The Magnitude Scale: Love It or Hate It

by Steve White (Kitt Peak Observatory)

All astronomers, amateur and professional alike, eventually become familiar with the magnitude scale: the system for describing the apparent brightness of things in the sky. If you want to have any chance of seeing something, you need to know how bright it is, and all objects, be they stars, planets, or galaxies, are described using the same system. If you want to get anywhere in astronomy, it helps to know this system. Too bad it's such a complicated mess!

Well, now, that's not really fair of me. It has advantages, too. Let's examine the magnitude scale step by step, and you can form your own opinion.

How would you describe the brightness of a star? Would you refer to lux, or candlepower, or ergs per second? How about Janskys? It's a tough question. The magnitude scale simply assigns a number to a star, with no units. The bigger the number, the fainter the star. A very bright star, for example, might have a magnitude of 0.2, or 1.5. A star barely bright enough to see from Tucson might be 4.5, while a star so faint that it can barely be seen in the dark skies of Kitt Peak might be 6.2. The brightest star in the night sky, Sirius, blazes away at -1.5 (a negative magnitude!).

This, by the way, brings me to my first complaint. Why in the world does a larger magnitude mean a dimmer star? Clearly a brighter star deserves a higher number. The magnitude scale, by granting higher magnitudes to faint objects, is counterintuitive.

Wait a minute. This weird trait may be useful after all. When the ancient Greeks looked at the sky, they saw only a few thousand stars, all brighter than magnitude 6. In 1610, when Galileo pointed his first telescope at the stars, he found tens of thousands more, fainter than magnitude 6, but brighter than about magnitude 9. Our CCD camera on the Visitor Center Telescope can detect stars as faint as magnitude 20! The Hubble Space Telescope? About magnitude 29. As technology improves, astronomers keep finding fainter and fainter objects, not brighter and brighter ones. If our magnitude scale gave bigger numbers to brighter objects, all the recently discovered ultrafaint objects would have teeny-weeny magnitudes! Actually, they would probably have negative magnitudes, which would give us the same problem all over again.

Another characteristic of the magnitude scale is that it is logarithmic (Gadzooks, a mathematical word! Please bear with me). This is like the Richter Scale for earthquakes, where a 5.0 is ten times stronger than a 4.0, which is ten times stronger than a 3.0. On the Richter scale, a difference of "one" on the scale means a factor of ten in earthquake strength. The scale for brightness needs to work like this as well, otherwise the numbers for magnitudes would just be too big (the brightest star is 1000 times brighter than the unaided-eye limit, and is a trillion times brighter than the Hubble Space Telescope limit. If the magnitude scale wasn't logarithmic, an average star's magnitude might be a number like 498,000,000! Pretty inconvenient).

So, a star of magnitude 5 must be ten times brighter than a star of magnitude 6, right? Not a chance! This is my second complaint, and it's a doozy: A difference of "one" on the magnitude scale does not represent a factor of ten. Oh, no. It represents a factor of 2.511886432.... Good grief! Needless to say, the factor is usually rounded to 2.5, so a star of magnitude 2 is 2.5 times brighter than a star of magnitude 3, which is 2.5 times brighter than a star of magnitude 4. However did this horrible monstrosity come about? Well, some astronomer decided that a 1st magnitude star looked about 100 times brighter than a star of magnitude 6. This is a difference of five magnitudes, and a factor of 100. If a difference of "five" means a factor of 100, then a difference of "one" means a factor of the fifth root of 100, or about 2.5 (in other words, 2.5 x 2.5 x 2.5 x 2.5 x 2.5 = 100, more or less. You can try this on a calculator. Go ahead, no one's looking!).

My final complaint seems negligible by comparison, but it reveals another important feature of the magnitude scale. How bright, exactly, is magnitude zero? I have mentioned that the star Sirius shines at -1.5. There are three other stars bright enough to have negative magnitudes (Canopus at -0.7, Alpha Centauri at -0.3, and Arcturus at -0.1), as well as the Sun (at -26.5!), the Moon (around -12 when full), and five planets (Mercury, Venus, Jupiter, and sometimes Mars and Saturn). Apart from these eleven objects and the occasional bright comet or meteor, everything else in the sky has a positive magnitude.

The Sun, Moon, and planets are fairly unique, but is there anything special about these four bright stars? Not at all. Interestingly, the fifth brightest star in the night sky, Vega, has a magnitude of exactly 0.00, and represents the "zero point" of the magnitude scale. Why Vega? Why not Sirius? I haven't been able to find a good answer to that one, and I've been digging.

As any field of science progresses, patterns and idiosyncrasies that get started arbitrarily can be adopted by enough people so that they stick, and cannot be changed. There's plenty of this in astronomy, and the magnitude scale is a perfect example. What can we do? Look on the bright side. The magnitude scale is unnecessarily complicated and awkward, but once you learn it, you have a valuable tool that turns all those strange numbers into meaningful information. If you are interested in astronomy, it is worth the effort!

Addendum:

Magnitudes of Planets, February 2004

Mercury	M= -.2
Venus	M= -4
Mars	M= 0.7
Jupiter	M= -2.2
Saturn	M= 0.1
Uranus	M= 5.7
Neptune	M= 7.8
Pluto	M= 13.9