Gyrokinetic particle simulations of toroidal momentum transport in tokamak

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Goal: to study toroidal momentum transport in the core region of tokamak

We use global gyrokinetic toroidal code GTC (electrostatic) with adiabatic electrons [Lin at al. Science 281, 1835 (1998)].

Momentum transport is simulated in a presence of ITG turbulence.

The following simulation parameters are used (GA-standard case):

$R/a=3$; $R/L_T=9$; $R/L_n=3$; $R/\rho_i=700$; $T_e/T_i=1$;

Shifted Maxwellian equilibrium velocity distribution

$$F_{LM}(\varepsilon,\mu,\psi)=\frac{n(\psi)}{(2\pi)^{3/2}\left(T(\psi)/m\right)^{3/2}}\exp\left[-\frac{\mu B(\psi)}{T(\psi)}-\frac{m\left(v_z-u(\psi)\right)^2}{2T(\psi)}\right]$$

$$v_z=\sigma\sqrt{\frac{2}{m}\left(\varepsilon-\mu B(\psi)-e\Phi(\psi)\right)}$$

Toroidal velocity satisfies the radial force balance: $u=-\frac{cI}{B}\Phi'(\psi)$

Gyrokinetic equation for the perturbed distribution $w=\delta f/F$

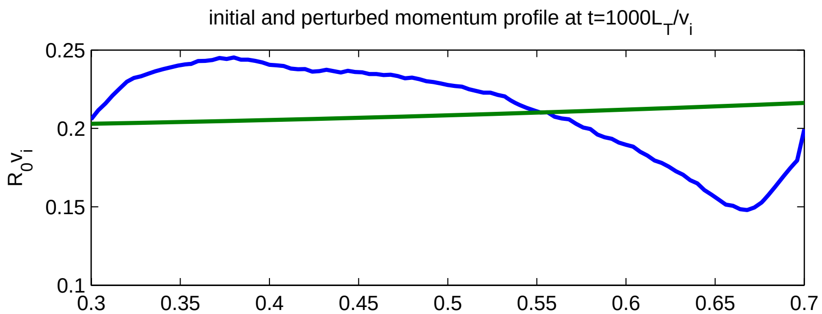
$$\frac{dw}{dt}=-\kappa\cdot\mathbf{v}_\chi+\frac{m}{T}(v_z-u)\frac{cI}{B}\Phi''\nabla\psi\cdot\mathbf{v}_\chi-\frac{e}{T}(v_z-u)\mathbf{z}\cdot\nabla\delta\chi+\left(\frac{\mu B}{T}+\frac{m}{T}(v_z+u)(v_z-u)\right)\frac{\nabla B}{B}\cdot\mathbf{v}_\chi$$

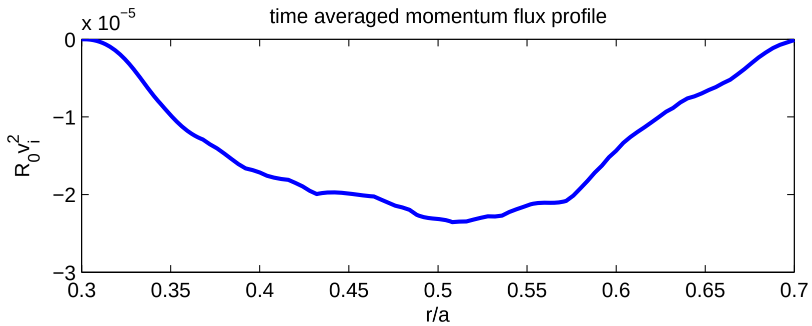
$$\mathbf{v}_\chi=\frac{c}{B}\mathbf{z}\times\nabla\delta\chi \qquad \kappa=\nabla\ln n+\left[\frac{m}{2T}\left(v_\perp^2+(v_z-u)^2\right)-\frac{3}{2}\right]\nabla\ln T \qquad \frac{cI}{B}\Phi''=-u'-\frac{B'}{B}u$$

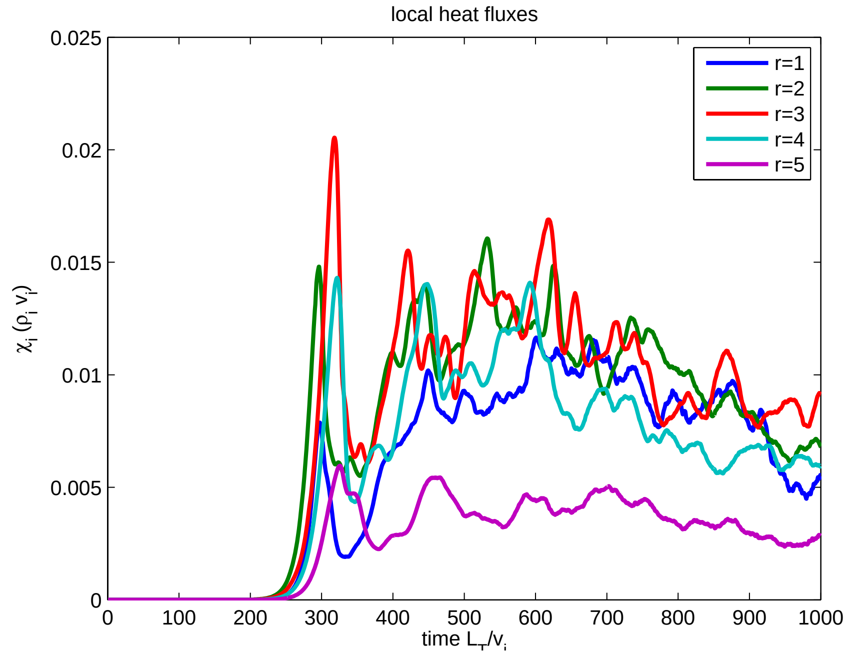
Constant angular velocity $\omega=0.2R_0/v_i$

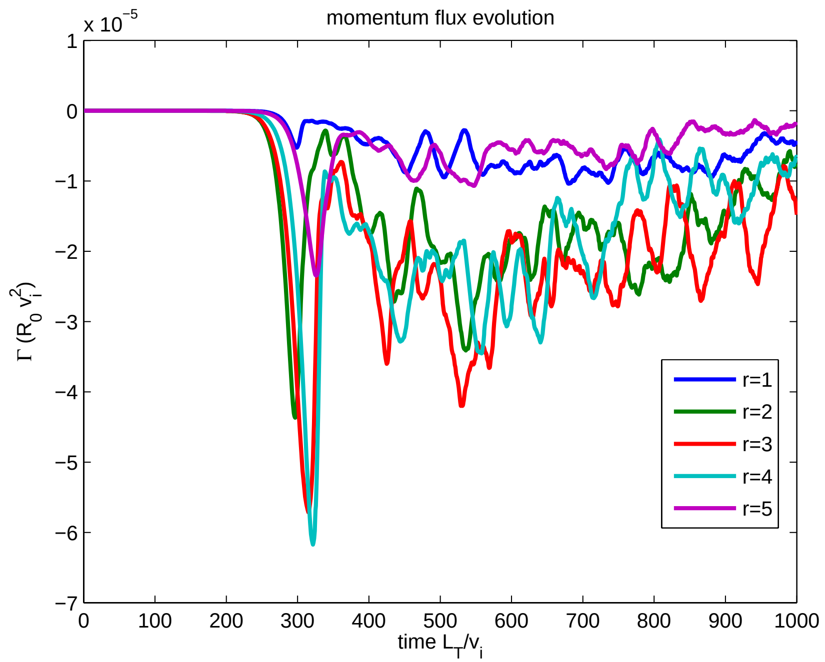
Perturbed angular momentum: $\langle \delta L \rangle \equiv \langle R v_z \delta f \rangle$

Angular momentum flux: $\Gamma_{\delta L} \equiv \langle \delta L \, \delta v_r \rangle$

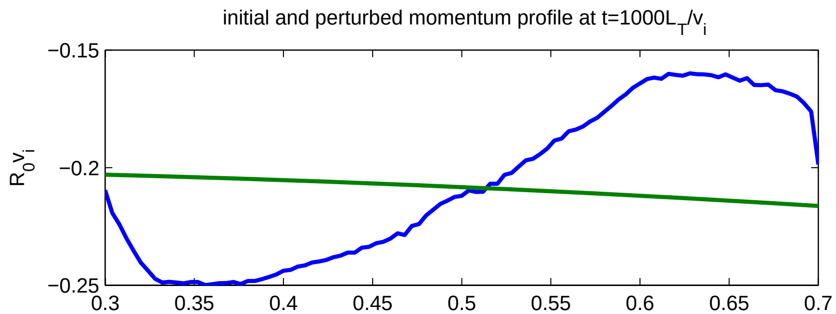


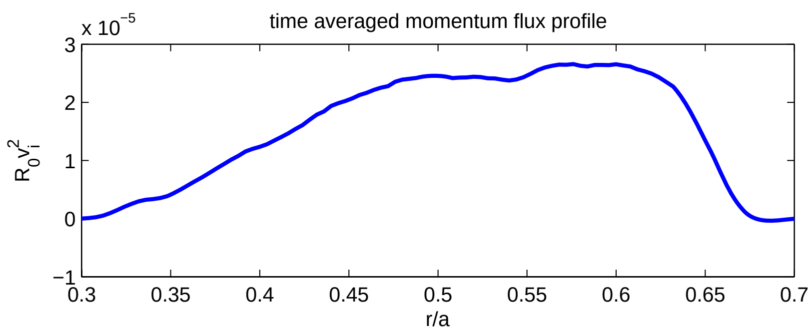


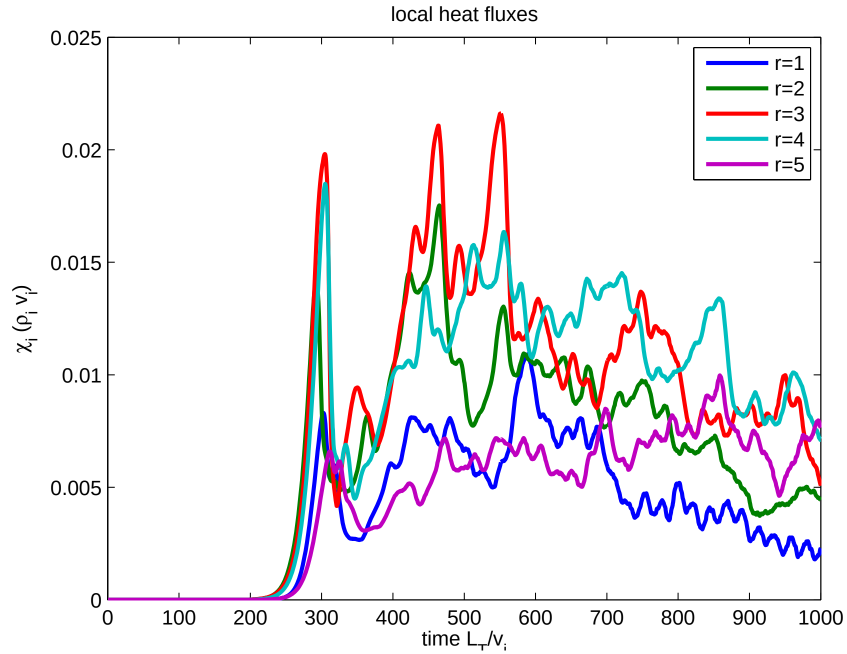


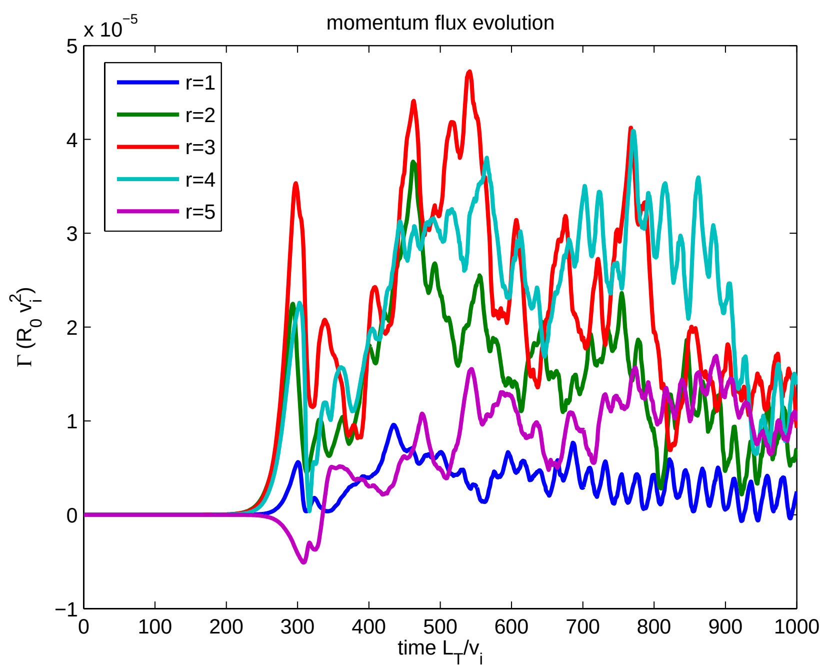


Constant angular velocity ω=-0.2R_0/v_i



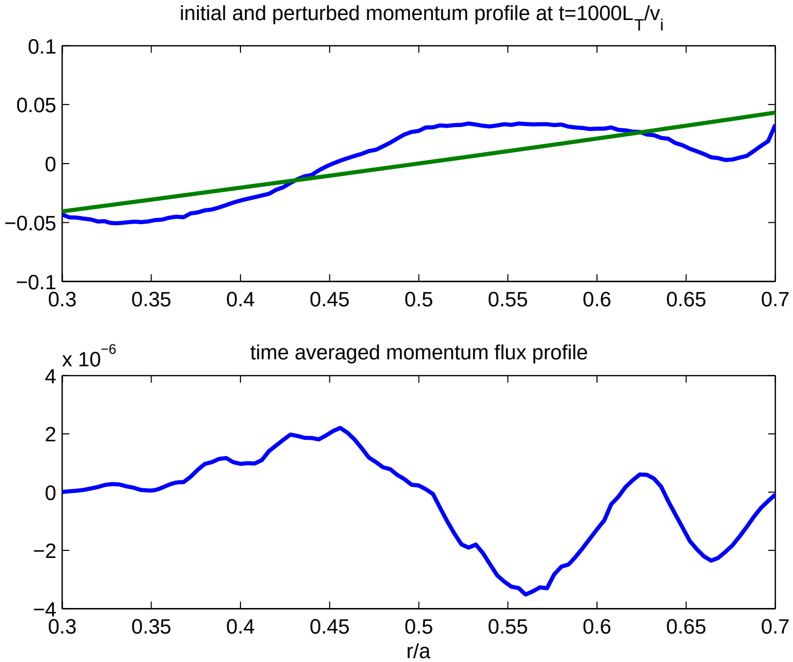




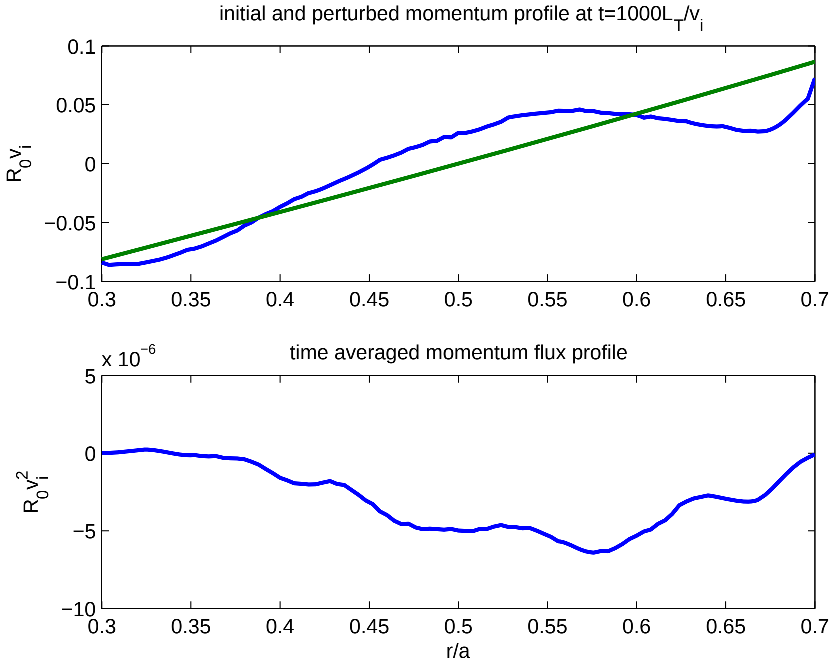


Sheared angular velocity

$\omega = (-0.1 + 0.2r/a)R_0/v_i$



$\omega = (-0.2 + 0.4r/a)R_0/v_i$



$\omega = (\omega_0 + \omega_1 r/a)R_0/v_i$

ω_0	ω_1	Γ_ϕ ($R_0 v_i^2$) x10^{-5}
0.1	0	-1.1
0.2	0	-1.4
0.4	0	-1.5
-0.1	0.2	0.03
0.1	-0.2	-0.4
-0.2	0.4	-0.4

Conclusions

Global gyrokinetic simulations of toroidal momentum transport has been carried out;

Significant redistribution (spinning up towards the center) of toroidal momentum is observed in case with constant angular velocity;

In case of sheared rotation a competition between diffusive and pinch fluxes is observed;