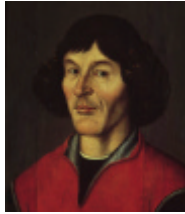


## Tycho & Kepler—9 Sept



Nicholas Copernicus  
(1473-1543)



Tycho Brahe  
(1546-1601)



Johannes Kepler  
(1571-1630)

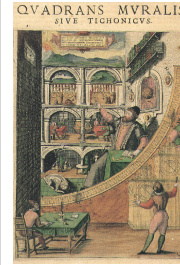


## Tycho Brahe's Observations

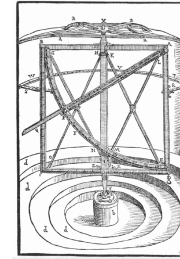
- On Uraniborg, Tycho measured positions of the planets for 20 years
- Highly accurate & reliable
- Accuracy limited by human eye, not by instruments. Superseded only with telescopes.
- Tycho measured & compensated for instrument flexure, the biggest error.



Uraniborg.



Great quadrant (1582)

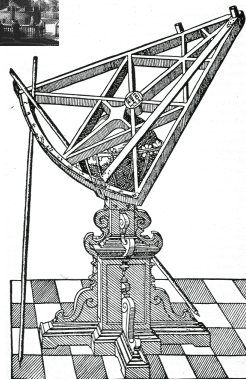


Revolving steel quadrant, 2 m radius (1588)



Brass azimuthal quadrant, 65 cm radius (ca 1576)

## Sextants at Uraniborg



Great quadrant (1582)

## Kepler & Tycho

Their meeting at Benatek (in Czechoslovakia): ...on 4 February 1600, Tycho de Brahe and Johannes Keplerus, co-founders of a new universe, met face to face, silver nose to scabby cheek. Tycho was fifty-three, Kepler, twenty-nine. Tycho was an aristocrat, Kepler a plebian. —Koestler, *The Sleepwalkers*, p302



## How did Kepler figure out the orbit of Mars from Tycho's observations?

- Tycho's observations are 2 dimensional
  - Declination: angle from celestial equator
  - Right ascension: angle from location of sun on vernal equinox
- Orbit is 3 dimensional
- Period of Mars
  - Opposition occurred on 22 January 1978
  - Next opposition: 25 February 1980 (56<sup>th</sup> day)
- Path of Mars

1. "Mars' actual direction reverses when it moves east to west with respect to the stars (retrograde direction)." Who said this? Copernicus or Ptolemy?

## Path of Mars

- Observations
  - On 21 March 1978, the right ascension of Mars is 7hr 46min (116.5° from the sun on the vernal equinox).
  - On 5 February 1980 (one Martian year later), Mars is at 11hr 03min (165.8°).
- Where is Mars?

## Summarizing questions

- If Tycho observed Mars for only two years, would Kepler have figured out the orbit of Mars?
- If Tycho's observations of Mars were done from an observatory on the sun, could Kepler have figured out the orbit of Mars?