hamburger sternwarte

Magnetic Fields during the formation of Massive Stars

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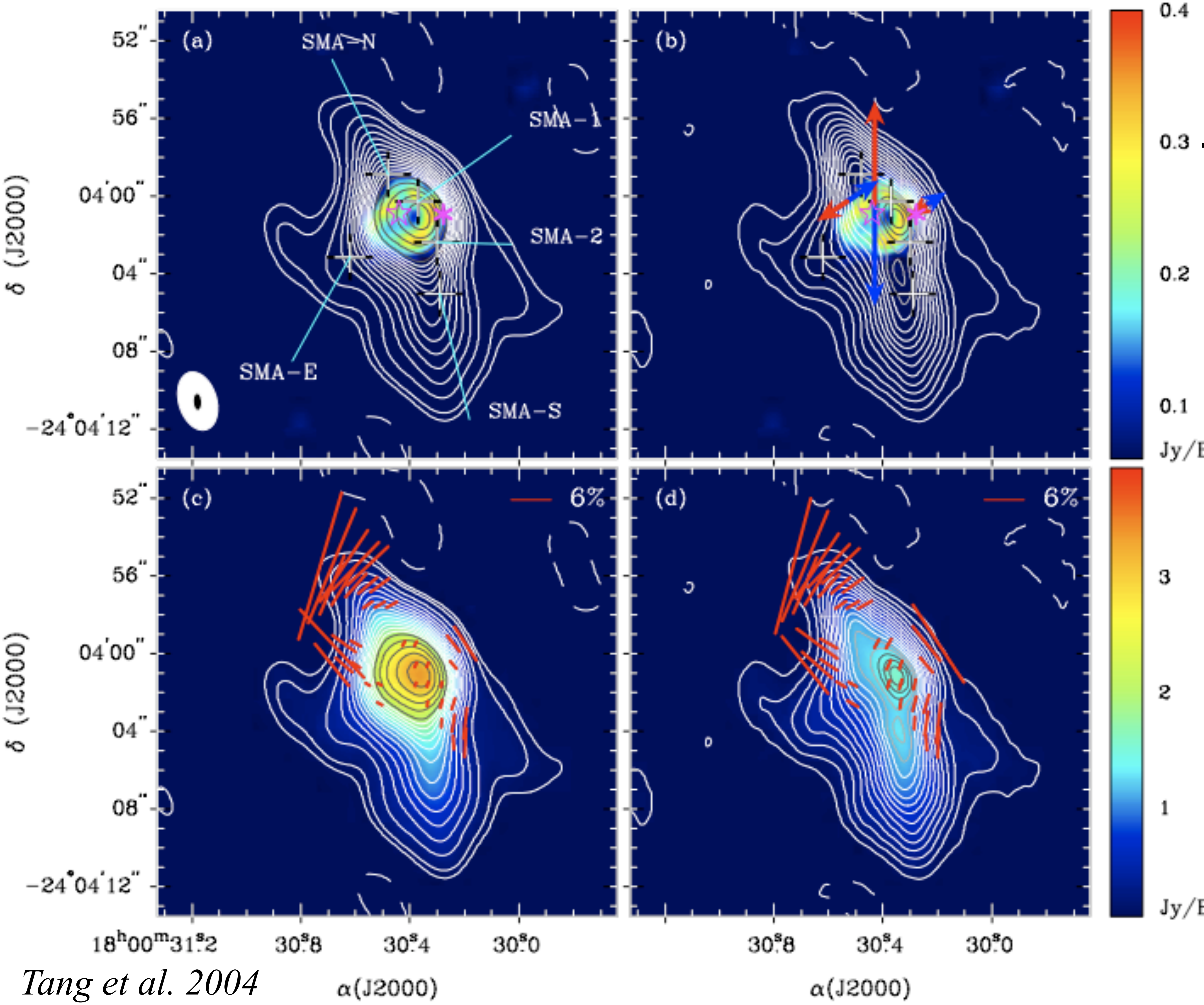
Emmy Noether-Programm
Deutsche Forschungsgemeinschaft
DFG

Magnetic fields during Massive Star Formation



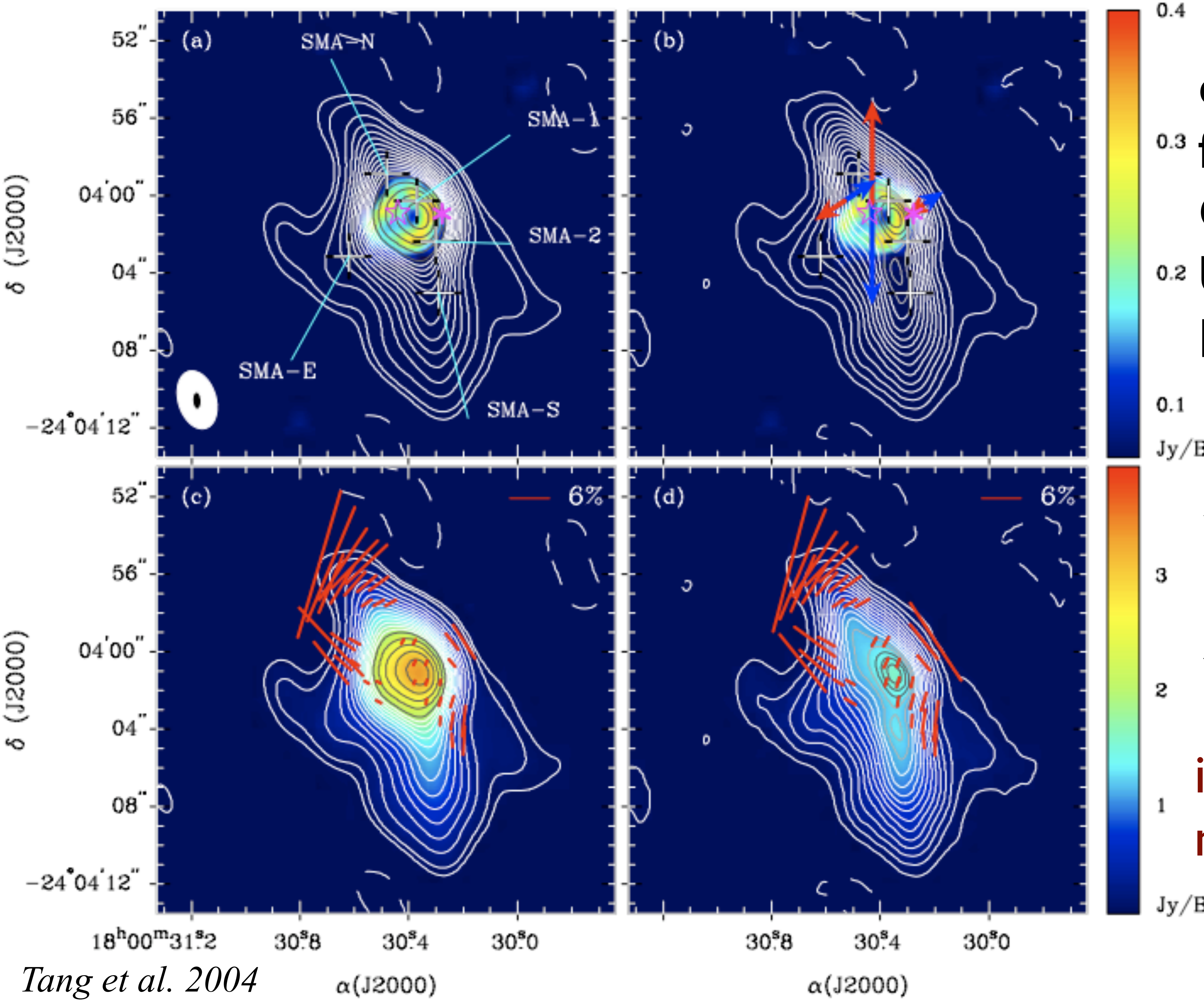
e.g. Massive star forming region G5.89-0.39 UHII

B ~ 2-3 mG

more: Ya-Weng Tang, Patrick Koch's talks

Tang et al. 2004

Magnetic fields during Massive Star Formation



e.g. Massive star forming region G5.89-0.39 UHII

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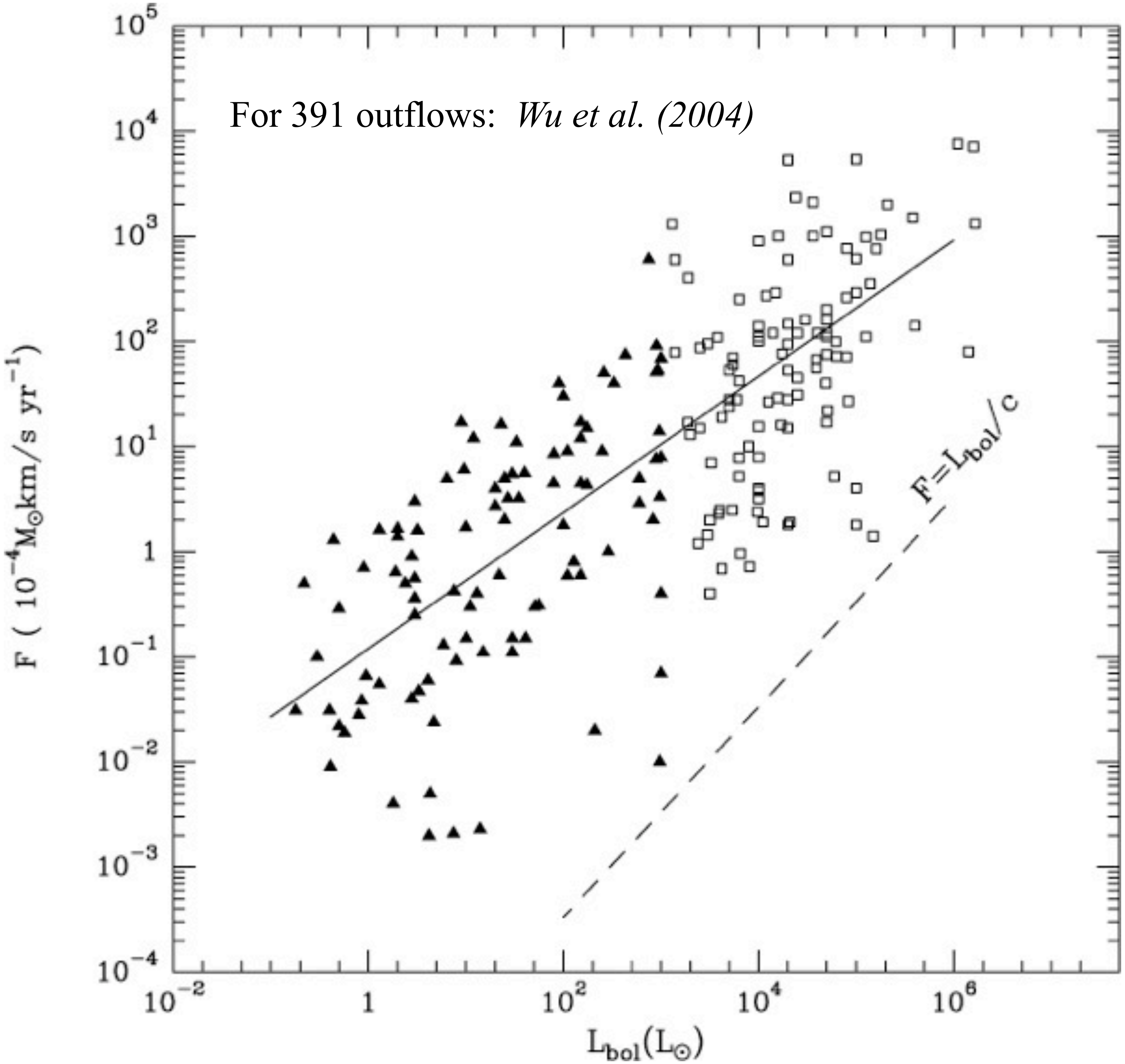
influence of magnetic fields?

Tang et al. 2004

Magnetic fields during Massive Star Formation?

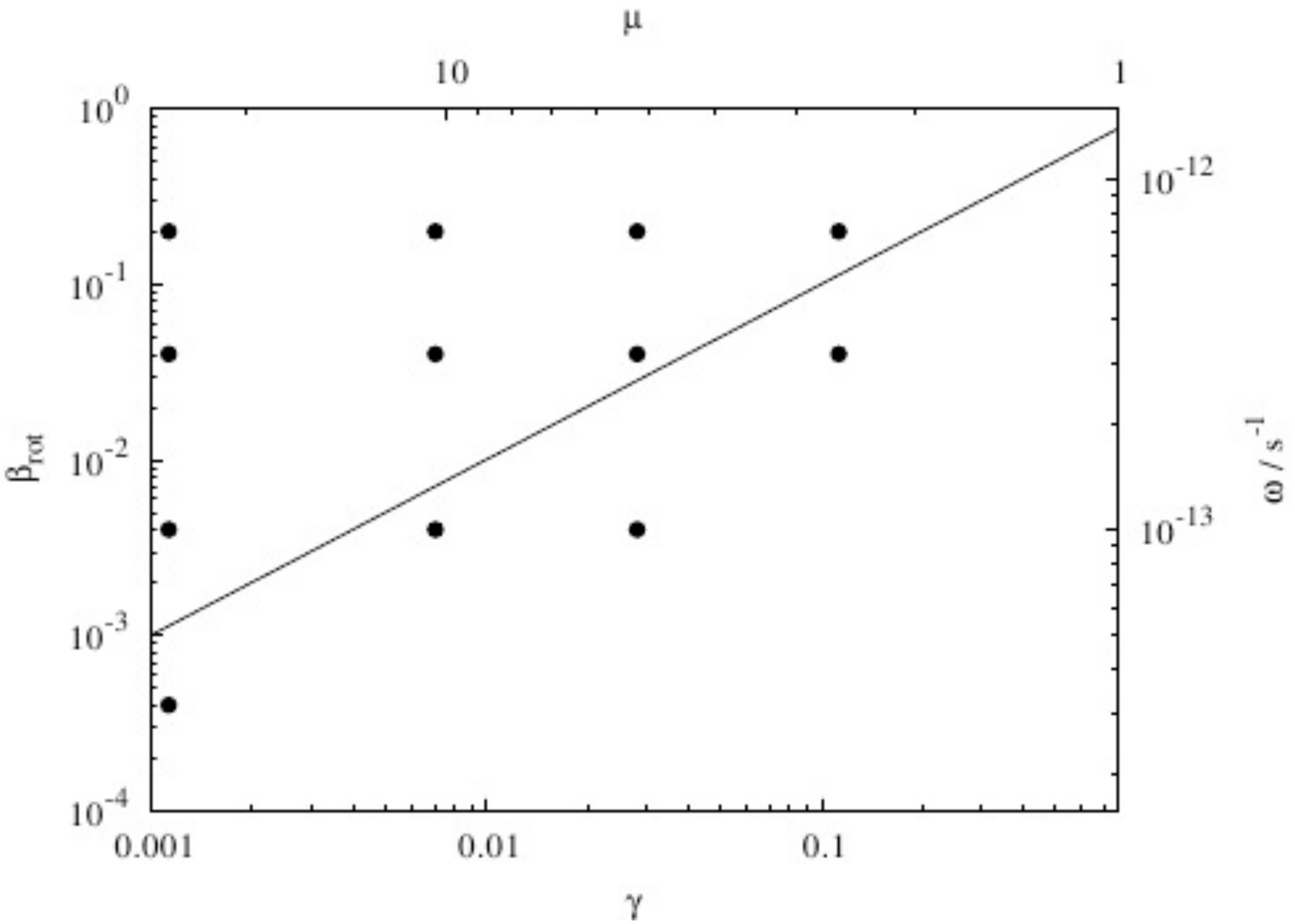


e.g. outflows launched by magnetic fields?

Collapse of Massive Cloud Cores

Parameter study with 3D Simulations of massive collapsing cloud cores

- $M_{core} = 100\ M_{sol}$
- $R_{core} = 0.125$ pc
- density profile: $\rho \sim r^{-1.5}$
- $\rho_{core} = 2.3\text{x}10^{-17}$ g cm^{-3}
- rotation with $\beta = 0.0004 - 0.2$
- mass-to-flux: $\mu = 2.6 - 26\ \mu_{crit}$
- $B_z = 1.3 - 0.13$ mG aligned with rotation axis
- resolution: 4.7 AU



Seifried, Banerjee, Klessen, Duffin, Pudritz 2011

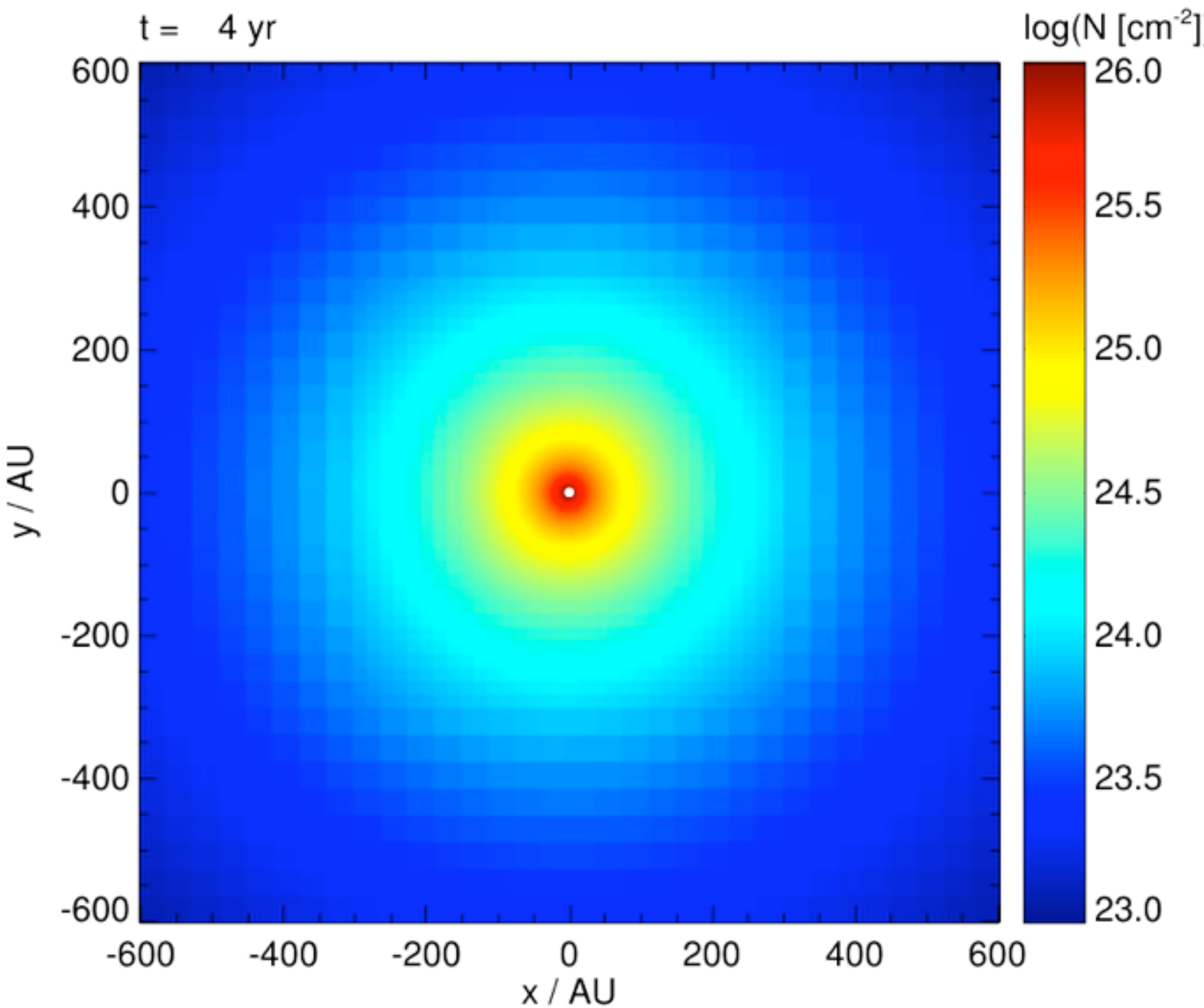
Collapse of Massive Cloud Cores

The disk structures

$\mu = 26\ \mu_{crit}$

Collapse of Massive Cloud Cores

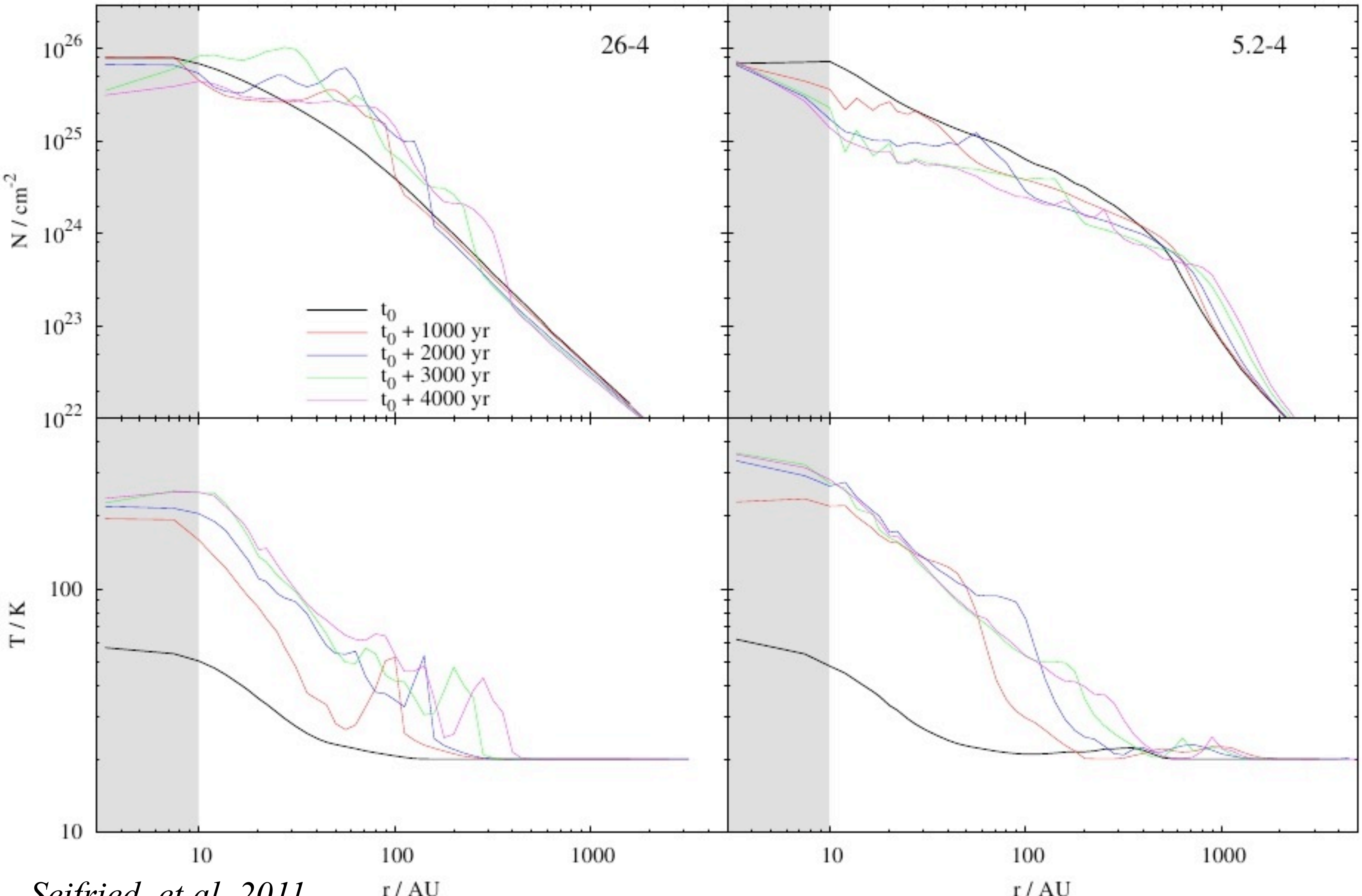
The disk structures



$\mu = 26\ \mu_{crit}$

Parameter study of collapsing cores

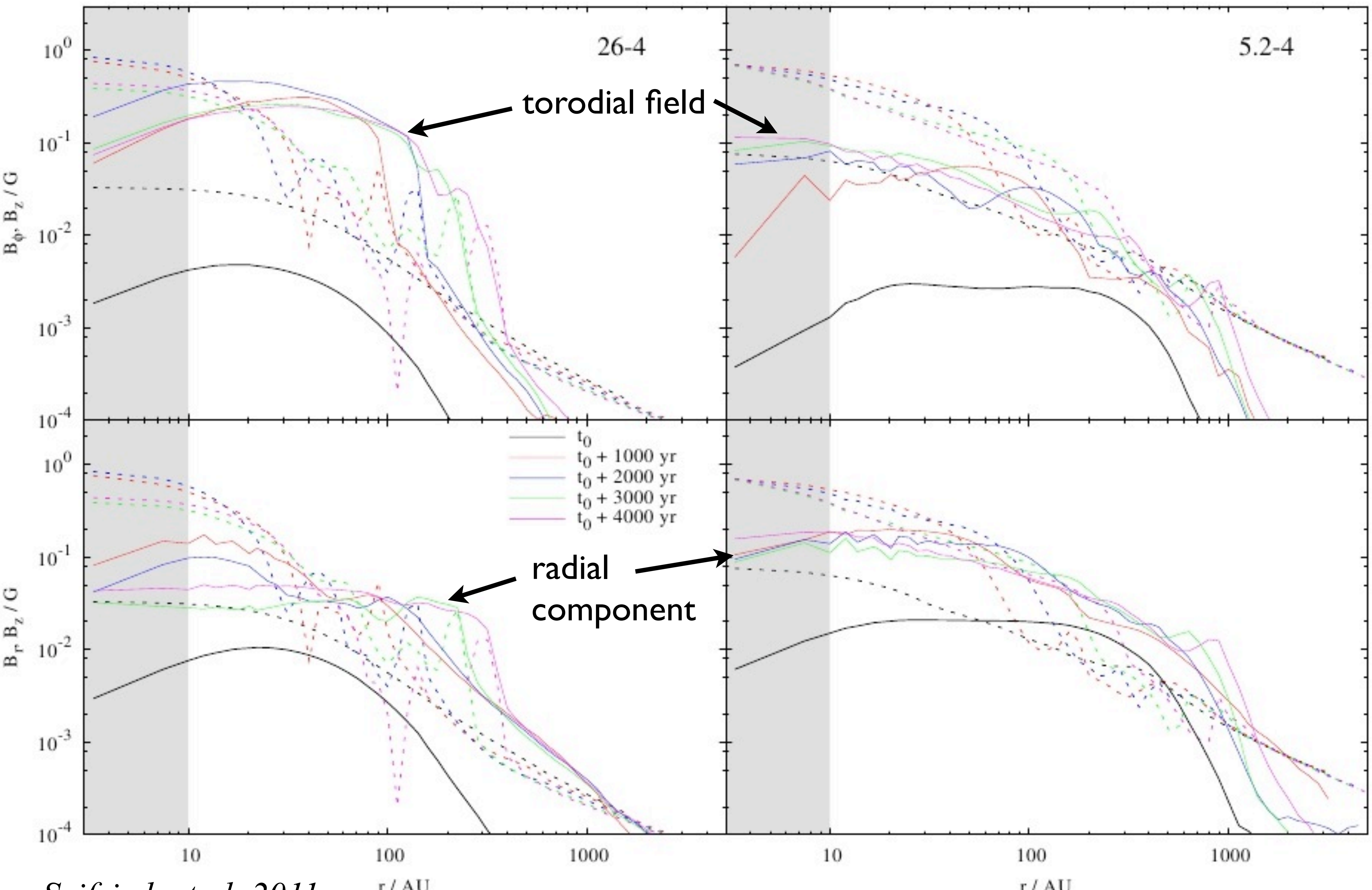
The disk structures



Seifried, et al. 2011

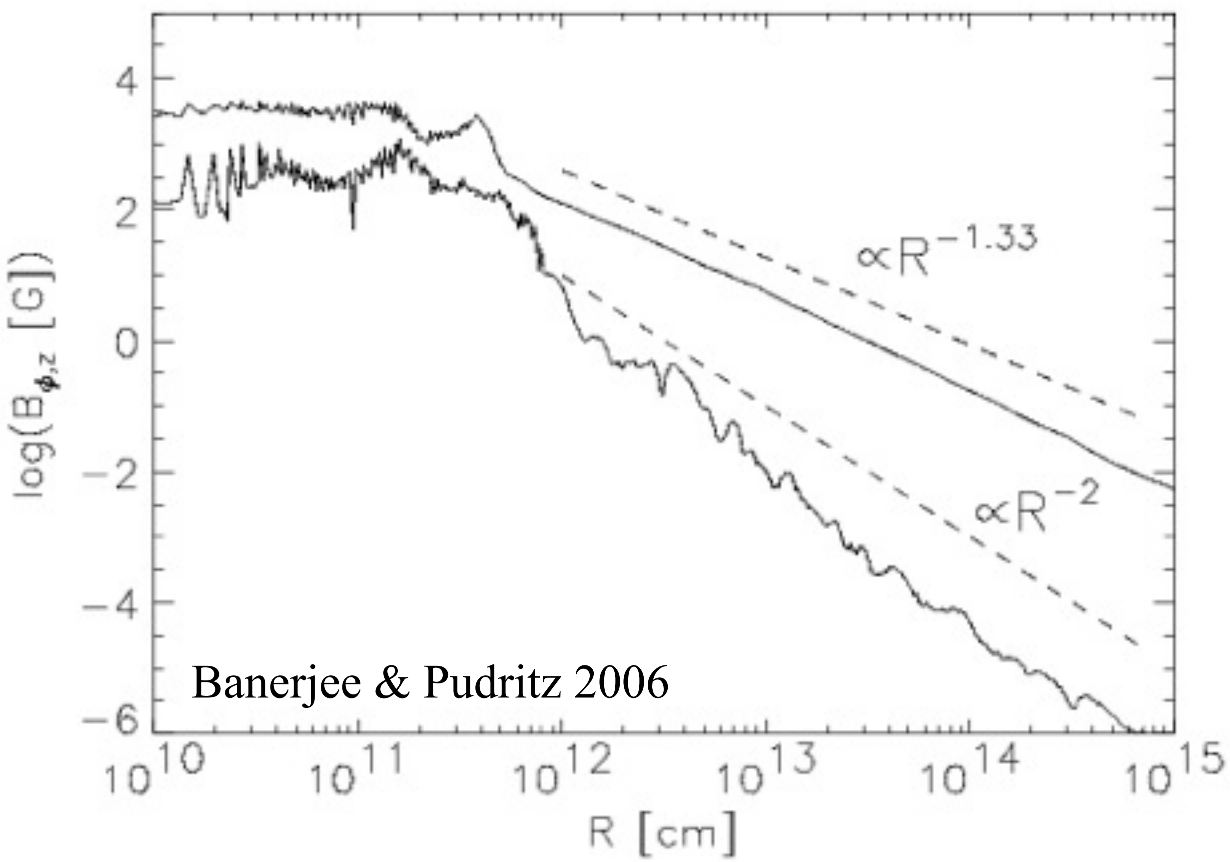
Parameter study of collapsing cores

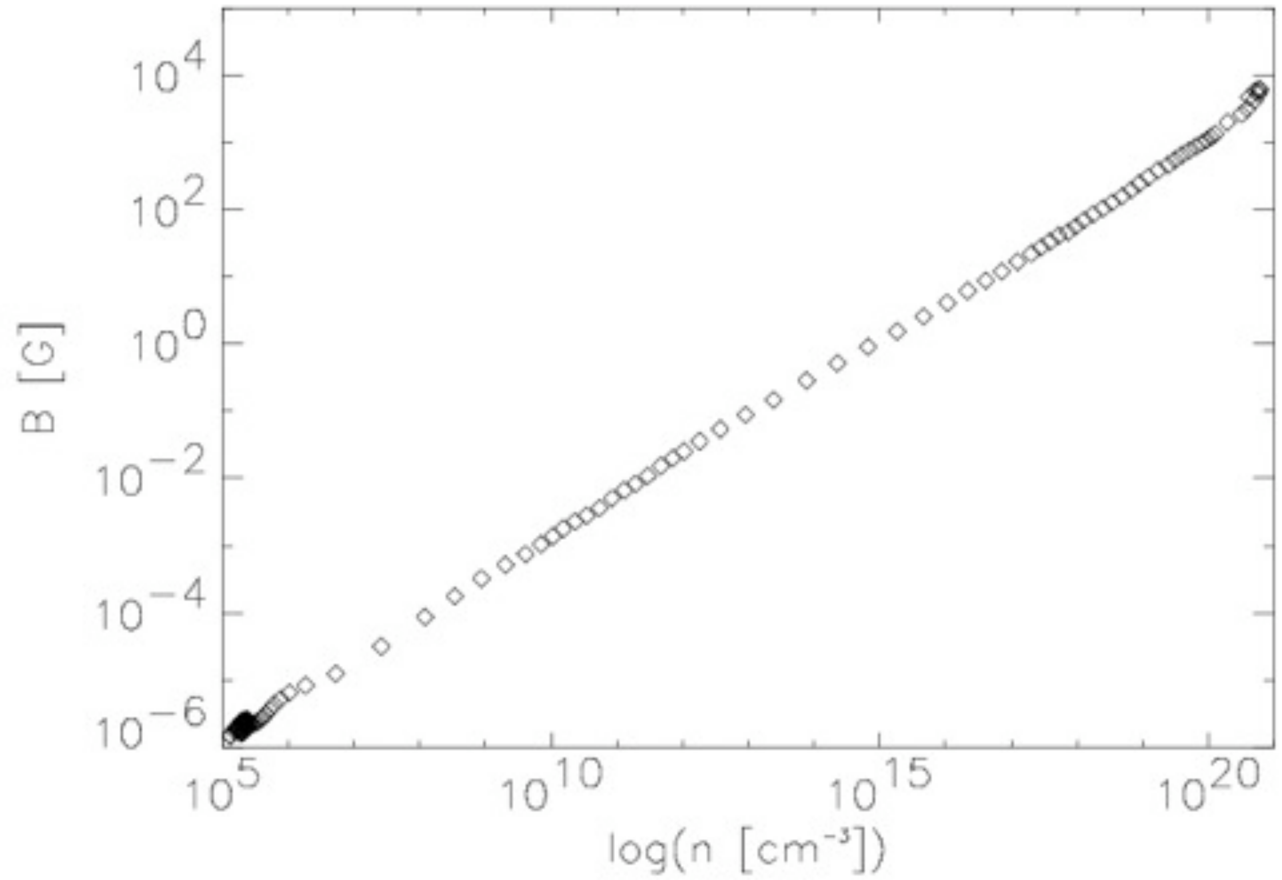
Magnetic field in the disk



Seifried, et al. 2011

Magnetic field during the collapse

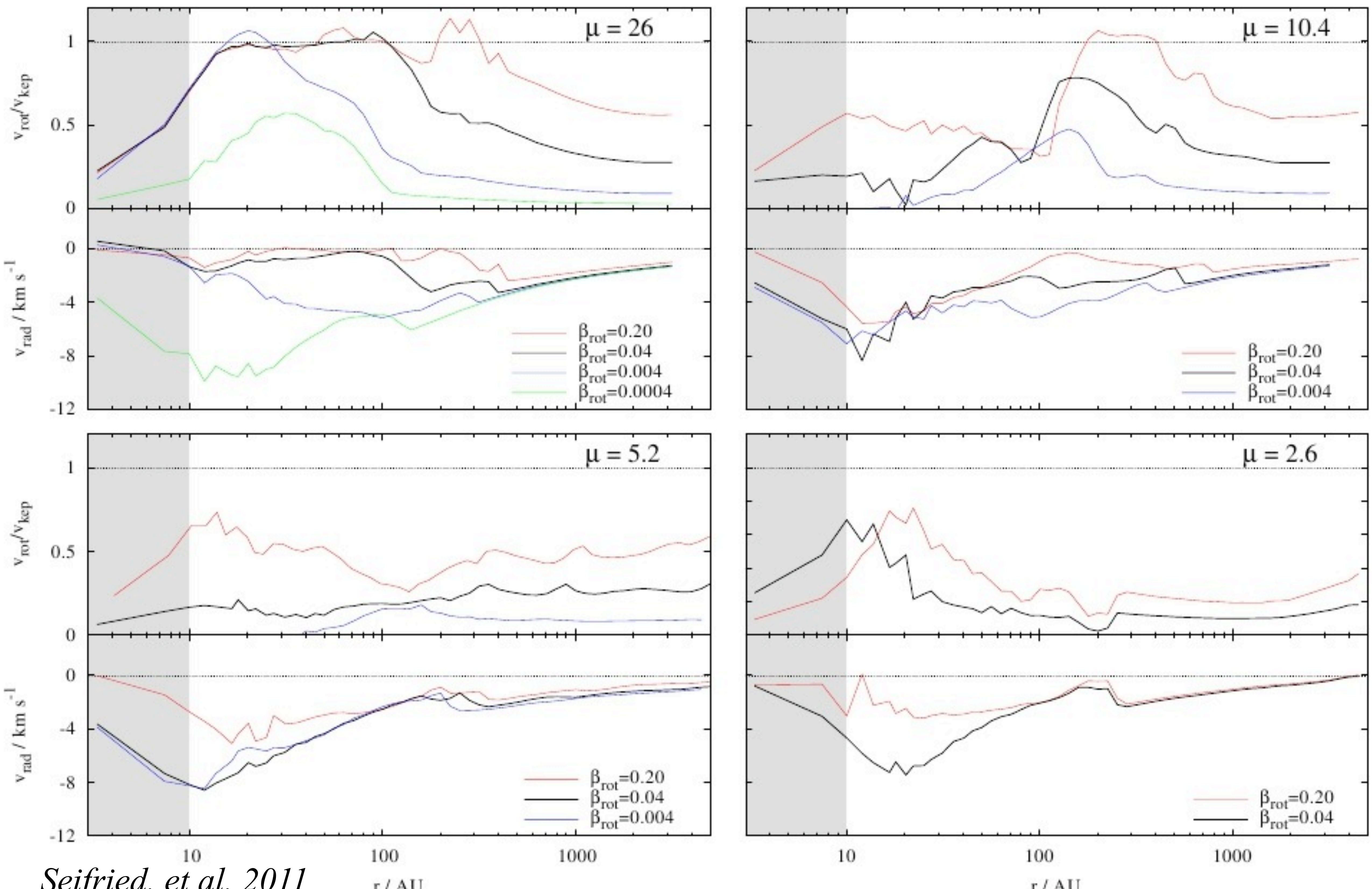




- $B_z > B_\phi$ in the core and disk (expectation from a stationary accretion disk $B \propto R^{-1.25}$; *Blandford & Payne 1982*)
- $B_{core} \propto n^{0.6}$
- Expected field strength in the protostar ~ $10^4 - 10^5$ G
- Flux problem (Jonathan's talk)

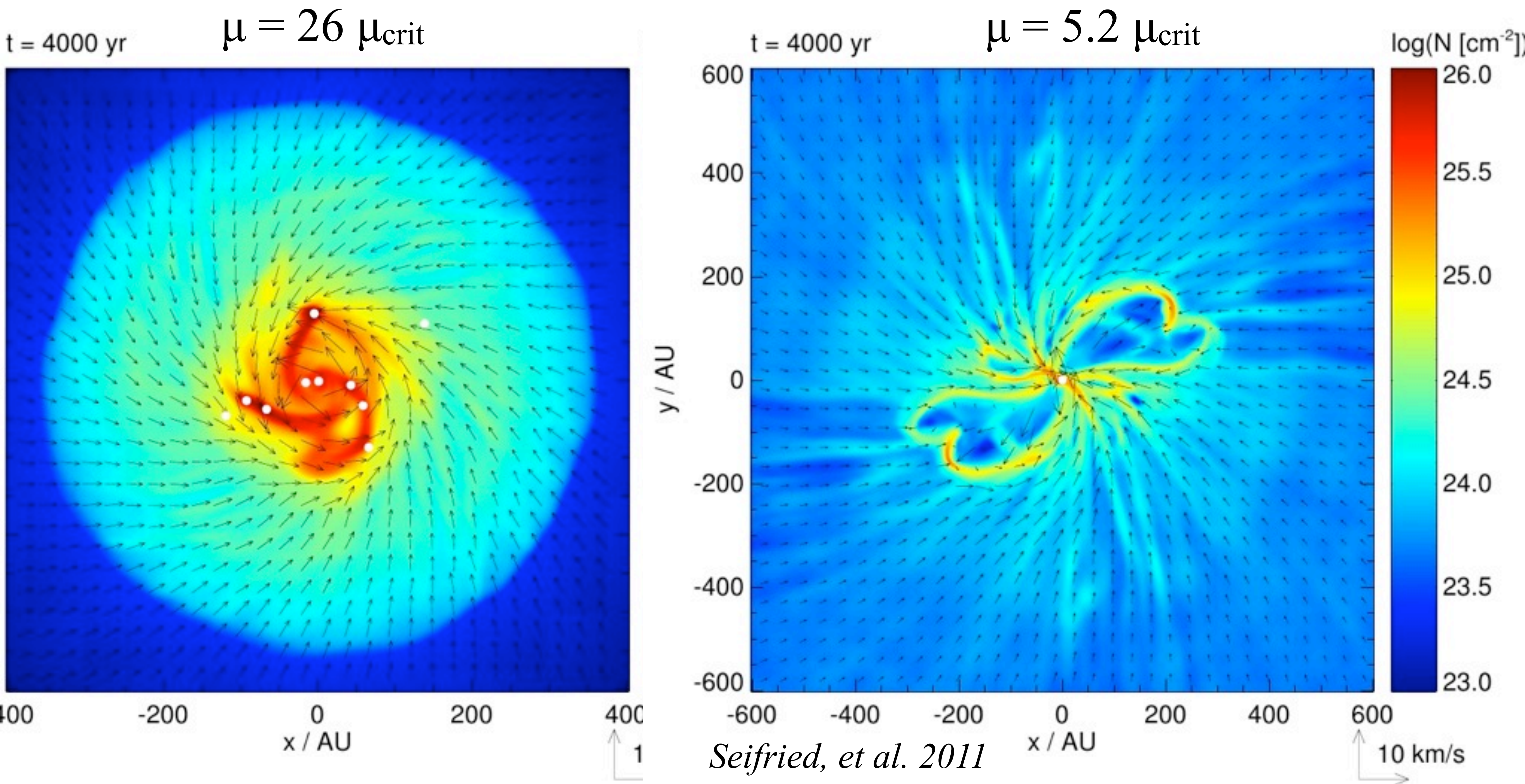
Parameter study of collapsing cores

velocity structure



Seifried, et al. 2011

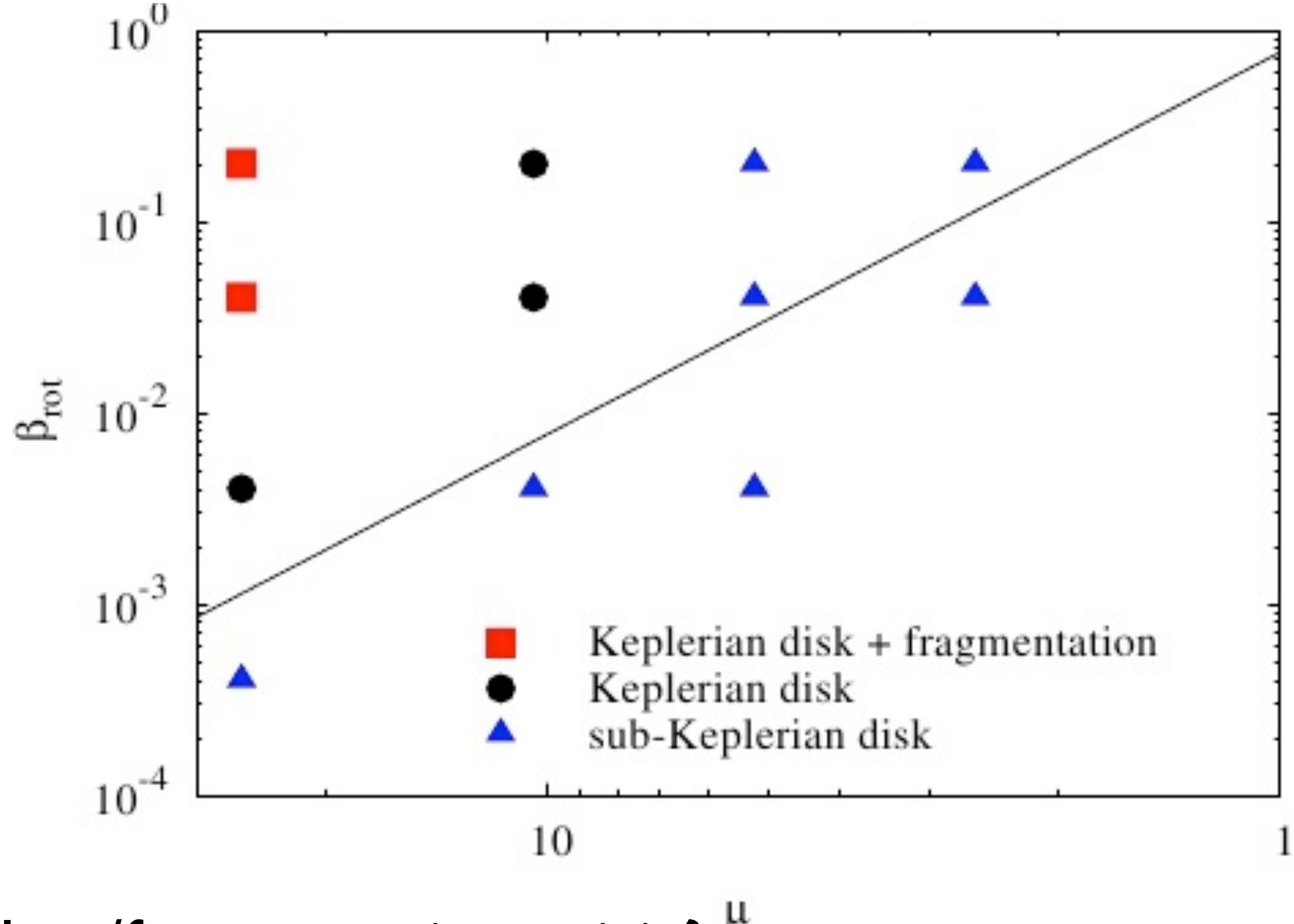
Parameter study of collapsing cores



stronger fields ⇒ efficient magnetic braking and suppression of fragmentation

Parameter study of collapsing cores

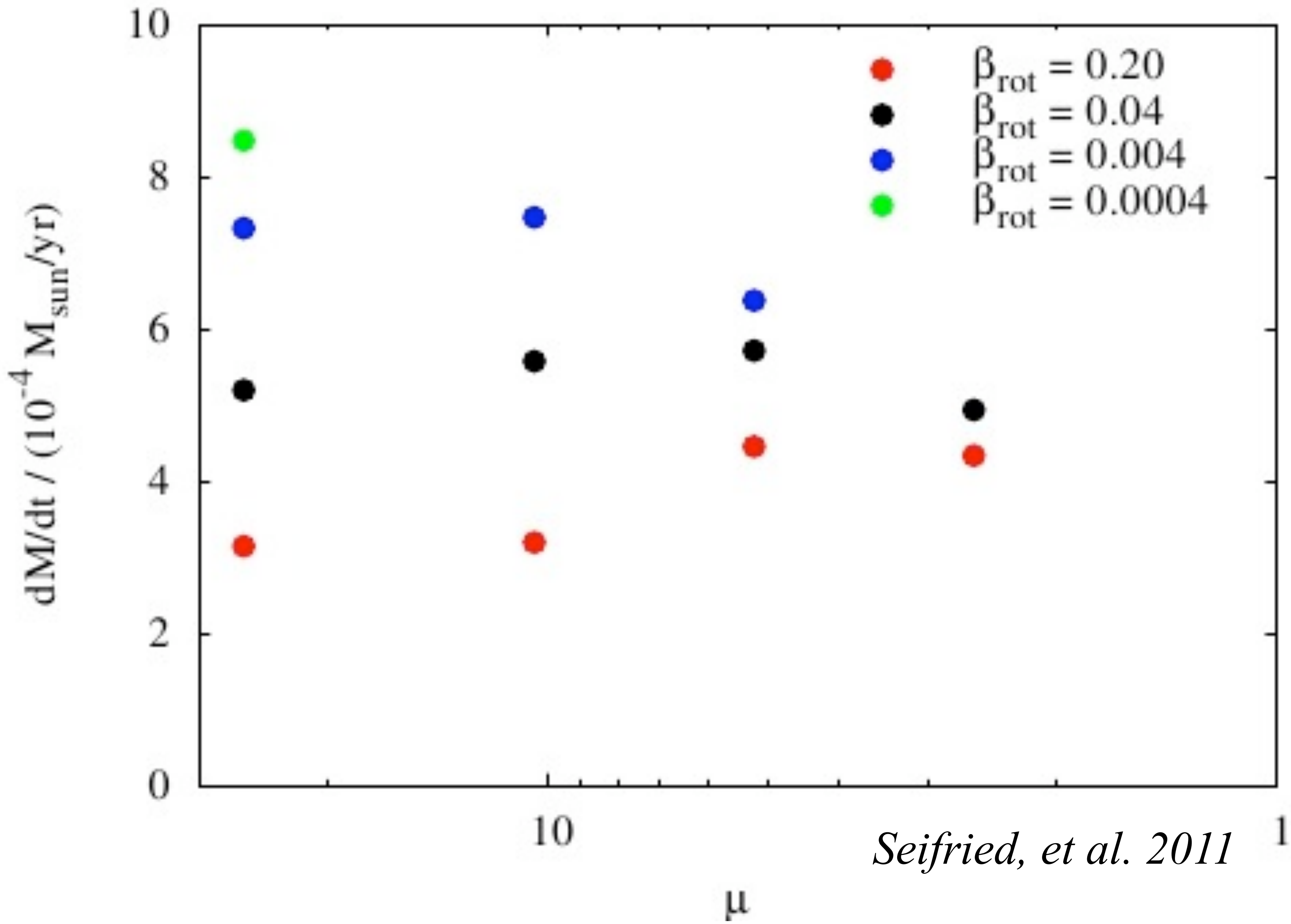
disk type / fragmentation



- flux problem/fragmentation crisis? (e.g Hennebelle & Teyssier 2008, Elisabete's talk)
- transfer of flux/angular momentum in subsequence evolution?

Parameter study of collapsing cores

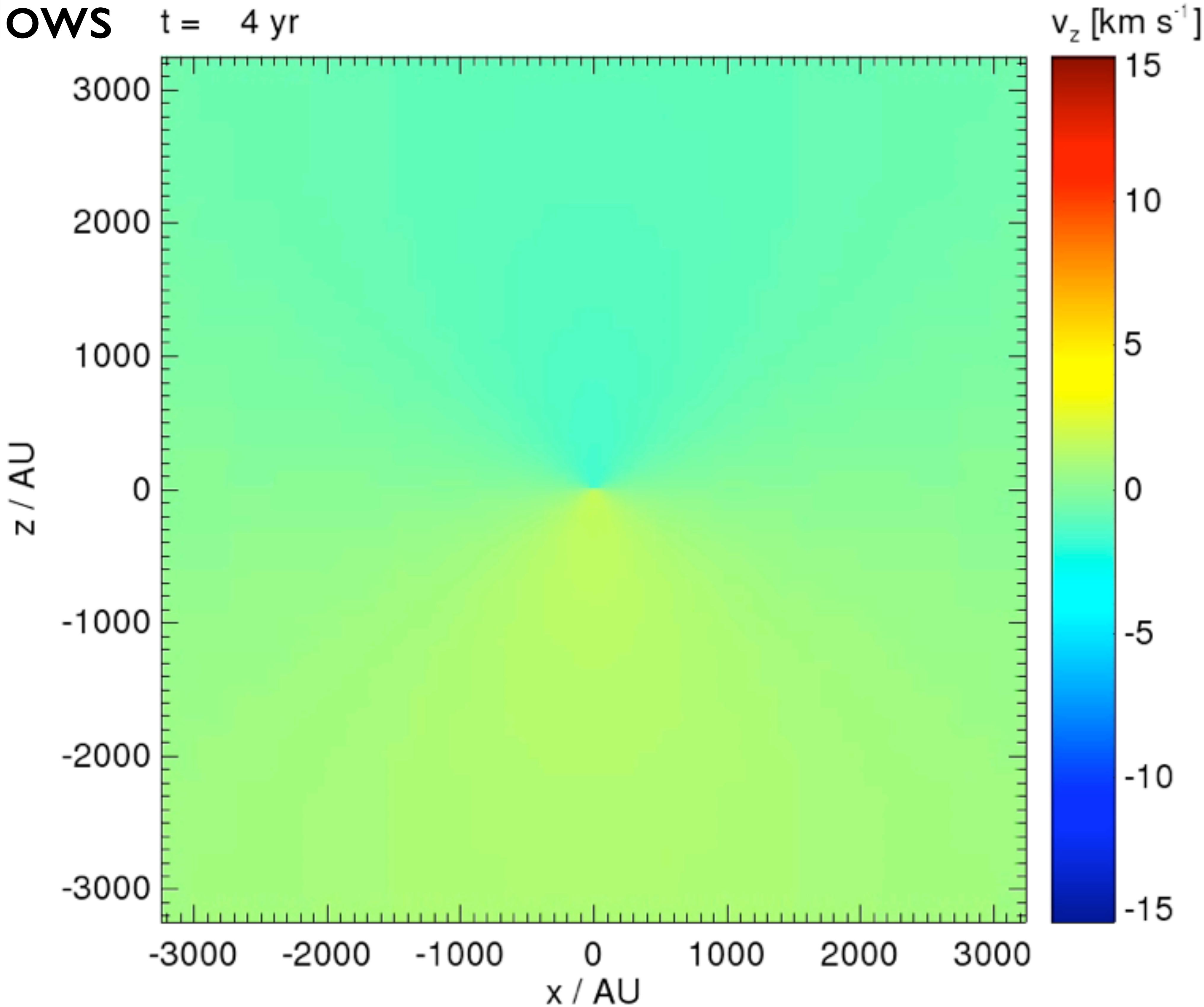
accretion rates



- weak dependence on B
- decreasing with increasing rotation

Parameter study of collapsing cores

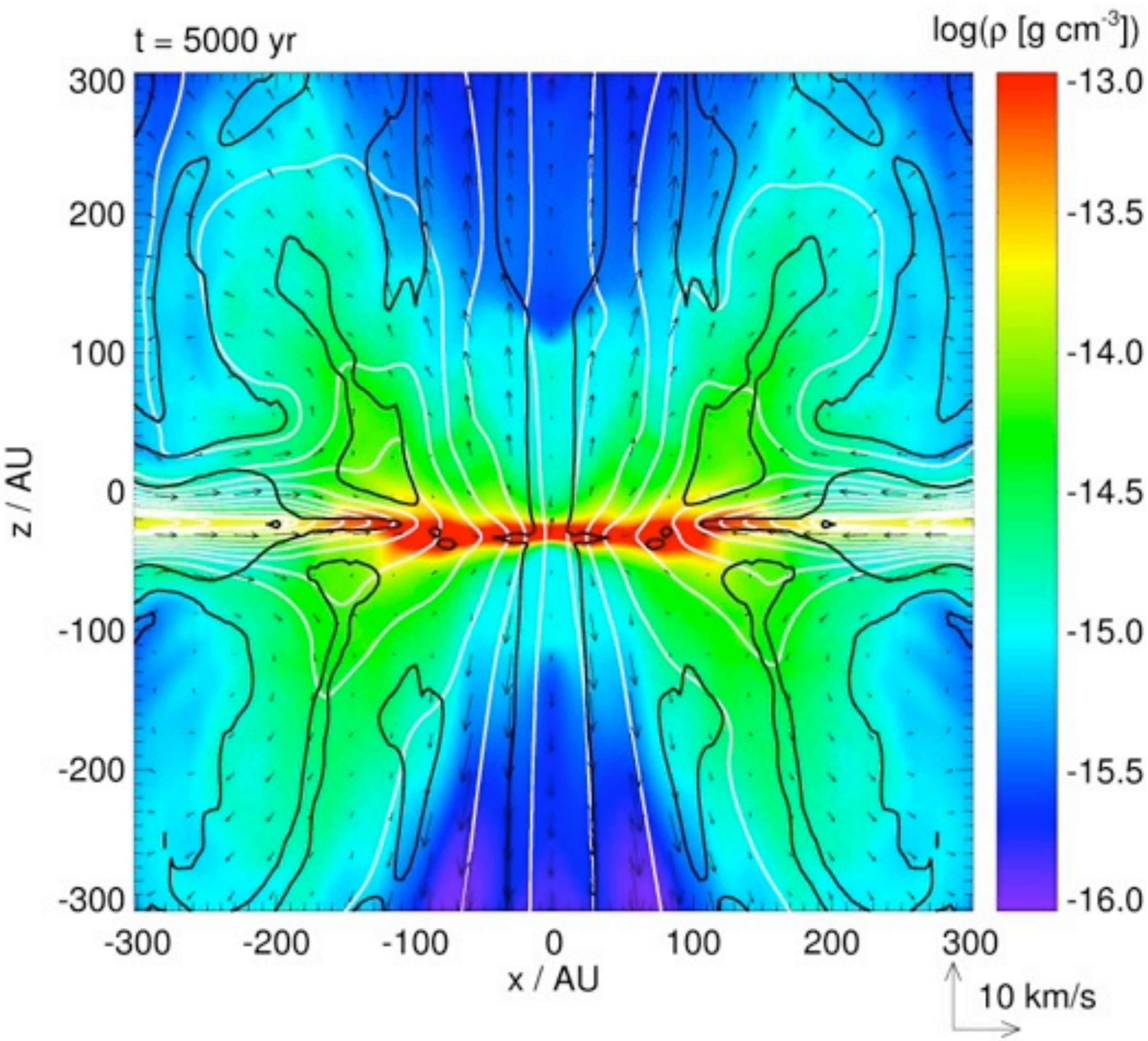
Outflows

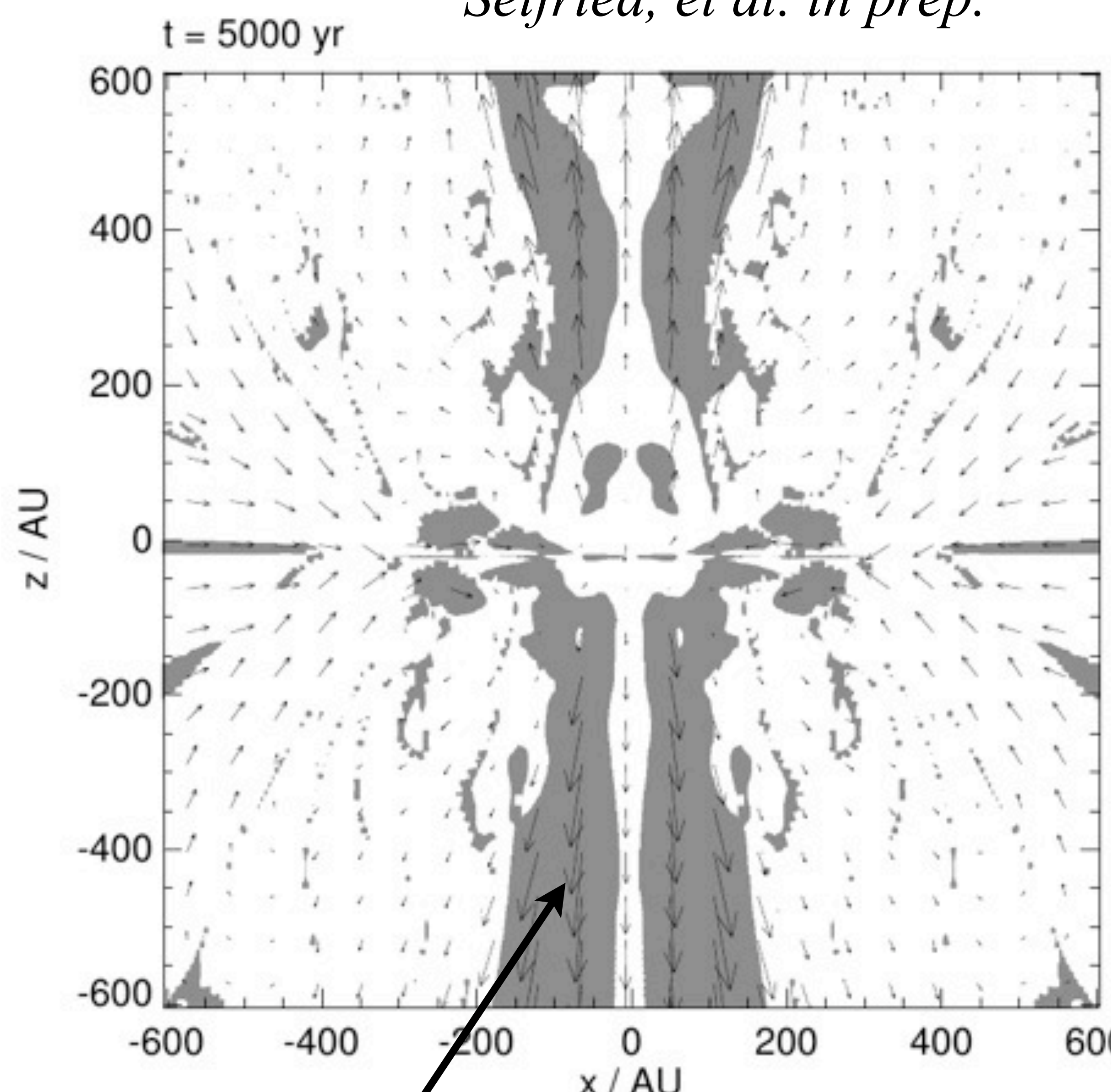


Parameter study of collapsing cores

Outflow / Lauchning mechanism

Seifried, et al. in prep.





$\mu = 26\ \mu_{crit}$

gray: magnetocentrifugal launching
(Blandford & Payne ’82)

Parameter study of collapsing cores

Outflow / Lauchning mechanism

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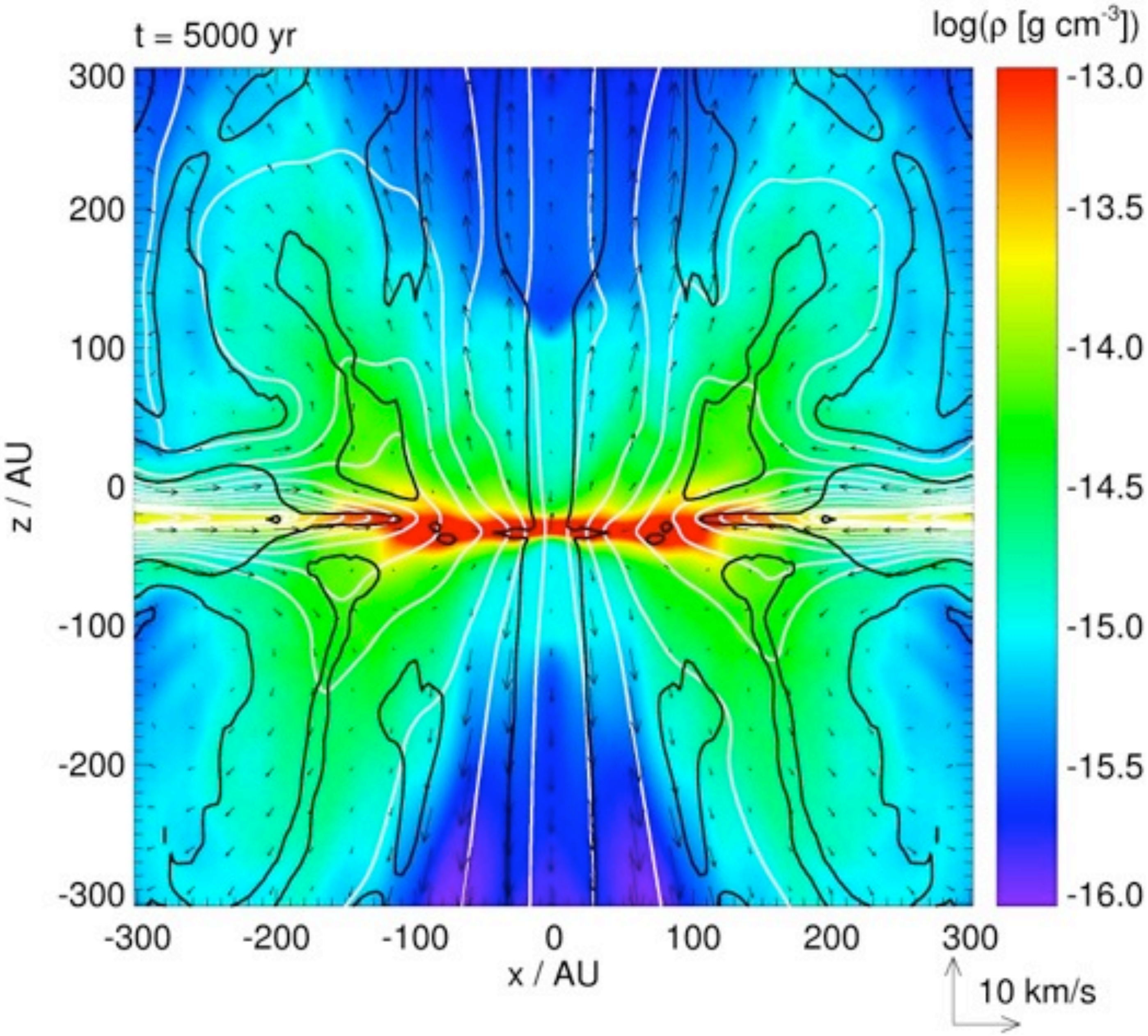
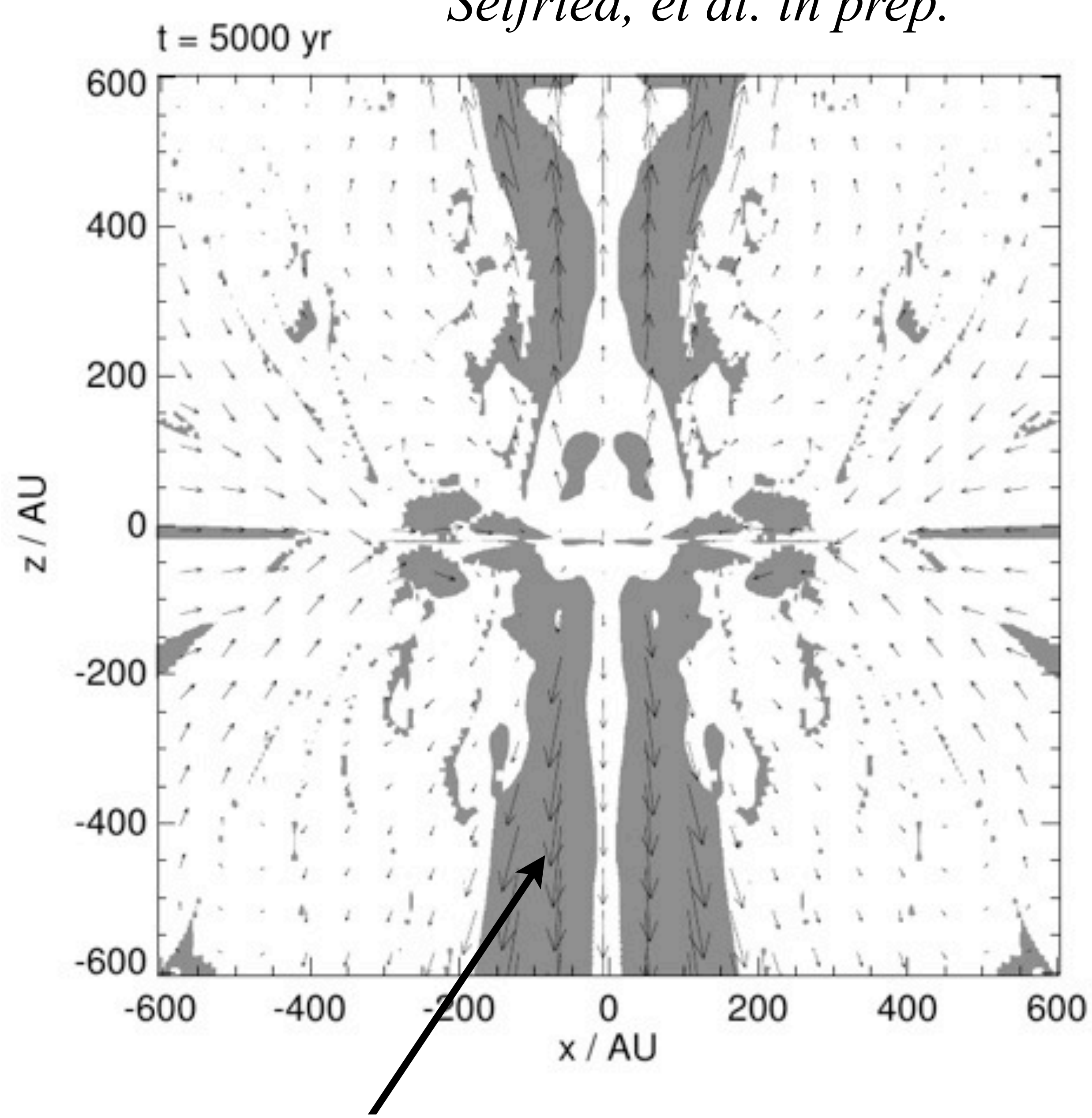


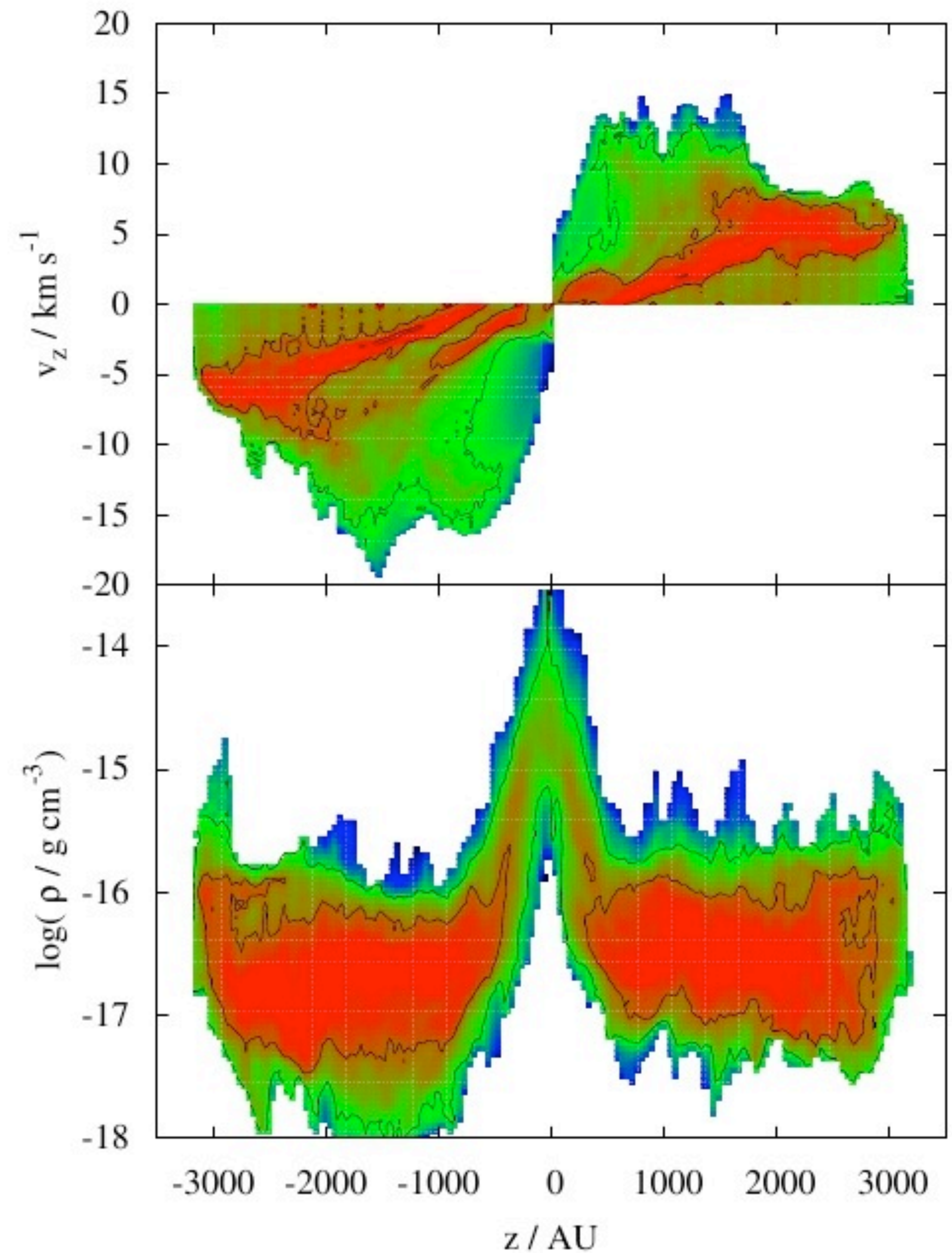


$\mu = 26\ \mu_{crit}$

$$\frac{r}{z}\frac{1}{GM}\left(\frac{v_\phi^2}{r^2}(r^2+z^2)^{3/2}-GM\right)\Big/\left(\frac{B_z}{B_r}\right) > 1$$

Parameter study of collapsing cores

weak magnetic field: $\mu = 26\ \mu_{crit}$



outflow structure:

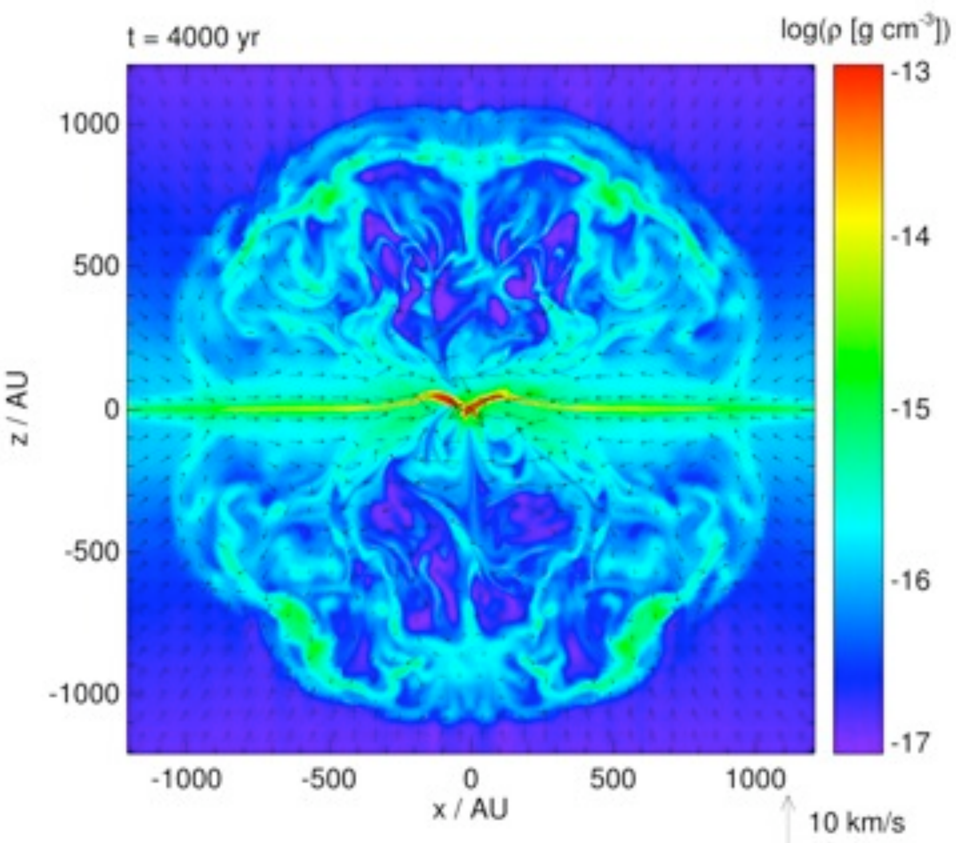
- bulk velocity increases with distance
- peak velocities correlate with density peaks

⇒ several shocks

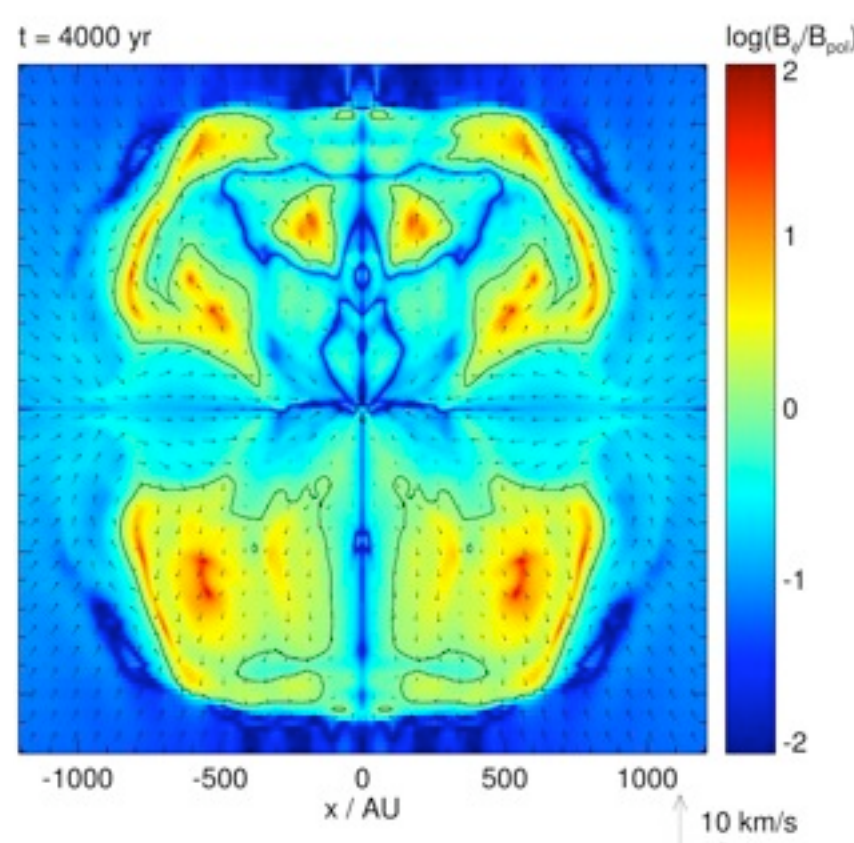
Parameter study of collapsing cores

Outflow / Lauchning mechanism

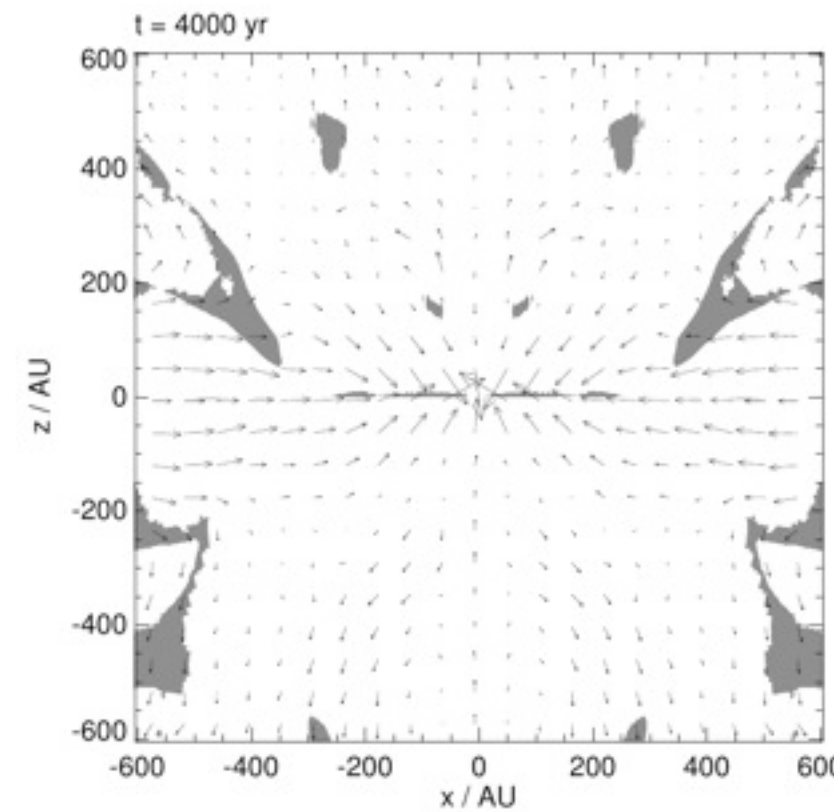
stronger magnetic field: $\mu = 5.2\ \mu_{crit}$



density



B_φ/B_p

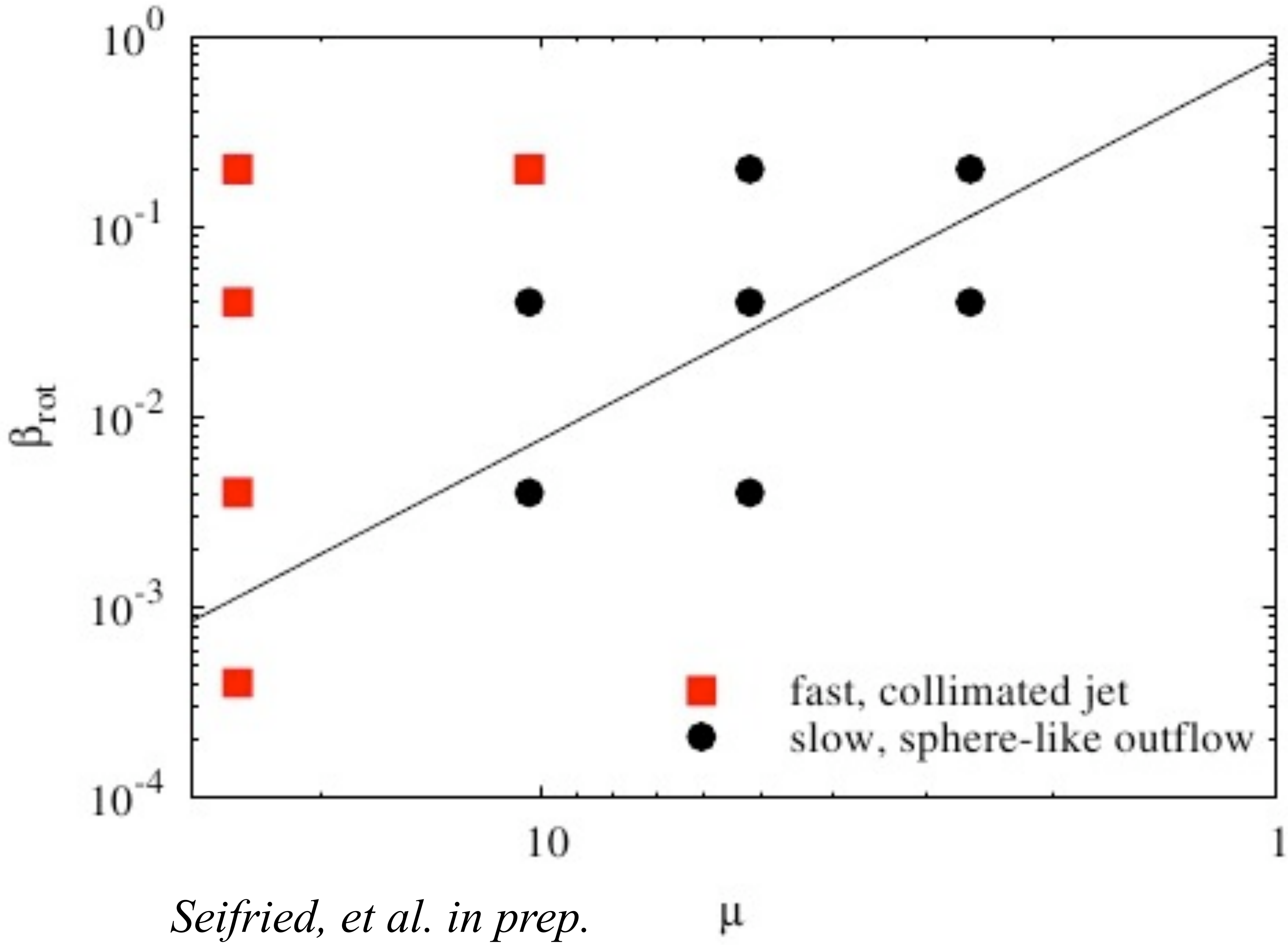


$$\frac{r}{z}\frac{1}{GM}\left(\frac{v_\phi^2}{r^2}(r^2+z^2)^{3/2} - GM\right) \Big/ \left(\frac{B_z}{B_r}\right) > 1$$

- inefficient magnetocentrifugal launching
- bubble like “outflow”

Parameter study of collapsing cores

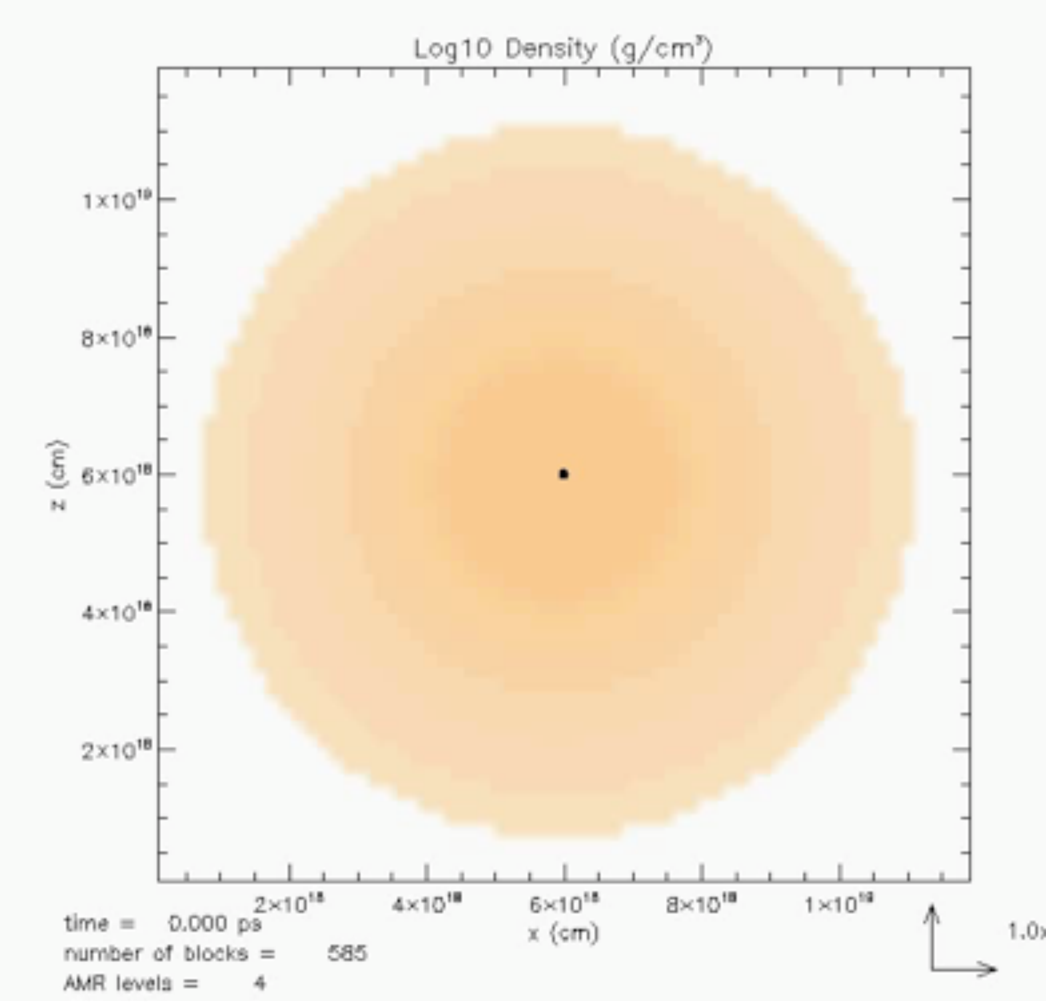
Outflow summary



Seifried, et al. in prep.

Massive Star Formation: Dynamics of HII Regions

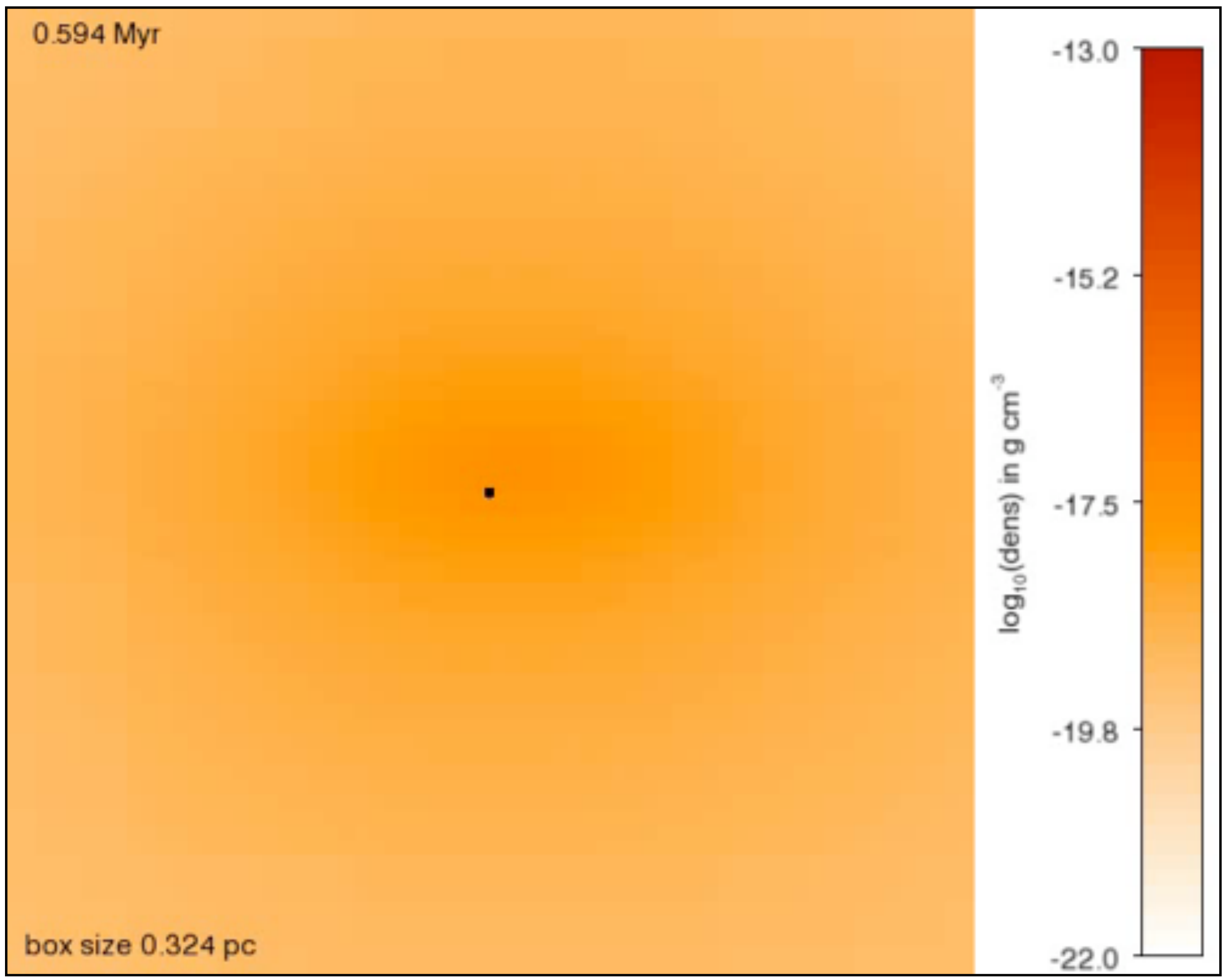
3D Simulations of collapsing cloud cores with ionization feedback from young massive stars (Thomas Peters, ITA)

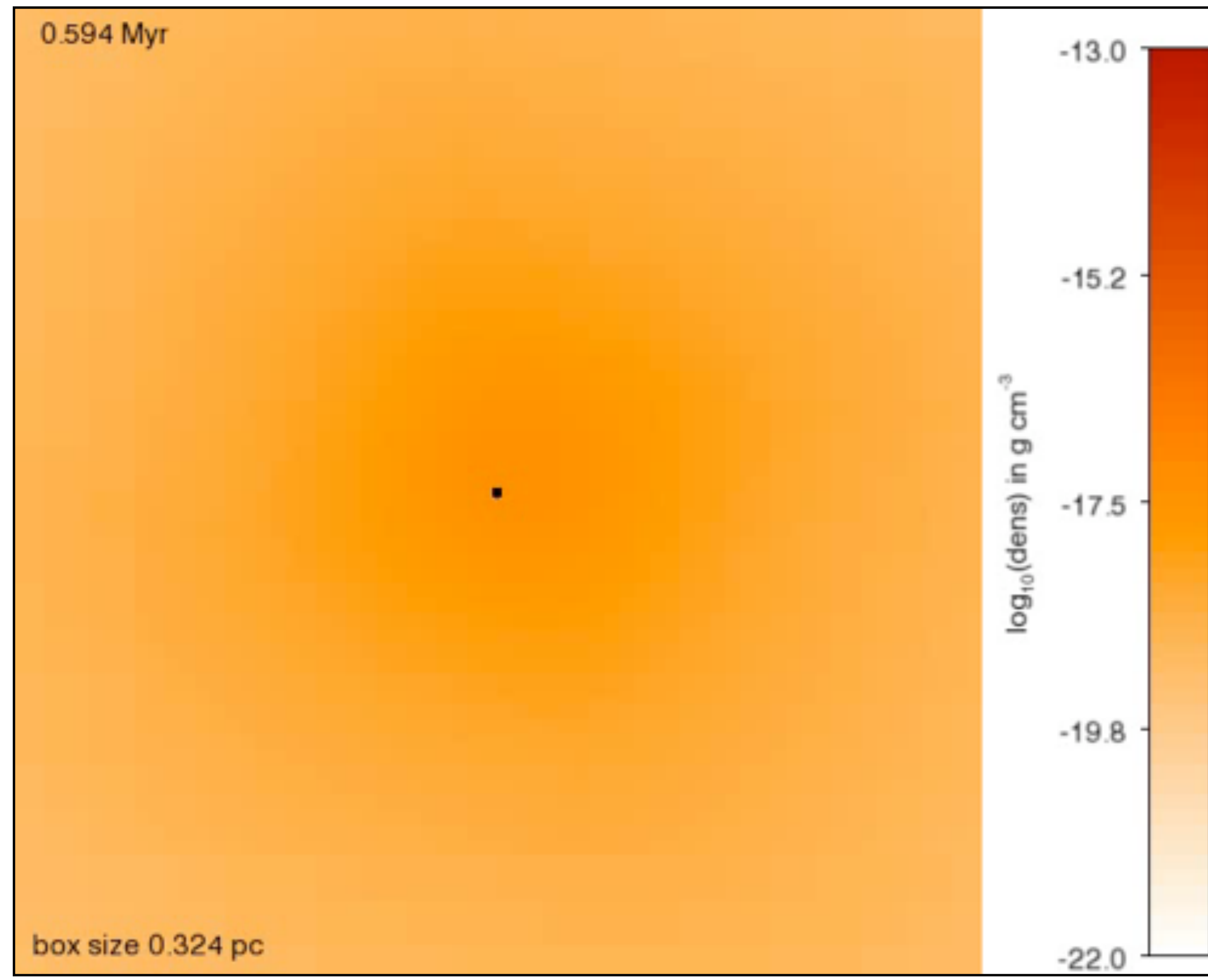


- massive core with $M_{core} = 1000\ M_{sol}$
- $R_{core} = 1.6$ pc
- $\rho_{core} = 1.27 \times 10^{-20}$ g cm^{-3}; $\rho \sim r^{-1.5}$
- initial core rotation with $\beta = 0.05$
- magnetized case: $\mu = 14\ \mu_{crit}$ ($B = 10\ \mu G$)
- accreting sink particles $\Rightarrow$ luminosity and temperature using ZAMS (*Paxton 2004*)
- highest grid resolution ~ 100 AU

Massive Star Formation: Dynamics of HII Regions

Simulations by Thomas Peters (ITA)





Disk edge on

Disk plane

Massive Star Formation: Dynamics of HII Regions

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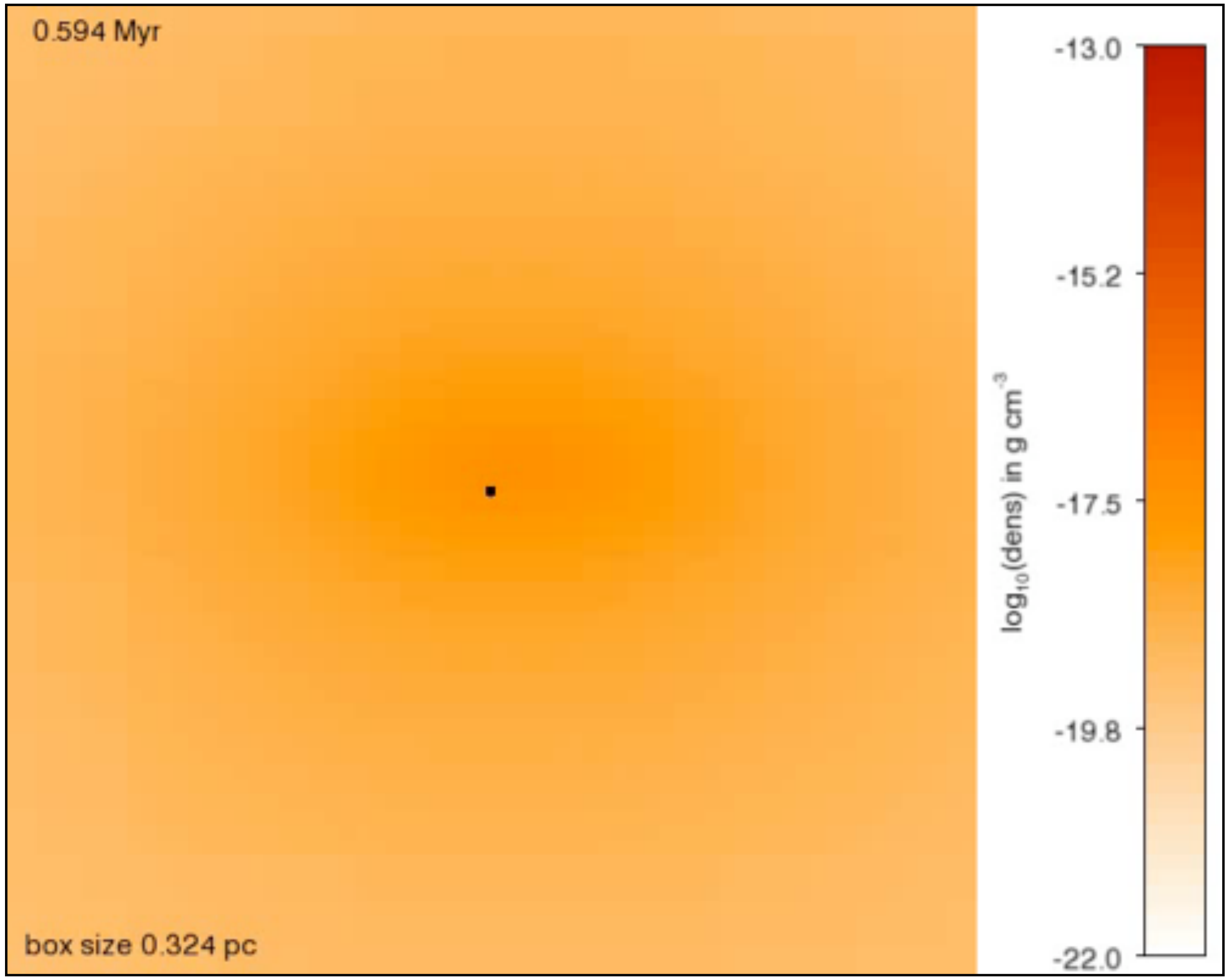
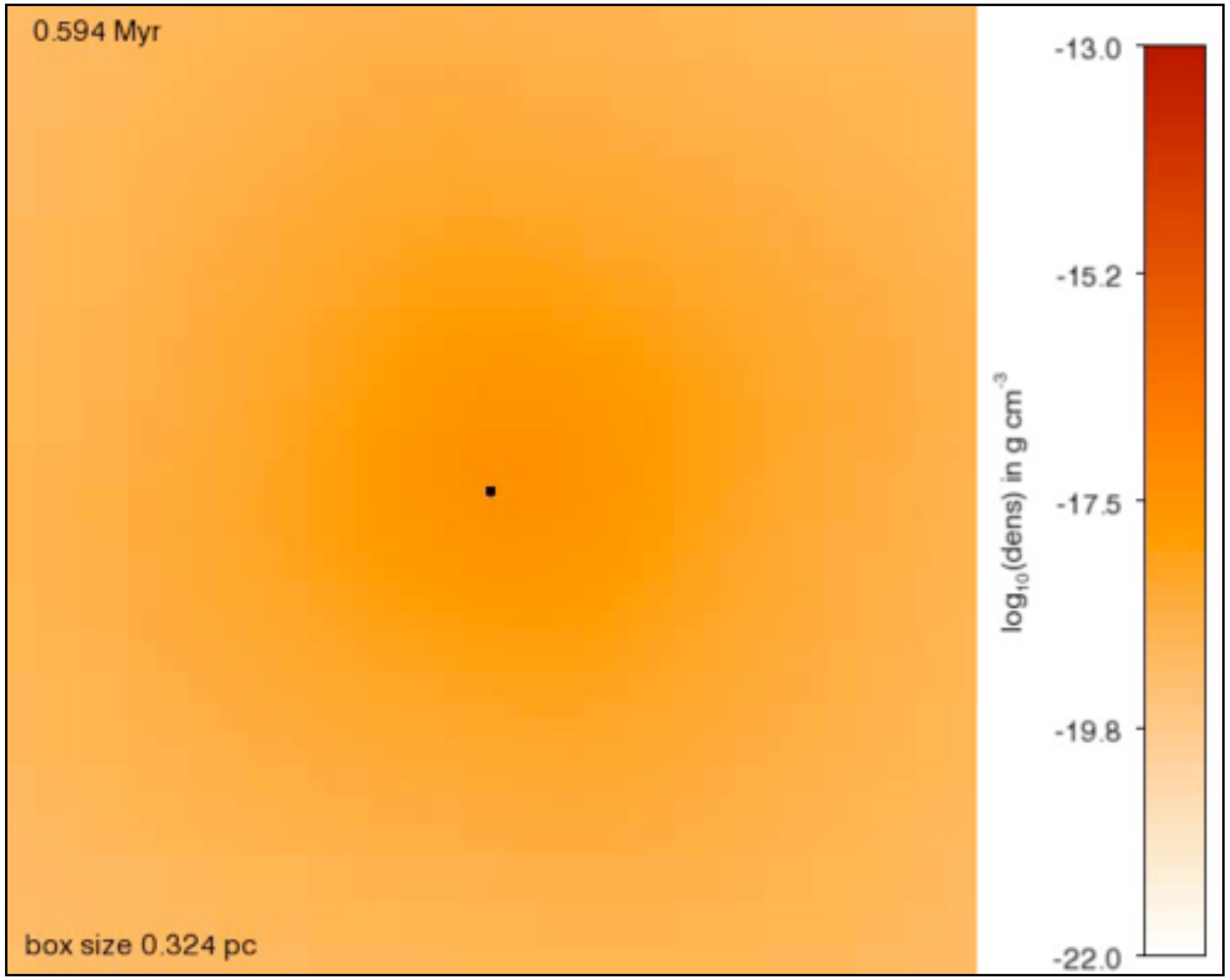
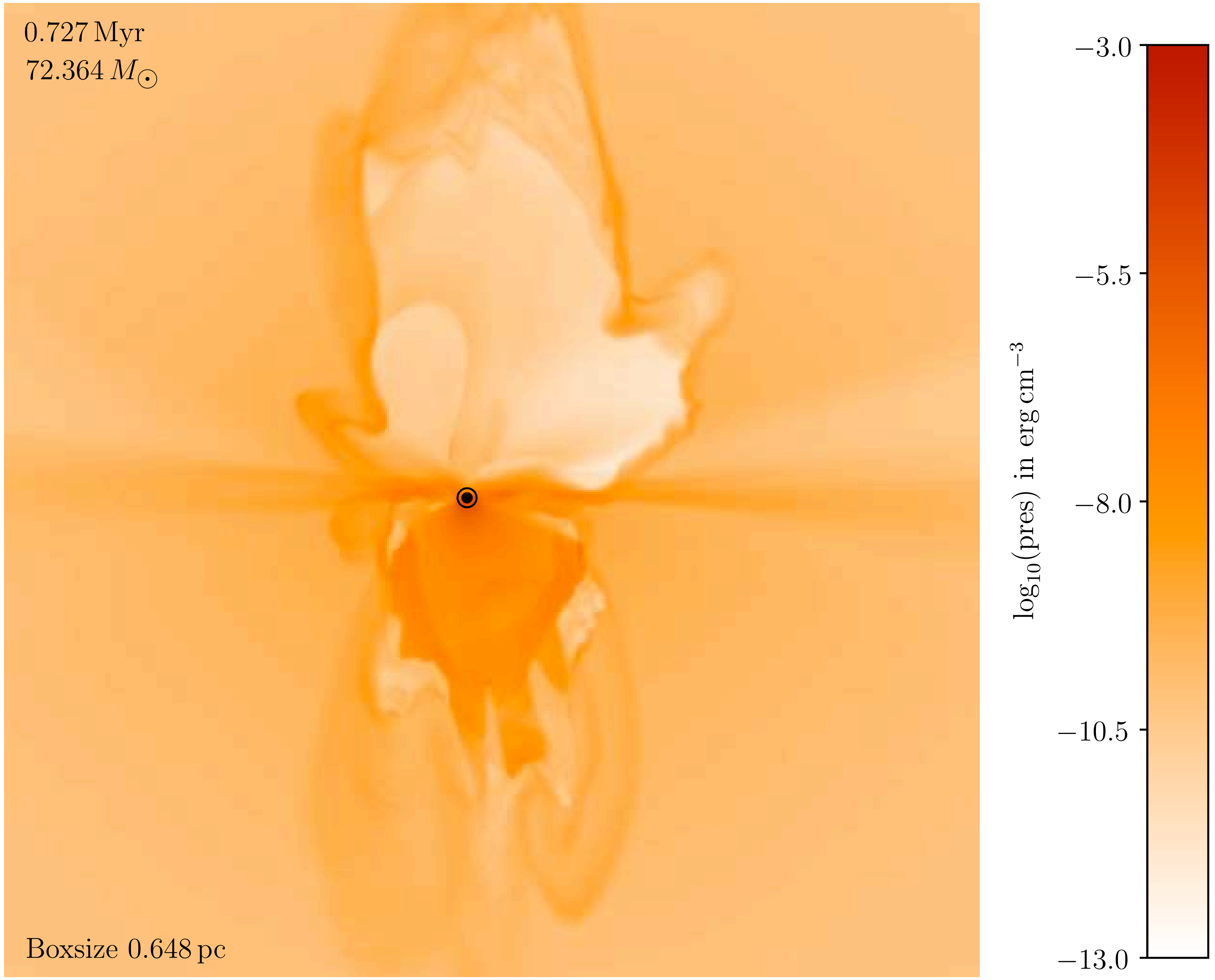


Disk edge on



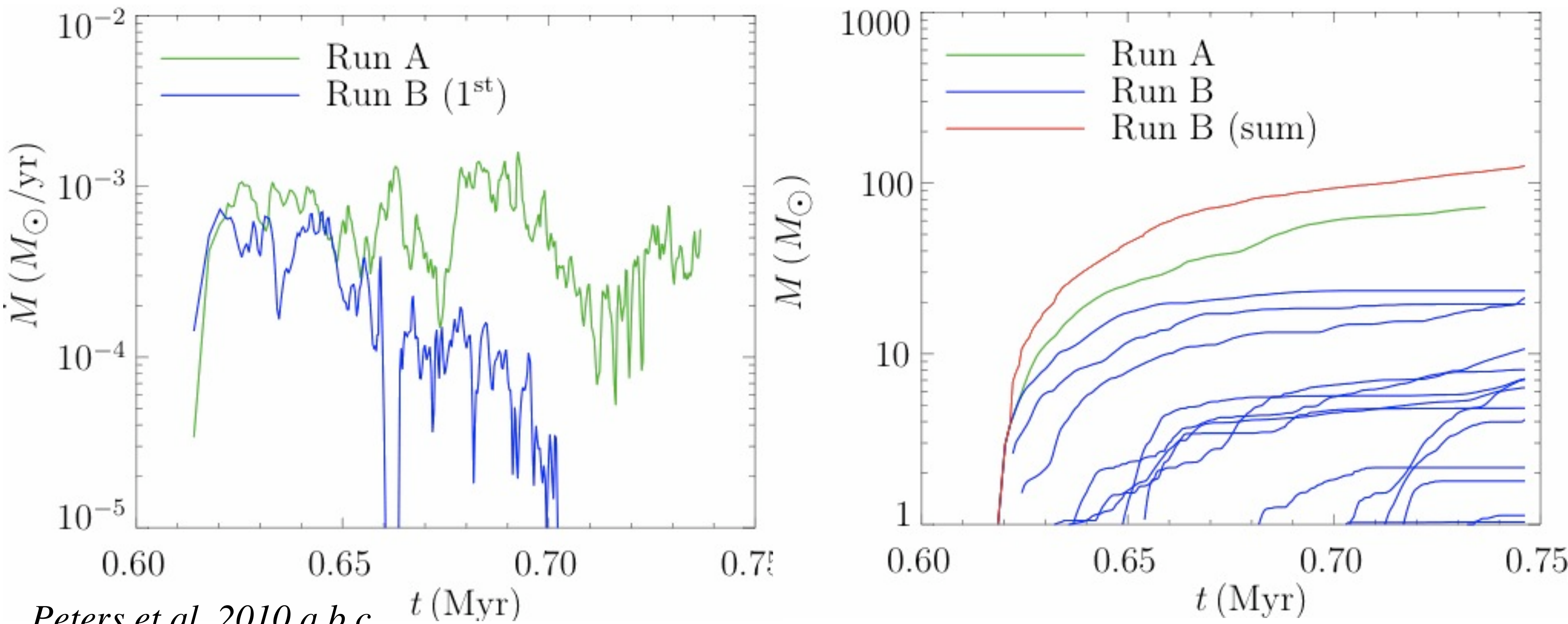
Disk plane

Dynamics of the H II Region and Outflow



- size and morphology of H II region is highly variable
- cometary H II region totally reverses within less than $10\,\mathrm{kyr}$
- changes like this have been observed!

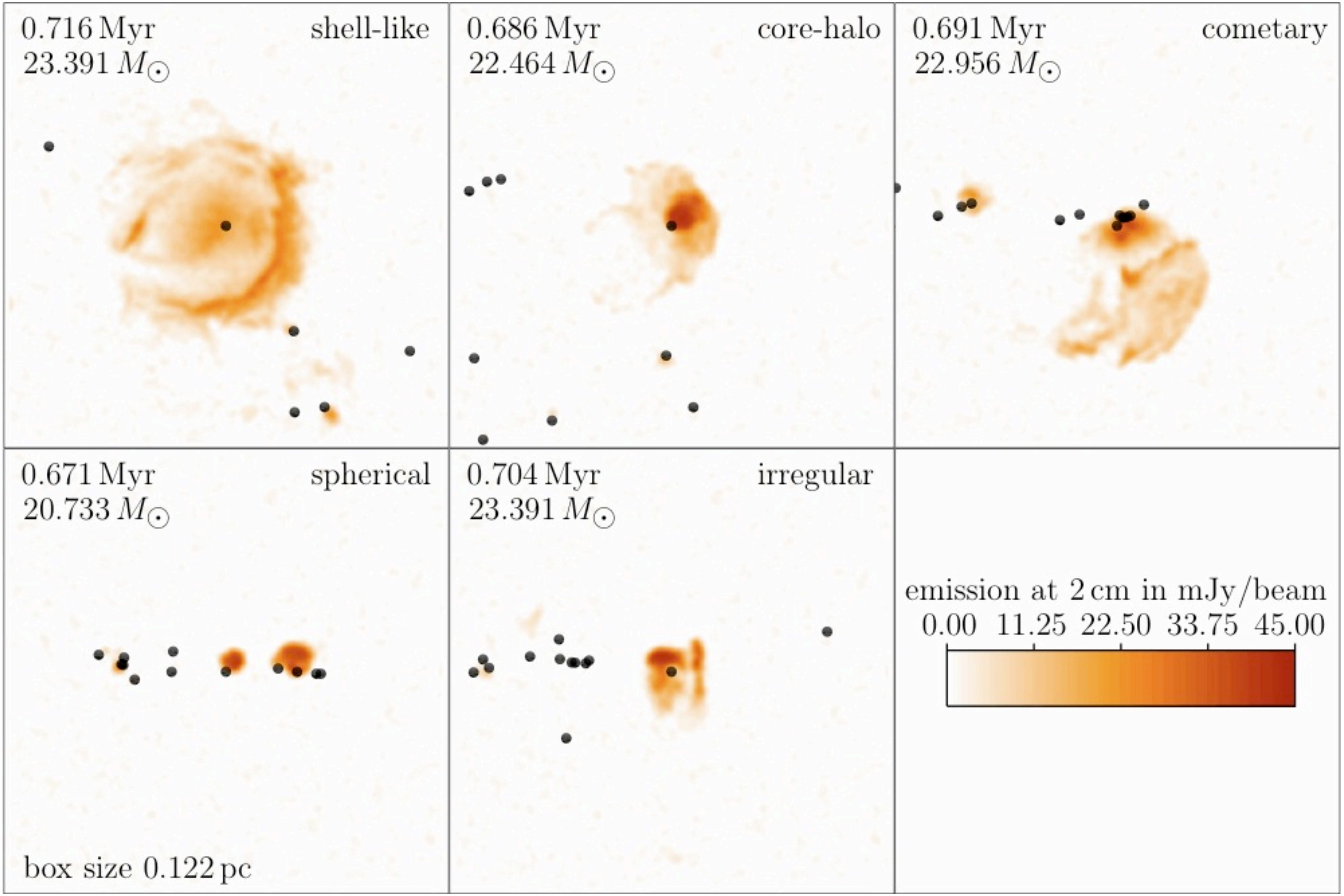
Multiple protostars: Dynamics of the H II Region



Peters et al. 2010 a,b,c

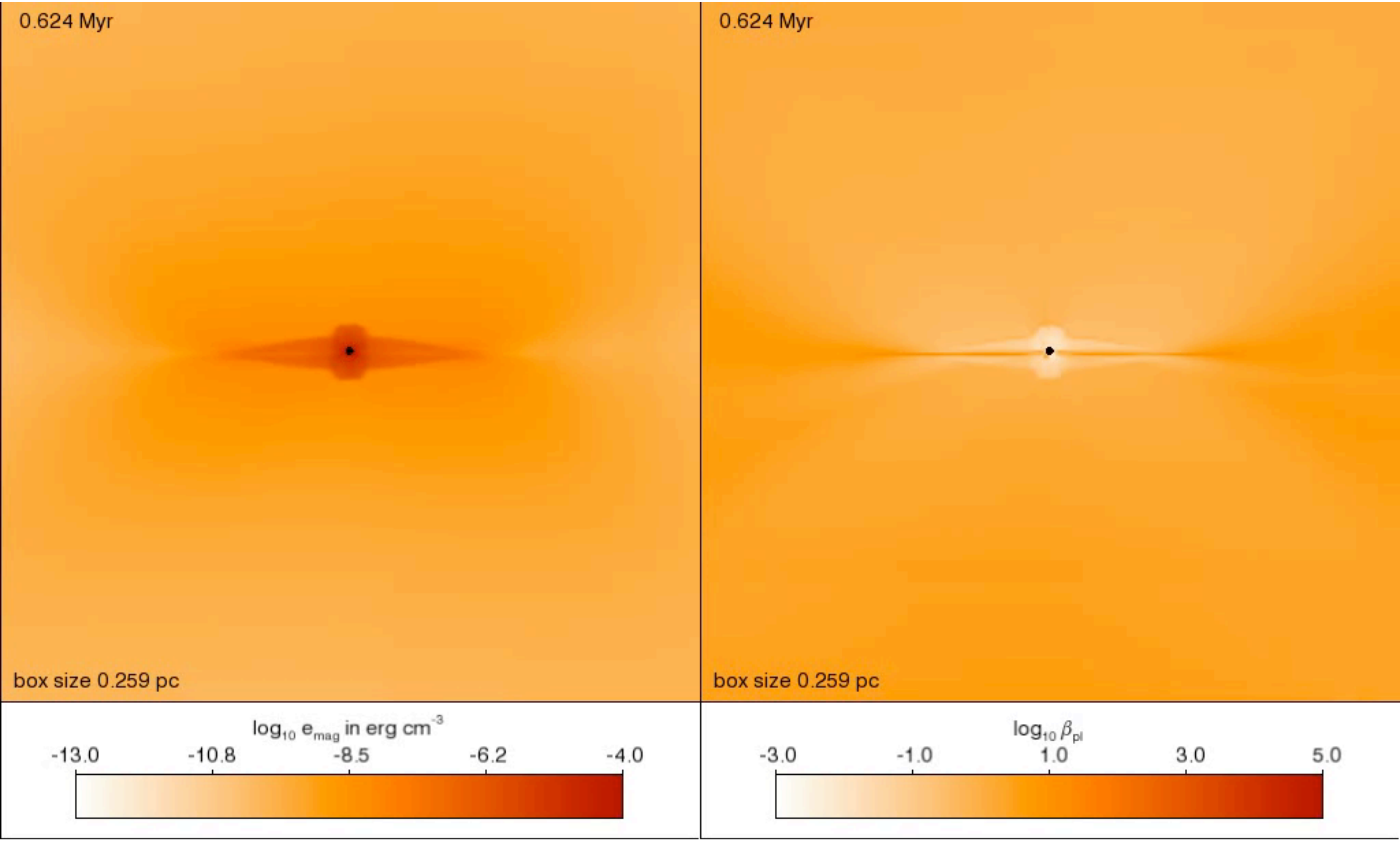
- ionization feedback does **not** shut off accretion
- **fragmentation**-induced starvation (FIS)
- massive stars form in cluster

H II Region Morphologies



Massive Star Formation: Dynamics of HII Regions

The magnetized case



Massive Star Formation: Dynamics of HII Regions

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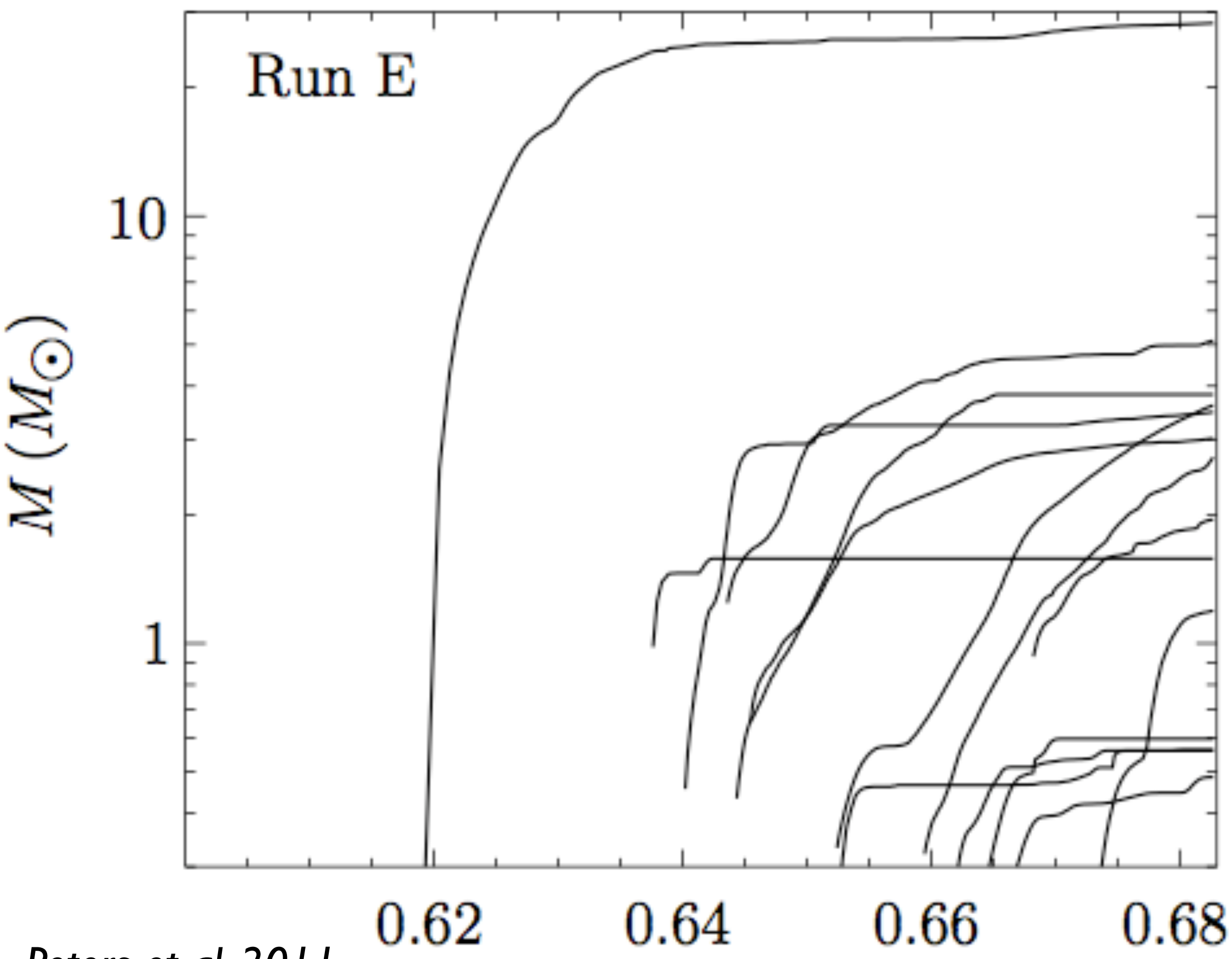
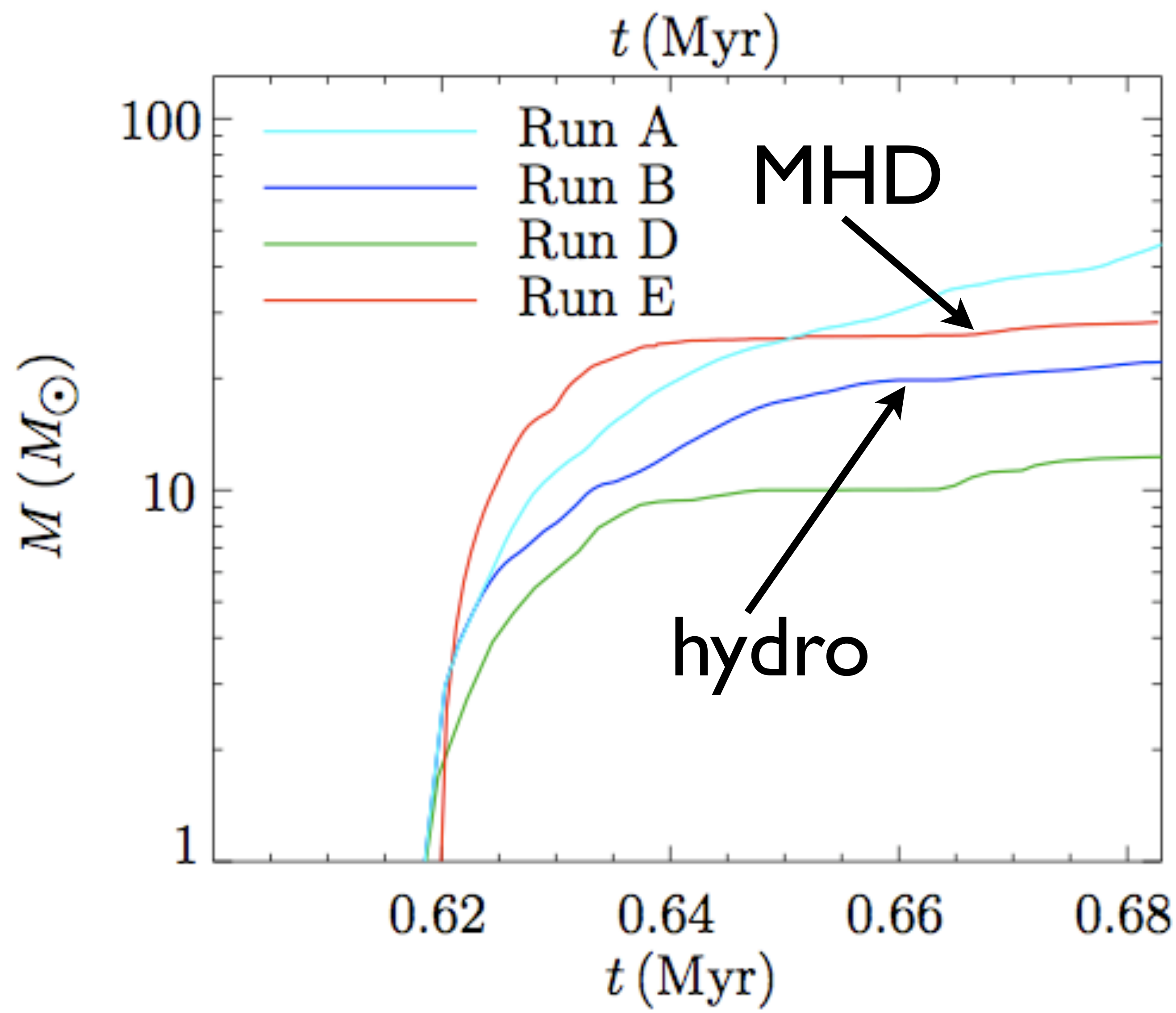
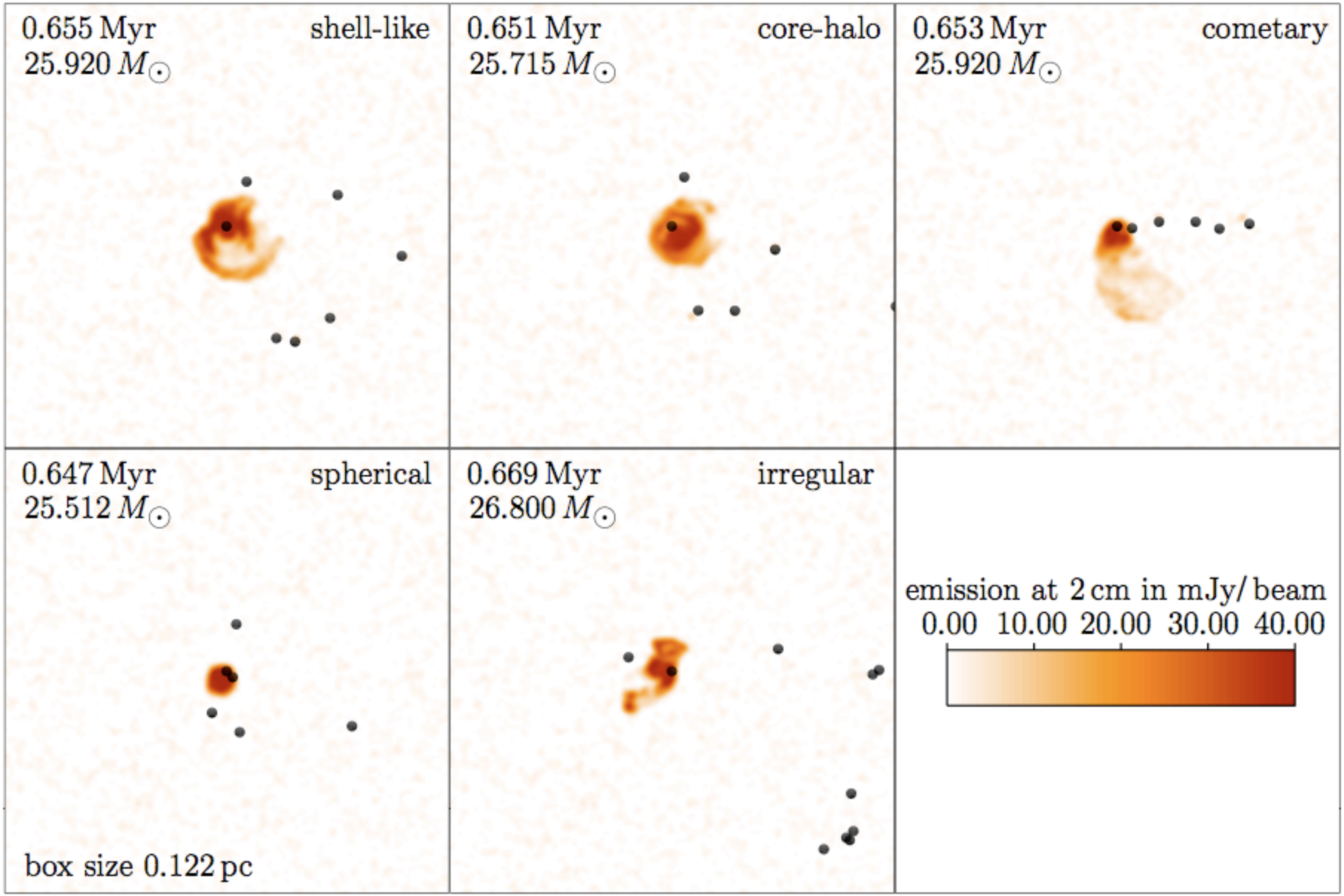


Peters et al. 2011



- suppression of fragmentation
- most massive star is more massive

H II Region Morphologies: the magentized case



Summary

Magnetic fields influence massive star formation

- Efficient transfer of angular momentum (magnetic braking)
- Suppression of fragmentation (FIS relaxed)
- Launch of outflows (less collimated than in the case of low mass stars?)
- smaller UCHII regions in the presence of magnetic fields