Telescopes: Crash Course Astronomy #6

Crash Course: Astronomy
https://youtube.com/watch?v=mYhy7eaazIk
https://nerdfighteria.info/v/mYhy7eaazIk

Iâ€™ve talked a lot about observing the night sky with your eyes; just simply going out and seeing what you can see. Itâ€™s pretty amazing what you can learn just by doing that, and of course thatâ€™s all we humans could do for thousands of years. But now we can do better. We can use telescopes. The first person to invent the telescope is lost to history; despite â€œcommon knowledge,â€• Galileo did not invent them. He wasnâ€™t even the first person to point one at the sky, or the first person to publish results! But he was a loud and persistent voice over the years, and his amazing string of discoveries using his crude instrument landed him firmly in the history books. Aggressive self-marketing sometimes pays off. You might think the purpose of a telescope is to magnify small objects so we can see them better. Thatâ€™s how a lot of telescopes are marketed, but to be honest thatâ€™s not exactly the case. If you want to be really general, the purpose of a telescope is to make things easier to see: To make the invisible visible, and to make the things already visible visible more clearly. A telescope works by gathering light. Think of it like a bucket in the rain: The bigger the bucket, the more rain you collect. If your bucket is big enough, youâ€™ll get plenty of water even when itâ€™s only sprinkling out. In the case of a telescope, the â€œbucketâ€• is an optical device like a lens or a mirror that collects light. We call this device the objective, and the bigger the objective, the more light it collects. Look at your eyesâ€¦ well, thatâ€™s tough, so letâ€™s think about our eyes for a moment. They also work as light buckets, but they only collect light through our pupils, which even under the best of circumstances are less than a centimeter across; a very tiny bucket indeed. But we can do better. To extend the analogy, a telescope is like a bucket with a funnel at the bottom. All that light that it collects is then concentrated, focused, and sent into your eye. It turns a trickle of light into a torrent. The amount of light it collects depends on the area of the objective. That means if you double the diameter of the collector, youâ€™d collect four times as much light, because the area of the collector goes up as the square of the radius. Make a bucket 10 times wider, and you collect 100 times as much light! Clearly, as telescopes get bigger their ability to show us faint objects increases enormously. In fact that was one of Galileoâ€™s first and most important discoveries: Stars that were invisible to the naked eye were easily seen through his telescope, even though it only had a lens a few centimeters across. Those faint stars didnâ€™t emit enough light for his eyes to see them, but when he increased his collecting area with a telescope, they popped into visibility. The primary way telescopes work is to change the direction light from an object is traveling. I can see a star with my eye because light from that star is sent in my direction, into my eye. But most of that light misses my eye, falling to the ground all around me. The telescope collects that light, bounces it around, and then channels it into my eye. When the very first telescopes were built, this changing of the direction of light was done using lenses. When light goes from one medium to another â€“ say, from going through air to going through water or glass â€“ it changes direction slightly. You see this all the time; a spoon sitting in a glass of water looks bent or broken. The spoon is doing just fine, but the light you see from it is getting bent, distorting the image. This bending is called refraction. The way light bends depends on whatâ€™s bending it (like water or glass) and the shape of the object doing the bending. It so happens that if you grind a piece of glass into a lens shape, it bends -- or refracts -- the incoming light in a cone, focusing it into a single spot. Itâ€™s a light funnel! This refraction has a couple of interesting results. For one thing, the light from the top of a distant object is bent down, and the light from the bottom is bent up. When this light comes to a focus, it means you see the object upside-down! It also flips left and right, which can be a little disconcerting, and takes getting used to when youâ€™re using a refracting telescope. For another thing, the lens can magnify the image. Thatâ€™s again because the light is bent, and the image created of object observed can appear larger than the object does by eye. It depends on a lot of factors including the shape of the lens, the distance to the object, and how far away the lens is, but in the end what you get is an image that looks bigger. That has obvious advantages; a planet like Jupiter is too far away to see as anything other than a dot to the eye, but a telescope makes it appear bigger, and details can then be seen. When Galileo and other early astronomers pointed their telescopes at the sky, multitudes were revealed: Craters on the Moon, the phases of Venus, Jupiterâ€™s moons, the rings of Saturn, and so much more. The Universe itself came into focus. When astronomers talk about using a telescope to make details more clear, they use a term called resolution. This is the ability to separate two objects that are very close together. Youâ€™re familiar with this; when youâ€™re driving on a road at night a distant car coming toward you appears as a single light. When it gets closer, the light separates out â€" resolves â€" into two headlights. A telescope increases resolution, making it easier to, say, split two stars that are close together, or to see details on the Moonâ€™s surface. The resolution depends in part on the size of the objective; in general the bigger the telescope objective the better your resolution is. Resolution is more useful than magnification when talking telescopes. Fundamentally, there is a limit to how well your telescope resolves two objects, but thereâ€™s no limit to how much you can magnify the image. If you magnify the image beyond what the telescope can actually resolve, you just get mush. Refracting telescopes are great, but they suffer from a big problem: Big lenses are hard to make. They get thin near the edge, and break easily. Also, different colors of light bend by different amounts as they pass through the lens, so you might focus a red star, say, and a blue one will still look fuzzy. No less a mind than Isaac Newton figured a way around this: Use mirrors. Mirrors also change the direction light travels, and if you used a curved mirror you can also bring light rays to a focus. Telescopes that use mirrors are called reflectors. The advantages of reflectors are huge: You only have to polish one side of a mirror, where a lens has two sides. Also a mirror can be supported along its back, so they can be manufactured much larger more easily and for less money. Although there have been many improvements made over the centuries, most big modern telescopes at their heart are based on the Newtonian design, and in fact no large professional-grade telescopes made today have a lens as their objective. Nowadays, itâ€™s all done with mirrors. And that brings us to this weekâ€™s aptly named Focus On. The most common question Iâ€™m asked (besides, â€œHey, who does your hair?â€•) is, â€œHey, Phil, kind of telescope should I buy?â€• Itâ€™s a legitimate question, but itâ€™s very difficult to answer. Imagine someone walked up to you and asked, â€œWhat kind of car should I buy?â€• Thatâ€™s impossible to answer without a lot more information. Same for telescopes. Do you want to look at the Moon and planets, or fainter, more difficult to spot galaxies? Are you really devoted to this, or is it more of a pastime? Is this for a child or an adult? These questions are critical. Most small â€˜scopes are refractors, which are good for looking at detail on the Moon and planets (they tend to magnify the image more than reflectors do). But theyâ€™re tricky to use because they flip the image left and right and up and down. Bigger â€˜scopes are good for fainter objects, but are more expensive, and can be difficult to set up and use. I hate hearing about a â€˜scope that just collects dust because it was bought in haste. So hereâ€™s what I recommend: Find an observatory, planetarium, or local astronomy club. Theyâ€™re likely to have star parties, public observing events, where you can look at and through different kinds of telescopes. Their owners are almost universally thrilled to talk about them â€" as an astronomer, I can assure that the problem with astronomers isnâ€™t getting them to talk, itâ€™s shutting them up â€" so youâ€™ll get lots of great first-hand advice and experience. Also, I usually recommend getting binoculars before a telescope. Theyâ€™re easy to use, fun to use, easy to carry around, and you can get good ones for less money and still see some nice things. Even if you decide not to get more into astronomy as a hobby, they can also be used during the day on hikes and for bird watching. I have a couple of pair of binoculars and I use them all the time. Thereâ€™s a third aspect to telescopes thatâ€™s very important, beyond resolution

and making faint things easier to see. They can literally show us objects outside of the range of colors our eyes can see. In the year 1800, William Herschel discovered infrared light, a kind of light invisible to our eyes. In the time since weâ€™ve learned of other forms of invisible light: radio, microwave, ultraviolet, X-rays, and gamma rays. Astronomical objects can be observed in all these flavors of light, if we have telescopes that are designed to detect these flavors of light. Radio waves pass right around â€œnormalâ€• telescopes, ones that we use to observe visible light. X-rays and gamma rays pass right through them as if they arenâ€™t even there. But weâ€™re smart, we humans. We learned that giant metal dishes can and will bend radio waves, and can be formed just like gigantic Newtonian mirrored telescopes. In fact, different forms of light need different kinds of telescopes, and once we figured out how, weâ€™ve built â€˜em. We can now detect cosmic phenomena across the entire spectrum of light, from radio waves to gamma rays, and have even built unconventional telescopes that detect subatomic particles from space as well, such as neutrinos and cosmic rays. Because of this, we have learned far more about the Universe than Galileo could have imagined. And weâ€™re in the midst of another revolution, too. The actual biophysics is complicated, but in a sense our eyes act like movie cameras, taking pictures at a frame rate of about 14 images per second. Thatâ€™s a short amount of time. Photographs, though, can take far longer exposures, allowing the light to build up, allowing us to see much fainter objects. The first photographs taken through a telescope were done in the 1800s. This has led to innumerable discoveries; for example, in the 20th century giant telescopes with giant cameras revealed details in distant galaxies that led to our understanding that the Universe is expanding, a critically important concept that weâ€™ll dive into later in the series. And now we have digital detectors, similar to the ones in your phone camera, but far larger and far more sensitive. They can be dozens of times more light-sensitive than film, able to detect in minutes objects that wouldâ€™ve taken hours or more to see using film. These digital cameras can also be designed to detect ultraviolet light, infrared, and more. We can store vast amounts of that data easily on computers, and use those computers to analyze that huge ocean of information, performing tasks too tedious for humans. Most asteroids and comets are discovered using autonomous software, for example, looking for moving objects among the tens or hundreds of thousands of fixed stars in digital images. This has also ushered in the era of remote astronomy; a telescope can be on a distant mountain and programmed to scan the sky automatically. It also means we can loft telescopes into space, above the sea of air in our atmosphere that blurs and distorts distant, faint objects. We can visit other worlds and send the pictures and data back home, or put observatories like the Hubble Space Telescope into orbit around the Earth and have it peer into the vast depths of the Universe. I would argue that the past century has seen a revolution in astronomy every bit as important as the invention of the telescope in the first place. In the early 17th century the entire sky was new, and everywhere you pointed a telescope there was some treasure to behold. But with our huge telescopes and incredibly sensitive digital eyes now, thatâ€™s still true. We learn more about the Universe every day, just as we learn that thereâ€™s more to learn every day, too. Thatâ€™s one of the best parts of being an astronomer; the Universe is like a jigsaw puzzle with an infinite number of pieces. The fun never ends. And remember: Even with all the wonders revealed by telescopes, your eyes are still pretty good instruments, too. You donâ€™t need big fancy equipment to see the sky. The important thing is to go outside. Look up! Thatâ€™s fun too. Today you learned that telescopes do two things: Increase our ability to resolve details, and collect light so we can see fainter objects. There are two main flavors of telescope: Refractors, which use a lens, and reflectors, which use a mirror. There are also telescopes that are used to look at light our eyes canâ€™t see, and with the invention of film, and later electronic detectors, we have been able to probe the Universe to amazing depths. Crash Course is produced in association with PBS Digital Studios. This episode was written by me, Phil Plait. The script was edited by Blake de Pastino, and our consultant is Dr. Michelle Thaller. It was co-directed by Nicholas Jenkins and Michael Aranda, and the graphics team is Thought CafÃ©.