

# Announcements

- ⇒ Lab 4 starts next week
- ⇒ Assignment 3 due Wednesday Nov. 8
  - Office hours: Tomorrow 2:30-3:30 in my office
  - Tuesday: (see web page). Henn 312 (back room)
- ⇒ Discussion of equilibrium radionuclides
- ⇒ Midterm : Is out of 69 marks total
  - Appeals are considered IN WRITING ONLY
  - (The multiple choice section is only out of 32 points)
  - (Short-answer question 3 is only assigned 2 points.)
- ⇒ Mercury transit on Wednesday Nov 8.

# Planetary rotation

(Nov. 3, 2006)

# Terrestrial planet spin properties

Planet	Obliquity (axis tilt) (degree)	Orbit Period (Earth years)	Spin Period (Earth days)
Mercury	<del>0.000</del> 0.07	0.241	58.6
Venus	177.300	0.615	-243
Earth	23.500	1.000	1.000
(Moon)	6.6800	27.3 days	27.3 days
Mars	25.200	1.880	1.03

# **How were the spin rates of the planets determined?**

**A. Watching the surface in a telescope**

**B. Observing rotation with spacecraft**

**C. Bouncing radar off planet**

**D. Watching the Weather Channel(TM)**

**ANSWER: Most of the above.**

**A. Watching the surface in a telescope**

**Mars, Moon**

**B. Observing rotation with spacecraft**

**Confirmation for Venus, Mercury**

**C. Bouncing radar off planet**

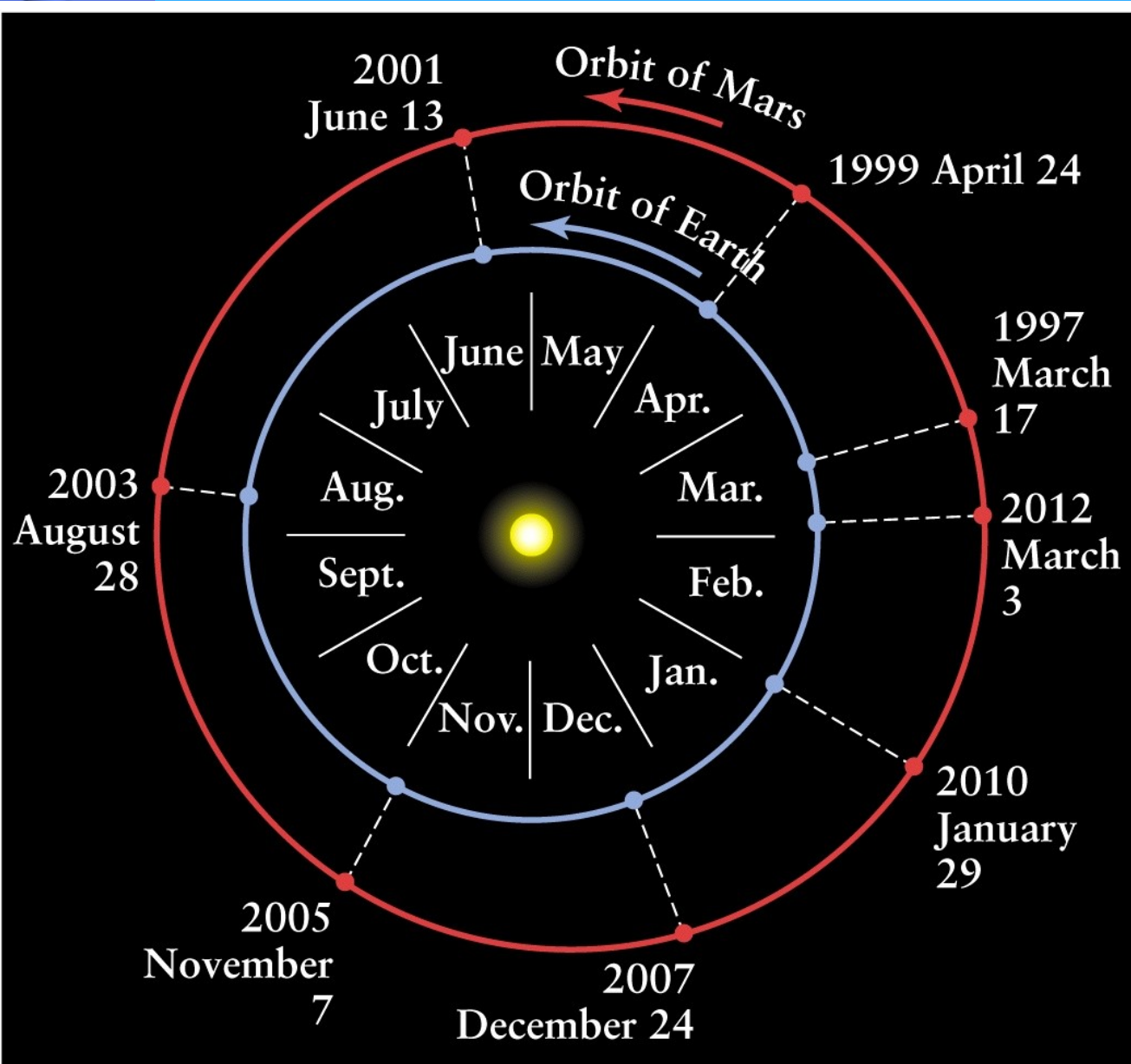
**Venus, Mercury**

# The orbit of Mars : conjunctions vary in Earth-Mars distance

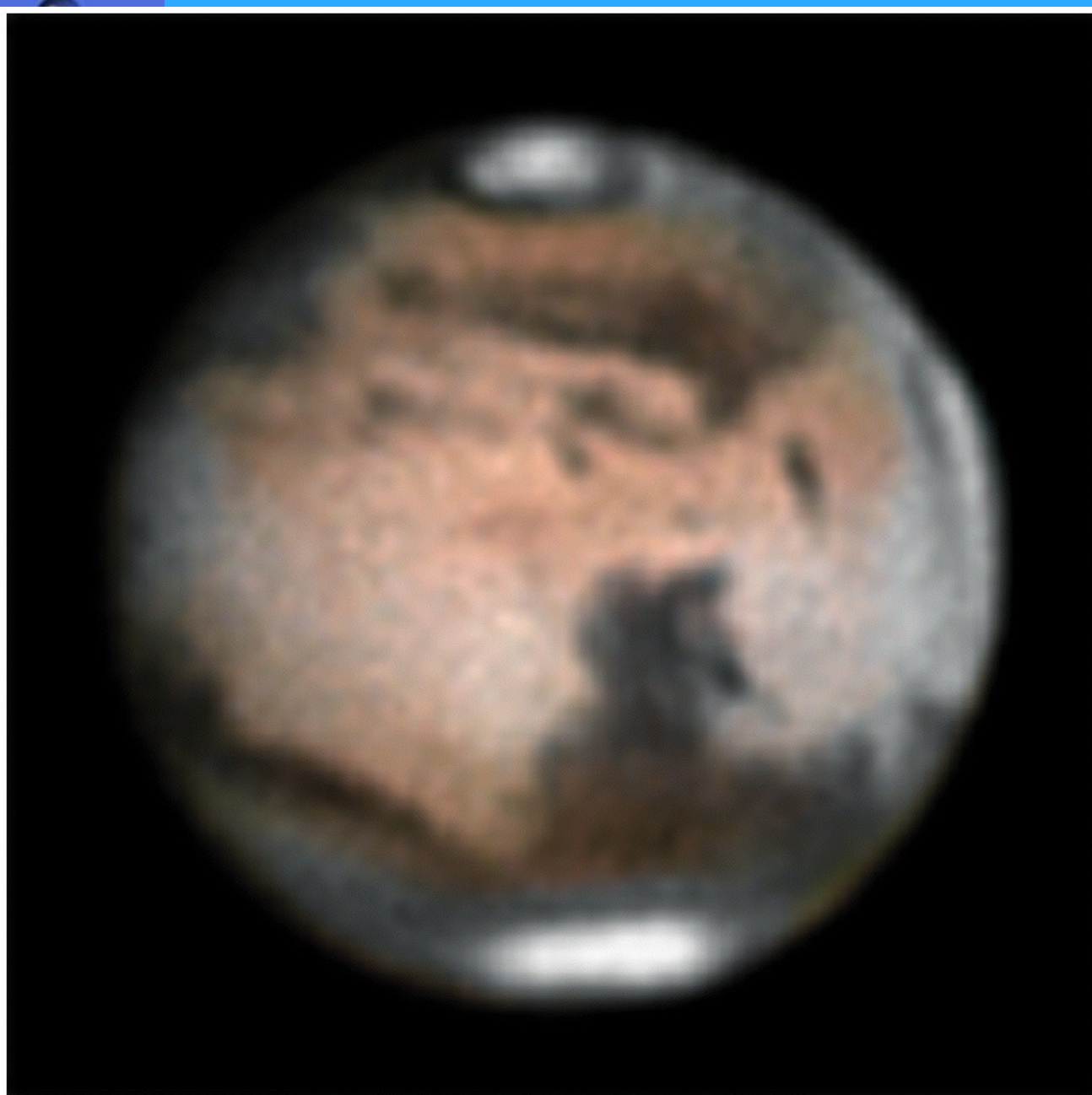
**Synodic Period**  
**780 days**  
**(calculate this!)**

**Distance varies:**  
**0.37 AU at best**

**<--- Note Nov 7/2005  
and Dec 24 2007  
oppositions**



# **Spin period of Mars was established by watching it with ground-based telescopes**



**Cassini determined  
spin period (1666!)**

**24h 37.5min**

**--Saw polar caps**

**Herschel measured**

**obliquity of**

**25 degrees**

**--Earthlike!**



# **ASIDE : Late 19<sup>th</sup> century astronomers thought they could see canals on Mars!**



**Schiaparelli: used  
'canali' for features**

**Millionaire Lowell  
drew detailed maps**

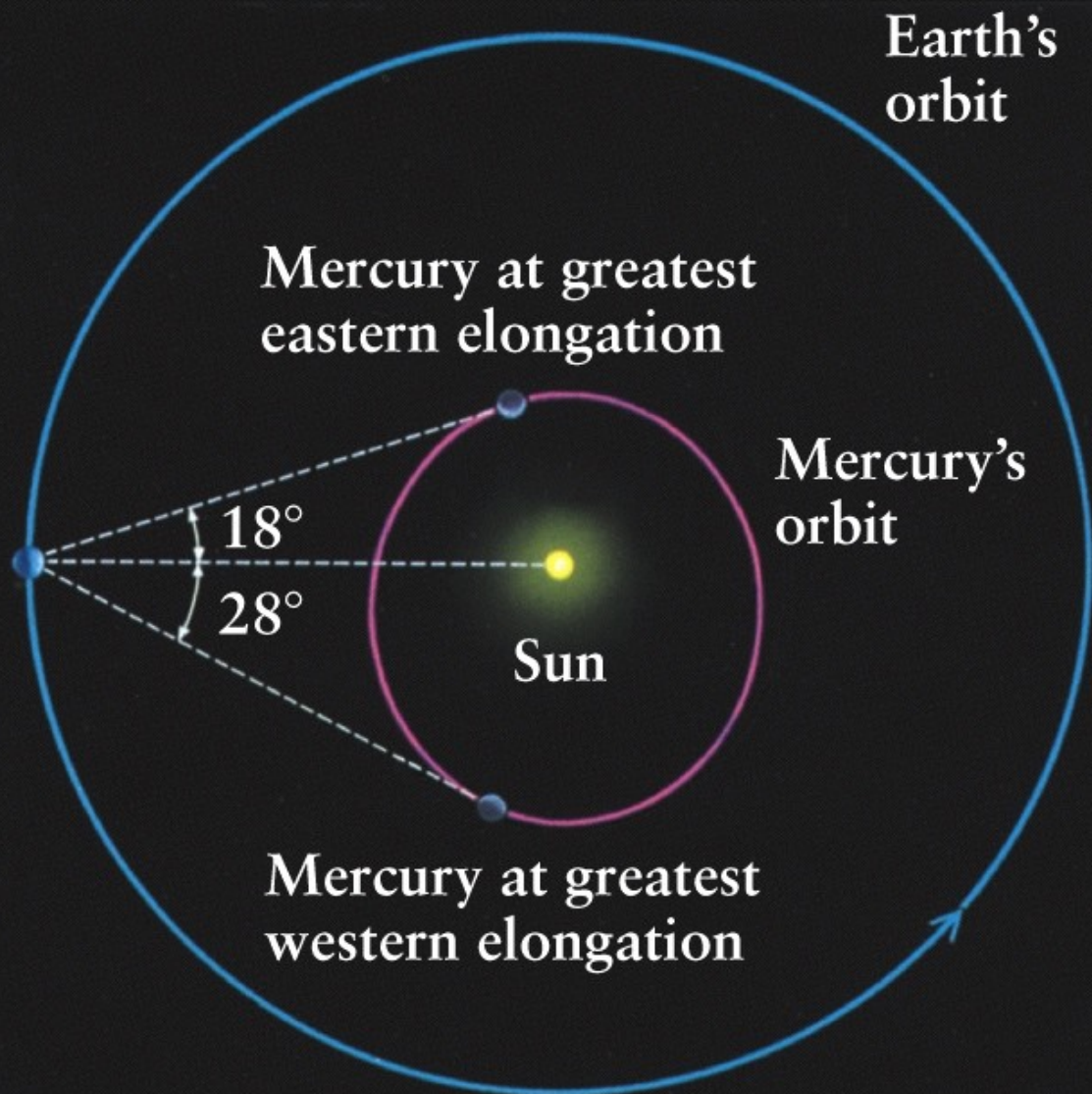
**Life on Mars!?**  
**Fueled 100 years of  
fanciful speculation**



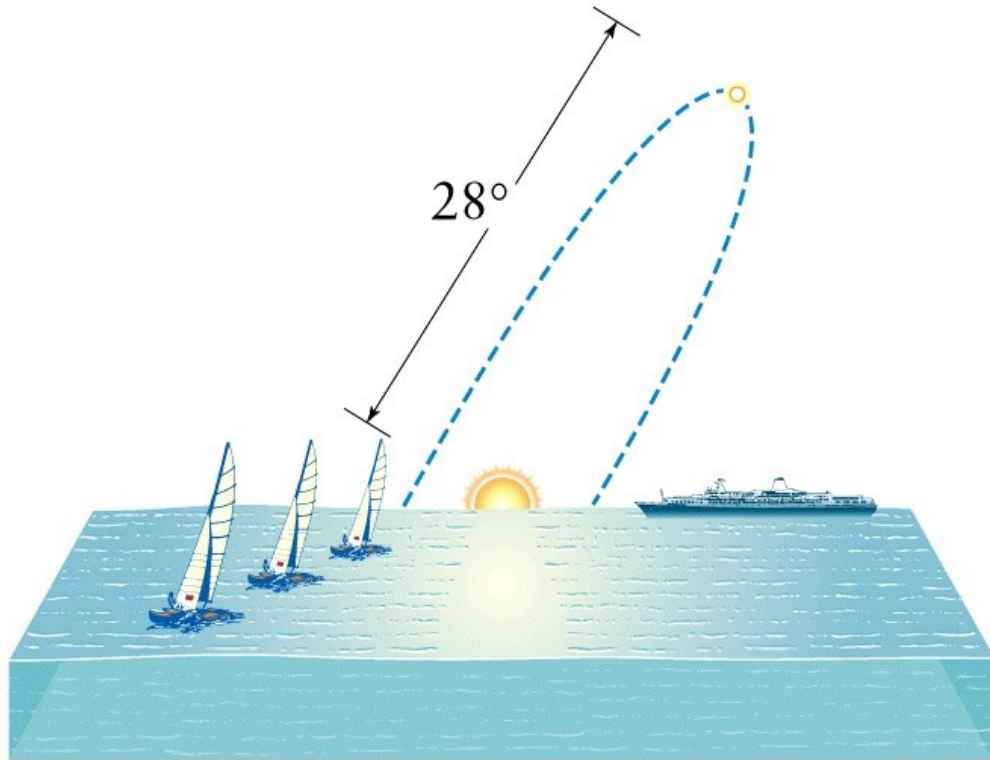
# Mercury observations are difficult!

**Mercury never  
gets very far  
from the Sun in  
the sky.  
( $a=0.387$  AU)**

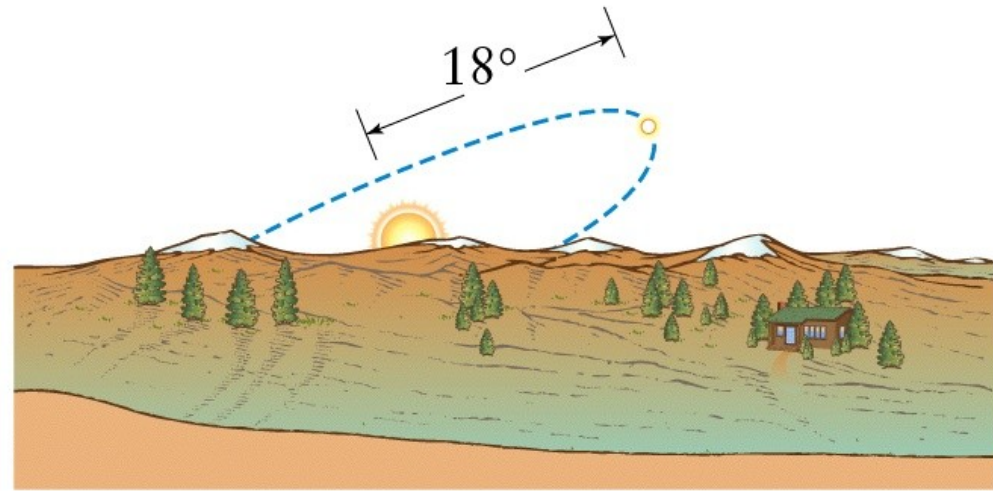
**Orbit eccentric  
( $e=0.21$ )  
so elongation  
angles are  
variable.**



# Mercury is never far above the horizon



Favorable elongation

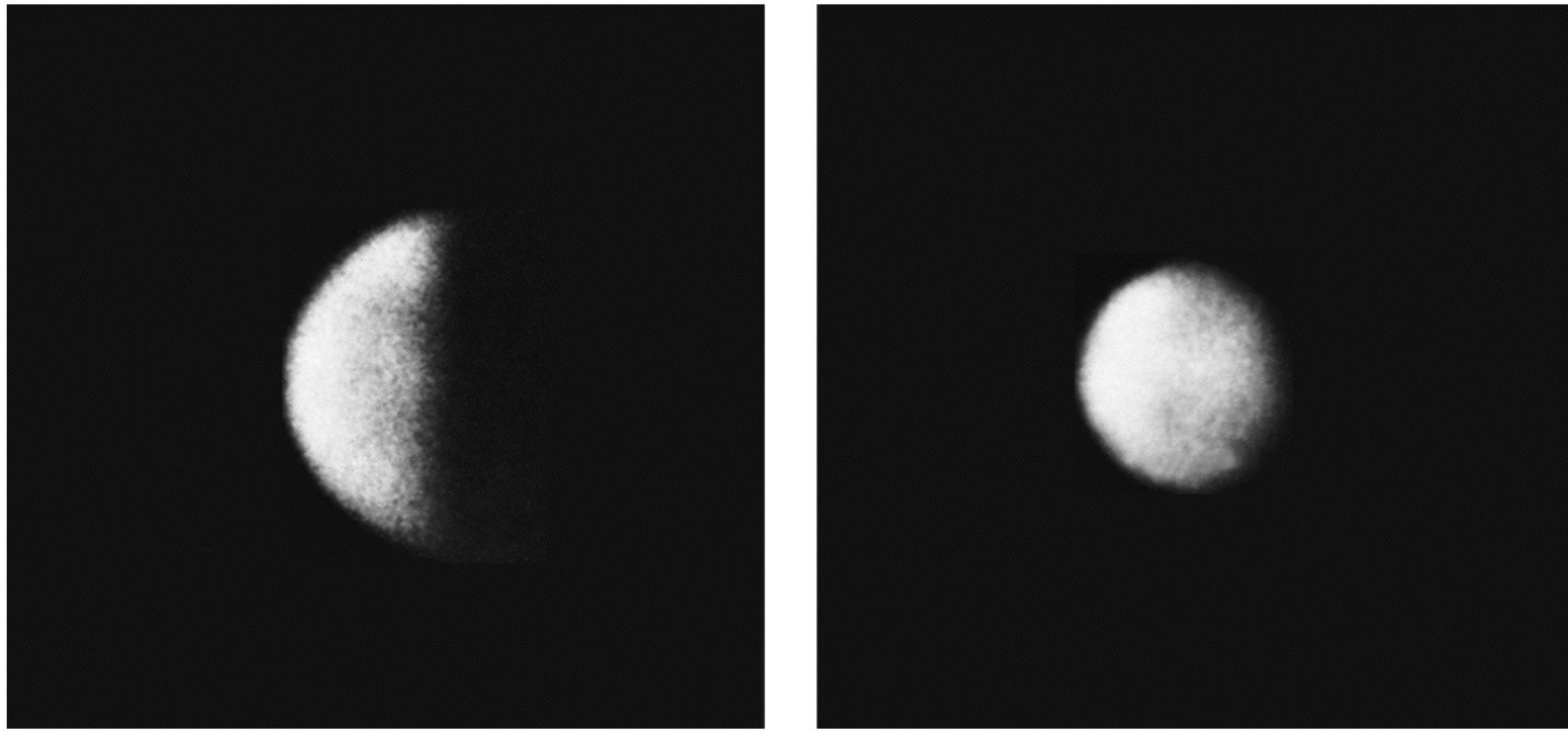


Unfavorable elongation

**Mercury's 7-degree orbital inclination also causes varying 'elongation quality'**



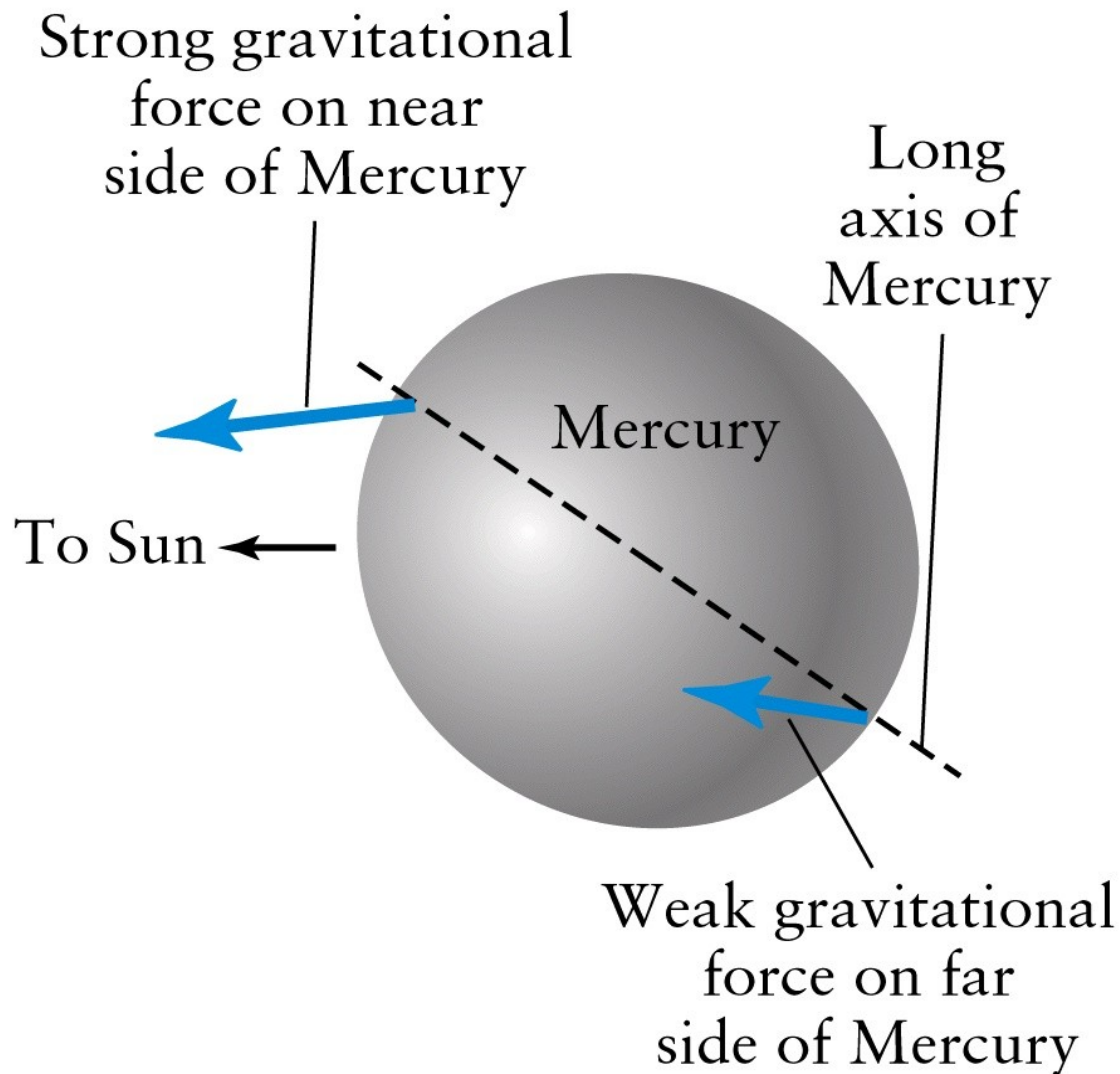
# Telescopic observations of Mercury



- The same Schiaparelli observed Mercury (1880s)
  - Very difficult to observe and detail poor.
  - It was obvious that day was very long.
  - Mistakenly concluded planet synchronously spinning (1:1 spin-orbit resonance like the Moon)**

**Recall that the Earth's tides have 'locked' the lunar spin by slowing it down.**

**Theory: The same could have happened to Mercury.**



a Tidal forces on Mercury

**<--- physical situation**

**-Sun's tides distort  
Mercury**

**-Differential pull on the  
resulting 'bulges' would  
slows spin rate until  
planet rotates with 88-day  
period (same as orbit)**

**But Mercury is **NOT** synchronously rotating**

**-If so, the dark side of Mercury *would be* coldest  
place in the solar system!!!  
(would NEVER see the Sun)**

**- First clue: Blackbody emission at radio  
wavelengths detected from 'dark' side.**

**In 1965 a radar experiment showed rotation was  
about 59 days using Doppler effect.**

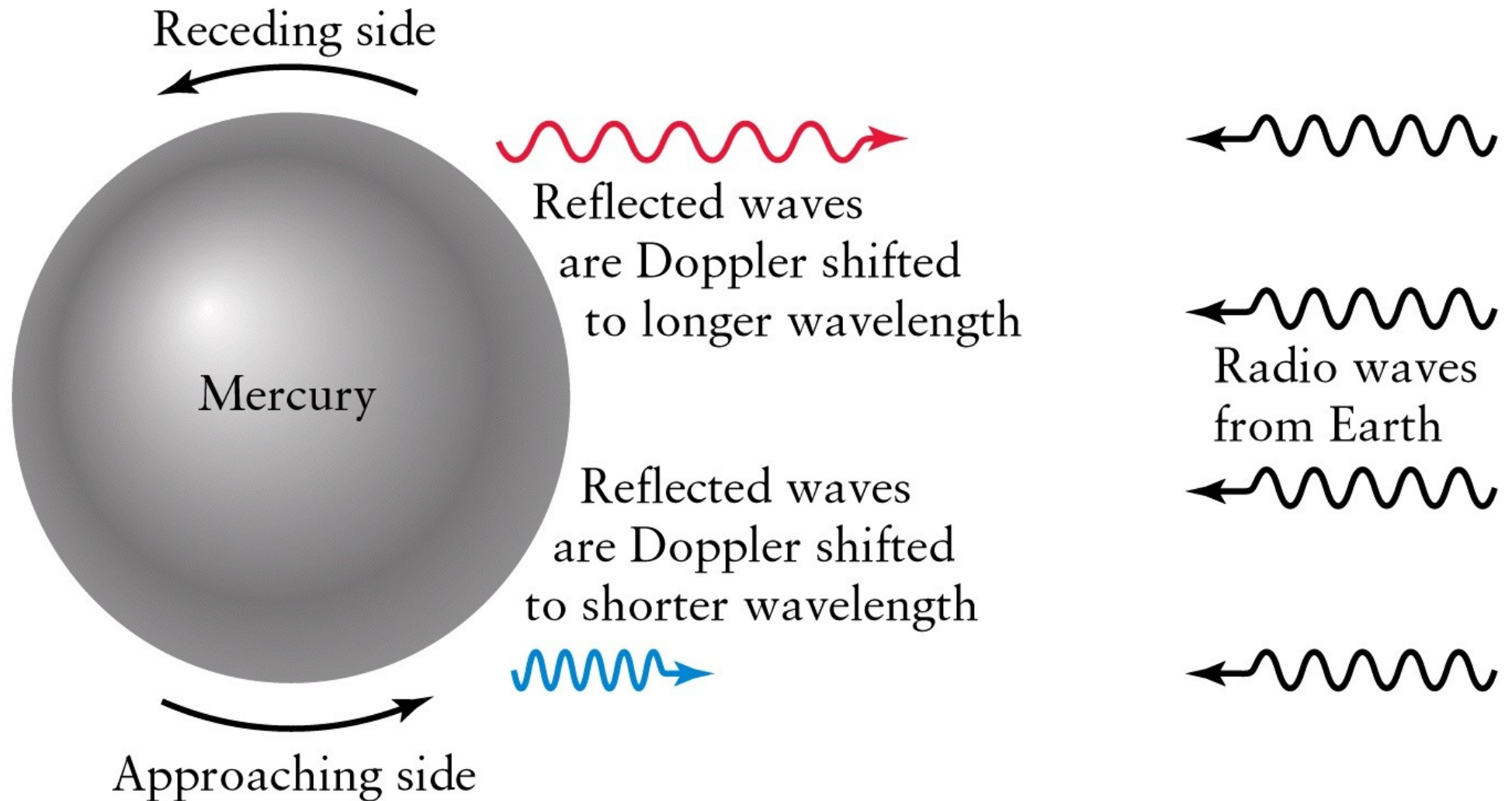


# Doppler broadening of radar waves bounced off Mercury and Venus detected their spin periods





# Doppler broadening of radar waves bounced off Mercury and Venus detected their spin periods



**So if only one wavelength is sent out, a variety of wavelengths will return. Max. shift set by doppler.**

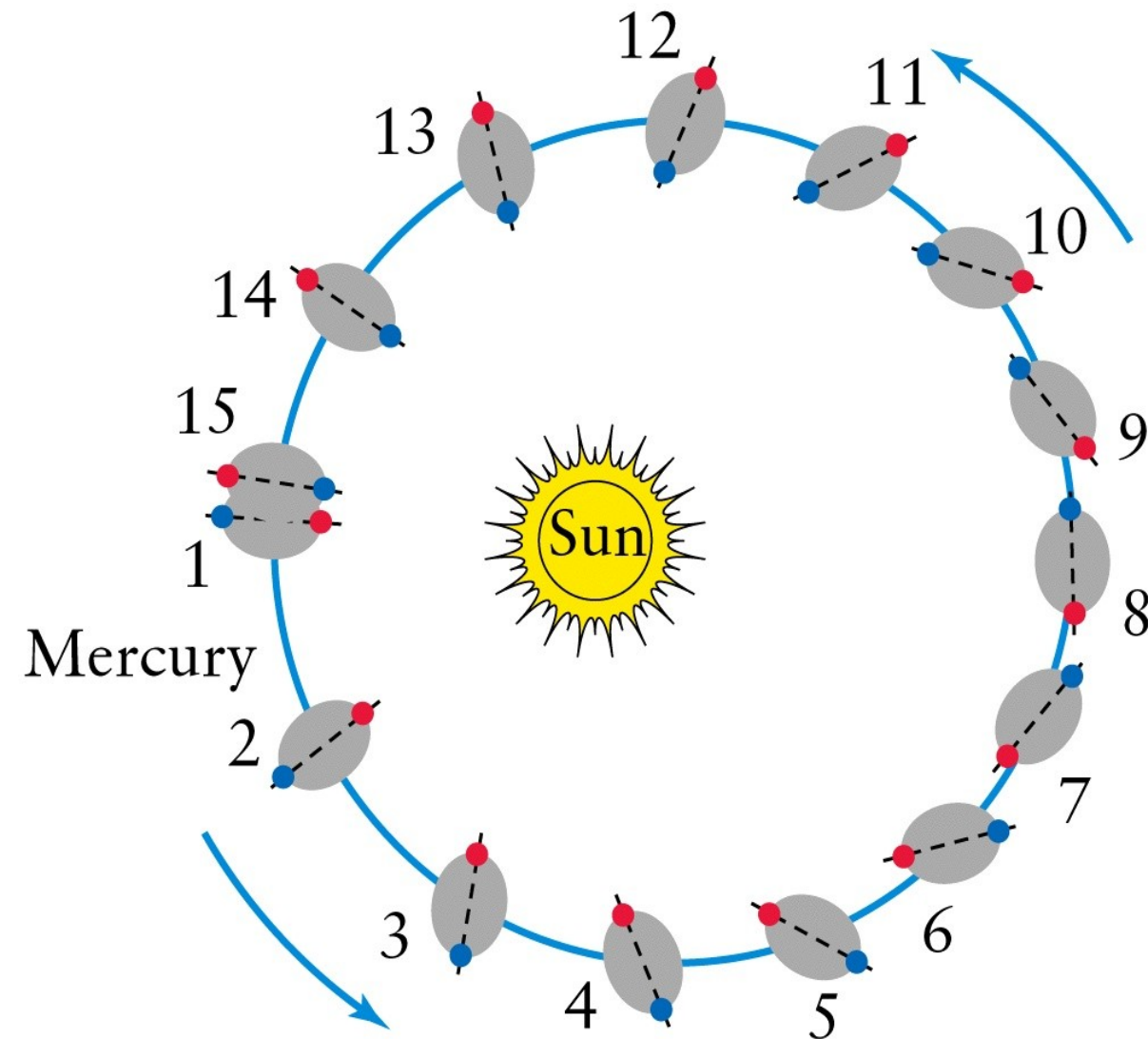
# Mercury is in a 3:2 spin-orbit resonance

G. Colombo postulated 59-day spin was close to 58.646 (exactly  $\frac{2}{3}$  of orbital period) and perhaps in 3:2 lock

Spins 3 times every 2 orbits (1.5 per orbit)

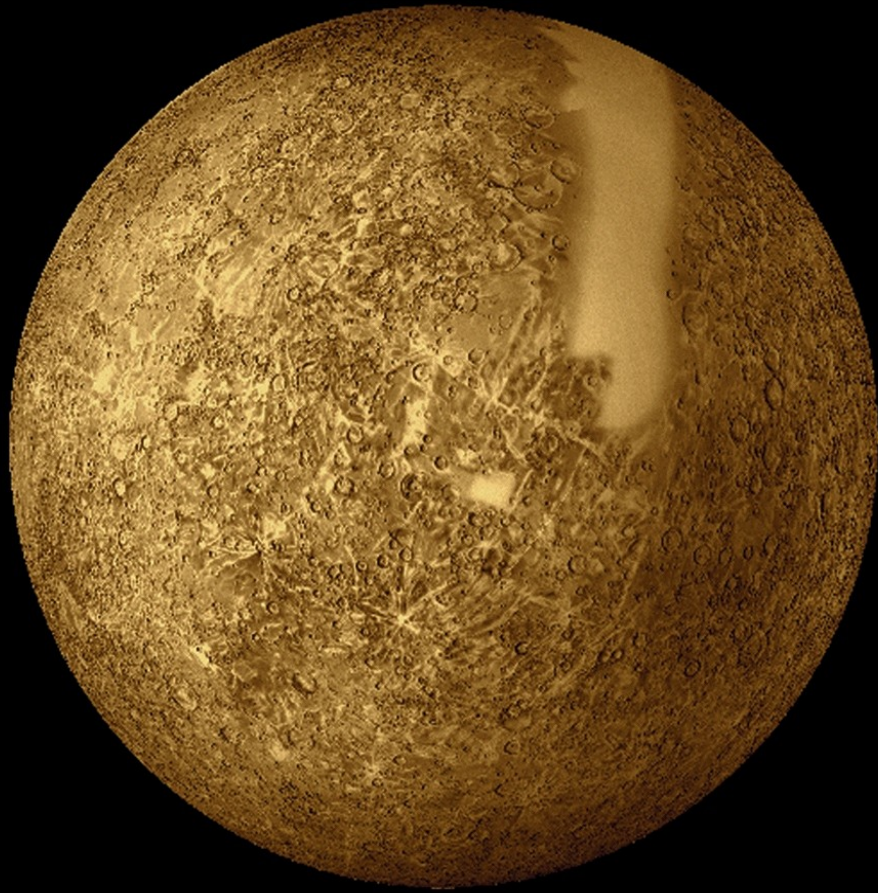
-Sun's tides de-spun planet and it became 'trapped' in this spin state.

**Confirmed by Mariner 10**



c 3-to-2 spin-orbit coupling

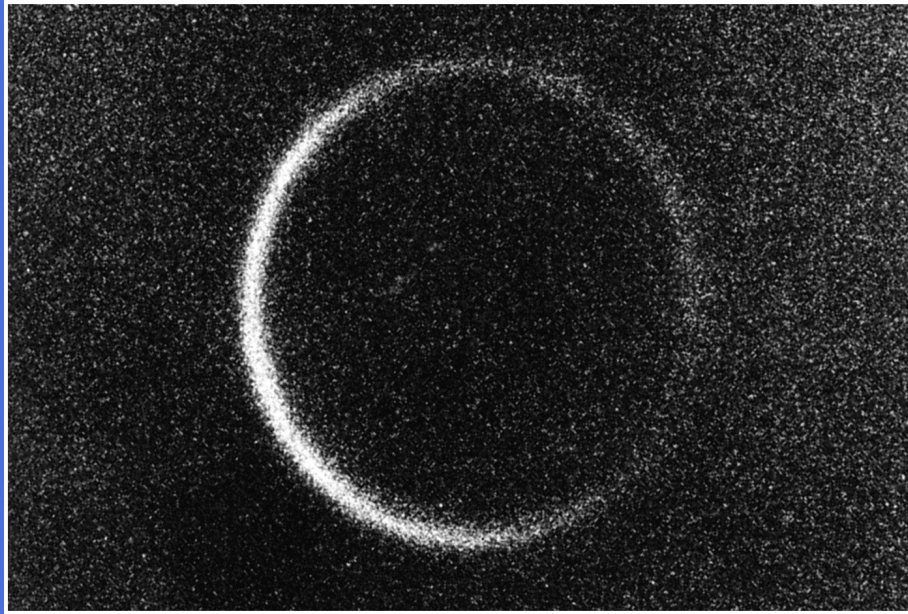
# Because of this resonance, Mariner 10 could not map all of Mercury's surface



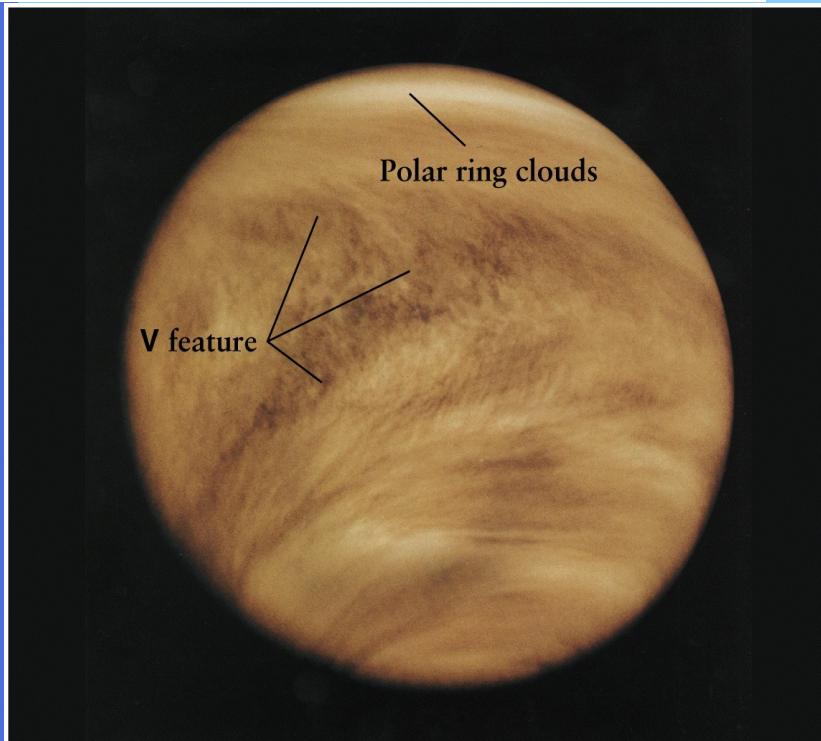
- Mariner 10 was not in orbit around Mercury
- It came close only at the same point every two orbits
- Thus same side was facing the Sun each time!



# Surface of Venus obscured by atmosphere



Atmosphere of Venus can be seen in visible (near inferior conjunction at left) but it is so thick it totally obscures the surface and is **featureless** in visible light.



Later ultraviolet images showed some cloud structure.

These upper atmospheric features circle the planet in about 4 days (**backwards** at 250 km/hour!)

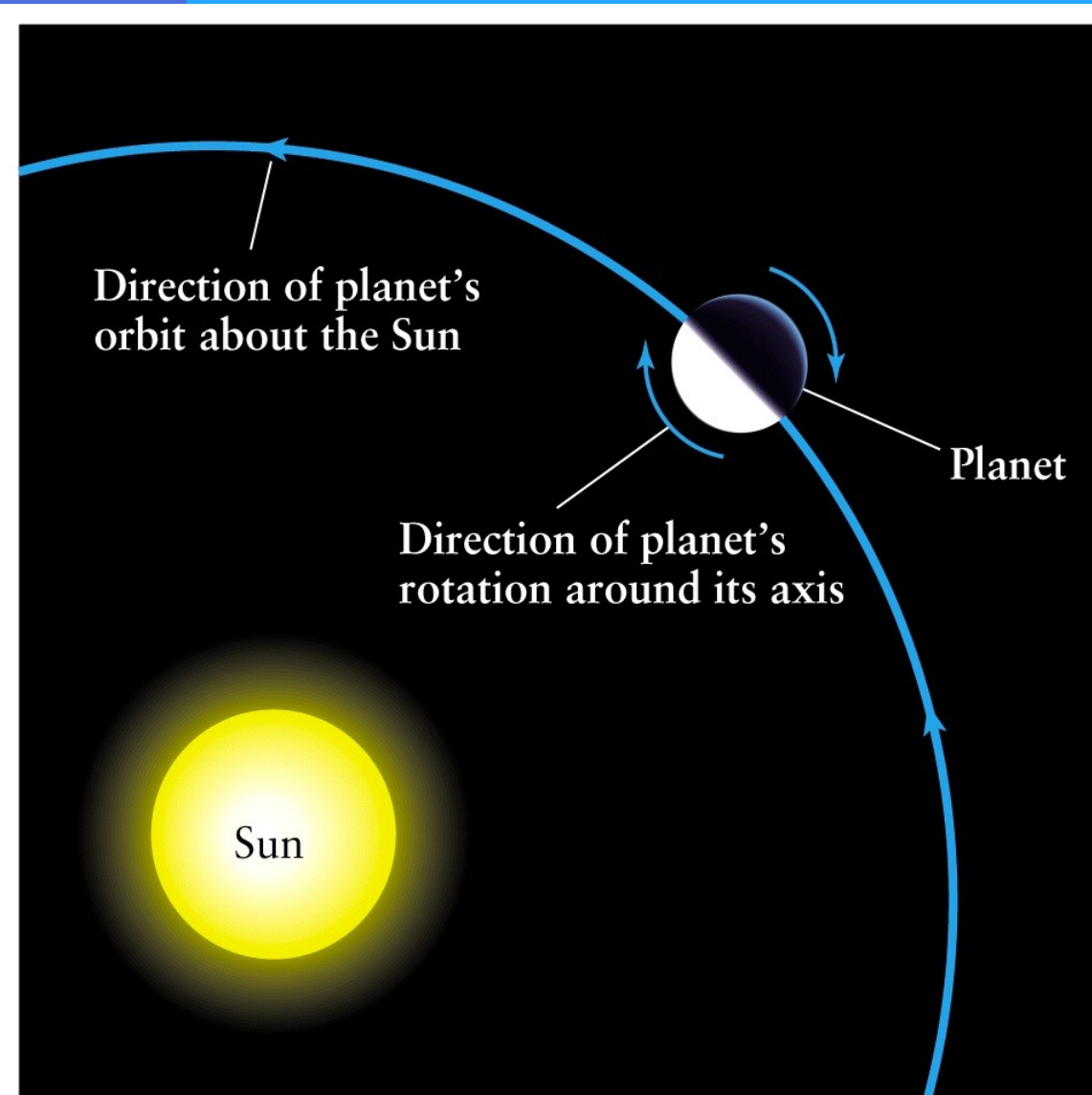


# Radar reflection showed **retrograde** spin!

Doppler-shift experiment showed spread in wavelength that indicated Venus spun **BACKWARDS** (retrograde)

Rotation period of 243 Earth days (**sidereal**)  
-But venusian **mean solar day** is about 117 Earth days (longer than Mercury)

-Origin of planetary and atmospheric rotation is a **MYSTERY**



b Retrograde rotation

# Origin of Earth's spin



- ⇒ Earth's Moon formed during a *giant impact*
- ⇒ The initial spin of the Earth was *set* during this collision
- ⇒ Remember that the Earth's spin is continually slowing down due to tidal friction caused by Moon

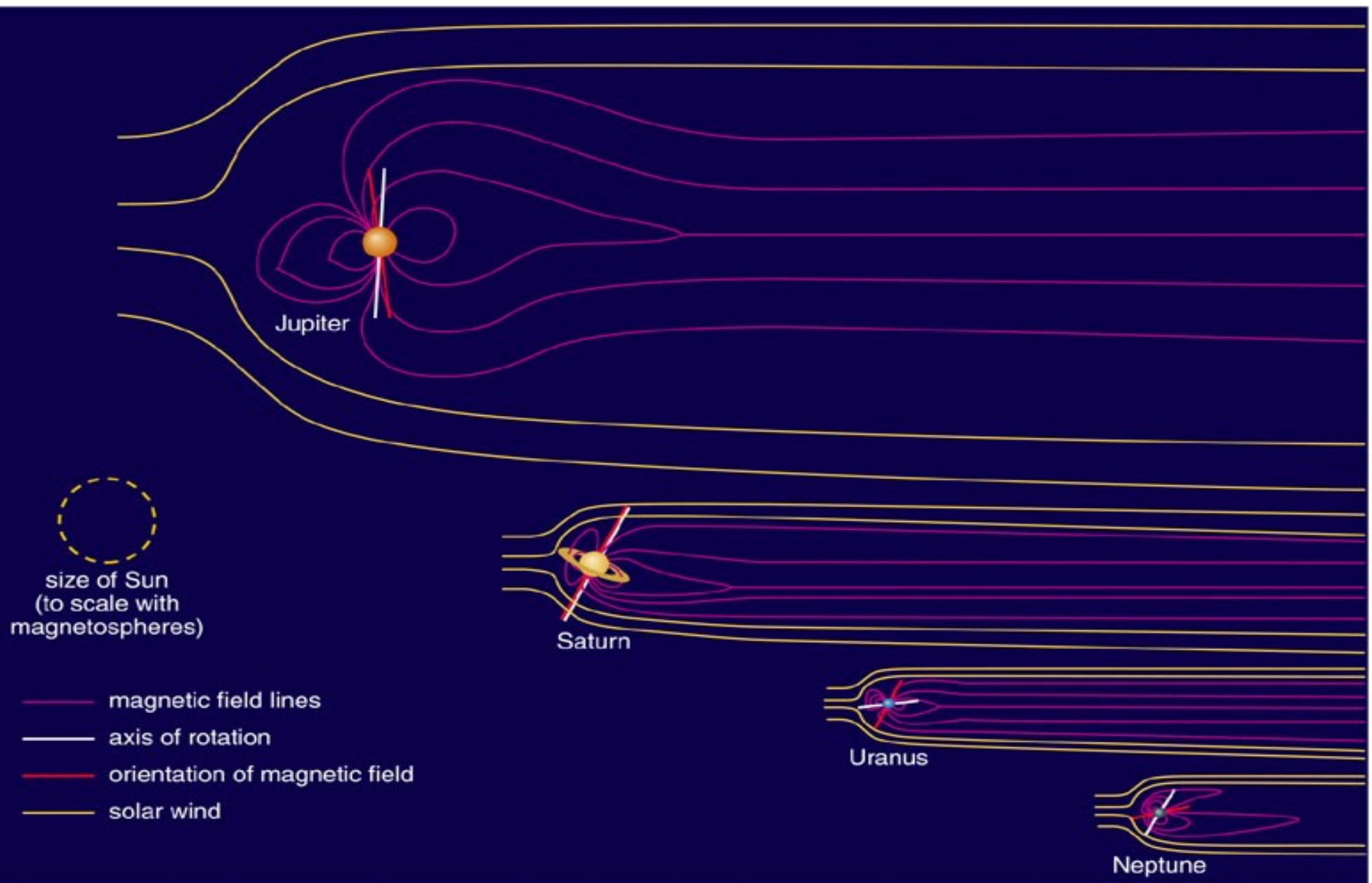
- ⇒ VENUS : Could the spin of Venus have been set by it accreting a retrograde satellite?
  - Tidal friction would cause satellite to spiral *towards* Venus, not away.

# Outer planet spin properties

Planet	Obliquity (degrees)	Orbit Period (Earth years)	Spin Period (Earth hours)
Jupiter	3.1	11.9	9.9
Saturn	26.7	29	11
Uranus	97.9	84	17.200
Neptune	28.8	164	16.100
Pluto	119.6	248	6.4 days

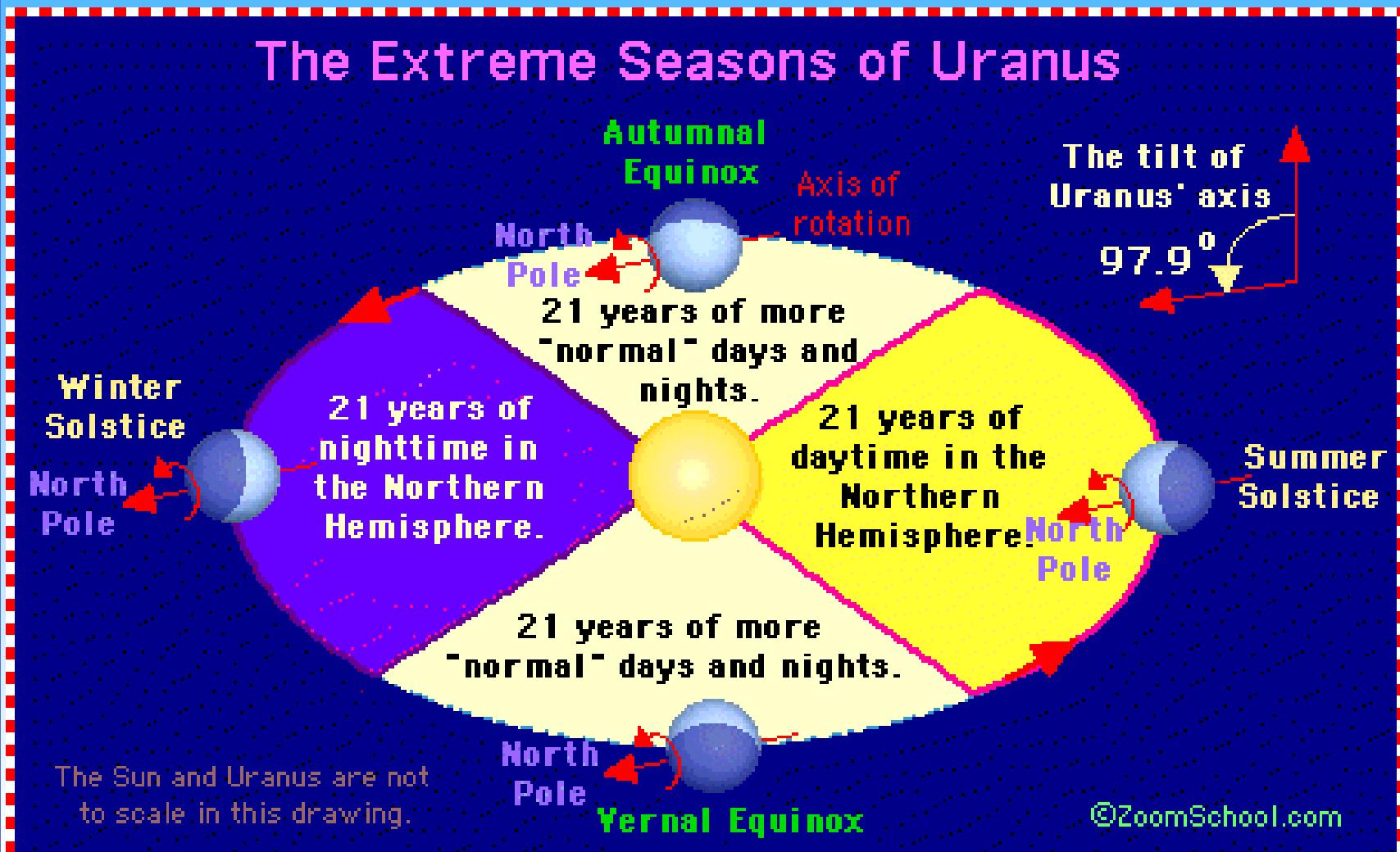
# The giant planets :

## A variety of spin and magnetic axes



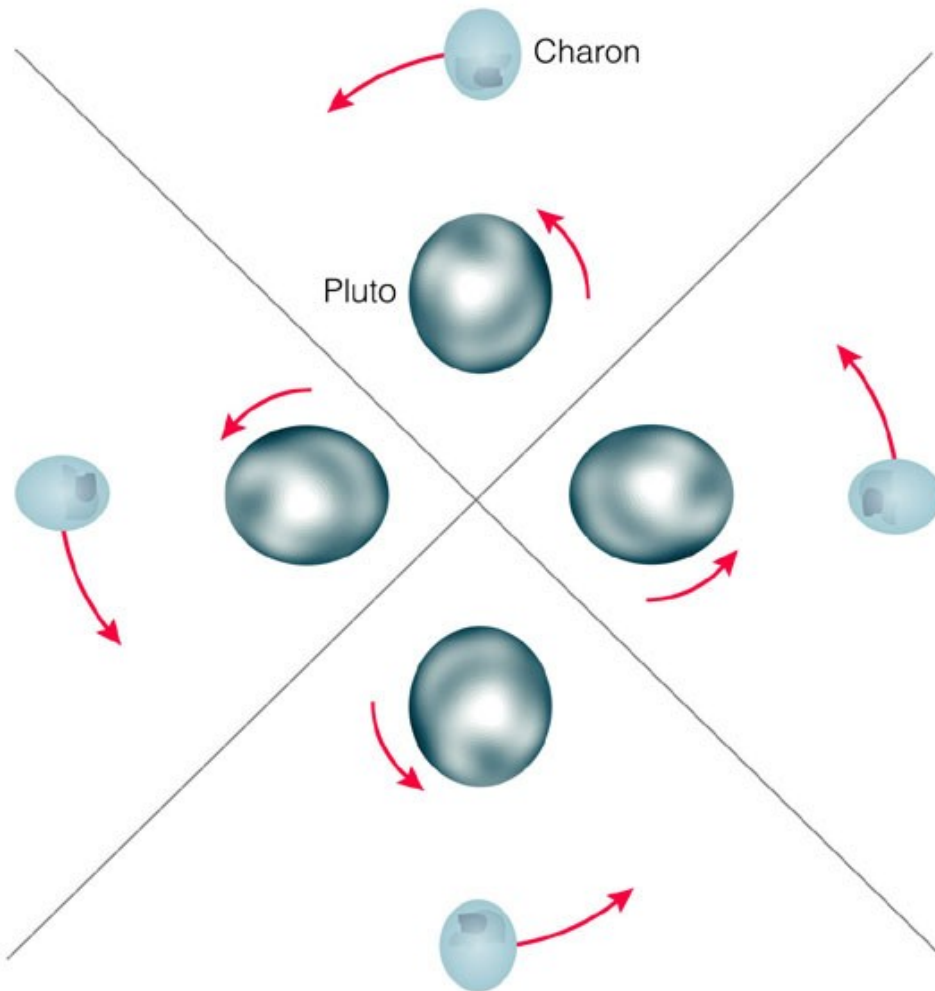
# The extreme case of Uranus

- The large spin obliquity causes extreme seasons
- Is the axial tilt the result of a huge collision when Uranus was forming?





# Pluto and Charon : The ultimate tidal dance



- Pluto has tidally de-spun Charon (just as Earth has de-spun our Moon)
- But Charon is big enough that IT has also de-spun Pluto!
- Both objects thus have the same hemisphere facing each other.



# Outer planet satellites

ALL the big, close, outer planet satellites have been tidally despun to a state of **synchronous rotation**

That is :

Spin period = orbit period