

# Ancient Astronomy Final

Monday, Dec. 11, 2023

Covering Evans Chapters 5-7. I hope you enjoy working the following seven selections.

## 1. Solar Theory and the Equation of Time (5 pts)

We worked hard on the solar theory, but when the dust settled, most of the work was summarized in this single table:

TABLE 5.4. The Equation of Time (local apparent minus mean time)

Date	Equation	Date	Equation
Jan 20	-11 min	Jul 23	-6 min
Feb 19	-14	Aug 24	-3
Mar 21	-7	Sep 23	+7
Apr 20	+1	Oct 24	+16
May 21	+4	Nov 23	_____
Jun 22	-2	Dec 22	_____

(a) The table caption describes three things. I have been abbreviating those things as “EoT,” “LAT,” and “LMT.” Interpret the table caption as an equation relating EoT, LAT, and LMT:

EoT =

(b) Solve this equation for LMT...

(c) There is no table entry for Dec. 11, however, Dec. 11 is 18/29 of the way — which is about 7/12 of the way — from Nov. 23 to Dec. 22. The value for Nov. 23 is +14 and the value for Dec. 22 is +2. So interpolate to get a value for EoT on Dec. 11:

(d) If you went outside and saw a local apparent time of 8:00am, what would you say the LMT is?

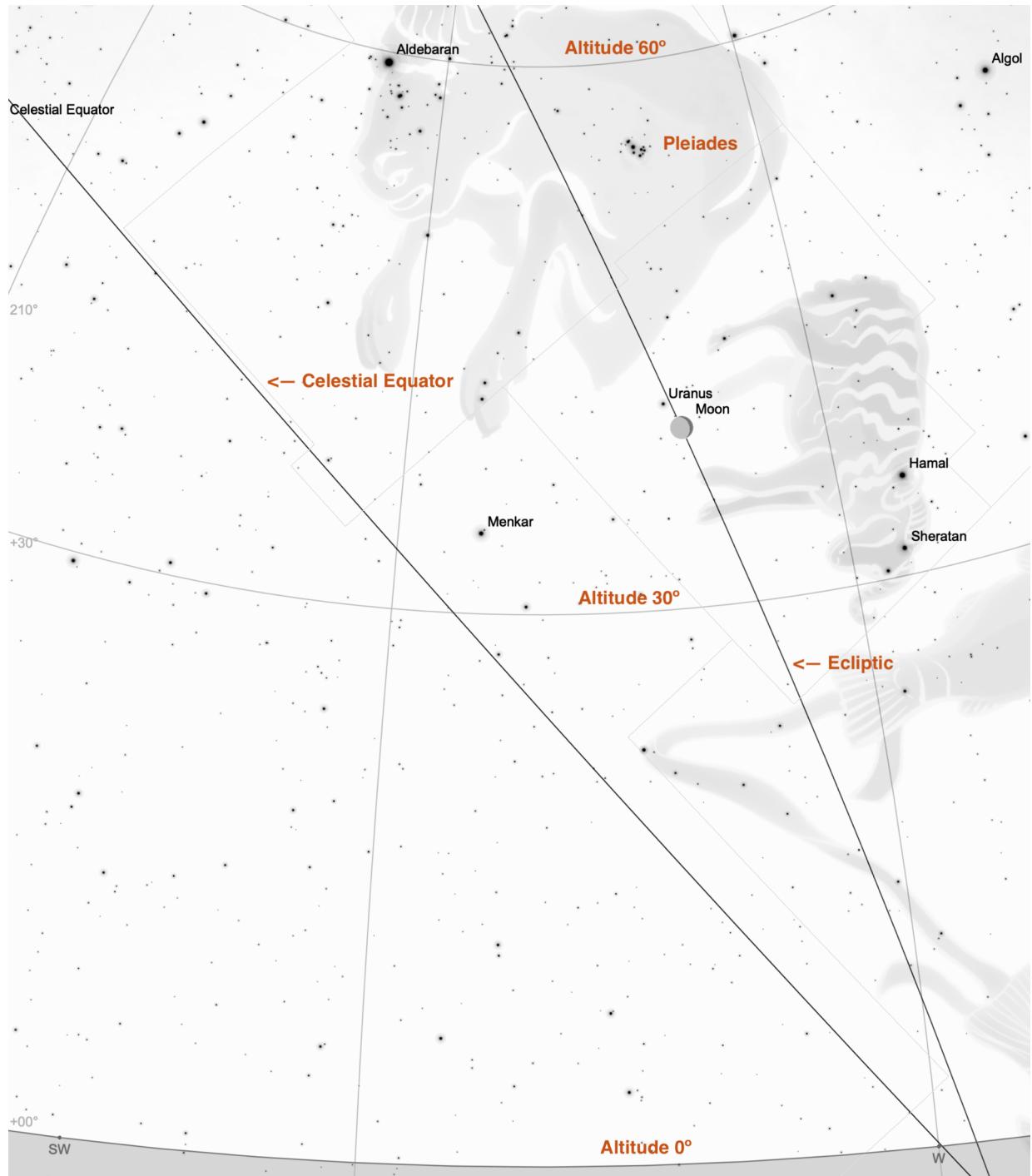
(e) Our longitude is  $118^\circ$  W. The nearest multiple of  $15^\circ$  is  $120^\circ$  W and that is the standard for PST. However, we like to use MST at Deep Springs, and the standard for MST is  $105^\circ$  W. So the MST standard is  $13^\circ$  further east than the LMT you calculated. Correct the LMT you got in (d) to get the time in MST.

A HINT (which might or might not help you double-check your answer to (e)):

According to Tim, Deep Springs observes MST and is in the future. The rest of California is in the past.

## 2. Ecliptic Longitude of the Pleiades (4pts + 2pts EC)

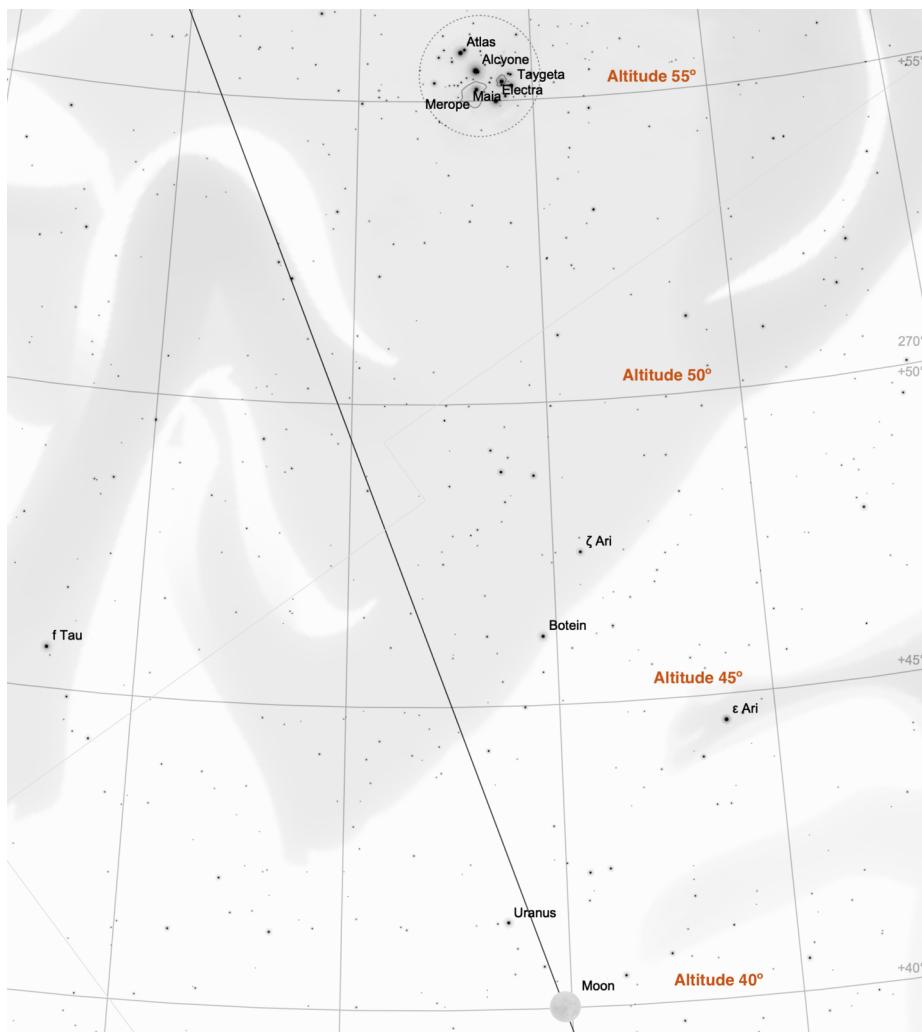
At 4am on November 8, 2022, the Moon was eclipsed by the Earth. At Deep Springs, the western sky looked like this:



## 2. Ecliptic Longitude of the Pleiades (CONT'D)

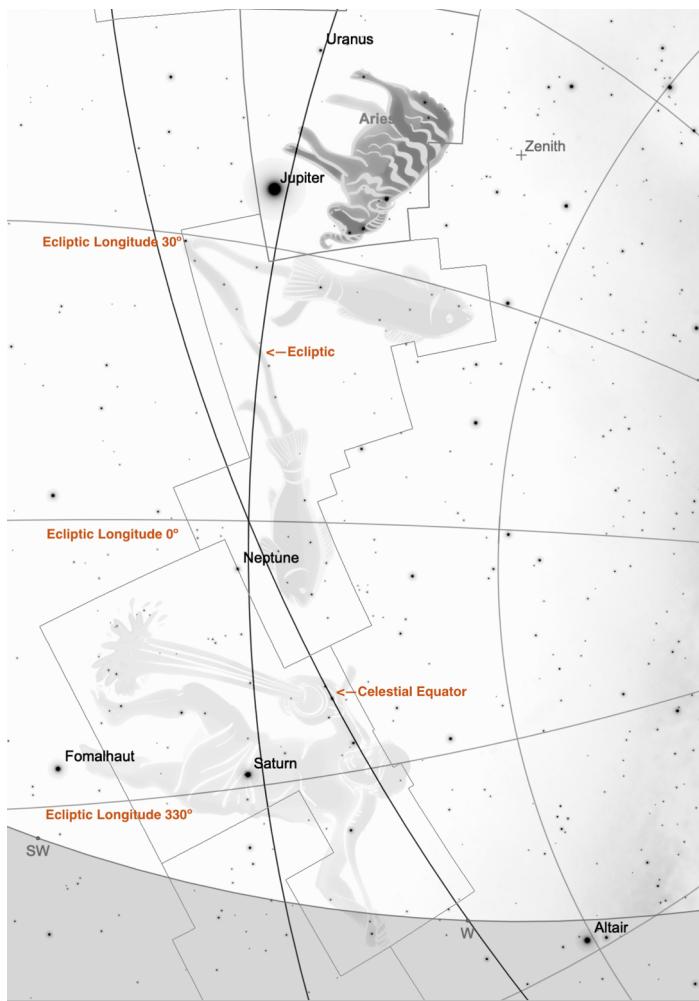
- (a) Measure the distance between the  $0^{\circ}$  degree line of altitude and the  $30^{\circ}$  line of altitude in millimeters. Do not worry about the fact that the lines are slightly curved. (HINT: I got 90mm.) Using your measurement, how much of a degree does one millimeter represent? Leave it as a fraction.
- (b) Connect a line from the Pleiades to the Ecliptic that is perpendicular to the Ecliptic. Measure the distance from the Moon to the Pleiades along the Ecliptic. Convert your measurement to degrees using the conversion factor in (a).
- (c) The Sun was at Ecliptic longitude  $226^{\circ}$  during the Eclipse. What was the Ecliptic longitude of the Moon? Add your result from (b) to the Ecliptic longitude of the Moon to get your estimate of the Ecliptic longitude of the Pleiades.

**EXTRA CREDIT:** Use the blowup below to significantly improve your accuracy. Begin by re-measuring the scale. Then take into account the parallax of the Moon. You need to move the Moon up by the parallax amount, which was  $3/4^{\circ}$ . You also need a more accurate value for the Sun's Ecliptic longitude. It was  $225 \frac{3}{4}^{\circ}$ , not  $226^{\circ}$ . In the blowup, when you drop your perpendicular, use Alcyone as the center of the Pleiades. I am looking for an answer accurate to  $1/4^{\circ}$ .



### 3. Precession of the First Point of Aries (4 pts)

Below are the constellations of Aries (the Ram), Pisces (the Fishes), and Aquarius (the Water Pourer). On this star chart, the intersection point of the Celestial Equator and the Ecliptic was the location of the first point of Aries in the year 2000.



(a) Measure how many millimeters are between the  $0^\circ$  line and the  $30^\circ$  line, along the Ecliptic. (HINT: If you don't get 36mm, measure again.) Do not worry about the fact that the Ecliptic line is a bit curved. Using your measurement, how much of a degree does one millimeter represent? Leave it as a fraction. Do a quick, crude estimate of how many degrees the First point of Aries has moved since it left Aries.

(b) Measure how many millimeters along the Ecliptic the First Point of Aries will have to move to get to the boundary of Aquarius. (The constellation boundary is the boxy line enclosing the Water Pourer.) Convert your measurement to degrees using the conversion factor you found in (a), and then multiply by the rate of precession of 72 years per degree. Add the result to 2000. When is the dawning of the Age of Aquarius?

## 4. Interpretation of Planetary Observations (5 pts)

(a) Chapter 7 opened with 13 years of observations. Use the extract below to find the retrograde of Jupiter in 1982. Just mark the beginning and the end, the way Evans does:

Year	Date	J.D. 244	Sun	Mer	Ven	Mar	Jup	Sat
1982	Jan 30	5000	310	315	297	197	219	203
1982	Feb 9	5010	320	304	293	198	219	203
1982	Feb 19	5020	330	305	295	199	220	203
1982	Mar 1	5030	341	314	299	199	220	203
1982	Mar 11	5040	351	326	306	197	220	202
1982	Mar 21	5050	0	341	314	194	220	201
1982	Mar 31	5060	10	359	323	190	219	200
1982	Apr 10	5070	20	18	334	187	218	199
1982	Apr 20	5080	30	40	344	183	217	199
1982	Apr 30	5090	40	59	355	181	214	198
1982	May 10	5100	49	71	6	180	213	197
1982	May 20	5110	59	75	17	181	212	197
1982	May 30	5120	69	72	29	182	211	197
1982	Jun 9	5130	78	66	40	185	211	197
1982	Jun 19	5140	88	67	52	189	210	197
1982	Jun 29	5150	97	75	64	193	211	197
1982	Jul 9	5160	107	89	76	197	211	197
1982	Jul 19	5170	116	109	88	202	211	198
1982	Jul 29	5180	126	131	100	208	212	198
1982	Aug 8	5190	135	150	112	214	212	199
1982	Aug 18	5200	145	166	124	219	214	199
1982	Aug 28	5210	155	181	137	225	215	200
1982	Sep 7	5220	164	191	149	232	217	201
1982	Sep 17	5230	174	198	162	239	218	202
1982	Sep 27	5240	184	194	174	245	220	203

(b) Now that you have the ecliptic longitude at the beginning of retrograde and the ecliptic longitude at the end of retrograde, what is your best estimate for the ecliptic longitude of opposition?

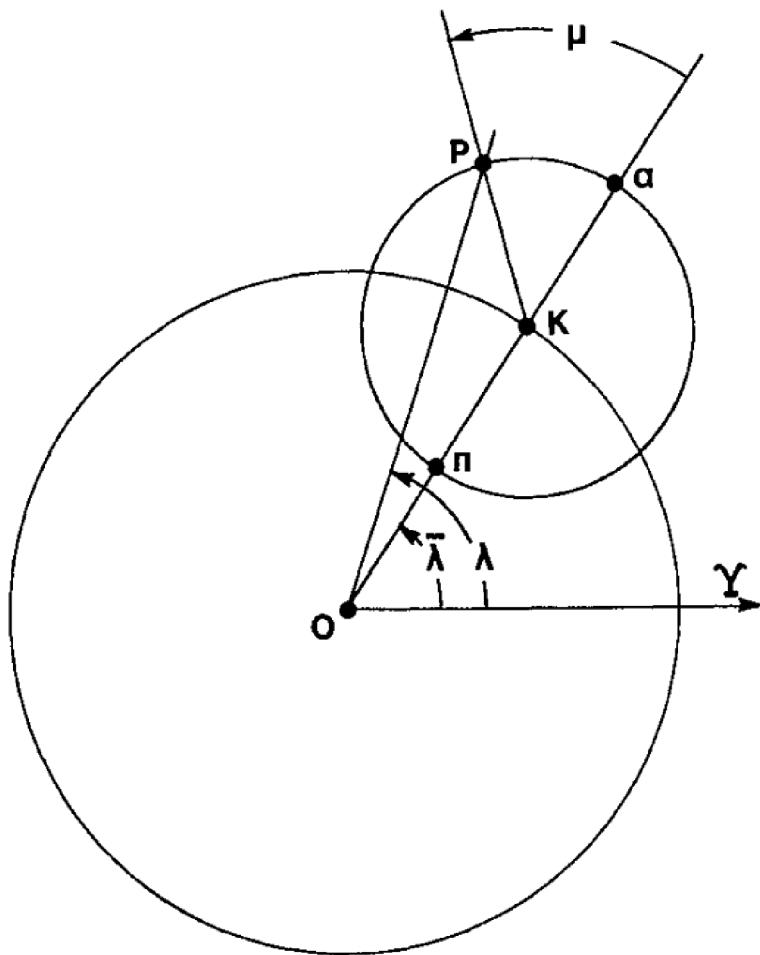
(c) On what Julian date and calendar date did this occur? You will have to interpolate. You can probably do the interpolation in your head, but show very briefly how you did it.

(d) If I told you that the next opposition was on Julian date 2445485, from just these two oppositions what is your best estimate of the synodic period?

(e) If I told you that the opposition in (d) was at ecliptic longitude  $246^\circ$  what would your estimate of  $f_\mu$  be? Feel free to leave it as a fraction. (HINT: It is not  $\frac{31^\circ}{398\text{days}}$ ! How many degrees does the epicycle spin between oppositions? That is what goes in the numerator of  $f_\mu$ .)

## 5. Calculations of Planetary Positions in the Theory of Apollonius (4 pts)

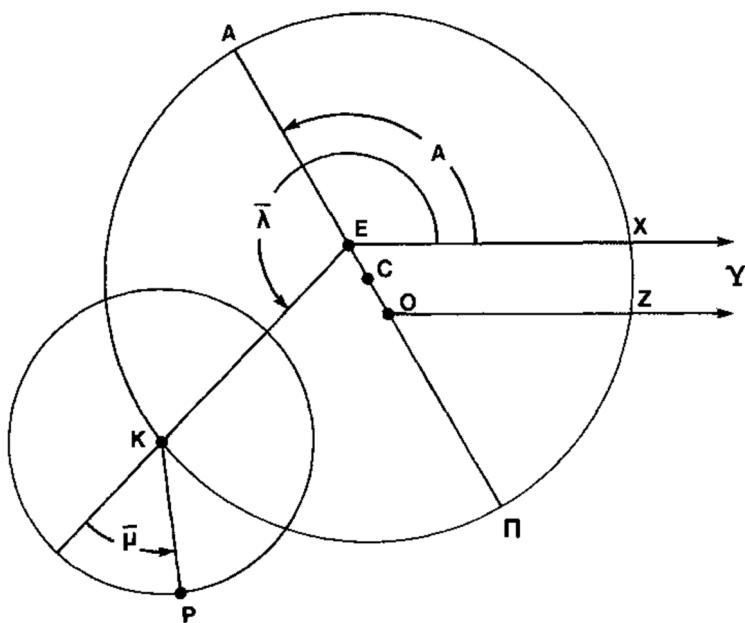
Below is Moore Fig. 7.17, which shows Apollonius's theory:



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- (a) Measure the deferent angle, add  $35^\circ$  to it, draw in the new  $K'$ , and label it  $K'$ .
  - (b) Measure the epicycle angle,  $\mu$ , add  $90^\circ$  to it, and draw in the new  $P'$ .
  - (c) Label the new resulting ecliptic longitude  $\lambda'$ .
  - (d) Measure  $\lambda'$  with a protractor.

## 6. Calculations of Planetary Positions in the Theory of Ptolemy (4 pts + 1pt EC)

Below is Moore Fig. 7.32, which shows all the important ingredients of Ptolemy's theory:



(a) What are each of these symbols in the diagram...

The direction of the First point of Aries:

The angle from the First point of Aries to the apogee:

The angle that the deferent has spun about the equant:

The angle that the epicycle has spun about the deferent:

The symbol that represents us (the Earth):

(b) Draw in the line showing the direction of the planet from us.

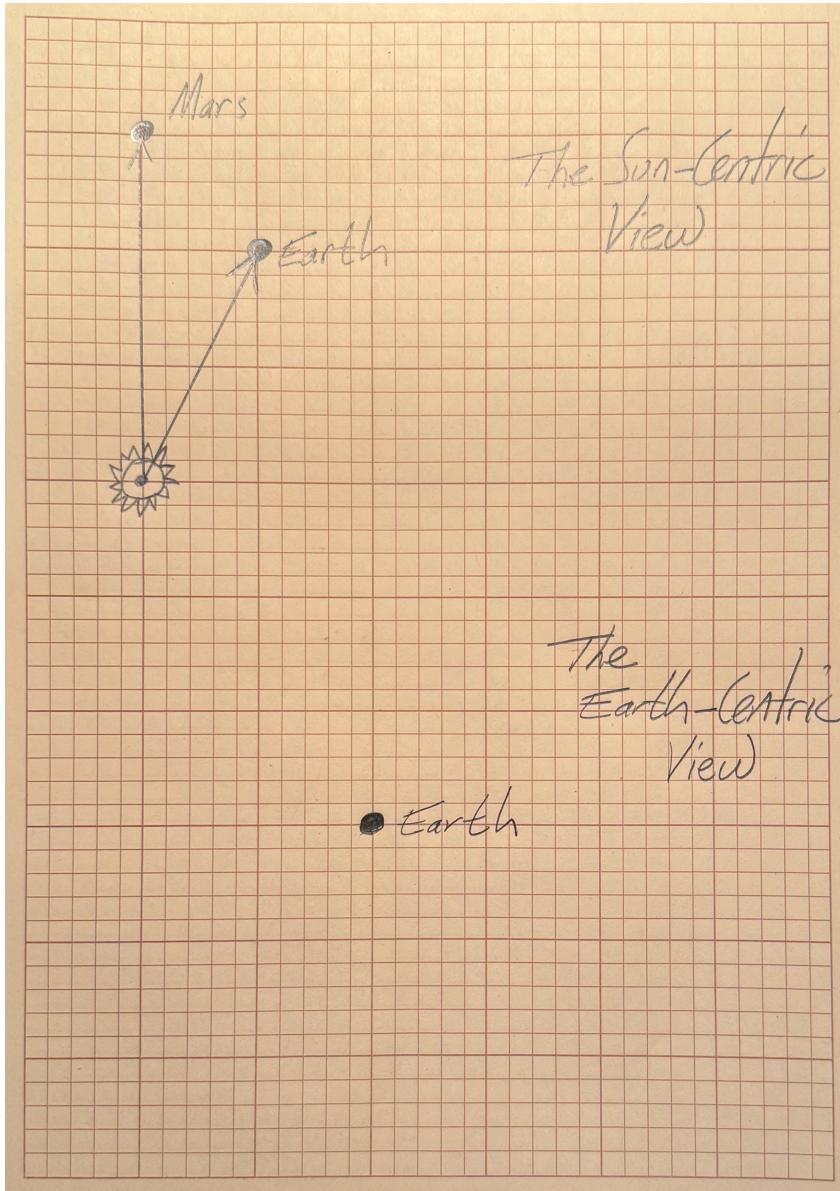
(c) Measure the ecliptic longitude of the planet using a protractor.

**EXTRA CREDIT**

Suppose an upcoming opposition *in the middle of a retrograde* occurs when  $\bar{\lambda}$  has increased by  $40^\circ$ .

Accurately draw the new positions of K and P and label them K' and P'.

## 7. The Equivalence of Earth-centric and Sun-centric Predictions (4 pts)



- In the Earth-centric view, draw in the vector that represents the Sun relative to the Earth. Use the grid lines and a ruler to do this accurately.
- In the Earth-centric view, draw in the vector that connects Earth to the deferent. Use the grid lines and a ruler to do this accurately.
- In the Earth-centric view, draw in the epicycle vector (that connects the deferent to Mars). Use the grid lines and a ruler to do this accurately.
- Are the Sun and Mars in the same positions relative to the Earth as they were in the Sun-centric view?  
(HINT: Yes, if you did it right.)
- So if it isn't a problem that Ptolemy has an Earth-centric view, what is one of the things that Ptolemy actually got wrong?

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Name \_\_\_\_\_

*When the Moon is in the Seventh House  
And Jupiter aligns with Mars  
Then peace will guide the planets  
And love will steer the stars*

*This is the dawning of the Age of Aquarius  
The Age of Aquarius  
Aquarius! Aquarius!*

1. / 5
2. / 4 (+2)
3. / 4
4. / 5
5. / 4
6. / 4 (+1)
7. / 4

**GRAND TOTAL**

/ 30 MAX