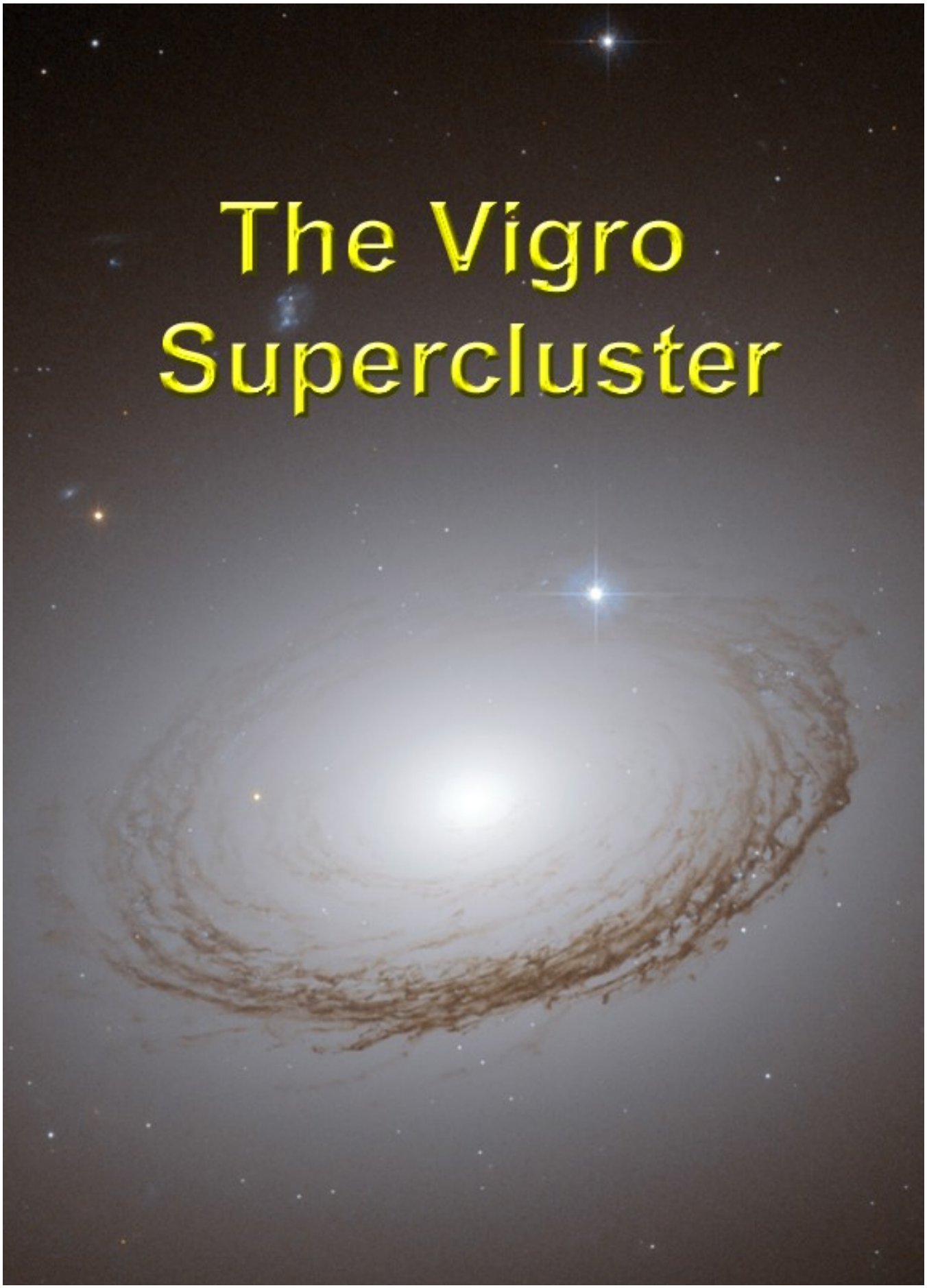

The Vigro
Supercluster

The Virgo Supercluster

{Abstract *– In this segment of our "How far away is it" video book, we cover our local supercluster, the Virgo Supercluster.*

We begin with a description of the size, content and structure of the supercluster, including the formation of galaxy clusters and galaxy clouds. We then take a look at some of the galaxies in the Virgo Supercluster including: NGC 4314 with its ring in the core, NGC 5866, Zwicky 18, the beautiful NGC 2841, NGC 3079 with is central gaseous bubble, M100, M77 with its central supermassive black hole, NGC 3949, NGC 3310, NGC 4013, the unusual NGC 4522, NGC 4710 with its "X"-shaped bulge, and NGC 4414.

At this point, we have enough distant galaxies to formulate Hubble's Law and calculate Hubble's Red Shift constant. From a distance ladder point of view, once we have the Hubble constant, and we can measure red shift, we can calculate distance. So we add Red Shift to our ladder.

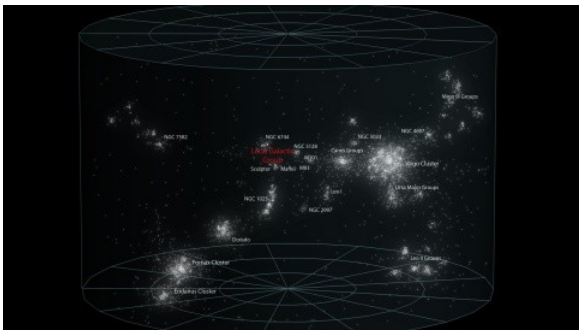
Then we continue with galaxy gazing with: NGC 1427A, NGC 3982, NGC 1300, NGC 5584, the dusty NGC 1316, NGC 4639, NGC 4319, NGC 3021 with is large number of Cepheid variables, NGC 3370, NGC 1309, and 7049.

We end with a review of the distance ladder now that Red Shift has been added.}

Introduction

> **[Music:** *Antonio Vivaldi – "The Four Seasons – Winter" – Vivaldi composed "The Four Seasons" in 1723. "Winter" is peppered with silvery pizzicato notes from the high strings, calling to mind icy rain. The ending line for the accompanying sonnet reads "this is winter, which nonetheless brings its own delights." The galaxies of the Virgo Supercluster will also bring us their own visual and intellectual delight.***]**

Superclusters are among the largest structures in the known Universe. The Virgo Supercluster, also known as the Local Supercluster, is 110 million light-years in diameter. It contains 4,000 luminous galaxies, organized into 100 galaxy groups and galaxy clusters. The Virgo Supercluster's volume is approximately 7,000 times larger than our Local Group and 100 billion times larger than the Milky Way.



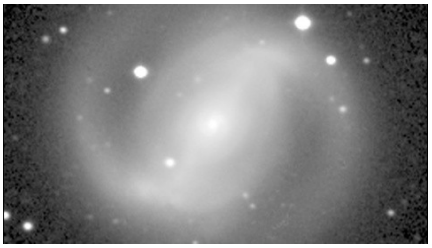
For the first time, we are at a distance where we can see that galaxies are not just evenly distributed throughout space. In this picture, each galaxy is a point of light. And these points are crowded together into galaxy clusters. And these clusters are crowded together into galaxy clouds. And these clouds of galaxy clusters are grouped up into the supercluster.

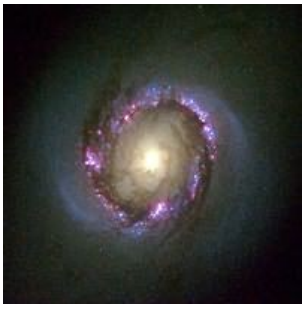
[Additional info: The supercluster has a shape – it has a disk with a halo. It is hard to see in two-dimensions and it is much less defined than our galaxy disk and halo, but it is there. We see a disk of clouds from the Virgo III Groups in the upper right; through the Virgo Cluster at the center; down to the Eridanus Cluster at the lower left. The Leo II groups are below the disk, and our local galaxy cluster is above the group along with NGC 7582. The center is the Virgo Cluster, around 53.8 mly away. It has from 1300 to 2000 member galaxies. This cluster forms the heart of the Virgo Supercluster.**]**

Let's take a look at some of the galaxies in the Virgo Supercluster.

NGC 4314 – 40 mly

This ground based image of the barred-spiral galaxy NGC 4314 was taken by the McDonald Observatory in Texas. It shows the entire galaxy, including the bar of stars bisecting the core and the outer spiral arms, which begin near the ends of this bar. That's normal enough.





But this Hubble image reveals clusters of infant stars that formed in a ring around the core. This close-up view by Hubble also shows other interesting details in the galaxy's core: dust lanes, a smaller bar of stars, dust and gas embedded in the stellar ring, and an extra pair of spiral arms packed with young stars. These details make the center resemble a miniature version of a spiral galaxy.

[Additional info: While it is not unusual to have dust lanes and rings of gas in the centers of galaxies, it is uncommon to have spiral arms full of young stars in the cores.**]**

> **[Music:** *Pietro Mascagni – "Intermezzo for Cavalleria rusticana" (Rustic Chivalry) – Mascagni's Cavalleria rusticana, released in 1890, created a new style for music. It represented a move from romanticism to realism. It was our study of the Virgo Supercluster that helped mankind begin to understand the true enormity of the Universe, putting to an end more romantic notions of our place in the cosmos.***]**

NGC 5866 – 44 mly

This is a unique view of a galaxy tilted nearly edge-on to our line-of-sight. The image highlights the galaxy's structure: a subtle, reddish bulge surrounding a bright nucleus, a blue disk of stars running parallel to the dust lane, and a transparent outer halo. The dust lane is slightly warped compared to the disk of starlight. This warp indicates that NGC 5866 may have undergone a gravitational tidal disturbance in the distant past, by a close encounter with another galaxy.

Zwicky 18 – 45 mly

Hubble snapped a view of what may be the youngest galaxy ever seen. Zwicky 18 may be as young as 500 million years old. The galaxy is classified as a dwarf irregular galaxy. This galaxy is typical of the kinds of galaxies that inhabited the early universe.

NGC 2841 – 46 mly

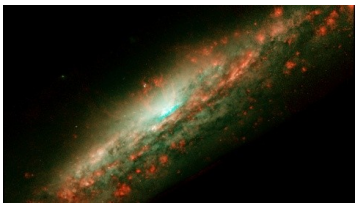
Hubble reveals a majestic disk of stars and dust lanes in this view of the spiral galaxy NGC 2841.

A bright cusp of starlight marks the galaxy's center. Spiraling outward are dust lanes that are silhouetted against the population of whitish middle-aged stars. Much younger blue stars trace the spiral arms. Notably missing are pinkish emission nebulae indicative of new star birth.

It is likely that the radiation and supersonic winds from fiery, super-hot, young blue stars cleared out the remaining gas, and hence shut down further star formation in the regions in which they were born.

NGC 3079 – 50 mly

This picture shows a bubble in the center of the galaxy's disk. The structure is more than 3,000 light-years wide and raises 3,500 light-years above the galaxy's disk.



This is a close-up view of the bubble. Gaseous filaments at the top of the bubble are whirling around in a vortex and are being expelled into space. Eventually, this gas will rain down upon the galaxy's disk where it may collide with gas clouds, compress them, and form a new generation of stars.

M100 – 50 mly

Messier 100 is a perfect example of a grand design spiral galaxy, a type of galaxy with prominent and very well-defined spiral arms. These dusty structures swirl around the galaxy's nucleus, and are marked by a flurry of star formation activity that dots M100 with bright blue, high-mass stars.

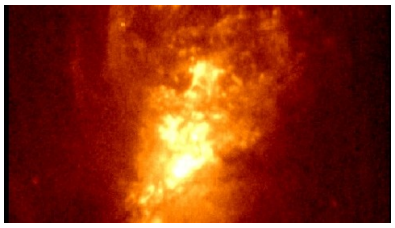
[Additional info: This galaxy has an **active galactic nucleus** — a bright region at the galaxy's core caused by a supermassive black hole that is actively swallowing material, which radiates brightly as it falls inwards. The galaxy's spiral arms also host smaller black holes, including the youngest ever observed in our cosmic neighborhood, the result of a supernova observed in 1979.**]**

M77, NGC 1068 – 50 mly

Messier 77 is a spiral galaxy containing a supermassive black hole.

[Music: *Saint-Saëns – "The Carnival of the Animals - The Swan" – Composed in 1886, the piece evokes a swan elegantly gliding over the water being propelled along by feet that are moving fast, but hidden from view beneath the water. Not bad background music for M77 with its galaxy altering central wind driven by an unseen black hole.***]**

The X-ray images and spectra obtained using Chandra's Spectrometer show that a strong wind is being driven away from the center of the galaxy at a rate of about a million miles per hour. This wind is likely generated as surrounding gas is accelerated and heated as it swirls toward the black hole. A portion of the gas is pulled into the black hole, but some of it is blown away.



High energy X-rays produced by the gas near the black hole heat the ouflowing gas, causing it to glow at lower X-ray energies. These results help explain how an "average"-sized supermassive black hole can alter the evolution of its entire host galaxy.

NGC 3949 – 50 mly

One of the ways we construct the form of our home Milky Way galaxy is to examine galaxies that are similar in shape and structure. Spiral galaxies like NGC 3949, pictured in this Hubble image, fit the bill. Like our Milky Way, this galaxy has a blue disk of young stars peppered with bright pink star-birth regions. In contrast to the blue disk, the bright central bulge is made up of mostly older, redder stars.

NGC 3310 – 59 mly

Most galaxies form new stars at a fairly slow rate, but members of a rare class, known as **starburst galaxies**, blaze with extremely active star formation. The galaxy NGC 3310 is forming clusters of new stars at a prodigious rate. There are several hundred star clusters visible in this image as the bright blue diffuse objects that trace the galaxy's spiral arms. Each of these star clusters represents the formation of up to about a million stars.

NGC 4013 – 55 mly

NGC 4013 is a spiral galaxy, similar to our own Milky Way. This Hubble picture reveals, with exquisite detail, huge clouds of dust and gas extending along, as well as far above, the galaxy's main disk. Viewed pole-on, it would look like a nearly circular pinwheel. Even at 55 million light-years, the galaxy is larger than Hubble's field of view, and the image shows only a little more than half of the object.

[Additional info: When light passes through a volume containing small particles, it becomes fainter and redder. By studying the color and the amount of light absorbed by these distant clouds in NGC 4013, astronomers can estimate the amount of matter in them. Individual clouds contain as much as one million times the amount of mass in our Sun.**]**

NGC 4522 – 60 mly

NGC 4522 is a spectacular example of a spiral galaxy that is currently being stripped of its gas content by its strong central winds. Scientists estimate that the galaxy is moving at more than 6 million miles per hour. A number of newly formed star clusters that developed in the stripped gas can be seen in the Hubble image. The picture highlights the dramatic state of the galaxy with an especially vivid view of the ghostly gas being forced out of its center. Bright blue pockets of new star formation can be seen to the right and left of center.

[Music: *We return to Mascagni's "Intermezzo for Cavalleria rusticana".***]**

NGC 4710 – 60 mly

Here we are zooming into NGC 4710 in the Virgo Cluster. This magnificent giant galaxy is tilted nearly edge-on to our view from Earth. This perspective allows astronomers to easily distinguish the central bulge of stars from its pancake-flat disk of stars, dust, and gas.

When staring directly at the center of the galaxy, one can detect a faint, ethereal **"X"-shaped** structure. Such a feature, which astronomers call a "boxy" or "peanut-shaped" bulge, is due to the vertical motions of the stars in the galaxy's bar and is only evident when a galaxy is seen edge-on.

NGC 4414 – 62 mly

In 1995, the majestic spiral galaxy NGC 4414 was imaged by the Hubble as part of the Key Project on Extragalactic Distance Scales. An international team observed this galaxy on 13 different occasions over the course of two months.

Based on their discovery and careful brightness measurements of Cepheid variable stars in NGC 4414, the Key Project astronomers were able to make an accurate determination of the distance to the galaxy - 62 million light-years.

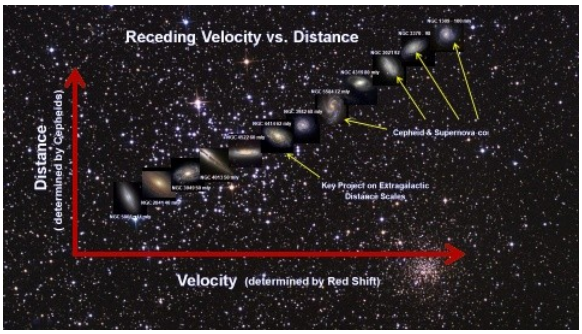
Hubble' Law

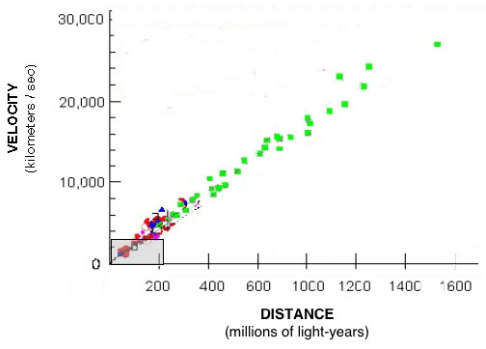
This takes us to the final rung in our Distance Ladder – Red Shift and Hubble's law.

[Music: *For Hubble's law, we return to Antonio Vivaldi's "Four Seasons".***]**

Edwin Hubble along with others suspected that the Milky Way was not an island universe. In 1923, after finding the V1 Cepheid in Andromeda, and determining that Andromeda was an entire galaxy over a million light years from our own, he turned his sights on other spiral and elliptical 'nebula' and found that they were galaxies as well. In his studies of these galaxies, he measured their radial velocity as determined by the shift in spectral lines as we discussed in our segment on Planetary Nebula. He found that, except for a few near-by galaxies, all the spectra shifts were to the red - they all were moving away from us.

Using galaxies in our local volume, he found what we see here with galaxies in the Virgo Supercluster: Simply stated, the further away a galaxy is, the greater the red shift, and therefore, the faster it is receding away from us. The relationship is linear (a straight line), so the equation is simple: The receding velocity of a galaxy is equal to its distance times a constant now called the Hubble Constant.





This constant has been refined over time, and the distances used to see how far it holds has increased by orders of magnitude with our modern ability to determine distances with space telescopes like Hubble analyzing Type 1a Supernova out to billions of light years. The gray box shows the region that [Edwin]Hubble probed.

The current best value for the Hubble Constant is 13.6 miles/sec per million-light-years. That is, the receding velocity of a galaxy goes up by 13.6 miles/sec for each additional million light years away from us it is.

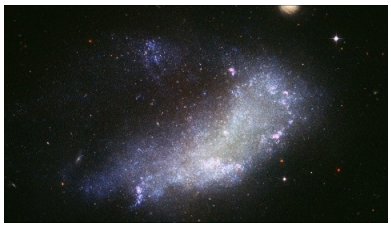
Let: v = a galaxy's receding velocity
r = distance to the galaxy
H_0 = the Hubble constant
We have:
$v = H_0 r$

From a distance ladder point of view, now that we have the Hubble constant and we can measure red shift, we can calculate distance.

$$v = H_0 r$$
$$r = v/H_0$$

NGC 1427A – 62 mly

[Music: *Back to galaxies and back to Mascagni's "Intermezzo".***]**



NGC 1427A is plunging headlong into the Fornax cluster at nearly 400 miles per second. This is a spectacular example of the resulting stellar rumble. This galaxy will not survive long as an identif1able galaxy passing through the cluster.

[Additional info: Within the next billion years, it will be completely disrupted, spilling its stars and remaining gas into intergalactic space within the Fornax cluster.**]**

NGC 3982 – 68 mly

Though the universe is full of spiral galaxies, no two look exactly the same. NGC 3982 is striking for its rich tapestry of star birth, along with its winding arms. The arms are lined with pink star-forming regions of glowing hydrogen, newborn blue star clusters, and obscuring dust lanes that provide the raw material for future generations of stars.

NGC 1300 – 69 mly

The Hubble telescope captured a display of starlight, glowing gas, and silhouetted dark clouds of interstellar dust in this image of the barred spiral galaxy NGC 1300 - a prototypical barred spiral galaxy. **[**Blue and red supergiant stars, star clusters, and star-forming regions are well resolved across the spiral arms, and dust lanes trace out fine structures in the disk and bar.**]**

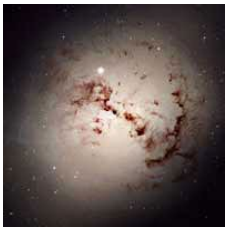
NGC 5584 – 72 mly

NGC 5584 contains Cepheid variables and one recent Type 1a supernova. As you know, we use these two standard candles as reliable distance markers to measure the universe's expansion rate. NGC 5584 was one of the eight galaxies astronomers studied to measure this rate. In total, the project analyzed more than 600 Cepheid variables, including 250 in NGC 5584.

NGC 1316 – 75 mly

NGC 1316 is one of the brightest ellipticals in the Fornax galaxy cluster.

[Additional info: Hubble enabled uniquely accurate measurements of a class of red star clusters inside the galaxy. Astronomers conclude that these star clusters constitute clear evidence of the occurrence of a major collision of two spiral galaxies that merged together a few billion years ago to shape NGC 1316 as it appears today.**]**



NGC 4639 – 78 mly

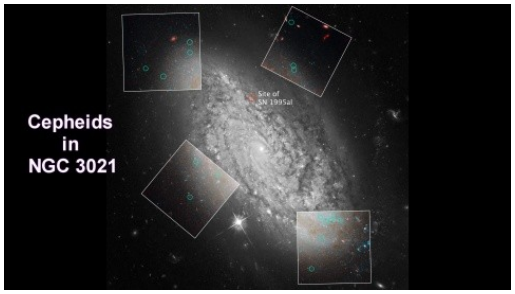
This Hubble image shows NGC 4639, a spiral galaxy located 78 million light-years away in the Virgo cluster of galaxies. The blue dots in the galaxy's outlying regions indicate the presence of young stars. Among them are older, bright Cepheids stars. After using Cepheids to calculate the distance to NGC 4639, the team compared the results to the peak brightness measurements of SN 1990N, a type 1a supernova located in the galaxy. Once again, Type 1a supernovae were found to be reliable standard candles.

NGC 4319 – 80 mly

This Hubble image shows the inner region of NGC 4319. The unusually dark and misshapen dust lanes in the galaxy's inner region are evidence of a disturbance, probably caused by an earlier interaction with another galaxy.

[Music: *We return to Saint-Saëns' – "Swan".***]**

NGC 3021 -92mly



This galaxy was one of several hosts of recent type 1a supernovae observed by astronomers to refine the Hubble constant. In the 1930s, Edwin Hubble made precise measurements of Cepheid variable stars in this galaxy, highlighted by green circles in the four inset boxes. These Cepheids are used to calibrate the supernova that was observed in the galaxy in 1995.

NGC 3370 – 98 mly

In 1994, NGC 3370 hosted a type 1a supernovae designated SN 1994ae. This stellar outburst briefly outshone all of the tens of billions of other stars in its galaxy. Although supernovae are common, with one exploding every few seconds somewhere in the universe, this one was special. This supernova was one of the nearest and best observed supernovae since the advent of modern, digital detectors.

NGC 1309 – 100 mly

NGC 1309 is one of about 200 galaxies that make up the Eridanus galactic group. It was home to type 1a supernova SN 2002fk. Its light reached Earth in September 2002. It also contains a number of Cepheid variables resolved by the Hubble Space Telescope. And, once again, the type 1a was shown to be an excellent standard candle.

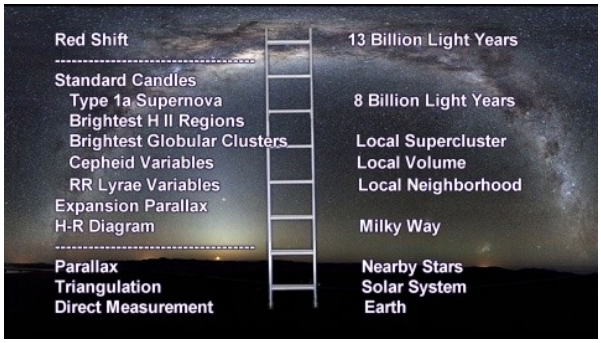
NGC 7049 – 100 mly

NGC 7049 is the brightest of a cluster of galaxies, called **Brightest Cluster Galaxies** or BCG for short. Typical BCGs are some of the oldest and most massive galaxies. **[**The globular clusters in NGC 7049 are seen as the sprinkling of small faint points of light in the galaxy's halo.**]**

Distance Ladder

[Music: *We end with Antonio Vivaldi's "Four Seasons".***]**

Direct Measurements, Triangulation, and Parallax took us across Earth, the Solar System and nearby stars. We added expansion parallax for planetary nebula and a number of powerful standard candles that were verified against stars that could be measured via parallax. This took us all the way across the Milky Way and into our local Supercluster – the Virgo Supercluster.



Here, Cepheid variables confirmed the accuracy of type 1a supernova as an excellent standard candle. This is critical because, even with the Hubble Space Telescope, we can't see Cepheid stars much further than 100 million light years. But we can see type 1a supernova out to 8 billion light years. In addition Cepheids and type 1a's have given us Red Shift as a way to tell distance. This rung is only limited by what is visible and we'll see in later segments, we can see out to around 13 billion light years.

The Hubble constant is not only critical for determining distance via red shift, it showed that the universe was expanding with time. This in turn implied that going backwards in time, everything was getting closer. This leads directly to the big bang theory. But we'll go into that later in our segment on the Cosmos.

Here we have just seen a few of the galaxies in the vast Virgo Supercluster. But Virgo is only one of millions of superclusters in the observable Universe. In the next segment, we'll take a look at our local group of superclusters.