Comets: Crash Course Astronomy #21

Crash Course: Astronomy
https://youtube.com/watch?v=yB9HHyPpKds
https://nerdfighteria.info/v/yB9HHyPpKds

Hey, Phil Plait here and this is Crash Course Astronomy. Since humans have been human weâ€™ve looked to the skies for portents of the future. The Sun, the Moon, the planets, the stars; theyâ€™ve all been used for prognostication. And so have comets. A fuzzy blob, moving slowly across the stars? How could soothsayers resist? But now we know a lot more about comets. Theyâ€™re beautiful, fascinating, and can bring both life and death upon our little world. Comets have been seen the sky since antiquity. Comet Halley, for example, is shown in the Bayeux Tapestry, which depicts the Norman invasion of the British Isles in the year 1066. It was seen by ancient Chinese and Greeks, too. In general, and like everything else in the sky, comets were considered omens or harbingers of human events. Sometimes they were good omens â€" William the Conqueror liked his chances in 1066 after seeing one â€" and sometimes bad â€" that same comet didnâ€™t do so well for King Harold II. A comet bright enough to see with the naked eye shows up in the heavens every few years or so, and some can get spectacularly bright. In 2007, I saw Comet McNaught very near the Sun in broad daylight! When you think of a comet, you probably picture a fuzzy blob and a long tail stretching away from it. Fair enough. But thereâ€™s a bit more to them than that. Comets are in many ways similar to asteroids. Theyâ€™re roughly hewn chunks of stuff left over from the formation of the solar system. Unlike asteroids, which are mostly rock with a dash of ice and maybe metal, comets are a more balanced mixture of ice and rock. And by â€œiceâ€• I mean frozen water -- but also frozen carbon dioxide, carbon monoxide, methane, ammoniaâ€¦ things we normally think of as gases on Earth. And by â€œrockâ€• I do mean rocks, but also gravel and dust. In fact, astronomers sometimes call comets â€œdirty snowballs,â€• which isnâ€™t a half-bad term. Itâ€™s that ice that makes comets, well, comets. When theyâ€™re way out in deep space theyâ€™re so cold that theyâ€™re basically inert lumps of ice and rock. But many are on elliptical orbits that take them from those sub-freezing depths into our neck of the woods, where the Sun can warm them. As they heat up the ice turns directly into a gas â€" a process called â€œsublimationâ€•. The gas then flows away from the comet, creating a cloud around it. This makes the comet look fuzzy, and actually in the past theyâ€™ve been called â€œhairy starsâ€•. I like that term too, and in a sense we still use it. The solid part of the comet is called the nucleus, and the gaseous cloud around it is called the comaâ€"Latin for â€œhairâ€•. In fact, thatâ€™s why we called them â€œcomets.â€• As the ice sublimates, the bits of rock and gravel and dust embedded in it can be freed and leave the nucleus as well. This material is what forms the cometâ€™s tail, but how that happens depends on which material youâ€™re talking about. The gas and the dust from comets form two different tails. Gas molecules emitted by the comet get ionized by the Sunâ€™s ultraviolet light. That means they lose electrons, becoming chargedâ€¦ and charged particles are highly susceptible to magnetic fields. The solar wind is a stream of charged particles blown out by the Sun, and carries a magnetic field with it. As the wind hits the ionized gas from the comet, it picks up those particles and carries them downstream, away from the Sun. The solar wind is usually moving far, far faster than the comet, so this â€œion tailâ€• winds up pointing directly away from the Sun. The dust, on the other hand, is influenced more by sunlight. Light from the Sun exerts a small but inexorable pressure, and this pushes on the dust particles. The dust streams away, but because the pressure isnâ€™t as intense as the solar wind is on the gas tail, the dust tail blows away more lazily, and tends to lag behind the comet in its orbit. That means the two tails usually point in two different directions! In some comets, like 1997â€™s incredibly bright and gorgeous Comet Hale-Bopp, this is pretty obvious. The dust tails look white or a teeny bit yellowish, due to reflected sunlight, while the ion tail glows blue or green, depending on the primary constituents of the gas. Carbon monoxide tends to emit blue light, while carbon molecules glow a ghostly green. A cometâ€™s tail can stretch for tens of millions of kilometers. But, despite their length, tails are incredibly low density, as low as a few hundred atoms per cubic centimeter. The air you breathe is a million billion times denser! In 1910, Earth passed through the tail of Comet Halley. This caused some public fear because cyanogen, a deadly gas, had been detected in the tail! But of course nothing happened; it turns out getting a gazillionth of the toxic dose isnâ€™t that a big of a problem. Broadly speaking, comets are classified by their orbits. If they have orbital period less than 200 years theyâ€™re called short-period comets. These tend to orbit the Sun in the same plane as the planets, and go around the Sun in the same direction as well. From Earth, we see them sticking near the ecliptic, the line across the sky that marks the annual path of the Sun. Comets that take longer than two centuries to go around the Sun are called long-term comets, and have orbits that are tilted every which-way. That means they can appear anywhere in the sky. But this raises an interesting point: Comets go away. Every time they get near the Sun and start outgassing, they lose mass. Over time they get smaller. Eventually, they shouldâ€¦ evaporate. Pffffft! Some do this all at once because they dive into the Sun, skimming our starâ€™s surface. We call those sundivers or sungrazers. Many of those may actually be pieces from a bigger comet that broke up in space nearly a thousand years ago. But besides those, we know of some comets with orbits that can be short, some with periods of just a few years. Even a century is like a single flap of a mosquitoâ€™s wing compared to the lifetime of the solar system! How can comets be billions of years old if their orbits bring them close to the Sun all the time? Astronomers wondered about this very thing. Over the years they came up with an idea: Maybe, out past Neptune, thereâ€™s a repository of comets. Chunks of dirty ice, millions of them, billions, orbiting the Sun where itâ€™s perpetually cold. They could have orbits that last for millennia or more. But then something tweaks them, makes them fall toward the Sun. In fact, there may be two such regions, since we have both short period and long term comets. Turns out: this idea is correct! We now know enough about those distant regions of the solar system that they deserves their own episode, so weâ€™ll dive into that topic later. So. What do comets look like up close? Like, really close? Studying them from Earth is hard. The coma obscures the nucleus, making it nearly impossible to see it directly. Ahhh, â€œfrom Earthâ€•. If you instead send your telescope to a comet, things change. We first did that in the 1980s, the last time Comet Halley came around. Several nations sent spacecraft to fly past the comet, and the Soviet mission Vega 1 was the first to successfully get pictures of the nucleus. The low-resolution images revealed a dark lump highlighted with two bright spots, later determined to be jets of gas streaming away. These images were used to better determine the position of the nucleus, and a few days later the European probe Giotto zipped past the nucleus at an incredibly close distance of just 600 kilometers. Those pictures were more detailed, and showed us a flying mountain, an irregular chunk 15 x 8 kilometers in size. And it was dark, reflecting only 4% of the light that hit it. That makes the nucleus as black as asphalt! You might think that all that ice would be shiny, but itâ€™s not that simple. Most of Halleyâ€™s nucleus is covered in thick dust laced with darker molecules, with only a few spots emitting gas. Most likely, there are deposits of ice under the surface, and only some of them receive enough heat from the Sun to sublimate and blow out gas. This has been seen with other comets as well; the gas is emitted from specific spots on the comet, venting out from cracks in the crusty surface. The surfaces of comets must be inhomogeneous, different in different places. That fact was brought home magnificently in 2014 by another European mission, Rosetta. It went into orbit around the comet 67P/Churyumovâ€"Gerasimenko, and found it to be a bizarre little object. Measuring about 4 kilometers end-to-end, 67P has two lobes connected by a narrow neck, looking very much like a cosmic rubber ducky. The surface is completely devoid of craters; clearly the surface is very young. Images show jets of gas emitted from very specific places on the surface, and there are wide circular pits here and there which may be gas vents, growing wider over time as the ice below is depleted. Surprisingly, the surface is fairly tough and hard, when some scientists expected it to be fluffier. The comet

has a very low density, similar to rubble-pile asteroids, so it was expected that the surface would be soft. Rosetta sent down a lander named Philae to set down on the surface, using harpoons to anchor itself, but instead the lander bounced, unable to penetrate the tougher-than-expected material. One idea to explain this is that the ice is porous and fluffier inside the comet, but as it nears the Sun the ice at the surface warms and changes its structure, forming that harder crust. As for the double-lobed thing, well thatâ€™s a bit baffling. We see some asteroids shaped that way as well. Itâ€™s possible 67P used to be two separate comets that had a low speed collision and stuck together. Or maybe it used to be one big lump, but over the eons the ice in the middle sublimated more, leaving behind the two lobes. Rosetta is the first time in human history weâ€™ve had a probe orbiting a comet, studying it up close and long-term. Weâ€™re still learning, still figuring this stuff out. Incidentally, I mentioned earlier that a) comets have lots of ice in them, and 2) they also get really close to Earth sometimes. In fact, they can hit us! Now not to get all technical and scientificy, but that is what we would call â€œbad,â€• as weâ€™ll discuss in an upcoming episode. But billions of years ago lots of comets hit the Earth not long after our planet formed. Together with asteroids â€” many of which are also rich in water ice â€” they may have brought a significant amount of water to Earth! Scientists are still wrestling over the details of this, and it may be a while before the actual numbers are nailed down, but itâ€™s an intriguing thought. Even more interesting? In 2004, NASAâ€™s Stardust space probe physically passed through the coma of comet Wild 2, collecting samples that were returned to Earth. Careful analysis of the material found the presence of organic, carbon based molecules in them. And not just any random molecules, but complex ones, including amino acids! These are the building blocks of all life on Earth; amino acids are what our bodies use to create proteins. Itâ€™s possible that the ingredients of life on Earth didnâ€™t start here, but instead were brought to our planet from comet impacts. Or, at least, there was a mix of the two. If thatâ€™s the case, then in a sense, all life on Earth is part alien. How about that? But what gets me are the philosophical ramifications of this. When we look into space, when we examine our celestial neighbors, when we send probes to comets and survey what we find, weâ€™re looking at our own origins. Comets are like time machines, allowing us to investigate our past, four billion years back, hinting at the secrets of the origin of life itself. And you thought astronomy was just lying out in a field and looking up. Well, it is, but if you let it, itâ€™s also a whole lot more. Today you learned that comets are chunks of ice and rock that orbit the Sun. When they get near the Sun the ice turns into gas, forming the long tail, and also releases dust that forms a different tail. Weâ€™ve visited comets up close and found them to be lumpy, with vents in the surface that release the gas as ice sublimates. Eons ago, comets (and asteroids) may have brought a lot of water to Earthâ€¦ as well as the ingredients for life. Crash Course Astronomy is produced in association with PBS Digital Studios. They have a ton of good shows over on their channel so you should head on over there and take a look. 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 directed by Nicholas Jenkins, the script supervisor and editor is Nicole Sweeney, the sound designer is Michael Aranda, and the graphics team is Thought CafÃ©.