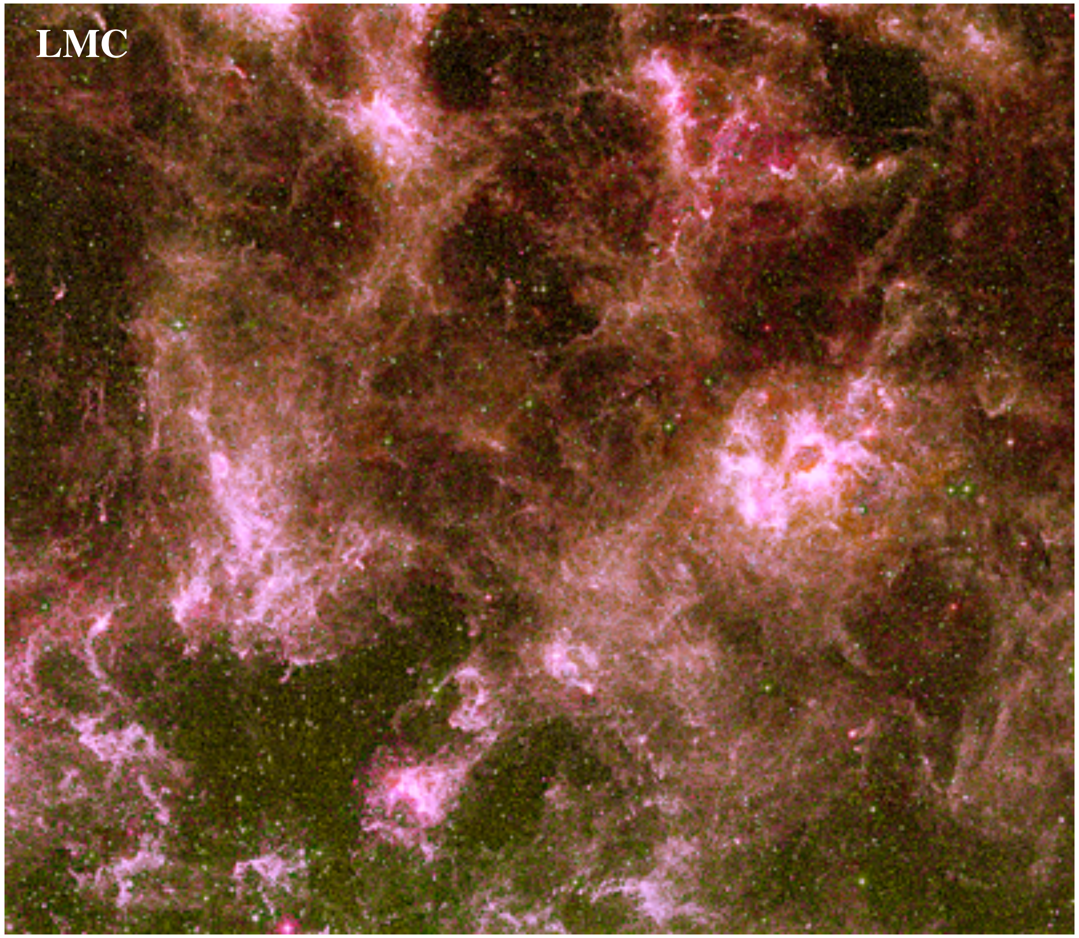
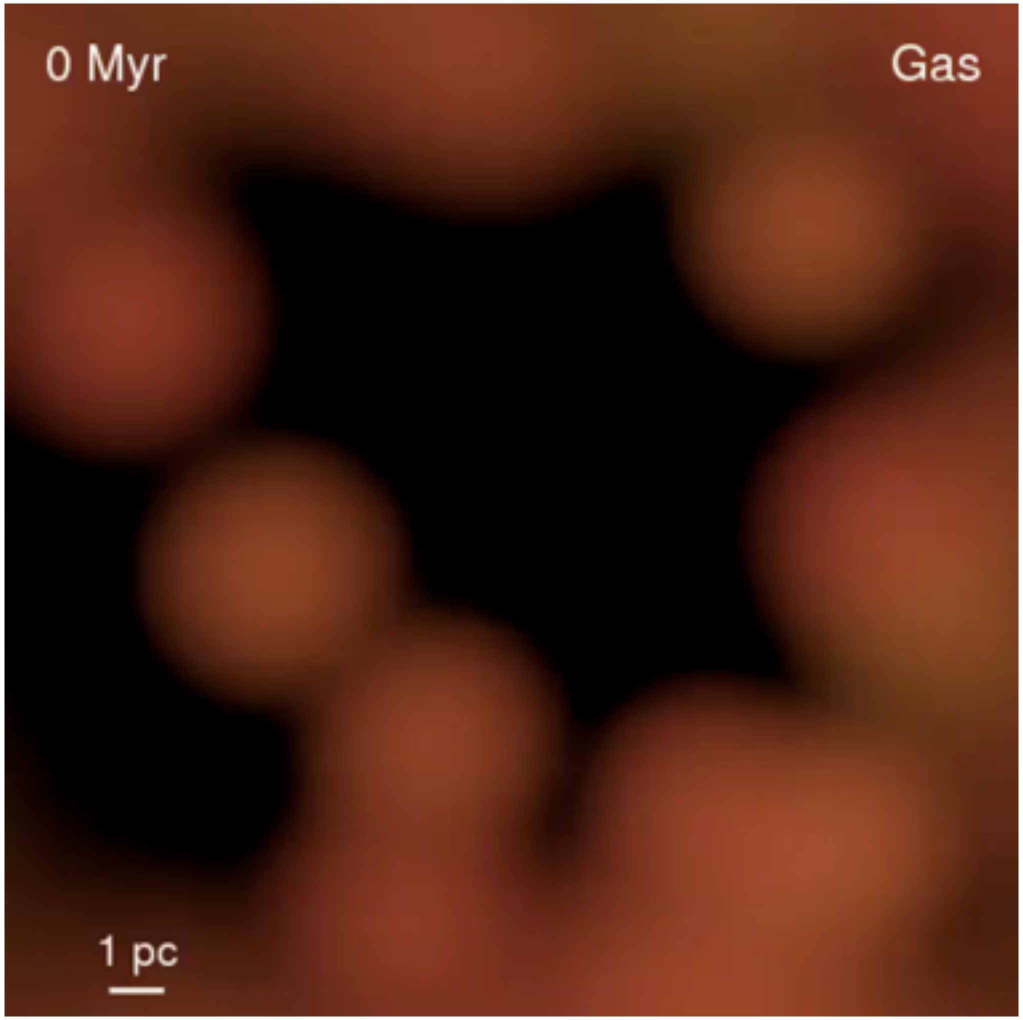
The Turbulent ISM

SUPER-SONIC TURBULENCE DOMINATES (ALMOST) ALL SCALES



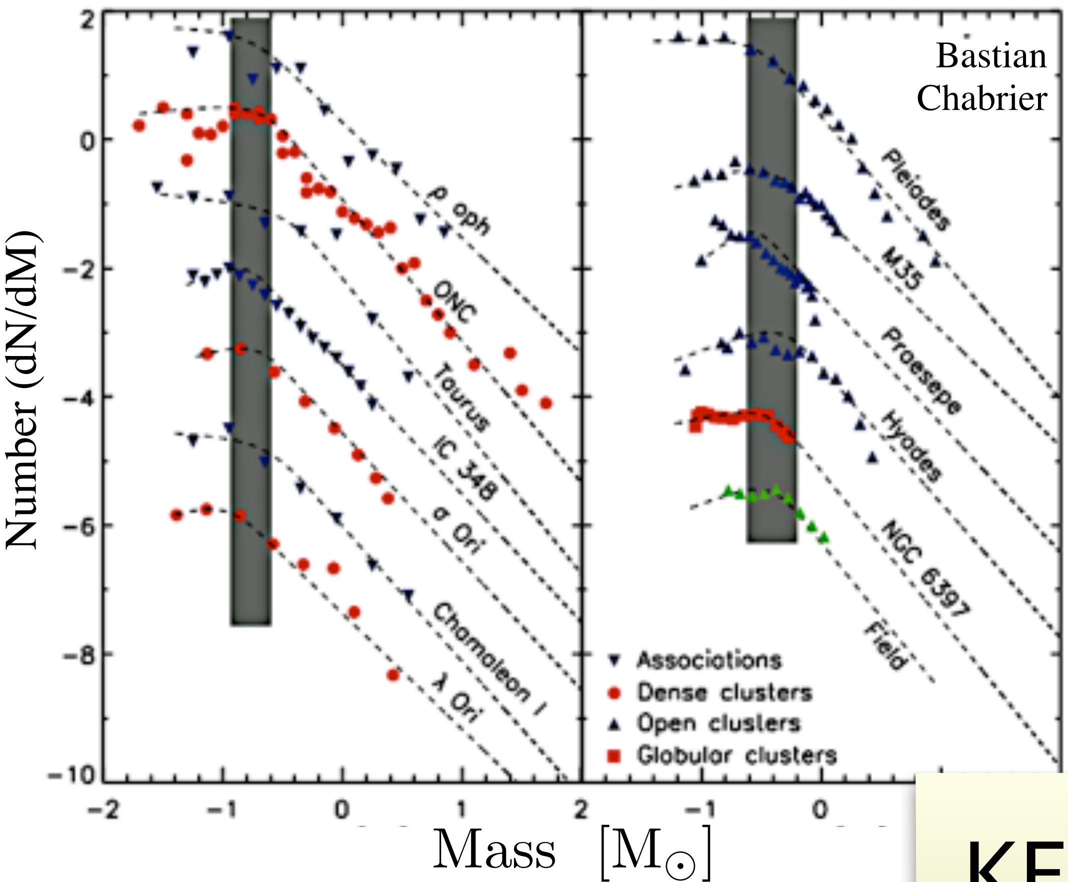


- Gravity
- Turbulence
- Magnetic, Thermal, Cosmic Ray, Radiation Pressure
- Cooling (atomic, molecular, metal-line, free-free)
- Star & BH Formation/Growth
- "Feedback": Massive stars, SNe, BHs, external galaxies, etc.

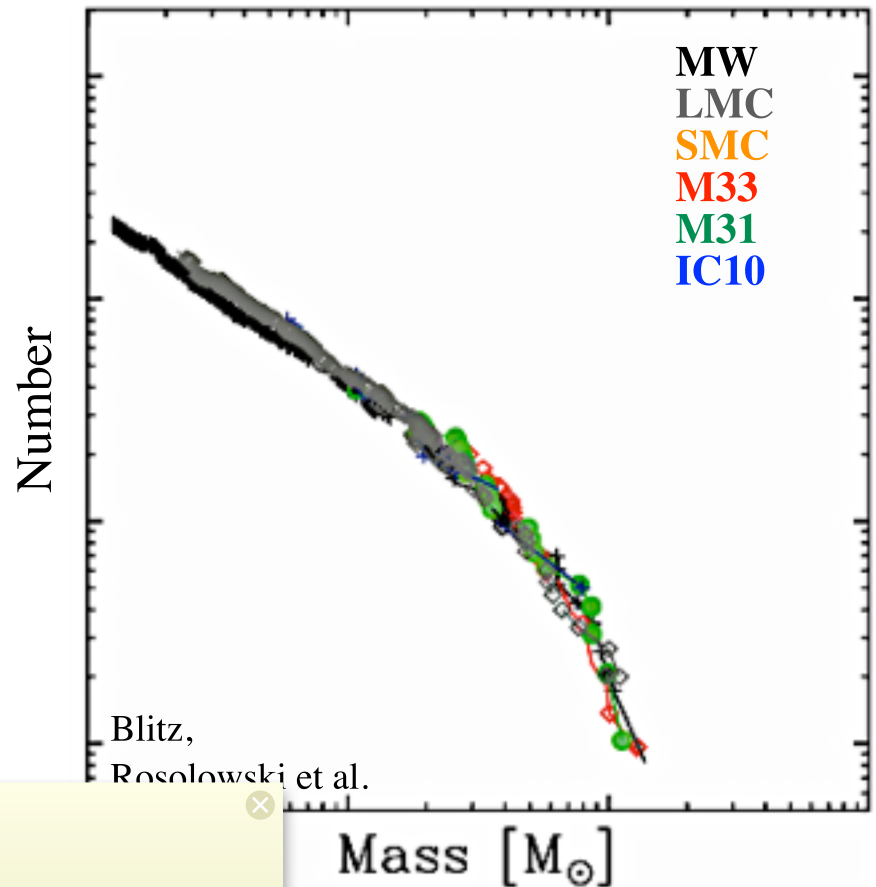
The ISM

YET THERE IS SURPRISING REGULARITY

Stars & Pre-Stellar Gas Cores:



Giant Molecular Clouds:



KEEP PWRLAW LABELS?

The ISM

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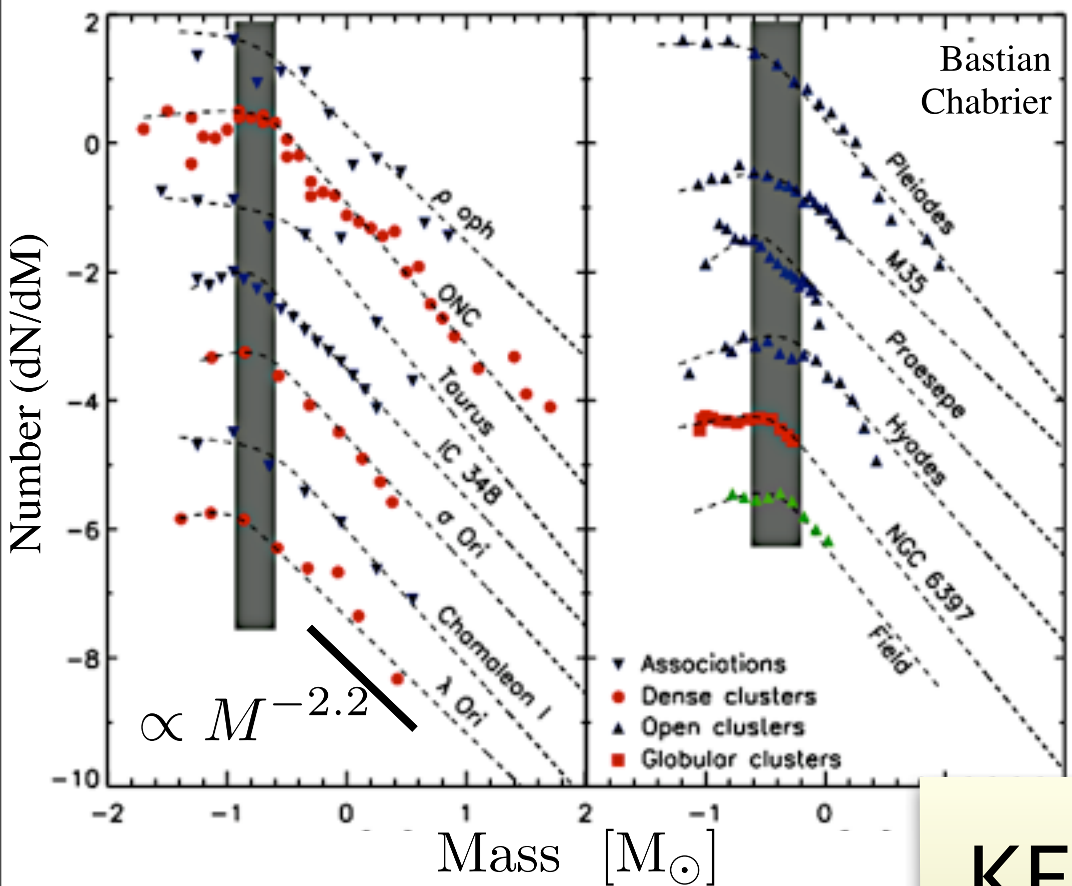

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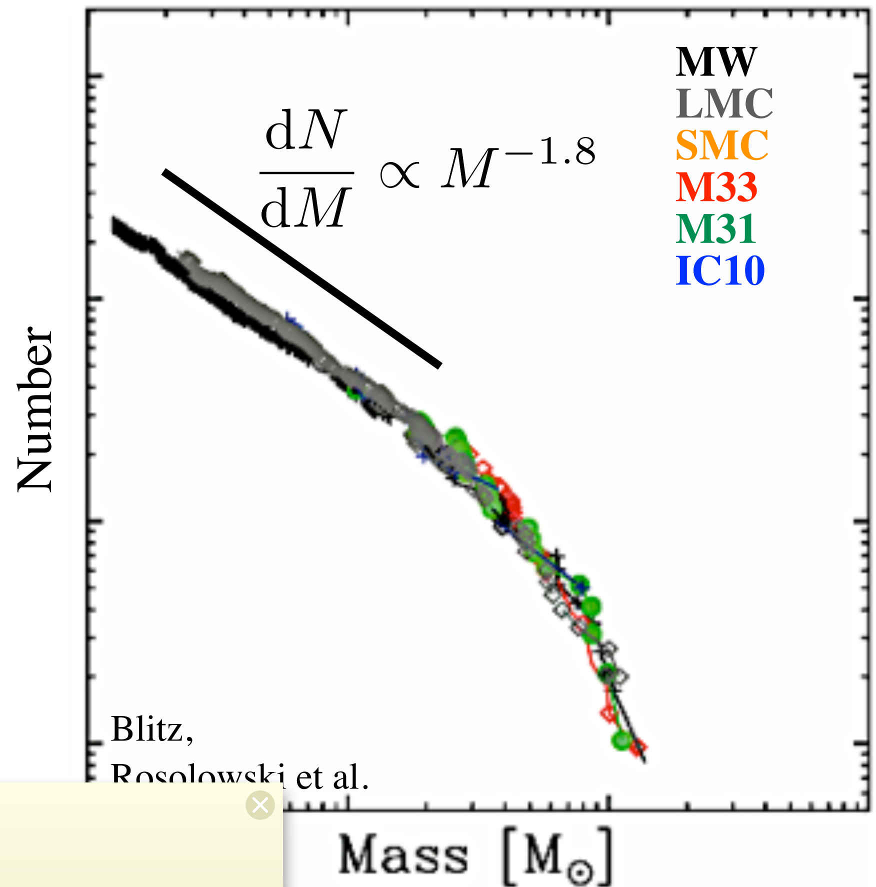

KEEP PWRLAW LABELS?

Super-Sonic Turbulence

BASIC EXPECTATIONS

$$E(k) \propto k^{-p} \qquad \mathrm{d}E \equiv E(k)\,\mathrm{d}k$$

$$(k\,E(k) \sim u_t(k)^2)$$

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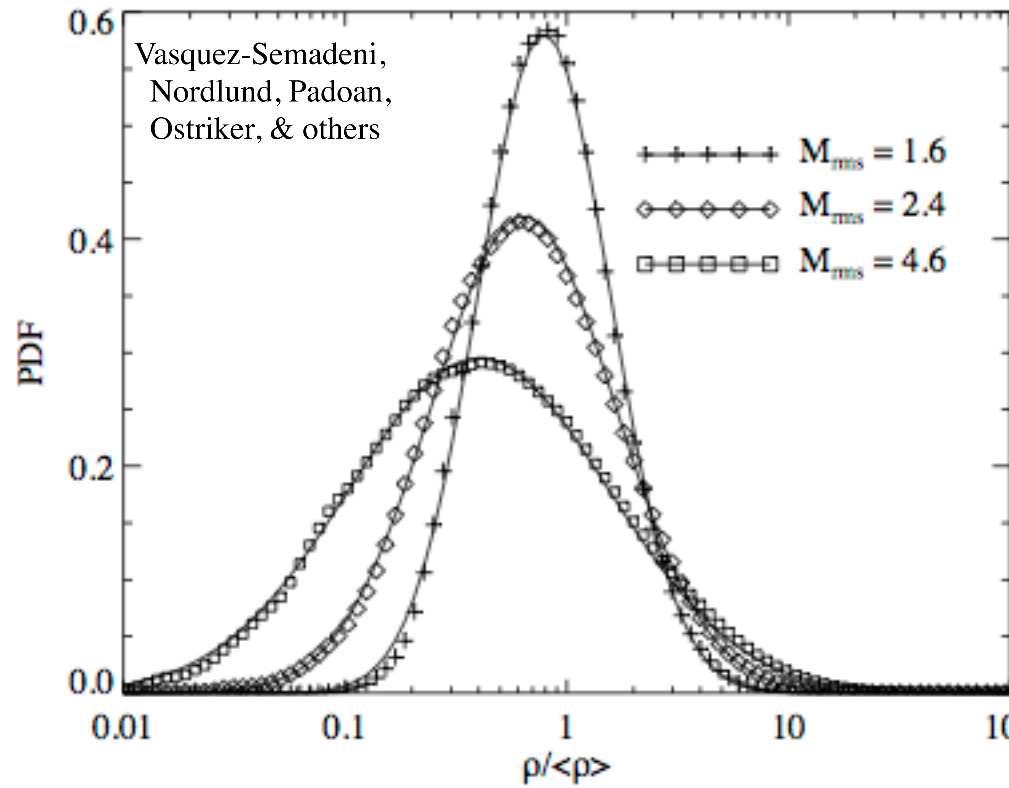

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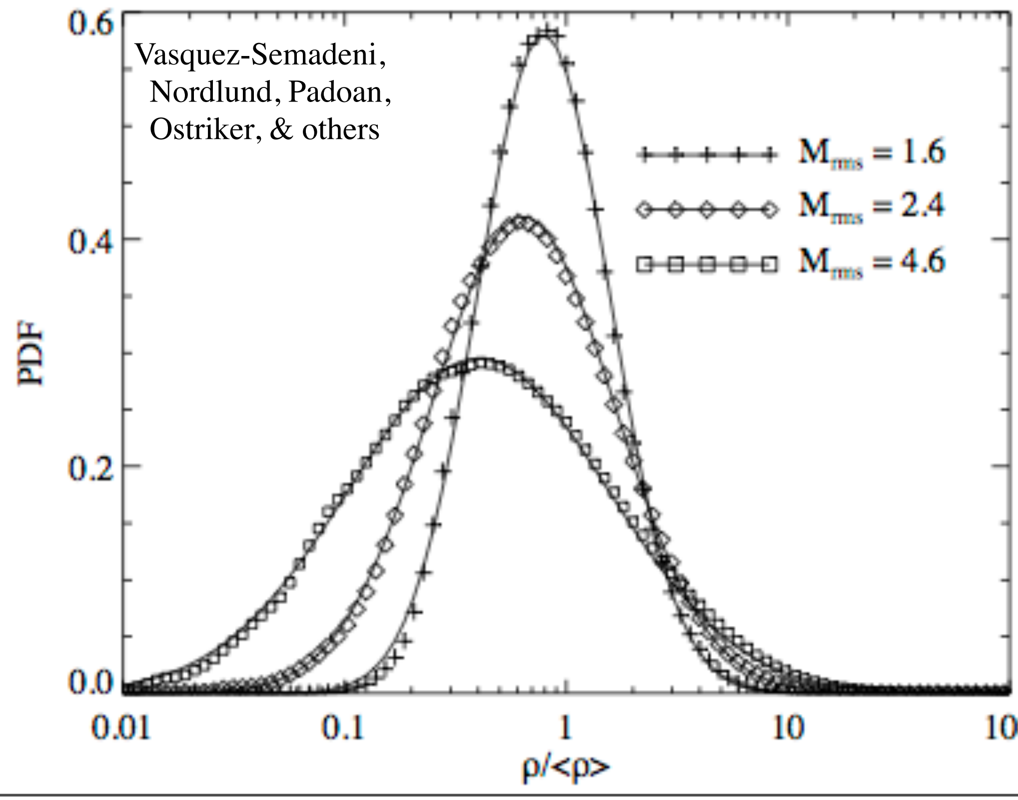
$$\frac{\partial \ln\rho}{\partial t} = -\mathbf{u}\cdot\nabla\ln\rho - \nabla\cdot\mathbf{u}$$

$$\frac{\partial \mathbf{u}}{\partial t} = -(\mathbf{u}\cdot\nabla)\,\mathbf{u} - c_s^2\,\nabla\ln\rho$$



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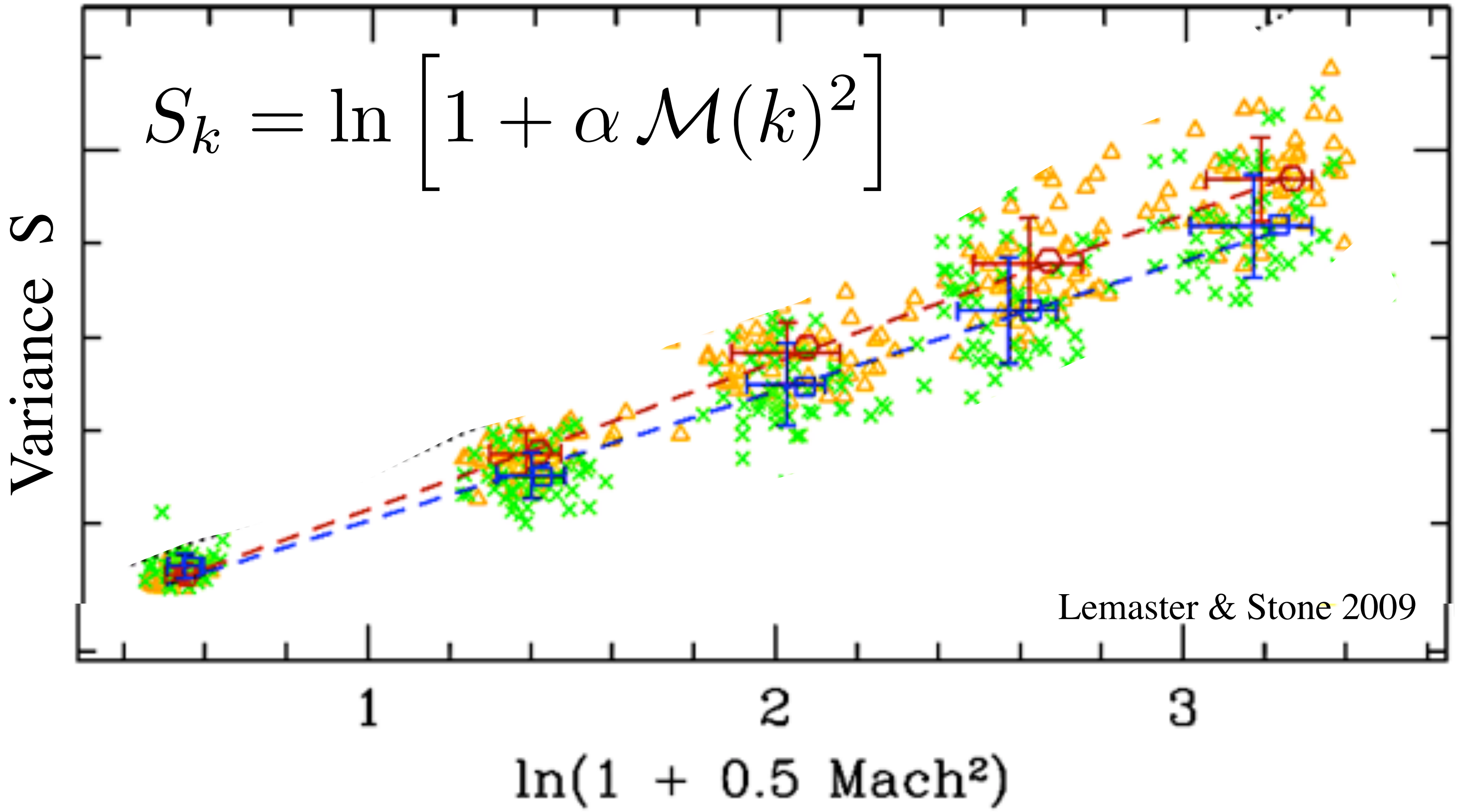

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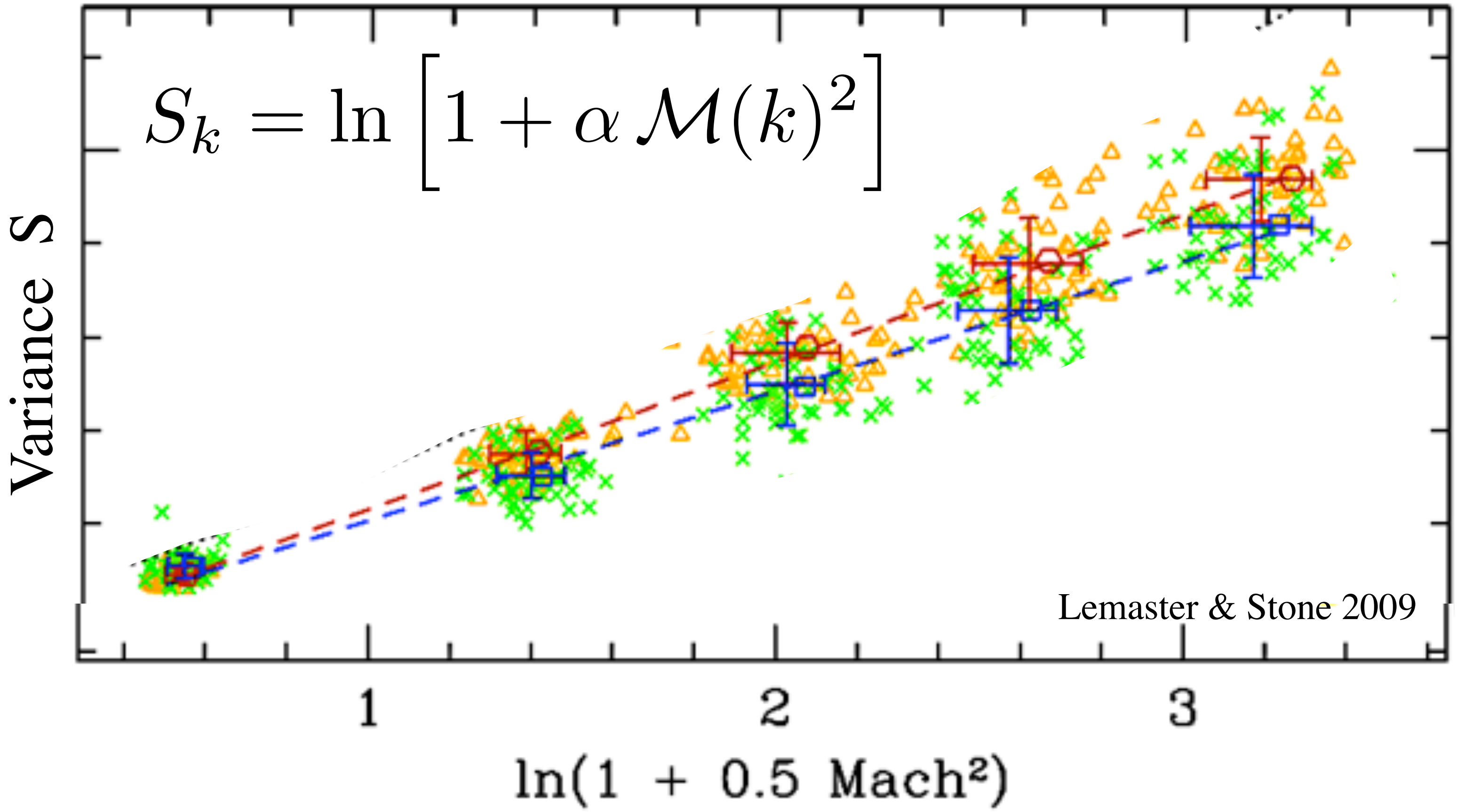
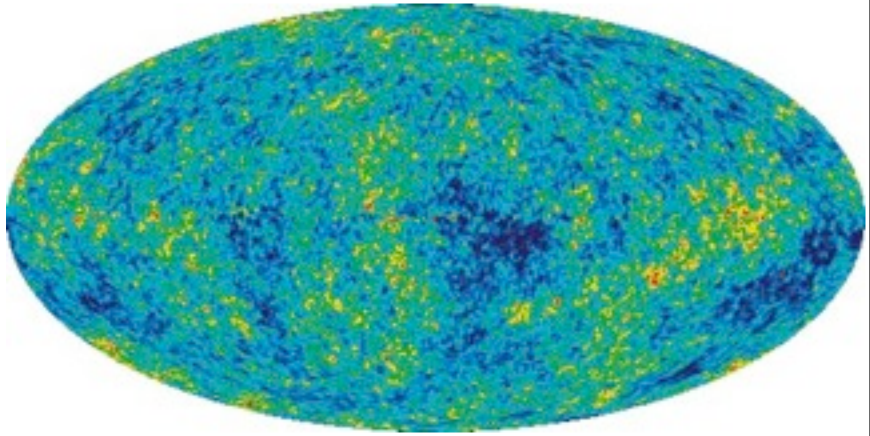


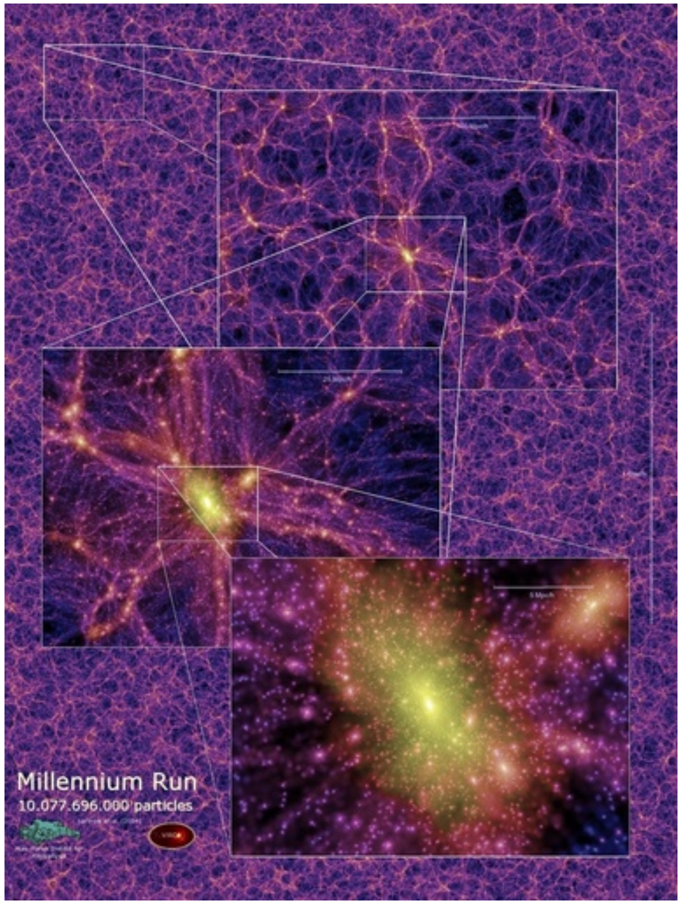
$$S_k = \ln\left[1 + \alpha\,\mathcal{M}(k)^2\right]$$

$$S(R) = \int \mathrm{d}\ln k\, S_k\, |W(k,\, R)|^2$$

Extended Press-Schechter / Excursion-Set Formalism



- Press & Schechter ‘74:
  - r Fluctuations a Gaussian random field
  - Know linear power spectrum P(k~1/r):
    variance $\sim k^3 P(k)$



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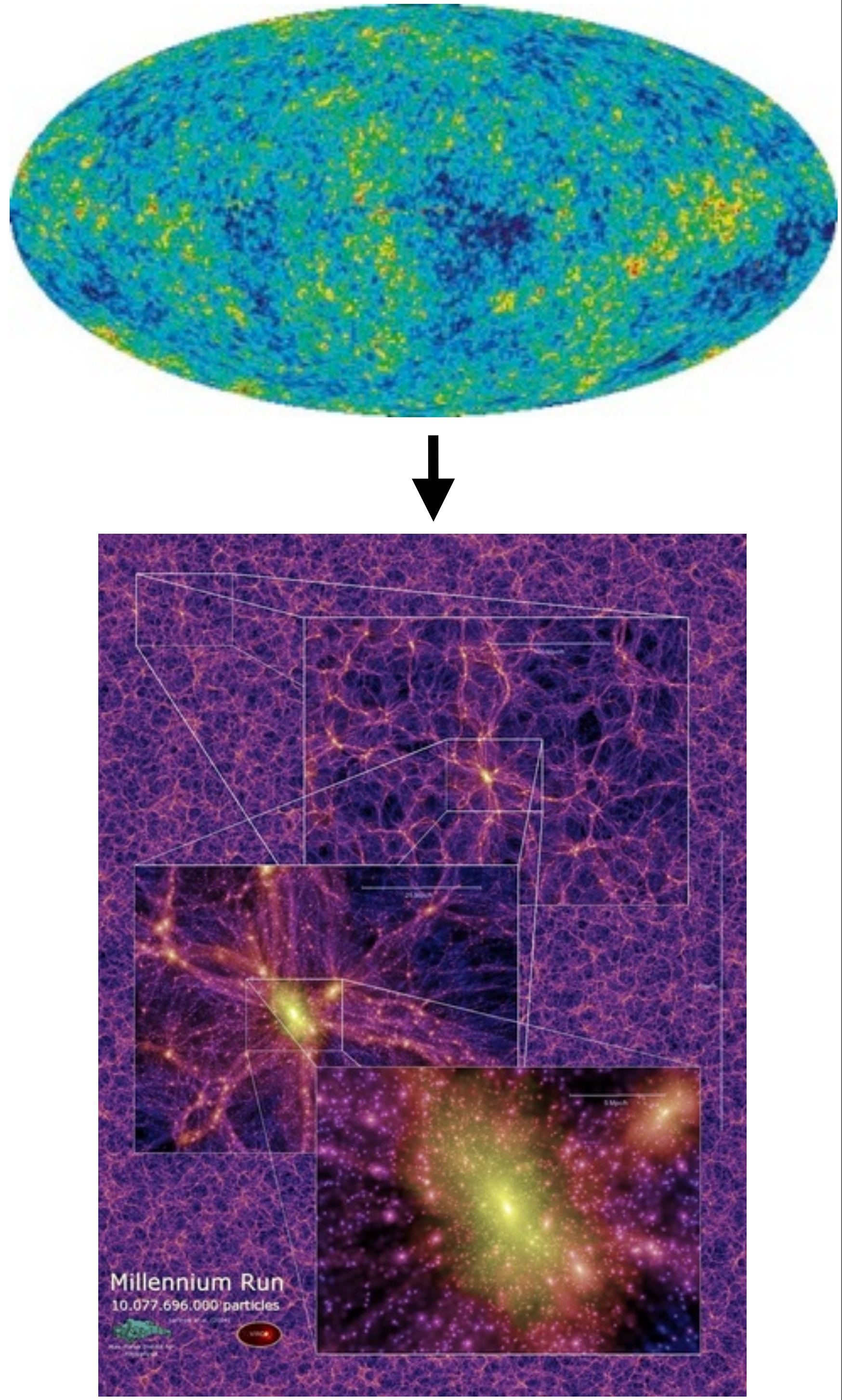
  - Turnaround & gravitational collapse

$$\bar{\rho}(< R \sim 1/k) > \rho_{\rm crit}$$



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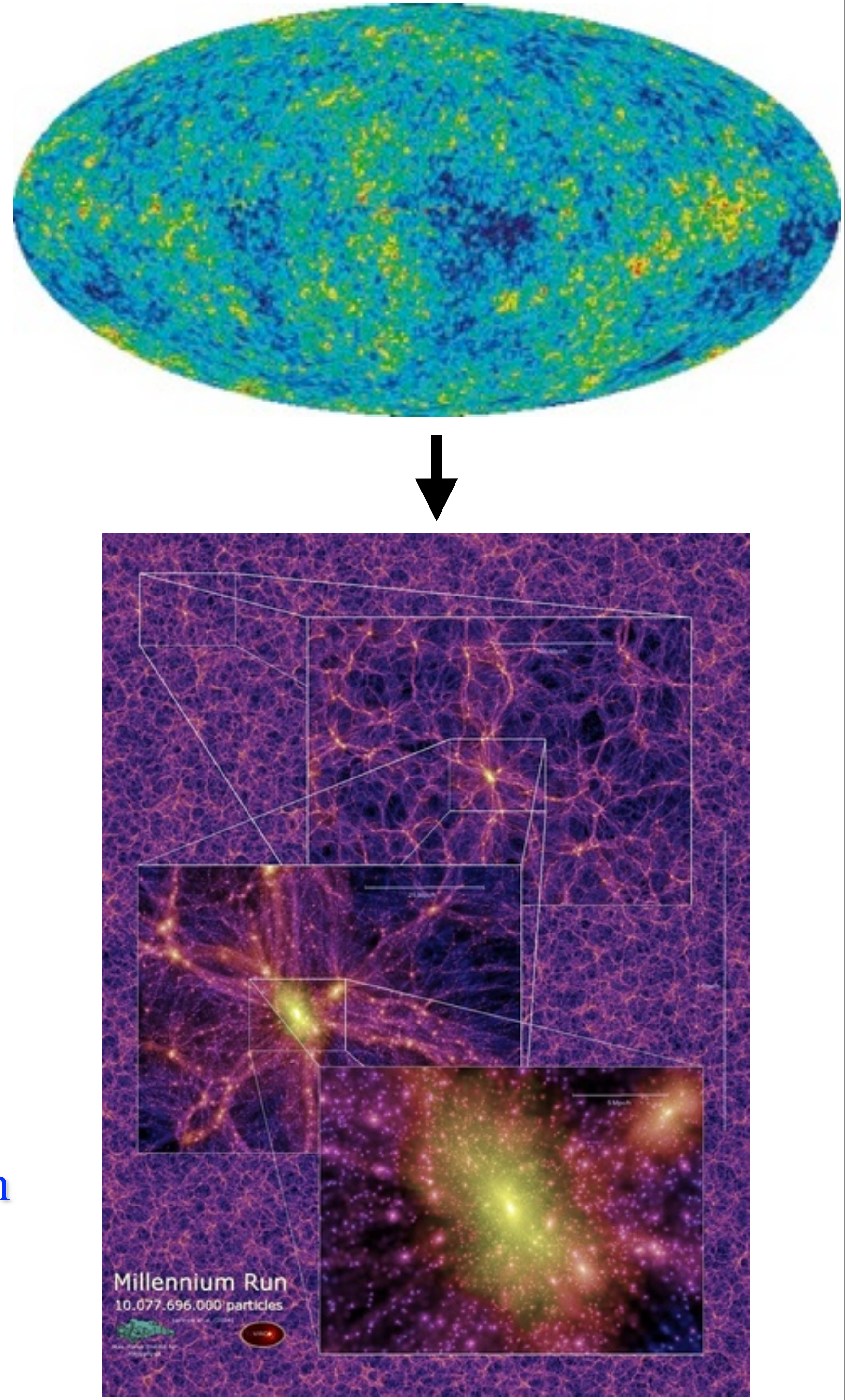

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- Generalize to conditional probabilities,
  N-point statistics, resolve "cloud in cloud" problem
  (e.g. Bond et al. 1991)

What Defines a Fluctuation of Interest?

DISPERSION RELATION:

$$\omega^2 = \kappa^2 + c_s^2\, k^2 + u_t(k)^2\, k^2 - \frac{4\pi\, G\, \rho\, |k| h}{1 + |k| h}$$

Chandrasekhar ‘51, Vandervoort ‘70, Toomre ‘77

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Gravity

Mode Grows (Collapses) when $w<0$:

$$\rho > \rho_c(k) = \rho_0\,(1 + |kh|)\left[\left(\mathcal{M}_h^{-2} + |kh|^{1-p}\right) kh + \frac{2}{|kh|}\right]$$

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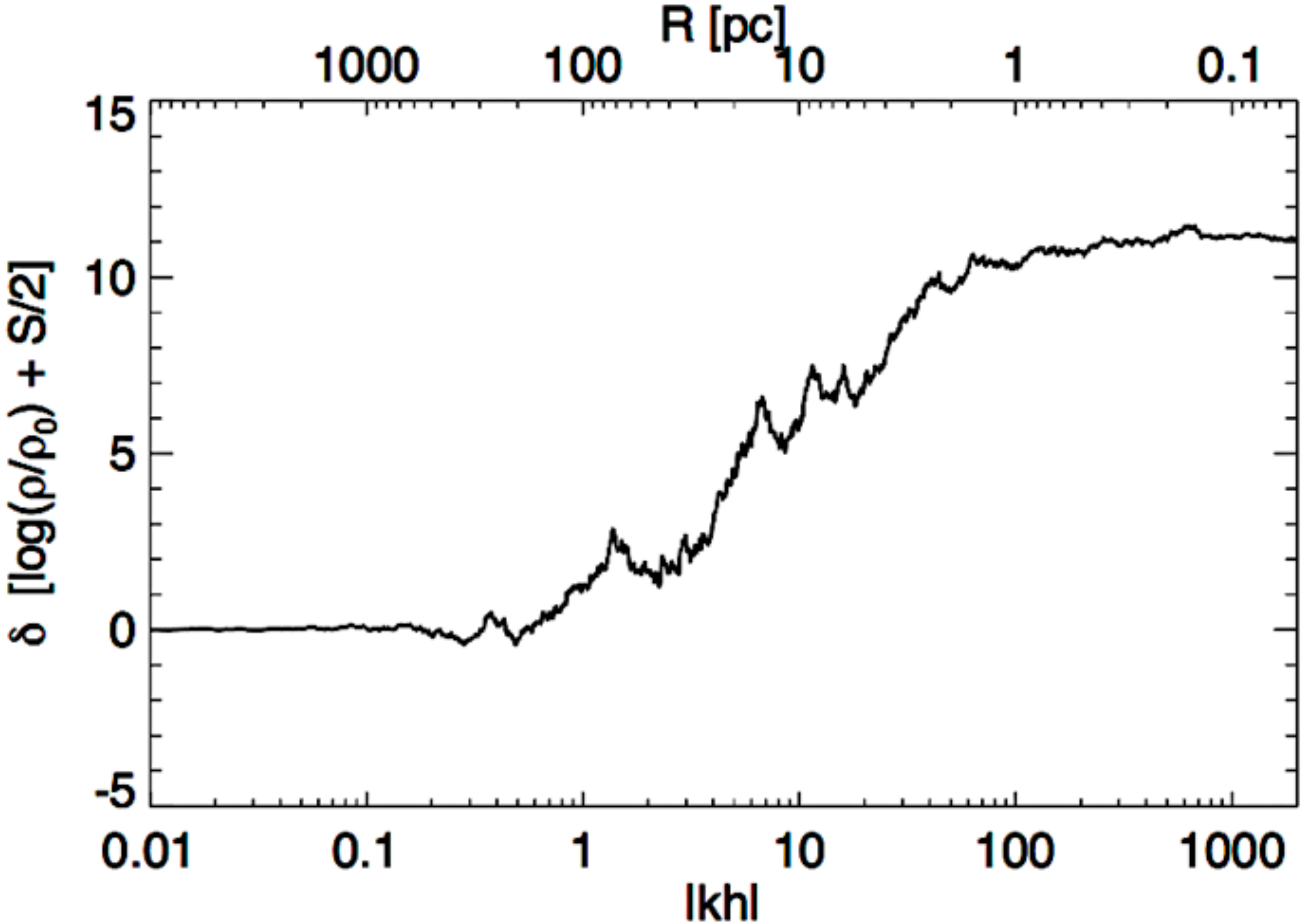
“Counting” Collapsing Objects

EVALUATE DENSITY FIELD vs. “BARRIER”



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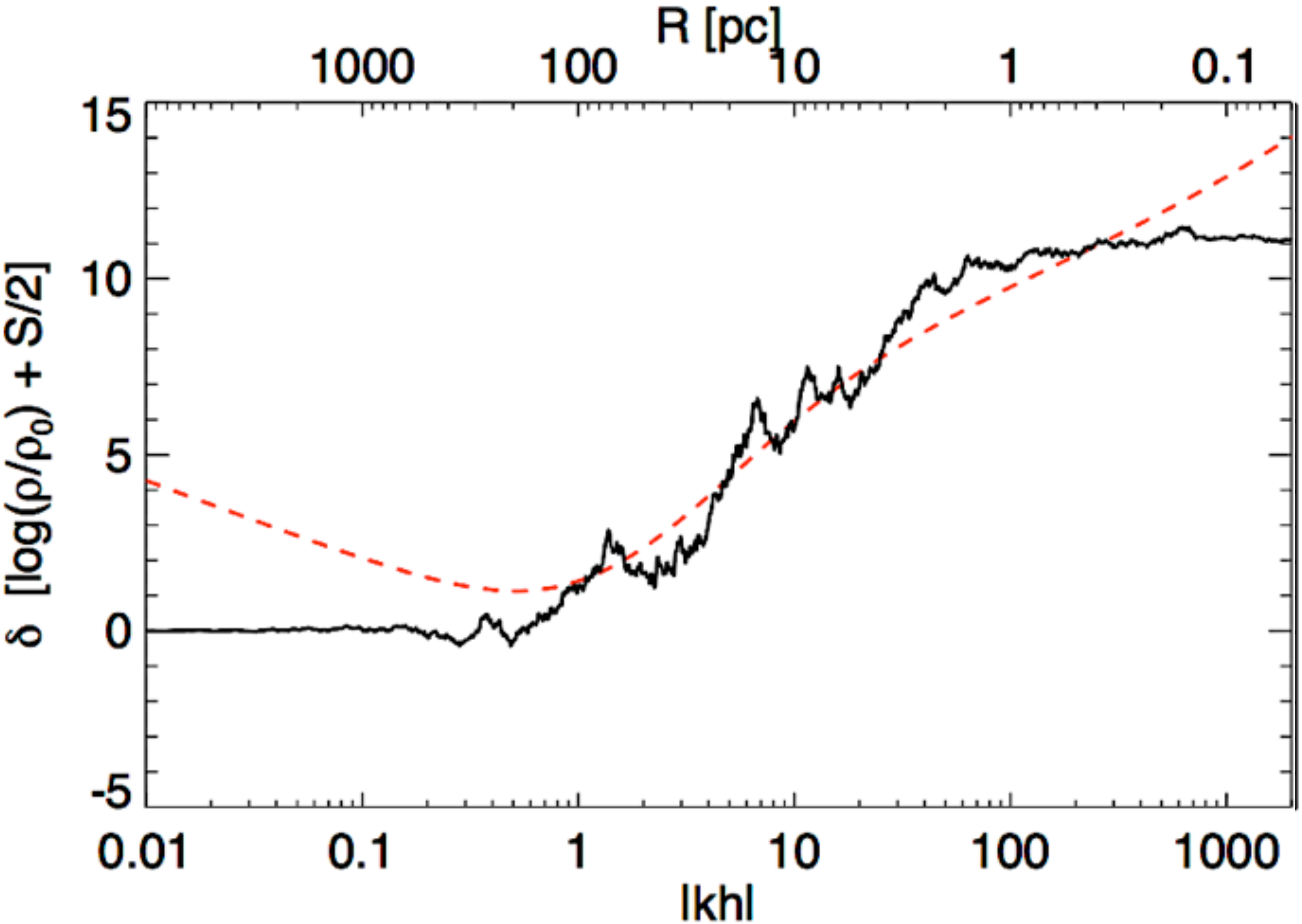

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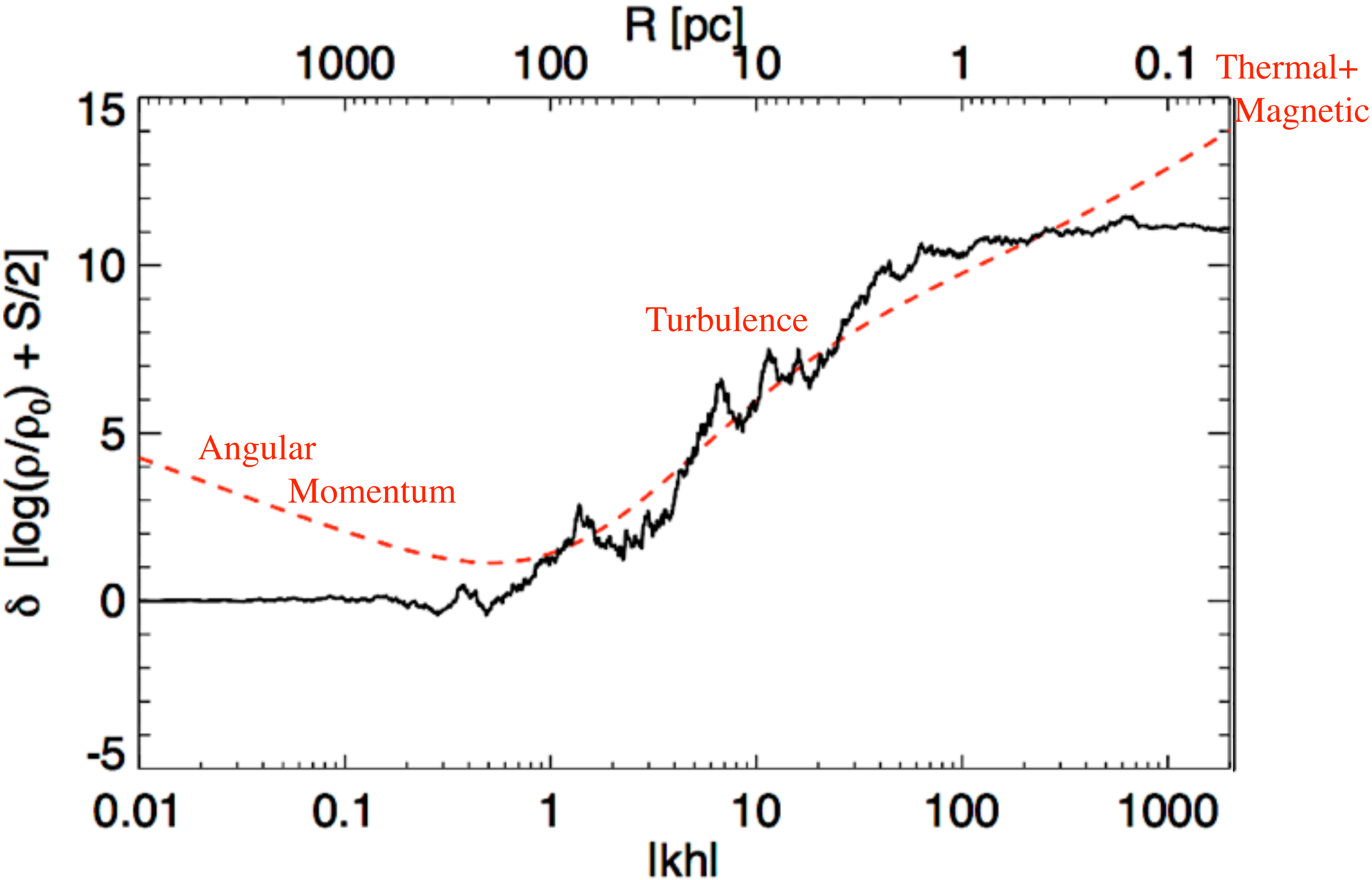

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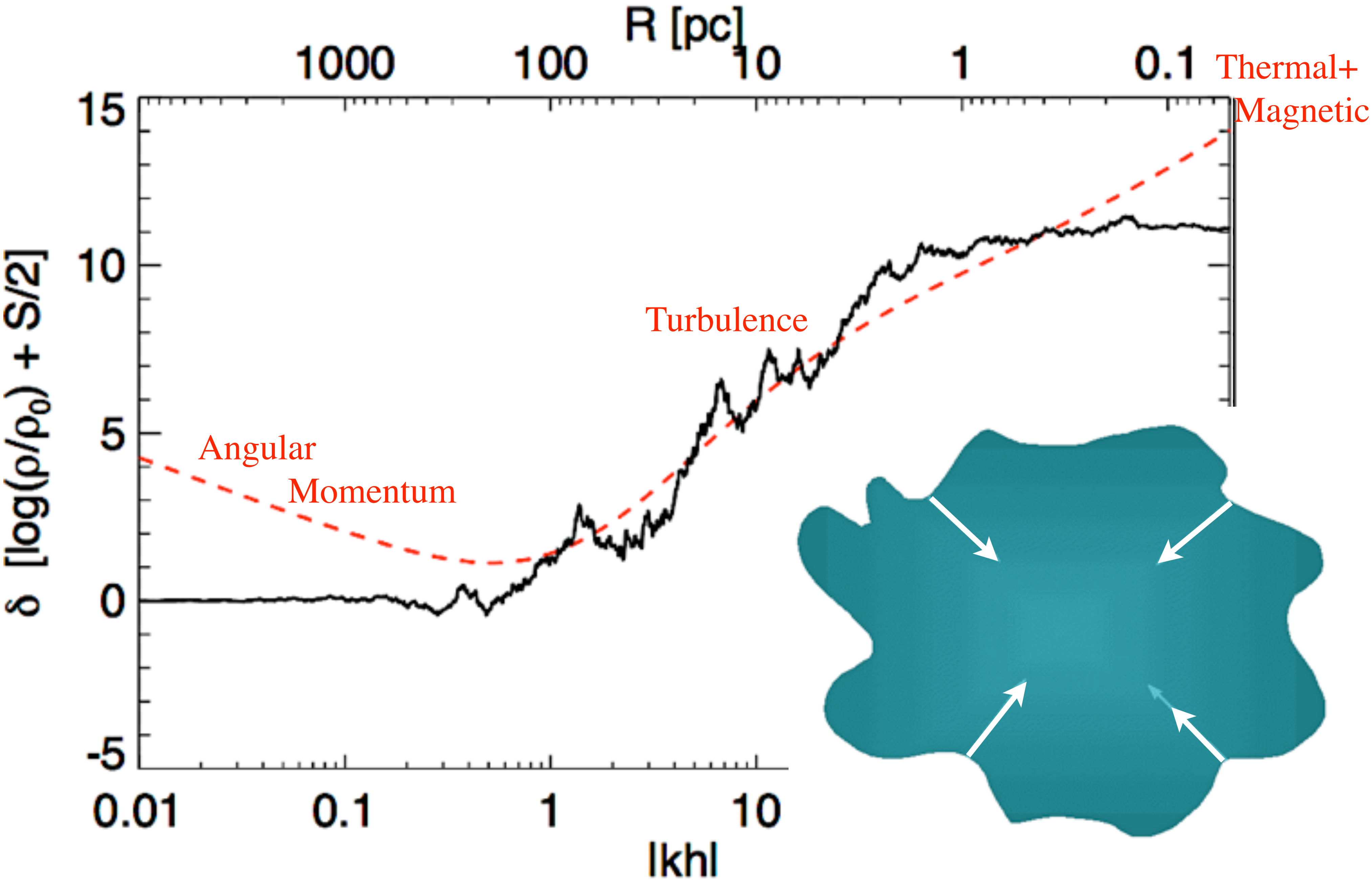

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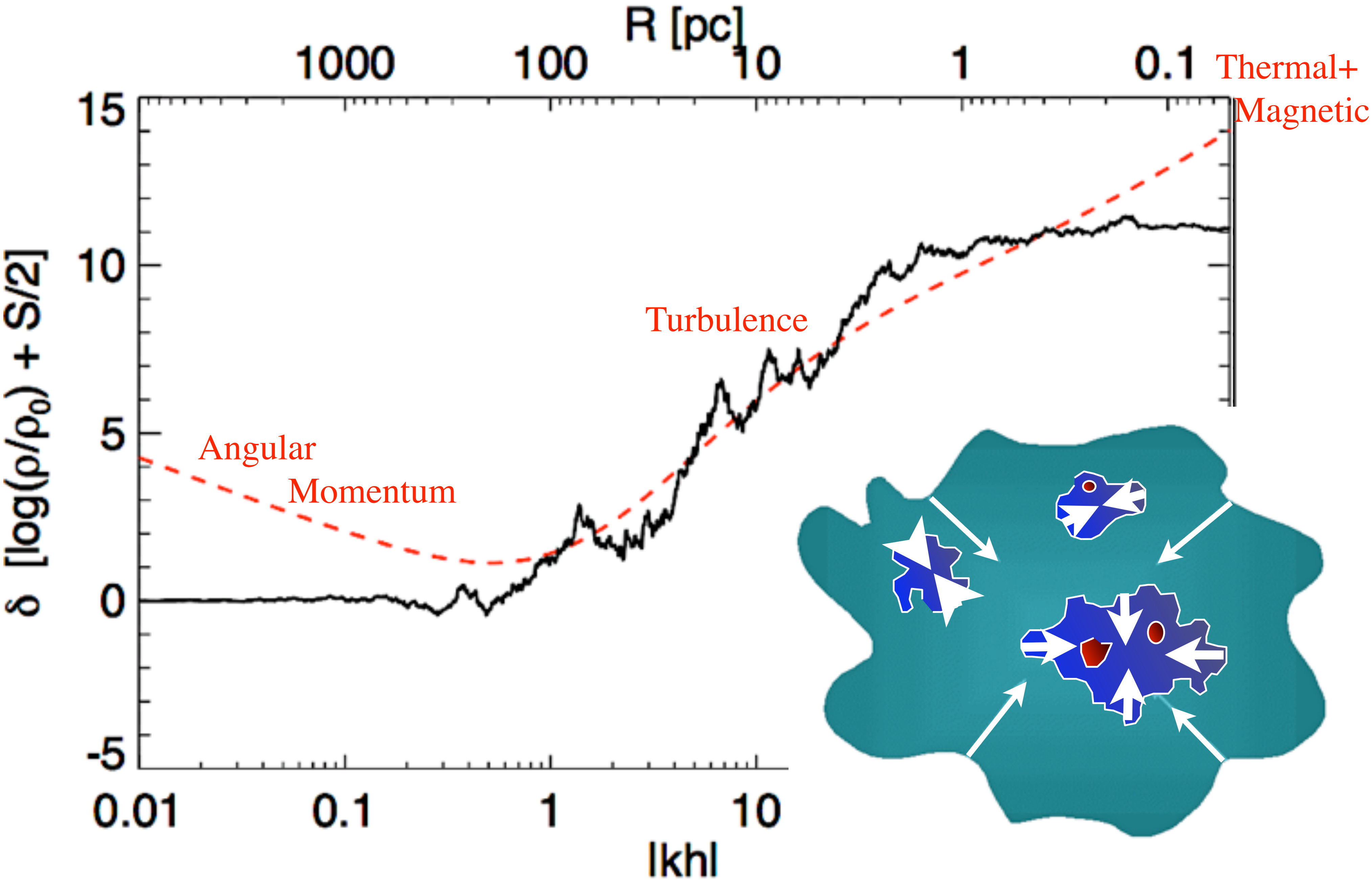

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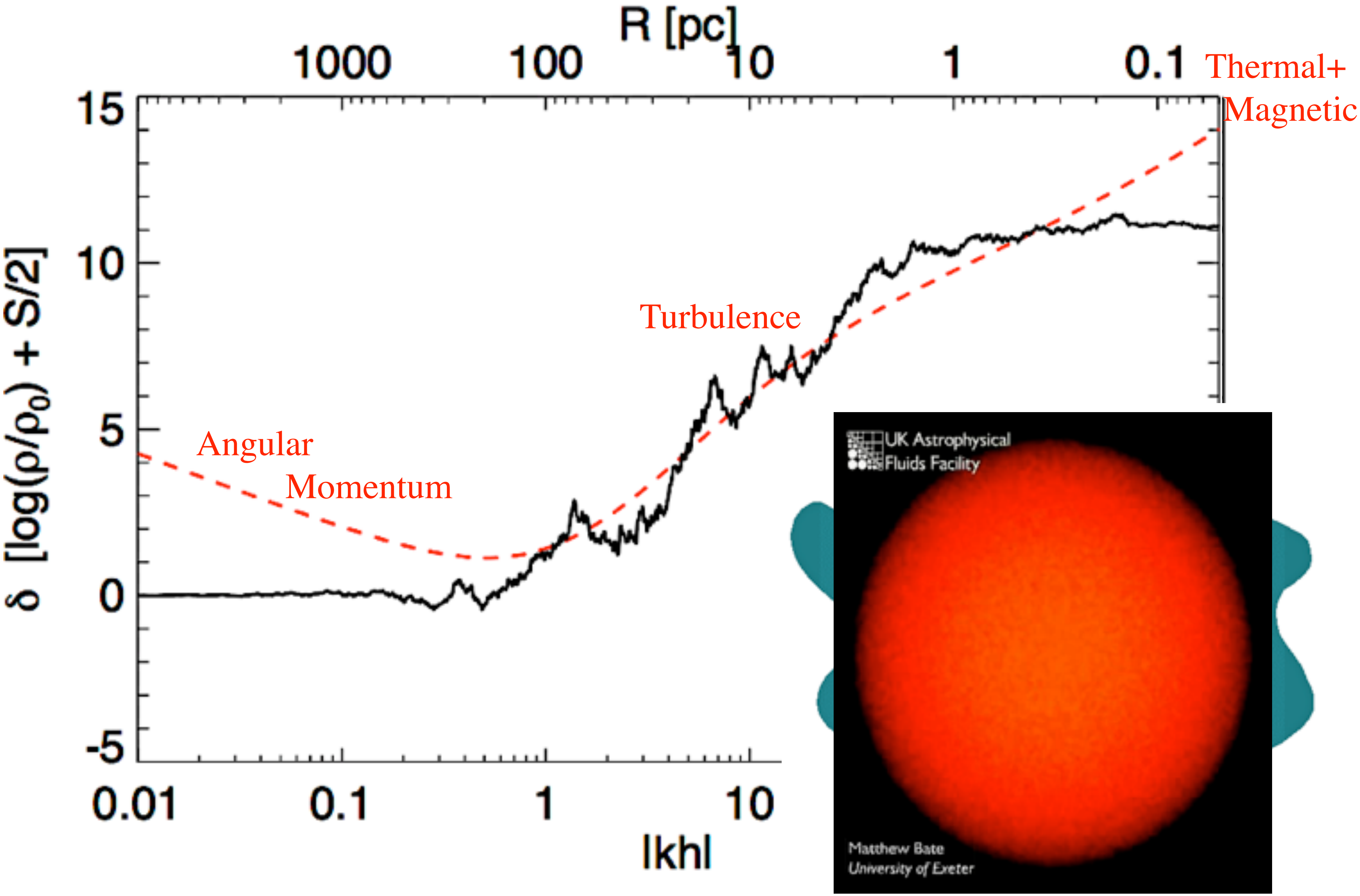

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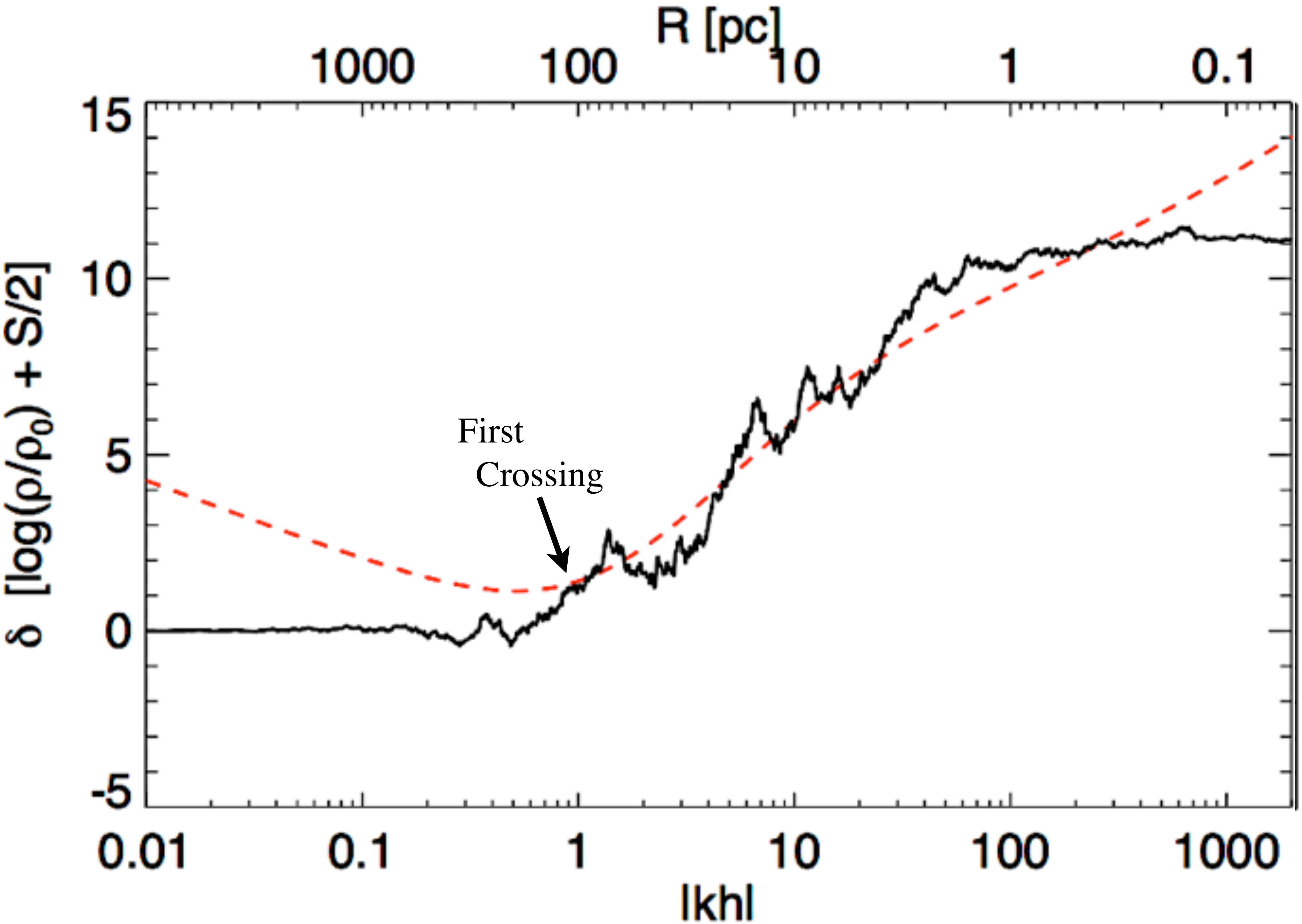

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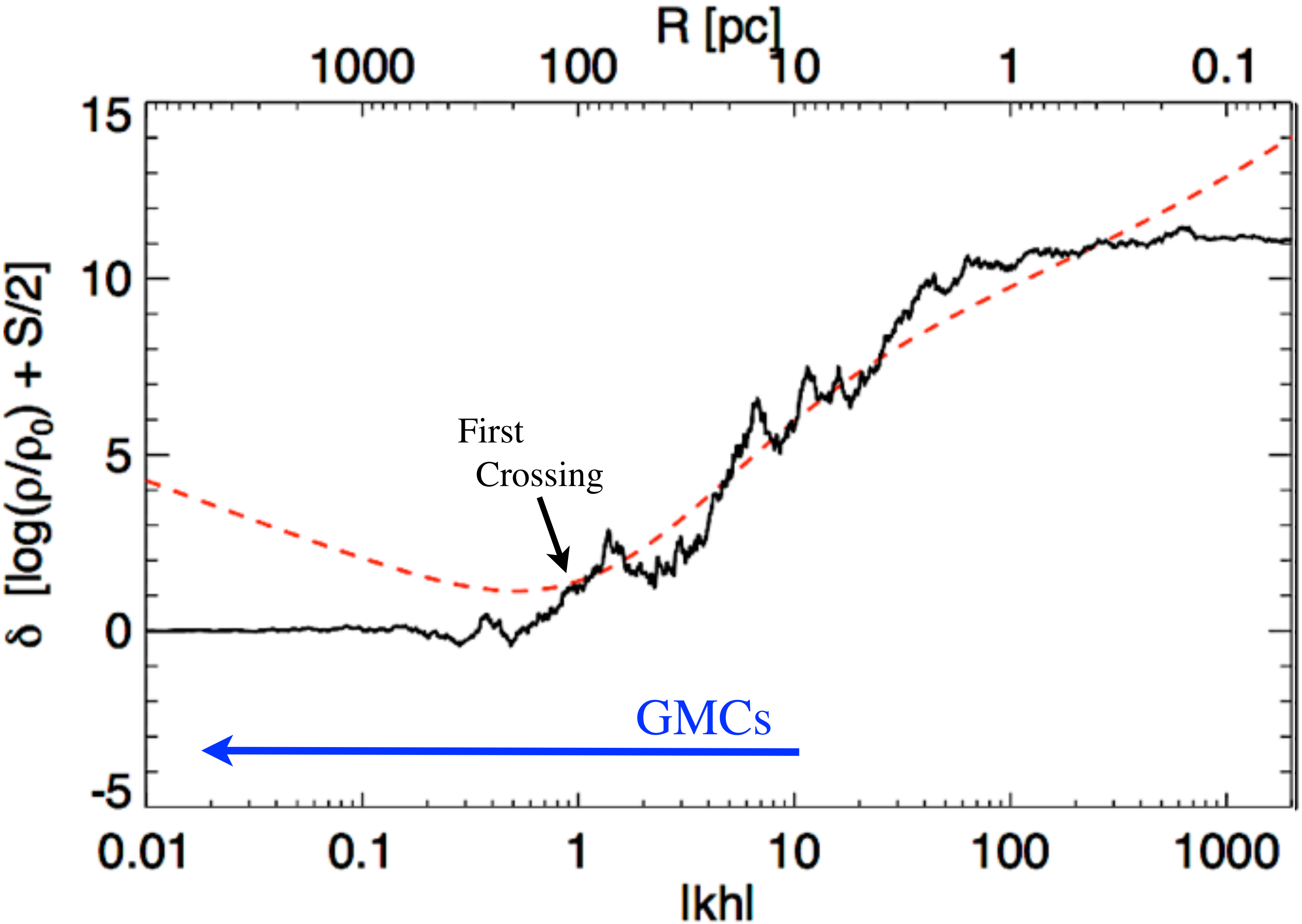

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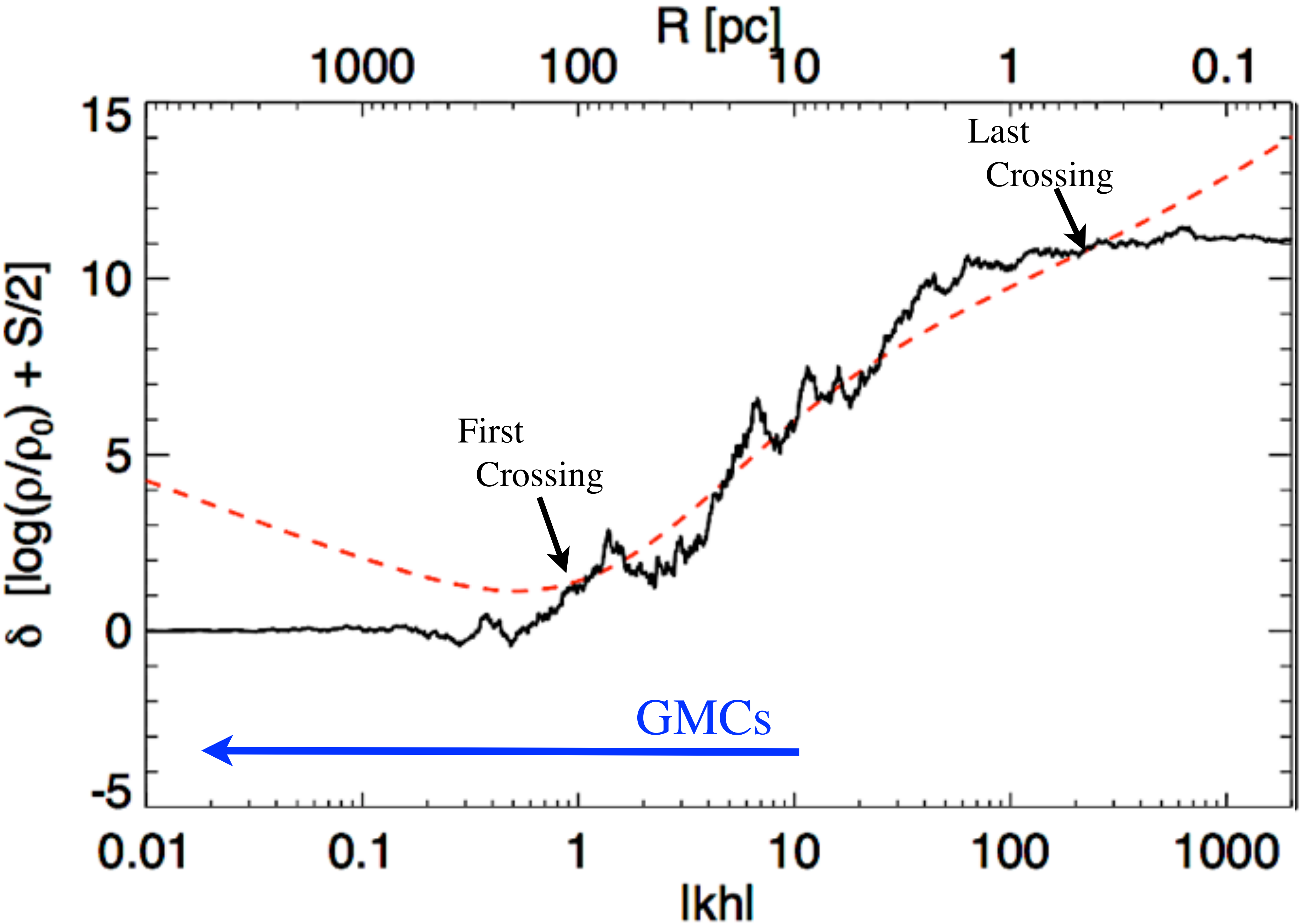

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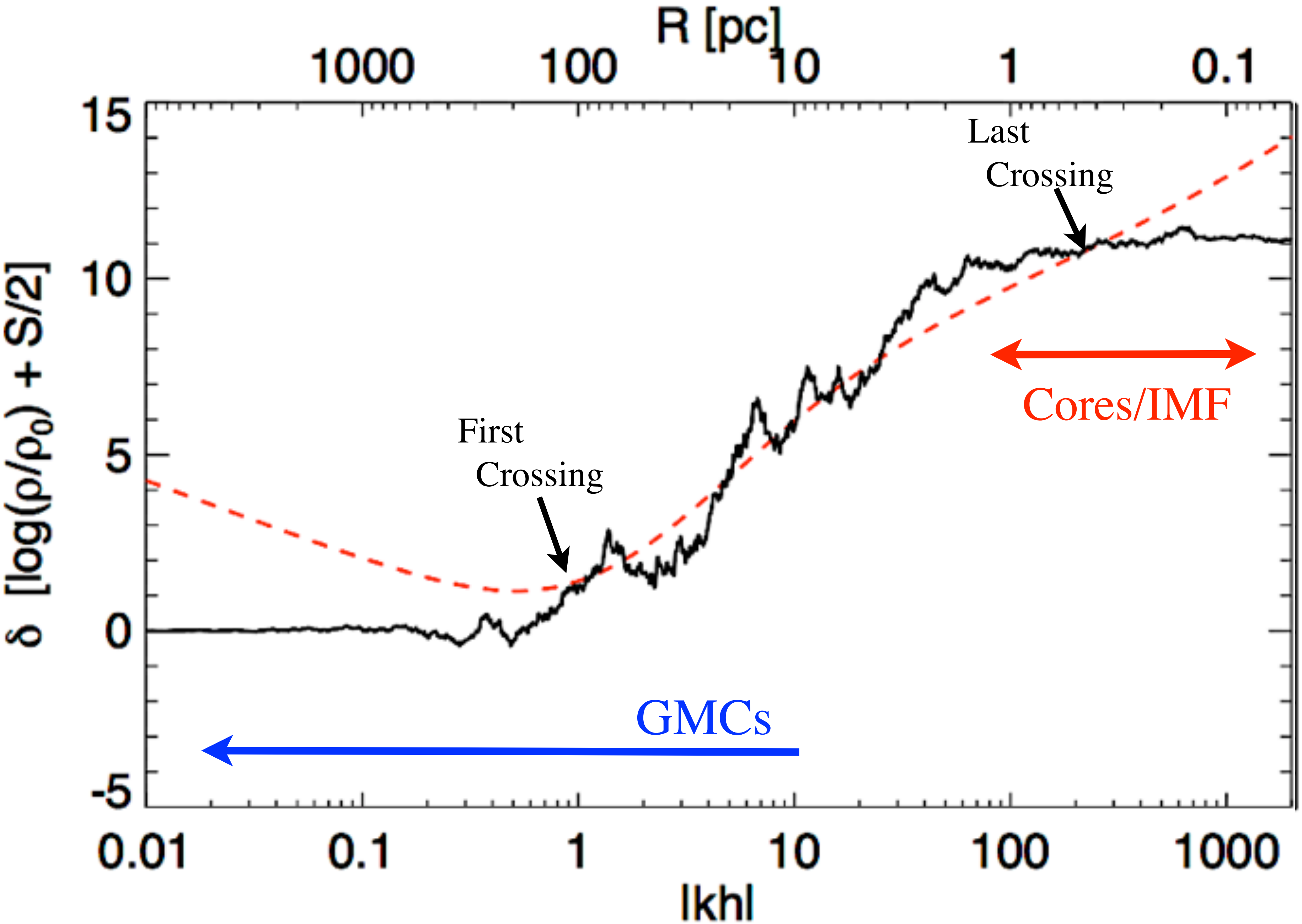
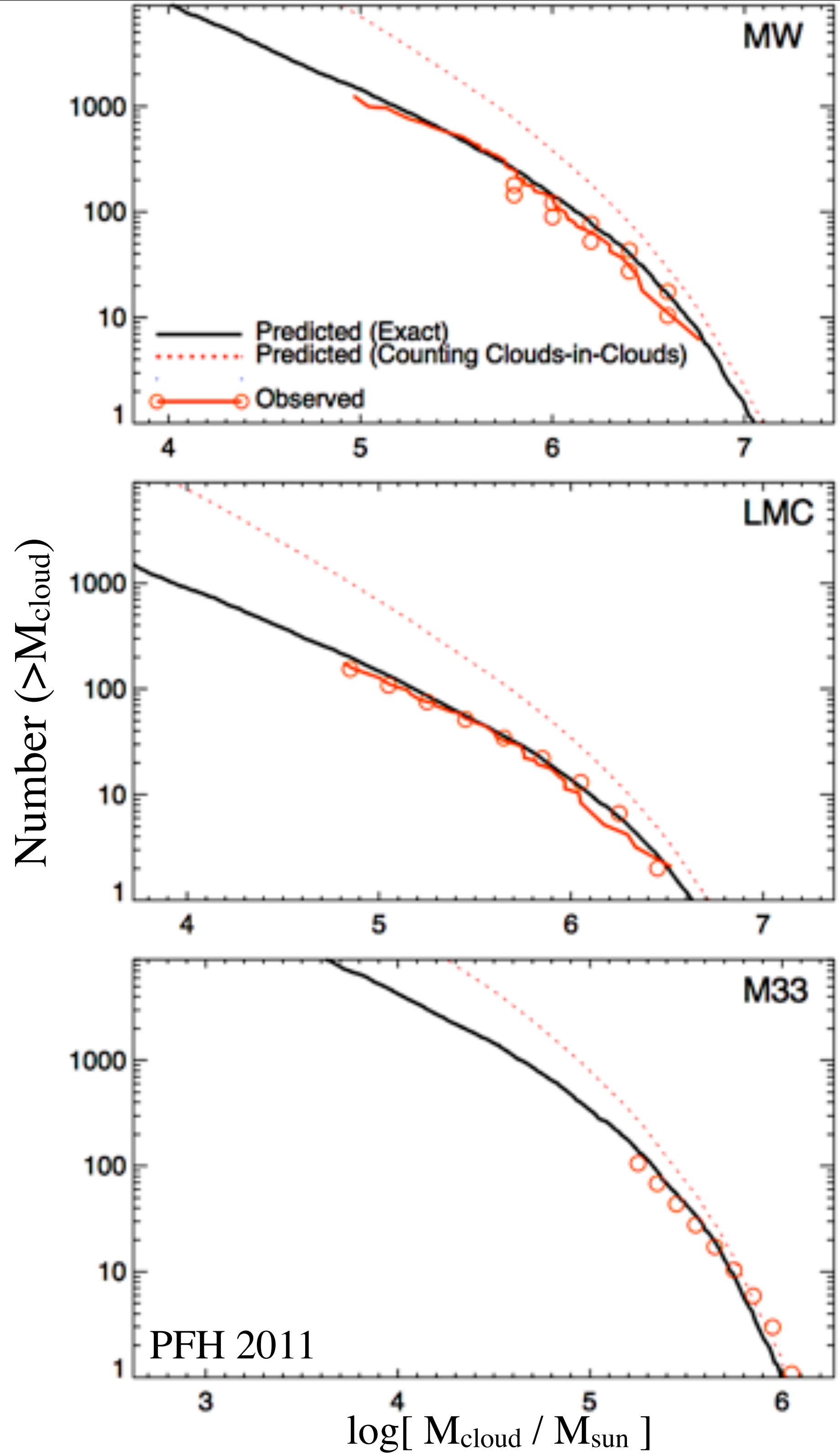


The "First Crossing" Mass Function

VS GIANT MOLECULAR CLOUDS



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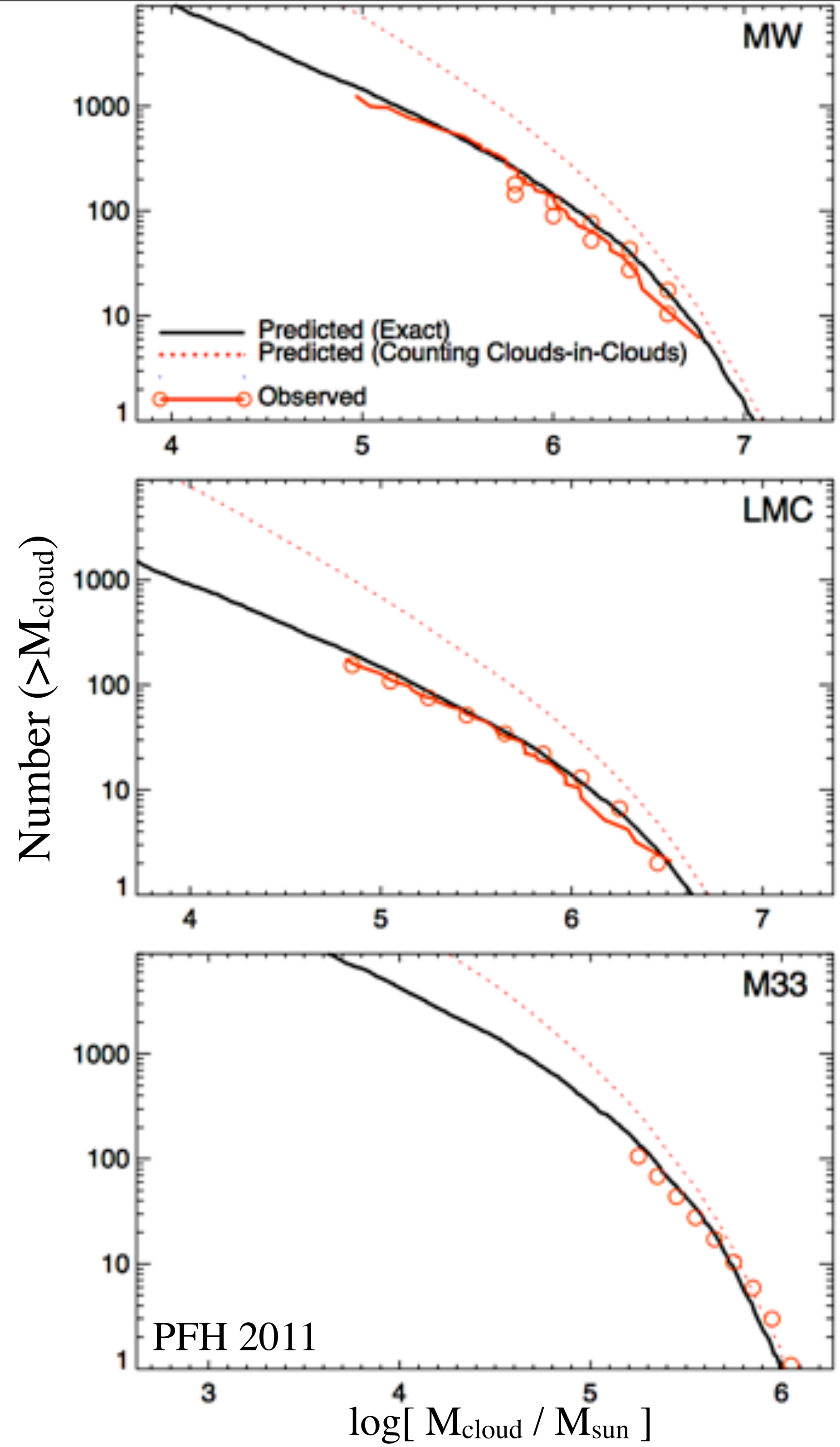

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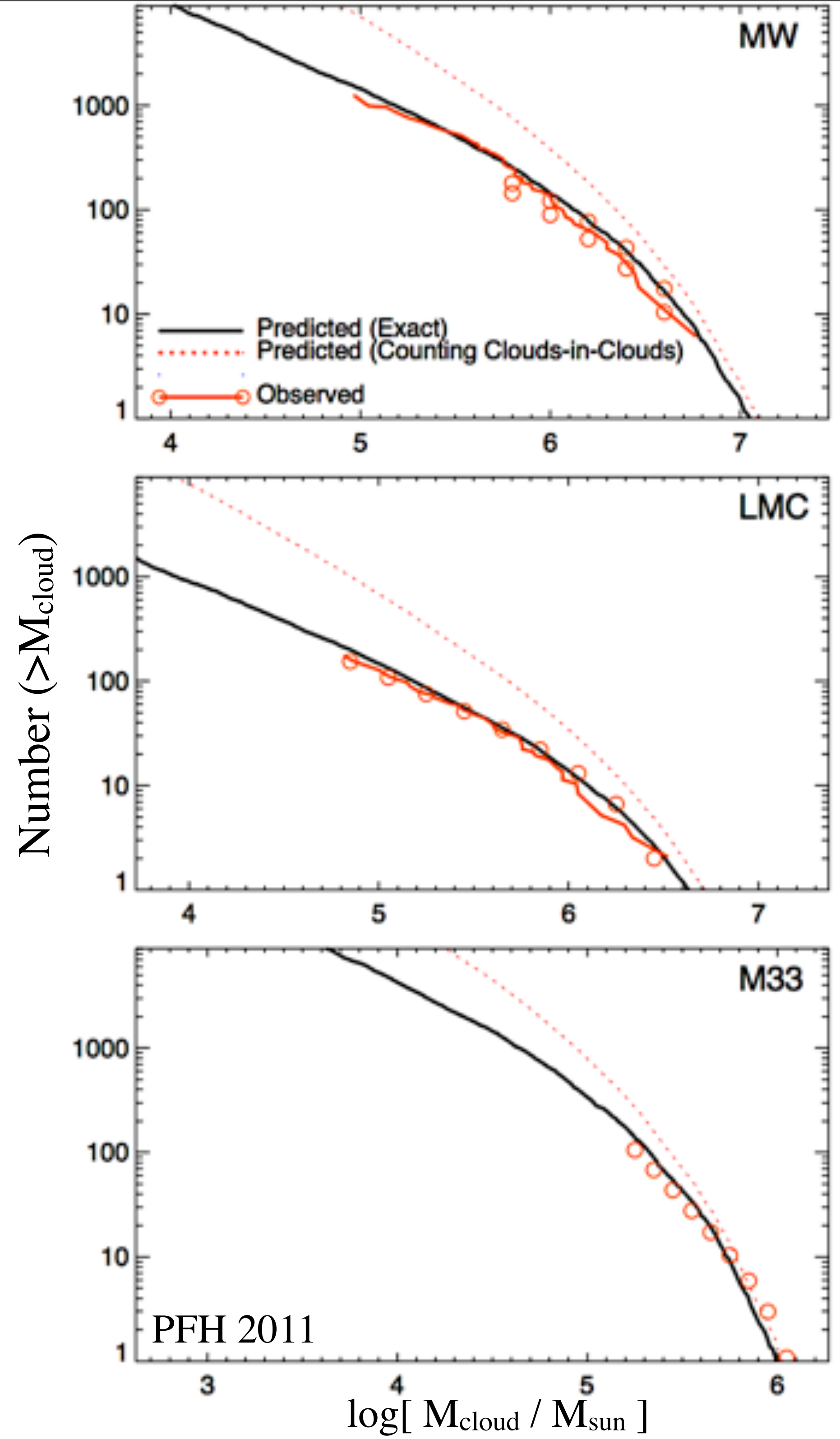

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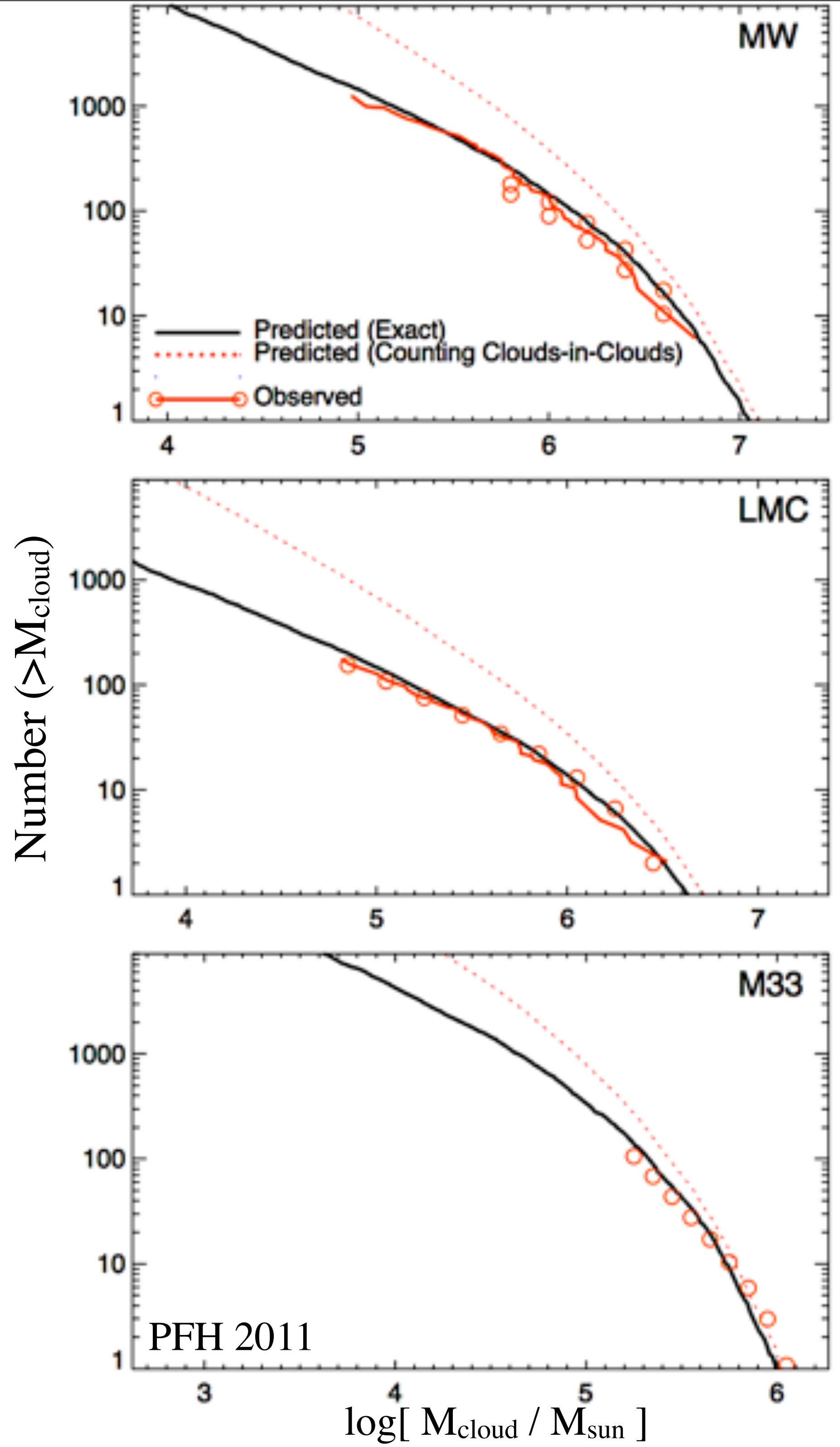
$$\alpha \approx -2 + \frac{(3-p)^2}{2\,S\,p^2}\ln\left(\frac{M_J}{M}\right)$$

$$\approx -2 + 0.1\,\log\left(\frac{M_J}{M}\right)$$



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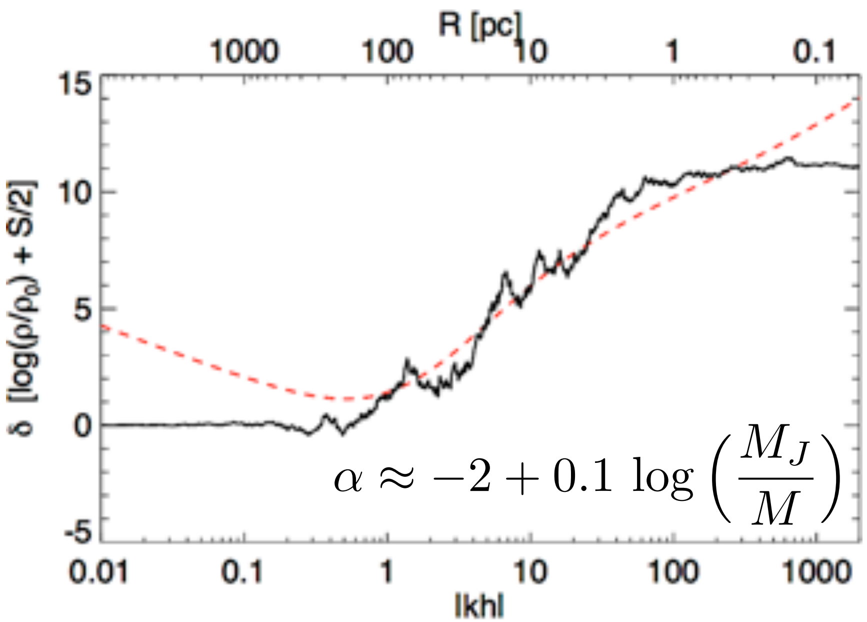
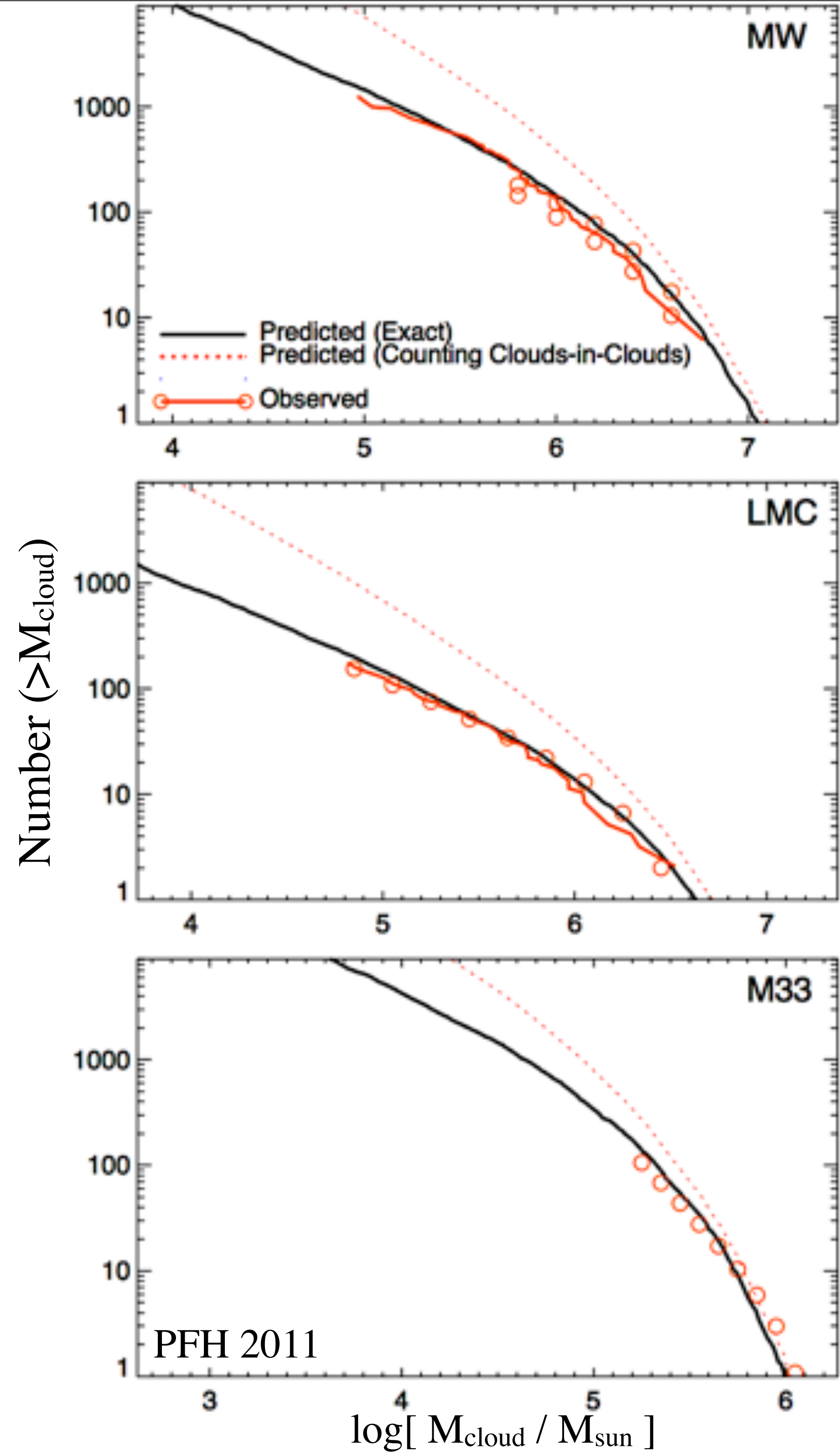
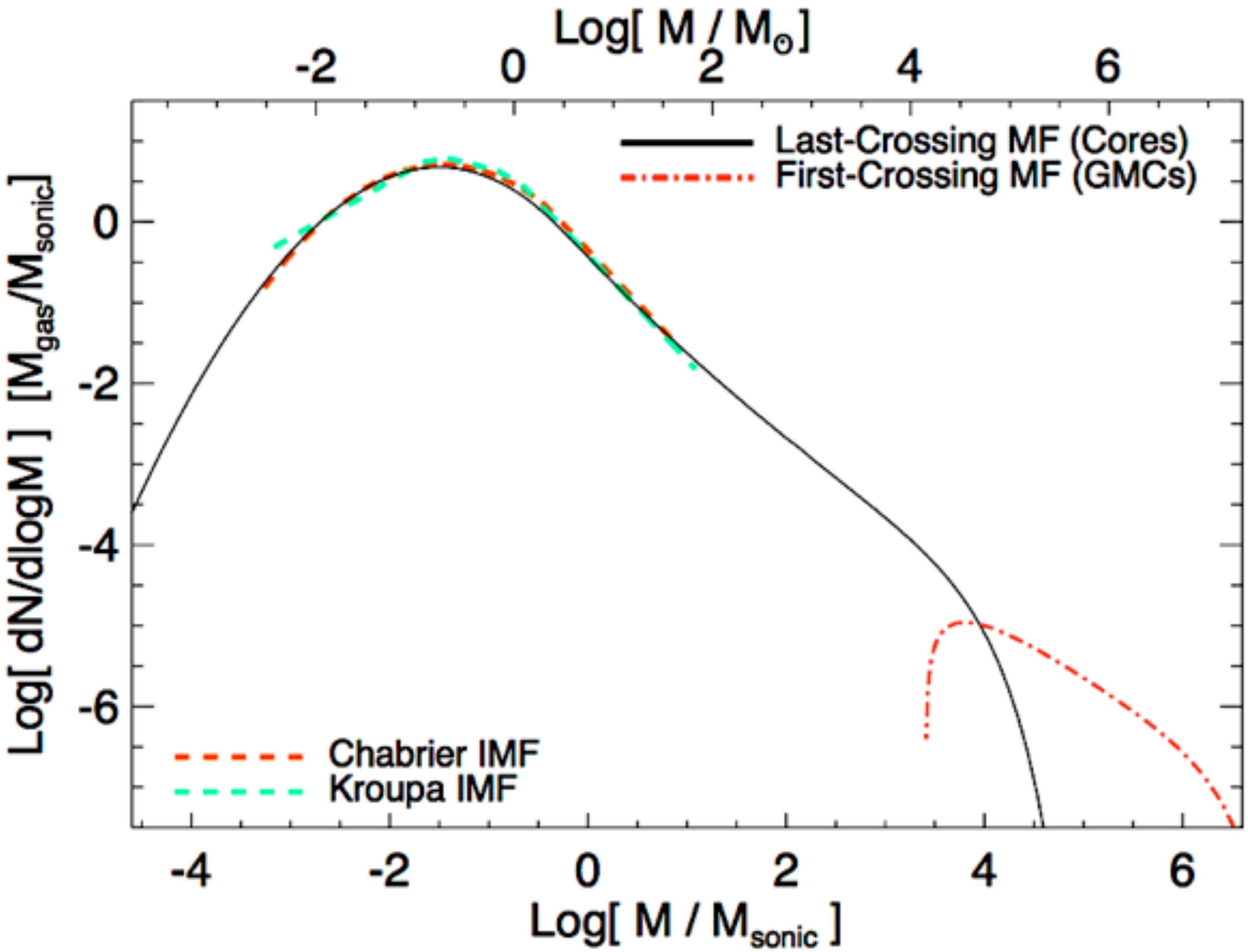




The "Last Crossing" Mass Function

VS PROTOSTELLAR CORES & THE STELLAR IMF



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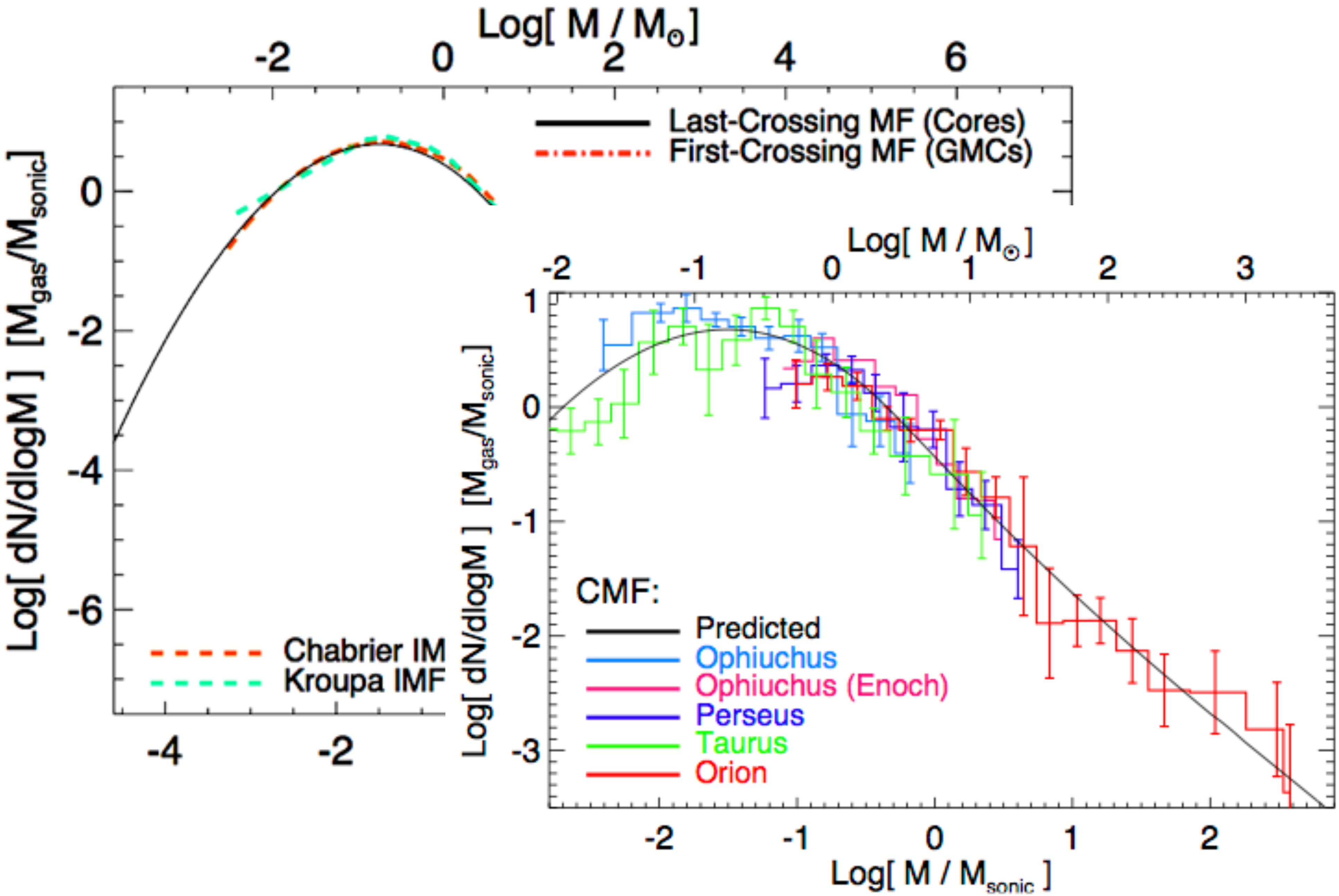
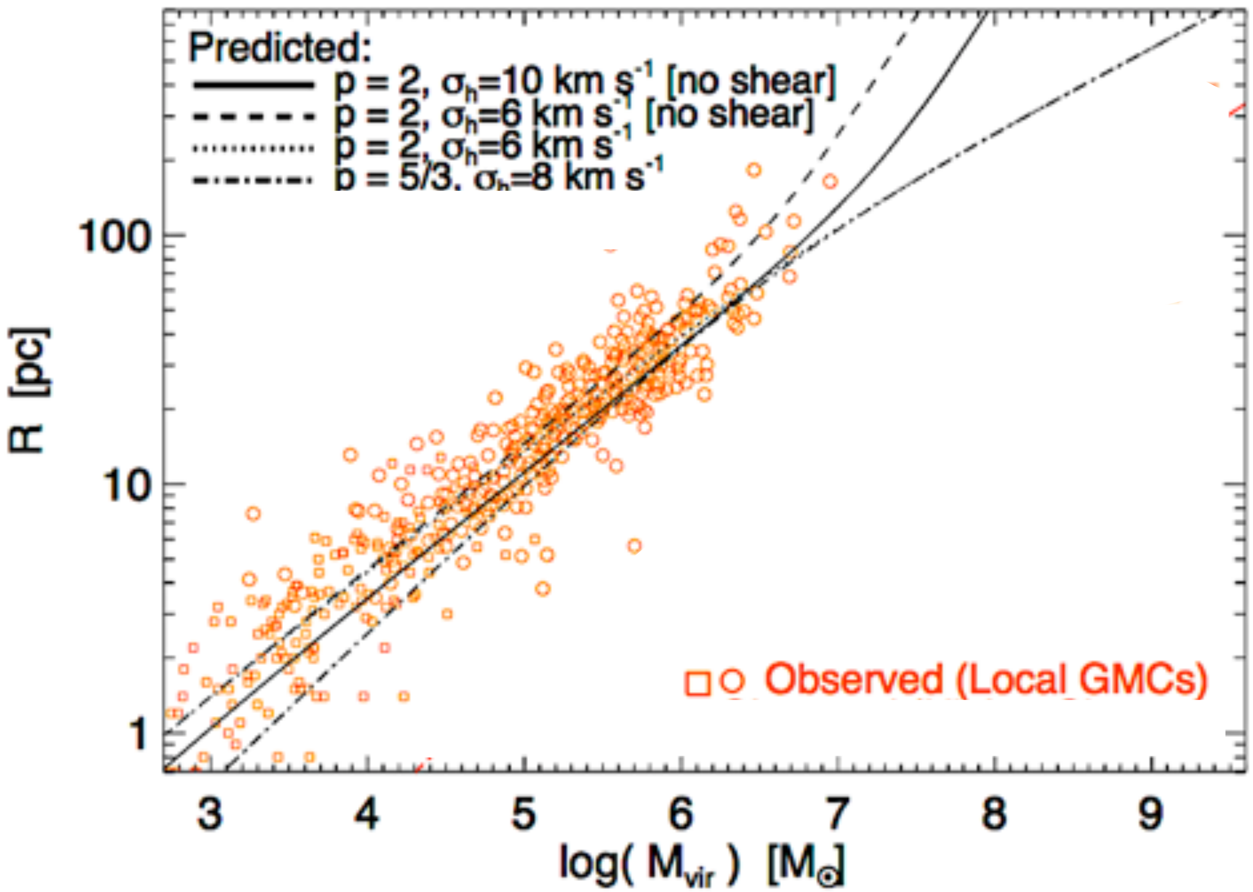


Structural Properties of "Clouds"

LARSON'S LAWS EMERGE NATURALLY



KEEP?

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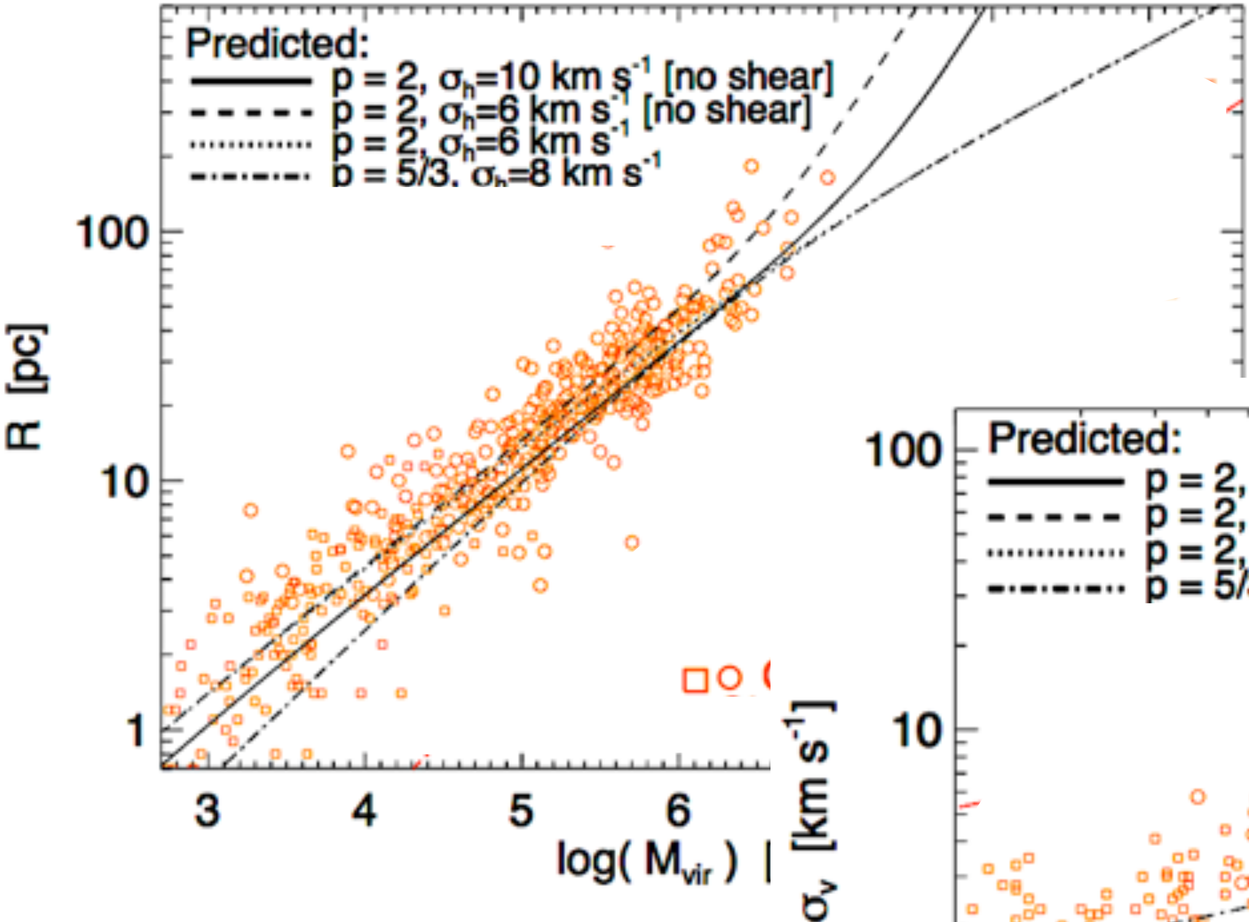
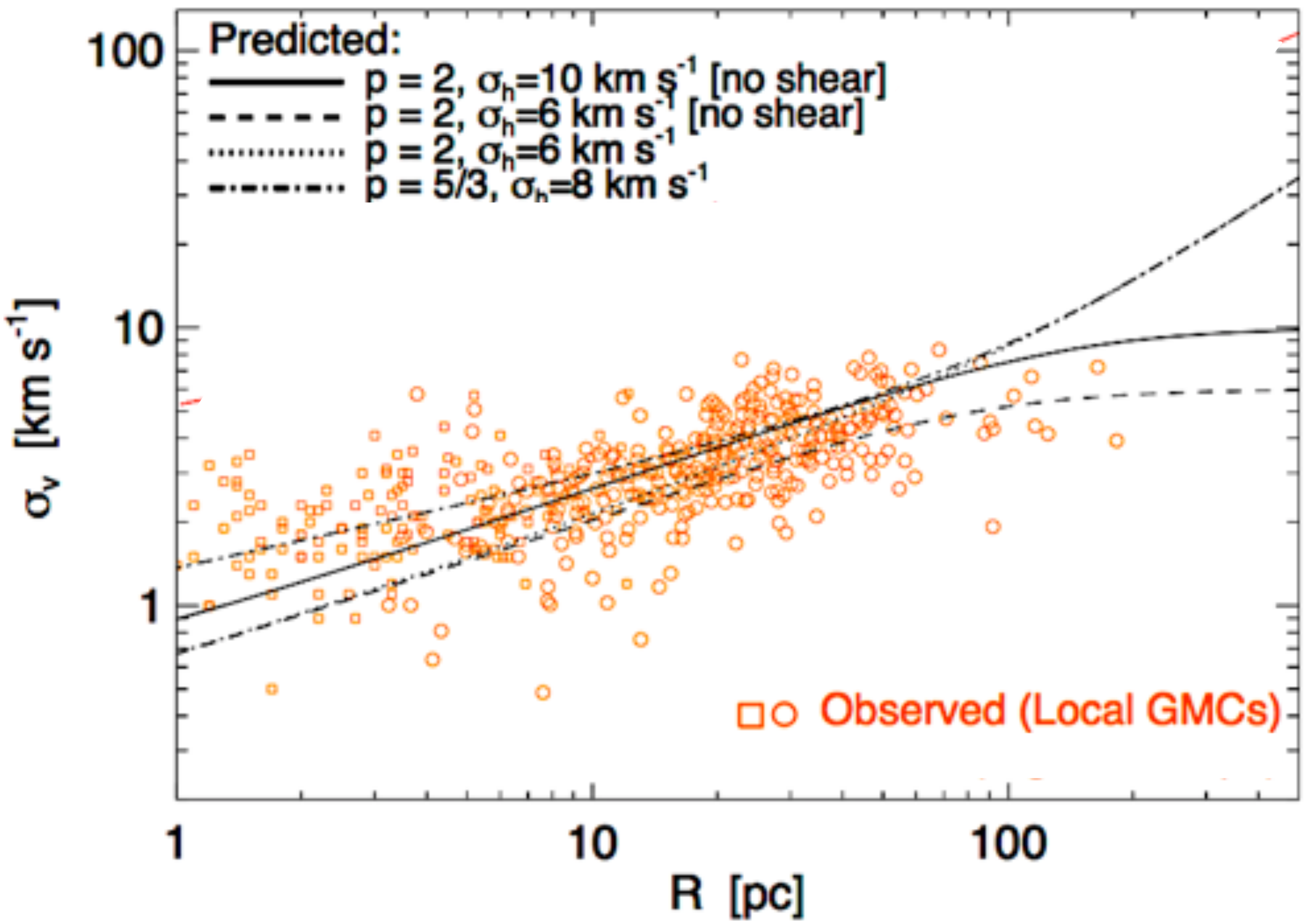




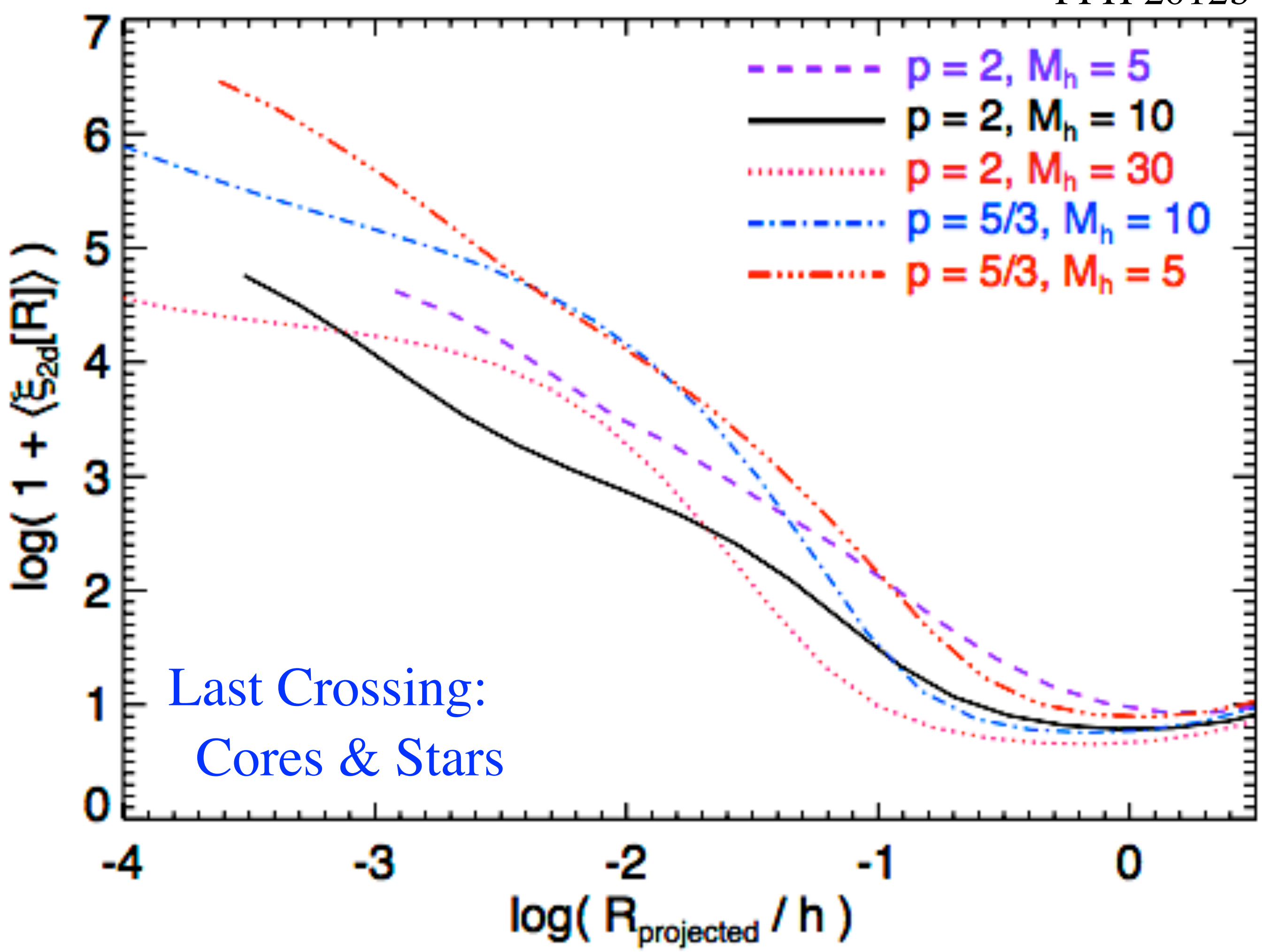
KEEP?

Clustering

PREDICT N-POINT CORRELATION FUNCTIONS

$$1 + \xi(r \,|\, M) \equiv \frac{\langle n[M \,|\, r' < r] \rangle}{\langle n[M] \rangle}$$

PFH 2012b



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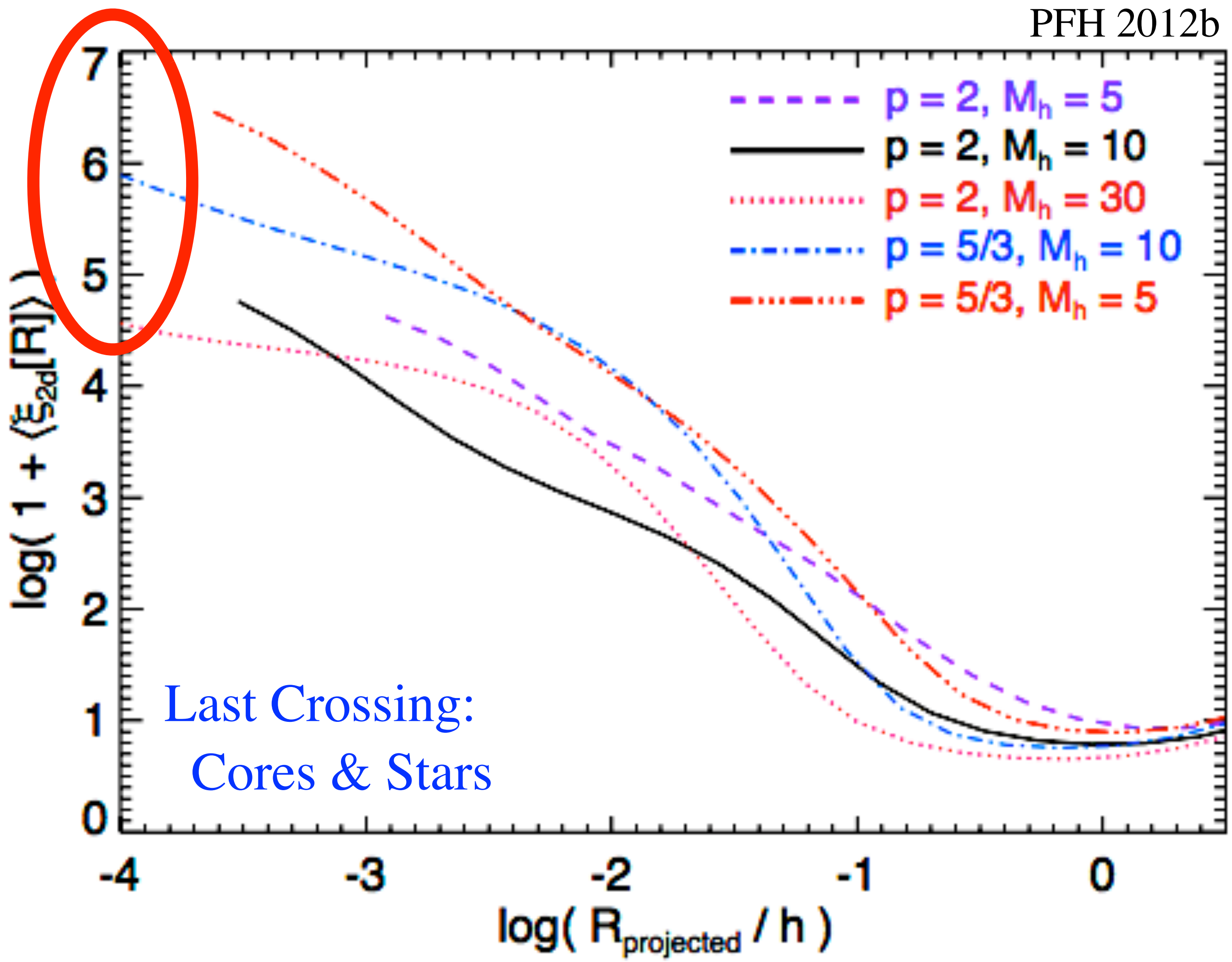

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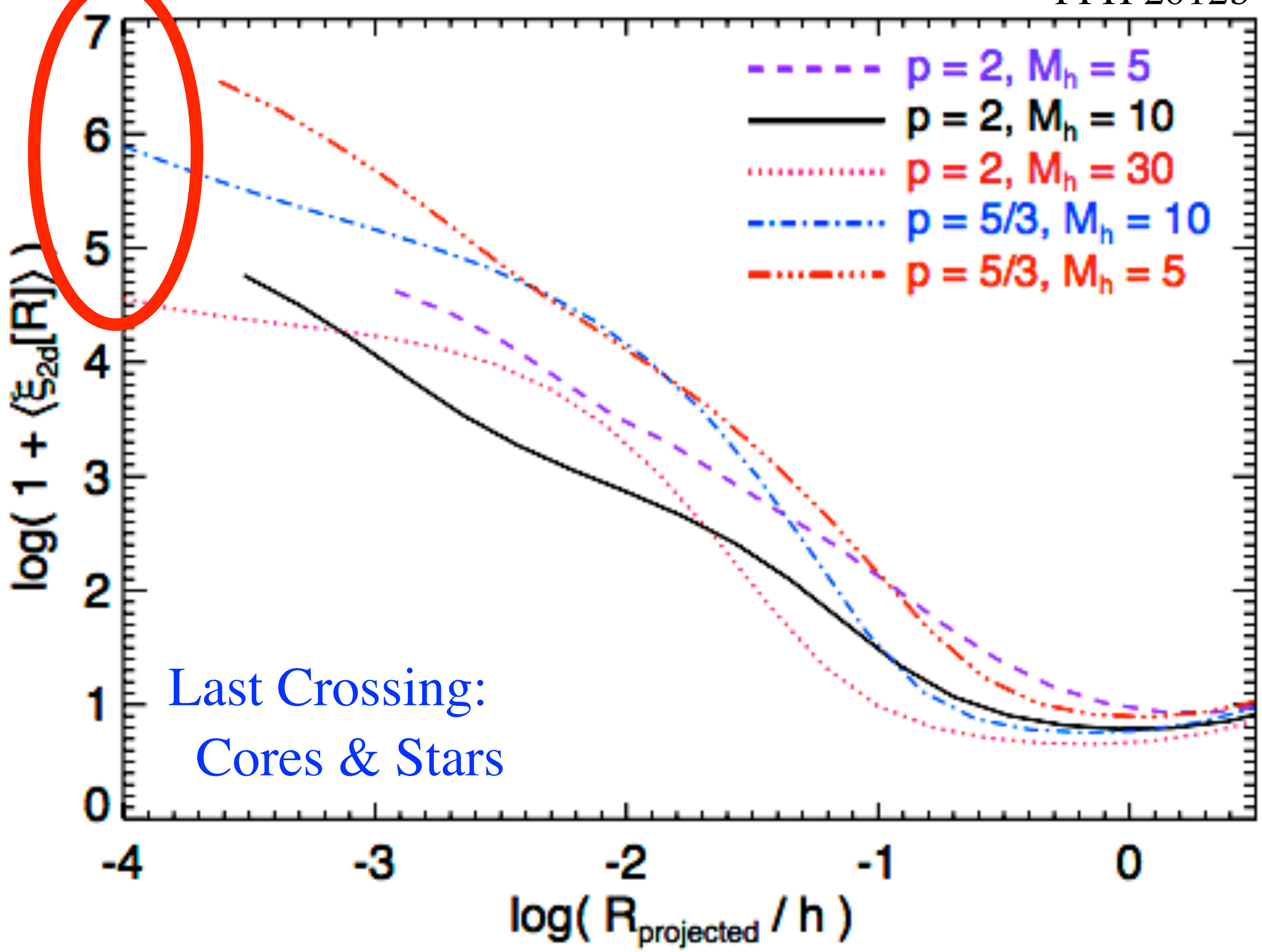
PFH 2012b

Why Do Stars Form in Clusters?

$$S \sim \ln \mathcal{M}(k)^2$$
$$\sim \ln r^{3-p}$$



Evolve the Fluctuations in Time

CONSTRUCT "MERGER/FRAGMENTATION" TREES

$$p(\delta\,|\,\tau) = \frac{1}{\sqrt{2\pi\,S\,(1-\exp[-2\tau])}}\,\exp\left[-\frac{(\delta-\delta(t=0)\,\exp[-\tau])^2}{2\,S\,(1-\exp[-2\tau])}\right]$$

$$\tau \equiv u_t(k)\,k\,t \sim \frac{t}{t_{\rm cross}}$$

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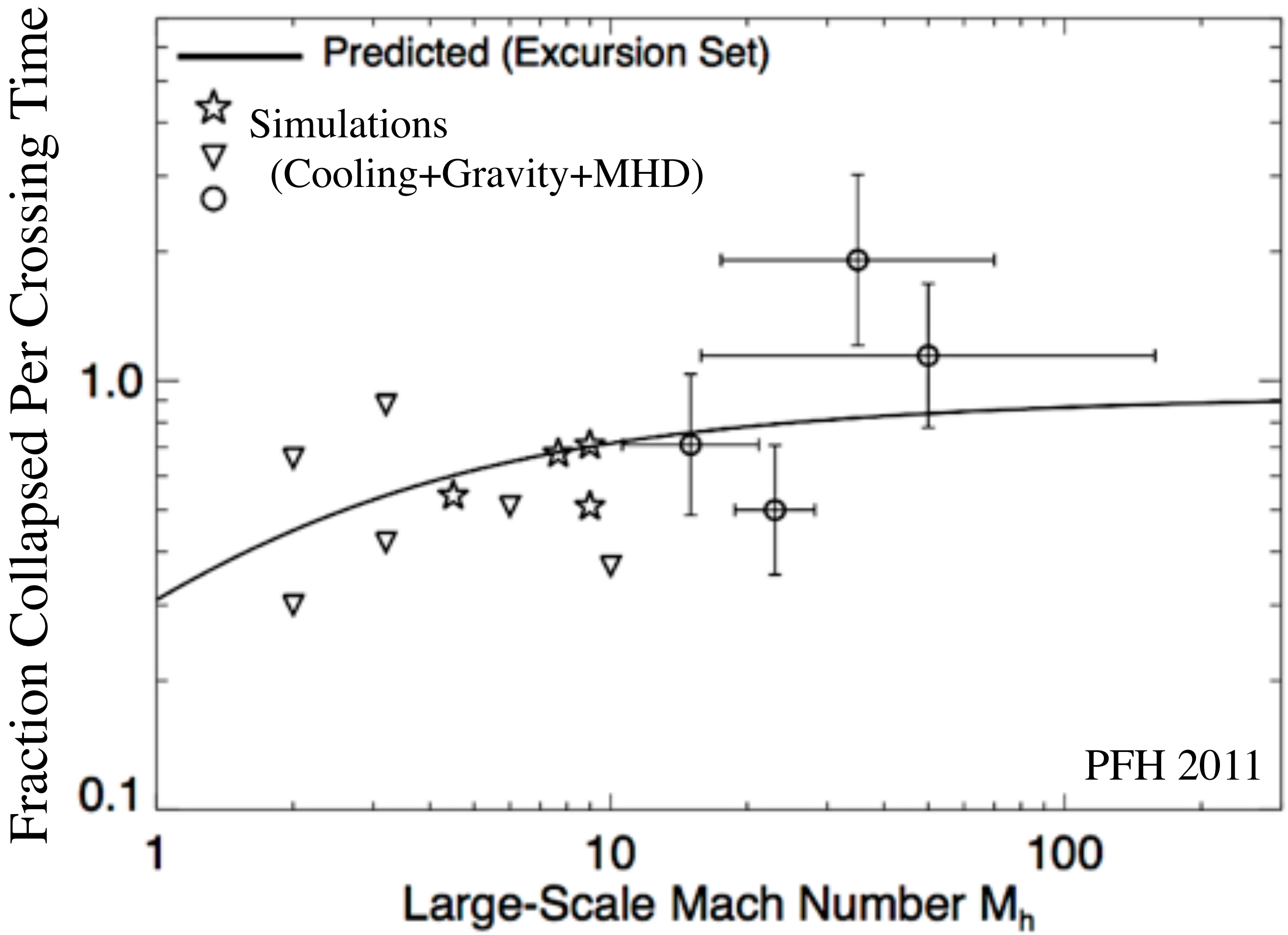

Open Questions:

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