What's possible with CHI on NSTX?

Xianzhu Tang
Los Alamos National Laboratory

and

Allen H Boozer
Columbia University

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Two scenarios

- Sustained CHI current drive.
  - Axisymmetric open field equilibrium
    Ref. Tang and Boozer, PoP, 2003.
  - Threshold for 3D instability – normalized voltage.
    Ref. Tang and Boozer, PoP, 2004a.
  - Instability cascade for relaxation
    Ref. Tang and Boozer, PoP, 2004b.

- Transient CHI for startup (Tang, Boozer, Raman, APS/DPP'02)
  - Pinching off axisymmetric plasmoid. (Tang'02,forum)
  - Pinching off saturated 3D plasma. (Tang'03,forum)

- What has been done experimentally
  - used to be long pulse sustained discharge
  - current focus on pinching off axisymmetric plasmoid.

Physics of sustained CHI

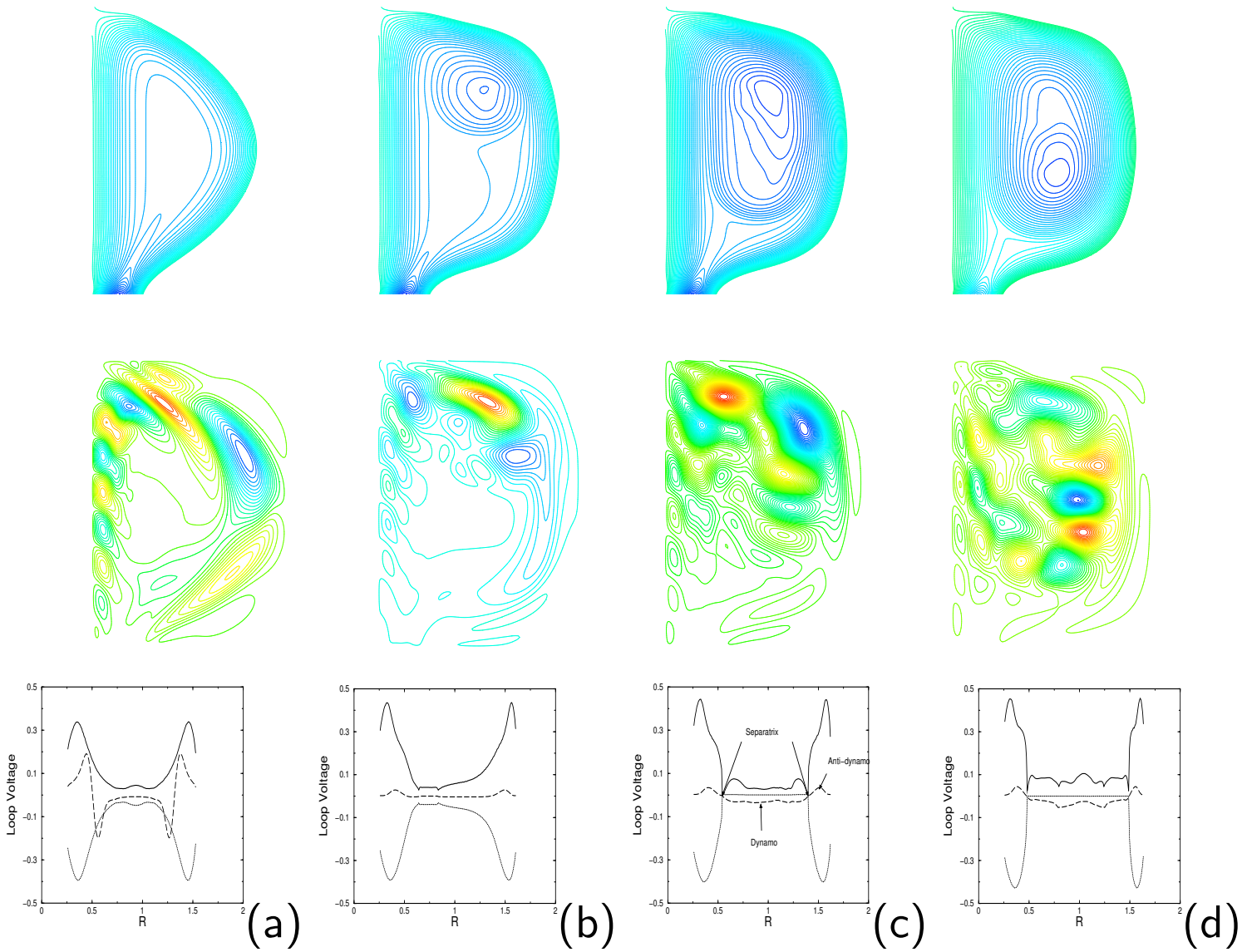
- Initial open field equilibrium (Tang and Boozer, PoP, 2003)
  - First principle: parallel Ohm's law closes Grad-Shafranov equation.
  - Grad-Shafranov flow inherent (for driving j_φ).
  - Valid in the limit of $\rho \to 0$.
  - Determination of Grad-Shafranov potential.

- Onset of current driven instability (Tang and Boozer, PoP, 2004a)
  - parallel current gradient is the drive.
  - critical dimensionless parameter

$$\hat{\mathcal{V}} \equiv \mu_0 \mathcal{V}/(\eta B_0 q_0).$$

    $\hat{\mathcal{V}} > 1$ unstable.
  - m is smaller than but comparable to q_0

- Dynamical relaxation via 3D *instability cascade* (Tang and Boozer, PoP, 2004b)
  - Mean field evolution for CHI given.
  - $\nabla\Phi$ provides effective loop voltage only on open flux.
  - open flux kinks $\rightarrow$ anti-dynamo on home flux surface but dynamo loop voltage on interior closed flux.
  - secondary closed flux modes excited $\rightarrow$ further inward penetration of dynamo loop voltage.
  - Room for incorporating additional physics for core relaxation.


Loop Voltage
R
Separatrix
Anti–dynamo
Dynamo
(a)
(b)
(c)
(d)

Physics of Transient CHI

- Why transient?
  - long pulse CHI has questionable flux surface quality (confinement). (2001-2)
  - axiysmmetric reconnection (pinch-off) $\rightarrow$ axisymmetric plasmoids. (Tang, Boozer, Raman, APS/DPP'02)
  - good startup poloidal flux for hand-off.
  - HIT-II success on transient CHI-OH coupling (Raman, PRL, 03, PoP, 04).

- Two ways to do it.
  - fast rise and fast clamp. (initial motivation, current XP).
  - fast clamp (or free decay) of a saturated CHI plasma works better. (Tang, APS/DPP'03)
  - edge cooling might help the decaying process to axisymmetry (Sovinec, APS/DPP'03)

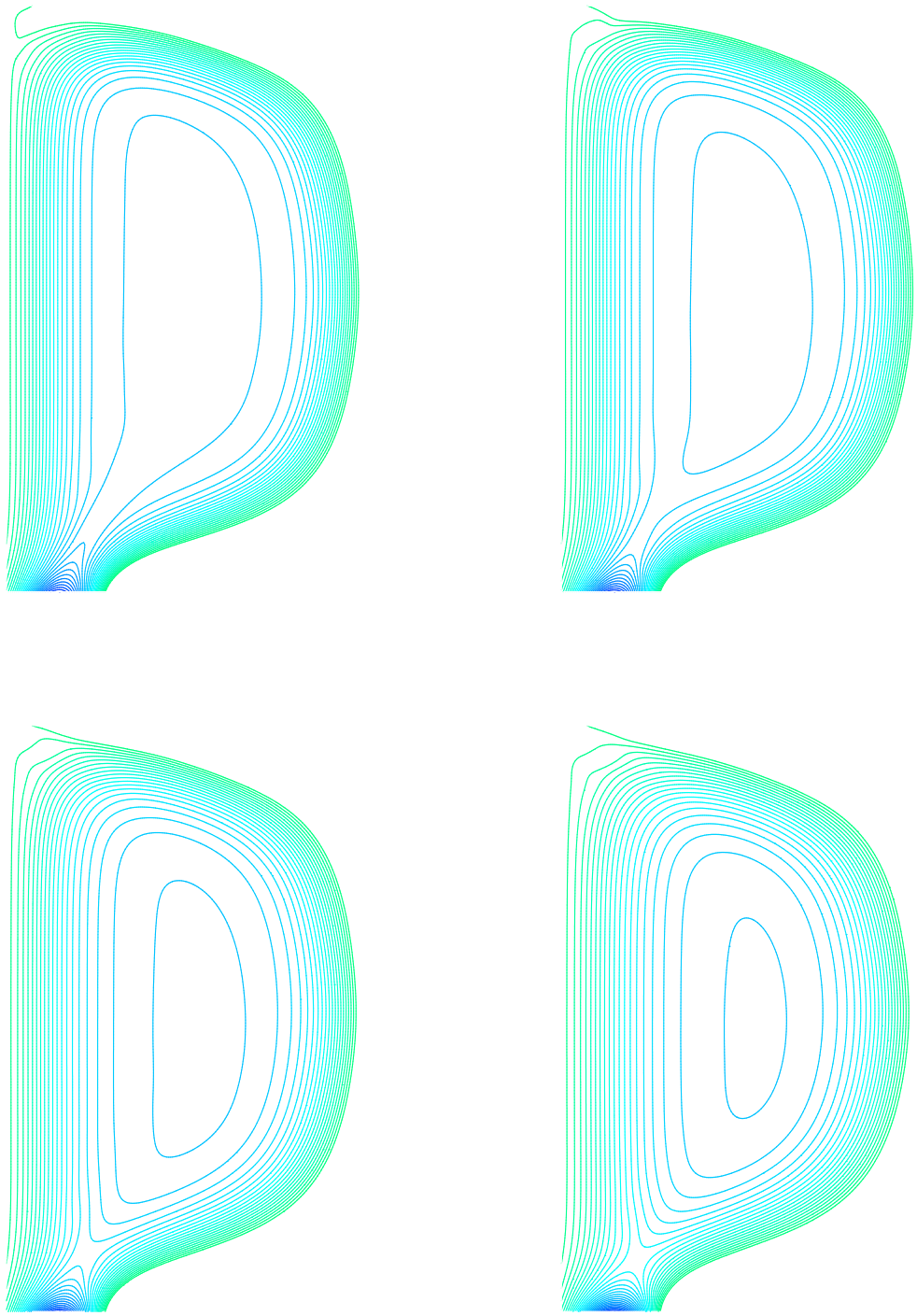


Figure 1: Axisymmetric ramp down: poloidal Flux χ over time. (forced 2D reconnection by voltage modulation)

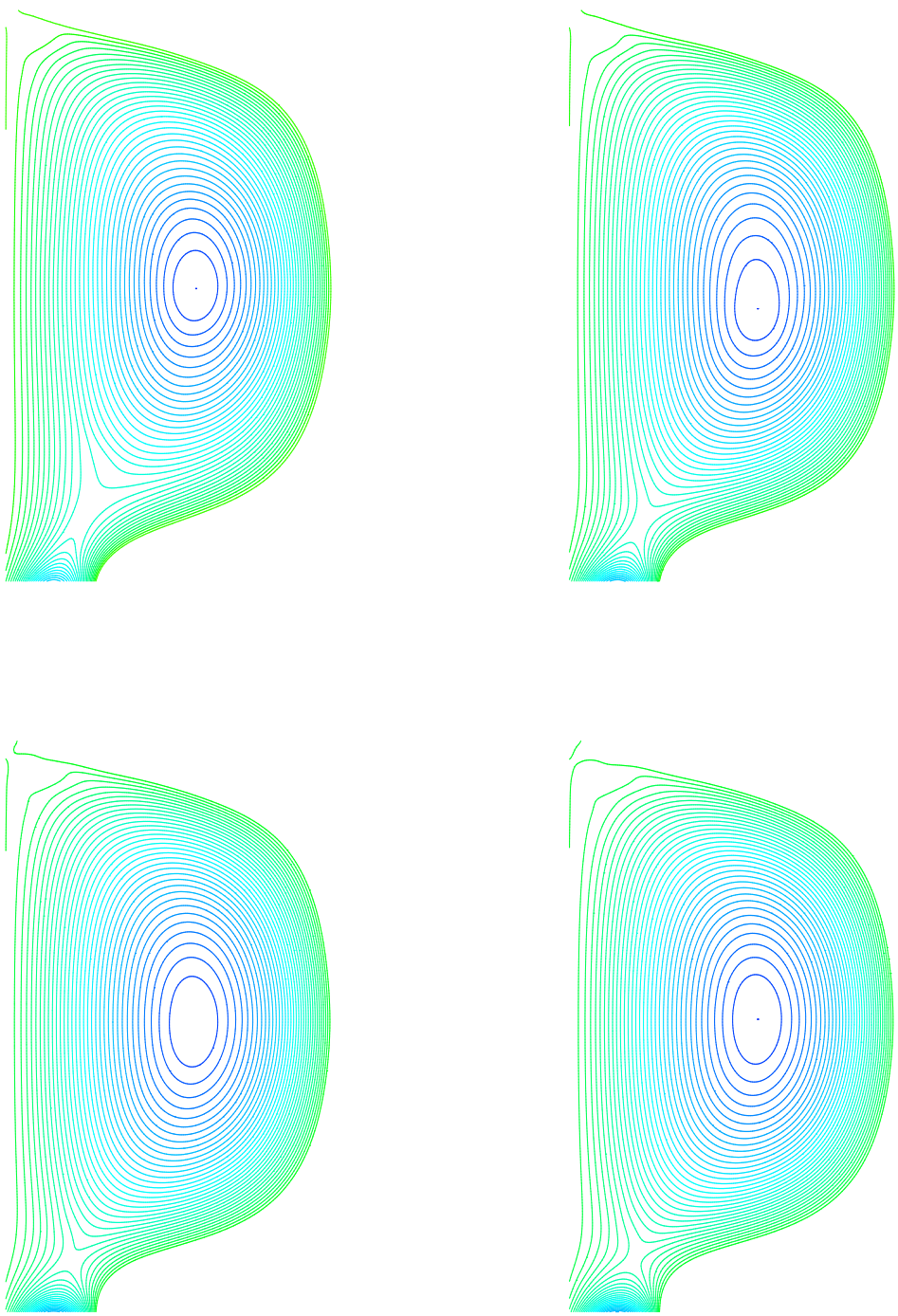


Figure 2: Ramp down of the nonlinearly saturated state

Bottom Lines

- Transient CHI works for startup. XP is sound.
- Relaxation physics is well estabilshed. More physics useful to assess transport and dynamo mechanisms.
- Relaxed CHI obtains more poloidal flux, quality usually not good enough.
- Unlike spheromak, the eventual poloidal flux comparable to injector flux for NSTX CHI. (New theory work from Tang and Boozer, 2004)