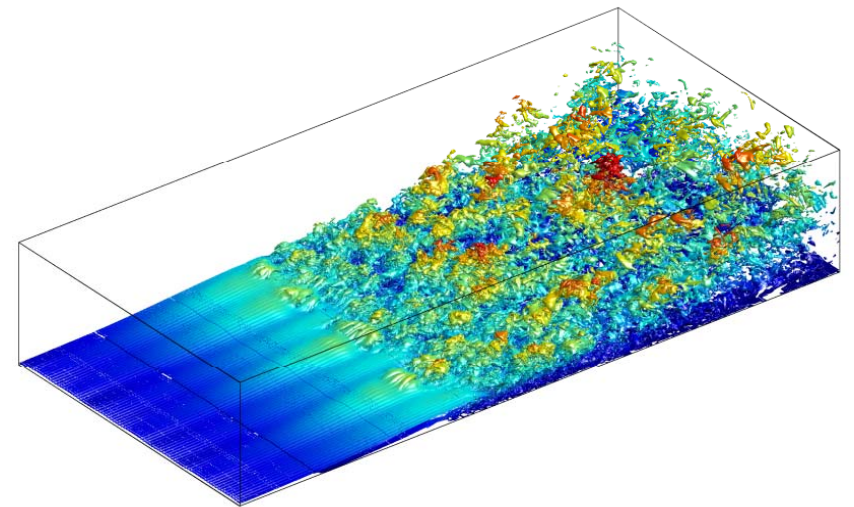
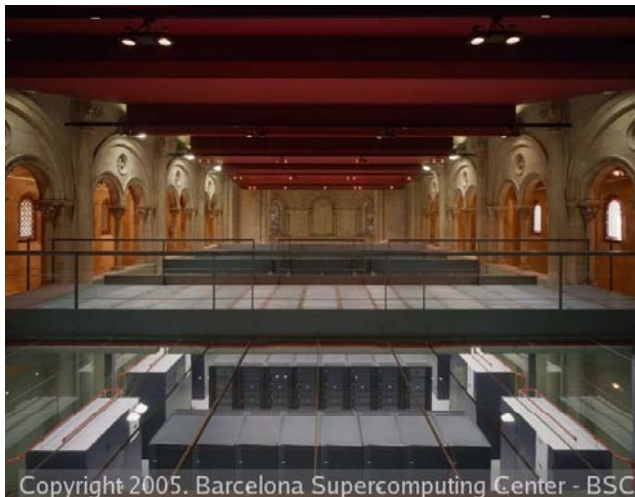


# Some Simulation Results in Wall-Bounded Turbulence

**Javier Jiménez**

**School of Aeronautics, Madrid  
And  
CTR, Stanford**



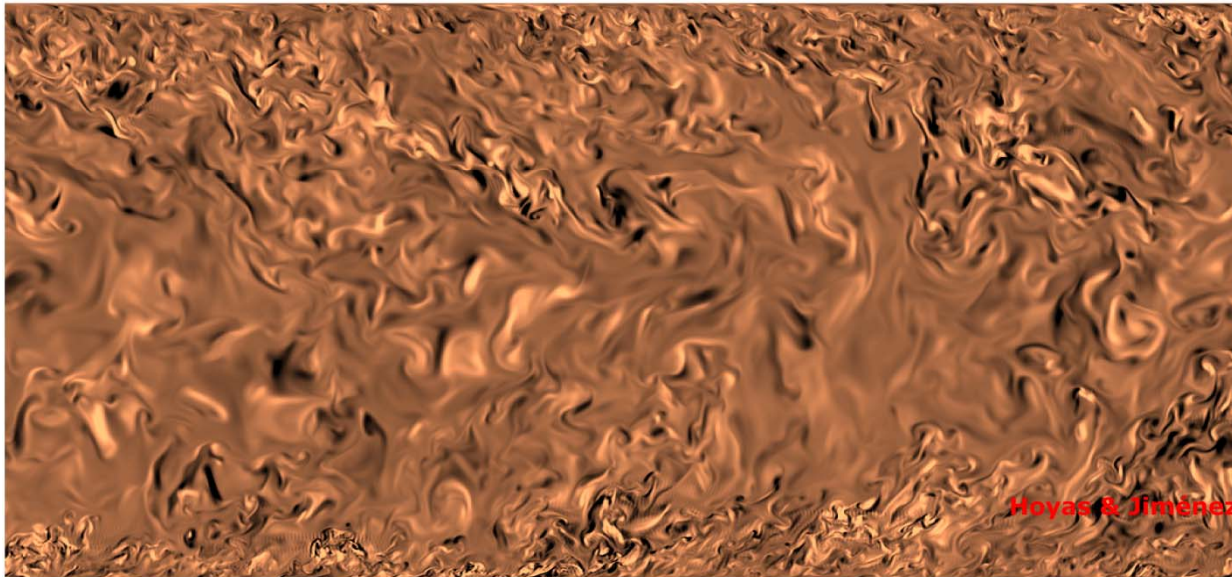
# Wall Turbulence

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**Anisotropic,  
Inhomogeneous,  
Intermittent,  
Very useful ...**



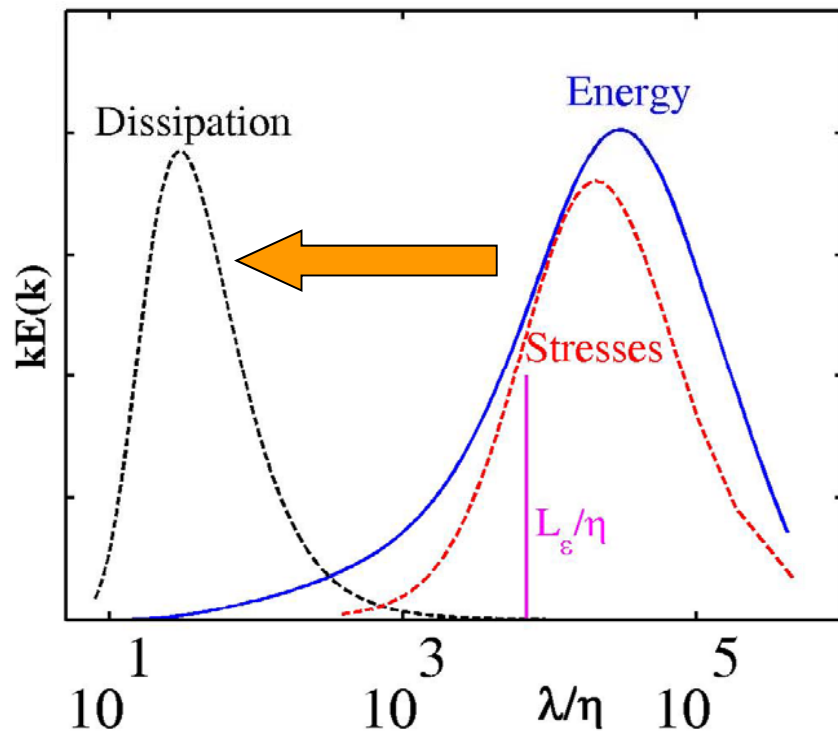
**WALL**



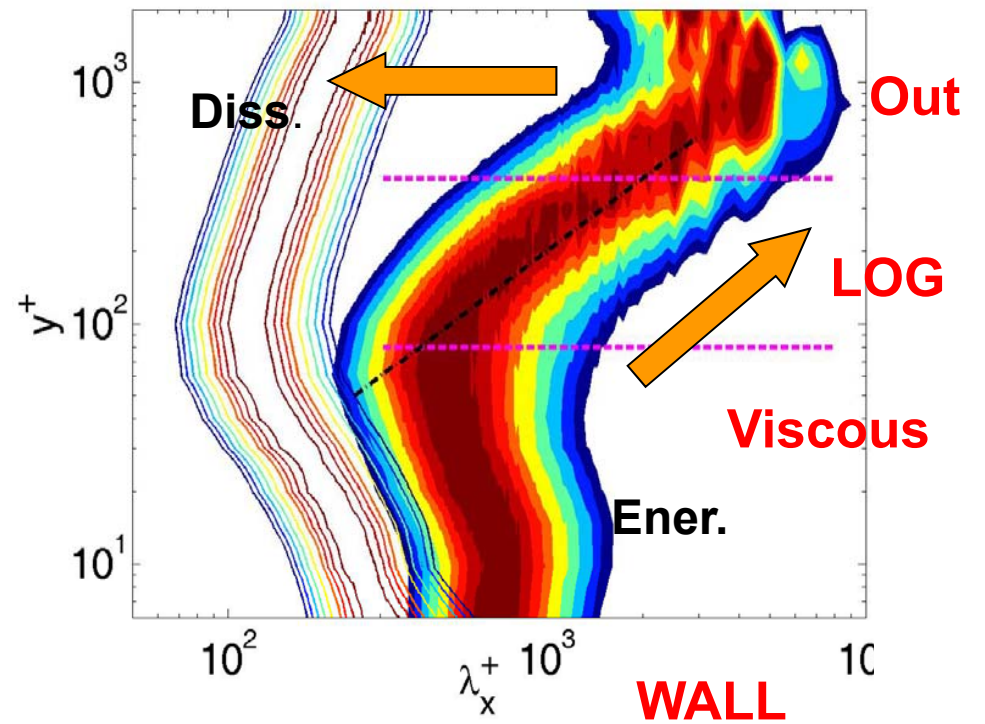
**WALL**

# The Energy Cascade

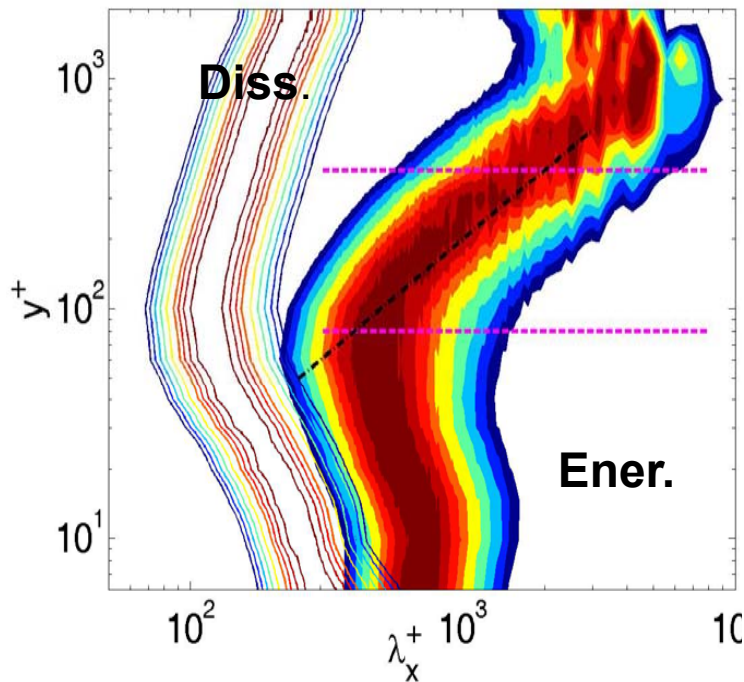
## Isotropic Cascade



## Wall Turbulence



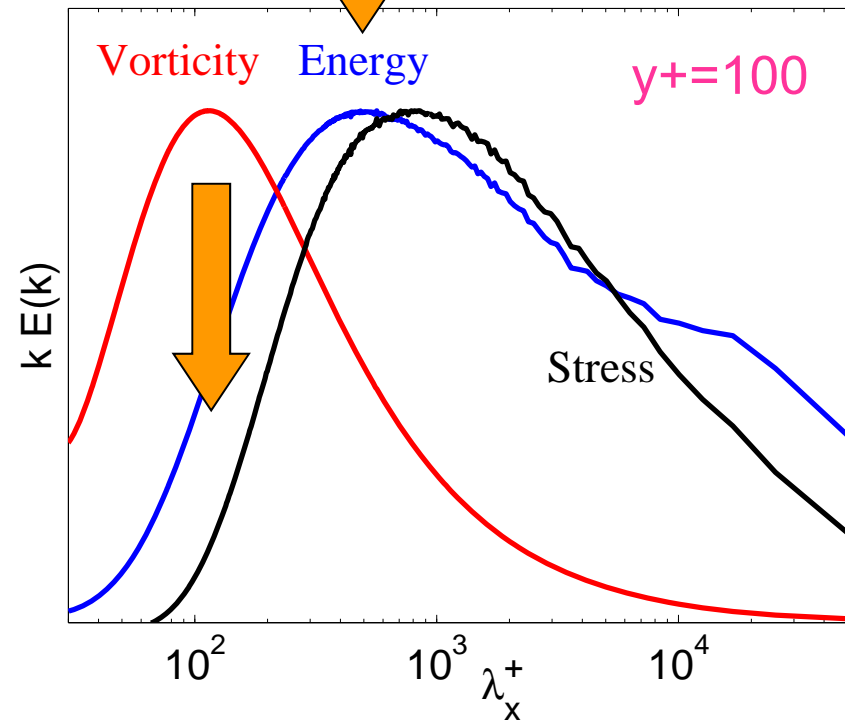
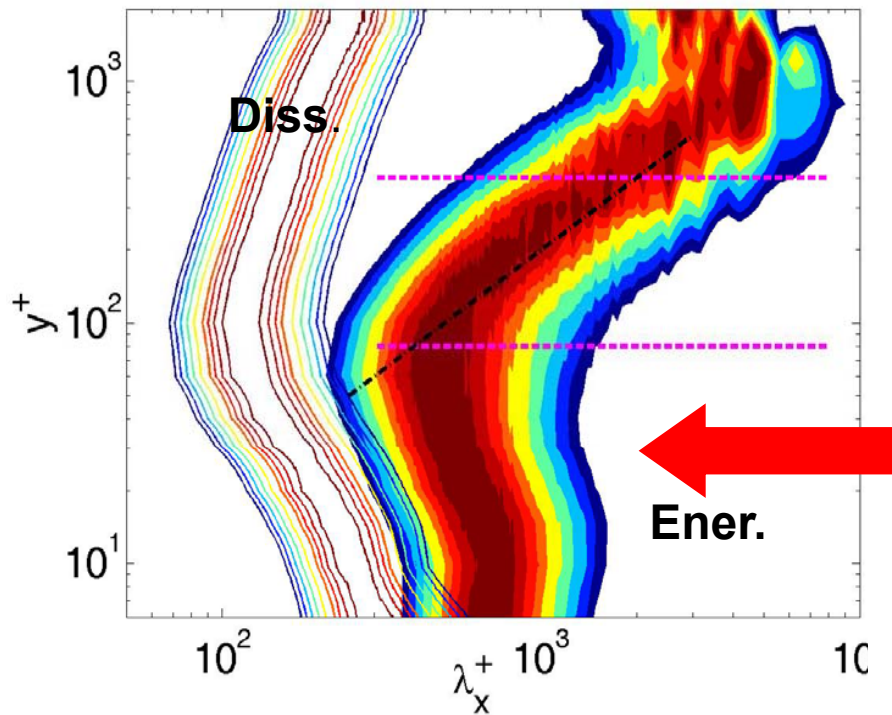
# The Range of Scales ( $\delta^+ = 2000$ )



	Velocity	Energy Product.	Energy Dissipat.	Momentum Scales (y)
Outer	0.18	0.19 → 0.21		0.80
Log	0.17	↑ 0.28 → 0.28		↓ 0.16
Visc.	0.65	↑ 0.53 → 0.51		↓ 0.04

**WALL**

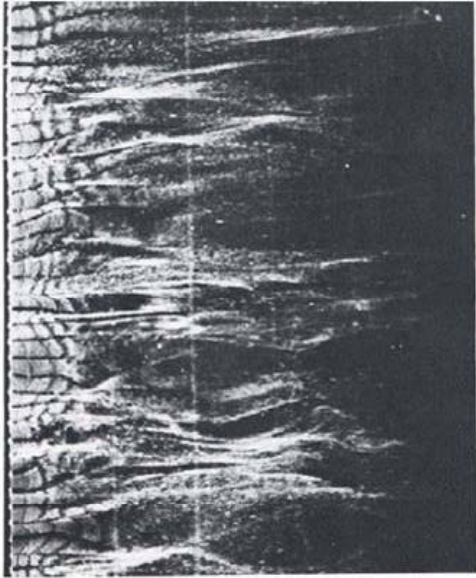
# The Viscous Layer (DNS 1990's)



**Scale of Energy = Stress = Dissipation  
ONE Scale**

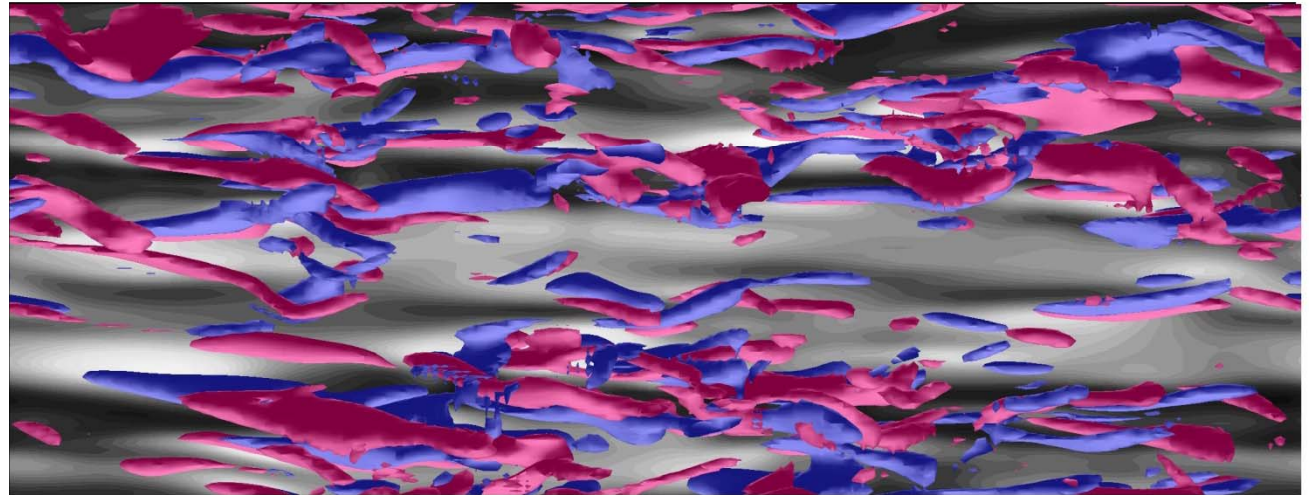
# Viscous Layer Kinematics

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Pre-KMM87

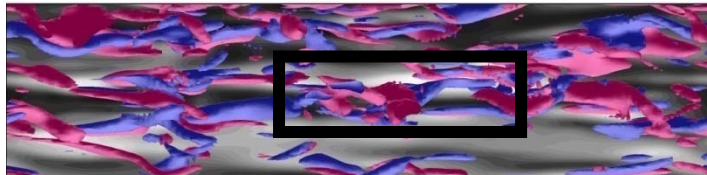
**DNS** by Kim, Moin, Moser 1987



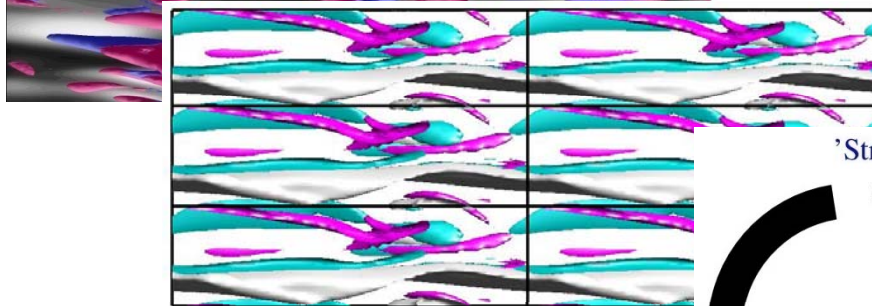
Vortices, Streaks, ..

# Viscous Layer Dynamics

1987



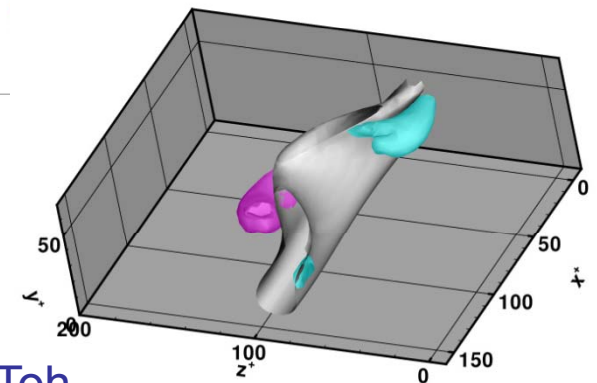
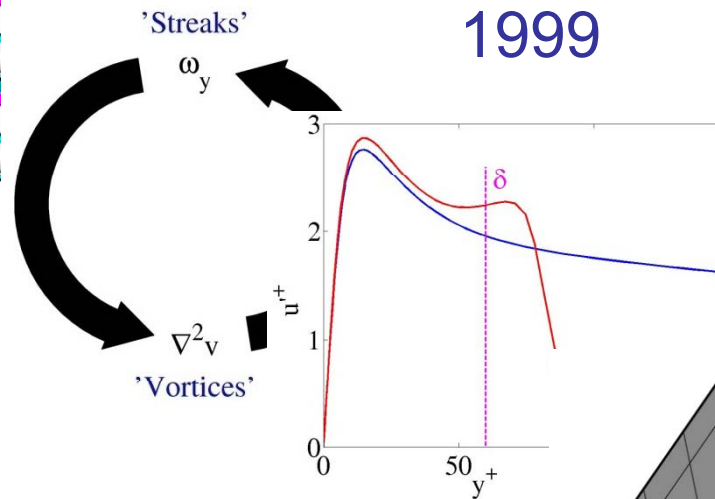
1991



1994

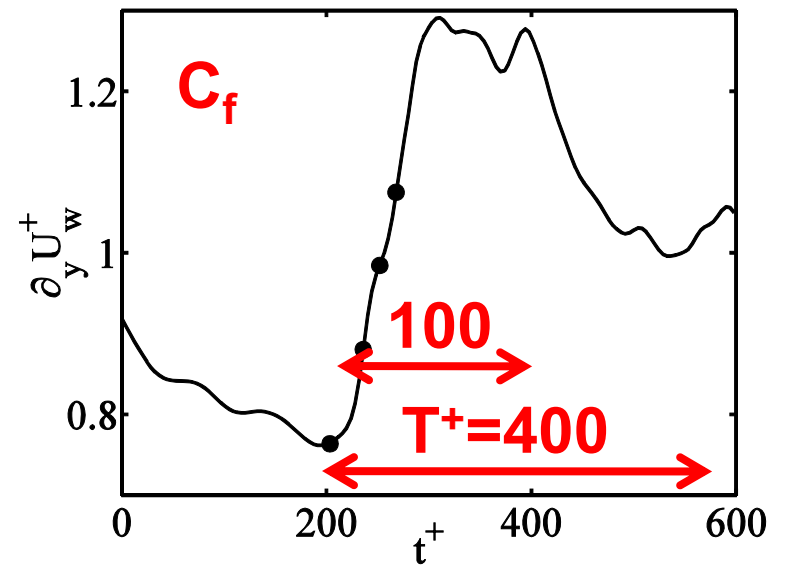
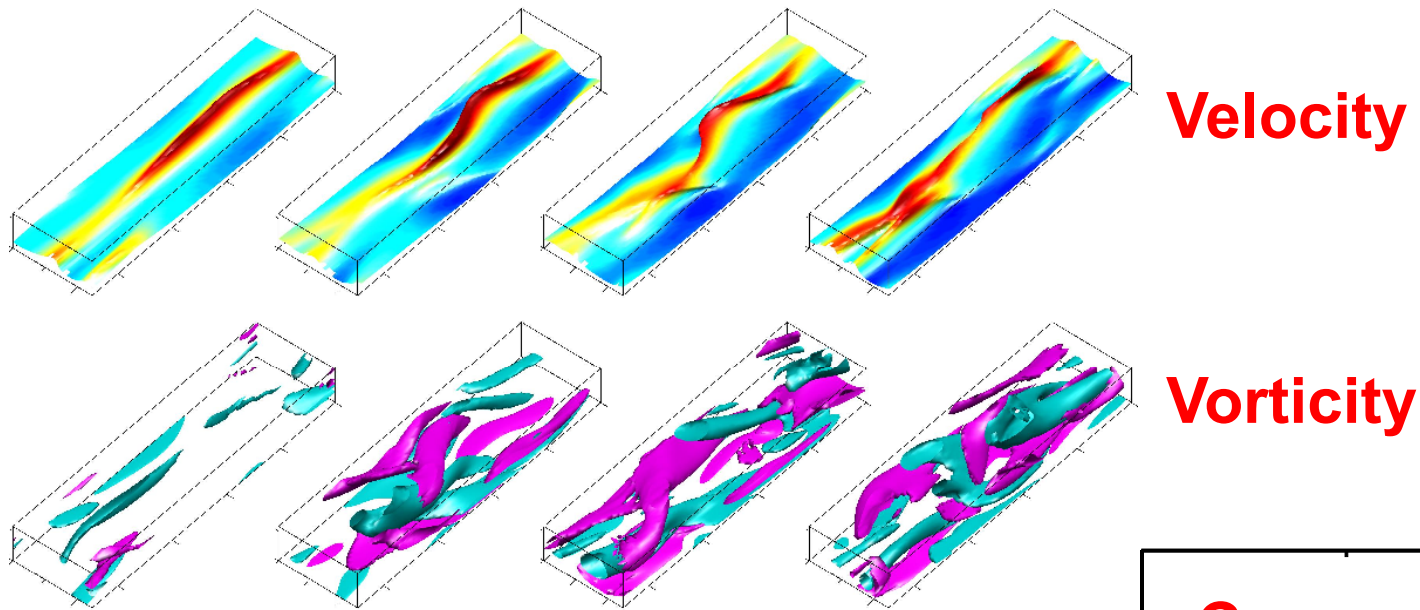
1999

1990-2001



Kim, Moin, Moser, Spalart,  
 Kline, Robinson, Jiménez, Hamilton,  
 Waleffe, Aubry, Holmes, Lumley, Stone,  
 Schoppa, Hussain, Pinelli, del Alamo, Flores, Busse,  
 Ehrestein, Itano, Koch, Kawahara, Kida, Nagata, Simens, Toh,...

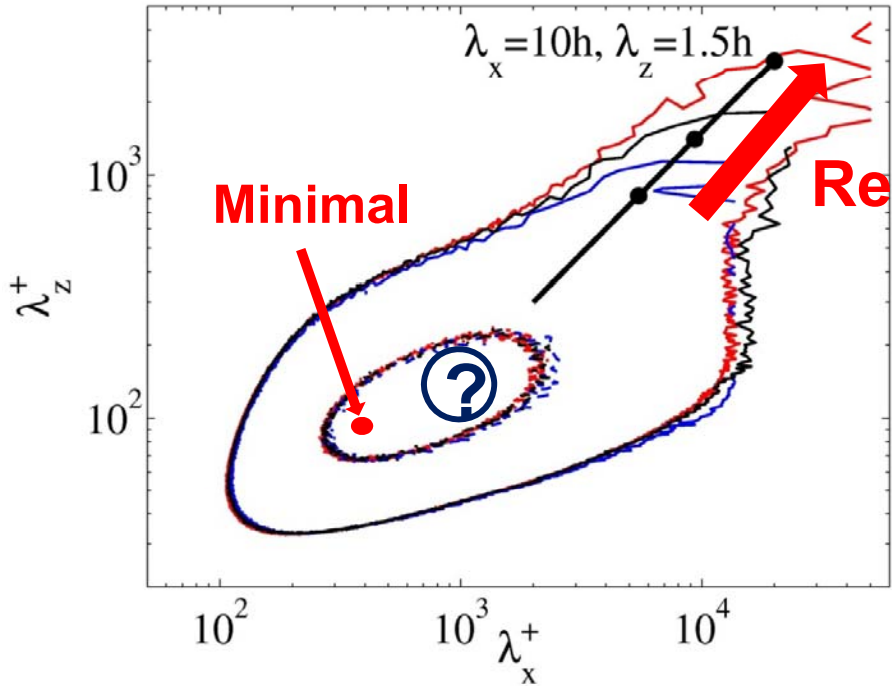
# Minimal Boxes **Burst**



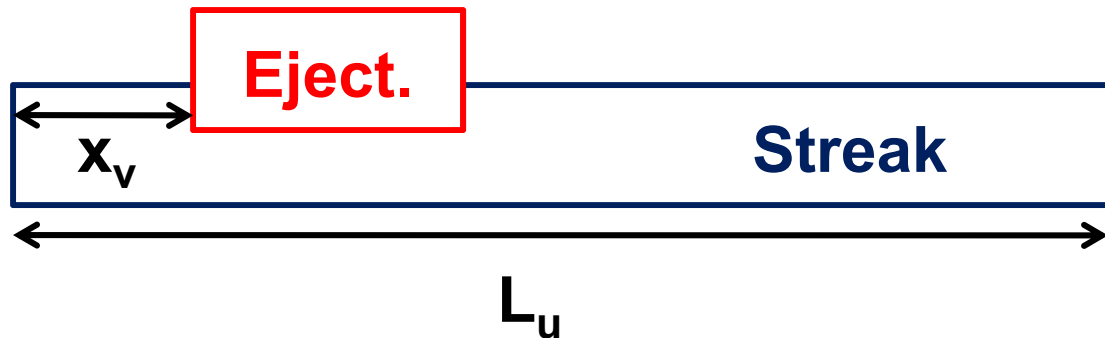
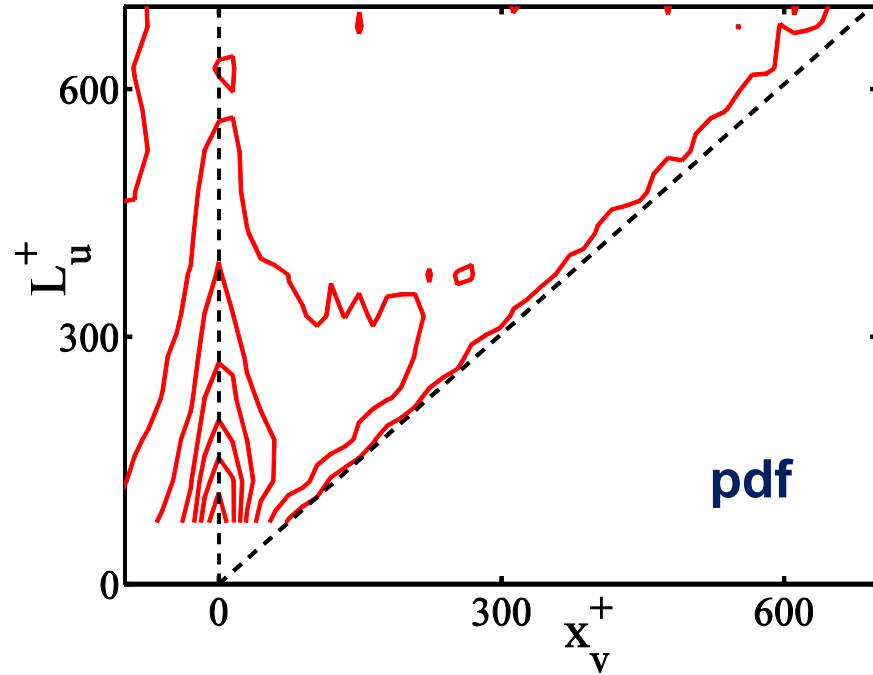
Jiménez et al. (2005)

# Streaks are Longer (Wakes)

## Energy Spectrum $y^+=15$



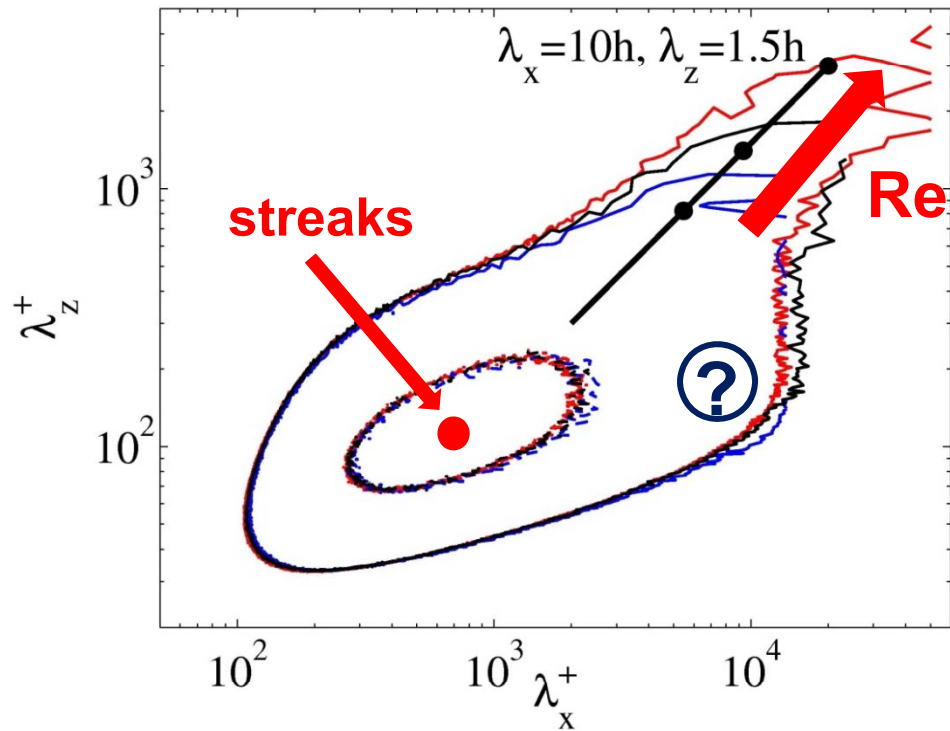
## Ejections within streak



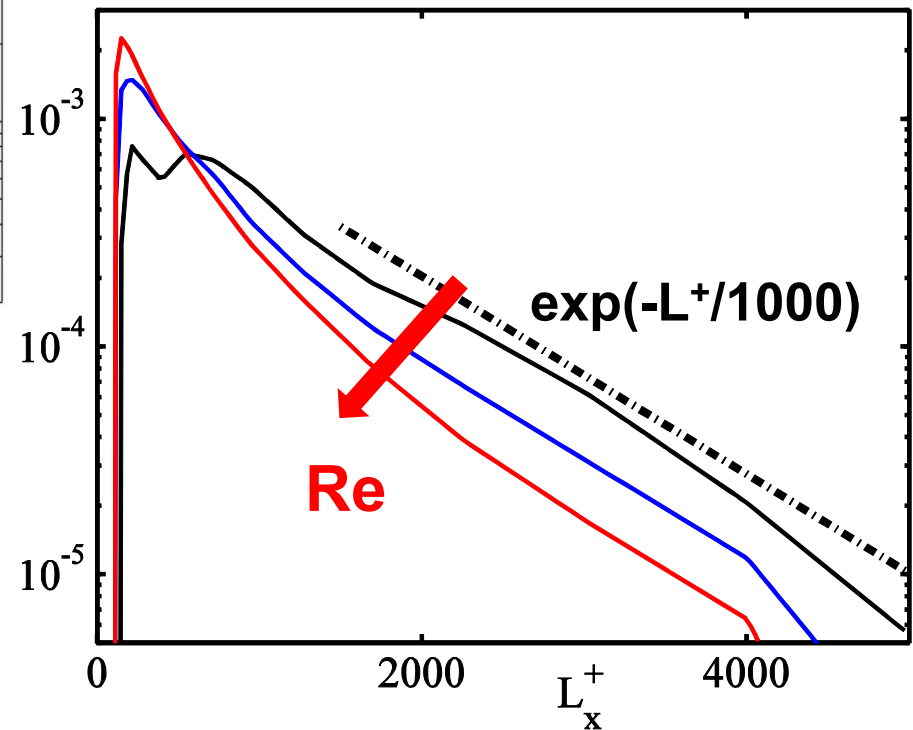
Jiménez et al. (2004)

# Streaks are **much** Longer

## Energy Spectrum $y^+=15$

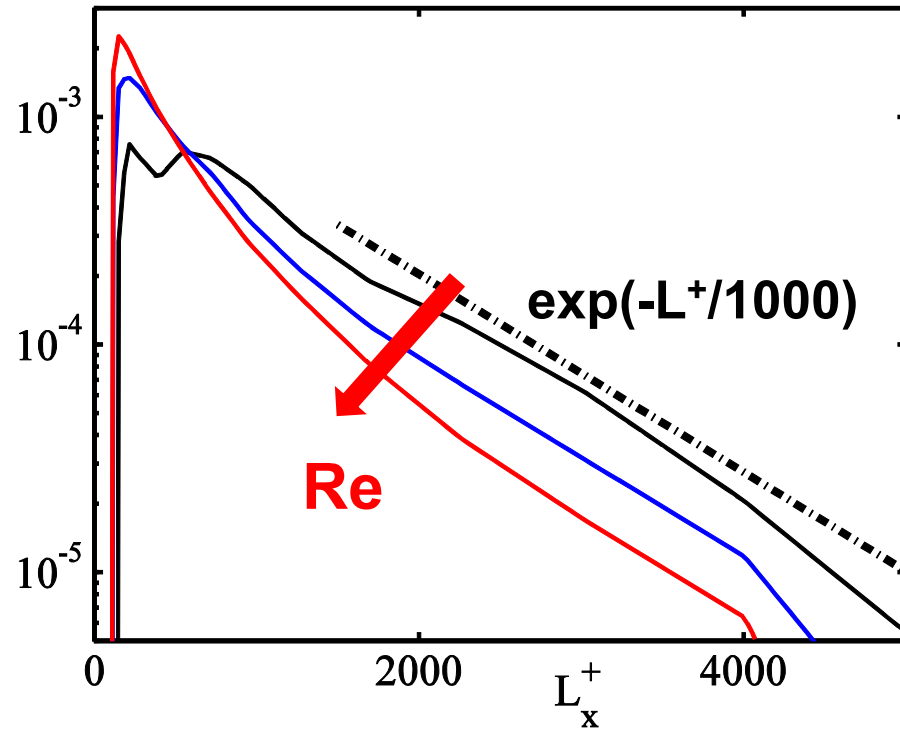


## Pdf of Streak Length



Jiménez et al. (2004)

# Poisson's Accretion



$$\frac{q}{L_0} \frac{q}{L_0} \frac{q}{L_0} \dots (1-q)$$

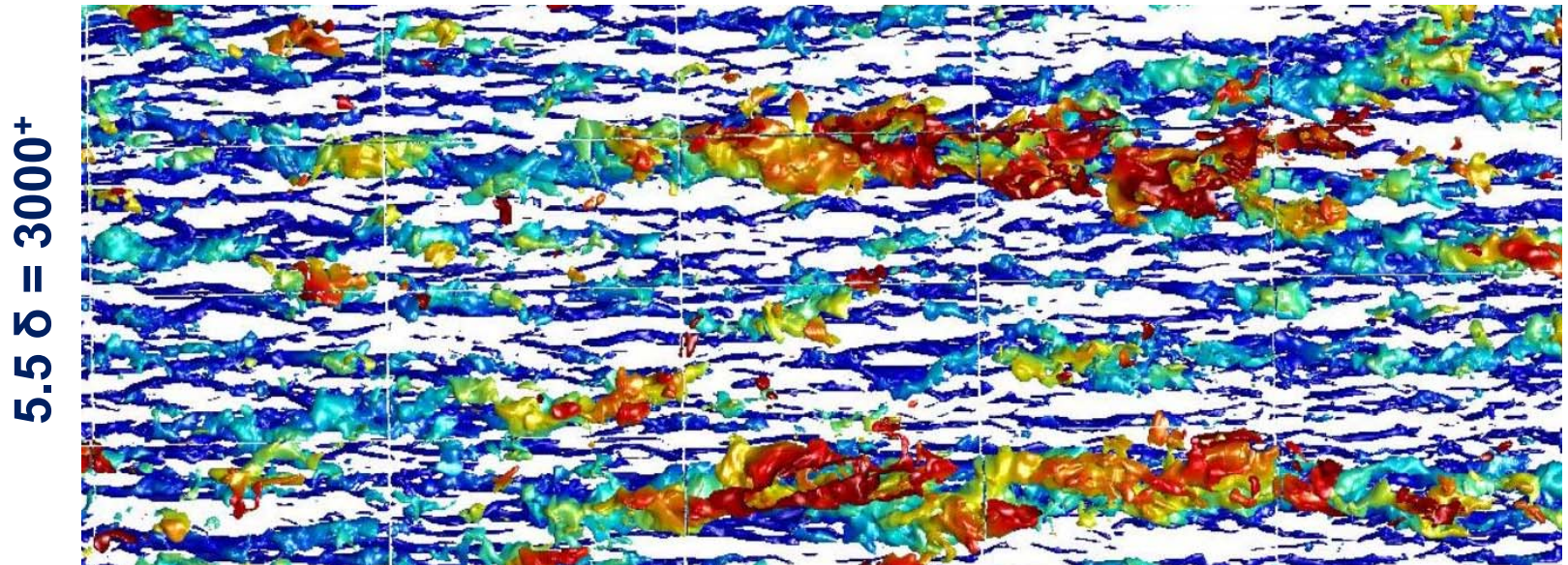
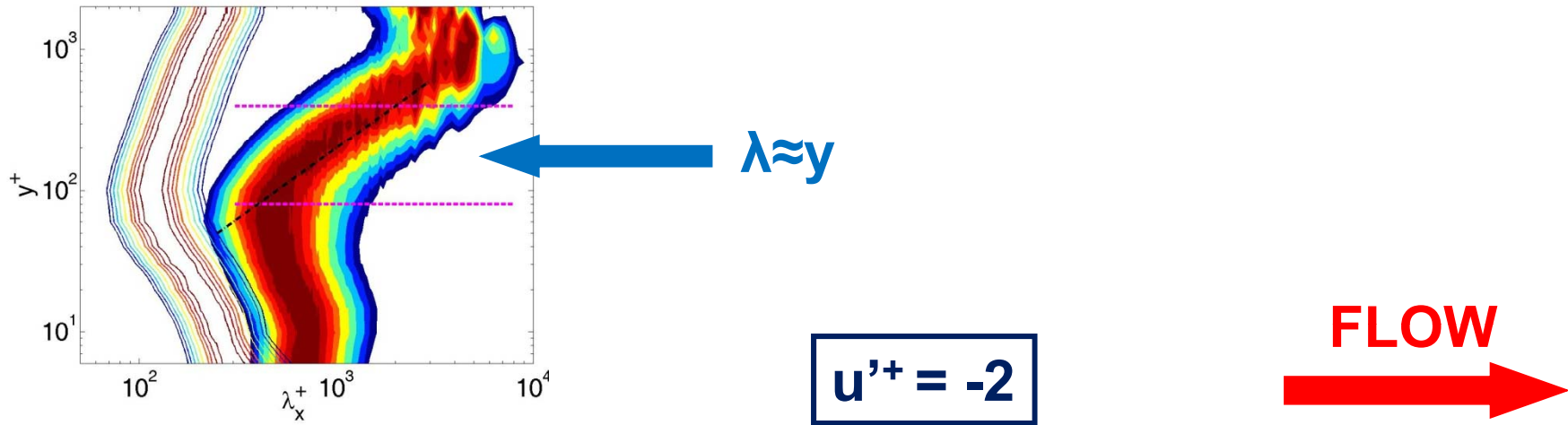
$$P(n) = q^n (1-q)$$

$$P(L) = \exp(-L |\log(q)| / L_0)$$

$$L_0^+ \approx 500; q \approx 0.6$$



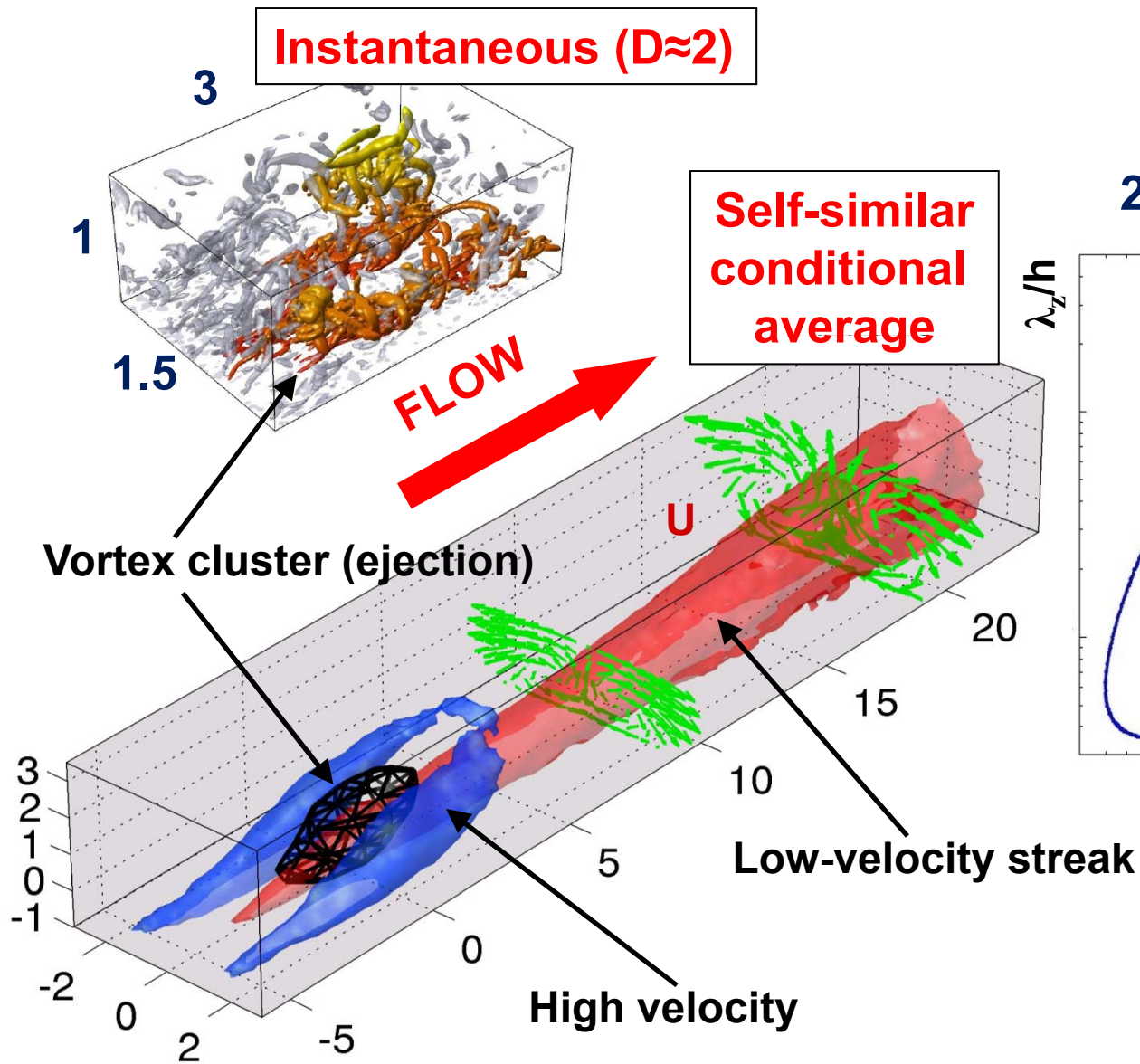
# Logarithmic Layer (DNS 2000's)



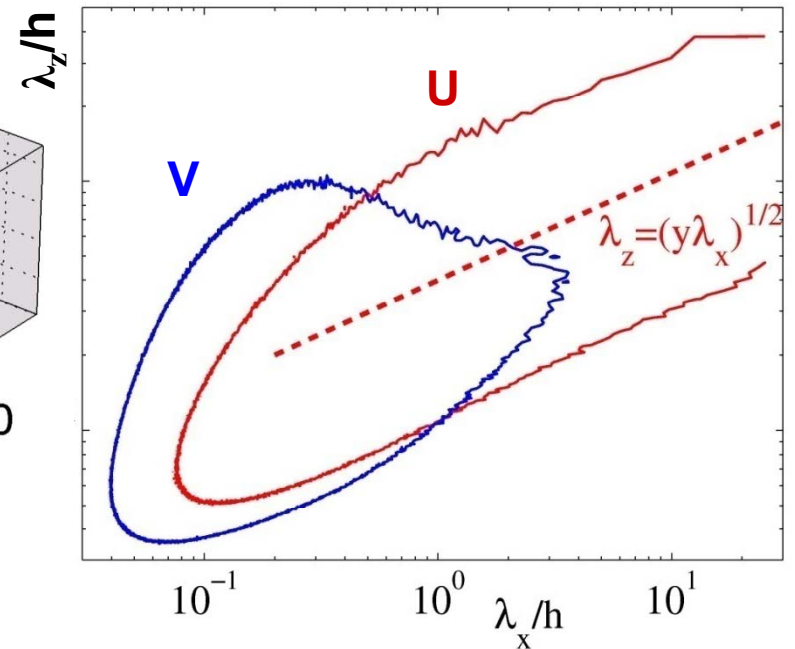
Flores (2007)

$15.5 \delta = 8500^+$

# Vortices and Streaks (log-layer)

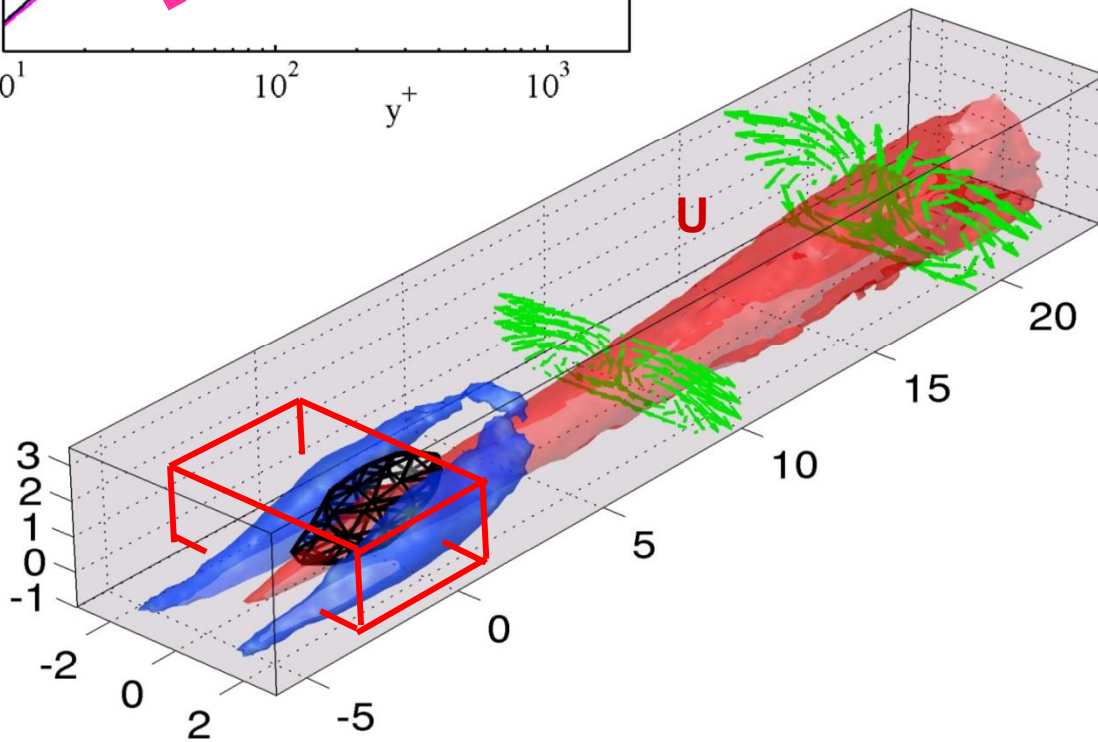
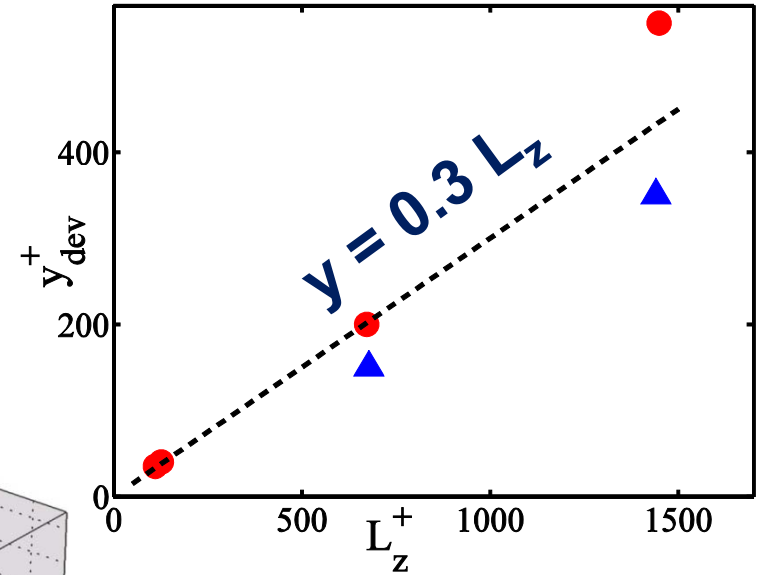
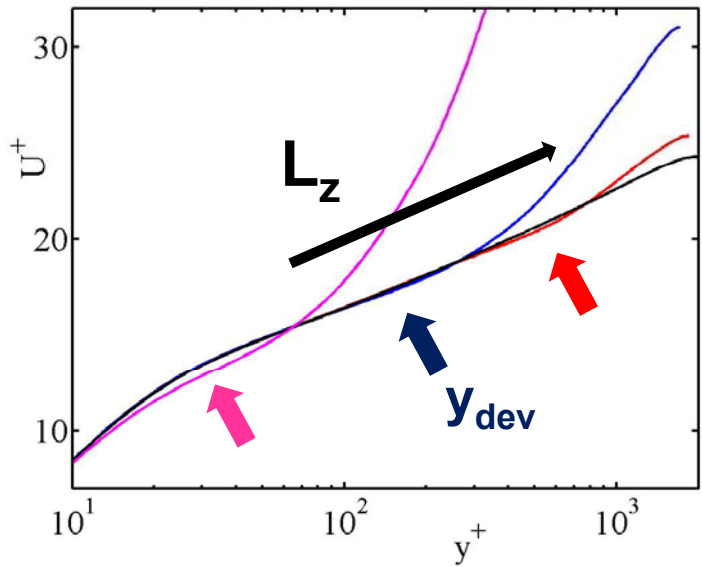


**2-D Spectrum at  $y/h=0.1$**



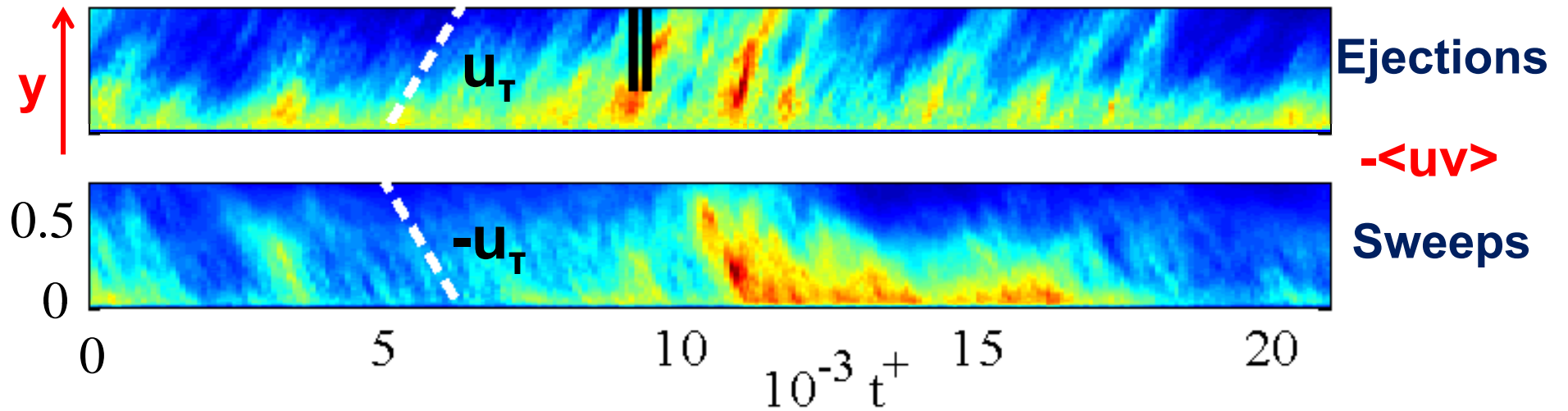
Del Alamo et al. (2006)

# Vortices run in Minimal boxes

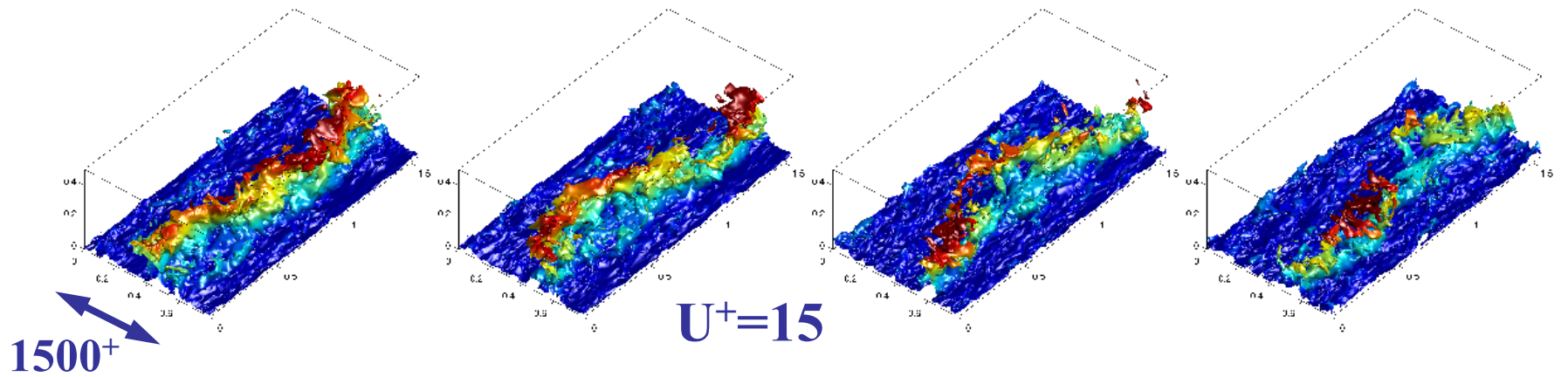


Flores. (2007)

# Minimal Boxes **Burst**

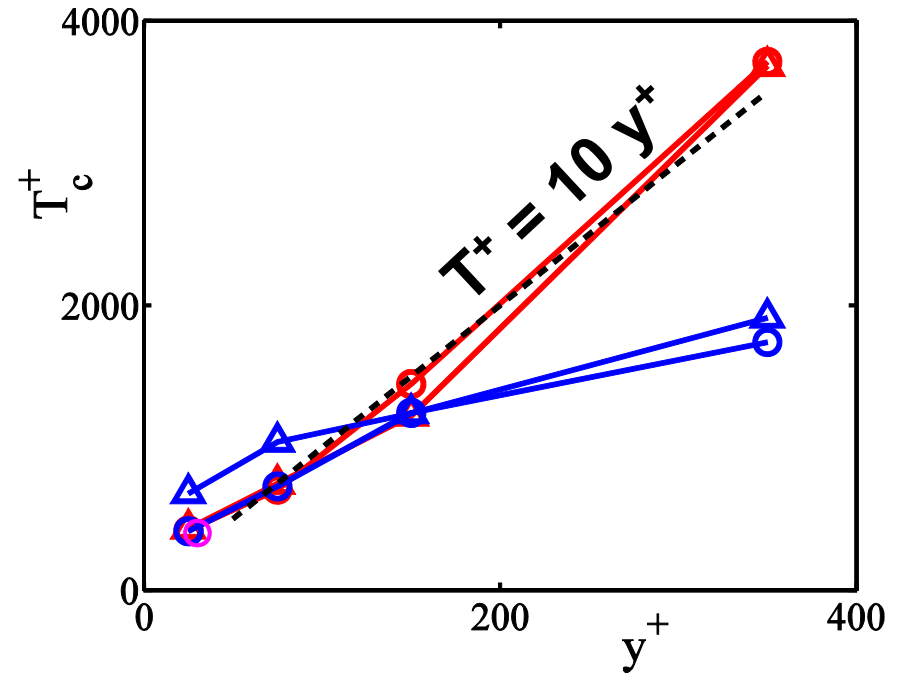
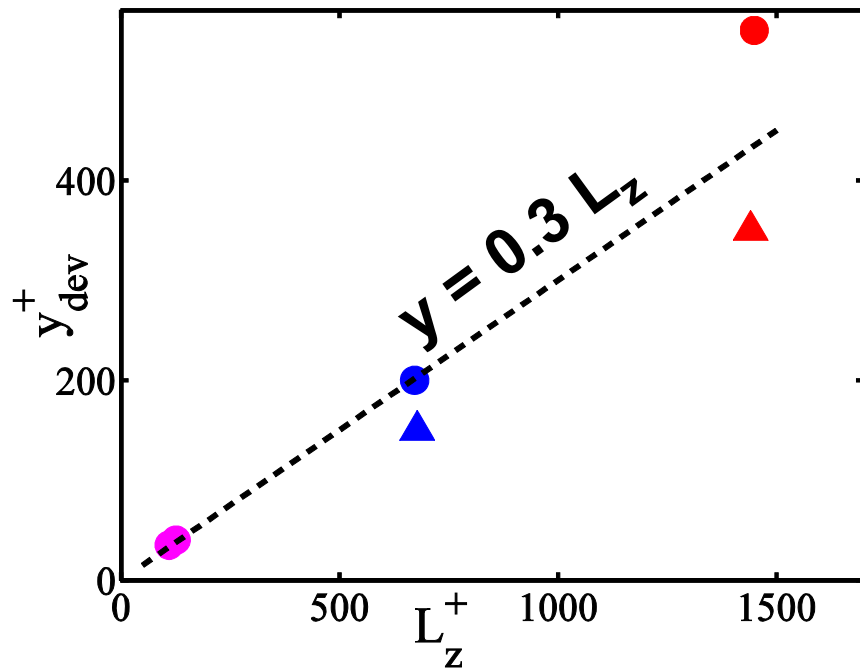


**TIME**  $\longrightarrow$



**Flores (2007)**

# Period grows with Height



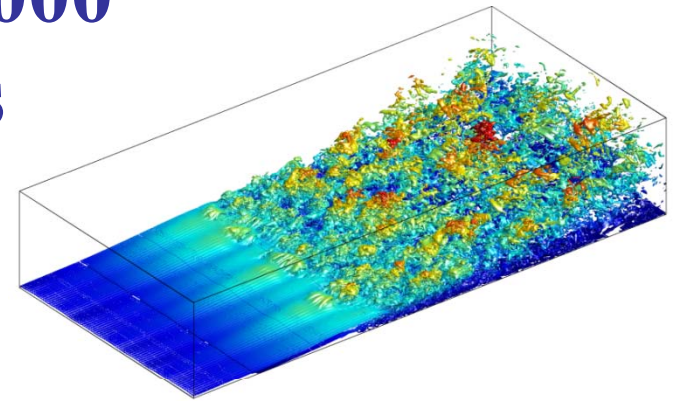
Flores (2007)

# The near Future

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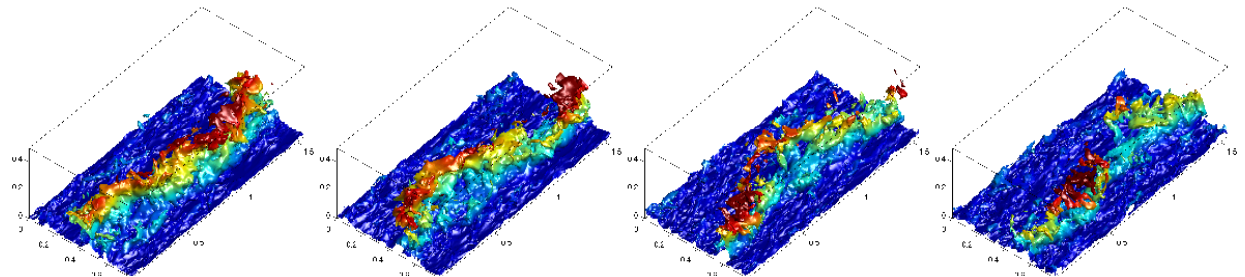
## Simulations of the outer layer

- Boundary layers,  $\delta^+ = 500-2000$
- Adverse pressure gradients
- Jets and free shear flows



## Exploit the logarithmic layer

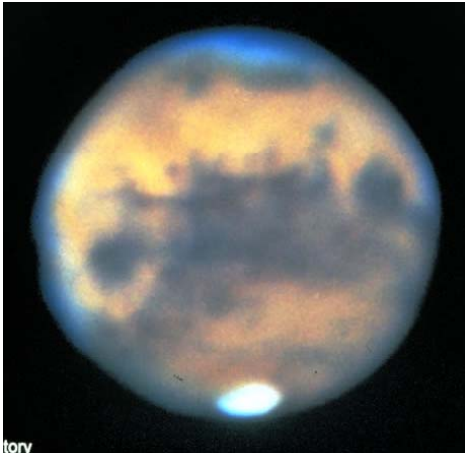
## Fully resolved Space-Time data sets



# Mars

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Pre -1960's



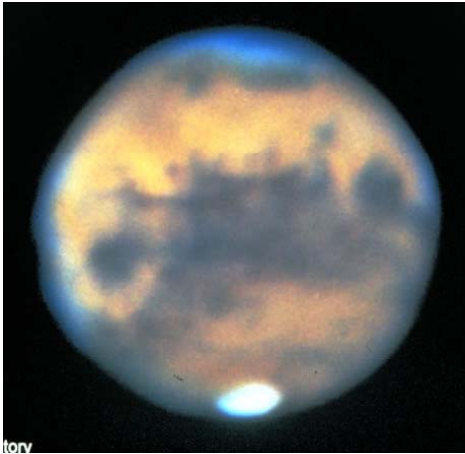
Post-2007



# Mars

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Pre -1960's



Post-2007



**“No speculation”**

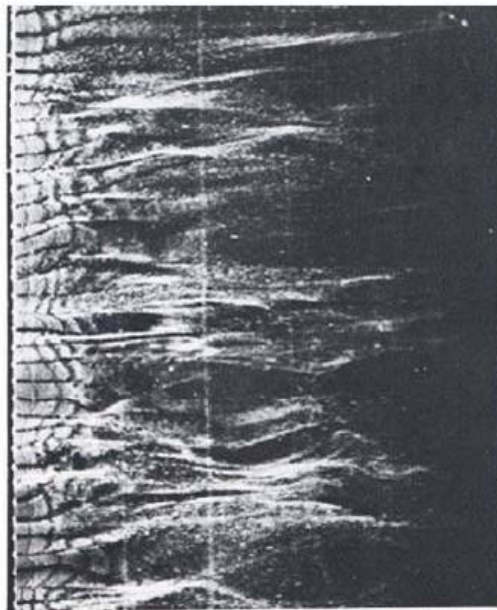
# Turbulence

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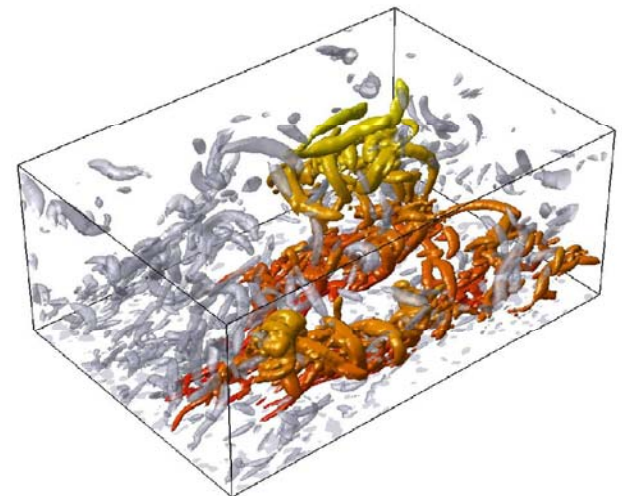
Pre -1950's



1960's ...



2000's



# **Turbulence now**

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**Today, “anything” that is proposed in turbulence  
can be tested**

**(in large part because of computers)**

**Turbulence is  
Not driven any more by data acquisition**



**But by data analysis**