Fragmentation and Relative Importance between Gravity, Magnetic Field, and Turbulence in IRDC G34

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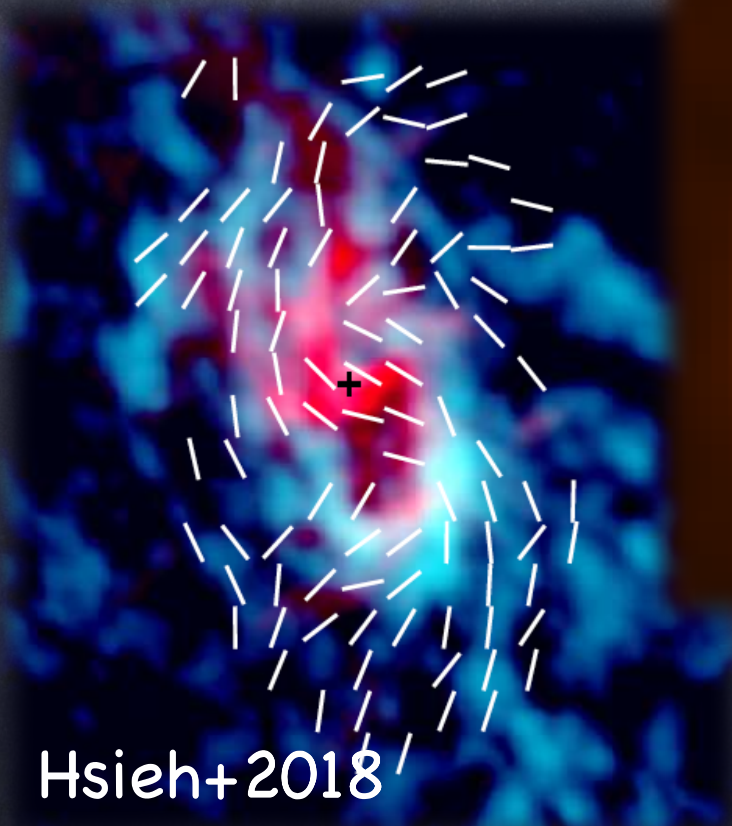
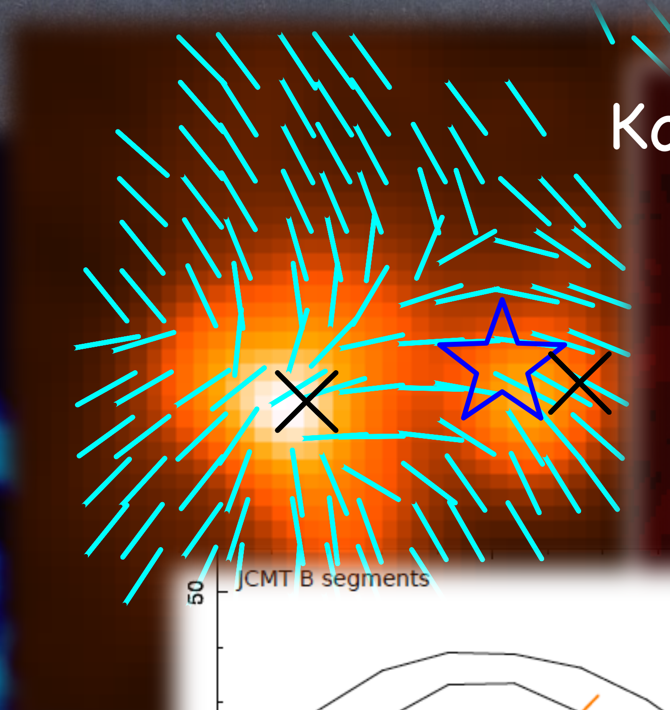
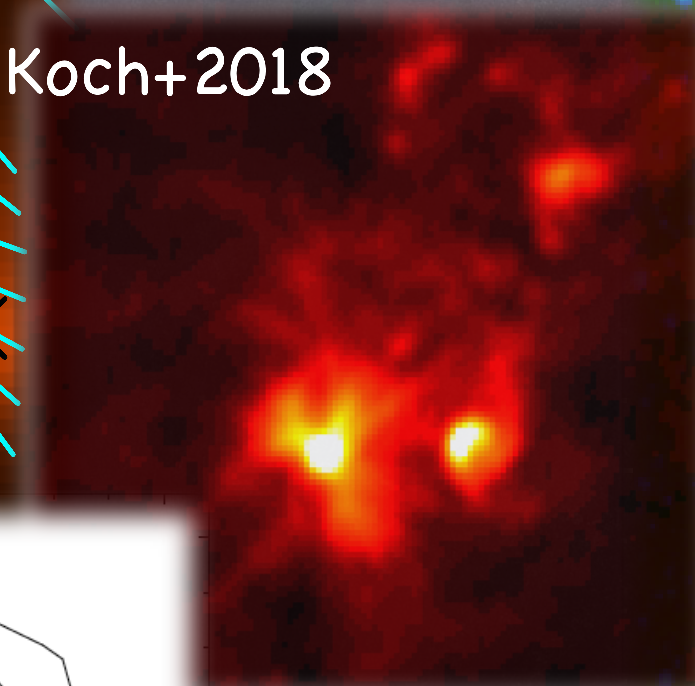
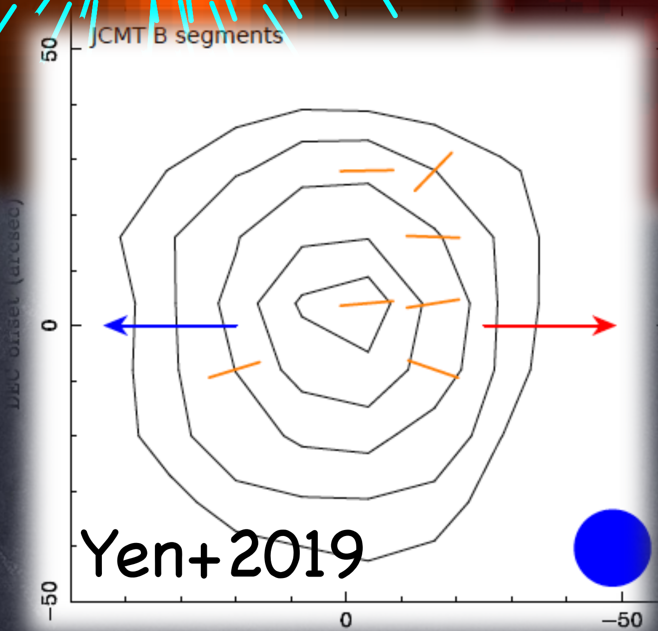
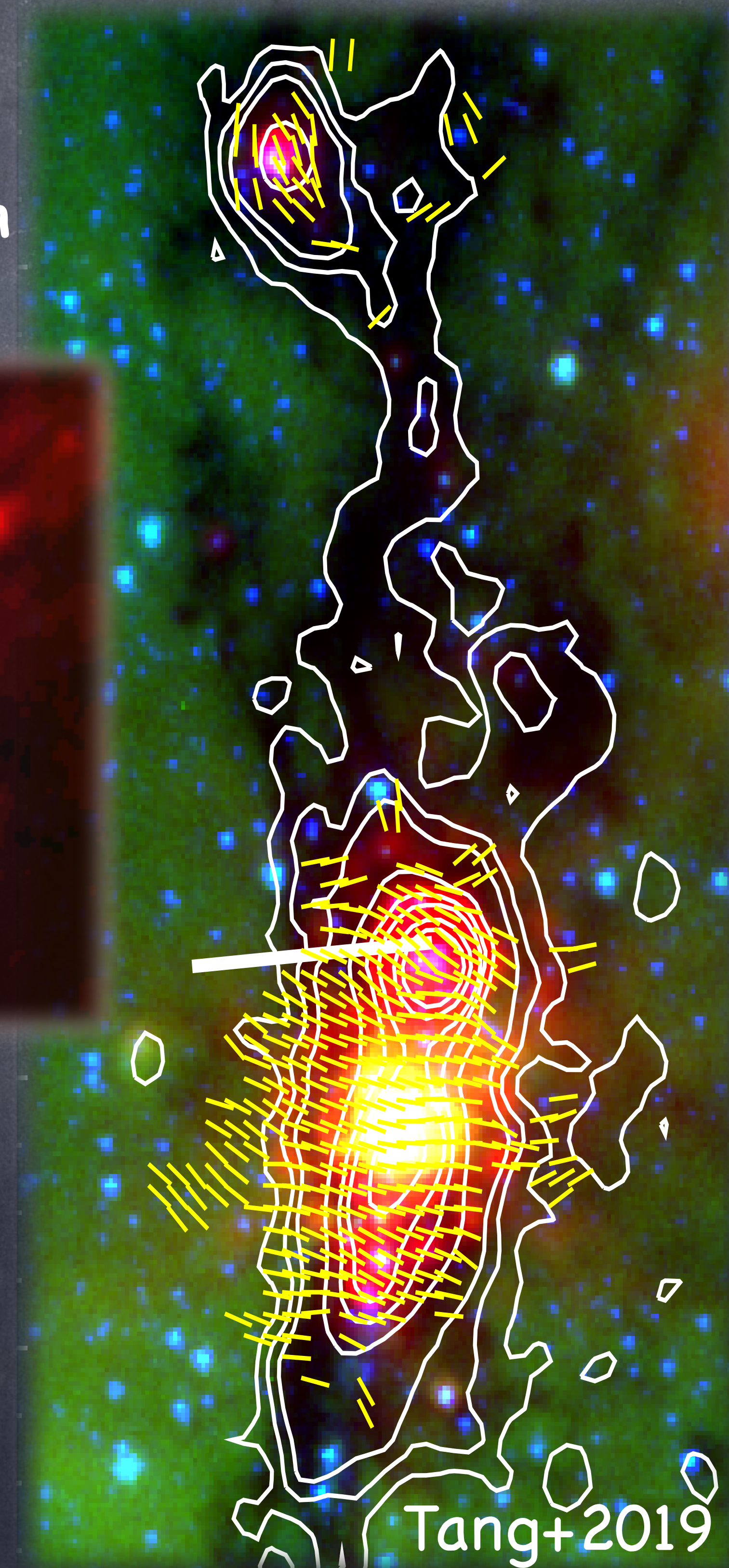




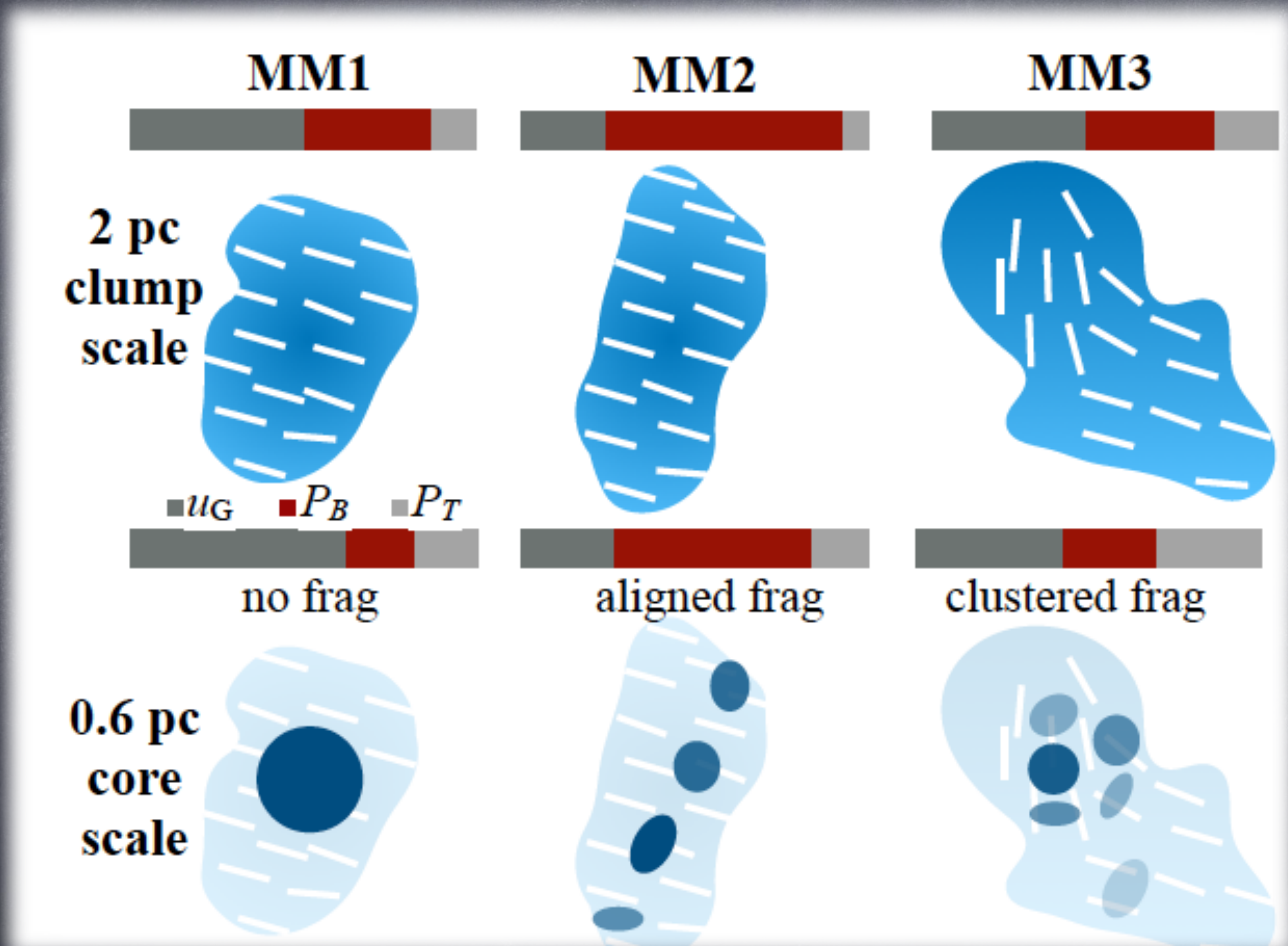


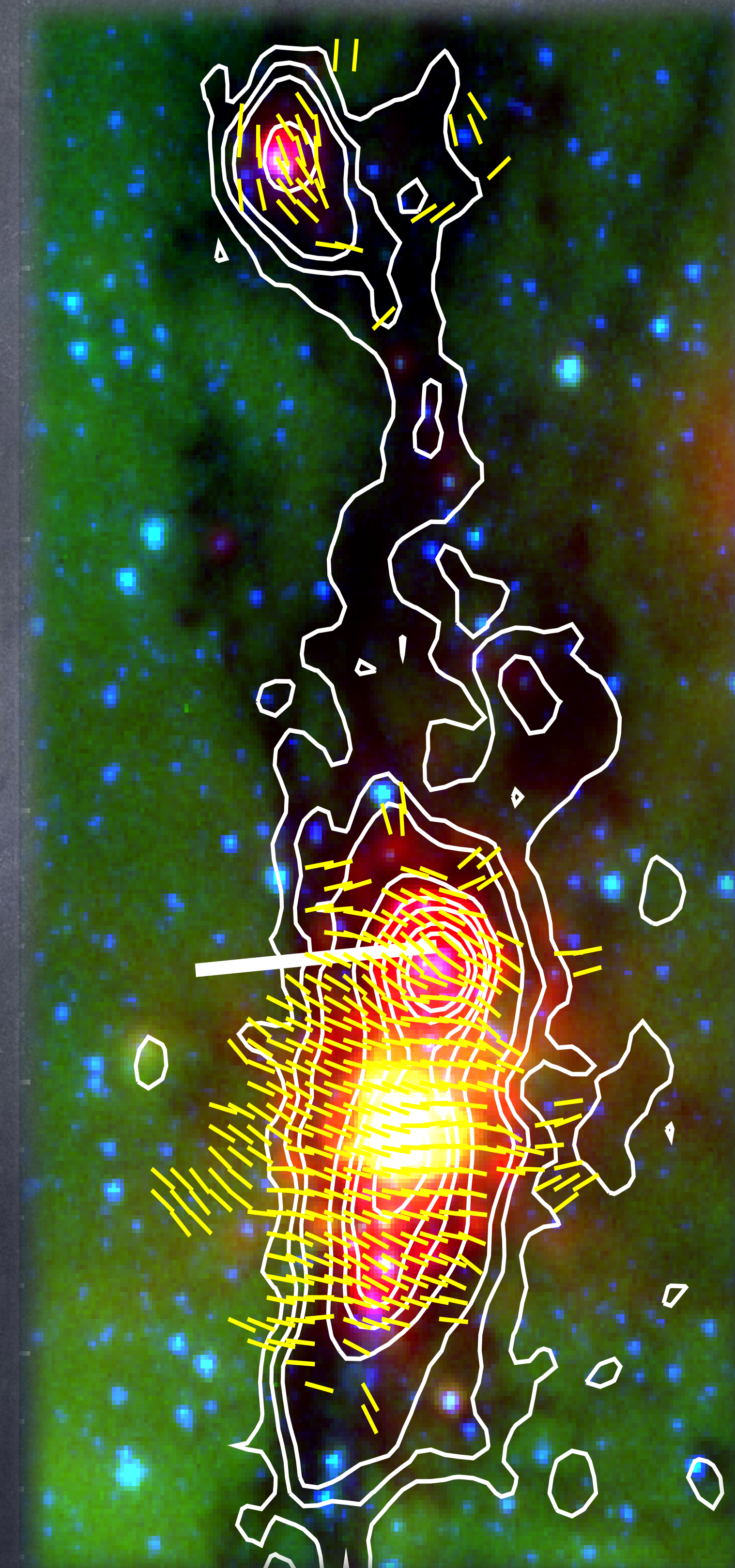




JCMT Users Meeting; November 7, 2019

Fragmentation and Relative Importance between Gravity, Magnetic Field, and Turbulence in IRDC G34





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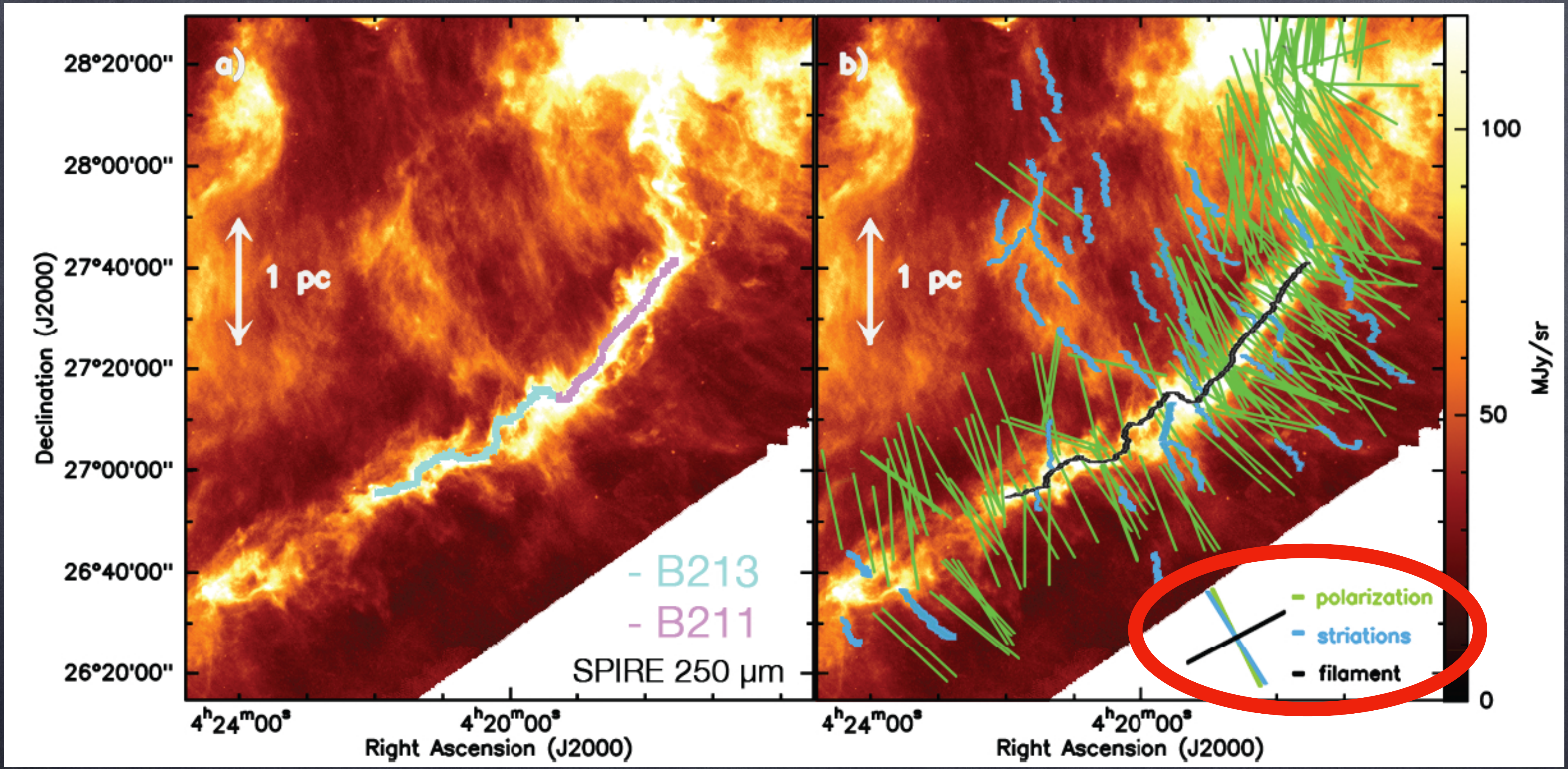
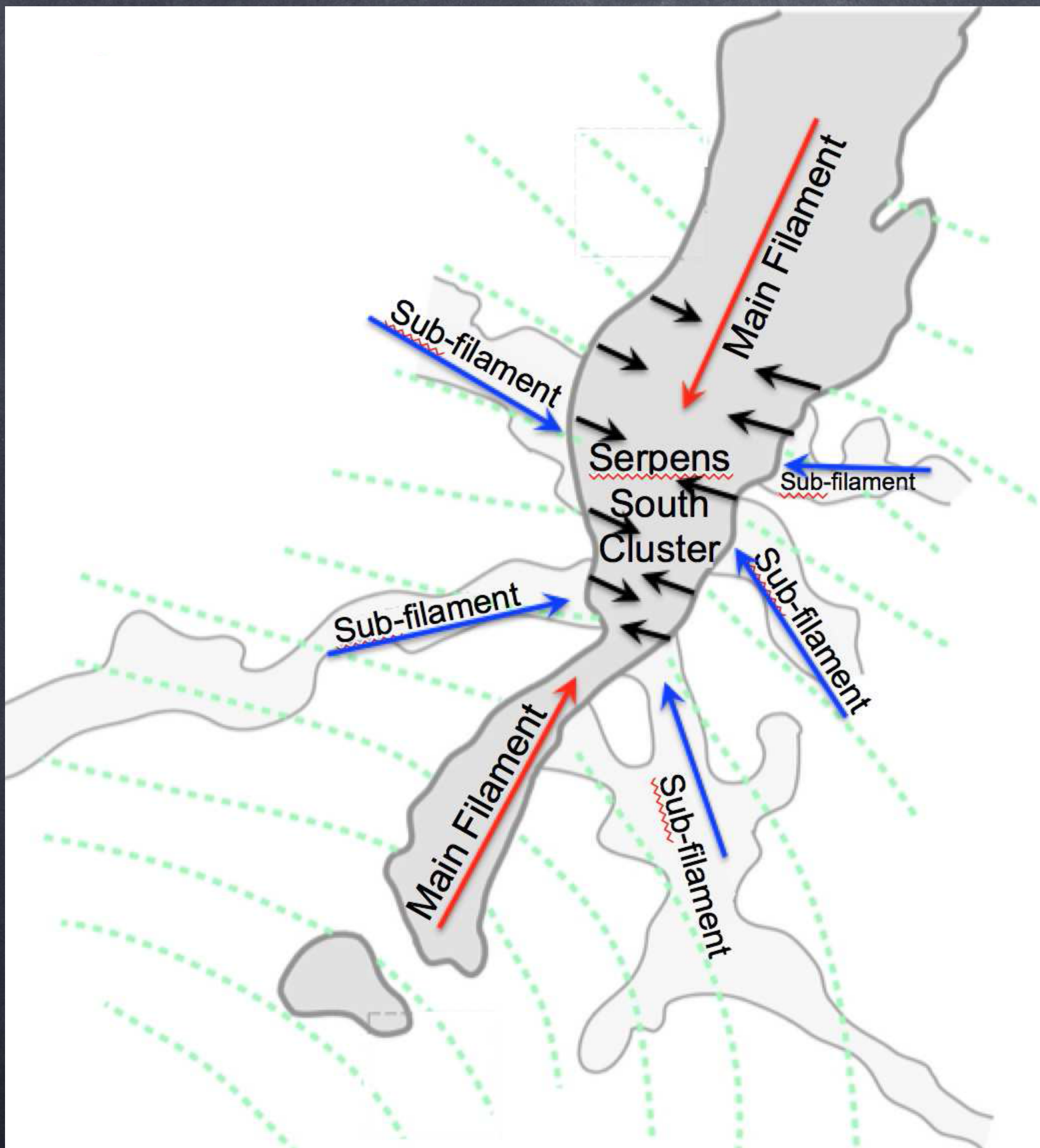
Filaments and Magnetic Fields



- *Taurus molecular cloud; Herschel / SPIRE 250 μm (~ 18" resolution; Palmeirim+2013)*
- *polarization: optical (Heyer+2008; Heiles+2000) and infrared (Chapman+2013)*
- *B-field ∥ striations ⊥ filament*

Filaments and Magnetic Fields: Proposed Scenario



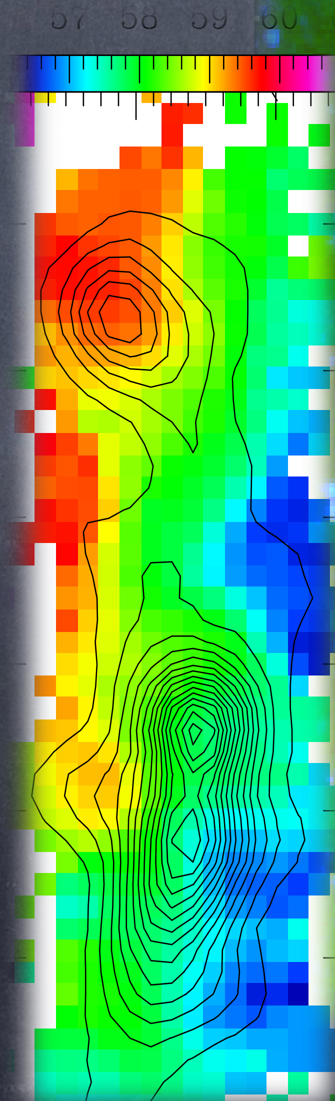
- accretion of background material through striations or sub-filaments along B-field lines
- radial contraction within main filament
- longitudinal infall along main filament
- important ancillary line data: coherent velocity structures

- formation steps: (1) large-scale MHD flows (turbulent?) lead to filamentary network with universal filament width ~ 0.1pc; (2) *densest filaments fragment into prestellar cores* by gravitational instability (critical line mass ~ 16 M_solar/pc, critical density ~ 2 x 10^4 cm^-3)

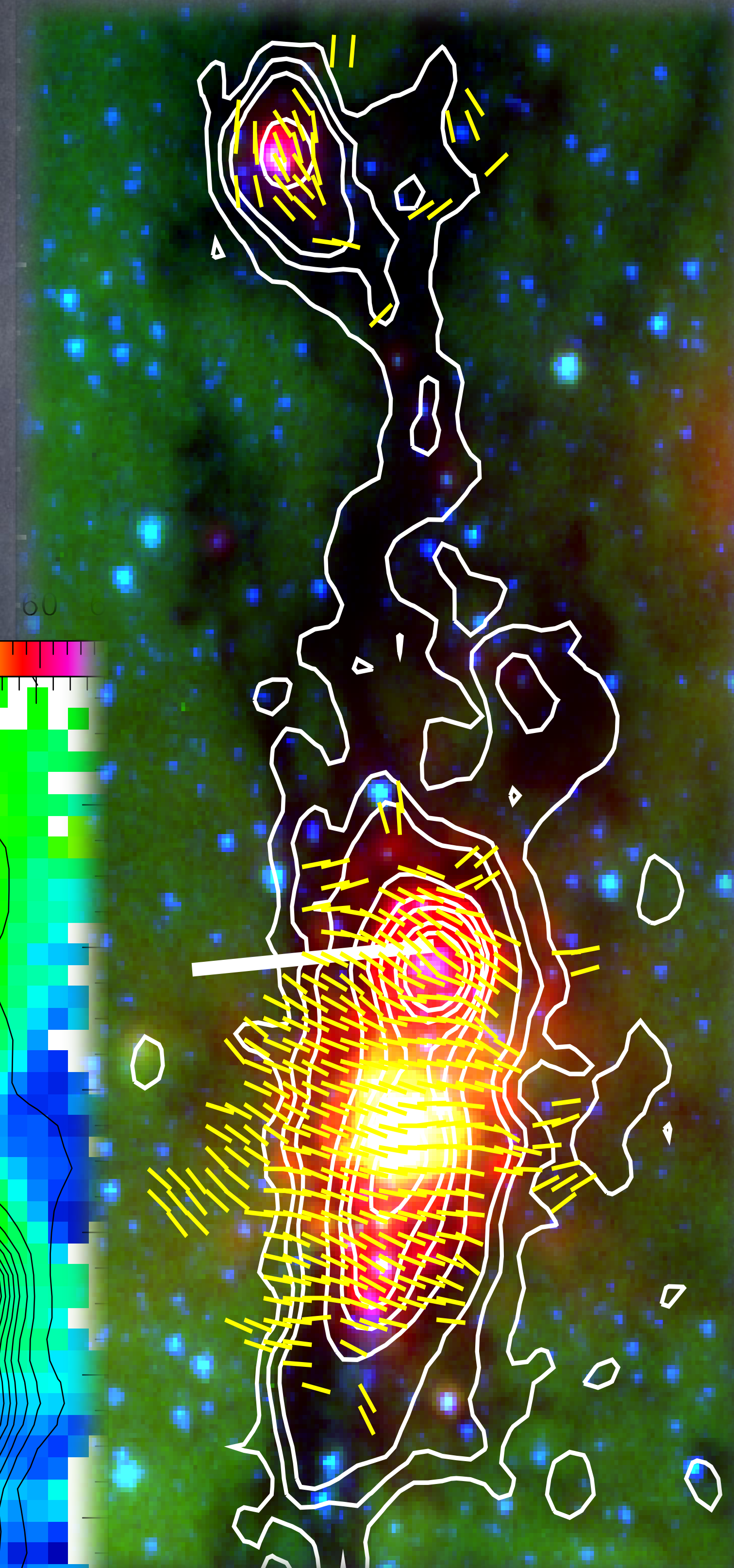
(e.g. André+2010; Menshchikov+2010; Molinari+2010; Sugitani+2011; Kirk+2013; Arzoumanian+2013; André+2014;)

IRDC G34.43

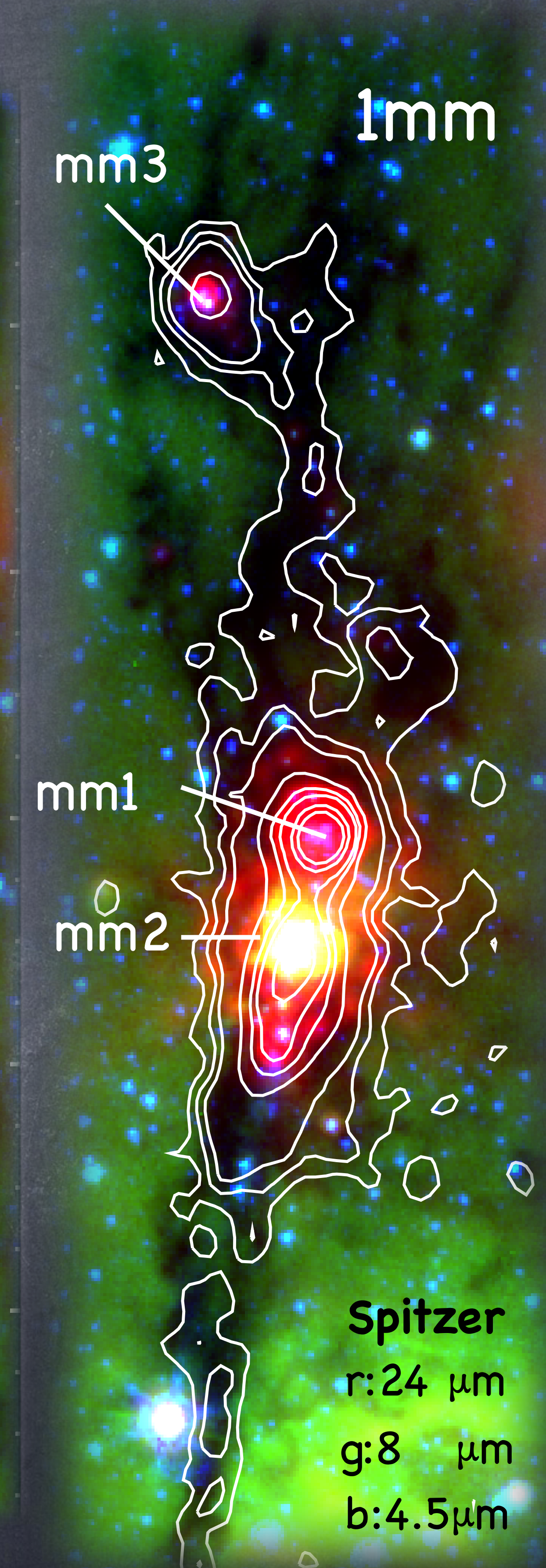
- distance: 3.7 kpc, elongated length ~ 8 pc
- mass: 1200 M_sol (mm1), 1300 M_sol (mm2)
  300 M_sol (mm3)
- overall, very small viral parameter
  ($\alpha \sim 0.2$), system gravitationally bound, but
  SF efficiency only ~ 7%.
  additional support from B-field ?
- observed with the CSO/SHARP
  (350μm, resolution 10")
- polarization percentage 0.4 - 10%
- B-field clearly organized
  perpendicular to longer axis around
  mm1/mm2; more aligned with longer
  axis on mm3, small dispersion
- add line kinematics:
  N_2H+ (1-0) from IRAM-30m (θ~28"),
  clear large-scale gradient



Peretto+2017



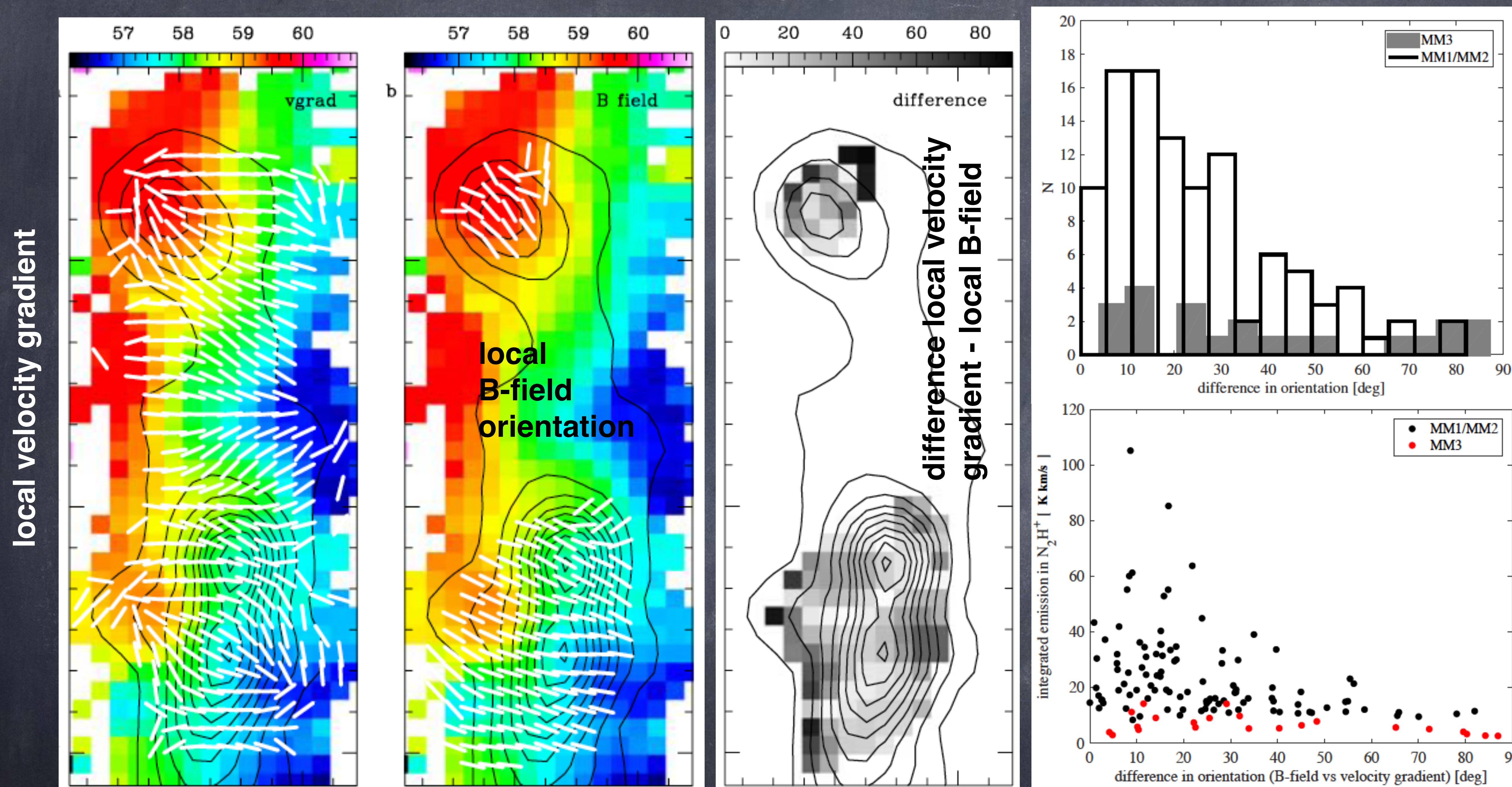
Tang, Koch+2019



Rathborne+2006

B-field, velocity gradient, turbulence & gravity

which component is dominant? negligible?   - benchmark analysis

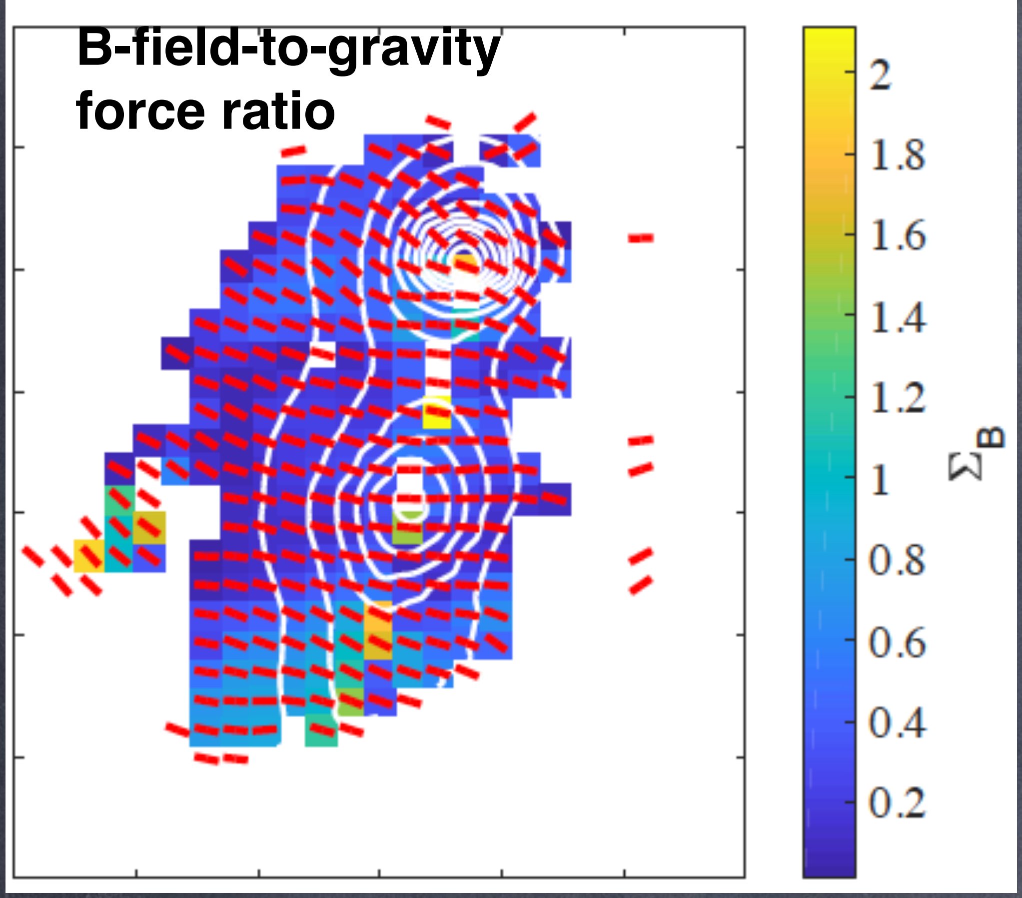


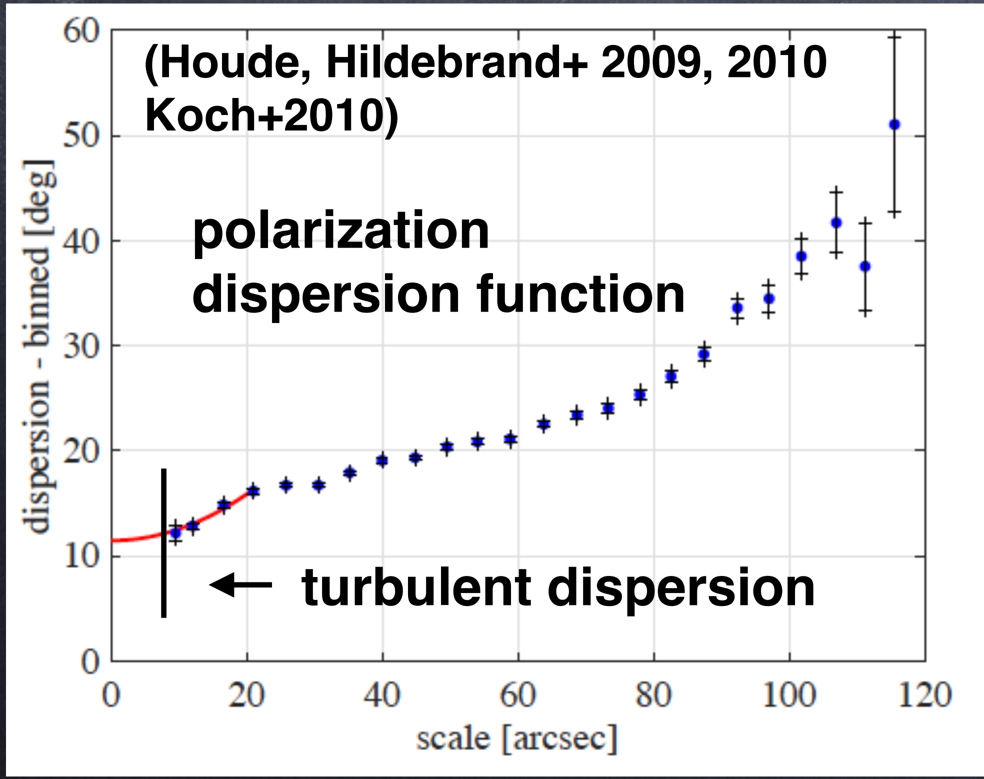
B vs v: small differences and spatially not random, but organized

(Tang, Koch+2019)

B-field, velocity gradient, turbulence & gravity

which component is dominant? negligible? - benchmark analysis





Polarization - Intensity gradient technique

$$\Sigma_B \equiv \frac{\sin\psi}{\sin\left(\frac{\pi}{2} - |\delta|\right)} = \frac{F_B}{|F_G + F_P|}$$

$$B = \sqrt{\frac{\sin\psi}{\sin\left(\frac{\pi}{2} - |\delta|\right)}(\nabla P + \rho\nabla\phi)4\pi\ R}$$

Koch+2012ab, 2013

- *competition gravity vs B-field*
- *map of local field strength, local force ratio*

B vs G: spatially not random, but organized

and also DCF, virial parameters, mass-to-flux ratio, energy comparison

Analysis — Gravity vs Turbulence vs B-field

2 pc clump area

Object	$\frac{\sqrt{\langle B_t^2\rangle}}{B_0}$	$\left(\frac{\sqrt{\langle B_t^2\rangle}}{B_0}\right)_N$	N	$\triangle\phi_B$ (°)	$B_\perp$ (mG)	$\langle\Sigma_B\rangle$	λ_{obs}	α_{vir}	$\alpha_{B,vir}$	P_T	P_B (10^{-9} dyn/cm^2)	u_G	Relative importance
MM1	0.21±0.02	0.59±0.18	9±6	17.3±0.8	$0.19^{+0.05}_{-0.04}$	0.42±0.02	$1.2^{+0.3}_{-0.2}$	$0.4^{+0.1}_{-0.2}$	$0.9^{+0.5}_{-0.3}$	$2.0^{+0.8}_{-0.7}$	$5.7^{+3.5}_{-2.1}$	7.7	G∼B>T
MM2	0.11±0.01	0.33±0.12	10±8	9.0±0.5	$0.34^{+0.10}_{-0.09}$	0.89±0.02	$0.6^{+0.3}_{-0.1}$	$0.4^{+0.2}_{-0.2}$	$2.4^{+1.6}_{-1.1}$	$2.0^{+1.0}_{-0.9}$	$18.4^{+12.4}_{-8.5}$	6.5	B>G>T
MM3	0.35±0.03	0.71±0.38	5±5	20±5	$0.06^{+0.04}_{-0.03}$	0.63±0.04	$1.3^{+1.0}_{-0.9}$	$0.6^{+0.2}_{-0.3}$	$1.2^{+1.4}_{-0.7}$	$0.3^{+0.2}_{-0.2}$	$0.6^{+1.0}_{-0.5}$	0.7	G∼B∼T

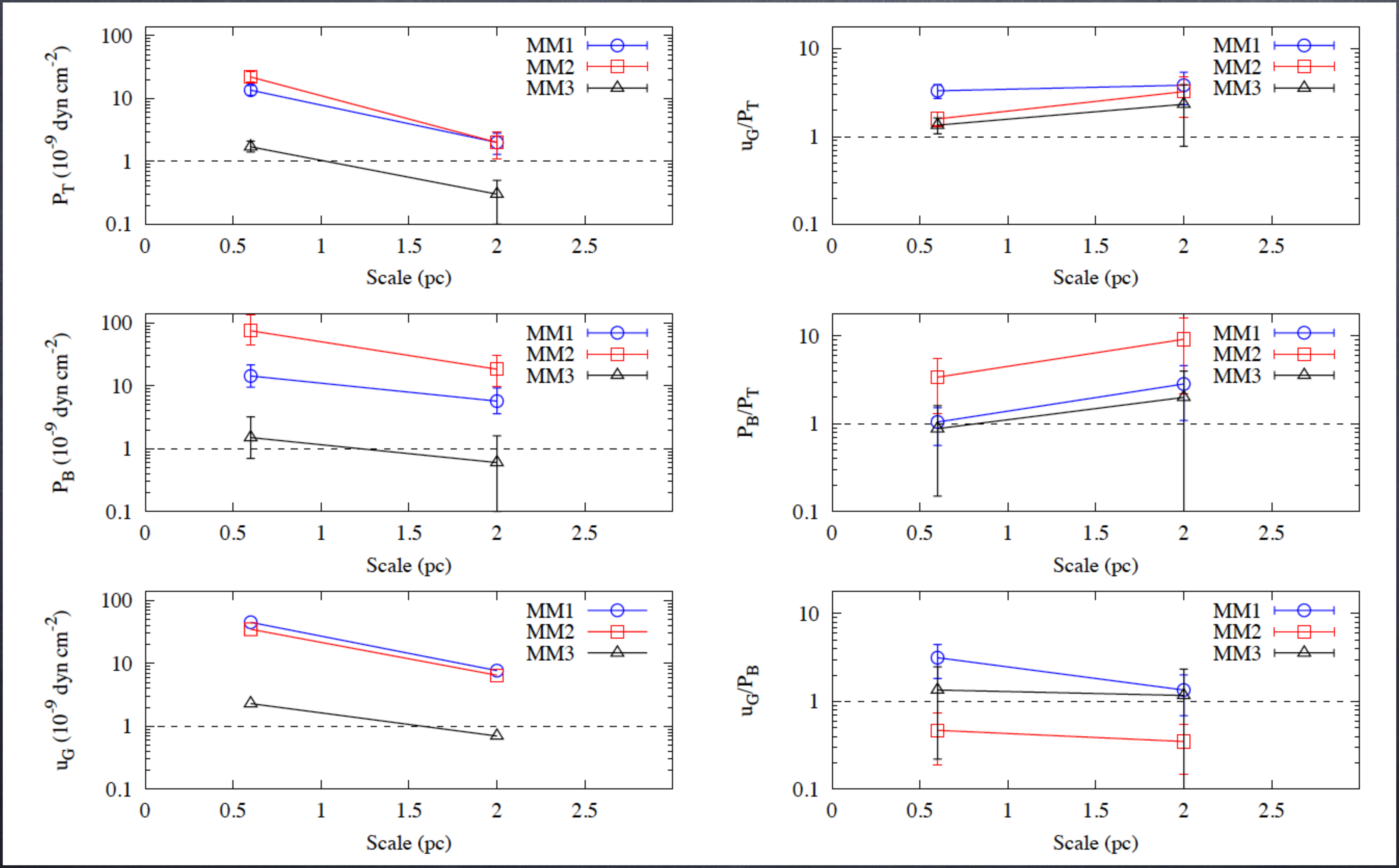
0.6 pc core area

Object	$\frac{\sqrt{\langle B_t^2\rangle}}{B_0}$	$\left(\frac{\sqrt{\langle B_t^2\rangle}}{B_0}\right)_N$	N	$\triangle\phi_B$ (°)	$B_\perp$ (mG)	$\langle\Sigma_B\rangle$	λ_{obs}	α_{vir}	$\alpha_{B,vir}$	P_T	P_B (10^{-9} dyn/cm^2)	u_G	Relative importance
MM1	0.20±0.03	0.98±0.22	25±13	18±2	$0.49^{+0.11}_{-0.09}$	0.55±0.04	$1.1^{+0.3}_{-0.2}$	$0.5^{+0.1}_{-0.1}$	$1.1^{+0.4}_{-0.3}$	$13.6^{+2.6}_{-2.4}$	$14.3^{+7.2}_{-4.8}$	45.1	G>B∼T
MM2	0.15±0.03	0.54±0.17	14±10	10±2	$1.12^{+0.37}_{-0.26}$	0.68±0.05	$0.5^{+0.1}_{-0.2}$	$0.9^{+0.1}_{-0.1}$	$4.9^{+3.3}_{-1.7}$	$22.0^{+4.3}_{-3.9}$	$74.9^{+57.6}_{-30.8}$	35.0	B≥G>T
MM3	0.32±0.03	1.06±0.46	13±11	20±5	$0.16^{+0.07}_{-0.05}$	0.66±0.05	$0.9^{+0.4}_{-0.3}$	$0.9^{+0.3}_{-0.2}$	$2.1^{+1.4}_{-0.8}$	$1.7^{+0.4}_{-0.3}$	$1.5^{+1.7}_{-0.8}$	2.3	G>T∼B

isolated single numbers have limited information
need for joint analyses

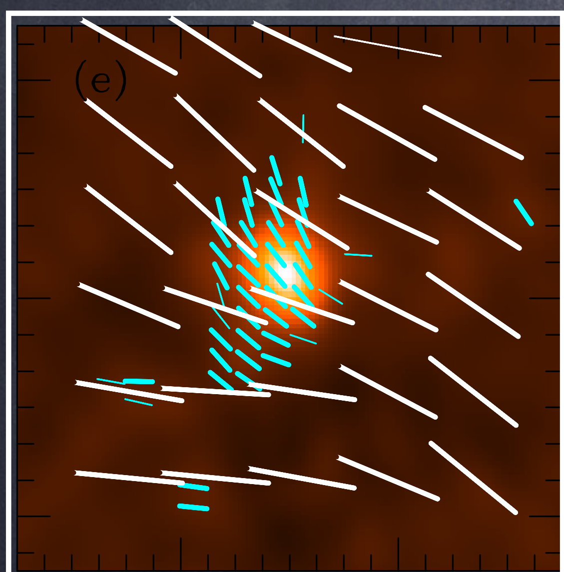
Analysis — Subtle Balance G vs T vs B

u_G P_T P_B Ratios

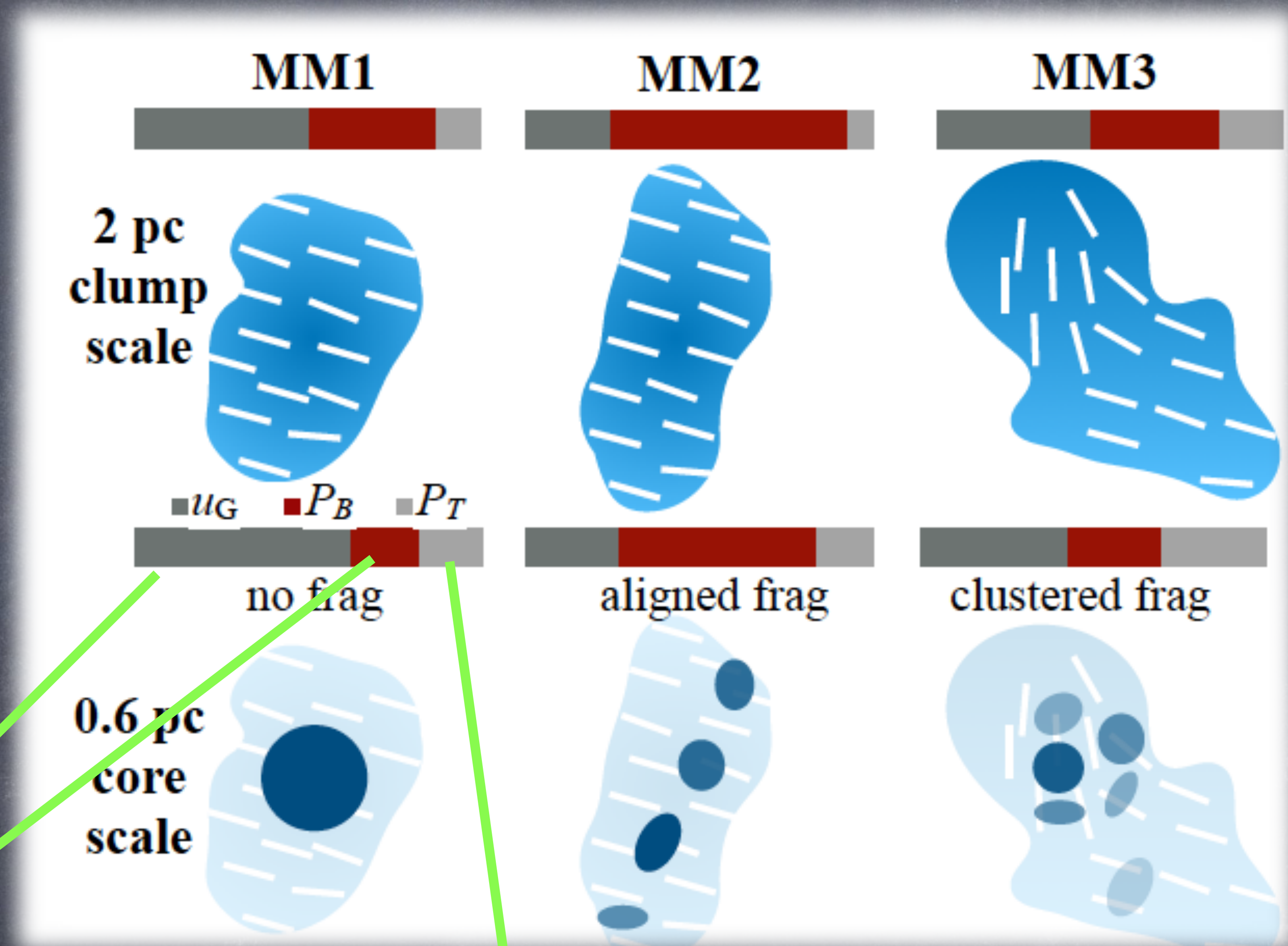


Analysis — Subtle Balance G vs T vs B
Consequence for Fragmentation

no fragmentation



MM1



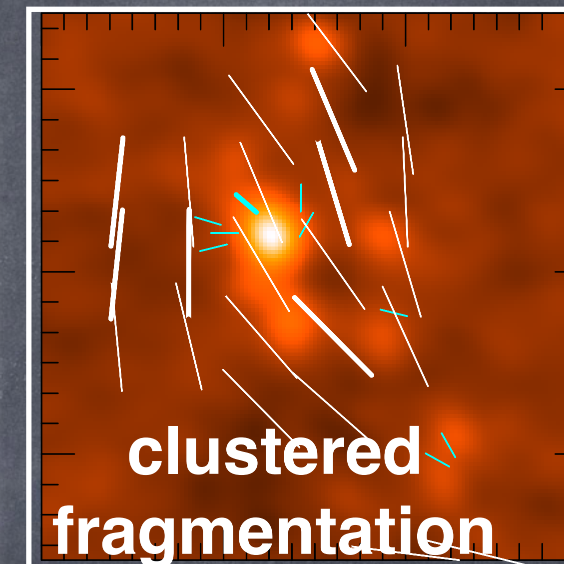
G

B

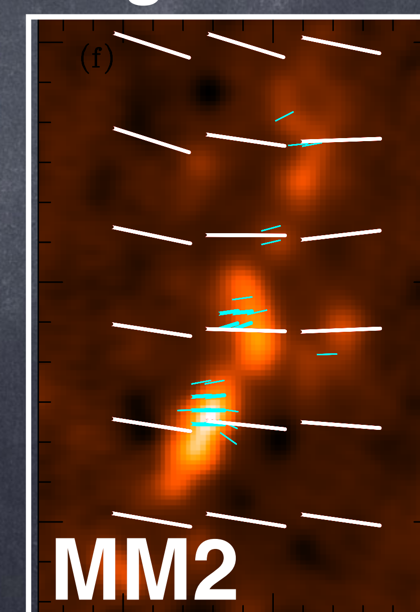
T

(Tang, Koch+2019)

MM3



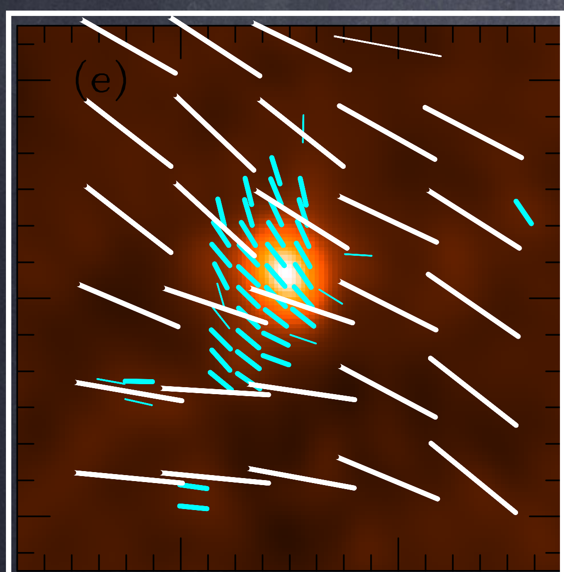
aligned
fragmentation



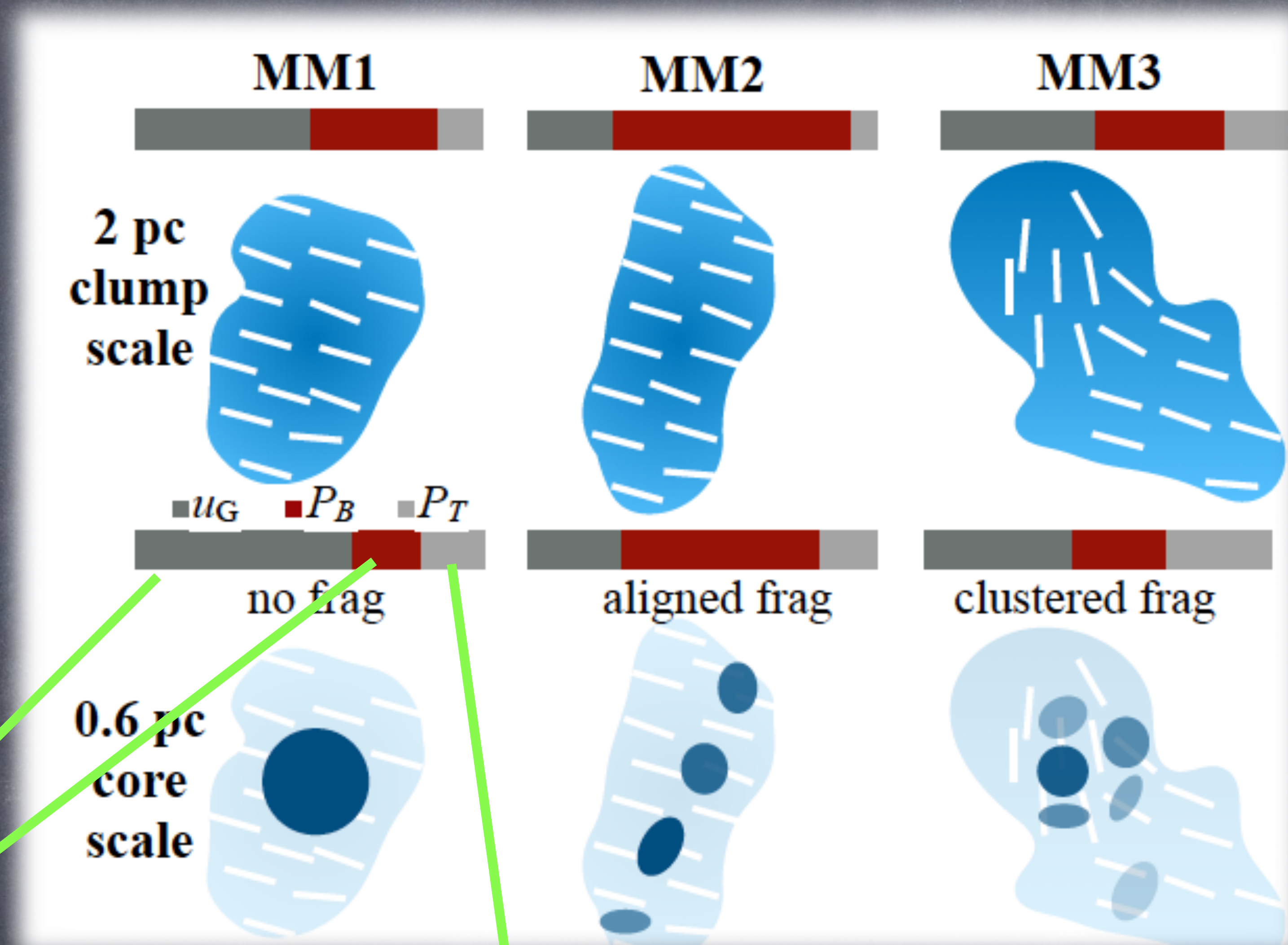
different relative importance between B-field, turbulence, and gravity seems to control fragmentation towards next smaller scale; also seen in simulation work by e.g., Seifried+2015

Analysis — Subtle Balance G vs T vs B
Consequence for Fragmentation

no fragmentation



MM1



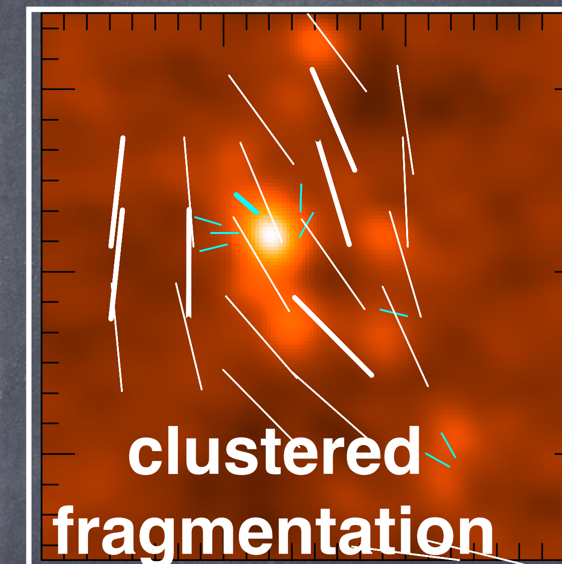
G

B

T

(Tang, Koch+2019)

MM3



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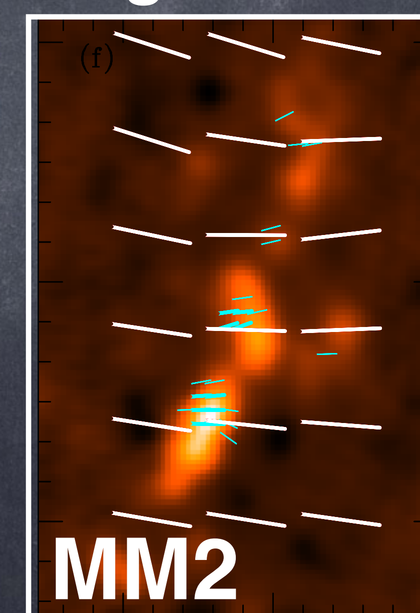
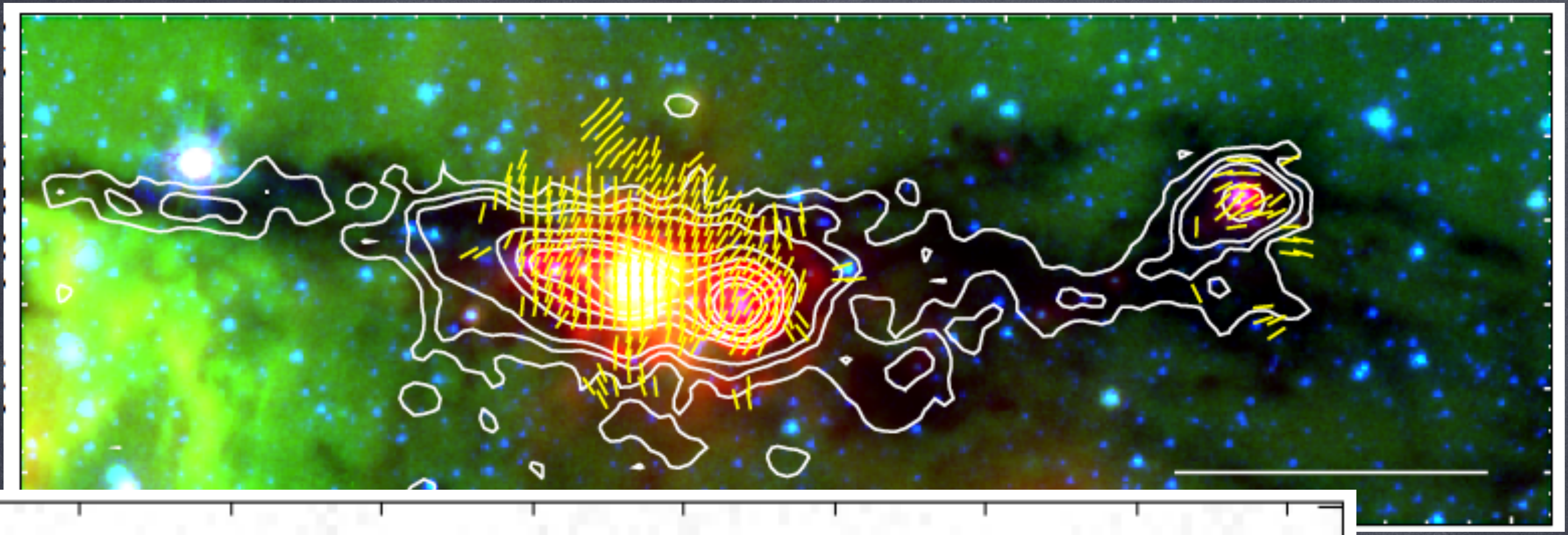
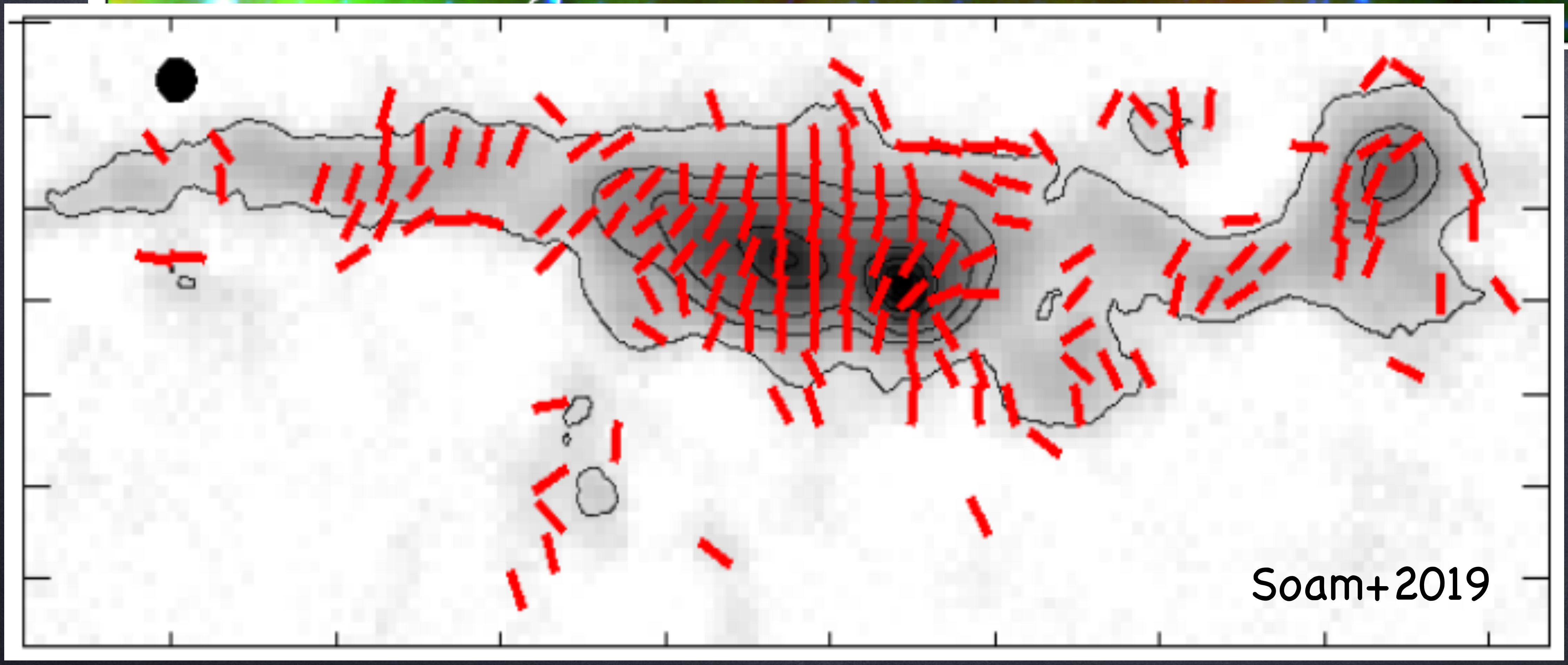
fragmentation



JCMT / POL-2 science:
ideally suited to probe "initial conditions" for fragmentation

CSO / SHARP 350 µm vs JCMT / POL-2 850 µm





JCMT
POL-2

Conclusions

- role of B-field is variable (both in scales and locations)
- JCMT / POL-2 “intermediate” resolution between several-arcmin scales and (sub-)arcsec scales: “initial-condition” scale to map B-field morphologies
- generally: joint analyses is important
  B-field needs to be compared to turbulence, gravity (and more? feedback etc)
- need for ancillary (matching) data, in particular line kinematics;
  good and complete coverage is essential! smaller / larger areas give different results!
- example: initial-conditions for fragmentation in IRDC G34;
  balance between G, B, T derived for clump and core scales, trends across 2 different scales are different and can explain different fragmentation types
- need to develop analysis tools: δ is a key observable, leading to local field strength measurement and local force ratio Σ_B