Effect of Solar Eclipse on Solar Radiations in Different Wavelengths and Earth's Atmospheric Parameters Observed during Annular Solar Eclipse in South India on 26 December 2019

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Abstract - *Annular solar eclipse was observed from South India on 26 December 2019. Present study was carried out near Palakkad, Kerala where eclipse was observed between 08:06:07 and 11:10:42 IST with Sun coverage of 93.2% during maximum eclipse. Study of effects of eclipse on electromagnetic radiations (radio, visible, ultraviolet) from Sun and local atmospheric parameters (temperature, relative humidity) are presented in this article. With progress of eclipse, radiations in all wavelengths were reduced with different profile and then a minimum was observed at the time of annularity. During the eclipse, ambient air temperature was decreased whereas relative humidity was increased.*

Key Words: *Annular Solar Eclipse, radio Sun, Visible light intensity, ambient temperature, relative humidity*

1. INTRODUCTION

On 26 December 2019, annular solar eclipse was observed from southern part of India. The study was conducted to investigate the effect of Annular Solar Eclipse on parameters such as: (1) Electromagnetic radiations received from sun like radio waves, visual light and ultraviolet radiations. (2) Atmospheric parameters like ambient Temperature, Relative Humidity. There is much of the literature available regarding similar studies in past[1, 2]. The observations during the eclipse on 26 December were in line with the observations in past. Novelty of this study was observations using Affordable Small Radio Telescope (ASRT) which was built using DTH satellite dish antenna. Amateur astronomers rarely work in the area of radio astronomy.

Fig -1 shows predicted path of the annular solar eclipse happened on 26 December 2019 in southern part of India. Annularity was expected to be 93.2% and for little more than 3 minutes. Jyotirvidya Parisanstha, an amateur astronomers association at Pune, India had planned an expedition to the eclipse belt to carry out experiments with the objectives mentioned above. A team of 26 volunteers participated in this expedition. Three sites were selected for observations: one on the centre line and two on the edge of the annularity belt. The centre line site was to the north of Coimbatore,

Fig -1: Predicted path of annular solar eclipse on 26 December 2019 in India with the three observation sites selected by Jyotirvidya Parisanstha teams for observations (map adopted from http://xjubier.free.fr/en/site_pages/SolarEclipsesGoogleMaps.html)

Tamilnadu (11°06'56.75" N, 77°11'18.152" E); two sites on the edge of the belt were near to Erode, Tamilnadu (11°25'57.634" N, 77°42'24.835") and Palakkad, Kerala (10°46'49.070'' N, 76°36'42.954'' E). The sites were selected such that they have no obstructions on horizons or path of sun in sky, away from high tension wires, big structures or buildings or trees as they create noise in radio observations. The teams near to Coimbatore and Erode could not carry out observations because of clouds and precipitation. The sky near Palakkad was clear and team there got complete set of observations which are presented in this article. Different phases of eclipse captured by the team at Palakkad are shown in Fig -2.

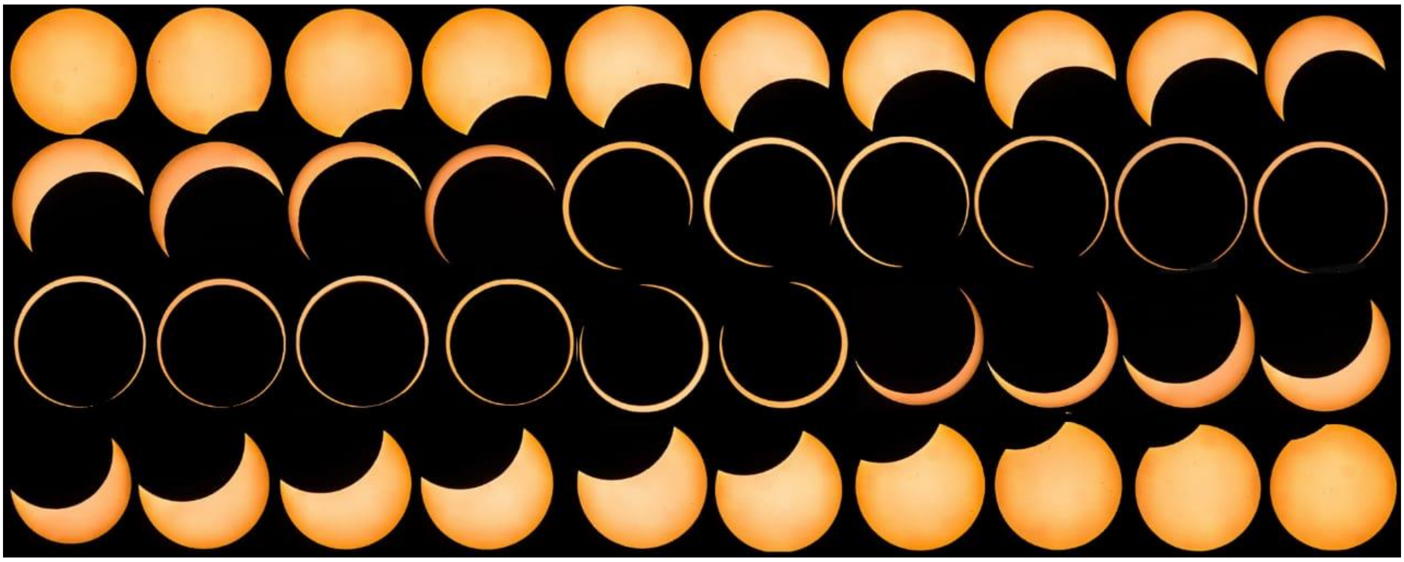

Fig -2: Phases of annular solar eclipse on 26 December 2019 observed from site near Palakkad, Kerala. Photos by: Milind Joshi, Prabhanjan Bongarde and Prathamesh Jaju of Jyotirvidya Parisanstha. (Photography Setup: Celestron NexStar 130SLT telescope mounted on Sky watcher EQ3 German equatorial mount on manual mode; Camera: Nikon D3200 DSLR camera; Eyepiece projection with 25 mm eyepiece)

2. MATERIALS AND METHODS

The observations in radio wavelength were carried out using Affordable Small Radio Telescope[3, 4], whereas other observations like UV and ambient light intensity, temperature, relative humidity were measured using microcontroller based sensors.

2.1 Affordable small radio telescope (ASRT)

The Affordable Solar Radio Telescope (ASRT) is a radio telescope made using DTH satellite TV antenna operating in the Ku band which extends from 12 to 16 GHz. As described in the report by Madki and Joshi[3], a setup shown as per Fig -3 was built.

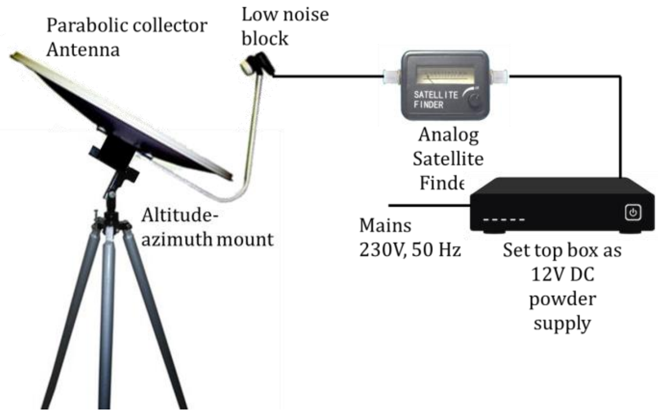

Fig -3: Schematic of ASRT

The satellite dish antenna has a parabolic dish reflector and a Low Noise Block (LNB). The dish reflects incoming radiation towards LNB which provides the signal amplification without adding much noise. An analog satellite finder was used to detect signal coming from LNB. Sun is a broad band emitter, so the radiation from the sun can easily be detected with ASRT. When dish is pointed towards the sun, deflection on satellite finder is observed which is function of solar activities like coronal mass ejection, sun spots etc.

In the present set-up, Solid SF-45 Satellite Signal Finder is used to measure the strength of sun's radio emission. Low Noise block (LNB) used was, Inverto Ultra Low Noise and High-Gain LNB. It provides higher conversion gain yet with lowest noise figure and superior phase noise performance. RG-6 co-axil cables as well as low impedance RG-6 female connectors are used to make the connections. An altitude-azimuth mount for the dish antenna was used to track the sun during the eclipse time.

Radio observations were started around 35 minutes before the visual eclipse started and then radio flux was recorded manually every 10 minutes during the eclipse time. This was because the limitation on automating the tracking of sun and automation of recording the readings on satellite finder. The decimal fraction of the solar flux received during eclipse as against total solar radio flux received at the observation site before and after the eclipse was calculated for analysis of the data.

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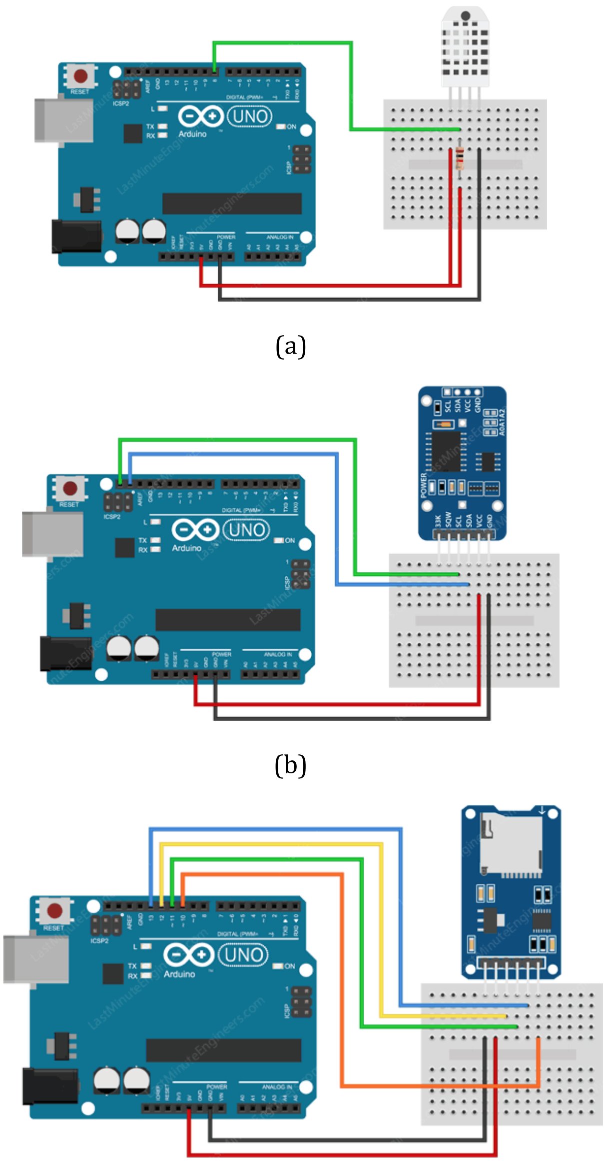
2.2 Microcontroller based experimental setups

Arduino Uno board was used to acquire real-time data from different sensors and was logged in a SDHC card. The log also includes the precise time stamps for analysis. The microcontroller board and the peripherals were powered by a lithium polymer battery with a 5 V regulated DC supply. Light dependent resistor data terminal was connected to the analog pin (A0). DHT22 sensor is connected to digital pin 8. GUVA-S12SD Sensor is connected to analog pin (A1). The setup is designed in such a way that it can be installed on site very quickly while still maintaining the rated accuracy.



(a)

(b)

(c)

Fig -4: Wiring diagrams (a) DHT22 sensor for ambient temperature and humidity (b) DST3231 RTC for time measurement (c) Data logging

Ambient light intensity is measured using a CdS(300) photo-resistor with a series resistance for calibration. This setup is connected to the analog pin of the Arduino Uno board. The analog value is measured every 5 seconds. The sensor was not directly pointed towards the Sun to avoid overheating of the sensor.

The DHT22 sensors used, are made of two parts: a capacitive humidity sensor and a thermistor. Chip inside the sensor does analog to digital conversion and spits out a digital signal with the temperature and humidity. Adafruit DHT Humidity & Temperature Sensor Library is used for calibration of the sensor[5]. Temperature and Humidity was measured every 5 seconds.

Output signal was digital signal via single-bus. Sensing element is polymer capacitor. Operating range is: Humidity: 0-100%RH; temperature: -40 to 80 °C. Accuracy was: Humidity: ± 2% RH; Temperature: < ± 0.5 °C. Resolution: Humidity: 0.1% RH; temperature: 0.1 °C. Repeatability: Humidity: ± 1% RH; temperature: ± 0.2 °C. Humidity hysteresis: ± 0.3% RH.

GUVA-S12SD sensor was used to measure intensity of ultraviolet radiations. This sensor utilizes a photodiode sensitive to 240-370nm range of light (which covers UVB and most of UVA spectrum).The analog value was received and logged using an Arduino Uno board. The 10 bit ADC of Arduino Uno board gives an output between 0-1023, which was logged. This sensor was exposed to direct sunlight all time during the eclipse.

The DST3231 RTC was used to log timing. The DS3231 is a low-cost, accurate real-time clock (RTC). It consists of an integrated temperature compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input, and maintains accurate timekeeping when main power to the device is uninterrupted. The device time is set 5min before the start of experiment. As the time set in the device is provided by Global Positioning System (GPS), the device provides extremely accurate timings.

The oscillator frequency undergoes a change because of change in ambient temperature. As a change in ambient temperature is expected during the course of the experiment, a temperature compensated timing device was used. DS3231 IC provides an effective solution for accurate timing in environments with variations in ambient temperature.

Data logging set up was used to save the Date, Time, Temperature, Humidity, Ambient Light Level and Ambient Ultra Violet Level into a SD card. Arduino will be capable of reading all these parameters and storing them into a file (.txt) for analysis of the data. A class 10 SDHC memory card is used to store the data which was then processed using Microsoft Excel 2016.

3. RESULTS AND DISCUSSION

The annular solar eclipse with 93.2% occulted sun was observed from the site near Palakkad, Kerala on the edge of the annularity belt. Location of observation site was 10°46'49.070'' N, 76°36'42.954'' E. Magnitude of the eclipse was 0.965. Timings of eclipse were:

First contact (Partial eclipse begins):	08:06:07 AM IST
Second contact (Annular eclipse begins):	09:27:42 AM IST
Maximum Eclipse:	09:29:14 AM IST
Third contact (Annular eclipse ends):	09:30:47 AM IST
Fourth contact (Partial eclipse ends):	11:10:42 AM IST

3.1 Effect eclipse on electromagnetic radiations

Observations in radio wavelength

To the best of authors' knowledge, there was just one attempt made in past to record radio emissions from sun using ASRT or similar set-up; which was during total solar eclipse in USA on 21 August 2017[6, 7].

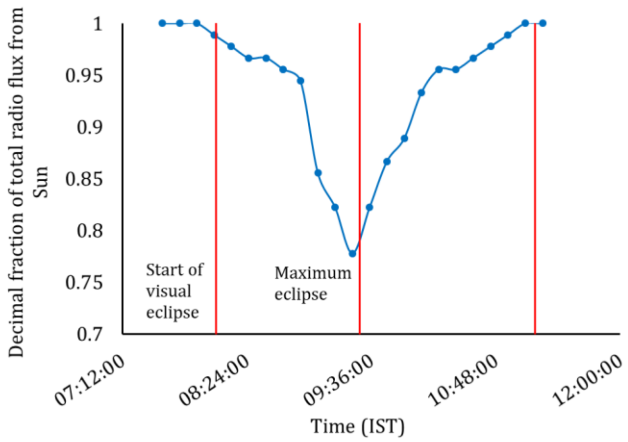


Fig -5: Solar radio flux received on Earth's surface during an annular solar eclipse as a fraction of the total flux measured using ASRT

Fig -5 shows decimal fraction of the total solar radio flux received on Earth's surface during an annular solar eclipse on 26 December 2019 measured using ASRT (setup described in section 0) from the observation site near Palakkad, Kerala. Drop in radio flux was observed little earlier than the visual eclipse started. This is because size of sun in radio wavelength is bigger than visual sun. Radio waves are low energy waves and are emitted by solar corona which is an outer layer of the Sun than photosphere. Hence sun appears bigger in radio waves than in visual waves. As we go higher and higher in wavelength, size of sun increases. Size of radio sun may be up to 1.5 to 2 times the visual sun depending on the wavelength selection. The waveband used in present observations is Ku band which is low wavelength band and close to microwave band in the electromagnetic spectrum. Hence size of sun is marginally bigger than visual sun. Hence moon started occulting the radio sun (corona) earlier than the visual sun (photosphere) and hence drop in the radio flux was detected little early than visual eclipse started.

Initially, drop in the flux was slow and sharp drop was detected towards mid eclipse. Flux started increasing again after the third contact. And increased up to maximum solar flux which was before start of the eclipse after the fourth contact and was nearly stable after the same. Observations are in line with the reports by Reeve and Monstein[7]. Since frequency of the recording of observation was lower, a perfect bell shape curve was not observed as expected. Also the observation site was not on the centre line of the annularity belt and hence moon occulted the sun's disc off-centre. The radio waves emission on sun's surface may not be even on its surface because coronal mass ejection and sun spots are also major sources of radio waves. As verified with data from SOHO[8] during the eclipse days, it was quiet sun and hence the graph of drop and increase in solar flux (Fig -5) is nearly symmetric.

Observations in visual waveband

Visual light intensity was measured during the eclipse from the observation site at Palakkad, Kerala. Fig -6 shows variation of ambient light in visual waveband measured every 5 seconds. Daily, as altitude of sun increases in the sky, ambient light intensity increases. This is because of absorption of light in the atmosphere and as we move from horizon to zenith, the thickness of atmosphere through which light rays pass decreases. During the present experiments, recording of data was started at 7:30 AM IST and this increasing ambient light intensity trend can be seen initially in the graph. Eclipse started at 8:06:07 AM IST, and

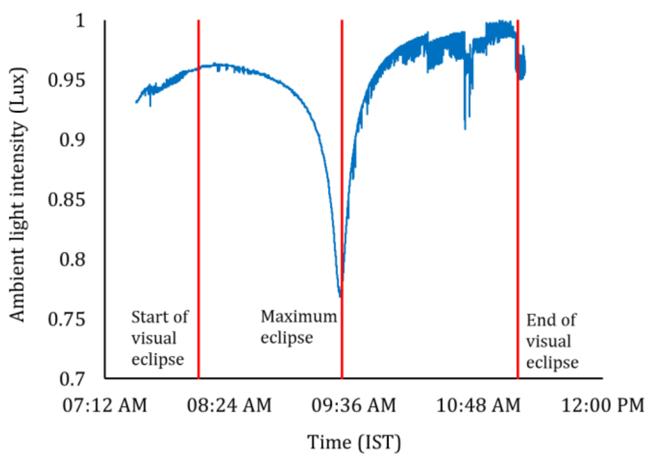


Fig -6: Variation of visual light intensity (Lux) with time during Annular Solar Eclipse light intensity started decreasing at around 8:17 AM IST. This may be because drop in light intensity may be lesser due to occultation of moon than increase in altitude of sun in the sky. But after that decrease in light intensity started. Initially, the decrease in the intensity is smaller. There is sharp decrease in the intensity observed towards mid eclipse and intensity again started increasing after third contact. The rate of increase in ambient light intensity after third contact was more as compared to rate of decrease of ambient light intensity between first and second contact. This may be combined effect of going away of moon from sun's disk and rise of altitude of sun in sky. Little disturbances observed towards the end of the eclipse because of some incidental local obstructions. The drop of intensity in visual waveband is in line with the drop in radio waveband as expected.

Variation in ultraviolet waveband

Ultraviolet (UV) light intensity was measured during the eclipse from the observation site at Palakkad, Kerala. Fig -7 shows variation of UV light measured every 5 seconds. As can be seen, the recording of UV intensity measurement after around 10:10 AM IST is having much noised data, but overall trend during the eclipse can be understood. UV intensity was increased initially, before eclipse, just similar to visual band light intensity. But visual light intensity went on increasing till 8:17 AM IST whereas UV intensity was observed to be increasing till 8:32 AM IST. This may be because of combined effects of: (1) Increase in UV intensity because of increase in altitude of sun may be higher than decrease in UV intensity because of occultation of sun by moon. (2) UV rays comes from inside layer of photosphere which means size of sun is smaller when observed in UV band as compared to observed in visual waveband. But this effect is marginal. (3) UV light scattering is more in atmosphere than visual light because of shorter wavelength. Authors could not get similar reports in literature to cross check and confirm.

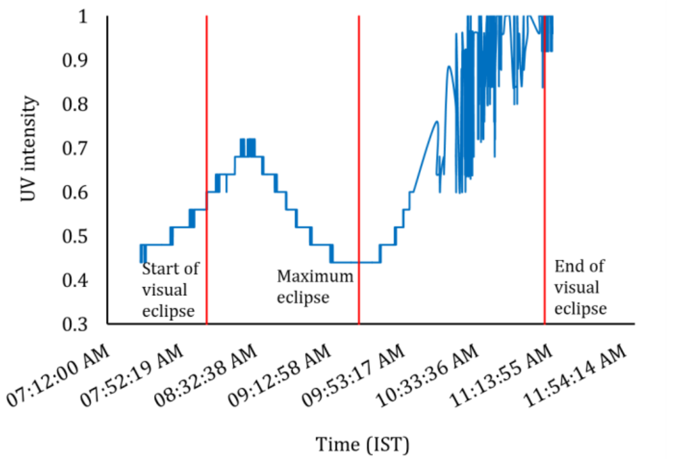


Fig -7: Variation of UV intensity with time during Annular Solar Eclipse

Minima in UV intensity was found at maximum eclipse and then UV intensity started increasing again. The much noised data after 10:10 AM IST was unexplained.

3.2 Effect of eclipse on local atmospheric parameters

Effect of eclipse on ambient temperature and humidity were measured under atmospheric parameters study. Observations were started at 7:30 AM IST. The trend in temperature and humidity during eclipse is shown in Fig -8. The temperature went on increasing with increase in altitude of the sun in sky. The increase continued up to around 8:35 AM IST. Eclipse started at 08:06:07 AM IST. Thus delay of around 30 minutes was observed when ambient temperature started decreasing because of eclipse. This may be because of heat capacity of the air. After 8:35 AM IST, decrease in temperature was observed which continued till around 9:35 AM IST (mid eclipse: 09:29:14 AM IST). Short delay of around 6 minutes was observed here. The decrease in temperature is attributed to decrease in

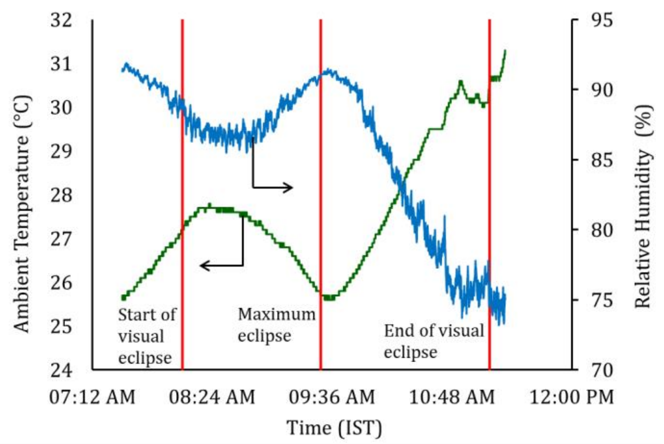


Fig -8: Effect of eclipse on atmospheric parameters

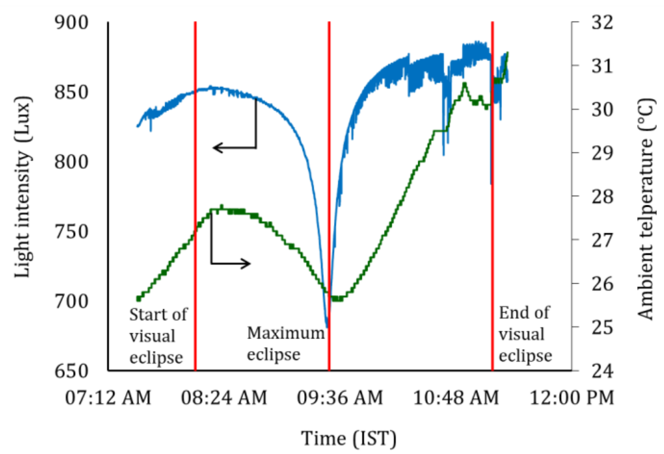


Fig -9: Effect of eclipse on ambient light intensity and temperature solar energy reaching the observation site because of eclipse. Temperature then went on increasing. Fig -9 shows ambient light intensity and temperature plotted together. This helps to correlate the relation between energy received from sun and ambient temperature. The relation between light intensity and temperature is complex and beyond scope of this study as it involves more factors like altitude of sun, air mass, humidity, wind direction and speed etc. Similar to light intensity, rate of decrease in temperature between first and second contact was found lesser than rate of increase of temperature between third and fourth contact.

Relative humidity was decreased with increase in temperature and was decreased till around 8:35 Am IST (Fig -8). It then started increasing with drop in temperature and maxima was observed at around 9:35 AM IST. It then started decreasing with increase in temperature. Thus inverse relation of relative humidity with temperature was confirmed. Fig -10 shows relation of relative humidity with temperature with R^2 as 0.965.

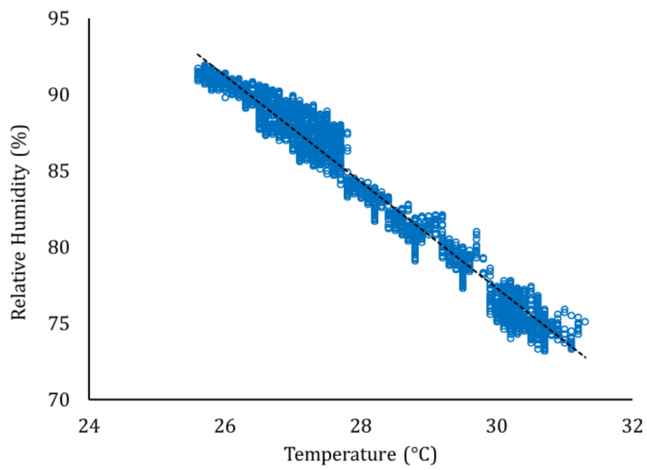


Fig -10: Relation between ambient temperature and relative humidity

4. CONCLUSION

The observation of eclipse in multiple wavelengths was important and showed that since different electromagnetic waves are emitted by different layers of sun, size of sun is different in different wavelength and hence time of start and end of eclipse in each wavelength is different. A more systematic study is needed though; which authors are planning for annular solar eclipse of 21 June 2020. Effect of eclipse on atmospheric parameters like temperature and humidity are well established and are confirmed in this study. More parameters like wind speed and wind direction needed to be combined with this study.

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