Plasma blobs in a basic toroidal experiment: Origin, dynamics and induced transport

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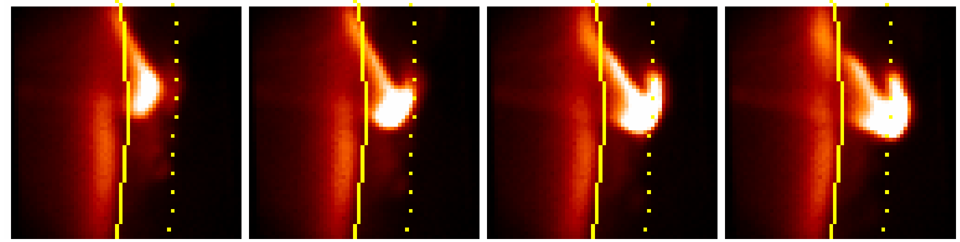
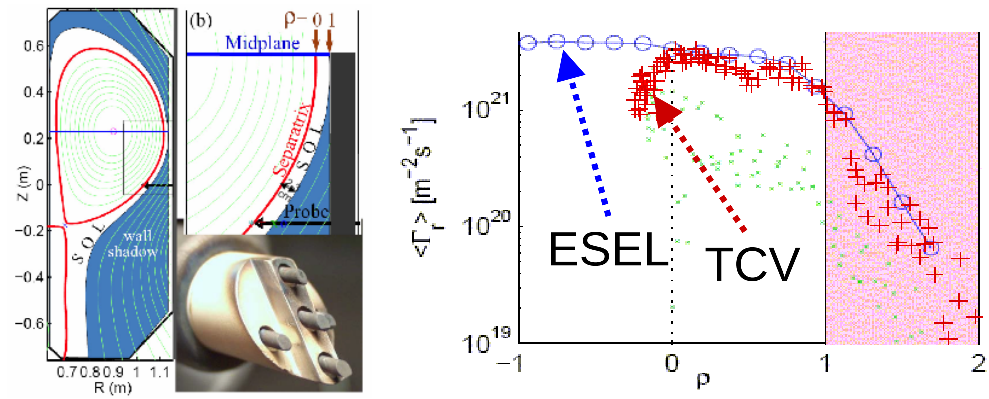
Motivation

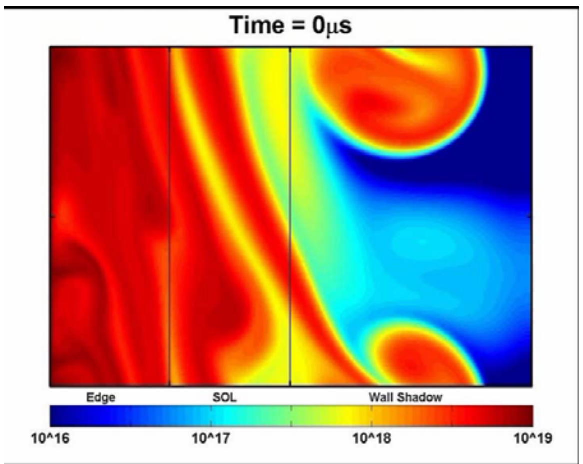
- Blobs: *"Intermittently encountered, isolated propagating structures of increased plasma density"*
  - Large bursty events dominate SOL particle transport
  - Localized wall loads may become critical for ITER
- Idea: setup relevant test scenarios in basic experiments
  - Configuration in TORPEX with core-SOL-like transition
  - Exploit better diagnostics

NSTX gas-puff imaging (Courtesy R. Maqueda)



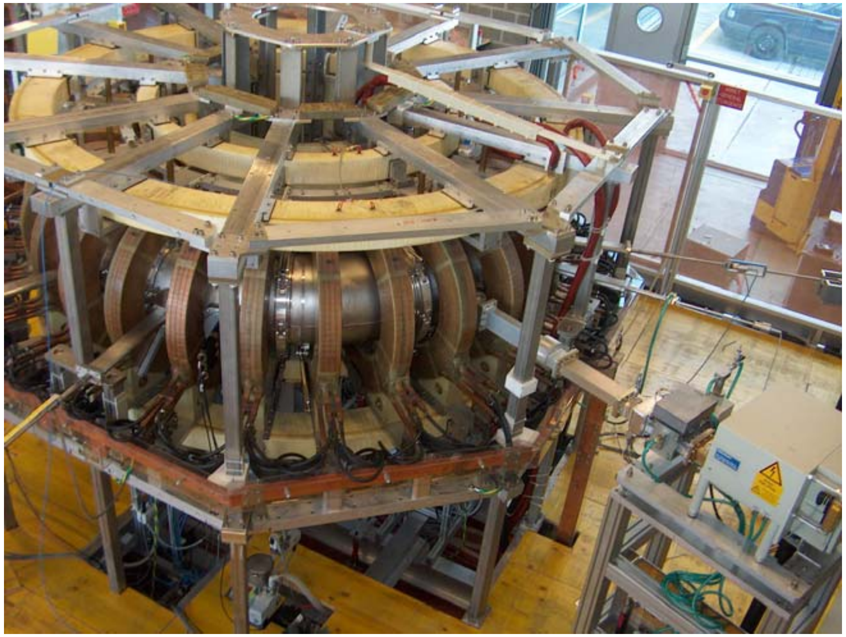
TCV Langmuir probe (Courtesy J. Horacek)

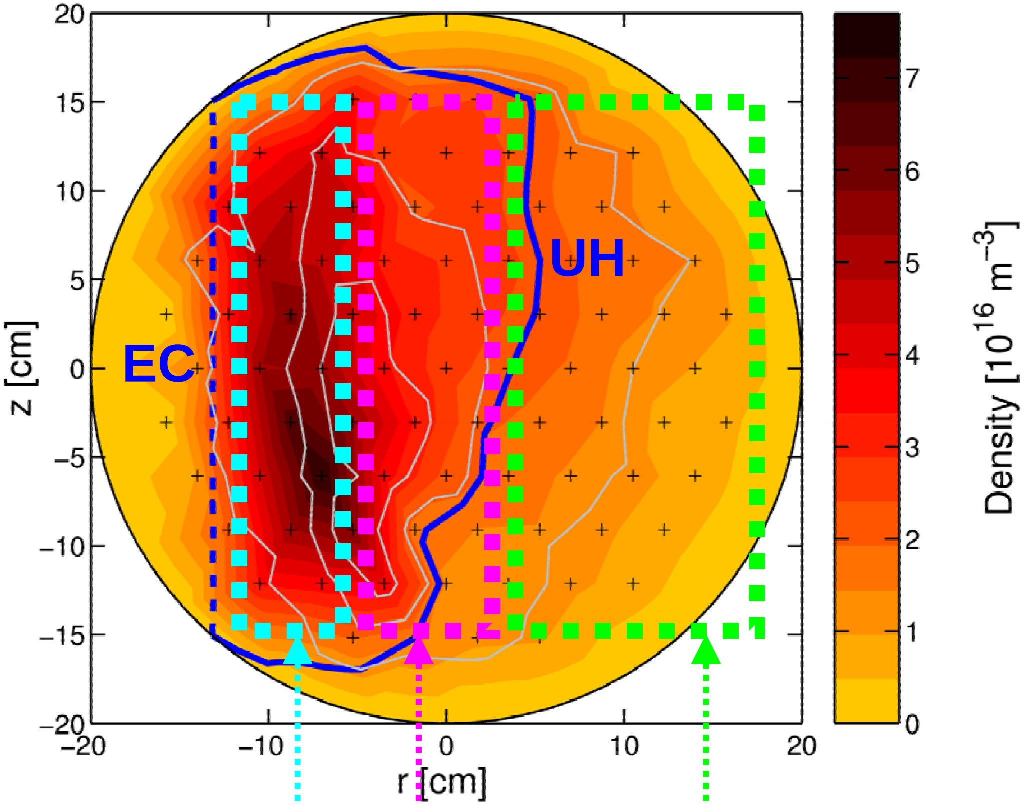




Fluid simulations (ESEL; V. Naulin): Quantitative agreement with LP measurements

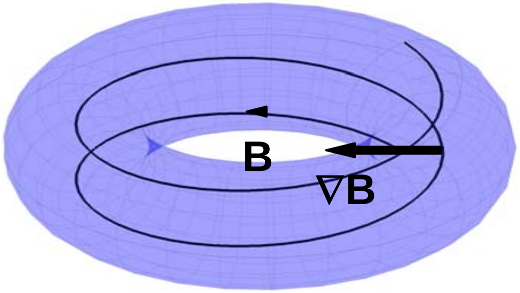
TORPEX – Core-SOL-like configuration





- R = 1 m
- rf waves
- B ~ 0.1 T
- n ~ 10^{17} m^{-3}
- T_e ~ 5-8 eV
- ρ_s ~ 1-15 mm

Magnetic-field topology *different* from tokamak

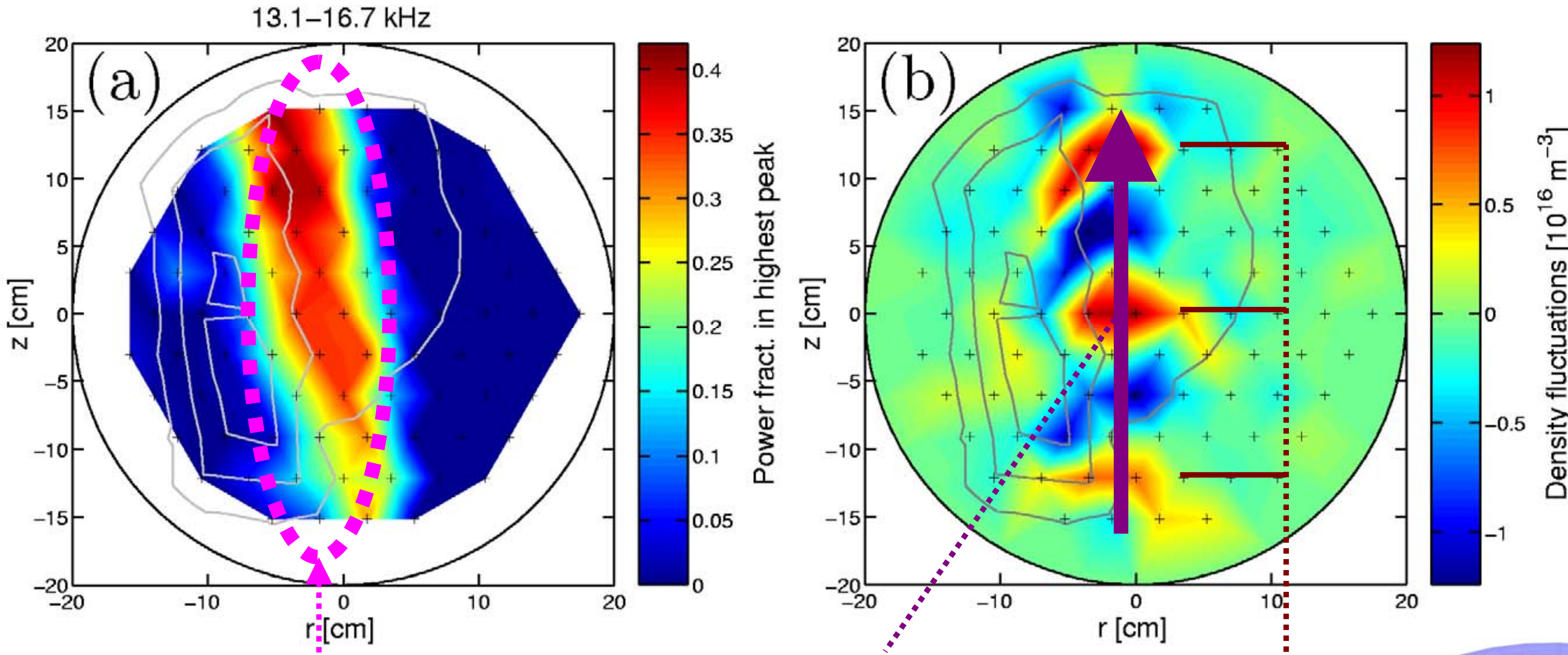


Core-like region (slab-like)

Transition region

SOL-like region (source free)

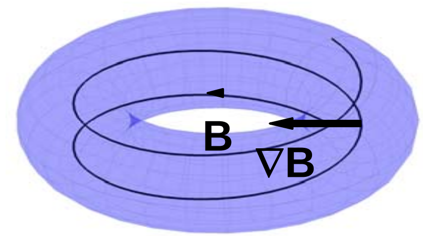
A Drift-Interchange (D-I) wave propagates vertically upward along outboard profile slope



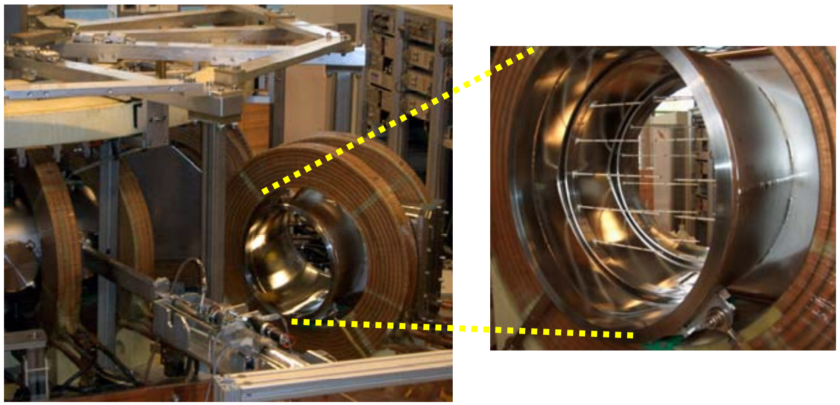
40% of spectral power @ ~15 kHz

~1500 m/s

$k_{||} \sim 0$



- Diagnostic: 2D Langmuir probe array
  - 86 tips (here: I_{sat})
  - 4 μs resolution

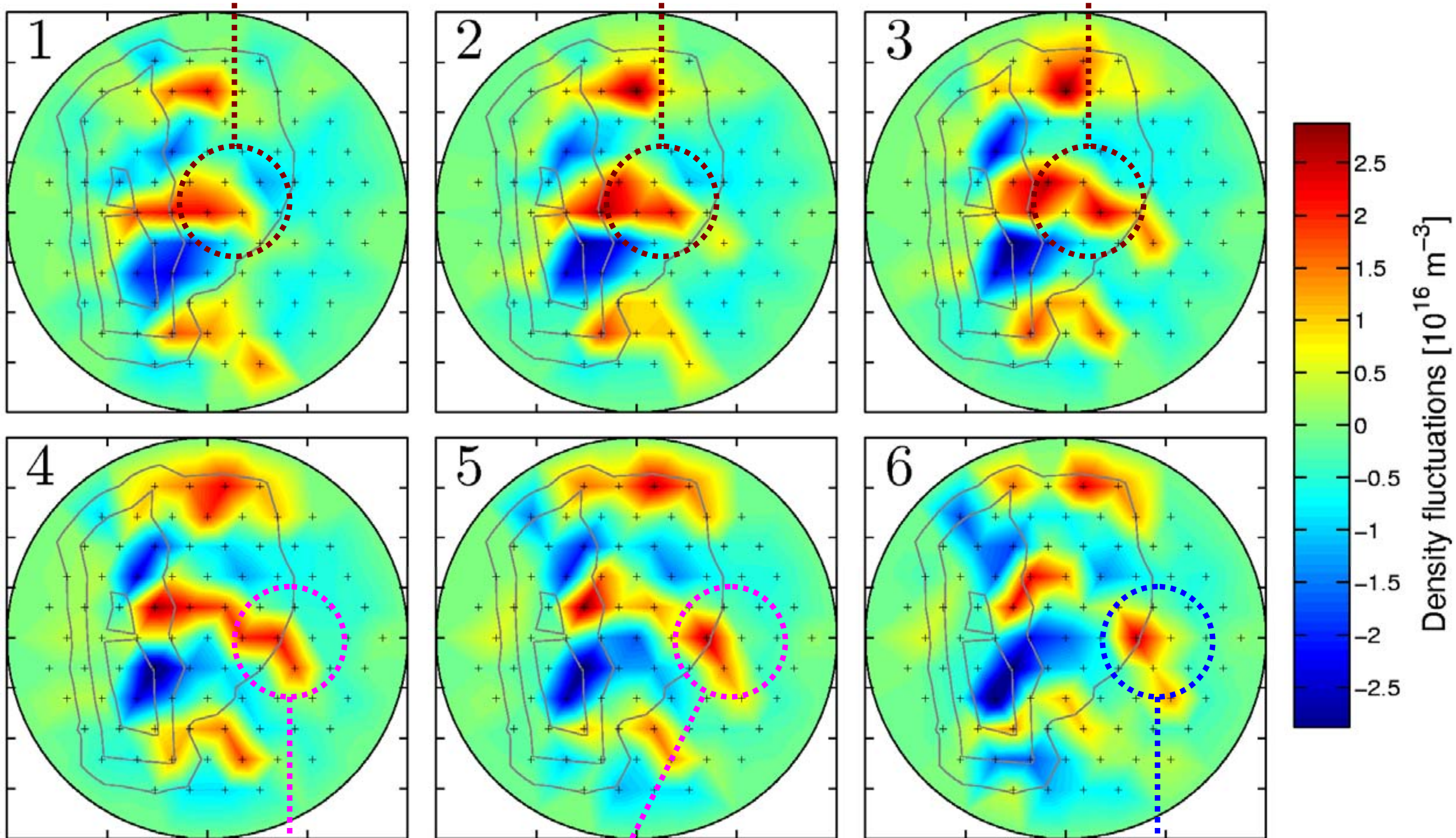


CRPP

Blob ejection from wave crests of D-I wave

Wave crests of D-I wave radially unstable and elongate

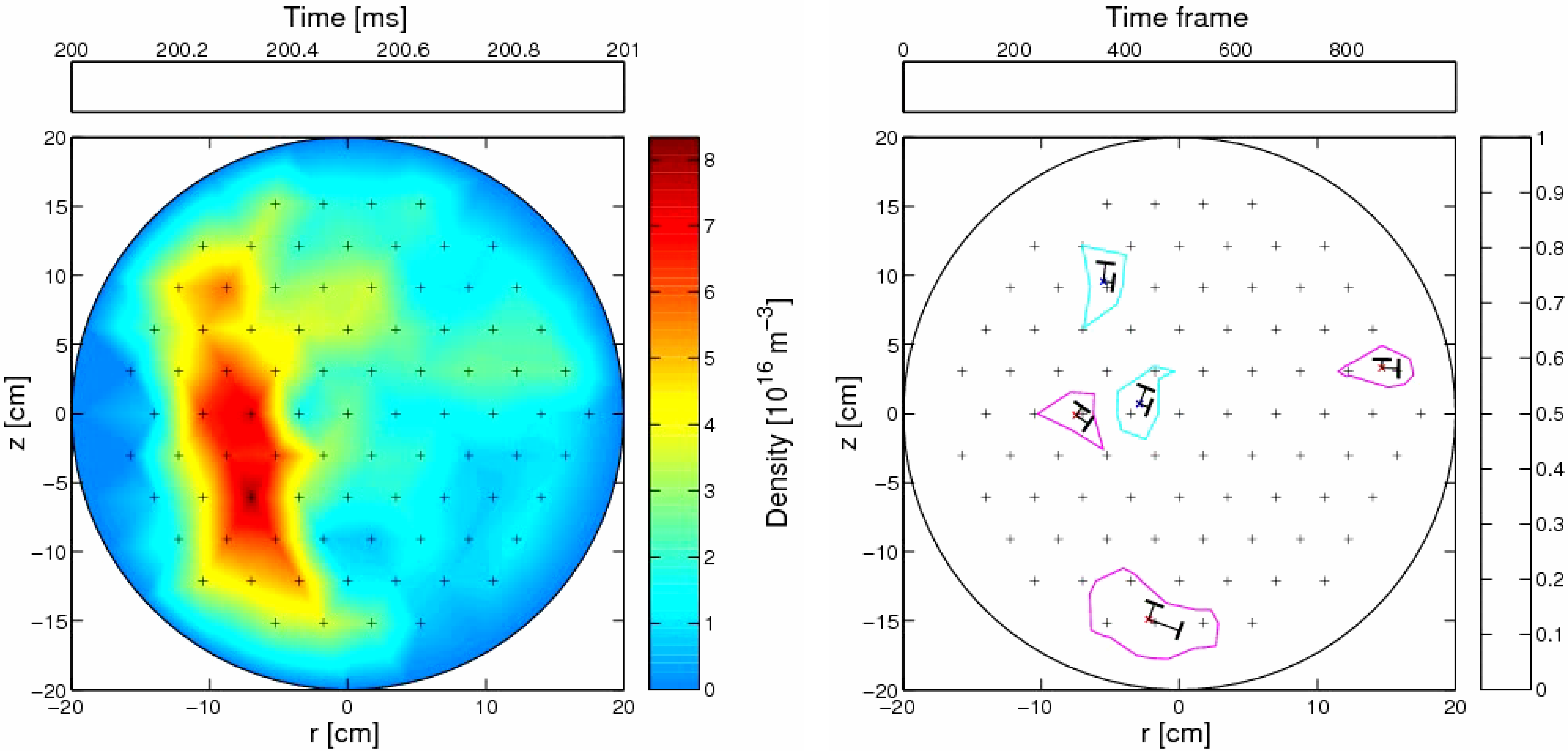
Resolution: 12 µs



Outer part lags behind and gets “sheared off”

A blob completely detaches and continues to propagate radially outward

Quantitative analysis of blob dynamics

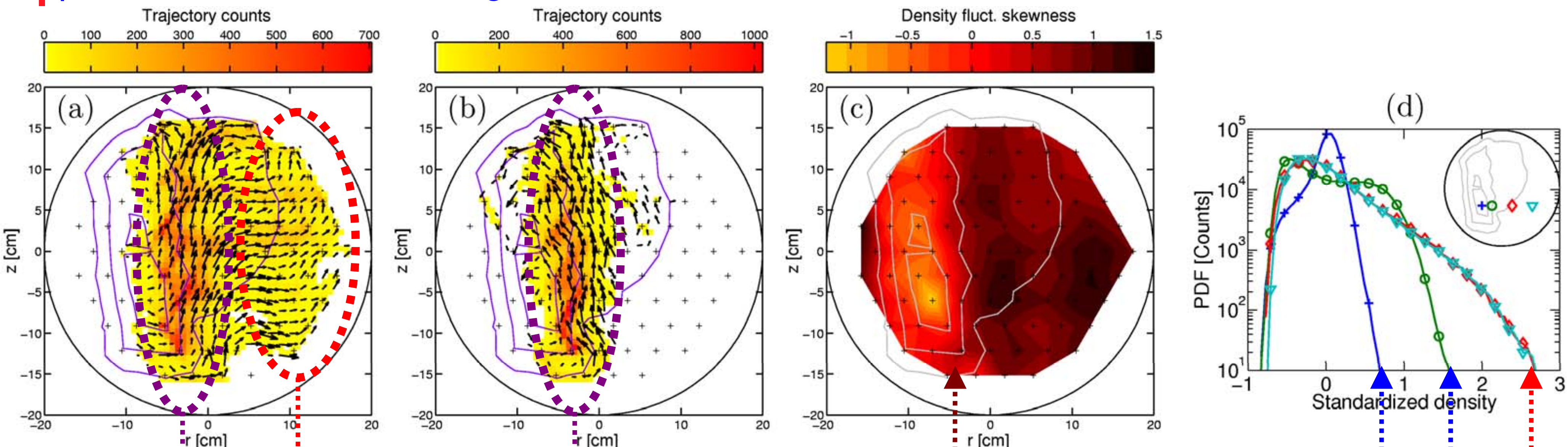


- Pattern-recognition approach: S. H. Muller *et al.*, PoP **13**, 100701 (2006)
  - Pos./neg. structures from threshold segmentation ($\delta n > \delta n_{th}$ / $\delta n < -\delta n_{th}$)
  - Trajectories from tracking criterion

Statistical analysis of trajectory database

- Spatial abundance of trajectories / average motion patterns
  - Blobs in many aspects similar to tokamak observations

positive structures negative structures



Radial propagation
$v_{r,blobs}$ = 1-2 km/s

Skewness gradient
from core to SOL

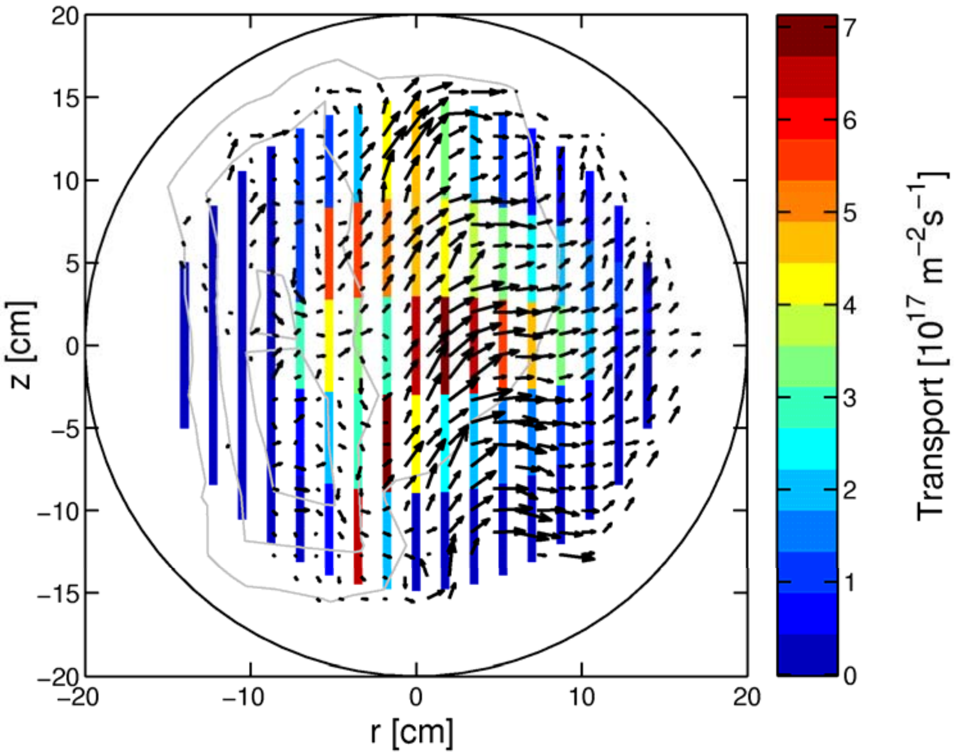
Wave region:
double-humped PDFs

Vertical propagation
(positive and negative wave crests)

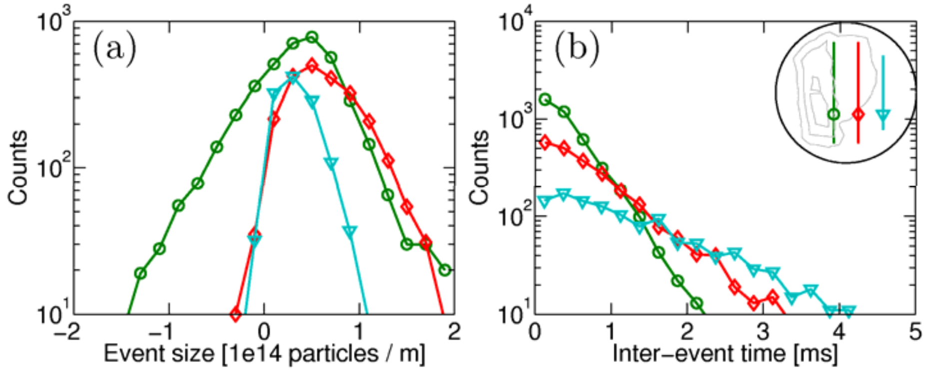
SOL region:
“Universal-type” PDFs

Blob-induced transport

- Instantaneous fluxes during events from ensemble average (arrows)
- Time-average transport by counting “transport events” through test surfaces



Statistics of transport events



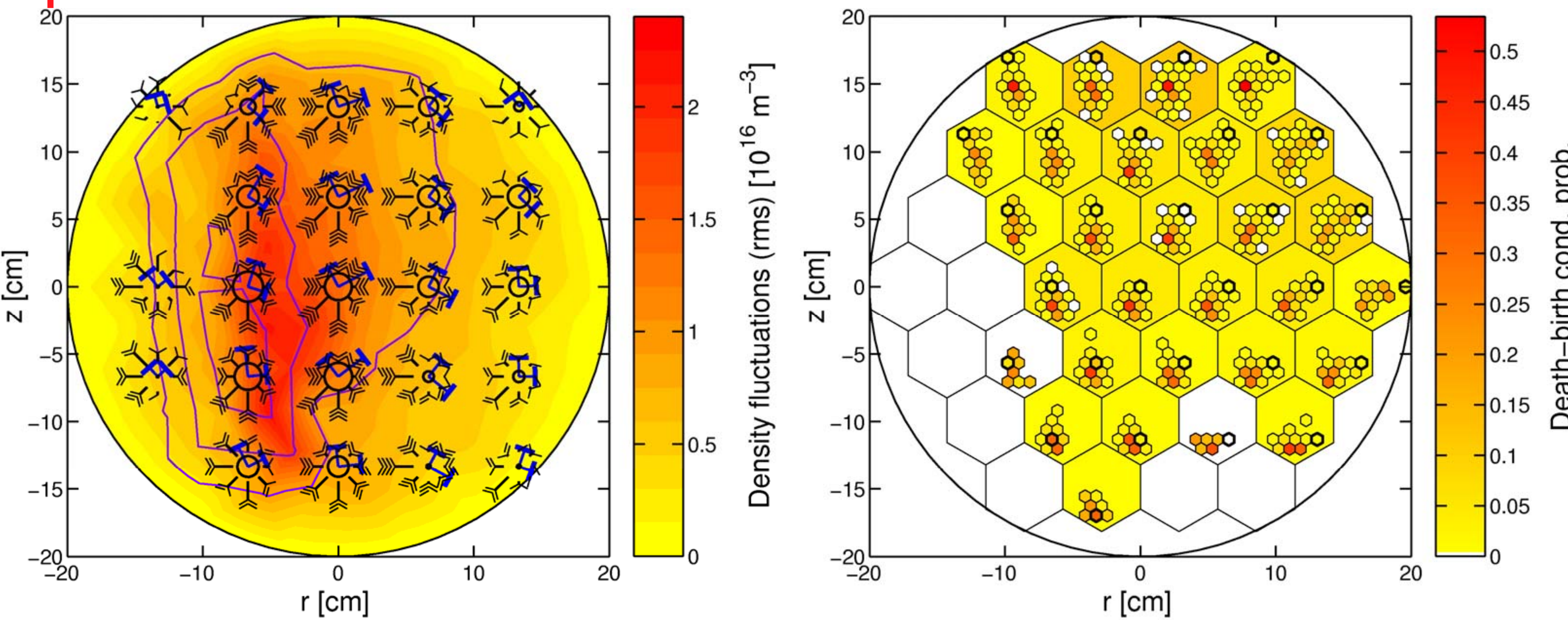
- Inter-event times distributed exponentially
  - Increasing time constants for increasing radial position
- Size of inst. fluxes: ~3 x 10^{19} m^{-2}s^{-1}
- Parallel losses: ~5 x 10^{18} m^{-2}s^{-1}

Conclusions

- Relevant scenario to test blob models in a basic toroidal experiment identified
  - Blobs are observed with ***very similar properties*** to tokamak observations
  - Magnetic-topology change seems ***not essential*** for blob formation
- Origin of blobs in TORPEX
  - Blobs are sheared-off from elongated wave-crests of a Drift-Interchange wave (Mechanisms? $\rightarrow$ *Ivo Furno, next talk*)
- Transport properties
  - Fluxes during events ***10 x larger*** than steady-state parallel losses
  - Time-average effect ***10 x smaller*** than steady-state parallel losses

- **Outlook**: use data from tokamak SOLs, basic toroidal devices and linear devices ***together*** to validate SOL simulation codes

Pilot chart and death-birth conditional prob.



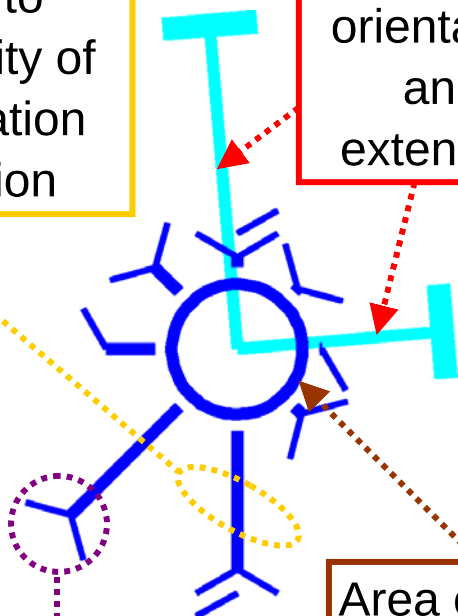
- Clear change in average structure orientation in ejection region
- Deceleration from ~1750 m/s to 1000 m/s along radial propagation
- Conditional birth probability of blobs reaching the far SOL peaks at (-5,-10) cm
  - Blobs travel distances of order of minor radius as coherent structures

Legend

Pilot chart

Prop. to probability of propagation direction

Average orientation and extension

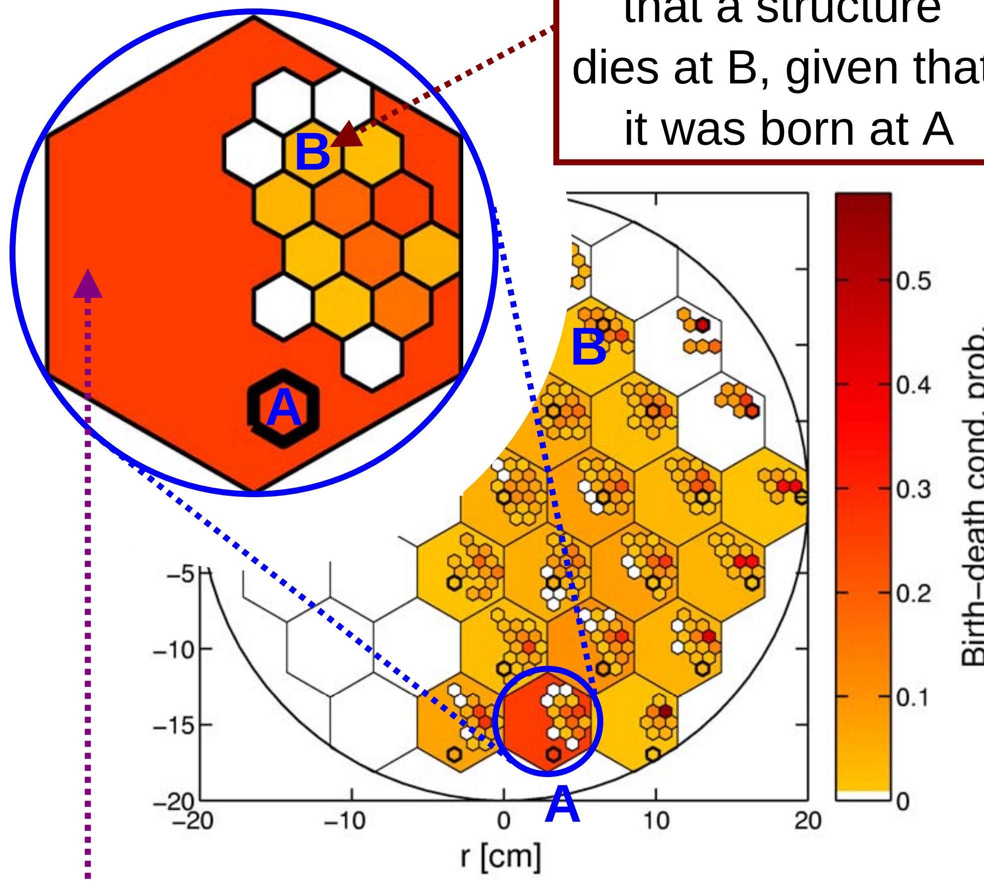


Each half tail: 250 m/s

Area of circle prop. to # trajectories

Birth/death chart

Color: probability that a structure dies at B, given that it was born at A



Background color: probability that a structure is born at A