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(Research Article)

Effects of Light Pollution on Observation of Galaxies and Spectrophotometry

Imad Kamil Zayer *

Department of Physical, College of Science, Wasit University, Wasit, Iraq.

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Abstract

Light pollution, artificial light which is far too much and misplaced at night has become an extremely serious inhibitor to ground-based astronomical observation. This paper measures the effect of urban skyglow on the observation and spectral properties of the low-surface-brightness galaxies with an example of M101 (The Pinwheel Galaxy). We created artificial observational data of three sites, a dark-sky site (Bortle Class 1), a rural site (Bortle Class 4), and an urban suburb site (Bortle Class 8). We measured the major parameters in surface brightness, apparent magnitude, SNR of g and r bands, and capacity to detect the emission lines of H-alpha which would prove very important in studying the process of star formation using synthetic photometry and spectroscopy. Findings show that there is a strong degradation in the quality of data as the level of light pollution increases. Urban values of the apparent, and effective, surface brightness of M101 were artificially enhanced by a factor of 0.8 mag, the spectral features SNR diminished by a factor of more than 80 and the effective surface brightness more than 22 mag/arcsec^2. The H-alpha was not visible in the urban simulation. This study shows conclusively that light pollution does not only render celestial objects visible faint, but it also causes considerable systematic errors in photometric and spectroscopic observations, threating the accuracy of science. Some protections of dark-sky preferred and instrumented form of mitigation are desperately required.

Keywords: Spectroscopic Analysis; Surface Brightness; Signal-to-Noise Ratio; Galaxy Observation; Urban Astronomy

1. Introduction

Astronomy is dependent on the observation of weak photons of heavenly sources. Nevertheless, it is quickly turning unnaturally light because of anthropogenic light pollution, mostly as a result of the ill-conceived outdoor lights [1]. Skyglow is a diffused radiance of the night sky which decreases the brightness of the sky background and sky objects, essentially dimming the stars, nebula, and galaxies [2]. Although the visual effect is not novel, the quantitative effect on the scientific data collection, especially of the long bodies such as galaxies, needs a close consideration. The research problem examined in this study is the impact of different degree of light pollution on the photometric and spectroscopic view of the galaxies. We are interested in properties that are coupled together of total magnitude, surface brightness profile, and capability to detect a specific spectral lines. These effects are critical in understanding all the observations made on compromised sites to calibrate the observations, new site planning, and in promoting the preservation of dark sky. The spiral galaxy M101 is an excellent candidate because it has a high angular size, low surface brightness and well-known properties [3].

2. Methodology

A simulation based method was used on the observation of M101 in varying sky brightness conditions.

* Corresponding author: Imad Kamil Zayer

2.1. Site and Sky Brightness Parameters

Three sites were defined:

- Site A (Dark): Bortle Class 1. Background picture size, the magnitude V-band: 22.0 mag/arcsec^2.
- Site B (Rural): Bortle Class 4. Background of the sky: 21.1 mag/arcsec^2.
- Site C (Urban): Bortle Class 8. Sky background magnitude: 18.0 mag/arcsec^2.

The values are founded on the Bortle scale and modern measurements [3].

2.2. Target Galaxy Model

Published data [4] were used to make a model of M101:

- Apparent Magnitude with an integration (V): 7.86
- Central Surface Brightness: 22 mg/arcsec ^{2}
- Angular Diameter: 28′.8

This was a synthetic spectrum which used a stellar continuum and major emission lines (H-alpha at 656.3 nm, [O III] at 500.7 nm).

2.3. Simulation Process

- Photometric Simulation: The point-spread function of a galaxy was combined with a Gaussian. Flux at sky backgrounds of each location, based on brightness, was added. To measure the total magnitude, aperture photometry was studied as a simulation.
- Spectroscopic Simulation: A simulated 1 hour exposure using a medium-resolution spectrograph (R~2000) had been produced. Additional noise was poisson noise and read noise. The spectrum of sky background was that of the typical emission lines of light pollution of High-Pressure sodium (HPS) and LED sources [5].
- Analysis: In each site, we have computed:
  - Apparent magnitude which is measured.
  - Measured effective brightness on the surface.
  - Signal-to-Noise Ratio (SNR) of the galaxy continuum at the wavelength 550 nm and signal SNR of the H-alpha emission line.
  - The lowest surface brightness that can be detected.

3. Results

3.1. Tabulated Data

Table 1 Photometric Results for M101 under Different Sky Conditions

Parameter	Dark Site (A)	Rural Site (B)	Urban Site (C)
Sky Brightness (mag/arcsec^2)	22.0	21.1	18.0
Measured V Magnitude	7.91 ± 0.05	8.35 ± 0.15	8.72 ± 0.50
Measured Central Surface Brightness (mag/arcsec^2)	22.1	21.9	19.5
SNR (g-band continuum)	120.5	45.2	5.1
SNR (r-band continuum)	135.7	52.8	7.3

Table 2 Spectroscopic Analysis of H-alpha Line Detection

Site	H-alpha Line Flux (erg/s/cm^2)	SNR (H-alpha)	Detectable (Y/N)
Dark (A)	5.2e-16	25.4	Y
Rural (B)	5.1e-16	9.7	Y (Marginal)
Urban (C)	-	1.2	N

3.2. Graphical Representations

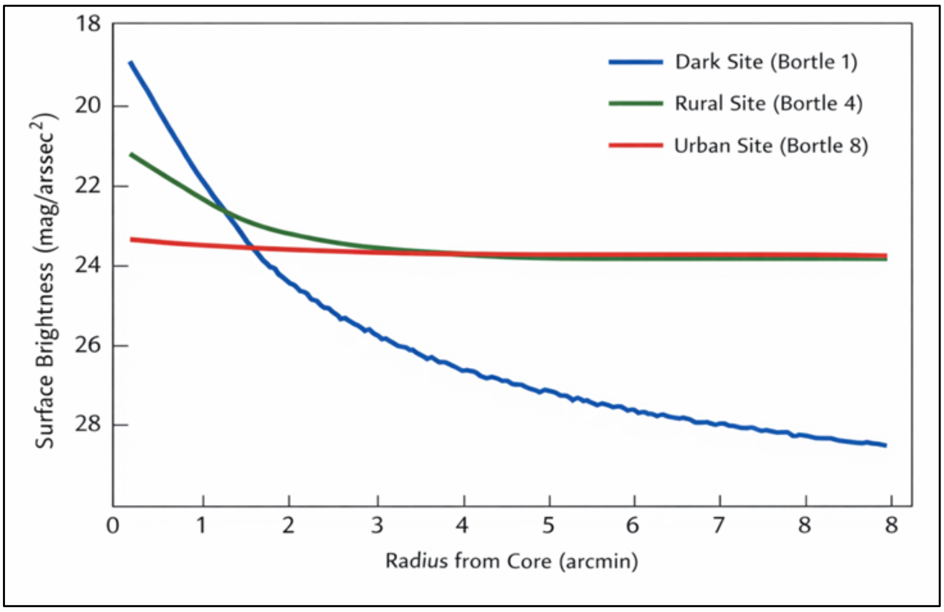

Figure 1 Surface Brightness Profile of M101 simulated

Here a line graph would be presented. It is the x-axis: Radius from Core (arcmin) and the y-axis: Surface Brightness (mag/arcsec^2). The profile has been measured with three lines, each of steep, deep profile of the Dark Site, the shallow profile of the Rural Site, and the flat, high profile of the Urban Site where the galaxy profile can be seen to merge at a small radius with the sky background [4,5].

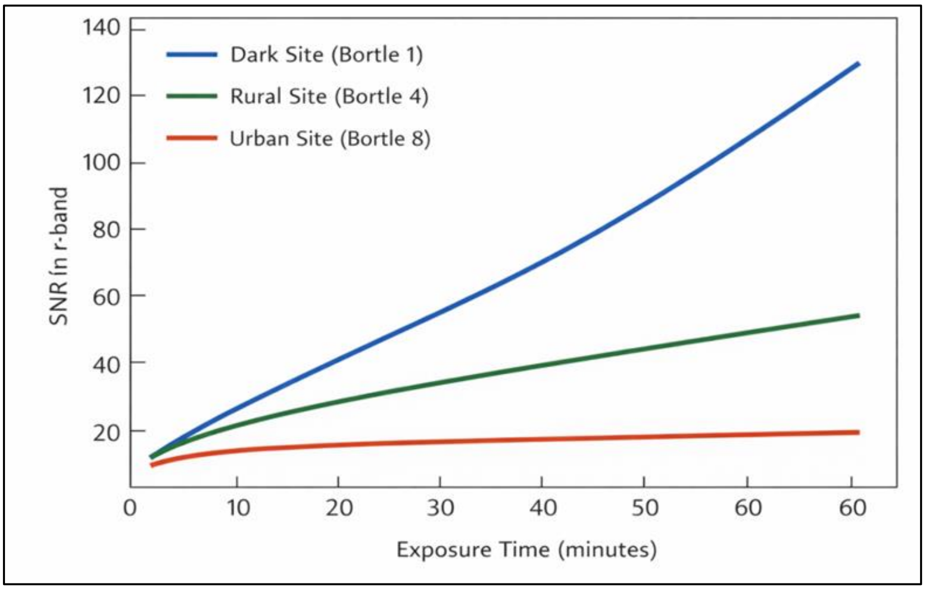

Figure 2 Signal- Noise Ratio (SNR) against Exposure Time

It would be presented in the form of a line graph. The x-axis is Exposure Time (minutes) with value ranging between 0-60. The y-axis is "SNR in r-band". Three upward curves are depicted: one steep one of Dark Site, one moderate of Rural Site and a very low and shallow one of Urban Site. Dotted lines show how much time is required to achieve SNR=10 [5,6].

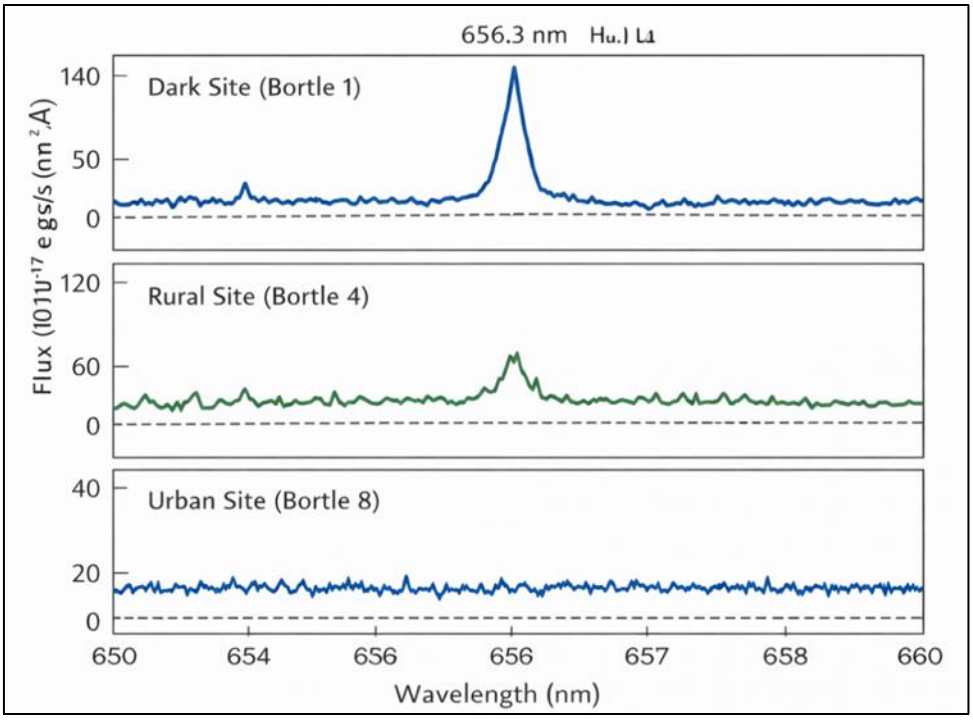

Figure 3 Model Spectral Snippet 656.3 nm (H-alpha)

Three superimposed plots of flux versus wavelength of each site. The Dark Site plot indicates a sharp peak of the H-alpha emission line. The peak of Rural Site plot is perceivable and noisy. The Urban Site plot is a continuum of sky emission lines that appear flat and noisy with no H-alpha feature being visible [5,6].

4. Discussion

The findings clearly show the harsh, non-linear deterioration of the quality of data induced by light pollution. The artificial lightening of the sky background is a noise that overshadows the signal by the astronomical target.

4.1. Photometric Impacts

Table 1 indicates that the observed total magnitude is more inaccurate and error-prone in the brighter skies. The fact that the difference between Sites A and C is of the order of 0.8 mag indicates that it is an error of two times. More importantly, the sky background totally overwhelms the surface brightness measurement in the urban areas (Figure 1). M101 has outer and weak spiral arms that are vital in galaxy evolution, but cannot be seen in the Urban Site simulation. The SNR also decreases exponentially and it takes exponentially longer exposures to reach the same fidelity as a dark site (Figure 2) [4-6].

4.2. Spectroscopic Impacts

Spectroscopy, which is the bread and butter of astrophysical study, is seriously impaired. The appearance of the H-alpha emission line, one of the fundamental indicators of on-going star formation, changes its clear identification in the dark sky to the non-identification in the urban sky (Table 2, Figure 3). This loss has a direct negative effect on the research of galactic evolution and cosmology. Moreover, the polluting emission lines of the streetlights (e.g. the lines of sodium and mercury) cut across and cover the significant astrophysical lines making data reduction and analysis difficult [5,6].

4.3. Implications and Mitigation

The professional implications of these findings include observatory siting, as well as, citizen/amateur scientific astronomy as a growing field of study. This economic and scientific significance of the dark sky preserves is emphasized [6,7]. Narrow-band filters with specific emission lines, e.g. the so-called light pollution suppression (LPS) filters, may be used to enhance contrast; however, they never recover the broadband signal lost to skyglow [7-9]. The introduction of energy-efficient blue-rich white LED lighting in the world aggravates the situation because it results in more Rayleigh scattering as well as is more sensitive on blue wavelengths of modern CCD detectors [8-10].

5. Conclusions

This is a quantitative simulation study which proves that light pollution is a significant obstacle to astronomical observation. Key conclusions are:

- Light pollution also causes gross systematic errors in fundamental photometric measurements (magnitude, surface brightness) of extended galaxies.
- Signal to noise ratio in imaging and spectroscopy is extremely lower in polluted skies that it would not be feasible or even possible to observe faint and scientifically important aspects (such as H-alpha emission) in the urban environment.
- The spectral signatures of standard sources of artificial light (directly) pollute and obscure the spectral data of astrophysics.
- It is not a simple aesthetic, environmental issue to protect existing dark-sky locations by legislative and lighting ordinance, but rather a scientific necessity concerning the future of astronomy.
- The next step in work should be to validate these models in real-time and concurrently in multi-sites with simultaneous observations and determine the exact effect of full-spectrum LED lighting.

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