The Spitzer Space Telescope represents the infrared segment of NASA’s “Great Observatory” program. Working outside of the visible spectrum presents a set of challenges in clear communication of astronomical concepts, some of them unique to this powerful telescope. We present a number of case studies of challenges for press release visualization, including visual representation of infrared data, presenting spectra, producing meaningful artwork and illustrations, and approaching non-standard image problems.

The Spitzer Space Telescope is the most powerful infrared observatory to date. Building on the extensive legacy of such instruments as the Infrared Astronomical Satellite (IRAS) and the Infrared Space Observatory (ISO), Spitzer has opened the door to a new era of infrared imaging and spectroscopy. The span of Spitzer’s infrared reach is illustrated in Figure 1. The three instruments on Spitzer include two capable of imaging, the Infrared Array Camera (IRAC) and the Multiband Imaging Photometer (MIPS), as well as the Infrared Spectrograph (IRS). Since Spitzer has no filter wheel (or in fact no moving parts) there are a set number of bands observed by this telescope.

**SEEING INFRARED**

**ABSTRACT**

**CHALLENGES OF SPITZER**

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The Spitzer Space Telescope represents the infrared segment of NASA’s “Great Observatory” program. Working outside of the visible spectrum presents a set of challenges in clear communication of astronomical concepts, some of them unique to this powerful telescope. We present a number of case studies of challenges for press release visualization, including visual representation of infrared data, presenting spectra, producing meaningful artwork and illustrations, and approaching non-standard image problems.

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**Figure 1.** Spitzer’s Infrared Window. The wavelength coverage of the Spitzer Space Telescope is shown in comparison to visible light.
The scientific context of Spitzer is also indicated in the backdrop of Figure 1. The wavelength range spanned by Spitzer detectors is shown relative to visible light and near-infrared the J, H, and K bands (commonly observed from the ground). Behind this are two curves approximating the relative strength of starlight and dust emission. Spitzer picks up on the long wavelength side of stellar blackbody radiation and extends throughout the regime of complex molecules and dust emission.

Infrared observations can take an astronomically familiar object and reveal striking new views of it. Perhaps most apparent is the fact that dark, obscuring dust clouds become increasingly transparent, and ultimately luminescent, at longer wavelengths of light. Spitzer can thus peer deeply into visibly hidden regions and map the distribution of dust within the Milky Way and beyond. Infrared observations sample the more numerous base population of smaller, cooler stars better, tracing the underlying mass distribution in galaxies.

The primary imaging instrument on Spitzer is IRAC. It consists of four 256x256 detectors with each one sampling a set wavelength (3.6, 4.5, 5.8, 8.0 microns). There is an offset between the area covered by the 3.6/5.8 and 4.5/8.0 micron detectors, so full spectral sampling of an area requires multiple observations at different pointings. IRAC images are easily expanded over large areas by mosaicing dozens, even thousands, of individual images.

At the shortest of the IRAC wavelengths, starlight is the primary contributor in most observations, or more generally the blackbody radiation from objects at temperatures of thousands of degrees Kelvin. This drops off quickly, and in the longer wavelength channels IRAC easily detects the emission from “polycyclic aromatic hydrocarbons” (PAHs), a common family of organic molecules that is ubiquitously associated with dust clouds. There are other emission features from hot gasses that show up in the various channels, and a particularly strong line from hot hydrogen gas is often seen in the 4.5 micron channel.

Images made from IRAC, or indeed any infrared detector, are by necessity “false” colour. The detector images must be mapped into colours that the human eye can perceive. IRAC images produced for media/outreach purposes generally use all four channels. Since the human eye only distinguishes the three colours red, green, and blue, at least one channel must be mapped to an intermediate colour. The colours are chromatically ordered, with the shortest wavelengths being represented by the bluest colours, and so forth. This provides the most natural-looking images and is better representative of what human vision would perceive if it were shifted into this infrared band.
A colour IRAC image of the starforming Tarantula Nebula is seen in Figure 2. This image uses a colour mapping of 3.6, 4.5, 5.8, and 8.0 microns mapped to blue, green, orange, and red respectively. This choice has proven to be well suited for virtually all IRAC images. Stars appear blue as they are brightest at the shortest wavelengths. The PAHs are strongest at 5.8 and 8.0 microns, so they are mapped to similar red/orange colours. In regions like this with hotly-ionized hydrogen gas, the 4.5 micron feature shows up very distinctly as green. Since the IRAC bands are fixed, we have chosen to use this colour map consistently for virtually all IRAC imagery. The greatest advantage is that the image colours correspond to the phenomena noted previously, and that the IRAC images on the Spitzer site can be meaningfully compared to one another.

Our workflow is now based on the FITS Liberator plug-in (developed in collaboration between ESA/ESO/NASA) and Adobe Photoshop. The raw astronomical data is taken either from the Spitzer archives or directly from the principal investigator who may have performed advanced cleanup processing on it. Each channel is read into a separate Photoshop layer using the FITS Liberator. In the case of high dynamic range datasets, an appropriate stretch function is selected to enhance faint structure without burning in bright regions. The same stretch is used for all channels to maintain meaningfully consistent colour. Any final alignments between layers are made using Photoshop tools. Colours are assigned to each layer and they are combined using the "Screen" blending mode.
The long-wavelength MIPS instrument extends Spitzer’s imaging capabilities to wavelengths of 24, 70, and 160 microns. Thermal blackbody emission from dust dominates at these wavelengths. MIPS presents a set of unique challenges public imagery. Basic physics dictates that the resolving power of a telescope is determined by the ratio of the wavelength of light being observed and the diameter of the telescope mirror. For Spitzer this is a fixed diameter of 83 cm. Therefore, compared to a 24 micron image, a 70 micron image will be about 3 times blurrier, and at 160 microns that increases to a factor of 7. Because of the dramatic variations in resolution, multi-band colour composites are not practical for MIPS data. For the composite to be meaningful, all of the data would need to be convolved to match the lowest resolution. For public imagery we usually choose to present only the 24 micron image due to its relative clarity.

A MIPS image of the DR21 starforming region is shown in Figure 3. The image is in colour though we are only presenting a single channel of data. Because colour images are more visually appealing than greyscale ones, MIPS 24 micron pictures are generally produced using a pseudocolour gradient applied to the greyscale values. We have chosen a so-called “heat” gradient for MIPS images, mimicking the range of colours seen due to thermal emission from an object at increasing temperatures. Because this colour gradient has an intuitive connection with thermal processes, it seems well-suited to use with these images that are showing the thermal emission from clouds of dust almost exclusively.
In some cases when a region has been observed by both the IRAC and MIPS instruments, it is desirable to make a single image that combines both datasets. This can be particularly instructive in highlighting the differences between the PAH emission (primarily from organic molecules on the outsides of molecular clouds illuminated by nearby stars) and the thermal dust emission. The first can show the extent of a cloud surface, while the latter can probe the heat distribution through the cloud. The Spitzer IRAC/MIPS view of the Trifid Nebula is shown in Figure 4. In this image, the starlight at 3.6 and 4.5 microns is mapped to blue and cyan, the PAH emission at 8.0 microns is mapped to green, and the warm dust emission at 24 microns is mapped to red. The 4.5 micron channel was added in as cyan to help brighten up the starlight. Pure blue does not appear bright even on a good monitor, and prints very darkly, so bringing in more cyan greatly improves visibility of the stars. The 5.8 micron channel (which still has a somewhat strong contribution from stars) was dropped so that the PAHs would stand out as vividly green in the 8.0 micron channel (where the starlight is almost gone). Thermal dust emission is red, and regions with strong PAH and thermal dust blend to yellow. Note that the resolution limits discussed for MIPS affect this image. The 24 micron image is also 3 times blurrier than the 8.0 micron image. Even though resolutions are mismatched, visually the image is not degraded since the eye will readily focus on the bands of higher resolution. The lower 24 micron resolution can even help pick out a significant science result: very young stars are surrounded by envelopes of very warm gas that is especially bright at 24 microns. Since the longer wavelength image is blurrier, these protostars jump out due to their red haloes.
While consistent colour mapping has many advantages when creating a library of easily compared images, sometimes unusual situations do crop up. In these cases, different techniques can create useful images for print. In a recent press release, Spitzer detected a “light echo” in the dust clouds around a supernova remnant. The observations consisted of two MIPS images of the same part of sky taken a year apart. Flipping between the two images, it is easy to see a substantial shift in the illumination of the dust clouds around the remnant. This was easily captured in an animation accompanying the press release, but a good print representation was required as well. Unfortunately the motion is sufficiently subtle that it is hard to detect when the images are viewed side-by-side. A different approach is shown in Figure 5. Here the observations from the two epochs are combined as two complementary colours, cyan and orange. Anything that is identical in the two images comes out as greyscale (since adding two complementary colours yields white). However, the offset of the echo in the two source images splits into two colours in the combined image. At a glance, colour now provides the cue about what has changed between the two images. With proper colour choices, this technique can in principle be extended to cover 3 or more observing epochs.

Some of the most fundamental science from Spitzer is the result of analysis of spectra from the IRS instrument. Unfortunately the general public cannot readily interpret a spectrum (or often graphs of any kind). Features indicating the presence of various compounds are difficult to recognize in the context of the basic graph, and are visually unappealing to all but the most devoted astronomy enthusiasts. When a fundamental Spitzer result is interesting enough to warrant publishing the original spectrum as part of the press release, the goal is to package it visually in a way that aids a non-technical viewer in its interpretation. This can involve a combination of three techniques: 1) colour code features in the spectrum, 2) add astronomical images of
the object from which the spectrum was derived, and 3) include artist’s visualiza-
tions of the inferred result.

Figure 6 presents an example utilizing all three techniques. In this IRS result, spectra
from known protoplanetary disks around young stars were found to have ice-coat-
ed dust grains, potentially providing the building blocks for comets, atmospheres,
and someday, life. Two similar spectra from similar objects are included, and the ice
features are colour-coded and labelled. Behind each spectrum an inset shows the
Hubble image of the corresponding disk. The backdrop is an artist’s concept of an
ice-coated dust grain, rendered with depth-of-field to imply small sizes. The goal is
that, taken together, these visual elements will help the casual viewer understand the
basic nature of the result, connecting it to the data (at least in an abstract sense).

Many astronomical observations can imply a relatively spectacular result, but in a
very indirect manner. In these cases it is often desirable to provide an artist’s visual-
alization, a still image and/or an animation, to communicate the result in a more excit-
ing way. Moreover, such a visualization can often convey a variety of complex ideas
that would be very difficult to put into words alone.

In a recent press release, two Spitzer researchers detected light from two known
planets around other stars directly. The systems are very similar, with the planets
orbiting their stars in around three days. The planets’ orbits are aligned to our view
so that they pass directly in front of and behind their stars. The dip in the stars’ light
(caused by the transit of the planet in front of the star) had already been established, but Spitzer detected the dip in the systems’ total light when the planets passed behind their stars for the first time ever. In order to allow the audience to understand how the data plot is related to this result we would need clear visualization aids. The scientists presented these results in a live press conference, so we produced two animations to assist their explanations on a variety of science points.

In all such artist’s visualizations, we first define a set of science/education goals that need to be evident in the final product. The visualizations are developed in such a way as to adhere to these goals, but also to be as aesthetically appealing as possible given these constraints.

The goals of the first animation (Figure 7 a-b) were to convey the following points: 1) In visible light the planet is seen only in reflected sunlight, 2) in infrared light the planet glows on its own, 3) the brightness of the planet relative to the sun is much higher in the infrared, 4) the planet is very large and very close to its star. To address these, we start with a visible light view of the system, and switch to an infrared view. The relative colours are chosen to reflect real changes in colour due to two objects at very different temperatures. Even the cloud patterns, which do not look like Jupiter, were artistically adapted from a research paper showing results of computer models of the atmospheres of so-called “hot Jupiters.” For the second animation (Figure 7 c-f) the goals were to convey: 1) the eclipsing geometry of the system, and 2) show how the total observed light from the system drops as the planet moves behind the star. The 3D simulation of the system, shown from above and from the line of sight, helped establish our viewing angle. By overlaying an animated graph of the combined light of the system, the drop in light associated with the secondary eclipse of the planet helped clarify the data plot shown afterwards.
In these case studies for the Spitzer Space Telescope we have surveyed some of the logic applied to our scientific visualizations. These represent one set of solutions that we feel have worked well for specific problems faced in Spitzer press releases. The astronomical community must continue to push the boundaries of visualization in all areas, using its power to better educate and inform the public. As more powerful tools for image presentation, composition, and rendering become commonly available, the challenge is to develop new approaches to help people see and understand the Universe.