NEVF 169 — 09 — 30.3.2021

minule: e–i termální srážky

i–i srážky

2 populace iontů o teplotě T
rozdělení rychlostí $f_1(\vec{v}_1)$ a $f_2(\vec{v}_2)$ – maxwellovské s drifty $\vec{v}_{d1}$ i $\vec{v}_{d2}$

minule:
$$\frac{d\vec{p}}{dt} = -\int f_1(\vec{v}_1)\,\nu_{12}(\vec{v}_1)\, m_1 \vec{v}_1\, d\vec{v}_1 \qquad \text{platí pro } v = 0:\ f_2(\vec{v}_2) = \delta^3(\vec{v}_2)$$

$$\nu_{p12}(g) = n_2\, g\, \sigma_{p12}(g) \qquad m_1 \vec{g}$$

$$\frac{d\vec{p}}{dt} = -\int f_1(\vec{v}_1) f_2(\vec{v}_2)\, g\, \sigma_{p12}(g)\, m_1 \vec{g}\, d\vec{v}_1 d\vec{v}_2$$

$$\frac{d\vec{p}}{dt} = -\int f_1(\vec{v}_1) f_2(\vec{v}_2)\, g\, \underbrace{\frac{m_2 m_1}{m_1+m_2}}_{\mu} 4\pi b_{90}(g) \ln\Lambda_c\, d\vec{v}_1 d\vec{v}_2$$

$\ln\Lambda_c \sim$ const. | odvození viz
$v_{d1}, v_{d2} \ll v_{TH}$ ↓ materiály …

$$\frac{d\vec{p}}{dt} = v_d\, g_{TH}\, \mu\, 4\pi b_{90}(g_{TH}) \ln\Lambda_c\, n_1 n_2 \frac{2}{3\sqrt{2\pi}}$$

$$\vec{v}_d = \vec{v}_{d1} - \vec{v}_{d2} \quad ; \quad g_{TH} = \sqrt{\frac{k_B T}{\mu}}$$

$$= \frac{2}{3\sqrt{2\pi}} \left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)^2 \frac{4\pi}{\mu^2 g_{TH}^3} \ln\Lambda_c\, n_1 n_2\, \mu\, v_d$$

– pro srážky typu 1–2: $p_1 = n_1 m_1 v_d$

$$\frac{dp}{dt} = \bar{\nu}_{p12}\, n_1 m_1 v_d$$

$$\bar{\nu}_{p12} = n_2 \frac{2}{3\sqrt{2\pi}} \left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)^2 \frac{4\pi}{\mu\, g_{TH}^3} \frac{\ln\Lambda_c}{m_1} \qquad \text{obecné pro Coul. srážky}$$

$$\mu = \frac{1}{2} m_i \qquad g_{TH} = \sqrt{\frac{2 k_B T}{m_i}} \qquad -\ 1 \text{ a } 2 \text{ stejné ionty}$$

$$\bar{\nu}_{pii} = \frac{1\, n_i}{3\sqrt{\pi}} \frac{q_i^4}{(4\pi\varepsilon_0)^2} \frac{4\pi}{\sqrt{m_i}\,(k_B T)^{3/2}} \ln\Lambda_c$$

analogicky pro elektrony
$$\bar{\nu}_{pee} = \frac{1\, n_e}{3\sqrt{\pi}} \frac{q_e^4}{(4\pi\varepsilon_0)^2} \frac{4\pi}{\sqrt{m_e}\,(k_B T_e)^{3/2}} = \frac{\bar{\nu}_{pei}}{\sqrt{2}}$$

PŘENOS ENERGIE

$$\bar{\nu}_E = \frac{2 m_1}{m_1 + m_2} \bar{\nu}_p$$

Příklad

svazek elektronů s rychlostí v_1
nechť $\frac{1}{2} m_e v_1^2 \gg k_B T$
$\Rightarrow v_2$ zanedbatelné

$$\nu_p = n_2 \left(\frac{q_1 q_2}{4\pi\varepsilon_0}\right)^2 4\pi \frac{m_1 + m_2}{m_1^2 m_2 v_1^3} \ln\Lambda_c$$

e–e: $\frac{2}{m_e^2}$ e–i: $\sim \frac{1}{m_e^2}$

$$\nu_{pee} = n_2 \frac{q_e^4}{(4\pi\varepsilon_0)^2} \frac{8\pi}{m_e^2 v_1^3} \ln\Lambda_c \ ; \ \nu_{pei} = \frac{Z^2}{2} \nu_{pee}$$

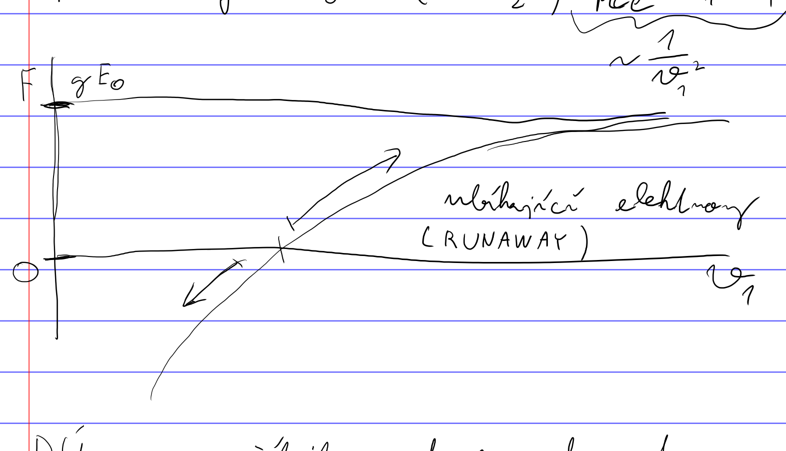
$$\frac{dp_1}{dt} = -(\nu_{pee} + \nu_{pei})\, p_1 \qquad | \ p_1 = n_1 m_1 v_1$$

$$\frac{d(m_1 v_1)}{dt} = \underbrace{-(\nu_{pee} + \nu_{pei})\, m_1 v_1}_{F_f \text{ antiparalelní k } \vec{v}_1} \qquad \text{Newton: } F = \frac{d(m_1 v_1)}{dt}$$

$$F_f = -\left(1 + \frac{Z^2}{2}\right) \nu_{pee}\, m_1 v_1$$

– přidáme el. pole $F_e = + q_e E$ (urychlující)

$$F = F_e + F_f = q_e E - \left(1 + \frac{Z^2}{2}\right) \underbrace{\nu_{pee}}_{\sim \frac{1}{v_1^2}} m_1 v_1$$



DÚ vypočítejte odpor plazmatu

– termální plazma, teplota T
– el. pole $\vec{E} \rightarrow v_d \ll v_{TH}$
– vodivost: $\vec{j} = \sigma \vec{E}$; $v_{di} \approx 0$

$$\frac{d(m_e v_d)}{dt} = q_e E - \bar{\nu}_{pei}\, m_e v_d$$