Unstable Stewartson layer in a differentially rotating neutron star

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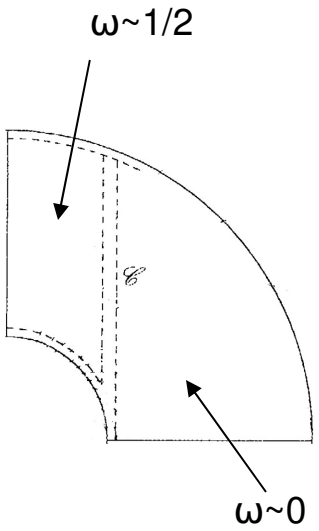
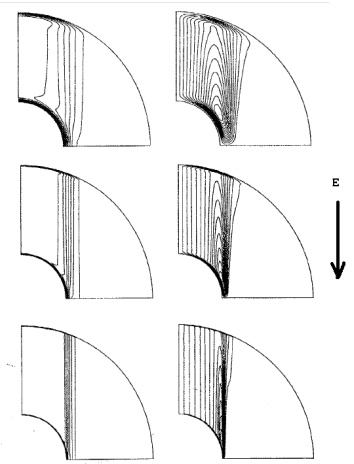
Stewartson layer

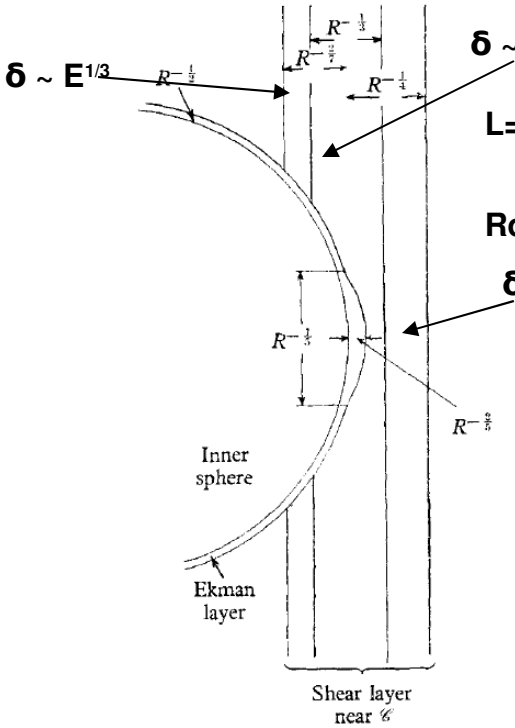
- **Rapid overall rotation Ω + small dif. rot ΔΩ (inner sph.)**
- **Taylor Proudman th.:flow aligns with rot. axis. dU/dz ~ 0**
- **Stewartson L. : Detached layer at tangent cylinder.**

- **Linear theory (Ro~0):**
  Proudman '57, Stewartson '57,'66, Busse 68
- **NL Numerical sims.: Hollerbach '98,'03,'04, Dormy 98,05**

- **Astro trigger: psr glitch, flow transition?**
- **KHI: ACP03, MM05, PMGO06, GA08**
- **Solve HVBK for rotating superfluid in NS**

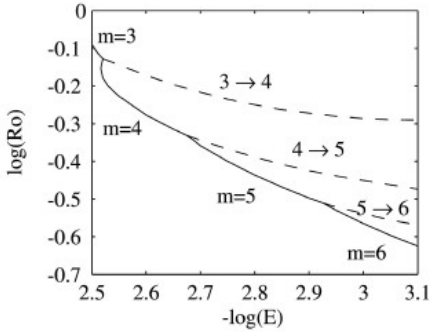




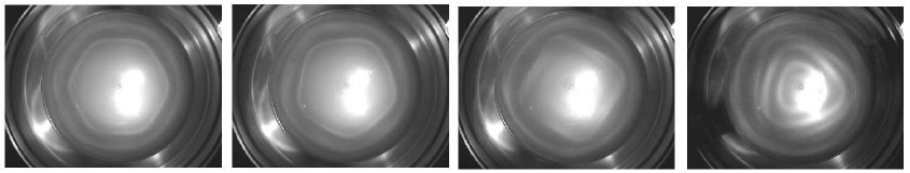


$L=(R_2-R_1)$, $t=\Omega^{-1}$, $U=(R_2-R_1)\,\Delta\Omega$:

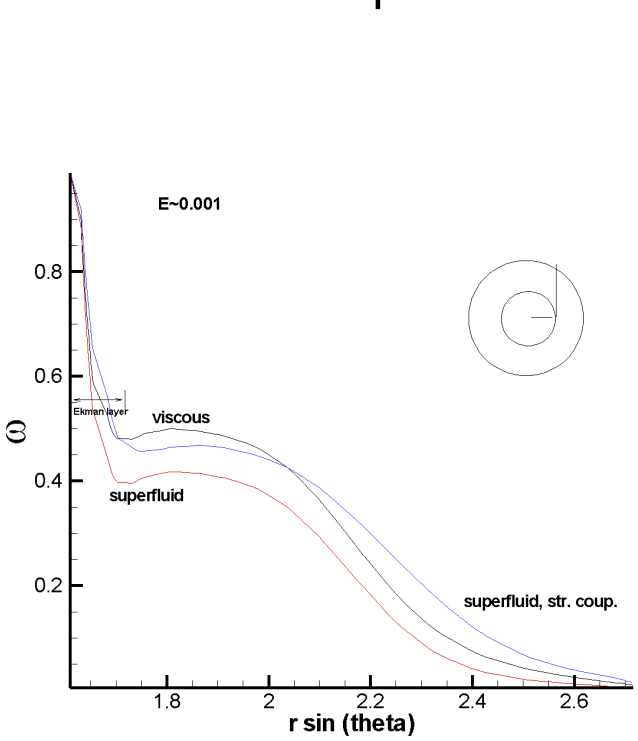
$Ro=\Delta\Omega/\Omega$, $E=\nu/(R_2-R_1)^2\Omega$

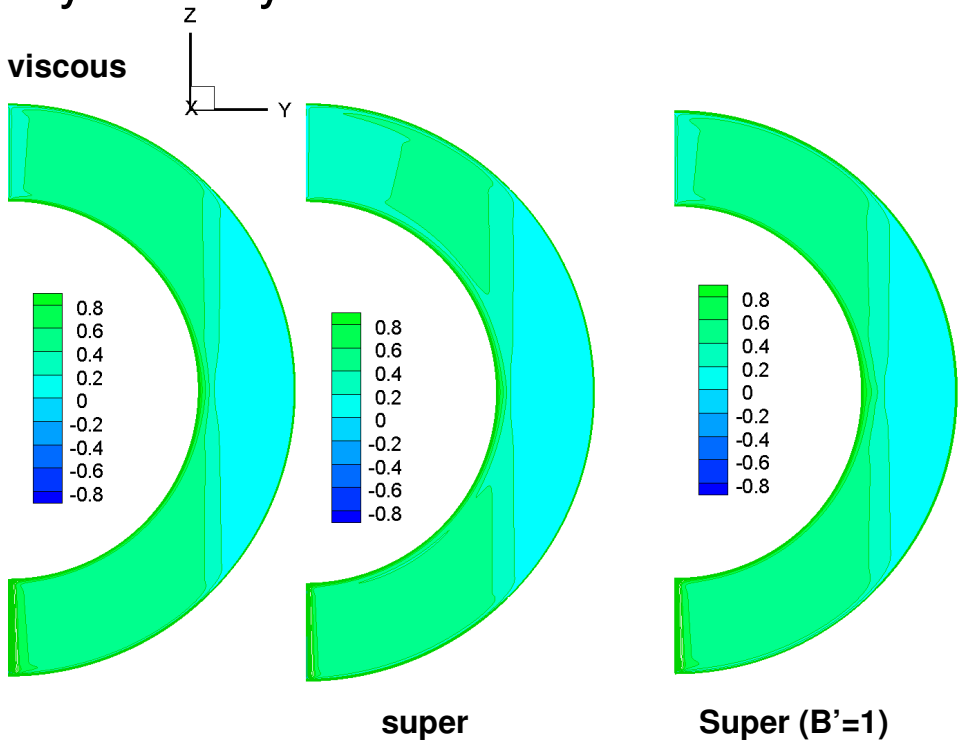


$E=10^{-3.1}$ m=6, 5, 4, 3



Superfluid Stewartson layer: axisymmetric states





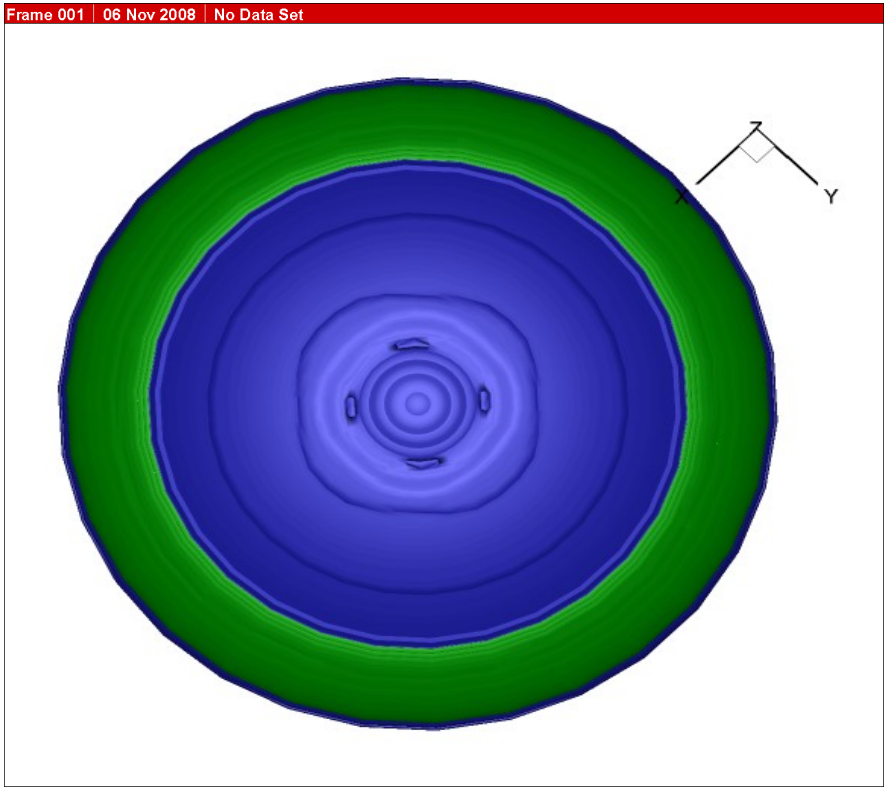
- Layer thickness roughly ind. of Ro: v (grad v) balanced by grad P.
- For fixed E, Ro ↑ => KH instability => nonaxisymmetric flow
- For $E=10^{-3.1}$, most unstable m=6, for Roc~0.24 (m=5 for Roc~0.3, m=4 Roc~0.4, and back, but history dependant)
- Progression to high m as E is reduced (but diff for Ro < 0 in SCF).

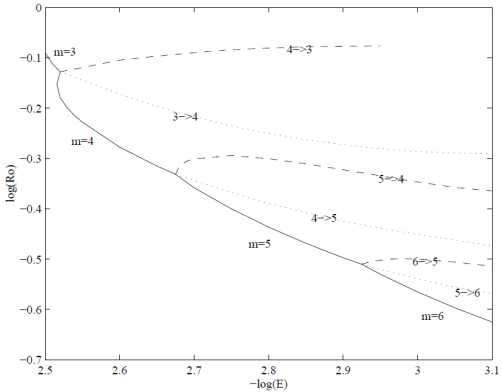
- Similar conclusions for superfluid (runs in progress), layer wider.
- In progress: find most unstable modes for Ro <<1, $E<10^{-3}$ ($Ro\sim10^{-4}$, $E\sim10^{-11}$ in NSs, LIN)
- DGI may be excited in the layer => superfluid turbulence in the layer?

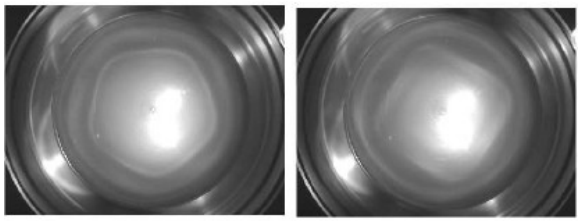
3D instabilities

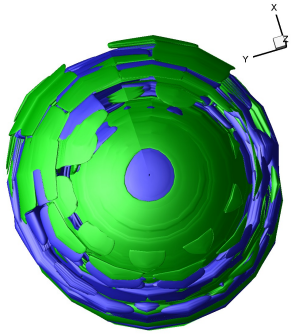
m=5, Ro=0.2 -> 0.3, E=$10^{-3.1}$

m=4, Ro=0.3 -> 0.4, E=$10^{-2.8}$





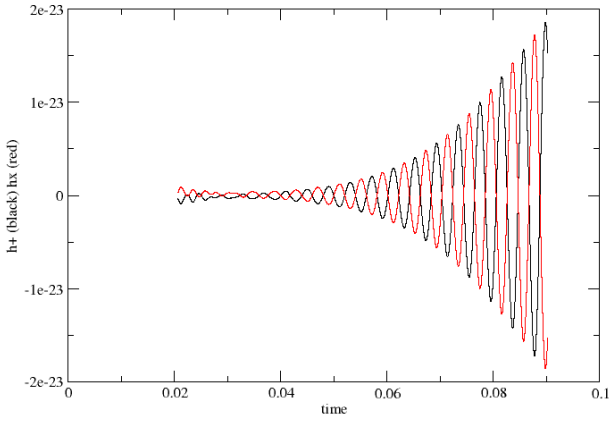


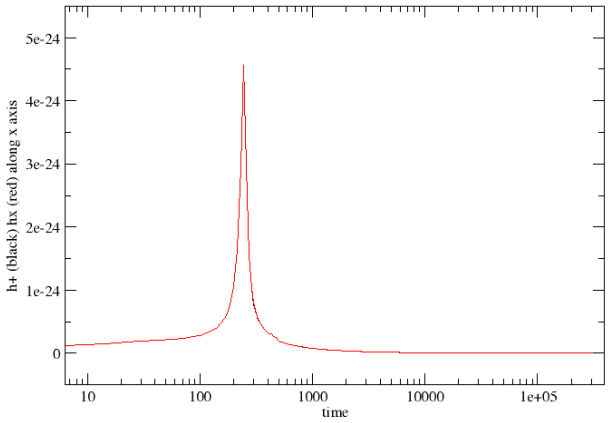


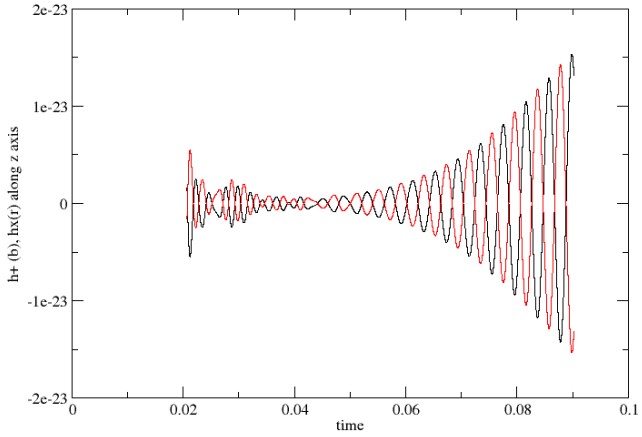
Gravitational waves

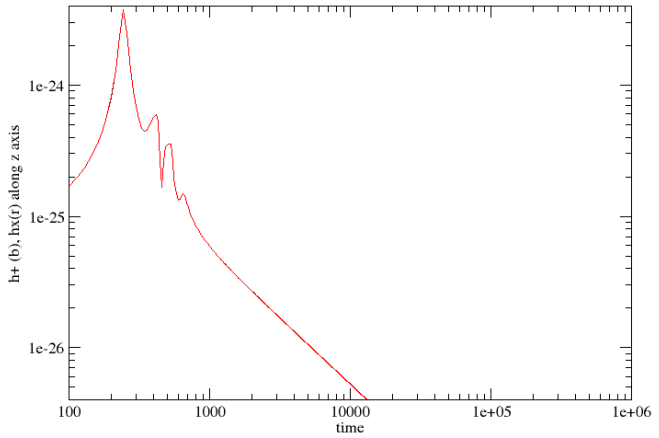
Steady diff rot ->Ro ↑

$$h_{ij}^{TT} = (4G/rc^4)\int d^3\boldsymbol{x}\, T_{ij} \qquad T_{ij} = \rho\gamma^2 v_i v_j + p\delta_{ij}$$
$$T_{00} = \rho\gamma^2 \approx \rho(1 + |\boldsymbol{v}|^2/c^2)$$
$$h_{ij}^{TT} = \frac{2G\rho}{rc^6}\frac{\partial^2}{\partial t^2}\int d^3\boldsymbol{x}\, |\boldsymbol{v}|^2 \left(x_i x_j - \delta_{ij}\frac{|\boldsymbol{x}|^2}{3}\right)$$



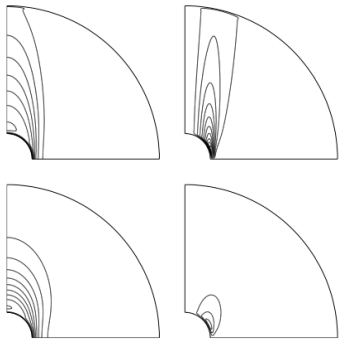






Work in progress

- **Superfluid phase diagram: (E,Ro). Lin, code**
- **Include spin-down ($d\Omega/dt < 0$)**
- **Include stratification: an. app. $(\rho v)_{,t}=0$** ⟶



- **Layer gets 'squashed' -> Taylor columns**
- **Compare Ro ~ E^x w/glitch data**
- **Does the 3D transition has any effect on the torque (shear suppression)?**

- **Precession. Diff modes excited**

- **Magnetic field (layer widens), kin. app.**

- **Gravitational waves from hydrodynamic isotropic turbulence (MP 08):**
  formalism of Kosowsky, Gogoberidze for 1st order phase transitions in early universe
  Wasserman: GR from clusters of quantized vortices