	100 YEARS INTERNACIONAL ASTRONOMICAL UNION 1919-2019	

The Power of the Sun and how to measure it

Introduction: Bunsen photometer

To measure the power of one star, the Astronomers use the photometer, an instrument that measures the amount of light in a given location and It permits determine the amount of energy per unit of time (the Power) from an unknown source compared to a well characterized source. Historically, there are several photometers proposed for comparing light sources. In this work we will focus on that of Robert Bunsen (figure 1), a German chemist and physicist from 19th century. He built many of the devices he needed in his experiments. Perhaps the best known is the lighter that bears his name, but he also invented the oil spot photometer.

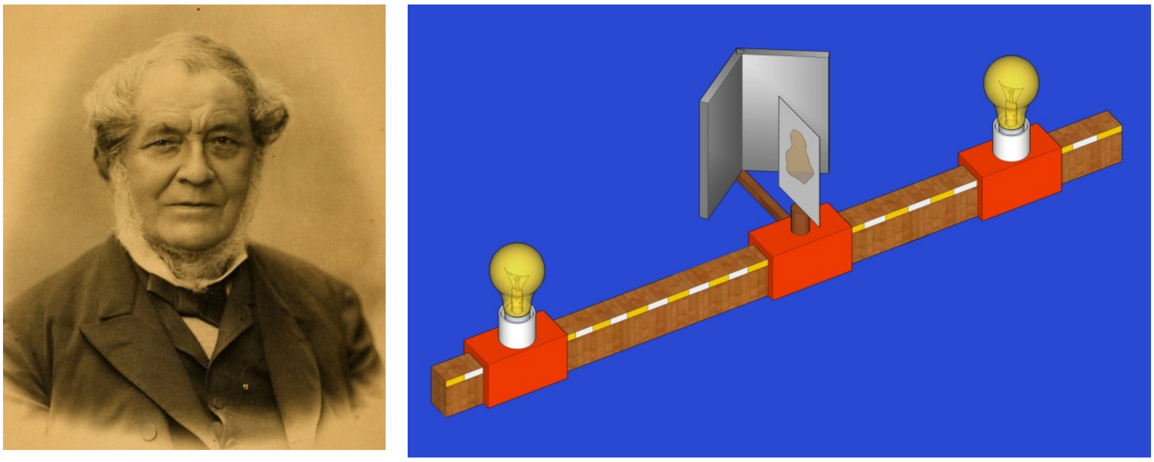

Fig. 1 Robert Wilhelm Bunsen and his oil spot photometer

The photometer invented by Bunsen allowed to compare the intensity of two light sources, one known and one not.

To do so, just place both sources on the ends of a tape measure. A plain white paper with a small oil stain is placed between the sources. In the stained area, the paper becomes semi-transparent. When moving the paper between the two sources of light, there comes a time when the stain is barely visible. In this position, the illuminance that reaches both sides of the paper is the same. Illuminance is the flow that arrives per unit area. As the luminous flux that comes out of a bulb is distributed radially between the surface of a sphere of radius d and area = $4\pi d^2$, the further away, the less illuminance. If both sources are bulbs of the same type, the number of lumens that come out per watt is similar, and in the calculations, we can substitute the luminous flux for the electrical power.

That is, if P_1 and P_2 are the electric powers of the two lamps, and d_1 and d_2 are the distances from the paper to each of the light sources, the following must be fulfilled-

$$\frac{P_1}{4\pi {d_1}^2} = \frac{P_2}{4\pi {d_2}^2} \quad => \quad \frac{P_1}{{d_1}^2} = \frac{P_2}{{d_2}^2}$$

If, for example, the lamps are 100 W and 60 W halogen lamps (figure 2), the position where the oil stain is not visible will occur:

$$\frac{100}{{d_1}^2} = \frac{60}{{d_2}^2}$$

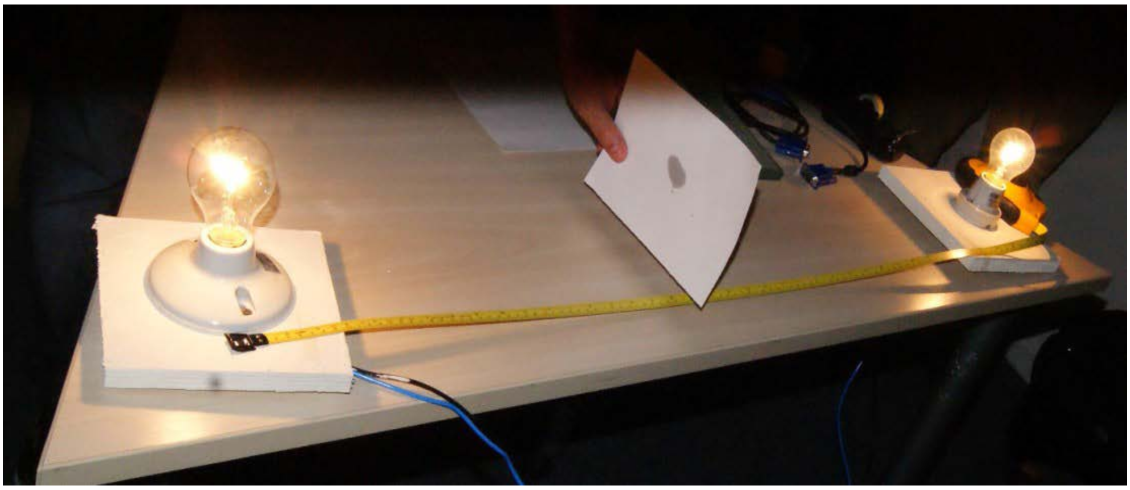

Fig. 2. As the stain looks dark, there is little light behind it and you should approach the bulb on the right until the stain disappears.

We can do a classroom experience to check the functionality of the oil spot photometer. We will compare a 60W standard bulb with two other sample bulbs, 40W and 100W. To do this, we prepare a chart (see Table 1), so that the student can record the data accurately, including whether the lamp is transparent or the glass is painted and what colour the light it produces is. **As always in Science, we must register the results.**

Table 1. Power estimation experiment: results

Lamp used as a pattern			Lamp used as a sample			
Type of bulb	Indicated power (W)	Distance bulb-paper (m)	Type of bulb	Indicated power (W)	Distance bulb-paper (m)	Calculated Power (W)

Experiment 1: Determination of the power of the Sun with the oil spot photometer

However, the most interesting use of the Bunsen photometer is the determination of the power or luminosity of the Sun. Using the oil spot photometer, we will calculate the power of the Sun comparing it with, for example, a 100 W bulb (figure 3).

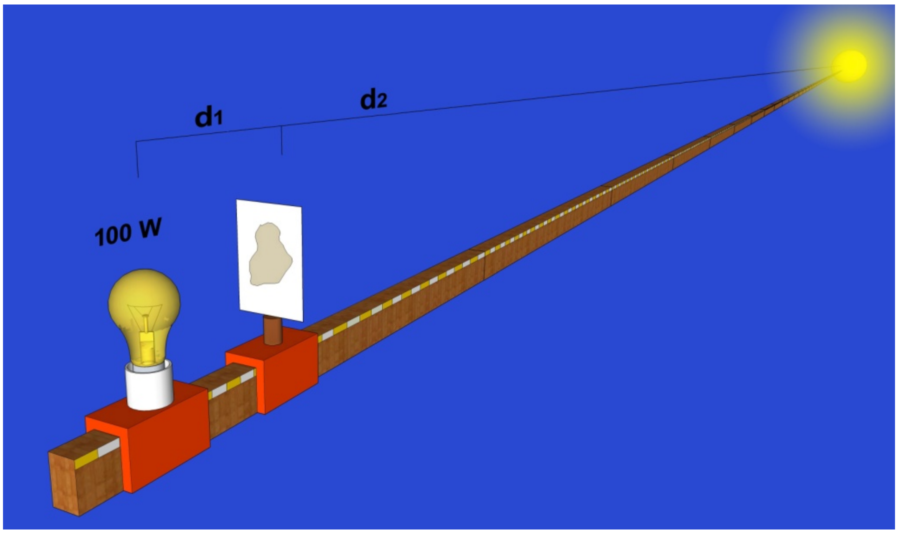

Fig. 3: Comparing the power of the Sun with a 100W lamp

On a sunny day, the photometer and a halogen bulb of at least 100 W are installed outdoors (the more the better). The photometer is placed between the Sun and the bulb, at a distance that the spot almost disappears. The distance d_1 is measured in meters, from the photometer to the filament of the lamp (figure 4).

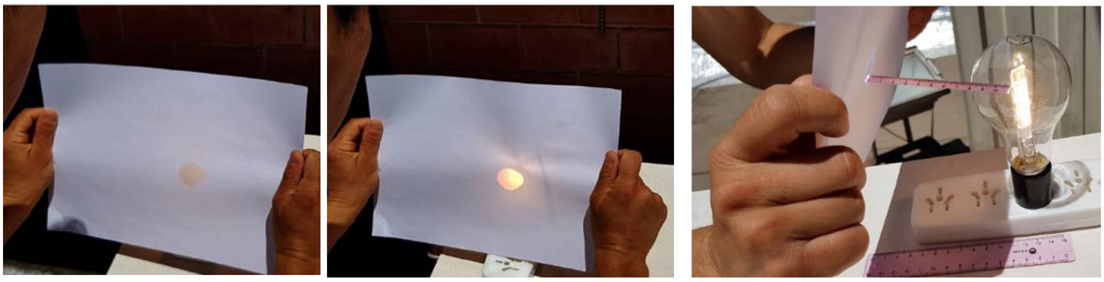

Fig. 4. When the stain is not visible, the distance from the paper to the filament is measured.

Knowing that the distance of the Sun from the Earth is approximately d_2=150.000.000 000 m (1 astronomical unit), the power of the Sun P_{Sun} can be calculated with the same formula as the previous activity, known as the inverse law of squares:

$$\frac{100W}{{d_1}^2} = \frac{P_{Sun}}{{d_2}^2}$$

Note that the luminous efficiency of the Sun and the halogen bulb are not the same, but the result obtained should not differ much from the actual luminosity of the Sun, which is $3{,}83 \cdot 10^{26}$ W.

Experiment 2: Determination of the Sun's power for inclusion

We can perform another experiment (figure 5) to estimate the solar luminosity, replacing the paper with the oil stain by our face. On a sunny summer day, it is possible to compare the heat that comes from the Sun on one of the cheeks of the face and the heat that comes from a 100 W bulb in the other. The distance of the bulb to the face should be changed until the student (with closed eyes or blind) has exactly the same feeling of heat in the skin of both cheeks. Measuring the distance d of the bulb to the face and the known distance R to our Sun (150 x 10^9 m), we can estimate the luminosity of the Sun with the same formula.

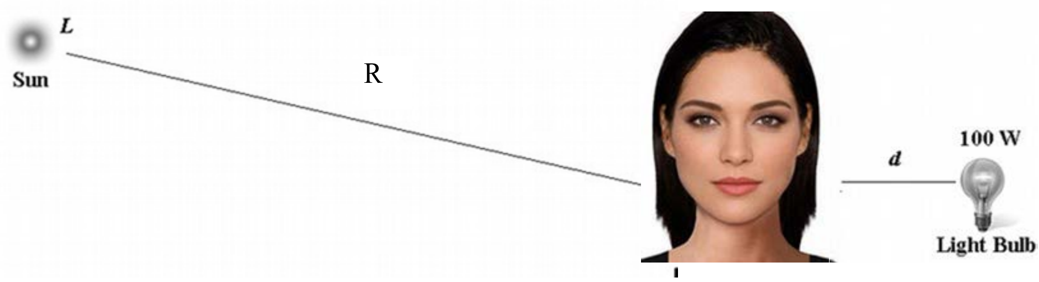

Fig. 5. Application of the relationship P_{Sun} / R^2 = P / d^2

The 'same sensation' means the same intensity of heat from the Sun and from the lamp. Assuming that the efficiency of the Sun and the light bulb were similar at these wavelengths, the mentioned law of the inverse of the squares can be applied.

The value of the distance *d* will be about 10 cm. With this value, the result of the Sun's Luminosity comes out around 2.2x10^{26} W, a little lower than the real one. The reason is that the atmosphere is not transparent to infrared radiation, and then, the Sun appears at these wavelengths weaker than it really is. But the simplicity of the method compensates for the lower precision in the result.

Autors:

Alexandre de Costa, Beatriz García, Ricardo Moreno, Rosa M. Ros, NASE members.

Bibliography:

- J. A. Belmonte, F. Berthomieu, A. Costa, H. Deeg, S. Deustua, J. Fierro, B. García, M.K. Hemenway, R. Moreno, J.M. Pasachoff, J. Percy, R.M. Ros, M. Stavinschi, ***14 steps to the Universe***, Rosa M. Ros y Beatriz García edi., Barcelona, 2018.
- A. Costa & A. L. Gonçalves, Solar Physics. Theory and applications, ***Astronomy at our Schools,*** EAAE-IAU Course on Astronomy Education, EAAE Summer School, Alexandre Costa and Rosa M. Ros Ed., Portugal, Loulé, 2016.
- B. García, R. Moreno, The meaning of the Sun and the distance to the stars: The power of photometry in Astronomy, Barcelona 2018.

Finally, send this sheet with the results and two or three photos of each Experience to newsletter.nase@gmail.com

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ACTIVITIES TO MAKE AND SEND

Perform the Experience 1 (with oil spot), the Experience 2 (with face cheek) or both, obtain the value for the Sun Power and record the results of each Experience in the following Results Table:

Table of Solar Power experiments results

Teacher's name				
School, Country				
Day and hour				
Type of Measurement	Patron		Results	
Experiment 1: Oil spot	Type of bulb	Indicated power (W)	Distance bulb-paper (m)	Calculated Solar Power (W)
Experiment 2: Cheek of the face	Type of bulb	Indicated power (W)	Distance bulb-cheek (m)	Calculated Solar Power (W)

Project launch: March 21, 2019 (equinox)
The activity will be open until: June 21, 2019 (solstice)
The results will be disseminated worldwide under the initiative IAU100