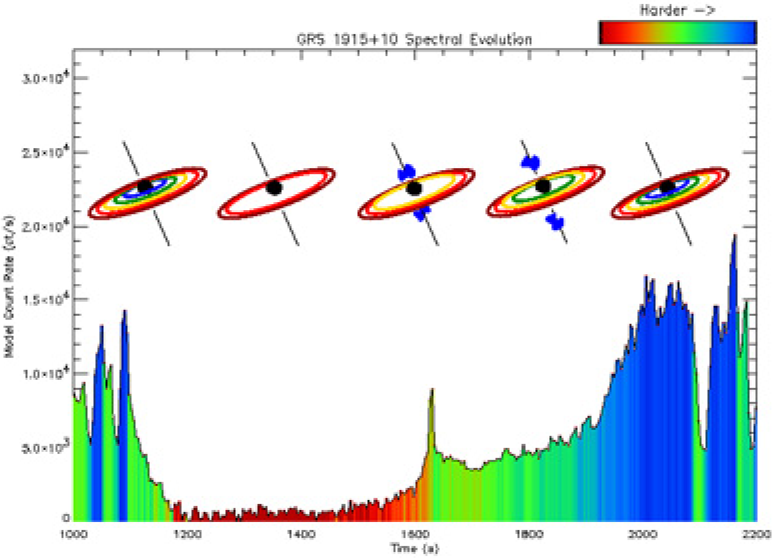
Satellite Data Results - Level 1

Black Holes -> X-ray -> Proportional Counter



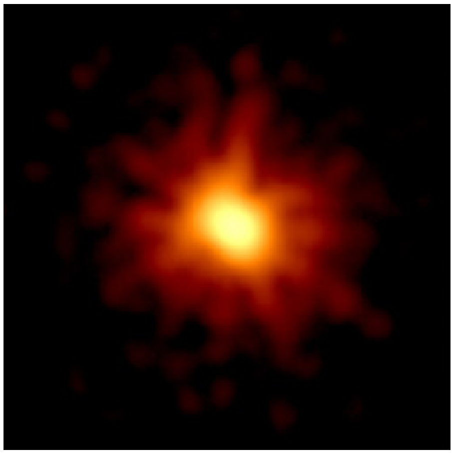
The data your satellite produces might look like this real data from the Rossi X-ray Timing Explorer's All-Sky Monitor, an instrument that has proportional counters. One of the types of graphs that can be made from the data a counter collects is called a light curve, which shows the intensity of the X-rays collected by the instrument over time.

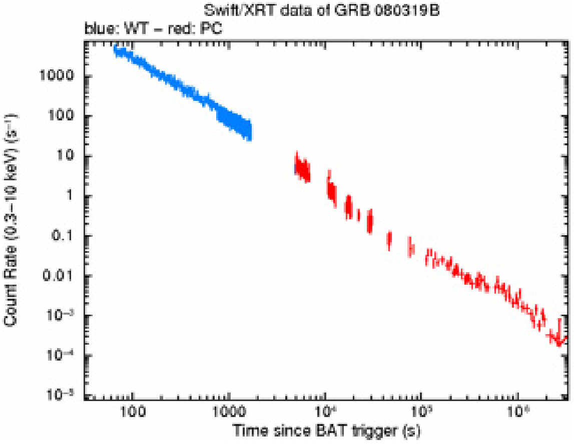
This particular light curve is from a black hole named GRS 1915+105. It has a disk of matter around it, called an accretion disk, which was transferred from its companion star. This black hole is unusual though, because every half hour or so it throws off the inner portion of its accretion disk, causing a jet that travels at relativistic speeds (near the speed of light). The accretion disk re-forms itself after each eruption as the black hole transfers more matter from its companion star. (This is illustrated by the diagram above the light curve.) This X-ray data, from 1998, showed for the first time that the inner part of an accretion disk could be completely disrupted, and ejected as a jet. It also showed that while black holes have strong gravity, the gas pressure and radiation forces in the inner portion of the accretion disk are powerful enough to completely overcome gravity and blow large amounts of material away as jets.

Learn more about RXTE: http://heasarc.nasa.gov/docs/xte/learning_center/index.html

Image Credit: NASA/Craig Markwardt

Black Holes -> X-ray -> Camera
AND/OR
Black Holes -> X-ray -> Spectrometer





The data your satellite produces might look like this real data from the X-ray Telescope (XRT) on the Swift satellite. The XRT is an imaging spectrometer, which means that it has the capability to be both an imager and a spectrometer, allowing the creation of light curves (intensity of light over time) and spectra (intensity of light over different wavelengths). The XRT has two main ways of recording the X-ray intensity, one suitable for bright objects (in blue on the graph, labeled WT) and the other for fainter ones (in red, PC). In PC mode, the XRT takes snapshot images every 2.5 seconds. They can be stacked up to create a clear image like the one of the left, or a light curve can be created from individual snapshots or groups of snapshots.

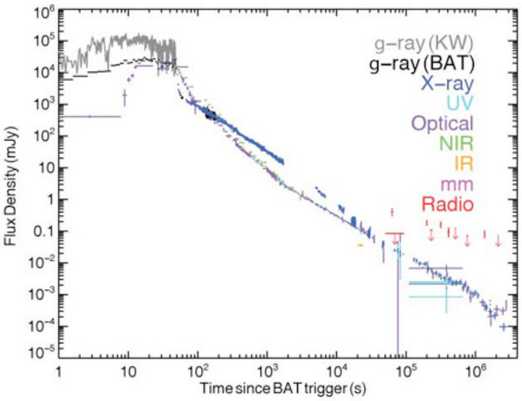
In particular, the XRT is used to observe the X-ray afterglow of gamma ray bursts (GRBs). GRBs are huge explosions in space, and scientists think they happen either when a very massive star explodes or when two very dense neutron stars collide. Either way, it's thought that a GRB signals the birth of a black hole.

Both the camera image (left) and light curve (right) show GRB 080319B, which was detected by Swift in March of 2008, though the original event occurred around 7.5 billion years ago. This GRB was so bright that not only did it have an X-ray afterglow, but it was visible to the naked eye for nearly 30 seconds! Scientists think that the afterglow was so bright because the GRB's gamma ray jet was focused in the direction of Earth. This allowed astronomers an unprecedented chance to examine its structure.

Learn more about Swift: http://swift.sonoma.edu/

Image Credit (left): NASA/Swift/Stefan Immler
Image Credit (right): This work made use of data supplied by the UK Swift Science Data Centre at the University of Leicester. Evans et al. (2007)

Black Holes -> Optical -> Spectrometer
AND/OR
Black Holes -> Optical -> Camera



The data your satellite produces might look like this real data from the Ultraviolet/Optical Telescope (UVOT) onboard the Swift satellite. It's rare for optical astrophysics to be done from smaller satellites because they are expensive to build, and ground observatories are capable of amazing optical observations; however, sometimes larger satellites will have a small telescope onboard capable of observing wavelengths complementary to its primary one. For example, the gamma ray satellite Swift has the UVOT, which has the capability to be both an ultraviolet imager and spectrometer, allowing the creation of light curves (intensity of light over time) and spectra (intensity of light over different wavelengths).

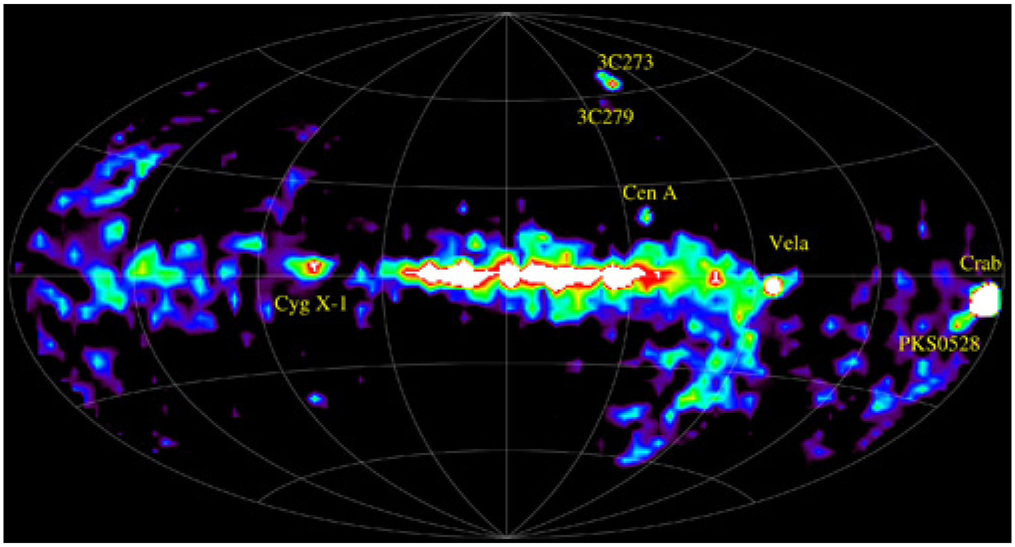
Additionally, in the case of Swift, having UVOT onboard is the best way to ensure having X-ray and optical data at the same exact time, something important for the study of gamma ray bursts (GRBs). GRBs are huge explosions in space, and scientists think they happen either when a very massive star explodes or when two very dense neutron stars collide. Either way, it's thought that a GRB signals the birth of a black hole. Though GRBs are bursts of gamma rays, they also emit light at other wavelengths; frequently, they have an afterglow that's visible in the X-ray, optical, and ultraviolet.

The UVOT captured this image of the optical afterglow of GRB 080319B (left), and also contributed data (both optical and UV) to this light curve (right). This GRB emitted light in nearly every part of the spectrum. By far the brightest GRB afterglow ever seen, it was so bright that it was visible with the naked eye for 30 seconds. This is incredible, considering this GRB explosion took place 7.5 billion light years away from the Earth. Never before has anything so far away come even close to naked-eye visibility. Scientists think that the afterglow was so bright because the GRB's gamma ray jet was focused in the direction of Earth. This allowed astronomers an unprecedented chance to examine its structure.

Learn more about Swift: http://swift.sonoma.edu/

Image Credit (right): NASA/Swift/Stefan Immler, et al.
Image Credit: (left) Nature/Racusin et al.

Black Holes -> Gamma-ray -> Scintillator
Galaxies -> Gamma-ray -> Scintillator



The data your satellite produces might look like this real data from the Imaging Compton Telescope (COMPTEL) instrument that was onboard the Compton Gamma Ray Observatory (CGRO). COMPTEL was the first instrument to survey the entire gamma ray sky; this all-sky map is the result.

This image shows that the gamma ray emission is very concentrated along the plane of our galaxy - this means that most of the gamma rays being detected come from inside the Milky Way. Bright gamma ray objects include Cygnus X-1 (a stellar black hole that is orbiting another star), Vela (a dense rotating star called a pulsar), and the Crab (the remains of an exploded star with a pulsar at its center).

Some of the objects visible here are actually outside of our galaxy. Centaurus A is a galaxy located about 11 million light years away. It is thought to have a supermassive black hole at its center with a jet that travels near the speed of light, and it also appears to be colliding with and cannibalizing another galaxy. 3C273 and 3C279 are quasars, a type of very distant (billions of light years away from us) active galaxy. An active galaxy is one that has a nucleus with higher-than-normal levels of emission, likely because of the presence of a massive black hole with an accretion disk at its center. When matter in the accretion disk spirals into the black hole, it is heated up by friction and strong gravitational forces to the point where emits radiation, often in the form of X-rays and gamma rays.

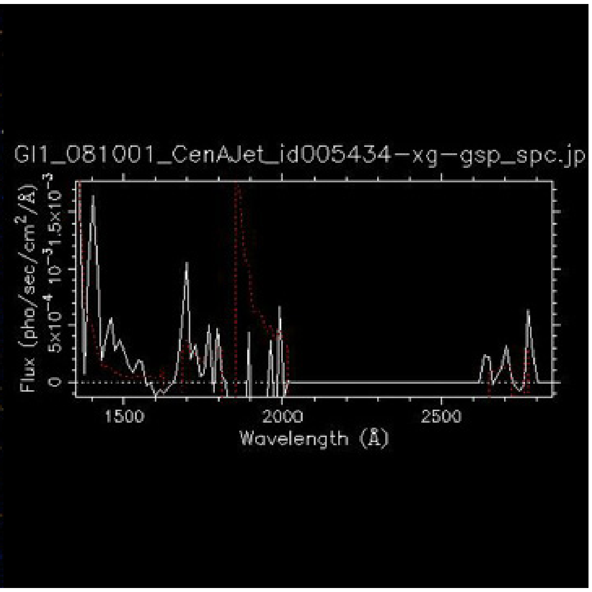
Learn more about CGRO: http://heasarc.gsfc.nasa.gov/docs/cgro/index.html

Image Credit: COMPTEL team, Max Planck Institute for Extrasolar Physics (MPE), Germany

Black Holes ->UV -> Camera

Black Holes ->UV ->Spectrometer

Star Formation -> UV -> Camera
Star Formation -> UV ->Spectrometer
Galaxies -> UV ->Spectrometer



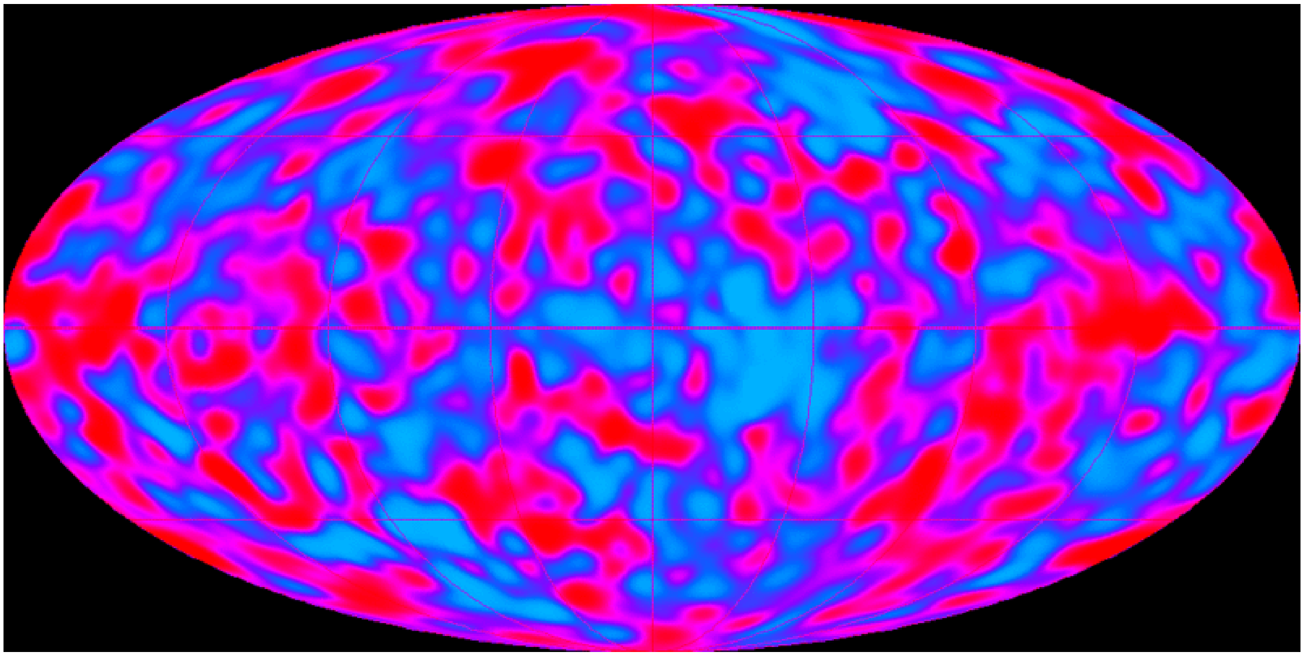
The data your satellite produces might look like this real data from the GALEX mission, which had a single instrument onboard that was both an imager and a spectrometer at UV wavelengths. Having just one instrument that can do multiple things is a good way to maximize science results on smaller missions where there may not be much money or space.

The image at left shows Centaurus A, a galaxy that contains at its center a black hole with powerful jets. The blue regions near the top of the image are star forming regions triggered by radiation, wind, and shocks caused by the jets interacting with surrounding clouds of dust and gas. The graph on the right is a spectrum, which shows the intensity of light over different wavelengths of Centaurus A's jet.

Learn more about GALEX: http://www.galex.caltech.edu/

Image Credit: (left) NASA/JPL-Caltech/SSC
Image Credit: (right) GALEX

Early Universe -> Microwave -> Radiometer



The data your satellite produces might look like this real data from the COsmic Background Explorer (COBE). COBE was a cosmology satellite that was launched in 1989. One of the purposes of the mission was to study the early universe to learn more about the cosmic microwave background (CMB) - that is, the radiation released after the Big Bang but long before the formation of galaxies, when the universe was less than 400,000 years old.

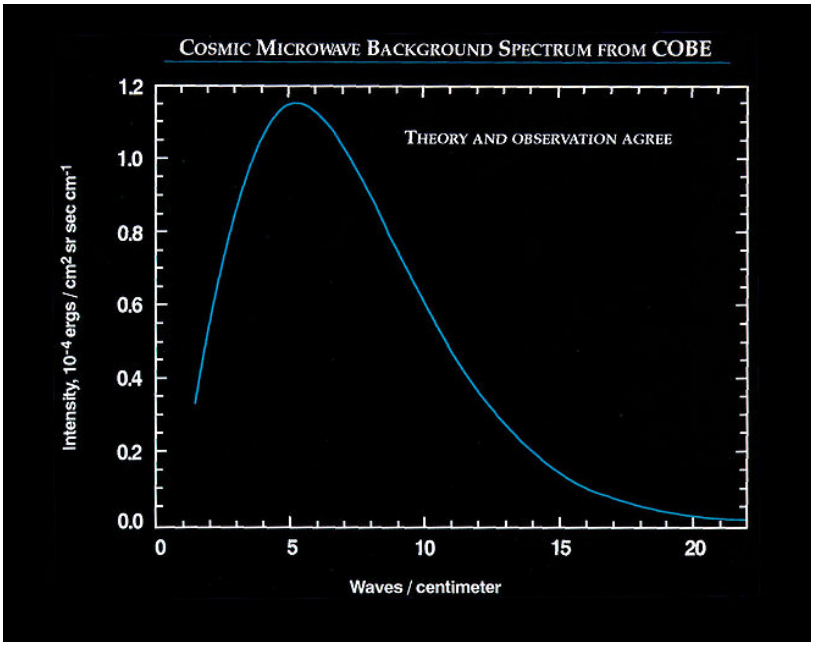
COBE had three instruments aboard: a radiometer to map variations in the CMB (DMR), a spectrophotometer to measure the spectrum of the CMB (FIRAS), and an infrared detector to map dust emission (DIRBE). COBE used its Differential Microwave Radiometer (DMR) to map the tiny variations in the intensity of the CMB over the sky to show how matter and energy were distributed when the universe was still very young. Through a process still poorly understood, these early structures developed into the galaxies, galaxy clusters, and large scale structure that we see in the universe today. The above image shows the first two years of DMR data.

These observations of the distribution of matter in the early universe (along with the calculation of the CMB's spectrum) provided important evidence to support the Big Bang Theory. George Smoot and John Mather, principal investigators for COBE's radiometer and spectrophotometer, respectively, shared the Nobel Prize in Physics in 2006 for their work.

Learn more about COBE: http://lambda.gsfc.nasa.gov/product/cobe/

Image Credit: NASA/COBE

Early Universe -> IR -> Spectrometer



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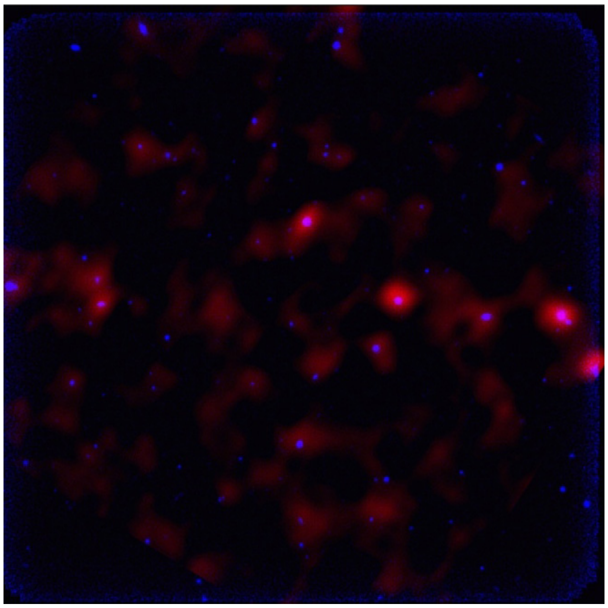
COBE had three instruments aboard: a radiometer to map variations in the CMB (DMR), a spectrophotometer to measure the spectrum of the CMB (FIRAS), and an infrared detector to map dust emission (DIRBE). Far Infrared Absolute Spectrophotometer (FIRAS) data was used to produce this spectrum (a graph of intensity of light over different energies) of the CMB, which turned out to exactly match theoretical prediction. This data is so exciting to cosmology that when it was shown at the January 1990 American Astronomical Society meeting, it received a standing ovation!

Both the observation of the distribution of matter in the early universe and of the CMB's spectrum provided important evidence to support the Big Bang Theory. George Smoot and John Mather, principal investigators for COBE's radiometer and spectrophotometer respectively, shared the Nobel Prize in Physics in 2006 for their work.

Learn more about COBE: http://lambda.gsfc.nasa.gov/product/cobe/

Image Credit: NASA/COBE

Early Universe -> IR -> Camera



The data your satellite produces might look like this real data from the Infrared Space Observatory (ISO), a European satellite launched in 1995. ISO had four instruments, including a camera (ISOCAM), a photometer (ISOPHOT), and two spectrometers (SWS and LWS). This image shows Infrared Space Observatory CAMera (ISOCAM) data at an infrared wavelength of 7 microns (red) combined with a ground-based image from the University of Hawaii's 2.2-meter telescope at an infrared wavelength of 2 microns (shown in blue).

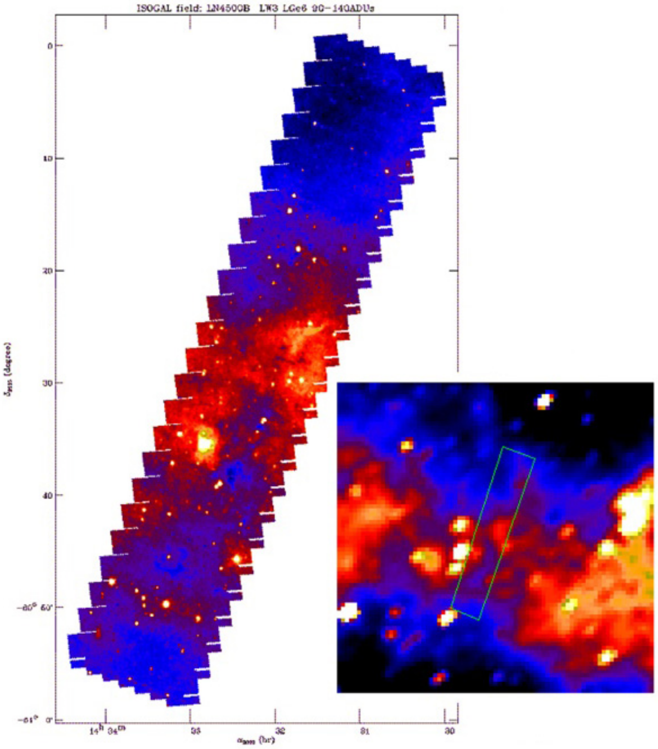
These galaxies may emit so strongly in the infrared because they are undergoing a period of rapid star formation; such galaxies are thought to arise from galaxy mergers and are called “starburst galaxies.” There are a remarkably high number of possible starburst galaxies (27!) in the small bit of sky shown in this image. Starburst galaxies are relatively rare amongst galaxies close to our own so these are likely very far away. Additionally, they are perhaps half the age of our own galactic neighborhood, dating back at a time when the universe (which has since expanded) was smaller and more crowded with galaxies, which made galaxy collisions more likely.

This area of the sky, located in the constellation of Ursa Major, is known as the Lockman Hole; it is essentially a window in the dust of our own galaxy, allowing us the clearest view outside of our galaxy and back into the past of our universe.

Learn more about ISO: http://www.esa.int/export/esaSC/120396_index_0_m.html

Image Credits: ESA/ISO and ISOCAM, University of Hawaii 2.2-metre telescope and Y. Taniguchi et al.

Star Formation -> IR -> Camera



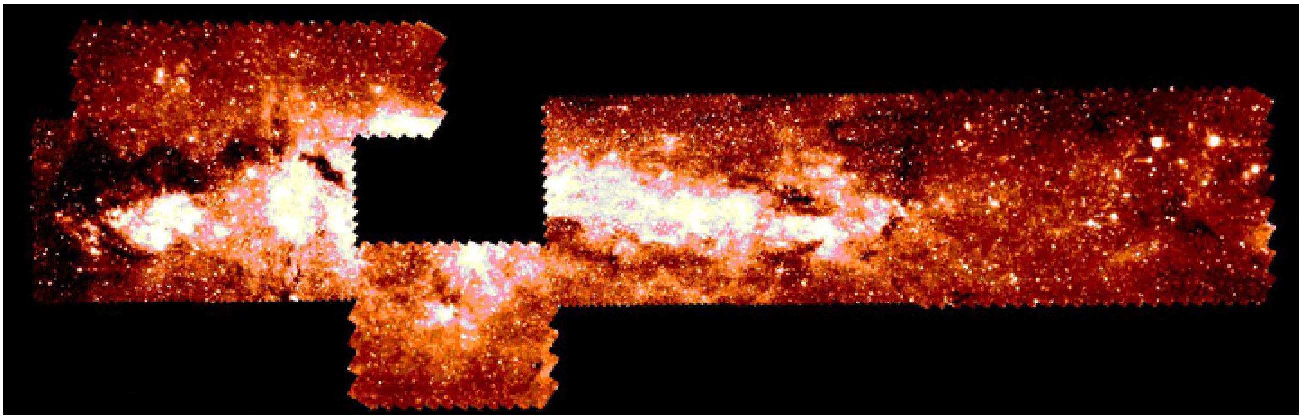
The data your satellite produces might look like this real data from the Infrared Space Observatory (ISO), a European satellite launched in 1995. ISO had four instruments, including a camera (ISOCAM), a photometer (ISOPHOT), and two spectrometers (SWS and LWS). This scan across a portion of our Milky Way galaxy in the constellation Centaurus was done by the Infrared Space Observatory CAMera (ISOCAM) at an infrared wavelength of 15 microns. To the right of the ISOCAM scan is a smaller image of the Milky Way from the infrared satellite IRAS (launched in 1983), which shows not only what part of the sky the ISOCAM image covers (outlined with the green rectangle), but also demonstrates how much clearer and more detailed the later ISOCAM data is.

The brightest regions emitting infrared light in this image are shown in yellow, and the faintest are blue or black. Stars appear as small bright dots, and larger bright yellow/orange clouds are star-forming regions, one of which is near the center of the image. Stars are formed in dense clouds of dust and gas that absorb visible light, which is why infrared telescopes are used for peering inside stellar nurseries. Some of the purple/blue patches shown on this image are dust that is too dense and cold for even ISO to see through.

Learn more about ISO: http://www.esa.int/export/esaSC/120396_index_0_m.html

Image Credits: ISO scan: ESA/ISO, ISOCAM and M. Pérault et al. (ISOGAL team) IRAS field: IRAS project and IPAC

Galaxies -> IR -> Camera



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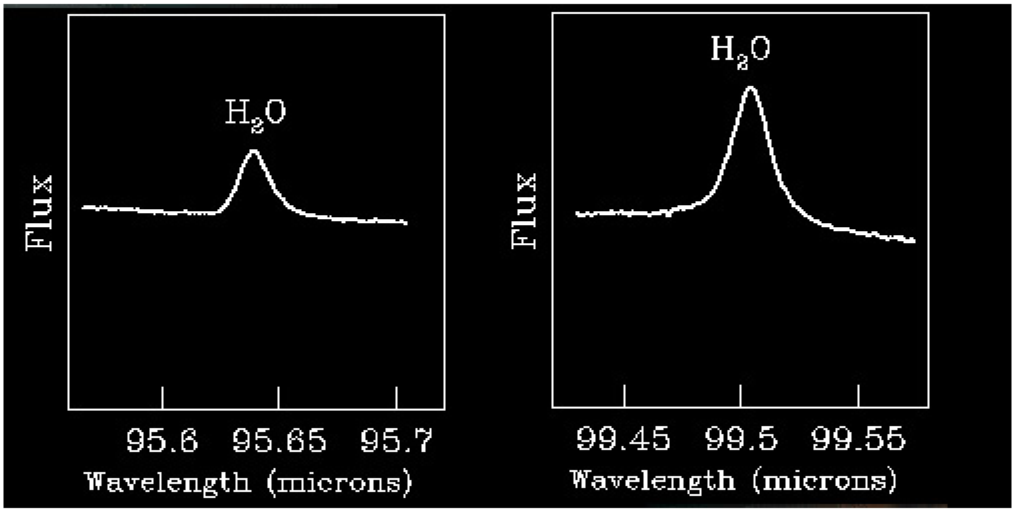
This image shows the region around the center of the Milky Way galaxy; the center itself is missing from this mosaic because it's so bright it would have swamped ISO's detectors. As an infrared telescope, ISO can see through the clouds of dust and gas near the galactic center, observing things previously unseen by other telescopes. For example, ISO found 100,000 previously unidentified red giant stars. Red giant stars are relatively low mass in a later phase of their stellar evolution. Studying red giant populations can give us clues about history of star formation in our galaxy. Because the mass of stars is tied to their age, astronomers can tell how long ago a given population of stars was born. During their evolution, red giant stars enrich their environment, adding carbon and other elements necessary to the existence of life to the clouds of interstellar dust and gas. The motion of these red giant stars can also show the mass distribution in the Galactic Center and may be evidence that our Galaxy grew by cannibalizing smaller, nearby galaxies.

Learn more about ISO: http://www.esa.int/export/esaSC/120396_index_0_m.html

Image Credit: ESA/ ISO, CAM, S. Ganesh (PRL, IAP), A. Omont (IAP), ISOGAL Team

Star Formation -> IR -> Spectrometer
Exoplanets -> IR -> Spectrometer



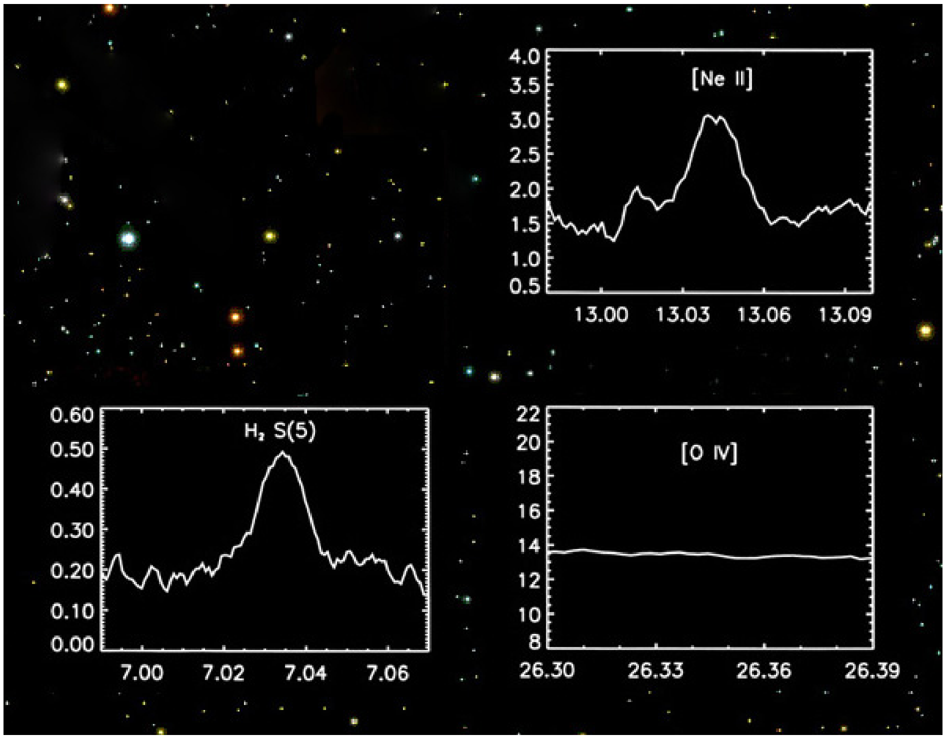
The data your satellite produces might look like this real data from the Infrared Space Observatory (ISO), a European satellite launched in 1995. ISO had four instruments, including a camera (ISOCAM), a photometer (ISOPHOT), and two spectrometers (SWS and LWS). These spectra, graphs of intensity of infrared light over different wavelengths (or energies), are from the Long Wave Spectrometer (LWS), and they show the presence of water vapor near the Orion Nebula, a star-forming region.

Stars (and solar systems of planets) are formed in dusty clouds of gas like the Orion Nebula. Spectroscopy, particularly of infrared light, can help us to learn more about these regions, including the temperature and density, how the clouds of dust are collapsing into stars, and the amount and distribution of different molecules. In the dust around young stars, astronomers have found substances also common on Earth, like water ice, carbon dioxide, and silicates. According to European Space Agency astronomer Alberto Salama, in the Orion nebula, where many stars are being born, ISO detected enough water to fill the Earth's oceans 60 times a day.

Learn more about ISO: http://www.esa.int/export/esaSC/120396_index_0_m.html

Image Credit: ESA

Galaxies -> IR -> Spectrometer



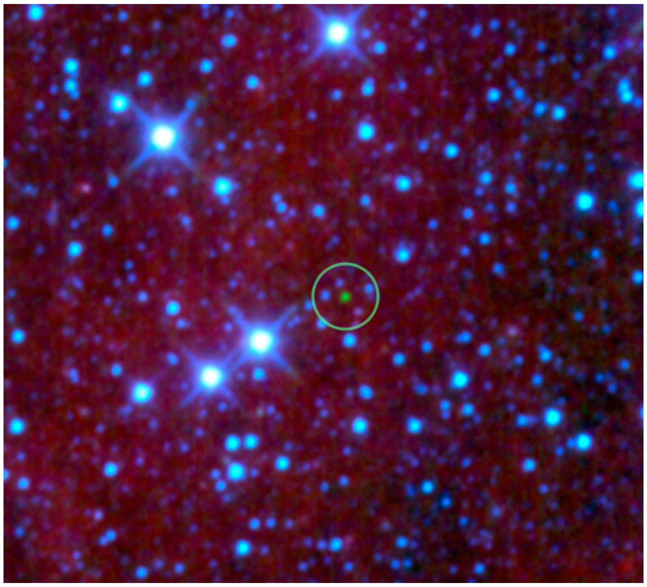
The data your satellite produces might look like this real data from the Infrared Space Observatory (ISO), a European satellite launched in 1995. ISO had four instruments, including a camera (ISOCAM), a photometer (ISOPHOT), and two spectrometers (SWS and LWS). These spectra, graphs of intensity of infrared light over different wavelengths (or energies) are from the Short Wave Spectrometer (SWS), and they show active star formation in the galaxy Arp 220. Arp 220 is the brightest and closest of a special class of galaxies first discovered using the IRAS satellite. These Ultra-Luminous InfraRed Galaxies, or ULIRGs, are 100 times more luminous in infrared than visible light.

ULIRGs are thought to be created by a merger of galaxies. The collision causes interstellar dust and gas to compress, which increases the rate of star birth. The clouds in these star-forming regions obscure and absorb visible and UV light, but the heated dust radiates brightly in the infrared. This ISO SWS spectrum of Arp 220 has emission lines that show that this ULIRG is powered by intense bursts of star formation. It is, however, believed that the most luminous ULIRGs may be powered by supermassive central black holes.

Learn more about ISO: http://www.esa.int/export/esaSC/120396_index_0_m.html

Image Credit: ESA

Exoplanets -> IR -> Camera



The data your satellite produces might look like this real data from the camera on the Wide-field Infrared Survey Explorer (WISE) which was launched in 2009. The image shows a field of blue stars and a green dot that has been circled. The green dot is actually a brown dwarf star. Sometimes when clouds of interstellar gas collapse to form a star, the resulting object isn't massive enough to ignite hydrogen fusion at its core. Such objects are called brown dwarfs - they're not quite planets, but not quite stars either. (They're classified as sub-stars.) Though brown dwarfs are more massive than planets, they do share some traits with gas giant planets. The coolest brown dwarfs can have atmospheres that contain gases like methane, just as gas giants in our solar system do. Studying brown dwarfs can help us to learn not only about the low-mass end of star formation but about the chemical makeup of extrasolar planets.

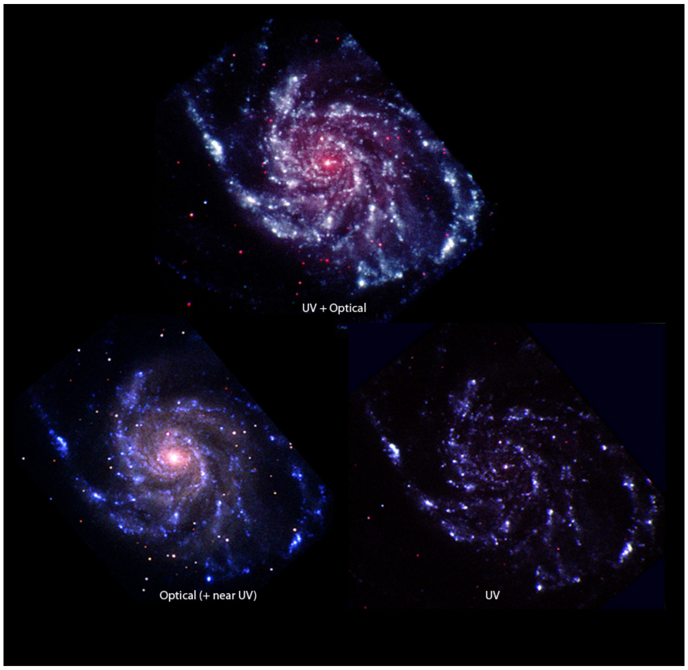
The brown dwarf shown here has a long name based on its location in the sky: WISEPC J045853.90+643451.9. It was the first ultra-cool brown dwarf discovered by WISE. Its temperature is only around 600 Kelvin, or 620 degrees Fahrenheit.

In this image, blue represents the shortest wavelengths of infrared light (3.4 microns) and red, the longest (12 microns). Infrared light of 4.6 microns is color-coded green. The methane in the brown dwarf's atmosphere absorbs the shorter wavelength infrared light, but the dwarf star is too faint to give off the longer wavelength infrared light, which is why it appears green in the infrared.

Learn more about WISE: http://wise.ssl.berkeley.edu/

Image Credit: NASA/JPL-Caltech/WISE Team

Galaxies -> Optical -> Camera
AND/OR
Galaxies -> UV -> Camera



The data your satellite produces might look like this real data from the Ultraviolet/Optical Telescope (UVOT) onboard the Swift satellite. Sometimes larger satellites will have a small telescope onboard capable of observing wavelengths complementary to its primary one. For example, the gamma ray satellite Swift has the UVOT, which has the capability to be both an imager and spectrometer at ultraviolet and optical wavelengths.

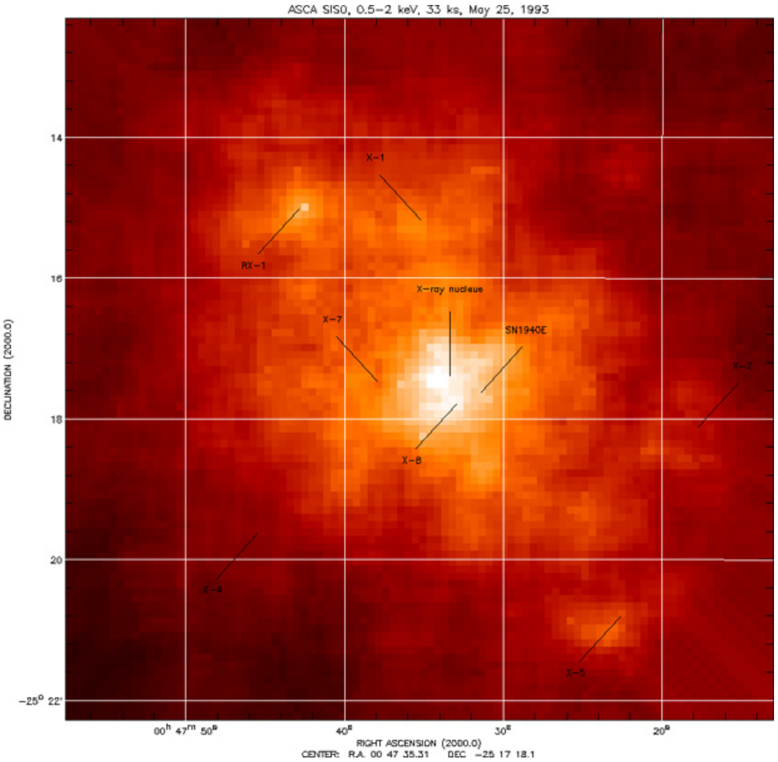
All three images are UVOT data of M101, the Pinwheel Galaxy, and made by using filters. Each filter is sensitive to light of a different color, ranging from ultraviolet light through to the blue to yellow portion of the visible spectrum. The image at top center combines both optical and UV light, with the shortest ultraviolet wavelengths shown as blue, and the longest optical wavelengths as red.

The images on the bottom have been separated into optical light (bottom left) and ultraviolet light (bottom right). The ultraviolet image shows hot, young stars being formed in the spiral arms, whereas optical light reveals the cool, old stars in the central regions of the galaxy. (There are a few red foreground stars that belong to our own galaxy.) The image at bottom left has color-coded the near-UV, blue, and yellow light to blue, green, and red, respectively. The image at bottom right shows light from the shortest ultraviolet wavelength as blue, and light from the next two shortest ultraviolet wavelengths as green and red, respectively.

Learn more about Swift: http://swift.sonoma.edu/

Image Credit: NASA

Galaxies -> X-ray -> Camera



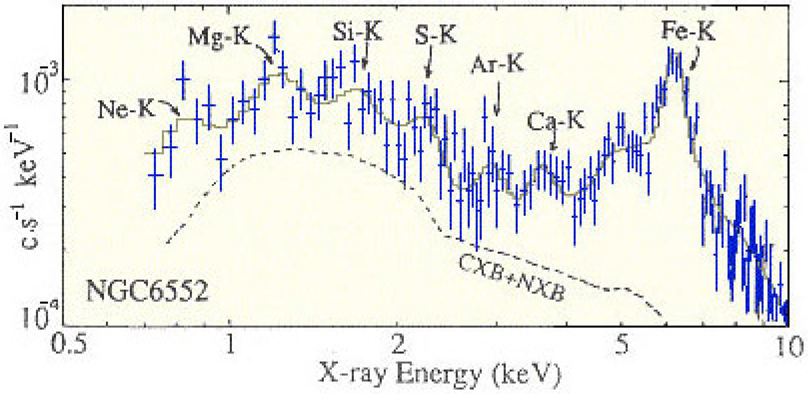
The data your satellite produces might look like this real data of the galaxy NGC 253 from the ASCA satellite, a Japanese X-ray astronomy mission launched in 1993. ASCA had two Solid-state Imaging Spectrometers (SIS), which were CCDs that could image as well as measure the position, time, and brightness of X-rays. From this information, graphs like light curves (intensity over time) and spectra (intensity over different wavelengths) can be made.

This galaxy is what is called a "starburst galaxy" because of its high rate of star formation. It has great clouds of dust that obscure its nucleus, though it is quite bright at X-ray energies. There are also other bright X-ray sources visible in the galaxy; one of them, just to the right of the nucleus is the remnant of a supernova explosion, called SN1940E.

Learn more about ASCA: http://heasarc.gsfc.nasa.gov/docs/asca/

Image Credit: A. Ptak, ASCA Project

Galaxies -> X-ray -> Spectrometer
Galaxies -> X-ray -> Proportional Counter



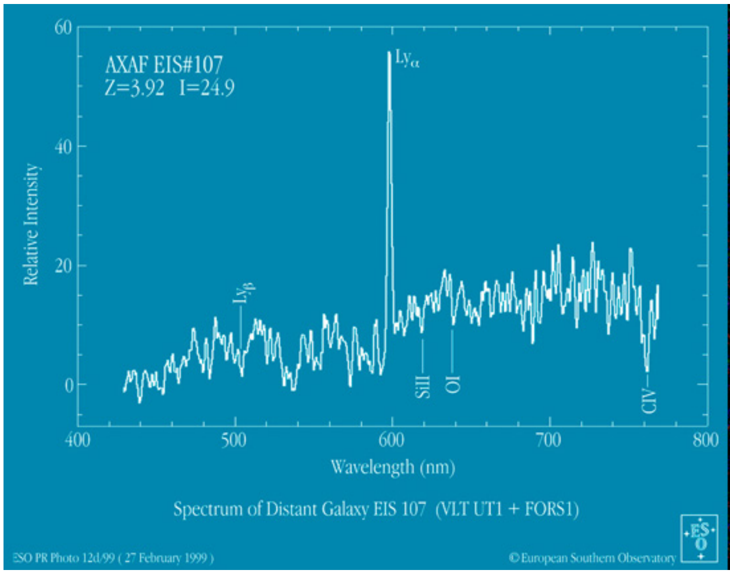
The data your satellite produces might look like this real data from the ASCA satellite, a Japanese X-ray astronomy mission launched in 1993. ASCA had two Gas Imaging Spectrometers (GIS) instruments, which were imaging gas scintillation proportional counters. The GIS could measure the position, time, and brightness of a source of X-rays, as well as be used as an imager. The graph at the top is a spectrum, showing the intensity of the X-rays collected versus energy. The spectrum is of barred spiral galaxy NGC 6552, located about 350 million light years away in the constellation Draco.

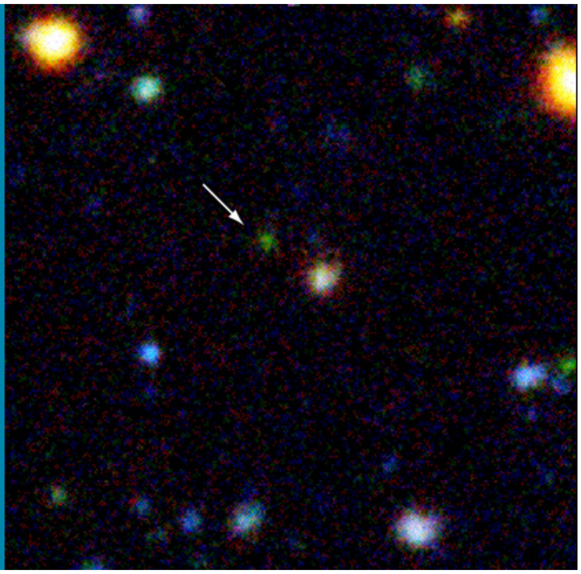
This spectrum shows that the galaxy has an active nucleus hidden by dust and gas which absorb much of the its radiation. X-rays scattered into our line of sight by the dust and gas are the only ones the instrument can detect.

Learn more about ASCA: http://heasarc.gsfc.nasa.gov/docs/asca/

Image Credit: ASCA Project/NASA

Galaxies -> Optical -> Spectrometer
Star Formation -> Optical -> Spectrometer
Star Formation -> Optical -> Camera





The data your satellite produces might look like this real data from the ground-based European Southern Observatory (ESO) of the very distant galaxy EIS 107. It's rare for optical astrophysics to be done from smaller satellites because they are expensive to build, and ground observatories are capable of amazing optical observations.

At left is an optical spectrum (intensity of light over wavelength) made from data from ESO's Very Large Telescope's (VLT) Arnu telescope using the FOcal Reducer and Spectrograph (FORS1) instrument, which does spectroscopy at visible wavelengths of light. The most prominent features in the spectrum are the Lyman Alpha emission line (a spectral line of hydrogen) and absorption lines of oxygen atoms, and silicon and carbon ions. The absorption lines in the spectrum of a galaxy will show what elements are present in the stars that make up the galaxy. If a spectrum is detailed enough in the right range of wavelengths, it can be used to determine the ages of populations of stars in the galaxy. The presence of the Lyman Alpha line (tall spike at center) might mean that this particular galaxy is a starburst galaxy, one that is exhibiting bursts of rapid star formation.

At right is a true-color image of EIS 107 from ESO's New Technology Telescope (NTT). This image was taken at a combination of ultraviolet, optical, and infrared wavelengths.

Learn more about ESO's VLT: http://www.eso.org/public/teles-instr/vlt.html

Image Credit: ESO