Blob propagation characteristics in the scrape-off layer on the HL-2A tokamak

Longwen Yan, Jun Cheng, et al.

Southwestern Institute of Physics, Chengdu, China

Outline

- Motivation
- Experimental setup of 5-tip array
- Blob experimental results by 5-tips
- Probe arrangement with poloidal 10-tip and radial 8-tip arrays
- Blob experimental results by the two probe arrays
- Summary

Motivation

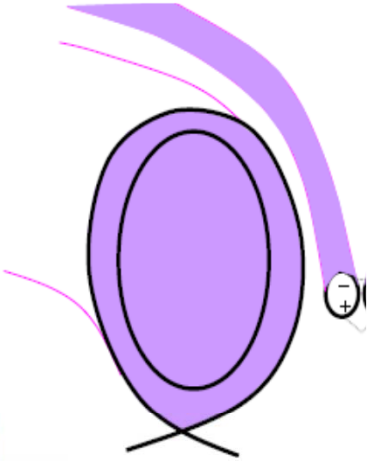
HL-2A

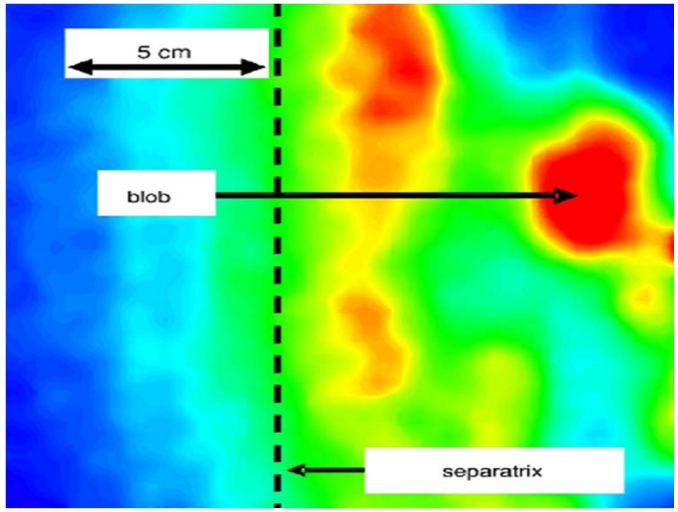
- Blob can carry a significant fraction of cross-field transport in fusion devices
- Blob convective transport is responsible for high heat load on the first wall
- Studying blob propagation, generation mechanism and relevant transport
- Estimating particle flux loss carried by blobs

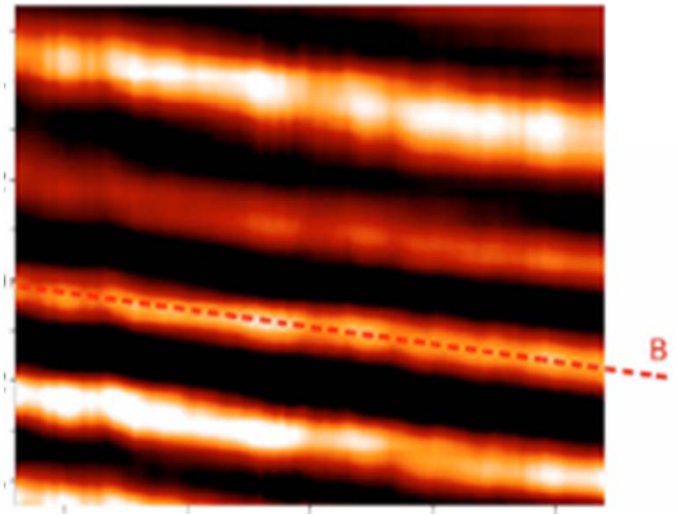
Blob characteristics

HL-2A

- **Experiment observation**
  - Intermittent coherence structure:
  - 2D-blob: in poloidal-radial plane
  - 3D-filament: along a magnetic field line







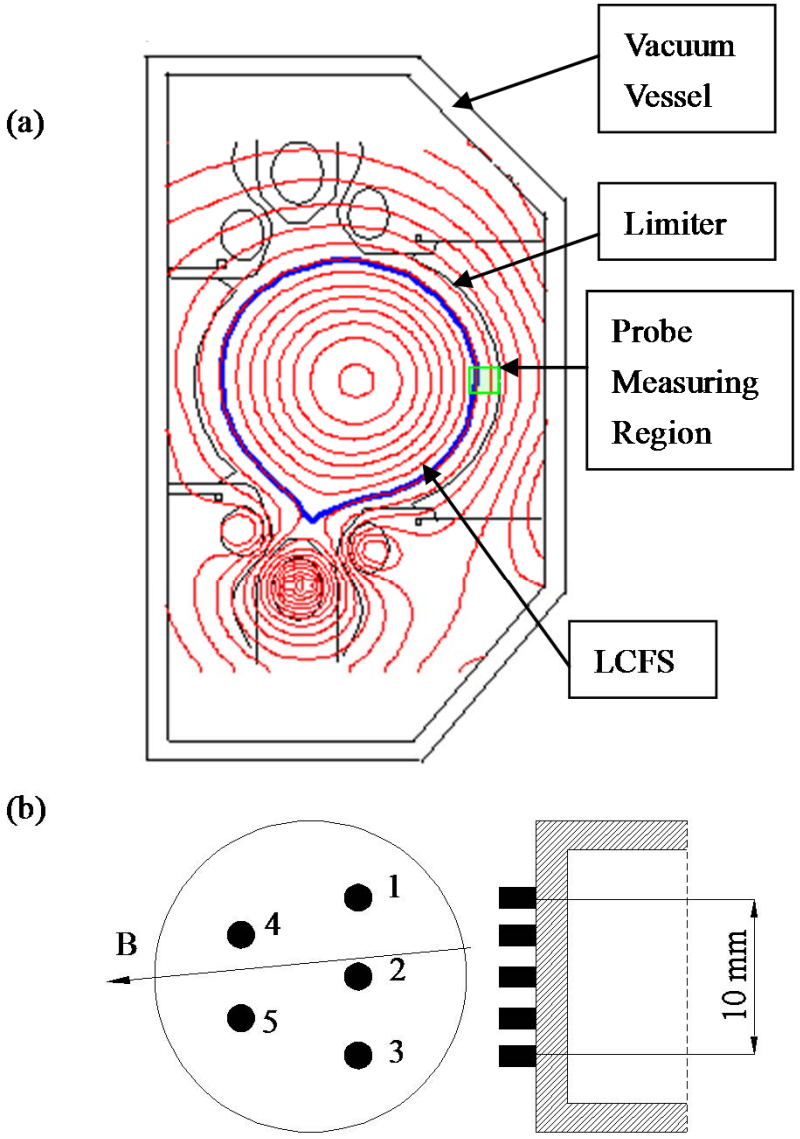
- **Typical characteristics of a blob or filament**
  - Higher density, temperature than bulk plasma
  - Small parallel wave number: $k_r \sim k_\theta >> k_{//}$

Outline

- Motivation
- **Experimental setup of 5-tip array**
- **Blob experimental results by 5-tips**
- Probe arrangement with poloidal 10-tip and radial 8-tip arrays
- Blob experimental results by the two probe arrays
- Summary

Experimental setup of 5-tip array

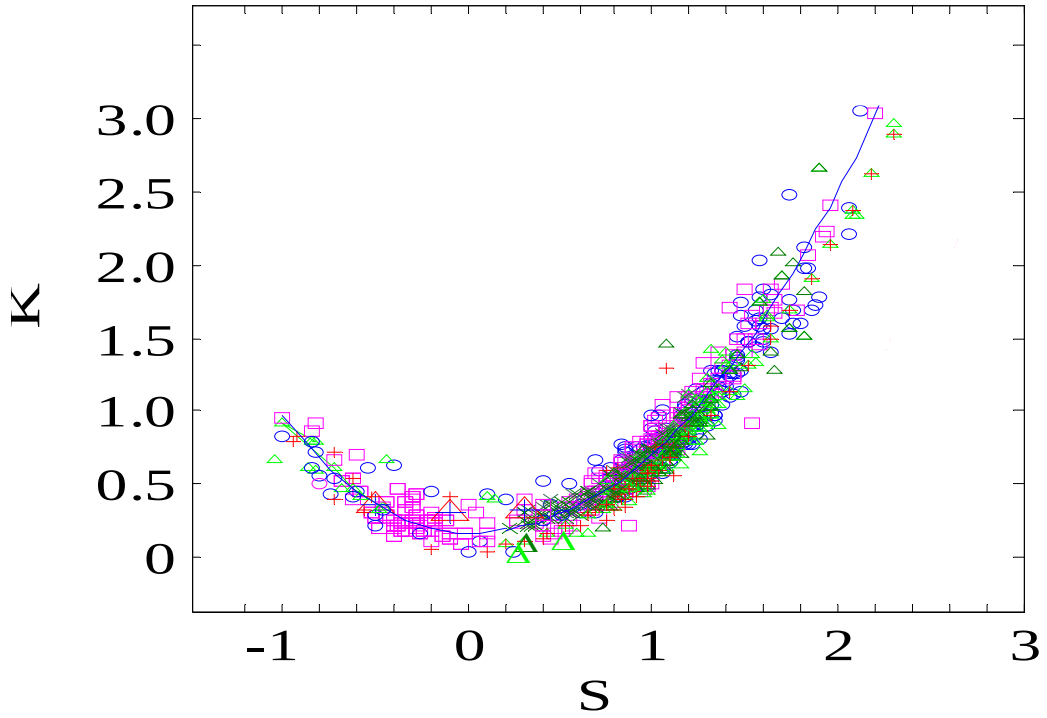
HL-2A



- Statistical characteristics: PDF, skewness, kurtosis
- Nonlinear coupling: wavelet bicoherence
- Estimating particle flux

- Each tip has 3 mm in length, 1.5 mm in diameter and 5 mm in poloidal separation
- Tips 1–3 measure I_{s1}–I_{s3}, but tips 4-5 for $E_\theta=(V_{f4}-V_{f5})/d_\theta$
- Tips 2 and 5 used for I_s, the other tips for float potentials

Parabolic kurtosis via skewness



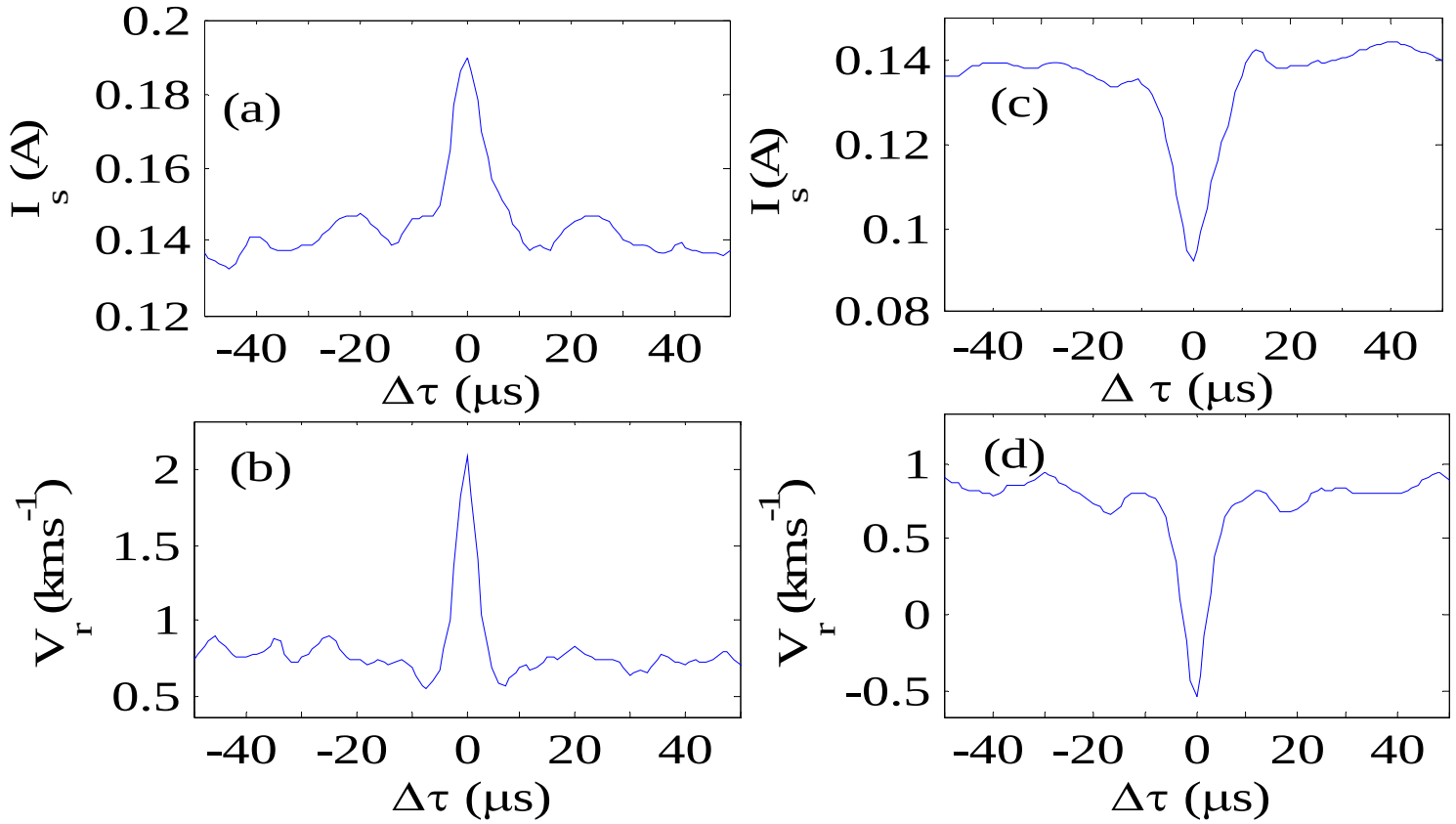
- The least square fitting of kurtosis via skewness

$$K=(1.12\pm0.15)\ S^2+(0.28\pm0.12)$$

- Kurtosis has a minimum when S = 0

Coexistence of blob and hole

HL-2A

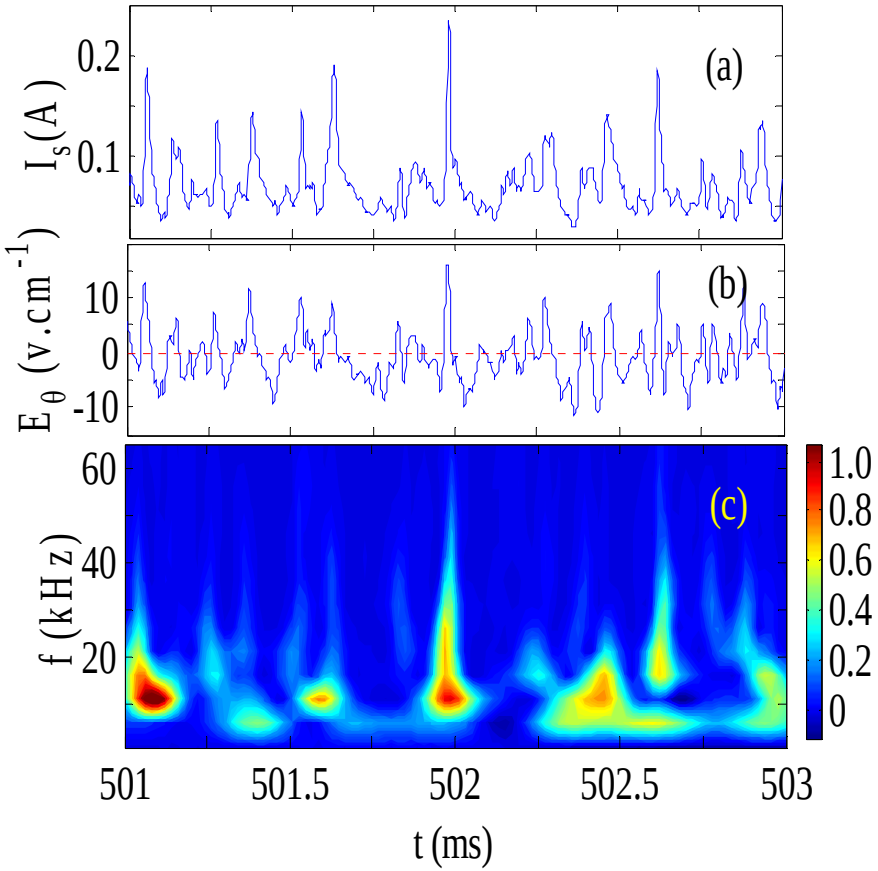


- **The measured position is inside separatrix 8 mm**
- **Opposite radial velocity (V_r) indicates that density blob propagates outward but hole travels inward**

Convection transport by blobs

HL-2A

Raw data I_s, E_θ and temporal particle flux



- The E_θ has the similar waveform with I_s
- Large burst routinely responds to large particle flux
- Large blobs in 18% time can carry for 58% particle loss

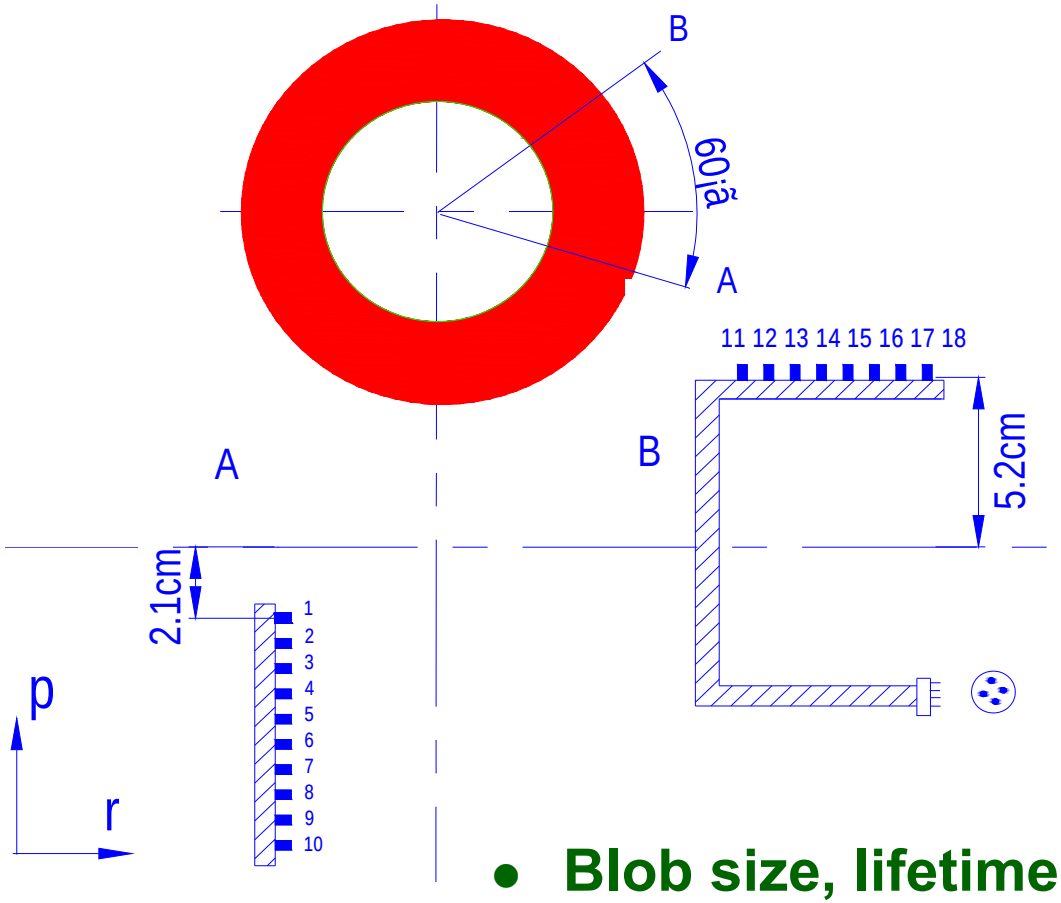
Blob generation rate is estimated as 8.0 $\times 10^3$ s^{-1}

Outline

- Motivation
- Experimental setup of 5-tip array
- Blob experimental results by 5-tips
- **Probe arrangement with poloidal 10-tip and radial 8-tip arrays**
- **Blob experimental results by the two probe arrays**
- Summary

Poloidal & radial probe arrays

HL-2A

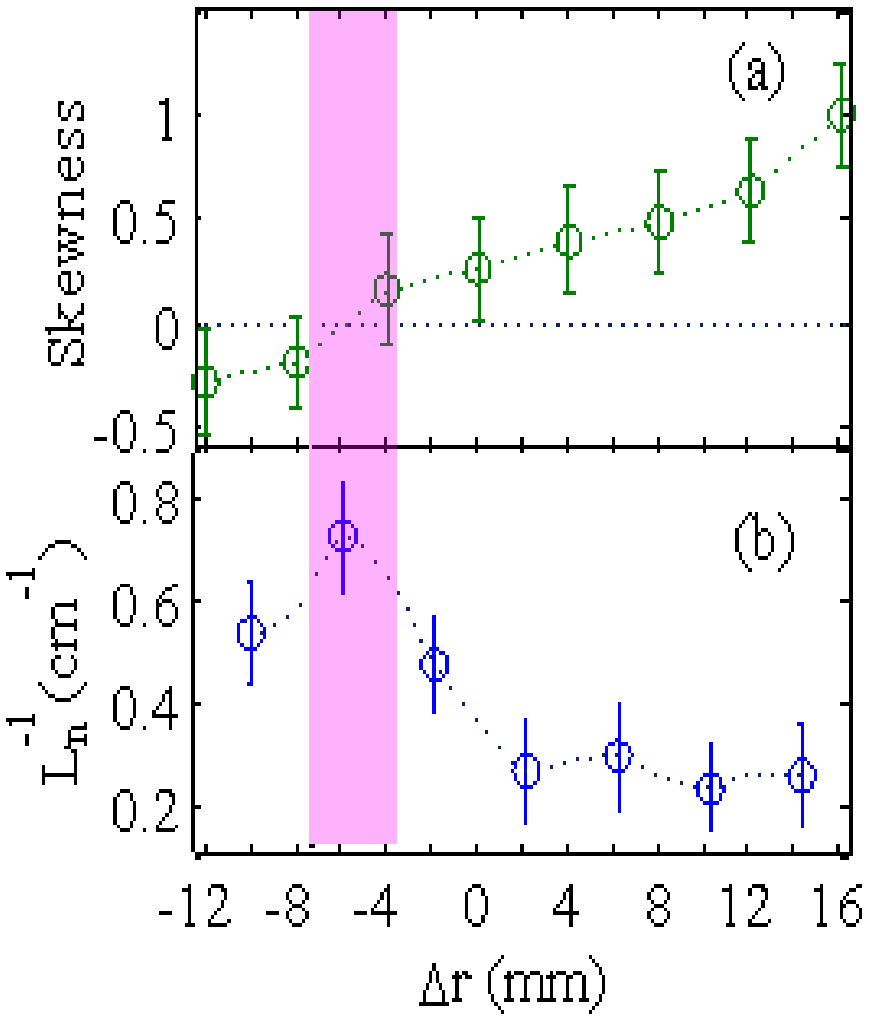


- Tip one in poloidal ten tip array A is 2.1 cm below midplane
- Radial 8-tip array B is 5.2 cm above midplane
- 4-tip array for n_e & T_e
- Tip separation is 4.0 mm with 2.0 mm in length and 1.5 mm in diameter
- Toroidal separation of array A and B is 210 cm

- Blob size, lifetime, propagation velocity
- Blob toroidal correlation along a field line
- Blob 2D images similar to fast camera

Blob birth zone with S = 0

HL-2A



- Radial 8-tip array is used
- Neglected temperature fluctuation, inverse density decay length is given by

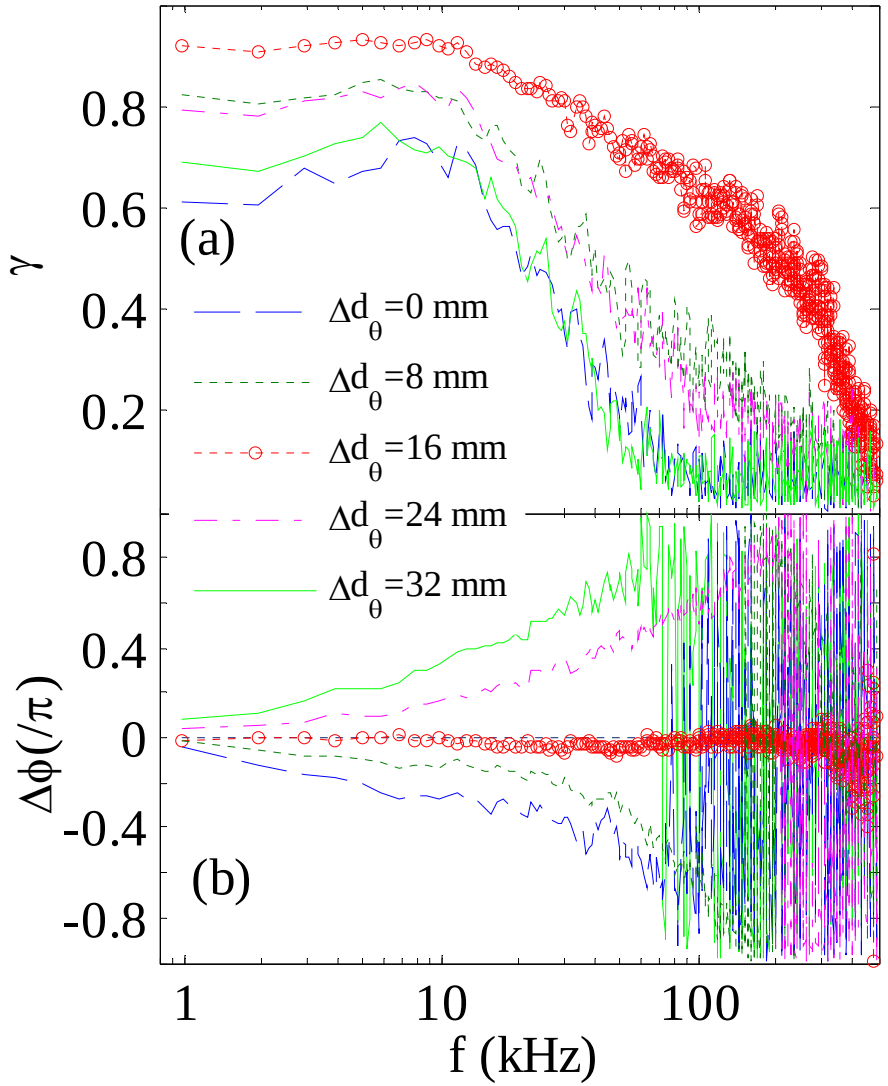
  $L_n^{-1} = -\nabla n_e/n_e$

  $\approx 2(I_{s1}-I_{s2})/((I_{s1}+I_{s2})\Delta d)$

  where I_{s1} and I_{s2} have radial separation Δd=4 mm

- Skewness changes its sign near $\Delta r \sim$ -6 mm
- L_n^{-1} has the maximum when skewness is zero

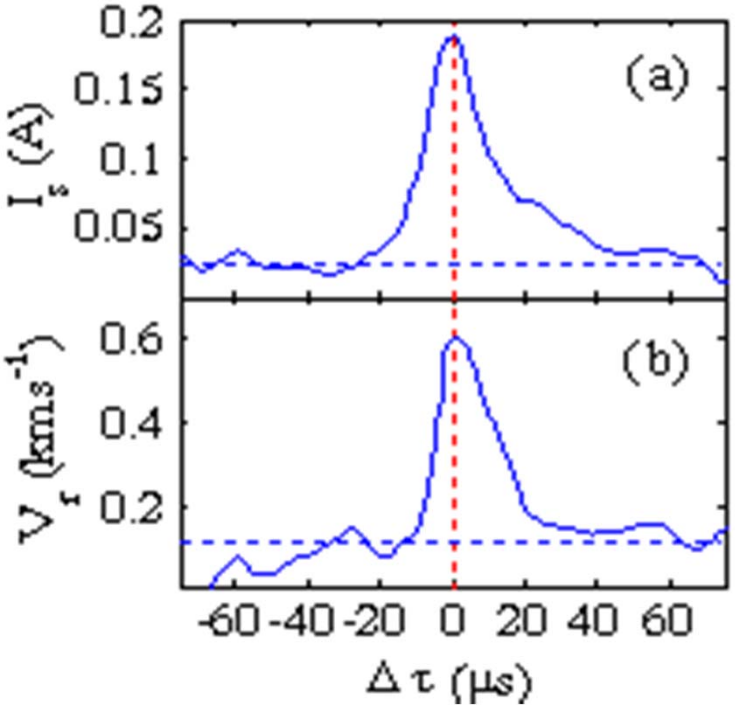
Interchange mode feature

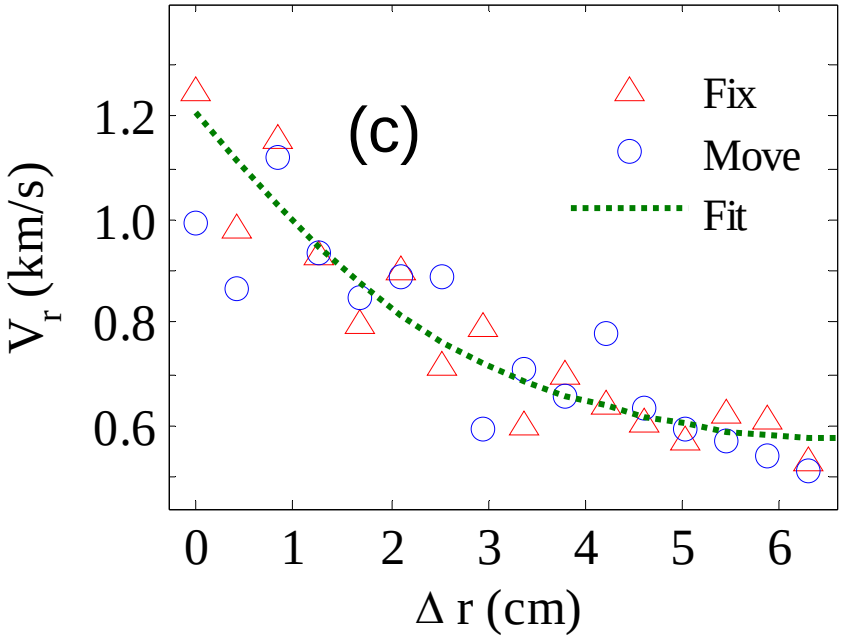


- Suitable I_p, B_t and probe position, there is a significant correlation and zero phase shift along a magnetic field line
- Interchange mode is responsible for blob generation

Blob radial propagation

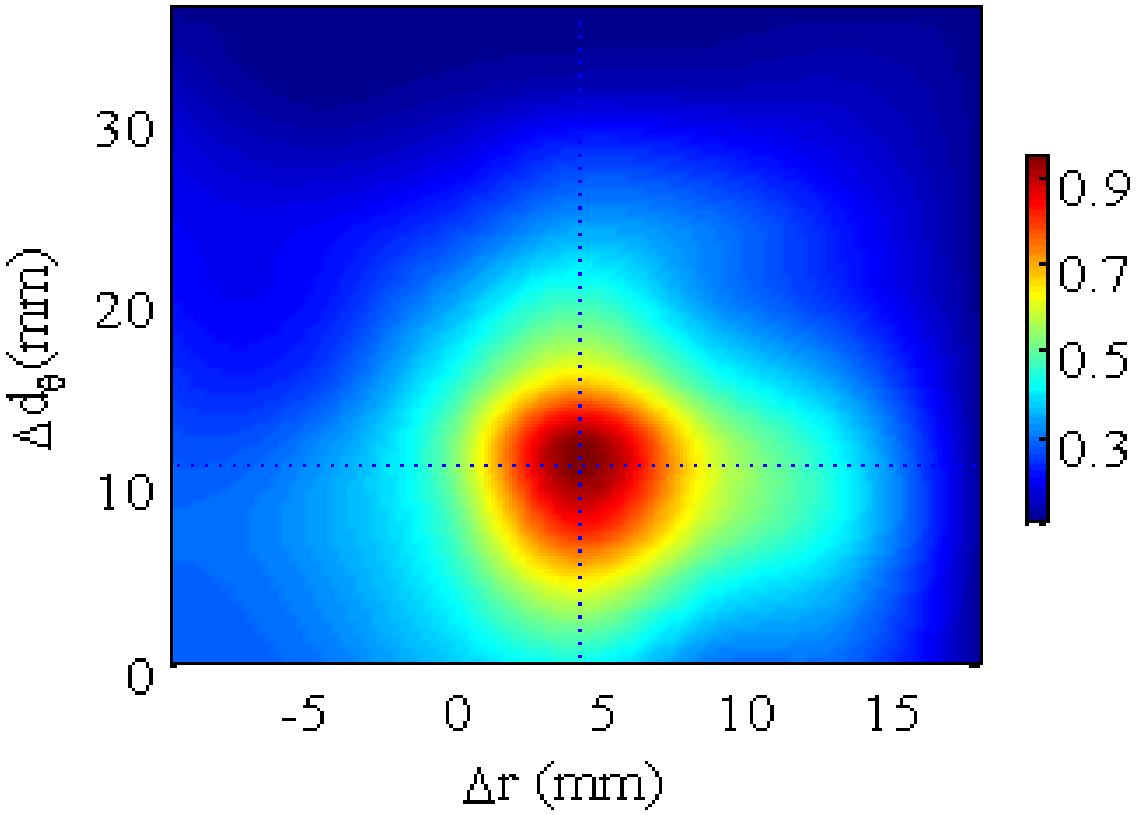
HL-2A





- Cross-conditional average (CCA) picks a blob up (a)
- The V_r is estimated with E_θ/B_t and ref. signal I_s (b)
- The peak of CCA means radial velocity of a blob
- Blob radial velocity decreases with the distance (c)
- Two reference signals for V_r estimation: one used a movable probe; the other is for a fixed probe signal

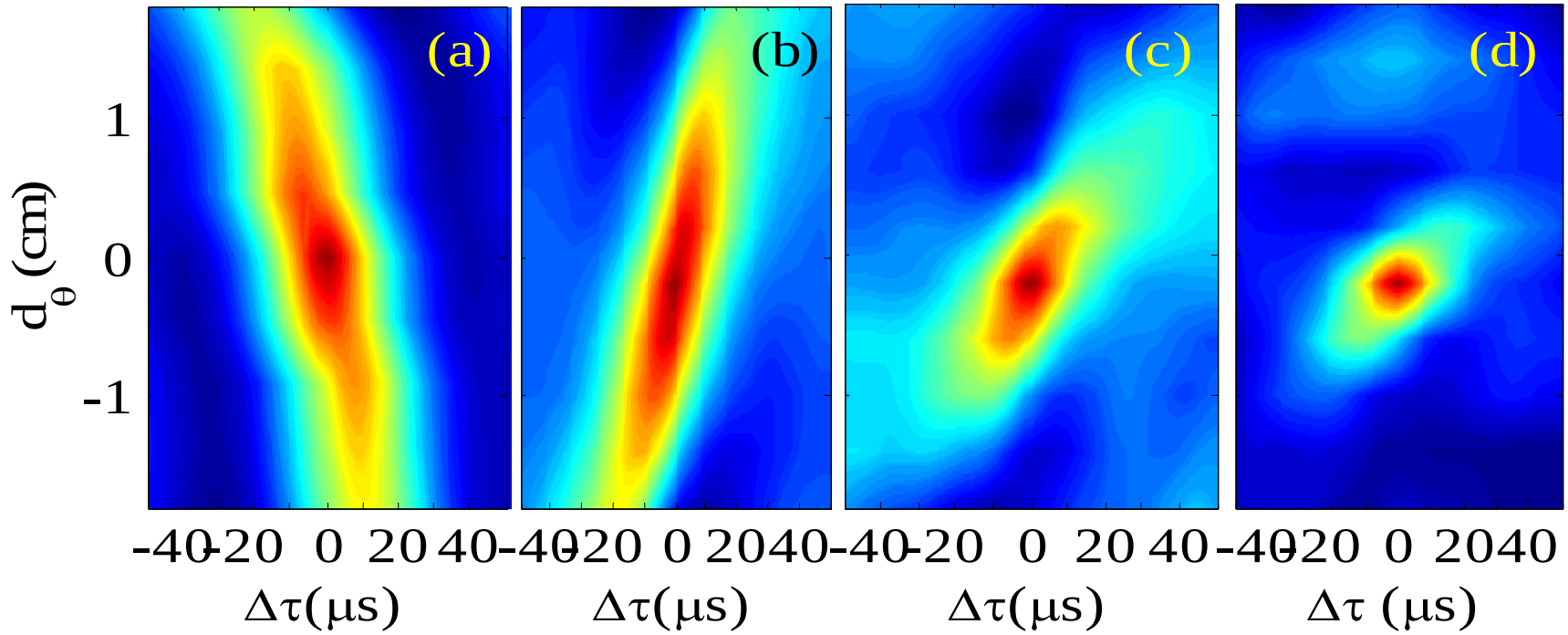
Blob 2D coherence image



- **The maximum coherency is larger than 0.9**
- **The blob has radial and poloidal correlation lengths of ~10 mm and ~15 mm, respectively**

Poloidal propagation reversion

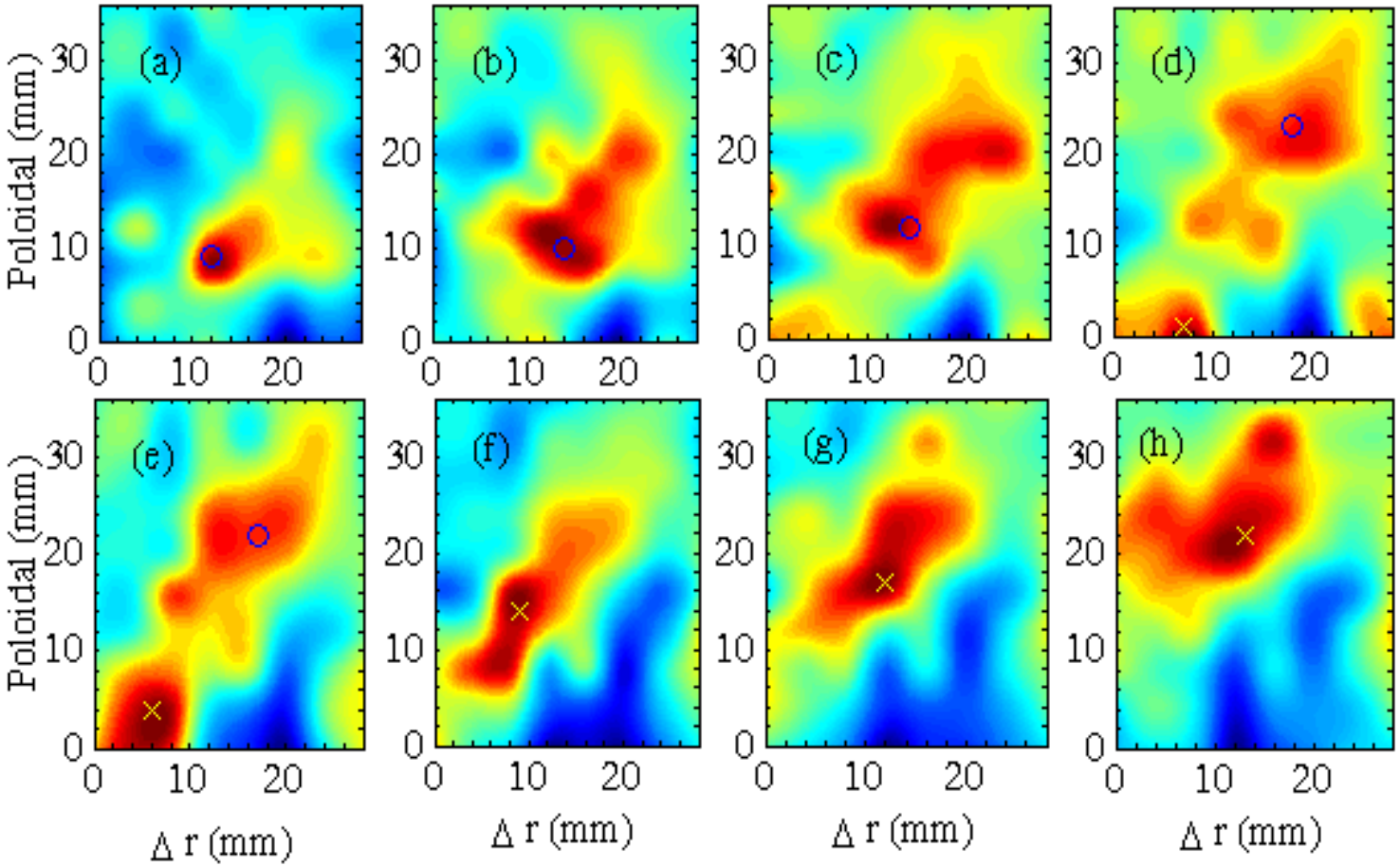
HL-2A



- **Blob size, life time and propagation velocity can be obtained from figure (a)-(d) at Δr = -5, 5, 15, 25 mm**
- **Poloidal velocity is estimated as 0.8-2.1 km/s**
- **The velocity changes its direction across separatrix, consistent with E×B drive mechanism**

Blob propagation outward

HL-2A



- The poloidal-radial images with time interval of 5 μs
- Blob poloidal and radial sizes less than 10 mm
- Two blobs with space of 20 mm and lifetime of 25 μs

Summary

- A novel combination of poloidal 10-tip and radial 8-tip probe arrays, toroidally separated by 210 cm is used
- Parabolic kurtosis versus skewness is observed
- Blobs and holes coexist inside magnetic separatrix
- Large blobs in 18% time can carry for 58% particle loss
- Blob generation zone responds to zero skewness
- Interchange mode is responsible for blob generation due to zero phase shift along a field line
- Blob radial velocity decreases with the distance
- Poloidal propagation changes sign across separatrix
- Blob poloidal-radial propagation and inclination are clear

Thank you for your attention !