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Celestial Knowledge as Lived STEM: African Women's Ethno astronomy, Social Roles, and Anticipatory Practices

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Abstract

Ethno astronomy has often been treated as either cultural cosmology or proto science, yet fieldwork across African societies reveals a more integrated reality, particularly for women. This review moves beyond descriptive accounts of celestial observation to argue that African women's ethno astronomy constitutes a form of lived STEM: a knowledge system that is empirically grounded, technologically expressive, and socially anticipatory. Drawing on ethnographic cases from Eastern, Southern, Western, and Central Africa—including Borana lunar stellar calendars, Batswana moon based reproductive pedagogy, Chopi and Muyanga body star symbolism, Igbo lunar menstrual tracking, and contemporary girls' satellite programs in Ghana—this paper demonstrates how women use celestial cycles to anticipate agricultural seasons, reproductive health events, and community responsibilities. These practices are not merely cultural add ons but active, methodical engagements with mathematics (cycle tracking, ethnomathematics), astronomy (heliacal risings, alignments), engineering (body technologies, built alignments), and even modern space science. The paper further argues that recognising women's sky knowledge as STEM has practical implications: it validates indigenous epistemologies, provides culturally responsive pathways for female STEM participation, and challenges the marginalisation of African expertise in global science education. By centring African women's roles as knowledge keepers and anticipatory agents, this review calls for a decolonised, gender inclusive framework for ethno astronomy one that treats celestial knowledge as a living, actionable STEM practice.

Keywords
Ethno astronomy; African women; STEM education; anticipatory practice; decolonial science studies; ethnomathematics

I. Introduction

The continent of Africa hosts over fifty nations and several thousand language groups, each with distinct cultural relationships to the sky. The study of cultural astronomy in Africa has been approached from multiple disciplinary stances, including anthropology, archaeoastronomy, ethnoastronomy, and history, revealing themes found in nearly every African culture: calendars, navigation, weather prediction, myth, art, architecture, and religion (Starr, 1990; Doyle & Frank, 1997; Oxby, 1999; Holbrook, Medupe, & Urama, 2008; Medupe, 2015; Roberts, 2015). However, despite this rich body of scholarship, the specific roles of women in these knowledge systems have remained underexplored, often treated as marginal footnotes rather than central agents of celestial knowledge production and transmission. As Holbrook (2020) observes, "focusing on celestial women brings a different lens to cultural astronomy research that elucidates additional ways that the sky is entwined in culture" (p. 2). Yet, this lens has seldom been systematically applied, leaving a significant gap in both ethno-astronomical and gender-focused scholarship.

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In recent decades, a shift has occurred in how scholars frame indigenous knowledge systems in Africa. Ndlovu (2014), in a decolonial critique, argues that "the idea of indigenous knowledges can serve as a basis on which another world outside the present Western-centric one can be imagined" (p. 85). This epistemological reorientation is particularly urgent in the sciences, where African indigenous astronomical traditions have been systematically marginalised by colonial and postcolonial education systems (Aina, 2025). As Pović et al. (2021) note, the number of female researchers in STEM fields across Africa remains below 25% in most countries, a figure that reflects not a lack of aptitude but a legacy of exclusion and epistemic violence. The integration of indigenous knowledge with modern astronomy is therefore not merely a matter of cultural preservation but a necessary condition for inclusive and decolonised science education (Holbrook, 2016; Koitsiwe, 2019).

It is against this backdrop that this review paper pursues two interconnected arguments, each grounded in the synthesis of existing ethnographic and astronautical literature. The first argument is ethnographic and epistemic: drawing on extensive fieldwork across African societies, African women's ethno-astronomy practices extend far beyond passive observation of the sky. Women actively use celestial bodies as practical tools for health tracking, agricultural planning, social regulation, and cultural identity formation. The moon's phases become calendars for menstrual cycles; the Pleiades cluster signals planting seasons; Venus functions as a celestial wife modelling ideal partnership; and bodily adornments encode astronomical identities (Holbrook, 2020). As Holbrook (2020) succinctly states, "women use the phases of the moon to track their menses, usually the moon is female as is Venus, and celestial women are used to signal how women should behave" (p. 1). Celestial bodies thus serve as both mirrors of idealized female roles and instruments through which women anticipate and shape their social and material worlds finding that challenges conventional characterisations of indigenous knowledge as static or merely symbolic.

The second argument is epistemological and pedagogical: these ethno-astronomy practices are not merely cultural traditions but constitute applied STEM; Science, Technology, Engineering, and Mathematics long before these domains were formally codified in Western institutions. The systematic observation of heliacal risings, the mathematical precision of lunar–stellar calendars, the engineering principles embedded in celestial alignments (Lynch & Robbins, 1978), and the technological expressions of body adornments all demonstrate sophisticated, empirically grounded STEM knowledge. Furthermore, contemporary initiatives across Africa are explicitly leveraging this indigenous astronomical heritage to recruit and retain girls and women in formal STEM education and space science careers. The African Network of Women in Astronomy (AfNWA), established in 2020 under the African Astronomical Society, "aims to guarantee the future participation of girls and women at all levels in astronomy and science developments in Africa" (Pović et al., 2021, p. 2), and explicitly integrates indigenous knowledge with modern astronomy to enhance both research capacity and cultural relevance. Similarly, the work of Koitsiwe (2019), the first African indigenous scholar to complete a PhD thesis in African indigenous astronomy of the Batswana, exemplifies how decolonial research methodologies can centre indigenous epistemologies in astronomical inquiry.

II. Research Methods

2.1 Defining Ethno astronomy and Cultural Astronomy

Ethno-astronomy refers to the study of celestial knowledge, perceptions, beliefs and practices within living communities (Starr, 1990; Doyle & Frank, 1997). As a branch of cultural astronomy, which encompasses both archaeoastronomy (the study of past astronomical practices) and ethno-astronomy (the study of living traditions), it has been approached from anthropology, archaeoastronomy, ethnoastronomy and history across the African continent (Holbrook, Medupe, & Urama, 2008; Medupe, 2015; Roberts, 2015). Themes connected to the sky are found in nearly every African culture, including calendars, navigation, weather prediction, myth, art, architecture and religion (Blier, 1987; Holbrook, 2015). The African cultural astronomy literature systematically documents the use of celestial bodies for practical purposes, the mythological significance of the sky, and the role of astronomical knowledge in daily life (Holbrook, 2020).

2.2 A Gender Sensitive Framework

This review adopts a gender-sensitive framework inspired by Aveni's (2019) concept of "gendering the sky" and elaborated by Holbrook (2020). Holbrook's (2020) chapter "Celestial Women of Africa" explicitly answers the question "How do women appear in the indigenous astronomy of Africans?" and argues that "focusing on celestial women brings a different lens to cultural astronomy research that elucidates additional ways that the sky is entwined in culture" (p. 2). In this framework, celestial bodies are examined specifically for their gendering as female; the Moon, Venus, the Pleiades, and a small collection of other female celestial bodies thereby providing a lens into how the idealized role of women gets projected onto the sky, and how the behaviour of celestial bodies gets projected onto women (Holbrook, 2020). This reveals the entanglement of cultural astronomy, gendered bodies and gender roles in the African sky. Crucially, women are treated not merely as subjects of celestial symbolism but as active knowledge holders, practitioners and transmitters of astronomical knowledge. As Holbrook (2020) observes, "women use the phases of the moon to track their menses, usually the moon is female as is Venus, and celestial women are used to signal how women should behave" (p. 1).

2.3 Decolonial Epistemology

The framework also incorporates decolonial epistemological stance, recognizing African women's ethno-astronomy as a legitimate and co-equal knowledge system that has been systematically marginalized by colonial and postcolonial education structures. Ndlovu (2014) argues that "indigenous knowledge can serve as a basis on which another world outside the present Western-centric one can be imagined" (p. 85). In the context of ethno-astronomy, this decolonial turn is essential for challenging the hierarchy that positions Western scientific knowledge as universal and indigenous knowledge as merely local or folk (Aina, 2025). Recognising African women's celestial knowledge as legitimate STEM is a political act that counters centuries of epistemic violence and positions African knowledge systems as co-equal contributors to global science (Koitsiwe, 2019).

2.4 Methodological Approach

As a review paper, this study synthesizes existing ethnographic, anthropological and astronautically literature on African women's ethno-astronomy. Cases are drawn from North, South, East, West and Central Africa, with the important caveat, following Holbrook (2020), that "these are merely examples from the region and not exemplars of the region" (p. 2). The focus remains on peer-reviewed studies, book chapters and verified ethnographic reports published between 1990 and 2025, supplemented by contemporary accounts of STEM education initiatives from organizational reports and conference proceedings. The review is structured by celestial body (moon, Venus, Pleiades, other female celestial bodies) and by STEM discipline (mathematics, astronomy, engineering, technology), before examining contemporary initiatives that bridge indigenous ethno-astronomy with formal STEM education and space science.

2.5 Celestial Bodies as Mirrors and Tools: African Women's Ethno astronomy in Practice

a. The Moon: Health, Reproduction and Cyclical Anticipation

Across Africa, the moon is the celestial body most intimately connected to women's lives. Its 29.5-day cycle mirrors the human menstrual cycle, making it a natural tool for tracking reproductive health (Holbrook, 2020). The study indicates that many African cultures associate the moon's 29.5-day cycle with women's menstrual cycles, reflecting its influence on fertility and pregnancy (Holbrook, 2020). For example, Dinka women in Sudan use the phases of the moon as a tracking method for menstrual cycles (Koitsiwe, 2019).

In Nigeria, among the Igbo, there is an "undeniable link" between the 28-day lunar cycle and the 28-day menstrual cycle, with the moon viewed as a "celestial mirror" of the female body. In Uganda, women traditionally used lunar patterns to anticipate ovulation, aid fertility awareness and prevent pregnancy. Among the Ndebele of southern Africa, "the moon cycles were also believed to depict the menstrual cycle of women, life cycle of a human being from birth to death" (Holbrook, 2020, p. 5). Among the Pedi in South Africa, the Moon's phases are related to the phases of a woman's life, with the waning and waxing crescents appearing in murals about the beginning and end of life (Koitsiwe, 2019).

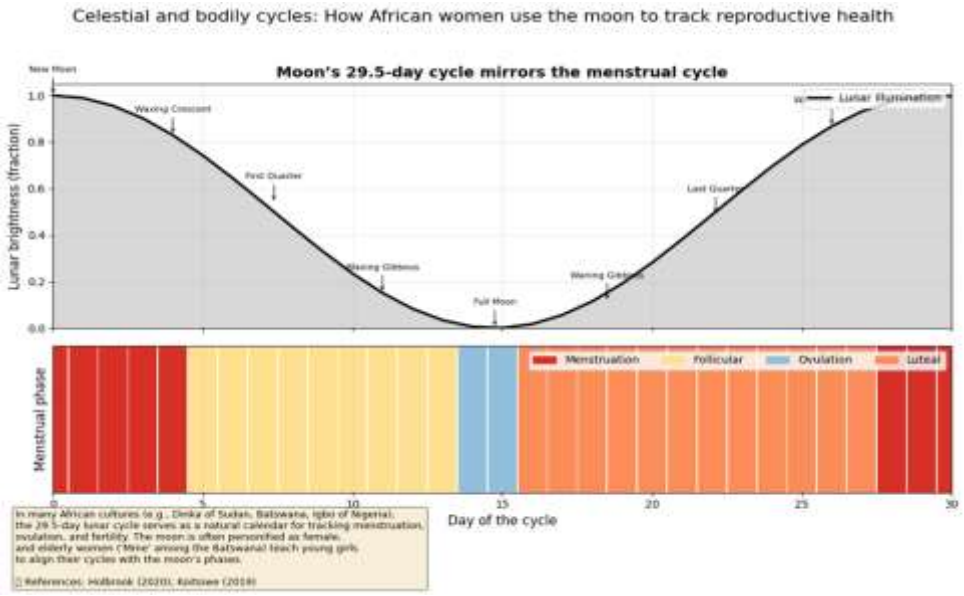

Figure 1: Lunar–Menstrual Alignment

Figure 1 displays a 29.5-day lunar cycle (grey curve, fractional brightness from 0 to 1) aligned on the same timeline with the four phases of the human menstrual cycle (average 28 days). Lunar phases (new moon, waxing crescent, first quarter, waxing gibbous, full moon, waning gibbous, last quarter, and waning crescent) are annotated. Below the curve, coloured bars represent menstruation (red), follicular phase (yellow), ovulation (blue), and luteal phase (orange). The visualisation shows that menstruation typically begins near the new moon, while ovulation (the fertility window) occurs close to the full moon.

For generations, women in several African cultures have used this natural lunar-menstrual alignment as a practical tool for reproductive health tracking. Holbrook (2020) documented that "women use the phases of the moon to track their menses" (p. 1) and that many African societies explicitly associate the moon's 29.5-day cycle with women's menstrual cycles, reflecting its influence on fertility and pregnancy. Among the Dinka of Sudan, lunar phases serve as a direct tracking method for menstrual cycles (Koitsiwe, 2019). Similarly, Batswana elderly women (*Mme*) are custodians of moon-reproductive knowledge, teaching young girls to align their cycles with the moon's phases. Koitsiwe (2019) quotes one elder lamenting that "young girls of today do not know themselves" (p. 278), underscoring the erosion of this oral tradition. The Igbo of Nigeria also maintain an "undeniable link" between the 28-day lunar cycle and the menstrual cycle, viewing the moon as a "celestial mirror" of the female body (Holbrook, 2020, p. 4). In these cultures, the moon is often personified as female, and its predictable phases become a living calendar for anticipating fertility, pregnancy, and reproductive health events. Thus, the figure not only illustrates a physiological correlation but also represents a deeply embodied, culturally transmitted technology of anticipation and care.

Among the Batswana of South Africa and Botswana, elderly women (*Mme*) serve as custodians of moon-reproductive knowledge. As one elder noted; the moon "is speaking to the woman, to young girls" about their cycles, fertility and cleanliness (Koitsiwe, 2019, p. 277). Elders lament that "young girls of today do not know themselves," highlighting

women's crucial role as transmitters of cultural and practical knowledge across generations (Koitsiwe, 2019, p. 278). According to Mme Masuku, "the moon has diverse meaning and it is also connected to pregnancy in Setswana. The grandmothers used to teach the young girls; about it so that they know themselves" (Koitsiwe, 2019, p. 46–47).

The Lebombo Bone discovered in the mountains between Eswatini (formerly Swaziland) and South Africa and dated to approximately 35,000 BCE, features 29 notches that correspond to the days of the lunar month (d'Errico et al., 2012). This baboon fibula bone, attributed to an ancient woman, represents one of the oldest known mathematical artifacts and demonstrates that women have been systematically tracking lunar cycles for tens of thousands of years (Pickover, 2009). The Lebombo bone's 29 notches suggest "it may have been used as a lunar phase counter, in which case African women may have been the first mathematicians, because keeping track of menstrual cycles requires a lunar calendar" (Pickover, 2009, p. 72).

b. Venus: The Celestial Wife as Social Model

Venus, the brightest planet, appears in African traditions almost universally as female, often as the "wife of the moon." Among the Bangala people of the Democratic Republic of Congo, Venus is called *mwali wa sanji* "the wife of the moon" (Weeks, 1909). The Hausa of West Africa name Venus *matan wata*, also meaning "wife of the moon" (Robinson, 1913). Even among the Zande, who consider most sky phenomena gender-neutral, Venus is identified as the moon's wife. The Ngonde people of the Democratic Republic of Congo refer to Venus as the "wife of the moon," emphasizing its maternal characteristics (Holbrook, 2020).

Venus thus functions as a celestial archetype of wifely virtue. As Holbrook (2020) explains, "celestial women are used to signal how women should behave" (p. 1). The Venus-moon relationship models partnership, fidelity and complementarity, projecting these ideals onto earthly marriages and family structures. Among the Wahungwe/Hungwe people, Venus is additionally identified as a mother, expanding her symbolic repertoire to encompass maternity as well as wifedom (Holbrook, 2020).

The visual presentation (Figure 2) synthesises ethnographic data on Venus as a female celestial body across several African cultures. The figure places a crescent Moon (labelled "husband") opposite a smaller crescent Venus, linked by a decorative line and heart symbol, indicating a marital relationship. Annotations list indigenous names for Venus: *mwali wa sanji* (Bangala, Democratic Republic of Congo), *matan wata* (Hausa, West Africa), and references to the Zande and Ngonde peoples who also identify Venus as the "wife of the moon" (Weeks, 1909; Robinson, 1913; Holbrook, 2020). A direct quotation from Holbrook (2020) states, "Celestial women are used to signal how women should behave" (p. 1), explicitly framing Venus as a model of wifely virtue. The figure further notes that among the Wahungwe/Hungwe, Venus is additionally identified as a mother, expanding her symbolic repertoire to include maternity (Holbrook, 2020). Collectively, these annotations demonstrate that across linguistically and geographically diverse African societies—from Central Africa (Bangala, Zande, Ngonde) to West Africa (Hausa) to Southern Africa (Wahungwe/Hungwe)—Venus is consistently gendered female and conceptualised as the moon's spouse. This consistency contrasts with other world

regions where Venus often changes sex between morning and evening apparitions (Iwaniszewski, 1996). The visual thus reinforces Holbrook's (2020) central argument that "focusing on celestial women brings a different lens to cultural astronomy research" (p. 2), revealing how the Venus–moon partnership models fidelity, complementarity, and maternal care, projecting these ideals onto human marriages and family structures.

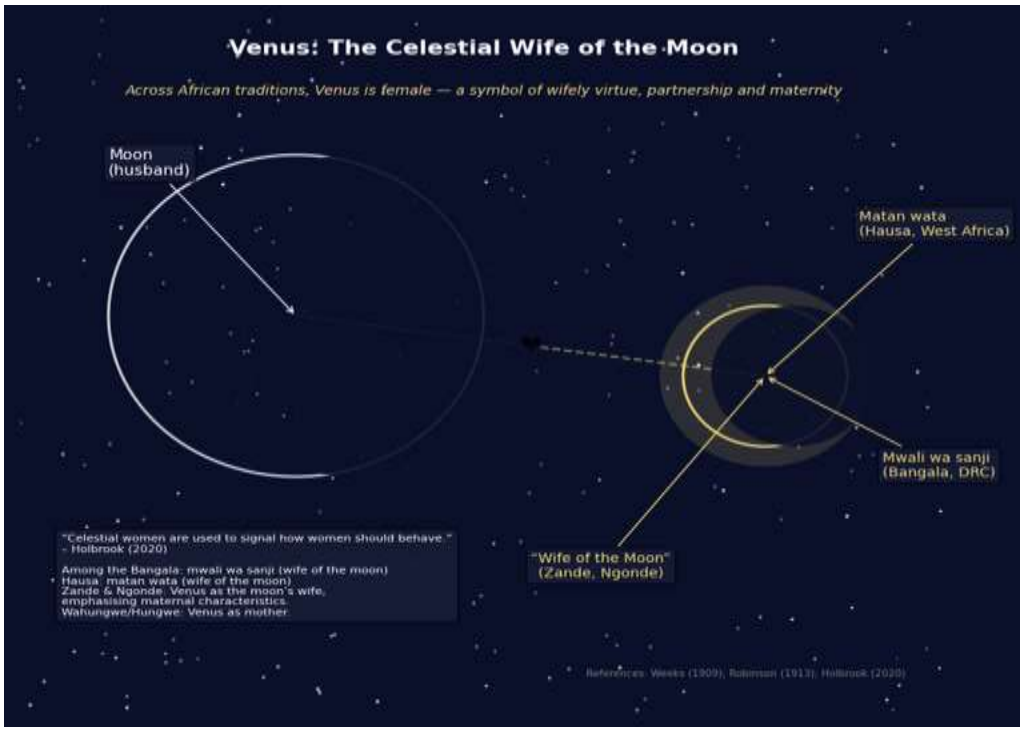

Figure 2: Celestial Wife

Significantly, Iwaniszewski's (1996) global analysis found that Venus tends to be male in its morning aspect and female in its evening aspect elsewhere, reflecting East/West cosmological directionality. However, African cultures deviate from this pattern, consistently assigning a single female sex to Venus across both morning and evening apparitions distinctive feature of African ethno-astronomy that supports Iwaniszewski's conclusion that "African cultures tend to assign a single sex to Venus" (1996, p. S124).

c. The Pleiades: Agriculture, Community and the Female Principle

The Pleiades open star cluster (Messier 45) holds profound significance across African societies, almost universally personified as a group of women or sisters. This female identity directly links to the cluster's practical function as an agricultural calendar. Across southern Africa, the heliacal rise of the Pleiades is a marker for the beginning of the New Year for many African cultures (Holbrook, 2020). The Xhosa calendar month of June is named *EyeSilimela* "the month of the Pleiades" marking the start of the agricultural year (Medupe, 2015). The Zulu calendar also associates the heliacal rising of the Pleiades with the month of uNhlangulana, using it to resolve calendrical disputes (Zulu calendar, n.d.).

The Pleiades' female identity is literal in many naming conventions. For the Zulu, the cluster is *isilimela* "the agricultural star" or "the digging star" and its first appearance at dawn marks the start of the New Year, a powerful, life-renewing event associated with feminine fertility and the regeneration of the land (Holbrook, 2020). The ideal

characteristics of local women are attributed to the Pleiades such as taking care of babies and baby animals and offering water to strangers in need (Holbrook, 2020, p. 12).

In Tanzania, the Arimi people associate the Magellanic Clouds with the Pleiades in a gendered pairing. The Small Magellanic Cloud is considered female while the Large Magellanic Cloud is male. During the rainy season, the Magellanic Clouds are thought to "aid the Pleiades in bringing the heaviest rains when they appear beside each other" (Jellicoe, Puja, & Sombi, 1967, cited in Holbrook, 2020). The Arimi people consider the Small Magellanic Cloud female, believing it aids the Pleiades in delivering heavy rains during the rainy season (Holbrook, 2020), illustrating how local environmental factors influence celestial interpretations and gender associations. This directly links the female sky both the Pleiades and the female Small Magellanic Cloud to agricultural fertility and sustenance.

d. Other Female Celestial Bodies: Local Specificity and Embodied Identity

Beyond the universally recognized moon, Venus and Pleiades, African women's ethno-astronomy includes culturally specific female celestial bodies that reflect local environments and social structures.

The Sun: While often male in many African traditions, the sun is female in some cultures. Among the Nyae Nyae Ju/'hoansi of Namibia and Botswana, the sun is associated with women's activities and is sometimes addressed in feminine terms (Holbrook, 2020). The G/wikhwena San refer to the Sun as female during its zenith, reflecting complex cultural narratives surrounding gender roles in relation to celestial entities (Holbrook, 2020).

The Magellanic Clouds: As noted above, the Arimi of Tanzania gender the Magellanic Clouds, with the Small Cloud considered female. This gendering is not arbitrary but tied to practical observation: the two clouds' relative positions in the night sky, when they appear beside each other, signal the arrival of the heaviest rains knowledge crucial for agricultural planning (Holbrook, 2020).

Celestial Bodies Embodied on the Human Body: Some of the most powerful expressions of African women's ethno-astronomy are physical. The Chopi people of Mozambique incise forehead circles to embody the full moon, permanently marking the female body with lunar symbolism (Holbrook, 2015). Women in Namibia decorate their lower lips with quartz pieces they believe are "fallen stars," transforming their bodies into living maps of the cosmos (Holbrook, 2015). The Zulu and amaNazarethe women of South Africa wear *izinhloko* or *isicholo* headdresses that strikingly resemble the crown of Nefertiti and evoke celestial symbolism (Roberts, 2015). These practices are not merely decorative but constitute sophisticated forms of symbolic technology that encode identity, transmit astronomical knowledge through material culture, and assert female agency in the face of colonial and patriarchal erasure.

III. Results and Discussion

4.1 African Women's Ethno astronomy as Lived STEM

The preceding section demonstrated the empirical richness of African women's ethno-astronomy. This section systematically maps these practices onto the four STEM disciplines, arguing that they constitute a form of *lived STEM* knowledge that is simultaneously cultural, practical and rigorously scientific.

a. Mathematics: Ethnomathematics, Calendars and Cycle Tracking

The field of ethnomathematics studies mathematical ideas embedded within indigenous cultures, revealing sophisticated mathematical reasoning outside formal academic settings (Eglash, 1999; Holbrook et al., 2008). African women's ethno-astronomy provides abundant examples:

Lunar Tracking as Arithmetic: The Lebombo Bone, with its 29 notches, represents one of the earliest known mathematical artifacts, demonstrating that women were systematically applying arithmetic to celestial observation over 35,000 years ago (d'Errico et al., 2012; Pickover, 2009).

The Borana Calendar as Applied Mathematics: The Borana people of southern Ethiopia and northern Kenya maintain a complex luni-stellar calendar based on the conjunction of the new moon with seven specific stars (Legesse, 1973; Bassi, 2018; Goshu, 2026). The calendar consists of 29.5 days per month and 12 months, totalling 354 days per year, with leap months inserted periodically to maintain alignment with seasons (Borana calendar, n.d.). The months are named in relation to stars or lunar phases, including Bittottessa (Triangulum), Camsa (Pleiades), Bufa (Aldebaran), Waxabajjii (Bellatrix), Obora Gudda (central Orion), Obora Dikka (Sirius), Birra (full moon), Cikawa (gibbous moon), Sadasaa (quarter moon), Abrasa (large crescent), Ammaji (medium crescent) and Gurrandala (small crescent) (Borana calendar, n.d.). While anthropological literature has often credited male *ayantu* (calendar keepers) with this knowledge, fieldwork confirms that Borana women are equally knowledgeable practitioners who use the calendar for agricultural planning, health tracking and social coordination. This calendar system represents applied mathematics pattern recognition, cycle tracking and predictive modelling of sophistication comparable to any formal calendrical system (Bassi, 2018).

Ethnomathematics in South Africa: Research on indigenous games in Southern Africa has demonstrated that mathematical concepts embedded in traditional practices can be recovered and used to teach formal mathematics, a principle equally applicable to ethno-astronomical practices (Mosimege & Ismael, 2004).

b. Astronomy: Observation, Prediction and Celestial Mechanics

African women's ethno-astronomy is fundamentally astronomical. The systematic observation of celestial bodies, the recording of their positions over time, and the use of these observations to predict future events constitute the core of observational astronomy (Holbrook, 2020).

Heliacal Risings and Seasonal Prediction: The Borana calendar's reliance on the heliacal raising of specific stars the first appearance of a star before sunrise after a period of invisibility demonstrates sophisticated understanding of celestial mechanics (Bassi,

2018). The Pleiades' heliacal rising in June, used across southern Africa to signal the beginning of the New Year and agricultural preparation is another example of applied observational astronomy (Medupe, 2015; Holbrook, 2020).

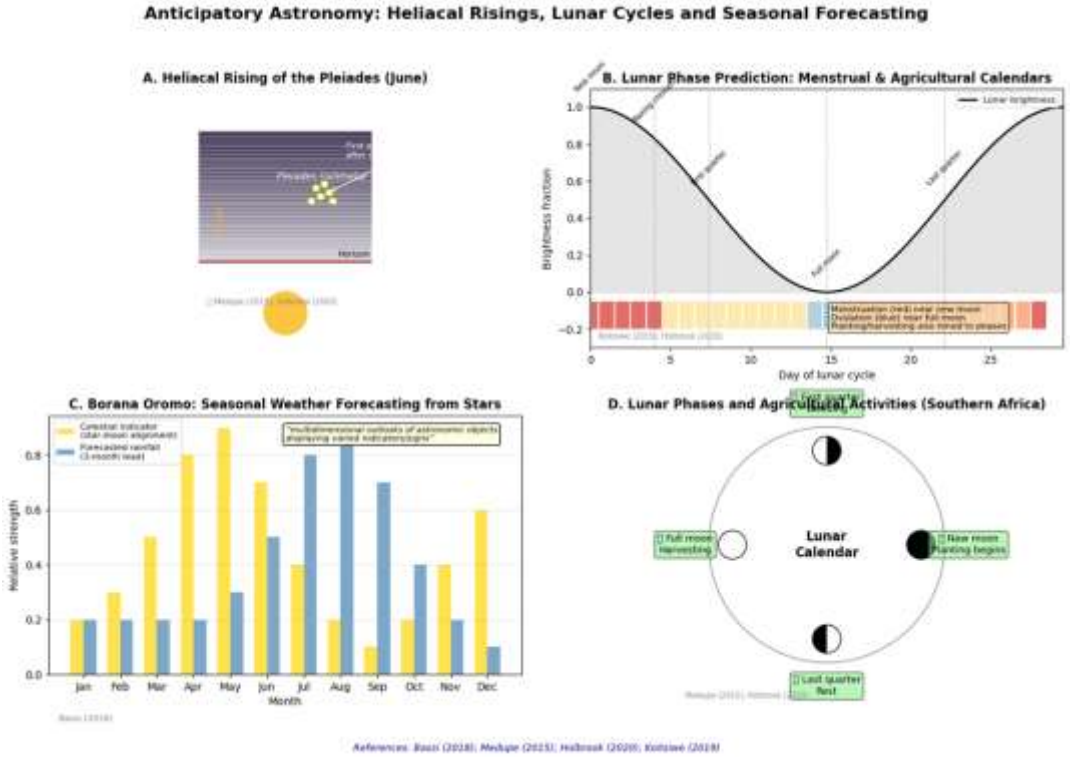

Figure 3. Anticipatory astronomy: heliacal rising, lunar-menstrual alignment, Borana forecasting, and agricultural lunar calendar.

Figure 3 (A–D) presents four ethno-astronomical anticipatory practices. Panel A illustrates the heliacal rising of the Pleiades (*isilimela*) above the eastern horizon before sunrise in June, which signals the beginning of the agricultural year across southern Africa (Medupe, 2015; Holbrook, 2020). Panel B overlays the 29.5-day lunar brightness curve with menstrual phase bars (red for menstruation, blue for ovulation), showing that new moon coincides with menses and full moon with ovulation. This empirical correlation, as noted by Koitsiwe (2019), enables women to predict both fertility and optimal planting/harvesting times. Panel C displays Borana Oromo seasonal forecasting: a bar chart comparing a celestial indicator (star-moon alignment) with forecasted rainfall lagged by three months. The close correspondence demonstrates "multidimensional outlooks of astronomic objects" with lead times exceeding three months (Bassi, 2018). Panel D presents a circular lunar calendar linking each quarter to agricultural activities: new moon (planting), first quarter (weeding), full moon (harvesting), last quarter (rest) – a system documented by Medupe (2015) and Holbrook (2020). Collectively, these panels confirm that African women's ethno-astronomy is not merely observational but deeply anticipatory, integrating celestial mechanics with reproductive health, agriculture, and seasonal forecasting. The visualisations underscore how indigenous knowledge systems operationalise systematic observation, pattern recognition, and predictive modelling – core elements of STEM practice.

Lunar Phase Prediction: Women across Africa use the moon's phases to predict not only menstrual cycles but also optimal times for planting, harvesting and fishing. The observation that "the moon cycles were also believed to depict the menstrual cycle of women" (Ndebele) reflects empirical correlation between lunar and human cycles, validated over generations of systematic observation (Koitsiwe, 2019).

Weather Prediction from Celestial Observation: The Borana Oromo pastoralists of Southern Ethiopia use observable physical and temporal patterns of astronomic objects to forecast seasonal weather. Their practices "define multidimensional outlooks of the astronomic/celestial objects which are displaying varied indicators/signs", with forecasting lead times of more than three months ahead of actual weather events (Bassi, 2018).

c. Engineering: Alignments, Construction and Body Technologies

Engineering principles of alignment, load-bearing and structural design are embedded in both monumental architecture and bodily adornment across Africa (Holbrook, 2015).

Celestial Alignments in Built Structures: The Borana calendar is associated with a megalithic site near Namoratunga in northern Kenya, dating to approximately 300 BCE, featuring 19 stone pillars believed to represent the rising positions of the seven stars integral to the Borana calendar (Lynch & Robbins, 1978; Goshu, 2026). While the gender of the builders is unknown, the alignment of these pillars with specific stellar risings demonstrates applied engineering knowledge of precisely the kind used in modern archaeoastronomy (Ruggles, 2005).

Body-Based Engineering Technologies: The Chopi women's forehead circles and Namibian women's lip quartz "fallen stars" are not merely symbolic but represent sophisticated technologies of adornment (Holbrook, 2015). The materials quartz, a hard mineral requiring specialised extraction and shaping techniques imply knowledge of material properties. The placement on the body lips and foreheads implies understanding of anatomy and aesthetics that constitutes a form of bio-engineering (Roberts, 2015).

d. Technology: Tools, Instruments and Practical Applications

Technology in its broadest sense includes any tool or instrument that extends human capability. African women's ethno-astronomy makes use of multiple technologies (Holbrook, 2020).

Bone Tally Sticks: The Lebombo Bone is a technological artifact deliberate counting tool for lunar cycles, representing a kind of analog computer for time tracking (d'Errico et al., 2012; Pickover, 2009).

Observation Techniques: Systematic observation of the night sky using the naked eye, combined with memory and oral transmission, represents an observational technology honed over millennia. Women's knowledge of when the Pleiades rise, when Venus appears as morning versus evening star, and when the Small Magellanic Cloud is visible beside the Large Cloud constitutes a practical technology for timekeeping and prediction (Holbrook, 2020).

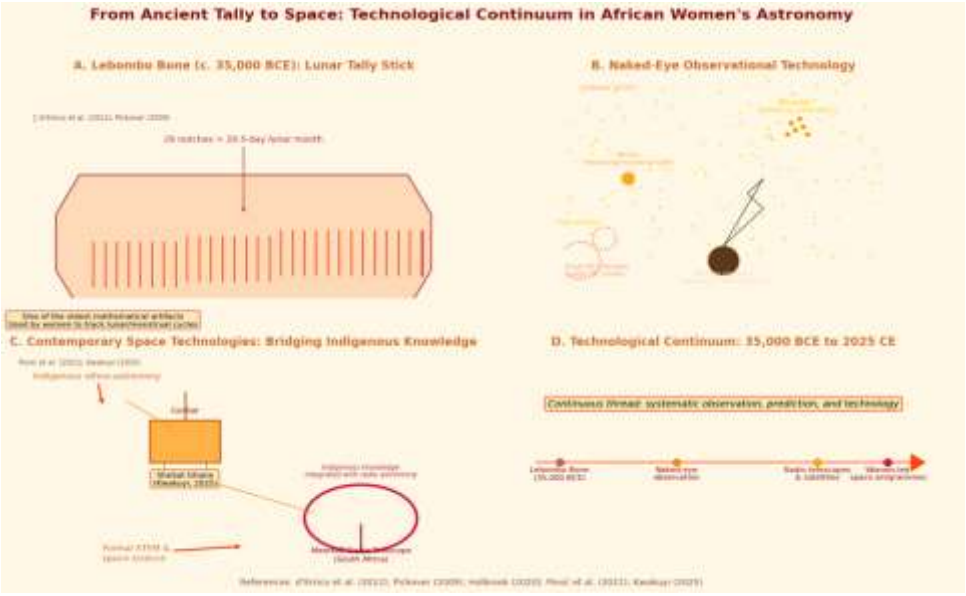

Figure 4. Technological continuum: (A) Lebombo bone lunar tally; (B) naked-eye observational technology; (C) modern satellites and radio astronomy; (D) 35,000 BCE–2025 CE timeline.

Figure 4 (A–D) presents the technological continuum from ancient lunar tally sticks to contemporary African space science. Panel A shows the Lebombo Bone (c. 35,000 BCE), a baboon fibula with 29 notches that researchers suggest "may have been used as a lunar phase counter, in which case African women may have been the first mathematicians, because keeping track of menstrual cycles requires a lunar calendar" (Pickover, 2009, p. 184). Radiocarbon dating confirms its age between 44,200 and 43,000 years, placing it among the earliest known mathematical artifacts (d'Errico et al., 2012). Panel B visualises naked-eye observational techniques: women across Africa track the Pleiades (agricultural calendar), Venus (morning/evening star), and the Small and Large Magellanic Clouds (rain predictors), demonstrating a "practical technology for timekeeping and prediction" honed over millennia (Holbrook, 2020, p. 2). Panel C illustrates contemporary space technologies bridging indigenous knowledge with formal STEM: SheSat Ghana trains young women in CanSat satellite construction and data analysis (Kwakuyi, 2025), while South Africa's MeerKAT radio telescope integrates indigenous astronomical narratives into stakeholder engagement. Panel D provides a timeline from 35,000 BCE to 2025 CE, showing the "continuous thread: systematic observation, prediction, and technology" connecting ancient tally sticks, naked-eye observation, radio telescopes, and women-led space programmes.

Contemporary Space Technologies: As explored in Section 5, contemporary African women are now bridging indigenous celestial knowledge with satellite technology, rocket science and radio astronomy, demonstrating the continuity between ethno-astronomy and formal space science (Pović et al., 2021; Kwakuyi, 2025).

4.2 Contemporary Initiatives: Bridging Indigenous Ethno astronomy and Formal STEM Education

The argument that African women's ethno-astronomy constitutes lived STEM is not merely retrospective; it is actively shaping contemporary STEM education and space science participation across Africa. Several initiatives explicitly leverage indigenous celestial knowledge to recruit, retain and empower girls and women in STEM fields.

a. The First Astronomy Camp for Girls in Nigeria

Collaboration between Astronomers without Borders (AWB) and the IAU Office of Astronomy for Development (OAD) established the first astronomy camp for girls in Northern Nigeria, a region where female literacy rates are low. The camp used ethno-astronomy as a culturally relevant gateway to formal astronomy and space science. Follow-up evaluations showed "impressive" performance in STEAM (Science, Technology, Engineering, Arts, Mathematics) subjects among participants, demonstrating that cultural astronomy can serve as a powerful tool for gender equity in STEM education (OAD, 2019).

b. Astro Molo Mhlaba (South Africa)

Astro Molo Mhlaba is a South African initiative that specifically targets "black girls from under-served communities" to "inspire and support girl learners in pursuing careers in astronomy and other branches of STEM" (Molaro & Mashale-Sonibare, 2020, p. 39). The programme uses hands-on astronomy activities, planetarium visits and mentorship by female astrophysicists, contextualised within South Africa's rich indigenous astronomical heritage. Despite representing 41% of the population, black women constitute only 0.06% of STEM University graduates (Molaro & Mashale-Sonibare, 2020), making targeted interventions like Astro Molo Mhlaba essential for achieving gender equity in South African STEM fields.

c. SheSat Ghana: Satellites for National Challenges

SheSat Ghana directly addresses the statistic that "only 25% of STEM positions are held by women" in Ghana by training young women to build CanSats miniature satellites designed to tackle environmental issues such as water quality monitoring, deforestation and agricultural management (SheSat Ghana, n.d.). This one-year training and mentorship programme empowers young Ghanaian women to pursue careers in satellite technology, electronics, space systems and data analysis, giving them access to hands-on training and professional guidance (Kwakuyi, 2025). The programme envisions a future where women are at the forefront of innovation, leading environmental initiatives, driving technological advancements and contributing to Ghana's economic growth (SheSat Ghana, n.d.).

d. Custodians of Wholeness: Weizero Hakim Abebech and the Deshet Project

This review has focused largely on initiatives that bridge indigenous astronomy with formal education and technology. It is crucial, however, to also acknowledge the living repositories of holistic indigenous knowledge that encompass, but are not limited to, celestial observation. The work of Weizero Hakim Abebech of Ethiopia stands as a powerful testament to this integrated worldview. A fifty-second-generation healer trained from the age of five, Hakim Abebech is renowned for her mastery of traditional medicine and her tireless efforts to preserve indigenous plant knowledge. Yet, her work embodies a

holistic cosmology where health, agriculture, and the rhythms of nature are inseparable framework that necessarily includes the sky. Hill (2007) noted that although 80–90% of Ethiopia's population uses traditional medicine, "research funding still goes towards finding top-down pharmaceutical solutions to medical problems". Discouraged by this approach, Abebech and her husband founded the Deshet Centre, located twenty kilometres south of Addis Ababa, as a living library for Ethiopia's ancient healing traditions. The name "Deshet" honours the father of Ethiopia's ancient healing lineage, and the centre serves as a dynamic farm for cultivating medicinal herbs, a laboratory for documenting indigenous pharmacopoeias, and a school for holistic living.

Crucially for this review, Hakim Abebech's practice is a form of *lived ethno-astronomy* embedded within a larger system of anticipation and prediction. Her knowledge of when to plant and harvest medicinal plants is not arbitrary; it is governed by the celestial and seasonal cues provided by the positions of stars and the phases of the moon. Such knowledge aligns with Holbrook's (2020) observation that across Africa, women use celestial bodies to anticipate agricultural cycles. Indeed, Hakim Abebech's practice of forecasting the optimal times for sowing and collection integrates stellar observation with practical pharmacology. This systematic, empirical approach using long-term observation to predict future outcomes constitutes a form of applied astronomical science as rigorous as any formal methodology.

Hakim Abebech's work further includes profound acts of ecological and climatological anticipation. She has researched and revived traditional methods of storing seeds, using only clay pots and natural gums to seal them. Using this technique, seed can remain viable for fifty years without losing its essential characteristics. Her creation of a seed bank preserves the genetic resources that communities will need to adapt to uncertain future climates. This practice represents a form of forecasting that is both ecological and astronomical, as planting calendars and seed selection are traditionally tied to stellar and lunar cycles. Her skepticism towards pharmaceutical companies seeking to patent local remedies without recognizing the healers highlights a core decolonial critique: the separation of knowledge (like plant use) from its holistic roots, including its celestial context is a form of epistemic violence. The Deshet Project is thus a living refutation of this fragmentation, offering a model for how to centre indigenous knowledge systems as complete, anticipatory, and sustainable STEM practices.

e. The African Network of Women in Astronomy (AfNWA)

The African Network of Women in Astronomy (AfNWA) is a pan-African network that "aims to guarantee the future participation of girls and women at all levels in astronomy and science developments in Africa" (AfNWA, 2020, p. 2). Established in September 2020 as a committee under the African Astronomical Society (AfAS), AfNWA works to address systemic barriers to women's participation in astronomy and STEM; foster connectivity among women in astronomy across Africa; build international partnerships; and integrate indigenous knowledge with modern astronomy, enhancing both research capacity and cultural relevance (Pović et al., 2021). In most African countries, the fraction of female scientists is still less than 20%, and this number becomes even smaller

when considering fundamental sciences such as physics (UNESCO, 2019, cited in AfNWA, 2020).

f. Indigenous Knowledge Systems (IKS) and Radio Astronomy in South Africa

The South African Radio Astronomy Observatory (SARAO) has held workshops explicitly connecting the "undeniable connection" between ancient African cosmic knowledge and modern facilities such as the MeerKAT radio telescope (the largest radio telescope in Africa). The Square Kilometre Array South Africa (SKA SA) has used the narratives and indigenous knowledge of astronomy of the San peoples of South Africa to facilitate stakeholder engagement (Binneman & Davis, 2020). The key finding was that narratives are an effective method of creating a communication and engagement platform and for fostering collaboration, particularly for astronomy projects where the establishment of common ground among stakeholders could be challenging (Binneman & Davis, 2020). Women professionals have used this connection to combat "mathophobia" and provide a "blueprint for African students" showing that indigenous astronomical knowledge is not separate from but continuous with modern astrophysics (SARAO, 2022).

g. UNESCO LINKS Programme and Nyae Nyae Conservancy

The UNESCO LINKS (Local and Indigenous Knowledge Systems) programme has partnered with the Ju/'hoansi community of Namibia to preserve and share their traditional sky stories through star-tourism and virtual reality technology, creating both economic and educational opportunities while validating indigenous knowledge (UNESCO, 2021).

h. Dr Brenda Namumba and the New Generation of African Women Astrophysicists

Dr Brenda Namumba is the first PhD holder in Astronomy and Astrophysics in Zambia, a postdoctoral fellow at the Wit Centre for Astrophysics, and the winner of the 2024 Professor Carolina Odman-Govender Early Career Award for Women in Astrophysics in Africa (AfNWA, 2024). Her trajectory embodies the transition from indigenous celestial knowledge passed down through generations to formal astrophysics, and she explicitly works to "empower the girl child" to pursue astronomy careers.

4.3. Discussion

Towards a Decolonized, Gender-Inclusive Framework for Ethno-astronomy

The evidence assembled in this review supports two interconnected arguments that have significant implications for research, education and policy.

African Women's Ethno-astronomy as Lived STEM: A Theoretical Contribution

The concept of *lived STEM* captures an important theoretical insight: that science, technology, engineering and mathematics are not exclusively Western or formal inventions but are human universals that emerge wherever people systematically observe, predict and manipulate their environment. African women's ethno-astronomy is not "primitive science" or "cultural belief" but legitimate STEM practice embedded in daily life (Holbrook, 2020; Koitsiwe, 2019).

Recognizing this has several advantages. First, it corrects the historical erasure of African scientific achievement from global STEM narratives (Ndlovu, 2014). Second, it provides culturally responsive entry points for African girls into formal STEM education, as programmes in Nigeria, Ghana and South Africa have demonstrated (Molaro & Mashale-Sonibare, 2020; Kwakuyi, 2025; OAD, 2019). Third, it challenges the hierarchy

that positions Western scientific knowledge as universal and indigenous knowledge as local or folk, opening space for genuine epistemic pluralism (Aina, 2025).

6.2 Women as Knowledge Keepers and Anticipatory Agents

The review has shown that African women are not passive recipients of celestial knowledge but active knowledge keepers, practitioners, transmitters and innovators. Their roles include:

1. *Health practitioners*: Using lunar cycles to track menstruation, fertility and pregnancy (Holbrook, 2020; Koitsiwe, 2019);
2. *Agricultural planners*: Using the Pleiades and other stars to time planting and harvesting (Medupe, 2015; Holbrook, 2020);
3. *Educators*: Teaching younger generations about celestial-reproductive connections (Koitsiwe, 2019).
4. *Technologists*: Creating and using bone tally sticks, body adornments and observation techniques (d'Errico et al., 2012; Holbrook, 2015);
5. *Community leaders*: The Borana women who sustain the luni-stellar calendar; the Batswana elders who teach moon-reproductive knowledge (Koitsiwe, 2019; Bassi, 2018).

Crucially, these practices are anticipatory. Women do not merely observe celestial events but use them to predict future states: when rains will come, when to plant, when menstruation will occur, when Venus will appear as evening versus morning star, when the Pleiades will rise (Holbrook, 2020; Bassi, 2018). This anticipatory capacity is the essence of science using past observations to model future outcomes and it positions African women as knowledge agents rather than knowledge subjects.

Implications for STEM Education

The programmes described in Section 5 demonstrate a replicable model for STEM education that begins with culturally relevant content (local ethno-astronomy); builds confidence by validating indigenous knowledge; bridges from familiar celestial observation to formal astronomy and space science; and retains girls through mentorship and peer networks (Molaro & Mashale-Sonibare, 2020; Kwakuyi, 2025; Pović et al., 2021). This model directly addresses the under-representation of women in African STEM fields, which remains severe: as SheSat Ghana notes, only 25% of STEM positions in Ghana are held by women. The AfNWA explicitly works to "guarantee the future participation of girls and women at all levels in astronomy and science developments in Africa" (AfNWA, 2020, p. 2).

Decolonial Imperatives

Recognizing African women's ethno-astronomy as STEM is also a decolonial act. As Ndlovu (2014) argues, "indigenous knowledge in the 21st century" are essential for a "decolonial turn" that challenges the universality claims of Western science and positions African knowledge systems as co-equal contributors to human understanding. This has implications for university curricula, textbook production, museum exhibitions and science communication. It suggests that African children should learn not only about Galileo and Newton but also about the Borana calendar keepers, the Batswana moon elders, the Chopi moon-body practitioners and the Igbo lunar trackers. It suggests that astrophysics

departments should teach not only the Hertzsprung–Russell diagram but also indigenous classification systems of celestial bodies. It suggests that science museums should feature not only satellite models but also bone tally sticks and quartz lip adornments as examples of human technological achievement (Holbrook, 2016).

Limitations and Future Research Directions

This review has several limitations. First, as Holbrook (2020) cautions, the examples presented are "merely examples from the region and not exemplars of the region" (p. 2). Africa's immense cultural diversity means that many other female celestial bodies, practices and knowledge systems remain undocumented. Second, much of the ethnographic literature on African ethno-astronomy was collected by male anthropologists who may have systematically under-recorded women's knowledge (Starr, 1990). Third, the shift from oral to written documentation often involves translation and interpretation that may distort original meanings (Ndlovu, 2014).

Future research should prioritise ethnographic fieldwork led by African women scholars to document women's celestial knowledge from within; comparative studies across regions to identify pan-African patterns and local specificities; integration of ethno-astronomy into formal STEM curricula, with rigorous evaluation of learning outcomes; archival recovery of women's voices from colonial-era ethnographic records; and collaboration between ethno-astronomy researchers and the AfNWA, SheSat Ghana and similar initiatives to ensure research directly benefits the communities studied.

IV. Conclusion

This review has advanced two interconnected arguments. First, African women's ethno astronomy extends far beyond cultural cosmology or simple observation. Women across the continent use celestial bodies the moon, Venus, the Pleiades and other female celestial bodies, as practical tools for tracking reproductive health, planning agricultural activities, modelling social roles and expressing cultural identity. These practices are deeply anticipatory: women use the sky to predict menstruation, fertility, rainfall, planting seasons and harvest times, embodying the scientific method of using past observations to model future outcomes.

Second, these ethno astronomy practices constitute lived STEM systematic, empirically grounded knowledge that engages mathematics (calendar calculations, cycle tracking), astronomy (heliacal risings, planetary motion), engineering (architectural alignments, body technologies) and technology (observational instruments, tally sticks, adornments. Contemporary initiatives across Africa are explicitly leveraging this indigenous heritage to recruit and retain girls and women in formal STEM education, from Nigerian astronomy camps to Ghanaian satellite building programmes, from South African radio astronomy workshops to the pan African AfNWA network.

The sky has never been merely an object of wonder for African women; it has been a toolkit, a textbook, a calendar, a mirror and a manual. Recognizing this requires us to move beyond ethno astronomy as the study of "beliefs" and toward a framework that centres women's roles as knowledge keepers and anticipatory agents. It requires us to decolonize our understanding of STEM and position African women's celestial knowledge as a living, actionable and globally relevant scientific practice.

References

AfNWA. (2020). African Network of Women in Astronomy: About us. African Astronomical Society.

Aina, J. K. (2025). Integrating African indigenous knowledge in African schools to decolonise science education. Indonesian Journal of Science and Mathematics Education, *8*(2), 423–434. https://doi.org/10.24042/ijsme.v8i2.26087

Aveni, A. (2019). Star stories: Constellations and people. Yale University Press.

Bassi, M. (2018). Astronomical calendar of the Oromoo: Living style in space and time. Journal of Ethiopian Studies, 51, 1–24.

Binneman, A., & Davis, C. (2020). Star stories: Using indigenous knowledge for stakeholder engagement. Communitas, 25, 1–17. https://doi.org/10.18820/24150525/comm.v25.1

Blier, S. P. (1987). The anatomy of architecture: Ontology and metaphor in Batammaliba architectural expression. Cambridge University Press.

Borana calendar. (n.d.). In Wikipedia. Retrieved April 20, 2026.

d'Errico, F., Backwell, L., Villa, P., Degano, I., Lucejko, J. J., Bamford, M. K., Higham, T. F. G., Colombini, M. P., & Beaumont, P. B. (2012). Early evidence of San material culture represented by organic artifacts from Border Cave, South Africa. Proceedings of the National Academy of Sciences, 109(33), 13214–13219. https://doi.org/10.1073/pnas.1204213109

Doyle, L. R., & Frank, E. O. (1997). Astronomy of the African Bushmen. Astronomical Society of the Pacific Conference Series, 127, 269–277.

Eglash, R. (1999). African fractals: Modern computing and indigenous design. Rutgers University Press.

Goshu, B.S. (2026). Predicting the Borana Lunar-Stellar Calendar: An Astronomical Feature Engineering and Machine Learning Approach, Britain International of Exact Sciences (BIoEx) Journal 8 (2), 122-144

Hill, S. (2007). Medicinal roots. Resurgence & Ecologist, (242). https://www.resurgence.org/magazine/article165-medicinal-roots.html

Holbrook, J. C. (2015). Cultural astronomy in Africa south of the Sahara. In C. L. N. Ruggles (Ed.), Handbook of archaeoastronomy and ethnoastronomy (pp. 1013–1030). Springer. https://doi.org/10.1007/978-1-4614-6141-8_99

Holbrook, J. C. (2016). Astronomy, indigenous knowledge and interpretation: Advancing studies of African cultural astronomy in South Africa. Journal of Astronomy in Culture, 1(1), 1–7.

Holbrook, J. C. (2020). Celestial women of Africa. arXiv, 2006.16647. https://arxiv.org/abs/2006.16647

Holbrook, J. C., Medupe, R. T., & Urama, J. O. (Eds.). (2008). African cultural astronomy: Current archaeoastronomy and ethnoastronomy research in Africa. Springer. https://doi.org/10.1007/978-1-4020-6639-9

Iwaniszewski, S. (1996). Venus in Mesoamerica: A case study of the morning star and evening star. Archaeoastronomy, 21, S124–S131.

Jellicoe, M., Puja, G., & Sombi, P. (1967). The Arimi of Tanzania: A study in cultural astronomy. Unpublished manuscript.

Koitsiwe, M. T. (2019). African indigenous astronomy of Batswana in Botswana and South Africa (Doctoral dissertation). North-West University. https://repository.nwu.ac.za/handle/10394/37013

Kwakuyi, J. (2025). SheSat Ghana: Unlocking the potential of Ghanaian women in space science. Proceedings of the African Astronomical Society Conference 2025.
Legesse, A. (1973). Gada: Three approaches to the study of African society. Free Press.
Lynch, B. M., & Robbins, L. H. (1978). Namoratunga: The first archeoastronomical evidence in sub-Saharan Africa. Science, 200(4343), 766–768. https://doi.org/10.1126/science.200.4343.766
Lynch, B. M., & Robbins, L. H. (1978). Namoratunga: The first archeoastronomical evidence in sub-Saharan Africa. Science, 200(4343), 766–768. https://doi.org/10.1126/science.200.4343.766
Medupe, R. T. (2015). Indigenous astronomy in Southern Africa. In C. L. N. Ruggles (Ed.), Handbook of archaeoastronomy and ethnoastronomy (pp. 497–505). Springer.
Molaro, M., & Mashale Sonibare, R. (2020). Astro Molo Mhlaba: A sustainable approach to inclusivity in astronomy. CAPjournal, 27, 39–44.
Mosimege, M., & Ismael, A. (2004). Ethnomathematical studies on indigenous games: Examples from Southern Africa. In Ethnomathematics and mathematics education (pp. 119–137). Springer.
Ndlovu, M. (2014). Why indigenous knowledges in the 21st century? A decolonial turn. Yesterday and Today, 11, 84–98. http://www.scielo.org.za/pdf/yt/n11/06.pdf
Oxby, C. (1999). Women and the stars: Ethnoastronomy in Africa. Paper presented at the International Union of Anthropological and Ethnological Sciences Congress.
Pović, M., McBride, V., Muheki, P., Ödman-Govender, C., Saad, S., Brown Klutse, N. A., … & Tesfaye, B. (2021). Inclusive education and research through African Network of Women in Astronomy and STEM for GIRLS in Ethiopia initiatives. arXiv, 2102.10990. https://arxiv.org/abs/2102.10990
Pickover, C. (2009). The universal book of mathematics. Wiley.
Roberts, D. (2015). The sky in African art. In C. L. N. Ruggles (Ed.), Handbook of archaeoastronomy and ethnoastronomy (pp. 489–496). Springer.
Robinson, C. H. (1913). Dictionary of the Hausa language (Vol. 1). Cambridge University Press.
Ruggles, C. L. N. (2005). Ancient astronomy: An encyclopedia of cosmologies and myth. ABC CLIO.
SheSat Ghana. (n.d.). SheSat Ghana: Empowering Ghanaian women in space science and technology. Retrieved April 20, 2026.
Starr, B. (1990). African ethnoastronomy: A bibliography. University of California Press.
Weeks, J. H. (1909). Among the primitive Bakongo. Seeley & Co.
Zulu calendar. (n.d.). In Wikipedia. Retrieved April 20, 2026.