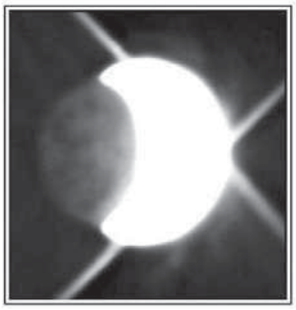
Short paper

Mapping the infrared thermal emission from the surface of Venus, 2017 April–May

Richard McKim

A report of the Mercury & Venus Section (Director: R. J. McKim)

Employing a novel narrow-band filter technique, Australian BAA observers Phil Miles & Anthony Wesley have been able to achieve a new level of resolution for amateur imaging of the infrared thermal emission from the nightside of Venus. In addition to revealing topographic details, images from 2017 April–May reveal at least one compact, infrared-bright spot located within a topographic depression upon the surface. We discuss the interpretation of this bright spot, and the question of whether it was or was not a temporary feature.



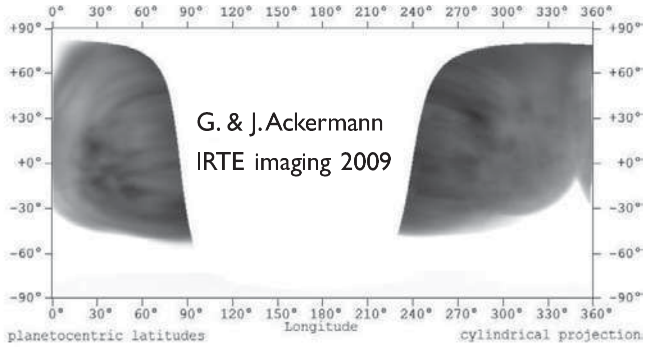


Figure 1. *Left:* The IR thermal emission (IRTE) and surface detail captured by G. & J. Ackermann (Zaberfeld–Michelbach, Germany) with a 317mm DK Cass., Schott 1000nm filter and AVT F033B camera, 2009 Mar 14, 18:29UT. The sunlit crescent is heavily overexposed. *Right:* Surface map from all the 2009 IR thermal emission data by G. & J. Ackermann. North is uppermost in both parts.

Introduction

Ever since the eastern elongation of 2004,[1,2] amateur astronomers have succeeded in taking images of the infrared thermal emission (IRTE) from the nightside of Venus. Since temperature decreases with height above the surface, the infrared albedo gives a measure of altitude, and earlier results are known to correlate well with *Magellan* spacecraft altimetry. We show two examples of such work and comparison mapping in Figures 1 and 2.

However, the maps produced from our ground-based images at each successive inferior conjunction have shown unchanging features – until now. At the 2017 western (morning) elongation, Venus was well placed for southern hemisphere observers, and Phil Miles & Anthony Wesley (Figure 3) teamed up to try to obtain still better resolution of the features visible by means of the IRTE.

High resolution imaging of the IRTE

On 2017 May 19, Miles & Wesley sent the Director a link to a webpage they had created which portrays their current work.[3] I spoke about their results at the May Ordinary Meeting of the BAA, and now give some extracts from their online report:

'One of us (Anthony) had attempted this in 2013 using an older generation camera and 1000nm longpass filter with some success, but we thought that much better results might be possible with the new cameras and better equipment available in 2017. Phil was keen to try this and so we started a project to do this over the 2016/'17 [inferior] conjunction. In particular we thought that using Phil's 508mm aperture scope in combination with the more modern Point Grey camera should allow for a significant increase in signal to noise when looking for the very faint thermal signal at 1010nm. Christophe Pellier had proved the concept in 2004, and others have since repeated this detection, but in all cases there has been a significant problem with the glare (reflected

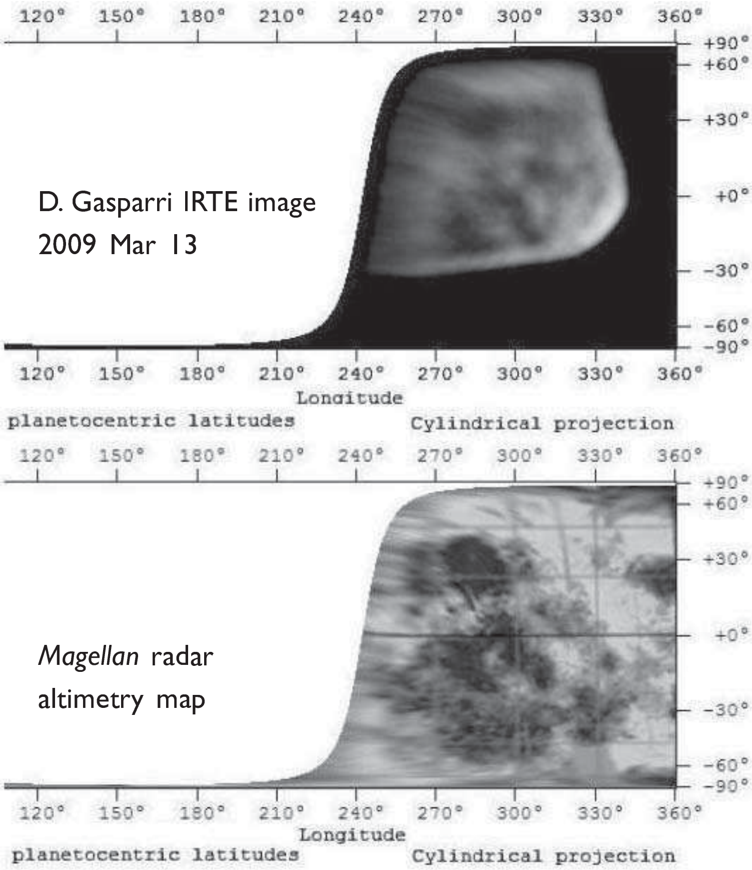


Figure 2. The IRTE and surface detail mapped by D. Gasparri (Perugia, Italy), with a 235mm SCT, ST-7XME camera, Schott 1000nm filter, 2009 Mar 13. *Top:* Surface map for Mar 13; *Bottom: Magellan* radar altimetry map. North is uppermost in both parts.

Figure 3. The 508mm f/4 Newtonian reflector of Phil Miles (left) with Anthony Wesley (Rubyvale, Queensland, Australia).

sunlight) from the lit crescent.

'In amateur scopes the light scatter from this source can dominate the image, making it very difficult to separate from the thermal signal. After the experience in 2013 Anthony purchased an additional filter – a Semrock bandpass filter covering 850–1020nm. When used in conjunction with the existing Thorlabs 1000nm longpass filter this gives an effective narrowband filter centred on 1010nm with a bandpass of 20nm [Figure 4]. He thought this might be better than just the 1000nm longpass on its own as it should block much more of the unwanted reflected sunlight: however, he had never tried the filter so we didn't know if it would be of any use.

'As Phil was going to use his 508mm f/4 Newtonian he set about doing everything he could to reduce unwanted stray light, including making a magnetic cover for the primary inspection mirror which is permanently attached opposite the focuser, blocking the area around the outside of the primary mirror with adhesive foam, and repainting all internal surfaces with black chalkboard paint.

'Phil's first attempt using only the Thorlabs FELH1000 on April 11 showed promise; the thermal signal was clearly visible but no discernible features were present. This was repeated on the 12th with the same result. The next tests on the 13th, 16th & 17th using 2×2 binning looked somewhat better but due to poor seeing no features were seen.

'These tests were done during the very early stages of the morning elongation of Venus, so it was still close to the Sun and difficult to image. Looking at the images we realised that there was still far too much light reaching the camera sensor. Anthony had a Thorlabs 1050/10nm bandpass filter which Phil tested on the 18th without success. It seems there is no thermal signal at 1050nm. On the 19th Phil added the Semrock 835/170 filter to his system, stacking it onto the Thorlabs 1000nm longpass filter and making an effective narrowband filter 1010/20nm [Figure 5]. This produced the best image so far and although there were numerous sharp diffraction spikes in the resulting data, surface features were at last seen. Another test on the 23rd showed similar results. Features were visible but there was still a lot of interference from artifacts generated internally.

'On the 24th we decided to rotate the camera approximately 45° every 15 minutes so that the separate images could be combined to reduce the in-camera generated spikes. By chance one of these rotations produced a much smoother image with almost no spikes, so the following day a test was done using only that alignment with excellent results; all camera orientations are now done in that position, as shown on the April 26 raw image. It seems that some of the internally created artifacts can be reduced to very low levels by choosing the correct orientation for the bright crescent of Venus.

'Further stray light reduction was also helped by placing several baffles comprised of black rubber washers of the correct diameter at each filter, and a fibre washer at the top of the camera extension tube, so only the f/4 cone is visible to the sensor… The clear glass protective window in the camera was also removed to minimise the number of sources of reflections and scattered light. The Barlow was removed as well and the system operated at its native focal length of 2000mm, i.e., the camera is at prime focus, further reducing scattered light. The final results are very good, with many features clearly visible in the more recent images.'

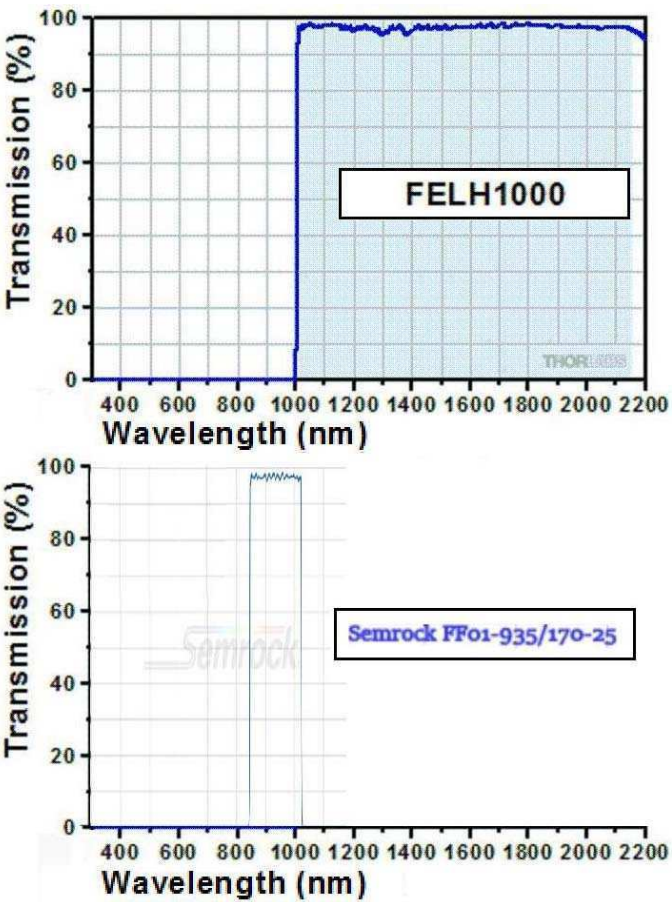


Figure 4. Transmission curves of the two filters used by Miles & Wesley (to scale). When combined they form a 1000–1020nm narrowband filter centred upon the peak thermal emission from the surface of Venus.

Observational results and their interpretation

The authors drew attention to a particularly bright spot near the equator and close to the boundary with the dayside of the planet. Animated images clearly showed that this shared in the slow rotation of the other IRTE surface features, and the collage in Figure 6 clearly shows this also. Javier Peralta (of the *Akatsuki* mission[4]) made a comparison of their work with altimetric data, and a part of the resulting chart is shown in Figure 7. As explained already, higher altitude surface features (green/yellow in the elevation map) show up dark in the IRTE images.

I discussed these results by email with Prof Fred Taylor and Dr Colin Wilson of Oxford University, and they agreed with me that the most exciting possibility would be that the bright spot was an actual volcanic eruption. This would be a 'first' for our Australian colleagues, and whatever it may turn out to be, the high quality of their work is undeniable. Colin Wilson kindly made the following comments, which I quote with his permission:

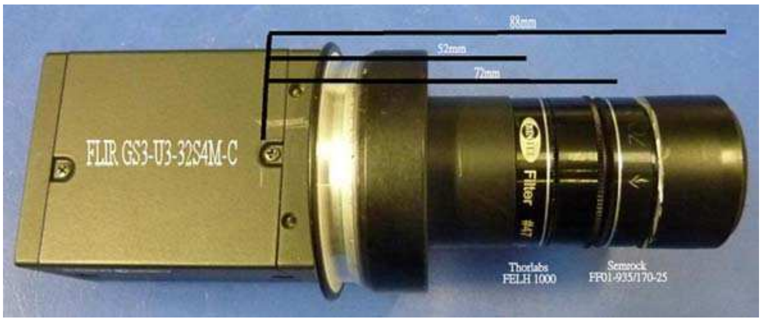


Figure 5. The two filters combined with a FLIR (formerly Point Grey Research) Grasshopper3 GS3-U3-32S4M (mono) camera.

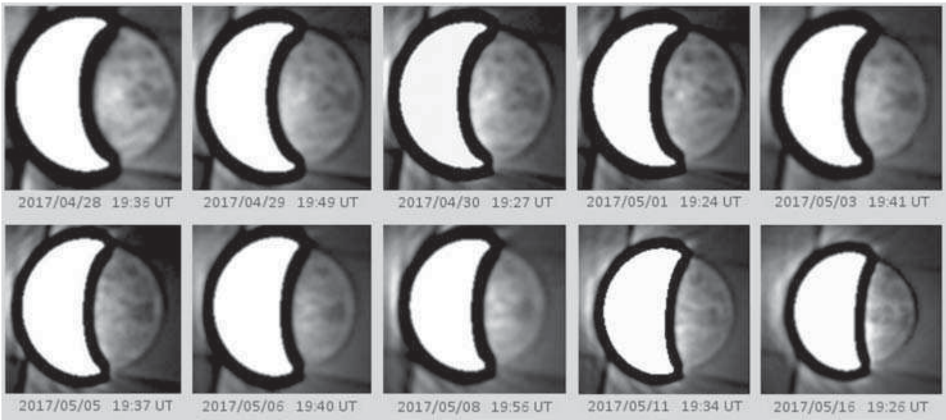


Figure 6. A selection of images taken on 2017 April 28–May 16 with the telescope of Figure 3 and camera and filter combination of Figures 4 and 5. The sunlit crescent (calculated phase rising from 0.25 to 0.39) is heavily overexposed, and a specific bright feature is visible in the first four frames. Other such features may also be present. North is uppermost. *P. Miles & A. Wesley.*

‘This is indeed an exciting observation… there are ample reasons to expect active volcanism to this day on Venus. Venus Express*’s Venus Monitoring Camera (VMC) imaged Venus at the same 1 micron band used by Anthony Wesley & Phil Miles – it did find one example of apparent changes in surface temperature, located on the side of a volcanic vent…’ (See the ESA press release summarising this and other evidence.[5])*

‘It would be fair to say that this observation from Venus Express *was not universally accepted as being proof of active volcanism. The discovery paper was only able to find one location on Venus where these temperature anomalies were occurring; furthermore, imaging at a single wavelength means that no correction can be made for spatial variations in cloud cover (remember that the surface is being imaged through a cloud deck which is typically >20 km thick; we know that it is variable, and that this will affect imaging of the surface).*

‘As to results from Akatsuki*, you can see a good selection of first results in this presentation made in December 2016.[6] The IR1 camera images use the same 1 micron band as the recent observations by Miles & Wesley… The IR2 camera is slightly longer wavelengths (1.7 and 2.3 μm), which reveal lower cloud patterns… some of these images are shown in the presentation linked above. The IR1 and IR2 cameras should be ideal at revealing volcanic activity both at the surface and in the clouds above; unfortunately, both have been turned off since 2017 March, I understand, due to some technical problems,[7] which is a pity!*

‘As to the new observation: the overlay with Venus topography prepared for Miles & Wesley by Javier Peralta shows very convincingly that they are seeing changes in emission associated with surface topography, with higher terrain being colder as expected. This in itself is a tremendous achievement – the image quality is some of the best I’ve ever seen. However, I’m sceptical that the bright spot they’ve seen represents a hot lava flow.’

The feature is extraordinarily bright. Measurement shows that it was no larger than 700km in diameter: not being fully resolved, it could be considerably smaller.

If this was a 700km flow it would represent, writes Wilson, *‘an event so large that it occurs on Earth only once a millennium or so. No events this large were detected during the eight-year* Venus Express *mission, nor have any been reported yet from the Japanese* Akatsuki *orbiter. So what other explanations could there be for the bright spot? One explanation is cloud variability: data from* Venus Express *show us that cloud variability causes brightness variations typically of order ±10% at 1μm wavelength; a 20–30% variation is therefore 2–3 times the standard deviation. This combined with the effects of imperfect removal of stray light artifacts, seems to be the most likely explanation of the bright spot in the images.*

‘If the bright spot appears to be fixed in geographic longitude, then that could either suggest topographic influence on cloud features – something which has been suggested recently – or even the influence of volcanic plumes on cloud features. Note that this explanation is heavily informed by a recent paper by Nils Mueller et al. *describing their (unsuccessful) search for lava flows using the VIRTIS imaging spectrometer on* Venus Express[8]*… Further such observations will help us to understand cloud variability better, and might even one day provide evidence of active volcanism.’*

The location of the bright spot shown in Figure 7 is in a lowland area just south of Eastern *Eistla Regiones* (which is centred upon 16°N, 40°E). Members may recall the remarkable work of Daniele Gasparri in 2009 from his article in *Sky & Telescope*[9] in which he subtracted pairs of his nightside IRTE images to secure direct evidence of large-scale lower cloud of the type referred to by Colin Wilson above.

These indirectly inferred clouds were large and ill-defined: could they influence the results secured by Miles & Wesley? It is possible, though the bright spot is in a lowland, not highland, area. A second brighter spot a little way following the first appears to further brighten as it approaches the CM on May 6 & 8. I am grateful to Dr J. H. Rogers for the following remark: ‘I wonder if these spots are intrinsically warmer places on the planet’s surface, which appear brighter when they are in this position close to the centre of the disk because of the reduced path length through clouds there, especially if the clouds are partially broken.’[10]

Whatever the final interpretation, the research of Miles & Wesley should provide considerable impetus for further ground-based observations.

Conclusion

The research described here offers new scope and also new challenges for ground-based observers. The technique is potentially capable of detecting any very large area of enhanced surface temperature. In bringing it to the attention of members, the Director would like to encourage others to attempt to replicate the results at the next inferior conjunction. In particular, we urgently need to know whether the bright features imaged in 2017 were of a temporary or a permanent nature.

Address: 16 Main Street, Upper Benefield, Peterborough PE8 5AN, UK. [richardmckim@btinternet.com]

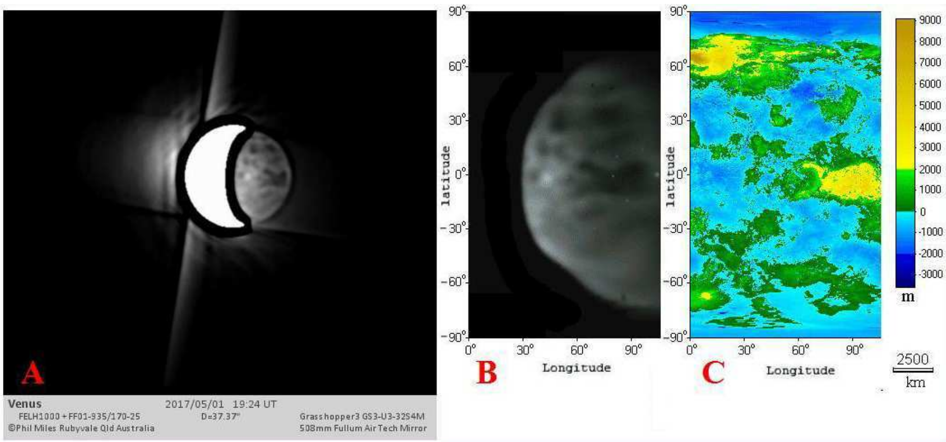


Figure 7. A comparison of the bright feature imaged on 2017 May 1 with *Magellan* altimetry: it just follows the central meridian and is located within *Eistla Regiones*. At 19:24UT the CM longitude was 37.1° (*WinJUPOS*). North is uppermost.

Jupiter's South Equatorial Belt cycle in 2009–2011: II. The SEB Revival

John H. Rogers

A report of the Jupiter Section (Director: John H. Rogers), using data from the JUPOS team

A Revival of Jupiter's 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, seven plumes appeared at the source and at least six 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 western 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.

Introduction

The SEB Revival is the grandest meteorological phenomenon to be seen on Jupiter,[1] but only occurs at irregular intervals. Since the modern era of high-resolution imaging began, observers and scientists have looked forward to an opportunity to investigate one in detail. The Revival that began in 2010 has been better observed than any before it.

As described in our previous paper,[2] sometimes the usual large-scale convective activity in the SEB ceases, the disturbances on the SEBs jet disappear, and the belt begins to brighten. This is an SEB Fade, and is inevitably terminated by a SEB Revival. The Revival always begins at a single longitude, which becomes a persistent source region, and three 'branches' stream out from it in the central, southern, and northern parts of the SEB.[1,3] The southern and northern branches follow the rapid jets which bound the SEB: the SEBs retrograde jet (westwards) *[see Footnote 1]*, and the SEBn prograde jet (eastwards). The typical pattern has been described from the 14 SEB Revivals from 1919 to 1990,[1,3] and the following introduction is largely quoted from Rogers (1995),[1] ch. 10.3.

The Revival always begins when a very dark spot or streak appears across the latitudes of the SEB. Often it is associated with a brilliant white spot on its *p.* side; sometimes the white spot has been recorded a few days before the streak, in the southern half of the SEB (13–17°S). It is possible that the white spot always appears first, but visual observers were less sensitive to bright than to dark features. There is usually no visible precursor at the source longitude, but two Revivals appeared adjacent to small dark slow-moving spots on SEB(S).

From the source point, intense disturbance and/or dark belt

Footnote 1: The SEBs jet

The SEBs jet, with a peak at ~19.5°S, is the fastest retrograde jet on the planet. The peak speed is up to DL2~ +133°/month according to spacecraft and ~+120°/month for easily visible spots. These dark jetstream spots were initially recorded by visual observers during SEB Revivals, and then during episodes of long-running normal activity. Images from *Voyager* and *Cassini* during normal activity showed that they were anticyclonic vortices.[1]

The zonal wind profiles (ZWPs) for the SEBs jet from four spacecraft were compared by Rogers *et al.* (2016).[20] The *Cassini* ZWP[30] generally appears to be the most reliable; it had a peak speed of DL2= +128°/month (u= –62.0 m/s) at 19.7°S. ZWPs from *Voyager* and *Hubble* gave lower peak values that may not represent the true peak wind speed. However, even the *Cassini* value may have been influenced by small spots which did not quite attain peak wind speed, and the maximum speed from *New Horizons* (DL2 = +133.4°/month, u= –64.5 m/s, at 19.5°S)[31] despite being the fastest and derived from fewest data points, may in fact be the best estimate of the actual jet peak.[6] (An independent analysis of the same images by Grischa Hahn confirmed a speed of ~+130°/mth in some sectors.[32]) Our ground-based feature-tracking from 2005 to 2015 supports a peak speed of DL2 = +133 and possibly a broader underlying jet, as shown in Figure 7 of Rogers *et al.* (2016)[20] and Figure 10 herein. It is possible that the underlying jet is invariant, but the measured ZWP appears truncated to various degrees, due to crowding by vortices or masking by slower cloud layers.

McKim: IRTE emission from Venus: Continued from previous page

References

1 R. J. McKim, *J. Brit. Astron. Assoc.,* **114**(5), 241–242 (2004)
2 R. J. McKim *et al.*, *ibid.*, **117**(2), 65–76 (2007) and **118**(3), 131–114 (2008)
3 **http://www.astrogem.com.au/venus/**
4 *Akatsuki* (Japan Aerospace Exploration Agency (or JAXA)) has a website at: **http://global.jaxa.jp/projects/sat/planet_c/index.html**
5 **http://www.esa.int/Our_Activities/Space_Science/Venus_Express/Hot_lava_flows_discovered_on_Venus**
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10 This comment was made by J. H. Rogers in refereeing this paper, and is quoted with his permission.

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