**INST 2403**

**Copernicus’ vs Ptolemy’s Explanation of Retrograde Motion**

We saw that planetary motion as observed in the sky constitutes a strange pattern. It is much harder to explain than the motion of the Sun and the Moon, because the planets move mostly like the Sun and the Moon, but about once a year slow down, and reverse the direction of the motion with respect to the stars (not with respect to the horizon!), showing so called retrograde motion. See below for a typical pattern for the planet Mars (in 1994-95). Note that Mars is largely following the ecliptic, which is inclined 23.5 degrees with respect to the Celestial Equator.



**Ptolemy’s Explanation**

These complicated patterns of motion in the sky had to be explained. Ptolemy did so by assuming that the planets are moving on spheres around the Earth, which explains why Mars largely follows a circle – the ecliptic – and moves eastward (towards larger Right Ascension) with respect to the stars (not the horizon!). The retrograde loop was explained by an ad hoc introduction of a smaller *epicycle* that is attached to the Martian sphere. Mars is assumed to move around the smaller circle, which can explain why it sometimes moves “backwards”, i.e. towards smaller RA (roughly westward).

1. In the picture above, when is Mars moving in a retrograde fashion?
2. For how long is Mars moving retrograde?
3. How large is its retrograde loop? (In degrees? In million km? Can we tell?)
4. Qualitatively sketch the alleged epicyclic motion of Mars by drawing a dot on a small circle (epicycle) which rolls around a big circle (deferent). Trace the motion of the dot as this contraption moves.
5. What can we see in the sky of the “back and forth motion” of Mars? Use words like “closer/farther”, “prograde/retrograde”.
6. Does this theory work, i.e. does this describe the appearances of Mars that we actually see in the sky? Explain.

**Copernicus’ Explanation**

Ptolemy’s explanation works, but it seems awkward and ad hoc. To replace it with a more pleasing theory, Copernicus went back to Aristarchus’ heliocentric model of the solar system, where both the planets and the Earth orbit the Sun in circles.

Here is some (simplified) data that we will use to see if Copernicus’ explanation works.

* Aug 26, 2007 : RA 70°
* Sep 25, 2007: RA 88°
* Oct 25, 2007: RA 100°
* Nov 23, 2007: RA 103°
* Dec 24, 2007: RA 93°
* Jan 23, 2008: RA 84°
* Feb 22, 2008: RA 86°
* Mar 23, 2008: RA 98°
* Apr 22, 2008: RA 113°
1. When is Mars moving retrograde?

1. Remember that RA is the angle from the vernal equinox, the direction in which Sun is standing on March 21 every year. **Mark this direction on the attached chart**, see figure below. Keep in mind that the vernal equinox is infinitely far away, so for some other date you have to put your protractor parallel to that direction to count the RA angle again from the vernal equinox, see **second** figure below for some fictitious planet at RA 45° on December 10.





1. Now draw in the direction in which Mars is seen from Earth on the 9 dates in the table.
2. Where is Mars along these lines of sight? For that we would have to know the actual shape, size and orientation of Mars’ orbit. Copernicus did not know, but we know since Kepler that Mars’ orbit is a slightly eccentric circle with a radius about 1.5 times bigger than the Earth’s orbit’s. Draw in Mars orbit.
3. How is Mars moving along its orbit? Always in the same direction, or moving back and forth?
4. Why is this a “better” explanation of the pattern we see in the sky?

