ABSOLUTE AND APPARENT MAGNITUDES
(© Constantine Thomas, 28th May 2005)

The ability to determine the brightness of stars as seen from alien worlds could be quite handy when it comes to making a description of a world seem more 'real'.

To do this, you first need to know what magnitudes *are*. The Magnitude scale is basically the way that astronomers quantify the brightness of stars and other objects (including planets, asteroids, spacecraft etc) that they see in the sky.

Magnitudes for stars range in practise from about -10 to +17, but the possible range of values is theoretically unlimited. The lower the number, the brighter the object. So magnitude 17 object is incredibly dim, and a magnitude -10 object is very bright. There are two different quantities used - the **Absolute Magnitude**, and the **Apparent Magnitude**. **Apparent Magnitude** is a more intuitive concept and is more familiar to us - it's simply the brightness of the object as seen by the viewer. **Absolute Magnitude** is a bit more esoteric - it's the brightness that the object WOULD have if it was placed at a distance of 10 parsecs from the viewer. Since this distance is standardised, astronomers can use that to figure out the actual luminosity of the object - usually a star - being viewed (but we usually know that already, as world-builders).

The magnitude scale is set up so that a difference in magnitude of 5 between two objects corresponds to an increase in brightness by a *factor* of 100 - i.e. the scale is logarithmic. If the difference in magnitude is 0, then the objects have the same brightness (as seen by the viewer).

magnitude difference	0	1	2	3	4	5	6	7	8	9	10
relative difference	1	2.5	6.3	16	40	100	250	630	1600	4000	10000

The relative brightness difference can be calculated by raising 2.512 to the power of the magnitude difference: $(2.512)^{\Delta m}$.

EXAMPLE: If a star has an apparent magnitude of +2 and a planet has an apparent magnitude of -5 (due to light reflected from its surface or cloudtops) as seen from a planet's surface, then the planet appears about 630 times brighter in the sky than the star.

To give you an idea of scale and the numbers used, consult the table below. Planets don't have absolute magnitudes (at least, not in the same sense as stars. I'll get to that in a separate document) - the apparent magnitudes given for planets correspond to when they are brightest as seen from Earth:

Object	Absolute Magnitude	Apparent Magnitude
Sun	4.83	-26.74
Full Moon	-	-12.5
Mercury	-	-1.9
Venus	-	-4.6
Mars	-	-2.91
Jupiter	-	-2.94
Saturn	-	0.43
Uranus	-	5.32
Neptune	-	7.78
Pluto	-	13.56
Alpha Centauri	4.38	0.01
Sirius	1.47	-1.43
Van Maanen's Star	14.21	12.38
Vega	0.58	0.03
Betelgeuse	-5.14	0.45
Antares	-5.28	1.06
Andromeda Galaxy	(-20.64)	3.50
3C 273 (quasar)	(-35.44)	12.8

As a general (not vastly accurate, but close enough) rule of thumb, the highest apparent magnitude that the naked eye can see under ideal viewing conditions is about +6. Objects can cast visible shadows around an apparent magnitude -4 (you'd need a very dark night to see them though - they'd get progressively more noticeable as the object's magnitude decreases). Around an apparent magnitude of between -18 and -21, the object is so bright that its light could scatter in an atmosphere and 'turn night into day' to some extent - at the lower end of this range, the sky would be noticeably "not black" (it would be a very deep blue), especially around the object. Brighter objects would brighten the sky more noticeably and make it a paler blue.

1) CALCULATING THE ABSOLUTE MAGNITUDE (M) OF A STAR

Let's say you are describing a scene on a planet, and want to figure out how bright a distant companion star is. You could be doing this for descriptive purposes, but it might be bright enough to cast shadows, or even possibly turn night into day if the world has an atmosphere! Before we can calculate the Apparent Magnitude, we first have to calculate the **Absolute Magnitude** of the star. To do this, we to know the Luminosity of the star in solar units (*L*), which we should already know as world-builders and GMs. Then plug that into the equation below:

$$M = 4.83 - 2.5\log_{10} L$$

where:

M = Absolute magnitude of the star (magnitude if viewed from 10 pc)
L = Luminosity of star expressed in solar units.

M is constant for a given luminosity - it only changes if the luminosity of the star itself changes (which would happen if it changes into a red giant or white dwarf, or if it is a variable star).

The mathematical jiggery-pokery required to derive this is rather complex, but trust me - this is correct!

2) CALCULATING THE APPARENT MAGNITUDE (m) OF A STAR

Using *M* we can now calculate the **APPARENT MAGNITUDE** of the star, which is how bright it is in the sky at its actual distance from the viewer (which is the information we actually are trying to figure out here).

This is much simpler. All we need to do is to take *M* calculated above and *d* (the distance of the star - the units used can be pc, ly, AU, or km, but see the comments below), and plug them into the equation below:

$$m = M + 5\log_{10}(d / C)$$

C is a constant that depends on the units that the distance to the star is measured.

if *d* is in **parsecs**, then *C* = 10 (= number of pc in 10 pc)
if *d* is in **lightyears**, then *C* = 32.616 (= number of ly in 10 pc)
if *d* is in **AU**, then *C* = 2062641.61 (= number of AU in 10 pc)
if *d* is in **kilometres**, then *C* = 3.08571e14 (= number of km in 10 pc)

That should cover every practical eventuality for the distance units :).

3) EXAMPLES

First, let's test this out on some familiar stars.

a) Procyon is an F5 IV star that is 7.36 times brighter than Sol and 11.4 lightyears from Earth. What are its Absolute (M) and Apparent (m) magnitude?

> $M = 4.83 - 2.5\log(7.36)$, so $M = 2.66$.
>
> $m = 2.66 + 5\log(11.4/32.616)$, so $m = 0.38$.
>
> These values agree with the real values, so this shows that the equations work :).

b) What is the apparent magnitude of Sol as seen from Procyon?

> The Absolute Magnitude of the sun is 4.83 (looking at the M equation, $\log(1) = 0$, so $M = 4.83$).
>
> $m = 4.83 +5\log(11.4/32.616)$,so $m = 2.54$
>
> Sol would appear as a fairly inconspicuous yellow star, visible to the naked eye, in Procyon's sky.

c) What is the apparent magnitude of Sol as seen from Neptune? Neptune is 30 AU from Sol.

> We know the Absolute Magnitude of Sol already. Its Apparent Magnitude from Neptune is therefore:
>
> $$m = 4.83 + 5\log(30/2062641.61) = -19.36$$
>
> At magnitude -19.36, Sol would still look brighter than the full moon seen from Earth as seen from Neptune. It would obviously cast shadows, and would scatter light in Neptune's cloudtops so that the sky would probably be a deep blue as seen by a viewer sitting in the planet's upper atmosphere.

Next, let's use that old Traveller staple, the Regina system to test these out. We'll assume for now that Regina doesn't orbit a gas giant, and is a planet orbiting at 1.6 AU from its primary *Lusor* - an F7 V star with luminosity of 9.8 Sols (since Regina would be relatively close to Assiniboia, this assumption wouldn't really affect the answers we get). *Speck* is a white dwarf with luminosity 0.00003 Sols that improbably orbits Lusor in a close orbit - we'll assume that it is located at 1.55 AU from Regina. *Darida* is a distant M6 V companion with a luminosity of 0.006 Sol, located at 5000 AU from Regina.

a) How bright is Lusor as seen from Regina?

> First, we calculate M: $4.83 -2.5\log(9.8) = 2.35$.
> Then, we calculate m: $2.35 +5\log(1.6/2062641.61) = -28.20$
>
> As one might expect, Lusor is about four times brighter than Sol as seen from Earth.

b) How bright is Speck as seen from Regina?

> After doing the calculations... $M = 16.14$, and $m = -14.49$
>
> Speck is surprisingly bright - if it were just on its own it would be about 6.25 times brighter than the full moon from Earth! It would be bright enough to cast shadows. But given the glare from Lusor (which it is always very close to in the sky), you probably wouldn't actually be able to see Speck from Regina with the naked eye.

c) How bright is Darida as seen from Regina?

> For Darida, $M = 10.38$ and $m = -2.69$.
>
> From Regina, Darida would be a red star a little bit dimmer than Mars as seen from Earth.

(Thanks to Cham, Spaceman Spiff, Selden, and Fridger on the Celestia Boards for helping me figure out the equations!)