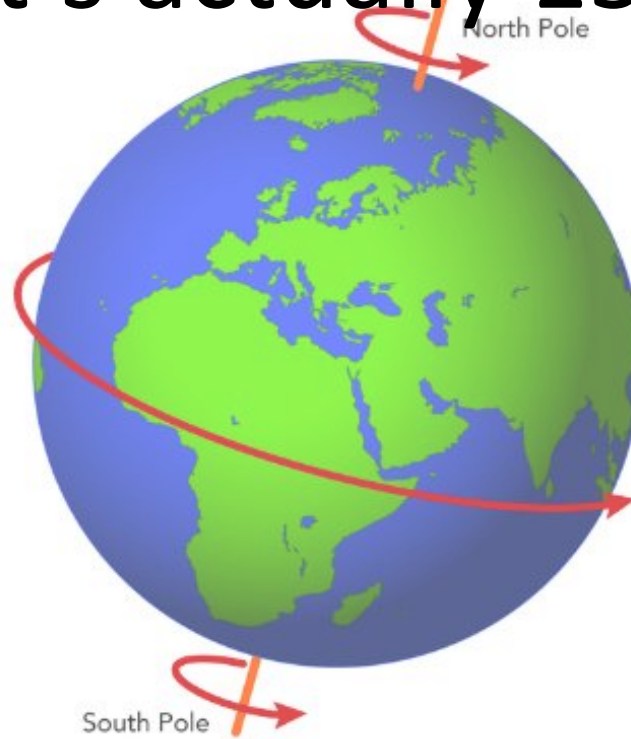


# The Weird Problem of Mars Going Backwards



# How fast does the Earth spin?

- You can find out by doing the shadow stick project (A9) - it's actually  $15^\circ$  per hour



# Back to Mars...

- The picture below was made by overlaying 29 pictures of Mars, each taken a few days apart in 2003.



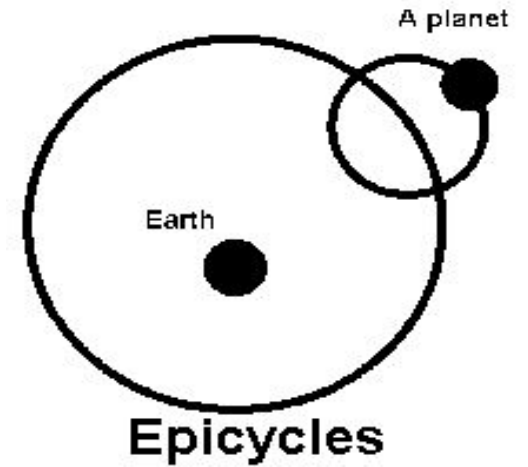
- Question: Describe what Mars appears to be doing.

- Ancient people, like the Greeks and the Arabs, were very good Astronomers. They knew, from careful observations, that Mars and other planets did this, but they couldn't explain it.
- Famous astronomers and mathematicians of the time, like *Aristotle* (384 - 322 B.C.) and *Ptolemy* (87 - 150 A.D.) believed that the Earth was at the centre of everything and that the sky was like a great dome, with stars stuck to it, that turned around the Earth.
- The 'retrograde' motion of Mars was a bit of a problem as no one knew why it went 'backwards'!
- Any ideas?

Ptolemy could think of only one explanation - he thought that each planet must move in its own circle as it went around the Earth. He called these circles EPICYCLES.

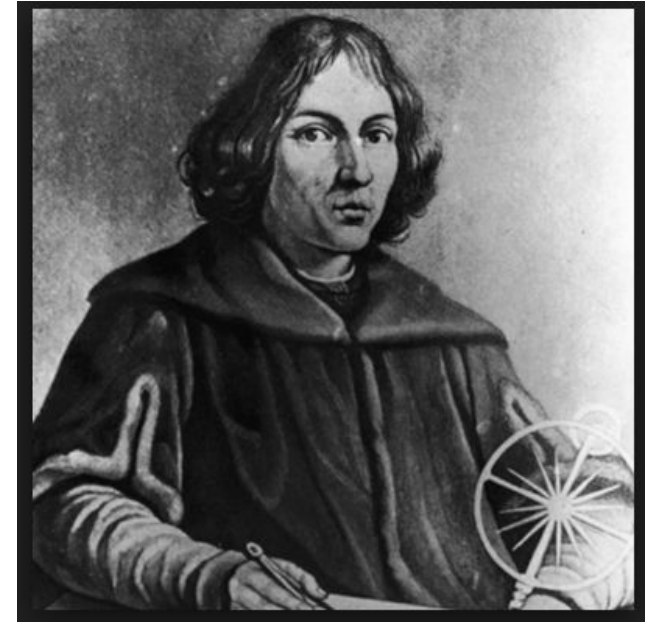
Many centuries later, Isaac Newton realised that gravity was needed to make objects like the Moon travel in orbit around the Earth.

Question: If Newton was right, what was the problem with Ptolemy's idea, even though he looks like a pretty clever bloke in the picture?

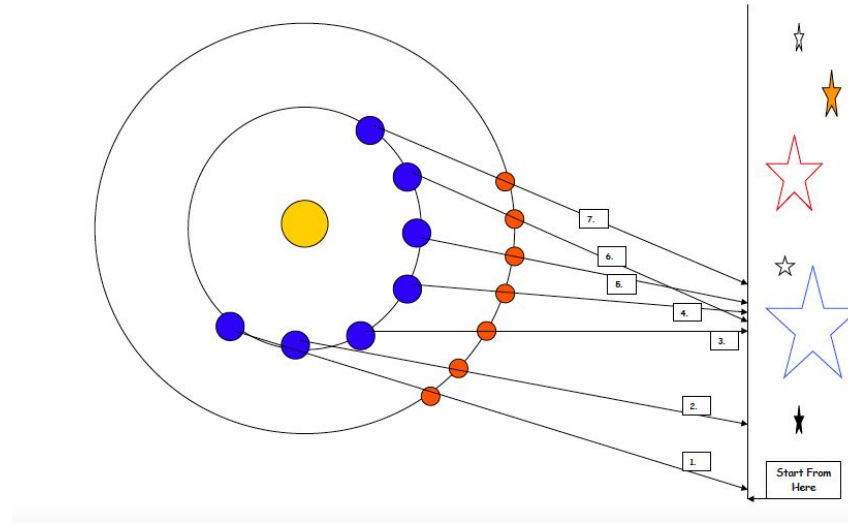


- Later on in history some people began to look more carefully at astronomical observations and the patterns that they showed. One of the most famous of these was Nicolaus Copernicus (1473 – 1543) from Poland. He was very careful not to make too much fuss about his results because he was a Canon in the Catholic Church and didn't want to be excommunicated or burnt for heresy. He hand wrote a little book in about 1514, but he didn't put his name in it. In his book, he said these things:

- *There is no one centre in the universe.*
- *The Earth's centre is not the centre of the universe.*
- *The centre of the universe is near the sun.*
- *The distance from the Earth to the sun is tiny compared with the distance to the stars.*
- *The rotation of the Earth accounts for the apparent*
- *daily rotation of the stars.*
- *The apparent annual cycle of movements of the sun is caused by the Earth revolving round it.*
- *The apparent retrograde motion of the planets is caused by the motion of the observer on the Earth*



- Let's see if Copernicus's ideas can explain the weird motion of Mars.
- You will need to print this diagram of the Earth and Mars orbiting around the Sun which is in a separate pdf document.

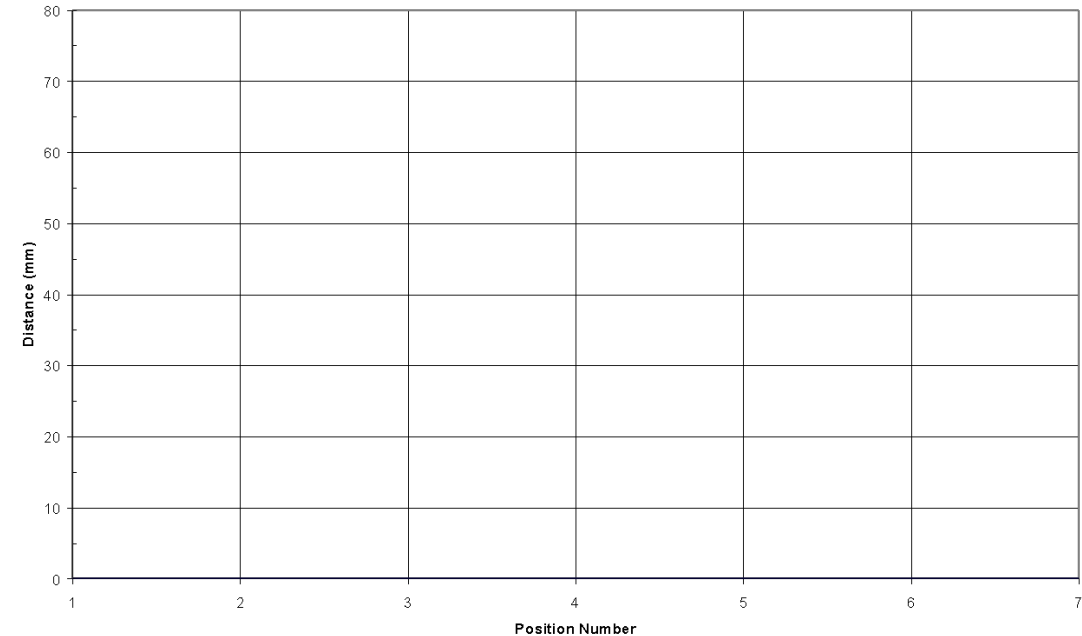


- Question: Why does Mars take longer than Earth to complete one orbit around the Sun?
- The lines drawn from Earth to Mars show the 'line of sight' between the two planets – the direction along which you would be looking to see Mars in the sky. The stars in the background are very far away, so they don't appear to move as much as Mars does.

- Using the printed worksheet, measure, in mm, the distances between the START of the vertical, 'background star' line and where it touches the END of each of the numbered arrows. Plot the results on this graph:

Line of Sight Number      Distance from Start (mm)

- 1
- 2
- 3
- 4
- 5
- 6
- 7

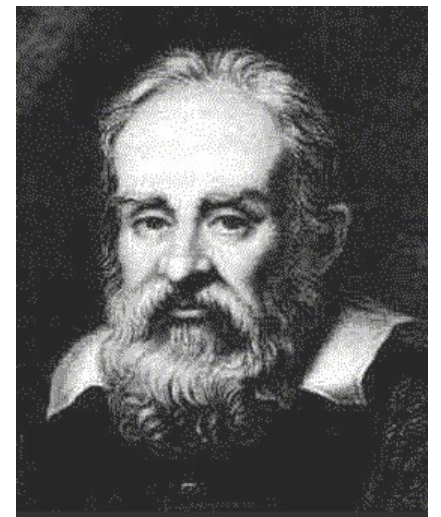


Question: Was Copernicus right - does the graph show that Mars goes backwards at some point? Looking at the worksheet again, is it really going backwards? What is really happening? (Think of it like runners staying in their lanes on an athletics track - an inside runner would see an outside one in front, then alongside and then behind as they overtook them. Pretty obvious if you could see a bird's eye view of the Solar System)

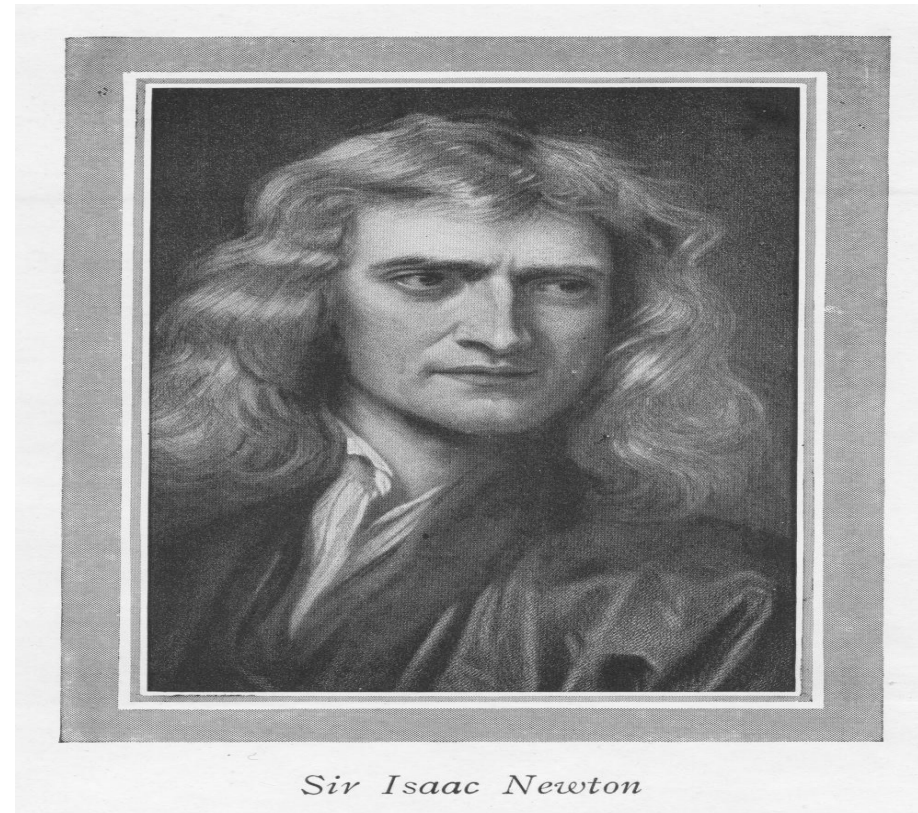


- Galileo Galilei was a famous Italian astronomer who lived and worked a hundred years later than Copernicus. However, even then he was called before the Inquisition, in 1633, for agreeing with Copernicus in his own books.
- Galileo discovered four things that the church didn't like:
  - The planet Jupiter had at least four moons – nobody had seen these before
  - Our Moon was not a perfect disk – it had mountains and valleys when he looked with his telescope
  - The planet Venus showed phases like our Moon – crescent, half, three quarters, full
  - There are millions more stars than you can see with the naked eye
- Question:

Why do you think that the Catholic Church was so unwilling to let Galileo publish scientific evidence and ideas at this time in history?



- Isaac Newton used Galileo's ideas about gravity and orbits to work out his own theory of gravity.



Question: How does Newton's theory of gravity explain why the Sun must be at the centre of the Solar System with ALL the planets orbiting it? What is significant about the Sun's mass compared to the planets?

Where are all the women in this story? Find out who these women are and the amazing science they did:



Caroline Herschel - first paid, woman scientist



Annie Jump Cannon - invented the system of classification of stars



Henrietta Swan Leavitt - discovered Cepheid variables

# Is the Earth really spinning?

- Check in Stellarium - speed up the time!
- [www.stellarium.org](http://www.stellarium.org)
- Or go outside and check your shadow stick!