Roy Eisenhardt interviews Timothy Ferris

Rocky Hill Observatory

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Roy Eisenhardt: So Tim, we're here at Rocky Hill, which is actually a very prominent player in your movie *Seeing in the Dark*. It's fascinating to sit here with you and imagine the context of this situation, when you think back on your early life as it was documented in the movie. Give us a sense of the place where we're sitting now and how this relates back into your early childhood in Florida.

Timothy Ferris: If you start out with a little telescope observing the stars and you keep at it over the years, as I have, it's kind of a dream to one day have an observatory where you can always go and use the telescope conveniently. After decades of hauling telescopes around in the back of vans and going up to high altitude locations and so forth, I did finally build an observatory, here on Sonoma mountain. We did some site-testing first and that's important. Before you build an observatory, you want to put a telescope on that location and make sure that it works, because the way the ground releases heat at night in your immediate vicinity is one of the most important considerations. You can have starlight that comes ten million light years and down through the atmosphere of the earth still in good form, and then gets scrambled in the last twenty or thirty feet reaching your telescope. So you want to be careful how you build. I looked to Clyde Tombaugh, the amateur astronomer turned professional who discovered the planet Pluto, for advice on building this observatory and uh he gave me the basic tips: Don't interfere with the local environment anymore than you have to. Find a good spot and then don't mess it up. Don't put asphalt down. Use primarily wood. Building an observatory is very much like any other ecological thing. If you find the right place and then you make sure you haven't made it the wrong place in the process of building your little structure there.

Roy: I noticed a large concrete pier in the center of this building. Is that partially an earthquake prevention?

Tim: Every observatory is really two structures. There's one that supports the telescope and then a separate structure which is everything else. The reason is that a telescope, in magnifying say a planet, by 500 times when you look through it, also magnifies every vibration in a building. So if you had your telescope just sitting on the floor, you'd have a 500x magnification of every footstep that someone took. So what you want to do is put the telescope on a concrete slab that in turn is supported on something firm. In this case, we had to go down some distance to reach bedrock. And then you build your observatory around it. The separation between the telescope and the rest of this structure is only three quarters of an inch, but we've ridden out a couple of earthquakes now and and they've stayed separated.

Roy: While we're on this, what type of telescope do you have installed here now?

Tim: Isaac Newton back in the seventeenth century invented what we call today the Newtonian telescope. It's the simplest and most popular form, and that's what I have. It uses a light-gathering mirror which reflects the light back to a flat secondary mirror, which just gets the light out of the way of the light path so you can look at it without sticking your head in the light path. It's very simple and yet it took an Isaac Newton to come up with it. The telescope here is an 18-inch Newtonian reflector mounted on an old drive that I bought used, a 30-

year-old drive. It's been fiddled with over the years, rather like what used to be the case with a stereo system: You keep changing individual components to improve things as you go along. The telescope can be used both visually or, by putting a digital camera on it, photographically. And like so many telescopes today, since it's completely controlled by a computer, you can control it right there, as you're standing there, or you can control it remotely. The room in which we're sitting is one floor below the telescope and if it's freezing cold out, it's sometimes rather inviting to put a camera on, let the telescope image away and come downstairs here and have a cup of tea.

Roy: It seems like astronomy is so accessible to us, starting with the notion of lying somewhere in the field and looking up at the sky and just thinking about what all of that is. Maybe we start with that level of astronomy for people.

Tim: One of the great things about stargazing is that it's immediately at hand for so many people. You know, you could get into scuba diving or bird watching, but the stars are always up there. Even from a light-polluted location, if you use a little effort with binoculars or a small telescope, there's usually something you can see—even if it's just the rings of Saturn or the moons of Jupiter. And kids can get into it. You can enjoy stargazing just by going out and learning a couple constellations with your kids. What happens as you get more involved in uh astronomy is that you're probing further into space. It's sort of as if you started out just swimming, then snorkeling, and then you got interested and so started scuba-diving.There's literally no limit to how far you can take that. It is a genuinely infinite subject in which there is no limit to how much one can learn.

Roy: So when I lie there on my back and see the constellations, I'm really seeing history.

Tim: Yes, everything you see in the sky belongs to the past. And the further away it is, the further you're seeing into the past. Many of the bright stars we see in the sky just by looking up at night are hundreds of light years away—so their light is centuries old. If you use a pair of binoculars or a telescope, you're seeing further back in time. The Andromeda galaxy, which is easily seen with a pair of binoculars, is over two million light years away. So you're seeing light there that's as old as the human species. It's easy, with a telescope, to see objects that are tens or hundreds of millions of light years away. So there's an inherent connection between um astronomy and history. You can't look at into the universe without also exploring its history. It comes with the territory.

Roy: Even the light from the moon is delayed, what three seconds?

Tim: Just under two seconds. Light travels 186,000 miles a second. The moon is 240,000 light years away. So if you have a conversation with someone who is on the surface of the moon -- which has happened in our history--there's a little built-in lag.

Roy: If someone wanted to use binoculars to stargaze, what would you recommend they get?

Tim: The best choice, to get started stargazing, is a pair of borrowed binoculars. Nothing will show you quicker what works for you and what you like. I always caution people not go out and spend a lot of money buying something expensive at the beginning of any hobby. I have some expensive fly-fishing equipment that I never made proper use of, and it gazes at me with a reproachful look from my closet every time I open the closet doors. So borrow a pair of binoculars. If you're interested in getting a telescope, go to a public stargazing session of your local amateur astronomers. You can locate your nearest amateur astronomers on our Web site in about one minute flat. Many have public nights, typically once a month at the dark of the moon, and you can go out and see what things look like through different telescopes and learn how it is to use different telescopes. That's a tremendous help in deciding, say, "Do I want a big instrument that I'm going to trundle out in the backyard?" or, "Do I want a more portable instrument that I can take with me on vacations and road-trips?" A little time spent like that can save you money later on.

Roy: If I wanted to borrow binoculars and my friend had a pair of opera glasses and a set of glasses from a World War II navy ship and some bird-watching glasses, which one should I pick?

Tim: A larger pair of binoculars -- meaning a larger objective lens, the second number in the binocular, such as a 7x50 as opposed to a 6x25, will give you more light-gathering power, and that's going to show you more in the night sky. So typically the best binoculars for looking at the stars are the biggest ones. The only trouble is that pretty soon they get too big to be held comfortably. You get into using very large binoculars with tripods and such.

Roy: I've noticed they have now image stabilizers in the binoculars. Do those work?

Tim: Image-stabilizing binoculars work OK, and they can be a real help for astronomical use. The only problem is that they have batteries and the ones I've had really eat up batteries in a hurry. So if you're going to go out stargazing with image-stabilized binoculars, bring extra batteries.

Roy: Let's move to telescopes. There are, I gather by watching the movie, many different sorts of telescopes. Could you explain the different types that we see in the film?

Tim: All telescopes have basically two components. There's something to gather the light—either a big lens or a big mirror. All the telescopes that amateur astronomers use today are either reflecting telescopes, with a light-gathering mirror, refracting telescopes, with a lens, or the increasingly popular combinations of the two, in which you have a correcting lens and a mirror. These compound telescopes—the most popular are the Schmidt-Cassegrain type—fold the optic path two or three times within the tube, so you get the equivalent of a big telescope in a small package.

A lot of people still make their own telescopes. If you really want a lot of light-gathering power for the lowest price, then building a big telescope in your garage is the best way to go. There's been a tremendous advance in the portability of big telescopes. There are amateur astronomers now -- and we saw a few of them in the film -- who have telescopes bigger than anything in the world a century and a half ago that they can fold up ingeniously and take to a dark sky site in the back of an ordinary SUV or a station wagon.

Roy: How hard is it to build your own telescope?

Tim: Well, it all depends on who you are. If you're handy, you can build a pretty nice telescope in a month or two. People used to grind their own mirrors, and many still do, but mirrors have become pretty inexpensive. So a lot of times its, if you want to save some time, buy a good quality mirror and just make the telescope that houses it.

Roy: One thing I get confused on is that the effect of the length of the telescope, the diameter, the mirror and the size of your magnifier optic. Can you put those straight for me?

Tim: Sure. Once you've gathered a bunch of light with the mirror or a lens, then you do something with it. Typically, if you're going to look at an object, that means you use an eyepiece to magnify the image. If you didn't have all that light-gathering power, the magnification would make the image too dim to see. But the combination of the two means you can get a bright magnified image of uh Jupiter or a distant galaxy. The aperture of a telescope, the diameter of the mirror or lens that's doing the light gathering power, is the primary way telescopes are characterized. If someone says to you, "I have a six inch reflector," that means she has a telescope that uses a six-inch diameter mirror. The second quantity is the focal length. How long does light travel back from, in this case, the mirror until it comes to a focus at the eyepiece. A long focal-length telescope tends to have a narrower field of view: It's great for planets and more forgiving of optics. Small imperfections in optics are less visible when you have a long focal length. But it also makes for a big telescope that’s not so portable. Short focal length means more critical focus, particularly for taking pictures. On my F/5 telescope—meaning that the focal length is only five times the diameter of the light-gathering mirror—the tolerance to keep my camera in focus is one-tenth of a millimeter. So you have to really be careful to hold focus over a course of a night’s imaging. Most telescopes, like most things generally, are compromises between those two. You find a sweet spot. You get enough aperture so you can see dim objects, but short enough focus to still have a portable telescope. Longer focal length gives you a more magnification with any given eyepiece.

Roy: I assume it's like a camera? That if the higher the magnification, the more the light falloff that I'm getting access to?

Tim: Yes, with any given telescope, the the higher power the eyepiece you use, the dimmer the image is going to be. So no matter what the size of the telescope, there's going to come some point where the image gets too dim. Before you reach that point, though, you may also reach the point where the atmosphere no longer supports the magnification. Never buy a telescope that's advertised as having a certain power. If you see an ad in a magazine for a 500 or 1,000 power telescope, avoid that that vendor. Because any telescope can be set to any power by using a strong eyepiece, but what matters is to find the powers that will work with a given aperture in your existing conditions, and the biggest determination of that is the atmosphere.

Roy: How about the nearness and or size of the object I want to look at? For example, looking at Andromeda versus looking at the moon.

Tim: A galaxy like Andromeda covers a fairly big piece of sky. More distant galaxies can look very small. The moon's a big object, half a degree in diameter. Planets are have a disk that looks a lot larger than a star. So there's no one telescope that's perfect for all these objects. The question comes down to field of view. I've always myself liked a wide field of view. It gives you the sense that you're still out there in space. And we have today a lot of telescopes that will give you a good flat, yet wide, field of view—a sense of space-walking—and I find that very pleasant to see. A sharp image for instance, of Saturn or Jupiter against a starry background really gives you a sense of what's going on out there.

A lot of times nowadays people come back from expensive vacations to faraway places and the first thing they talk about was how dark the sky was, and how many stars they could see. That's because light pollution has robbed so many people of their view of the sky at home. Fortunately it's a reversible process. There's no reason why we should keep our skies so bright. It's to no one's advantage and we waste over three billion dollars a year just paying the electrical bills to shine lights up into the sky. But in the meantime, there's a lot to be said for a portable telescope because you can take it with you. Set it up and enjoy the views under dark skies at a high altitude.

Roy: Since you brought up light pollution, it reminds me of an article I read recently about actual communities that are forming that have light uh regulations so that everybody can observe in the dark sky.

Tim: There's an increasing move toward dedicated astronomy communities, in places like Chiefland, Florida, and in New Mexico and elsewhere, where a group of astronomers will band together and buy land in a dark-sky site that they have reason to think will stay dark. In this sense, astronomers are friends of other folks, such as ranchers and people with vacation homes, who want to keep the environment the way it is, including the sight of the night sky. You also find that a lot of the telescopes at these sites are internet telescopes controlled from elsewhere. If you have a compound with a million dollars worth of telescopes and people that want to keep the sky dark, then that's political clout that helps preserve the dark skies.

Roy: Back to the telescope, because I, this is my chance to find out everything I never understood. I can figure out how to plot in three dimensional space with an x, y and z type-axis. And I understand latitude and longitude. But how do you plot the location of a particular star or galaxy or planet? What's the process by which you do that?

Tim: Objects in the sky are located by a grid that's just like latitude and longitude here on earth. It's really just a projection of the terrestrial grid onto the sky—since the sky looks like the inside of a sphere, although of course it isn't. One set of those lines is called declination. And that's the angle going north south from the equator toward either pole. Plus declination for the north and minus for the south. And the other one's called by the rather awkward term right ascension or RA. It's counted in hours, 24 hours around the globe. So if you know the right ascension and the declination of an object in the sky, you know exactly where to point the telescope.

Roy: And how do I go and look that up?

Tim: You can look up the coordinates of an object in a star atlas or increasingly just on computers. More and more the star atlases are on computers. And since many telescopes are controlled by computers, it's increasingly possible to just ask the telescope to point at a particular object and it will do it without your ever having to know where the thing is. You can watch the telescope go and then you say, "Okay, now I know where the great cluster M13, in Hercules, is located at this moment tonight." And that sense it's a learning tool. Some die-hard astronomers say, "I still like to find it myself. I like to do what's called star-hopping. You know. start on a bright star and find my way to the dim object." This often happens with looking at comets because comets inherently are hard to predict. They kick around a lot in their trajectory so even if you know the proper orbit of a comet, you don't really know where it's going to be exactly every night. So when you're looking for a new comet, there often aren't good enough coordinates to aim the telescope automatically. You often must find your way to it. But as someone who has spent decades finding things visually and now uses the computer, I have to admit that most of the time I just tell the computer where to aim the scope.

Roy: There's a wonderful scene in the movie where a young boy is given some books to look at. The top one is about morality and the bottom one is about stars.

Tim: That's Edward Emerson Barnard, who had little education, was born into poverty, and was impoverished all his childhood. His father died too young for him to know him. His mother tried to get by by making candles. But Barnard, for some reason, was interested in the night sky and taught himself a lot of the night sky without ever knowing that there was any such thing as astronomy. At about age 13, having taught himself a lot about the night sky all on his own, he discovered astronomy through a book that he was loaned as a surety on a loan by a guy he knew was never going to repay the loan. It was a book the guy literally found in an alley. The front of the book was all sermons, so when Barnard first looked at it, he just saw these sermons and he tossed it aside, saying, "That's a bad loan". Later he happened to find that in the back of the same book was a complete astronomy book bound into it. It was actually one of the best-selling astronomy books of the day. So you had religion and science together in this one volume. That's a little confusing to understand in a film, so we made it two books, in which the first book is a religious tract and the second one is the astronomy book, in the same edition that Barnard saw back in that night in the summer of 1871.

Roy: What really intrigued me about that scene is that he simply went outside with a chart from the book and lay down on his back without any optical assistance and learned the sky.

Tim: There's a tremendous amount you can do without any optics at all. I'm still learning the night sky. I was learning a bit of a constellation last night. Just in a few minutes outside looking up I realized that I had kind of lost sense of the structure of Virgo-- the constellation right next to Leo; a rather dim constellation. I had forgotten how Virgo hooks up, and was trying to remember that. There's always something you can learn and enjoy in the night sky, just by paying attention. People overlook this because they don't realize that if you walk out of a bright room, your eyes do not immediately adjust to the darkness. If you just leave a restaurant, get in your car and drive home, you'll look up and see perhaps five or six stars. That's because your eyes have been dazzled. It takes about twenty to thirty minutes for your eyes to adjust to the dark—to become what they call dark-adapted. If you'll give it that time, you may see a thousand stars.

Roy: Are there things you should not do if you're trying to be dark-adapted?

Tim: Even a brief exposure to light will re-set your eyes back where they were, so if you've taken time to get dark-adapted, avoid even brief exposure to bright light. If you have to be in bright light for some reason, close or cover one eye. At least then you'll have one eye that you can see with properly.

Roy: What's the effect of alcohol or coffee or other stimulants?

Tim: Alcohol and nicotine reduce your ability to see dim objects. So if you're out to really see dim stuff, you should avoid alcohol and nicotine. I don't know that coffee has any ill effect. At star parties, you do see people drinking a lot of coffee. Many seem to feel that coffee and chocolate chip cookies benefit night vision. I don't know whether that's true.

Roy: I've read several places about averting your eye off the center when you're looking at an object. Can you explain that?

Tim: If you look directly at a dim object through a telescope, you won't see it to the best advantage. The way the eye is constructed, it sees dim things best not at the center but a little bit off-center. It's a hard discipline to master, but you need to look just a little away from the object you want to see, and you will instantly see that it comes out much more vividly. This is typically true with galaxies and nebulae. There's a planetary nebula called the Blinking Planetary because it demonstrates this so clearly. When you look at it, you don't see much. As soon as you look sideways, it comes out as this glowing ball. And of course, the tendency of the brain as soon as something appears like that is to look right back at it, at which point it'll dim down again. So it takes a little getting used to. It's called averted vision.

Roy: Averted?

Tim: Averted vision. Twice in the film you hear people mention averted vision.

Roy: How far, on a clear night, can you can see out into space?

Tim: [Laughs] On a clear night, you can see pretty much forever. [Laughs] You can see quasars five billion light years away. That's light that's older than the Earth. It's easy to image and also to see galaxies that are hundreds of millions of light years away. It's kind of astonishing, considering that we're only sixty miles from a major city and there's some light pollution in the sky. Our skies are not the wonderful skies you would find in the Chilean Andes or the Australian Outback or the middle of the South Pacific. But that's one of the secrets of star gazing: From the middle of a city--from Times Square in Manhattan to a site that's dark enough that you can have a lot of fun and see stuff with a small telescope—is often less than an hour's drive. So it is possible to get out there, and there's tremendous happiness and satisfaction in taking advantage of this fact and having a look at nature on the big scale.

Roy: You used the term quasar. Some of us think we know what that is, but it'd be interesting to hear your explanation of what that is.

Tim: A quasar is a bright point of light at the center of a galaxy. Galaxies typically have massive black holes at their centers. Black holes are objects so massive that not even their own light can escape. They're kind of holes in space, really--hence the name--and they seem to be integral to the formation of galaxies. You might wonder why you would get light from a black hole, but when material spirals down into the black hole, it will try to shed energy every way it can, including light and x-rays and other forms of radiation coming from the material just before it disappears into the black hole. So when you're feeding a black hole, as typically happened a lot when galaxies were just forming--there was a lot of ambient gas and dust around -- you'll get this very bright, glowing region right around the black hole. We sit it around some black holes today, but it was much more common when the universe was young, so we see these points of light—quasars--all over the sky. They date from billions of years ago because they were much more common in the early universe. You can go out with a backyard telescope and see a quasar. It doesn't look like much, just like another star. but you'll be seeing light that's billions of-of years old.

Roy: Yeah. The term "quasar," where did that come from?

Tim: It stands for quasi-stellar object. When they were first being charted back in the 60s, they were known only to be dots of light with spectra that did not resemble those of stars. So when you would break the light down into its component parts, it didn't make any sense. One day Martin Schmidt at Caltech was looking at a quasar spectrkind of crankily writing notes for a paper. He had a cold, he didn't feel that well, and he was thinking. "Here's another of these objects. We can't make any sense out of this one either." Then he suddenly realized that what was happening was that the whole spectrum was shifted tremendously toward the red end, that it was an understandable spectrum of hydrogen, shifted far to the red. Now a red shift means that an object is far away in the universe. That shift is caused by its velocity in the expanding universe. So the object wasn't a star at all. It was as bright as a star. It was a pinpoint of light like a star. But it was actually billions of light years away in the expanding universe. No one had considered that, because to be that bright-looking on the sky and be that far away, it would have to have a source of energy that no one had heard of before. And that's what quasars are. They're extreme amounts of energy pumped out from the vicinity of black holes.

Roy: You use the term "expanding." Are they expanding at a differential rate than other parts of the universe?

Tim: The universe has an overall global expansion that's quite smooth. It's as if the Earth were expanding and you were just looking at objects on the surface of the Earth. If the Earth were expanding at a rate such that the distance between you and me doubled at an hour, then that would have a rate of, in our case, about 10 feet per hour. But if we look further away, we look to a city 1000 miles away, it would -- it would also double its distance. So it would have a velocity, relative to us, of 1000 miles an hour. And that's what you see in the universe. The further away an object is, the faster it's receding—from us and from everybody else. All these things were once all together. Not in a particular place: All places were together too. So in the beginning of the universe, all of space and all of time was wrapped up in a volume smaller than the nucleus of an atom.

Roy: Is that why we see a red shift, what you just described?

Tim: Yes. The red shift is light's way of telling you that the object that emitted the light is moving away. When a galaxy is moving away from us, and us from it, the light is shifted to a lower frequency--similar to the way that, when you hear an ambulance go by, the siren drops to a lower frequency as it speeds away. We see red shifts all over the universe and they're directly related to the distance of the objects. It's from those red shifts that it was also discovered that the expansion rate of the universe is increasing. So there's this amazing fact that we live in a universe that's not only expanding, but is currently expanding at an ever-increasing rate.

Roy: One of the elements that comes through so strongly both in your book *Seeing In the Dark* and in the film is the way that people seem to select certain parts of the universe that they want to specialize in and study. I wonder if we could talk about those different layers or distances. Let's start with our own moon.

Tim: Every amateur astronomer has his or her own preferences as to the kind of things they like to see, and the Moon fascinates some of them, while others find it dead and dull. You can get beautiful views of the Moon along what's called the terminator, the region between sunlight and shade. The shadows are so stark on the Moon, in the absence of an atmosphere, that when you have a mountain peak illuminated by the rising sun and beneath that it's just black, it looks like a rock hovering in space. So most lunar observers like to observe along the terminator. But the full moon can be hypnotizing too. I like to observe the Apollo landing points, like that of Apollo 11, the first place that humans set foot on the Moon. If you look at it during a full moon, particularly through binocular eyepieces where you're -- you're really seeing a lot of light, there's something magical about it, something enchanting. It's a kind of a Jonathan Swift landscape. And to realize that there are still these lunar bases sitting there is fascinating.

Roy: How was our moon created?

Tim: The best theory now is that the Moon was created by an a glancing impact on Earth from an object almost the size of Mars, when the Earth was very young and had just formed its crust. Planets like the Earth, when they form, differentiate. You've got a molten ball, in which the heavier elements, typically iron, sink toward the core, so you get an iron core, ,while the lighter elements, the silicates, tend to float toward the surface. As the surface cools off, you will get a crust. And that's the planet we live on today. It's still molten down below, and we're living on the crust. Once the crust had formed, but very early in the Earth's history when there were still a lot of other protoplanets going around, evidently a big one came by and hit the surface and blew a lot of that crustal material off, formed a ring. The Earth, for a little while, had a ring like Saturn and that ring coalesced into the Moon. The reason that astronomers believe that's the case is that the Moon's a lot lighter than the Earth; it has a lot less iron and a lot more silicates. S so there had to have been a mechanism to have formed the Moon from the surface materials, and we do know that in the early days, there were an awful lot of planetary impacts. So the Earth being here and having its moon seems to be the chance result of the fact that we had a glancing impact with a protoplanet.

Roy: We're not talking about a Jurassic impact; we're talking about much earlier?

Tim: This would have happened soon after the Earth formed, well over four billion years ago. Everything back then was getting hammered with debris. Most of the craters you see when you observe the Moon date from that era.

Roy: I gather that the orbit of the Moon is actually not consistent distance, that it's gradually moving away?

Tim: The Moon is climbing in its orbit, owing to its tidal interaction with the Earth. When the Moon was young, it was really big in the sky, and it's still pretty big even today, but it will keep climbing, and getting smaller in the sky, for billions of years to come.

Roy: You mentioned impact and another seemingly popular object of observation are the asteroids and the comets. Maybe we could start with an explanation of the difference between those two.

Tim: Asteroids are rocks orbiting the Sun, and there are a lot of them. If you get into amateur astronomy and you want to discover asteroids, you can hook up a digital camera to an ordinary backyard telescope and probably discover an asteroid in a night to a week or so. People who are experienced at it can discover asteroids almost every clear night. There are just millions of asteroids out there. Most of them -- but not all—lie in a band between Jupiter and Mars, but enough of them come near the Earth as to be a cause of concern. A big asteroid impact on the Earth -- you know, we've had them historically -- could cause a lot of trouble, a lot of loss of life and property.

Comets, on the other hand, look like asteroids initially, but they typically come from further away, and as they approach the Sun they get heated up. They start to glow and the volatile materials that they contain start to outgas and you get this beautiful tail. So a comet's a much more satisfying object to look at through a telescope.

Roy: Why have comets been associated in the past with disasters happening -- for example, around Julius Caesar's time and so forth? What gave them that association?

Tim: People tend to be frightened of what they don't understand, and since people understood virtually nothing about the night sky until science came along, big changes in the sky did frighten Comets can be quite big in the sky and can appear threatening. In a sense, they *are* threatening, since a big comet striking the Earth would be a terrible event. Also, comets were exploited by those who took advantage of the fact that what someone can predict, he can pretend to control. There's always somebody willing to step forward and say, "There's this terrible disaster threatening. God is unhappy with you. But if you do what I say, it'll come out okay." And you know, if you realize it's going to come out okay anyway, and if it doesn't there'll be no one around to blame you, then you can take a step up on your dubious career path.

Roy: That's a very interesting concept. Scientists tend to take the other direction which is not to make predictions. But what are we dealing with in terms of the probability of an asteroid of significant size hitting the Earth in the next 100 years, let's say?

Tim: We don't really know exactly how to calculate the odds of an impact, because we don't have anything like a complete record of the impacts of the past. The Tunguska event in Siberia, back in the early 20th Century, had it occurred over a city today, would result in massive loss of life. The right way to assess a risk is to take the likelihood of it occurring which we don’t exactly know for impacts from outer space, times the potential damage. That's how the insurance companies do it.

So it makes sense to take out an insurance policy against asteroid and comet impacts, by making a proper census of what's out there. NASA has been trying to do that, although recently the funding has been cut.

Roy: There's been discussion about if we were to learn an asteroid is a high probability, what could we do about it? I've read everything from blow it up to nudge it slightly to change its orbit. Help us on that.

Tim: If you find an asteroid that's going to hit Earth in the future, you don't want to blow it up; blowing it up just turns a bullet into a shotgun blast. What you want to do is to alter its orbit. The earlier you get there, the less energy it takes to alter the orbit. The Earth is a very tiny target in space. It's hard to hit the Earth. So if you have an asteroid that's actually going to hit the Earth in the future -- two years, five, or ten years in the future -- it takes only a very slight change in the orbit to deflect the asteroid. The easiest thing to do is to send a rocket there—tt doesn't even have to have people with it—land it on the asteroid, and then use rocket's engine to change the orbit a little bit, give it some time, watch how the elements play out, and just gently nudge it out of the way.

Roy: Makes a lot of sense, yeah. If an amateur is looking for asteroids through a telescope, what are the detectable signs? What do you look for?

Tim: Most amateur astronomers who are looking to discover asteroids just image space along the ecliptic, which is the plane where the planets and most of the asteroids orbit. Because the asteroids are moving around the Sun, you'll get a-a pinpoint image of the stars but you'll see a little streak with the asteroid. I get those streaks all the time in images that I take of other objects, and I assume that they're all catalogued asteroids, but some of them aren't. If you're looking to discover a new asteroids, you just take all the ones you've imaged and you check them against the catalogues. Computers will do this for you now. And then maybe one will come up that has not been catalogued. You follow that one a bit longer and you send the data to a central clearinghouse and they'll tell you if you've discovered an asteroid. If you have, they'll tell you that you're free to name it for yourself, or for your child or for your aunt, but they'll ask that you please do not attempt to name it for your housecat.

Roy: [Laughs] Is that really the rule?

Tim: The International Astronomical Union has a few naming rules and one is to please not name asteroids after pets. You can, however, name them after people you admire. So for instance, John Lennon has an asteroid named for him.

Roy: Well, I guess that leaves my cats out. So we move now to the next level out which we will call the planets. I say "we will call" because I want to talk about what that term means. Maybe that's where you should start, the current thinking about what is the definition of a planet. Let's start with recent thinking about what the definition of a planet is.

Tim: A planet is an object that shines by reflected light of its home star -- in the case of our solar system, the Sun -- and which is large enough to avoid being classified as an asteroid. It turns out there are a lot more objects orbiting the Sun than people used to think. Back when we were all taught that there were nine planets and the outermost was Pluto, astronomers hadn't yet discovered that there are millions of objects like Pluto beyond Pluto. They're called Kuiper belt objects, after the astronomer who first charted them. Pluto is a Kuiper belt object that happened to get pulled into an orbit that brings it inside the orbit of Neptune, so it was naturally mistaken for a planet. But if we hadn't changed the definition of Pluto, we would have ended up saying that all these thousands of other Kuiper belt objects were all planets, too, and that would have been a bit confusing. Kuiper belt objects resemble like comets, and Pluto's a lot like a comet. As it gets a little closer to the Sun, Pluto starts to outgas volatiles and develop a little atmosphere; when it gets further away, it doesn't. Observing the planets is a lot of fun, particularly with a small telescope 'cause they're so accessible. Jupiter and Saturn are large enough that you can see them much of the year, and even a small telescope will show you their many satellites and the changing features, in their atmospheres. The atmospheres of these giant planets like Jupiter and Saturn are opaque: They're made of colored gas that you can actually see, so you can see their weather patterns changing—rather like the map that the weather forecaster shows you on the evening news. Jupiter revolves on its axis once in only ten and a half hours, so you see the whole planet in the course of a night and you can see it changing. It's fascinating to observe these things. Mars varies in its distance a lot from the Earth, so you want to observe it when it's close at hand, during what's called opposition. During those oppositions, you can see quite a bit of detail on Mars.

Roy: Opposition meaning?

Tim: An opposition meaning when -- when a planet appears opposite the Sun in the sky. Since the Earth is orbiting between the Sun and Mars, when we see the Sun on one side of the sky and Mars on the other it means that we're on a line in between those two.

Roy: Why are the larger, more gaseous planets on the outer part of the solar system?

Tim: Astronomers think that it's because all the planets formed from a gaseous medium, in a disk surrounding the young Sun, and that the heat of the Sun blew away the colder and more volatile materials from the center innermost planets, leaving just the cores. Planets like the Earth resemble the cores of the giant outer planets.

Roy: Let me go to a different part of this question. How long have we known there are planets outside of our own solar system?

Tim: When I was a boy growing up and reading the popular astronomy books, it was hypothesized that lots of other stars ought to have planets. There wasn't anything about the Sun that made it unusual. There are billions of stars like our Sun in our galaxy alone, stars with similar composition, rotating at similar rates. And since the Sun has planets, it seemed reasonable to assume that others stars do too. The trouble is that you couldn't see them. And you still can't. The planets are much too close to their stars, they're lost in the glare, and the stars are much too far away. There's still no telescope on Earth that can actually directly see a planet of another star. But techniques were developed in recent decades that allow you to extract the information that the planets are there from the very subtle dynamics of the stars—just by the way the star is slightly tugged on gravitationally by its planets. Hundreds of planets of other stars have been discovered in this way, and it now seems clear that stars typically do have planets.

Roy: In the movie, you have a scene of an exoplanet transecting another star. Is that another way that they've been verified?

Tim: Yes, the methods that are used now to detect extrasolar planets tell you if a star has planets, but they don't tell you the orientation of the system. Planets form in a disk, and continue to orbit their star in that disk thereafter. That's what we see here in the solar system and that disk projected on the sky is what we call the ecliptic, where the Sun and Moon and all the planets orbit. So when the professional astronomers identify a star that has planets, the question immediately arises, does the plane of orbit of these planets happen to be such that those planets are going to pass between the star and the Sun. You still can't see them, but what you see is a very slight change in the brightness of the star caused by this miniature eclipse.

And that's where amateur astronomers come in. We saw one of them in the film. If you monitor these stars and keep close track on their brightness hour by hour, you can tell if a planet transits it. What's more, you can tell the size of that planet and how long it takes to go around its star. If that planet transits, then other planets may transit as well, so you may discover other planets. It's possible now for an amateur astronomer with a backyard telescope to actually discover planets, something that hasn't happened since the William Herschel discovered the planet Uranus hundreds of years ago.

Roy: Now you made an interesting distinction just before. You were saying "this is where the amateur astronomer comes in." Why is it that the amateur astronomer adds value to the monitoring of these exoplanets? What is [different] from the professional?

Tim: Well, professional astronomers have beautiful big telescopes. But there's a lot of demand on the time for those telescopes. So it's hard to get a professional telescope allocated to burn up a lot of time to just try to discover a planet. Most of the planets discovered by professional astronomers are not going to be transiting because the planes of their orbits are oriented at random. So you can't really get hundreds of thousands of dollars of telescope time allocated to you to keep looking at stars trying to find one that's transiting.

But amateur astronomers can do whatever they please with their telescopes, and there are amateurs who are quite interested in monitoring these stars and finding planets. They've been working with the professionals because they can afford to take telescope time while the professionals can't. It doesn't take a big professional telescope to do job. It can be done with a backyard telescope and a CCD camera. They're not the cheapest things in the world—you can spend the price of a good racing bicycle to a medium-class motorcycle on this gear--but it's within the range of many amateur astronomers.

Roy: What is the actual percentage change, if that's the right term, of the amount of light fall-off from the blocking by that planet?

Tim: Typically less than one percent. It's a subtle effect, and there's a shot in the film in which you can see the light curve that Ron Bissinger actually obtained at his observatory in Pleasanton, California. You can see there's a lot of scatter in it, but altogether, they add up to a smooth curve that shows you that a planet has come in front of the star and then it's gone back out away from it again.

Roy: So that's a very interesting point about the contribution of the amateur. What other examples are there where the amateurs fill in a volunteer need?

Tim: Amateur astronomers for many years searched for exploding stars—supernovae—in other galaxies, discovering a number of them visually. I used to do that, look for supernovae; it's a great excuse for looking at galaxies, which are beautiful things to see through a telescope. If you have a few hours one night you can say, "Well, I'm looking to see if there's a new star there that doesn't belong. That could be an exploding star." You might never make a discovery, but in the process, you're looking at dozens of galaxies. Amateurs have been making contributions in other areas, too, including the detection of what's called the optical counterpart to gamma ray bursts. Gamma ray bursts are the most energetic events in the universe. They're created in at least two different ways that aren't at all well understood yet. One of them, the one that we depict in the film, involves the aftermath of the explosion of a star and the creation of a black hole. What you get is a gamma ray burst, which typically has been traveling through space for billions of years. When it reaches a NASA satellite in orbit, the satellite can pinpoint pretty well where it is in the sky. And that satellite automatically sends a message to everyone who wants to hear about it, everyone who's signed up to hear about this gamma ray burst. My cell phone gets gamma ray burst messages every day or so. I look at them to see, you know, are they in my sky? If you get lucky and catch one in your sky at night and you've got a telescope and a camera, you can try to get the optical component. It will fade away in just an hour or two, but it’s very interesting in terms of understanding the physics of the entire object--because here's an explosion so titanic that you can see it halfway across the observable universe, often further than that, and it's all going to be over in a matter of minutes or hours. So it's a very exciting thing. The more telescopes that are available, the better the chance of getting that image. And that's why amateurs are involved in this.

Roy: And it's photographed?

Tim: Yeah, during that time that you see it, it'll appear as bright as an ordinary star through a telescope. If you just use an astronomical digital camera, what they call a CCD camera, that camera automatically records the relative brightness of every star in the field. You know the real brightness of the other stars, so those images are instantly usable as data. They tell you the changing brightness of the gamma ray burst. Right near here, at Sonoma State University, is one of the world centers for collecting and analyzing these observations. It's something of a cottage industry and it doesn't require big, expensive labs, so people of all sorts are involved.

Roy: Again, the amateur contribution is the volume of telescopes spread all around the world that can be in the right conditions to observe this.

Tim: New telescopes are coming online all the time, and most of them are amateur telescopes. Every serious amateur astronomer that gets into some field of scientific research adds to the total data-gathering capacity of the planet. Recently the astronomical date-gathering rate has been doubling about every 14 to 18 months. We can't keep that going on forever, but there's a very healthy increase in the number of eyes that the Earth has trained on the rest of the universe.

Roy: How valuable is observation of weather on the planets?

Tim: It's very useful. We're conducting an experiment here on Earth with the release of greenhouse gases into the atmosphere, and we don't really understand how the atmosphere of the Earth works all that well. We would not like not to have a nasty surprise arise because of our ignorance of how our own planet works. In science, you can't really understand things very well by just having one example. Fortunately, there are other planets and they have weather. And so, by studying their weather you can understand more about the weather here on Earth. And amateur astronomers have helped with that too. Dust storms on Mars, the appearance of bright, upwelling white plumes called white spots on Saturn, of new cyclones and other storms on the surface of Jupiter, have all been observed and are observed to this day by amateur astronomers

Roy: Tim, we've been talking about astronomer observers and their contributions to the professional core, particularly as it related to planets. Let's now move out to the next distance and talk about the stars. First of all, we tend to use the term "star" as something that's different from our own solar system. But that's actually not accurate, right?

Tim: The Sun is a star, and every star in the sky is a Sun.

Roy: So the potential of multiple solar systems in the universe is almost immeasurable, I assume?

Tim: A conservative estimate of the number of planets in our one galaxy is one *trillion*. If we already knew about every planet in our galaxy, and if all you had to do your entire life was just to go paging through the atlas looking at one planet after another, you wouldn't have time in your lifetime to look at them all. You wouldn't have time in 10,000 years to look at them all.

Roy: How much of our own galaxy, the Milky Way, can we actually see from Earth?

Tim: A lot of our own galaxy is blocked from us at the visual wavelengths by the fact that we're in the disk of the spiral galaxy. The galaxy has the dimensions of a vinyl phonograph record. We're in the disk, and the gas and dust in the disk blocks our view of some of the more distant parts of our own galaxy. You can see this when you look up at the Milky Way at night. The Milky Way is the disk of our galaxy, and if you look at the summer Milky Way, which is when it's warm and most people are out and looking at the night sky, you can see a big black riff running right through the center. That's the disk, where most of that dust exists, and it keeps us from seeing much further away. You can see through it in radio wavelengths, but if we only had our one galaxy, it would have been kind of hard to piece together the way it looks. It's by virtue of the fact that there are thousands of other galaxies to view through a telescope that we can piece together the anatomy of our own galaxy. And that's really how this galaxy was figured out, by observing other galaxies and recognizing these similarities.

Roy: I take the next nearest galaxy to us is Andromeda? How far away is Andromeda?

Tim: Well, the Andromeda galaxy, at a little under 2.3 million light years, is the next big spiral. It looks like our galaxy, although it's actually about twice as massive as ours is. All these big galaxies are attended by lots of smaller galaxies that orbit them and merge with them. The Milky Way's swarm includes the Magellanic Clouds and various other dwarfs—clouds made of stars--and the Andromeda galaxy has its swarm. In a special effect in the film, we see some of the globular star clusters that surround the Andromeda galaxy. They're those golden spherical objects that go by. And they are also attendant to major galaxies.

When you see one big spiral, it's typically a member of a pair. And that's true of us and the Andromeda galaxy.

Roy: In order to observe Andromeda, coming back to our telescope size, what would be the approximate size of brightness you would need for that?

Tim: On a really dark-sky site, you can see the Andromeda Galaxy without any optics at all, as a patch of fuzzy light in the sky. With binoculars, you immediately get a sense that there is this large oval of gray light. A small telescope will show you the two primary satellite galaxies hovering near Andromeda, and under good conditions you may begin to see the spiral arms. Medium-size telescope, meaning something you can carry around in your arms -- sort of like a bassinette -- will show you the spiral arms, the major nebulae in the galaxy, and you can really tell that you're looking at a spiral galaxy.

All this is a bit elusive, though. Deep space objects viewed just with the eye don't look like their photos. They don't have those brilliant colors that you see in the photos. The colors are real, but the levels of brightness are too low to trigger the color receptors of the eyes, through a normal telescope. It takes a pretty big telescope before you start to see colors in deep space objects. On the other hand, the colors of bright things like comets and planets are readily visible even through a small telescope.

Roy: That makes me think -- does the red, green, and blue parts of the wavelength that our cameras tend to measure, are those delivered differentially so that you need to adjust those colors, or are they accurate?

Tim: You can get the colors of astronomical objects either by simply making a time exposure with a digital color camera attached to a telescope. Now you've got a big telephoto lens, so to speak, and you can see the colors of deep space objects with an exposure of just a few seconds or a few minutes, depending on the size of the telescope.

A decent size telescope will render some of those colors to the eye, too. In the Orion Nebulae, for instance, you can see some of the beautiful reds, which are created by excited hydrogen gas, and the greens, which are excited oxygen and neon in the nebulae. But some of the really beautiful color photos that we see in the film, such as Rob Gandler's huge mosaics, are made by exposing a black and white digital camera -- CCD camera -- through different filters. You do an unfiltered exposure and three filtered exposures in the three primary colors, and then combine them to get the color result.

Roy: So let's talk -- you mentioned deep space. Let's go to that as kind of our last, part of this line of discussion. What are we looking at when we look out there and see darkness? I mean, when you don't see something.

Tim: Anywhere you look on the sky, there's something. If it looks empty through a given telescope, a bigger telescope or a long exposure image through that telescope will show you that there's stuff there. There's stuff in every direction, at different distances out. The Hubble Deep Field, which shows thousands of galaxies is an area on the sky smaller than your little fingernail at arm's length--and amateur astronomers have been making these deep field photos as well—shows that everywhere you look, there are thousands of distant galaxies in every tiny little bit of the sky. There are at least a hundred billion galaxies out there, and hundreds of billions of stars in each galaxy. So the potential for learning about the universe is virtually unlimited.

Roy: And in order to understand that, I wonder if we could understand just -- the broadest way -- the nature of dark matter?

Tim: Dark matter is the majority of material in the universe, but it emits no light. Its presence is intuited by the virtue of the fact that it affects objects gravitationally. When you look at the rate that stars in a galaxy orbit, there is clearly a lot more material inside that orbit than is giving off light. When you look at the orbits of galaxies in clusters of galaxies, there's even more. So the majority of material in the universe is in the form of dark matter, and no one yet knows what it is. All this wonderful stuff that we're observing is less than ten percent of the total inside any given volume in space.

Roy: In an odd way, we can, we can observe or at least sense the cosmic, [microwave] background.

Tim: Yes, the energy from the Big Bang is still around as microwave energy. You can pick it up with radio telescopes. And you can pick a little of it up with an ordinary TV set. If you take an old-fashioned pair of rabbit ears and hook them up to a TV, about one percent of the noise you see on there on the screen is from the Big Bang.

Roy: Hm, fascinating. Tim, would like to wrap up his discussion about amateur astronomy, but I'd like -- wonder if you have a general -- some general words of inspiration to people out there who are thinking of getting into this, but quite don't know where to start, or what to do.

Tim: If you're interested in getting into stargazing, one prospect is to make use of the "Seeing in the Dark" website. It was constructed as a tool to help you get started in stargazing, and to help support you at any subsequent level, from just getting a start chart and making a red light flashlight in a couple of minutes to get out and have a look, learn some constellations, to looking at objects through binoculars or a small telescope. We're here to help, and so are plenty of other people, many of whom are linked to our website. I think the main this is to learn something and have fun. I think it's healthy for people to understand their wider environment. The world's a lot less troubling when you understand the systems that it's part of, in the huge scope of space and time in which human life exists. People used to ask -- and maybe they still do -- "Doesn't this make you feel insignificant, that everything out there is so big?" But I really think the reverse is true, that one feels much better about the human condition when one understands it in its natural context. That context extends out through the stars and the wider universe. It's all nature, and it's always good for the mind and heart to understand nature and our place in nature. That's what stargazing is all about.

Roy: We're moving now to a -- a separate conversation, relating to the making of "Seeing in the Dark."

Tim, people have -- hopefully been fortunate enough to read your book, but beyond that, hopefully have been fortunate enough to have seen your movie now, "Seeing in the Dark." and we thank you for producing such a beautiful work. As a general way of getting into discussing a movie, could you tell me about what inspired you to put in the amount of effort and thought to produce that film?

Tim: Stargazing's a beautiful subject. I don't know any site in nature that's more inspiring than a dark, star-filled night sky, and I wanted to make a film that would do justice to the aesthetics of stargazing. I don't believe it's ever been done. I've never seen a night sky in a film that was anything like the real thing. More often the stars are just inserted as a kind of decoration or backdrop. And that's okay, but this is a film about that backdrop, and so we had to enlist a lot of technical leverage to try to give you something of the feeling of being out there. One of my ambitions, from early on in the film, was to create scenes in which the sights and sound and the ambiance would, would, give you a sense of what it's like to be out stargazing at night.

Roy: Most films, when they try to teach science, tend to instruct, and place a narrator between the subject and the viewer. your film approaches that differently.

Tim: I’ve made a couple of “presenter” films myself and, there are a lot of advantages to just getting in front of the camera and explaining things. But for a stargazing film, that posture didn't really seem appropriate.

If you want to look through a telescope, you don't want an expert to step in between you and the telescope and give you a lecture. At the most, as you look through the telescope, you might like a guide to whisper in your ear a few things about what you're seeing. It's a shift that has been talked about in educational terms as a shift from the paradigm of the "sage on the stage" to the "guide at your side." It's a a turn of ninety degrees. And that turn seemed appropriate for a film about stargazing. So there's very little to-camera talking and my being in the film. Mostly the basic dynamic of the film is that you're looking out there, and I'm trying to help make that experience meaningful by telling you a little about what you're seeing, and how you're seeing it.

Roy: And you also, in the film, talk to the viewer through amateurs, which creates a much -- in my judgment -- a much less intimidating, feeling for the viewer. And I was interested that one of your amateurs actually was telling us about the nature of the scientific method.

Tim: I think it's great that Robert Smith, a former NFL running back, is the chief exemplar of the scientific approach to the world in our film. Robert started out in mathematics, but became to generalize his interest to embrace science more generally. And as he points out in the film, science is not a matter of learning a lot of facts. It's not something that has to be so hard. It's just simply understanding that to take an idea seriously, it has to be a testable idea, and preferably allowed to have been tested. That simple step, which has been a huge step in human history, is still unknown to the majority of the human species.

And if the day comes -- as I hope it will -- that most humans under -- understand science and technology, and understand how to use a scientific way of evaluating concepts, that the world is going to be a more peaceful and a whole lot more enlightened place than it is now. There hasn't been time for that to happen yet, because science is only some four hundred years old, and four hundred years is an instant in terms of intellectual history. It's a very short period of time for new ideas to spread.

Roy: The film was written by you and produced by you and, narrated by you. I sense in it a lot of subtlety with respect to the integration of music and astronomy. Could you tell us about that?

Tim: Stargazing involves two opposite extremes. On the one end, you have the individual observer -- often solitary, or just one or two people may be looking through a telescope in a quiet little spot somewhere, a backyard or a national park. At the other extreme, you've got the enormity of what's out there, the sheer beauty and awe of the wider universe. So I wanted to make a film with that dynamic, and no middle. The scale of the film is either cosmic or it's very personal.

And to bring out the personal aspect of that experience is not necessarily intellectual. It's an aesthetic experience, too. It's an immersion in nature that you're doing when you're stargazing. I wanted the film to be visually beautiful, to answer to the beauty of the subject, and I wanted the music to be equally powerful and deep. I wanted nothing in the film to be cosmetic. It was always conceived of as being a kind of handmade, localized film. In it, we don't travel the world going to exotic locations, because that's not what it's about. It's not about what you could do if you could go somewhere else. It's about what you can do right at home. And I wanted the investment in the film -- the artistic investment -- to be similar to what you see with amateur astronomers: That it's what I do. It's not what a big company does; it's not a glossy product; it's something that's from the heart.

It means a lot to me that the music in this film -- the modern music -- was composed by just two people, and the older music was predominantly the work of individual artists, often people who were very far out of mainstream, and weren't playing much for anybody beyond themselves and their immediate circle of friends. The theme of time in the film is a personal one, as well.

The film tells a generational story, about the relationship between human time scales and cosmic time scales, in a way that's never stated in the script and which is personalized around my own life, because it's a personal experience and it has to be somebody, and the only person whose experience I can tell that intimately is my own.

Roy: Music is an art form that works off time, as well as what you just mentioned. Is that part of the reason for the coincidence?

Tim: Music, like cinema, is an inherently time-bound art form. A painting doesn't change over time, but a piece of music or a piece of cinema has to, by definition. You can't freeze music and still hear it. So the relationship between time, which is the real theme of "Seeing in the Dark," and music, was important to me from the beginning. I was fighting from years ago until the final days of sound mixing to make sure that we got the music we wanted, and we got it right. We were really helped out there by Mark Knopfler and Guy Fletcher, who came through for us in a terrific, terrific way. I really think all the music in this film is exactly what one would want.

Roy: You were really helped out also by the fact that when you were young, the ozone layer let those blue stations through.

Tim: Back in those days we called it ozone layer, but it's actually the ionosphere. When you're out stargazing as teenagers, as we were, we had this shortwave radio, and we discovered that -- as everyone does who uses a radio at night -- that as the night goes on and the sun's been down for a while, the ionosphere, which is fragmented by sunlight, reforms, and you get a mirror for radio waves so that stations from much further away start to bounce down. That's how we heard WLAC in Tennessee, which was a station that played old roots blues music we'd never heard before.

South Florida was segregated racially in those days, and the radio was segregated. Most of the stations were intended for white audiences, and the two stations that black listeners were targeted for were resolutely upscale; the last thing they wanted to do was to go back and hear roots music, because they were trying to advertise to more urbanized, higher-income black families. But of course, black rural music from the United States in the 20s and 30s is some of the best folk music ever recorded anywhere in the world. And it meant a lot to us teenagers. It got me involved in music, got me started playing guitar. We tried to indicate a little of that, in these early scenes in which my son, Patrick, plays me at age seventeen, and then returns to play himself. To play himself, plays a lot better guitar than he does when he's playing me, which is in interest of authenticity.

Roy: Did he have to, actually, cut down on his -- his guitar playing skills?

Tim: Yeah, a lot. Patrick in that early scene is playing at a very tiny fraction of his ability. And that's not really just because, you know, I wasn't such a great guitar player, but also because his character in the film is attempting to play a piece that he's only just heard for the first time.

Roy: What about cinematography and camera techniques? Did you use anything special in this?

Tim: Optics in astronomy is all about what you could call a wide bandwidth: It's about getting as much as the information and as little noise as possible. The whole reason amateur astronomers spend so much time and effort on good optics is to get as much signal as possible. And I thought the film should do that too. So it's a deep-focus film, because the night sky looks like a surface, but it has depth. And that's what a telescope does: it takes you into those depths. That's the theme of the film, established in the very first lines. And we spent a lot of attention to the quality of our images. Quality lenses in cameras, pure 30-frame-per-second, 1080p, high definition shooting, because that's the highest quality you can put on a screen. That's higher quality than a 35 millimeter, 24-frame feature film.

The idea of the film is to make sure that you get a sense of what's out there as clearly as you can. Try to see this film in HD on a big screen: I think you'll be surprised.

Roy: What about the special effects?

Tim: The special effects were done by Don Davis, who I've worked with over the years in the past. I believe Don to be the most accomplished astronomical effects person in the world.

The great thing about Don is not only does he have a ton of experience at creating effects at high-def resolutions, because he's done a lot of these Imax and Omnimax planetarium shows, but he really understand the astronomy. So when I would say to Don, "We want an accurate Orion Nebula. We want to fly through the Orion Nebula -- go into the Trrapezium and make a turn almost as if you were doing a gravitational acceleration around those giant stars," he knows exactly what you mean. It doesn't take a lot of explaining. And what comes back as a motion study will be exactly right from the beginning.

And then it was just a matter of working out the incredible detail of this beautiful object.

Roy: Finally, at the end of the movie, you and Patrick are walking at a distance but talking. And you're talking about Galileo and Kepler. And I suspect that wasn't an accident.

Tim: [Laughs] No. Galileo was one of the first people, and the first scientist, to look through a telescope at the night sky. He built his own telescope to do that. And Kepler was the most brilliant astronomer of the era. something that Galileo was loath to admit-- Galileo fearing, I think, competition from Kepler, who was really about his only competition. Galileo never sent him a telescope, so Kepler never owned a telescope. Einstein said that it would always hurt him to think of how Galileo had treated Kepler. Notwithstanding all that, Kepler -- who just didn't have any jealousy or smallness in him -- backed Galileo's observations, and it was his intellectual authority that made the world take Galileo seriously, when Galileo's critics were saying that he was just a victim of optical illusions—that he was like someone looking through a kaleidoscope and saying, "Oh, the world's all fragmented."

Kepler was the guy that stood up for him and made people take Galileo seriously. You have to remember Galileo was an unknown minor professor at Padua before he started publishing his telescopic observations.

Kepler and Galileo also represent the poles of science--of theory and observation. Not exclusively -- no one's ever exclusively one or the other. But Kepler was a theoretician, and Galileo's reputation was based on his observations. So there was a dialogue between them. It was often interrupted because of personal human considerations, but it has continued on down through this day, and it will continue as long as there's science. The dialogue between Patrick and myself is meant to sound like a piece of a conversation that's been going on before, and will continue to go on indefinitely into the future, as I sincerely hope the scientific dialogue will.

Roy: Finally, a question on imagery here. movie opens with the imagery of water and a conversation with you and Patrick walking. The movie ends with the imagery of water. Is there a connection?

Tim: On one level, the whole film takes place one night here at this observatory. It begins before sunset, and ends after sunrise with the same walk past the same pond, which is right near where we're sitting. Water has been a major symbol in my own intellectual development, predominantly because of Taoism. I was quite influenced by Taoism as a younger person. And I'm still fascinated by the Taoist emphasis on the limitations of words, on the fact that words are great, but there are always going to things that you can't describe in words. Which is what Kurt Gödel discovered about mathematics as well--that no mathematical model, no matter how accomplished, can verify its own validity. There's always some wider frame that you'll need. These are very intriguing ideas to me, and they have a lot to do with the frames of reference that you encounter in astronomy, when you begin to realize that your life here is set in these other spatial, temporal frames, which you are free to consult for a better understanding of the one that you live in. The surface of the pond resembling the surface of the sky, the realization you can look *into* it, and that there are all sorts of strange denizens of those depths. I was reminded of the cycles of human life since we shot this film starting fifty years to the month after I'd first gotten my first telescope. The cycle of different generations, the symbol of water running through time, and the association of music--all those elements are bound up in these scenes. Not because the viewer's expected to parse them all out and create some kind of a postmodern symbolism kit out of it. But because they all go into real life and the real experience of the real people that are out there looking at the stars.

Roy: Well, thank you, Tim, very much.

Tim: Thank you, Roy.