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Observations and numerical modelling of a convective disturbance in Jupiter's South Temperate Belt.

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Abstract

Moist convective storms in Jupiter are frequent and can trigger meteorological disturbances of local to planetary-scale [1, 2]. In February 2018 a system of convective storms erupted inside an elongated cyclonic region in Jupiter's South Temperate Belt (STB), known as the STB Ghost, which at that time was located near the large anticyclone Oval BA. The storms were active only for a few days but developed a persisting turbulent pattern in the STB Ghost that endured months, shaped its structure and resulted in many small features, possibly small anticyclones, expelled outside the cyclone. The remains of the STB Ghost interacted with oval BA and merged with a cyclonic cell, first dissipating, and later recovering its structure as an elongated and turbulent cyclone. We analyzed ground-based observations obtained with small telescopes, observations at the 2.2m telescope at Calar Alto Observatory, the Hubble Space Telescope and the JunoCam instrument on Juno. We also run simulations with the EPIC General Circulation Model modified to take into account the effects of the storms. The successful simulations resemble closely the first stages of the disturbance and required water moist convection for the source of the initial storms. A scale comparison with similar convective storms that do not trigger planetary-scale disturbances strongly suggests that the energy source for most of the storms observed in Jupiter is water condensation instead of ammonia.

1. The STB Ghost

The STB Ghost is a low-contrast elongated cyclone located at Jupiter's South Temperate Belt (STB). Throughout 2017 the Ghost grew to a size of (28,000 ± 1,400) km x (5,500 ± 1,200) km the day of the onset of the convective activity. The Ghost was drifting longitudinally with a speed of (3.36 ± 0.03) m/s, slightly approaching to Oval BA. We used HST and JunoCam images to measure the wind field of the Ghost, obtaining peak winds on the outer collar of the Ghost of (60 ± 10) m/s and (80 ± 20) m/s respectively.

2. Development of the disturbance

The development of a bright spot inside the STB Ghost was reported by amateur astronomers on 4 February 2018 (Figure 1). The convective nature of the bright spot was demonstrated with observations in the strong methane absorption band. On 6 and 7 February 2018 two other convective spots were observed. We followed the evolution of this South Temperate Belt Disturbance with observations provided by amateur astronomers, our own observations, HST images through 2017-2018 and JunoCam observations. The bright clouds of the storms expanded and scattered following the Ghost's internal wind field. The turbulence generated by the storms was initially contained inside the STB Ghost, and ended up perturbing the region for several months. A large dark tail was generated westward of the STB Ghost, along with several small features, and was expelled to the west while the Ghost approached to Oval BA, interacting with a small cyclonic cell northwest of Oval BA and Oval BA itself. As a result of the interaction the Oval BA accelerated its drift speed and the Ghost decelerated. By the end of October 2018 the activity seemed to have ended with a morphology similar to the one before the disturbance started, with a cyclonic cell created from the interaction between the Ghost and Oval BA. Between October and December 2018 this cyclonic cell recovered its structure as an elongated and turbulent cyclone.

Figure 1: Initial observations of the convective outbreaks in the STB Ghost.

3. EPIC simulations

We have used the Explicit Planetary Isentropic-Coordinate (EPIC) atmospheric model [3] to simulate the phenomenology observed and explore the source of the convective activity. The simulations require an interaction between the STB Ghost, the Oval BA and the convective storms. The different elements were introduced sequentially at different days through perturbations of the modelled atmosphere. The convective storms were introduced following [4]. We explored the parameter space checking different properties of the atmosphere, Ghost, Oval BA and storms. The atmosphere of our successful simulation is based on [5] and has a thermal structure based on the Voyager thermal profile extrapolated below wet adiabatically, zonal winds using HST observations from 2016 [6] and a vertical wind structure with decreasing winds above the clouds and constant in depth. Figure 2 shows the comparison between HST observations a few days after the start of the convective eruption and the potential vorticity map of our simulation, showing that our simulation reproduces well the first stages of the disturbance.

4. Summary and Conclusions

We have characterized the STB Ghost before the outbreak of the storms and the evolution of the STB Disturbance and the formation of new structures. The energy required by our simulations to reproduce the observations is on the order of $2.5 \cdot 10^{22}$ J. A scale analysis shows that this energy is compatible only with storms powered by water moist convection requiring at least a solar water abundance. The comparison of the characteristics of these storms with storms developing planetary-scale disturbances and the expansion rate of other moist convective storms in Jupiter, suggests that most of the storms observed in Jupiter are powered by water condensation.

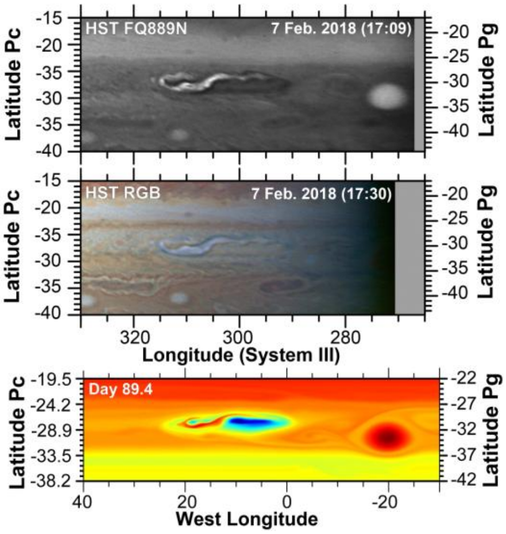

Figure 2: Comparison between HST observations on 7 February 2018 and the potential vorticity map of our successful simulation.

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