A Pulsar Discovery

Imagine the situation in the astronomy community in 1968. A graduate student doing some ordinary measurements of radio stars has come across a phenomenon that is truly extraordinary. A star is blinking on and off ten times per second. How could this be? How could a star turn its radio emissions on and off so rapidly? In any star there exists a fire of incredible temperature—hotter than the largest furnace on earth. How could it turn on, then off, over and over again?

MORRISON

Astronomers all over the world begin to look for other "pulsars," and sure enough, such objects are everywhere in the skies. In the year following the initial discovery, 27 pulsars are discovered. All, however, can only be detected by their radio waves. These radio sources emit relatively small amounts of energy.

A race begins. Would anyone locate a pulsar which emitted so much energy that it could be observed with ordinary light? If an optical pulsar could be found, it would be a major help in solving the "pulsar problem." Some of the most famous astronomers enter the race, equipped with the world's largest telescopes. The winners, however, are two unknown young scientists who had only recently met. What's more, they had never before operated a telescope. This is their story.

Don't try to learn about pulsars from this exhibit. Try to learn about science itself, and the people who practice science. Pay attention to the procedures, not the particular facts. Listen carefully and you will hear more than the excitement of a moment of discovery. You will hear people who want the discovery to be real, but who do not hide from the possibility that it is all a mistake.

In this exhibit, John Cocke and Michael Disney describe the events leading up to their discovery.

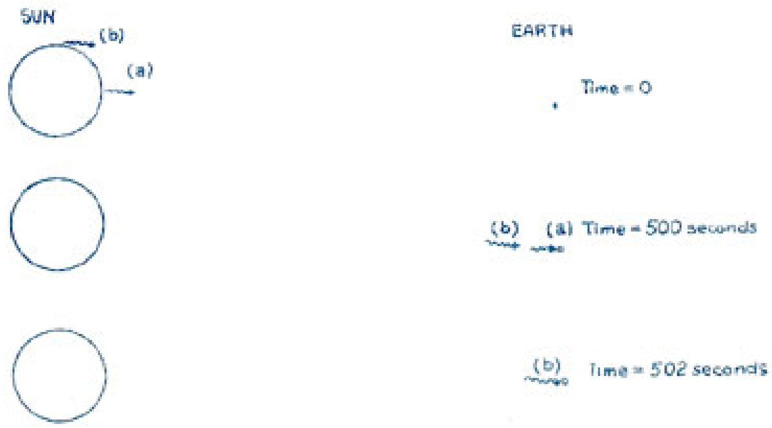
Philip Morrison, Professor of Physics at the Massachusetts Institute of Technology, gives background information and his own personal recollections. But that is not all. Incredible as it may seem, a tape recorder installed to keep track of the data also recorded all the conversation on the night of the discovery. The scientists only wanted to note the steps in their observations, but in fact the microphone heard everything they said. As you listen to excerpts of that audio, you will witness an actual discovery. You will share the excitement of this historic evening.

We begin with Philip Morrison...

MORRISON: In '68 January or February of that year—I remember myself meeting at the airport a friend who just returned from Great Britain, an astronomer. And he said, "Have you heard the latest?" And I said, "Well, what's that?" He said, "They've got something that pulses every second—a stellar signal that pulses every second." I said, "Oh, that couldn't be true!" "Yes," he said, "it's absolutely true. They announced it recently. They've studied it for about five or six months. It's extraordinary."

That was the announcement of the discovery of what we now call a pulsar, which was announced by the group at Cambridge University in England—the first to discover it—very early in the winter of 1968 as I recall, about January or February. Indeed, the graduate student, Jocelyn Bell, had first picked up the first pulsar several months before. But in Cambridge, they sat on these results for several months, because the whole thing was so extraordinary and so unexpected, that they didn't want to release it until they had a chance to confirm it.

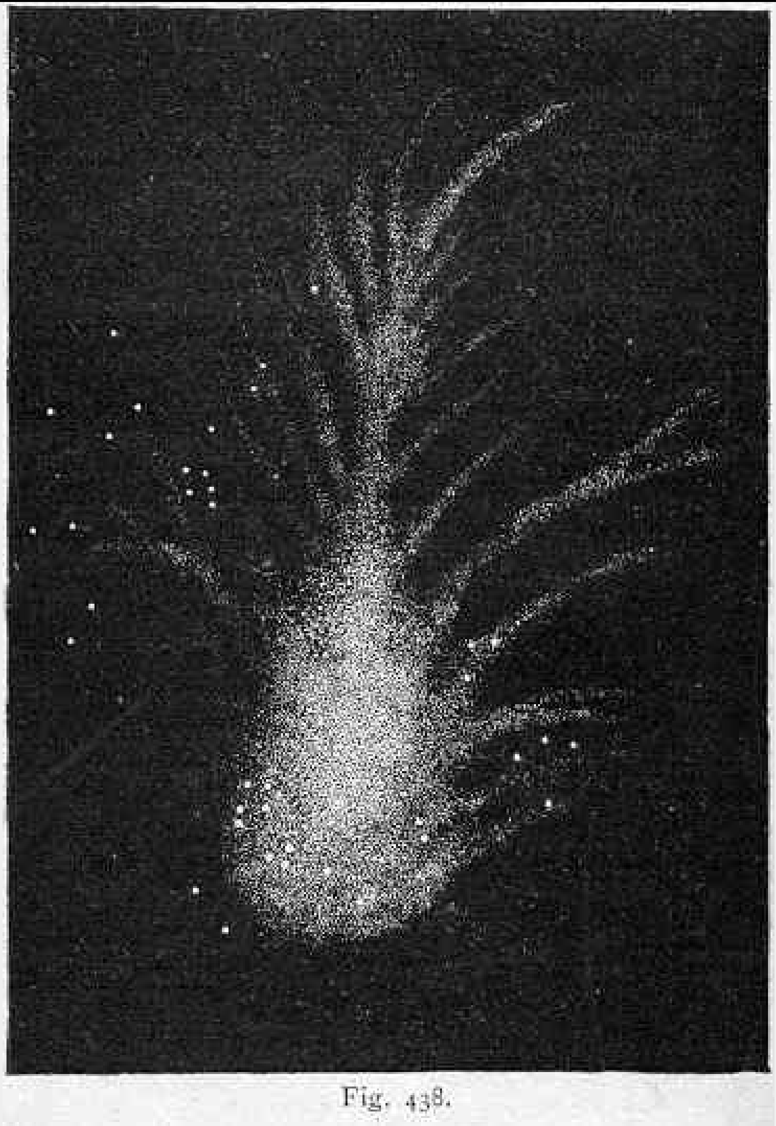
The reason of course is quite simple. We think of the stars quite sensibly as being— well we say the fixed stars—as being eternal, long-lived, everlasting. And even though we know that's not 100% true—that the star sometimes explodes a little bit, making a nova, or explodes disruptively flinging itself apart entirely, making a supernova—still those are not really fast events from a human time scale. If they take a few seconds or a day, that would be remarkable for a star. You don't see much happening on the stars in a second.



And yet these people heard unmistakably from some middle distant stars, radio signals that went tick, tick, tick, tick, like that—very sharp ticks—lasting a fraction of a second, repeated every half second or second or so. It's interesting to hear the audio recording—the tape recording—of the radio astronomer's clicks when he records such a pulsar. So we knew something remarkable was going on and people gave it a name, pulsar.

By late summer of that same year—of course the whole astronomical community was galvanized in looking at it—and everybody with a radio telescope began looking in radio waves for pulsars, here, there and everywhere because it was clear they were there for the finding. And the number discovered grew by leaps and bounds. I don't remember how many, but certainly there were dozens by the end of the year.

This is a story from the vintage year of 1968.



Drawing of the Crab Nebula by William Parsons, the Third Earl of Rosse, made about 1844.

Click here for the sound of a pulsar (168K download).

(From "The Sounds of Pulsars")

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To play audio files (ranging in size between 40-800K) click on this icon:

COCKE: Disney's a very outgoing type, and as it turned out, we both arrived in Tucson about the same time, in the middle of August, in '68, I guess that was. We were both staying at the same motel before—you know, while we were looking for a more permanent place to live.


COCKE

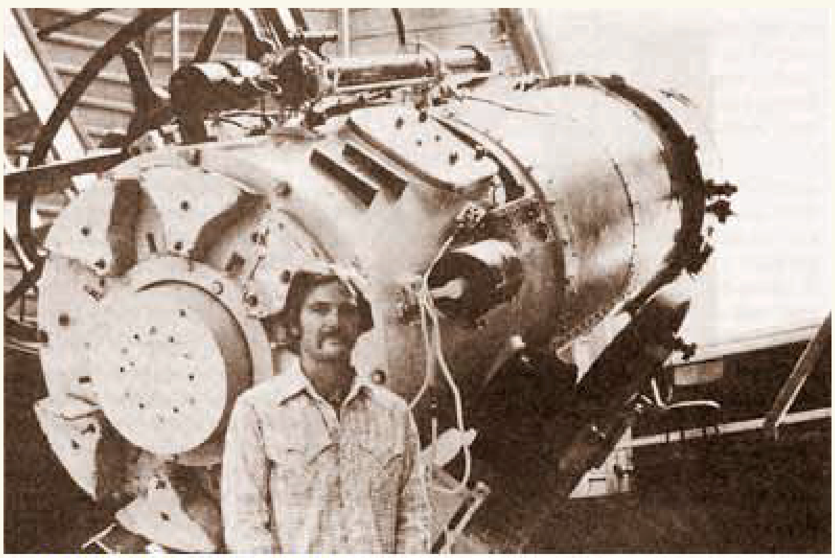
And so as I recall, my wife and I met Disney and his wife at the swimming pool, at the motel, and started talking about what we were doing in Tucson, and it turned out that we were both astronomers and were both going to be at Steward Observatory.

DISNEY: Well, I felt completely out of my depth there, and there were all these clever people rushing up and down mountains and measuring real stars and things, and telescopes, and I was a pure theoretical astronomer and I didn't really know what a real telescope looked like.


DISNEY

COCKE: We had both thought that it would be a good thing to get experience at the telescope, just as a thing in itself. And we had also thought from time to time about doing something really relative to pulsars. Everyone was interested in them, I suppose, when they were discovered. It immediately became a very, very popular thing to try and work on. What we proposed to do first was to search known white dwarfs for optical pulsations.

DISNEY: Well, the first thing we did was to apply for some observing time, which much to our amazement we got a little bit of: thus, 3 or 4 nights on a rather small telescope—on the 36" telescope at Steward. These types of experiments were usually done by people with colossal telescopes and all sorts of modern equipment. And in fact we would never have got time, I don't think—being complete novices—on a decent large telescope. So it was kind of fortunate for us that we did have a small telescope. So they said, "Oh well, they'll only waste two or three nights on a small telescope anyway." Well, it was very funny, really, because they thought, first of all, it was a huge joke that two theoreticians were going to observe anyway. I mean, it's a kind of stock joke they have in all observatories that anybody who uses a pen and pencil and his brain and mathematics is totally hopeless with his fingers and is bound to put his foot through or his fingers through all the equipment and so on and can't observe. So there were jokes all around the Observatory which we took in fairly good spirit, because we kind of agreed with everybody.



COCKE AT THE 36" TELESCOPE

But a couple of things completely changed the whole outlook of what we were doing. First of all, a paper arrived from Australia of an English astronomer out there called Mike Lodge who discovered another pulsar which was near a supernova remnant. Now, it'd been predicted all along that the place you would find a neutron star would be close to or inside a supernova remnant. And more importantly, this new pulsar that Mike Lodge had discovered, was a very, very fast one. It pulsed on and off 11 times a second.

University of Arizona's 36" telesciope at Kitt Peak

MORRISON: That made everyone realize that you couldn't turn a whole star's radio emission on and off that fast, no matter what you did. And the only answer—and there was an answer available and everyone began to believe that then—was that the star that was doing the radio pulsing—that the pulsar must be a very tiny star indeed. We knew of two small kinds of stars. Let me call them condensed stars—that's what we tend to call them. There is a class of star called a white dwarf. White dwarf matter is the most condensed form of normal matter with nuclei and electrons that we know about. And if you make a star out of white dwarf matter, the star shrinks down to the size of a planet a few thousand miles across. And so such a star might somehow emit pulses maybe a second or a half-second or just possibly a tenth of a second but hardly very sharp ones that were sharp compared to the tenth of a second spacing. And so the possibility that a white dwarf was the source of the pulsars that we heard was still—I think, as I recall it—I still thought it was an open question, but it didn't look very good.

Because of course there is another kind of matter, and another kind of condensed star that goes with it, and that is what people call a neutron star. It is one big nucleus. The electrons have disappeared entirely or almost entirely, and in their place is nothing but nuclear matter. But not a single nucleus, but nuclei fused together, so you have one nucleus as big—well, as massive as the sun, but of course enormously condensed—little condensed objects as massive as maybe one-half or one-fifth or one-tenth the star they started from. But only as big—no longer as big as a star or as big as a planet—but only as big as a mountain. And of course, spinning, because everything spins. And as you know, as you make something smaller it tends to spin more and more rapidly. And now that thing—you see it only takes light a ten-thousandth of a second to cross that star—and so that can be expected to make quick pulses.

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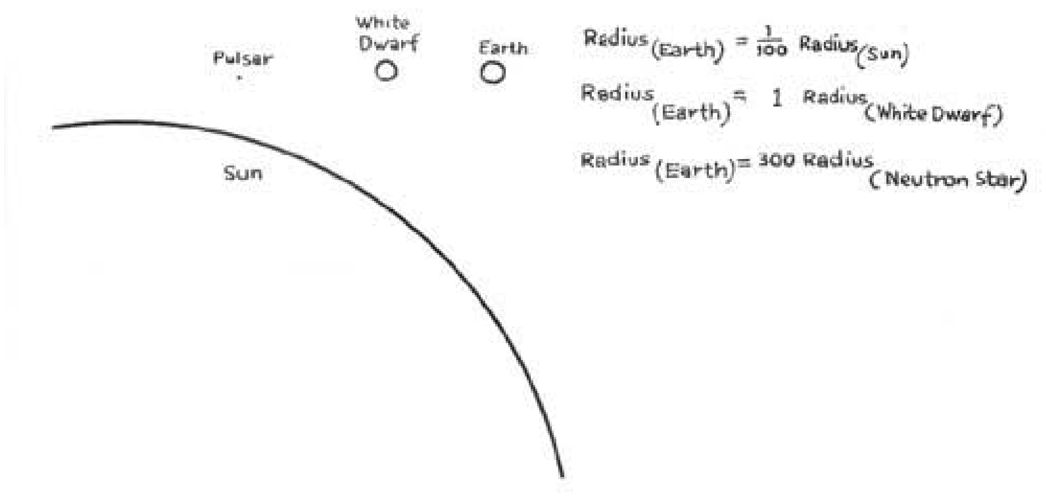

COCKE: It pretty well convinced people and convinced us, too, that pulsars were indeed not white dwarfs but rather neutron stars. And then finally—I think maybe a month later—the discovery of the radio pulses from the general direction of the Crab Nebula was announced.

DISNEY: What was more, they discovered that this pulsar was pulsing about 30 times a second. So, it was even faster than the one they discovered in Australia.

COCKE: People were talking about it, wondering what in the world these things were, and why. And everyone was being rather astounded at the apparent connection with the Crab Nebula.

DISNEY: And the reason why everybody was excited was because it looked as if pulsars were the first actual sight of something which people had been prognosticating for thirty years—namely neutron stars. That's to say, objects which are made out of incredibly dense material—so dense that the usual analogy is that a teaspoonful of it would weigh a billion tons.

COCKE: Well, this was what really pinned it down for us, because what we then did was, we went to do a rather more thorough study of the Crab Nebula ourselves to see if we could pinpoint where, within the Nebula, the pulsar might be.

DISNEY: Radio telescopes don't have very good directional resolution. And, in fact, the uncertainty was so great that it could have been literally thousands of stars. So before we could look for a particular place, we got to make some guess—do some detective work as to where we should look. And, it seemed the logical place to start off was to look right in the center of the Nebula. I mean—what's supposed to happen in a supernova explosion is that once upon a time it was a star, and then the center of it collapsed to this neutron star and the outside is completely blown off.

Crab Nebula; note that the picture alternates between two images made nearly 30 years apart, which illustrates the expansion of the Nebula with time.

COCKE: As it turns out, at the center of the Crab Nebula, there's a double star. And Baade's Star is the South Preceding component of that double star, and precedes it in its motion across the sky as the Earth turns. And we found that Baade's Star was indeed a very peculiar object in its own right. It had a continuous spectrum in the optical, and no absorption of emission lines of any sort, and had been presumed by Baade and by Minkowski to be the core left over from the supernova explosion that produced the Crab Nebula. So, what we did was—we said, "Well, why don't we make some observations of Baade's Star itself, to see whether or not it might be pulsing at the same period that the radio pulsar had been discovered to pulse at."

I remember asking a couple of very well known, very prominent astrophysicists, asking them whether or not they felt that the pulsar would ever be detected optically. And they all were very, very negative about it, and they said, "Oh, no, I doubt very much that will ever happen."

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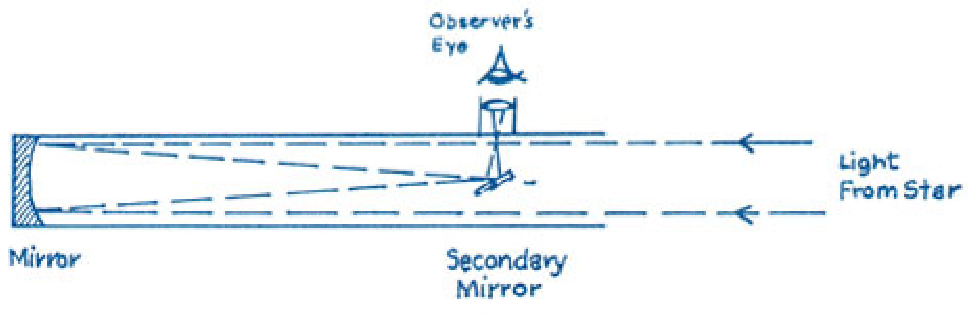
DISNEY: In fact, looking for pulsars in the optical is rather a complicated experiment, requires all sorts of equipment which we'd no idea about at the time. And Ray Weymann, who is one of the senior scientists at the Observatory, suggested to us that there was an ideal piece of equipment already in the Observatory belonging to Don Taylor. Now, Don Taylor is a bit of an electronic wizard. This little piece of equipment he had—which is a kind of a miniature computer—you can plug the signals in from the telescope onto it at once. And you can look at the screen and you can see all these little dots which show the signals coming in—the lights coming in. And you can watch it climbing up the screen, and, if it's pulsing, you'll see a little wave developing in the middle of the screen.

MORRISON: They knew the timing from the radio work—33.2 milliseconds, or something of the sort. Knowing that number was indispensable. They superposed the light that was coming—the weak light that was coming—by cutting it every 33 milliseconds and putting the light, folding it up every 33 milliseconds—folding it up and folding it up electronically—so it added up and the pulse slowly grew out of the noise. Because in a single pulse, their telescope didn't get enough photons in to make a smooth curve at all. It just got a jagged noisy appearance. It was just this superposition that made it possible.

DISNEY: So we decided to go in with Don Taylor, which was a hell of a good thing. We went up the mountain one night and took a photograph of the Crab Nebula so that we could pinpoint all these little stars that were in the center of it. They're far too faint for us to see with a tiny little telescope like a 36" telescope. So what we were going to have to do was to take a photograph on which you can see these stars; and then using a sort of automatic guider, it's called—it's a thing for setting the telescope off from a star that you can see to a piece of sky where the stars are too faint to see—you can do it automatically by steering the telescope to the place you want.

COCKE: We all went. All three of us went up to Kitt Peak, and Don Taylor and Bob McCallister, who is the night assistant, worked around with the electronics, I remember, while Disney and I turned our attention to the telescope itself.

DISNEY: The Observatory in Arizona is on a very remote mountain peak inside an Indian reservation. And up on the top of the mountain you live in a little dormitory where you cook for yourself. So we had to get all our food, load all the equipment into the car at the University, and then drive out across the desert. And then ride up the mountain—this very spectacular winding road up the side of the mountain—to the very top where the Observatory is situated. And then, Don, who was keeping very close guard on all his equipment in case we did anything with it, carried it all up—we helped him—up into the dome. I should say, the telescope we were using was an old fashioned Newtonian telescope, where the light comes down and you have to work at the top end of it. So you climb up right underneath the dome, so you're working right up against the stars as it were, looking down inside the telescope—the top-end of the telescope. And all our equipment was up on the little mezzanine floor, which was up beside the top of the telescope.



Newtonian Reflector

Well, we got it all set up and we cooked ourselves a meal and then we went out into the dome. I didn't realize, to begin with, how cold it could be observing. So there I was sitting around in a sports jacket and freezing to death and regretting it like mad. It's very, very, very dark inside—of course, as it has to be—and so you lunge around with a torch [flashlight] in your hand. And of course you're not supposed to turn on the torch during the critical moments, because even the smallest piece of torch light can ruin the observations, ruin the observer's eyesight, and generally foul things up. So there you are walking around up on this high platform—with no guard rail on it, I might say—hoping to God you're not going to step off the edge, and hoping that you're not going to bang your head on all the sharp projections the telescope has on it.

And then, Don got all his electronics ticking over, and all the dials were reading the right thing. The lights were flashing and the voltages were all correct. And what we were doing was trying to learn to set the telescope on the right place in the Crab—that's the very center of it where Baade's Star was. And so we spent the whole of the first night making a bit of a hash of this.

COCKE: Well, it was very exciting, but I was quite nervous, and I had the distinct feeling of wondering, really, what in the hell I was doing there. The second night we actually did some observations.

DISNEY: John and I were doing two things: looking through the telescope measuring off distances, and calculating exactly where we were in the Nebula. And about 11 o'clock that night, I think, everything was going—we were set on the central object, we were all quite excited, and we were sure everything was all right. And then we switched it all on and watched this screen with all these little dots climbing up it. What we were looking for, was that several of these dots should race out in front of the others, because this would tell us it was a pulse of light coming from this pulsar.

Pcture of 36" telescope dome at Kitt Peak, taken in Winter, where the first official optical pulsar was discovered. The telescope is the one on the left.

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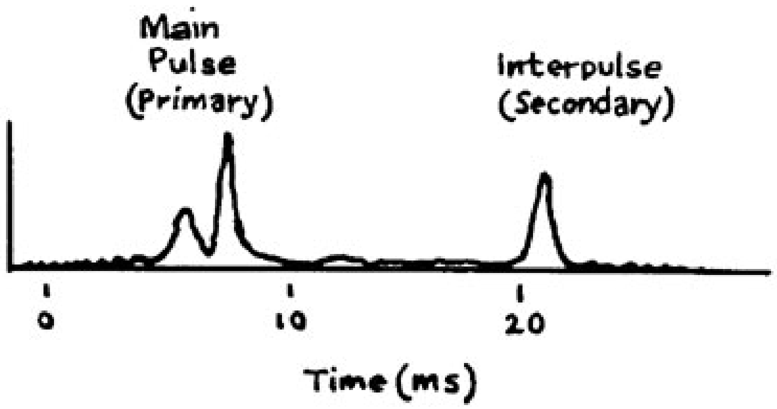


COCKE: The Crab pulsar has two pulses in it—a big one, the primary one, and a shorter, fatter, secondary pulse. They come more or less spaced evenly between each other. The radio pulse looks like that, and so we had felt probably that's what the optical pulse would look like too.

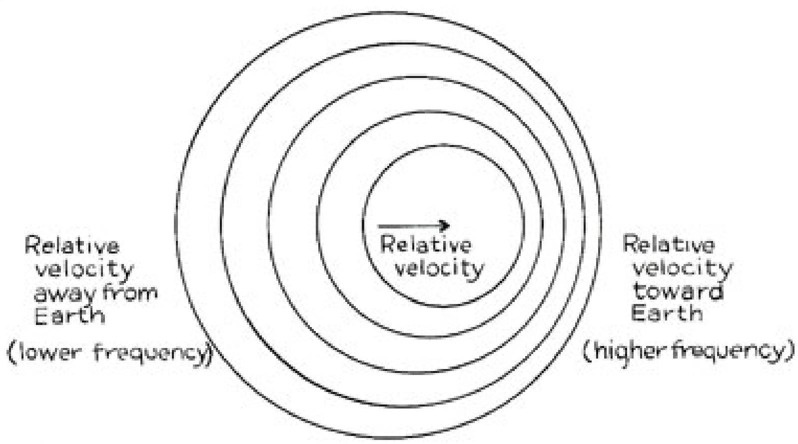
DISNEY: Well, for a few moments we were quite excited because we really thought that Baade's Star would be the place to find this pulsar. And, in fact, there was no sign of a pulsar at all, so we were all a little bit let down. And Don decided that he had to go back to the University in Tucson. So, the next day he showed us how to work all the equipment. By now we were pretty familiar with it and realized it really wasn't as terrifying as it all looked at first. And so on the third night, John and I observed on our own. We weren't exactly on our own at all, in fact, we had Bob McCallister, you know, prevented us from making a lot of mistakes, and was actually working some of the electronic equipment for us. We repeated essentially what we had done the previous night, and we didn't find any pulsar at all.

COCKE: I do remember feeling pretty discouraged about the whole thing. Of course, we weren't very optimistic to begin with—or at least, I wasn't. And so, I wasn't feeling as discouraged as I would have if I'd had really high hopes.

DISNEY: We had two more nights to go, and then it turned out they were both cloudy, so there was nothing we could do anyway. And then it just happened. The person who was observing after us—Bill Tifft, his name was—he said that his wife was sick and he couldn't come observing—there were a couple of more days we could have. So we decided well, anyway, we might as well use them.

COCKE: The next two days then were spent more or less walking around the mountain under the clouds, trying to think what to do next. Until then I remembered that it would probably be a good thing to go and re-check the calculations that I did.

DISNEY: And when I came up the mountain in the evening of the next day, John and I cooked dinner and he told me something very interesting. Because the earth is moving around the sun, the actual period—the apparent period—of these pulses from the pulsar changes as the earth is moving either towards the pulsar or away from it. When the earth is moving towards the pulsar, the pulse is going to appear to come more quickly than they would normally. And when we're moving away, they'd rather come more slowly. It's like a train coming towards you. The note drops, it's what's called the Doppler effect. And so we'd had to make corrections to the known period, the radio period of the pulse.



And John said, "Look," he said, "we made a mistake doing this." And so we sat down over the kitchen table in the Observatory and spent an hour going over all these calculations again. And, by Jove, that's exactly what we had done—we'd made an error in making this correction. So we hadn't really looked for the pulsar at all because our timing gear had been set at the wrong period.

COCKE: It was an error of 2 PI, actually. I had mistakenly approximated the sine of an angle by the angle divided by 2 PI. Well, I felt like a real idiot. And I was a bit dumbfounded, because now, having gone through all that time to make these observations, now I was faced with the prospect of having to go back and do the whole darned thing over again—again with the feeling that it was utterly futile anyway, and that, really, the whole thing was a waste of time.

DISNEY: So Bob McCallister, the night assistant, John Cocke and I went up into the dome, reset the timing gear at the new period that we'd worked out, and then we sat back to go right through the whole procedure again starting to look at Baade's Star, the South Preceding star.

On the night of January 15, 1969—at Steward Observatory—John Cocke, Michael Disney and Bob McCallister adjusted the timing gear and set the 36-inch telescope on Baade's Star. They were unaware that while they were observing, they were also tape recording their own voices. On this part of the audio, you will hear portions of that candid recording (in italics on this script) as well as more excerpts from the interviews with John Cocke and Michael Disney and closing remarks by Philip Morrison.

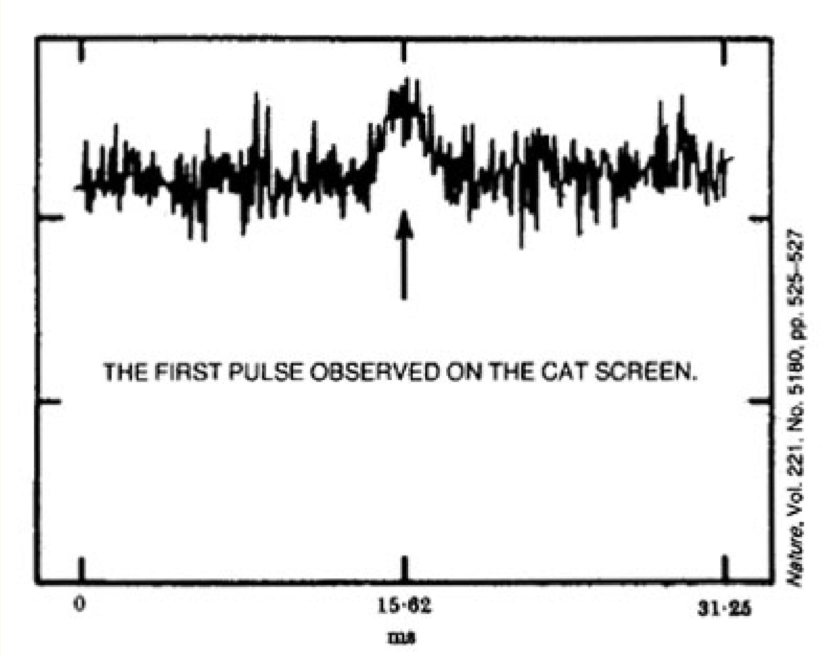
DISNEY: We all crouched in front of the telescope, or at least in front of the electronics, because the telescope runs itself once you've set it correctly. We all crouched in front of the electronics looking at this little screen, watching these green dot coming up the middle.

MC CALLISTER: This next observation will be observation number 18.

DISNEY: We've got a bleeding pulse here.

COCKE: Hey. Wow, you don't suppose that's really it, do you? Can't be.

DISNEY: It's right bang in the middle of the period, look. I mean, right bang in the middle of the scale. It really looks something from here at the moment.



COCKE: Hmm!

DISNEY: It's growing, too. It's growing up the side a bit, too!

COCKE: God, it is, isn't it. Hmm!

DISNEY: Good God, you know that looks like a bleeding pulse.
{laughter)
It's growing, John.

MC CALLISTER: It is.

DISNEY: Look.

MC CALLISTER: It is. Hey, you're right.

COCKE: We saw the pulse come up almost immediately. And we were both—both Disney and I—were completely dumbfounded by the whole thing.

DISNEY: I shan't ever forget that, because it was right in the middle of the screen. It seemed—on the very first run that we made with this new timing—it seemed, well, it just seemed incredible. And I can remember crouching in front of it and my eyes popping out on stalks, and saying, "My God, there's a bleeding pulsar out there." And John was swearing to himself, and Bob McCallister was, I don't know quite what he made of it. None of us really believed it.

COCKE: God, I hate to believe it right now, though. (laughter) Well, we're up to 2,000 counts. We're now at 750, 700.

(inaudible)

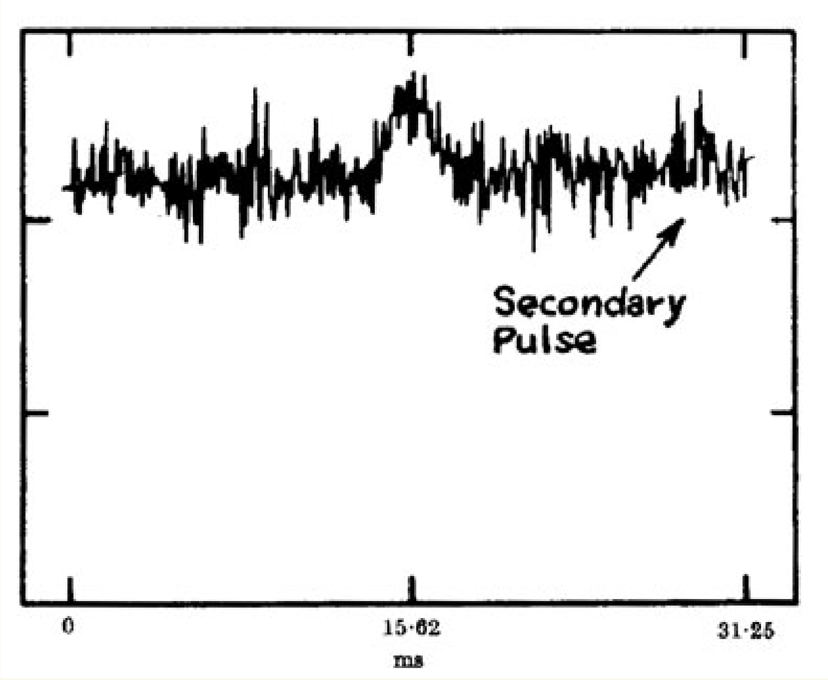
DISNEY: It's really building up. Look at that.

COCKE: It is, isn't it. Yeah.

DISNEY: There's not one left behind now. See, look, not one of those dots left behind.

COCKE: By God, yeah, uh huh.

(crosstalk)



DISNEY: There's a second something over here.

COCKE: Well, we expect two: a small pulse and a larger pulse, remember?

DISNEY: Uh huh. Right. I wasn't too sure of this one, but—.
That's a bleeding pulse.

COCKE: It is, isn't it. God. I don't believe it.

(laughter)

DISNEY: I don't believe it—I won't believe it until we get a second one.

COCKE: I won't believe it until we get the second one and until the thing has shifted somewhere else.

DISNEY: God, just come and look at it down here.

(laughter)

This is an historic moment. Hmm!

COCKE: I hope it's an historic moment. We'll know when we take another reading. And, if that spike there is again right in the middle—that spike is right in the middle and that scares me.

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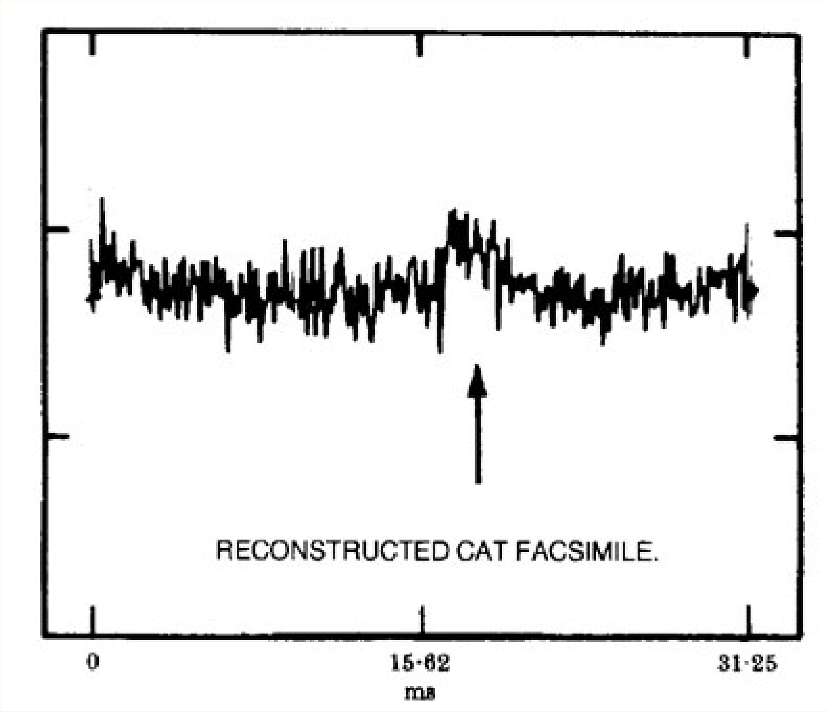
DISNEY: We decided to try to determine whether or not it was an electronic artifact or it was the real thing. And we'll switch all the electronics off and switch it on again.

MC CALLISTER: This is run on number 19 on SP star—on South SP star. We're on our way. Back here and do some of my paper work. Okay, I'm caught up.

(inaudible)

DISNEY: We got Don's number? Beginning. It's moved over.

COCKE: Yeah, it has, hasn't it?



DISNEY: My God, it's still there. It's as good as it was, or better than it was, last time.

COCKE: But, it's still right in the middle of the screen.

DISNEY: No, it isn't. It's moved to the right. See look.

MC CALLISTER: I'm going to have to turn it down.
Sorry about that.

DISNEY: It's growing!

(laughter)

Yeah, that's it! By God, we've got it!

COCKE: Now, now.

DISNEY: I think the best way to look at these things is: forget the dots—just look underneath here at the dots at the bottom.

COCKE: Right.

DISNEY: Hmm? It's much clearer then.

COCKE: It disturbs me that it's right in the middle of the screen.

DISNEY: It hasn't. It isn't. John, look.

COCKE: It's moved a little bit.

DISNEY: Yeah, it's moved to the right.

COCKE: Uh huh. Hey, Bob, the frequency generator is still going, all the time, isn't it?

MC CALLISTER: Hopefully.

(crosstalk)

COCKE: It should be in the same place, because the frequency generator is still going

(crosstalk)

MC CALLISTER: If you've got the right frequency it would be more or less the same place, wouldn't it?

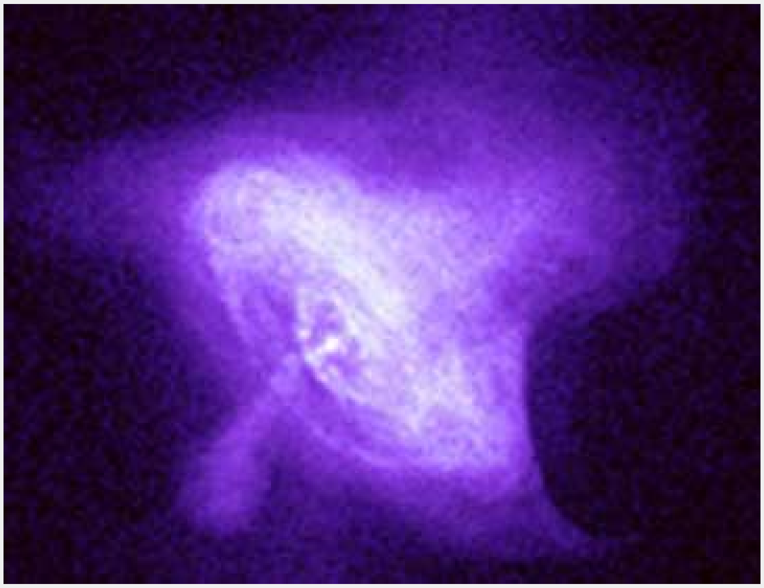
DISNEY: It should be more or less; it won't be exactly the same place.

COCKE: If we have exactly the same frequency—

DISNEY: If we've got the pulse dead right—

(crosstalk)

That's a bloody pulse, isn't it? Should we go and ring Don up?



Crab Nebula images in x-rays by NASA's Chandra Observatory

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DISNEY: So, we were absolutely hysterical with excitement and it took us some time to start thinking coherently. I think John Cocke was the one who cooled off first.

COCKE: Let's move off that position and move somewhere else, and see if we get the same thing. All right? I hope to God this isn't some sort of artifact in the instrumentation.

DISNEY: We moved the telescope a little bit off the star so that we wouldn't be looking at the star at all.

MC CALLISTER: This is beginning observation number 20.

DISNEY: This time a little pulse began to appear in the middle of the screen and I think our hearts all fell then because we were getting pulsations now from the place where it shouldn't be coming from. And we thought it really was some electronic artifact. And I don't think anything was said. Anyway, we stopped that run.

COCKE: We changed the frequency so that the computer was not running synchronously with the pulsar.

MC CALLISTER: This is the beginning of observation number 21. The change of frequency setting to check the results of the three previous observations.

COCKE: And so we did that, and then we found that there was no pulse there, as we would expect.

DISNEY: And I suggested, I think, that maybe we hadn't set the telescope off quite far enough and that some of the light was leaking around the corner. So we moved the telescope well off this time.

COCKE: Off Baade's Star—off somewhere in some other part of the Nebula.

MC CALLISTER: The observation beginning now is observation number 22. It's .75 millimeters north of SP star.

COCKE: And we did that and we discovered nothing—no pulse at all.

DISNEY: So that was good. And now the real crunch came as we moved the telescope back on the pulsar, we set the timing right and—

MC CALLISTER: This is observation number 23. It's a repeat of observation number 18 of this night.

DISNEY: (inaudible) small prayer—

(crosstalk)

Here she comes.

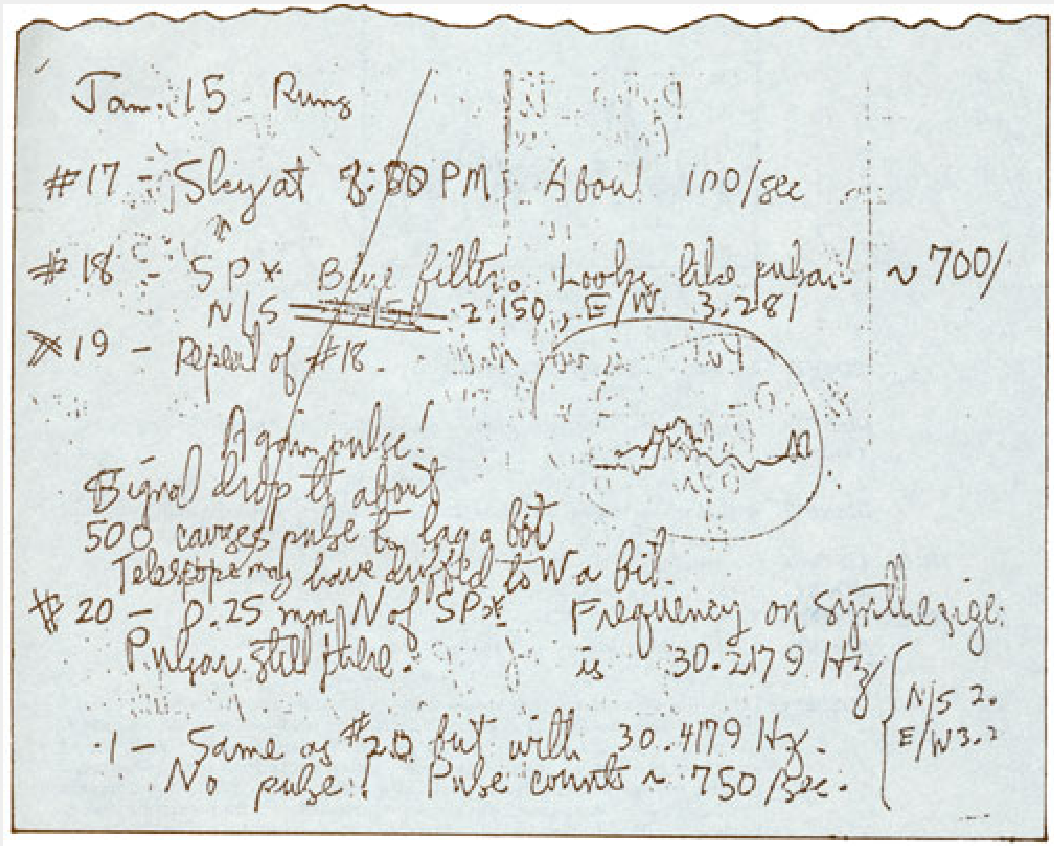
COCKE: There?

DISNEY: I think so. Look, see. Look at the hole at the bottom.

COCKE: Ah, yes. Right. There it is. I'll be damned.

DISNEY: Wait a mo'—it's building up around here now. There's definitely something here.

COCKE: Yeah, there is, ah huh. Yeah, that's the one.



Jan. 15 Runs

#17 - Sky at 8:00 PM. About 100/sec

#18 - SP* Blue filter. Looks like pulsar! ~700/

N/S 2.150, E/W 3.281

#19 - Repeat of #18.

Again pulse!

Signal drop to about 500 causes pulse to lag a bit

Telescope may have drifted to W a bit.

#20 - 0.25 mm N of SP* Frequency on synthesizer is 30.2179 Hz

Pulsar still there!

N/S 2. E/W 3.2

-1 - Same as #20 but with 30.4179 Hz.

No pulse! Pulse counts ~ 750/sec.

Extract from Laboratory notes of John Cocke, night of 15 January, 1969.

DISNEY: See, look it, look it. See the—

COCKE: Uh huh.

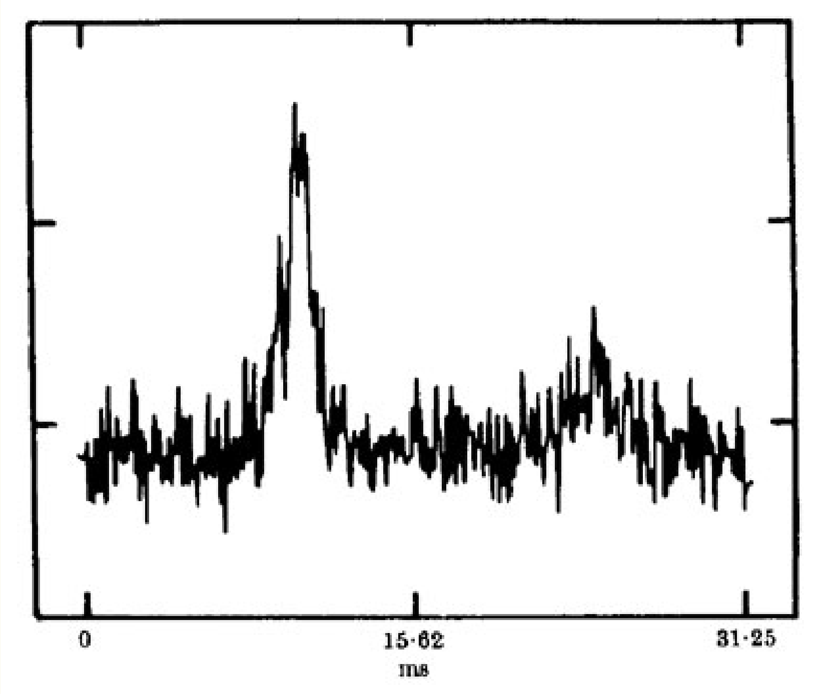
DISNEY: Right, could we have the gain down?

Yeah, it's building up nicely. Look at that.

COCKE: That's about the right spot for it, too, now that we've fiddled around all this time.

DISNEY: Is it? I don't know—

(crosstalk)



COCKE: It's there all right, isn't it? Look at it.

God.

DISNEY: Look, John, there's definitely two pulses. See, look, they're split by a half-cycle.

COCKE: Uh huh. Yeah. Right.

(crosstalk)

DISNEY: Well, that's just about—there couldn't be anything more definite than that could ya?

MC CALLISTER: Come on, tape, hold out.

COCKE: Are we running out of tape there?

MC CALLISTER: Yeah.

DISNEY: Any room for the American National Anthem on that?

(laughter)

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DISNEY, COCKE, TAYLOR

DISNEY: I know one of the things that passed through my mind and that was, it seemed a terrible shame that Don Taylor wasn't there after he'd done so much towards it. So I went downstairs and rang him up. I said, "Don, we found the pulsar." And I could hear him sort of thinking things over in his mind and wondering what could possibly have gone wrong. But anyway, he made several suggestions. But he said he'd be up tomorrow to come have a look for himself, but in the meantime to keep fairly quiet about it. Well, we did a few more runs and convinced ourselves that we'd seen the pulsar, and then we rang our wives up.

COCKE: Taylor was very skeptical. He was even more skeptical than I had been. And—of course, by then, I was utterly convinced that we had it. And so—what we did was—we made just a continuing series of observations throughout the night of the pulsar in various colors and things like that. And then we closed up shop and went to bed.

And then the next evening, Taylor came up. And we set things up again and did another run or two for him, and I think he probably did some more tests then himself. So then, he was convinced that what we had was the real thing.

Crab Nebula as seen in visible light with ESO's Very Large Telescope in Chile

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A Pulsar Discovery

DISNEY: And so, we spent the rest of the night, then, trying to measure exactly where the pulses were coming from. It really was very close to Baade's Star, but it might have been one of two stars in the middle of the Nebula. And so we sent off a telegram, then, to the International Astronomical Union, which is a place where you tell a very exciting discovery which you want confirmed immediately. We sent it off to them, and they sent it to all observatories around the world.

Well, what was really worrying us is we couldn't eliminate the possibility that, which—you know, we didn't know really—which of the two stars in the middle of the Nebula was the pulsar. We knew it was one of them, we couldn't be absolutely sure. And to do that, we really needed a bigger telescope. And we realized now that, having sent this telegram off, there'd be a lot of people working on the pulsar. And indeed, it turned out that the people at Kitt Peak National Observatory itself, on the very same mountain, were going to work on it the following night, too.

There was a lot of interesting stuff to be done. And we weren't sure really, how we were going to do any of it, because we didn't have the right telescope. Well, we came to the conclusion that if we were going to find out which star it was, we were going to need a smaller diaphragm—that's a very small thing which can discriminate between one bit of the sky and the other—and we had to do it before the next evening.

So I remember, we spent the whole day with some kitchen tinfoil from the kitchen trying to make a tiny little hole in this thing, about a tenth of a millimeter square. We finally succeeded in doing this, to everyone's amazement. We had—I can remember all four of us working on it, John, Don, Bob McCallister, and myself— and we had a microscope, which we'd found somewhere in the building. And we were looking through this microscope—this tiny piece of kitchen tinfoil—working with pairs of tweezers and razor blades and so on. And when the guy who was making the actual cuts—I think John was actually doing the brain surgery—everybody held their breath tight after he drew a line, or cut a line, in the tinfoil. But anyway, around about 5 o'clock we finally had the diaphragm, which we gingerly placed into the telescope.

And by this time, we'd had several phone calls from people, either congratulating us, or asking questions about the pulsar. We knew they were all going to work on it, so we felt this tremendous rush to get this thing and prove which star it was. It was kind of a race, you see.

Well, as soon as it was dark, we set everything up. And Don Taylor had a damn clever idea. In order to find the pulsar exactly, he was going to find it by ear, by listening to his photometer. That's to say, he let the incoming light waves cause a microphone to make a little brrrrrrgh noise, and when we were on the pulsar, it would make a louder brrrrrrgh. And so Don would be sitting there in the dark with his ear against the microphone, while John and I were watching the screen. And Don would drive the telescope about fairly blindly around in the right position. When he got to the right position with this very tiny diaphragm, the brrrrrrgh would suddenly rise in tone. And we'd watch the screen to see if it was pulsing source as well. And just about half past eight, nine o'clock, we finally picked up one of the stars this way. And it had a pulse. We could see the pulse on the screen, and Don could hear it on the microphone. And we were positive now it was the South Preceding star. That's to say, Baade's original guess at the right star.

COCKE: A couple of days later, after things had quieted down a little bit, our wives came out, and they cooked a special dinner for us with wine, things like that. And I was really, really, all very, very cordial and very exuberant.

DISNEY: Yes, well there was pandemonium up on the mountain after that. I don't think anything had been seen like it. We were having great big dinner parties with lots of wine and everything else. And going up to observe. And every now and then wives climbing up the stairs and peering between our shoulders to watch the screen. And Inge saying, "Claire, come have a look. There's a lovely little pulse here. Hold it, John. Hold it, Mike." All very unprofessional. But anyway, it was exciting. I wouldn't have missed it. I don't think science should become too solemn.

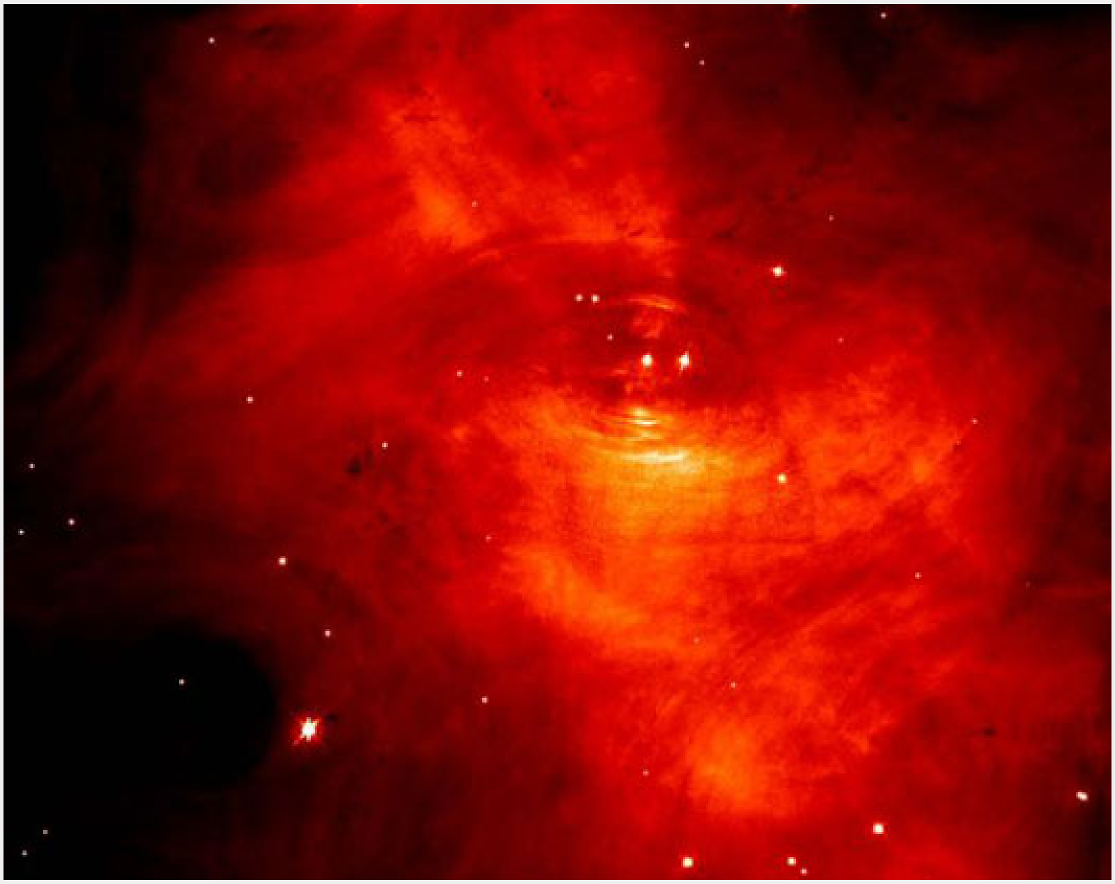
Image of the Crab Nebuila taken in visible light with the Hubble Telescope

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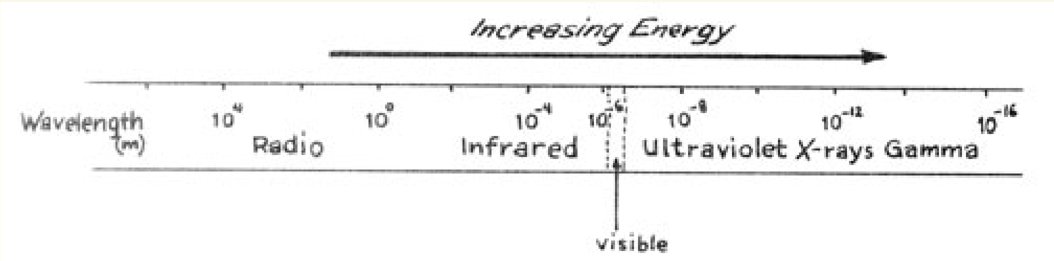
MORRISON: I was delighted when I heard a few days after the event—sometime in the middle of January 1969—that it was John Cocke, Mike Disney and Taylor who had found the optical pulsar. Because I still think it is fair to say that the discovery of the optical pulsar in the Crab Nebula is the best single discovery in optical astronomy in the past—well, since it happened. I don't know of any better. And it is charming because, as the tape explains, it was done by relative amateurs in optical astronomy. And I like that very much.

Now—well, you have it in the radio—why is it interesting to have it in the optical? Radio telescopes are typically not 200 inches, but 200 feet in diameter. And they have very powerful amplifying equipment. Therefore, the radio telescopes are really, very much more sensitive in real energy terms than the optical telescopes. So, if you see a pulsar in the optical, from the same point in space from which you've heard a pulsar by radio, you have proved that it is making very much more light in the optical band than it is radio power in the radio band. And it turns out that that amount of energy which the Crab Nebula is pouring out is significant for its evolution.



The pulsar in the Crab Nebula is slowing down. We know it's slowing down. But now we understand why it's slowing down: because it's giving out all that energy. The radio pulsar—we couldn't explain that by, because radio takes away no energy—but the optical light takes away very much more energy. And, indeed, within a year or so after this, it was discovered by wonderful experiments with rocket work that it was not only a radio pulsar, at the lowest energy—an optical pulsar, at ten thousand times more energy than the radio or a hundred thousand times— but even an x-ray pulsar giving x-ray pulses, which are themselves about ten or a hundred times more powerful than the optical pulses. And this enormous emission of pulsed energy over all wave bands has given us an insight to a spinning neutron star.

It is rather unusual that men like John Cocke and Mike Disney undertook to do experimental work. And of course they were able to do that only because they had a very, very, ingenious experimental colleague, Taylor, who had made the equipment that they were going to use. Their idea was how to use it—how to do an experiment with existing instruments—on a new context that nobody had tried before in order to find something that was plausibly suggested, but which many people disbelieved in and therefore did not have the energy to try. What you have to have in this kind of work—pioneer exploratory work—is what a friend of mine once called the necessary "don't know how." You have to be able to trust your intuition or your hunch or your logic which is not yet convincing, in spite of the experts' view—"Well, it isn't very likely to happen."

DISNEY: We were incredibly fortunate the first time we went observing, we had a very exciting experience like this. I don't think there could have been very many moments in astronomy when the immediacy of a discovery was so apparent. I mean it happened—there it happened in real time.

COCKE: It gave me a taste of what it's like to do something really, really exciting and interesting. And it also sort of brought me into the general feeling for what happens when you do something really good like that. After that, I became much more optimistic about things that I was doing and things that other people were doing, and I felt that, really, you only had to look in the right places and look often enough, and you'd find something.

DISNEY: This is how I see astronomy—I think it's true of science in general—it's a form of big game hunting. You go off into some thicket or other—you think there's something big in there. You're not sure what it is, and you track it down. If it was a cerebral—primarily a cerebral activity—then people with first class brains would be the people who are best at science. But I think that's very far from true. I think the most important thing in my opinion at least—and I say this very humbly because, I mean, I think scientists are so different from one another, it's difficult to generalize, but I think the important thing is to want to get the answer, to really want to get the answer, to really come back with that trophy as it were. That's far more important.

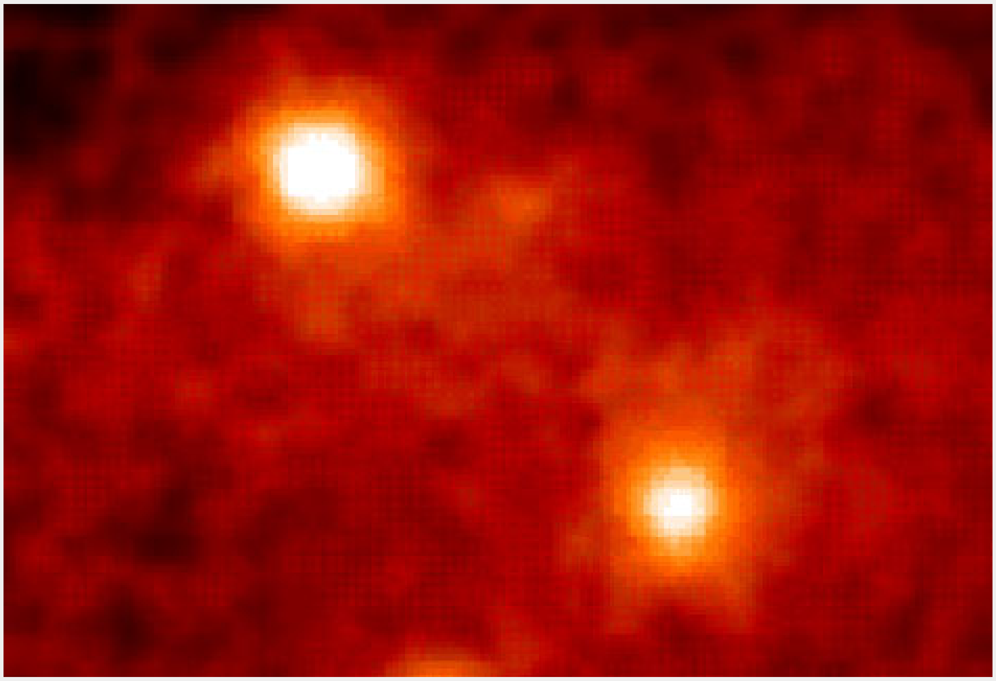


Image of the Crab Nebula and nearby region as seen in gamma ray wavelengths.

- For more on pulsars and their history, see our readings and links page
- We need your feedback so we can do more exhibits like this! Both our funding and our enthusiasm could falter if we don't hear from users. Please e-mail us or use the online form to tell us how useful this was to you (a brief word is great, comments and suggestions better still).

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A Pulsar Discovery

About This Exhibit

This exhibit is based on the educational package, *Moments of Discovery, Unit 2: A Pulsar Discovery*, by Joan N. Warnow with Arthur Eisenkraft and Spencer Weart, audio by Bill Schwarz, published by the American Institute of Physics in 1984 with support from the Public Understanding of Science Office of the National Science Foundation, the Heineman Foundation, and the Friends of the AIP Center for History of Physics.

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For further information

Further information on the history of physics can be obtained from the AIP's Center for History of Physics in College Park, MD.

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- Telescope. Credit: Photograph by Jim Scotti.

- Picture of Disney and Cocke at Steward Observatory , 1969. Photograph by Robert M. Broder.

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- Expanding Crab Nebula. Credit: Adam Block (KPNO Visitor Program), NOAO, NSF.

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- Telescopes in winter. Photograph by Jim Scotti.
- Picture of Taylor at Steward Observatory , 1969. Photograph by Robert M. Broder.

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- Crab image. Credit: J. Hester and P. Scowen (ASU), NASA. Picture of Disney, Cocke, and Taylor at Steward Observatory , 1969. Photograph by Robert M. Broder.

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- Crab in gamma ray. Credit: NASA, Compton Gamma Ray Observatory.

Voice credits

Excepts from interviews for this exhibit with Jon Cocke, by Joan Warnow and Spencer Weart in February 1975; with Michael Disney, by Inge Disney in February 1975; and with Philip Morrison by Joan Warnow in July 1975.