Gravitational Collapse in Turbulent Clouds

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and
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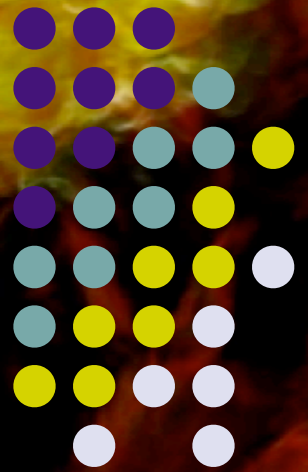


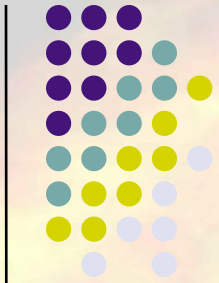
Ta ta! – at this conference:

- Selfgravity and sink particles by the ***driven supersonic MHD turbulence mafia ;-!***
- Magnetic fields by the ***SPH-never-crashes-and-produces-great-movies mafia ;-!***

Main questions:

- **What determines the Star Formation Rate?**
  - **Is it really ”independent of density” (Krumholz & Tan, 2007) – if so why?**
- **What determines the Initial Mass Function?**
  - **Is it really ”the same everywhere” (Elmegreen 200X, ...) – if so why?**

Other questions:



Other questions:

- What is the distribution of magnetic fields in star forming regions?
  - Why is there a B-n relation?
- How do magnetic fields influence star formation (star formation rate + initial mass function)?
  - WDYM 'how'?!
  - 1) 'how much??', 2) 'how does it work??'

Numerical Models with Selfgravity and Magnetic Fields

- **AMR MHD code (RAMSES; Theyssier et al.) with selfgravity and barotropic equation of state**
  - **$512^3 \rightarrow 8192^3$; refining on Jeans' mass only**
  - **HD and MHD**
- **Unigrid MHD code (Stagger Code; ÅN et al.) with selfgravity and sink particles**
  - **500^3 and 250^3 experiments**
  - **HD and MHD, with and w/o driving, ...**

We really must use MHD to get things right!

- Pre-stellar core mass distribution
  - and hence the IMF
- Initial level of turbulence and angular momentum in BE-like cores
  - initial conditions for collapse
- Loss of angular momentum, fragmentation
  - and we need to make jets!!

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    - Quantitatively similar results in MHD
    - HD is more demanding – some aspects differ
      - STAR FORMATION RATE IS ~THE SAME

Trends Investigated

- Dependence of SFR
  - on mass density
  - on Mach number
  - on magnetic field strength
- Dependence of IMF
  - on MHD vs. HD
  - on time
  - on density

Initial States

- Snapshots from driven turbulence, Mach~10 (Padoan et al 2007, ApJ)
  - 1000^3 HD, Stagger Code
  - 1000^3 MHD, Stagger Code

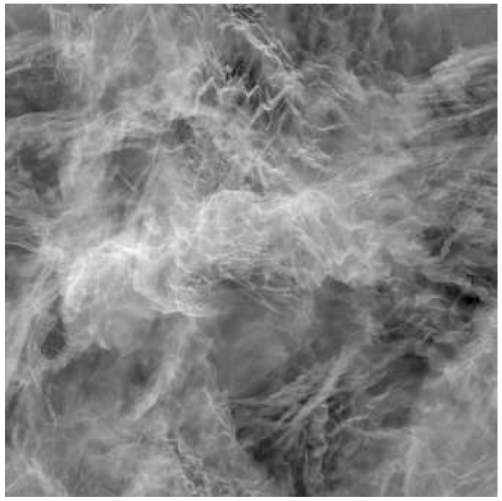

FIG. 1.— Logarithm of projected density from a snapshot of the Stagger-Code HD run.

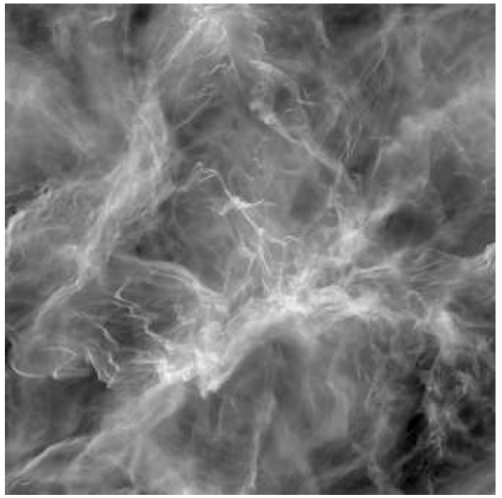

FIG. 2.— Logarithm of projected density from a snapshot of the Stagger-Code MHD run.

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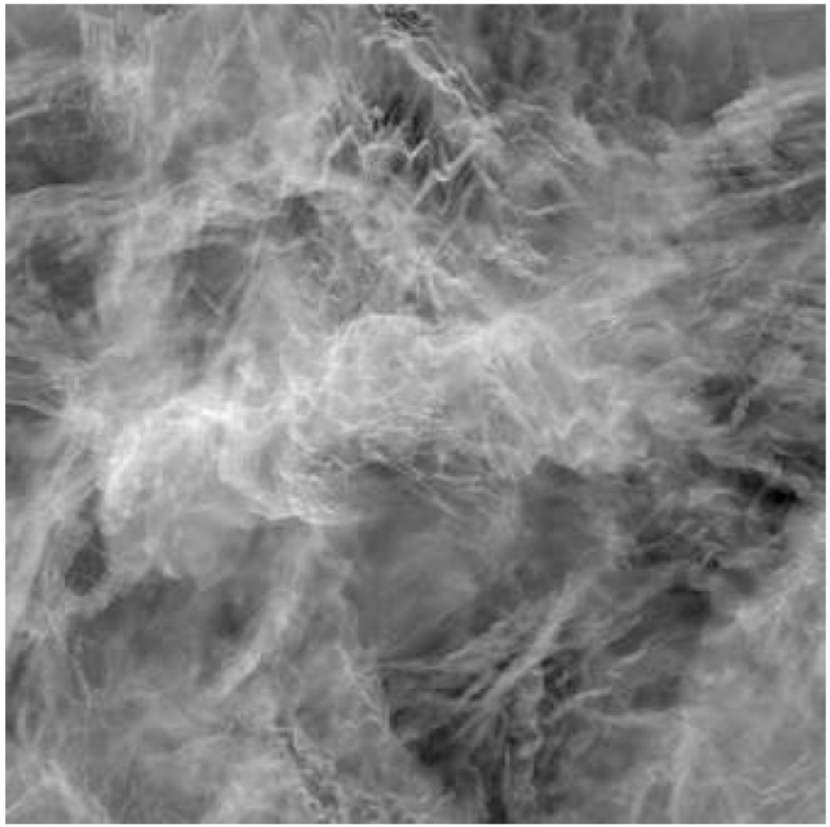

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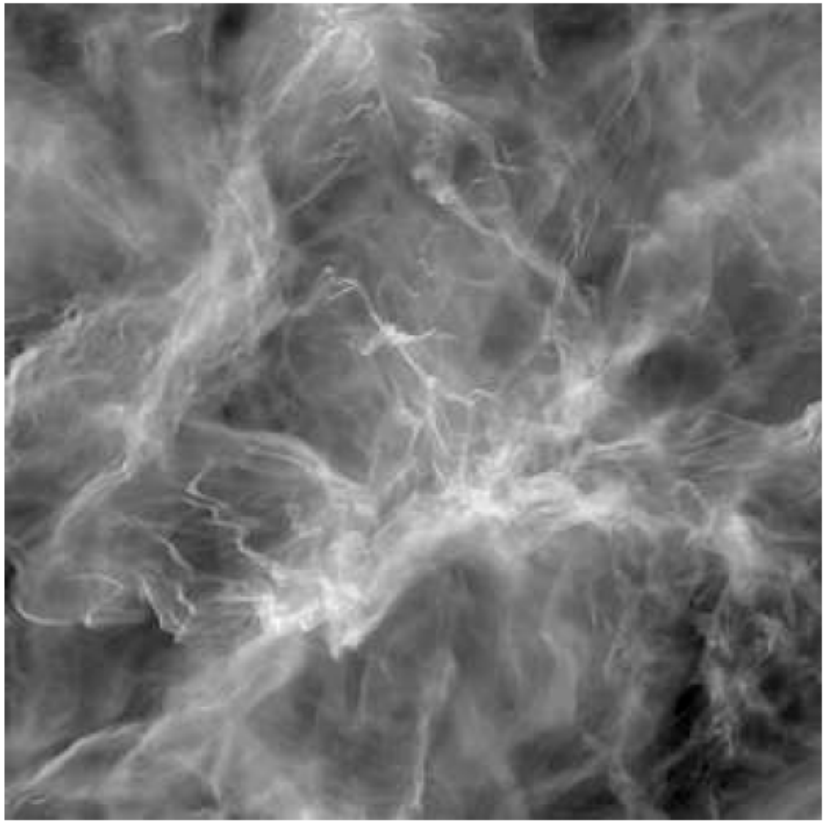

FIG. 2.— Logarithm of projected density from a snapshot of the Stagger-Code MHD run.

AMR MHD Code (RAMSES) with Selfgravity (no sink particles yet)

- Base grid 512^3
  - takes care of turbulence (HD & MHD)
- Local refinement (AMR) $\rightarrow$ 8192^3
  - *only* on Jean's length (Truelove crit.)
  - takes care of collapsing regions
- Barotropic Equation-of-State
  - avoids having to keep refining for ever

RAMSES: decaying HD-turbulence (initially Mach~10)

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Unigrid MHD Code (Stagger) with Selfgravity and Sink Particles

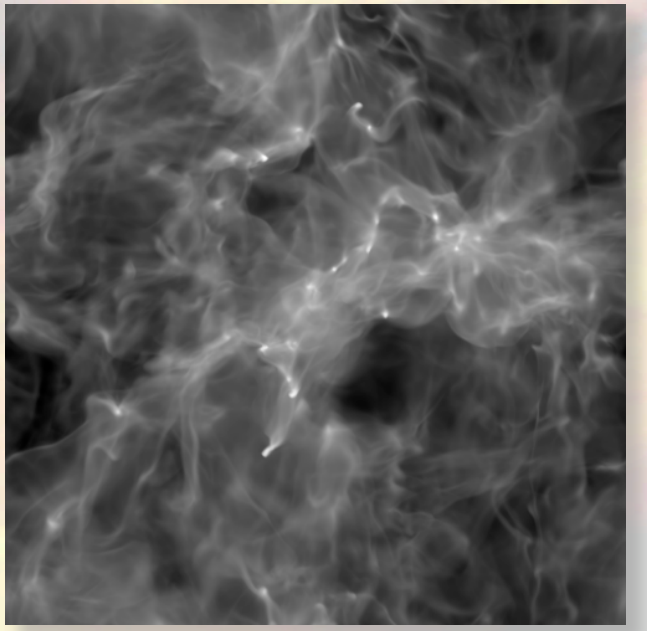
- Resolution 500^3
  - exploratory at 250^3
- Sinkparticles 'swallow' excess collapsing mass
  - simple recipy
- FFT gravity solver (MPI- and OpenMP)
  - potential from both gas and particles

STAGGER: decaying MHD-turbulence (initially Mach~10)

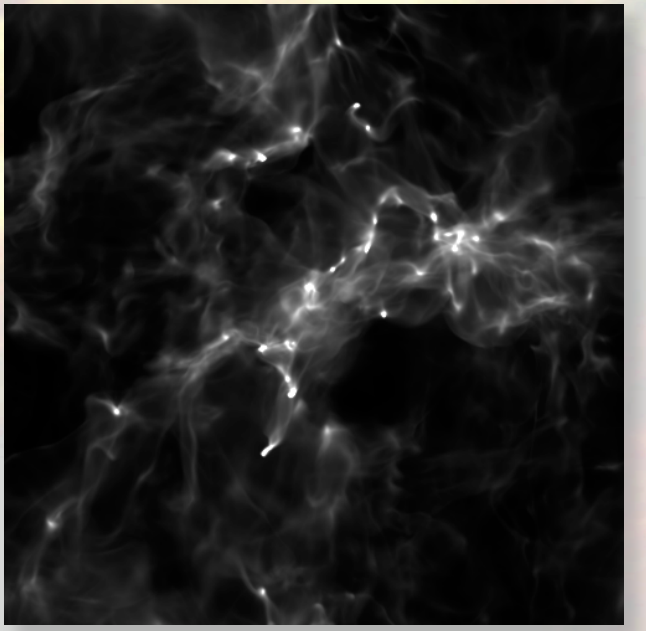
A note about comparing simulations and observations

- Really needs to be done in a ’forward’ sense (construct ’synthetic observations’ from the simulation data)! See below:

Log scaling



Linear scaling



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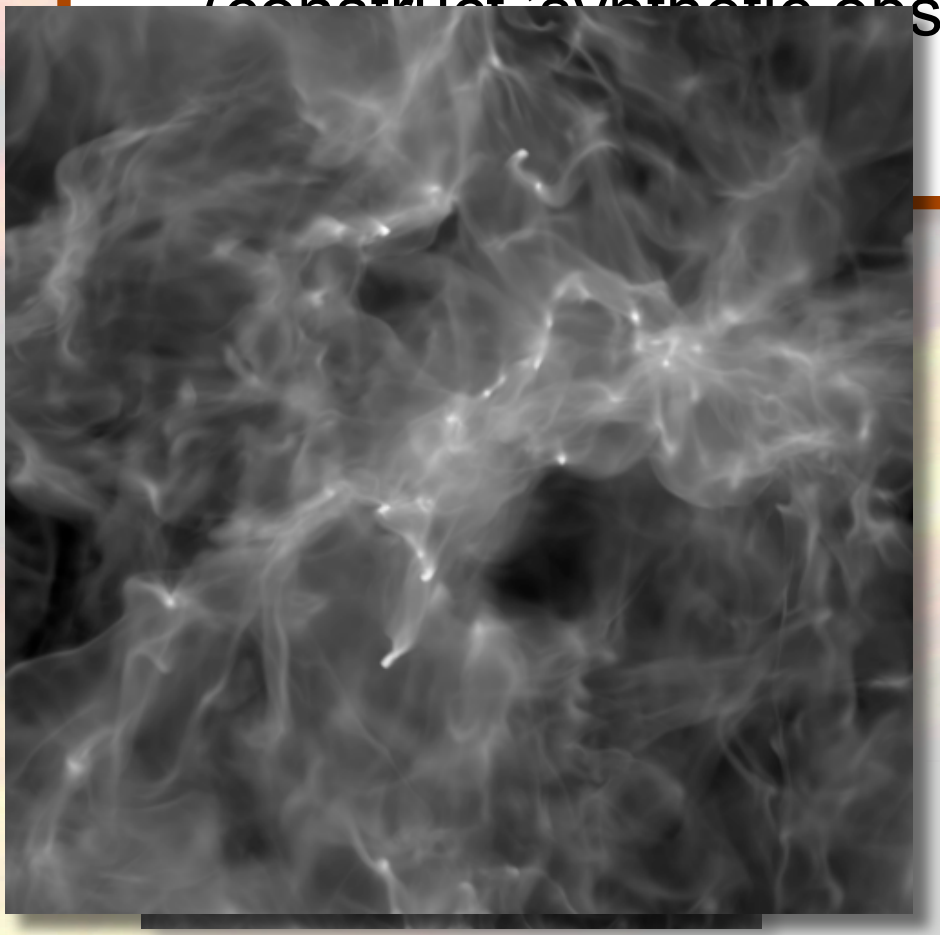

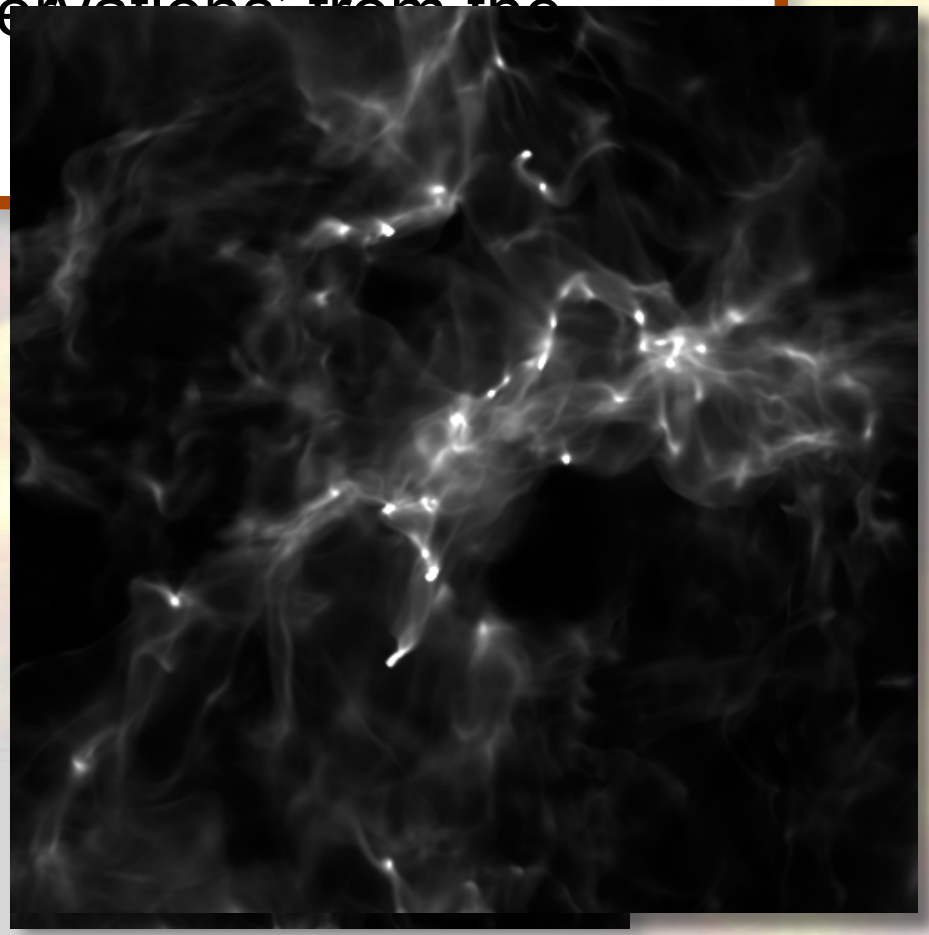

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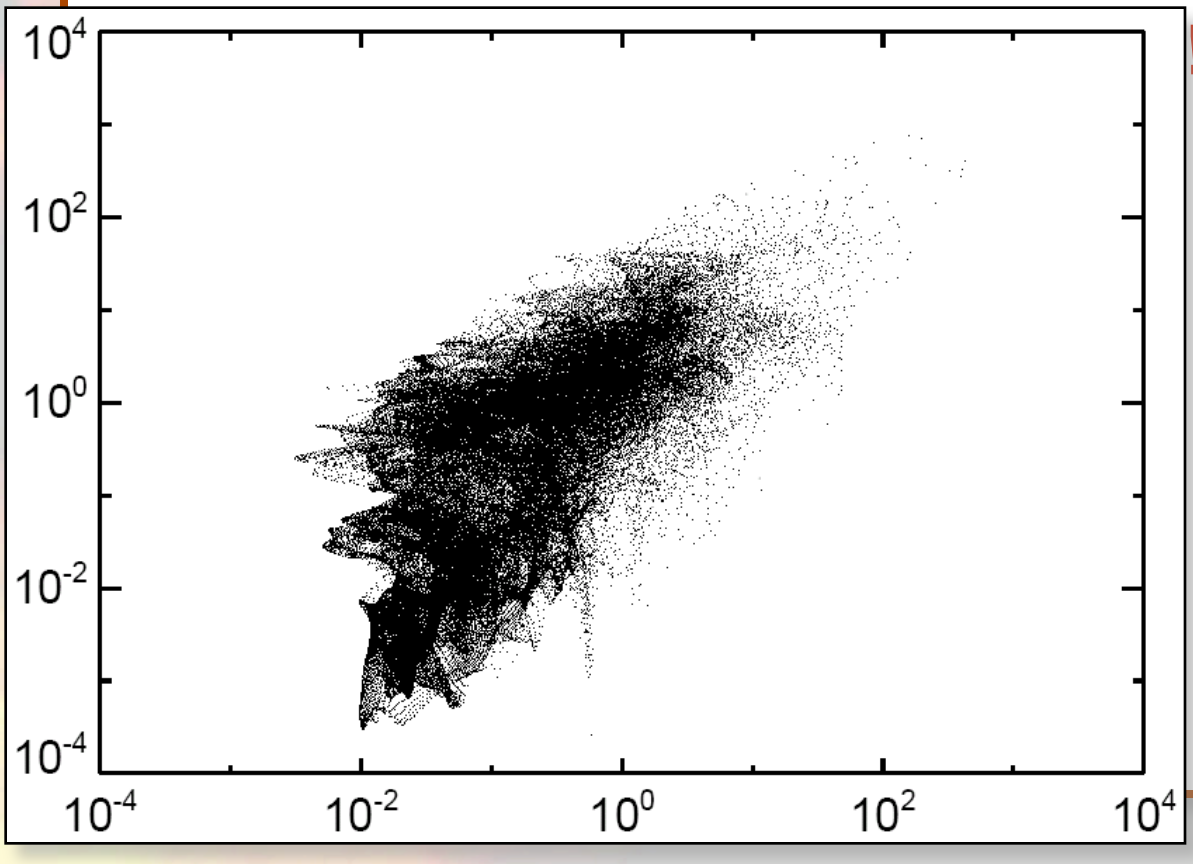

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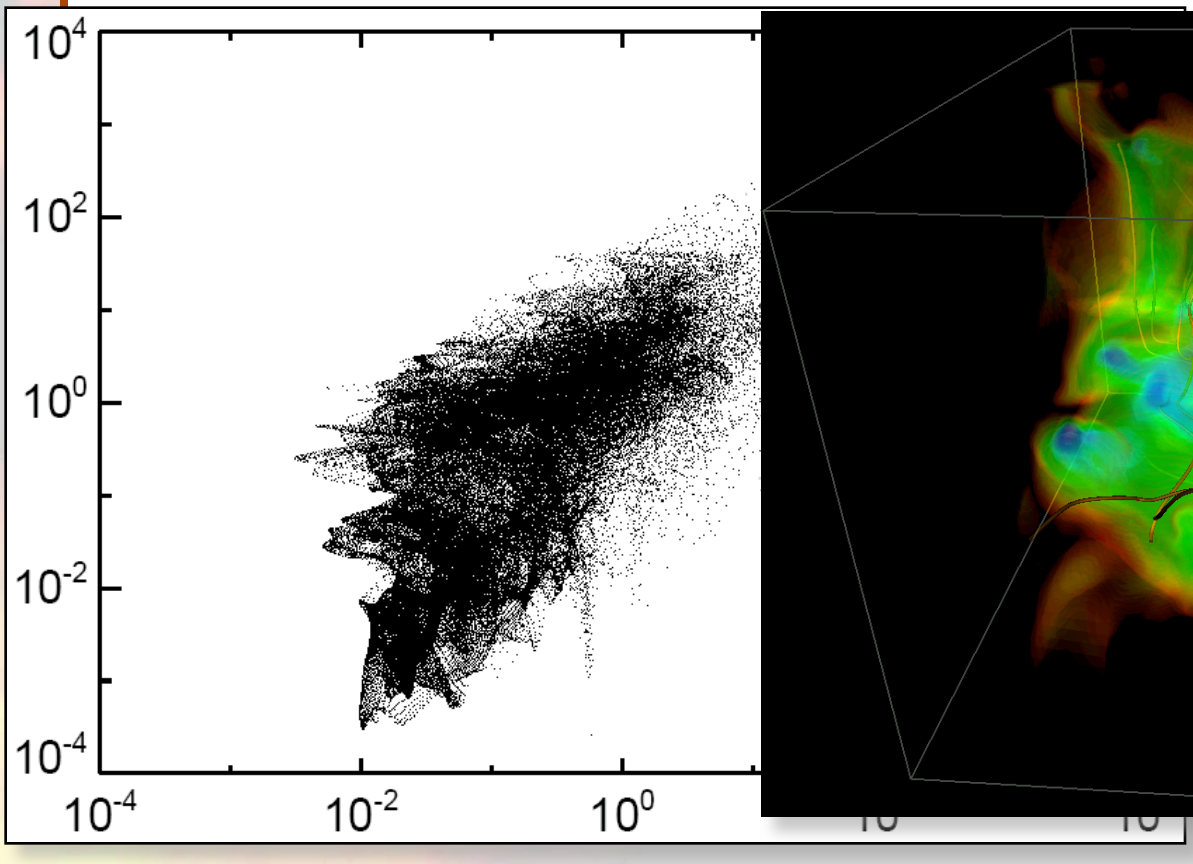

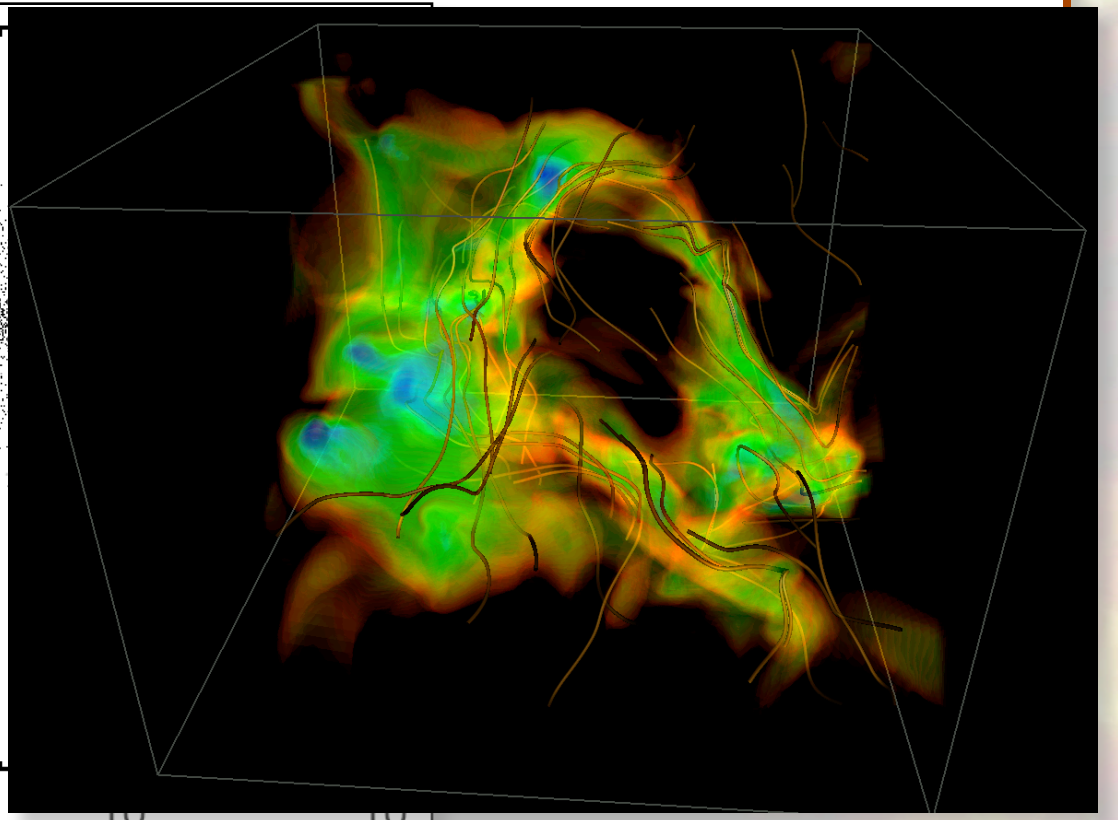

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The Importance of Magnetic Fields

- **What is the distribution of magnetic fields in star forming regions?**
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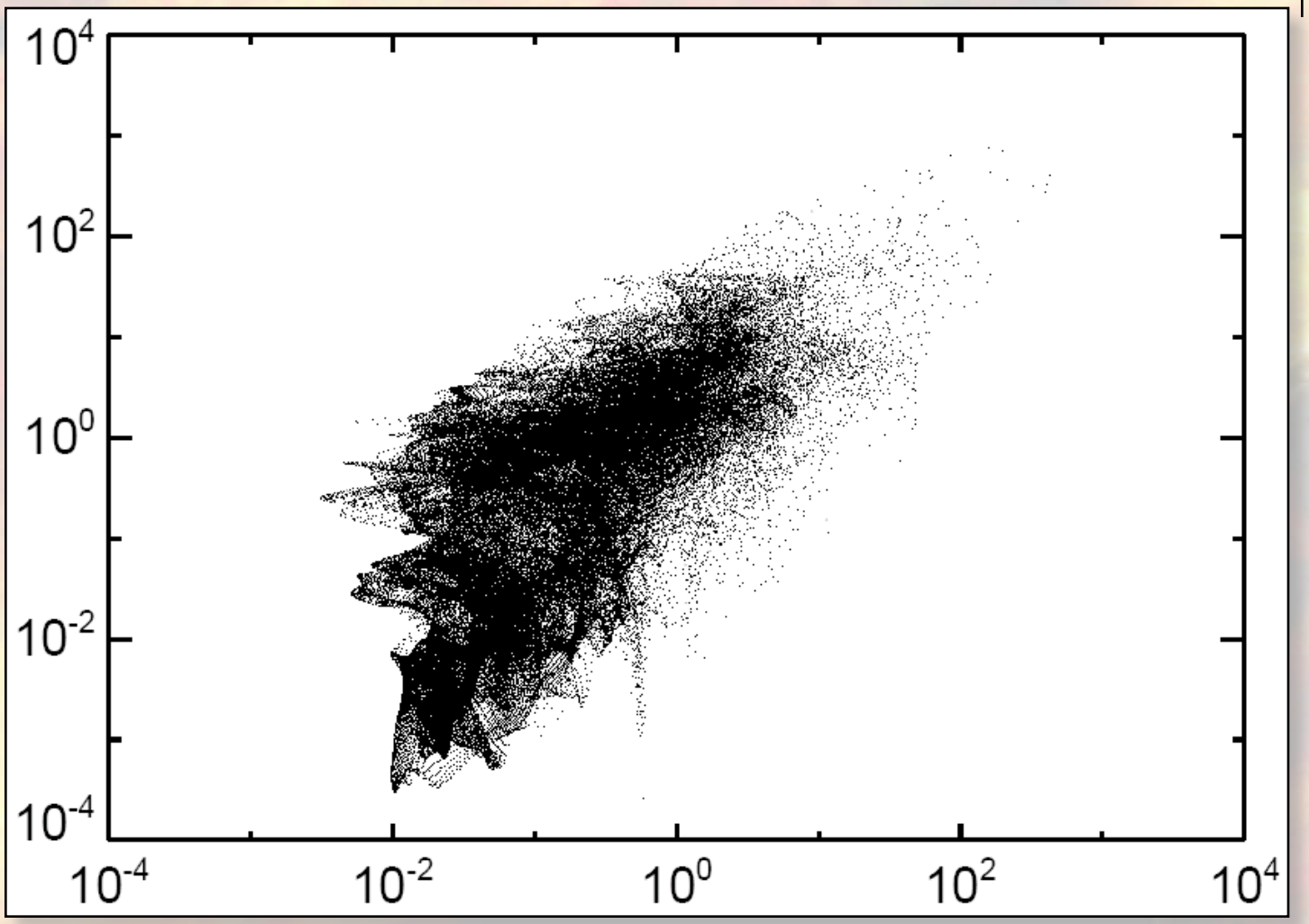
  - **Visualizations; even more apparently a mess!**
- **Why is there a B-n relation?**
  - **Good question – and it has an answer!**

The B-n relation explained



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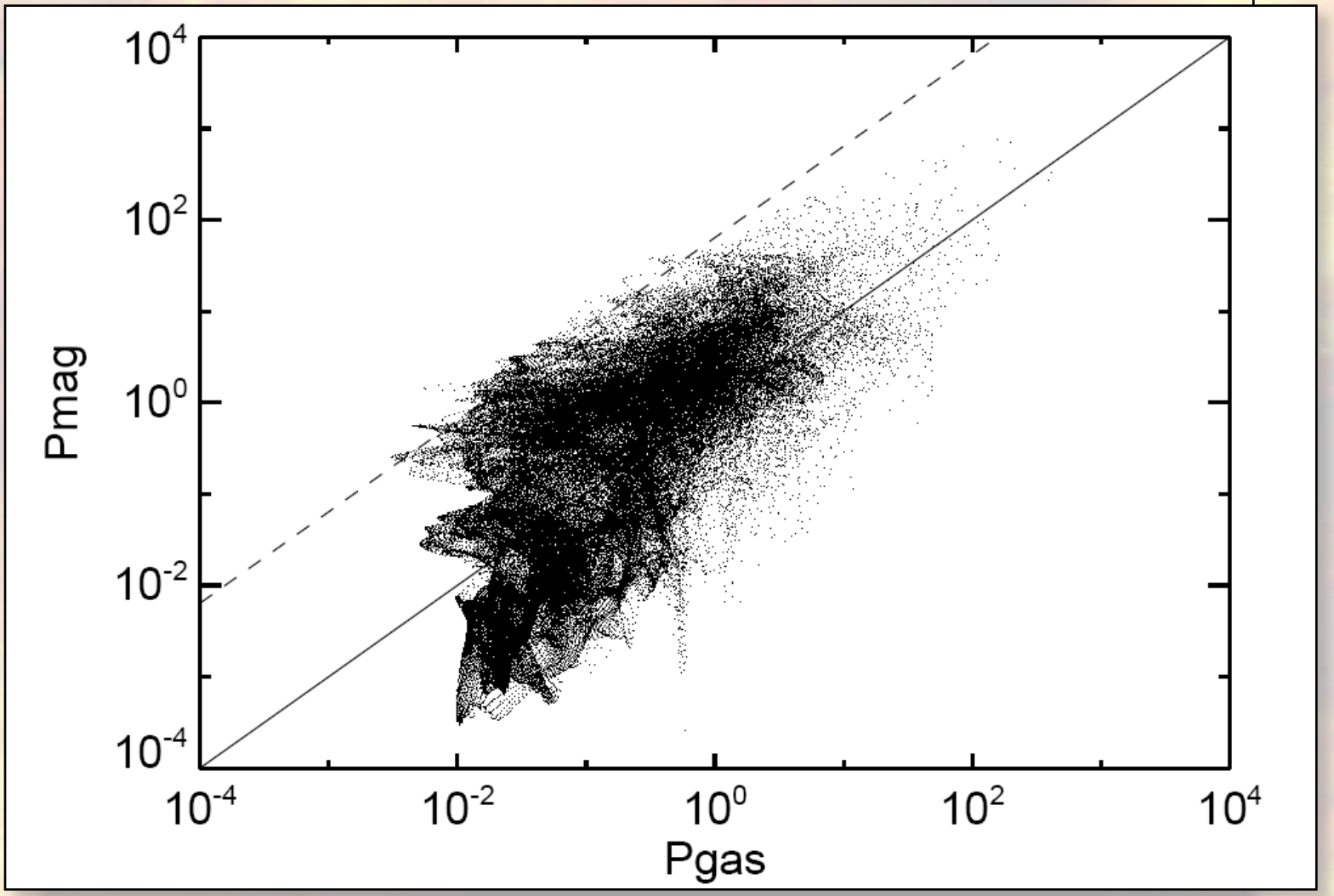

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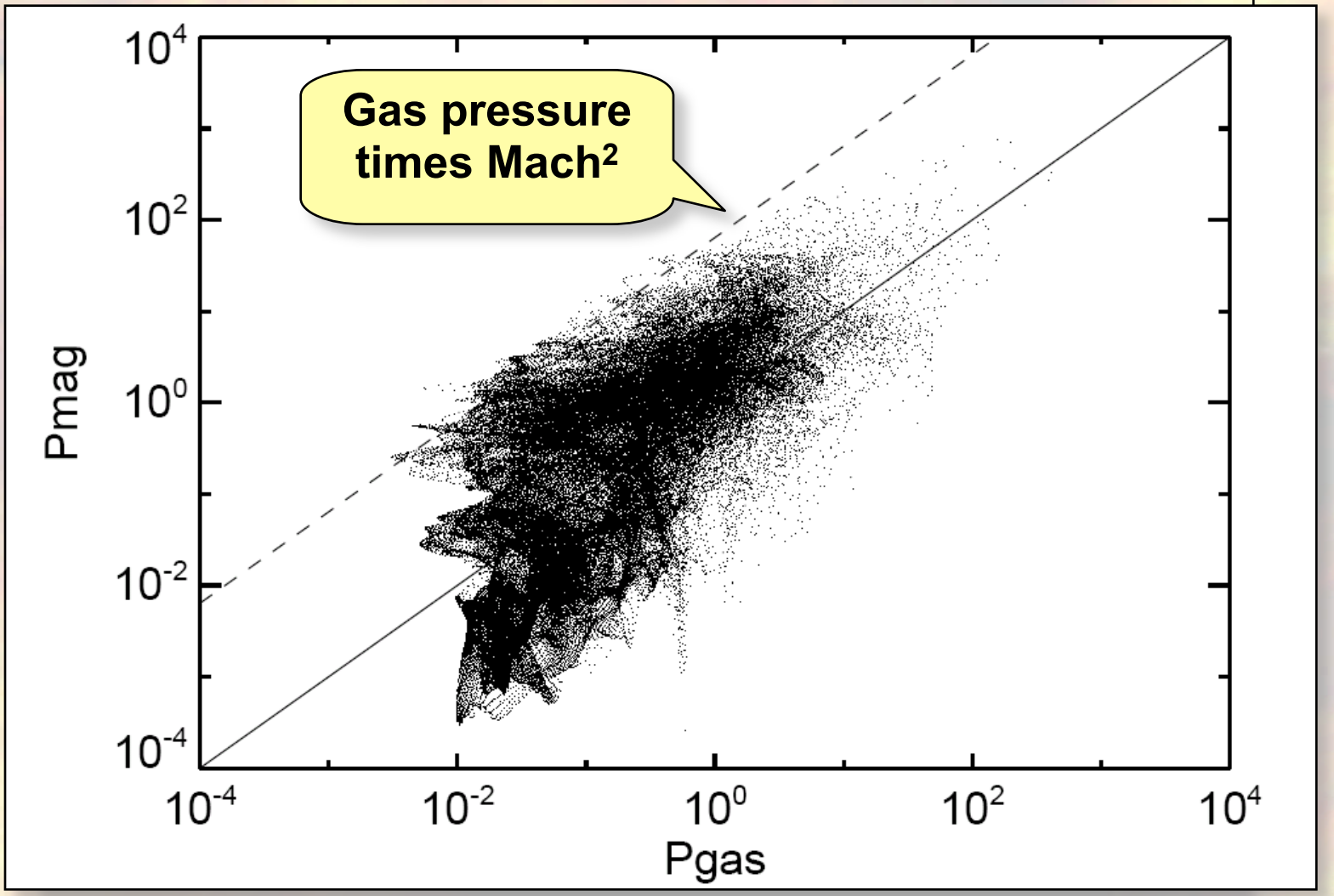

Visualizing the distribution and importance of B

- VAPOR (NCAR) visualization of a decaying MHD experiment after about one free fall time

- Notice particularly
  - Magnetic field topology
  - Importance of magnetic pressure (cf B-n rel.!)

Dependence of SFR on density, Mach number, and B

- Exploratory runs – mostly at 500^3
- Mass density
  - $G\langle\rho\rangle L^2/c^2 = 5, 10, 30, 50, 100$
- Mach number / driving
  - Mach~10, decaying & maintained
  - Mach~3, decaying
- Magnetic field
  - $P_{\langle B\rangle}/P_{Th} = 0, 1/10, 1$
  - $\langle P_B \rangle/P_{Th} \sim 0, 2, 5$

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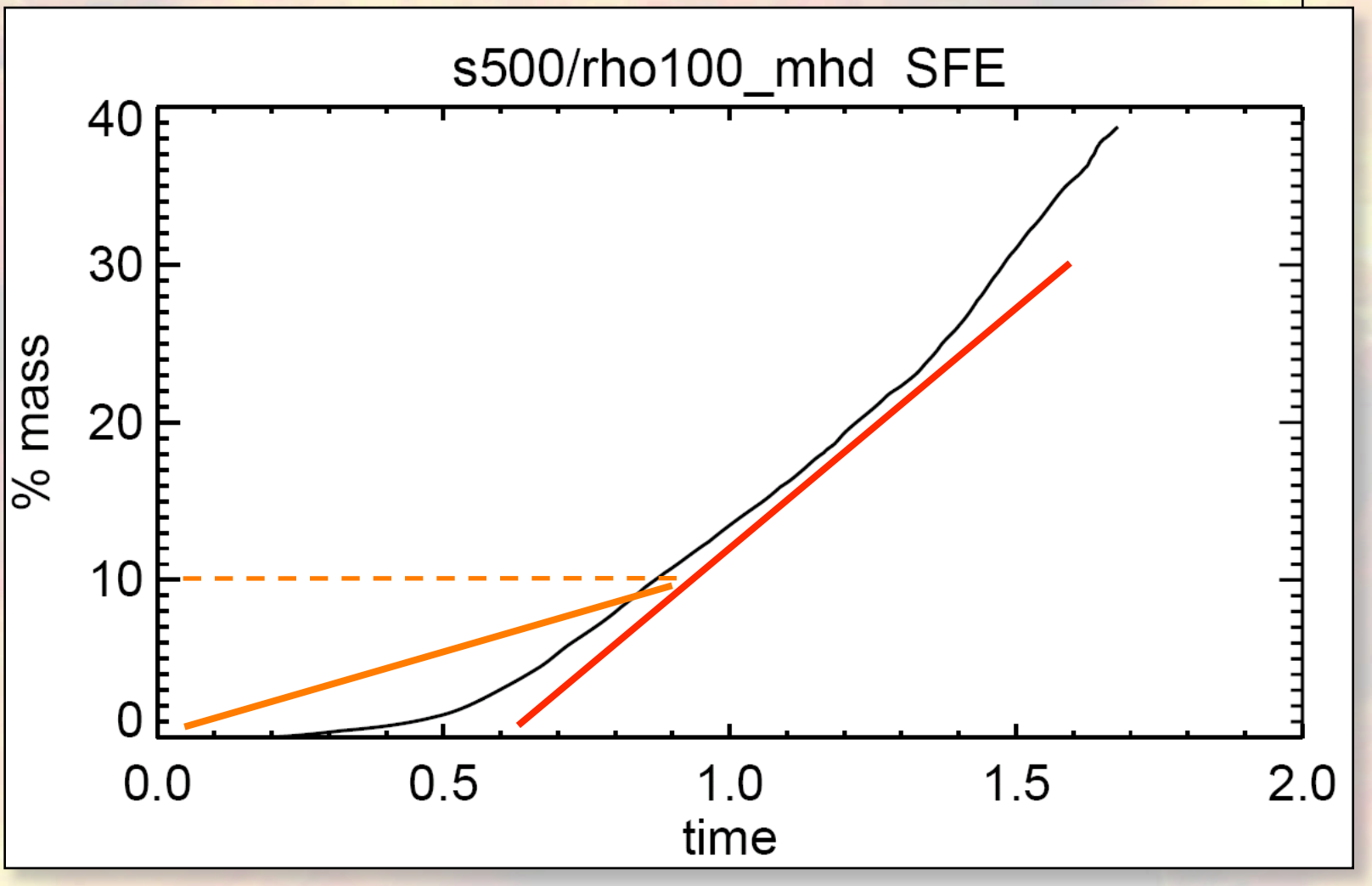
VBK03 ~ 50,
$\Rightarrow L_J/L \sim 1/4$

Dependence of SFR on Mass Density – G' = 100



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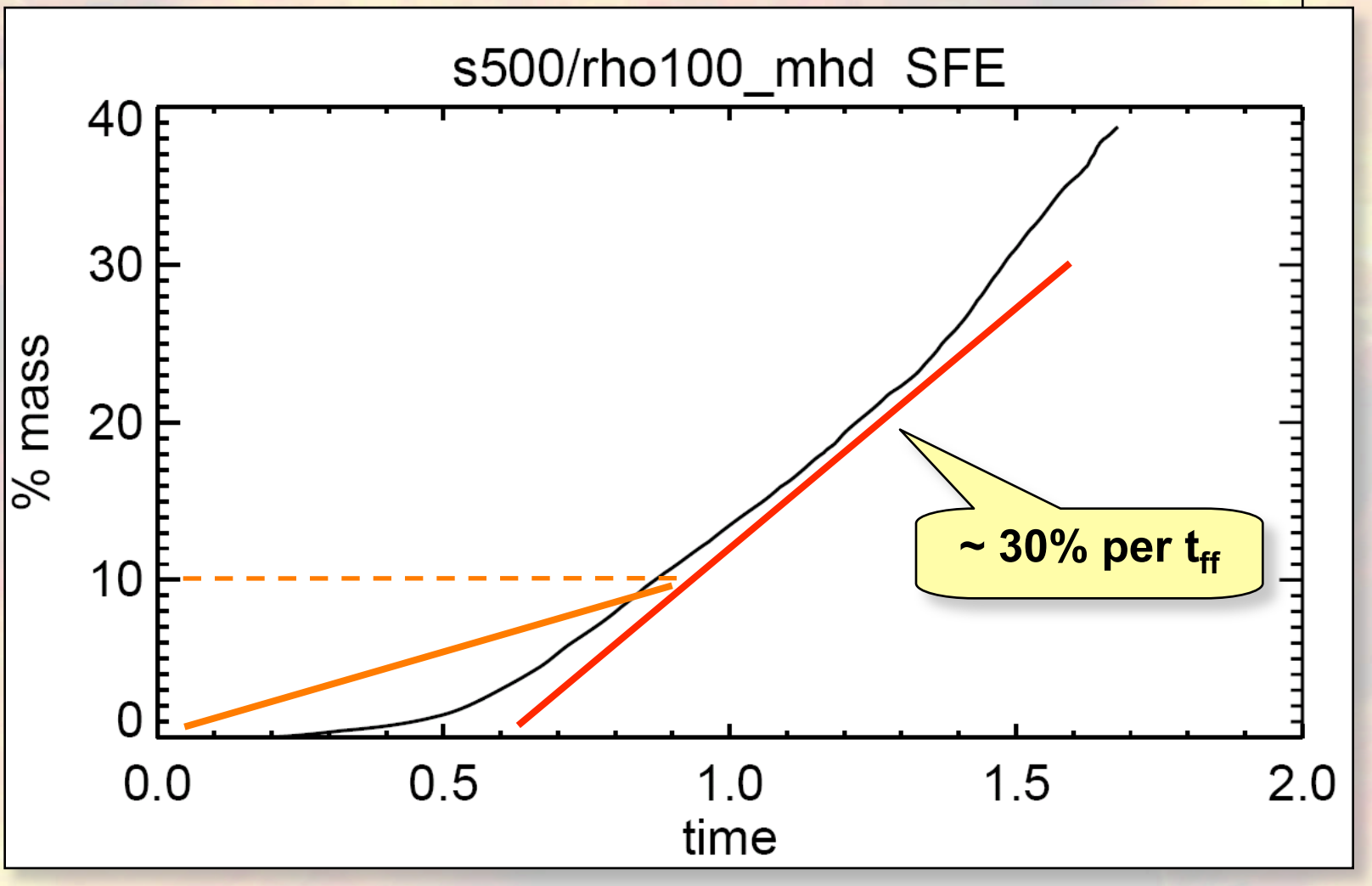

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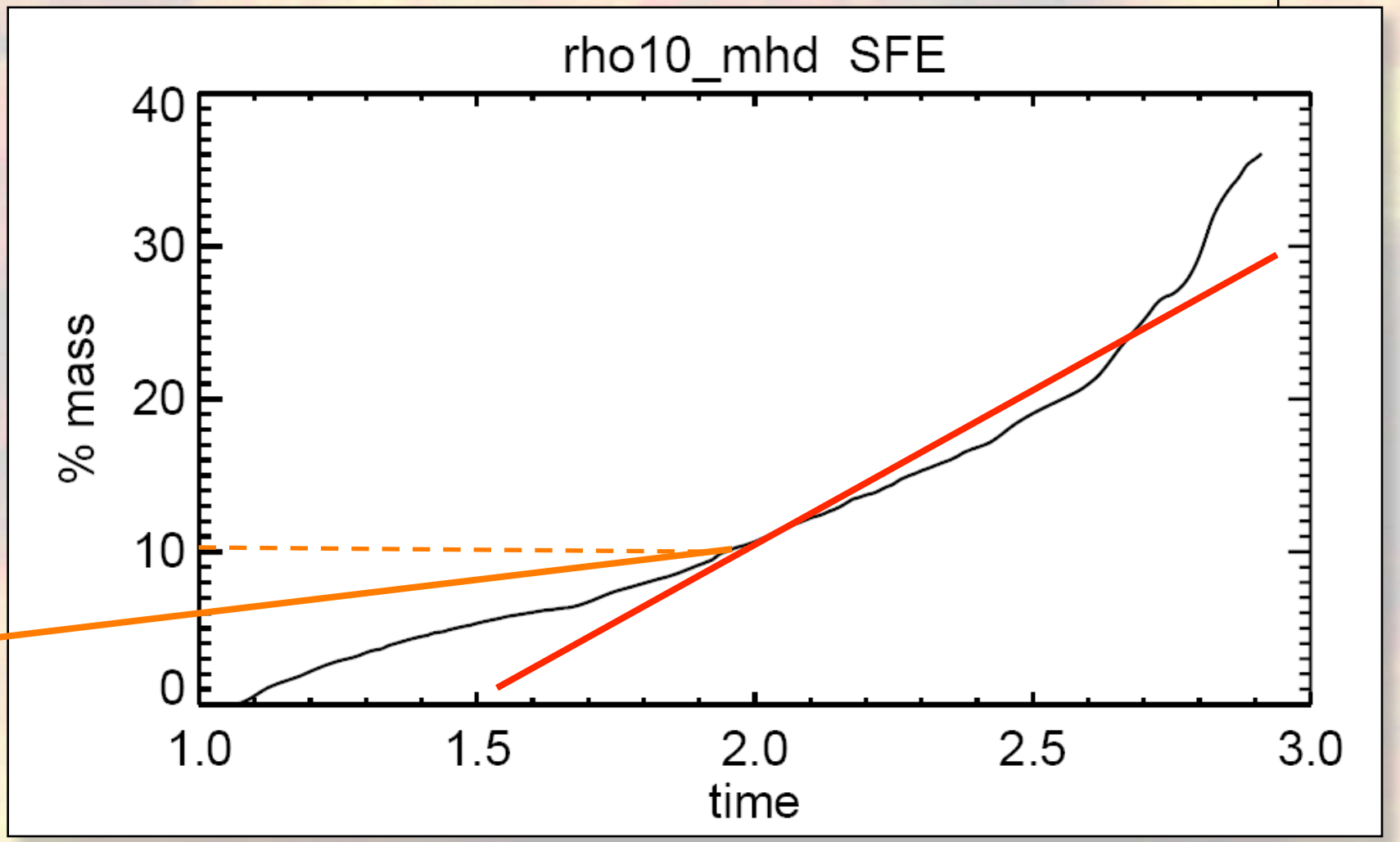

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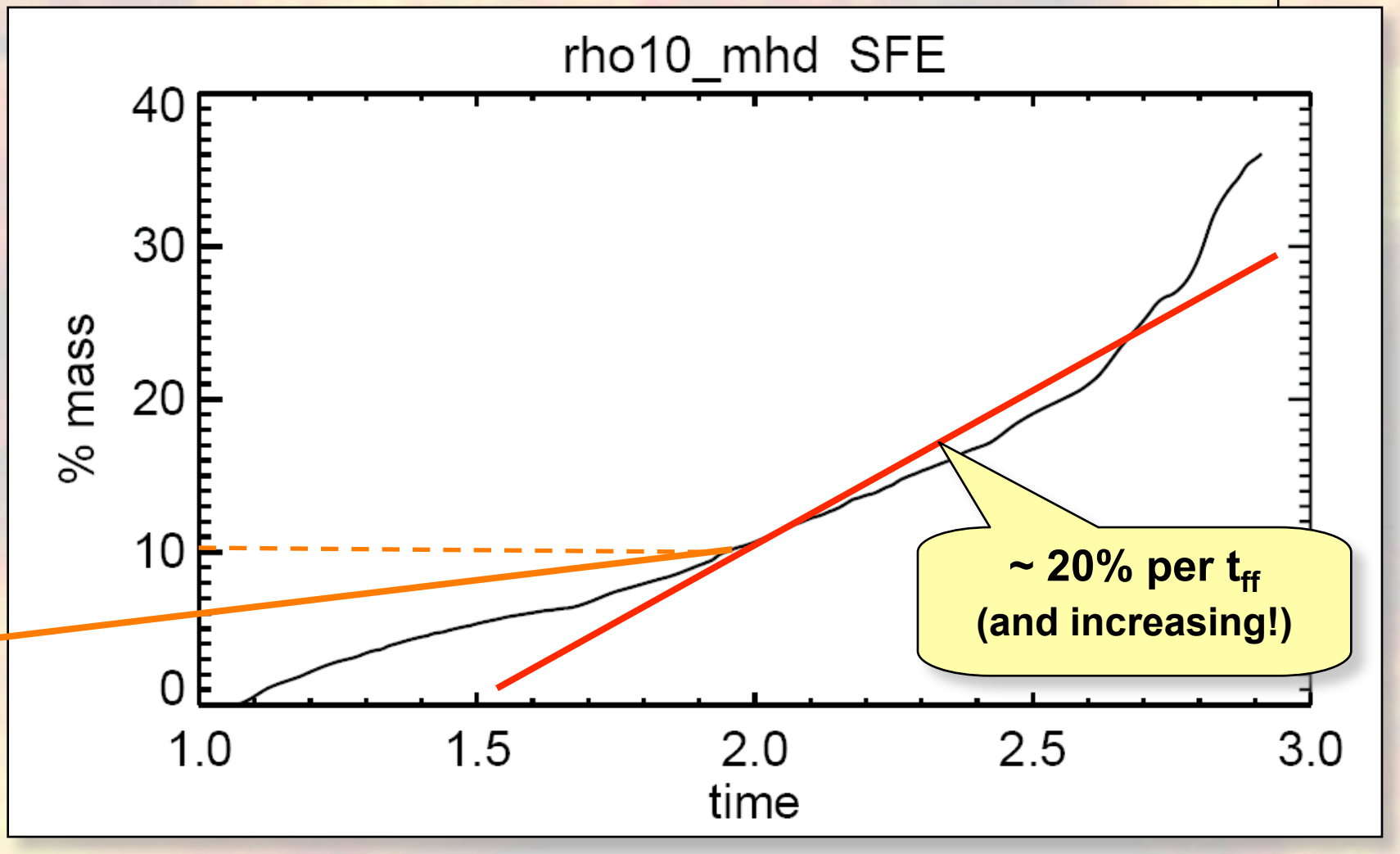
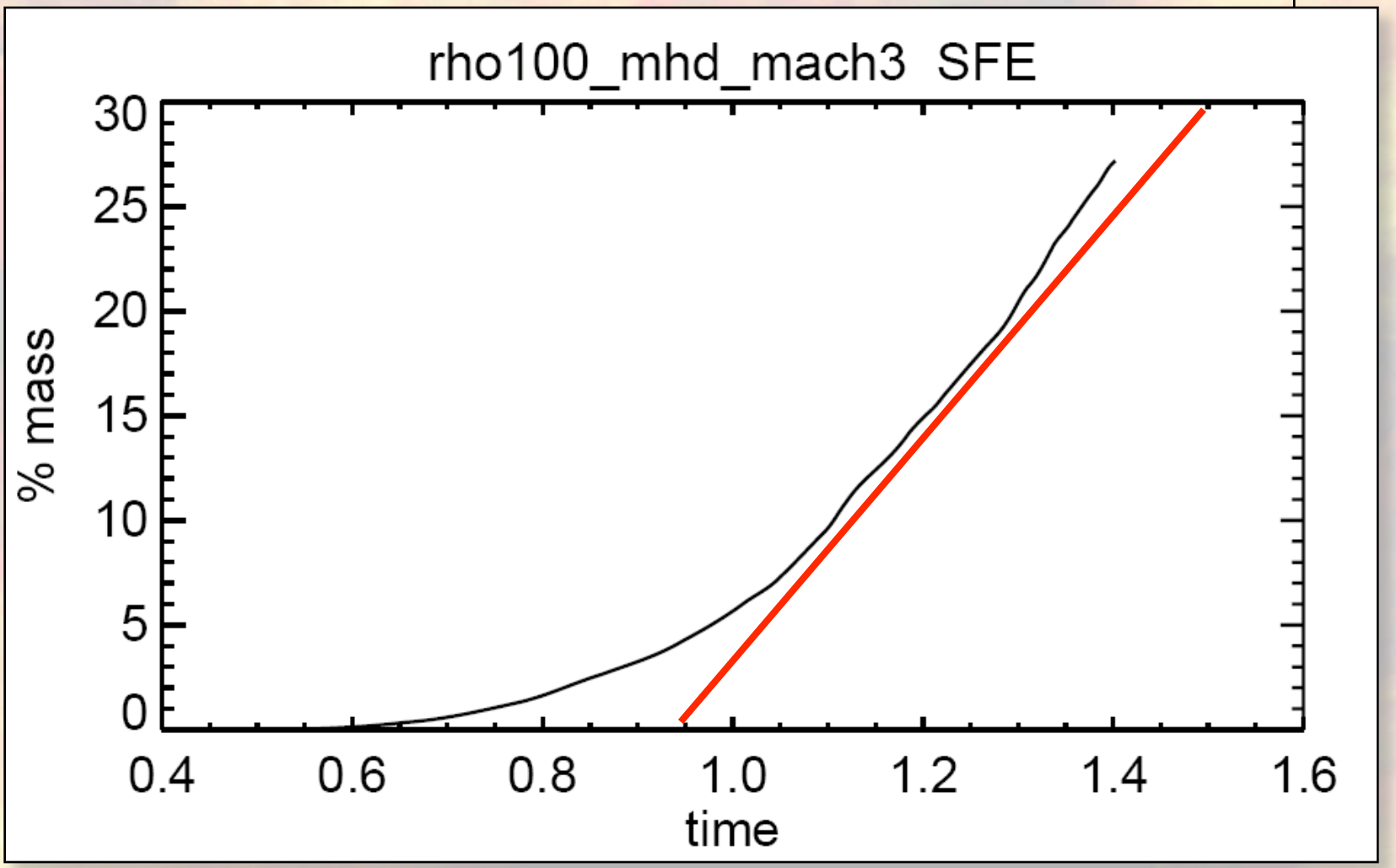


Dependence of SFR on Mach Number



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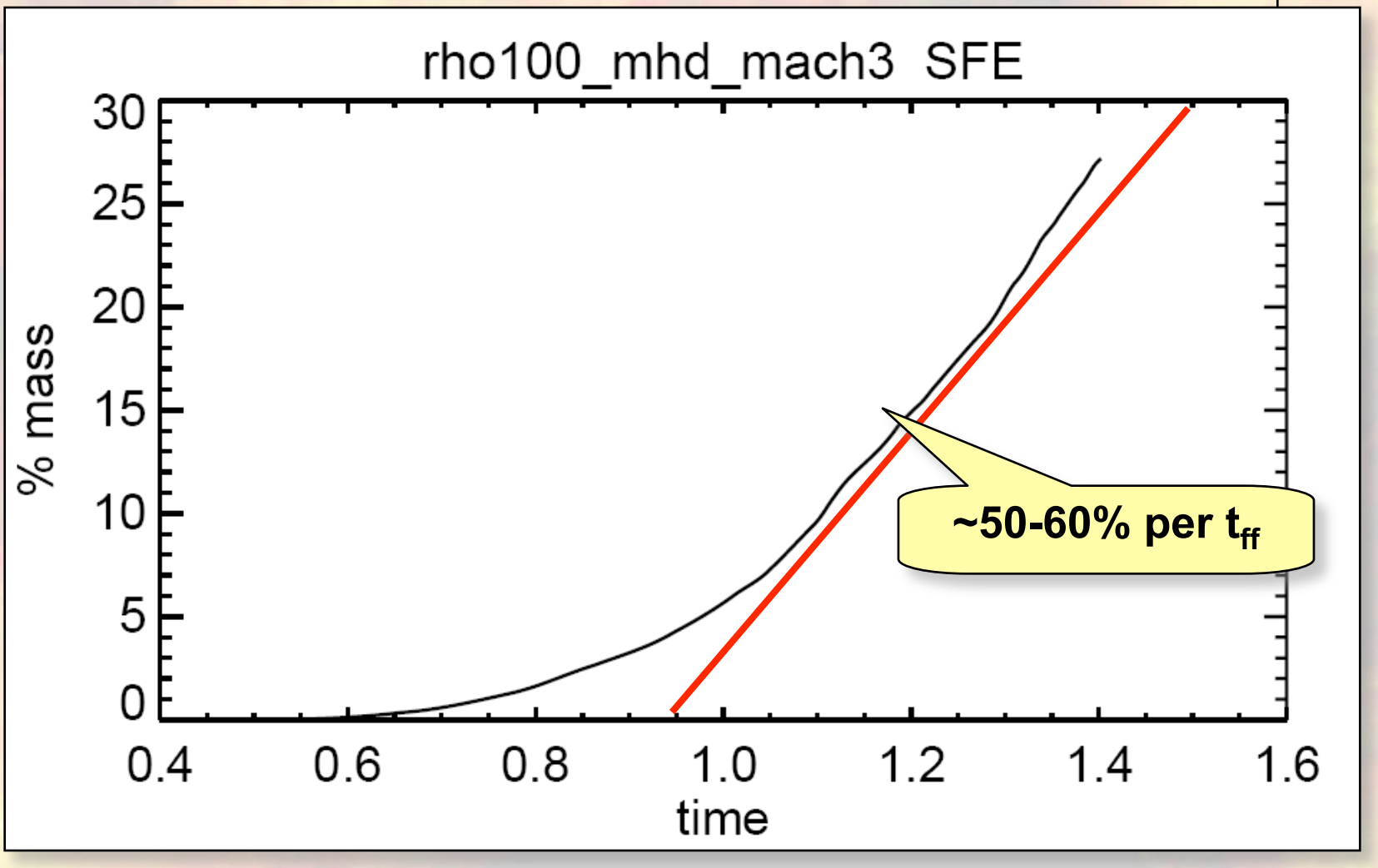
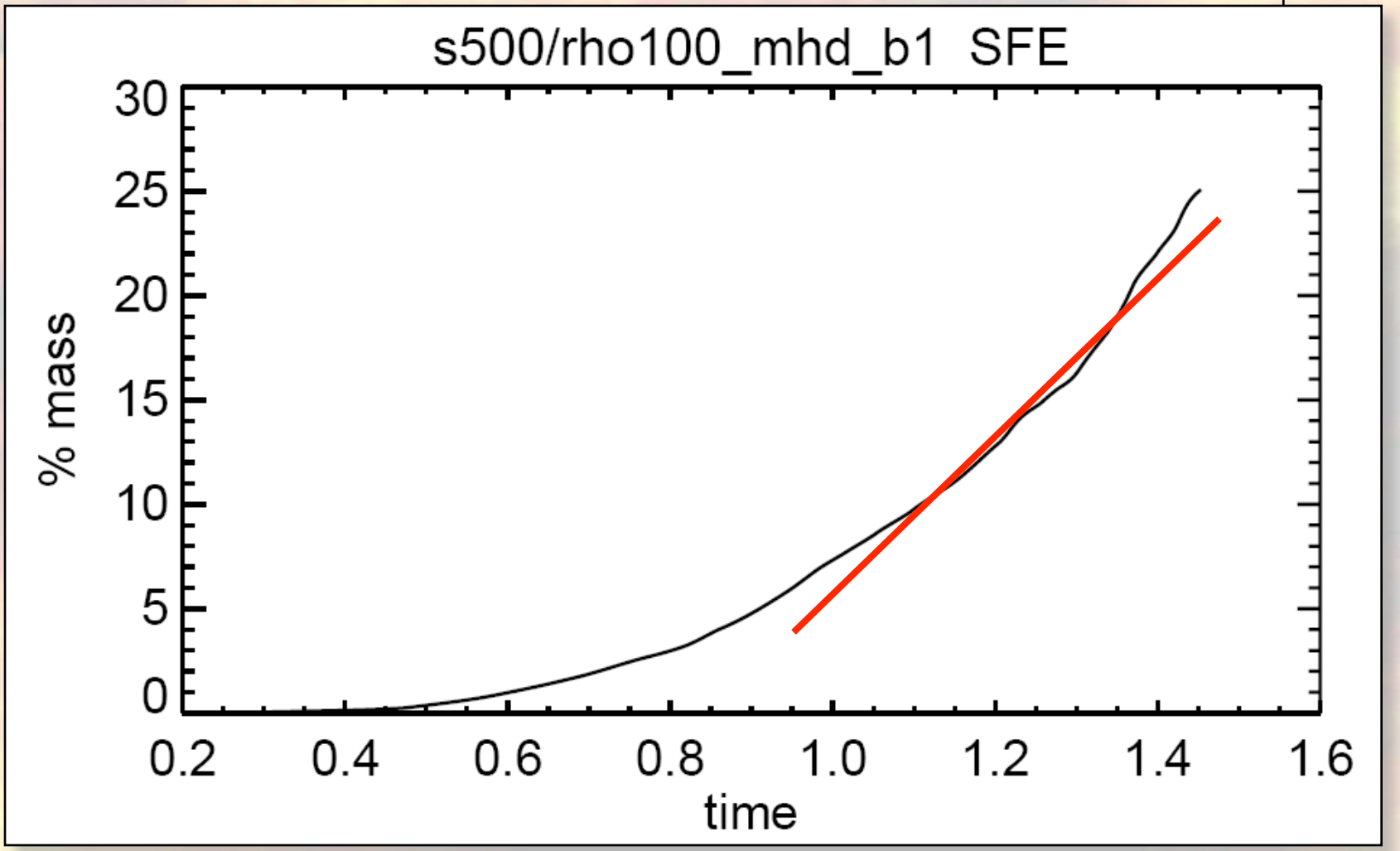


Dependence of SFR on B – this case has $E_B/E_{th} \sim 5$!



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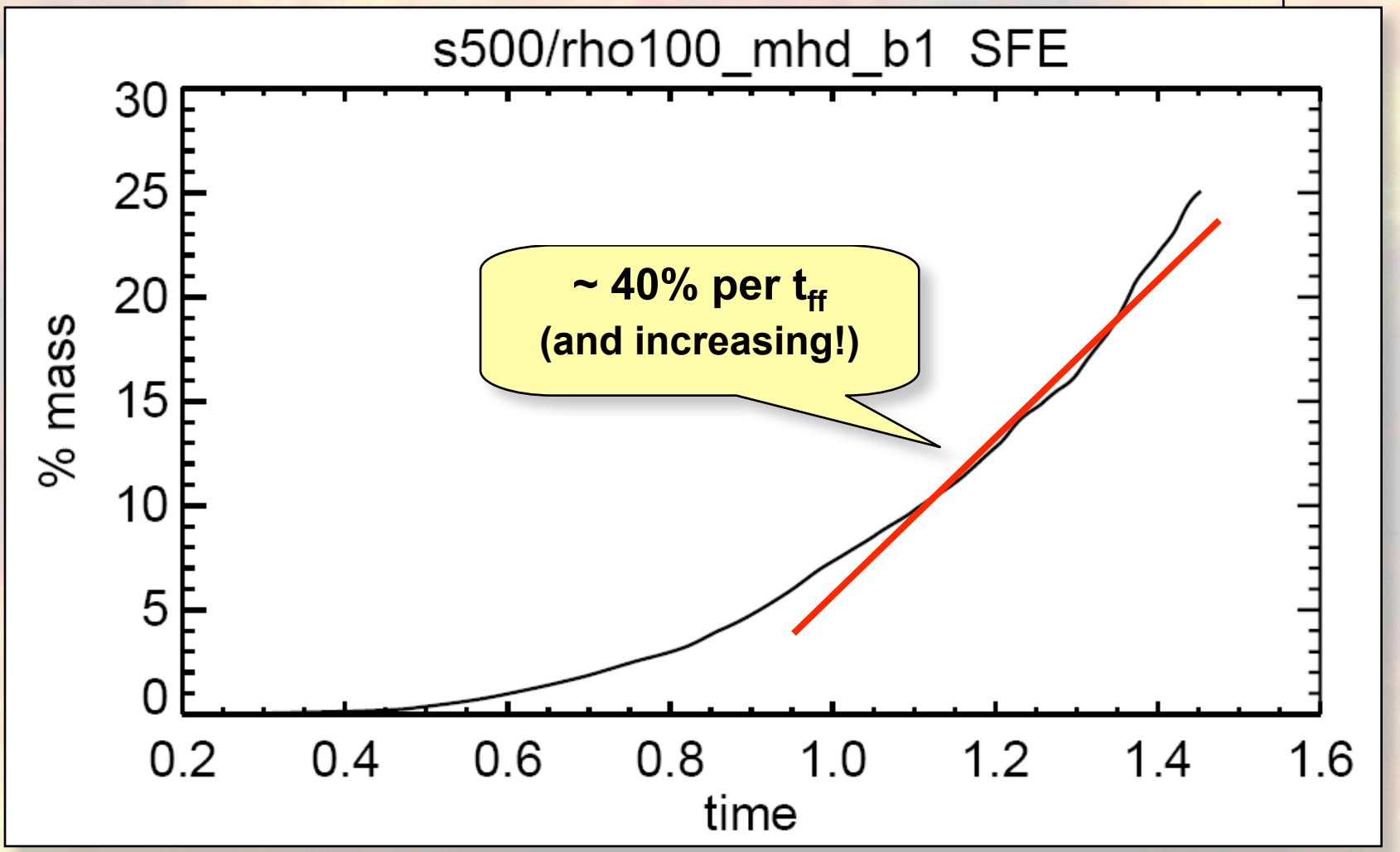

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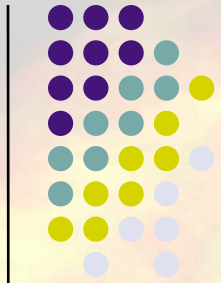

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- **The IMF is significantly different in HD and MHD**
  - **Observed levels of B ⇒ must use MHD!**
  - **The MHD case is consistent with Salpeter**


Thanks for your attention!