Introduction to Astronomy: Crash Course Astronomy #1

Crash Course: Astronomy
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=====Intro (0:00) =====

Hello, and welcome to Crash Course Astronomy! I'm your host, Phil Plait, and I'll be taking you on a guided tour of the entire Universe. You might want to pack a lunch.

(Intro)

Over the course of this series we'll explore planets, stars, black holes, galaxies, subatomic particles, and even the eventual fate of the Universe itself.

===== Science (0:30)=====

But before we step into space, let's take a step back. I wanna talk to you about science. There are lots of definitions of science, but I'll say that it's a body of knowledge, and also a method of how we learned that knowledge. Science tells us that stuff we know may not be perfectly known; it may be partly or entirely wrong. We need to watch the Universe, see how it behaves, make guesses about why it's doing what it's doing, and then try to think of ways to support or disprove those ideas. That last part is important. Science must be, above all else, honest if we really want to get to the bottom of things.

Understanding that our understanding might be wrong is essential, and trying to figure out the ways we may be mistaken is the only way that science can help us find our way to the truth, or at least the nearest approximation to it. Science learns. We meander a bit as we use it, but in the long run we get ever closer to understanding reality, and that is the strength of science. And it's all around us! Whether you know it or not, you're soaking in science. You're a primate. You have mass. Mitochondria in your cells are generating energy. Presumably, you're breathing oxygen. But astronomy is different. It's still science, of course, but astronomy puts you in your place.

===== Our Place (1:43) =====

Because of astronomy, I know we're standing on a sphere of mostly molten rock and metal 13,000 kilometers across, with a fuzzy atmosphere about 100 km high, surrounded by a magnetic field that protects us from the onslaught of subatomic particles from the Sun 150 million km away, which is also flooding space with light that reaches across space, to illuminate the planets, asteroids, dust, and comets, racing out past the Kuiper Belt, through the Oort Cloud, into interstellar space, past the nearest stars, which orbit along with gas clouds and dust lanes in a gigantic spiral galaxy we call the Milky Way that has a supermassive black hole in its center, and is surrounded by 150 globular clusters and a halo of dark matter and dwarf galaxies, some of which it's eating, all of which can be seen by other galaxies in our Local Group like Andromeda and Triangulum, and our group is on the outskirts of the Virgo galaxy cluster, which is part of the Virgo supercluster, which is just one of many other gigantic structures that stretch most of the way across the visible Universe, which is 90 billion light years across and expanding every day, even faster today than yesterday due to mysterious dark energy, and even all that might be part of an infinitely larger multiverse that extends forever both in time and space.

See? Astronomy puts you in your place.

===== What is Astronomy? (2:59) =====

But what exactly is astronomy? This isn't necessarily an obvious thing to ask. When I was a kid, it was easy: Astronomy is the study of things in the sky. The sun, moon, stars, galaxies, and stuff like that. But it's not so easy to pigeonhole these days.

Take, for example, Mars. When I haul my 'scope out to the end of my driveway and look at Mars, that's astronomy, right? Of course! But what about the rovers there? Those machines aren't doing astronomy, surely. They're doing chemistry, geology, hydrology, petrology... everything but astronomy!

So nowadays, what's astronomy? I'd say it's still studying stuff in the sky, but it's branched out quite a bit from there. Borders between it and other fields of science are fuzzy, a theme I'll be hitting on several times over this series. Humans might like firm, delineated boundaries between things, but nature isn't so picky.

===== Focus On: Astronomers (3:50) =====

And that brings us to our first edition of "Focus On"

This week's topic: Astronomers! Who are we? What do we do?

I used to look through telescopes for a living, or at least study the data that came from detectors strapped onto them. But now I talk and write and make videos about astronomy, and relegate my viewing to my personal backyard telescope. But I still consider myself an astronomer, so that should give you an idea that there's a lot of wiggle room in the profession.

In fact, when I worked on Hubble Space Telescope, I was actually hired as... a programmer! I coded in the language used by the folks helping to build and calibrate a camera that was due to launch into space and be installed onto Hubble by an astronaut.

Once the data from that camera are taken and analyzed, you have to know what to do with them. Do the observations fit the physical model of how stars blow up, or how galaxies form, or the way gas flows through space? Well, you better know your math and physics, because that's how we test our hypotheses. And someone who does that is generally called an astrophysicist.

Of course, those telescopes and detectors don't create themselves. We need engineers to design and build them and technicians to use them. Most astronomers don't actually use the telescopes themselves anymore; someone who's trained in their specific use does that for them. Some of those instruments go into space, and some go to other worlds, like the Moon and Mars. We need astronomers and engineers and software programmers who can build those, too.

And then, at the end of all this, we need people to tell you all about it. Teachers, professors, writers, video makers, even artists.

So I'll tell you what: If you have an interest in the Universe, if you love to look up at the stars, if you crave to understand what's going on literally over your head, then who am I to say you're not an astronomer?

===== History of Astronomy (5:28) =====

However you define astronomy, humans have been looking up at the sky for as long as we've been humans. Certainly ancient people noticed the big glowy ball in the sky, and how it lit everything up while it was up, and how it got dark when it was gone. The other, fainter glowy thing tried, but wasn't quite as good at lighting up the

night. They probably took that sort of thing pretty seriously. They probably also noticed that when certain stars appeared in the sky, the weather started getting warmer and the days longer, and when other stars were seen, the weather would get colder and daytime shorten.

And when humans settled down, discovered agriculture, and started farming, noticing those patterns in the sky would have had an even greater impact. It told them when to plant seeds, and when to harvest.

The cycles in the sky became pretty important. So important that it wasn't hard to imagine gods up there, looking down on us weak and ridiculous humans, interfering with our lives. Surely if the stars tell us when to plant, and control the weather, seasons, and the length of the day, they control our lives too... and astrology was born.

Astrology literally means "study of the stars"; as a word it's been used before science became a formal method of studying nature. It irks me a bit, since it got the good name, and now we're stuck with "astronomy," which means "law or culture of the stars." That's not really what we do! But what the heck. Words change meaning over time, and now it's pretty well understood that astronomy is science, and astrology... isn't.

Millennia ago, astrology was as close to science as you got. It had some of the flavors of science: astrologers observed the skies, made predictions about how it would affect people, and then those people would provide evidence for it by swearing up and down it worked. The thing is, it really didn't; the fault of astrology lies in ourselves and not our stars. People tend to remember the hits and forget the misses when predictions are made, which is why they sometimes sit in casinos pumping nickels into machines that are in proven to be nothing more than a method for reducing the number of nickels you have.

But astrology led to people to really study the sky, and find the patterns there, which led to a more rigorous understanding of how things worked in the heavenly vault.

It wasn't overnight, of course. This took centuries. Before the invention of the telescope, keen observers built all sorts of odd and wonderful devices to measure the heavens, and in fact it was before the telescope was first turned to the sky that a huge revolution in astronomy took place.

It is patently obvious that the ground you stand on is fixed, rooted if you will, and the skies turn above us. The sun rises, the sun sets. The moon rises and sets, the stars themselves wheel around the sky at night. Clearly, the Earth is motionless, and the sky is what is actually moving. In fact, if you think about it, geocentrism makes perfect sense that all the objects in the sky revolve about the Earth, and are fixed to a series of nested spheres, some of which are transparent, maybe made of crystal, which spin once per day. The stars may just be holes in otherwise opaque sphere, letting sunlight through.

Sounds silly to you, doesn't it?

Well, here's the thing: If you don't have today's modern understanding of how the cosmos works, this whole multiple-shells-of-things-in-the-sky thing actually does make sense. It explains a lot of what's going on over your head, and if it was good enough for Plato, Aristotle, and Ptolemy, then by god it was good enough for you. And speaking of which, it was endorsed by the major religions of the time, so maybe it's better if you just nod and agree and don't think about it too hard.

But a few centuries ago things changed. Although he wasn't the first, the Polish mathematician and astronomer Copernicus came up with the idea that the sun was the center of the solar system, not the Earth. His ideas had problems, which we'll get to in a later episode, but it did an incrementally better job than geocentrism.

And then along came Tycho Brahe and Johannes Kepler, who modified that system, making it even better. Then Isaac Newton - oh, Newton - he invented calculus partly to help him understand the way objects moved in space. Over time, our math got better, our physics got better, and our understanding grew. Applied math was a revolution in astronomy, and then the use of telescopes was another. Galileo didn't invent the telescope, by the way, but made them better; Newton invented a new kind that was even better than that, and we've run with the idea from there.

Then, about a century ago, came another revolution: photography. We could capture much fainter objects on glass plates sprayed with light-sensitive chemicals, which revealed stars otherwise invisible to us, details in galaxies, beautiful clouds of gas and dust in space.

And then in the latter half of the last century, digital detectors were invented, which were even more sensitive than film. We could use computers to directly analyze observations, and our knowledge leaped again. When these were coupled with telescopes sent in orbit around the Earth - where our roiling and boiling atmosphere doesn't blur out observations - we began yet another revolution.

===== Astronomy Today (10:26) =====

And where are we now?

We've come such a long way! What questions can we routinely ask that our ancestors would not have dared, what statements made with a pretty good degree of certainty?

Think on this: The lights in the sky are stars! There are other worlds. We take the idea of looking for life on alien planets seriously, and spend billions of dollars doing it. Our galaxy is one of a hundred billion others. We can only directly see 4% of the Universe. Stars explode, and when they do they create the stuff of life: the iron in our blood, the calcium in our bones, the phosphorus that is the backbone of our DNA. The most common kind of star in the Universe is so faint you can't even see it without a telescope. Our solar system is filled to overflowing with worlds more bizarre than we could have dreamed.

Nature has more imagination than we do. It comes up with some nutty stuff. We're clever too, we big-brained apes. We've learned a lot but there's still a long way to go.

So, with that, I think we're ready. Let's explore the universe.

===== Recap (11:29) =====

Today you learned what astronomy is, and that astronomers aren't just people who operate telescopes, but include mathematicians, engineers, technicians, programmers, and even artists. We also wrapped up with a quick history of the origins and development of astronomy, from ancient observers to the Hubble Space Telescope.

===== Credits (11:46) =====

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 Café.