Geek Week, 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"??)*


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# Start with Earth – because we know it!

- Rotation on axis (n-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? Dr. Scott, please demonstrate … (so n-axis = E->W)
- Suppose we did **not** turn on our axis – where would the sun rise and set as we orbited (n-orbit)? Dr. Scott, we're waiting!
- So, the effect of the orbit is a "west to east" motion of the Sun – interesting! (n-orbit = W-E !!)
- 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, n-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 n-orbit is higher
- At aphelion, planet slower, thus n-orbit smaller
- Let's call them n-per and n-ap (both of these are basically "n-orbits")
- Remember, if the rate due to the orbit (now n-per, n-ap) is bigger than the axis rate … the sun moves "differently" in the sky (West to East)
  - Thus .. If the n-axis rate is *between* those two ….

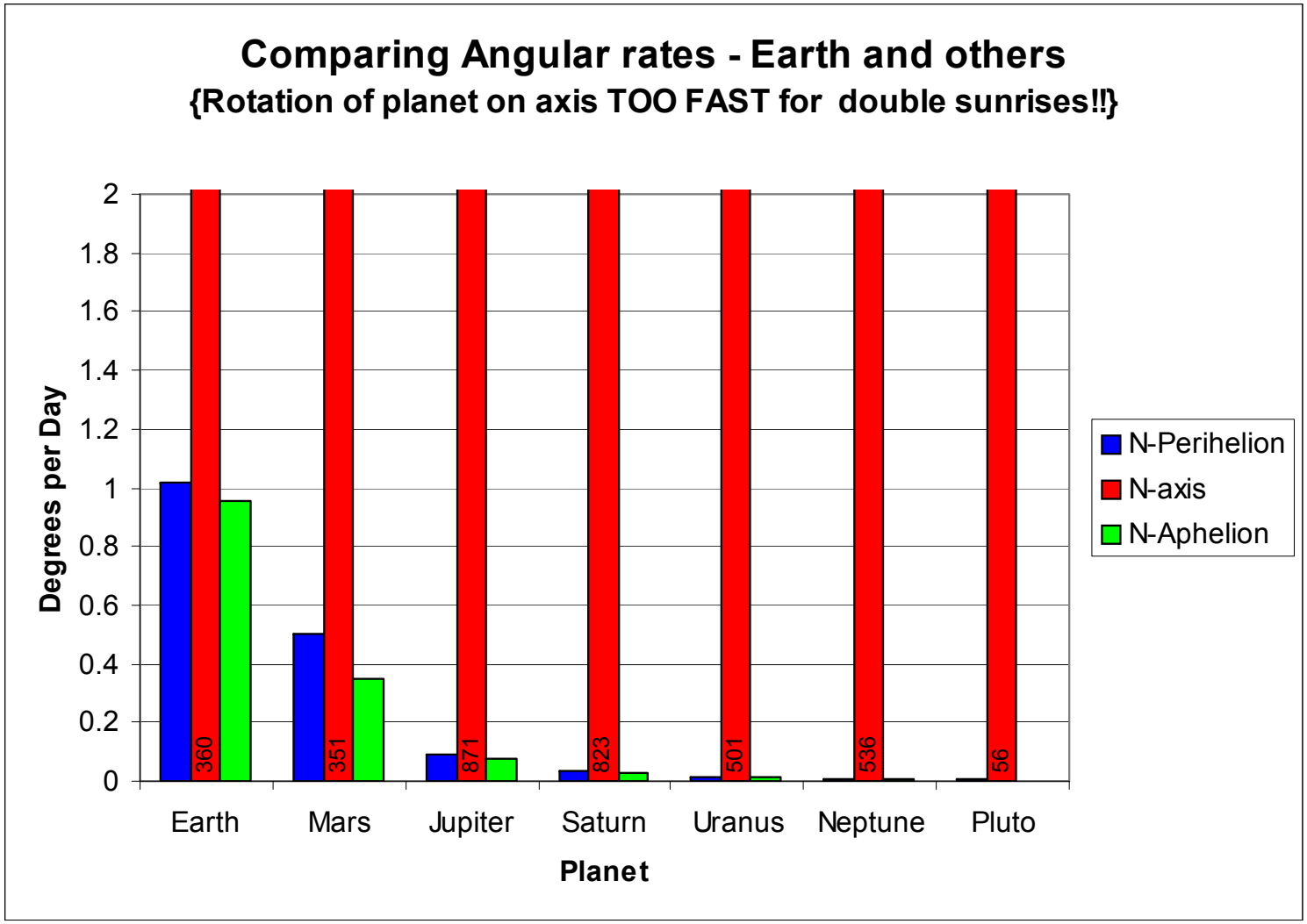
# Data Chart for all the planets

| Planet | ecc | a *(AU)* | Orbit Period *(days)* | mean *(deg/day)* | Axis period *(days)* | n-axis *(deg/day)* | n-per | n-ap | Nper>Naxis>Napp? |
|---|---|---|---|---|---|---|---|---|---|
| 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 |

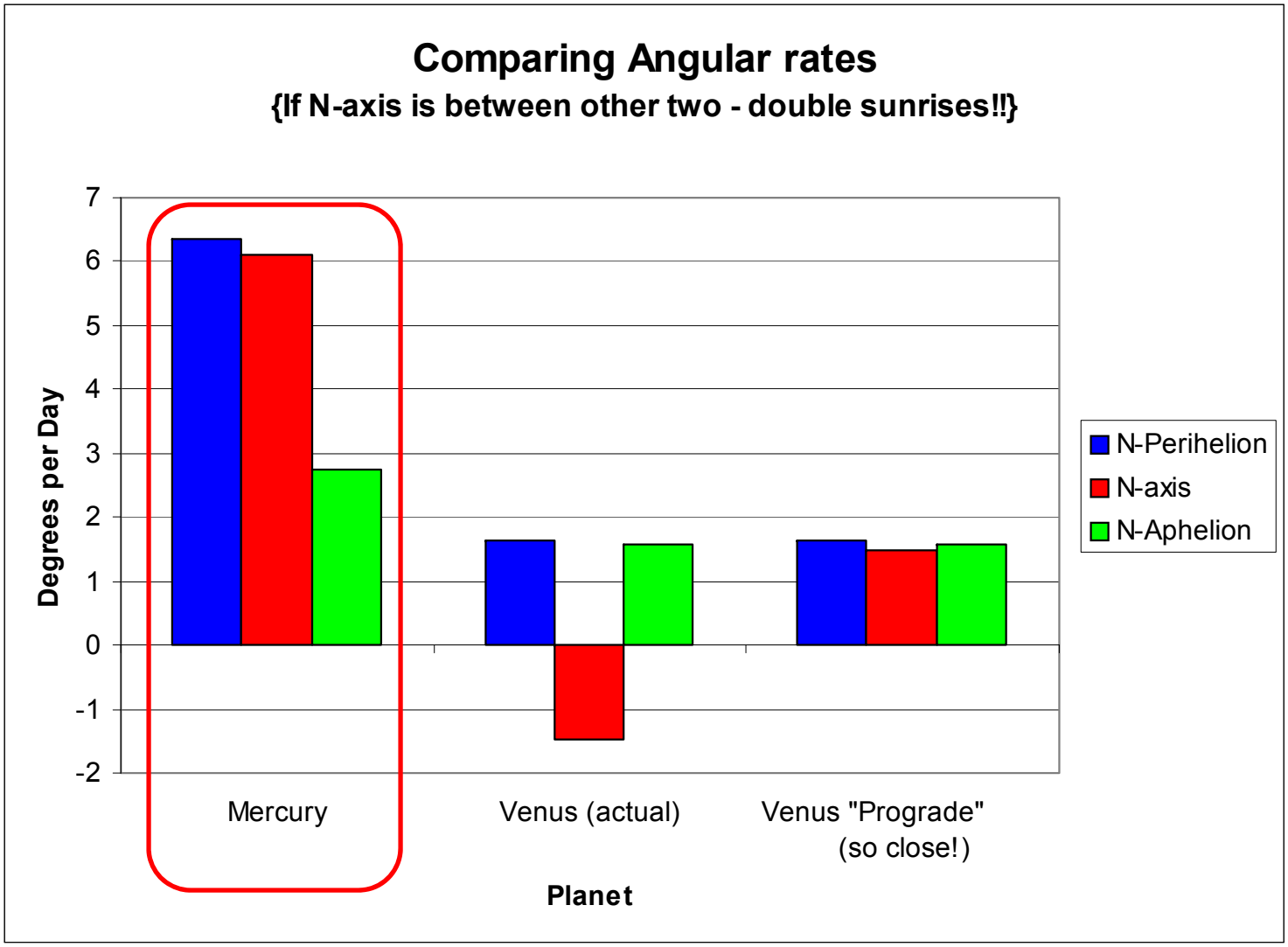
**ecc**=eccentricity – how circular (0) or elliptical (>0) is the orbit?
**a** = semi-major axis – rough distance from sun
**orbit period** = time for planet to orbit once around the Sun
**mean** = mean daily motion = 360 degrees / orbit period
But, depending on eccentricity, can be higher or lower at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

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

# Earth and Beyond … if n-axis < n-perihelion … Doh!



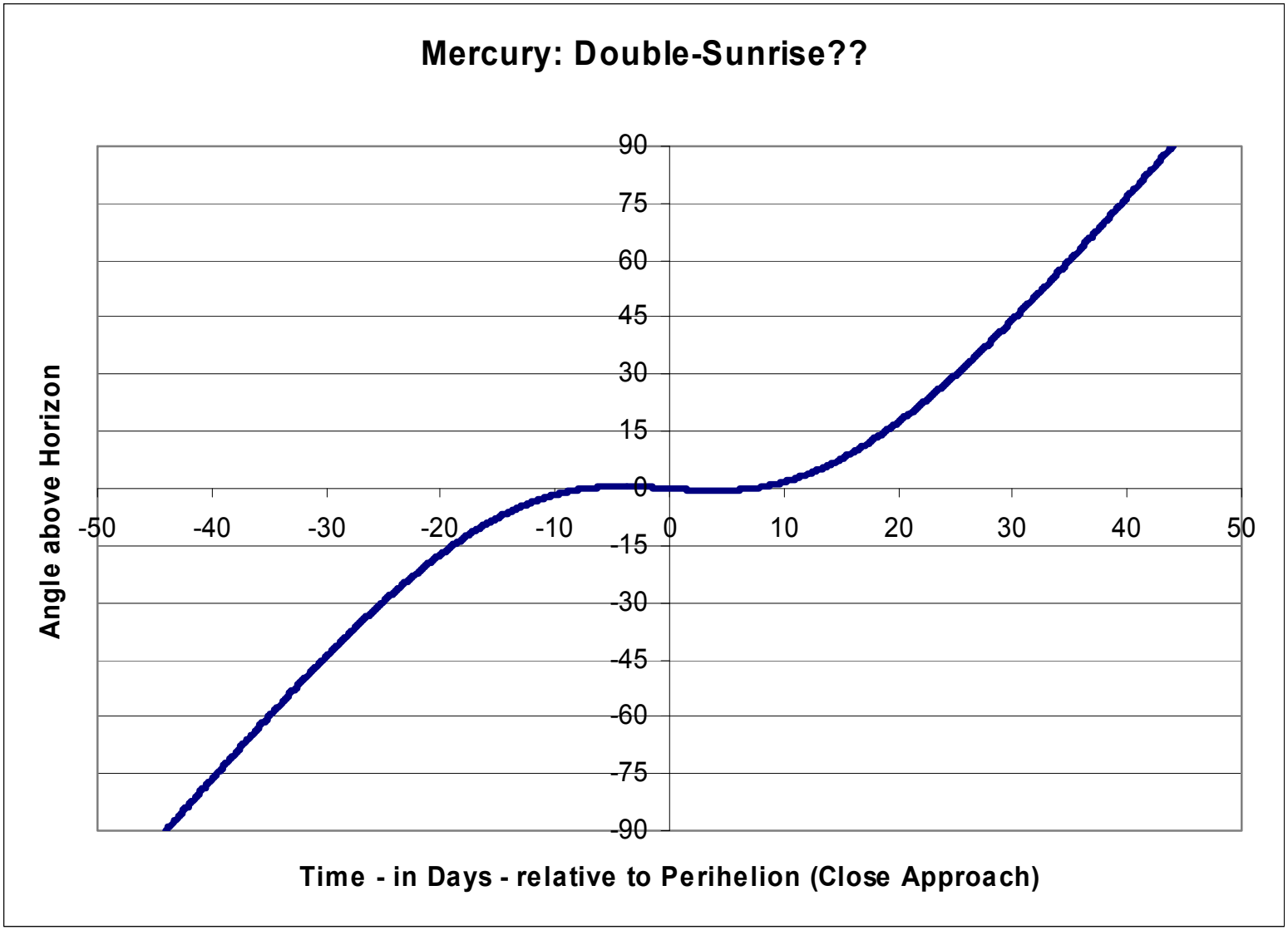
# Mercury/Venus … if n-axis < n-perihelion …



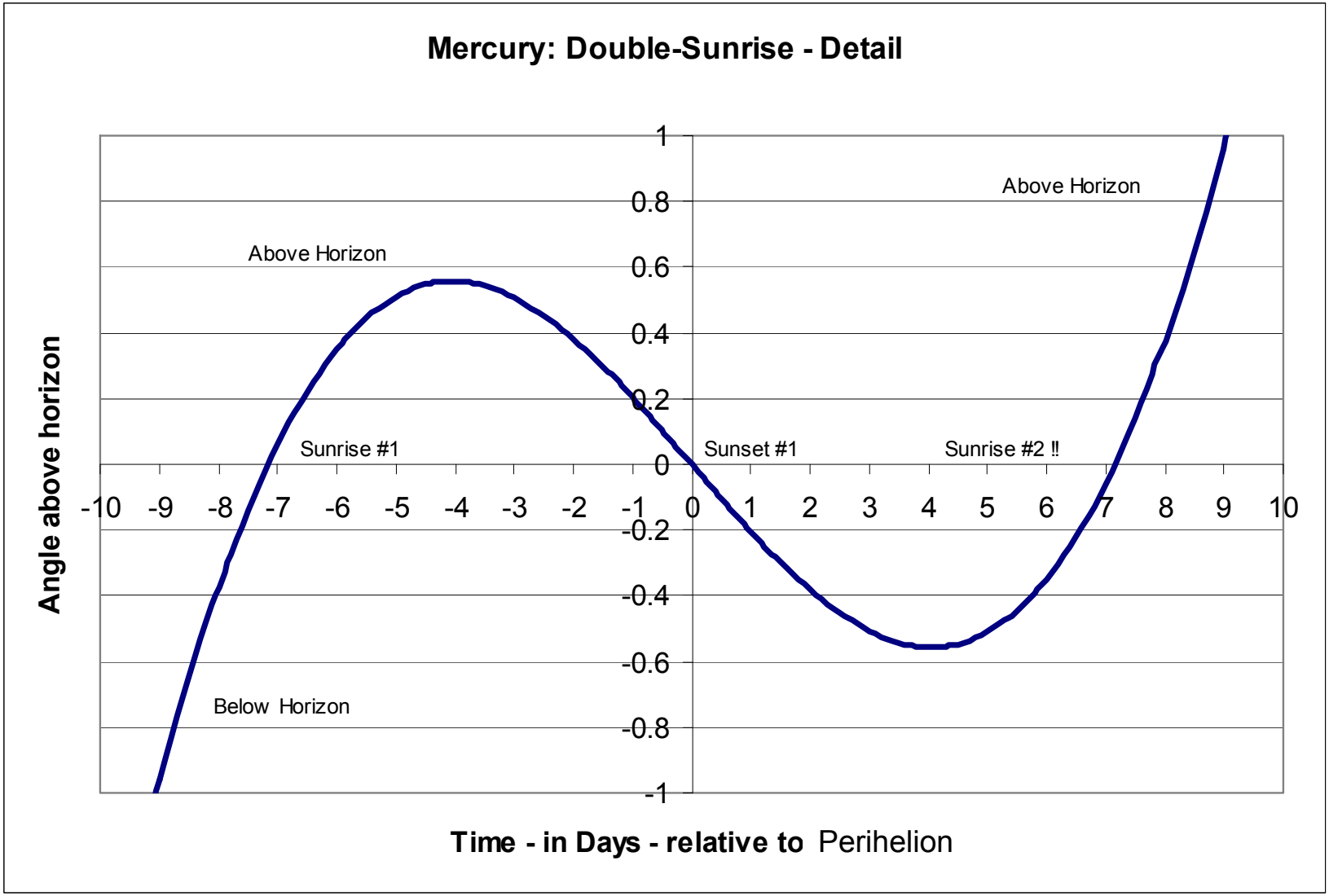
# Mercury … what does this mean?

- Mercury orbits the sun faster at the perihelion (close approach) compared to the aphelion
- The normal axis rotation (n-axis gives the East to West motion of the sun) is a little slower than the orbit rate at perihelion (n-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??
Angle above Horizon
90
75
60
45
30
15
0
-15
-30
-45
-60
-75
-90
-50
-40
-30
-20
-10
0
10
20
30
40
50
Time - in Days - relative to Perihelion (Close Approach)

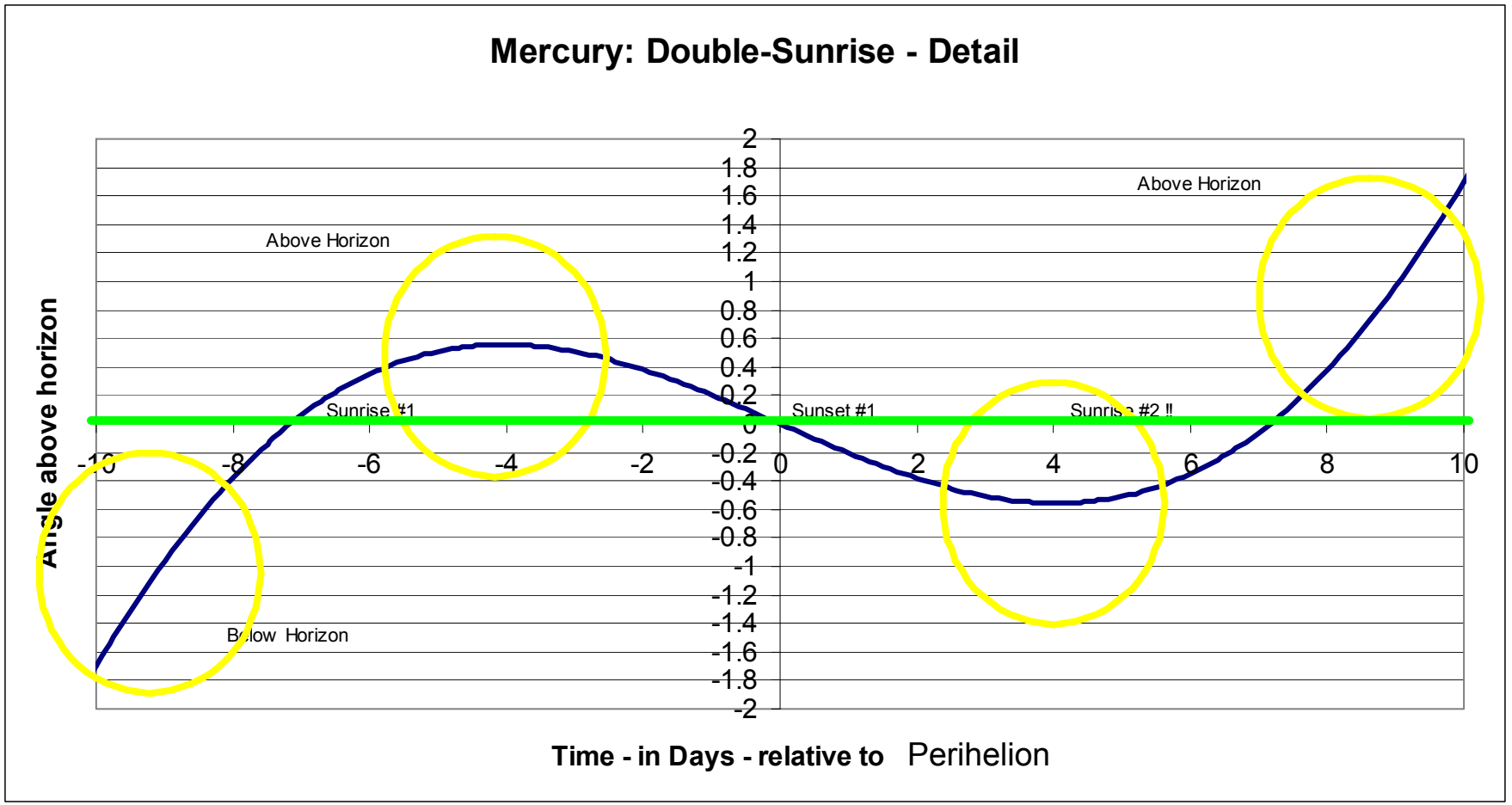
# Oh – there we go!



# 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 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!

# 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)
- 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)
- Thanks to the Arts and Sciences Seminar committee for letting me do my Astro-gig once a year!

# 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)
  - 1/6$^{th}$ 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) |