Solen

G.Gamow

December 6-10, 2016

In my mid-teens I read many popular books on science, which in practice meant astronomy and physics exclusively. One of the favorite authors was Gamow, whose 'One, two, three infinity...' especially the mathematical introduction made a deep impression on me, especially the fourth dimension. Many of the books I probably did not understand, I was mathematically unsophisticated and in popular books there were formulas, something nowadays are thought of as anathema to any books that addresses the general public. The point is, however, that a mathematics or physics books without formulas is more or less pointless, it is only with a formula or two you can get engaged with a theory to see what is up and what it can lead to. In those days writers did not shy away from them.

This particular book was issued by Aldus, and I am a bit taken back by the price of 11:50 SEK, which at that time fifty years ago, no doubt would correspond to fifteen to twenty times that today, a rather hefty outlay, which I back then took in stride. It was originally published as 'A Star Called the Sun' in 1964 and appeared in a Swedish translation the next year. I do not know when I read it, I did not take notes, but it would have been interesting to know. Now it is an act of nostalgia, not always a pleasant one, to read it again. At the time life was opening up and I was learning for the future, now there is not much of a future left for which to invest.

The book starts with the problems, encountered by the Ancient Greeks to determine the distance to the Sun, meaning the scale of the solar system. The distance to the Moon could be affected by parallax methods using the rotation of the Earth, and was known fairly accurately at the time of Ptolemy. The relative distances of the planets to the sun was likewise known by the 16th century once the Copernican system was accepted. Assuming that Venus encircles the sun it is trivial to compare its distance to that of the Earth by measuring maximal extension from the Sun. By the end of the 17th century the Dane Römer was able to determine the velocity of light through the 'Doppler-effect' of the Galilean moons' rotation around Jupiter.

How much of what I read did I remember? Much of the book is taken up with basic physics, as any book on astronomy is compelled to, and it is hard to know how much of that I learned from the book or what I had picked up from other books or would do so later. There is one thing in the beginning that strikes me now, but apparently not back then, namely the computation of how much energy the Sun generates by mass and time which is surprisingly small. I made that calculation some years ago and was very surprised that the metabolism rate of the Sun was much lower than that of a human, obviously having completely forgotten that I must have read about it some forty years earlier.

So there is the usual stuff: The spectral theory of atoms explained by the Bohr model, what makes it possible for us to determine, pace August Comte, the chemical composition of the stars without having to visit them[1]. More interesting though to determine absolute velocities of stars relative us in the line of sight, which has tremendous consequences, something one cannot appreciate without manipulation of formulas and their logical interconnections. This being a book on the Sun it is unavoidable that there will be a descriptive discussion of the Sun, its surface and its interior. It is a bright disc which is hot, but not that hot really at a mere $6000^o K$ this is a temperature that can be effected on a rather large scale on Earth. The surface is not spotless but marred by sun spots which occur at fairly regular intervals. Those always appear dark, not to say black, on pictures, but they are not dark only in comparison with their brighter surroundings. Would we look at them in isolation they would be blindingly bright, in fact if the rest of the Sun's disc would be obscured and we would only see the spots, they would shine brightly and illuminated the Earth like thousands of Full Moons. Closer inspection shows that the entire surface of the Sun is in turmoil, showing a granular structure as a liquid in full boil. In fact the Sun should be thought of not as liquid or gaseous but as a huge plasma of great temperature and extraordinarily complicated electro-magnetic activity. Plasma enjoys the same equations as gases, in particular the same general law

$$P = R\frac{\rho T}{\mu}$$

where P is pressure, T absolute temperature, ρ density, μ molecular weight, and R a universal proportionality constant. Now ρ can be replaced by M/V mass per volume and we get the familiar $PV = R\frac{M}{\mu}T$. Now $M = k\mu$ where k is the number of molecules. This leads to the somewhat surprising fact that if the number of particles double, but keeping the mass, volume and temperature constant, then the pressure doubles. In a plasma, the atoms are no longer tied to each other, molecules break up, H_2 turning into $2H$, and it becomes even more drastic when electrons become free, the end result is that an atom of weight K and atomic number Z breaks up in $Z + 1$ particles with average $\mu = \frac{K}{Z+1} \sim 2$ except for Hydrogen and Helium when we get $1/2, 4/3$ respectively. (The case of $Li^6 = 3/2, Be^8 = 8/5$ etc). Those considerations make the analysis of plasma rather independent of the chemical composition. Now the basic model for the Sun is that of a very small reactive zone in which energy and thus heat is generated, this is surrounded by a convective zone of great movement in which material is constantly mixing providing the reactive zone with fresh fuel. Finally most of the Sun is taken up by a conductive zone where heat is slowly transferred by conduction. According to a theory of the Swedish astronomers Alfvén and Walén, the electro-magnetic field create toroidal structures which whirl up to the surface and erupt as pairs of sun spots.

Then there is a chapter on radioactive decay in which it is pointed out that when it comes to α-decay (the emission of α particles i.e. nuclei of helium) their energy slowly decrease with the half-time. Thus those of U^{238} with a half-life of $4.5 \cdot 10^9$ years $14 \cdot 10^{16}$ seconds have an energy of 4.05MeV [2] while those emitted from Po^{214} with a half-life of

[1] It is interesting that Comte apparently took it for granted that the celestial objects were made of the same stuff as on Earth.

[2] 1 eV is the energy that is needed to lift one electron one Volt, it corresponds to $1.6 \cdot 10^{-19}$J or $4 \cdot 19^{-20}$ calories.