

Plans for Extending COGENT to Model Snowflake Divertors

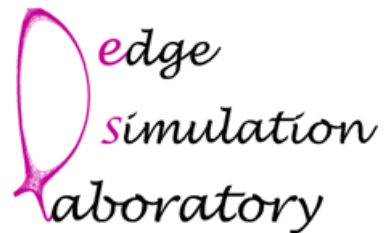
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ESL Team Meeting, GA, Sept 30-Oct 1, 2014

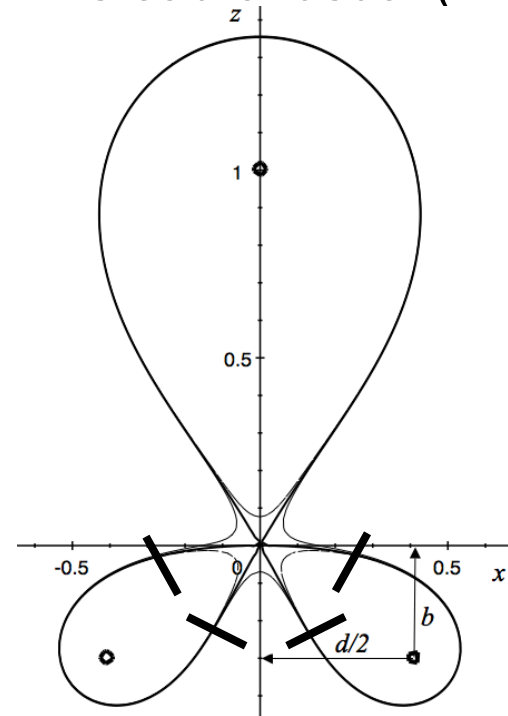
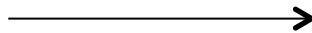
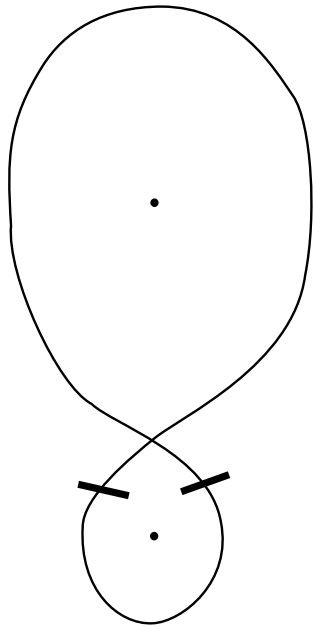
This work was performed for USDOE, at LLNL under contract DE-AC52-07NA27344, at CompX under sub-contract from LLNL, and at LBNL under contract DE-AC02-05CH11231

OUTLINE

- What and why of snowflake divertors
- Exact versus approximate snowflake divertors
- Objectives for modeling snowflakes with COGENT
- COGENT gridding strategy for conventional divertor tokamaks
- Strategy for extension to snowflakes: simple!
- First step: model and test local region about poloidal field null

Snowflake divertors: What and Why

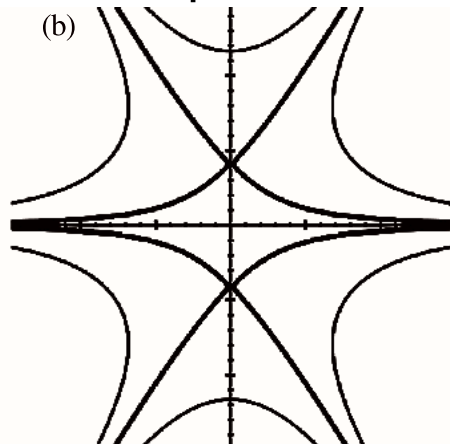
- What: Extra coil(s) to produce 2nd-order null instead of usual (1st-order) x point in SOL.



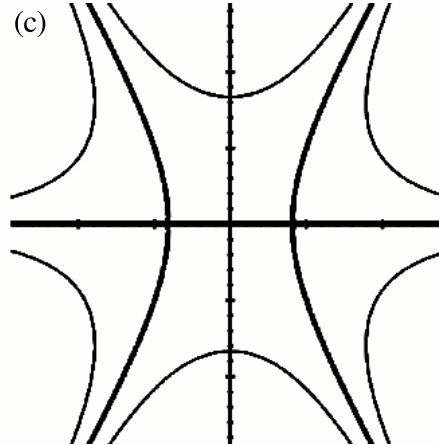
- Why:
 - Primary benefit, spreading of heat load via increased flux expansion.
 - Secondary benefits: further spreading among multiple divertor legs via MHD convection
 - Further isolation of main SOL and divertor legs RE instabilities (increased shear)
 - Other benefits, e.g. reduced peak heat load during ELMs

Exact versus approximate snowflake divertors

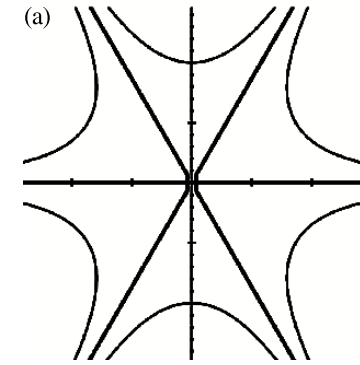
- Exact snowflake: perfect tuning of coils to achieve 2nd-order null
- Structurally unstable: if one of the coils has current a bit too high or low, the 2nd-order null splits into 2 nearby 1st-order nulls
- Snowflake plus:



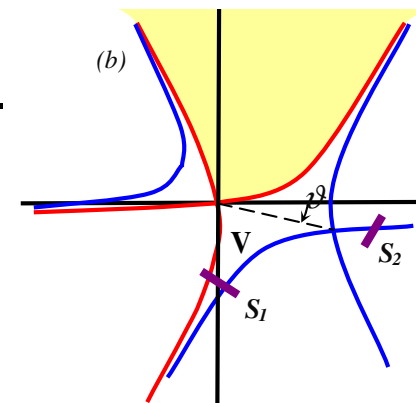
Snowflake minus:



- Above examples are symmetric approximate snowflakes. They needn't be. e.g.:



- If the 1st-order nulls are close enough, macroscopic behavior mostly indistinguishable from exact snowflake.

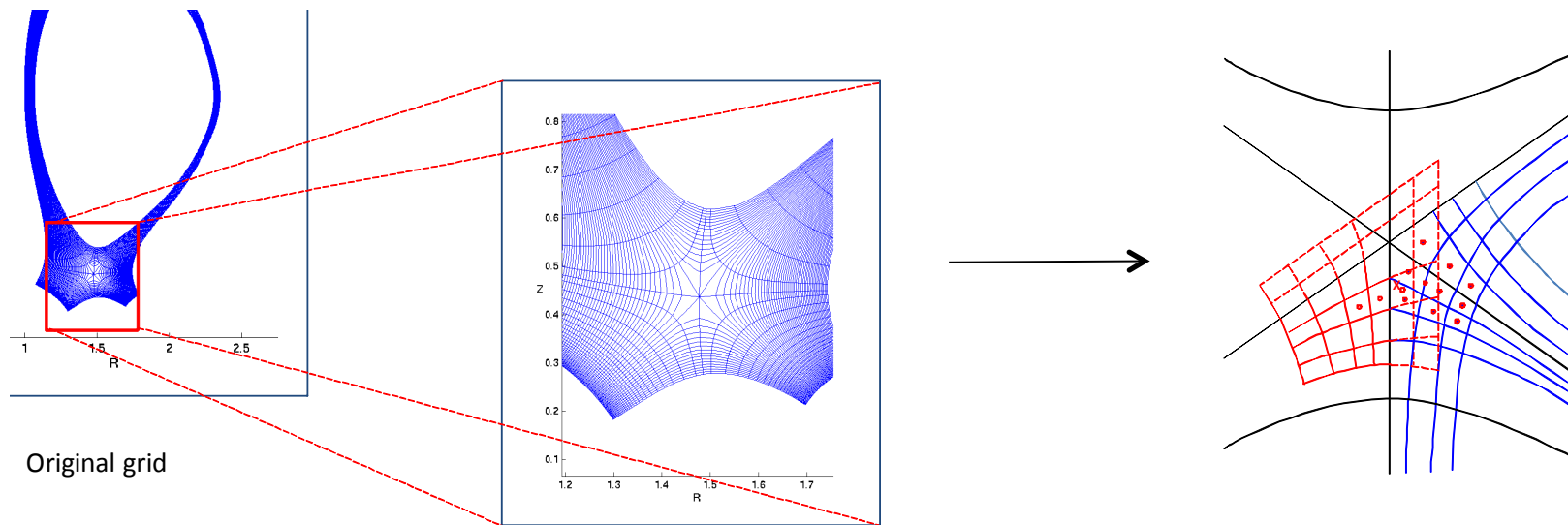


Objectives for modeling snowflakes with COGENT

- Snowflake divertors are getting a lot of attention at DIII-D and elsewhere, need to model them.
- Initial objectives similar to those for conventional divertors:
 - Neoclassically driven flows and radial transport in presence of divertor losses
 - Distribution of collision-driven losses to divertor plates
- Have divertor geometry in the mix as COGENT capability is expanded (e.g. to include 5-D physics)

COGENT gridding strategy for conventional divertors: abandon field-line following near x point

- When the divertor version of COGENT was first developed it was noted that the nominally 4th-order discretization was yielding results for advection converging more slowly than $(\Delta x)^4$
 - Explanation: curvature, metrics becoming singular as x point is approached.
- Solution: Gridding that follows flux surfaces away from x point but departs so as to preserve smoothness near x point
 - Flows near x point not flux-surface-following anyway
 - Use 4th-order interpolation to fill ghost cells



Strategy for extension to snowflakes: simple!

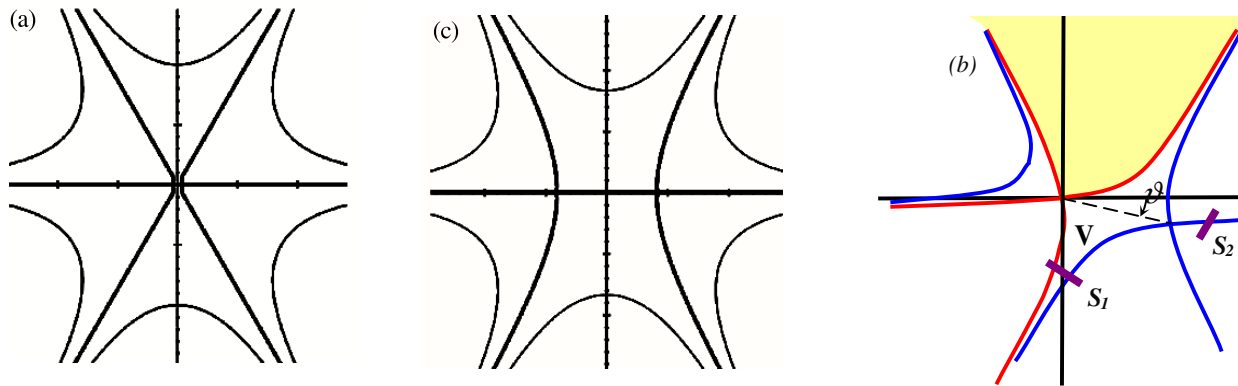
- Implication of extrapolated grid strategy for snowflake divertor: Since field-line following is abandoned anyway, a single grid structure generated for an exact snowflake divertor geometry is likely to work for nearby approximate snowflakes

First step: model local region about poloidal field null

- Ryutov et al PPCF '08: cubic expansion of flux surface about null.
 - Neglecting current near null, have flux function
$$\Phi = l_1x + l_2z - q_3x^2 + 2q_2xz + q_3z^2 + c_1x^3 - 3c_4x^2z - 3c_1xz^2 + c_4z^3$$
 - And fields
 - $(R + x)B_x = l_2 + 2q_2x + 2q_3z - 3c_4(x^2 - z^2) - 6c_1xz,$
 - $(R + x)B_z = l_1 - 2q_3x + 2q_2z + 3c_1(x^2 - z^2) - 6c_4xz.$
- With suitable choices of coefficients, can make exact snowflake and approximate snowflakes
- Strategy:
 - Starting from exact snowflake coefficients, generate extrapolated grid as discussed above
 - Do runs with **B** on this grid evaluated for exact and approximate snowflakes, compare physics results (next slide)

REMARKS

- Will use grid generator developed by P. Schwartz, which does least-squares optimization of grid smoothness and field line following with weights that vary with field-line curvature
- Initial testing with pure advection (no collisions): Initiate (half) Maxwellian in main SOL; predictable difference of fluxes on various divertor plates depending on type of approximate snowflake



- Subsequent studies: add collisions (neoclassical); add model of MHD convective mixing near null; full SOL. Compare with analytic models that may be available, and with experiments