Using Handheld Unihedron SQM-L Sky Quality Meters for DarkSky International Dark-Sky Places Annual Reports

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This paper is to assist those tasked with the purpose of demonstrating and monitoring the darkness of the sky at a dark sky place. It's based on the author's experience over the past 15 years at locations ranging from urban centers, national parks and Chile.

The discussion here is specifically about the sky quality meters (SQMs) manufactured by Unihedron, the SQM-L**(1)** model. However, many points will apply to any dark sky measurements with similar technology from different manufacturers.

A second paper will cover datalogging meters for sky quality measurements (SQMs).

Locations

Choose locations that are the darkest, as well as the most frequently used for night-sky gatherings in the dark sky place. For an extended place, also consider representative geographical dispersion. These guidelines are presented by DarkSky**(2)**:

"It is best to take a number of measurements at various locations to show the gradient of the brightest to darkest areas within the site, as well as show the 'typical' nighttime experience within the location. Places where night sky viewing is popular are important to capture. Consider public gathering places like visitor centers, parking lots, and campgrounds to capture the brightest measurements, and more remote sites for the darkest (safety for both humans and wildlife should always be a priority, so please choose sites accordingly)"

Pick the Best Nights

For the purposes of demonstrating a dark sky place, you want to pick only the best nights! No moon (10 degrees or more below the horizon), no twilight, highest transparency. After all, you are demonstrating the darkness of the skies. Not close to light sources from any nearby buildings, etc. Having said this, note if any deleterious conditions are present on the nights of the measurements. This includes any distant lights that may be visible or light domes.

Astronomical twilight is defined as when the sun is more than 18 degrees below the horizon. Use a planetarium program like Stellarium or a source such as timeanddate (https://www.timeanddate.com/worldclock/astronomy.html) to determine this for the geographic measurement location.**(3)** They can also be used to determine the lunar altitude.

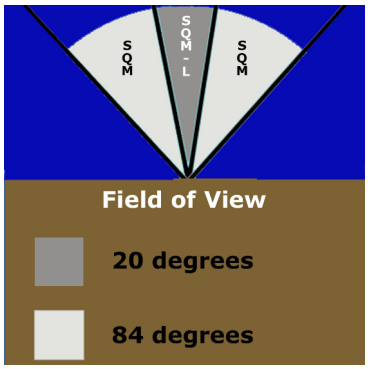
Look for deep-sky objects potentially visible to the unaided eye such as the Andromeda Galaxy (M31), Triangulum Galaxy (M33), Great Cluster in Hercules (M13), Bode and Cigar Galaxies (M81 and M82), etc. Note their visibility (easy, hard, averted vision, etc.) and altitude in the sky. This helps to determine if the transparency is good. In general, if the brighter of these objects and faint

constellation patterns aren't visible in an otherwise dark location, the transparency is too poor to take SQMs.

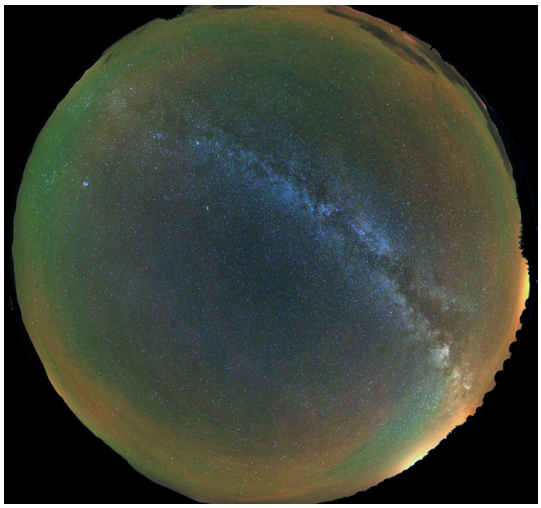
Clouds will look bright above light pollution sources. They will look dark in a truly dark location with no light pollution. So clouds can either brighten or dim SQMs.

Natural Sources of Note

The Milky Way can brighten SQM-L measurements by up to 0.4 mags.**(4)** This effect is strongest for the darkest sites, as magnitude is a logarithmic scale and the effect adds logarithmically to the sky background per Pogson's Law. You can determine if the Milky Way is in the 20-degree wide field of the SQM-L with a planetarium program. If it is, either reschedule or note that the Milky Way is in the beam in your report. (The original SQM has an even wider beam of 84 degrees.)



Nights with auroral activity should not be chosen to collect SQMs. Instead, photograph the aurora!



Airglow is light emitted at night by chemical recombination reactions of molecules that were energized by solar radiation during the day. It's brighter around times of solar sunspot maximum approximately every 11 years but always present to some extent. It's brightest near the horizon as this is the longest sightline through the air and appears as a colorless gray glow to the eye. (Even short-exposure imaging will reveal its characteristic pink and green bands.) If seen, note its presence.

Zodiacal light is generally not visible at the zenith and therefore not a concern; however, the related zodiacal band and gegenschein can be. Note if zodiacal light is visible at the time of your SQMs.

Taking Measurements

Allow the meter to reach thermal equilibrium with the outside air. A rapidly cooling (heating) meter gives less accurate readings. Take into account for your task that it can take 15-45 minutes to get within a degree C of outside temperatures if transferred from an inside to an outside environment (this includes the cab of your vehicle). Also flush the meter – take several rapid, preliminary results before recording results – for greater stability. Once readings are within a few hundredths magnitudes of each other recording can begin.

Holding the meter overhead, point it straight up toward the zenith.

Observe and record four readings each while facing N E S W. The measurements should go quickly and the complete set only take a few minutes. Record the time and temperature for the first south measurement (9th data point).

Average the result. This is the value you use in the report for that time and place. The data spreadsheet**(5)** will calculate the average and a sample standard deviation (SD) for the set. A good set will have a SD value under 0.1.

A Worked Example

OBSERVATIONAL DATA
Location:
Blue Mesa, Petrified Forest National Park and International Dark Sky Park

Conditions:
Clear with slight haze low in the northwest. Meter temperature 26°C. Bortle 3; Andromeda Galaxy low in NE, bright.

North	East	South	West
21.34	21.40	21.42	21.21
21.34	21.38	21.37	21.23
21.36	21.39	21.36	21.25
21.36	21.40	21.38	21.26

Mid-time of measures 1050PM MST July 6, 2024

REDUCTION
Calculation of magnitude per square arcsecond (mag./arcsec^2)

Add all 16 observations (N = 16) and divide by 16. This is the mean or $\overline{x}$

$\overline{x}$ = 21.34 mag./arcsec^2 is the reported value for sky quality.

How good is this value?

$$SD = \sqrt{\frac{\Sigma(x-\overline{x})^2}{N-1}}$$

Standard deviation (SD) is the accepted way to determine this. A low SD means the measurements are close to the average, high not as close.

1) Subtract the mean from each value x to get the deviation of each measurement.
2) Square the difference to eliminate negatives.
3) Add up (Σ) all 16 resulting numbers.
4) Divide by 1 less than the number of measurements (sample) to get the variance.
5) Take the square root. This is the standard deviation.

Deviations

North	East	South	West
21.34–21.34=0	21.40-21.34=0.06	21.42-21.34=0.08	21.21-21.34=-0.13
21.34–21.34=0	21.38-21.34=0.04	21.37-21.34=0.03	21.23-21.34=-0.11
21.36-21.34=0.02	21.39-21.34=0.05	21.36-21.34=0.02	21.25-21.34=-0.09
21.36-21.34=0.02	21.40-21.34=0.06	21.38-21.34=0.04	21.26-21.34=-0.08

Squares

North	East	South	West
0*0=0	0.06*0.06=0.0036	0.08*0.08=0.0064	-0.13*-0.13=0.0169
0*0=0	0.04*0.04=0.0016	0.03*0.03=0.0009	-0.11*-0.11=0.0121
0.02*0.02=0.0004	0.05*0.05=0.0025	0.02*0.02=0.0004	-0.09*-0.09=0.0081
0.02*0.02=0.0004	0.06*0.06=0.0036	0.04*0.04=0.0016	-0.08*-0.08=0.0064

Sum
Σ = 0+0+0.0004+0.0004+0.0036+0.0016+0.0025+0.0036+0.0064+0.0009
+0.0004+0.0016+0.0169+0.0121+0.0081+0.0064

= 0.0649

Variance
0.0649/15 = 0.00433

Standard deviation (the square root of above) is 0.07 magnitudes for the dataset that yielded SQM of 21.34.

Discussion

Q: What caused this SD value?
A: Perhaps the transparency. Notes indicate haze in the sky near the horizon.

Q: I have two meters at the same location. Yet they vary by 0.1 mag./arcsec**2 or more. What could have caused readings to be different?

A: Differences between meter measurements may be caused by:
-Pointing
-Age of the SQM darkens results
-Cover dirty
-Modification of meter

REFERENCES

1 - Sky Quality Meter–L and its instructions
https://www.unihedron.com/projects/sqm-l/
https://www.unihedron.com/projects/sqm-l/Instruction_sheet.pdf

2 – Night Sky Quality – Condensed.pdf. Undated document, DarkSky International.

3 - How to How to conduct a night sky quality survey – Dark Sky International, November 15, 2024
https://darksky.org/resources/guides-and-how-tos/how-to-conduct-a-night-sky-quality-survey/

4 - Certification of the Chile AURA Observatory Site as an International Dark Sky Sanctuary, 2015, page 19.
https://darksky.org/app/uploads/2015/08/AURA_IDSS_application.pdf

5 - SQM Data Spreadsheet and Fieldsheet - New Mexico DarkSky 2026