THE DEEP FIELD

BY STEVEN SWIRYN

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Wait for a clear, dark night. Hold a straight-pin between your finger and thumb. Now, stretch it to arm's length so that the pinhead covers a tiny piece of the night sky, not over a star, but in the space between the stars. Imagine taking a snapshot of that dark spot. Opening the camera's shutter for only the fraction of a second you would need to snap the snapdragons and nasturtiums in your sunny garden will reveal nothing. You need to gather more light.

The Hubble Space Telescope, during ten days in December, 1995, gathered all the faint, un-flickering[1] light it could for 200 hours of just such a pinhead point of sky north of the Big Dipper. They named it the Deep Field, a nondescript, "empty" piece of sky, chosen not, as are almost all Hubble tasks, to image some known object like the Seven Sisters star cluster, or a dust cloud the shape of a horsehead, or that rugby-shirted brawler, Jupiter, but to see what, if anything, dazzled out there in the cold dim distance of space.

The result resembles a jeweler's pad of black velvet with a spill of precious stones. The image[2] shows only eight or nine foreground stars[3] out of the 250 billion or so in our own Milky Way galaxy. Behind them—beyond them—are thousands of multi-colored jewels of myriad shapes and sizes, each one a galaxy, each one another entire Milky Way of billions of stars. The Milky Way is not just the elegant "cloudy" streak that we city dwellers, sadly, don't get to see anymore because of light pollution. It's the name for our entire galaxy. "Galaxy" comes from the Greek word for milk. Think "galactic" and its cognate, "lactation."

The eight or nine local sparkles in the image of the Hubble Deep Field (HDF) are like the first raindrops on a windowpane at the furtive beginning of a summer shower, through which you have taken a photo of the distant purpled mountains. The presence of the raindrops on the window locates us inside our modest earthen home, looking out toward the distant majesty we cannot touch. In 1995 Robert Williams, former Director of the Space Telescope Science Institute,[4] chose a location for the Deep Field to be as empty of nearby stars and interstellar dust as possible, as if you had avoided as much of the rain-dropped window as possible to see the farthest mountains. Three years later, a second Deep Field image, this time over the southern hemisphere in the constellation, Tucana, showed a similar plethora of distant galaxies.

That speck of night sky in Ursa Major or in Tucana is one of twenty-five million possible pinhead-sized specks (fields of view) that surround the earth and, if you gathered

Hubble Deep Field-North, HDF-N, Jan. 15, 1996
R. Williams (STScI), the Hubble Deep Field Team and NASA

its light for 200 hours, each of these other sky-specks would reveal thousands of jewel-like whorls, blobs, or bars, each one a galaxy. In every direction, over every bit of our celestial sphere. Twenty-five million pieces of sky, each with thousands of galaxies, each galaxy with billions of stars. The numbers, we feel—we can't think that high so we must feel—are too big.

If the numbers overwhelm, so, too, do the distances. If you glanced at the Deep Field photograph, instead of studying it, you might overlook the foreground stars. It's the mountains, and not the raindrops on the window, that are the subject of the photo. The window is only a foot from your camera and the mountains twenty miles—distances with which we are familiar. But distances even to these foreground Milky Way stars are mostly hundreds or thousands of *light years* away! One light year is six trillion miles. Yes, but how far is that? You can try, "over two hundred billion marathons," but that doesn't help much. What about sixty-five thousand times as far as the sun? Or, about 150 thousand times the length of all the world's highways. More than one tank of gas, even in your hybrid. The "mountain majesties" of the Deep Field, each a galaxy, are not twenty, or hundreds, but millions or even billions of light years away. It's not just the number of objects, but the distances, that overwhelm.

Also overwhelming is the time. We are looking at a photograph of the past. Not of yesterday, when the nasturtiums bloomed, only to be snatched by my wife and thrown into

the dinner salad; or of the mid-20th century, when my dad coached high school basketball (so did Edwin Hubble, a half century earlier); or of the Mesozoic Era of 100 million years ago in the time of dinosaurs; but billions of years ago. Toward the beginning of time.

You are always looking back in time. What you see is the light reflected, or, in the case of a firefly or a star, light created, and then traveling to your eye. That travel takes time. Light, though, moves so fast it can circle the earth seven-and-one-half times in a second. That's why a light year is such a vast distance. The light reflected off the mail carrier on the front stoop hits your eye with imperceptibly brief delay. Still, the mail carrier slipped those bills and advertisements into the slot just *before* you saw her do it. When the distances are greater, the delay becomes perceptible. Light takes more than a second to arrive here from the moon; more than eight minutes from the sun. In a second, light moves 186,000 miles; in a year, the distance called a *light year*. Yes, a light year is not a measure of time, but a measure of distance.

Betelgeuse, the red giant at Orion's eastern shoulder, and 700 light years from the earth, began to dim in late 2019, suggesting that it was ready to explode into a supernova—the death of a star. By early 2020, it appeared to stop dimming, and has been reprieved. If you did see Betelgeuse explode into a supernova tonight, you would be seeing what happened to that star seven hundred years ago, at the time of another great plague—the black death—because the light from such an explosion would take that long

to get here. And if Betelgeuse exploded tonight, you wouldn't get to see it at all, unless you have Methuselean genes. You and I have not been reprieved.

The more you appreciate how fast light travels, the more astounding become the distances to the bright stars. How do we measure how far away a star or galaxy is? You can't pace it off like I learned to do in scouts. My eyes are set apart, not just to make space for my nose, but so I can perceive distance. Parallax, the perception that a nearby object seems to shift its position against its background if, observing from a slightly different angle, you look with one eye closed and then the other, was used to measure "nearby" distances, most famously, the distance from earth to the sun, taking advantage of the transit of Venus.[5] However, the parallax method becomes unworkable at the large distances of most celestial objects; the distance between your two eyes, or opposite sides of tiny earth itself, or even opposite sides of the earth's orbit around the sun with one observation in June and one in December, are all too narrow to measure the angle accurately.

What about brightness? Surely a closer star will, other things equal, be brighter than one farther away. When, as a child, I got a flashlight for my birthday, shining it down a long hallway at my big sister didn't seem that bright to her. The next morning I brought it right next to her eyes and pulled up her eyelid to wake her. After seven decades, she still complains about how bright, as opposed to her dim little brother, the flashlight shone when it was close.

But the stars are not identical like sixty-watt lightbulbs; their brightness varies by a factor of thousands. Sirius, the Dog Star, which can be found by scanning southeast from Orion's belt, is the brightest star in our sky, other than the sun. Sirius is "only" eight light years from us. Being so close, it appears bright. Polaris, the north star, is only the forty-eighth brightest, yet Polaris is 450 light years away. Its *apparent* brightness is only forty-eighth, but its *absolute* brightness is much greater than Sirius. From equal distances, Sirius would be twenty-five times as bright as our sun; Polaris, over two thousand times as bright.

Polaris is a *variable* star. It gets slightly brighter and dimmer every four days, that is, with a period of four days. In 1912, Miss Henrietta Leavitt, a "computer"[6] at Harvard Observatory, discovered that for certain variable stars the period had a predictable mathematical relationship with absolute brightness. This led to the ability to compute distance. The observed period—the time between peaks of brightness—gives you absolute brightness. The apparent brightness, what you actually see, compared with absolute brightness calculated from the period, gives you distance. The prototype for such stars was not Polaris, but a star in the constellation Cepheus, the king of Ethiopia, spouse of Cassiopeia, daddy of Andromeda. These variable stars are called Cepheid variables.

Thanks in part to the computations of Henrietta Leavitt, Edwin Hubble made a

name for himself, and a name for the Space Telescope, with two giant discoveries: first, that certain celestial objects called nebulae were not dust clouds within our Milky Way, but distant galaxies; second, that these galaxies are moving away from each other.

All of the objects one sees with the naked eye in the night sky, all the stars, including Betelgeuse, Polaris and Sirius, five planets and our moon, shooting stars, comets, and dust clouds, are a part of our Milky Way galaxy. Stargazing from the northern hemisphere, there are few exceptions; the brightest is the Andromeda galaxy. If you know where to look, halfway between Pegasus and Cassiopeia, and there is no moon glare or much light pollution, you can find the Andromeda galaxy as a "faint fuzzy," bigger than the full moon, but dim and diffuse. Early in the twentieth century, astronomers argued whether this Andromeda "nebula" was a cloud of dust within the Milky Way or a huge object beyond our own galaxy. Charles Messier, who in 1764 catalogued the Andromeda galaxy as M31 in his list,[7] thought it hovered only 16,000 light years distant, which would place it within the Milky Way. In 1923, Edwin Hubble confirmed the true distance by observing a Cepheid variable, "V1," in the Andromeda "nebula."[8]

Hubble, who as a teenager had set the Illinois state high school high jump record at a track meet held at Northwestern University, where I now teach, studied astronomy at the University of Chicago. Later, at Mt. Wilson in California, observing Cepheid variable V1 within the Andromeda nebula, Hubble could calculate that M31 lurked 2.5 million light

years distant,[9] more than ten times the farthest reaches of our Milky Way; a separate galaxy. Not at all part of the neighborhood you would invite to a Milky Way block party, though Andromeda is one of the closest of the galaxies. Again, we are looking back in time; the light Edwin Hubble collected at Mt. Wilson left the Andromeda Galaxy 2.5 million years ago, even before our ancestor, Homo erectus, evolved in Africa.

All those galaxies in the Deep Field are moving. When Amtrak rushes by, its roar changes from higher to lower pitch as it passes.[10] This *doppler effect* results from the crowding of sound waves as the train approaches, and their stretching apart after it goes by. If we apply that understanding to starlight instead of sound, the spectrum created by a prism shows the same doppler effect. The visible light spectrum is blue-shifted—to higher frequencies—if the star is moving towards us and red-shifted—to lower frequencies, red being towards the low frequency end —if the star is moving away.

Hubble, calculating spectral shifts and comparing them with distance measurements from Cepheid variables, proved that in every direction galaxies were moving away from us, a red shift, as if all coming from the same focus.[11] Hubble also proved that the farther away the galaxies were, the more extreme the red shift, that is, the faster they were moving away. The universe is expanding.

Picturing the oldest galaxies in a Deep Field as they were billions of years ago, we

appreciate the earliest moments of the universe and changes that take place as it ages. Now there is an Ultra Deep Field and, more recently, built of ten years of Hubble exposures, an Extreme Deep Field—each one able to see dimmer galaxies, farther back, closer to the time of the Big Bang.

The James Webb Space Telescope has extended Deep Field observations since its launch on Christmas day, 2021. Larger than Hubble,[12] with better resolution of the dim distance, the JWST collected a Deep Field as one of its first images. The JWST instruments are sensitive to light in the infrared range of the electromagnetic spectrum, with the advantage that infrared better penetrates interstellar dust—dust which otherwise hides the objects behind it. For events of the earliest period after the Big Bang, the red shift is extreme enough to have stretched the light from its original ultraviolet and visible ROYGBIV range to the longer wavelengths of infrared. JWST gets us farther back in time than we can see with Hubble.

So many, so far, so old! Does it make me feel insignificant? Distant? Short-lived? No, it somehow makes me feel grand. The wonders I can wander in; the delightful mystery stories I can spin with my grandchildren. Does it make me feel alone? Not a chance. With billions of stars in each of billions of galaxies, often circled by their own "exoplanets,"[13] it is inconceivable that we earthlings are the only life in town.

The Hubble Deep Field, its image first published in 1996, is a spiritual statement. What surrounds us? Where have we come from? The world is not 6,000 years old; it's closer to fourteen billion—we have seen its photograph. Does that mean that God does not exist? Of course not. Though I'm not a believer myself, any omnipotent God that you may believe in could easily have set all this in motion.

There is a chair where I sit and read, left on our glassed-in sunporch by the previous owner of our house. Once, I am certain, it was an energetic young chair with plush cushions, unfaded upholstery, and a fresh swivel that still allows me to ease my eyes to the backyard as blossoms celebrate the river birch and the crabapple. Now the chair sags a bit, tilts a bit, even squeaks, though so softly it evokes distance more than decay. I often lift my head from my book and, stretching my neck and shoulders, stare down at the garden and imagine. There are days when I see only the raindrops on the window. Others, I rest my book on my knee, set my glasses on the table near my now-cold coffee and listen for the doppler effect, to sense what's coming at me and what's receding. I have lived three quarters of the last century of the one hundred forty million centuries represented in an image of celestial history. The Deep Field is a long look back, yet also a look forward. Tonight, if the sky is clear, I will zip my soft green fleece against the chill of Chicago's early spring to keep vigil as Betelgeuse sinks in the west. A poet has said, "Friend, tell me what to do, since I am a man in love with the setting stars."[14]

Endnotes

1. The HST, being above the earth's atmosphere, does not have to deal with the twinkle, twinkle of little stars.

2. https://science.nasa.gov/asset/hubble/hubble-deep-field-image-at-full-resolution/

3. The foreground stars can be recognized by their "diffraction spikes," making them look even more star-like.

4. This decision of Williams and his team to image an "empty" piece of sky, committing precious Hubble-time resources with the risk they would find only emptiness, was one of the most difficult in the project's planning phase.

5. Twice every 243 years, eight years apart (the last time in 2004 and 2012) we can observe Venus from distant sites ("eyes") on Earth as it passes directly between the Earth and the Sun, measure the parallax angle between the sites, and compute the distance from Earth to Sun. This distance has been known accurately since the transit of 1769 when one "eye" was the major scientific purpose of Captain Cook's voyage to the South Pacific.

6. In 1912, only the men at the Harvard Observatory could call themselves "Astronomers." The women worked in a separate building, cataloguing and measuring glass plate

photographs and other data.

7. Messier was searching for comets, and when he found interesting objects that turned out not to be comets, he catalogued them as M1 through M110 so he wouldn't get misled by them again. Finding all 110 objects in the night sky is a fun exercise for stargazers. Though it can be done in one night as a "Messier Marathon" if you are experienced, it took me more than two years of sporadic vacation observations away from city light pollution.

8. NASA has posted photos of Hubble's V1 here: https://science.nasa.gov/asset/hubble/cepheid-variable-star-v1-in-andromeda-galaxy/

9. Hubble's actual estimate was 1.5 million light years, a million light years too low. But it was accurate enough to place the "nebula" well outside the Milky Way. It's not that he was sloppy in his calculations, only that the amount of interstellar dust interposed between us and Andromeda, attenuating its apparent brightness, was not then known.

10. Amtrak may not deserve the word "rushes." The earth spins on its axis at just over 1,000 mph—doesn't it turn its 25,000 mile circumference back to its starting place in 24 hours?—and whirls around the sun at 66,000 mph. The sun, in turn, whips around the center of the Milky Way at more than 500,000 mph! You, too, are moving this rapidly, and by now have covered a startling amount of ground (space).

11. The “Big Bang.”

12. The primary mirror (the light-collecting “bucket”) of the JWST is twenty-two feet in diameter compared to eight feet for Hubble and it gathers about five times as much light.

13. An exoplanet is a planet outside our solar system, usually revolving around a star. However, though life must be out there somewhere, it may be so far away that we would never meet. Or, it destroyed itself long ago. Or, it found us boring and didn’t bother to stop by.

14. Robert Bly, from the title poem in *The Night Abraham Called to the Stars*.

Author

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