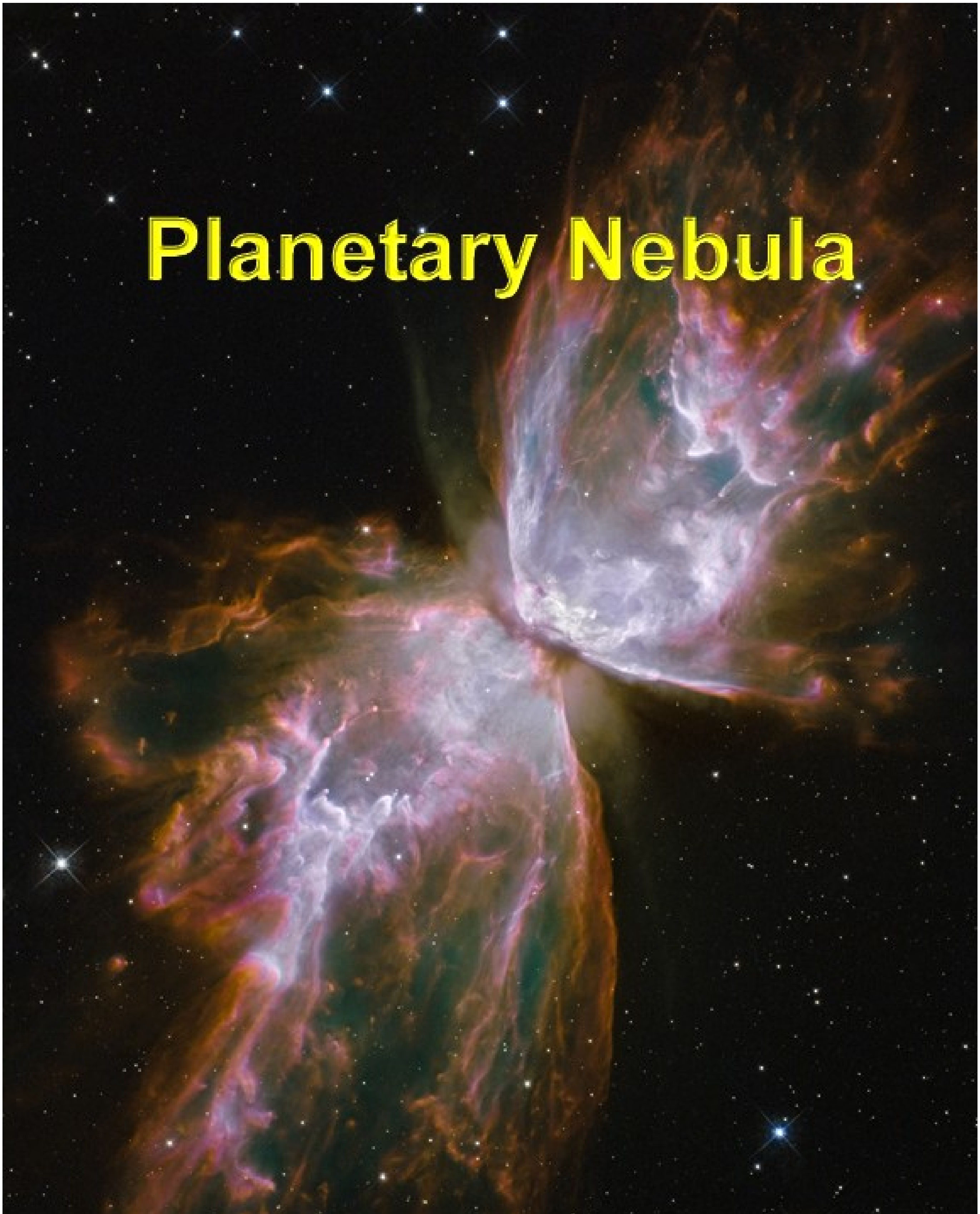

Planetary Nebula

Planetary Nebula

{Abstract *– In this segment of our "How far away is it" video book, we cover Planetary Nebula.*

We begin by introducing astrophotography and how it adds to what we can see through a telescope with our eyes. We use NGC 2818 to illustrate how this works.

We then show a clip illustrating the end-of-life explosion or nova that creates objects like the Helix Planetary Nebula (NGC 7293), and show how it would fill the space between our Sun and nearest star, Proxima Centauri.

Then, we use the Cat's Eye Nebula (NGC 6543) to illustrate expansion parallax. As a fundamental component for calculating expansion parallax, we also illustrate the Doppler Effect and how we measure it via spectral line shifts.

We continue with a tour of the most beautiful planetary nebula photographed by Hubble. These include: the Dumbbell Nebula (M27, NGC 6853), NGC 5189, Ring Nebula (M57), Retina Nebula (IC 4406), Red Rectangle (HD 44179), Ant Nebula (Mz 3), Butterfly Nebula (NGC 6302), Rotten Egg Nebula (OH231.8+4.2), Kohoutek 4-55, Eskimo Nebula (NGC 2392), NGC 6751, SuWt 2, Starfish (He 2-47), NGC 5315, NGC 5307, Object MyCn18, Little Ghost Nebula (NGC 6369), NGC 2440, IC 4593, and culminating with a dive into the Necklace Nebula (PN G054.2-03.4).

We conclude by noting that this will be the most likely end for our Sun, but not for billions of years to come.}

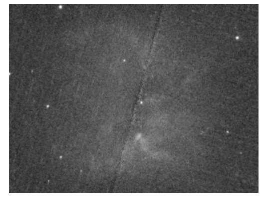
Introduction

> **[Music:** *Georges Bizet - Entracte to 'Carmen' Act III – The music of "Carmen" has been widely acclaimed for its brilliance of melody, harmony, atmosphere and orchestration, and for the skill with which Bizet represented, musically, the emotions and suffering of his characters. As it evokes emotions around the death of Carmen, so we feel for the fiery death of stars.***]**

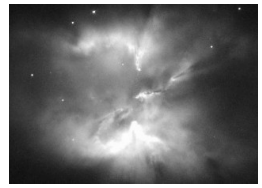
Planetary Nebulae represent some of the most beautiful objects in the Milky Way. In this segment, we'll talk about what they are and how far away they are. And I'll show you some of the spectacular pictures taken by the Hubble Space Telescope.

Astrophotography

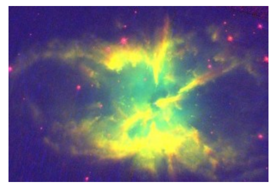
But first, I'd like to take a minute to go over how we create these photographs. When someone looks through a telescope, the light from the object falls on a person's eye. To take a photograph, all you have to do is replace the eye with a photographic plate.



Here we see Planetary Nebula NGC 2818. It's what someone would see if they were looking through the telescope. It's just a wisp. It's very nebulous. That's how it gets its name Nebula by the way. To the untrained eye, it might look like nothing at all. But if we increase the time exposure, and let more and more light from the object fall on the photographic plate, we get dramatically better results. We get a much sharper image. It's no longer a wisp. We begin to see there's something serious there with structure.



Then repeating the process with a filter using a small frequency band of light gives us the first pass on color. Repeating the process with different bands and combining the photo's produces the full astronomical photo effect. The frequencies bands chosen can represent different temperatures of gasses, or different colors might be used to represent different elements present in the nebula. In NGC 2818 we have: red represents nitrogen; green represents hydrogen; and blue represents oxygen.



<u>Star Nova</u>

As you can see, Planetary Nebulae are not about planets. They're about stars. It got the name 'planetary' when early astronomers using small primitive telescopes first spotted these objects. They looked like disks similar to Jupiter and Neptune. Planetary Nebulae are actually stars like our Sun that are going through a typical end-of-life cycle.

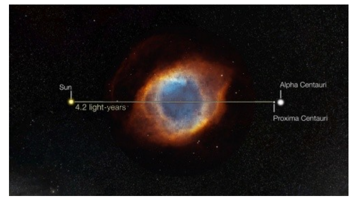
They have ejected much of their mass into their surroundings and then collapsed in a "Nova" explosion that ejects a massive amount of additional material at much higher velocities. The faster moving material crashes into the slower moving stuff to create spectacular formations.

[**Music:** *Johann Sebastian Bach's - Air 'on the G String'. This is perfect music for these wispy and beautiful Planetary Nebula remnants.*]

Helix Nebula, NGC 7293 – 650 ly

This Helix Nebula is just one of them. Here we have the fluorescing tube or doughnut where we are looking right down the middle of it. A forest of thousands of comet-like filaments, embedded along the inner rim of the nebula, point back towards the central star, which is a small, super-hot white dwarf. That's what's left after a nova explosion. Each filament is around the size of our entire solar system!

Based on the nebula's distance of 650 light-years, triangulating its angular size corresponds to a huge ring with a diameter of nearly 3 light-years. It would fill most of the space between our Sun and our nearest star – Alpha Centauri.



Let's take a look at some of the most beautiful Planetary Nebula scattered across the galaxy.

NGC 6543, Cat's Eye Nebula – 3,264 ly

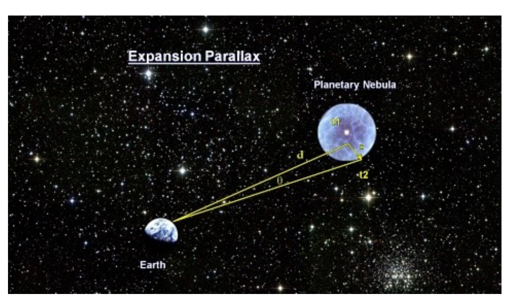
The Cat's Eye is one of the most complex planetary nebulae ever with surprisingly intricate structures including concentric gas shells, jets of high-speed gas and unusual shock-induced knots of gas.

These features made the Cat's Eye Nebula perfect for developing a new way to figure out how far away Planetary Nebula are. The fact is we don't know a lot about the distance to most of these objects. There may be as many as 25,000 Planetary Nebula in the Milky Way, but only 50 have distances that have been measured with some reasonable accuracy. This is due primarily to the nature of the nebulae themselves.

You'll recall that two of our most useful tools for figuring out 'How far away is it?" are standard candles (like Cepheids) and parallax. But because Planetary Nebula stars are surrounded by the debris of their own ejection, it is hard to get a good luminosity reading for standard candles, and equally hard to locate a good star nearby to use for parallax calculations.

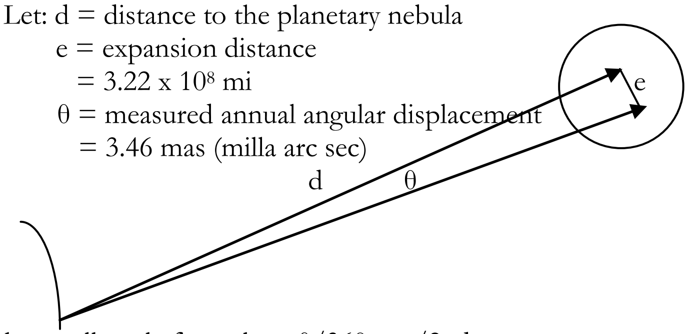
Expansion Parallax

In recent years, however, observations made using the Hubble Space Telescope have allowed a new method of determining distances. All planetary nebulae are expanding, and observations several years apart and with high enough resolution can reveal the angular growth of the nebula in the plane of the sky. Using the Doppler Effect to approximate the velocity of the expanding material, we can calculate the distance the nebula expanded. With that, simple Trigonometry gives us the distance to the Cat's Eye – 3260 light years plus or minus 877 light years.



<u>Cat's Eye Expansion Parallax</u>

Let: d = distance to the planetary nebula
e = expansion distance
= 3.22×10^8 mi
θ = measured annual angular displacement
= 3.46 mas (milla arc sec)



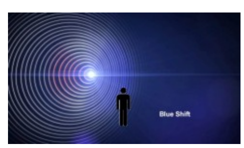
Using the small angle formula $\theta/360 = e/2\pi d$
Solving for d we have $d = 360/2\pi \times e/\theta$
Converting to mas we get $d = 206265000 \text{ mas} \times e/\theta$
Entering values for e and θ $d = 206265000 \times (3.22 \times 10^8 \text{ mi})/3.46 \text{ mas}$
Solving for d we get $d = 1.92 \times 10^{16}$ mi
Converting to light years we have $d = 1.92 \times 10^{16} \text{ mi} \times (1 \text{ ly})/(5.88 \times 10^{12} \text{ mi})$
= 3260 ly

<u>Doppler Effect</u>

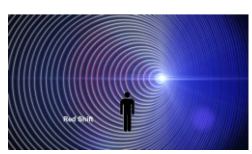
We mentioned the Doppler Effect as part of this expansion parallax derivation. We also mentioned the Doppler Effect in our section on stars. So let me take a minute to go over how we measure and use this effect.

Most people have had the experience of hearing the pitch of a car horn, train whistle or ambulance siren drop as the source moved past.

As the sound source moves toward the observer, the sound waves are compressed, making the pitch of the sound higher.



As the sound source moves away from the observer, the sound waves are stretched out, making the pitch of the sound lower.



In a similar way, light from an approaching star has its wavelengths shortened, or *blue shifted*, and light from a receding star has its wavelengths lengthened, or *red-shifted.*

The key to measuring the Doppler Effect is that *spectral lines* change position. The change in position is easily measured on a photographic plate - the further the shift, the faster the speed.

With this Doppler Effect, we can determine three important things about stars:

1. We can determine how fast stars and star materials are moving toward or away from us.
2. We can detect and measure the orbital motion of binary star systems.
3. We can even determine how fast a star is rotating.

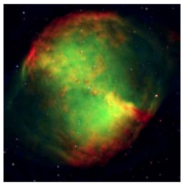
Let: v = velocity
λ = at rest wavelength
$\Delta\lambda$ = difference in wavelengths
c = speed of light
We have:
$v = c(\Delta\lambda)/\lambda$

With this we can now add expansion parallax as one more rung on our distance ladder.

Dumbbell Nebula, M27, NGC 6853 – 1,200 ly

Let's take a look at just some of the most beautiful planetary nebula scattered across the galaxy and photographed by the Hubble Telescope.

Here we have the Dumbbell discovered back in 1764. **[Additonal info:** In this three-colour composite, we have: hot helium – blue; oxygen atoms – green; atomic hydrogen – red.**]**



[Music: *Ridolfo Luigi Boccherini – "Minuet":. Written in 1771, it is one of his most popular works. The Minuet is perfect music to accompany the dance of nova remnants around their White Dwarf stars.***]**

NGC 5189 – 1,780 ly

The intricate structure of the stellar debris forms a dramatic reverse S-shape. The structure visible within NGC 5189 is particularly dramatic.

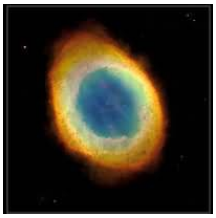
Looking at the detail, the nebula shows a series of dense knots in the clouds of gas.

Now what's going on here is that the radiation from the dying star is carving the knots into shape, much like water flowing around a rock in a stream. And these are all pointing towards the centre of the nebula.

The knots are a reminder of just how vast the planetary nebula is. They might look like mere details in this image, but just like in the Helix Nebula, each and every one is the size of our entire Solar System.

NGC 5189's shape is reminiscent of a lawn sprinkler, with matter being expelled from the star, which is wobbling as it rotates. Similar structures have been seen before, especially in planetary nebulae with binary stars at their centers. This is a likely explanation for 5189, but to date, only one star has been found at the nebula's centre.

Ring Nebula, M57 – 2,300 ly



Here we are zooming into the Ring Nebula, one of the earliest and most famous of all planetary nebula. As you can see, it closely resembles the Helix Nebula we covered earlier.

We are looking almost directly down one the poles of the structure, with a brightly-colored barrel of material stretching away from us. From Earth's perspective, the Ring Nebula looks like a simple elliptical shape with a fuzzy boundary. But the new Hubble observations show clearly that the nebula is actually shaped more like a distorted doughnut.

The main structure of the nebula is a broad ring of nitrogen. That's the red ring you see. The hotter gas is oxygen seen in green here and it fills the interior. What's even hotter still is helium seen here as blue oblong lobes stretching out perpendicular to the nebula's main structure and looking like a rugby ball.

IC 4406, Retina Nebula 1,900 ly

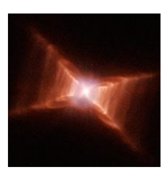
Our first Planetary Nebulae were facing the Earth so that we could see down the tube. On this one, the Retina Nebula, we are viewing the donut from the side.

[**Additional info:** This side view allows us to see the intricate tendrils of dust that have been compared to the eye's retina.

In this one: Oxygen is rendered blue; Hydrogen is shown as green; and Nitrogen as red.

HD 44179, Red Rectangle – 2,300 ly

The red rectangle is one of the most unusual nebulae known in our Milky Way because of its unusual rectangular shape.



Ant Nebula, Menzel 3, Mz 3 – 3,000 ly

This unique planetary nebula resembles the head and thorax of a garden-variety ant. It has intriguing symmetrical patterns. It could be that there is a binary star system at the heart of the nebula creating the symmetrical patterns.

Butterfly Nebula NGC 6302 – 3,800 ly

My favorite, and one of the most beautiful of all celestial objects, this planetary nebula looks like a delicate butterfly. But it is far from serene. What resemble dainty butterfly wings are actually roiling cauldrons of gas heated to more than 36,000 degrees Fahrenheit, tearing across space at more than 600,000 miles an hour.

OH231.8+4.2, Rotten Egg Nebula – 4,500 ly

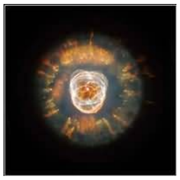
Here we have the Rotten Egg nebula. It has a large amount of sulfur compounds. **[Additional info:** This is how it earned the nickname.**]**

Object Names: Kohoutek 4-55, K 4-55

Kohoutek 4-55 is named after its discoverer, Czech astronomer Lubos Kohoutek. **[Additional info:** You may have heard about the comet he discovered that also bears his name.**]**

Eskimo Nebula, NGC 2392 – 5,000 ly

This is nicknamed the "Eskimo" Nebula because, when viewed through ground-based telescopes, it resembles a face surrounded by a fur parka. Although this bright central region resembles a ball of twine, it is, in reality, a bubble of material being blown into space by the central star's intense "wind" of high-speed material.



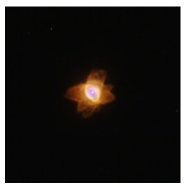
NGC 6751 – 6,500 ly

NGC 6751 is strikingly unusual for planetary nebula. It looks like a giant eye. The nebula is a cloud of gas ejected several thousand years ago from the hot star visible in its center.

<u>SuWt 2 – 6,500 ly</u>

SuWt2, the central star is actually a close binary system where two stars completely circle each other every five days. The interaction of these stars and the more massive star that sheds material to create the nebula formed the ring structure. The burned out core of the massive companion has yet to be found inside the nebula.

<u>He 2-47 Starfish – 6,600 ly</u>



This nebula is dubbed the "starfish" because of its shape. The six lobes of gas and dust, which resemble the legs of a starfish, suggest that He 2-47 puffed off material at least three times in three different directions.

[Music: *Back to Georges Bizet - Entracte to 'Carmen' Act III.***]**

<u>NGC 5315 – 7,000 ly</u>

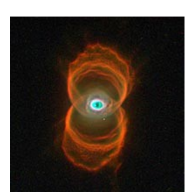
NGC 5315 is a chaotic-looking nebula and reveals an x-shaped structure.

<u>NGC 5307 – 7,900 ly</u>

NGC 5307 displays a spiral pattern, which may have been caused by the dying star wobbling as it expelled jets of gas in different directions.

<u>MyCn18 – 8,000 ly</u>

MyCn18 is a young planetary nebula. The object has an hourglass shape with an intricate pattern of "etchings" in its walls.



<u>NGC 6369 – 3,500</u>

This object is known to amateur astronomers as the "Little Ghost Nebula," because it appears as a small, ghostly cloud surrounding the faint, dying central star.

[Music: *We finish off with Johann Sebastian Bach's - Air 'on a string of G'.***]**

<u>NGC 2440 – 3,600 ly</u>

This nebula's chaotic structure suggests that the star shed its mass episodically. During each outburst, the star expelled material in a different direction. This can be seen in the two bow tie-shaped lobes.

<u>Necklace Nebula, PN G054.2-03.4 – 15,000 ly</u>

The Necklace Nebula consists of a bright ring, measuring 12 trillion miles across, dotted with dense, bright knots of gas that resemble diamonds in a necklace. The knots glow brightly due to absorption of ultraviolet light from the central stars.

Although most stars go through this process, only a few can be seen in the Milky Way. This is because over a relatively short time (millions of years), the ejected gasses get so far away from the star, that they are no longer fluorescing or reflecting light from the central dying star. Then all we see are the White Dwarfs.

<u>Conclusion</u>

Our Sun will end its life as one of these Planetary Nebulas. The Hubble images like these show that our Sun's fate probably will be more interesting, complex, and striking than astronomers imagined just a few years ago, but not until several billions of years from now.