

## KIRCHHOFF<sup>1</sup>

### THE ABSORPTION SPECTRUM OF THE SUN

(From "Researches on the Solar Spectrum and the Spectra of the Chemical Elements," 1861; translated by Henry E. Roscoe, 1862.)

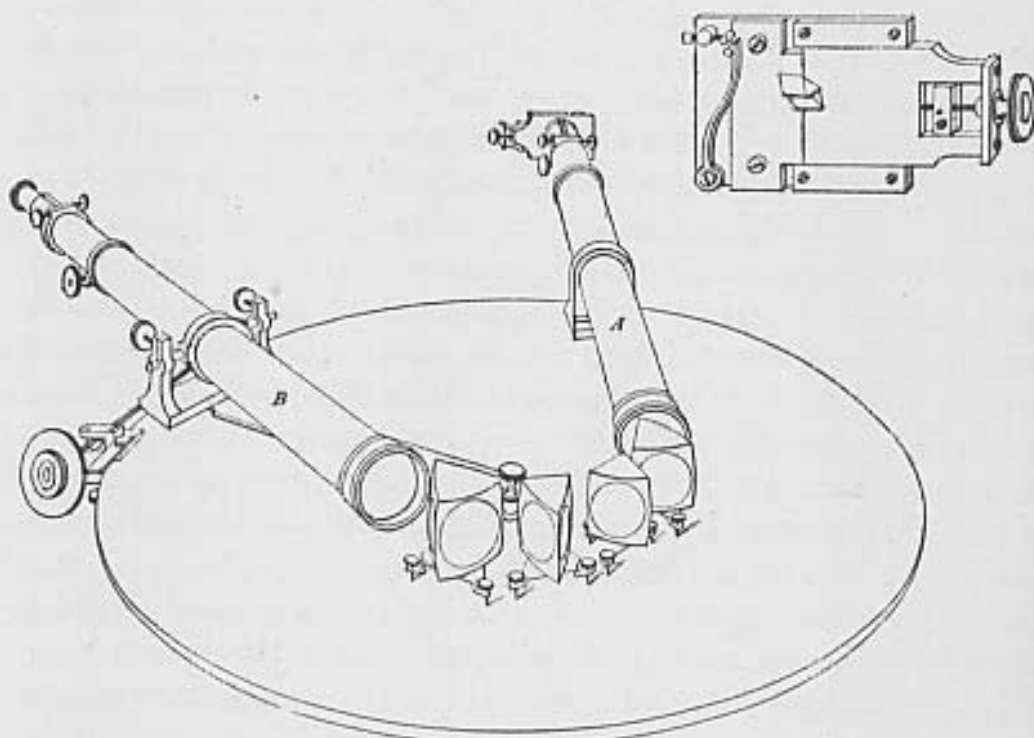
In the course of the experiments already alluded to, which Foucault instituted on the spectrum of the electric arc formed between the carbon points, this physicist observed that the bright sodium lines present were changed into dark bands in the spectrum produced by the light from one of the carbon poles, which had been allowed to pass through the luminous arc; and when he passed direct sunlight through the arc he noticed that the double *D* line was seen with an unusual degree of distinctness. No attempt was made to explain or to increase these observations either by Foucault or by any other physicist, and they remained unnoticed by the greatest number of experimentalists. They were unknown to me when Bunsen and I, in the year 1859, commenced our investigations on the spectra of coloured flames.

In order to test in the most direct manner possible the truth of the frequently asserted fact of the coincidence of the sodium lines with the lines *D*, I obtained a tolerably bright solar spectrum, and brought a flame coloured by sodium vapour in front of the slit. I then saw the dark lines *D* change into bright ones. The flame of a Bunsen's lamp threw the bright sodium lines upon the solar spectrum with unexpected brilliancy. In order to find out the extent to which the intensity of the solar spectrum could be increased, without impairing the distinctness of the sodium lines, I allowed the full sunlight to shine through the sodium flame upon the slit, and, to my astonishment, I saw that the dark lines *D* appeared with an extraordinary degree of clearness. I then exchanged the sunlight for the Drummond's or oxyhydrogen lime-light, which, like that of all incandescent solid or liquid bodies, gives a spectrum containing no dark lines. When this light was allowed to fall through a suitable flame coloured by common salt,

<sup>1</sup> Gustav Robert Kirchhoff (1824-1887), German physicist, established the science of spectrum analysis and applied it to celestial objects.

dark lines were seen in the spectrum in the position of the sodium lines. The same phenomenon was observed if instead of the incandescent lime a platinum wire was used, which being heated in a flame was brought to a temperature near to its melting point by passing an electric current through it.

The phenomenon in question is easily explained upon the supposition that the sodium flame absorbs rays of the same degree of refrangibility as those it emits, whilst it is perfectly transparent for all other rays. This supposition is rendered probable by the



The apparatus employed by Kirchhoff for the observations of the Solar spectrum.

fact, which has long been known, that certain gases, as for instance, nitrous acid and iodine vapour, possess at low temperatures the property of such a selective absorption. The following considerations shew that this is the true explanation of the phenomenon. If a sodium flame be held before an incandescent platinum wire whose spectrum is being examined, the brightness of the light in the neighbourhood of the sodium lines would, according to the above supposition, *not* be altered; in the position of the sodium lines themselves, however, the brightness is altered, for two reasons; in the first place, the intensity of light emitted by the platinum wire is reduced to a certain fraction of its original amount by absorption in the flame, and secondly, the light of the flame itself is added to

that from the wire. It is plain that if the platinum wire emits a sufficient amount of light, the loss of light occasioned by absorption in the flame must be greater than the gain of light from the luminosity of the flame; the sodium lines must then appear darker than the surrounding parts, and by contrast with the neighbouring parts they may seem to be quite black, although their degree of luminosity is necessarily greater than that which the sodium flame alone would have produced.

The absorptive power of sodium vapour becomes most apparent when its luminosity is smallest, or when its temperature is lowest. In fact we were unable to produce the dark sodium lines in the spectrum of a Drummond's light, or in that of an incandescent wire, by means of a Bunsen's gas-flame in which common salt was placed; but the experiment succeeded with a flame of aqueous alcohol containing common salt. The following experiment proposed by Crookes likewise very clearly shews this influence of temperature. If a piece of sodium is burnt in a room, and the air thus filled with the vapour of sodium compounds, every flame is seen to burn with the characteristic yellow light. If a small flame in which a bead of soda salt is placed be now fixed in front of a large one, so that the former is seen projected on the latter as a background, the small flame appears to be surrounded with a black smoky mantle. This dark mantle is produced by the absorptive action of the sodium vapours in the outer part of the flame, which are cooler than those in the flame itself. Bunsen and I have produced the dark lines in the spectrum of a common candle-flame, by allowing the rays to pass through a test tube containing a small quantity of sodium-amalgam, which we heated to boiling; so that the sodium vapour effecting the absorption had in this case possessed a temperature far below the red-heat. The same phenomenon is observed in a much more striking manner if a glass tube is used containing some small pieces of sodium first filled with hydrogen, and then rendered vacuous and sealed. The lower end of the tube can be heated so as to vaporize the sodium. By means of this arrangement, which was proposed by Roscoe, the heated vapour of the sodium, when viewed by the sodium-light, is seen as a dark black smoke which throws a deep shadow, but is perfectly invisible when observed by the ordinary gas-light . . .

The sodium flame is characterized beyond that of any other coloured flame by the intensity of the lines in its spectrum. Next

to it in this respect comes the lithium flame. It is just as easy to reverse the red lithium line, that is, to turn the bright line into a dark one, as it is to reverse the sodium line. If direct sunlight be allowed to pass through a lithium flame, the spectrum exhibits in the place of the red lithium band a black line which in distinctness bears comparison with the most remarkable of Fraunhofer's lines, and disappears when the flame is withdrawn. It is not so easy to obtain the reversal of the spectra of the other metals; nevertheless Bunsen and I have succeeded in reversing the brightest lines of potassium, strontium, calcium, and barium, by exploding mixtures of the chlorates of these metals and milk-sugar in front of the slit of our apparatus whilst the direct solar rays fell on the instrument.

These facts would appear to justify the supposition that each incandescent gas diminishes by absorption the intensity of those rays only which possess degrees of refrangibility equal to those of the rays which it emits; or, in other words, that the spectrum of every incandescent gas must be reversed, when it is penetrated by the rays of a source of light of sufficient intensity giving a continuous spectrum.