Index Card, 10/30

(a) How did the discovery of a pulsar in the Crab Nebula confirm astronomers' ideas about what happens in a supernova produced by a massive star? What was seen from SN 1987A that yielded further confirmation of this picture?

(b) The Crab pulsar's period is 1/30th of a second. There is also a pulsar in the Vela nebula, a much older supernova remnant. What would you predict for the period of the Vela pulsar: do you expect it to be shorter or longer than that of the Crab? Explain.

Index Card, 10/30

(a) What was shown by the discovery of the Crab pulsar and from observations of SN 1987A?

Most responses to this question were inadequate, and would have received little or no credit on a quiz. Typical answers simply stated as "fact" some of the events thought to occur during the supernova process, or described various properties of pulsars, but essentially did not answer the question. The hoped-for responses were: (1) Finding a pulsar in the Crab Nebula, a well-known supernova remnant, implied that *pulsars are indeed neutron stars*, formed during the core collapse. (2) The key point about SN 1987A was that *a neutrino burst was seen*, emitted when the core is "neutronized." However, no pulsar has been seen in the remnant of SN 1987A to date.

The Serendipitous Discovery of Pulsars

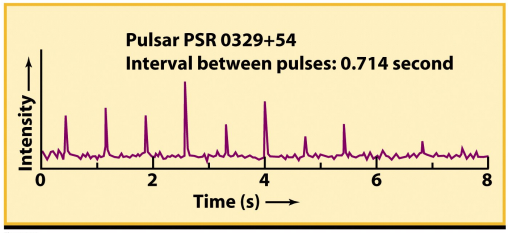

Figure 21-2
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- Using a radio telescope in 1967, Jocelyn Bell noticed very regular pulses of radio emission from one place in the sky
- When several similar sources were discovered in known supernova remnants (the Crab Nebula), it was realized that they were coming from a spinning neutron star—a *pulsar.*

Correct Points & Clarifications

- "The discovery [of the Crab pulsar] confirmed that neutron stars are produced by supernovae." It would more accurate to say that the neutrinos from SN 1987A proved this. The Crab indicated that there was an association between pulsars and supernovae.
- A number of groups mentioned the rapid rotation rate of the Crab pulsar; this does support the idea that the object formed when the core collapsed was extremely small, even smaller than a white dwarf.

Errors and Misconceptions

- "The outer layers of the supernova disperse which allowed us to see the middle…" So what?
- "..a pulsar star made of carbon." No, white dwarfs are made of C; neutron stars are made of neutrons!
- "SN 1987A showed a beam of a pulsar …" No pulsar has been seen in SN 1987A, nor other emission from a neutron star, but the neutrinos were seen in 1987.
- "SN 1987A showed strong magnetic fields." No.
- "Astronomers theorized about the existence of pulsating stars." Again, no. No one really thought about the fast rotation a neutron star would have.

Errors and Misconceptions

- "It confirmed there would be heavier elements made in supernovae, just like how pulsars are very dense." Neutron stars/pulsars are vastly denser than even the heaviest ordinary elements, such as lead.
- "That it [what?] explodes. The star was expanding." The neutron star is the collapsed core, which is the part of the star that *did not* explode and expand!
- "Astronomers could see a small star in the nebula clouds." How does this answer the question?
- "…the SN remnants disintegrated causing the neutron star to rotate." Conservation of angular momentum caused the collapsed core to rotate rapidly.

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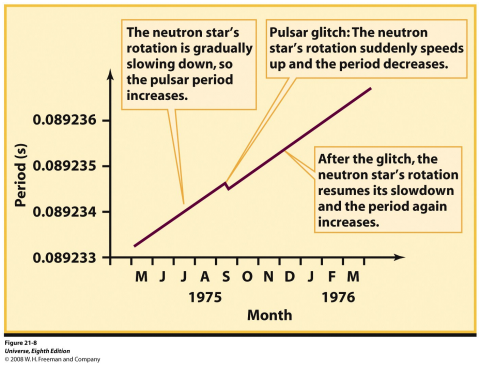
(b) Would you expect the Vela pulsar, located in an older supernova remnant, to have a period shorter or longer than the one in the Crab nebula?

The class did better on this question; most students understood that slowing down the spin rate resulted in a longer period.



Correct Points & Clarifications

- "The period of the Vela pulsar would be longer, because it's older, & [pulsars] slow down over time."
- "The period for Vela's rotation must be longer than the Crab's because kinetic energy is lost over time, so the rotation slows down."
- "It should be shorter, because of the slowing over time and the dwindling of light particles." Wrong way around: slower rotation means a longer period. And "dwindling of light" means dimming, not slowing.
- "The crust is cracked…" Starquakes that break the crust actually cause sudden shortenings of the period.