UNDERSTANDING SOLAR CYCLE AND IT'S IMPLICATIONS ON SOCIETY: A NEED TO PREDICT ITS END TIME

Sun and moon are the two cosmic entities readily visible from earth. Disregarding the size, mass and distance from earth, moon appears to be comparatively near and sun a little more far. Humanity has already travelled to the moon and with its brief stopover gained an opportunity to understand it from close quarters. The sun is a different ball game altogether. The influence of sun on earth is thousand fold more than that of moon. All the natural processes on earth are single handedly driven by the sun. It is intimately connected with each and every life form on earth, be it large or small. The sun is both distant and close, imparting it an aura of omnipotence.

Though the sun is away from earth by a whopping 1500 lakh kilometers, its diameter of 14 lakh kilometers makes it so unmistakably close to us. It is also almost 110 times bigger and has almost three and a half lakh times more mass than our planet. Such gigantic figures make it a force to reckon with. Our technological advances have sent quite a number of satellites to far corners of space. But, even after all these years only a solitary satellite has breached the boundaries of 'our' space and the sun is thousand times light years ($1LY = 9.5 \times 10^{12}$ km) still farther away.

From time immemorial sun has been revered and worshipped. But, it also has been critically examined by the likes of Galileo, Christopher Scheiner, and Johann Fabricius who were greatly fascinated by dark spots mushrooming on sun. Today we call them sunspots which were reported for the first time in 1609. The initial enthusiasm for observing sunspots waned after 1645 because they disappeared completely for almost seventy years. The sun-gazers lost interest because of this 'disappearance' and went on to explore other phenomena. The world would have forgotten the fascinating realm of sunspots had it not been for Heinrich Schwabe. Schwabe was interested in finding an unknown planet hence kept strict vigil on sun. The bright background of sun can make it easier to spot a dark object. In the hope of getting hold on an elusive planet, Schwabe maintained dedicated record of blemishes seen on sun for almost 17 years from 1826. The data that he compiled made him understand a pattern in the appearance and disappearance of the sunspots which he published in an article in 1843.

Rudolf Berne read this article which sufficiently influenced him to count the sunspots. Later he combined his and Schwabes' data to devise the 'Zurich Sunspot Number'. This is a statistical measure that brought out sunspot cycle of approximately 11years. Later, George Ellery Hale deduced that sunspots are greatly magnetic and a lot cooler than the surrounding region. Sunspots originate in groups and form two sets, one with a positive or north magnetic field while the other has negative or south magnetic field. Depending upon the dynamical processes on the sun the sunspot numbers vary and they follow a cyclic behavior. The sunspot number initially increases, attains maximum and then decreases to attain minimum. This entire activity called as solar cycle and it nearly takes 7-11 years. When sunspots are in the phase of 'minimum' hardly any sunspots occur. But again sunspot activity picks up and a new cycle begins.

The counting of periodic acceleration and deceleration in sunspot cycle was earlier an academic exercise. But not anymore. Climate change is beginning to strike at the very roots of human existence. The struggle to come up trumps with a long drawn out war on climatic vicissitudes is gaining momentum all over the world. The fight to deal with usual suspects is on. However, the sunspot cycle, which is the manifestation of the degree of energy hurled out by the sun, adds to a growing list of variables that influences our climate. The crest and trough of a solar cycle defines the rate of energy released by the sun. It also signifies the amount of energy available for earth to soak in. The variability in energy levels (UV and solar irradiance) and the ability of different atmospheric units to act unequally in this miasma can have serious repercussions on tropospheric rainfall patterns and storm generation episodes. This has wide implications on studies related to climate change.

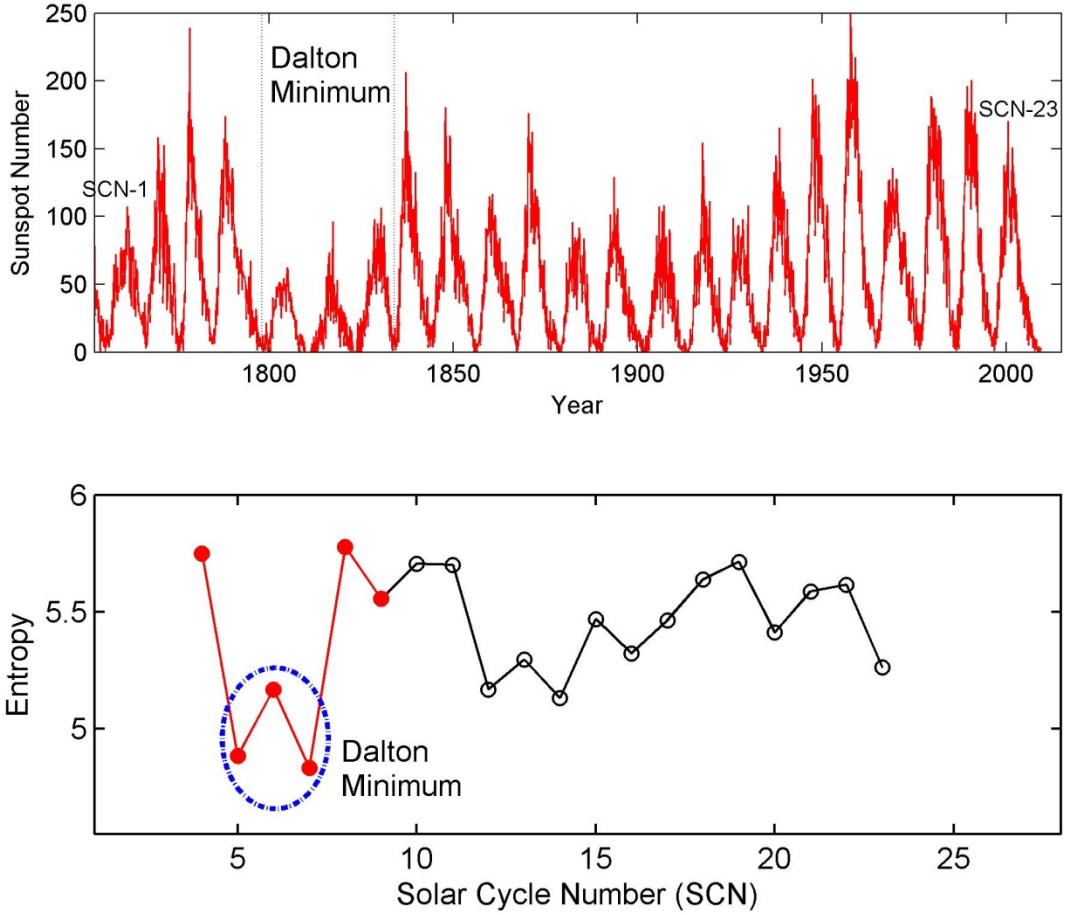
The study of solar cycle is thus important and has a plethora of societal benefits. In terms of space research these studies are all the more important because the life of astronomers and expensive equipment is at stake. Because of this, forecasting the initiation and tapering of solar cycle has gained importance the world over. The American and European bloc is leading the race to gainfully understand and predict the impending solar cycles. Solar cycle prediction is a dicey affair. The predictions related to solar cycle 24 have gone woefully wrong. The predicted minimum was off by nearly two years. When we translate this in common man's lexicon it reads- decreased UV radiation reached earth. The sub context to this corollary is that it may have interfered with the global climate.

Solar cycle indeed has direct implications on our life and near Earth space. The first solar cycle lasted from August 1755 to March 1766 and the current 24th, started in Jan 2008 and is likely to end shortly. A lot is riding on the next 25th cycle. The compilation of all solar cycle data has revealed two prolonged minimums during 1645 to 1715 called the Maunder minimum and between 1790 and 1830 called Dalton minimum. Europe and some other parts of the world experienced lower than average temperatures during these years. Some of the methodology and models adopted do well in predicting solar cycles, but falter on the start and end time of the cycle. Some of these employ the numerical or physical approach, which are refined along the way with the advancement of solar cycle. None of the prevalent models have cared to presage the descent time or the ending time of a solar cycle.

This is about to change. A group from Indian Institute of Geomagnetism led by Dr. Bharti Kakad has done just this. With her colleagues, Dr. Amar Kakad and Prof D. S. Ramesh, she has developed a model, based on Shannon entropy, to forecast the descent time of solar cycle. Claude Shannon, the father of information theory, developed equations that are widely used in space weather, climate and earth related studies. Sunspot cycle contains the averaged out numbers of sunspots that go back a long way to 1755. This time series is not uniform. It contains many aberrations in terms of statistical requirements. This long data series was maneuvered in a ready-to-use format by removing the obvious 'trend' and subjecting it to Shannon entropy. When this data went through a set of statistical procedures and out came the results, Bharti Kakad and her colleagues found that the descent time for solar cycles 12 through to 23 was well within an error margin of 0.4 years. Their model also reveals the grand minima of Dalton and Maunder associated with lowest entropy values. The mathematical jigsaw that this research group developed needs Shannon entropy of a particular solar cycle (say 2nd) to predict the descent time of 4th solar cycle. Using all the data and mathematical formulations at their disposal they have predicted the descent time of the present 24th solar cycle to be 6.84 years, which in common language means the present cycle will close at about February 2021. Some of the illustrious names have foretold the possibility of grand minimum like Dalton during 2030-2050. But, Bharti Kakad's model suggests that no such thing to occur during solar cycle 25.

Bharti Kakad had also developed a model to forecast the peak and ascent time of the upcoming solar cycle during 2011. The peak and ascent time of solar cycle 24 predicted by their model are

in good agreement with actual observations. Now they have developed model to predict descent time of upcoming solar cycle. Despite this fact what Bharti Kakad and her team has done is immensely creditable. People from the scientific arena as well as from the general populace should know of this achievement. The Indian scientific community is not lagging behind their international counterparts.



Upper panel shows the variation of monthly sunspot numbers for all the solar cycles (SCs) from 1 to 23. The lower panel shows the Entropy of SCs 4 to 23. The entropy estimates for SCs 10–23 (filled circles) are based on daily sunspot number data, whereas those for SCs 4–9 (open circles) are obtained from the prediction model equation. The least entropy values coincide with the well known Dalton minimum.

The above popular science article, written by Praveen Gawali, is based on the following original research article:

"A new method for forecasting the solar cycle descent time" (2015). Bharati Kakad, Amar Kakad, and Durbha Sai Ramesh. J. Space Weather Space Clim., 5, A29.

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