Astronomy Cast Episode 281 for Monday, November 19, 2012: Explosions in Space

Fraser: Welcome to Astronomy Cast, our weekly facts-based journey through the Cosmos, where we help you understand not only what we know but, how we know what we know. My name is Fraser Cain; I'm the publisher of Universe Today, and with me is Dr. Pamela Gay, a professor at Southern Illinois University – Edwardsville. Happy Thanksgiving, Pamela!

Pamela: Happy Thursday in Canada!

Fraser: Exactly. Thanksgiving already happened a long time ago, but you know what's really weird is we're getting Black Friday in Canada now.

Pamela: You are?

Fraser: Yeah, so we're getting…all of our stores are now are doing Black Friday events, but it doesn't mean anything. What is this Black Friday? Canadians all know because we see Americans go crazy every year for shopping, but we…and had never had sales that were called Black Friday and Cyber Monday, and now this is the first year. Clearly, there's some kind of conspiracy – they're all getting together and doing it.

Pamela: But you bought something?

Fraser: So, I bought a new lens for my camera, thanks to the upcoming Black Friday. I bought a new 50 mm lens for my camera – a nifty fifty, so…cool! Alright, just to remind everybody that this is a…we record these episodes of Astronomy Cast as a live Google plus hang-out. We do this every Monday at noon in theory – although we're not doing it on Monday right now, but normally we do it on Monday, so if you want to watch us record live, ask questions, see what we look like, you can do that. Alright, well, let's get rolling.

[advertisement]

Fraser: Today's episode actually was a suggestion from a reader, this is a…from a listener, and I don't remember the person's name, but someone's like, "Oh, I want to hear explosions in space!" so we both thought that was a cool idea, so we both thought that was a cool idea. We've all seen the classic, science fiction space explosions full of lights and loud sounds -- beautiful on the screen but totally lacking in any kind of science. What's wrong with science fiction? What would chemical and nuclear explosions really look like? What would we hear? And what are some natural explosions that nature detonates in space? Let's just sort of dismantle a TV science fiction-trope. You've got this like you know Star Wars or Star Trek, and you've got one space ship shooting its rockets at the other space ship, and the rockets hit the hull and you get these explosions with flames coming out…

Pamela: That's only going to sort of happen if you hit the fuel tanks.

Fraser: And the sound [sound effects]…right? So what's wrong?

Pamela: Well, Yeah. "What isn't wrong?" is a more valuable question. So first of all, any time you have explosion, you need two things: you need a fuel and you need an oxidizer. This is where we mix multiple chemicals and rockets. It's where when we have solid propellant…it's a mixture of chemicals. It's why the Hindenburg exploded so beautifully is it had just a little bit too much…yeah, it just wanted to go because of that fuel oxidizer mix. Now, in space you don't have air, so you have to bring your own oxidizer with you. In space, you don't have the air pressure that comes with the air, which we don't think about as being important in explosions, but those are part of what moderate the speed at which explosions take place, so if you imagine blowing up something on a bonfire, so you take -- don't do this, I don't recommend this, but should you choose to, if you take a rocket engine from a model rocket, toss it onto a fire…

Fraser: Should a very bad person decide to throw a rocket engine into a fire…

Pamela: …it will go "kabloom!" and that's in part because you have the air pressure holding in the rapidly expanding explosion, so it slows it down to a velocity at which you can see the explosion taking place, and it also… that rocket engine does have its own fuel and oxidizers, so here all we're talking about is the "kabloo-ey!" part is moderated by having that atmosphere pressure on it. Now, if instead of looking at a rocket engine, you are a truly bad person, you decide to blow up, say, a nuclear weapon in the Earth's atmosphere…

Fraser: …or in a bonfire. Throw a nuclear weapon in a bon fire.

Pamela: Yeah, I don't think the bonfire…a nuclear weapon would happily sit on the bon fire going, "I'm a nuclear weapon."

Fraser: Yeah, but sure, you detonate a nuclear weapon…yep.

Pamela: Yeah, so should you go through all the steps necessary to purposely explode a nuclear weapon in the Earth's atmosphere, all of the energy released in that explosion is going to cause the atmosphere to fluoresce, it's going to create all these clouds that we're used to, but all of this generated because atmosphere is there. Now, you take away that atmosphere, and you go into outer space with that rocket engine, and you find some way to detonate it (because there's not going to be a bonfire in outer space), well, that rocket engine's going to poof in fractions of a second. You probably won't see…entirely combust, and it's going to give off light, it may give off shrapnel, all of it is going to expand in perfect sphere assuming it's a spherical explosion. Now usually rocket engines are cylinders, so it will probably be a cylindrical explosion, but none-the-less, it will be…an expanding explosion's over like that because there's nothing to confine the explosion -- just "pshoo" done, except you won't hear the "pshoo" noise I made with my mouth.

Fraser: Of course, of course. We'll get to that in a second, right, so I guess the point being though that if you had like a balloon filled with hydrogen, and you tried to light that on fire without any oxidizer, it wouldn't work.

Pamela: Right.

Fraser: Right? Unless you could somehow turn your balloon into the size of a star, and then you could have some fusion reactions going.

Pamela: That's slightly different.

Fraser: Yeah, but if you hit an electric spark to this balloon nothing would happen. You would pop the balloon and the hydrogen gas would escape because there's no oxidizer to make the explosion happen, but with a rocket engine, or maybe with gun powder, with dynamite. With a bullet the oxidizer is contained within the explosive itself, right?

Pamela: Yeah, so that's part of the mixture that they use for many of these different things. Now, the interesting thing when we look at spacecraft exploding is there's this always billowing flame, and you only get that while the ship's atmosphere is escaping, and that's going to be an extraordinarily rapid process. And if you've ever gone past some sort of a refinery at night, you may have seen at the top of the giant columns that they have for processing things, sometimes if they have excess gas, they'll burn it at the top. Well, what you have the potential of seeing is if you get a very, very small hole and there's too much oxygen in the air mix, and we're pretty good about not doing that, we learned that lesson during the Apollo era, but if there's too much oxygen in the mix, you can end up with a flame coming off as the oxygen burns up, but you need a fuel to be burning as well, so you've like taken and put a cylinder of fuel on, and as the…and that's not going to happen, that's not how you attack things in space, so mostly you simply get: it explodes, things fly apart, it's done in fractions of a second. Not exciting.

Fraser: No, but I mean, things like a gun for example would work in space.

Pamela: Yeah, totally, totally. Well, it depends on the mixture that you use because, I mean, not all gun powder is made the same.

Fraser: Right, but the point being that the oxidizer is inside the bullet.

Pamela: As long as…well, inside the bullet doesn't matter… I'm trying to remember how modern bullets work. I'm just going to shut up. I don't know how modern bullets work. I just know how like a Civil War era ones, where they taught us where you put the stuff in, drop the bullet in, and…yeah.

Fraser: Well, it's the same thing. It's caseless. You've got the bottom part of the bullet, and in that is the gun powder, and the gun powder contains the oxidizer, and then it shoots out the little bullet-y part from the front.

Pamela: Then you're good; then you're good -- as long as there's oxidizer.

Fraser: OK, but like a stick of dynamite would work, but if you like tried to light the fuse, that wouldn't work because…

Pamela: No, it would not work.

Fraser: So you would need some kind of electric, some kind of detonator.

Pamela: No candles.

Fraser: Right, OK. So that's sort of the first part, so whether or not the thing's even going to explode is one question. Then the question is what is going to happen from the expansion, the kind of…you know, as you mentioned, right? That let's say these missiles, these chemical missiles crash into the Battlestar Galactica, and they're going to be able to explode, and there would be atmosphere inside the spaceship, for example, but you're going to get shrapnel coming out, but you're not going to necessarily get these gouts of flames unless there's additional fuel inside the spaceship that you're lighting on fire.

Pamela: No. Right, so the giant explosion myth – just get rid of it. What you can end up with is much a peeling apart type of an event, sort of like if you imagine a torpedo hitting a ship. No one when they think of a torpedo hitting a ship is really worried about flames rushing out the side of the ship. When you hit a spacecraft, you're going to end up deforming that part of the hull if you break through. You're going to end up puncturing that part of the hull, and normally the hull evenly supports the pressure against it from the inside atmosphere. Now, if you create a weak point in the hull, the hull can end up bowing out from the pressure inside has now found the weak point, and that weak point is just going to shred open. This is like if you've ever had a bad blue jean experience -- that one small hole in the knee ends up…soon your entire knee if exposed. That same thing can happen to a ship. Now, there's probably not going to be the flame-age, there's probably not going to be the giant expanding cloud of glowing plasma material because, really, where's all that stuff coming from?

Fraser: Right I'm just trying to think what you would see.

Pamela: Shrapnel.

Fraser: Yeah exactly. You'd see this missile coming in…

Pamela: You'd see shrapnel.

Fraser: It would pierce the hull; you would see this bright flash of the explosion…

Pamela: Flash of light…

Fraser: … and then you would see whatever was left. So like one millisecond later after the flash went away, you would see the damage, and the damage would be, you know, a gaping hole on the side of the ship…

Pamela: And it might take time for the ship's deformation to continue to take place as things weaken. We've all watched something slowly fall apart, and that's possible where it takes time for the stresses on the system to shred the internal scaffolding of spacecraft, but that's what you're looking at is basically the air pressure inside and the structural integrity of the spacecraft falling apart.

Fraser: Now, let's talk about the sound. Let's talk about the sound, which is that other piece of the puzzle, which again, every now and then some movie director bravely tries to makes it soundless, right?

Pamela: And humans don't like that.

Fraser: And people don't like that. That just isn't right. They did it in the new Star Trek movie, I think, where you could see, you know, it was the outside of the ship, and it was just completely quiet.

Pamela: And Battlestar Galactica did it sometimes.

Fraser: Yeah, but even then they were just like, "OK, people hate this. We've got to put in sound." So what would really happen? I'm on my ship…whatever, I'm even like a hundred meters away from your ship. Your ship gets…

Pamela: 100 meters is a pretty good distance for a small explosion.

Fraser: Well, that's what I'm thinking, right? Yeah.

Pamela: So what ends up happening is all the energy from that explosion spreads out in a sphere. So there's what's called a "1 over r squared Law," so every time you double your distance from where the explosion took place, the amount of energy that's going to whack you goes down by a factor or 4.

Fraser: And I highly recommend people watch Mythbusters. They do some really great high-speed video of it. They slow it down, slow motion of these explosions, you can actually see that expanding, you know, the expanding shock wave as it's leaving the explosion, and that's the thing that's gonna…if you're close enough, that's going to hit you, right?

Pamela: Now, for a small explosion, that shock wave is not going to contain within itself enough energy to do very much unless you're very, very close, and if you are very, very close, then it might be just a thwack on your hull and you hear the…basically, the escaping gas whomping you, but beyond that shock wave hitting you, there's no source of noise.

Fraser: Right.

Pamela: And so any time you hear a noise in space, if you hear explosions, that's probably your own spacecraft, and the noise is transferring through the hull and through the air in your spacecraft. Other than that, you're not going to hear explosions.

Fraser: Right, but you're not going to get that explosion of, like, in the atmosphere you've got the shock wave, which sweeps by in a 1000th of a second, and then right after that you've got the air molecules bumping into each other, dispersing the energy from the explosion.

Pamela: So you have: the light goes past you first, then you have the sound wave hits you (that's the main shock wave), and after that it's just dissipating heat.

Fraser: But you're…and so really all you're going to get is that pressure wave, but the pressure wave has no medium to move through, right?

Pamela: Well, so in space, it's no longer the same sort of a pressure wave. In space, you have the material that was confined in whatever exploded moving out, and so it's not pushing with it all of the air molecules, which is where you don't get it carried as far as you do here on Earth. Instead what you get is whatever was here now is here, and it's that expanding material that's going to hit you, but it's the material that was tied up in the explosion, not the whole sphere of expanding gas that got super-heated by the explosion.

Fraser: Now, with an explosion here on Earth, you know, even if you're, you know, depending on how powerful the explosion is and if you're roughly close to the explosion, you're going to get hit by that pressure wave, that shock wave and you could very well just get killed by it. The energy isn't going to work the same way when it's out in space, right?

Pamela: No, no, and that's the thing is you really need to be an exploding star before you have enough energy to do something like that. It's…the energy very quickly dissipates; it just…there isn't the atmosphere to take in the energy and then impart the force on your body.

Fraser: Right, so we've got that example. That first example of like a chemical rocket shoots in silently, you see a bright flash, and then you see some wreckage, you see some damage on the ship, what it struck and exploded, and then…

Pamela: Well, and even in nuclear weapons…

Fraser: That's my next question. So with a nuclear weapon what would we see?

Pamela: The exact same thing, but faster. So you'd actually see less of it because your brain just can't register what's happening because there is no atmosphere to fluoresce, and so it's just this flash of energy, and the thing with a nuclear weapon -- unlike a conventional weapon, it is going to vaporize everything that made up the original weapon, and so when you detonate that nuclear weapon in space, it's a flash and you're done.

Fraser: It's gone.

Pamela: And you probably won't even see very much of the flash because the majority of the light is given off in wavelengths we don't see with our eyes.

Fraser: And it's given off at light speed, right? But the point is when you've got a nuclear explosion in the atmosphere, you're seeing not just the explosion itself…

Pamela: You're seeing the atmosphere fluoresce -- that's what you're really seeing.

Fraser: You're seeing the atmosphere fluoresce, you're seeing reflections off of things, you're seeing things heat up…and so out in space that won't happen; you'll just be suddenly blinded, or if you have sunglasses on you will have registered a really bright flash and be gone, and then whatever was hit by the explosion is also gone, and that's that. How damaging would a nuclear weapon be to a spaceship? Not as damaging?

Pamela: Well, it's all a matter of how big is the spacecraft vs. how big is the nuclear weapon, so that's always going to be true, but since you don't have the shock waves, since you don't have the fluorescing atmosphere, you're basically looking at destroying the structural integrity of the spaceship, and there's not going to be the after effects of fire and things like that, so in the grand scheme of things, might as well go with the conventional weapon, but the difference is you can pack much more energy into a smaller volume using a nuclear weapon.

Fraser: Also, some really wonderful radiation…you could really dose people.

Pamela: But in space, it really doesn't matter because your spacecraft's been destroyed. The fact that it's now nuclear and destroyed doesn't…

Fraser: Well, if you're a little further away and you want to just irradiate them, that's all.

Pamela: Yeah, but space already has that problem. We call them coronal mass ejections.

Fraser: So right, I think we've kind of put to bed, I think, here, what science fiction says about explosions, and then what reality says about explosions, and I hope…it really would make for a…I wish somebody would do it, but it also would be a fairly…

Pamela: It would make such a lame movie.

Fraser: It would be so boring! Yeah, exactly! "Flash" and then…actually it would probably be easy from an animation standpoint because all you've got to do is have a quick flash, and then you've got a torn apart piece of spacecraft, and animate everything in between.

Pamela: It would be something so…oh,what do they call that French cuisine where you whole meal is like two peas and a beautiful piece of carrot? Whatever they call that type of French cuisine -- it would be that style of movie.

Fraser: Right. It would be very quick, very small, and you wouldn't have to have any sound. This would be good. We're making science fiction…

Pamela: Silent and beautiful.

Fraser: OK, let's talk about some natural explosions in space.

Pamela: Much more interesting.

Fraser: Yeah, the kind of output I think people are really hoping for. What are some examples of some natural explosions that people can see?

Pamela: Well, I think the most interesting one we've seen within our lifetime locally is when Shoemaker-Levy 9 hit Jupiter. It caused planet-sized explosions and that was a matter of you had all of the kinetic energy of this impacting group of fragments hitting Jupiter, which the force was enough to cause chemical reactions. There's plenty of oxidizer in the atmosphere, and "whoosh!" And I don't know why I make sound effects. It's natural – we've been trained to make sound effects. Well, unless you were in the atmosphere of Jupiter because the atmosphere of Jupiter would happily have provided the sound effects. So yeah, these giant expanding balls of super-heated gas undergoing chemical reactions that led to the emission of light -- that's the fancy scientific way of saying the sucker exploded. Yeah, so there you get massive compression leads to chemical reactions leads to exothermic reactions that give off light, heat, expanding gas due to the ideal gas laws – all of these things. It's high school physics writ planet-sized, and it's just awesome.

Fraser: If you could have gotten really close -- close enough to really see what was really going on because all we saw in the pictures was these black splotches on the surface of Jupiter, but if you could have seen it, would you have seen a mushroom cloud? You know, right after the bright flash of the impactor, right?

Pamela: Well, the mushroom cloud is a manifestation of how the atmosphere shapes explosions. It's…the models that I saw, it was just like flame thrower out the side of Jupiter, so I'm good with that model because that's just your expanding gas expanding into the areas of lower density.

Fraser: OK. Well, let's go -- you actually hinted at this before – let's go to coronal mass ejections because that's kind of an explosion coming from the Sun.

Pamela: It's an energy release. Another way to say explosion is energy release, and with our Sun, it would get these magnetic loops that are filled with plasma, contain huge amounts of energy, and when the magnetic coils decide to reconnect in different places, or just plain break, all of the plasma and energy tied up in that magnetic loop gets released, and it sprays out into space and you get this shock wave of light moving through first, then behind that you get variable speed particles that come, and when a lot of these particles hit our Earth's atmosphere, this is when you see the Northern and Southern Lights, and this is -- "beautiful" is the only way to describe it. The Solar Dynamic Orbiter, Camilla the chicken's favorite spacecraft…SDO has taken spectacular videos of these things happening, and as our Sun moves to be more and more active in the next year, we'll probably get to see more examples of these, and this is going to be the first time we've had a spacecraft this capable of high-resolution imaging watching all of this energy getting released into space.

Fraser: So here's my idea for a science fiction story…you tell me how you like this: they're battling around the atmosphere of a star, and one captain tricks the other captain into parking their spaceship right along one of those magnetic field lines…

Pamela: No captain is that stupid.

Fraser: …and then predicting that's where a coronal mass ejection is going to take place, and then it will destroy their spaceship.

Pamela: The thing is we're used to looking at still images of magnetic field lines, and the reality is when you look at the movies on SDO, it's like watching a waterpark, except, like, plasma. It's what our brain interprets as flame flowing through loops, and it's moving, and it's dynamic and it's awesome, and it would be much more like trying to dodge the flames in Hell if you tried to fly your spacecraft through it.

Fraser: But if you could see some big magnetic field line, and predict that a coronal mass ejection was about to happen, you could trick the person into going out in front of it.

Pamela: Well, if you were that good, I wouldn't say any parking should be involved; I would say take the barnstormers' approach of: you fly your spacecraft through the loop. And these things are planet-scaled, so like some…yeah, we don't have the sense of scale; we imagine them being Enterprise starship-sized, and they're not. This is more like fly the Death Star through it with room to spare.

Fraser: Yeah. OK, so now, the classic example of an explosion is, of course, the supernova.

Pamela: Of course, of course, and this is just a matter of a giant nuclear bomb in a lot of ways. It's take a star -- it could be a white dwarf that has been accreting matter, it could be a neutron star that's been accreting matter (although a neutron star would be a recycled supernova), take just a regular everyday overly-large star that has all of its own mass, and if the center of the star is not pushing out with sufficient light pressure to support the outer atmosphere, then that outer atmosphere can come crashing in, and as it crashes in, as that material compresses…this is the same idea that's behind a nuclear weapon. With a nuclear weapon, they use shaped explosives to "smush" (for lack of a better term) all of the isotopes inside the nuclear weapon together, and that causes fusion reactions, which release huge amounts of energy. Now, with a collapsing star you end up with the exact same situation. With your classic giant star explodes, you go through millions of years of hydrogen, helium, carbon, nitrogen, oxygen, silicon…all the way up through ending up with an iron core. Once you have that iron core, you can no longer fuse two atoms together, and through the fusing process produce energy that then holds out the outer part of the star. When you get to that point, no more light getting produced to support the star, star collapses, you then end up with the atoms getting compressed to the point that they break apart, energy is given off in the breaking apart stage, and it's kind of violent.

Fraser: It blows my daughter's mind that, you know, that all of the gold in our house was formed in that moment that a supernova went off.

Pamela: Well, and it's one of these things where the universe prior to having enough supernovae going off wasn't actually capable of supporting the creation of planets like Earth. We could not have formed much, much earlier in the universe unless we were in just the right location where a supernova had gone off. It's taken billions of years for all of the content form so many generations of supernovae to sufficiently mix to create galaxies like our own that are just filled with planets.

Fraser: Now hypernova, that's just a flavor of supernova, right?

Pamela: It's just a giant one that has magnetic fields that trigger gamma ray bursts.

Fraser: Yeah, and a gamma ray burst's the biggest.

Pamela: A hypernova.

Fraser: Hypernova, yeah.

Pamela: It's what you see when you're pointing along the beamed energy.

Fraser: Again, some clever captain, after ruining one spaceship from a coronal mass ejection, then flies the spaceship through the potential beam of a gamma ray burst, and then "zot!"

Pamela: We can't predict those well enough, and really, anywhere within a few thousands light years and you're crispy.

Fraser: I know! Exactly! So, you know, leads them on a merry chase into the left half of the galaxy at which point a gamma burst destroys an entire half of a galaxy, so yeah.

Pamela: That doesn't actually happen. I love the fervor with which you describe this. It's really quite awesome.

Fraser: If you are half a galaxy away, and you are in the beam, then "zap." That's all I'm saying…that's all I'm saying.

Pamela: It doesn't destroy planets; it doesn't destroy half the galaxy. It might destroy your atmosphere.

Fraser: It wipes out your ozone layer.

Pamela: And it's…7000 light years is the danger zone, and galaxies are like 180,000 light years, so it's a much smaller fraction.

Fraser: Right, but If you get hit by the beam directly…you know what's a good book for this is Death from the Skies by Phil Plate.

Pamela: Phil Plate's...

Fraser: Highly recommend…he will show you all the ways the universe is trying to kill you.

Pamela: And we have a poster. You can buy our poster for Christmas. It's an awesome poster.

Fraser: I'm actually wearing the shirt right now.

Pamela: We might be out of stock on the shirts. I think we did a limited edition run.

Fraser: We should make a color version of this shirt…alright well, you know what, I think we've clearly reached the natural ending, but I would love to see people email us suggestions of maybe the best possible explosion they've ever seen. So what is the best space science fiction explosion…?

Pamela: OK, so not real explosions.

Fraser: Not real, although real ones are great too, but the best science fiction explosion you've ever seen. Who has handled it the best? Is it a YouTube clip? Just drop us an email: info@astronomycast.com. We'd love to see them and see if we can find the one that we like best, and I'll post it on Google plus, or mention it in a future episode. That would be really cool. OK, well, thank you very much, Pamela, and have a good Thanksgiving.

Pamela: My husband's Canadian -- we're ignoring it the way you are.

Fraser: Oh, perfect! That would be best. Alright, we'll see you later.

Pamela: Bye.