MHD Instabilities at the Disk-Magnetosphere Interface: 3D Simulations

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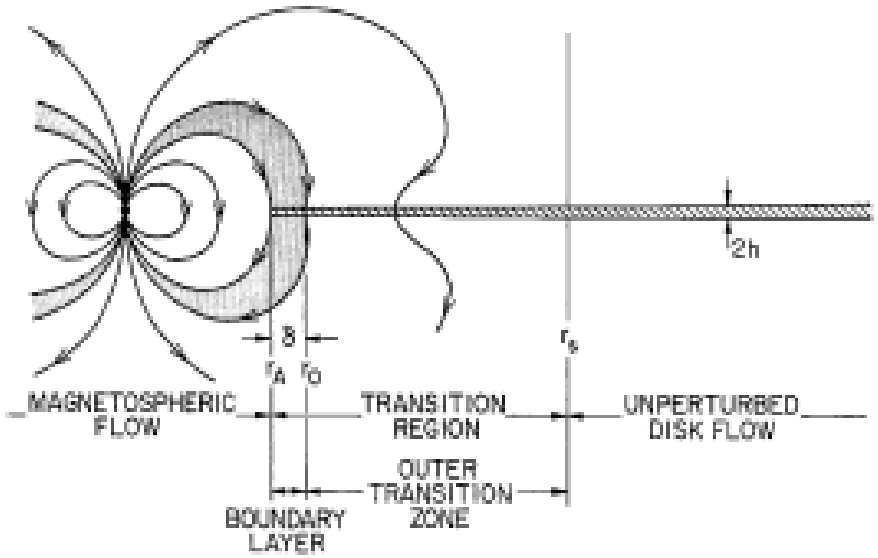
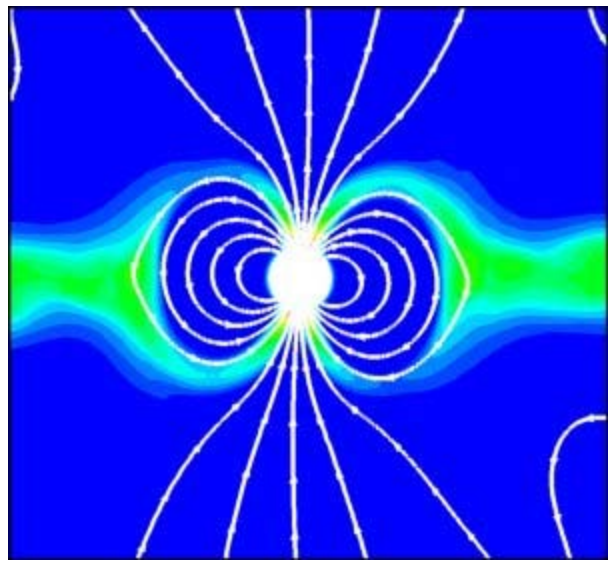
Standard accretion picture



(Ghosh & Lamb 1979)

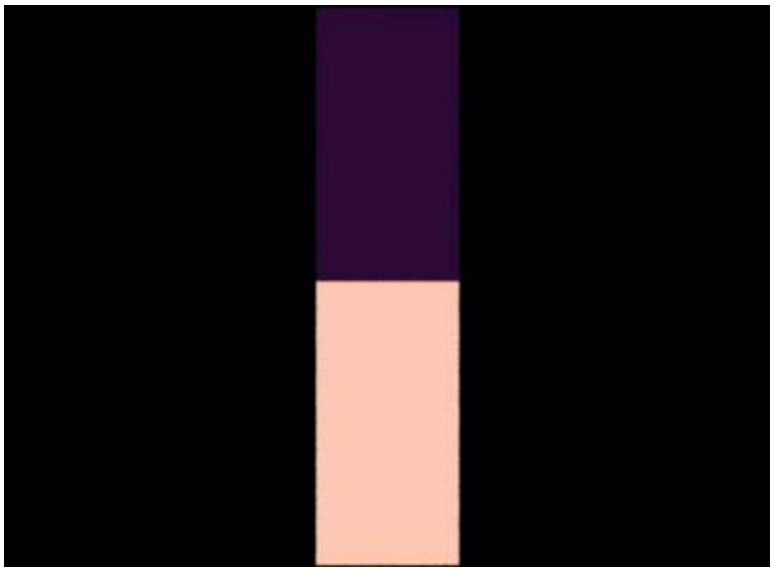


(Romanova et al 2003)

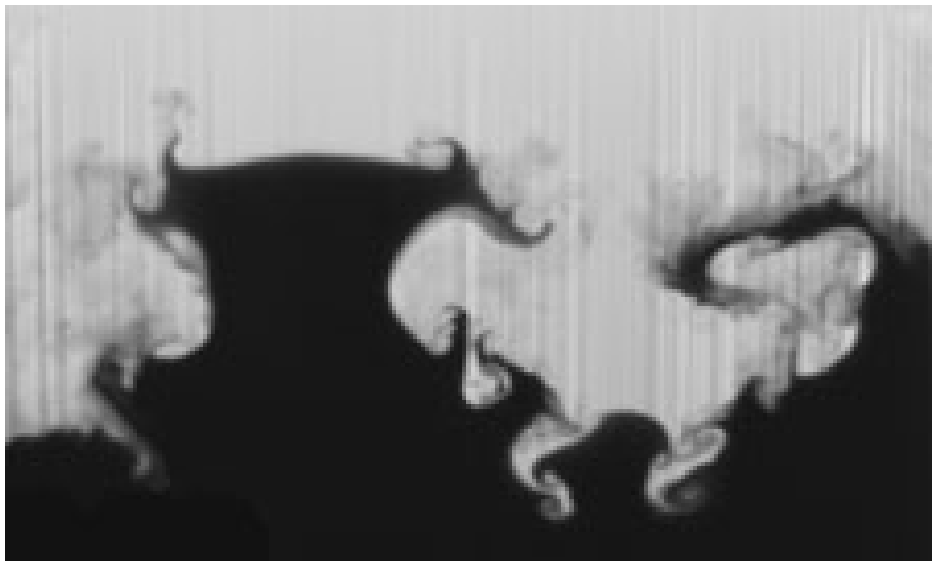
- Disk matter stopped by magnetosphere
- Flows around magnetosphere
- Funneled onto polar region

Instabilities

- Rayleigh-Taylor instability



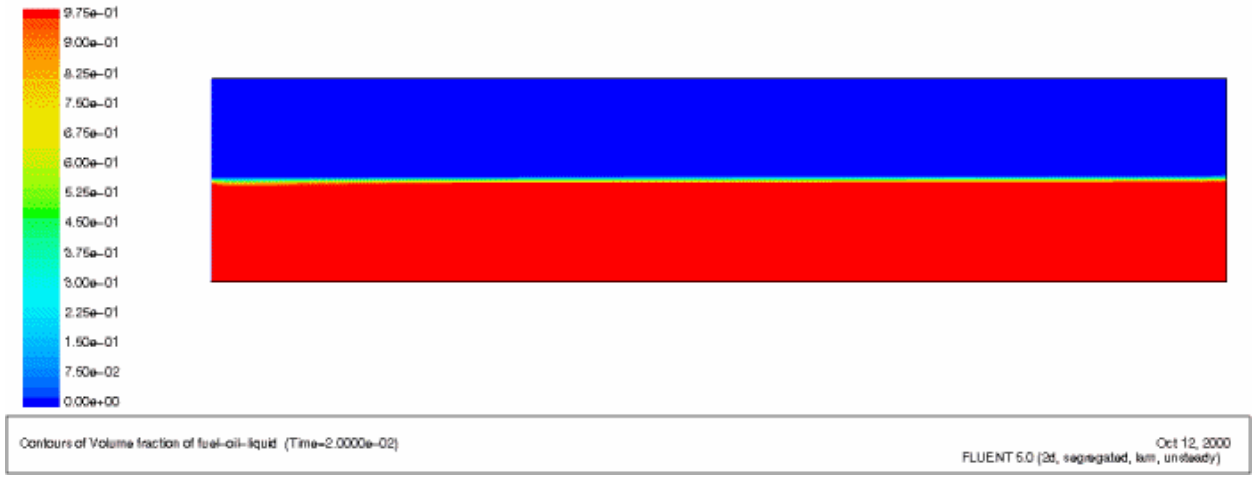
(http://www.enseeiht.fr/hmf/travaux/CD0001/travaux/optmfn/hi/01pa/hyb72/rt/anim1.mpg)



(Jones & Jacobs 1997, http://www.ame.arizona.edu/research/fluidlab//RMISTE.htm)

Heavy disk matter supported against gravity by light magnetospheric matter – Rayleigh-Taylor unstable

- Kelvin-Helmholtz instability



(http://www.enseeiht.fr/hmf/travaux/CD0001/travaux/optmfn/hi/01pa/hyb72/kh/kh_theo.htm)

Magnetosphere and disk rotate with a different angular velocities – Kelvin-Helmholtz unstable

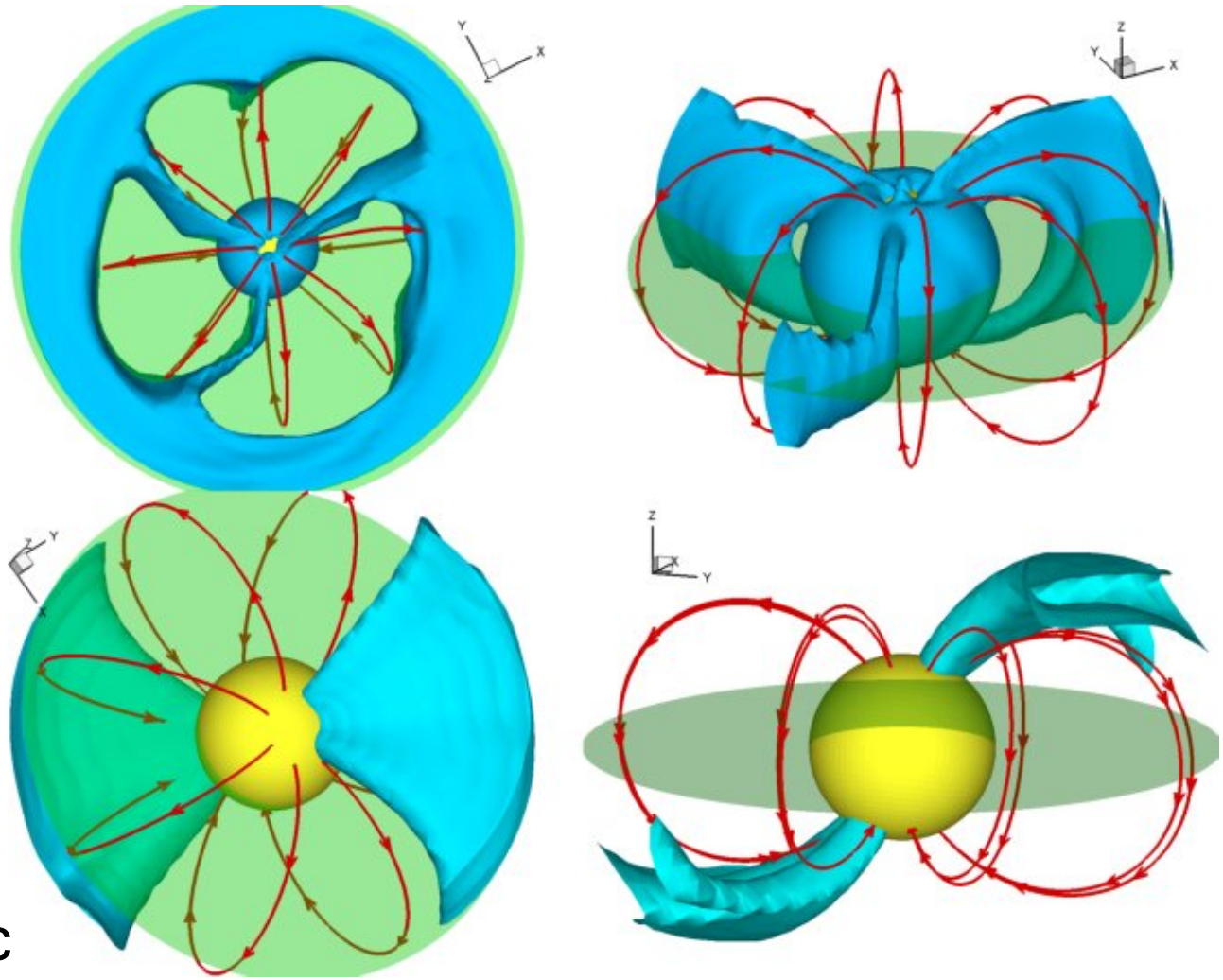
Instabilities seen in 3D simulations

Accretion through instability

- Tall, thin tongues of matter in equatorial plane
- Sneak through magnetosphere
- Hit star closer to equator than funnels

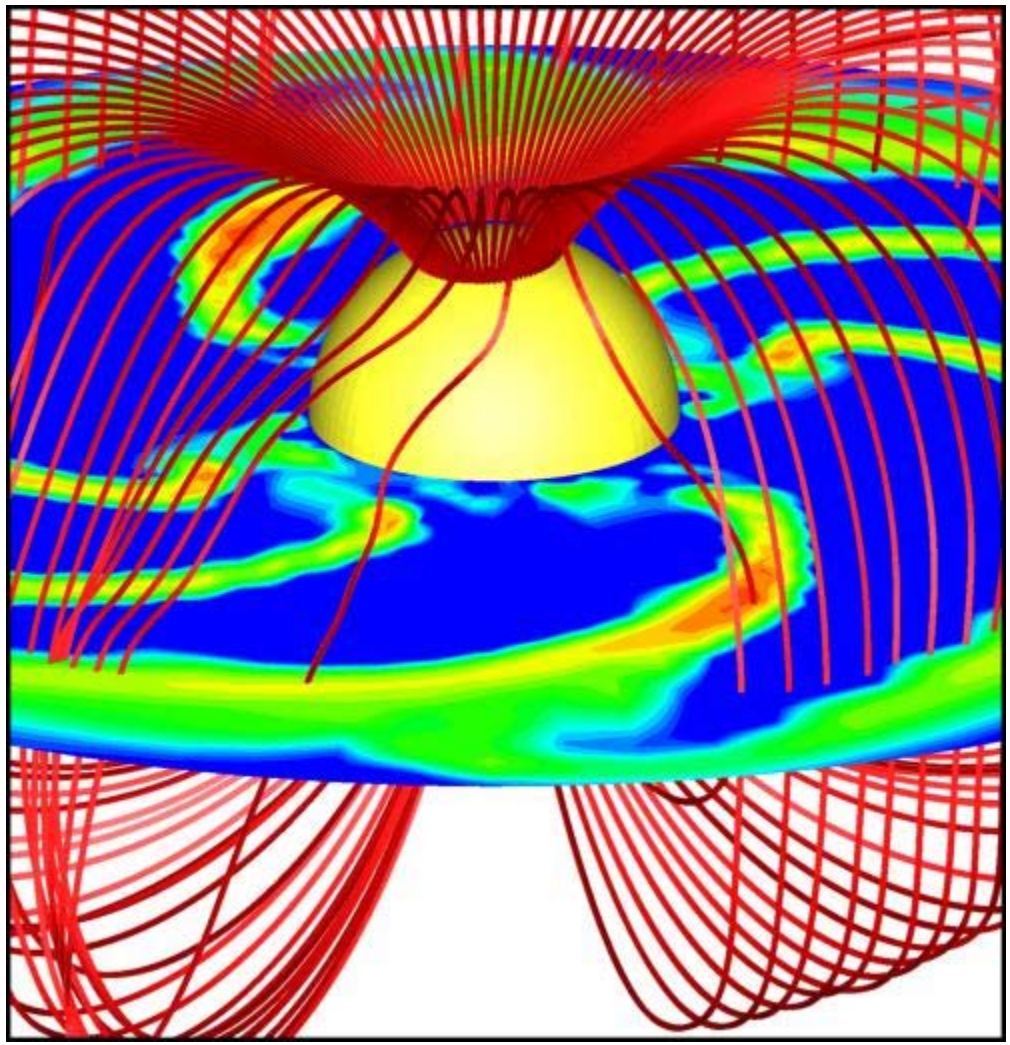
Funnel accretion

- Wide and flat funnels
- Go around magnetosphere
- Hit star near magnetic poles

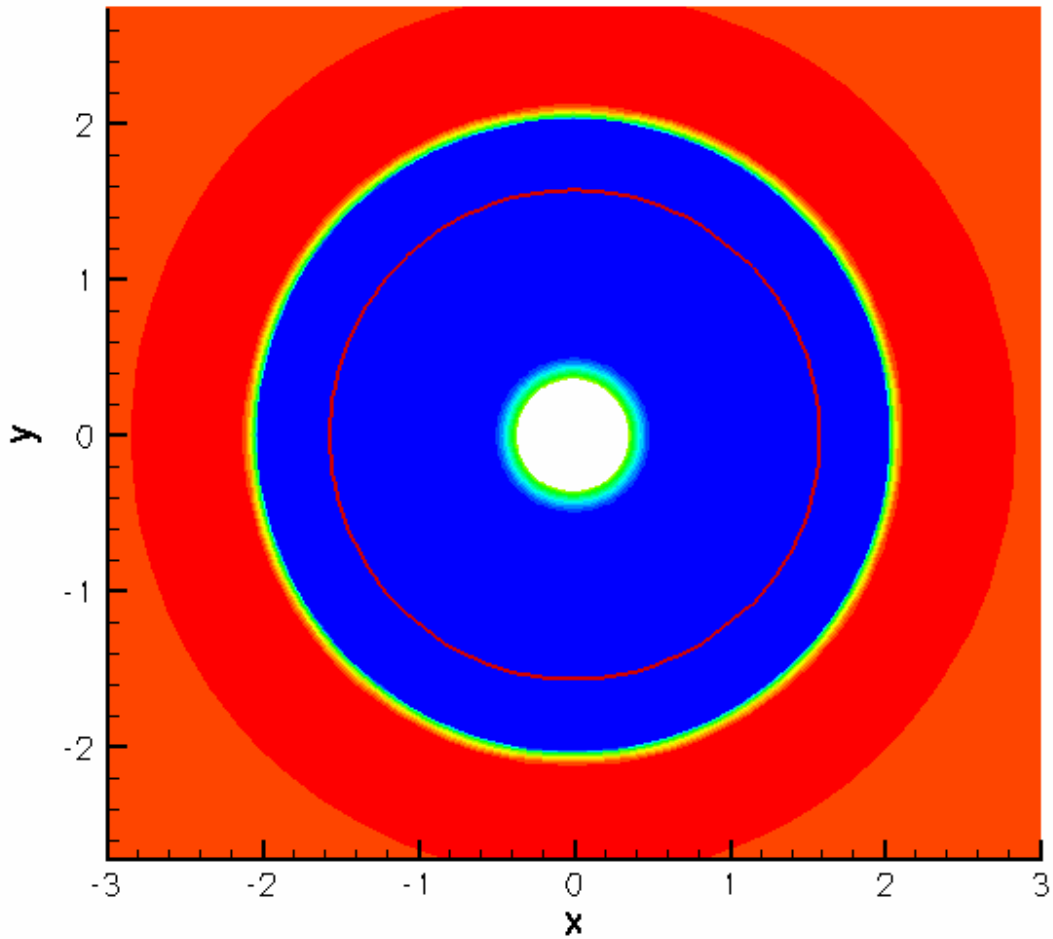


Kulkarni & Romanova 2007, in preparation

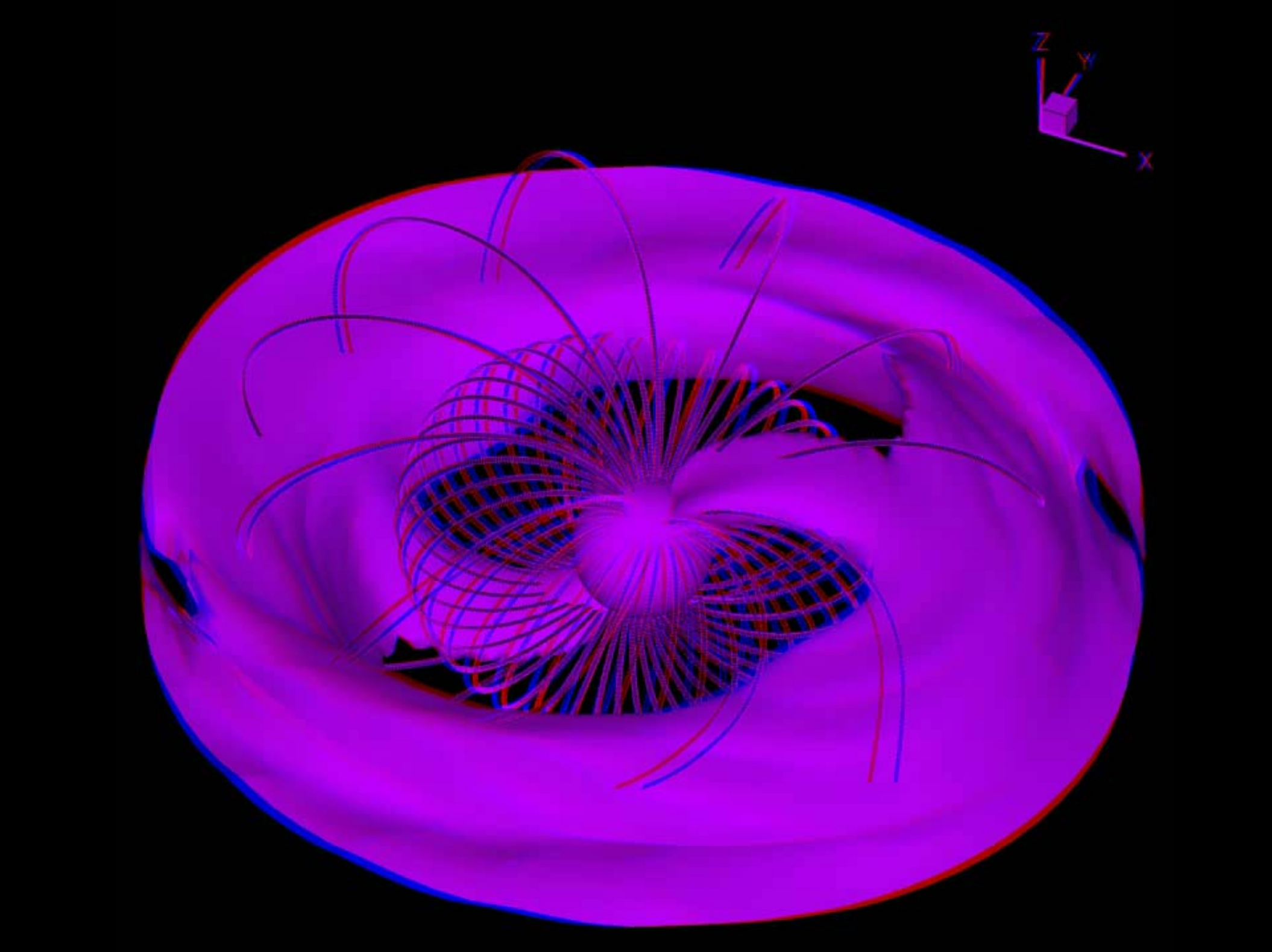
Structure of magnetosphere

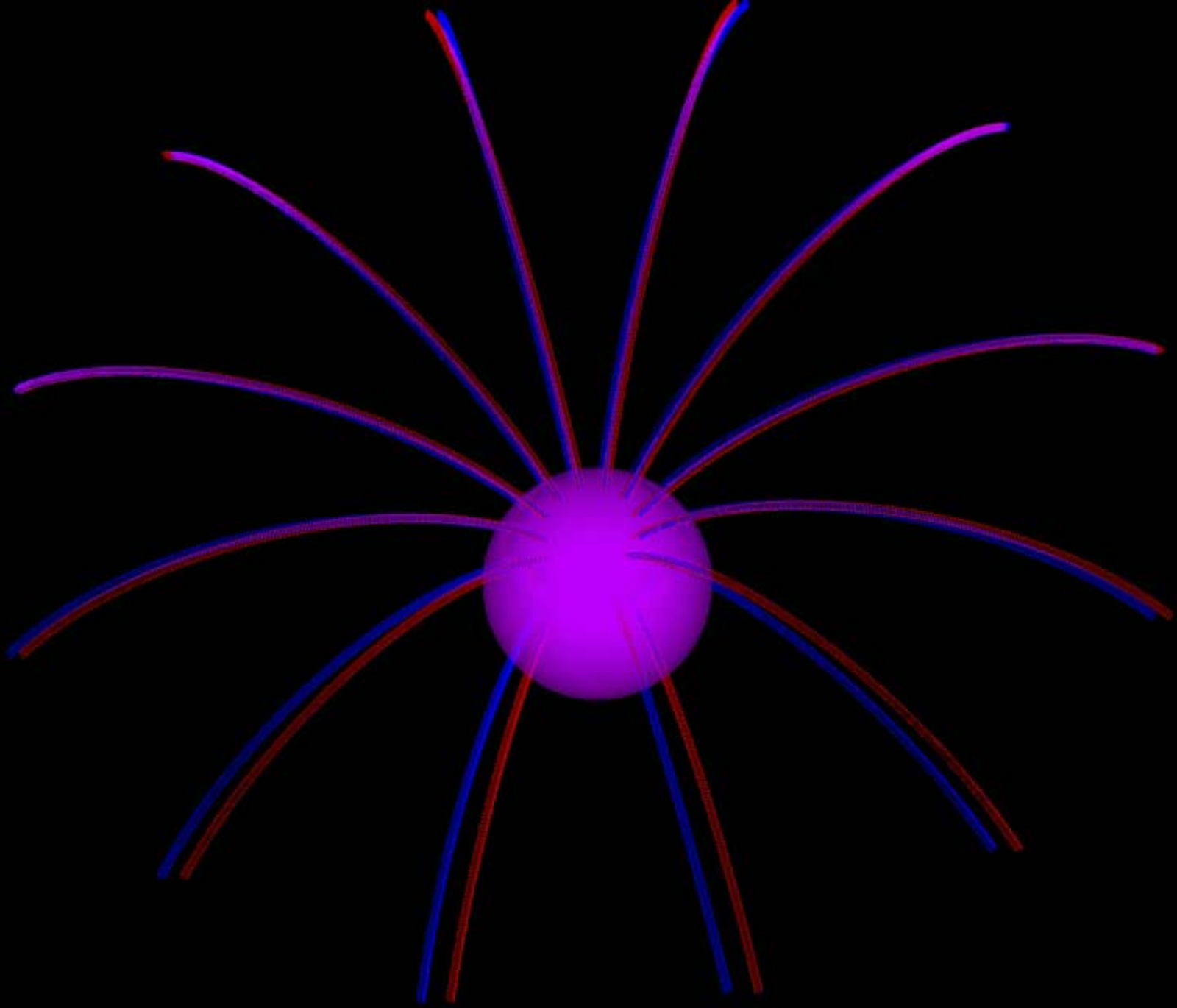


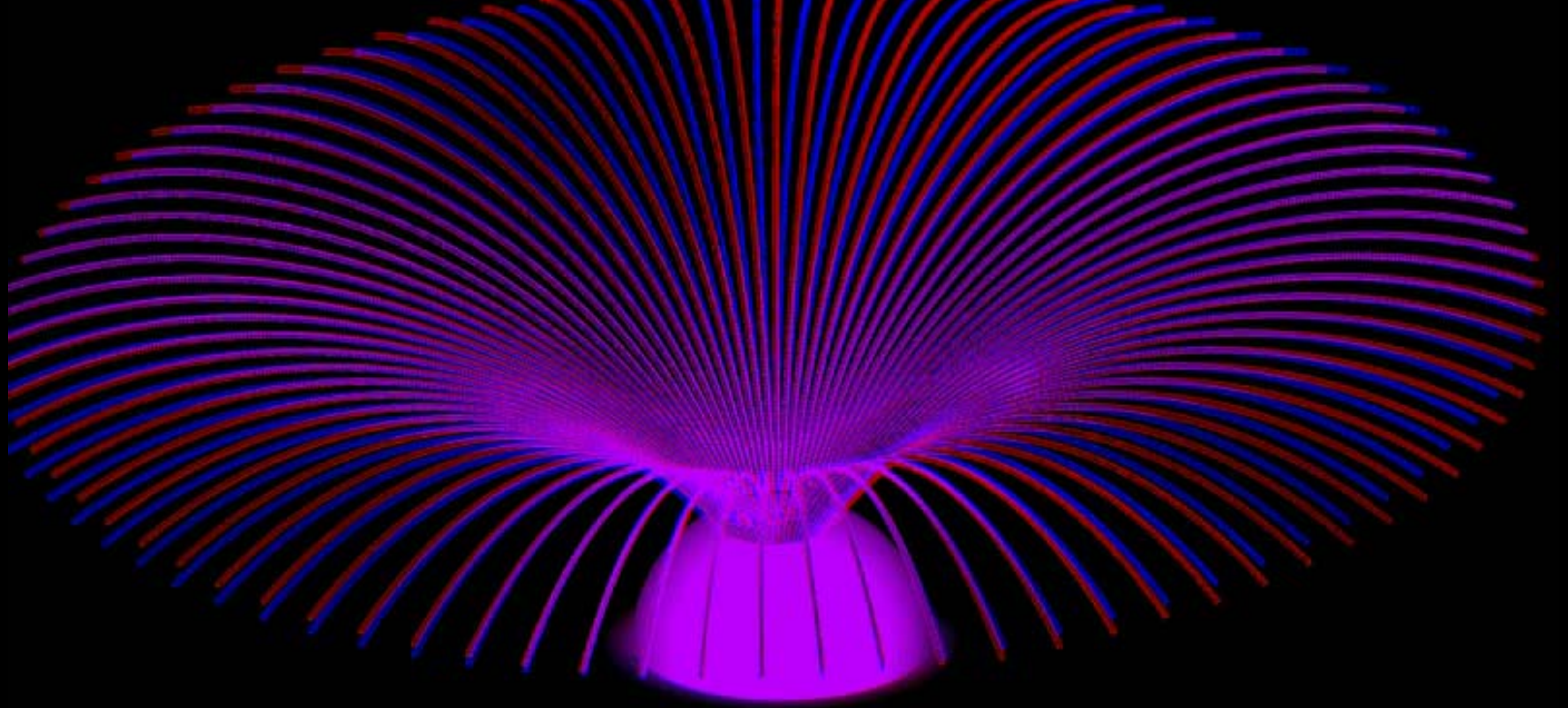
Tongues push aside magnetic field lines



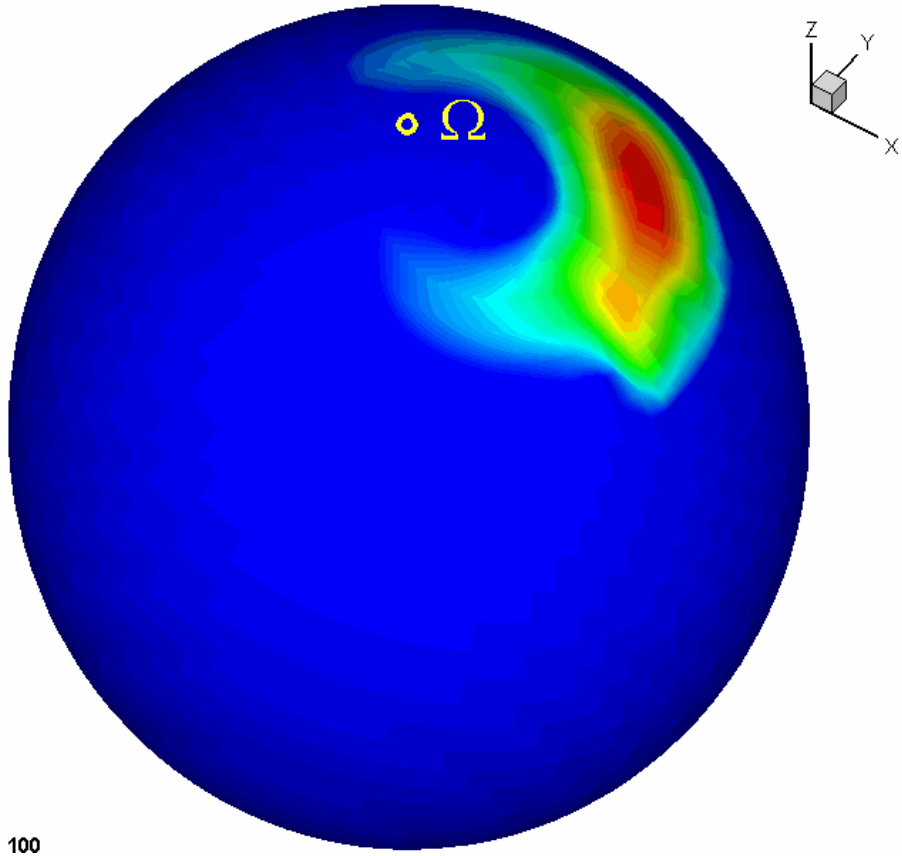
- Usually 2-7 tongues
- Density of the same order as the funnels
- Grow and move on dynamical timescales

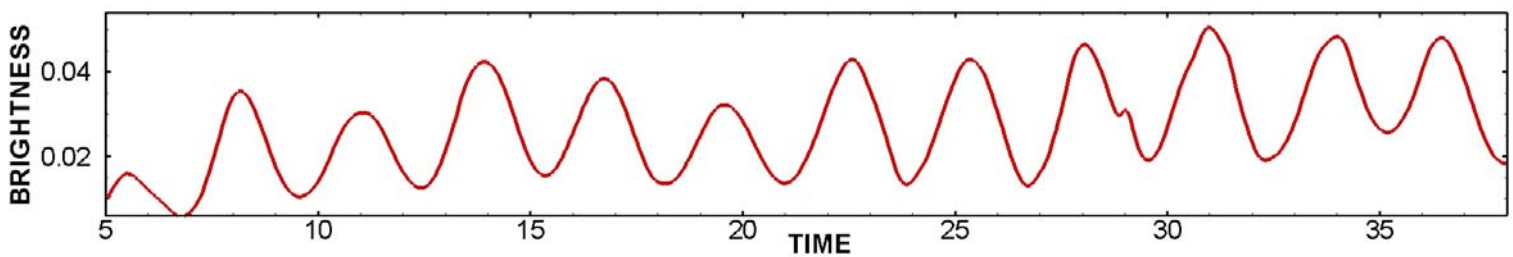

Z
Y
X





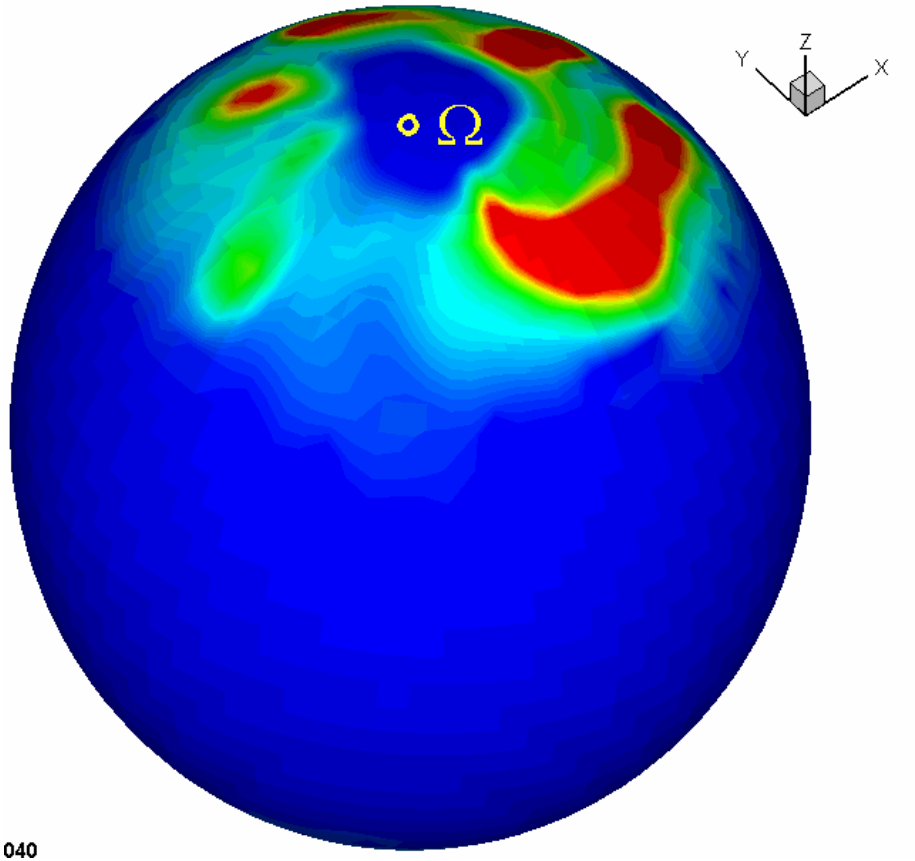
Hot spots – with funnel accretion

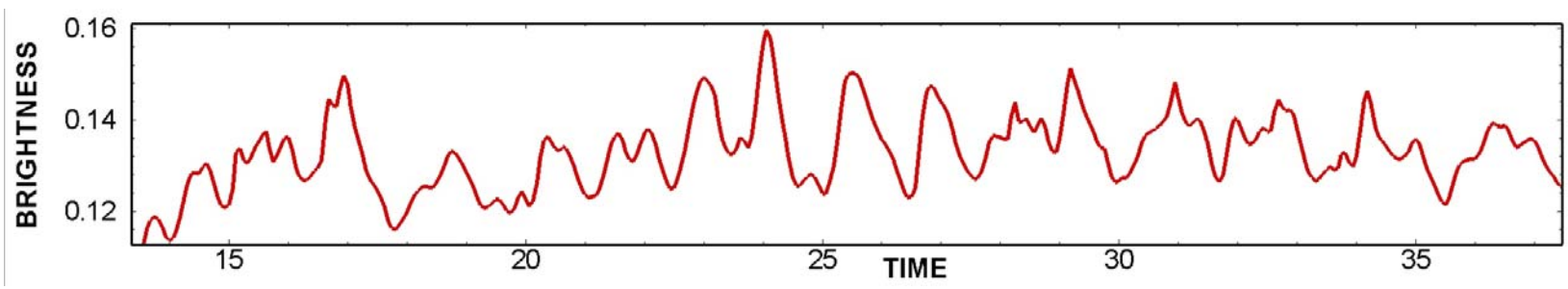




Frequency: Ω_*

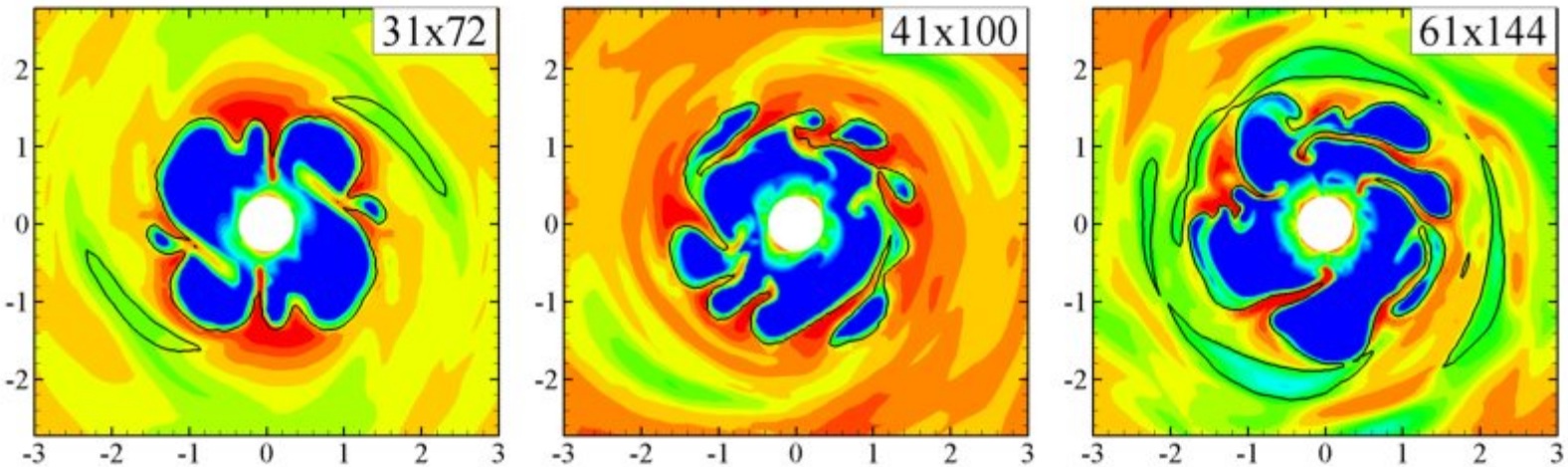
Hot spots – with instability





Frequencies: 2 Ω_*, 5Ω_*

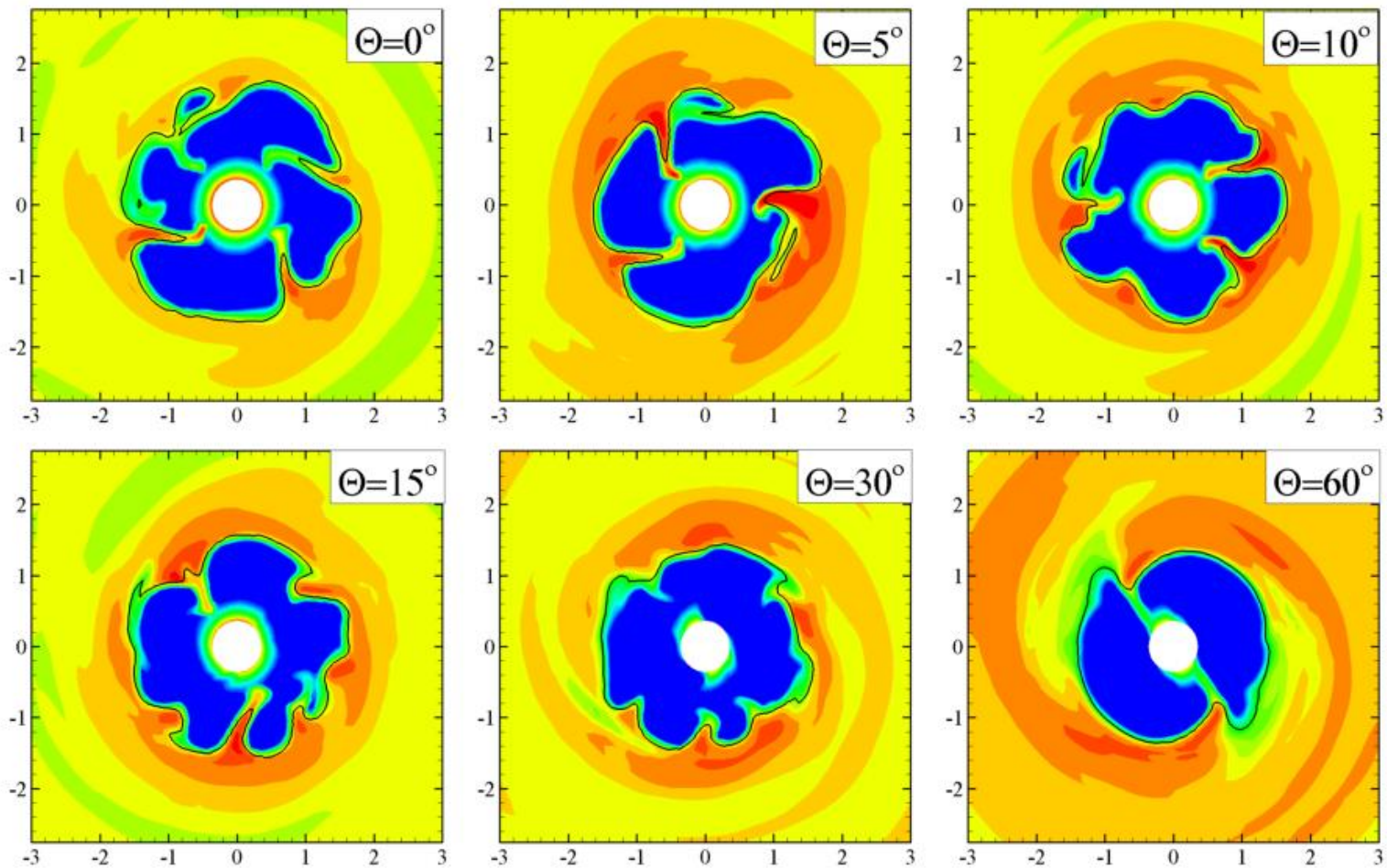
Artefact of grid?



- Number and behavior of tongues unaffected by grid resolution
- Width of each tongue spanned by many grid cells: therefore, instability not triggered by individual grid cells

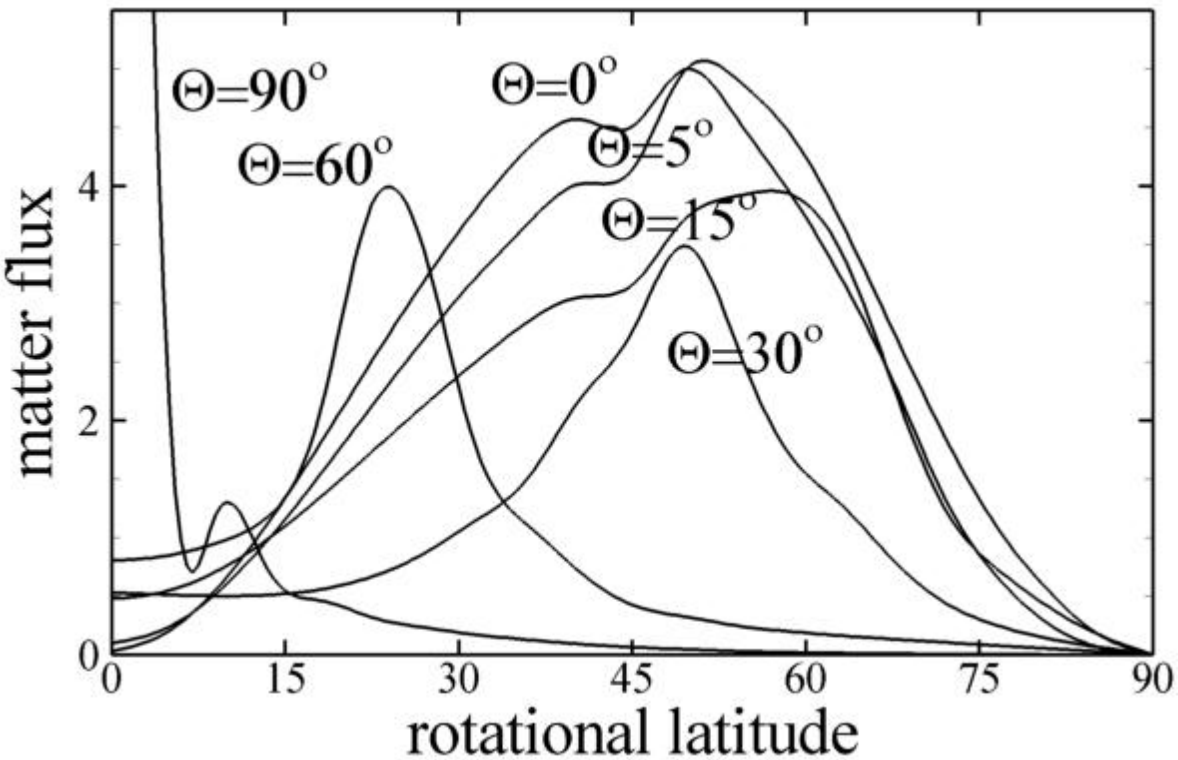
No, the effect is real!

Dependence on misalignment angle



Instability disappears for Θ > ~30°

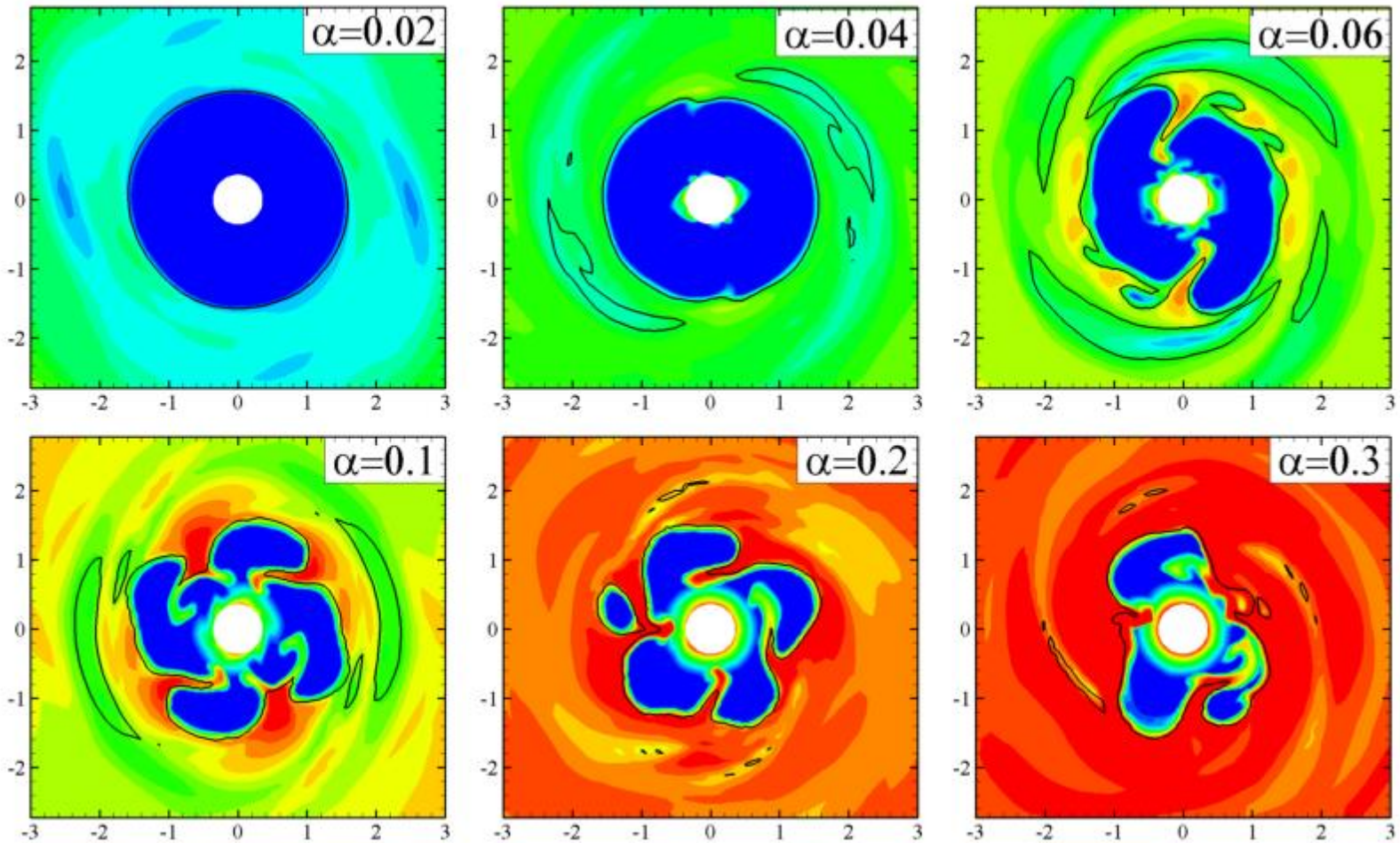
For large misalignment angles, funnel flows energetically more favorable



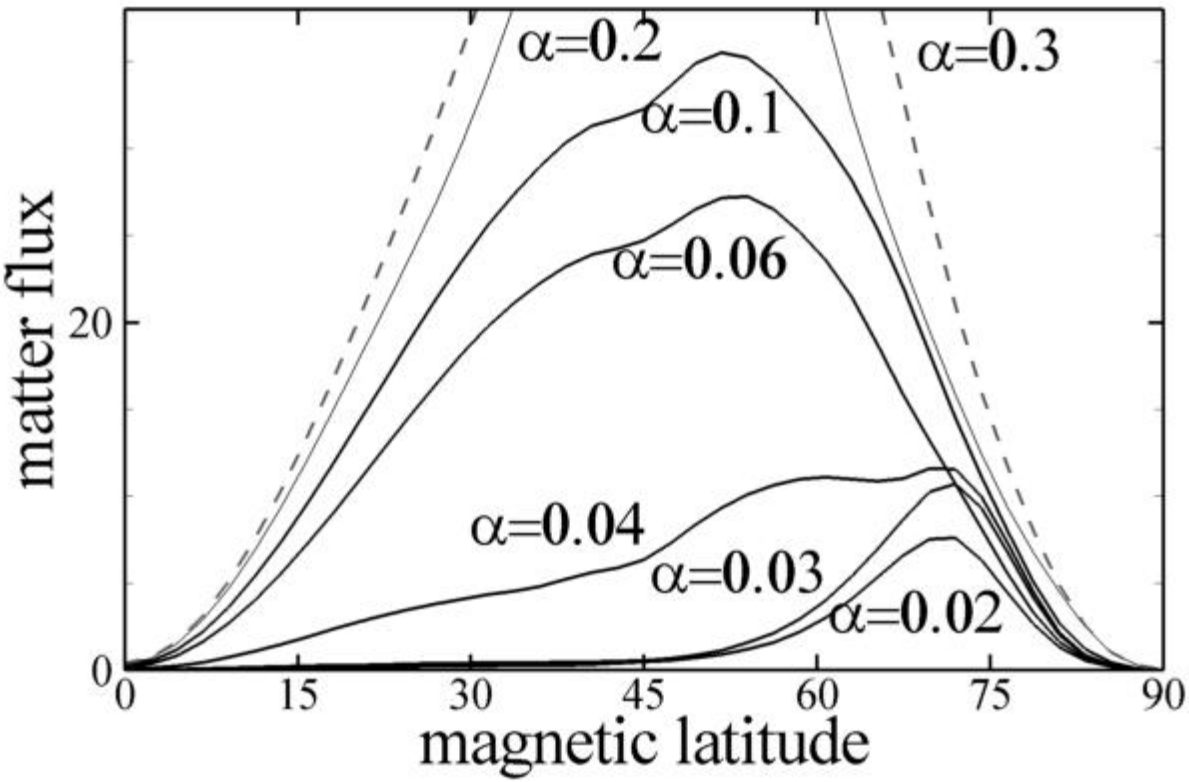
In the presence of instability, accretion latitude independent of misalignment angle

Dependence on accretion rate

Θ = 5°



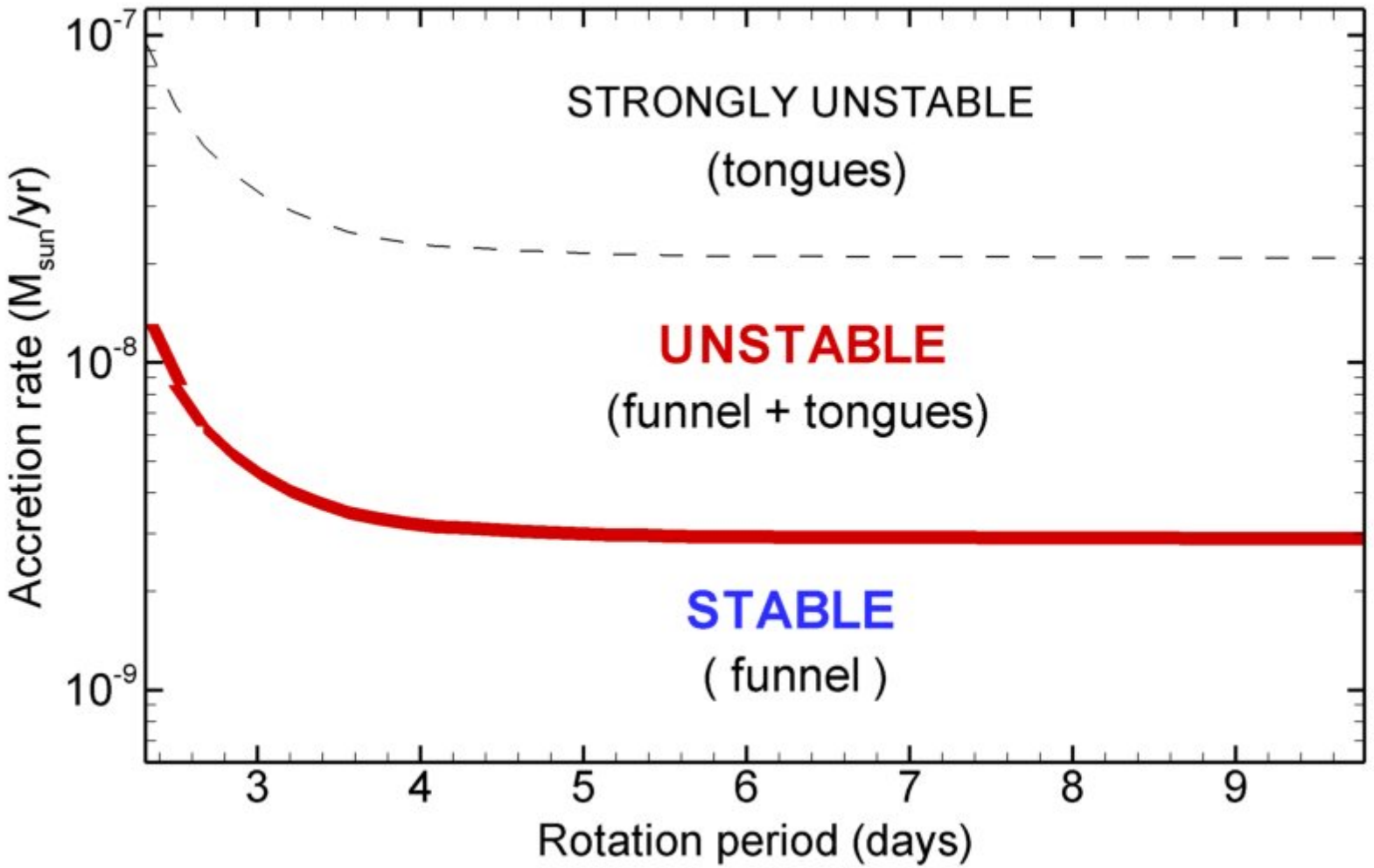
Instability disappears for low accretion rates

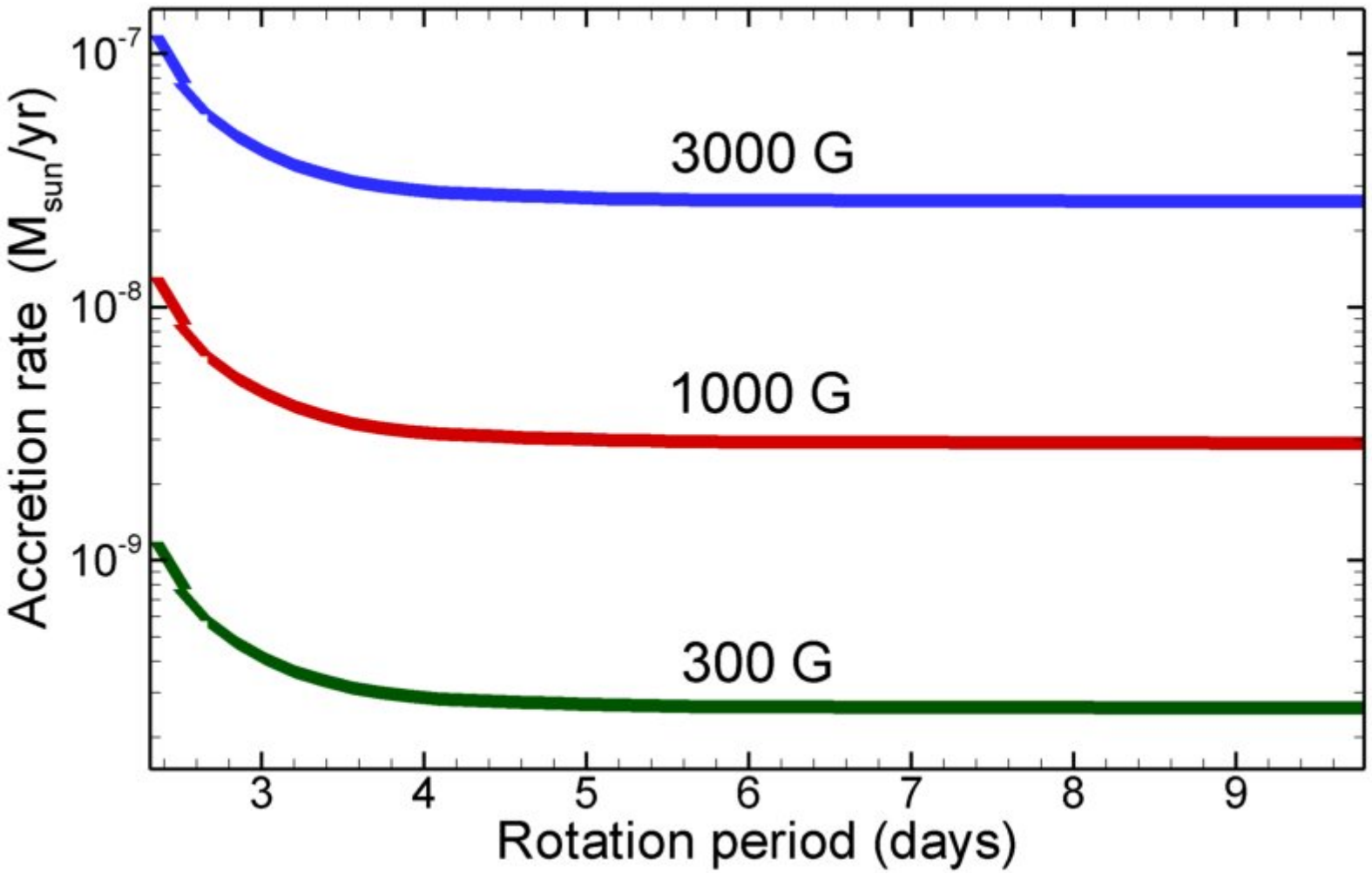

α=0.2
α=0.3
α=0.1
α=0.06
α=0.04
α=0.03
α=0.02
matter flux
20
0
0
15
30
45
60
75
90
magnetic latitude

Regimes of Instability

$M = 0.8\ M_{sun}$, $R = 2R_{sun}$, $B = 1000$ G

$\Theta = 5^{\circ}$




Accretion rate (M_{sun}/yr)
10^{-7}
10^{-8}
10^{-9}
3000 G
1000 G
300 G
3
4
5
6
7
8
9
Rotation period (days)

Summary

- Accretion through instabilities expected to be fairly common
- Accretion streams and hotspots completely different from those in funnel flows
- Significant effect on variability and spectra
- Possible effect on planet migration