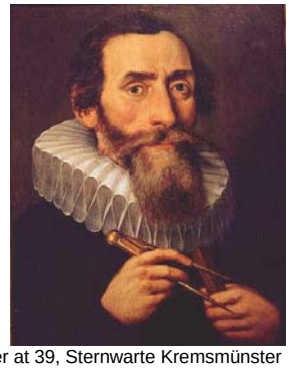
# Kepler's Laws

- Hwk1: max is 28
  - If you want a question regraded, write a note on the front & give me the paper.
- Figure added to Homework 2
  - See link on syllabus
- Read pages in Galileo's *Starry Messenger* for Mon
  - See link on syllabus
  - How & when did Galileo know that he had discovered moons of Jupiter?
- The discovery of the laws of motion, the first science.
  - *De Revolutionibus Orbium Coelestium*, Copernicus, 1543
  - *Astronomia Nova*, Kepler, 1609
  - *Philosophiae Naturalis Principia Mathematica*, Newton, 1687
- How Kepler figured out the path of Mars from Tyco's observations.
- Kepler's three laws.



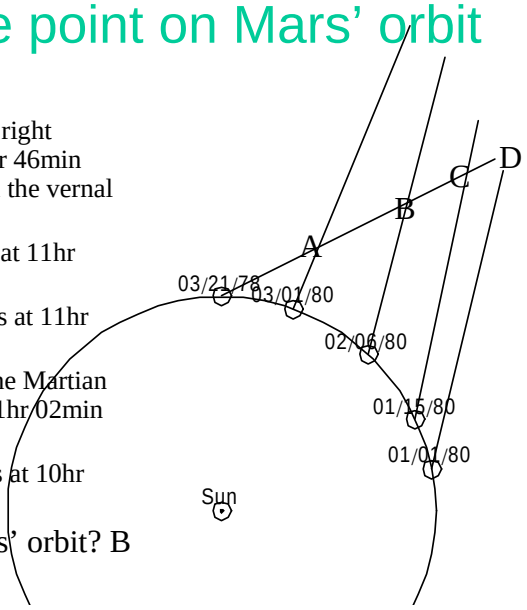
Kepler at 39, Sternwarte Kremsmünster
http://members.nextra.at/stewar/

| | |
|---|---|
| Copernicus | 1473–1543 |
| Columbus sails | 1492 |
| Tycho Brahe | 1546–1601 |
| Shakespeare | 1564–1616 |
| Johannes Kepler | 1571–1630 |
| Jamestown | 1607 |
| King James Bible | 1611 |
| Harvard College | 1636 |
| Isaac Newton | 1642–1727 |

# Determining one point on Mars' orbit

- Observations
  - On 21 March 1978, the right ascension of Mars is 7hr 46min (116.5° from the sun on the vernal equinox).
  - On 1 Jan 1980, Mars is at 11hr 06min (166.5°).
  - On 15 Jan 1980, Mars is at 11hr 12min (168.0°).
  - On 6 February 1980 (one Martian year later), Mars is at 11hr 02min (165.5°).
  - On 1 Mar 1980, Mars is at 10hr 30min (157.5°).

1. Which point is on Mars' orbit? B

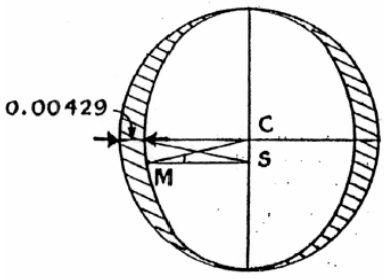


# Kepler Solves Mars Orbit

- Kepler's *Astronomia Nova*, 1609, in Sleepwalkers, by A. Koestler.
- Kepler describes the orbit: "The conclusion is simply that the planet's path is not a circle—it curves inward on both sides and outward again at opposite ends. Such a curve is called an oval. The orbit is not a circle, but an oval figure." —Ch. 44
- "What happened to me confirms the old proverb: a bitch in a hurry produces blind pups… But simply I could not think of any other means of imposing an oval path on the planets. When these ideas fell upon me, I had already celebrated my new triumph over Mars without being disturbed by the question whether the figures tally or not." —Ch. 45

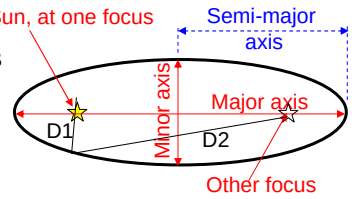
# Kepler discovers Kepler's First Law of Planetary Motion

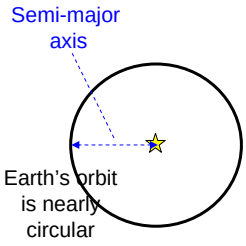
- "… I was wondering why and how a sickle of just that thickness (0.00429) came into being. While this thought was driving me around, while I was considering again and again… that my apparent triumph over Mars has been in vain, I stumbled entirely by chance on the secant of the angle 5° 18', which is the measure of the greatest optical elongation. When I realized that this secant equals 1.00429, I felt as if I had been awakened from a sleep…" —Ch. 45 (a year's work later)



# Kepler's First Law of Planetary Motion 1605

- The path of a planet is an ellipse.
  - Ellipse is figure for which D1+D2 does not change
  - The sun is at one focus.
  - Eccentricity = (dist between foci)/(major axis)
- Modern extension
  - The path of an object controlled by the sun's gravity is an ellipse, parabola, or hyperbola.
  - The sun is at one focus.




# Kepler's Second Law 1602

- The line joining the planet and the sun sweeps out equal areas in equal amounts of time
  - Planet moves slowly when it is far from sun
  - Planet moves rapidly when close to sun

Kepler2ndLaw

## Third Law 1618

- The size and periods of the planetary orbits are related by
  $P^2 = a^3$
  - where P is the period in years and
  - a is the half of the major axis in astronomical units

1. A 10th object (planet?) was found beyond the orbit of Pluto. ___ has the shorter period.
   A. Pluto
   B. 10th object
   C. Not enough information to answer

3rd Law
http://web.cuug.ab.ca/~kmcclary/fastsolar.html

## Questions concerning Kepler's Laws

- K1: A planet's path is an ellipse with the sun at one focus.
- K2: A planet "sweeps" out the same area in an equal amount of time.
- K3: The planets' periods P and semi-major axes a are related by
  $P^2=a^3$

- A planet, which has an almost circular orbit, and a comet, which has a highly elliptical orbit, have the same periods. Draw their orbits on a single picture.

1. Grading: sun's position
2. Grading: lengths of major axes.

# Questions concerning Kepler's Laws

- A planet's path is an ellipse with the sun at one focus.
- A planet "sweeps" out the same area in an equal amount of time.
- The planets' periods P and semi-major axes a are related by
  $P^2=a^3$

- A planet, which has an almost circular orbit, and a comet, which has a highly elliptical orbit, have the same periods. Draw their orbits on a single picture.

1. Grading: sun's position
   A. Centered for comet
   B. <u>Offset for comet</u>
2. Grading: lengths of major axes.
   A. <u>Same for both</u>
   B. Different