Seeing the World in a Different Light: Infrared

Nicholas Wood

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Big Ideas:

Light, infrared, ultraviolet, x-rays, radio waves, gamma rays etc. are all the same thing: electromagnetic radiation, they only differ in that they have different wavelengths (different amounts of energy). The visible light we see is only a tiny sliver of the EM spectrum.

There is much more around us in the world and the universe than we can perceive with our senses. Our eyes and other sense organs evolved to help our survival in our day to day environment. To learn about things beyond our every day world, we can use special instruments to "see" what we normally could not.

Cameras that can see infrared have many uses in science and technology.

Science behind the concept:

Visible light is a small part of the electromagnetic spectrum, with wavelengths of ~700 to 400 nm. Blue light has shorter wavelengths, red light longer. EM radiation with a slightly longer wavelength than red light is infrared, meaning "below red." Objects with any heat at all radiate infrared, the more the hotter they are. Most of the infrared radiation around us, like the visible light, comes from the sun.

Infrared cameras and telescopes have huge variety of applications in science technology and and industry from TV remote controls to infrared astronomy. They are especially useful to astronomy by allowing us to see past cosmic dust in the universe. e.g. the Spitzer telescope.

Most digital cameras can detect near-infrared light. By removing the infrared filter and using a visible light filter, you can use the camera to explore some aspects of infrared, e.g. you can see the infrared flashes which are emitted from TV remotes, and a visible light filter or a pair of sunglasses, which appear dark in visible light, look clear since infrared passes easily through them.

Concepts:

The electromagnetic spectrum: light is only one type of EM radiation, just like different wavelengths of light give different colors, different wavelengths beyond visible light give different kinds of radiation.

Infrared is another kind of EM radiation with wavelengths just longer than those of visible light. Our eyes cannot see it, but we can sense it as heat.

Even though we can't see it, infrared radiation is all around us. The sun and other starts give it off in addition to visible light, and any object that has heat gives off some infrared.

Though infrared is invisible to the naked eye, there are instruments that allow us to see it.

You can see heat with infrared, so infrared cameras help you see you both non-living things (such as engines) and living things (such as animals) give off heat.

Different plants and different surfaces reflect infrared differently, so aerial infrared photographs tell you a lot about the vegetation patterns etc. of an area.

Infrared telescopes are very helpful to astronomers because they allow them to see through cosmic dust which blocks visible light to see many more features of the universe.

Infrared waves can be used like radio waves to send signals. This is how a TV remote control works.

There are things that cannot be seen with the naked eye, but still very much exist and have effects that we can observe.

Connections with SciTech:

Current SciTech exhibits which tie in with infrared would include the exhibits on heat, since heat produces infrared radiation, and the sun telescope and other light exhibits, since it involves ideas about the electromagnetic spectrum.

As far as *Outreach to Space* exhibits, the best connection is with the gas emission spectra exhibit, since it deals with the concept of a spectrum of wavelengths, and also suggests ways astronomers use EM radiation to learn about distant objects, in this case, learning about stars from their spectra.

Connections to other sponsors:

Other U of C projects: Research done at NASA infrared telescope facility, SOFIA

Hands-on activities:

Using a small digital camera as described above, with a video screen, visitors could explore the world in infrared, with various objects to look at with the camera. A remote control is a very cool demonstration of this, as are filters and sunglasses, which pass visible light but not infrared, and vice-versa. Also other objects that reflect light and infrared differently, e.g. some dark objects (and also plants) reflect a lot of near

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infrared and look white.

Panels with a normal photograph of an object that can be lifted or slid over to reveal an infrared image of the same object (see below).

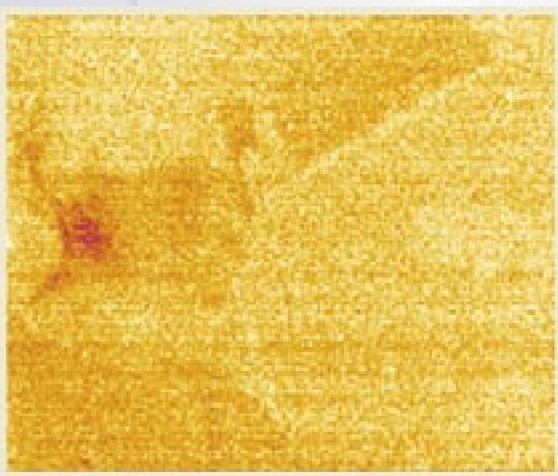
Visualizations/graphics:

As a complement to the infrared camera, examples of heat infrared images would illustrate more of what could be learned from infrared. Sets of pictures, one in visible and one in infrared are a possibility, perhaps with a panel that could be lifted up to show what the object looks like in infrared. Some pictures would be of everyday objects: people, hair dryer, car, animals; some aerial (landsat) infrared photos; and astronomical photos (the one of Orion is particularly striking) to illustrate how astronomers use infrared.

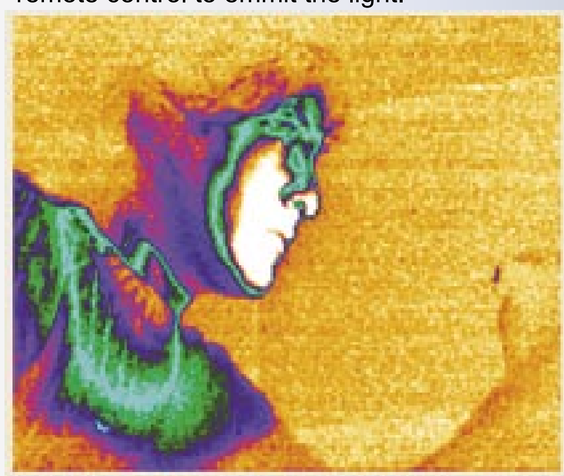
An illustration of the size of different wavelengths in the spectrum, from the size of a molecule to the size of the earth.

Camera output in BW with no ir light

Camera output in BW with the use of a ir remote control to emmit the light.



Camera output with image proccessing with no ir light *



Camera output with image porccessing with the use of a ir remote control to emmit the light.*

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Changing Your Mind About the Universe

Chaz Shapiro

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Big Idea:

The history of science, astronomy in particular, can be realized as the periodic abandonment of old ideas which could not explain new observations.

Science

The main science concept is to understand models – given an observation, the learner must decide which model is correct OR reject a model based on evidence.

Exhibit components:

a. The Earth is NOT flat

- i. Ship's mast appears first on horizon (Aristotle)
- ii. Star heights vary with latitude (Aristotle)
- iii. Shadows in Syene and Alexandria (Eratosthenes)
- iv. Lunar eclipses (Aristarch of Samos)

b. The Earth is NOT at the center

- i. Retrograde motion of planets (Copernicus 1543)
- ii. Jupiter's moons justified Earth-moon system (Galileo 1609)

c. The Sun is NOT at the center

- i. Cluster distribution (Shapley 1918)
- ii. Differential rotation of nearby stars about galactic center (Oort 1927)
- iii. Interstellar extinction (Trumpler 1930)
- iv. Sagittarius is radio loud (Jansky 1932 - after acceptance)

d. Galaxies are NOT stationary – or – the Universe is NOT static

- i. Hubble's discovery of expansion (1929)
- ii. Einstein's GR predicts dynamic Universe

e. Most matter is NOT luminous – dark matter

- i. Cluster binding energy (Zwicky)
- ii. Galactic rotation curves
- iii. Lensing, CMB

f. The Universe is NOT decelerating

- i. SNe Ia data (1998)

ii. CMB (WMAP, SDSS 2003)

Possible connections to Sci-Tech

a. Current exhibits about space seem to teach a physical concept – these may compliment this exhibit since the learner must use some physical concept to judge a model.

b. The *Outreach to Space* exhibits (which are about space travel, not astronomy) may add meaning to this exhibit. The amazing things we see in telescopes are actually “there” in the sense that we may travel to them. The laws that govern them are the same laws that exist on Earth and on the way.

Connections to other sponsors

a. Kavli – does research in dark matter, dark energy

b. Flash

c. Geowall – may be used to illustrate the shape of the Milky Way

d. Other

Related, fun, hands-on activities for the exhibit – still thinking about this

Visualizations, graphics

a. Dark Matter might be demonstrated by exciting a collection of black and white ping-pong balls under a blacklight. Only the white balls are visible. The motion of the white balls will appear mysterious – it should be clear that they are not the only objects involved. A setup containing only white balls could be used for comparison.

b.The shape of the galaxy could be demonstrated using panoramic images of the Milky Way (eg. from 2MASS). We immerse the learner in a wrap-around display and ask him to guess the shape of the collection of stars he is in. There could be 2 versions, one with dust and one without. Immersagrams might be a cool medium for this.

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KABOOM! The Big Science of Explosions

Dan Siegal

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Big Ideas

1. All explosions -- from the everyday small ones to the huge astronomical ones -- share the same characteristics.

2. How explosions are shown in movies or on television is not necessarily how they actually happen.

3. The Big Bang was not really an explosion.

Description of the science behind the concept

All explosions, be they from supernovae, nuclear bombs, dynamite, pop cans, or inflated balloons are essentially the same process: a release of energy in a sudden and often violent manner as the result of internal pressure, often with the generation of high temperature and a loud sound. The energy is released in the form of a pressure wave that (in free space) expands spherically from the point of explosion, and decreases with the 3rd power of the radius. This is not always the way that explosions are shown in movies or on television, and this is definitely not the way the Big Bang happened (see Sky and Telescope August 1993, or http://background.uchicago.edu/~whu/).

Connections to SciTech

Currently SciTech does not have any exhibits on Big Bang cosmology, nor does it have any exhibits on the differences between how physical phenomena are shown/understood in the popular media and how they actually occur. There are a couple of exhibits related to the concept of "pressure": the hot-air balloon and the Outreach to Space exhibit on vacuum.

Connections to Sponsors

Both the Kavli Institute and the Flash Center are connected with this exhibit concept: the Kavli Institute through the Big Bang cosmology component, and the Flash Center through the supernovae visualization component.

Exhibit Description

The exhibit opens with an archway, on which is written the exhibit title "KABOOM! The Big Science of Explosions". The sides of the archway are made up of monitors showing famous explosions in the movies (e.g. Star Wars, The Matrix, Armageddon, Dr. Strangelove, Star Trek VI, The Terminator, The Incredibles, …). It would be particularly useful to have video segments from movies that visitors in our target age group are familiar with. In the way that electronics store customers are attracted to the TV department when familiar movies are playing, similarly museum visitors can be attracted to the exhibit with familiar segments. It might also have the additional effect of “demystifying” the exhibit. This component of the exhibit is by no means necessary.

Inside the exhibit are computer stations where visitors can “explode” various objects (e.g. pop cans, nuclear bombs, stars) by pushing down on replicas of the plungers used to detonate TNT. Once a plunger has been pushed, a countdown appears on the screen, followed by a real-time movie/simulation of the object being exploded, and then a slow-motion video of the same explosion. The goal is to relate the explosions of everyday objects to the explosions of astronomical objects by using the same computer station interface for all simulations. Variations to this activity include the ability to vary the playback rate with a control knob, or allowing the visitors to adjust various explosion parameters.

The Big Bang component of the exhibit will have some information about what the Big Bang is, and why it is not like a “traditional” explosion. There will be mention of the contest held by Sky and Telescope magazine for the renaming of the Big Bang with some of the suggested names posted, and a suggestion box and papers so that visitors can make their own name suggestions. Suggestions will be posted on a corkboard.

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You Be the Scientist.

Jennifer Gaskins

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Big Idea

Scientists develop theories by collecting facts, considering models that explain the facts, and rejecting models that are inconsistent with the facts

Science and/or technology behind the concept:

There can be more than one model that explains known facts.

(A person's experiences along with prevailing cultural attitudes influence the model he/she creates.)

Throughout history scientists have modified theories as new information became available.

Examples:

- flat earth model ➔ spherical earth
- geocentric universe ➔ heliocentric universe
- newtonian gravity ➔ general relativity
- Greek atom ➔ Thomson atom ➔ Rutherford/Bohr atom ➔ Schrodinger (quantum) description
- static universe ➔ steady-state universe ➔ big bang/inflation

Ideas appropriate for SciTech exhibits:

See below.

Connections to SciTech

a. With their current exhibits – I'm not aware of any current exhibits which deal with the scientific process.

b. With the new Outreach to Space Exhibits – most cosmology is done from the ground, but instrumentation could be included.

Connections to other sponsors

a. Kavli – since this exhibit concept deals with the scientific process, almost any research could be connected. Particularly accessible research might be: CMB, prediction of substructure, and cosmic rays.

b. Flash – again, could treat the scientific process.

c. Geowall – could use Andrey's simulations for structure formation or an Auger air shower event

Hands on activities for the exhibit

Provide lab coats so visitors can dress the part.

• **Experiment:** An item or simple system is enclosed in a box (ex. sand, liquid, a simple circuit with contact points on the outside, a tube or labyrinth that a small marble could go though with various openings to the outside of the box). Visitors could shake, feel, or use tools to "test" what's inside the box. A few models are presented; visitors need to choose which ones are possible and which are ruled out by their experiments. Include at least one box for which 2 models are possible. This also ties into cosmologists' challenge of learning about something without being able to see or touch it directly.

• **Quiz:** visitors consider historical models (solar system, atom, or even modern cosmology) and historical evidence/arguments (such as Olber's Paradox). Small models or other tangible information, along with relevant observed facts are provided. Visitors eliminate models based on consideration of evidence. This could involve computer software to make a more high-tech interactive experience or simply lifting a panel to check answers.

• **Puzzle:** scientific evidence for various models is presented as pieces of a puzzle. The central piece has the name and a picture of the model. Only puzzle pieces with evidence supporting that model fit together with it.

Visualizations, graphics

Geowall or computer software as mentioned above.

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The Sun and Stars

Header Hudec

Big Idea:

The sun is a star.

Description:

The exhibit would get the point across that our sun is a star similar to those we see in the night sky. This is a fundamental concept of astronomy of which, sadly, many people are not aware. An exhibit aiming to bring about an understanding of what our sun is, namely that it one star among billions in the universe, would put into perspective our place in the universe, serving as a foundation for understanding more complex astronomical concepts.

This concept need not be a stand-alone exhibit but could be incorporated into another exhibit regarding the sun and stars. Its importance is in that it is a key point which needs to be understood in order to allow for a clear understanding of more complex concepts.

Components:

- The concept of scale would need to be illustrated to get the point across that our sun is a star similar to those we see in the sky. An exhibit could illustrate what a star, (the one nearest our solar system), looks like standing on the earth; children could then move to other side of the exhibit which would illustrate what our sun would look like if you were standing on a planet in orbit around the 'star'.
- Another components could explain what the sun/stars are composed of, why they have no surface and why they give off energy.
- Also, a description could be given regarding the life cycle of stars and different types of stars.

Connection to Sci-Tech:

a. current exhibits –Sci-Tech is currently working on exhibits that would include a solar telescope as well as Geowall exhibits of journey through space and the solar system. The sun topic ties in with the solar telescope to give visitor a better idea of what they are viewing and the perspective aspect goes along with journey through the universe and solar system Geowall exhibits.

b. outreach to space – uses telescopes to view stars, this exhibit would help people get a better understanding of what they are looking at.

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Connection to sponsors:

a. Kavli – understanding stars is the first step in enabling kids to understand the grander concepts of cosmology

b. Flash – would connect with the explosions and lifecycle of a star

c. Geowall – could be used to demonstrate the perspective aspect

Activities to consider:

• The aspect regarding perspective as to whether you are on earth or on a planet in another solar system could be made interactive by requiring kids to move from one location to another to gain each perspective.

Visuals, Graphics

• This exhibit concept could be illustrated through the use of GeoWall, whereby a computer program could allow one to "travel" from our solar system to another and view the night sky from both perspectives.

• This concept could also be demonstrated through an exhibit whereby one side illustrated one perspective and the other side illustrated the other perspective.

• Visual images of stars at different stages depicting the different kinds of star.

Impact of Cosmic Event on our Daily Lives

Anshu Dubey

draft 01.05

Introduction

We all know about the impact some of the space objects have on our lives. For instance, without the sun, there wouldn't be solar system and life on earth. However, there are many cosmic events that we never associate with ourselves. They happen too far away and don't seem to have any impact on us. The fact is that a lot of cosmic events have an impact on day to day lives, in many unexpected ways. They could be happening on the sun, or they could be happening far away in deep space. This topic is an extremely important one in presenting space science to public. However, it doesn't have much merit as an exhibit by itself. Instead it could be used to enhance some of the pre-existing exhibits, and even those that are being proposed by the current group.

Connection to exhibits

This topic covers a wide range of science and technology. Some of the examples are:

1. Tides because of relative motion of moon and sun
2. Solar eclipse and disorientation of animals and birds.
3. Solar Wind and flares: Power surges, changing the orbits of satellites, disruption in communication, shortening of mission lives etc, geomagnetic storms
4. Cosmic rays: Changes in weather through cloud formation, disruption in computer memory.

Of these, the formation of clouds by cosmic rays and geomagnetic storms tie up with the weather exhibit, Also the fact that rain absorbs microwave and causes disruption in communication. Satellite orbit change and mission life change and disruption of memory in spacecrafts are directly connected to the "outreach to space" exhibit. Similarly there is plenty of material here for tie-up with the current proposals, specifically with "Sun" and "cloud chamber". Solar flares are caused by explosions on the surface of the sun, and as such have connection with the "explosion" concept as well.

Connection to Sponsors

Since it is a really broad topic, there are connections with all our sponsors. Kavli and FLASH both have connections with cosmic rays, and solar convection and mhd are being studied by scientists at UofC. Solar flares would form extremely fascinating visuals for the GeoWall. The Imax movie called "Solar max" has some truly spectacular visuals of solar flares, as does NASA website. There are also movies from simulations of solar convection that can be obtained from FLASH.

Activities

We could borrow from the planetarium quiz format for matching question with answer, and add a little graphic display of the phenomenon, when they match. We could also add an exhibit called solar weather station in the weather section, similar in character to all the other ones (lightening, flashes etc).

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Sizing Up the Solar System

Brenda López

Image source: http://gw.marketingden.com/planets/planets.html

Big Idea

Few school children comprehend the actual scale of the Solar System. Using an interactive VR game format, the distance between the sun and each planet; and planets and their moons or other satellites can be demonstrated. Distance and relative size of the planets can be conveyed through artistic perspective. Speed of light is also presented.

Science behind the concept

The speed of light can be an effective means of presenting distance in space; specifically, the time it takes a beam of light originating at the sun to reach each planet in the Solar System. However, a real-time simulation of traversing the Solar System at the speed of light is infeasible as a hands-on exhibit because traveling as a light beam from sun to Pluto would take 5.3 hours. Perspective is an equally effective means of presenting distance in space, and more feasible given the limitless possibilities of navigating Space in VR.

I propose designing an interactive VR program with three distinct scenes; the first presents the entire Solar System and speed of light concepts. The second scene is a user controlled game which puts the user on a straight trajectory from the sun intercepting each planet as they move forward through space. As the user lands on each planet, the relative scale between the other planets and the sun can be observed. The perspective continues to change as the user progresses. Along the way, the user can find descriptive signs for each planet, satellites and interesting facts. The third scene is a 'virtual vacuum' that spins space down into an environment such as a garden, where the planets appear in relative distance from the user.

SciTech exhibits

A GeoWall installation already exists at SciTech. Design of an interactive VR game that a non-expert user can easily handle.

Connections to SciTech Hands-On Museum

Currently SciTech has a floor mat to represent the size of the solar system where visitors (especially kids) can jump and compare the planets.

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Related fun hands on activities

A large-scale comparative matrix of common objects (light bulb, marble, balls, etc.) to describe the relative sizes of the planets to the sun.

See what people would like to see*

Visuals, Graphics

- "The nine planets" is one of the most popular Solar System visualizations.
- SSS (Solar System Simulator) offers a clear and interactive way of analyzing the solar system in VR.

References

*** The Thousand Yard Model, or the Earth as a Peppercorn**
http://www.noao.edu/education/peppercorn/pcmain.html

This is a classic exercise for visualizing just how BIG our Solar System really is. Both the relative size and spacing of the planets are demonstrated in this outdoor exercise, using a mere peppercorn to represent the size of the Earth.

*** Solar system size calculator**
http://www.exploratorium.edu/ronh/solar_system

http://www.exploratorium.edu/ronh/solar_system/index.html
The Exploratorium page explains different ways to make a scale model of the Solar System to learn the real definition of "space."

*** What people would like to see**
http://www.vendian.org/mncharity/dir3/solarsystem
a. A web-based "spreadsheet" which allows one to give/take objects (lightbulb, marble, various balls, etc), rather than just measurements.
b. Scaled orbital and solar system velocities too, even though they are rather small in real-time.
c. Adjustable time so one can `run around the room for five years.'
d. Kid-accessible descriptions of "invisible" solar system structure (solar wind and planetary envelopes and wakes)
e. Light issues (running around at light speed, truncated light cones from flashing flashlights, etc)
f. A visual spreadsheet webpage. So a `not necessarily numerate child' (though I'd enjoy it too) could just click among `If the Sun (picture) is the size of a: [light bulb (picture)], [pin-head (picture)], Earth the size of a: [globe (picture)], etc. and get a diagram of the solar system - pictured on a desktop if it fits, or in a room, or amidst cars and buildings, an air-photo of a town, a map, the Earth, etc. With appropriately sized objects suggested for the planets and such. If the page took a background image URL and meter/pixel number, folks could create links customized with local maps.

The Size and Distance of the Planets
http://cse.ssl.berkeley.edu/AtHomeAstronomy/activity_10.html
In this activity, you'll investigate the concepts of relative size and distance by creating a basic model of our Solar System.

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