**Cosmic Recycling**

Material produced in supernova explosions expands outward into the interstellar medium, mixing with the ambient gas. The shock from the expanding explosion can trigger the formation of new stars, and the new stars are enriched in the elements produced in the supernova.

On the next two pages are images of the Crab supernova remnant in Taurus. This supernova resulted from the core collapse of a massive star, and was observed by Arab, Chinese, and Japanese astronomers in 1054 CE. The Crab Nebula is at a distance of 6500 light years, and the nebula is expanding at a rate of 1500 km s-1. The core of the massive star collapsed to form a neutron star, now seen as a pulsar in the center of the expanding nebula. The position of the pulsar is marked in each image.

Ten knots of nebular gas are also marked in the images. Measure the distance from each knot to the pulsar in 1956 and in 1999, and record your measurements in the table below. The knots are easier to see in the higher resolution, 1999 image, so it will be easier to start with the 1999 image.

Note that the proper motions of the stars are too small to see on these images, so their positions are essentially fixed. Select and label three stars on different parts of the image outside the nebula itself, and measure the distance of each from the pulsar.

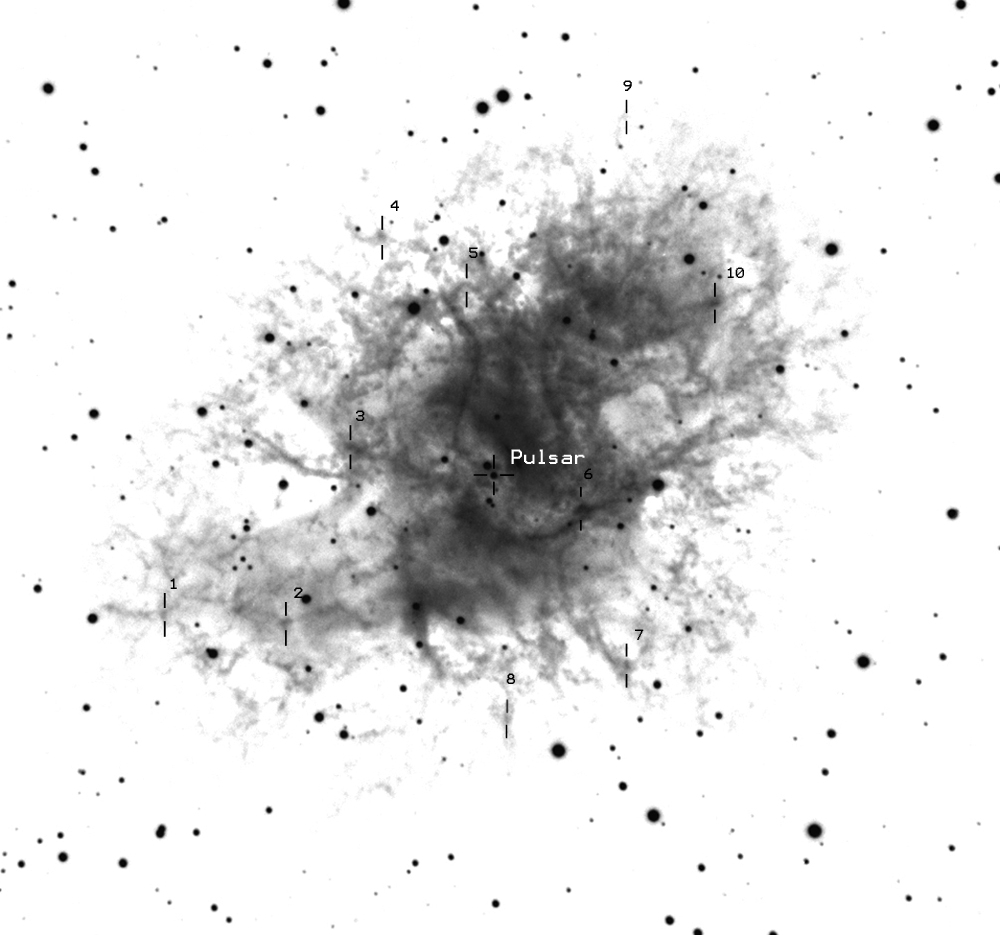
* Compute the distance the knot moved in 43 years.
* Calculate the speed of each knot in the image in centimeters per year.
* Using each knot’s speed and its distance from the pulsar in 1999, compute the number of years since the explosion occurred. (Remember, speed x time = distance!)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Knot | Distance in cm in 1956 | Distance in cm in 1999 | Difference in cm (1999-1956) | “Speed” in cm per year | Time since explosion |
| 1 |  |  |  |  |  |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |
| 6 |  |  |  |  |  |
| 7 |  |  |  |  |  |
| 8 |  |  |  |  |  |
| 9 |  |  |  |  |  |
| 10 |  |  |  |  |  |
| Star A |  |  |  |  |  |
| Star B |  |  |  |  |  |
| Star C |  |  |  |  |  |

How do your measurements of the time since the explosion compare to the known time of explosion in 1054 CE?

Why do knots closer to the center of the nebula appear to move more slowly? (Hint: what is their true direction of motion?)

**The Crab Nebula in 1956**



**The Crab Nebula in 1999**

