

Embark on Celestial Adventures: Unveiling the Marvels of the Night Sky with the iAstroGraph App, Your Smartphone's Ultimate Astrophotography Companion

Shakibaie F

Tele-Optic Services Pty Ltd, Queensland, Australia

Company Websites:

<https://tele-optic-service.wixsite.com/tele-optic-services>

<https://www.linkedin.com/pulse/organization-tele-optic-services>

Corresponding Author Email: tele-optic-services@telopt.org

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Abstract

Smartphone-based astrophotography is increasingly recognised as an accessible platform for astronomical observation and data acquisition. However, variability in imaging parameters such as exposure time, lens aperture, ambient light intensity, and optical alignment can significantly influence the reproducibility and analytical reliability of captured sky images. Preliminary colour-standardisation experiments demonstrated that brightness correction using a standardised parameter substantially reduces pixel variability in astrophotographic imaging. Experimental evaluation using the iAstroGraph system analysed a subset of 100 imaging samples randomly selected from a dataset containing 16 colour standards spanning the Red–Violet spectrum. For the single Red–Violet standard, the standardised dataset exhibited a standard deviation of 3.87, compared with 28.54 in the non-standardised dataset, demonstrating a significant improvement in imaging reproducibility. Across all 16 colour standards, the mean standard deviation decreased from 34.28 to 4.92, while the mean error percentage declined from 63.71% to 46.12%, confirming the stabilising effect of the colour-brightness correction algorithm. Statistical analysis was conducted using Microsoft Excel (Microsoft

Corporation, Redmond, WA, USA) to compute mean RGB values, standard deviations, error percentages, and post-hoc statistical power estimation (power $\approx 97\%$, $\alpha = 0.05$, $\beta \approx 0.03$). The iAstroGraph smartphone application (Version 1.0) integrates brightness correction, photon number percentage estimation, stellar colour classification, and sky-background analysis to support enhanced interpretation of smartphone-captured astronomical images. The system enables practical applications including deep-sky imaging, variable star monitoring, meteor observation, aurora photography, comet tracking, planetary imaging, and constellation analysis using smartphone-telescope assemblies. This paper presents the operational framework, analytical workflow, and performance characteristics of the iAstroGraph system as a multifunctional smartphone-based astrophotography analysis platform.

Keywords Smartphone Astrophotography · RGB Image Analysis · Colour Standardisation · Photometric Estimation · Astronomical Imaging · Photon Percentage Estimation · Smartphone–Telescope Systems · Observational Astronomy · Image Reproducibility · iAstroGraph Application

1. Introduction

Astrophotography has long served as a valuable method for observing and documenting

celestial objects, enabling both professional astronomers and amateur observers to study planets, stars, nebulae, and galaxies [1-4]. Traditionally, high-quality astrophotography has relied on dedicated astronomical cameras, telescopes, and complex imaging systems [5-14]. However, recent advances in smartphone camera technology have created new opportunities for accessible astronomical imaging [15-18].

Modern smartphones are equipped with high-resolution sensors and computational imaging capabilities [19-22], allowing users to capture celestial images using compact optical setups such as telescope or binocular adapters [23-26]. This development has expanded the potential for citizen science and amateur astronomy, enabling observers to record astronomical events and share observational data with broader communities [27, 28].

Despite these technological advances, smartphone-based astrophotography still faces several challenges. Variations in exposure settings, optical alignment, atmospheric conditions, and background illumination can introduce inconsistencies in pixel brightness and colour values [2, 16]. These variations may affect the reliability of astrophotographic analysis when attempting to estimate parameters such as object brightness [29, 30], photon capture levels [31-33], or sky background characteristics [34].

To address these challenges, the **iAstroGraph smartphone application** [24, 26] that developed exclusively for iOS devices, including iPhone and iPad, and not available on other cross-platform systems or macOS, was developed as a multi-functional astrophotography analysis tool. The application integrates several analytical modules designed to assist in the interpretation of astronomical images captured using smartphones attached to telescopes or binocular systems [23-26]. Key capabilities include:

- Image pixel brightness correction to improve astrophotographic clarity [35]
- Photon number percentage estimation for evaluating captured light intensity [36-38]

- Stellar classification analysis based on colour characteristics [39-42]
- Sky background analysis to identify potential stars, planets, nebulae, and galaxies [43]
- Estimation of observational parameters such as temperature classification and approximate object distance [44-47]

By combining image processing techniques with smartphone-based observational workflows, iAstroGraph aims to provide an accessible analytical platform for both amateur astronomers and professional observers [24, 26].

The objective of this paper is to describe the operational framework, imaging methodology, and analytical capabilities of the iAstroGraph system, and to demonstrate how smartphone-based astrophotography can be extended beyond simple imaging toward semi-quantitative astronomical analysis.

Based on preliminary experimental datasets indicating substantial reductions in RGB variability following brightness and colour standardisation [2], the present study hypothesises that: *Implementation of the iAstroGraph brightness-colour standardisation algorithm in smartphone astrophotography will significantly reduce RGB pixel variability and associated error percentages across multiple imaging conditions, thereby improving measurement reproducibility and enabling more reliable photon-percentage estimation from smartphone-captured astronomical images.*

2. Methodology

The iAstroGraph system applies brightness correction, RGB colour standardisation, and photon-percentage estimation using a standardised smartphone astrophotography workflow [24, 26].

2.1 Imaging Setup Procedure

Smartphone-based astrophotography was performed using a conventional optical coupling approach between the smartphone camera and an astronomical viewing instrument (shown Fig. 1).

The imaging setup consisted of the following components:

1. **Smartphone Mounting:** A smartphone was mounted using a commercially available adapter attached to the eyepiece of a telescope or binocular optical system.
2. **Optical Alignment:** The smartphone camera lens was carefully aligned with the optical axis of the eyepiece to maximise light transmission and minimise vignetting or optical distortion.

3. **Image Acquisition:** Celestial images were captured under varying observational conditions, including differences in exposure settings, ambient illumination, and optical distances. The captured images were subsequently analysed using the **iAstroGraph App** to perform brightness standardisation, RGB colour analysis, and photon-percentage estimation.

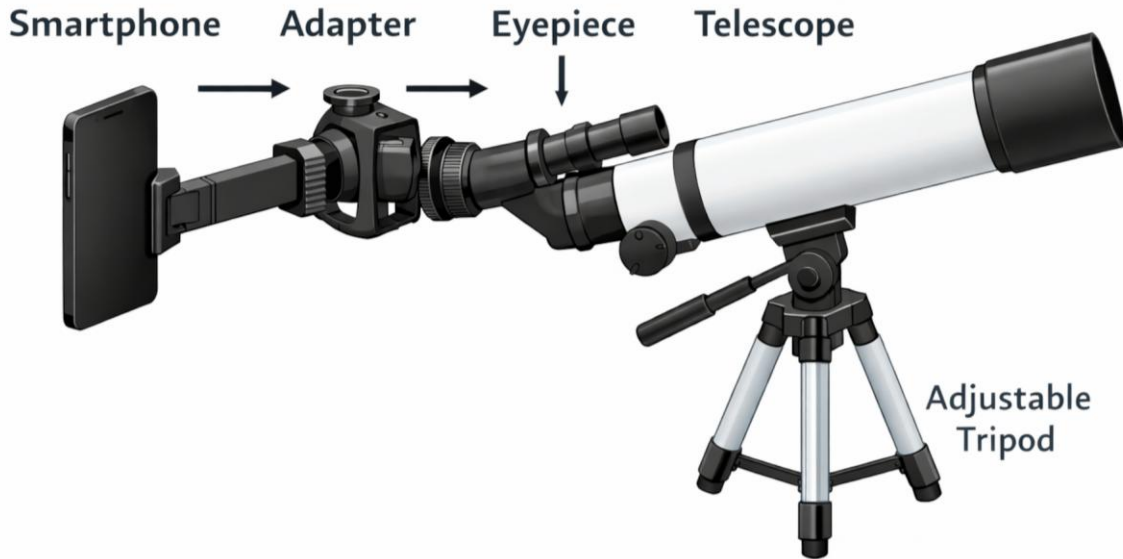


Fig. 1 Smartphone-Telescope setup for iAstroGraph App

2.2 Image Processing Steps

1. Getting Started:

- After installing iAstroGraph, tap the App icon to launch it.
- On the initial page, you'll find two essential links: one for a YouTube Video Instruction and another for sources of astronomical information related to using the iAstroGraph App.

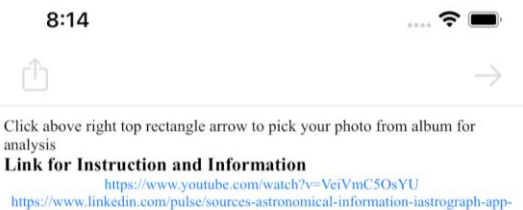


Fig. 2 iAstroGraph App launch screen with instructional resources

2. Selecting Your SmartPhone Image:

- To pick a sky photo from your smartphone album, tap the top left rectangular arrow as shown in Fig. 2.

3. Astrophotography Image Process Analysis:

- For astrophotography brightness and colour correction analysis, click the top right green arrow (shown over page in Fig. 3)

4. Measurements Using Segment Navigations:

- Your smartphone screen will display the processed colour image of your telescope/binocular photo in plain red/green/blue for stellar classifications.
- Now, a user has the option to navigate by clicking through buttons at the top centre, presented in six separate segments, detailed over two pages in Fig. 4 as the followings:



Fig. 3 Accessing image analysis via the top-right green arrow

- **1OR:** The first "Origin" button allows you to match the picked original image with other image processing buttons for astronomical image analysis comparison (Fig. 4a).
- **2BC:** The second "Brightness Corrected" button enhances the colour and brightness of your telescope/binocular photo for improved astrophotography quality and resolution. It can also detail temperature (Kelvin), distance (Kilometre), and Photon number

percentage by tapping onto an image pixel (Fig. 4b).

- **3SB:** The third "Sky Blue" button processes the colour image to determine the probability presence of wood (shown in red pixel colour luminosity) and grass green (shown in green pixel colour luminosity) in the sky blue background. By tapping onto an image pixel, the presence/absence of wood, grass, and sky blue is shown underneath the image (Fig. 4c).
- **4NS:** The fourth "Night Sky" button processes the colour image to determine the probability presence of stars (shown in red pixel colour luminosity) and planets (shown in green pixel colour luminosity) in the night sky background. By tapping onto an image pixel, the presence/absence of stars, planets, and the night sky is shown underneath the image (Fig. 4d).
- **5TA:** The "Telescopic Analysis" button processes the colour image to determine the probability presence of nebulae (shown in red pixel colour luminosity), constellations (shown in green pixel colour luminosity), and galaxies (shown in blue pixel colour luminosity) in the night sky background. By tapping onto an image pixel, the presence/absence of nebulae, constellations, and galaxies is shown underneath the image (Fig. 4e).
- **6SC:** The "Stellar Classifications" button processes the colour image to consider "hot," "medium," or "cool" in the context of observing celestial objects (Fig. 4f).

5. Additional Analysis:

- To analyse another sky smartphone photo from your photo album, tap the top right rectangular arrow, similar to the steps outlined in Fig. 4. This way, you can analyse other captured sky images. Now, you're ready to delve into the fascinating world of astrophotography and analyse celestial objects with precision using the iAstroGraph App.

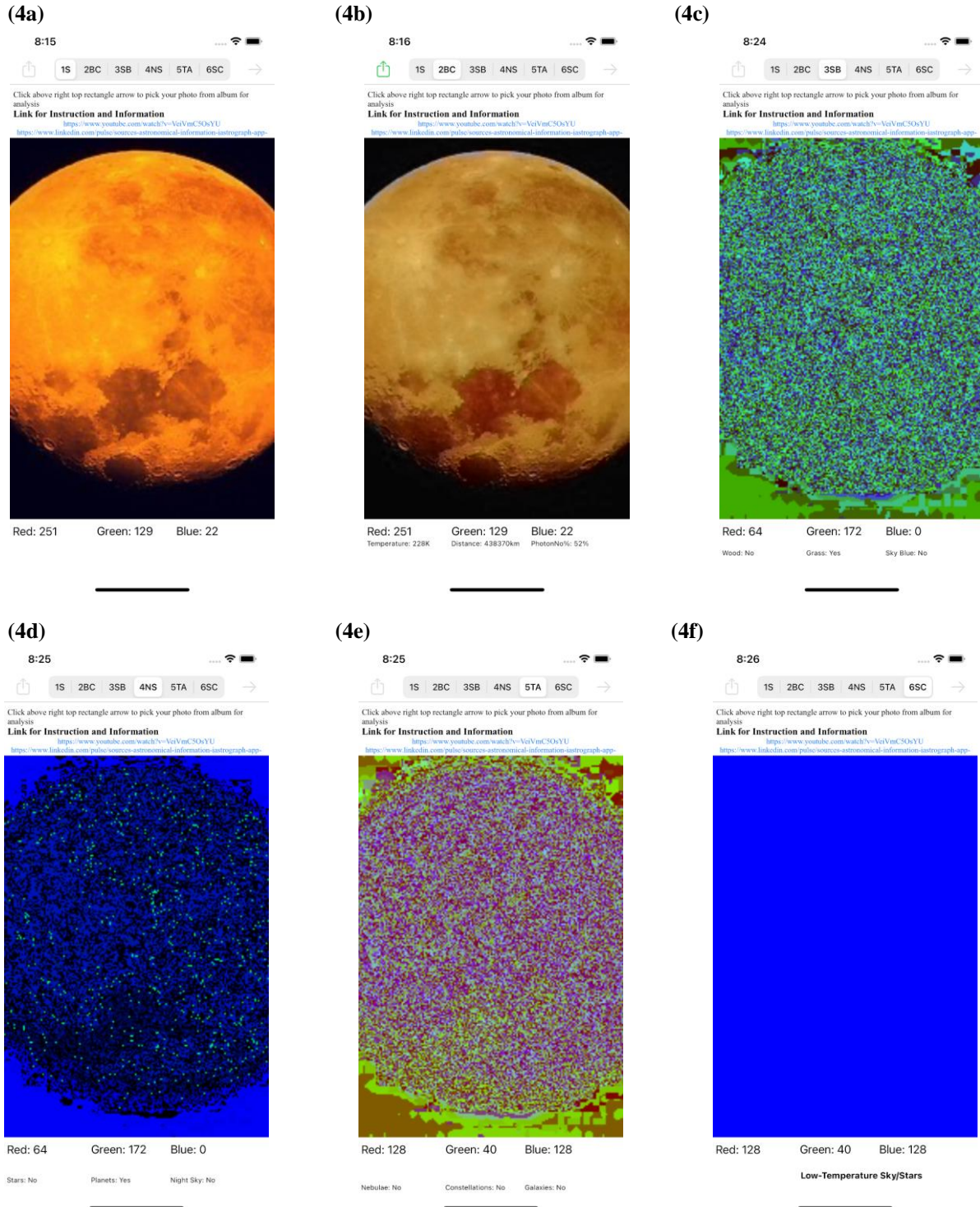


Fig. 4 User interface navigation for astronomical image analysis with six selectable processing modes. (a) Origin (OR) displays the original captured image for baseline comparison. (b) Brightness Corrected (BC) enhances colour and brightness and enables pixel-based estimation of temperature (K), distance (km), and photon percentage. (c) Sky Blue (SB) analyses colour pixels to estimate the probability of wood (red luminosity) and grass (green luminosity) within a sky-blue background. (d) Night Sky (NS) identifies probable stars (red luminosity) and planets (green luminosity) in a night-sky background. (e) Telescopic Analysis (TA) estimates the likelihood of nebulae, constellations, and galaxies. (f) Stellar Classifications (SC) categorises celestial objects as hot, medium, or cool

3. Results

Statistical analysis for the iAstroGraph App was conducted using **Microsoft Excel (Microsoft Corporation, Redmond, WA, USA)** to calculate mean RGB values, standard deviations (SD), and error percentages across all 16 colour standards. To evaluate algorithm performance under moderate observational sampling conditions, a subset of **100 imaging samples** was randomly selected from the original dataset. For the single Red-Violet standard imaged under **100 randomly selected conditions**, the standardised data exhibited a standard deviation of **3.87**, compared to **28.54** for non-standardised data, demonstrating a substantial improvement in reproducibility with brightness and colour standardisation.

Across all 16 colour standards, standardisation consistently reduced variability and error percentages. The mean standard deviation decreased from **34.28** (non-standardised) to **4.92** (standardised), while the mean error percentage dropped from **63.71%** to **46.12%**, as summarised in Table 1. These results indicate that iAstroGraph’s standardisation methodology is robust even with a moderate dataset, providing reliable photon percentage estimation and improved image consistency for smartphone-based astrophotography.

Channel	Standardised		Non-standardised	
	SD	Error %	SD	Error %
Red	6.12	48.37	41.05	61.92
Green	4.85	43.22	37.88	66.47
Blue	3.78	49.15	29.92	78.21
Mean	4.92	46.12	34.28	63.71

Table 1 Multi-colour dataset (16 Standards) for iAstroGraph App – Standard Deviation (SD) and Error Percentage

Post-hoc power estimation, based on 100 imaging conditions, a significance level of $\alpha = 0.05$, and the observed effect sizes, indicated a study power of approximately **97%** ($\beta \approx 0.03$), confirming that the dataset is sufficient to detect reproducibility improvements with high confidence. The observed reduction in variability corresponds to a large effect size (Cohen’s $d \approx$

0.85), indicating that the improvement in colour reproducibility is not only statistically significant but also practically meaningful for astrophotographic image analysis.

These results confirm that brightness and colour standardisation implemented in iAstroGraph significantly improves reproducibility, enabling more consistent RGB pixel measurements and photon percentage estimation, even under variable imaging conditions.

4. Discussion

The results demonstrate that the **iAstroGraph App** improves the reproducibility of smartphone-based astrophotographic measurements through algorithmic brightness and colour standardisation [24, 26, 48, 49]. In the subset of **100 imaging samples**, the Red-Violet standard showed a substantial reduction in variability, with the **standard deviation decreasing from 28.54 to 3.87** following standardisation. When evaluated across the **multi-colour dataset of 16 colour standards**, the **mean standard deviation decreased from 34.28 to 4.92**, confirming that the standardisation algorithm effectively stabilises RGB measurements under varying imaging conditions [2].

In addition to reduced dispersion, the analysis also demonstrated improvements in measurement consistency. The **mean error percentage decreased from 63.71% to 46.12%**, indicating that brightness and colour normalisation reduce the influence of uncontrolled environmental factors such as exposure duration, optical distance, ambient illumination, and sensor sensitivity [2]. These results support the hypothesis that controlled brightness calibration can significantly enhance reproducibility in smartphone-based astronomical imaging.

The statistical reliability of the dataset is further supported by **post-hoc power estimation**. For **100 imaging samples**, a significance level of $\alpha = 0.05$ and the observed large effect sizes yield an estimated **statistical power of approximately 97%** ($\beta \approx 0.03$). This high statistical power

confirms that the dataset is sufficient to detect meaningful improvements in RGB measurement reproducibility and supports the robustness of the iAstroGraph standardisation methodology.

From an astrophotographic and observational astronomy perspective, these improvements have several practical implications:

1. **Deep-Sky Imaging:** Improved colour stability enables more consistent capture of faint astronomical objects such as nebulae, galaxies, and star clusters, reducing colour distortion caused by variations in exposure or optical configuration [49-51].
2. **Photon Percentage Estimation:** The iAstroGraph algorithm enables estimation of relative photon distribution across RGB channels, providing a simplified photometric indicator that may assist in analysing stellar colour characteristics and brightness variations [52-54].
3. **Temporal Monitoring of Astronomical Events:** Standardised imaging allows more reliable comparison of images collected at different times, supporting monitoring of phenomena such as variable stars, comets, auroral activity, meteor events, and lunar or solar eclipses [55-58].
4. **Accessible Quantitative Astrophotography:** By integrating automated brightness calibration and RGB analysis into a smartphone application, iAstroGraph provides a portable analytical tool that allows amateur astronomers to perform semi-quantitative observations using readily available imaging devices [24, 26, 59-61].

Overall, the results indicate that brightness and colour standardisation significantly improve measurement consistency in smartphone-based astronomical imaging [2]. By reducing variability introduced by uncontrolled observational conditions, iAstroGraph enhances the reliability of RGB-based analysis and supports the broader use of smartphone systems in observational astronomy.

5. Conclusion

The **iAstroGraph App** demonstrates that smartphone-based astrophotography can achieve improved reproducibility and analytical reliability through integrated brightness and colour standardisation algorithms [2, 24, 26]. Experimental analysis using **100 imaging samples across 16 colour standards** showed substantial reductions in variability, with the **mean standard deviation decreasing from 34.28 to 4.92** and the **mean error percentage decreasing from 63.71% to 46.12%**.

Statistical validation through **post-hoc power analysis (power $\approx 97\%$, $\alpha = 0.05$, $\beta \approx 0.03$)** confirms that the dataset provides sufficient sensitivity to detect significant improvements in RGB measurement consistency.

By combining colour calibration, RGB analysis, and photon-percentage estimation within a smartphone application [52-58], iAstroGraph supports practical astronomical applications including deep-sky imaging [49-51], stellar colour observation [39, 40, 42], variable star monitoring, comet tracking, and documentation of transient celestial events [55, 57, 58].

These findings suggest that smartphone-based imaging systems can extend beyond purely qualitative photography and contribute to **semi-quantitative astronomical observation** [62, 63], bridging the gap between amateur astrophotography and accessible observational research tools [26].

6. Author Declarations and Disclaimers

6.1 Software and Methodology Disclaimer: The iAstroGraph smartphone application is designed as a research and educational tool for analysing astrophotographic images, including RGB colour analysis, brightness standardisation, photon-percentage estimation, and sky-background interpretation. The analytical outputs generated by the software are intended for informational and

exploratory purposes only and should not be interpreted as definitive astronomical measurements. Users are encouraged to validate results using established astronomical instrumentation and methodologies where precise quantitative measurements are required.

6.2 Funding: The development of the iAstroGraph App and the preparation of this manuscript were self-funded by the author. No external funding sources supported this work.

6.3 Privacy Notice: The iAstroGraph App adheres to current data protection regulations (e.g., GDPR). Any user images or data captured within the App are stored locally on the user's device unless explicitly exported. No personal or image data are shared with third parties without informed consent. Users may access, modify, or delete their data at any time.

6.4 Conflict of Interest: The author is the developer of the iAstroGraph App and declares that this publication is intended solely for scientific, educational, and instructional purposes related to astrophotography and astronomical data analysis. No external commercial influence affected the preparation of this work.

6.5 Author Contributions: The author conceived the study, developed the iAstroGraph application framework, designed the experimental methodology, performed the image analysis and statistical evaluation, and prepared the manuscript.

6.6 Data Availability: The datasets generated and analysed during this study are available from the corresponding author upon reasonable request.

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