MAX PLANCK INSTITUTE
FOR SOLAR SYSTEM RESEARCH

CONTINUATION AND DAMPING OF ZONAL FLOWS BY STABLY STRATIFIED LAYERS

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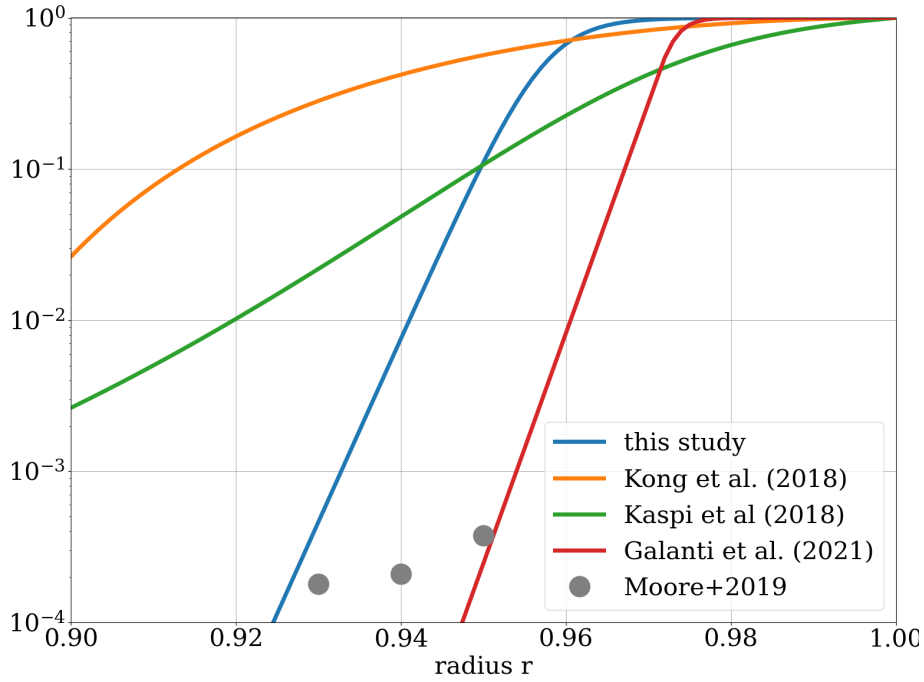
MOTIVATION – ZONAL WINDS ON JUPITER

- Juno's gravity measurements confirmed deep reaching winds
- models suggested 2000-3000 km depth, then sharp decay due to stable layer or increasing electrical conductivity, e.g.

Kaspi et al. 2018, Christensen et al. 2020, Dietrich et al. 2021, Galanti et al. 2021



various decay profiles for Jupiters zonal winds. *Dietrich et al., 2021, MNRAS*

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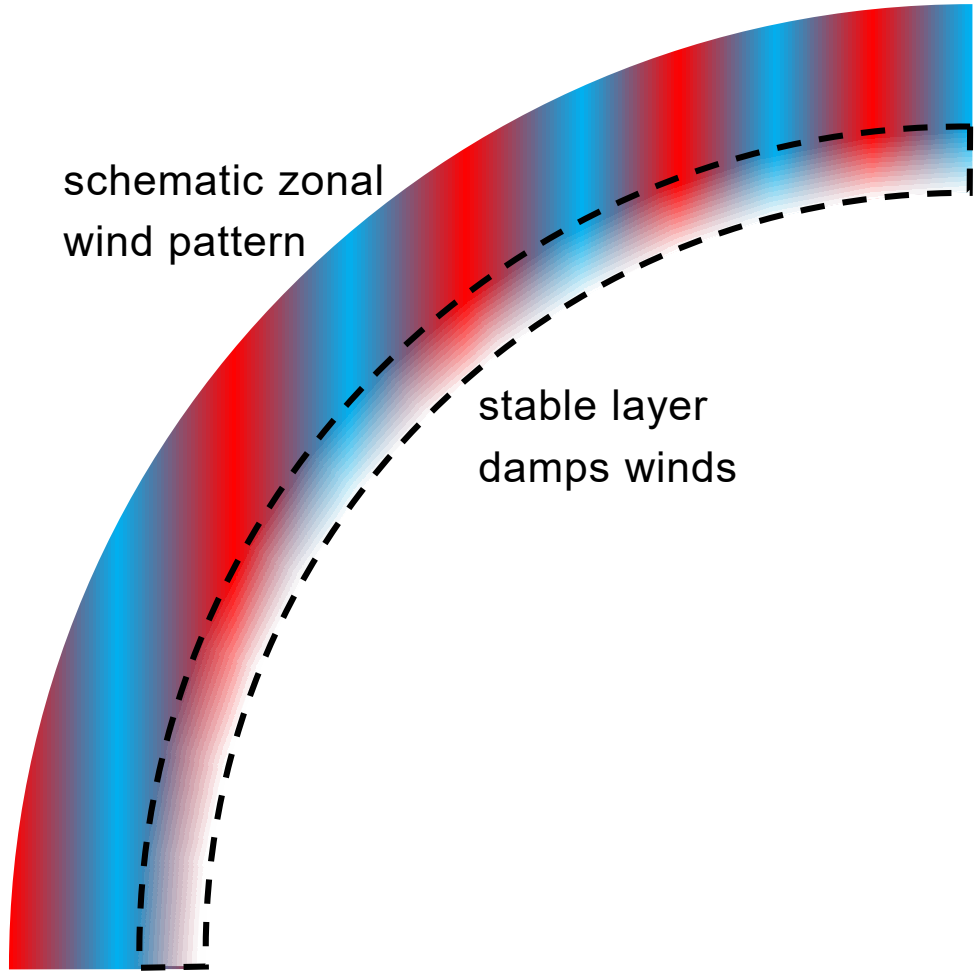
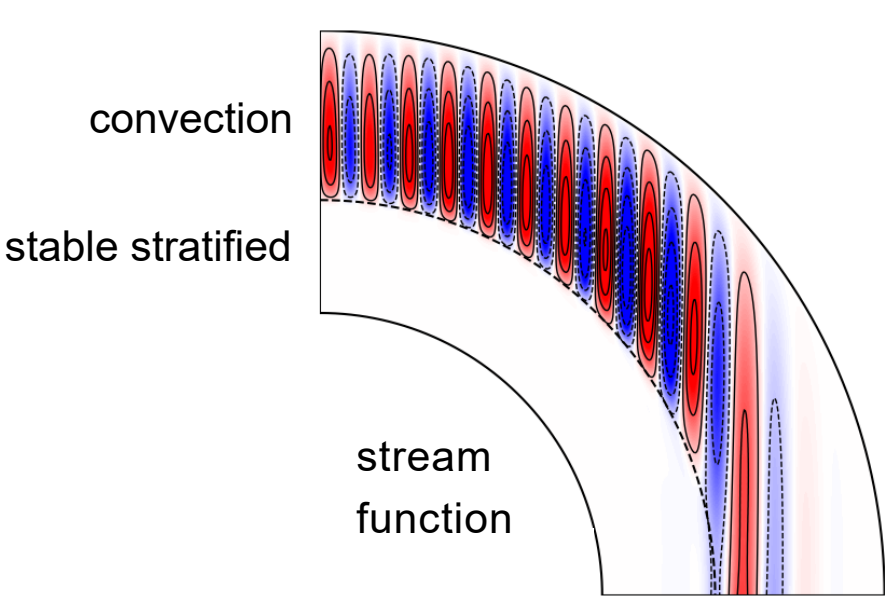
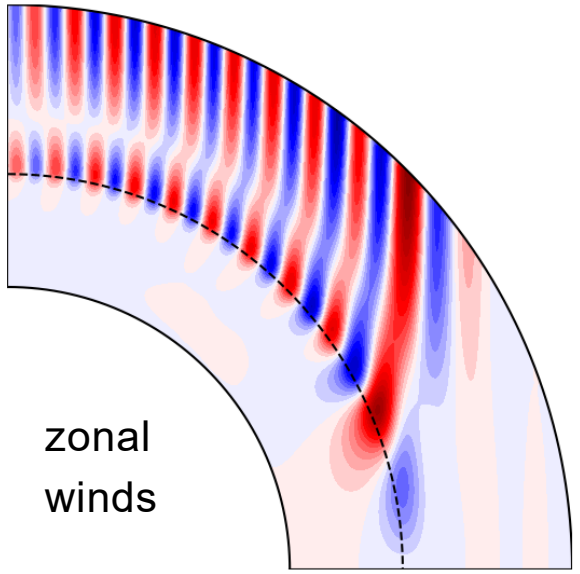
- **How does zonal flow interact with stable layer?**
- characterized by N/Ω, with N is BV freq, Ω the rotation rate
- due to compositional (N/Ω < 3) or thermal stratification (N/Ω = 1)

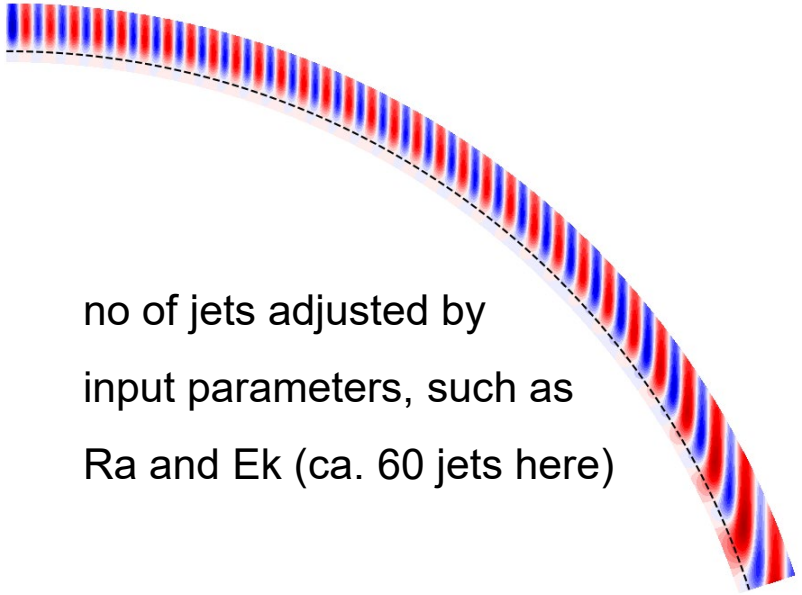


NUMERICAL MODEL SETUP – AXISYMMETRIC CONVECTION

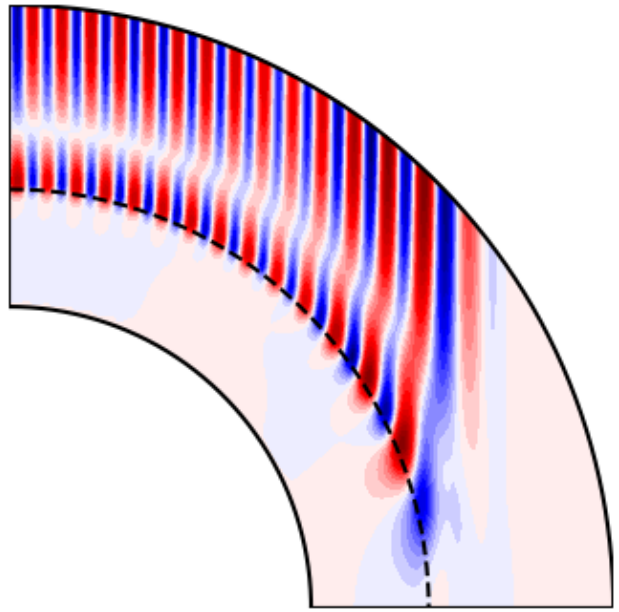
- solve only **axisymmetric** mode, very fast using MagIC
- **equidistant** meridional circulation cells, that drive zonal jets via Coriolis force ($\mathbf{u_\varphi \sim \Omega u_s}$)
- adjust N/Ω = 1..10 (thermal ... chemical stratification) and length scale
- study decay of zonal flow, i.e. radial derivative at boundary to SSL inside TC







RESULTS – LATITUDINAL DEPENDENCE

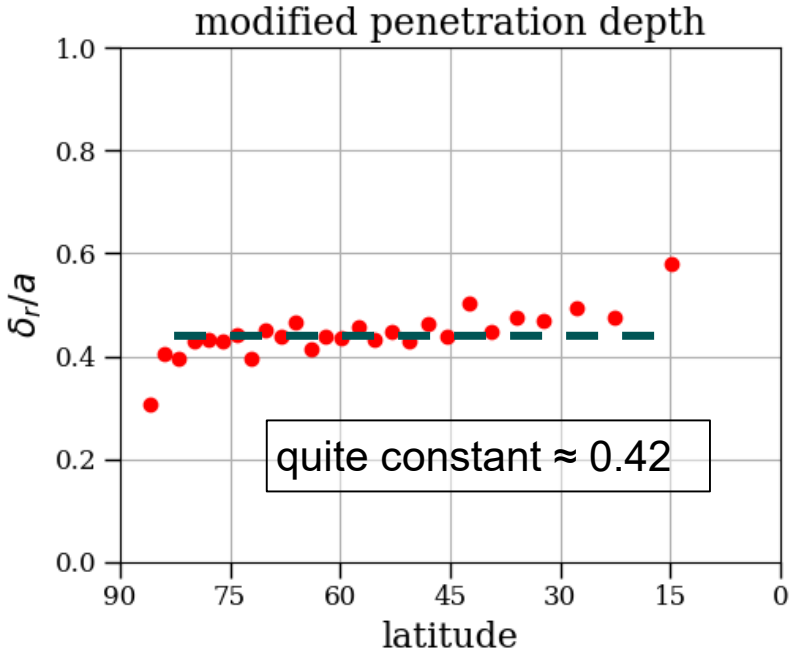


- calculate radial scale height for each jet

$$\delta_r = \left[\frac{1}{u_\varphi}\frac{\partial u_\varphi}{\partial r}\right]^{-1}$$

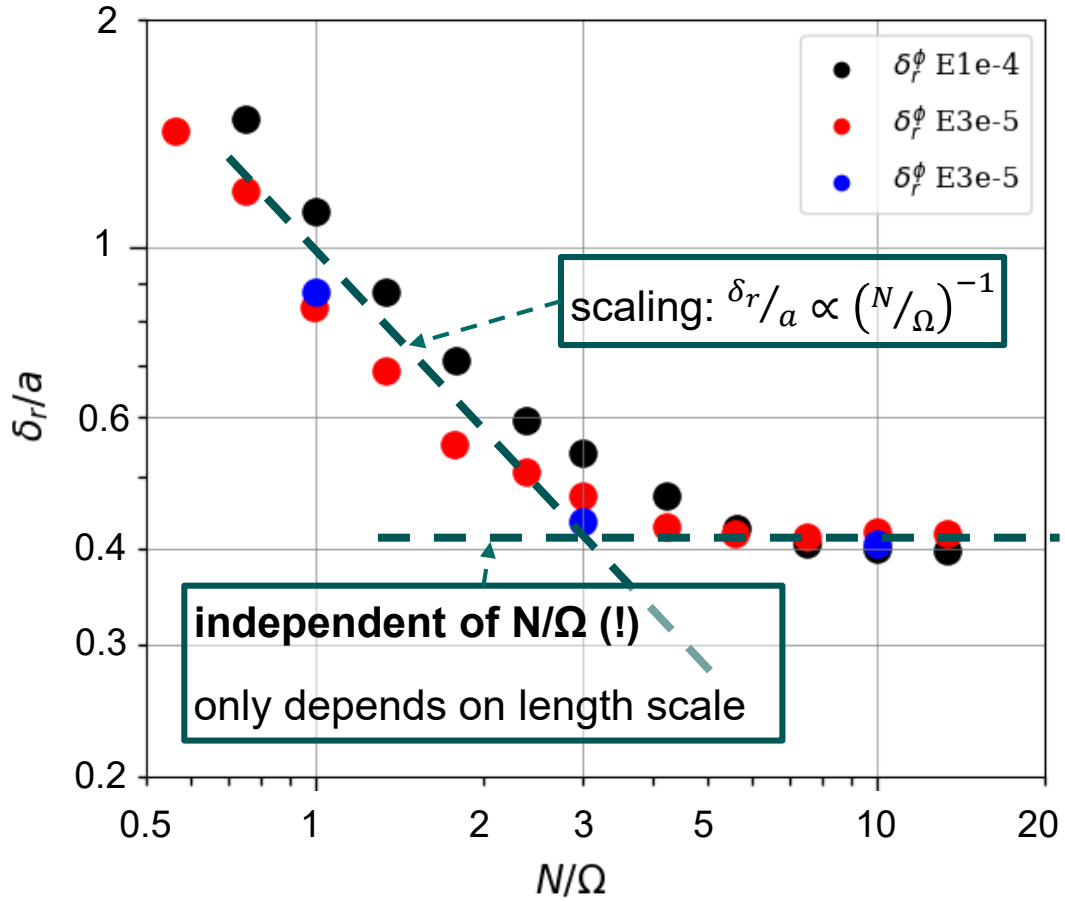
- closer to the equator jets extend deeper
- though equidistant, jets at the SSL appear different

- **thus normalize with arc length a**, *e.g. Takehiro& Lister, 2002* δ_r/a
- constant scaling for penetration scale height δ_r/a
- what happens for various N/Ω



RESULTS – DEPENDENCE ON STRATIFICATION

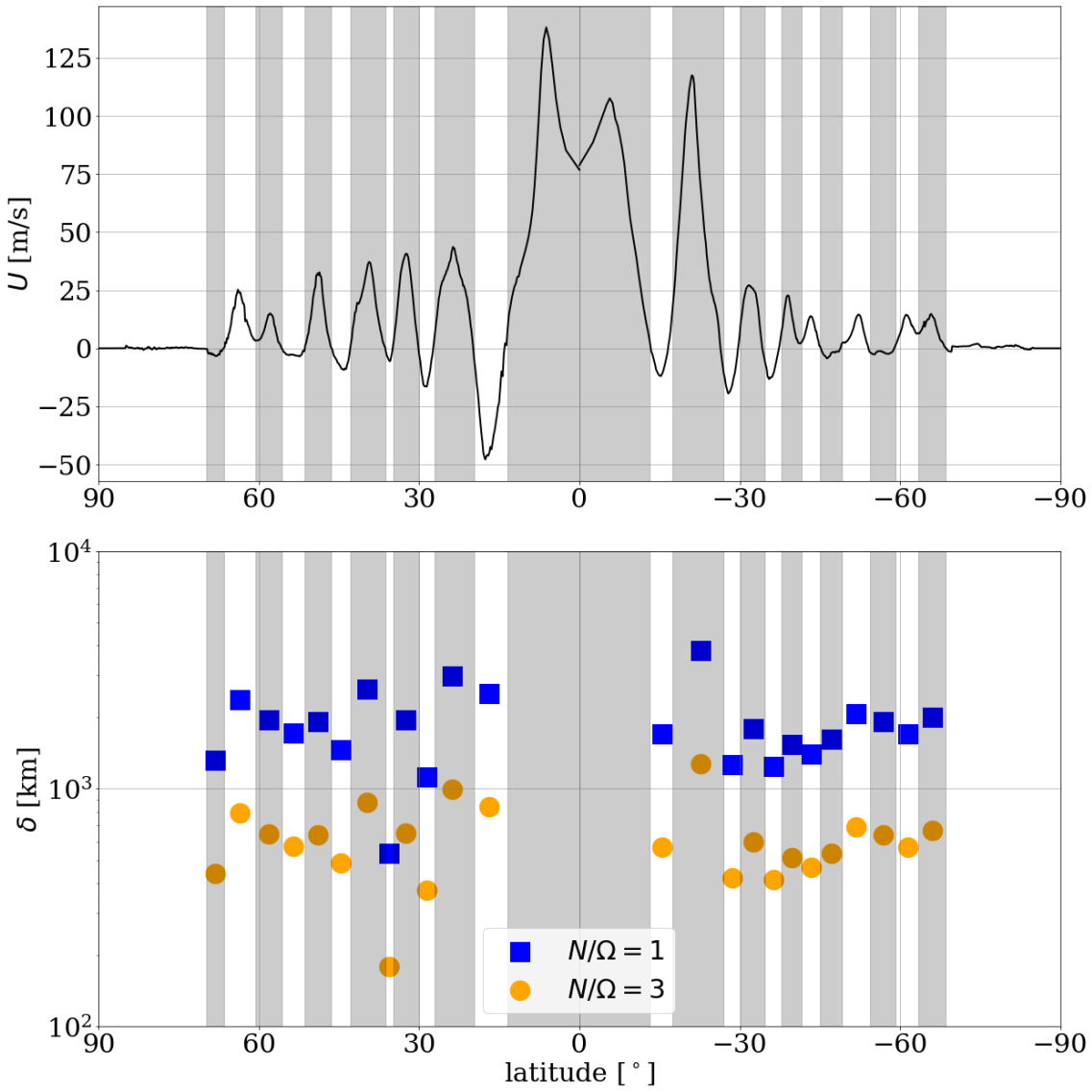
- study large numerical suite (ca. 45 models) and extract penetration scale height
- for moderate N/Ω, penetration scale height scales linearly *[Takehiro & Lister, 2001, 2002]*
- for large N/Ω, constant penetration scale height
- this in contrast to convective motions



APPLICATION TO JUPITER

- assume that mean jet width is a = 4000 km
- the penetration depth is ca. 2000 km for thermal stratification or 800 km for compositional strat.
- this requires either additional damping by electromagnetic effects or a compositional gradient by H/He separation
- we thus have to adopt the gravity inversion models

-> larger jets penetrate deeper into SSL



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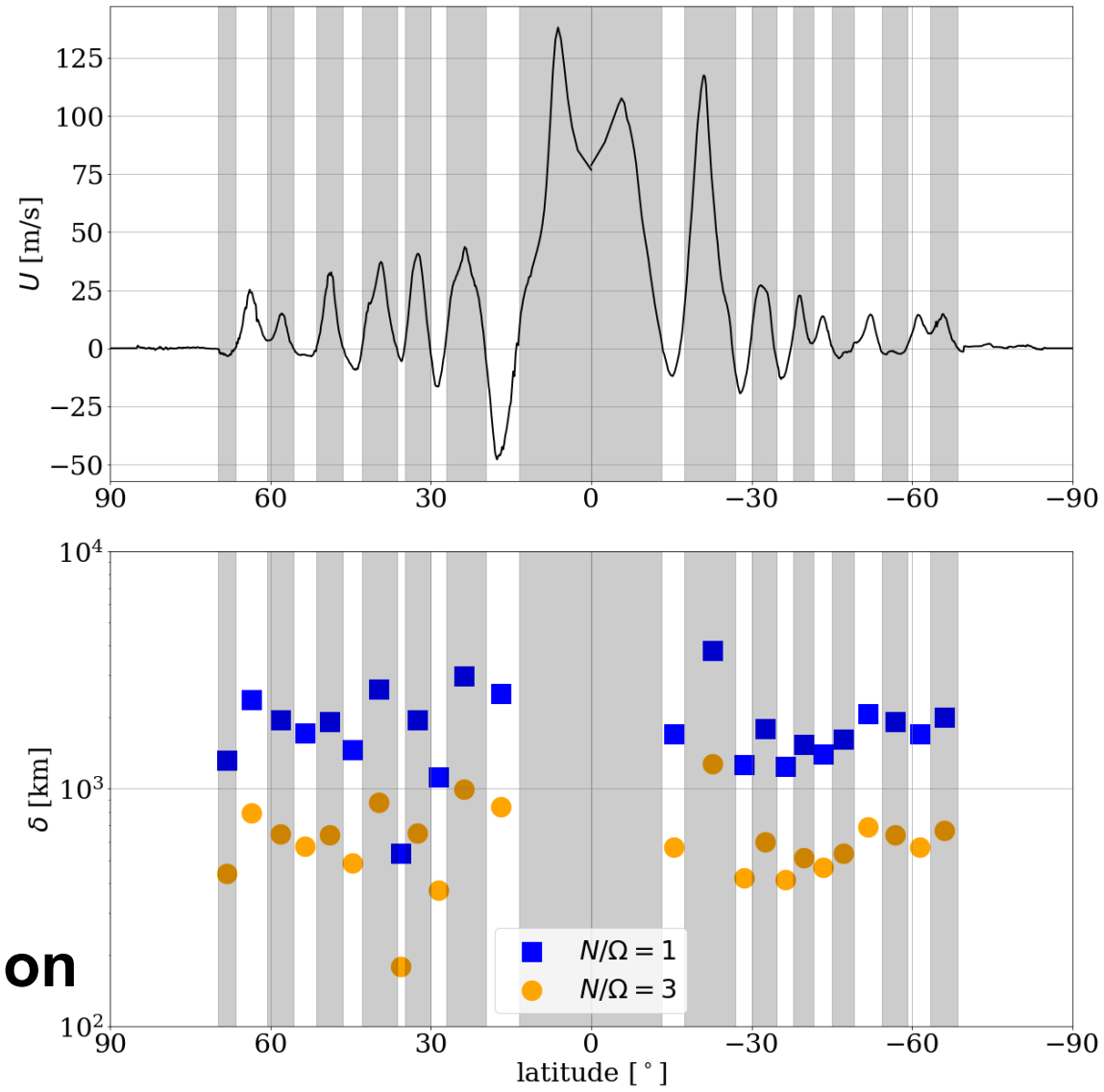
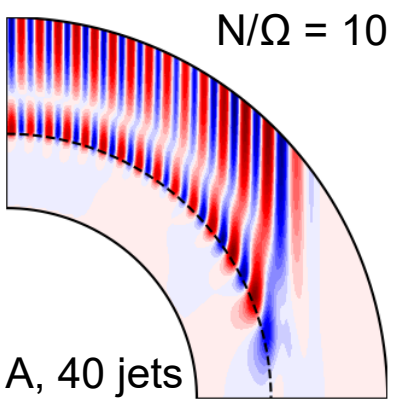
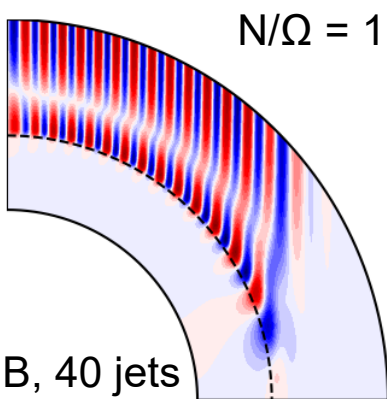
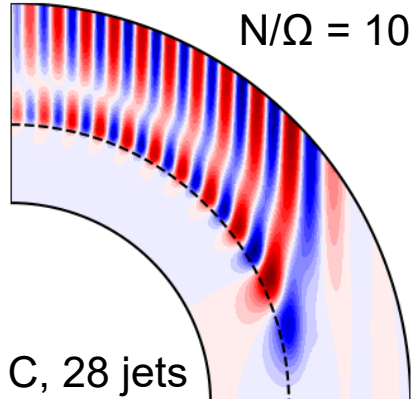
That's all for now, thanks for your attention

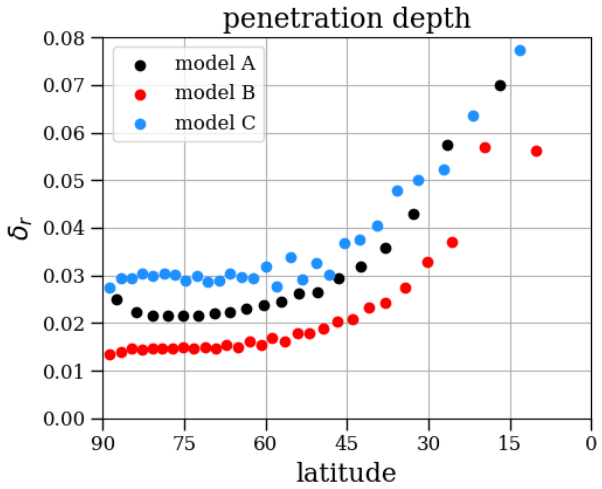


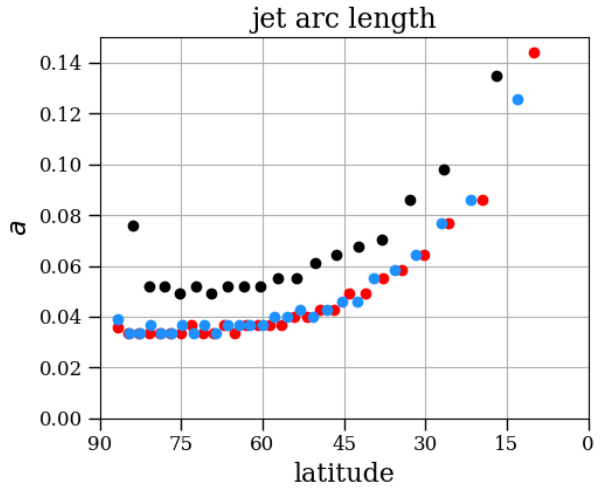
RESULTS – DIFFERENT MODELS

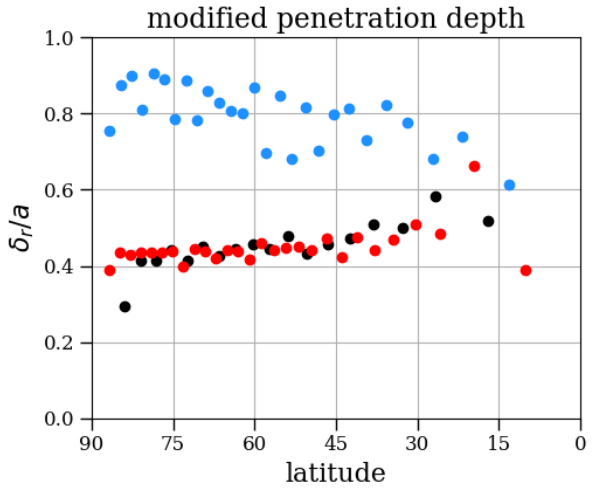












RESULTS – LATITUDINAL DEPENDENCE

- calculate radial scale height for each jet
- penetration scale height scales like N/ (Ω L), where N is BV freq, Ω the rotation rate and L jet width [*Takehiro & Sasaki 2018*]
- works well if modified with arc length of jet

$$\delta_r = \left[\frac{1}{u_\phi} \frac{\partial u_\phi}{\partial r} \right]^{-1}$$