



FAULKES TELESCOPE

**Ancient Cosmic Explosions**

# **Calculating the age of Supernovae Remnants**

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# Ancient Cosmic Explosions

## Calculating the age of Supernovae Remnants

In this activity, you will calculate the age of a supernova remnant by measuring the radius of the remnant in two images (one taken with FTN, the other taken 4 years earlier by the HST) and seeing by how much it has expanded. In the first part of the exercise, the age is calculated using an Excel spreadsheet. For the second part however, you must calculate the age yourself using the given formulae.

### Instructions

#### Part 1 - Age Calculation (using Excel spreadsheet)

1. Open the OIII FITS file of your Faulkes CasA image in DS9.

**File > Open...**

Adjust the scale and zoom so that you can see CasA

e.g. **Scale > 99%**

**Zoom > To fit**

You can also adjust the colour of the image by going to any of the menu options under 'color'

#### What can I see?

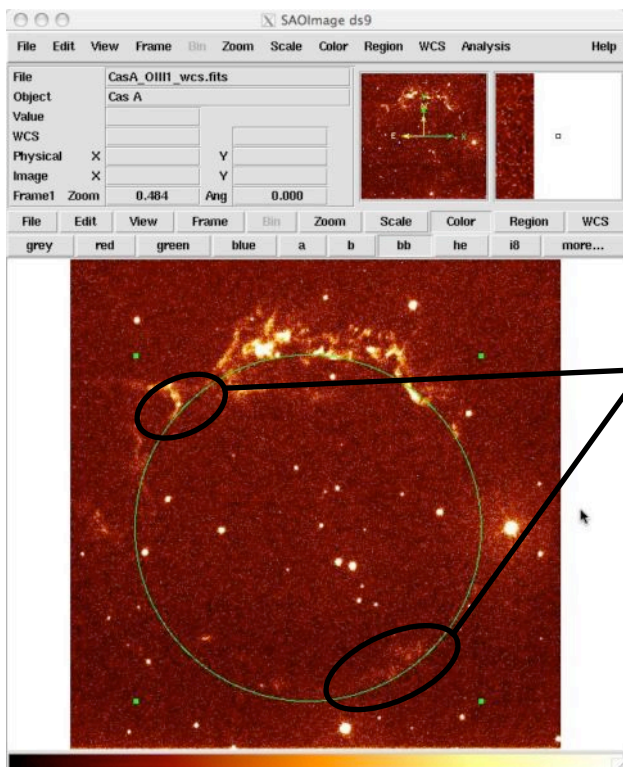
Cas A has a faint ghostly shell in the optical (as shown by the ring in the image). It also has bright filaments and 'knotty' clumps known as fast moving knots or FMKs. These FMKs are dense clumps composed mostly of oxygen which have been ejected by the star during the explosion and fly out at speeds greater than 5000 km/s. They 'squeeze' through gaps in the surrounding gas and so are further out than the actual blast wave.

2. Now you will determine the radius of the remnant by placing a circle over the shell. This tells us the angular size of the remnant. Go to:

**Region > Shape > Circle**

Draw a circle over the supernova remnant by clicking on the image and dragging to the edge of the remnant. Make sure that this circle is as big as the shell itself, as illustrated in the diagram overleaf.

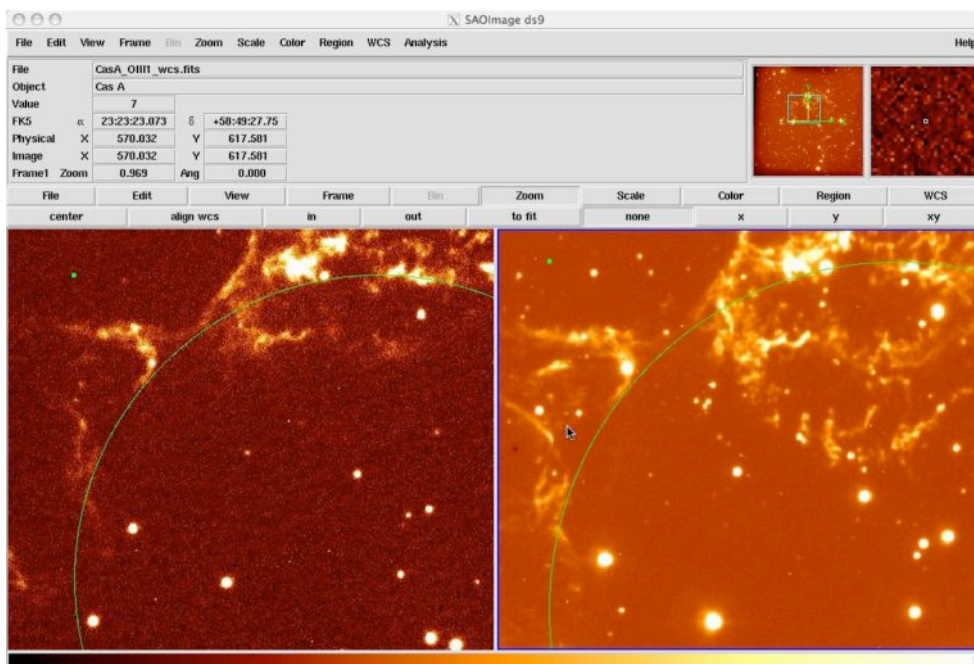
The circle size can be increased or decreased by clicking and dragging on any of the four corner points around the circle. The circle itself can be moved around the image by clicking inside the centre and dragging.



At this point it is important that the circle which you draw on this image, and the circle which you will draw on the HST image, encompass the same region of the Supernova remnant.

Here, the circle contains the shocked gas in the lower portion of the remnant, and touches just below a fast moving knot in the top of the image. These will be our reference points to which we draw the circle in both our images.

Below is a zoomed in view of this fast moving knot region, as seen in the FT data (left) and HST data (right). The circle is touching approximately the same place in both.



3. Double click on the circle, or go to

**Region > Get Info...**

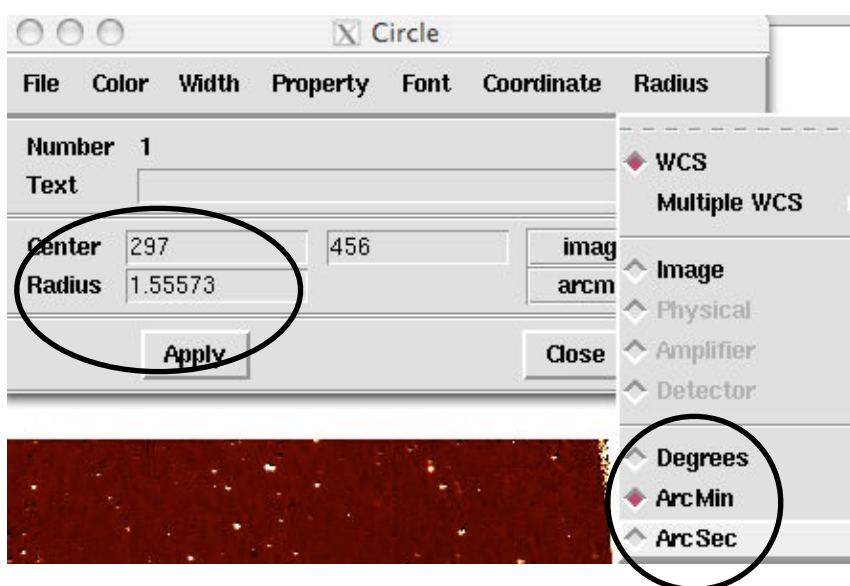
A box will pop up giving the central co-ordinates of the circle (this may be in image co-ordinates, not RA and Dec).

In the toolbar at the top of this box, go to

**Radius > WCS**

then

**Radius > arcmin**



Note the radius of the circle as given in this pop-up box.

*Radius in arcmins* = \_\_\_\_\_

4. Repeat steps 1-3 above, but with the CasA HST data. This data was taken with the Hubble Space Telescope in 2001. Remember to make sure that the circle you draw encompasses the same region as the circle in your FT image, as explained above.

The radius value for your HST image should be smaller than the value for the FT image. Enter your measured value below.

*Radius in arcmins* = \_\_\_\_\_

5. Now that you know the radius of your supernova remnant in 2 different years, you can use the Excel spreadsheet **ACE Calculation** to calculate the age of the remnant.

Open the spreadsheet and input the following into the boxes at the top of the spreadsheet:

- Distance to the remnant (this is 10,200 light years for CasA)
- Radius of the remnant as measured from the FT image (arcmin)
- Radius of the remnant as measured from the HST image (arcmin)
- Time difference between the 2 images (this is 4 years for the FT and HST CasA images)

What is the distance to the remnant?  light years

What is the radius of the remnant?  arcmin

What is the radius of the remnant in the Hubble Space Telescope image?  arcmin

What is the time difference between the two images?  years

The age of the supernova remnant is given at the bottom of this spreadsheet, in the region circled here:

Estimating the age of the shell							
distance (ly)	radius(arcmin)	radius (m)	volume (m cubed)	mass (kg and solar masses)	velocity (m/s)	diameter (m)	time (s)
15000	3.8	1.58E+17	1.64E+52	1.64E+31	1.75E+06	3.15E+17	1.80E+11
				8.2			
<b>VELOCITY =</b>						1748 KM/S	
<b>TIME =</b>						601 YEARS	

From your measurements of CasA, what is the age of CasA in years?

Age of CasA in years = \_\_\_\_\_

## Part 2 - Age Calculation (with Maths)

In this exercise you will estimate the age of the supernova remnant by firstly estimating the velocity of the expanding shell of material and then determining the radius of the shell.

You will need to have obtained values for the radius of your supernova remnant from both the FT and HST images of CasA. If you have worked through Part 1 of this activity, you should have these values noted above. If you have not, then go through Steps 1-4 above and note the values of the radii before continuing with the exercise below.

### Estimating the Age of a Supernova Remnant

After a massive star has reached the end of its life and exploded, a huge spherical bubble of expanding material will move outwards. After a certain amount of time, this shell of material will have moved a certain distance from the centre, depending on its velocity. A typical supernova explosion will eject about  **$10^{43}$  Joules** of energy into its surroundings.

We can use our knowledge of the energy ejected in the explosion, and the distance of the shell from the centre (the radius of the shell), to estimate the velocity,  $v$ , of the expanding supernova shell by rearranging the following formula:

$$\text{Kinetic Energy} = \frac{1}{2} M v^2 \quad [1]$$

where  $M$  is the mass of gas ejected in the explosion.

1. Rearrange equation 1 above so that you have an expression for the velocity,  $v$ .

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Now for the tricky bit! We need to work out the mass of the shell. We can do this, since

$$\text{Mass} = \text{density} \times \text{volume} \quad [2]$$

Remember that density is a measure of how much mass is in a given volume. For example, the density of water is  $1000 \text{ kg m}^{-3}$ , which means that  $1000\text{m}^3$  water has a mass of 1000kg. The same volume of lead would be much heavier since lead is 10 times denser than water.

In the space between the stars, the density of material is very low - there isn't much out there! In fact, the average density in space is about  $1 \times 10^{-21} \text{ kg m}^{-3}$ !

The volume of the supernova shell can be found by assuming that the shell is a sphere, and therefore working out the volume of a sphere

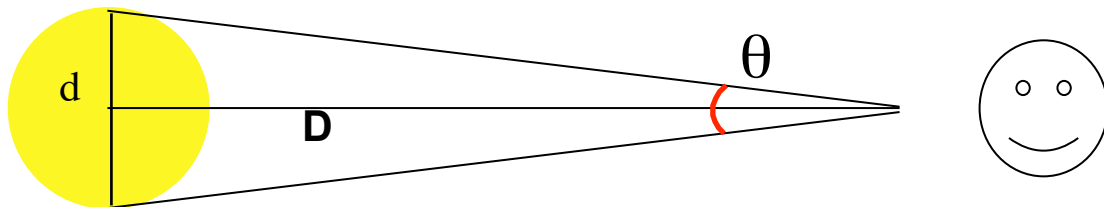
$$V = \frac{4}{3} \pi R^3 \quad [3]$$

where:

$V$  = volume of the sphere

$R$  = radius of the sphere in metres.

To convert the radius of the supernova remnant from arcminutes (the angular size on the sky), to standard units of metres, we need to use the small angle formula:



$$d = D \tan (\theta) \quad [4]$$

where:

$D$  = distance to supernova remnant **in metres**

$d$  = diameter of supernova remnant **in metres** = 2 x radius

$\theta$  = the angle of the supernova remnant on the sky **in degrees**

*Remember:* There are 60 arcmins in a degree and 1 lightyear is  $9.5 \times 10^{15} \text{ m}$ .

2 a). What is the radius of the supernova remnant in arcmin, as measured from the FT image?

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b). Using your answer to (a) above, and the information on the previous page, what is the diameter of the supernova remnant in arcmin and degrees?

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c). Using equation 4, calculate the diameter, and therefore radius, of the supernova remnant in metres.

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3. Calculate the volume of the supernova remnant (assuming it is a sphere) by using equation 3 above and your answer to question 2 (c).

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4. Using equation 2 and your answer to question 3, calculate the mass of the supernova remnant in kg. (density in space =  $1 \times 10^{-21} \text{ kg m}^{-3}$ )

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5. Calculate the velocity of the supernova remnant using your answers to questions 1 and 4.

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The time it has taken for the shell to move outwards from the exploding star is given by

$$\text{Time} = \text{distance} / \text{velocity} \quad [5]$$

Since the distance is the size of the remnant (i.e. the distance the shell has travelled after the explosion), the time taken is actually the **age of the remnant**. This assumes that the exploding material has been traveling outwards at a constant speed.

6. Calculate the age of the remnant in seconds using equation 5 and your answers to questions 2 (d) and 5.

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7. Finally, convert the age of the remnant from seconds into years (there are  $3 \times 10^7$  seconds in a year).

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