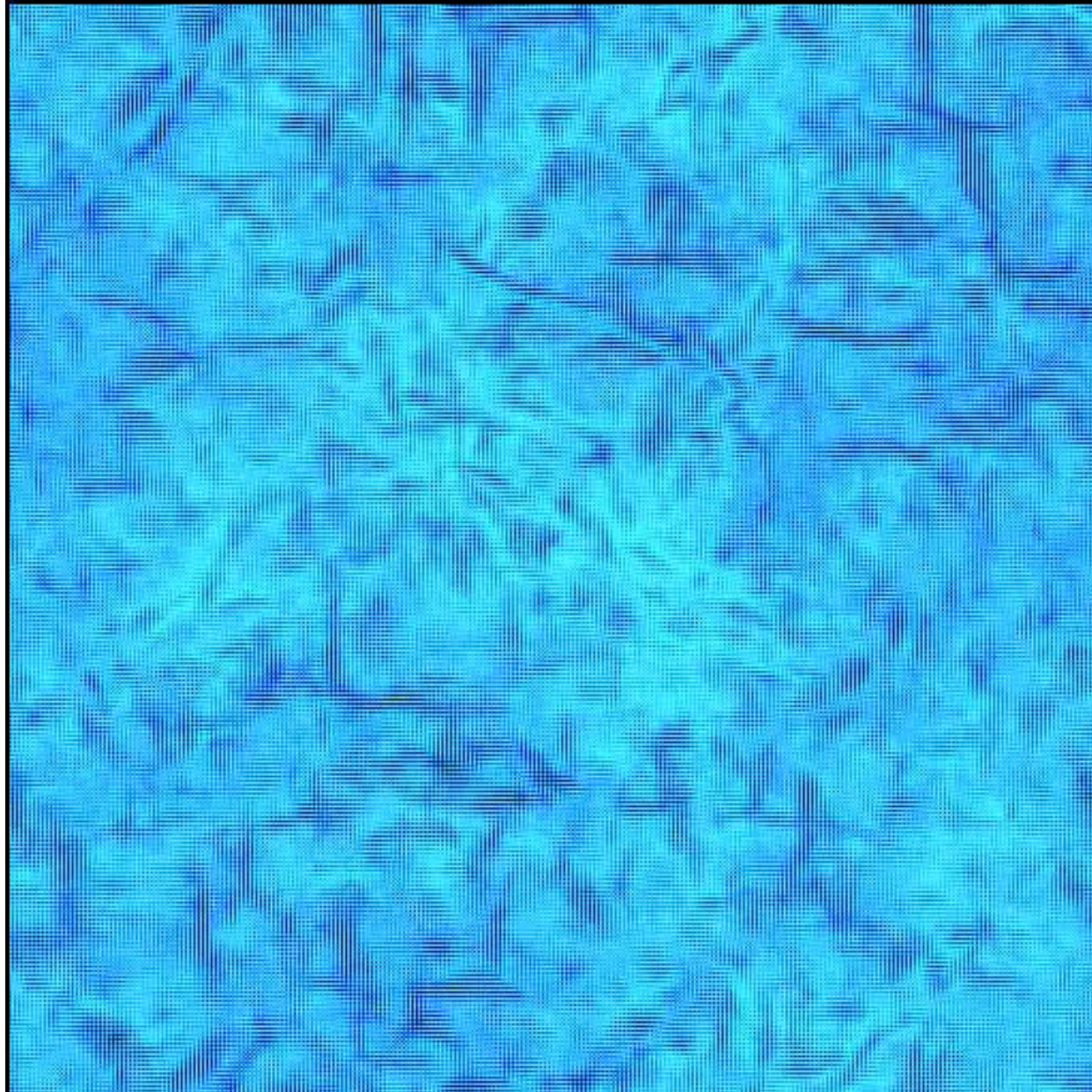


# Hierarchical Structure Formation & Chemical Evolution of Galaxies

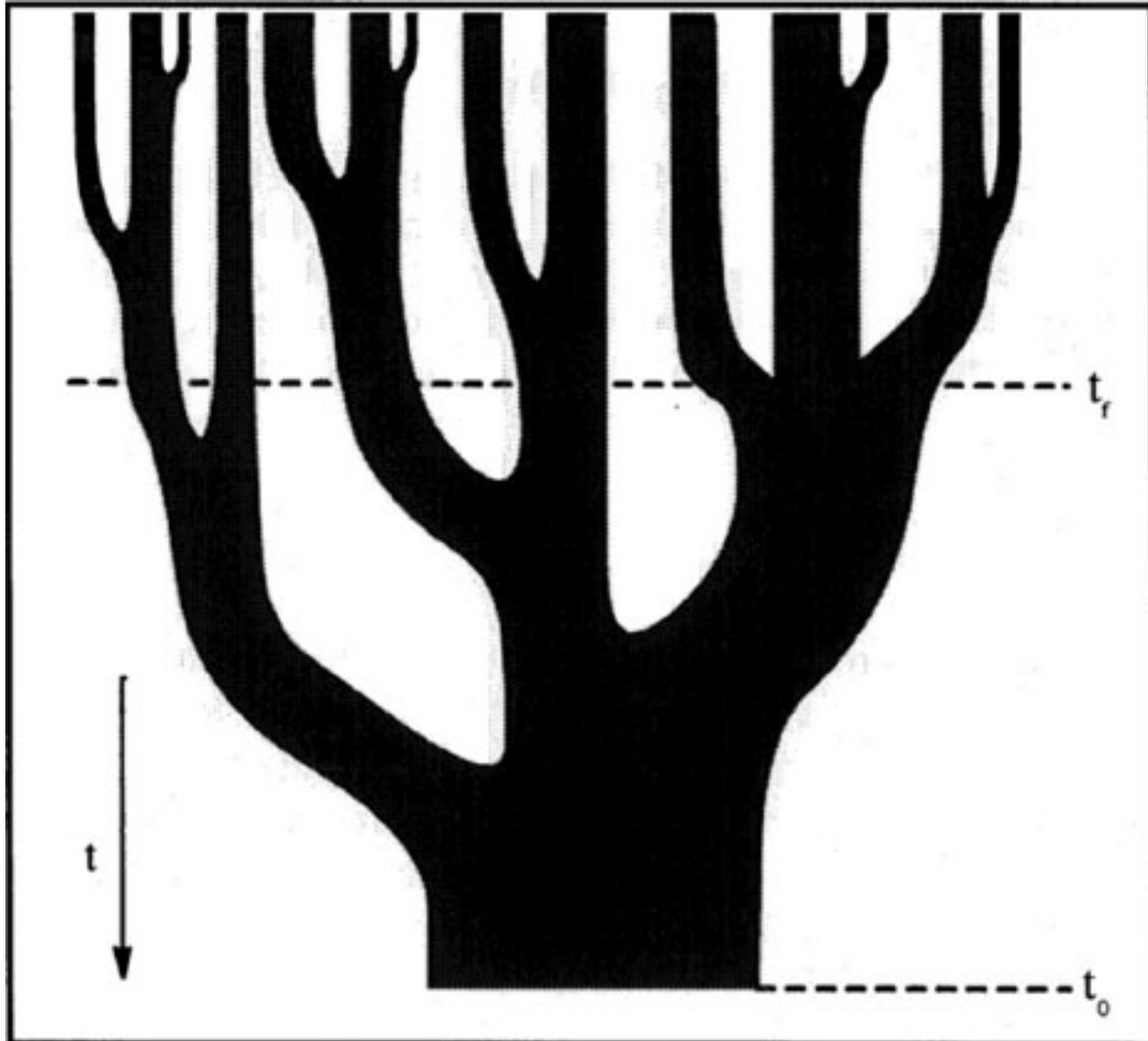
Yong-Zhong Qian  
University of Minnesota

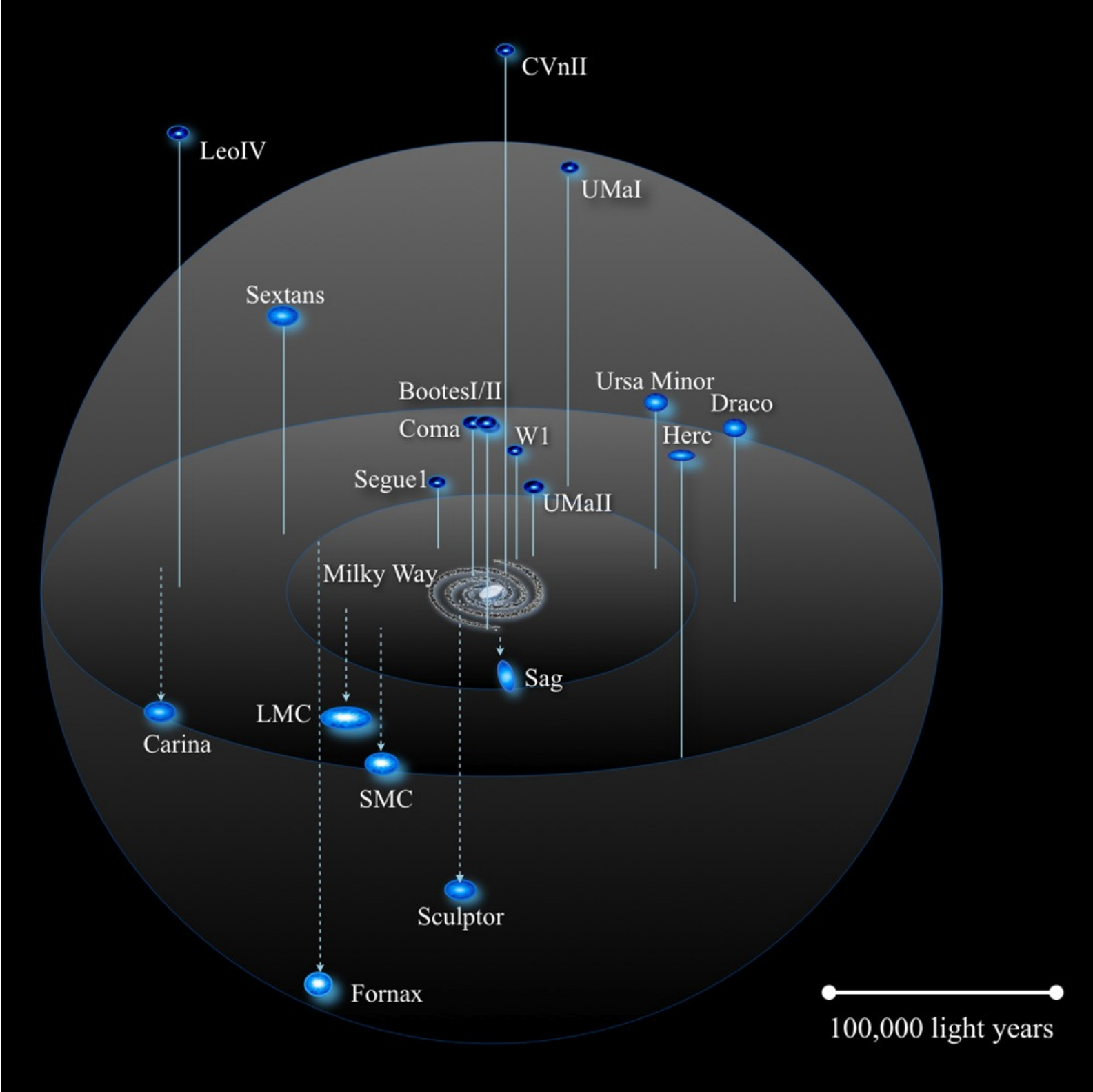
Neutrino & Nuclear Astrophysics  
2014 International Summer School on Astrocomputing  
July 25, 2014

# Hierarchical Structure Formation



# Merger Tree





# Properties of a Dark Matter Halo (Bryan & Norman 1998)

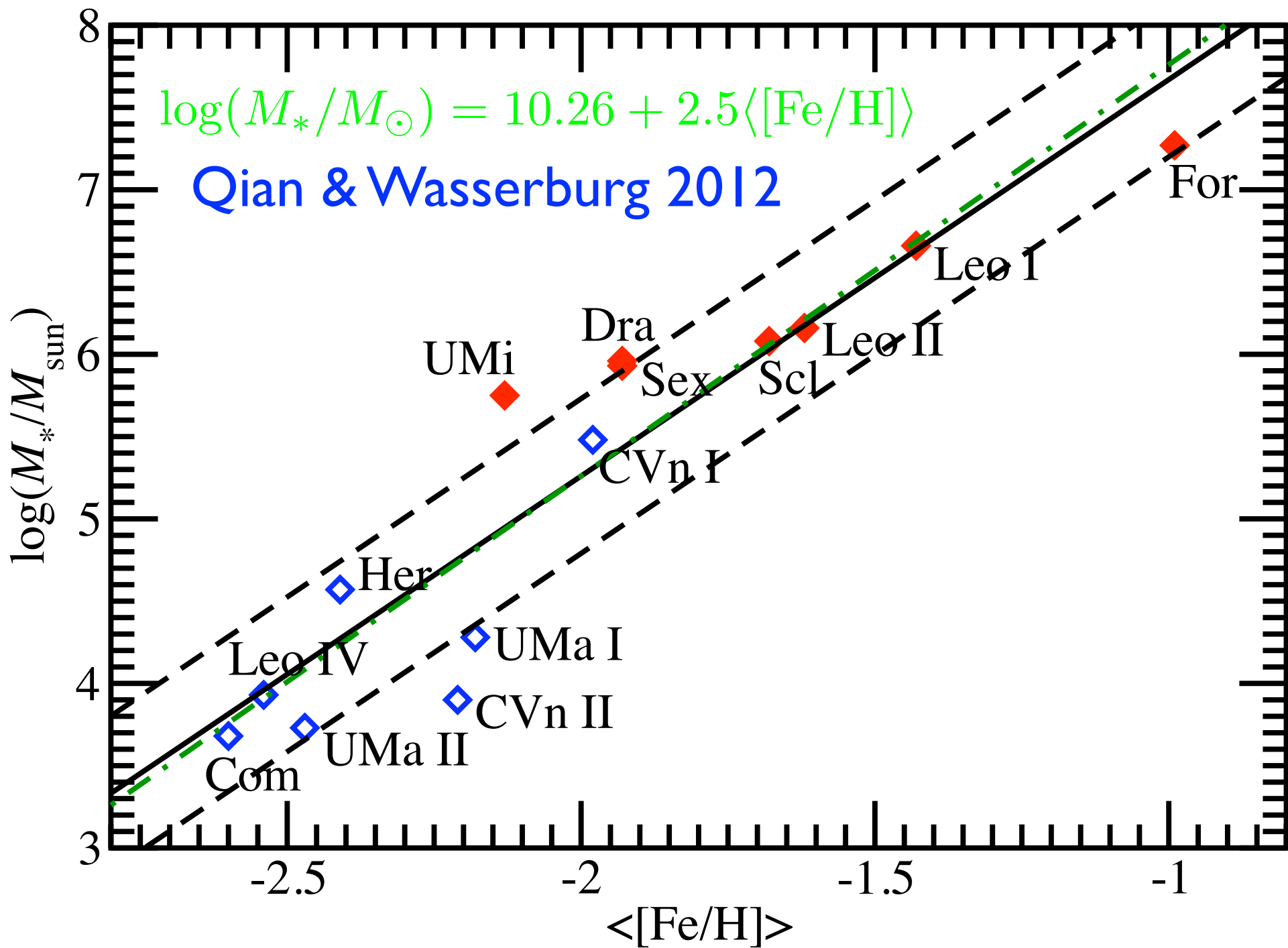
$$\rho_{\text{crit}}(z) = \frac{3H(z)^2}{8\pi G}, \quad \rho_h = \Delta_c(z)\rho_{\text{crit}}(z)$$

virial radius:  $r_{\text{vir}} = \left( \frac{3M_h}{4\pi\rho_h} \right)^{1/3}$

circular velocity:  $v_{\text{circ}} = \left( \frac{GM_h}{r_{\text{vir}}} \right)^{1/2}$

virial temperature:  $T_{\text{vir}} = \frac{GM_h\mu m_p}{2k_B r_{\text{vir}}}$

gravitational binding energy:  $E_G = \frac{GM_h^2}{2r_{\text{vir}}}$



$$\frac{dM_{\text{Fe}}}{dt} = P_{\text{Fe}}(t) - X_{\text{Fe}}(t)[\psi(t) + F_{\text{out}}(t)]$$

$$\int P_{\text{Fe}}(t)dt = \int X_{\text{Fe}}(t)[\psi(t) + F_{\text{out}}(t)]dt$$

$$P_{\text{Fe}}(t) \propto \langle Y_{\text{Fe}} \rangle \psi(t), \quad F_{\text{out}}(t) \propto \langle E_{\text{expl}} \rangle \psi(t) r_{\text{vir}} / M_h$$

$$\langle X_{\text{Fe}} \rangle = \frac{\int X_{\text{Fe}}(t)\psi(t)dt}{\int \psi(t)dt} \propto \frac{M_h}{r_{\text{vir}}} \propto M_h^{2/3}$$

$$\frac{dM_g}{dt} = F_{\text{in}}(t) - \psi(t) - F_{\text{out}}(t)$$

$$\int F_{\text{in}}(t)dt = \int [\psi(t) + F_{\text{out}}(t)]dt$$

$$M_h \propto M_* r_{\text{vir}} / M_h \Rightarrow M_* \propto M_h^2 / r_{\text{vir}} \propto M_h^{5/3} \propto \langle X_{\text{Fe}} \rangle^{5/2}$$

# Press-Schechter Formalism

primordial density fluctuations on various length scales

$$\delta(\vec{r}) = \frac{\rho(\vec{r})}{\langle \rho \rangle} - 1$$

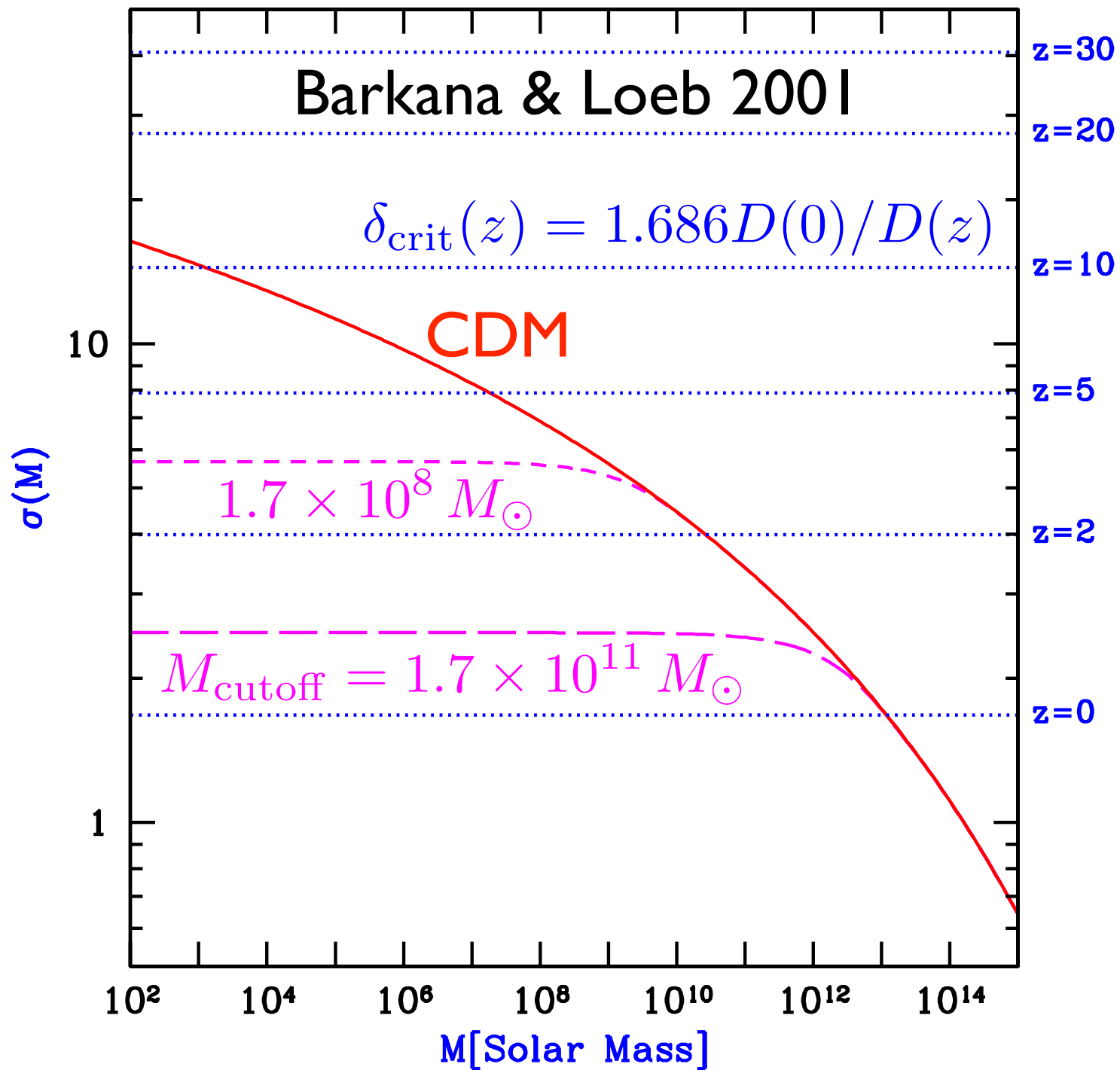
linear  
growth  
theory

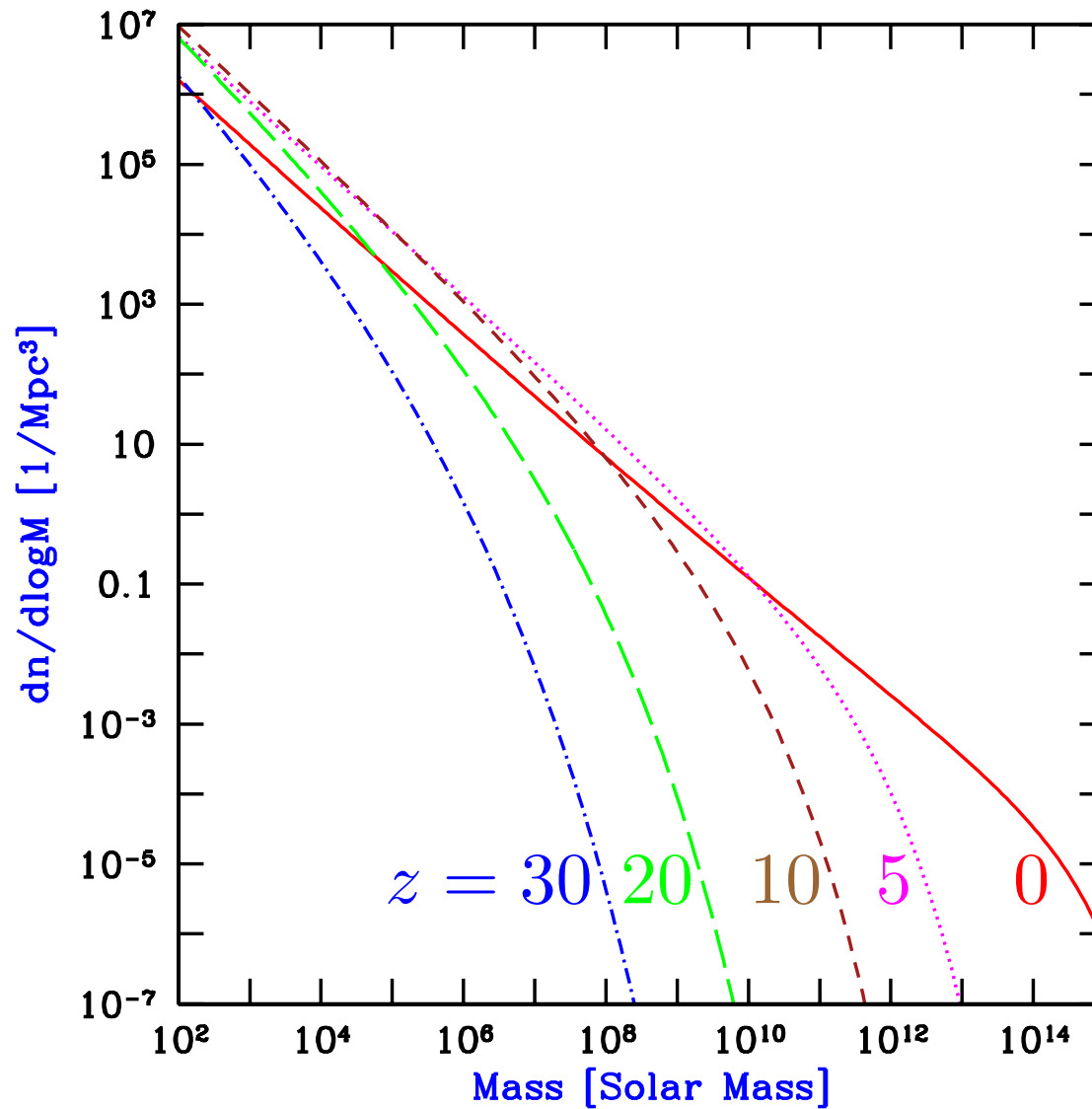
$$\delta_{\text{crit}}(z) = 1.686 \frac{D(0)}{D(z)}$$

present fluctuations on various mass scales

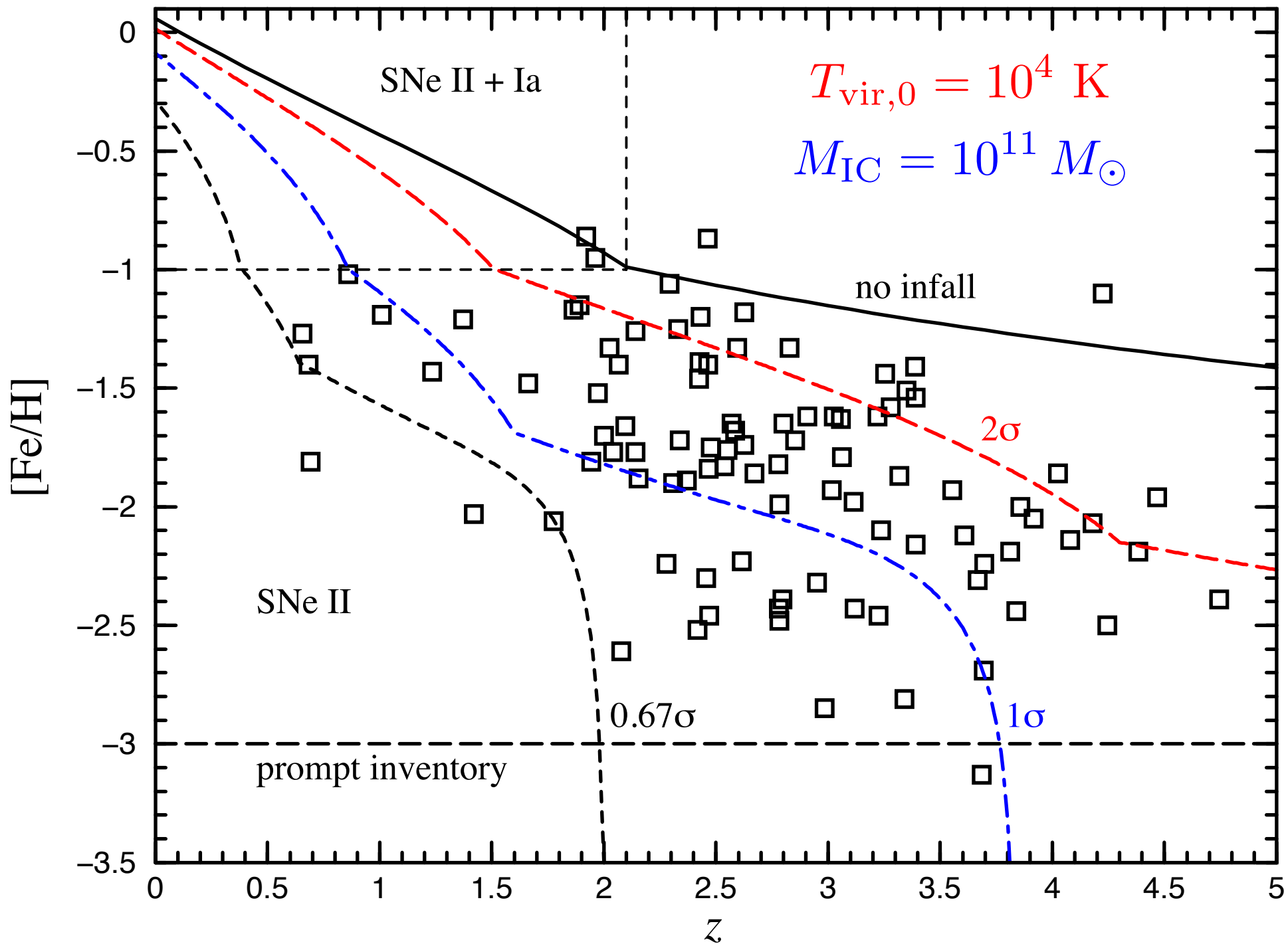
$$\sigma(M)$$







$$F(> M|z) = \sqrt{\frac{2}{\pi}} \int_{\delta_{\text{crit}}(z)}^{\infty} \exp\left[-\frac{\delta^2}{2\sigma(M)^2}\right] \frac{d\delta}{\sigma(M)}$$



$$\frac{dM_g}{dt} = F_{\text{in}}(t) - \psi(t) - F_{\text{out}}(t)$$

$$\frac{dM_{\text{Fe}}}{dt} = P_{\text{Fe}}(t) - X_{\text{Fe}}(t)[\psi(t) + F_{\text{out}}(t)]$$

$$\frac{dX_{\text{Fe}}}{dt} = \frac{P_{\text{Fe}}(t)}{M_g(t)} - X_{\text{Fe}}(t) \frac{F_{\text{in}}(t)}{M_g(t)}$$

$$\frac{P_{\text{Fe}}(t)}{M_g(t)} \sim \lambda_{\text{Fe}}, \quad \frac{F_{\text{in}}(t)}{M_g(t)} \sim \frac{1}{M_h} \frac{dM_h}{dt} = \lambda_{\text{in}}(t)$$

**quasi-steady state:**  $X_{\text{Fe}}^{\text{QSS}}(t) \sim \frac{\lambda_{\text{Fe}}}{\lambda_{\text{in}}(t)}$

