Astronomy Cast Episode 19:

Comets, Our Icy Friends from the Outer Solar System

Fraser Cain: There's only one topic we can do this week: Comets. We did an update on it already, but lets give people more explanation as we all look for Comet McNaught. Comet McNaught can actually be seen in daylight now, although I haven't tried this yet because of the weather here.

The trick is to stand behind a building so that the shadow just covers the Sun's glare, and you should be able to see the comet within a hand span of the Sun. You can use binoculars, but don't burn out your eyes! After a couple of days it will move back into the night sky, but to see a comet during the day is almost unprecedented.

Dr. Pamela Gay: It does happen occasionally. A lot of the great comets which are observable to the naked-eye stand a chance of being daylight objects when they are at their brightest, such as Hale-Bopp, but this one is way brighter than anything which has been seen for a long time.

Fraser: So what are comets?

Pamela: Comets are giant chunks of ice with bits of dust and rock mixed in; by ice, I mean not just frozen water, but things like frozen carbon dioxide and other frozen gases.

They formed in the outer parts of the solar system, from two different regions: some came from the Kuiper Belt, where Pluto resides, and some from edge of the solar system, in the region called the Oort Cloud. Various interactions can cause them to plunge into our inner part of the solar system, where the surfaces don't exactly melt (because the pressures of the solar system are so low), but the gases that are frozen inside the comet go straight from frozen ice to gas during a process called sublimation.

Fraser: So what kinds of interactions would cause these comets to come towards us, or rather, towards the Sun?

Pamela: Well, some have come towards us, plunging into the inner parts of the solar system for a variety of reasons. Sometimes a group of them will gravitationally interact during a three-body problem, and one of them gets ejected and goes flying off in our direction.

You can also get perturbations from the gas planets – Uranus, Neptune, Jupiter and Saturn – that gravitationally cause things to fly into the inner solar system. There are stories that, perhaps, interactions with other stars were involved, but as near as we can tell, the reality is that it is interactions with our own planets and similar stuff in the outer parts of the solar system.

Fraser: So if we were observing comets in their natural habitat, way out in the Oort Cloud or the Kuiper Belt, what would we see?

Pamela: I once heard Mario Livio say something really brilliant; he said that if you put Pluto in the inner part of the solar system it would grow a tail like a comet, and that is no way for a planet to behave. The truth is that comets are basically Pluto made small, 10-50 kilometer sized chunks of dust and rock. Take all the stuff that ends up on the side of the street after the snowplough has passed, which is mostly ice, but polluted with all sorts of road debris, and you have pretty much a comet.

Fraser: So what causes the tail? Coming towards the Sun causes the gases to heat up, but it's a pretty amazing transformation.

Pamela: As they come in, their surfaces sublimate and you get jets of material where a pocket of something like water-ice inside gets melted by the Sun and starts spewing material into space. The comet is in the process of moving and its motion causes some of the material to stream out, but there's also something called the solar wind.

Our Sun builds up pressure throughout the solar system, pushing material outwards, and when ionized material comes off the comet it gets pushed straight out by this solar wind. So, if you're looking at a comet, its tail will have nothing to do with its direction of motion; the tail always radiates straight away from the Sun, so you might see it flying straight into its tail if that is the direction that the Sun is pushing its tail.

Fraser: That is really the question I was going to ask. All this material is coming off the comet, and because it's in a vacuum it will have the same momentum, so it will move with the comet in a growing cloud. But it's the solar wind that is pushing the stuff away the moment it detaches from the comet.

Pamela: Exactly. The solar wind effectively pushes on the ion tail. Comets actually have more than one tail; sometimes they have up to three separate tails made up of different materials.

So if you have ions, atoms missing some of their electrons, these get pushed really hard by the radiation pressure of the solar wind, and go straight out and away from the Sun.

The material that sublimates off the surface - or gets blown off by sublimating material - will form a dust and gas tail, and this particular tail will appear more curved, as it carries the momentum of the original comet and it's getting pushed by radiation pressure. So this combination causes it to curve away and be not quite identical to the ion tail.

Now, a third type of tail was also discovered with Comet Hale-Bopp (which was the last really bright comet), and this was a sodium tail, so there is apparently a lot of sodium in that particular comet, and it formed its own separate tail in that particular situation.

Fraser: So you need fairly dark skies or a really bright comet to see some of these multiple tails. I remember with Hale-Bopp and Comet Hyakutake you could actually see the second tail.

Pamela: Comet Hyakutake was only bright for a few days, but Hale-Bopp was a naked eye comet that you could see without binoculars or a telescope for nine months and its tail got to be several degrees across the sky, so you could see it spanning the rooftop of a building. The two tails were very evident from darks sites, especially with binoculars.

Fraser: So when you say it can move towards its tail, I guess that as the comet is coming towards the Sun on some crazy orbit, the tail will be directly away from the Sun. Then as the comet moves away from the Sun again, it could be moving in the same direction as the tail, as if the tail were a pointer, not blazing away from it.

Pamela: That's exactly what happens. It's weird to see the tail always pointing away from the Sun while the direction of the comet is different. This is a neat thing in terms of observing comets, because if you go outside and are able to observe a comet right before or right after sunset you can draw a line through the tail to the Sun and it's a perfectly straight line every time.

Fraser: So what kind of damage happens to the comet if it's losing all this material as it heads in towards the Sun? What's happening to it?

Pamela: Well, it's losing some of its outer layers, and all sort of weird chemical reactions happen on the surface of the comet. When we send space-exploring satellites in to look at these things, we find they are not highly reflective snowballs like we expected, but rather all these chemical reactions have led to complex carbon molecules, coating the comet with a black soot.

In all reality, the surface of a comet is less reflective than black asphalt, and when the surface melts, weird reactions occur, and we end up with this sooty coating, other materials forming small jets and stuff ionizing off the surface.

Every time the comet goes around the Sun it gets a little smaller, sometimes they break up in the process, and eventually all the comets that come past the Sun enough times are going to melt away and be no more. Sometimes in the process of melting they lose all the stuff that makes them look like a comet and the end up instead looking like asteroids. There are several asteroids that we now suspect were actually once comets, but the comet part has died off.

Fraser: You mentioned that comets can break up; what process is going on there?

Pamela: Well, they can break up due to a lot of different things. They can get too close to Jupiter or the Sun and the gravitational pull tears the comets apart. In this case, the gravitational pull on the side of the comet closer to the object that's shredding it (e.g. the Sun or Jupiter) is so different from the gravitational pull on the side that is further away that the difference causes the body to break apart. This is called tidal force, the same thing that causes tides on the Earth due to the Moon.

When this happens, you can end up with a thing that's strewn out across space, as we saw with Comet Shoemaker-Levy 9 before it plunged into Jupiter. On a prior orbit, when it had got too close to Jupiter, it broke apart and it ended up as a string of objects.

Some think that Comet Encke that we see every few years was once a substantially larger comet that broke apart; periodically the Earth hits some of these parts. Some people suspect that objects which crashed into the Middle East during the Bronze Era, bringing a close to several great civilizations, might have been chunks of Comet Encke and that perhaps the Tunguska Event, where a mysterious object almost hit the surface in Siberia, might also have been a part of Comet Encke, just encountering the Earth as it traveled around the Sun.

Fraser: There's no crater, just a blasted area hundreds of kilometers across, with trees flattened, but no visible impact, so you could almost imagine that the piece of ice or snow was just blasted in the air or vaporized.

Pamela: Exactly. It got hot and none of it quite made it to the surface before melting and vaporizing.

Fraser: You have already moved towards the question that I will inevitably ask, which is whether we are at any risk from comets.

Pamela: Right now we don't know of any that are headed directly our way, but there is always the rogue chance that one is going to come at us. We are constantly finding new comets; the SOHO satellite was put in orbit specifically to observe the Sun, but it has also ended up helping people discover over a thousand different Sun-grazing comets, which approach very close to the Sun and in some cases melt or even fall into the Sun as they get near.

We did not know about all this stuff, and probably would not have found them if were not for this particular satellite. Now, imagine that one of these Sun-grazing comets comes around the Sun then heads straight towards us from out of the Sun's glare; we would never see it until it crashed straight into us. But there are a lot of different groups constantly watching the Earth for near-Earth objects – comets, asteroids, things that we don't know about – that might just decide to cream us some day in the future.

With so many different people, and so many different satellites and ground-based sets of detectors on the lookout, there's probably a good chance that we'll know beforehand what is going to happen before it happens.

Fraser: I guess the problem with long period comets from the Oort Clouds is that they don't have a regular orbit that we can calculate and predict (as we do with the near-Earth asteroids); five months warning is about as much as you get, so having those comets out there is nerve-wracking!

Pamela: This is one of those things that is hard to imagine; we know how long it takes Mars or Pluto to orbit, and we are so used to thinking everything has been discovered, but not so much with long-period comets such as Hale-Bopp and Hyakutake. They have orbits that, in some cases, are tens of thousands of years long and some only orbit the Sun once and then get flung out of the solar system forever.

If one of these distant objects comes in, we would not know about it, and if it's one that's particularly covered in soot we might not see it until it was very close. It's rare that a comet is visible as far out as Jupiter; Hale-Bopp surprised everyone by becoming bright enough to see with binoculars when it was about as far away as Jupiter. We don't get that much warning in general.

Fraser: So how are comets usually discovered? I guess now it's all about SOHO, but how are comets that pass by the Sun at the last minute discovered?

Pamela: There are several different ways. There are a lot of ground-based surveys looking for near-Earth orbits, such as Linear, and these are different programs which constantly survey along the ecliptic (the part of the sky where all of the planets and the signs of the zodiac can be found). They compare images from one night to the next, much the same way as you look for supernovae, looking for something new to appear in the sky. In this case, you look for something new that's moving.

While there are a lot of automated surveys, but there are still amateur astronomers who regularly find comets, and these are just folks that go out night after night and study the sky, and occasionally there is just a lucky person that looks at an old favorite star cluster or galaxy and sees something fuzzy nearby that shouldn't be there. When they look through their star charts they realize they may have discovered a comet.

So it's amateurs, and people using satellites, although those using satellites can be amateurs as well, as scientists don't have time to deal with all the data from SOHO, so it can be amateur astronomers going through the publicly available data that find the comets. Then there are ground-based surveys with big collaborations of people using automated surveys.

Fraser: If you find a comet, you get it named after you, right?

Pamela: Exactly. Originally comets were named after the people who calculated their orbits, but after a while that got boring, so over the past few years all of them have been named after the people who originally discovered them, and if more than one person discovers the same object, you end up with complicated names like Hale-Bopp and Shoemaker-Levy that incorporate both of the discoverers' names.

Fraser: So, I guess we should give listeners some observing advice. If you hear that there's a comet in the sky, what's the best way to see it with your own eyes?

Pamela: With comets, just like any other object, you want to go somewhere dark, and one trick here is that if the darkest location puts the city lights in the same part of the sky that you're looking at, don't go there. If the object you're looking for is in the South-South-West, figure out how to drive so that the nearest city is in the North-North-East, 180° around the sky, so that the object you are interested in is in the darkest part of the sky. Take finding charts, as it's a big sky and easy to get lost.

There are a lot of places online that you can download information from. Take a friend; the sky is best observed when you are with other people with whom you can talk and share your experience. A good pair of binoculars can go a long way. When you're not looking at the comet, take the time to explore and see what you can find out among the stars.

Fraser: One of the things we heard with the Stardust and Deep Impact missions was that scientists wanted to know a lot about comets because they maintain a history of the solar system; what kind of information are they finding from those missions?

Pamela: They've been trying to figure out the history of the solar system: is it true that comets are the source of the majority of the water here on Earth. That's kind of a neat result. If you look at the geological record and models of how our solar system formed, it seems that there might have been a period of time when the Earth was so hot that pretty much all the water on Earth got vaporized. So you have to figure out how we got water onto our watery planet, and people have thought that comets are an easy way to solve the problem. Collide enough comets into the planet Earth and you have oceans.

Recent results found that comets don't necessarily have the same type of water as the planet Earth. There's a different version of water called heavy water, made out of deuterium (hydrogen that has an extra neutron) that we have as part of our oceans. Comets have more deuterium in them (or at least the particular comet that was observed) than we find in ocean water, so if comets are all made the same way, either there had to be some way of getting rid of the deuterium on Earth, or perhaps our water came from some other mechanism. It's neat to study the history of our ocean water by studying comets.

Fraser: For me, one of the things about comets is that they are one of the most amazing things you can see in the night sky. Some of my favorite memories are looking for comets, as it's not something you do by yourself. So let's hear a comet memory!

Pamela: For me, it was the very first night I went out observing at McDonald Observatory. I had to get up at 7a.m. that morning, I had been up really late the previous night doing a homework set, and I was absolutely exhausted. The person who was teaching me how to use the telescope, Dr Philip MacQueen, said "You just have to stay awake till 5a.m.", and I thought "What's so special about 5 a.m.?" By about 5 a.m. I was hitting human zombie state, sprawling across the desk at a computer next to him. He nudged me and said, "OK, go outside."

I walked out of the front door of the observatory, and we were using a 30 inch telescope embedded into the side of the mountain; at the left side of the mountain above me were the historic 82 and 102 inch telescopes, and on the right this amazing Texas lightning storm, with the lightning flashing off the big domes. Straight in front of me, at least two fists wide, was Comet Hale-Bopp, just blazingly bright, spread out across the sky. If you showed this in a planetarium, no one would believe you that this was the real situation. I could see the Milky Way straight overhead and the comet was brighter than the Milky Way.

For the rest of that observing season, whenever I drove out to McDonald Observatory, I felt like I was following the comet to the domes, because the highways that I took almost constantly kept Hale-Bopp centered in my windshield. How weird and wonderful an experience can you get!

Fraser: Mine is of the same comet. We were living in Vancouver at the time and a friend and I spent the evening trying to find the best place to observe it. We went to various bright parts of the city, where you could just about make it out, and there are also a lot of mountains around Vancouver, so we couldn't get a really good view of it. So we decided to put in a long drive to see it.

We went out of Vancouver on a road that takes you towards Whistler, a ski resort about 100 kilometers outside Vancouver. When you turn the corner, the mountains shadow the light from the city and there is a series of beautiful lookouts that face perfectly west. So about 10-15 kilometers along this road the lights of the city faded away and we could stand at one of these lookouts and watch the comet blazing in the sky for as long as we wanted.

My other interesting time was last summer, when I visited Phil Plait from Bad Astronomy in San Francisco. He has a big telescope, which we got out, and there was a big comet out.

I am hoping that Comet McNaught is going to beat it all, so that I can take my kids out, no matter how cold it is, and we can see it. I hope people will have a good experience of when Comet McNaught comes back out of the Sun and into the morning skies. I hope people get the chance to go see it.

Pamela: It's really an amazing opportunity that seems to have come completely out of nowhere. This object was discovered last August and no one really expected it to get this bright. Now, all of a sudden, we have a daytime object. It's really amazing!

Fraser: That's good. I think we've had a good overview of comets, and I hope that people get a chance to see Comet McNaught. If you do, let us know, we would love to see any pictures and hear your stories of how you roped your friends into going out to see the comet and the good times that you had. Make some conversions! Thanks a lot Pamela!

Pamela: Thanks Fraser, it's been my pleasure.

This is not an exact transcript of the audio file; it has been gently edited to preserve clarity. Transcription and editing by Colin Humphries