JCMT observations of methanol in Cepheus A

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Outline

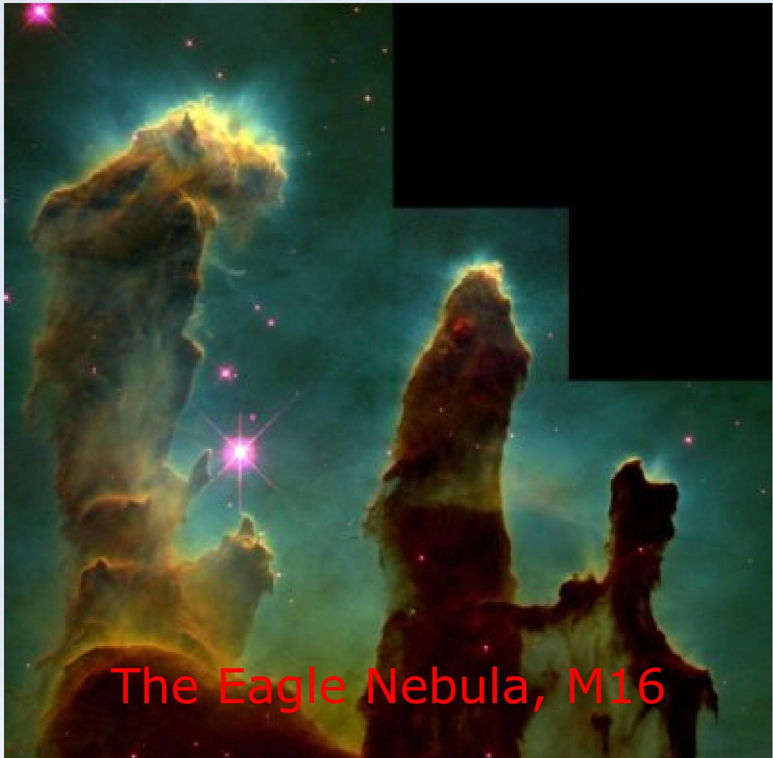
- Why and How
  - High-mass star-formation
  - 6.7 GHz CH_3OH maser (5_1-6_0 A^+)
- Results
  - Our data – rotation diagrams
  - Combined with SCUBA
  - non-LTE models
- Conclusions

High-mass star-formation

- Theories unclear for stars > $8M_\odot$

  Nearby massive stars are rare and evolve on short time scales. Typically form deeply embedded in clusters.

- 6.7 GHz methanol masers
  - Only in MSF regions
  - High resolution ~mas
  - Kinematics



Where/When do we find masers?

- Maser modeling (Cragg et al '05)
  - T: 100-300 K
  - n: 10^4-10^9 cm^{-3}
  - $N_M/\Delta v$: 10^{10}-10^{14} cm^{-3}

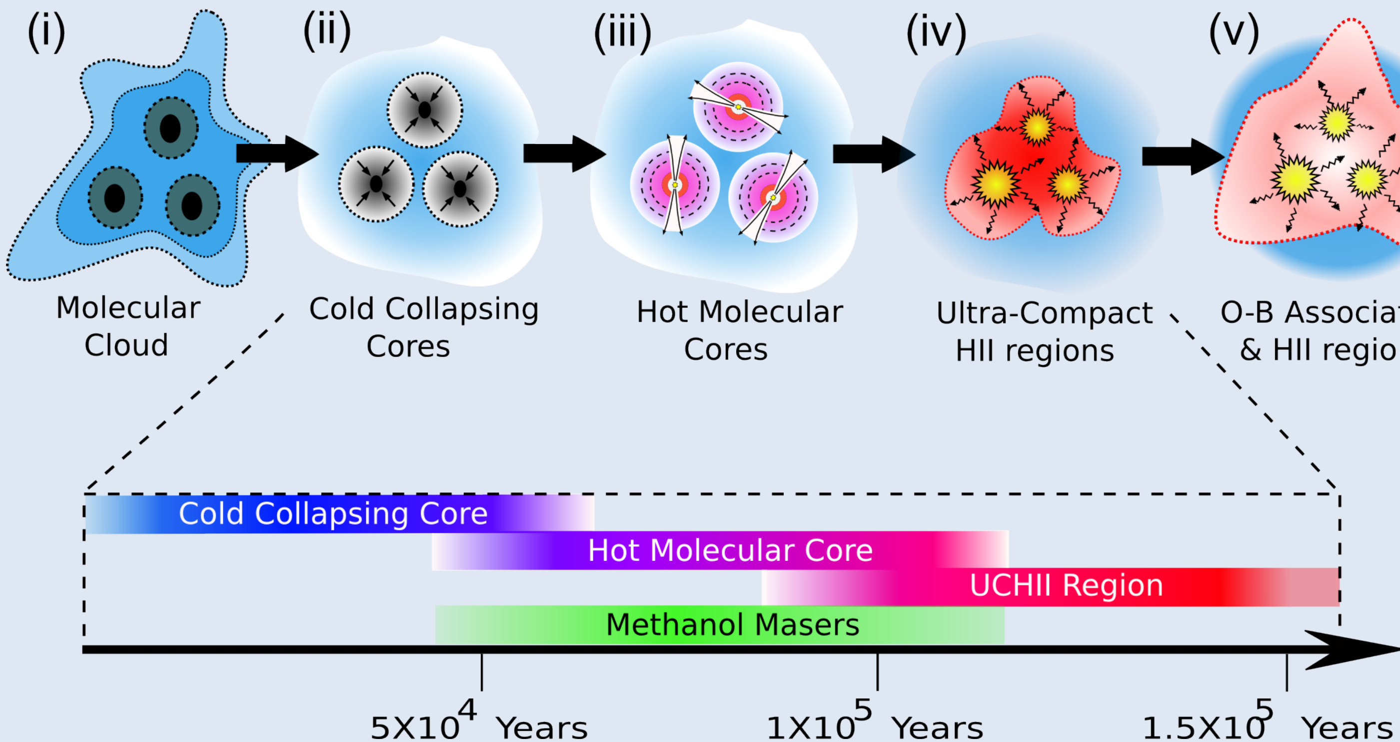
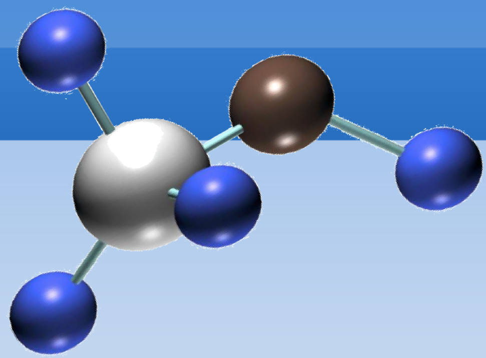
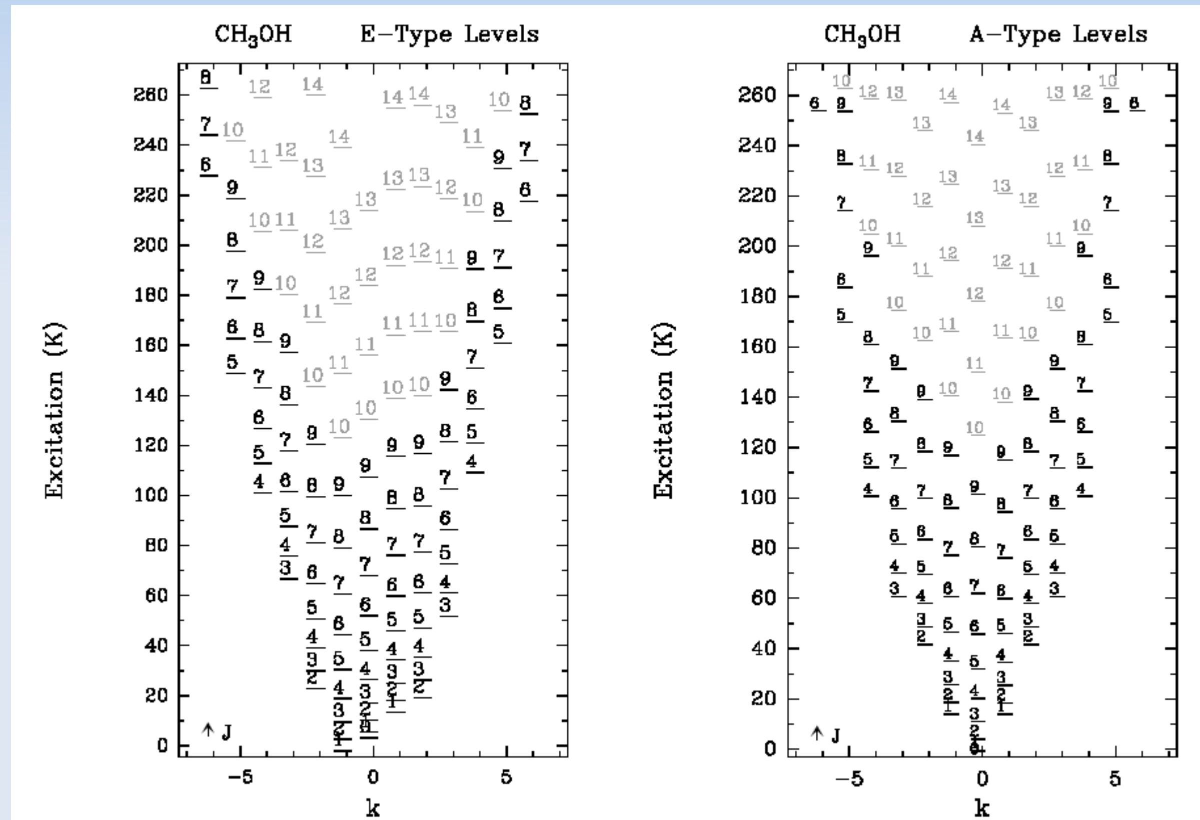


Image credit: Cormac Purcell

Methanol



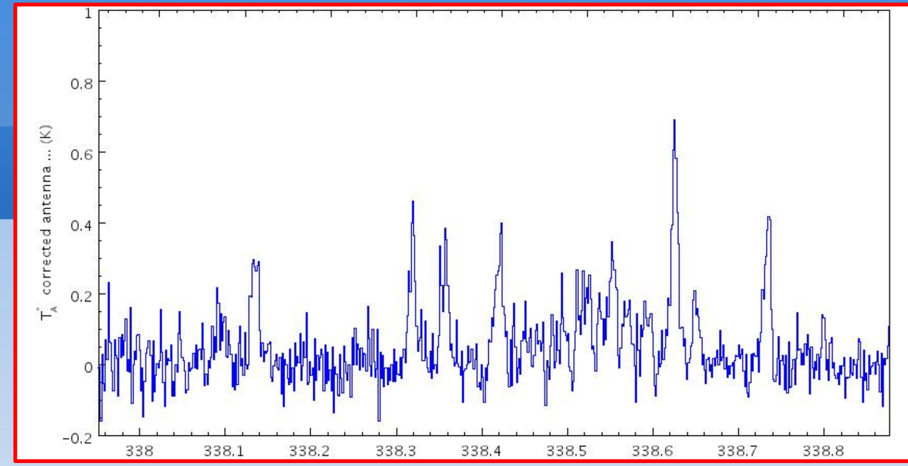
- Very rich spectrum
- Almost linear – good temperature probe
- Asymmetric – good density probe
- CH_3OH enhancement ~few 10^4 years

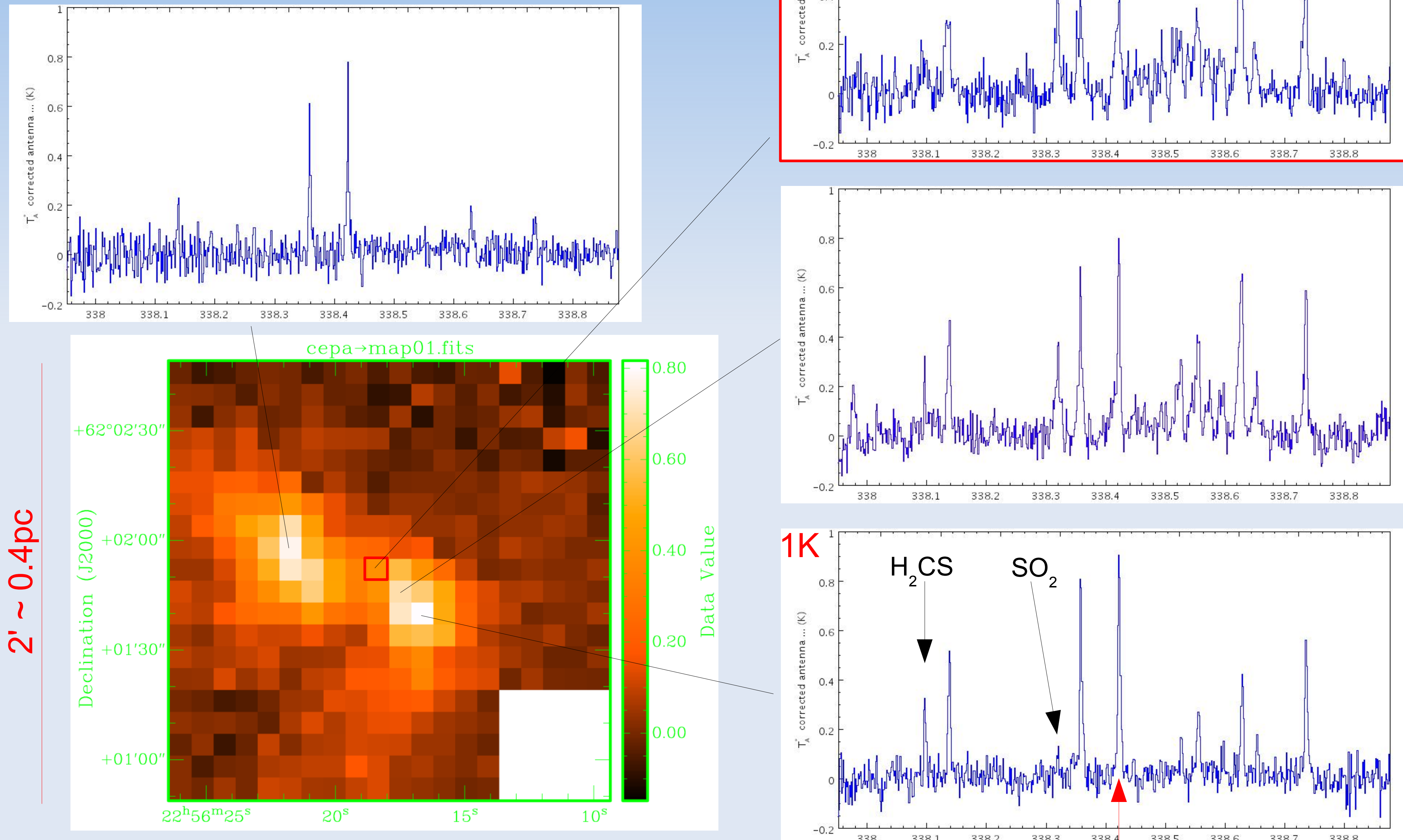


Sample & Observations

- Sample
  - 15 nearby high-mass star-forming regions
  - We have wide field EVN observations
- Observations – Cep A
  - Thermal methanol @ 338.4 GHz with JCMT
  - Multi-beam HARP, 16 receptors
  - Mapsize of 2' with a pixel spacing of 6”
  - Resolution 14”, matching SCUBA

Cep A – excited methanol gas





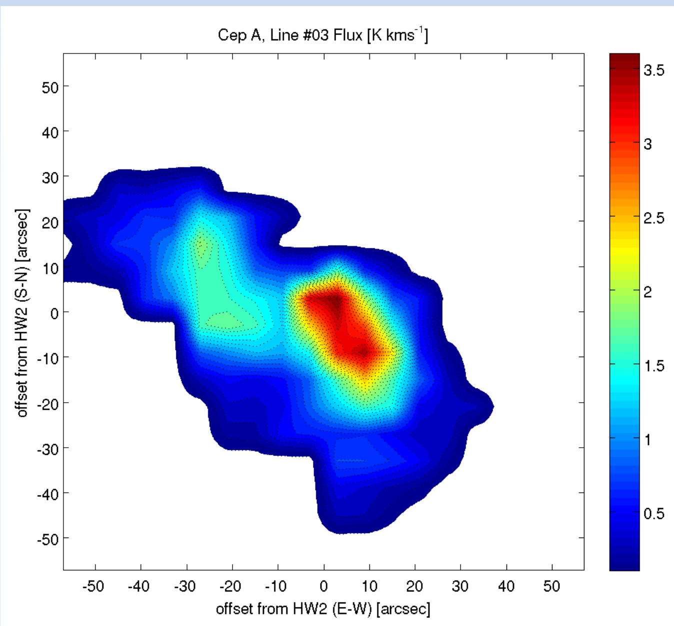
CH$_3$OH (7-6) 338.4GHz

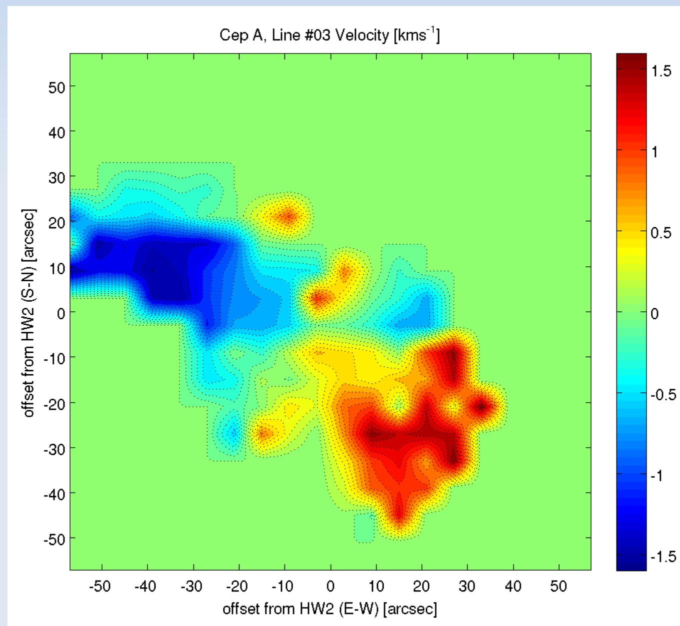
338.4 GHz

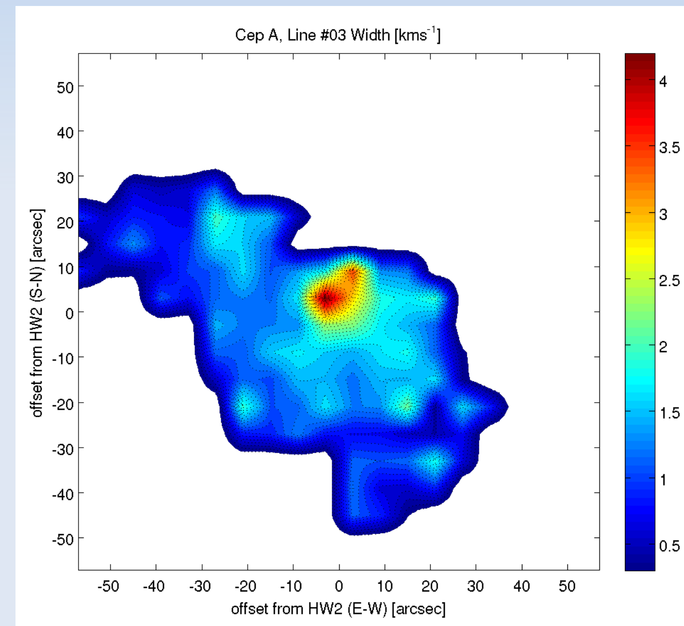
Cep A – CH_3OH Results

CH_3OH $(7_{-1}-6_{-1})$ E

Int. Flux [K kms^{-1}] **Center Velocity [kms^{-1}]** **Line Width [kms^{-1}]**





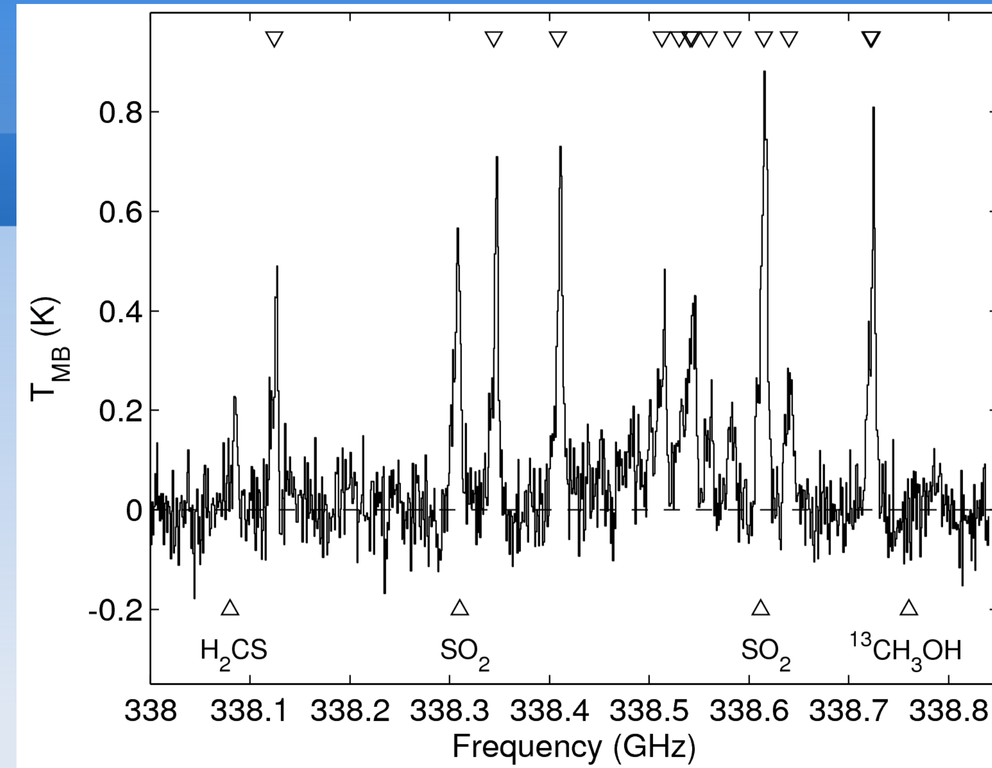


- Two intensity peaks in the center and one in the outflow
- Large scale velocity gradient - outflow
- Largest line width at position of HW2 (maser)

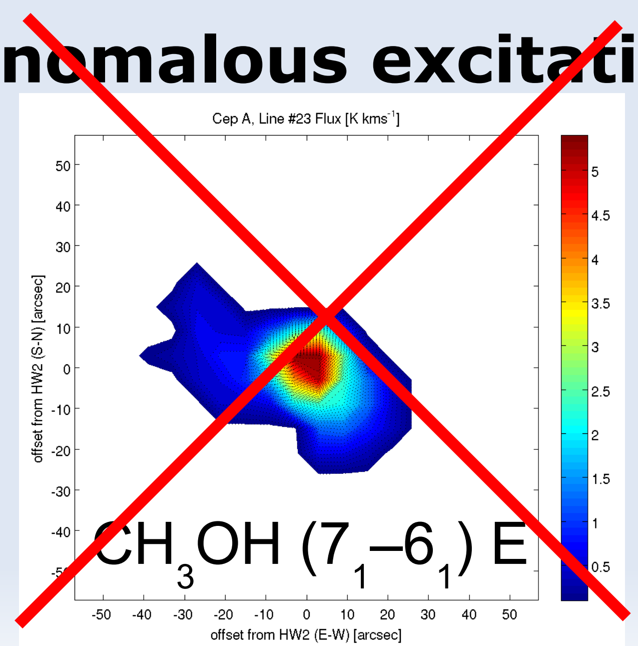
Cep A – Analysis

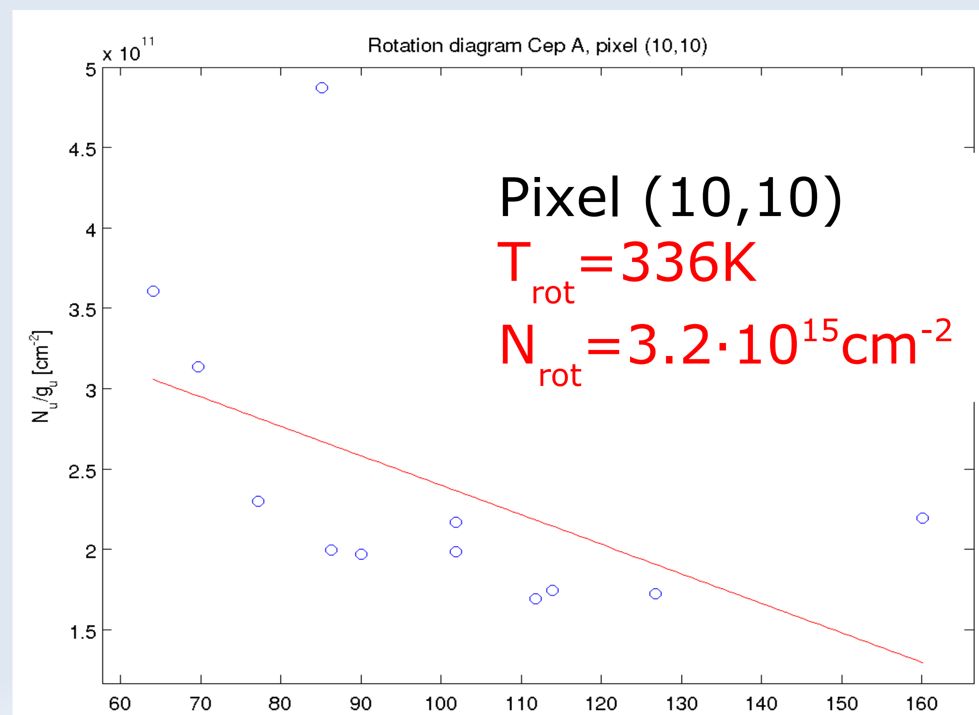
Rotation diagram analysis (Boltzmann plot)

- One excitation temperature
- Lines optically thin (τ«1)



Anomalous excitation

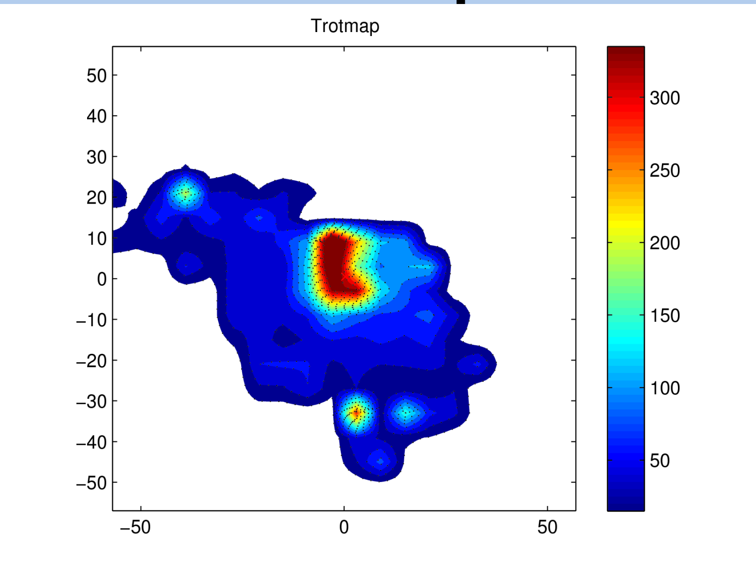




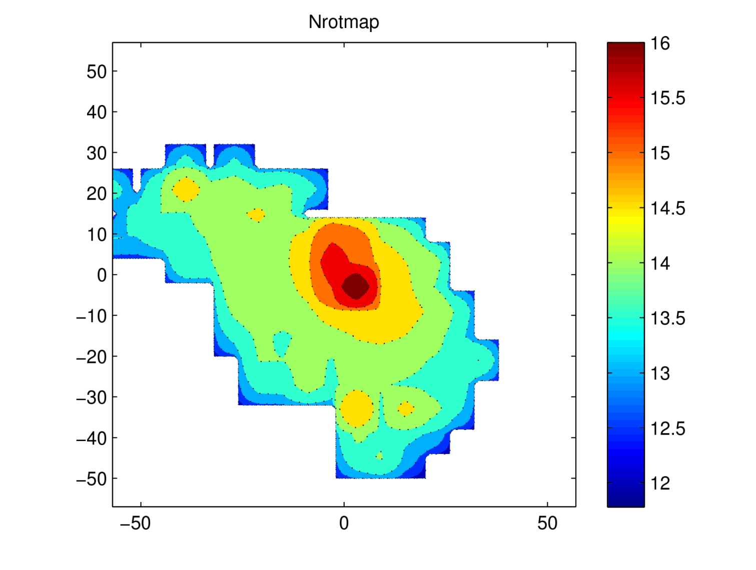
Cep A – CH_3OH Results

- $30 < T_{rot} < 300$ K
- $10^{12} < N(CH_3OH) < 10^{16}$ cm^{-2}
- 4 regions
  - T_{rot} peaks at position of HW2
  - $N(CH_3OH)$ peaks to the SW
  - Outflow feature to the NE
  - Envelope

Rotation temperature

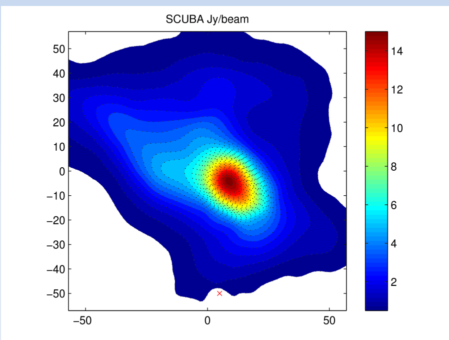


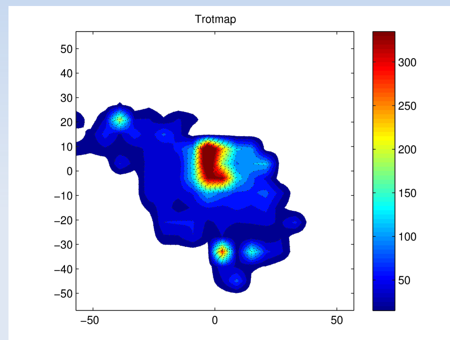
Column density



Hydrogen column density – $N(H_2)$

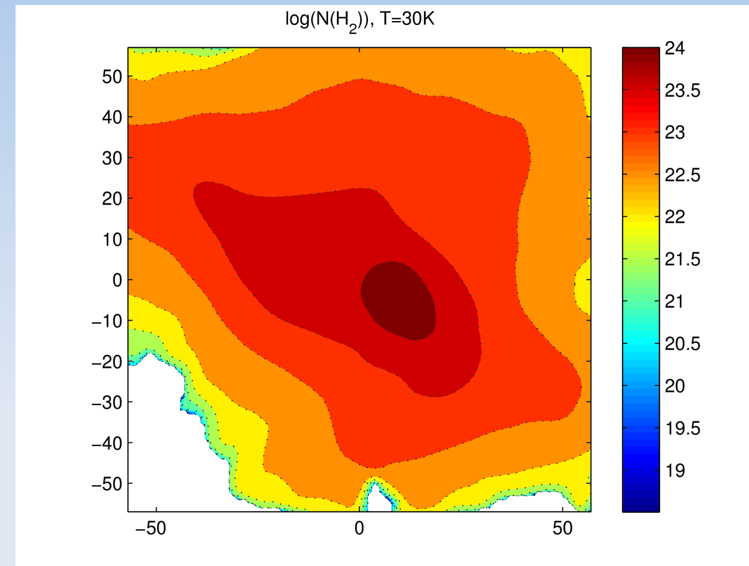
$$N(H_2)=\frac{S_\nu}{\kappa_d(\lambda)\Omega_{mb}B_\nu(T)2m_H}R$$



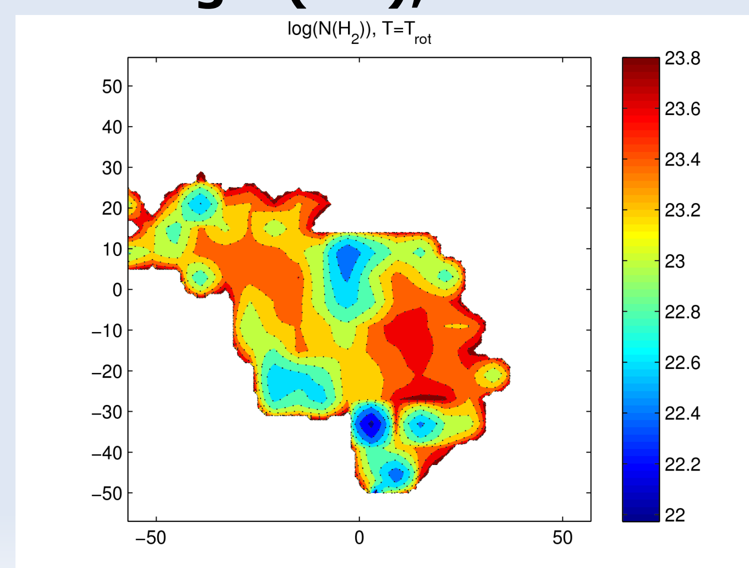


- Constant T => Scaled version of the SCUBA map
- $T=T_{rot}$ => Regions with higher T yields lower $N(H_2)$

log N(H2), T=30K



log N(H2), T=Trot

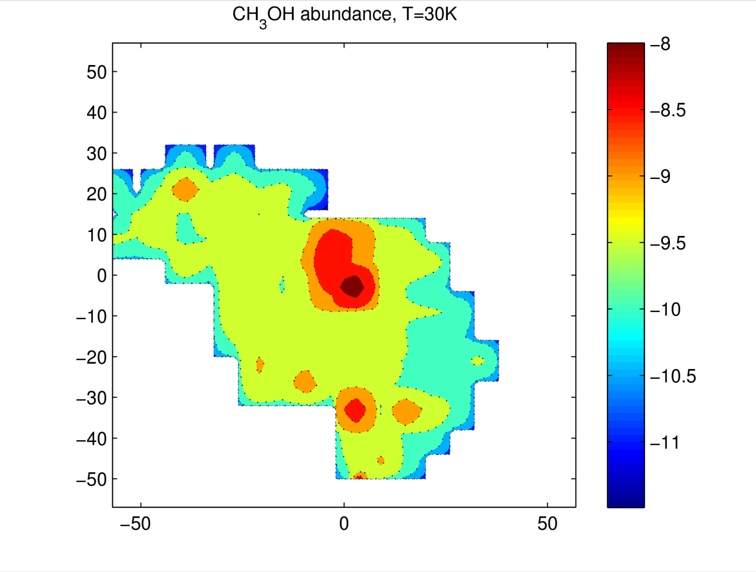


Methanol abundance – $x(CH_3OH)$

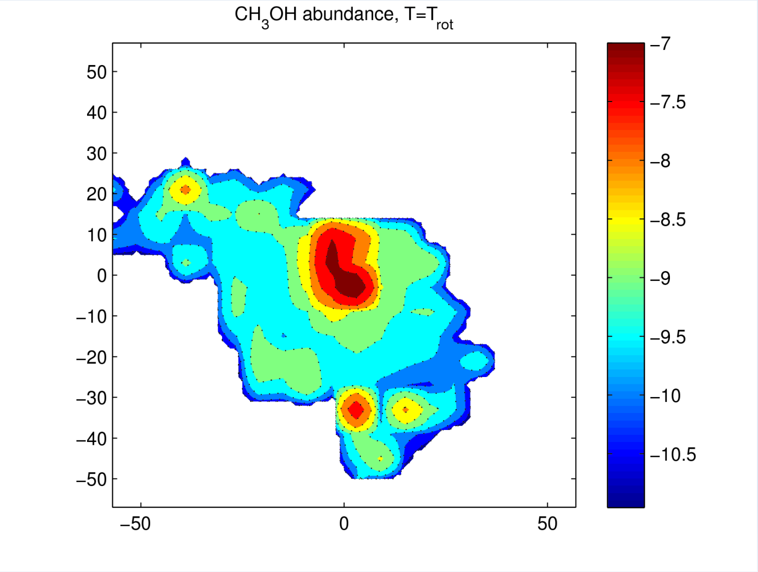
x(CH3OH)=N(CH3OH)/N(H2)

- Qualitatively agrees well
- $T=T_{rot}$ => Max abundance one magnitude higher than T=const
- Position of x(CH3OH) ~ N(CH3OH)

x(CH3OH), T=30K



x(CH3OH), T=Trot



Results I

- The 6.7 GHz methanol maser is more closely associated with the T_{rot} peak, rather than the column density or abundance peak.
- T_{rot} is not a kinetic temperature. It is a combination of the temperature T_{kin} and the density n.

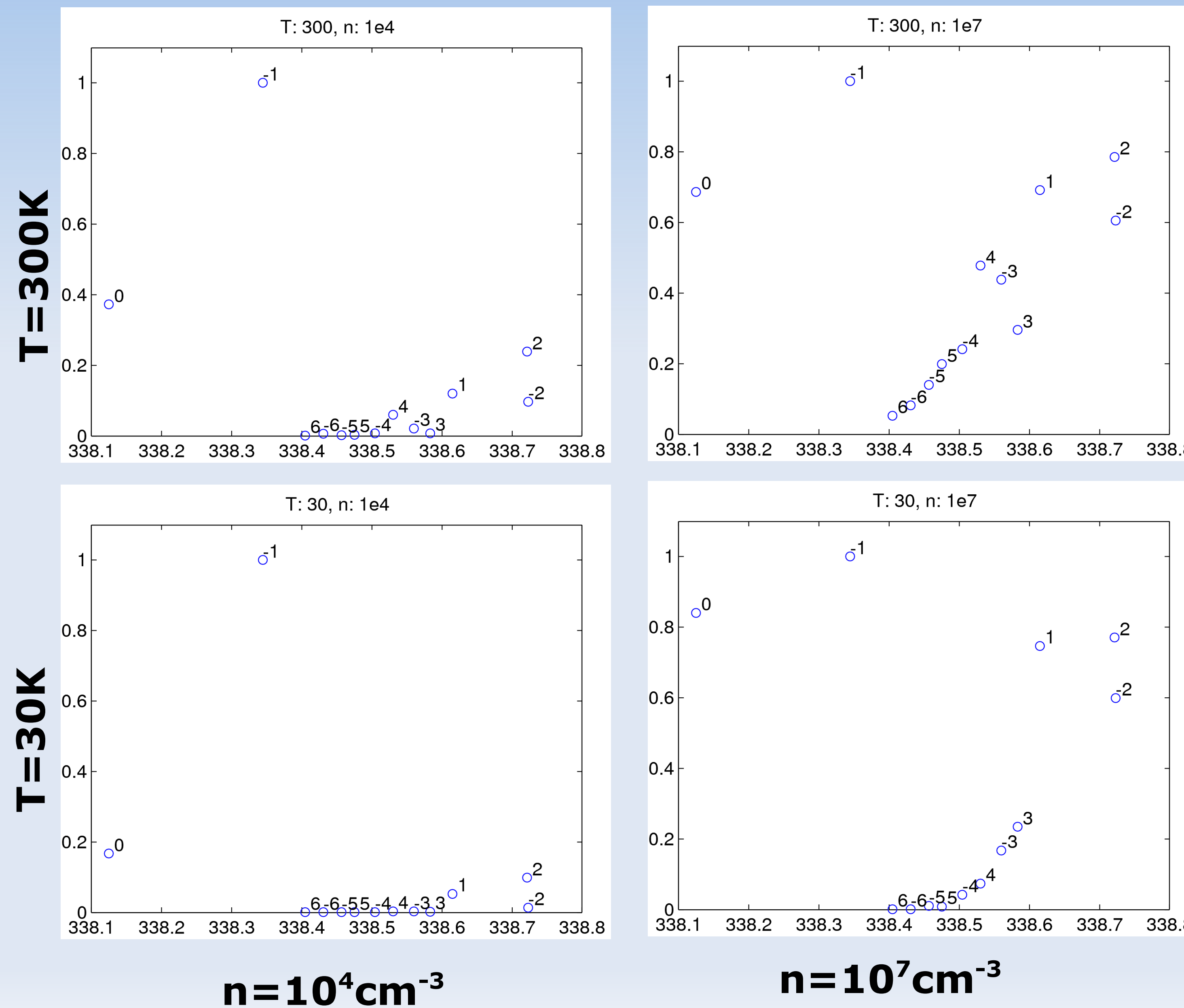
What are the physical conditions of the gas?

We have used RADEX for our non-LTE analysis to create synthetic spectra for a grid of physical conditions

RADEX non-LTE analysis

Excitation more sensitive to density than to temperature

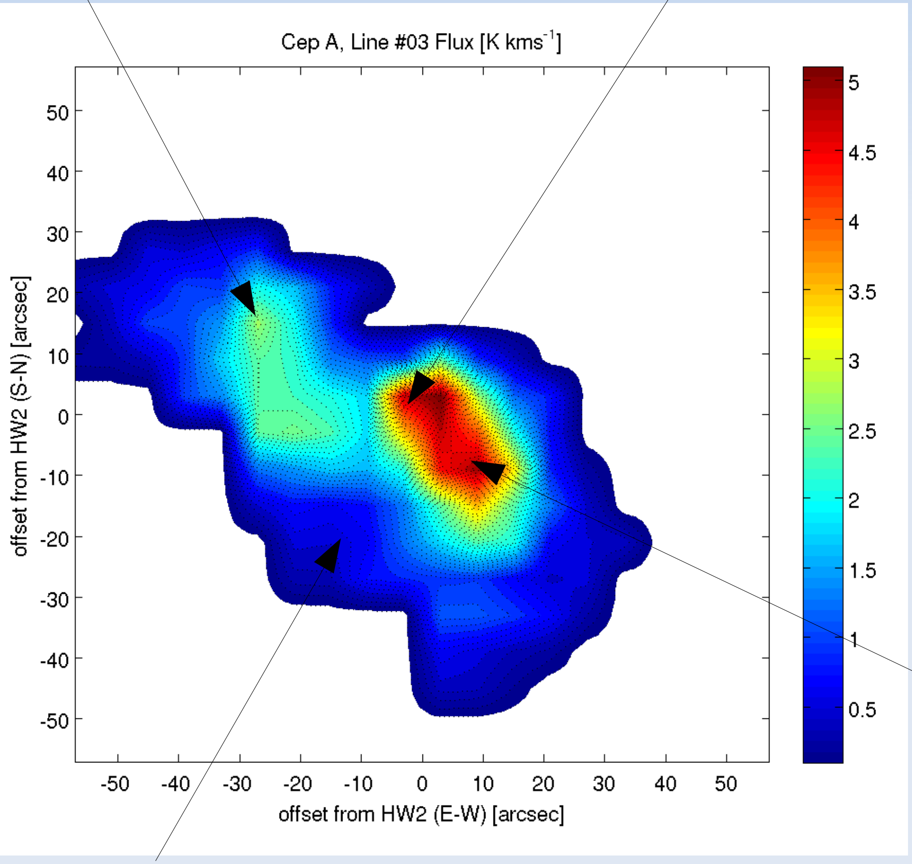
The non-LTE analysis validates τ«1



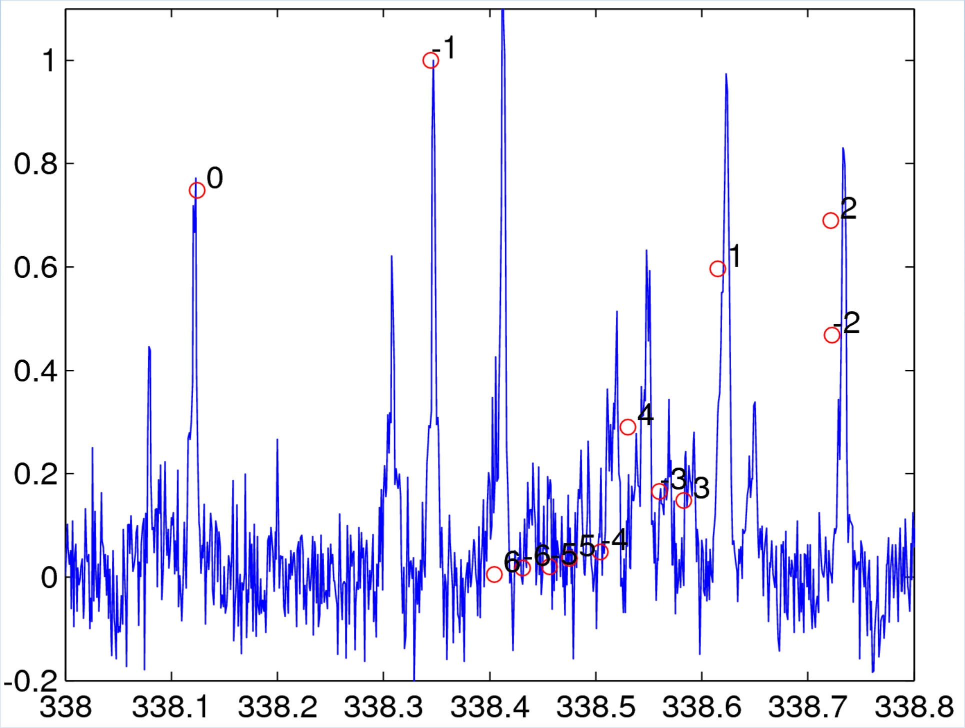
Physical conditions

Outflow NE
T_{high} & n_{low}

T_{rot} peak
T_{high} & n_{high}



T=119K, n=10^{6}cm^{-3}



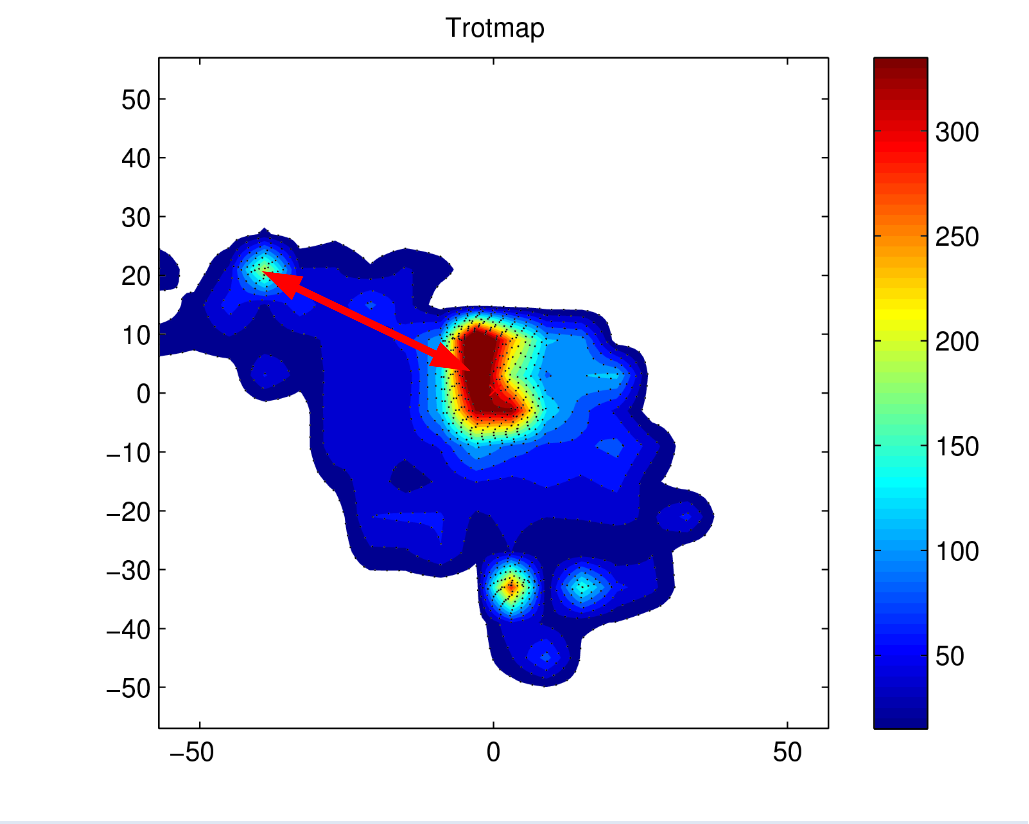
N_{rot} peak
T_{low} & n_{high}

Envelope
T_{low} & n_{low}

One last point... timescales

- Cep A @ 700 pc
- Outflow ~45" from HW2
- Shock velocity ~20km/s

- Dynamical age, t_{dyn}~10^4 yrs
- t_{dyn} ~ t_{chem}
- Supports same origin



Conclusions

- The 6.7 GHz methanol maser is most closely associated with the $T_{rot}(CH_3OH)$ peak.
- non-LTE analysis show T_{rot} to be more sensitive to density than temperature.
- Dynamical and chemical timescales support a common driving source for the region

- Continue with 14 more sources
- Next time (in GBG) Merlin