AstronomyCast Episode 240 for Monday, November 21, 2011
Astrophotography, Part 2: Techniques

Fraser: Welcome to AstronomyCast, 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 at Edwardsville. Hi, Pamela. How are you doing?

Pamela: I'm doing well. How are you doing, Fraser?

Fraser: Doing really well, too. So you wanted to plug something…

Pamela: I did. It's the Holiday season. We are recording on Thanksgiving Eve, and I know many of you are gearing up to give gifts, and if you have a kid, a comic book lover, or actually just about anyone in your life, we have roughly 1000 Hanny and the Mystery of the Voorwerp comic books, and we'd love it if you purchased 1 to 200, so go to Astrogear.com, and we're also going to be posting up new t-shirts and all sorts of stuff up there, so consider AstronomyCast as you're doing your Holiday shopping.

Fraser: And the second thing is we are once again recording this episode of AstronomyCast as a Google plus hang-out, so once again, we have eight of our closest friends listening in to the episode, and correcting us as we make mistakes, and suggesting ideas that we hadn't…hadn't even occurred to us as we are doing the recording, so thank you to everyone who is with us today, and you get to see the way the show really gets done. But if you want to do…participate in joining us in the future, all you have to do is circle either me or Pamela in Google plus. Google plus is free to join, you don't need an invitation, and then you can circle us, and then you'll see the announcements when we're about to do the episodes, and then you can join our hang-out and watch the show, and then hang out for, you know, usually half an hour afterward and we answer questions and talk about Space, or Thanksgiving, or whatever, so alright…Cool! Alright, well let's get on with it then. So in the first episode, we talked about the gear you'll need for your expensive astrophotography hobby. This week we continue our discussion and talk about the techniques you'll use to get those amazing photographs. Bring a hot drink and get ready for some cold nights, but trust us, it will all be worth it. So Pamela, before we get into this, do you have an anecdote of, like, just some brutal astrophotography observing work that you've done?

Pamela: Well, so I study variable stars, and I got to use the 30-inch at McDonald Observatory when I was a graduate student and it has a 1-degree field, which meant that not only did I get the variable stars I was looking at, but I got everything in the field around it. And the awesome thing about doing variable stars is you take image after image after image after image, which is exactly what you do when you want to get high-quality astrophotography images, so I spent lots of nights out there, and was able to build some pretty awesome images, but one of the things was is you get into a rut occasionally, you're sitting there, you're at your computer, you're taking image after image after image, and I was doing 600-second exposures and there was one point, I'm sitting there and the old man on the mountain, the engineer who babysat us made sure we didn't destroy the telescopes or anything, came into the observing room I was sitting in, and he was just like, "What are you doing?" in the standard, you-stupid-graduate-student tone of voice. I'm like, "I'm taking images." And just as he says that, an image comes onto my screen that's completely starless. I am looking at absolutely nothing, and I look at him and he looks at me, and he just uses his hand to beckon me outside and I get outside and the entire dome is just like underneath this thick wall of clouds that came out of nowhere as near as I'm concerned, so it's amazing how the sky can change in 600 seconds, and I felt rather foolish at that moment in time.

Fraser: So, right. So if you'd practiced some better technique, perhaps you would have noticed the fact that you were getting clouded out. And so last week, we talked about sort of the three main ways that you can do astrophotography. One is you take a really nice, you know, digital SLR camera, connect it onto a tripod and just do some really nice long exposure images. Ideally, track with the motion of the sky, and, you know, get those beautiful Milky Way images and star fields and things like that. The second way is you take your webcam, hook it up to the eyepiece of your sort of medium-level grade telescope, and get those amazing images of the planets and the Moon and things like that. And the third way is the, you know, the price of an SUV, where you hook up the CCD camera to your $20,000 Ritchey–Chrétien telescope and, you know, take some amazing Hubble-style deep sky photography. So then let's go back and run through those different methods and talk about what are the kinds of techniques that astrophotographers use to get those kinds of images. And I guess, you know, we should probably start with the images, you know, the sort of long-field stuff or the long-duration, long with the DSLR camera. What's your method to get the raw images?

Pamela: Well, the first thing you need is some sort of a camera that allows you to output in raw format, so that sounds kind of like, "Oh, of course it'll happen!" but when you're purchasing your DSLR camera, take that into consideration, and then remember to switch the setting.

Fraser: So, hold on a second here. You talk about raw format, and like I know that my Canon T3 will…I can take jpegs and I can take this raw format, and so I want to shoot with that raw format and that creates these monster digital files, right?

Pamela: Right, so what's happening is when you use jpeg images, it does some sort of a compression. And basically what it's doing is it's saying, "OK, this set of pixels over here – they're all the same color, so I'm going to store them together. This set of pixels over here – they're all the same color; I'm going to store them together," but when you store in raw format it actually stores the data for every single pixel separately, so it takes up a lot more space. It's the difference between saying, "pixels 1, 10 – 20, 100 are all black, and saying 1, 1 black, 1, 2 black, 1, 3 black."

Fraser: Right, so there's a like a compression and loss of data.

Pamela: Right, so with raw you have none of that loss of data, and it allows you to keep all the information for every pixel -- and you really need that for astrophotography.

Fraser: OK, but those files are BIG.

Pamela: They're HUGE, but it's worth it in the end. If you're trying to get the best image you can, why start out by throwing away data as you're taking your image?

Fraser: OK, so you've set these big, long exposure times, and how do you go through that process? How do you gather that much light?

Pamela: So there's two different things that you need to consider: one is how long are you going to keep your shutter open, and the other one is how open are you going to make your aperture. Now, the two of them actually go together. If you're going to try to take a short exposure of the night sky, open that aperture all the way out. If, on the other hand, you're looking to take a five-minute or ten-minute exposure, you might want to close your aperture down just a little bit as you're taking that full-sky image, so that light pollution, moonlight, um, all of these different factors don't cause the sky brightness to look so bright that it suddenly appears like you're taking a twilight image. As you take these long exposures, it's amazing how much sky brightness you pick up. So one thing that you actually want to do is you want to play, to experiment. You want to try that 300-second exposure with the aperture one click closed, that 300-second exposure with it two clicks closed, and you really don't want to go longer than 300 seconds, and you probably don't want to go longer than 30 seconds unless it's an ice-cold night and you're far away from granite and no supernova has gone off recently. And the reason I say that is if it's a warm night, then you're going to run into problems with the heat of your electronics bringing up the background noise in your images as you take longer and longer exposures, and if you're either in a very granite-rich area or there's some other reason – a solar storm or something else that's causing a lot of cosmic rays, those will cause all of these little, bright pixels in the background that are a pain to correct for, so by having reasonably short exposures, you don't get as many cosmic rays per image, and you don't…

Fraser: Are you kidding me? Is this like a joke?

Pamela: No, I'm not! This is a real concern.

Fraser: You're actually telling me that I have to be concerned that cosmic rays and radiation from granite is going to put noise into my beautiful astrophoto?

Pamela: This is an honest-to-God problem.

Fraser: Really?!

Pamela: This is one of those things that drove me crazy as a graduate student because a single cosmic ray hitting a star blasts that star out of usability, so you've only wrecked one pixel, but that one pixel exploded that star's values. Now, you can also get these glancing blow cosmic rays that cause stripes of bad pixels, and all these other annoying things, so yeah, you have to actually start worrying about cosmic rays, and the longer your exposure is, the more cosmic rays your exposure is going to have.

Fraser: If you say so…well, that sounds pretty weird to me. But, right, but what you're saying then is it's this balance between aperture and exposure, that you open up the aperture to pull in more light, and you don't have to necessarily do as long of an exposure, or you can shut down the aperture and do a longer exposure, and there's not going to be any one way that's going to make the best picture. As you say, it's about playing. It's about trying one idea, trying a different idea, and see what works best for your sky, your technique. You know, if you set the exposure too long, it might blow out the Moon. If you don't do it long enough, the stars are going to be too dim, so it's just a matter of finding that happy medium.

Pamela: And there's no one right answer because the Moon keeps changing in phase, everyone has a different characteristic to the light pollution -- one night your neighbor has the light on, the next night they don't – all of these things add up to chaos, but as you get practiced, you can look at the sky and say, "Ah, tonight I need to…" and you can do what you need to do. It's like learning to play violin. You instinctually learn where your fingers go every time, and you can make adjustments for temperature and other things through tuning that you know how to do instinctually.

Fraser: Right, right…OK, cool. And so, you know, we talked about the gear, but essentially you will be messing with your aperture and your exposure length, which, you know, every camera is different where the setting is on that, and you will be recording your photographs as raw images and then attempting to dump these into your, you know, some way of…your repository, and you're going to be processing it -- and that's a future show, that's episode 3 if we're going to talk about the processing methodology, but really it's just about… I mean is there anything else sort of technique-wise except you go out, you set up your camera, figure out your happy place with your exposure and your aperture, and record those raw images?

Pamela: Well, I think the one thing you have to remember to take into consideration is it's not one perfect picture you're trying to take digitally because you can add things together. What you're trying to do is get a series of images that aren't overexposed, a series of images that have that black sky and are still showing the stars, and then you stack those images together, and by adding them up, well, you don't have that many cosmic rays to worry about, comparatively, because you can take…one nice thing is you add them up and say, "Ah, there's a cosmic ray in only one of these ten images," and you can correct for it. If you only have one really long image, you can't correct for it. So you're going to add these images together, and it's as you add them together later in that next show we're going to have that you end up finding all of the nebula, you end up finding all of the faint galaxies. So your goal taking your picture is to keep your black sky and get as much light as you can while still having your black sky.

Fraser: And so even with those wide-field, you know, those beautiful images you see of the Milky Way rising up over some desert sky, you know, those are done with a series of shorter exposures that are then stacked?

Pamela: Yes.

Fraser: Or are they done with one big long exposure? So you wouldn't do a big, long like minutes-long, hour-long exposure. You would take a series of shorter exposures in a raw format and then stack them on computer.

Pamela: Exactly. And the other thing about images like that is you're worried about, well, the sky is rotating, and you can have your telescope set up perfectly, but no matter how perfectly it is, something is going to cause the tracking to not be absolutely perfect. Every telescope in the world there's something that is correcting that tracking, and unless you have some sort of an auto-guide system, you're going to slowly, over time have your stars drift, and by keeping your exposure shorter, you don't end up picking up that drift.

Fraser: But even if you have some kind of tracking, like, if you've got your, you know, you've got it connected on an equatorial mount, your connecting with the sky, that's still not the way to do it. The way to do it is to…

Pamela: It's still not good enough.

Fraser: It's not good enough.

Pamela: Over the course of minutes – and you're going to be taking exposure after exposure adding up to minutes – it's going to move one or two pixels, and that one or two pixels blurs your image.

Fraser: Makes it all blurry…yeah, OK, so we're taking…so we're going to capture, you know, even if we're tracking, we're going to capture a little piece of sky, and then we're going save that file, and then…and our camera might be tracking the whole time, where we take a little picture, take another little picture, and just build up that, OK that's perfect. OK, let's talk about that second method then. We talked about the…where you're taking the planetary astrophotography, where you've got your mid-range telescope, and you've connected your eyepiece, you've connected a cheapo webcam up to your eyepiece, and you're then capturing image after image after image. So what's the process there?

Pamela: So here it's often a matter of getting rid of as much light as possible. This sounds really strange, but when you're looking at Jupiter, when you're looking at Saturn, you're looking at something that's going to saturate your detector, and so sometimes you end up having to do crazy things like putting a cardboard cut-out on the front of your telescope. So, what you want is to have in every single frame a not-fully-saturated Jupiter. Ideally, you want to know at what point does your detector stop catching light. So there's usually numerical values associated with every pixel. The CCDs I've used have usually gone from zero, which is absolutely nothing, to around 5,000 counts, they really stopped functioning, and so you need to figure out what's that count at which it stops functioning and come about a third below that is where you want your maximum pixels to go. That way you can get a full dynamic range, you don't have to worry about blowing out your detector, and there's other things like where is your detector linear? Now, for pretty pictures you don't have to worry about that as much, but the idea is…ideally, you double the number of photons that hits a pixel and you double the brightness. Well, at a certain point, that pixel starts to fill up and you just can't add enough more photons to it to double how much it's detecting, and it loses sensitivity that… there's a whole bunch of other stuff, and I'd start to have getting into quantum efficiencies and that's beyond us right now.

Fraser: No, I'd like to go into that…but no, no, but I guess the part that I don't really follow then is, I mean, you're taking your webcam, and you're putting it onto your eyepiece and then you're just letting it run, right? You're just recording like the highest quality video that you can get, and then you're putting stuff in front of your screen, you know, some kind of cardboard cut-out in front of your screen, you're turning up and down the color balance, the "gain" of the camera itself to get that perfect happy medium, but then how long are you just letting it collect for?

Pamela: As long as you can.

Fraser: Like, hours?

Pamela: Sometimes, it depends on what you're trying to do. So, I've seen amazing videos that are taken where…so with Jupiter, the planet's kind of rotating, and if you go for hours, you can build up movies of the rotation of Jupiter, but if you just want a stunningly beautiful picture of Jupiter, there you just want to go a couple of minutes, and if you're taking several frames a second, a couple of minutes is going to give you more images than you know what to do with because the catch for using a webcam is after you're done capturing this video, you're going to go through it frame by frame by frame looking for the sharpest images, and you're going to throw out the ones that aren't sharp.

Fraser: Right. And that's again talking about technique, but yeah.

Pamela: So, here as you take your images, pick a nice beautiful night, get everything so that you're not saturating your images, and take a few minutes of frames on Jupiter, if you want to do that entire movie of its rotation, take a couple of hours, but if you just want a pretty picture, you're just looking at a couple of minutes of video.

Fraser: Right, so you're going to take a couple of minutes, you're then going to, yeah, you're then going to go through them frame by frame, so a couple of minutes is probably enough time because if you go longer than that in the case of, say, Jupiter, the object is going to have rotated and then that's going to introduce blur and more problems into it as well. So it's more about getting a whole pile of good frames you can then stack later. OK. Awesome.

Pamela: And this works for Mars, less blocking of the front of your telescope required, and Mars is particularly tricky because it's very tiny, so you want to push what your telescope's capable of doing. So this is where you want to get as much magnification as your telescope can support and as short an exposure as you can possibly get on your video camera. So wait until Mars is at its closest point to the Earth; wait until it's at opposition, and give it a try and you'd be surprised what you can get. Looking at it with your eye, your eye doesn't have the time resolution your video camera has, so you can get a sharper image with your video camera and then add all of those frames together and you can actually make out the icecaps, you can actually make out the volcanoes and the valleys. It's really quite amazing what you can do.

Fraser: Now, are you recording it in any special way, or are you just recording it straight in whatever color sensitivity your webcam wants to do? Like, do you need do it in black and white, or…?

Pamela: So, what I'd recommend is actually getting a black and white, low-light security camera or getting one of the two-cans, two-cams rather. The two-cams are the ones that are preferred by most astrophotographers, and I believe that those come in both black and white and color, and just follow the user's manual for your particular camera. One of the things that we run into as a problem with this show is technology is constantly changing, so I'm trying to talk generically, but where the technology's constantly changing, do what's recommended for your particular camera. Avoid compression as much as possible, and try and save things in as raw a format as you can.

Fraser: Right, so you're going to get…whenever you're listening to the episode of this show, go and lurk around the astrophotography forums and find out what webcam people are currently recommending.

Pamela: Cloudy Nights is an awesome place to go talk to people.

Fraser: Yeah, and/or IceHunters, which is Mike Salway's forum. Yeah, so that's to get that latest gear. We try to be timeless with this episode. Now, what about filters? We didn't talk about filters with the taking night sky, wide-angle stuff because you're just going to be using your camera with its different lenses, but are you going to want to use any kind of filter when you're doing the planetary stuff?

Pamela: When you start getting into been-there-done-that-let's-see-what-I-can-do-that's-the-next-step-up, that next step up in webcam work is where you start buying the filters. You can get filters that can accentuate the icecaps on Mars, that can accentuate the banding on Jupiter, but the place that filters really start to change your perspective on the sky is when you go that next level, to the "SUV's worth" of equipment, when you have that full CCD detector and when you have that either Schmidt Cass or Magneto Cass or Ritchey–Chrétien telescope.

Fraser: I know the filters are really important for the deep sky stuff with the CCD, but do the filters come into play with any of the planetary stuff?

Pamela: They can if you're trying to accentuate filter, when you're trying to accentuate features, but they aren't going to help you get that true color image. Now, what you can do is if you're in a very light-polluted area, there are some filters out there that specifically try to filter out the light produced by sodium lights, that specifically try to filter out some of the other compression lights. As we use more and more fluorescents, it makes it easier in some ways to filter out the light using narrow-band filters, but in general, if you're trying to get a pretty true-color image, you're not going to get it with filters. If you're trying to look at specific features, if you're trying to pull out the icecaps, pull out the valleys, that's when using the filters can help.

Fraser: And I know that some people use this technique for observing the Sun, and so obviously then you definitely want to get some solar filters.

Pamela: Yeah, you don't want to look at the Sun at all without a filter, and so there you're looking at one of basically two different things. You can get what's called a neutral density filter, which blocks all colors of light equally, and so you can get a neutral density filter that blocks 90% of the light in all wavelengths. You probably want to go even more than that when you're looking at the Sun. Now, the other direction you can go is you can get something called an H-Alpha filter, and that's a filter that only lets through the specific transition called H-Alpha in the hydrogen atom. This is one of the bomber lines; it's the one that allows you to see all of the neat corona, loops, and storms, and it accentuates sunspots, and if you have enough magnification it actually allows you to start seeing the convective cells on the surface of the Sun. Now, if you just go with a neutral density filter, all you're going to see is the sunspots and the bright stripes, the faculae that are caused by coronal loops, but with the H-Alpha you can start to see details in everything.

Fraser: OK, so I think we've kind of wrapped up the techniques for that second method. And the third method, and I think this is the one you know the most about, is the deep field, you know, big telescope, CCD camera connected to it…how on Earth do people get these amazing photographs?

Pamela: Lots and lots of patience and tracking, and the really, really best ones – what you're actually doing is you're sitting there, and you either have a second CCD chip that's auto-guiding your telescope, or you're sitting there with a hand paddle guiding your telescope as you watch a video screen output. It's like playing a video game of keeping the star on the target. Nowadays, a lot of times the software will do it for you, but when I was a graduate student, there was hour after hour of moving the telescope… Literally, you're pressing buttons, and it's just like the slowest-paced video game EVER. So you're making sure you're staying precisely on the star, or on a bright object in the field that you can put crosshairs on to make sure that you're staying focused, or staying pointed. You perfect focus, you very slowly step through and make sure you can't move a hair in either direction without making your stars become bigger blobs, so once you get your focus just right…and you can't…you actually have to be careful that you don't end up with square stars. This is going to sound really strange, but if you're on a telescope with a really large field of view and the atmosphere is perfect, when you get the telescope completely in focus as perfectly as it can be focused, sometimes the stars are one pixel in size, and that is unappealing and you can't do anything with it scientifically, so there are actually rare cases where you have to un-focus your stars slightly to make sure that they spread out across enough pixels. So it's this black art of if the stars are big enough, focus the telescope so they can get no smaller. If you do that and you have square stars, un-focus. So you play with focus, get it perfect; once it's perfect, you then start taking exposures. You want to have your exposures long enough that the sky stays black, but you're starting to get whatever faintness that you're looking for, whatever nebulosity, whatever arms on a galaxy, and you're not getting too many cosmic rays, so usually the longest you want to try and push is about 900 seconds for a perfect system. After 900 seconds, the number of cosmic rays just becomes annoying. Most systems you actually want to stay down around 300 seconds, so you get those 300-second exposures, and you do it one filter at a time. With these high-grade CCDs, the way you get extremely good resolution is all of the pixels are simply sensitive to light/no light, and so everything you do is black and white images. If you were getting color images, there'd actually be triplets of pixels that are sensitive to the red/green/blue of a color CCD. You get more resolution by doing black and white, so then to get color, this is where the filters come, so you actually put the red filter, the R filter, the whatever filters that you're using filter on, take the exposure. You then put the next filter on, and here's where it becomes a black art because your CCD is differently sensitive to light in different colors, so you might find, "Oh! Everything is starting to saturate! I'm starting to get to the point where I'm blowing out my CCD at 200 seconds in red. Now, I put the green filter on and -- oh, crud! At 250 seconds I'm starting to saturate!" So you have to figure out how do you play with the exposures, and that's also going to vary with, well, what are you looking at? Is it a blue galaxy? Is it an oxygen-rich nebula? Is it a red reflection nebula? All of these different (or a red transmission nebula, rather)…all of these different things you have to adjust your filters, you have to adjust your exposure times for.

Fraser: Wow! That's like way more complicated than the other methods. It's funny how it all scales up. The gear's more expensive and the method is a lot more complicated, but at the same time, you know -- greater risk, greater reward. I mean, you see some of those pictures, again, some of the best…guys John Chumack, there's a lot of them, Tom Davis… they produce these photographs that look like they came from the Hubble space telescope. Their ability, their technique is so good that it's just astonishing. So they are targeting that sweet spot, that you have the CCD hooked up, you get your filter on, you capture for 300-ish seconds and then store that image, that long-exposure image, but it's going to be like take one image, and then take another one, and then take another one, and then take another one, and then we'll talk about technique next week, or I'm sorry, about post-processing, but essentially you're stacking all those images together try and just keep…you're taking long-exposure after long-exposure and then creating a super long-exposure with all of those together, and if you've done your job right, you're going to get those beautiful faint, the nebulosity, the galaxy, the dust in the galaxies and all the beautiful pictures that come with astrophotography.

Pamela: And if you're just after pretty pictures, one of the really awesome tricks I learned from an amateur astronomer (because you can't use this data for science) is one of the tricks for bringing out all the details is remove the filters -- all of the filters -- from your camera, and create what's called an illuminance image. This is where you just capture as much light as you can to get the details, and then you use that as a mask in your final image, and if you're struggling to get enough light of a really faint object, when you then put your filters on, you can do what's called binning the CCD. This is where you combine the light that's hitting every four pixels into one, so that's a two by two bin, or you bin all the light that's hitting every 16 pixels into one – that's a 4 by 4 bin, and this allows you to get deeper images faster, and that's particularly useful if you're just not that sensitive a set of equipment. So you then put your red filter on, bin your CCD get all of your red light, put your green filter on, bin your CCD get all of your green light, and when you stack it together later, you're able to resurrect all of that detail using that illuminance frame. Now, if sensitivity isn't an issue, then you go the other direction, and you just do everything through filters, and you start playing with what are called narrow-band filters. There's two types of filters: there's broad-band filters and there's narrow-band filters. Broad-band filters are like, "I want all the shades of red. I want all the shades of green." Narrow-band are, "I want the light produced by the H-Alpha transition. I want the light produced by the specific oxygen lines produced in planetary nebula that are green." And here you're looking to bring out specific scientific neatness, awesomeness details by which filters that you're using.

Fraser: Yeah, and the terrible truth of astrophotography with a lot of the scientific stuff, the stuff from Hubble, is the pictures are completely fake. They've, you know, they've used one very narrow-band filter for one color, they've used another very narrow-band filter for a completely different color, and then a third one, and then they go that one is red, that one is blue, and this one is green, and then they merge them together and you get a…what looks like a beautiful colorful photograph, but actually has nothing to do with what the object really looks, and again, I think, this comes down to your experience. Are you trying to create a realistic view of what the object really looks like, or are you trying to create a very beautiful picture? And if you're trying to create a very beautiful picture, you'll want to learn which of those narrow-bands are going to give you the right combination of colors to make your image look beautiful -- and you will be part of the lie.

Pamela: [laughing] Well, it's not always a lie, sometimes it's…

Fraser: No, it's not always, but I know with a lot of the stuff with the Hubble and stuff that they aren't going for true color.

Pamela: Right. Right. What I love though is sometimes the universe just works and a lot of these nebula where you're looking at specific emission lines of gases, you get your oxygen narrow-band filter and that's green, and really that's all the green the nebula's producing. You get your hydrogen filter, and that gets you the red, and really that's all the red that's being produced, and by using these narrow-band filters, you're able to basically get rid of a lot of the background goop, and strictly see the light of the nebula.

Fraser: Very cool. Well, I think next week we'll go into the whole other half of this project, where you sit with a computer and process, process, process to get those final products that people see, so that'll be great. Alright well, thanks a lot, Pamela.

Pamela: That sounds great. I'll talk to you later, Fraser.