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Book Review

Nature's Third Cycle: A Story of Sunspots

by

Arnab Rai Choudhuri

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Human civilization has been shaped and dominated by two cycles of Nature — the cycle of day and night caused by the rotation of the Earth on its axis and the cycle of seasons caused by the motion of the Earth in its orbit around the Sun.

There is a third cycle involving the Sun-Earth system with a much longer period whose effect is a bit more subtle. This is the cycle of solar activity with a period of 11 years which causes enhancement and decline of several solar phenomena that impact on Earth's environment and are responsible for some spectacular events like geomagnetic storms or the aurorae seen in the northern latitudes. The book under review is a story of this third cycle, how and when it was discovered and then, the physical theory that describes it in detail, and finally, a critique on success and failure of the theory and its relation to other areas, e.g., climatology and global warming. The author is a distinguished solar physicist, who received his training from the most well-known solar physicist of the era and who then contributed very substantially to the theoretical developments in the field. There is no doubt that Arnab Rai Choudhuri is perhaps the most suited person to tell the story of the activity cycle of the Sun. As he says, it has become common in recent times to write popular books on cosmology and there have been few attempts to write at a popular level on the Sun and its behaviour, revealed through spectacular images of it obtained by advanced technological missions, as if the subject were not interesting enough to engage our attention. In this book, he has taken it upon himself to describe the Sun and its activity cycle in a manner that would excite the interest of the common reader in our parent star. The story is interwoven with the tale of his own career and in that sense the book is also autobiographical to some extent.

The story begins with sunspots, those dark patches on the surface of the Sun whose appearance and disappearance have been of great interest to astronomers for centuries. Sunspots can be seen with the naked eye but there is no historical record of when a sunspot was first seen by man. It appears a large sunspot was seen just before Emperor Charlemagne's death in 814 CE and its sighting was thus considered an evil omen. Scientific study of sunspots began with Galileo and his telescopic observations. It took more than two hundred years to discover the sunspot cycle. The book begins with a description of the first observation in 1859 by Richard Carrington of a solar flare that erupted at a big sunspot. This was followed by a sudden violent change in the Earth's

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magnetic field although the scientists of the period refrained from theorising on a connection between the two events. Carrington is also responsible for discovering the differential rotation of the Sun. In 1908, George Ellery Hale discovered magnetic fields in sunspots and the quest to understand them began. Fifty years later, in the mid-1950s Eugene Parker developed a theoretical model of the solar cycle and also predicted the existence of solar wind which was discovered a few years later. Parker employed the equations of magnetohydrodynamics and showed that a self-excited fluid dynamo is possible, contrary to what had been believed until then following the early work of Cowling. Parker derived the now famous '*dynamo equation*' whose solution led to an explanation of several aspects of the solar magnetic field. The Sun's toroidal field is responsible for making the sunspots. Very little was known about the Sun's poloidal field before this time. In his theory, Parker introduced the new idea of an oscillation between the Sun's poloidal and toroidal fields and showed how this would lead to a logical explanation of the solar cycle. It is remarkable that Parker's revolutionary theory appeared around the same time that the Babcocks discovered the poloidal field of the Sun. Rai Choudhuri, one of Parker's outstanding PhD students, carried the theory forward and has been at the forefront in solar research the last thirty years or more. He has done an excellent job of explaining the complex concepts in a simple language for the comprehension of a lay reader.

The book is complete in ten chapters with a foreword by Nigel Weiss, the distinguished solar physicist from Cambridge. The appendices at the end describe some of the technical details of the theories that have been discussed. There is a list of suggestions for further reading. After the initial chapters which are somewhat historical in nature, in Chapter 4 the author has introduced the physics of plasmas. This is done masterfully as expected, for the author had already written a more technical monograph on the subject, *The Physics of Fluids and Plasmas: An Introduction to Astrophysics*, Cambridge University Press, 1998. Then follow Chapters 5–7, which, according to the author, constitute the central backbone of the book. These describe in great detail the physics behind sunspot formation and the theory of the solar cycle. The many related secondary phenomena have also found their logical explanation. Chapter 8 is on the solar-terrestrial relationship and on the expanding solar corona which appears as solar wind in the Earth's environment. The Space Missions have made it possible to experimentally study some aspects of the wind. Chapter 9 explores some of the less understood themes like the long-term impact of the solar cycle on Earth's climate, what causes irregularities in a solar cycle, whether it is possible to predict the strength of a cycle etc. As the author delved deeper and deeper into these themes, the discussions have tended to become more technical and perhaps less interesting for the common reader. In Chapter 9 the discussion has revolved more around differing viewpoints of scientists working in the field, Choudhuri's own group pitted against other well known groups. A perusal of these later chapters invariably bring to mind the Prefatory Chapter of *Annual Review of Astronomy and Astrophysics* published by Annual Reviews, Inc., Palo Alto, California, where a distinguished astronomer describes his or her own professional journey complete with interesting anecdotes and insights to how scientific research progresses.

For me a surprising omission in the book is that of the work done at Kodaikanal Observatory where in the year 1909, John Evershed discovered the phenomenon of radial motion in the sunspots. Kodaikanal Observatory is one of the three in the world that have an unbroken record of investigations on solar magnetic field and spectroheliograms of the Sun. The Ionosphere Laboratory, a part of the Observatory, has done commendable work on solar-terrestrial relationship. A book by

an Indian author completely ignoring the work done on Indian soil is somewhat surprising. More recently, during the last quarter of the twentieth century, there have been solar physicists in India, outside of Rai Choudhuri's group, who have contributed substantially to the field but there is no mention of them or their work.

The weakest link in the book is Chapter 3 which describes the interior structure of the Sun and stars and goes on to describe the ultimate fate of stars when they run out of the nuclear fuel. The author seems to suggest that the heat generated by nuclear reactions at the core gives rise to the thermal pressure that balances the gravitational pressure of the stellar mass, a physical condition known as hydrostatic equilibrium. This is not quite true because, by definition, all normal stars, whether nuclearly powered or not, are always in hydrostatic equilibrium. It is the thermal pressure of the hot ionized gas in the interior that balances gravity at any radial point through the entire volume of a star. This point has been missed. Further, although Helium is the second lightest element in Nature, the author has erroneously called the isotope He^4 as the second lightest element, when in reality, it is Deuterium, with a single proton and a neutron in the nucleus, which is the second lightest isotope. And it is the formation of Deuterium in proton-proton scattering events that lead to the formation of the isotope He^3 and eventually to He^4 that provides the energy to power the Sun. The author has ignored the carbon-nitrogen-oxygen cycle which is responsible for the synthesis of helium from hydrogen in the more massive stars, approximately, mass M greater than 1.5 solar masses,with the CNO isotopes behaving as catalysts. In the Sun the CNO cycle is very weak. The Fig. 3.3 displayed in this chapter is rather funny. It shows a shaded region outside the solar core which is rather mysterious and remains unexplained in the text! I wish the author gave as much attention to this chapter as he did to the rest of the book.

The style of writing is distinctly pedagogical as the second person pronoun is liberally used in explaining things as if a student were listening to the discourse and trying to understand. It is also amusing to see that the author is quite fond of using superlatives while introducing the major scientists and their work. While Maxwell is the 'greatest theoretical physicist in the intervening period between Newton and Einstein', and William Herschel, 'the greatest astronomer of his age', George Gamow is 'one of the greatest science popularisers of all time' and Subrahmanyan Chandrasekhar is the 'greatest theoretical astrophysicist the world has so far seen'. The list goes on and on! Nevertheless, the book is indeed a valuable addition to the literature on modern solar physics and should be read by all interested in our parent star and its myriad phenomena.