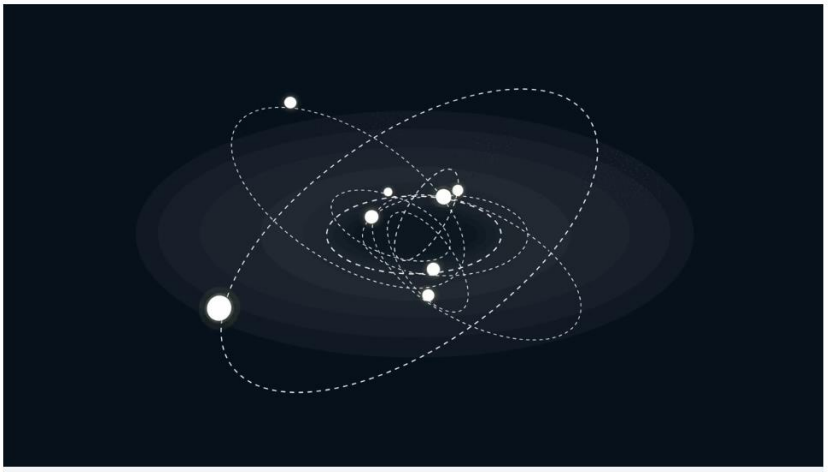
ROYAL OBSERVATORY GREENWICH

Finding the mass of the black hole in the Milky Way

Key Stage 4

Topics covered: Gravity, Kepler's third law, black holes, straight-line graph

Watch the video "What's inside a black hole?"
https://vimeo.com/88896853



It is thought that every galaxy contains a supermassive black hole in the centre. This includes our galaxy the Milky Way.

Kepler's third law states that the orbital period of a planet, T, squared is proportional to its distance from the Sun, R, cubed.

$$T^2 \propto R^3 \qquad (1)$$

If T is in years and R is in astronomical units, AU (1 AU is the distance between the Earth and the Sun), then:

$$T^2 M = R^3 \qquad (2)$$

where M is the mass of the black hole in solar masses e.g. M = 1 means the mass is 1x mass of the Sun.

The values in the table on the next page are the distances (in AU) and orbital periods (in years) of stars orbiting the supermassive black hole in the Milky Way.

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1. Plot a graph of T^2 (x-axis) vs R^3 (y-axis) and find the mass of the black hole from the gradient of the graph (this will be in solar masses).

2. The mass of the Sun is 1.989×10^{30} kg. Work out the mass of the black hole in kilograms.

Star	**Distance from centre, R (AU)**	**Orbital Period, T (years)**
S2	1023	15.8
S38	1156	18.9
S21	1772	35.8
S5	2080	45.7
S14	2130	47.3
S18	2205	50
S9	2438	58
S13	2471	59.2
S31	2479	59.4
S12	2562	62.5

Data from Gillessen. S., et al. 2009, ApJ, 692, 1075

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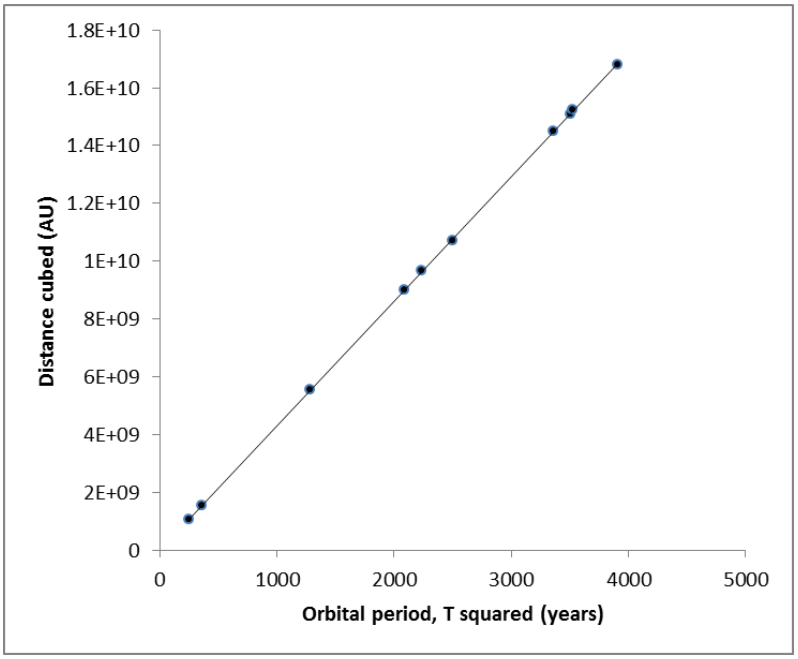
Finding the mass of the black hole in the Milky Way: ANSWERS

Key Stage 4

1.



2. M = 4 million solar masses = 7.96 x 10^{36} kg