The Star Formation Law in a Multifractal ISM

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The Star Formation Law

$$\dot{\Sigma}_{\rm SF} \propto \Sigma_{\rm gas}^{n_{\rm gas}} \qquad\qquad n_{\rm gas} \simeq 1.5$$

Observationally established for:

- global SF and gas density
- local SF and gas density averaged over scales from kpc to ≈ 500pc

Traditional Interpretation

$$\left.\begin{aligned}\dot{\rho}_{\rm SF} &\propto \frac{\rho_g}{\tau_{\rm SF}} \\ \tau_{\rm SF} &\propto \rho_g^{-0.5}\end{aligned}\right\} \dot{\rho}_{\rm SF} \propto \rho_g^{1.5} \Longrightarrow \dot{\Sigma}_{SF} \propto \Sigma_g^{1.5}$$

Free-fall but not only

h ≈ const.

Complications

- Conceptual
  - Star formation a local phenomenon only takes place at very dense cores at ~ 0.1 pc scales
  - Mean density dependence of timescale assumed not necessarily meaningful

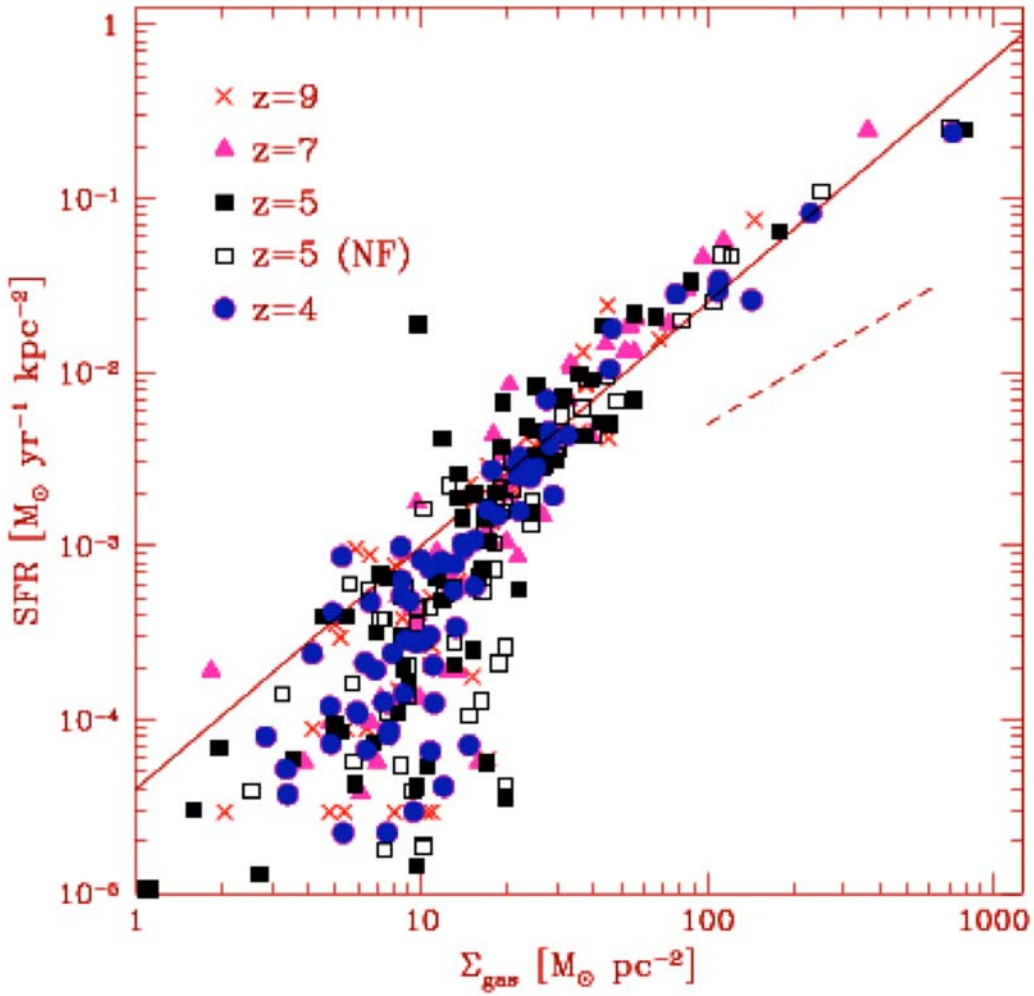
$$\dot{\rho}_{\rm SF} \propto \frac{\rho_g}{\tau_{\rm SF}}$$

$$\tau_{SF} \propto \rho_g^{0.5}$$

Complications

- In simulations

  Large-scale SF law reproduced in ART sims assuming ***constant*** SF timescale



Kravtsov (2003)

Complications

- Observational
  - In dwarf galaxies

$$\dot{\Sigma}_{SF} \propto \Sigma_g^{n_{\rm gas}} \qquad n_{\rm gas} > 1.5$$

e.g. : NGC 6822 de Blok & Walter (2006)

M33 Heyer et al. (2004)

IC10 Leroy et al. (2006)

  - SF correlates linearly with dense gas

$$\dot{\Sigma}_{\rm SF} \propto \Sigma_{\rm den.gas}^{n_{\rm den}} \qquad n_{\rm den} \simeq 1$$

Gao & Solomon (2004)

Wu et al. (2005)

From Small to Large

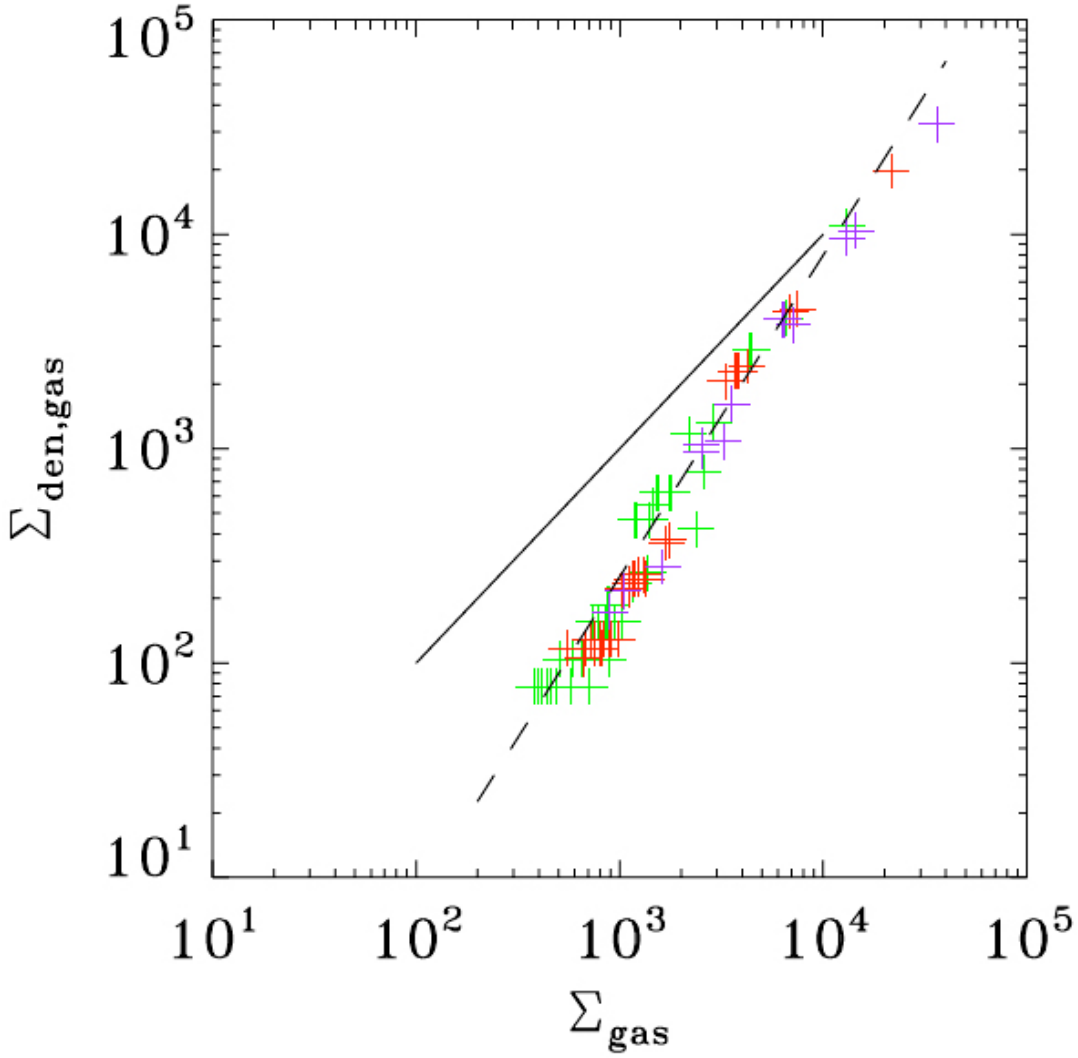
$$\left.\begin{aligned}\dot{\Sigma}_{SF} &\propto \Sigma_{g}^{n_{\rm gas}} \\ \dot{\Sigma}_{\rm SF} &\propto \Sigma_{\rm den.gas}^{n_{\rm den}}\end{aligned}\right\} \quad \Sigma_{\rm den.gas} \propto \Sigma_{\rm gas}^{n}$$

$$n = \frac{n_{\rm gas}}{n_{\rm den}} \simeq n_{\rm gas} \simeq 1.5$$

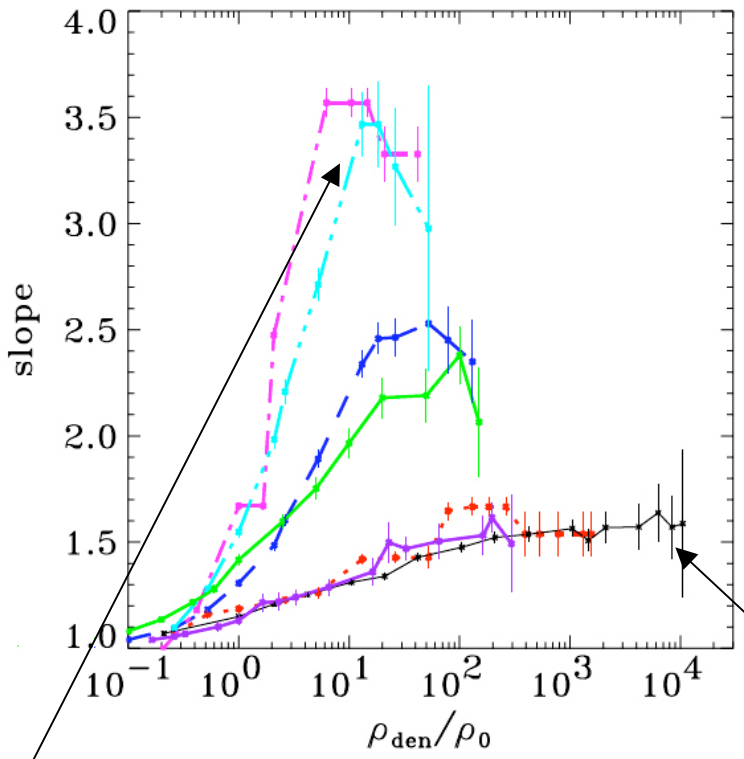
Non-linear correlation of total gas density and dense gas is implied

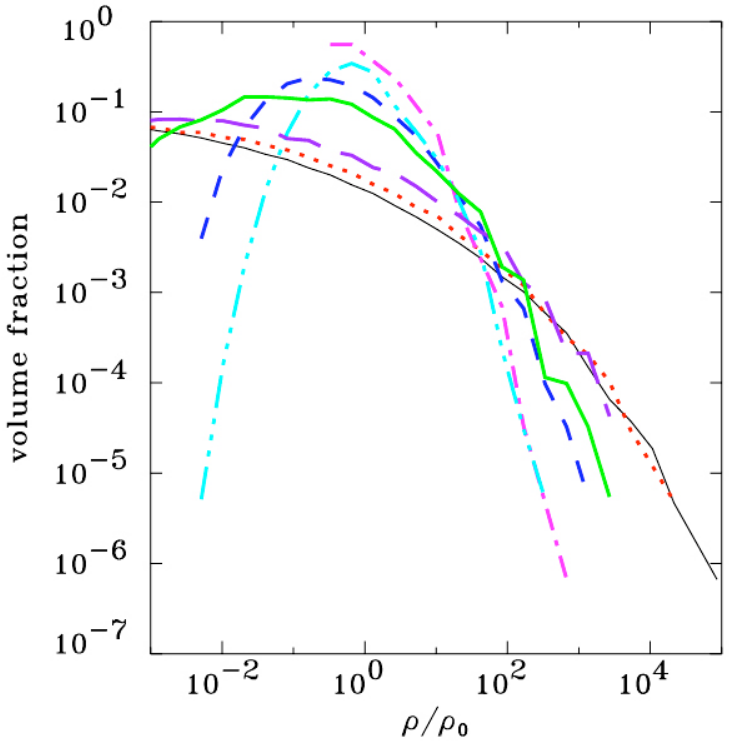
Multifractal ISM?

Multifractal density field generated using random-β model of fully developed turbulence



How robust is this scaling?





Slope saturates to higher values for narrower pdfs appropriate for dwarfs

Tassis et al. (2008)
Wada & Norman (2007)

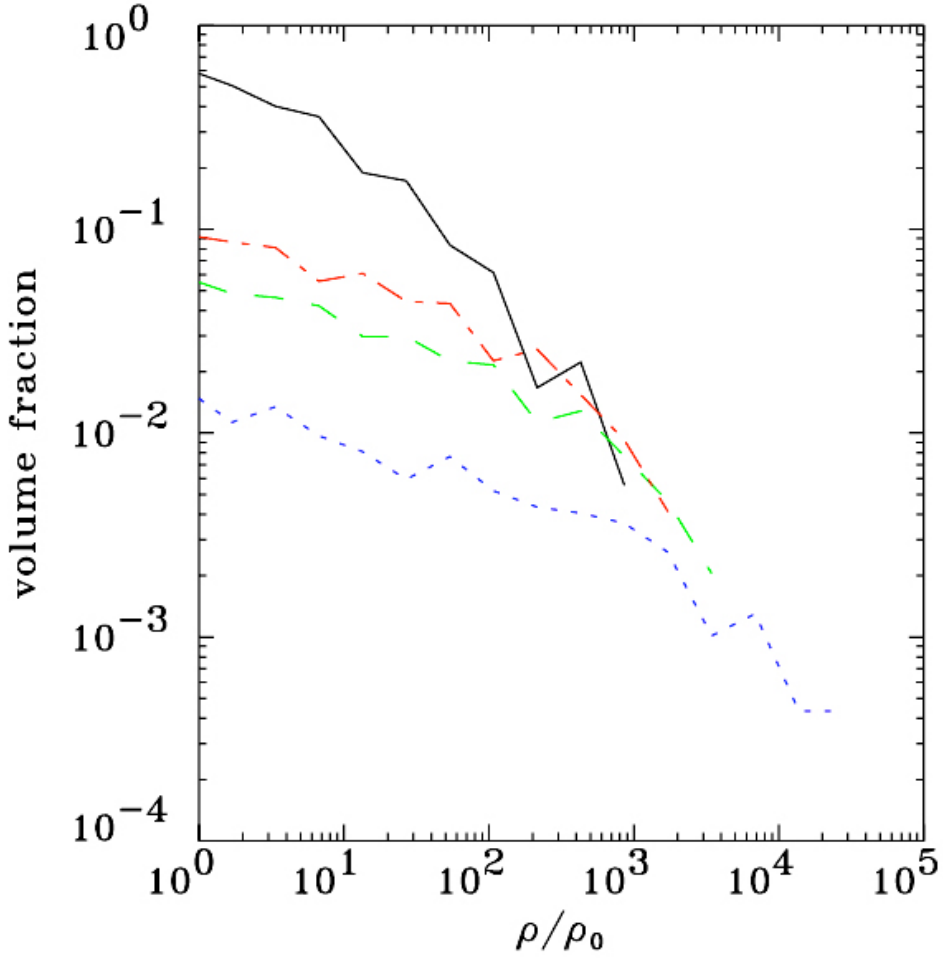
Slope saturates close to 1.5 for wide pdfs

Not sensitive to ρ_{den} def.

Implications for the pdf

- PDF not universal in the galaxy

  Higher average surface density => Wider pdf



Conclusions

Multifractal Topology of ISM
(observationally & theoretically motivated)
+
SF timescale roughly constant at high densities
(observationally & theoretically motivated)

Can naturally explain the SF law with its complications