Astronomy Cast Episode 70:
How To Win A Nobel Prize

Fraser Cain: Just a couple of shows ago we showed you how to get a career in Astronomy. Now you have your career as a research astronomer. Obviously, the next goal is win a Nobel Prize. We're here at the American Astronomical Society Meeting in Austin, which is just one tiny step a person has to take to win that Nobel Prize.

Dr. Pamela Gay: And there are a few Nobel Prize winners floating around this meeting.

Fraser: So it's not impossible.

Before you get that phone call in the middle of the night from Sweden you will need to come up with an idea, do some experiments, write a paper, get published, and a bunch of other stuff. I'm probably over-simplifying it Pamela.

Pamela: Oh, way over-simplifying it.

Fraser: Obviously not everyone is going to win a Nobel Prize, but why don't we start somewhere and talk about how people can go from zero to getting their research done.

Pamela: Well, in general you have to start with an idea. You have to start with a question, a "what if" and work on trying to solve that "what if." Nobel Prizes have gone to people who said, "what if you look at the Universe in the radio; what if you explore what is coming through galaxies by simply tuning your telescope to look at radio light instead of looking at optical light?"

There are all sorts of different people who have simply said "well what if" and then there's the hard part; it's easy to come up with the "what if".

You then spend years following that "what if" with careful theoretical work with careful building of instrumentation, with carefully looking at your noise to see what is it in the noise that no one else has ever discovered.

The cosmic microwave background came from a group of scientists working to study the microwave emission of our galaxy and instead coming up with the microwave emission of the universe.

Fraser: I read that one of the ways that some of the greatest research happens is that it starts out with someone looking and going, "huh, that's funny."

Pamela: And most of us go huh that's funny and we blame our instruments and move on. The truly great people won't let things go. They just keep delving in and exploring deeper until they're able to say, "well I've ruled out everything. This is something new. This is something exciting." Then they followed up with figuring out what it is, and it's a collaborative process with different people shaking ideas out on other people who can then go, "no that's crazy but what if"…and you follow all the "what ifs" until you find the truth.

Fraser: Okay. Let's start at the beginning then. Let's say you have an idea or you look at your data and think, "huh, that's funny." What's the next step?

Pamela: Math.

Fraser: Okay.

Pamela: The first step is you go through and do a statistical analysis. You see if you can repeat it. You have to be able to repeat something. If it happened only once never to be repeated again, it probably wasn't real.

Fraser: Right, I guess what I'm saying is how will you get access to telescopes? How will you get access to the equipment you need to even follow your crazy ideas?

Pamela: Let's say you're not trying to figure out what the noise in your data is but rather you come up with this idea of "I think foo is true about galaxies" and you want to figure out how to prove to the rest of the entire scientific community that is true. Well the first step is you do a literature search and make sure no one else has ever studied foo.

Fraser: So where would you do a literature search?

Pamela: There are two places to go. There is the NASA ADS website which is pretty much a collection of all the published journals. Some of them unfortunately, you have to pay huge subscription fees to get access to the most recent articles. But there is hope.

There is another site XXX.lanl.gov It's ArchiveX, it sounds like a porn site but it's run out of Lawrence Livermore National Labs and it's where pretty much everyone goes to dump a copy of their latest research. Often people dump a copy before it has even gone through peer review to get feedback from the community - what questions do people have and what ways can you make your paper better before you take it to publication?

Fraser: Right. These all have search engines you can put in key words, you can put in search of the text. It's all available, you can read their research and make sure that whatever your idea is, nobody else has, or you find what everyone else thinks on the subject and you can decide whether your thinking is absolutely brand new or just a variation of what somebody else thought about.

I guess when you see what other people thought about it helps you search and refine your thinking and you come up with new ideas.

Pamela: Then you need some sort of an infrastructure to put your idea in. "I think Galaxies might have foo because"... And then you go through and demonstrate what is the evidence that this could be out there waiting to be found. What are the breadcrumbs that are leading you to discover this new foo about galaxies?

Once you've put these breadcrumbs together and found the path through the woods, then you write telescope proposals. You write grant proposals. You try to get the time and the money that will allow you to study this effect. This is it's own peer-review process.

You send out a proposal for telescope time and you'll either get telescope time or you'll get feedback that says, "well we didn't give you time because we are concerned about the following things. Follow up on this. Tell us more; convince us better".

Fraser: You have to sell to the telescope managers that your idea is worth exploring.

Pamela: It's actually a committee of hopefully your peers or the people you hope to be peers with in the future. It's a select group of scientists who sit down and it's not always the same group of people every time. They go through all the proposals and sometimes hundreds of proposals looking for forest nights of telescope time to be available to them.

These people go through and use their wisdom and ability to use the scientific method to examine your argument. Think of them as the jury in a court case and you are the lawyer making your opening statement. You have to sell your idea and only once you've convinced them that your idea is worth pursuing do you get the ability to pursue it.

Fraser: But as you've said, there are other avenues you can go to. There are networks of amateurs and there are other ways. You make the same pitch to multiple missions to multiple telescopes.

Pamela: One of the best ways to do it is first you go to some easily accessed ground-based telescope and get some preliminary observations. With the preliminary observations you say either we have a hint of this being possible or we can't eliminate this as being possible because the observations aren't good enough using this telescope so clearly we need a bigger and better telescope.

They want you to first use the cheap, easily available resources before you can get the Hubble Space Telescope time – the very large telescope time. It's a matter of did you do your homework or not. It's big resources and there are not a lot of resources out there to share.

Fraser: So you have written your proposal, your peers have come back and said this sounds like it's worth pursuing so they'll schedule you time on the equipment?

Pamela: You get time on the equipment; they then often just ship the data to you. A lot of the telescopes now are what they call Q-based. You say, "these are the conditions that need to be met for my observations to be taken," and a night assistant automatically gets your data and ships it to you either over the internet or perhaps on a DVD.

Fraser: So you don't have to go to the telescope?

Pamela: No, not at all.

Fraser: You don't have to head out to space to look through the Hubble?

Pamela: No, definitely not that one.

Fraser: But in many cases, the proposal is approved and you're in. At the time that they promised your data will come to you and you can start crunching it.

Pamela: It's all beautiful magic. Once you get your telescope data that is just the start. It can take months to get your data reduced to a point where you have numbers you believe are actually true.

You get your data, you reduce it, you play with it, try this, try that and a couple of months down the line you have something where you can make graphs and plots.

From your graphs and plots you have to try to figure out what does my graph and my plot mean? In some cases you can get completely new science just by graphing two variables no one every thought to graph before.

Fraser: But in many cases you have an idea of what you should be expecting with your galaxy theory and you are now looking through the data and checking to see if your theory matches reality.

Pamela: Yes.

Fraser: And as you are saying, there could very well be any number of interesting things that poke up in the data that are completely separate from what you're working on and that probably must just work into brand new proposals to look for more information.

Pamela: Every new question you answer ends up creating ten, fifteen, twenty, a thousand more questions, more ideas, more things you just need another ten nights of telescope time to explore.

Fraser: But even if you get a no result, that's still useful because that just means that your theory is wrong and that's okay.

Pamela: Or sometimes you just simply haven't come up with a better way to do something.

One of the more frustrating aspects of my doctoral dissertation is that I successfully proved that that if you look at one radio source you have roughly 23% probability of finding a cluster of galaxies around that. We already knew that. But if you look at a grouping of six radio sources, you have a 27% a whole 4% better chance of finding a galaxy cluster. It wasn't really easy.

Fraser: Intriguing.

Pamela: It wasn't really useful though because it takes a lot of time to find the clustering and prove that it is real. It was a very sad result, but is was a true result and it was worth sharing to prevent anyone else from following this bad avenue of exploration.

Fraser: All right, so let's say that you got your data, you've crunched your numbers and you believe you now have a result.

Pamela: Then you publish. Often the first step is coming to a meeting like this one, the American Astronomical Society meeting and putting a poster presentation together.

This is where you have a 48-inch x 48-inch sheet of paper to convince everyone of the vague outline of your idea. Show your graphs. Give captions. Give a few hundred, maybe a thousand words of text in big enough letters that someone slinking past with their coffee trying not to attract any attention will be able to read as they slink past.

Fraser: I can't overstate that it really looks like a kid's science fair with posters around. It really seems like you would expect it was a lot fancier but it is like a big piece of paper with a bunch of pretty pictures on it and some graphs and a person standing beside it trying to get people to come take a look at it.

Pamela: It's just amazing the diversity of people. My very first time I presented was at AAS in San Antonio, TX and the person hanging the poster next to me was Erica Bonvetnse (?) who had written the textbook I was using that semester and was another variable star astronomer and many, many other things. She's just awesome.

I totally fan-girled over this woman older than my grandmother – that's probably not true. But I made her sign her book and then she just stood there dutifully next to her poster just like I, the little meek undergrad did.

So you see everyone from high schools students in some rare cases to the most senior faculty standing quietly next to their poster waiting for someone to come by and actually care.

Fraser: So you have to do your time with your poster.

Pamela: Yes.

Fraser: All right. That's only one part of the conference. The other parts are the meetings.

Pamela: There are meetings and oral presentations, but posters are the primary way to convey information. There are also 5-minute oral presentations.

Fraser: Posters are the primary. It blows me away that standing beside a poster is the way that you communicate your research and your ideas to other astronomers.

Pamela: Well what's great about is if your options are give a 5 minute oral presentation or present a poster, with your 5 minute oral presentation you have no time to say anything – that's 3 overhead slides; 3 powerpoint slides.

At your poster, you can stand there and you can have a dialogue with your peers. You can find out who has data on this source that is sitting in a drawer unprocessed because they took it for some project they decided not to do. You can interact, you can get great ideas.

That is what's important about doing these poster and oral presentations is dialoguing with other people. Finding out what don't you know that is hidden in somebody else's head or drawer or some journal article that you just missed because it is easy to miss one or two. There are thousands and thousands out there.

You go through this process of dialogue. Science is a collaborative effort. Very few people work in any sort of isolation and we generally refer to the people who work in isolation as cranks because science is dialogue. Each person's idea is growing on everyone else's ideas.

Once you've gone through these presentations, then you're ready to sit down and spew out your five to ten page journal article that you then submit to a journal for final publication.

Fraser: So once you've gotten all the feedback from your poster presentation, you've sat in a bunch of meetings, you've had a chance to collaborate with some of your peers, you then go back to your quiet office space and write up your findings.

Pamela: Yes. You write up your findings.

Fraser: Now that you have a journal article what do you do with it?

Pamela: You hope that somebody reads it. This is where if you write a really good paper and it catches someone's attention, if you have a really remarkable finding you might actually write a press release for it or go to your University Press Officer and get them to write a press release for it. If you're lucky, people will read your paper and most papers really get read like ten times.

Fraser: Where will they read your paper?

Pamela: In the journals that come out.

Fraser: So your paper isn't guaranteed to go in a journal.

Pamela: No, you take your paper and submit it. The step that we all painfully try and forget is when you get your referee's report back.

So, you submit your paper to the journal. The journal then finds someone who's not one of your direct collaborators and is quite often your direct competitor, sends your paper to them and asks them should we publish this? They will generally say, "yes, but make all of the following corrections." Often you have to go through three rounds before you actually you get the yes.

The first round will be: this is worth publication but needs serious revision. You then revise. It then comes back and says: much better and if you're really lucky that's when they say yes fix these four sentences that you wrote stupidly.

Occasionally you have to go to a third before they finally say yes, this is worth publishing. Often referees are extremely useful since they are coming at it from outside of the problem they are able to say, I think I know where you're going with this idea but I shouldn't have to guess. Flesh this out so that anyone reading this knows what you're thinking.

Sometimes they write just the most amazingly vague things like expand on paragraph six. And I think, what about paragraph six do I need to expand upon? You're just wondering, how dumb can this person be?

Fraser: Of course, any of the people who would have worked on any of Pamela's papers in the past they were wonderful.

Pamela: Right and the grant process is the exact same way. So you get back these referee reports, make all the changes, eventually get your paper accepted and then it often comes out several months later.

Fraser: And that's the peer review process, right? You're submitting your paper to your peers – in many cases your enemies – and they're trying everything they can do to find a hole in what you've thought of. Trying to make sure the words you're using are as clear as possible before the journal is willing to publish it.

So you run that gauntlet, you do the final edit; no one else can nitpick any other problem with your journal article; it gets published into a journal. What are the journals?

Pamela: The primary ones in astronomy are the Astronomy Journal, the Astrophysical Journal, the publications of the Astronomical Society of the Pacific, the monthly notices of the Royal Astronomical Society, Nature and Science and Astronomy and Astrophysics. Nature and Science are big only because they have the biggest press engines.

A lot of really great science comes out in the Astrophysical Journal that is totally worth being in Nature and Science but the authors just don't feel like jumping through that hoop. Nature and Science are hard to work with.

Fraser: They want to make it all pretty slick with pictures.

Pamela: With the Astrophysical Journal, you know it's going through peer review, it's going out to your peers which doesn't necessarily happen with Nature and Science. You get your journal article in Astrophysical Journal or one of the other journals and now you hope somebody reads it.

If you're lucky and people read your work, that's when you start getting invited to give university talks. You are invited to give talks at conferences like this one and at other conferences out there and your idea starts to build and is shared and starts to become a foundation of what we do.

Fraser: So what will happen is future researchers will be referencing your work in their work. Citations, is that right?

Pamela: Citations are sort of the thing that we all want the most. It's one thing to publish ten journal articles a year, but if no one ever cites them or no one ever reads them, what good are they?

Given the choice of inviting a speaker who's written three papers that each have a thousand references and that happens very, very rarely, but it occasionally happens, or someone who's written a hundred papers that have never been cited by anyone other than the author, go with the person with a thousand citations.

They clearly did something that somebody (and in this case a lot of somebodies), care about and need to know.

Fraser: Right and so it's almost like the citations are the votes from other researchers that the work that you've been doing is of value and is a high contribution to the field.

Pamela: It's just like how many links does the Podcast website have; how many links does the blog have pointing at it.

Fraser: It's almost like the same model that Google works on that the more links to a website the more popular Google has decided that website is so the more likely it is to show up in future searches.

Pamela: The way it actually ends up happening in some cases is someone finds a cool effect and that cool effect ends up taking on the names of the authors. So you have the Butcher-Oemler effect in galaxy evolution. You have the Geller Hook diagram. These are all people and those are the names on the journal article that brought forward this new idea that now bears that idea's name.

Fraser: You get to have your name just run along with it for the rest of the time that it gets used.

Pamela: Forever.

Fraser: That's the way to go.

Pamela: Yes. So now anyone who is out there doing large-scale structuring Geller Hook…is still there. For a long time galaxy formation was the Agen Linden Bell model. I hope I got those names correct otherwise I'm going to be laughed at later. But Searles Zin model – there's all these different it's just the names of the people on the article and that's what you remember and those names go on to sum up all the ideas in those journal articles, those key papers to our fields.

Fraser: If you want to be a working astronomer, how often should you be publishing?

Pamela: It depends on what you do. There are people out there who are amazingly prolific and put out one paper a month or more in some cases. All because you're chewing out a whole lot of papers doesn't mean you're doing excellent science.

Fraser: No, but in some cases I guess – like Mike Brown at CalTech who is the person who found the tenth planet. I guess he's got the right technique, the right team…

Pamela: And he's just chewing out discoveries.

Fraser: Exactly. Oh, new planet, new large Kuiper Belt object and just keeps them coming out. In those cases I think you don't really no need to slow down or stop. But if you're going to come up with something really deep in foundation you might as well take your time and get the citation.

Pamela: It depends on what field you're in. If you're a theorist, you might spend a year or two carefully delving through the mathematics and get one publication out of it and you worked very hard the entire time.

In other cases you might be someone who is studying things that it takes two years worth of observations and then all of the analysis that goes in the observations.

Fraser: Think of the people on the Gravity Probe B mission where it will take two years or three years for that to finally gather all of the data to be able to decide and in the end it will be just one sentence like: Yes, Einstein was right again.

Pamela: The number of publications that makes sense for you is really going to depend on what type of science you're doing. There are people like Michael Brown who just chew out papers at a phenomenal rate and then there are other people that two papers a year and they are highly respected scientists. You just have to put all the different pieces together.

Fraser: That's kind of good for the regular folk but now the people who really want to win the Nobel Prize, are there any other further steps you can take or is it you've already done your bit?

Pamela: You've either got it or you don't.

Fraser: So you either thought of something foundational that's going to change everything or keep working.

Pamela: One of the key aspects that I've seen in all the Nobel Prize winners that I've interacted with is these are the people that when you walk through the University halls at 8 p.m. are at their desk. When you walk through the hallways at 6 a.m., they're at their desk.

They go home for 6 hours maybe and they're constantly dedicated, they run a tight ship in terms of keeping their grad students on track and keeping their undergrads on track. Everyone works hard, dots all their I's, crosses all their T's, pays attention and is thorough.

Fraser: There is a level of almost organization and hard work and focus and dedication that goes above and beyond the regular researching that happens.

Pamela: These are the type of people that in a few cases after they get the Nobel Prize, they decide to go and play in another field and within a matter of months they'll be at the top of that field too. There's just a level of both genius and dedication that qualifies someone to be capable of getting a Nobel Prize.

Fraser: In many cases I know the Nobel Prizes aren't awarded until in some cases ten or twenty years. It's almost like you have to wait until the research is totally incontrovertible, that everyone assumes it is completely true and they use it repeatedly.

Pamela: It becomes part of the canon.

Fraser: It's not like you're going think this year we came up with a wonderful discovery and later this year we're going to get a call from Sweden. It's this year we'll come up with a wonderful discovery and then over the next ten years it's proven and re-proven and everyone really thinks it is right.

Ten years after that if things have really settled down then you'll get your call. You can almost, from what I've heard from people who've got it, you can start to feel that you're in that zone; you're starting to have a chance to win one of the prizes. I thought this could be easy, but I guess it's not.

Pamela: No, it's not.

This transcript is not an exact match to the audio file. It has been edited for clarity. Transcription and editing by Cindy Leonard.