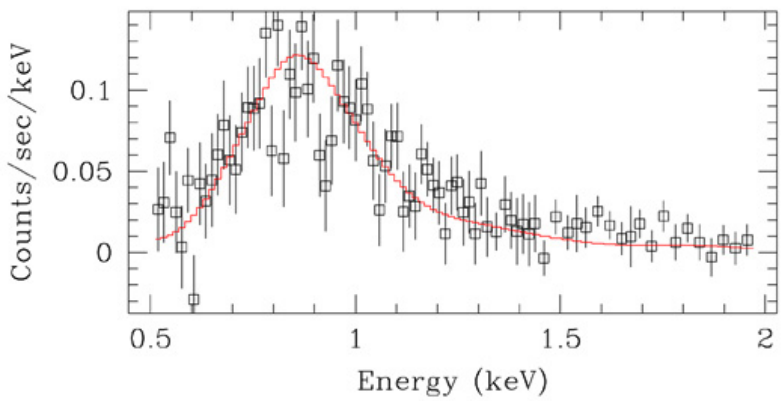
Satellite Data Results - Level 2

Medium-> Black Holes -> X-ray -> camera
Medium -> Black Holes -> X-ray -> spectrometer
Medium -> Black Holes -> optical -> camera
Medium -> Galaxies -> X-ray -> camera
Medium -> Galaxies -> X-ray -> spectrometer
Medium -> Galaxies -> optical -> camera



The data your satellite produces might look like this real data from the ACIS instrument on the Chandra satellite. The ACIS is an X-ray imaging spectrometer, which means it has a CCD for imaging but can also measure the spectrum (or intensity over different wavelengths) of a source.

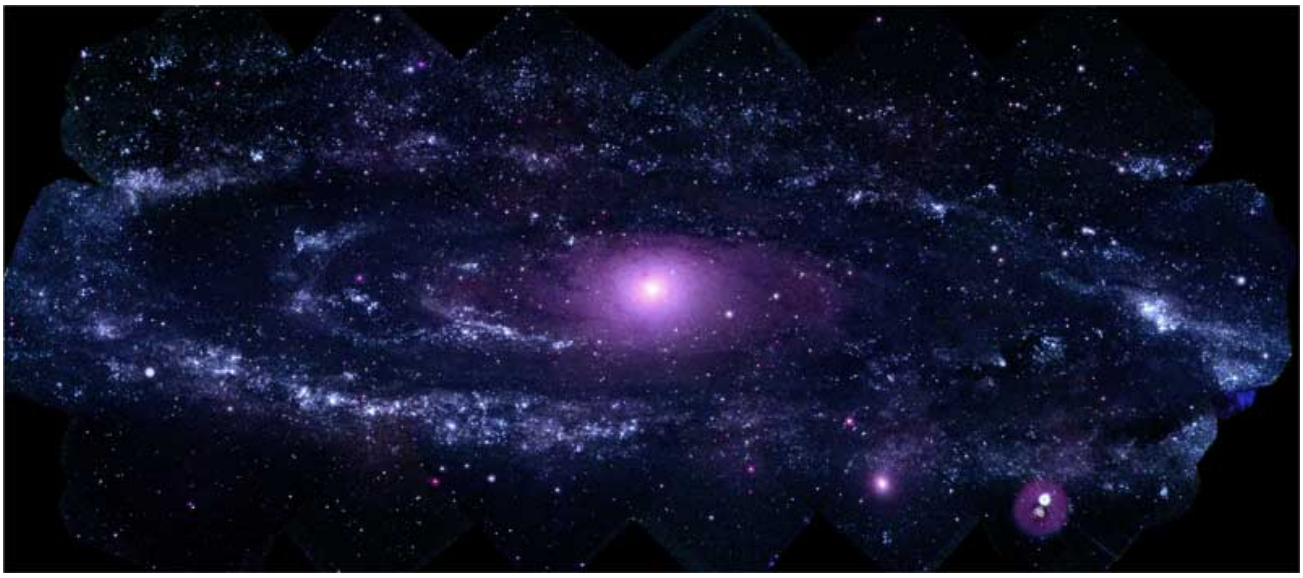
The image on the right shows Centaurus A, a galaxy that contains at its center a black hole with powerful jets. The image is a composite of X-ray data from the ACIS (shown in blue), microwave data from the Atacama Pathfinder Experiment (APEX) telescope in Chile (orange), and a visible light image from the Wide Field Imager on the Max-Planck/ESO 2.2 meter telescope in Chile. Studying the same object at different wavelengths of light can give us a more complex view of it. The visible light image shows background stars and the dust lanes in the galaxy, but the jet and lobes powered by the central black hole are only revealed in the X-ray and microwave observations. From these, scientists have learned that Centaurus A's jet extends 13,000 light years from the central black hole, with the material in it traveling at about half the speed of light.

At left is an X-ray spectrum of one of the arc-like structures of extremely hot gas that surround the jets emitted by the black hole.

Learn more about Chandra: http://chandra.si.edu/

Image Credit: (right) X-ray: NASA/CXC/CfA/R.Kraft et al.; Submillimeter: MPIfR/ESO/APEX/ A.Weiss et al.; Optical: ESO/WFI (left) NASA/CXC/SAO/M. Karovska et al.

Medium -> Galaxies ->UV -> Camera
Medium -> Star Formation -> UV -> Camera



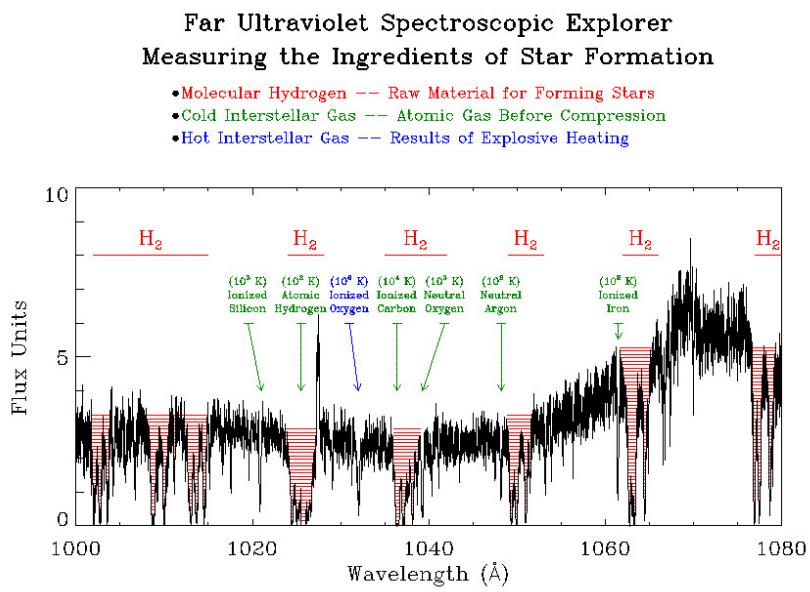
The data your satellite produces might look like this real data from the Ultraviolet/Optical Telescope (UVOT) on the Swift satellite. Sometimes larger satellites will have a smaller telescope onboard that is capable of observing wavelengths complementary to its primary one. For example, the gamma ray Swift satellite has the UVOT, which has the capability to be both an ultraviolet imager and spectrometer. This ultraviolet image of M31 (or the Andromeda Galaxy) is a mosaic of 330 separate images. Even though the UVOT is a relatively small telescope, this is the highest-resolution image of this galaxy yet recorded in the ultraviolet. It will allow astronomers to study the star formation processes in M31 in more detail than before.

This image reveals some 20,000 sources of ultraviolet light, particularly hot, young stars and dense star clusters. The materials needed to make new stars in spiral galaxies like M31 (and our own Milky Way) tend to lie in the disk and spiral arms, rather than in the central bulge where these materials have been depleted. In this image, the galaxy's central bulge is smoother and redder than the spiral arms, due to its population of older and cooler stars. Clusters of stars are especially numerous in a 150,000 light year diameter ring, dubbed Andromeda's "ring of fire." It is thought that the unusually intense star formation there is triggered by the many small satellite galaxies that orbit M31. They cause tides that boost interactions within the gas clouds - and the result is new stars.

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

Image Credit: NASA/Swift/Stefan Immler (GSFC) and Erin Grand (UMCP)

Medium -> Galaxies ->UV -> Spectrometer
Medium -> Star Formation -> UV -> Spectrometer
Medium -> Black Holes -> UV -> Spectrometer



The data your satellite produces might look like this real data from the spectrograph on the Far Ultraviolet Spectroscopic Explorer (FUSE) satellite, which was launched in 1999. The ultraviolet spectrum above, which shows intensity of light over a range of wavelengths, is of a quasar called ESO141-G55.

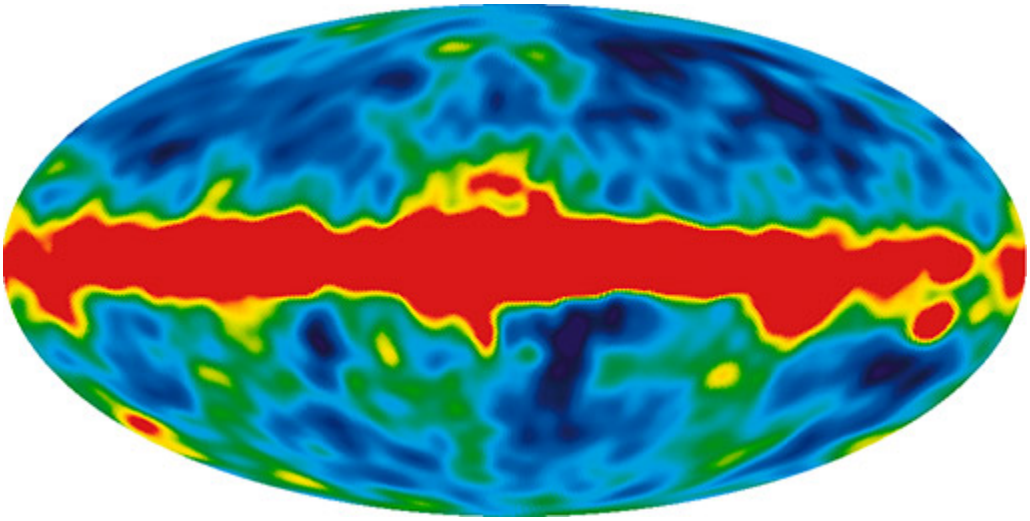
Quasars are distant galaxies with supermassive black holes at their centers that spew massive amounts of energy from a small region around that black hole. The light from a quasar has to pass through clouds of gas in the space between galaxies and also inside our own galaxy before it reaches us here on Earth. Different elements in these clouds, like helium or hydrogen, absorb specific wavelengths of light, and by looking at the spectra of quasars, we can determine which elements are present in these clouds. This technique can work with objects other than quasars, however using a quasar allows you to use an ultraviolet source that is outside of our galaxy and thus beyond the molecular clouds being studied.

In the above spectrum, lines caused by the presence of molecular hydrogen are color-coded red, while other lines from oxygen, silicon, carbon, etc, are represented in green (cold gas) and blue (hot gas). Molecular hydrogen and cold interstellar gas clouds are very important for the formation of new stars and planets.

Learn more about FUSE: http://archive.stsci.edu/fuse/

Image Credit: J. M. Shull and J. B. Tumlinson (University of Colorado) and NASA.

Medium -> Early Universe -> Microwave -> Radiometer



The data your satellite produces might look like this real data from the COsmic Background Explorer (COBE), 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.

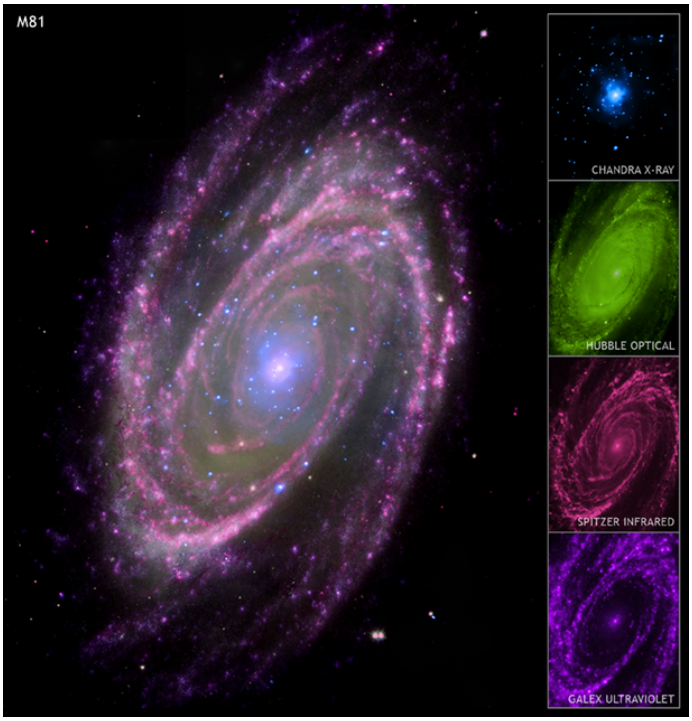
COBE had three instruments aboard: a radiometer to map variations in the CMB (DMR), a spectrophotometer to measure the spectrum of the CMB (FIRAS), and an infrared detector to map dust emission (DIRBE). COBE used its Differential Microwave Radiometer (DMR) to map the tiny variations in the intensity 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 the large scale structure that we see in the universe today. The above all-sky image shows the first four years of DMR data. The large red band is the microwave emission from our own galaxy. Though this image is relatively low resolution, there are obvious cold and hot regions visible.

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, both received 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

Medium ->Black Holes -> UV -> Camera



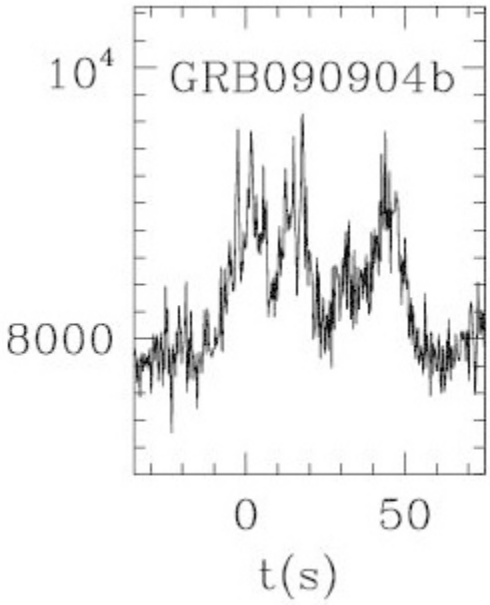
The data your satellite produces might look like this real data from GALEX, which has a single instrument that is both an imager and a spectrometer at ultraviolet wavelengths. Pictured is the spiral galaxy M81, which has a supermassive black hole at its center. This image is a composite that includes X-ray data from the Chandra X-ray Observatory (blue), optical data from the Hubble Space Telescope (green), infrared data from the Spitzer Space Telescope (pink), as well as the ultraviolet data from GALEX (purple).

Each wavelength in this image illustrates a different process occurring in M81. A disk of material spinning around this galaxy's central black hole mainly produces X-rays and optical light, hot gas around the black hole largely gives off ultraviolet light and X-rays, and the jets generated by the black hole are seen in the radio (not shown) and X-ray. These new observations were used, along with a detailed theoretical model, to compare the properties of M81's central supermassive black hole with those of stellar-mass black holes. The results of the study showed that black holes feed the same way regardless of size, supporting an implication of Einstein's Theory of General Relativity - that black holes of all sizes have similar properties.

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

Image Credit: X-ray: NASA/CXC/Wisconsin/D.Pooley & CfA/A.Zezas; Optical: NASA/ESA/ CfA/A.Zezas; UV: NASA/JPL-Caltech/CfA/J.Huchra et al.; IR: NASA/JPL-Caltech/CfA

Medium ->Galaxies -> gamma-ray -> scintillator
Medium ->Black Holes -> gamma-ray -> scintillator



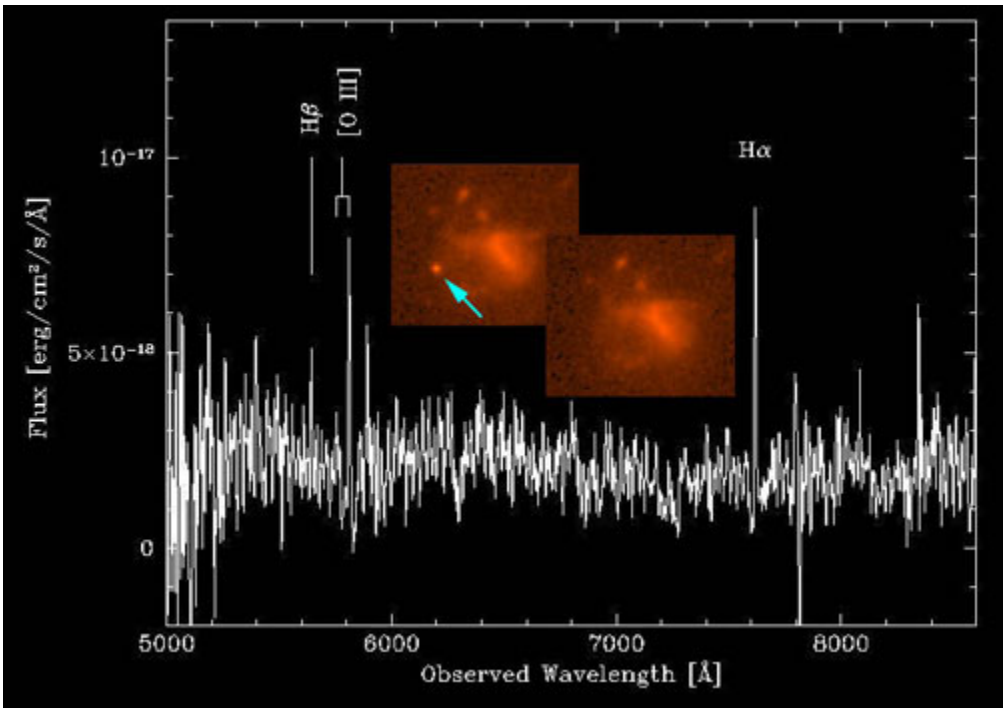
The data your satellite produces might look like this real data from the Gamma ray Burst Monitor (GBM) on the Fermi gamma ray satellite. The GBM has 12 sodium iodide scintillators that can detect X-rays and low-energy gamma rays, as well as two bismuth germanate scintillators that detect high-energy gamma rays. The GBM's job is to detect 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 neutron stars collide. Either way, it's thought that a GRB signals the birth of a black hole. When one occurs, the GBM informs an international network of observers which enables immediate follow-up observations of the burst.

Data from the GBM can be used to produce light curves (graphs of intensity of light over time) and spectra (graphs of intensity of light over different wavelengths) of GRBs. The above graph is a light curve of GRB 090904b, which occurred on September 2, 2009. It had a single bright pulse that lasted about 21 seconds, though it appears to have had an X-ray afterglow that lasted for hours after the burst.

Learn more about Fermi: http://glast.sonoma.edu/

Image Credit: NASA/Sonoma State University

Medium ->Black Holes -> optical -> optical spectrometer



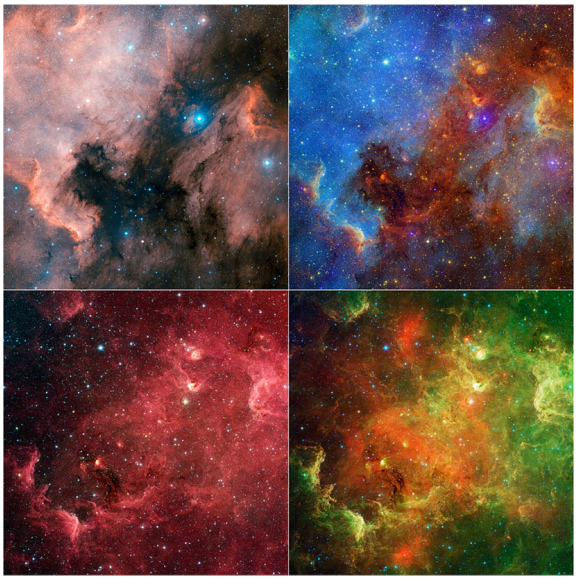
The data your satellite produces might look like this real data from the Gemini Multi-Object Spectrograph, a ground-based instrument. It's rare for optical astrophysics to be done from small or medium-sized satellites because they are expensive to build, and ground observatories are capable of amazing optical observations. The above spectrum shows the intensity of light over optical and infrared wavelengths for a galaxy within which a gamma ray burst (GRB) occurred. From the spectrum, the redshift of the galaxy was determined, which gave us this galaxy's distance from us. Redshift is a shift in the observed wavelength of light that occurs when the emitting object is moving away from the observer; the lines in that object's spectrum show this shift.

The color inset images of the galaxy are from the Hubble Space Telescope and show the GRB (left, with arrow) and the same region one month later, after the GRB had faded. 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. GRBs are huge explosions in space, and scientists think they happen either when a very massive star explodes or when two neutron stars collide. Either way, it's thought that a GRB signals the birth of a black hole. Research shows that GRB050709 was likely produced by a collision of two neutron stars, or possibly a neutron star and a black hole.

Learn more about the Gemini Multi-Object Spectrograph: http://www.gemini.edu/?q=node/10003

Image Credit: Gemini Observatory/AURA

Medium -> Star formation -> IR -> Camera
Medium -> Star formation -> Optical -> Camera



The data your satellite produces might look like this real data from both the infrared Spitzer Space telescope and the optical Digitized Sky Survey, which uses ground-based data.
It's rare for optical astrophysics to be done from small or medium-sized satellites because they are expensive to build, and ground observatories are capable of amazing optical observations.

Shown in all four images is the North America nebula, so named because in visible light, the shape of the reddish dust and gas clouds resembles the shape of North America and the Gulf of Mexico. Infrared images show a completely different picture - a star forming region full of young stars that were otherwise invisible behind the clouds of dust.

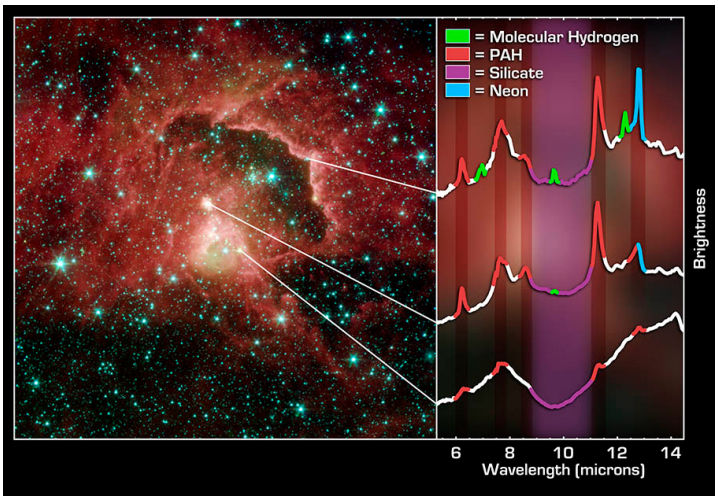
In the upper left is a true-color, visible-light view of both the North American nebula and the reddish Pelican nebula (to the right of the dark cloud). In the upper right is a combined visible and infrared image; here visible light light is blue and infrared is represented by green and red. The nebulae appear blue and less opaque, and the dust (black at visible wavelengths) glows in the infrared and is more transparent.

On the bottom left is data from Spitzer's InfraRed Array Camera (IRAC) and on the bottom right is infrared data from both IRAC and the Multiband Imaging Photometer for Spitzer (MIPS), which sees longer infrared wavelengths. In both of these infrared images, shorter wavelengths are represented in blue and longer wavelengths in red. It is in the infrared that the stellar nurseries behind the clouds of dust and gas are revealed. Dust and gas can absorb visible light, but infrared light can penetrate, allowing us to view inside the dusty cocoons that envelop baby stars. Astronomers study detailed images like this in order to determine how the stars inside these dust cocoons are forming.

Learn more about Spitzer: http://www.spitzer.caltech.edu/

Image Credit: NASA/JPL-Caltech/L. Rebull (SSC/Caltech)

Medium -> Star Formation -> IR -> Spectrometer



The data your satellite produces might look like this real data from the Spitzer Space Telescope. At left is an InfraRed Array Camera (IRAC) image of a star-forming region in the constellation Cepheus, located 21,000 light years away from us. Shorter wavelengths are shown in blue and longer in red. To the right is a spectrum of this region from the InfraRed Spectrometer (IRS).

When clouds of dust and gas are shocked by gravitational disturbances, it can lead to the formation of proto-stars. These baby stars (which are less than a million years old) are hidden from visible-light view inside the clouds from which they formed. The only way to observe baby stars is to observe the infrared light they emit, which can penetrate the dusty shrouds around them. When these stars age, the material around them is eventually blown away by their strong winds and radiation, which reveal them to visible-light observations.

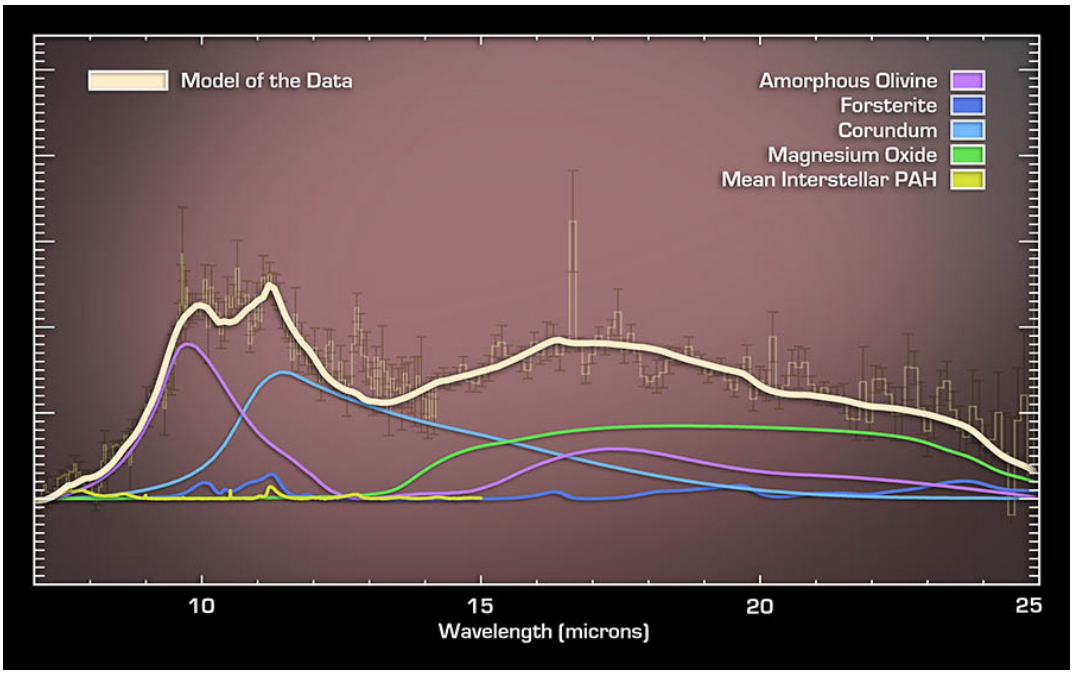
The image and spectrum give us information about the different stages of star formation. The greenish yellow dot near the center of the image is a star that astronomers think is less than a million years old because spectra of the region (bottom graph at right) reveal the presence of silicate dust. This indicates that the star is still deeply inside the cloud that collapsed to form it. Wisps of green surrounding the star and its nearby environment illustrate the presence of hot hydrogen gas.

Above and just left of center is a large, bright pinkish mature star that may be on the verge of emerging from its cocoon. This star is still shrouded by its birth material, which is being heated up by the star. The oldest stars are fully exposed and can be seen as blue specks located just left of the concave ridge (right and above center). This ridge was formed when energetic particles and photos of ultraviolet light from nearby star clusters blew away the surrounding dust and gas. The spectra of both the ridge (top graph) and the pinkish mature star (middle graph) show the presence of carbon rich molecules called polycyclic aromatic hydrocarbons (PAHs), which are found on barbecue grills and in automobile exhaust on Earth.

Learn more about Spitzer: http://www.spitzer.caltech.edu/

Image Credit: NASA/JPL-Caltech/S. Carey and J. Ingalls (SSC/Caltech)

Medium -> Early Universe -> IR -> Spectrometer
Medium -> Exoplanets -> IR -> Spectrometer
Medium ->Galaxies -> IR -> Spectrometer



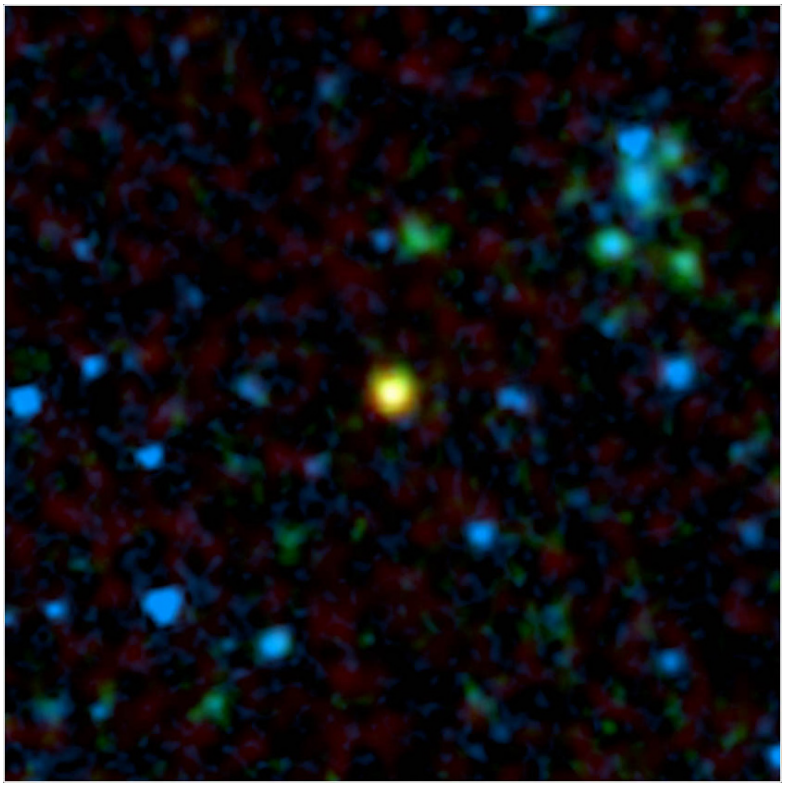
The data your satellite produces might look like this real data from the InfraRed Spectrometer (IRS) on the infrared Spitzer Space Telescope. This graph of intensity of light over wavelength (called a spectrum) is of a quasar located 8 billion light years away and may solve a mystery about where the dust in the young universe originated.

Dust is an important ingredient in the formation of stars, planets, and, indeed, life. Dust has been seen as far back as when the universe was a tenth of its current age of 13.7 billion years. Though dying sun-like stars are responsible for creating the dust in our current era, these stars didn't exist in the early universe. One theoretical source of dust is the outer winds of quasars, a type of very distant galaxy with an energetic, supermassive black hole at the center. The spectrum above supports this theory, as it shows the presence of dust grains in quasar PG 2112+059. The grains include corundum (the mineral form of sapphires and rubies), forsterite (peridot), and periclase (naturally occurring in marble), which are minerals not typically found in galaxies without quasars. This suggests that this dust was freshly formed in the quasar's winds. Because PG2112+059 is 8 billion light years away from us, the light it emitted started traveling to us 8 billion years ago at a much earlier time in our universe's history. Quasars could very well explain where the dust used make the first generations of stars in the early universe came from.

Learn more about Spitzer: http://www.spitzer.caltech.edu/

Image Credit: NASA/JPL-Caltech/T. Pyle (SSC)

Medium -> Early Universe -> IR -> Camera



The data your satellite produces might look like this real data from the Spitzer Space Telescope InfraRed Array Camera (IRAC) and Multiband Imaging Photometer for Spitzer (MIPS) instruments combined with ground-based radio data from the Very Large Array telescope (red). The image shows a field of galaxies, most emitting infrared light at wavelengths of 3.6 microns (IRAC data in blue) and 24 microns (MIPS data in green). Normal galaxies do not produce strong radio waves, however the object at the center, which is color-coded yellow emits both infrared and radio light. This object is a distant quasar, a super-massive black hole circled by a ring, or torus, of gas and dust.

When this image was captured in 2005, 10 of the 21 quasars found by Spitzer were thought to be hidden by a torus of dust, and the rest were presumed to be buried at the center of a dusty galaxy. The quasar shown here is one that is being obscured by a torus of dust. Clouds of dust and gas that are opaque to visible light are transparent to infrared light, which is what allows telescopes like Spitzer to observe quasars.

Learn more about Spitzer: http://www.spitzer.caltech.edu/

Image Credit: NASA/JPL-Caltech/A. Martinez-Sansigre (Oxford University)

Medium -> Galaxies -> IR -> Camera

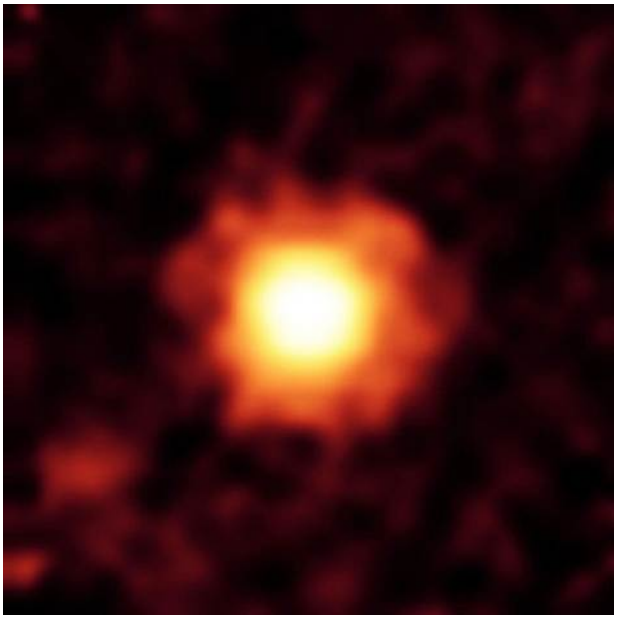
The data your satellite produces might look like this real data from the camera on the Wide-field Infrared Survey Explorer (WISE) satellite, which was launched in 2009. This mosaic of images shows an infrared view of M31, also known as the Andromeda Galaxy. WISE used all four of its infrared detectors to capture this picture; longer wavelengths are red, shorter wavelengths colored blue. The contrast between young and old populations of stars is striking. Older, mature stars appear as a blueish haze, while in yellow/red are rings of dust heated by massive, newborn stars.

Clusters of new stars are especially numerous in a 150,000 light year diameter ring, dubbed Andromeda's "ring of fire." It is thought that the unusually intense star formation there is triggered by the many small satellite galaxies that orbit M31. They cause tides that boost interactions within the gas clouds - and the result is new stars. Two of Andromeda's largest satellite galaxies are visible in this image: M110 (fuzzy, blue, below center) and M32 (smaller, blue, just a bit above and left of center).

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

Image Credit: NASA/JPL-Caltech/UCLA

Medium -> Exoplanets -> IR -> Camera



The data your satellite produces might look like this real data from the Spitzer Space Telescope's Multiband Imaging Photometer for Spitzer (MIPS) instrument at an infrared wavelength of 70 microns.

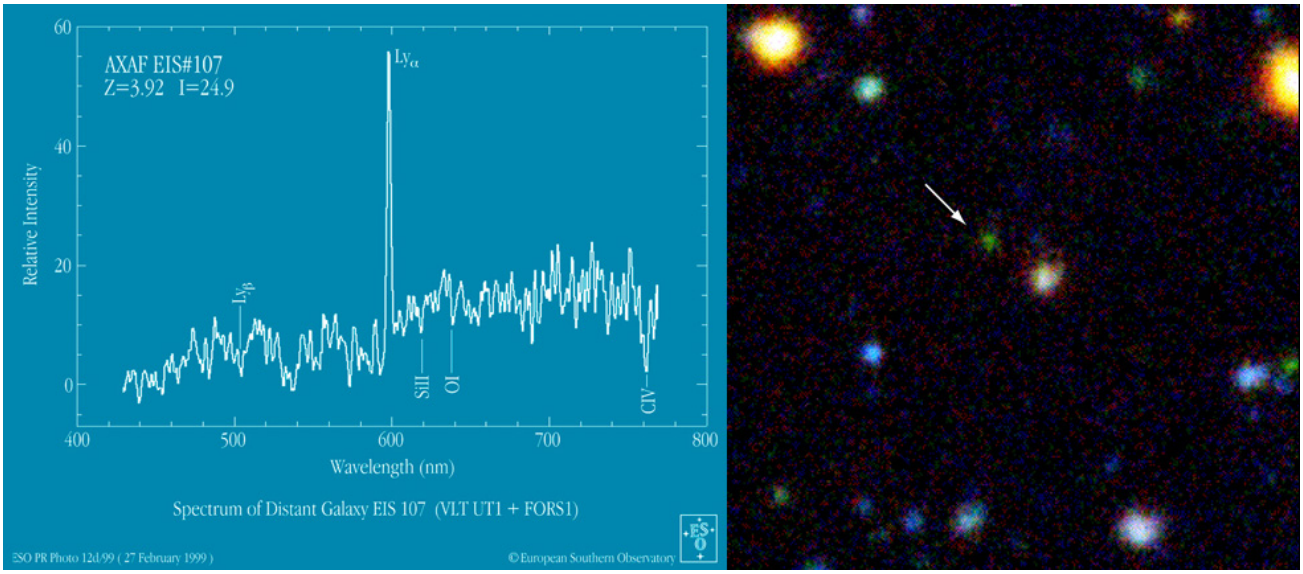
Shown in this image is the young star HR 8799, which has a giant halo of very fine dust around it (in orange-red). The brightest parts of it (yellow-white) likely correspond to a cold disk similar to our own solar system's Kuiper belt, which lies beyond Neptune's orbit. The extended dust halo has a diameter of about 2,000 astronomical units, or 2,000 times the distance between Earth and the sun. (By comparison, Pluto's orbit has an average diameter of 39.5 astronomical units.)

Three giant, young planets (each about 10 times the mass of Jupiter) in unstable orbits around this star are gravitationally disturbing smaller, comet-like bodies similar to those in our Kuiper Belt, causing them to collide which is kicking up the huge halo of dust. These massive planets probably haven't reached their final stable orbits yet, so this system will continue to be active for a while. Astronomers think our solar system went through a similar period when it was young, where Jupiter and Saturn moved quite a bit, throwing comets around, sometimes into Earth. The most extreme part of this phase, called the late heavy bombardment, when wet, snow-ball like comets crashed into Earth, may explain how our planet got water.

Learn more about Spitzer: http://www.spitzer.caltech.edu/

Image Credit: NASA/JPL-Caltech/K. Su (Univ. of Arizona)

Medium -> Star Formation -> Optical -> Spectrometer
Medium -> Galaxies -> Optical -> Spectrometer



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 small or medium-sized satellites because they are expensive to build, and ground observatories are capable of amazing optical observations.

At left is an optical spectrum (graph of 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