Observing Uranus and its satellites, 2006–2016

John Sussenbach

For amateur astronomers the distant planet Uranus is a considerable observing challenge. With its angular size of about 3.6 arcseconds it is not easy to detect details in its atmosphere, and imaging of its faint satellites requires relatively long exposure times. Nevertheless, with the development of new digital cameras with increased sensitivity the planet and its satellites have become interesting objects of study. In this report covering the period 2006–2016, progress in imaging Uranus by the author is demonstrated. In particular this shows that the detection of features in the atmosphere of Uranus has become a promising field for future investigation.

Introduction

Uranus is one of the remote gas giants of our Solar System. The planet was discovered by William Herschel in 1781 using a 7-foot reflector with an aperture of 6.2 inches [157mm]. Observed from the Earth the planet has a very small angular size of about 3.6 arcseconds and is a real challenge for small telescopes. Visually it is a pale tiny greenish-blue disk. Occasionally some bands have been recorded visually by amateurs.

A concise report of the discovery and history of observation of this planet is the classic book *The Planet Uranus* by A. F .O'D Alexander.[1] Uranus is unique in the extreme tilt of its axis of rotation of 97.8°. The planet has more than 25 satellites of which only the five largest can be detected with amateur telescopes (Figure 1). With larger telescopes faint banding has been reported visually.

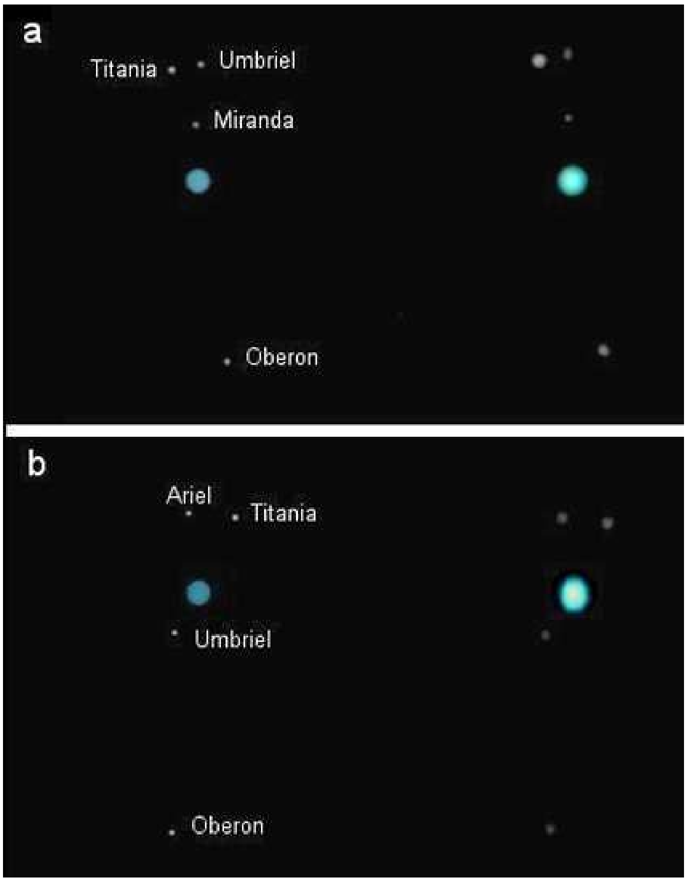

Figure 1. Uranus and satellites. **a)** 2004 July 24, 00:53 UT; **b)** 2004 July 27, 00:37 UT. *Left:* simulations; *right:* images with a C11 [279mm SCT] at prime focus. *All images by J. Sussenbach unless otherwise noted.*

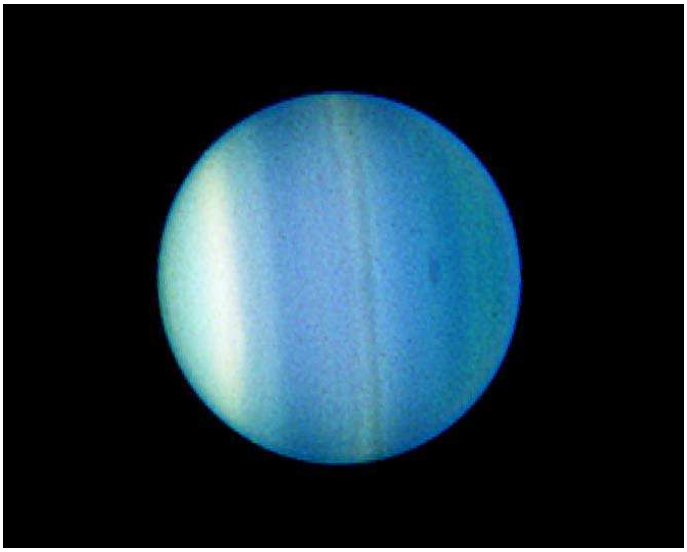

Figure 2. Uranus imaged on 2006 Aug 23 with the Hubble Space Telescope. *NASA, ESA, L. Sromovsky & P. Fry (Univ. of Wisconsin), H. Hammel (Space Science Inst.) & K. Rages (SETI Inst.)*

Atmospheric features on Uranus

In contrast to Jupiter and Saturn, Uranus is rather featureless. NASA's *Voyager 2* spacecraft flew close to the planet in 1986 and revealed some banding and white clouds in the Uranian atmosphere. The Hubble Space Telescope has imaged bands and spots on the distant planet (Figure 2).

This image also illustrates one of the consequences of the peculiar large tilt of Uranus' axis. During its 84-years' revolution around the Sun, in certain phases only the northern hemisphere is illuminated by the Sun and 42 years later the southern hemisphere. The appearance of Uranus in the period 2006–2016 is shown in Figure 3. In this paper all Uranus images are presented for the appropriate date with north at the top. In 2007 the Earth passed the equatorial plane of Uranus (on 2007 February 20, May 3 and August 16, respectively) leading to a view of the planet very similar to the 2006 image.

At the start of this century amateur astronomers in increasing numbers began digital imaging of the planets using webcams and

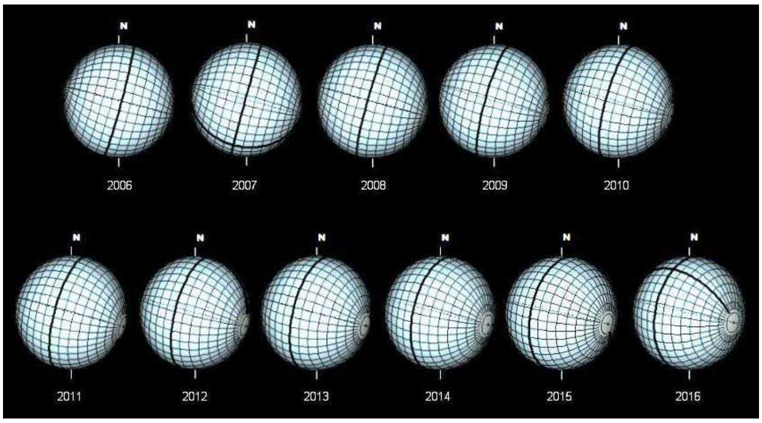

Figure 3. Appearance of Uranus from 2006 July 1 to 2016 July 1. (*WinJUPOS*[2] *simulations*).

other cameras. In the beginning Jupiter, Saturn and Mars were the favourite objects. However in 2006 August & September members of the Dutch Working Group on the Moon and Planets initiated a campaign to image Uranus.[3] The objective was to investigate what amateurs can detect and observe with the help of the latest digital cameras and other technical equipment.

It should be noted that circumstances for observing Uranus from The Netherlands were quite unfavourable during this apparition. In 2006 the altitude of the planet was not more than 30°. Despite these conditions several acceptable images were obtained (see **http://maanenplaneten.nl/documenten/report_uranus_campaign_2006.pdf**). The general conclusion was that with amateur instruments no details could be imaged on the tiny blueish disk of Uranus in RGB or IR (Figures 4 and 5). No distinct spots or other features could be detected in the RGB, R or IR images. Limb darkening was very clear and in some images the southern hemisphere was a bit brighter than the northern.

I imaged Uranus in the years that followed, but since it travelled through the summer ecliptic, conditions for high resolution imaging of the planet were not very favourable. In 2008 I noticed in the images that the northern hemisphere was a bit brighter than the southern, and this difference became more distinct in the years that followed. In 2012 I also noticed faint banding on the southern hemisphere and this became clearer in the following years (Figures 6 & 7).

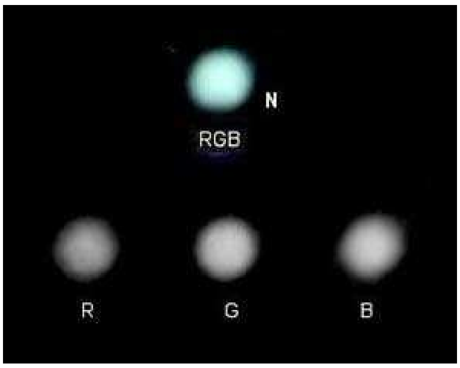

Figure 4. Uranus on 2006 Aug 22. C11, ATK2HS camera with Astronomik RGB filters.

Figure 5. Uranus on 2006 Sept 11. C11, ATK2HS camera with Astronomik RGB filters or Baader IR filter.

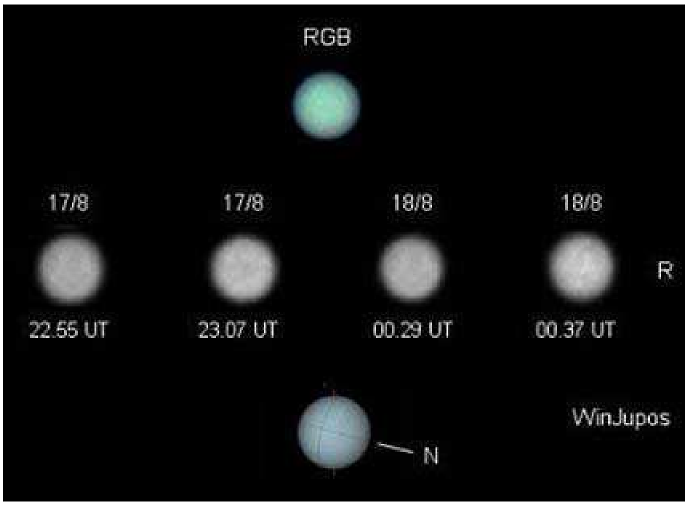

Figure 6. Uranus on 2012 Aug 17 & 18. C11, Flea3 camera and Astronomik RGB filters.

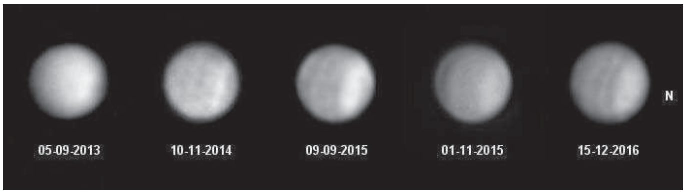

Figure 7. Uranus from 2013 Sept 5 to 2016 Dec 15. C14 [355mm SCT] and different types of cameras. Red long pass (>610nm) or IR filters.

In particular the northern hemisphere is brighter than the southern in 2015 and 2016. In addition a distinct banding pattern is present, with a darkening of the north polar region and two darker bands in the northern temperate and tropical zone. Subsequently, towards the south pole a brighter zone can be distinguished and a relatively dark band in the most southern region (Figure 7).

Separation of the bands is highly dependent on the seeing conditions. It is striking that in the course of the years the dark banding pattern has become more pronounced. This is probably a seasonal effect. The bands are most easily detected when red or infrared filters are used.

In the past, besides banding, no other features have been detected except for some occasional bright spots. Anthony Wesley and others detected a bright spot in 2014.[4] Spots on Uranus are in

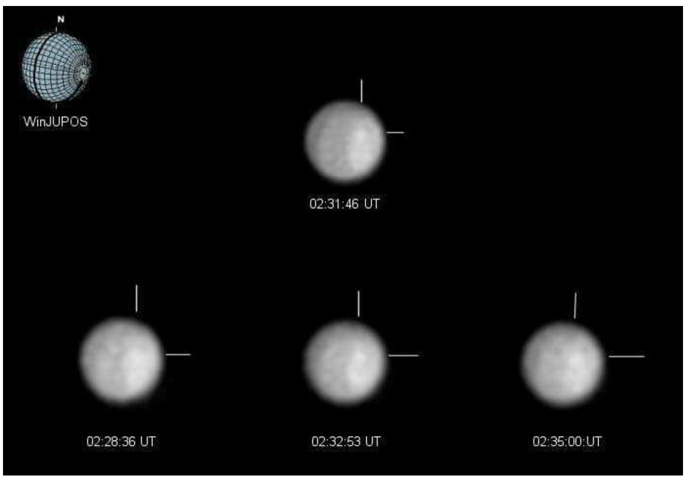

Figure 8. Bright spot on Uranus, 2016 Aug 15. C14, ASI290MM camera & IR filter. At the top the combination of the three lower images. In the left upper corner a *WinJUPOS* simulation.

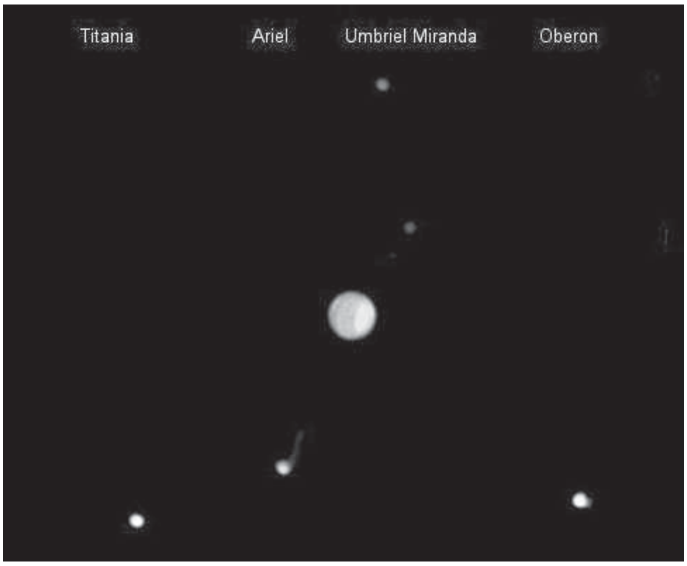

Figure 9. Uranus and satellites, 2015 Sept 9. C14, ASI224MC camera & IR filter.

general short-lived. Interestingly, on 2015 August 15 I noticed a bright spot on the northern hemisphere (Figure 8). Since the images are rather grainy, one should be aware of the possibility of artefacts. However, when the images obtained at 2:28:36 UT, 2:32:53 UT and 2:35:00 UT are compared, in all three images a bright spot is found with the same coordinates (longitude 241.9°, latitude +56.7°). Unfortunately, bad weather conditions did not permit a follow-up of these observations.

Satellites of Uranus

Uranus has five major satellites, Miranda (magnitude +16.3), Ariel (+14.2), Umbriel (+14.8), Titania (+13.9) and Oberon (+14.1). Direct imaging of these satellites leads to overexposure of the Uranus image. For Figure 9 a briefly exposed Uranus image is combined with a longer exposed satellites image.

Miranda is the most difficult satellite to record, because it is sometimes positioned very near to Uranus and consequently disappears in the glare of the planet. In 2015 from Earth we viewed the north pole of Uranus and the orbits of the satellites were seen as ellipses as projected onto the sky. However, in 2007 the Earth passed through the equatorial plane of Uranus and in the period 2006–2008 the satellites moved apparently in a straight line.

In 2007 the satellites occasionally showed mutual occultations. Due to the faintness of the satellites these events were not easy to detect. On 2007 August 13 at 03:04 UT an interesting event took place: the partial occultation of Umbriel by Ariel (Figure 10).

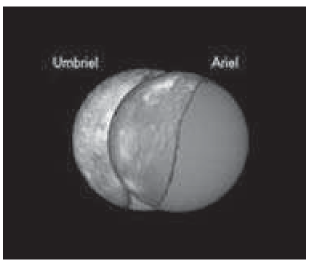

Figure 10. *WinJUPOS* simulation of partial occultation of Umbriel by Ariel, 2007 Aug 13, 03:04 UT.

To record the partial occultation I used the C11 SCT and an ATK 2HS camera. The images of Uranus and its satellites were made at the prime focus of the telescope. Frames were collected with an exposure time of 3 seconds per frame. The first image was made at 02:40 UT and the last at 03:17 UT. A total of 352 frames was obtained. The brightness of the combination of Ariel and Umbriel was compared to that of Titania. Since no photometric equipment was available an alternative procedure was applied.

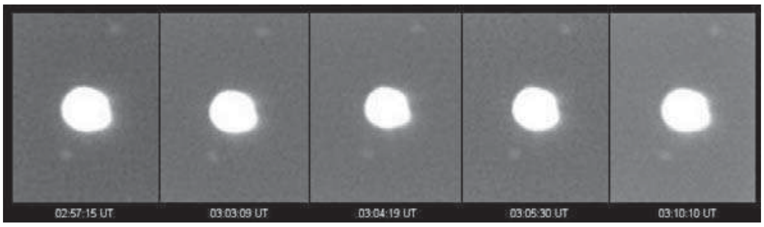

Figure 11. Images of Uranus and satellites Ariel, Umbriel and Titania during the partial occultation of Umbriel by Ariel on 2007 Aug 13. 279mm SCT and ATK2HS camera.

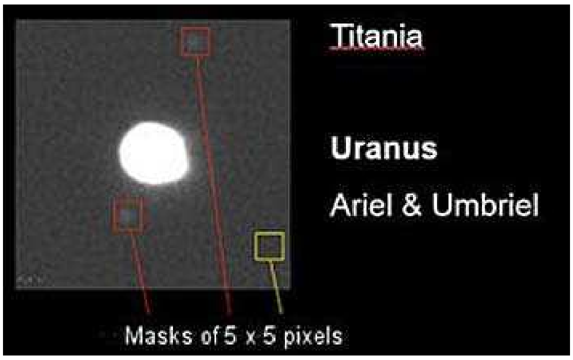

Figure 12. Photometric analysis of the occultation of Umbriel by Ariel using 5×5 pixel masks. The values for Ariel plus Umbriel and for Titania were corrected for background values and the ratio (A+U)/T was calculated.

Frames were grouped in batches of 20 frames and stacked with *Registax 4* followed by a slight sharpening using the wavelet function of *Registax 4*. A selection of images is shown in Figure 11. The brightnesses of the combination of Ariel (A) & Umbriel (U), and of Titania (T), respectively, were measured using the colour sampling tool of Photoshop CS2 with masks of 3×3 and 5×5 pixels (Figure 12). With these masks the images of the satellites are fully captured with a limited amount of background. Before measurement the images were enlarged to 300%. The brightness values of the satellite images (red masks Figure 12) were corrected by subtracting the background values (yellow mask Figure 12). Subsequently the ratio (A+U)/T was calculated. The results of the 3×3 and 5×5 masks were averaged and the final result plotted (Figure 13). As shown in Figure 11 the background values increased in the course of the occultation due to the fact that the occultation took place shortly

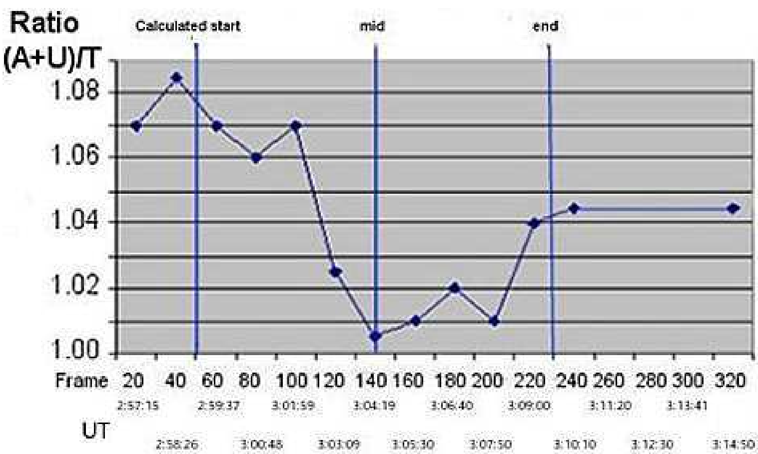

Figure 13. Photometric analysis of the partial occultation of Umbriel by Ariel on 2007 Aug 13 using masks of 3×3 & 5×5 pixels. The theoretical values of the start and finish of the occultation were calculated with *WinJUPOS*.

before sunrise. At 02:57:15 UT the altitude of the Sun was −11.2° and at 03:10:10 UT it was −9.7°.

Figure 13 indicates that indeed a drop in brightness of the combination of Ariel & Umbriel took place relative to the brightness of Titania, close to the times calculated with *WinJUPOS*.

Conclusions

The results presented in this report indicate that with the current generation of digital cameras a new field of imaging has opened up. The remote gas giants Uranus and Neptune are now open for investigation with amateur telescopes. In particular the seasonal changes in the Uranian atmosphere are now within the reach of amateurs. In some recent reports it is shown that even on the tiny disk of Neptune bright spots have been detected.[5,6] Comparison of the occurrence of bright spots on Uranus and Neptune suggests that at least in the current stage of its orbit Neptune shows more atmospheric activity than Uranus.

Unfortunately, it will be another 30 years before the Earth will again pass through the equatorial plane of Uranus and we will be able to study mutual occultations and eclipses of its satellites. But there are other challenges on Uranus. Recently, amateurs have reported the detection of its ring system using the 1.06m telescope of the Pic du Midi Observatory.[7] There are also indications that the rings can be detected with smaller telescopes.[8,9]

It is evident that with the current and future generations of cameras with good sensitivity in the IR region new steps will be made by amateurs in the exploration of the remote gas giants in our Solar System. The development of cameras with increased sensitivity in the methane band (800–1000nm) will be very welcome for this type of study.

Address: Meekrap-oord 3, 3991 VE Houten, The Netherlands. *[john@jsussenbach.nl]*

References

1 Alexander A. F. O'D., *The Planet Uranus*, Faber & Faber, London, 1965
2 *WinJUPOS*: **http://www.grischa-hahn.homepage.t-online.de**
3 Sussenbach J. S., 'Report of Uranus campaign 2006', Working Group Moon and Planets, **http://maanenplaneten.nl/documenten/report_uranus_campaign_2006.pdf** (2006)
4 Carlisle C. M., 'Bright spot in Uranus's atmosphere', **http://www.skyandtelescope.com/astronomy-news/bright-spot-uranus-atmosphere-11252014/** (2014)
5 Hueso R. *et al.*, 'Neptune: long-lived atmospheric features in 2013–2015 from small and large telescopes', *Icarus*, **295**, 89–109 (2017)
6 Sussenbach J. S., Kivits W. & Delcroix M., 'Bright features on Neptune in 2015', *J. Brit. Astron. Assoc.*, **127**(2), 79 (2017)
7 Arditti D., 'Amateur detection of Uranus' rings', *ibid.*, **127**(1), 50 (2017)
8 Miles P. & Wesley A., 'Positive detection of the Uranus ring using a 0.5m amateur telescope', **http://www.acquerra.com.au/astro/uranus-ring/#2**
9 Peach D., 'A second positive detection', *ibid.*

Received 2017 January 5; accepted 2017 March 29