A PELICAN BOOK

H. W. NEWTON

The Face of the Sun

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A special job of astronomers during the International Geophysical Year, when this book first appears, is the study of the surface of the sun. The tools which modern technical skill has newly placed at their service, among them radio telescopes such as that at Jodrell Bank, are adding almost daily to our knowledge of the constitution and the activity of the one star we can observe at what, in terms of stellar distances, may be called 'close range'.

Here is the story of what men have learnt about the sun during the three-and-a-half centuries since Galileo's early telescope first disclosed the existence of sunspots. The fifty-thousand-mile-long tongues of gas which shoot out from the sun's surface into space, the streams of solar particles which enter earth's atmosphere to cause magnetic storms that disturb our radios, and to paint the night sky with displays of the Aurora Borealis, the obscure effects of solar activity on our weather conditions are described, discussed, and so far as is yet possible explained.

And – because our sun, we may suppose, is in many ways typical of many of the countless stars of remotest space – we are given in these pages a glimpse of happenings far beyond our own system, in similar stars at the remotest bounds of the universe.

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Introduction

THIS book dealing with the sun has been written around the observed features of sunspots and their highly interesting associated phenomena. The dark spots themselves, exclusively known as 'sunspots', have been studied by generations of solar observers since the invention of the telescope in 1608–10. From old Chinese annals and medieval European records, it is known that occasionally dark spots were seen with the naked eye when the sun's brilliant disk was dimmed by mist or smoke from forest fires.

Besides the dark spots there are associated bright spots or structures that have been more fully revealed by new techniques only in the last sixty years or so. Of these bright markings the most interesting is the so-called solar flare that lasts but a small fraction of the lifetime of the associated sunspot. Because of their short duration and the special technique required for seeing them, solar flares have been systematically studied only for the past twenty-five years. But a rich harvest of results has followed. The more intense flares are responsible for the troublesome fade-outs experienced on long-distance short-wave radio communication and appear to play an essential part in the occurrence of geomagnetic storms with their luminous counterpart, auroral displays. During the last few years the radio telescope has entered this field of research as an entirely new and powerful tool for probing the sun's secrets.

The story thus unfolded is a continuous one, from a few scattered observations made of sunspots with the unaided eye, through the early telescopic era of the seventeenth and eighteenth centuries to the progressive revelation of solar phenomena by new methods of observation. Although now requiring a very technical approach, the study of sunspots has touched upon the lives of many men of diverse vocations, but all having a compelling interest in astronomy.

The subject is almost entirely factual. However interesting and important theories may be they have a habit of going out of fashion, and in any case they usually require a mathematical approach for their full understanding. A phenomenon faithfully recorded, though not very well understood then, has again and again stood the test of time and has been vindicated when knowledge of the matter was more complete. Periodically the sun performs a great natural experiment. Visible features like sunspots increase rapidly in frequency to reach a peak in some 3½ to 4 years; thereafter there is a decline to minimum, the whole cycle being completed in about 11 years. At the present time the sun's activity has risen to a peak of the 11-year cycle, though this maximum phase may well continue into 1958. So sunspots are now plentiful, and for a few years a small proportion of spots will no doubt be discovered by observant individuals when mist or city fog sufficiently reduces the glare of the sun's disk. A personal discovery like this is always quite exciting. The interest thus begun would certainly be stimulated by observation of sunspots through quite a small telescope, when some of their broader features, as described in the following pages, may be verified.

To such observers, and to many others who have a general interest in the vast field of natural events, the story of solar spots may add yet another subject for reflection.

CHAPTER ONE

The Solar Furnace

THE sun and its family of planets revolving in orbits around it comprise an entity known as the Solar System. Separated by vast distances from the sun and from one another, are the stars – some 3,000 millions of them – forming the Galactic System, whose extension into remote space is marked by the Milky Way.

Astronomical evidence shows conclusively that the sun is one of the stars, or, conversely, that the stars are suns, essentially of the same nature as our sun. But to the races of mankind, dwelling on the fifth planet in order of size and the third outwards from the centre of the solar system, the sun is a unique star, on whose unfailing flood of light and heat life on this planet is dependent.

In this age of press-buttons and the large-scale generation of light and power we are apt to overlook this vital fact that was more than dimly appreciated by primitive peoples and by older civilizations with their sun-worship.

The sun is also a unique star to us, because it is the only star that presents a disk for the study of any features that may appear on it.

Even the nearest stars are so far away that at the focus of the biggest telescopes yet made their images are still only points of light.

The diameter of the sharp circular boundary of the sun's gaseous body is not far short of a million miles – 864,000 miles, to be precise. At the sun–earth distance of 93 million miles this great dimension as compared with terrestrial standards has shrunk to an apparent angular size of only 30 minutes of arc, or 1/180 part of a right angle. As seen from the sun, the earth, nearly 8,000 miles in diameter, would present only a tiny disk of barely 17 seconds of arc across, or rather less than 1/100 the apparent size of the sun as seen from the earth. Thus the earth intercepts only a very small fraction of the radiant energy pouring continuously from this great solar furnace.

To understand how great, by terrestrial standards, this fraction of intercepted solar radiation is, requires an imaginative illustration such as the following, quoted from *Worlds Without End* by Sir Harold Spencer Jones:

> The proportion of this radiation which the Earth receives is only one part in 2,200 millions. Yet the energy received by the Earth in the form of solar radiation amounts to nearly 5,000,000 h.p. per square mile of surface. If we were able to utilize all this energy and valued it at the rate of ¼*d.* per Board of Trade unit, the monetary value of the solar energy striking the Earth every second would be £200,000,000.

By radiant energy is meant the whole range of electromagnetic radiation, which includes not only visible radiation, which we know as light, but also invisible radiation, to which our eyes do not respond. For instance, it is now known that the range of wavelengths (or frequencies) of the sun's radiation includes very long wavelengths (as compared with the very short wavelengths of light) of a few metres, such as those now employed in radar.

That part of the sun's radiation of wavelengths too short to be perceived as light is known as ultra-violet radiation, and at still shorter wavelengths there are the X-rays. When visible radiation from the sun is passed through a glass prism with accessory slit and lenses the progressive change of wavelength of the ensuing spectrum is perceived by the eye as the change of colour from deep red, through orange, yellow, green, and blue, to deep violet. Nature produces this spectrum of sunlight in the rainbow.

The small fraction of the sun's radiant energy intercepted by the earth does not all reach the ground. Besides the general dilution, most marked when the sun is rising or setting, or with the low winter sun, the earth's upper atmosphere absorbs certain parts of the total radiation, as shown in Fig. 1. In particular there is a sudden cut-off beyond deep violet light owing to absorption by a layer of ozone at a height of 15–20 miles above the earth's surface. Without this screening of the sun's ultra-violet radiation, sunlight would be very harmful to human life. The observation of the quality of sunlight before it passes earthwards through the ozone layer is being made possible by sending up suitable recording equipment in high-altitude rockets. At times of certain eruptions on the sun, to be described later, such observations will be of very special interest.