Observing Uranus and its satellites (2006-2016)

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For amateurs the distant planet Uranus is quite a challenge. With its angular size of about 3.6” 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 investigation. 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.

1. Introduction

The planet Uranus belongs to 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. Observed from the Earth the planet Uranus has a very small angular size of about 3.6 arc seconds and is a real challenge for small telescopes. Visually it is a pale greenish blue tiny disk. Sometimes some bands have been recorded visually by amateurs. A concise report of the discovery and history of observation of this planet is the book entitled *The Planet Uranus* by A.F.O’D Alexander (1). Uranus is unique in the extreme tilt of the axis of rotation of 97.8 degrees. The planet has more than 25 satellites of which only the 5 largest can be detected with amateur telescopes (Fig. 1). With larger telescopes faint banding has been reported visually.

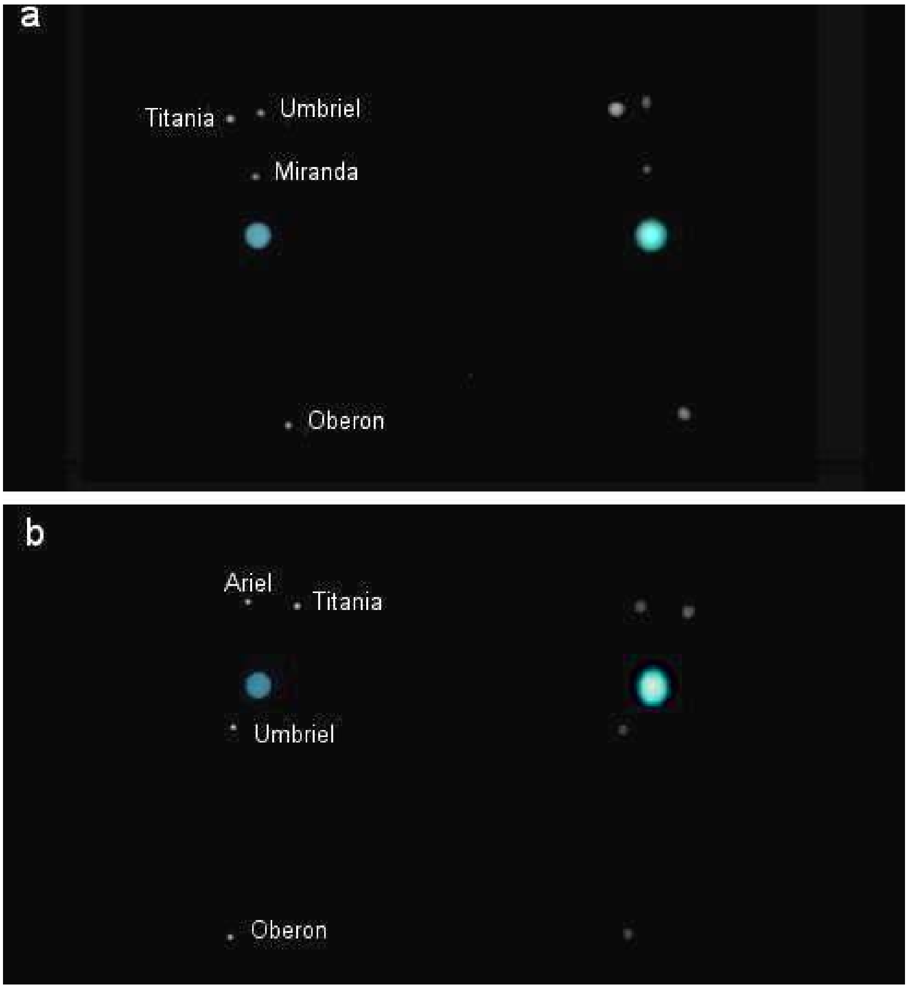

Fig. 1. Uranus and satellites. a. Taken on 24 July 2004 at 00.53 UT and b. taken on 27 July 2004 at 00.37 UT. Left: simulations: right images with a C11 at prime focus.

2. Atmospheric features on Uranus

In contrast to Jupiter and Saturn the planet Uranus is rather featureless. NASA Voyager 2 spacecraft flew close to Uranus in 1986 and revealed some banding and white clouds in the Uranian atmosphere. Also the Hubble space telescope has revealed bands and spots on the distant planet (Fig. 2).

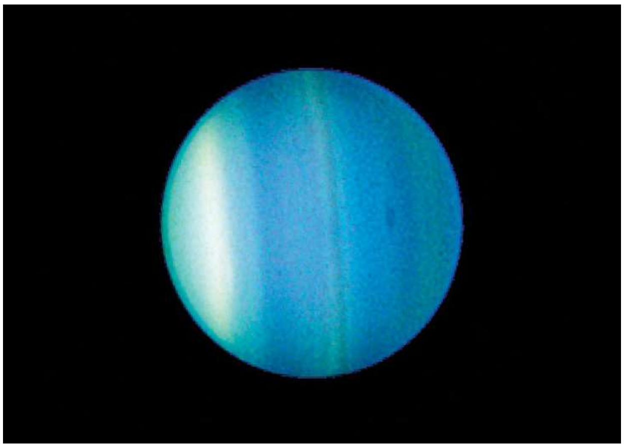

Fig. 2. Uranus image taken in 2006 with the Hubble Space telescope

This image also illustrated the consequence of the peculiar big tilt of Uranus. 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. In Fig. 3 the appearance of Uranus is shown in the period 2006-2016. 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 20 February 2007, 3 May 2007 and 16 August 2007, respectively) and leading to a view of Uranus very similar to the 2006 image.

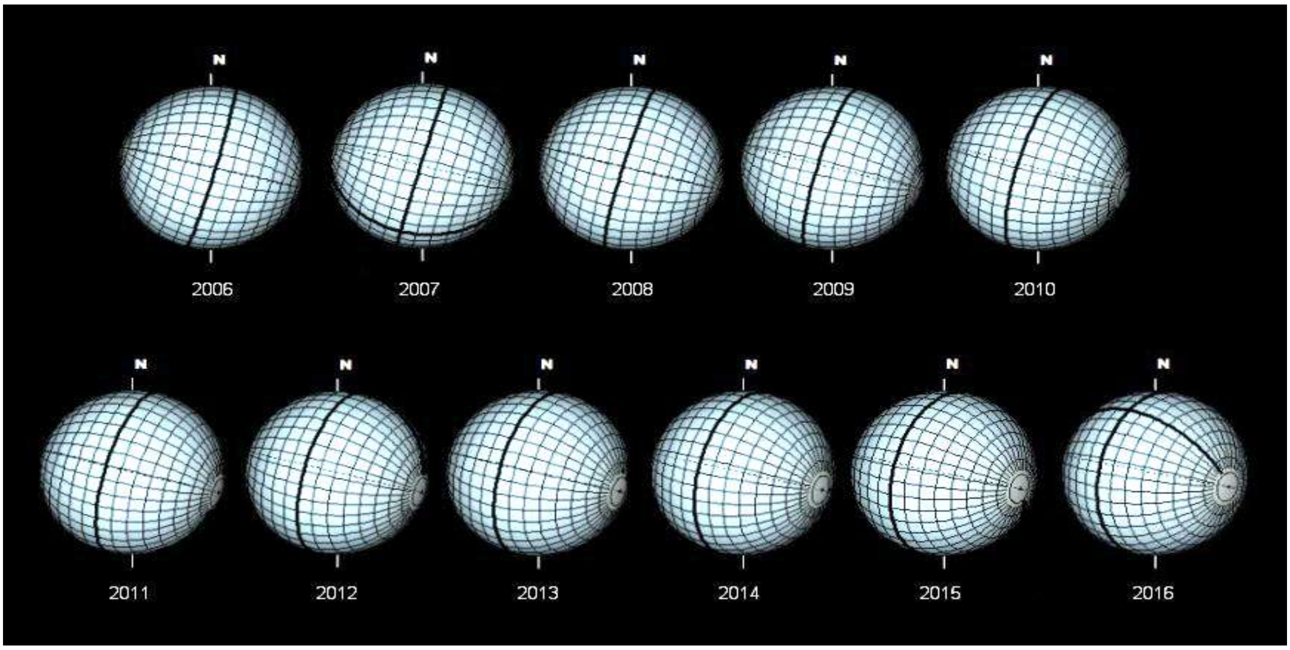

Fig.3 Appearance of Uranus from 1 July 2006 till 1 July 2016 (WinJUPOS animations(2))

At the beginning of the 21st century amateur astronomers in increasing numbers started digital imaging of the planets using webcams and other cameras. In the beginning Jupiter, Saturn and

Mars were the favourite objects. In August and September 2006 the 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 the circumstances for the observation of Uranus from The Netherlands were quite unfavourable during this apparition. In 2006 the altitude of Uranus was not more than 30º. Despite these conditions a number of decent 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 and IR (Figs. 4 and 5). No distinct spots or other features could be detected in the RGB, R and R images. Limb darkening was very clear and in some images the Southern hemisphere was a bit brighter than the Northern hemisphere.

Fig. 4. Uranus on 11 September 2006. C11, ATK2HS camera plus Astronomik RGB filters or Baader IR filter

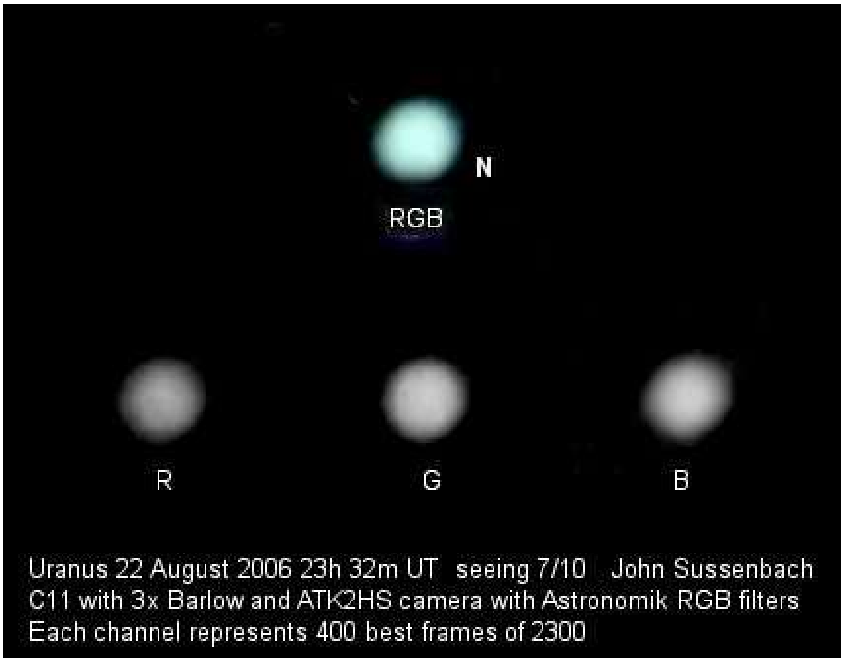

Fig. 5 Uranus on 22 August 2006. C11, ATK2HS camera with Astronomik RGB filters.

I imaged Uranus in the years that followed, but due to the fact that Uranus travelled through the summer ecliptic conditions for high resolution imaging of this planet were not very favourable. In 2008 I noticed in the images that the Northern hemisphere was a bit brighter than the Southern hemisphere 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 more distinct in the years that followed (Figs. 6 and 7).

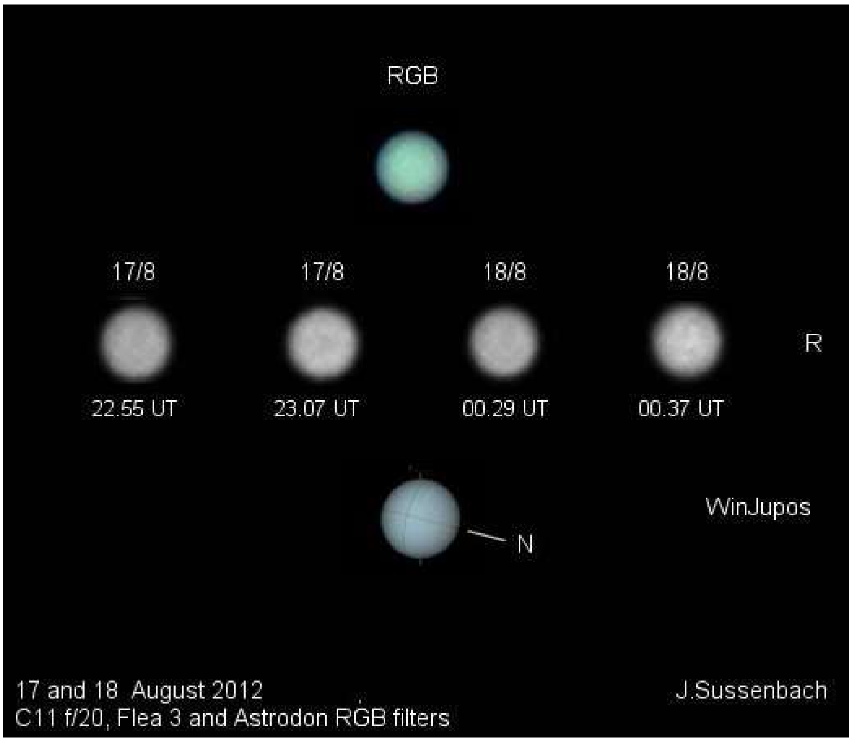

Fig. 6. Uranus on 17 and 18 August 2012. C11, Flea3 camera and Astronomik RGB filters.

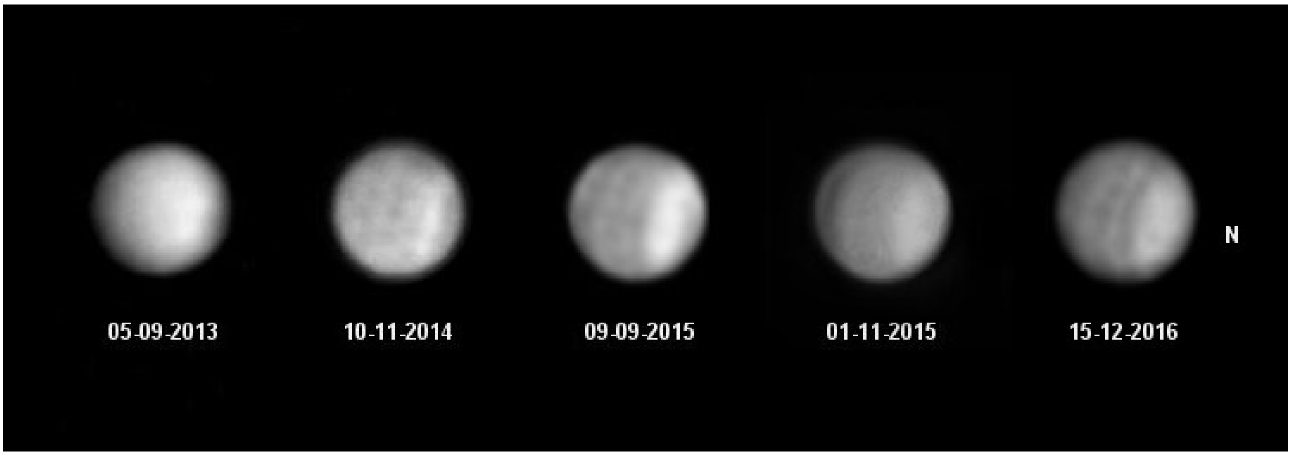

Fig.7. Uranus from 5 September 2013 till 15 December 2016. C14 and different types of cameras. Red long pass (>610nm) or IR filters

In particular in the Uranus images of 2015 and 2016 the Northern hemisphere is brighter than the Southern hemisphere. 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, in the direction to the South pole a brighter zone can be distinguished and a relatively dark band in the most Southern region. (Fig.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 general short-lived. Interestingly, on 15 August 2015 I noticed a bright spot on the Northern hemisphere (Fig. 8). Since the images are rather grainy, one should be aware of artefacts. However, when images obtained at 2:28:36 UT, 2:32:53 UT and 2:35:00 UT were compared, in all three images a bright spot was found with the same coordinates (longitude 241.9°, latitude + 56.7°). Unfortunately, bad weather conditions did not permit a follow-up of these observations.

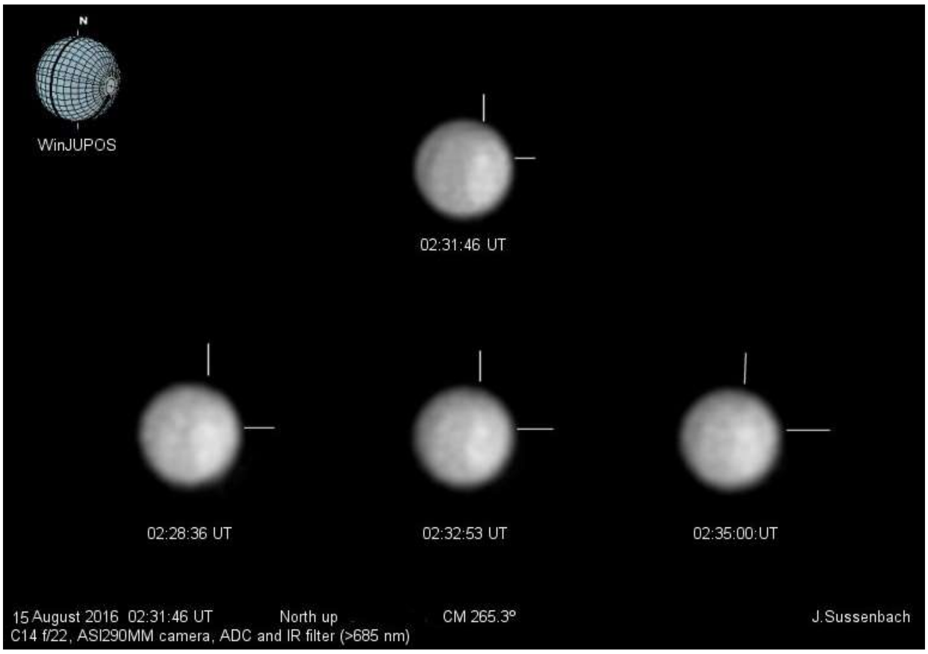

Fig. 8. Bright spot on Uranus 15 August 2016. C14 and ASI290MM camera and IR filter. At the top the combination of the three lower images. In the left upper corner a WinJUPOS simulation.

3. Satellites of Uranus

Uranus has 5 major satellites Miranda (magnitude +16.3), Ariel (+14.2), Umbriel (+14.8), Titania (+13.9) and Oberon (+14.1). Imaging of these satellites leads to overexposure of the Uranus image. For Fig. 9a briefly exposed Uranus image is combined with a longer exposed satellites image.

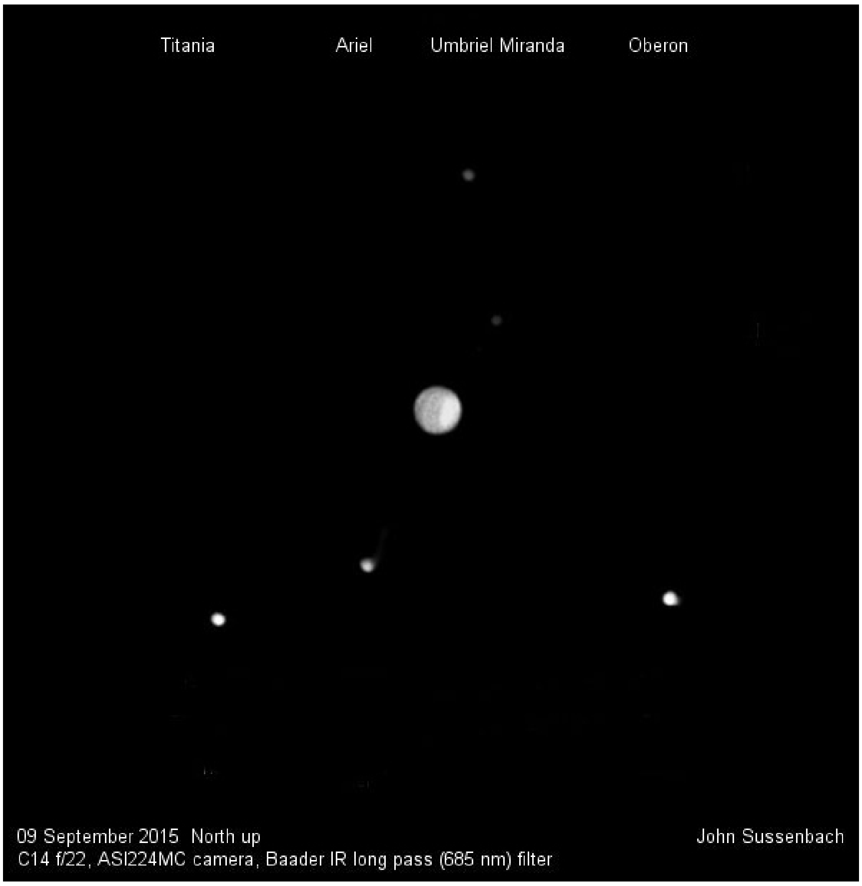

Fig. 9. Uranus and satellites 9 September 2015. C14, ASI224MC camera and IR filter.

Miranda is the most difficult one 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 looked at 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 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 13 August 2007 at 03.04 UT an interesting event took place: the partial occultation of Umbriel by Ariel (Fig. 10).

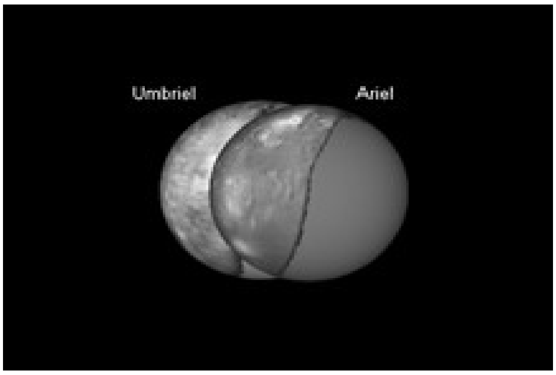

Fig.10 WinJUPOS simulation of a partial occultation of Umbriel by Ariel (13 August 2007 3.04 UT)

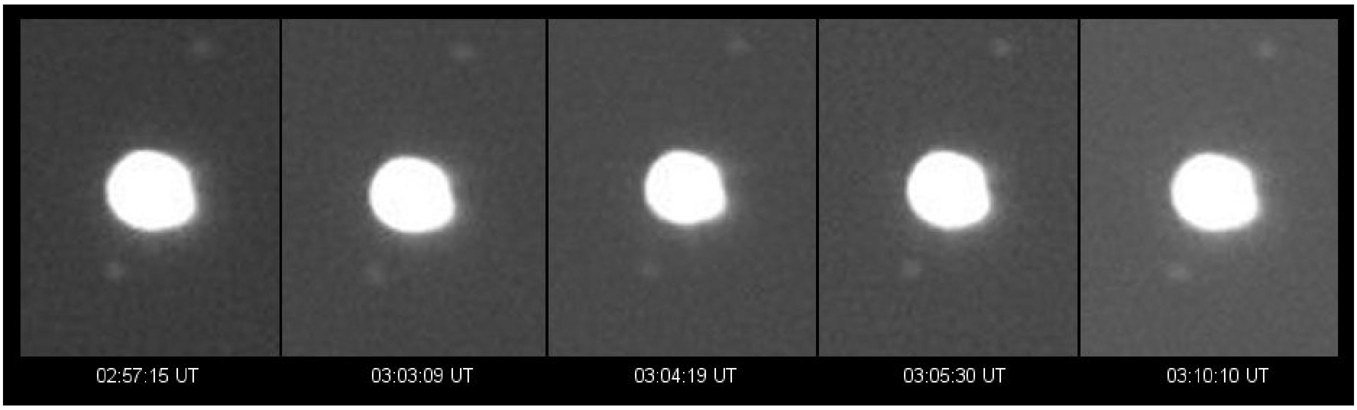

Fig 11 Images of Uranus and the satellites Ariel, Umbriel and Titania during the partial occultation of Umbriel by Ariel on 13 August 2007. C11 and ATK2HS camera.

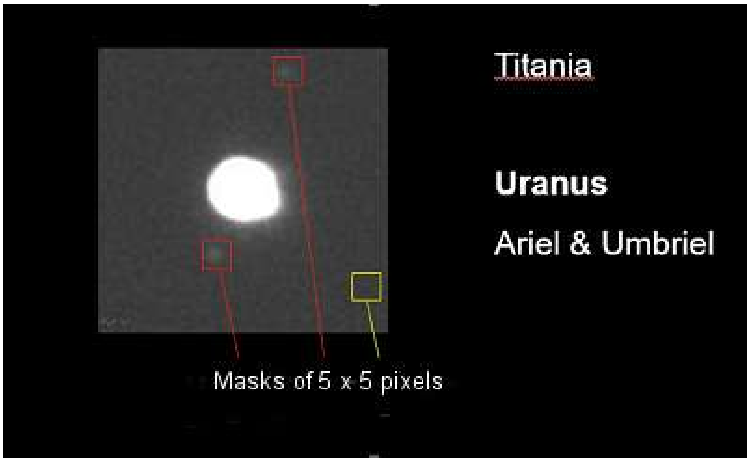

Fig. 12 Photometric analysis of the occultation of Umbriel by Ariel using 5 x 5 pixel masks. The values for Ariel plus Umbriel and for Titania were corrected for background values and the ratio (A+U)/T was calculated.

For the recording of the partial occultation I used a 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 2h40m UT and the last at 3h17m 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.

Frames were grouped in batches of 20 frames and stacked with Registax 4 followed by a slight sharpening step using the wavelet function of Registax 4. A selection of images is shown in Fig. 11. The brightnesses of the combination of Ariel (A) and Umbriel (U), and of Titania (T), respectively, were measured using the colour sampling tool of Photoshop CS 2 with masks of 3 x 3 and 5 x 5 pixels (Fig. 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 Fig.12) were corrected by subtracting the background values (yellow mask Fig. 12). Subsequently the ratio (A+U)/T was calculated. The results of the 3 x 3 and 5 x 5 masks were averaged and the final result plotted (Fig. 13). As shown in Fig. 11 the background values increased in the course of the occultation due to the fact that the occultation took place shortly before sunrise. At 02:57:15 UT the altitude of the Sun was -11.2º and at 03:10:10 UT -9.7º.
Fig. 13 indicates that indeed a drop in the brightness of the combination of Ariel and Umbriel took place relative to the brightness of Titania and close to the times calculated with WinJUPOS.

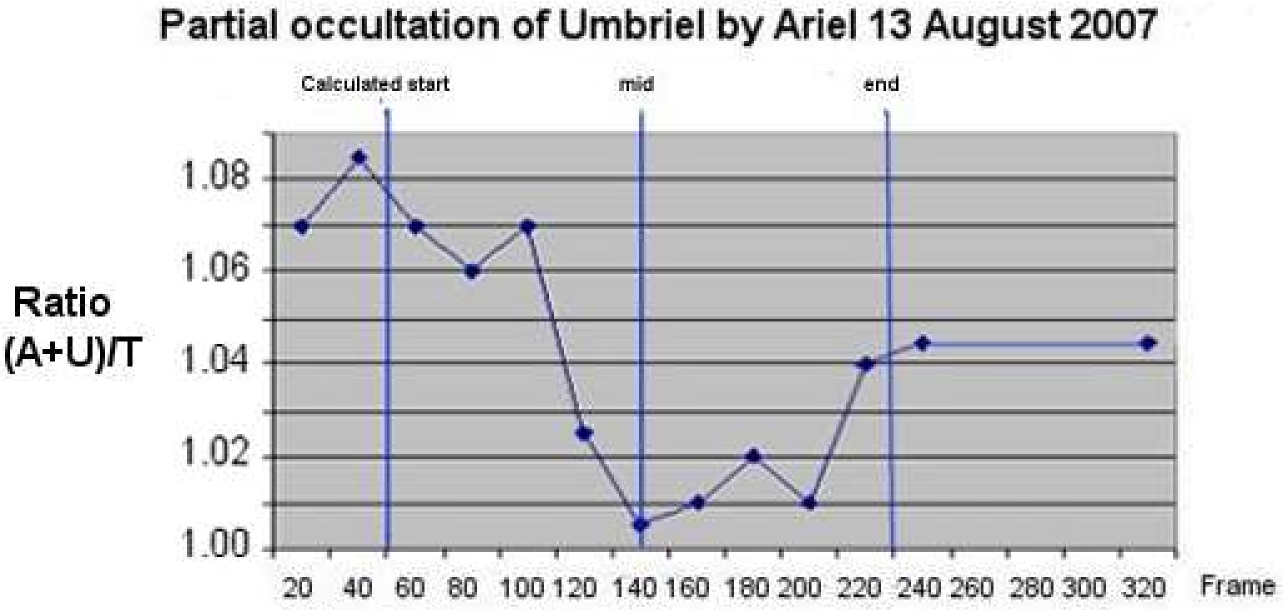

Fig. 13 Photometric analysis of the partial occultation of Umbriel by Ariel 13 August 2007 using masks of 3 x 3 and 5 x 5 pixels. The theoretical values of the start and finish of the occultation was calculated with WinJUPOS.

4. 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 Neptune shows more atmospheric activity than Uranus.
Unfortunately, it will take another 30 years before the Earth will pass the equatorial plane of Uranus again 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 the ring system of Uranus using the 1.06 meter telescope of the Pic du Midi observatory (7). Interestingly, there are also indications that the rings can be detected with smaller telescopes (8, 9). It is obvious 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 (800-1000 nm) will be very welcome for this type of study.

5. References

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