larger than the Rosetta or be it a binary, as shown in Fig. 2 with Rosetta for comparison.

2014 MU69's shadow traces its most likely binary shape, as seen in the stellar occultation that occurred over Argentina on 17 July 2017. The best-fit red circles reveal MU69's possible doubled-lobed – or binary – nature

1 *MNASSA* Vol **76**, Nos 5 & 6, June 2107
2 *MNASSA* Vol **76**, Nos 7 & 8, August 2107

## The real meaning of magnitude per square arc-second

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Intuitively, observing faint objects with low surface brightness against a bright sky will be difficult. In order to achieve some kind of metric, amateur astronomers frequently quote sky brightness in terms of magnitude per square arc-second (mpsas). A very good night sky will have a brightness of 21.8 mpsas or greater while inner-cities are subjected to 15 mpsas rendering all but the brightest stars invisible.

In conversation, the editor of this journal asked "…but what is it?"

We'll start with how stellar magnitudes are defined. In short, they are a logarithmic scale which – apart for slight corrections - uses Vega as a zero reference. In the visible part of the spectrum, Vega's emission corresponds to a black body with a surface temperature near 11 000 kelvin. The received energy per photometric band is given by Bessel 1979 [1]. An alternate set of measurements are presented in Bessel 1990 [2].

| | Bessel (1979) | | |
|---|---|---|---|
| **Photometric Band** | **Effective wavelength** | **FWHM Bandwidth** | **Mag zero flux** |
| | nm | $d\lambda/\lambda_0$ | Jy |
| **U** | 360 | 0.15 | 1810 |
| **B** | 440 | 0.22 | 4260 |
| **V** | 550 | 0.16 | 3640 |
| **R** | 640 | 0.23 | 3080 |
| **I** | 790 | 0.19 | 2550 |

The Jansky (Jy) is a curious unit that's normally used in radio astronomy. This identity quoted by Wirth & Huchra [3] can be useful

$$1\,\text{Jansky} = 1.51\times10^{7}\,\frac{\text{photons}}{\text{sec}}\times\frac{1}{\text{m}^2}\times\left(\frac{d\lambda}{\lambda_0}\right)^{-1} \qquad (0.1)$$

**As an example**

Suppose we're interested in the B-band flux at the top of the atmosphere coming from a 17.3 magnitude star. We can calculate it directly

$$\begin{aligned}\text{Flux} &= 10^{-0.4\times17.3}\times4260\,\text{Jy}\\ &= 5.12\times10^{-4}\,\text{Jy}\\ &= 5.12\times10^{-4}\times1.51\times10^{7}\times0.22 \qquad (0.2)\\ &= 1700\left(\frac{\text{photons}}{\text{sec}}\times\frac{1}{\text{m}^2}\right)\end{aligned}$$

**So what is it really**

We're considering visible photons, so let's calculate the number of V-band photons corresponding to 21.8 mpsas. Each square arc-second of the sky will deliver

$$\begin{aligned}\text{Flux} &= 10^{-0.4\times21.8}\times3640\,\text{Jy}\\ &= 6.94\times10^{-4}\,\text{Jy}\\ &= 6.94\times10^{-4}\times1.51\times10^{7}\times0.16 \qquad (0.3)\\ &= 16.8\left(\frac{\text{photons}}{\text{sec}}\times\frac{1}{\text{m}^2}\right)\end{aligned}$$

This is (barely) detectable to the dark adapted eye, let's assume the eye is dilated to 6.5 mm and the visual acuity is a disc ~2 arc-minutes in diameter. This means the eye is responding to about 6.3 photons per second. Quite astonishing.

The manufacturers of a popular *Sky Quality Meter* supply this expression [4]

$$\text{Illuminance} = 1.08 \times 10^{5-0.4\times\text{mpsas}} \left( \frac{\text{cd}}{\text{m}^2} \right) \qquad (0.4)$$

The candela is defined as a basic SI unit but it's effectively given by:

$$1\,\text{cd} = \frac{1}{683}\frac{\text{watt}}{\text{sr}} = 3.441\times 10^{-14}\frac{\text{watt}}{\text{arcsec}^2} \qquad (0.5)$$

So that (1.4) can be re-written as:

$$\begin{aligned} \text{Illuminance} &= \frac{1.08\times 10^5}{683} \times \frac{\text{sr}}{4.255\times 10^{10}\text{arcsec}^2} \times 10^{-0.4\times\text{mpsas}} \\ &= 3.719\times 10^{-9} \times 10^{0.4\times\text{mpsas}} \qquad (0.6) \\ &= 3.719\times 10^{-9-0.4\times\text{mpsas}} \left( \frac{\text{watt}}{\text{m}^2\text{arcsec}^2} \right) \end{aligned}$$

So that for 21.8 magnitude skies, we get:

$$21.8\text{mpsas} \approx 0.709\times 10^{-17}\frac{\text{watt}}{\text{m}^2}\frac{1}{\text{arcsec}^2} \qquad (0.7)$$

For comparison, Bessel's values give:

$$21.8\text{mpsas} \approx 0.607\times 10^{-17}\frac{\text{watt}}{\text{m}^2}\frac{1}{\text{arcsec}^2}$$

This suggests that the Unihedron SQM-L exaggerates the mpsas measurement by $709/607 = 1.168 = 0.17$ magnitudes. The difference is consistent with the author's measurement of 21.97 mpsas (Leeuwenboschfontein, Karoo, 2016.12.30) and the Cerro Tololo Inter-American Observatory site's moonless measurement of 21.8 mpsas [5].

### References


1. UBVRI Photometry II: The Cousins VRI system, Bessel, M. S., *PASP* 1979 vol **91** p 589 available from http://iopscience.iop.org/article/10.1086/130542/pdf

2. UBVRI Passbands, Bessel, M. S., *PASP* 1990 vol **102** p 1181. Available from http://iopscience.iop.org/article/10.1086/132749/pdf

3. Wirth GD & Huchra, J, Astronomical Magnitude Systems, Harvard-Smithsonian CfA, https://www.cfa.harvard.edu/~dfabricant/huchra/ay145/mags.html

4. Unihedron SQM Frequently Asked Questions – there's a calculator here http://unihedron.com/projects/darksky/magconv.php

5. CTIO / NOAO Newsletter No. 10 quoted in [3].


## The bright bolide of 2017 June 15


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### Introduction

On the early morning of 15 June, 2017, as thousands of South Africans were on their way to work, a spectacular bolide was widely observed from the Eastern Cape, Kwazulu-Natal, Free State, Gauteng and Mpumalanga provinces. This event was the brightest since the super-bolide of 21 November, 2009 (Cooper 2011) and the Daytime Bolide of 12 March, 2013