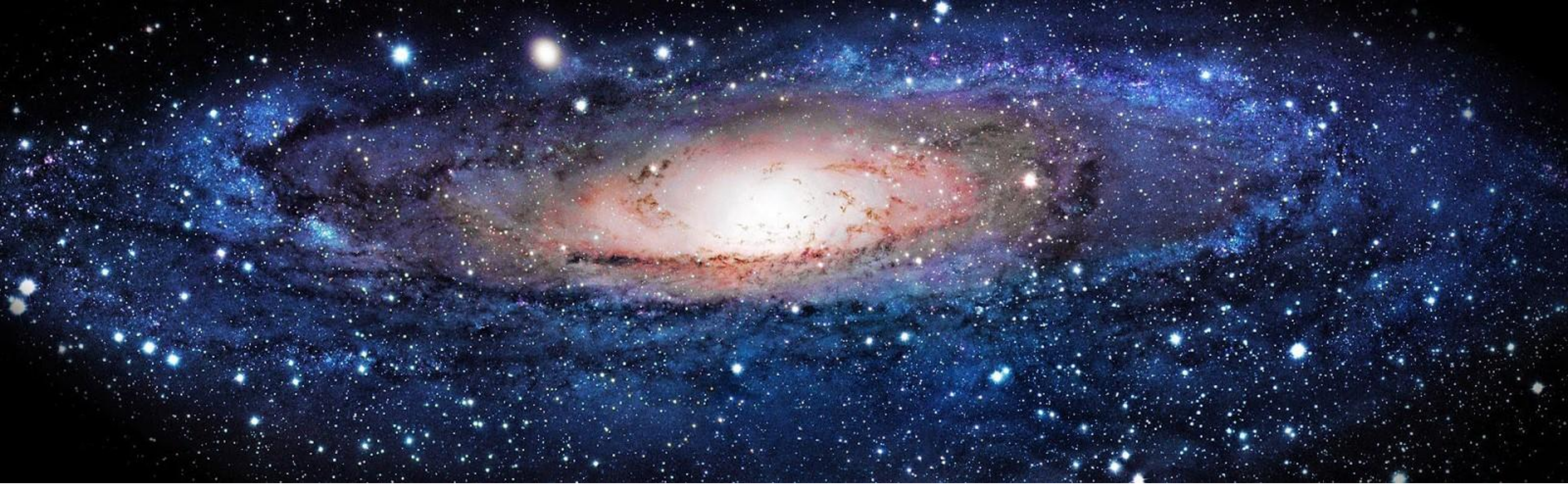


Майнор. Астрофизика.

Семинар 7. (14.10)

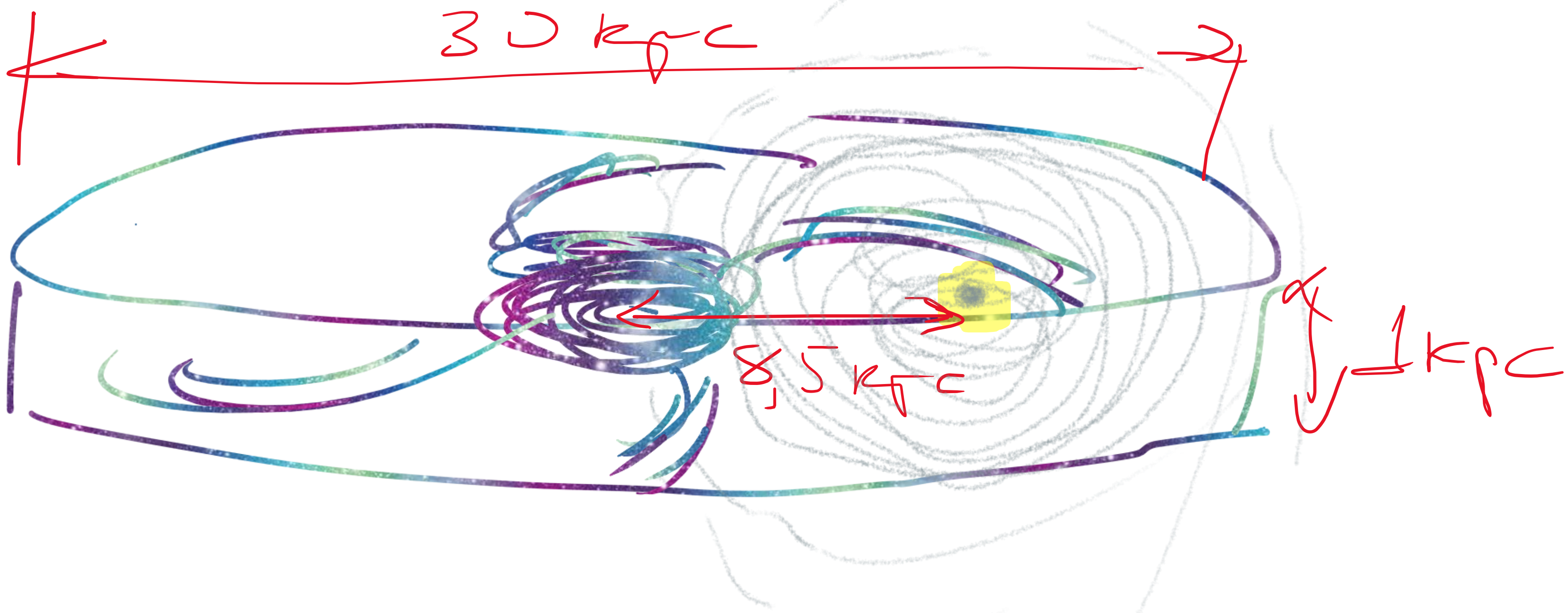
① Параллакс

Gaia 5 kpc (10%) $V = 15^m$

Hipparcos 100 pc 10% → 1 kpc

5 kpc: ⇒ $\pi'' = \frac{1}{5000} = 0.''0002$

100 pc ⇒ $\pi'' = \frac{1}{100} = 0.''01$



② Jeans: ρ, T

$n \leq 1\,cm^{-3}$

a) $E_{TOT} = \underset{>0}{E_{kin}} + \underset{<0}{E_{pot}}$

$\begin{cases} E_{TOT} > 0 & \text{ne clez.} \\ E_{TOT} < 0 & \text{clez.} \end{cases}$

$$2E_{kin} + E_{pot} = 0$$

$$2 \cdot \frac{3}{2} kT \cdot N = \frac{3}{5} \frac{G M_J^2}{R}$$

$$N = \frac{M}{m_0}$$

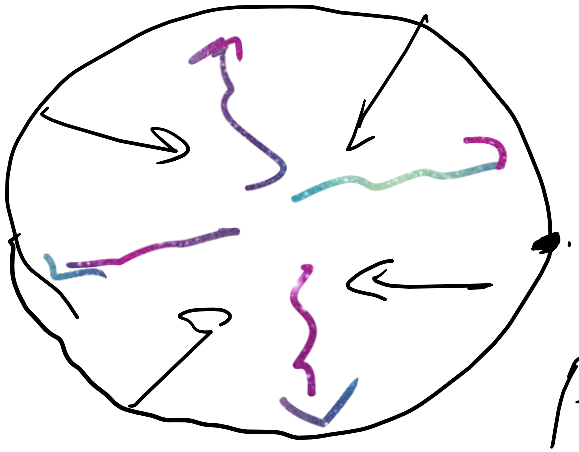
$$M = \frac{4}{3}\pi R^3 \rho$$

$$\frac{kT}{m_0} = \frac{1}{5} \frac{G M_J}{R_J} \Rightarrow \frac{1}{5} \frac{G}{R_J} \frac{4}{3}\pi R_J^3 \rho = \frac{kT}{m_0}$$

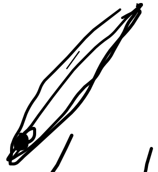
$$R_J = \left(\frac{15\, kT}{4\pi G m_0 \rho} \right)^{1/2}$$

$$M_J = \frac{5kT}{G m_0} R_J = 3 M_\odot \frac{T}{10K} \frac{R_J}{10^{15}\,cm}$$

8)



$$t_{ff} = \frac{R}{v_{ff}(R)} \sim \frac{1}{\sqrt{G\rho}}$$



t_{ff} 길면

$$t_s = R/c_s \qquad c_s^2 = \frac{\partial P}{\partial \rho} \sim \frac{P}{\rho}$$

$$PV = \frac{M}{\mu} RT \Rightarrow P = \frac{M}{V}\frac{RT}{\mu} = \rho\frac{RT}{\mu}$$

$$\frac{M}{V} = \rho$$

$$c_s = \sqrt{\frac{R}{\mu}T} \qquad R = k \cdot N_A \qquad N_A = \frac{\mu}{m_0}$$

$$c_s = \sqrt{kT/m_0}$$

$$\frac{R_J}{c_s} = \frac{1}{\sqrt{G\rho}}$$

$$R_J = \frac{c_s}{\sqrt{G\rho}} = \sqrt{\frac{kT}{m_0 G\rho}} = \sqrt{\frac{RT}{\mu G\rho}}$$

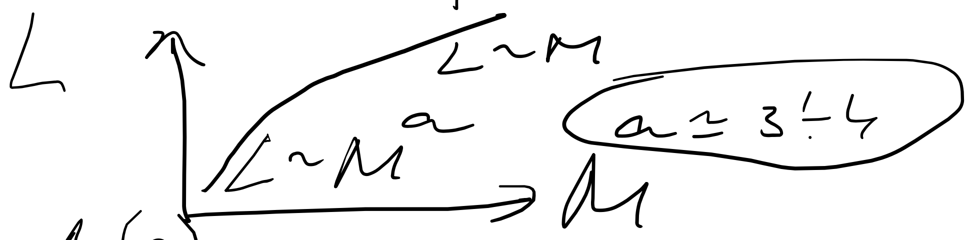
$$M_J = \frac{4}{3}\pi R_J^3 \rho$$

③ M − L

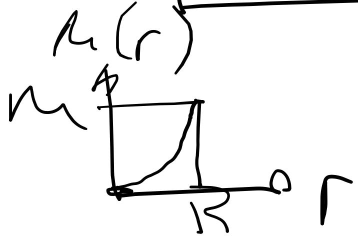
Маломассивные.

Давление: газовое + световое

$E = h\nu$ $\quad p = E/c$



$$\frac{dP}{dr} = -\frac{G M(r)\, \rho(r)}{r^2}$$



вириал $E_{pot} = -3PV$

$$P = \frac{-E_{pot}}{3V}$$

$$E_{pot} = -\frac{GM^2}{R}$$

$$P = \frac{GM^2}{4\pi R^4}$$

$$P = nkT \qquad n = \frac{\langle\rho\rangle}{m}$$

$$R = \left(\frac{3}{4\pi}\frac{1}{\rho} M\right)^{1/3} \sim M^{1/3}, \quad \rho \simeq const$$

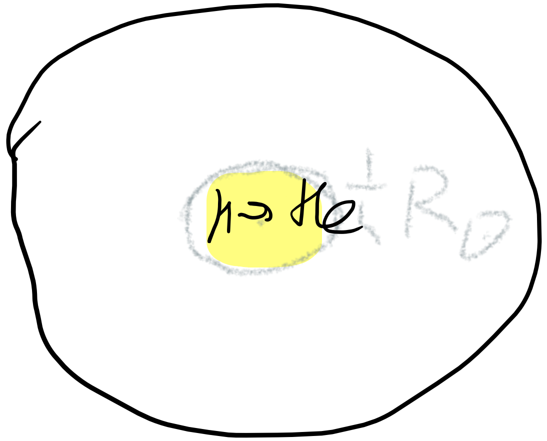
$$P = \frac{\rho}{m_0} kT \Rightarrow kT = \frac{GM^2}{4\pi R^4}\frac{m_0}{\rho} = \frac{G M m_0}{3R}$$

$$L = 4\pi R^2 \sigma T^4 = 4\pi \left(\frac{3}{4\pi}\frac{M}{\rho}\right)^{2/3} \sigma \left(\frac{\varepsilon M m_0}{3kR}\right)^4$$

$$L \sim M^{2/3} M^4 M^{-4/3} \sim M^{3\frac{1}{3}}$$

$\rho = const$, давл. – газове

4



$$L = N_{реак} \cdot E_{реакц}$$

$$\tau_{ГП} \sim M/L \sim \frac{M}{M^{3,\dots}} \sim M^{-2,\dots}$$

$\odot$ $\tau_{ГП} \sim 10^{10}$ лет

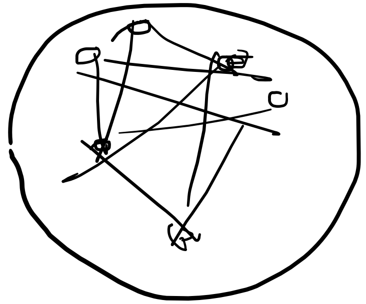
$\oplus \sim 4{,}568$ млрд. лет

$2M_\odot$ $\tau_{ГП} \sim 2$ млрд. лет

$\tau_{univ.} \lesssim 14$ млрд. лет.

5) M – R

$H \to He$, $m = 1$, $m = 4$



$E_k \sim E_{pot}$

$$E_k = \frac{3}{2} kT \cdot N \sim \frac{M}{m_0} kT$$

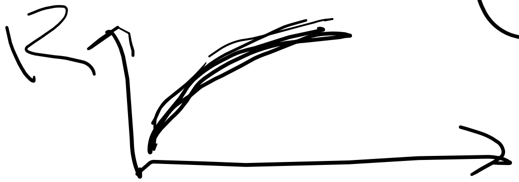
$$E_p = \iint \frac{G\, dm_1\, dm_2}{r_{12}} \sim \frac{GM^2}{R}$$

$$\frac{M}{m_0} kT \sim \frac{GM^2}{R}$$

$$R \sim M / T$$

$$T = 1{,}5 \cdot 10^7\ K \left(\frac{M}{M_\odot}\right)^{1/3} \sim M^{1/3}$$

$$R \sim M^{2/3}$$



6) Пульсации. $c_s(r)$

$$c_s^2 = \frac{\partial P}{\partial \rho} \Rightarrow c_s \sim \sqrt{P/\rho}$$

$$P \sim \frac{GM^2}{R^4} \qquad \rho \sim MR^{-3} \qquad c_s \sim \sqrt{\frac{GM}{R}}$$

$$P_{puls} \sim R/c_s \sim \frac{1}{\sqrt{G\rho}}$$

$$\ell \sim R$$

$$C_\rho \cdot \quad P_{puls} = 2\pi\sqrt{\ell/g} = \ldots \quad g \sim \frac{GM}{R^2} \; \ldots =$$

$$= 2\pi\sqrt{\frac{R^3}{GM}} \sim \frac{1}{\sqrt{G\rho}}$$

7 Blackbody

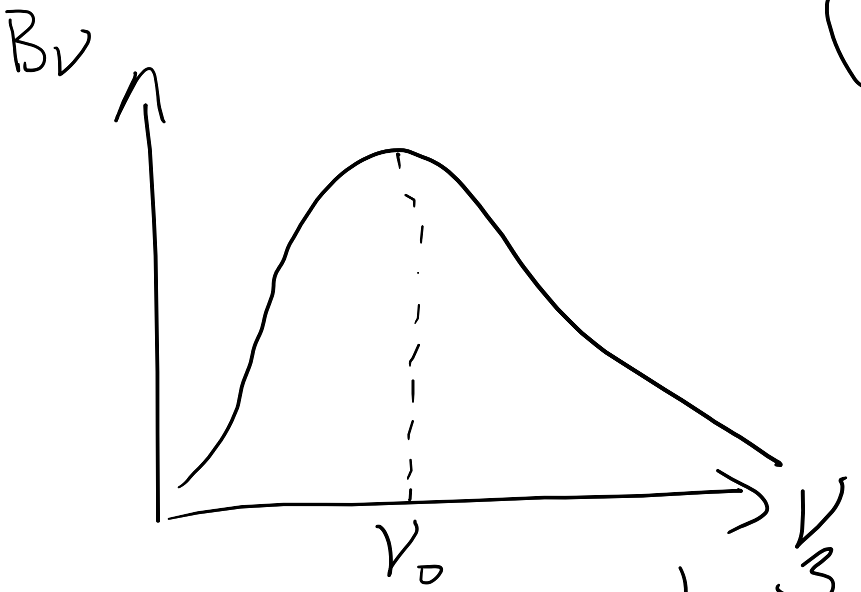
λ, ν, c

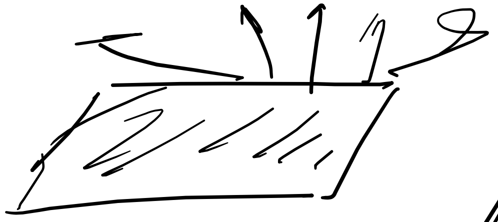
$$c = \lambda \cdot \nu$$

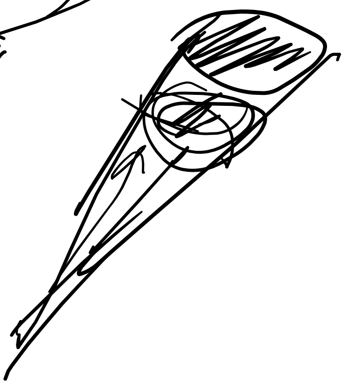
$$E = h\nu$$

$$[B_\nu] = \frac{\text{эрг}/c}{\text{см}^2 \cdot \text{Гц} \cdot \text{стерадиан}}$$

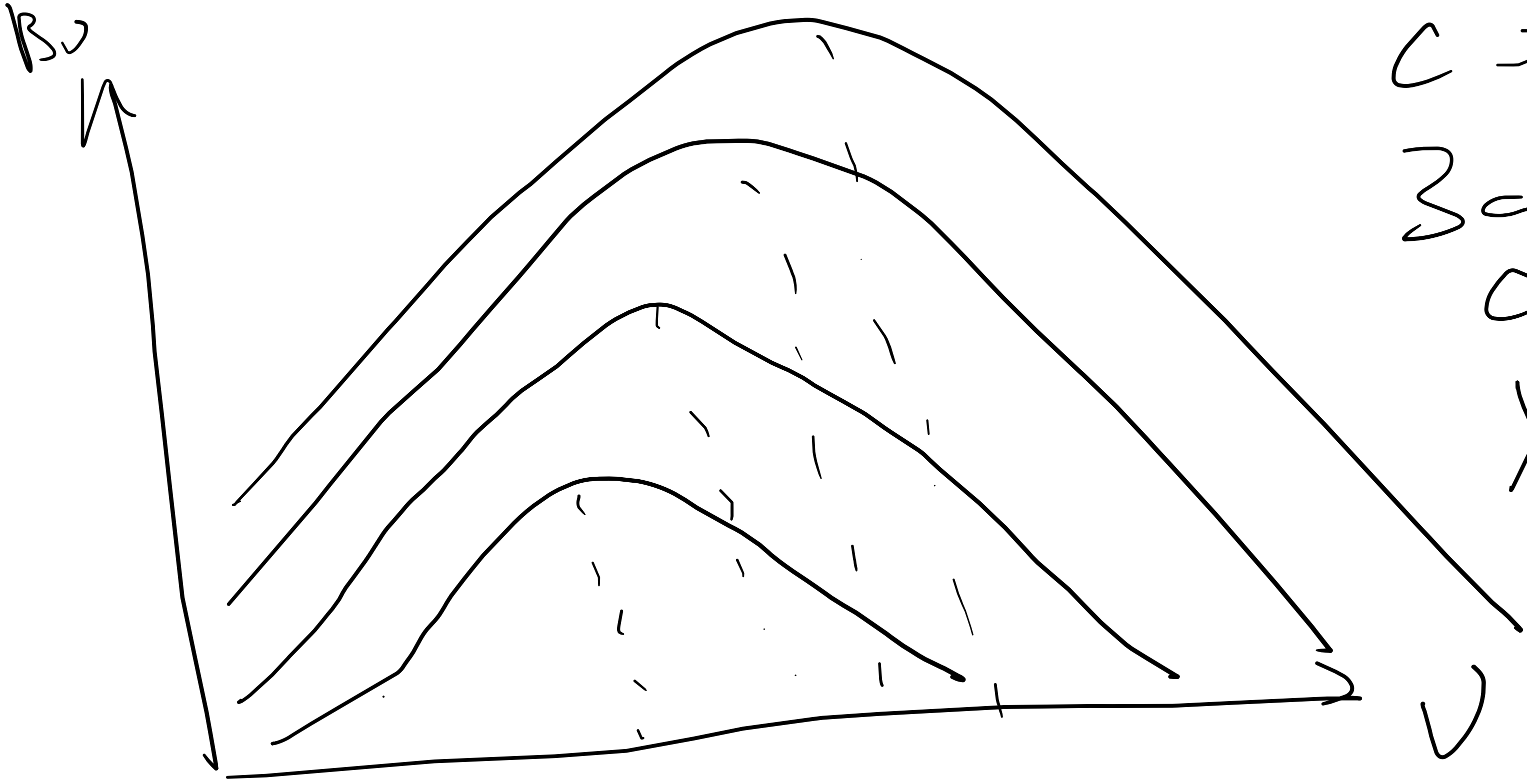
B_λ







$$B_\nu = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT} - 1}$$

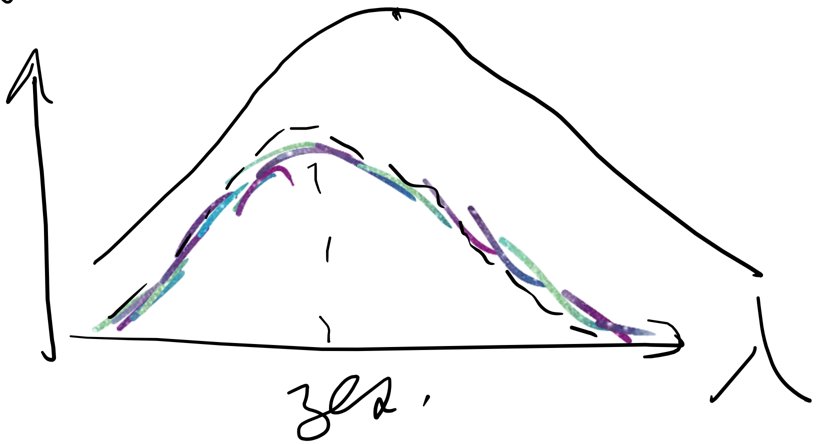


$c = \lambda\nu$

Закон смещ. Вина

$\lambda_{peak} \sim \frac{1}{T}$

$\nu_{peak} = T \cdot 5{,}879 \cdot 10^{11}\ \frac{Гц}{К}$



$E_{peak} = 3kT$

$10^4 K \to \sim 1$ эВ

Великолепная семерка.

$E_{peak} \sim 200\ eV$

$T \sim \frac{1}{3k} E_{peak} \sim 70\ eV \to 7 \cdot 10^5\ K$

$$B(\nu, T) = \frac{2h\nu^3}{c^2} \frac{1}{e^{h\nu/kT} - 1}$$

1) Рэлей-Джинс $\nu \to 0$

$$e^x = 1 + \frac{x}{1!} + \frac{x^2}{2!} + \dots$$

$$\lim_{\nu \to 0} e^{h\nu/kT} = 1 + \frac{h\nu}{kT} + \dots$$

$$e^{h\nu/kT} - 1 \approx \frac{h\nu}{kT}$$

$$B(\nu, T) = \frac{2h\nu^3}{c^2} \frac{kT}{h\nu} = \frac{2kT\nu^2}{c^2}$$

Виновский хвост

$\nu \to \infty$

$e^{h\nu/kT} \gg 1$

$$B_\nu(\nu, T) = \frac{2h\nu^3}{c^2} \cdot e^{-h\nu/kT}$$