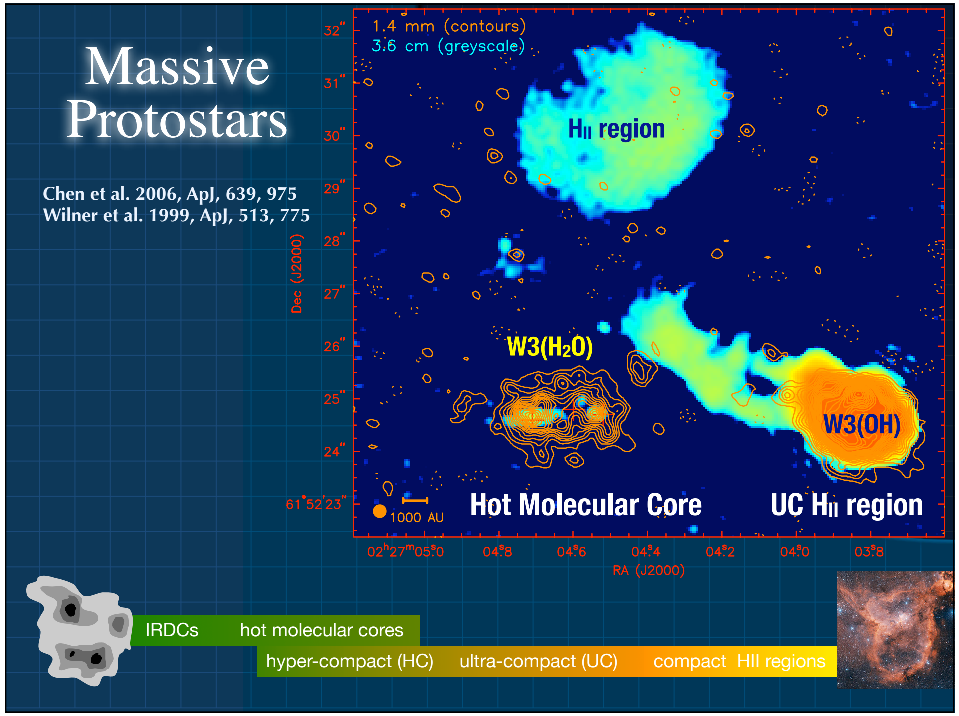
A Magnetized Jet in the Hot Core W3(H_2O)

Vivien Chen

(National Tsing Hua University, Taiwan)

Ram Rao (ASIAA), David Wilner (CfA), Sheng-Yuan Liu (ASIAA)

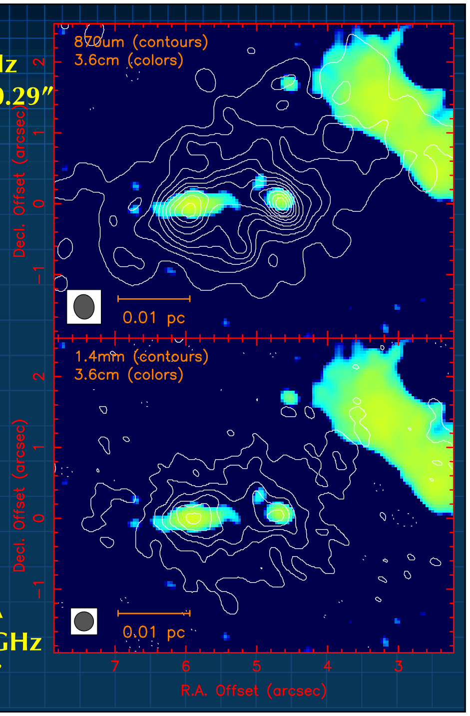


Massive Protostars
Chen et al. 2006, ApJ, 639, 975
Wilner et al. 1999, ApJ, 513, 775
1.4 mm (contours)
3.6 cm (greyscale)
HII region
W3(H2O)
W3(OH)
1000 AU
Hot Molecular Core
UC HII region
Dec (J2000)
RA (J2000)
IRDCs
hot molecular cores
hyper-compact (HC)
ultra-compact (UC)
compact HII regions

Physical Conditions

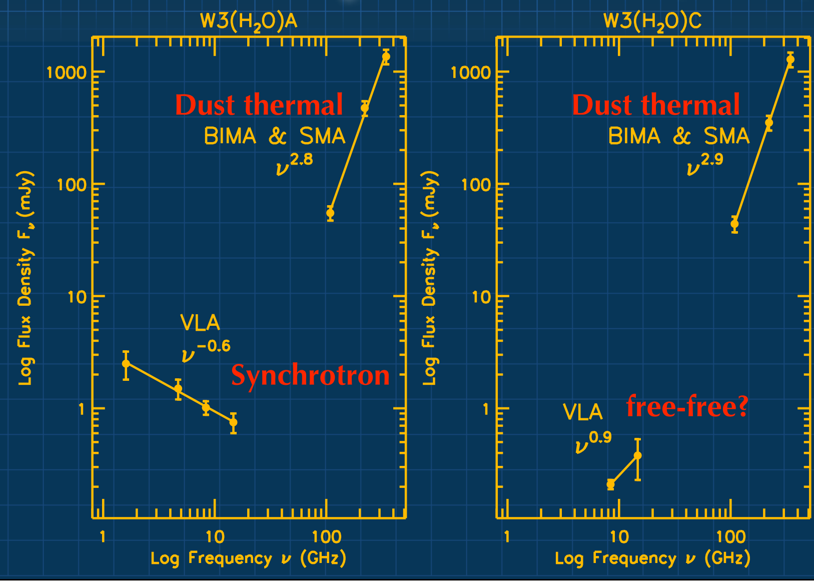
- Discovered in HCN, a.k.a. the Turner-Welch object (Turner & Welch 1984)
- d = 2.04 kpc (Hachisuka et al. 2006)
- Accreting protobinary system (Chen et al. 2006; Zapata et al. 2011)
  - T ~ 200 K
  - n_{H_2} ~ 1.5 x 10^7 cm^{-3}

SMA
345 GHz
0.35″x0.29″



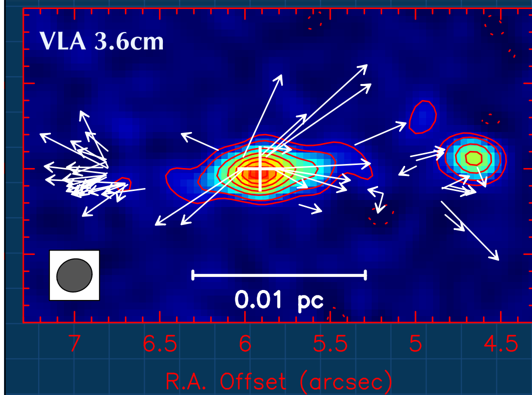
BIMA
221 GHz
0.27″

Continuum Spectra in W3(H_2O)



Synchrotron Emission in Jets

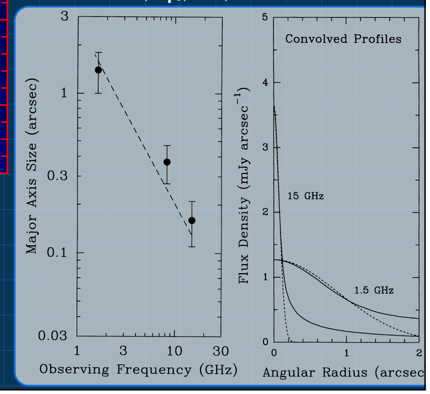
Wilner et al. (1999), Alcolea et al. (1993)



$$B(r) = 10\ \mathrm{mG} \left(\frac{r}{0\farcs2}\right)^{-0.8}$$

$$N_{\rm re}(\gamma, r) = 0.068\ \mathrm{cm}^{-3}\, \gamma^{-2} \left(\frac{r}{0\farcs2}\right)^{-1.6}$$

Reid et al. 1995, ApJ, 443, 238



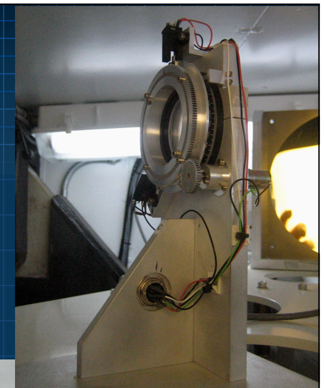
Observing Magnetic Fields

- **Plane-of-sky component, B_{pos}**
  - **Polarization in dust emission $\perp B_{pos}$**
    - Morphology of B_{pos}
    - Field strength inferred by the Chandrasekhar-Fermi method
- **Line-of-sight component, B_{los}**
  - **Zeeman splitting, e.g. OH/H_2O masers, HI, CN, etc**
    - Field strength directly measured
- **Total field strength, $B = (B_{pos}^2 + B_{los}^2)^{1/2}$**

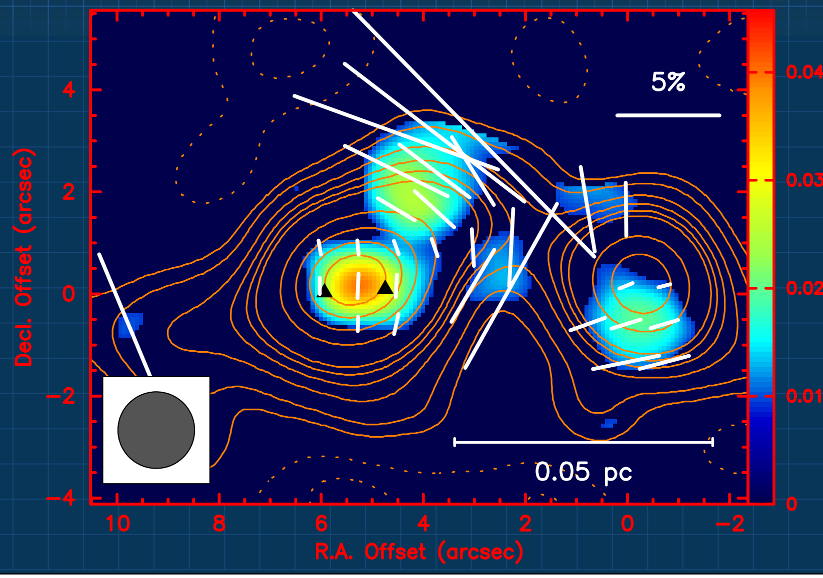
SMA Polarization Observations

- Compact + extended
- 1.5″ beam with natural weighting

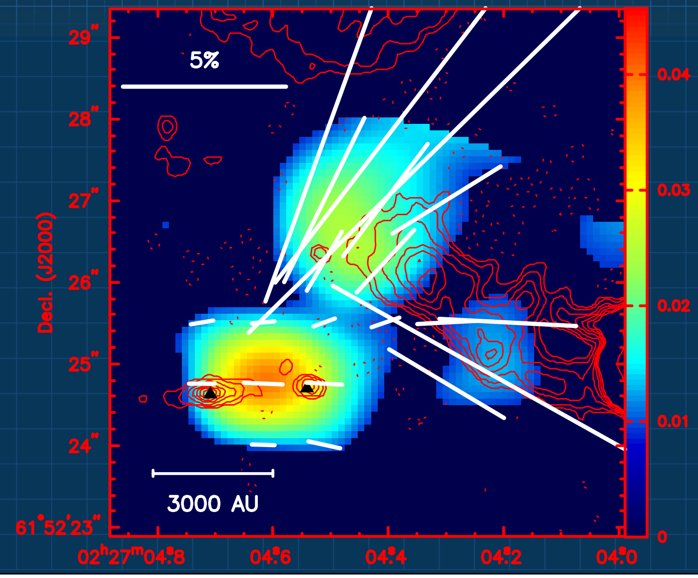
Courtesy: Derek Kubo



SMA 870μm Polarization Map



Magnetic Fields & Synchrotron Jet



Chandrasekhar-Fermi Method

- **Estimate the plane-of-sky magnetic field strength**
  (Chandrasekhar & Fermi 1953)
  - $\delta\theta$ **~ transverse component of the Alfvén wave perturbed by the turbulent gas**
  - **Velocity dispersion is isotropic**
- B_{pos} **= 16.3 mG for W3(H_2O)**

$$B_{\rm pos} = Q\sqrt{4\pi\rho}\,\frac{\delta v_{\rm los}}{\delta\theta}$$
$$= 69\ {\rm mG}\left(\frac{Q}{0.5}\right)\left(\frac{\mu}{1.36}\right)^{1/2}\left(\frac{n_{\rm H_2}}{10^7\ {\rm cm^{-3}}}\right)^{1/2}\left(\frac{\delta v_{\rm los}}{1\ {\rm km\,s^{-1}}}\right)\left(\frac{\delta\theta}{1^\circ}\right)^{-1}$$

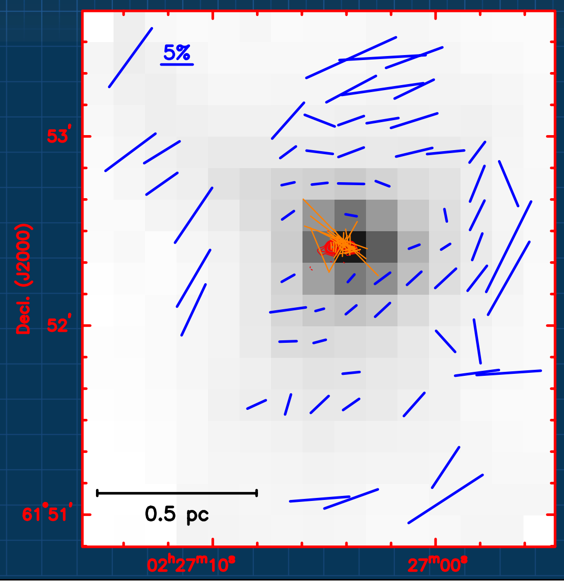
Q ~ 0.5 as long as $\delta\theta \lesssim 25$ (Ostriker et al. 2001)

Magnetic Field Strength

- H_2O masers Zeeman B_{los} = +42.1 mG (Sarma et al. 2002)
  - Arising in the postshock region, perhaps enhanced ~20
  - Preshocked gas B_{los} ~ 2.1 mG
- $B = (B_{pos}^2 + B_{los}^2)^{1/2}$ = 16.4 mG
  - Slightly higher but comparable to the synchrotron jet model (~ 10 mG)
  - Nearly on the plane of sky
  - Magnetic energy dominates over turbulence

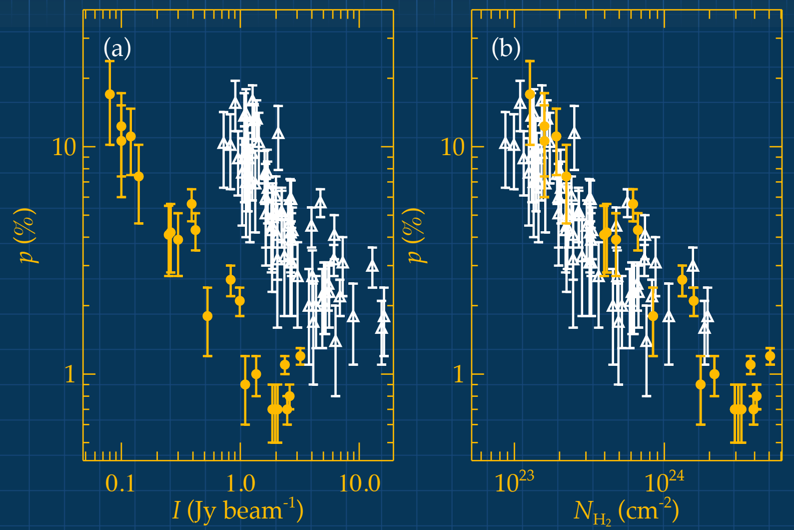
    $\beta_{\rm turb} = 3(\delta v_{\rm los}/v_A)^2 = 0.35$

JCMT SCUPOL Map



Matthews et al. 2009
ApJS, 182, 143

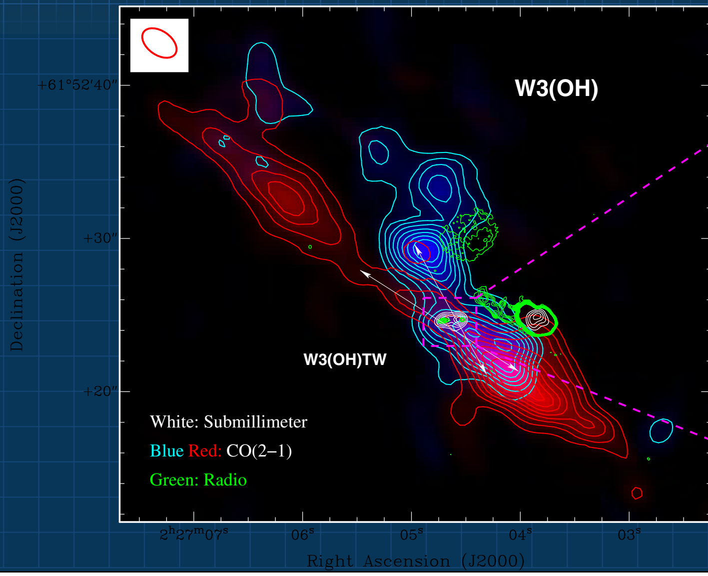
The Depolarization Effect



Summary

- SMA polarization map of W3(H_2O) at 870 μm
- Inferred B_{pos} is well aligned with the synchrotron jet
- Magnetic fields are close to plane of sky. The field strength is slightly higher but comparable to the synchrotron model
- Magnetic field energy dominates over turbulence
- The depolarization effect has a similar dependence with N_{H_2} for both SMA and JCMT measurements

CO Molecular Outflows



Zapata et al. (20