2013 Update

Introduction

Hello, and welcome to our 2013 update. Each year, I'll accumulate the key Hubble and other observatory discoveries that impact on our "How far away is it" story. We have some new information on a number of our segments from the Solar System to the Cosmos.

There was big news on Voyager. I will be updating the Heliosphere segment as well as covering the news in this update.

For the Milky Way, we have news from Proxima Centauri to a distant light echo variable star. We have a star that looked older than the Univers; a bipolar planetary nebula; one of the oldest globular clusters known; and a sneezing star birth nebula. We also have news on our galaxy's outer halo.

Outside the galaxy, we'll see the Magellanic Stream, which stretches nearly halfway around the Milky Way; the magnificent spiral galaxy M106 in the Virgo Supercluster; Supernovas in galaxy NGC 6984; and colliding galaxy NGC 922.

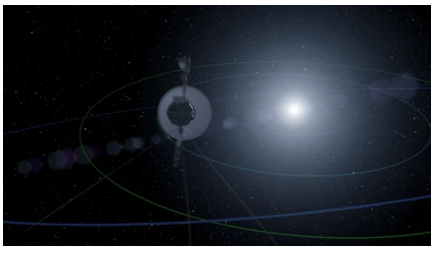
In the Cosmos we have two supermassive galaxy clusters; a very bright quasar; and a type 1a supernova over 10 billion light years away.

We'll conclude with a look at Gaia, a brand new satellite orbiting the L2 Lagrange point. It will map over a billion stars and give us the best look yet at our home galaxy.

Heliosphere

*[**Music:** James Horner – Braveheart Main Theme]*

In our segment on the Heliosphere, we covered Voyager 1 and Voyager 2. One of the great things to happen in 2013 was discovered in 2012 that Voyager 1 had left the Heliopause and entered interstellar space. For that, I have updated the Heliosphere segment. So I recommend that you watch it. You will actually hear what it sounds like outside the influence of our star, the Sun.



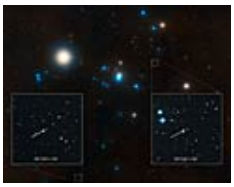
Stars

Proxima Centauri – 4 ly

In our segment on Nearby Stars, we covered our closest neighbor, Proxima Centauri. Here's a recent photo of the star taken by Hubble. Although it looks bright through the eye of Hubble, Proxima Centauri is not visible to the naked eye. Its average luminosity is very low, and it is quite small compared to other stars, at only about an eighth of the mass of the Sun.

[Note: However, on occasion, its brightness increases. Proxima is what is known as a "flare star", meaning that convection processes within the star's body make it prone to random and dramatic changes in brightness. The convection processes not only trigger brilliant bursts of starlight but, combined with other factors, indicated that**]** Proxima Centauri is in for a very long life. Astronomers predict that this star will remain a "main sequence" star for another four trillion years, a thousand times longer than our Sun.

Hyades stars – 150 ly *[Music:* Mozart – Flute and Harp Concerto- Andantino*]*



We noted in our coverage of the star Fomalhaut that planets form in the debris rings around new stars. Here the Hubble Space Telescope has found signs of Earth-like planets in an unlikely place: the atmospheres of a pair of burnt-out stars in a nearby star cluster.

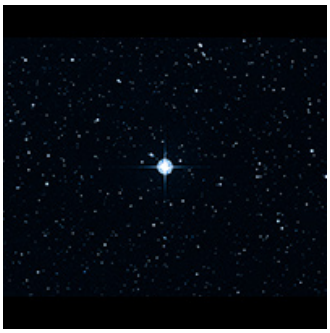
This illustration is an artist's impression of the thin, rocky debris disc discovered around the two Hyades white dwarfs. Seeing evidence of asteroids points to the possibility of Earth-sized planets in the same system. Asteroids are the building blocks of major planets. Once rocky embryos the size of asteroids are built, planets are sure to follow.

HD 140283 Methuselah star

In our final segment of the How far away is it video book, we examined the big bang and the current age of the Universe since that explosion. All stars were eventually born out of that explosion. Currently, based the Hubble Constant, we have the age at 13.8 billion years. But here is a

nearby star that at first glance looks like it is 16 billion years ole! That would make it older than the universe!

Hubble astronomers are coming to grips with this paradox by improving the precision of the observations used to estimate the age of this "Methuselah star." Hubble has helped refine the calculation to 14.5 billion years (plus or minus .8 billion years).



[Note: The ancient star is still spry for its age. It is speeding past us at 800,000 miles per hour. Its orbit can be traced back to the halo of our galaxy, which is a "retirement home" for stars that were born long before the Milky Way was even fully assembled.**]**

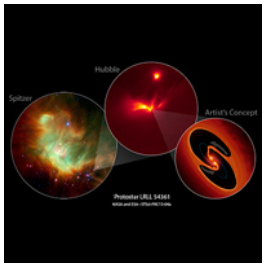
LRLL 54361 in IC 348 – 950 ly

You'll remember light echoes from our discussion on the star Monocerotis and supernova Cassiopeia A. This star exhibits the same phenomenon. LRLL 54361 was discovered by the Spitzer Space Telescope as a variable object inside the star-forming region IC 348, located 950 light-years away.

This mysterious infant star, swaddled inside a dusty blanket, behaves like a police strobe light. The newly discovered object offers clues into the early stages of star formation, when a lot of gas and dust is being rapidly sucked into a newly forming binary star.

[Note: Every 25.34 days, the object, designated LRLL 54361, unleashes a burst of light. The flashes may be due to material suddenly being dumped onto the growing protostars, unleashing a blast of radiation each time the stars get close to each other in their orbits. The phenomenon has been seen in later stages of star birth, but never in such a young system, nor with such intensity and regularity.**]**

The Hubble Space Telescope was used to confirm the Spitzer observations and revealed the detailed structure around the protostar. This video, created from a sequence of images from



Hubble shows a pulse of light emanating from the protostar. Most if not all of this light results from scattering off circumstellar dust in the protostellar envelope.

RS Puppis – 6500 ly

You'll remember Cepheid variable stars as a key standard candle in our distance ladder. Now Hubble has observed another Cepheid variable called RS Puppis that also illustrates light echoes.

RS Pup is unusual as it is shrouded by a nebula — thick, dark clouds of gas and dust. Hubble observed this star and its murky environment, capturing snapshots at different stages in its cycle producing this time-lapse video.

The dusty environment around RS Puppis enables this effect to be shown with stunning clarity. As the star expands and brightens, we see some of the light after it is reflected from progressively more distant shells of dust and gas surrounding the star, creating the illusion of gas moving outwards.

[Note: RS Puppis is over ten times more massive than our Sun, and around 15,000 times more luminous. This light echo enabled astronomers to measure the distance to RS Puppis very accurately. This measurement is the most accurate ever calculated for a Cepheid.**]**

Planetary Nebula

NGC 6537 - 3000 ly *[Music:* Massenet - Meditation*]*

You'll remember from our segment on Planetary nebula that they represent exploding stars at the end of their red giant life. NGC 6537 also known as the Red Spider Nebula is a bipolar planetary nebula with material flowing out in two primary directions like my favorite, the Butterfly nebula. In general, the directions for the flows from planetary nebula are quite random. But near the central bulge of the galaxy where the Red Spider is located, Hubble has found that bipolar planetary nebulae appear to be strangely aligned in the sky. Astronomers suggest that this behavior could have been caused by the presence of strong magnetic fields as the central bulge formed. Also, Hubble observations have revealed huge waves sculpted in the Red Spider Nebula. This warm and windy planetary nebula harbors one of the hottest stars in the Universe and its powerful stellar winds generate waves 100 billion kilometers high.

[Note: The waves are generated by supersonic shocks formed when the local gas is compressed and heated in front of the rapidly expanding lobes. Atoms caught in the shocks radiate the visible light seen in this image. The process appears to have been underway long enough to make the edges of the lobe walls look as if they have started to fracture into wave crests.**]**

Star Clusters

M15 - 35000 ly

This glittering cluster contains over 100,000 stars, and could also hide a rare type of black hole at its centre. This cluster of stars is known as Messier 15. It is one of the oldest globular clusters known, with an age of around 12 billion years.

Both very hot blue stars and cooler golden stars can be seen swarming together in the image, becoming more concentrated towards the cluster's bright centre. As well as stars, M15 was the first cluster known to host a planetary nebula, and it has been found to have a rare type of intermediate-mass black hole at its centre.

Intermediate-mass black holes are thought to form either from the merging of several smaller, stellar-mass black holes, or as a result of a collision between massive stars in dense clusters. A third possibility is that they were formed during the Big Bang. In terms of mass they lie between the more commonly found stellar-mass and supermassive types of black hole that we discussed in our segment on the Milky Way.

[Note: As well as this black hole, Messier 15 is known to house a planetary nebula. This nebula is visible as the bright blue object just to the left of the cluster's centre.**]**

Star Birth Nebula

V376 – 1956 ly

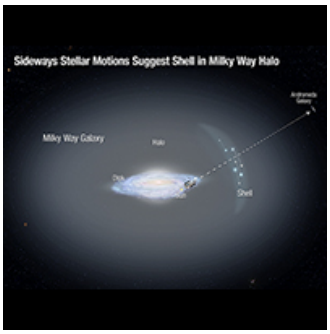
Look at the bright star in the middle of this image. Achoo! It has just sneezed. If you could carry on watching for a few years you would realize it's not just one sneeze, but a sneezing fit. This young star is firing off salvos of super-hot, super-fast gas before it finally exhausts itself. These bursts of gas have shaped the turbulent surroundings, creating structures known as Herbig-Haro objects. You'll remember that we covered these in our segment on the Orion Nebula. Soon, this star will stop sneezing, and grow up to be a star like the Sun.

Milky Way

Outer Halo

In our segment on the Milky Way, we covered a number of characteristics of the galaxy's halo. Here's a new one. Peering deep into the vast stellar halo that envelops our galaxy, astronomers using the Hubble Space Telescope have uncovered tantalizing evidence for the possible existence of a shell of stars that are a relic of the long ago birth of our Milky Way.

Hubble was used to precisely measure, for the first time ever, the sideways motions of a small sample of stars located far from the galaxy's center. Their unusual lateral motion is circumstantial evidence that the stars may be the remnants of a shredded galaxy that was gravitationally ripped apart by the Milky Way billions of years ago. These stars support the idea that the Milky Way grew, in part, through the accretion of smaller galaxies.



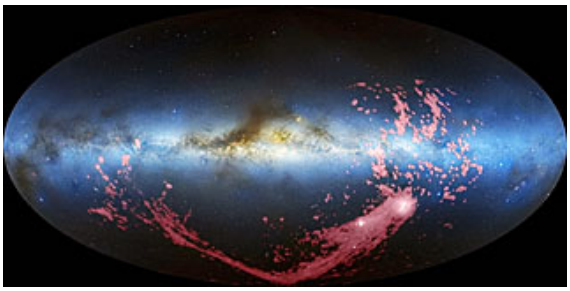
[Note: The research team was plucked the outer halo stars out of seven years' worth of archival Hubble telescope observations of our neighboring Andromeda galaxy. In those observations, Hubble peered through the Milky Way's halo to study the Andromeda stars. The Milky Way's halo stars were in the foreground and considered as clutter for the study of Andromeda. But for this team's study they were pure gold. The observations offered a unique opportunity to look at the motion of Milky Way halo stars. The team's goal is to put together a clearer picture of the Milky Way's formation history. By knowing the orbits and motions of many halo stars it will also be possible to calculate an accurate mass for the galaxy.**]**

Andromeda and the Local Group

Magellanic Stream – 160,000 ly

In our segment on the Andromeda and the Local Group, we covered the Large and Small Magellanic Cloud orbiting dwarf galaxies.

Astronomers using the Hubble Space Telescope have solved the 40-year-old mystery of the origin of the Magellanic Stream, a long ribbon of gas stretching nearly halfway around the Milky Way. New Hubble observations reveal that most of this stream was stripped from the Small Magellanic Cloud some two billion years ago, with a smaller portion originating more recently from its larger neighbor.



*[**Music:** Mascagni - Intermezzo]*

In the combined radio and visible-light image, the gaseous stream is shown in pink. Radio observations have been combined with visible light. The Milky Way is the light blue band in the centre of the image. The brown clumps are interstellar dust clouds in our galaxy. The Magellanic Clouds, satellite galaxies of the Milky Way, are the white regions at the bottom right.

[Note: Researchers determined the chemistry of the gas filament by using Hubble's Cosmic Origins Spectrograph to measure the amount of heavy elements, such as oxygen and sulphur, at six locations (marked with an "x") along the Magellanic Stream. The spectrograph observed light from faraway quasars that passed through the stream, and detected the spectral fingerprints of these elements from the way they absorb ultraviolet light.

These observations show that most of the gas was stripped from the Small Magellanic Cloud about two billion years ago — but surprisingly, a second region of the stream was formed more recently from the Large Magellanic Cloud.**]**

Local Supercluster Galaxies

M106 – 23.5 mly

Astrophotographer Robert Gendler has taken science data from the Hubble Space Telescope (HST) archive and combined it with his own ground-based observations to assemble a photo illustration of the magnificent spiral galaxy M106. It is a class of galaxy called a Seyfert galaxy.

Seyfert galaxies account for about 10% of all galaxies and are some of the most intensely studied objects in astronomy, as they are thought to be powered by the same phenomena that occur in quasars, although they are closer and less luminous than quasars. These galaxies have supermassive black holes at their centers which are surrounded by accretion discs of in-falling material. The accretion discs are believed to be the source of the observed ultraviolet radiation.

NGC 6984 – 180 mly

This spiral galaxy played host to a supernova explosion back in 2012, known as SN 2012im. Now, another star has exploded, forming supernova SN 2013ek — visible in this image as the prominent, star-like bright object just slightly above and to the right of the galaxy's centre.

[Note: Neither of these were Type 1a like those covered in our video book. SN 2012im is known as a Type Ic supernova, while the more recent SN 2013ek is a Type Ib. Both of these types are caused by the core collapse of massive stars that have shed their outer layers of hydrogen. Type Ic supernovae are thought to have lost more of their outer envelope than Type Ib, including a layer of helium.**]**

The observations that make up this new image were taken on 19 August 2013, and aimed to pinpoint the location of this new explosion more precisely. It is so close to where SN 2012im was spotted that the two events are thought to be linked; the chance of two completely independent supernovae so close together and of the same class exploding within one year of one another is a very unlikely event.

[Note: It was initially suggested that SN 2013ek may in fact be SN 2012im flaring up again, but further observations support the idea that they are separate supernovae — although they may be closely related in some as-yet-unknown way.**]**

Colliding galaxies

NGC 922 – 150 mly

Bright pink nebulae almost completely encircle this spiral galaxy. In our video book segment on Colliding Galaxies, we covered rings like this one. The ring structure and the galaxy's distorted spiral shape result from a smaller galaxy scoring a cosmic bull's-eye, hitting the centre of NGC 922 some 330 million years ago.

As the small galaxy passed through the middle of NGC 922, it set up ripples that disrupted the clouds of gas, and triggered the formation of new stars whose radiation then lit up the remaining gas. The bright pink color of the resulting nebulae is a characteristic sign of this process.
[Note: In theory, if two galaxies are aligned just right, with the small one passing through the centre of the larger one, the ring of nebulae should form a perfect circle, but more often the two galaxies are slightly off kilter, leading to a circle that, like this one, is noticeably brighter on one side than the other. The chances of seeing one of these galaxies nearby is therefore quite low.**]**

Despite the immense number of galaxies in the Universe, this is one of only a handful known in our cosmic neighborhood, the Cartwheel Galaxy, next, being the most famous example.

Cartwheel Galaxy – 500 mly ***[Music:*** *Mendelssohn - Violin Concerto in E Minor Op.64]*

Lying about 500 million light-years away, the cartwheel shape of this galaxy is the result of a violent galactic collision. The striking ring-like feature is a direct result of a smaller intruder galaxy — possibly one of two objects to the left of the ring — that careened through the core of the host galaxy. Like a rock tossed into a lake, the collision sent a ripple of energy into space, plowing gas and dust in front of it. Expanding at 200,000 miles per hour, this cosmic tsunami leaves in its wake a firestorm of new star creation.
Presumably the Cartwheel Galaxy was a normal spiral galaxy like our Milky Way before the collision. This spiral structure is beginning to re-emerge, as seen in the faint arms or spokes between the outer ring and bulls-eye shaped nucleus.

[Note: The ring contains at least several billion new stars that would not normally have been created in such a short time span and is so large (150,000 light-years across) that our entire Milky Way Galaxy would fit inside.**]**

Cosmos

Abell 68 – 2.1 bly

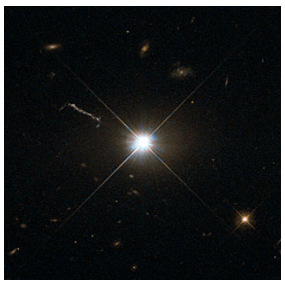
You'll remember the Einstein Rings we discussed in our segment on the Cosmos. Here again we see how the gravitational field surrounding this massive cluster of galaxies acts as a natural lens in space to brighten and magnify the light coming from very distant background galaxies.

In this photo, the image of a spiral galaxy at upper left has been stretched and mirrored into a shape similar to that of a simulated alien from the classic 1970s computer game Space Invaders! This galaxy is visible twice, because its light followed two separate paths around Abell 68 before reaching us.

Quasar 3C 273 – 2.5 bly

You'll remember Quasar Markarian in our How Far Away Is It segment on the "Cosmos". Quasars are the intensely powerful centers of distant, active galaxies, powered by a huge disc of particles surrounding a supermassive black hole. As material from this disc falls inwards, some quasars — including this one, have been observed to fire off super-fast jets into the surrounding space. In this picture, one of these jets appears as a cloudy streak, measuring some 200,000 light-years in length.

Despite its great distance, 3C 273 is still one of the closest quasars to our home. It was the first quasar ever to be identified, and was discovered in the early 1960s. Quasars are capable of emitting hundreds or even thousands of times the entire energy output of our galaxy, making them some of the most luminous and energetic objects in the entire Universe. Of these very bright objects, 3C 273 is the brightest in our skies. If it were located 30 light-years from our own planet — over seven times the distance between Earth and Proxima Centauri — it would appear as bright as the Sun in the daytime sky!



SN UDS10Wil – 10 bly

If you recall, type 1a supernova represent one of our most important standard candles because they are so bright we can see them from very far away.

In 2013, Hubble broke the record in the quest to find the furthest type 1a with the discovery of SN UDS10Wil, a supernova that exploded more than 10 billion years ago at a time the Universe was in its early formative years and stars were being born at a rapid rate.

[Notes: One of the debates surrounding Type 1a supernovae is the nature of the fuse that ignites them. In our segment on Supernova, we described the example of a giant star feeding a small companion until it reached its limit and explodes. This latest discovery adds credence to the other competing theory of how they explode. Although preliminary, the evidence favors the explosive

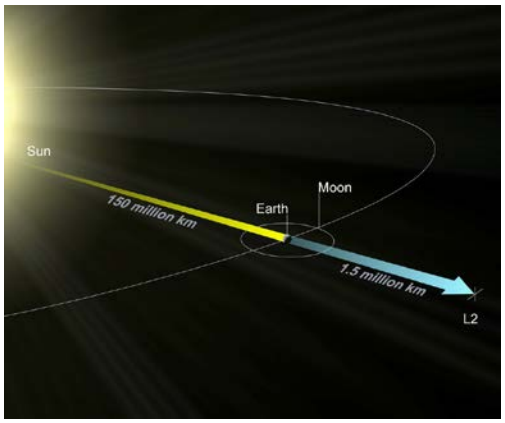
merger of two white dwarfs. Finding remote supernovae opens up the possibility to measure the Universe's accelerating expansion due to dark energy. However, this is an area that is not fully understood — and nor are the origins of Type 1a supernovae.**]**

The image at the far left shows the host galaxy without the supernova. The middle image, taken a year later, reveals the galaxy with the supernova. The supernova cannot be seen because it is too close to the centre of its host galaxy. To detect the supernova, astronomers subtracted the left image from the middle image to see the light from the supernova alone, shown in the image at far right.

GAIA ***[Music:*** *Rachmaninov - Piano Concerto No 2 in C minor**]***

You'll remember that we spent some time on the James Webb space telescope that's in development and scheduled for launch in 2018. Well we have a major new telescope that was launched in late 2013 called Gaia.

Here we see Gaia's blasted off on a Soyuz rocket from Europe's Spaceport in Kourou, French Guiana. It is now in its operational orbit around the L2 gravitationally stable Lagrange Point 1.5 million km from Earth. We covered Lagrange points in our segment on the Heliosphere.



Gaia is an ambitious mission to chart a three-dimensional map of our Galaxy. Gaia will provide unprecedented positional and radial velocity measurements with the accuracies needed to produce a stereoscopic and kinematic census of about one billion stars in our Galaxy and throughout the Local Group. If you recall form our segment on nearby stars, Hipparcos recorded parallax information for 118,000. Gaia will do over 8 thousand times this number.

Gaia will map each of the billion stars 70 times to record their position, movement and characteristics. The key to this is the billion-pixel camera at the heart of its dual telescope. This animation illustrates how the camera works.

With its two telescopes, Gaia looks at two patches of sky at the same time. Mirrors guide the light to the billion pixel camera. As Gaia rotates, the images move across the camera. As a star's image moves across the camera, its brightness and position are measured. Then the spectral footprint is recorded. The final camera area measures the stars radial velocity towards or away from us. For each star, the data is compressed and stored aboard Gaia. Around 2 million stars are examined in this way every hour creating 50 gigabytes of data every day. This data is then transmitted to the ground station where teams of astronomers examine it.

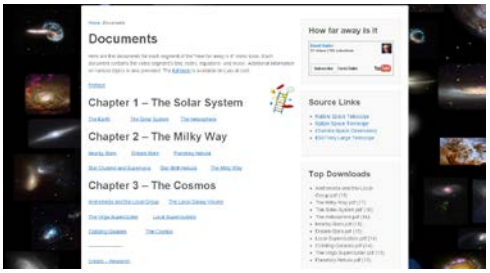
This animation illustrates how Gaia will scan the sky during its all-sky survey.

Science projects you can help with

Here is a website where you can help Hubble scientists in various activities including:

- Finding the age of star clusters in the Southern Pinwheel galaxy
- Hunting for planets around other stars
- Searching for star clusters in the Andromeda galaxy
- And more

And don't forget, every How Far Away Is It video segment, including this one has a document with the text, pictures and notes located on howfarawayisit.com/documents



Credits

As we did with the video book itself, here are the links to the Hubble and other locations where I found the information contained in this 2013 update. These are the places where you can go to find out more information.

Heliosphere

Voyager 1	http://www.jpl.nasa.gov/video/?id=1248

Stars

Proxima Centauri	http://www.spacetelescope.org/images/potw/
Hyades stars	http://www.spacetelescope.org/news/heic1309/
Methuselah star	http://hubblesite.org/newscenter/archive/releases/2013/08/
LRLL 54361	http://hubblesite.org/newscenter/archive/releases/2013/04/text/
RS Puppis	http://www.spacetelescope.org/news/heic1323/

Planetary Nebula

NGC 6537	http://www.eso.org/public/images/eso1338a/

Star Clusters

M15	http://www.spacetelescope.org/news/heic1321/

Star Birth Nebula

V376	http://www.spacetelescope.org/images/potw1350a/

Milky Way

Outer Halo	http://hubblesite.org/newscenter/archive/releases/2013/07/

Andromeda and the Local Group

Magellanic Stream	http://www.spacetelescope.org/images/heic1314a/

Virgo Supercluster

M106	http://hubblesite.org/newscenter/archive/releases/2013/06

Local Superclusters

NGC 6984	http://www.spacetelescope.org/images/potw1344a/

Colliding galaxies

NGC 922	http://www.spacetelescope.org/news/heic1218/
Cartwheel Galaxy	http://www.spacetelescope.org/images/potw1036a/

Cosmos

Abell 68	http://www.spacetelescope.org/news/heic1304/
Quasar 3C 273	http://www.spacetelescope.org/images/potw1346a/
SN UDS10Wil	http://www.spacetelescope.org/news/heic1306/
Gaia	http://sci.esa.int/gaia/
	http://www.youtube.com/watch?v=Qwjk22mnzQc
	http://www.youtube.com/watch?v=bbfb8VhH7L0
	http://www.youtube.com/watch?v=BnFyzZGWuYs