Self-Similar Kinetic Theory and Application to the Solar Wind

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Self-similar Kinetic Theory

Drift Kinetic Equation ($|\vec{V}| >> \mathrm{V}_{sw}$):

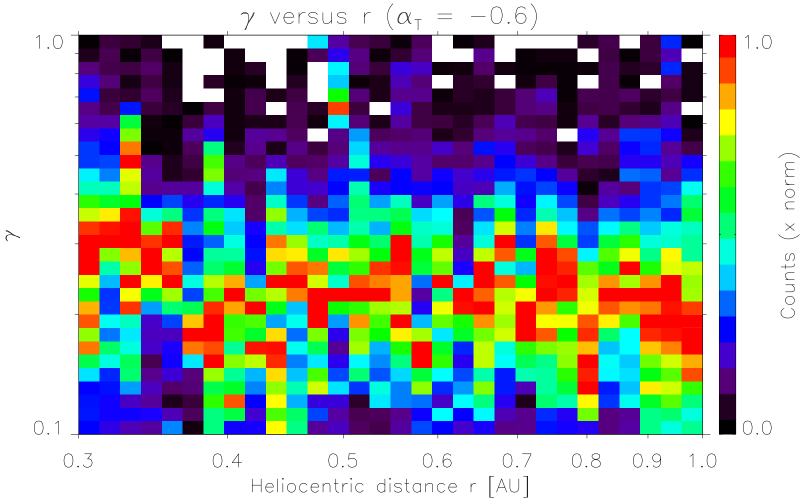
$$\frac{\partial f}{\partial t} + \mathrm{V}_{\parallel}\hat{b}\cdot\nabla f + \left(\mu_B B\nabla\cdot\hat{b} + \frac{q_e E_{\parallel}}{m}\right)\frac{\partial f}{\partial \mathrm{V}_{\parallel}} = \hat{C}(f)$$

If Knudsen number $\gamma \sim \frac{\lambda_{mfp}}{L_T}$ =constant, then for $\frac{\mathrm{V}}{\mathrm{V}_{th}} >> 1$, can reduce to an equation *independent of* $\mathbf{x}$ ($\frac{\partial f}{\partial t} = 0$)

$$f(\mathbf{x},\mathbf{V},t) \equiv \frac{NF(\mu,\xi,t)}{T(\mathbf{x})^{\alpha}}, \qquad \mu \equiv \mathbf{V}\cdot\hat{x}/\mathrm{V}, \qquad \xi \equiv \left(\frac{\mathrm{V}}{\mathrm{V}_{th}}\right)^2$$

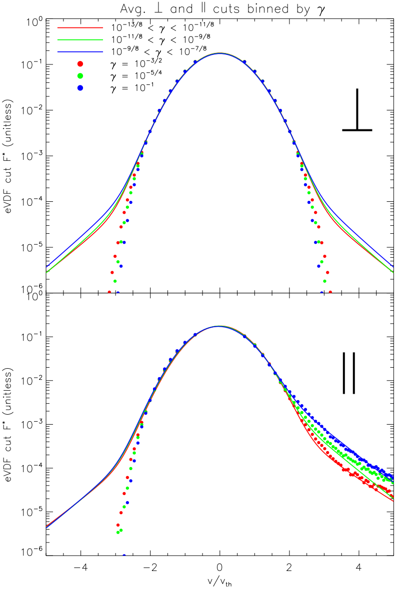
$$\gamma\Big[-\alpha\mu F - \mu\xi\frac{\partial F}{\partial \xi} + \frac{-\alpha_B}{2}(\alpha+1/2)(1-\mu^2)\frac{\partial F}{\partial \mu}\Big] +$$
$$\gamma_E\Big[\mu\frac{\partial F}{\partial \xi} + \frac{1-\mu^2}{2\xi}\frac{\partial F}{\partial \mu}\Big] +$$
$$\frac{1}{\xi}\Big[\frac{\partial F}{\partial \xi} + \frac{\partial^2 F}{\partial \xi^2}\Big] + \frac{\beta}{2\xi^2}\frac{\partial}{\partial \mu}(1-\mu^2)\frac{\partial F}{\partial \mu} = 0$$

Applicability: γ =constant?



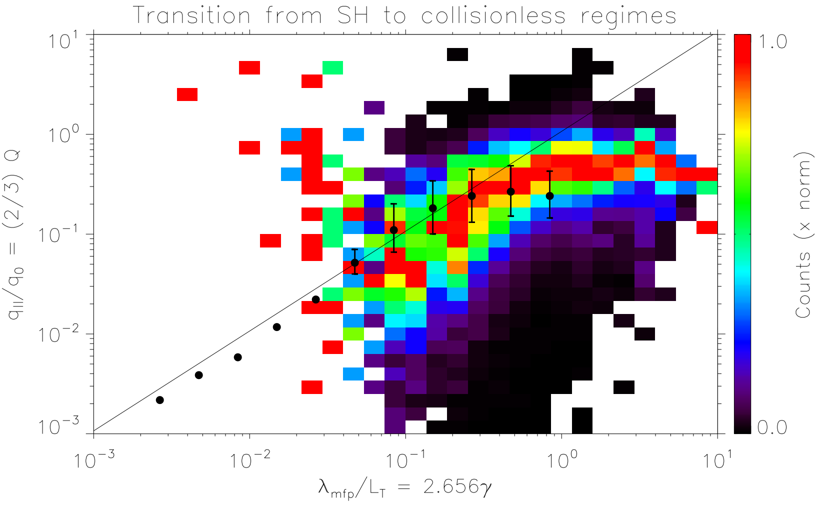
$\gamma \propto \frac{T(dT/dr)}{n}$ plotted versus heliocentric distance $0.3 < r < 1$ AU.
(Helios electron data)

eVDF Cuts



- Comparison of simulations (points) with Helios eVDF cuts (lines), ordered by γ
- High level of agreement in the core and strahl!
- Model response of the detector: Convolution

Transition from Spitzer-Härm to Collisionless limit



Conclusions

- In the solar wind $\gamma \approx$constant, allowing self-similar kinetic equation to be applied
- Can order eVDF profiles by γ. Average Helios cuts match the results of simulations for core and strahl electron populations, but not for the halo population.
- Transition from Spitzer to collisionless regimes is predicted.