QUADRIVIUM

ASSIGNMENT 12A:

ASTRONOMY - GEOMETRY IN MOTION

FOR

-ANNANDALE- TUESDAY, APRIL 23RD

OR

-FISHKILL- WEDNESDAY, MAY 1ST

NUREMBURG CHRONICLE-1493

-Grant Medieval Sourcebook- In Volume II Reader

Read Chapter 4, pp. 449-451 from Sacrobosco's *Sphere* (13th century). Immediately after p. 449 I added p. 133 from the original translation which describes the spirals of the sun. You may want to refer to the reading by me from 11b and the figures that precede the Sacrobosco section in the reader.

-Gingerich, Owen. "The Alfonsine Tables in the Age of Printing." **Read** pp. 93-95.

Homework (HW-12a) for Tuesday-Annandale or Wednesday-Fishkill.

-**Finish filling in the table** for scaled planet distances and sizes on the handout

-**Do the "Sexagesimal-to-Decimal" exercise** (and theorizing) that is on the reverse of this page.

-**Make a diagram** that helps to explain one or two of the astronomical ideas from any of the Sacrobosco readings we have done so far. Feel free to riff on my diagrams or the old woodcut diagrams. But draw up something that demonstrates that you understand something from the Sacrobosco readings. Be sure to write up a short description of what your diagram shows.

Notes on Figure 2.9

[Fig. 2.9 can be found on previous assignment sheet and in the reader]

A- The Celestial Axis- The whole system spins with a 24-hour period on this axis.

B- The Ecliptic- the path of the sun within the starry sphere.

C- The summer region of the Ecliptic (for Northern Hemisphere)

Su., Eq., Wi.- The Tropics and Equinoctial- These circles show a day in the sun's motion on the first day of summer (the summer solstice), the first day of the autumnal equinox and the first day of the vernal equinox, and the first day of winter (the winter solstice).

The Su. circle is called the "Tropic of Cancer."

The Eq. circle is called the "Equinoctial." The Equinoctial is the Celestial Equator.

The Wi. circle is the "Tropic of Capricorn."

[*Tropos* means turning... where the sun turns around.] The tropical circles are about 23º latitude north and south (from equator).

Arctic and Antarctic Circles- The circles that the pole of the zodiac traces out. These are the northern and southern boundaries for lands which can have 24-hour daylight. These circles are about 67º latitude (or 23º measured from the poles).

The Horizon- the shaded disk (labled in the figure), which changes depending on the observer's location and does not spin. It is fixed to the stationary earth. A person at the north pole would have a horizon equal to the Equinoctial circle. A person at the equator would have a horizon that intersects the two poles. The horizon shown in Fig. 2.9 is located approximately for Italy or southern France.

The Zodiac- the parallel circles above and below the ecliptic are the zodiac. It is 12º tall: 6º above the ecliptic and 6º below. It is a belt. The zodiac is made up of 12 signs, each taking up a 30º slice of the ecliptical pie. Thus each sign is 30º wide and 12º tall.

"Sexagesimal-to-Decimal"

The following chart is transcribed from a copy of the *Alfonsine Tables* made by Prosdocimo de' Beldomandi of Padua (1424). It is from a manuscript I studied several years ago in Florence. It was clear from the context that this chart was an extremely important part of the *Alfonsine Tables* but I was at a total loss over what it meant. After translating the Latin I was still baffled. "The difference between the flood and King Alfonso... The difference between Nebuchadnezzar and the era of the Arabs"? What do all the numbers mean? The key to figuring it out was realizing that all those numbers were in sexagesimal, base-60. The 4^m, 3^m, 2^m, and 1^m are 60^3, 60^2, 60^1, 60^0 respectively. With this insight it almost all fell into place.

For example, "the difference between the flood and King Alfonso" is 7:21:40:38 in sexagesimal and is 1,590,038 in decimal. I got that by multiplying 7 with 60^3, 21 with 60^2, 40 with 60^1, and 38 with 60^0 and adding up the results. You get 1,590,038. But what is that? Translate 5 or 6 of these sexagesimal numbers into decimal from the top third of the chart and see if you can figure it out. [You might have to do some Wiki-sleuthing.] Write up your results and your theories as to what it all means for the next class. [Hint: King Alfonso was crowned in 1252 and the incarnation of Christ was in the year 1.]

Florence, Biblioteca Medicea-Laurenziana. Manuscript Ashburnham 206. 19v

Tabula differentiarum anuis here ab altera exheris his positis
[Table of differences from one era to another]

			60^3 4^m	60^2 3^m	60^1 2^m	60^0 1^m
Differentiarum	diluvium (flood)	& regis alphonsi	7	21	40	38
Differentiarum	nabuchodonosor	& regis alphonsi	3	22	44	25
Differentiarum	mortis alesandri	& regis alphonsi	2	39	45	5
Differentiarum	alesandri magni	& regis alphonsi	2	38	32	44
Differentiarum	here cesaris	& regis alphonsi	2	10	49	19
Differentiarum	incarnationis christi	& regis alphonsi	2	6	57	59
Differentiarum	dyoclitianim	& regis alphonsi	1	38	11	13
Differentiarum	here arabum	& regis alphonsi	1	3	54	24
Differentiarum	yeldaghe't regis	& regis alphonsi	1	2	54	0
Differentiarum	diluvium &	nabuchodonsor	3	58	56	13
Differentiarum	diluvium &	alexandri macedonum regis	4	41	55	33
Differentiarum	diluvium &	alexandri magni	4	43	7	54
Differentiarum	diluvium &	here cesaris	5	10	51	19
Differentiarum	diluvium &	incarnationis xpi	5	14	42	39
Differentiarum	diluvium &	dyoclitiani	5	43	29	25
Differentiarum	diluvium &	here aragum	6	17	46	14
Differentiarum	diluvium &	here persa4	6	18	46	38
Differentiarum	nabuchodonosor &	mortis phylipi patris alexandri	0	42	59	20
Differentiarum	nabuchodonosor &	alexandri magni	0	44	11	41
Differentiarum	nabuchodonosor &	here cesaris	1	11	55	6
Differentiarum	nabuchodonosor &	incarnationis xpi	1	15	46	26
Differentiarum	nabuchodonosor &	dyoclitiani	1	44	33	12
Differentiarum	nabuchodonosor &	here arabum	2	18	50	1
Differentiarum	nabuchodonosor &	yes'daghe't regis persam	2	19	50	25

Useful translations:
- diluvium = flood
- regis alphonsi = King Alfonso X of Castile (r. 1252-1284)
- nabuchodonosor = Nebuchadnezzar
- mortis alesandri = Death of Alexander the Great
- here cesaris = Era of Caesar
- incarnationis christ i= in-carne-tion (birth) of Christ
- dyoclitianim = Emperior Diocletian
- here arabum = Era of the Arabs
- yeldaghe't regis = Persian King Yazdegerd
- here persa4 = Era of the Persians

Transcription and translations by Daniel Newsome.

Various inconsistancies and abbrebiations were retained for authenticity.

HW-12a: In-class anachronistic exercise and homework:

Measurements for a Scale Model of Modern Solar System (scaled to fit up to Mars... and Saturn)

Medieval astronomers didn't know the distances to the planets, but they all acknowledged that the distances were immense. Below are the modern measurements of those distances. I'm having you do the following exercise so that you can discover just how big astronomical distances are and, by comparison, how small the objects are.

			Scaled to 300" Sun to Mars (Chalkboard in Heg. 102)		Scaled to 5000" Sun to Saturn (Heg. 102 to Library)		Scaled to 150,000" Sun to Saturn (Heg. 102 to Bubby's)	
Visible Planets	Planet Diameter in miles	Distance from Sun: Orbital Radius in miles	Distance from Sun: Scaled orbital radius (Martian-scaled model)	Scaled Planet Diameter (Martian-scaled model)	Distance from Sun: Scaled orbital radius (Saturnine-scaled model)	Scaled Planet Diameter (Saturnine-scaled model)	Distance from Sun: Scaled orbital radius (Saturnine-scaled model)	Scaled Planet Diameter (Saturnine-scaled model)
Sun	864,576	0	0	1.83" 46.53mm	0			
Mercury	3,032	36,000,000	76.3" or 6.4'					
Venus	7,520	67,240,000						
Earth	7,918	92,960,000						
moon	2,158	distance from earth 238,900	distance from earth		distance from earth 1.3" 0.1'	0.012" 0.3mm	distance from earth	
Mars	4,212	141,600,000	**300" or 25'**					
Jupiter	86,882	483,800,000						
Saturn	72,368	888,200,000			**5000" 417'**		150,000"	
rings	172,000	n.a.			n.a.		n.a.	
			scaling factor is $\cong 2.12\times10^{-6}$		**scaling factor is** $\cong 5.63\times10^{-6}$		**scaling factor is** $\cong$	

E.g. Using the "Rule of Three," scale the modern measurements of the Solar System (up to an including Mars) to a chalkboard that is 300 inches long (25 feet).

$$\frac{Length\ of\ Model\ to\ fit\ Mars}{Actual\ Mars-to-sun\ distance} = \frac{300\ inches}{141{,}600{,}000\ miles} = \frac{Output\text{: }Scaled\ distance\ for\ model}{Input\text{: }Sun-to-Planet\ distance}$$

You have all the Sun-to-Planet distances and planet radii in the table above.
Cross multiply and divide to find x, your output....

$$Output, x_{in\ inches} = \frac{300\ inches}{141{,}600{,}000\ miles} \times (input\text{: }sun\text{-}to\text{-}planet\ distance\ in\ miles)$$

$$x_{inches} = (Scaling\ factor) \times \left(d_{planet(miles)}\right)$$

In this example, the **scaling factor is** $\frac{300\ inches}{141{,}600{,}000\ miles} \cong 0.00000211864407 \cong 2.12\times10^{-6}$

E.g. $x_{scaled\ distance\ to\ Mercury} = \left(2.12\times10^{-6}{}_{scaling\ fraction}\right)\times\left(36{,}000{,}000_{d\ to\ Mercury}\right) \cong 76.3\ inches$

E.g. $x_{scaled\ diameter\ of\ sun} = \left(2.12\times10^{-6}{}_{scaling\ fraction}\right)\times\left(864{,}576_{diameter\ of\ sun}\right) \cong 1.83\ inches$

To convert inches to millimeters just multiply the inches by 25.4. E.g. 0.0197" ≅ 0.5mm

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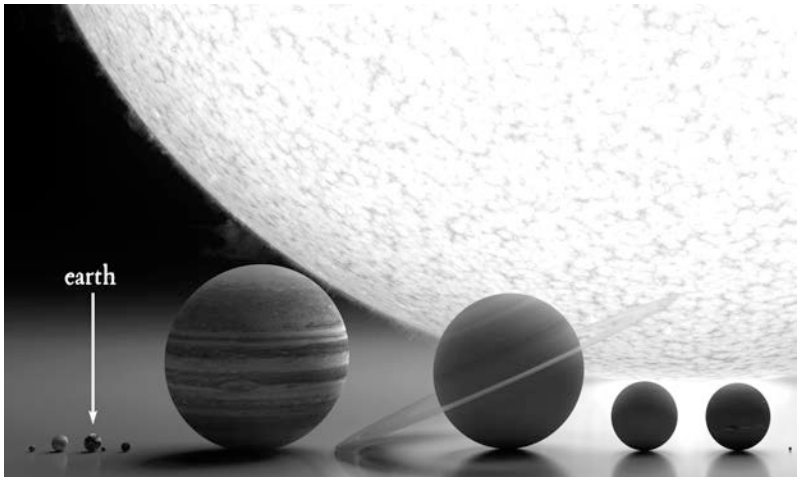

Fill in the rest of the table...

Your assignment for 12a (Annandale-Tuesday or Fishkill-Wednesday) is to figure out a <u>scale</u> solar system that includes Mercury, Venus, Earth (with moon), Mars, Jupiter, and Saturn. The scale will make Saturn 5000" from the sun (which is the distance from Heg. 102 to the reference desk in the library. [The scaling factor will be ca. 5.63 x 10^{-6}.]

Then figure out another solar system model to Saturn that is 150,000 inches (ca. 2.37 miles, the distance from Heg. 102 to Bubby's in Red Hook, as-the-crow-flies). Fill in the rest of the table with the appropriate conversions. Convert inches to feet or miles or millimeters where appropriate. Use your own judgment for when it is appropriate. You must figure out the scaling factor for this one.