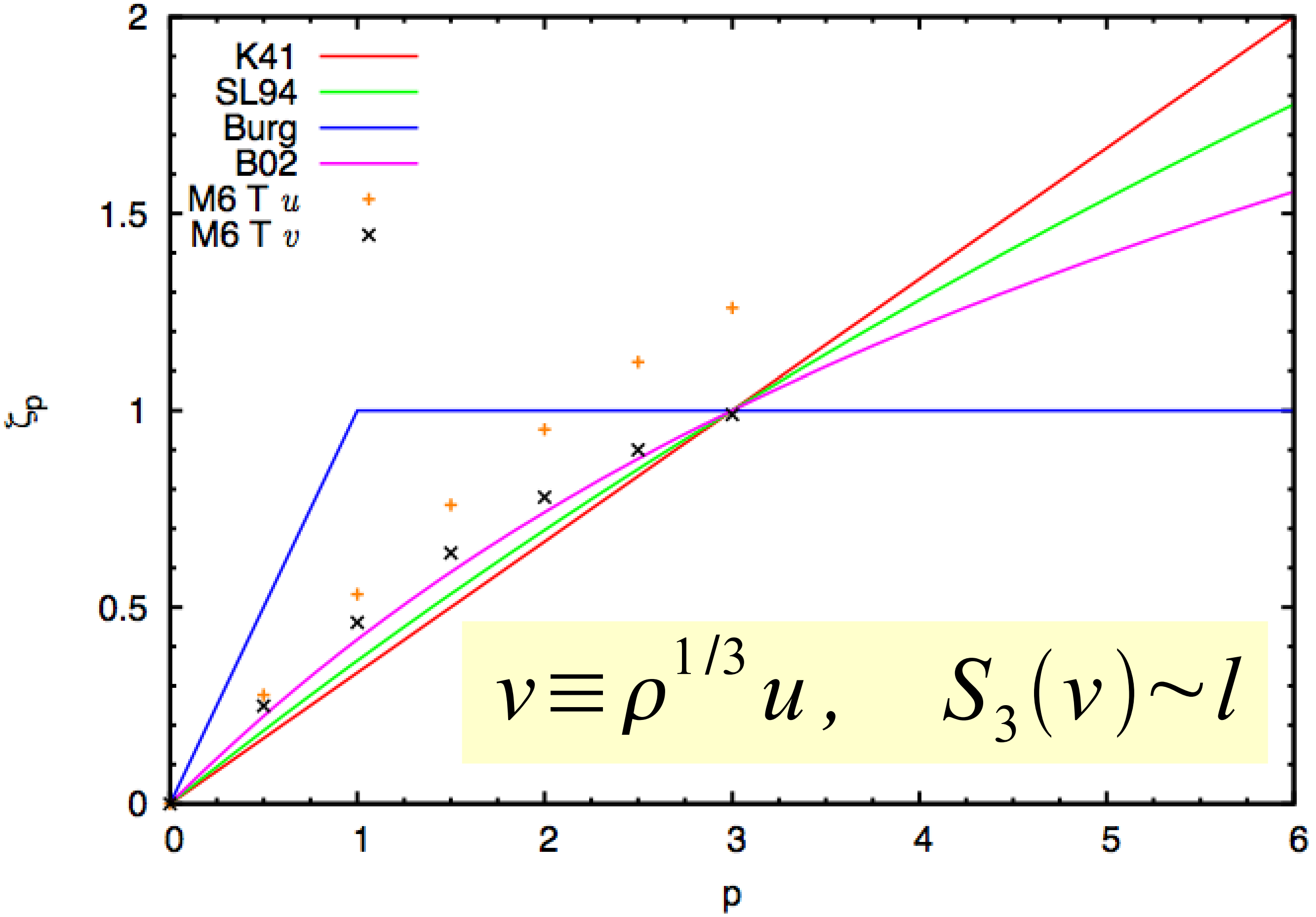
Workshop Summary (Highlights)

- Nature of Supersonic Turbulence
  - Extension of Kolmogorov cascade
  - New methods for measuring ISM turbulence
- Magnetic Field Strength
  - Correct use of Zeeman splitting upper limits
  - <B> in GMCs is well below equipartition
- Molecular Cloud Formation
  - New exceptional view of the Taurus region
  - Lots of AMR simulations coming up....
- Star Formation Rate
  - High sensitivity to $\alpha_{\rm vir}$
  - SFR determine its own $\alpha_{\rm vir}$
- MHD in SPH
  - One core one star
  - Brown dwarf origin
- Code Comparison and CADAC

Nature of Supersonic Turbulence

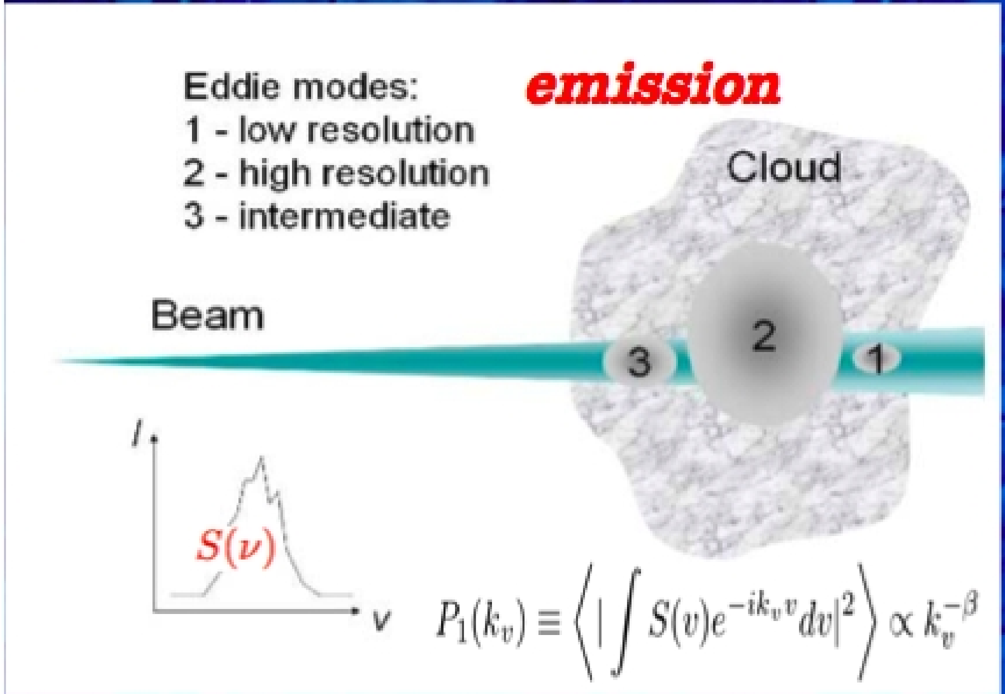


$$v \equiv \rho^{1/3} u\,, \quad S_3(v) \sim l$$

Kolmogorov cascade of energy per unit volume in supersonic turbulence:

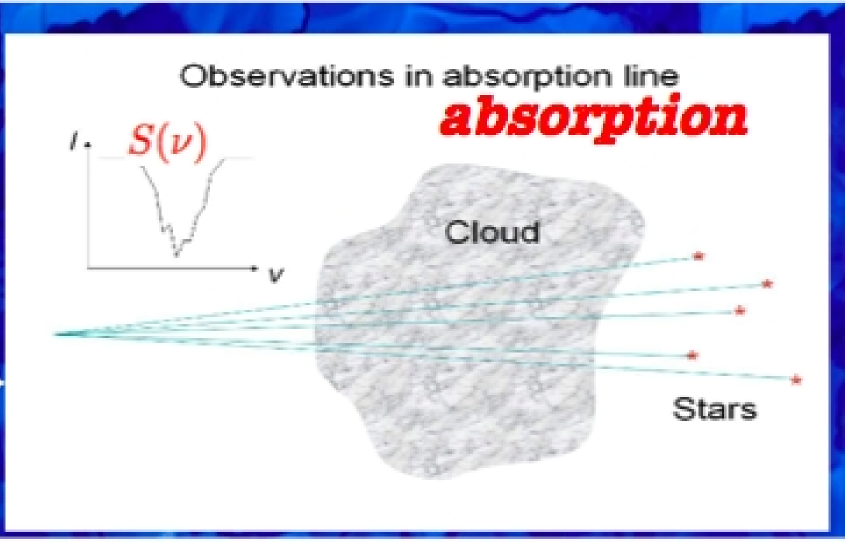
Is the third order scaling exactly linear? (Code comparison)

Velocity Coordinate Spectrum (VCS): Spectrum Along V-axis



$$P_1(k_v) \equiv \left\langle \left| \int S(v) e^{-ik_v v} dv \right|^2 \right\rangle \propto k_v^{-\beta}$$

New technique proposed in Lazarian & Pogosyan 06. Can work for resolved and unresolved objects.



Weak absorption case is simple. Saturated absorption lines are in Lazarian & Pogosyan 07

For shallow $\gamma < 0$ ***density***

LOS geometry	high resolution		low resolution
	pencil beam	flat beam	
parallel	$2(1+\gamma)/m$	$2(2+\gamma)/m$	$2(3+\gamma)/m$
crossing	$2(1+\gamma)/m$	(not a power law)	$2(2+\gamma)/m$

$\gamma = 0$ *for steep density*

Magnetic Field Strength in GMCs

A paradigm shift:

GMCs turbulence is super-Alfvenic (Padoan and Nordlund 1999)

--> GMCs are not magnetically supported.
--> Protostellar cores are not formed by AD-driven contraction in quasi-static clouds.

Historical “wish” for a strong B (no direct evidence):

- Turbulence decay (gone!)
- Low star formation rate (gone!)

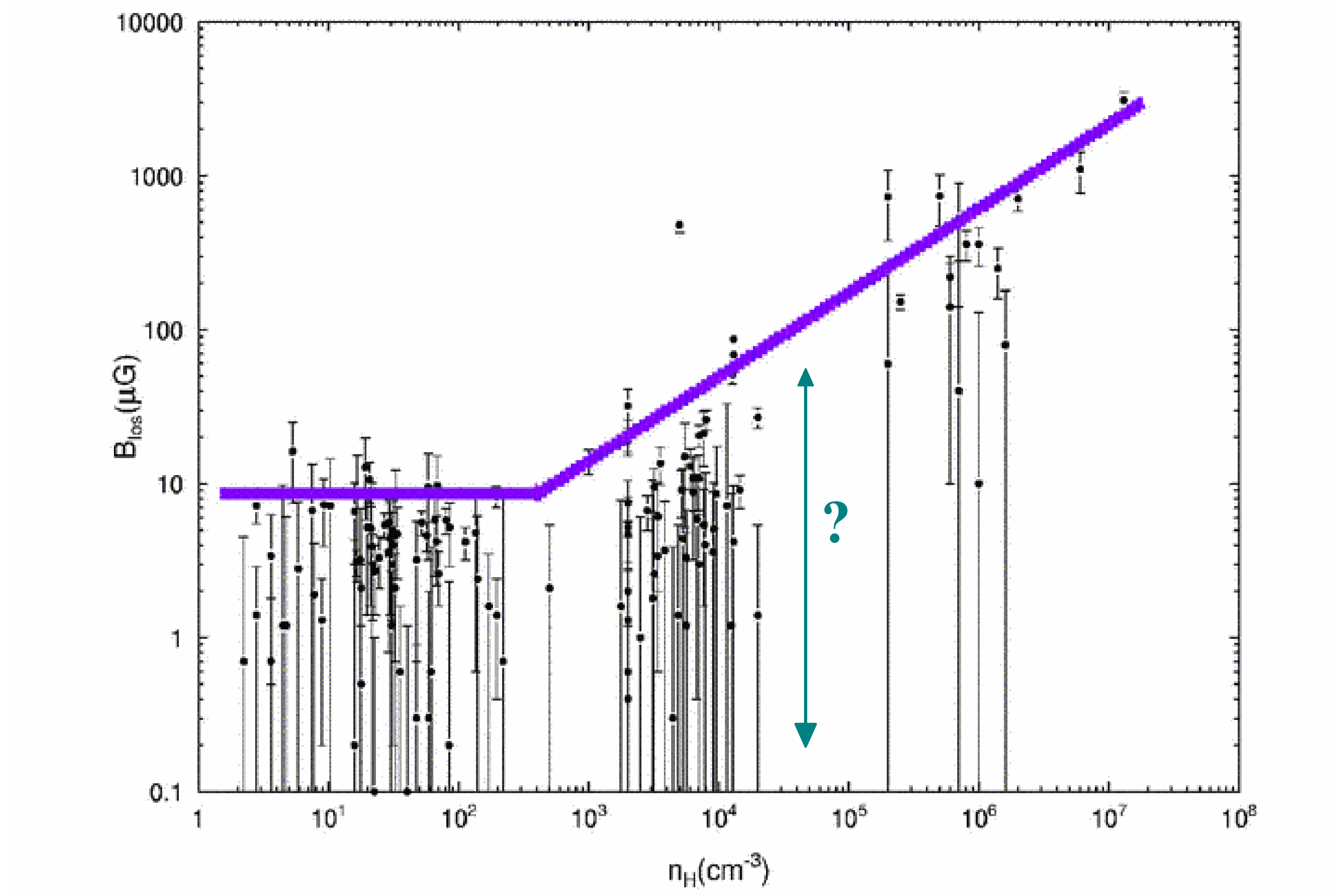
Zeeman Splitting measurements in dense regions:

Real B fluctuations or only random orientation of a constant B?

Crutcher et al. 2008:

Real fluctuations (large ones!), as predicted by the super-Alfvenic model

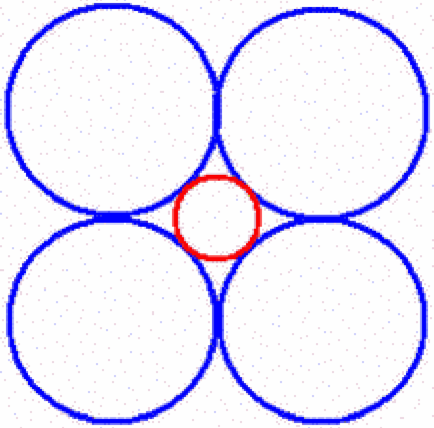
--> A strong <B> is ruled out

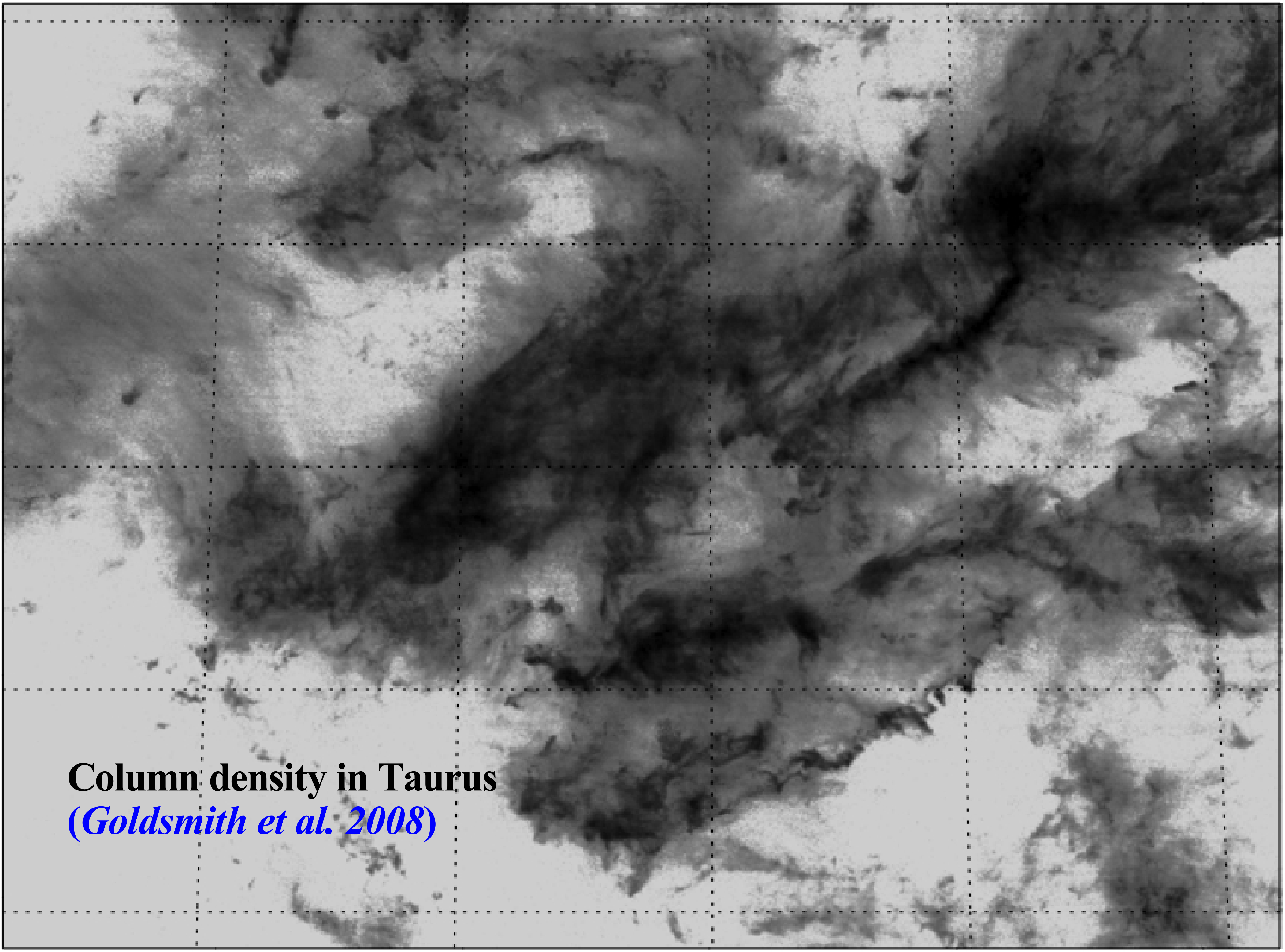


The Future

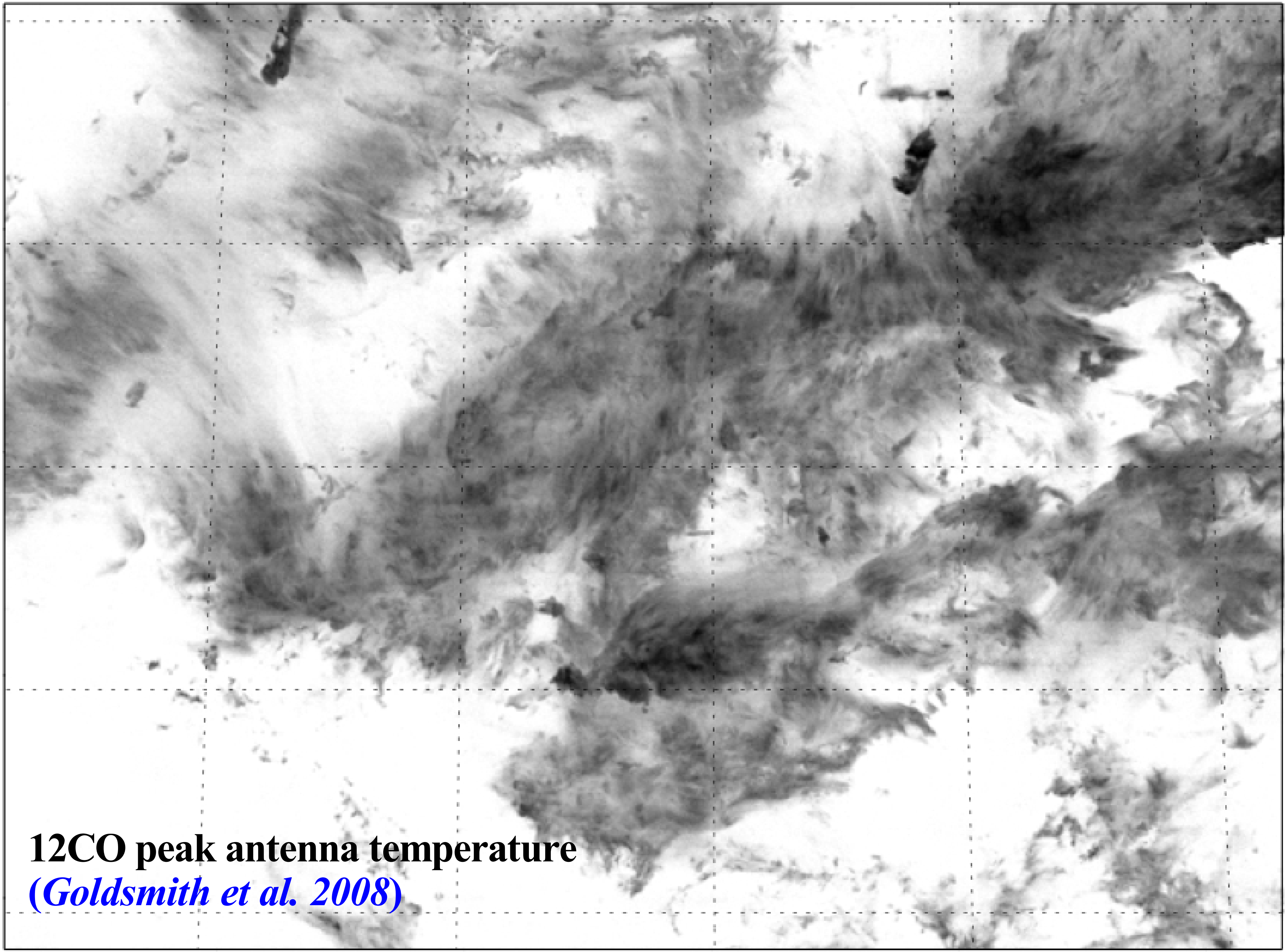
Measure differential M/Φ between core and envelope:

$$\frac{[M/\Phi]_{core}}{[M/\Phi]_{envelope}} = \frac{[T_{line}\,\Delta V / B_{los}]_{core}}{[T_{line}\,\Delta V / B_{los}]_{envelope}}$$



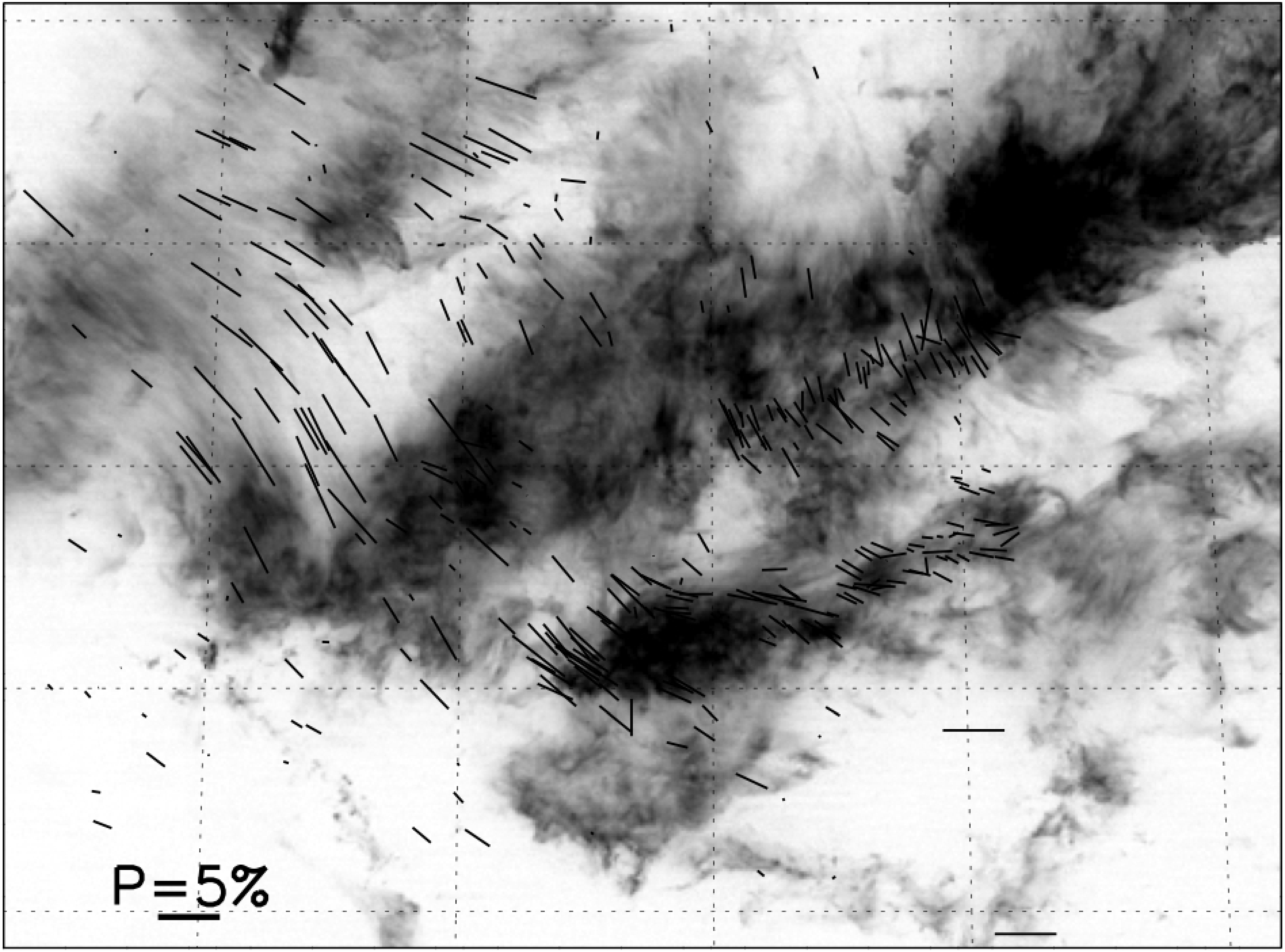


Column density in Taurus
(*Goldsmith et al. 2008*)



12CO peak antenna temperature

(*Goldsmith et al. 2008*)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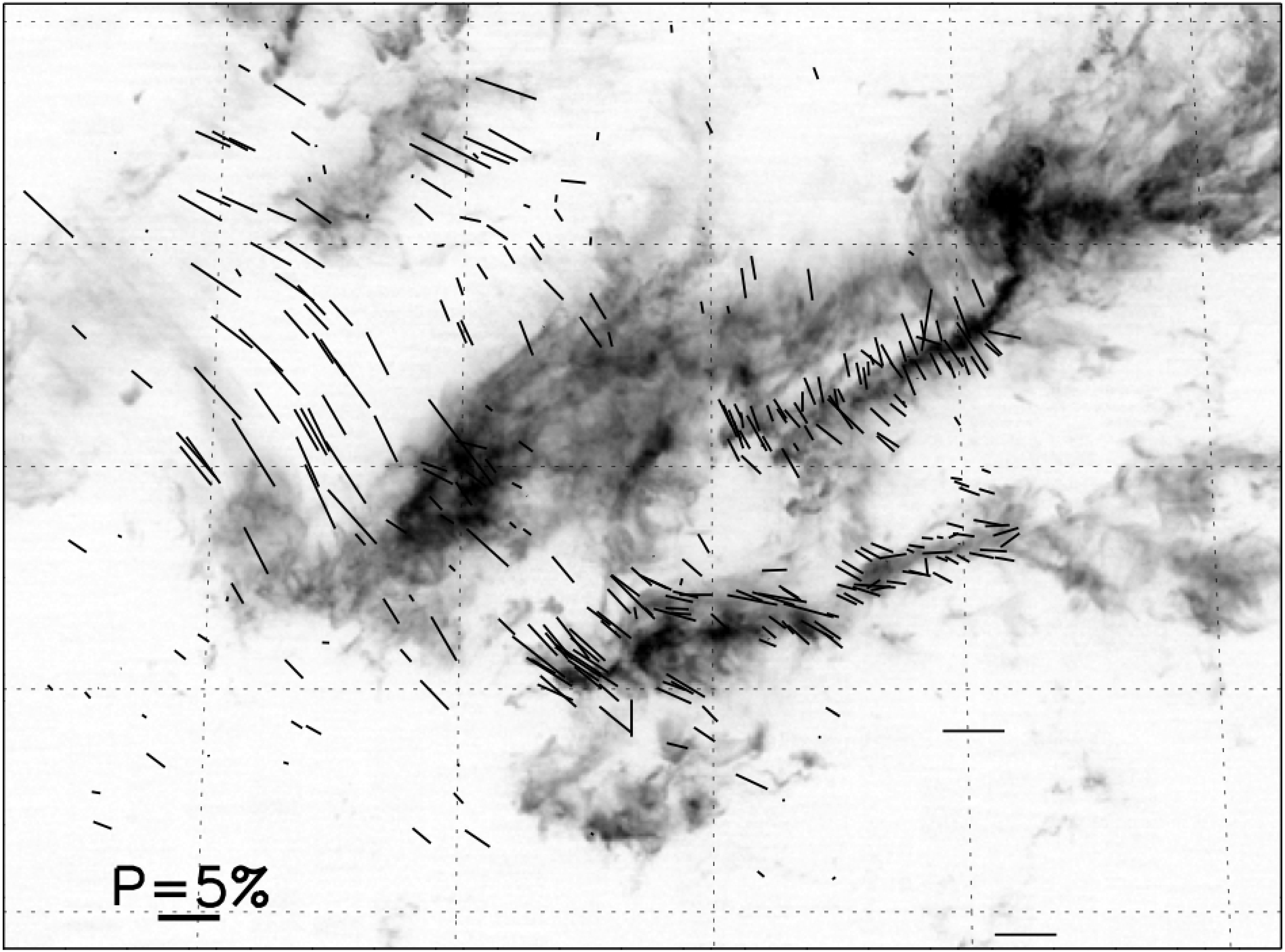
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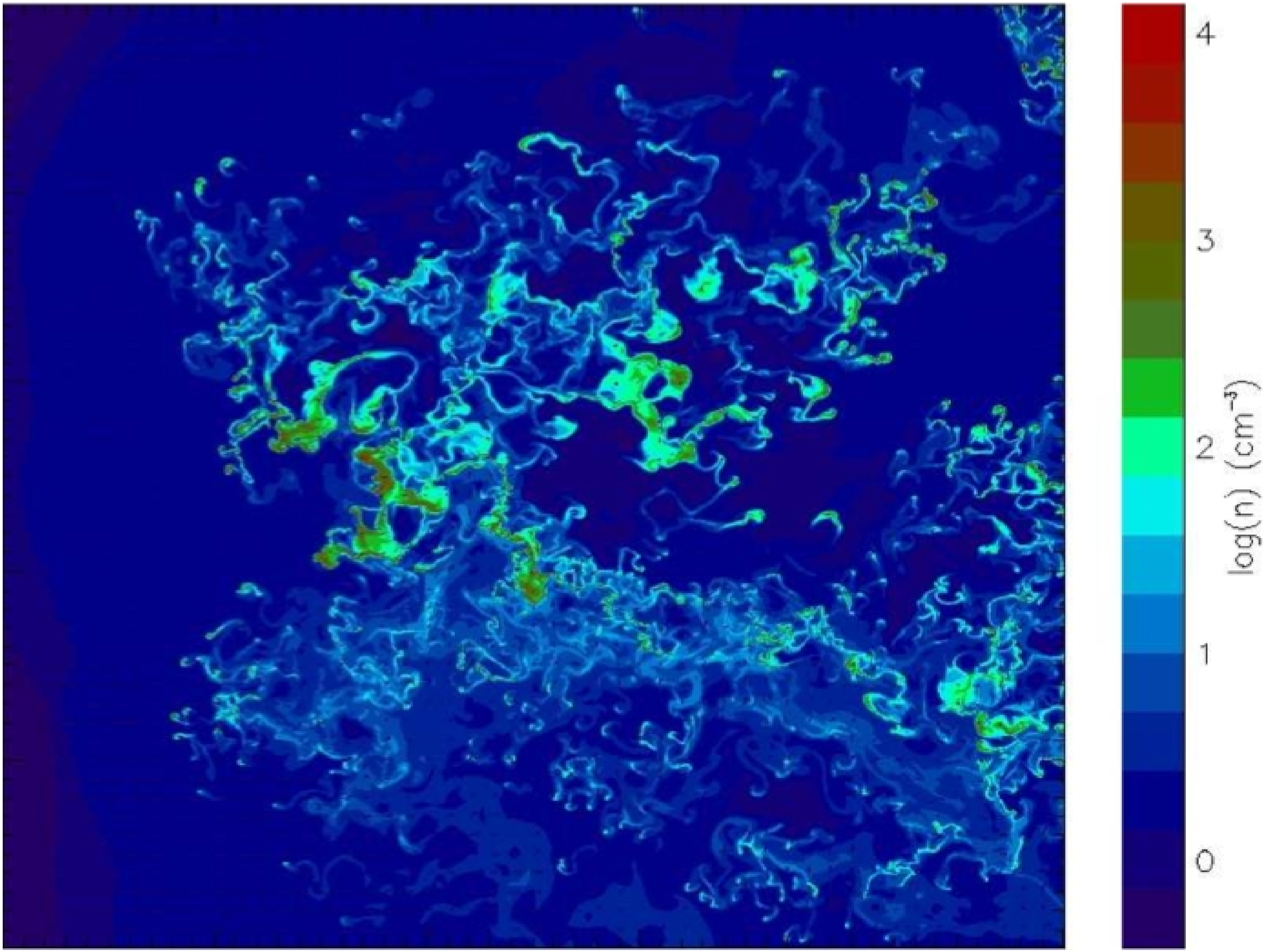


Hennebelle & Audit 2007

The Star Formation Rate and the Virial Parameter

The challenge: Low star formation rate, ~ 1% per free fall time:

1. Magnetic support + ambipolar drift (several problems)

2. Turbulence: Most of the mass is "sterile" due to turbulent support.

The $SFR_{\rm ff}$ due to turbulence may be derived from the **sonic scale**:
*(Padoan 1995, Vazquez-Semadeni et al. 2003, **Krumholz & McKee 2005**)*

$$SFR_{\rm ff} = 0.014 \left(\frac{\alpha_{\rm vir}}{1.3}\right)^{-0.68} \left(\frac{M_{\rm s}}{100}\right)^{-0.32}$$

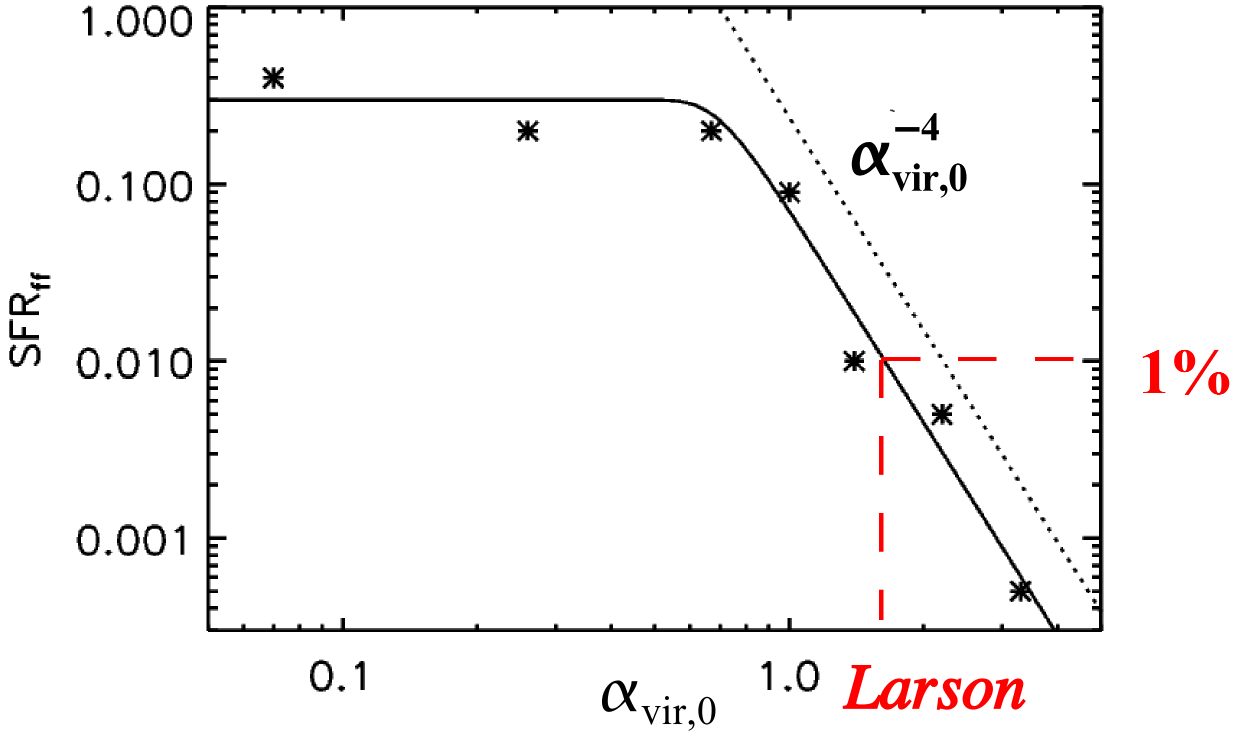
New simulations and new approach: Self-gravity + sink particles **in unigrid**

Dimensionless parameters: $\alpha_{\rm vir}, M_{\rm s}, M_{\rm A}$

Main result: Very strong dependence of $SFR_{\rm ff}$ on $\alpha_{\rm vir,0}$

Star formation is an on/off process, the "switch" is $\alpha_{\mathrm{vir},0} \sim 1$

With $\alpha_{\mathrm{vir},0} < 1$ the turbulence cannot provide support against rapid star formation:



The local α_{vir} is the reason for the global star-formation threshold:

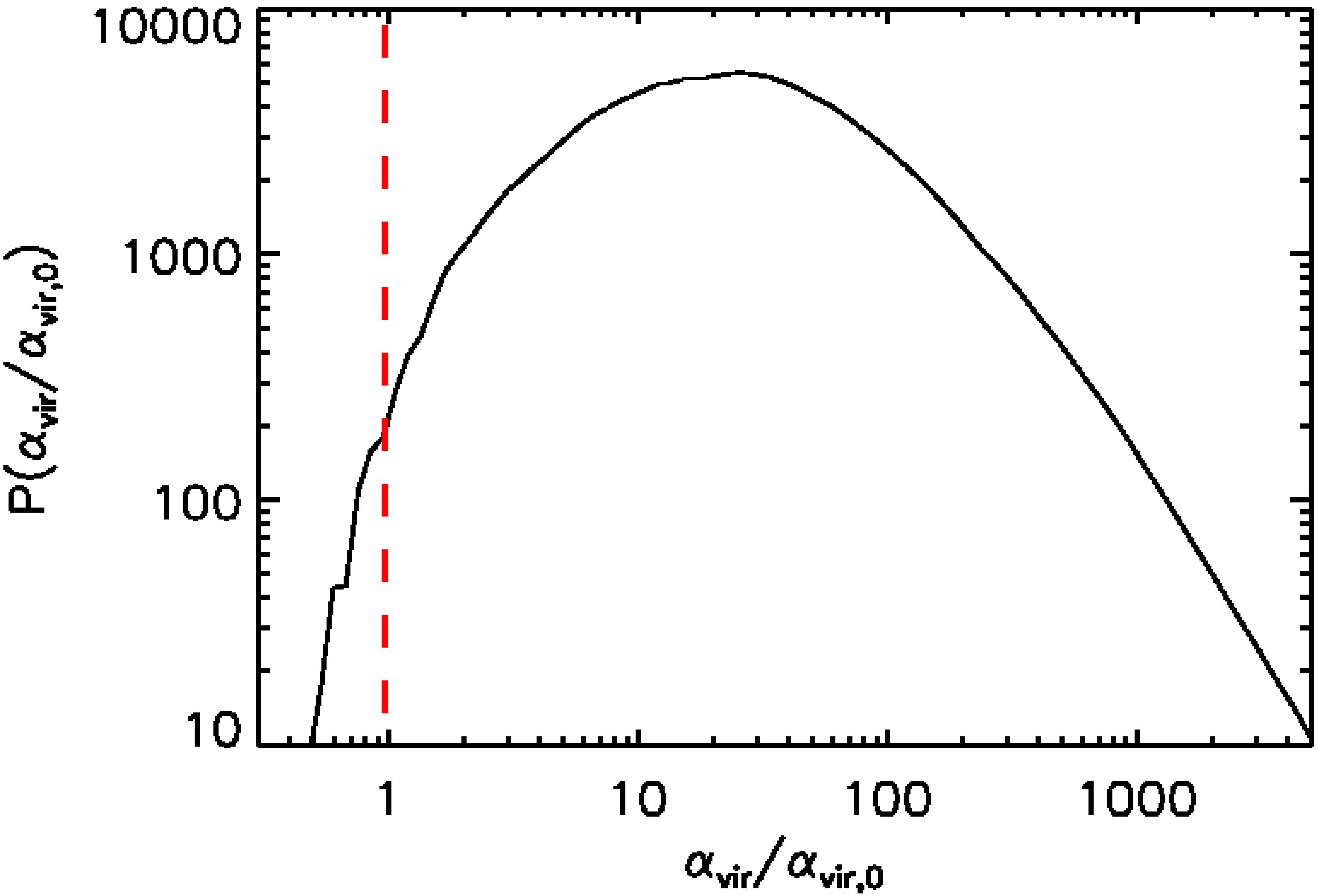
1. $\alpha_{\mathrm{vir}} < 1$ is required locally for collapse

2. The minimum local α_{vir} is comparable to the global $\alpha_{\mathrm{vir},0}$

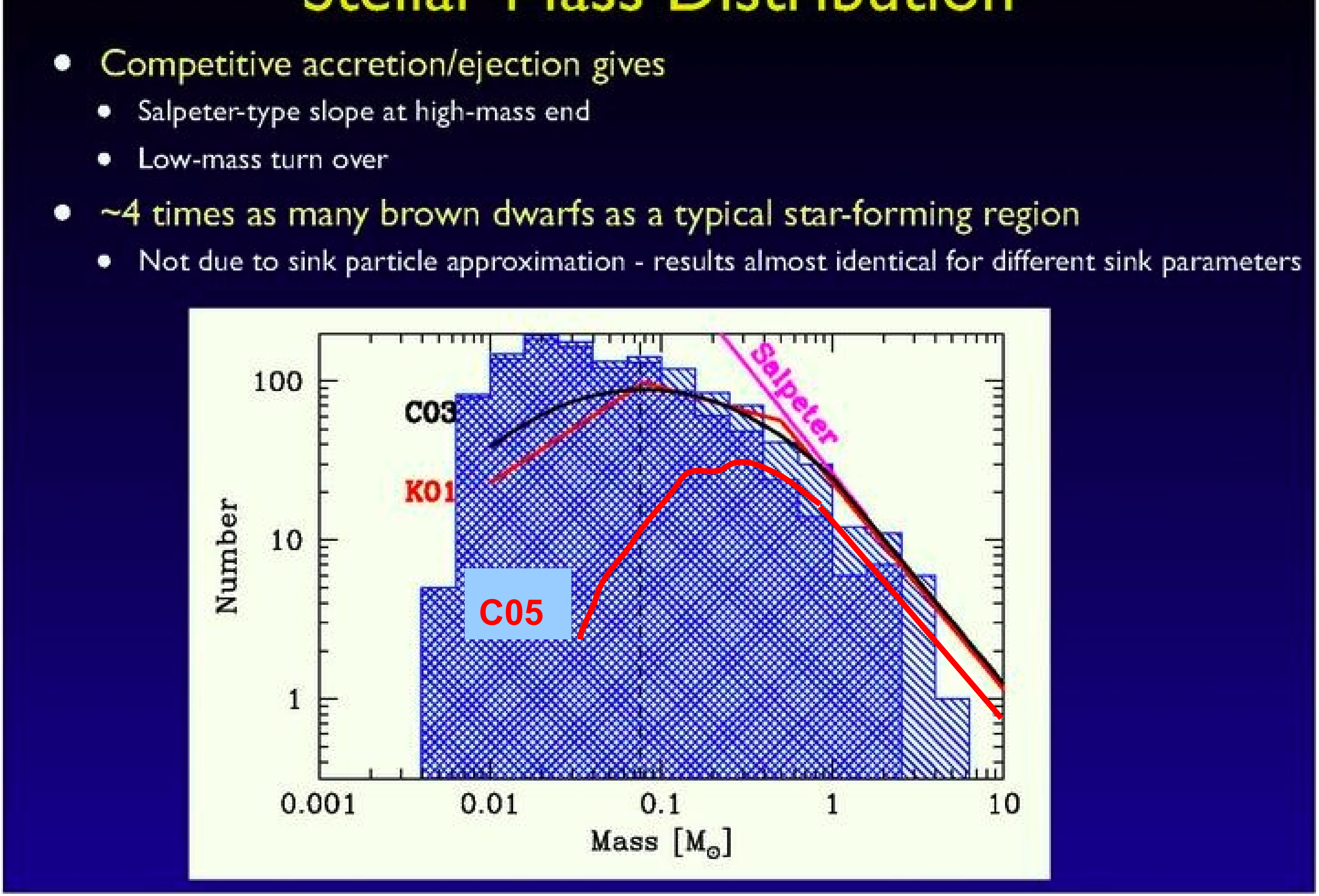
Mass-weighted histogram of the virial parameter (no self-gravity)

Fundamental property of supersonic turbulence due to oblique shocks:

The pdf of α_{vir} barely extends to its global value, $\alpha_{\mathrm{vir,0}}$:



The local α_{vir} knows about the global one



- Competitive accretion/ejection gives
  - Salpeter-type slope at high-mass end
  - Low-mass turn over
- ~4 times as many brown dwarfs as a typical star-forming region
  - Not due to sink particle approximation - results almost identical for different sink parameters

Bate et al. 2007

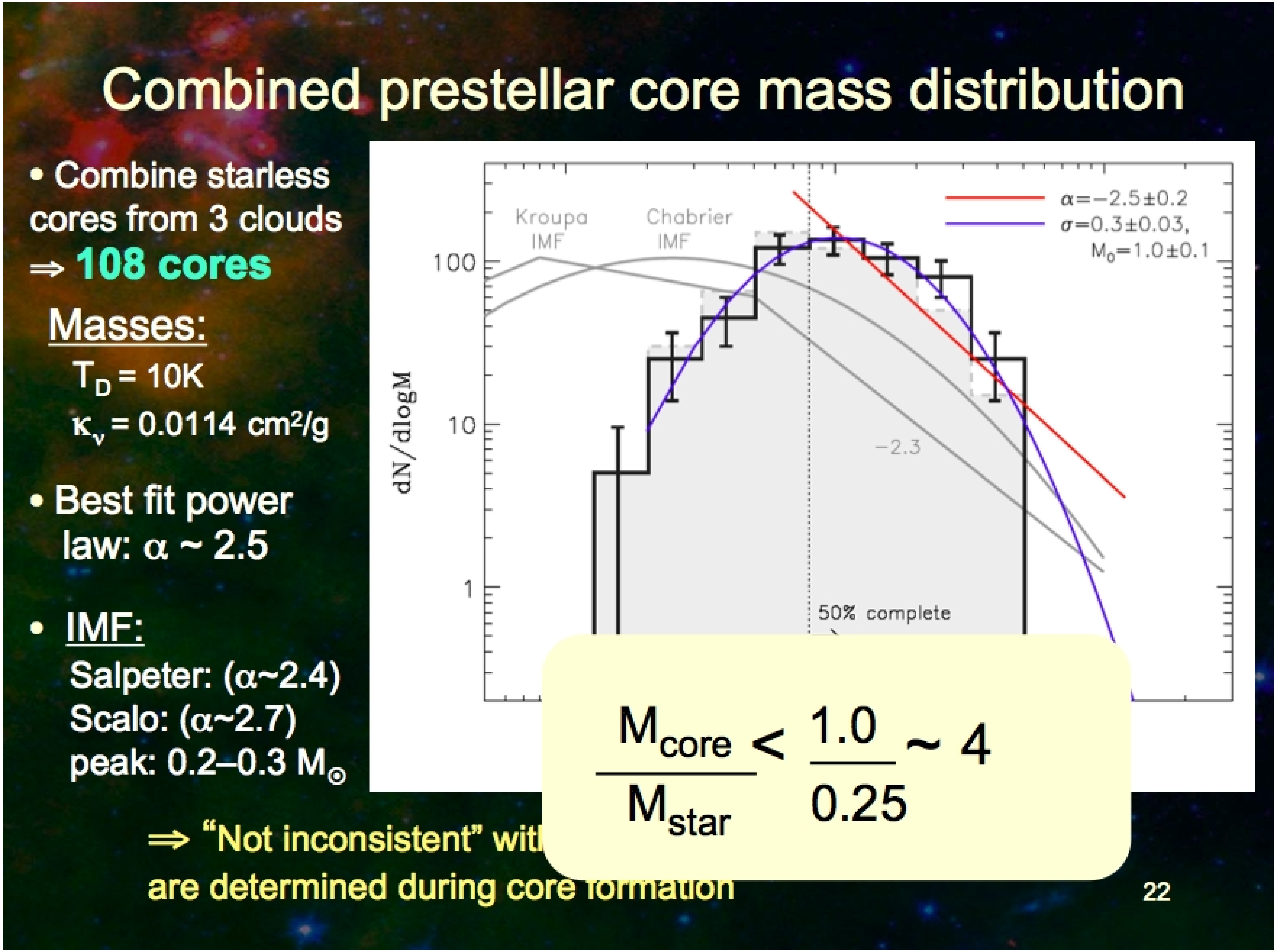
We must revisit previous results:

- Back to the one-core-one-star picture
- Origin of Brown Dwarfs from disk fragmentation is probably incorrect

We now know the characteristic mass of prestellar cores

--> One core one stars

Enoch 2007



Combined prestellar core mass distribution

- Combine starless cores from 3 clouds
  ⇒ **108 cores**

  Masses:
  $T_D = 10K$
  $\kappa_\nu = 0.0114\ cm^2/g$

- Best fit power law: α ~ 2.5

- IMF:
  Salpeter: (α~2.4)
  Scalo: (α~2.7)
  peak: 0.2–0.3 $M_\odot$

$$\frac{M_{core}}{M_{star}} < \frac{1.0}{0.25} \sim 4$$

⇒ “Not inconsistent” wit

are determined during core formation

Code Comparison and CADAC
(Computational Astrophysics Data Analysis Center)

Name	Code	Resolution	HD/MHD	AMR	Sinks	Present	By Tuesday....
Åke Nordlund	Stagger-Code	1,000^3	HD & MHD	No	Yes	Yes	Problem 1, 500^3
Alexei Kritsuk	Enzo	2,048^3	HD	Yes	Yes	Yes	Problem 1, 512^3
Daniel Price	Phantom-SPH	512^3, maybe 1024^3 (particles)	HD & hopefully MHD	No	No	Yes	Problem 1, 256^3
Charles Hansen	Orion	1024^3	HD	Yes	Yes	No	Problem 1, 512^3
Romain Teyssier	RAMSES	1024^3	HD & MHD	Yes	hopefully	No	
Anne-Katharina Jappsen	Gadget-2	to be decided	HD	No	Yes	No	
Jongsoo Kim	TVD or HLL	1024^3	HD	No	No	No	Problem 1, 512^3
Axel Brandenburg	Pencil Code	1024^3	HD & MHD	No	No	Yes	Problem 1, 512^3
Mario Flock	PLUTO	512^3	HD & MHD	No	No	No	
Christoph Federrath	FLASH	to be decided	HD & MHD	Yes	Yes	No	
Jonathan Carroll	Astrocub	1024^3	HD & MHD	No	No	No	
Pak Shing Li	ZEUS-MP	256^3, 512^3	HD & MHD	No	No	Yes	Problem 1
Hubert Klahr	F-TRAMP	to be decided	HD	No	No	Yes	Problem 1
Rolf Kuiper	Petsc	tbd.	HD	No	No	Yes	
Ralf Klessen	Gadget	tbd.	HD	—	Yes	No	Problem 2
Ruben Krasnopolsky	Zeus	tbd.	MHD	No	No	Yes	
David Collins	Enzo/PPM-L	1024^3	MHD	Maybe	Probably	Yes	