Jupiter in 2003/04:
INTERIM REPORT ON NORTHERN EQUATORIAL REGION

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Summary

The northern equatorial region [EZ(N) and NEBs] is particularly active and interesting this apparition, and is in a similar state to that during the Voyager encounters in 1979. Common features are:
1) Weak yellowish shading in EZ(N)
2) Prominent NEBs dark projections and bright plumes
3) A long-lived rifted region in NEB.
Moreover, two phenomena are being observed in 2004 which confirm discoveries made in the 1979 data:
4) NEBs dark projections are enhanced when passing the NEB rifted region;
5) In EZ(N), UV-bright areas are displaced from the corresponding visibly-bright areas.

Introduction

The features of the northern equatorial region are some of the most conspicuous on Jupiter, but they are still not fully explicable nor predictable. They include the great dark patches ('NEBs projections' or 'infrared hot-spots'), and bright areas that separate them, sometimes developing into white plumes. The dark patches are now known (since the Galileo Probe descended into one of them) to be deep clear cloud-free weather systems [see Minireview 2001], and the plumes are billowing white clouds. The region is overlaid by high-altitude haze which appears bright in methane wavebands but variably dark in ultraviolet. The region is also subject to episodes of obvious yellow or ochre colour, most recently in 1990-92; this colour is generally thought to be an intensification of the blue and UV absorption in the high-altitude haze.

This report analyses amateur imaging data from 2003/04 in the following wavebands: Visible (colour images); UV (centred at 340 or 360 nm, sensing mainly the high-altitude haze, which may be dark in this waveband); Methane (890 nm, also sensing the high-altitude haze, which reflects brightly in this waveband); and I-band (near-infrared, probing deeper into the main clouds, and revealing the dark NEBs projections with very high contrast).

I compare these data with Voyager images from 1979, which were taken in visible and UV (345 nm) wavebands, but not in the infrared.

Credit is due especially to Tomio Akutsu, Antonio Cidadao, and Christophe Pellier, for their multispectral images in 2003/04 and for discussions about them; to all other observers whose hi-res images are included; and to Hans-Joerg Mettig for performing the JUPOS measurements and analysis. For Voyager images, credit is due to NASA and the Voyager Imaging Team (leader Bradford A. Smith). The original images are obtained from the NASA website at: http://ringmaster.arc.nasa.gov/catalog/vgriss.html.

Analysis

1) Weak yellowish shading in EZ(N)

For most of the last 10 years, this pale yellowish shading has been evident in visible-colour images, and confirmed by the comparative darkness of EZ(N) in violet and (esp.) UV images. (Fig.1) It was absent in 2000/2001, when the whole EZ became bright white, but it became quite strong in 2001/02, and seems to be quite strong again in 2003/04.

This coloration is not strong enough to be seen by visual observers, so it does not qualify as a distinct coloration event. Thus the situation is at first glance very different from that in 1979, when there was strong yellow-orange colour over much of the EZ. However the difference is mainly in the EZ(S); the coloration in EZ(N) is actually quite similar in 1979 and 2004. (Recall that Voyager pictures are usually shown with exaggerated redness.) In both apparitions, the mixture of background colour, intricate festoons, and active plumes, produces a beautiful network of blue-grey, white, and yellow streaks in EZ(N).

Discussion: Although yellow coloration is generally thought to be in the high-altitude haze layer, there is no evidence that this layer is thicker than usual in 2004. Visible colour images do not suggest that the colour obscures other features, and methane images do not show any new reflective layer – in fact many of the dark NEBs projections are unusually prominent in methane images this apparition. This suggests that we are seeing a change in colour (increased blue and UV absorption) but not an increase in thickness of the high-altitude haze layer.

Fig.1: Examples of images in colour and UV by Akutsu, 2000-2004. All images in this report have south up.

2) Prominent NEBs dark projections and bright plumes

The array of dark bluish plateaux and projections and festoons on NEBs in 2004 is fairly typical, but perhaps more prominent than for several years. This is partly because the yellowish shading highlights the bright whitish areas between the projections, and some of these are active plumes (i.e. with a small bright core). The situation was the same in 1979, and in both years there are about 11 of the dark projections spaced around the NEBs. (See Fig.2: JUPOS chart, 2003/04, with the main persistent features marked and given provisional letters [a-h, k,l,m].)

Fig.2 shows that these features all have an exceptionally slow drift this year: they are retrograding at DL1 ~ +7 to +14 deg/month relative to System I. (This was not the case in 1979.)

Fig.2: Superimposed JUPOS charts for lats.+4/+7/+10 deg.N, 2003/04, with provisional nomenclature for the major NEBs projections.

3) A long-lived rifted region in NEB.

This was first identified by Mettig from his JUPOS charts of white spots in the NEB. Fig.3 includes the chart from 2003 Nov. to 2004 Jan., and identifies a 'source' white spot(s) (or rift) with DL2 = -3.6 deg/day, which has produced at least 4 spots (or spot-groups or rifts) with DL2 ~ -5.7 deg/day. The source was at L2 ~ 0 around Dec.3, when it seemed to become more active; and at L2 ~180 around 2004 Jan.18. Moreover the 'source' spot(s) are all between +11/+13 deg.N, whereas the more-prograding spots are distributed between +9/+12 deg.N.

Compilations of images were made to examine the structure of the source region. The first set, comprising the few suitable images from 2003 Dec., each showed a bright spot in the *southern* half of NEB near the proposed source. Although these spots may have been temporary clouds billowing from the source (as their positions are quite scattered), their latitude (11 to 13 deg.N) agrees with the drift rate for the source. There was also a subtle rift extending Nf. from the arrowed spot in each case, probably representing minor disturbance spreading Nf. from the source. From mid-Dec. the rift became more conspicuous (**Fig.4**: green zigzag underlining), but its drift implies that the focus of the disturbance was still at the same latitude. The rift developed rapidly: by mid/late Jan., 2004, there was a long white rift spanning and preceding the source region (Fig.5). This was passing the GRS (L2 ~ 90) in mid-Feb., and is still prominent in March.

The charts for 2002/03 (also in Fig.3) also showed many rapidly-moving white spots or rifts, between +9/+12 deg.N. It is possible that these were arising from the same source region, but it was not clearly defined. In contrast the chart for 2001/02 (not shown) showed most spots moving more slowly, from a persistent rifted region with DL2 ~-0.9 deg/day at +12/+13 deg.N, but more rapid and southerly rifts arising from it. Overall, the JUPOS analysis over the past few years provides a hi-res database of such spots which clearly shows the gradient of speed with latitude across the NEB.

In 1979, there was also a persistent rifted region, but it was centred slightly further north and moved more slowly, DL2 = -0.9 deg/day. Then as now, individual white spots were observed arising within it and accelerating to faster speeds, as dramatically shown in the Voyager movies [Smith et al., 1979; Book p.124]. This rifted region had arisen in 1977; it gradually expanded until it was ~120 deg. long in 1981, and by 1982, rifts could be seen at any longitude.

Discussion: Rifts in the NEB are turbulent cyclonic disturbances; the white spots are erupting white clouds which include thunderstorms. The nature of these persistent active regions, which generate transient rifts propagating p. (to S) and probably f. (to N), is mysterious and could be illuminated by further observations of the present one.

Fig.3: JUPOS chart of NEB rifts, 2002-2004 (by Hans-Joerg Mettig). This shows longitudes of all white spots in the NEB, colour-coded for each one-degree band of latitude, in a longitude system moving at DL2 = -5.0 deg/day.

Fig.4: Alignment of images in 2003 Dec.-2004 Jan. Dark NEBs projections are lettered as in Fig.2, and the NEB rifted region is underlined with green zigzag. [2003Dec_EqRset]

Fig.5: Alignment of images in 2004 Jan. [2004Jan_EqRset2]

4) NEBs dark projections are enhanced when passing the NEB rifted region.

I had previously reported that the dark patches/projections on NEBs are often intensified or enlarged or disrupted as they pass NEB rifts, as observed both visually and in Voyager images [JBAA, 1988; book p.139-141]. Few such interactions have been observed in recent years because the NEBs projections and/or the NEB rifts have not been sufficiently regular and persistent. The prominence of both in the present apparition affords an opportunity to look for these interactions again.

Indeed, compilations of images from 2003 Dec. and 2004 Jan. show several such interactions. (See Fig.2 for tracking of NEBs projections, and Fig.4 to Fig.7 for alignments of the Eq.R. in images.) The first enhancement noted was of proj. e (Jan.5), when passing a secondary rift some way p. the persistent one. Proj. g was also enhanced, very briefly when passing the main rifted region (Dec.27), then again much later (Jan.16). A classic example of enhancement of a projection as it passed the rifted region was proj. m (Jan.25); having become large and dark, it acquired a white core to become an active plume (Feb.1). Meanwhile proj. b, a long low plateau starting to pass the rifted region, was split by a new white spot (Jan.24) converting the p. half (proj.b1) into a bright-cored plume; this also merged with disrupted proj.a, p. it, so the whole sector was very disturbed as it continued to pass the rifted region, including intensification of dark proj. b1 (Feb.13). There were also continuing changes in projections which had already passed the rifted sector, i.e.lying p. it: thus proj. k dissipated (Feb.10) but revived (Feb.12). Fig.7 shows the rifted region in late February but there were no further enhancements of projections there at that time. (However a notable colour difference is appearing in the NEB, which is greyish p.the rifted region but quite reddish-brown f. it.)

The enhancement of proj. m is shown in detail in Fig.8, in I-band and methane wavebands as well as visible colour. In visible and I-band, the apparent enhancement is mainly due to new white spots which appeared p.and f. the dark projection, enhancing it by contrast, and extension of the dark projection into the belt, but no extension southwards. However both the dark projection and its festoon to Sf. also became darker in I-band, and apparently in visible colour (though these impressions could be susceptible to the image-processing). In methane, on the other hand, the formerly invisible projection appeared as a very dark feature extending even further south than the visible counterpart. This suggests that disruption of the overlying haze layer was a major part of the intensification in all three wavebands.

This can be compared with the account of another such enhancement given from Voyager images in 1979 [JBAA, 1988; book p.139-141]. The changes in visible shape were not the same, and this testifies to the very dynamic effects that these rifted regions have on the NEBs projections.

Fig.6: Alignment of images in 2004 Feb. [2004Feb_EqRset]

Fig.7: Alignment of images in 2004 Feb., continued, p.the GRS. This also shows the origin of the new South Equatorial Disturbance. [2004Feb_EqRset-cont-pGRS]

Fig.8: Detail of the enlargement of projection m, at different wavelengths, aligned in latitude. [NEBs_m_enlarge]. I-band shows detail within the main cloud layer; the methane waveband shows hazes above the main cloud layer.

5) In EZ(N), UV-bright areas are displaced from the corresponding visibly-bright areas.

In 2004, this phenomenon was discovered by T. Akutsu in his UV (340 nm) images, which mainly view the haze layer above the main clouds. Whereas white bays are seen at matching locations in visible, I-band, and methane images, in UV they are displaced f., sometimes even overlying the next visibly dark projection. This is especially evident in Akutsu's images on Jan.25, 27 (Fig.9), Feb.10 (Fig.10), and Feb.12.

That these UV-bright areas have not been remarked on before may be largely because the quality of the images has been improving, but also perhaps because these features are particularly conspicuous this apparition. These bright areas are all among the projections which are passing, or have recently passed, the rifted region (Fig.5, Fig.6). These bright bays are particularly prominent in visible light but are mostly not active plumes. In fact, active plumes L and b1 are bright in UV at the same location as in visible light. Other good images (including some by C. Pellier and D. Peach), in regions with 'normal' dark projections but no bright white bays, do not show prominent UV-bright areas.

In 1979, exactly 25 years earlier, the same mismatch can be seen in Voyager images. Fig.11 shows one rotation of the planet on 1979 Jan.26, during Voyager 1's approach. Of the 11 spaces between the 11 projections, 4 show distinct misalignment in UV (marked *). If reduced to the same resolution as ground-based images, the misalignment would be very similar to that observed in 2004. It occurs because the p. part is darker in UV than visible, whereas the f. edge is further f. in UV, sometimes overlying the next visibly-dark projection. Some of the UV borders are ragged with streaks, presumably in the high-altitude haze. The 4 bright bays in question appear prominent but largely undisturbed. One lies just p. the rifted region (which is alongside the GRS), which may well have enhanced the dark projections flanking it; the other three are elsewhere. In contrast, two active plumes (marked P) coincide in UV and visible, also as in 2004, and are very bright in UV.

Discussion on displacement of UV-bright areas: The UV-visible misalignment is not entirely surprising as the dark projections, being bluish, are known to be virtually invisible in blue and UV light, and the UV images view the haze layer overlying them. However one might have expected that the bright areas would correspond to the circulations between them and would therefore coincide in all wavelengths. It is generally thought that the visibly bright patches are circulation cells that lie between the dark NEBs projections [see Minireview, 2001, and Fig.12].

To investigate whether the UV pattern was due to any detectable flow or circulation in these cells, I assembled movies of the 3 consecutive mismatched bright areas on 6 consecutive rotations, 1979 Jan.26-28, in UV and green images (data not shown). Although there are some changes in UV appearances (in the streaks around the UV-bright areas), which are not correlated with visible changes, there is no sign of systematic motion. This is consistent with previous studies of the Voyager visible-light images; even Galileo, with targeted imaging on shorter timescales, found only incomplete evidence of the inferred motions, though consistent with UV and visible streak patterns (Fig.12). The inferred motions may well be present but not revealed by resolvable features.

So I suggest that the UV-visible misalignment is due to UV albedo of the haze layer (Fig.12,A): UV-dark ('yellowish') in the p. parts of the circulation cells, but UV-bright ('white') in the f. parts, which may overlie the adjacent blue-grey festoons. (Perhaps the haze particles reside at high altitude for different times in the p. and f. parts.) The methane images look different because the haze layer is always bright in methane bands, but it is partly transparent in the near-IR, at least at some times and places (esp. 2004), so the cloud-free dark projections can be seen through it. It is possible that major misalignments only appear when there is yellowish colour, i.e. enhanced UV absorption, as in 1979 and in 2004.

The situation with an active plume is different (Fig.12,B): the whole white plume is UV-bright. This may be due to white particles wafted up in the plume. The visual impression that white cloud could be expanding up and away in the f. direction has been confirmed from Voyager images [Hunt et al., 1981; JBAA, 1988; book pp.141-143]. One plume front was tracked [JBAA, 1988] as it happened to coincide with the dark patch expansion described above. In fact this was projection f shown in Fig.11, a few days later: it developed an active plume core, from which white cloud spread very rapidly f. in the EZ(N), forming a front between the white plume material and the orange EZ material, moving at DL1 = +3.5 deg/day, and actually crossing proj. g (the projection which was then expanding) without interacting with it. This was an alternative,, transient way in which a UV-bright area extended further f. than the visibly bright area.

Fig.9: 2004 Jan.27: the equatorial region imaged by T. Akutsu strips in visible colour, I-band, UV, and methane.

Fig.10: 2004 Feb.10: the equatorial region imaged by T. Akutsu strips in visible colour, I-band, UV, and methane.

Fig.11: Voyager images on 1979 Jan.26, UV and green filters, taken at 2-hour intervals to cover a whole rotation of the planet. Projections f and g are labelled as in my earlier reports; bright areas centred at different longitudes in UV are marked *; active plumes are marked P. (Amended from an earlier version that was distributed.)

Fig.12: Model for the bright and dark areas of EZ(N), showing the circulation patterns inferred from Galileo and Cassini imaging, and their relationship to visibly bright areas (indicated by the background shading) and UV-bright areas (labelled). It was Cassini's I-band movie, penetrating deeper, which clearly showed the faster NEBs jet in the main clouds. [For more on circulations of these EZ(N) cells, see Minireview, 2001.]

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