"Essential Astronomy" Quick Reference Guide for Outreach
(Evolving Draft – Version 10)

***NOTE*: NEVER LOOK DIRECTLY AT THE SUN – WARN PEOPLE OF THIS! ALWAYS BE AWARE OF THE LOCAL BELIEFS ABOUT ASTRONOMY. KNOW YOUR AUDIENCE!**

1. Astronomy Basics

Earth

- Round like a ball – why don't we fall off? (Gravity) Which way is up? (It's all relative)
- Earth rotates around axis, therefore Sun and stars move across sky and we have night and day
- Earth goes around (orbits) Sun:
  - We have seasons because axis is tilted – NOT distance of Earth from Sun. Tilted axis means days are different lengths in summer and winter. Notice also height of winter/summer Sun.
  - We see different stars or constellations at different times of the year e.g. Orion in summer, Scorpius in winter.
- Earth has atmosphere therefore no stars visible during day. Why is sky blue? Scattering of sunlight. On moon, no atmosphere therefore stars visible in daytime. Atmosphere causes twinkling of stars.
- We have not found planets like Earth (yet) so there's no place to go to (yet) – right now, this is home and this is it – so take care of the Earth.

Moon

- Moon's orbital period is 27.3 days but it takes 29.5 days from new Moon to new Moon. At any stage same face is visible to us (rate of rotation of Moon = time taken for Moon to go around Earth)
- Eclipses (lunar=moon, solar=sun). What causes eclipses? Demonstrate with balls, light source.
- Moon about a quarter the diameter of the Earth – less massive therefore gravity less on Moon
- No atmosphere therefore no weather to erode craters that were made billions of years ago. We had the same craters on Earth, but they've been hidden through erosion. A meteorite of about 10 km diameter could erase all civilisation on Earth. Such a meteorite may have been responsible for the extinction of the dinosaurs.
- Phases of the Moon caused by its position relative to the Earth and Sun and NOT by the Earth's shadow. Demonstrate using balls and a bright light source or double handed fist with sunshine.

Sun

- Sun is a star. The nearest star to our sun, Proxima Centauri, is 4.2 light years away (a light year is the distance that light travels in one year; speed of light ~300 000 km per second). If the Sun was a 1m ball in Cape Town, Proxima Centauri would be a 15cm ball in Cairo.
- Our Sun is a middle aged star (~4 billion years old and another 4 billion years before it burns out)
- Sun is made up of gas – mainly Hydrogen and Helium (90% H, 9% He by number of atoms, but 73% by mass of H, 24% He). Hydrogen fuses at the centre in the high temperature and pressure to form Helium – reaction is like thousands of atom bombs going off every second – this is what gives the eventual heat and light that we experience.
- Sun is about 150 million km away from the Earth and is MUCH bigger than the Earth which would just appear as a tiny dot if placed to scale against the Sun (see table below for scale).
- Sun is so far from us that its light takes about 8 minutes to reach the Earth – meaning if the Sun exploded this second, we would only know 8 minutes later.
- Solar flares are when the Sun ejects a massive amount of charged particles
- Sunspots are cooler spots on the Sun which, although actually very bright, appear dark in images because of the even brighter surroundings.
- The Sun and all objects orbiting it (planets, comets, asteroids, etc) are collectively called the solar system (note that Pluto is no longer considered a planet – as we found more objects similar to Pluto we had to refine our understanding and hence have redefined them as "dwarf planets" – therefore there are now only 8 "planets" in the solar system)

Stars

- Shooting stars? Proper name is meteor. Just pieces of rock or dust floating in space which burn up when they come into high speed contact with the Earth's atmosphere. We actually smash into them at 100000km/h – the atmosphere is like our windscreen. The average shooting star we see is caused by something the size of a grain of sand or tiny stone. Called meteorites if they hit ground.
- Just like the sun, stars are massive balls of gas with nuclear reactions taking place in the centre giving it the heat and light. The star's gravity keeps it together, in a nice round shape, and prevents the nuclear reaction from blowing up the star. There is a balance between the outward explosive force of the nuclear reactions and the inward force of gravity thus keeping the star stable.
- Constellations mean nothing scientific – e.g. different cultures have different patterns/stories. Thus any pattern is as valid as the next though Greek mythology is used the most. Note that the stars in

any given constellation are at different distances. (Astrology, which is based on mythology, is very different from Astronomy, which is based on scientific method)

- Life of stars:
  - **Birth**: Lots of hydrogen in the Universe; big gas balls are formed from gravity; pressure on the gas in the middle of the ball sparks nuclear fusion reaction which gives off lots of energy in the form of heat; gravity balances this nuclear explosive outward force and star is stable
  - **Life**: As the nuclear reactions proceed, the hydrogen is converted to helium then the helium is converted to carbon and so on, and with some massive stars going all the way to iron.
  - **Death**: As the star "burns" all of its usable fuel, or when only iron is there, no more outward force is present (iron reactions do not give off energy). Therefore the gravity will "win" as there is now no outward nuclear force anymore. Thus the entire star collapses under its own gravity and explodes throwing off its material. If the star is big enough (more than 8 times solar mass) then this explosion is called a supernova, during which heavier elements are produced and are thrown off into space - these later pull together under gravity to form planets - that's how we have so many elements on Earth. Smaller stars, like our sun, blow out their outer layers more gently to form beautiful "planetary nebulae".
- We are all stardust because all the elements that we are made up of came from inside stars and were scattered into space when the stars exploded.
- **Neutron stars**: when a massive star collapses as described above, it could compress the material into a neutron star which is essentially like a big atomic nucleus (no electrons, only neutrons). This results in a very dense object – so dense that a teaspoonful of that material would weigh as much as all the people on Earth.
- **Black holes**: NOTE: this is a very dense object and not a hole like we are used to thinking of holes. Called "black" because light can't escape it (therefore we'd never actually see a black hole, only the effects it has on objects around it). Referred to as a hole because it is so dense and has so much gravity that anything passing nearby would be pulled in and becomes part of the object.
- Extra-solar planets (**Exoplanets**): We've already discovered over 200 planets around stars other than our Sun. This number is growing very fast. However we have NOT found any that we could live on and we have NOT found any "aliens" (yet).

Galaxies

- Group of many stars usually with a massive object like a black hole at the centre.
- Galaxies like our Milky Way have about 100 billion (10^{11}) stars in it with a black hole in the centre.
- Milky Way is flattish like a disc with a bulge in the centre. It has spiral arms and our Sun is about two thirds out from the centre.
- Other galaxies may have different shapes and are classified accordingly
- There are at least thousands of billions of galaxies in the Universe, each with billions of stars.
- Galaxies that we look at from the Earth are usually millions to billions of light years away (imagine trying to communicate with "aliens" out there if light itself takes that long to travel between us)

Universe

- The Universe is about 13.6 billion years old and is expanding at an increasing rate.
- Big bang: Using the principle of the Doppler Effect (just like the sound of a passing car or motorbike – high pitch when approaching, low pitch when moving away), Edwin Hubble found that all the galaxies he measured seemed to be moving away from us. In fact they were also moving away from each other. Natural extension seems to imply that if they are moving away from each other they must have started off together somewhere – hence the idea of the big bang.
- Dark energy and dark matter together make up about 96% of the Universe, the remaining 4% is baryonic matter (the stuff we are familiar with):
  - **Dark energy**: Universe was found to be expanding but not just expanding – expanding an increasing rate! What is causing this expansion "boost". Is there some force "opposite" to gravity on those scales? The energy causing this is referred to as dark energy. Einstein actually introduced a term for this and then regarded it as his "biggest blunder".
  - **Dark Matter**: Seems that sometimes when studying galaxies and clusters of galaxies we come across something that obviously has gravitational attraction but cannot be "seen" – we can only see the effects of its gravity. This "stuff" is called dark matter.

2. Astronomy Software

(Lots available to download for free at http://www.midnightkite.com/software.html and similar sites)

Use **Stellarium** to show the sky from the Earth:

- Constellations and different mythologies – there is no single way of seeing it (settings->languages)
- Point out Milky Way – our galaxy – we are looking into the disc
- Rise, set and movement of the stars as well as Celestial Poles (change time rate)
- Blue sky and no stars in day because of atmosphere (remove atmosphere to see stars in day)

- Shooting stars (because of atmosphere – see above explanation under “Stars”)
- Moon’s changing rise position on horizon (speed up time a lot – centre and track moon)
- Changing phases/orientation of the moon (speed up time while moon is centred and tracked)
- Pick a random astronomical event at your location and go to that date (e.g. eclipses)
- Zoom in on planets – it will be in the same orientation when you look at it through a telescope e.g. the positions of Jupiter’s moons, angle of Saturn’s rings etc.
- Show Sun/Moon/stars on other side of Earth (remove ground)
- Varying distances of stars in constellations (click on stars)

Follow up Stellarium Demo with **Celestia** to fly into space
- Rotation of the Earth (and day and night) – show from all angles
- Expand on Stellarium demo – talk about Celestial Poles, Milky Way, LMC, SMC. Show constellation lines then fly to a star in the constellation and turn to look back.
- Show Moon’s orbit around the Earth
- Explain Earth-Sun-Moon system
- Fly to planets and look around – talk about moons around each planet
- Starting at sun, zoom out showing planets’ orbits and rates of orbit (point out Pluto’s “skew” orbit)
- Zoom out of Milky Way and look at it from different angles – stop amidst stars to look around
- Fly to other galaxies, look around, then return home

3. Outdoor Exhibits/Activities

Build exhibits outdoors that use shadows:
- Sundial (simple design with markings on the ground and a stick)
- Solstice stones (like our ancestors, align stones with the Sun during the different solstices)
- Rings on sticks/holes – be innovative – set up objects that will cast shadows at certain places at certain times of the year/day.
- Build scale model of the solar system using people/objects (see table below)

4. Indigenous Astronomy

Learn as much as possible about local knowledge of the sky and document it. Use at other events/activities, especially with children (check out www.saao.ac.za) Examples:
- Southern Africans used the constellation Isilemela (also known as Pleiades) to mark the start of the planting season (this constellation happened to appear in the sky around springtime every year)
- It was believed, in certain parts of Africa, that the Sun was swallowed every evening by a crocodile who passed it out of its other end every morning.
- Eclipses were (and still are) regarded as a bad omen to some cultures and people would hide during eclipses, especially pregnant women.

5. Naked Eye Observing

Locate star charts off the internet (e.g. www.heavens-above.com) or use a programme like Stellarium. The best way to know your way around the night sky is to PRACTICE. Take note of patterns in the sky that you may find easier to remember (these may not necessarily be the given constellations but it will help you).
Important points when you have nothing but the naked eye and a starry sky:
- Movement of stars across sky due to rotation of Earth (especially if you’re outside for hours)
- South Celestial Pole (point on the sky that does not rotate – demonstrate by spinning yourself)
- Southern Cross (Crux and pointers) – use to find South Celestial Pole (extend long side of cross and perpendicular bisector of the pointers – where they meet is South Celestial Pole)
- Orion (in the sword is the Orion Nebula where stars are being born). Tell African Starlore story of hunter (Aldebaran), 3 zebra (3 stars of belt), assegai (sword), lion (Betelguese), wives (Pleiades). Other constellations, a monthly **“What’s up”** and more indigenous stories/links at www.saao.ac.za.
- Note that constellations are just shapes in the sky – one shape is as valid as the next – we just happen to generally use the Greek mythology as a standard.
- 3D nature of the sky – point out differing distances of stars in some constellations. The sky appears as though it’s on a nice 2D sphere but it’s actually VERY 3 dimensional.
- Betelguese and Rigel – stars have colours due to temperature: blue=hotter, red=cooler
- Sirius – approx 8 light years away – brightest star in the sky – note blue colour
- Alpha Centauri – nearest star **system** to our Sun – approx 4.4 light years away – actually a triple star system (Alpha Cen A, B and Proxima Cen which is the closest **star** to our Sun)
- Planets (different planets visible at different times of the year). Planets, being closer, twinkle less than stars. Twinkling of stars caused by atmosphere. Compare stars close to horizon with stars directly above. Stars on horizon twinkle more because we look through more of the atmosphere.
- Milky Way – looking into the disc of our galaxy – try to visualise the orientation of the galaxy

- Andromeda, Large and Small Magellanic Clouds are neighbouring galaxies. The rest of what we see with the naked eye is all in our galaxy (and we are just one of the billions of galaxies out there)
- Satellites: Seen for a few hours after sunset or before sunrise. Predictions for these sightings (especially Iridium flares) can be found on www.heavens-above.com. Satellites appear to us as "moving stars" and are only visible because they reflect the Sun's light.

6. Using a Telescope

Interesting objects to look at with small telescopes/binoculars (use Stellarium or a star chart to find them in the sky and the time of the night/year when they are visible from your location – not all are always visible):

- Moon – point out craters, "terminator" (light/dark line)
- Saturn – point out rings and moons
- Jupiter – bands (lines across the disc) and moons – movement of moons noticeable in few hours
- Mars – red colour of disc, good telescopes can see ice caps
- Venus – phases just like the moon
- Orion's Nebula – fuzzy patch, cloud of dust and gas where stars are being formed.
- 47 Tuc – globular cluster, looks like a fuzzy patch – millions of stars clustered together – imagine what the sky would look like if the Earth was going around one of those stars
- Omega Cen – just like 47 Tuc
- Jewel Box – cluster of stars of different colours (different colours = different temperatures)
- Sirius – very bright and distinctly blue (blue = hotter, red = cooler)
- Betelguese – bright and distinctly red, near end of its life and ready to explode any millennium now
- Pleiades (Isilemela) – star cluster – good for binoculars (see Indigenous Astronomy section above)
- Alpha Centauri – 4.4 light years away – notice the double star (there's actually 3 stars Alpha Cen A, Alpha Cen B and Proxima Centauri further away, the latter being the nearest to our Sun)

7. Workshops and Activities

Try to engage hands on activities in all groups.
Some quick suggestions as a fast and easy activity for specific age groups:

Very young (Primary School):

- Solar system with people (ask kids to represent objects in the solar system and then move according to the movement of the planets/Moon/Sun)
- Scale model of the Universe (if Earth was this size then…). Example below.
- Try to draw your own shadow (see also www.unawe.org)

Older (High School):

- Observe stick shadows over the course of a day and plot positions every 30 mins. Build sundial.
- Build a telescope (plastic lenses and suppliers of such can be sought from SAAO)
- Observe movement of the Moon and its phases over a month.

Adults:

- Engage in conversations about indigenous astronomy

Scales and guide for building a scale model of the solar system:

Actual Object	Diameter (km)	Scaled (mm)	Examples of Demo Object	Orbit (x1000000 km)	Scaled (m)
Sun	1400000	280.0	Ball	0	0
Mercury	4900	1.0	Bead/Seed	60	12
Venus	12100	2.4	Bead/Seed	104	21
Earth	12800	2.6	Bead/Seed	150	30
Moon (Orbit around Earth)	3400	0.7	Grain of sand	0.37	0.074
Mars	6800	1.4	Smaller Bead/Seed	240	48
Jupiter	142800	28.6	Marble	800	160
Saturn	120600	24.1	Smaller Marble	1400	280
Uranus	51100	10.2	Tiny Marble/Pea	3000	600
Neptune	49400	9.9	Tiny Marble/Pea	4500	900
Pluto (dwarf Planet)	2300	0.5	Sand grain	5900	1180

***Some Astronomy Facilities in Southern Africa*: South African Astronomical Observatory; Southern African Large Telescope; Karoo Array Telescope; Hartebeesthoek Radio Astronomy Observatory; High Energy Stereoscopic System; Boyden Observatory; Hermanus Magnetic Observatory; UNISA Observatory (links to these plus info about International Year of Astronomy 2009 can be found on www.astronomy2009.org.za)**