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A planetary-scale disturbance in a long-living three-vortex coupled system in Saturn's atmosphere

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Abstract

The zonal wind profile of Saturn has a singular structure in the latitude range 50ºN-65ºN planetocentric, with a double peak that reaches maximum zonal velocities close to 100ms^{-1}[1]. A survey of Cassini ISS images shows that a system of three vortices formed in this latitudinal region in 2012 and has remained active until present, confirming that vortices in Saturn can be long lived [2]. In May 2015 a disturbance started to develop at the location of the triple vortex. Since at the time Cassini orbits were not favorable to the observation of the region, we were granted Director Discretionary Time of the Hubble Space Telescope to observe the region before the perturbation faded away. Here we report the dynamics and vertical structure of the three-vortex system and of the disturbance that developed at its location, based on HST and Cassini images. We also present results of numerical models to explain the stability of vortices in the region.

1. The three-vortex system: History, evolution and local motions

The appearance of the three vortices in Cassini ISS CB2 and MT3 filters (See figure 1), and their latitude in the zonal wind profile, suggest that the system is formed by one cyclone surrounded by two anticyclones. In the methane deep absorbing filter MT3, the central vortex appears dark relative to its surrounding, while the two other vortices are brighter, indicating that the central vortex is located lower in the atmosphere and the surrounding vortices higher, as expected from their cyclonic / anticyclonic character. The relative altitude of the different structures is confirmed by a radiative-transfer analysis of the system in a variety of filters. The three vortices are almost circular, with diameters ~2,000-3,000km, and their sizes have not changed noticeably in the years 2012-2015. We have tracked the motion of the system since 2012. The central cyclone is located at an average 58.5º±0.8ºN (planetocentric), drifting 11.55º/day, u=69.0±1.6ms^{-1}, essentially following the wind profile, with slight oscillations of amplitude ~10º and a period of ~8 months.

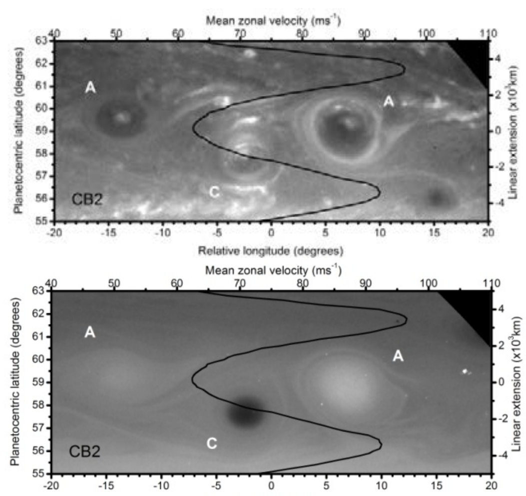

Figure 1: Map projections of Cassini ISS images (27 Feb 2013) showing also the zonal winds.

Using Cassini high resolution images, we have measured local motions within the vortices. They confirm the cyclonic/anticyclonic character of the vortices, and allow us to estimate the eddy vorticity which is (3±2)×10^{-5}s^{-1} in the cyclone, and -(5±2)×10^{-5}s^{-1} and -(3±2)×10^{-5}s^{-1} in the anticyclones.

2. The disturbance

On 13 May 2015, near Saturn opposition, the amateur community was stirred by the presence of a “rift” at the location of the vortices, which appeared in low-resolution observations as a single spot. Soon after, the region surrounding the spot appeared disturbed, and the perturbation extended longitudinally for ~2 months, at the end of which the perturbed region occupied about a third of the latitudinal circle. Using ground-based observations we found that the disturbance expanded eastwards at -1.65º/day. Cassini images at the time of the disturbance showed the presence of a vortex south of the system at 55ºN that was again visible at the expected location of the limit of the disturbance once it had subdued, in Sep 2015, and which could be found in earlier images, approaching the triple vortex at 1.70º/day, suggesting that the origin of the disturbance could have been the interaction of this new vortex with the three vortex system.

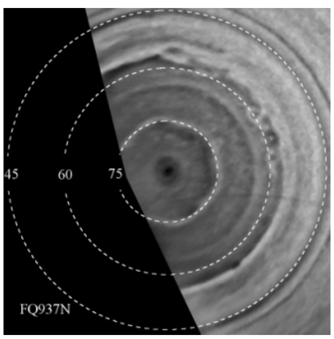

Figure 2: Polar projection of Saturn North hemisphere from a single HST/WFC3 image acquired on 30-06-2015.

HST/WFC3 images (Figure 2) allowed us to retrieve motions of local features in the perturbed region at the time of the disturbance. We find that they follow within error the average zonal wind profile, showing that the dynamics of the region is dominated by the advection by the zonal winds and supporting the hypothesis that the disturbed area is the result of the advection of the clouds created by the interaction of the system of vortices with the vortex at the south.

3. Numerical models

We modeled the triple vortex system by using the EPIC model [3] and a shallow water model (SW) [4] to study the possible mutual interactions among the three vortices. In the EPIC model, the vertical domain spanned between 500 and 200 mbar and was divided in three layers. No vertical shear for the zonal winds was assumed, and simulations had a 0.11 degree pixel^{-1} horizontal resolution. The vertical thermal profile was set to strongly stable with an average Brunt-Väisälä frequency of 7.7×10^{-3} s^{-1}. The SW model was a one-layer with a Rossby radius of deformation of ~300 km and a spatial resolution of 0.1 degree pixel^{-1}. Zonal winds were imposed as described in [4]. Figure 3 shows an outcome of the SW model in the form of potential vorticity field where the three vortices are present.

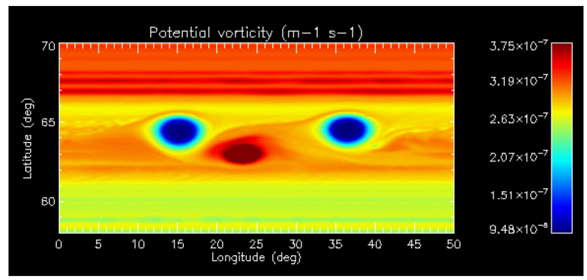

Figure 3: Potential vorticity from a one-layer SW simulation after 25 days. Latitudes are planetographic.

Acknowledgements

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