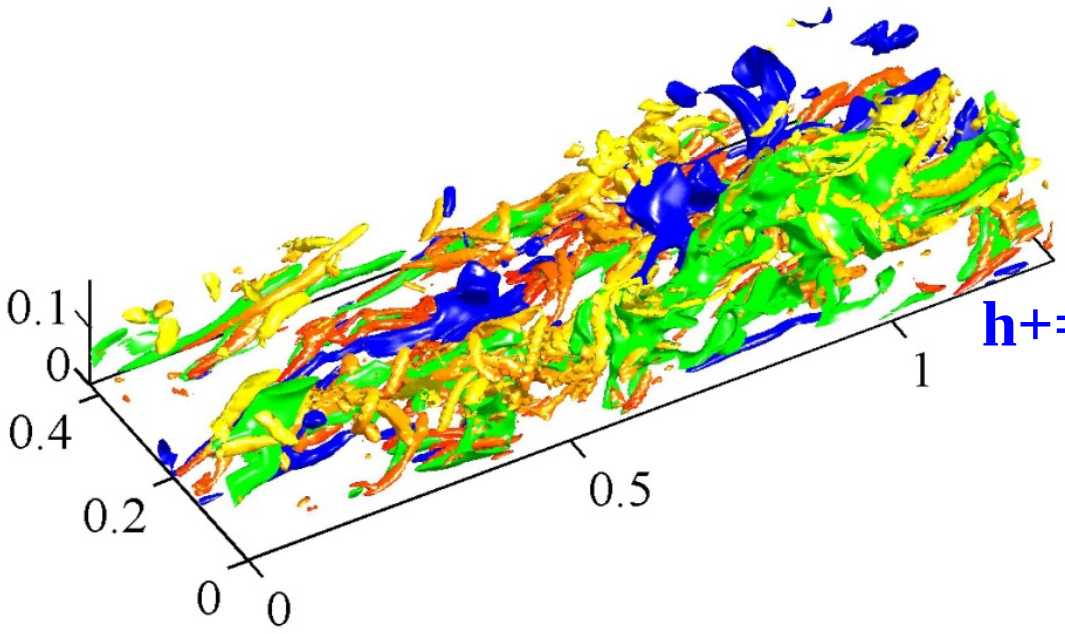
How Linear is Wall-Bounded Turbulence?

Javier Jiménez
School of Aeronautics, Madrid



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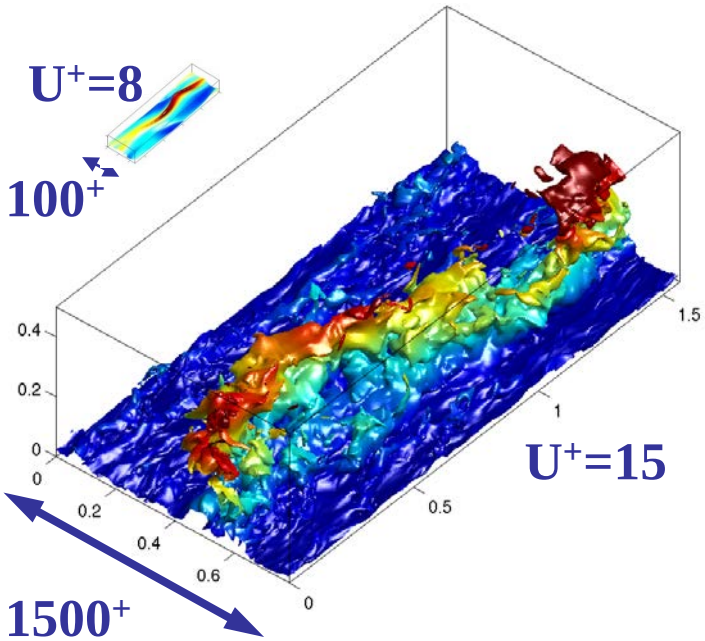
Jiménez, PoF (2013)

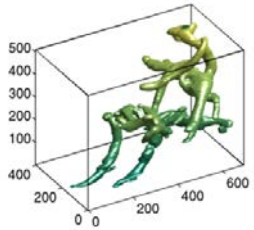
Structures

STREAKS

VORTICES

Buffer Layer





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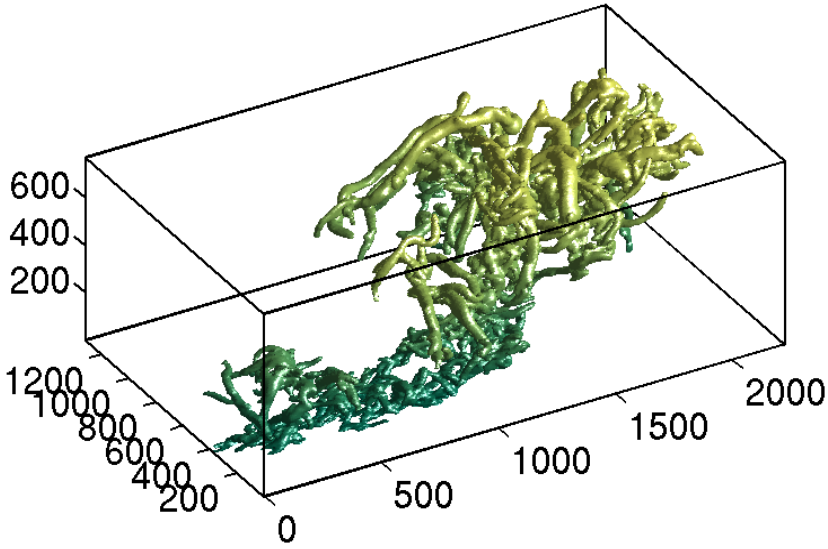


Logarithmic Layer

O. Flores (2006)

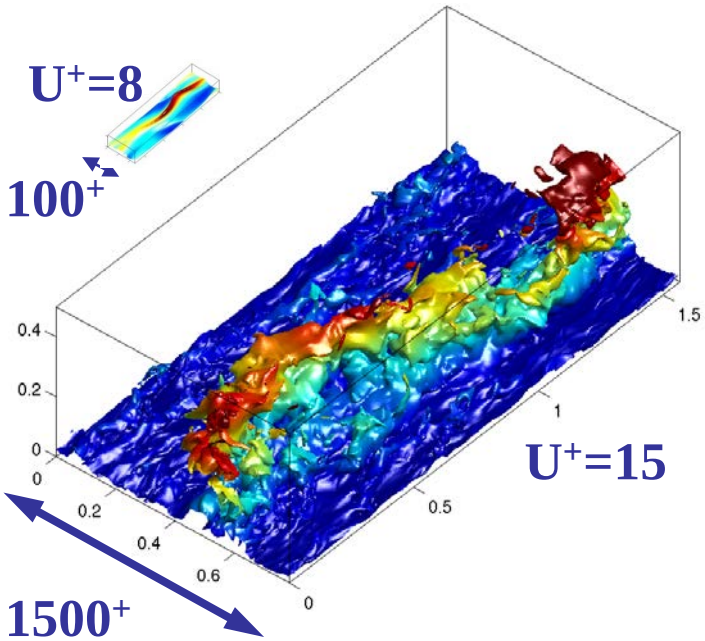
A. Lozano-Duran (2013)

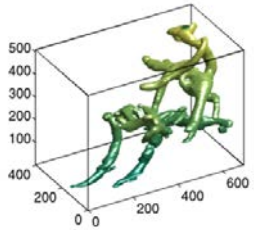
Structures

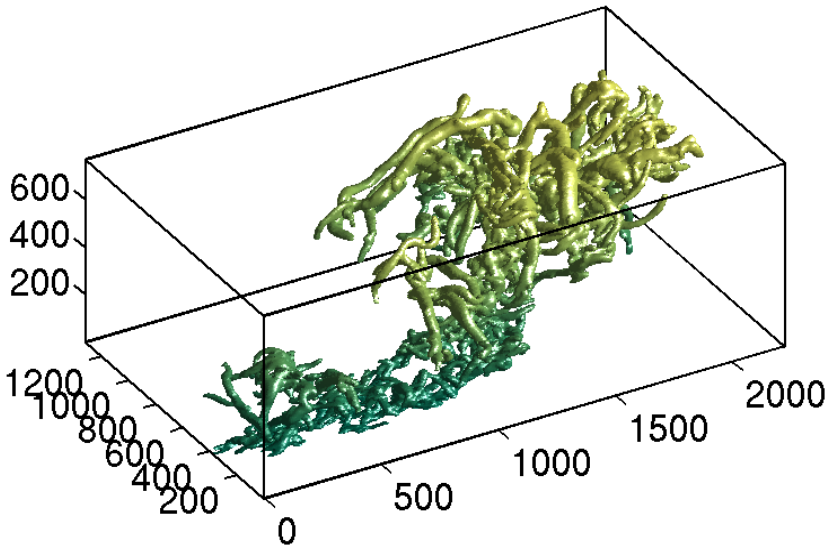
STREAKS

EDDIES (-uv)

Buffer Layer

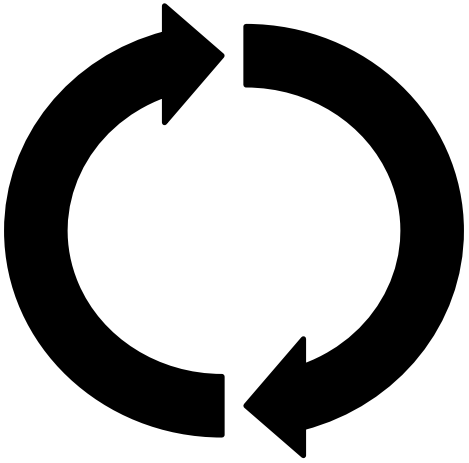


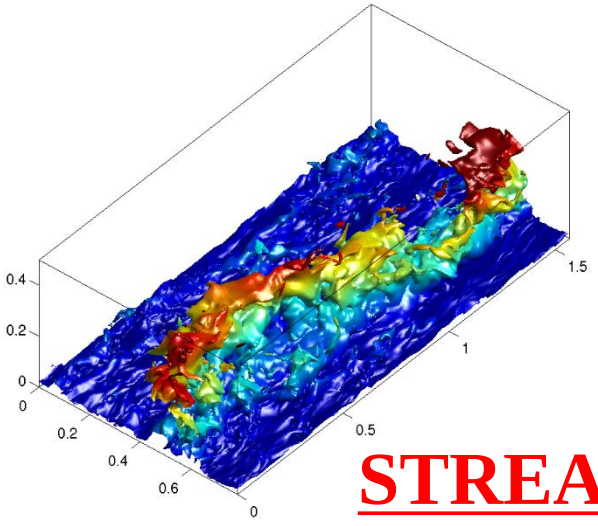




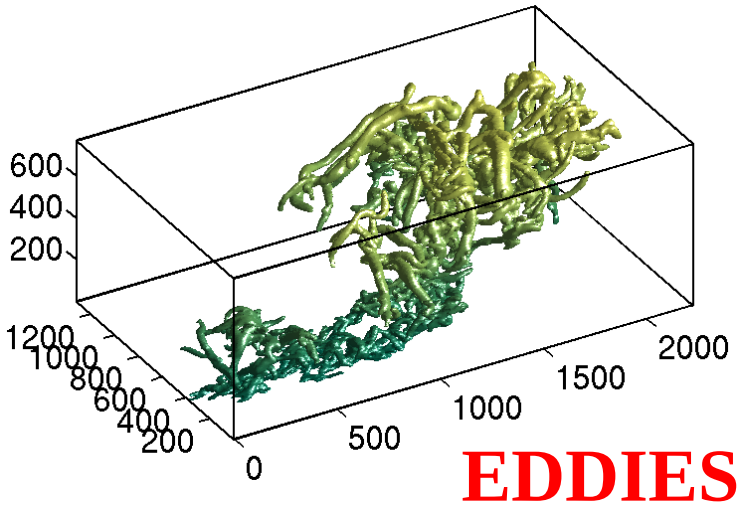
Logarithmic Layer

Where is the Energy Coming From?





STREAKS

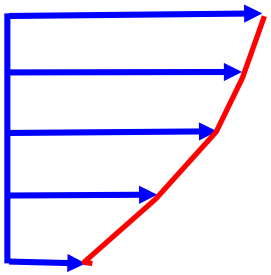


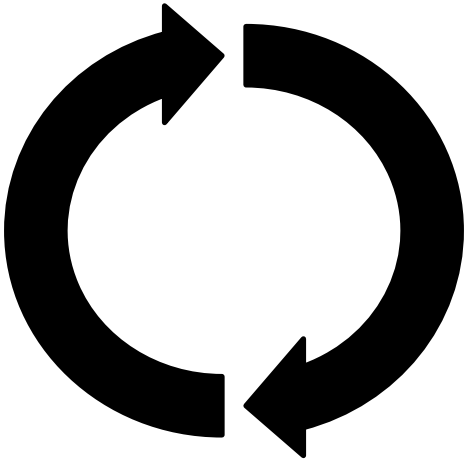
EDDIES

Where is the Energy Coming From?

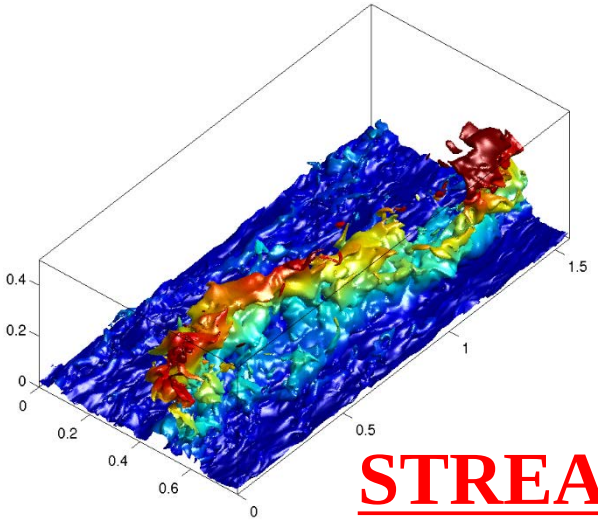
Streaks

Mean Shear

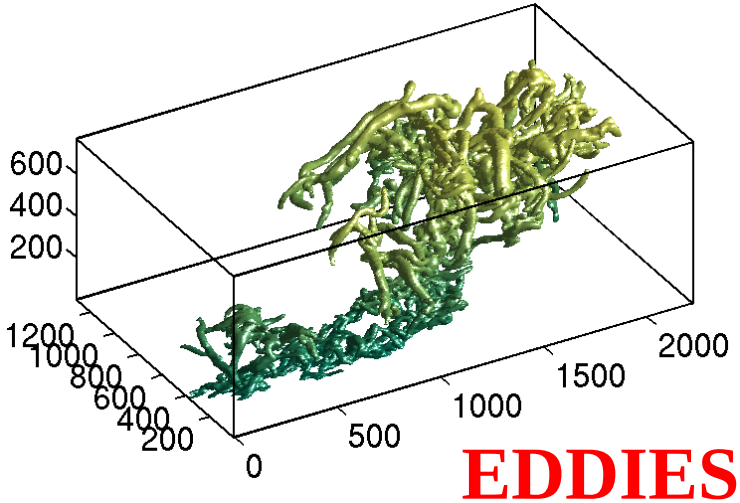




Eddies (-uv)



STREAKS

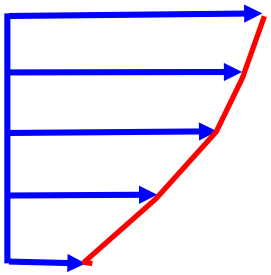


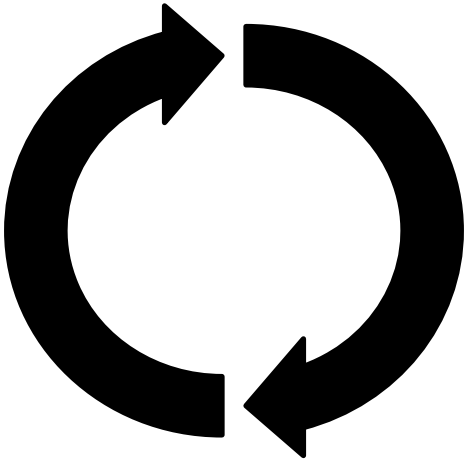
EDDIES

Where is the Energy Coming From?

Streaks

Mean Shear

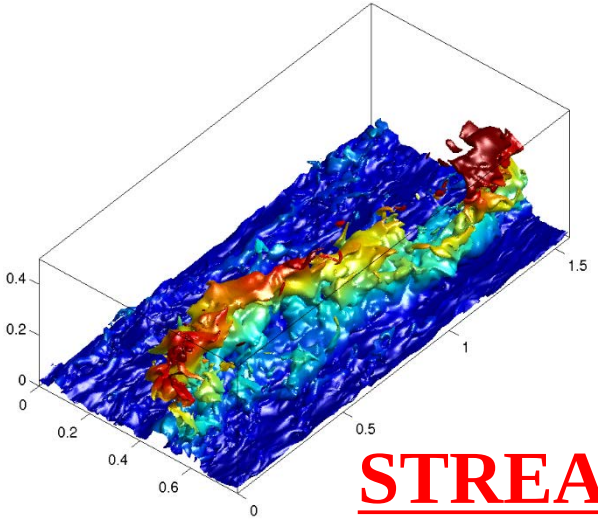




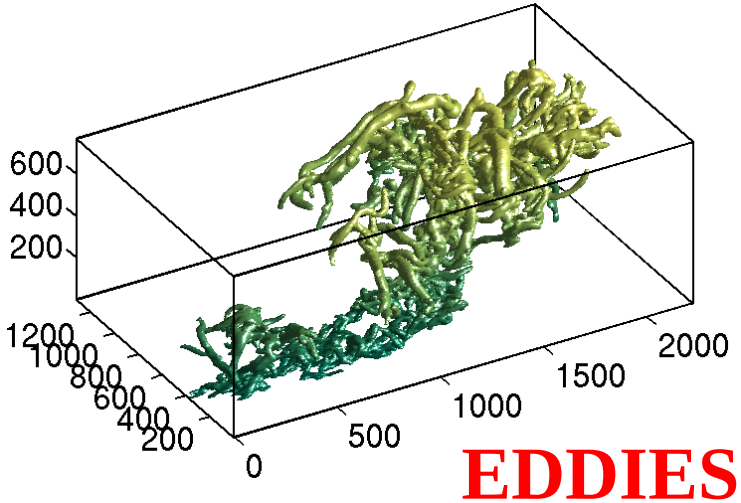
Eddies (-uv)

Mean+Perturbations = Linear ?

ONLY FOR: $Su_\lambda^2/\varepsilon >> 1$, $\lambda >> y/3$



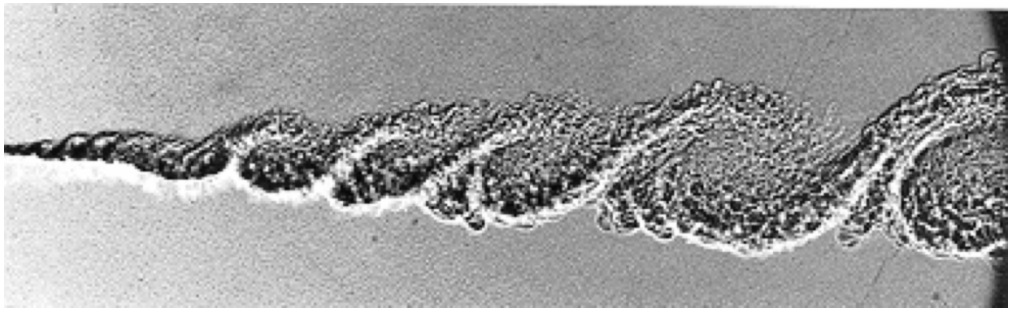
STREAKS

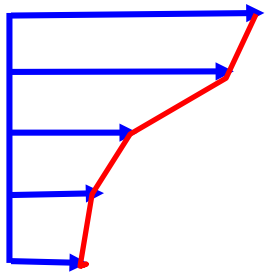


EDDIES

Linear Turbulence

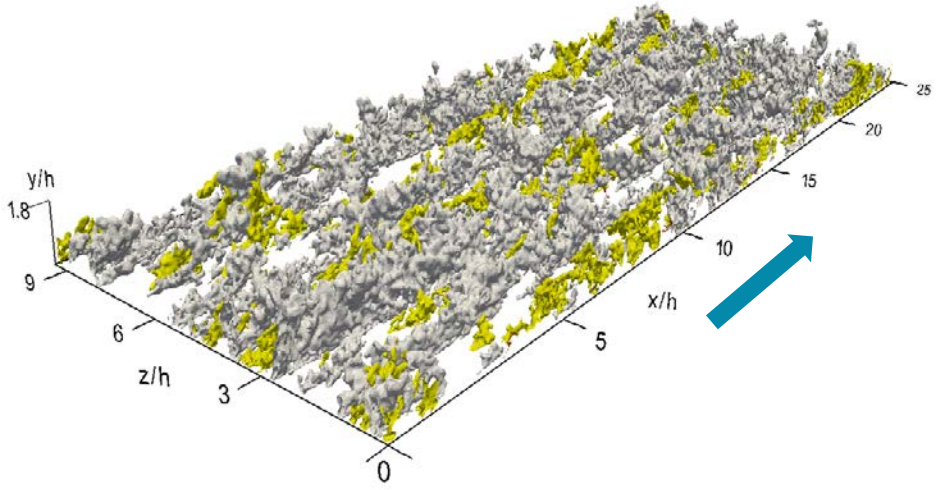
Free shear Flows

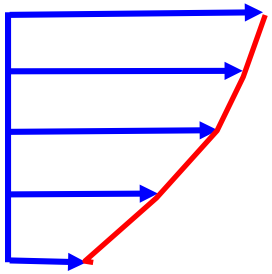




K-H Unstable

Wall-bounded Flows



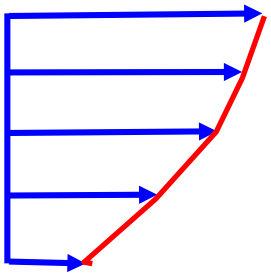


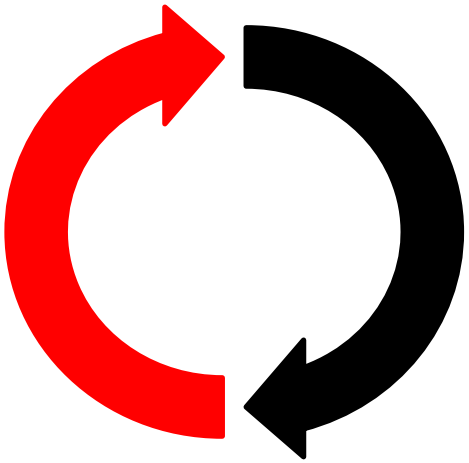
Stable

Where is the Energy Coming From?

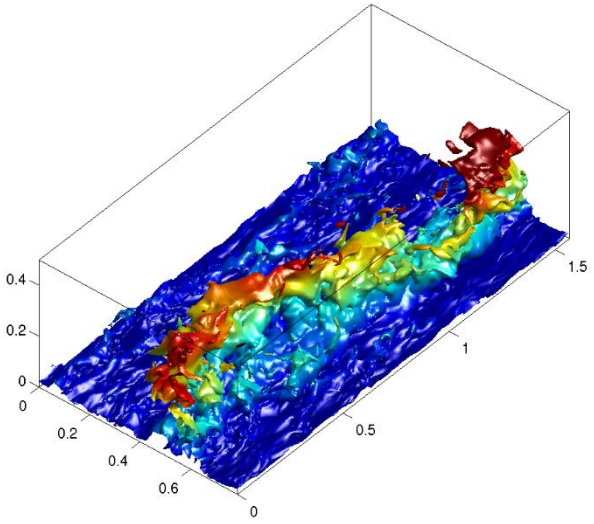
Streaks

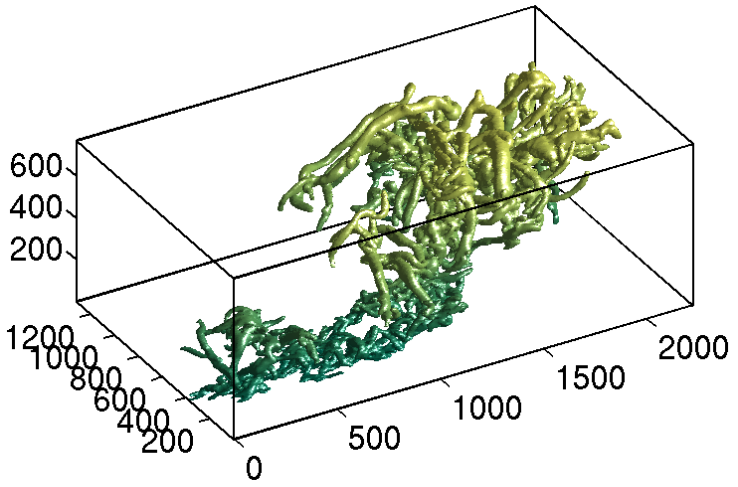
Mean Shear





Eddies (-uv)

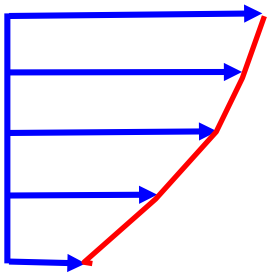


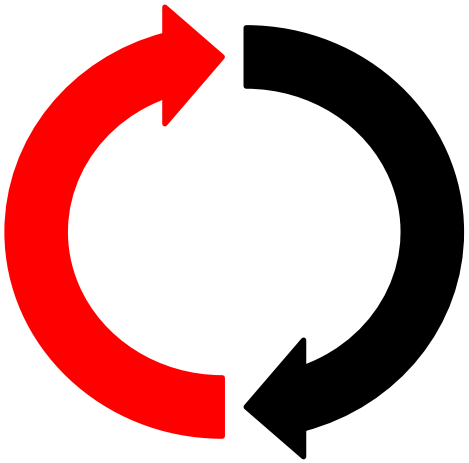


Where is the Energy Coming From?

Streaks

Mean Shear





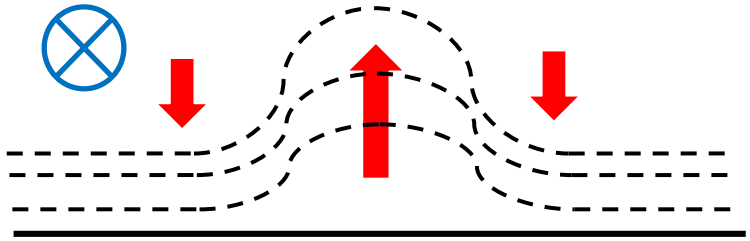
Eddies (-uv)

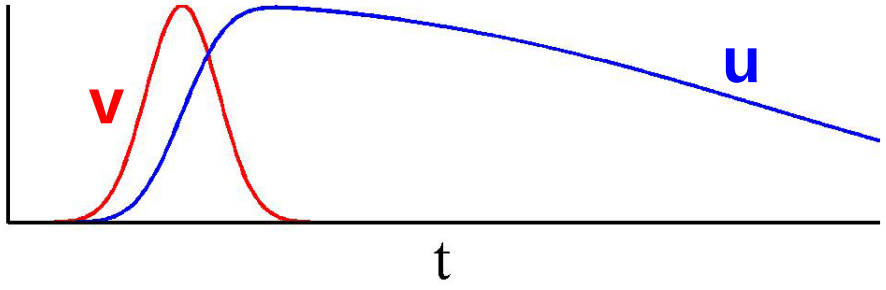
Linearised Squire Eq.

Lift-up

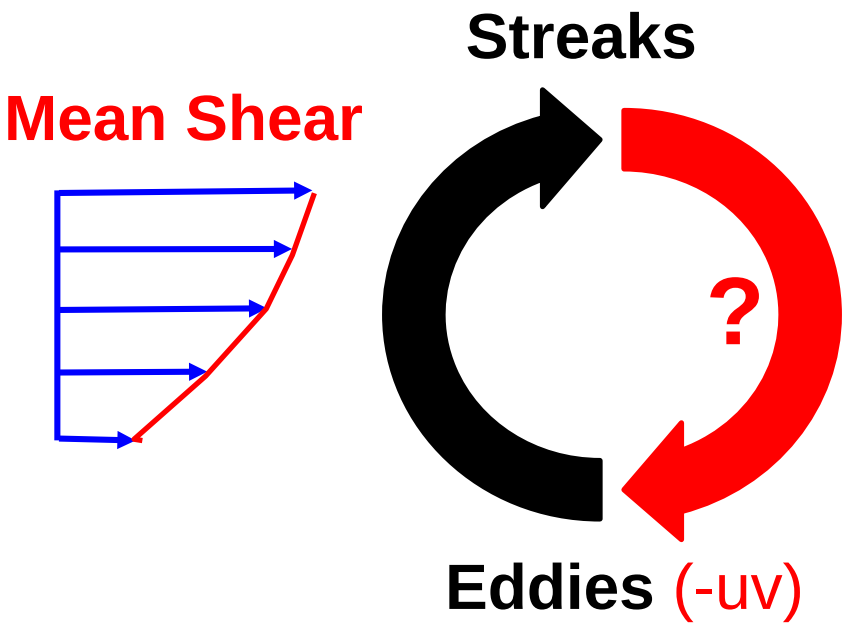
$$\left(D_t - \mu\nabla^2\right)\omega_y = -U'\partial_z v$$

“transient, viscous”





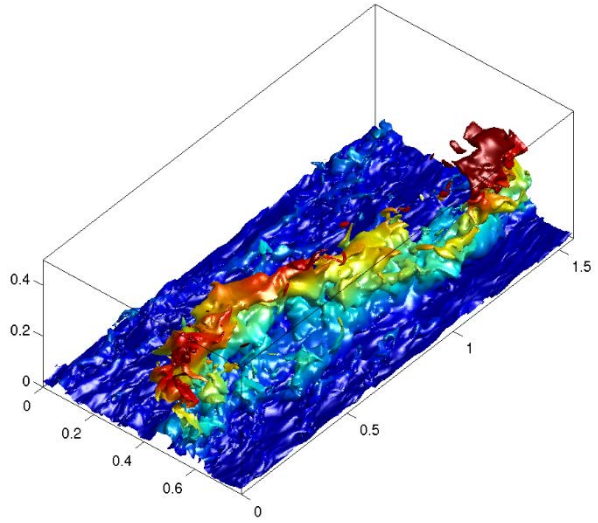
Where is the Energy Coming From?

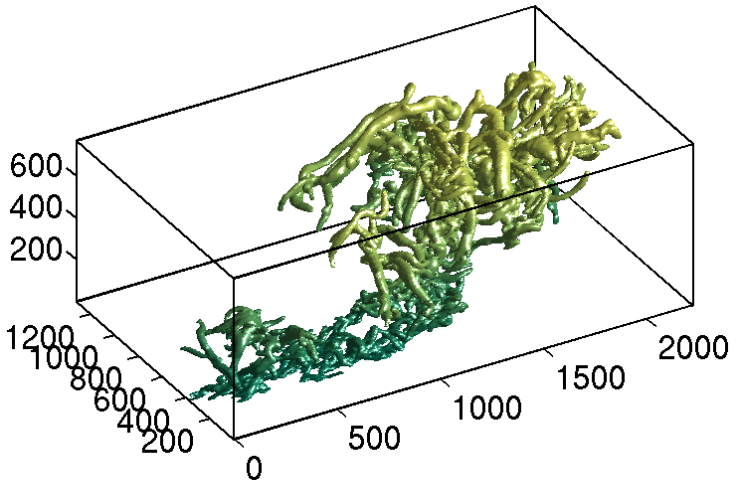


Linearised Orr-Sommerfeld
Kelvin-Helmholtz

$$\left(D_t - \mu\nabla^2\right)\nabla^2 v = U''\partial_x v$$

$$D_t = \partial_t + U(y)\,\partial_x$$





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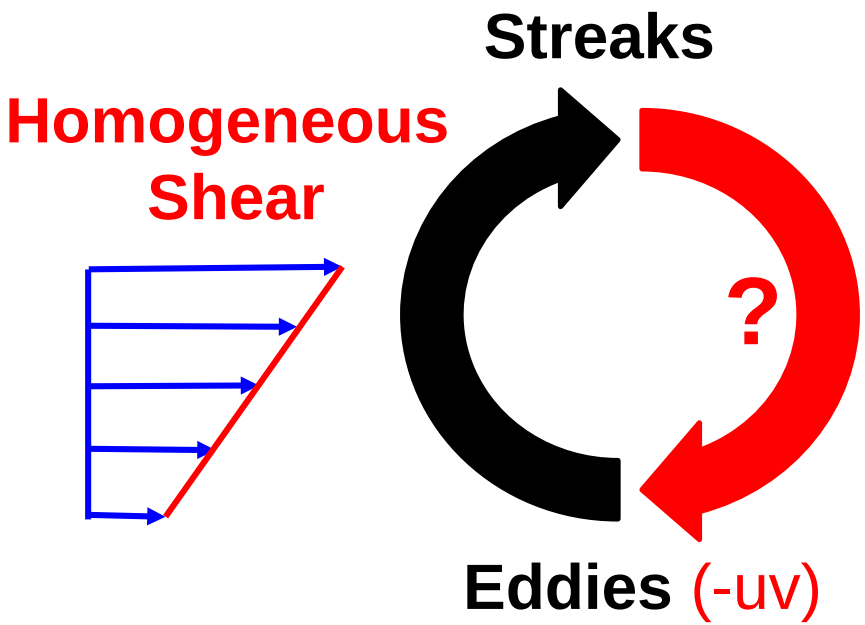

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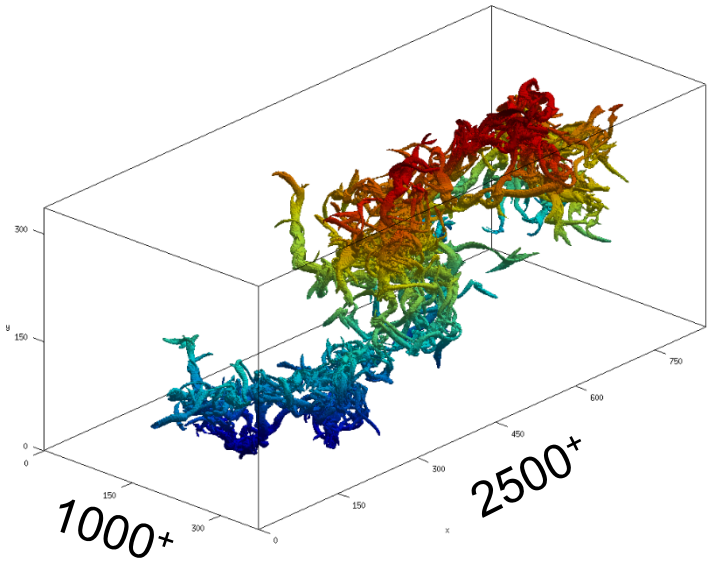
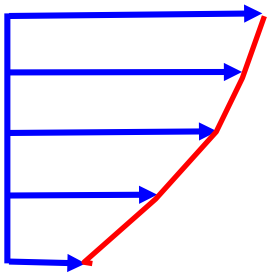


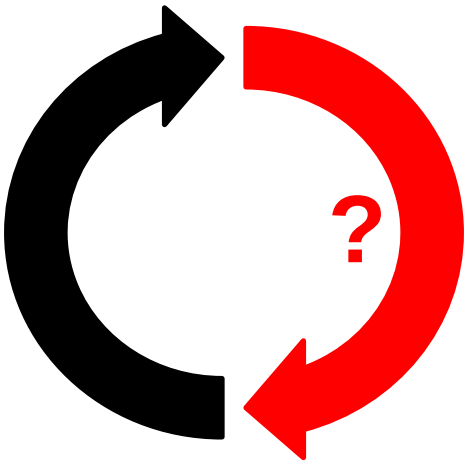
S. Dong (2013)

Where is the Energy Coming From?

Streaks

Mean Shear





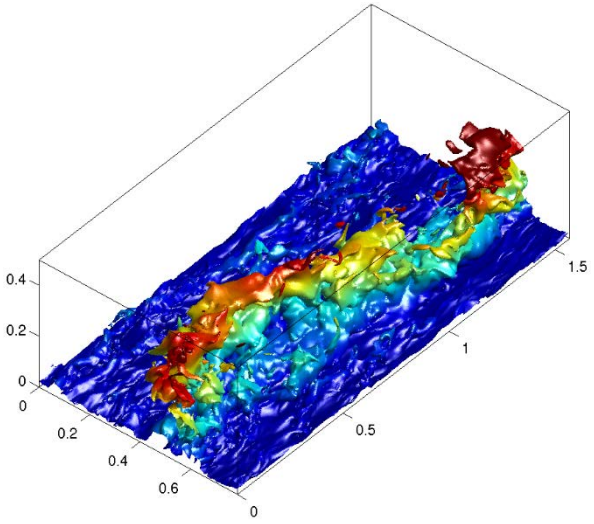
Eddies (-uv)

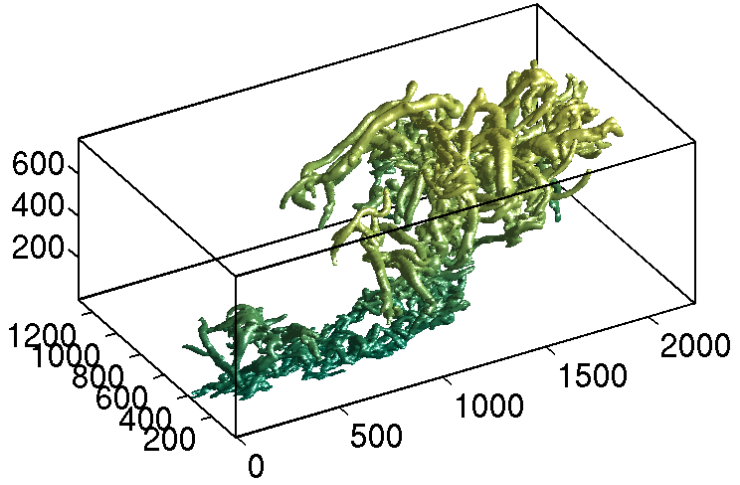
Linearised Orr-Sommerfeld

Orr

$$\left(D_t - \nu\nabla^2\right)\nabla^2 v = U''\partial_x v$$

$$D_t = \partial_t + U(y)\,\partial_x$$





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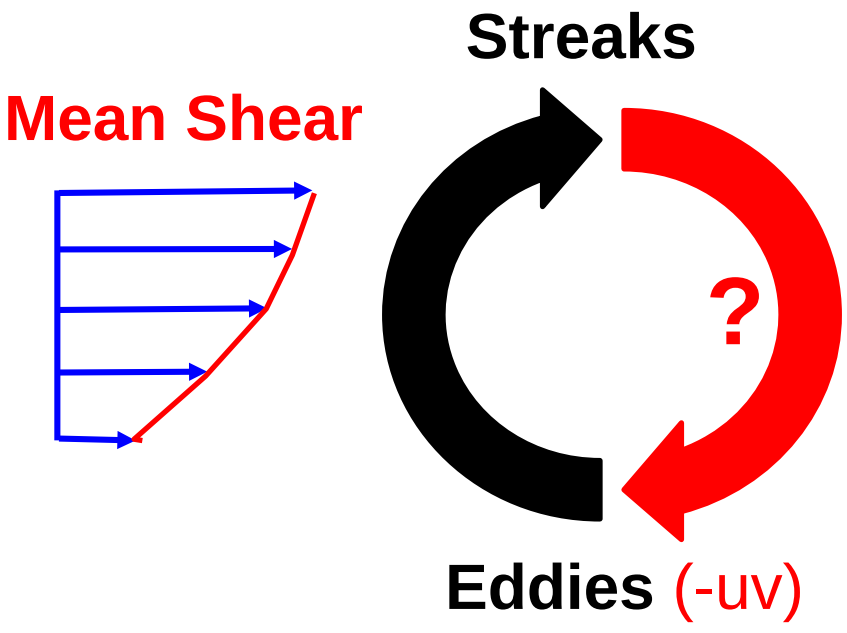


Linearised Orr-Sommerfeld

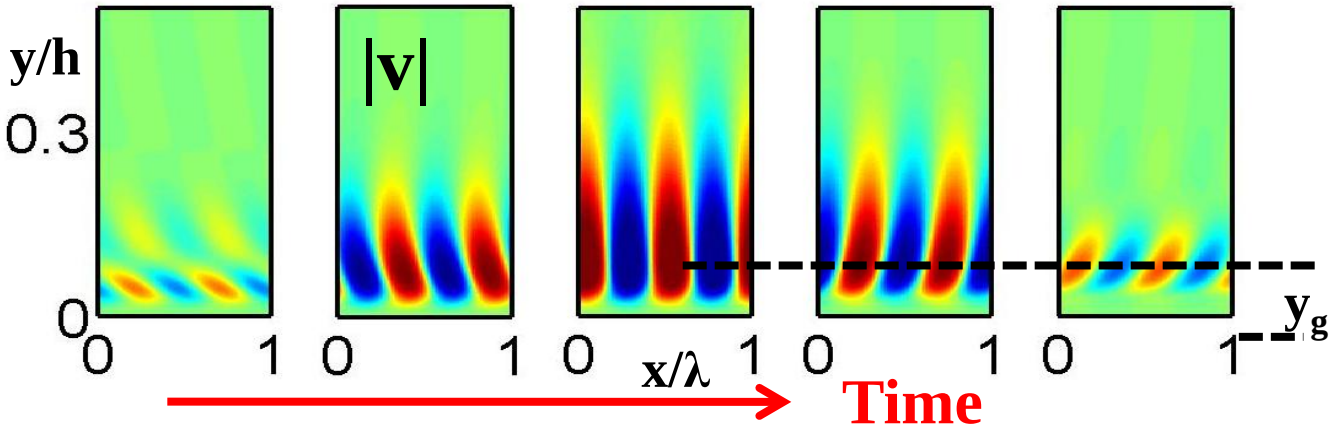
Orr

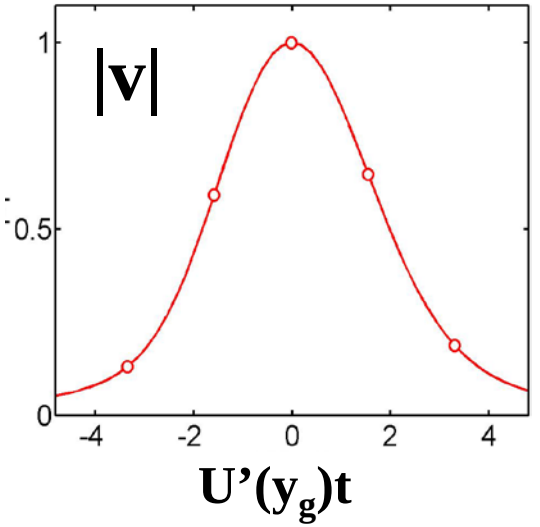
$$\left(D_t - \mu\nabla^2\right)\nabla^2 v = U''\partial_x v$$

$$D_t = \partial_t + U(y)\,\partial_x$$

"transient, inviscid"

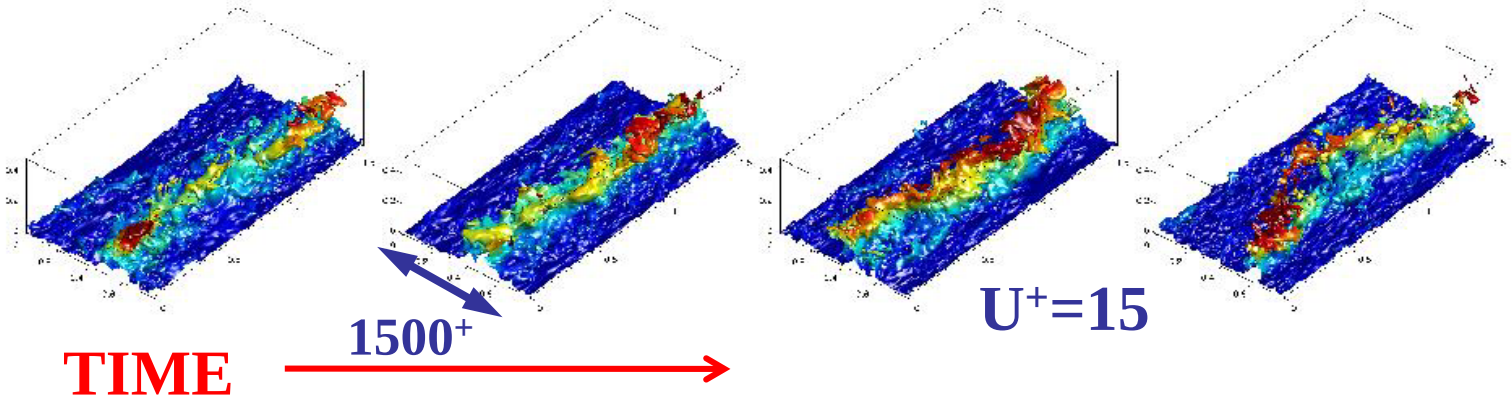
Channel, h^+=2000. λ/h=0.5

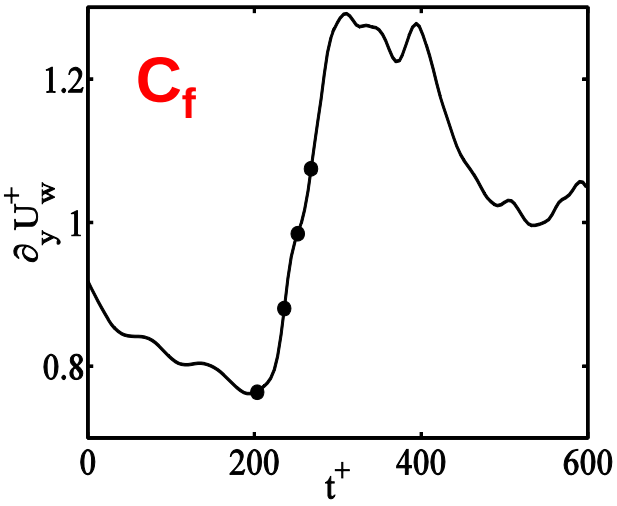


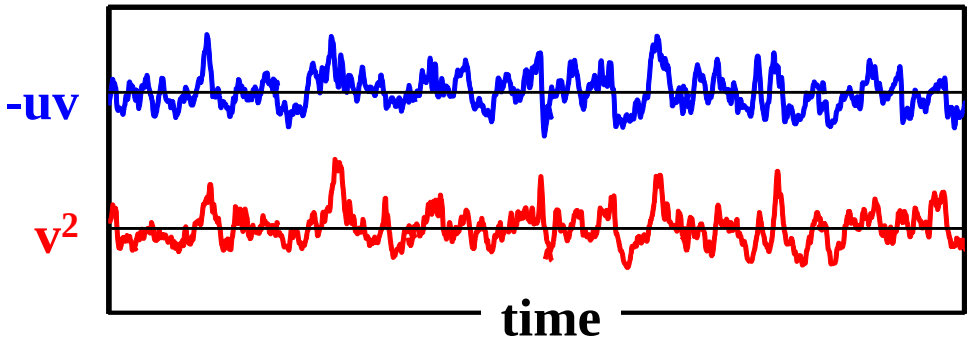


Wall Turbulence "Bursts"

"Minimal" Box, $h^+=1900$; $y/h=0.25$







Wall Turbulence "Bursts"

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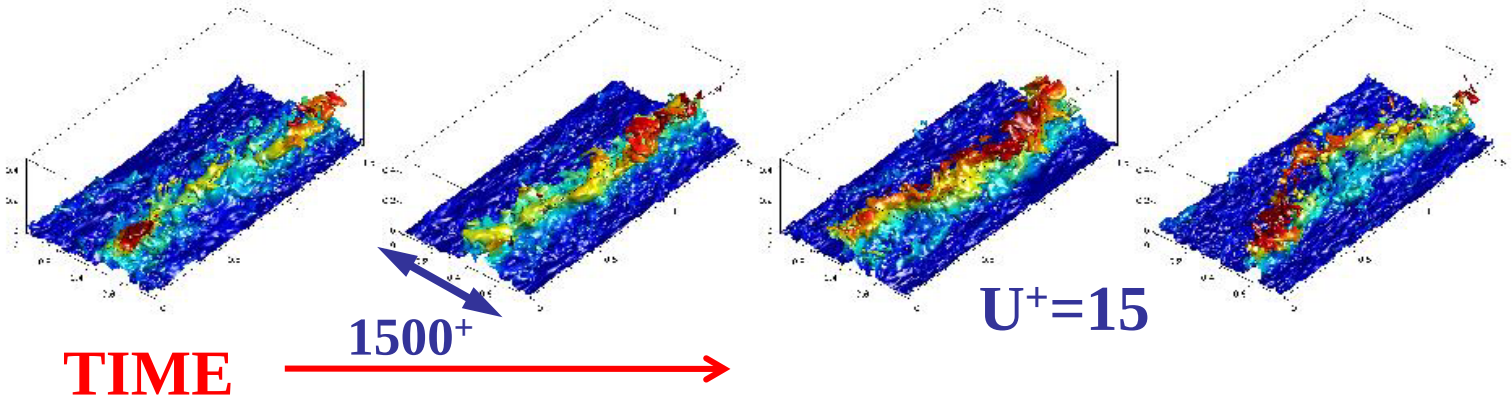
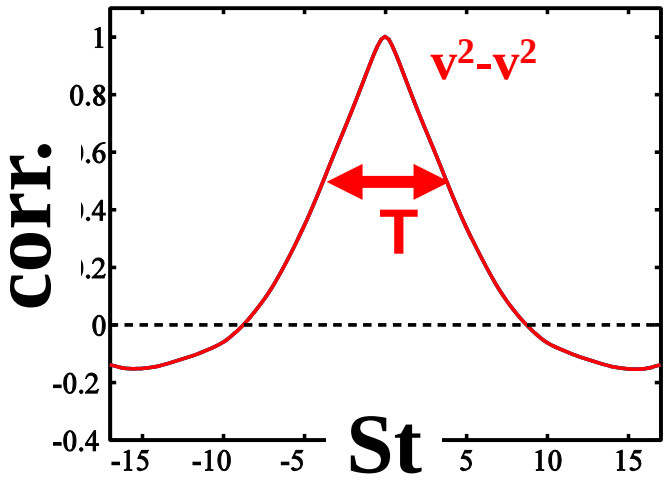
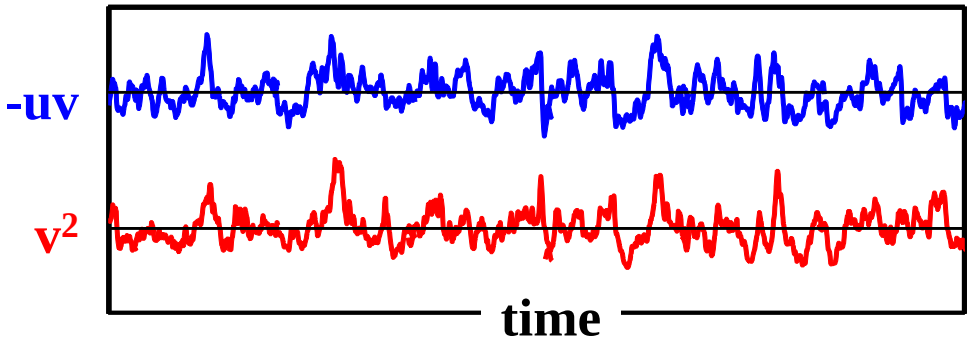
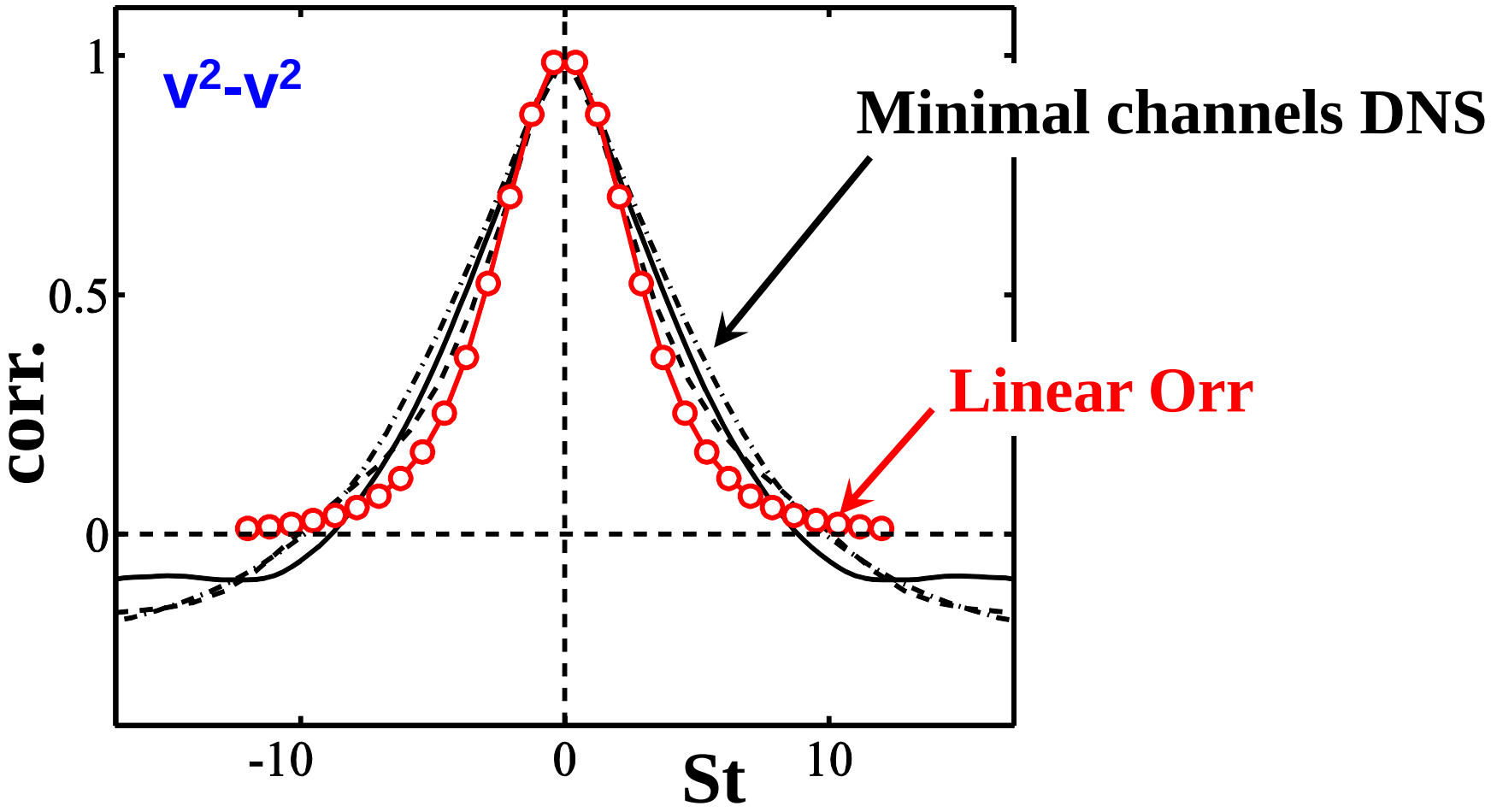




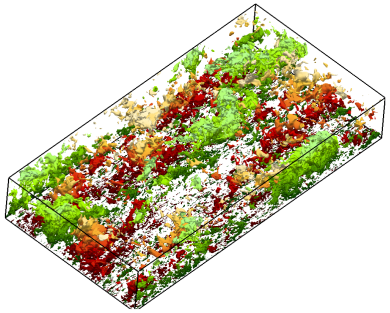


The Bursting Time History

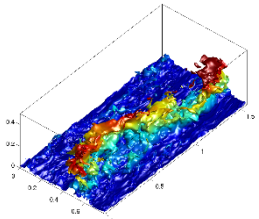


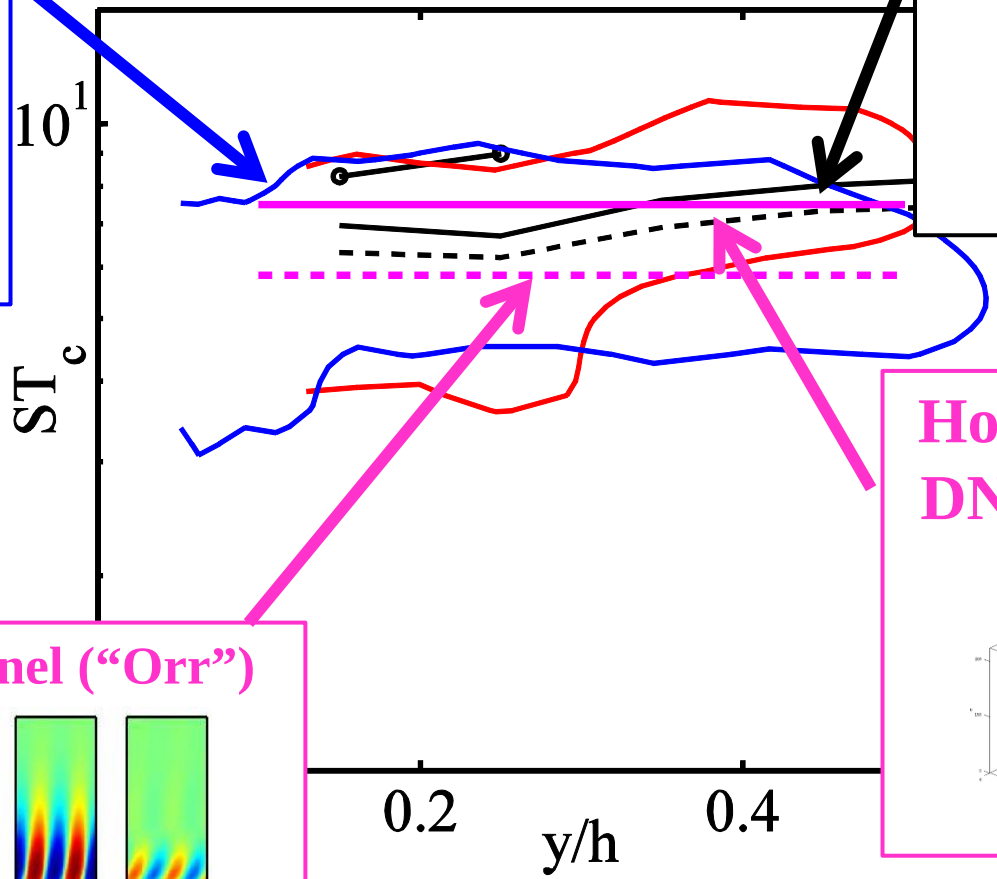
The Bursting Time Scale

Full Channels tracking

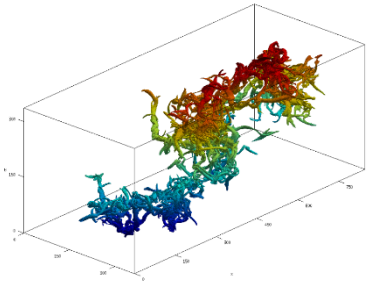


Minimal Box DNS Correlations

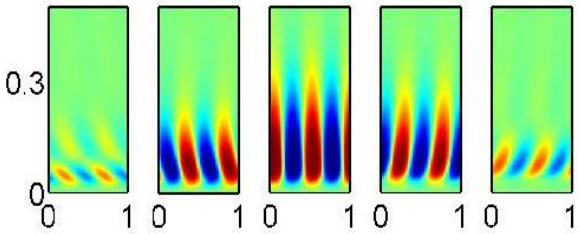




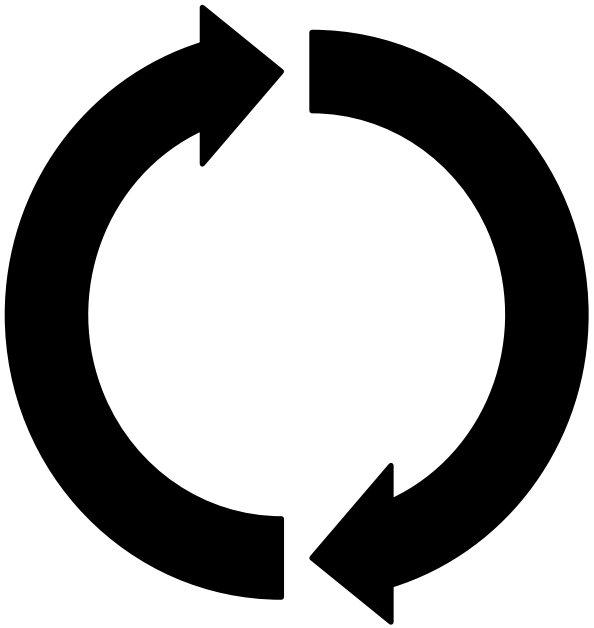
Hom. Shear Turb. DNS Correlations



LINEAR Channel ("Orr")

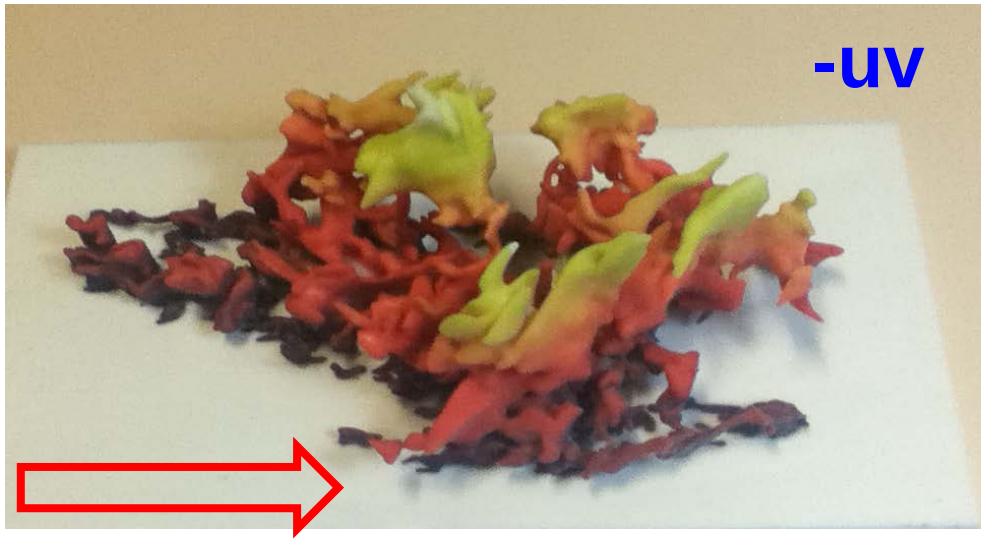


Summary



A Word for my Sponsored

Meet them in person at Pittsburgh



A. Lozano-Durán, O. Flores

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or from http://torroja.dmt.upm.es/