Planetarium Notes

Purpose

I hope you'll find these notes and the visit to the Planetarium a help in identifying particular stars and features in the night sky. If you absorb some of the facts you'll be able to point to stars and say something about how far away they are, what kind of stars they are and so on. A pair of binoculars or small telescope opens up the prospect of seeing the glories of star clusters, comets and features of the planets not seen with your naked eye. The Planetarium visit should help you find these by highlighting the location of reference stars and constellations.

Finding your way among the stars

- Star charts, such as the ones at the end of the course textbook, are usually printed with N to the top, W to the **right**, E to the left and S to the bottom. Orient the chart so that the **direction you are looking towards is next to you**. As printed, they are for looking South, which is why West is on your right.

- The centre point of the chart is the zenith (directly overhead), the circumference of the chart represents a flat horizon. If the star chart is to correspond with what you see, it must be printed for the correct latitude you are in. The star charts in the textbook are printed for a latitude much further South than Aberdeen (which is 57° N). This means that they are better suited to your Mediterranean holiday and that the constellations shown are not quite at the same height above the horizon we see them here.

- Since the stars rotate about the north celestial pole, sometimes the constellations appear upside down or sideways from the pattern you have in your mind. This is confusing, at least, it confuses me. Remember that star charts are printed for a particular time of day (e.g. 10 pm UT). For every 2 hours later you are, use the next month's chart. The patterns themselves on the charts are just historical legacy. Nowadays you will sometimes see 'new style' constellation patterns drawn. The constellations are the same but the imaginary lines joining stars can be a bit different. For example, the traditional pattern for 'Gemini', the twins, is little more than a buckled rectangle joining the brightest stars; the new style pattern shows two stick figures joining hands. Some constellations go back several thousand years, others are more recent. The current division of the sky into 88 named constellations, whose names and boundaries everyone now recognises, is the result of international agreement put in place by the International Astronomical Union (usually abbreviated IAU) in 1930.

- Bright stars are named with 'personal' names, often Arabic, and alternatively with a Greek letter followed by the *genitive case* of the Latin constellation name. E.g. Mizar is ζ Ursae Majoris, the 6th brightest star in Ursa Major (the great bear), since ζ (zeta) is the 6th letter of the Greek alphabet. Each constellation has a 3-letter abbreviation. It is UMa for Ursa Major. Now you know! Think of the complications as a valuable link with past cultures. If you use the abbreviations, you needn't worry about genitives.

- Naming the brighter stars in a constellation with a Greek letter is a scheme introduced by the astronomer John Bayer of Augsburg in 1603. When 24 stars have been so named, the letters of the Greek alphabet run out. What then? The first Astronomer Royal, John Flamsteed (1646 – 1719), produced near the beginning of the 18th century the most comprehensive star catalogue that had ever been made and in so doing introduced a different naming scheme. In Flamsteed's scheme, stars were simply numbered in each constellation, starting at the most westerly. A bright star may therefore have an Arabic name, a Greek letter *and* a Flamsteed number. Fainter stars that Flamsteed noticed will just have a Flamsteed number. Thus you might identify '51 Peg' or '22 And' as stars that haven't got a Greek letter in their respective constellations. What happens with stars too faint for Flamsteed to have recorded? That is another chapter of the story, not told here.

- However, there is one final bit of the historical star-naming scheme that is still with us. When Bayer was labelling stars according to their brightness, he recognised that there was a problem with variable stars. He reserved nine letters in our alphabet, R, S,…Z, for variable stars in each constellation. Thus R Lyrae is a variable star. Later astronomers realised that 9 letters was quite inadequate to cover the number of variable stars, so a second letter was added. Thus RR Lyrae is the 10^{th} variable star noted in the quite small constellation of Lyra. It happens to be a famous star.

Star charts

In the final pages, I've shown some views of the parts of the sky that include stars mentioned in later paragraphs. Alongside, I've put 'inverse video' pictures of the same areas, with the stars showing black and the names of selected stars printed nearby. A few constellation names have been added to help locate the stars on larger star charts. Look at the pictures on the left to try to remember the patterns and the ones on the right to identify stars. Although the pictures are small, the corresponding parts of the sky are large. Unfortunately, the fainter stars disappear in the printing process, much as real faint stars disappear with modest artificial lighting outside. If you view the original document on the course web page (http://www.abdn.ac.uk/physics/astro), you can enlarge the pictures and recover the stars.

Stellar distances

Distances are measured in light years (LY). The nearest stars are just over 4 LY away (α - Centauri and companions, not visible from Aberdeen), over 6000 times the enormous distance from the Sun to the outer planets Neptune and Pluto in our solar system. Two of the closest stars to us that are readily seen in the Aberdeen winter sky are **Sirius** (α Canis Majoris) at 8.6 LY and **Procyon** (α Canis Minoris) at 11.4 LY. Both these are multiple star systems. None of the other nearest stars are conspicuously visible from Aberdeen.

How far away are other bright stars in the sky? The Hipparcos survey gives the up-to-date values for most of the stars in this list:

Altair (α Aquilae)	16.8 LY
Vega (α Lyrae)	25.3 LY
Arcturus (α Boötis)	37 LY
Regulus (α Leonis)	78 LY
Polaris (α Ursae Minoris)	430 LY
Betelgeuse (α Orionis)	520 LY
Deneb (α Cygni)	1600 LY

Apparent Magnitudes

Usually represented by the symbol m, *apparent magnitude* is a logarithmic measure of the light received from a star. 5 steps of apparent magnitude represent a difference in the amount of light by a factor of 100. Apparent magnitudes are ordered like positions of merit, the smaller the number the higher the merit. Thus magnitude 2 beats magnitude 7 by a factor of ×100 in terms of amount of light (because 2 is 5 steps higher than 7). Stars and planets down to magnitude 6 are visible by eye on a dark, clear night away from artificial light.

Examples of stars of different apparent magnitude are:

Sirius (α Canis Majoris)	m = -1.44 the brightest star in the sky after the Sun
Arcturus (α Boötis)	m = -0.05 the brightest star North of the celestial equator
Vega (α Lyrae)	m = 0.03
Spica (α Virginis)	m = 1.0
Pollux (β Geminorum)	m = 1.16
Castor (α Geminorum)	m = 1.6
Polaris (α Ursae Minoris)	m = 2.0
Mizar (ζ Ursae Majoris)	m = 2.2
Pherkad (γ Ursae Minoris)	m = 3.0
Alcor (adjacent Mizar in Ursa Major)	m = 4.0
ε **Lyrae** (the "double-double")	m =5.0

Variable stars change their apparent brightness in time. Best known are:
Algol (β Persei) which changes from 2.1→ 3.4 and back in 2 days 21 hours (see lectures), and
δ **Cephei** the archetypal Cepheid variable, which changes from 3.5 to 4.4 and back in 5 days 9 hours. (Presumably Bayer hadn't noticed these were variable and hence gave them Greek letters).

Absolute magnitude

- Usually represented by M, the absolute magnitude is measured by calculating the amount of light a star would emit if it were located at 10 parsecs ≡ 32.62 LY. Since a good many bright stars in the sky are further away than 33 LY, they would be even brighter if they were at this distance. Some would be brighter than any star we now see. Just as with apparent magnitude, 5 steps difference is equivalent to the emission of ×100 in the amount of light.

- Most of the stars close to the Sun that we can see have an absolute magnitude very much less than the Sun. Many are too faint for the naked eye. They don't appear in these notes.

- If you compare absolute magnitudes with that of the Sun you can see how much brighter than the Sun a star is. This comparative brightness with the Sun is a measure of a star's **luminosity** L, on a scale with the Sun as 1. A few comparisons are listed below, taking figures from Koupelis & Kuhn's textbook, Appendix E.

- The luminosity of a main sequence star is related to its mass. The range of masses is much less than the range of luminosities. Quite a few of the bright stars in the sky are not main sequence stars but are some kind of giants located a long way away. Among those that are main sequence are Sirius, Vega, Altair, Spica, Regulus and Castor (both components).

	Absolute magnitude M	*luminosity L* compared with Sun	*Mass* compared with Sun
Sun	M = 4.83	× 1	× 1
Sirius (α Canis Majoris)	M = 1.4	× 24	× 2.5
Altair (α Aquilae)	M = 2.2	× 11	× 2.0
Vega (α Lyrae)	M = 0.6	× 49	× 3.0
Regulus (α Leonis)	M = -0.5	× 136	× 4.1
Spica (α Virginis)	M = -3.5	× 2150	× 9.0
Betelgeuse (α Orionis)	M = -5.1	× 940	
Rigel (β Orionis)	M = -6.7	× 41,000	
Deneb (α Cygni)	M = -8.7	× 258,000	

Colour and temperature

The colour of a star depends on little else than its temperature, in the same way as heated bodies on Earth change their colour with temperature. Cool stars are red, warmer orange, then yellow and white. The hottest stars appear blue. Most cool stars emit too little light for us to see them with our naked eyes. The red and orange stars that we do see are giants, much larger than the Sun with a correspondingly big surface area. They are stars in the latter stages of their lives – a prevue of what will happen to our Sun. A simple measure of colour is the B-V index, which is the difference in apparent magnitude of a star measured through a blue filter (B) and a yellow filter (V for visible). A blue star is comparatively brighter through the blue filter and therefore has a *smaller magnitude,* hence B-V is negative for blue, very hot stars.

Another more precise measure of temperature is the **spectral class** of a star, represented by one of the historical letters O, B, A, F, G, K, M, R, N, S. Each class letter has 10 subdivisions 0 – 9. The Sun is G2. An added Roman numeral gives additional details relating to the luminosity of the star. V here in the spectral class refers to main sequence stars, which comprise about 90% of all stars. Some bright stars arranged from hottest to coolest are:

	Class	**B-V**	**Temperature**
Spica (α Virginis)	B1 V	-0.23	~40,000°
Rigel (β Orionis)	B8 I (bright supergiant)	-0.03	
Sirius (α Canis Majoris)	A1 V	0.00	
Deneb (α Cygni)	A2 I (super giant)	+0.09	~15,000°
Procyon (α Canis Minoris)	F5 IV-V	+0.42	~8,000°
Capella (α Aurigae)	G5 III (giant)	+0.80	
Pollux (β Geminorum)	K0 III (giant)	+1.00	~5,000°
Arcturus (α Boötis)	K1 III (giant)	+1.23	
Aldebaran (α Tauri)	K5 III (giant)	+1.54	
Betelgeuse (α Orionis)	M2 I (supergiant)	+1.85	~3,000°

Binoculars or a telescope

What can you see with binoculars that you can't see with your naked eye? Here are a few things, but you will need a stand or some steady support to hold your optics still, otherwise the image just dances around:

- Thousands more stars, everywhere
- Features on the Moon. The moon is one of the best astronomical objects in the sky for a pair of binoculars. The craters show particular well at the terminator, where the

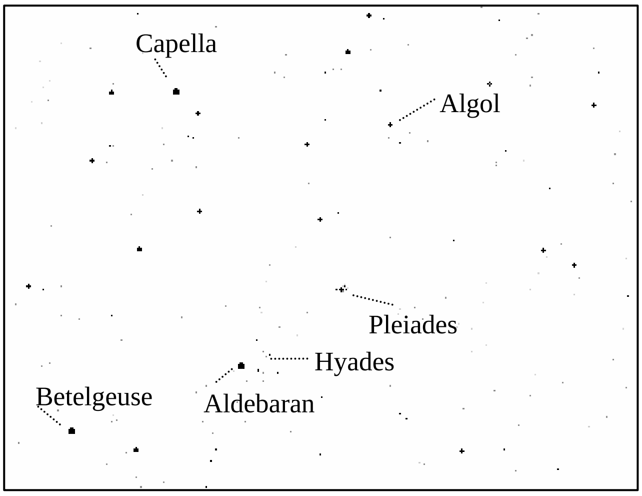
illumination of the Sun is at a glancing angle. The terminator changes day by day and the appearance of features changes too.

- The moons of Jupiter (Io, Europa, Ganymede and Callisto), whose relative positions change daily. With good binoculars you'll see the phases of Venus, Saturn's big moon Titan and, when they are well inclined, a good indication that Saturn has a ring. With my binoculars, I can't see the rings properly, just that something is there. Saturn is so far away that you need an instrument with a wide aperture and correspondingly better ability to see detail than a small pair of binoculars. The positions of the planets in the sky are given in reputable newspapers, in on-line astronomy journals (see our 'Astronomy links' web page) or using one of the computer programs now available. You can also see both Uranus and Neptune but you must know where to look and observe for some time to notice their motion relative to the background stars.
- Star clusters and galaxies. Messier listed many of those worth seeing through a modest telescope and they now have 'Messier numbers'. To locate them, you need to look at a star chart with their positions marked. See some of the references under 'Astronomical links' on the class web site. The clusters mentioned below usually cover an area about the size of the Moon, plus or minus a factor of 2. The open clusters are the best through a pair of binoculars, showing many stars within the field of view. Notable are:

- **M45** (the Pleiades, in *Taurus*) visible as 6 or 7 close stars with the naked eye but seen as dozens with binoculars, over an area of 4 Moon diameter's width; about 400 LY distant
- The **Hyades** a stretched out V-shaped open cluster in *Taurus* beside Aldebaran, covering about 10 Moon diameters, about 150 LY distant
- **Melotte 20** an open cluster around α Persei, which is the brightest star in it, around 550 LY
- **M44** (Praesepe or The Beehive) in *Cancer*, a busy open cluster about 520 LY distant
- **Melotte 111** the Coma Cluster in Coma Berenices, an extensive cluster just visible to the naked eye anticlockwise from the rump of Leo; about 260 LY distant
- **NGC 869** & **NGC 884** in *Perseus*, a double open cluster of stars about 7,300 LY. You need a dark sky to see these well
- **M35** a compact open cluster in *Gemini*, about 3000 LY. All the above are not too far apart and can be seen quite high in Aberdeen's winter sky. The last two being further away are distinctly fainter and the bigger the aperture of your instrument, the better
- **M42** (the *Orion* Nebula), looking like a distant headlamp in the sky, a cloud of glowing gas where stars are being born, 1500 LY
- **M13** the brightest globular cluster visible in the Northern sky, in *Hercules*, though it needs a dark sky and a larger aperture instrument to make much of an impression, about 23,500 LY
- **M10** and **M12**, 2 fairly close globular clusters in *Ophiuchus*, 14,000 LY and 18,000 LY
- **M15** in *Pegasus*, one of the best globular clusters in the Northern sky, 30,000 LY

With spiral galaxies, a pair of binoculars just shows a fuzz, if you are lucky(!), rather than the splendid detail you can see on professional photographs. A camera (CCD or film) is needed to show up the fainter light from the spiral arms.

- **M31** *Andromeda* galaxy, our sister spiral, though you won't see the spiral arm details it is astonishing just to see a diffuse object about 2 million LY distant
- **M81**, a tightly spiralled galaxy in *Ursa Major*, about 10 million LY away
- **M51** (the whirlpool galaxy) in *Canes Venatici*, a spiral galaxy face on, though you won't see the trace of the spiral arms without a camera; about 25 million LY away.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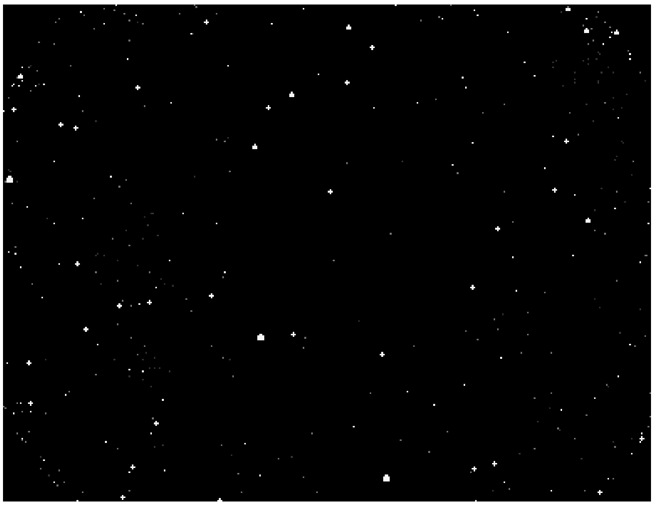
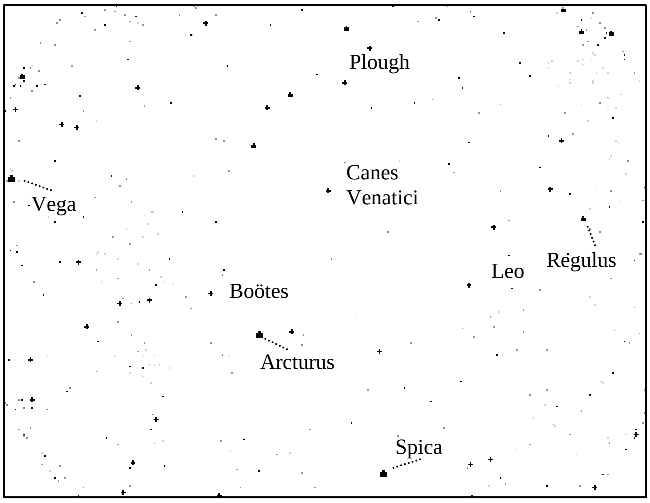
Algol
Pleiades
Hyades
Betelgeuse
Aldebaran

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Canes
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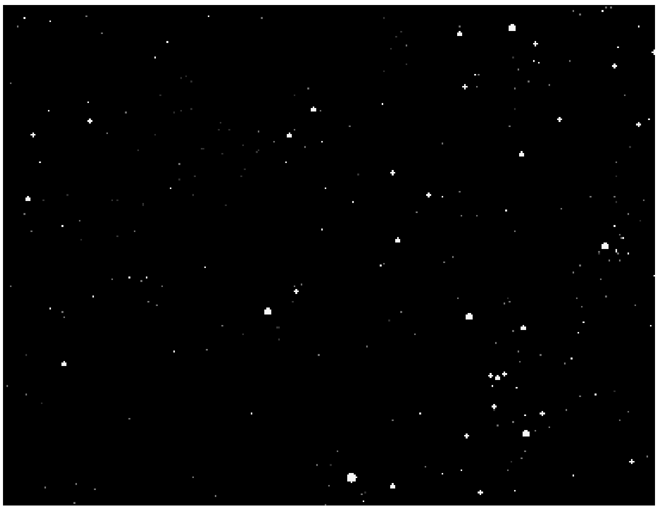
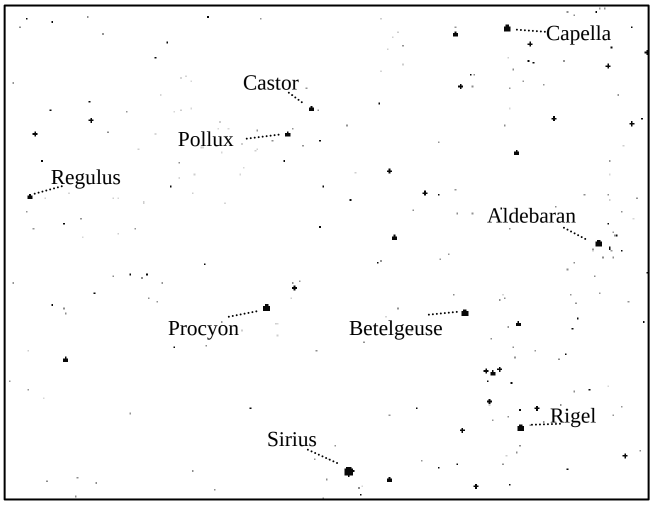
Arcturus
Spica

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Betelgeuse
Rigel
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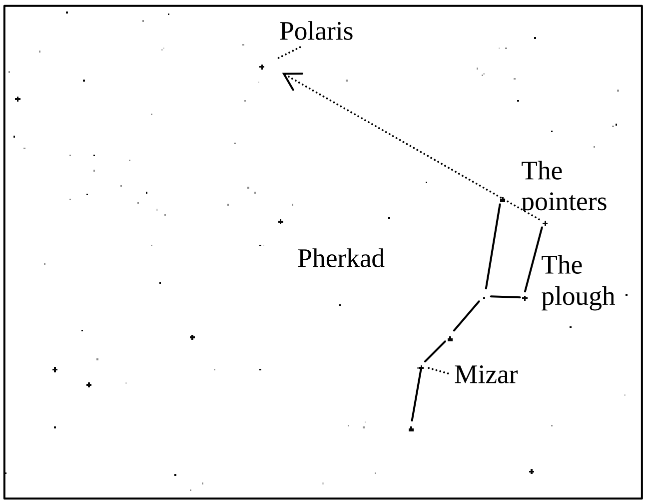
Polaris
The pointers
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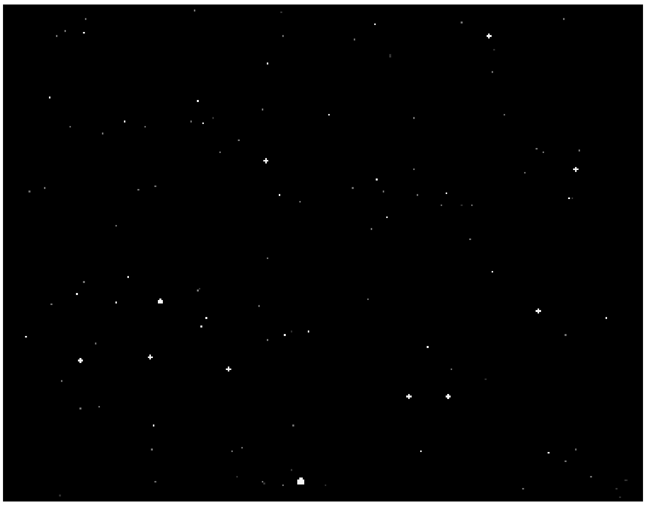
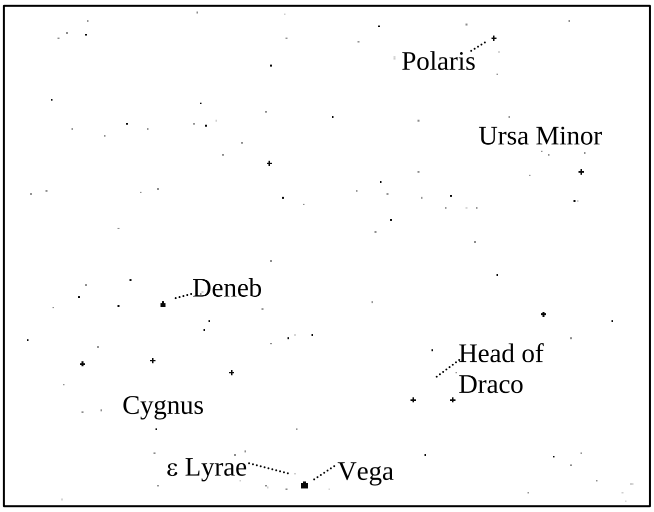
Mizar




Polaris
Ursa Minor
Deneb
Head of Draco
Cygnus
ε Lyrae
Vega

JSR