The Human Orrery

A Powerful Resource for Raising Universe Awareness

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What is an Orrery?

The answer brings in History, Culture, Cosmology, Religion, the Development of Scientific Ideas . . . An Orrery is:

1. A dynamic model of the Solar System;
2. A model of the world, dating back to early eighteenth century;
3. A table-top model to illustrate what was then still a new idea: that the Earth revolves around the Sun, and — contrary to immediate experience:
   - the Sun lies apparently motionless at the centre of the Solar System;
   - the Earth spins on its axis and Earth moves through space.
4. An orrery can illustrate some key observations, namely:
   - the planets nearer the Sun show phases, like the Moon;
   - the outer planets retrograde at certain points of their orbits;
   - the Jovian system provides a visual analogue for the structure of the Solar System.

Think: How do you know the Earth goes around the Sun?

Cross-Cutting Links: Use Orrery Science to Teach History

Think again: How do you know the Earth moves? Use the extraordinarily slow acceptance of the heliocentric picture to illustrate:

1. Development of scientific ideas; their interaction with society;
2. Key moments in history; key personalities; bringing 'science to life', e.g.
   - the labours of Copernicus, who in 1543 (on his death-bed) ultimately produced his famous *De Revolutionibus Orbium Coelestium;*
   - Martin Luther's disparaging remarks: "The fool will overturn the whole science of astronomy. But as the Holy Scriptures state, Joshua bade the Sun stand still and not the Earth." (Any modern parallels?);
   - the importance of careful observations (e.g. Tycho Brahe) and innovative — and intuitive — theoretical interpretations (e.g. Kepler);
   - Galileo Galilei's promotion of the heliocentric hypothesis, leading to his bruising encounter with the Church in 1633 (90 years after Copernicus) and his trial and subsequent sentence to life house arrest for heresy.
3. Explore modern concepts in development of scientific ideas; nature of scientific discovery; scientific revolutions and paradigm shifts.

The First Orrery

1. Invented by George Graham (c.1674–1751) around 1700; improved by John Rowley (1674–1728), the celebrated London instrument maker;
2. Presented around 1712 to John, fifth Earl of Orrery (1706/1707–1762); the name 'orrery' popularized by Irish essayist Sir Richard Steele (1672–1729).
3. Creation of first orrery sponsored by Charles Boyle (1674–1731), fourth Earl of Orrery: author, soldier and statesman.
   - grandson of Roger Boyle (1621–1679), first Earl of Orrery, and greatgrandson of Richard Boyle (1566–1643): the First (or Great) Earl of Cork.

Image ©Science Museum, London

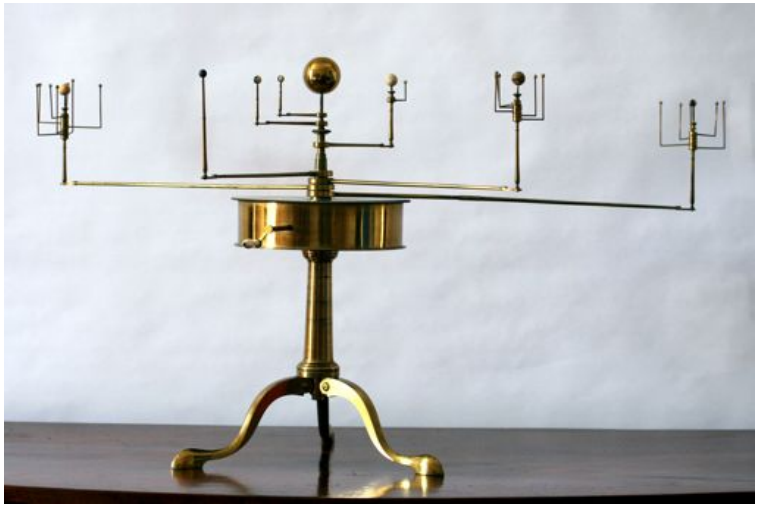
Key Players: Each a Fascinating Subject in Own Right

Richard Boyle

John and Charles Boyle

1. George Graham (1674–1751): English clockmaker and inventor; John Rowley (1674–1728): London instrument maker, later Master of Mechanics to George I. Rowley made an orrery for Prince Eugène of Savoy and another for Charles Boyle, fourth Earl of Orrery.
2. Richard Steele (1672–1729): Irish politician, writer and essayist.
3. Richard Boyle (1626/1627–1691): The 'Great' Earl of Cork. Richard's third son, Roger Boyle (1621–1679), the first Earl of Orrery. Richard's seventh and youngest son, Robert Boyle (1626/1627–1691), the 'father' of chemistry.
4. Charles Boyle (1674–1731): fourth Earl of Orrery; grandson of Roger Boyle.
5. John Boyle (1706/1707–1762): the fifth Earl of Cork and Orrery; married Henrietta (Harriet) Hamilton of Caledon, daughter of the first Earl of Orkney, and in 1738 acquired the Caledon Estate by marriage to the heiress Margaret Hamilton after Henrietta's death in 1732. Caledon is just a few miles from Armagh.

Early Orreries: Used to Explain the Heliocentric Theory

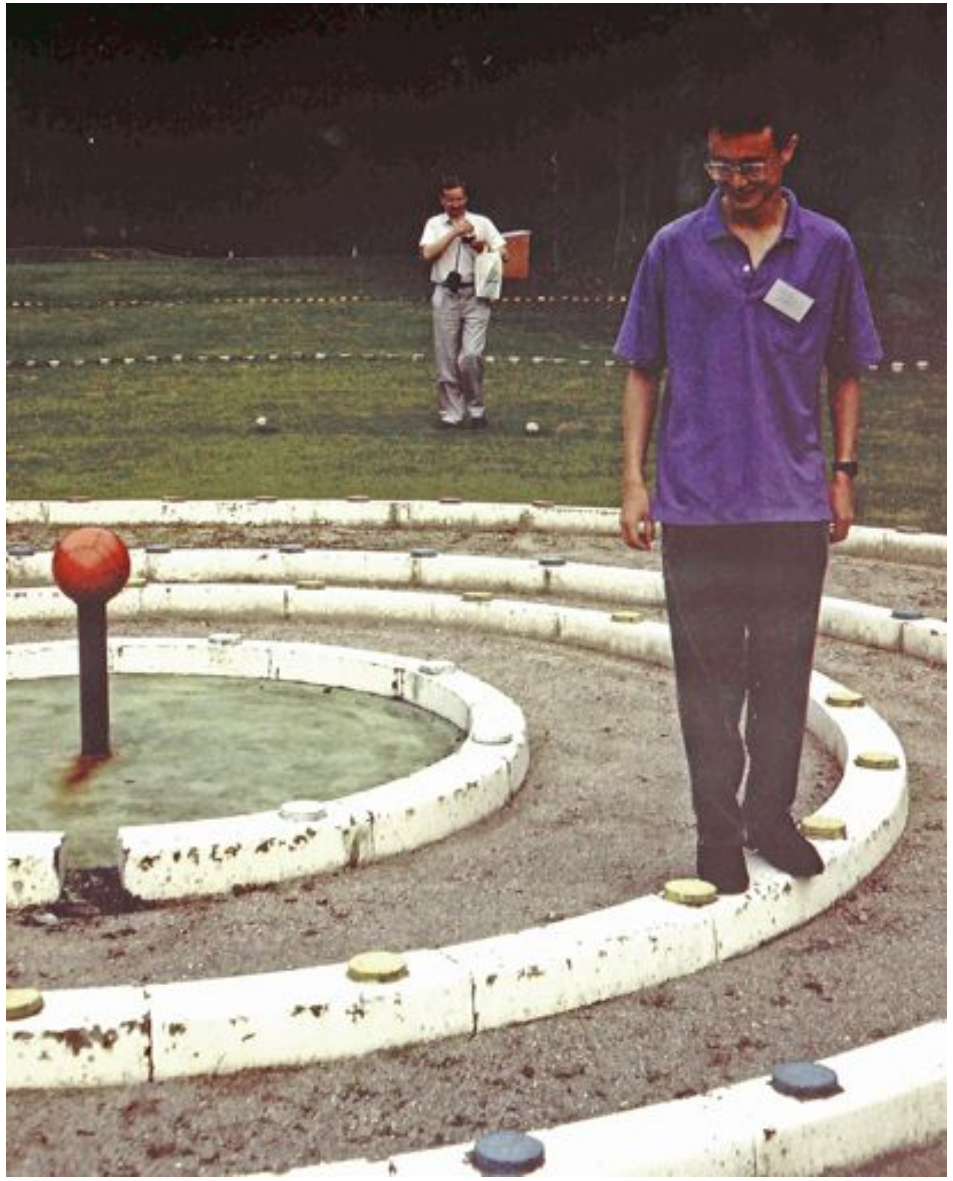


Early Human Orreries . . .

Are dynamic solar system models where people become the planets. The simplest models are:

1. Based on circular orbits; and so cannot accurately show planets' true positions in space versus time.
2. Usually not to scale; and so cannot be used for accurate measurements. This limits the range of possible activities.
3. Nevertheless, even simple models are fun to build and fun for play!

Human Orreries become much more interesting when laid out accurately. The concept is as versatile as a sundial.



Dynic Astropark Human Orrery (c.1997)

The Armagh Human Orrery: Key Features

(1) Scale: 1 m on ground = 1 AU in space, i.e. 1:150 billion.

(2) 16-day time-step.

(3) Six classical planets; one dwarf planet (Ceres); two comets (1P/Halley, 2P/Encke).

(4) The 13 ecliptic constellations; and 'signposts' to distant objects in the Universe (stars, galaxies etc.).

(5) Encourages comparison with observations and Universe Awareness.

The Armagh Human Orrery

The Peterborough Clone: The First in a School

Human Orrery at the King's School, Peterborough, England.
Image courtesy John Kinchin.

Laying Out the Armagh Human Orrery

Tools needed: (1) string and tape to measure heliocentric distance; (2) a protractor or other device to measure angles such as ecliptic longitude, measured from zero at First Point of Aries; (3) paint or old CDs to mark each object's location on ground; (4) hammer and nail to locate this precisely; and (5) a look-up table to connect each object's position on the 'map', e.g. (r, θ), with the time/date of its corresponding position in space.

Inspect the Human Orrery

1. Illustrates Kepler's First Law: that planets revolve around the Sun in nearly the same plane in elliptical orbits with the Sun at one focus.
2. Note the relatively small size of the Sun, which is shown to scale, and also that roughly 100 solar diameters equals 1 AU.
3. Note that there are four inner (or terrestrial) planets: two inside the Earth's orbit and one (Mars) beyond. Which ones show phases like the Moon?
4. Think: How many discs in each planet's orbit. Count all the discs!
   Think: Given that the diameter of the Sun is roughly 100 times that of the Earth and that twice the diameter of the Moon's orbit about the Earth would almost fit inside the Sun, could we show the Moon's heliocentric orbit on the Orrery. If so, what would be its shape?

Walk the Human Orrery



1. Demonstrates Kepler's Third Law: that planets closer to the Sun move much faster and have far less distance to travel in their orbits about the Sun than those farther out. Mathematically, "The square of the orbital period, P, is proportional to the cube of the semi-major axis, a"; i.e. $P^2 \propto a^3$.
2. People who keep walking the Human Orrery usually discover: (1) Mercury gets dizzy and falls over; (2) the outer planets move so slowly that they get bored (until Mercury falls over); and (3) the planets sometimes line up to produce a planetary massing on the sky.
3. This is a good time to get people to practice Universe Awareness: What do Earthlings see? What about people on Mars, or those on Jupiter? Get people to observe the planets and note their slow motion against the stars.

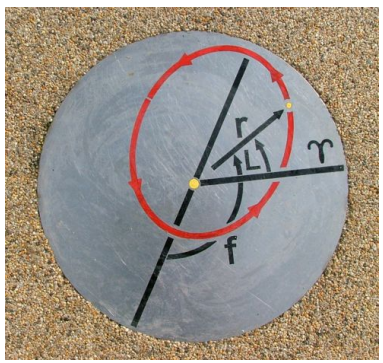
Run the Human Orrery

1. How fast can you go? How fast does each planet go? How far does each planet travel in one orbit around the Sun?
2. How long does it take you to run 20 complete orbits of each planet's ellipse? Construct a table or graph of your results.
3. Running encourages orrery play-time. Can have as much or as little 'science', 'mathematics' or teamwork in this playful physical activity as you like.

Dance the Human Orrery!

1. Dancing encourages physical activity, teamwork, coordination, movement and rhythm.
2. Develops familiarity with the main features of the Solar System.
3. Use dance as a tool to develop greater Universe Awareness. Can have as much or as little 'science' in this 'play activity' as you like.

Explore the Human Orrery



Can you figure it out? Remember, the Human Orrery is just a map; but with time and orbital motion built in. What is the time-step?; the scale?

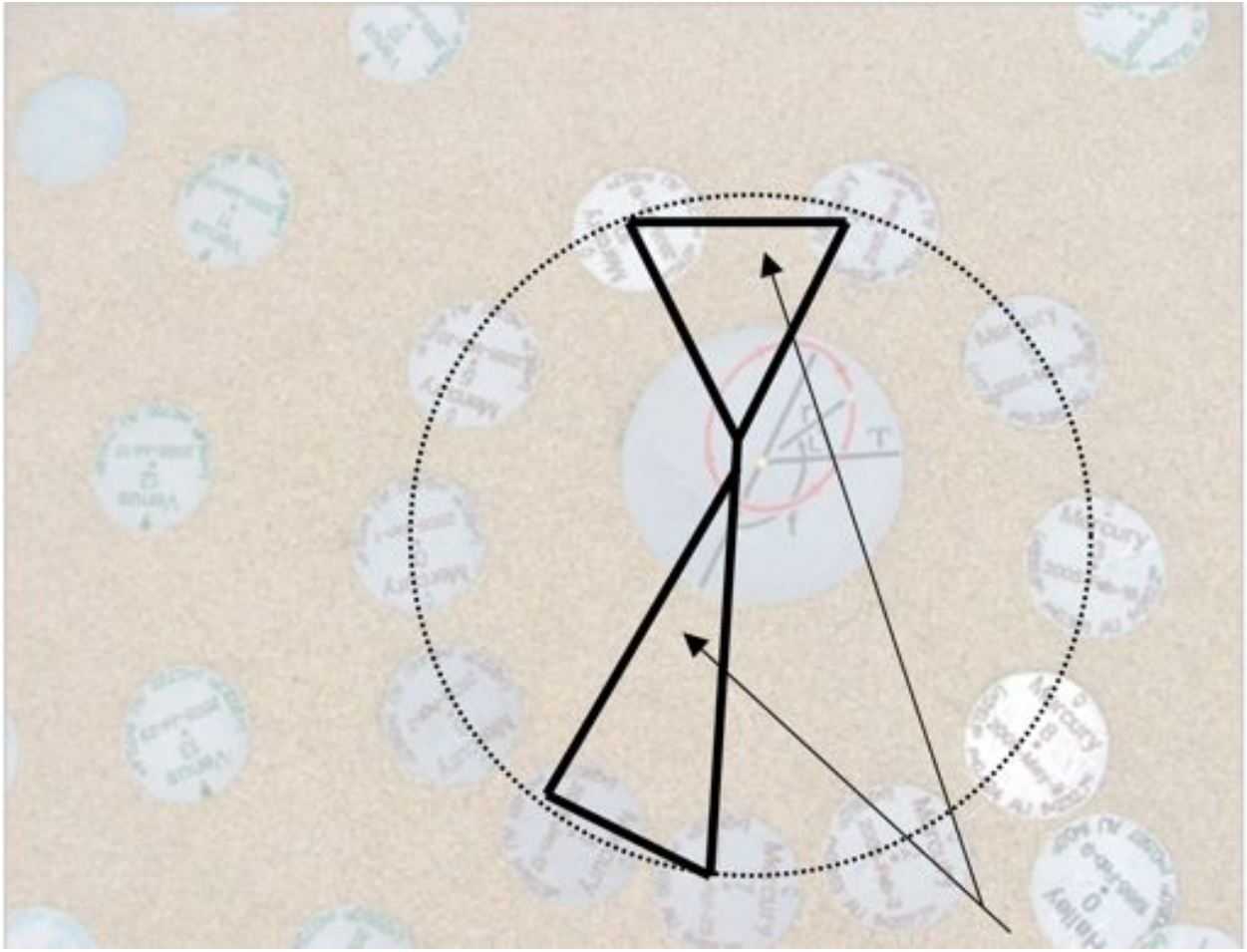
Measure the Human Orrery

Lots of examples, e.g. How fast does Saturn move in its orbit around the Sun?

1. Saturn travels $\approx$1 metre on the ground in 160 days.
   - That is, $\approx 1.5 \times 10^{11}$ m in space in 160 days.
   - i.e. $\approx 1.5 \times 10^{8}$ km in half a year, which is roughly 1.5×10^{7} seconds.
2. So Saturn moves at approximately 10 km s^{-1}. This practices arithmetic and determines the approximate speed of objects moving around the Sun.

Demonstrate Kepler's Second Law

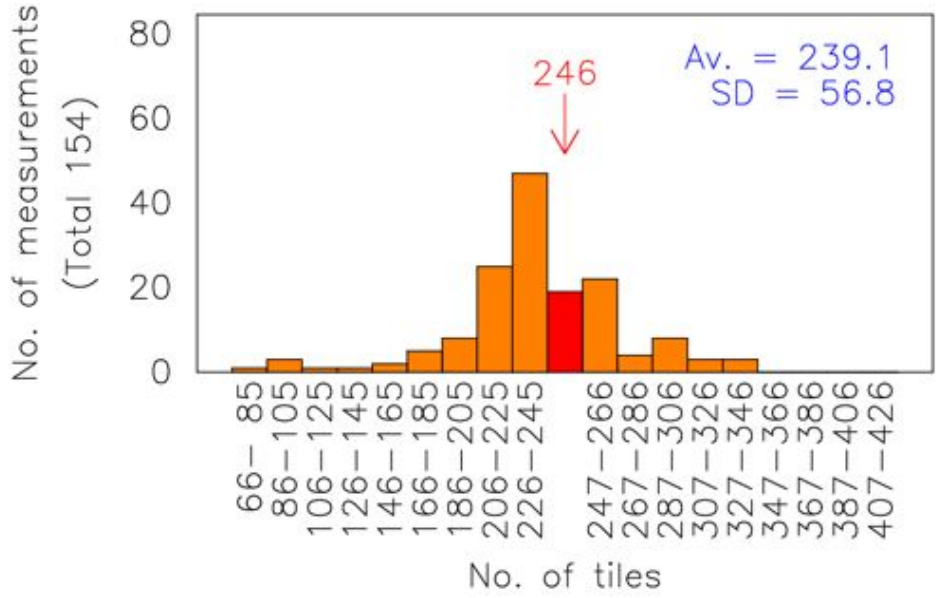
1. Kepler's Second Law: Objects orbiting the Sun under the influence of gravity alone sweep out equal areas in equal times.
2. Demonstrate this, e.g. by using the orbit of Mercury or Comet 2P/Encke.
3. Advanced students can check the formula for the area of a sector of an ellipse.



Illustrating Kepler's Second Law of 'Equal Areas'

Count the Human Orrery

1. Identify all the objects on the Orrery; classify them; count them; name them.
   - e.g. one star (the Sun); six planets; one dwarf planet (Ceres); and two comets (1P/Halley and 2P/Encke).
2. Break into groups and count all the discs you can see. Construct a table or bar chart (histogram) of your results.
3. Think: Should any of your data be discarded? What is the mean; the mode; the median; the range of your distribution?



Use the Human Orrery to introduce statistics.

Other Human Orrery Activities

1. Observing: Where are the planets today? Which are visible at night, which are evening or morning 'stars'; which constellations are they 'in'; how far away from Earth?; Is Earth visible at night from Mars?; from Venus?.

2. Meteor showers: For example, from comets Halley and Encke where (and when) their orbits cross that of the Earth. What times of year are these showers? When are the danger times for Venus or Mars? From which constellation do the meteors appear to come from?

3. Astrology: How many constellations does the Sun pass through in a year? In which does it spend the longest time; in which the shortest? Why is the First Point of Aries in Pisces?

4. History: Demonstrate the Triple Conjunction theory for 'Star of Bethlehem'; plot positions of Earth, Jupiter and Saturn for -6, i.e. (7 BC).

   Show that the first conjunction occurs in the morning sky around end-May; the second occurs near opposition around end-September; and the third occurs in early December, in the evening sky of that year.

Sleep the Human Orrery

Summary

1. The Human Orrery is a simple, yet powerful resource for raising Universe Awareness among all people, young and old.
2. It touches on history, many areas of Solar System astronomy, as well as mathematics, Earth's place in Space, and the relationship between objects in the near and distant Universe (e.g. planets, stars, distant galaxies etc).
3. The very wide range of Human Orrery activities lend themselves to including Human Orrery work into different areas of the school curriculum, familiarising children and their teachers with the structure of the solar system and the near Universe, of which the Earth is a part.
4. It helps people to appreciate the fully three-dimensional nature of the celestial 'sphere', overcoming the geocentric illusion.

Acknowledgements

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Some Human Orrery Publications

1. Bailey, M.E., Asher, D.J., Christou, A.A., 2005, "The Human Orrery: Ground-Based Astronomy for All", Astronomy and Geophysics, 46, No.3, 3.31–3.35.
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10. Kinchin, J., Bailey, M.E., Asher, D.J., 2012, "Human Orrery shows Kepler's Laws", Physics Education, 47, No. 2 (March), pp. 149–151.

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