Kinematics and detection of infall of IRAS 16293-2422

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NTHU

IRAS 16293-2422

- Location: ρ Ophiuchus star-forming region
- Class 0 protostar
- Binary system
  - Source A and B separated by 5”(600 AU) (Looney et al. 2000)
- Shows a rich chemistry, with hot-core-like (hot corino) properties

Data

- Science Verification data
- Band 4 (125-163 GHz), Band 6 (211-275 GHz), Band9 (602-720 GHz)
- X1ed.decimated.ms.I16293, X39.decimated.ms.I16293, X3bf.decimated.ms.I16293, X4fb.decimated.ms.I16293

↓ Combine data sets with task: concat

I16293_corrected.ms

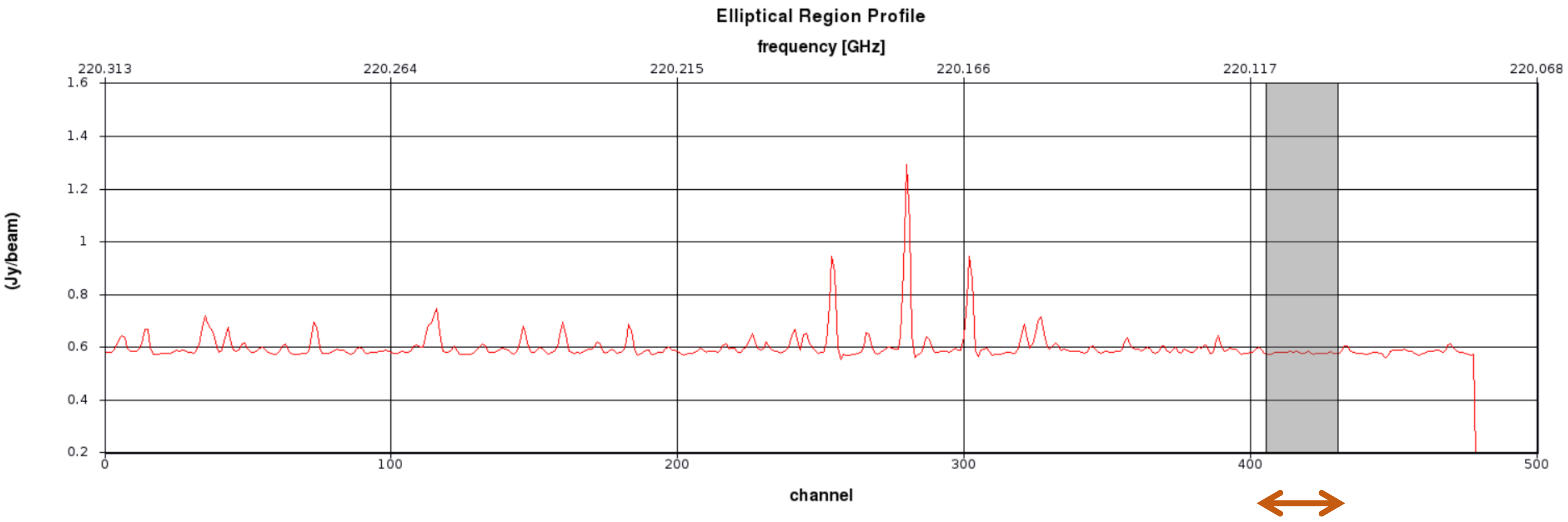
Observations

```
Data records: 224400       Total elapsed time = 19730.6 seconds
   Observed from   16-Aug-2011/23:07:54.9   to   17-Aug-2011/04:36:45.5 (UTC)
Fields: 2
  ID   Code Name                RA               Decl             Epoch   SrcId      nRows
  0    none IRAS 16293-2422-a   16:32:22.990000 -24.28.36.10000 J2000   0          112200
  1    none IRAS 16293-2422-a   16:32:22.715314 -24.28.32.32602 J2000   0          112200
Spectral Windows:  (1 unique spectral windows and 1 unique polarization setups)
  SpwID  Name   #Chans   Frame   Ch0(MHz)  ChanWid(kHz)  TotBW(kHz) CtrFreq(MHz) BBC Num  Corrs
  0              480    TOPO  220299.429      -488.281    234375.0 220182.4861        1  XX  YY
Sources: 1
  ID   Name                SpwId RestFreq(MHz)  SysVel(km/s)
  0    IRAS 16293-2422-a   0     -              -
Antennas: 16:
```

Source A

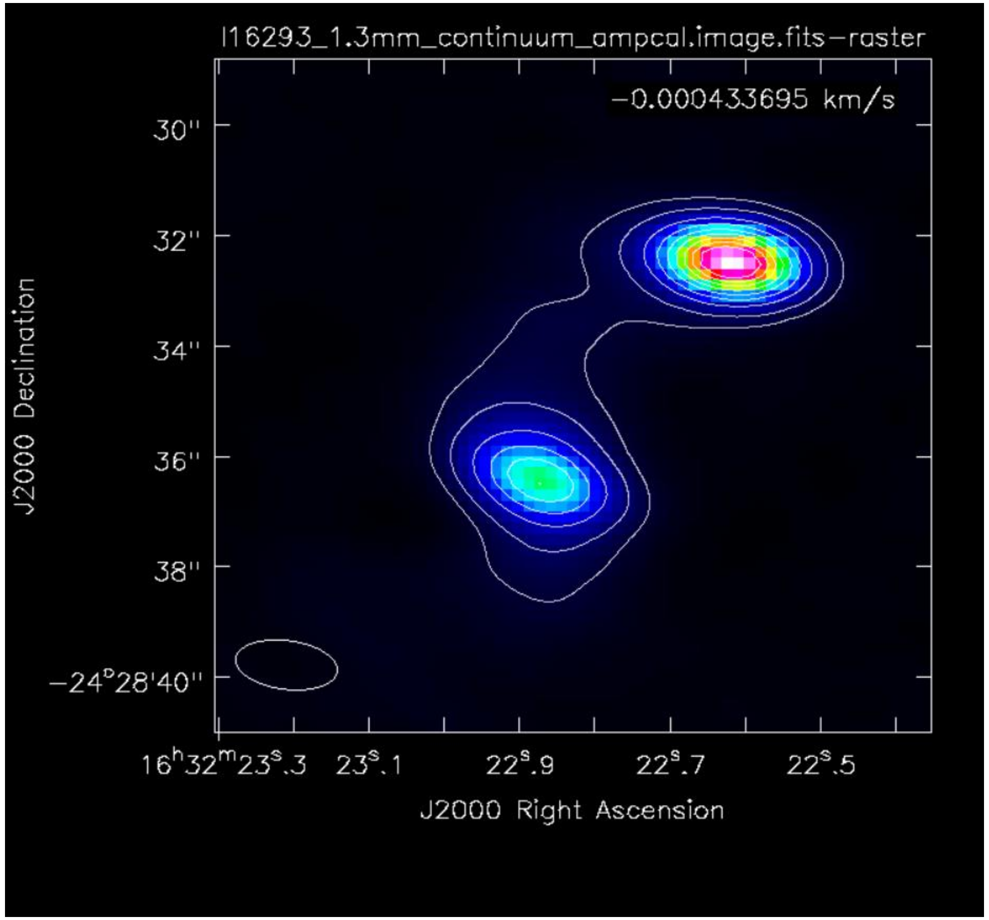
Source B

Spectral Profile



Chan: 405~430

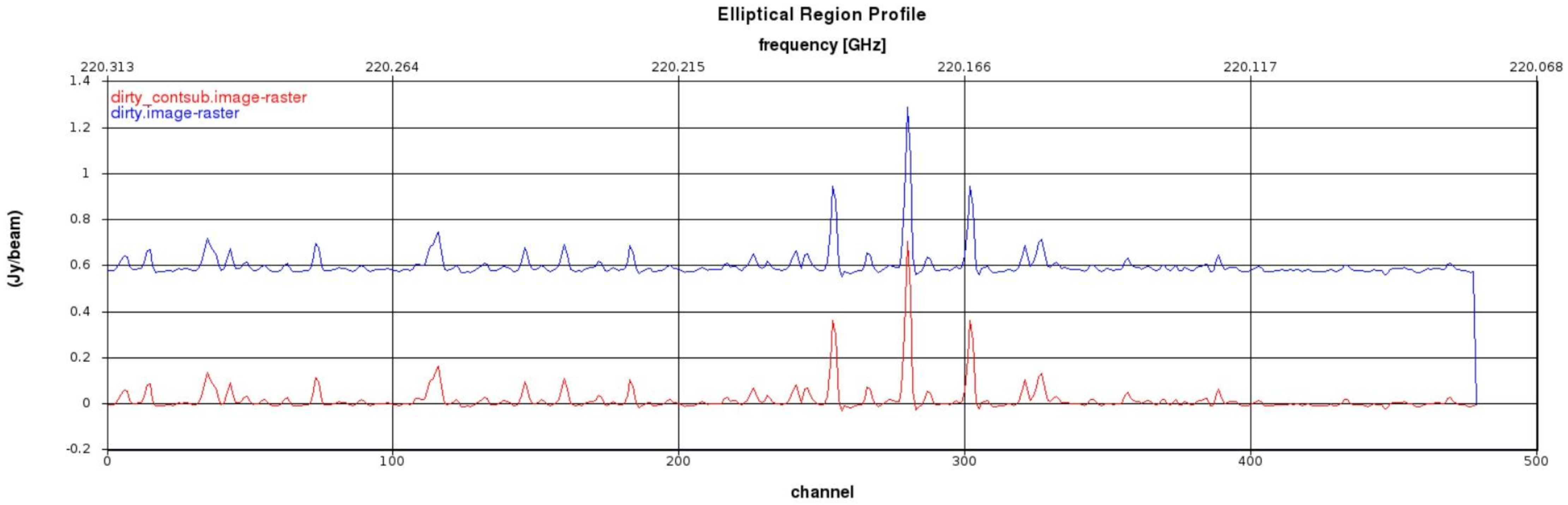
Continuum Map



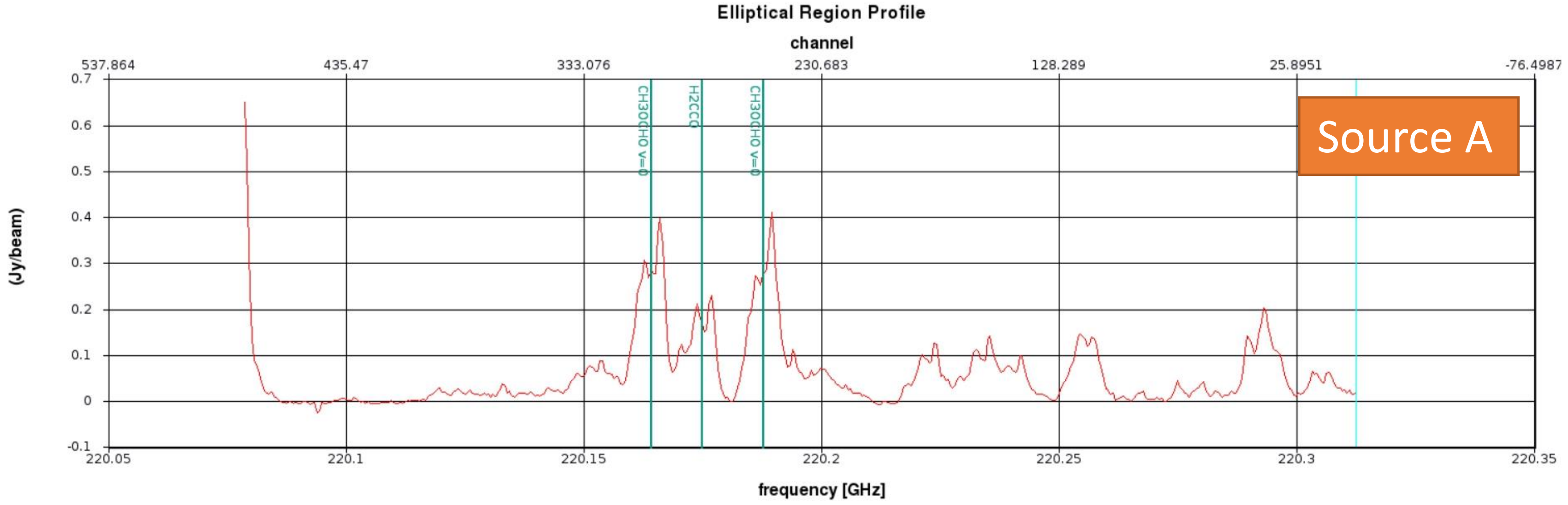
Continuum map after self-cal done by the paper

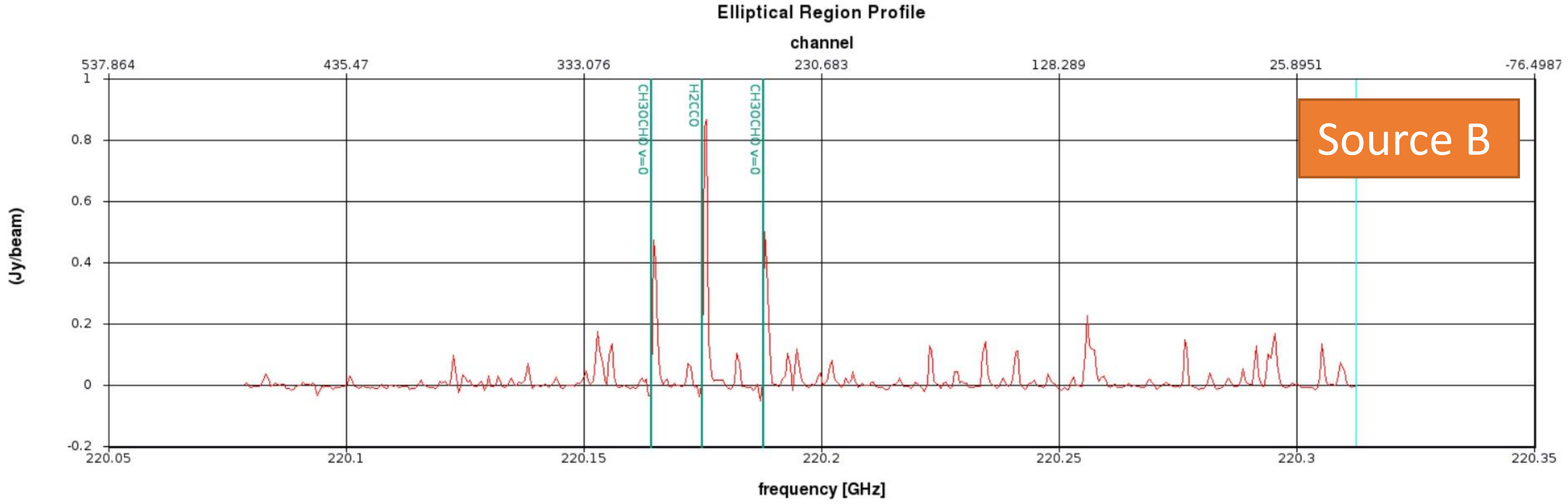
Subtract Continuum

Chan: 405~430



Channel Map



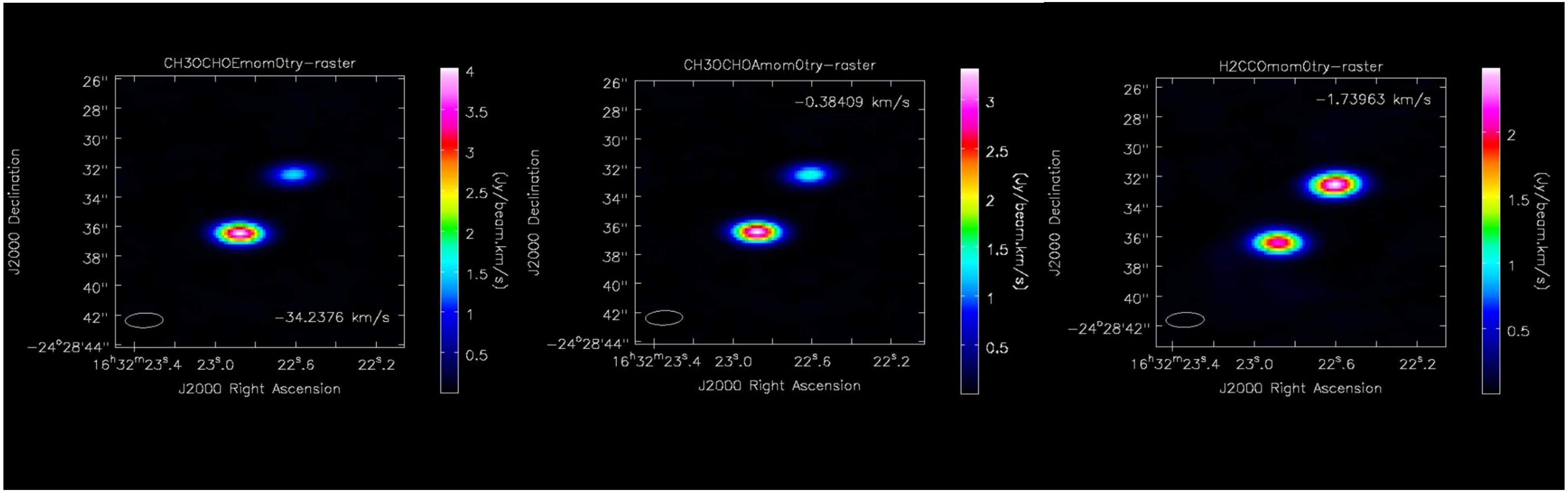


Molecule	Frequency (GHz)
CH_3OCHO-E	220.166888
CH_3OCHO-A	220.190285
H_2CCO	220.17757

Reframe by task: imreframe

Moment Maps

Moment 0



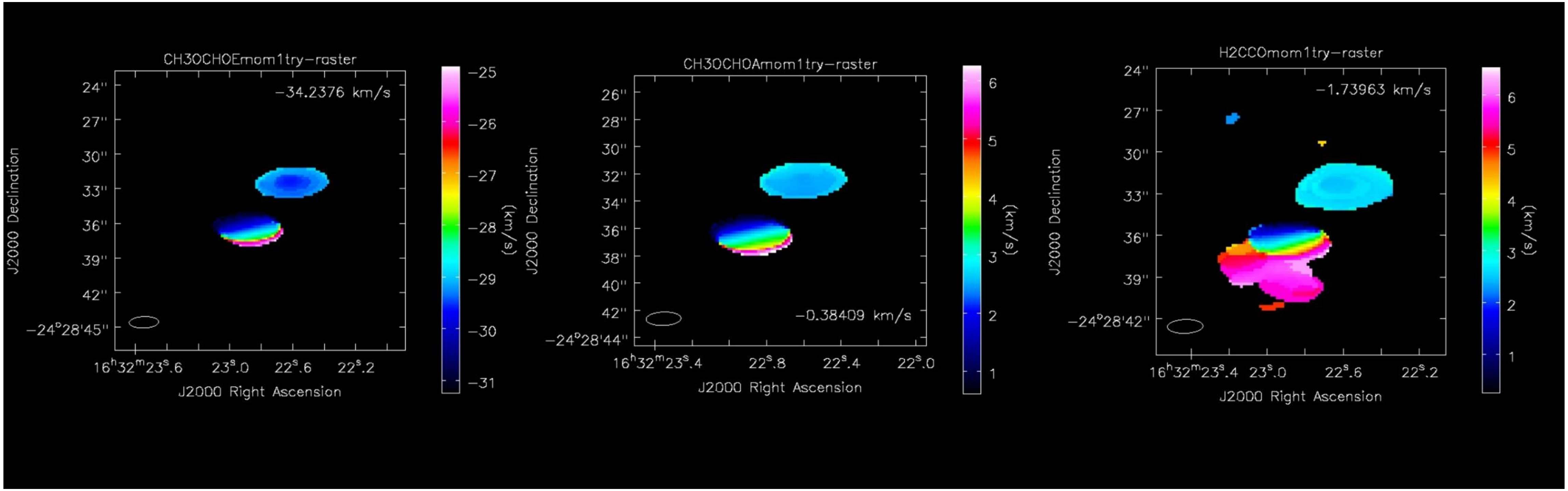
CH_3OCHO-E

CH_3OCHO-A

H_2CCO

Moment Maps

Moment 1

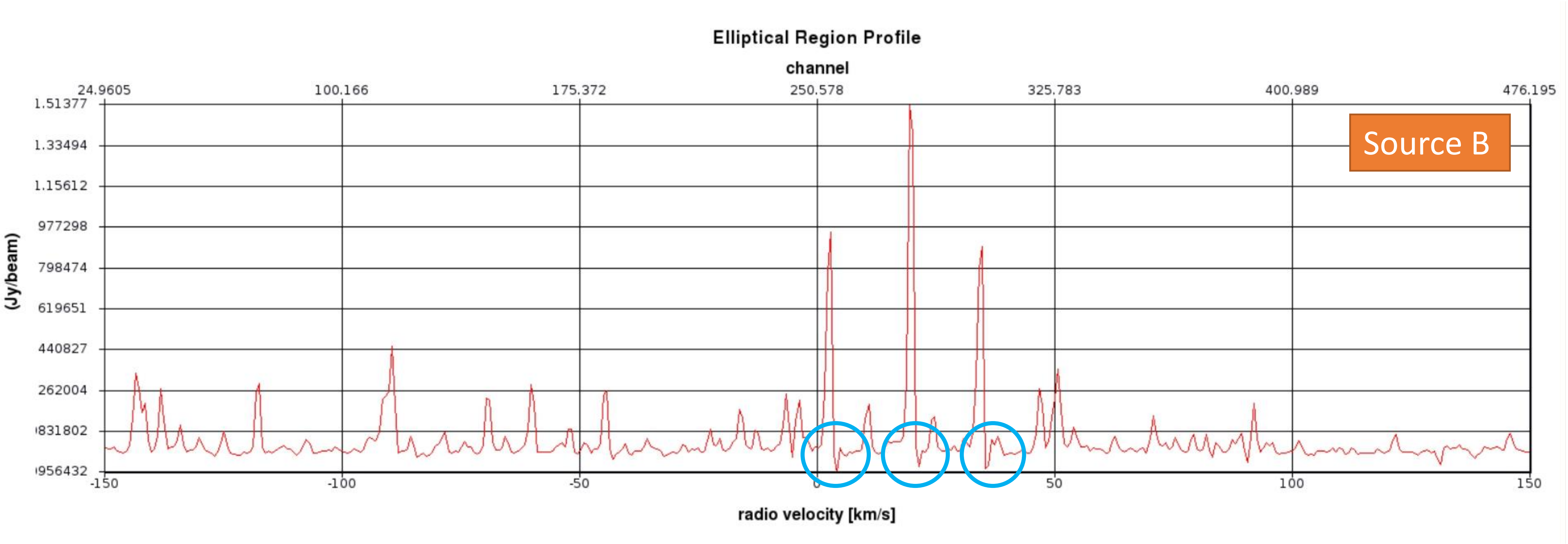


CH_3OCHO-E

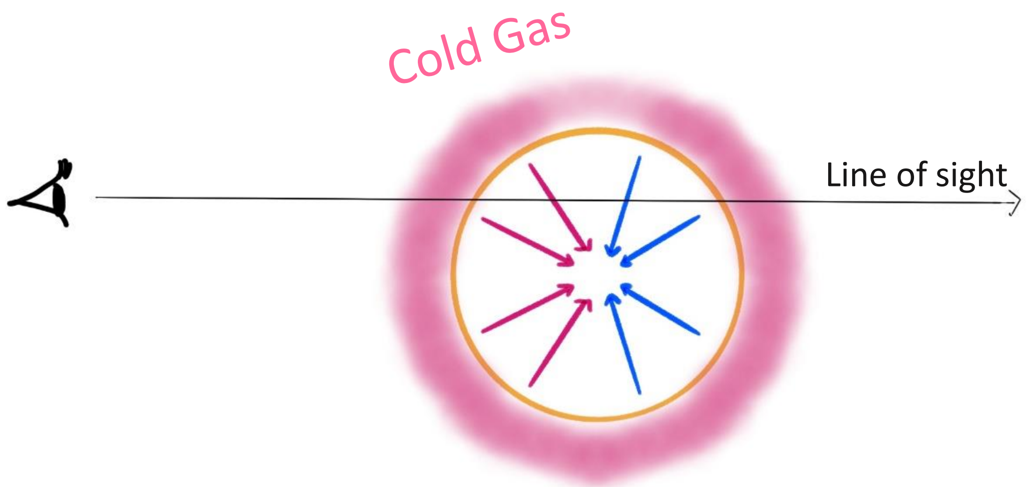
CH_3OCHO-A

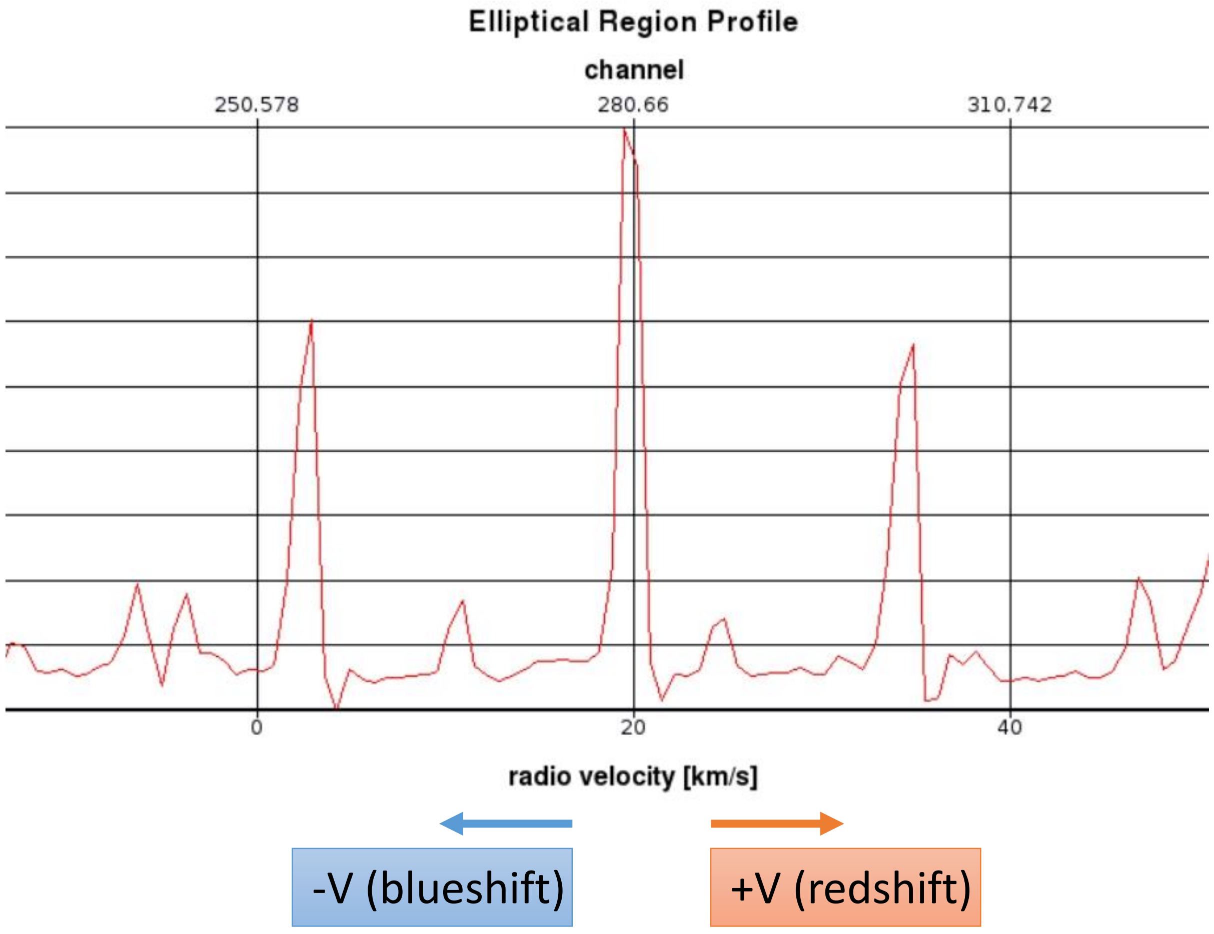
H_2CCO

Detect Inverse P-Cygni Profiles

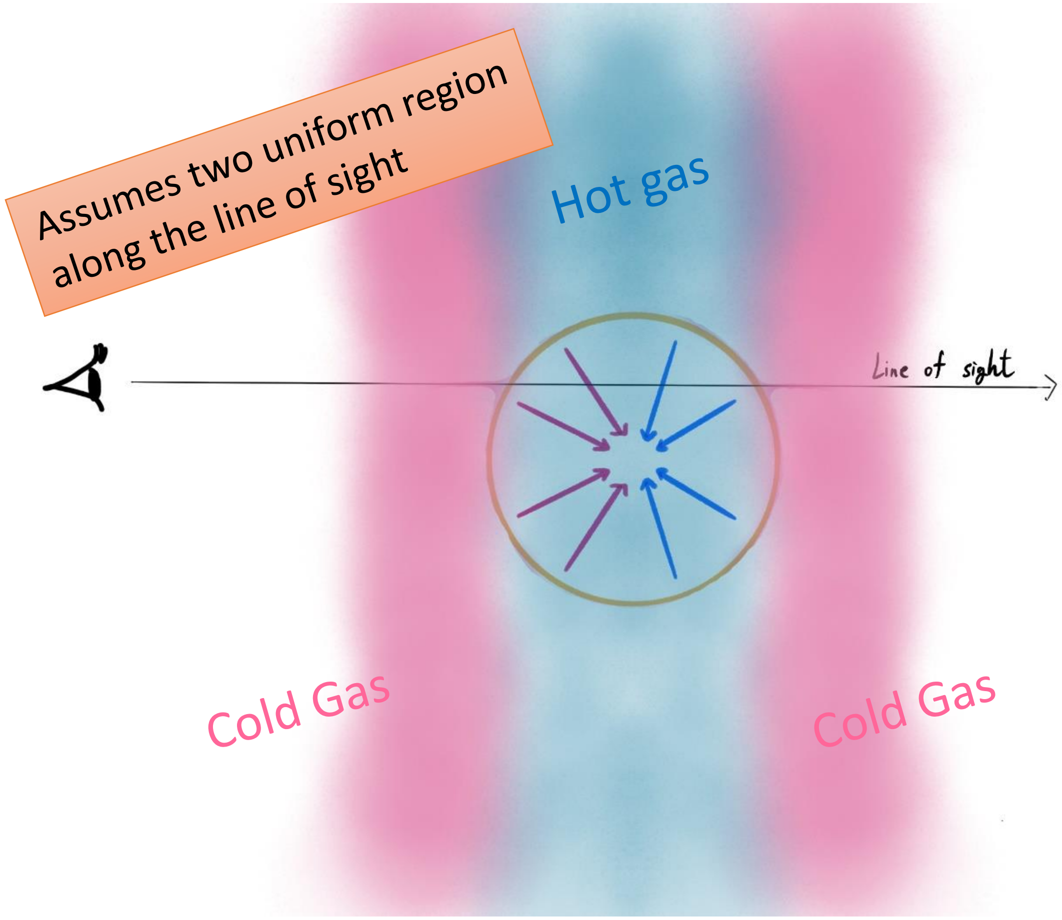


Inverse P-Cygni Profile: Infall Signature





Two-Slab Approximation



Describe by Myers et al. (1996)
Modification introduced by Di Francesco et al. (2001)

Expected line emission at velocity V can be expressed as

$$\Delta T_B = (J_f - J_{cr})[1 - e^{-\tau_f}] + (1-\phi)(J_r - J_b)[1 - e^{-(\tau_r + \tau_F)}]$$

where

$$J_{cr} = \phi J_c + (1-\phi) J_r$$

and

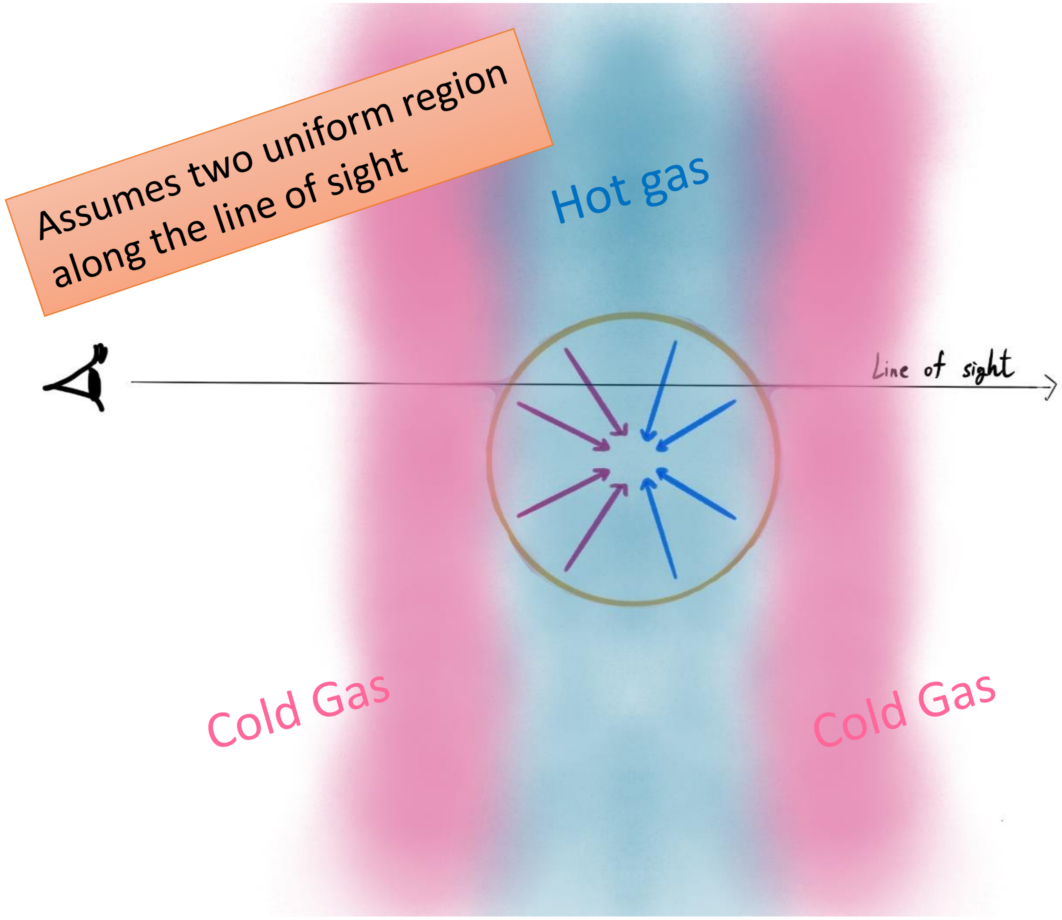
$$\tau_f = \tau_0 \exp\left[\frac{-(V - (V_{lsr} + V_{in}))^2}{2\sigma_v^2}\right]$$

$$\tau_r = \tau_0 \exp\left[\frac{-(V - (V_{lsr} - V_{in}))^2}{2\sigma_v^2}\right]$$

Radiation temperature is defined as

$$J_x = \frac{T_0}{[e^{T_0/T_x} - 1]}$$

Two-Slab Approximation



Fixed value

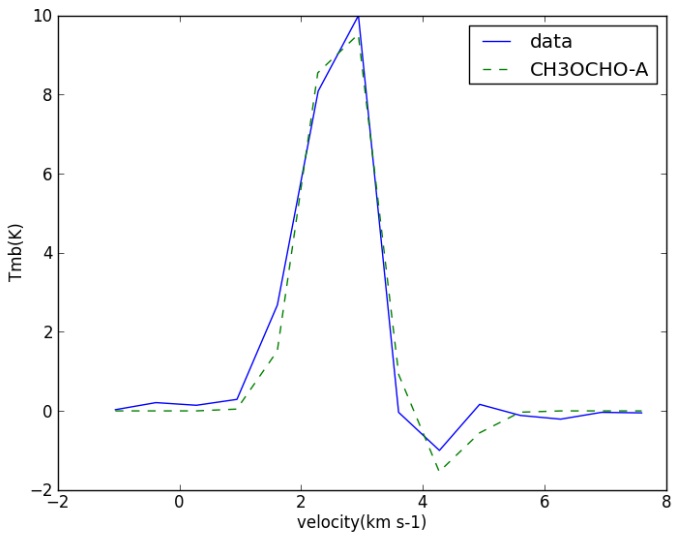
$T_f = 3\ K, T_c = 20\ K, T_b = 2.75\ K, V_{lsr} = 3.4\ km\ s^{-1}, \emptyset = 0.3$

(Pineda et al. 2012)

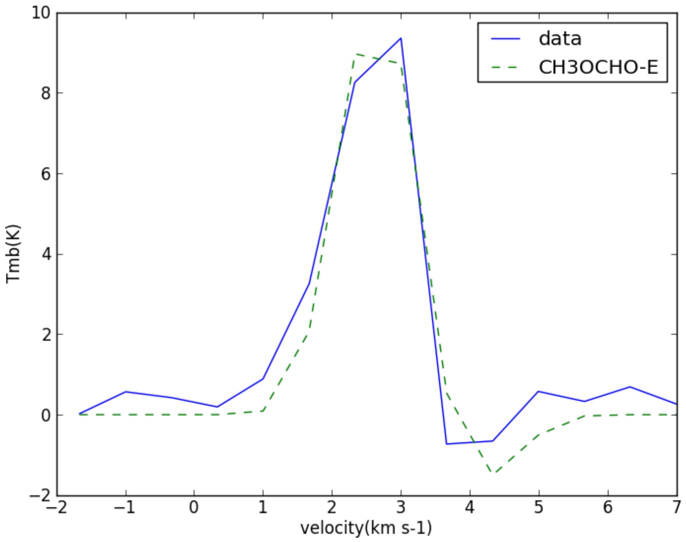
Free parameters for fitted "two-slab" model

- Infall velocity of the layers V_{in}
- Optical depth τ_0
- Velocity dispersion σ_v
- Excitation temperature of the layer of the rear T_r

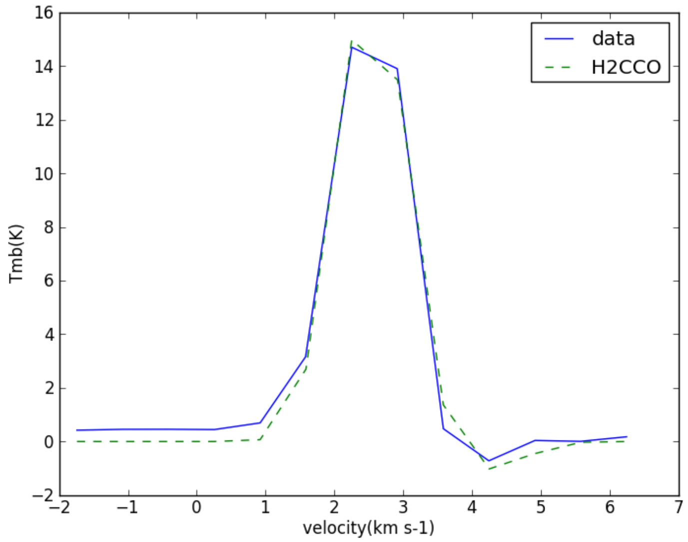
My Fitting Results



CH_3OCHO-A



CH_3OCHO-E



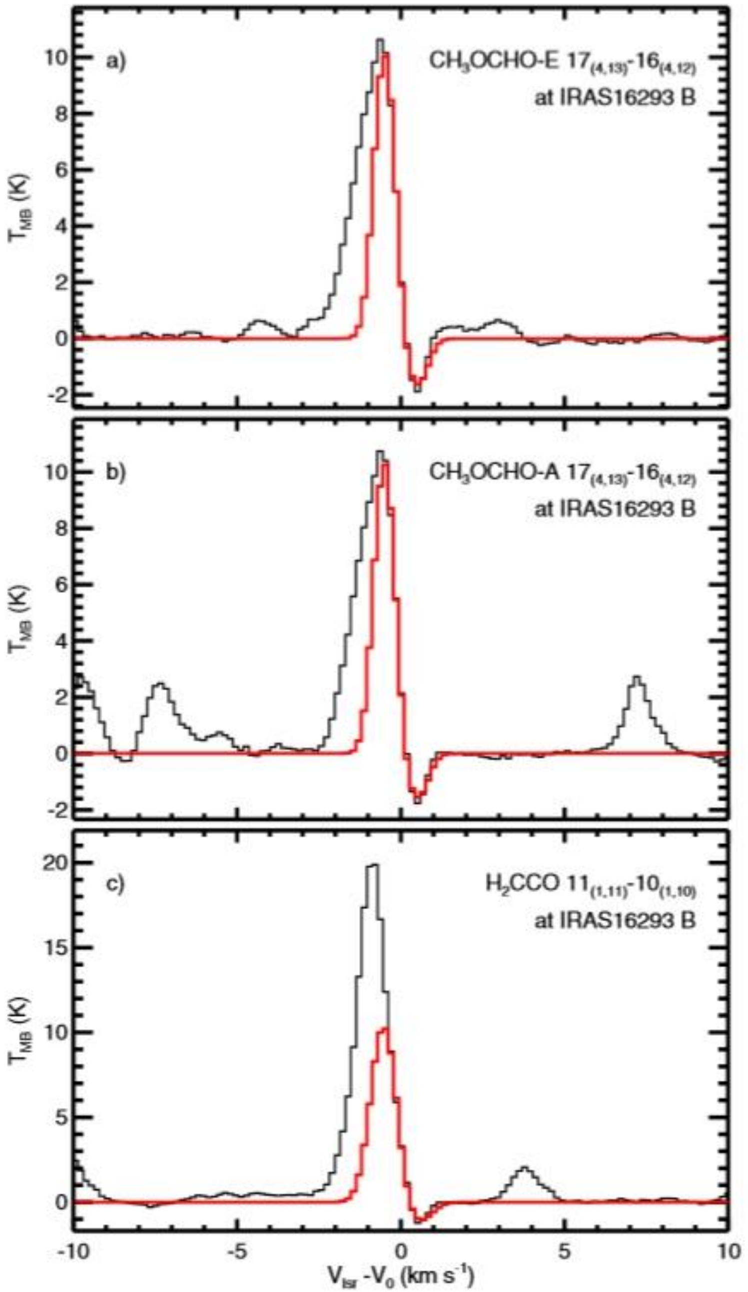
H_2CCO

Line	T_r (K)	τ_0	V_{in} (km s^{-1})	σ_v (km s^{-1})
CH_3OCHO-E	47.48	0.42	0.71	0.53
CH_3OCHO-A	49.35	0.41	0.72	0.51
H_2CCO	120.44	0.24	0.85	0.48

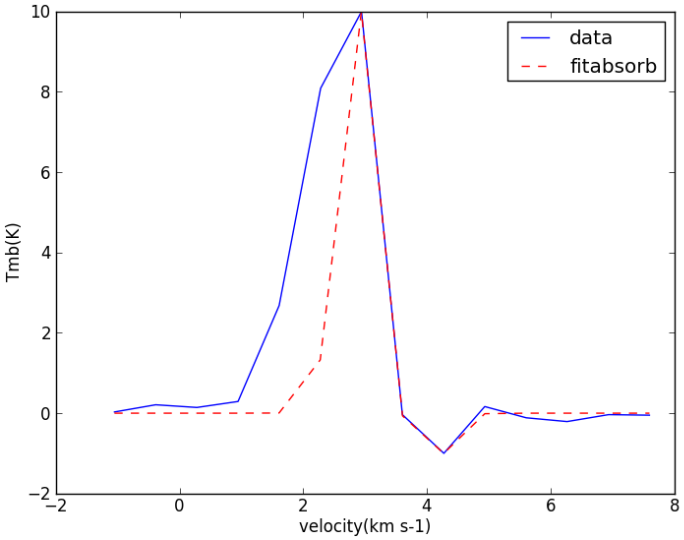
My Fitting Results

Line	T_r (K)	τ_0	V_{in} (km s^{-1})
CH_3OCHO-E	47.48	0.42	0.71
CH_3OCHO-A	49.35	0.41	0.72
H_2CCO	120.44	0.24	0.85

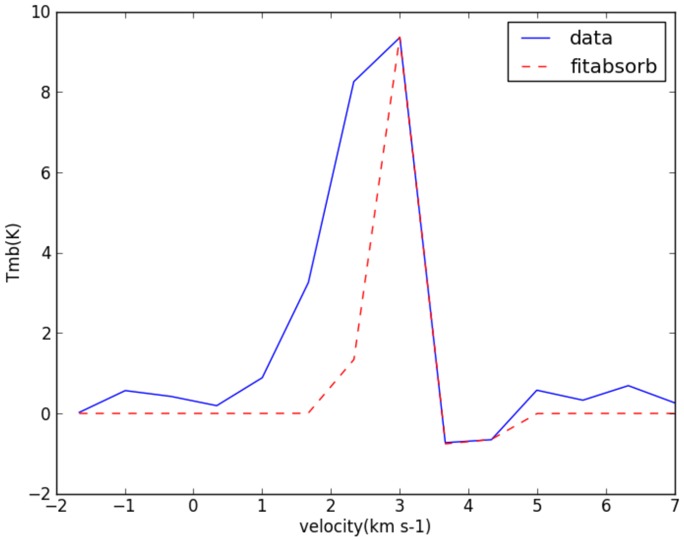
Line	T_r (K)	τ_0	V_{in} (km s^{-1})
CH_3OCHO-E	44 ± 3	0.48 ± 0.04	0.49 ± 0.02
CH_3OCHO-A	46 ± 3	0.45 ± 0.04	0.49 ± 0.02
H_2CCO	60 ± 10	0.33 ± 0.05	0.51 ± 0.07



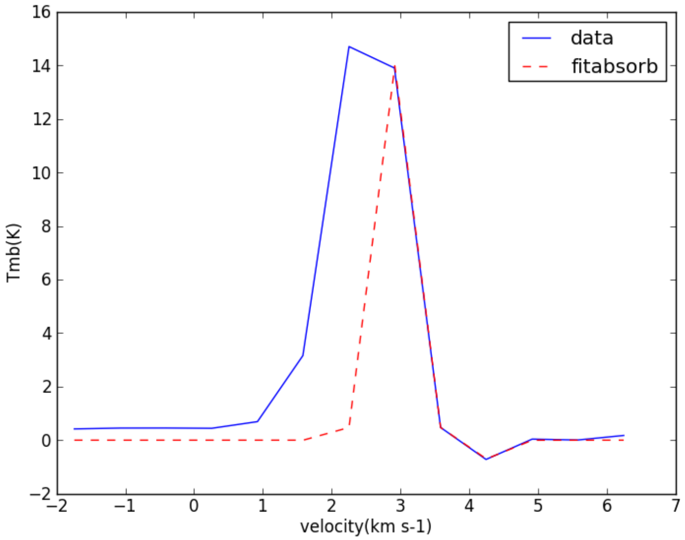
Fitting Result (Absorption Only)



CH$_3$OCHO-A



CH$_3$OCHO-E



H$_2$CCO

Line	T_r (K)	τ_0	V_{in} (km s^{-1})	σ_v (km s^{-1})
CH3OCHO-E	32.56	0.79	0.28	0.34
CH3OCHO-A	34.11	0.74	0.32	0.35
H2CCO	45.42	0.82	0.28	0.30

Infall Rates

Assuming spherical symmetry, $\dot{M}_{infall} = 4\pi r_{in}^2 n_{in} \mu m_H V_{in}$

r_{in}: infall radius, V_{in}: velocity, n_{in}: density, μ: mean molecular weight of gas=2.3

r_{in} can be estimated assuming the in-fall velocity is only free-fall,

$$M = \frac{V_{in}^2 r_{in}}{2G} = \frac{4}{3}\pi r_{in}^3 \mu m_H$$

Therefore, the accretion rate is estimated as

$$\dot{M}_{infall} = 4.2 \times 10^{-5} \left(\frac{V_{in}}{0.5 km\ s^{-1}}\right)^3 M_\odot yr^{-1}$$

(Pineda et al. 2012)

Infall Rates

$$\dot{M}_{infall} = 4.2 \times 10^{-5} \left(\frac{V_{in}}{0.5 km\ s^{-1}} \right)^3 M_{\odot} yr^{-1}$$

molecule	V_{in} (km s^{-1})	$\dot{M}_{infall}$ ($M_{\odot} yr^{-1}$)
CH_3OCHO-E	0.28	7.38×10^{-6}
CH_3OCHO-A	0.32	1.1×10^{-5}
H_2CCO	0.28	7.38×10^{-6}

My Result (fitting absorption)

Molecule	V_{in} (km s^{-1})	$\dot{M}_{infall}$ ($M_{\odot} yr^{-1}$)
CH_3OCHO-E	0.49 ± 0.02	4.2×10^{-5}
CH_3OCHO-A	0.49 ± 0.02	4.5×10^{-5}
H_2CCO	0.51 ± 0.07	4.8×10^{-5}

(Pineda et al. 2012)

Summary

- Different feature in moment map
  - Rotation of source A
- Infall rates of source B

molecule	V_{in} (km s^{-1})	$\dot{M}_{infall}$ $(M_{\odot} yr^{-1})$
CH_3OCHO-E	0.28	7.38×10^{-6}
CH_3OCHO-A	0.32	1.1×10^{-5}
H_2CCO	0.28	7.38×10^{-6}

～Thank you for listening～