HERSCHEL and the infrared

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Atarfe is its history, its first settlements, Medina Elvira, the Battle of Higueruela, the new settlers… but Atarfe is also Science; Atarfe is its heritage, the constructions that left their mark on our town that defined a way of life, some beliefs, that adapted to the new times and that have left a faithful testimony of our past…. but Atarfe is also Science; Atarfe is culture, theater, music, dance, concerts, arts, the public, the Medina Elvira Cultural Center, ….Atarfe is also Science; Atarfe is sport, facing challenges, overcoming obstacles, it is our facilities, our athletes, our promises, our fans... but Atarfe is also Science; Atarfe is its landscapes, its sunrises, the plain of Granada, the water, the mountains that surround it... but Atarfe is also Science; Atarfe is education, a reference in knowledge, knowledge, progress, future. Where educational centers are committed to teaching and scientific dissemination. Atarfe was the birthplace of Cecilio Jiménez Rueda and of men and women of science, of distinguished professionals in medicine, pharmacy and engineering, who sowed the seed of science and opened a path that today many of our students, neighbors and neighbors, continue. This is Atarfe. And where we have been able to enjoy the international program of Science in Action.

A commitment to the future, a long-awaited edition of Science in Action, reunion, emotion and enrichment. An edition that, held at the beginning of October 2021, attracted participants from all over the state to our town as well as other foreign countries such as Andorra, Bulgaria, Iran, Italia, Portugal and Romania.

I want to highlight the involvement of the entire town, in the organization of this edition, especially CienciAtarfe, that without them this reality would not have been possible. In addition to authorities, institutions, businesses, companies, public/private administrations, schools, teachers/professors, students... trying to make all participants and attendees feel at home, our hallmark being the welcome, attention, affection, closeness… facilitating at all times so that visiting teachers could do their educational work, being an enriching and positive experience for themselves and for the people in general.

Pedro Martínez Parra
Alcalde de Atarfe

This year the town of Atarfe became the headquarters of 'Science in Action' in its XXII edition. Given the pandemic situation, an online part and a face-to-face part have been developed. In this event the number of visiting countries has been reduced, but participants from Andorra, Bulgaria, Iran, Italy, Portugal, Romania and Spain have come to our town. We have enjoyed explaining to all visitors and students, scientific content and in particular Herschel's experiments with infrared detection and some of its applications.

Atarfe is a place of history, culture and science and many of our students continue to gain knowledge. In total, more than half of them were able to visit one of the eight tents organized by the Network for Astronomy School Education (NASE), within the framework of the International Astronomical Union (IAU) and in coordination with the UNESCO International Day of Light programme.

It is also fair to mention that other important institutions collaborated to promote the infrared scientific programme: the European Association for Astronomy Education (EAAE), the European Southern Observatory (ESO), the Higher Council for Scientific Research (CSIC), the CONICET of Argentina, the Cité des Sciences de Tunisia, the Ethiopian Space Science and Technology Institute (ESSTI) of Ethiopia, the National Astronomical Research Institute of Thailand (NARIT) and the Beijing Planetarium of China. These institutions have disseminated the Herschel Experiment Project throughout the world, from the March to the September equinox. The programme concluded with an online session in the last week of September and a face-to-face fair at the beginning of October, organized in Atarfe within the final of Science in Action, that is, Science on Stage Spain.

In particular, we must highlight the great work carried out by CienciAtarfe, which has invested great efforts in the infrastructure and organization of the event, excellently coordinating the movement of teachers and students from the different centres to the demonstration tents; as well as structuring family visits during the weekend to the Science in Action demonstration fair.

Finally, having participated on the front line of this scientific festival, from the Atarfe City Council, we hope that this initiative continues with successive successful NASE programmes.

Rosa M. Ros Ferré
President of Ciencia en Acción
and Science on Stage Spain

Introductión

The “Herschel and Infrared Experiment” is a project that emerged as a global proposal to celebrate “The International Day of Light” – 16th May each year - promulgated by UNESCO, on which the first successful use of a laser beam created by a human being occurred. It was a proposal open to all primary and secondary school teachers who participated in one of the more than 250 courses organized by NASE (Network for Astronomy School Education) during the 12 years that this astronomy didactic programme has been running since its constitution at the General Assembly of Rio de Janeiro of the IAU (International Astronomical Union) in 2009.

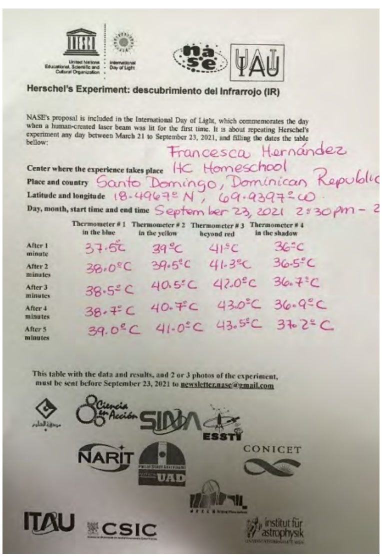
The “Herschel and Infrared Experiment” began with the synchronous online event “Bridges of Cultures” that took place on March 21st, 2021, celebrating the March equinox (March 20th) and ended on the September equinox of the same year (September 23rd). The final closing event was developed in two ways: an online version on September 28th, 2021 and a face-to-face event during the first weekend of October in the city of Atarfe (Granada, Spain), coinciding with the celebration of the event by Science in Action in which Herschel’s work was presented as “The Great Experience”.

Fig. 1: Group photo of the teachers who participated in the final face-to-face event of the Herschel Experiment in Atarfe.

In the framework of Science in Action, the first “Great Experience” proposed by NASE took place in 2019, also integrated into the proposals for the “International Day of Light”. On that occasion NASE invited us to calculate “The Power of the Sun” using the Bunsen oil slick photometer, created in the 19th century, easy to do with students all over the planet. In 2020, the proposed project was that of “The Parallel Earth”, which is very easy to replicate, does not require a complicated configuration and can be carried out in all countries with a minimum of financial resources. The countries, involved or not in NASE, were invited to repeat the experiment for half a year, between the equinoxes. In 2020, given the situation of the pandemic, the event could only be held online.

The year 2021 presented a new panorama for education in a mixed scenario. In general, teachers and professors with great dedication have been able to carry out the infrared detection experiment with their students and have been able to participate in the experience, especially online, but at the same time the face-to-face situation has begun to recover (Figure 1).

It is necessary to mention and thank the important cooperation of the Atarfe City Council and the group of CienciAtarfe teachers who supported the programme from all possible areas.
The detection and data collected by the students were collected on forms that were sent to the NASE secretariat. Examples of the logs and reports can be seen in Figures 2 and 3


United Nations Educational, Scientific and Cultural Organization · International Day of Light

Herschel's Experiment: descubrimiento del Infrarrojo (IR)

NASE's proposal is included in the International Day of Light, which commemorates the day when a human-created laser beam was lit for the first time. It is about repeating Herschel's experiment any day between March 21 to September 23, 2021, and filling the dates the table bellow:

Francesca Hernández

Center where the experience takes place HC Homeschool

Place and country Santo Domingo, Dominican Republic

Latitude and longitude 18.4967° N, 69.9397° ω

Day, month, start time and end time September 23, 2021 2:30pm – 2

	Thermometer # 1 in the blue	Thermometer # 2 in the yellow	Thermometer # 3 beyond red	Thermometer # 4 in the shadow
After 1 minute	37.5°C	39°C	41°C	36°C
After 2 minutes	38.0°C	39.5°C	41.3°C	36.5°C
After 3 minutes	38.5°C	40.5°C	42.0°C	36.7°C
After 4 minutes	38.7°C	40.7°C	43.0°C	36.9°C
After 5 minutes	39.0°C	41.0°C	43.5°C	37.2°C

This table with the data and results, and 2 or 3 photos of the experiment, must be sent before September 23, 2021 to newsletter.nase@gmail.com

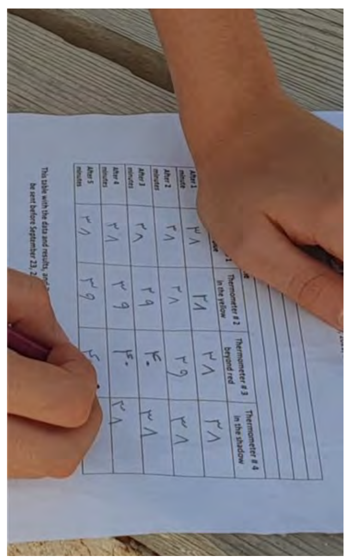


Fig. 2. Measurement sheets from Santo Domingo in the Dominican Republic (left)

Fig. 3. Sheets from one of the Bushehr groups in Iran (right).

1. The infrared

The infrared region of the electromagnetic spectrum was discovered by William Herschel (the discoverer of the planet Uranus) in 1800, using a prism and thermometers. To do this, he produced the visible spectrum by passing the white light of the Sun through a prism. He placed the thermometers in three regions of the spectrum: blue, red (colours detectable by the eye) and installed a third thermometer beyond the red, although close. With a fourth thermometer he measured the ambient temperature and discovered that the temperature shown by the thermometer in the area "below" red (and hence its name "infra" red) was higher than that of the environment, which showed that it was reached by an invisible but real radiation that heated the thermometer.

Herschel did other experiments with these "heat rays" (as he called them): they were reflected, refracted, absorbed and transmitted just like visible light. These "heat rays" were later called infrared rays or infrared radiation. Those discoveries were followed by others that led to various technical applications.

Bodies emit electromagnetic radiation at frequencies that depend on their temperature. For example, our bodies and those of animals emit infrared radiation that our eyes do not detect, but other devices do, such as night vision goggles, or modern clinical thermometers, which allow us to measure body temperature without contact (Figures 4 and 5).

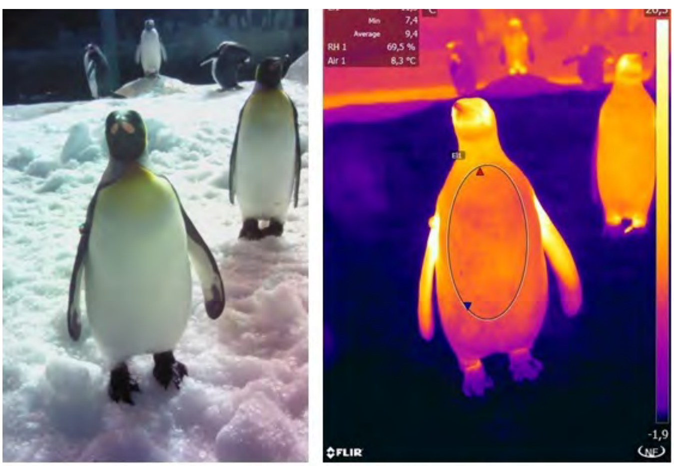


Fig. 4a and 4b: Photograph of penguins in visible and infrared light. Warmer and cooler areas are distinguished; Maximum (29.3ºC) and minimum (-1.9ºC) temperatures are indicated.

Fig. 5: Infrared thermometer. Measures body temperature without contact.

2. Herschel's experiment

The aim of our project was to repeat the experiment of 1800, by which the famous astronomer William Herschel discovered a form of radiation other than visible light. For this we need a glass prism, four thermometers, a permanent black ink marker, scissors, masking tape, a cardboard box and a white sheet. We paint the bulbs of the thermometers with the black marker to better absorb heat (it is also possible to coat the bulbs with black paint, you just have to let them dry). To record the data, a sheet must be prepared to indicate the time and temperature recorded by each thermometer (Table 1).

The experiment should be done outdoors on a VERY sunny day. If it is very windy, the experiment can be done indoors, as long as there is an open window through which the Sun enters directly. The prism is placed on the upper edge of the box, so that it is on the side of the Sun. A white sheet of paper is placed at the bottom of the box so that the spectrum is clearly distinguishable. The interior of the box must be all or almost all in shadow, which is achieved by the creation of the shadow by the walls of the box (Figures 6 and 7). The prism is carefully rotated until as wide a visible spectrum as possible is projected onto the sheet at the bottom of the box. After taping the prism in place, the three thermometers are positioned so that each bulb is in one of the colours: one in the blue region, one in the yellow region, and the third just beyond the visible red region. You must be able to see the graduated scale well, so as not to move the

Fig. 6: Box with the prism and the four thermometers in Santo Domingo, Dominican Rep.

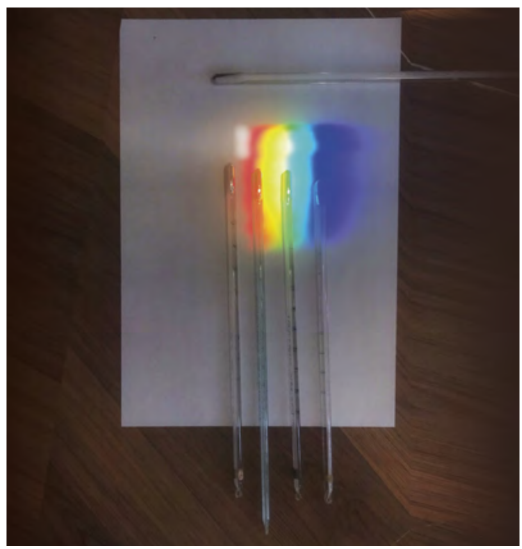


Fig. 7: What the three thermometers show in blue, yellow and infrared and in the shadow, after 5 minutes.

thermometer when you take the measurements. Put the fourth thermometer in the shade, not aligned with the previous ones.
The thermometers take about five minutes to reach their final temperatures. Every minute, record in the table the temperatures in each of the three regions of the spectrum and in the ambient one. Do not move the thermometers from their position on the spectrum or block their light, although the box can be moved slightly so that the region of the spectrum in which each thermometer is located does not change.
The thermometers in the blue and yellow (Figure 6) should indicate temperatures somewhat higher than in the ambient one. The thermometer in the shade but close to the red, also shows a temperature higher than that of the environment, so it is evident that some type of radiation from the Sun, invisible to our eyes, reaches it.
Teams from around the world, of different ages and diverse cultures, did this experiment and e-mailed their measurements during the half year the project was active. Several examples of different facilities, materials, spaces both in schools and on the street or at home are presented in Figures 8 to 17, and more extensively they can be found at www.naseprogram.org

DATA RECORD

	Thermometer 1 in the blue	Thermometer 2 on the yellow	Thermometer 3 beyond red	Thermometer 4 in the shade
After 1 minute				
After 2 minutes				
After 3 minutes				
After 4 minutes				
After 5 minutes				

Fig. 8: Primary school students conducting the Herschel experiment (Ramygala Gymnasium in Lithuania).

Fig. 9: Girls observing the experiment at an ITAU (Iranian Teachers Astronomical Union) convocation in Bushehr, Iran.

Fig. 10: Obtaining the temperature in different areas of the spectrum by Ihsan Muharrik with his student (MA Daarul Uluum Lido) in Bogor, Indonesia.

Fig. 11: A group of Mexican students (University of Guadalajara) conducting the Herschel experiment.

Fig. 12: Detecting the infrared: a group of Greek students in Athens (High School of Tositseio Arsakeio Ekalis).

13: Preparing the materials for the experiment at the Municipal Centre for Extracurricular Activites of Dolna Mitropolia, Baykal Village in Bulgaria.

Fig. 14. Playing and investigating at the same time in Malmo, Sweden.

Fig. 15. Preparing the experiment in Dakar in Senegal.

Fig. 16: Herschel family experiment in the municipality of San Cristóbal in Venezuela.

Fig. 17: Performing the experiment at the Philippine Normal University in Caloocan City, Philippines.

Fig. 18. Preparing the experiment in Agrupamento de Escolas Dr. Carlos Pinto Ferreira in Oporto, Portugal.

3. The Herschel Family: Astronomy and Music

The Hershel family was truly unique. The father of Carolina (Figure 19a) and William (Figure 19b), Isaac, was a very talented musician, who set out to give his six sons training in different disciplines: music, mathematics, astronomy and languages. Caroline Herschel fell ill at the age of 10, first with smallpox and later with typhus. These diseases stopped her growth permanently. Her parents realized that due to this physical situation, she could not get married. Her father was secretly giving Caroline music lessons and teaching her some astronomy.

Fig. 19 : Caroline Herschel

Fig. 20 : William Herschel

In 1772, William Herschel, working in Bath, England, asked his mother if his sister Caroline, who was then 22 years old, could come to live with him as a housekeeper. William saw that his younger sister had an aptitude for music and science, and taught her mathematics, astronomy and English. In figure 20 you can see the front door of the house of the Herschel brothers in Bath.

William gave concerts as an organist and conductor in the city of Bath and Caroline performed as a soprano. But William Herschel started building telescopes, and his reputation reached such a point that he decided to quit his job as a musician and devote all his time to astronomy.

Fig. 21. The Herschel Museum, at his home in Bath. (Credit: B.

Fig. 22: House of the Herschel brothers in Bath. Plaque on the wall facing the inner courtyard. (Credit: B. García)

Fig. 23: Optics workshop at the brothers' house in Bath. (Credit: B. García)

Caroline also decided to abandon her musical career to become her older brother's full-time assistant. Her job consisted of grinding and polishing mirrors (Figure 22), recording observations night after night, reviewing them during the day and doing algebraic calculations to establish astronomical distances. She went on to become a notable astronomer.

Together, they discovered a thousand double stars, and showed that many were binary star systems, physically related stars that revolved around the system's centre of gravity. This was the first physical proof of the action of gravity outside the solar system.

One of the stories that show the spirit of the wonderful Herschel family is derived from a letter from John Herschel, William's son, addressed to the director of the Dublin Observatory, Sir William Rowan Hamilton. In addition to informing him that Alpha Orionis was a variable star, he shares a song that all the family members sang together when they were gathered inside the 12-meter tube of the reflecting telescope (Figure 23), celebrating the new year of 1840:

Happy, happy let's sing
grinding and jingling
to the old telescope ...

The postscript reads: "The above was sung loudly by our entire family, Dad, Mom, Madame la Governante and seven juniors, at 0 hours, 0 minutes, 0 seconds of the mean hour, January 1st, 1840, inside the tube. We gathered fourteen but fourteen more could easily have fit. "

Part of that telescope is kept at the Royal Greenwich Observatory (Figure 24).

Caroline Herschel was the first woman to discover a comet. She saw it on August 1st, 1786, between the constellations of Ursa Major and Coma Berenice. As time and the

Fig. 24: Preserved section of the 12-meter telescope built by the Herschels. The Royal Greenwich Observatory. (Credit: B. García)

Detail of the previous photo. (Credit: B. García) comet were running fast, and her brother William was out of town on business, Caroline saw fit to immediately communicate her discovery to The Royal Society. At that time, it was unusual for a woman to do scientific work, and Caroline was her brother's assistant. Upon his return, William had to confirm the discovery.

A little later, in 1787, Caroline published an article in the Philosophical Transactions, the scientific journal of the Royal Society. She was the first woman to do so. In the period from 1786 to 1797 she discovered three nebulae and eight comets. In the years that followed, she catalogued every discovery she and her brother made. Two of the astronomical catalogues published by Caroline Herschel are in use today.

Her hard work led her to complete, in 1798, the "John Flamsteed Index of Fixed Star Observations", which included 560 stars that the English astronomer had not recorded in his catalogue of more than 3,000 stars. Caroline Herschel presented the list to The Royal Society. Subsequently, she published the "General Reference Index of each observation, of each star mentioned in the British Catalogues", also with The Royal Society.

When her brother died on August 25th, 1822, Caroline returned to Hanover, where she received numerous honours. Among them, the gold medal of the Royal Astronomical Society in 1828, of which she was made an honorary member in 1835, at the age of 85. On her 96th birthday, she received the Gold Medal of Science from the King of Prussia, for her achievements during her lifetime. Caroline Herschel died on January 9th, 1848, at the age of 97.

4. The Herschel Telescope at the Royal Observatory of Madrid

Throughout history, scientific discoveries have often been made thanks to great technological improvements, and in turn great technological innovations have taken place due to the requirements of scientific research of the time. In astronomy, a very clear example of this productive symbiosis between science and technology is the invention of the telescope. Until the beginning of the seventeenth century, astronomy was limited to the study of celestial objects that were visible to the naked eye, but the invention of this new observational tool in the Netherlands opened the door to much more distant and fainter objects and allowed answers to many key questions of science of that time. This process of expansion of the astronomical frontiers continued through the following decades and during the eighteenth century, when William Herschel, with the collaboration of his sister Caroline, designed and built in England some of the best telescopes of their time.

Fig. 26. Main building of the Royal Observatory of Madrid, built by the architect Juan de Villanueva.

Simultaneously, in the final years of the eighteenth century, the Royal Observatory of Madrid (figure 26) was founded in Spain. The astronomers of the new Observatory, aiming at producing the best possible science and with the support of King Carlos IV, ordered the construction of a large telescope for the Observatory from the best telescope-builder of the time, William Herschel. The telescope was built in England,

and once it was finished all its pieces had to be carefully packaged and sent by boat to Bilbao, in the north of Spain. From there, they were carried on carts to Madrid. After this long journey, and thanks to the detailed instructions provided by Herschel himself, the telescope was reassembled and started to observe the sky in 1804.

Nevertheless, science research is not only influenced by technology but also by key historical events: only a few years later, in 1808, France, under the rule of Napoleon Bonaparte, invaded Spain and a six-year war started. The French army arrived in Madrid, conquered the hill where the Observatory stands, due to its strategic relevance, and completely destroyed the new telescope, because they were in the middle of winter and used the wood to make a fire. However, the astronomers of the Observatory had foreseen this possibility, so they had hidden some of the most valuable pieces of the telescope just in time: its main mirrors and the documentation describing its design and construction (figure 27). These pieces remained hidden in the Observatory and the adjacent buildings, and ignored for centuries, until they were recovered at the end of the twentieth century. From that moment on, the great Herschel telescope in Madrid came back to life: using the surviving original elements and the same design and instructions provided by Herschel, an exact replica of the telescope was constructed.

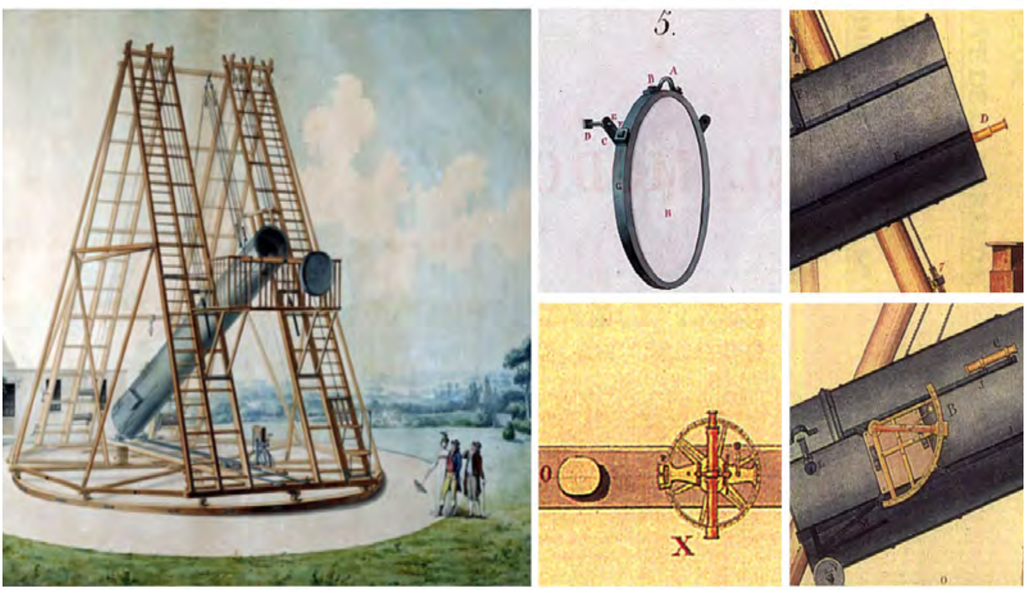


Fig. 27. Fragments of some of the plans and plates accompanying the shipment of the Herschel telescope to Spain at the end of the 18th century.

The reconstruction finished in 2004, and since then we can contemplate the replica of one of the best telescopes of the end of the eighteenth century in its original location, the Royal Observatory of Madrid (figure 27).

This telescope is relevant not only due to its scientific and historical value, but also because it allows us to understand how the astronomical observations were made back then. This is a reflecting telescope, with a main mirror of diameter of around 60 centimetres and a focal length of 7.6 meters. The rays of light coming from the astronomical object of interest enter the telescope through the top aperture and travel all the way to the bottom until they reach the main mirror. This mirror reflects them and makes them converge back towards the top of the tube, where the rays reached the eyepiece, and where the astronomer is observing. The tube of the telescope is supported by a large wooden structure, whose height approaches 10 meters. In order to move the telescope it is necessary to move the whole structure, which requires the force of several men and the use of an ingenious zip-like mechanism that controls the altitude at which the tube is pointing. Furthermore, as the Earth rotates, the telescope has to be moving continuously in order to keep pointing at the same celestial object. All-in-all

Fig. 28:. F The Herschel Telescope reconstruction.

the astronomical observations are an arduous and painstaking process.

William and Caroline Herschel managed to accomplish great scientific achievements thanks to their determination and hard work, as well as the quality of their telescopes. Maybe the most famous of those achievements was the discovery of Uranus by William Herschel in 1781, which implied not only the great discovery of a new planet, but also a change of perspective regarding the size of the Solar System and its components. Thanks to his observations William Herschel was also able to discover the two major satellites of Uranus, and even to estimate the mass of the planet. But those were not the only Solar System bodies studied by the Herschel siblings: Caroline Herschel was the first woman ever to discover a comet, which she did for the first time in 1786, and she managed to discover a total of eight during her life. As a recognition of her scientific merits the English King granted her an annual salary, which made her the first woman in history to become a professional scientist. The Herschel siblings also studied astronomical objects located beyond the Solar System: William Herschel accomplished a systematic statistical study of the stars observed in the sky, which allowed him to draw the first map of our galaxy, the Milky Way, and to estimate its size and shape (figure 29).

Scientific knowledge has made incredible progress since the time of William and Caroline Herschel. However, everything we know today is the result of the long learning process that we have all travelled through thanks to the curiosity, determination and relentless work of scientists such as William and Caroline Herschel, and to the development of wonderful instruments such as the great Herschel telescopes. If you want to know more, we wait for you at the Royal Astronomical Observatory of Madrid, to talk about the astronomy of the past and the present that will lead us to the astronomy of the future.

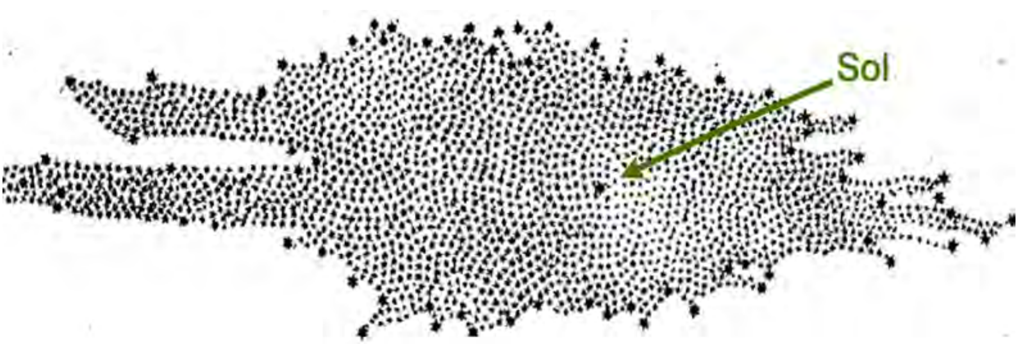


Fig. 29 : Map of the Milky Way by William Herschel, published in 1785. The position of the Sun is indicated with an arrow.

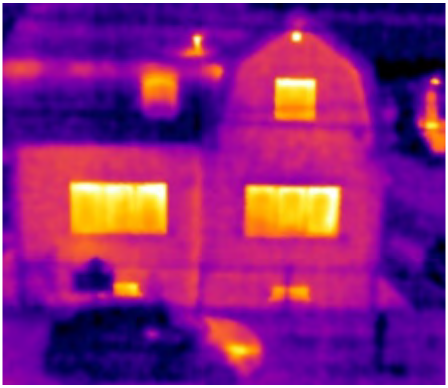
5. What can be done with an infrared thermal imager?

Infrared radiation was quite difficult to detect when the Herschel brothers discovered it in 1800 and that is true even a century and a half later. Today we are fortunate to be able not only to measure infrared radiation, but also to take pictures at wavelengths redder than our eyes can see.

Today we use infrared cameras for both scientific and technical purposes every day. For example, the Herschel Infrared Space Telescope observed dust and gas leaving aging giant stars like Betelgeuse. Infrared thermal cameras can check the thermal insulation of houses or a car engine.

Fig. 30: Herschel Space Telescope. (Credit: ESA)

Fig. 31: Betelgeuse dust and gas outflows. (Credit ESA / F. Kerschbaum)



F Fig. 32: Thermal insulation of a house.
(Credit: F. Kerschbaum)

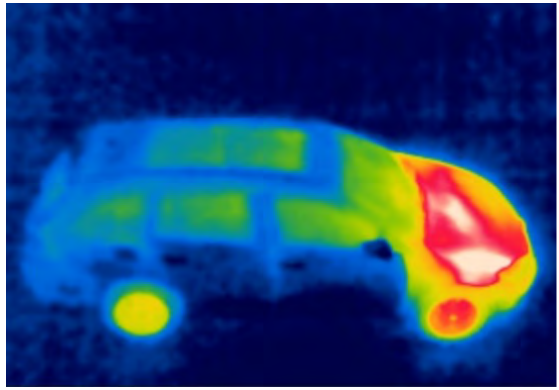


Fig. 33: Infrared image of a car.
(Credit F. Kerschbaum)

Fig. 34: Interview with the Herschel brothers using an infrared camera. (Credit: F. Kerschbaum)

But what do these strange colours mean in the pictures? To "see" and print infrared images, one has to "translate" the colours invisible to our eyes into colours we are used to. After this, each shade of colour corresponds to a certain measured temperature.

In the scene in figure 34, from an infrared interview, the arbitrarily chosen colours allow the different temperatures of the represented bodies to be estimated. The white areas on the faces are the warmest surfaces above 32°C, the yellow and greenish cloth areas show temperatures between 22°C and 27°C, while the lower sections are colder with temperatures below 20°C.

Today, infrared images of passing tourists are used in airports to check if someone has the flu or even a Covid-19 infection. As you can see, infrared cameras are very useful tools in our daily life, but also for doing science!

6. The Herschel Experiment online and in Atarfe: Eight tents distributed in the city

22 countries from 4 continents have participated in the Herschel 2021 experiment project: Austria, Finland, Lithuania, Philippines, India, Indonesia, Greece, Iran, Tanzania, Bulgaria, Romania, Tunisia, Portugal, Germany, Andorra, Spain, Senegal, Paraguay, Argentina, Dominican Republic, Sweden, Venezuela and Mexico. Written reports have been received of a hundred works distributed among primary and secondary schools, universities, Science Museums, Planetariums and professional astronomical observatories. It is difficult to estimate the thousands of students who have done them with the help of their teachers, even if they have not sent their results, but without a doubt it will have been a particularly enriching experience for all of them. "Observing the Invisible" is always surprising as well as motivating to continue with new experiences.

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The results received are displayed on the NASE website:
http://sac.csic.es/astrosecundaria/en/proyectos_con_unesco/experimento_herschel/experimentos/Lista.php.

The online session held on September 28th, 2021 was transmitted by streaming to the whole world, recorded and can be viewed on the NASE YouTube channel, at the following link: https://www.youtube.com/watch?v= uPz74-t2oDY

The project had a face-to-face closing event open to the public and a group of schools during the final edition of the International Festival "Ciencia en Acción" (Science on Stage-Spain) in Atarfe, Granada, Spain, on October 1st, 2nd and 3rd, 2021. Countries that decided to participate in this event had the opportunity to display their materials and share their work and discoveries with others in a public event. One of the objectives of both the International Astronomical Union, as well as NASE and Ciencia en Acción is the development of scientific activities with playful presentations within the framework of Citizen Science initiatives and the communication of Astronomy with the general public.

In this final event, six countries (Andorra, Bulgaria, Iran, Portugal, Romania, Spain) showed their Herschel experiments on infrared detection and some of its applications to more than 1500 students from Atarfe itself and from neighbouring educational centres (CEIP Atalaya, CEIP Clara Campoamor, CEIP Dr. Jiménez Rueda, CEIP Fernando de los Ríos, CEIP Medina Elvira, EE. PP. Sagrada Familia, IES Iliberis, IES Vega de Atarfe and Nova School Medina Elvira). Every 15 minutes a new group of 20-25 students, aged between 6 and 18 years, arrived and participated in the experiment and then gave their place to the next group. The process took place throughout the morning of Friday, October 1st. That part ended with a reception at the town hall and a glass of Spanish wine for all the foreign and local guests. Subsequently, a night visit to the Alhambra was made, in which visitors from Iran had the opportunity to read some of the decorative engravings on the walls. There are astronomical references there that surprised us all. In order to distribute it easily to the Atarfe students, 8 tents were arranged in locations close to the educational centres and that also offered their contents to the pedestrians of the municipality. The location of the eight tents was:

- Tent 1: Door of the Medina Elvira Cultural Center (the Andorran team) (Figure 24)
- Tent 2 and 3: Parque Arquitecto Ramón Gardón (two teams from Iran) (Figures 25 and 26)
- Tent 4, 5 and 6: Pink Floyd Park (one team from Spain, two from Romania and one from Bulgaria) (Figures 27, 28 and 29)
- Tent 7 and 8: Door of Atarfe Town Hall (one team from Spain and another from Portugal) (Figures 31 and 32)

Fig. 35. Tent 1 in front of the Medina Elvira Cultural Centre.
Group of teachers from Agora International School, La Massana, Andorra. (Credit R.M. Ros)

The CienciAtarfe team prepared the student visit schedule (Figures 3 from 35 to 40), the information that was given to the teachers and students of the schools, and it was disseminated in the days before and after the event, to the entire population through the local radio station.

Fig. 36. Tent 2 in Parque Arquitecto Ramón Gardón with one of the two teams from Iran. Professors at ITAU, Iranian Teachers Astronomical Union de Bushehr. (Credit R.M. Ros)

Fig. 37. Tent 3 in the Ramón Gardón Architect Park with the second Persian group, from Bushehr, ITAU Mehr Observatory, Iran. All this under the watchful eye of the giant-headed Charles Darwin. (Credit J. Paz)

Fig. 38: High school students in tent 4 of the group from Romania from Cluj-Napoca. (Credit J. Paz)


Fig. 39: Tent 5. Obtaining the temperatures in Herschel's experiment with the second group from Cluj-Napoca, Romania. (Credit J. Paz)

Fig. 40. Explaining infrared to a group of students, in tent 6 of the Pink Floyd park, by the group of Spanish teachers from the Huerta de la Cruz school in Algeciras. (Credit J. Paz)

Fig. 41: Group of students after visiting the tents in Pink Floyd Park, posing with the giant head of Galileo Galilei. (Credit J. Paz)

Fig. 42: The team from the Planetarium of Porto, Portugal, in tent 7 located in front of the Atarfe City Hall. (Credit R.M. Ros)

Fig. 43. The observing student operates an infrared thermometer in this group managed by a NASE member in tent 8. This Herschel experiment also had a tracking motor. (Credit R.M. Ros)

Fig. 44: Primary school students after attending the experiments in the Plaza del Ayuntamiento de Atarfe, accompanied by the giant-headed Marie Curie. (Credit J. Paz)

At the meeting, new devices and resources were also presented, such as a device with a tracking engine that allows the thermometers to be kept on the spectrum for a long period of time, as it follows the apparent movement of the Sun (Figure 43). Also applications for mobile phones which convert the colours of an image in the frames into primary colours (red, green and blue) and at the same time allow a false colour image, simulating infrared (Figure 34).

Fig. 45. Professor from Bulgaria with a mobile phone app (left) that allows viewing false colour images on the phone (right). (Credit C. Toma)

7. Herschel with a tracking engine

Herschel's experiment that was mounted in tent 8 was the traditional one, with a prism on the edge of a cardboard box, but we used a telescope tripod (Figure 43) and a digital thermometer, similar to clinical thermometers, but of wider temperature range, at least between 0°C and 50°C. The thermometer has a red laser pointer, which showed where it was measuring the temperature.

The solar radiation, decomposed into colours, falls on four black metal plates that are not in contact with each other, so that heat is not exchanged. They were obtained by cutting the side of a soda can, and painted black with a marker, to better absorb heat. They were glued on a sheet of foam cardboard or expanded polystyrene, which isolates them from the bottom of the cardboard box. To glue the metal plates we used double-sided tape. Each ends up being heated by the Sun.

We installed the box on the equatorial mount of a telescope. As we did not use the telescope tube, a rough alignment of the mount with the axis of rotation of the Earth was sufficient. As time passes, the displacement of the colour spectrum on the bottom of the box is remarkable, due to the Earth's rotation. These displacements were easily corrected with the tracking motor, or with the controls on the mount.

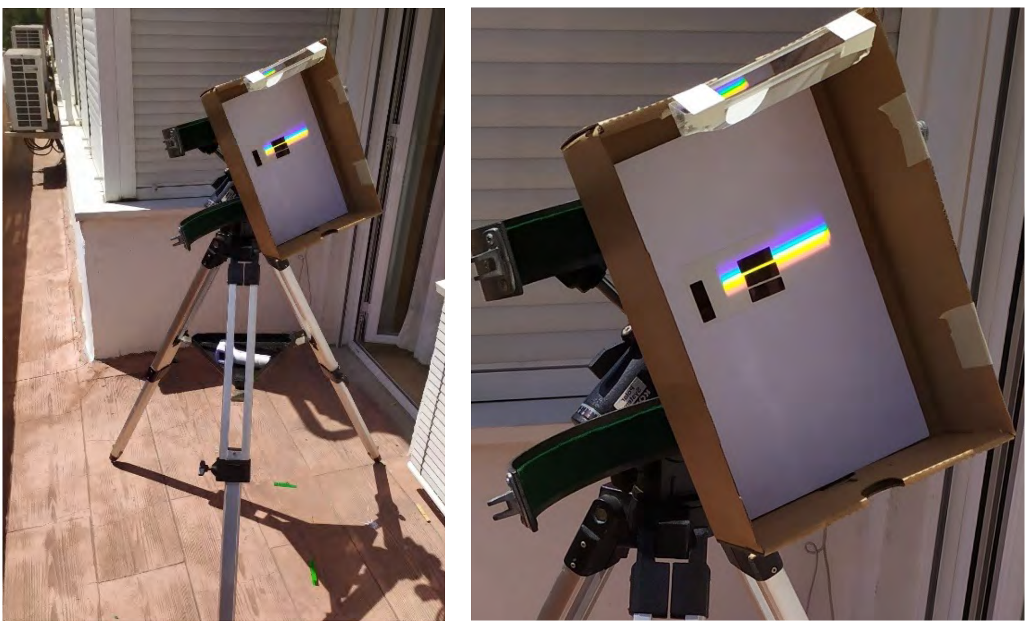

Fig. 47: Box on an equatorial mount of a telescope (left). Detail of the box (right).

It is experimentally verified that the plate that is in the shade has a notably lower temperature than the one that is beyond the red, apparently also in the shade (Figure 48). This shows that there is an invisible radiation that falls on it and that heats it.

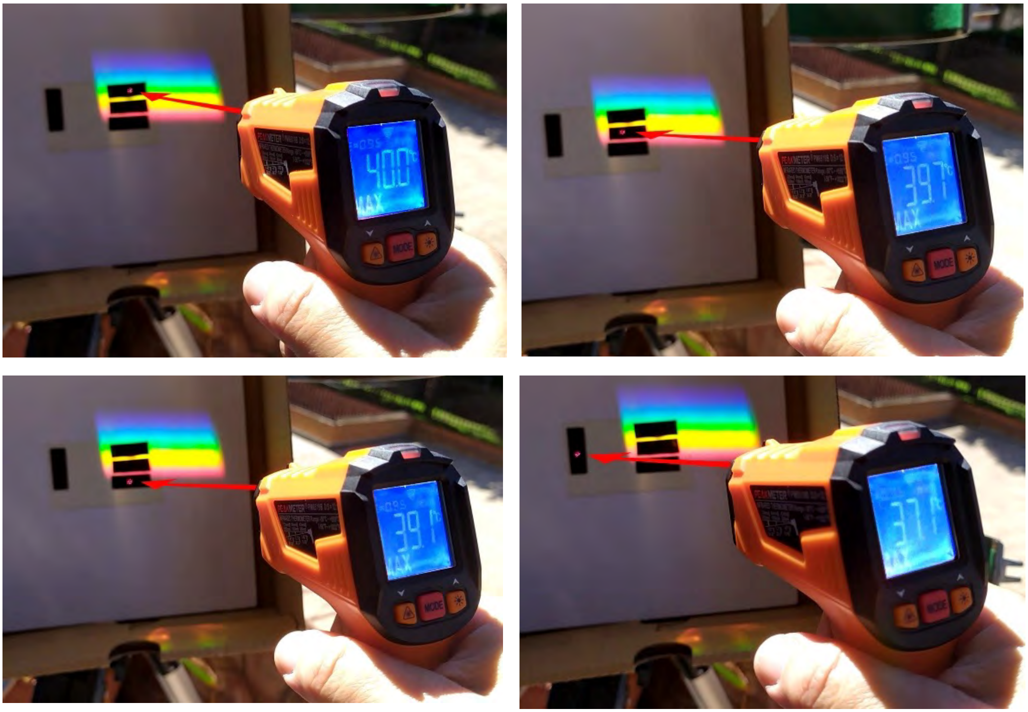

Fig. 48: The digital thermometer points with the red laser pointer to the surface where the temperature is measured. The recorded values are 40.0°C in green (top, left), 39.7°C in yellow (top, right), 39.1°C in infrared (bottom, left), and 37.1°C in shadow (bottom, right). It is evident that the infrared thermometer shows two degrees higher than the thermometer in the shade. Although it cannot be seen, there is radiation that reaches and heats the area below the red. For a good precision in the measurements, the thermometer should be about 25 cm from the black plates

EThis way of doing the experiment has the advantage of being visible at a distance, by several people at the same time, and that they can easily take the temperature measurements.

This video shows how to make the mount: https://youtu.be/qFOUs2IeeVQ

8. Results

NASE received more than a hundred written reports. These works can be seen on the NASE website.

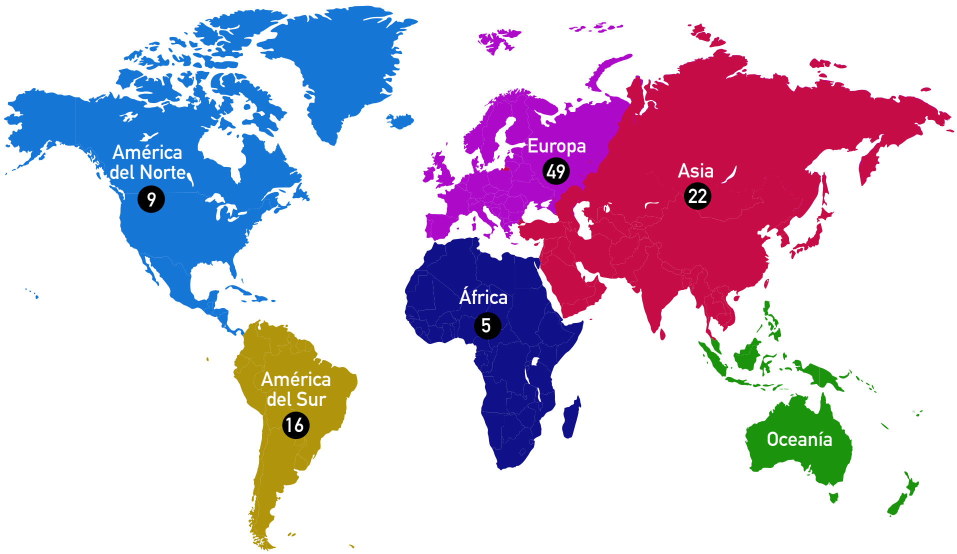

Fig. 49: Distribution by continents of the more than one hundred papers received.

The reports include evidence of the observations, a record of the five series of measurements on the thermometers, carried out at one-minute intervals, and photographs of the setup of the experiment, of the assistants, and the geographical and thermal data of the place of observation.

The most numerous participants are high school students. Although it is surprising that very young children have done the experiment, undoubtedly with the help of an adult. There are also several experiments proposed by university students.

The results have a common pattern: the thermometer in the shade shows 1 or 2 degrees lower than the thermometer in the infrared, which in turn is almost equal to or slightly higher than the thermometer in the blue and yellow, as you would expect.

A correlation of the measurements obtained with the energies of the Sun's radiation at different wavelengths, in its black body character, was outside the project's objectives. The precision of school thermometers, the small difference between the temperatures of the colours and the difficulty in controlling other parameters made it impossible, but it is a possibility for expanding this project for groups that want to delve deeper into the subject.

9. Conclusions

Locally, the results obtained in this project have been a success in Atarfe.

• Approximately 1500 students from 10 secondary schools in Atarfe had the opportunity to detect infrared radiation and learn some astrophysics.

• People who were walking through the city of Atarfe on October 1st found several tents where they discovered a new radiation that they could not see, but could be detected through the appropriate experiment, in the manner of Herschel, recording its temperature.

On a European and global scale, as a result of this project:

The EAAE (European Association for Astronomy Education) is going to join the global project proposal next year by launching the call jointly with NASE and promoting it among its affiliated professors and supporters, to realise this interesting experiment with infrared radiation.

NASE plans to repeat a new global project by 2022 involving countries on different continents and repeat a final event, probably in more than one country, to facilitate face-to-face meetings between various teams.

Finally, it is necessary to thank several international institutions that have provided support to the "Herschel Experiment Project" by promoting it in their countries and areas of influence:

Cité de la Science in Tunis, Tunisia
CONICET, National Council for Scientific and Technical Research, Argentina
CSIC, Higher Council for Scientific Research, Spain
EAAE European Association for Astronomy Education
ESSTI Ethiopian Institute of Space Science and Technology, Ethiopia
IFA Institute for Astrophysics of the University of Vienna
ITAU Astronomical Union of Iranian Teachers
SINA International Astronomical Student Network
NARIT National Institute of Astronomical Research of Thailand
Beijing Planetarium, China
Teaching School, National University of Cuyo, Mendoza, Argentina.

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37.6°C
37.2°C
36.8°C
37.6°C
37.1°C
37.7°C
37.8°C
37.5°C
36.8°C
36.6°C
36.6°C
36.6°C
37.5°C
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