Astronomy Cast Episode 29:
Asteroids Make Bad Neighbours

Fraser: This week's topic is near-Earth asteroids. Every year, we hear about a new space rock that may or may not get really close to the planet in the next few decades. How do astronomers find these things? Why are they buzzing around the Earth? What are the chances we'll get hit? What will happen if we do get hit?

That's a lot of questions, so you can start anywhere Pamela.

[laughter]

Pamela: Well, according to NASA, right now there's absolutely nothing that's going to hit us. So we're safe right now (right now).

Fraser: For the duration of this recording?

Pamela: For the duration of this recording and as far as they know, none of the known asteroids, comets, anything out there, is going to hit us. Period.

Fraser: All right, that buys us a little time and gives us a chance to talk about it. We'll check in again maybe at the end of the recording.

Pamela: Okay.

Fraser: Okay, what is a near-Earth asteroid, for starters? I guess the name kind of says itself

Pamela: Well the more general term is "near-Earth object" – we have these NEO's, and they get broken up into a bunch of different groups: There are the near-Earth comets, these are chunks of ice that decided they're going to come into near where we are and as they orbit the solar system, they get a little too close and they have the potential to hit us.

Fraser: Do they stay close, or do they zip through and then they're gone again?

Pamela: These are defined as things with periods less than 200 years that go out to the outer parts of the solar system, come in to the inner parts of the solar system, go back and forth, back and forth.

Now, periods less than 200 years means some of them do actually end up living in the inner part of the solar system. They end up living with orbits that never go out further than Mars or Jupiter. They've gotten perturbed by close encounters with Mars, close encounters with Earth. All the different planets' gravities have changed their orbits until their orbits keep them in the inner part of the solar system right in the way of potentially running into us. So far as we know, none of them are going to do that.

Fraser: I think we talked about a bunch of those comets in our meteorite episode.

Pamela: Exactly.

Fraser: Because they're the ones feeding the meteorites into the space dust that we crash through.

Okay. Right, so comets… what else?

Pamela: We also have near-Earth asteroids. These are chunks of rock. Some of them are crustaceous, carbon… they're basically dirt. Others have more metallic cores. They come in a variety of different things that resemble chunks of Earth's crust that have been placed in space. Again, these are things that are in near the Earth's orbit, by definition they have orbits smaller than 1 and 1/3rd of the Earth's orbit and they're hanging out.

Within in that, we also have all these other smaller orbit sizes, more dangerous things, so there are things called Apollos. These are things that have orbits that are greater on average than one Earth orbit, so you'd think that we're safe, because they're greater on average than one Earth orbit. Unfortunately, that means they can go in closer than Mercury and go way far out (well, not way far out, but moderately far out) and cross our orbit in the process. So, the Apollos can hit us as they cross our orbit. It keeps life interesting.

There are also these things called amors. These generally stay interior to Mars and outside of Earth's orbit, but sometimes they cross. Most of the time they're past the Earth's orbit and before Mars' orbit.

There are also (and I may mis-pronounce this) the Atens. These are Earth-crossing, near-Earth asteroids that have an average orbit size that's smaller than the Earth's orbit.

So we classify these strictly based on what does their orbit look like, what does the period of their orbit look like.

Fraser: So I guess with the Atens, it's the same deal; they're mostly inside our orbit, but they can reach out and bonk into us as well.

Pamela: So you can have something that their average distance from the Sun is less than the Earth's distance, but if they get close enough on the one side, they can cross the Earth's orbit on the other side.

Fraser: Now, there are some asteroids that are quite close to our orbit, aren't there? Like Toutatis, right?

Pamela: There's this special class called PHA's – Potentially Hazardous Asteroids. These are objects whose minimum orbit intersection distance (MOD) is 0.05 times the distance from the Earth to the Sun away from the Earth. They're averaging about 5% of the distance from our Sun, is how close they get to us. They're not necessarily going to hit us, but they get close enough that we can get really good pictures of some of them.

Fraser: How many of these asteroids are there?

Pamela: Of Near-Earth Objects, there's roughly 11-1200 of the 1km sized ones – the ones that can completely destroy the planet Earth.

Fraser: The big ones. Right. We'll talk about that in a bit.

[laughter]

Pamela: If you go to NASA's Near-Earth Asteroid site (it's conveniently named neo.jpl.nasa.gov), they actually go through and list, at any given moment, all of the asteroids and comets and things like that, that are going to get a little bit too close for comfort. There's a couple hundred just sitting there, with their statistics showing you how scarily close they're going to get, and how remarkably low the probability of them hitting us is.

Fraser: I've hard that there's, as you say, 1200 of the really big ones. But there's hundreds of thousands of little ones.

Pamela: Right.

Fraser: They're buzzing around us all the time.

Pamela: The fact is, we're constantly getting hit by small things. Anytime that you see a meteor going across the sky, that's a really tiny thing. Anytime you see a bullwood, an explosive burst from a meteorite, that's something hitting our atmosphere. So we're constantly hitting things that are floating around in our orbit. Most of these just cause pretty fireworks. Occasionally you get stories of people having something coming crashing through their roof that actually turns out to be a meteor. You find things in the desert, you find things in Antarctica. Most of these things are too small for us to have to worry about, and that's good because most of them are too small for us to see before they hit our atmosphere.

Fraser: How do astronomers find them?

Pamela: There's a bunch of different programs that go out and take picture after picture after picture of areas specifically along the ecliptic in the sky. This is the area in the sky that the sun travels through and where we see all the planets. More or less, the majority of the asteroids and comets confine themselves to the ecliptic. There are some exceptions, things get thrown around through gravitational interactions and to find asteroids and comets, they look for things that move in their pictures.

So, you take two pictures and subtract them. The thing that appears in both pictures but in two separate locations, that didn't subtract out, that's going to be your fast moving object that's in the inner-part of the solar system.

Fraser: I know they do this with computers now, but they used to do this manually. Didn't they have some kind of light-box they could flip back and forth?

Pamela: This is actually what Claude Tombaugh did when he was trying to find Pluto. He'd take multiple images, set up the exact same way on the sky, and put them side by side in a blink box that allowed him to flip back and forth between which of the two he was looking at and our vision allows us to see things... it's the persistency of vision. If you put a flashlight on a string and spin it, you'll see a wheel of light. The light's only in one given point in a moment, so our eye is able to perceive, "this should still be here" and then when we see something that has moved, we can actually see what appears to be motion when it goes back and forth between the two images. Our brain does neat tricks that allow us to perceive the motion of asteroids and planets in blinked pictures.

Fraser: We're not talking about a bunch of astronomers with their telescopes and cameras and looking at blink boxes, it's an industrial process these days, right?

Pamela: Nowadays there are multiple telescopes set up around the planet that scan each part of the sky along the ecliptic five times in a given night. They're constantly going through processing, looking for things and discovering new things on a regular basis and calculating the orbits in rapid fire.

A lot of times you have multiple teams working, where you have one telescope that's doing these five images a night discovery. "Okay, here's a new object that I haven’t seen before." Then you'll have folks going out on different telescopes following up and trying to do precise astrometry to calculate orbits. One of the telescopes that's used for that is the 30" out at McDonald Observatory which I worked on for my dissertation.

These folks are going out and calculating orbits, doing all the follow-up work which, in some ways, is the most important part because once you discover them, yay you know there's a new object, but that object could be going in any direction. It's the follow-up work, to see where it's moved several days, several months or several years later that allows us to figure out the long-term motion of these objects.

Fraser: How does that follow up work happen? That's where more people get brought in to the process, right?

Pamela: Exactly. So in this case, you'll have individuals going out to the telescope, taking large field images of the object. The large field allows you to get more stars involved in "okay, so, my moving object appears to be three arc-minutes off this objects, five arc-minutes off this object.." with all these different comparisons between multiple objects you can get very precise locations.

You do this multiple times and you can see how the object is moving across the sky. You can then build models of "I know that the Earth was here relative to the solar system on this day and the object appeared here. I know on this later day the Earth was here in the solar system, the object appeared here." How does everything have to be moving to make sense out of that?

Using, again, complicated computer software, they make very sophisticated orbital calculations that in the long term allow them to take into account "this object's going to be influenced by Mars, this object's going to be influenced by Jupiter" and figure out orbit after orbit after orbit. What is the risk of the object hitting the Earth?

Fraser: They're not looking at "will this rock hit us – is it on a collision course with us today?" They're able to calculate it out for orbits and orbits and orbits into the future.

Pamela: For hundreds of years. That's one of the really neat things about this. We can look to the future and figure out "when exactly might we get creamed?"

Fraser: So what range or what size of objects will these automated surveys turn up right now?

Pamela: It depends on the reflectivity of the object. A really reflective object you can see even when its smaller. On average for finding things that are from tens of metres to kilometres in size, majority of objects that we find are around several tens of metres in size. The solar system doesn't have (luckily) lots and lots and lots of these kilometre asteroids waiting to cream us.

So we're finding all different sizes and we find them, often, when they're very close to the Earth. In fact, there was one that was just 30m (100') in diameter that passed within about 1/10th the distance from the Earth to the Moon, back in 2004, that we discovered just three days before it passed that close to the Earth. So we're finding lots of smaller objects out there.

Fraser: So we're able to see the bigger objects at various points along the orbit, but the surveys are also turning up the really small objects as they zip right past us closely.

Pamela: Exactly.

Fraser: Yeah. What will it take, then, to find more of these objects? I don't want to find out about these objects three days before they're going to hit us. I want to know a hundred years before they're going to hit us.

Pamela: The trick is beating down the noise. These things are moving, which makes it hard to get a lot of photons from them. We don't know ahead of time exactly how fast they're moving. To get a good image of something, you want your telescope to track it across the sky. We know the rate that the stars move across the sky, and the asteroids will actually appear to move relative to the stars, so if it's a very small, faint object, we might need a 5-10 minute exposure to get good signal. But if we don't know over those five or ten minutes how fast the telescope needs to be moving, we're not going to get a good image.

If we go up into space, where we get rid of our atmosphere, that's one less thing that's going to be blocking the photons and interfering with the light, and it gets a bit easier to find them.

We also have to try different tracking speeds, bigger collecting areas – at the end of the day, you want to survey as much of the sky with as sensitive a detector as you can day after day after day. In space we're not limited by where the Sun is. Here on Earth we can only observe at night. If we go into space we can observe all the time, we just have to observe the direction near the Sun, but that opens a whole lot more of the sky to look at.

Fraser: Oh I see. It's like the place where you most want to look, which is toward the Sun, is invisible to us for most of the day.

Pamela: This is actually a real problem.

Fraser: Yeah.

Pamela: The things that are most likely to hit us are going to be on really elongated orbits and they're probably going to be coming straight out of the Sun as they come toward us. To see the things on the collision course, we need to be able to see near the Sun.

Fraser: What are the chances that an asteroid is going to hit us?

Pamela: Very very low. But there is this chance. There's a probability that we're going to get something like Tungesta, where a comet explodes in the atmosphere roughly every thousand years. As you move to larger and larger and more and more destructive objects, they happen more infrequently, but the probability is still there. The key is, currently we know of nothing that's going to hit us.

Fraser: We don't know of anything that's going to hit us, but we're fairly certain or almost sure that something's going to hit us eventually.

Pamela: Exactly.

Fraser: All right. Let's say, then, that we've got a 50m, one of those smaller objects, that does end up on a collision course with the planet. What would happen if it actually did hit the Earth?

Pamela: With one of these 50m ones, some of it's going to make it through the atmosphere and hit the Earth with a great deal of force. If it hits on land, it's going to create a big crater, throw a lot of dust into the air, destroy that area but it's not going to create global havoc.

Fraser: How much of an area? Are we looking at a small town, a city, a continent?

Pamela: Tucson would be toast if it got hit.

Fraser: That's just a 50m asteroid.

Pamela: Yeah.

Fraser: Okay.

Pamela: It's kind of alarming but kind of cool all at once. It's the "when it bleeds, it leads" section of astronomy.

Fraser: Yeah, that seems to be the directions I seem to take this show, but we'll try and keep it back on track.

[laughter]

Okay, let's go a little bigger then.

Pamela: From 50m you destroy a city, but when you get up to 1km, you destroy the planet.

Fraser: You don't actually blow up the planet?

Pamela: No, no. The Earth will still be there, and there will probably still be critters roaming around on it, but at this point you create essentially the asteroid impact version of the nuclear winter. You throw so much stuff up into the atmosphere that you cool the planet off a bit. You also create (if it hits water) you can have tsunamis that wipe out all the coastlines on one half of the planet. Some rather bad things happen.

In general, though, you always want asteroids to hit the ground. When they hit the ground, they throw up lots of dust, lots of dirt and earth. If they hit in the wrong place they might trigger volcanoes, but when they hit water, the water can cascade around the planet and destroy much, much larger sections.

Fraser: So how big of an object took out the dinosaurs? That was what, 65 million years ago, right?

Pamela: That's actually a bit controversial. There are people who are saying that might not actually have been the whole story.

Back in 1980, there was the discovery that there's an iridium layer around the crustaceous-tertiary boundary, where all the dead dinosaurs are located. People got to thinking "so, why is there iridium here?" Iridium is pretty rare on the Earth's surface, but it's found really commonly in asteroids. A pair of scientists got to thinking, a father and son (Louis and Walter Alverez) and suggested that perhaps an asteroid struck the Earth, deposited the Iridium, triggered mass extinctions and killed everything.

This was linked with the Yucatan crater, the Chicxulub (and I apologise for what I just did to the pronunciation of that). Since then, there've been some highly controversial studies that have said, "well, perhaps that crater isn't the only crater that was responsible for that particular extinction." There are several other craters that might also have been linked with it, as well as a huge volcanism event in India. Perhaps all of these things together worked to wipe out the dinosaurs, so we might actually have multiple asteroids to blame for the dinosaurs.

Fraser: Right. So, still it sounds like it was a pretty bad time to be a dinosaur.

Pamela: It was definitely a bad time to be a dinosaur.

Fraser: All right, so now we've freaked everybody out

[laughter]

But I guess the hope of these automated asteroid watching programs is to find these asteroids and maybe give us a chance to do something about it. Once again, let's rewind, so we haven't got hit, we've got some time, what can we do?

Pamela: Well,

Fraser: And how much time would we need? I mean, when you think about *Armageddon* or *Deep Impact* or any of those asteroid disaster movies, it's always some astronomer, "Oh my God!" looking through their telescope and you've got six months and then kaboom.

Pamela: Okay, so first of all, you're not going to identify that it's going to wipe the planet out from one observation. My personal greatest annoyance with *Deep Impact* was that they seemed to be working from one picture and it takes lots and lots of pictures to build an accurate orbit.

That aside, you want to discover these things as far in advance as possible. If something's far, far away, you can basically walk up to it, thwomp it and change its orbit enough that it won't hit the Earth. If something's really close, you have to exert a much stronger force to divert it the same amount because it has less time to divert over.

So we want to find things years in advance if possible. That will give us the time to build what we need to build, to go out to it, tap it and push it in a new direction, or go out and stand in front of it and gravitationally attract it in a new direction. Things that are close, it's a lot harder to divert.

Fraser: So, what are the best or feasible strategies that we've got right now to divert them? In all of those disaster movies it's always a space shuttle full of nuclear missiles. That can work?

Pamela: That would lead to total destruction of the planet Earth.

With an asteroid, if it's nice and intact, it hits and it destroys, like, a continent (if it's a big one) and the rest of the time it has repercussions: you have, basically, nuclear winter. But you only have mass total crater-forming carnage on the one place. If you knock the asteroid into ten thousand little pieces, all of those pieces are going to hit the planet. So we're now going to have carnage that wraps itself around the globe.

Fraser: Sort of like the Shoemaker-Levy 9 collision with Jupiter, right?

Pamela: Exactly. As the planet rotated, new parts of the comet hit Jupiter and we ended up with this shoestring of pockmarks on the face of Jupiter.

Fraser: So if you flew up with your nuclear weapons, blew up an asteroid into a lot of parts, then it would just be like hitting the Earth with shotgun pellets. Big ones.

Pamela: Exactly. Yeah.

Fraser: Once again, you're not going to completely destroy the Earth, we're just merely wiping out major life.

Pamela: Exactly. No big deal.

Fraser: Earth's still going to be fine.

[laughter]

And the bacteria under the surface of the planet will finally have it's day.

[laughter]

Pamela: Something new will emerge.

Fraser: Yeah. Rise of the slime.

Pamela: Exactly. So don't blow up asteroids.

Fraser: Okay, but that's the major idea that everyone's had for – I mean, that's the big idea, right?

Pamela: If you're going to go visit an asteroid, with the space shuttle, attach the space shuttle, fire the engines and just push it in a new direction. Now, our space shuttle is never going to go that far. Our space shuttle struggles to go more than several hundred miles above the surface of the Earth.

Fraser: And our space shuttle wouldn't have the fuel. I can just imagine the amount of fuel it would take to push. All right. Get real. Let's hear some realistic strategies here.

Pamela: To get real, you build yourself a fairly reasonable size space probe, put what's called an ion engine on it, which is where you literally take ions, accelerate them using magnetic fields, and as they leave the spacecraft, they're going in one direction and conservation of momentum causes the space craft to go in the opposite direction. You can get these little ions which don't have a lot of mass, going at huge velocities. Since they're going extremely fast, your much larger mass will still get some velocity that's noticeable pushing it forward.

Well, if this works to move spacecraft, it will also (if you give enough time) work to move entire asteroids. You can go out and push an asteroid using an ion engine.

Fraser: So you just equip an asteroid with an ion engine.

Pamela: Exactly.

Fraser: And have it start pushing… and use fuel, I guess, from the asteroid, and eventually you'll change the orbit.

Pamela: You can also go out and just gravitationally pull on it. This is one of those things that it doesn't seem like it will work, but it actually does. If you take a big chunk of metal (which a space craft can be), stick it near the asteroid, the mutual gravitational gravitation of the two will change the path of the asteroid just enough to prevent it from hitting the Earth.

Fraser: I did a podcast on this, on the Universe Today podcast feed, where there's actually a really good proposal right now. They take an ion-powered space craft, with a tether down to a chunk of mass like a nuclear reactor, and they put the reactor as close as possible to the asteroid itself and then fire the ion engine continuously. The asteroid would be attracted to the reactor, to the mass on the spacecraft, and obviously the spacecraft would be way more attracted to the asteroid itself, so you fire the engine and you continuously tugging against the pull of gravity. As long as you have enough fuel, you can be slowly pulling the asteroid away from its current orbit. There's some really neat proposals out there right now that are going around. That seems like the most feasible strategy I've heard so far.

Pamela: So, all we have to do is budge them a small amount. There's also this – it's not related to protecting the Earth by deflecting an asteroid, but the Planetary Society has this really neat contest going on about how do you tag an asteroid.

One of the problems we have is getting extremely accurate orbits. In the case of asteroids that look like they have some sort of a probability of hitting us, we want to work as quickly as we can to get as accurate an orbit as we can to figure out if we need to make the financial expenditures necessary to go out and divert it.

We recently had a scare with the asteroid Apophus. It's not going to hit the Earth. It's not going to hit us any time. So, we know that it's not a worry, but we thought it was for a while. The Planetary Society put out this call for proposals on how could you go out and put a radio transponder on an asteroid so that we can track it and get accurate positions over time. One of the first steps to diverting an asteroid is actually just radio tagging it, like you might radio tag an endangered species, so we can keep track of it as it migrates through the solar system.

Fraser: And the better you know its position, the better your chances of predicting its future position and knowing whether or not its going to hit the Earth.

Pamela: Exactly.

Fraser: Good, well I think that gives us a really good overview of the threat. I think asteroids make bad neighbours.

[laughter]

Pamela: Well, they might have future uses as things that we can mine for elements, so bad neighbours, good neighbours, it all depends on how we're exploding them.

Fraser: I guess so.

All right, thanks Pamela. We'll talk to you again next week.

Pamela: It's been my pleasure, Fraser.

This transcript is not an exact match to the audio file. It has been edited for clarity.