The 2016 outbreak on Jupiter's North Temperate Belt and jet from ground-based and Juno imaging

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Abstract

A new outbreak of convective plumes on the peak of Jupiter's fastest jet, which had been predicted the previous year, began in autumn, 2016. It was observed just after solar conjunction by the NASA Infrared Telescope Facility, by JunoCam, and by amateur astronomers. It unfolded in essentially the same way as previous such outbreaks, leading to revival of the North Temperate Belt with a notably red component. The maturation of this belt was monitored at high resolution by JunoCam.

1. Introduction

Each of Jupiter's 3 major belts is subject to planetary-scale cycles in which a quiescent preparative phase with increased cloud cover is followed by a sudden vigorous outbreak of activity. In the North Temperate Belt (NTB), the most distinctive feature of its cycle is a sudden outbreak of several vertically extended convective plumes, very bright at all wavelengths from UV to near-IR, which travel at 165-175 m/s, the maximum speed of the planet's fastest jet at 23-24ºN (NTBs jet) [1,2]. The plumes are typically followed by expanding chains of slower-moving dark spots and streaks on the jet, which merge to form a new NTB south component (NTB(S)) which turns an intense orange colour within a few months. We refer to these events as 'super-fast NTB outbreaks'; they have also been termed 'NTB Disturbances' [2] and 'NTB Revivals'. Outbreaks of this type occurred every 4.9 (±0.2) years from 1970 to 1990 (assuming an unobserved event in 1985) [1]. Further super-fast outbreaks occurred in 2007 and 2012.

The NTBs jet at cloud-top level gradually accelerated over several years before the 2007 outbreak [2,3], while the NTB was whitened. This behaviour is in accord with Voyager observations, and with modelling [2,4]. Therefore, in early 2015, when the jet again had intermediate speed (Fig.1) and the belt had become visibly pale, a prediction was issued for another outbreak in late 2016 or early 2017 [5].

The event duly began during solar conjunction in autumn 2016, and was discovered by G.O. by IR imaging scheduled to coincide with Juno's perijove 2 on Oct.19. Fortuitously, Juno's 'public outreach' camera, JunoCam, had been taking distant low-resolution images of Jupiter every 30 minutes up to Oct.14, and the early stages of the outbreak could be discerned in these images. So, although Juno returned no science data at perijove 2, it was instrumental in recording the earliest stages of this outbreak. Ground-based imaging by several amateurs, in visible light and near-IR and the 0.89-micron methane band, then tracked the plumes until they disappeared around the start of November. The early stages of the outbreak are described with further details of the spot motions and with modelling in [6].

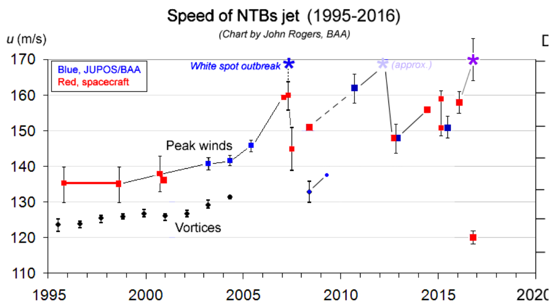

Figure 1. Chart of NTBs jet peak speed over recent decades.

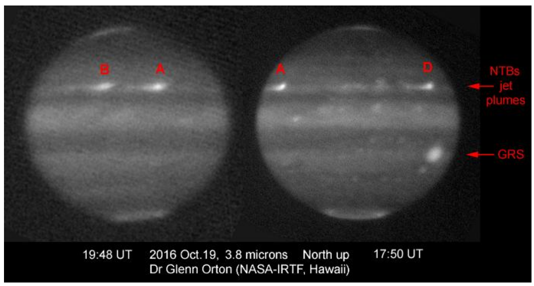

Figure 2. Discovery images of the NTB plumes, 2016 Oct.19 (from SpeX on the IRTF at 3.8 μm, sensitive to gas absorption).

2. Methods

The methods for obtaining and analysing the early JunoCam, infrared, and amateur images are described in [6]. Subsequent JunoCam images were obtained as described [7] [& see separate abstract], thanks to members of the public voting for the so-called 'Big Red Stripe' target. Ground-based images were provided by the world-wide network of amateur observers who contribute to databases such as PVOL2, ALPO-Japan, and JunoCam. Maps were made from them by M.V. using WinJUPOS.

3. Results

The discovery images in mid-IR on Oct.19, taken from the NASA IRTF on Hawaii, revealed 3 brilliant plumes on the NTBs jet (Fig.2), as well as numerous small 'hot spots' at 5 microns which are believed to correspond to visibly dark spots. JunoCam images from Oct.11-14 showed that the outbreak then contained 4 super-fast plumes, and was already widespread, with chains of dark bluish spots following the plumes. We measured the rapid speeds of the plumes and slower speeds of the dark spots, and estimated that the larger group of plumes and spots had appeared in mid-September, and the smaller group in early October.

The JunoCam measurements of plumes A and D connected up well with measurements from IRTF and amateur images over the following 2 weeks. Continuity of plumes B and C was less clear, as only one of them was observable after Oct.14. The mean speed of plumes A, C and D, from observations before and after Oct.14, was 170 (±6) m/s. The speeds were typical, except that plume C was, marginally, the fastest ever recorded (~179 m/s).

Plumes A and D were both last seen when they caught up with the dark spots preceding them: plume D on Oct.28, and plume A on Oct.31.

At that time, the reviving NTB(S) consisted of very dark spots or streaks, starting to merge into a continuous belt. The NTB(S) reddened rapidly in late Nov., and remained outstandingly orange and almost featureless into spring, 2017. The NTB(N) was all turbulent in Nov-Dec., then became a well-defined, very dark grey belt in Jan., and even more regular from Feb. onwards. The NTB was essentially uniform in longitude, except for one turbulent sector of NTB(N) which probably persisted from 2015 and thus survived the NTBs jet outbreak.

JunoCam took close-up images of the maturing NTB at perijoves 3, 4 & 5, dramatically showing the complex texture of the reviving belt.

4. Conclusions

Given that only 3 previous NTB outbreaks were well observed, the present observations are a valuable confirmation of their stereotyped nature. The initial plumes were so far apart that they must have appeared in at least two locations independently, as has also been observed previously; and only in the 1975 outbreak were 4 plumes recorded, by amateur visual observers [1]. The JunoCam images of the maturing NTB revival will allow measurements of the evolving scale of the turbulence.

We cannot yet predict whether another such outbreak will take place 4-5 years after this one. This will become clearer over the coming year or two, according to whether the jet speed remains low or accelerates up towards super-fast speed again.

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