Ordinary Meeting, 2007 March 28
held at New Hunts House, Guys Hospital, London Bridge, London SE1

Richard Miles, President

Ron Johnson, Hazel Collett and Nick James, Secretaries

The President opened the fifth meeting of the 117th Session and invited Mrs Hazel Collett to read the minutes of the previous meeting, which were approved by the audience and duly signed. He announced that 33 new members were proposed for election; those 30 who had been proposed at the previous meeting were approved and declared elected. Mr Nick James, Papers Secretary, announced that six papers had been approved for *Journal* publication:

[2 by John Rogers, 2 by Jeremy Shears, 1 by Ron Livesey, 1 by Richard Baum]

The President announced that the next Ordinary Meeting would be an *Out of London* meeting, to be held in Birmingham on April 21 in association with the Society for the History of Astronomy. Before then, the Association's 41st Winchester Weekend would be taking place over the weekend of March 30 – April 1. Advance notice was given of the annual meetings of the Variable Star Section, to be held in Edinburgh on May 5, and of the Instruments and Imaging Section, to be held in Northampton on May 12.

Later in the month, the BBC's *Sky at Night* series would celebrate its fiftieth anniversary; its first broadcast had been on 1957 April 24. All but one of the monthly programmes over those 50 years had been presented by Sir Patrick Moore – now the longest-serving presenter of any television programme in the world. To congratulate him, the Association would be presenting him with a card on the day of the anniversary; the presentation would be broadcast on the *Sky at Night* on May 6. Members were invited to leave short personal messages for Sir Patrick on the Association's website; 217 messages had already been received.

The President then introduced the evening's first speaker, Prof Fred Taylor, Edmond Halley Professor of Physics in the Atmospheric, Oceanic and Planetary Physics Group at Oxford University – a group which he had formerly headed for several years.

The *Venus Express* Mission

Venus Express, Prof Taylor explained, was the first spacecraft to be sent to Venus by the European Space Agency (ESA). It had started making scientific observations in autumn 2006, and would continue to operate for several years to come. Before describing its work, he set the scene with a brief historical look at our understanding of Venus.

Venus was, of course, a striking naked-eye sight, second only to the Sun and Moon in brightness. Several factors contributed to make it so bright. It was close to the Earth – its orbital radius was 0.7 AU, which in comparison to 1.5 AU for Mars meant that it was nearly always the closest of the planets. It was large – having a radius of 0.95 times that of the Earth (R_E), it was the second largest terrestrial planet in the Solar System after the Earth, and much larger than either Mars (0.53 R_E) or Mercury (0.38 R_E). Also, it had a high reflectivity – it was enshrouded in high-albedo clouds and as a result, its overall albedo, 0.65, was much higher than those of the other planets; the albedo of the Earth, by contrast, was a mere 0.37.

Venus' nature had long been the subject of intense speculation, among both astronomers and the wider public. This interest had been fuelled in part by its conspicuous appearance, but also by the opacity and permanence of the clouds in its atmosphere: before the space age, hard facts about the surface beneath had been few and far between. Popular astronomy books from the 1950s had typically depicted steamy tropical forests, an abundance of water to account for the thick clouds above, and a climate somewhat warmer than the Earth's. Though this picture was now known to be far from the truth, it had not been unreasonable given the information available at the time.

By a simple calculation, using the albedo of Venus and its distance from the Sun, it was possible to estimate how much solar radiation it absorbed. Rather surprisingly, one found that it absorbed less than the Earth; its reflectivity was so high that it more than offset for Venus' being closer to the Sun. This had led some astronomers in the 1950s to argue that its climate might actually be cooler than the Earth's.

The first indication that these ideas were awry had come shortly before the space age: early radio astronomers had detected intense microwave emission from Venus and had suggested that its most likely source was high-temperature thermal emission from the planet's surface. At the time, however, these arguments had been widely ignored in favour of alternative suggestions that the microwave emission might arise from aurorae or lightening.

In December 1962, NASA's *Mariner 2* had flown past Venus – the first spacecraft to have visited it or, indeed, any of the planets. On board had been a microwave radiometer, which had determined conclusively that Venus' microwave emission emanated from its surface and had suggested a surface temperature of around 1000 K. This had come as a great surprise; there had been no plausible theory at the time to explain how such a high temperature could be maintained, and consequently many had continued to look for ways to deny the result.

Conclusive evidence that these high temperatures were real had come in 1970 with the first landing of a probe – *Venera 7* – onto the surface; this had been the first time that data had been returned from the surface of any other planet. Following *Venera 7* there had been a flurry of seven further Soviet landings, from *Venera 8*, in 1972, through to *Venera 14*, in 1982. These had measured a consistent surface temperature of around 730 K (450°C) – slightly cooler than earlier predictions, but still hot enough to glow visibly red/brown hot, and to melt tin or lead. Another surprise had been the incredibly high pressure measured on the surface – 92 times terrestrial. The atmosphere had been found to be composed mostly of carbon dioxide (97%), with only a trace of water vapour (0.002%). The images returned had shown blasted, desolate volcanic planes, with none of the trees which might have been expected 15 years earlier.

Around this time, the Greenhouse Effect had been realised to be extreme in Venus' thick CO_2-rich atmosphere – an idea forwarded principally by Carl Sagan, then a student. At last, a theoretical explanation for Venus' high surface temperature had been formed. The speaker argued that forming a better understanding of Venus' climate had become an urgent matter; the calculations used to understand the Greenhouse Effect in its atmosphere were essentially the same as those being used to make predictions of climate change on our own planet. In due course he would describe some surprising meteorology seen in Venus' atmosphere, which models could not yet reproduce. Given the similarities between Venus and the Earth, one had to conclude that our understanding of the climates of terrestrial planets was actually very patchy.

Moreover, while the Greenhouse Effect might appear to have tied up the question of why Venus was so hot, it had actually just moved it to a deeper level. How had Venus' atmosphere come to be so thick and CO_2-rich in the first place? Why was it so different from the Earth's? These questions could not be answered satisfactorily at present.

Based upon the images and measurements returned by the *Venera* missions, a modern cartoon of Venus would show a planet strewn with active volcanos, spewing large quantities of CO_2 and sulphur compounds into its atmosphere. An observer on the ground would see a lemon yellow sky, coloured by the abundance of sulphur compounds – mostly sulphuric acid – in the atmosphere. There appeared to be no lightening, though this was still subject to controversy. Perhaps surprisingly, *Venera* images indicated that the cloud cover would appear patchy to a surface observer; the Sun appeared to shine through in places. This would not be expected from the all-enveloping visual appearance of the clouds as seen from above.

Prof Taylor explained that the leading theory of Venus' evolution was that it and the Earth had started out as similar planets four billion years ago. Back then, Venus, like the Earth, had had extensive water oceans. The Earth, like Venus, had had a thick CO_2-rich atmosphere. It was thought that subsequently, most of the CO_2 in the Earth's atmosphere had dissolved into its oceans and there undergone chemical reactions to form carbonate rocks. On Venus, the oceans had boiled away more rapidly, because of its being closer to the Sun. Once in the atmosphere, the H_2O molecules had been broken apart by solar radiation, leaving H^+ and O^+ ions. These were light enough to rise through the atmosphere and escape into space. The apparent lack of any magnetic field around Venus would have accelerated this process: while the Earth's magnetic field deflected most solar wind particles, stopping them from impinging upon its atmosphere, molecules such as H_2O in Venus' atmosphere would be much more exposed to ionising solar wind particles.

Credence was added to this theory by estimates of the amount of carbon locked up in rocks on the Earth's surface. Working backwards, supposing that this had once all been in the form of gaseous CO_2, the Earth's atmosphere would then have had a similar thickness to that seen on Venus today.

The last satellite to have studied Venus' atmosphere prior to *Venus Express* had been *Pioneer Venus* (1979) – co-incidentally, the first part-UK-built satellite to have visited any other planet. It had carried an infrared radiometer, which had mapped the temperature of the cloud tops. Most notably, it had recorded a curious feature around the north pole: two hot spots rotating around the pole, separated by 3,000 km, now termed the *polar dipole*. Models of the circulation of Venus' atmosphere predicted it to have a *Hadley Cell* similar to that seen at equatorial latitudes on the Earth – on our planet, air rose at the equator, moved away from the equator at high altitude, sank at latitudes of around ±30°, and flowed back towards the equator at low altitude. The principal difference on Venus was that the Hadley Cell was expected to reach all the way from the equator to the poles, dominating the dynamics of the entire atmosphere, not just the equatorial latitudes. This model would predict a single hot spot to be seen centred on each pole, where air was descending, in contrast to the two spots seen around the north pole by *Pioneer Venus*.

Until the recent work of *Venus Express*, it had been impossible to say how Venus' south pole behaved; it had not been observed by *Pioneer Venus* and the low obliquity of Venus' rotation axis to the ecliptic meant that its polar regions were unobservable from the Earth. It was now known from early *Venus Express* results that the south pole also showed a polar dipole.

Desire to study the polar dipole had been one of the central pillars of the science case for *Venus Express*, and explained the choice of its orbit: a highly eccentric 24-hour polar orbit, which passed low over the north pole and flew high over the south pole, giving a good view of both.

The speaker turned to discuss *Venus Express* in more detail. He explained that it was ESA's first mission to Venus, and was so-named because it was the successor mission to *Mars Express*; it had in fact used many spare parts from its forerunner. It had been built in the UK by *Astrium* in Stevenage, had then been shipped to Toulouse for testing, and then onto Kazakstan for launch aboard a *Soyuz* rocket on 2005 November 9. Because of Venus' proximity, the flight time had been short: orbital insertion had taken place on 2006 April 11. Several months of engineering checks had followed, and the first routine scientific data-taking had begun in autumn 2006.

To date, no results from *Venus Express* had been published; the first would appear in a special issue of *Nature* shortly.[1] However, the speaker went on to offer an initial preview of its early results.

First, an imaging spectrometer, *VERTIS*, was mapping Venus' near-infrared emission. Although Venus' atmosphere was opaque to visible light, the speaker explained that there were 7-8 narrow wavelength windows in the near-infrared in which none of its atmospheric constituents were absorbent. In these windows, the surface could be seen quite clearly. The maps produced by *VERTIS* essentially traced the temperature of Venus' surface, which in turn broadly followed its topology: mountains appeared cool and valleys warm, for the same reason as on Earth. For comparison, radar topology maps from NASA's *Magellan* (1989-1994) probe had been converted into predicted temperature maps, using a simple model to relate altitude to temperature.

The correspondence between the two maps was good, providing compelling evidence that *VERTIS* was indeed predominantly mapping surface topology. However, regions where the two maps deviated were of especial interest. Currently, the *VERTIS* images were being searched for 'hot spots' which were absent from the *Magellan* maps; these might indicate the presence of a recent volcanic eruption and associated lava flows. Although *Magellan* had identified many lava flows by their characteristic texture, none of these could be dated, and so it was unclear whether Venus' volcanism was historic or ongoing. If a lava flow could be shown to be hot, then that would suggest it to be fresh. Several candidate hot spots had already been identified, but none had yet been confirmed.

Turning to *Venus Express*' other instruments, Prof Taylor described experiments which were mapping the three-dimensional distribution of H^+ and O^+ ions in Venus' atmosphere. Such maps would be used to test the theory that water was being lost by the dissociation of H_2O molecules. As yet, however, it was too early to report any results from this work.

A key objective of the mission had been to understand Venus' climate: how its atmosphere behaved, and why there was so much of it. Amateur planetary imagers would be familiar with the observation that while Venus' disk was featureless in optical light, cloud markings became apparent when an ultraviolet filter was used. *Venus Express* was tracing the motions of clouds in a similar way, using a UV camera. Early images had revealed at least three distinct vertical layers of cloud moving past one another at different speeds and with different albedos. Sometimes these showed turbulent wave-like motions, while at other times they appeared to flow more smoothly. These experiments were still at an early stage, and so no analysis could be presented as yet.

Returning to the work of *VERTIS*, the speaker described how near-infrared images of the night side of Venus, taken at 1.7 μm, appeared to show yet another cloud layer, with quite different morphology again. Whereas UV images recorded solar radiation reflected off high-altitude clouds, these images showed thermal emission from the surface as scattered from low-altitude clouds. As a result, they traced cloud structures at much lower altitudes. These images had sparked a discussion about the origin of the Ashen Light – a glow on the night side of Venus' disk, first recorded in 1643, and which most observers claimed to be able to see on occasion.[2] Calculations of the opacities of the clouds structures seen by *Venus Express* suggested that they were low enough that the thermal red-hot glow of the surface might occasionally penetrate through them, becoming visible as an optical glow.[3]

In these 1.7-μm images there was a sharp dichotomy between the textures of the clouds seen at low and high latitudes. In equatorial regions, the clouds appeared turbulent and wavy, but in the polar regions much smoother flow was seen. The boundary between these two regimes was remarkably sharp. Tracking the motion of individual features allowed wind speeds to be estimated; these also showed a dichotomy. Fast wind speeds were seen at equatorial latitudes, bounded by a sharp transition to much calmer conditions around the poles. The fastest wind speeds yet recorded by *Venus Express* had been around 120 m/s (290 mph), for the high-altitude clouds above the equatorial regions.

Experiments mapping the distribution of the minor constituents in Venus' atmosphere from their line emission were proving to be especially rich sources of information on its chemistry. As an example, it was thought that carbon monoxide (CO) was produced predominantly in its upper atmosphere by the dissociation of CO_2 by solar radiation. In this model, the observed density of CO would be expected to be greatest in those regions where the atmosphere was descending. In a simple Hadley Cell circulation model, the atmosphere would rise around the equator and sink at the poles, though, as had already been discussed, *Pioneer Venus*' infrared radiometers had detected a curious dipole feature around the north pole which did not fit a simple Hadley Cell model. CO density profiles produced by *Venus Express* showed a peak at latitudes of around ±70°, roughly matching the latitudes of the two eyes of the polar dipole. They appeared, therefore, to be in agreement with the radiometer maps.

On the other hand, maps of the oxygen airglow line (1.27 μm) showed the distribution of molecular oxygen (O_2). The principal source of O_2 was the recombination of oxygen atoms shed from CO_2 in the production of CO, and so it was expected, like CO, to be spread fairly uniformly across the planet. In fact, it was found to form clumpy cloud-like features, which were quite unexpected. Moreover, its concentration did not peak at latitudes of around ±70°, where the CO concentration peaked, but rather at the pole itself. The morphology of the O_2 clouds at the pole seemed strongly to suggest a downflow, though this idea would be placed on firmer ground in due course, once movies were made and the movements of individual clouds could be traced. The speaker speculated that CO and O_2 might sit at different altitudes in the atmosphere, and that these might descend in different places. But without any clear understanding of the polar dipole at present, it was impossible to be sure.

Prof Taylor closed with a discussion of the polar dipole itself. From its highly elliptical orbit, *Venus Express* had been able to take low-resolution images of Venus' south pole, confirming for the first time that it had a dipole similar to that seen by *Pioneer Venus* at the north pole. It had also been able to take high-resolution images of the north pole as it swooped low over it. Both dipoles had been seen to change size and shape whilst rotating around the pole, but they always retained their essential structure. Close up images of the north pole showed that the two hot spots were circulation features, but they were not independent: a thin filamentary feature connected them.

Prior to *Venus Express*, the leading theory had been that the two hot spots formed a double vortex, but this filamentary feature ruled out that interpretation. The speaker explained that it had become something of a personal challenge for him to explain this weather system, and so he had put a lot of thought into it over the past six months. Cautioning that the idea was very speculative, he noted that the morphology of the dipole reminded him of a *Lorenz Strange Attractor*. The latter geometric shape had been discovered by meteorologist Edward Lorenz in the 1960s, in an early attempt to use a computer to model atmospheric dynamics. The speaker wondered whether this superficial similarity in appearance might indicate a deeper connection. He was working on the hypothesis that the dynamics of Venus' polar dipoles were described by the same equations which Edward Lorenz had been working on when he had discovered the Strange Attractor. It was not yet clear how the equations could relate to Venus' poles, but he was hopeful that an explanation might be found.

Looking ahead, the speaker explained that *Venus Express*' original mission had been funded for 500 days, until 2007 October. Following the success of its first few months of operation, ESA had recently announced funding for a further 500 days of operation, lasting until 2009 June. Members interested in learning more were referred to two special issues of the journal *Planetary and Space Science*[4], which described the instrumentation in detail, including several experiments which the speaker had not had time to mention. The first results of the mission would be published in a special issue of *Nature* shortly.[1]

Following the applause, Mr Roger Dymock asked why Venus had no magnetic field. Prof Taylor replied that this was a mystery. It was thought to have an iron core similar to the Earth's, and this would be capable of supporting a magnetic field. One research direction was to ask whether the slow rotation rate of Venus was a factor. Another possibility was that Venus' lack of magnetic field was a transitory phenomenon; it was believed that the Earth's magnetic field changed direction from time to time, and would be absent for several thousand years whilst such a transition was taking place. However, if Venus' lack of magnetic field was a purely transitory phenomenon, then a problem remained as to how to explain the lack of water on Venus.

The President then introduced the evening's second speaker, the Director of the Mercury and Venus Section, Dr Richard McKim.

BAA Studies of the Venusian Atmosphere

Dr McKim opened by remarking that Venus was a very easy planet to see, but a tricky one to observe. Visual telescopic images revealed little more than its phase. To begin, he looked back in history to the work of Charles Boyer, by day a magistrate in French equatorial Africa and by night an amateur astronomer, who in 1957 had observed that distinct features became apparent on Venus' disk when a violet filter was used. He had gone on to observe that these repeated with a four-day period, and so had concluded that Venus had a four-day rotation period.

It was now known that violet light did not show the surface of Venus, but rather high-altitude clouds, and so this rotation period was now ascribed to the atmosphere rather than to the planet itself. Boyer had subsequently observed its rotation speed to be surprisingly constant, refining it to 3.99525 days. Two features were especially clear, one Y-shaped and the other Ψ-shaped, separated by around 90°. Both were orientated with their stems approximately parallel to the equator.

Within the past few years, it had become possible for amateurs to take high-resolution ultraviolet images for the first time. In these, the disk markings first noted by Boyer were especially clear. This advance in technology had led the speaker to suggest that the BAA should now make new measurements to refine Boyer's estimate of their rotation speed. He had begun by taking all of the UV images which had been submitted to the Mercury and Venus Section in 2004, and using the fork of the Y-shaped feature as a reference point with which to calculate its rotation. He had derived a rotation period of 3.995 days, which showed their rotation speed today to match with remarkable precision that measured half a century earlier.

Dr McKim reported that he was also now receiving near-infrared images from amateurs. Whilst these were often featureless, banding and other markings occasionally showed up. Analysing images received in 2004, he had estimated their rotation period to be 5.0 days; he suggested that the cloud structures being seen here were at low altitudes, as described by Prof Taylor earlier.

On six occasions in 2004 May, Christophe Pellier had imaged the 1-μm near-infrared emission of the night-side of Venus. These showed faint albedo markings which appeared stable over several days and seemed therefore to correspond to actual surface topology. If real, these ground-breaking observations represented the first amateur observations of the surface of Venus.[5,6]

A more detailed account of the observations described by Dr McKim can be found in his report of the activities of the Mercury and Venus Section in 2004.[6]

Following the applause, Mr Nick James asked why the rotation rate of the upper atmosphere of Venus had been so constant over the past 50 years. Dr McKim invited Prof Taylor, in the audience, to respond. Prof Taylor agreed that this was mysterious, especially given that the rotation rate seen was around 50 times faster than that of the surface below. Some recent theoretical studies had tried to reproduce this behaviour; they had shown that the gas heating which resulted from the absorption of solar radiation by clouds in the upper atmosphere could actually drive fast winds of precisely the kind seen. However, an explanation of why these winds were so constant was less forthcoming. Prof Taylor offered the thought that Venus had no seasons – it was in a near-circular orbit with little axial inclination – and so perhaps there were no seasonal variations to drive large-scale changes to wind patterns?

The President then introduced the evening's final speaker, Dr Stewart Moore, Director of the Deep Sky Section, who would be presenting this month's Sky Notes.

The March Sky

Dr Moore explained that he would begin his Sky Notes by talking about the Sun, and would then work outwards through the Solar System, concluding with the Deep Sky. He explained that the solar disk was quite featureless at the moment; its 11-year sunspot cycle was nearing its minimum. Solar Cycle 23 would shortly give way to Solar Cycle 24, which was expected to peak in around five years time. The coming cycle was forecast to be unusually active, with the possibility of significant disruption to communications satellites. On March 19 there had been a partial solar eclipse visible from East Asia and northern Alaska, though to the speaker's knowledge, no BAA members had travelled to observe it.

Mercury was poorly placed at present, despite its current evening apparition having recently passed greatest westerly elongation on March 22. It appeared highest in the sky at those times of year when the ecliptic was inclined as steeply as possible to the horizon at sunrise or sunset; presently, however, the ecliptic skirted close to the horizon. The next favourable opportunities to observe Mercury from northerly latitudes would be its morning apparitions in June and August.

Venus was much better placed; it was a magnificent mag –4 object in the evening sky. It was presently moving through Taurus and the speaker noted that it would pass within 3° of M45 on April 12; these might make an attractive pairing if viewed through binoculars. Venus would reach greatest elongation on June 9. The speaker warned members of the extreme danger of pointing telescopes close to the Sun whilst it was above the horizon; extreme care was necessary when observing either Mercury or Venus.

Mars was now rising just before dawn, and would steadily improve through the year, reaching opposition on December 24. Jupiter was disappointing at the moment; it rose at around midnight, but remained low in the sky throughout the night. It would reach opposition on June 5, but at that time of year the ecliptic was quite flat along the UK horizon at midnight, and so even then, Jupiter would have a typical altitude of only 17°; for comparison, its peak altitude in the UK sky during its 2002 apparition had been 44°.

Saturn, by contrast, was high in the sky, having recently passed opposition on February 10. Among recent highlights, it had been occulted by the Moon on March 2; a number of members had taken images, and the speaker praised especially those by Damian Peach. A second occultation would take place later in the early morning on March 29, albeit shortly after Saturn had set in the UK sky. Observers in these parts would, however, be able to see Saturn and the Moon drawing very close at around 3-4 am UT.

Another forthcoming occultation of interest would be that of mag 1.35 star Regulus on March 30; Regulus would disappear behind the Moon's dark limb at 03h30 UT and reappear from its bright limb at 04h19 UT. This would take place at low altitude – barely above 10° – but given the brightness of Regulus, it would be visible from even quite light polluted skies, given a good horizon.

Two meteor showers would be active in the coming month: the Virginids, peaking on April 10 with a ZHR of around 5, and the Lyrids, peaking on April 22 with a ZHR of around 10.

Two novae had been discovered within the past month, both by Japanese observers. On March 15, Akihiko Tago had discovered a mag 7.4 nova in Cygnus (V2467 Cyg), and then on March 19, Hideo Nishimura had discovered a mag 10.2 nova in Ophiuchus (V2615). Both of these, however, were low in the UK sky, and would be very tricky observing targets.

In the deep sky, this time of year was best known for the rich array of galaxies accessible in the evening sky: both the Virgo and Coma Galaxy Clusters were well placed. Directing a wide-field instrument at M84 (mag 9.1) and M86 (mag 8.9) – two of the largest galaxies of the Virgo cluster, separated by 17' – a vast number of NGC galaxies were visible within a single 1° field. The speaker also recommended M104 (mag 8.0) – the Sombrero galaxy – an edge-on spiral with dark dust lane, and NGC 4564 (mag 9.6) in Coma – perhaps the best non-Messier galaxy in the sky at this time of year.

To close, the speaker congratulated Mr Ron Arbour upon having recently discovered two supernovae in quick succession: SN 2007av in NGC 3279 on March 20, and SN 2007ax in NGC 2577 on March 22. The latter supernova was Mr Arbour's 18th discovery. The speaker noted that prior to these, Mr Arbour had gone for two years without any supernova discoveries; his last had been 2005au, which he had discovered on 2005 March 19. It was good to see him active once again.

The speaker then handed over to Mr Nick James, who showed a video of the recent total lunar eclipse of March 3. Dr Moore noted that this had been an exceptionally good eclipse: it had taken place at a sociable evening hour, and the sky had been clear across most of the UK throughout. Mr James explained that he would show a series of frames taken using a camera on a tracking mount. He had used a frame interval of two minutes during the partial phases, and one minute during totality. A total of 180 images had been taken. As a result of his tracking mount, the background starfield appeared stationary between frames, meanwhile the Moon moved across the field of view as it moved through the Earth's shadow. He remarked that these images provided a compelling illustration of how large the Earth's shadow was with respect to the Moon itself.

Following the applause, the President adjourned the meeting until April 21.

Dominic Ford

References

[1] Due for publication in autumn 2007 at time of writing.
[2] See, e.g., Baum, R.M., *J. Brit. Astron. Assoc.*, **110**, 325 (2000)
[3] Taylor, F.W., *On the Origin of the Ashen Light of Venus*, in *Yearbook of Astronomy, 2004* (P. Moore, ed.), 217-222, Macmillan (2003)
[4] Taylor, F.W. (ed.), *The Planet Venus and the Venus Express Mission*, in *Planetary and Space Science*, **54**, 13-14, 1247-1496 (2006)
[5] McKim, R.J., *J. Brit. Astron. Assoc.*, **114**, 241 (2004)
[6] McKim, R.J., *ibid.*, **117**, 65 (2007)