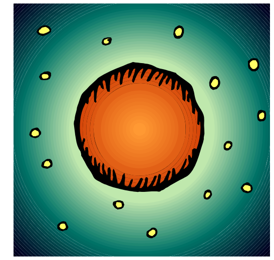
Warren Amateur Astronomy, Spring 2016



2016 is a Leap Year … why is that so, and what is the history of the calculation?

Why are we so Earth-centric .. What if we lived on Mars, would we need leap years there? Come to the talk and find out!

Leap Year, Shmeep Year!

-- what's the big deal?

Dr. Scott Schneider

Department of Natural Sciences - Physics

Thursday, April 21st, 2016

Can I get a copy of the talk?

Well, the talk has only **just** begun .. But, ok!

http://vnatsci.ltu.edu/s_schneider/astro/index.shtml

note the underscore:

`http://vnatsci.ltu.edu/s_schneider/astro/index.shtml`

Don’t read ahead and give away all the goodies!

Topics covered in this talk

- Orbit period of the Earth around the Sun
  - Compared to Earth solar day
- Corrections to the calendar to add leap days
  - Thanks Mr. Caesar!
- Weird leap day rules – Thanks, your Holiness, Pope Gregory!
  - Why/How do they work?

Orbit period of the Earth

- Orbit period of the Earth around the Sun = 365 days, right?
- Actually, ***365.24219*** solar days
  - Oh, that pesky 0.24219 – arrgh!
- Can’t have a calendar with a fixed number of days
- *When was this problem noticed?*

Brief History of Leap Time

- Early calendars allowed rulers to hold festivals to honor the "gods"
- Months added/removed at the whim of rulers
  - calendars drifted relative to Sun/Moon cycles
- "Intercalation" – adding a day to bring months "in synch" with seasons
- Skip over early calendars – jump to Julius Caesar (~45 BC)
- Julius Caesar had a leap year calendar created = +Y/4
  - Not permanent solution (and 3-year confusion!)
  - SEP? (Someone Else's Problem)

Brief History of Leap Time - continued

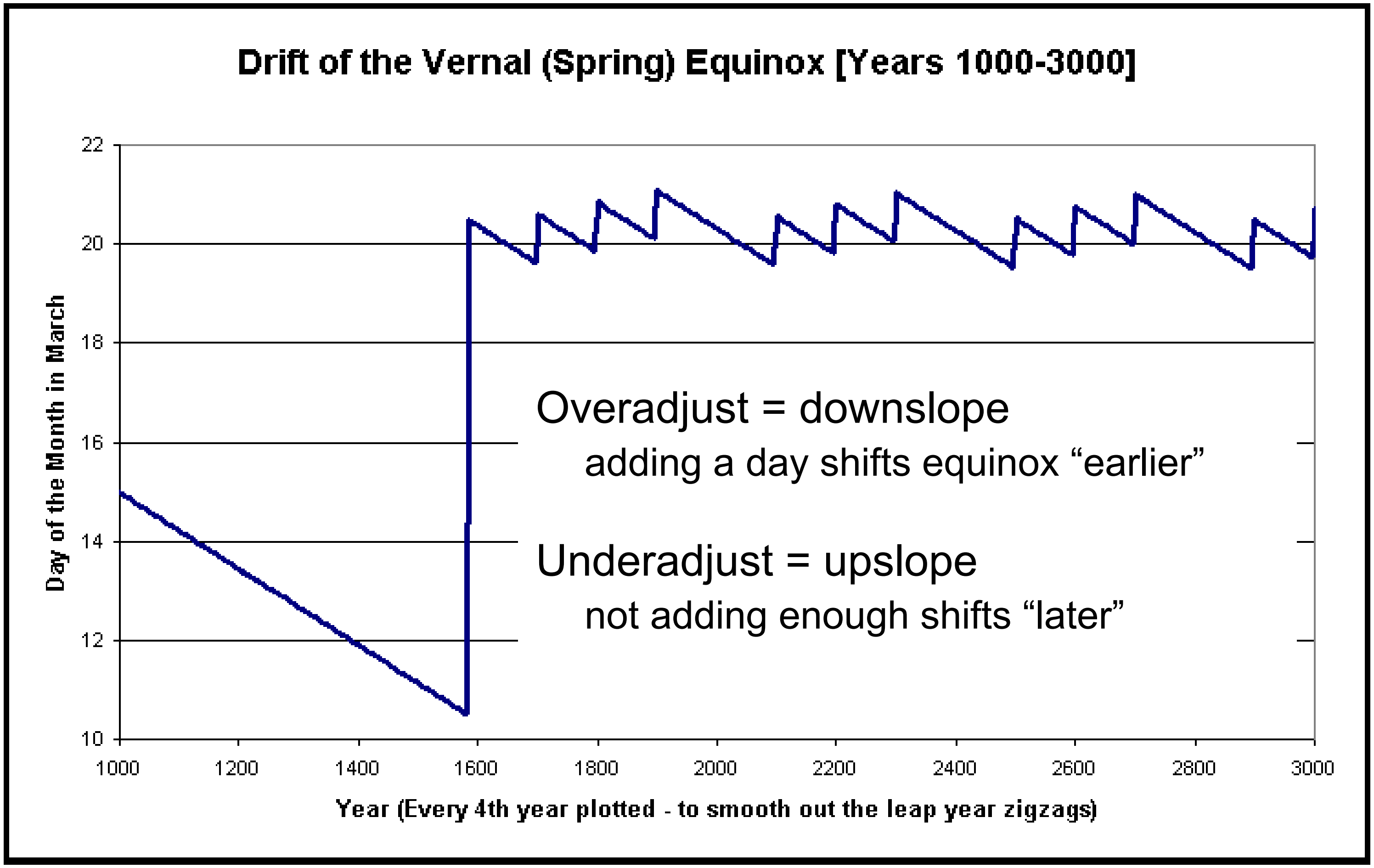
- By 1400's, Popes frustrated - Easter kept shifting
  - Also, Vernal (Spring) Equinox kept drifting earlier
- Pope Gregory finally commissioned current rules
  - *Successful, but a Y5K problem looms!*
- Gregorian Reformation – October, 1582
  - Needed to eliminate some days - Oct 4th then Oct 15th
- Add if /4 years, not if /100, add if /400

Leap Formula = +Y/4 -Y/100 +Y/400

"integer divisions"

Follow Spring Equinox Date

- **Spike before 1600? – Gregorian Reformation!**



Why does the 4-year rule work?

- Let's round *365.24219* to 365.25 = *365 + ¼*
- Each 365 days, Earth doesn't quite make it around
  - Takes ¼ day more
  - Would mean the "seasons" would eventually drift
  - 365 **undercounts** the number of days of orbit
- Solution - every 4 years .. Add one day
  - Chosen to be **my Brother's** wedding anniversary day
    - Happy 6th anniversary! … seems more like 24 years, go figure!
  - (Also known as February 29th – Leap Year Day)
    - Some see it as a "free" day to do something different
- *So, that solves the problem right?*

Why is the 4-year rule not enough?

- 365.25 > *365.24219*
  - check my math please?
- We **over-adjust** with the 4-year rule
  - Extra time each year = 0.25-0.24219=+0.00781 days
    - 11 minutes a year extra
- Every 128 years, would add up to an extra day
  - Seasons would start shifting again – sheesh!

- So – we have a century correction
  - If Year divisible by 100, don’t add Leap Year Day
  - Even though it must also be divisible by 4!
- 1700, 1800, 1900 not leap years
  - *1600 was .. What about 2000?*

Why is the 100-year rule not enough?

- If use 4 year and skip 100 year – 365.24
  - *365.24219* > 365.24 (= 365 + 1/4 - 1/100)
- We under-adjust with the 100-year rule
  - Missing time each year = 0.24291-0.24=0.00219 days
    - 3 minutes a year too few
- Every 450 years, would end up losing a day

- So – we have a 400-year correction
  - If Year also divisible by 400, add Leap Year Day
- 1600, 2000 = leap year – as will be 2400

- *Ok … but we are done with changes now, right?*

"Y5K" problem

- Using +Y/4-Y/100+Y/400 = 365.2425 > *365.24219*
- We over-adjust with the current rules *(see previous graph)*
  - Extra = 0.24291-0.2425=0.00031 days
    - 26 seconds each year too much
- ~Year 4900 (round to 5K) – extra day accumulated

- One solution: Could skip every 3600 years
  - Needs adjustment in 31,000 years
- Another solution: Could skip every 4000 years
  - Adjust in 17,000 years
- Another solution: Could skip every 3000 years
  - Adjust in 42,000 years

- SEP! *(But, that's it .. Right?)*

"Y5B" problem yet looms …

http://www.y5b.com/

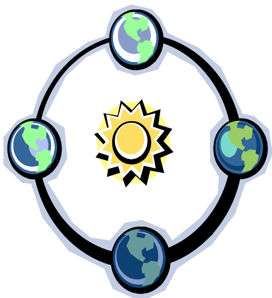
Benefit to the 400 year rule…?

- Since 2000 was divisible by 400, can have a 28 year calendar
- Each 4 years, we add a day – after 7 of those …
- Calendars from 1901 can be used in 1929
  - 1902 same day-for-date as 1930, etc.
- 2081 will be "last 28 year calendar"

- So, dust off those 1988 calendars, still relevant!
  - *First Internet Virus (1988 Internet Worm)*
  - *Comic strip Foxtrot first appeared*
  - *Microsoft Windows 2.1 !!!*
  - *Skrillex and Michael Cera born*

Acknowledgments

- Calculations from **Astronomy Morsels III** by **Jean Meeus**
    - If you want to do astronomy calculations – he is THE source of information!
- Graphs courtesy of Microsoft Excel
- Presentation by … um, oh yeah, Powerpoint
- Websites, as linked in this talk
- “Mapping Time: The Calendar and its History” – E.G. Richards
    - ISBN 0 19 850413 6 - Excellent reference!



Warren Amateur Astronomy, Spring 2016

You think a "day" should be shorter than a "year", and only one sunrise per day, right?

Two Sunrises on Mercury

-- Count 'em TWO!

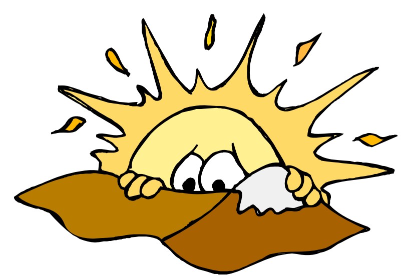
(And, a "day" longer than the "year"??)

Dr. Scott Schneider

Department of Natural Sciences - Physics

Lawrence Technological University

Thursda, April 21st, 2016



Start with Earth – because we know it!

- Rotation on axis (w-axis) is ~360 deg/day (pretty fast)

- If we were not moving around the Sun, we would see the Sun rise in the East and set in the West …right? *Scott, please demonstrate* … (so w-axis = E->W motion)

- Suppose we did **not** turn on our axis – where would the sun rise and set as we orbited (w-orbit)? *Scott, we're waiting!*

- So, the effect of the orbit is a "west to east" motion of the Sun – interesting! (w-orbit = W-E motion !!)

- So, if the rate due to the orbit is bigger than the axis rate … the sun moves "differently" in the sky (West to East)

But, w-orbit not quite that simple …

- All the planets have elliptical orbits
- Mercury is more eccentric than other inner planets
- At perihelion, the planet moving faster, so the w-orbit is higher
- At aphelion, planet slower, thus w-orbit smaller
- Let's call them w-per and w-ap (both of these are basically "w-orbits")
- Remember, if the rate due to the orbit (now w-per, w-ap) is bigger than the axis rate … the sun moves "differently" in the sky (West to East)
  - Thus .. If the w-axis rate is *between* those two ….

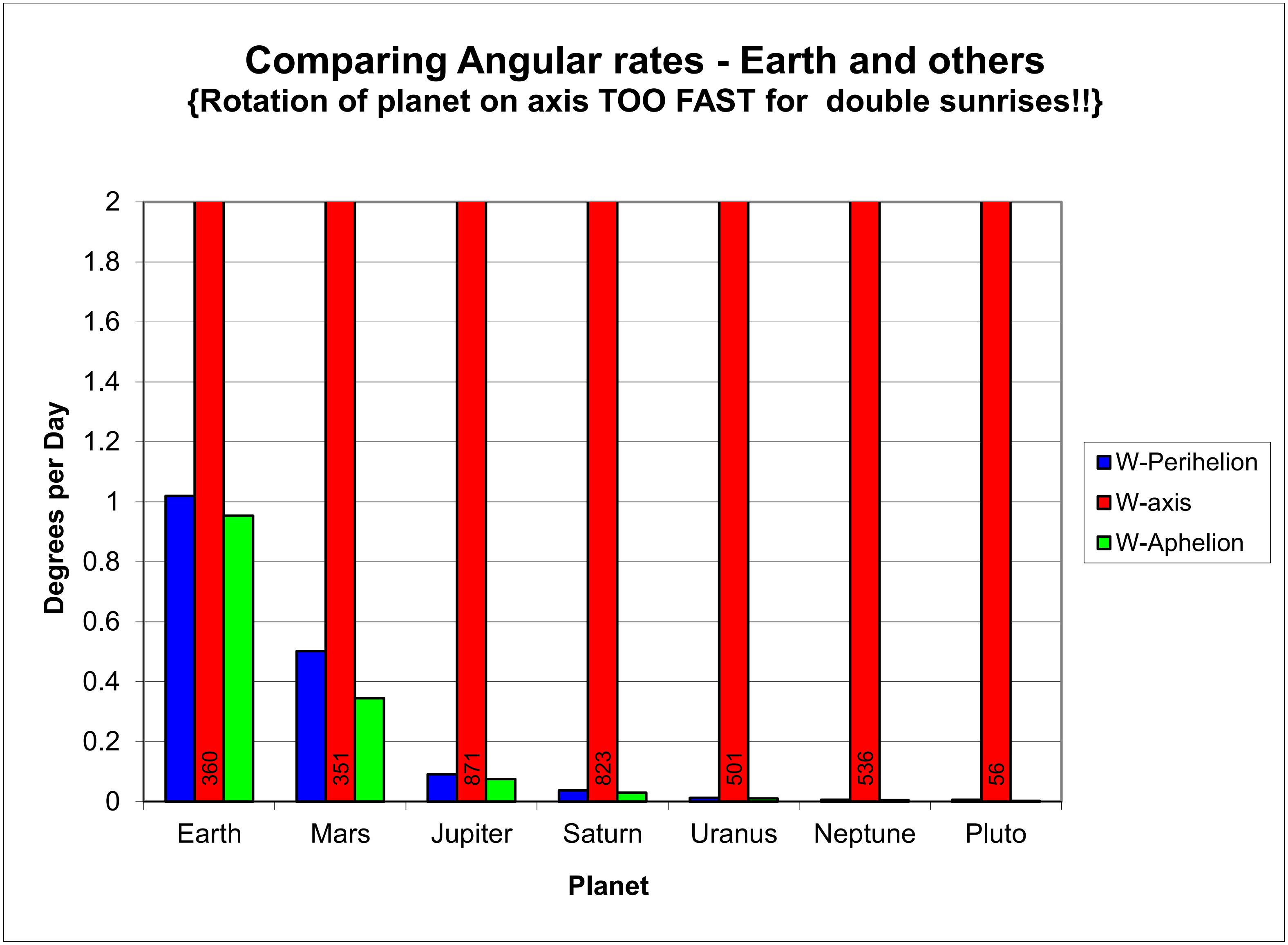
Data Chart for all the planets

Planet	ecc	a	Orbit Period	mean	Axis period	w-axis	w-per	w-ap	Wper>Waxis>Wapp?
		(AU)	(days)	(deg/day)	(days)	(deg/day)			
Mercury	0.206	0.39	87.97	4.09	58.81	6.12	6.35	2.76	YES!!!
Venus	0.007	0.72	224.70	1.60	-243.69	-1.48	1.62	1.58	no - backwards!
Earth	0.017	1.00	365.25	0.99	1.00	360.00	1.02	0.95	no
Mars	0.093	1.52	868.98	0.41	1.03	350.89	0.50	0.35	no
Jupiter	0.048	5.20	4331.87	0.08	0.41	870.53	0.09	0.08	no
Saturn	0.056	9.54	10760.27	0.03	0.44	822.86	0.04	0.03	no
Uranus	0.047	19.18	30684.65	0.01	0.72	501.16	0.01	0.01	no
Neptune	0.009	30.06	60189.55	0.01	0.67	536.31	0.01	0.01	no
Pluto	0.248	39.53	90465.12	0.00	6.41	56.21	0.01	0.00	no

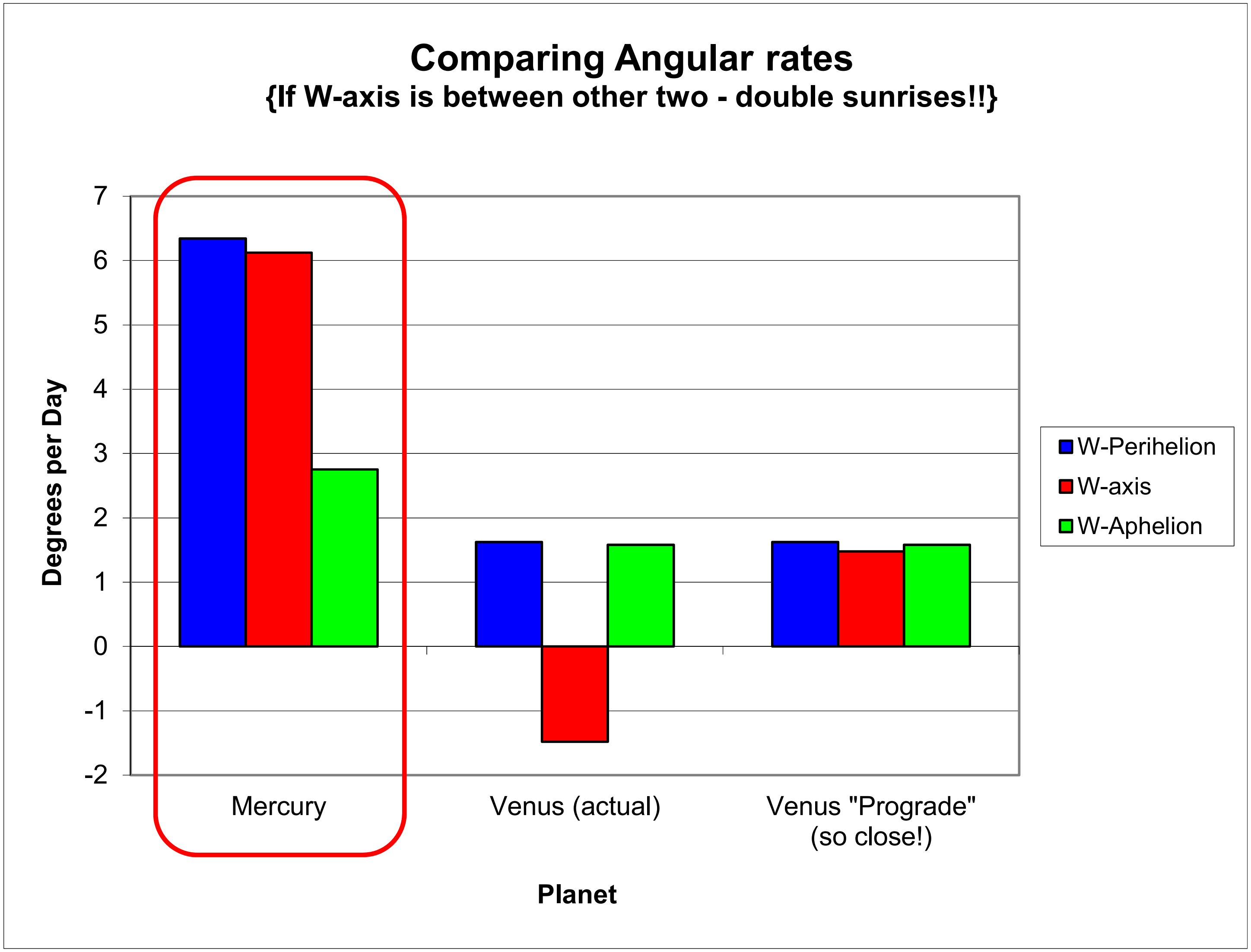
ecc=eccentricity – how circular (0) or elliptical (>0) is the orbit?
a = semi-major axis – rough distance from sun
orbit period = time for planet to orbit once around the Sun
mean = mean daily motion = 360 degrees / orbit period
But, depending on eccentricity, can be higher or lower at different points
axis period = fixed rotation on axis (how fast is the planet turning on axis)
w-axis = daily rotation rate on axis (fixed) = 360/(axis period)

Mercury has more eccentric orbit .. W-orbit changes at perihelion/aphelion!!
w-per = daily motion at perihelion (close approach distance to Sun) > n-ap
w-ap = daily motion at aphelion (far approach distance to Sun) <n-per

Earth and Beyond … if w-axis < w-perihelion … Doh!



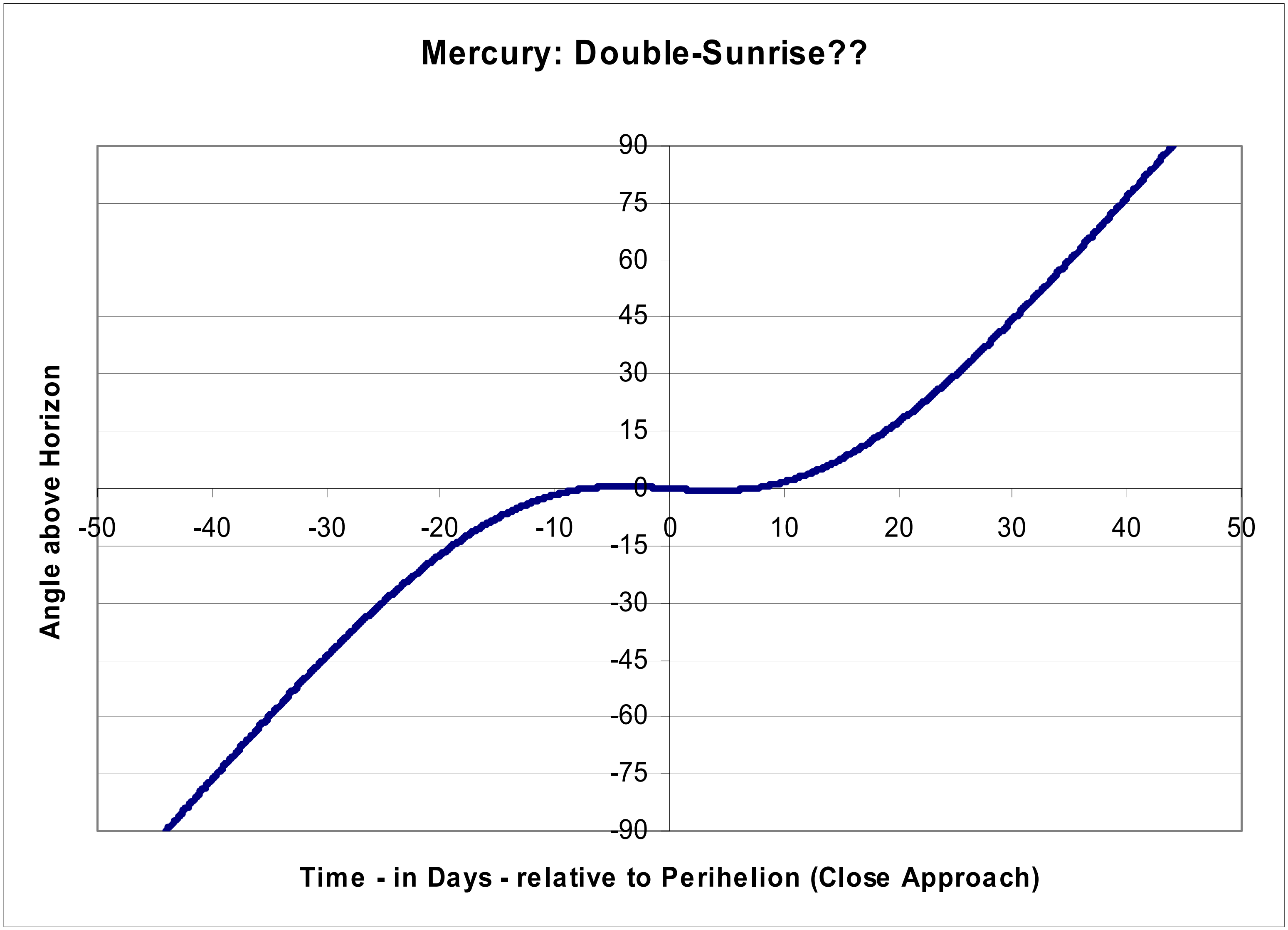
Mercury/Venus … if w-axis < w-perihelion …



Mercury … what does this mean?

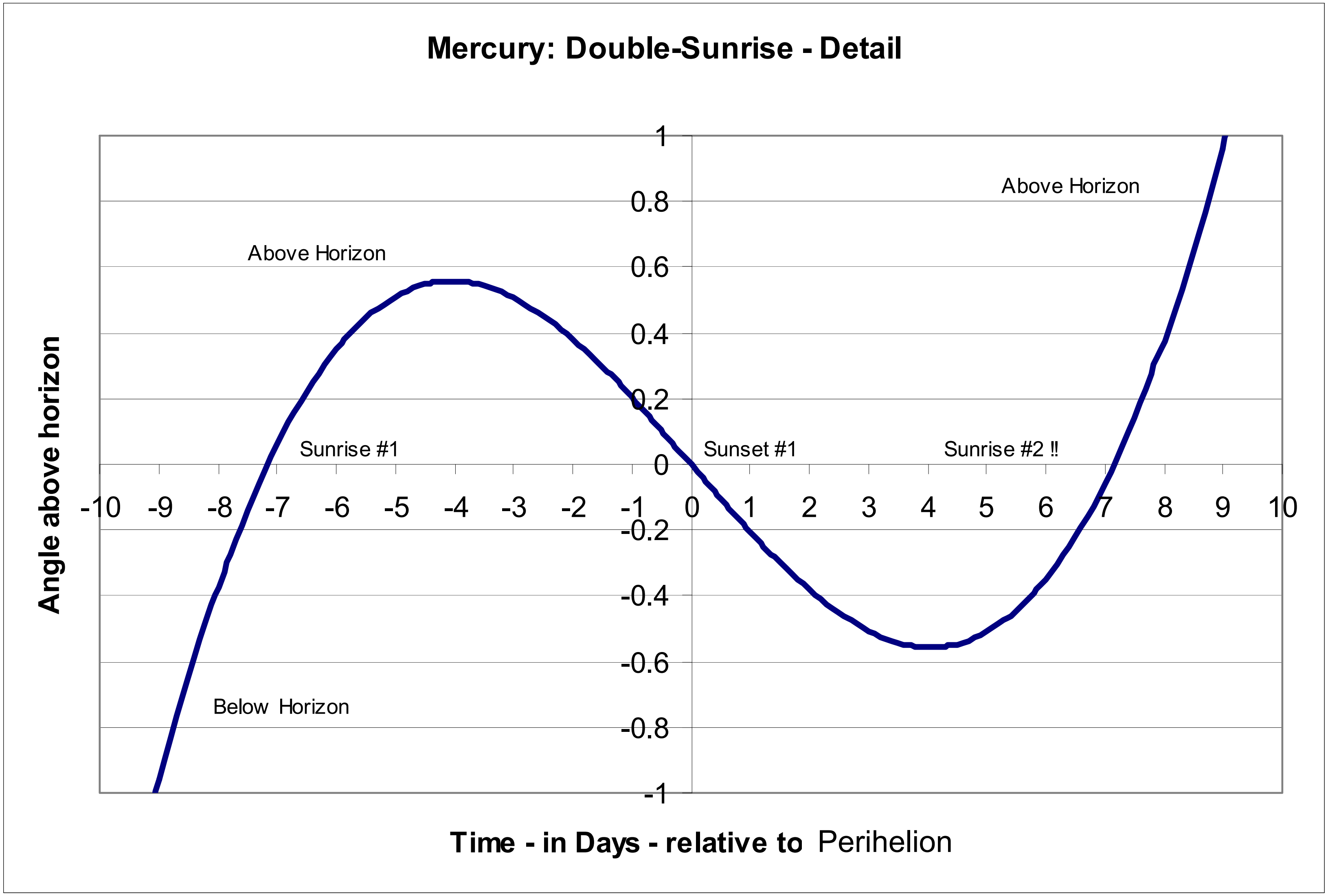
- Mercury orbits the sun faster at the perihelion (close approach) compared to the aphelion
- The normal axis rotation (w-axis gives the East to West motion of the sun) is a little slower than the orbit rate at perihelion (w-per gives the West to East motion)
- This means as Mercury approaches the perihelion location – the Sun will momentary “stop” in the sky, then reverse a little, then go forward again!
- If this happens to occur around the sunrise time … **double-sunrise**, baby!
- Let’s plot angle above the horizon (for center of Sun) against days near the perihelion …

Ta-Da ??



Mercury: Double-Sunrise??
90
75
60
45
30
15
0
-15
-30
-45
-60
-75
-90
-50
-40
-30
-20
-10
0
10
20
30
40
50
Angle above Horizon
Time - in Days - relative to Perihelion (Close Approach)

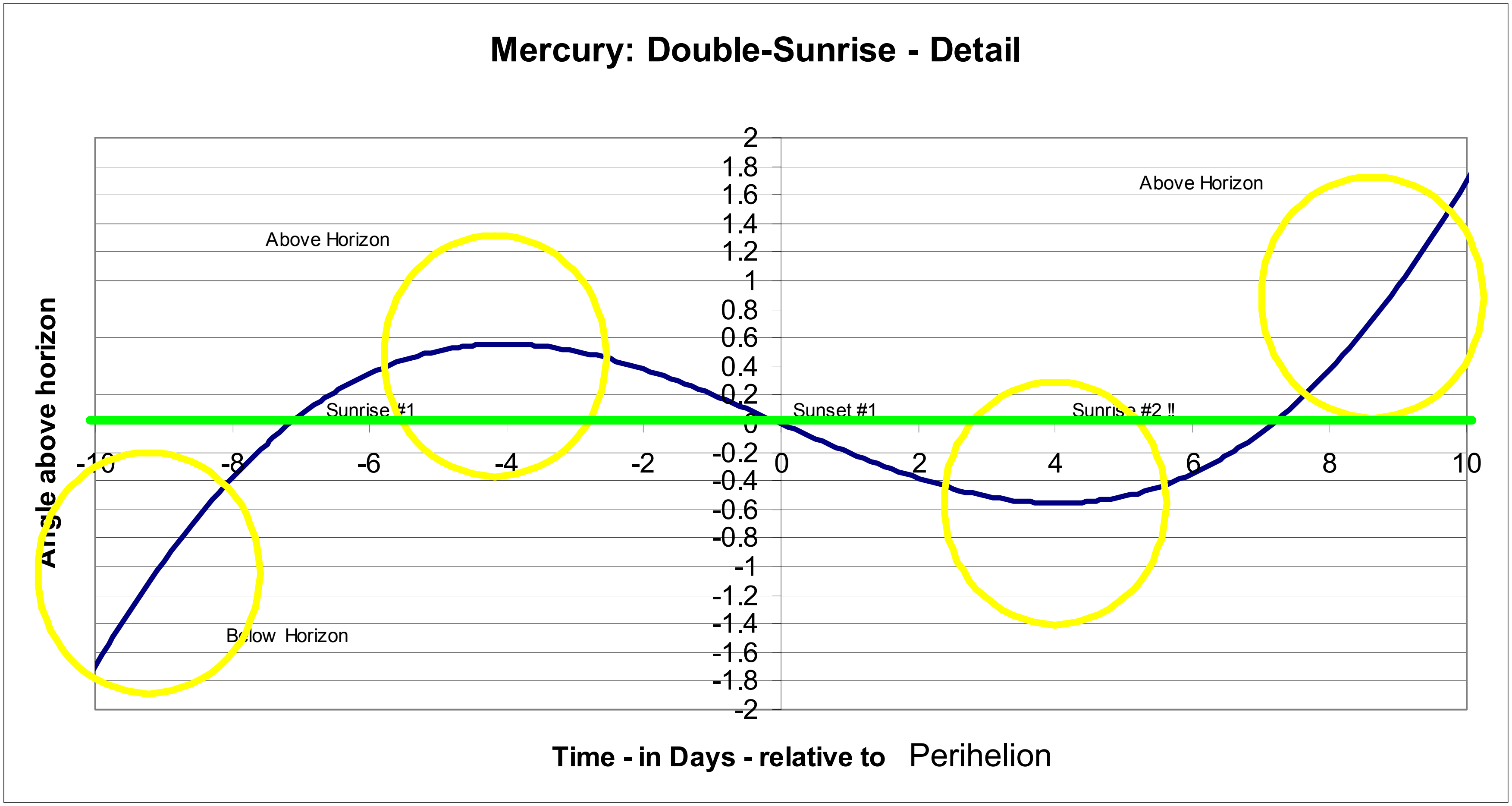
Oh – there we go!



How much of the sun is involved?

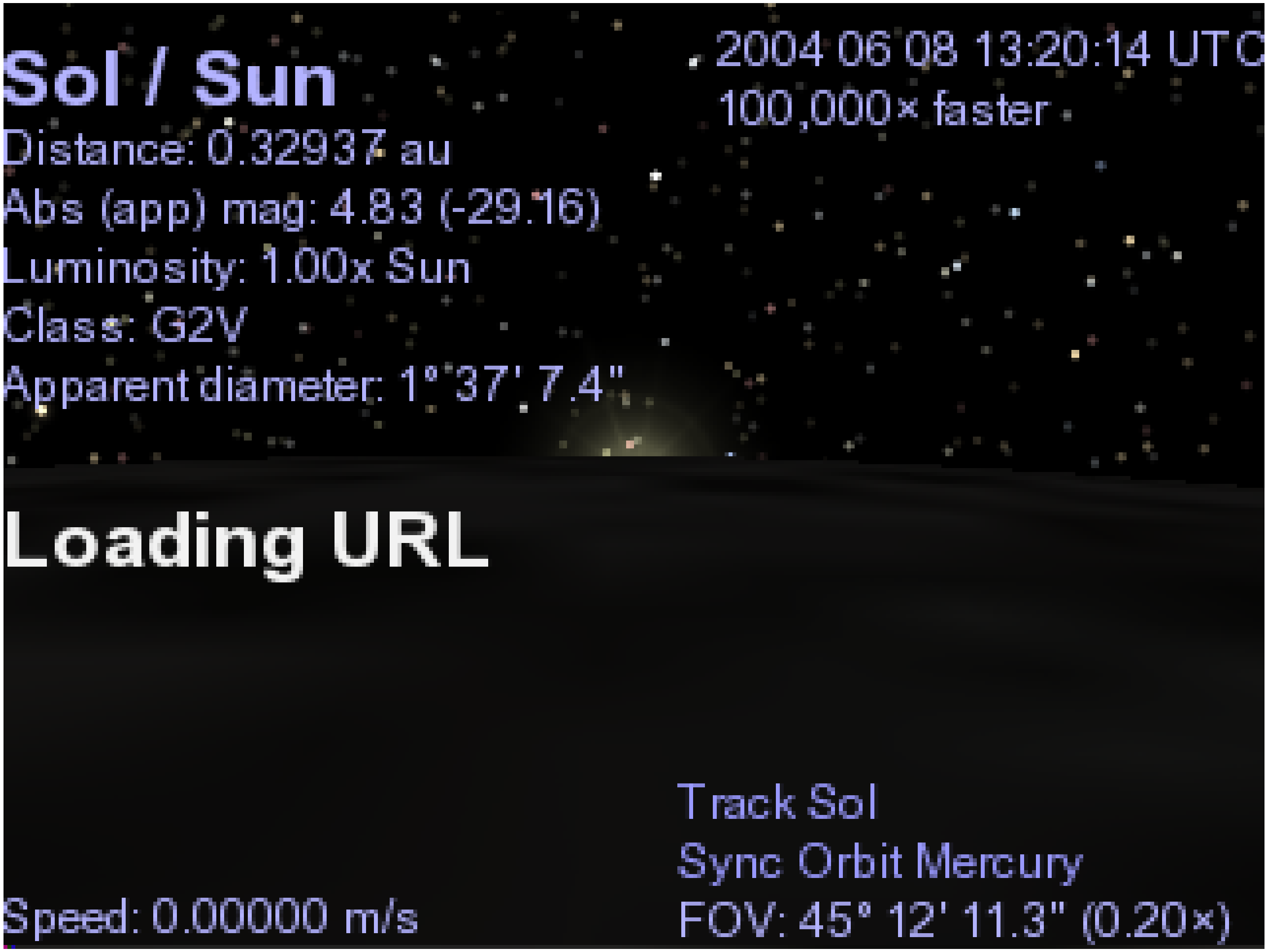
- Graph plots the center of the Sun (so for the leading edge – it would actually occur a little earlier)
- At Mercury's distance – the Sun has an angular size of about 1.73 degrees across the diameter – thus center to edge is about 0.86 degrees
- The center rises a maximum of **0.55 degrees** + 0.86 = ~ 1.4 degrees, so not all of Sun above horizon (more than half shows then sinks again, then rises)

Let's put some Suns on the graph!



Green line for the grassy (?) horizon!

Old internet animation videos ..



Old internet animation videos .. zoom

Will Mercury always do this?

- Yes and no … there is a critical eccentricity …
- Mercury's eccentricity varies between about 0.12 and 0.23 (currently 0.206) .. *those pesky other planets and GR!*
- If the eccentricity is exactly 0.191059 .. Sun would just momentarily "stop" and then go forward (but no double-sunrise, just a paused one!)
- If eccentricity below 0.191059 – n-axis > n-per and back to a boring single sunrise per day
- Currently Mercury's eccentricity on the rise – so many more years of double-sunrises!

Acknowledgments

- Calculations from **Astronomy Morsels III** by **Jean Meeus**
  - If you want to do astronomy calculations – he is THE source of information!
- Graphs courtesy of Microsoft Excel
- Presentation by … um, oh yeah, Powerpoint
- Online animation from Celestia (and some guy named Harry)

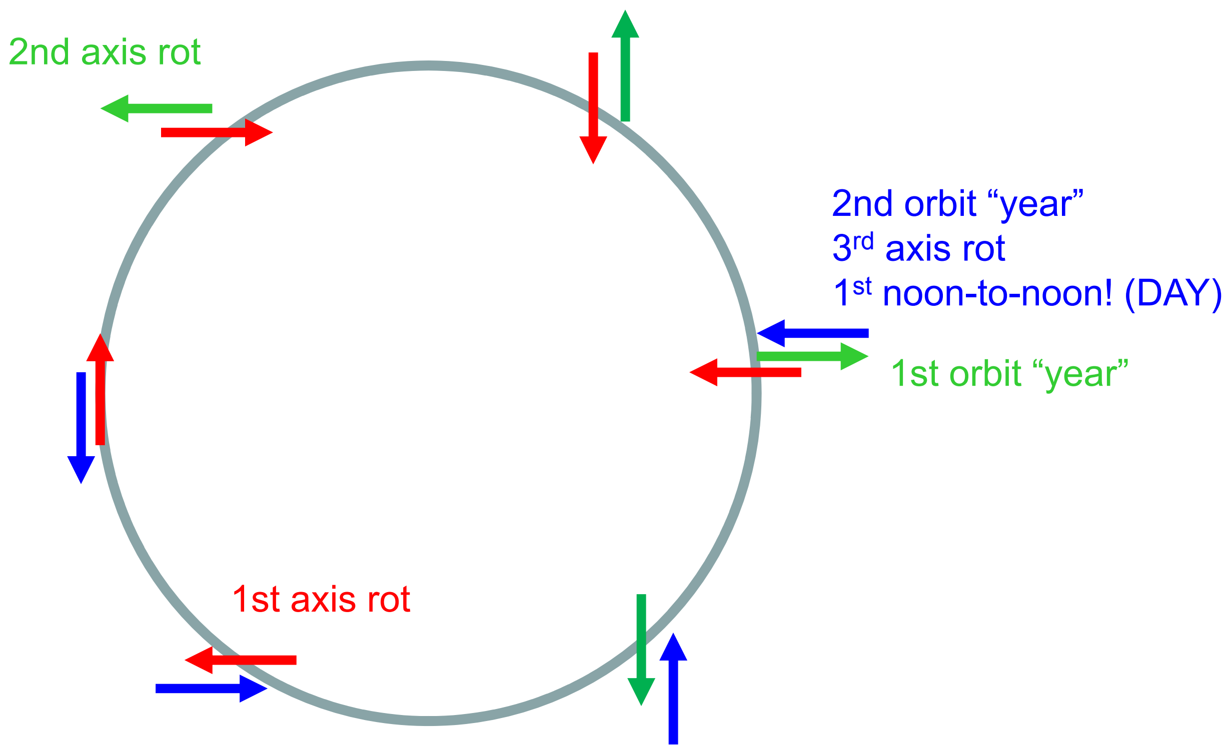
Bonus! - Mercury – “Day” longer than “Year”?

- Mercury orbit the sun = 87.98 days ~ 90 days
- Mercury period on axis = 58.6 days ~ 60 days
  - Every 15 days, 90 degrees on axis (look for colors indicating full rotation on axis)
  - 1/6th way around sun (60 degrees, 120, 180, 240, 300, 360, etc)

Year 1!	*Year 2!!*
Day 0 – 0 deg - noon (W)	
Day 15 – ccw 60 (S)	Day 105 – ccw 60 (N)
Day 30 – ccw 120 (E)	Day 120 – ccw 120 (W)
Day 45 – ccw 180 (N)	Day 135 – ccw 180 (S)
Day 60 – ccw 240 (W)	Day 150 – ccw 240 (E)
Day 75 – ccw 300 (S)	Day 165 – ccw 300 (N)
Day 90 – ccw 360 (E)	Day 180 – ccw 360 (W)

Bonus! - Mercury – “Day” longer than “Year”?

Year 1!	*Year 2!!*
Day 0 – 0 deg - noon (W)	
Day 15 – ccw 60 (S)	Day 105 – ccw 60 (N)
Day 30 – ccw 120 (E)	Day 120 – ccw 120 (W)
Day 45 – ccw 180 (N)	Day 135 – ccw 180 (S)
Day 60 – ccw 240 (W)	Day 150 – ccw 240 (E)
Day 75 – ccw 300 (S)	Day 165 – ccw 300 (N)
Day 90 – ccw 360 (E)	Day 180 – ccw 360 (W)



Retrogrades, Marvin the Martian, and the Universe, oh my!

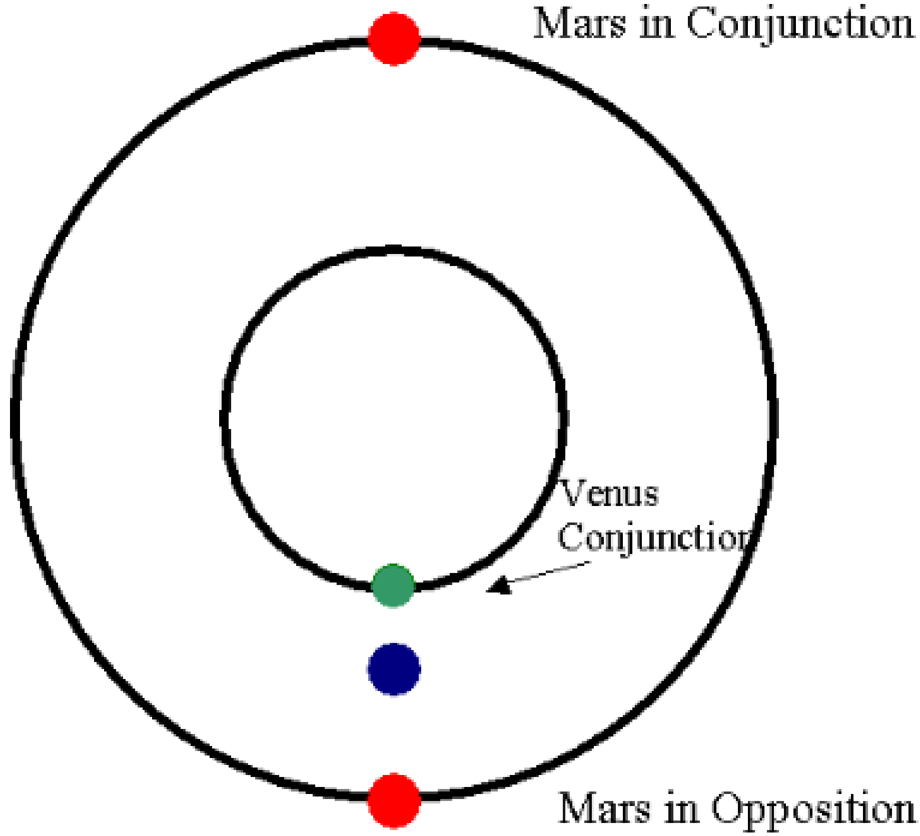
Dr. Scott Schneider

How to find your way in the Solar system :

- **All planets go around the Sun**
  - **also, in the same “direction”**
- **Define reference plane as Earth-Sun**
  - **Called the ECLIPTIC**
  - **All other planet orbits tilted, relatively**
- **Venus has an orbit tilt of about 3^0**
  - Save this info for later!

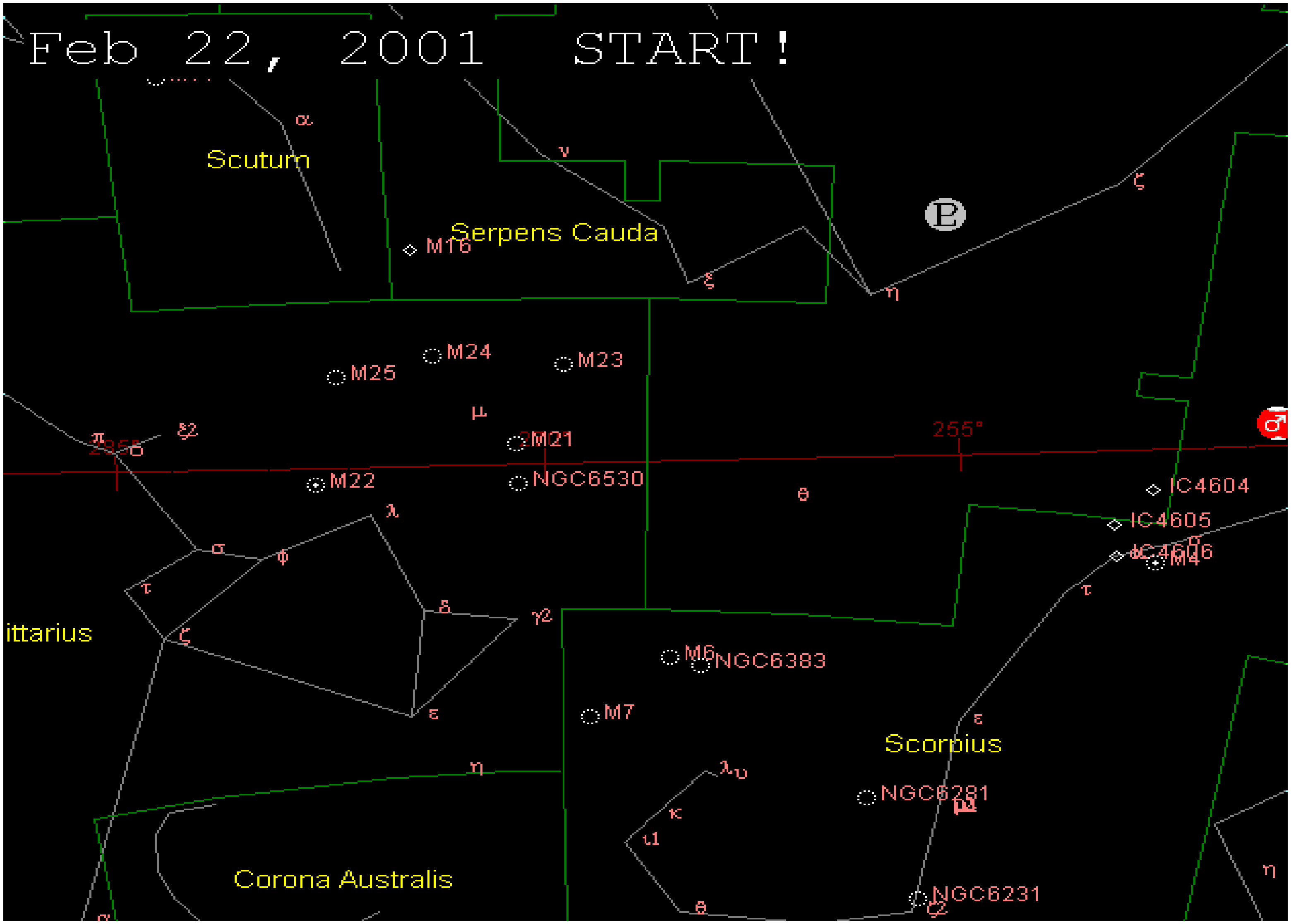
Retrograde Motion

- Outer planets – location moves “backward” against the distance stars
- Occurs at times of Opposition
- Inner planets have “conjunctions” .. Could have transits!



Mars Retro Example

Retrograde Motion



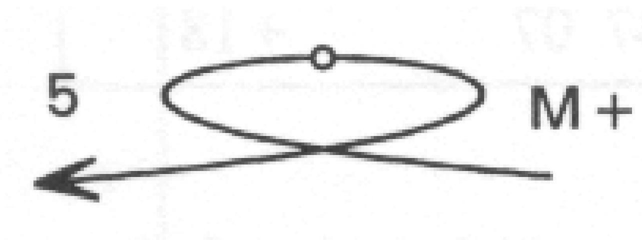
Mars Retro Example

Shape of the retrograde loops?

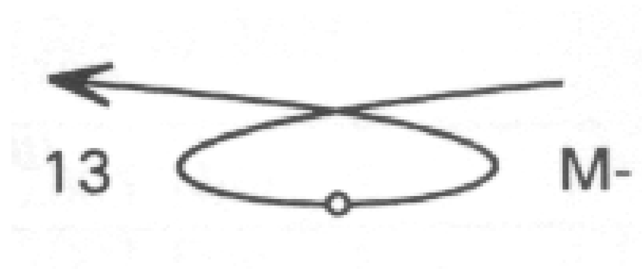
1. The outer planets have orbits tilted relative to the ecliptic.
2. Earth moves faster in orbit than outer planet.
3. As Earth moves past opposition point, angle between Earth and outer planet changes orientation in space .. points to different background stars!
4. During time of opposition, outer planet changes latitude above ecliptic.

High or Low above ecliptic

As outer planet moves toward highest point in it's motion, retrograde motion give "top loop" shape.



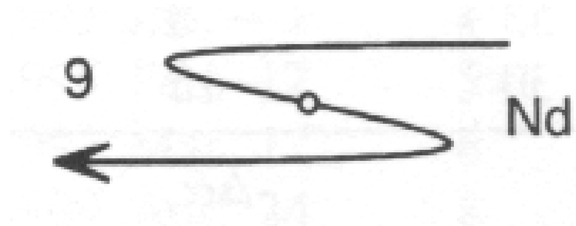
180 degrees away, as outer planet moves toward lowest point in it's motion, retrograde motion give "bottom loop" shape.



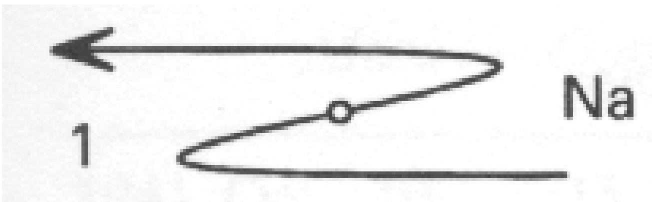
The "dots" are the moment of opposition.

Crossing above/below ecliptic

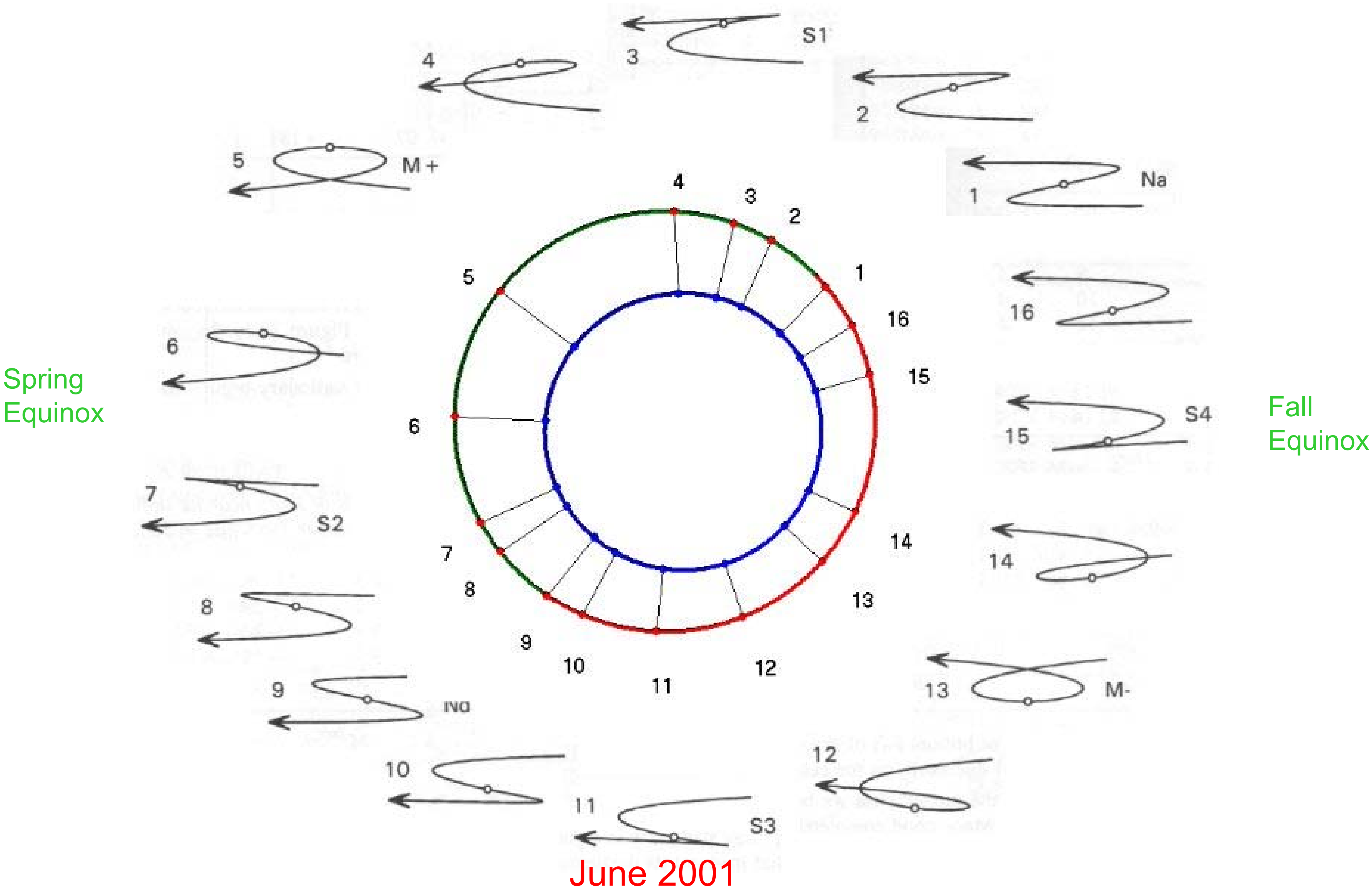
As outer planet through the descending node (high to low), retrograde motion gives a dropping "S" shape.



As outer planet moves through ascending node (low to high), retrograde motion gives a rising "S" shape.



16 basic shapes – depends on time of year!



16 basic shapes – depends on time of year!

Mars — Opposition dates and type of the loop, 1941 to 2035

1941	Oct.	10	15	1973	Oct.	25	16	2005	Nov.	7	1
1943	Dec.	5	3	1975	Dec.	15	4	2007	Dec.	24	4
1946	Jan.	14	4	1978	Jan.	22	4	2010	Jan.	29	5
1948	Feb.	17	5	1980	Feb.	25	6	2012	Mar.	3	6
1950	Mar.	23	6	1982	Mar.	31	6	2014	Apr.	8	6
1952	May	1	8	1984	May	11	9	2016	May	22	10
1954	June	24	12	1986	July	10	12	2018	July	27	12
1956	Sep.	10	14	1988	Sep.	28	14	2020	Oct.	13	14
1958	Nov.	16	1	1990	Nov.	27	2	2022	Dec.	8	3
1960	Dec.	30	4	1993	Jan.	7	4	2025	Jan.	16	4
1963	Feb.	4	5	1995	Feb.	12	5	2027	Feb.	19	5
1965	Mar.	9	6	1997	Mar.	17	6	2029	Mar.	25	6
1967	Apr.	15	7	1999	Apr.	24	8	2031	May	4	8
1969	May	31	10	2001	June	13	11	2033	June	28	12
1971	Aug.	10	13	2003	Aug.	28	14	2035	Sep.	15	14

References

Jean Meeus – TRANSITS – Willmann-Bell

Jean Meeus is an Astronomer from Belgium – does some absolutely amazing astronomical calculations. Has three other excellent books :

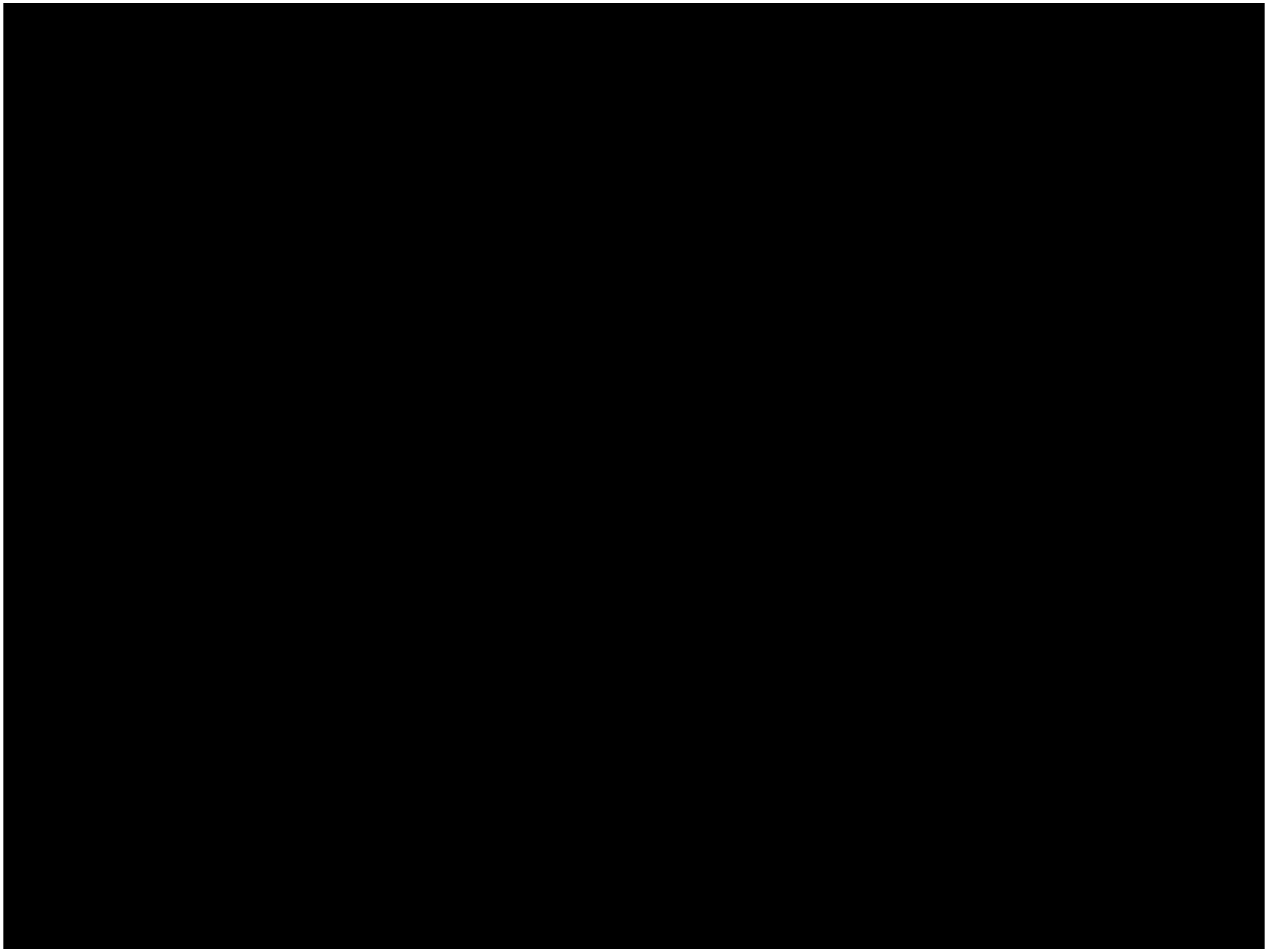
Astronomical Algorithms

Astronomy Morsels

More Astronomy Morsels

What about Marvin? Why so very very angry?

What about Marvin? Why so very very angry?

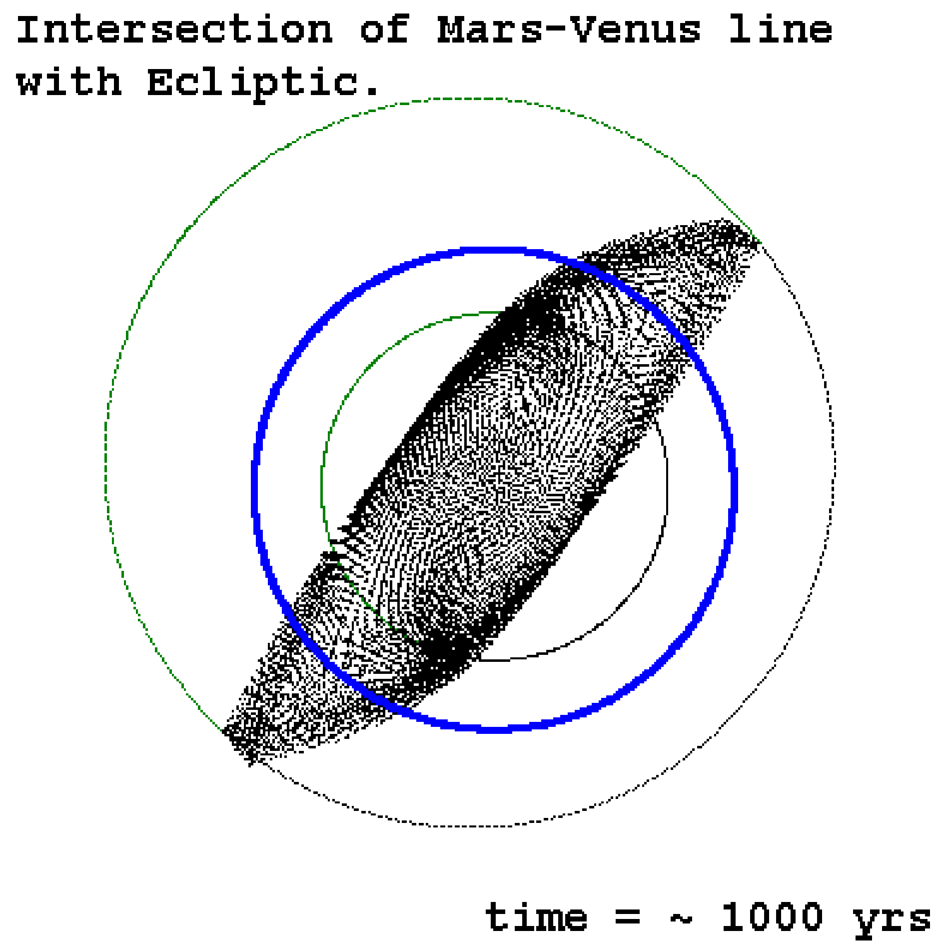


What about Marvin? Why so very very angry?

Wanted to blow up the Earth because it blocked his view of Venus!

Conditions for blocking ..

- How often does Earth block Venus?
- Calculate the location where the Venus-Mars line crosses the ecliptic – if the Earth is there also – block!



After the computer pulled a few all-nighters …

From the year 1000 to 3000 …

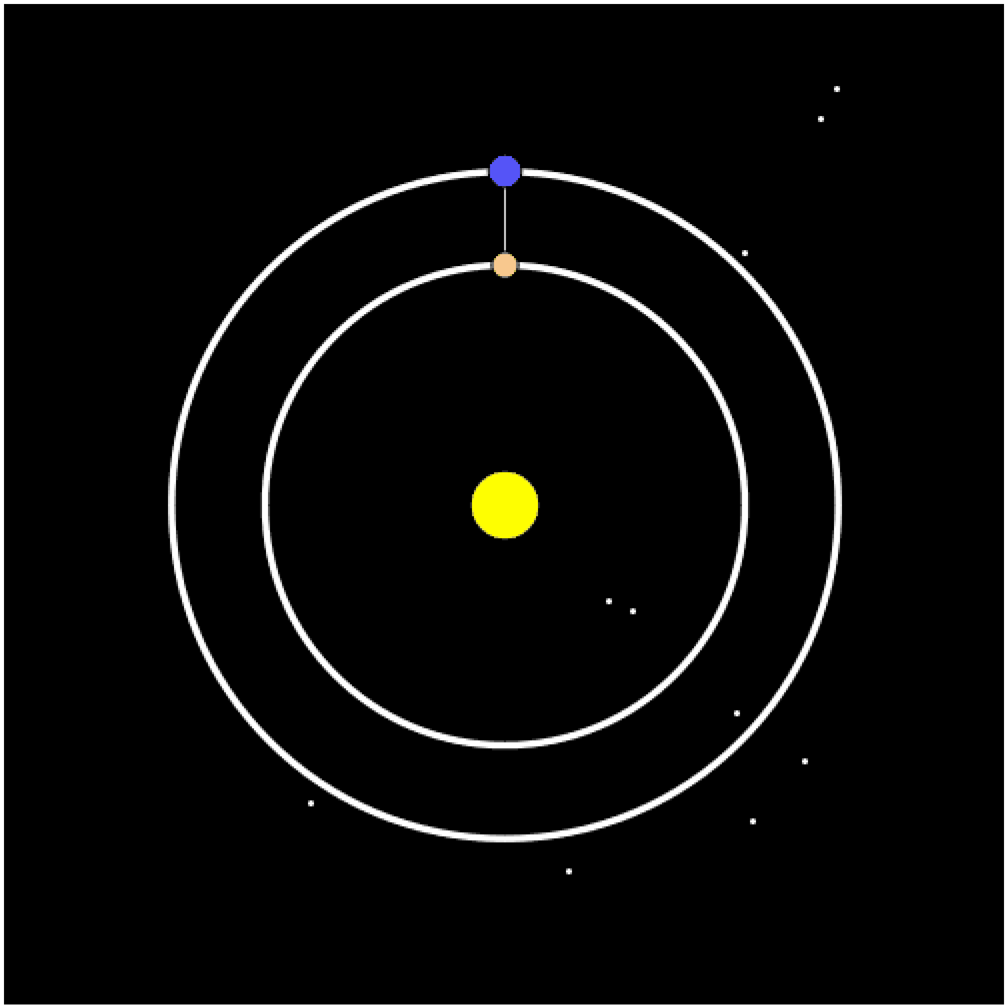
Only one time =

Nov 8th, 2746 ~ 7:45 pm

Conclusion …

Marvin needs to decaffeinate!!

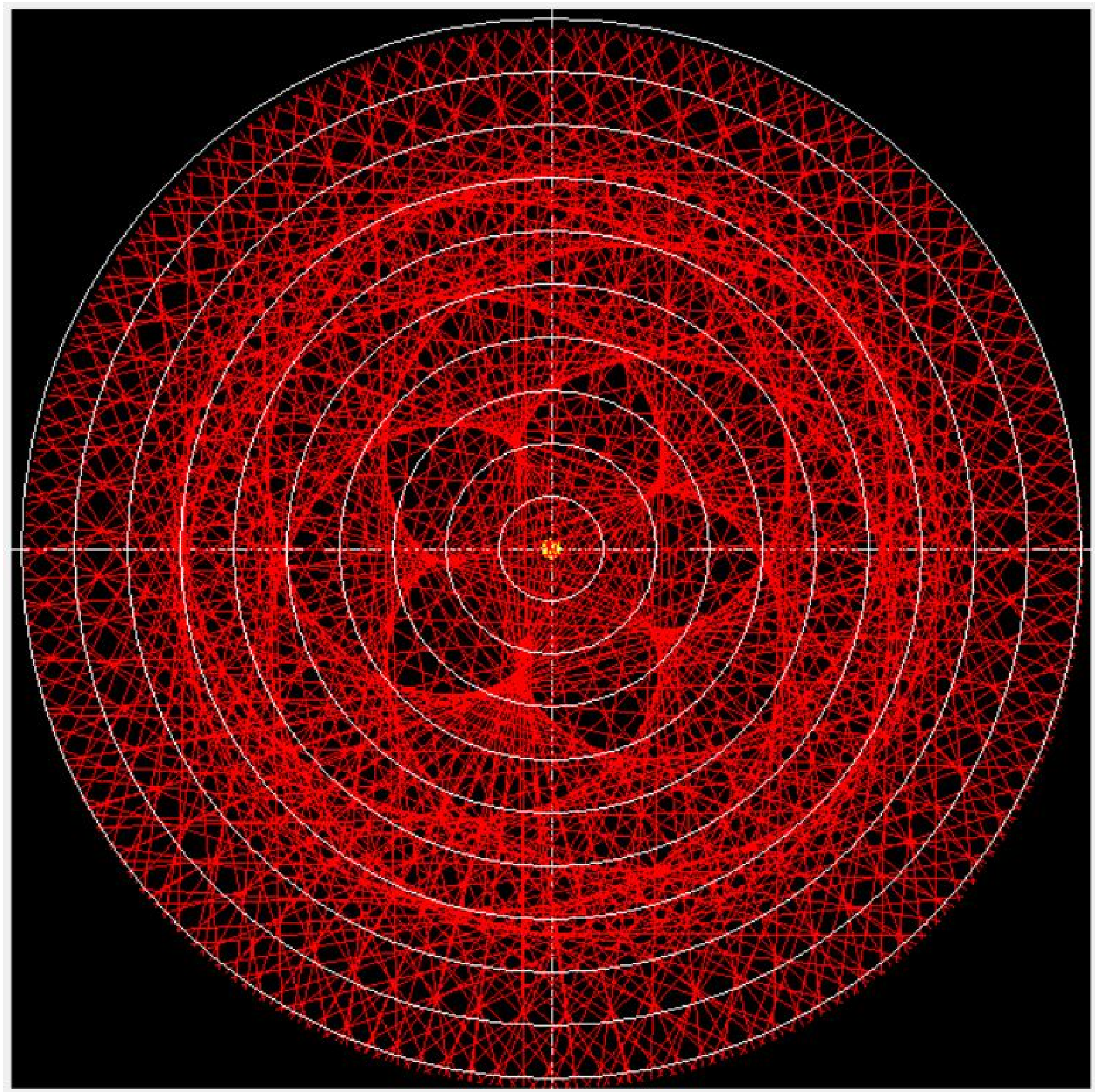
There is an image going around the 'net ..



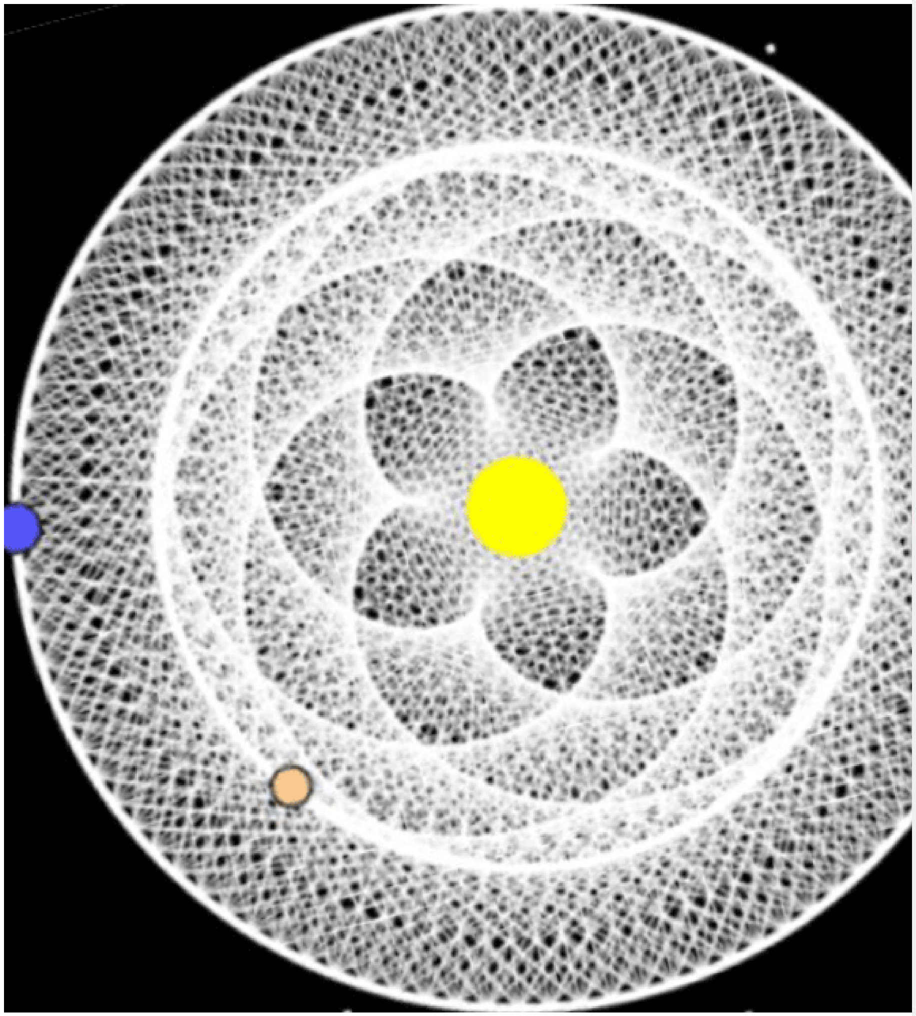
Has to do with the orbits of Earth and Venus being close to a 13-8 ratio (13 orbits for Venus about 8 orbits for Earth)

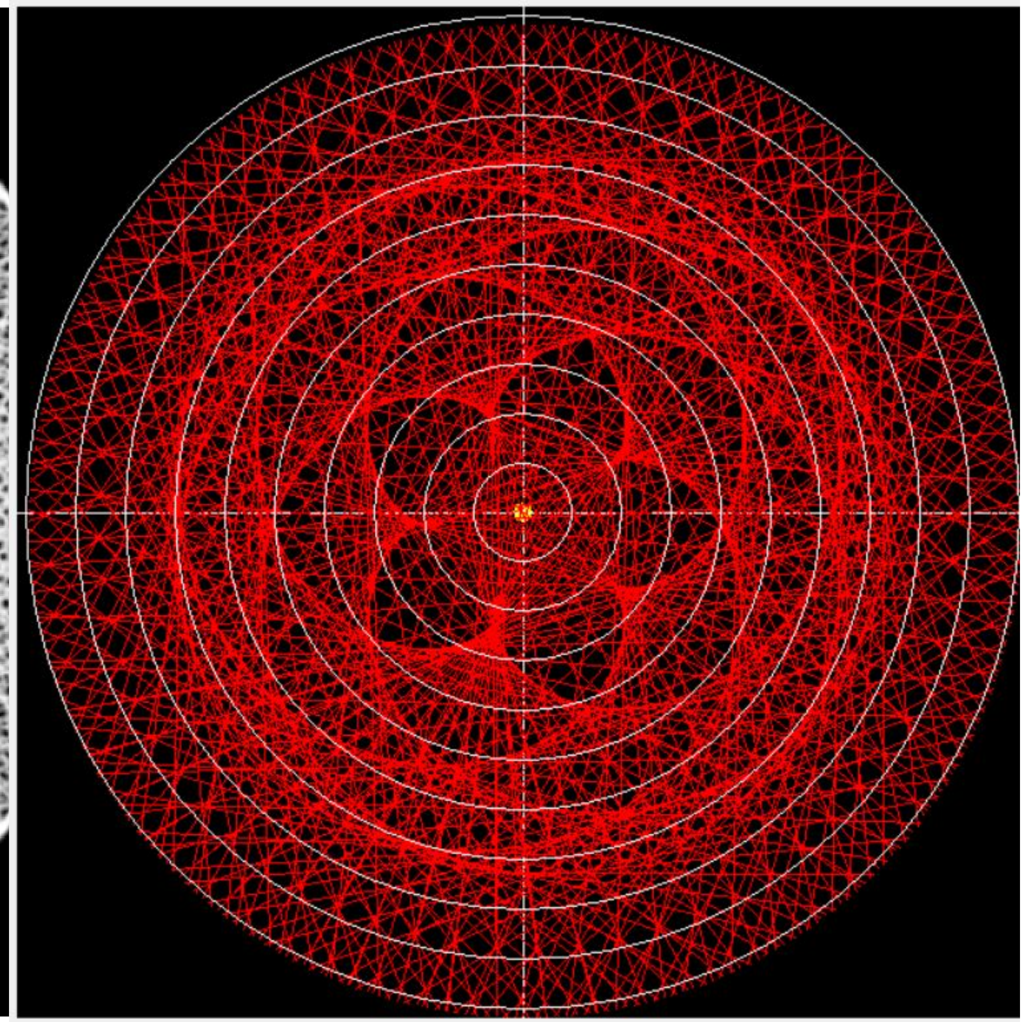
I was skeptical at how perfect the pattern looks. (*It was from the internet ..*)

So, I calculated my own pattern from actual numbers:



If rotate other image a little .. Pretty close!





Internet image .. Perfect symmetry – Mine .. Not bad!

[redacted]