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Title:	RESPONSE TO "COMMENT ON "MAGNETIC TOPOLOGY EFFECTS ON ALCATOR C-MOD SCRAPE-OFF LAYER FLOW""
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Response to "Comment on 'Magnetic topology effects on Alcator C-Mod scrape-off layer flow' "

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Abstract

In his comment to our recent work [Simakov A N, Catto P J, LaBombard B and Glasser A H 2008 *Plasma Phys. Control. Fusion* **50** 105010], Aydemir has asserted that poloidal plasma flow reversal is not a valid response to toroidal magnetic field reversal in an up-down symmetric tokamak, and that the toroidal plasma flow must reverse instead. We show that this assertion is wrong due to his misunderstanding of the corresponding symmetry transformation.

Aydemir asserts that magnetic field and plasma flow symmetry properties of a tokamak with axisymmetric applied fields (fluctuations need not be axisymmetric) as described in our recent work [1, 2], which serves as a basis of [3], are wrong. In particular, he claims that poloidal plasma flow reversal is not a valid response to toroidal magnetic field reversal in an up-down symmetric tokamak, and that the toroidal plasma flow must reverse instead [4]. Here we show that Aydemir's assertion is wrong. Indeed, as shown in [5], all levels of plasma description including the Euler-Lagrange equations based on the Darwin Lagrangian, Maxwell-Boltzmann equations, and magnetohydrodynamic (MHD) equations corroborate our prediction. The MHD equations are simpler and therefore possess a wider class of symmetries including the flow symmetry described by Aydemir.

The incorrect assertion of Aydemir is due to his misunderstanding of our symmetry transformation. In particular, he thinks that we believe a simultaneous reversal of toroidal magnetic field and poloidal plasma flow in an up-down symmetric tokamak is described by the transformation

$$\begin{aligned}&(R,\phi,z,B_R,B_\phi,B_z,E_R,E_\phi,E_z,v_R,v_\phi,v_z)\rightarrow\\&(R,\phi,z,B_R,-B_\phi,B_z,E_R,-E_\phi,E_z,-v_R,v_\phi,-v_z),\end{aligned}\tag{1}$$

where the cylindrical coordinate system (R,ϕ,z) is used, $\boldsymbol{B}$ and $\boldsymbol{E}$ are the magnetic and electric fields, and $\boldsymbol{v}$ is the plasma flow velocity, a particle velocity, or a kinetic velocity variable depending on a context. However, the correct symmetry transformation and the one we use in this case is [5]

$$\begin{aligned}&(R,\phi,z,B_R,B_\phi,B_z,E_R,E_\phi,E_z,v_R,v_\phi,v_z)\rightarrow\\&(R,\phi,-z,-B_R,-B_\phi,B_z,E_R,E_\phi,-E_z,v_R,v_\phi,-v_z).\end{aligned}\tag{2}$$

It is easy to see that transformation (2) corresponds to reversal of toroidal magnetic

field and poloidal plasma flow, but not poloidal magnetic field and toroidal plasma flow; while satisfying the Maxwell equations, and leaving the Darwin Lagrangian ((1) of [5]), the kinetic equations ((6) of [5]), the extended MHD equations ((11) of [5]), and even the reduced MHD equations ((1) of Aydemir's comment) unchanged – including time derivatives. Transformation (1) clearly does not possess these properties, as is pointed out by Aydemir in his comment.

At the same time, the symmetry transformation of Aydemir [4] that describes simultaneous reversal of toroidal magnetic field and toroidal plasma flow,

$$(R, \phi, z, B_R, B_\phi, B_z, E_R, E_\phi, E_z, v_R, v_\phi, v_z) \rightarrow$$
$$(R, \phi, z, B_R, -B_\phi, B_z, -E_R, E_\phi, -E_z, v_R, -v_\phi, v_z), \tag{3}$$

does satisfy (1) of his comment and the Maxwell equations in the axisymmetric limit (including fluctuating as well as applied fields), but *not* the more general Euler-Lagrange and Maxwell-Boltzmann equations. It is therefore an artifact of the MHD model and, contrary to the Aydemir claims, is likely irrelevant for predicting tokamak magnetic field and plasma flow symmetries.

Finally, it is worth noting that neoclassical transport theory predicts directly that toroidal magnetic field reversal causes poloidal plasma flow reversal [6, 7], but not the toroidal plasma flow reversal, in all regimes of plasma collisionality.

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