The power of the Sun

AND HOW TO MEASURE IT

AN "IAU-100 YEARS UNDER ONE SKY" PROJECT

Rosa M.Ros
Beatriz García
Alexandre Costa

Ajuntament d'Alcoi

Autores: Rosa M Ros,
Beatriz García,
Alexandre Costa

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The city of Alcoi has had the privilege of becoming the stage in which 'Science in Action' has turned 20 years old. An edition that, held at the beginning of October 2019, attracted to our city participants from nine countries such as Andorra, Argentina, United States, Greece, Italy, Portugal, Romania, Tunisia and, of course, Spain, which they enjoyed not only nourishing themselves with knowledge in astronomy but also extending them to those who visited them through the development of the project 'The power of the Sun', sponsored by the International Astronomical Union, which was carried out, in various formats, on four enclaves located in streets, squares and parks of Alcoi.

The City of Alcoi had the privilege of being able to co-organize and disseminate the work around the aforementioned scientific activity of 'The Power of the Sun', proposed by Network Astronomy for School Education within the project '100 Years Under One Sky', both framed in the International Astronomical Union and together with important action programs such as 'Youth Mobile de Barcelona (YoMo)' and 'Science in Action', as well as with relevant entities such as the European Association for Astronomy Education, the Higher Council for Scientific Research, the CONICET of Argentina, the Cité des Sciencies of Tunisia, ESSTI of Ethiopia, NARIT of Thailand and the Planetarium of Beijing. All of them have helped spread the 'The Power of the Sun' project worldwide from Alcoi.

For the Alcoyans, it has been an honor to welcome this activity because of its triple scope: a local scope, with the determined active participation of teachers and students of different ages from a dozen educational centers in our city, as well as residents of our municipality; an inclusive scope, given its explicit openness to people with functional diversity thanks to the support of the National Organization of the Spanish Blind (ONCE); and a

universal reach, adding the presence of teachers with their disciples from beyond our borders, with the coordination and patronage of the International Astronomical Union, and the concert of this activity with the remaining observations that have been deployed throughout the world.

This great celebration of science has turned two decades, Alcoi has hosted an outstanding edition and we have witnessed the importance of this international program to which we wish a long life.

Toni Francés Pérez
Mayor of Alcoi

During 2019 I had the pleasure of coordinating the global activities that celebrate the International Astronomical Union's centenary. As we reach the end of the initiative, it is time to reflect on what has been accomplished as well as on the different actions carried out around the world. Although it is important to consider aspects like the large number of activities carried out, around 5000 events in 140 countries, or the millions of people who have actively participated in them, the vital aspect is to look beyond these numbers. The true legacy of these global initiatives is to ignite a spark that will make them perpetuate over time and that they will be as inclusive as possible, allowing anyone to participate in them without barriers.

In this sense, the actions carried out by NASE for more than a decade and, in particular, the global campaign "The Power of the Sun" are the perfect examples of such initiatives that use the important role of astronomy to support education, inclusion or development.

That is why it is important to recognize the effort and congratulate the organizers for the commitment made and for adhering the activity to the International Astronomical Union's centenary celebrations. I am sure that actions like this have had a great impact on their participants and will serve as an example to inspire other people to carry out inclusive activities that, as indicated in the centenary motto, continue to unite us in the future under one sky.

Jorge Rivero González
IAU's 100th Anniversary Celebrations Coordinator
International Astronomical Union

Introduction

This project was born as part of IAU-100 Years Under One Sky. It was a proposal open to all the teachers that participated in one of the more than 150 courses organized by NASE (Network for Astronomy Education) along the 10 years since NASE has been in action.

At the same time another project for teachers widely known in Spanish speaker countries called Ciencia en Acción celebrated its 20th year anniversary. On this occasion, this project wanted to celebrate the occasion with a special "Big Experiment" and the experiment "Power of the Sun" seemed a good proposal. A final event of the project "Power of the Sun" was organized to be performed in the first weekend of October 2019, in the city of Alcoy, where the XX Ciencia en Acción was organized in cooperation with the Municipality of Alcoy and the FECYT (Fundación para la Ciencia y la Tecnología) of the Ministry of Science, Innovation and Universities.

In order to invite the several countries that participated in the "Power of the Sun" experiment, Ciencia en Acción asked for the cooperation of YOMO (Youth Mobile Festival of Barcelona), that gave support for ten teams of teachers and students from ten countries. In the end, due to visa pro-

Foto de grupo de los estudiantes y profesores que participaron en el evento final de la Potencia del Sol

blems, the Iranian team had to participate online, and only nine countries were present in Alcoy.

The activity was performed in different ways, allowing blind and non-blind persons to be part of one of the most exciting experiments which permits not only to talk about the Sun's power and about how to measure it, but also to talk about history of Science and the power of scientific method.

Group photo of the students and teachers that participated in the final event of the Sun's Power experiment

It is necessary to mention the important cooperation of the Alcoy town hall that support the Power of the Sun experiment developed during Ciencia en Acción.

1. Power of the Sun: IAU-100 Years NASE Campaign

In 2019 the International Astronomical Union celebrated the first centenary. As in other special occasions, NASE (Network for Astronomy School Education) organized globally a special experiment involving the countries that are part of this Working Group of IAU. In 2015, the project was reproduce the detection of the infrared with the same method used by William Herschel in 1800 (see web site), in 2019 NASE proposed to calculate the power of the Sun using the Bunsen's photometer, created in the XIX century, simple to make with secondary school students on all the planet.

The Bunsen's method uses 2 light sources separated by an know distance and a piece of paper with a spot of oil between them; the paper is moved between the sources and when the illumination on each side of the paper will be the same, the spot "disappears".
This method can be extended to determine the power of an unknown light source, for example the Sun, replacing one of the sources for our star: the paper will be illuminated by two sources, one will be a bulb of a known power (for example 100 watt or more) and the other face of the paper, will receive the illumination by the Sun.

This project, that is very easy to replicate, does not request a complex setup and can be performed in all countries with minimal economic resources. All countries, either involved or not in NASE, were invited in order to repeat the experiment along half a year, between the equinoxes, from March 21^{s} to September 23rd.

In general, the teachers and professors conducted the experiment together with the students, but in other cases, the students with the support of their teachers and local institutions participated in a local festival and invited the inhabitants in their city to be part of the experience.

The measurements were sent to NASE. A couple of the report sheets can be seen in tables 1 and 2.

100 YEARS INTERNACIONAL ASTRONOMICAL UNION 1919-2019

The power of the Sun and how to measure it

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	Jose Manuel Escobedo (Alexandra Johnson)			
School, Country	North Davis Prep Academy		USA (Layton, UT)	
Day and hour	14 Sep 2019 4:20PM		29.4°C 1.326 m in elevation	
Type of Measurement	Patron		Results	
Experiment 1: Oil spot	Type of bulb	Indicated power (W)	Distance bulb-paper (m)	Calculated Solar Power (W)
	Soft white halogen	100 W	.076	3.9×10^{26}
Experiment 2: Cheek of the face	Type of bulb	Indicated power (W)	Distance bulb-cheek (m)	Calculated Solar Power (W)
	Soft white halogen	100 W	.076	3.9×10^{26}

participant 1

participant 2 .076 3.9×10^{26}

100 YEARS INTERNACIONAL ASTRONOMICAL UNION 1919-2019

Comment mesurer la puissance du Soleil ?

ACTIVITÉS À REALSER ET À ENVOYER

Réaliser soit la première expérience (avec la tâche d'huile), soit la deuxième expérience (avec la joue du visage) ou bien les deux, ensuite calculer la valeur de la puissance du Soleil et enregistrer les résultats de chaque expérience dans le tableau des résultats suivant

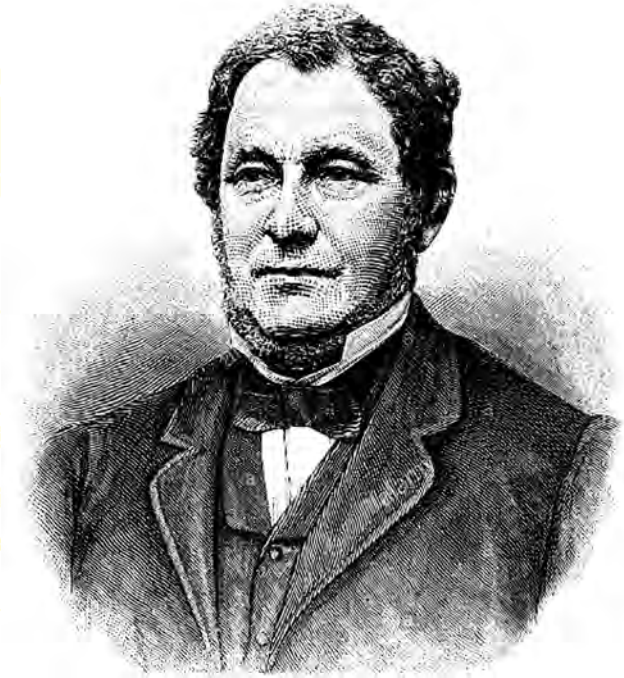
Tableau des résultats des expériences

Nom de l'enseignant	Imen Titouhi, Sarra Snoussi, Hichem Ben Yahia			
Lycée, Pays	Cité des sciences à Tunis		Tunisia	
Jour et Heure	20 juin 2019		12h00	
Types de mesures	Plan		Résultats	
Expérience 1 la tâche d'huile	Type de lampe	Puissance indiquée (W)	Distance Papier-lampe (m)	La puissance solaire (w)
	Lampe à incandescence	75	$6.5.10^{-2}$	**$3.99\ 10^{26}$**
Expérience 2 La joue du visage	Type de lampe	Puissance indiquée (W)	Distance joue-lampe(m)	La puissance solaire (w)
	Lampe à incandescence	75	$9\ 10^{-2}$	**$2.08\ 10^{26}$**

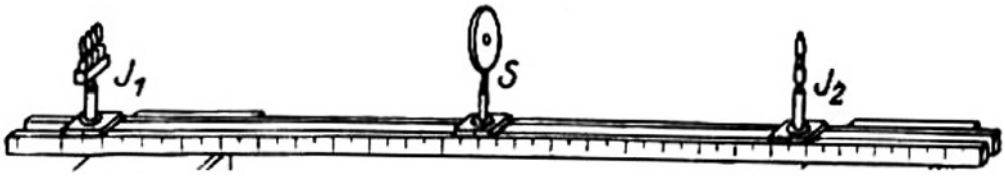
Tabla 1: Hoja de medición de Cité des Sciencies en Tunez (izquierda)
Tabla 2: Hojas del North Davis Preparatory Academy en USA

2. The Method

To measure the power of one star, the Astronomers use a photometer, an instrument that measures the amount of light in a given location and this allows the measurement of the amount of energy per unit of time (the Power) and unit of surface that arrives from an unknown source in order to compare it with a standard calibrated source.



Robert Wilhelm Bunsen (source Alamy stock photo)



Simple design for the Bunsen's photometer

Historically, there are several photometers proposed for comparing light sources. In this book the focus is on that of Robert Bunsen, 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.

The photometer invented by Robert Bunsen compares the intensity of two light sources, one that was known and one that was not. To do it, he just placed both sources on the ends of a tape measure. A plain white paper with a small oil drop 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 flow that arrives per unit area that reaches both sides of the paper is equal.

3. The Experiment

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 P1 and P2 are the electric powers of the two lamps, and d1 and d_2 are the distances from the paper to each of the light sources, the following condition must be fulfilled

$$\frac{P_1}{4^2 \pi d_1^{\,2}} = \frac{P2}{4^2 \pi d_2^{\,2}}$$

Then, suppressing 4π in both sides of the equation we have

$$\frac{P_1}{d_1^2} = \frac{P_2}{d_2^2}$$

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

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

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

Every team try this experiment and email to us their results during the half a year that the projects was active.

4. The Experiment in Astrophysics: Classical Sun power determination

The Bunsen photometer can be used in order to determinate the power or luminosity of the Sun, sing the star as one of the light sources and a bulb of, at least, 100 Watt as the other.

On a sunny day, the photometer and a halogen bulb are installed outdoors, with the photometer (the paper with the oils spot and the rule) placed between the Sun and the bulb, at a distance that the spot almost disappears. When the stain is not visible, the distance from the paper to the filament is the value of "d". Knowing the distance of the Sun from the Earth (approximately D=150.000.000 000 m,) the power of the Sun "Psun", can be calculated with the law of the inverse of the squares:

$$\frac{100W}{d^2} = \frac{P_{Sun}}{D^2}$$

Every team in the world tried this experiment and email to us their measurements during the half a year that the project was active.

The experiment was executed by groups of all ages and with different cultural backgrounds. Several examples of the different kind of experiments carried out and that can be find in www.naseprogram.org

Students obtaining the power of the Sun in China. (Shantou Jinshan Middle school, Shantou City, Guangdong Province).

Involving very small children in La Cité des sciences à Tunis, Tunisia

Obtaining the Sun's power by a team of students involved in Astronomy Association of Bushehr, Iran

5. The Experiment in Astrophysics: simplified Jacob's staff.

In the middle age the Jacob's staff was used to determine the altitude of several stellar objects. Jacob's staff, also known as "ballastella of Jacob" or "radius astronomicus". Essentially, it had a main stick from which end it was observed and a cross stick or secondary stick, that runs over the previous one.

n this case, the author produced a specific device for the Sun's photometry. He produced a photometer that is adapted from Jacob's staff to use in order to compare the power of the Sun with the power of a light bulb. The device had the lamp at the end of the main stick with a ruler. The cross stick was substituted by a piece of PVC with an opening were it was possible to fix a piece of paper with the oil drop. This piece was moving as the secondary stick on the Jacob's staff.

An ancient observer using a Jacob's staff

6. The Experiment in Astrophysics: determine the Sun's power with the face

One innovative way to perform the experiment to estimate the solar luminosity, consists to replace the paper with the oil stain by the face. On a sunny 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 on the other. The distance of the bulb to the face should be changed until the "photometer", now the participant, feels exactly the same heat on both cheeks. Measuring the distance d of the bulb to the face and knowing the distance D to the Sun (150 x 109 m), we can estimate the luminosity of the Sun with the formula,

$$\frac{100W}{d^2} = \frac{P_{Sun}}{D^2}$$

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.

Note that the luminous efficiency of the Sun and the halogen bulbs are not precisely the same as announced by the seller, and that the atmosphere is not transparent to infrared radiation, and therefore, the Sun appears at these wavelengths weaker than it really is. The result obtained should be lower than the actual luminosity of the Sun, which is 3.09·1026 W but of the same order of magnitude.

The value of the distance d should be about 10 cm. With this value, the result of the Sun's Luminosity comes out around 2.2 10^{26} W, a little lower than the real one. Nonetheless the simplicity of the method compensates for the lower precision in the result.

NASE proposed this second experiment as compliment of the traditional one to the county members of the working group. This proposal, permits to include blind people to have an active participation, measuring the power of our star and producing scientific results.

Comparing cheek to cheek in Tunisia. (Lycée Mohamdia, Ben Arous Tunis, Tunisia).

Involving adult neighbors in Utah, USA Anything goes

Introducing power if the Sun in the street in Dakar, Senegal. (This bubble was not the recommended one).

EIn this case the group of the students are from Santa Maria, Catholic Senior High School, Malang-Indonesia

Some teams prepared special projects, as was the case of the campaign organized by the secondary school Colegio Huerta de la Cruz in Algeciras in order to take the measurement of the Power of the Sun every day from the March 21st to September 23th and to get the average of these measurements. It is necessary to mention that this period included the summer holidays in Spain, but they continued making observations and measurements day after day. This was a very serious responsibility for the students that carried out the process and delivered the results.

Poster prepared by Juan A. Prieto and his students from Colegio Huerta de la Cruz in Algeciras, during the Diverciencia Festival on May 16th and 17th 2019. The mayor of the Algeciras city was one of the person who participated in the experiments.

7. The Experiment in Alcoy: An example of Citizen Science

The measurements of the Sun's power were developed in the countries where the teams could be created for this purpose in special environments such as schools, universities, planetariums and astronomical associations were the professors conducted the experiment with students and the results were emailed.

However, this project is a good example of what is possible to make involving a government and a community in a public experience. One of the goals of IAU and NASE is the development of activities in the cities, in the framework of the Citizen Science initiatives and the communication of Astronomy with the public.

The International Festival "Ciencia en Accion" (that is to say with Science on Stage-Spain) in Alcoy, Spain, on October 5th, was the moment to present this experiences with the community in Alcoy: the countries that decide to participate during the final event had the opportunity to deploy their setups and to share with others their work and discoveries. This meeting was a special opportunity supported by the Youth Mobil Festival of Barcelona (YOMO) that invited all the participants for accommodation and meals.

In this final event, nine countries (Andorra, Argentina, Greece, Italia, Portugal, Romania, Spain, Tunisia and USA) shown their experiments and participated of the experience that included also the local community. There were 4 tents assembled in different areas of the city of Alcoy and a schedule for the visits of 10 local secondary school. The event was also open to the people that were walking in the city.

The municipality of Alcoy was interested to give, on October 5th, 2019, the opportunity to local scholars to participate in the experiments and to obtain their own value of the Sun's Power. The four tents were distributed in

Map of Alcoy with locations and schools with more students

different areas of Alcoy in order that the schools had a tent close to them and the students could easily visit and test the experiments. The position of the four tends were:

- Tent 1: Hispanidad Avenue (in the Poliesportiu)
- Tent 2: Plaça de Dins (in front of the Town Hall)
- Tent 3: Plaça Ferrándiz i Carbonell (close to the Ciencia en Accion final event in the UPV)
- Tent 4: Cervantes Park

Tent in the front of the City Hall

Tent in the Cervantes Park

The Education Department of the Municipality organized a timetable of visits for groups of 20-30 students in order that every group past for the three experiments described in this book.

In the previous days, the newspapers and the TV channel gave information about the event and made reports during the observations too.

TV reporter during the activities

FBunsen photometer with the oil paper and detail of the oil stain

Obtaining the Power of the Sun with the oil paper and a bulb.
n this photo can see the stain

Obtaining the Power of the Sun with the oil paper
and a bulb. In this photo you can see the bulb

Obtaining the Power of the Sun with the cheek (the observer with the eyes close)

In each tent there were the three experiments mentioned and each group of students made the three experiments in the described order.

The observer passes experiment 1 (Bunsen photometer in the tent at the end), experiment 2 (Power of the Sun with the oil paper in the middle) and finally the experiment 3 (Power of the Sun using cheek sensitivity in the front of this photo)

Student with the Jacob's adapted device ready to use. In the PVC we can see a black "U" which is the place where we can put the paper with the oil spot

Using the Jacob's device adapted for measure the Power of the Sun. We can see the bulb at the end of the main stick and the white PCV perpendicular to it.

8. Results

A total of 296 reports, including 482 observations were received by NASE from all the world and the final result in average for the Sun's power was $2.10\ 10^{26}$ W. This value is near the expected as was mentioned before.

During the half year that the project was running several teams also tried to study the different results according to the different kind of skin of the people but they have not obtained any particular results that reveal Sun's Power differences depending on the skin.

The experiment was made also in association with ONCE (Spanish National Organisation of Blind people), with blind people in Alcoy, during the "Ciencia en Acción Festival".

The blind people have more sensitivity.

Experiment with the cheek with a member of the ONC

A greater sensitivity of this group was observed in relation to others that were not blind. This was probably because the lack of a sense enforces the development of a greater sensitivity of the other senses to perceive their surroundings. In conclusion, the sensitivity in the blind was greater and for this group the average of their results was $3.09\ 10^{26}$ W.

Contrary to the widespread idea that a blind person develops with difficulty, it is evident, when integrating and inclusive experiences are proposed, that a person with visual impairment can function as efficiently as a seer, both in the acquisition of experimental data, and in their analysis.

The interest in science and the discovery of the natural world is part of the human species and that is why it is of fundamental importance to integrate society as a whole in citizen science experiences, overcoming prejudices and helping to modify segregation behaviors. Once all people are considered really equal, we will be able to run the limit of inequality of opportunities.

9. Some comments about gender of teams participating in the final event

There were nine countries participating in the closing session in Alcoy. The organization tried to promote the girls' participation if it was possible. A team from Iran was invited but could not participate at the end because they did not receive the VISA before the date that they should begin their trip. This team was composed by a teacher and four girls that in the end had the chance to participate online and explain their experience by Skype.

For the rest of teams the number of teachers were more or less balanced: 45% women and 55% men. Among the students, the percentage of

The Iran team participating online

girls included in the nine teams was 77% and the boys 33%. In the case of the group of blind participants the majority were women. The 67% women, in front of 33% of men.

10. Conclusions

The cooperation was a success in different areas:

- Students from 10 secondary schools in Alcoy had the opportunity to ob tain the Power of the Sun and learn astrophysics from other students and teachers motivated.
- The people walking in Alcoy city on October 5th found several teams of students that taught to them about science and astronomy and invite them to be the main observer in a physic experiment.
- everal teams of teachers and students visit another country to know other people interested and motivated by science in general and astronomy in particular

The success was so big that:

- the Festival YOMO has invited NASE to organize an experiment related to the Power of the Sun on 29th February 2020 in Barcelona.
- the program CEA plans a new "big experience" related to a similar activity that can be organized in several points of the city in order to extend to the public the experiments.
- the Working Group NASE plans to repeat a new global project for 2020 that involve countries in different continents and to repeat a finale event probably in more than one country in order to facilitate the face to face meeting between several teams.

Finally it is necessary to thanks to several international institutions that give support to the "Power of the Sun project" promoting it in their countries and influence areas:

Cité de la Science in Tunis, Tunisie
CONICET, National Council for Scientific and Technological Research, Argentina
CSIC, Spanish National Research Council, Spain
EAAE European Association for Astronomy Education
ESSTI Ethiopian Space Science and Technology Institute, Ethiopia
NARIT National Astronomical Research Institute of Thailand
Planetarium of Beijing, China

BIBLIOGRAFÍA

• 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, B. García, J.A. Prieto, R.M. Ros, Photometers and Photometry in Astronomy: The Global Inclusive Campaign to Determine the Sun's Power, IAU Symposium 358, Astronomy for Equity, Diversity and Inclusion, Tokyo, 2019.

• 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., Loulé, 2016.

• Exploratorium, Oil Spot Photometer-Compare the brightness of two light sources using an oil spot on a white card. https://www.exploratorium.edu/snacks/oil-spot-photometer

Ajuntament d'Alcoi

IAU
100 Years: Under One Sky