Unstratified hydrodynamic keplerian-like flows: Turbulent or not turbulent ?

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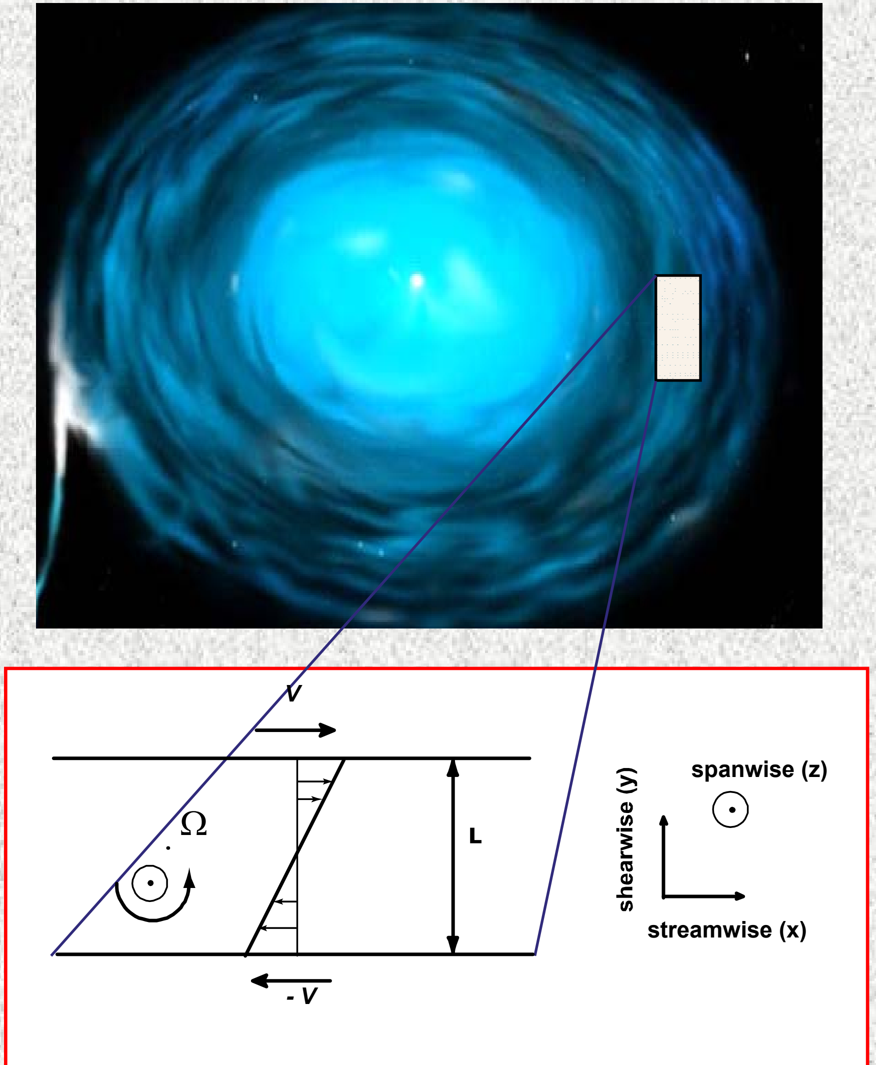
Modelling



Boundary conditions:

Periodic+rigid (experiments on rotating plane Couette flows)

Shearing sheet (local disk model)

Equations and characteristic quantities

Rotating plane Couette and shearing sheet:

$$\frac{\partial w}{\partial t} + w.\nabla w = -\frac{\nabla P^*}{\rho} - 2\Omega_0 \times w + \nu \Delta w$$

Scales:

$$\text{Length: } L; \quad \text{Time: } t_S = S^{-1}, \quad t_\Omega = (2\Omega_0)^{-1}, \quad t_\nu = \frac{L^2}{\nu}$$

Dimensionless numbers:

$$\mathrm{Re} = \frac{\text{advection}}{\text{dissipation}} = \frac{t_\nu}{t_S} = \frac{|S|L^2}{\nu}; \quad R_\Omega = \frac{\text{Coriolis}}{\text{advection}} = \frac{2\Omega_0}{S}$$

Linear stability limits:

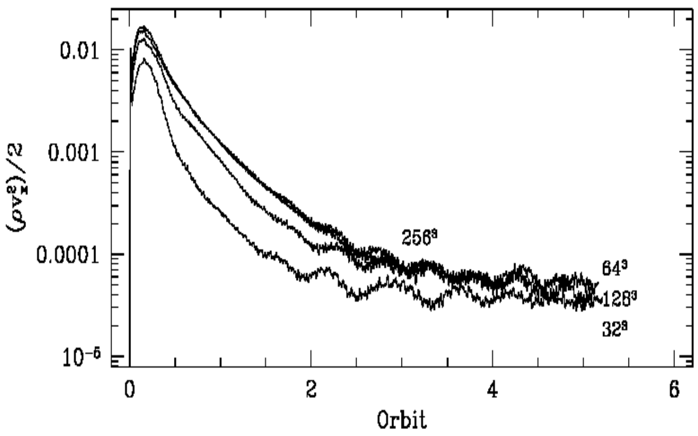
$$\kappa^2 = S^2 R_\Omega (1+R_\Omega) < 0 \Leftrightarrow -1 < R_\Omega < 0$$

N.B.: $R_\Omega > 0$: cyclonic rotation ; $R_\Omega < 0$: anticyclonic rotation

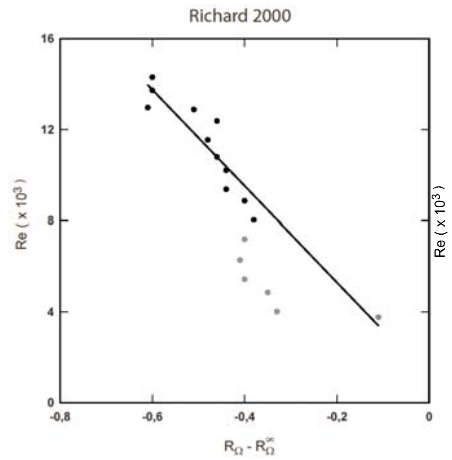
Keplerian : $R_\Omega = -4/3$

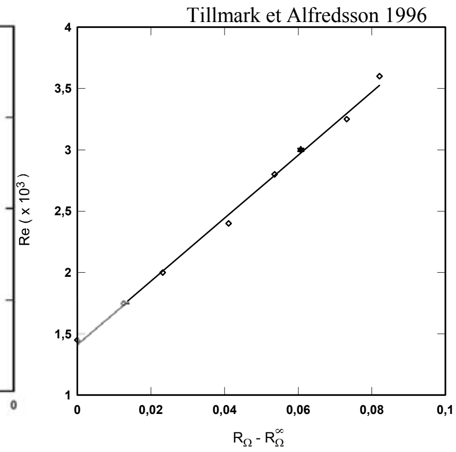
Experiments vs simulations

Simulations



Expériences





BHW99: Coriolis force induces loss of of turbulence in keplerian-like flows

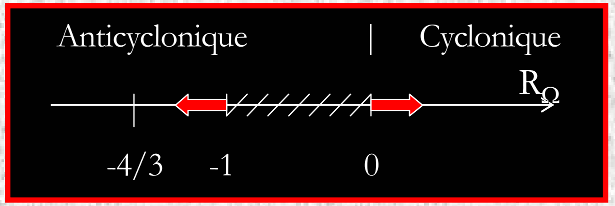
TA96, R00: turbulence for high enough Reynolds number in keplerian-like flows

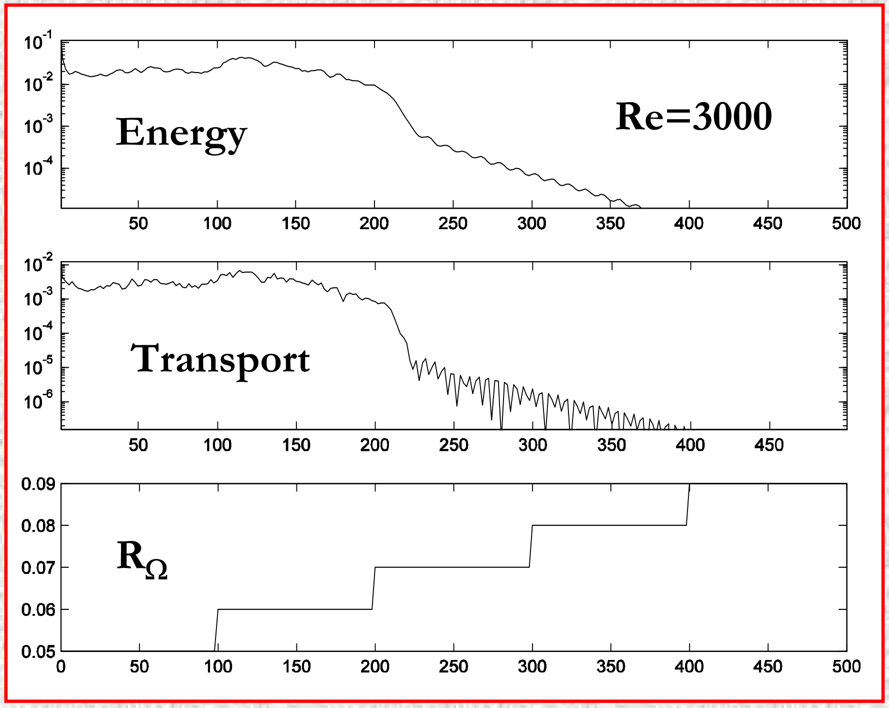
Resolution/Reynolds limited ?

Boundary conditions ? Secondary flows ?

Simulations revisited

1. **Choose a resolution**
2. **Choose a Reynolds number**
3. **Evolve from marginal stability until turbulence is lost**



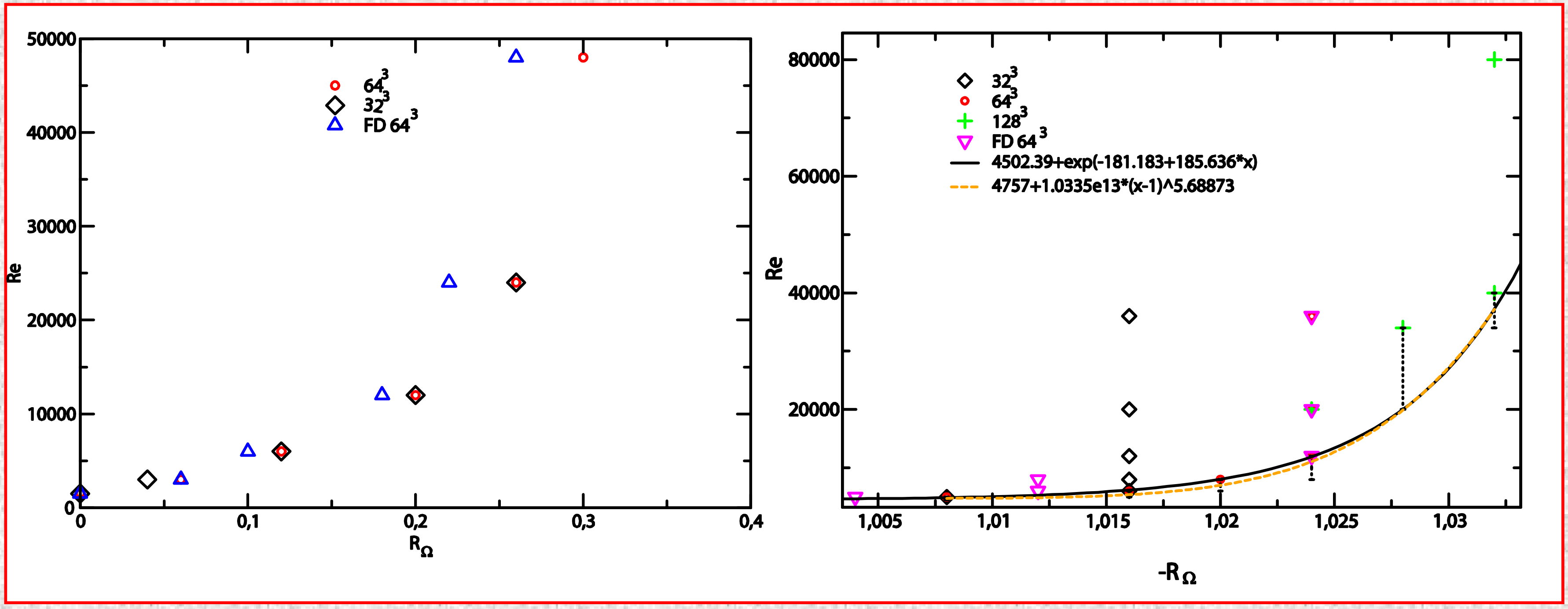


Aims:

Characterize the link between resolution and Reynolds number

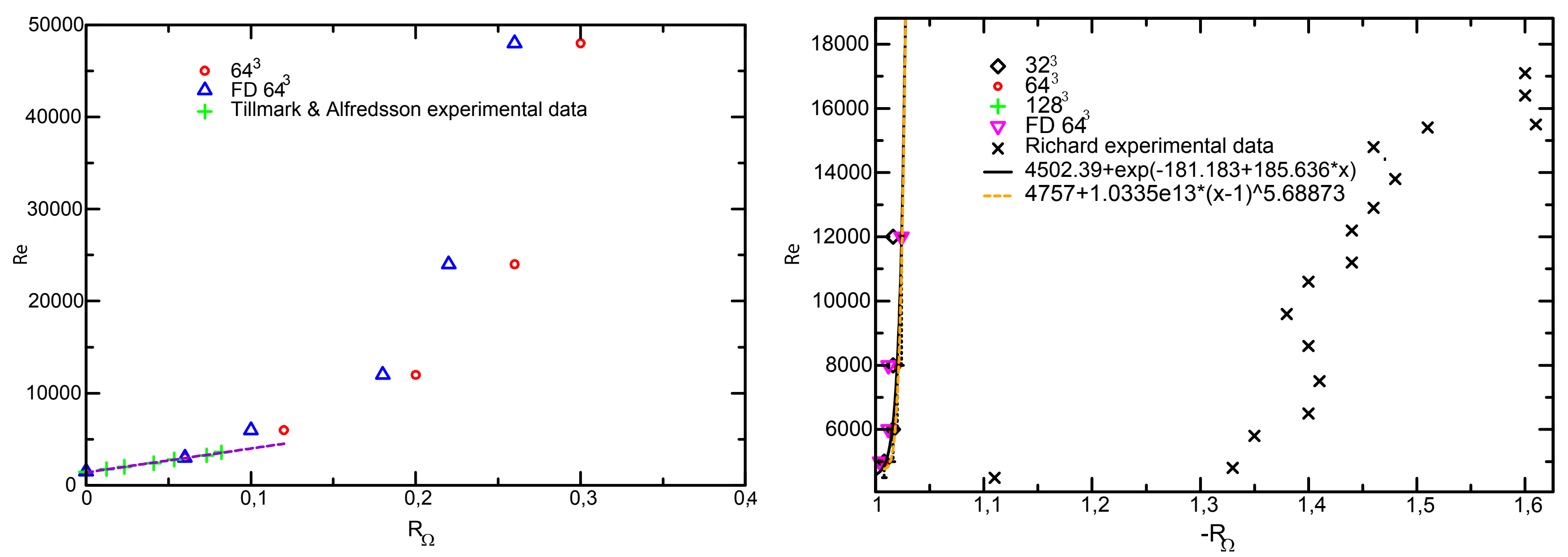
Quantify turbulent transport

Transition Reynolds number



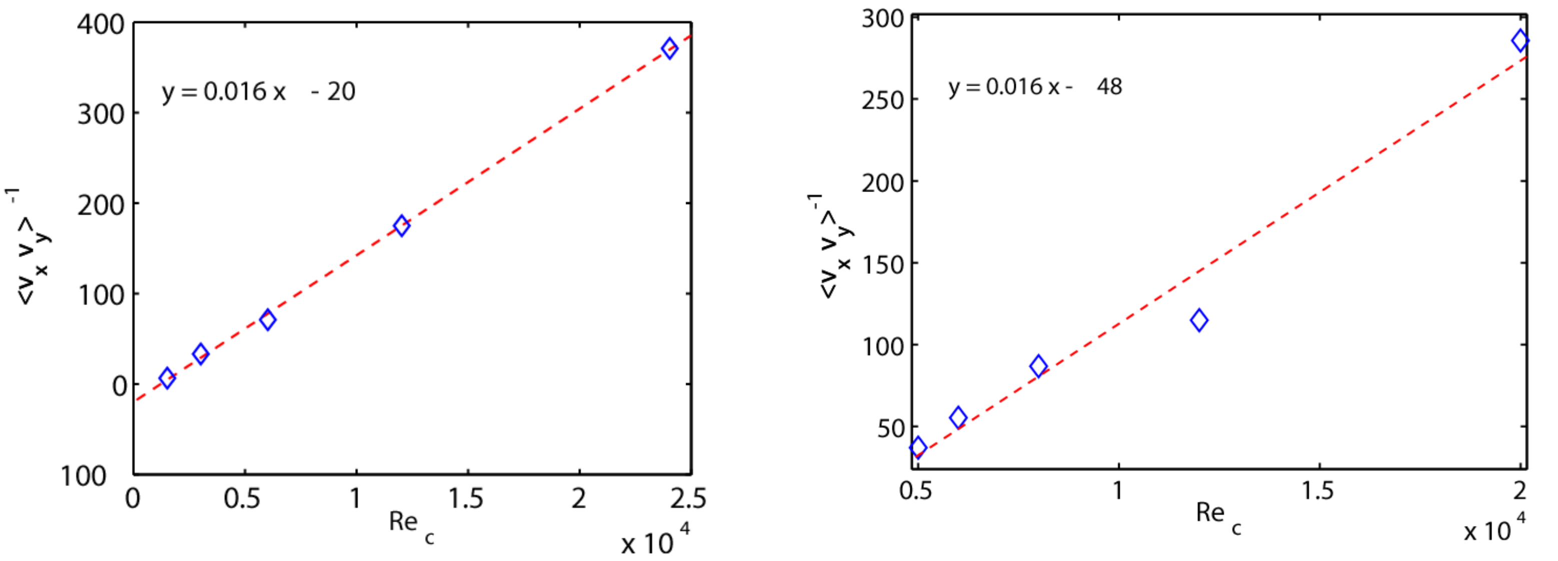
- Turbulence not quenched by a stabilizing Coriolis force
- Resolution demand increases extremely steeply with increasing Coriolis force for anticyclonic flows
- Keplerian regime out of reach

Simulations and experiments:



- **Cyclonic flows: little role of boundary conditions and aspect ratio**
- **Anticyclonic flows: experiments more easily perturbed by secondary flows (from stability criterion)**

Turbulent transport



- **$<v_x v_y> \sim$ 5 / Rg (both cyclonicities)**
- **Minimal extrapolation $\longrightarrow$ $\alpha < 10^{-5}$**

hydrodynamic subcritical turbulence not relevant to accretion disk disk transport

Conclusions

Large resolution demand to simulate keplerian flows flows (1.000^3 to 10.000^3)

Coriolis force does not quench turbulence in linearly linearly stable flows but efficiently reduces turbulent transport

Transport orders of magnitude too small for astrophysical purposes