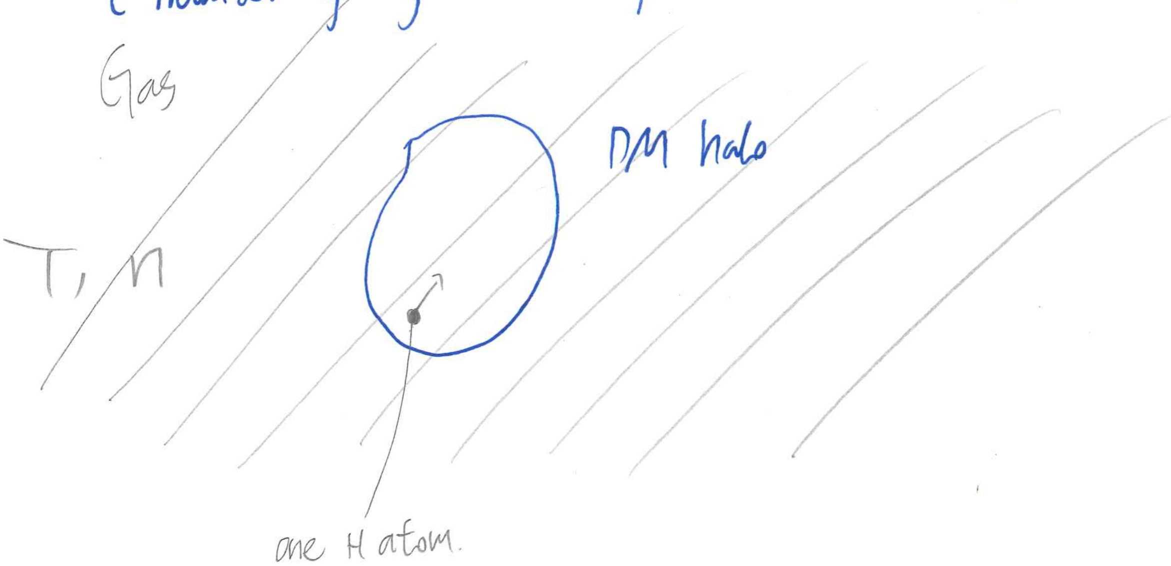
We talked about the virialization of DM halos in precious lectures. This lecture we turn our attention to the baryonic component.

- Baryonic Collapse.

Q1: Can collapsing ("virializing") DM induce gas to collapse with it?

This question is not a very straightforward one. As the gas collapses, the pressure may be high enough to stop the collapse.

A1: Consider at temperature T and number density n (number of gas atom per cm^3, unit of cm^{-3}).



→ Gas will collapse if its kinetic energy < its gravitational potential energy. 03-01-2016.

Consider that one H atom:

$$E_{kin} < |E_{pot}|$$

$$E_{kin} \cong \text{thermal energy}$$
$$\cong \text{random kinetic energy}$$
$$= 3 \cdot \frac{1}{2} \cdot k_B T$$
$$= \frac{3}{2} k_B T \simeq k_B T$$

3 "degrees of freedom" in all x, y, z directions

Boltzmann constant

$$|E_{pot}| \simeq \frac{G M_{halo}}{R_{vir}} \cdot m_H$$

$$k_B T < \frac{G M_{halo}}{R_{vir}} \cdot m_H$$

Define: "Virial temperature" T_{vir}

$$T_{vir} \equiv \frac{G M_{halo} \cdot m_H}{R_{vir} \cdot k_B}$$

Use:

$$M_{halo} = \frac{4\pi}{3} \cdot R_{vir}^3 \cdot \rho_{vir}$$

$$\rho_{vir} \cong 200\, \underbrace{\bar{\rho}(z_{vir})}_{\rho_{m,0}(1+z)^3}$$

$$\Rightarrow \quad T_{vir} \propto M_{halo}^{2/3} \cdot (1+z_{vir})$$

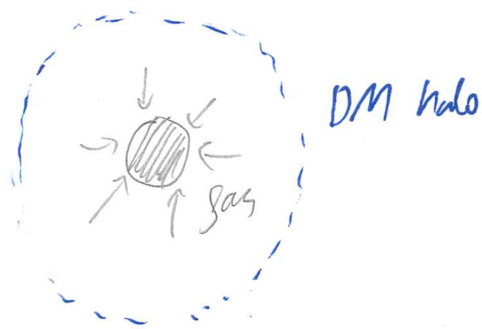
Plug in typical number,

$$T_{vir} = (10^4 K) \cdot \left(\frac{M_{halo}}{10^8 M_\odot}\right)^{2/3} \cdot \left(\frac{1+z_{vir}}{10}\right)$$

Note: Gas cannot collapse if $T > T_{vir}$!

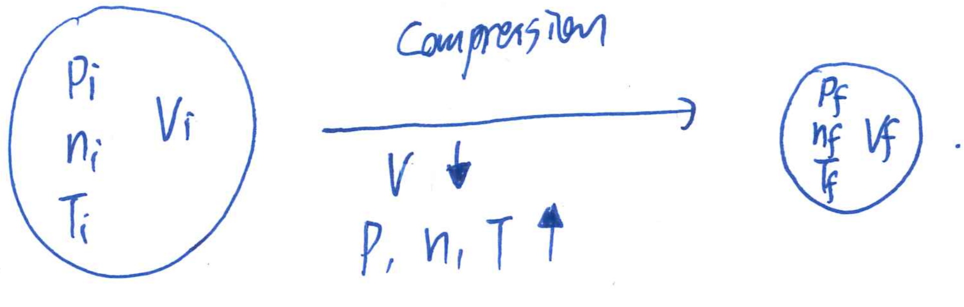
Q2: What happens to gas if $T < T_{vir}$?

A2: It will collapse with the DM halo.



Quick aside: "adiabatic compression" 03-01-2016

Consider a cloud of gas with pressure, number density, temperature, and volume of P_i, n_i, T_i, and V_i;



Adiabatic law:

$$P V^{\gamma} = \text{const.}$$

γ = adiabatic index $= 5/3$ (for atomic H)

$$\Rightarrow \quad P_i V_i^{\gamma} = P_f \cdot V_f^{\gamma}$$

Using the ideal gas law

$$\begin{cases} P = n k_B T \\ n m_H = \rho = \dfrac{M}{V} \end{cases}$$

$$\Rightarrow \quad T_i n_i^{-2/3} = T_f n_f^{-2/3}$$

$$\text{i.e.} \quad T \propto n^{2/3}$$

It shows that the gas temperature increases with increasing density. Therefore, in order to form stars, we need to have a way of removing energy. Otherwise, the gas pressure will prevent further collapse.