

# Seeing in the Dark

**Timothy Ferris**

**11.7**

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## I. Passion

**1. The Sky Like Water.** Black screen. Fade up epigram:

Fifty years  
I've hung the sky with stars.  
Now, I leap through!

-- Dogen

Exterior, late afternoon, abstract reflections in a pond. Theme music.

**Timothy Ferris (TF)**  
**(V/O)**

The sky is like water.

TF walking towards us along a path. His image is reflected in the pond.

**TF (V/O)**

On this side, the bright, familiar world; on the other, the mysterious depths.

**[Super title and head credits]**

**Seeing in the Dark**  
**A Film by Timothy Ferris**

**TF (V/O)**

Look *through* the sky, *into* the starry depths, and you'll find more out there than anyone has imagined, or *can* imagine. And it all starts close to home.

Tilt down through trees to TF walking through the woods to Rocky Hill Observatory (RHO).

**Music by**  
**Mark Knopfler**  
**and**  
**Guy Fletcher**

**Written, Produced, and Narrated by**  
**Timothy Ferris**

**TF (V/O)**

I **started** exploring the night sky fifty years ago, and got so involved in it that I eventually constructed a permanent home for my telescope, on Sonoma Mountain.

LS RHO, afternoon.

**Directed by  
Nigel Ashcroft**

Interior, afternoon, RHO. TF enters, goes to bookshelf, opens a faded blue loose-leaf notebook, and pages through to an old pencil drawing.

**TF (T/C)**

Once the observatory was built, I was unpacking some old books from back home and I found my original journal. In it was a blueprint, drawn when I was about thirteen years old, for an observatory. It envisions a one-story structure, but otherwise it's identical to the building I'm standing in. As they say, all dreams begin in childhood.

TF replaces book, heads upstairs.

**2. Voices.** Still of stars over a pond.

**TF (V/O)**

Amateur astronomers say they love stargazing—which is what the word “amateur” means, to do something for the love of it. But it can be hard to put love into words.

Robert Smith, on the beach at Key Biscayne.

**[Lower-Third Super]**

Robert Smith  
NFL Running Back

**Robert Smith**

It opens up an entire new world or entire new worlds, I think. And just by looking and – you know, I've been through it so many times and I can. I always anticipate that moment, like when the first time a kid sees Saturn, I mean, that's the same way that I was when I first saw it, as a grown man. I mean, there's always this wow factor. You know, this I can't believe that I'm actually seeing this.

Steve O'Meara, at Harvard College Observatory, with cutaway to easel move on a starry winter sky.

**[Lower-Third Super]**

Steve O'Meara  
Artist

**Steve O'Meara**

To have a telescope and to see, look beyond the limits of the earth, is one of the greatest things that we can all do. The stars are intangible, something that humans cannot touch, beyond our reach. And it lends itself to wonder.

Rob Gendler, at home; cutaway to Gendler IC443, the Jellyfish nebula.

**[Lower-Third Super]**

Rob Gendler  
Radiologist

**Rob Gendler**

The supreme challenge of astrophotography is that we're imaging exceedingly dim and distant objects and as they move across the sky under very low light conditions. It's an extraordinary technological challenge, but it's extremely fulfilling. And it's very addictive, so I found myself kind of consumed by the hobby.

Michael Koppelman, in his observatory and studio.

**[Lower-Third Super]**

Michael Koppelman  
Musician

**Michael Koppelman**

There's so many stars in the sky that professional astronomers can't look at them all. So chances are when I'm looking at a star, I'm the only one on earth looking at that star at that moment in time. Knowing it's my data and my star, and it's sort of a possessive feeling of being in the right place at the right time, and being the only person on earth paying attention right now to that star.

Debra Fischer, in Pleasanton CA.

**[Lower-Third Super]**

Debra Fischer  
Astrophysicist

**Debra Fischer**

We had just confirmed the presence of a planet orbiting a star. I ran outside, and I found the star, and then my view widened as I took in the sky just filled with stars, and imagined that most of them had planets, maybe with beings looking back at me.

Barbara Wilson at New Mexico Skies; cutaway to easel move on Milky Way photo.

**[Lower-Third Super]**

Barbara Wilson

Teacher

**Barbara Wilson**

The grandeur, absolute grandeur. Getting out under a dark sky. Seeing the Milky Way arch from one horizon to the other, is.... I can't imagine anybody not being totally awed by that kind of a sight.

Exterior, night, Barbara Wilson and TF observing.

**Barbara Wilson**

Isn't that beautiful?

**TF**

Do you ever dream about these sights?

**Barbara Wilson**

Oh, sure. Don't you?

**TF**

Yeah.

**Barbara Wilson**

Yeah.

**TF**

There's something indelible about them.

**Barbara Wilson**

Yeah! You go to sleep and you see stars behind your eyelids.

**3. Deerfield Beach.** Black screen going to blue sky as TF opens the roof to expose the RHO observing deck. LS RHO, the roof rolling off. MS deck: TF removes the telescope caps, etc., to prepare for observing.

**TF (V/O)**

Space and time are kin. When you look at a star a thousand light years from Earth, you're seeing light that's a thousand years old. With a telescope, you can see galaxies whose light is millions of years old... and quasars more than five *billion* light-years away. *Their* light is not only "older than the hills," it's older than planet Earth.

Exterior, dusk, TF at age twelve, wearing Sears Roebuck shirt and jeans that clearly have been washed and ironed hundreds of times. He sets up a pathetic telescope—a black 1.6" refractor mounted on a junked camera tripod.

**TF (V/O)**

I started stargazing in rural Florida in 1956. I was twelve years old. I'd learned from library books that the earth was not *the* world but *a* world, a planet, and that if you had a telescope you could see something of the other planets.

**[Lower-Third Super]**

Deerfield Beach, 1956

Young TF looks to the sky to aim the telescope. Reverse angle, deep-focus LS: Over his shoulder we see the wavering garnet dot of Mars between coastal clouds over the darkening ocean.

**TF (V/O)**

Mars was coming close to Earth, growing brighter in the sky every night, and I wanted to have a look...

He peers at Mars through the telescope. F/X his telescopic view of Mars.

**TF (V/O)**

My first telescope didn't show much, but I could make out the white polar caps and dark "continents" of Mars, and I wanted to see more.

**4. Key Biscayne I: Pacific Rd.** Exterior, late afternoon, the front lawn at 365 Pacific Road, Key Biscayne. MS TF, age seventeen, mowing the lawn in front of his house with a manual mower.

Music: The Marcells singing "Blue Moon":

"Blue moon, you saw me standing alone...."

**TF (V/O)**

I mowed lawns for the next few years to make the payments on a better telescope, and formed an astronomy club with a few friends from high school. On clear nights we'd pack up our telescope, binoculars, and star charts, and set out to explore the dark night skies that adorned Florida in the fifties.

Cut to approaching car—a 1957 Ford Fairlane convertible . Music goes distant, coming from car radio.

**[Lower-Third Super]**

Key Biscayne, 1961

The lawn. TF finishes a row of mowing, hears the car approaching, turns our way. He squints, then smiles. Using his t-shirt to wipe the sweat from his eyes, he walks to the car as it comes to a stop. In it are three 17-year-old high-school students. Kathy is driving. Charles and Betsy are in the back seat.

**Charles**

Hi, Tim!

The four teenagers gather up a 2.4” Unitron telescope and tripod, a pair of 7x35 Bushnell binoculars, a National steel guitar in its case, a folding card table, star charts, and a 1958 Zenith Trans-Oceanic radio. They load the gear into the trunk of the Ford.

MS interior, ’57 Ford, day. TF climbs into the driver’s seat and starts the car. The radio comes on, playing a WQAM station break. ECU Kathy, riding shotgun, instantly punches a radio button with her left big toe, changing the station. From the radio comes Ferlin Husky singing Smokey Rodgers’ “Gone”:

“Since you’ve gone  
The Moon, the Sun, the stars in the sky  
Know the reason why I cry...”

MS the Ford speeding away.

Exterior, golden hour; the kids in the Ford drive by.

**TF (V/O)**

It was a futuristic time, when Americans drove cars that resembled rocket ships....

Thunderous rocket launch, circa 1960.

**TF (V/O)**

...and real rockets were soaring into space from Cape Canaveral, two hundred miles north of us.

Easel shot of rocket trail photo from Key Biscayne.

**TF (V/O)**

One night I took a time-exposure photo of a rocket arcing across the sky, headed for the Moon. It fell short by almost two hundred thousand miles, but you could tell that the planets, which had been alluring sights through a telescope, were becoming *destinations*.

Easel move on TF Echo satellite photo, going to MS the car arriving at the Cape Florida light.

**TF (V/O)**

Watching the Echo One satellite glide overhead, brighter than most stars, we could sense that space began close to home, just a few hundred miles up. The universe wasn’t all that far away. We lived *in* the universe.

MS trunk of Ford closes, revealing Cape Florida lighthouse in the background.

**5. Key Biscayne II: Cape Florida.** Exterior, early evening, the teenagers observing on the beach.

**TF (V/O)**

Back then we had big skies and small telescopes: We couldn't observe much beyond the Moon, the planets, and a few bright star clusters. We had a lot of fun, though, and came to cherish the telescope as an instrument of deliverance, the keys to a vast and spectacular kingdom.

Telescopic POVs of the Moon, Jupiter, and a globular star cluster.

**TF (V/O)**

We marveled at the battered gray Moon. We watched storms larger than Earth churn across the face of Jupiter. We peered into globular star clusters that hang over the galaxy like starry chandeliers.

Long zoom out on Gendler Cone Nebula mosaics: At each stage we see a complex system that turns out to belong to an even larger system.

**TF (V/O)**

Such things were so big, so beautiful, so old or hot or cold as to balloon our sense of the plausible. They produced a sensation that I could not put into words at the time, but later found expressed in Einstein's description of his first encounter with science—that it showed him a way "to free myself from the chains of the 'merely-personal,' from an existence...dominated by wishes, hopes, and primitive feelings.

Continuing the long zoom...

**TF (V/O)**

"Out yonder," said Einstein, "there was this huge world, which exists independently of us human beings and which stands before us like a great, eternal riddle, at least partially accessible to our inspection and thinking. The contemplation of this world beckoned like a liberation."

The kids at a star chart; then, Charles tuning the radio. ECU the radio dial; it goes to WLAC and "Dark Was the Night" comes through.

**TF (V/O)**

At night, when broadcasts from distant radio stations bounced off the ionosphere, we could hear music from far away while looking farther still. That's how we first heard the blues, wafting out of our portable radio with the vicissitudes of what we called the "ozone."



LS exterior, night, the beach. A half dozen teenagers are sitting around a campfire, while a few remain at the telescope in the background. Sitting on its fringe, TF picks out “Dark Was the Night” on the National guitar, using a crude bottleneck slide. He’s playing to himself more than for the others, learning the song. It starts tentatively, then gets stronger.

**TF (V/O)**

I came to think of music and the stars as landmarks to steer by. I didn’t yet know that this was already an old story back when Kepler and Galileo talked about the music of the spheres, but I could sense a resonance between the night sky and the tricky matter of plucking a few strings in just the right way to put human hearts in tune with the cosmos.

Akira Fujii TF of southern stars wheeling across the skies, going to TF playing and glancing up at the starry sky.

Then, move on Akira Fujii/Don Davis sky.

Music out.

**6. Robert Smith.** Exterior, night, Watson Island with the Miami skyline in the background. Robert Smith is showing kids the view through his telescope.

**TF (V/O)**

Nowadays, amateur astronomers have better equipment than they did when I was a boy. The global positioning system on Robert Smith’s telescope lets him find stars too dim to see in the light-polluted skies over Miami. Robert is a sometime football coach who likes to introduce his players to the wonders of the night sky.

**Robert Smith**

Because it's a GPS scope, all you have to do is enter in an object and it takes it to you and stays with it as the Earth rotates...

Exterior, day, Smith at Key Biscayne.

**Robert Smith (V/O)**

When you look at the sky – I mean it sounds hokey -- but it's like a connection to the infinite. Everything looks so tantalizingly close, and when you know how far those things are, you know that you can never get them get to them in your lifetime, but you can see them instantly by looking through an eyepiece. And that's that's amazing to me. And that's the greatest part about actually viewing the sky, to me, is knowing what it is I'm looking at, knowing the process that created it, knowing the life cycle of it, and then realizing just in a general sense how far away it is. And I can still see it. It's incredible.

Smith walking on the beach, Key Biscayne. Then, a clip of Smith scoring a touchdown.

**TF (V/O)**

Robert retired at age twenty nine after establishing himself as the best running back in the history of the Minnesota Vikings. He quit at the peak of his career, saying that having learned how to play the position he no longer found it intellectually stimulating.

Intercut Smith showing views through his telescope to kids on Watson Island.

**Robert Smith**

When I think of science, I don't just think about discovering facts or observing -- I think about it as more of a philosophy, and questioning everything, and examining everything....

It takes diligence not just accepting what you're being told but carefully examining all angles of any issue. That's the great thing about science. It doesn't start with the conclusion and then try to fit the facts in. It takes the facts and you work towards a conclusion.

Robert talking with the kids at Watson Island.

**Robert**

Once you can start seeing individual stars, focus off to the field of view, on the side somewhere, and then you'll be able to see it a little bit better. I think we're good here. Just give it a shot. Anybody, go ahead. Give it a shot. Andromeda's pretty much right in the middle of the field of view.

**Kid**

Oh, okay.

**Robert**

And once you're able to see stars, focus your eye off to one side or the other. And then that hazy patch in the middle is the galaxy itself.

Cut to galaxies: Rob Gendler shots of M81, and IC342 plus HST photo of galaxies NGC2207/IC2163.

**Robert**

I like looking at the galaxies, imagining something or someone being in those galaxies, hundreds of millions of years from now, seeing you... millions of years after you're gone. You know things like that just kind of blow my mind.

**7. Stellafane.** Exterior, day, John Vogt and his daughters unloading and assembling their telescope.

**TF (V/O)**

Some stargazers still build their own telescopes.

A century ago, the thirty-two inch reflecting telescope that John Vogt made in his garage would have ranked among the wonders of the astronomical world. Today it's a transportable instrument that he and his daughters, Patty and Jennifer, can set up in about fifteen minutes.

Overlapping dialog between John and his daughters as they assemble the telescope, then step back to admire it after aiming it into the sky.

**TF (V/O)**

With a telescope this large, you can see bright stars in broad daylight, and by night perceive some of the colors of dim nebulae that otherwise are apparent only in photographs.

Exterior, day: Stellafane observers with their telescopes; the turret telescope and pink clubhouse; TF walking through the crowd.

**TF (V/O)**

For over a century, amateur telescope-makers have met annually here at Stellafane—Latin for “shrine to the stars”—to test their handiwork under the dark skies of rural Vermont.

A judge examines a handmade telescope.

**Judge**

Is that Sonotube, beefed up?

**Telescope Maker**

No, it's sewer pipe, beefed up.

TF with telescope maker Doug Zubenel.

**TF**

These parts look vaguely familiar to me, these plastic parts. Where have I seen these before?

**Doug Zubenel**

You've seen them in the plumbing section of the hardware store.

**TF**

Yeah, that's what I thought! So this is, PVC?

**Doug Zubenel**

PVC. Yeah.

**TF**

So there are two entire telescopes in this one tube—two complete optic paths?

**Doug**

When there is information coming into both eyes there is a forty percent increase in contrast of any object.

**TF**

Forty percent!

**Doug Zubenel**

As opposed to just closing an eye and looking through one telescope.

TF and Jim Podpolucha.

**Jim Podpolucha**

Some people like looking at the moon, some people like looking at the sun, some people like planets, some people like to make mirrors. I kind of like making a whole telescope. It's kind of like my part of it that I like.

**TF**

What's it made of?

**Jim**

It's irrigation pipe.

**TF**

It's irrigation pipe? And then you've got a nice handle here, which is something a lot of telescopes lack. I know a lot of the ones I've used.

**Jim**

Motorcycle handlebars, yeah.

TF moving the telescope...

**TF**

Really? Is that what this is? It does give you that feel, doesn't it, that you can really pilot it.

**Jim**

Yeah.

**TF**

I'll bet you get nice images with that long focus.

Exterior, day, the turret telescope and pink clubhouse, dissolving to archival still photo of same from the same perspective.

**TF (V/O)**

Stellafane was founded in the nineteen twenties by the engineer and explorer Russell Porter.

Easel move on archival photos of Russell Porter in front of the turret telescope, Porter on an arctic expedition, construction of the turret telescope, and completed telescope, dissolving to the same telescope today. Then, WS Stellafane.

**TF (V/O)**

Porter's experiences in the arctic—where he was shipwrecked and stranded for a year—prompted him to construct an igloo-like observatory at Stellafane where he could study the stars from the comfort of a warm, enclosed room. Stellafane retains an egalitarian quality—of seemingly ordinary people making extraordinary things to put themselves and their neighbors in touch with the great beyond.

Telescope makers with their telescopes.

**Normand Fullum**

Hello everyone. My name is Normand Fullum. I live in Hudson, near Montreal. I am a telescope maker as a hobby. Myself, I'm a planetary observer. I love to look at the planets and the moon and when I'm sitting down looking at the rings of Saturn or the cloud bands of Jupiter, thousands and millions of kilometers away, it blows my mind. Every time! I've been observing for twenty-five years and every time I look at the Saturn it takes my breath away. Wow, it's so good!

**Joe Manning**

This is something I put together with leftover cedar strips I had from a canoe project that I made a couple of years ago.

**Dave Kelly**

The corrector lens was ground during the days of Hurricane Gloria in 1985. There was no electric power and there was nothing else to do in the house, and too early to go to bed. It'll rotate 360 degrees around. I've always wanted that in a scope, never had it, and I finally got it. If I want anything else better, I'm just going to make another telescope.

**Ross Sackett**

The light from the sky comes down and hits the concave primary mirror. And then that's focused up towards the eyepiece and there's a flat mirror here that bounces the image out of the focal plane, so out of the axis of the scope, so you're not in the light. And then an eyepiece here that magnifies the image.

**David Clark**

The idea is to turn it at the rate that the earth is turning so that it will follow an object in the sky. And you can do that by just squeezing this bicycle brake handle

and it turns that little wheel, and you can get it to rotate at just the speed that the earth is turning so that the object you're looking at will stand still in the field.

Exterior, dusk, Chris Houghton and sons.

**Chris Houghton**

Let me line it up.

**Son**

Cool.

**Chris**

Should be about there. Want to give it a shot?

**Son**

Sure.

**Chris**

You're looking at Jupiter...

**Son**

Wait what am I looking at?

**Chris**

...and it's about ten times bigger than the earth in diameter but about a thousand times more massive than the earth.

**Son**

Woah!

Chris to camera.

**Chris Houghton**

When you observe celestial objects you can think in the context of what's known about them or you can think in the context of what's not known about them. Right? And I think once you get to the point of thinking in the context of what's not known about them, then it becomes quite interesting.

## II. Vision

**8. Sidewalk Astronomers.** Exterior, night, a San Francisco sidewalk, the city skyline in deep-focus background. Stargazers are inviting passers-by to have a look through their brightly-painted, hand-made telescopes.

**TF (V/O)**

Today more people can get a glimpse of the big picture, thanks to the efforts of groups like the San Francisco Sidewalk Astronomers, who offer city dwellers free views through telescopes they've fashioned on the cheap. They get surprisingly good results making their telescope tubes from salvaged concrete-casting molds, and their light-gathering mirrors from ordinary window glass.

**Sidewalk Astronomer**

And what you're looking at there, that's Jupiter.

Passer-by, looking through the telescope.

**Passer-by**

That's fabulous!

**Sidewalk Astronomer**

You like it, huh?

**Passer-by**

Yeah!

Pan up to sky; dissolve to Francis Kenny Stellafane TL.

**TF (V/O)**

Whether you built, borrow, or buy a telescope, the aim is to *see*—to see nature beyond the range of everyday human experience.

**9. Steve O'Meara's Saturn.** Exterior, Harvard yard; Stephen James O'Meara walking, carrying a drawing case.

**TF (V/O)**

Sometimes a stargazer makes a discovery while observing simply for the love of it. That's what happened to Steve O'Meara, a hawk-eyed observer who taught himself astronomy as a boy.

Akira Fujii photo of ruddy lunar eclipse.

**Stephen James O'Meara**

My first memory, as a child, was of an astronomical experience. I was sitting on my mother's lap and we were looking up at an intensely red lunar eclipse – this brilliant red ball – and I thought this was marvelous, and that color just burned itself into my soul, and I wanted to learn more.

Exterior, Harvard College Observatory, dusk; Steve unlocks the front door, enters.

**TF (V/O)**

Steve learned the night sky so well that Harvard University gave him keys to its observatory when he was fourteen years old.

Interior, Harvard College Observatory dome; Steve climbing the stairs.

**Stephen**

For many years after school I came to the observatory, I observed with the telescope. I went to the library; I studied the books. I met the astronomers; I lived here. The beauty of this observatory is that the directors knew how to observe. This, this is truly a temple to the stars. It really is dedicated to observing one object, all night, perhaps for years. The telescope can be just moved simply by the hand, and once you're seated, you don't want to leave.

Interior, dome, Steve arriving and going up to the observer's chair.

**TF (V/O)**

Steve calls himself "a nineteenth-century observer in the twenty-first century." He likes to use telescopes the way astronomers did before photography was invented—by spending hours looking intently at just one object, and making drawings to record its elusive details

Steve in the chair, going to HD video footage of Saturn by Kenneth Crawford and Michael A. Mayda: The ringed planet wavering in the night air, showing only some of the fleeting details that emerge as we intercut with Steve's drawing.

**Stephen**

The way I observe, as of many years ago, is still visual. There are very fine moments, where everything just becomes pristine and sharp, and it's at those moments that I'm able to pick out the finest detail on a planet.

Steve drawing at the telescope.

**TF (V/O)**

Scrutinizing Saturn through this old telescope, young Steve sometimes saw dark, radial features crossing Saturn's rings, like the spokes on a wheel.

CU Steve's original drawing of the spokes, going to easel moves on Voyager stills showing the spokes.

**Stephen**

When I made my first observations of the spokes, it was deemed impossible.

**TF (V/O)**



Astronomers dismissed them as an optical illusion—until the Voyager space probe reached Saturn and photographed the spokes.

Stephen to camera.

**Stephen**

This was a moment of elation for me. I felt sincere happiness, but at the same time I was thinking back to the scientists of the 18th and 19th centuries... They would look and could only wonder at what they were seeing.

Saturn flyby f/x, moving down and over the rings.

**TF (V/O)**

Saturn's rings are two hundred thousand miles wide and less than half a mile thick. The spokes may consist of dust particles that pick up an electrostatic charge from lightning in Saturn's atmosphere, leaping up off the icy rings like scraps of tissue paper levitating to a comb.

**10. Extrasolar Planets.** Easel move on Hubble Space Telescope (HST) starfield near the center of the Milky Way.

**TF (V/O)**

Our galaxy contains about a *trillion* planets orbiting stars beyond the sun. Nobody has yet managed to see one of these "exoplanets" directly, but astronomers have found indirect evidence of hundreds of them circling nearby stars, and now many amateur astronomers are getting into the hunt.

**Transit Meter F/X:** Paired with ongoing video of Venus transit, a simple, moving line graph showing the sun's brightness as it was before the transit and now on a slightly reduced level.

**TF (V/O)**

Their approach is to look for planets *transiting* distant stars. When Venus passed in front of the Sun on June eighth, two thousand four, it functioned as a miniature solar eclipse, blocking about one per cent of the sun's light. Too subtle to be noticed by the eye, the dimming as can be detected with a telescope and digital camera—not only for the sun but for many other stars as well.

**Starfield F/X:** Moving through space, we pass near stars with protoplanetary disks that are oriented away from our line of sight.

**TF (V/O)**

Planets form from disks, like giant versions of Saturn's rings. They're too small and dim to be seen in the glare of their parent star.

We approach a final star whose planets orbit on a plane seen edge-on, and we stop moving once the star has swollen to the size of the sun in our Venus-transit footage. Add our brightness graph. Initially its line is flat, at maximum brightness. As a large planet passes across the disk, the brightness line drops, as it did for the Venus transit. It remains low until the planet exits the disk, whereupon it returns to normal.

**TF (V/O)**

But when a planet happens to be oriented so that it transits its star as seen from Earth, the slight dimming of the star's light shows up as a light curve. The shape of the curve reveals not only the presence of the exoplanet but how large it is, and how long it takes to orbit its star. An amateur astronomer who first records such a light curve has, in a sense, discovered a new world.

Ron Bissinger, in his back yard.

**Ron Bissinger**

When I saw that little planet go in front of that star I was thinking and looking up in the sky that that planet actually passed in front of that star when Abraham Lincoln was president. To me that's tremendously deep...

Ron opening up his observatory.

**TF (V/O)**

From his home observatory in Pleasanton, California, Ron Bissinger spotted the telltale dimming of a star, a hundred fifty light years from Earth, that signaled the presence of a transiting planet.

Ron on camera, going to he and Deborah in conversation, with cutaway to computer screen during their tracking two-shot.

**Ron Bissinger**

I'm very, very fortunate to be in one of the areas of science where a rank amateur such as myself can sit in a back yard and actually contribute to science. Deborah Fisher and I have been working for several years through this group called Transit Search. Deborah identifies stars that have potential exoplanets. What they don't know is whether the exoplanet is transiting.

Deborah Fischer, going to Ron at work. We see light curves on his computer screen like the ones we just saw in the f/x.

**Deborah Fischer**

There aren't enough professional astronomers to carry out the intense monitoring of stellar brightness that we need on all of our stars. So one of the things that's been wonderful is to have an organized group of amateur astronomers to follow up and look for the transits.

Ron at home.

**Ron**

The more planets we find the more we learn about them. The more we learn about them the more we understand the likelihood that there could be life elsewhere out in the universe....

TF at the RHO telescope, going to TF footage of star HD98618.

**TF (T/C)**

I'm looking at a star that's almost identical to the sun. It's known as HD98618 and it's located in the bowl of the Big Dipper only 126 light years from earth, which is right next door on the galactic scheme of things. Even at that close distance, it's too dim to be seen with the unaided eye. If we lived there and we looked back our way, the sun, too, would be just one star among many seen through the eyepiece of a telescope, and the earth would be too dim to see at all, even with our most powerful telescopes. Kind of makes you wonder just how many other small worlds there are out there, unknown to us, each with a story waiting to be told.

**11. Lives of the Stars.** Jack Newton Sun TL; prominences erupting from the solar surface. Then, Mick Palmeriti Pleiades TL, the star cluster emerging from a blue sky which darkens to black, followed by TF TL shots of Alberio and Vega.

**TF (V/O)**

The Sun and the Milky Way's one hundred billion other stars all have roles to play in the galaxy's history, and one of the pleasures of stargazing is to perceive how each individual object fits into the galactic ecosystem.

Easel shot moving in on a spiral arm in HST shot of the galaxy M101.

**TF (V/O)**

Stars form in the spiral arms of galaxies like ours, and it is mainly the light from the hottest young blue-white stars—which live fast and die young—that sets the arms aglow. These new stars blow away the surrounding dust and gas to announce their birth to the wider world.

Easel shots of Neil Fleming IC1396, Rob Gendler M7 and B72 (the Snake nebula).

**TF (V/O)**

Panning along the Milky Way with binoculars or a low-power telescope, you can see the products of our galaxy's star-making machinery—what the poet John Milton, having interviewed Galileo on the subject, described as "a broad and ample road, whose dust is gold, and pavement stars."

Easel moves on HST Ring Nebula, Gendler Helix, HST IC418, HST Cat's Eye, Gendler Veil Nebula.

**TF (V/O)**

When stars die, much of their material is vented back into the galactic ecosystem, to be recycled into new stars. Space is littered with the departing shells of exhausted stars, each as intricately patterned as a shed snakeskin.

TF Orion Rising TL, dissolving into Gendler Orion Hunter mosaic, moving toward the Orion nebula.

**TF (V/O)**

The nearest spot where you can see new stars being born to replace the old is the Orion nebula, fifteen hundred light years from Earth.

**Orion Nebula F/X:** Cruising into the Orion Nebula, as if aboard a spaceship. (All camera moves are flight-like—akin to those of a small airplane—not computer-like; the idea is “you-are-there” rather than schematic.) A dark cloud obscures our view momentarily; then we break through to see the stars of the Trapezium against glowing green gas and, behind that, the ashen gray, red, and blue light of the larger nebula. We fly through the multiple star system Theta Orionis....

**TF (V/O)**

Thirty light years wide, the Orion nebula harbors enough material to make ten thousand suns. But on the galactic time scale its existence is fleeting as a flower that blossoms but for a day. Soon, having created a bouquet of new stars, the nebula will fade to black.

**12. E. E. Barnard.** Easel move on Axel Mellinger Milky Way

**TF (V/O)**

Time-exposure photography made it possible to discern the anatomy of the Milky Way galaxy from our perspective inside it, rather like Jonah tracing the ribs of the whale that had swallowed him.

Easel shots: William Draper portrait, then Draper's human and Moon photos.

**TF (V/O)**

The word *photography* was coined by an astronomer, and the first man to photograph a human face--John William Draper, whose sister Dorothy posed for him in 1839—also made the first photograph of the moon, later that same year.

Easel shots: Barnard Milky Way photo, archival photos of Barnard as a boy, Barnard with portable photographic wagon.

**TF (V/O)**

Edward Emerson Barnard, whose photographs would reveal the structure of the Milky Way was born into poverty in Nashville during the Civil War and put to work in a photographer's gallery at age eight.

Exterior, twilight, a weary young Barnard—he's about fourteen years old—trudges home from work. Super:

**[Lower-Third Super]**  
Nashville, Tennessee, 1871

**TF (V/O)**

Barnard's boyhood was, he said, "so sad and bitter that even now I cannot look back on it without a shudder."

Barnard pauses at a candle that marks the entrance to his home, lights a candle of his own from it, and takes this candle with him as he sits on a tree stump.

**TF (V/O)**

To "soften the sadness," as he put it, Barnard sought companionship in the night sky. "I got to know the stars so well," he recalled, "that ... I would miss them as I would have missed a friend; and when they again came around, I welcomed them as I would welcome that friend."

Barnard removes three books from his pack. CU their title pages: Two are wretched tracts of little interest, but the third is Thomas Dick's *The Sidereal Heavens*.

**TF (V/O)**

Books were Barnard's salvation, and his life changed when he borrowed a book about astronomy, a subject he'd scarcely known existed.

ECU the book as he comes upon its star charts.

**TF (V/O)**

Comparing the book to the sky, he discovered that others had studied the stars long before him—unheralded shepherds of old, and the ancient Greeks and Arabs naming the stars and linking them to form constellations.

Barnard takes the book and candle to a nearby wagon, reclines to observe the sky.

**TF (V/O)**

"In less than an hour," he recalled, I "had learned the names of my old friends; for there was Vega and the stars in the Cross of Cygnus and Altair and others that I had known from childhood." He would always remember that night as "my first intelligent glimpse into astronomy."

Music cue. From Barnard's POV we see Cygnus and Leo, each first unadorned, then with superimposed constellation figures.

Easel shot of a mature Barnard, dissolving to Gendler photo of IC59.

**TF (V/O)**

Barnard grew up, got married, and enrolled at Vanderbilt University simultaneously as both a student and a teacher, sweeping the skies with a small telescope that friends made him from a broken spyglass they found in the street. He enjoyed stargazing for its own sake, noting that "everything [in the sky] is interesting and numberless objects are beautiful in the extreme."

Barnard observing, in his fur coat.

**TF (V/O)**

But cameras can reveal what the eye cannot see, and he soon devoted himself to astrophotography, shooting pictures while keeping warm in a tattered coat made of reindeer hide.

Easel move on photos from Barnard's *Photographic Atlas of Selected Regions of the Milky Way*.

**TF (V/O)**

Using an old portrait lens, Barnard mapped the Milky Way's glowing reefs of stars, which he said resembled "the billowy clouds of a summer afternoon."

Move on Gendler Horsehead nebula, in B&W.

**TF (V/O)**

At first, Barnard thought the dark regions were gaps between the stars. But his opinion changed when he studied a black cloud in Orion called the Horsehead.

Photo of Williamina Fleming.

**TF (V/O)**

The Horsehead nebula was identified on a photographic plate in eighteen eighty-eight by Williamina Fleming, who was working as a housekeeper for the director of Harvard College Observatory when he recruited her as an astronomy researcher.

Pull back on Gendler Horsehead—B&W going to color—and dissolve to ongoing move back from a spiral arm in HST galaxy NGC 1300 2005 01.tif.

**TF (V/O)**

Bernard and other astrophotographers eventually found that bright patches like the Orion Nebula are just the most conspicuous parts of a much more extensive system of black clouds that run through the galaxy like the roots of a forest.

### **13. Rob Gendler.**

Camera move on Samuel Palmer's "The Comet of 1858" (start on comet, zoom back and truck right to take in onlookers).

#### **TF (V/O)**

Historically, a few painters have tried to depict nature by night, as when Samuel Palmer recorded this view of the great comet of eighteen fifty-eight as seen from Dartmoor, in Devon.

Akira Fujii photo of comet McNaught. Then, Gendler's Andromeda galaxy.

#### **TF (V/O)**

Photography is the medium of choice for modern artists of the night like Akira Fujii, who took this shot of Comet McNaught over Australia in two thousand seven...and Rob Gendler, who photographed the Andromeda galaxy, known as M31, in remarkable detail through a portable telescope from his home in suburban Connecticut.

Exterior, street near Rob Gendler's home in Connecticut; Rob and his son riding bicycles. Then, Rob rolling a telescope out of his garage onto the driveway.

#### **TF (V/O)**

Inspired by the photos he saw at New York's Hayden Planetarium as a boy, Rob started shooting pictures from just outside his garage. His equipment consisted of a small, high-quality telescope, a digital camera, and a laptop computer.

Exterior, the street outside the Gendler home, twilight. MS Rob puts a piece of cloth atop a long pole; LS he drapes it over a nearby streetlight, just as the light sputters into a glow.

#### **TF (V/O)**

Rob reduced local light pollution by shrouding the nearest streetlamp under a barbeque cover.

#### **Rob Gendler**

From an ordinary place, a driveway in a fairly light-polluted suburban location, you can image distant worlds that are, you know, thirty, forty, fifty million light years away—clusters of galaxies in a few minutes. That's what keeps me going in astrophotography, the anticipation of that fresh sense of discovery that comes with every image.

Over-the-shoulder shot of Gendler at his computer, composing a photomontage.

### **Rob**

A big project I did, I set out to do a long focal-length mosaic of M31. I made a chart, I planned out the frames and the exposures and how I was going to proceed with the mosaic. I started at the core of M31 and I added more frames, and more frames, and finally got to this point after about forty frames, about fifty hours of imaging over three months' time. And then I used color data from an older image to make a color version of this long focal-length mosaic of M31.

Francis Kenny TL of stars wheeling over domes at New Mexico Skies. Then, MS his telescope in motion.

### **TF (V/O)**

When he'd done all he could from the suburbs, Rob had a telescope installed at a high-altitude location called New Mexico Skies. He's taken thousands of photographs with his new telescope over the internet, but he's never visited the site nor ever seen his observatory.

### **Rob Gendler**

It's kind of an amazing thing that it can actually be done. To be able to image two thousand miles away from a dark-sky observatory when you're sitting in the comfort of your home.

Gallery of Gendler images: Open cluster M52; globular cluster M15; Rosette, Flaming Star, and Trifid nebulae; and IC2177. Then, galaxies NGC 6946 and IC342, followed by NGC891, Centaurus A, NGC2841, NGC7479, NGC5905, NGC3718, Galactic Group in Leo (NGC 3628, M65, M66).

### **TF (V/O)**

Rob Gendler's telescopic images reveal a universe full of colors that the eye can only dimly perceive. Most of these clouds lie within a few thousand light years. Within a few tens of millions of light years loom hundreds of bright galaxies, some resembling the Milky Way. A spiral galaxy seen edge-on silhouettes the dark disk of dust and gas from which new stars will be made. Farther out we encounter cannibal galaxies, like this giant elliptical swallowing a spiral, in a painless but spectacular consolidation.

Each galaxy is a bright efflorescence on invisible oceans of dark matter, evolving and interacting over time. One such galaxy gave rise to our Sun, the Earth, and us. What else—and who else— have the other galaxies made?

**14. Internet Astronomy.** Easel shot of San Francisco by night, circa 1944; then TF shot from the same spot, B&W going to color, showing increased lights.

[Super over first shot]  
**San Francisco, 1944**



[Super over second shot]  
**San Francisco, 2007**

**TF (V/O)**

Meanwhile, the average human's view of our own galaxy has deteriorated to the point that only one in five persons alive today has ever seen the Milky Way. To avoid light pollution, many astrophotographers now take their photos with remote-controlled telescopes.

LS, a bright red SUV climbs a mountain road in New Mexico, dwarfed by surrounding views that go on forever.

**TF (V/O)**

To find out how quickly can such an internet telescope be set up, we dispatched an experienced crew to New Mexico Skies. Their mission: To establish a working telescope at this amateur enclave in an empty dome equipped only with electricity and a web connection.

Exterior, New Mexico Skies, day. The Bisque brothers pull up in the van, pile out—they're wearing matching outfits—and start unloading gear, moving with the easy efficiency of a practiced crew in action.

**TF (V/O)**

Team Bisque consists of four brothers who taught themselves astronomy and went on to develop systems that enable amateur astronomers to control telescopes from anywhere in the world that offers internet access, whether it's an apartment in Chicago or an internet café in Istanbul.

Interior/exterior, day, a dome at New Mexico Skies: The Bisque brothers open the dome and install the mount.

**TF (V/O)**

The first step is to install a computerized mount that can point at any object in the sky and track it accurately during each time-exposure photograph.

Adding counterweights; narration start near the end of this shot. We see the telescope go by as TF describes the design.

**TF (V/O)**

The telescope is a commercial, off-the-shelf instrument that combines a lens and a mirror to produce a flat image suitable for astrophotography.

Screwing on the CCD camera...

**TF (V/O)**

The digital camera uses an air-cooled imaging chip, to reduce thermal noise. It's good gear, but the whole rig cost no more than the automobile the Bisques brought it up in.

Plugging in cables to the circuit board. Then, the telescope in motion as the Bisques click on the power.

**TF (V/O)**

Once it's hooked up to the internet, the imaging system can be tested from a thousand miles away.

Exterior, Rocky Hill, day: TF hurries through the rain, enters the observatory.

Interior, RHO. As the phone rings TF enters, revealing rain outside. Pulling off his wet rain gear, TF answers the phone. Dialog intercuts between RHO and New Mexico Skies.

**TF**

Hello? Hey, Tom, how you doing?

**Tom Bisque**  
(on the phone)

I think we're good to go. Everything looks like it's in good condition. Go ahead and pick a target.

**TF**

All right, let's see. I'm going to M109—a spiral galaxy; should be bright enough for a short exposure.

The new telescope at New Mexico Skies slews obediently.

**Tom**

She's moving.

**TF**

Now, according to me it's on it now.

**Tom**

From what I can tell of it, yes, it should be there now.

**TF**

Now let me try taking a short exposure here and see—this will be just enough to tell whether it's pointed at the galaxy.

The image appears on TF's monitor.

**TF**

And, yeah, there it is! Hey, that's amazing! How long did it end up taking you, altogether?

**Tom**

Oh, this, I'd say, total, three hours.

**TF**

Well, that's amazing. Thank you! Talk to you later.

Exterior, New Mexico Skies, day: The Bisque brothers, their work done, relax on the deck to reflect.

**Bisque Brothers**

(in conversation)

"It's almost unbelievable that light that's come from, say, 2.5 million light years away is now photons that have been gathered somewhere else in the world that are sitting there on your monitor."

"As soon as we got these systems completed, amateurs were breaking all the records for discovering minor planets and supernovas. And now, it's at the point where lots of science can be done and discoveries will be able to be made by people, by kids sitting at their computer with maybe their parents telling them to hurry up and get to bed. But they can actually collect scientific data, reduce it, and do astronomy. Whereas before this, if you're not a professional astronomer with a big telescope, you're not able to do that."

"This is a very exciting avenue to open some minds, expose them, show them, teach them, and let them feel like even though, you know, I may not have the opportunity, I can pursue this, and I can contribute."

"Absolutely."

"You can't help but change your view of this world when you sit out in the wonderment of space. I mean, it just opens up your mind until you have to start to try to contemplate and grasp what's out there."

### **III: Science**

**15. Gamma Ray Burst. GRB F/X:** A tremulous giant star collapses and explodes. As the light of the explosion and the sound of its rumbling thunder subsides, we see a newly-formed black hole surrounded by a glowing, rotating accretion disk. Two blue-white jets protrude from its poles. Camera POV starts at an angle of about 45 degrees to the disk, elevates toward a plan view.

**TF (V/O)**

How far can a backyard stargazer see? Consider the story of a giant star that exploded in a distant galaxy, long before the Earth was born.

Camera POV reaches plan view and encounters the jet, blasting the screen to white.

**TF (V/O)**

The remains of the star formed a black hole that spat out a jet of high-energy light called gamma rays. Moving at the velocity of light, the gamma-ray burst sped across space for eleven billion years, reaching Earth on April eighteenth, two thousand six.

Dissolve from pure white to: Exterior, dusk, a stark landscape in rural Minnesota. Michael Koppelman opening up his “Starhouse Observatory,” a small white shed topped by a dome.

**TF (V/O)**

A NASA email announcing the event reached the musician and amateur astronomer Michael Koppelman at the little observatory he built in Minnesota for about the cost of a new motorcycle. Michael set out to detect a glint of light from the explosion before it faded from view.

Michael working aiming his telescope. Then, CU an email message on Michael’s computer screen.

**Michael Koppelman**

I’ve been on the e-mail list for Gamma Ray events for a few years. There's a new satellite up there that's detecting them quicker than we ever have. And what's cool is they basically have a system when, when that gamma ray burst goes off, there's an email in my email box some time around sixty seconds afterwards. Getting there fast is the whole thing with a gamma ray burst because they disappear so fast.

One night I was in my little warm room and I saw the email. I was like, "Oh cool, a GRB." I looked up the coordinates and it was like five degrees above the horizon, which is in the trees for me—I mean, right in the weeds; just a little star light was coming through. And it got out of the trees and I was taking pictures and I looked at them and I didn’t see anything. Went back, started looking at the data and once I’d kind of stacked all I had it, I found the glow and I looked it up in the catalogs and double-checked the position. It was right where they said it would be.

Interior, Michael in his home recording studio.

**Michael**

I calculated how far away it is and it was further away than the known universe, like there wasn't enough times since the universe started for the light to get here. I

was like, "Wait, what the heck?" So it turns out you have to fold an relativity and all this stuff. And then when you do you get a distance, and I think it was around eleven billion light years away. I just love to show people this picture to say, you know, this dot, this little pale blue dot, this left eleven billion years ago. You know like the earth wasn't here when that light left. That's pretty amazing that I have a CCD detector that big that caught probably, literally, a couple hundred photons from this thing, you know? It's pretty dang cool.

Koppelman in his studio playing his song "Like Snow."

**Michael**

As a musician you're searching for this sort of messy perfection of it all fitting together right, like it adds up to zero at the end. No rounding errors, no nothing: It's perfect. Like Einstein said about physics, there is a perfection when you get to the right answer. I mean  $E$  equals  $mc$  squared—three letters. Three letters and a number and it tells us so much about the world, you know? And yet we get so wrapped up in the things we get wrapped up in that we don't realize that really the universe is so big we can't really explain or understand it.

Michael on camera, with music continuing under...

**Michael (T/C)**

The questions never end. They start at the beginning of the universe and they end at the end of the universe and it's all this complexity in between. So I sort of finally found something that I can never exhaust, you know, as hard as I try.

**16. William Herschel.** MS exterior, night, an exhausted William Herschel play oboe by a campfire.

**TF (V/O)**

Michael Koppelman's capturing of ancient light followed in the footsteps of another musician turned amateur astronomer, William Herschel, who probed deep space two centuries earlier.

**TF (V/O)**

As a teenager Herschel played oboe in his father's unit, the Hanoverian Foot Guards' band, but deserted on his father's orders when they came under attack by the French during the Seven Years' War—, on the twenty-sixth of July, seventeen fifty seven.

Herschel fleeing across the countryside.

Bath rooftops at dawn—misty, eighteenth century. Music up to match and incorporate Herschel's oboe solo.

**TF (V/O)**

Herschel fled to England and settled in the fashionable town of Bath, where he became a successful conductor and composer.

Table move of Herschel's working at his desk. He stops while working on a music score, opens a copy of Jamie Ferguson's *Astronomy Explained*.

**TF (V/O)**

He was awakened to the wonders of the night sky by reading a popular book called *Astronomy Explained*, by Jamie Ferguson, who had learned the stars as a shepherd boy tending his flocks.

Easel shot of Herschel telescopes.

**TF (V/O)**

He set to work making his telescopes and eyepieces by hand, from mahogany and cocus, the woods used in oboes he had played as a boy. "I determined to accept nothing on faith," he said, "but to see [everything] with my own eyes."

Herschel drawings of nebulae, going to modern photos of each; then, Herschel portrait.

**TF (V/O)**

Observing for decades on virtually every clear night, Herschel sketched thousands of spiral "nebulae." He thought they might be new solar systems forming and he didn't live long enough to learn that each spiral was actually a galaxy of stars, millions of light years away. But he was more justified than he realized when he said, toward the end of his life, "I have looked farther into space than ever [a] human being did before me."

CU Herschel's observing logbooks.

**17. Barbara Wilson.** Barbara at New Mexico Skies.**Barbara Wilson (V/O going to T/C)**

I got hold of copies of William Herschel's work, and amazed at what he was able to see. He made some mistakes, but he also made some very intuitive guesses about the structure of the universe, the Milky Way...

Barbara using a telescope.

**TF (V/O)**

Barbara Wilson is a visual athlete who was inspired by Herschel's example to seek out dim and distant objects that others assumed they could never see.

Barbara and TF observing at New Mexico Skies.

**TF**

Hey Barbara, what are you looking at?

**Barbara**

A little open cluster, in the Milky Way—NGC 1907.

View of NGC 1907 through the telescope.

**TF**

Oh, yeah, it's quite . . . And this is one of the objects that Herschel observed, in his great "sweeps" of the galaxy?

**Barbara**

Yes, this is one of his open clusters that he picked up that other people didn't...

**TF (V/O)**

Barbara *interrogates* the night sky,

HST M87 with jet.

**TF (V/O)**

She's shown me things that few have *ever* seen, like the plasma jet protruding from a black hole at the center of a galaxy in Virgo...

HST gravitational lens 2003 01...

**TF (V/O)**

We once *tried*, without success, to see a gravitational lens—the slivered images of distant galaxies, magnified by the warped space surrounding galaxies closer to home.

Barbara t/c, going to long pull back on HST HEIC 0619.

**Barbara**

When you look deep into the cosmos and you realize that these objects may no longer exist, that the light has traveled across the eons of the universe and into your eye, it gives you a different perspective on life, in general. If people would just you know spend some time looking out, looking up, and it's just beautiful. Just beautiful.

**18. Andromeda.** Exterior, Rocky Hill Observatory observing floor, night. CU computer-screen star chart as TF slews the telescope. As the telescope slews to a stop, TF sights along it.

**TF (V/O)**

You could spend many lifetimes exploring our home galaxy, but its neighbor, the Andromeda galaxy, just over two million light years from Earth, proffers a particularly alluring view of light dating from the dawn of the human species.

**Andromeda F/X:** Moving to the Andromeda galaxy, cruising over its disk and through the halo of the central bulge—a spray of golden stars.

**TF (V/O)**

The Andromeda galaxy happens to be tilted in such a way that starlight reaching us from its far side is a hundred thousand years older than the light from its near side. When light from the far side began its long journey to our eyes, the first true humans did not yet exist. By the time the near-side light started out, they did. To see a galaxy is to *see* time.

**19. The Sands of Spacetime.** Exterior, night, TF TL of stars rising over RHO. Distant sound of Patrick playing and singing, Blind Willie McTell’s “Mama, ‘Tain’t Long fo’ Day”:

“Wake up Mama, don’t you sleep so hard  
Wake up Mama, don’t you sleep so hard  
For these old blues [are] walking all over your yard.”

MS, observing floor at Rocky Hill Observatory. The telescope, carrying out an automatic observing run, finishes an exposure—which shows up on the computer screen in the background—and slews to another nearby position to start a new exposure. Music, still O/S, is somewhat louder.

“Blues grabbed me at midnight, didn’t turn me loose till day  
Blues grabbed me at midnight, didn’t turn me loose till day  
Didn’t have no mama to drive these blues away.”

**TF (V/O)**

Today’s automated telescopes can photograph hundreds of objects on their own, without human intervention—leaving stargazers free to meditate anew on time, music, and the stars.

CU the screen: Image of a galaxy comes in. Intercut more shots of the telescope slewing with CU of different galaxies appearing on the screen. CU screen: New galaxies are appearing every couple of seconds, at ever-increasing distances, one after another. On last verse of song, cut to:

Interior, night, RHO downstairs; Patrick Ferris is playing and singing as TF listens:

**Patrick**  
(singing)

Big star fallin’, mama t’aint long fo’ day



Big star fallin', mama t'aint long fo' day  
 Maybe the sunshine will drive these blues away

**TF**

That's nice. Whose song is that?

**Patrick Ferris**

Blind Willie McTell.

**TF**

Nineteen twenties?

**Patrick**

Nineteen twenty-seven.

**TF**

Remember that Blind Willie Johnson song, "Dark Was the Night"? NASA put it on Voyager, shot it right out of the solar system?

TF plays a the opening bars of "Dark Was the Night" but is interrupted by sound of a computer alarm O/S.

**TF**

Sounds like we got our galaxy images for the night. Let's go check 'em out.

They head upstairs.

Exterior, predawn, RHO observing floor. Patrick and TF emerge from the stairs, check the sky.

**TF**

It's not bright yet, but it's getting there. Want to take a look at the Whirlpool galaxy, while there's still time?

**Patrick**

Sure. I'll grab an eyepiece.

TF removes the camera from the telescope and puts it away while Patrick fetches an eyepiece from the wooden optics case.

**TF**

You know, using a telescope is a bit like playing a musical instrument: What you get out of it depends on how much you put into it.

Patrick hands the eyepiece to TF, who puts it in the telescope and focuses it; Patrick has a look.

Jack Newton Whirlpool galaxy TL.

**TF**

When you look at this galaxy, try looking a little *away* from it—what they call “averted vision.”

CU Patrick at the eyepiece, intercutting with view of the galaxy through the telescope.

**Patrick**

Oh, yeah. I can see the spiral arms. How far away is it?

**TF**

Thirty some-odd million light-years.

**Patrick**

After the dinosaurs.

**TF**

That’s right. Around the time of the first bears. Early whales. Long before human beings.

Observatory deck; Patrick looks east at the brightening sky. Then, reddening dawn sky.

**Patrick**

Here comes the Sun.

MS Patrick and TF on the deck.

**TF**

(Off glancing toward the east)

“The fireplace of the world,” as Johannes Kepler called it. You know, Kepler put his reputation on the line to defend Galileo’s observations against the professors and priests who claimed that telescopes only produced optical illusions.

(Pausing to look at the RHO telescope)

Kepler even wrote an ode to the telescope: “O you much-knowing tube, more valuable than any scepter!”

High angle on observatory roof closing, on sound of observatory roof rolling shut. Start title theme, backtimed to end at conclusion of credit roll.

**20. Sunrise.** RHO exterior, dawn. Patrick and TF emerge through the front door, walk up the path.

**Patrick**

So why did people refuse to look through Galileo’s telescope?

**TF**

Dogma. Not just religious dogma, but the dogmatic habit of mind—the idea that everything worth knowing can be found in the pages of some allegedly infallible book. Galileo studied what he called “the book of nature,” and in the four centuries since, we’ve turned maybe the first few pages of that book. All the rest of it’s still out there, waiting to be discovered. There’s virtually no limit to what we can learn.

Walking past the pond...

**Patrick**

Sounds too good to be true.

**TF**

Well, you know what Michael Faraday said about that.

**Patrick**

(recalling)

The guy who invented the electric motor?

**TF**

That’s him! Blacksmith’s son; taught himself science, found the connection between light and magnetism; set the stage for Einstein’s uniting of space and time.

**Patrick**

What would Faraday have thought about that?

Wide angle on the pond; the figures are tiny now...

**TF**

Within the laws of nature, he said, “*nothing* is too wonderful to be true.”

Wide-angle locked camera shot on pond. Theme music up.

Learning to See in the Dark. CVPR 2018 <http://cchen156.web.engr.illinois.edu> python rawpy tensorflow. The file lists are provided. In each row, there are a short-exposed image path, the corresponding long-exposed image path, camera ISO and F number. Note that multiple short-exposed images may correspond to the same long-exposed image. The file name contains the image information. For example, in "10019\_00\_0.033s.RAF", the first digit "1" means it is from the test set ("0" for training set and "2" for validation set); "0019" is the image ID; the following "00" is the number in the sequence/burst; "0.033s" is the exposure time