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.

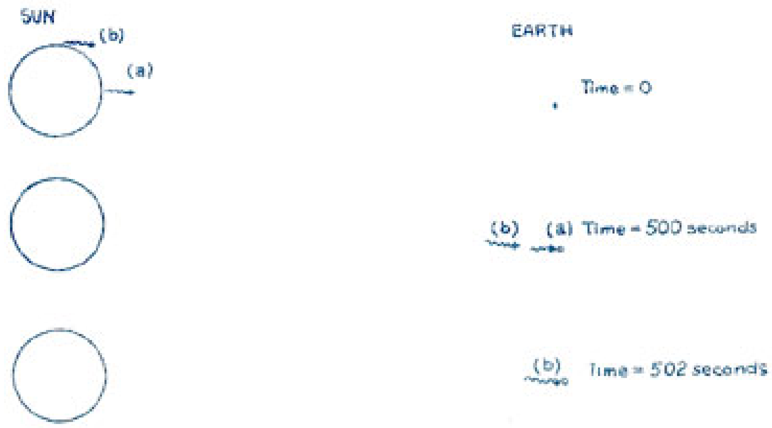
Philip Morrison, Professor of Physics at the Massachusetts Institute of Technology, gives background information and his own personal recollections. But that is not all. Incredible as it may seem, a tape recorder installed to keep track of the data also recorded all the conversation on the night of the 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.

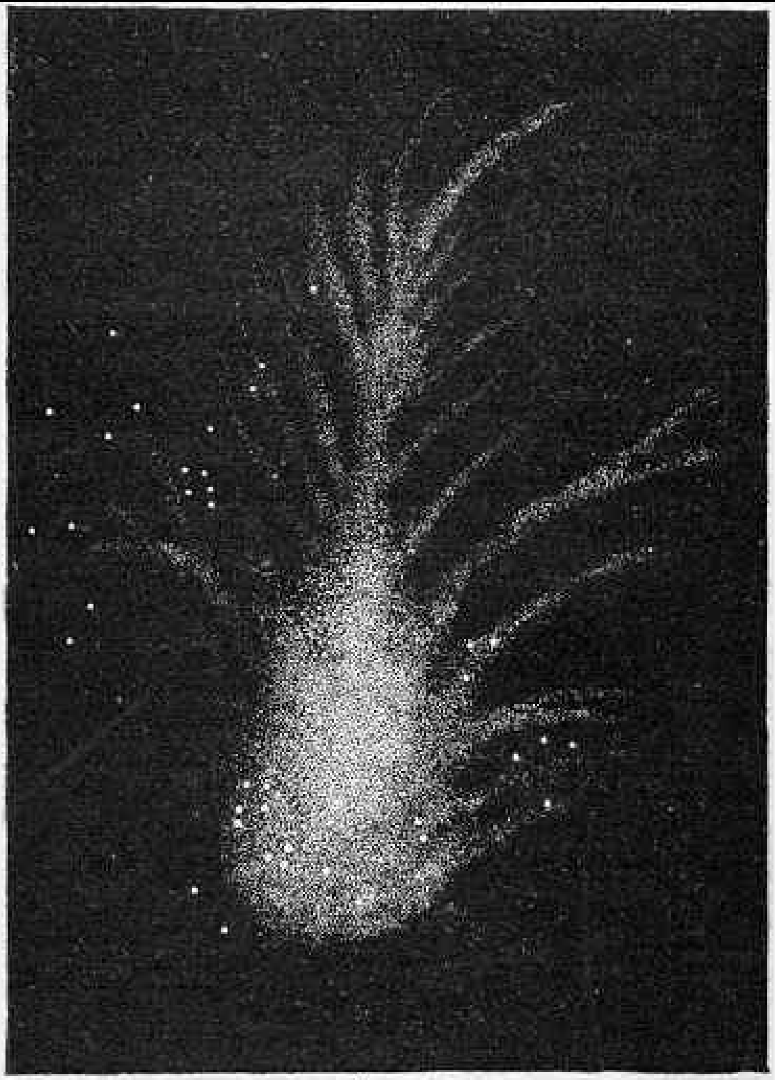


Fig. 438.

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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Moments of Discovery

The breakthroughs as they happened

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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

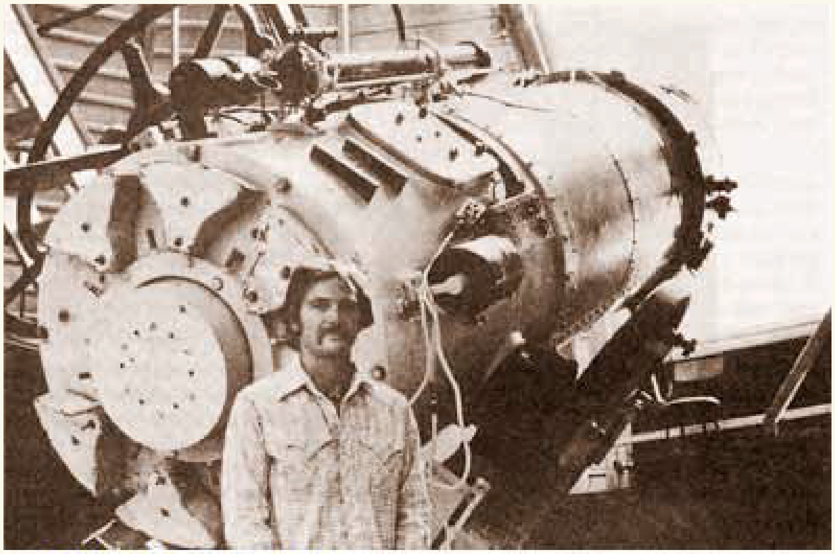
And so as I recall, my wife and I met Disney and his wife at the swimming pool, at the motel, and started talking about what we were doing in Tucson, and it turned out that we were both astronomers and were both going to be at Steward Observatory.

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.

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.

University of Arizona's 36" telesciope at Kitt Peak

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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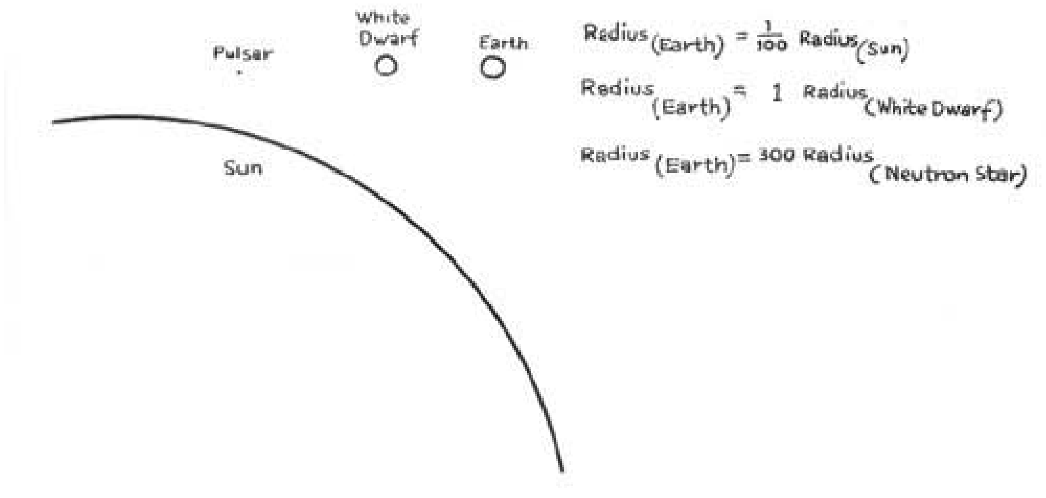

COCKE: It pretty well convinced people and convinced us, too, that pulsars were indeed not white dwarfs but rather neutron stars. And then finally—I think maybe a month later—the discovery of the radio pulses from the general direction of the Crab Nebula was announced.

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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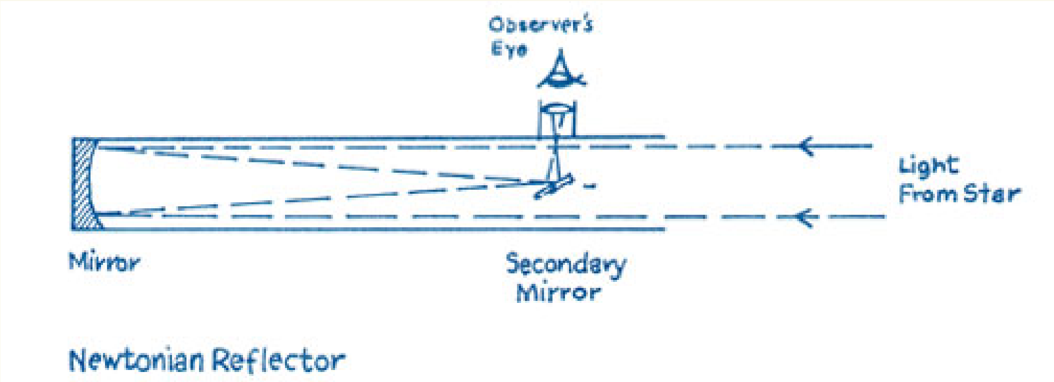
DISNEY: In fact, looking for pulsars in the optical is rather a complicated experiment, requires all sorts of equipment which we'd no idea about at the time. And Ray Weymann, who is one of the senior scientists at the Observatory, suggested to us that there was an ideal piece of equipment already in 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.



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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