

N V N I R M I T I

DRAFT
INTRODUCTION

Taking inspiration from pioneering efforts like the Kerala Sastra Sahitya Parishad, during the last two decades of the 20th century the people's science movement (PSM) spread to all the states of the country. Not only many local and state level organisations but also national networks like All India People's Science Network and Vigyan Prasar came up to take forward the task of the movement. The total solar eclipses (TSE) played an important role. We have been singularly fortunate, for during the last two decades, there have been three total solar eclipses which were visible from India, on 16 Feb 1980, 24 Oct 1995 and 11 August 1999.

During an eclipse, lakhs and crores of people get turned on to science. Superstitions also abound, and a debate between science and superstition inevita-

bly takes place in the public arena. The science movement gets an opportunity to take a step forward. But TSEs are one day wonders. Bad weather can confine and package knowledge and education, which can then be sold to those with sufficient purchasing power, the sun is available to everyone. With the methods in this booklet, it will be possible to perform non-trivial scientific experiments and see sunspots at no cost even with a little piece of broken mirror. You, the reader, will undoubtedly produce new ways to project and study sunspots finding them maybe even in the shade of a banyan or coconut tree. Every child in every town and village will have seen sunspots. New knowledge will be discovered, as "All the world's a laboratory". Let us know of your efforts.

GETTING STARTED

Is there anything more important to us than the Sun? From time immemorial, our ancestors, human

beings from all lands and cultures have prayed to and worshipped the Sun in different ways.

In ancient times the priest and the scientist were often one and the same person. The astrologer was also the astronomer. What we today know as the method of science was not well understood. The ancient astronomers/astrologers discovered many truths, but also believed in many myths which we do not accept today as true. And despite centuries of prayers and salutations they did not seem to have discovered some simple and wonderful things about the sun like Sunspots. (Further advances in the history of science may disprove this statement). Their methods, evidently, had many shortcomings and limitations.

In the first year of the new millenium, we are indeed a very lucky persons. We are lucky because the year 2000/2001 is going to be a sunspot maximum year. This happens only once in eleven years. After reading this book, within a few hours you will

have seen sunspots. Very few persons have witnessed this wonderful phenomenon. Even many scientists have never seen sunspots with their own eyes.. As we write these words the sunspots have become so big that on some days you can actually see them with your own eyes, without magnification, if you look carefully at the sun with a good quality solar filter , tested for safety.***

But even if you don't have a filter, rush to Chatrapati Shivaji Terminus of Central Railways in Mumbai, go to platform 2/3 between 11 AM and 3 PM. Don't forget to buy a platform ticket or this might end up as a high cost way of seeing sunspots! Scan the platform floor with your eyes.

Here and there you will see a few circular patches of light, some bright and some dim. Some are big and some are small. These discs of light occur because of sunrays streaming down from small holes in the high roof of the railway station. Choose a large, dim disc. Hold a white piece of paper so that

the disc forms on it and examine the image closely. You will notice one or more small grey shadow spots on the light disc. What are these dark spots ? Convince yourself that they do not depend on which hole the light is streaming from. They are spots on the face of the sun itself.

WHAT ARE SUNSPOTS ?

To answer this question you have to answer some of the questions at the end of this booklet. To this day nobody has given a satisfactory and clinching answer as to why the sun has measles every eleven years. Today we know that sunspots are huge cyclones which occur on the sun and which last for several days and even several months. The large ones are so huge that they are several times the size of the earth. On planet earth cyclones occur in cer-

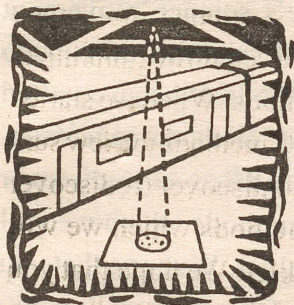
tain seasons. Seasons occur because of the rotation of the earth around the sun once in a year. Why do cyclones occur on the sun seasonally every eleven years or so ? If you answer this question satisfactorily you will go down in history as a very great scientist.

SUNSPOTS WITHOUT A TELESCOPE

According to the *Encyclopaedia Britannica*, "With the invention of the telescope, Galileo Galilei, Johannes Fabricius, Christoph Scheiner, and Thomas Harriot almost simultaneously (1610-1611) discovered sunspots, but it was the genius of Galileo that recognised their true nature as solar phenomena."

Duncan Steel in his recent book 'Eclipse', writes : "For centuries large sunspots had been observed with the naked eye by the Chinese when dust storms blew in from Central Asia, blanketing parts of northern China. They had similarly been noticed in Eu-

rope, but it was only when telescopes appeared in the seventeenth century that continuous monitoring of these dark markings on the solar surface was feasible.”



We disagree. Observation and continuous monitoring of sunspots is possible without a telescope by a number of low cost/ no cost (LCNC) methods. As we have just discovered, you can see sunspots on the railway platform at CST, without any telescope. (The image at CST railway station is the result of the principle of the pinhole camera)

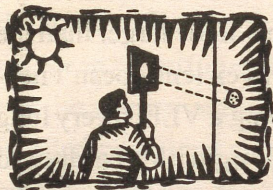
A telescope is an instrument to gather and concentrate the light reaching us from astronomical objects like the planets and stars which is extremely faint. But the sun is different. Its light reaching us is not too faint but too strong. It does not need to be

gathered and concentrated . If anything, its intensity needs to be reduced . We can study and understand many wonderful things about the sun without using a telescope.

The task of the people's science movement (PSM) is to bring science and scientific thinking to the people using LCNC methods. When we started working at developing LCNC methods to view sunspots we were quite happy to discover (rediscover ?)not one but many such methods which we will briefly describe in this booklet. We hope that you too will experience the thrill of discovery while working out the experiments here and maybe discovering new methods yourself.

VERY LONG FOCAL LENGTH CONVEX LENS:

It is commonly believed that a convex lens concentrates the light from the sun. This however is true



only if the focal length of the lens is not too large. As the focal length of the lens increases the size of the sun's image increases. For a very long focal length (VLFL), the diameter of the sun's image disc can be quite large, larger than the lens itself. (In a pinhole camera also, the size of the image depends on the distance of the screen from the pinhole).

In general the following formula is true :

$$\frac{\text{diameter of the sun's image disc}}{2 \times \pi \times f} = \frac{1/2 \text{ degree}}{360 \text{ degrees}}$$

(This is because the sun subtends an angle of about $1/2$ degree at the earth.)

From this we deduce :

$$\frac{\text{diameter of sun's image (in cm)}}{2 \times 3.14 \times \text{focal length in cm.}} = \frac{1}{720}$$

For a 50 mm diameter lens with a focal length of

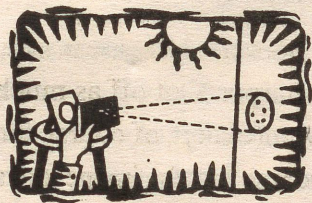
6 metres, the image of the sun will be larger than the lens itself, showing that a convex lens doesn't necessarily concentrate light. Using a VLFL (very long focal length) convex lens, along with a cardboard shade with a hole cut in the centre (see fig), you can get a nice big image of the sun on which sunspots are clearly visible, if the lens is of reasonably good quality.

Where can you get a good quality VLFL convex lens ? These are not easily available in toyshops selling lenses as the focal lengths available there are usually much smaller. But from your local optician it should be possible to get a lens "of number + 0.25". This lens will have a focal length of around 4 metres, which should be good enough. *

PINHOLE MIRROR CAMERA

This is by far the simplest method to project sunspots, which works because the sunlight intensity is so strong. This experiment can be done in any room

which has a window or door opening outside, and which can be sufficiently darkened by putting cloth over the apertures from where light enters. Complete darkness is not necessary. Just how much darkness is needed you can discover for yourself by trial and error.



Take any available small mirror (like a face mirror selling on the footpaths for Rs 10) and keep it on a stool outside the room in a place where the sun shines on it. Adjust the angle of the mirror so that the sunlight is reflected in a bright patch on a wall of the darkened room. Increase the distance of the mirror so that it is about 20-25 metres from the wall. As you increase the distance the light patch will become more and more circular. This is the sun's image with the mirror acting like a large 'pin hole'. At this stage the sun's image will be bright and diffuse, i.e. not sharp.

The next stage is to take an opaque piece of card paper and punch a hole in it of around 2-3mm diameter with an ordinary paper punch. Now hold this paper about 30 cm in front of the mirror so that the punched hole is in the centre of the light patch which now forms on the card paper. What happens to the image on the wall 20 metres away ?

Surprisingly, the image does not decrease in size. It becomes dimmer and sharper. Cut off as much light as possible in the room (except of course the light coming from the mirror) so that the image looks clearer. Now keep a white piece of paper on the wall so that the image forms on this white screen. The sunspots should be clearly visible on this image during this period of sunspot maximum.

HOW SUNSPOTS MOVE.

You can study how sunspots move by taping the white paper screen to the wall and tracing the outline of the sun's disc. Mark the position of the sun-

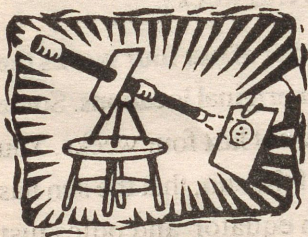
spots and write the date next to it. Next day again form the image of the sun so that it exactly fits the circular outline. Again mark the date and position of the sunspots, which will have moved. Do this experiment every day for several weeks.

You will discover that after about four weeks the large sunspots return to their original locations. Some of the smaller sunspots may not last four weeks. You will discover the rotation of the sun, that the sun has a tilted axis of rotation, an equator and poles just like the earth. (Remember however that the direction of rotation is changed by reflection in the mirror, and the image is again inverted by the pinhole camera effect. Figure out the real direction of rotation.)

SUNSPOTS WITH A TELESCOPE

You can make a simple telescope with which to project sunspots. Though you can look directly at the sun through the telescope with a proper filter,

we do not recommend this method as most common filters are not safe, and a telescope concentrates light making eye damage more likely. Galileo, in later life, became blind.



A simple telescope can be made with only two lenses. The front lens(objective) is long focal length (about 1 metre is ideal), and the eyepiece should have a short focal length of around 5 cm or less. You will also require one long tube (1 metre), and one short tube which slides inside the longer tube with some packing. (see fig)

The magnifying power of the telescope is given by the following formula :

$$\frac{\text{focal length of the objective}}{\text{focal length of eyepiece}}$$

i.e. for 1 metre and 5 cm., the magnification is 20.

The telescope can be used for projecting sunspots as shown in the figure. The advantage of this method is that with good lenses you can get excellent resolution and study some details of the sunspot structure.

WHY STUDY THE SUN ?

Q : Why study the sun ?

A : Because it is there.

This is a perfectly good answer, but there are even stronger reasons to study and understand the sun. Here is one of these :

The earth is full of the most wonderful, strange and interesting things. But there is something which is even more wonderful, strange and interesting than our planet earth- the Universe. More than four hundred years ago, a man called Giordano Bruno, said that the sun does not go around the earth, but the earth goes round the sun, that the stars are distant suns which may have planets on which life exists,

and that we may not be alone in the universe. He was asked to withdraw his statements which went against the teachings of the Catholic Church. Bruno refused to compromise what he believed was the truth. Exactly four hundred years ago, on 17th february 1600, Bruno was burned alive by the Inquisitors .

Today, we know that Bruno was right, and the Church wrong. The stars are suns like ours, and that some of them have planets. We have travelled to the moon, and our satellites have reached the planets of our solar system.

We now realise that there is only one story - the story of the universe. All the subjects we study in school- physics, chemistry, biology, geography, history are all parts of this single story. Our wonderful earth is only a very, very small incident in this great story.

The other parts of this story are hinted to us only as shining objects in the sky. To know the rest of the

story we have to travel to the stars. There is one and only one way to travel to the stars - via the light rays (including the invisible portions of the light spectrum) that reach us from them. Optics, therefore, is our pathway to the universe, photons are the time machines for our universal journey.

The sun is not only the source of light , life and energy for us on earth. It is our nearest star. It is our most important hint to the universe. If you want to understand the universe, study the sun.

As we have seen in this booklet, we do not require expensive equipment, or university degrees to begin our investigation. We can do non-trivial , precise and significant experiments with everyday materials. What are some of the questions that we need to answer ?

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QUESTIONS

Here are some questions that need to be answered. Many of these questions can be answered by experiments with everyday materials. Some experiments may require the cooperation of friends and colleagues in different states and countries. But today with internet communication reaching every district and taluka this can be done easily and quickly. Some questions have not yet been answered by LCNC methods. But maybe if you think and work hard at it, you will discover a new LCNC method to answer questions that have hitherto required expensive and sophisticated equipment.

- How big is the sun ?
- How far away is the sun ?
- How heavy is the sun ?
- What can we understand from studying shadows cast by the sun ?
- How hot is the sun?
- What is the sun made of ?
- How much energy is released from the sun ?
- How does the sun move ?
- How does the earth move with respect to the sun ?
- What are sunspots ?

- What emissions from the sun can be observed other than light emissions?
- How does the solar activity affect events on earth ?
- What is the structure of the sun ?
- How much energy reaches us from the sun ? How can we use it ?

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