A Small Preamble

There are two prevalent technologies being used in digital cameras these days (including the types of cameras used to take astronomical photographs). One is based on what are called *charge couple devices*, or CCD's, and the other is based on what are called *complementary metal oxide semiconductors*. Both convert light to electric charge from which an electrical signal might be formed, and neither is better than the other.

For the sake of amusement, I'm going to explain how the CCD works. We will start with a black and white picture.

The following Web sites discuss these technologies (sites compliments of Raymond Jimenez).

http://en.wikipedia.org/wiki/Active_pixel_sensor

Additionally, according to Raymond's research, the pixel pattern used in these devices is discussed at.

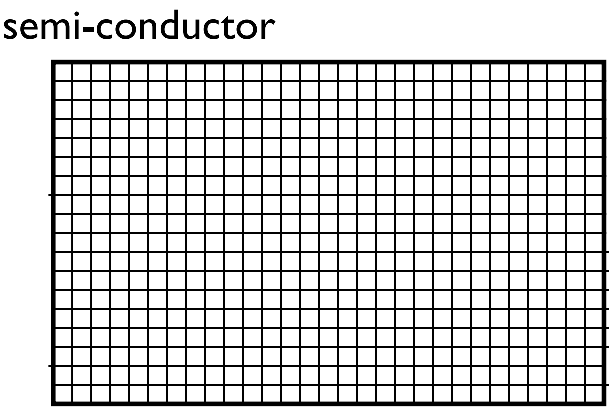
http://en.wikipedia.org/wiki/Bayer_pattern

In short, light striking a CCD plate frees electrons in the plate. The number of electrons freed in a particular area of the plate dictates how bright the light is in that area. A single counting device is used to register this count for all areas on the plate and a computer uses that information to generate an image.

Light striking a CMSO plate also frees electrons in the plate. The difference is that each pixel on the CMSO has its own counting mechanism (the make-up of these devices utilizes what are called "active sensor pixels"). The device usually uses amplifiers, noise reduction circuitry and digitization circuitry to generate the output. It is, therefore, more complicated in design and more expensive. It is used in cell phone cameras.

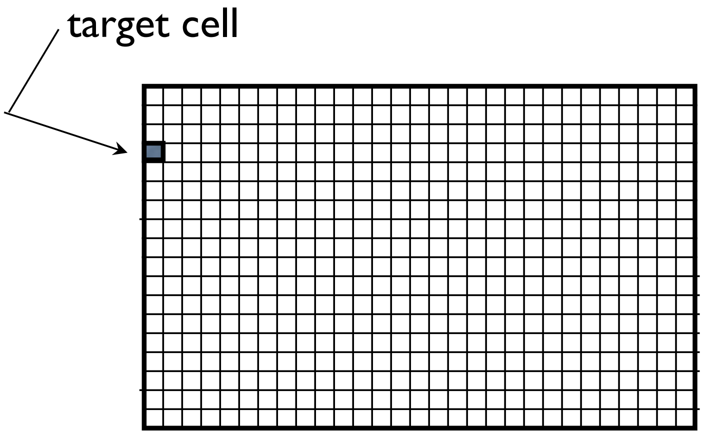
A ccd is nothing more than a block of semi-conducting material that has been manipulated in a clever way.

The block is sectioned into tiny square cells with each cell's wall being created by a potential barrier--a voltage that keeps free electrons from traveling from one cell to another.

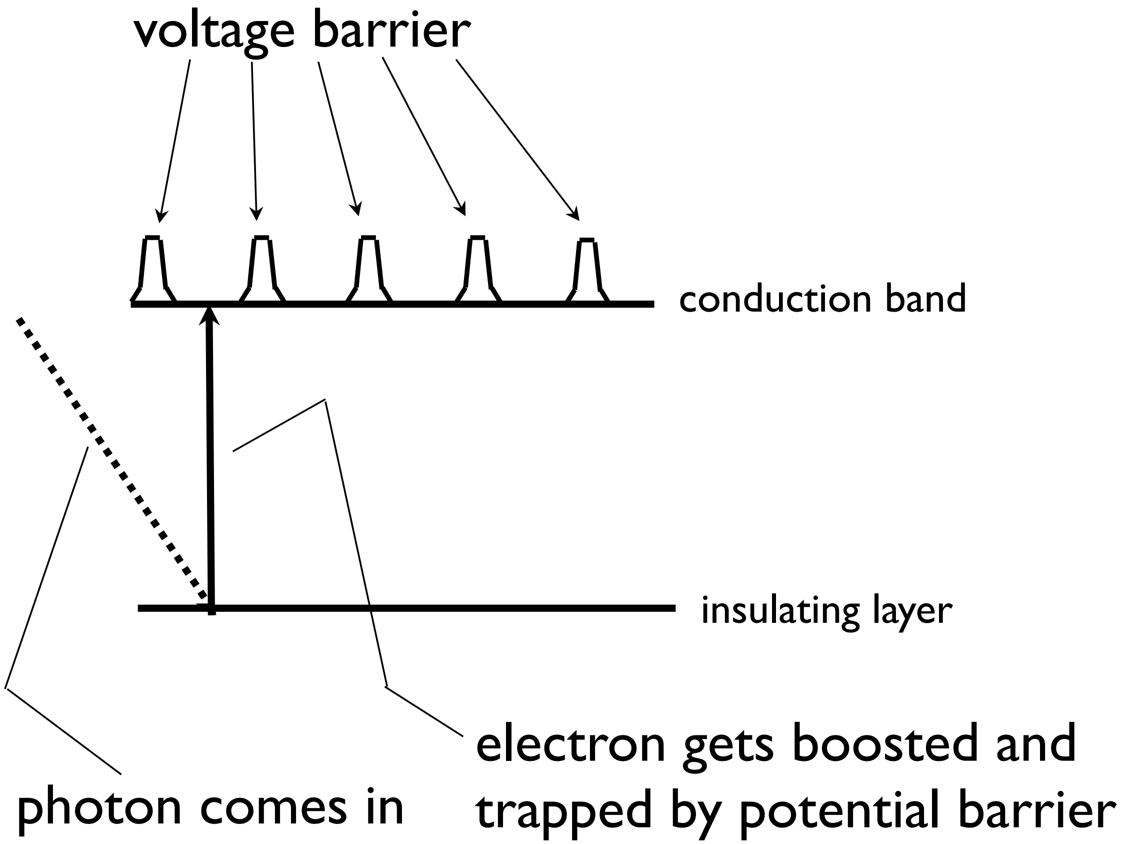


So let's assume a photon of light strikes the semi-conductor. In fact, let's assume the light enters the cell that has been blackened in the sketch.

What then occurs?

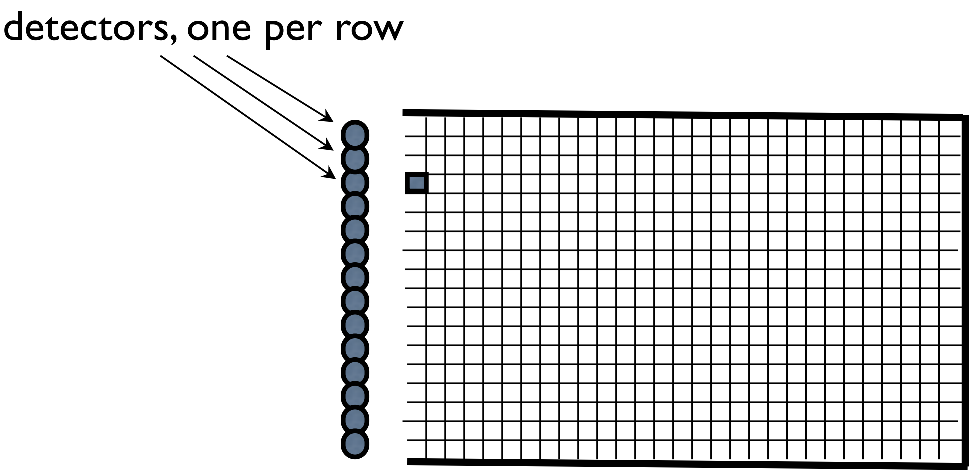


When the photon is absorbed by the semi-conductor, its energy goes into exciting an electron in the semi-conductor's insulating layer into what is called "the conduction band." (Note that if, in the conduction band, the voltage barriers did not exist, the electron would be free to move about as though it was not attached to any particular atom, much like an outer-shell electron does in a metal.)



So after a short period of time (a few thousandths of a second), let's assume a large number of electrons have accumulated in the conduction band of our cell. (In fact, electrons have accumulated in all of the cells--we are just interested in our one cell for the time being).

At this point, a clever thing happens. The outside voltage barrier is dropped, and the electrons in all of the outside cells are motivated by a secondary voltage to move into detectors to the left.

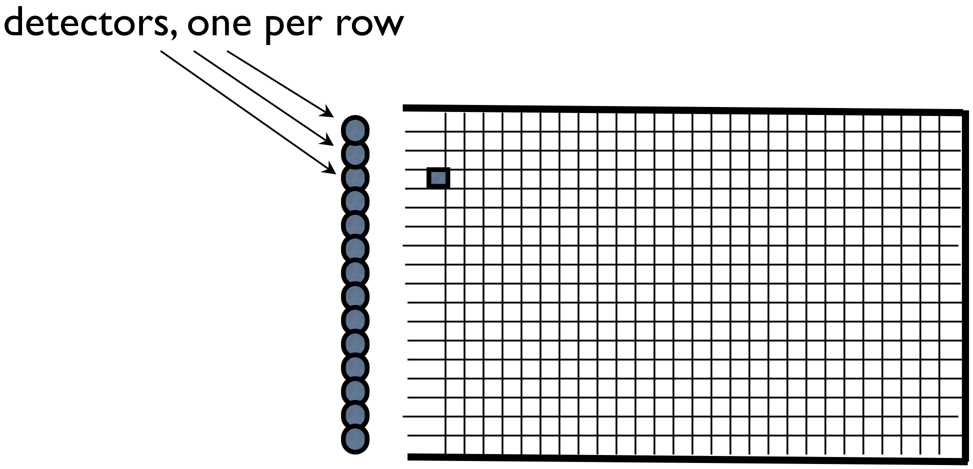


barrier dropped with electrons moving into detector

Once the electron count of the first column of cells has been counted and stored in memory, the second voltage barrier is lowered and a similar thing is done with the electrons in the second group of cells.

This continues until all of the electrons in all of the cells have been counted.

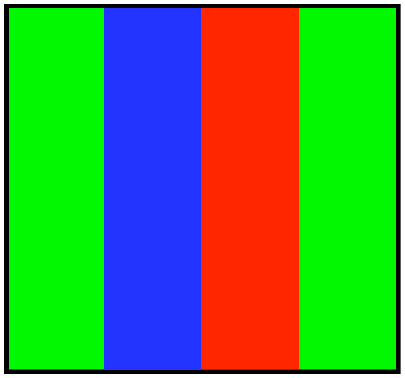
A computer then compares the electron counts from the various cells and deduces in which areas there was abundant light, and in which area there was little light. From that information, a black and white picture can be created.



barrier dropped with electrons moving into detector

Ccd’ s used for color pictures are normal ccd’ s with one big difference. Each cell has overlaid upon it four filters--one that is green, one blue, one red, then another green (green is over-represented because our eyes are particularly sensitive to green light even though it embodies only a very, very small range within the optical spectrum).

an individual cell with voltage barrier up



For a given cell, then, the electrons that accumulate under, say, the blue filter have to be generated by blue light that has been able to pass through that blue filter.

The only additional complexity over a black and white picture has to do with the detector's count. The computer has to be a little more aware of timing in the sense that the first electrons from a cell will be from the first green filter, the next set from the blue filter, etc.

Once it has all the data, the computer decides what color best represents each cell. Putting it all together yields a color photo.

Clever, eh?

A Word About Color

So why am I telling all of this?

Let's say an astronomer is looking for stellar nurseries. How does one find areas where stars might be born?

It turns out that massive, hot, young stars are found in regions where ionized hydrogen is recombining with free electrons. The energy given off when this interaction takes place produces what is called the *hydrogen-alpha spectral line*.

So if you are looking for hot, young stars, the trick is to look at the light from a candidate area through a hydrogen-alpha filter. If there is hydrogen-alpha activity going on, light will pass through the filter and show up in your photograph.

The optical pictures you are about to see are overlays of several photographs of a particular area in space produced *using different filters* (in many instances, the hydrogen-alpha filter being one of them).

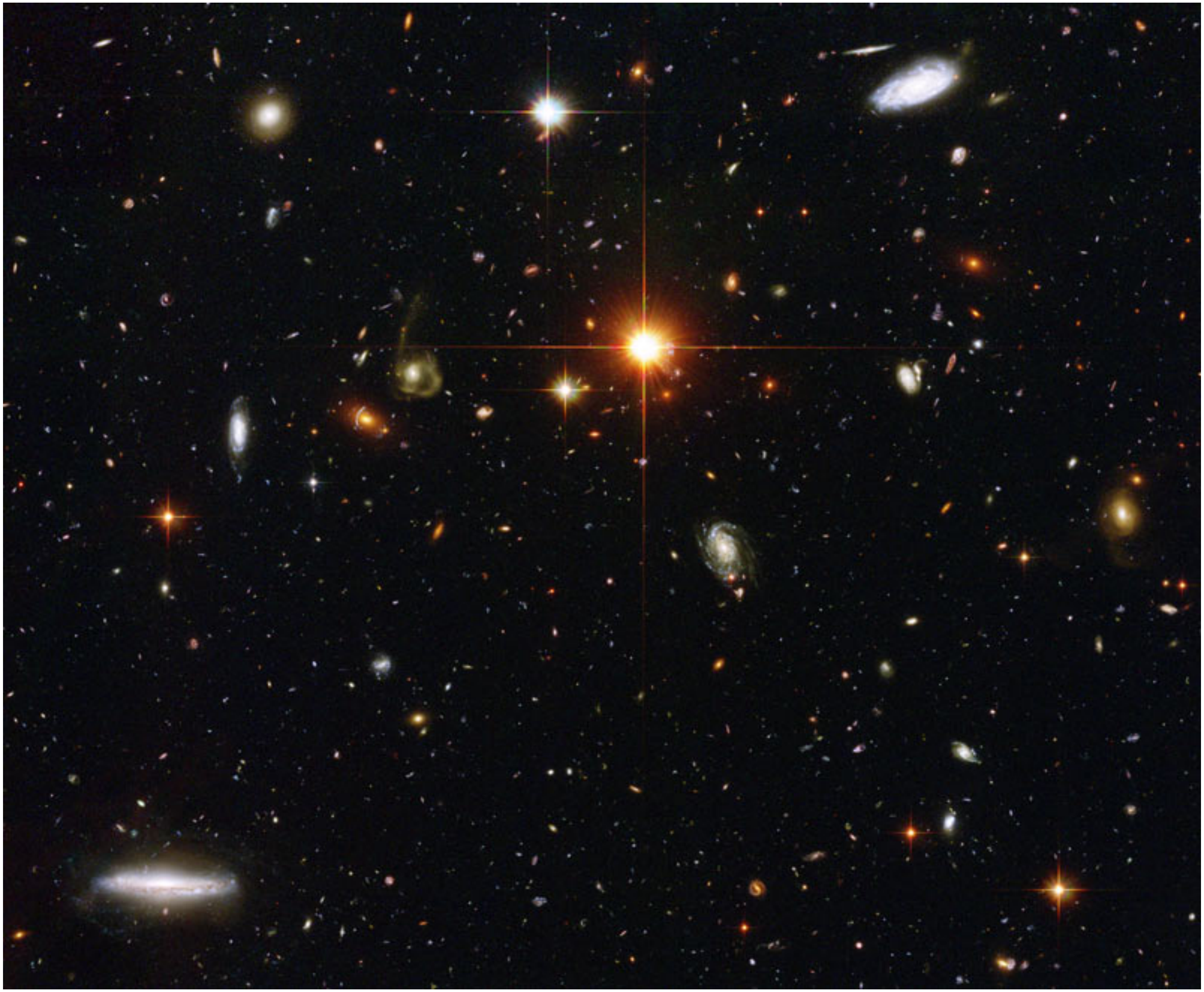
All of the optical pictures are from the Hubble space-based telescope.

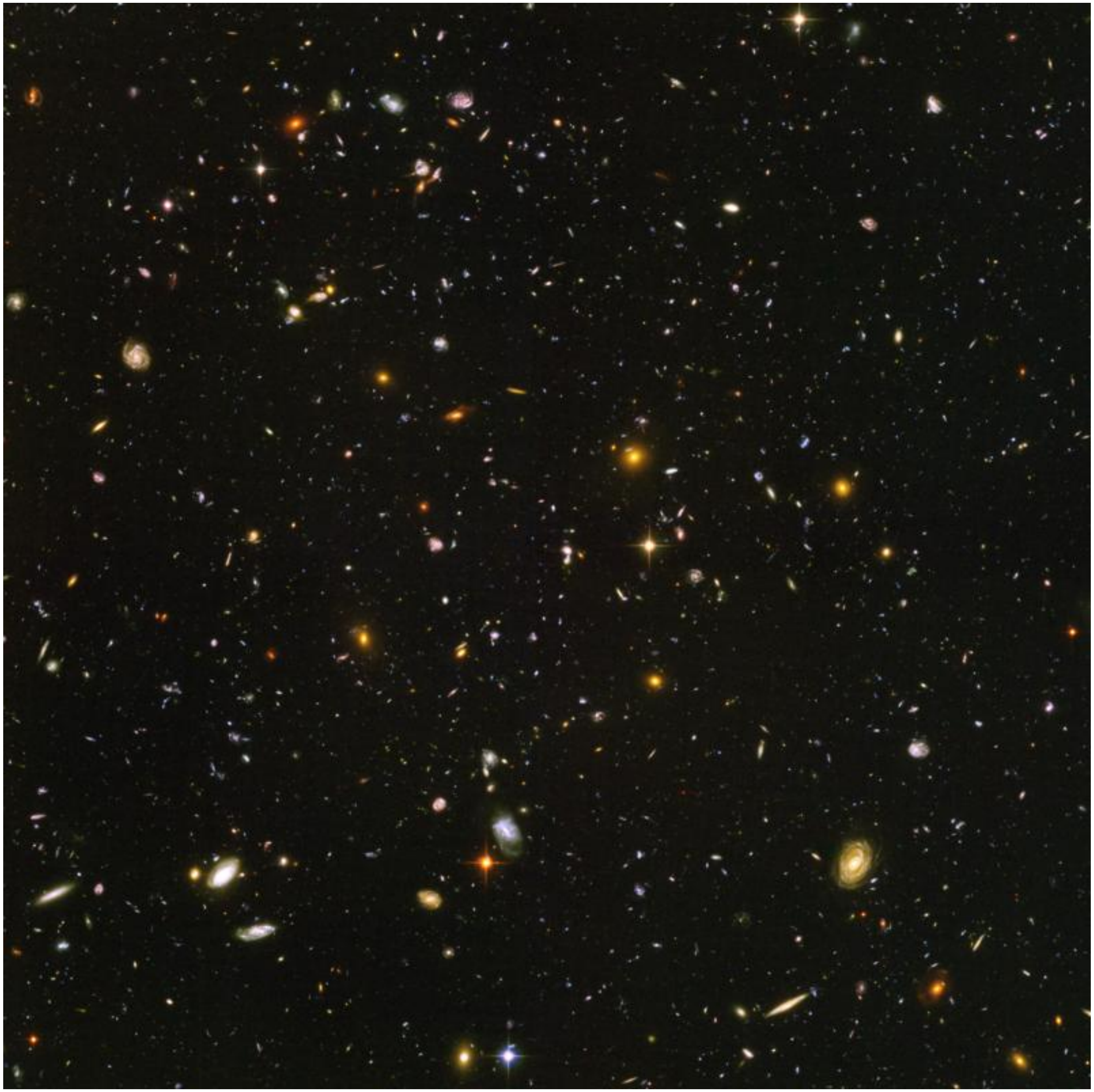
The X-ray photos were taken by the Chandra land-based telescope. (In them, blue is associated with higher frequency X-rays whereas red is associated with lower frequency radiation.)

The Infrared photos were taken by the Spitzer space-based telescope. Their color is generally redish.

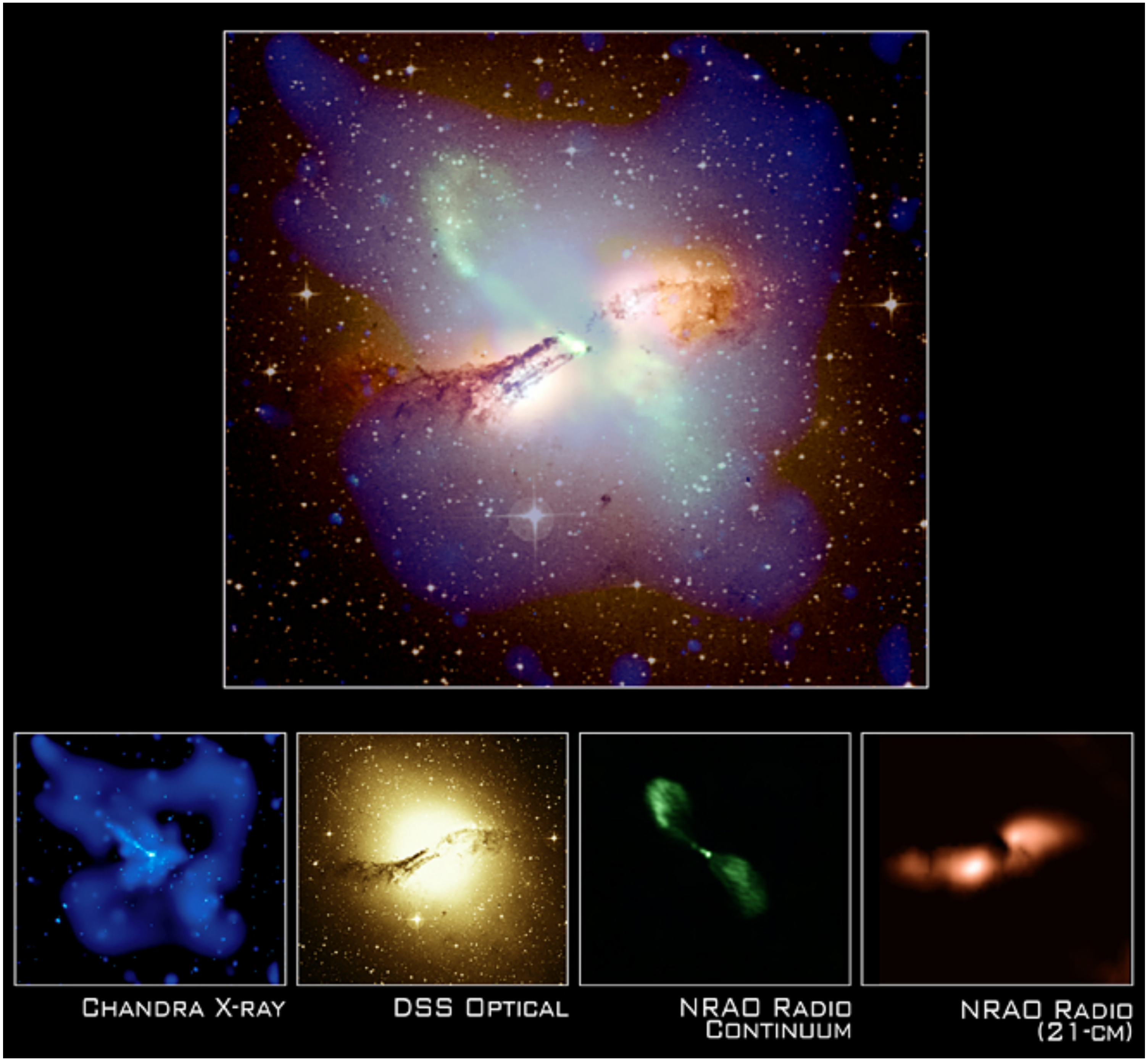
The point is, if you were to look in a telescope at many of the celestial objects you are about to view, they would look different. Why? Because your eyes are quite sensitive to green light but not particularly sensitive to the red of the hydrogen-alpha line.

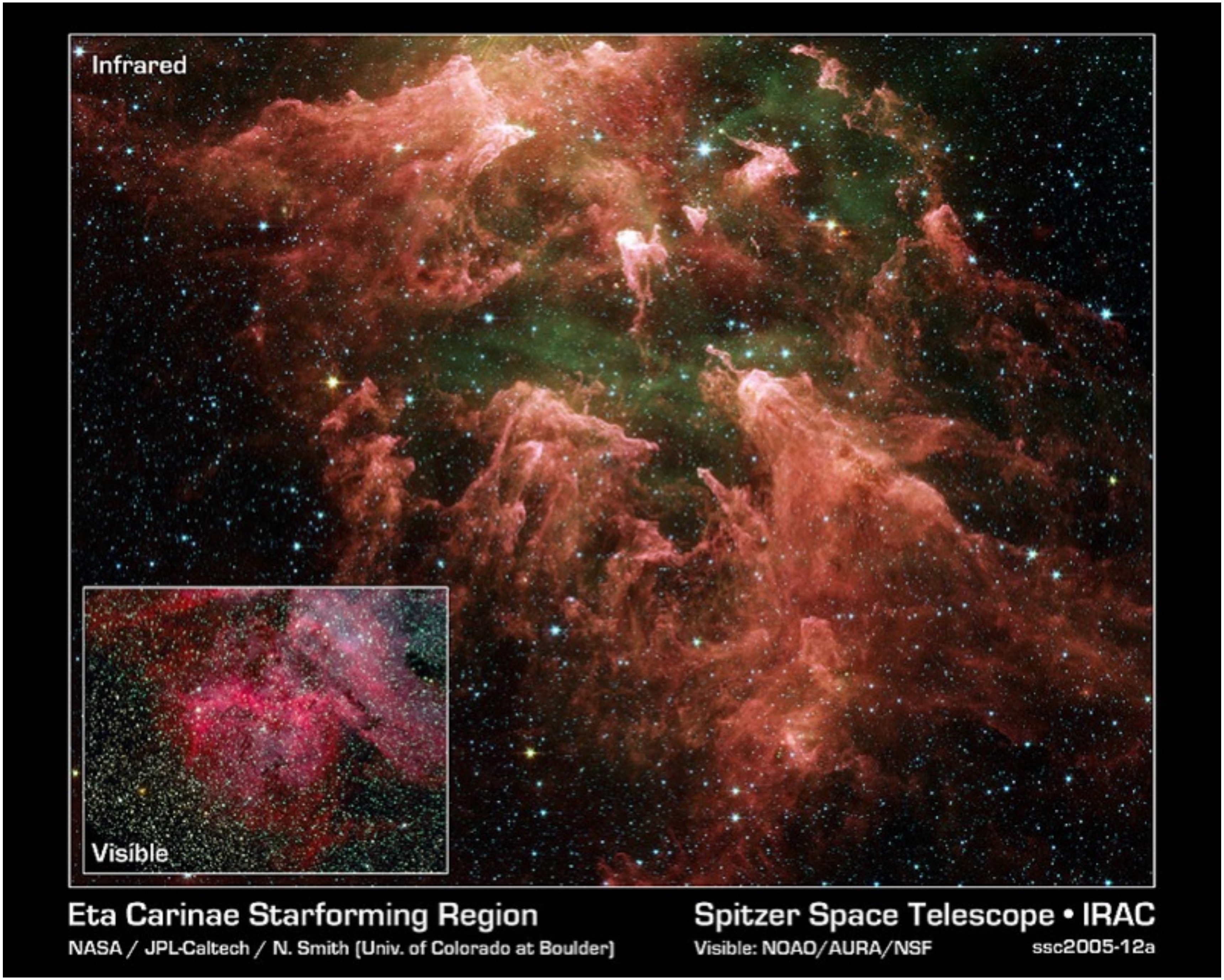
Deep Sky Space





Composites


CHANDRA X-RAY
DSS OPTICAL
NRAO RADIO CONTINUUM
NRAO RADIO (21-CM)



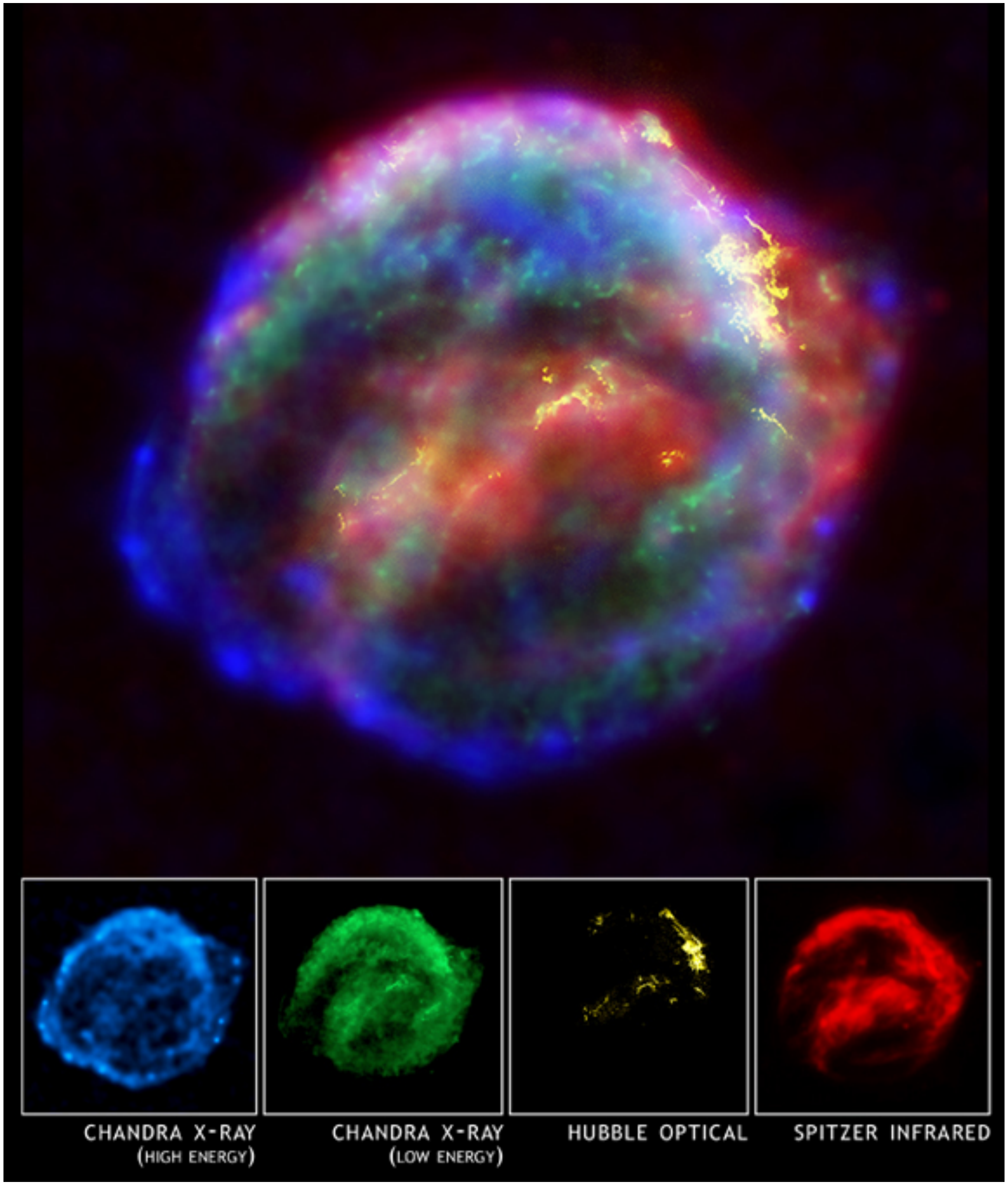
Eta Carinae Starforming Region

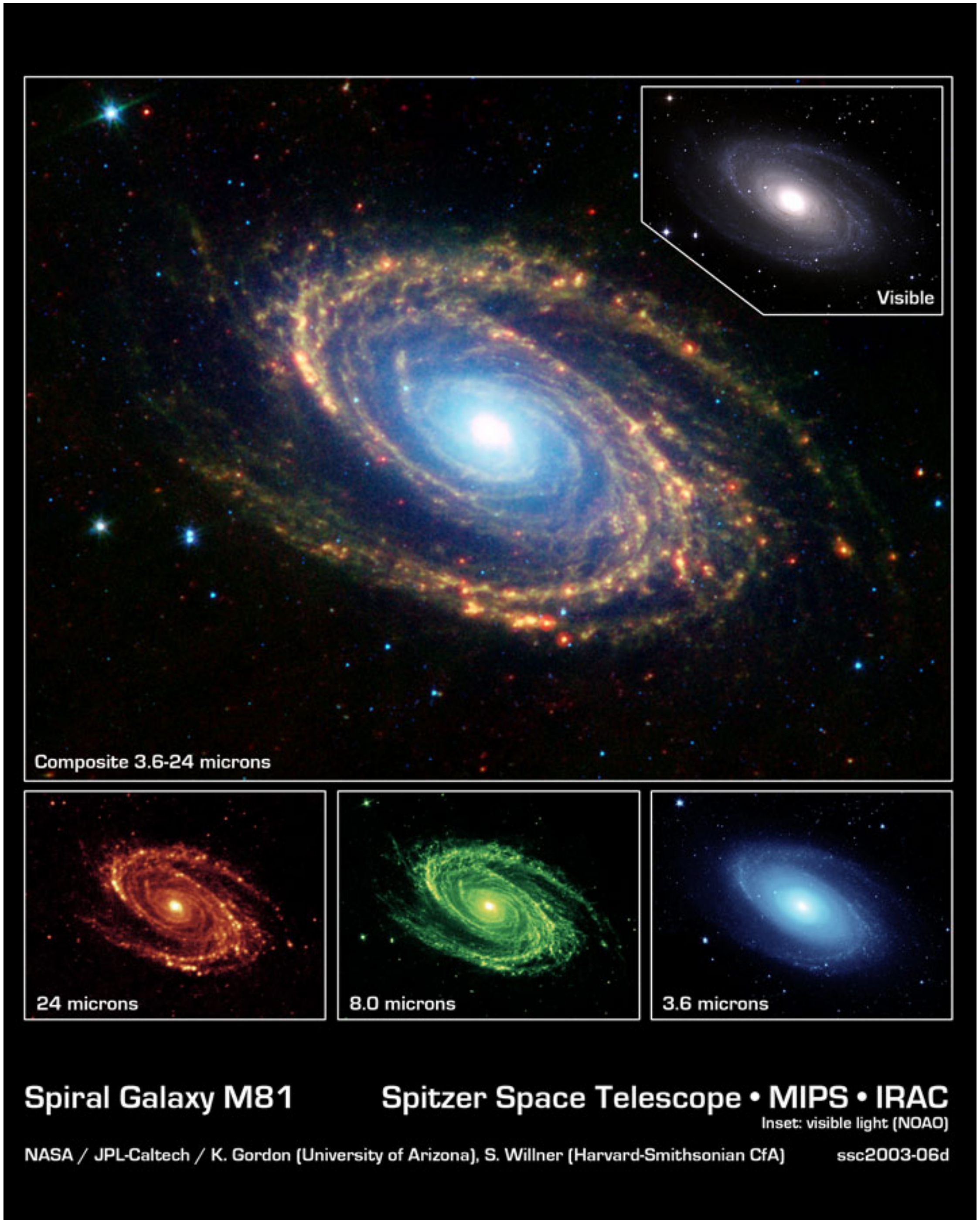
NASA / JPL-Caltech / N. Smith (Univ. of Colorado at Boulder)

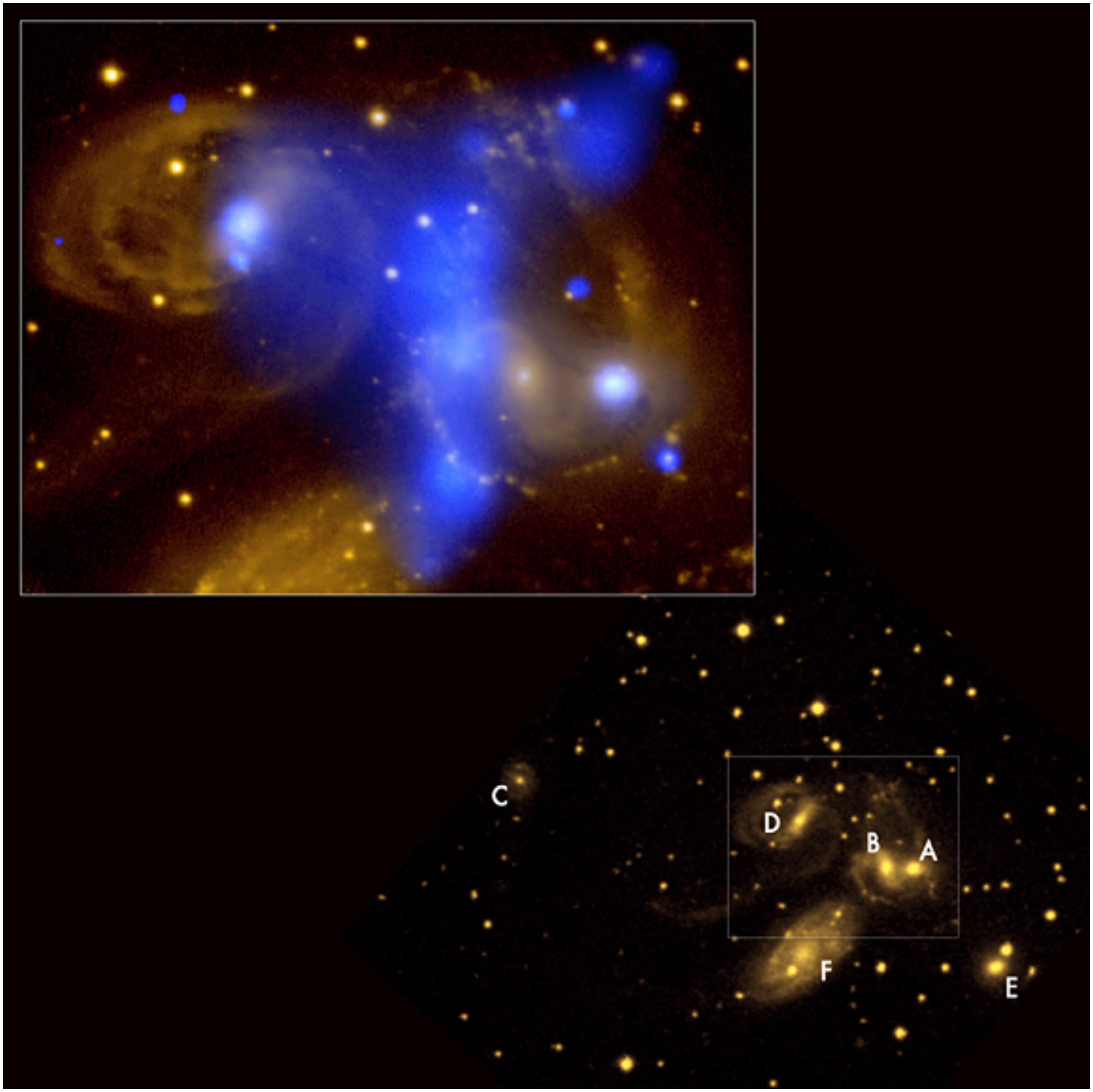
Spitzer Space Telescope • IRAC

Visible: NOAO/AURA/NSF

ssc2005-12a


CHANDRA X-RAY
(HIGH ENERGY)
CHANDRA X-RAY
(LOW ENERGY)
HUBBLE OPTICAL
SPITZER INFRARED


Visible
Composite 3.6-24 microns
24 microns
8.0 microns
3.6 microns
Spiral Galaxy M81
Spitzer Space Telescope • MIPS • IRAC
Inset: visible light (NOAO)
NASA / JPL-Caltech / K. Gordon (University of Arizona), S. Willner (Harvard-Smithsonian CfA)
ssc2003-06d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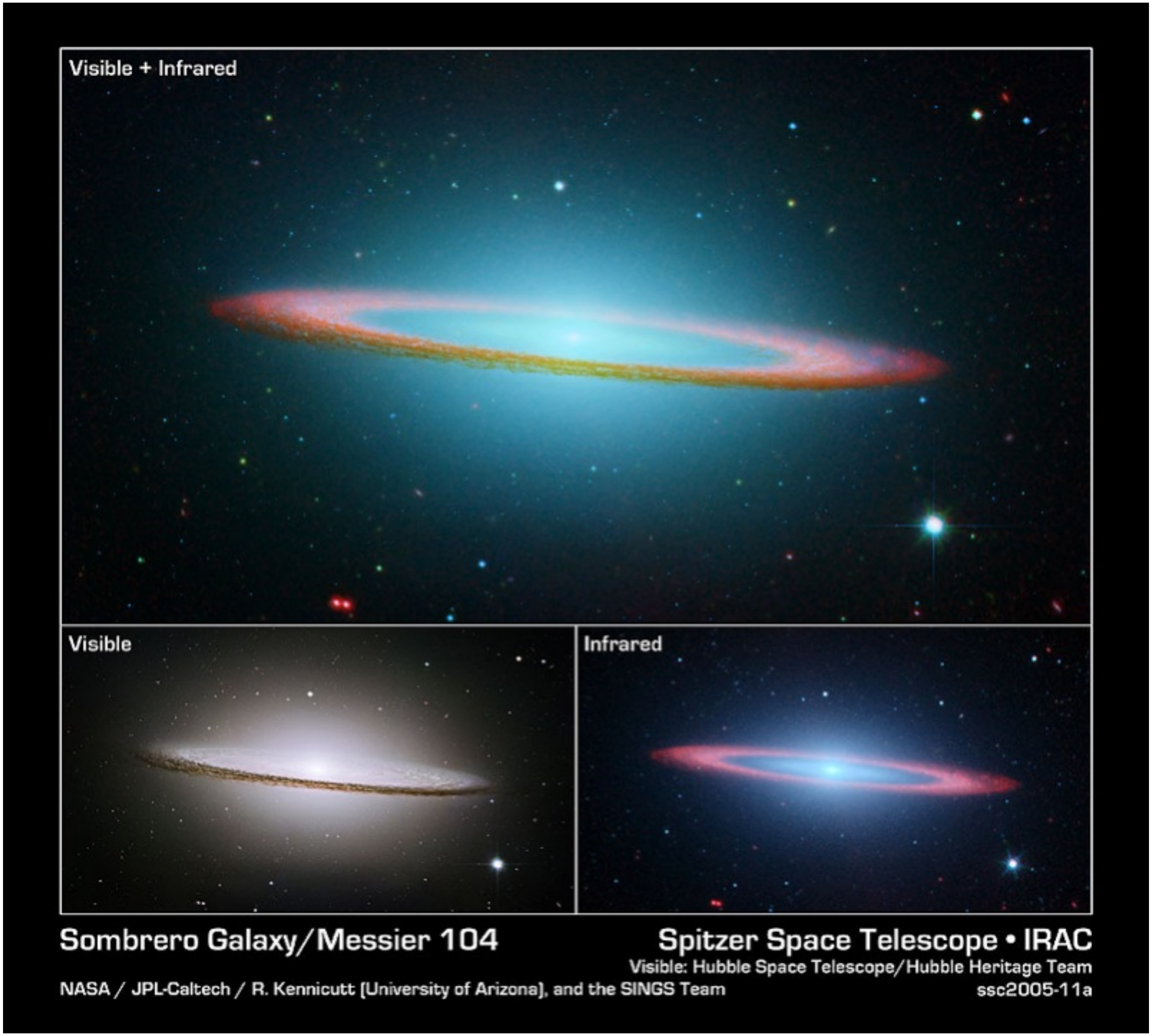


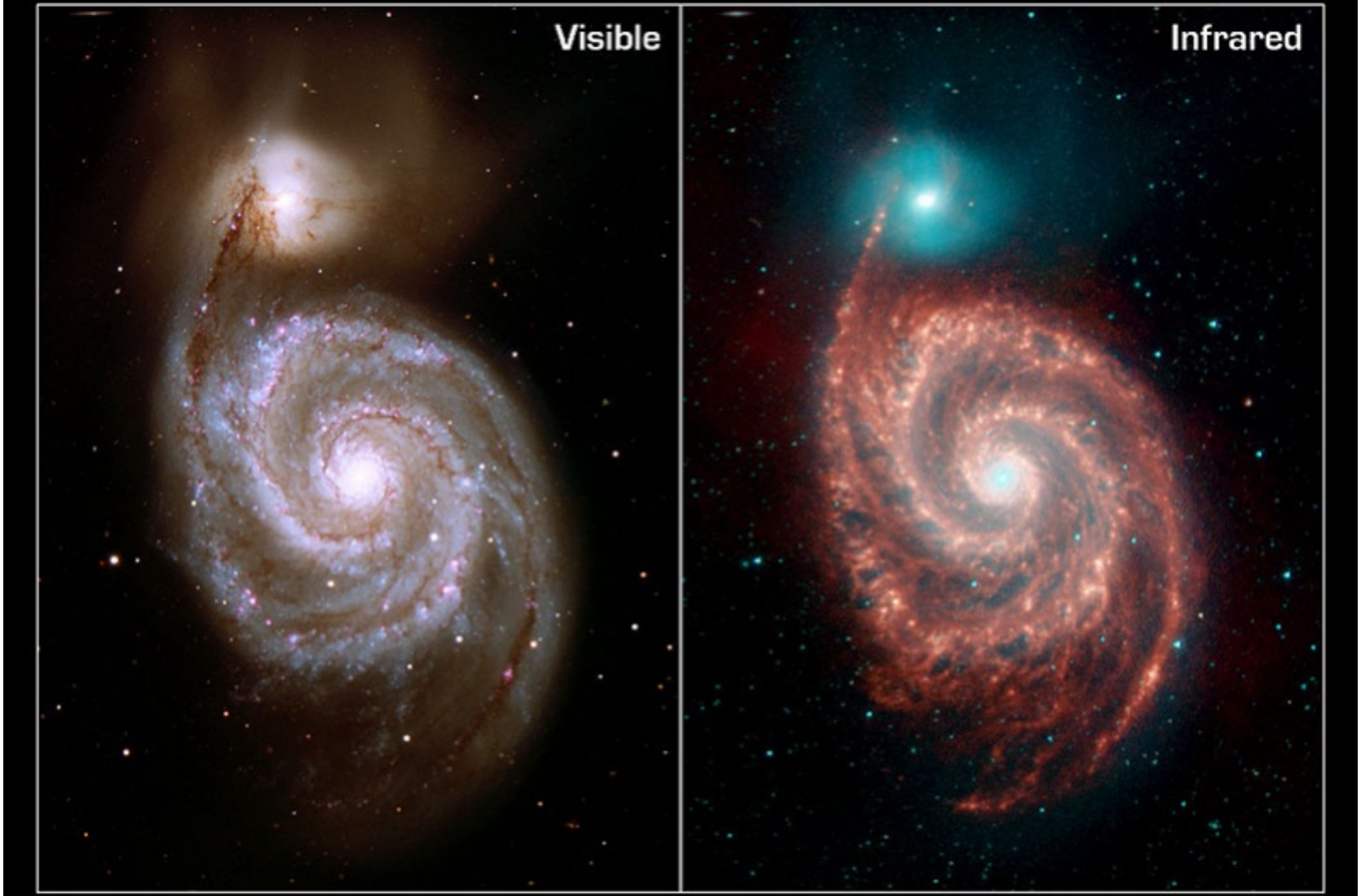
Sombrero Galaxy/Messier 104

Spitzer Space Telescope • IRAC

Visible: Hubble Space Telescope/Hubble Heritage Team

NASA / JPL-Caltech / R. Kennicutt [University of Arizona], and the SINGS Team

ssc2005-11a



Spiral Galaxy M51 (“Whirlpool Galaxy”)

Spitzer Space Telescope • IRAC

NASA / JPL-Caltech / R. Kennicutt (Univ. of Arizona)

ssc2004-19a