A Photographic Method for Measuring Sky Glow

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Purpose

Several approaches have been used to measure the visibility of stars in relation to atmospheric illuminance and sky glow. (Isobe, S.; Gartsang; R.H., Upgren, A.R; Walker, M.F.). More recently, satellite imaging has been used to create a map of the United States that estimates sky glow based on light emissions from the ground (Albers, S.).

While each of these methods have advantages, the amateur astronomer is faced with several obstacles to using them:
-Photometric methods require specialized equipment;
-Visual methods are subject to numerous biases, and limited to stars brighter than 7mv;
-Satellite imagery represents large geographic areas, but does not show local variations.

We chose to address these problems by developing a photographic method for measuring sky glow that uses visual magnitudes (mv) of stars to avoid visual biases. This method can discriminate local differences in sky glow, and is useful for identifying dark sky sights for astronomical observation. It can also be used as a teaching tool to illustrate sky glow caused by cities

Choice of Stars Photographed

Photography of Polaris and surrounding stars was chosen to allow for adequate exposure times without star image trailing. A good selection of stars with visual magnitudes (mv) between 15 and 1.9 are apparent within the 11 degree field of view photographed.

At the latitude of Madison, WI (43 degrees north), photography of Polaris also provides for nominal representation of extinction and aerosol phenomenon encountered between the zenith and horizon.

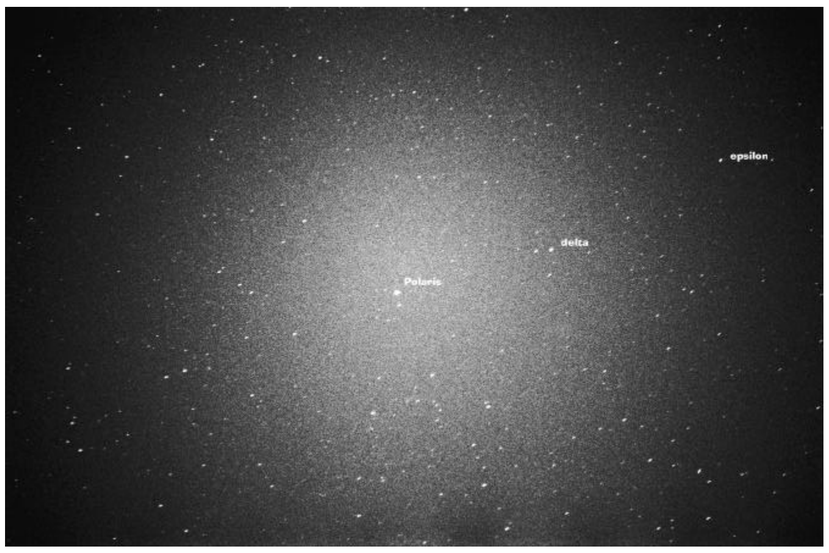
Reading Stellar Magnitudes

To avoid artifacts caused by variations in film development or printing, only exposures from a single roll of film were compared. Examination of exposures from a single site using the 12X loupe quickly indicated the most suitable exposure to read (i.e. showing the faintest stars at the threshold of sky glow)

For each chosen exposure, four reference stars at the threshold of detection were identified and their visual magnitudes and Guide Star Catalog (GSC) numbers recorded.

Some experience was required by the reader before consistent criteria for identifying and selecting threshold stars were achieved. This experience included gaining familiarity with asterisms in the vicinity of Polaris and recognizing which stars were above the threshold of detection for a dark site, while below the threshold of detection for an incrementally brighter site.

Sky Glow Above Madison Wisconsin
(as seen from 65 kilometers west)



Stars Around Polaris
(Madison)

Stars Around Polaris
(65k west)

Materials & Methods

Camera: Minolta SRT101, manual, 35mm SLR, 100mm f2.5 lens, bulb release, tripod.

Film: Kodak TMAX P3200 (TMZ 35/36) developed as shot at 3200ASA

Contact Prints: Out-of-sleeve exposure 5.0 seconds w/ #30 magenta filter

Stellar Magnitudes: Manual identification from within an eleven degree field of view centered on Polaris. Taken from contact prints using 12X loupe. GSC # and mv identified using TheSky Level II version 5.0 for Windows.

Location of Sites

We selected sites located on a transect west from the primary regional source of light pollution (Madison, WI). We chose a series of locations at increasing distances from the city center to a distance of 65 kilometers. Additional locations to the northwest and southwest were selected for comparison.

Photography

Night sky photographs were taken on moonless nights, that were free from clouds or haze, between January and July 1999. Photography commenced 1.5 - 2.5 hours after sunset depending on the season.

Rural sites were free from local light sources or glare from distant lights. Suburban and urban locations were chosen as representative of typical areal light levels.

The camera was mounted on a tripod, and a series of exposures were then taken using a bulb release. One roll of film (36 exposures) was used for all sites on a given night.

Film Exposure

Exposure times ranged from 5-90 seconds, timed with a hand held stopwatch illuminated by a low-light green-LED flashlight shielded from the camera lens. Several series of preliminary exposures at each location were required to determine the exposure time used for quantitation.

Exposed prints selected for quantitation showed light haze from light pollution; bright stars not overexposed; and the faintest stars not underexposed. Three or four exposures of slightly differing lengths were normally required at each site to obtain a suitably exposed print.

Data Reduction Example

June 17, 1999 – site #1, 33 kilometers west of Madison, WI
Four stars at the threshold of detection were identified on contact print:

GSC#	mv
4628:53	12.36
4627:80	11.16
4628:31	11.63
4628:73	12.60
Average	11.94mv

A nominal 0.4mv correction factor for atmospheric extinction was applied:

mv=11.54

We defined the sky glow threshold level as 0.5mv fainter than the average mv corrected for extinction:

Tmv=12.04

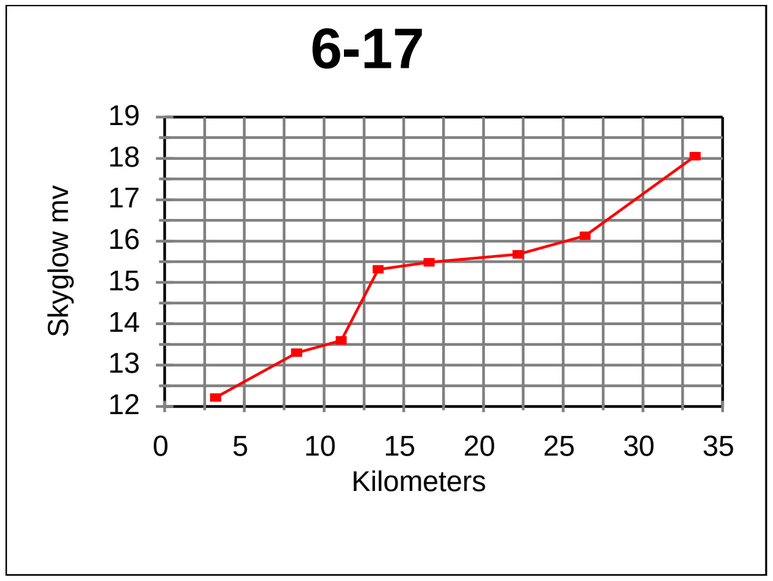
Then, we corrected Tmv to account for the difference in photographic image brightness between the stars (point sources proportional to the square of the aperture), and the sky glow (an “extended object” proportional to the square of the focal ratio):

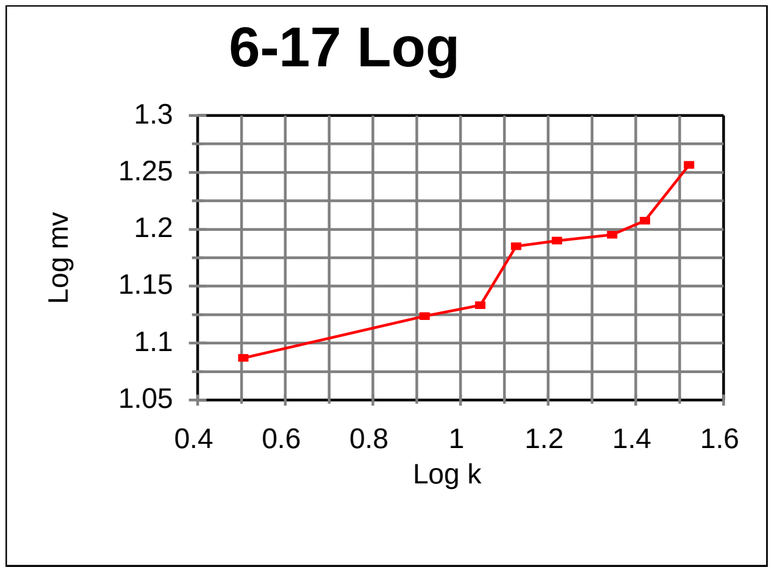
Aperture - 40mm, D^2 = 1600;
Focal ratio - 2.5, f^2 = 6.25
Ratio of point source to extended object brightness - 1600/6.25 = 256

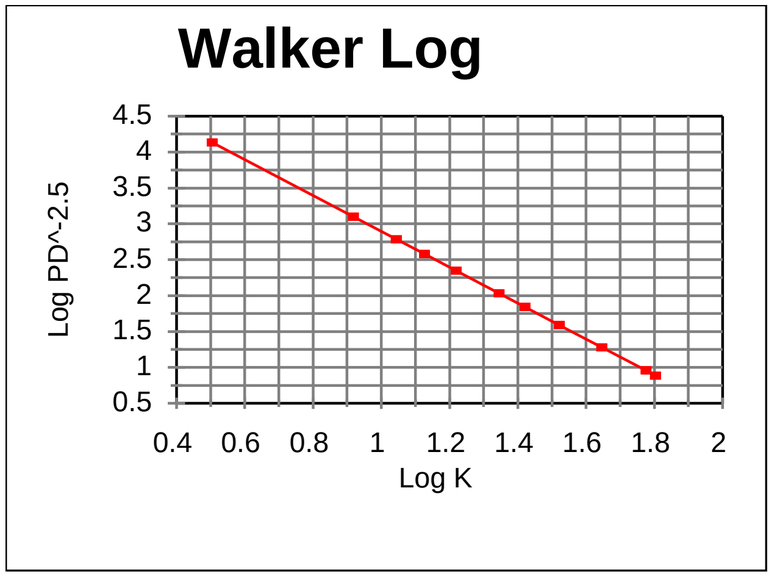
So, the actual Tmv relative to the mv of the stars:

Log 1/256=0.4(x-Tmv)

Thus, sky glow = 6.02Tmv + 12.04mv = 18.06mv



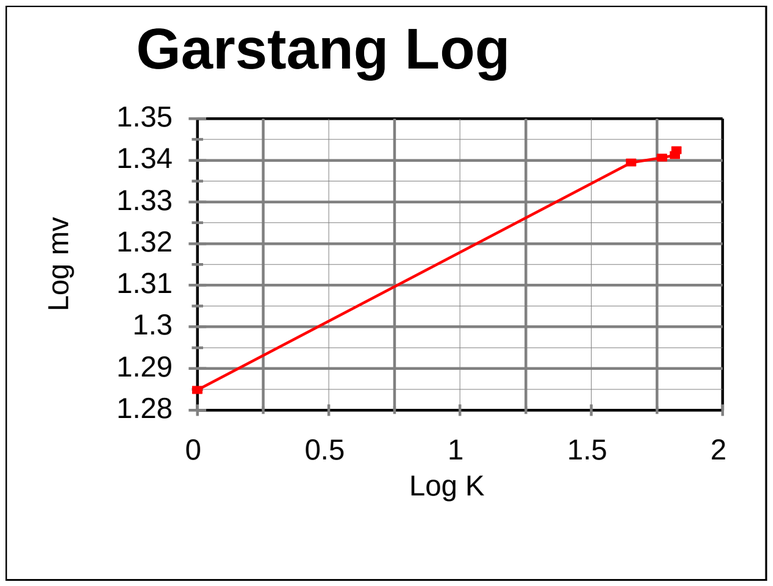




Discussion

The method we have described is able to discern changes in sky brightness over distances as small as a few kilometers, and over a range of at least 10mv. While the results of this method are not directly comparable to photometric or visual methods, the resulting profile of sky glow vs distance is similar to predictions based on population alone. (6-17 Log, Walker Log, Garstang Log)

As an internally consistent method for measuring sky glow, this photographic method combines ease of use, lack of visual bias, good reproducibility, with a permanent record of observed conditions. It has proven useful for identifying dark sky locations for amateur astronomy, especially if travel distance is a consideration.



Acknowledgments

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*** For More Information**
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