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Herschel and His Discovery of Infrared

The Herschel Experiment

An Example of the Herschel Experiment

School/Science Fair Results

Herschel's Original Prism

(Science Museum London link)

Reconciling The Herschel Experiment

Last Updated: May 15, 2000
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# Descubrimiento de los rayos infrarrojos – El experimento de Herschel

Educación y programas educativos
[página en inglés]

# Herschel Discovers Infrared Light

**Sir Frederick William Herschel (1738-1822) was born in Hanover, Germany and became well known as both a musician and as an astronomer. He moved to England in 1757 and, with his sister Caroline, constructed telescopes to survey the night sky. Their work resulted in several catalogs of double stars and nebulae. Herschel is famous for his discovery of the planet Uranus in 1781, the first new planet found since antiquity.**

**Herschel made another dramatic discovery in 1800. He wanted to know how much heat was passed through the different colored filters he used to observe sunlight. He had noted that filters of different colors seemed to pass different amounts of heat. Herschel thought that the colors themselves might be of varying temperatures and so he devised a clever experiment to investigate his hypothesis.**

**He directed sunlight through a glass prism to create a spectrum -- the rainbow created when light is divided into its colors -- and then measured the temperature of each color. Herschel used three thermometers with blackened bulbs (to better absorb**

**the heat) and, for each color of the spectrum, placed one bulb in a visible color while the other two were placed beyond the spectrum as control samples. As he measured the individual temperatures of the violet, blue, green, yellow, orange and red light, he noticed that all of the colors had temperatures higher than the controls. Moreover, he found that the temperatures of the colors increased from the violet to the red part of the spectrum. After noticing this pattern, Herschel decided to measure the temperature just *beyond* the red portion of the spectrum in a region apparently devoid of sunlight. To his surprise, he found that this region had the highest temperature of all.**

**Herschel performed additional experiments on what he called calorific rays (derived from the Latin word for *heat*) beyond the red portion of the spectrum. He found that they were reflected, refracted, absorbed and transmitted in a manner similar to visible light. What Sir William had discovered was a form of light (or radiation) beyond red light, now known as infrared radiation. [The prefix *infra* means below.] Herschel's experiment was important because it marked the first time that someone demonstrated that there were types of light that we cannot see with our eyes.**

**Recent developments in detector technology have led to many useful applications using infrared radiation. Medical infrared technology is used for the non-invasive analysis of body tissues and fluids. Infrared cameras are used in police and security work, as well as in military surveillance. In fire fighting, infrared cameras are used to locate people and animals caught in heavy smoke, and for detecting hot spots in forest fires. Infrared imaging is used to detect heat loss in buildings, to test for stress and faults in mechanical and electrical systems, and to monitor pollution. Infrared satellites are routinely used to measure ocean temperatures, providing an early warning for El Nino events that usually impact climates worldwide. These satellites also monitor convection within clouds, helping to identify potentially destructive storms. Airborne and space-based cameras also use infrared light to study vegetation patterns and to study the distribution of rocks, minerals and soil. In archaeology, thermal infrared imaging has been used to discover hundreds of miles of ancient roads and footpaths, providing valuable information about vanished civilizations.**

**New and fascinating discoveries are being made about our universe in the field of infrared astronomy. The universe contains vast amounts of dust, and one way to peer into the obscured cocoons of star formation and into the hearts of dusty galaxies is with the penetrating eyes of short-wavelength infrared telescopes. Our universe is also expanding as a result of the Big Bang, and the visible light emitted by very distant objects has been red-shifted into the infrared portion of the electromagnetic spectrum.**

# Herschel Infrared Experiment

PURPOSE/OBJECTIVE: To perform a version of the experiment of 1800, in which a form of radiation other than visible light was discovered by the famous astronomer Sir Frederick William Herschel.

BACKGROUND: Herschel discovered the existence of infrared light by passing sunlight through a glass prism in an experiment similar to the one we describe here. As sunlight passed through the prism, it was dispersed into a rainbow of colors called a *spectrum*. A spectrum contains all of the visible colors that make up sunlight. Herschel was interested in measuring the amount of heat in each color and used thermometers with blackened bulbs to measure the various color temperatures. He noticed that the temperature increased from the blue to the red part of the visible spectrum. He then placed a thermometer just beyond the red part of the spectrum in a region where there was no visible light -- and found that the temperature was even higher! Herschel realized that there must be another type of light beyond the red, which we cannot see. This type of light became known as *infrared*. *Infra* is derived from the Latin word for "below." Although the procedure for this activity is slightly different than Herschel's original experiment, you should obtain similar results.

MATERIALS: One glass prism (plastic prisms do not work well for this experiment), three alcohol thermometers, black paint or a permanent black marker, scissors or a prism stand, cardboard box (a photocopier paper box works fine), one blank sheet of white paper.

PREPARATION: You will need to blacken the thermometer bulbs to make the experiment work effectively. One way to do this is to paint the bulbs with black paint, covering each bulb with about the same amount of paint. Alternatively, you can also blacken the bulbs using a permanent black marker. (Note: the painted bulbs tend to produce better results.) The bulbs of the thermometers are blackened in order to absorb heat better. After the paint or marker ink has completely dried on the thermometer bulbs, tape the thermometers together such that the temperature scales line up as in Figure 1.

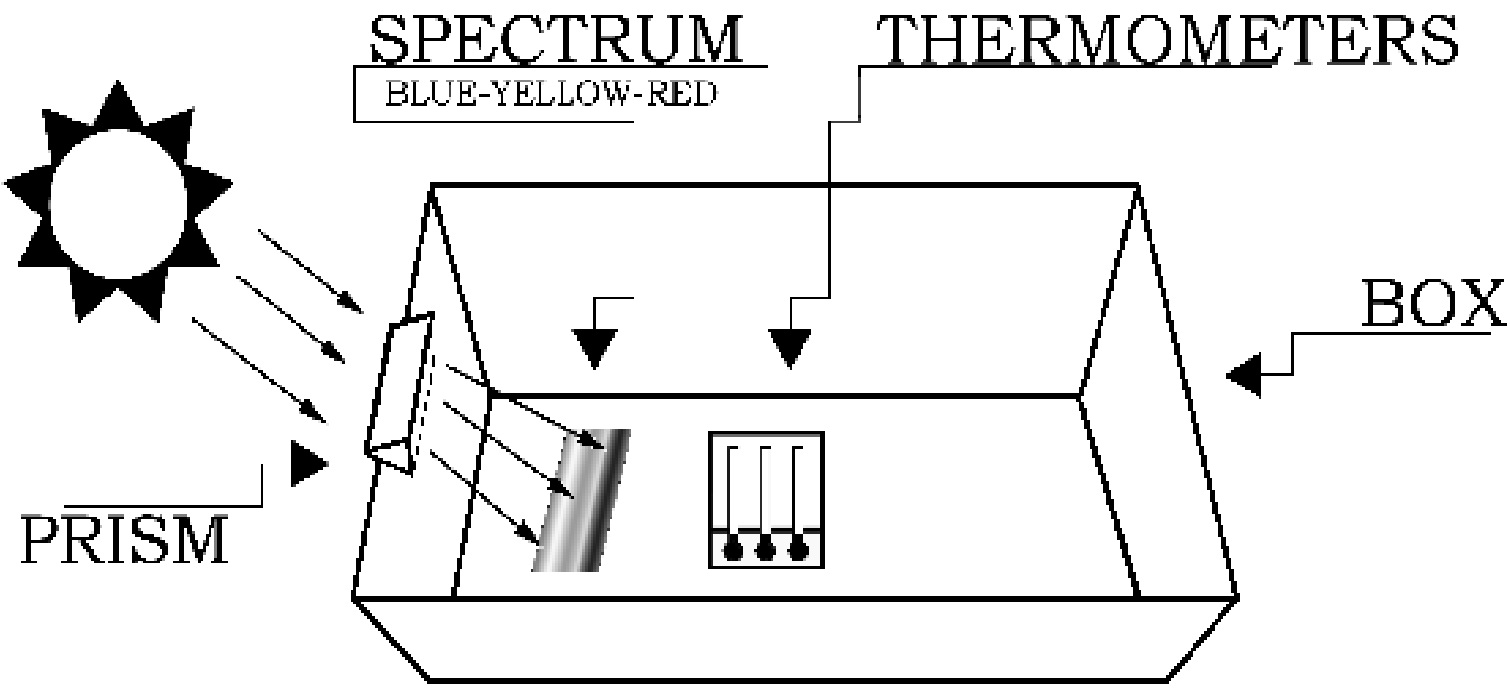



Figure 1

PROCEDURE: The experiment should be conducted outdoors on a sunny day. Variable cloud conditions, such as patchy cumulus clouds or heavy haze will diminish your results. The setup for the experiment is depicted Figure 1. Begin by placing the white sheet of paper flat in the bottom of the cardboard box. The next step requires you to carefully attach the glass prism near the top (Sun-facing) edge of the box.

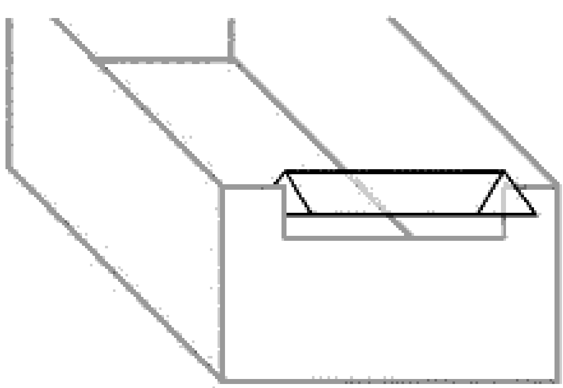


Figure 2

If you do not have a prism stand (available from science supply stores), the easiest way to mount the prism is to cut out an area from the top edge of the box. The cutout notch should hold the prism snugly, while permitting its rotation about the prism's long axis (as shown in Figure 2). That is, the vertical "side" cuts should be spaced slightly closer than the length of the prism, and the "bottom" cut should be located slightly deeper than the width of the prism. Next, slide the prism into the notch cut from the box and rotate the prism until the widest possible spectrum appears on a shaded portion of the white sheet of paper at the bottom of the box. [To see images showing the setup, click here.]

The Sun-facing side of the box may have to be elevated (tilted up) to produce a sufficiently wide spectrum. After the prism is secured in the notch, place the thermometers in the shade and record the ambient air temperature. Then place the thermometers in the spectrum such that one of the bulbs is in the blue region, another is in the yellow region, and the third is just beyond the (visible) red region (as in Figure 3).

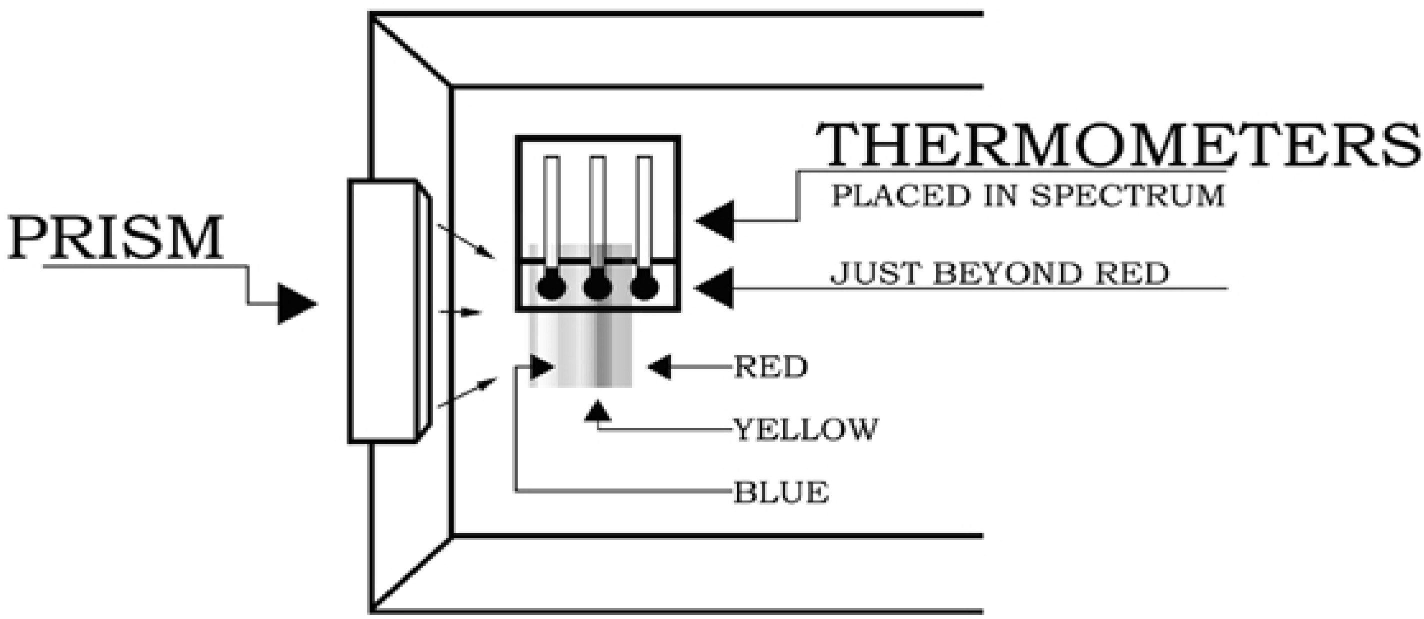



Figure 3

It will take about five minutes for the temperatures to reach their final values. Record the temperatures in each of the three regions of the spectrum: blue, yellow, and "just beyond" the red. Do not remove the thermometers from the spectrum or block the spectrum while reading the temperatures.

DATA/OBSERVATIONS:

| | Thermometer #1 | Thermometer #2 | Thermometer #3 |
|---|---|---|---|
| **Temperature in the shade** | | | |

| **Temperature in the spectrum** | **Thermometer #1 (blue)** | **Thermometer #2 (yellow)** | **Thermometer #3 (just beyond red)** |
|---|---|---|---|
| **After 1 min** | | | |
| **After 2 min** | | | |
| **After 3 min** | | | |
| **After 4 min** | | | |
| **After 5 min** | | | |

*Note: Depending on the position of the prism relative to the Sun, the colors of the spectrum may be reversed from what is show in the figures.*

QUESTIONS: What did you notice about your temperature readings? Did you see any trends? Where was the highest temperature? What do you think exists just beyond the red part of the spectrum? Discuss any other observations or problems.

REMARKS TO THE TEACHER: Have the students answer the above questions. The temperatures of the colors should increase from the blue to red part of the spectrum. The highest temperature should be just beyond the red portion of the visible light spectrum. This is the infrared region of the spectrum. Herschel's experiment was important not only because it led to the discovery of infrared light, but also because it was the first time that it was shown that there were forms of light that we cannot see with our eyes. As we now know, there are many other types of electromagnetic radiation ("light") that the human eye cannot see (including X-rays, ultraviolet rays and radio waves). You can also have the students measure the temperature of other areas of the spectrum including the area just beyond the visible blue. Also, try the experiment during different times of the day; the temperature differences between the colors may change, but the *relative* comparisons will remain valid.

For further information on the Herschel infrared experiment see:
*http://sirtf.caltech.edu/Education/Herschel/herschel.html*

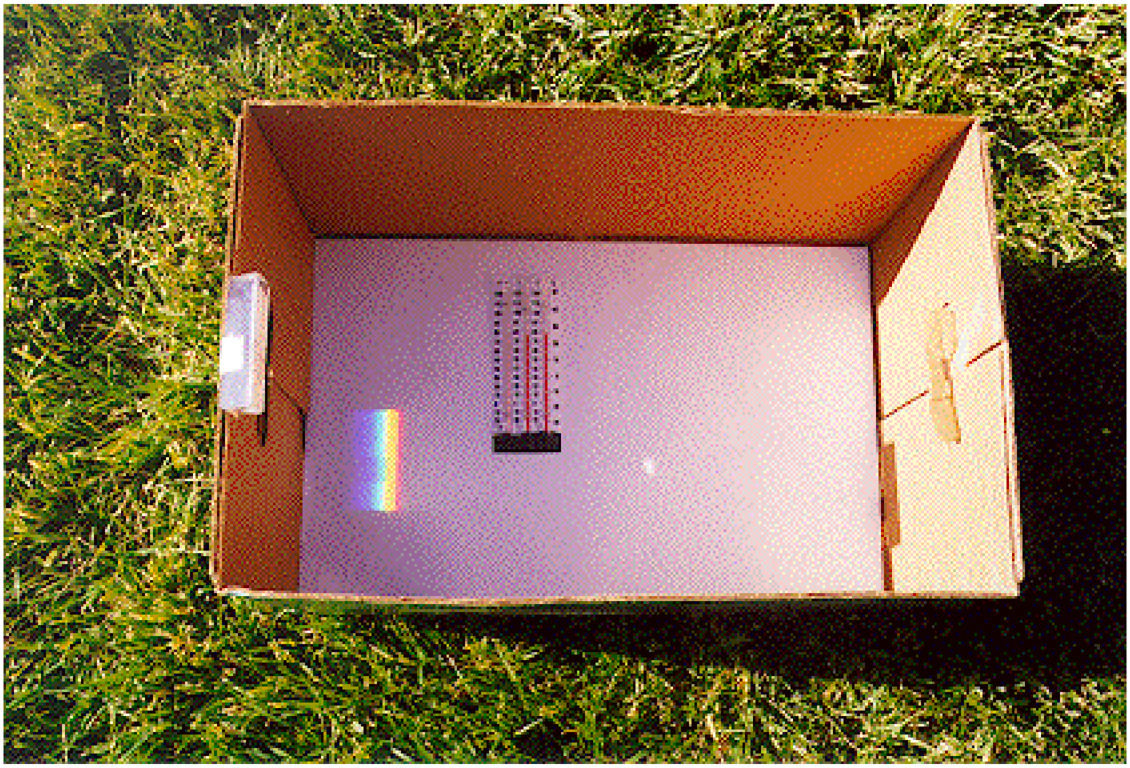
For further information on Infrared and Infrared Astronomy see:
*http://www.ipac.caltech.edu/Outreach/Edu/*

If you wish to have your results posted online you may send them to *outreach@ipac.caltech.edu*

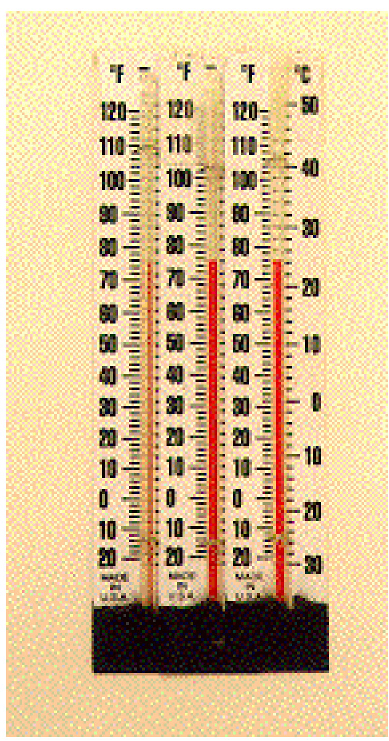
# Herschel Infrared Experiment

In the year 1800, Sir William Herschel discovered the existence of infrared by performing an experiment very similar to the one we show here. Herschel passed sunlight through a prism. As sunlight passes through the prism, the prism divides it into a rainbow of colors called a spectrum. A spectrum contains all of the colors which make up sunlight. Herschel was interested in measuring the amount of heat in each color. To do this he used thermometers with blackened bulbs and measured the temperature of the different colors of the spectrum. He noticed that the temperature increased from the blue to the red part of the spectrum. Then he placed a thermometer just past the red part of the spectrum in a region where there was no visible light and found that the temperature there was even higher. Herschel realized that there must be another type of light which we cannot see in this region. This light was called infrared.

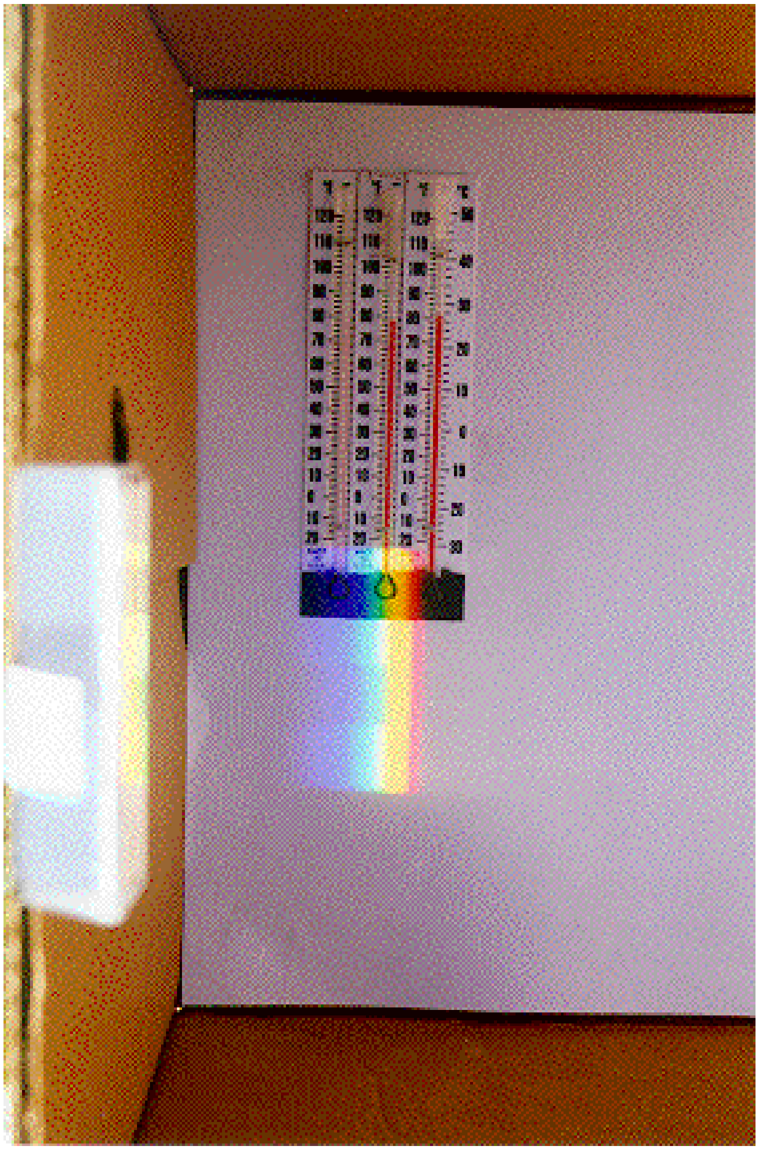
It is very easy to recreate this experiment. All you need is an equilateral glass prism, 3 alcohol thermometers, scotch tape, a white piece of paper and a south facing window sill or a box. The cost of the prism we used was about $7.50 and the thermometers were 75 cents a piece. You will need to blacken the bulbs of the thermometers to make this experiment work. To do this we masked the thermometers with masking tape exposing only the bulbs and then spray painted the bulbs with a flat black paint. The bulbs of the thermometers were blackened to better absorb heat.



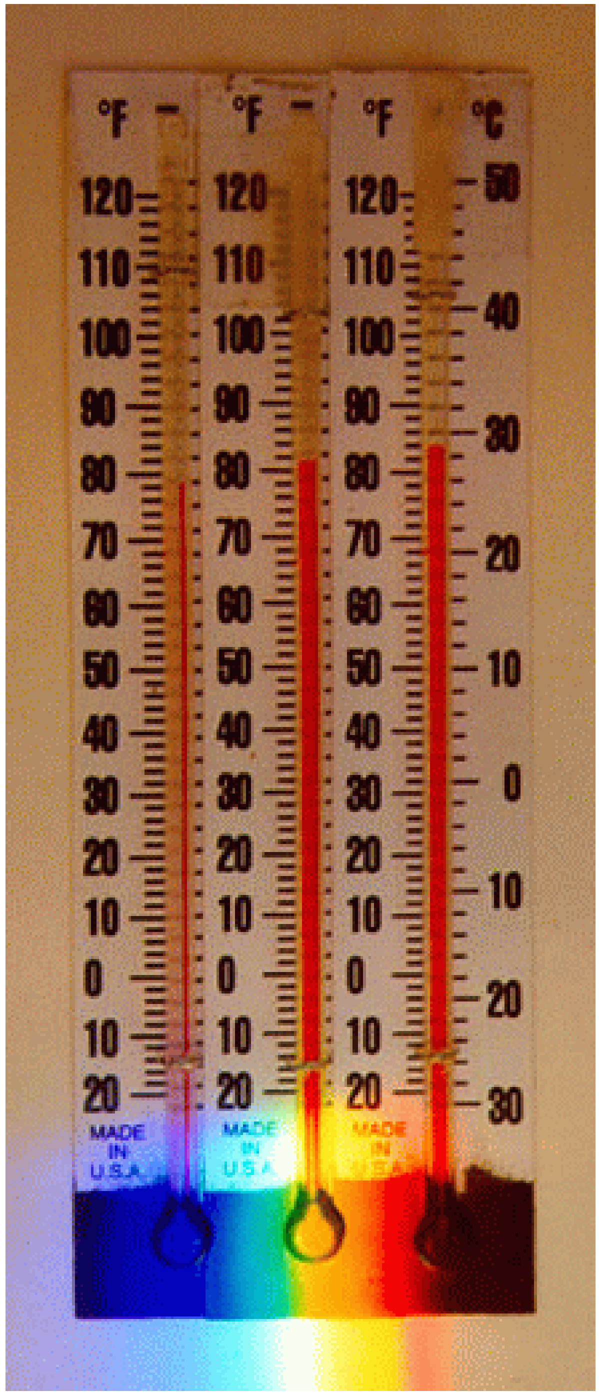
In the above image you can see how to set up this experiment for use outdoors. We placed a white piece of paper at the bottom of a cardboard xerox paper box. Next we rotated the prism until a good wide spectrum appeared on the white paper at the bottom of the box and then taped the prism into place. To get a good spectrum we had to tilt the box up on the prism end by placing a rock under it.



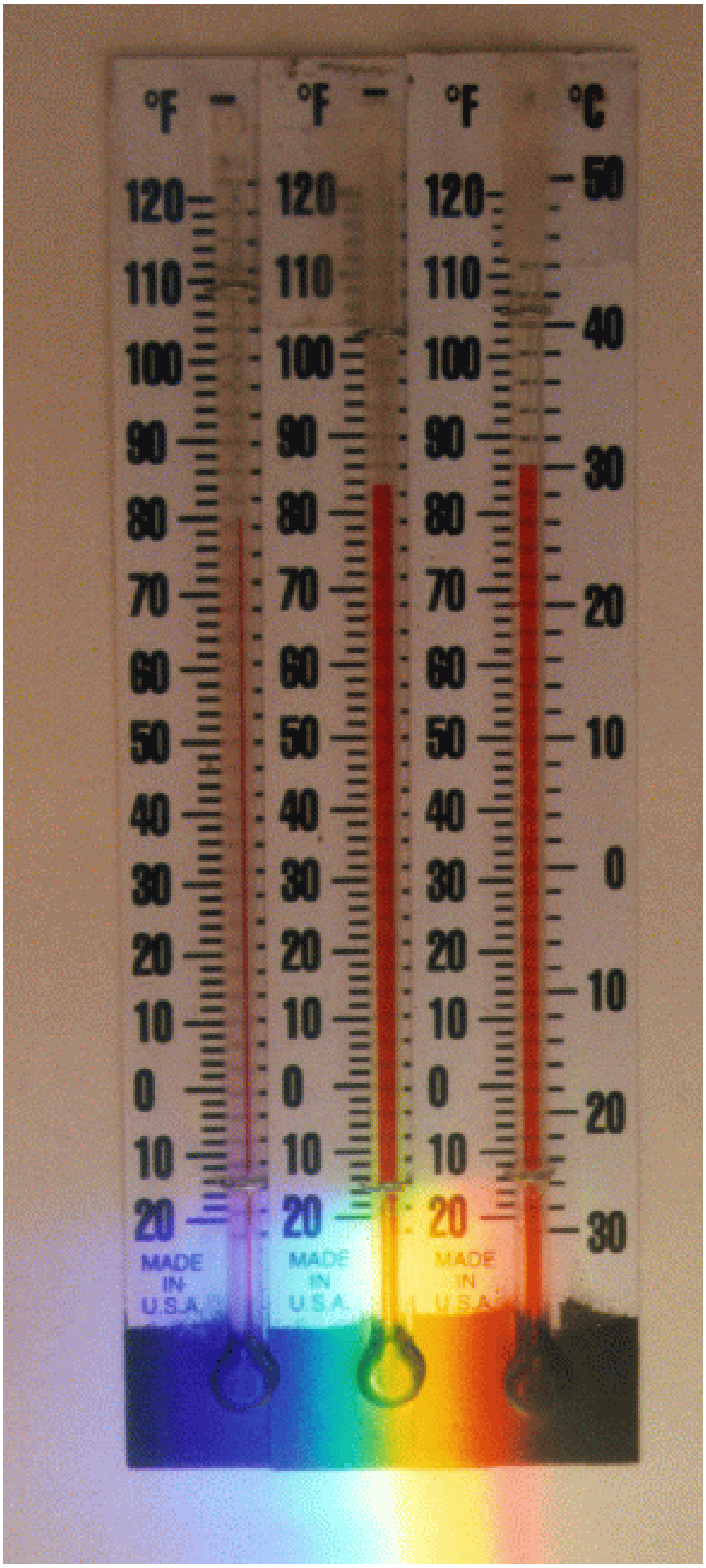
First check the temperature of the thermometers away from the spectrum in the shaded area of the box. The above image shows the temperature before the thermometers are placed in the spectrum. All 3 read 76 degrees which is the outdoor shade temperature.



Now let's place the thermometers in the spectrum. We will place the left bulb in the blue part of the spectrum, the middle bulb in the yellow part of the spectrum, and the right bulb just past the red part of the spectrum in a region where there is no visible light.




The above image shows the temperature readings after about 1 minute. It takes a few minutes for the temperatures to reach their final value. Within 1 minute you can already see a difference in temperature. The thermometer in the blue part of the spectrum shows the lowest reading which is not much higher than shade temperature. The yellow part of the spectrum is showing a much higher temperature than the blue. The thermometer on the right, which is in the dark region just past the red, is showing the highest temperature of all 3 regions. (The sun had moved slightly by the time this picture was taken, and hence the right-most bulb just started to have a small portion of the red spectrum shining on it then.)



The differences between the 3 temperature readings continue to grow larger until the final temperatures are reached (shown above). You can now see that the dark area shows a much higher temperature than the areas which are in regions of light. Final readings are:

Final readings are: blue: 80 degrees yellow: 83 degrees infrared: 86 degrees

Notes:

1. The differences between the temperatures of the colors of the spectrum vary with the width of the spectrum, which depends on time of day, and the distance from the prism, which is proportional to the height of your box. In all cases the trend of temperature increasing from blue to infrared should still show up.

2. All the wavelengths farther than the infrared are compressed to a small region just beyond the red (see Reconciling The Herschel Experiment). For typical box depths of 0.3 m, no solar wavelengths are beyond 0.4 cm from the end of the red, so the "infrared" thermometer must be placed immediately next to the end of the observed spectrum.

3. If you can arrange to have the prism more distant from the projected spectrum, the wavelengths will be spread out farther, giving more room to explore the infrared. However, the difference in the thermometer readings will be smaller since they will intercept less energy.

Herschel's experiment was important not only because it led to the discovery of infrared light, but also because it was the first time that someone showed that there were forms of light that we cannot see with our eyes. As we now know, there are many other types of light that we cannot see and the visible colors are only a very small part of the entire range of light which we call the electromagnetic spectrum.

# Herschel Infrared Experiment Results


Science Fair Poster - Courtesy of Brett F.

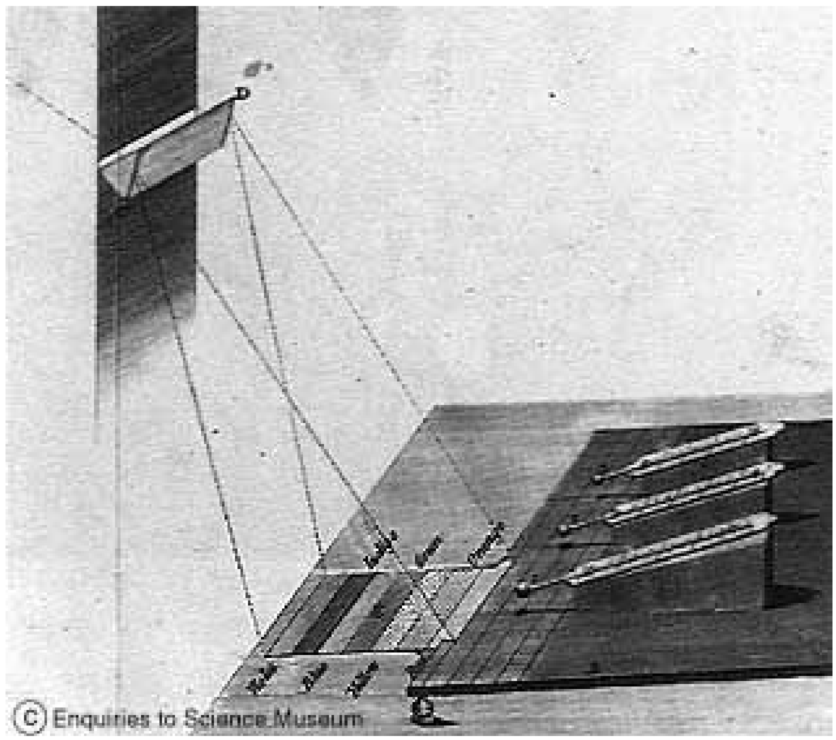
| Name/Grade | Date/Time | Shade temp | Temp in blue/violet | Temp in yellow | Temp just beyond red |
|---|---|---|---|---|---|
| **Bell Gardens Intermediate / 7-8** | Jan/1:00 pm | | 81 F | 90 F | 100 F |
| **Bell Gardens Intermediate / 7-8** | Jan/1:00 pm | | 81 F | 91 F | 101 F |
| **Bell Gardens Intermediate / 7-8** | Jan/1:00 pm | | 80 F | 93 F | 102 F |
| **Bell Gardens Intermediate / 7-8 (class 2)** | Jan/11:00 am | 70 F | 78 F | 79 F | 79 F |
| **Bell Gardens Intermediate / 7-8 (class 2)** | Jan/1:00 pm | 70 F | 92 F | 94 F | 96 F |
| **Bella Vista Elementary / 4** | Jan/? | | 76 F | 78 F | 80 F |
| **La Merced Intermediate / 7-8** | Jan/1:00 pm | 70 F | 91 F | 93 F | 96 F |

| | | | | | |
|---|---|---|---|---|---|
| **Montebello Intermediate / 7-8** | Jan/1:00 pm | 69-70 F | 72 F | 76 F | 77 F |
| **Brett F./ 5** | Mar 20/9:50 am | 75 F | 80 F | 86 F | 89 F |
| **Brett F./ 5** | Mar 27/2:15 pm | 74 F | 84 F | 88 F | 90 F |
| **Brett F./ 5** | Mar 28/12:15 pm | 72 F | 85 F | 88 F | 90 F |
| **Traci H./ 6** | Apr 2/11:35 am | 66 F | 70 F | 74 F | 76 F |
| **Traci H./ 6** | Apr 2/3:50 pm | 68 F | 72 F | 76 F | 82 F |
| **Katie B./ 9** | Feb /11am | 70 F | 105 F | 107 F | 108 F |
| **Katie B./ 9** | Feb /2pm | 80 F | 97 F | 98 F | 103 F |

# Herschel's Prism and Mirror *c1800*

These items were used by William Herschel in the first investigations of the solar spectrum beyond the visible region, when he discovered infrared radiation.

The mirror was slowly rotated to keep a beam of sunlight in a constant direction while the prism split it into its constituent colours. Herschel found that the highest temperature was just beyond the red part of the spectrum, the area we now know as the 'infrared'.


*Inventory Number: 1876-565 and 6*

Astronomy and optics | Chemistry | Classical physics | Communications | Earth sciences | Flight and space | Mathematics and computing | Medical sciences | Nuclear physics | Power | Road and rail transport | Water transport

# Reconciling The Herschel Experiment

In a famous experiment, Sir William Herschel discovered the infrared region of the solar spectrum in the year 1800. He used a glass prism to disperse the sun's rays and a thermometer to record the "temperature" of each of the wavelengths. To his surprise, he found that the highest reading of the thermometer was in a region beyond the reddest rays, and thus discovered the infra-red ("below-red"). See Discovery of Infrared.

On first consideration, this result is surprising. The energy peak of the solar spectrum is at 0.60 micron (orange light), and definitely not in the infrared. So why did Herschel observe the highest reading in the infrared?

The answer turns out to be the experimental design, and a failure to correct for refraction. In Herschel's setup, sunlight is refracted by a prism. The index of refraction of course must vary with wavelength so that the sunlight would be dispersed into its various colors. If the index of refraction varied linearly with wavelength, Herschel would not have needed to correct for that variation, since the wavelengths would be uniformly spaced along his table.

However, since the index of refraction varies non-linearly with wavelength, the wavelengths will not be uniformly spaced along Herschel's measuring table. The actual spacing of the wavelengths versus distance along his table for an incidence angle of 45° from air into glass shows that the infrared region is much more highly concentrated than optical wavelengths. (The plot shows the spacing along the spectrum divided by the distance from the prism. Hence to get the actual spacing in cm or inches, multiply by the distance from the prism in cm or inches.) The relative concentration factor is shown normalized to 0.60 micron.

The net result is that Herschel's observed "temperature" should then peak in the infrared. The energy vs. wavelength plot for the "45° glass" model given above shows that Herschel's observed "temperature" should keep increasing toward longer wavelengths. However, when properly corrected for the relation between wavelength and distance along his table, he should have finally published the "no wavelength concentration" curve shown in that plot!

A good referee should have caught this mistake. (;-)

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*Go To Table of Contents for:*


- *All Analysis Webpages*

- *All of Tom's Webpages*

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*Comments and feedback: Tom Chester*
*Last update: 21 July 1999.*

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Place mouse over titles (in blue) to view description.

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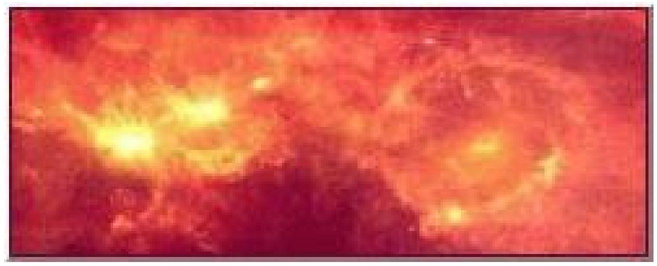

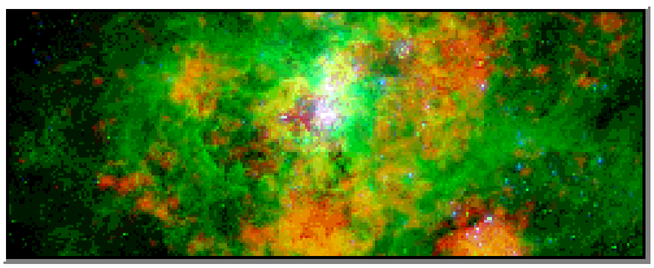

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Multiwavelength Astronomy
Multiwavelength Messier Museum

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The Herschel Experiment
What is it? - Learn About Infrared Images
Educational Links
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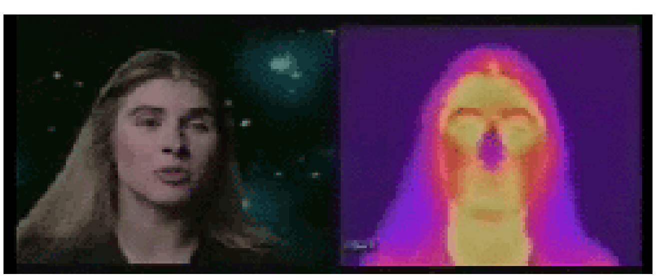

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Infrared Astronomy Gallery
Infrared - More Than Your Eyes Can See
2MASS Movie of the Galactic Center
Infrared Yellowstone

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2MASS Public Outreach and Education
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Last Updated: 6/20/01
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# Space Infrared Telescope Facility

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SIRTF Science Center

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Schedules
Legacy Science
First Look Survey

Visitor Information
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## Web Pages Down Sept 13-17

Electrical power to the SIRTF Science Center (SSC) will be interrupted from Thursday, September 13 (noon) through Monday, September 17 (noon) as we transfer from the Pasadena electrical grid to Caltech power. Network access to the SSC, including the SIRTF Web site, will be unavailable during this time.

**New Web Site**

Welcome to the newly redesigned SIRTF public Web site! Note that the "SCIENCE" button at the top of this page provides a general description of the SIRTF science program. SIRTF researchers should visit the companion SIRTF Science Center (SSC) Web site, accessible by clicking on the "RESEARCH" button (above right) or on the SSC logo (lower left).

**SIRTF Technology**

As part of our new look, an illustrated look at the technology behind SIRTF is available by clicking on the "TECHNOLOGY" button above. You can learn about the major components of the SIRTF observatory in just a few minutes.

### Featured SIRTF Image

**SIRTF CTA is lifted into the 'Brutus' test chamber**

### SIRTF PROFILES

This new feature introduces you to a member of the SIRTF team In the coming weeks and months, you will have the opportunity to learn about the scientists, engineers, managers, and administrative staff who are working to make SIRTF a reality.

### MISSION STATUS

Development of the Observatory continues in anticipation of a July 2002 launch.

SIRTF Launches in [ ] Days

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*This Page was last updated on: 27 August 2001*
***Doris Daou***

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