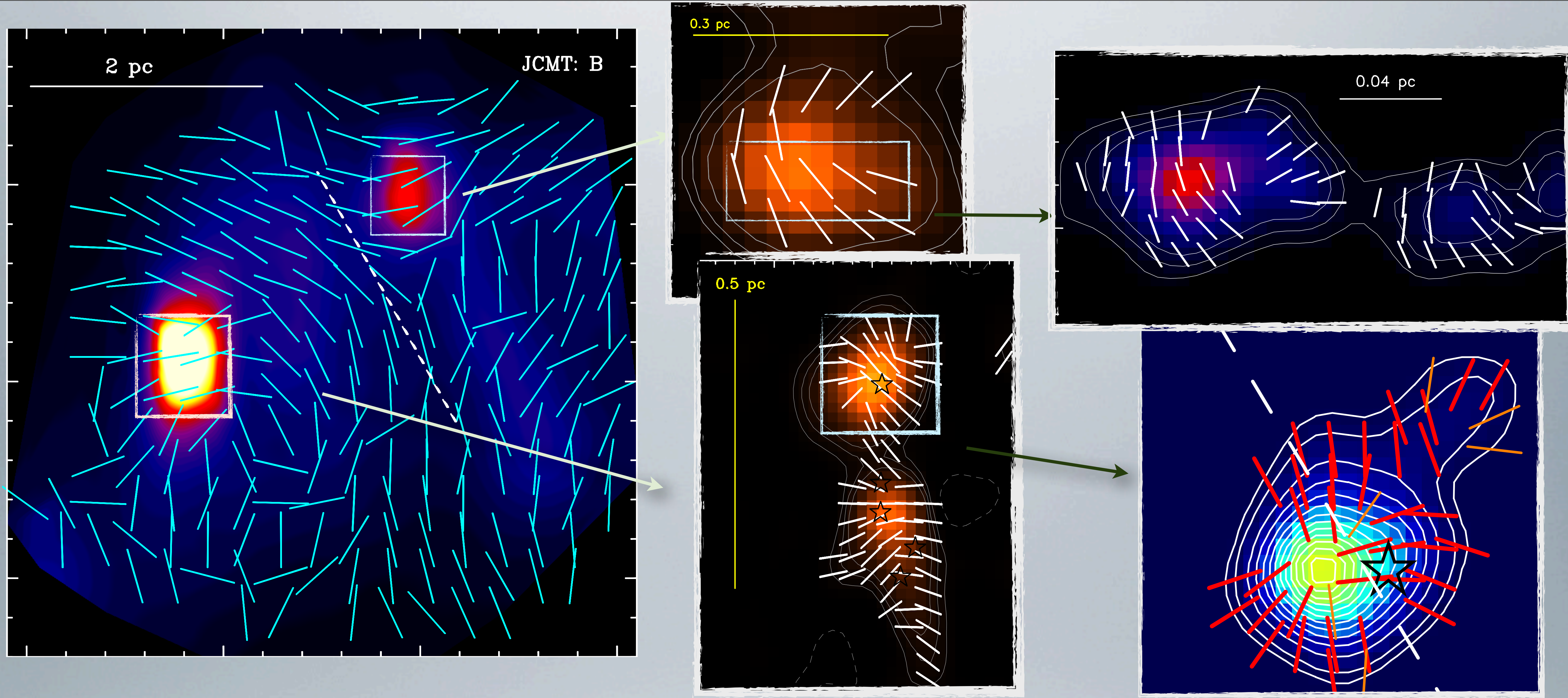

Magnetic Field Morphologies in Star Forming Clouds at mpc Angular Resolution

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1. B field morphologies from pc to mpc scale

1.1 Star forming cloud:

Color scale:

- dust continuum emission at 850 □m

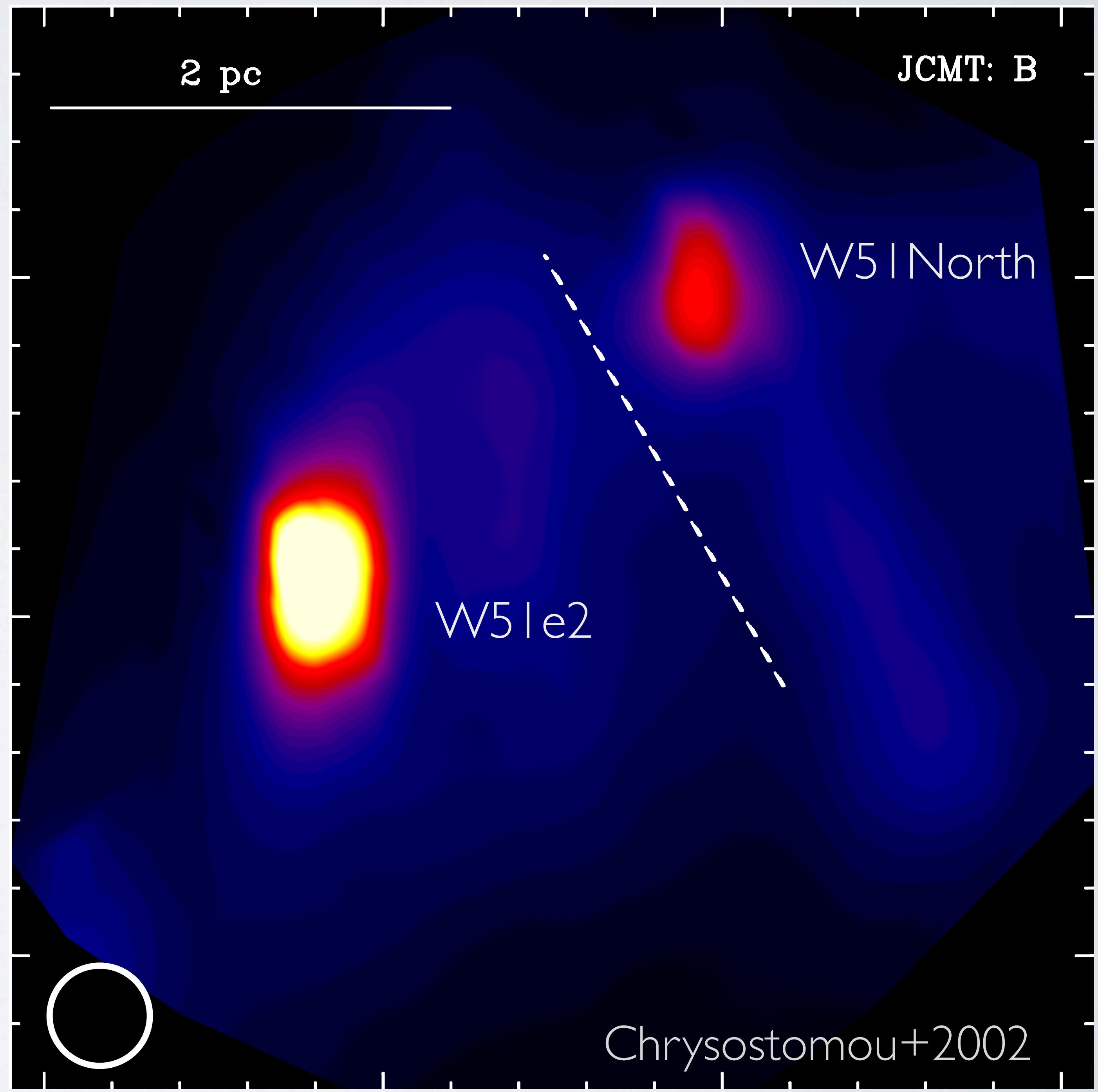
- trace dense region

W51A:

- A star forming cloud in our Galaxy

- Distance: 7 kpc

- Two brightest cores: W51e2, W51 North



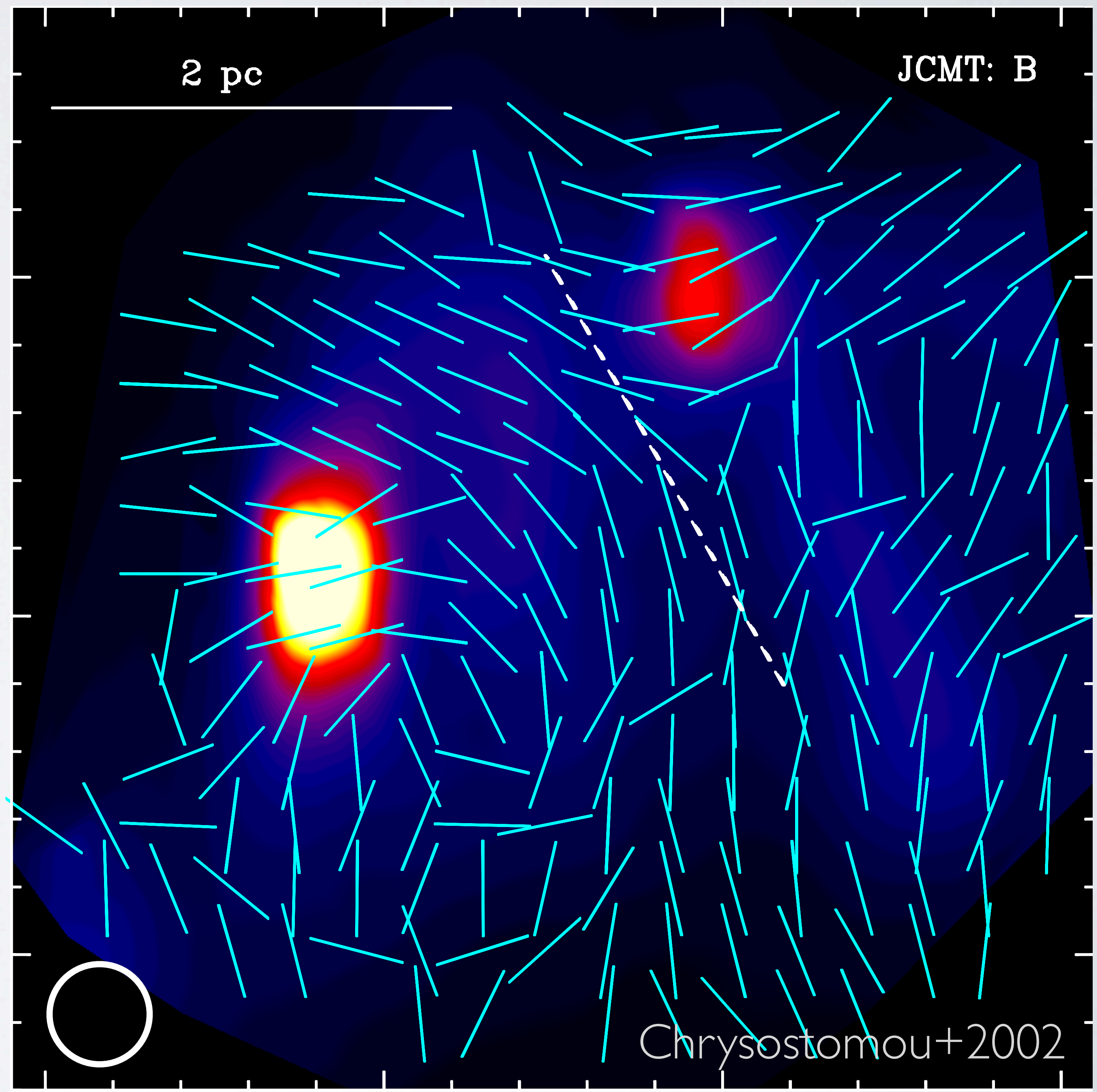
1.1 W51A: magnetic field

Color scale:

- dust continuum emission at FIR (850 μm)
- dense gas: n >10^3 cm^{-3}

Cyan segments:

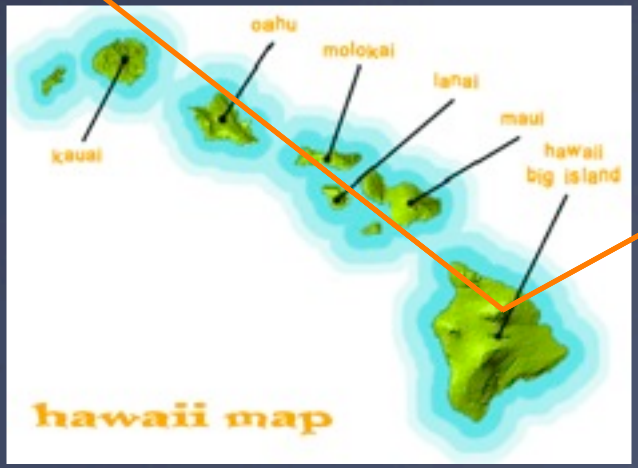
- B field orientation traced via the polarization of FIR emission
- uncertainties: ~10°
- JCMT image: 15" resolution
- B field varies significantly across the cloud



Tuesday, May 14, 13

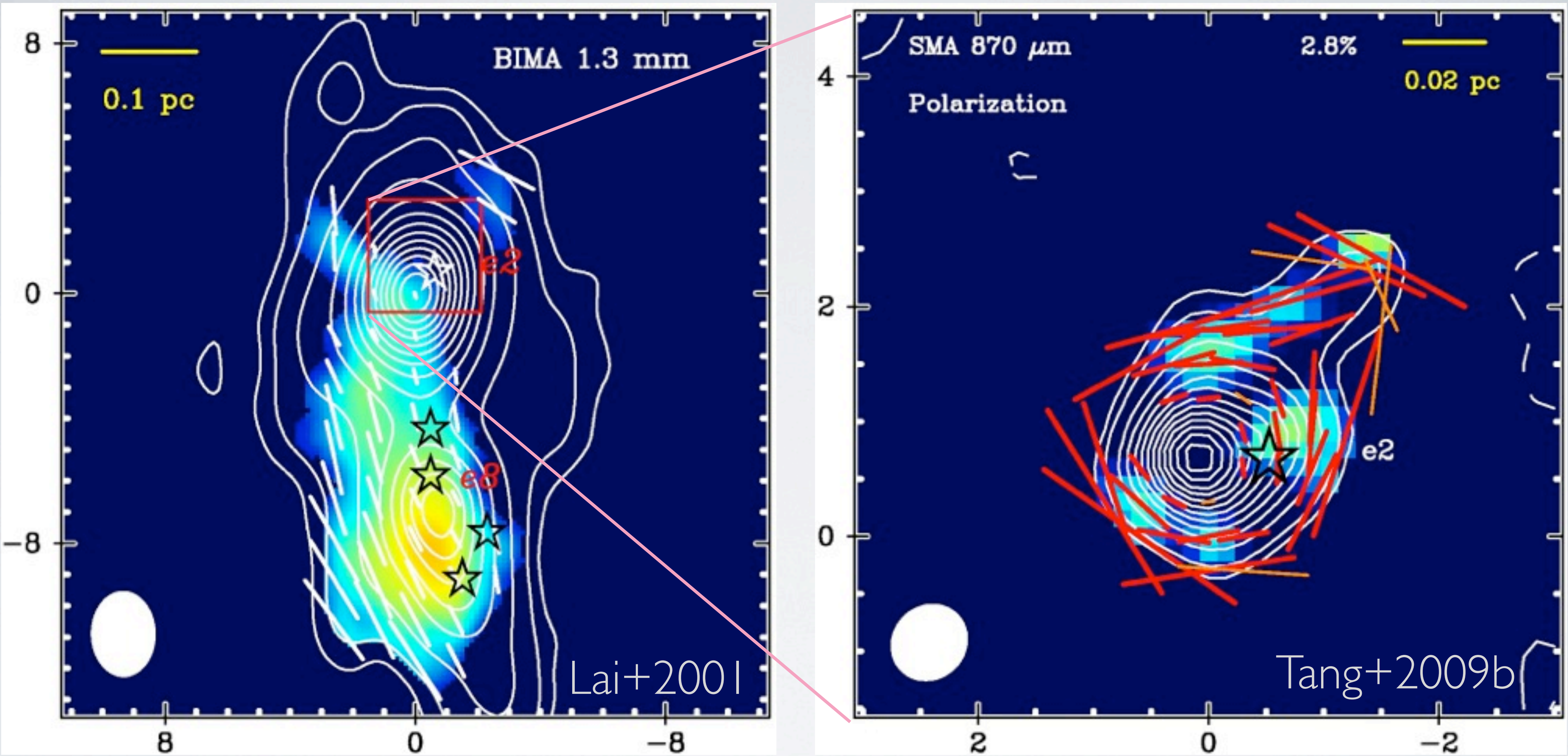
Observations

Sub-Millimeter Array (SMA)



* 8 x 6-m antennae
* Frequency: 345 GHz (870 μm)
  - ➔trace thermal dust emission
* Quarter-wave plates
  - ➔ measure dual polarization
  - ➔Stokes I, Q, U & V
* Angular resolution: ~1"

Importance of high angular resolution

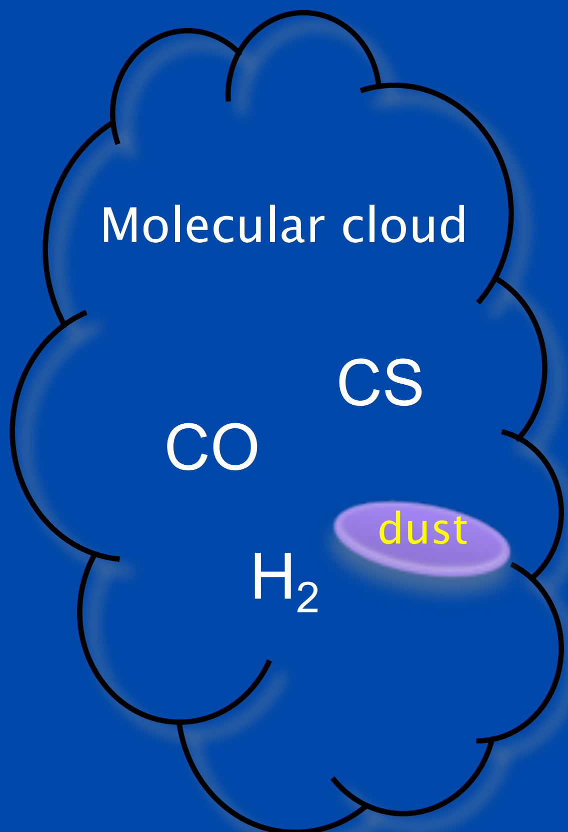


color scale: polarization intensity

Complex B field morphologies where the polarization signals can be averaged out.

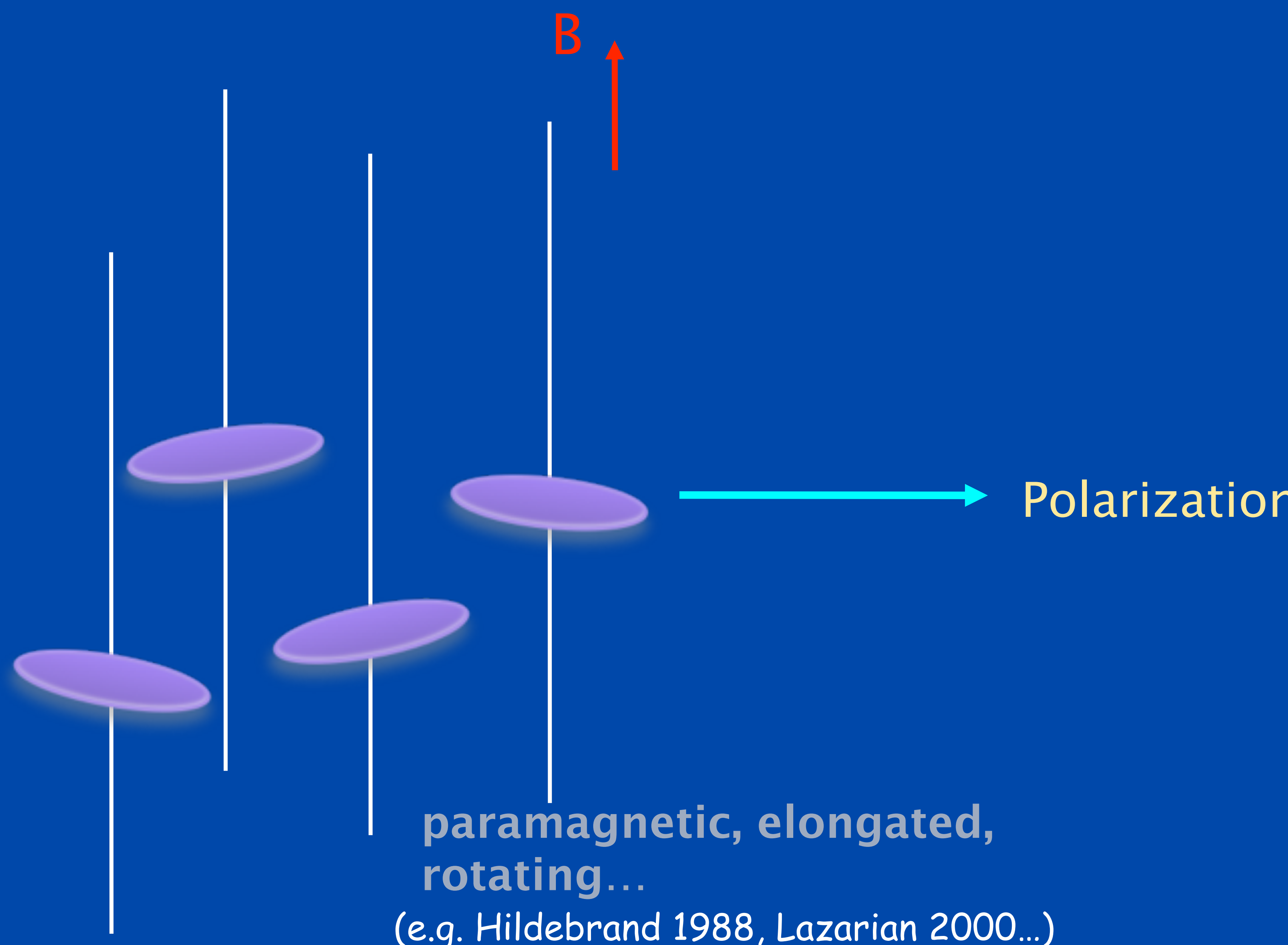
Example: the depolarization regions in W51 e2

Dust Polarization Mechanism



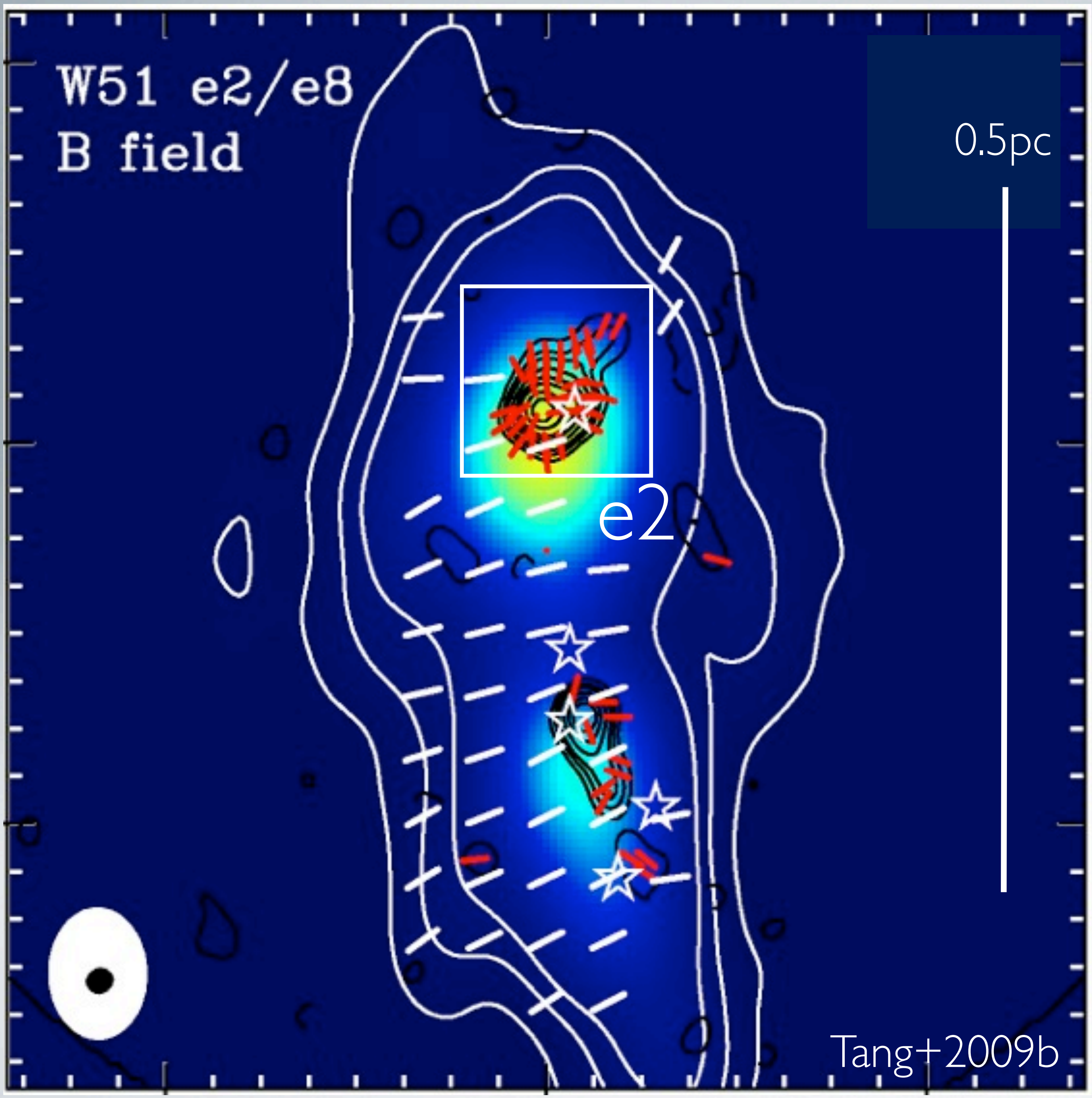
$n_{H_2} \sim 10^{4\text{-}7}$ (cm $^{-3}$)

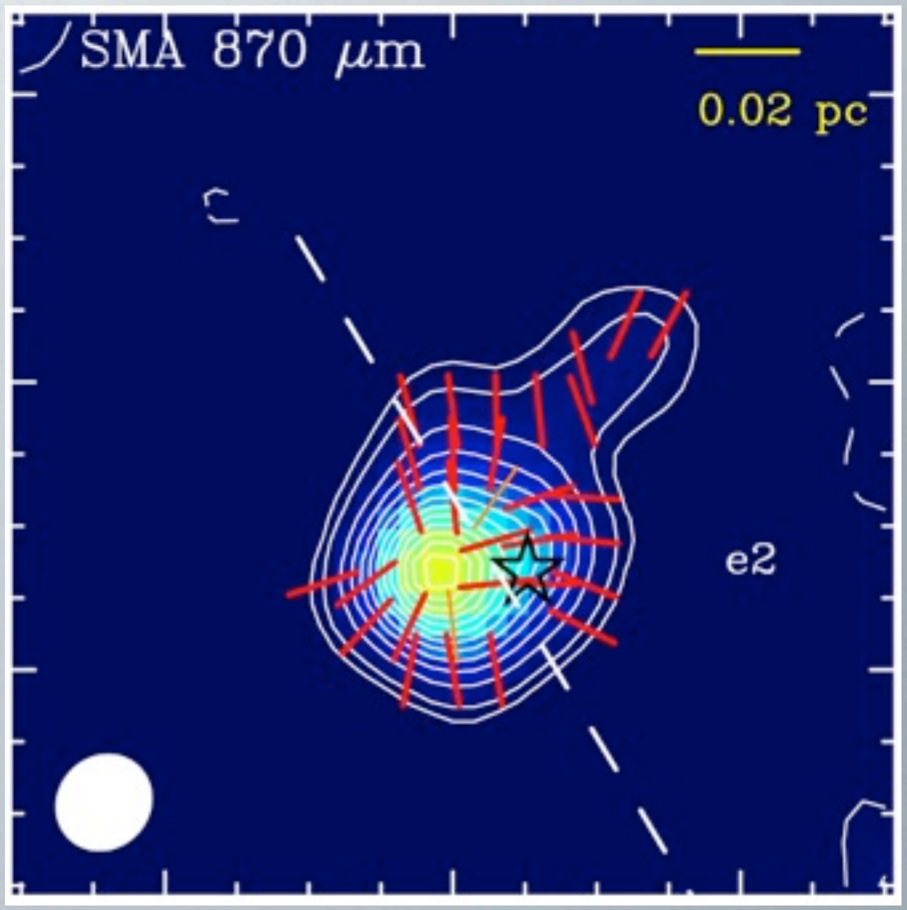
$T \sim 10$ (K)



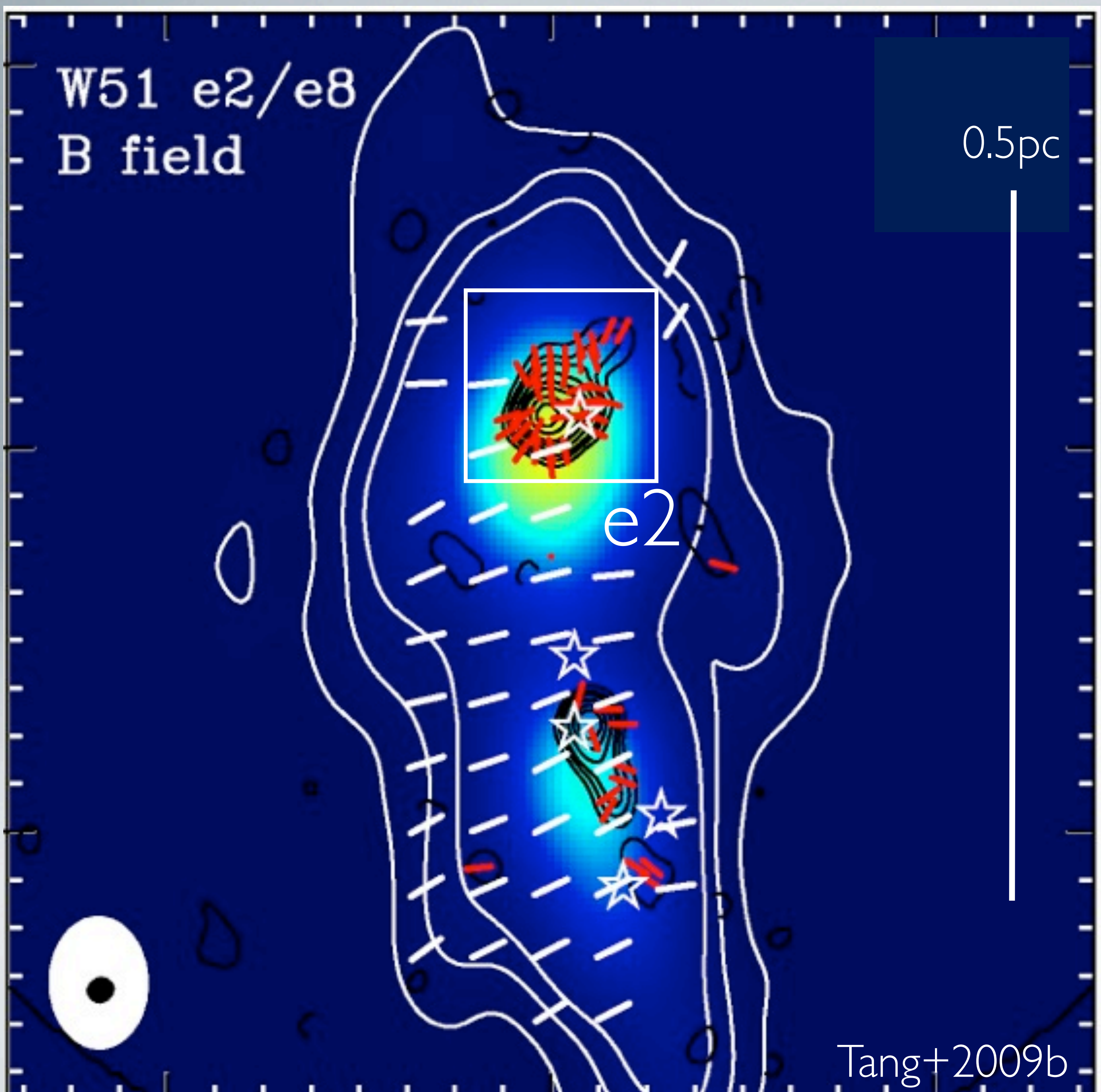
- individual dust particle: dipole
- in submm: linear polarization from thermal dust emission
- coherent alignment mechanism: B field is one possibility
- mechanism provides only projected field orientation/morphology
- need something more to derive field strength

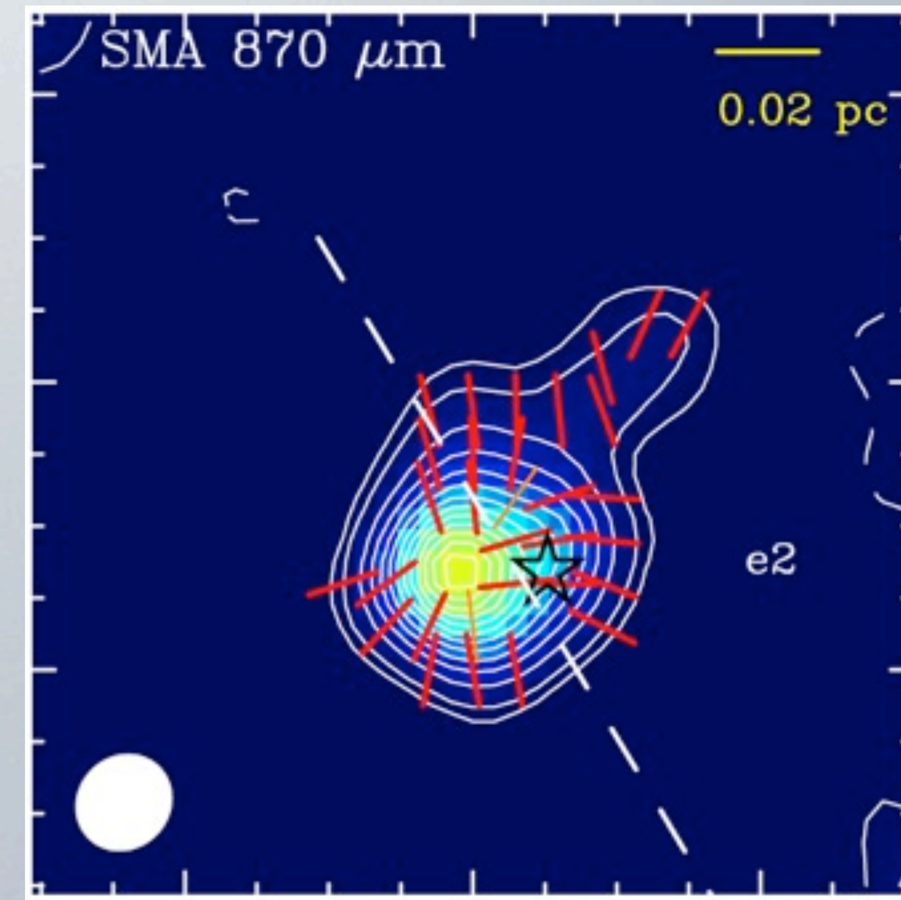
Correlation of intensity gradient and B field

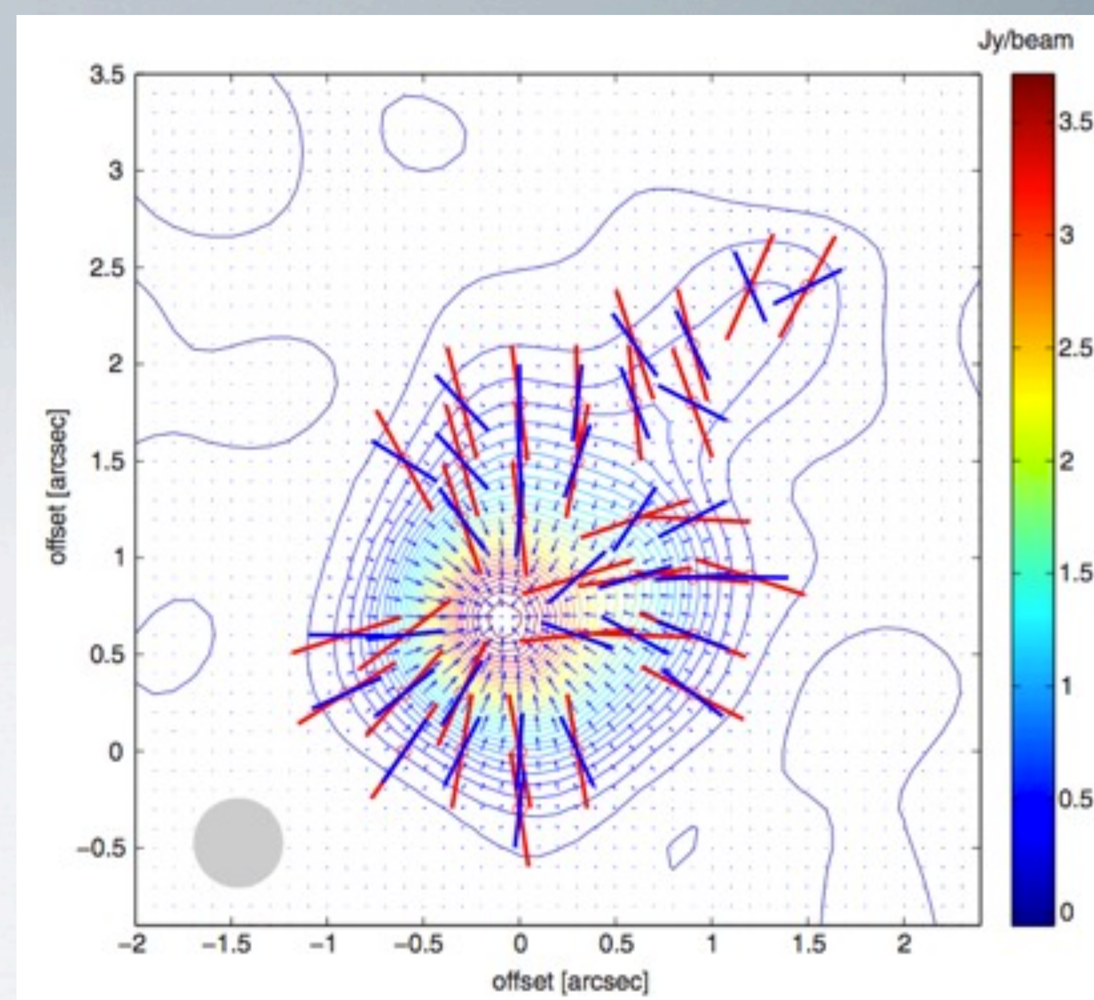




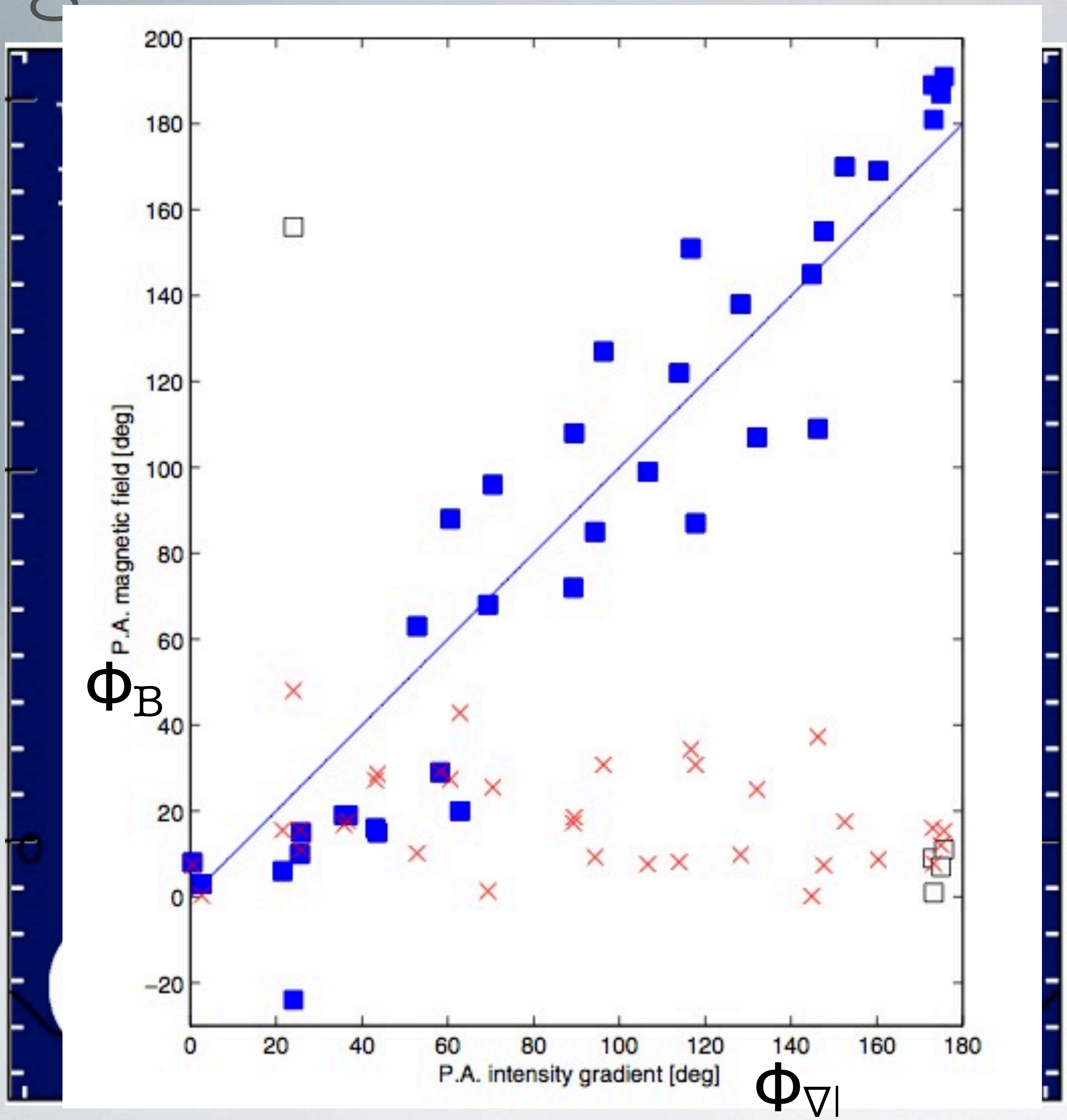
Correlation of intensity gradient and B field

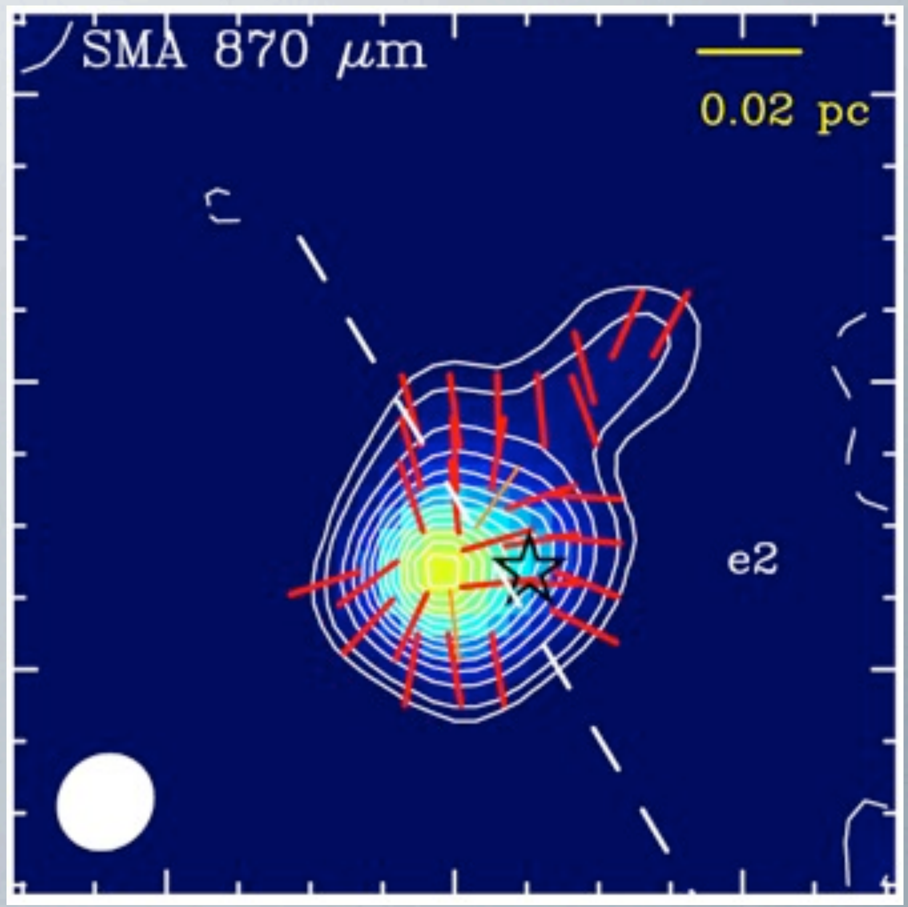


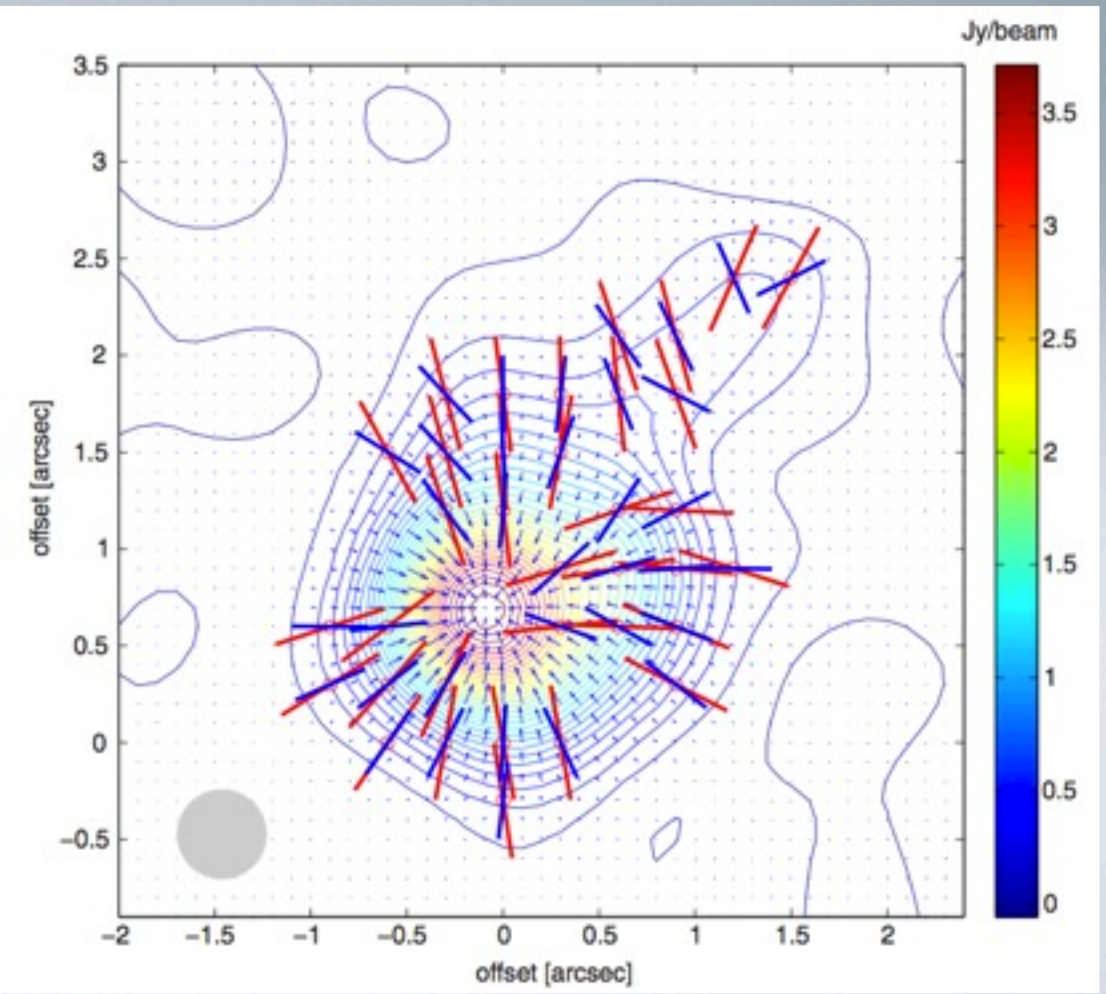




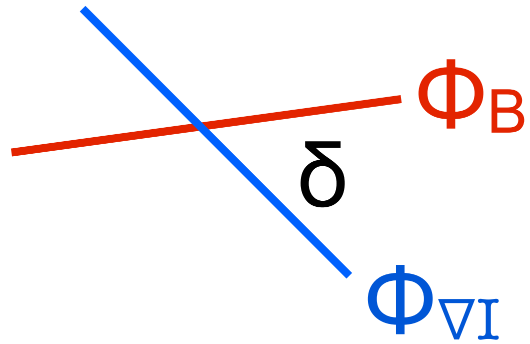
Correlation of intensity gradient and B field







What does this „correlation“ mean?



- is everything simply radially aligned by gravity?

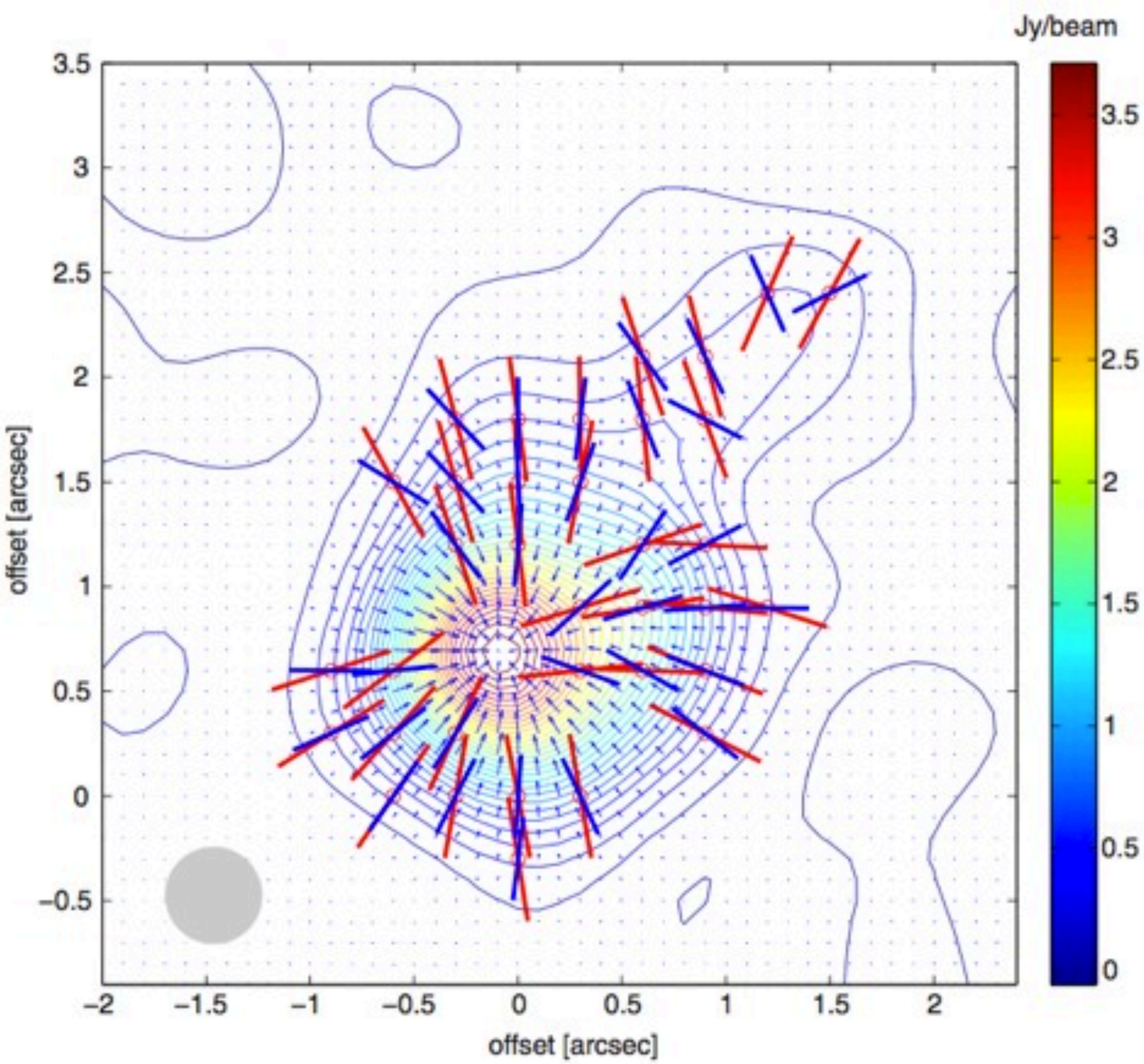
  No! – distribution of deviations is non-Gaussian but bimodal

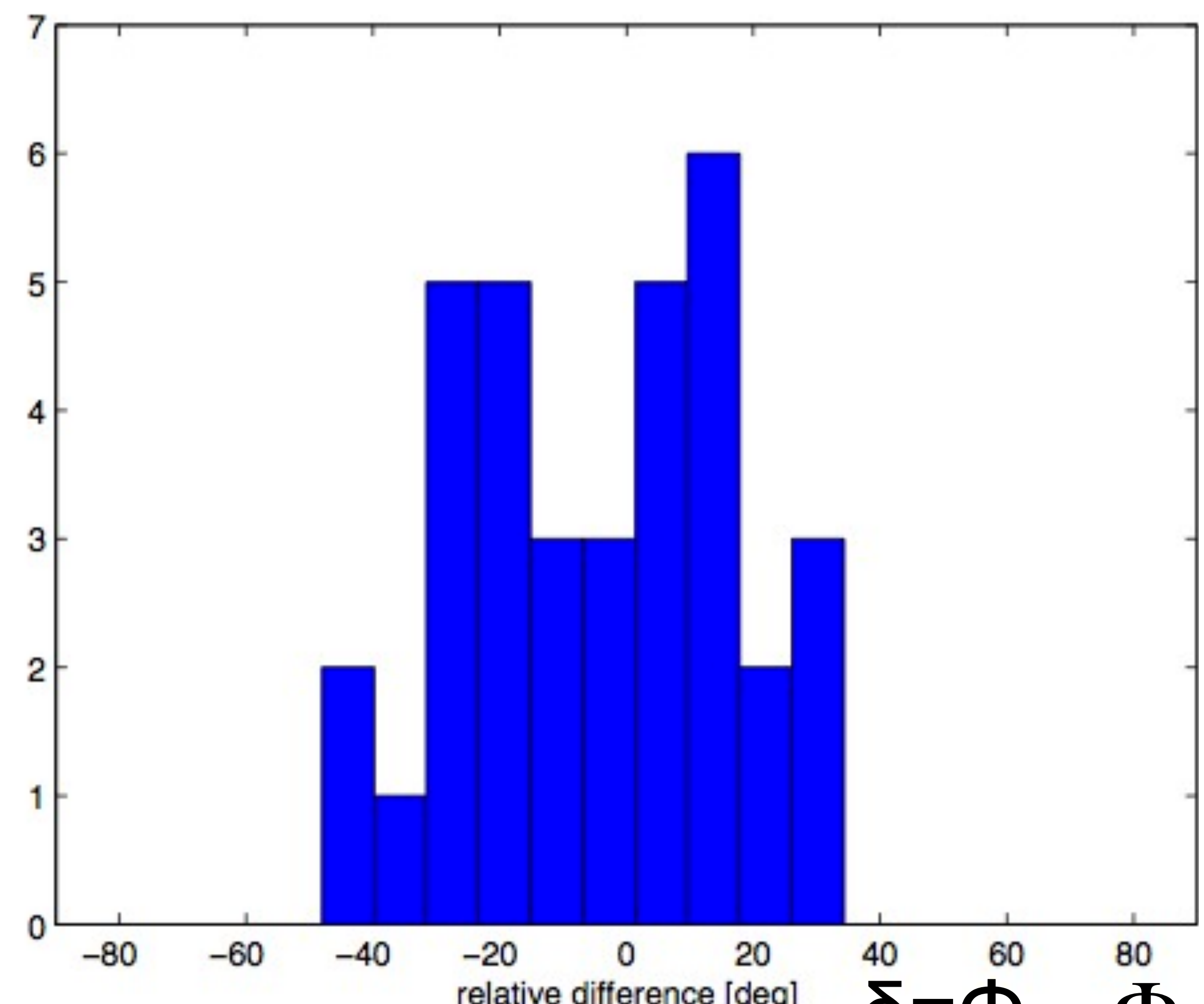
  – mean deviation larger than measurement uncertainties

- some deeper physical insight? check some MHD....

  → **polarization-intensity gradient method** to **derive local field strength**

(Koch, Tang & Ho 2012a,b)

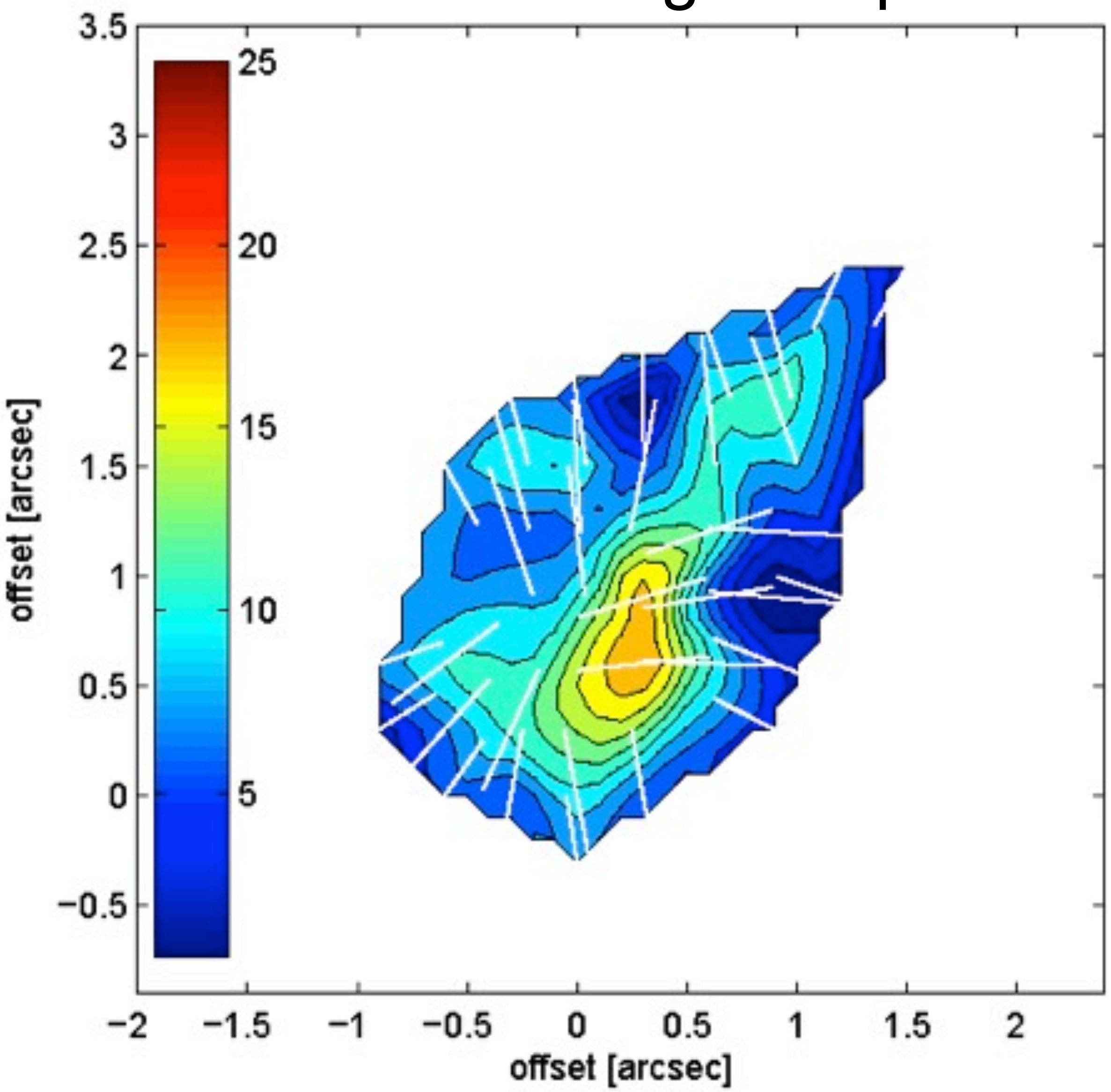




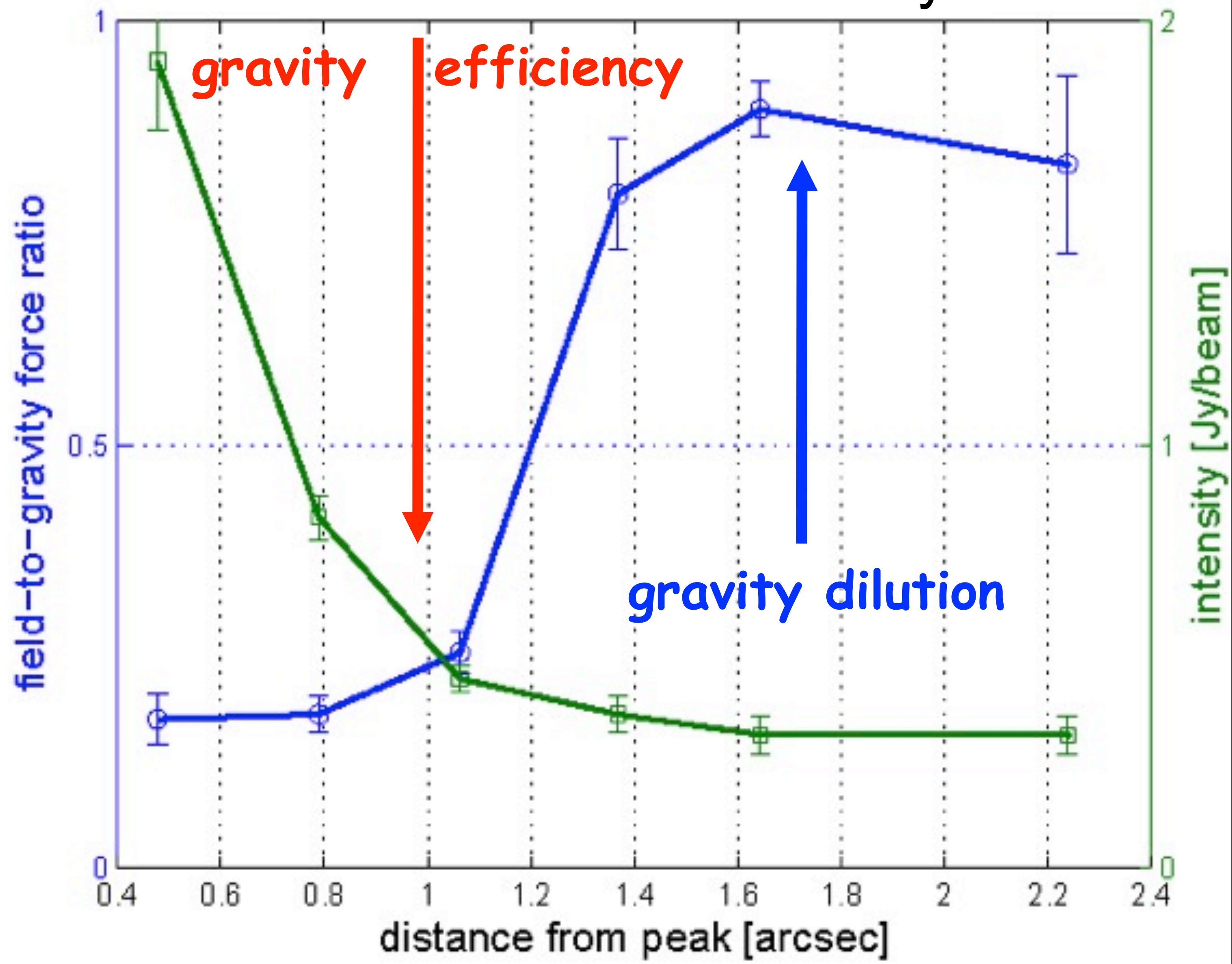
$\delta = \Phi_{\nabla I} - \Phi_B$

application of polarization-intensity gradient method

local field strength map



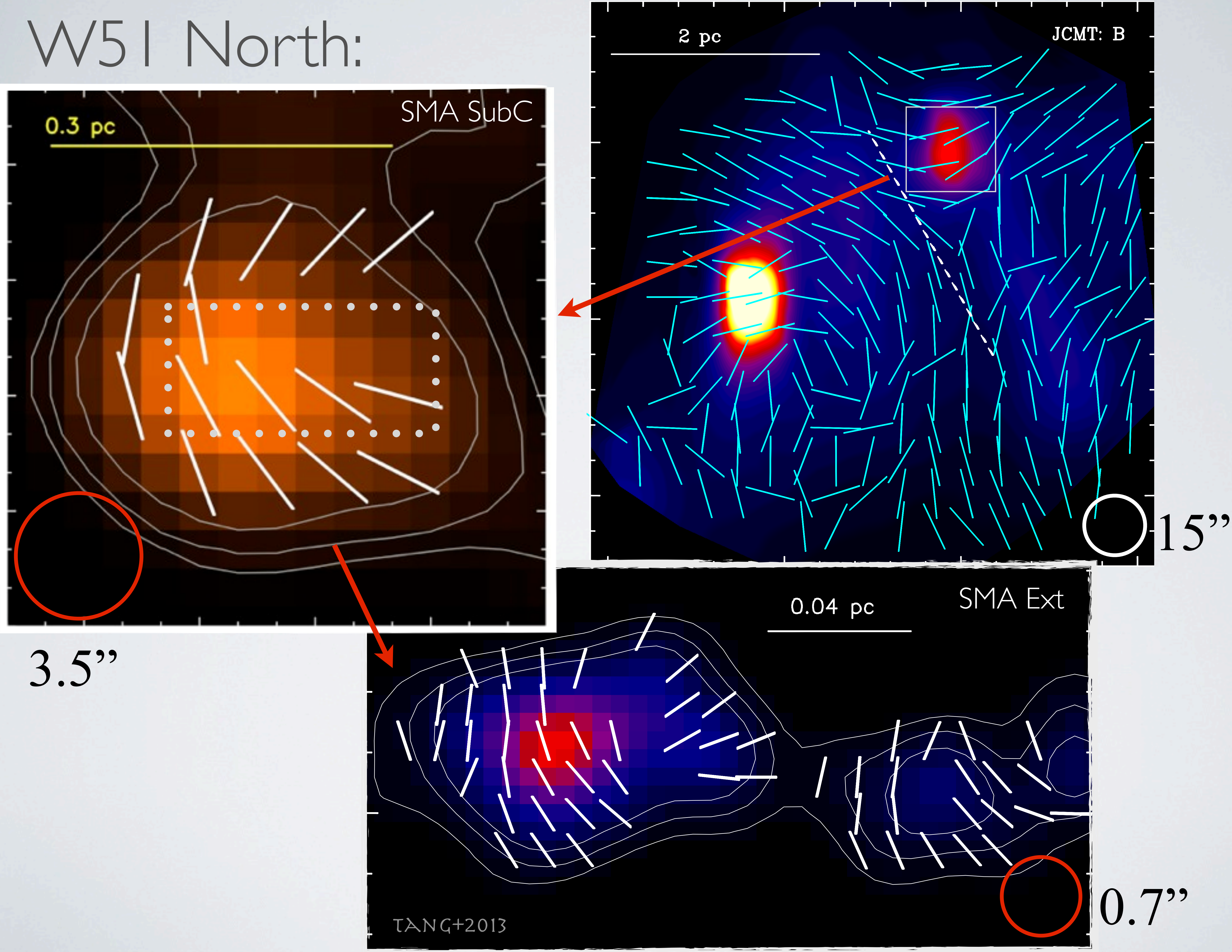
Star formation efficiency

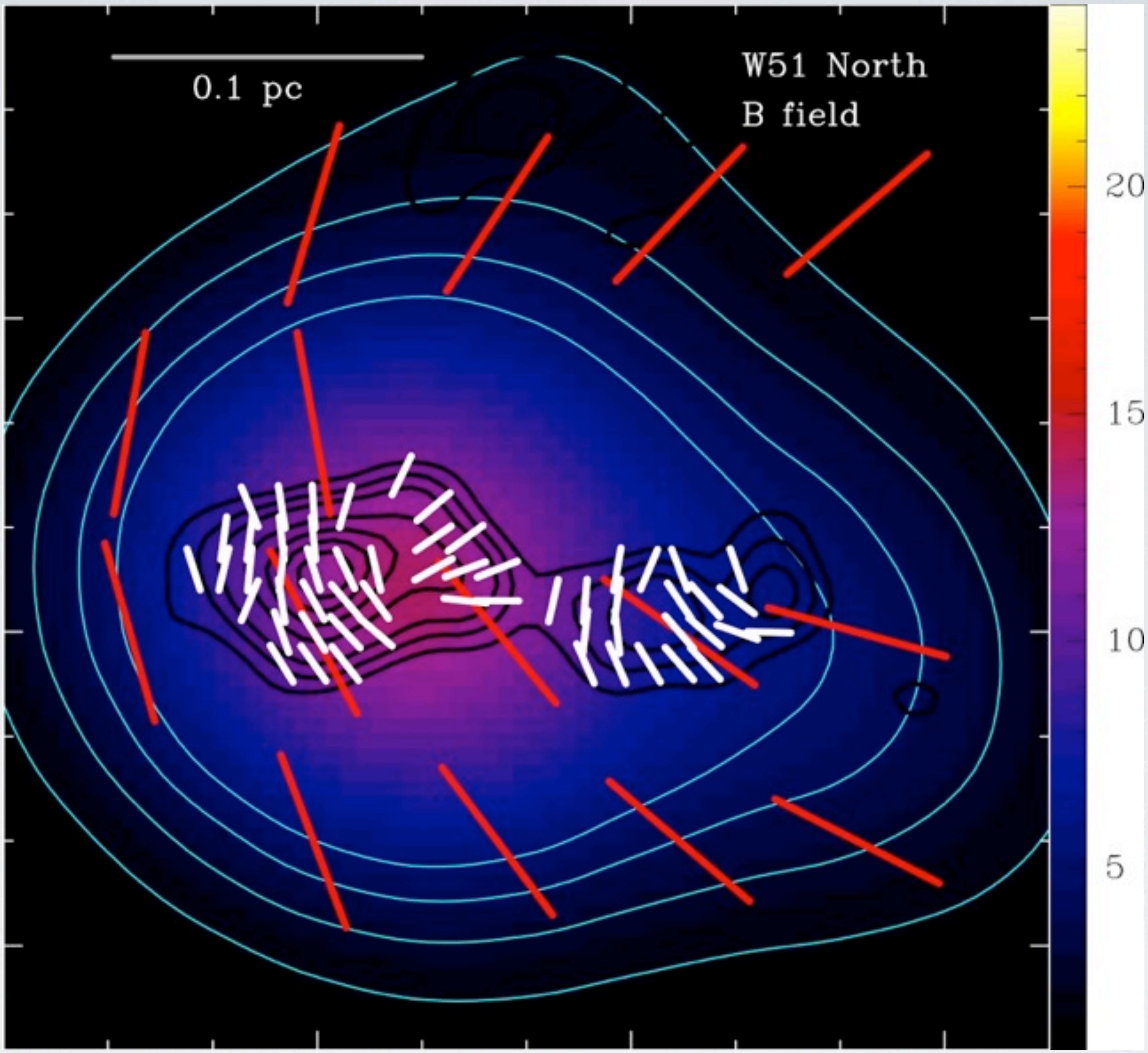


- other methods only give local or averaged B strength values (Zeeman, Chandrasekhar-Fermi method)

- estimate gravity dilution
- star formation efficiency reduced to ~10% of free-fall efficiency

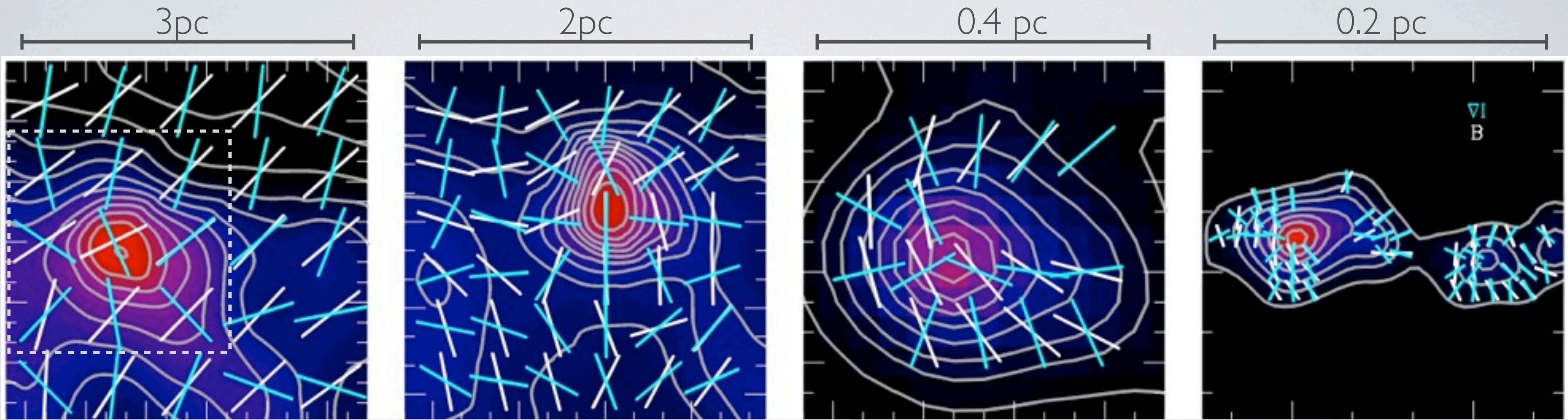
W51 North:





W51 N (SMA SubC+Ext)

Correlation of gradient I and B: tighter in the core regions than outside of core regions



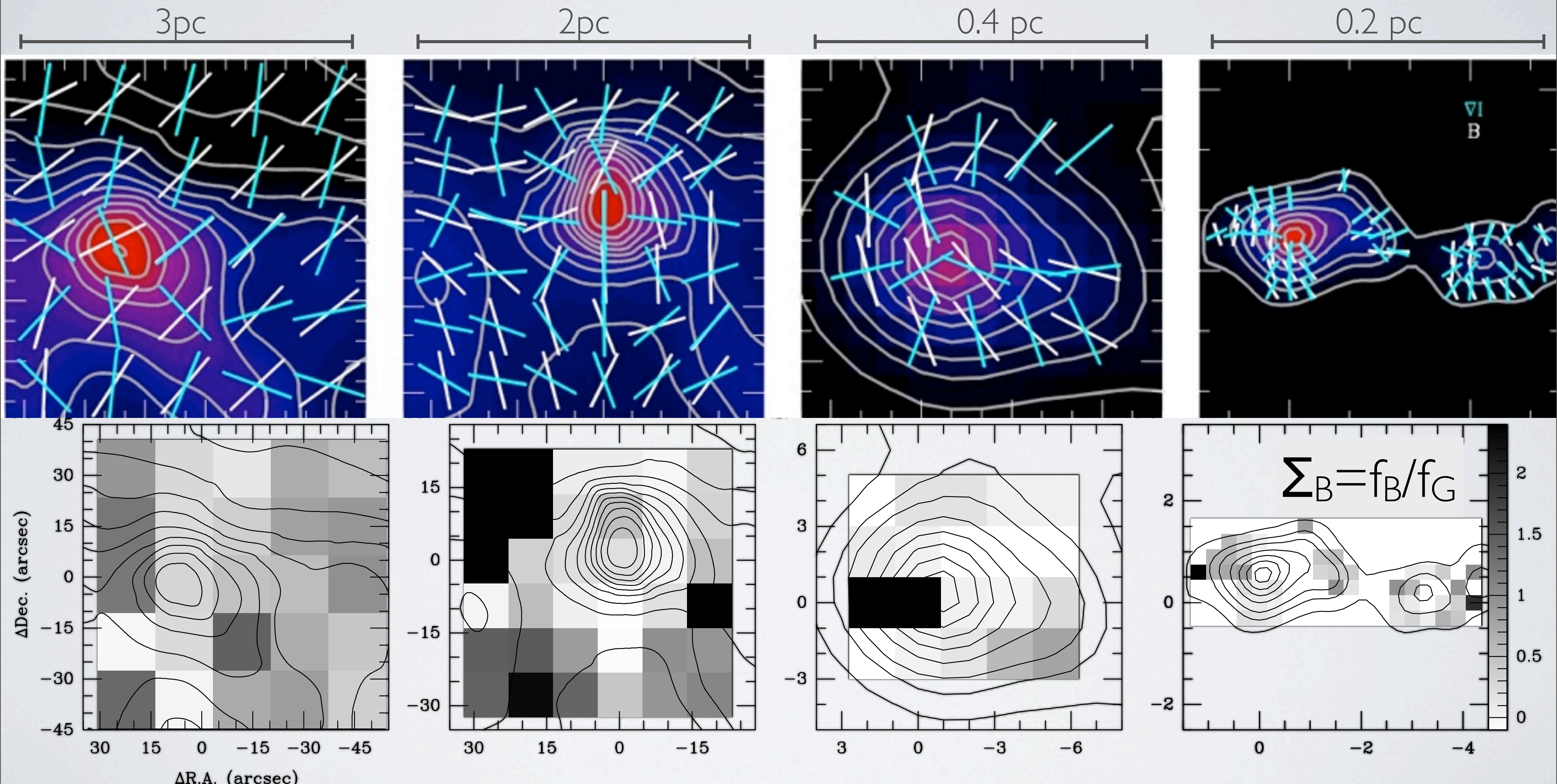
Angular resolution	20''		15''		3.5''	0.7''
	CSO, 350 μm		JCMT, 850 μm		SMA, 850 μm	SMA, 850 μm
Correlation coefficient of ϕ_B $\phi_{\nabla I}$	0.81		0.70		0.78	0.88
	0.59	0.88	0.66	0.73		
mean of $\lvert\phi_B-\phi_{\nabla I}\rvert$	40		44		37	35
	51	34	48	38		
	envelope	core	envelope	core	core	core

TANG+2013, APJ

Tight correlation of intensity gradient and B field at core region: purely observational quantities

Intuitive picture: in denser regions the gravity will dominate the system and the B fields will be dragged by the motion of material

Correlation of intensity gradient and B: quantitative analysis on the force ratio

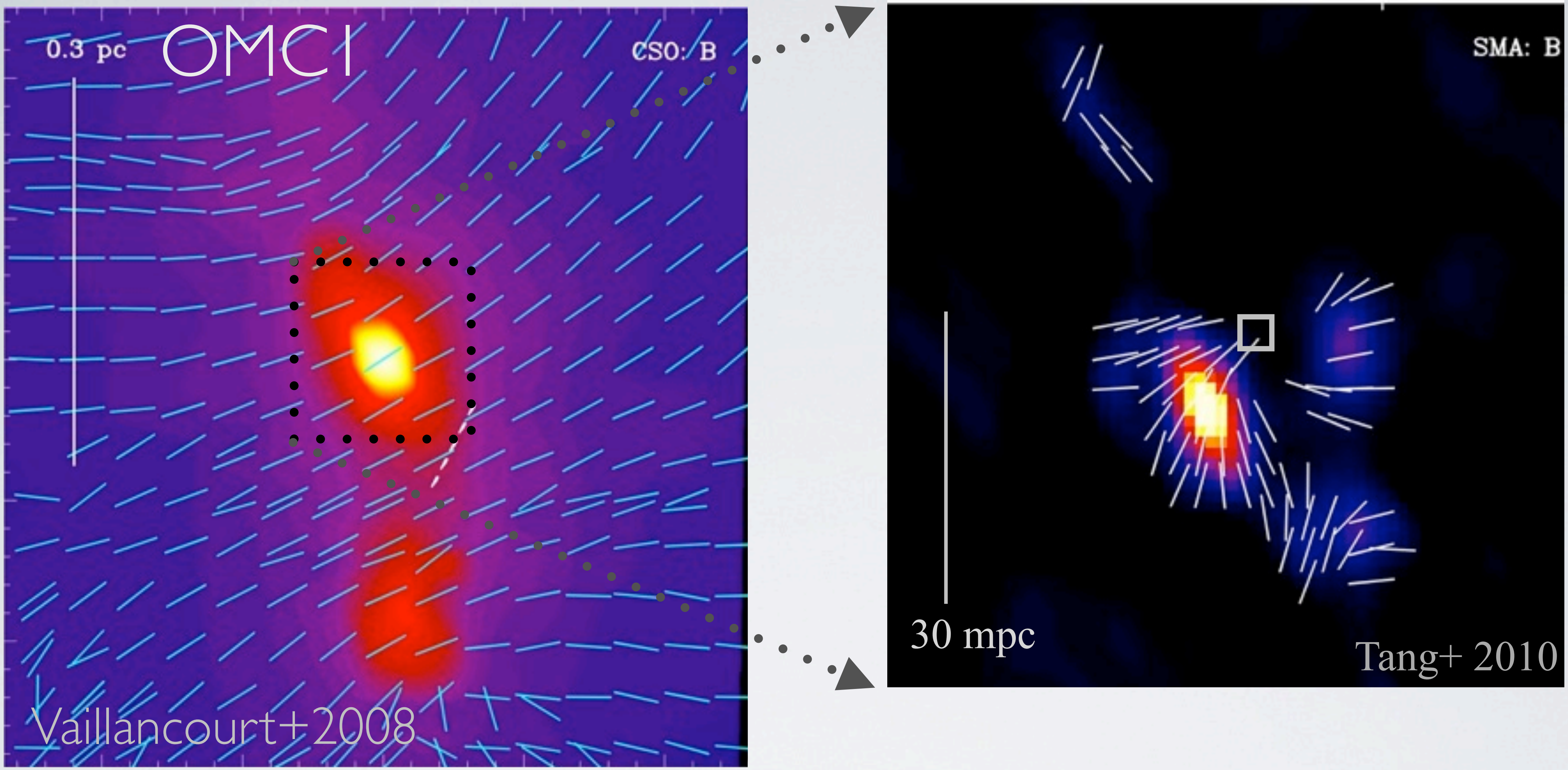


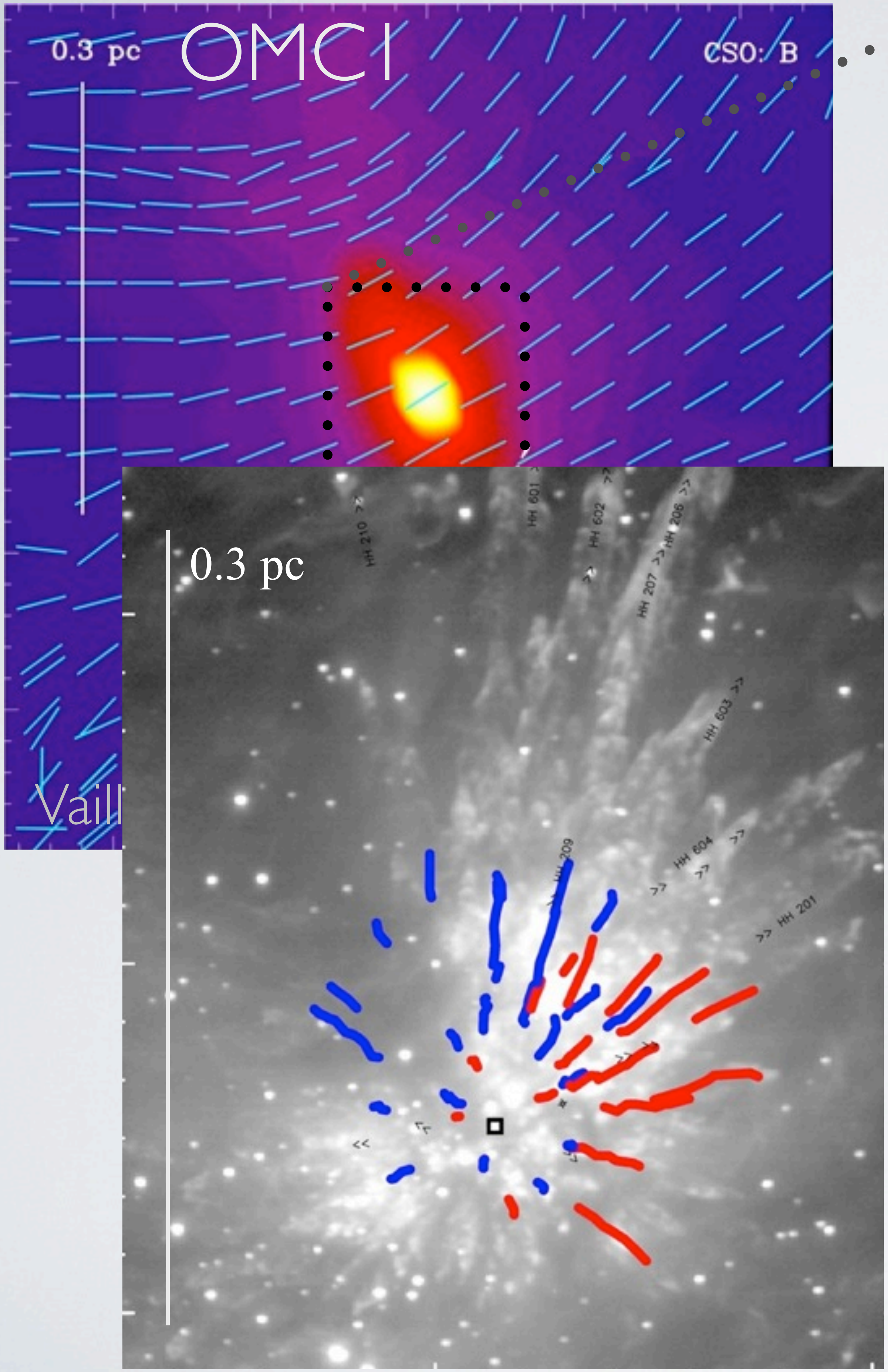
TANG+2013, APJ

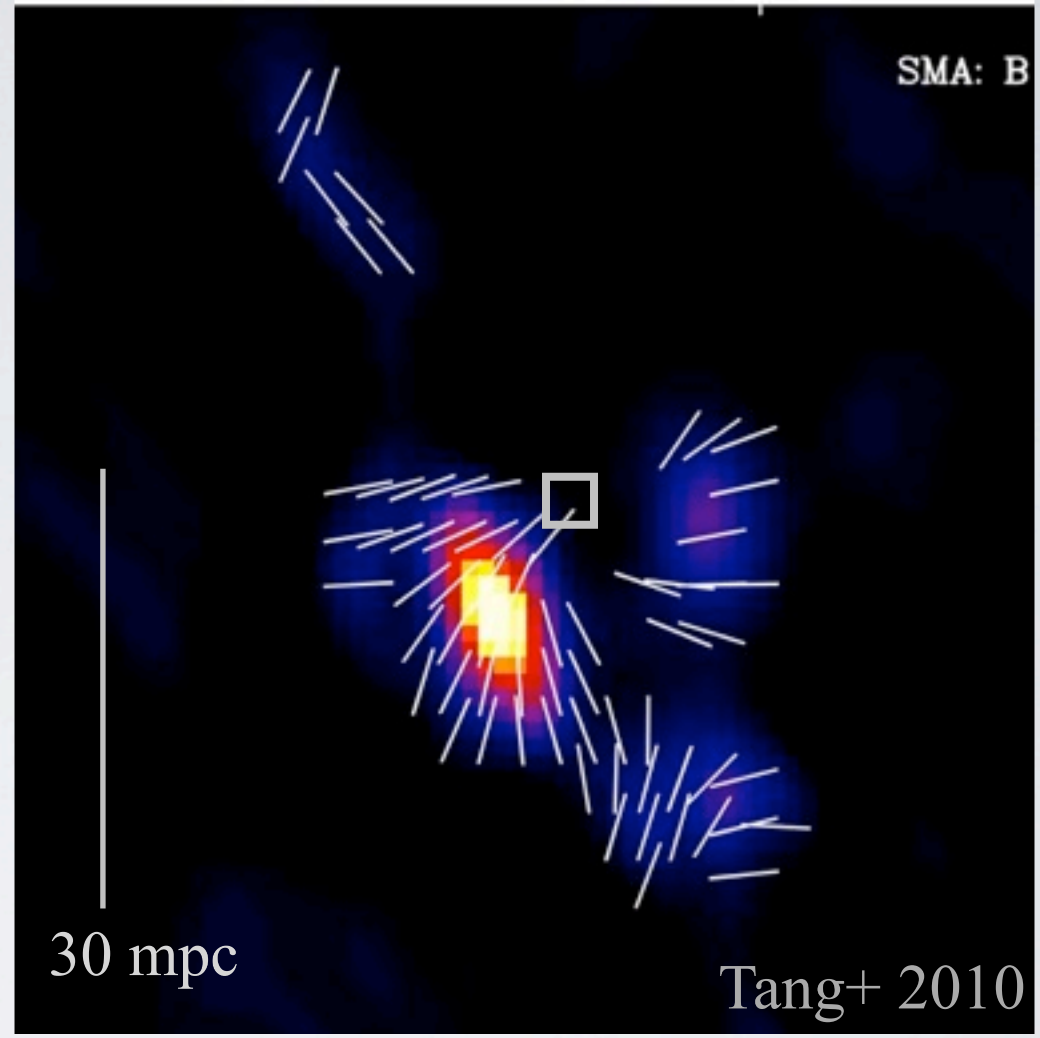
Summary

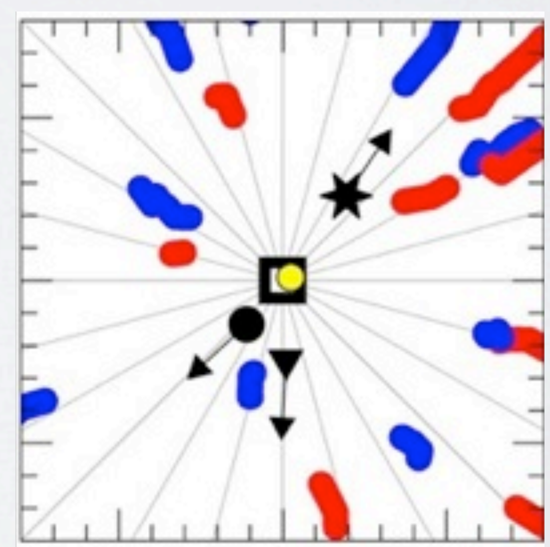
- B field morphologies show more variations at higher angular resolution
  - De-polarization seen with lower angular resolution is partly due to more complex underlying B field morphologies
- Analysis of the PA of the intensity gradient and PA of the B
  - B field shows tighter correlation with intensity gradients toward denser regions at both pc and mpc scales
  - Based on our analysis of the force ratio of gravity to B field tension ($\Sigma_B = f_B/f_G$), we also found that Σ_B is smaller in the core regions.
  - Development of the B field strength map based on the **polarization-intensity gradient method.**

2. B field shaped by stellar feedbacks


0.3 pc
OMC1
CSO: B
Vaillancourt+2008
SMA: B
30 mpc
Tang+ 2010





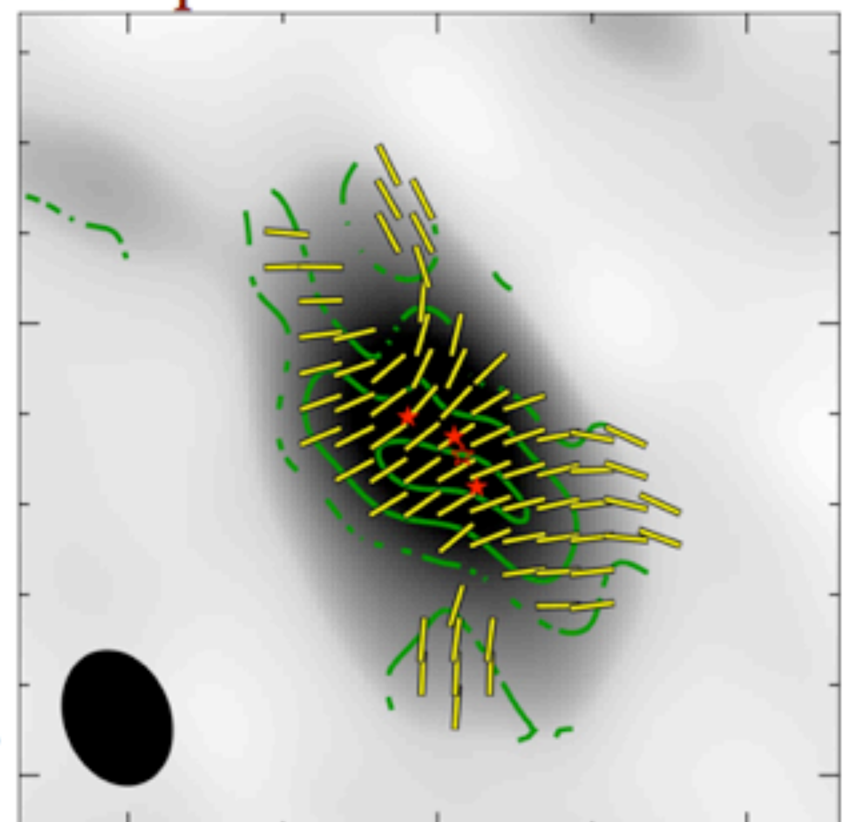


Color lines: CO outflow Zapata+2009
Background: H_2 jet

SMA Legacy Project: Filaments, Star Formation & Magnetic Fields

Q. Zhang (CfA), J.M. Girart (ICE, IEEC-CSIC), K. Qiu (MPIfR), P. Koch, Y.-W. Tang, R. Rao (ASIAA), S.P. Lai (NHTU), P. Frau (OAN, CAB-CSIC), H. Li (MPIA)
& H.-Y. Liu, H.-H. Chen,, P. Ho, H.-R. Chen, E. Keto, Z.-Yun Li, S. Bontemps, T. Csengeri, M. Padovani

Goal: Get a large sample of massive molecular clumps to investigate the role of magnetic fields in formation and fragmentation of massive filaments. Compare observations with radiative transfer modeling and simulations



So far:

- ✓ More than 30 tracks (beam ~ 1arcsec)
- ✓ High fraction of dust polarization detections
- ✓ Some sources show a complex B configuration BUT …
- ✓ Some show hour-glass morphology with the B direction almost parallel to the outflow
- ✓ Some sources maintain the main direction observed at larger scales

THANKS