March 24 - A

- Equation of state

Start from $e = \frac{E}{N}$ or $\epsilon = \frac{E}{V} = ne$

$$P = -\frac{\partial E}{\partial V} = n^2 \frac{\partial e}{\partial n} = n\frac{\partial \epsilon}{\partial n} - \epsilon$$

from $e(n) \to P(n)$

Equation of state (EOS)

$$P = P(n, T)$$

@ $T = 0$

Recall $10^9 K \sim 86$ keV

Fermi energy of isospin-symmetric matter @ equilibrium ~ 20 MeV

$$\frac{T}{T_F} \sim 10^{-3}$$

Simplest EOS: ideal gas

$$P(n,T) = nT$$

collection of non interacting classical particles

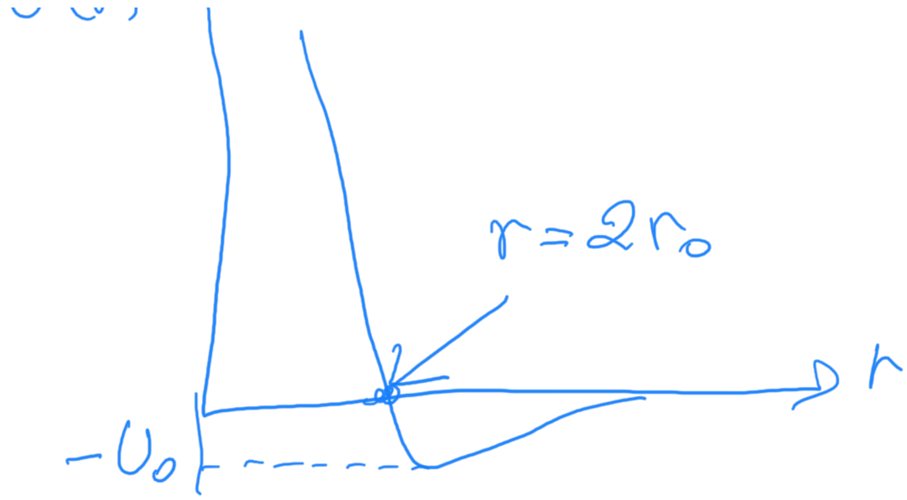
In general, use virial expansion

$$P(n,T) = nT\left[1 + n B(T) + n^2 C(T) + \dots\right]$$

the functions $B(T), C(T) \dots$ only depend on temperature, and describe interaction effects.

- Simplest model
  Van der Waals fluid

$P(n)$



EOS

$$P=\frac{nT}{1-nb}-an^2$$

a, b simply related to the interaction potential

In the limit $\frac{U_0}{T}\ll 1$

$$b\approx \frac{16\pi r_0^3}{3}=4\left(\frac{4}{3}\pi r_0^3\right)$$

$$a\simeq 2\pi\int_{2r_0}^{\infty} r^2 dr\,|U(r)|^2>0$$

$$\left[P+\left(\frac{N}{V}\right)^2 a\right](V-nb)=NT$$

Critical point

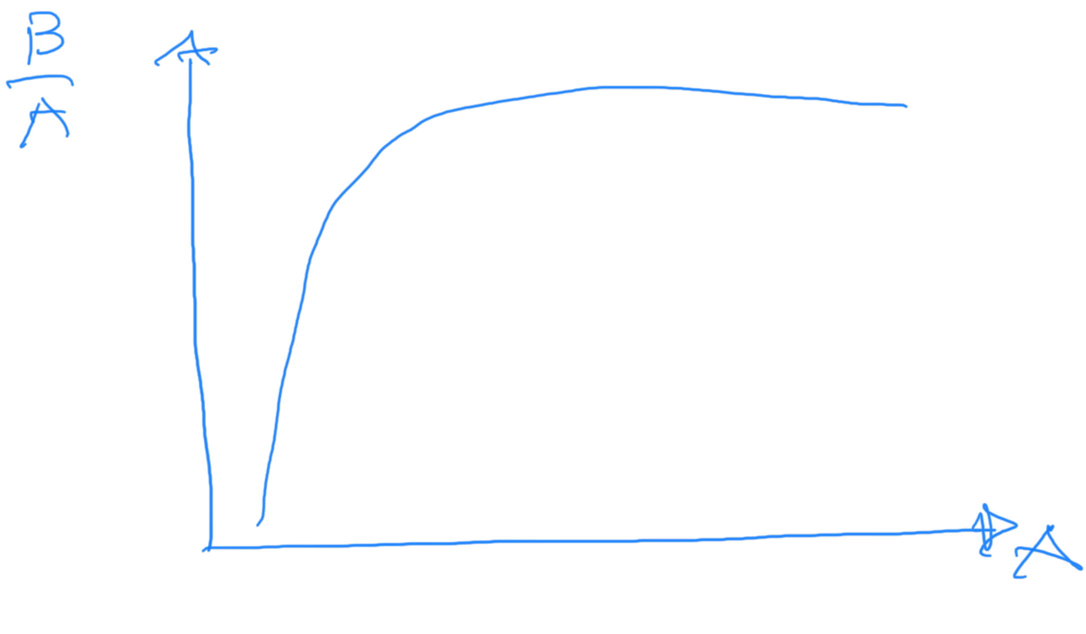
$$T_c = \frac{8a}{27b} \qquad P_c = \frac{a}{27b^2}$$

Observation of the EOS provides information on the underlying microscopic dynamics

EOS of baryon matter

isospin-symmetric matter

Empirical information



Empirical mass formula

$$\frac{B}{A} = a_0 + a_1 A^{-1/3} + \cdots$$

$$\lim_{A\to\infty} \frac{B}{A} = a_0 \simeq -16 \text{ MeV}/A$$

Nuclear densities (measured by electron-nucleus scattering)

$$d\sigma_A \sim |F(q)|^2 \, d\sigma_{\text{Point}}$$

$$\rho_{ch}(r) = \int \frac{d^3q}{(2\pi)^3} F(q) e^{i\vec{q}\vec{r}}$$

$$\rho_{ch}(0) \approx 0.16 \text{ fm}^{-3}$$

independent of A

$\#$

$$\frac{E(n)}{A} = a_0 + \text{const} \frac{(n-n_0)^2}{2}$$

$+ \ldots$

leads to violation of causality at finite n.

<u>Dynamical model needed!</u>