

HOW FAR ... ? HOW OLD ... ? HOW MUCH BIGGER ... ?

How many galaxies are there in the universe?

In this project, you are going to use a photo taken by the Hubble Space Telescope to estimate the number of galaxies in the universe, but to do this you will first need to find out how we measure three-dimensional space.

Measuring the sky

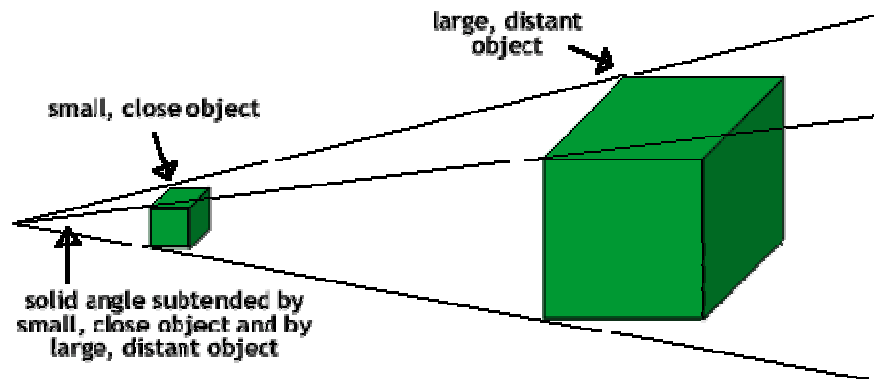
You are familiar with using degrees to measure angles. We can also use an angle to indicate the length of an arc of a circle. Suppose we have a circle of radius 1 unit. Complete the table below for lengths of arcs of that circle (use multiples or fractions of π):

Angle at centre (degrees)	Length of arc
360	
180	
90	
60	
135	
64	
273	
x	

You should find that for any angle x , the arc length is $2\pi/x$. We can therefore measure the length of an arc of a circle in terms of the angle at its centre.

The universe that we see through a telescope is not flat like a circle, but spherical (if we ignore the fact that we can't see through the Earth!), so it is measured in *square degrees* (degrees multiplied by degrees). An angle measured in square degrees is called a *solid angle*, and it is the angle in three-dimensional space which corresponds to an object in the same way as the angle at the centre at the centre of a circle corresponds to an arc of the circle. The technical term for this is *subtends*. A quarter-circle subtends an angle of 90 degrees, a semi-circle subtends an angle of 180 degrees, and so on.

A solid angle in space is a measure of how big that object appears to an observer looking at it from a particular observation point. For instance, a small object nearby could subtend the same solid angle as a large object far away.



A solid angle is related to the surface of a sphere in the same way an ordinary angle is related to the circumference of a circle.

The section of the sky that you are going to work on is a square of side length corresponding to an angle of 1/80 of a degree.

Calculating the number of galaxies in the universe

You will need:

- "How many galaxies there are in the universe?" worksheet
- Hubble deep space photo - section 1
- Hubble deep space photo - section 2
- Hubble deep space photo - section 3
- a high resolution photo of the Hubble ultra-deep field (not essential to print this out, but available online if you want one)

You have three sections of the photo with a grid superimposed on each section. Each section is $1/80 \times 1/80$ square degrees of sky. We have superimposed a grid of nine squares on each section to break down the task of counting galaxies into smaller tasks. You will need to decide on an effective way to count the galaxies:

- no one wants to have to count galaxies in a lot of squares!
- but to ensure a reasonably accurate result, you should have at least three estimates of the number of galaxies for each square