

A short historical account and guide to regular observation of Uranus

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We provide a guide to making observations of the planet Uranus. Many amateurs now have access to relatively large telescopes and, with Uranus moving north, we suggest it is time that it is observed in the same serious fashion as the other major planets.

Introduction

Uranus is a planet which has long been neglected by amateur astronomers. This is not unreasonable from the northern hemisphere viewpoint; the planet has been located well south of the celestial equator, and as it has a orbital period of some 84 years, this means it has been moving slowly through the southern constellations for much of the 20th century. This, combined with a small disk size of less than 4 arcseconds and a seemingly bland, featureless, green surface seems justification enough to consider Uranus as a low priority object, not worthy of frequent observation.

Today however, the situation is a little different. Uranus started on its slow northward climb some time ago and in 2011, it will come to opposition on September 26 in the constellation of Pisces (see Figure 2) and hence, for northern hemisphere observers, the planet is more accessible and less the subject of poor seeing. Also, the planet may be far more dynamic than was previously realised and there is some recent evidence to show that changes have been occurring on the planet.

This paper has two objectives. Firstly, we shall examine some historical and some recent observations, accounts and discoveries. Reviews of past observations give us an idea of what to expect. They also show us irregularities, which are important to verify with repeat observation; thus we have devoted two sections to these subjects. The second aim of the paper is to provide a guide for regular observation. This has been split into two sections: firstly we present some methods for those who wish to pursue visual observation, and secondly we discuss methods and equipment for those wishing to undertake photography.

Historical observations

The planet Uranus was discovered by Sir William Herschel in 1781. Herschel was by profession a musician, but he gave this up when astronomy took over his life. He became engaged in mapping star clusters of the Milky Way and making

regular observations of the planets using his home made 6-inch (15.2cm) Newtonian reflector from his house at 19 New King Street, Bath (now the Herschel Museum).

On 1781 March 13, Herschel noticed a strange object in the constellation

of Gemini. It was clearly not a star for it had a perceptible disk and a greenish hue. Initially Herschel named the object (which he initially believed to be a comet) after his patron King George III. In some texts of the period the planet is referred to as *Georgius Sidum* or George's Star.

Once its orbit was calculated it was soon realised that the suspected comet was in fact a planet, and from mankind's perspective, the solar system became a lot more extensive. It was also realised that the planet had been seen many times before, but no one had recognised it for what it was. Flamsteed, for example, had observed it on no fewer than six occasions between 1690 and 1750.¹

As news of both the planet's discovery and position spread, astronomers began to observe it with the largest telescopes that were available at the time. Interestingly, Herschel believed he observed a ring system around the planet, however subsequent observations by him and other astronomers showed that this appeared not to be the case and the ring system was abandoned.¹

Soon, some astronomers began to report intriguing features on the disk, while others failed to see anything. W. F. Denning's book *Telescopic work for starlight evenings*¹ gives various accounts. It seems that in early 1870, one Mr Buffham used a 9-inch (22.8cm) reflector at powers of $\times 212$ and $\times 320$ and was able to observe bright spots and zones on the disk, which he used to make an estimate of the planet's



Figure 1. Drawing of Uranus made by Patrick Moore on 1977 April 10 at 00:55UT, 15" (38cm) reflector $\times 600$, seeing AI. P. A. Moore.

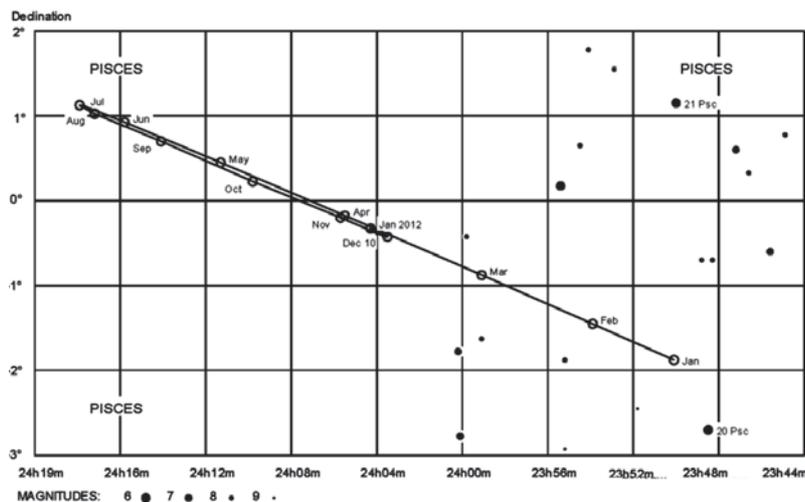


Figure 2. Finder chart showing the location of Uranus during 2011. (BAA Handbook)

rotation; a figure of 12 hours was reached (the modern accepted period is just over 17 hours). However Lord Rosse with his 72-inch (1.82m) reflector on the night of 1873 Jan 16, with very good seeing and definition, was unable to see anything at all on the disk.

During May and June of 1883, Prof Young used the 23-inch (58cm) refractor housed at Princeton Observatory to observe the planet.¹ He was able to see two faint equatorial belts. Further observations hinted at atmospheric activity; on 1884 March 18 two observers, Thollon & Perrotin, used the 14-inch (35cm) Nice telescope and observed dark spots on the disk ‘similar to those on Mars, towards the centre of the disk, and a white spot was seen on the limb’. There are many other interesting accounts and intriguing historical observations of the planet, many of which can be found in the comprehensive work by the historian A. F. O’Donel Alexander, which gives a chronological history of observations of the planet.³

Herschel believed he had discovered six satellites of Uranus but it became clear that four of these were actually background stars. His first two satellites, subsequently named Titania and Oberon, were genuine discoveries. A third, Ariel, was found by William Lassell on 1847 Sept 14, and the fourth, Umbriel, by O. Struve on 1847 Oct 8. There is some controversy over the 1847 discovery dates of Ariel and Umbriel and this convoluted story is discussed in Alexander’s book.³ It was clear by studying the orbits of the satellites that Uranus had a considerable axial tilt of 98°, more than a right angle.

Astronomers continued to observe the planet into the 20th century. Some were of the opinion that Uranus was featureless and there was little on the disk, as in a drawing made by Patrick Moore (Figure 1). Other observers saw faint belts and spots, but the general consensus was that it was a rather bland world. Certainly the features appeared to be elusive; however S. J. O’Meara managed to derive a rotational period for Uranus using seven visual observations he made of clouds on the Uranian disk with the Harvard College Observatory’s 0.23m refractor in 1981. O’Meara obtained a value between 16–16.2 hours, not too far from the established 17h 14.4m today.⁴

In 1869 Angelo Secchi recorded dark lines in a spectrum

of Uranus, and in 1864 these dark spectral lines were photographed by William Huggins (in the *Journal Nature* 4 (1871) p.88, Huggins recalled that in 1864 he found the light of Uranus and Neptune too faint to be examined well enough with a spectroscope. In 1871 he charted and measured six absorption lines in the visible spectrum).³ In 1902 H. Deslandres showed that the planet had a retrograde rotation.² These results were confirmed by P. Lowell and V. M. Slipher at the Lowell Observatory in 1911. In 1933, R. Mecke identified the gas methane (CH₄) in the atmosphere of Uranus, and by 1934 the first internal model of the planet was proposed by R. Wildt, who suggested that the planet had a hydrogen rich atmosphere, beneath which was a large layer of ice, then finally a rocky core.²

This did not remain the dominant model for long however because in 1951, W. Ramsey from Manchester proposed an alternative interior model of the planet. Ramsey suggested the planet was composed largely of methane, ammonia and water.² This is the model which we still favour today.

Another major discovery made using Earth-based telescopes came on 1977 March 10 when quite by chance, a ring system was discovered around the planet. On this day the star SAO 158687 would be occulted by Uranus (the prediction was made by BAA member Gordon Taylor), and as the star was relatively bright with apparent magnitude +8.9, this would be a good opportunity to measure the apparent diameter of the planet, and provide information about the gases present in its upper atmosphere.

It was realised that the occultation would only be visible to southern hemisphere observers, so the Kuiper Airborne Observatory was used. On board, J. Elliott, E. Dunham & D. Mink prepared to observe the occultation. Some 35 minutes before the event, the star was seen to wink five times, and after emersion this observation was repeated symmetrically. This was also observed by J. Churms in South Africa. This phenomenon could only be explained by the presence of a ring system around the planet.⁵

Earth based telescopes, and their attentive observers, had discovered the planet, its satellites and then by accident, its rings. Further major discoveries would come from a spacecraft.



Figure 3. Image of Uranus by Voyager 2. Left: true colour, right: false colour. During this time the planet had a somewhat bland appearance. (NASA/JPL)



Figure 4. An image of Uranus in the methane waveband taken by the HST on 1998 August 8, showing storms present on the disk of the planet. NASA/E. Karkoschka (Univ. Arizona)

Recent discoveries

On 1986 Jan 24, the spacecraft *Voyager 2* passed Uranus and so far, has been the only spacecraft to visit and survey the planet. Most of our detailed knowledge of Uranus and its satellites comes from the *Voyager* mission. The spacecraft approached the planet pole on and flew over the equator some 80,000km above the cloud tops.² During its flyby, *Voyager 2* was able to tell us a lot more about Uranus and its satellites. *Voyager 2* also took many high-resolution images of the planet (Figure 3).

Radio waves were detected from the planet and it appeared that there was little temperature variation from the equator to the poles. The upper atmosphere was found to be composed largely of hydrogen (86%) and helium (13%) with only a 2% abundance of methane.² The atmosphere consists of the troposphere (up to 50km above the reference 1-bar pressure level), the stratosphere (50–4000km above the reference level) and then the thermosphere and the ionosphere. It has been found that exosphere extends to a great distance, probably out to the ring system, which may have implications for the appearance and structure of the Uranian rings.⁶

The lowest and densest part of the atmosphere is the troposphere where it is believed the temperature of the cloud tops is around -225°C , and their composition may be ammonium hydrosulphide and water. Beneath the cloud layers the planet is thought to have a thick region composed largely of ices – water (H_2O), ammonia (NH_3) and methane (CH_4). The water ice is probably the most abundant of the ices. At these sorts of depths inside Uranus, these molecules behave like a liquid. Beneath all this there may well be an iron silicate core, although the fact that Uranus has no internal heat source (unlike Jupiter, Saturn and Neptune) may suggest that there is no well defined core at the centre of the planet.²

Voyager 2 also confirmed the existence of the ring system and discovered a number of new satellites. The satellites themselves were found to be rather extreme in geological

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terms. Maps and discussions of the main satellites can be found in Reference 2. Of all the satellites, Miranda is perhaps the strangest. The surface of this moon seems to be a bizarre mixture of old cratered terrain as well as cliffs and coronae, indeed it has been suggested that Miranda was once a larger body which was broken up by an impact with another body and then re-formed. Of course no one can be certain, but given Uranus' peculiar orbital inclination, and the geological structure of the surfaces of its satellites, it seems that the planet itself may have been the victim of a violent collision in its early history.

After *Voyager*, the Hubble Space Telescope has been used occasionally to observe Uranus. In 1997 July and October, observed in the near-IR, discrete clouds were seen on the planet (Figure 4).⁷ Observations in 1998 with the HST also recorded outbreaks of storms with estimated wind speeds of 500 km/h. More recently, observations made

with the UKIRT, IRTF and Gemini-North telescopes have shown that Uranus has become more active, with visibility of the equatorial zone and dark mid-latitude belts reported, along with the South Polar Zone at 45°S fading and a corresponding northern one (at 45°N) starting to form.⁷ The Spitzer infrared space telescope has shown substantial variability in stratospheric emission as a function of longitude.^{8,9} It is clear then that Uranus is indeed an active world, and that the activity may only occur locally rather than globally (as the function of longitude results show).

Observations by amateurs may show some changes. Visual observations made during the 2010–2011 apparition by Abel, Gray & McKim suggest that some faint cloud bands were visible, but these subsequently may have faded (Figure 5). A bright equatorial zone was also observed, and this subsequently seems to have dimmed as is shown in the images by Peach and Lawrence (Figure 6). It should be emphasised that the markings on Uranus in the visual spectrum can be elusive and hard to pin down. There has been some disparity and agreement with both visual observations and images and we are only going to be able to tackle the appearance of Uranus' features by collecting many more observations (both visual and photographic) than we have done in recent years. Visual observers with medium apertures should be aware that one can be misled into seeing belts which may in fact just be contrast effects if a bright equatorial zone is present.

Visual observations

Observing Uranus visually is not an easy task. Even at opposition the disk size never exceeds 4 arcseconds. Nevertheless, for observers with telescopes of 200mm or larger, it is possible to observe the faint cloud belts and the brighter equatorial zone which seem to come and go on the planet. There are four useful lines of inquiry the visual observer can

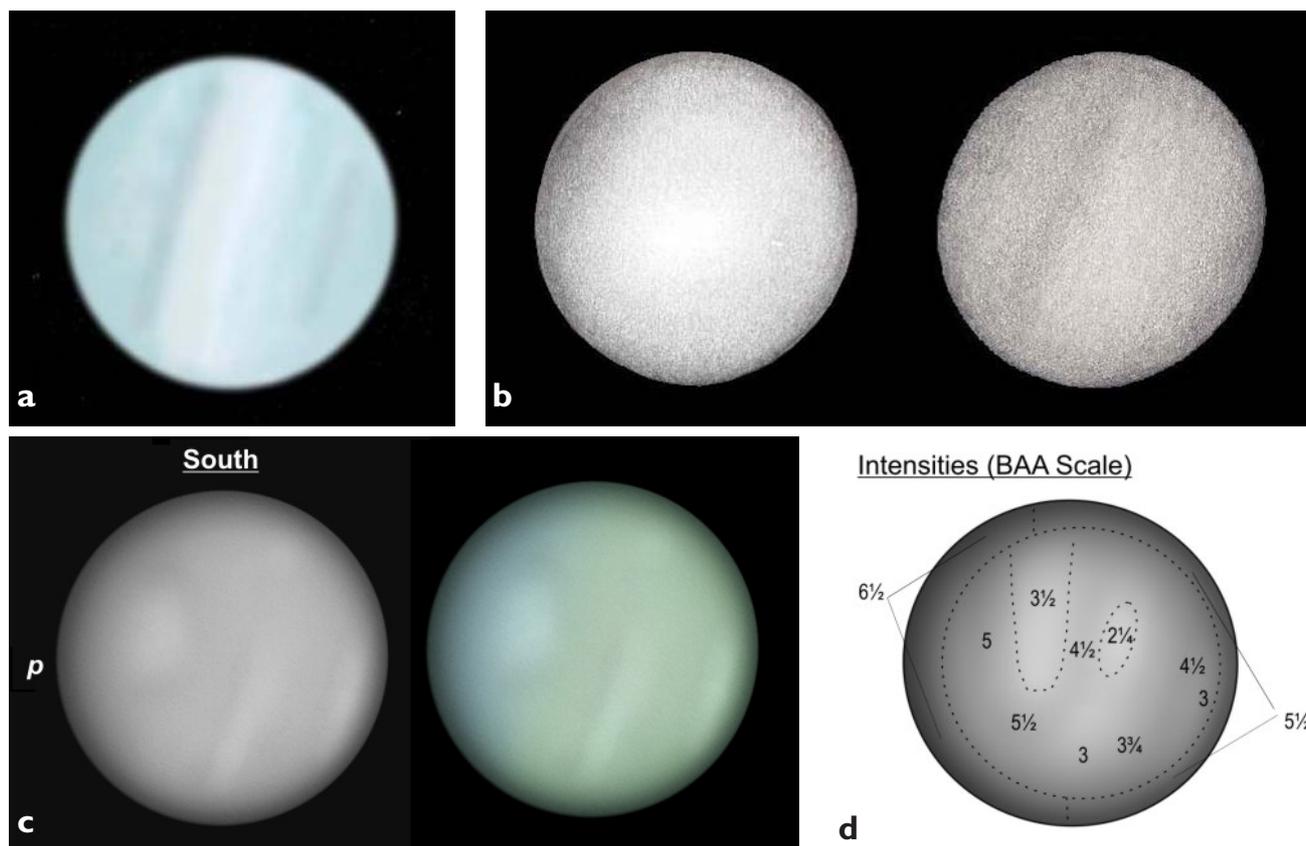


Figure 5. A selection of drawings made by BAA members during 2010 & 2011.
(a) Paul Abel, 2010 Sept 8, 22:36UT. 203mm Newtonian, x312 & x400, seeing AII.
(b) Richard McKim, 410mm Dall-Kirkham, x410. *Left*, 2010 Sept 24, 21:40UT, AII; *right*, 2010 Oct 4, 20:45UT, AIII. Brighter equator shown.

embark on: *disk drawings, intensity estimates, colour estimates and magnitude estimates.*

Disk drawings

These should be made using blanks which are 50mm in diameter, and templates of these can be found on the BAA Saturn Section website.⁹ There isn't the same sense of urgency to get the drawing finished in 10 minutes or so as there is with Jupiter and Saturn, but still observers should make a drawing as quickly as they can. As usual observers should record the date, time (in UT), telescope and the magnification used. It is also very helpful if observers record the CM longitude with their drawings, and this can be obtained from the WINJUPOS program.¹¹

Intensity and colour estimates

As we have seen, there is some observational evidence to suggest that the equatorial zone of the planet varies in brightness. Observers should make another disk drawing and then assign intensity estimates to the various regions of differing brightness. Observers should use the BAA scale of intensity which is a number which ranges from 0 (extremely bright) to 10 (black sky). As with disk drawings, observers should note the date, time, telescope and magnification used, and the CM longitude.

(c) David Gray, 2010 Dec 16, 17:05UT. 415mm Dall-Kirkham, x365 & x535, AII. The right hand image has been coloured in Corel Photopaint X4 using impressions recorded at the telescope.
(d) David Gray, 2011 Jan 21, 17:20UT, 415mm Dall-Kirkham, x270 & x535. The drawing shows intensity variation on the disk, useful work when undertaken with a large aperture instrument.

Magnitude estimates

These can be made by any observer with any sized telescope (though a wide field is preferred so that useful guide stars are available for comparison.) There is evidence to show that Uranus varies a little in magnitude,¹² so observers who make magnitude estimates as part of their astronomy work are invited to make regular estimates of the planet to see if these observations can be repeated. The Variable Star Section of the BAA gives details on how to estimate magnitudes.¹³

A Wratten W#15 (deep yellow) filter may be used with larger instruments to sharpen up the appearance of the planet and help emphasise any belts suspected. Observers should make as many observations as possible over all longitudes so that a general picture can be built up, and hence help address some of the puzzling questions we have discussed regarding the disparity of the visual appearance of belts and zones on the planet.

Naturally, if a storm or some other unusual phenomenon is observed, the Saturn Section should be notified at once so that other observers and professional astronomers can be made aware of it.

Imaging Uranus

Unlike the other major planets, Uranus is a very challenging object to photograph in any detail or quality. The very low surface brightness (even lower than that of Saturn) makes imaging this distant world quite a challenge, though with practice and care some surprisingly good results are possible.

Subtending an angular size of typically only 3.7" at opposition, larger aperture telescopes are required to attempt serious high resolution imaging of the planet. Using apertures smaller than 200–250mm will prove very tough, especially when using colour filters.

Ensuring the telescope is accurately collimated and properly cooled is, of course, very important to achieving good results. Unlike its giant cousins, Uranus lacks any striking belts or zones in visible light. Even true colour images from the Hubble Space Telescope show only faint low-contrast banding. To stand a chance of recording cloud detail in imagery, IR filters should be employed. These penetrate deeper into the planet's atmosphere and often reveal belts/zones or even storms not visible at all in shorter wavelengths such as unfiltered light or true colour. Since Uranus is so faint, red light filters that pass light from 600nm onward would be a good choice for most telescopes. Red to IR filters passing from 700nm or more need large aperture telescopes to be employed successfully although they are likely to reveal more detail. Methane band filters, such as those used for imaging Jupiter and Saturn, are not realistically employable on amateur size telescopes due to the very low surface brightness Uranus exhibits.

Since Uranus has such a small apparent diameter a fairly long focal length is required. You should aim for a focal ratio of around f/30 to f/40 to provide an appropriate image scale. Uranus rotates rather more slowly than Jupiter and Saturn so the time window within which it is necessary to obtain a single image is quite reasonable. Eight to 10 minutes is fine without the possibility of grossly smearing any transient detail that may be present on the disk. For detection of the general belt/zone pattern much longer runs could be employed in a particular wavelength (on the order of an hour or more if possible) to help improve the signal/noise ratio of the image.

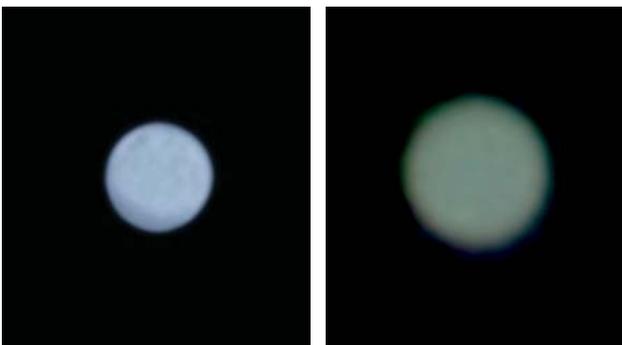


Figure 6. Images of Uranus.
(left) Damian Peach, 2010 Sept 25, 03:18UT, 355mm SCT.
(right) Pete Lawrence, 2010 Sept 21, 23:25UT, 355mm SCT.

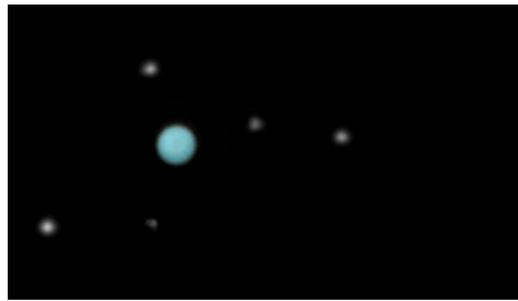


Figure 7. Uranus and its brightest satellites imaged by Ed Grafton of Texas using a 356mm reflector and SBIG CCD camera on 2002 July 19. Faint innermost Miranda is clearly visible, though not an easy target.

Focusing on Uranus itself can be quite challenging, and we would recommend using a nearby star for focusing purposes rather than Uranus itself. The strong limb darkening coupled with its tiny angular diameter can make trying to focus on the planetary disk a frustrating experience. During 2010 nearby Jupiter provided an excellent focusing gauge, though nearby stars will prove equally effective.

Steady seeing will be vital in obtaining good images. Imagery obtained in poor seeing will likely be of little use so we advise waiting for nights of good seeing to target the planet. From the UK, imaging in unfiltered light is best avoided as the altitude is not high enough to escape the deleterious effects of atmospheric dispersion. Concentrating on filtered work is recommended for the best, and most useful, results.

Great care must be taken not to over-process the images since this can cause artefacts that may be misleading as to the detail actually recorded. This remains an issue in general within amateur planetary photography and when dealing with an object like Uranus it is all too easy to process an image much too harshly in the attempt to reveal detail. If a bright centre or dark inner ring begins to appear on the image you've gone too far with the sharpening and should reduce the level. Over-processed images are of little value and can lead to spurious and misleading conclusions.

Other excellent targets for CCD observers are Uranus' five main satellites. Even small telescopes will easily detect the brightest four (Ariel, Umbriel, Titania and Oberon) though faint innermost Miranda will prove a challenge even for large aperture telescopes. Exposures of a few seconds with small telescopes will easily pick up these small frozen worlds. Their motions as with the satellites of Jupiter and Saturn can be easily followed from night to night.

With the equipment available to amateurs today and the amazing results being obtained imaging Mars, Jupiter and Saturn, distant Uranus is a planet that now warrants far more attention from photographers, and the opportunity is there to make real and valuable contributions to the study of this neglected world.

Conclusion

We have seen that the planet Uranus is not the bland, inert world we once thought it to be. There are many reasons for believing that the planet may be more dynamic than previ-

ously thought, but the overwhelming lack of observation hinders any real conclusion as to how active the planet really is. We can only speculate as to what interesting phenomena may have been missed during the many decades of neglect. Recent observations, although far from conclusive, do strongly hint that there are some interesting changes occurring on the planet, and since (for northern hemisphere observers) the planet is at last climbing higher in altitude, we strongly urge observers with large telescopes to observe Uranus in the same rigorous and serious fashion as they would do for Venus, Mars, Jupiter and Saturn.

The Saturn Section will be grateful to receive any and all such observations made of the planet. Given the recent impacts on Jupiter and the enormous white storms of Saturn, who knows what surprises are in store for regular observers of Uranus?

Acknowledgments

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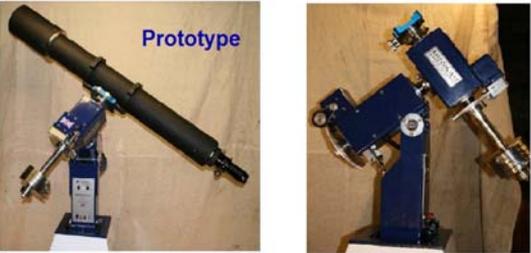
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