A model for gamma-ray binaries, based on the effect of pair production feedback in shocked pulsar winds

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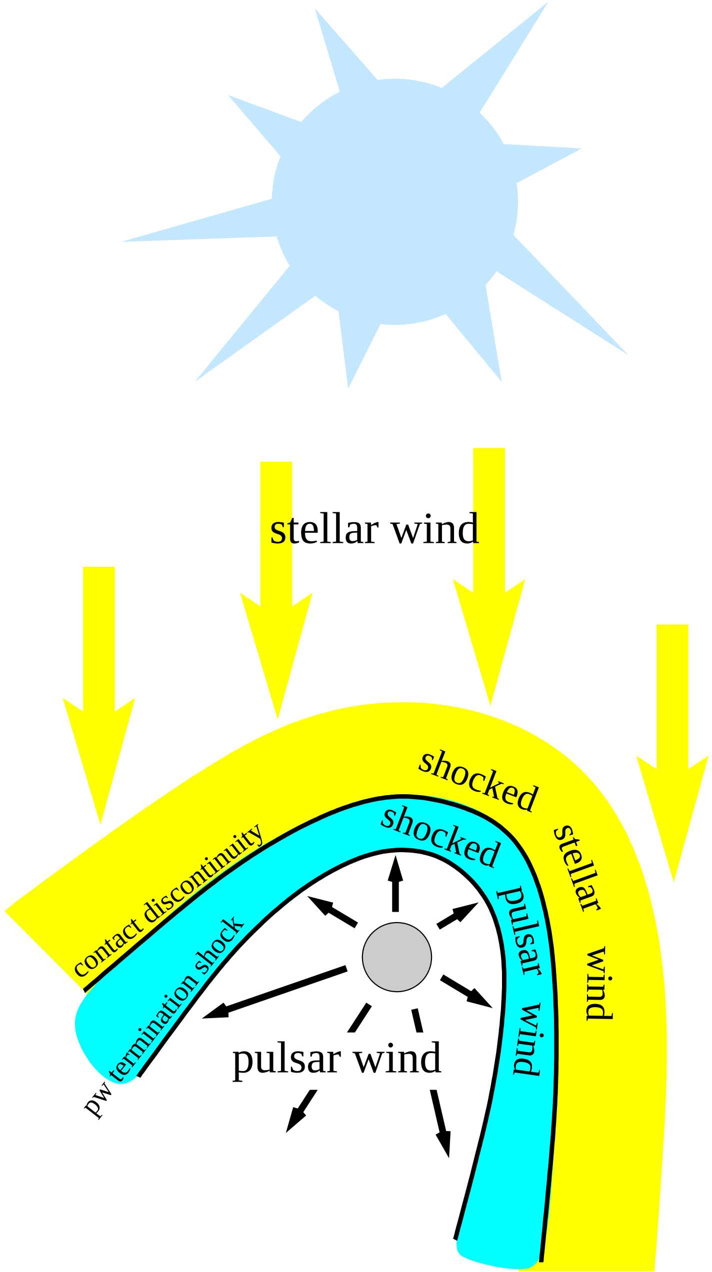
Three(?) blocks at the basement of all models

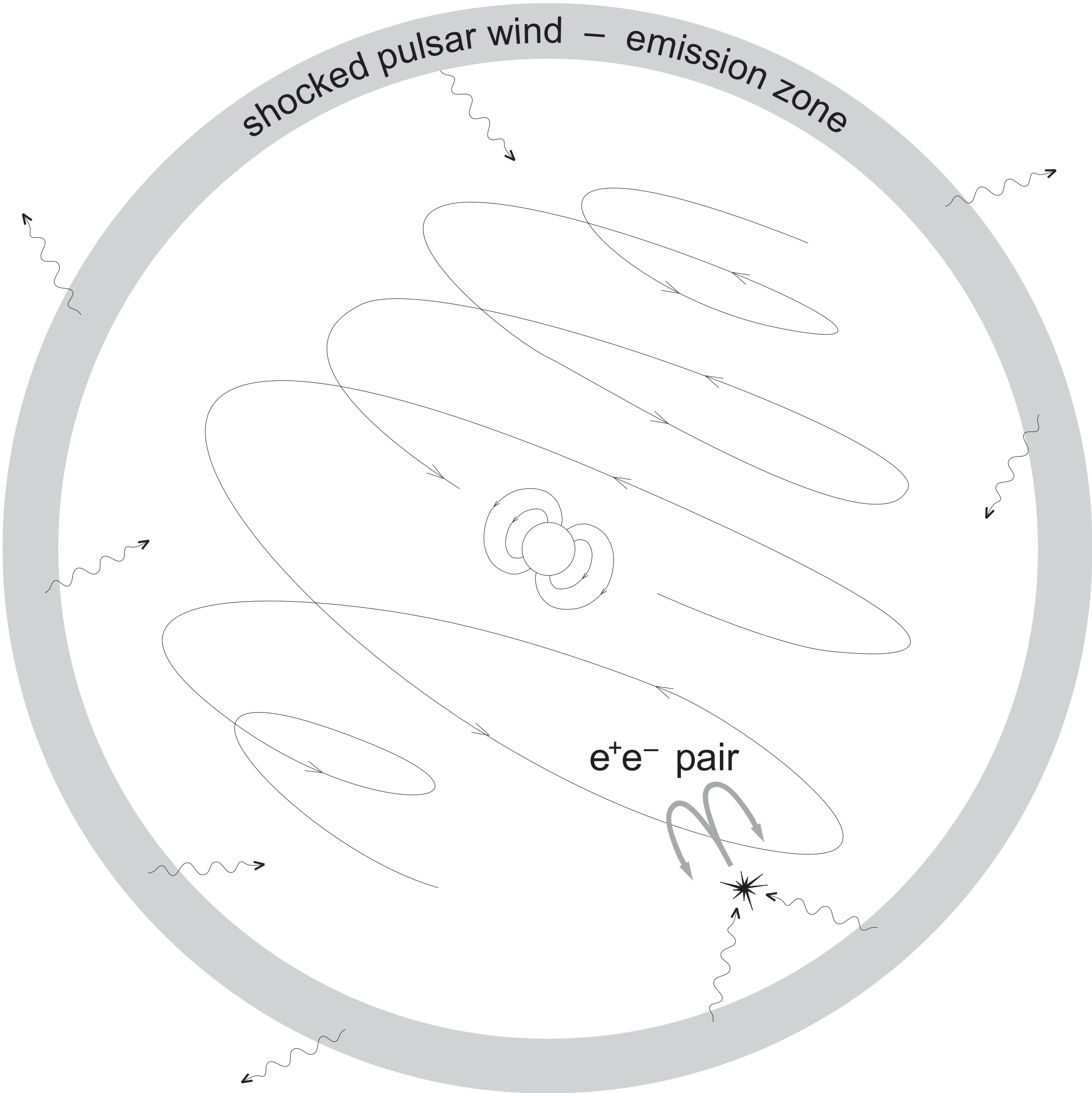


Relativistic MHD:
interaction of stellar and pulsar winds, shocks

Production of energetic particles:
likely diffusive shock acceleration

Radiative processes:
synchrotron and inverse Compton radiation, absorption of energetic photons in the massive star's surrounding and further cascading

Pair feedback in pulsar wind



Some of high-energy photons from the source produce pairs inside the pulsar wind zone

These pairs are then picked up by the pulsar wind

Pair feedback: is it important?

feedback through creation of secondary pairs
and their puckup by the pulsar wind

We know:

luminosity in the sub-MeV – few MeV range, $L_{\rm MeV} = 10^{35}$erg/s

orbital distance, $D = 3 \times 10^{12}$cm

massive star's mass loss rate,
$\dot{M} = 3 \times 10^{-7} M_{\odot}$/yr

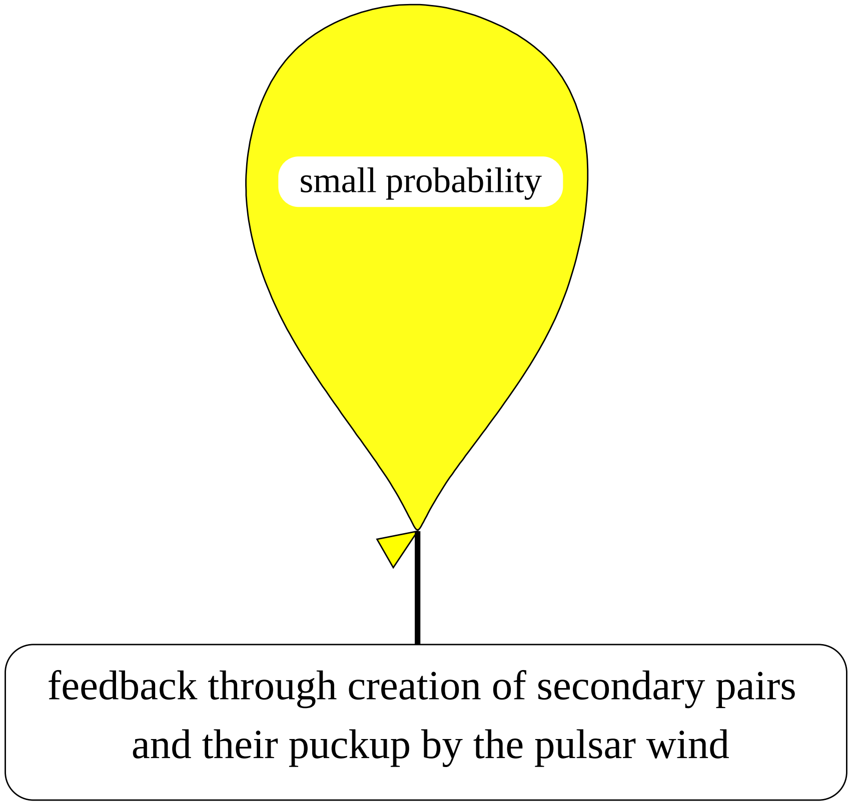
and wind velocity, $U_w \equiv \beta_w c \simeq 0.01c$

pulsar's power, $W_p = 10^{36}$erg/s

We can calculate:

size of the emitting region
and then $\gamma - \gamma$ opacity

Pair feedback: is it important?



Optical depth for $\gamma-\gamma$ pair production

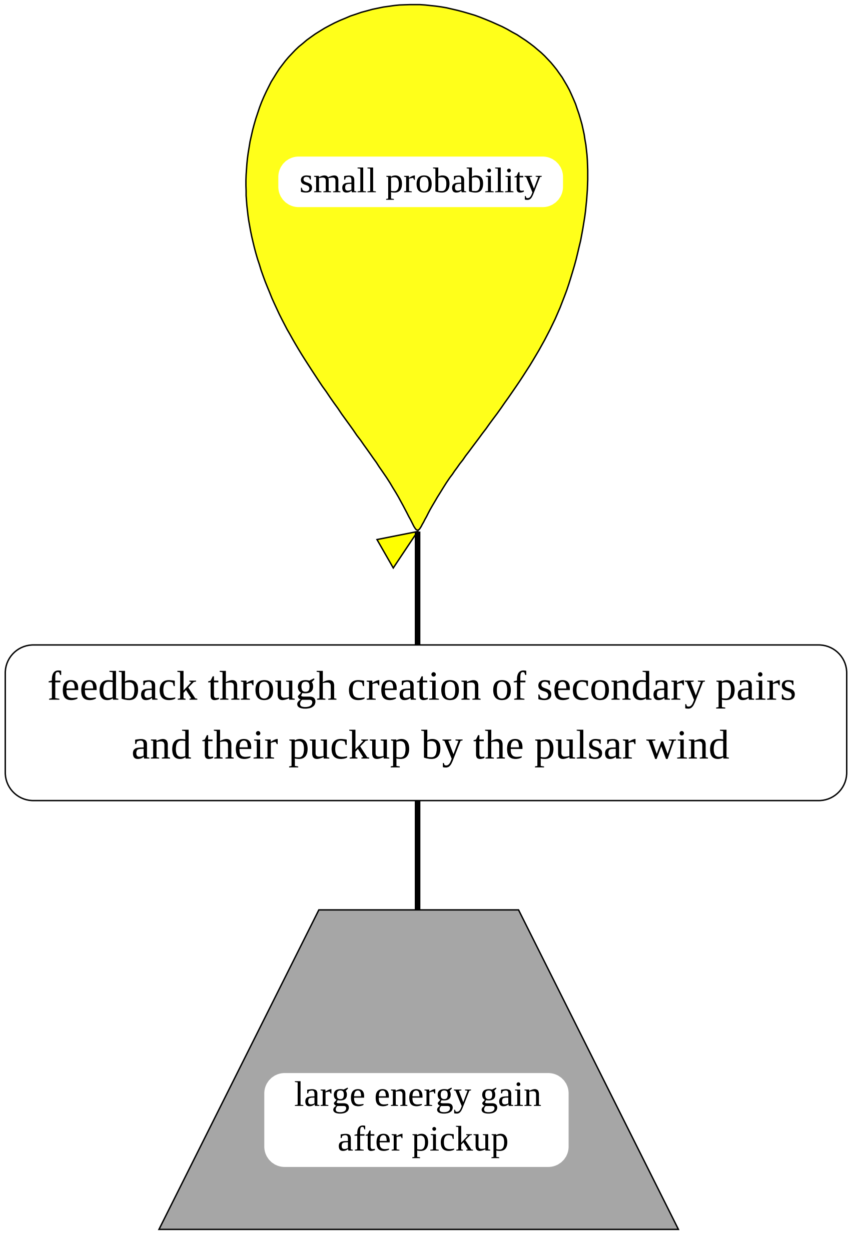
$$\tau_{\gamma\gamma} = \frac{\sigma_{\gamma\gamma}}{4\pi D c}\,\frac{L_{\mathrm{MeV}}}{m_e c^2}\left(\frac{\dot{M} U_w c}{W_p}\right)^{1/2}$$

$$\tau_{\gamma\gamma} \sim 10^{-7} \ll 1$$

with corrections for power-law spectrum,

$$\tau_{\gamma\gamma} \sim 10^{-6}$$

Pair feedback: is it important?



Secondary pairs are picked up by ultrarelativistic pulsar wind

with Lorentz factor $\Gamma > 10^3$

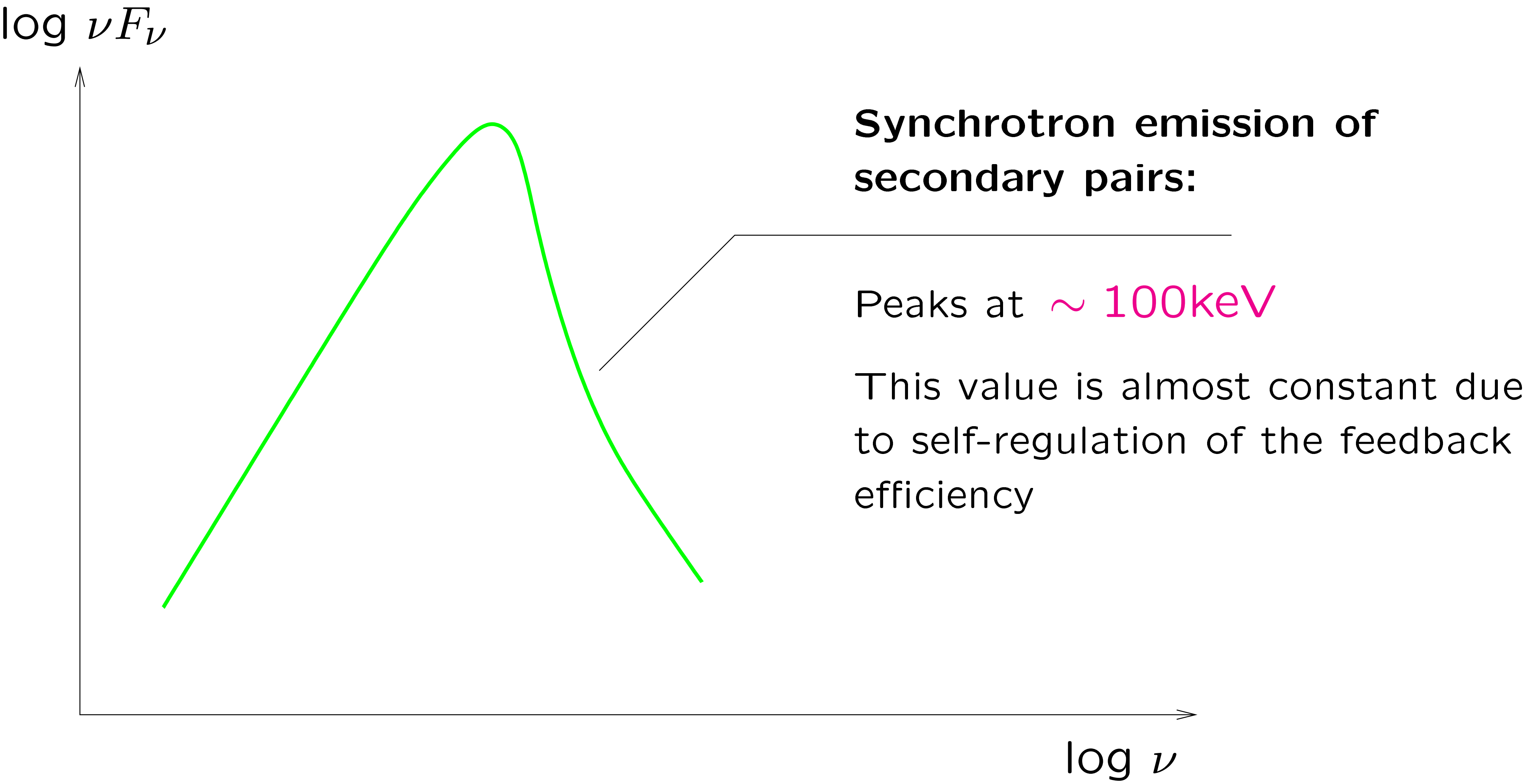
Each secondary pair

increases its energy in Γ^2

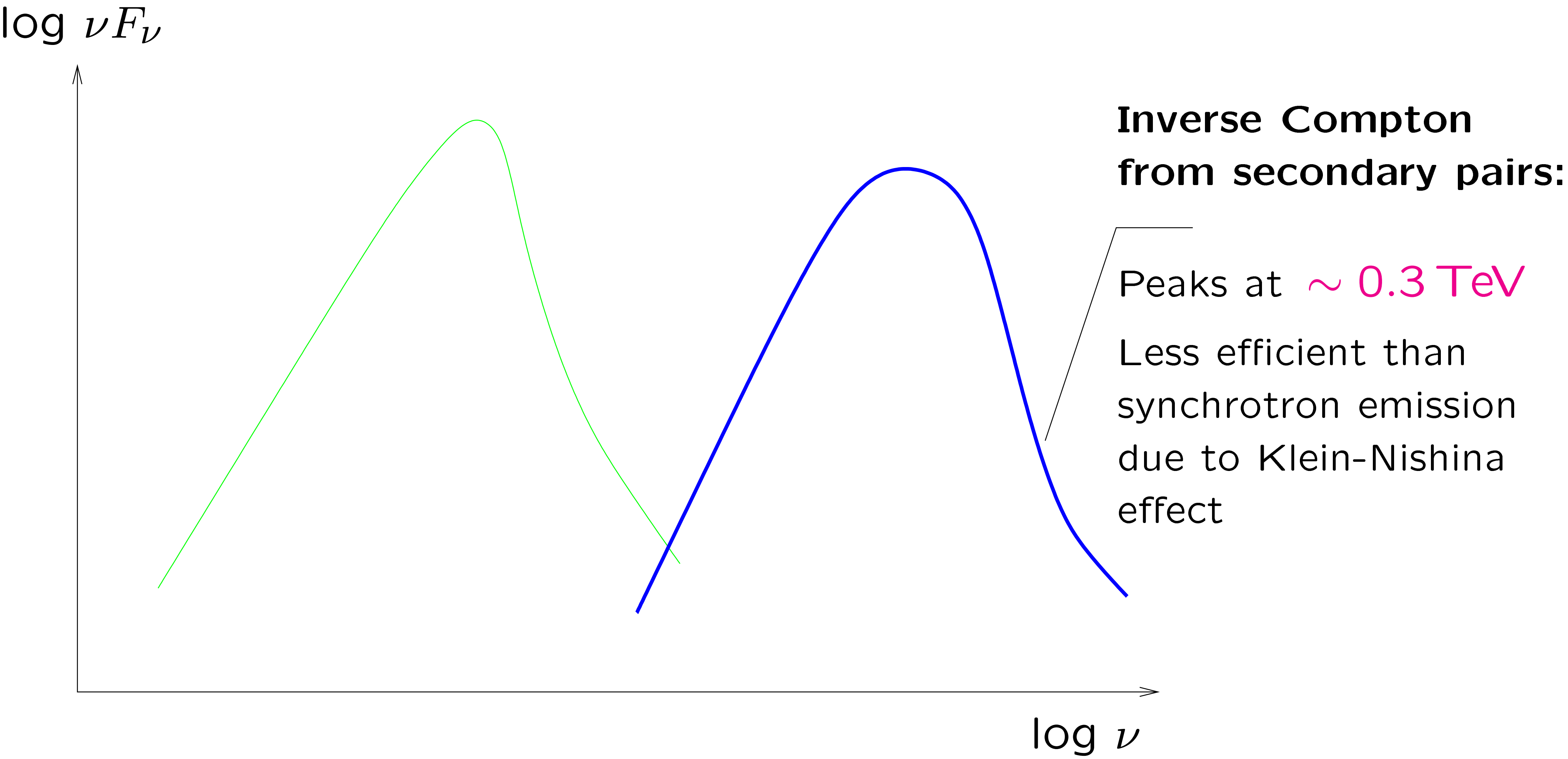
Overall feedback efficiency

$\eta_f = \Gamma^2 \tau_{\gamma\gamma} \gtrsim 1$

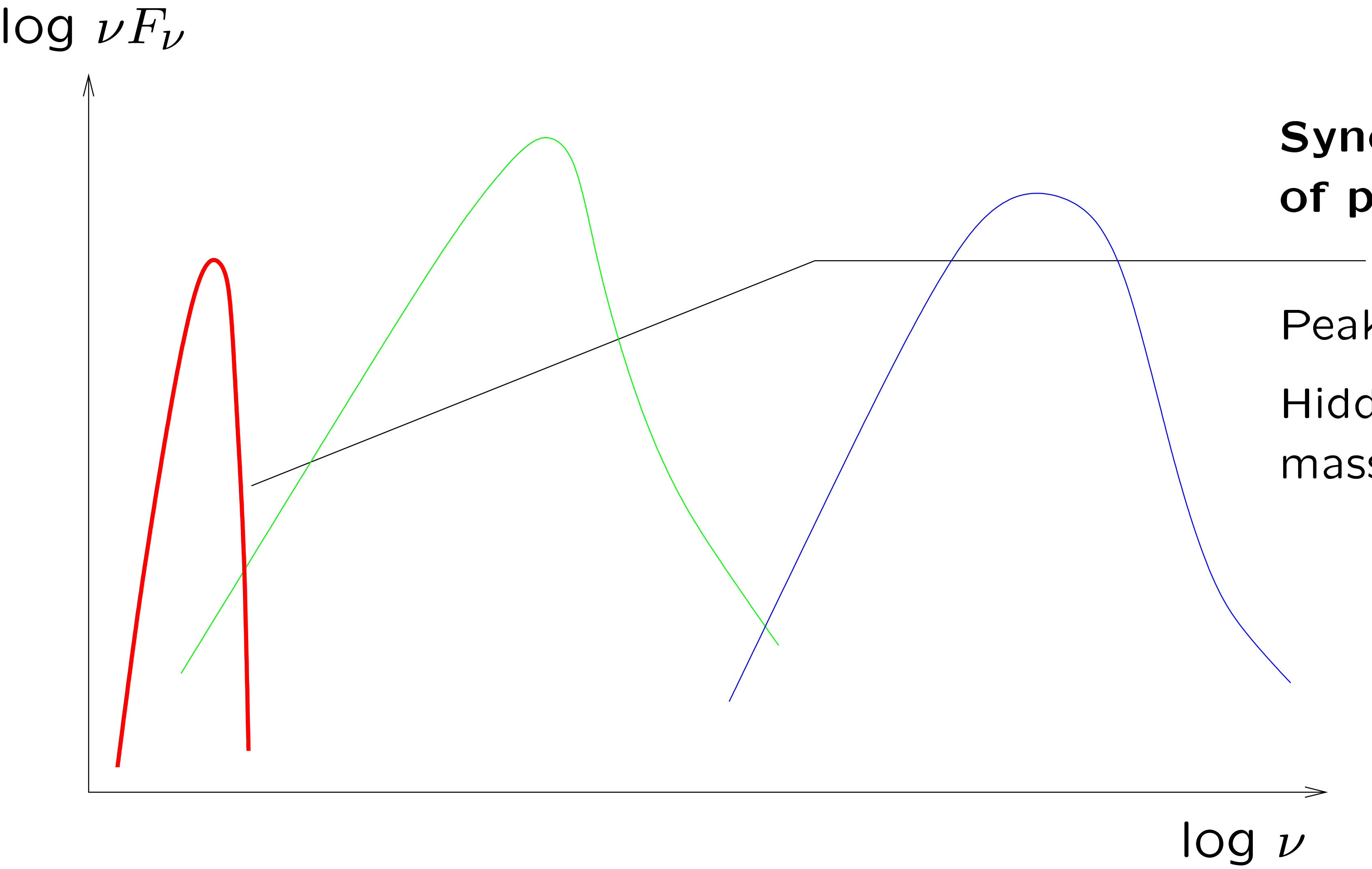
Model broad-band spectrum



Model broad-band spectrum



Model broad-band spectrum

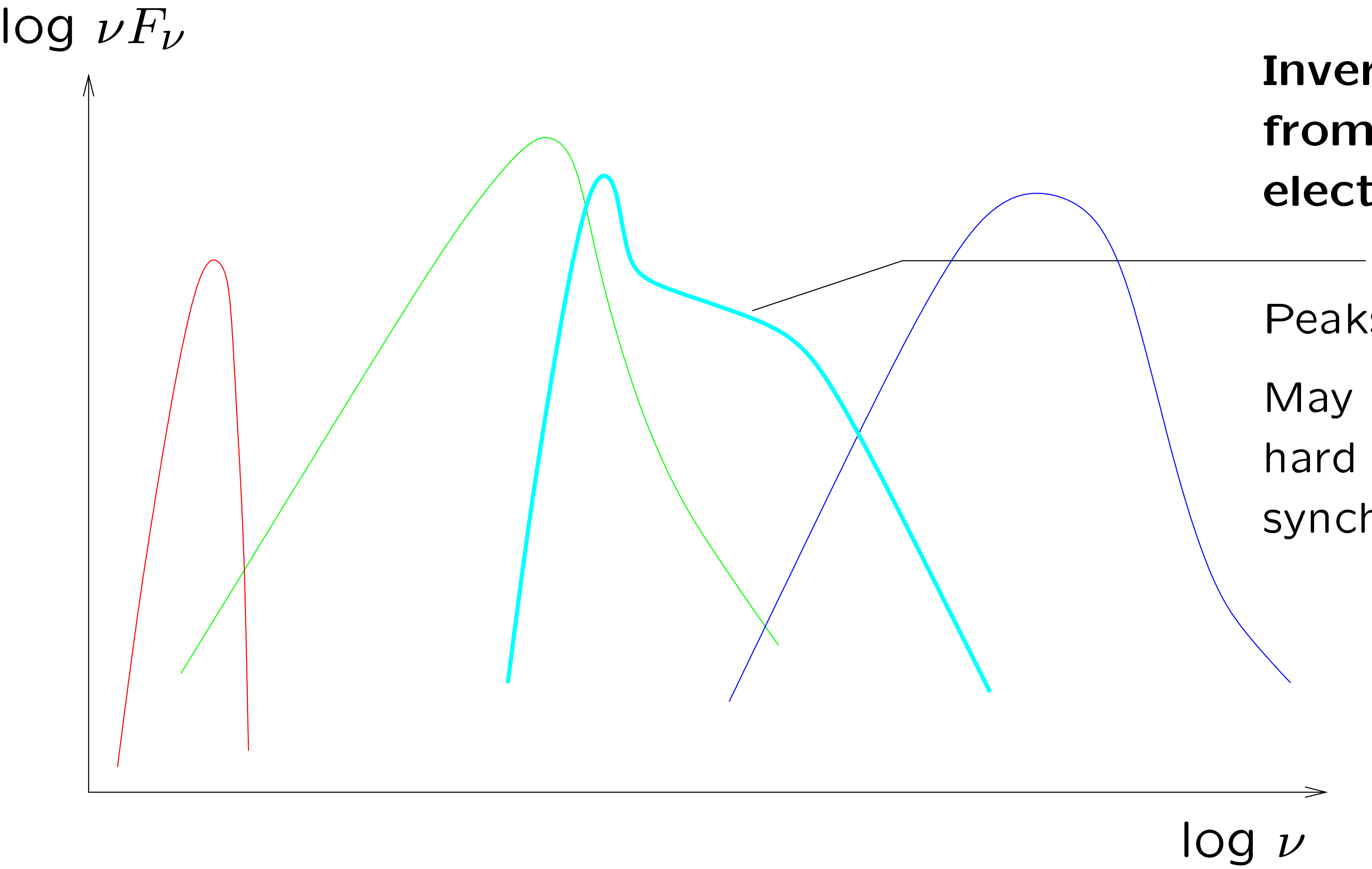


Synchrotron emission of primary electrons:

Peaks in infrared range

Hidden by emission of massive companion

Model broad-band spectrum



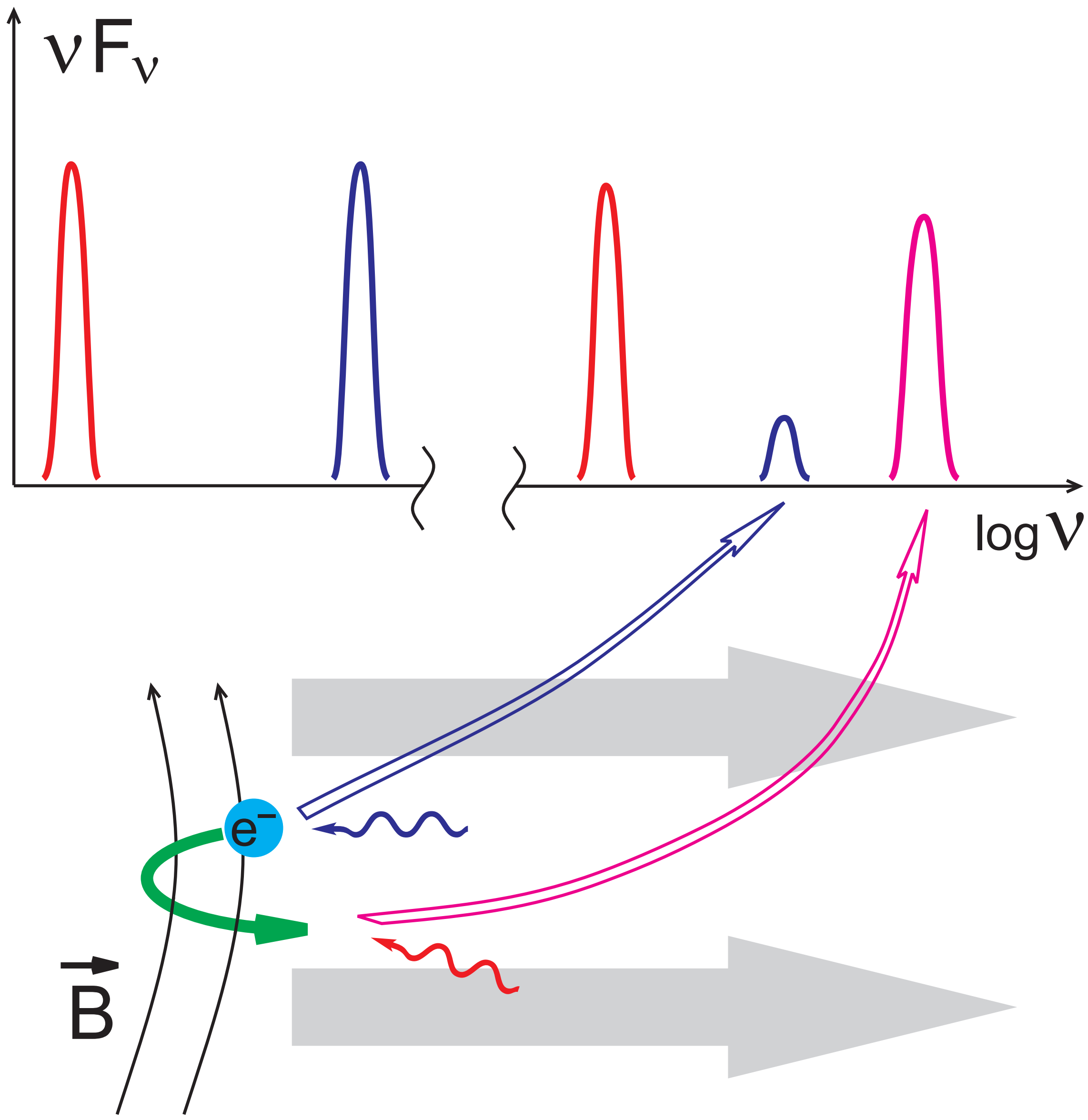
Inverse Compton from primary electrons:

Peaks at $\sim 10\,\mathrm{MeV}$

May compete with the hard tail of secondaries' synchrotron emission

Thank you

Recoil-assisted inverse Compton



Thomson regime:

$$E_{\rm IC} = \gamma^2 E_b \qquad L_{\rm IC} \propto \gamma^2 w_b$$

Klein-Nishina regime (direct):

$$E_{\rm IC} = \gamma m_e c^2 \qquad L_{\rm IC} \propto E_b^{-2} w_b$$

Klein-Nishina (recoil-assisted):

kick Lorentz factor $\quad \gamma_k = \dfrac{\gamma\, E_{b,2}}{2 m_e c^2}$

$$E_{\rm IC} = (\gamma\gamma_k)^2 E_{b,1} = \gamma^4 \frac{E_{b,1} E_{b,2}}{4 m_e^2 c^4} E_{b,2}$$

$$L_{\rm IC} \propto (\gamma\gamma_k)^2 w_{b,1} \times \gamma^{-1} E_{b,2}^{-2} w_{b,2}$$
$$\propto \gamma^3 w_{b,1} w_{b,2}$$