The magic of non-rotating methanol disks

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Star formation

- **Building up evidence that high-mass stars form in similar fashion as low mass stars**
  - Accretion disks needed to overcome radiation pressure
  - Expect disks to exist when outflow is present
- **Methanol masers exclusively associated with high mass star formation**
  - Small percentage of (H/U)CHII regions association
  - High mass cores in all other cases
- **Not clear what the physical agent is**
  - Not clear what the evolutionary stage is
  - How can we use methanol masers for understanding star formation?

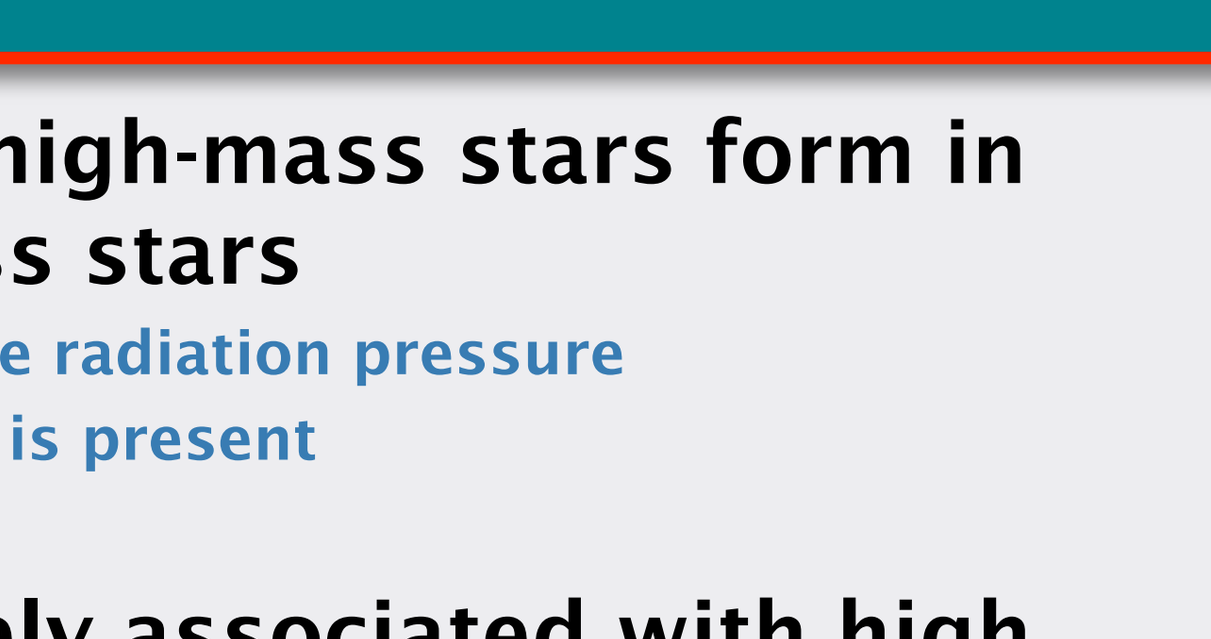
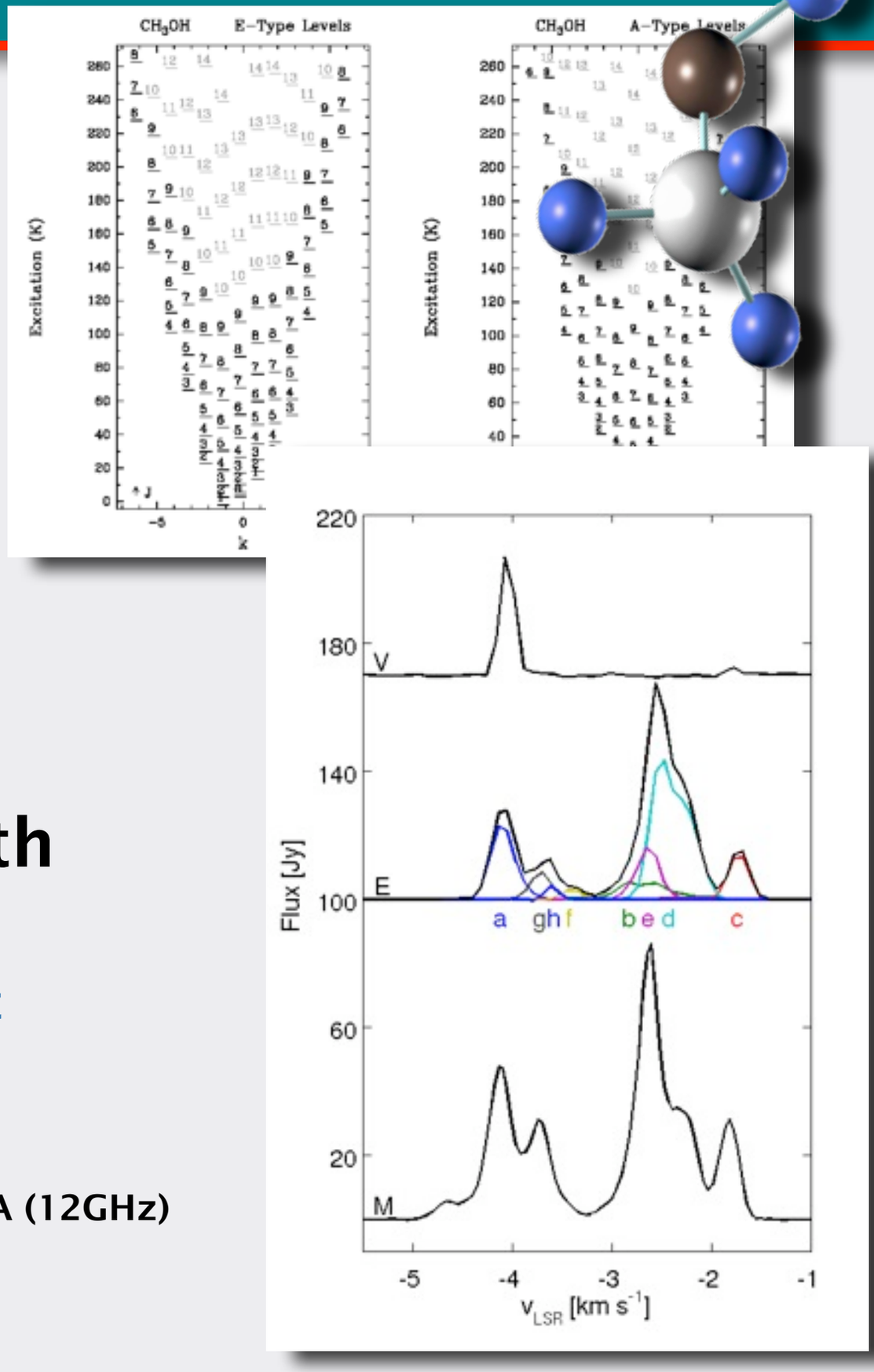


Image credit: Cormac Purcell

Methanol

- Very rich spectrum
- Maser modeling shows (Cragg et al '05)
  - High abundance of methanol
    - Requires grain chemistry and shocks
  - T: 100-300 K
  - n: 10^4-10^9 cm^{-3}
  - For long amplification paths
  - IR from dust
- 6.7 GHz can be studied with EVN with AU resolution
  - Even if most emission resolves out
  - Trace kinematics

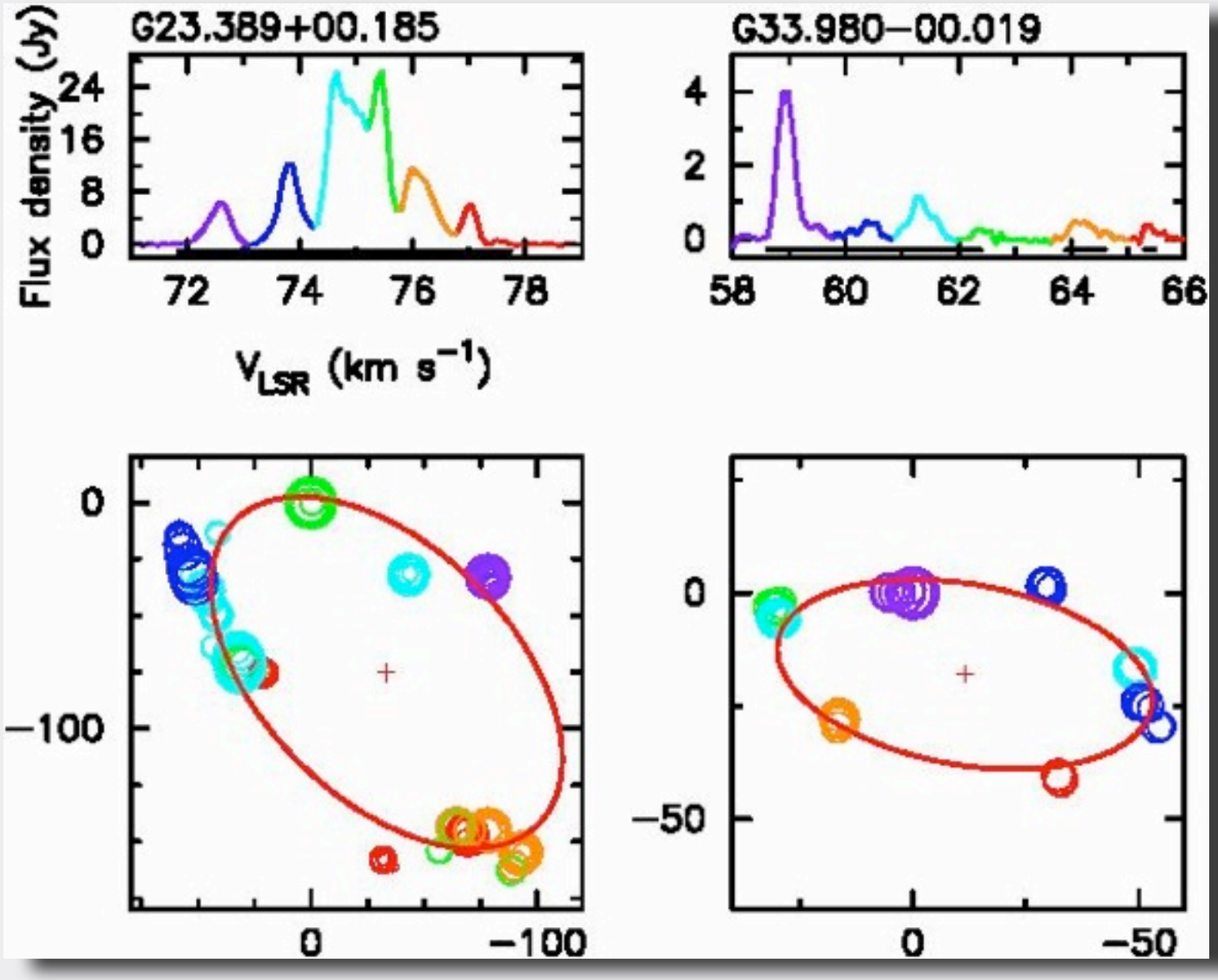


Cep A spectra MERLIN, EVN, VLBA (12GHz)

Important EVN result

- 9/31 (30%) masers look elliptical
  - From blind maser survey
  - EVN sensitivity and 8 station imaging

Bartkiewicz et al 2009,
A&A 502 155



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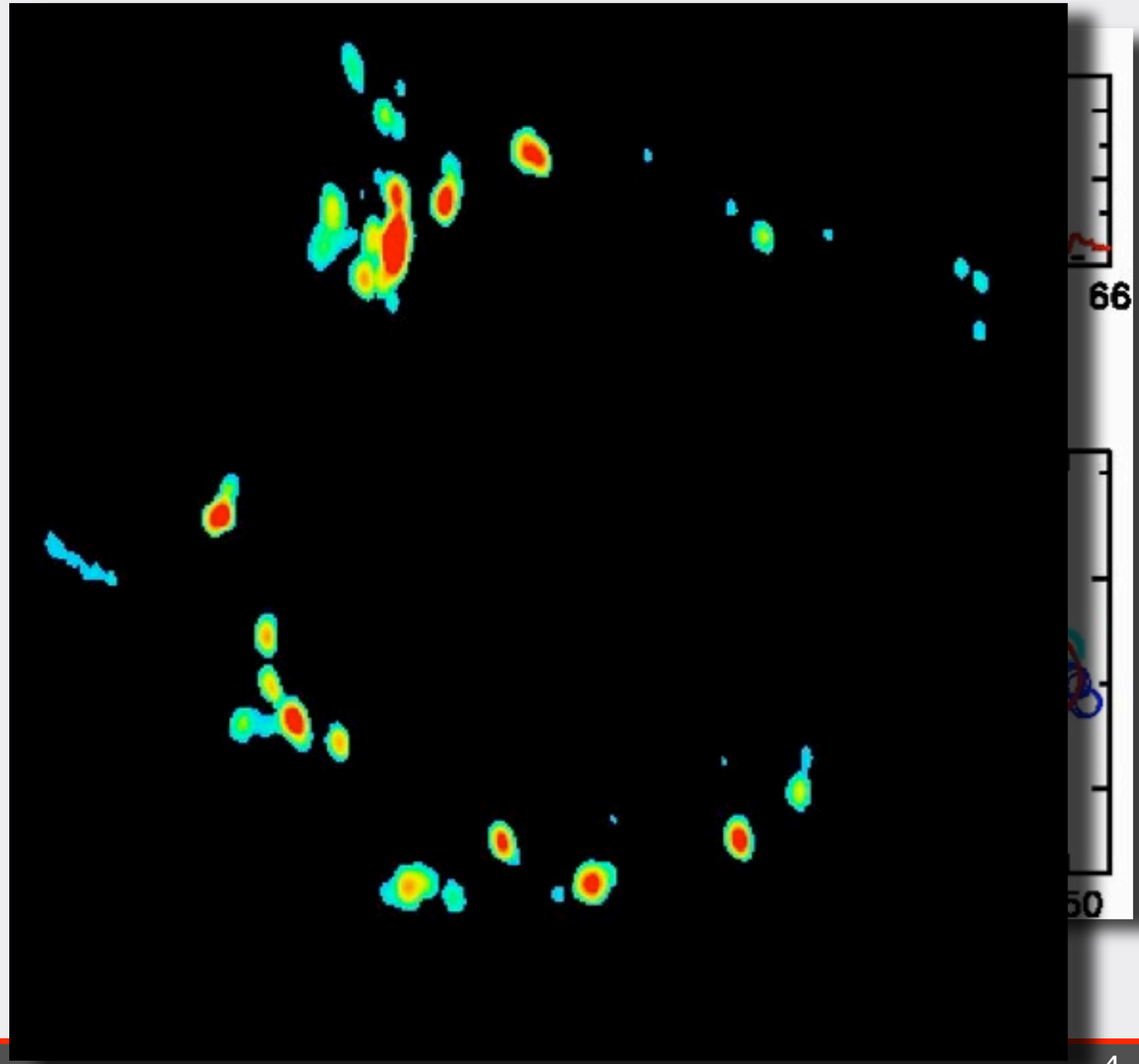
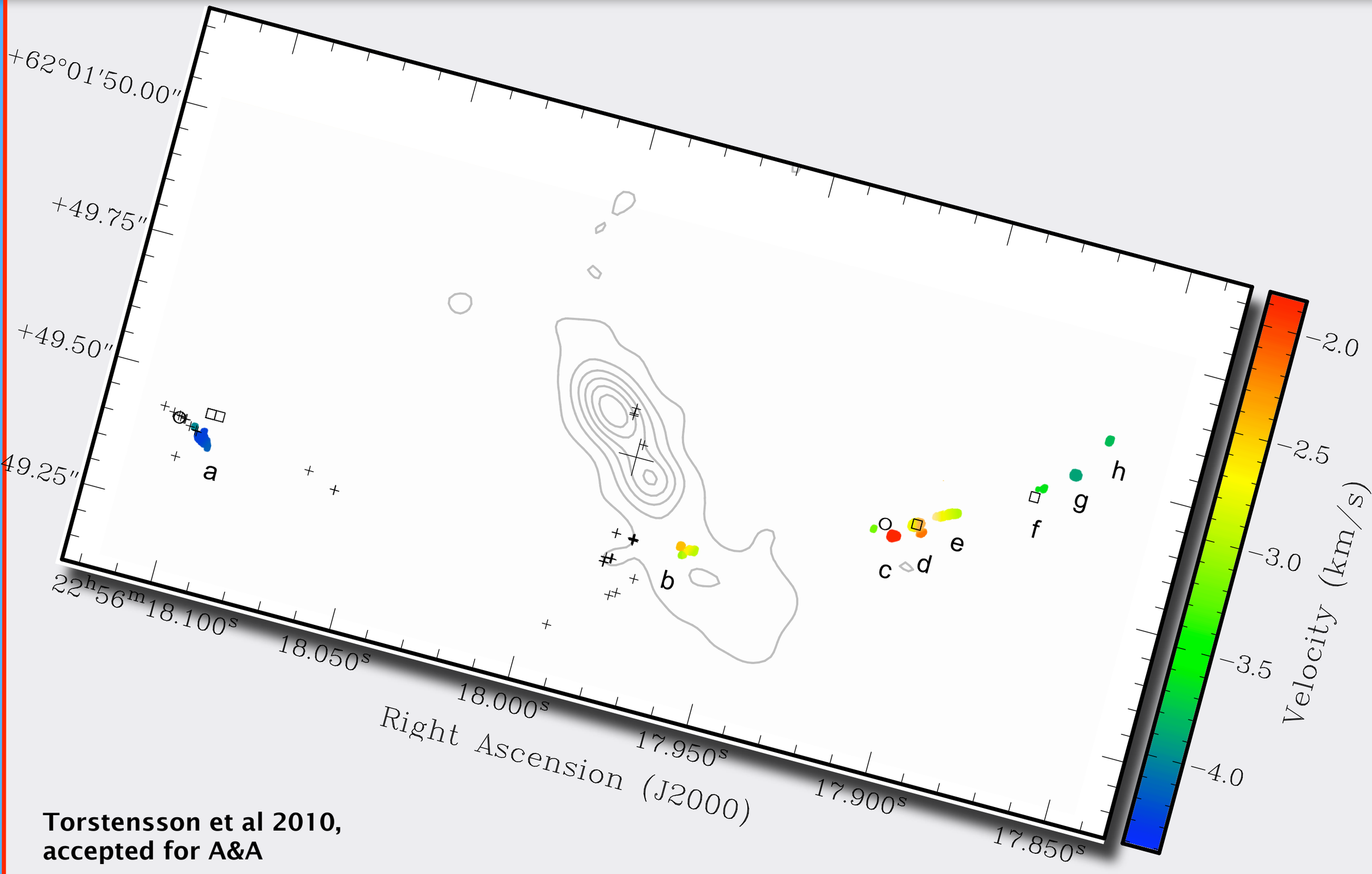
Bartkiewicz et al 2005,
A&A 442 L61



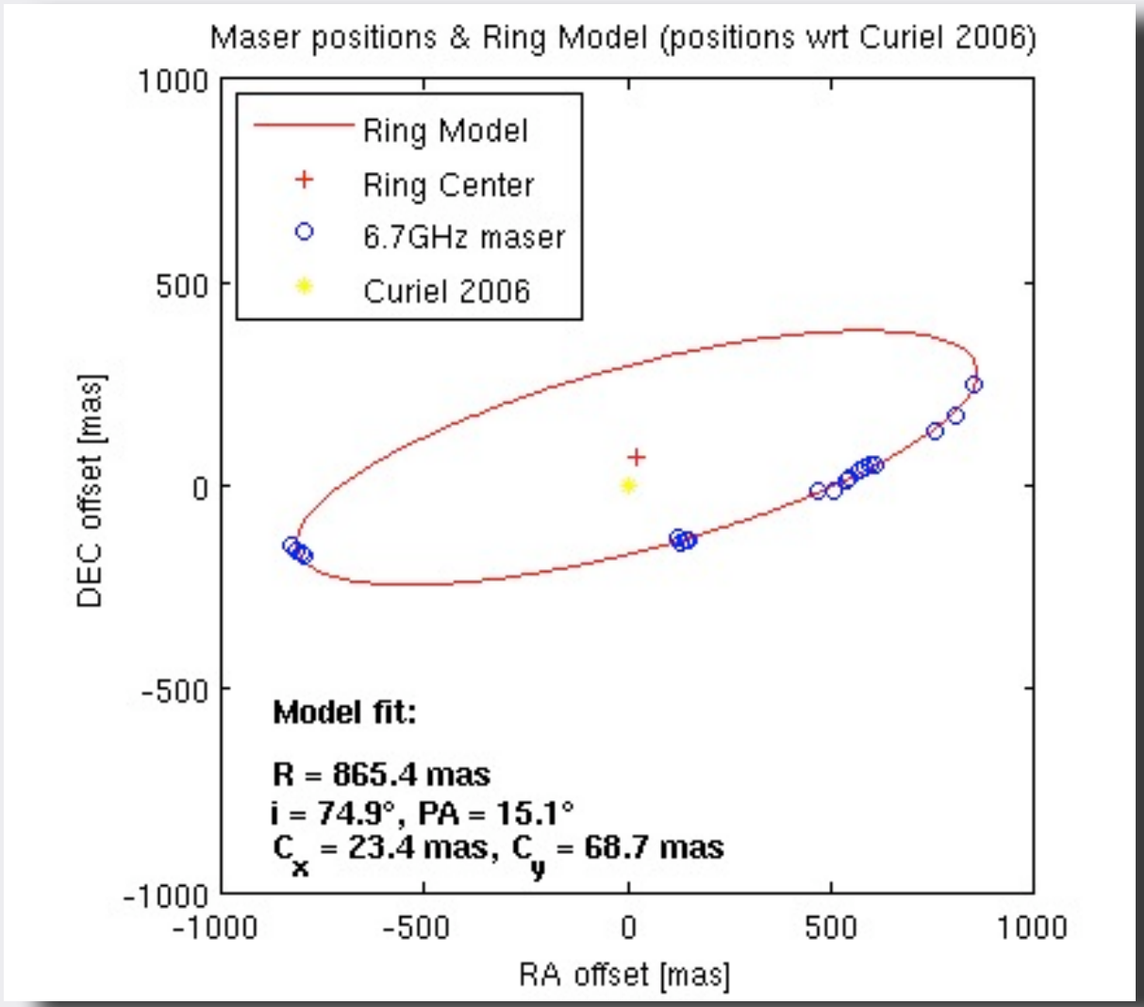
Close massive SFR Cep A

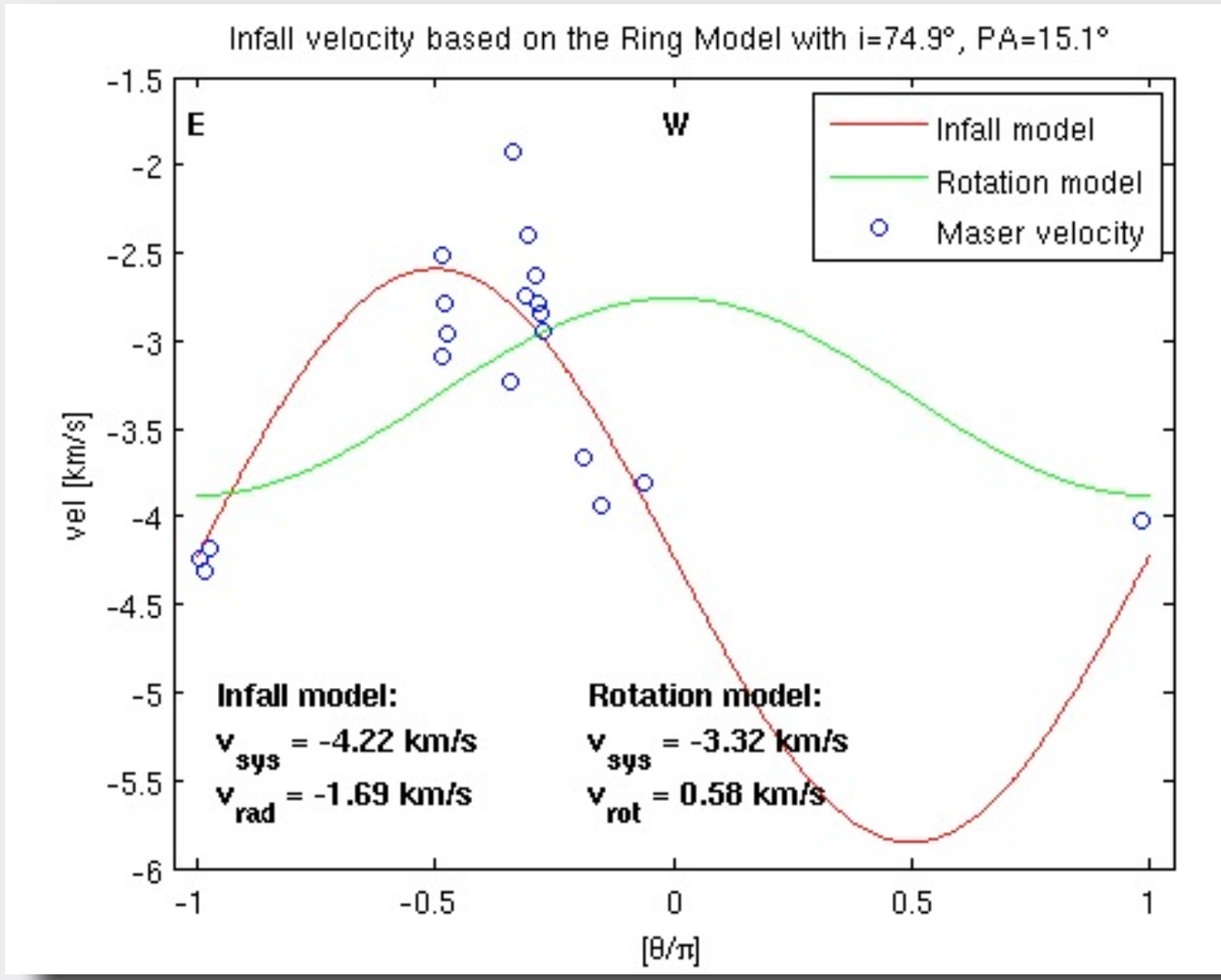


Torstensson et al 2010, accepted for A&A

Cep A - Modelling

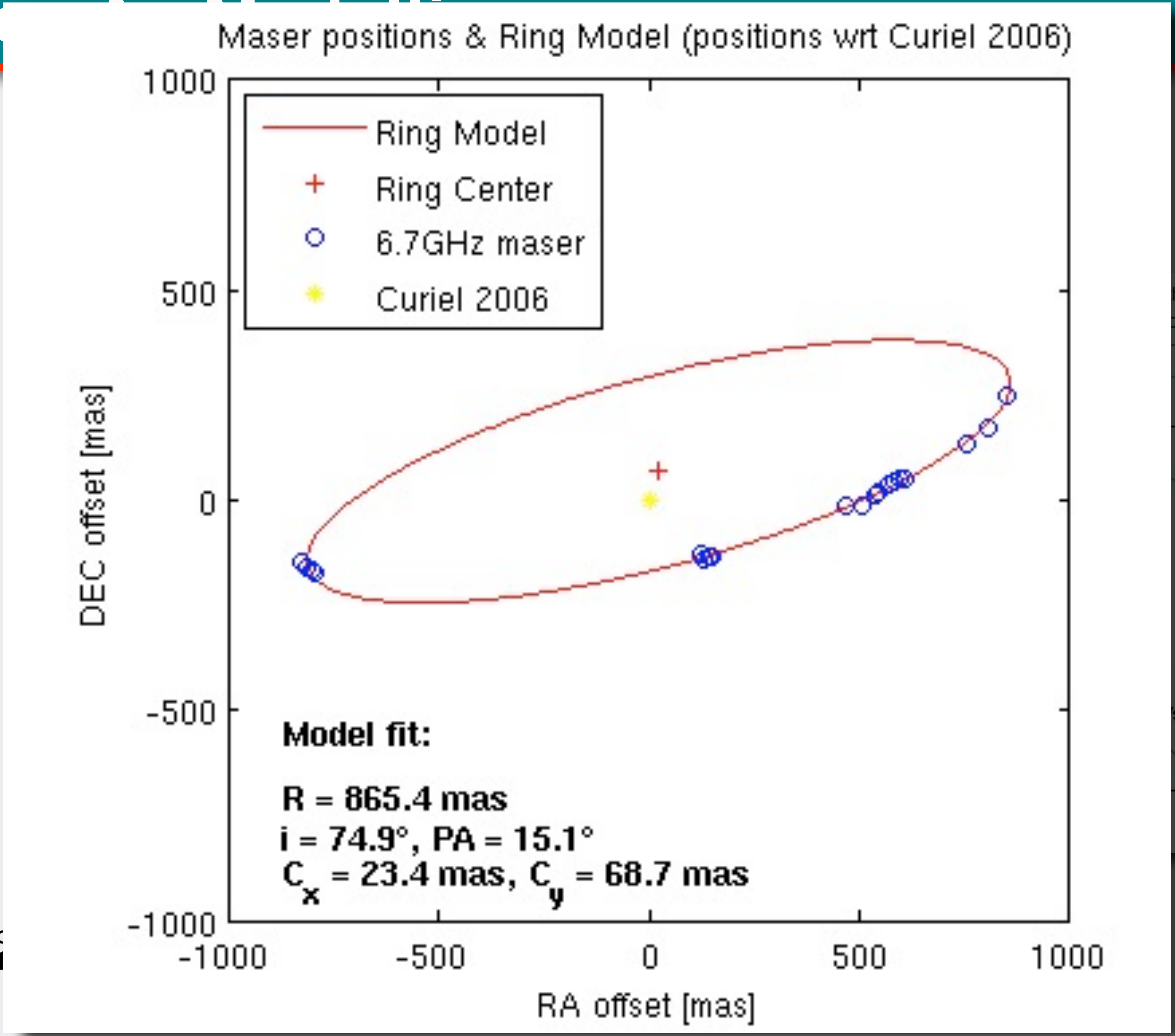
- **Fit ellipse to maser positions r ~ 600 AU**

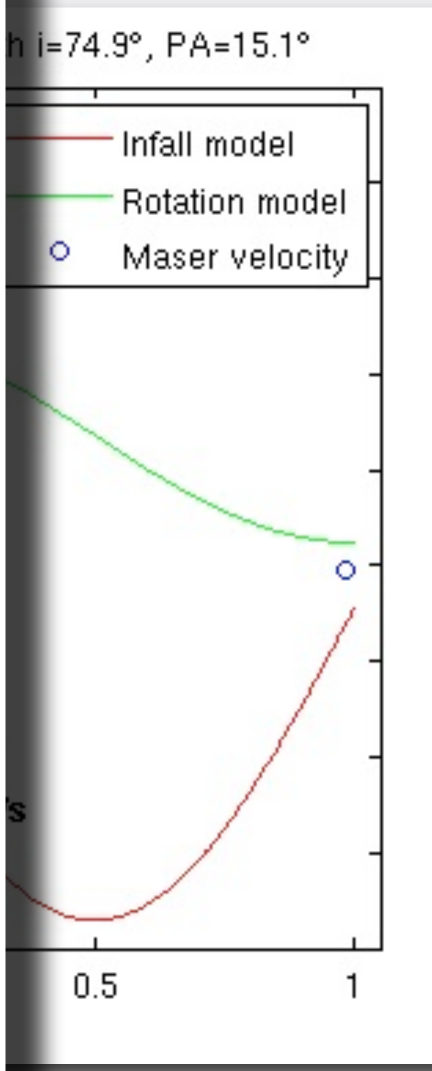




Model the velocity field based on the fit
Infall velocity of 1.7km/s

Co... Modelli...





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Mo...
Inf...

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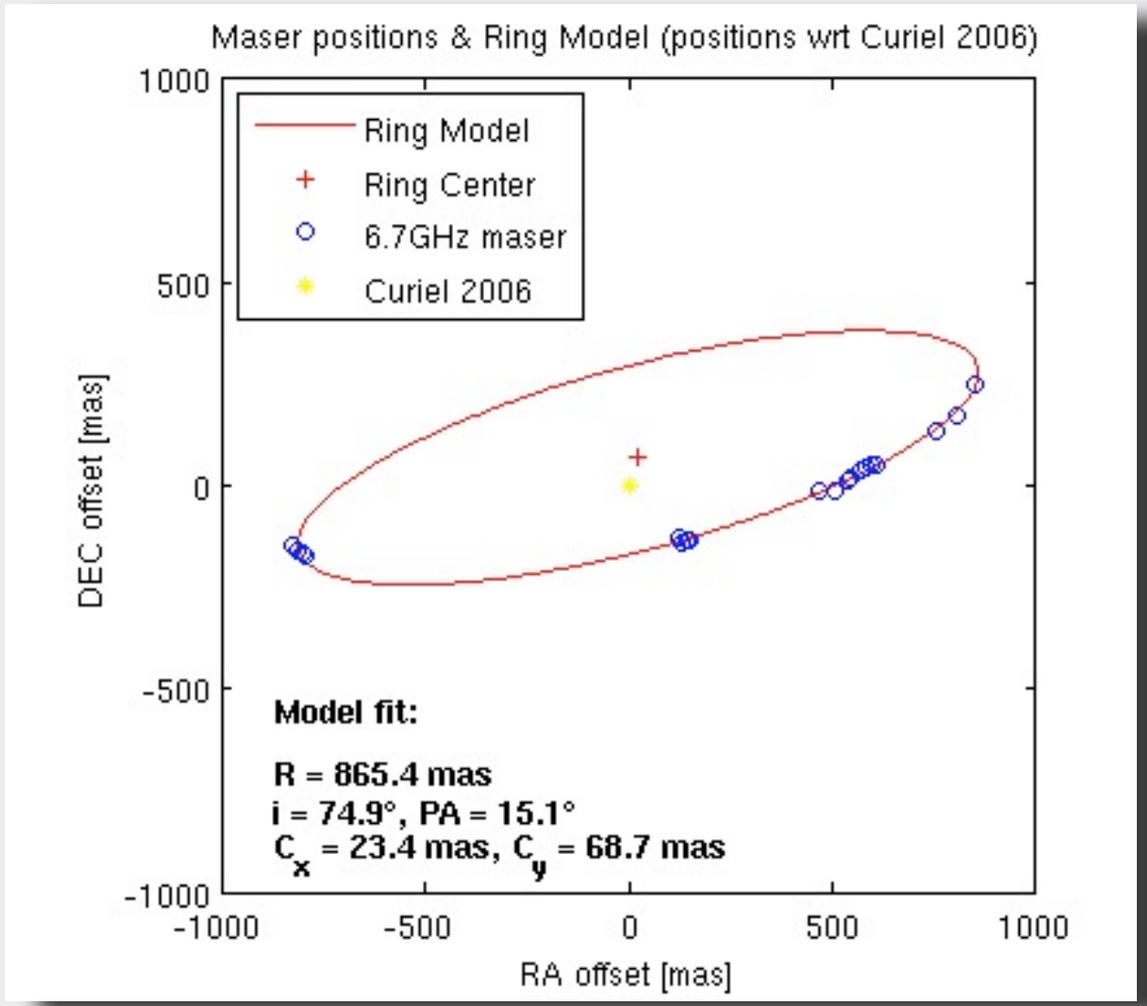

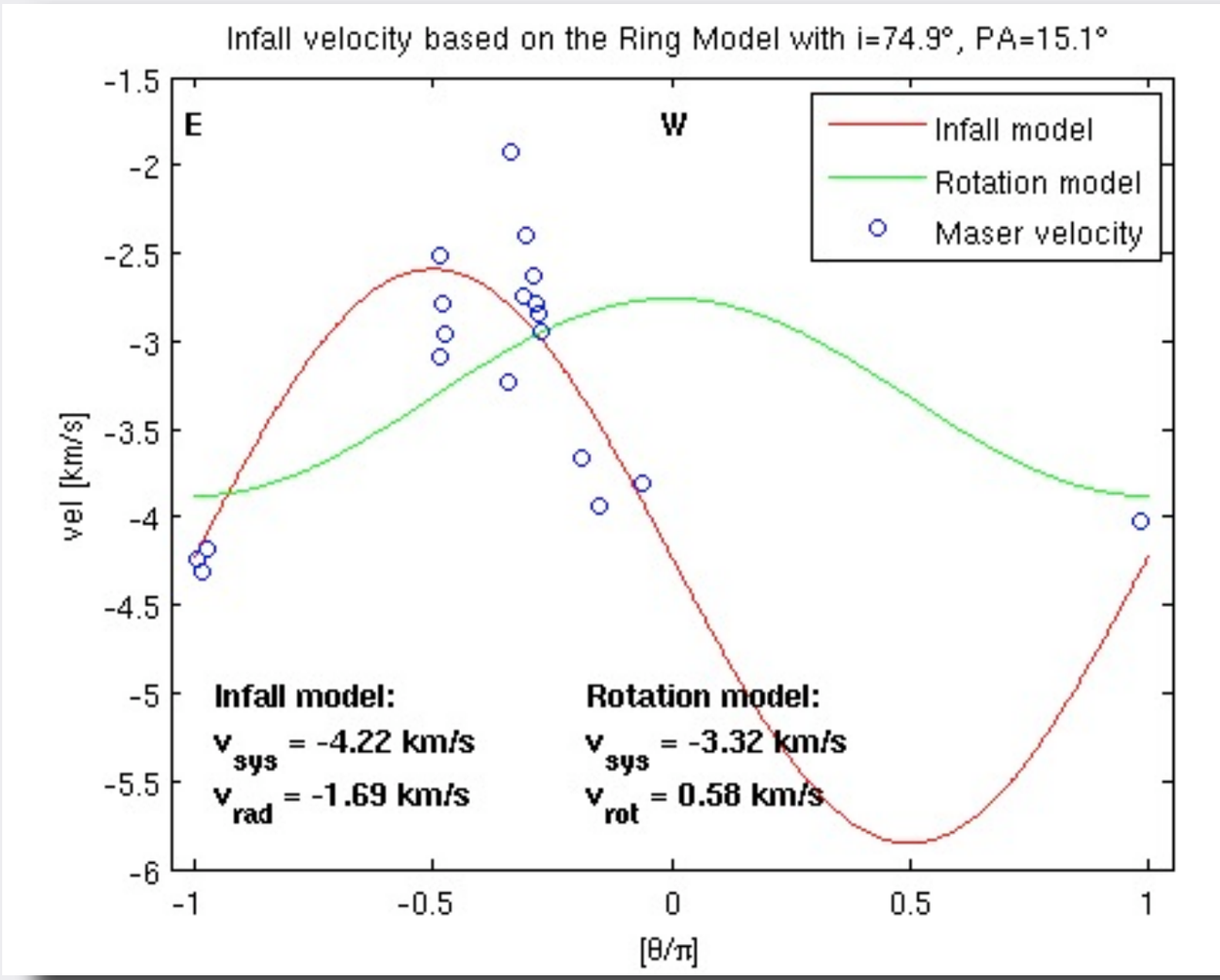

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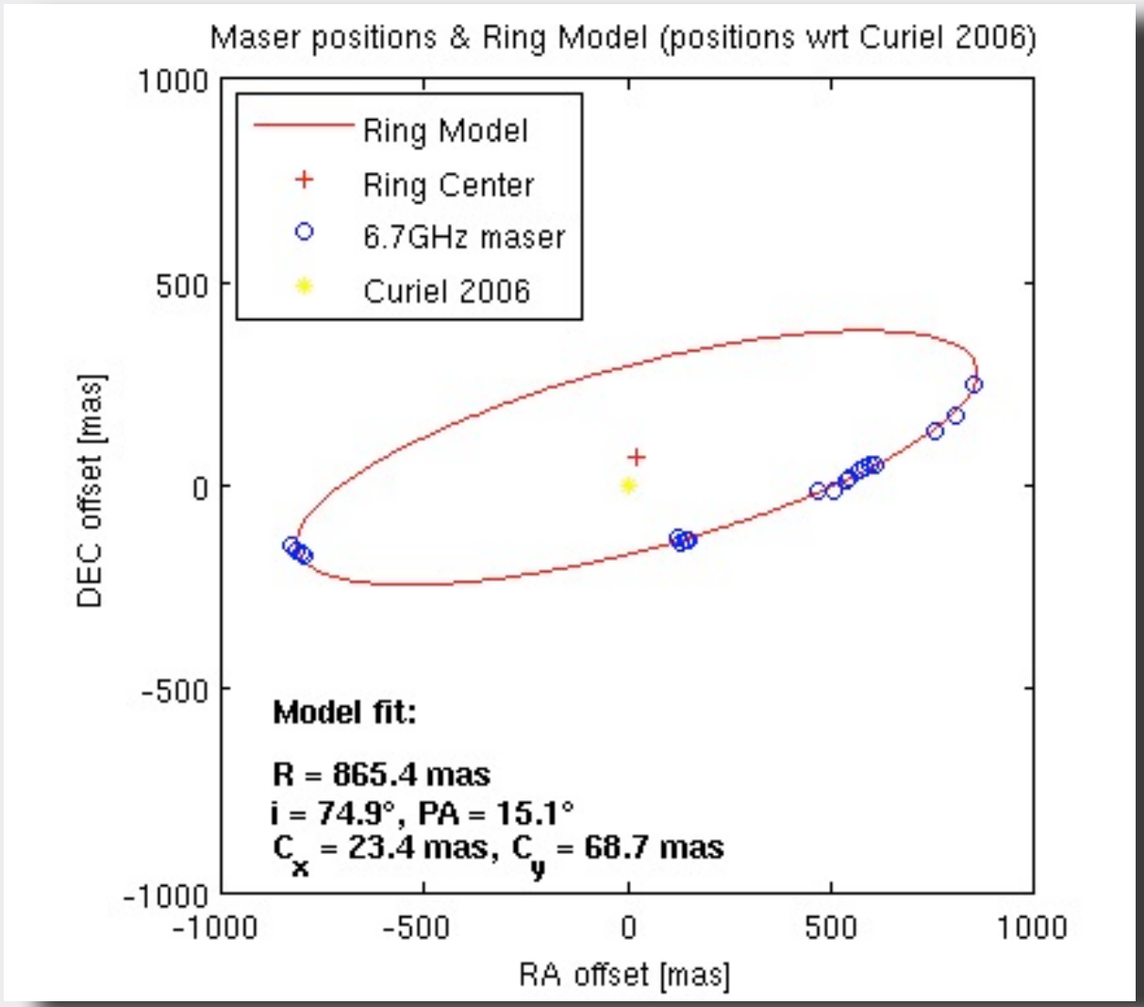

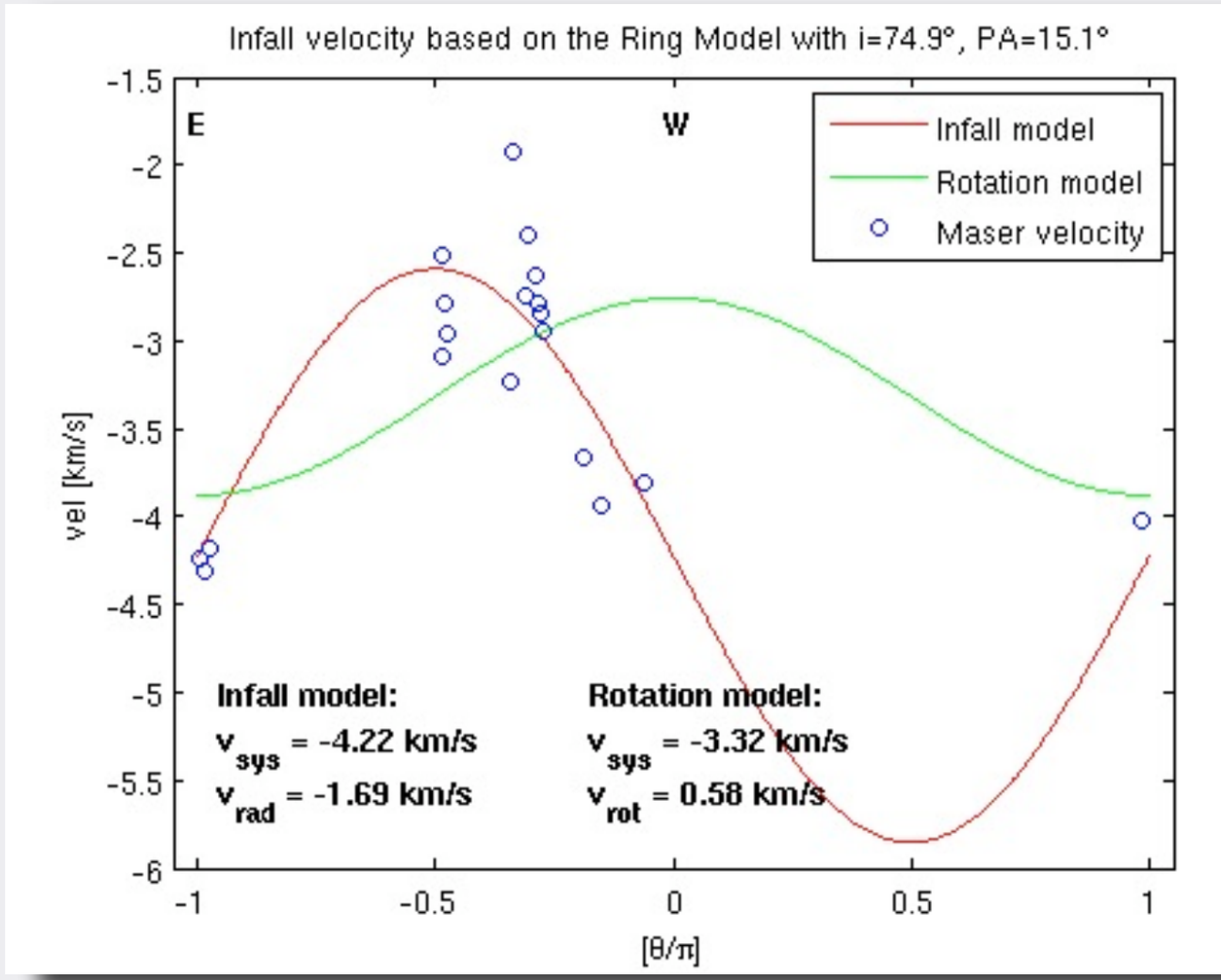

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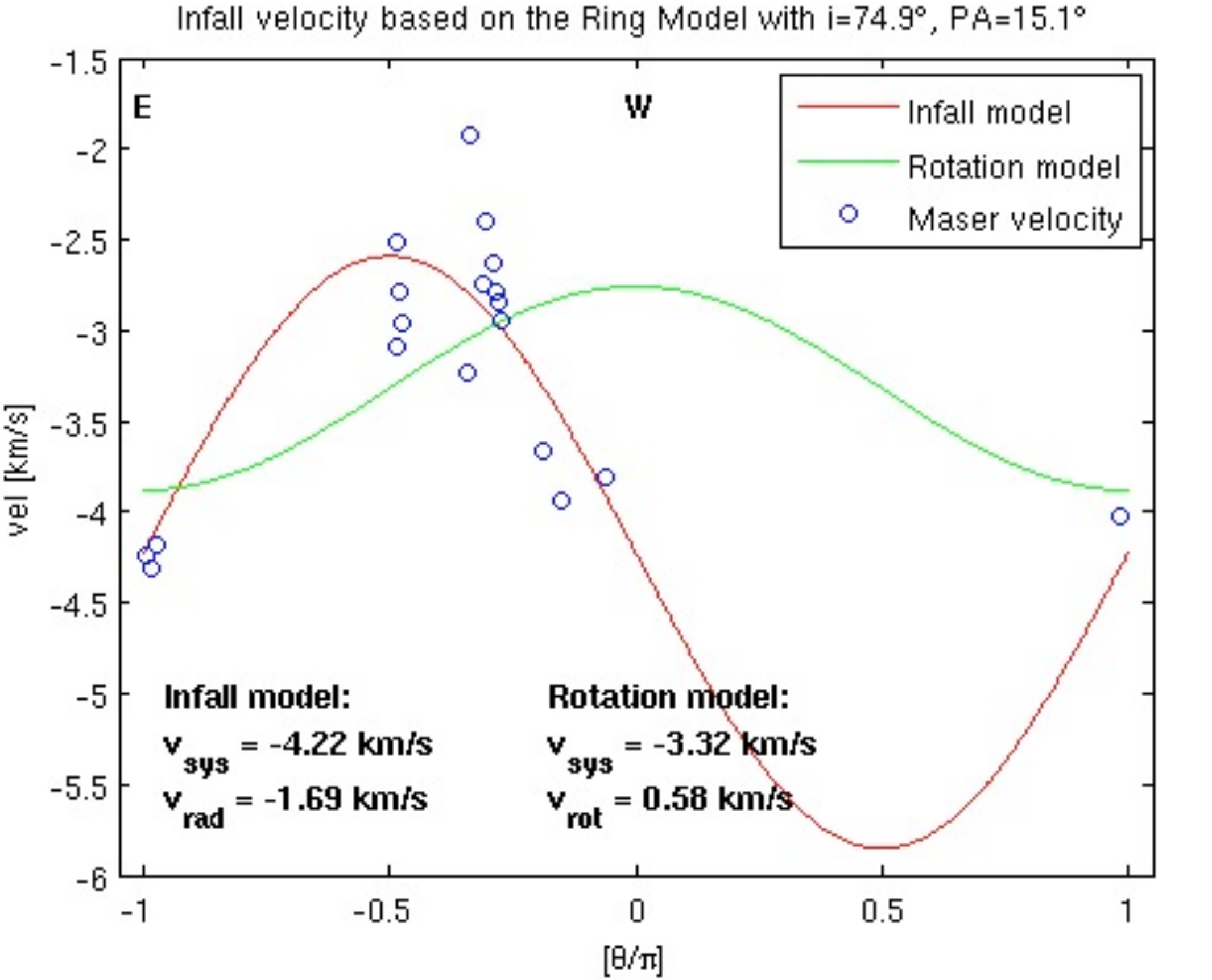
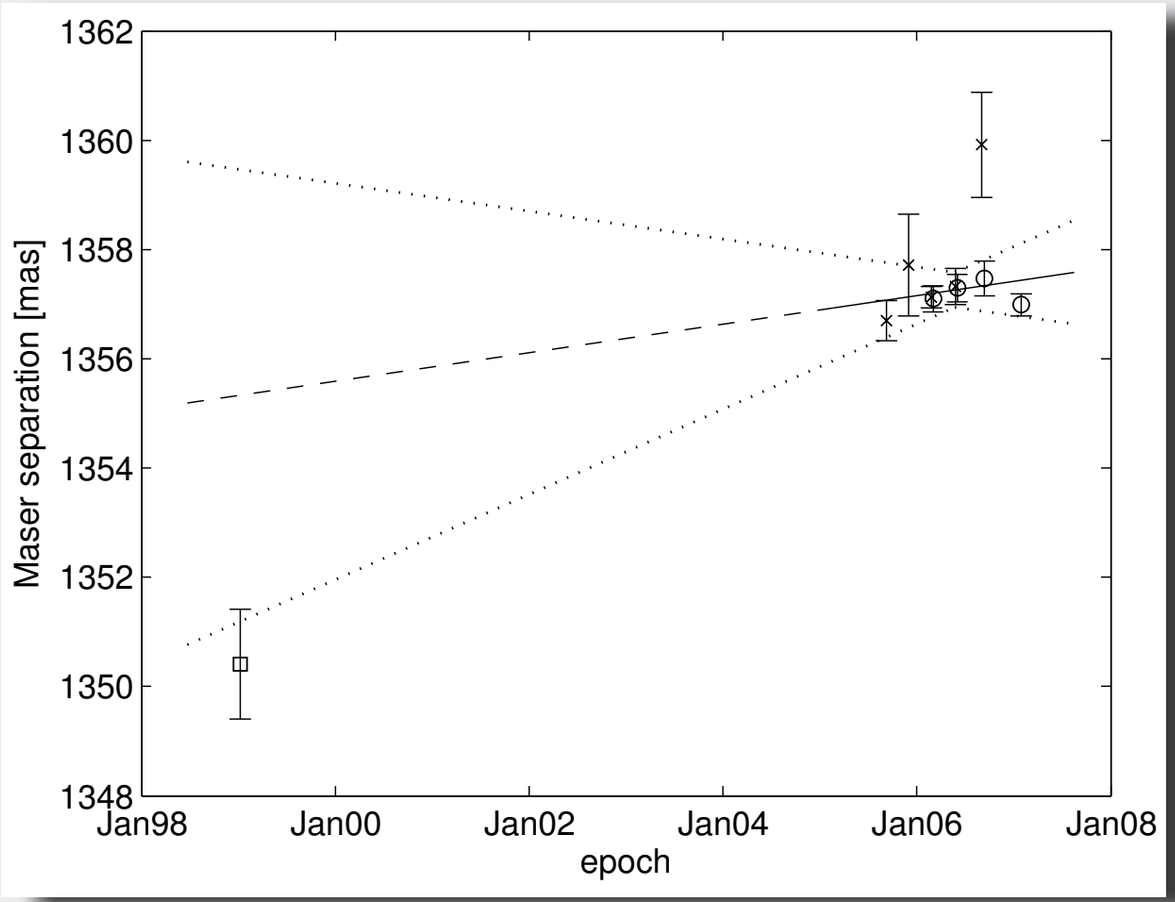
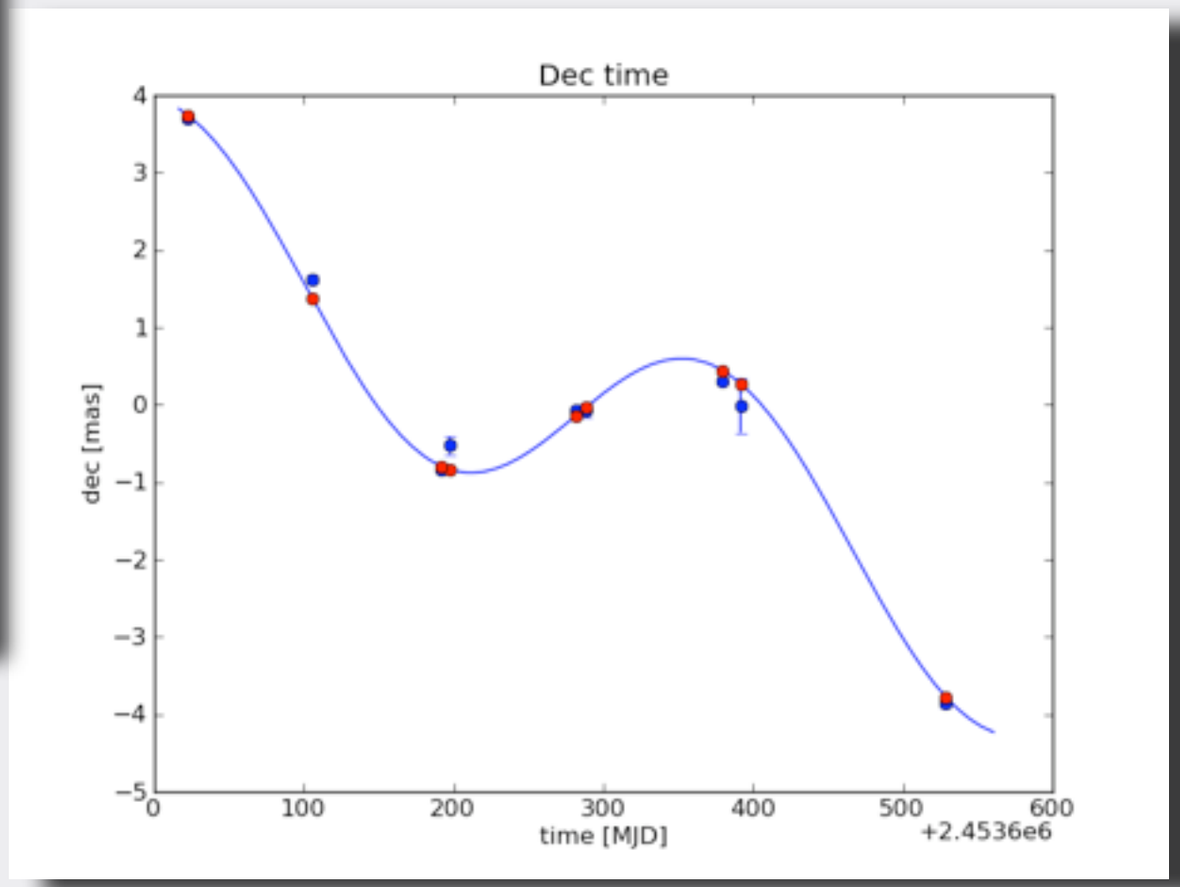

Infall velocity based on the Ring Model with i=74.9°, PA=15.1°
E
W
Infall model
Rotation model
Maser velocity
vel [km/s]
[θ/π]
Infall model:
v sys = -4.22 km/s
v rad = -1.69 km/s
Rotation model:
v sys = -3.32 km/s
v rot = 0.58 km/s

Proper motions of 12 GHz (VLBA)

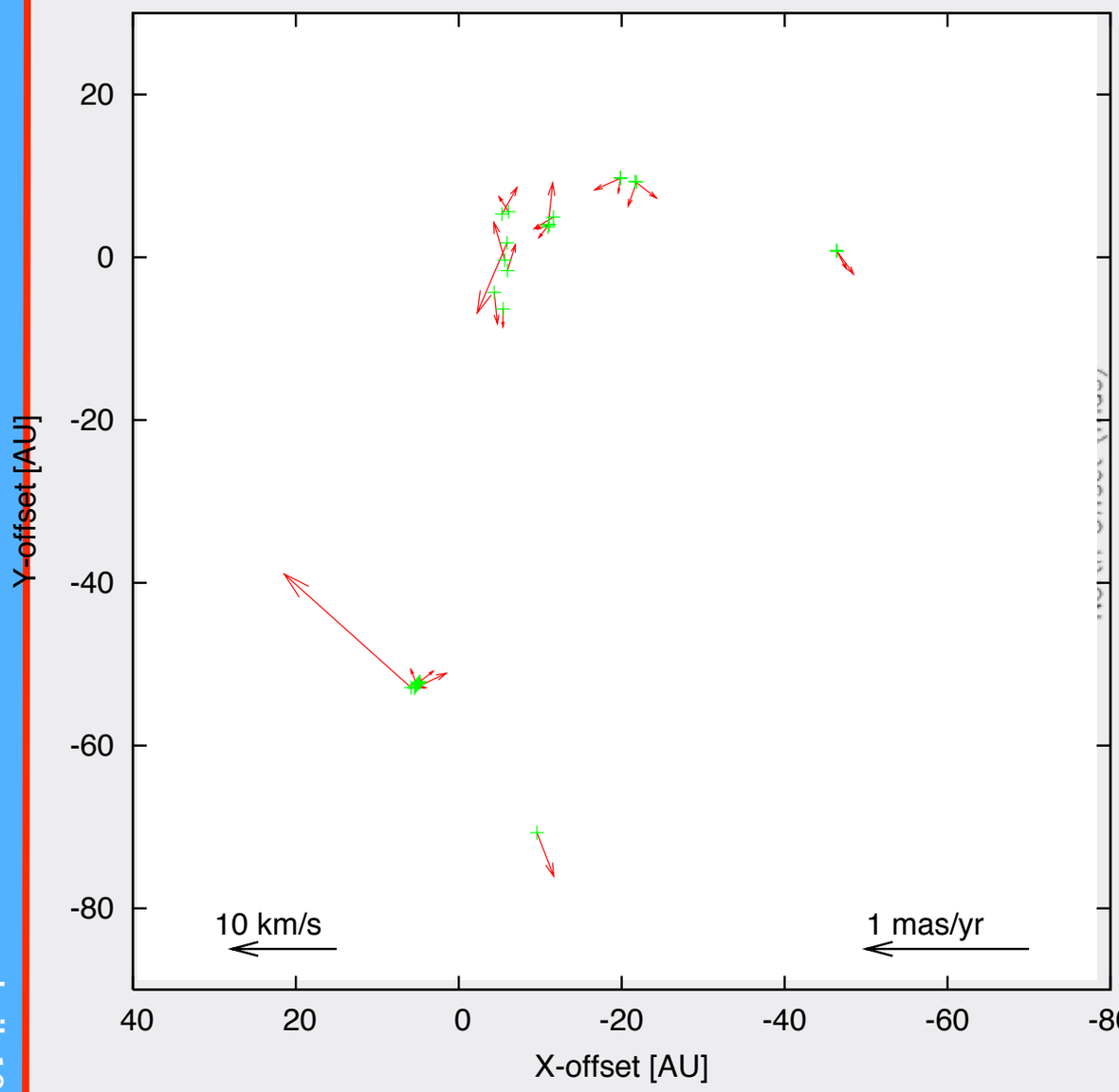
- **No clear sign op internal motions between East and West sides < 2.5km/s**
  - **But able to confirm the parallax distance by Moscadelli et al 2009**

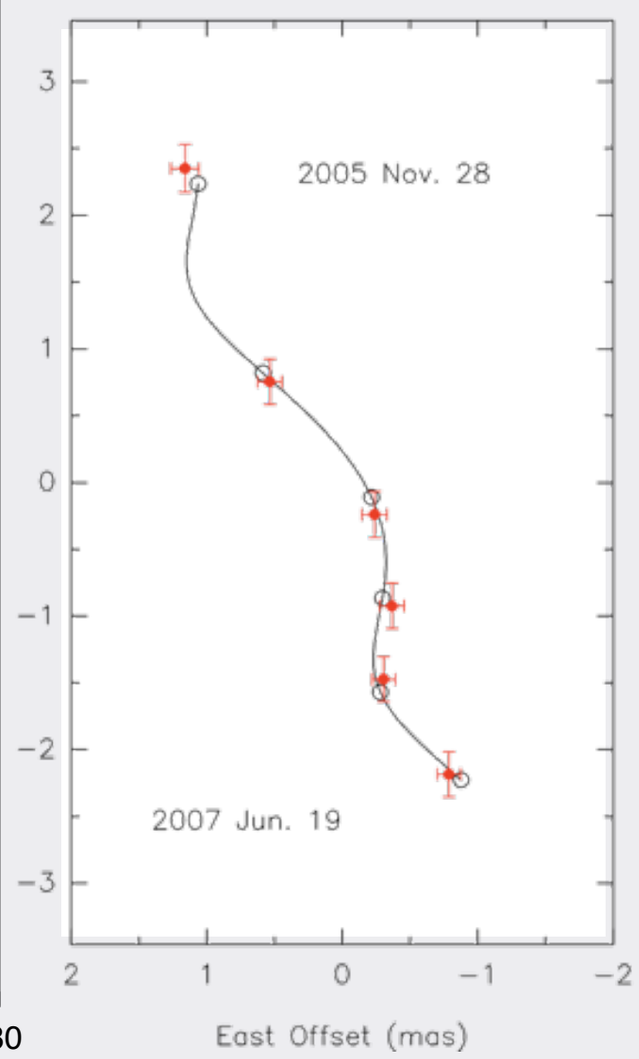


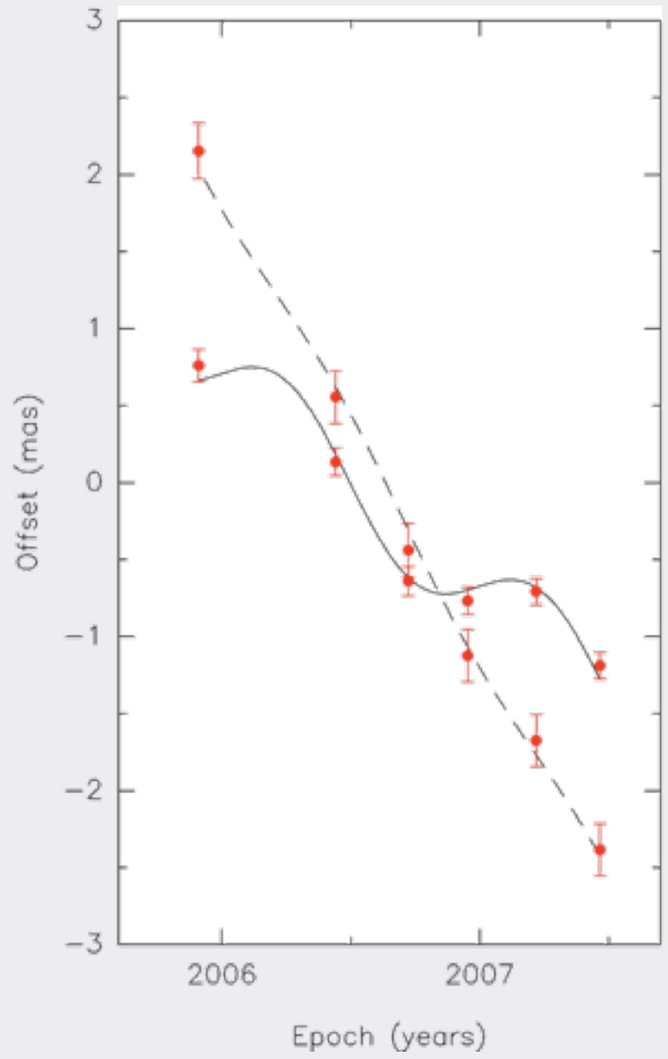


Similar results for ring source

- **VLBA 12GHz astrometry does not show structural motions**
  - **But measure parallax distance**
    - **3.19kpc closer than near kinematic distance (5kpc)**

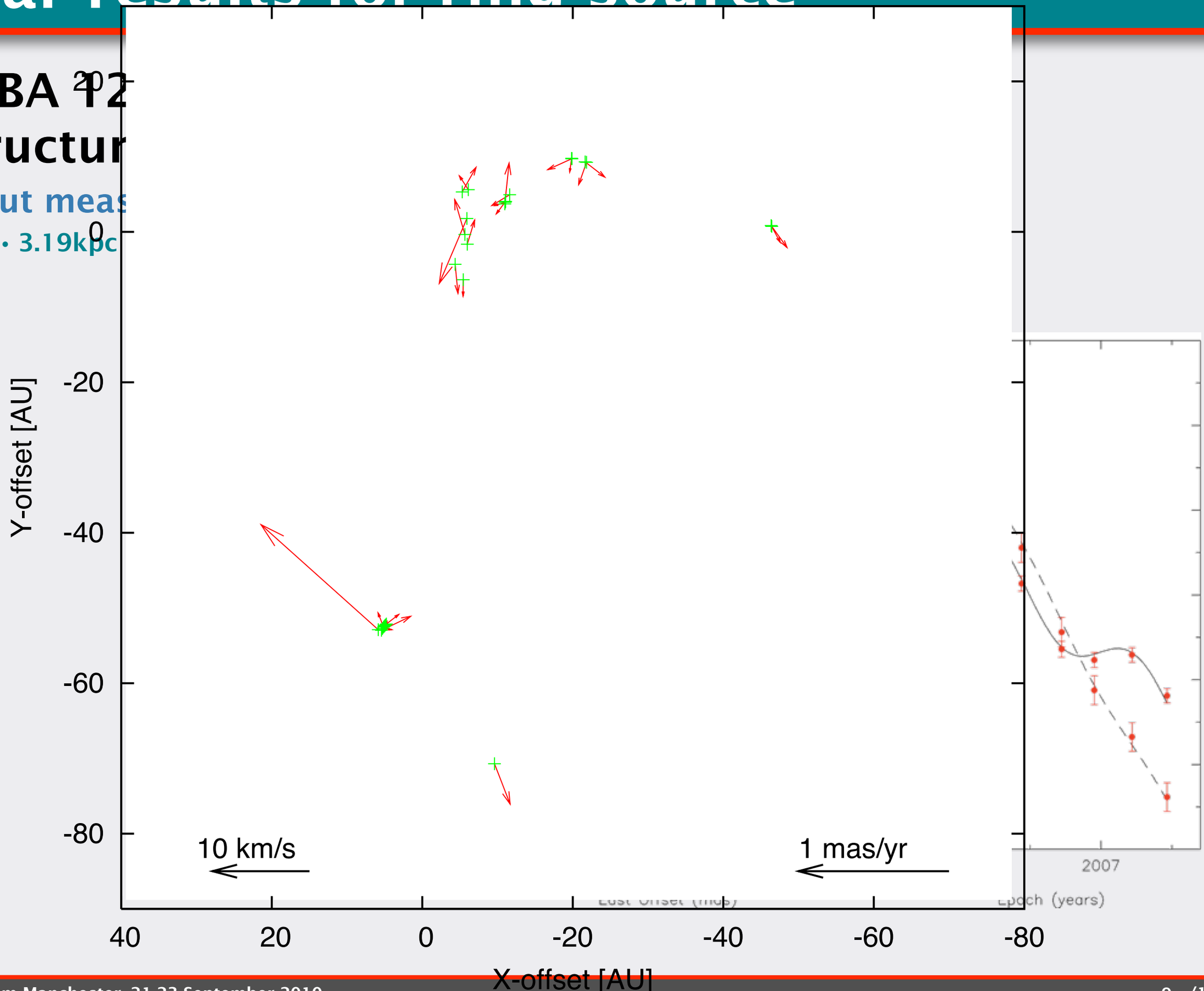






Similar results for ring source

- VLBA 12
  structur
  - But meas
    - 3.19kpc



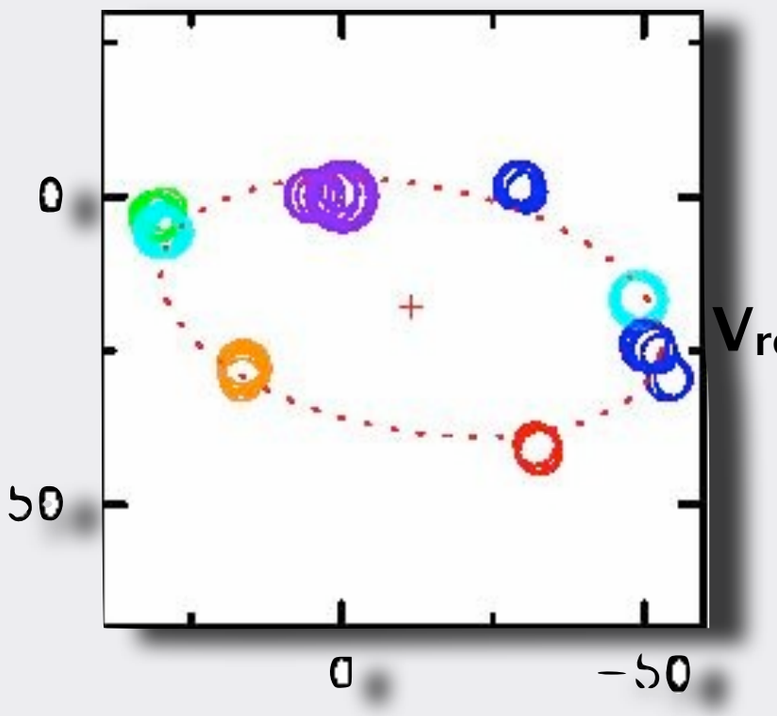
Comparing physical parameters

	Cep A	Ring source
Distance	700pc	3.19kpc
Methanol ring diameter	1200AU	812AU
Enclosed mass (luminosity est)	$18M_o$	$20M_o$
Expected rotation velocity	6.5km/s	5.1km/s
Inclination	$<20^o$	74^o

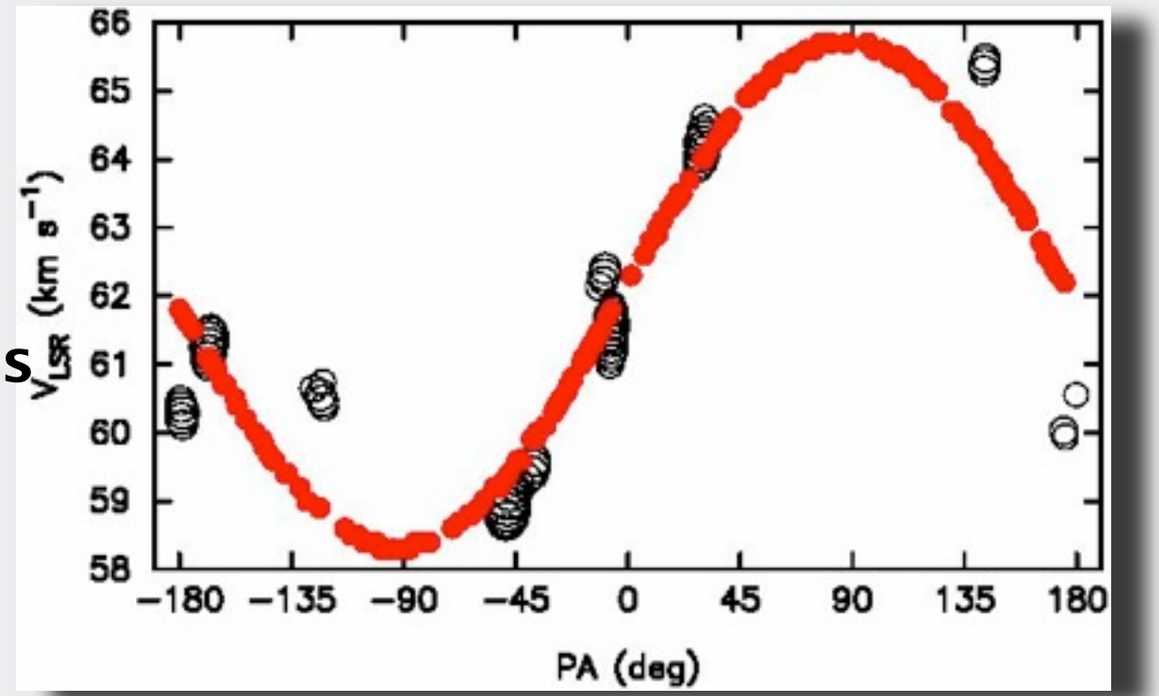
- No sign of rotation
  - In radial motions or proper motion
  - Consistent with EVN sample
- In fact velocity structure erratic
  - some spurs or gradients seen in individual spots

Similar for EVN sample

- **No significant rotation detected either**
  - **But detection of radial motions quite common**
  - **Could be Infall or outflow**
    - **Sign of inclination is ambiguous**
    - **Depends on what is front or back**



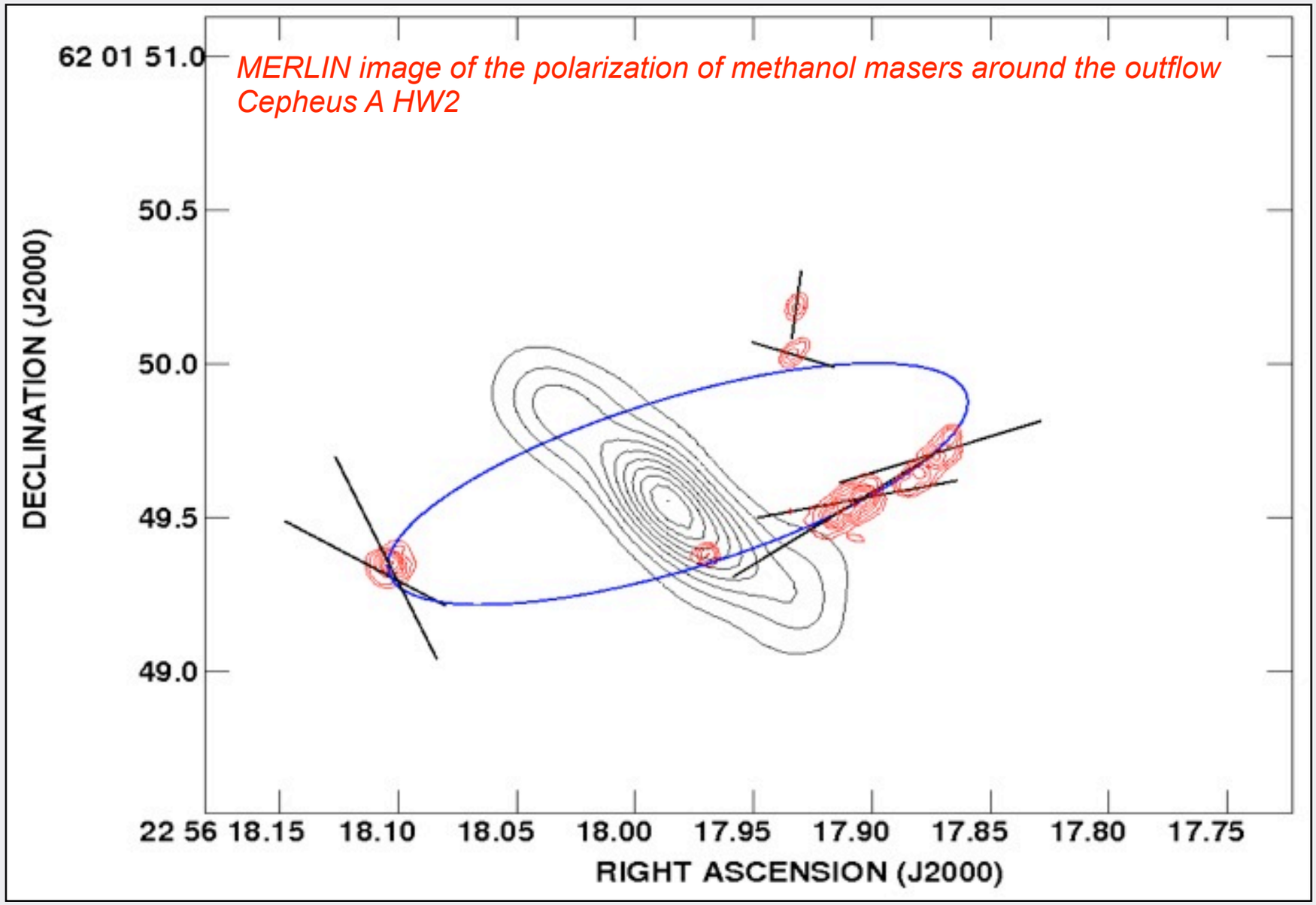
V_{rot}=0.2 kms



Model & data: G33.980-00.019

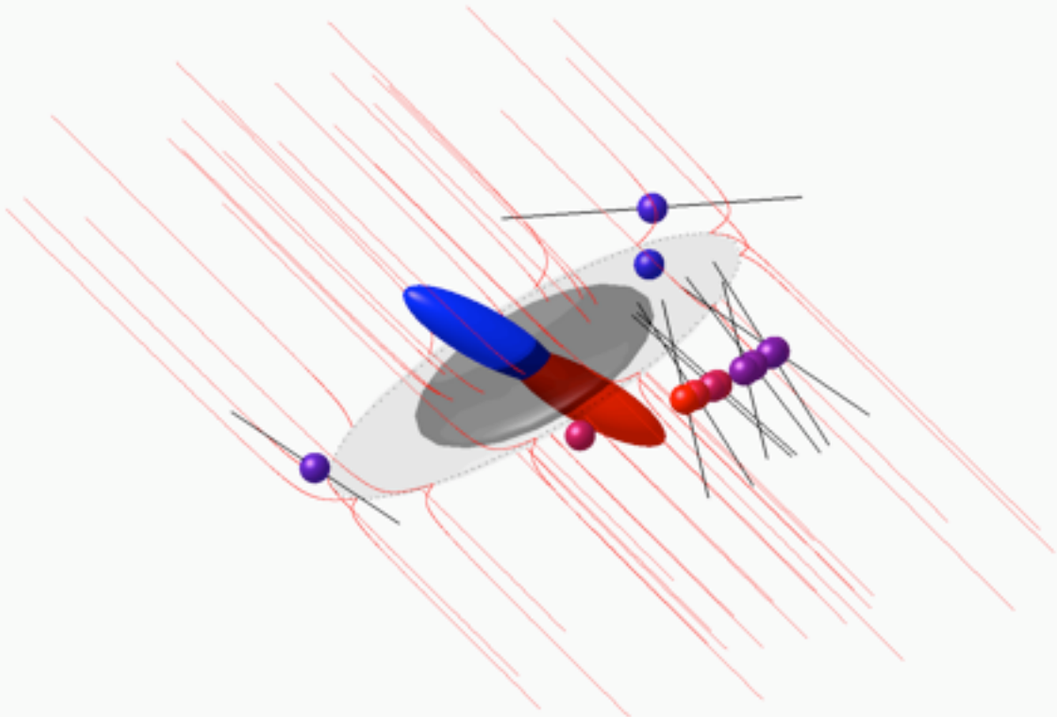
Pre-shock, post-shock, spurrs

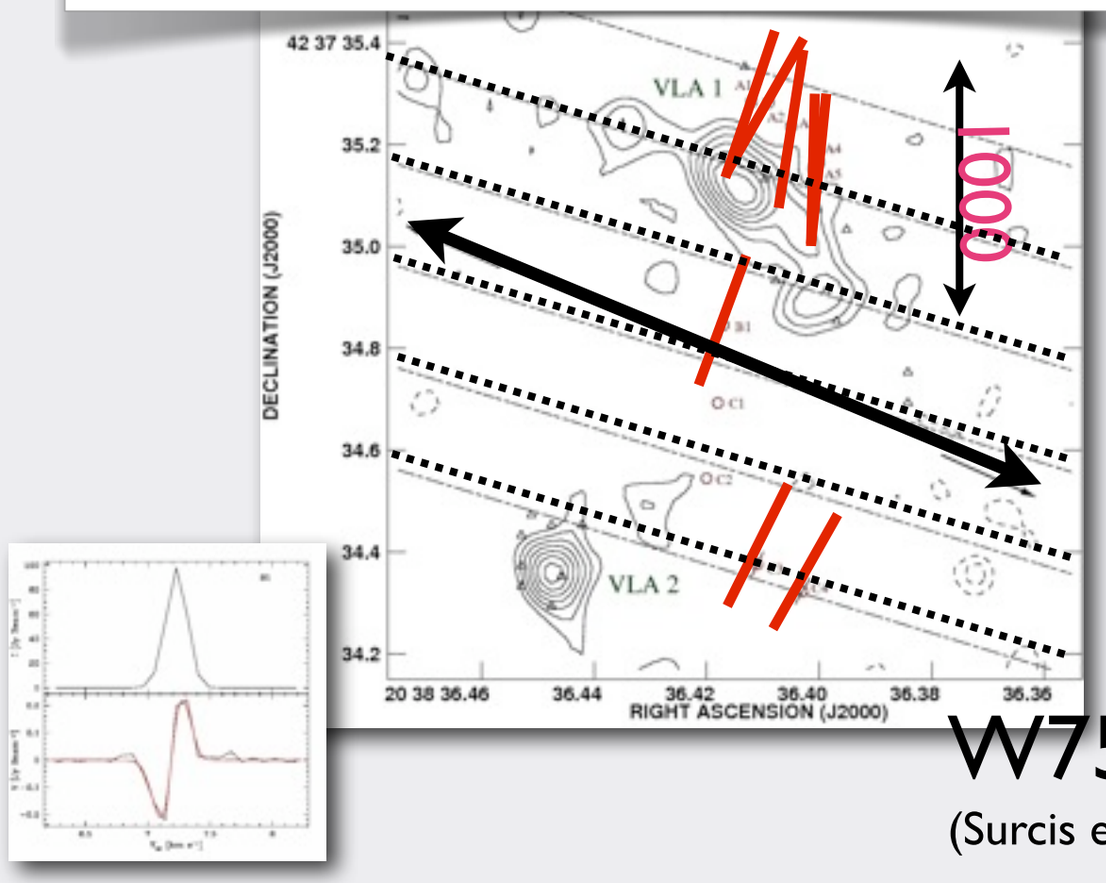
- **Gravity is not the dominant force at maser location**
  - **So what is?**
  - **Thermal pressure, radiation pressure, magnetic fields?**



Magnetic force

- Detected a 23 mG field
  - By combining Effelsberg and MERLIN data
- Deprojection structure perpendicular to “disc”
  - Similar orientation as outflow
- Conditions for collapse along field lines
  - Magnetic field dominates over turbulent support
- Similar results found in other sources



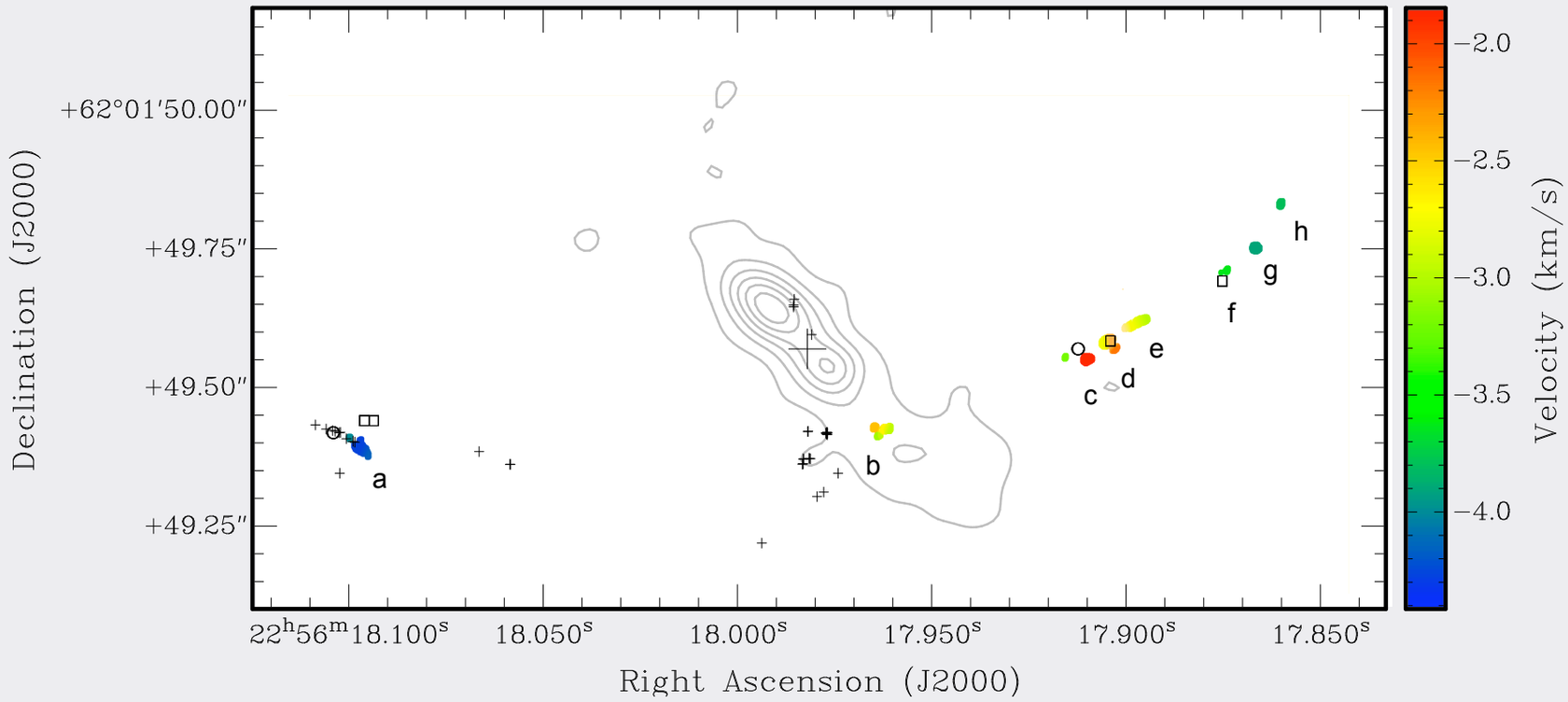


W75N

(Surcis et al. 2010)

Working hypothesis

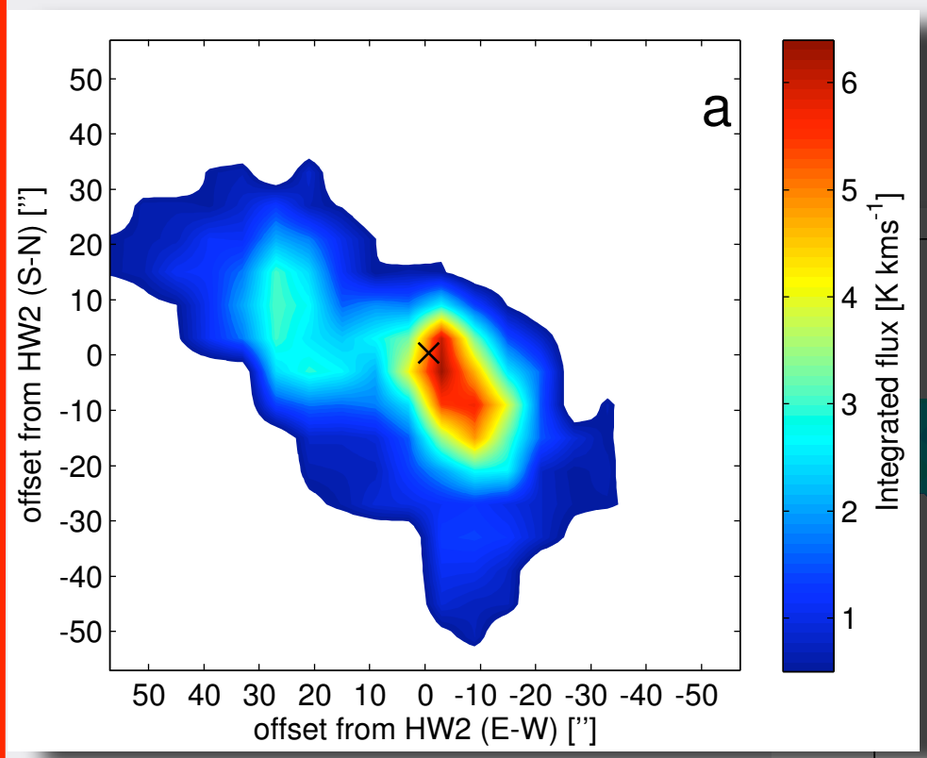
- **Radial motions in Cep A seems to be infall**
  - See only front side masers
  - Possible absorption of back side by free-free optical depth
  - Or maser effect, amplifying background

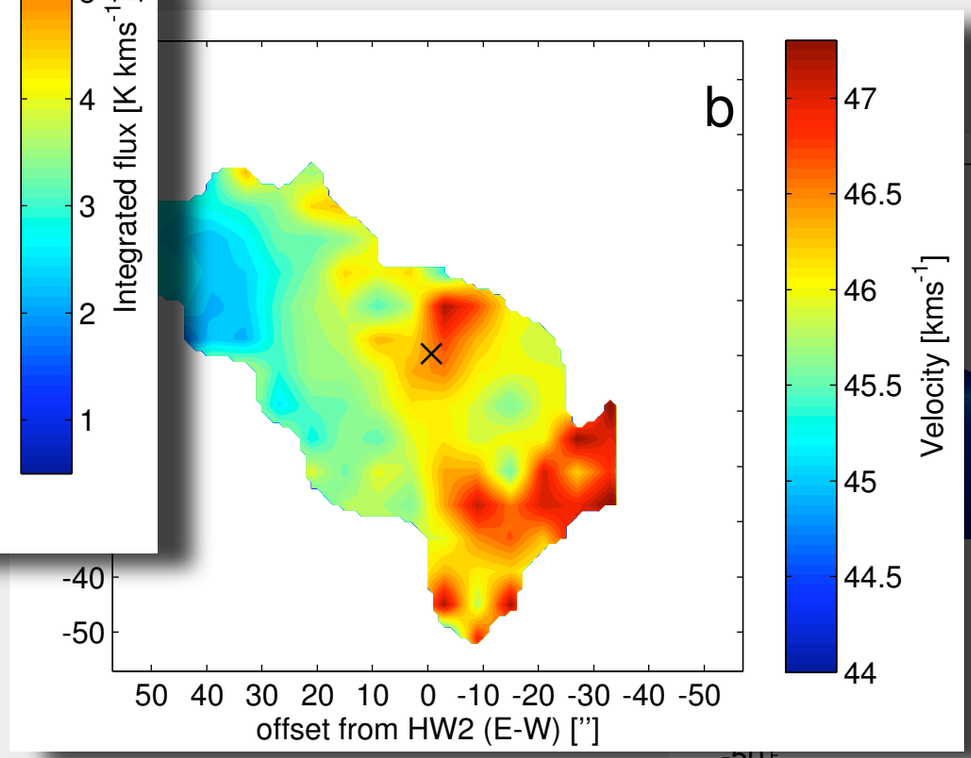


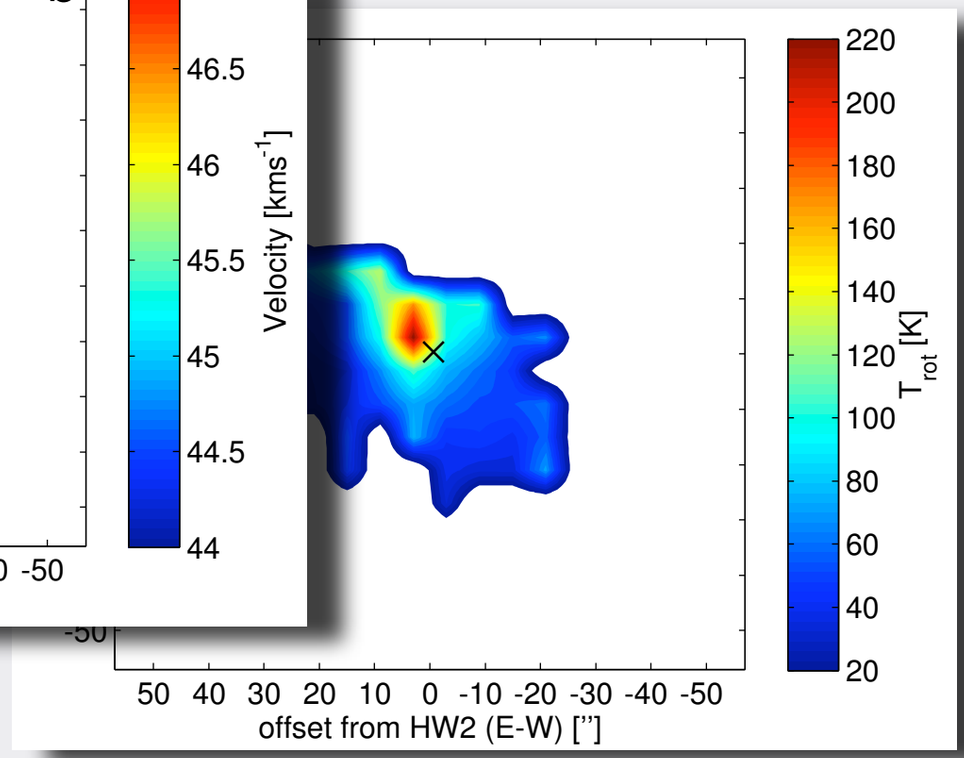
- **Masers on interface accretion and the disk**
  - Methanol masers in pre-shock gas?
  - Also identify as the place where methanol is released from grains
    - Such large scale structures unique to high mass sources?

Other ways to address the issue

- **Find the physical conditions**
  - And the methanol abundance from thermal transitions
- **Seems to indicate methanol is generated close in**
  - and entrained in large scale outflow







Conclusion

- **Evidence is building up that methanol masers originate in the accretion disk/infall interface at least in a fraction of sources**
  - Can possibly explain few more non ring sources
  - But quite possible association with outflow also exist
  - Identification of physical structure and evolutionary stage closer
    - Makes them really suited to use for signposts
    - Good news for astrometry
    - Dynamics of the masers connected to shock internals

Contributing to the understanding of how new worlds form.