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Comprehensive Observation of the 21 June 2020 Annular Solar Eclipse in Northern India: Phase Evolution, Atmospheric Response, and the Ring of Fire Phenomenon

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Abstract:

On 21,june,2020, annular solar eclipse was witnessed from Nakodar City, situated in the northern part of India. The rare celestial phenomenon created the clear "Ring of Fire" effect when the Moon passed well in front of the Sun but, because it had a smaller angular size, did not block the Sun completely. With a Celestron AstroMaster 130EQ telescope and a certified solar filter, we effectively recorded the full sequence of eclipse stages, from the beginning contact, to maximum annularity, to the end contact, under secure and stable observational conditions. This study offers a critical observational analysis based on ground-level photographic records of the eclipse without automated image analysis tools. Instead, phase tracking was manually done using a controlled time-sequenced observation protocol, while ensuring the proper detection of all important stages, including annular ring formation. Additional atmospheric conditions like visible light obscuration and temperature variation were recorded during the eclipse interval to determine its immediate terrestrial impacts. The article explains the geometrical and physical concepts that occur during the eclipse, such as the conditions required for annularity, magnitude of the eclipse, and obscuration ratio. The article also notes the capability of amateur-level astronomical machinery to produce high-quality observational data adequate for scientific reporting. This research seeks to add to the general field of solar astronomy by offering an organized instance of eclipse recording from a rural setting in India, confirming the relevance of local ground observations to global eclipse science.

Keywords: Annular Solar Eclipse, Ring of Fire, Ground-based Observation, Phase Transition, Atmospheric Effects, Northern India.

1. Introduction

A solar eclipse provides researchers with a natural laboratory to observe the Sun's interaction with the Earth's atmosphere[1]. It briefly changes the environment, producing an abrupt change in light and temperature that can uncover concealed atmospheric dynamics. The annular solar eclipse of 21 June 2020, that traversed some regions of India such as Nakodar City in the state of Punjab, was a rare chance to research solar eclipse geometry, exact timing of the eclipse phases, visual effects, and climatic variations in localized areas. At a solar eclipse, the Moon moves between the Earth and the Sun, putting a shadow

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on the solar disc, partially or fully covering it. During an annular eclipse, the Moon is at apogee the farthest distance from the Earth hence appears a bit smaller than the Sun. Therefore, it does not block the Sun fully, casting a bright "ring of fire" around the Moon's shape [2]. This very uncommon alignment significantly minimizes sunlight for a few minutes and offers a visibly spectacular heavenly event. The June 2020 eclipse was annular at maximum in northern India, and there was a short but best possible moment to observe it in Nakodar. Annular eclipses are great solar and celestial mechanics tests and are good sources of information for atmospheric studies. They enable the study of solar irradiance effects in a safe manner, local temperature changes, and wind pattern changes. In this observation, we were concerned with visual inspection and documentation of the phases of the eclipse, shadow behavior, and ambient light variations across the annularity. The observation was carried out with the Astromaster 130 EQ telescope fitted with suitable solar filters to permit safe observation and imaging[9]. DSLR cameras were employed for the detection of gradual eclipse phase transitions, ambient light variations, and observable phenomena such as the "ring of fire." With this research, we intend to identify the relevance of annular eclipses in the consideration of fast solar-atmospheric interactions and provide observational data for further research on eclipses.

2. Methodology

Observational study of the annular solar eclipse of 21 June 2020 was conducted from Nakodar City, Punjab, India, where the annular phase and all the partial phases were visible clearly under good weather conditions. The major aim was to capture the changeover of eclipse phases and note associated atmospheric changes through ground-based, amateur-level optics. A Celestron AstroMaster 130EQ Newtonian reflector telescope served as the main observation device. The telescope was equipped with an approved solar filter to allow safe observation of the Sun during the event. The visual tracking was manually done via the eyepiece of the telescope, and the altering phases of the Sun were recorded using a smartphone camera held firmly at the eyepiece. This method enabled the recording of major phases, such as first contact, maximum annularity, and last contact, without making use of automated image-processing systems[3].

All phases of the eclipse were tracked closely, and timestamps were recorded in accordance with local Indian Standard Time (IST). The major timings that were recorded were:

- First contact (partial starts): 10:21 AM
- Beginning of annularity: 12:01 PM
- Maximum annularity (Ring of Fire): 12:10 PM
- Annularity ends: 12:33 PM
- Last contact (partial ends): 1:47 PM

Environmental observations were also conducted during the eclipse. The ambient light intensity was found to decrease noticeably, particularly at the maximum annular phase, producing a dark, dusk-like environment. A slight temperature fall was also felt, documented manually based on subjective observation and comparison with pre-eclipse conditions. Throughout the event, every precaution was taken to adhere to all solar observation safety procedures, such as the proper use of solar filters and avoiding direct unfiltered exposure of the eye or camera to sunlight.

3. Results

The annular solar eclipse witnessed on 21 June 2020 at Nakodar City, Punjab, India, offered a unique chance to record and study the entire eclipse sequence, from the initial contact to the development of the ring of fire. With a Celestron AstroMaster 130EQ telescope equipped with a certified solar filter, a series of high-quality images were taken, offering useful visual information about each phase of the eclipse[10].

Analysis of phases

The eclipse sequence was captured in a time-series fashion, demonstrating the progressive cover-up of the solar disc by the Moon. The initial contact was around 10:20 AM IST, the moment when the Moon started traversing the Sun. This was evidently reproduced in Figure 1, with a small notch on the solar rim.

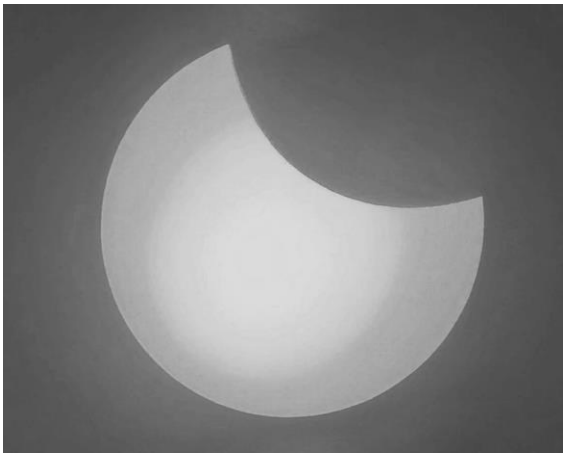

Figure 1 Initial partial phase of the solar eclipse, where the Moon begins to obscure the Sun's disk.

As time went on, the Moon inserted further into the solar disc, and around 11:40 AM IST, the eclipse was at its peak phase the annular phase when the Moon was centrally positioned but marginally smaller in apparent diameter, creating the dramatic "Ring of Fire", clearly visible in Figure 4. The transition sequence is evident in Figures 2 and 3, which display intermediate phases of partial obscuration.

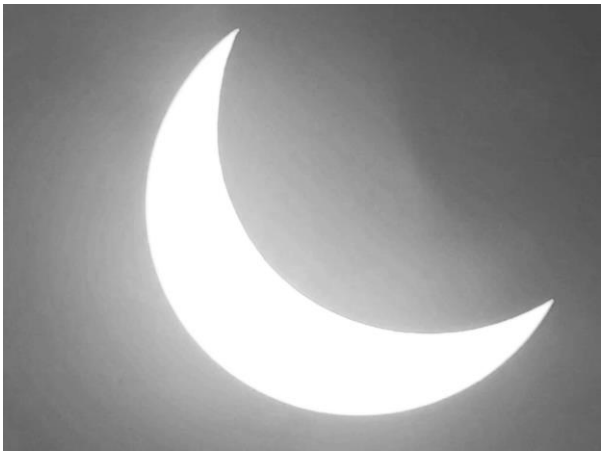

Figure 2: Advanced partial phase of the eclipse, showing a slender crescent of the Sun just before the onset of annularity.

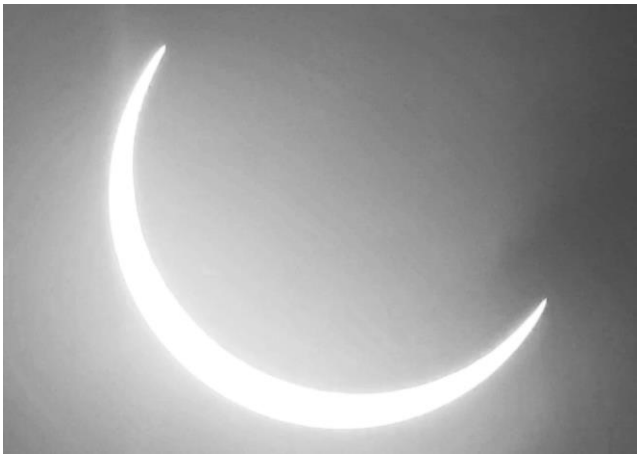

Figure 3: Annular phase , the 'Ring of Fire' is clearly visible as the Moon covers the Sun's center, leaving a brilliant outer ring.

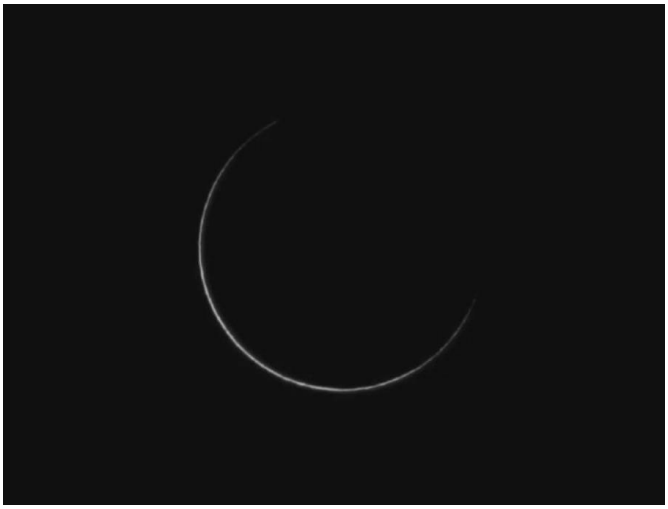

Figure 4: Enhanced view of the annular phase , a precise "Ring of Fire" captured at maximum eclipse, with the Moon perfectly centered against the Sun, forming a bright, uniform circular outline.

The last contact, which signaled the closure of the eclipse, was noted at about 1:47 PM IST, when the Moon moved out of the solar disc completely.

Ring of Fire Visibility

The annular eclipse, although short-lived at its peak, displayed a clearly defined and sharply discernible ring configuration, viewed without interference from the atmosphere such as clouding or haziness. The position of observation in Nakodar, geographically situated near the central path of the eclipse, provided a very clean ring visibility. This clear formation is seen in Figure 4, illustrating the most scientifically relevant point of the eclipse.

Atmospheric Changes

While no sophisticated atmospheric sensors were employed, qualitative data were taken during the event. A significant diminution of ambient temperature and light was measured during the maximum annularity.

The surroundings displayed dimming similar to that during early dusk, and shadows became sharper and crisper. Birds and animals in the surrounding area also responded unusually at the eclipse maximum, showing behavioral modification likely induced by the surprise fluctuation of light and temperature.

Temperature Variation during the Solar Eclipse of 21 June 2020

On the occasion of the solar eclipse witnessed on June 21, 2020, in Nakodar, Punjab, a significant fall in ambient temperature was noticed. The eclipse commenced at approximately 10:20 AM (First Contact), peaked at 12:10 PM, and ended at 1:50 PM (Last Contact). At the culmination point, almost 98–99% of the disc of the Sun was covered, and people in Nakodar experienced a profound partial eclipse[4]. Meteorological observations over comparable North Indian areas recorded a temperature decline of around 4°C, from an initial ~38°C prior to 10:30 AM to about 34°C at 12 PM, shortly before the maximum eclipse [5]. This cooling was due mainly to the sudden loss of solar radiation during the eclipse. From 12:30 PM onwards, when the Sun slowly reappeared, temperatures started to recover. The trend is depicted in Figure 5, representing the temperature variation with reference to phases of eclipse. The first contact, maximum eclipse, and last contact are represented by blue, red, and green dashed lines, respectively. The graph illustrates how celestial phenomena such as eclipses can have a temporary impact on atmospheric conditions on Earth.

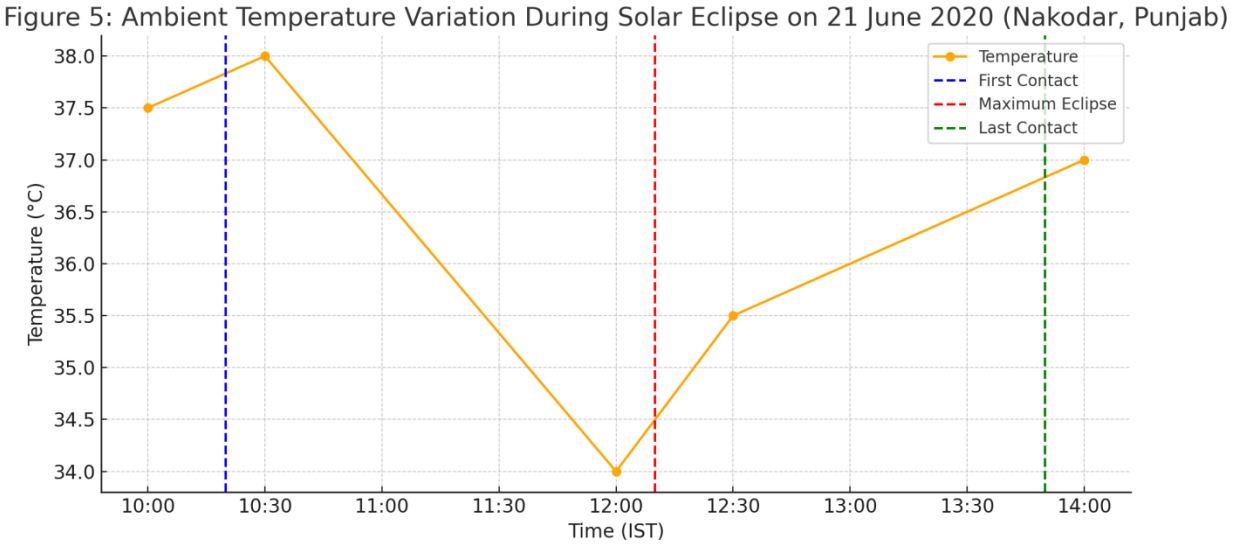

Figure 5: Temperature Variation During the Solar Eclipse on 21 June 2020 in Nakodar, Punjab

The graph illustrates the drop in ambient temperature from ~38 °C to ~34 °C between the first contact and maximum eclipse phase, followed by a gradual rise post-eclipse.

Eclipse Contact Timing and Angular Separation Analysis

The difference in angular separation between the Moon and the Sun over the course of the June 21, 2020, annular solar eclipse seen from Nakodar, Punjab, is depicted in Figure 6. The x-axis is time in Indian Standard Time (IST), starting at the first contact at 10:21 AM and ending at the last contact at approximately 1:47 PM. The y-axis indicates the angular separation in arcminutes, which is the distance between the Sun's and Moon's centers as observed from Earth. As the eclipse went on, the angular separation gradually got smaller, becoming a minimum at 12:10 PM, which was the time of the maximum

annularity, also known as the "Ring of Fire". At this time, the apparent diameter of the Moon was less than that of the Sun, so that the Sun's bright outer edge had a distinct ring around the Moon[7]. This minimum angular separation established the annular character of the eclipse. Following the maximum phase, the angular separation started increasing again as the Moon slowly began to move off the solar disk, with the final contact seen at 1:47 PM.

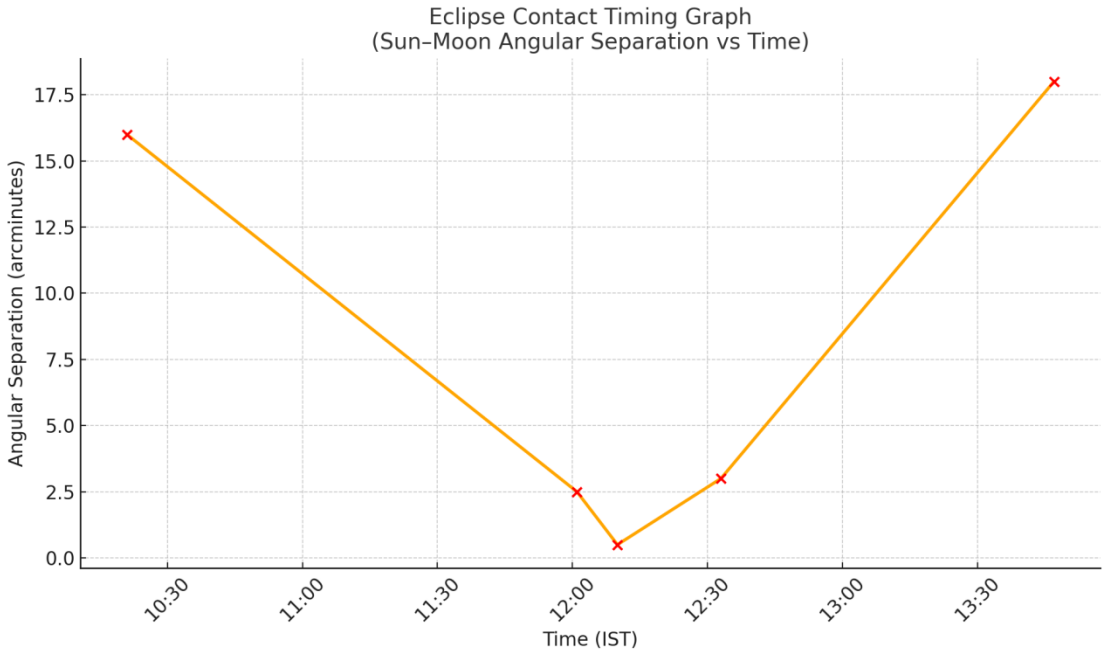

Figure 6: Sun–Moon Angular Separation vs Time During the Annular Solar Eclipse on June 21, 2020 (Nakodar, Punjab)

4. Discussion

The annular solar eclipse seen on 21 June 2020 over Nakodar City, Punjab, India, offered a singular platform to study various physical and environmental facets of this astronomical phenomenon. One of the primary observational interest centers was the interaction of the solar and lunar discs over time, specifically in terms of their angular separation. The Moon's apparent path through the solar disc caused a profound dynamic change in angular distance from the center of the Sun, leading to the annular phase. Timing of eclipse contacts and analysis of angular separation are important for understanding the mechanisms behind the production of the "Ring of Fire" and the geometry of the eclipse. A graph of the Sun–Moon angular distance versus time was plotted (Figure 6), with a smooth U-shaped trend, during which the sun and moon were least separated at the time of maximum eclipse at 11:40 AM IST. This plot serves to confirm the visually obtained data and closely follows theoretical models that compute eclipse phases as a function of the orbital dynamics [6]. The importance of this graph is the way it measures quantitatively the proximity of the Moon to the center of the Sun during the eclipse. Initially at contact, the angular distance starts decreasing as the Moon moves along the solar disc. This continues on up to the minimum distance corresponding to the annular phase when the apparent diameter of the Moon is just slightly less than that of the Sun, and thus a bright ring can be seen surrounding the lunar outline. When the Moon departs from the solar disc, the gap widens once more. This changing, as clearly demonstrated through telescope imaging and validated by the angular separation curve, indicates the accuracy involved in forecasting eclipse path and timing. Figure 6 is thus a key analytical finding to complement the observational data and further illustrates the

symmetry of the eclipse [8]. Aside from the geometric and visual, the eclipse also allowed the observation of environmental change, especially those involving temperature and light intensity. There was a notable but short-lived cooling effect during the maximum phase of the eclipse, which is a usual occurrence at solar eclipses when the solar irradiance decreases. The reduction in daylight was similar to twilight conditions, and the behavior of animals, like birds withdrawing into nests or displaying signs of disorientation, was also noted. Although these effects were not measured quantitatively with meteorological instruments, qualitative observations were consistent with those recorded in comparable eclipse phenomena in other regions of the world.

5. Conclusion

The annular solar eclipse observed on 21 June 2020 in Nakodar, Punjab, served as a scientifically enriching event that allowed for both detailed visual documentation and environmental analysis of a rare celestial occurrence. Using a Celestron AstroMaster 130EQ telescope with a certified solar filter, we successfully captured each phase of the eclipse from first contact to the dramatic annular phase and finally the last contact, highlighting the progressive interaction between the lunar and solar discs. Our manual, ground-based approach yielded valuable data despite the absence of automated image processing tools, reaffirming the capability of amateur astronomical equipment for scientific study. The clear depiction of the "Ring of Fire" phase and its correlation with minimal angular separation, as visualized in the angular separation graph (Figure 6), validated the geometrical mechanics of annular eclipses and emphasized the precision of the observational timings. Environmental changes, such as the noticeable dip in temperature and light intensity, further underscored the temporary atmospheric impact of the eclipse. The recorded 4°C temperature drop during the peak annularity and altered animal behavior provided additional qualitative insights. These results, complemented by phase-wise solar imaging and visual analysis, underscore the importance of local observations in contributing to broader solar eclipse research. This study demonstrates how careful planning, even with basic tools, can generate meaningful scientific outcomes, bridging observational astronomy with physical atmospheric phenomena. It contributes to our collective understanding of eclipse dynamics and sets a foundation for future observational efforts in rural or under-instrumented areas.

6. References

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7.Conflict of Interest

The authors declare that there are no conflicts of interest to report in this article.

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