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Namibian Astronomy: Exploiting Favorable Conditions for Multi-Wavelength Observatories

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Namibia offers some of the most favourable environmental conditions for astronomical research worldwide. Its arid climate, and consistently clear skies provide extended observing windows throughout the year. As home to Africa's first International Dark Sky Reserve, the country experiences exceptionally low levels of light pollution, supported by a sparse population and limited industrial activity. These factors create natural conditions ideal for astronomical observations across the electromagnetic spectrum. Long-term measurements at the High Energy Stereoscopic System (H.E.S.S.) site show night-sky brightness levels comparable to leading international observatories, confirming the stability of Namibia's dark skies at these sites. Radio-frequency interference surveys at H.E.S.S. and Mt. Gamsberg reveal no significant interference across key astronomical bands, including those relevant for the planned Africa Millimetre Telescope. Together, these findings highlight Namibia's exceptional potential for multi-wavelength astronomy, combining optical, gamma-ray, and millimetre-wavelength observations within one region. The results presented here strengthen the case for Namibia as a potential natural hub for coordinated astronomical infrastructure in the southern hemisphere.

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1. Introduction

The global search for dark, stable, and radio-quiet sites continues to shape astronomy's infrastructure. While long-established observatories in Chile, Hawaii, South Africa and the Canary Islands remain central to global astronomy, the growing emphasis on coordinated optical, millimetre, and γ-ray observations has highlighted the need for additional locations capable of supporting multi-wavelength infrastructures. Namibia stands out with its arid climate, sparse population, and natural protection from light pollution [1], and its southern location provides favourable access to the Galactic Centre and other southern-sky regions.
This study evaluates Namibia's observational environment using quantitative measurements of sky brightness, and radio-frequency interference (RFI), with the aim of assessing its suitability for simultaneous optical, millimetre, and gamma-ray observations and identifying areas requiring further characterisation.

2. Methods

Ground-based measurements and satellite data were combined to assess suitability for multi-wavelength astronomy. Three environmental parameters were analysed: night-sky brightness, RFI, and radiance computed with a light pollution propagation model. Considered together, these datasets provide a consistent basis for comparison with major international observatories.

2.1 Night-sky brightness measurements

Night-sky brightness at the H.E.S.S. site was monitored with a Sky Quality Meter (SQM) within the ATMOSCOPE system [3]. An SQM reports sky brightness in magnitudes per square arcsecond, with larger values indicating darker skies; the instrument's dynamic range spans from about $0\,\mathrm{mag\,arcsec^{-2}}$ (bright conditions at dawn or dusk) to roughly $24\,\mathrm{mag\,arcsec^{-2}}$ (almost complete darkness) [4]. Only dark-time data were retained, defined by solar elevation below -18° and the Moon below the horizon. The dataset spans 2013–2017 and underwent quality control involving removal of cloudy intervals, and aggregation into five-minute medians. These steps reduce short-term instrumental and atmospheric fluctuations while preserving long-term behaviour. Distributions were summarised with quartiles to characterise central tendency and seasonal variability.

2.2 Satellite radiance and comparative analysis

To contextualise Namibia's sky brightness globally, we drew on VIIRS Day/Night Band radiance data from [5], who computed night-sky radiance indicators from Suomi NPP satellite measurements using consistent calibration and atmospheric corrections across major observatories. Their dataset provides a uniform benchmark for comparing Namibia with long-established facilities.
Zenith and 30° elevation radiance values from [5] are shown in the comparative plot, with blue and orange bars denoting the two elevation angles and values expressed as ratios relative to the natural sky background ($22.0\,\mathrm{mag\,arcsec^{-2}}$). The horizontal reference lines mark the 1% (zenith) and 10% (30°) radiance thresholds above natural darkness (approximately $22.0\,\mathrm{mag\,arcsec^{-2}}$, $\sim 174\,\mu\mathrm{cd\,m^{-2}}$ [5]). Sites below these thresholds are considered world-class dark-sky environments. Within this framework, Namibia's sites fall in the same low-radiance regime as leading facilities such as Paranal,

Mauna Kea, and La Palma. The South African Astronomical Observatory at Sutherland (SAAO) also exhibits extremely low radiance, darker than Mauna Kea and La Palma in these data, and provides a particularly relevant regional benchmark.

2.3 Radio-frequency interference surveys

RFI was surveyed at H.E.S.S. and Mt. Gamsberg across 9 kHz–40 GHz using a Harogic SAN-400 real-time spectrum analyser in combination with an Aaronia Hyperlog antenna. The main purpose of the survey was to investigate the viability of these two sites to host the African Millimetre Telescope (AMT) [6]. Due to high free-space path loss and the absence of likely interfering equipment such as radar sensors [7] or 6G transceivers [8], no RFI is anticipated in the AMT's primary observation bands at 86, 230, and 325 GHz. Special high-dynamic-range measurements were performed in the 23 –32 GHz range, corresponding both to the operating band of the WVRIII+ water-vapour radiometer on site [9] and to the envisaged K-band VLBI receiver for the AMT dish. These measurements employed a high-gain lens-corrected horn antenna with a front-end low-noise amplifier to improve the system noise floor. Results are reported as received power (dBm) versus frequency.

3. Results

3.1 Night-sky brightness and long-term stability

Figure 1 presents the density map of night-sky brightness measurements taken at H.E.S.S. from 2013 to 2017 (time on the x-axis; mag on the y-axis; colour encodes measurement density).

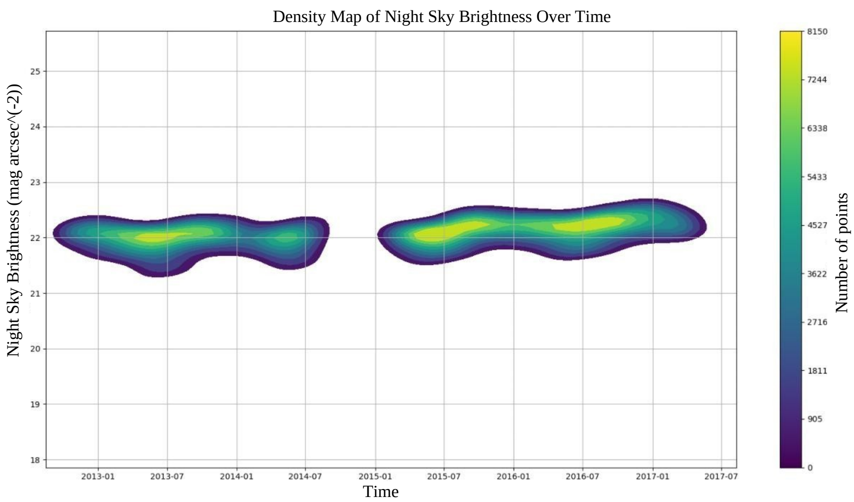

Figure 1: Density map of night-sky brightness over time (2013–2017) at the H.E.S.S. site. Brighter colours indicate higher measurement density; larger magnitudes correspond to darker skies.

The median brightness is 22.06 mag arcsec^{-2}, with an interquartile range of 21.77–22.26 mag arcsec^{-2}, computed from the 25th and 75th percentiles of the full dark–time SQM dataset. These values are consistent with benchmark sites such as Mauna Kea (22.05) and La Palma (21.9) in the V-band [10, 11]. The narrow interquartile spread indicates limited variability and sustained darkness. No

significant secular trend is apparent over the five-year interval. Seasonal structure is modest: winter shows a wider spread, likely due to the bright Milky Way band passing overhead, while summer appears narrower and more uniform. A brief gap in late 2014 and early 2015 reflects instrument downtime.
These measurements place the site near the expected natural sky background of ∼22 mag arcsec^{-2}, supporting high-sensitivity optical and near-infrared observations essentially unaffected by light pollution.

3.2 Comparative radiance across observatories

Figure 2 summarises the results from [5], comparing VIIRS-derived radiance values for major observatory sites.

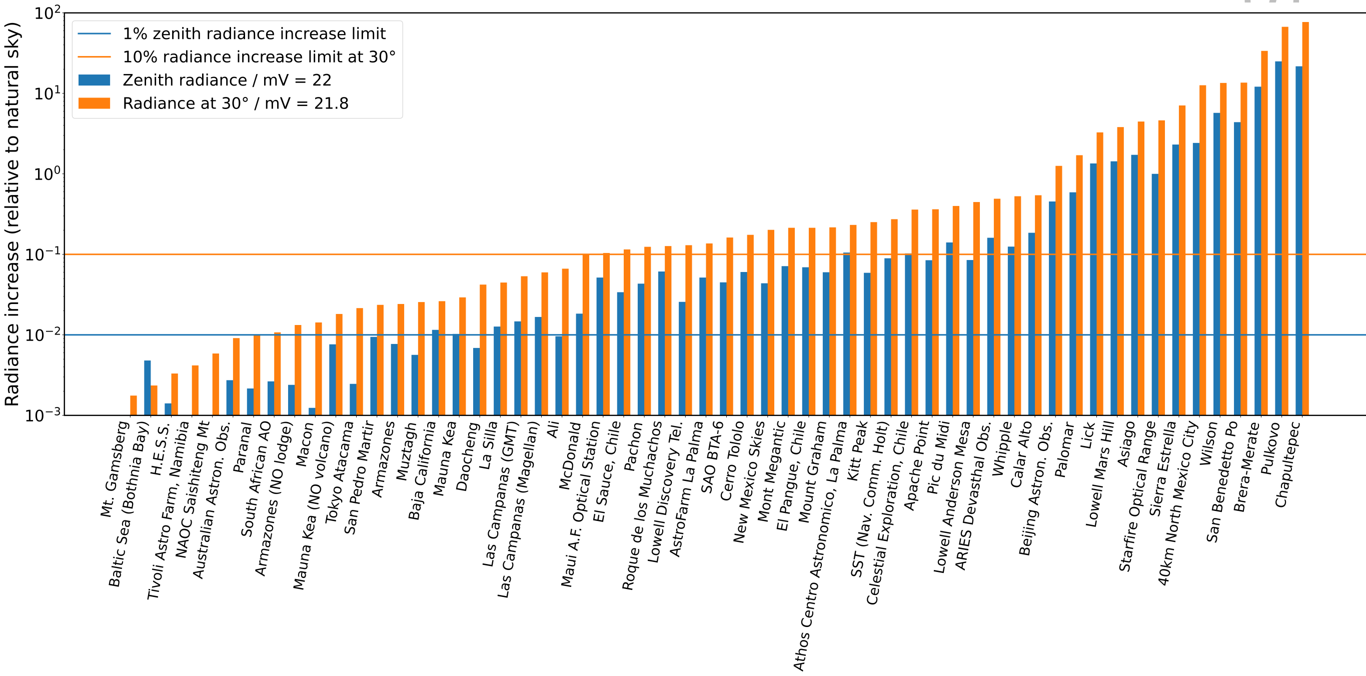

Figure 2: Night-sky radiance at major observatories [5]. Blue and orange bars show zenith and 30° radiance, respectively. The blue and orange lines mark the 1% and 10% increase limits above natural darkness. Sites below these thresholds are considered as world-class dark-sky environments.

According to their analysis, both Mt. Gamsberg and the H.E.S.S. site fall well below the 1% and 10% thresholds, placing them among the darkest observatory environments currently surveyed. The zenith and 30° radiance levels are several times fainter than those measured at typical northern-hemisphere observatories such as Kitt Peak or Calar Alto. These results indicate exceptionally low background sky brightness, confirming that Namibian sites offer sky conditions comparable to the world's premier astronomical locations.

3.3 Radio-frequency interference environment

Figure 3 summarises the measured spectrum at H.E.S.S. across 9 kHz–40 GHz for both polarisations and multiple directions. No significant RFI was detected within the bands used by WVRIII, 23.7-

31.9 GHz and 31.55-31.75 GHz.

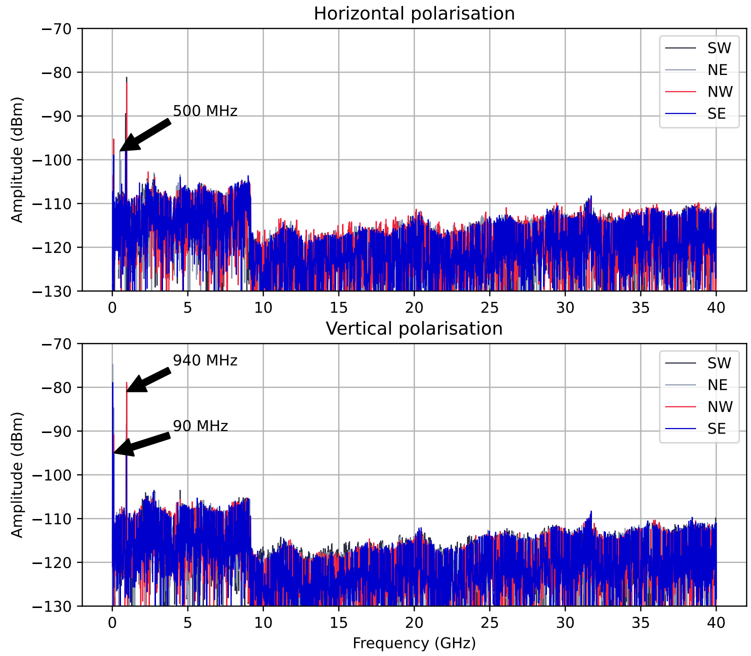

Figure 3: Measured RFI spectrum at H.E.S.S. showing amplitude (dBm) versus frequency.

No measurable interferers were detected in the water-vapour bands, down to at least a 1% measurement uncertainty, consistent with the protection thresholds defined by ITU-R RA.769 [12]. Low-frequency features near 20 MHz, 65 MHz, 940 MHz, and 2.4 GHz are consistent with broadcast and communications services and lie far from the intended astronomical and radiometric bands, but should be considered for planning of the IF bands. Directional scans do not reveal persistent local emitters. Continued monitoring is nevertheless advisable given the evolving spectrum usage.

4. Discussion and conclusion

Namibia's combination of dark and clear skies and minimal radio-frequency interference establishes it as one of the most favourable environments for coordinated multi-wavelength astronomy. The measured night-sky brightness values are comparable to those of premier international observatories, while RFI surveys confirm a largely interference-free spectral environment across key bands. A median night-sky brightness of 22.06 mag arcsec^2, absence of RFI in the bands of interest, and VIIRS radiance below 0.01 collectively indicate site conditions on par with those of Chile's Atacama Desert and Hawaii's Mauna Kea.

The H.E.S.S. site offers well-developed infrastructure and long-term operational experience, whereas Mt. Gamsberg, designated as the future location of the AMT, provides equally advantageous environmental characteristics. Together, these sites could support optical, radio, and gamma-ray facilities, facilitating truly coordinated multi-wavelength observations. Their combination of high

atmospheric transparency, low radio interference, and relative accessibility provides an exceptional foundation for such synergy, from which the AMT is expected to particularly benefit.
Ongoing challenges include the increasing presence of satellite constellations, which pose potential risks to both optical and radio observations. Technical and regulatory vigilance, together with systematic monitoring of site and atmospheric parameters, will be essential to safeguard Namibia's advantages and to consolidate its emerging role as a leading southern-hemisphere node for multi-wavelength astrophysics.

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