Methanol masers in Cepheus A

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JOINT INSTITUTE FOR VLBI IN EUROPE

estrela

Outline

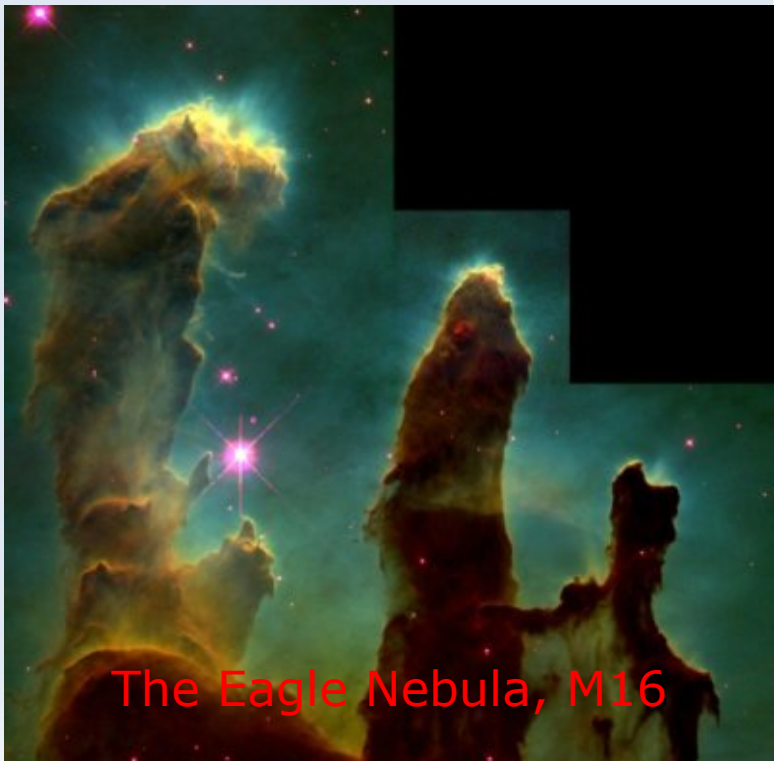
- High-mass star-formation
  - 6.7 GHz CH_3OH maser (5_1-6_0 A^+)
- The methanol masers in Cep A HW2
  - EVN observations
  - A model
- Thermal methanol emission in Cep A
- Conclusions

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


The Eagle Nebula, M16

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}

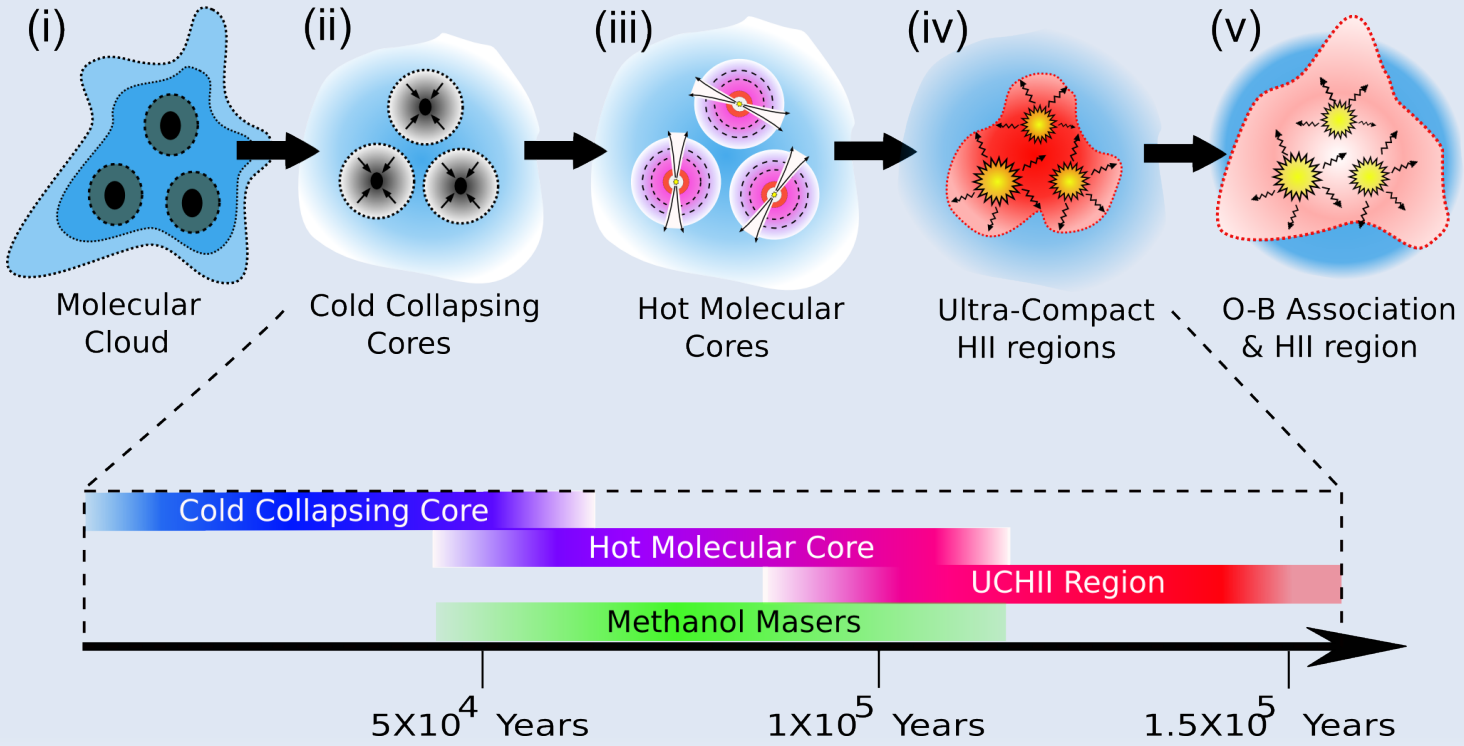


Image credit: Cormac Purcell

Sample & Observations

- Sample
  - 12 nearby IR selected sources
  - 24 sources from the blind Toruń survey
- Observations
  - 6.7 GHz methanol maser observations with EVN
    - ~2' FOV, phase referenced
    - small scale kinematics & resolve confusion
  - Radio continuum VLA & ATCA
    - Find and characterize the exciting source(s)
    - Hyper-compact HII regions
  - Thermal methanol @ 338.4 GHz with JCMT
    - Large scale distribution & excitation of the methanol gas

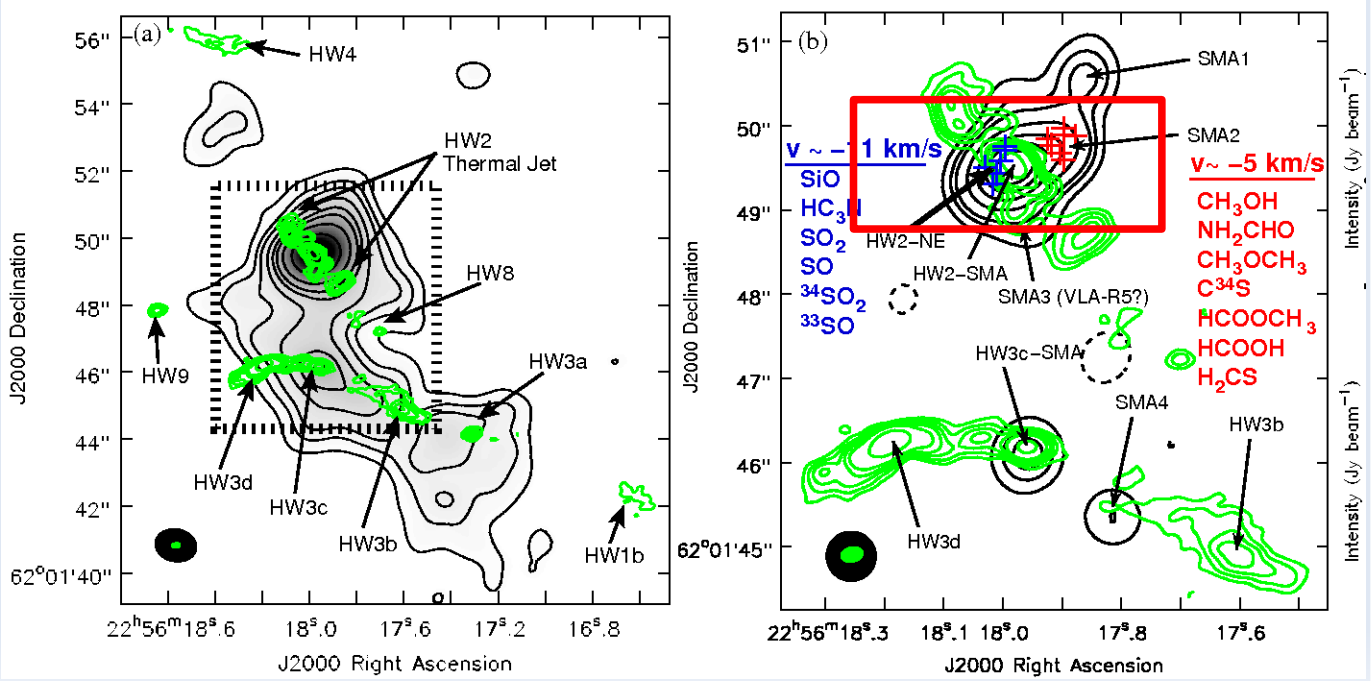
Cepheus A - HW2

- Nearby MSF region (700pc)
- Large scale molecular outflows
- Thermal jet ~500km/s (Curiel 2006)
- Disk r=500AU, $M_* \sim 20 M_\odot$ (Patel et al 2005)

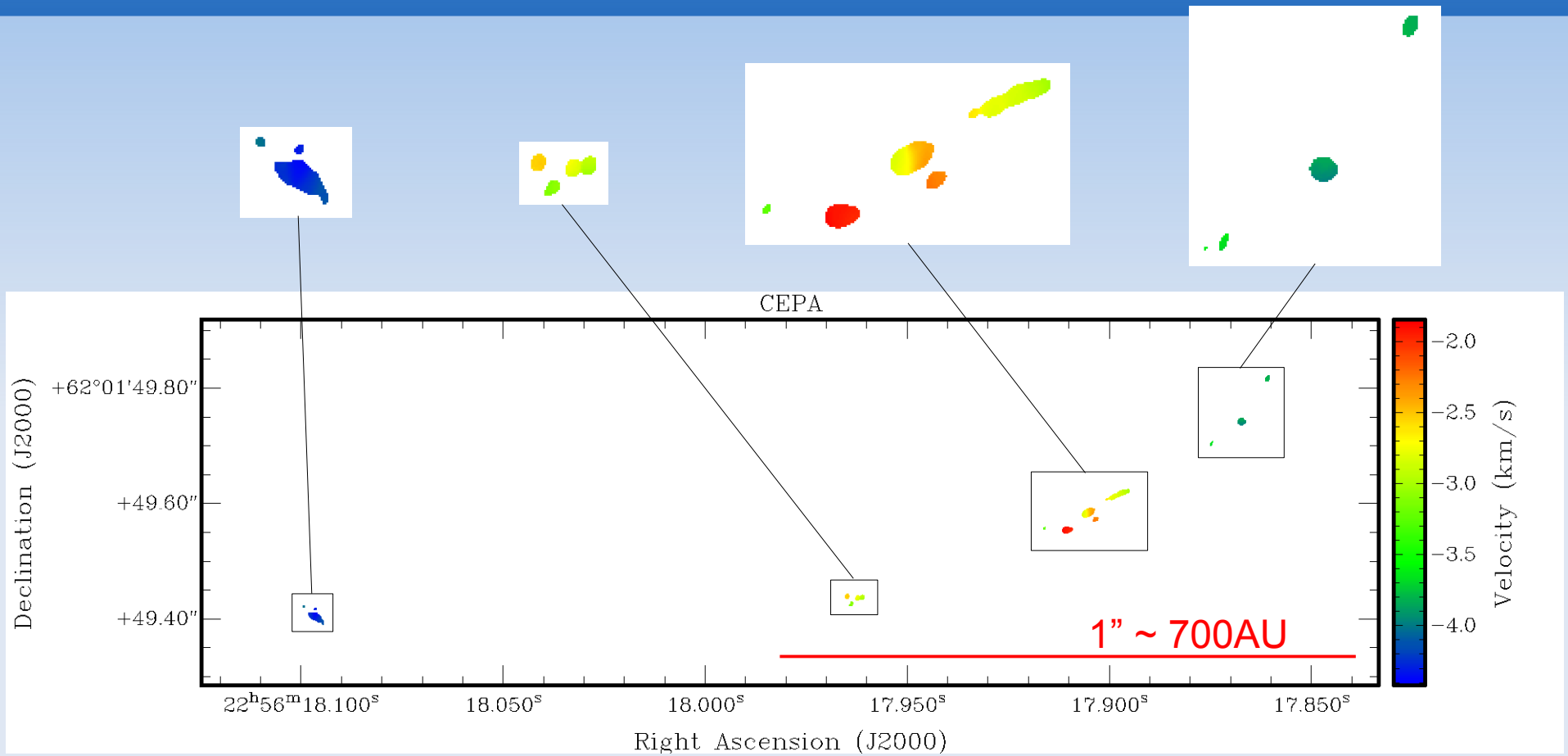
Black – 875 um continuum (SMA)

Green – 3.6 cm continuum (VLA)

Brogan et al. 2007

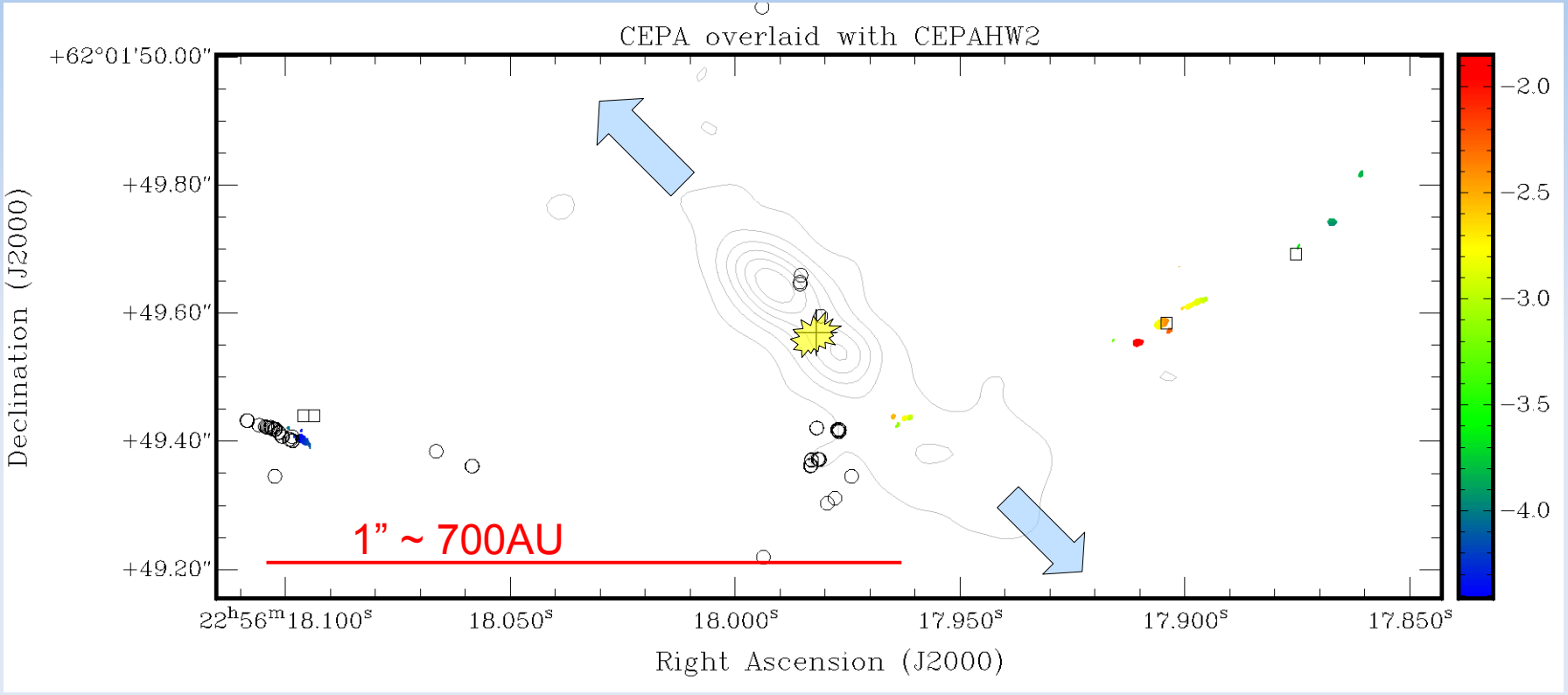


Cep A – VLBI observations



- Filamentary emission
- Small velocity gradient
- Indicates ONE single structure

Cep A – VLBI observations



- 6.7 GHz methanol maser (vel. colour)
  - K-band continuum (22 GHz) – thermal jet (Torelles '98)
  - 12 GHz CH_3OH, H_2O masers (Minier '01, Vlemmings '06)
  - Central object & proper motion outflows ~500km/s, episodic (Curiel '06)

Paper-cup model

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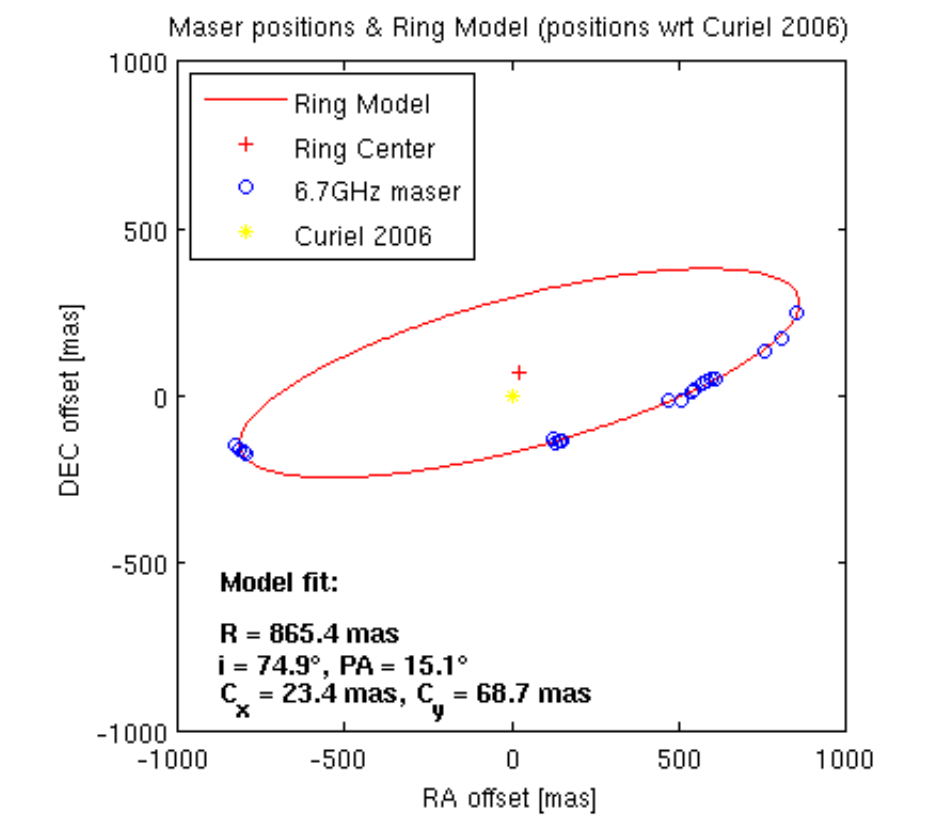
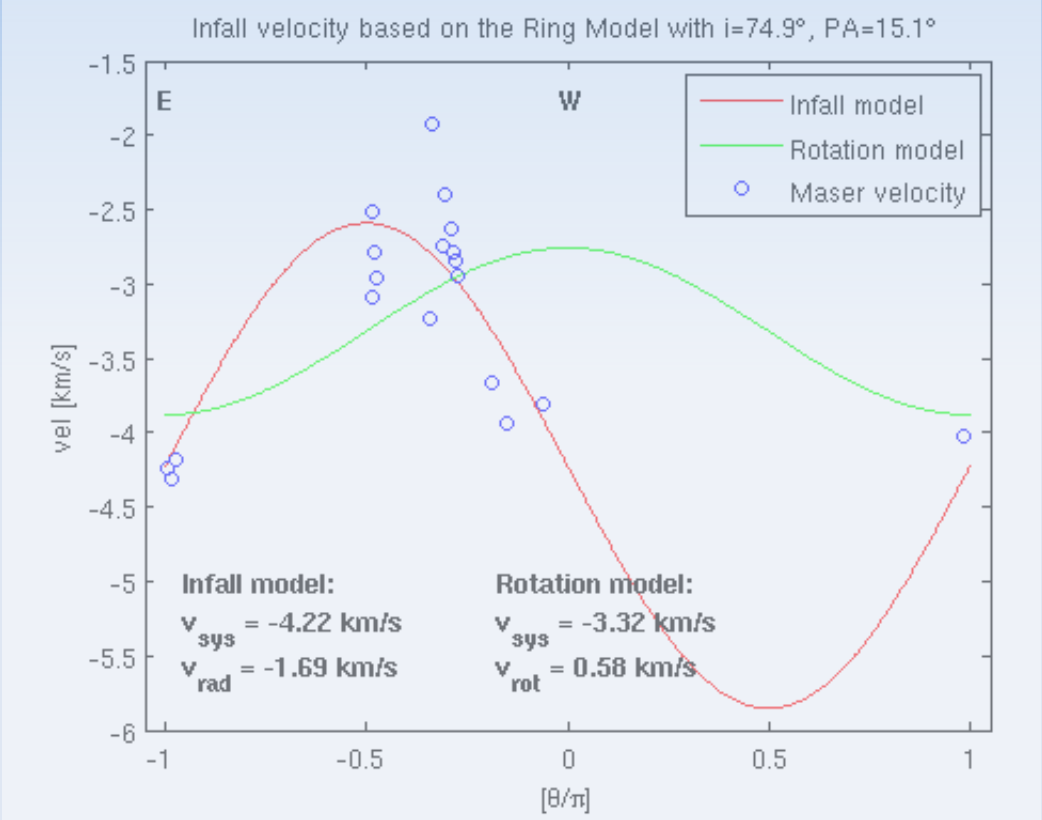
Cep A - Modeling





- Fit ellipse to maser positions r ~ 600 AU
- Model the velocity field based on the fit
  - Infall velocity of 1.7km/s

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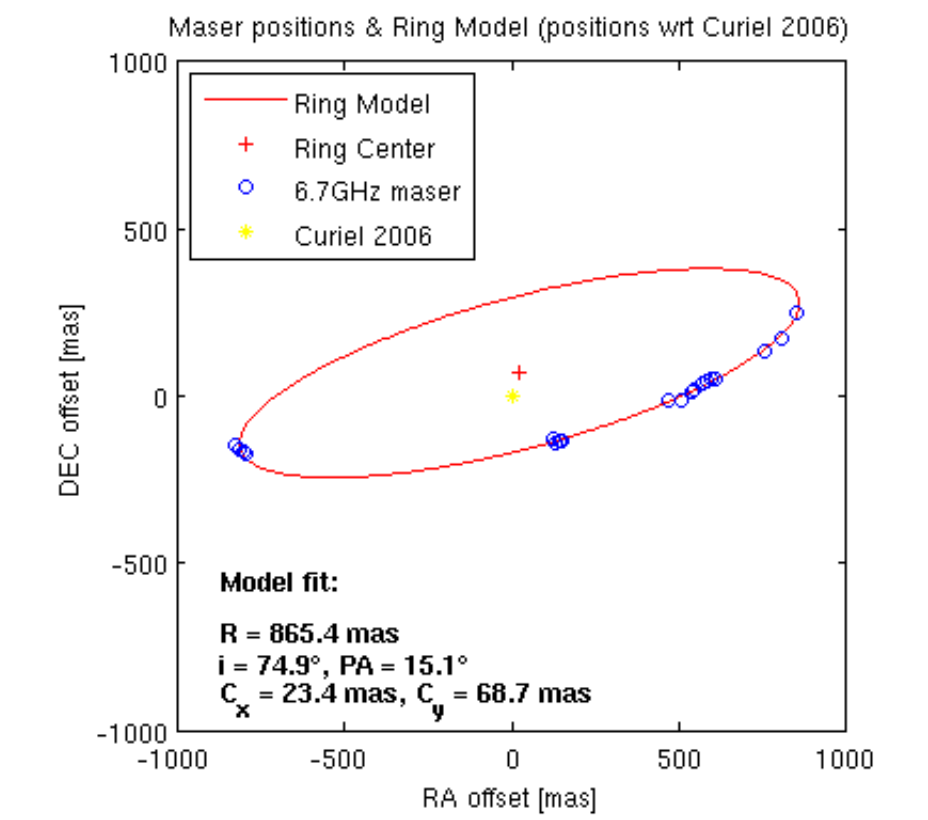

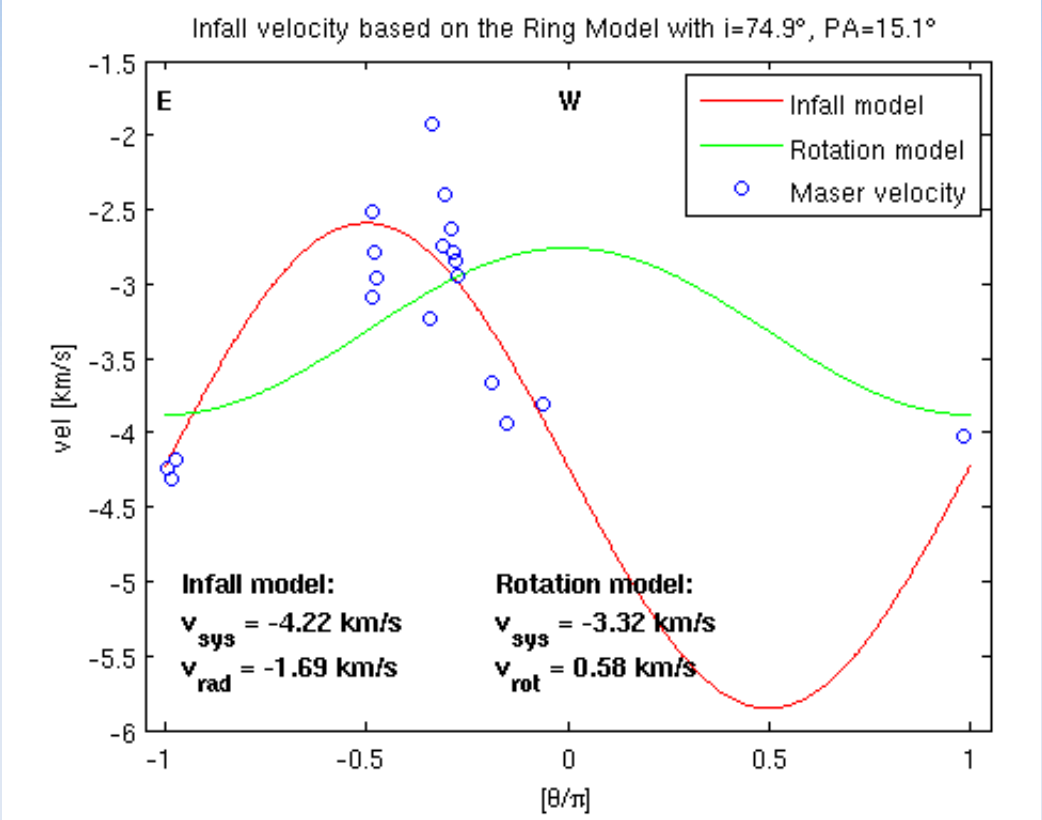

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Cep A - HW2

- Ring structure of methanol masers in the equatorial region of Cep A HW2
- Radius ~600AU
- Velocity field suggest infall ~1.7km/s
  - along magnetic field lines? (Vlemmings)
- Shock interface, accretion shock?

Posters by Sugiyama, Fujisawa

Cep A – Wide-field imaging

- Using ParselTongue image and search an ~2.5 armin field
- Divided in ~4700 tiles of 2048x2048 pixels
- No other 6.7 GHz methanol masers in the field, rms ~ 5mJy

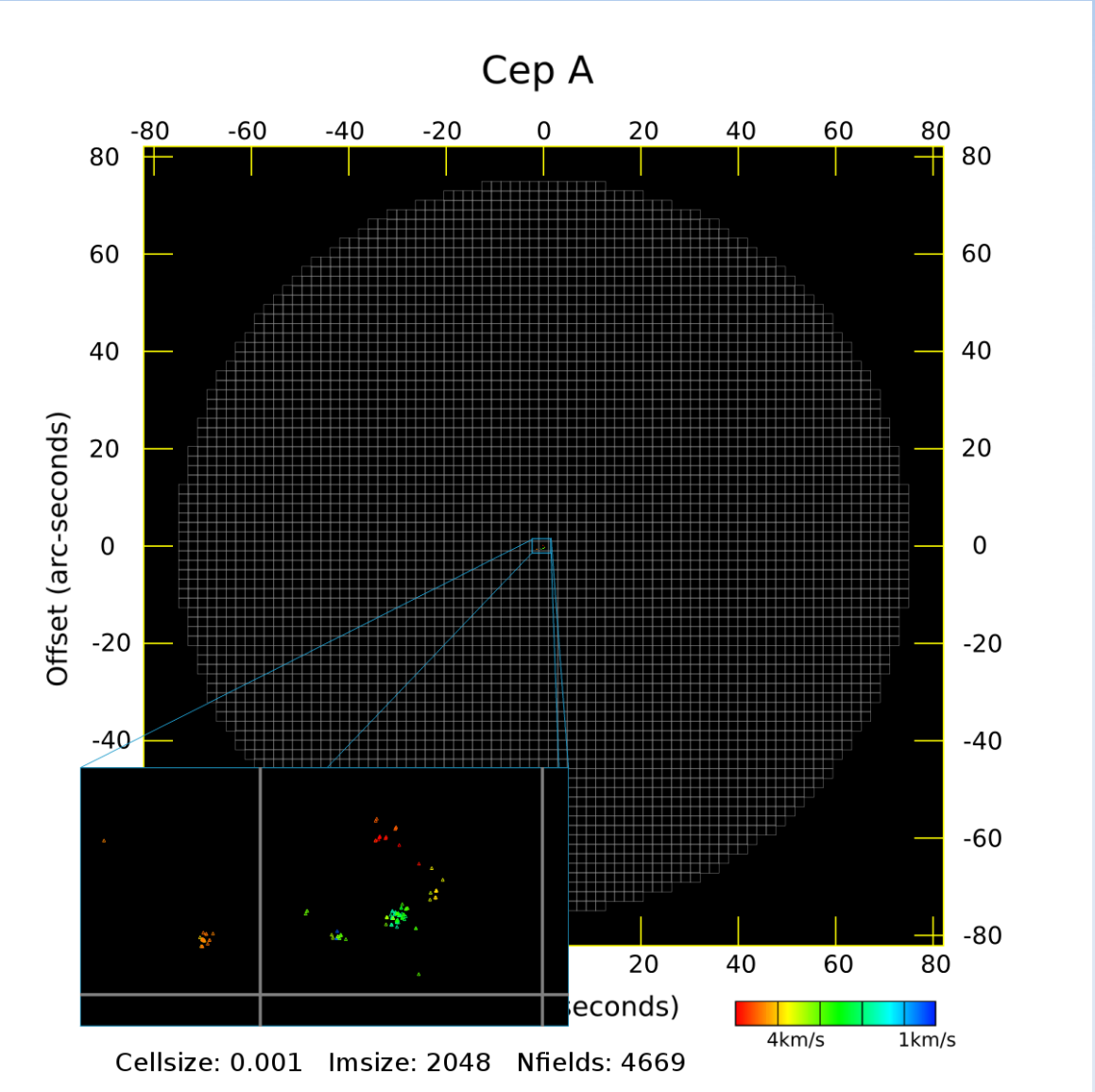
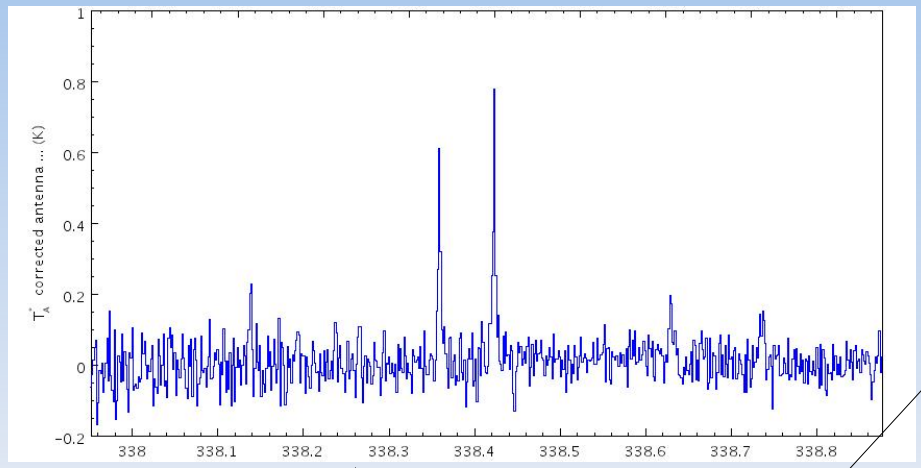
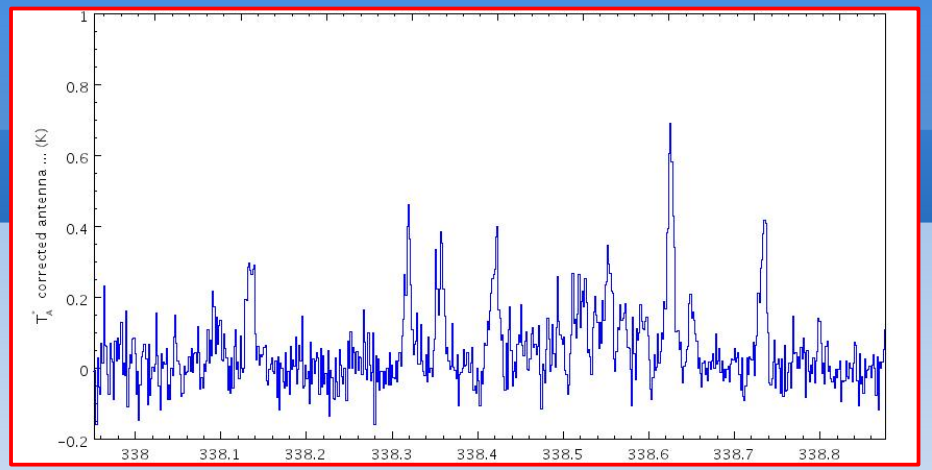
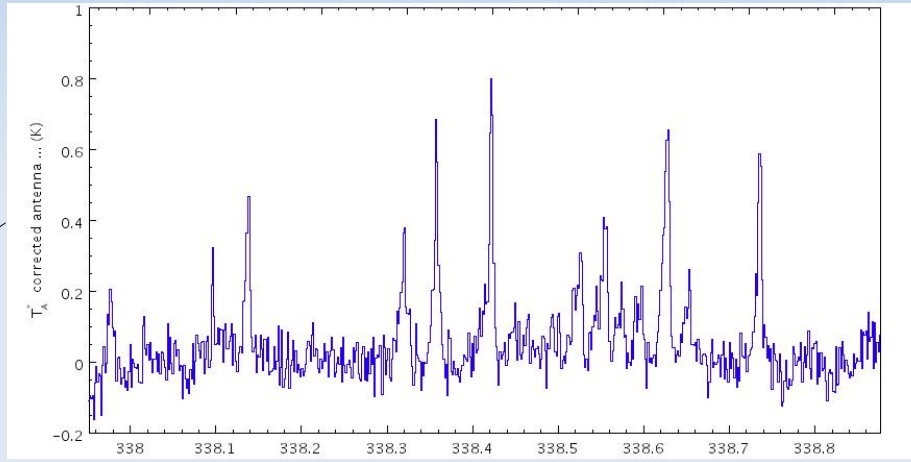


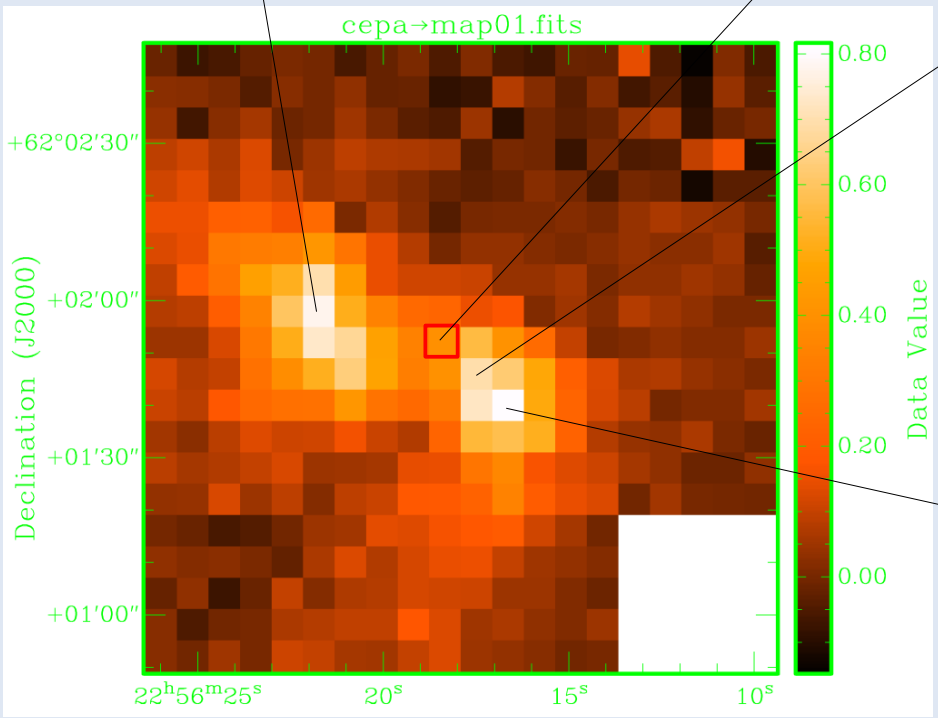
Image credit: Stephen Bourke

Cep A – excited methanol gas

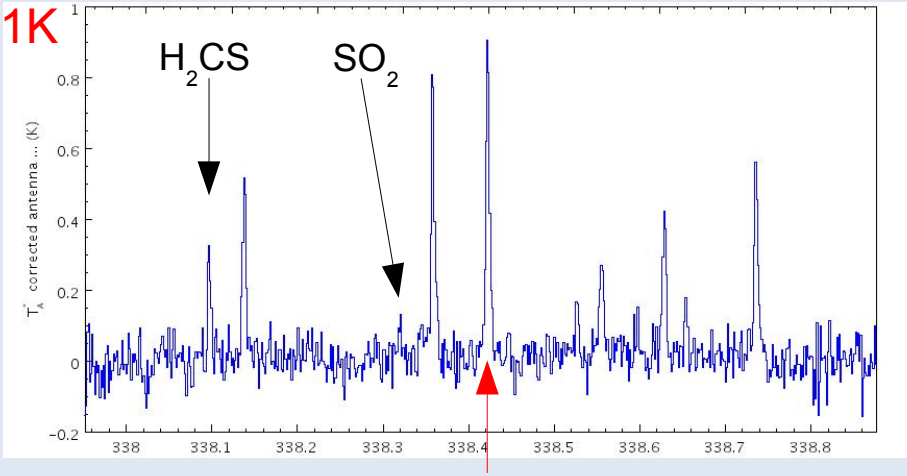








2'

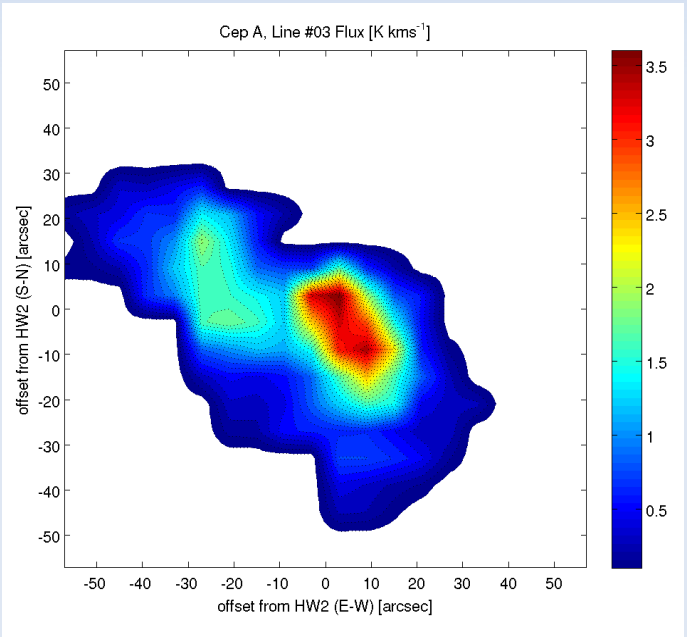


CH_3OH (7-6) 338.4GHz

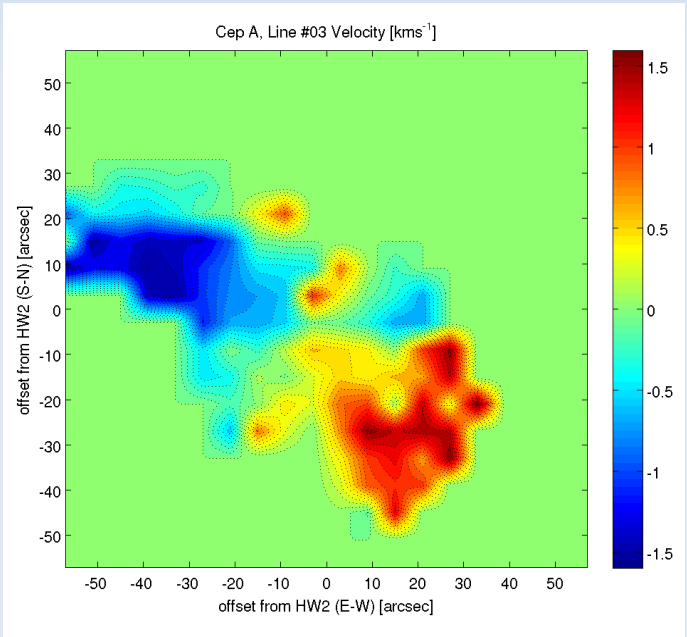
Cep A – CH_3OH Results

CH_3OH (7_{-1}–6_{-1}) E

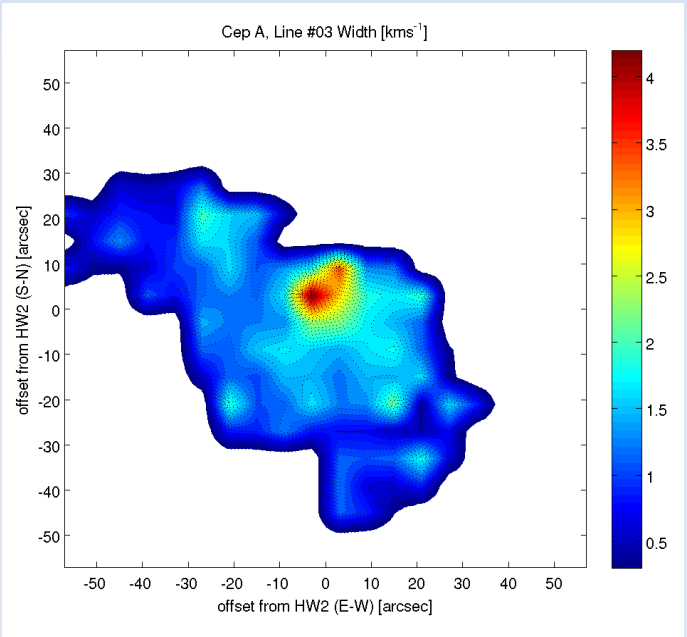
Int. Flux [K kms^{-1}]



Center Velocity [kms^{-1}]



Line Width [kms^{-1}]



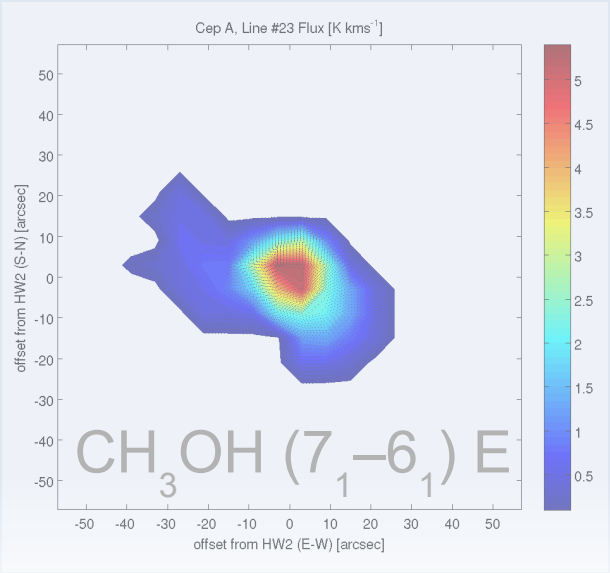
Cep A – Analysis

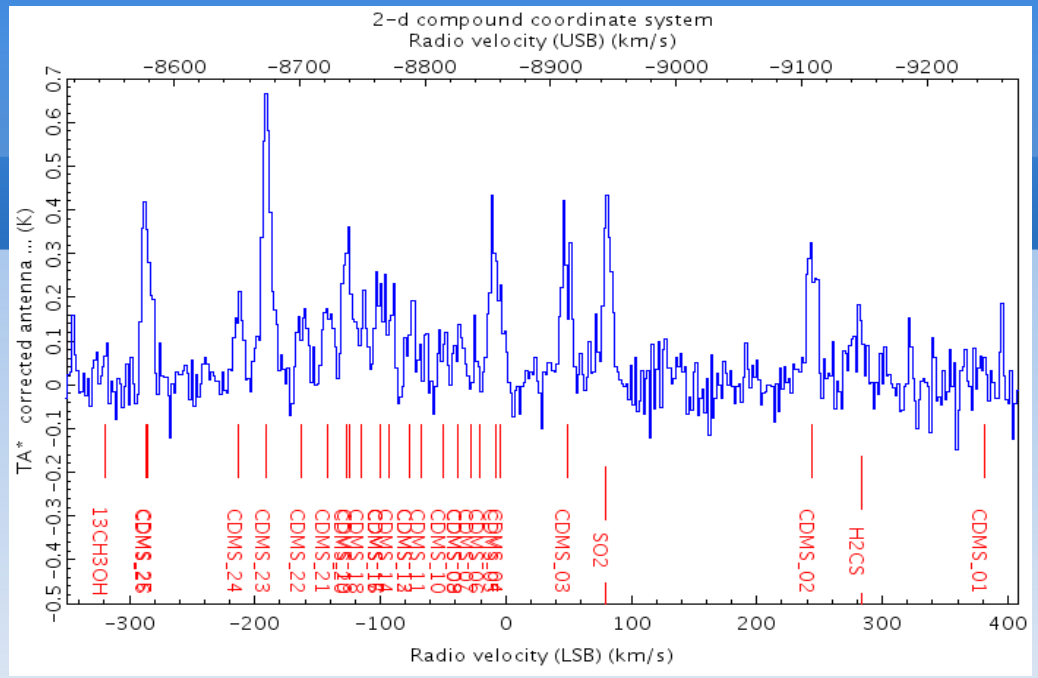
Rotation diagram analysis (Boltzmann plot)

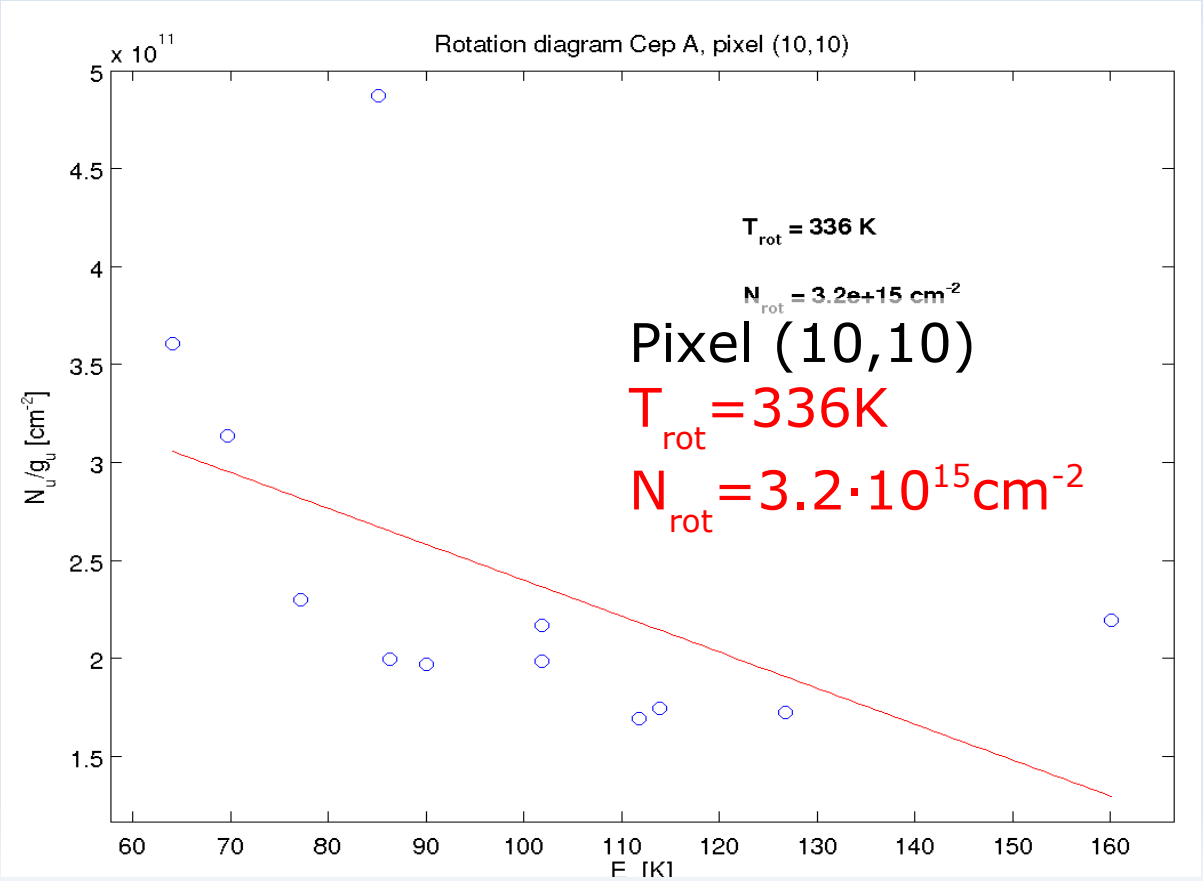
- One excitation temperature
- Lines optically thin (τ«1)

Anomalous excitation

- Is this related to the methanol maser?







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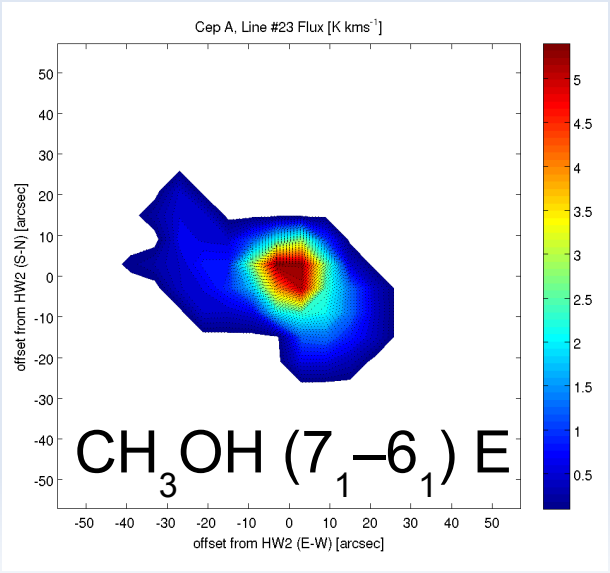
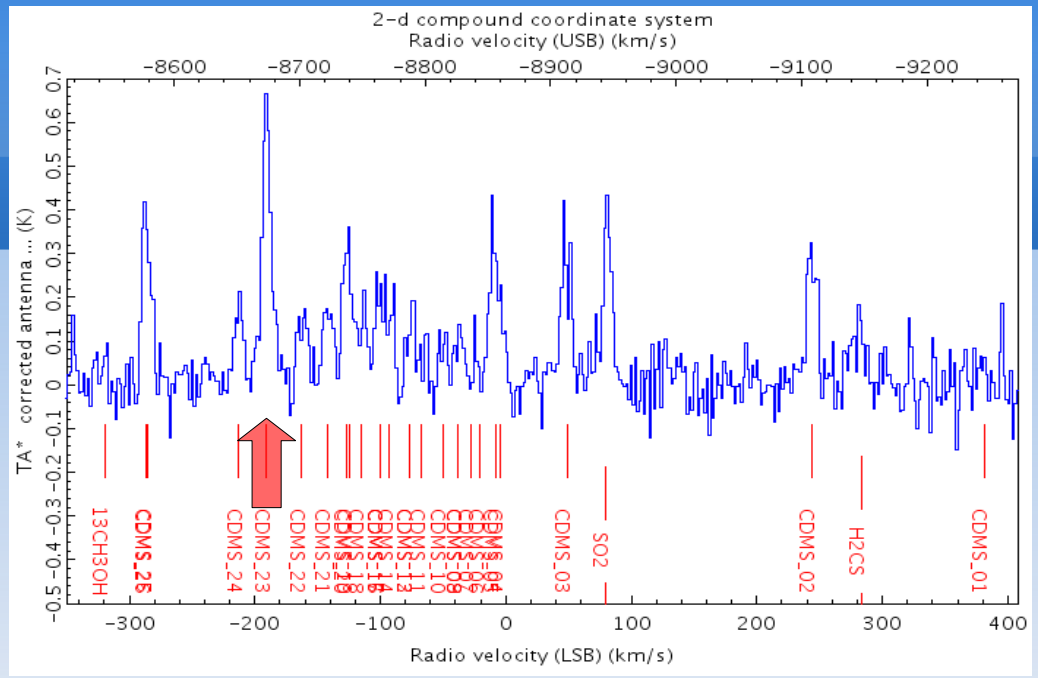
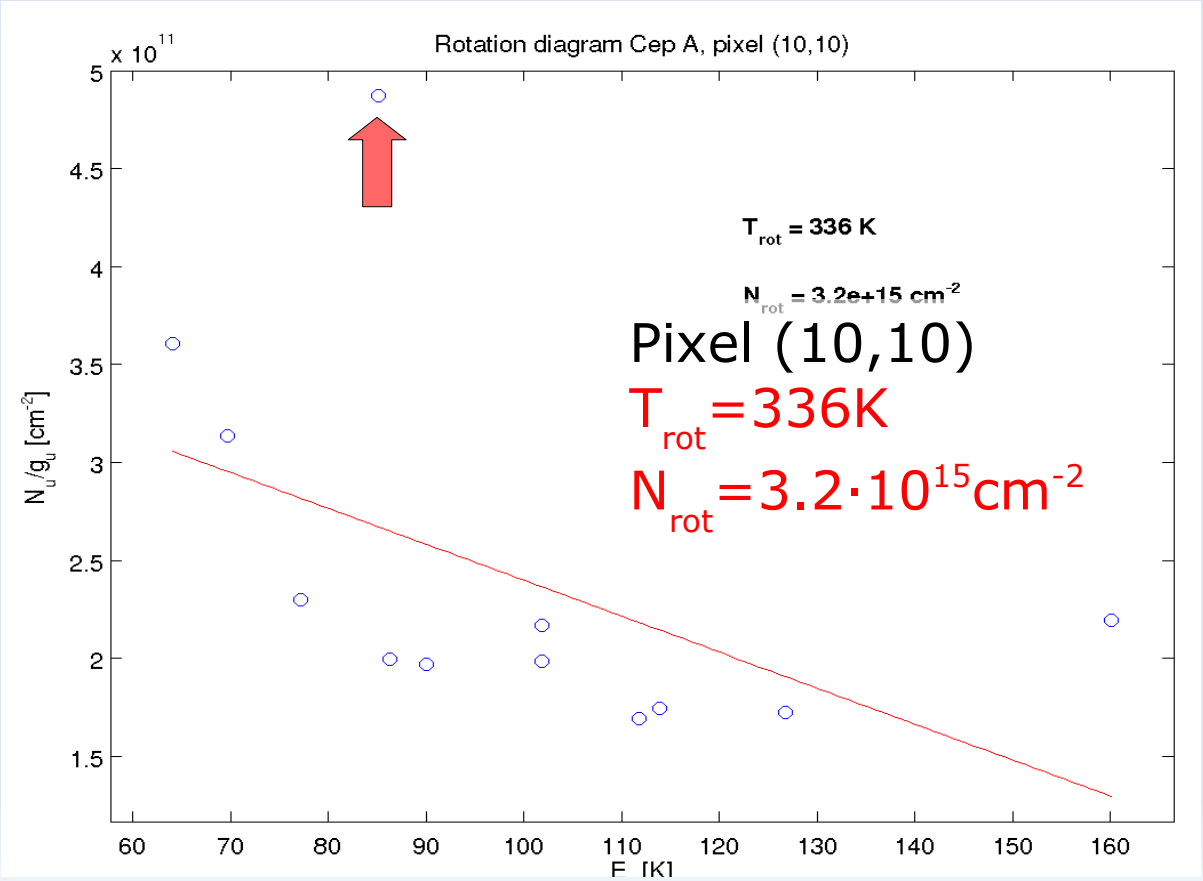
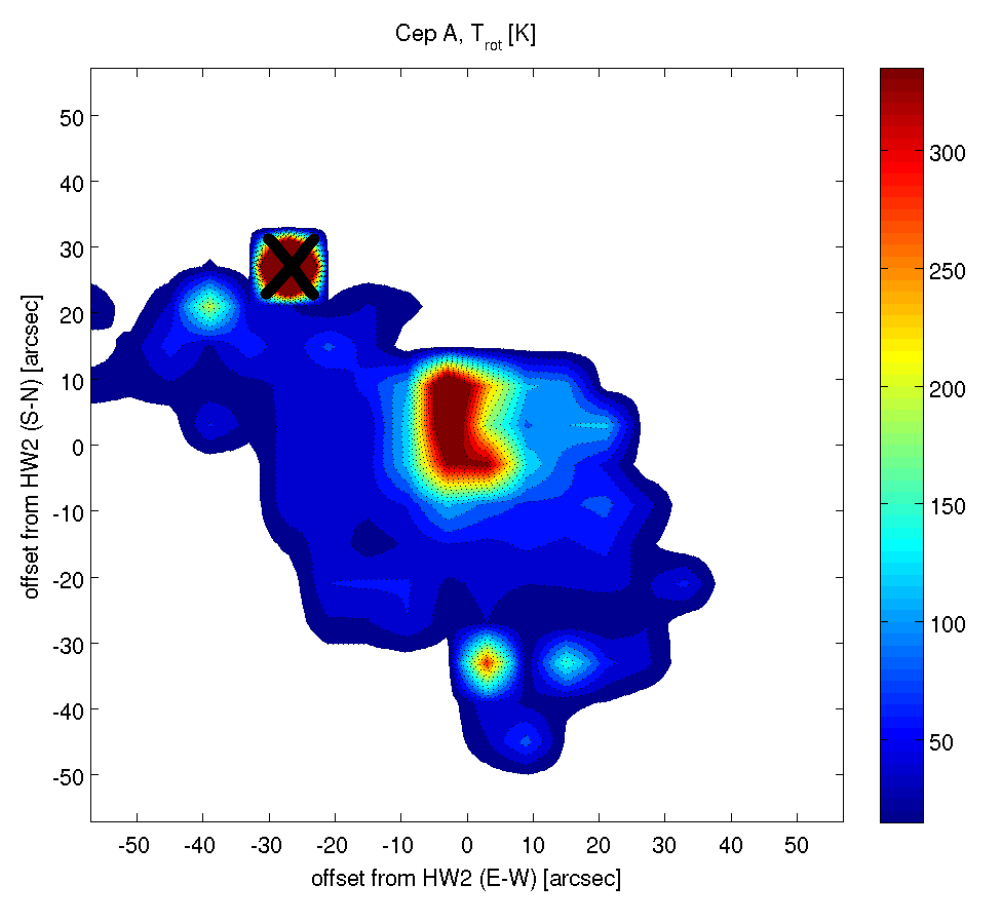




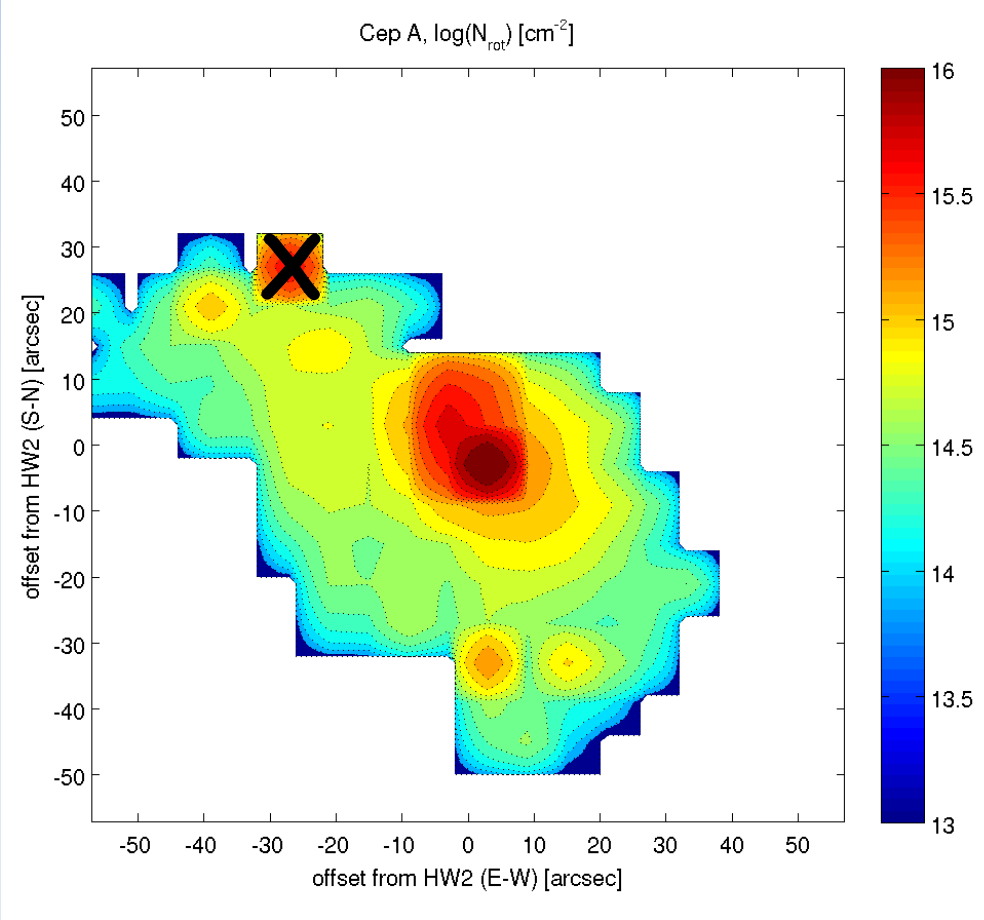


Cep A – CH_3OH Results

Rotation temperature



Column density



- Dust map – n(CH_3OH)
- Non-LTE analysis – n(CH_3OH), T

Conclusions

- Ring structure of methanol masers in the equatorial region of Cep A HW2
- Radius ~600AU
- Velocity field suggest infall ~1.7km/s along magnetic field lines?
- Shock interface - accretion?

- Anomalous excitation could point towards methanol masers