Vol. 3 No. 4
Scientific Voyage: ISSN: 2395-5546
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A COMPREHENSIVE ANALYSIS ON SUNSPOTS: AN ODYSSEY WITH THE ASTRONOMY CLUB

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ABSTRACT

The article presents a comprehensive overview record on sunspot observations conducted over a span of over four months. The study aimed to characterise and monitor sunspot activity on the Sun's surface. High-resolution images and data were acquired using Dr. Maddy's 150mm EQ Refractor Telescope, enabling the precise measurement of sunspot positions, sizes and magnetic field properties. Complementary validations were analysed as well. The observations reveal a dynamic and evolving sunspot population with periodic variations and long-term trends. The findings contribute to our understanding of solar activity and its potential implications for space weather. This work underscores the importance of continued sunspot monitoring for space research and solar science. With this comprehensive analysis, we have presented an article which would be directly accessible and exploitable for future research.

Keywords: Sunspot, Heliophysics, Coronal Mass Ejections, Solar monitoring

1 INTRODUCTION

The Aztecs thought that their Sun god had pockmarks on his face. The ancient Chinese referred to them as stars inside the solar orb.One Renaissance astronomer argued that they were actually undiscovered planets. Today, some believe that their appearance is linked to waves of UFO sightings and paranormal activity. Others offer them as an alternative explanation for anthropogenic change. The rest of us wonder if they are the reason for dropped cell phone calls or static-plagued radio stations. Yes, we are talking about 'Sunspots', the peculiar dark areas that pop up frequently on the surface of the sun. The earliest record of sunspots is found in the Chinese book named "I Ching", published in the ninth century. The text describes that a Dou and Mei were observed in the sun, which refers to small obscurations. Sunspots were first observed telescopically in December 1610 by English astronomer Thomas Harriot. His observations were recorded in his notebooks and were followed in March 1611 by observations and reports by Frisian astronomers Johannes and David Fabricius. So what are Sunspots? They are areas of strong magnetic field concentrations (with field strengths of a few kG), which look darker than their surroundings on the solar surface. Sunspots usually ranges 5 to 50 millimetres and lifetimes from a fraction of a day up to three months. They are typically confined to the activity belt of an equatorial belt, which is between the equator and ±35 degrees latitude (Solanki, 2003).

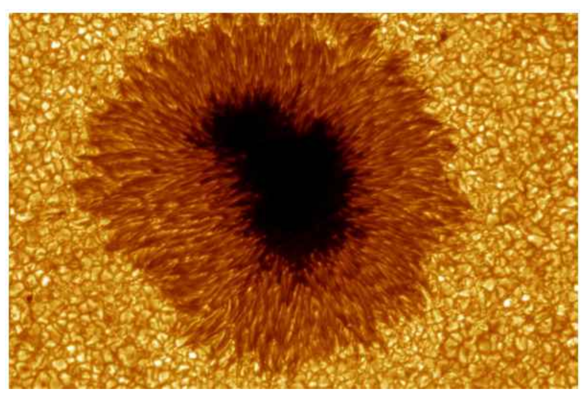

Fig. 1. Image of a Sunspot associated with AR 397 and observed with the Swedish Solar Telescope, at wavelength 630.2 nm (Fe I) on 3rd July 2003

According to the Royal Museums Greenwich, as the sun rotates at different speeds with the equator rotating faster than the poles, a "differential rotation" is created.

The interior and exterior of the sun rotate separately; the outside

Fig. 2. Image Captured by GCECT Astronomical Club on 27/09/2023 clearly depicts the clustered sunspots

rotates more quickly at the equator than at the solar north and south poles. Over time, that uneven movement twists and distorts the sun's main magnetic field. This disturbance in the sun's magnetic field forms pores that can grow and join together to form larger pores or proto-spots that eventually become sunspots. A group of sunspots is thus collectively known as an active region. The dark interior of a sunspot, called the umbra, is about 1,600 degrees cooler than the rest of the sun's surface. It is surrounded by a larger, lighter area called the penumbra, which is about 500 degrees cooler than the rest of the sun. Their darkness is due to a strongly reduced radiative flux caused by the suppression of convection by the magnetic field. This results in the dark appearance of sunspots.

According to the National Weather Service (NWS), the magnetic field in active sunspot regions can be some 2,500 times stronger than that of the Earth's. The strong magnetic field inhibits the influx of hot, new gas from the sun's interior, causing sunspots to be cooler and appear darker than their surroundings.

Now, there arises a random question in our mind that is why do sunspots occur in groups? Loops, which are like the magnetic field from a horseshoe magnet embedded in the Sun's visible surface, push through this photosphere. The magnetic loops have north polarity and a south polarity where they enter and exit the Sun called "feet". If the magnetic field at the base of the loop is strong enough, it prevents the conveyor belt-like transport of energy from the Sun's interior to the surface because charges cannot cross magnetic field lines.

Sunspots usually appear in pairs or in groups on either side of the sun's equator, between 40 degrees and 50 degrees latitude north and south. The turbulent motions in the Sun's interior fragment the loops in the solar magnetic field. Sunspots generally appear in opposite-polarity pairs or groups when the magnetic field is fractured. If one foot of the magnetic loop becomes too spread out, it may be too weak to form a sunspot, and the opposite-polarity sunspot will appear as an individual but the ghost of its partner's magnetic field still remains. And sometimes the magnetic field can emerge to the surface fractured and tangled, leading to a great and confusing sunspot group. Further, a directory of outcomes were observed. The magnetic field lines near sunspots often tangle, crucifix and reorganise. This can cause a sudden explosion of energy called solar flare.The solar flare explosion's energy can be equivalent to a trillion 'Little boy' atomic bombs dropped on Hiroshima and Nagasaki in 1945. Solar flares release a lot of radiation into space. When powerful enough, it can even disrupt satellite and radio transmission on the Earth. Its severeness can also cause 'geomagnetic storms' that can damage transformers in power grids. Solar flares are sometimes accompanied by a Coronal Mass Ejection (CME). CMEs are huge bubbles of radiation and particles from the Sun's corona (outermost region of the Sun's atmosphere). They explode into space at very high speed when the Sun's magnetic field lines suddenly reorganise. Sunspots can cause geomagnetic storms in Earth's magnetosphere. During a solar maximum, when sunspot numbers are at their peak, the Sun emits more radiation than usual (referred to as CME). Plasma emitted from the Sun shoots millions of electrons and protons towards Earth. These charged solar particles can enter the atmosphere and create mesmerising auroras, but they can also disrupt infrastructures such as satellites, navigation, communication and the power grids.

2 OUR JOURNEY AND OBSERVATION

2.1 JOURNEY

The Astronomy Club embarked on its journey with a shared passion for the cosmos. It was the time when we were in the freshman year of our college (Batch : 2021-25) and suddenly we witnessed the telescope at our Physics laboratory. Our curiosity to know about it dragged us to our Prof. Dr. Nilesh Mazumder , our Physics professor, who briefed us about it. It was bought and operated under the supervision of Prof. Dr. Saibal Roy during the COVID pandemic which was halted for almost a year after that. This curated a sense of engrossment among us and thus in its infancy, we emanated a plan to organise the first ever Summer Sky Watching Camp completely under the supervision of Dr. Nilesh Mazumder, Dr. Prasenjit Paul Dr. Saibal Roy in the year 2022. Since it was the first time so we captured a few images of the moon and even witnessed a few sunspots with the telescope without the use of any filter and were more or less successful in the objective. This marked the infant stage of our Astronomy Club.

As the club gained momentum, it organised the Winter Sky Watching Camp where we captured Jupiter using the barlow lens along with the moon. This was a great achievement for us as despite the climatic and other chaotic challenges, we came up even better defeating all those. With this we realised that we can captivate not just the sun, moon or jupiter but even other celestial objects. Astronomy themed talks and meetings became regular occurrences, fostering a sense of wonder and connection with the celestial world. It was marked by a continuous pursuit of both theoretical and practical understanding , creating a dynamic and engaging environment for all involved.

To pursue our zeal and follow it with the microscopic phenomenons of the celestial objects and upgrade ourselves to a level higher, Prof. Dr. Nilesh Mazumder was approached by us. We shared our opinions to expertise the setup even better in usage. He guided us and so we reached out to our honourable principal Prof. Dr. Krishnendu Chakraborty. We presented our views to him with appropriate analysis and thus requested him for the purchase of essential assistive instruments of the telescope such as several filters like that of the moon filter, solar filter, planetary filters, CMOS, etc. Thus emerged the need of a team to chalk out the plans and function properly. This led to the formation of the GCECT Astronomy Club. Its members are the interested collegiates from all the years of the college.

The GCECT Astronomy Club after getting its recognition started working full-fledgedly. As it started maturing, it sought to leave a lasting impact. Its initiatives expanded with the club hosting regular Sky Watching Camps, Astrophotography, Astronomy Quizzes and several other activities contributing to scientific educational programs and providing valuable insights. Our journey had many ups and downs. One of the major challenges was the setback of the telescope. Many instrumental parts were rusted which was revived by our approach to the service centre of Dr. Maddy's telescope. The journey, though challenging at times, was characterised by a collective dedication to spreading the joy of astronomy and fostering a sense of scientific curiosity.

In retrospect, the Astronomy Club's journey was not merely about witnessing the celestial bodies; it was about fostering a community of enthusiasts. From its humble beginnings to becoming a beacon of astronomical passion, the club's trajectory mirrored the vastness of the cosmos it sought to explore and share. The sense of camaraderie and shared enthusiasm propelled the club to new heights, transforming it from a small interest group to a recognized entity within the college entity. The Astronomy Club of GCECT thus abides by its motto that is - where the universe is our playground and the celestial objects are our guiding lights.

2.2 *INSTRUMENTAL ANALYSIS*

Our journey as an Astronomical Club had the privilege to use Dr. Maddy's 150mm EQ Refractor Telescope. It impressively boasts a 150mm aperture and a focal length that extends up to 1200mm, allowing a persuasive magnification of up to 554 times. It is equipped with an EQ-4 equatorial mount featuring setting circles, which aids in precise sky object location and tracking. The telescope's sturdy tripod, constructed with steel legs, provides exceptional stability and eliminates vibrations. A key feature of this telescope is its optical design, which falls under the refractor category. The eyepiece's dimensions are 1.25 inches, and it comes

Fig. 3. Dr. Maddy's 150mm EQ Refractor Telescope

with PL eyepieces of 25mm and 6.5mm. Additionally, there is a 3X Barlow lens and a 10x30 finder scope with 1.5x erecting capability. One notable advantage of the refractor telescope is the absence of a central obstruction, which can positively impact image clarity and attributes. It is a remarkable instrument for exploring the wonders of not just the night sky but also that of the day.

Fig. 4. Converter lense, Solar filter, CMOS camera(8-24mm)

The Sun is the celestial object that can easily harm us. The same solar rays that cause sunburn will also burn the retinas of our eyes. So, in order to safely practise solar viewing, we need the right equipment. For our 6 inch telescope we purchased a solar filter fitting perfectly.

To zoom from low to high power in an instant, we use a multi-coated 8-24MM ZOOM EYEPIECE which is compatible with

Observation Month with year	Number of Sunspots
April 22’	5
July 23’	8
Aug 23’	11
September 23’	23
October 23’	5

Table 1. Sunspots observed over the years

any telescope that accepts 1.25” eyepieces having 40 to 60 degree field of view, with 15 to 18 millimetres eye relief.

We, being future engineers, implemented digital technology to capture minutest of the details. Equipped with the new high-sensitivity SONY IMX225 CMOS colour sensor, the BRESSER HD moon and planet camera delivers amazing image results with very short exposure times. The particularly low noise level ensures an exceptionally high brilliance and no cooling is required. Due to the high native pixel resolution of 1280x980, stunning images of the sun were taken. Windows was used to capture pictures and the ToupSky software was used which not only offers the necessary basic functions for image and video recording but also various obliging special functions for image post-processing and for setting up the guider. Functions such as live image display, exposure settings, white balance, dark image capture, stacking, timelapse recordings and much more can be individually configured.

3 OBSERVATIONS AND RESULTS

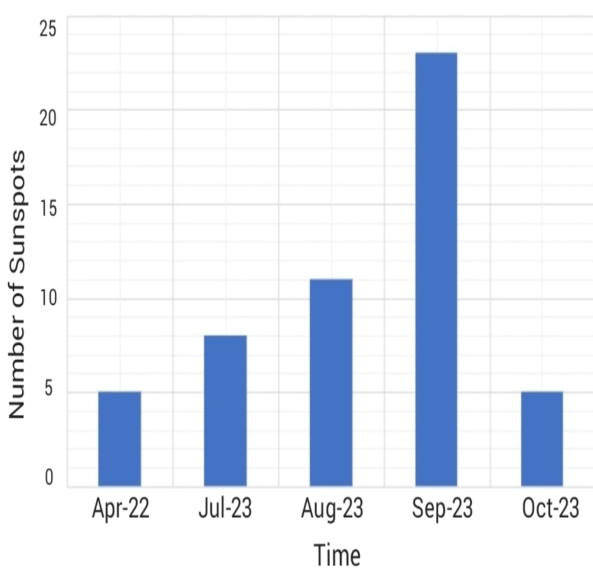

Fig. 5. Number of Sunspots VS Time graph

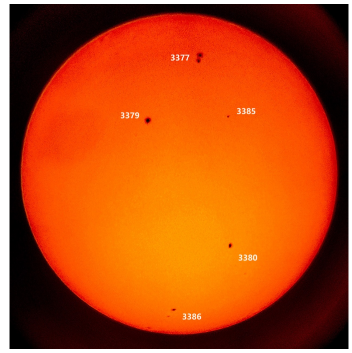

Fig. 6. Captured on July 27,2023 by GCECT Astronomy Club

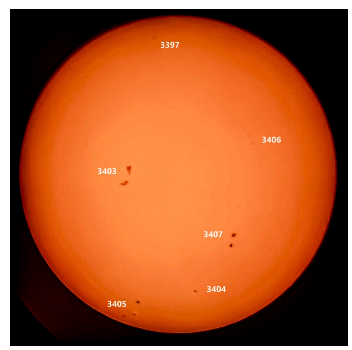

Fig. 7. Captured on August 16,2023 by GCECT Astronomy Club

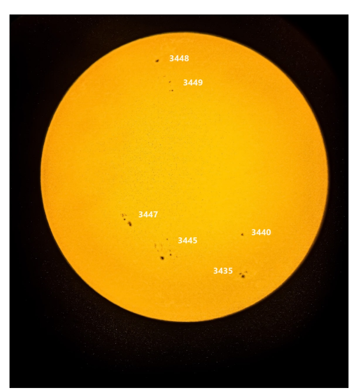

Fig. 8. Captured on September 27,2023 by GCECT Astronomy Club

Table 2. Observed on July 27, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3379	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3377	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3385	A	unipolar	alpha	No Penumbra
3380	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3386	C	bipolar	beta-delta	Penumbra with spot on one polarity only

Table 3. Observed on Aug 16, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3379	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3377	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3385	A	unipolar	alpha	No Penumbra
3380	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3386	C	bipolar	beta-delta	Penumbra with spot on one polarity only

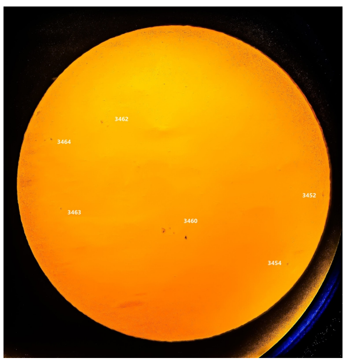

Fig. 9. Captured on October 11,2023 by GCECT Astronomy Club

3.1 April 9, 2022

Location: GCECT Hostel rooftop

Weather: Clear skies, no clouds

Time: 9:00 AM

This day marked an extraordinary attempt or beginning for our Astronomy club. We gathered at the hostel rooftop early in the morning and the enthusiasm was palpable. It was the first day of sunspot observation directly without the use of any filter. We only had our 6 inch EQ4 refractive telescope along with a 1.25" eyepiece sun filter. Our observation was accomplished from the college's hostel rooftop.The spots were not directly visible through our naked eyes at that phase of time. So, a paper as a screen was used so as to observe the filtered view of the low intensive sun body to witness the dark spots on its surface. Since it was the beginning phase of our observation, merely 1 to 2 spots were noticed. Solar filter vanquished due to the high intensity of the solar rays. This marked the end of the sunspot observation for the day.

3.2 July 27, 2023

Location: GCECT Hostel rooftop

Weather: Mid monsoon, passing clouds

Time: 7:00 AM

It was a glorious day with the first attempt to capture Sunspot pictures using a solar filter. The core members of the club assembled the setup. As of then, we had our solar filter with a celestron converter eyepiece (8mm-24mm). The first challenge for us was the weather, hence we had small windows for a very short period of time. Somehow we had managed to find a clear window and finally were successful in capturing some pictures of clear sunspots. But after the first attempt, some instrumental errors occurred in our EQ4 mount, so we just ended up capturing some partially satisfied images of sunspots but our target was not fulfilled yet.

3.3 August 16 , 2023

Location: GCECT Hostel rooftop

Weather: Sunny day

Time: 03:00 PM

The instruments were assembled. CMOS camera was used for the first time along with the software ToupSky for capturing the photographs. The telescope was then set up in the observation plane and aligned our cross-viewer with the middle of the Sun. It proceeded to take pictures of the Sun with the attached solar filter. During the session, we came across the over-magnification problem of the CMOS camera which restricted us to take a full length picture of the Sun. To overcome the problem, a 0.5X extender was placed before the eyepiece and attached CMOS to it, which significantly reduced the magnification and allowed us to capture and observe the sunspots effectively. A series of photographs featuring the sunspots was captured using the mentioned software.

Table 4. Observed on Sept 27, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3448	H	unipolar	alpha	Penumbra, symmetric<2.5 degree
3449	B	Bipolar	Beta	No Penumbra
3447	C	Bipolar	Beta-delta	Penumbra with spot on one polarity only
3445	C	Bipolar	Beta-delta	Penumbra with spot on one polarity only
3435	D	bipolar	Beta	Penumbra on spots of both polarities
3440	A	Unipolar	Alpha	No Penumbra

Table 5. Observed on Oct 11, 2023

region	Configuration group	Magnetic type	Spot classification type	Penumbra type
3462	D	Bipolar	Beta	Penumbra on spots of both polarities
3464	D	Bipolar	Beta	Penumbra on spots of both polarities
3463	C	Bipolar	Beta-delta	Penumbra with spot on one polarity only
3460	E	Bipolar	Beta	Penumbra with spot on one polarity only
3454	H	Unipolar	Alpha	Penumbra, symmetric<2.5 degree
3452	D	Bipolar	Beta	Penumbra on spots of both polarities

3.4 September 27, 2023

Location: GCECT Hostel rooftop

Weather: Clear skies, no clouds

Time: 9:00 AM

An attempt to capture a cluster of sunspots was targeted but whether we were lucky enough or not was the question of the day. This time with double the hope, energy and enthusiasm, we were again ready to capture at least some clusters of sunspots. In that unencumbered situation, we had finally got some clear clusters of sunspots. For us it was a great achievement as a crawling club. By this time we were well adapted and habituated to the instrumental faults. In fact, we learnt how to repair an EQ 4 mount to some extent ourselves. That day we succeeded our target and our expectations rose one level up.

3.5 October 11, 2023

Location: GCECT Hostel Rooftop

Weather: Radiant and sunlit

Time: 01:00 PM

It was a higher attempt of our solar observation , till date we had some satisfying data collection but we were heading for some more data. Sun was overhead and it was challenging for us to set the telescope as well as taking clear pictures. As you already know we were facing problems with our EQ4 mount. But it didn't stop us from collecting data and we finally ended up with some sunspot images. It was our last observation for the report and all the dedication and hard work of the team members finally have reflected in the results. We were slowly heading towards our next goal of writing this article and sharing our journey and data analysis with our beloved readers.

4 RECORDED DATA AND ANALYSIS

Sunspots vary in shapes and sizes. Few clusters of sunspots have a more complex magnetic structure than others and are more likely to produce solar flares. Despite such a diversity of shape and sizes astronomers have been able to define broad categories of sunspot groups. The first component of the classification scheme is the sunspot configuration group. There are 7 classes with each class representing an evolutionary stage that a sunspot group may go through during the course of its development and decay.A uni polar group is a single spot or compact cluster of spots with the greatest separation of spots less than 3 degrees. A bipolar group has two or more spots forming a group with a length (along its major axis) of 3 degrees or greater. More than half of the observed sunspot groups receive an Alpha or Beta classification, where bigger sunspots are often more complex and get a Beta, Beta-Gamma or Beta-Gamma-Delta classification. The records of sunspots observed through out the year are shown below:

5 CONCLUSION

The article, thus, provides an overview of the sunspot observation on the basis of the pictures taken by Dr. Maddy's 150mm EQ Refractor Telescope. The present review is, therefore, rather a list of existing records than a review of the physical understanding achieved from them. The members encourage efforts of digitising astronomical manuscripts to make them available and preserve them from potential loss.

All in all, our introspection has provided valuable insights into the dynamic nature and behaviour of sunspots. The thorough analysis presents a better understanding of the sunspot activity and its impact on solar phenomena. This research underscores the importance of ongoing observation in the field of astronomy. The findings presented in this article contribute to the growing body of knowledge in solar science and highlight the dedication of our club members to the exploration of the cosmos. We hope that this research inspires further studies and encourages others to engage in the fascinating world of solar observation. The knowledge gained from this study can have significant implications for space exploration, satellite operations, and climate research. Also, continued observations and research into sunspots will be essential for refining our models and predictions related to solar activity. This will even help to mitigate the potential impacts of solar events.

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