On the dynamical nature of Saturn's North Polar hexagon.

Masoud Rostami, [1] Vladimir Zeitlin, and Aymeric Spiga

Laboratoire de Météorologie Dynamique (LMD),

Université Pierre et Marie Curie (UPMC),
Ecole Normale Supérieure (ENS), Paris, France

27 March, 2017
EGU General Assembly 2017

[1] Email: mrostami@lmd.ens.fr

Topic: Dynamical nature of Saturn's north polar hexagon

Saturn's North Polar hexagon

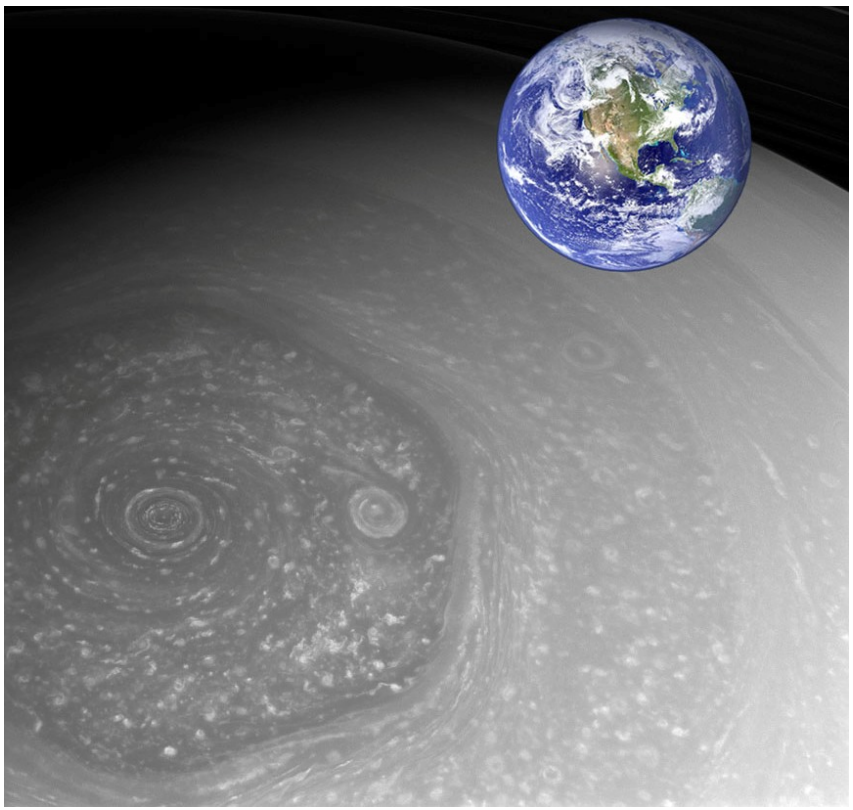

Figure: Saturn's North Polar hexagon (NASA's Cassini Imaging Team)

A short history of hexagon

- First Visible imagery acquired by Voyager 1 & 2 in 1980-1981.
- Hexagon has been observed again after ≈35 years by Cassini.
- Morales (2015) proposed an alternative "meandering jet" model which matches the morphology of Saturn's hexagon, provided that an *ad hoc* vertical shear of the jet is introduced.
- There is not enough convincing dynamical explanation of the existence and origin of Saturn's North pole hexagon, as well as the absence of its counterpart at Saturn's South pole.

Initial velocity profiles

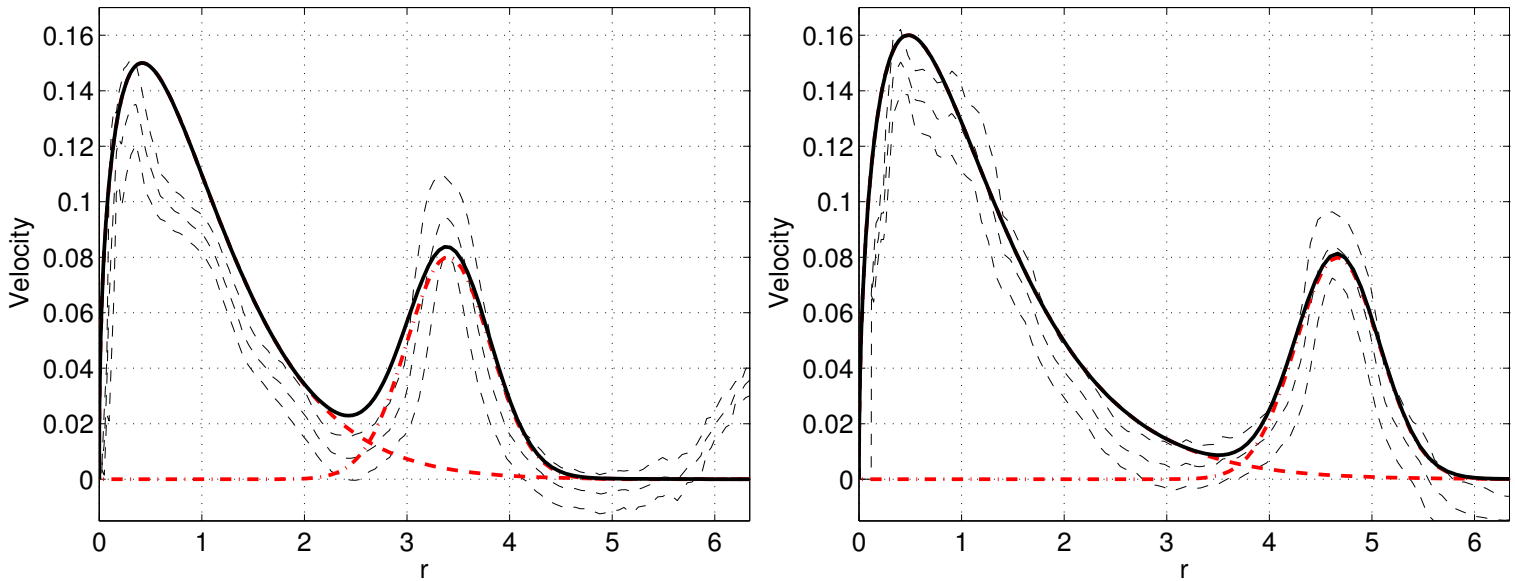

Figure:

Dashed lines $\rightsquigarrow$ *Observed zonal velocity profiles + margins*
Solid lines $\rightsquigarrow$ *Analytical velocity profiles*
Left panel $\rightsquigarrow$ *Northern hemisphere*
Right panel $\rightsquigarrow$ *Southern hemisphere*

Initial potential vorticity (PV) profiles

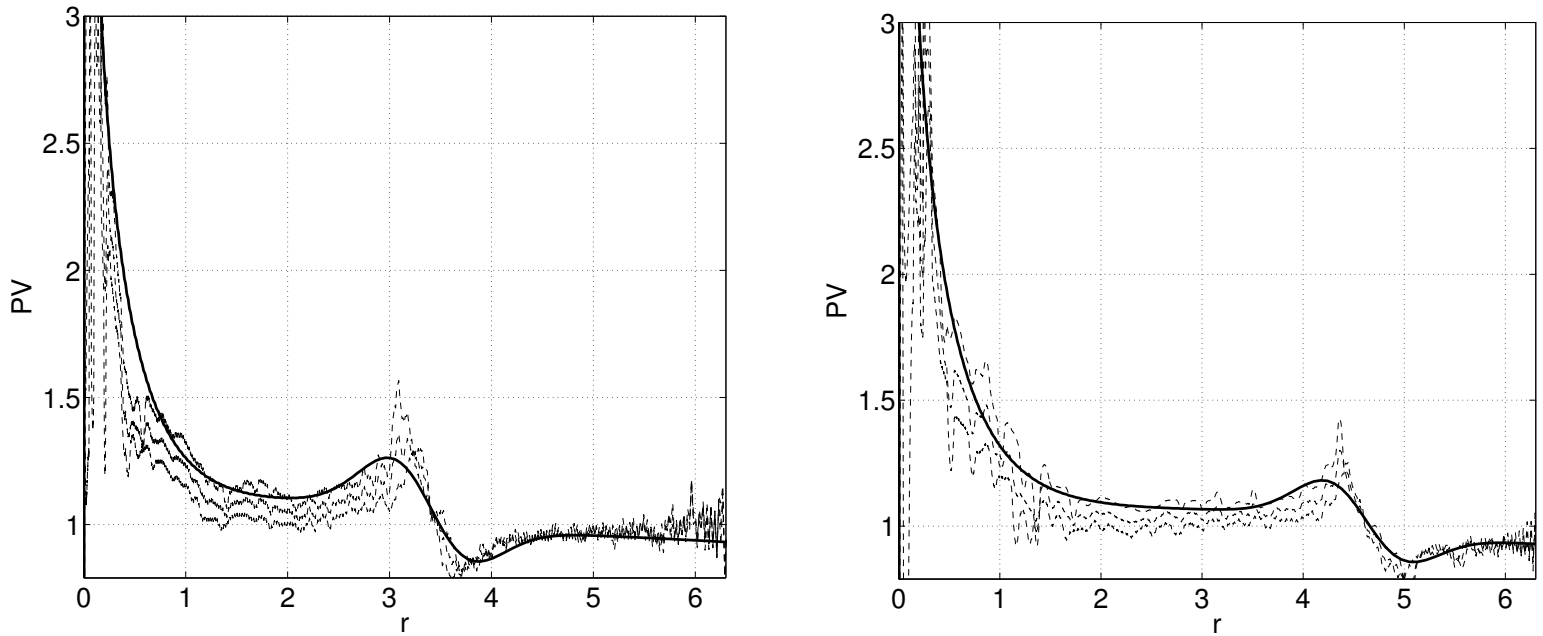

Figure:

Dashed lines $\rightsquigarrow$ PV distributions of observed profiles + margins
Solid lines $\rightsquigarrow$ PV distributions of Analytical fit
Left panel $\rightsquigarrow$ Northern hemisphere
Right panel $\rightsquigarrow$ Southern hemisphere

Results of linear stability analysis

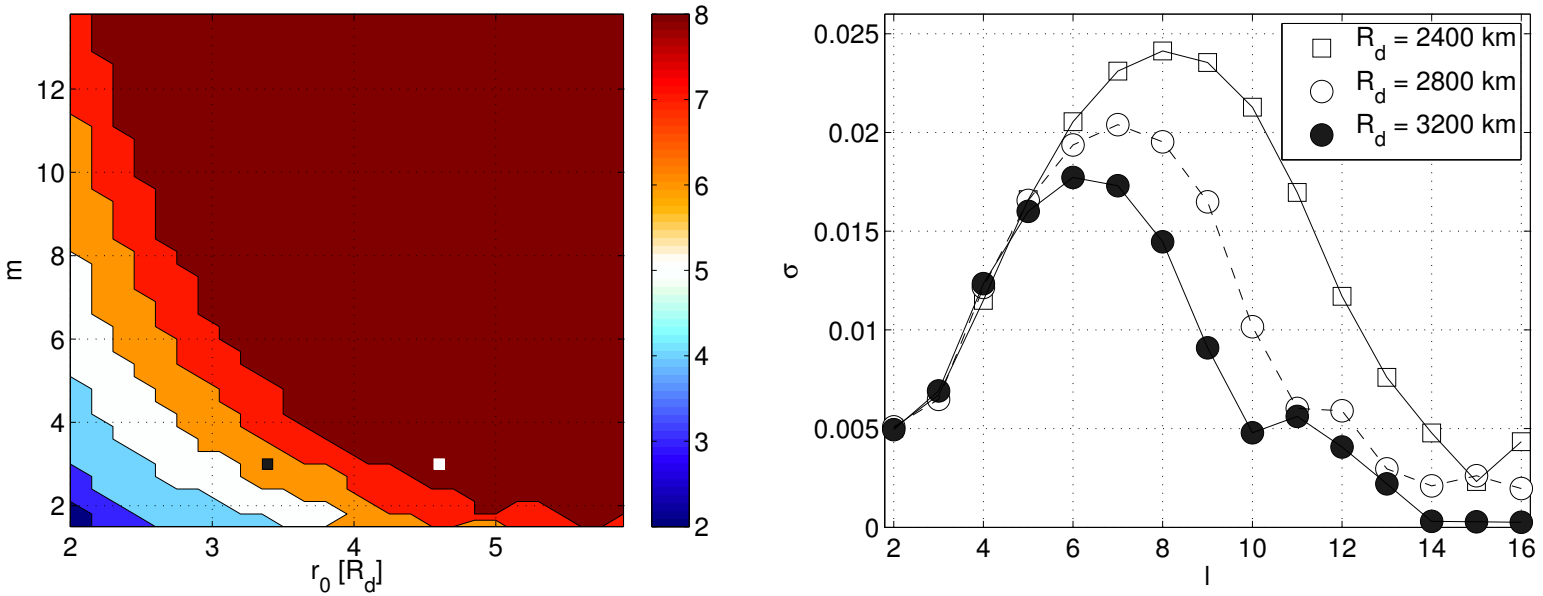

Figure:

Left panel ⇝ Distribution of azimuthal wavenumbers
$r_0[R_d]$ ⇝ Distance of jet from the pole
m ⇝ A parameter related to the curvature of the jet's velocity
Black square ⇝ Jet's situation (Northern hemisphere)
White square ⇝ Jet's situation (Southern hemisphere)
Right panel ⇝ Linear stability growth rate (jet-only)

Nonlinear saturation of "*jet-only*" case (pressure and PVA)

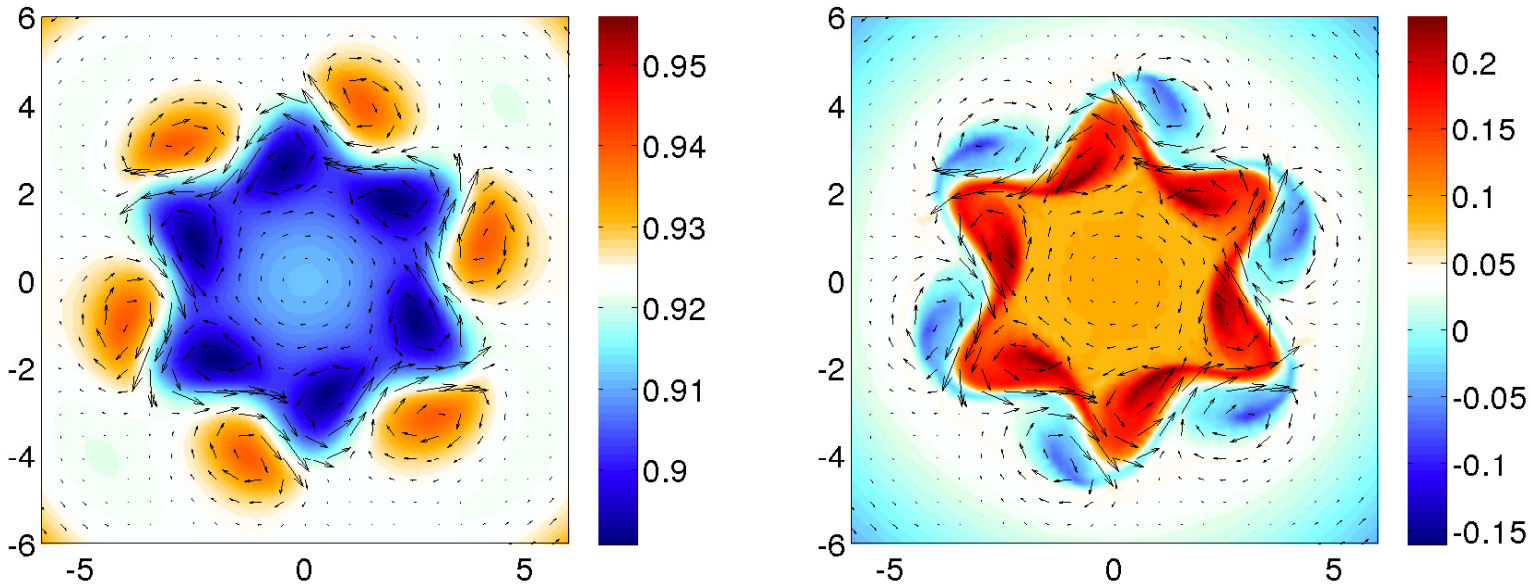

Figure:

Left panel $\rightsquigarrow$ Pressure ($time = 150\ {f_0}^{-1}$)

Right panel $\rightsquigarrow$ PVA ($time = 150\ {f_0}^{-1}$)

Nonlinear saturation of "*jet-only*" case (pressure)

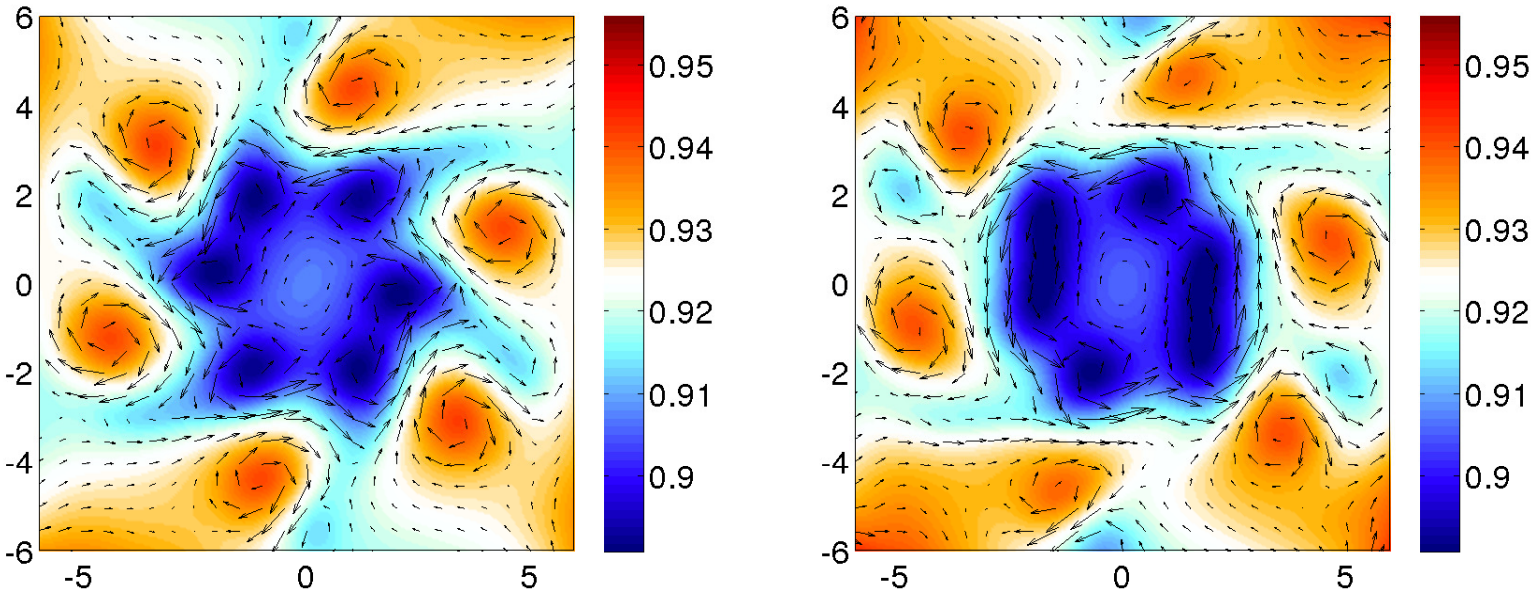

Figure:

Left panel $\rightsquigarrow$ *Pressure* (*time* $= 350\ f_0^{-1}$)

Right panel $\rightsquigarrow$ *Pressure* (*time* $= 450\ f_0^{-1}$)

Nonlinear saturation of "*jet+vortex*" case (pressure)

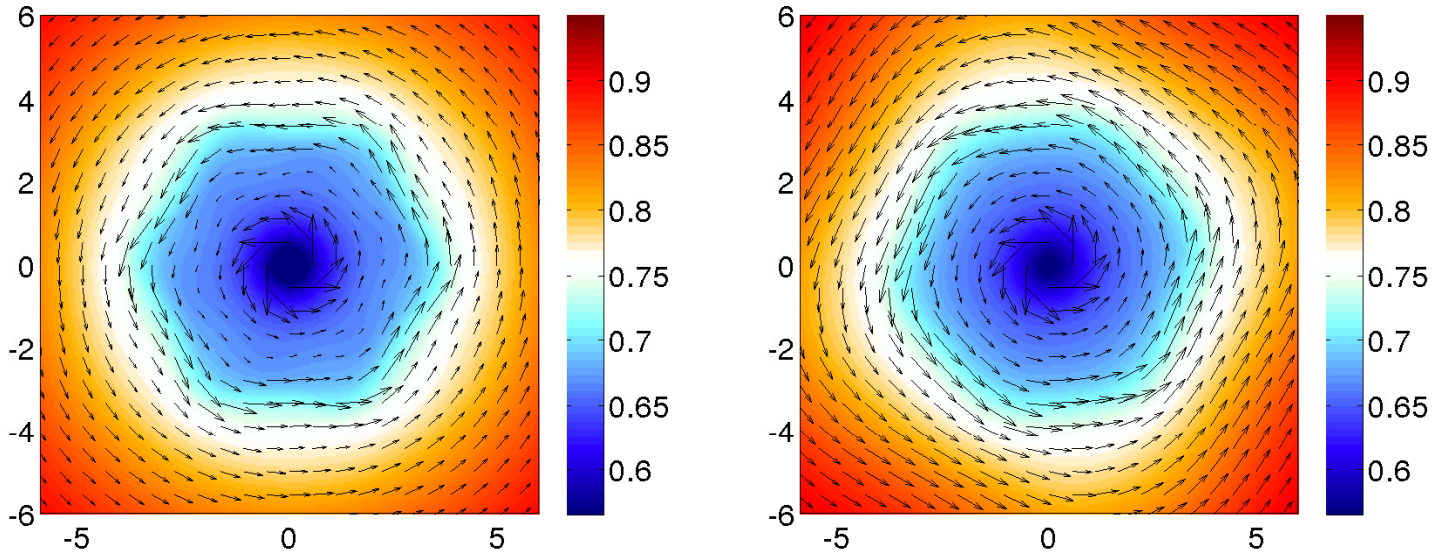

Figure:

Left panel $\rightsquigarrow$ *Pressure* $(time = 150\ {f_0}^{-1})$

Right panel $\rightsquigarrow$ *Pressure* $(time = 1000\ {f_0}^{-1})$

Nonlinear saturation of "*jet+vortex*" case (PVA)

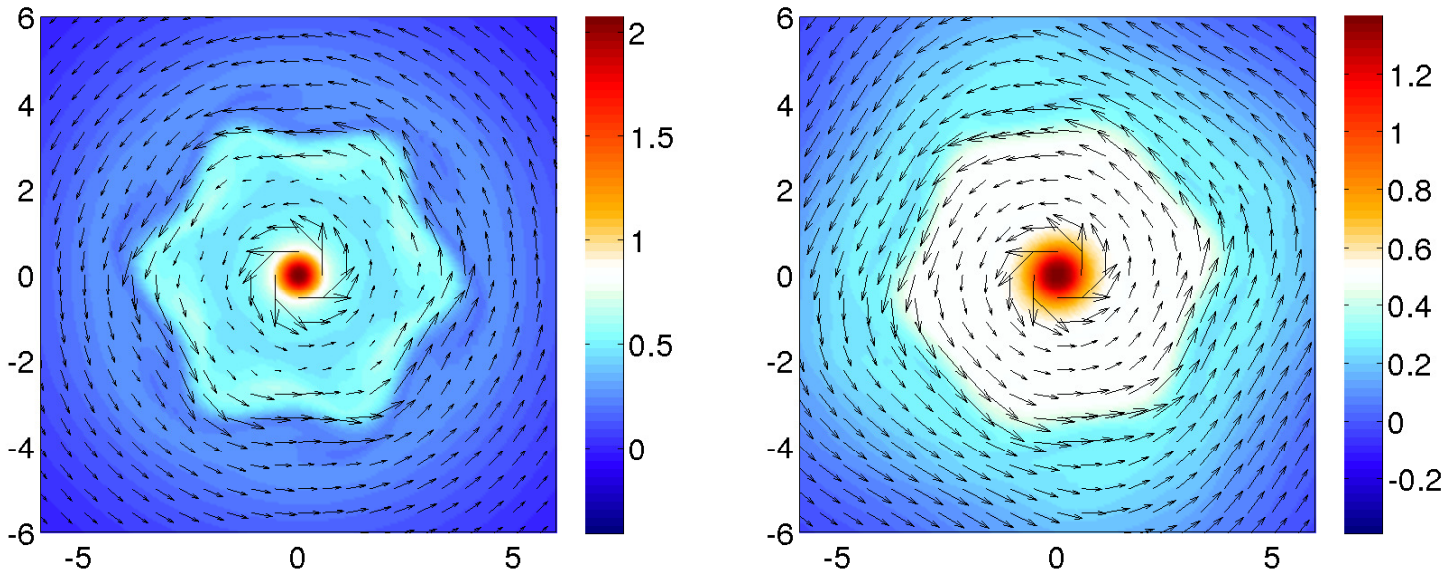

Figure:

Left panel $\rightsquigarrow$ *PVA* ($time = 150\ f_0^{-1}$)

Right panel $\rightsquigarrow$ *PVA* ($time = 1000\ f_0^{-1}$)

Radial distribution of zonally averaged PVA

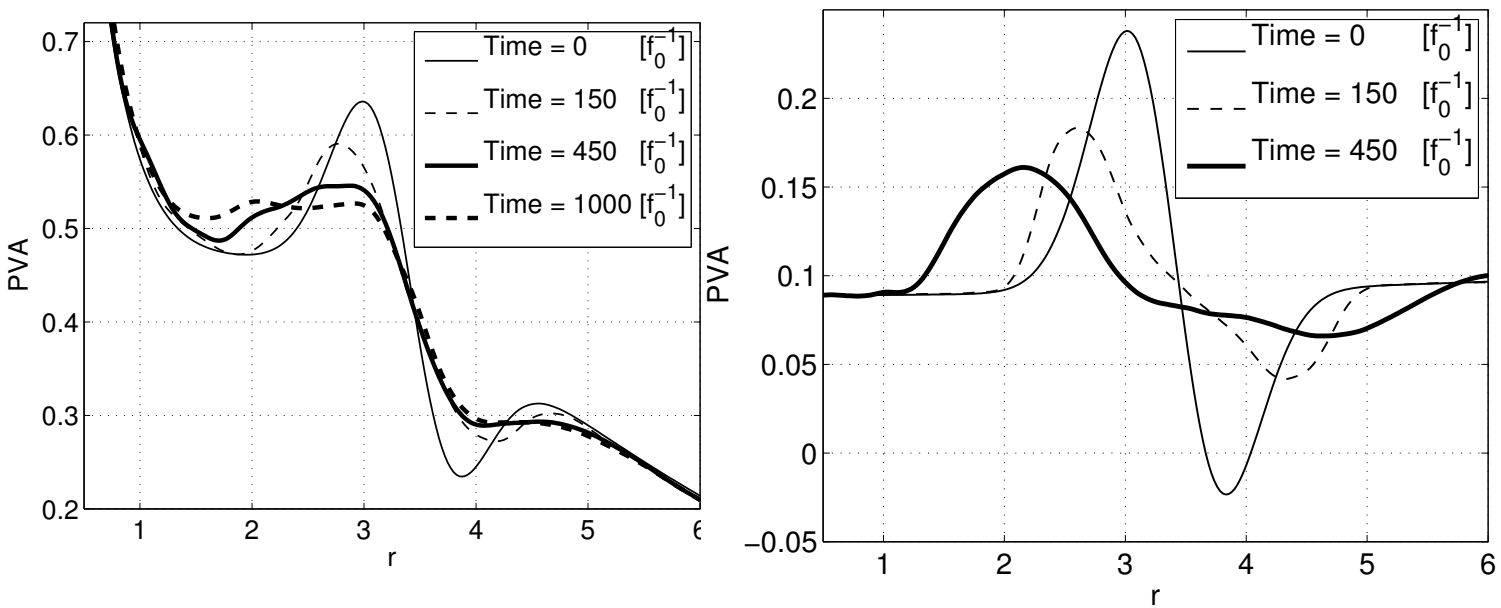

Figure:

Left panel $\rightsquigarrow$ *"jet+vortex "*

Right panel $\rightsquigarrow$ *"jet-only"*

Emerging $l = 6$ from white noise (jet+vortex, NH)

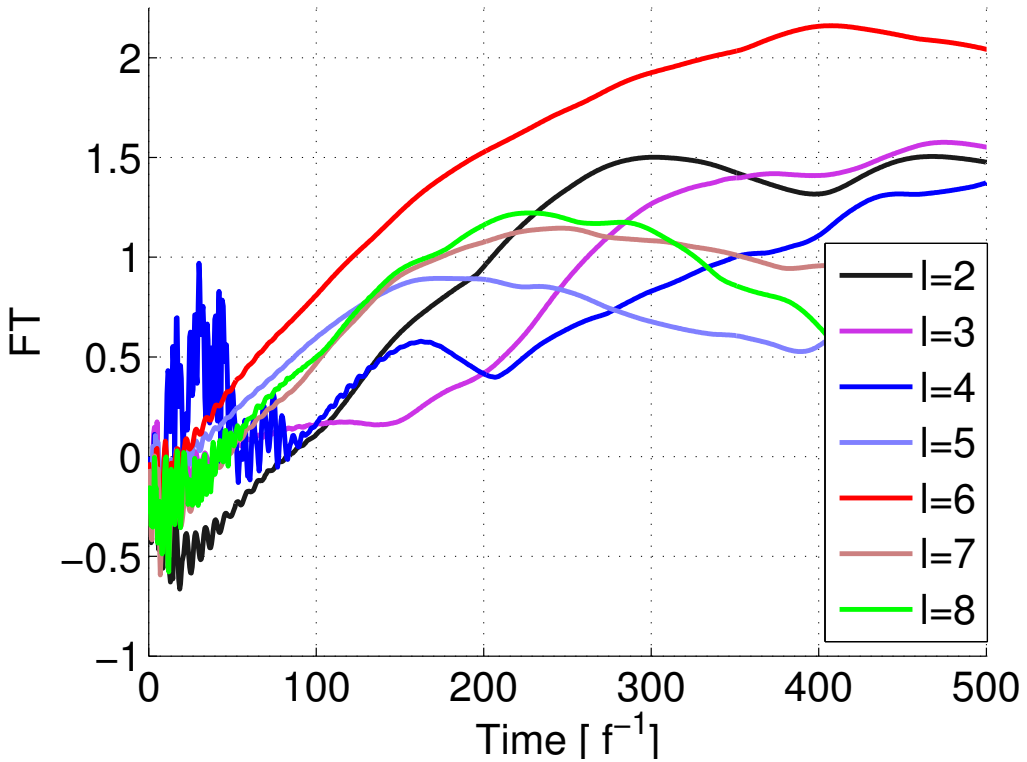

Figure: *Evolution of the logarithms of the normalized amplitudes of the Fourier modes of the azimuthal velocity.*

Angular momentum, M

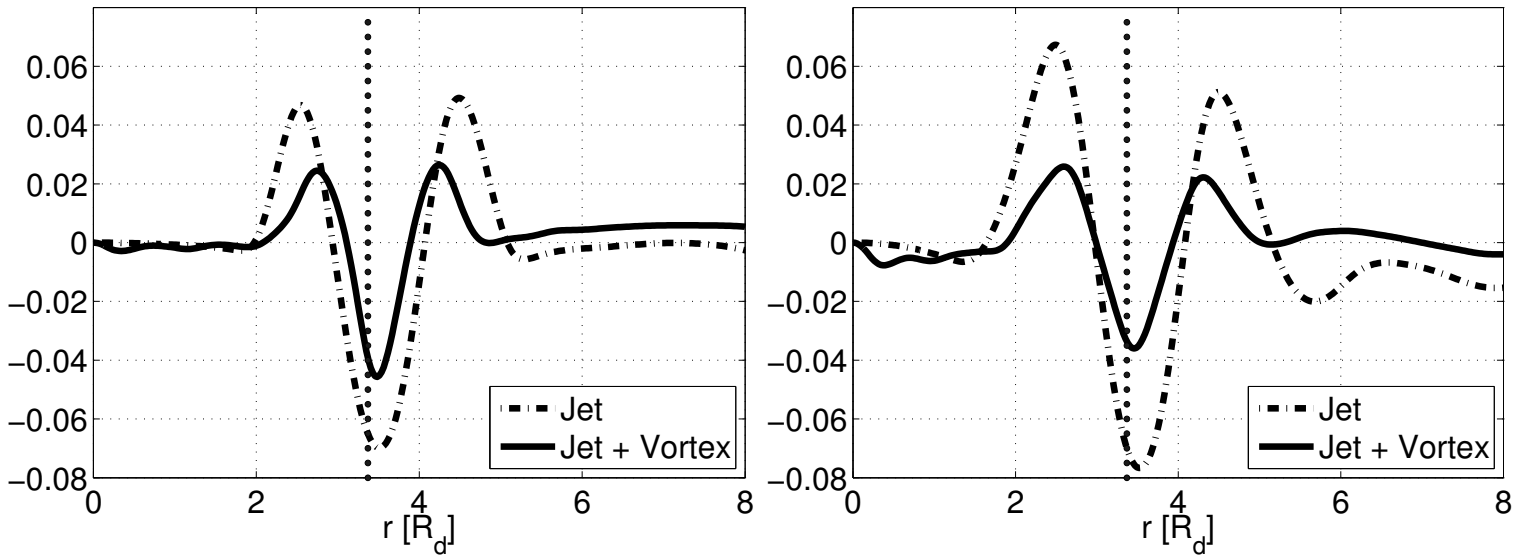

Figure:

Left panel $\rightsquigarrow \triangle M(t = 200\ f_0^{-1})$

Right panel $\rightsquigarrow \triangle M(t = 450\ f_0^{-1})$

Vertical dashed line $\rightsquigarrow r_{max}, [V(r_{max}) = V_{max}]$

Conclusion

- ***Result of linear stability analysis***:
  (a) the most unstable mode depends on the latitude of the circumpolar jet and curvature of its azimuthal velocity profile.
  (b) the difference in morphology between the hexagonal northern polar jet and the southern polar jet can be explained by linear stability analysis.
- ***Result of non-linear stability analysis***:
  developing barotropic instability of the "jet+vortex" system produces a long-living structure akin to the observed hexagon, which is not the case of the "jet-only" system. The north polar vortex, thus, plays a decisive dynamical role.