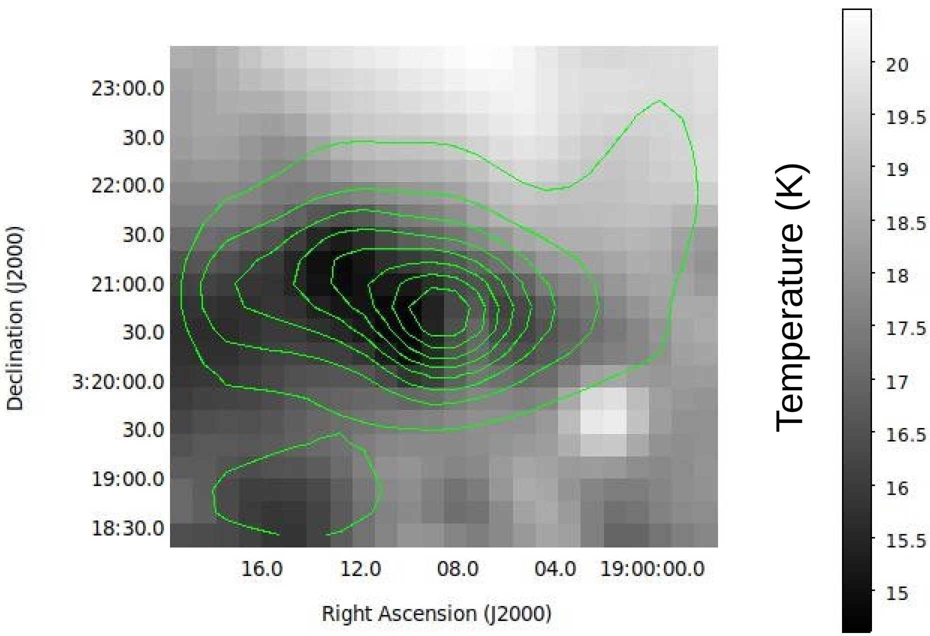


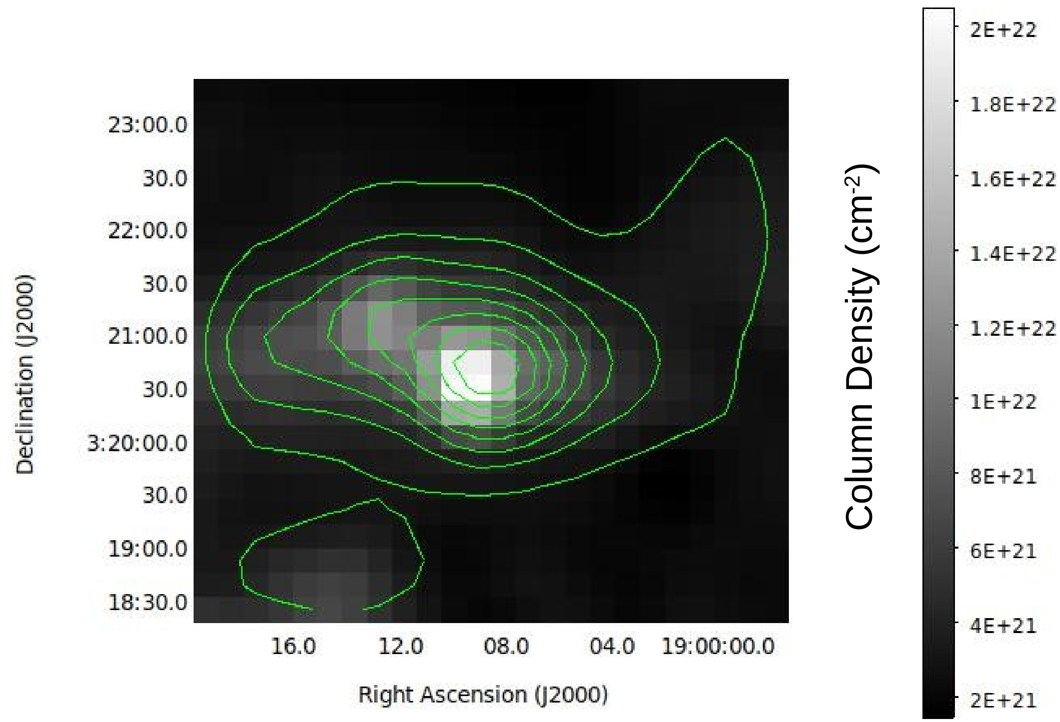
Flux (Jy/ pixel)

FREQUENCY (Hz)

Characterization of Dust Emission

SED Fitting Results





T_{dust} ranges from 15-20 K

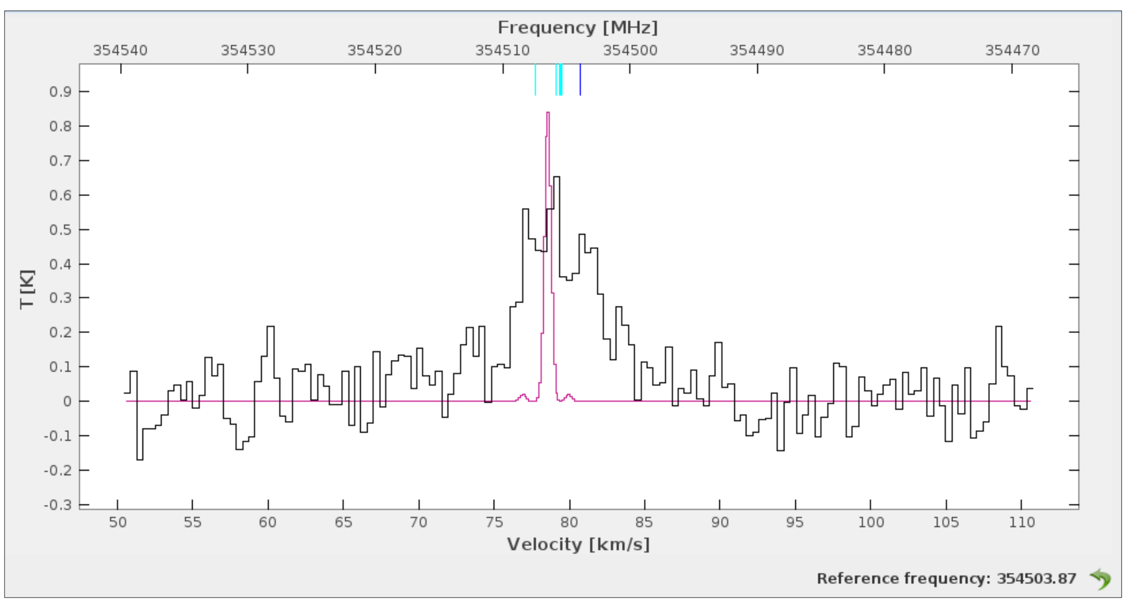
$N(H_2)$ ranges from $7{\times}10^{21}$ - $2{\times}10^{22}$ cm^{-2}

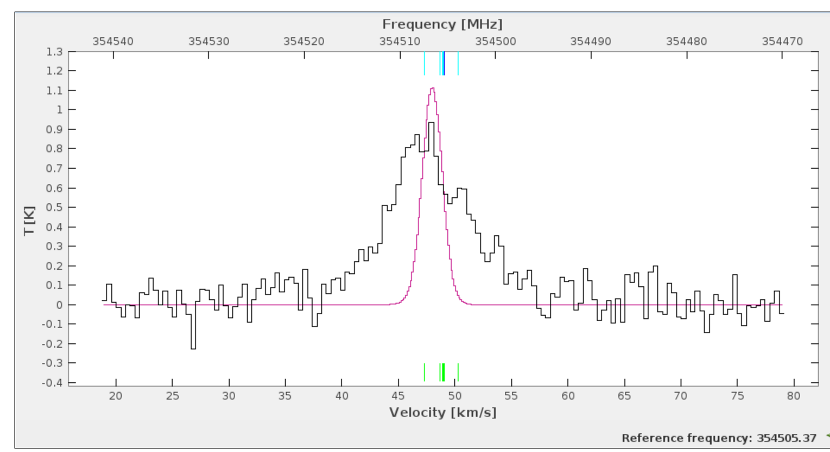
Core Density Gas Tracers

HCN : Hyperfine Fitting

- HCN (J=4-3) : $n_{crit} \sim 10^5$-10^6 cm^{-3}
- relatively abundant

J	F	J'	F'	Frequency (GHz)
4	4	3	4	354.503893
4	3	3	2	354.505316
4	5	3	4	354.505458
4	4	3	3	354.505503
4	3	3	4	354.505841
4	3	3	3	354.507447



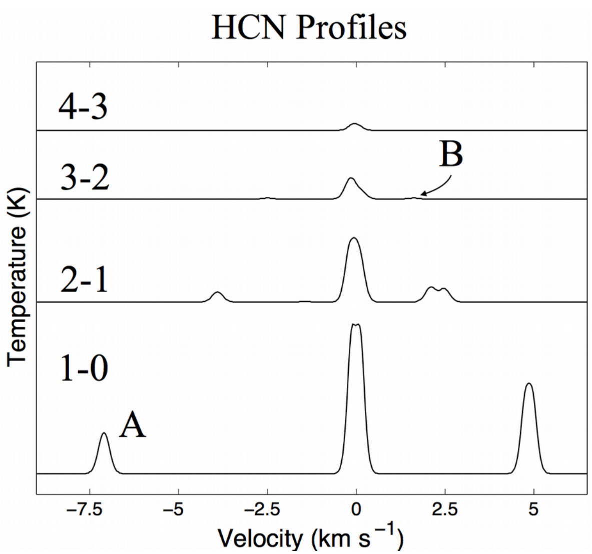


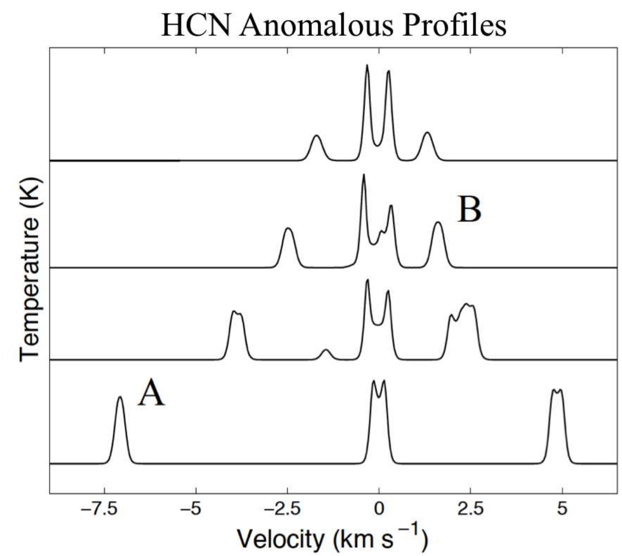
AG 41.05 -0.25

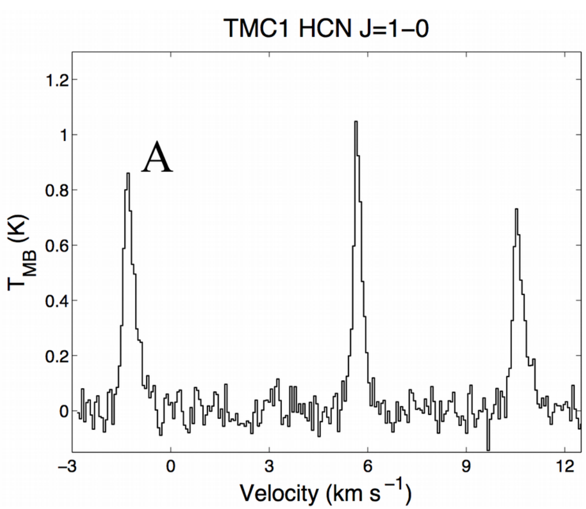
Mullins, 2016

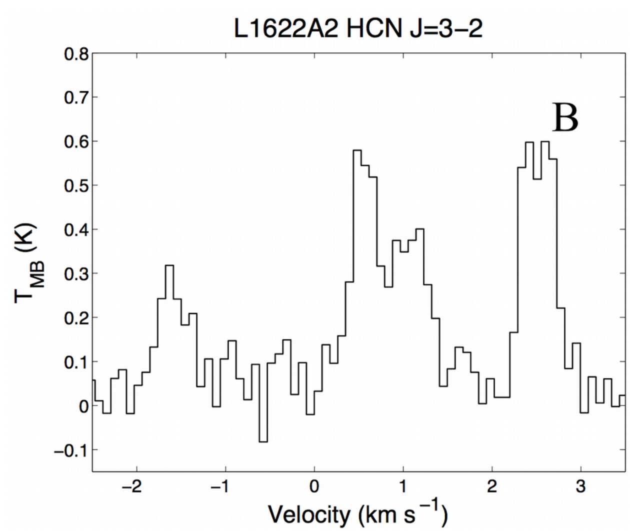
Core Density Gas Tracers

HCN : Hyperfine Fitting









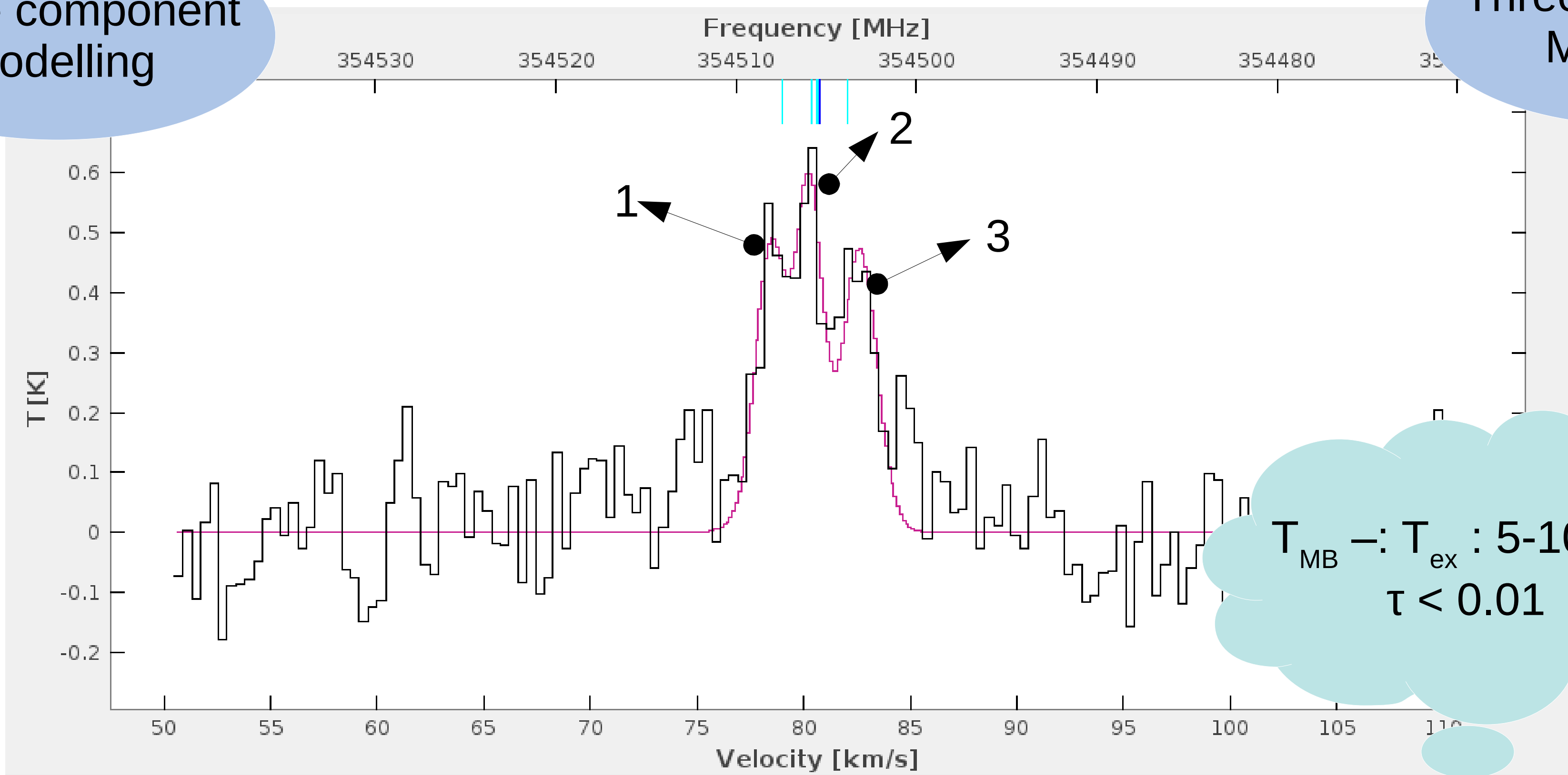
Mullins, 2016 ; Loughnane and Redman, 2012

Core Density Gas Tracers

HCN : LTE Hyperfine Fitting

Single component Modelling

Three component Modelling



T_{MB} –: T_{ex} : 5-10 K

$\tau < 0.01$

N(HCN) = 9×10^{11} cm^{-2}

X(HCN) = 4×10^{-11}

Very low

(1×10^{-9}, 9×10^{-9})

Why ??

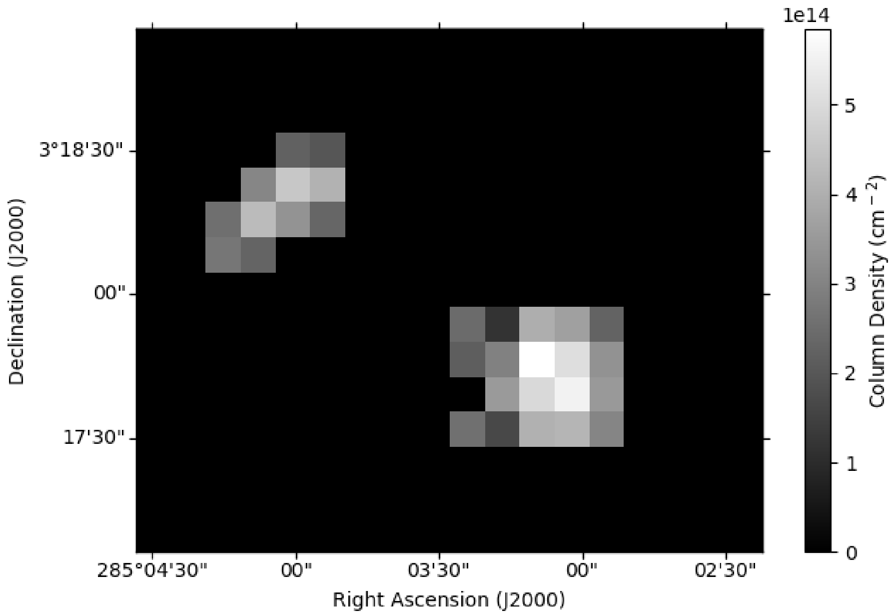
Core Density Gas Tracers

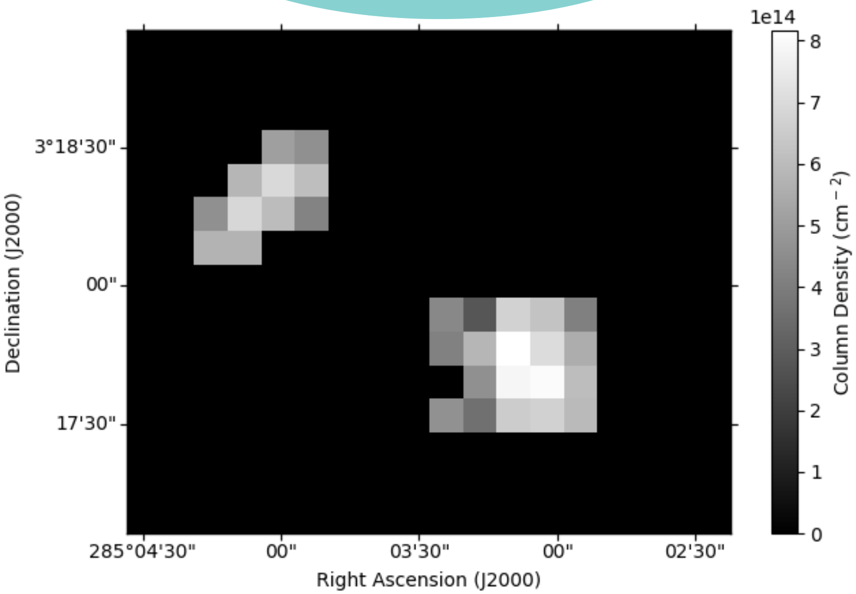
HCN : non-LTE Hyperfine Fitting

- Estimate of **$n(H_2) \sim 5\times10^4$ cm^{-3}** (R_{eff} = 0.62pc & $N(H_2)=2.1\times10^{22}$ cm^{-2})
- Temperature is **not** constrained.
- **^{13}CO** & **Dust** Temperature : 27 & 19 K.

$N(HCN) = 5\times10^{14}$ cm^{-2}

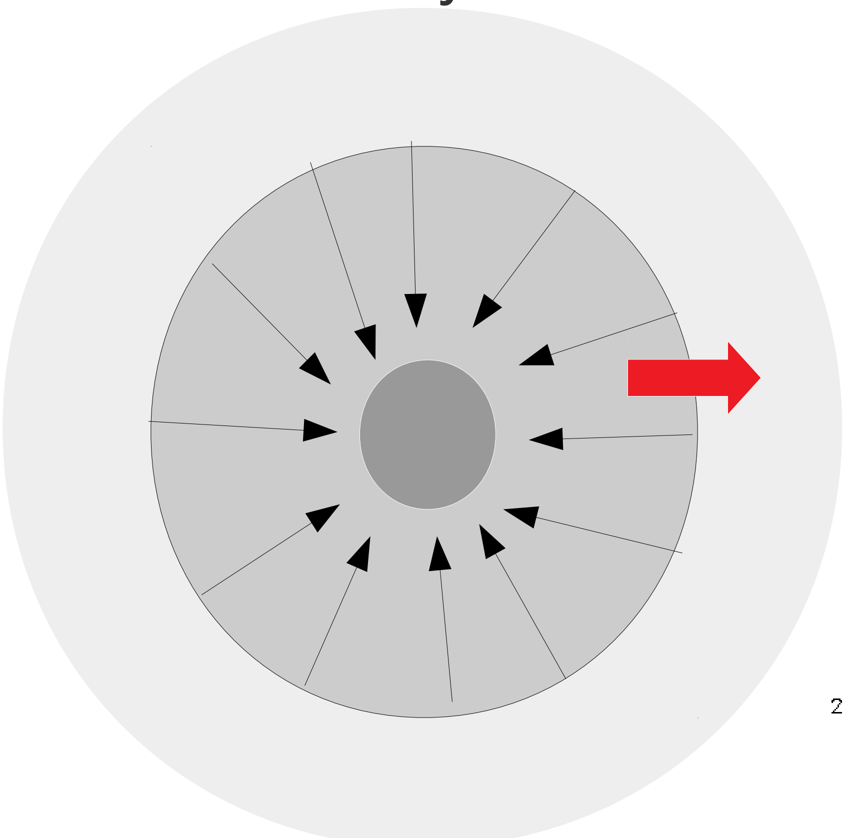
$X(HCN) = 4\times10^{-9}$

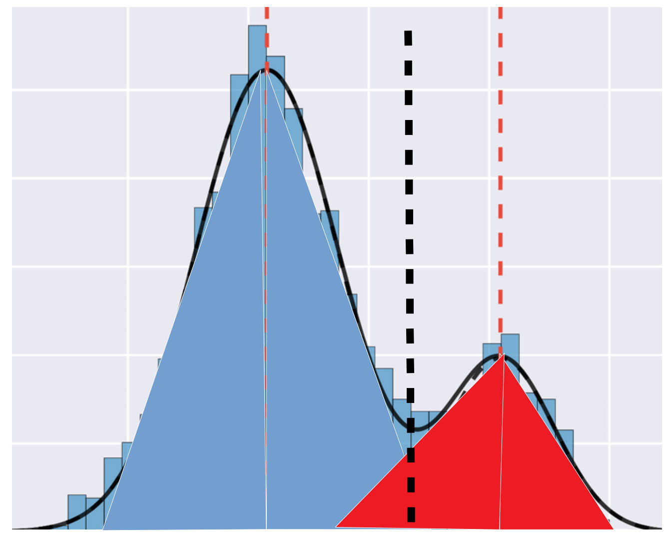


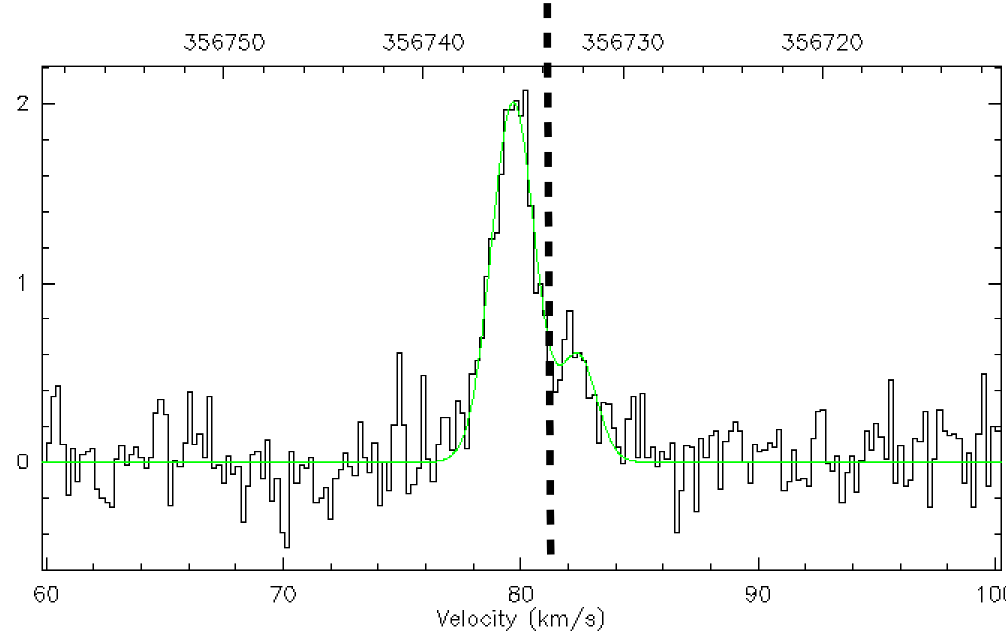


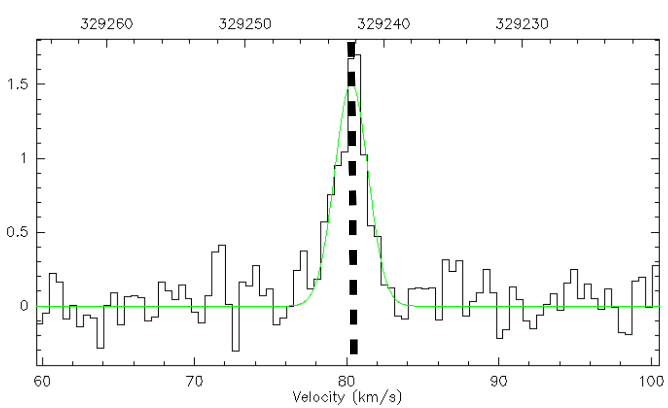
Core Density Gas Tracers

HCO^+ : The Infall Tracer



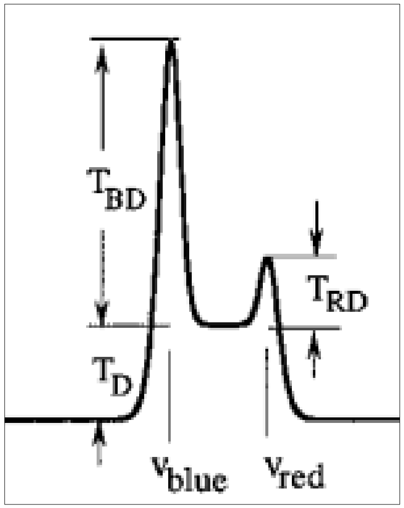






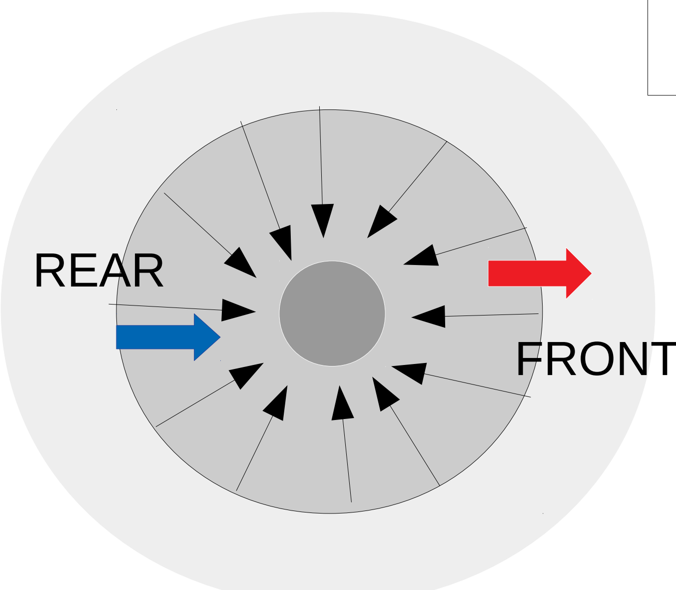
Core Density Gas Tracers

HCO^+ : Radiative Modelling



$$V_{in} = V_{thick} - V_{thin}$$ ~ 0.5 – 0.75 km/s

$$V_{in} \approx \frac{\sigma^2}{v_{red} - v_{blue}} \ln\left(\frac{1 + eT_{BD}/T_D}{1 + eT_{RD}/T_D}\right)$$ ~ 1.12 km/s

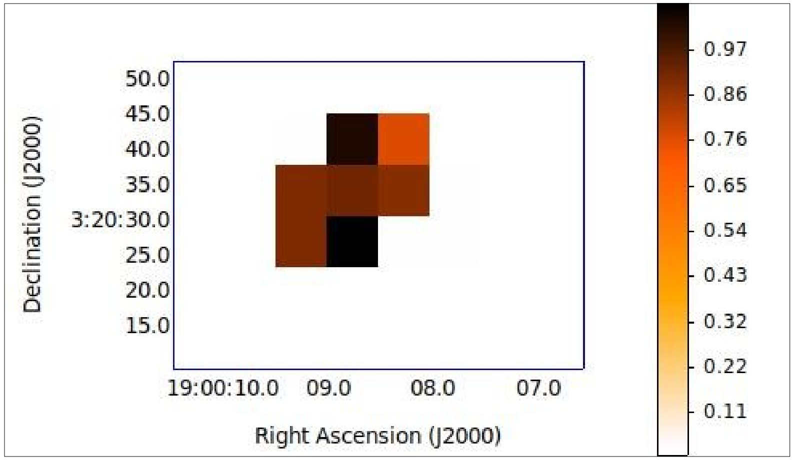


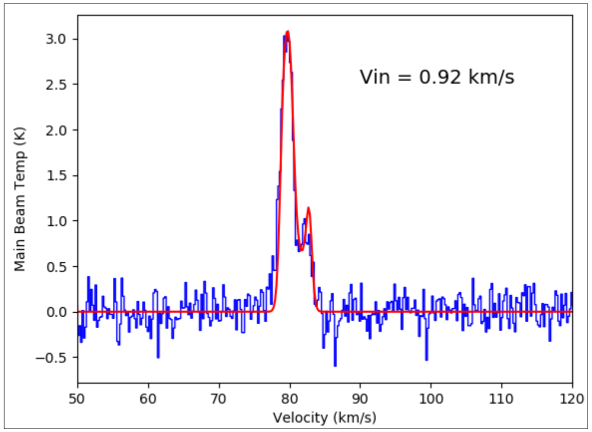
$$\begin{aligned} \tau_f(v) &= \tau_0 \exp\left[-(v - v_{LSR} - v_{in})^2/2\sigma^2\right] \\ \tau_r(v) &= \tau_0 \exp\left[-(v - v_{LSR} + v_{in})^2/2\sigma^2\right] \end{aligned}$$

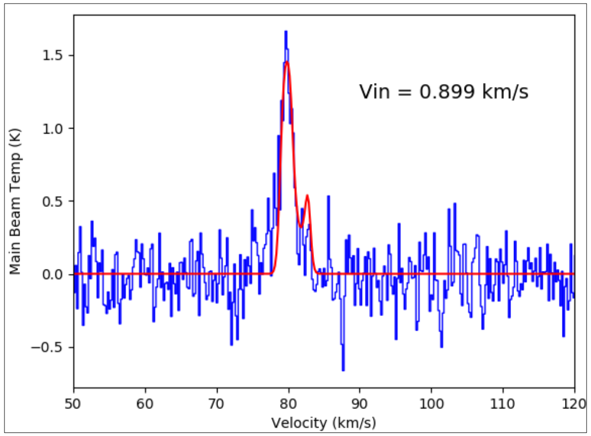
Vries and Myers, 2004; Meyers 1996

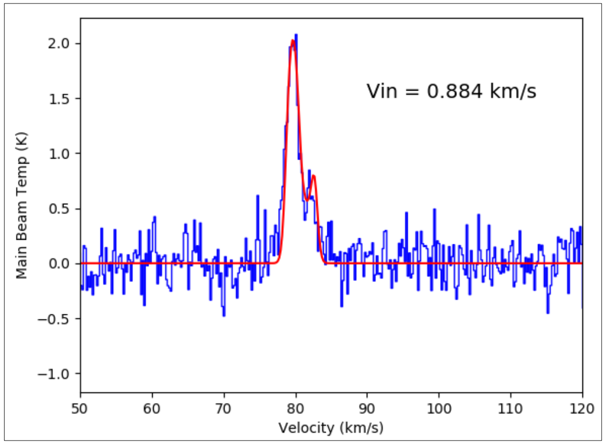
Core Density Gas Tracers

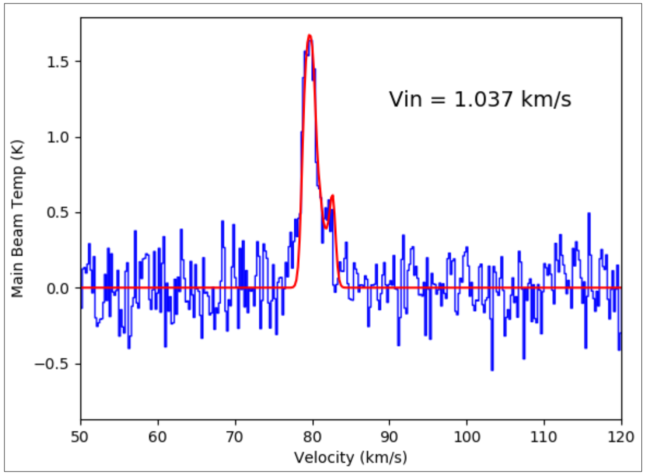
HCO^+ : Radiative Modelling

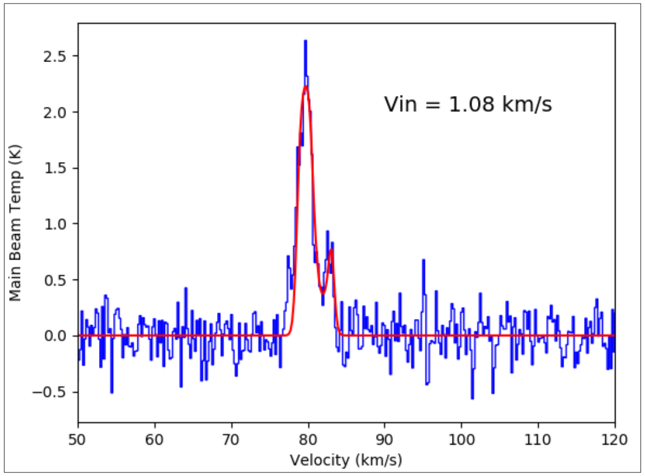












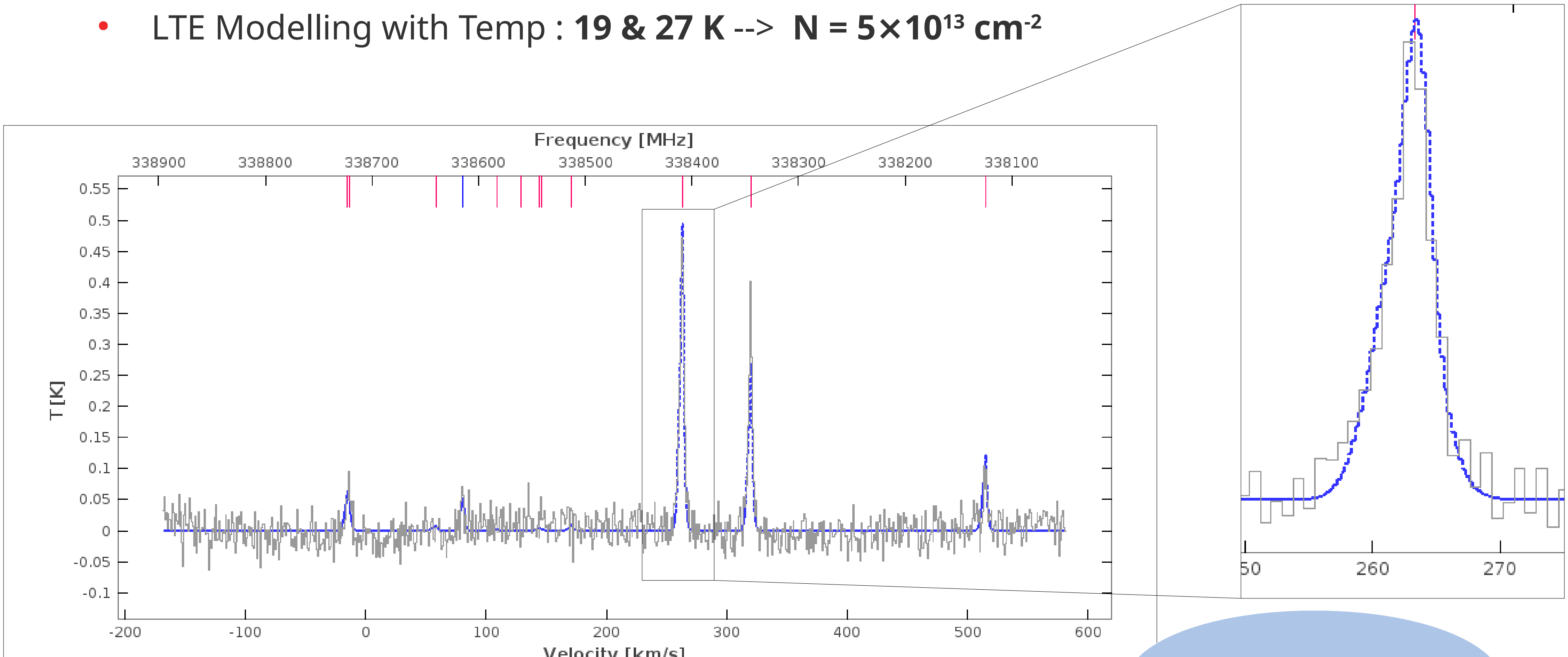
Core is in **infalling** stage ; Average V_{infall} ~ **0.926 km/s**

$\dot{M} = 4\pi R^2\rho .\ V_{inf} = \mathbf{3.9\times10^{-3}\ M_\odot/yr}$

Core Gas Tracers

CH_3OH : LTE Radiative Modelling

- **J=7-6** hyperfine transition; several series of lines closely packed.
- LTE Modelling with Temp : **19 & 27 K** --> **N = 5×10^{13} cm^{-2}**



N = 1×10^{15} cm^{-2}

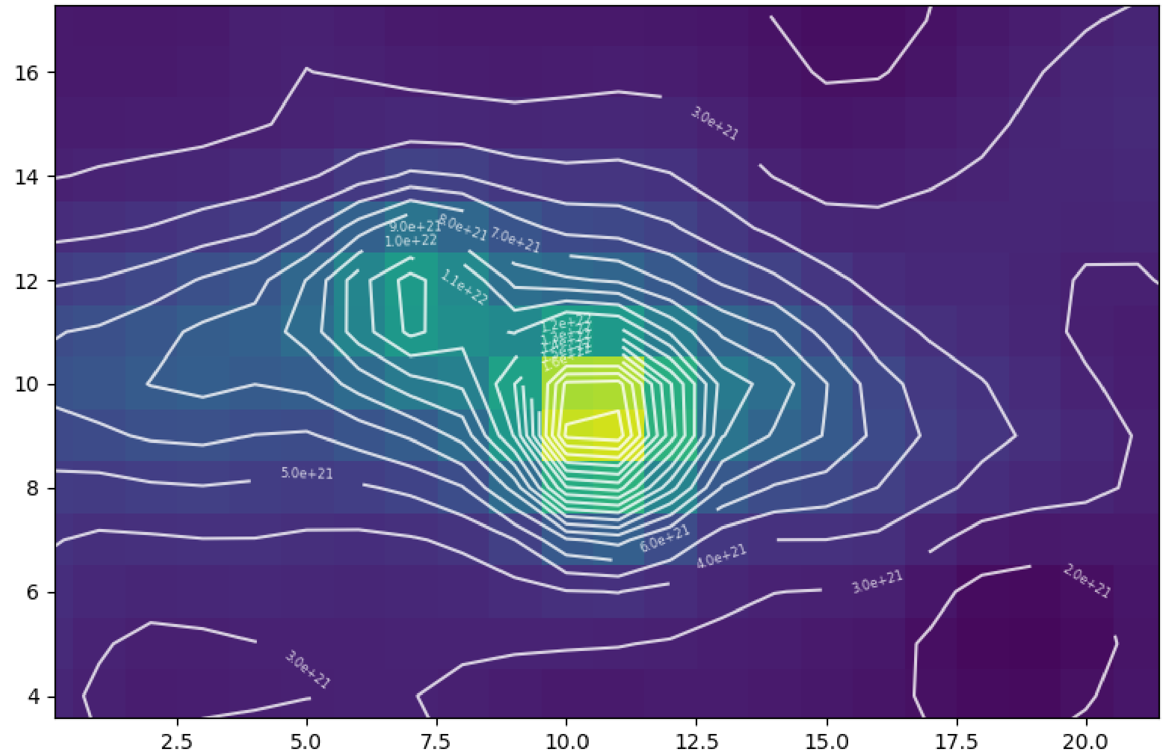
Optimum fit at Temp **~ 9 K** ; suggest CH_3OH emission is due to **subthermal** excitation

Properties of Core

Density profile

$$n(r) = n_o(r/r_o)^{\alpha}$$

$$N(r) = \int n.dl$$



- Theory of low mas star formation from singular **isothermal sphere** predicts powerlaw index : $\mathbf{n \propto r^{-2}}$

Future Work

- Modelling of all other 1-2 **sources** which are in different evolutionary stages **:**
  - CO & its isotopologue maps
  - Dust emission maps
  - HCN, HCO^+, CH_3OH, N_2H^+ maps
  - Density profiles

Thank you !!