Astrochemical modeling to Planck cold clump G224.4-0.6

Jixing Ge

Email: gejixing666@gmail.com

Co-authors: Diego Mardones, Jinhua He, Jonathan Rawlings, Sheng-yun Liu, Jun-ong Lee, Tie Liu, Lei Zhu, Qiang Chang,

Natalia Inostroza and Siyi Feng

Department of Astronomy, Universidad de Chile

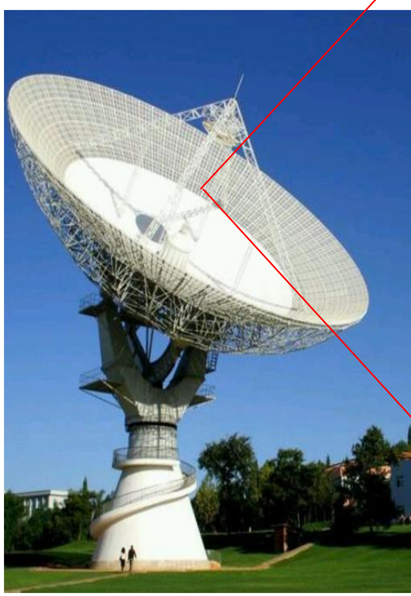
FONDECYT:3170768

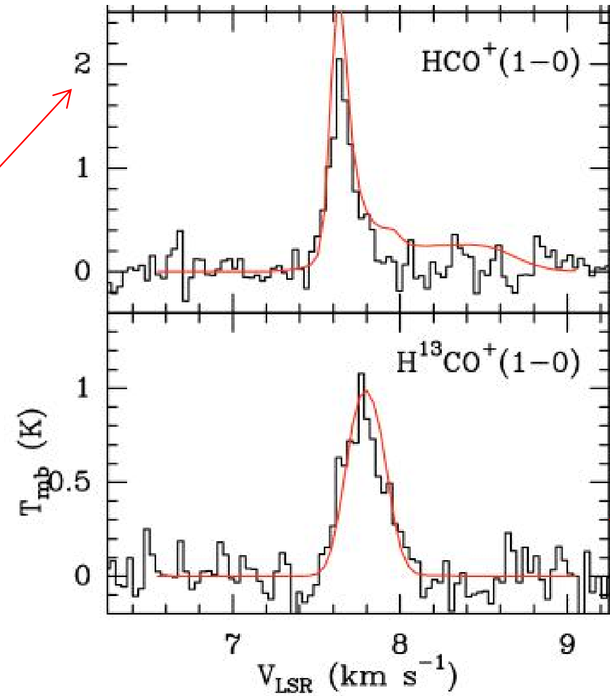
12-09-2019

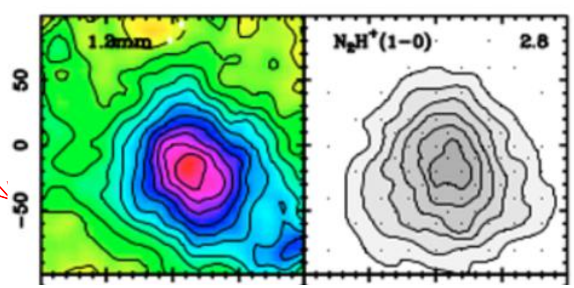
outline

- Background
- Physical and chemical models for G224.4-0.6
- The three-dimensional projection effects
- Discussions
- Conclusions

From observation to physics







Line width (Non-thermal features)

Excitation temperature

Column densities

Abundances

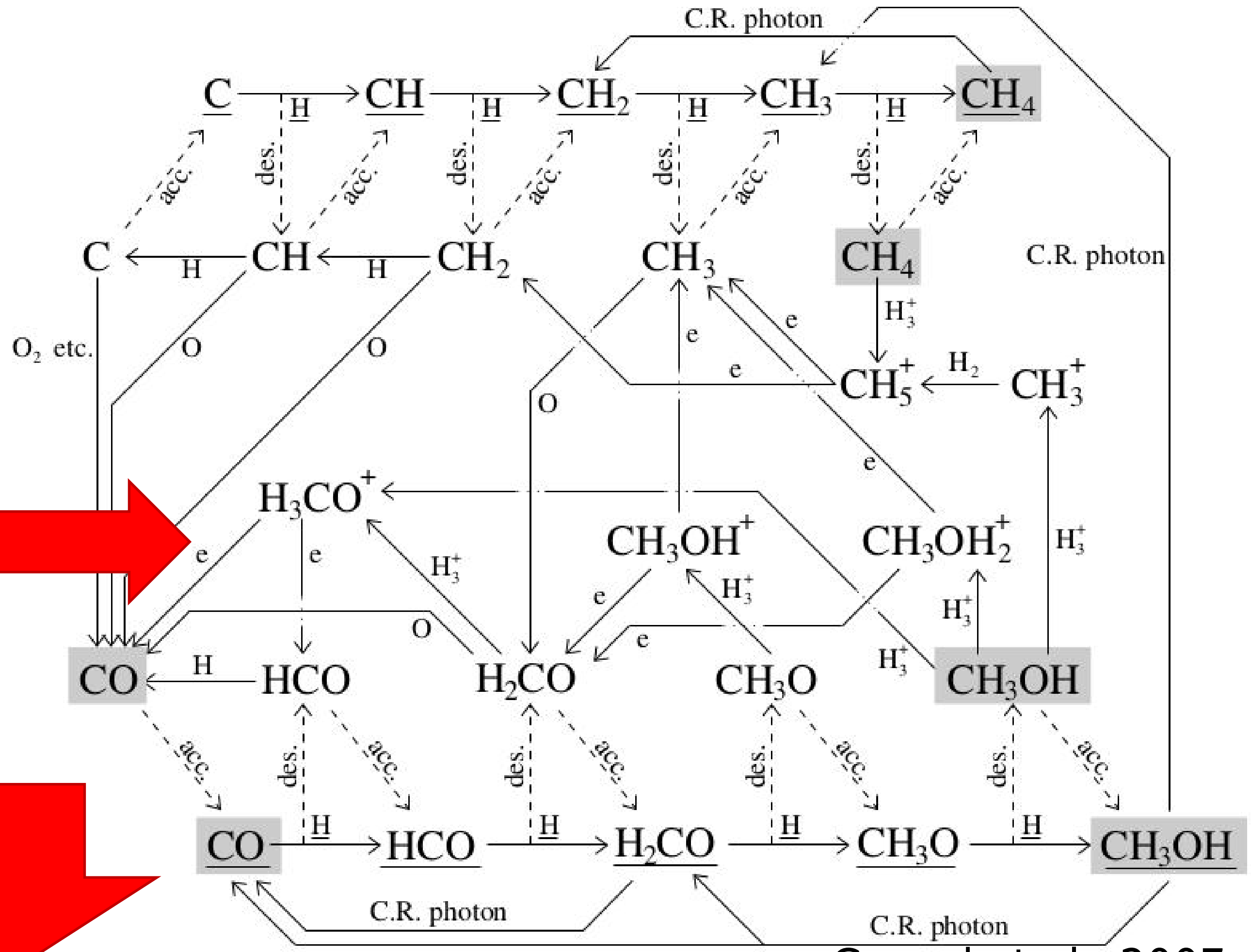
density, extinction, temperature, ……

Molecular distributions

Tafalla et al., 2006, A&A 455, 577–593

From observations to chemistry

Physical parameter:
density,
extinction,
temperature,
radiation field ……



Garrod et al., 2007.

(1)The formation pathway of molecules.
(2) to constrain physical parameters.

- **H3+ + N2 -> N2H+ + H2, N2H+ + CO -> HCO+**
- **strong depletion of molecules such as CCS, HC3N**
- **For COMS, CH3OH is mainly formed on dust grains and then released by some non-thermal desorption mechanism in cold dark clouds.**

gas-grain chemical model

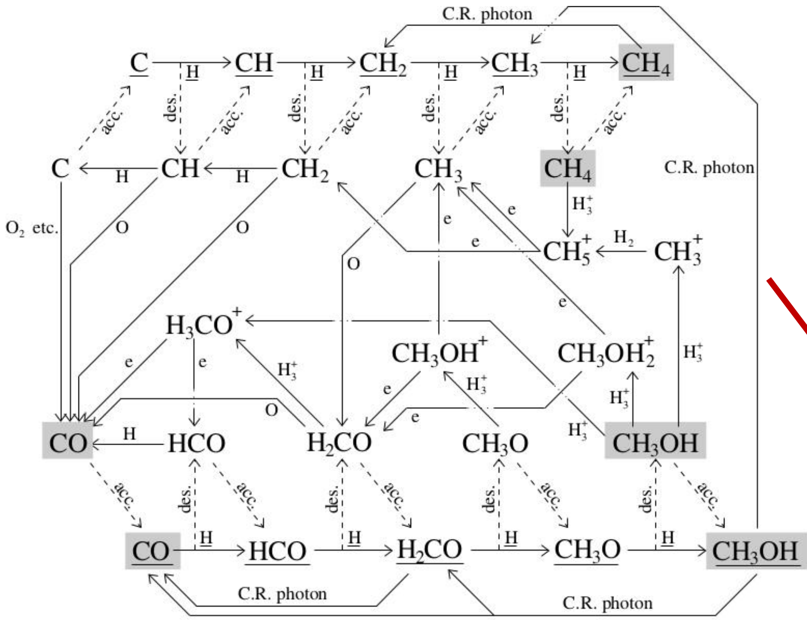
Gas-phase:

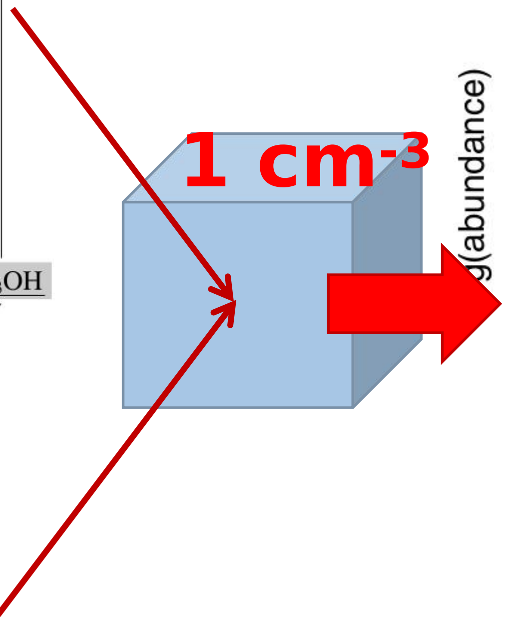
$$\frac{\mathrm{d}n_i}{\mathrm{d}t} = \sum_{l,m} k_{lm} n_l n_m - n_i \sum_{i \neq l} k_l n_l + k_i^{\mathrm{des}} n_i^s - k_i^{\mathrm{acc}} n_i$$

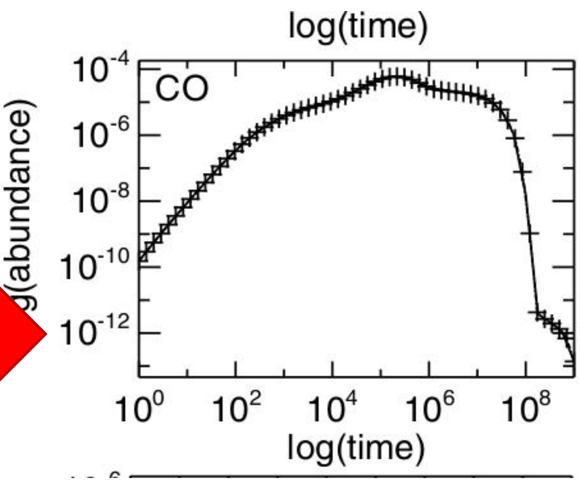
dust surface:

$$\frac{\mathrm{d}n_i^s}{\mathrm{d}t} = \sum_{l,m} k_{lm}^s n_l^s n_m^s - n_i^s \sum_{i \neq l} k_l^s n_l^s - k_i^{\mathrm{des}} n_i^s + k_i^{\mathrm{acc}} n_i$$

single-point gas-grain chemical model

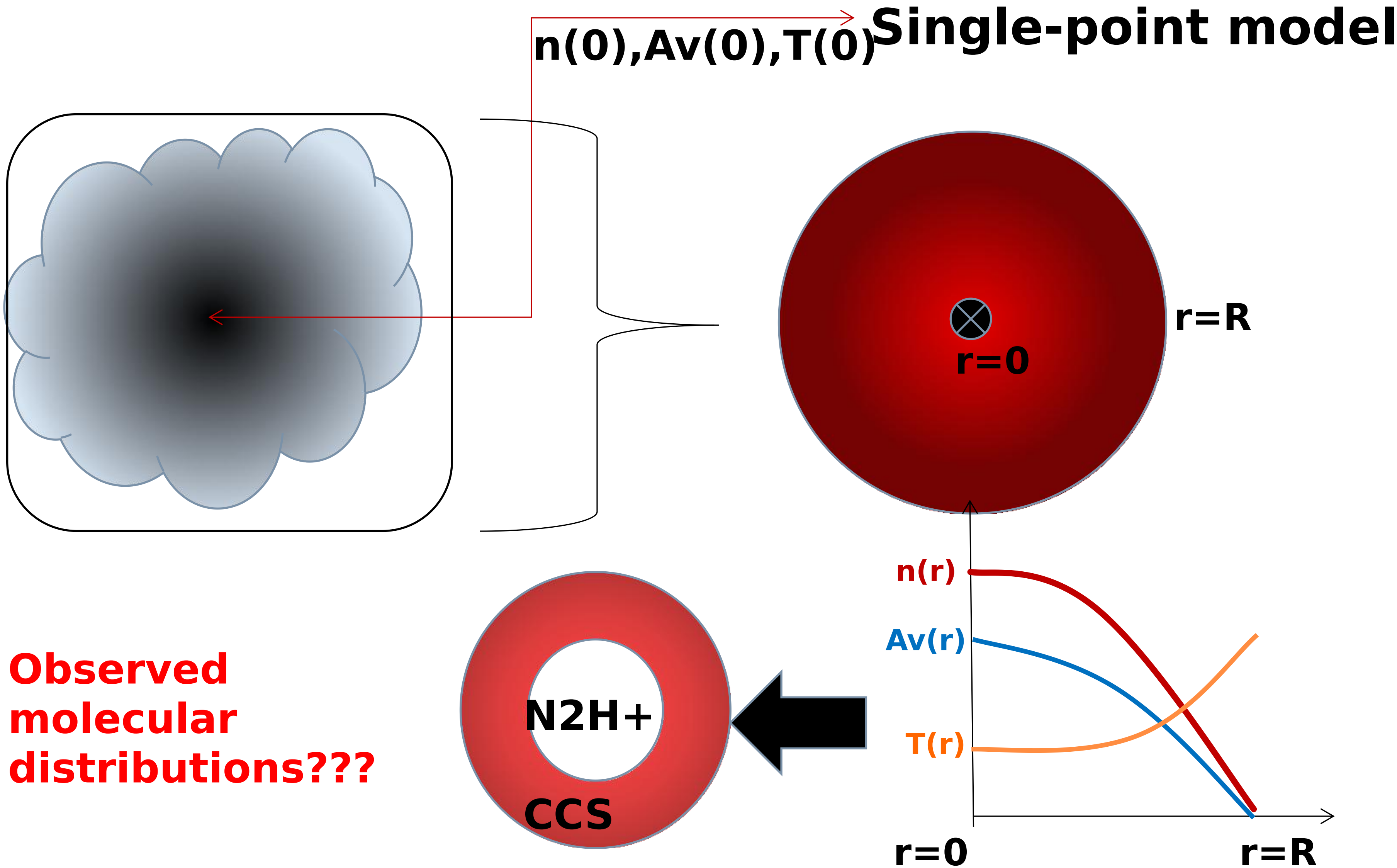






Physical parameter:
density,
extinction,
temperature,
radiation field ……

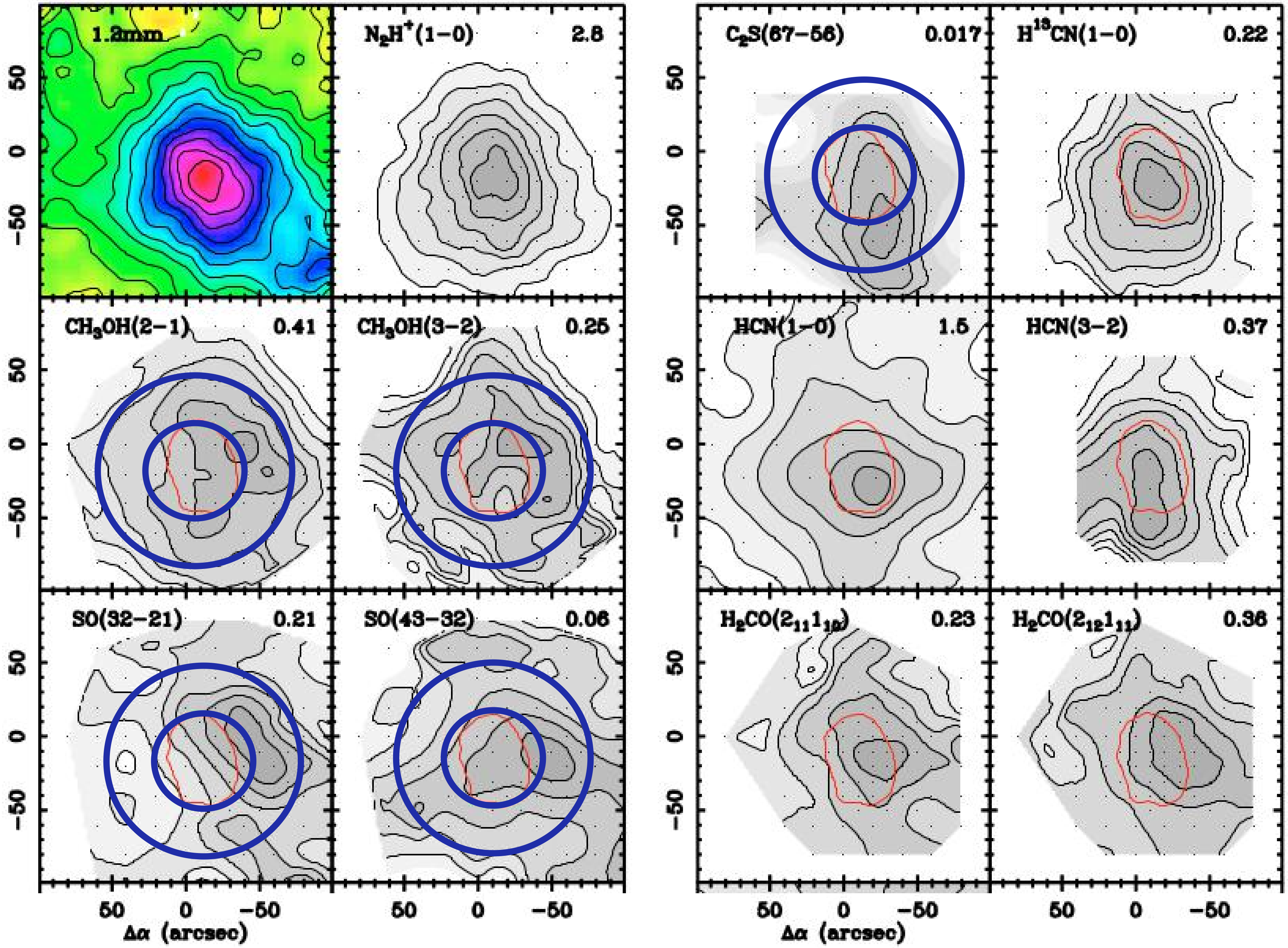
Observations .vs. models???



L1571B core

Tafalla et al., 2006, A&A 455, 577–593

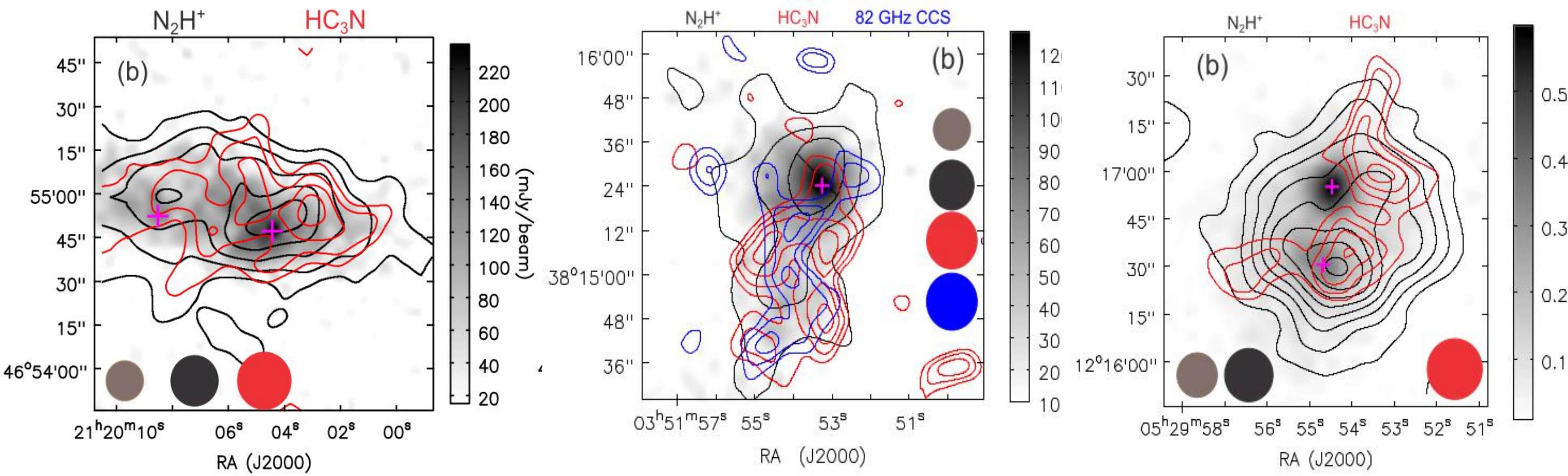
red contour=75% N2H+



Irregular distributions in some sources in our survey (SCOPE, Tie liu et al., 2018)

(Planck cold clump: Td<15K, nH>1e4 cm^{-3})

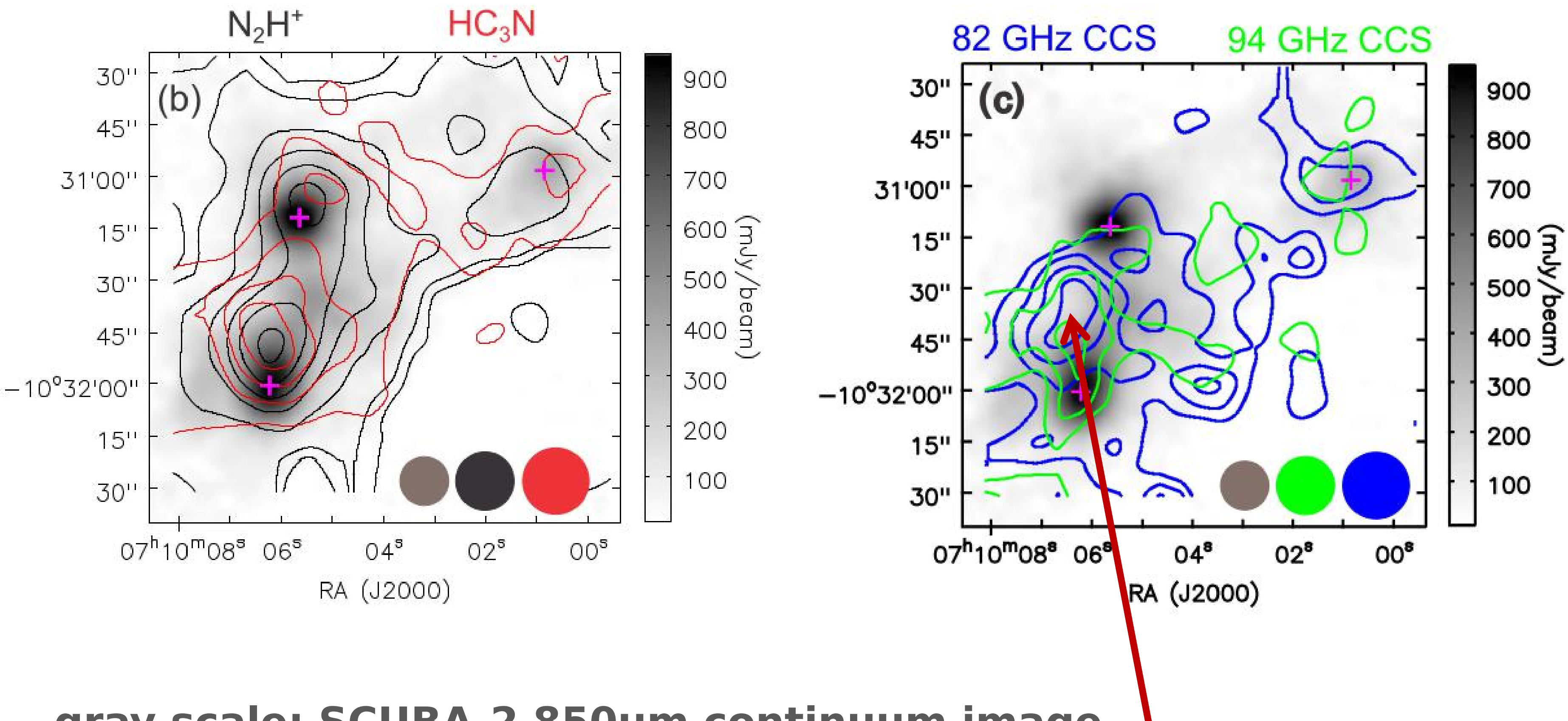
G089 **G157** **G192**



Tatematsu et al., 2017, Apj

gray scale: SCUBA-2 850um continuum image
Black contours: N2H+
Red contours: HC3N
Blue contours: CCS

G224.4-0.6



gray scale: SCUBA-2 850um continuum image

Black contours: N2H+

Red contours: HC3N

Blue contours: CCS (82 GHz)

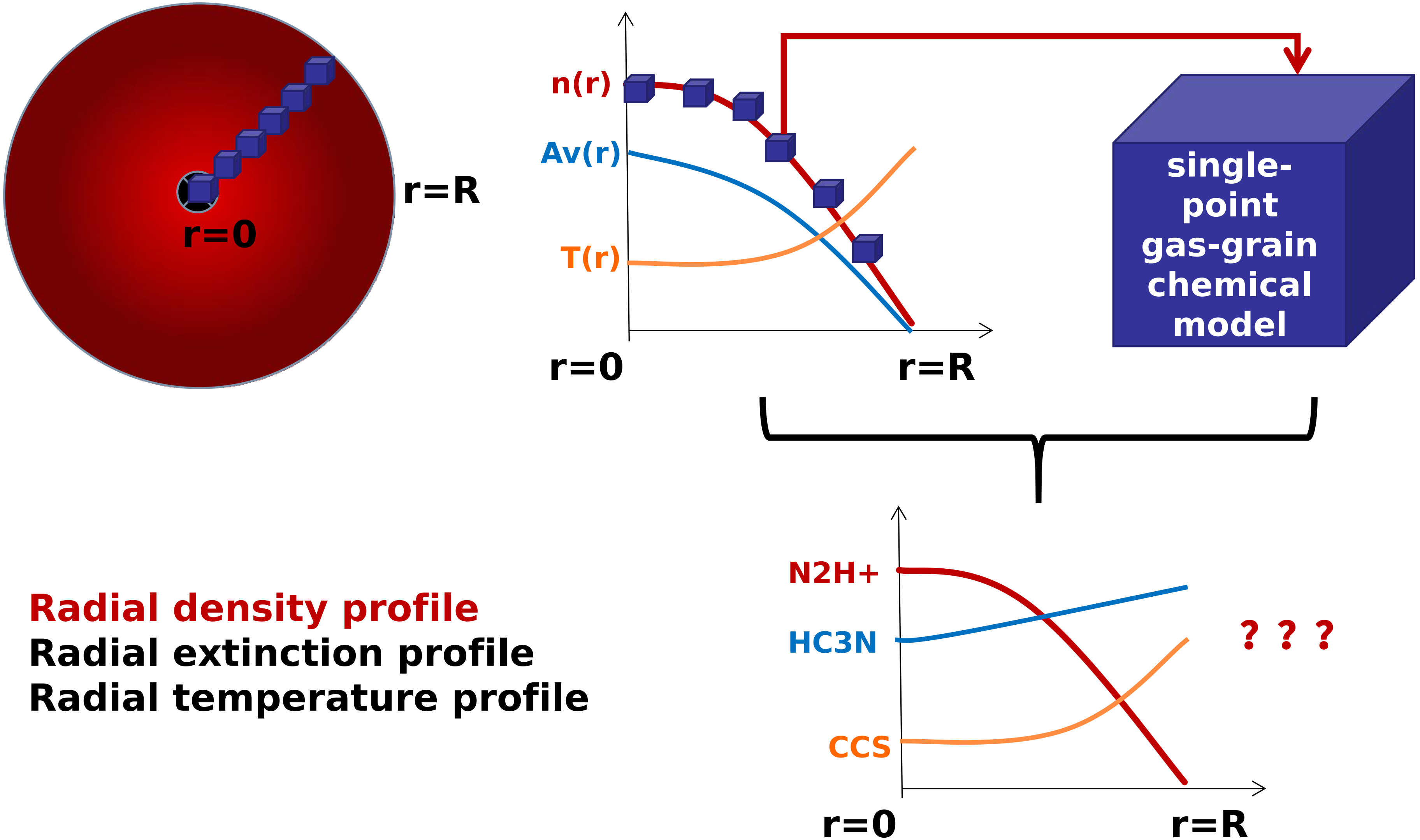
Green contours: CCS (94GHz)

CCS peak show offset from continuum peaks??

- **How to solve this problem???**

Submitted to ApJ.
Title:Three dimensional projection effects on chemistry in a Planck galactic cold clump

To do chemical model for cloud core, we need ????

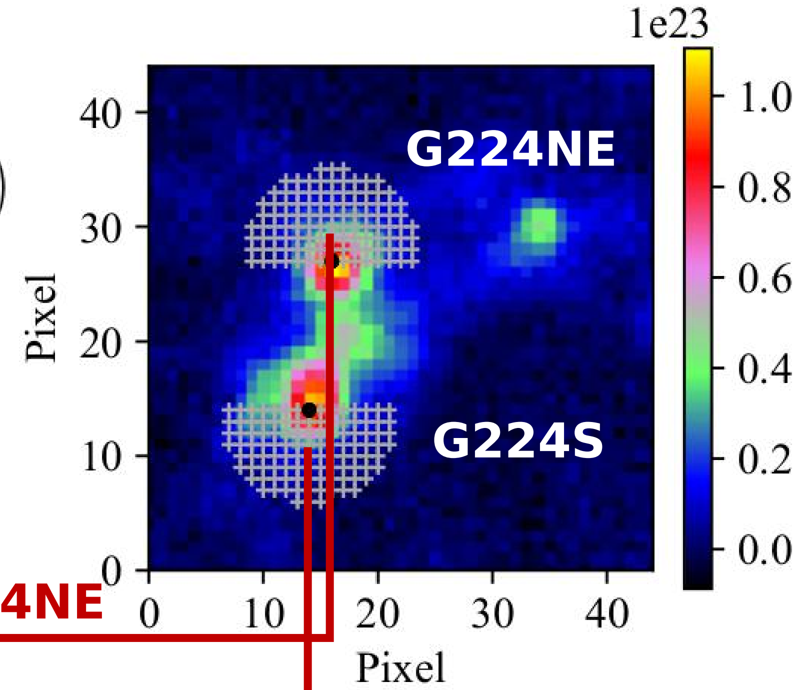


Radial density profile
Radial extinction profile
Radial temperature profile

SCUBA-2 850um -> H2 column density map

Kauffmann et al. (2008):

$$N(\mathrm{H_2}) = 2.02 \times 10^{20}\,\mathrm{cm^{-2}} \left(\mathrm{e}^{1.439(\lambda/\mathrm{mm})^{-1}(T_\mathrm{d}/10\,\mathrm{K})^{-1}} - 1\right) \left(\frac{\kappa_\nu}{0.01\,\mathrm{cm^2\,g^{-1}}}\right)^{-1} \left(\frac{S_\nu^{beam}}{\mathrm{mJy\,beam^{-1}}}\right) \left(\frac{\theta_\mathrm{HPBW}}{10\,\mathrm{arcsec}}\right)^{-2} \left(\frac{\lambda}{\mathrm{mm}}\right)^{3}$$



Upper-half of G224NE

Lower-half of G224S

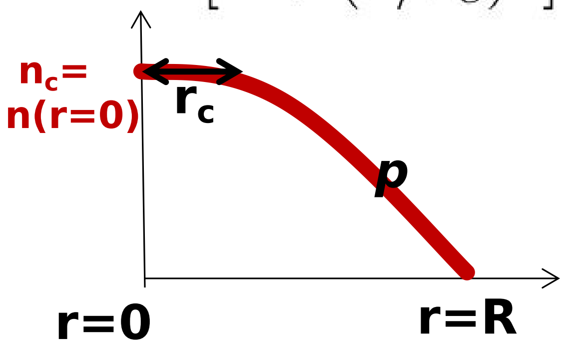
radial H2 column density profiles (black points)

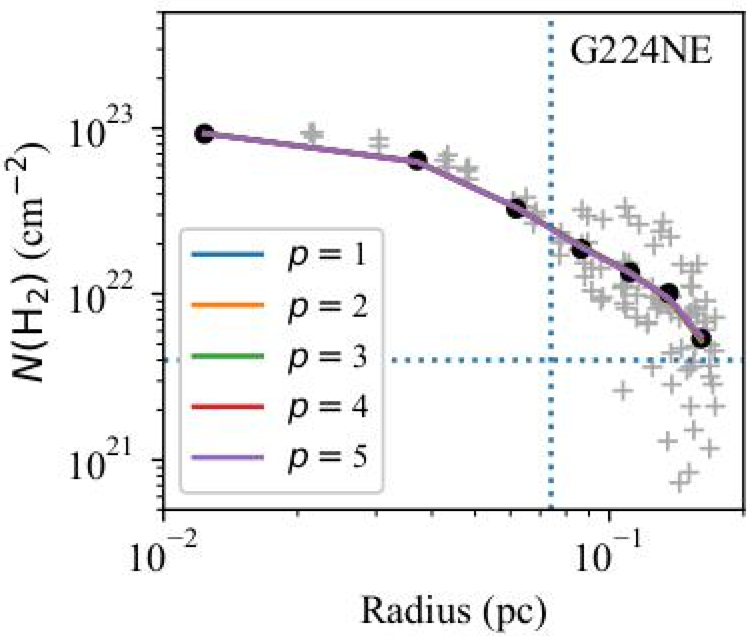
Fits to radial H2 column density profile using Plummer-like density structure

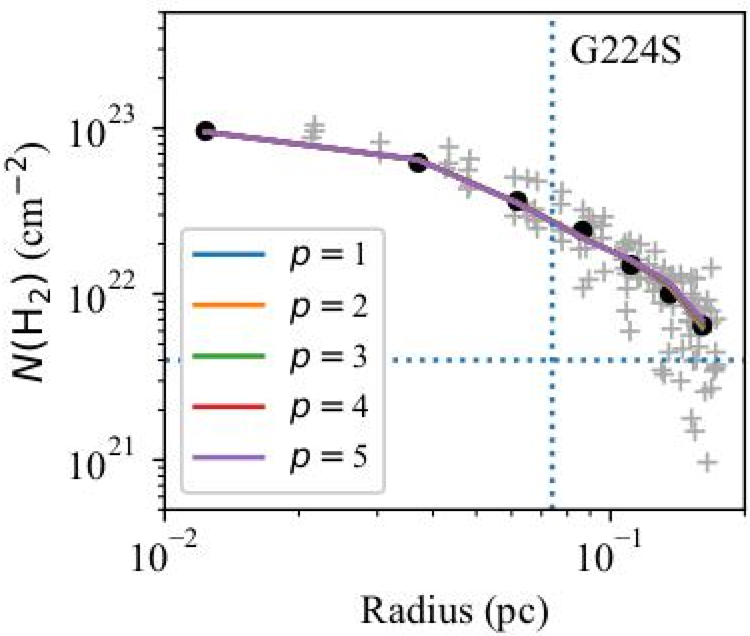
$$n(r) = \frac{n_c}{[1+(r/r_c)^2]^{p/2}} + n_{\rm b}$$

N(H2) along line-of-sight

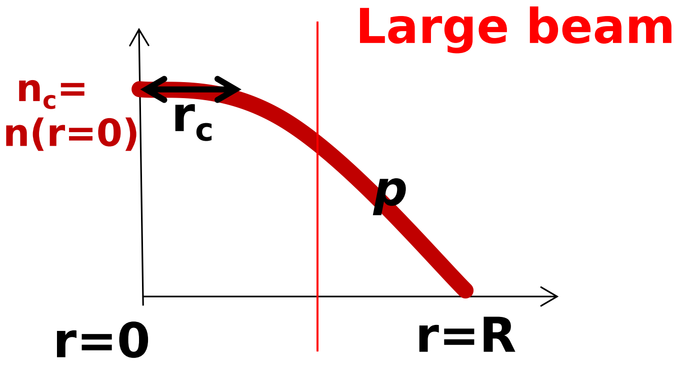
fits obs. profile using MC (lines in figure)







p	n_c (cm^{-3})	r_c (cm)	n_b (cm^{-3})
	G224NE		
1	4.4e+08	1.3e+13	2.8e+03
2	3.8e+08	1.4e+15	1.2e+04
3	2.2e+08	8.1e+15	1.5e+04
4	5.0e+07	2.4e+16	1.6e+04
5	2.2e+07	4.0e+16	1.7e+04
	G224S		
1	4.3e+08	1.3e+13	6.2e+03
2	3.9e+08	1.3e+15	1.6e+04
3	2.9e+08	6.6e+15	1.9e+04
4	1.3e+08	1.6e+16	2.0e+04
5	5.9e+07	2.8e+16	2.1e+04

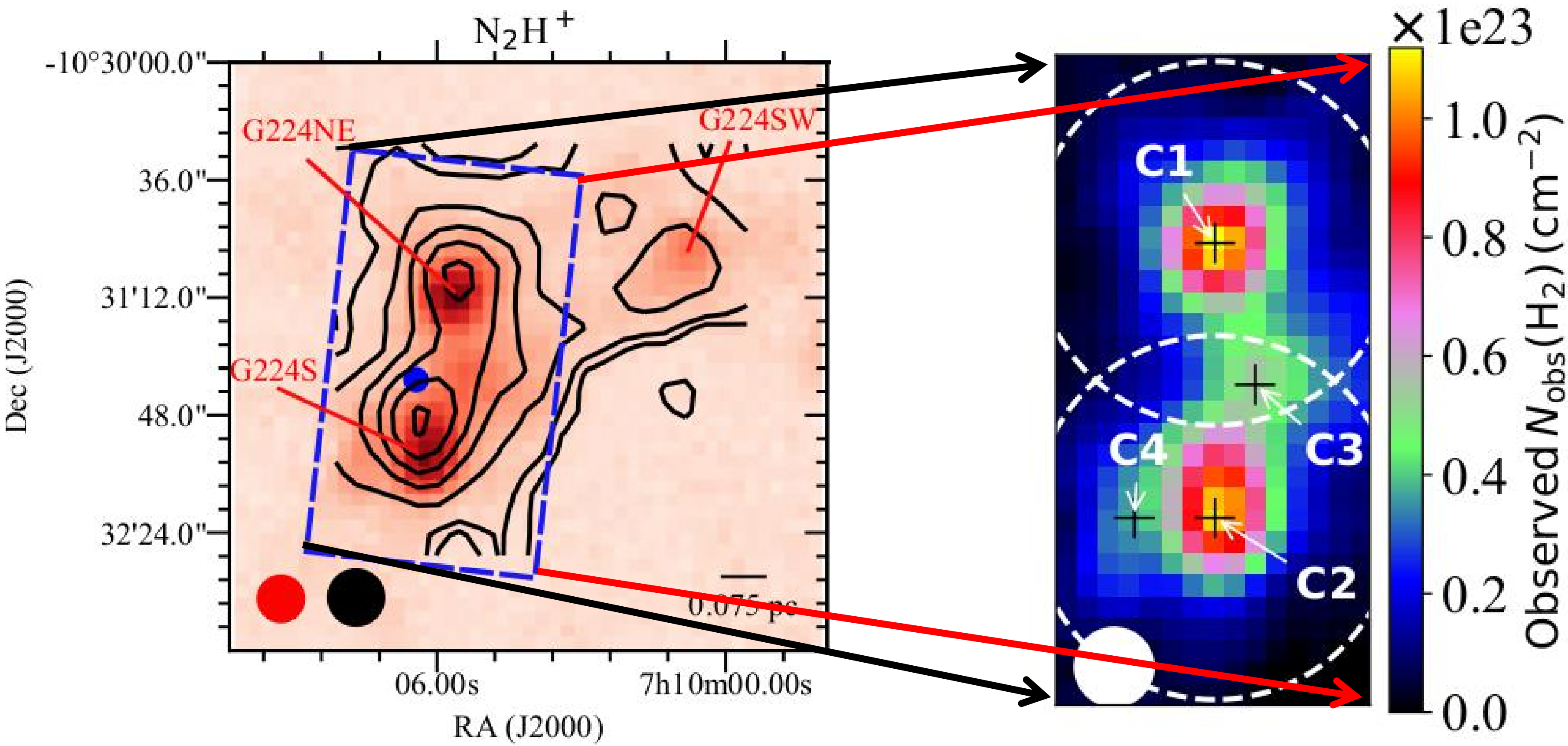


background:
n_b~1e4 cm-3

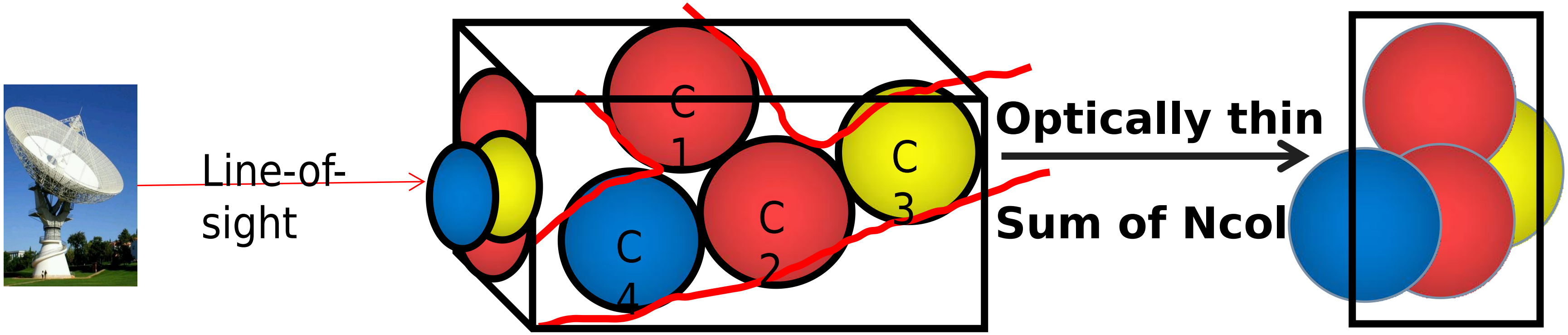
2-D fitting

2-D fitting to H2 column density map

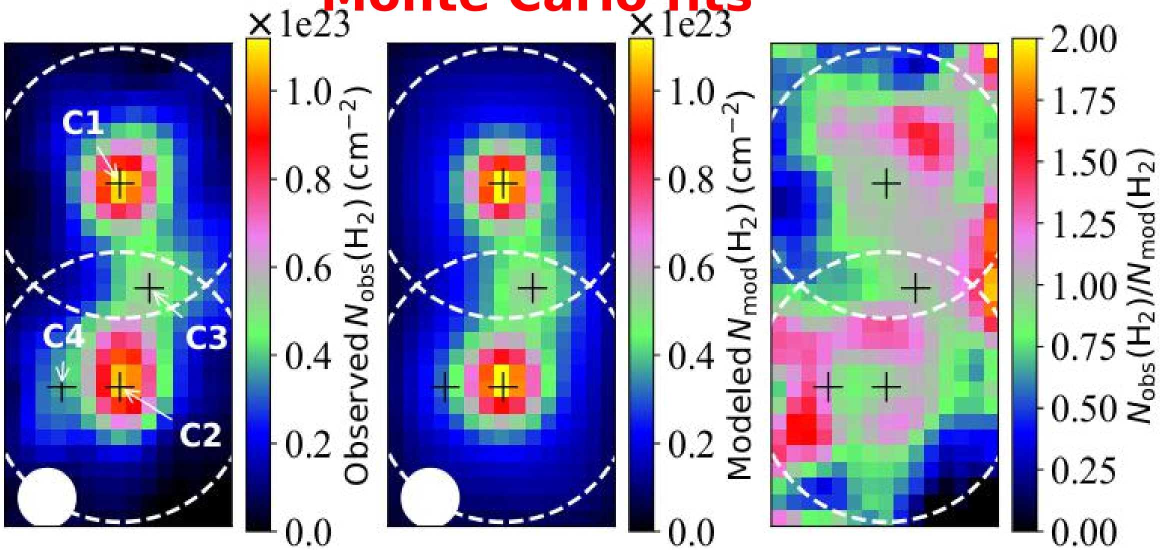
4-cores are needed.



Comparison between Obs. and Mod. H2 map



Obs. **4-cores Model Monte Carlo fits** **Obs/Mod**

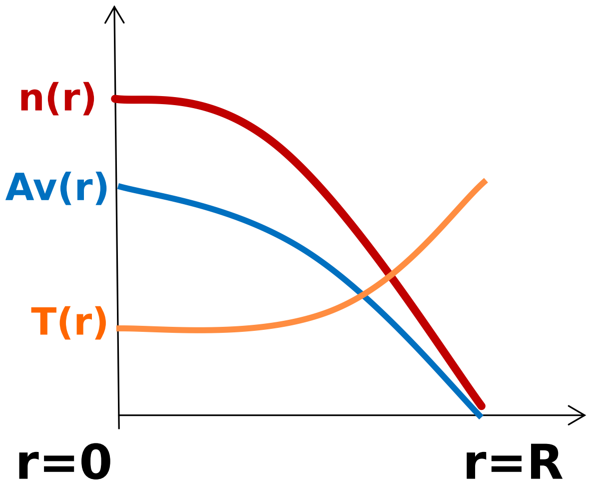


12 free parameters =4x(nc,rc,p)

fixed background as 1e4 cm^{-3}

The main obs. features can be well reproduced by the four-cores model within a factor of 2.0.

For each core



$$A_V = N(H_2)/2.2 \times 10^{21} \text{ (mag)}$$

Güver & Özel (2009)

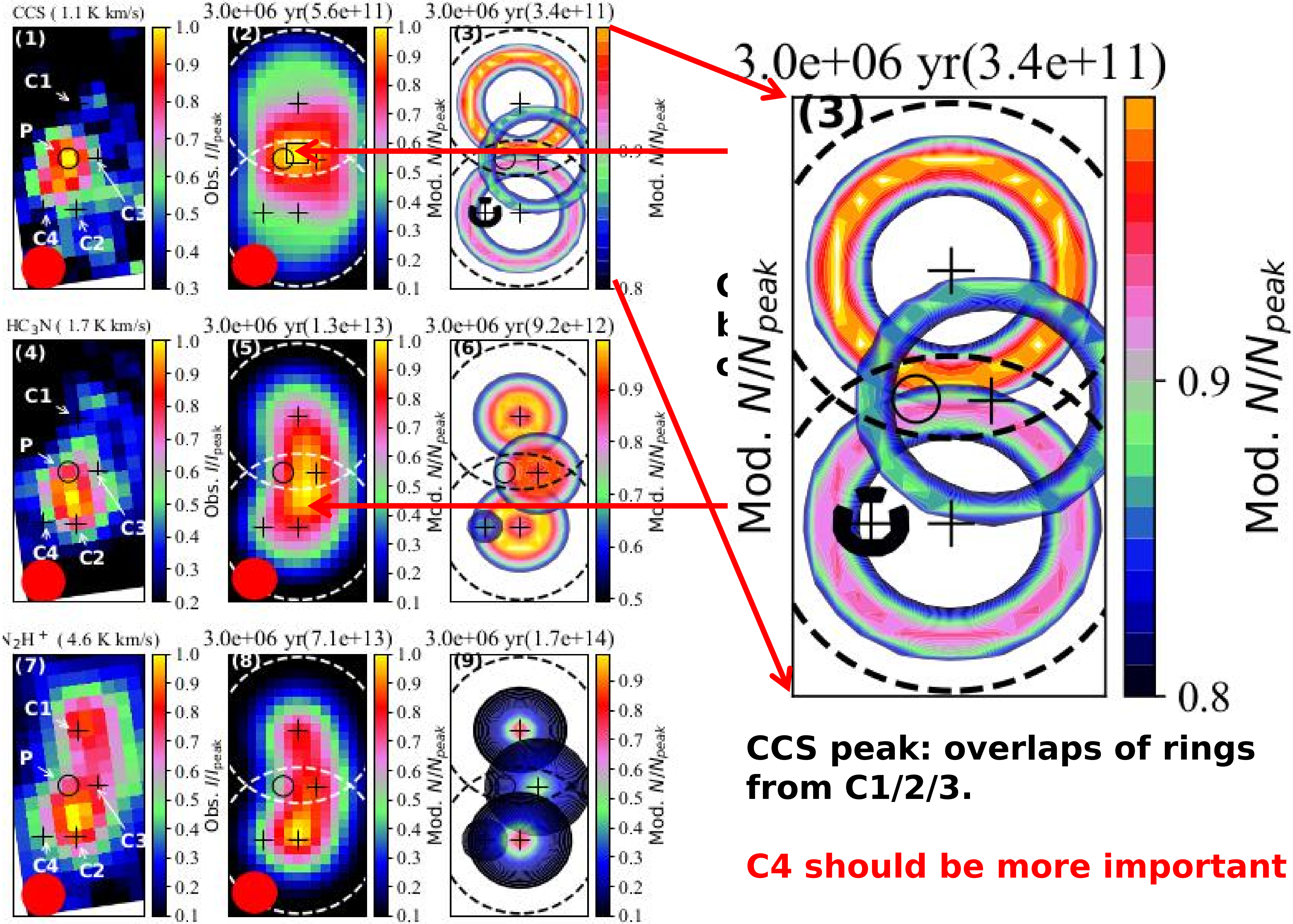
$$T_d(A_V) = [11 + 5.7 \tanh(0.61 - \log(A_V))] \, \chi_{uv}^{1.0/5.9}$$

Hocuk et al. (2017)

species	n_i/n_H	species	n_i/n_H
H_2	0.5	S^+	8.00×10^{-8}
He	9.00×10^{-2}	Fe^+	3.00×10^{-9}
C^+	1.20×10^{-4}	Na^+	2.00×10^{-9}
N	7.60×10^{-5}	Mg^+	7.00×10^{-9}
O	2.56×10^{-4}	Cl^+	1.00×10^{-9}
Si^+	8.00×10^{-9}	P^+	2.00×10^{-10}

dust-to-gas mass ratio=0.01

(e.g. Wakelam & Herbst 2008;
Hincelin et al. 2011;
Furuya et al. 2011;
Majumdar et al. 2017).



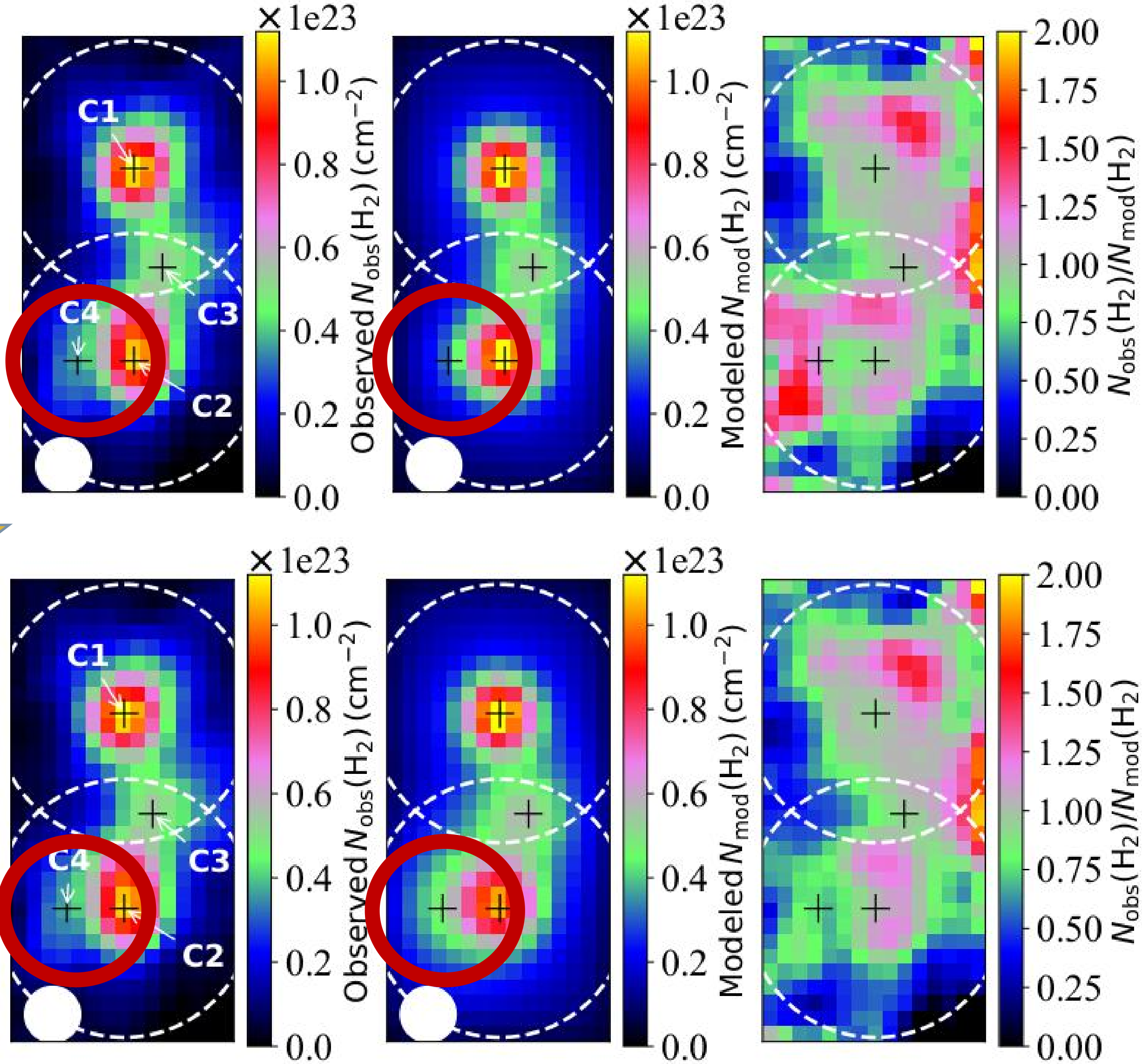
CCS peak: overlaps of rings from C1/2/3.

C4 should be more important

initial core density model

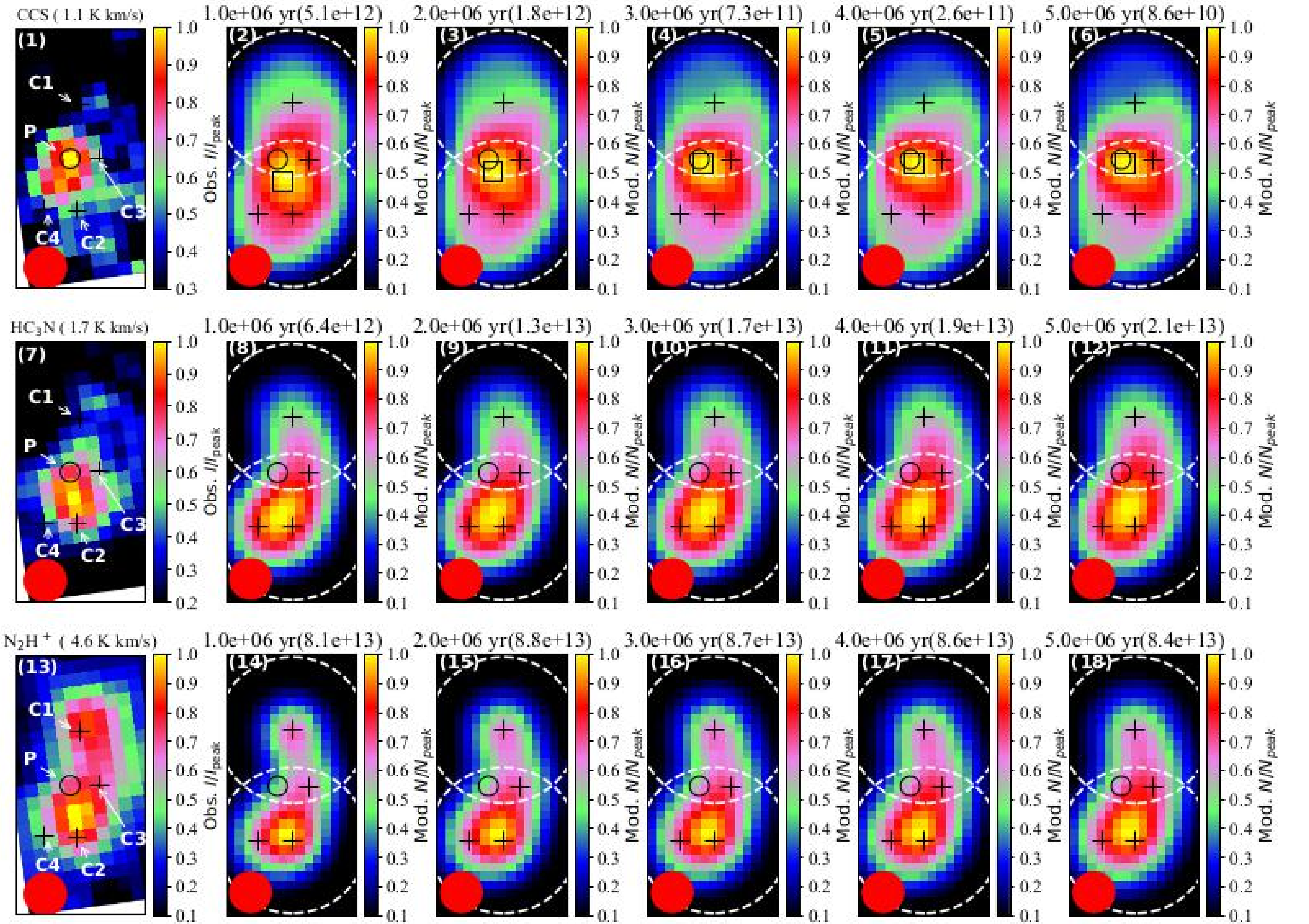
By checking physical & chemical structures

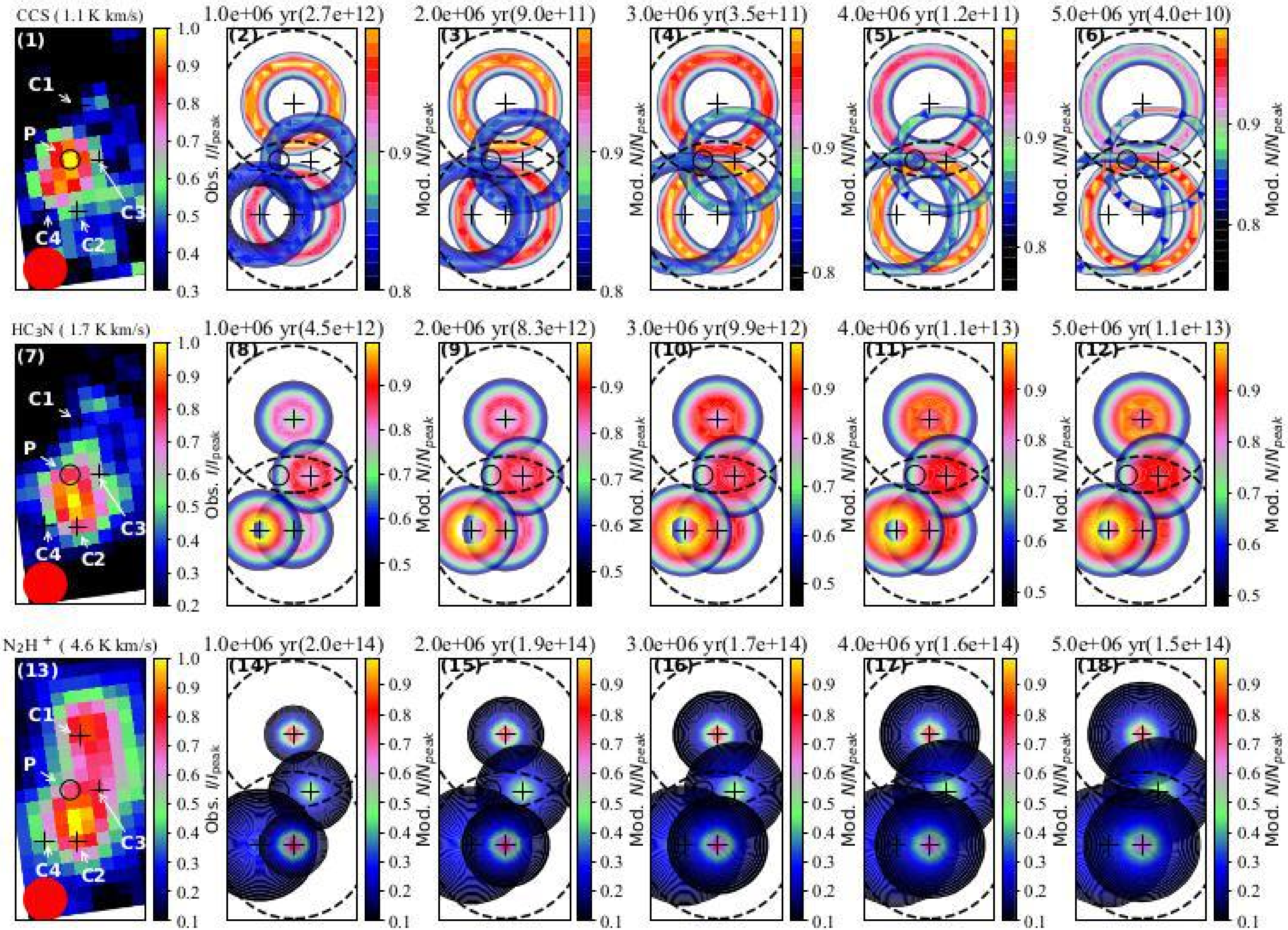
Adjusted core density model



	Center coordinate (J2000)	*initial core density model* p	n_c (cm^{-3})	r_c (cm)	*adjusted core density model* p	n_c (cm^{-3})	r_c (cm)
C1	07:10:05.7, -10:31:10.7	3.6	3.2×10^{8}	1.3×10^{16}	3.6	3.2×10^{8}	1.3×10^{16}
C2	07:10:06.2, -10:32:00.3	4.3	5.9×10^{6}	6.2×10^{16}	4.3	$\mathbf{4.4}\times10^{6}$	6.2×10^{16}
C3	07:10:05.3, -10:31:36.7	1.8	2.8×10^{6}	1.7×10^{16}	1.8	2.8×10^{6}	1.7×10^{16}
C4	07:10:07.3, -10:31:57.7	3.1	1.9×10^{5}	7.3×10^{16}	**1.5**	$\mathbf{1.0}\times10^{5}$	$\mathbf{1.1}\times10^{17}$

Modeled molecular distributions using adjusted core density model





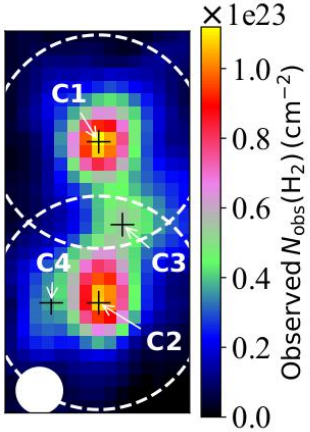
CCS (1.1 K km/s)
1.0e+06 yr(2.7e+12)
2.0e+06 yr(9.0e+11)
3.0e+06 yr(3.5e+11)
4.0e+06 yr(1.2e+11)
5.0e+06 yr(4.0e+10)
HC3N (1.7 K km/s)
1.0e+06 yr(4.5e+12)
2.0e+06 yr(8.3e+12)
3.0e+06 yr(9.9e+12)
4.0e+06 yr(1.1e+13)
5.0e+06 yr(1.1e+13)
N2H+ (4.6 K km/s)
1.0e+06 yr(2.0e+14)
2.0e+06 yr(1.9e+14)
3.0e+06 yr(1.7e+14)
4.0e+06 yr(1.6e+14)
5.0e+06 yr(1.5e+14)
C1
P
C2
C3
C4
Obs. I/Ipeak
Mod. N/Npeak

Discussions

temperature effects

Dynamical processes

Velocity along line-of sight

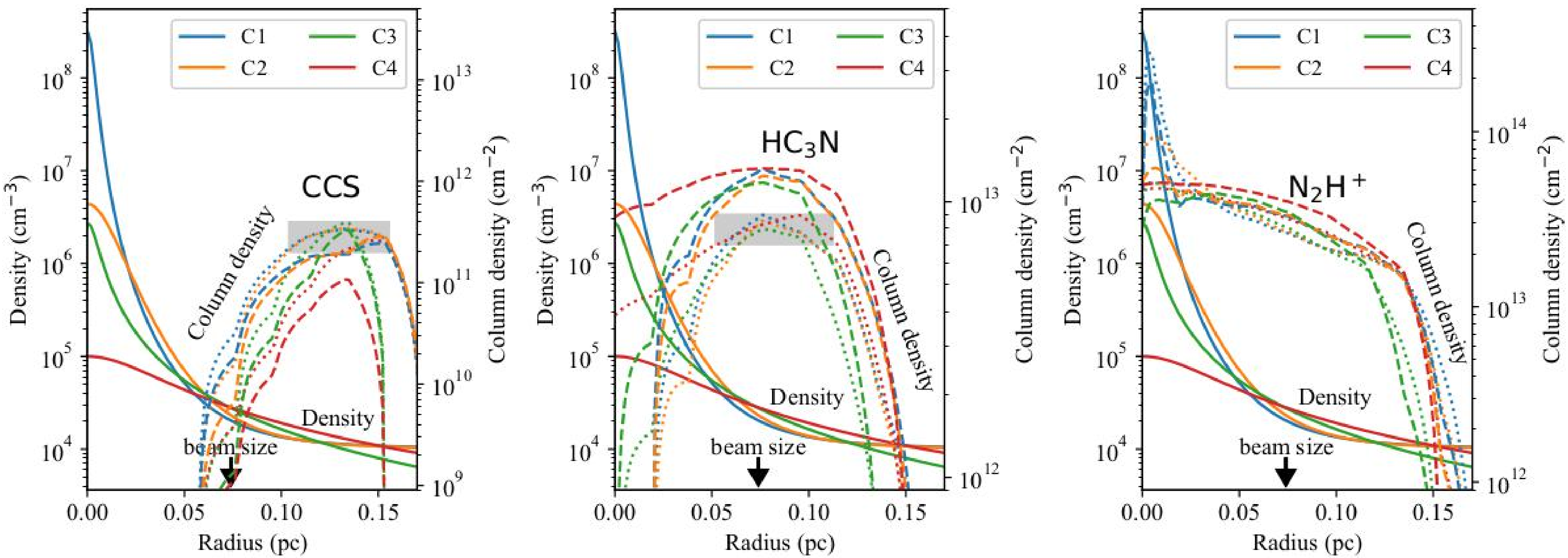


Chemical age

application

temperature effects

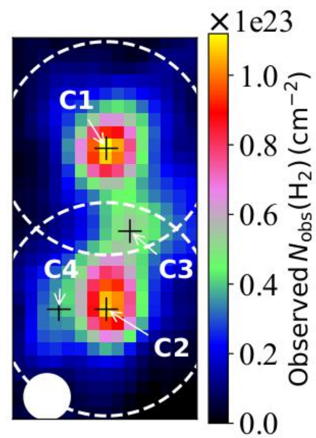
solid line:density profile
dotted line: model with Td(r)=Td(Av)
dashed line: model with Td(r)=10K



Discussions

temperature effects

Dynamical processes

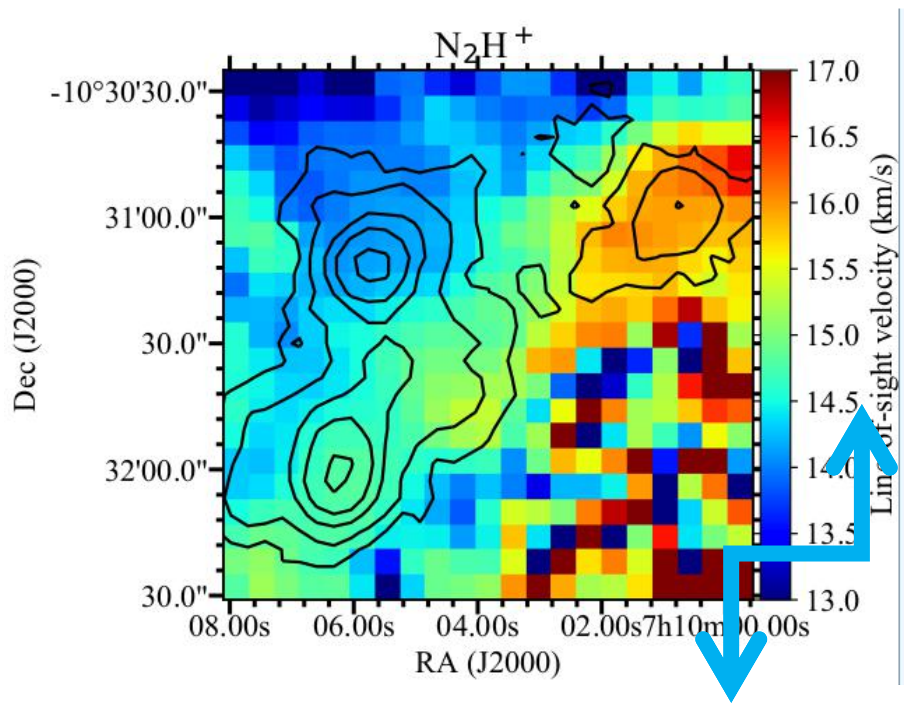


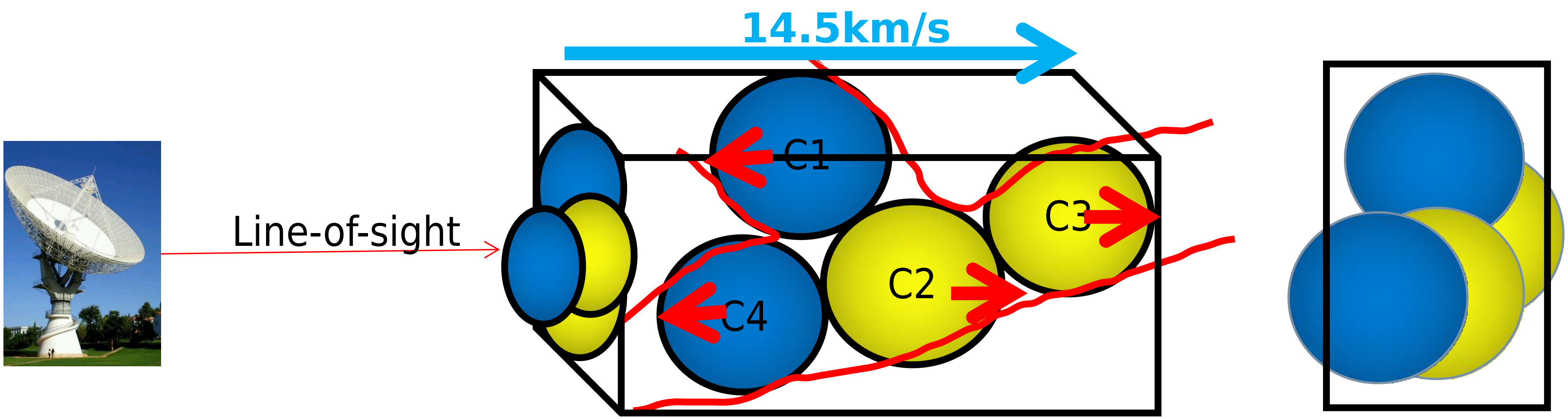
Velocity along line-of sight

Chemical age

application

Line-of-sight velocity map (Moment 1 map)



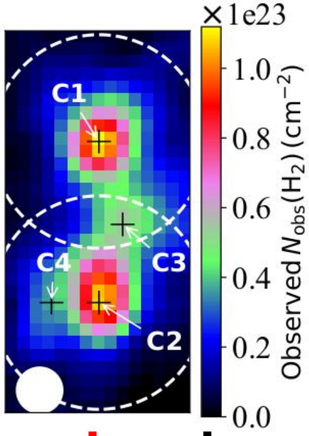


Discussions

temperature effects

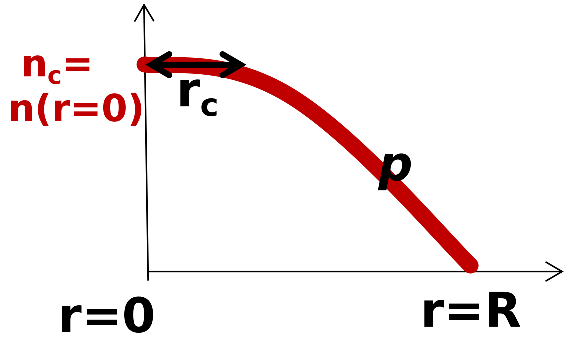
Velocity along line-of sight

Chemical age



Dynamical processes

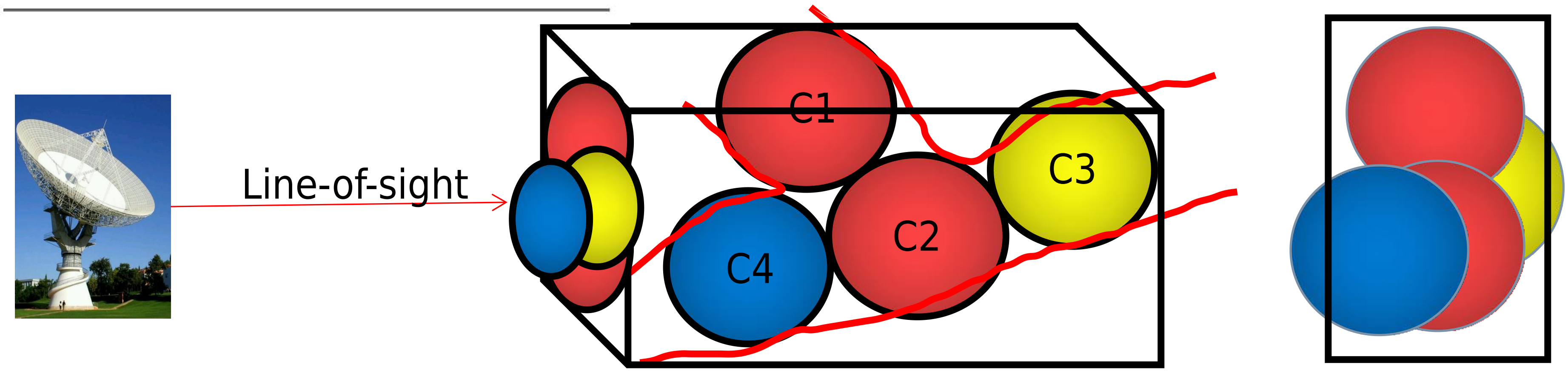
application



initial physical conditions

species	n_i/n_H	species	n_i/n_H
H_2	0.5	S^+	8.00×10^{-8}
He	9.00×10^{-2}	Fe^+	3.00×10^{-9}
C^+	1.20×10^{-4}	Na^+	2.00×10^{-9}
N	7.60×10^{-5}	Mg^+	7.00×10^{-9}
O	2.56×10^{-4}	Cl^+	1.00×10^{-9}
Si^+	8.00×10^{-9}	P^+	2.00×10^{-10}

initial chemical conditions



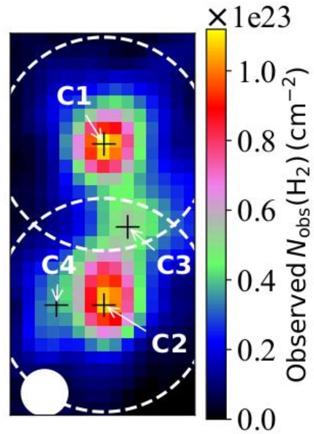
Turbulence
Magnetic field
.....

Discussions

temperature effects

Dynamical processes

Velocity along line-of sight



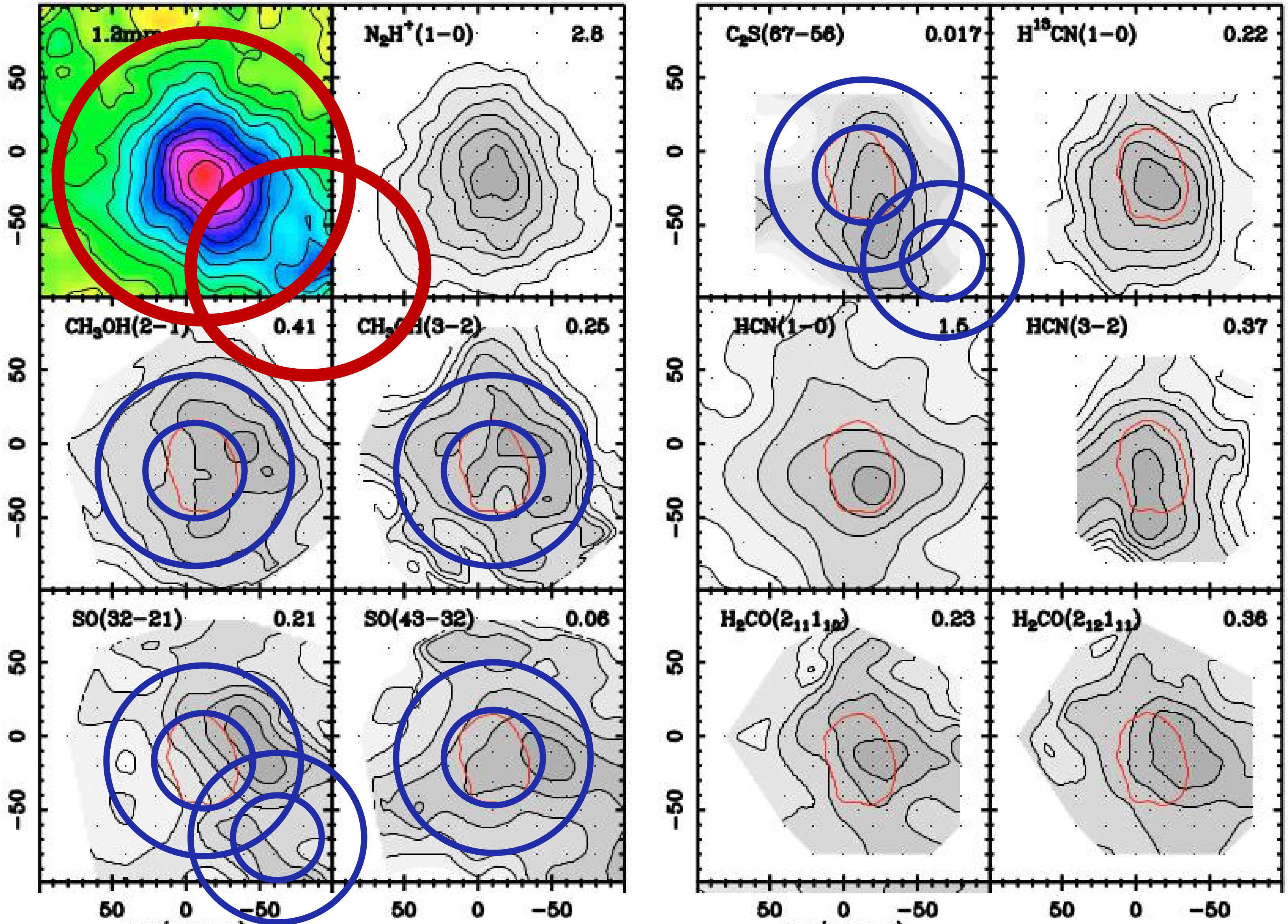
Chemical age

application

L1571B core

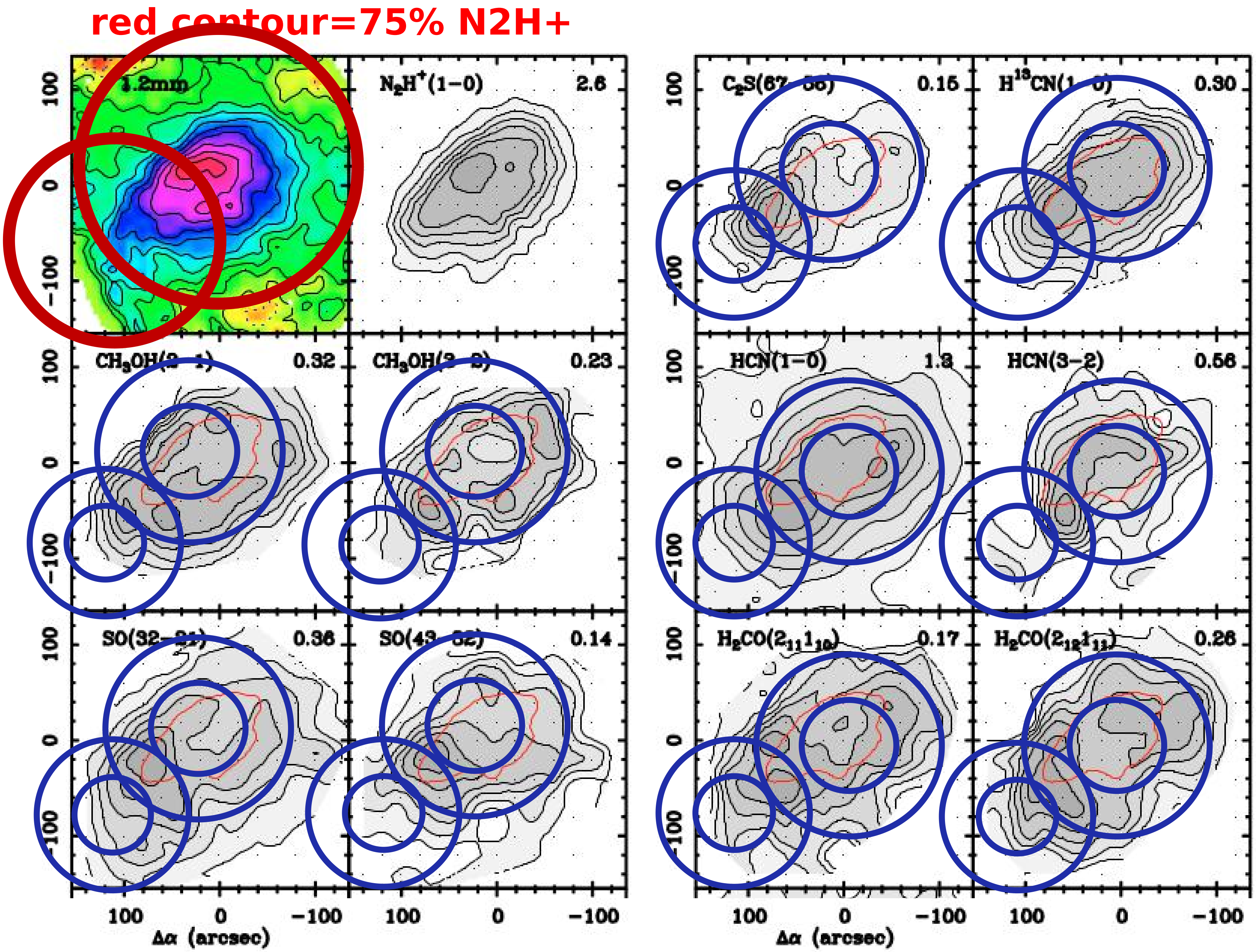
Tafalla et al., 2006, A&A 455, 577–593

red contour=75% N2H+



L1498 core

Tafalla et al., 2006, A&A 455, 577–593



Conclusions

- **The three-dimensional projection effects commonly exist in space can be approached by multiple-cores models.**

- **The overlapping effects of ring of molecules (e.g. CCS and HC3N) are the key factors for their peak offsets to dust peaks.**

- **The multiple-cores approach has great potential to explain many observed molecular distributions in cloud dense cores.**

Thank you for your attention