Interpretation of Edge Turbulence Images Near the X-Point of C-Mod

S.J. Zweben, J.L. Terry, B. LaBombard, M. Greenwald,
O. Grulke, R.H. Cohen, D.D. Ryutov, M. Umansky,
J. Krommes, T. Stoltzfus-Dueck, D.P. Stotler

PPPL, MIT, Greifswald, LLNL

- Understand observed turbulence with theoretical models
- Eventually use models to predict / design SOL transport

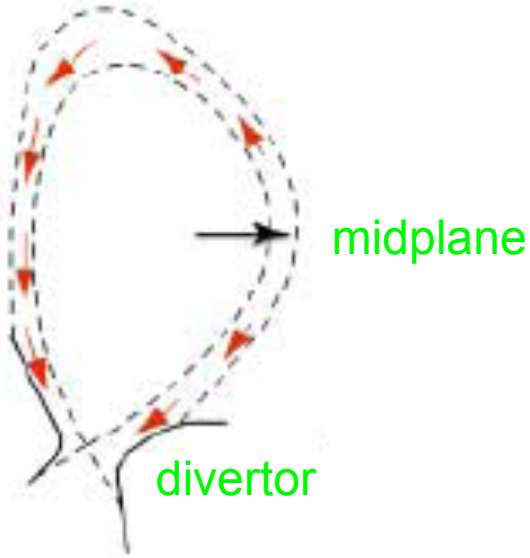
APS DPP 2007

Alcator C-Mod

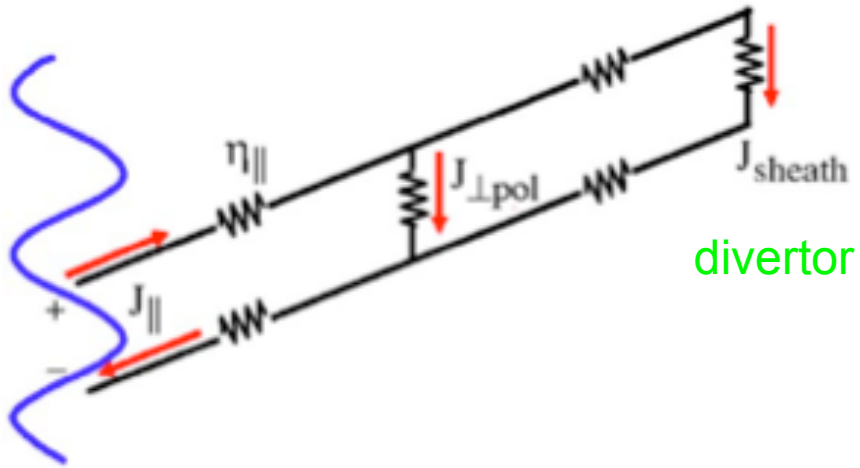
Simple Model of SOL Turbulence

- Particle flux driven out at midplane, flows along B to divertor
- Charge separation drives currents along and across B field

particle flow



current flow



Myra et al, PoP '05

Parallel Propagation Timescales

- How long does it take fluctuations to propagate along the B field from the outer midplane to the X-point region ?
  ($n \sim 5 \times 10^{13}$ cm^{-3}, $T_e \sim 20$ eV => $L_{||} / \lambda_{ei} \sim 10$ SOL)

density: $v_i \sim c_s$ => $t_{||,i} \sim 100$ μsec

potential: $D_\varphi \sim v_e^2 \tau_e (k_\perp \rho_s)^{-2}$ => $t_{||,\varphi} \sim 0.1$ μsec

=> Potential fluctuations near X-point are quickly coupled to potential fluctuations at the midplane along B

Resulting electric field fluctuations near the X-point will cause local density fluctuations in that region

Comparisons of Model with Data

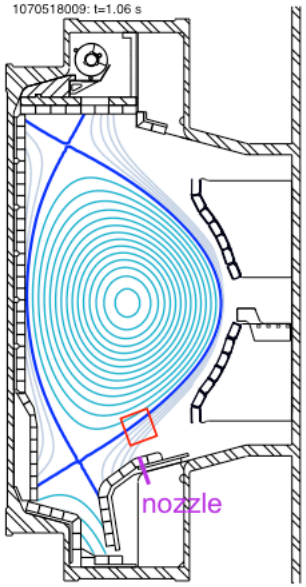
- Timescale: X-region turbulence timescales should be similar to midplane turbulence timescales (in the same shot)

- Structure: X-region turbulence structure should follow outer midplane structure mapped along magnetic flux tubes

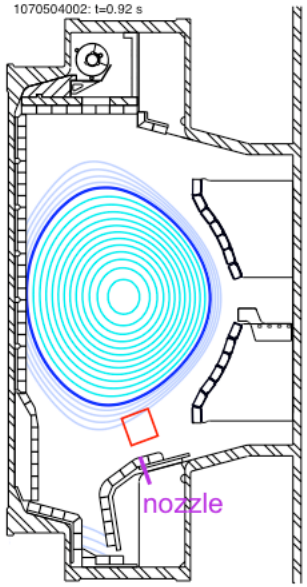
- Velocity: X-region turbulence velocity should follow outer midplane velocity but mapped along flux tubes

see: Ryutov, Phys. Plasmas (2006); Ryutov and Cohen Cont. Plasma Phys (2008)

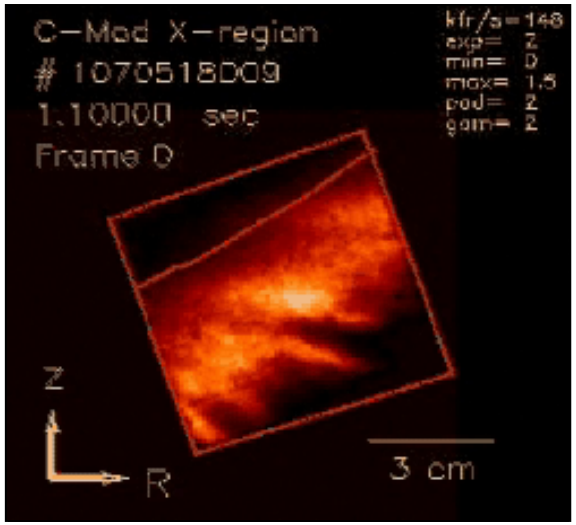
Double Null vs. Limited Cases

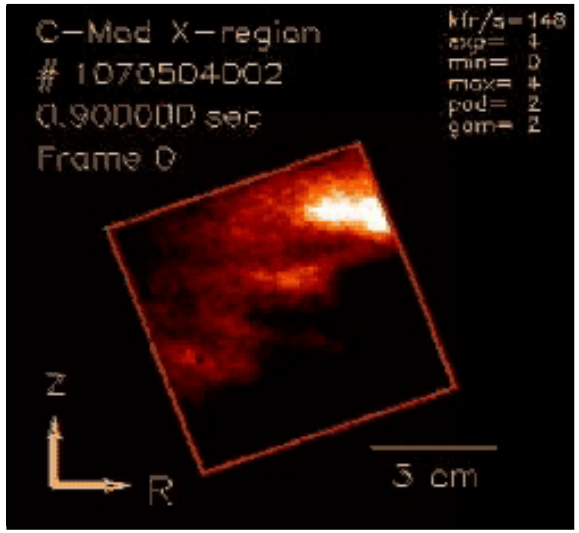


DN
0.8 MA
5.6 T
Ohmic
(#1070518009)

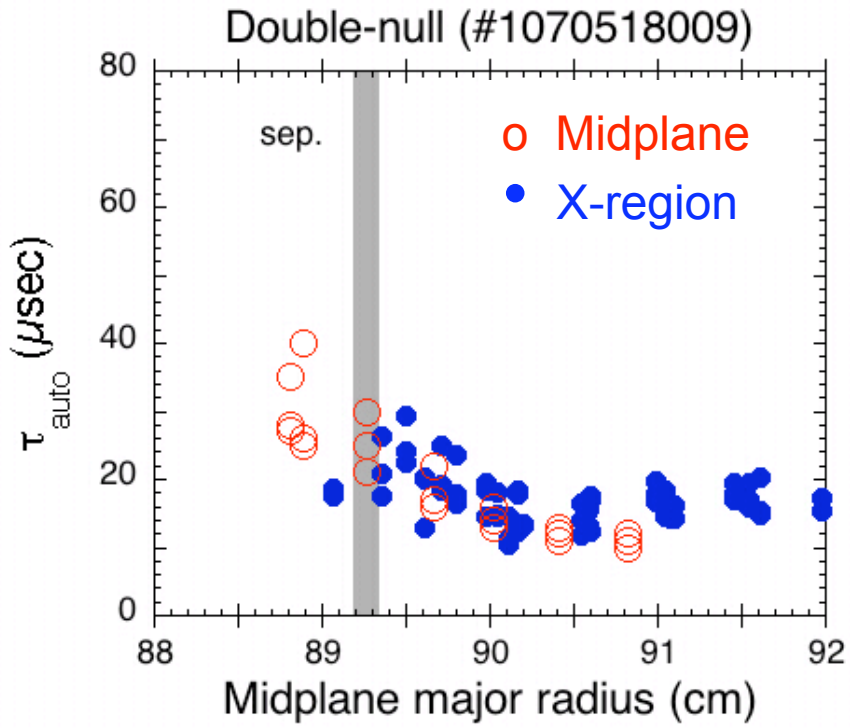


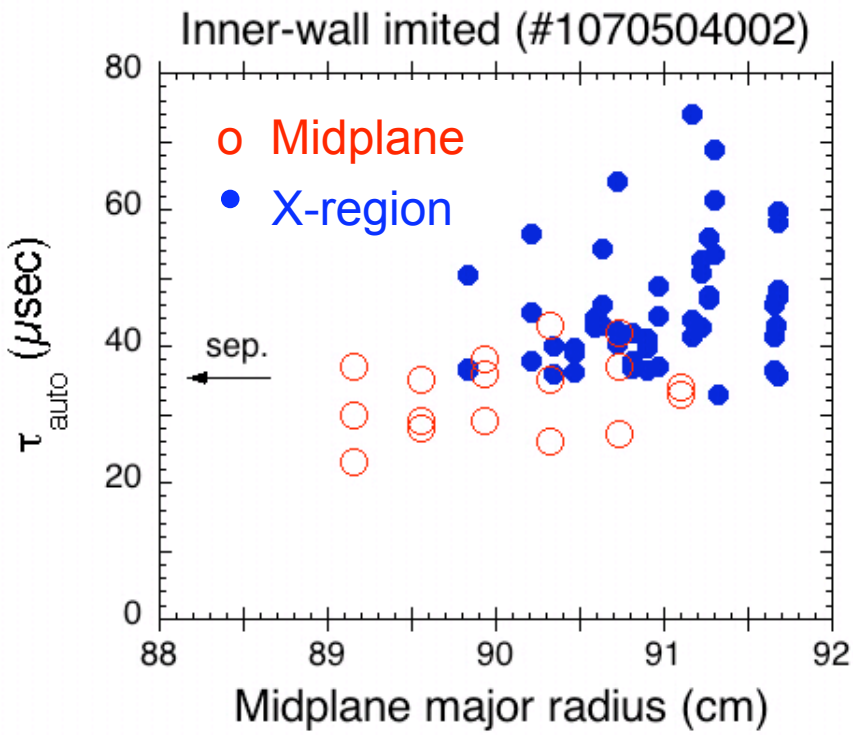
Limited
0.8 MA
5.4 T
Ohmic
(#1070504002)





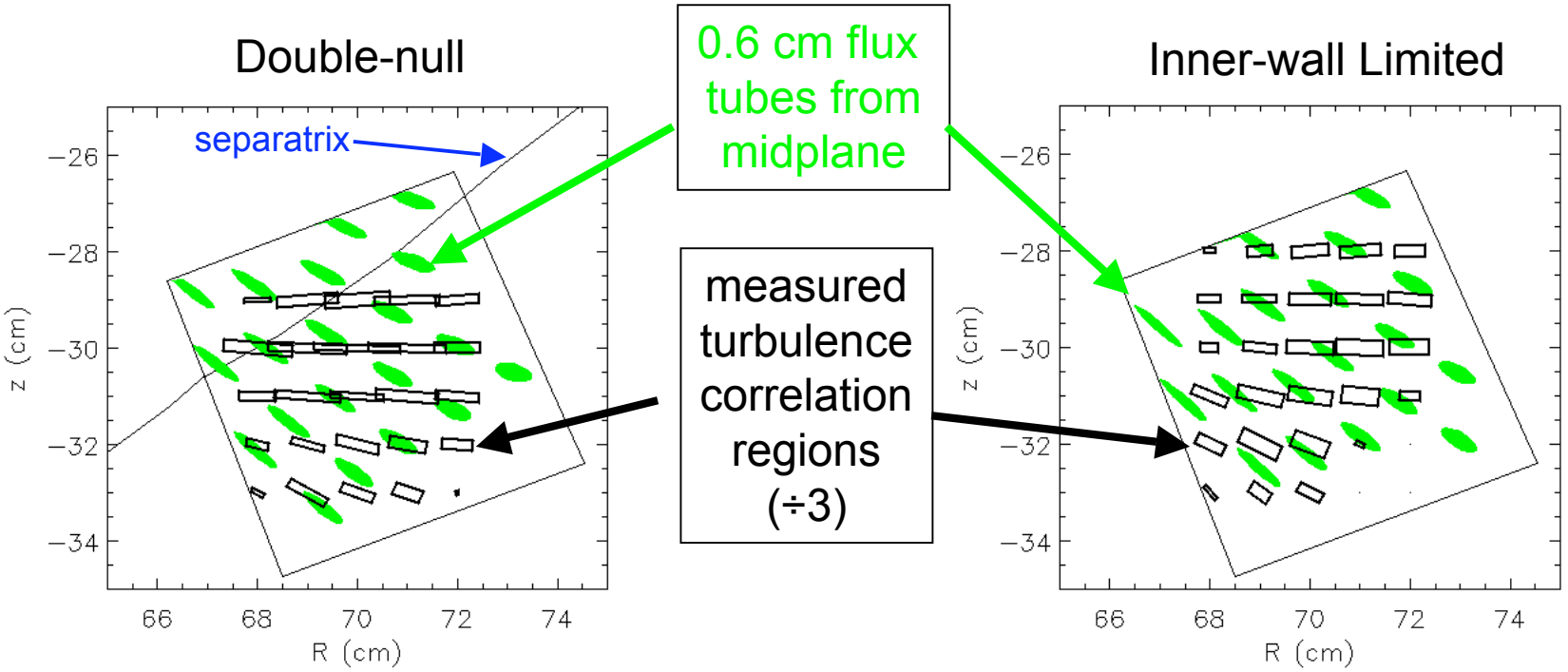
Autocorrelation Time Comparison





- Turbulence timescales similar near midplane and X-region
- Also significant cross-correlation seen (Grulke PoP '06)

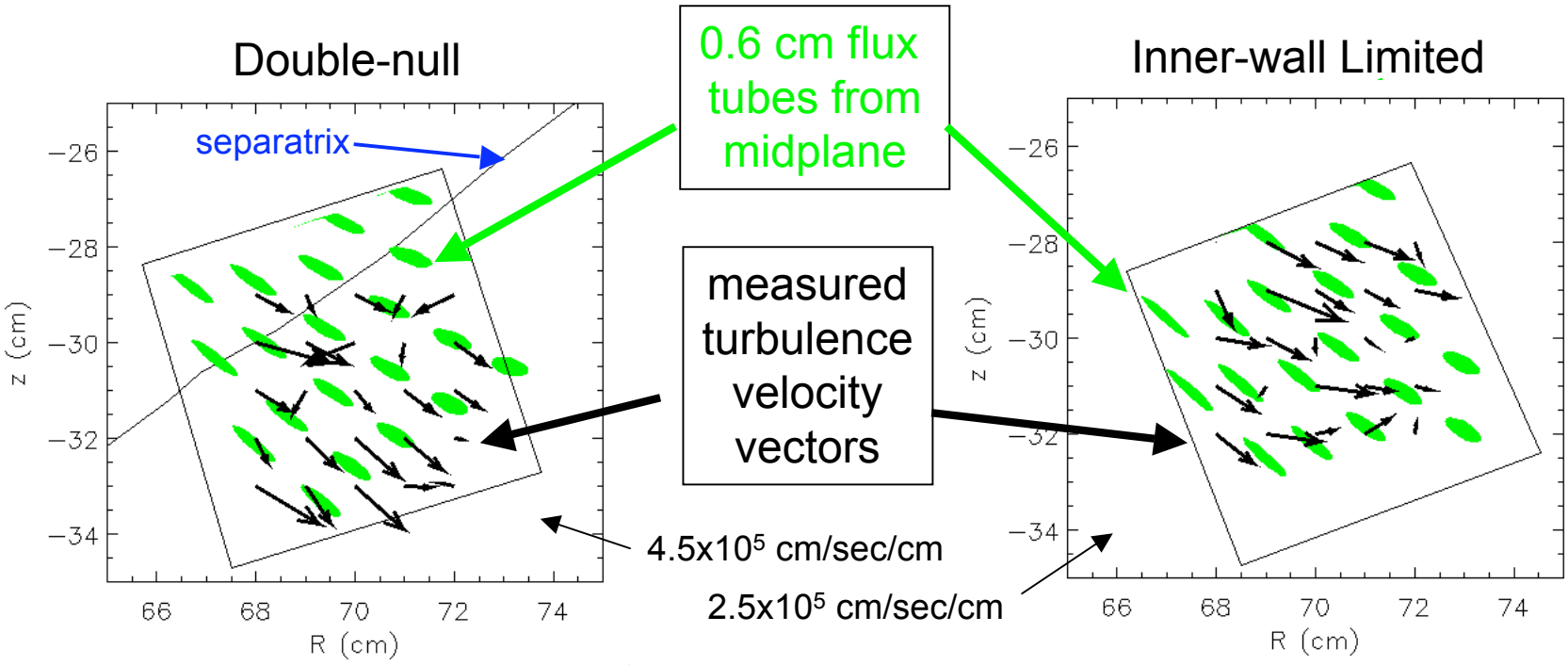
Spatial Structure Comparison



- X-region structures are elongated about as expected for the limited case, but more than expected for the DN case

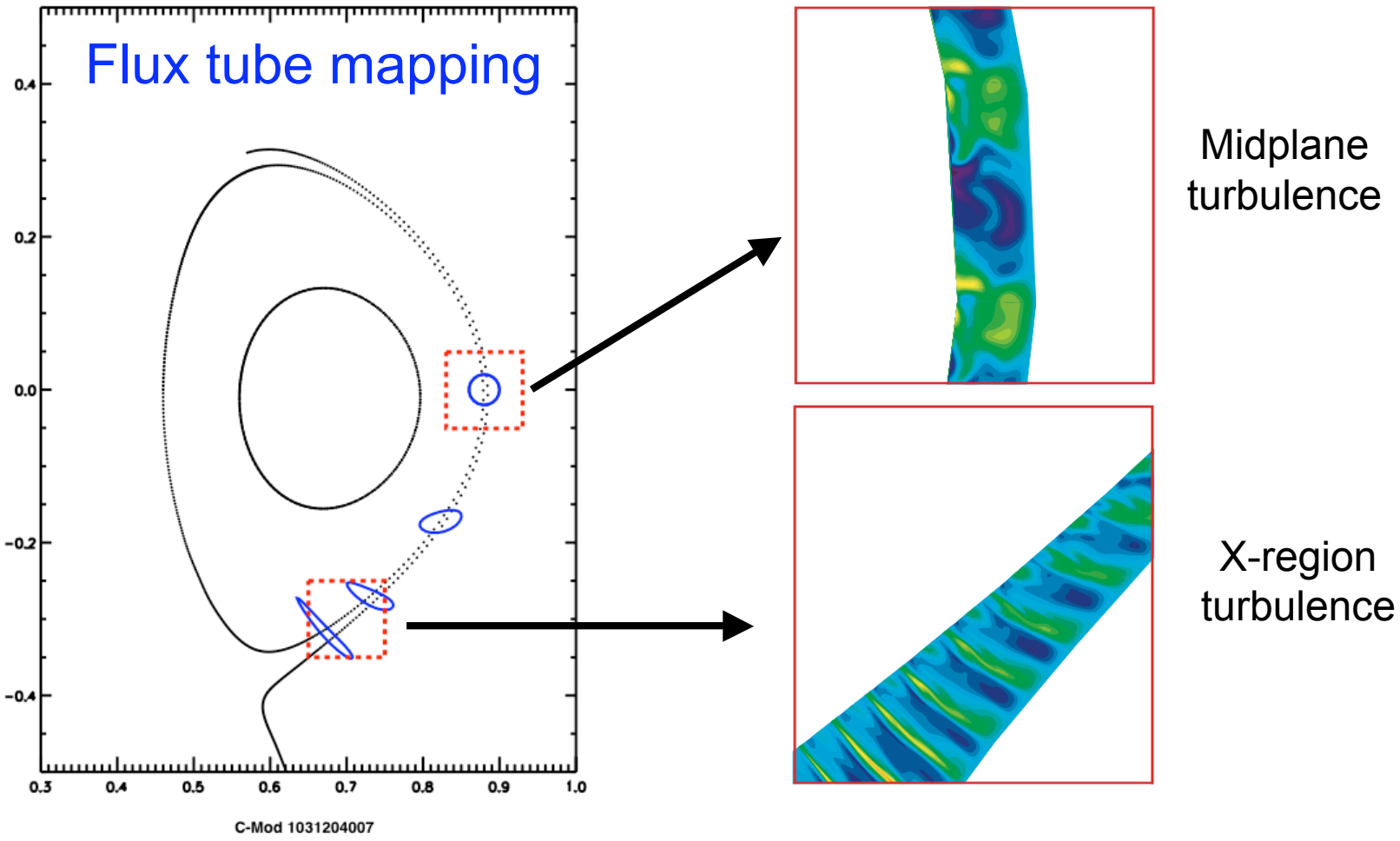
- Angle in (R,z) plane more horizontal than expected for both cases (i.e. not due to presence of X-point)

Turbulence Velocity Comparison



- Velocity largely outward across flux surfaces, as expected
- Velocity ~3 x larger than at midplane, roughly as expected

BOUT Results for a LSN Case



- BOUT shows radial fingers of turbulence near X-point, roughly consistent with flux tube mapping

Summary

- X-region turbulence timescales and velocities are roughly consistent with simple flux tube mapping model

- Correlation lengths and directions are partially consistent with simple flux tube mapping model

- Inconsistency may be due to finite size of GPI gas cloud, or possibly may be some new physics