Surface Brightness

By Paul Markov, April 2000.

During my first several years of deep sky observing I had never heard of the term "surface brightness". This quantitative measure of the brightness of a deep sky object is extremely important to deep sky observers, but most observing lists, including The Messier Catalogue and The Finest NGC objects in the Observer's Handbook, fail to list it. Even the well respected Burnham's Celestial Handbooks do not list it. Surface brightness cannot be used alone to evaluate an object's visibility, rather it complements the more widely available magnitude data.

The definition of surface brightness is the measure of an object's brightness per unit area. Typically surface brightness is expressed as stellar magnitudes per square arc-minute or arc-second. Galaxies observed by amateurs have an average surface brightness of about 13.5, which means that each square arc-minute of an average galaxy is as bright as a magnitude 13.5 star. To better appreciate how faint this is, aim your telescope at a magnitude 13.5 star then defocus it until it appears one arc-minute across. To help you keep things in perspective remember that the more striking deep sky objects have a surface brightness of just 12.5.

The concept of surface brightness is rather simple and can be easily explained with an analogy. Suppose you aim a flashlight on a wall – it will produce a circle of light of a certain size and brightness. Now take a couple of steps away from the wall – you will notice how the circle of light gets bigger, but also that its brightness has decreased considerably. This simple experiment demonstrates that although the total light output of the flashlight stayed the same, its surface brightness (i.e. the circle of light on the wall) decreased because the same amount of light is now spread out among a larger area.

Another more practical experiment you can try at the telescope to better understand surface brightness is to point your telescope at a moderately bright star and then start defocusing the image. You will notice that as the star is more and more out of focus it will appear larger and fainter. You will reach a point where the star's image in your field of view is very large and is nearly invisible. Of course, the star's magnitude did not change, rather you just made its surface brightness much less by spreading out its total light over a larger area.

The Messier Catalogue has some particularly difficult objects due to their low surface brightness, but many observers do not find out how difficult these are until after spending a long time searching at the eyepiece. M74, for example, has been labeled by many as the most difficult Messier object and I can attest to that since it was the very last Messier object I found while completing my Messier list. Its magnitude is a "bright" 9.4, however because it measures 12 x 12 arc-minutes, its surface brightness is a feeble 14.2. This means that each square arc-minute of its area appears as bright as a 14.2 magnitude star! For comparison, consider NGC 4431 a magnitude 12.9 galaxy in Virgo. Its size is a tiny 1.7 x 1.0 arc-minutes, giving it a surface brightness of 13.5, which is brighter than M74!

On the other hand, there are certain Messier objects whose magnitude is low, but because they are tiny, they have a high surface brightness - a good example is the Ring Nebula, M57 in Lyra. This magnitude 9 planetary nebula is just 1.3 x 1.0 arc-minutes and is visible through a telescope from downtown Toronto because its total light output is concentrated in a small area. Now compare M57 to the Helix nebula NGC 7293 in Aquarius. At first you would think that the Helix would be even easier to see than M57 because its magnitude is 6.3, but after checking its size, a whopping 16 x 12 arc-minutes, you should know this is actually a very challenging object, requiring dark country skies.

Does all this mean we can "throw away" the magnitude data and start using surface brightness alone? Unfortunately it is not quite that simple. Consider the following possibility: a galaxy could be very large, which means we would expect a low surface brightness, but it could have a very bright nucleus. This indicates that although we will have a very hard time seeing the entire galaxy, we will still be able to spot it because of its bright nucleus. The perfect example of this case is M31, the Andromeda galaxy – it has a magnitude of 3.4, but a surface brightness of only 13.5 due to a size of 178 x 140 arc-minutes.

So where can you get this crucial data for every deep sky object you may want to observe? You can buy The Deep Sky Field Guide to Uranometria 2000.0 for about $75, or you can download the Saguaro Astronomy Club database for free at http://www.saguaroastro.org. Both provide the same information, with the main difference being that one comes in a printed book format, while the other is just software. I am sure there are other catalogues and books that provide surface brightness information so check with you local astronomy store.

What I have written in this article is but a simple explanation of surface brightness. The discussion is much more complex and involves how the human eye responds to light at different wavelengths and colours. For a much more thorough explanation see the article by Roger N. Clark called "What Magnitude is it?" in the January 1997 issue of Sky & Telescope.

So if someone asks you to find UGC 9749, a magnitude 10.9 galaxy in Ursa Minor, do not even set up your scope until you determine its surface brightness. You will have saved yourself a lot of time and aggravation by first finding out that this apparently easy object has a surface brightness of 17.8!