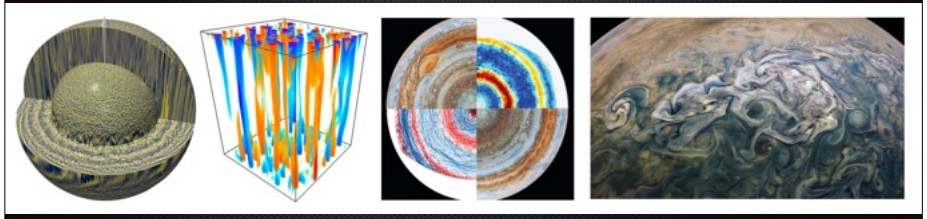
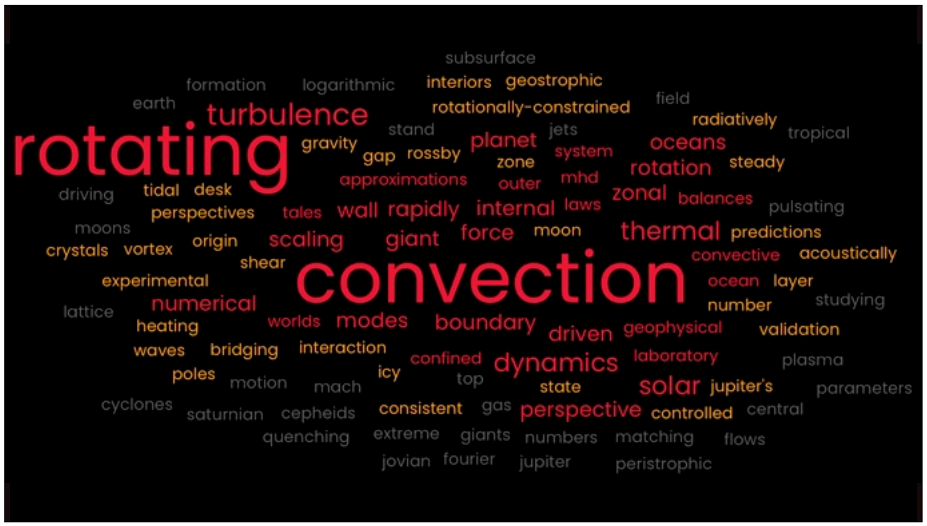
A Lead-off-Pub-Crawl-Full-Meeting-Overview



Jon Aurnou; aurnou@ucla.edu



Non-dimensional Parameters

- Ratios of terms, or times or lengths, or…
  - Focus here on time scales
- $\tau_\Omega = 1/(2\Omega)$
- $\tau_\nu = L^2/\nu$
- $\tau_U = L/U$
- $\tau_\kappa = L^2/\kappa$

Non-dimensional Parameters

- Ekman $E = \tau_\Omega/\tau_\nu = \nu/(2\Omega L^2)$
- Reynolds $Re = \tau_\nu/\tau_U = UL/\nu$
- Rossby $Ro = \tau_\Omega/\tau_U = U/(2\Omega L) = ReE$
- Rayleigh $Ra = \tau_\nu\tau_\kappa/\tau_U^2 = \alpha g \Delta T L^3/(\nu\kappa)$
  - Supercriticality $\widetilde{Ra} = Ra/Ra_{crit}$

Non-dimensional Parameters

- Prandtl $Pr = \tau_\kappa/\tau_\nu = \nu/\kappa$
- Convective Rossby $Ro_C \approx Ro_\ell = \sqrt{RaE^2/Pr}$
- Nusselt $Nu \approx \tau_\kappa/\tau_U \approx (uL/\kappa)(\theta/\Delta T)$
- Cylinder Aspect Ratio $\Gamma = D/H$
- Spherical Radius Ratio $\chi = R_i/R_o$

Momentum Conservation in a Rotating Fluid

$$\rho\frac{d\vec{u}}{dt} + 2\rho\Omega\hat{z}\times\vec{u} = -\nabla p + (\rho\vec{g} + \rho\Omega^2\vec{s}) + \mu\nabla^2\vec{u}$$

Inertia Coriolis Pressure Gravity Centrifugal Viscosity

Momentum Conservation in a Rotating Fluid

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Inertia Coriolis Pressure Gravity Centrifugal Viscosity

Momentum Conse

$$\rho\frac{d\vec{u}}{dt} + 2\rho\Omega\hat{z}\times\vec{u} = -$$

Inertia Coriolis

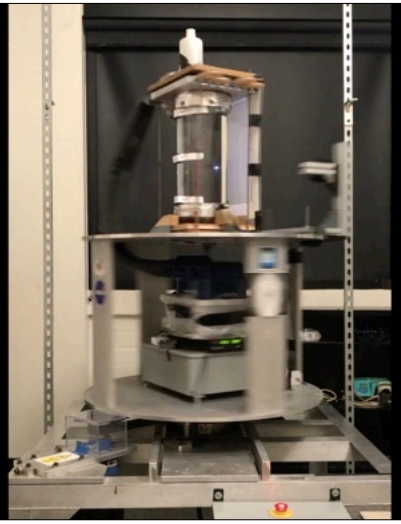
Momentum Conse

$$\rho\frac{d\vec{u}}{dt} + 2\rho\Omega\hat{z}\times\vec{u} = -$$

Inertia Coriolis

convection

Jewel Abbate



spinlabucla

Shadow-graph

$Ra \sim 4e11$

$Pr \sim 21$

62K_76rpm.mov
Ra = 4.2e11
Ek = 6.5e-7
Fr = 0.633
Ro = 0.092

RBC_60K_0rpm.mov
Ra = 4.0e11
Ek = inf
Fr = 0

0 rpm

Shadow-graph

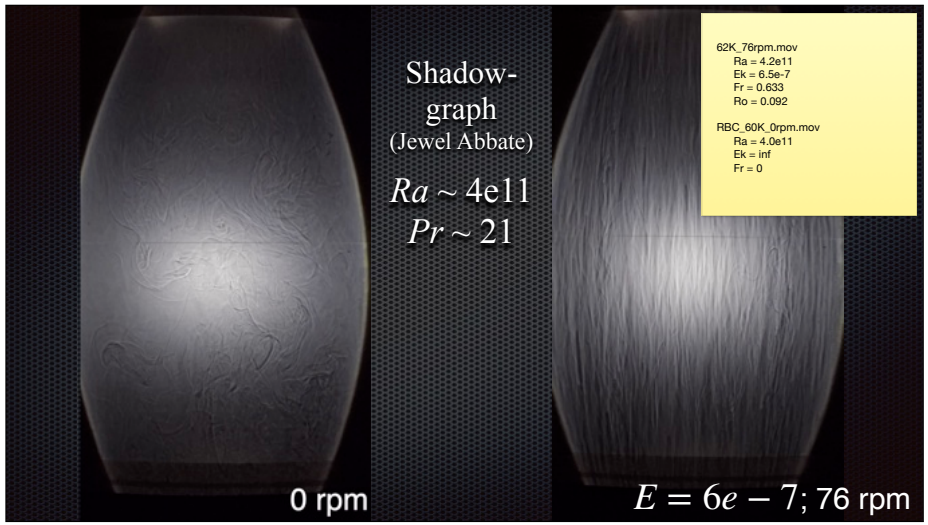
$Ra \sim 4e11$

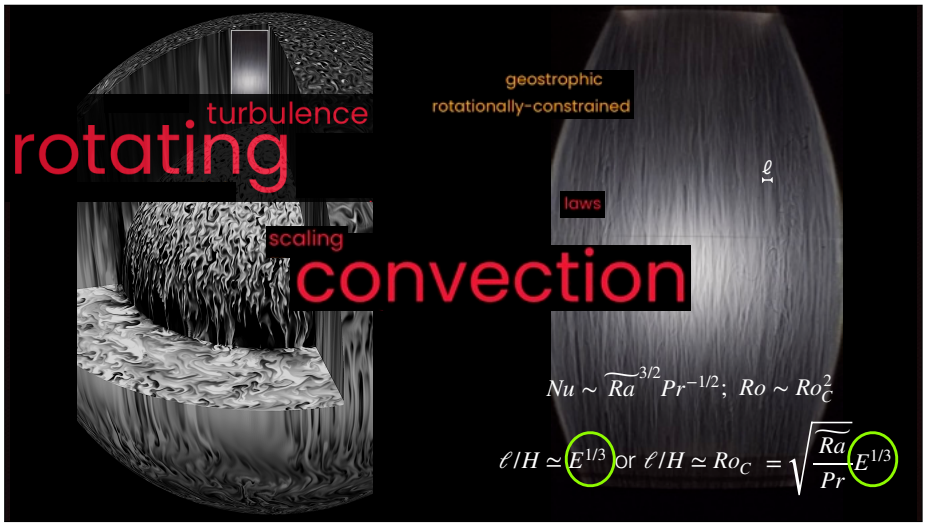
$Pr \sim 21$

0 rpm

convection

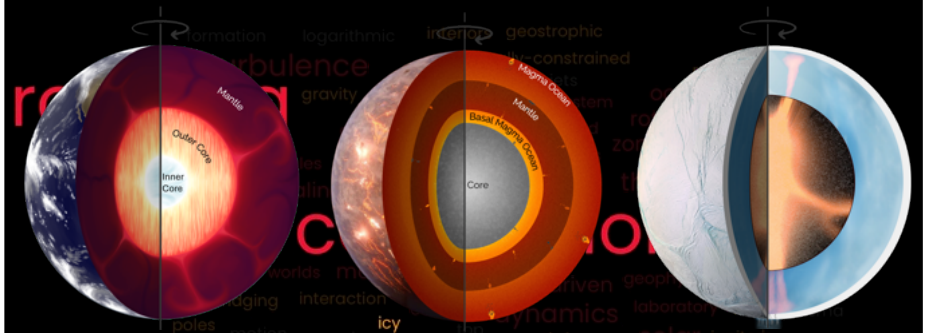
rotating convection





rotating

convection



Images: J. Cheng, J. Abbate, ESA

rotating

convection

Image: Henning Dalhoff

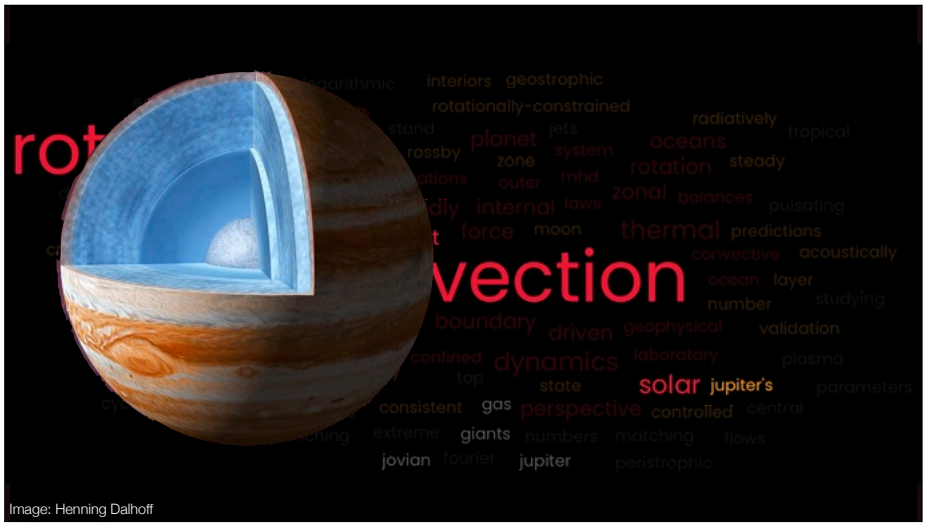


Image: Henning Dalhoff

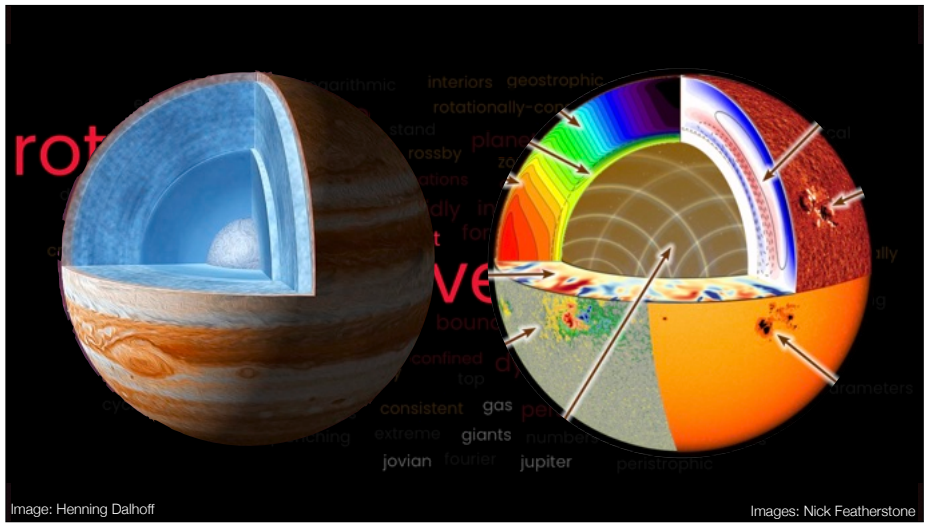


Image: Henning Dalhoff

Images: Nick Featherstone

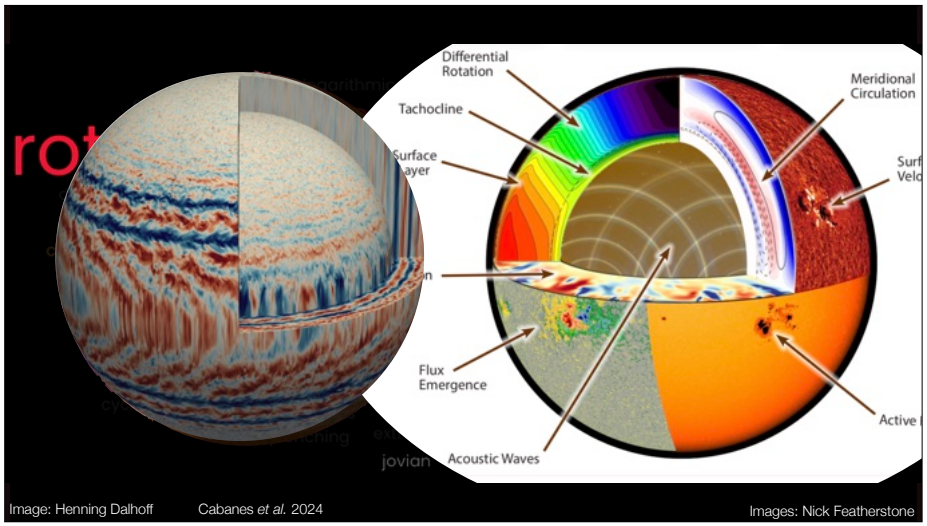
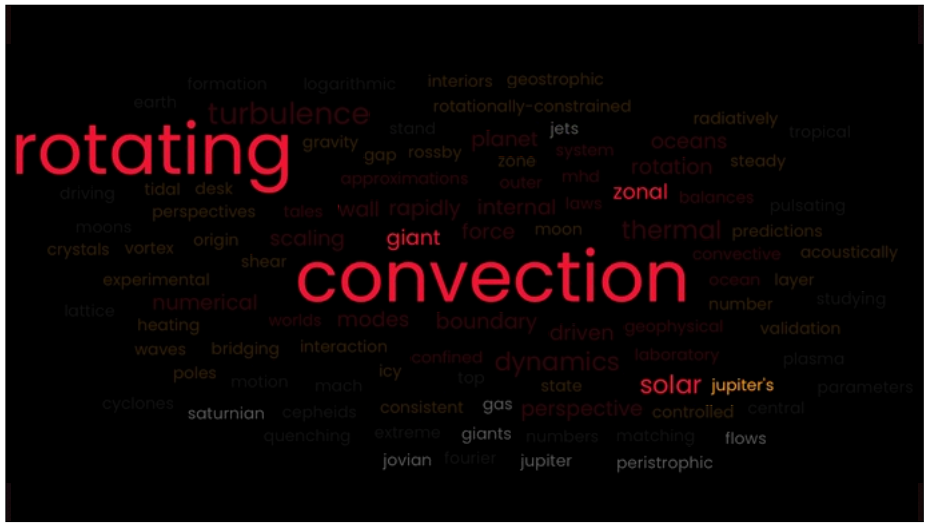
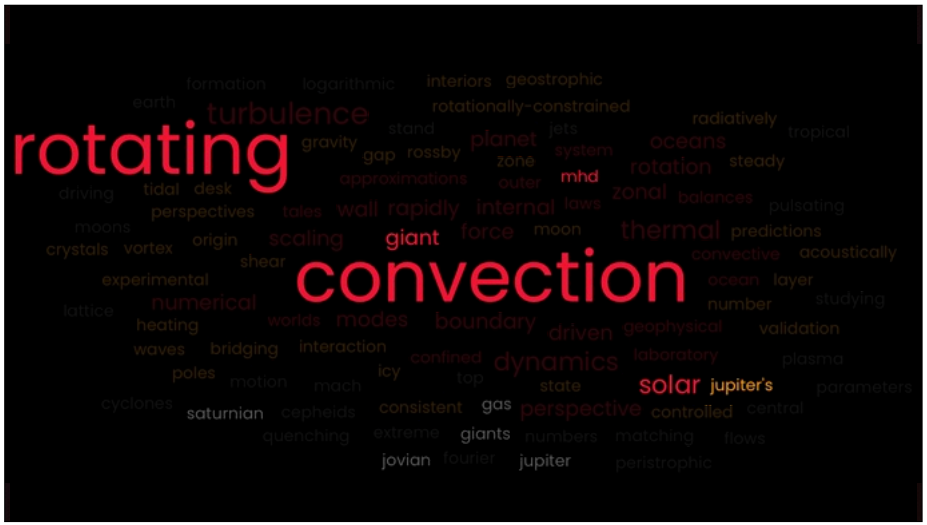


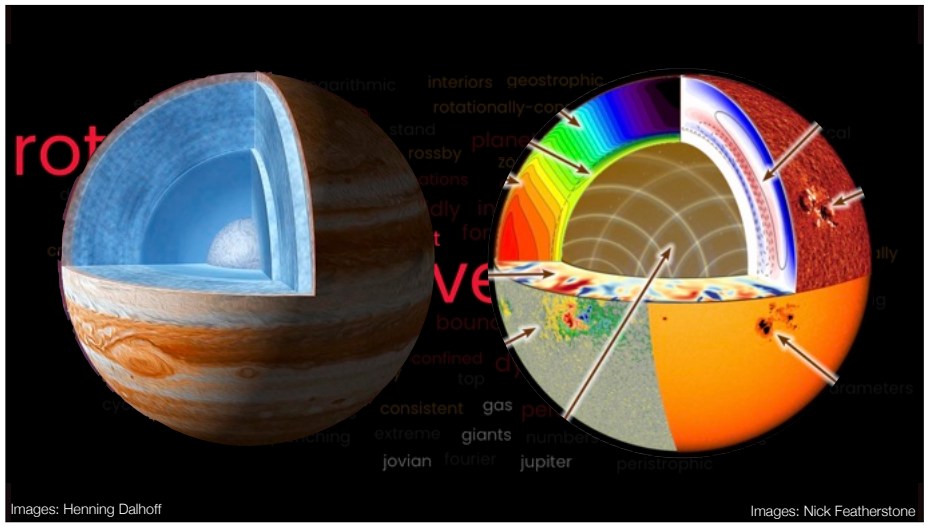
Image: Henning Dalhoff

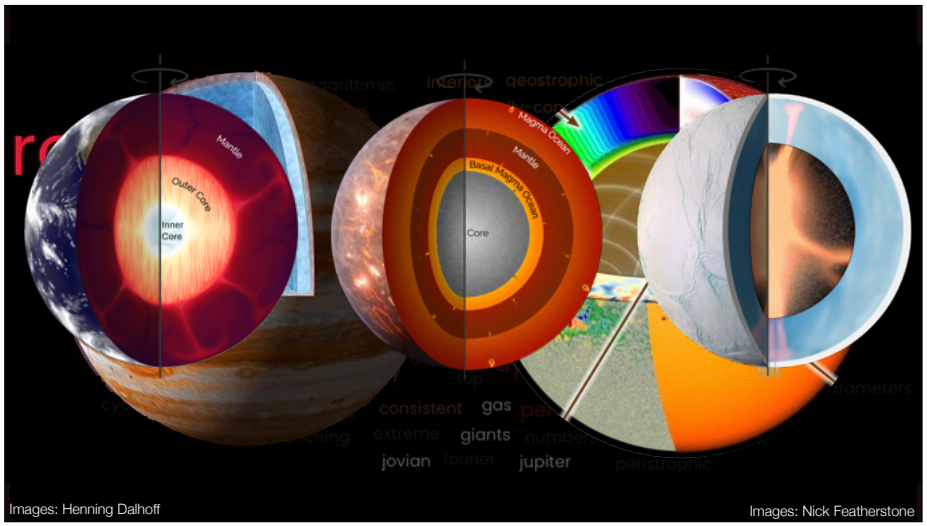
Cabanes *et al.* 2024

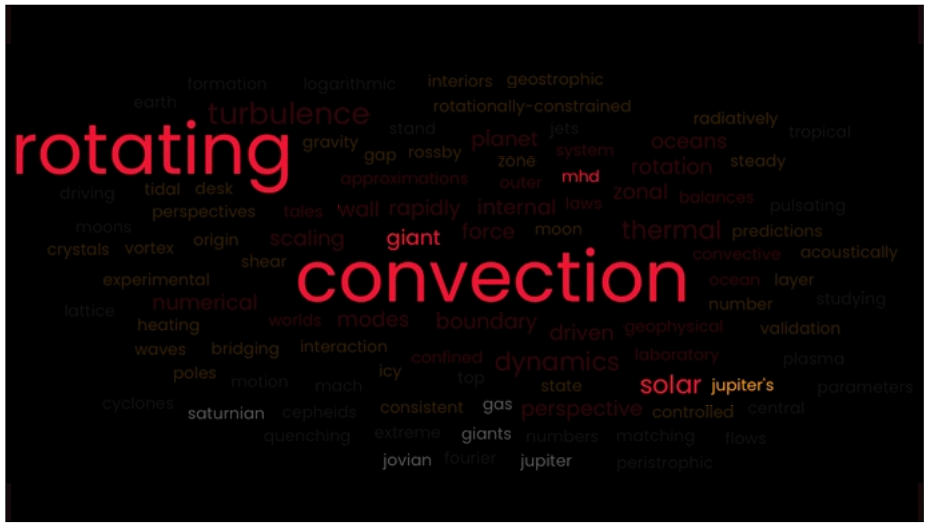
Images: Nick Featherstone






interiors geostrophic
consistent gas
extreme giants
jovian fourier jupiter
Images: Henning Dalhoff
Images: Nick Featherstone


Mantle
Outer Core
Inner Core
Magma Ocean
Basal Magma Ocean
Core
interiors geostrophic
consistent gas
extreme giants
jovian fourier jupiter
Images: Henning Dalhoff
Images: Nick Featherstone


rotating
convection
turbulence
interiors geostrophic
rotationally-constrained
radiatively
gravity
planet
oceans
rotation
steady
mhd
zonal
rapidly
internal
thermal
predictions
giant
force
moon
scaling
vortex
origin
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numerical
modes
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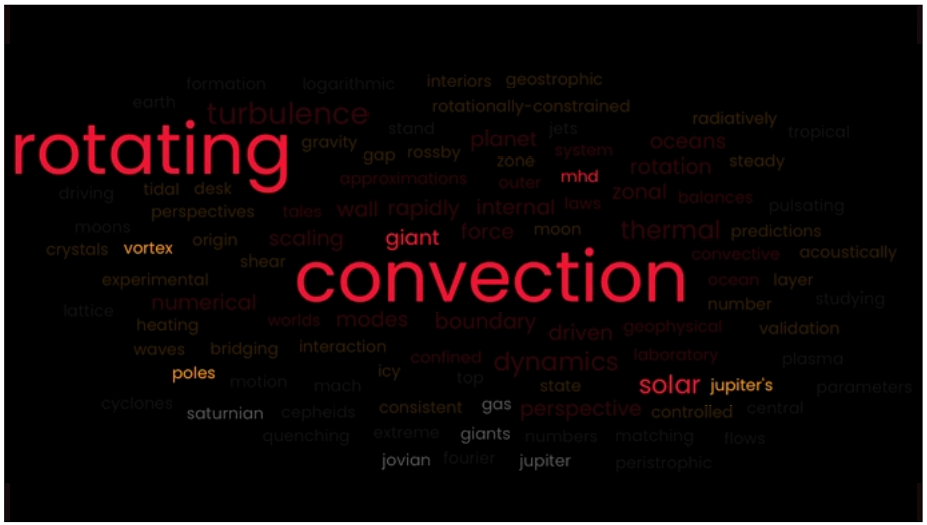
fourier
jupiter


rotating
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interiors geostrophic
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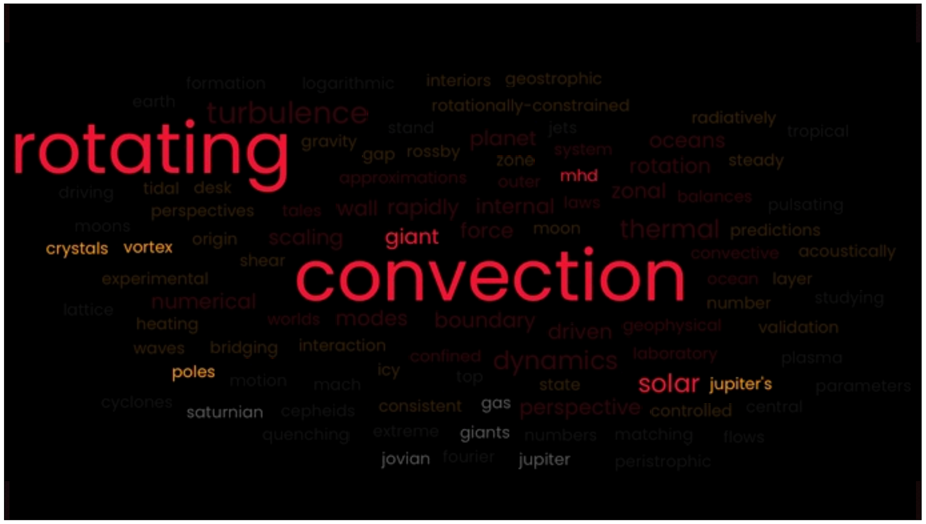
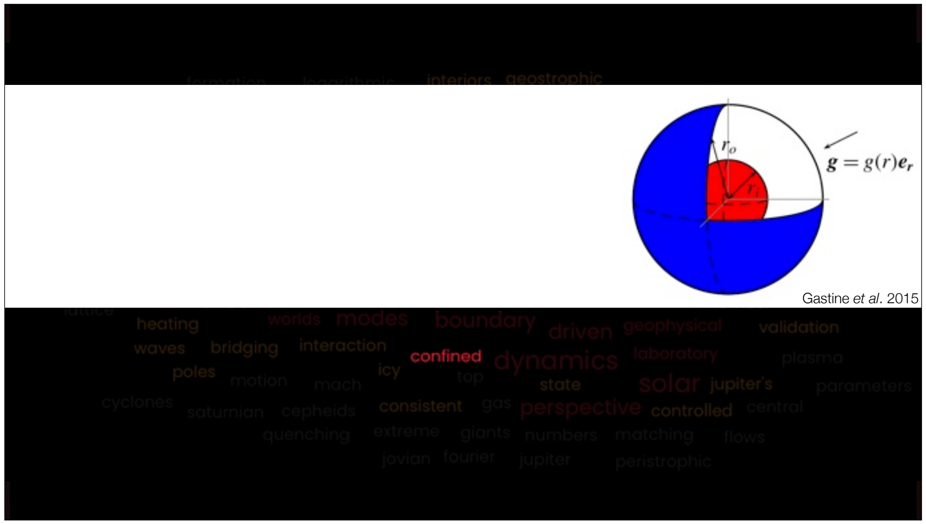
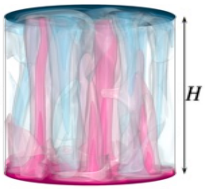
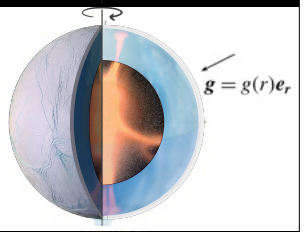
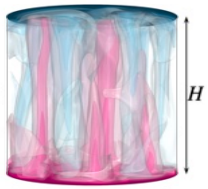


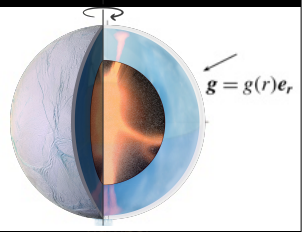


Gastine *et al.* 2015

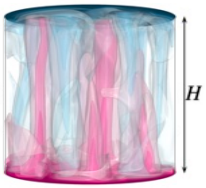


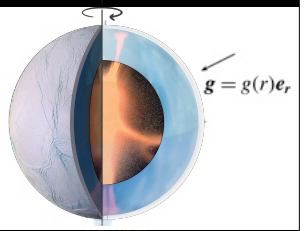






Turbulence **Fluid Physics** **Geophysics**
Astrophysics





Turbulence **Fluid Physics** **Geophysics**
Astrophysics

Observational **Theory** **Numerical** **Laboratory**

rotating convection

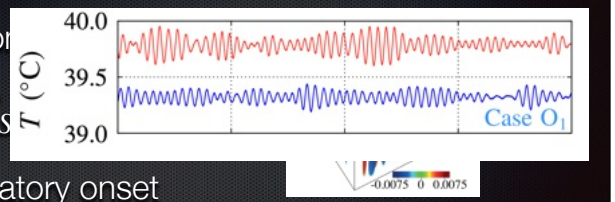
rotating convection

rotating convection

$$Pr = \frac{\tau_\kappa}{\tau_\nu} = \frac{\nu}{\kappa}$$

Pr-dependent Bulk RC Onset

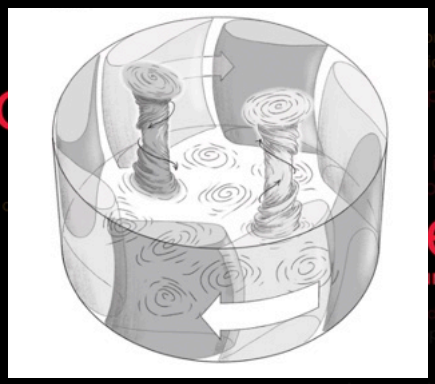
- $Pr > 0.67$: Statio
  - $Ra_S \sim E^{-4/3}$; ℓ_S
- $Pr < 0.67$: Oscillatory onset
  - $Ra_O \sim (E/Pr)^{-4/3}$; $\ell_O \sim (E/Pr)^{1/3} H$
    - Does turbulence vary with Pr at $\widetilde{Ra} \ggg 1$?

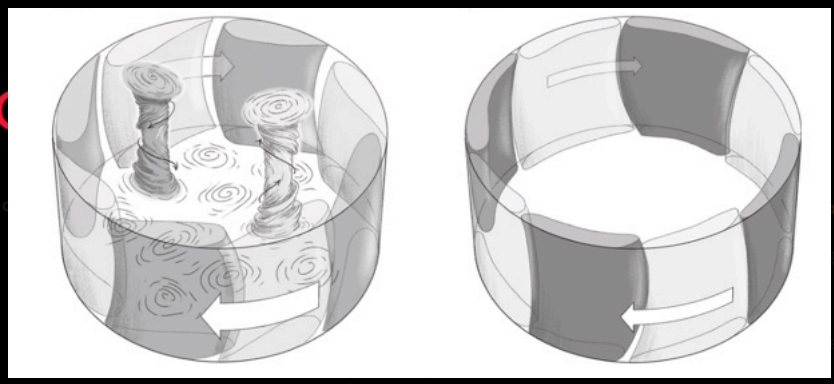


rotating convection

$$Pr = \frac{\tau_\kappa}{\tau_\nu} = \frac{\nu}{\kappa}$$

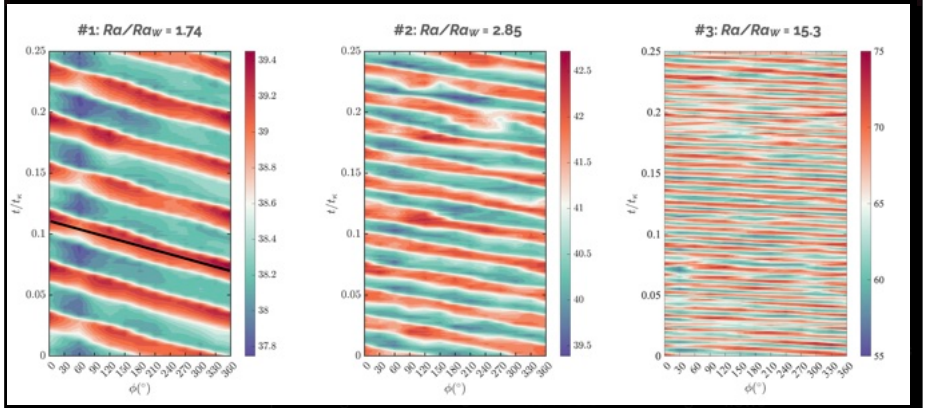
rotating convection





Wall Mode Onset

- $Ra_W \sim E^{-1}$
  - First convective mode in $Pr \gtrsim 1$ fluids
- $Ra_W \sim \Gamma^{-1}E^{-1}$ in slender cylinders (Vasil et al. 2025)
  - $\rightarrow Ra_W \sim E^{-4/3}$ as $\Gamma \sim E^{1/3}$

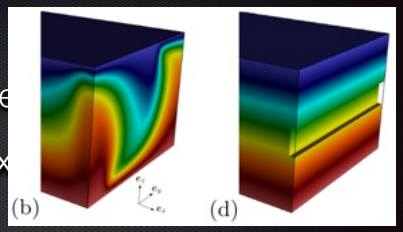


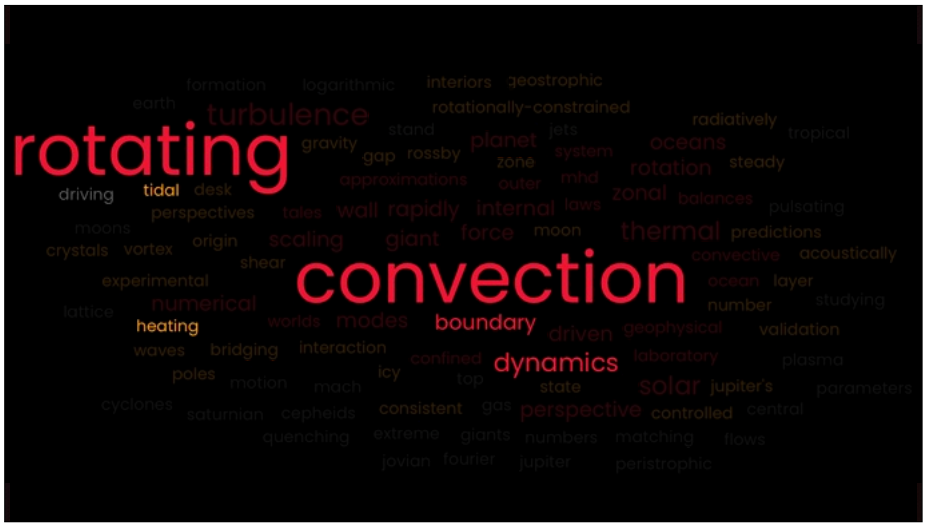
$\Gamma = 1/2;\ Pr = 0.026$

Image: J. Abbate

Wall Mode Onset

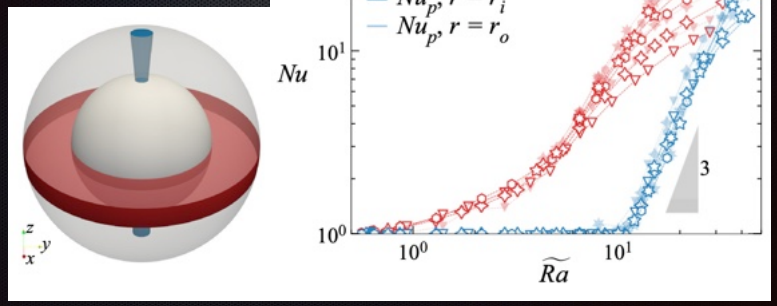
- WM's oft invade the bulk and ge
  - When/how can cylindrical ex
    GAFD systems?
  - Can we truncate with fins (Terrien *et al*. 2023)?
    - Why should we want to?: Fluid Physics vs. GAFD





Boundary Conditions

- Uniform



Gastine & Aurnou 2023

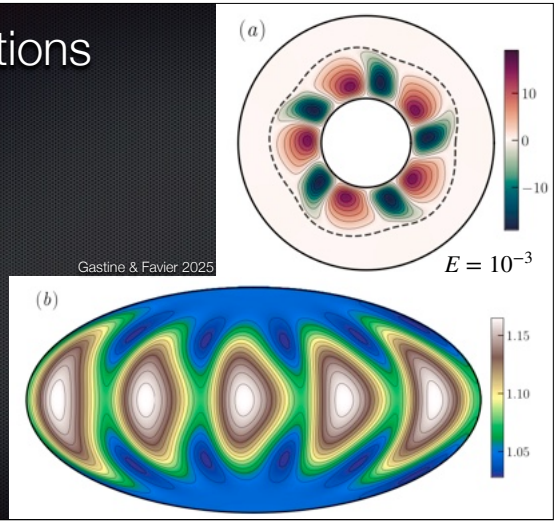
Boundary Conditions

- Uniform
- Heterogeneous

Lonner *et al*. 2022

Boundary Conditions

- Uniform
- Heterogeneous
- Melting



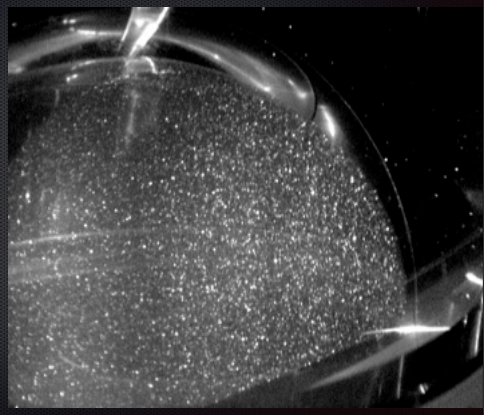
Gastine & Favier 2025

Boundary Conditions

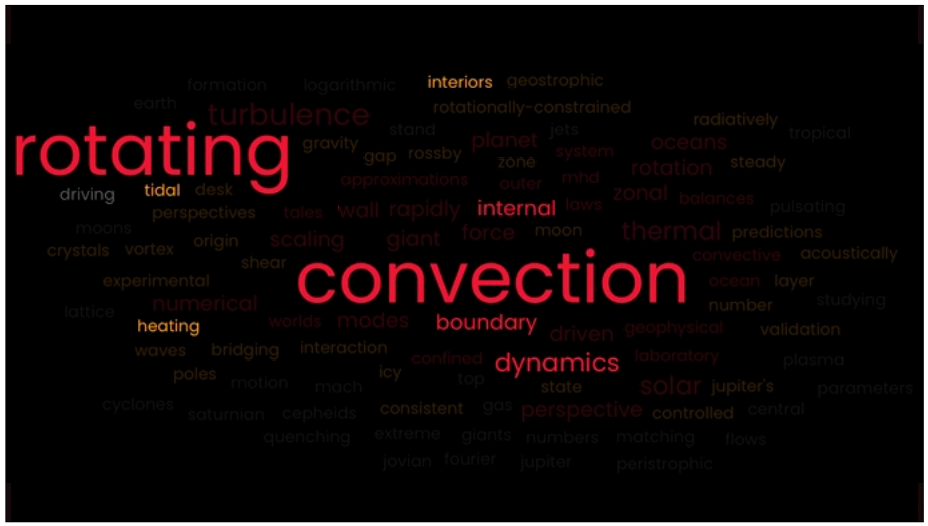
- Uniform
- Heterogeneous
- Melting
- Topographic

Boundary Conditions

- Uniform
- Heterogeneous
- Melting
- Topographic

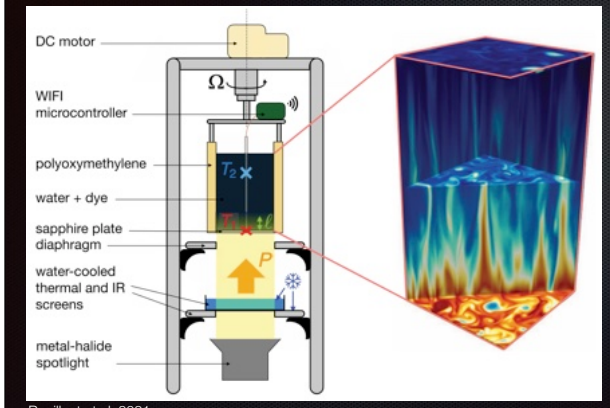


Movie: Jerome Noir



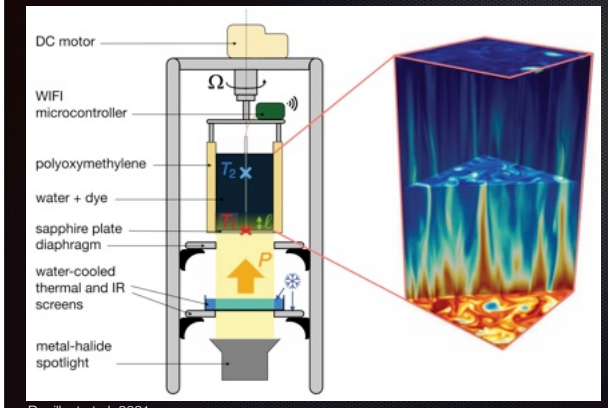
Internal Heating

Internal Heating



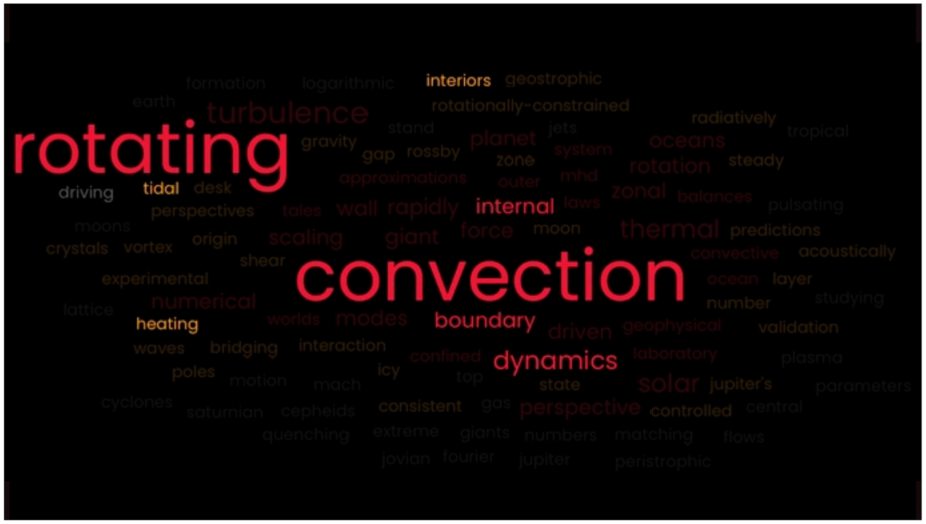
Bouillaut et al. 2021

Internal Heating



Bouillaut et al. 2021

Putterman et al. 2021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earth turbulence rotationally-constrained radiatively tropical
rotating gravity stand planet jets oceans
gap rossby zone system rotation steady
approximations outer mhd
driving tidal desk zonal balances
perspectives tales wall rapidly internal laws pulsating
moons origin scaling giant force moon thermal predictions
crystals vortex shear convective acoustically
experimental convection ocean layer
lattice numerical number studying
heating worlds modes boundary driven geophysical validation
waves bridging interaction confined laboratory plasma
poles motion mach icy top dynamics state solar jupiter's parameters
cyclones saturnian cepheids consistent gas perspective controlled central
quenching extreme giants numbers matching flows
jovian fourier jupiter peristrophic


formation logarithmic interiors geostrophic
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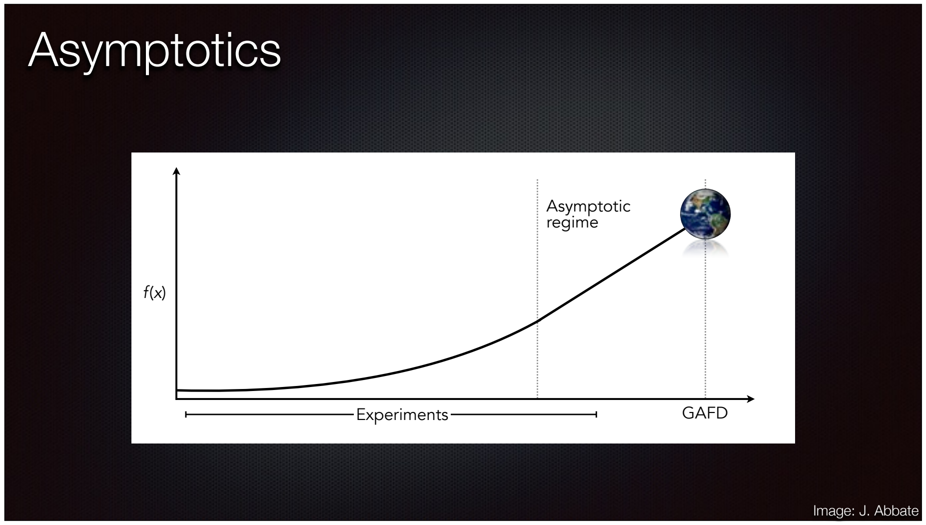
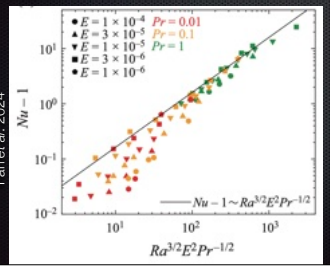
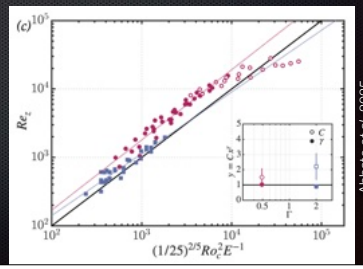

Asymptotics
Asymptotic regime
f(x)
Experiments
GAFD
Image: J. Abbate

Asymptotics

- How do asymptotically extreme RC systems behave?
- Can laboratory-numerical experiments reach these regimes?



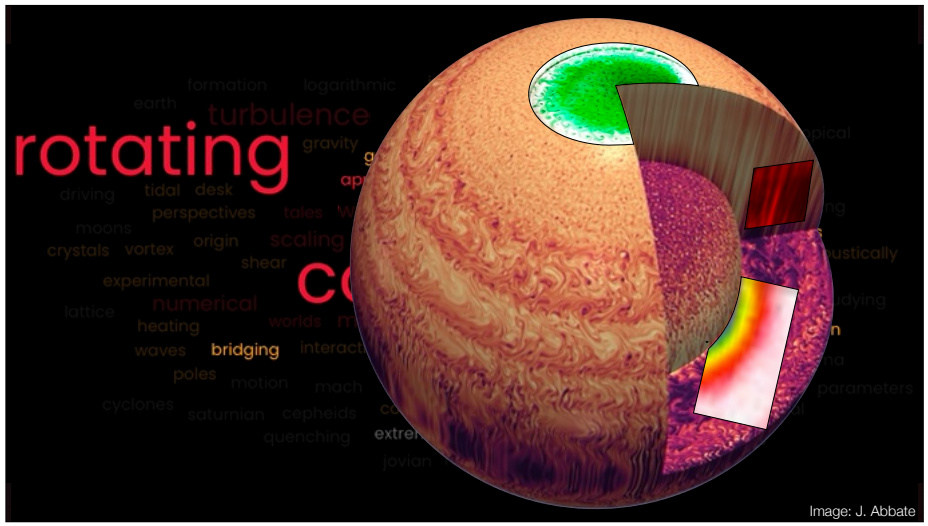
Fan *et al.* 2024

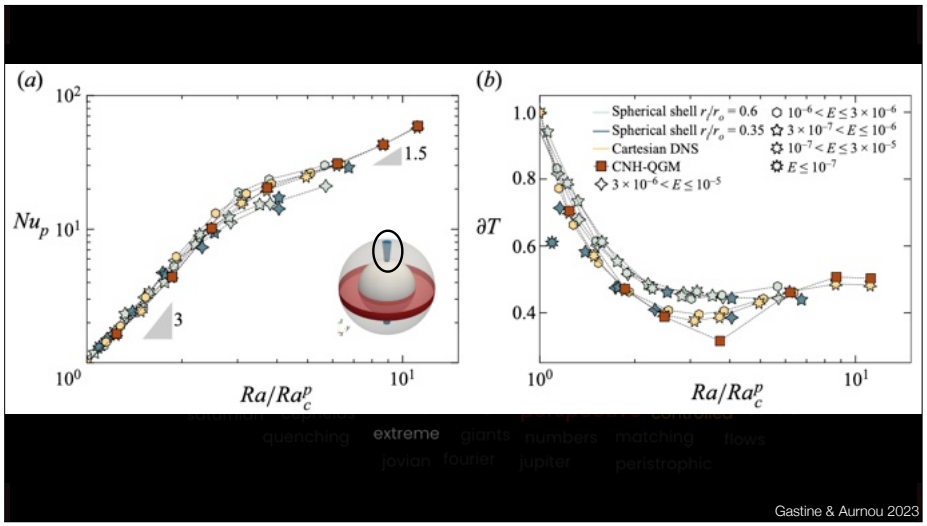


Abbate *et al.* 2025

Reduced Models

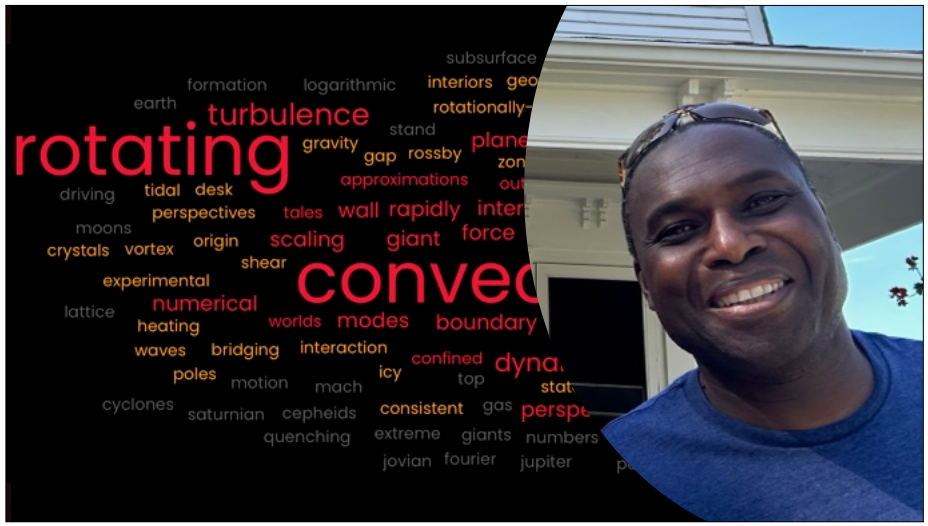
- Under what conditions do reduced systems accurately model GAFD flows?


rotating
turbulence
convection
Image: J. Abbate


(a)
(b)
Nu_p
Ra/Ra_c^p
∂T
1.5
3
Spherical shell $r_i/r_o = 0.6$
Spherical shell $r_i/r_o = 0.35$
Cartesian DNS
CNH-QGM
$3 \times 10^{-6} < E \leq 10^{-5}$
$10^{-6} < E \leq 3 \times 10^{-6}$
$3 \times 10^{-7} < E \leq 10^{-6}$
$10^{-7} < E \leq 3 \times 10^{-5}$
$E \leq 10^{-7}$
Gastine & Aurnou 2023


rotating
turbulence
convection


rotating
turbulence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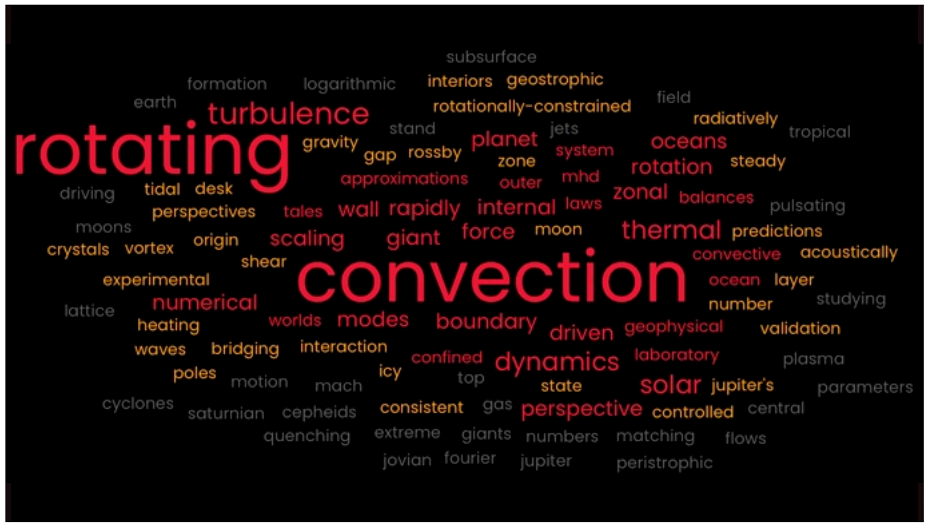
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Aurnou Venmo

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- Last 4 digits: 9808