A Statistical Method for Transforming Temporal Correlation Functions from One-Point Measurements into Longitudinal Spatial and Spatio-Temporal Correlation Functions

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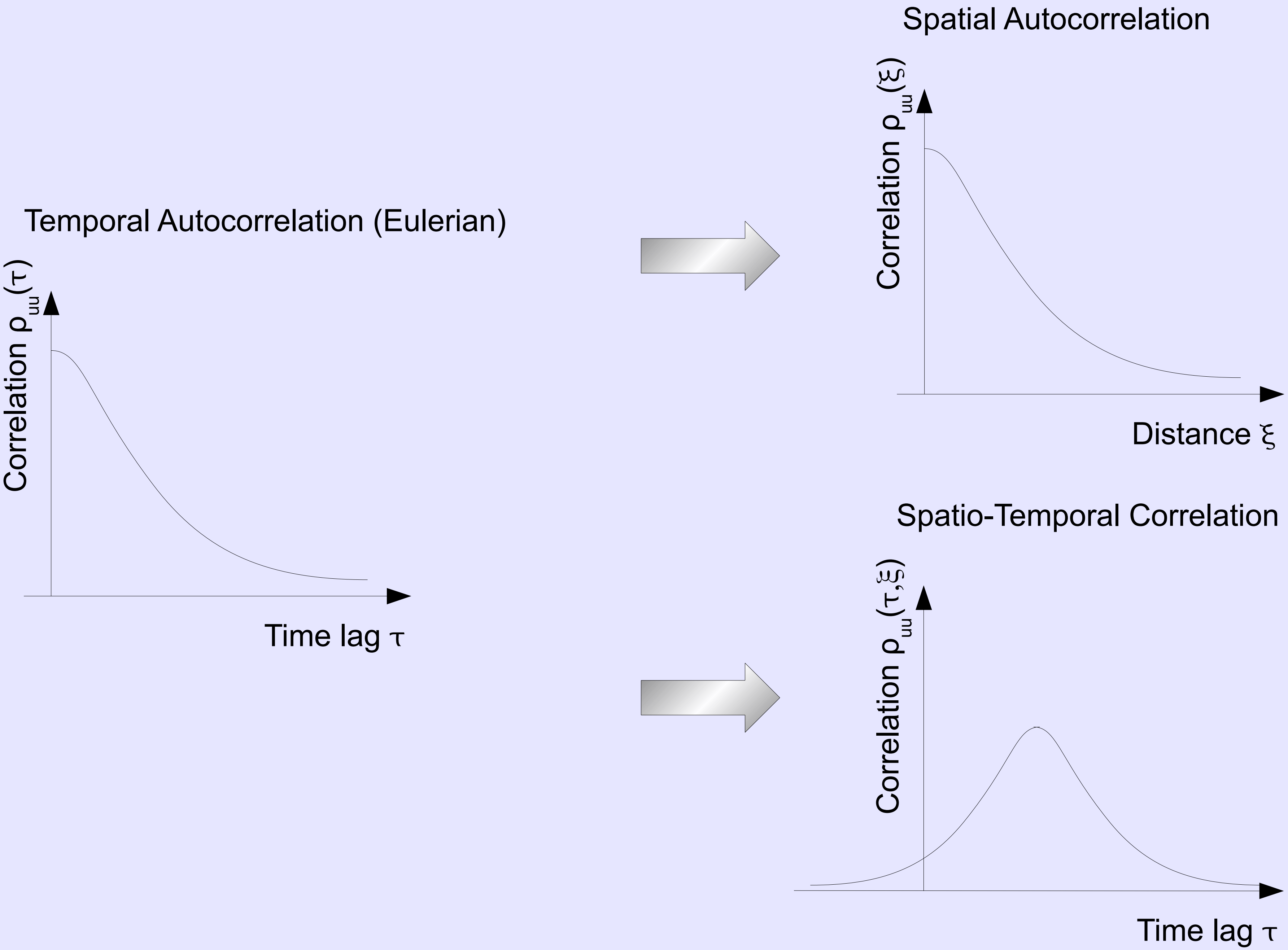
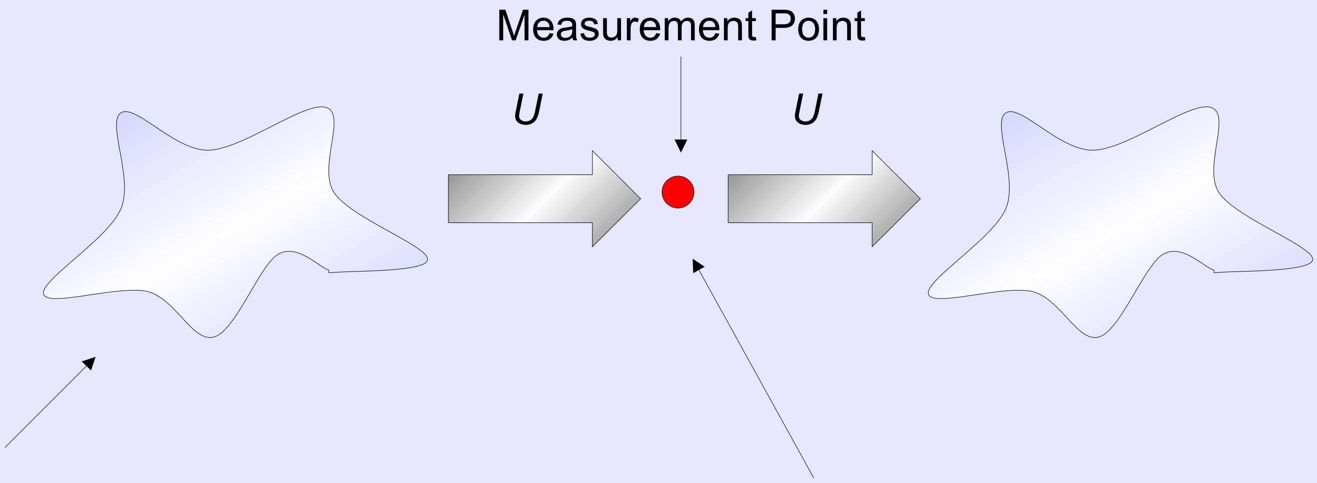
An Alternative to Taylor's Frozen Flow Hypothesis


Temporal Autocorrelation (Eulerian)
Correlation $\rho_{uu}(\tau)$
Time lag τ
Spatial Autocorrelation
Correlation $\rho_{uu}(\xi)$
Distance ξ
Spatio-Temporal Correlation
Correlation $\rho_{uu}(\tau,\xi)$
Time lag τ

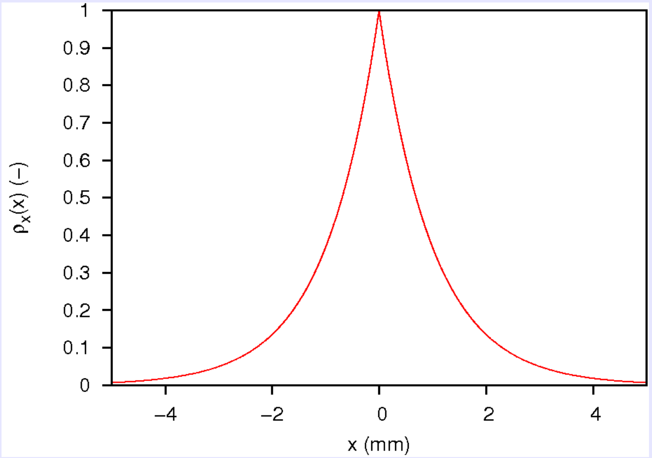
- Taylor's Frozen Flow Hypothesis

$$U \gg u'$$

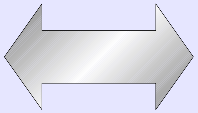
Local quantities (like gradients)
As well as “structures”



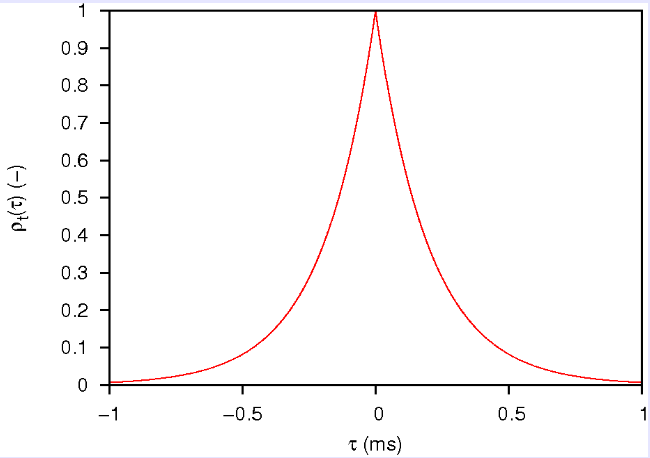
Spatial Autocorrelation Function



$$U = \frac{x}{\tau}$$

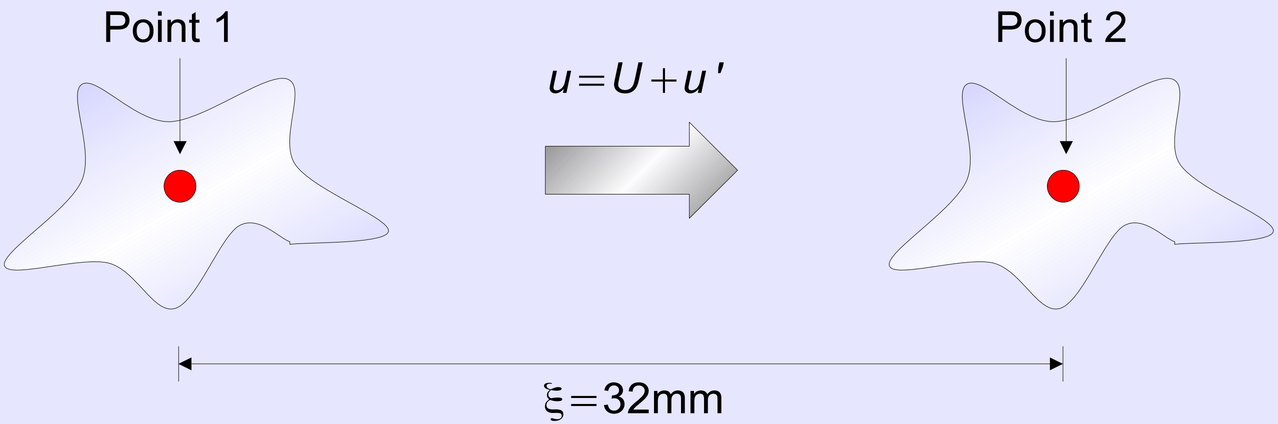


Temporal Autocorrelation Function (Eulerian)

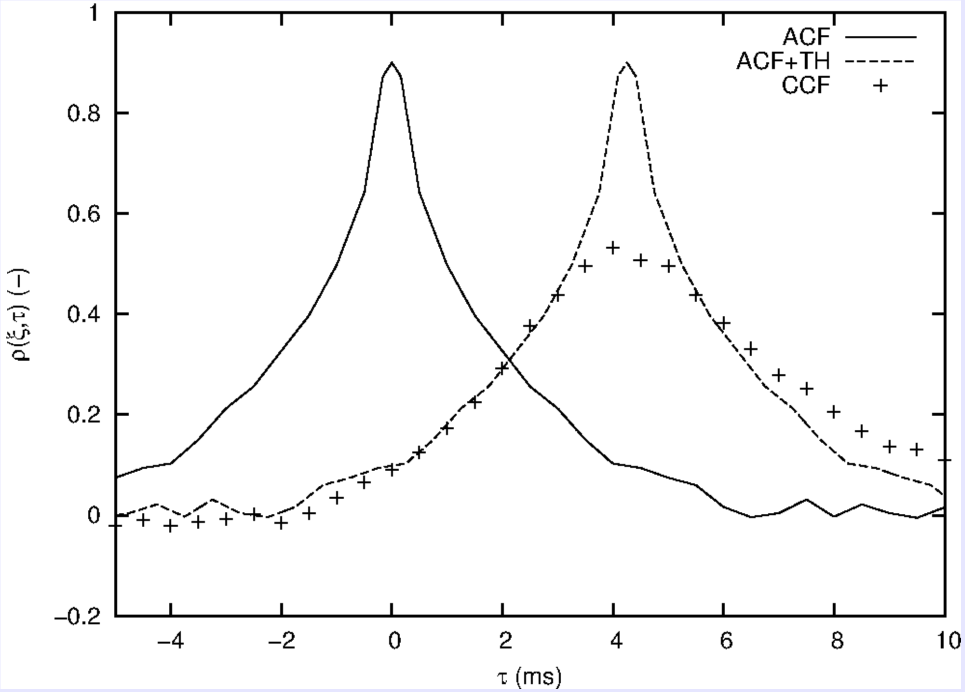


- Variable Velocity

Corrections for Local quantities (like gradients)
“Structures” ?



Spatio-Temporal
Correlation Function



- Corrections for Gradients
- Frequency dependent transfer functions
- Elliptical Model

- Velocity Statistics

Probability density $f_u(u)$

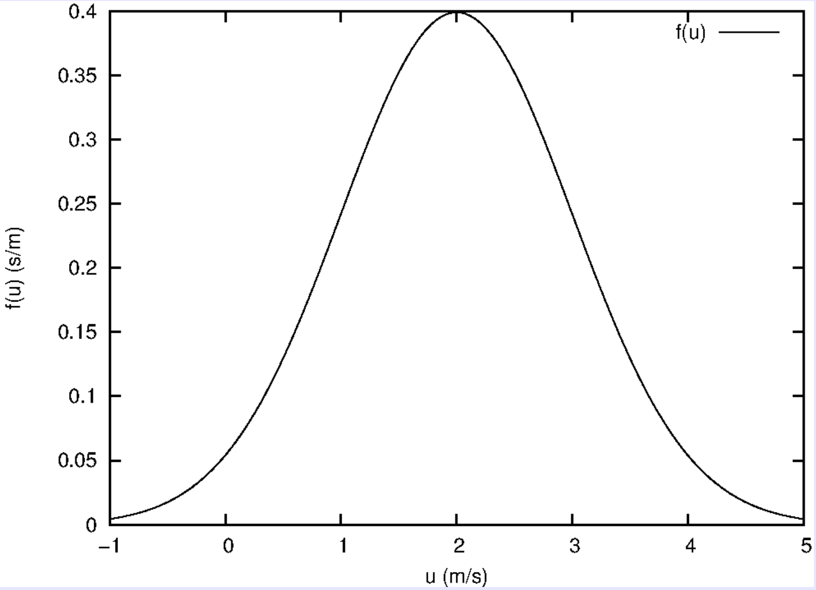
- Time-of-Flight Statistics

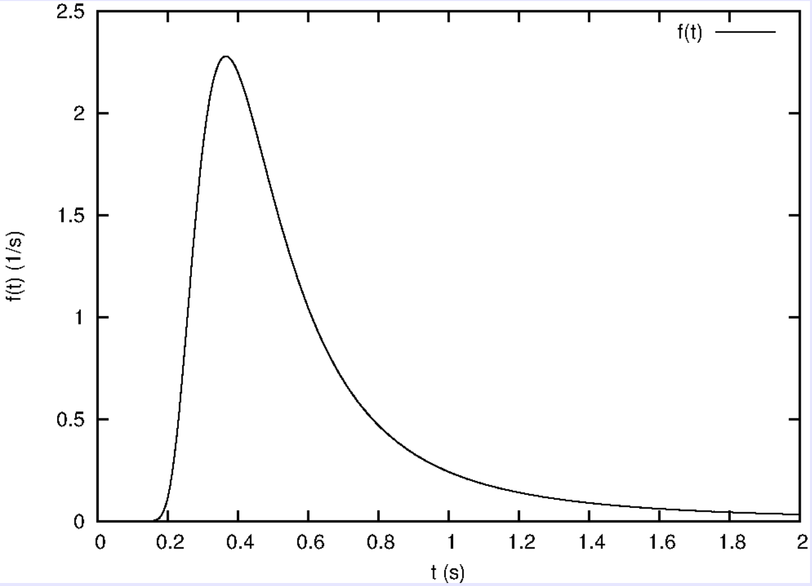
Time of Flight $t = \frac{\xi}{u}$

Probability density $f_t(t) = \frac{|\xi|}{t^2} f_u\left(\frac{\xi}{t}\right)$

- Average

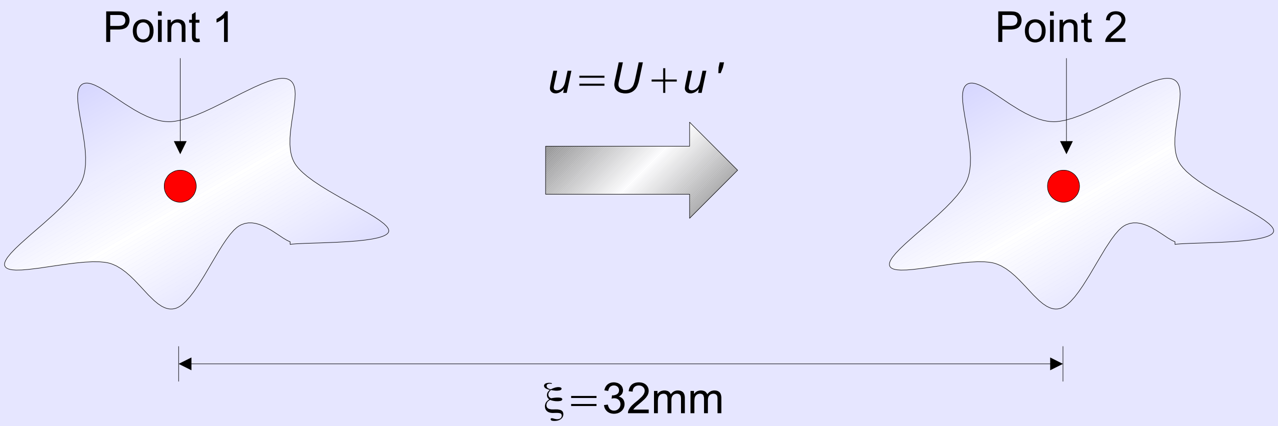
$$\rho(\xi, \tau) = \int_{-\infty}^{\infty} \rho(0, \tau - t) f_t(t) \, dt$$



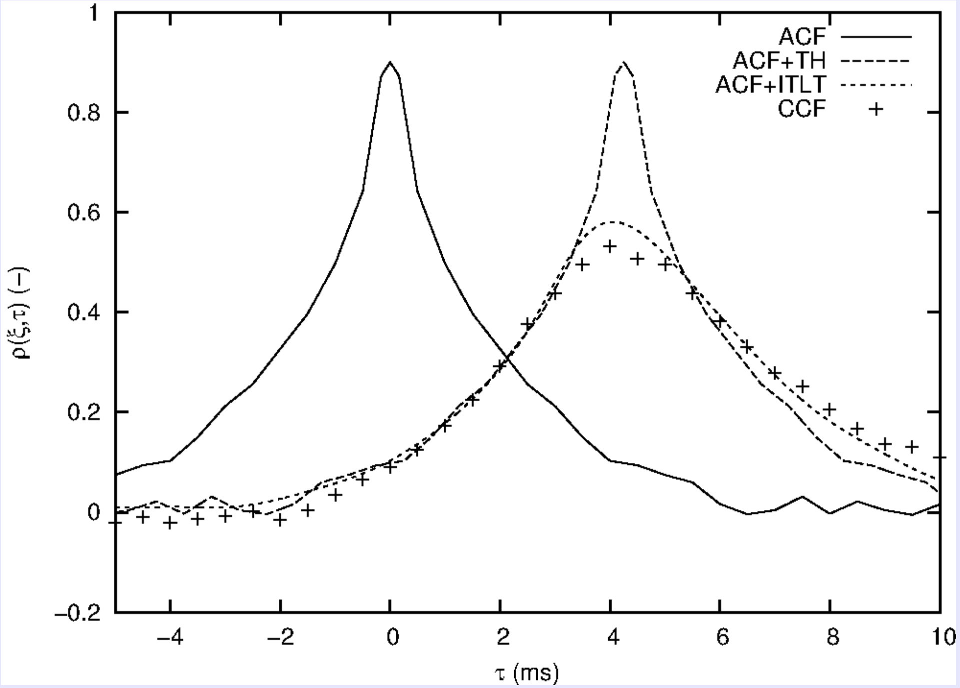


- Variable Velocity

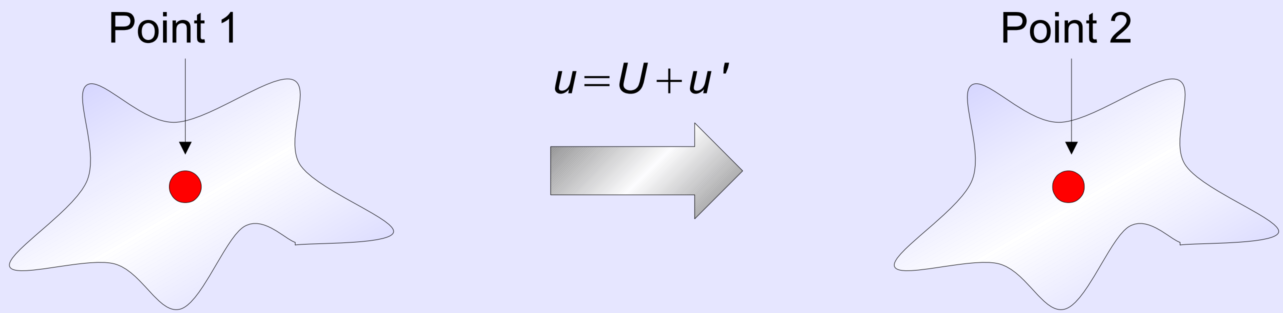
Corrections for Local quantities (like gradients)
"Structures" ?

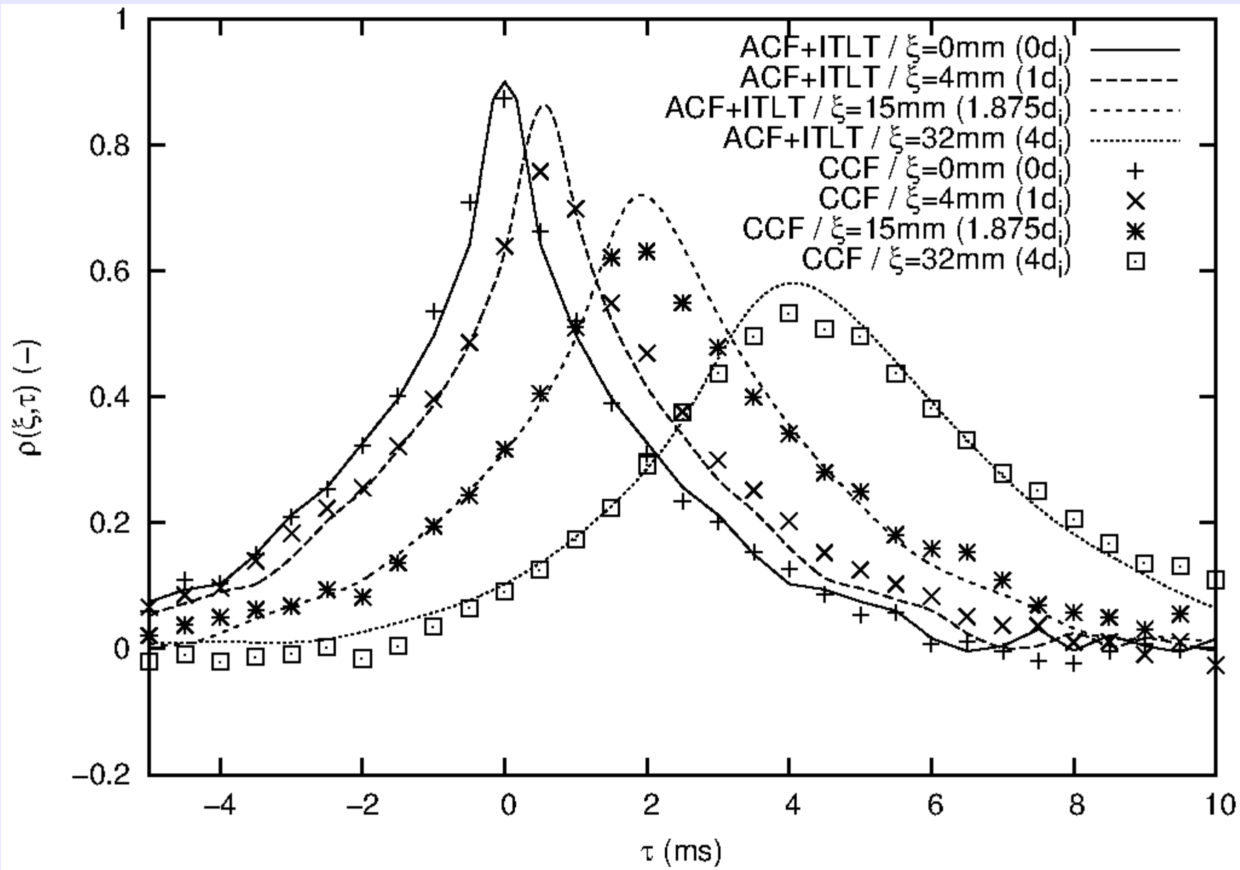


Spatio-Temporal
Correlation Function

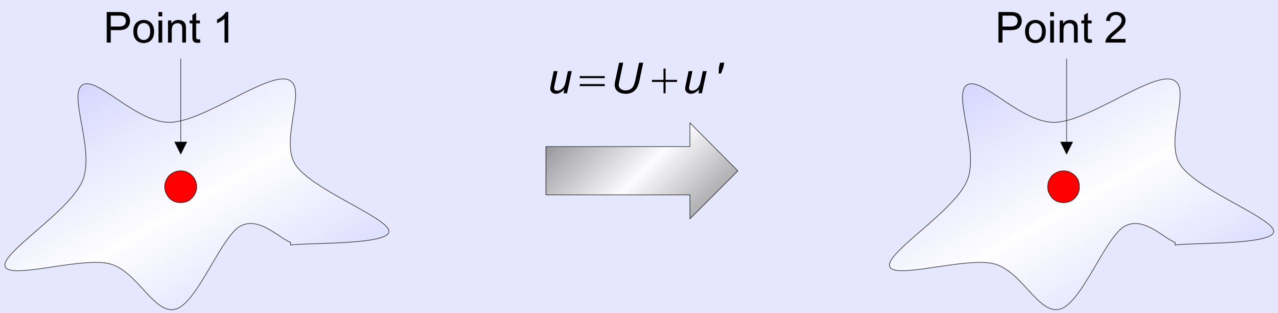


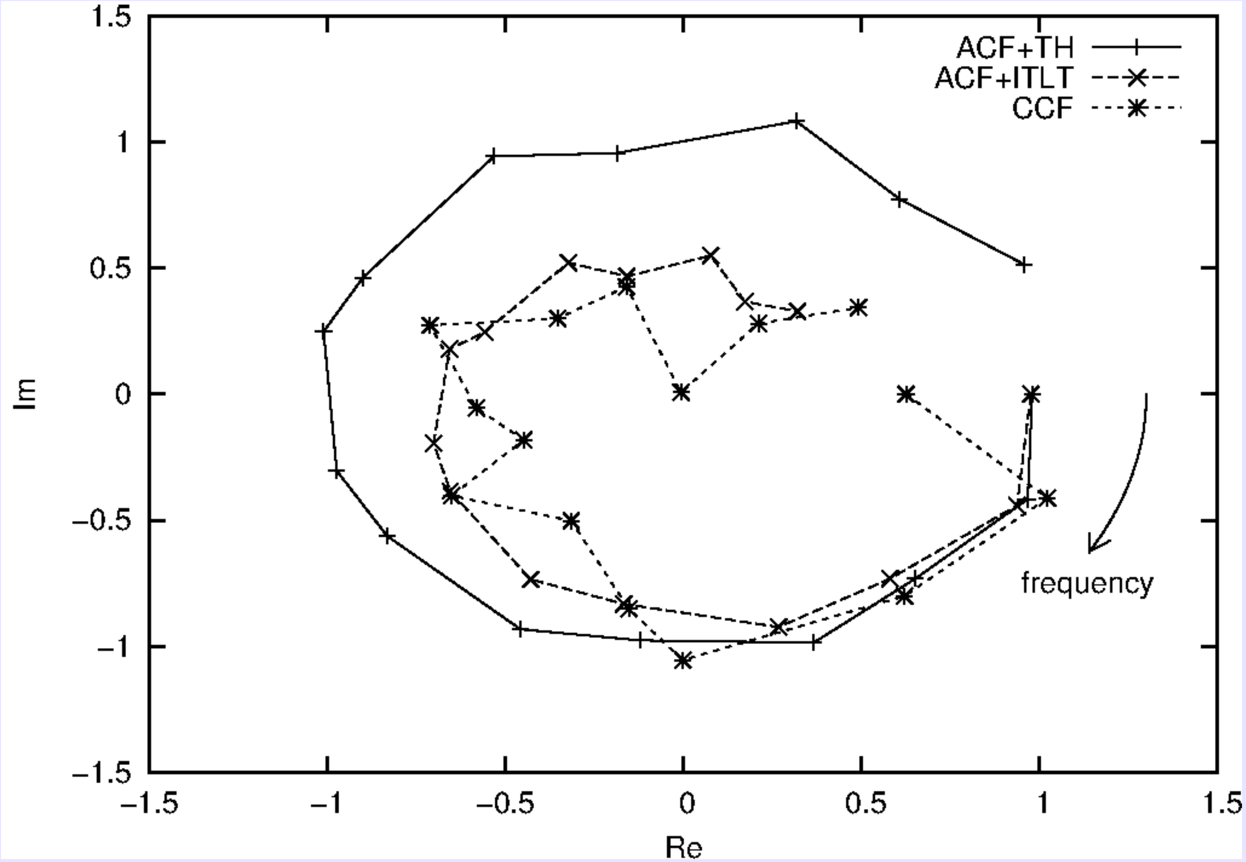
- Spatio-Temporal Correlation





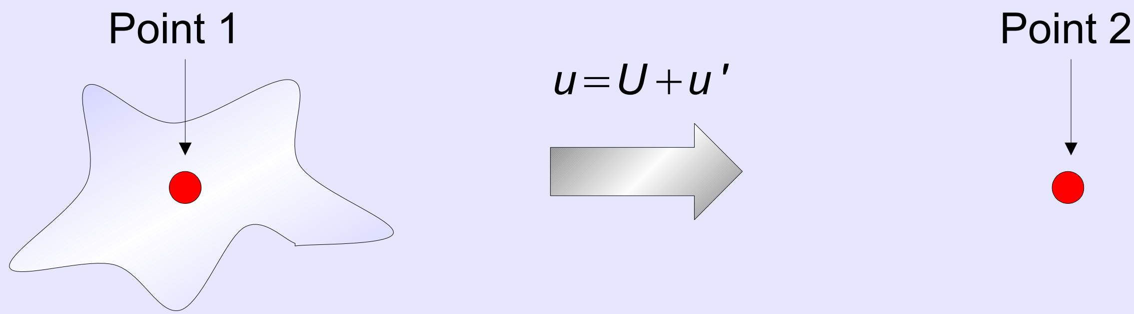
- Spatio-Temporal Correlation





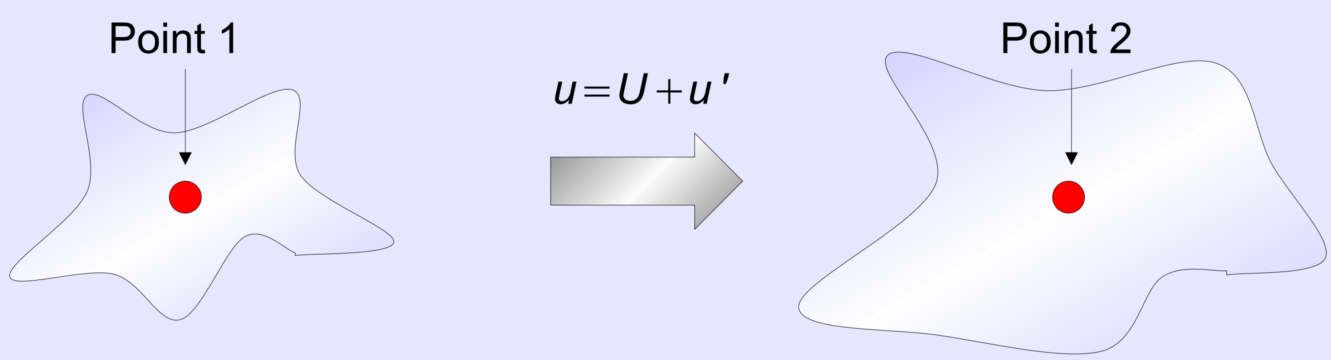
- No correlation (random walk)

first arrival: $f_t(t)=\sqrt{\frac{\lambda}{2\pi t^3}}\,e^{\frac{-\lambda(t-\mu)^2}{2\mu^2 t}}$ (inverse normal distribution) $\mu=\frac{\xi}{U}$



- Decaying Correlation

$f_t(t)=?$



- Project:
  - (Multiple) Arrival Time PDF for Correlated Random Walk
  - Prediction of the Spatio-Temporal Correlation
  - Proof in Turbulent Jet
  - Proof in Boundary Layer
  - Proof of Corrections to Gradients