TURBULENCE IN PLANETARY CORES

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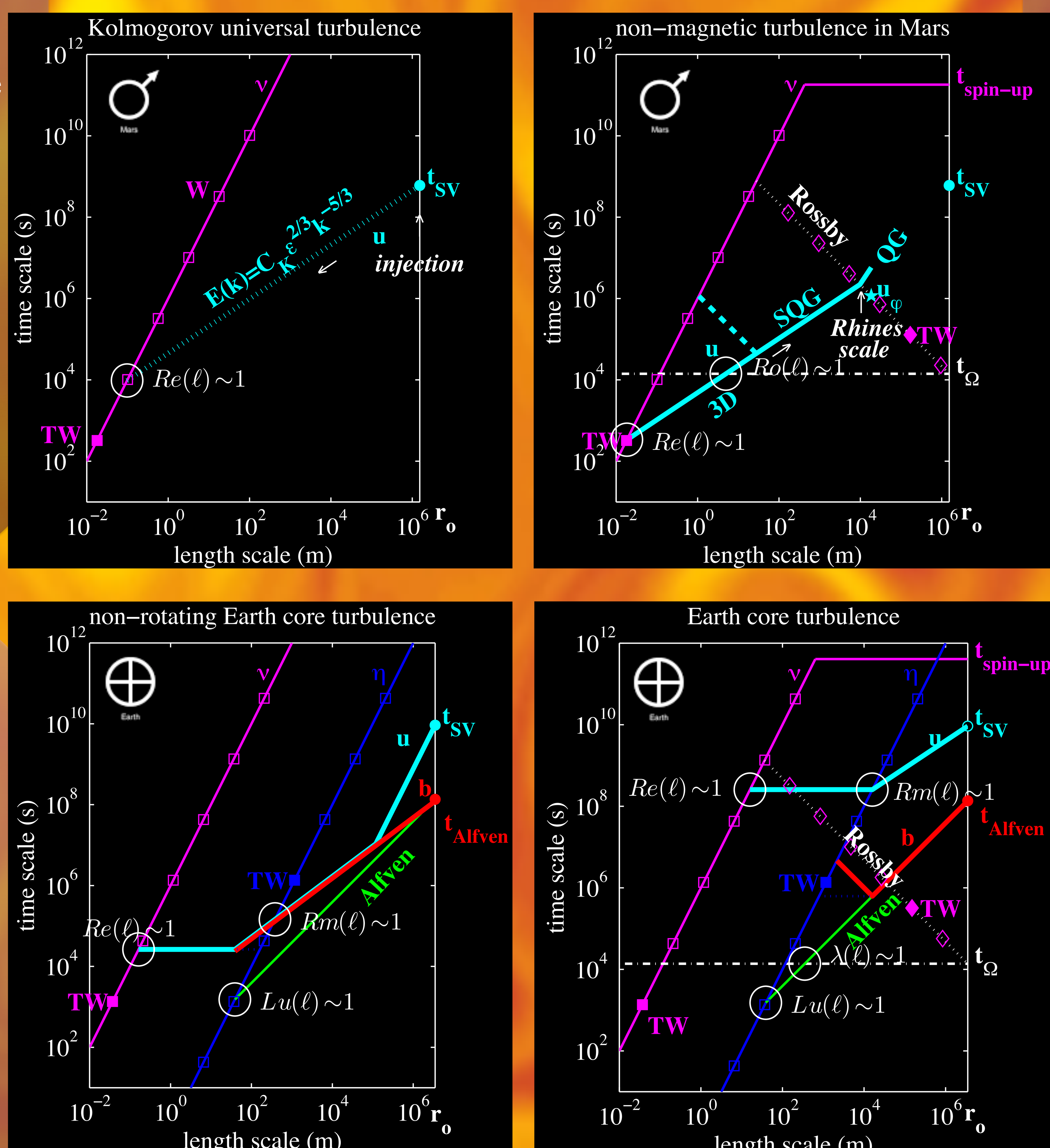
1 Introduction

- Turbulence involves a range of scales.
- We only know the large scales of flow and magnetic field in the Earth's core.
- Numerical simulations of the geodynamo provide scaling laws for large-scale quantities but cannot resolve the complete range of scales.
- Here, we explore plausible turbulent regimes in planetary cores, using the known properties of the fluid (viscosity, magnetic diffusivity), the rate of rotation, and the presence or absence of a magnetic field.

2 τ-ℓ regime diagrams assumptions

- Time-scales τ and length-scales ℓ are related by various physical processes
- Regime changes occur when τ(ℓ) lines intersect
- Dimensionless numbers can we written as time-scale ratios
- The scale ℓ at which a dimensionless number is ~1 is more important than the value of that number at the integral scale
- Turbulent dynamics is controlled by the shortest time-scale process

3 τ-ℓ regime diagrams



Dissipation can be graduated along the viscous line, the magnetic diffusion line, and the Rossby line for dissipation in the Ekman layer.
It places strong constraints on the acceptable regimes.

Note that an energy density spectrum $E(k) \sim k^n$ translates into a $\tau(\ell) \sim \ell^{3/2-n/2}$ law.

Rossby : *propagation time of ℓ-size Rossby waves*
Alfvén : *propagation time of Alfvén waves (large-scale B)*
u : *ℓ-size eddy turnover time*
b : *time of ℓ-size Alfvén waves*

QG = *Quasi-Geostrophic*
SQG = *Semi-Quasi-Geostrophic*

Values used to draw the figures:
$\nu \sim 10^{-6}$ m²/s
$\eta \sim 1$ m²/s
$t_{SV} \sim 300$ years
B ~ 3 mT

4 Results and key issues

- When both rotation and a strong magnetic field are present, the dynamo operates in a quasi-geostrophic regime.
- Growth time of Taylor columns ~ $z/\Omega\ell$ → implies large region of semi-quasigeostrophic regime
- Equipartition of magnetic and kinetic energies in MHD turbulence → would lead to too much dissipation
- Inhibition of turbulence when both rotation and magnetic field are present

5 Conclusions

- Rotation plays an important role in limiting the *dissipation* of the dynamo.
- This might explain the absence of a magnetic field on Venus.
- Dissipation occurs on relatively large length-scales in the Earth's core. Magnetic dissipation dominates.
- 3D Alfvén waves can propagate at short scales, but turbulent cascades are always under the influence of rotation.
- The new tool we introduced (τ-ℓ regime diagrams) can be useful in other complex turbulent systems.

References

- Turbulence in the core, H-C. Nataf & N. Schaeffer, in Treatise on Geophysics, Second Edition, Vol. 8 Core Dynamics, P. Olson and G. Schubert Eds, Elsevier B.V., to appear in May 2015.
- and lots of references therein…

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Physics of Exoplanets Conference, KITP, Santa Barbara, February 23-27, 2015