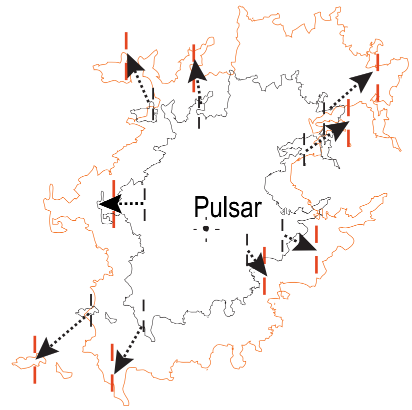
THE CRAWL OF THE CRAB - 2

Introduction

Two images of the Crab Nebula supernova remnant, taken 46 years apart, clearly show the expansion of the gas due to the explosion. In this exercise, you will determine the age of the Crab by measuring how much it has expanded over that period of time. You will convert the amount of expansion to a rate of expansion, and from there work backwards to determine the year the star exploded to form the Crab Nebula. In a sense, you're trying to find the "birthday" of the Crab-- except this method isn't accurate enough to find the exact day, so really you're finding the birth *year* of the Crab.



As the gas in the Crab expands, it moves away from the central pulsar. The expansion depicted here is exaggerated, and is not to scale.

Procedure:

First, examine both images. They are presented in grey scale (what most people erroneously call "black and white"), and are reversed such that bright objects like stars are black, and dark objects like the background sky appear white. This is an old astronomer's trick to make faint detail easier to see. You can see that the gas is not smooth; there are filaments and knots of gas scattered throughout the nebula.

One image was taken in February 1956, and the other in November 1999. Both images look similar at first glance, but if you look carefully you'll see some differences. The images are at the same scale; the nebula itself has changed during the time interval between the two images. It is this change that you will measure, and from that determine when the Crab was born.

1 Near the center of the nebula is a star marked "pulsar". That is the collapsed core of the star that originally exploded. We can assume for this exercise that all the gas started at that star, so you will measure the expansion relative to the pulsar.

On both images, there are 11 knots of gas marked. Starting with the image from 1956, carefully measure the distance in centimeters (to the nearest 0.05 cm or better if you can) of each knot from the pulsar.

Repeat these measurements for the 1999 image. Some of the knots are extended, or spread out a bit. For knots like that, pick an obvious feature to measure, like the center of the knot, or the edge on one side. Make sure you pick the same feature in both images! If you don't your measurements will not be accurate. On the worksheet there is room for you to make short comments on what part of the knot you measured. This might help you if you need to go back and remeasure.

-------------- **Tips** --------------

Tip 1: measure each knot in both images before going on to the next knot rather than measuring all the knots in one image and then in the other. That way, you can be more consistent in the way you measure each knot.

Tip 2: it might help to measure the knots on the 1999 image first, since it has better resolution and shows the structure of the knots more clearly.

Tip 3: sometimes measuring to the edge of a knot is easier than measuring to the center.

2

Now it's time to measure how much the nebula expanded: subtract the separation between each knot and the pulsar in 1956 from the angular separation in 1999. You can use centimeters for this measurement; the images have been scaled so that one cm is the same angular size on each of them. That means that one centimeter is the same physical distance in both images. Why is this important?

a. Examine the numbers you just calculated. Are the expansion amounts all roughly the same (within, say, 10% of each other), or is there a large variation? Do you expect all the numbers to be about the same?

b. Now look at the amount of expansion for each knot compared to the distance of the knot from the pulsar. Do you see any trends?

c. To see if any trends exist, plot on your graph paper the expansion amount for each knot versus its distance from the pulsar in the 1999 image. Using your ruler, draw in a best-fit line to the points. Can you make any general statements about a relationship between the distance from the pulsar for a given knot and its speed of expansion? Try to think of a physical reason for this.

3

To determine the age of the nebula, you need to find the expansion rate, the amount it has expanded versus time (this is, in a sense, the speed of expansion on the sky).

Given the dates of the two images (February 11, 1956 and November 10, 1999) calculate the time elapsed between them to the nearest 0.1 years. After that, divide the expansion amounts or separation you calculated in Question 2 by the time difference to get an expansion rate in centimeters/year.

4

Now that you have the rate of expansion, you can calculate the age of the nebula. Starting with:

rate = distance / time

which can be rearranged to:

time = distance / rate

Use the expansion rate (in centimeters/year) you calculated in Question 3, and the distance of each knot from the pulsar (in centimeters) for 1999 you found in Question 1, to calculate the age of the nebula.

Are the ages all roughly the same (within, say, 10% of each other), or is there a large variation? Why would this be?

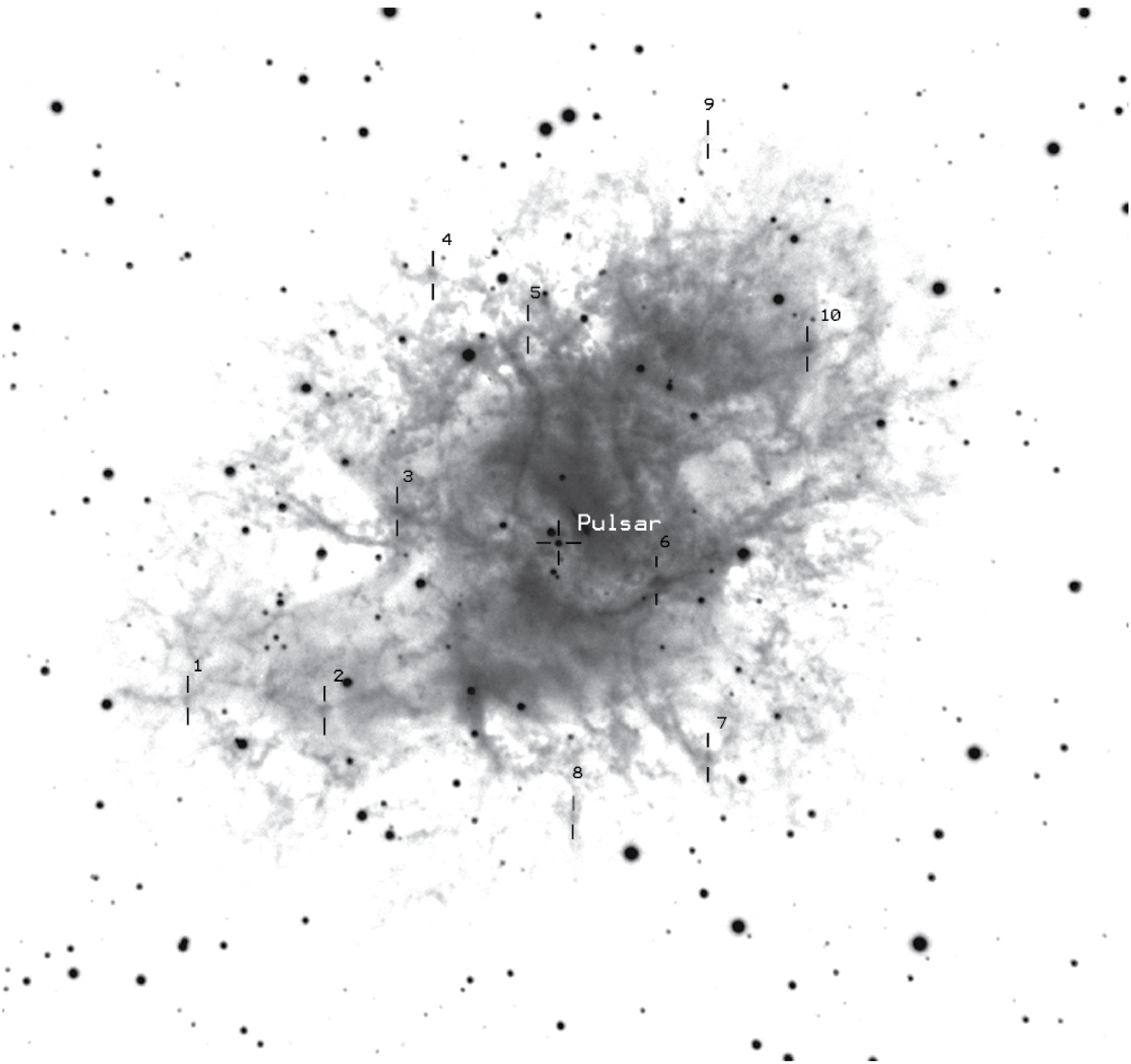
Calculate the average age of the nebula using the ages you derived for each of the knots.

Given the date of the image you used to find the age, in what year did the star explode to form the Crab Nebula?

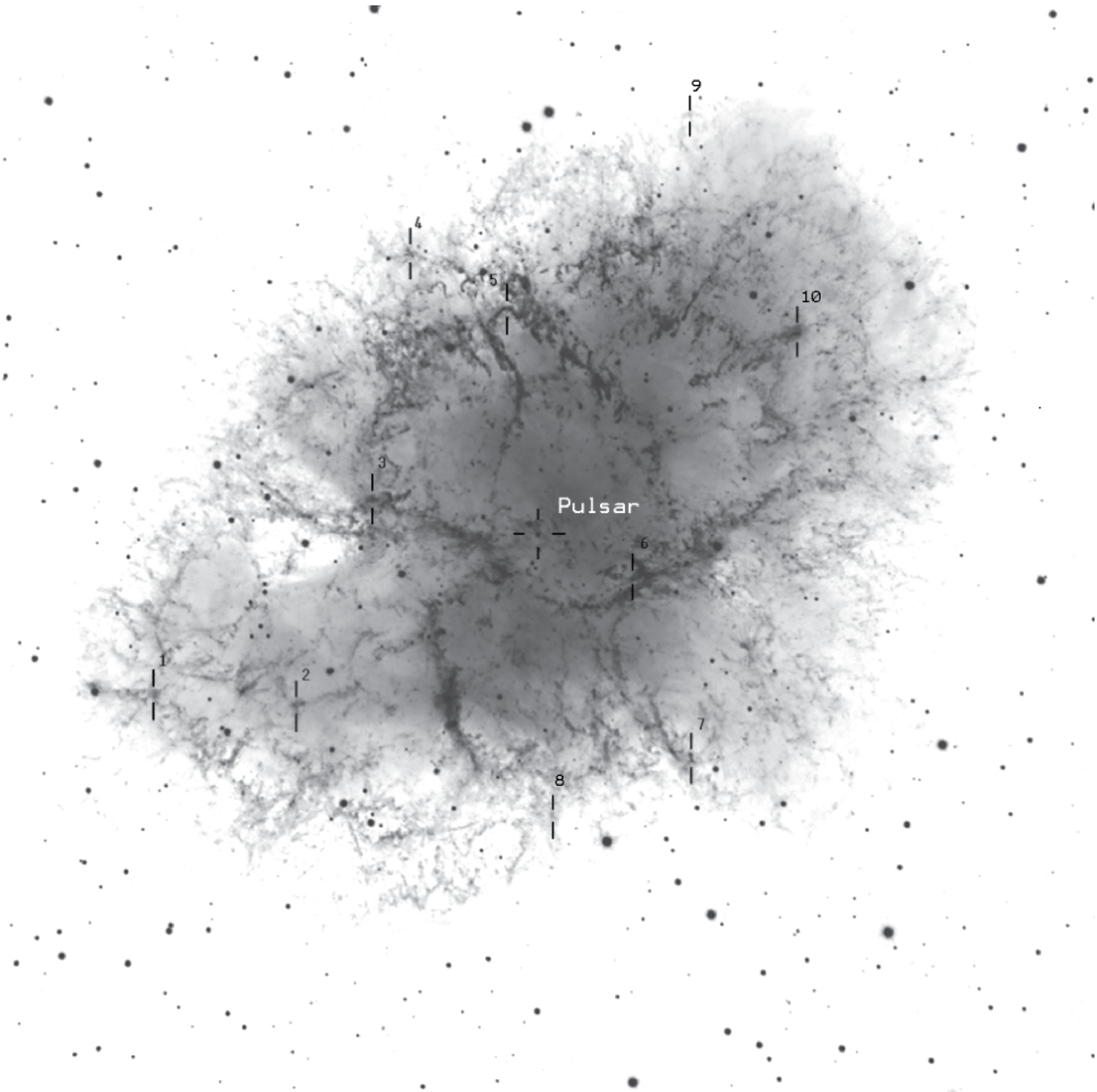
Calculate this number for each knot, and find the average year.

Scientists think the star that formed the Crab nebula blew up in 1054. How close was your answer?

The Crab in 1956



The Crab in 1999



STUDENT WORKSHEET

THE CRAWL OF THE CRAB

Name: __________

Datee: __________

1

knot	Distance from Pulsar (cm)		
	1956	*1999*	*Comments*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

2

knot	Change in Separation from 1956 to 1999 (cm)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

a)

b)

c)

3

knot	Expansion rate (cm)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

3

Elapsed Time ______________ (years)

4

Knot	Age of nebula (years)	Year of the explosion
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

AVERAGE: __________ (years)

AVERAGE: _______________