Rethinking quasisymmetry

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Quasisymmetric stellarators brought about a renaissance in stellarator design by producing a concept which has the superior neoclassical performance of tokamaks, but without the liability of disruptions. However, it was soon realized that exactly quasisymmetric configurations were likely not possible. Though not rigorously proven, the overdetermination of solutions near the axis was taken as evidence of this impossibility [D. Garren, A. Boozer, Phys. Fluid B, 3, 2822 (1991)]. The reason behind this limitation was however not made clear. How fundamental is it? Is there a way around it?

To answer these questions and deepen our understanding we reformulate the notion of quasisymmetry (QS) from a single particle perspective [E. Rodriguez, et al., Phys. Plasmas, 27, 062501 (2020)]. Unlike other formulations, the new formulation makes no assumptions regarding the nature of the underlying MHD equilibrium, but reduces to the standard form of QS in a static, ideal, isotropic pressure equilibrium. Generalizing the form of equilibrium to include anisotropic pressure shows that the conventional overdetermination problem of quasisymmetric fields disappears. The near-axis-expansions program with anisotropic pressure now fits the problem perfectly (same degrees of freedom as constraints) [E. Rodriguez, et al., Phys. Plasmas, 28, 012508 (2021)]. Furthermore, we formulate a variational principle with constraints that naturally produce quasisymmetric equilibria with anisotropic pressure. Numerical solutions based on expansions will be presented [E. Rodriguez, et al., arXiv:2012.02077, to appear in PRE]. This reformulation and broader view on the problem opens a new perspective and framework for QS, suggesting that there may exist solutions that are very close to QS even in ideal, static, isotropic pressure equilibrium. Additional properties such as the role of flows or the presence of current singularities and islands can now be explored from a broader perspective.