Collaborative papers from Jupiter Section members in 2016-2017 (& our own full-length papers for JBAA):

Kardasis E, Rogers JH, Orton G, Delcroix M, Christou A, Foulkes M, Yanamandra-Fisher P, Jacquesson M, & Maravelias G. **'The need for professional-amateur collaboration in studies of Jupiter and Saturn.'** JBAA 126 (no.1), 29-39 (2016).
https://britastro.org/node/7134

Abstract

The observation of gaseous giant planets is of high scientific interest. Although they have been the targets of several spacecraft missions, there still remains a need for continuous ground-based observations. As their atmospheres present fast dynamic environments on various time scales, the availability of time at professional telescopes is neither uniform nor of sufficient duration to assess temporal changes. On the other hand, numerous amateurs with small telescopes (with typical apertures of 15-40 cm) and modern hardware and software equipment can monitor these changes daily (within the 360-900nm wavelength range). Amateur observers are able to trace the structure and the evolution of atmospheric features, such as major planetary-scale disturbances, vortices, and storms. Their observations provide a continuous record and it is not uncommon to trigger professional observations in cases of important events, such as sudden onset of global changes, storms and celestial impacts. For example, the continuous amateur monitoring has led to the discovery of fireballs in Jupiter's atmosphere, which provide information not only on Jupiter's gravitational influence but also on the properties and populations of the impactors. Photometric monitoring of stellar occultations by the planets can reveal spatial/temporal variability in their atmospheric structure.

Therefore, co-ordination and communication between professionals and amateurs is important. We present examples of such collaborations that: (i) engage systematic multi-wavelength observations and databases, (ii) examine the variability of cloud features over timescales from days to decades, (iii) provide, by ground-based professional and amateur observations, the necessary spatial and temporal resolution of features that will be studied by the interplanetary mission Juno, (iv) investigate video observations of Jupiter to identify impacts of small objects, (v) carry out stellar-occultation campaigns.

Rogers, JH, Fletcher, LN, Adamoli, G, Jacquesson M, Vedovato M & Orton, GS (2016).
'A dispersive wave pattern on Jupiter's fastest retrograde jet at 20ºS.'
Icarus 277 (2016) 354–369. http://dx.doi.org/10.1016/j.icarus.2016.05.028
also preprint at:
https://arxiv.org/abs/1605.07883 & https://britastro.org/node/7718

A compact wave pattern has been identified on Jupiter's fastest retrograding jet at 20°S (the SEBs) on the southern edge of the South Equatorial Belt. The wave has been identified in both reflected sunlight from amateur observations between 2010 and 2015, thermal infrared imaging from the Very Large Telescope and near infrared imaging from the Infrared Telescope Facility. The wave pattern is present when the SEB is relatively quiescent and lacking large-scale disturbances, and is particularly notable when the belt has undergone a fade (whitening). It is generally not present when the SEB exhibits its usual large- scale convective activity ('rifts'). Tracking of the wave pattern and associated white ovals on its southern edge over several epochs have permitted a measure of the dispersion relationship, showing a strong cor- relation between the phase speed (−43.2 to −21.2 m/s) and the longitudinal wavelength, which varied from 4.4 to 10.0 deg longitude over the course of the observations. Infrared imaging sensing low pressures in the upper troposphere suggest that the wave is confined to near the cloud tops. The wave is moving westward at a phase speed slower (i.e., less negative) than the peak retrograde wind speed (−62 m/s), and is therefore moving east with respect to the SEBs jet peak. Unlike the retrograde NEBn jet near 17°N, which is a location of strong vertical wind shear that sometimes hosts Rossby wave activity, the SEBs jet remains retrograde throughout the upper troposphere, suggesting the SEBs pattern cannot be interpreted as a classical Rossby wave. 2D windspeeds and thermal gradients measured by Cassini in 2000 are used to estimate the quasi-geostrophic potential vorticity gradient as a means of understanding the origin of the a wave. We find that the vorticity gradient is dominated by the baroclinic term and becomes negative (changes sign) in a region near the cloud-top level (400–700 mbar) associated with the SEBs. Such a sign reversal is a necessary (but not sufficient) condition for the growth of baroclinic instabilities, which is a potential source of the meandering wave pattern.

Rogers JH (2017) **'Jupiter's South Equatorial Belt cycle in 2009-2011: I. The SEB Fade.'** *JBAA* 127 (3) 146-158. Available on this web page.

Abstract:

Cycles of fading and revival of the South Equatorial Belt (SEB) are the most spectacular large-scale events that occur on Jupiter. The most recent started in 2009, when the SEB suddenly ceased its convective activity and began to fade. Modern amateur images, combined with measurements by the JUPOS team, have revealed several new insights into the process. The following phenomena were observed in this SEB Fade and in some or all previous ones.

1) Fading began within a few months after convective activity ceased.
2) As soon as the convective activity stopped, a series of dark cyclonic ovals ('barges') appeared in the SEB, suggesting reconfiguration of the retrograding jet.
3) As the SEB faded, the Great Red Spot (GRS) became isolated and increasingly red.
4) The GRS decelerated (i.e. increased westward drift):
5) As the SEB faded, a bright plume erupted intermittently on the north edge of the GRS, and induced a blue-grey streak preceding it. The plume was methane-bright, i.e. it extended to high altitude.
6) A chain of faint spots developed all along the SEBs, constituting a wave-train with a drift rate less than full retrograding jet speed, while several gaps in the chain moved with full jet speed.
7) There was an outbreak of spots on the STBn jet.

These processes may be general characteristics of SEB Fades. Some of them are not merely aspects of quiescence and increased cloud cover, but distinct positive phenomena, indicating climatic conditions unique to the SEB Fade.

Rogers JH (2017) **'Jupiter's South Equatorial Belt cycle in 2009-2011: II. The SEB Revival.'** *JBAA* (in press).

Available at: http://arxiv.org/abs/1707.03356

Abstract:

A Revival of the South Equatorial Belt (SEB) is an organised disturbance on a grand scale. It starts with a single vigorous outbreak from which energetic storms and disturbances spread around the planet in the different zonal currents. The Revival that began in 2010 was better observed than any before it. The observations largely validate the historical descriptions of these events: the major features portrayed therein, albeit at lower resolution, are indeed the large structural features described here. Our major conclusions about the 2010 SEB Revival are as follows, and we show that most of them may be typical of SEB Revivals.

1) The Revival started with a bright white plume.
2) The initial plume erupted in a pre-existing cyclonic oval ('barge'). Subsequent white plumes continued to appear on the track of this barge, which was the location of the sub-surface source of the whole Revival.
3) These plumes were extremely bright in the methane absorption band, i.e. thrusting up to very high altitudes, especially when new.
4) Brilliant, methane-bright plumes also appeared along the leading edge of the central branch. Altogether, 7 plumes appeared at the source and at least 6 along the leading edge.
5) The central branch of the outbreak was composed of large convective cells, each initiated by a bright plume, which only occupied a part of each cell, while a very dark streak defined its west edge.
6) The southern branch began with darkening and sudden acceleration of pre-existing faint spots in a slowly retrograding wave-train.
7) Subsequent darker spots in the southern branch were complex structures, not coherent vortices.
8) Dark spots in the southern branch had typical SEBs jetstream speeds but were unusually far south. This suggests either a complex vertical structure of the SEBs jet, or a real acceleration westwards on the south flank of the jet.
9) Part of the revived SEB became overlaid with orange, methane-bright haze.

L.N. Fletcher, G.S. Orton, J.H. Rogers, R.S. Giles, A.V. Payne, P.G.J. Irwin, M. Vedovato (2017), **'Moist Convection and the 2010-2011 Revival of Jupiter's South Equatorial Belt',** *Icarus*, 286, 94-117 (http://dx.doi.org/10.1016/j.icarus.2017.01.001) Available at: http://arxiv.org/abs/1701.00965

Abstract

The transformation of Jupiter's South Equatorial Belt (SEB) from its faded, whitened state in 2009-2010 (Fletcher et al., 2011b) to its normal brown appearance is documented via comparisons of thermal-infrared (5-20 µm) and visible-light imaging between November 2010 and November 2011. The SEB revival consisted of convective eruptions triggered over ~100 days, potentially powered by the latent heat released by the condensation of water. The plumes rise from the water cloud base and ultimately diverge and cool in the stably-stratified upper troposphere. Thermal-IR images from the Very Large Telescope (VLT) were acquired 2 days after the SEB disturbance was first detected as a small white spot by amateur observers on November 9th 2010. Subsequent images over several months revealed the cold, putatively anticyclonic and cloudy plume tops (area 2.5 M km^2) surrounded by warm, cloud-free conditions at their peripheries due to subsidence. The latent heating was not directly detectable in the 5-20 µm range. The majority of the plumes erupted from a single source near 140-160ºW, coincident with the remnant cyclonic circulation of a brown barge that had formed during the fade. The warm remnant of the cyclone could still be observed in IRTF imaging 5 days before the November 9th eruption. Additional plumes erupted from the leading edge of the central disturbance immediately east of the source, which propagated slowly eastwards to encounter the Great Red Spot. The tropospheric plumes were sufficiently vigorous to excite stratospheric thermal waves over the SEB with a 20-30º longitudinal wavelength and 5-6 K temperature contrasts at 5 mbar, showing a direct connection between moist convection and stratospheric wave activity. The subsidence and compressional heating of dry, unsaturated air warmed the troposphere (particularly to the northwest of the central branch of the revival) and removed the aerosols that had been responsible for the fade. Dark, cloud-free lanes west of the plumes were the first to show the colour change, and elongated due to the zonal windshear to form the characteristic 'S-shape' of the revival complex. The aerosol-free air was redistributed and mixed throughout the SEB by the zonal flow, following a westward-moving southern branch and an eastward moving northern branch that revived the brown colouration over ~200 days. The transition from the cool conditions of the SEBZ during the fade to the revived SEB caused a 2-4 K rise in 500-mbar temperatures (leaving a particularly warm southern SEB) and a reduction of aerosol opacity by factors of 2-3. Newly-cleared gaps in the upper tropospheric aerosol layer appeared different in filters sensing the ~700-mbar cloud deck and the 2-3 bar cloud deck, suggesting complex vertical structure in the downdrafts. The last stage of the revival was the re-establishment of normal convective activity northwest of the GRS in September 2011, 840 days after the last occurrence in June 2009. Moist convection may therefore play an important role in controlling the timescale and atmospheric variability during the SEB life cycle.

Rogers JH (2017) **'Jupiter's North Equatorial Belt and Jet: I. Cyclic expansions and planetary waves.'** *JBAA* (in press). Available at: http://arxiv.org/abs/1707.03343

Abstract:

This article presents a synopsis of the activity in Jupiter's North Equatorial Belt (NEB) from 1986 to 2010, and of the speeds of dark formations on its south edge and bright streaks ('rifts') in its interior. In particular I discuss NEB expansion events (NEEs), which took place every 3-5 years during this time, and how the various features of the NEB are involved in them.

I present evidence that the NEE affects not just the northern edge, but the whole width of the belt. It begins with an outbreak of a bright rift that is more northerly and slower-moving than usual; this is often involved with the first ejection of dark material northwards into the N. Tropical Zone, but typically the rift also expands southwards across the width of the NEB. NEBs dark formations are usually affected, as they are during individual interactions with rifts at other times; they may be disrupted, or intensified, and they usually undergo deceleration. The expansion of the dark NEB to the north occurs concurrently, and is followed by the appearance of new dark 'barges' and white ovals flanking the NEBn jet.

The speed of the NEBs dark formations varies with their mean spacing, consistent with the prevailing hypothesis that they are planetary Rossby waves. In most apparitions since 2000 we have also detected smaller, faster features (~120 m/s). I propose that these represent waves of the same type, but with higher frequency, and that their speed is slightly less than the true wind speed at cloud-top level under normal conditions.

Tollefson J, Wong MH, de Pater I, Simon AA, Orton GS, Rogers JH, Atreya SK, Cosentino RG, Januszewski W, Morales-Juberias R, Marcus PS.
‘Changes in Jupiter’s Zonal Wind Profile in Light of Juno.’ *Icarus* 296, 163-178 (2017), online in June (https://doi.org/10.1016/j.icarus.2017.06.007)
Abstract:
We present five epochs of WFC3 HST Jupiter observations taken between 2009–2016 and extract global zonal wind profiles for each epoch. Jupiter’s zonal wind field is globally stable throughout these years, but significant variations in certain latitude regions persist. We find that the largest uncertainties in the wind field are due to vortices or hot-spots, and show residual maps which identify the strongest vortex flows. The strongest year-to-year variation in the zonal wind profiles is the 24 °N jet peak. Numerous plume outbreaks have been observed in the Northern Temperate Belt and are associated with decreases in the zonal velocity and brightness. We show that the 24°N jet peak velocity and brightness decreased in 2012 and again in late 2016, following outbreaks during these years. Our February 2016 zonal wind profile was the last highly spatially resolved measurement prior to Juno ’s first science observations. The final 2016 data were taken in conjunction with Juno’ s perijove 3 pass on 11 December 2016, and show the zonal wind profile following the plume outbreak at 24 °N in October 2016.

A. Sánchez-Lavega, J. H. Rogers, G. S. Orton, E. García-Melendo, J. Legarreta, F. Colas, J. L. D'Auvergne, R. Hueso, J. F. Rojas, S. Pérez-Hoyos, I. Mendikoa, P. Iñurrigarro, J. M. Gomez-Forrellad, C. J. Hansen, G. Eichstaedt, P. Miles, A. Wesley .
‘A planetary-scale disturbance in the most intense Jovian atmospheric jet from JunoCam and ground-based observations.’ *Geophysical Research Letters* (2017) 44, 4679–4686.
DOI:10.1002/2017GL073421
Abstract:
We describe a huge planetary-scale disturbance in the highest-speed Jovian jet at latitude 23.5°N that was first observed in October 2016 during the Juno perijove-2 approach. An extraordinary outburst of four plumes was involved in the disturbance development. They were located in the range of planetographic latitudes from 22.2° to 23.0°N and moved faster than the jet peak with eastward velocities in the range 155 to 175 m s 1. In the wake of the plumes, a turbulent pattern of bright and dark spots (wavenumber 20–25) formed and progressed during October and November on both sides of the jet, moving with speeds in the range 100–125 m s 1 and leading to a new reddish and homogeneous belt when activity ceased in late November. Nonlinear numerical models reproduce the disturbance cloud patterns as a result of the interaction between local sources (the plumes) and the zonal eastward jet.

L.N. Fletcher, G.S. Orton, J.A. Sinclair, P. Donnelly, H. Melin, J.H. Rogers, T.K. Greathouse, Y. Kasaba, T. Fujiyoshi, T.M. Sato, J. Fernandes, P.G.J. Irwin, R.S. Giles, A.A. Simon, M.H. Wong, M. Vedovato. **‘Jupiter's North Equatorial Belt expansion and thermal wave activity ahead of Juno's arrival.’** *Geophys. Res. Lett.*, 44, 7140-7148 (2017).
DOI: 10.1002/2017GL073383.
Available at: arXiv:1708.05179v1 [astro-ph.EP]
Abstract
The dark colors of Jupiter’s North Equatorial Belt (NEB, 7-17N) appeared to expand northward into the neighboring zone in 2015, consistent with a 3-5 year cycle. Inversions of thermal-IR imaging from the Very Large Telescope revealed a moderate warming and reduction of aerosol opacity at the cloud tops at 17-20N, suggesting subsidence and drying in the expanded sector. Two new thermal waves were identified during this period: (i) an upper tropospheric thermal wave (wavenumber 16-17, amplitude 2.5 K at 170 mbar) in the mid-NEB that was anti-correlated with haze reflectivity; and (ii) a stratospheric wave (wavenumber 13-14, amplitude 7.3 K at 5 mbar) at 20-30N. Both were quasi-stationary, confined to regions of eastward zonal flow, and are morphologically similar to waves observed during previous expansion events.

& see:

L.N. Fletcher (2017) *Geophysical Research Letters* 44 (10), 4725-4729.
Commentary: 'Cycles of activity in the Jovian atmosphere' DOI: 10.1002/2017GL073806
Abstract:
Jupiter's banded appearance may appear unchanging to the casual observer, but closer inspection reveals a dynamic, ever-changing system of belts and zones with distinct cycles of activity. Identification of these long-term cycles requires access to data sets spanning multiple Jovian years, but explaining them requires multispectral characterization of the thermal, chemical, and aerosol changes associated with visible color variations. The Earth-based support campaign for Juno's exploration of Jupiter has already characterized two upheaval events in the equatorial and temperate belts that are part of long-term Jovian cycles, whose underlying sources could be revealed by Juno's exploration of Jupiter's deep atmosphere.

R. Hueso, A. Sánchez-Lavega, P. Iñurrigarro, J. F. Rojas, S. Pérez-Hoyos, I. Mendikoa, J. M. Gómez-Forrellad, C. Go, D. Peach, F. Colas, & M. Vedovato.
'Jupiter cloud morphology and zonal winds from ground-based observations before and during Juno's first perijove'
Geophysical Research Letters 44, 4669–4678. DOI: 10.1002/2017GL073444
Abstract:
We analyze Jupiter observations between December 2015 and August 2016 in the 0.38–1.7 μm wavelength range from the PlanetCam instrument at the 2.2 m telescope at Calar Alto Observatory and in the optical range by amateur observers contributing to the Planetary Virtual Observatory Laboratory. Over this time Jupiter was in a quiescent state without notable disturbances. Analysis of ground-based images and Hubble Space Telescope observations in February 2016 allowed retrieval of mean zonal winds from -74.5° to +73.2°. These winds did not change over 2016 or when compared with winds from previous years with the sole exception of intense zonal winds at the North Temperate Belt. We also present results concerning the major wave systems in the North Equatorial Belt and in the upper polar hazes visible in methane absorption bands, a description of the planet's overall cloud morphology and observations of Jupiter hours before Juno's orbit insertion.