A Front-End Evaluation for Multi-Wavelength Light Exhibits at the Adler Planetarium

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Abstract

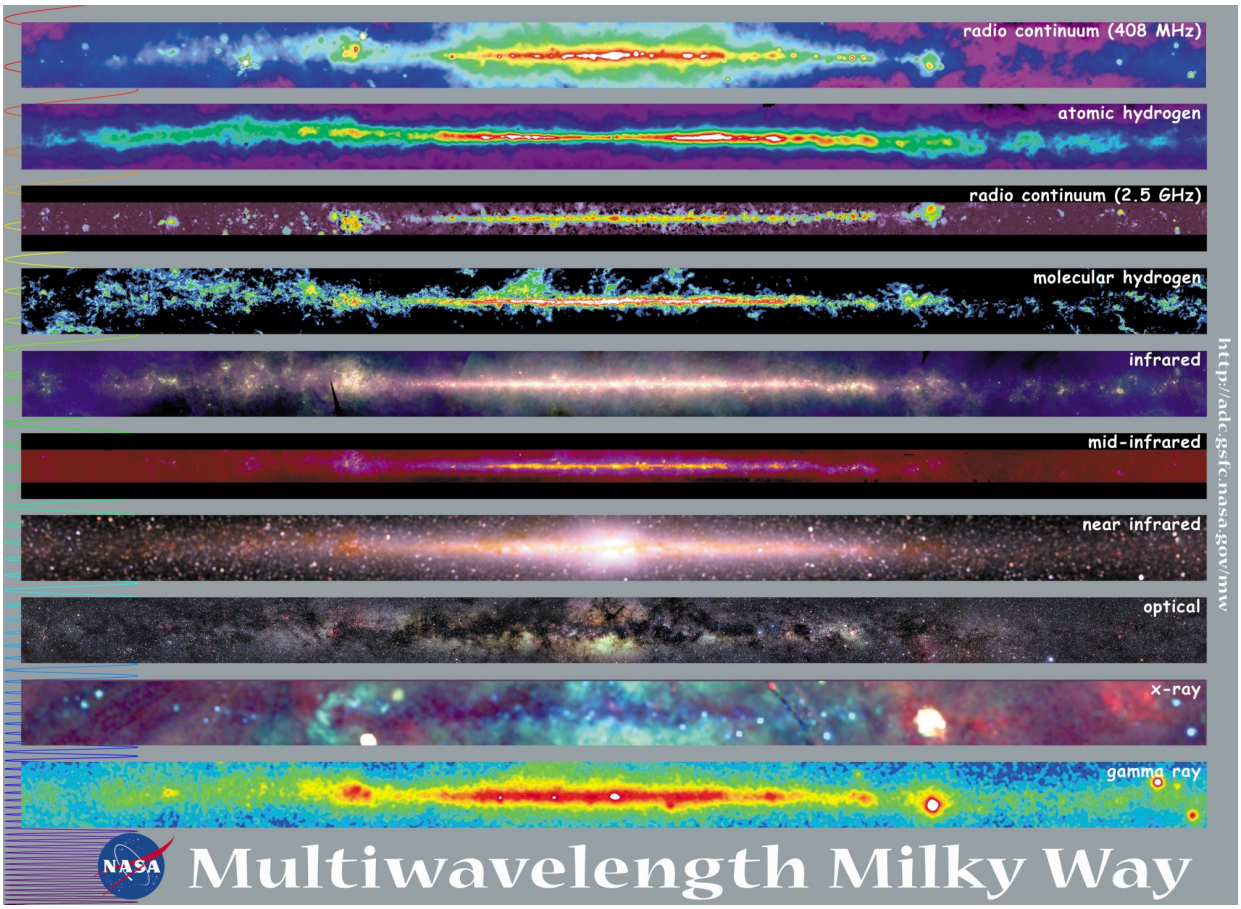
As a part of its Deep Space Adventure Gallery, the Adler Planetarium and Astronomy Museum is designing new exhibits related to multi-wavelength astronomy. Developing the public's understanding of non-visible forms of light, as well as the scientific information provided by visible and non-visible light, will be central to these presentations. The project summarized in this paper is a front-end evaluation that explores the knowledge museum visitors have concerning the nature of light and the relationship of different measurement instruments.

Introduction

Multi-wavelength astronomy is the use of multiple frequency bands of light in the observation of an astronomical object. Each band – including visible and non-visible light – reveals different characteristics of objects. Examples of information obtained from various bands include:

- Far-infrared - Reveals warm gas and dust around star forming regions
- Near-infrared - Emitted by long-lived, low- and medium-mass stars; able to penetrate dusty regions
- Microwave - Thermal emission from high-redshift objects and the cosmic background; emission from rotational transitions in molecules
- X-ray - Thermal emission from hot gas around galaxies, galaxy clusters, and compact objects (e.g., black holes and active galactic nuclei)
- Ultraviolet - Thermal emission from massive, short-lived stars; emission from ionized hydrogen
- Visible - Thermal emission from intermediate-mass stars; emission lines from nebula
- Radio - Emission from energetic electrons around supernova; emission from spin transitions neutral hydrogen

Astronomers put different observations of an object together to form a detailed description of it. The figure below shows observations of the Milky Way collected at different frequency bands.



Multi-wavelength images of the Milky Way Galaxy. Each horizontal stripe shows an observation of the Milky Way for a different frequency band. (Image from NASA/GSFC.)

Visitors to a multi-wavelength astronomy exhibit will learn about types (bands) of light that are not visible to the human eye, and that there are means of detecting non-visible light. They will also learn how observations of an object in different bands provide additional information about it. To help the Adler Planetarium in its exhibit design, this study aims to uncover the level of experience that visitors have with the concept of non-visible light, and what common (mis)conceptions they may have.

Specifically, the goals of this study are two-fold:

1. Gauge the level of public understanding of non-visible forms of light
2. Determine how easily the public can draw conclusions about the state of an object using visible and non-visible information

Our study incorporates verbal interviews of visitors to the Adler Planetarium. Our interview questions focus on interpretations and comparisons of images made from visible and non-visible observations of terrestrial objects. Objects were chosen based upon the ease at which they could be recognized in visible-light images. In each case, or "application," the non-visible image (either infrared or X-ray) provided information about the object that could not be gained from the visible image.

The interview questions were developed in two stages. A set of preliminary questions and objects were developed and later refined for the final set of questions. In both the infrared and x-ray cases, we attempted to assess how familiar the concepts (visible and non-visible light), the terminology ("infrared" and "x-ray"), and related technologies (infrared cameras and medical x-ray machines) are to the visitors.

Interviews

We conducted a total of 49 interviews of visitors to the Adler Planetarium over the course of three interview sessions. While some were individual interviews, most involved groups of people consisting of families with young children, adult couples, or small groups of teenagers or young children. We interviewed both men and women, from ages 5 to 65 years.

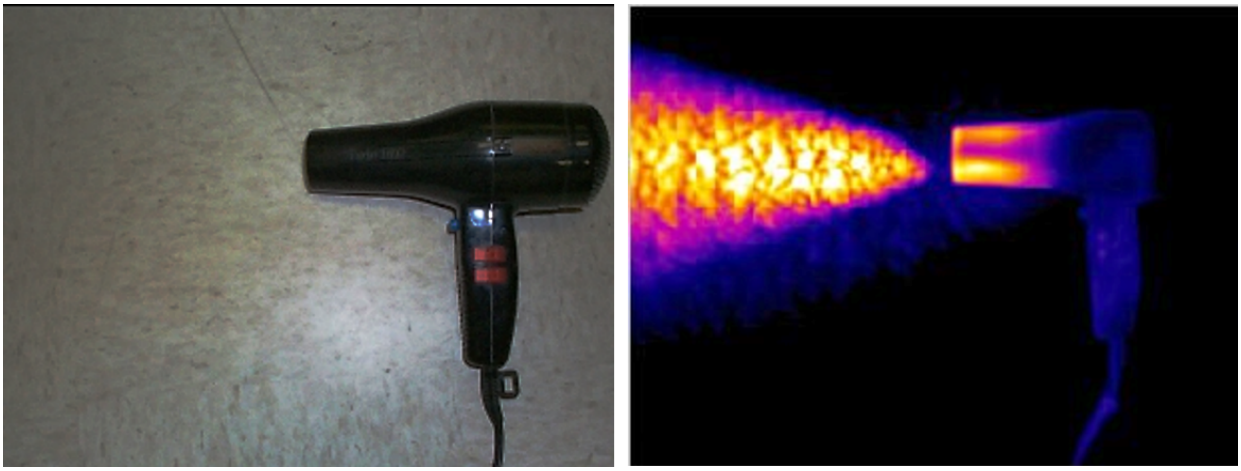
Questions written for the first interview session used a variety of objects imaged in infrared and x-rays. For each question, we identified a small field of possible responses, allowing us to efficiently indicate responses during the interviews; responses outside of this set were also noted during the interviews. For the second and third interview sessions, we decided to use images of only two objects (the hair dryer and the hand). We further standardized our questions with a wider selection of possible responses. During the course of the last two sessions, we found that each interviewer adjusted the verbal presentation of the questions to optimize the ease at which visitors could comprehend and answer them (e.g., simplified vocabulary for younger children).

The Adler Planetarium made additional resources available, such as the existing infrared camera exhibit, and the "UV Cart," which contained an ultraviolet camera and various objects to image with it. These arrangements would be very useful for exploring possible visitor interactions with an exhibit. For the purposes of this front-end study, however, we chose to stay with the questions about the hair dryer and hand images because they required little of the visitor's time, allowing us to efficiently evaluate a number of visitors.

Infrared Application

During our preliminary interviews, each visitor was presented with visible and infrared images of either a running sink or an operating hairdryer. Visitors were asked if they could identify the object shown, and if they could determine what the infrared image revealed about the object. The pairs of images used are displayed below:

Infrared application images. I. *Left.* Visible light image of sink with running hot water. *Right.* Infrared image of sink with hot water. (Images from NASA/IPAC.)



Infrared application images. II. *Left.* Visible-light image of hairdryer lying on floor. *Right.* Infrared image of hairdryer. (Images from NASA/IPAC.)

Preliminary Questions

For the preliminary interviews, each visitor was presented with either the sink or the hairdryer images. For each question below, the planned responses were as follows:

- No response
- I don't know
- Accurate description (record list of descriptions given)
- Other (record other information provided)

Question 1. Can you tell what are these images?

Question 2. Can you tell why they look different?

Final Questions

For our final set of interviews, we selected the hairdryer example for all visitors questioned. While most visitors were able to quickly focus on the desired aspects of the hairdryer images (the hot floor and nozzle), the images of the sink were unclear and visitors became distracted from the key components. We concluded that a single set of images would give the most uniform set of responses to the questions. The final set of infrared questions used only the hair dryer example:

Question 1. These images show the same object. Can you describe what is shown in each image?

- No response
- Does not know
- Hair dryer
- Visible and infrared images
- Heat
- Other (list responses)

Question 2. What does the image on the right tell us?

- No response
- Does not know
- Heat or temperature
- Infrared picture shows hot hairdryer output, hot floor or air
- Hair dryer is on
- Other (list responses)

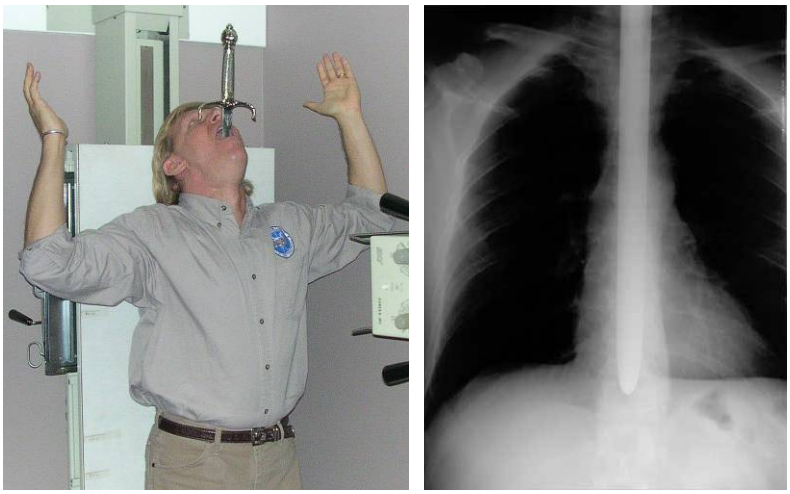
Nearly every person/group interviewed correctly identified each image as a hair dryer. Many concluded that the infrared hair dryer image showed the distribution of heat on the hair dryer and in the air flow output; however, only a few used the terminology "infrared." When asked how the image was produced, many said that the infrared image was taken using a "special camera or glasses that lets us see heat," while others mentioned x-rays (3 responses), microscopes (1 response), and radiation (3 responses). Three people (ages 5, 10, mid 20s) said that the infrared hair dryer was blowing fire; it was unclear whether these visitors recognized that the infrared image depicted the same hair dryer shown in the photograph.

A small percentage of the sample correctly concluded that while the infrared image showed hair dryer on, the state of the visible hair dryer was unclear.

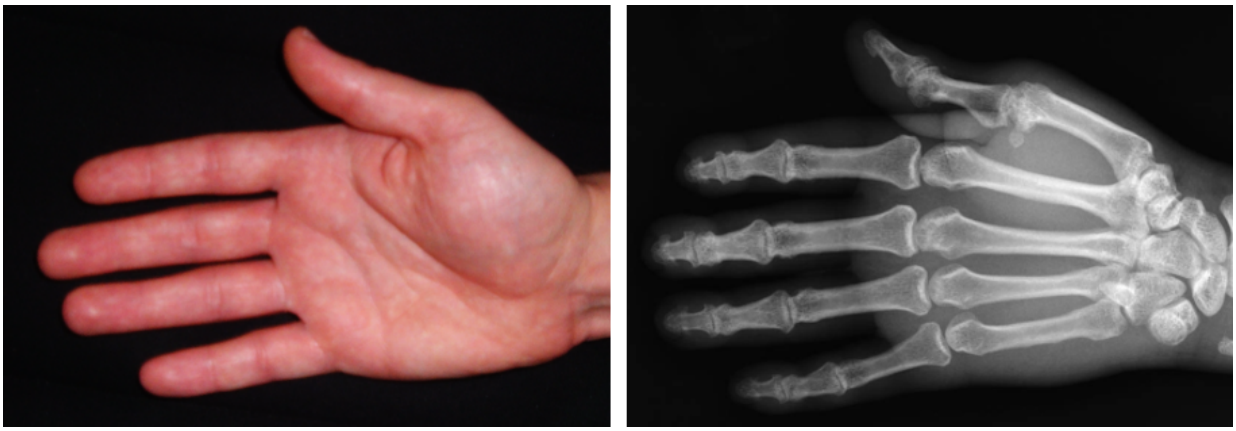
Of the sample that associated the infrared image with temperature distribution, most said the orange and yellow colors corresponded to the hottest part of the hair dryer and air flow. However, it is unclear how this conclusion was reached, since orange and yellow colors are often associated with heat, while blue and purple temperatures are associated with cold. One person said that "the hottest part is blue . . . in fire, the hottest part is blue, but not in thermal." It might be productive to conduct this interview again using an infrared image with a gray scale color table.

X-Ray Application

During our preliminary interviews, visitors were shown visible and x-ray images of either a human hand or a person swallowing a sword. Respondents were asked to identify the object depicted, and to discuss the information provided by the x-ray image. Visitors were also asked to explain why they thought the images looked different.



X-ray application images. I. *Left.* Man swallowing sword. *Right.* X-ray image of sword-swallowing. (Image from Sword Swallowers Association International.)



X-ray application images. II. *Left.* Visible-light image of hand. *Right.* X-ray image of hand. (X-ray image from Harvard Medical School.)

Preliminary Questions

For the preliminary interviews, each visitor was presented with either the sword-swallowing or the hand images. For each question below, the planned responses were as follows:

- No response
- I don't know
- Accurate description (record list of descriptions given)
- Other (record other information provided)

Question 1. Can you tell what are these images?

Question 2. Can you tell why they look different?

Question 3. Do you know why the bones are visible in this picture (show x-ray) and not in this (visible light)?

Final Questions

Most visitors could easily focus on the desired aspects of the hand and the hand x-ray (visibility of soft tissue versus bones). However, the novelty of sword-swallowing images quickly distracted visitors from the directive of the interview questions. As in the case of the infrared images discussed above, it was concluded that one set of images would be more effective for the second and third interview sessions. The final interview questions used only the images of the hand and the hand x-ray.

Question 1. These images show the same object. Can you describe what is shown in each image?

- No response
- Does not know
- Hand
- Bones, skeleton
- X-ray and visible images
- Other (list responses)

Question 2. Why can you see bones in the bottom image but not in the top one?

- No response
- Does not know
- X-rays penetrate skin
- Visible light does not penetrate skin
- X-rays show what is inside
- Other (list responses)

Most of the respondents identified the non-visible image as an x-ray of a hand. While most used the terminology "x-ray," when asked how the image was produced, there gave a variety of responses including radiation (3 responses), CT scan (1 response), radio waves (1 response), UV rays (1 response), and ionized light (1 response). A significant percentage said that x-rays penetrate the skin and a small percentage said that x-rays cannot penetrate dense material. A few believed that bones have special properties, such as high concentrations of calcium (from drinking milk) and phosphorus, that makes them visible in an x-ray.

A few commented that one shouldn't have too many x-rays taken, since they can be very dangerous. Similarly, some visitors mentioned cancer and that x-rays are "radioactive." The visitor's concerns suggest that the relationship between radiation and light might be a worthwhile topic for the prospective exhibit.

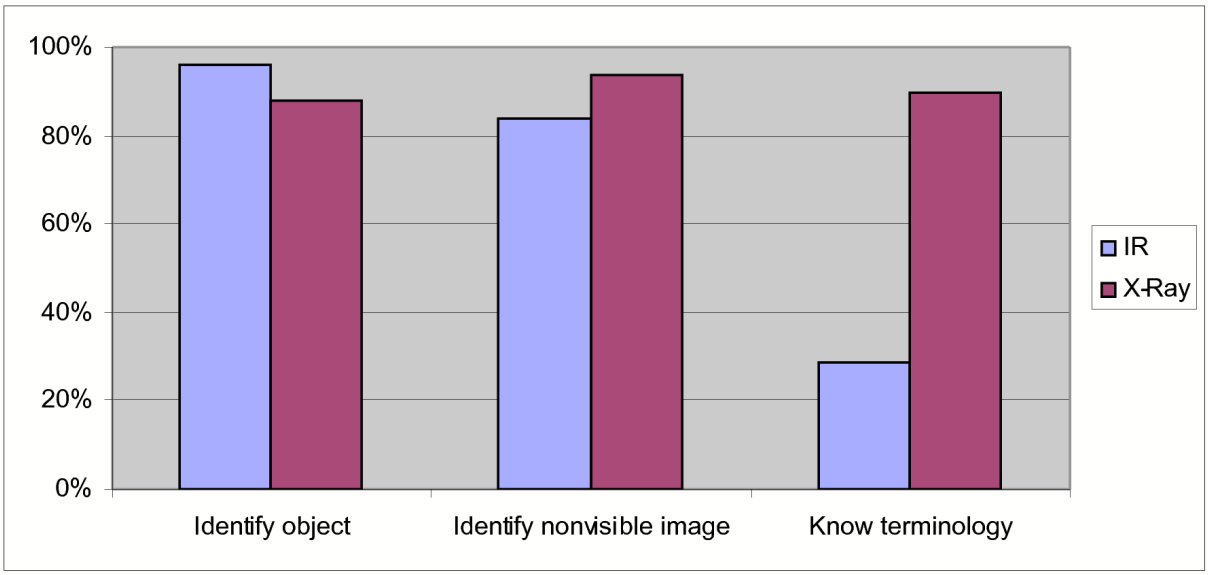
Results and Interpretations

The use of images is critical for gauging two levels of understanding about multi-wavelength light:

1. Scientific concepts (comprehension of the scientific nature of infrared and x-rays as light)
2. Technical application (understanding how technologies incorporate infrared and x-ray light)

Quantitative results were computed by looking for responses that fit into broad categories, such as whether or not the visitor used terminology associated with infrared light or x-rays. Since these results were compiled from written records of responses, numbers indicating the frequency of recognition or knowledge should be considered lower-bounds.

Results from the most basic questions (identification of object and familiarity of terms) are shown in the chart below. It is evident that we were successful in finding objects with a high frequency of recognition. Although the chart below shows that more people correctly identified the visible hair dryer than the visible hand, we don't believe this necessarily indicates that the hair dryer is easier to recognize. There is some evidence of a greater public awareness of the terminology associated with x-rays.



Recognition of objects and terminology. Chart shows percentage of interviews where the object, non-visible image, and terminology were positively recognized for the infrared (blue bars) and x-ray (red bars) applications.

Overall, the respondent's comprehension of the properties of light and the information provided by non-visible light appears to be varied and imprecise. For example, at least 63% understood that x-rays penetrate the skin, but at little as 14% seem to know that visible light does not penetrate the skin. Furthermore, although visitors know some terminology concerning infrared and x-ray images, they show a limited familiarity with the respective imaging technology. Only a few respondents understood how infrared and x-ray images were made, or how non-visible light could be "seen." The interview data is inconclusive for determining whether or not people are aware that the multi-wavelength properties of light make it possible to "see" different information about an object. Nonetheless, the utility of technological applications (infrared and x-ray imagery) was understood without a robust grasp of scientific properties of light; the data provided by the images (heat, bones) could be processed without understanding how multi-wavelength light was used to create the images. It is difficult to determine whether or not the respondents associate x-ray and infrared light with non-visible light.

Discussion and Recommendations

The primary goal of this evaluation was to gauge the level of public understanding of non-visible forms of light. However, we find ourselves unable to draw conclusive results from the data collected during these interviews.

Inconclusive interview data may be the result of overly general and unsuitable questions. For example, when asked, "Why can you see bones in the bottom image but not in the top one?" many visitors said that x-rays allow the bones to be seen through the skin. This response does not reveal whether the interviewees understand the properties of x-rays that allow the bones to be seen through the skin. To follow this question, we spontaneously asked some respondents if they knew why x-rays enable us to see bones through the skin. Future interviews should include specific questions that determine whether the public can define an x-ray in terms of light and if they understand how x-ray technology (e.g., medical x-ray equipment) functions. The responses to these questions should be treated as categorically as possible to highlight areas of high and low knowledge concerning x-rays and x-ray technology. It is also not clear whether respondents understand that the infrared images register emitted light, while the x-ray light in medical examples is typically projected through an object to create an image that indicates absorption. Future interviews should include questions to evaluate how readily people recognize emitted versus absorbed light. We anticipate that the proposed exhibit would benefit by exploring the distinctions between applications of emitted versus absorbed multi-wavelength light in astronomy.

The method of presenting images is crucial to ascertaining how people comprehend the differences between visible and non-visible light. Asking non-comparative questions, while showing paired images of objects in both visible light and infrared/x-ray caused confusion. For example, when shown images of a hairdryer in visible and infrared light side-by-side and asked whether the hair dryer in the former image was on or off, respondents looked to the infrared picture to determine if the hairdryer was on. As such, it was not always clear that respondents made distinctions between information provided by visible versus infrared light (i.e., that you can't "see" heat in visible light). We suggest that the images be shown separately before asking comparative questions that require both images.

We suggest that at least one additional session of interviews be conducted. These interviews should reflect the changes, refinements, and adjustments to questions and the use of images as discussed above. We believe further interviews may provide a more categorical and conclusive survey regarding what Adler's visitors know about the nature of light and multi-wavelength imaging instruments.