Erratum: Models and methods for nonlinear magnetohydrodynamic simulations of stellarators

Nikita Nikulsin

March 2022

Some of the results reported in Chapter 4 of the doctoral dissertation [1] were affected by a bug in JOREK that has now been fixed. Due to the bug, only the first term, $F_0\phi$, in the Dommaschk potential (equation (4.1) in Ref [1]) was correct, whereas all of the other terms were evaluated with the toroidal angle ϕ having the opposite sign. Thus, when trying to evaluate $\chi(R, z, \phi)$, the affected subroutine would return $F_0\phi + \sum_{m,l} \chi_{m,l}(R, z, -\phi)$. However, since the $F_0\phi$ term is dominant in Wendelstein 7-A, the simulation results seemed reasonable and the bug went unnoticed.

After fixing the bug and repeating the stellarator simulations, Figures 4.2, 4.3, 4.5 and 4.6 had to be replaced. For completeness, a re-plotted Figure 4.4 is also provided here; although the posistions of the individual points in the Poincare plots has changed, there is no visible change in the positions of the flux surfaces in Figure 4.4.
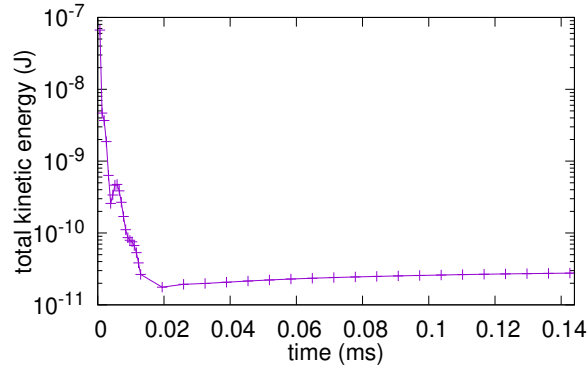

Figure 4.2: The total kinetic energy of the plasma in the $\beta = 0.022$ % case during the first 0.144 ms of the simulation (20 time steps of 1 and 20 time steps of 10 JOREK time units) showing the damping out of motion due to the neglect of fourth order terms in the force balance.
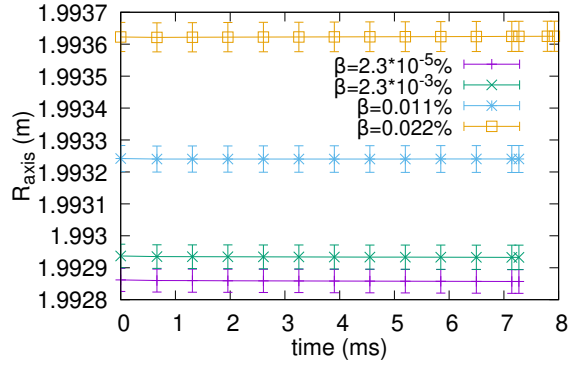

Figure 4.3: The R coordinate of the magnetic axis as a function of time for the four different β cases.
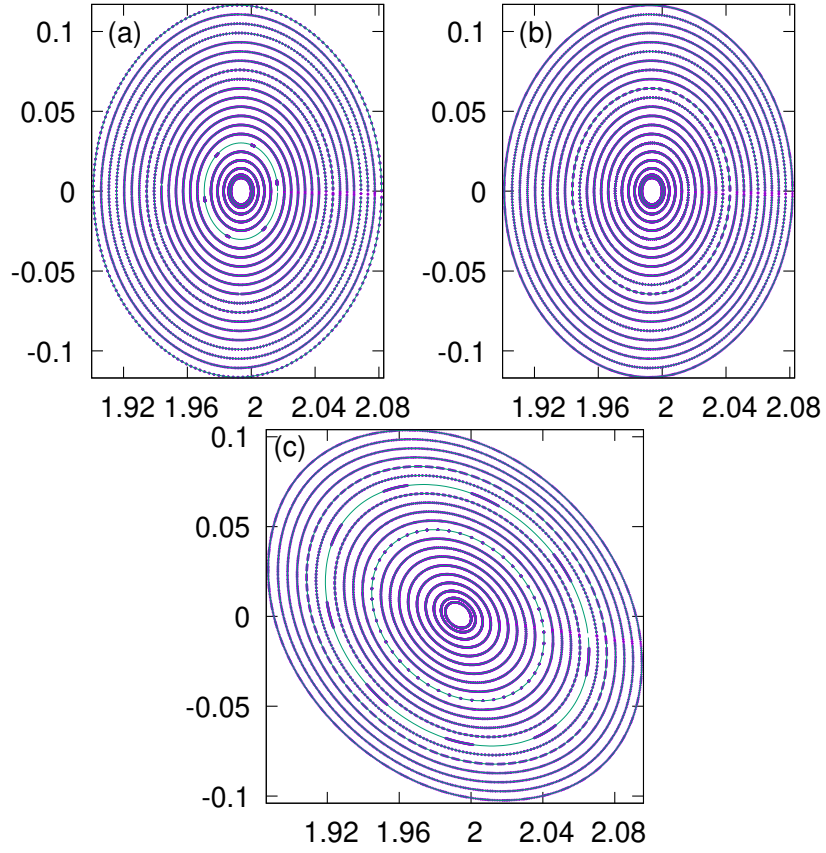
Figure 4.4: The Poincare plots for the $\beta = 0.022$ % case at $t = 0$ and $\phi = 0$ (a), at $\phi = 0$ after the simulation is over ($t = 7.275$ ms) (b), and at $t = 0$ and $\phi = 3\pi/10$ (3/4 of the way through one period) (c).
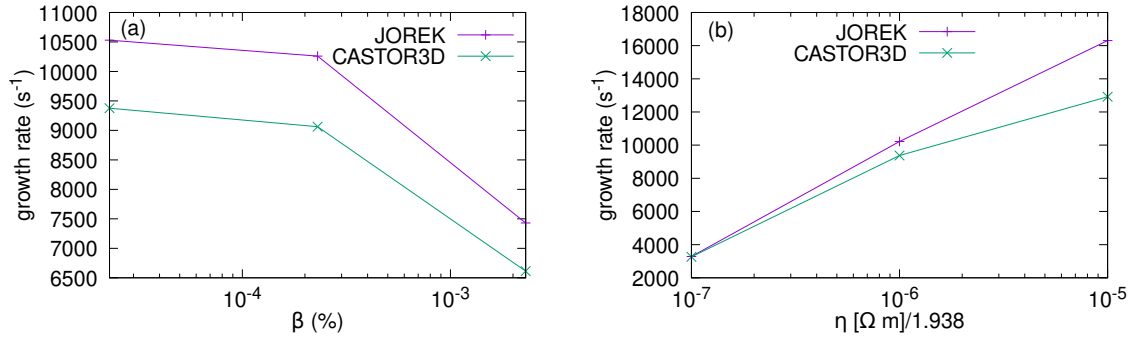

Figure 4.5: The JOREK and CASTOR3D growth rates at $\eta = 1.938 \cdot 10^{-6}$ Ω·m and differing betas (a), and at $\beta = 2.3 \cdot 10^{-5}$ % and differing resistivities (b).
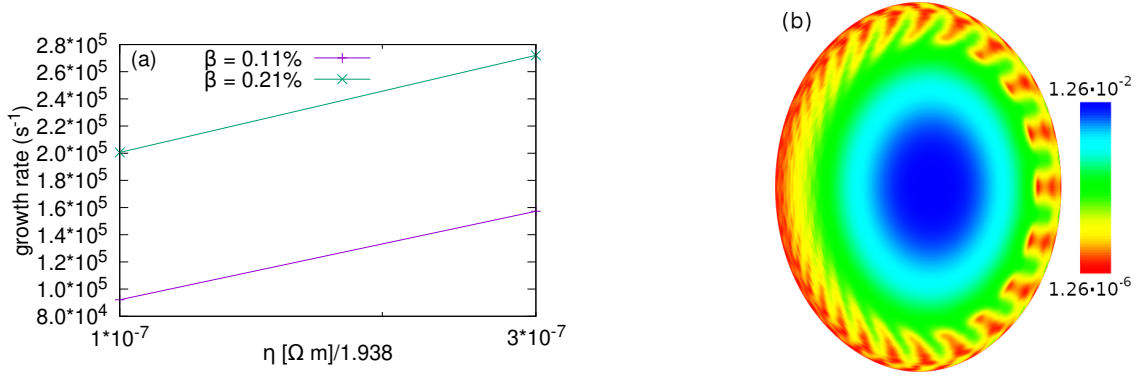
Figure 4.6: The ballooning mode growth rates at two different values of β and resistivity (a), and the temperature plot (JOREK units) in the $\beta = 0.21\%$, $\eta = 1.938 \cdot 10^{-7}$ Ω·m case at $t = 0.110$ ms on the $\phi = 0$ poloidal plane (b).

All tearing and ballooning mode growth rates converged at the same values of hyperviscosity, resolution, time step size, number of Fourier modes (only varied for tearing modes, as discussed in Ref [1]) and number of poloidal planes as before. When re-running the ballooning mode simulations, the first phase, which was done with the implicit Euler scheme, consisted of 30 time steps of length $6.484 \cdot 10^{-4}$ ms for all cases, not just the $\beta = 0.21\%$, $\eta = 5.814 \cdot 10^{-7}$ Ω·m case. This was followed by the second phase, which was done with the Crank-Nicolson scheme, as before. Due to the more accurate representation of the magnetic field after the bug was fixed, there was less noise in the simulation (see Figure 4.2 and compare it to the original Figure 4.2 in Ref [1]), and so it took longer for the ballooning mode to appear. Thus, the temperature plot in Figure 4.6 b had to be taken at a later time ($t = 0.110$ ms instead of $t = 0.081$ ms in the original simulation).

Bibliography

[1] Nikita Nikulsin. *Models and methods for nonlinear magnetohydrodynamic simulations of stellarators.* PhD thesis, Technische Universität München, München, 2021.