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Comparative Analysis of Astrophotography Performance Across Various Smartphone Brands

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ABSTRACT

This study focuses on astrophotography results by applying the average pixel intensity value (mean) to measure the impact of night sky brightness. This approach is illustrated using photos taken with the Samsung S21 FE and Poco X6 as examples. The mean value indicates the brightness or darkness level of an image and serves as a standard for assessing the influence of light pollution on astrophotography. The analysis reveals that images captured with the Samsung S21 FE have a mean value of 48.852, indicating a higher brightness level compared to the Poco X6, which has a mean value of 30.399. This difference suggests that photos taken with the Samsung S21 FE are more likely to be affected by environmental lighting. By understanding the mean value, photographers can determine the ideal time, location, and position for capturing the night sky, thus avoiding light interference and optimizing their results.

I. Introduction

Astrophotography, the art of capturing celestial objects and phenomena, has experienced significant advancements over the past decade. Traditionally, this field was exclusive to professional astronomers or photographers who had access to specialized, high-end equipment, including advanced telescopes, dedicated cameras, and complex image-processing software. The technical expertise required to operate such tools also made astrophotography a pursuit limited to enthusiasts with extensive knowledge and resources.

However, technological advancements, particularly in smartphone camera systems, have revolutionized the accessibility of astrophotography. Modern smartphones are now equipped with powerful sensors, enhanced image processing algorithms, and dedicated night modes, allowing users to capture stunning images of the night sky without the need for professional gear. Features such as long exposure, AI-assisted stabilization, and improved low-light performance make it possible for anyone to photograph stars, planets, and even faint celestial objects with remarkable clarity.

This democratization of astrophotography has opened new doors for amateur astronomers, hobbyists, and nature enthusiasts. With just a smartphone, individuals can explore the wonders of the night sky, from vibrant star trails to detailed images of the moon and constellations. As technology continues to evolve, the line between professional and amateur astrophotography becomes increasingly blurred, empowering more people to connect with the cosmos in ways previously unimaginable [1]. According to data from the International Astronomical Union (IAU), the number of amateur skywatchers using smartphones for astrophotography has increased rapidly since 2018. This surge is largely driven by advancements in smartphone technology, including enhanced camera sensors, improved night modes, and sophisticated image processing algorithms. These innovations have made it easier for enthusiasts to capture stunning images of the night sky without the need for expensive, professional-grade equipment.

The growing popularity of mobile astrophotography is also fueled by the rise of social media platforms, where users can share their astronomical captures and inspire others to explore the hobby. Platforms like Instagram, X (formerly Twitter), and specialized forums such as Reddit's r/Astrophotography have created vibrant communities where both beginners and seasoned photographers can exchange tips, showcase their work, and discuss the latest techniques. This accessibility has democratized the field, transforming what was once a niche pursuit into a widespread hobby enjoyed by millions worldwide.

Furthermore, the development of user-friendly astrophotography apps has further empowered smartphone users. Applications such as SkySafari, Stellarium, and PhotoPills not only help users identify celestial objects but also guide them on the best times and locations for capturing the night sky. These tools, combined with advancements in computational photography, enable smartphones to capture long-exposure images, stack multiple frames, and reduce noise, resulting in clearer and more detailed photographs of stars, planets, and even distant galaxies.

Educational initiatives and online tutorials have also contributed to this trend. Many universities, observatories, and amateur astronomy clubs now offer workshops and webinars on smartphone astrophotography, encouraging more people to engage with the night sky. This increased accessibility has not only enhanced public interest in astronomy but has also sparked scientific contributions from citizen scientists. For example, smartphone users have helped identify new comets, track satellite movements, and document rare astronomical phenomena, showcasing the potential of mobile technology in contributing to real scientific discoveries.

As smartphone cameras continue to evolve, the future of astrophotography looks even more promising. Innovations such as AI-driven image enhancement, improved optical zoom, and higher-resolution sensors will further bridge the gap between professional and amateur astrophotography. In essence, what was once a complex and costly endeavour is now an accessible and rewarding activity, inspiring a new generation of skywatchers to explore the wonders of the universe from the palm of their hand.[2] Several reasons are driving this trend, including:

1. Enhanced Smartphone Camera Quality: Modern smartphone cameras have seen significant improvements in sensor size and resolution. Current flagship models often feature sensors as large as 1/1.28" with resolutions of 48MP, while some even boast 1/1.3" sensors with up to 200MP resolution. This advancement allows smartphones to capture more light, a crucial factor for astrophotography, where low-light performance determines image clarity and detail. These improvements enable users to capture not just bright objects like the moon but also fainter celestial features, such as star clusters and nebulae.[3]
2. Advancements in Computational Photography: The powerful processors found in modern smartphones play a vital role in enhancing astrophotography results. These processors are equipped with advanced image processing algorithms that reduce noise, improve dynamic range, and enhance details, even under challenging lighting conditions. Features like multi-frame stacking and AI-driven enhancements ensure that the final image is clearer and more vibrant, making astrophotography more accessible to casual users [4].
3. Accessibility and Portability: Compared to professional astrophotography equipment, smartphones are not only more affordable but also significantly more portable. While traditional setups often require bulky cameras, tripods, and telescopes, smartphones can easily fit into a pocket, allowing users to capture stunning night sky images anytime and anywhere. This convenience has democratized astrophotography, enabling enthusiasts from all backgrounds to explore the cosmos without a substantial financial investment [5].

However, despite these advancements, the quality of smartphone astrophotography results can still vary significantly depending on the brand and model used. Key factors such as sensor size, aperture, and software features like night mode play a crucial role in determining the final image quality. A study conducted by the University of Arizona previously compared several leading smartphone models for astrophotography but focused primarily on bright celestial objects, such as the moon and prominent planets. This study, while insightful, did not fully explore how different smartphones perform when capturing more challenging targets, like the Milky Way or faint deep-sky objects [6]. Therefore, this research aims to address that gap by comparing the astrophotography results of two prominent smartphone brands, focusing specifically on their ability to capture complex celestial targets, such as the Milky Way galaxy. By examining the differences in image quality, noise levels, and overall performance, this study seeks to provide valuable insights into how smartphone technology continues to shape the future of amateur astrophotography.

II. Method

This study is an empirical field research project employing a comparative approach. Primary data is obtained through direct astrophotography using several selected smartphone brands. The research aims to compare the astrophotography results from five flagship smartphone models, including the Samsung Galaxy S21 FE and Poco X6 5G. The evaluation of astrophotography images will be based on both technical and aesthetic criteria, as follows:

1. Technical Aspects: resolution, noise levels, dynamic range, detail clarity, and colour accuracy.
2. Aesthetic Aspects: Sharpness, contrast, composition, and the ability to capture celestial objects effectively.

In addition to the researcher's objective analysis, third-party evaluators will also be involved in providing unbiased assessments. This approach ensures a more quantifiable evaluation of the images used as research data. The image capture process will be conducted at locations with dark skies, far from urban light pollution. Shooting sessions will take place under clear weather conditions and during the new moon phase to achieve the darkest possible sky. Another way to enhance stability and prevent motion blur is to use a tripod alongside smartphones. To achieve optimal results, manual settings will be applied on each smartphone, including:

- Exposure time: Up to 30 seconds
- ISO: Range of 100–150
- White balance: 5000K–6700K

III. Results and Discussion

On July 14, 2024, between 11 PM and 1 AM, the author conducted an astrophotography session using a smartphone in Candipuro Village, Candipuro District, Lumajang Regency. Due to its relatively remote location, far from the light pollution of urban areas, the sky conditions in this village were exceptionally clear. This presented an excellent opportunity to capture detailed images of celestial objects, as the dark sky environment significantly enhanced visibility.

During the session, several bright celestial objects, such as prominent stars and planets, were still clearly visible. The Milky Way's faint band of light stretched across the sky, providing a breathtaking backdrop for astrophotography. However, the primary challenge was the limited sensitivity of smartphone cameras compared to Interchangeable Lens Cameras, such as DSLRs or mirrorless systems. This limitation made it more difficult to capture finer details and faint objects in the night sky, especially deep-sky objects like nebulae and distant star clusters.

To overcome these challenges, the author employed several techniques to optimize the smartphone's performance. A tripod was used for stabilization, preventing motion blur during long exposures. The camera was set to manual mode, allowing adjustments to shutter speed, ISO, and white balance for better light capture. The exposure time was extended to 30 seconds, while the ISO was carefully adjusted between 100 and 150 to balance light sensitivity without introducing excessive noise. Additionally, the white balance was set between 5000K and 6700K to achieve more natural color tones.

The results revealed clear differences in image quality depending on the smartphone used. While brighter stars and planets were relatively easy to capture, dimmer objects, such as the Milky Way's galactic core, appeared more pronounced when the settings were fine-tuned. This session highlighted both the potential and the limitations of smartphone astrophotography, emphasizing the importance of proper technique and ideal environmental conditions for achieving the best results [7]. To overcome these limitations, the author used a tripod for stabilization, set the shutter speed to manual mode, and adjusted the ISO to capture more light without causing overexposure.

Figure 1 Image taken using the Samsung S21 FE(left) and Poco X6 5G (right)

Based on the images above, it can be concluded that astrophotography in Lumajang shows significant potential, especially for capturing the Milky Way and other bright celestial objects, due to the minimal light pollution in the area. This low level of artificial light interference creates an ideal environment for night sky photography, allowing celestial bodies to appear more prominent and detailed. These photographs not only offer stunning visual aesthetics but also demonstrate the capabilities of smartphone-based astrophotography, particularly when supported by proper techniques, precise camera settings, and optimal sky conditions.

In Figure 1, the image on the left was taken using the Samsung S21 FE, while the image on the right was captured with the Poco X6 5G. A notable difference is observed, particularly in terms of image clarity, sharpness, and color accuracy. Both smartphones were set to identical settings: ISO 1600, aperture f/1.8, shutter speed of 30 seconds, and white balance at 5000K. Despite the uniform camera settings, the results varied significantly, highlighting how much the internal processing of each smartphone impacts the final image quality.

The Samsung S21 FE produced a brighter image with more pronounced highlights, but it also exhibited a higher level of noise, especially in the darker areas of the sky. It suggests that Samsung's image processing prioritizes brightness enhancement, possibly by boosting exposure and sharpening during post-processing. While this approach can make the stars appear more prominent, it may also reduce the overall clarity of finer celestial details.

On the other hand, the Poco X6 5G delivered a darker but cleaner image with less noticeable noise. The stars appeared more defined, and the background sky maintained a more natural, deep black tone. It shows that the Poco X6 5G employs a more conservative image processing approach, focusing on preserving detail rather than artificially enhancing brightness. As a result, the Milky Way structure appeared more refined, though the overall image seemed slightly dimmer compared to the Samsung counterpart.

He observed differences that can be attributed to the distinct image-processing algorithms employed by each smartphone brand. Every smartphone manufacturer implements proprietary computational photography techniques, which influence how raw data from the camera sensor is processed into the final image. Samsung tends to prioritize vibrant colours and enhanced brightness, while Poco leans toward detail retention and noise reduction. These differences ultimately lead to variations in the final photographic results despite identical shooting conditions and camera settings.

Moreover, the performance gap also highlights the importance of understanding a smartphone's strengths and limitations when engaging in astrophotography. While both devices demonstrated impressive capabilities, achieving optimal results often requires users to experiment with settings and understand how their specific device handles low-light photography. The use of additional equipment, such as a tripod for stability, further enhances the ability to capture sharp and detailed night sky images.

In conclusion, this comparison underscores that while advancements in smartphone technology have made astrophotography more accessible, the quality of the final results still heavily depends on the device's image processing capabilities. Both the Samsung S21 FE and Poco X6 5G are capable of capturing stunning astrophotography. However, the choice between them may depend on individual preferences—whether one prioritizes brighter, more eye-catching images or darker, more detailed representations of the night sky [8].

Digital Image Analysis

In digital image analysis, the term mean or average intensity is commonly used to determine how bright or dark a specific area within an image appears. This mean value is essentially calculated from the intensity of each pixel within a selected area, providing a general overview of brightness levels in that region. In astrophotography, the mean intensity helps assess the brightness conditions of the night sky surrounding the photographed celestial object, which can be influenced by factors such as light pollution, moonlight, and atmospheric conditions.

Understanding the mean value is particularly useful when comparing images taken under different conditions or with different devices. It serves as an objective metric to evaluate how well a smartphone camera captures faint celestial objects without being overly affected by background brightness. A higher mean value typically indicates a brighter image, which may result from light pollution or the camera's internal processing. In comparison, a lower mean value suggests a darker sky, often associated with better observation conditions.

However, the author believes the initial evaluation was purely subjective and based on visual inspection and personal judgment. To ensure a more accurate and unbiased comparison between the images captured by the Samsung S21 FE and the Poco X6 5G, the author incorporated third-party evaluation. For this purpose, the author utilized AstroImageJ, a widely recognized software for astronomical image analysis. This software allows for precise quantification of various image parameters, including mean intensity, signal-to-noise ratio (SNR), and background brightness.

By analyzing specific sections of the images with AstroImageJ as shown in figure 2, we obtained objective data that complemented the subjective observations. This quantitative approach not only strengthened the credibility of the analysis but also provided deeper insights into how each smartphone's camera processed light under identical conditions. The results revealed significant variations between the two devices, further emphasizing the importance of using standardized image analysis tools when comparing astrophotography results.

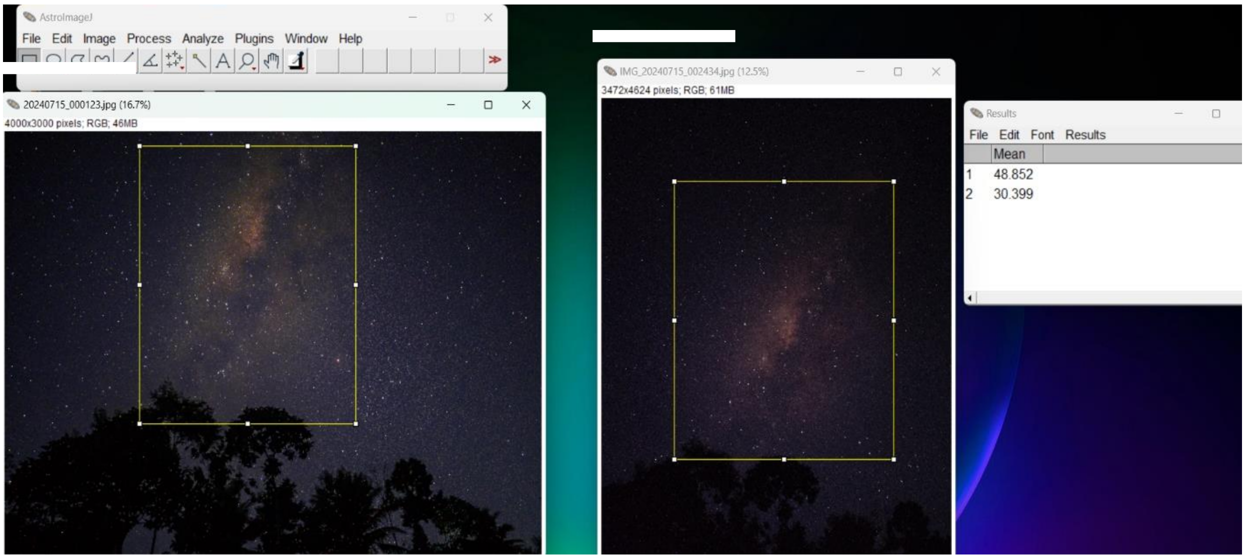

Figure 2. Image Processed in AstroimageJ

In this analysis, two different mean intensity values were observed. The image captured using the Samsung S21 FE showed a mean value of 48.852, while the image taken with the Poco X6 had a lower mean value of 30.399. It indicates that the image from the Samsung S21 FE appears brighter compared to the darker appearance of the image produced by the Poco X6.

Several factors could contribute to this difference. One potential cause is the varying sensitivity of each smartphone's camera sensor, which affects how light is captured and processed. The Samsung S21 FE, known for its advanced image processing algorithms, tends to enhance brightness and detail, which could explain the higher mean value. In contrast, the Poco X6, while equipped with strong hardware, might prioritize noise reduction and contrast, resulting in a darker overall image.

Additionally, ambient lighting conditions during the capture process might have played a role, even though both images were taken under the same sky conditions. Slight variations in how each smartphone interprets light, combined with differences in post-processing, can significantly affect the final output.

This variation highlights the importance of understanding the technical aspects behind smartphone astrophotography. A higher mean value does not necessarily mean better image quality, as it could also indicate overexposure or increased background brightness. Therefore, evaluating images based solely on brightness can be misleading without considering other factors like noise levels, contrast, and detail retention [9].

In astrophotography, a lower mean value typically indicates a darker sky, which is ideal for capturing celestial objects with minimal light interference. Darker skies allow the camera to focus more on the light emitted by stars, planets, and other astronomical objects without being overpowered by background brightness. This condition enhances the contrast between the objects and the sky, making faint details more visible.

The lower mean value observed in the Poco X6 image suggests that the smartphone was able to capture a relatively darker sky, potentially resulting in better contrast and less washed-out details. On the other hand, while the higher mean value in the Samsung S21 FE image reflects increased brightness, it could also indicate the presence of more background light, either from residual light pollution or the smartphone's internal image processing.

Thus, while a brighter image might initially appear more visually striking, it does not always equate to better quality in astrophotography. A balanced approach, where brightness is sufficient to reveal celestial details without overwhelming the image, is often preferred. Understanding the mean value helps photographers adjust their camera settings and choose the best conditions for astrophotography, ensuring the final images are both clear and true to the night sky's natural appearance.[10] The lower mean value observed in the Poco X6 image indicates a darker sky, a condition generally preferred by astrophotographers for capturing clearer and more detailed celestial objects. In contrast, the higher mean value recorded by the Samsung S21 FE suggests a brighter sky, potentially influenced by ambient light during the shooting process or the smartphone's image processing characteristics.

Beyond assessing sky conditions, the mean value serves as a practical benchmark for comparing different locations or times of image capture. For instance, when searching for the ideal spot for astrophotography, one can take images from various locations and analyze their mean values. A lower mean signifies darker skies with minimal light pollution, while a higher mean often indicates significant light interference, which can hinder the visibility of faint astronomical objects.

This approach allows astrophotographers to make informed decisions about the best times and places for night sky photography. It also highlights how technological differences between smartphone models can influence image outcomes, even under identical shooting conditions. By understanding and utilizing the mean value, photographers can optimize their settings and locations, ensuring more consistent and high-quality results in astrophotography sessions.[11]

In addition to using the mean value to assess sky brightness, there is also a specialized tool designed for direct measurement called the Sky Quality Meter (SQM). This device provides an objective and standardized reading of sky brightness, typically expressed in magnitudes per square arcsecond (mag/arcsec²). The higher the SQM reading, the darker the sky, indicating better conditions for astrophotography and astronomical observations.

The SQM works by detecting the overall light intensity from the sky and converting it into a numerical value. For example, an SQM reading of 21.5 mag/arcsec² or higher indicates excellent sky conditions with minimal light pollution, while readings below 20 mag/arcsec² suggest significant light interference.

Using an SQM alongside image analysis provides a more comprehensive understanding of sky conditions. While the mean value from image pixels reflects the brightness perceived by the camera, the SQM offers an independent measurement unaffected by camera settings or processing algorithms. This combination allows astrophotographers to evaluate potential observation sites better, compare conditions across different locations, and plan their sessions for optimal results.

Furthermore, the SQM can be valuable for long-term monitoring of light pollution trends, helping researchers and enthusiasts advocate for dark sky preservation initiatives. .[12] The Sky Quality Meter (SQM) measures light pollution levels at a specific location, expressed in magnitudes per square arcsecond (mpsas). Astronomers and astrophotographers commonly use this unit to gauge sky darkness. A higher SQM reading indicates a darker sky, which is ideal for astronomical observations and astrophotography.

To determine suitable locations for astrophotography, SQM data offers a more consistent and objective assessment compared to visual evaluations or mean value calculations from images. This is because SQM measures sky brightness directly, without being influenced by camera settings or image processing algorithms. This accuracy makes the SQM an essential tool for identifying optimal dark-sky locations for capturing celestial objects, especially when the goal is to photograph under pristine sky conditions.

In addition to tools like the SQM, the type of camera used also plays a significant role in astrophotography. DSLR and mirrorless cameras are generally preferred over smartphones due to their larger sensors, which excel at capturing details in low-light conditions. A larger sensor can gather more light, a crucial advantage when photographing the night sky. Moreover, DSLR and mirrorless cameras offer greater flexibility in manual settings, allowing users to fine-tune exposure time, aperture, and ISO according to the shooting environment.

Unfortunately, most smartphones lack this level of control and sensor capability, making them more susceptible to the effects of light pollution and limited in capturing faint celestial objects. However, advancements in smartphone technology, including improved night modes and computational photography, have somewhat bridged this gap, allowing casual enthusiasts to capture impressive astrophotography results without professional equipment [9].

With a DSLR or mirrorless camera, the resulting astrophotography images are significantly sharper, more detailed, and more true to the natural colors of the night sky. These cameras excel in low-light conditions, effectively reducing noise that commonly appears in smartphone photos taken under similar circumstances. The superior sensor technology and manual control options in DSLRs and mirrorless cameras enable the capture of high-quality astrophotography, revealing intricate details of celestial objects that are often beyond the reach of smartphone cameras.

To achieve the best results, it is ideal to combine two key factors: choosing the darkest possible sky location using SQM readings and utilizing a DSLR or mirrorless camera for the shoot. This approach ensures optimal image quality, with clear, detailed, and vibrant depictions of the night sky. By employing both advanced equipment and ideal environmental conditions, astrophotographers can capture stunning and scientifically accurate images of celestial wonders.

IV. Conclusion

The astrophotography observation in Candipuro, Lumajang, revealed that the location holds significant potential for night sky photography due to its minimal light pollution. While smartphone cameras have limitations compared to DSLR or mirrorless cameras, efforts were made to optimize image quality by manually adjusting the shutter speed and using a tripod for stability. However, despite identical camera settings on the Samsung S21 FE and Poco X6, the resulting images differed in brightness and sharpness, likely due to the distinct image processing algorithms employed by each smartphone.

To achieve a more objective analysis, the author utilized AstroImageJ to compare the brightness levels of both images. The analysis indicated a higher mean brightness value in the photo taken with the Samsung S21 FE. In astrophotography, a lower mean value generally signifies a darker sky, which is preferable for capturing fine details of celestial objects. Thus, while the Samsung image appeared brighter, the lower mean value of the Poco X6 image suggested a darker sky with less surrounding light interference.

Tools like the Sky Quality Meter (SQM) can be highly beneficial in further enhancing the accuracy of astrophotography site selection. Unlike camera-based measurements, SQM readings provide direct and consistent assessments of sky brightness, offering an objective evaluation of light pollution in a specific location. This allows astrophotographers to identify sites with optimal sky conditions for capturing celestial phenomena.

Although smartphones can produce impressive night sky images, DSLR and mirrorless cameras remain superior for astrophotography. Their larger sensors and extensive manual controls allow for greater light capture, resulting in sharper images with less noise. By combining a dark sky location—identified through SQM readings—with high-quality camera equipment, astrophotographers can achieve stunning, accurate, and detailed representations of the night sky.

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