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Characterising turbulent cascades and zonal jet formation from observations of Jupiter and Saturn

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Processes leading to the formation of zonal jets and super-rotation through nonlinear interactions of turbulent eddies have much in common[1,2] between plasmas and rotating flows in geophysics and astrophysics. Among the latter, the most spectacular examples include the intense patterns of zonal jets found in the atmospheres of the gas giant planets Jupiter and Saturn.

Recent analyses of wind measurements from tracking cloud motions in spacecraft images of those planets[3,4] indicate that scale to scale transfers of kinetic energy act from small to large scales over a wide range of length scales, much as anticipated for 2D or geostrophic turbulence paradigms.

At the smallest resolvable scales, however, there is evidence in observations of a forward (downscale) transfer, at least at low and middle latitudes on Jupiter (e.g. see Fig. 1). Moreover, the upscale transfers at the largest spatial scales are evidently dominated by spectrally non-local eddy-zonal interactions (see Fig. 1b), in contrast to more classical scenarios, associated with the generation of intense zonal jets and equatorial super-rotation.

Most analyses to date have emphasised the global mean interactions for both planets, thereby focusing on the spatially homogeneous components of the turbulence. Here we present some new analyses of spectral energy transfers on both Jupiter and Saturn that resolve variations in latitude (see Fig. 1 for an example). The results resemble energy transfers found in some recent numerical model studies[5]. They indicate significant variability and inhomogeneity between different locations, with a clear distinction between the tropics, the extratropical middle latitudes and the polar regions. We discuss these in light of other observations and models of gas giant circulation.

References

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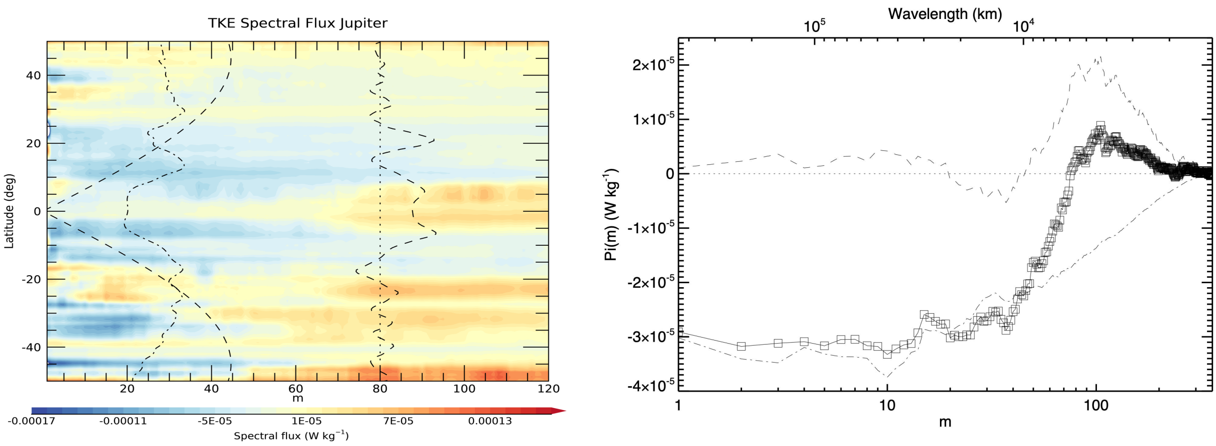

(a) (b)

Figure 1: Semi-spectral fluxes at the cloud tops of Jupiter, computed from velocity fields derived from images obtained by the Cassini mission during its fly-by in December 2000. (a) total KE fluxes as a function of latitude and zonal wavenumber m (smoothed in latitude by 5º) and (b) KE fluxes averaged over ±50º latitude showing total KE fluxes (square symbols), eddy-zonal fluxes (dash-dotted line) and eddy-eddy fluxes (dashed line). Negative fluxes are upscale.