

Back to basics: naked-eye astronomical observation

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Abstract

For pupils of both sexes and all ages from about six upwards, the subject of Astronomy holds many fascinations—the rapid changes in knowledge, the large resource of available IT packages and above all the beautiful pictures from Hubble and the large Earth-based telescopes. This article, however, stresses the excitement and importance of naked-eye (unaided) first-hand observation, where light pollution allows, and suggests some techniques that may be used to enthuse and introduce youngsters to the glory of the night sky without recourse to computer screens.

Background

As the evenings close in and with the hope of occasional clear nights, the motivation and interest generated by ‘in the cold’ observing for groups of pupils becomes possible. From an early age, I remember my father taking me out on perhaps warmer autumn nights initially and then more extreme December nights, to guide me round the sky: “1: The twins and Canis Minor; 2: Sirius, the brightest shiner; 3: Orion beneath the Goat; 4: Aldebaran we note; 5: the Pleiades do shine, most see seven, some see nine” springs easily to mind. I also recall early August on deck-chairs counting Perseid meteors, and the first sight of Jupiter’s moons in binoculars. These images remain with me as much as with ‘novices’ today.

I am a huge fan and supporter of the initiatives to bring Astronomy and Astrophysics into the classroom, among them the Faulkes Telescopes, the Telescopes in Education project and all the excellent internet sites and remote telescope operation facilities and software (some of my favourites are listed at the end). Pupils are entranced by the colours and detail now apparent. The ‘Pillars of Creation’ poster, star formation in the Eagle Nebula, has sparked more questions

about distances and origins of life etc than any other source in my laboratory. But these same pupils who have such an interest in the nebulae, galaxies and origins/fate of the universe come out on a dark night and know nothing of the stars they can actually see with their own eyes.

I am lucky: despite my early interests, I have never been able to afford a telescope and have made use of binoculars picked up second-hand. However, through my Astronomy degree and now my teaching position, I have had access to some fine optical telescopes, the 0.94 m James Gregory at St Andrews University and now the ‘Barclay Equatorial’ 10” Cooke refractor (ex-Radcliffe Observatory, Oxford) which, with finances from Marlborough College and the expertise of astronomer and designer E Norman Walker (ex-RGO), we have just finished refurbishing and modernizing (see the February 2003 issue of *Astronomy Now* magazine). In awaiting the completion of the project, the pupils (and younger observers—see figure 1) had to ‘make do’ with binoculars and small telescopes. It soon became clear how inspiring and important it is to let pupils see and ‘discover’ objects with their own eyes: the gasps



Figure 1. Young observers with small instruments.

and shrieks as Saturn's rings or Jupiter's moons are seen, changing positions night by night, or eventually locating the Andromeda galaxy (M31) without fail with the unaided eye and knowing the photons to have taken two million years to reach us. All this without the colour and glamour of the big images and without star maps and software. Somehow it feels less like work, observing in the cold night air.

The greatest problem is, of course, the weather. Here I have to admit that, as a wet weather fall-back, computers come into their own. But the excitement of wrapping up in many layers, the ability to stay out perhaps later than usual and share hot chocolate and cake bars while awaiting the first meteor, even if few are seen, is a big draw. Light pollution is also a desperate problem and may well add travel time to any meeting, in order to reach dark country skies, and may render observing in city centres impractical save perhaps for solar work (see later). Sadly, few see the importance of dark skies, apart from astronomers and energy savers. But when the skies are dark (and this is one positive side to power cuts, as I witnessed eight times last Christmas) the full glory of the night sky is apparent.

Plans for an observing evening

So what can one do and see? The age range of the pupils is a critical factor for the depth of discussion and the level of difficulty of 'objects' that it is planned to view, but the seven-year-olds from the local primary school will not forget Saturn's rings or how to find their way about. A basic idea of direction finding is a must and location of North

and the Pole Star (Polaris) is a starting point from which other directions follow. This is, of course, on every KS3 syllabus, but no number of drawings or pictures replace the ability to locate Polaris 'cold'.

So my order of introduction:

1. Stars have different brightnesses and, depending on the observing site, only a pitiful few (the brightest) of the thousands potentially visible will be seen. So pattern recognition is important (of course, one can use a 'planisphere' or look up positions on suitable software, but hitting pupils with Local Time, Right Ascension and Declination is best done in warm classrooms). Small children can easily pick out a pattern once shown, and the red illuminated pocket guides made by Celestial Seeker (www.daMert.com) have been ideal.
2. It is important that pupils realize the limits of their eyes and that in low light levels:
 - (a) they can only detect shades of grey (the 'cones' detecting red, green and blue only switch on above a given photon arrival rate (for stars this is approximately apparent magnitude -1 unaided, see later). Of course, in telescopes and binoculars one can see hints of colour, and cataloguing and comparing colours in optical binary stars is itself a rewarding, if more advanced, project, and pupils should not expect to see the colours possible using photographic techniques; and (b) they need to be open as wide as possible (dark adapted). This can easily be seen with a red bulb in a room if pupils are paired up looking into each other's eyes and then the white light is turned on. Do this in advance of your observing session and they will appreciate why they should bring a red torch (or a normal one with red plastic covering) and avoid looking at bright white lights. It takes a good 3–5 minutes for eyes to see at their best. Even then we can only see the brightest stars (which is why binoculars and telescopes as 'large eyes' are so much better at light gathering). The limiting magnitude is linked to the diameter of the lens used. The larger the diameter of the main lens (or mirror in a reflecting telescope), the better.

3. For older pupils. Star brightnesses are given a scale (logarithmic to match the nonlinear response of the eye) for their 'magnitude' as apparent to us on the Earth's surface. The smaller the number the brighter the object. Most well known constellations will have 0 or 1st magnitude stars. A few objects will be seen even earlier as the Sun sets—these are likely to have negative magnitudes; the brighter planets may be -1 or -2 and the Moon may reach -13 . A difference of 5 magnitudes is a factor of 100 in brightness, so each extra magnitude represents a $2.5\times$ decrease in brightness. On a clear dark night without optical aid, stars of 6th magnitude, i.e. a factor of 250 dimmer than the brightest, may be seen. More realistically, 3rd or 4th magnitude may be possible. Limiting magnitude is greatly affected by clouds/mist/moisture and thermal currents. These are generally classed as 'seeing' conditions. With binoculars or telescopes, the limiting magnitude goes up with their diameter.
4. Distances on the sky are hard to describe, though directions referred to the normal compass points or clock positions relative to a given reference point are rapidly picked up. Once pupils have covered angles, they readily accept that all objects appear to be on a tilted dome above our head. The apex of the dome is Polaris and the dome (which astronomers call the Celestial Sphere), and the stars on it, rotate about this point (as the Earth rotates, i.e. 15° per hour, 360° in 24 hours); there are then 180° from E to W or N to S horizons. To measure each degree, the 'rule of thumb' is used. The knuckle of a thumb held at arm's length gives a good approximation to 1° . One can check this against the 0.5° of a full Moon (also the Sun of course, but I don't suggest this!). A fist's width gives 5° and thumb tip to little finger tip of the spread hand gives 15° (an estimate of the furthest 'distance' a star (near the Equator) is likely to move in an hour). Risk assessments these days make solar viewing hazardous, especially if the audience is young, instructions are not easily obeyed and "do not look directly at the Sun" can be misheard—the dangers cannot be

overemphasized. A quick demonstration of a focused Sun on a piece of paper soon illustrates the likely result on the unprotected retina. With older groups images of the Sun projected onto non-white screens can be great for observing/counting and following sunspots. I use binoculars in the end of a Hoover Box with a screen at one end and the top cut away for viewing, which gives roughly a 3 cm disc.

Stars and constellations

Back to Ursa Major (I used to avoid Latin names, but many children love the associated myths and folklore). The Pointers are separated by 5° and are 15° from Polaris. A longer observation session easily notes the circumpolar rotation of the stars and in particular Ursa Major. An SLR camera on manual shutter speed can nicely photograph circular star trails while aimed at Polaris (another good project is to estimate Earth's rotation speed from this). Pointing at Polaris not only establishes North, but the arm's angle with the ground (altitude) gives the observer's latitude. Before leaving Ursa Major, most can see the double star Mizar and Alcor (figure 2) in the 'handle' and the handle's curve leads down to the bright red giant star Arcturus. Roughly equidistant the other side of Polaris from the 'Saucepan' is Cassiopeia, the 'W' (or 'M' depending on viewing time). This and Orion (in winter) make the next best easy viewing.

Orion is a beginner's best with the easily identifiable 'belt' of three bright stars leading up

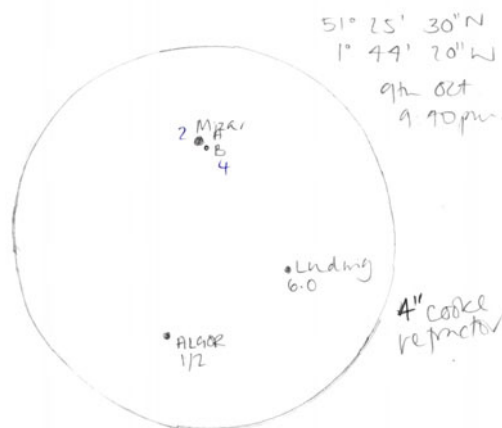


Figure 2. Sketch of the double star Mizar and Alcor.

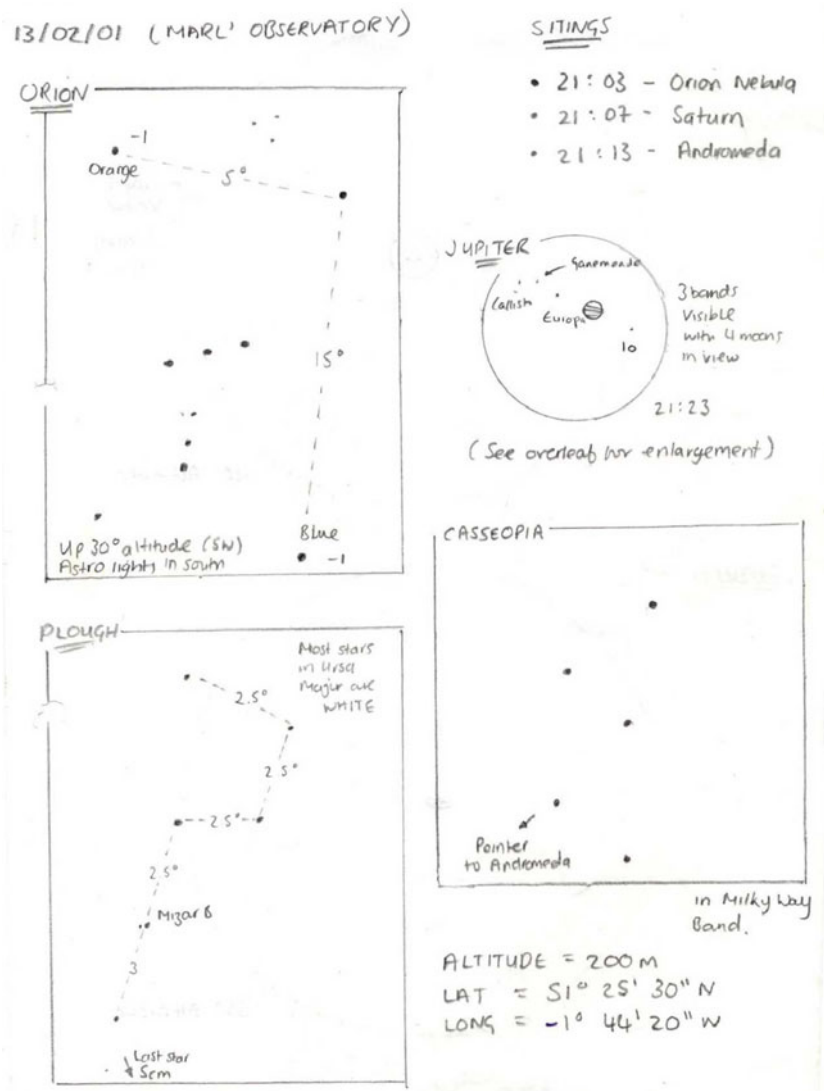


Figure 3. Sketches of Orion, the Plough, Cassiopeia and Jupiter.

to the 'V' of Taurus with the red 'eye' of the bull Aldebaran at the tip of the 'V' (surrounded by an old Open Cluster, the Hyades), then on to the Pleiades, a young Open Cluster of bluer stars (Seven Sisters). Orion's 'left shoulder' is obviously orange (the red giant star Betelgeuse). Leading down from the belt is Sirius (The Dog Star), nearly always one of the brightest objects in the sky and our nearest star easily visible in the northern hemisphere at a distance of mere 8 light-years. A divergence here into light travel times (about 1 second from the Moon and 8 minutes from the Sun) brings scale into perspective. In Orion's

sword there is of course the stellar 'nursery', the Orion Nebula (figure 3), which is easily visible unaided as a fuzzy patch in the centre of Orion's sword. Drawing constellations may be limited, but it leads to familiarity and attention to detail as well as bringing in descriptive terminology: brightness, separation.

Planets

What is really needed to make for a successful observation is a planet (their positions are easily checked on software or in the astronomical magazines or on the internet). Venus, as an early

evening object in the West following the Sun down, is so bright that it can be seen before any other object (save the Moon) and like the Moon it shows its phases in binoculars. The GCSE Astronomy course offered only by Edexcel (Specification 1672) has always encouraged observations and drawings. Some of these are shown, and the pride with which a muddy rough sketch drawn in the light of a red torch is handed in is immense. Mars (especially this year when it reached perigee (nearest to Earth) in August) shows its red colour and even some markings in binoculars. Jupiter and Saturn must be the prizes for young observers. The excitement of the early renaissance astronomers first using a Galilean telescope and identifying real disc and structure can be imagined.

Practical needs

Even small binoculars will show Jupiter's moons or Saturn's rings, and to draw these (figure 4), noting their rotation and comparing them with computer simulations or position graphs in astronomy magazines, quickly hooks observers. I always advise the purchase of manageable binoculars with good optics (not always those recommended for astronomy). Binoculars are sold as $X \times Y$, where X is the magnification and Y is the aperture in mm. Y is really more critical and $>10\times$ magnification or >60 mm aperture are generally too heavy or bulky for child use and really require a tripod, making them less adaptable. I acquired second-hand 8×40 East German Zeiss and these have always remained my favourites.

Making simple refractor telescopes has also proved great fun with a collection of poster

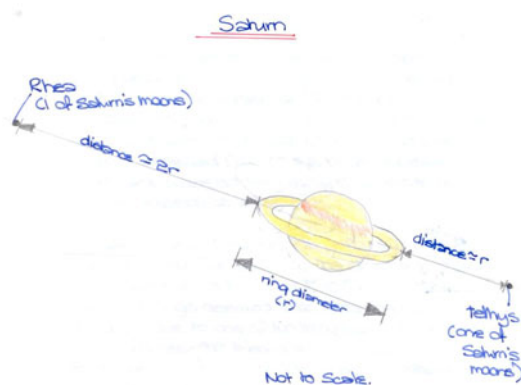


Figure 4. Sketch of Saturn.

tubes and some 60 mm diameter aperture converging lenses from physics optical supplies (with combinations of focal length). However, 60 cm focal length objectives and 20 cm focal length eyepieces, i.e. $3\times$ magnification and fitting within a 1 m tube, seem ideal. Pupils love using their own telescope for viewing the Moon and soon adapt the tubes to include focusing and edge masking.

Meteor showers/aurorae

Meteor showers can be inspirational, but not if the pupils are freezing. Many layers, hat and gloves are essential and deck-chairs help cricked necks. In comfort, even a few 'shooting stars' an hour is acceptable. Recording times, colours, brightness, direction, duration and any detail makes the task more memorable, and results can be displayed later or even submitted to the International Meteor Organization. The Perseid shower on 11–13 August is the most popular, being in summer and warm, though one may have to wait up later for the fainter ones to be seen; they are also predictably high in number (perhaps 60 per hour). The excitement of the well modelled and predicted Leonid storms since 1998 has been an added bonus, though the frustration of clouded peak times has been palpable; sadly their occurrence is in decline. However, Orionids in October and Geminids in December are decent targets. Preparation is easy and star maps showing the radiant (apparent entry point of the meteors into the atmosphere), a clipboard and pencil and red torch make observations more scientific. Comets are notified in advance, either via the internet or via the British Astronomical Association (it is worth considering school/society membership), and other unusual events such as the lining-up of five planets last year spawn new interests and are the 'icing on the cake'. Aurorae are truly ethereal and mesmerize observers, though they are not totally predictable. spaceweather.com is a good source of likely events.

The excitement and interest generated by images of galaxies published in books or collected directly via remote telescopes are undoubted, but pupils can be left with the idea that high levels of technology are required and most have little idea of what can be seen by eye. The Moon and stars are familiar to us all during the year, even if not on a nightly basis in city lighting,

but once some introduction has been made not only do they become familiar objects, enabling some degree of direction finding, but also the sight of the whole sphere of the Moon at a New Moon (due to Earthshine) can give a sense of scale and even the feeling of gravity holding this large 'rock' in orbit. A study of the Moon's surface in binoculars or a small telescope can generate super hand drawings: the skill and accuracy and observational techniques, with each pupil becoming a mini-Schiaparelli, are surely a useful tool in any scientific work. One four-hour GCSE coursework Moon map expanded to 40 hours—the pupil in question just did not wish to stop.

I can heartily recommend the GCSE course, which leads to a single-tier two-hour paper of progressive difficulty. It is generally considered harder than other GCSEs, in that for teenagers the background knowledge required often has not been assimilated, and in most schools timetabling will be limited. Hence those capable of following an extra course tend to be a highly motivated and select few. Numbers are low and only significant support from the astronomy community saved the specification a couple of years ago. If numbers could increase, then its future would be assured. It is a shame that an AS course is not yet available as an incentive for sixth-formers, for whom it could certainly be timetabled. It would encourage a continuation in a science, especially for girls, where the other sciences (especially Physics) may be dropped.

Many planetaria and courses exist for both pupils and teachers, and the Royal Observatory Greenwich posts information on its website. Some of the other sites that I have found most useful are listed below, but to see bands on the surface of Saturn and gaps between the rings, and storms on Jupiter enabling the planet's rotation to be followed, are as inspiring as they must have been long before the computer age.

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Useful references for beginner observers

Redshift 4 CD-ROM, Focus Multimedia Ltd

Astronomy Now magazine, Pole Star Publications Ltd

Norton's Star Atlas 2000 ed Ian Ridpath

Marshall N *GCSE Astronomy* (Mickledore Publishing)

Internet sites that are readily accessible

- Gary W Kronk's comet and Meteor shower calendar and facts
www.comets.amsmeteors.org
- NASA on Sun–Earth links
sunearth.gsfc.nasa.gov
- Hubble's Education site Hubble.stsci.edu
- International Meteor Organization
www.imo.net
- Satellite tracking, especially for the International Space Station
liftoff.msfc.nasa.gov/realtime/jtrack
- Goddard Space Flight Centre, for space missions www.gsfc.nasa.gov
- Royal Observatory Greenwich
www.rog.nmm.ac.uk
- Solar weather, sunspots, aurorae alerts
www.spaceweather.com
- Educational project run with a school telescope www.projectgalileo.org.uk

For more information on the Edexcel GCSE course see www.edexcel.org.uk



Charles Barclay is Head of Physics at Marlborough College, Wiltshire and runs the Astronomy GCSE course there. He directs the College's Blackett Observatory with its 10" refractor. He runs Summer School courses in Solar Observing and is happy to give talks and arrange visits.