Accretion Disk Boundary Layers

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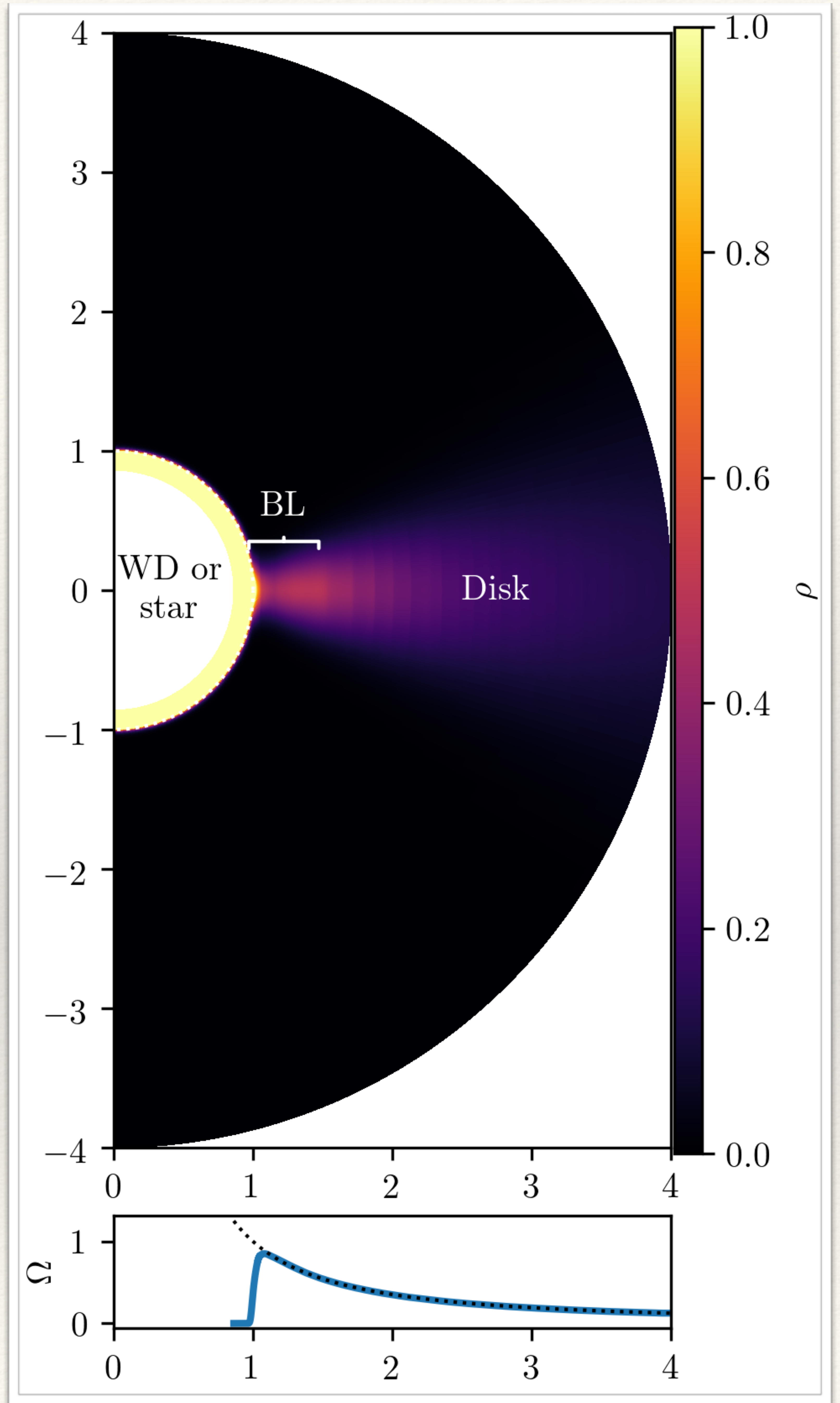
The Boundary Layer

$$P_{\text{disk, ram}} > P_{\star,\text{mag}}$$

- Where the disk meets the star
- MRI doesn't work
- How does angular momentum transport here work?

Mach number

$$\mathcal{M} = \frac{v_{\text{kep}}\left(R_\star\right)}{C_{\text{s}}} \gg 1$$



The Boundary Layer

$$\mathscr{M} = \left(\frac{8\pi}{3}\frac{G^3\sigma m_u^4}{k_b^4}\right)^{1/8} M^{3/2}\mu^{1/2}\dot{M}^{-1/8}R^{-1/8}\tau^{-1/8}$$

$$(\text{CV hot}) = 32\left(\frac{M}{0.6M_\odot}\right)^{3/8}\left(\frac{\mu}{0.6}\right)^{1/2}\left(\dot{M}_{-9}\frac{R}{9\text{ Mm}}\frac{\tau}{10^4}\right)^{-1/8}$$

$$(\text{CV cold}) = 270\left(\frac{M}{0.6M_\odot}\right)^{3/8}\left(\frac{\mu}{2}\right)^{1/2}\left(\dot{M}_{-11}\frac{R}{9\text{ Mm}}\frac{\tau}{5}\right)^{-1/8}$$

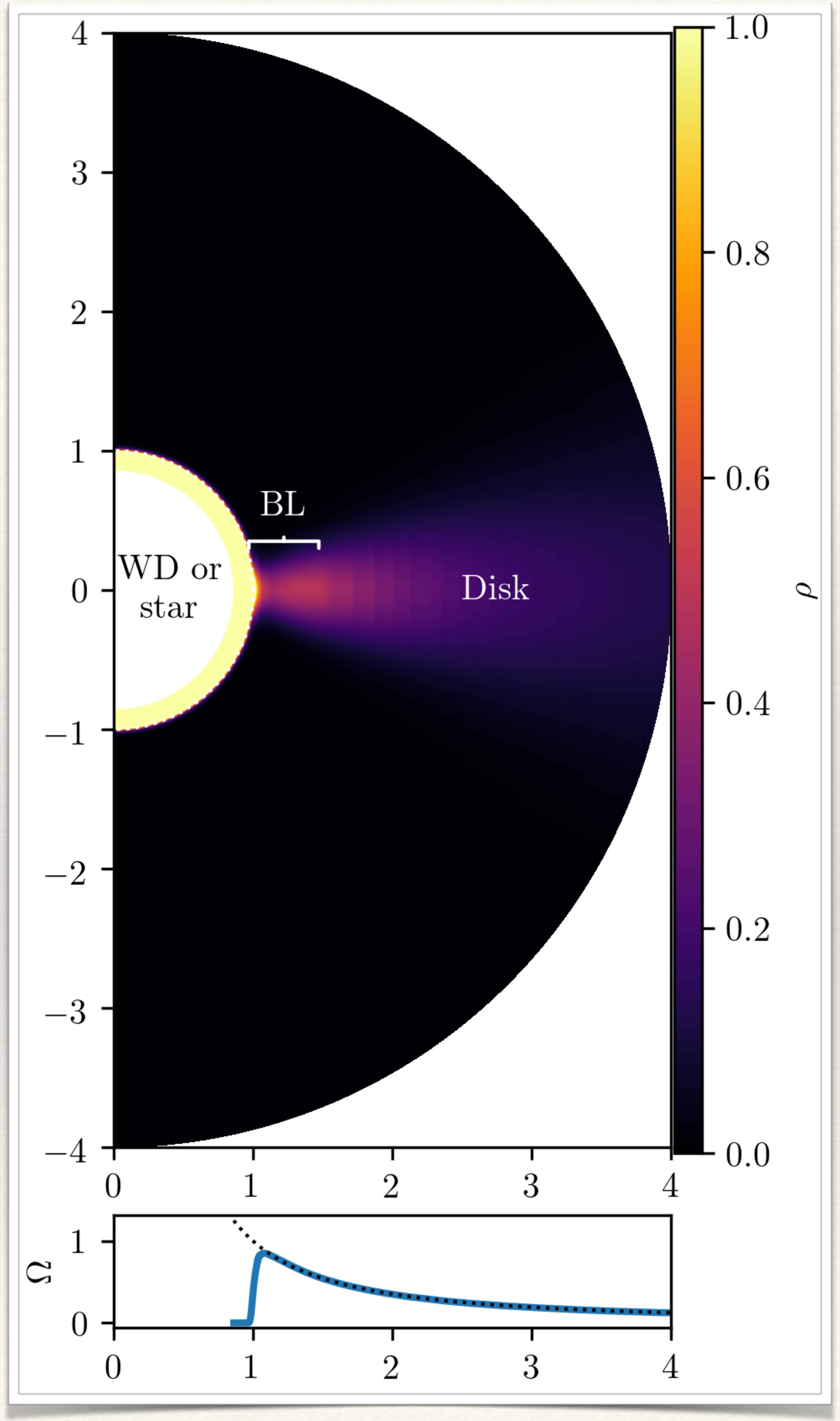
$$(\text{AM CVn hot}) = 55\left(\frac{M}{1.1M_\odot}\right)^{3/8}\left(\frac{\mu}{1.4}\right)^{1/2}\left(\dot{M}_{-9}\frac{R}{4.7\text{ Mm}}\frac{\tau}{5\times 10^4}\right)^{-1/8}$$

$$(\text{AM CVn cold}) = 330\left(\frac{M}{1.1M_\odot}\right)^{3/8}\left(\frac{\mu}{4}\right)^{1/2}\left(\dot{M}_{-12}\frac{R}{4.7\text{ Mm}}\frac{\tau}{2000}\right)^{-1/8}$$

$$(\text{PPD}) = 53\left(\frac{M}{M_\odot}\right)^{3/8}\left(\frac{\mu}{2}\right)^{1/2}\left(\dot{M}_{-8}\frac{R}{2R_\odot}\frac{\tau}{75}\right)^{-1/8}$$

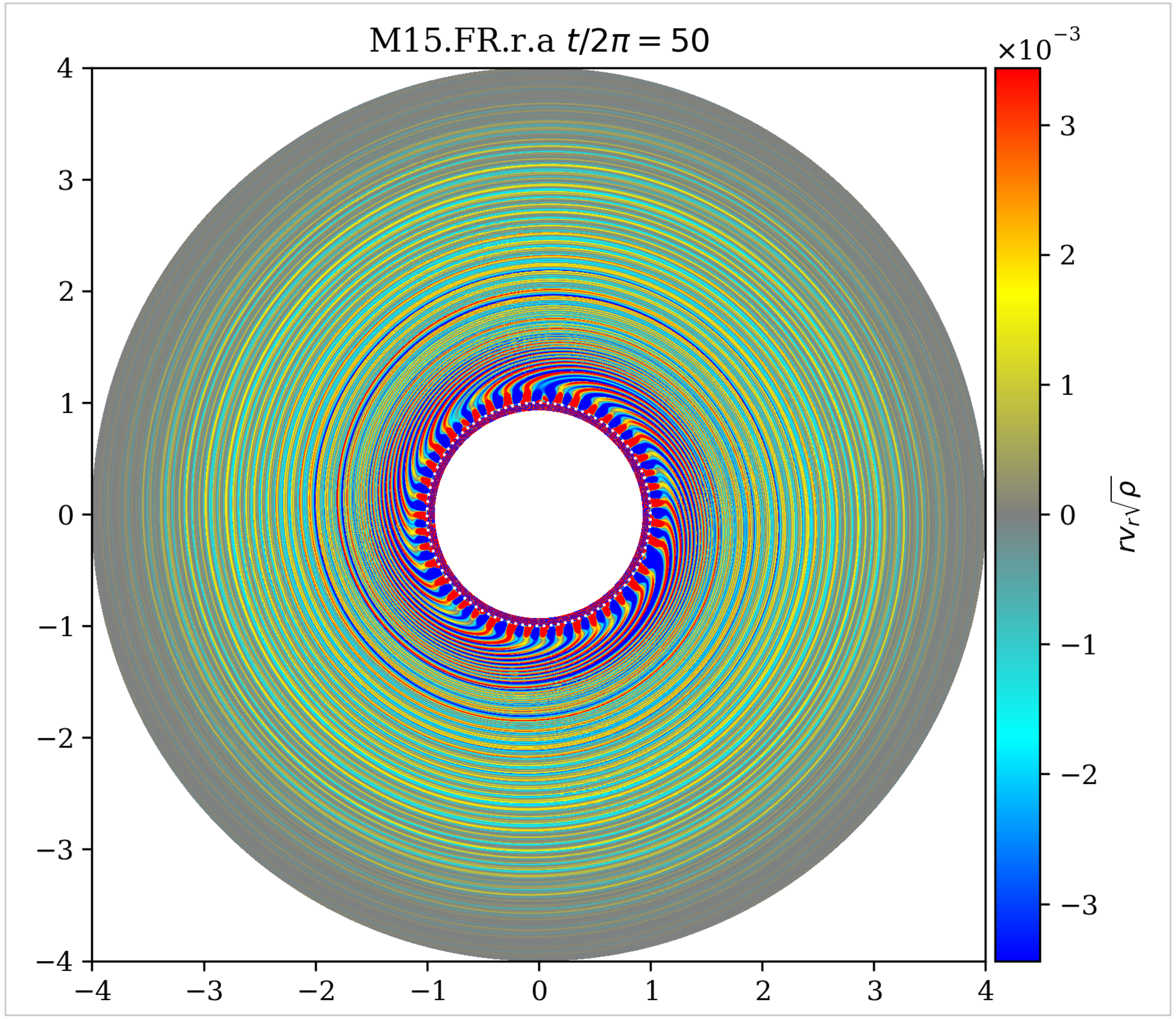
$$(\text{FU Ori}) = 5.3\left(\frac{M}{M_\odot}\right)^{3/8}\left(\frac{\mu}{0.6}\right)^{1/2}\left(\dot{M}_{-5}\frac{R}{2R_\odot}\frac{\tau}{6\times 10^5}\right)^{-1/8}$$

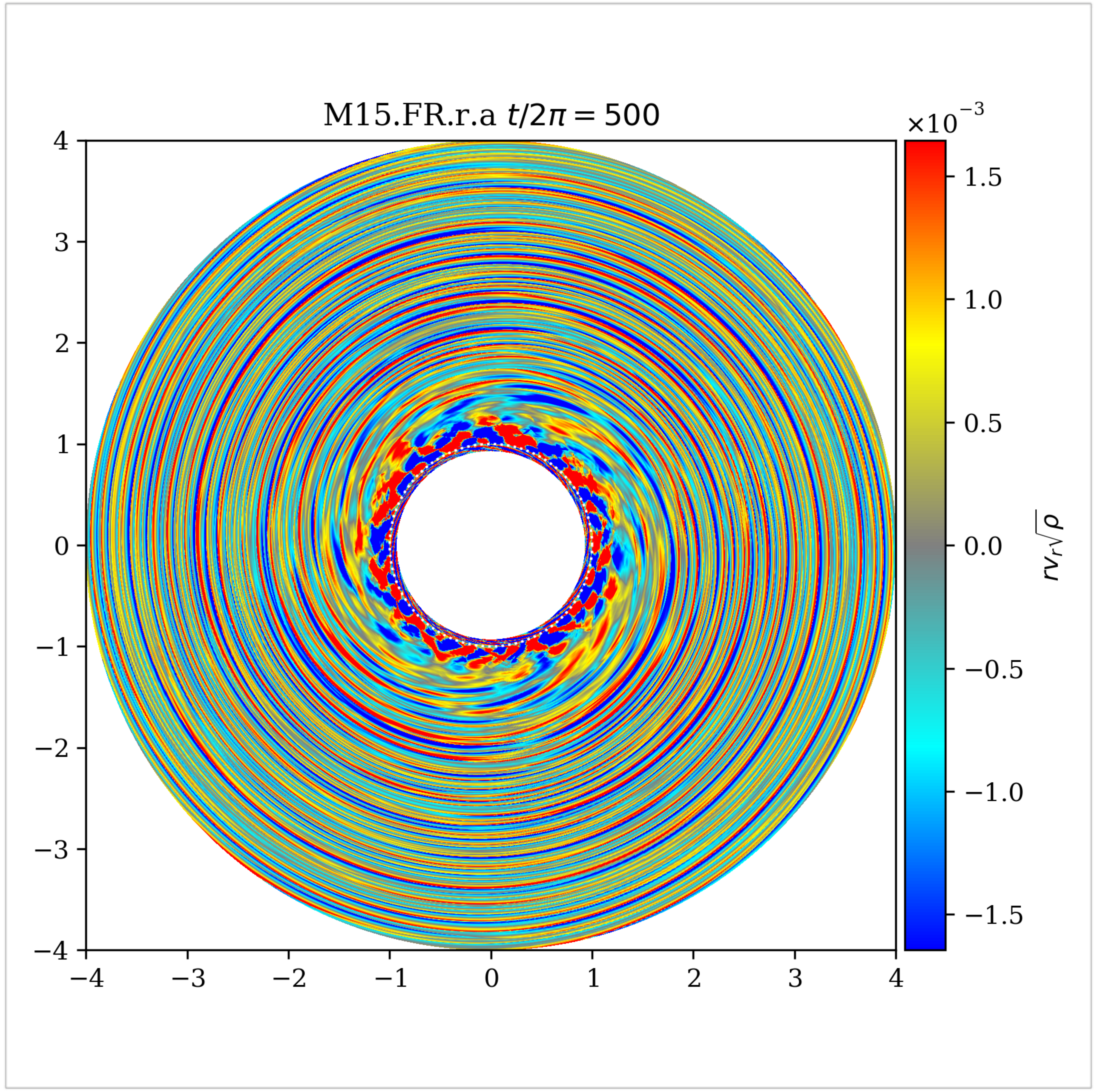
Numeric considerations $h_\star \sim \mathscr{M}^{-2},\ dt \sim \frac{h_\star}{\mathscr{M}} \sim \mathscr{M}^{-3}$



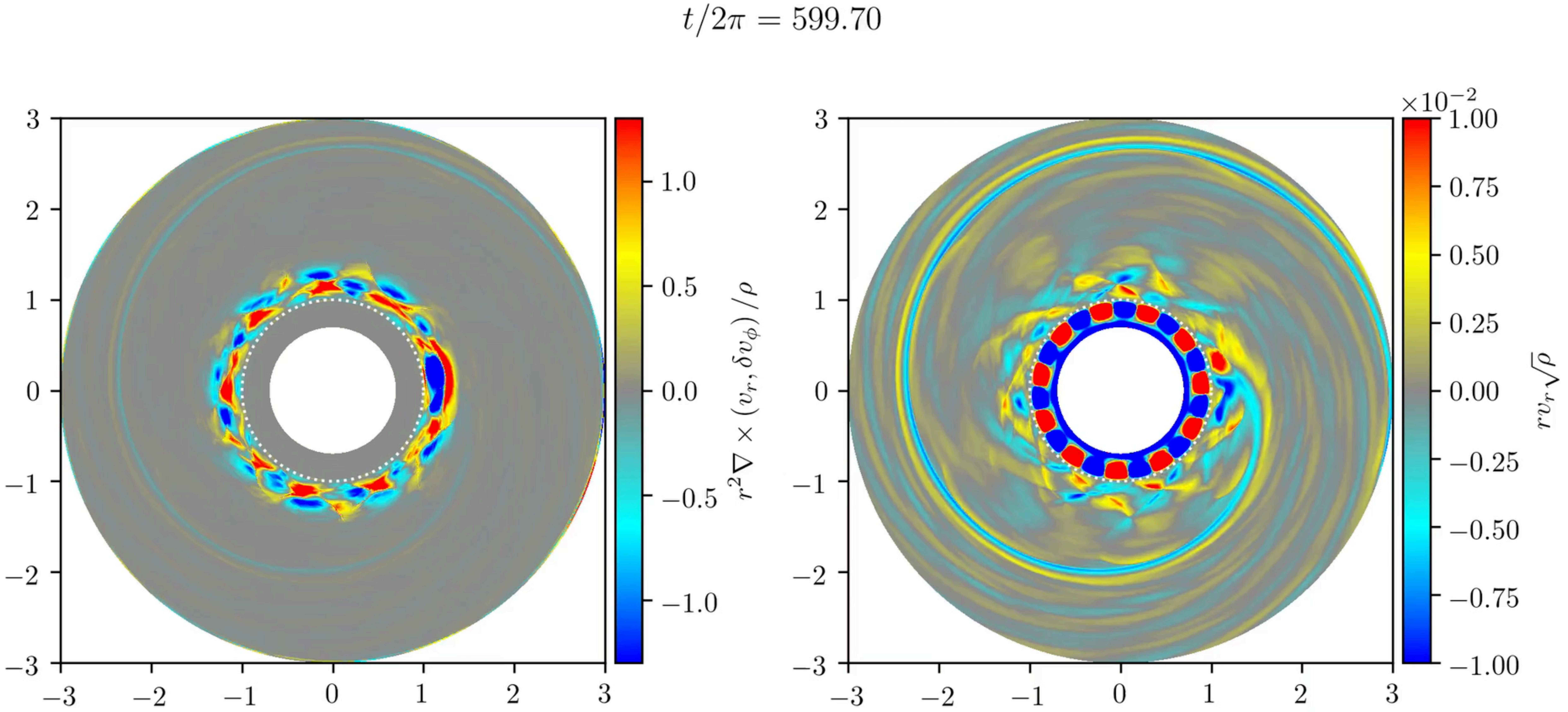
Supersonic Shear

Hydrodynamically Unstable



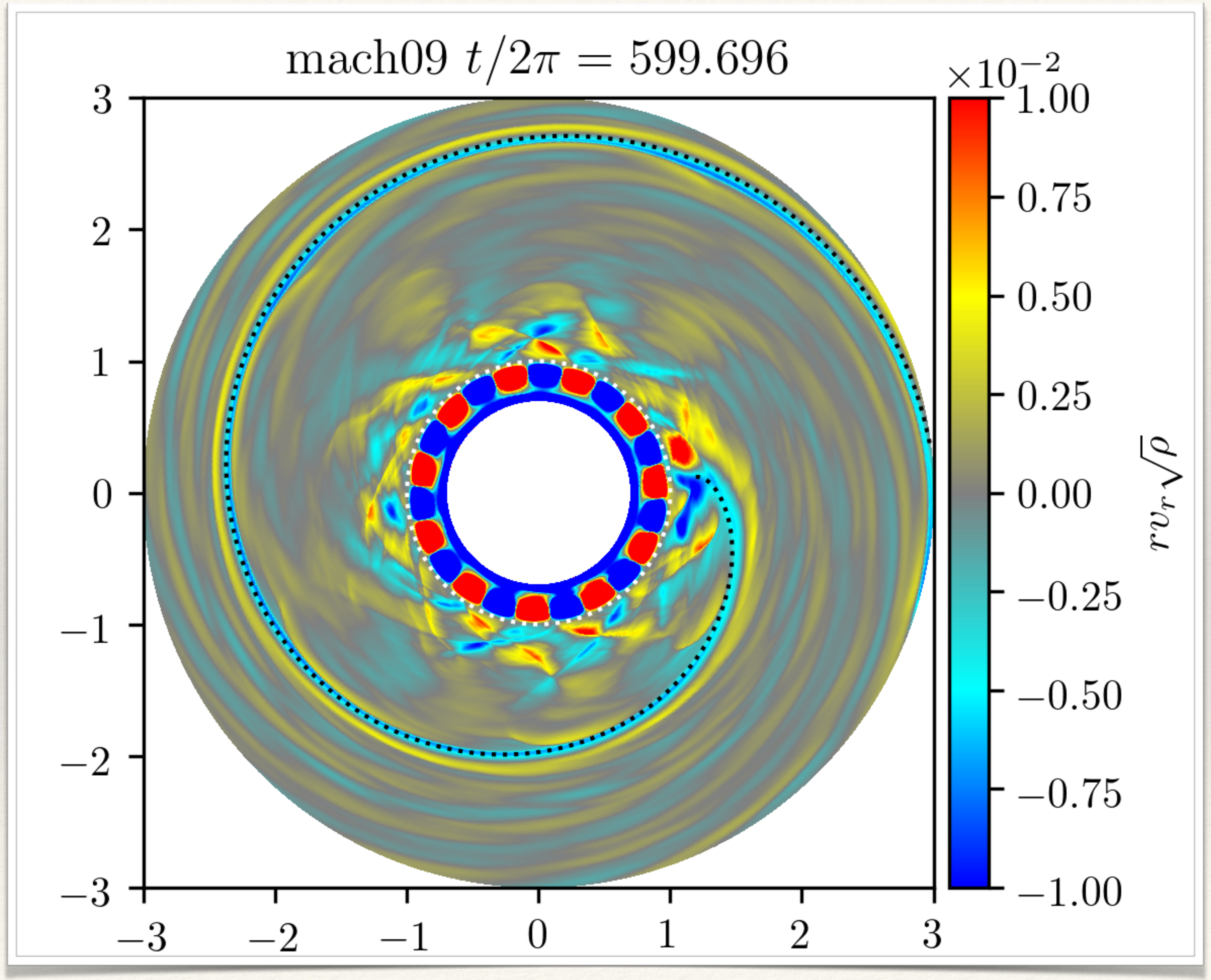


Possible DNO

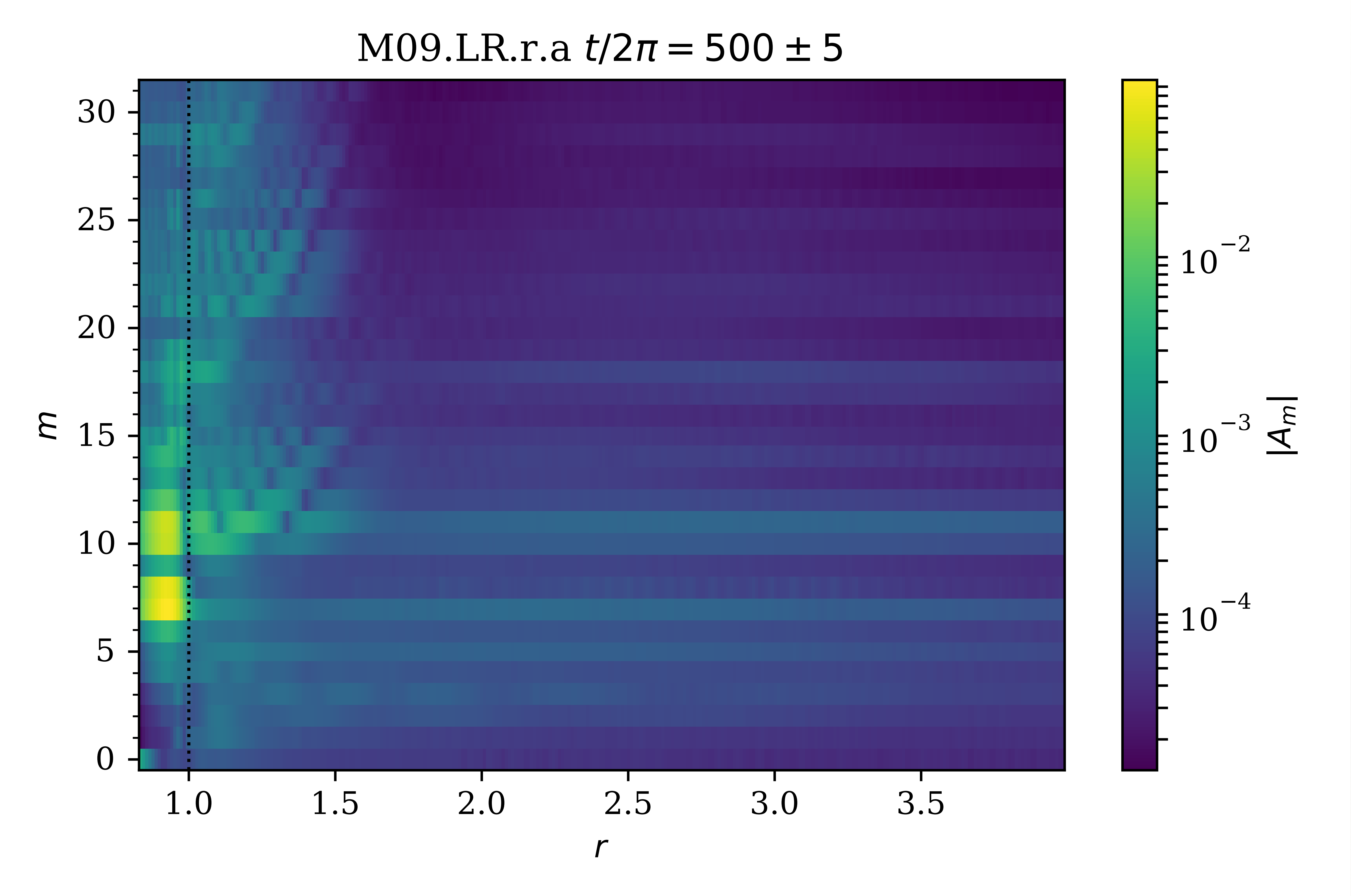


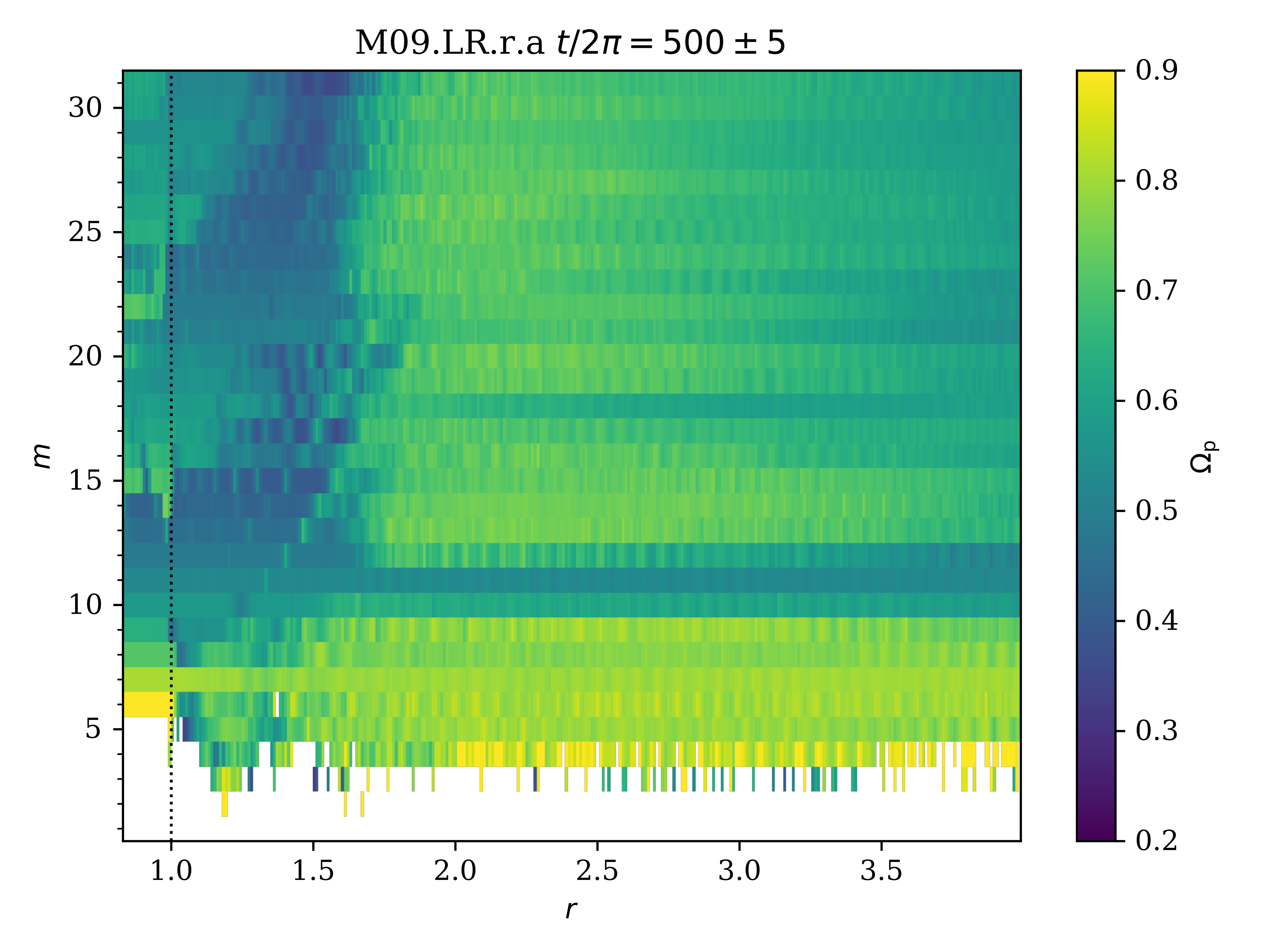
One-armed Spiral

$$\phi = \phi_0 - \mathrm{sign}\left(r - r_p\right)\left[2\sqrt{\frac{R_\star}{r}} + \frac{r}{R_\star}\left(\frac{R_\star}{r_p}\right)^{3/2} - 3\sqrt{\frac{R_\star}{r_p}}\right]$$

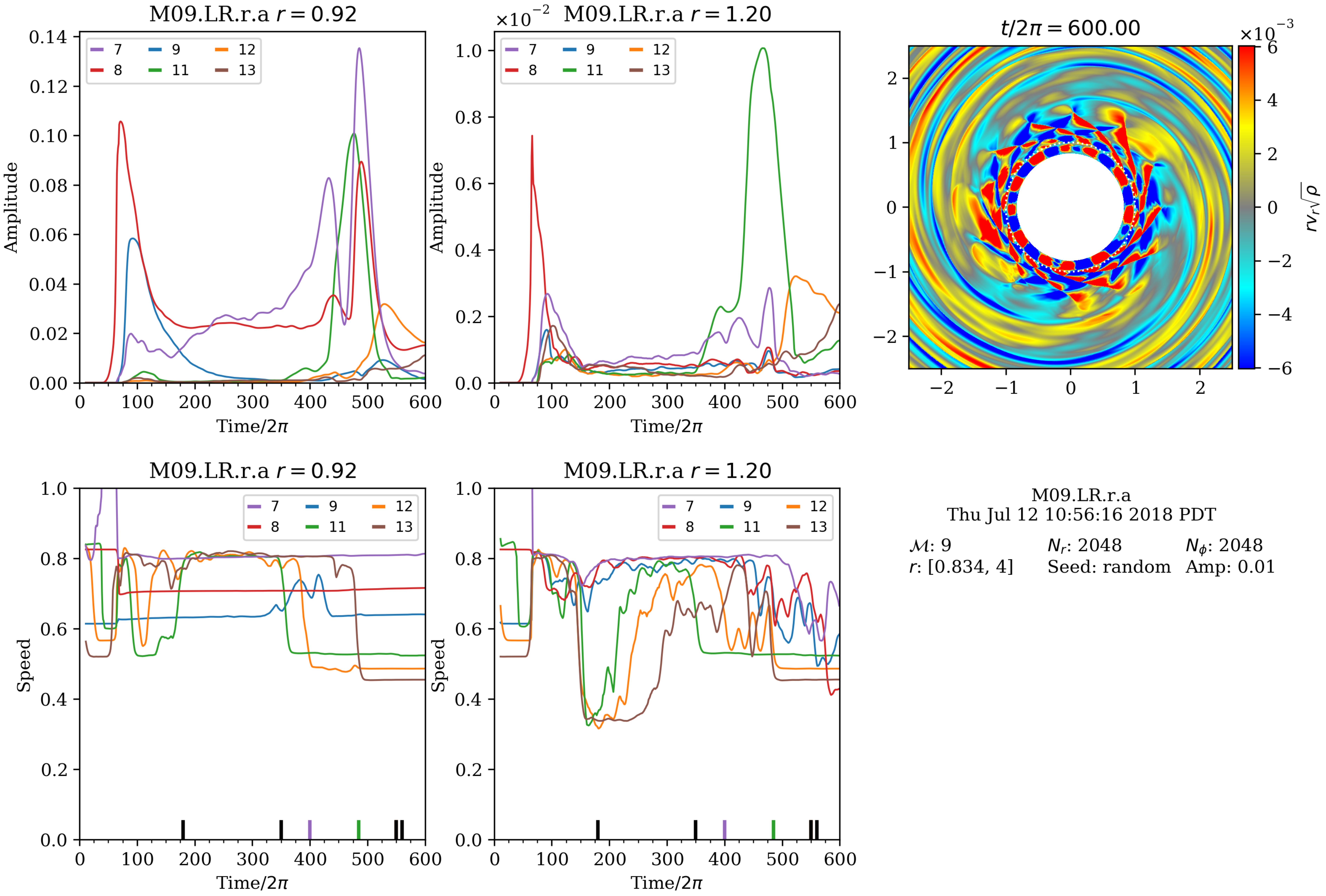


Azimuthal Wave Modes





Diagnostic for M09.LR.r.a

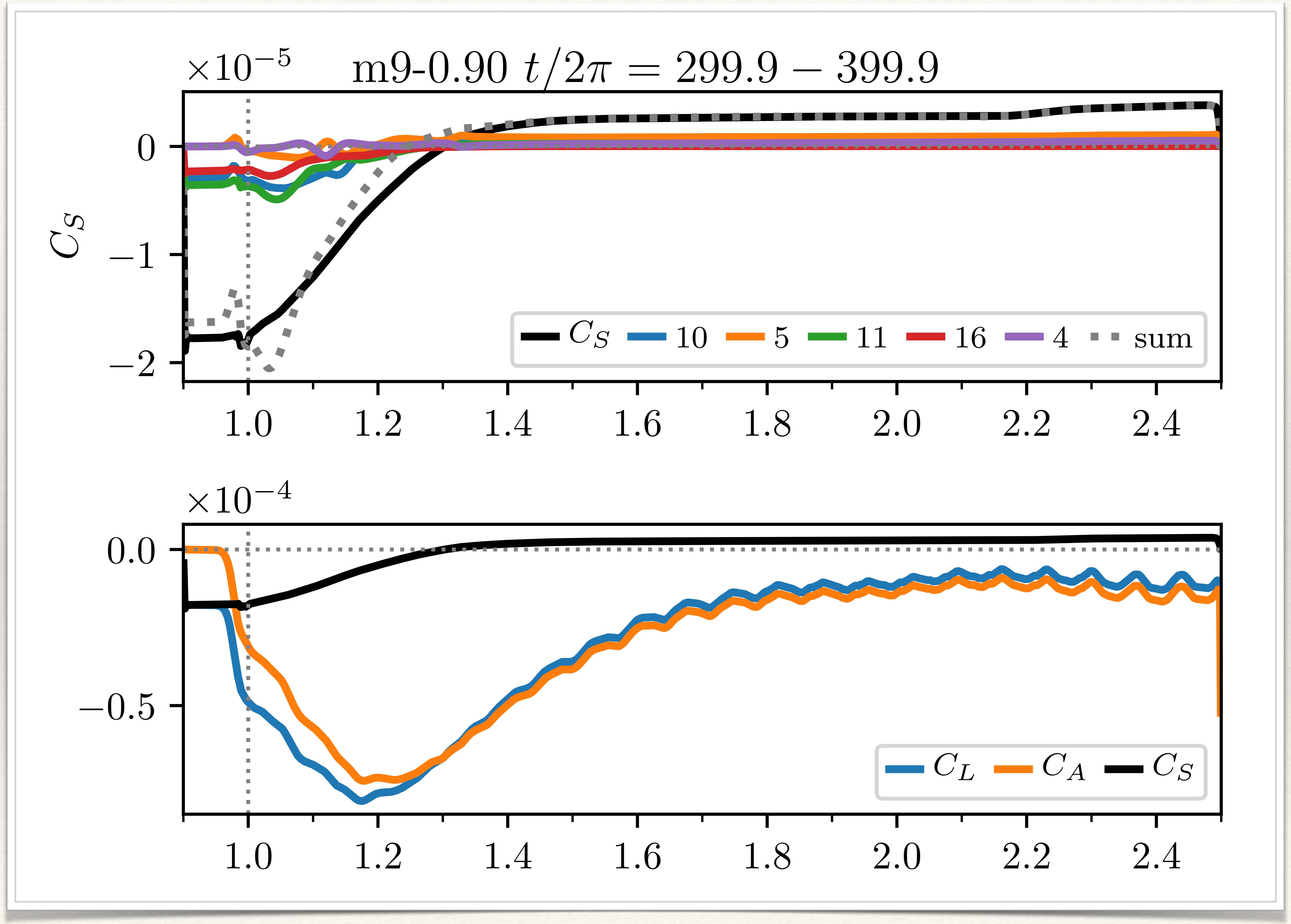


Angular Momentum Transport

C_S = Stress Transport

C_A = Advective Transport

$C_L = C_S + C_A$ = Total Transport



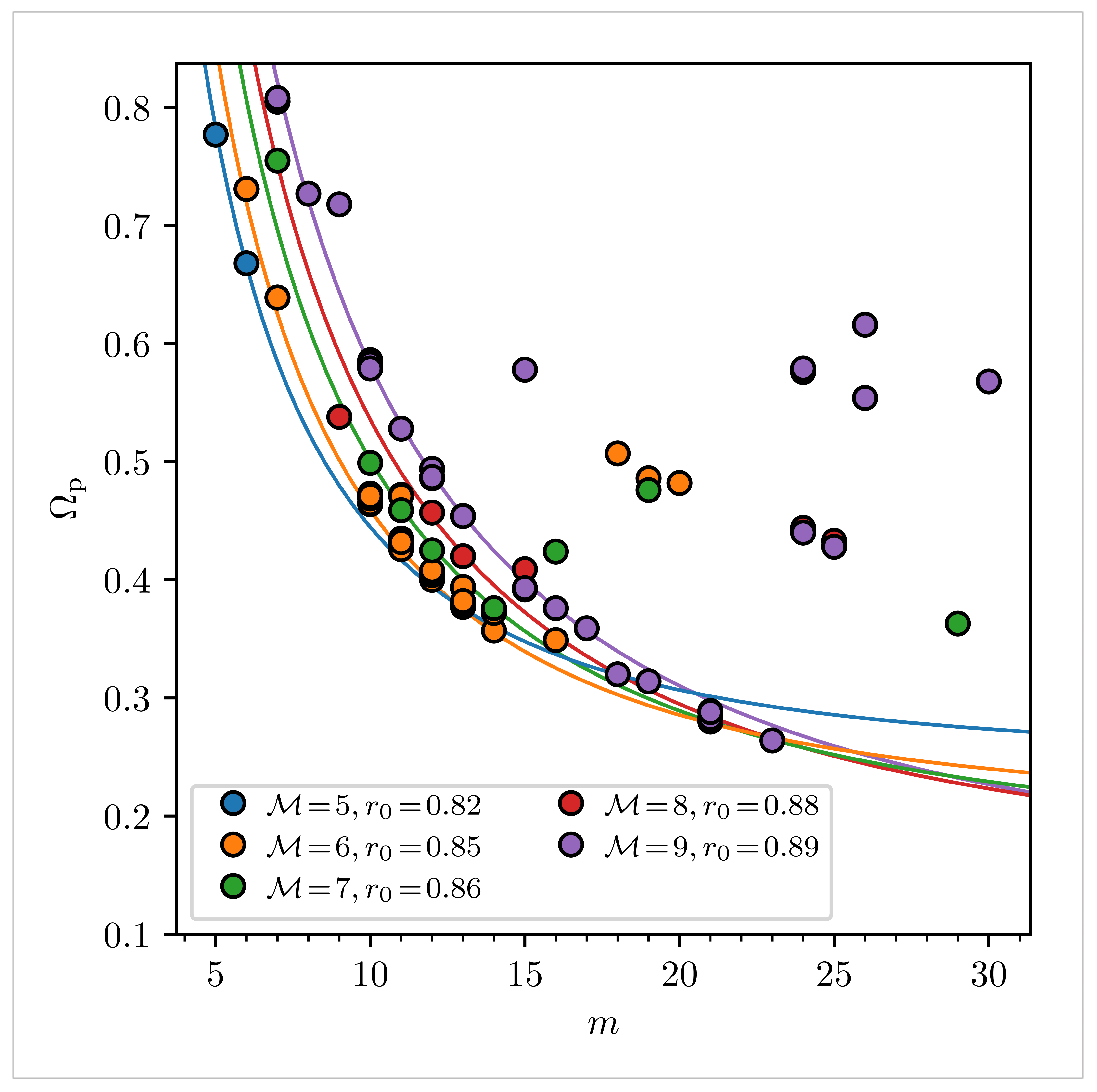
2D Runs

Sim Class	M	Runs done	Nr	Nphi
2DM5	5	2	1024	1024
2DM6	6	4	1024	1024
2DM6HR	6	6	2048	2048
2DM7	7	1	2048	2048
2DM8	8	1	2048	2048
2DM9LR	9	7	2048	2048
2DM9	9	7	4096	4096
2DM9HR	9	1	8192	8192
2DM10	10	1	4096	4096
2DM11	11	1	4096	4096
2DM12	12	5	4096	4096
2DM13	13	1	8192	8192
2DM14	14	1	8192	8192
2DM15	15	1	8192	8192

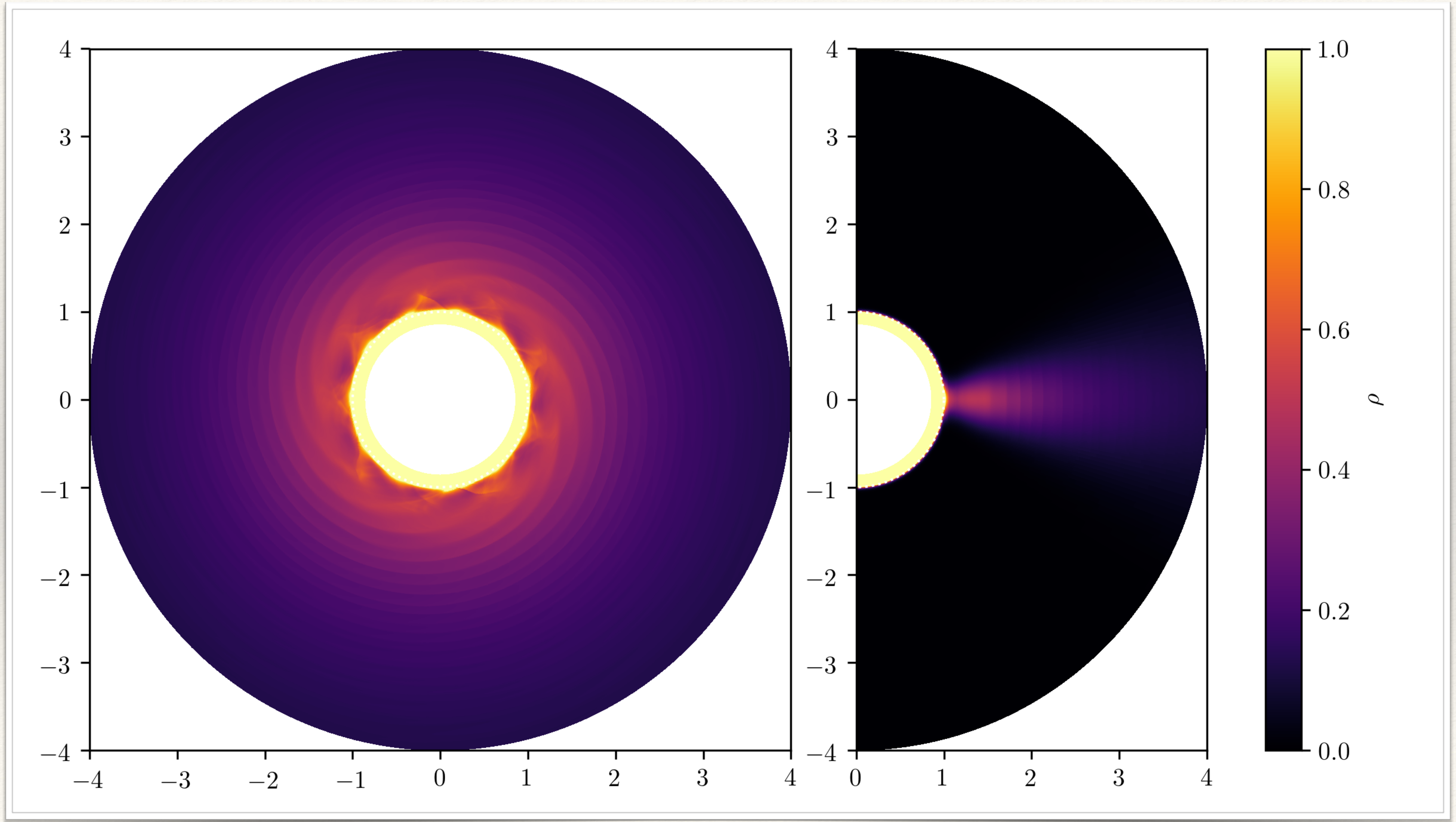
Dispersion Relation

Curves are single parameter fit.

$$\frac{\Omega_p}{\Omega(R_\star)} = \sqrt{\mathscr{M}^{-2} + \left(\frac{\mathscr{M} R_\star}{2 m r_0}\right)^2}$$



3D Preliminary Results



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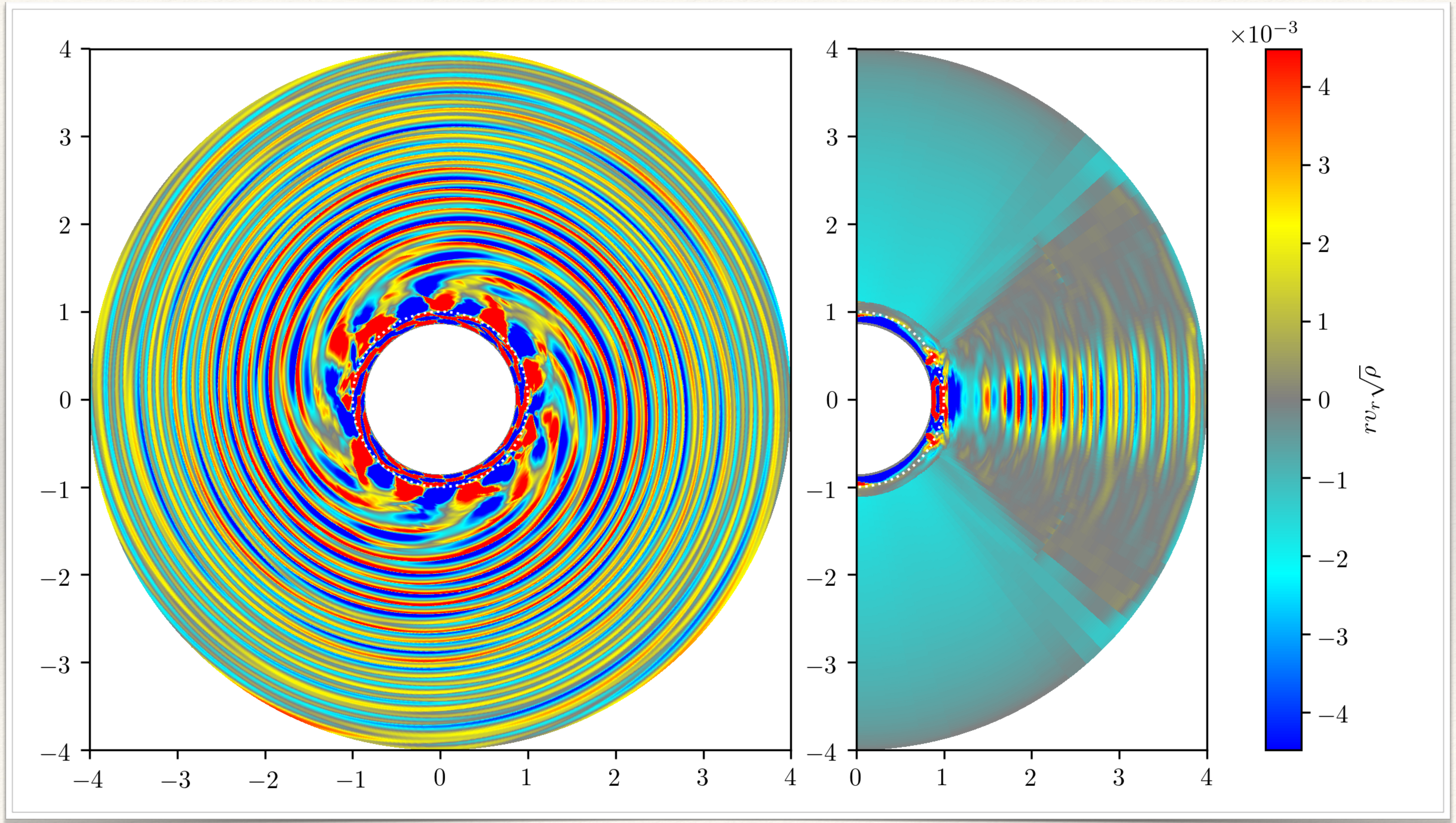

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Summary

Accretion Disk Boundary Layers

- Stable to MRI
- Supersonic shear ⟶ AM Transport
- Possible explanation of DNO
- Fourer decomposition
- Working on 3D