Measuring the ligth

A celestial body emits luminosity, <<L>>, or radiated energy per second in any direction, so for instance, the Sun emits $Lo = 4 \cdot 10^{33} erg \cdot \sec^{-1}$. The knowledge of the celestial body luminosity is important, it talks about physical processes developing in it.

Each square centimetre of the body's surface emits to the space a flux, <<q>>, or radiated energy per second and square centimetre. If the body emits energy in a uniform way trough all it's spherical surface we'll have

$$L = 4\pi R^2 \cdot q$$

Where R is the body's radius. If the light were not extinguished in its path, all the light emitted from the body would reach the sphere of radius r in a way that

$$4\pi R^2 q = 4\pi r^2 f$$

Where f is the flux received at the distance r, and so we have,

$$f = q\frac{R^2}{r^2}$$

We can see that the flux is inversely proportional to the square of the distance, the light from the more distant bodies weakens as distance grows very quickly.

When instead of a punctual body we observe an extended one, like for instance a near comet, we can distinguish and specify the incoming light from different areas of the object, we define then, the intensity, <<I>>, as the radiated energy per second by a region of the object that we can see under a solid angle of one square second.

If we add the light coming from all the areas of the object we'll obtain the total flux emitted by the source that reached here,

$$f = \int_S I ds$$

We have seen how the flux received on earth depended strongly on the object's distance, more precisely according to the inverse of the squared distance. The intensity, I, however is of great interest because it doesn't depend on the distance. Effectively, the true area at the source is that of a solid angle of one square second, will be greater when r grows, it will actually grow with the second power of the distance. On the other hand the light will be lost with the second power of the distance. Both effects compensate and the net result is that the intensity doesn't depend on the distance. Therefore the intensity informs us directly about physical processes developing in the source. When we observe a source with high detail (high spatial resolution) we are able to obtain the intensity, I, with greater precision and in more source areas, the values shouldn't differ apart from the errors made when observing with low spatial resolution.

Photometry

Hipparcos (190 ac – 120 ac) classified stars into 6 categories, being the most brilliant the first magnitude and the barely perceptible to the naked eye sixth magnitude. To accommodate Hipparcos scale, we define the magnitude, m, of a star, by means of the formulae,

$$M = -2.5\log\frac{f}{fo} \quad (1)$$

Where f is the flux at the earth and fo a constant. To be noted in this formulae is the logarithm (The Hipparcos eye had a more or less logarithmic response, like any human), the minus sign (accounting for the fact that the more brilliant stars have the lower magnitudes like in the Hipparcos categories) and the constant fo (to adjust and make the scale match the Hipparcos model). The magnitude is hence, closely related to the flux.

If a star has a very high magnitude, i.e. it is very weak, it's due to it's distance or because the star is intrinsically weak. In order to compare stars we define the absolute magnitude, <<M>>, as the magnitude the star would have situated at a standard distance of 10 pc, one pc (parsec or second of parallax) is the distance at which one astronomical unit subtends and arc of one arc second and is more or less 3.26 light years.

The absolute magnitude is related to the luminosity and it's easy to prove knowing the Suns absolute magnitude and luminosity Mo and Lo that,

$$M = 4.72 - 2.5\log\frac{L}{Lo}$$

When the source is extended, we use the magnitude per squared second, μ, which is in turn related to the intensity as in

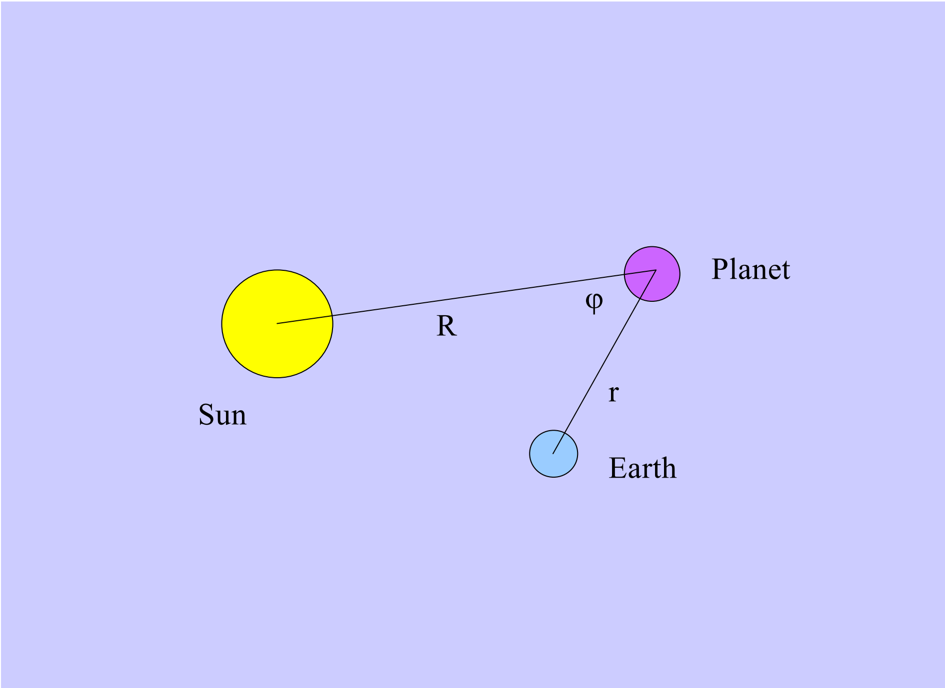
$$\mu = -2.5\log\frac{I}{fo}$$

In practice, the observing field will not be 1 squared second, depending on the characteristics of the telescope, but a solid angle A. If we detect m using A, it's easy to find that

$$\mu = m + 2.5\log A$$

Whenever we admit that in any point of A the magnitude is constant.

Planetary Photometry



When observing planets, the observed magnitudes depend on various factors,

1 – The distance from the planet to the Sun
2 – The distance from the planet to the Earth
3 – The phase angle φ

Let I_0 be the intensity of the light reflected by the planet into the Sun's direction, the intensity in another direction specified by the phase angle φ will only depend on I_0 and φ, i.e.

$$I = Io \cdot f(\varphi)$$

Where $f(\varphi)$ equals 1 when the phase angle φ is zero. The flux, emitted by the planet, that reaches the Earth is,

$$F = \frac{I}{r^2 \cdot R^2}$$

Now we can write the magnitude as a function of the flux according to (1)

$$m = -2.5\log\frac{F}{fo}$$

$$m = -2.5\log\frac{I}{fo \cdot r^2 \cdot R^2}$$

$$m = C - 2.5\log\frac{Io \cdot f(\varphi)}{fo \cdot r^2 \cdot R^2}$$

Thus, we have,

$$m = m_0 + 5 \cdot \log(r \cdot R) - 2.5\log f(\varphi)$$

where m_0 is the magnitude the planet would have when situated at 1 a.u. of the Sun and at a 1 a.u. of the Earth, with a phase angle of zero.

The standard HG system

Bowell defined the HG magnitudes system, that has been adopted by the MPC, the formulae used to compute asteroidal and cometary magnitudes is :

$$m = H + 5 \cdot \log r + G \cdot \log R$$

Where H and G are "constants" computed for each object, H basically the object's absolute magnitude and G accounts for the brightness change depending on the distance to the Sun.

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