# Planetary Transits

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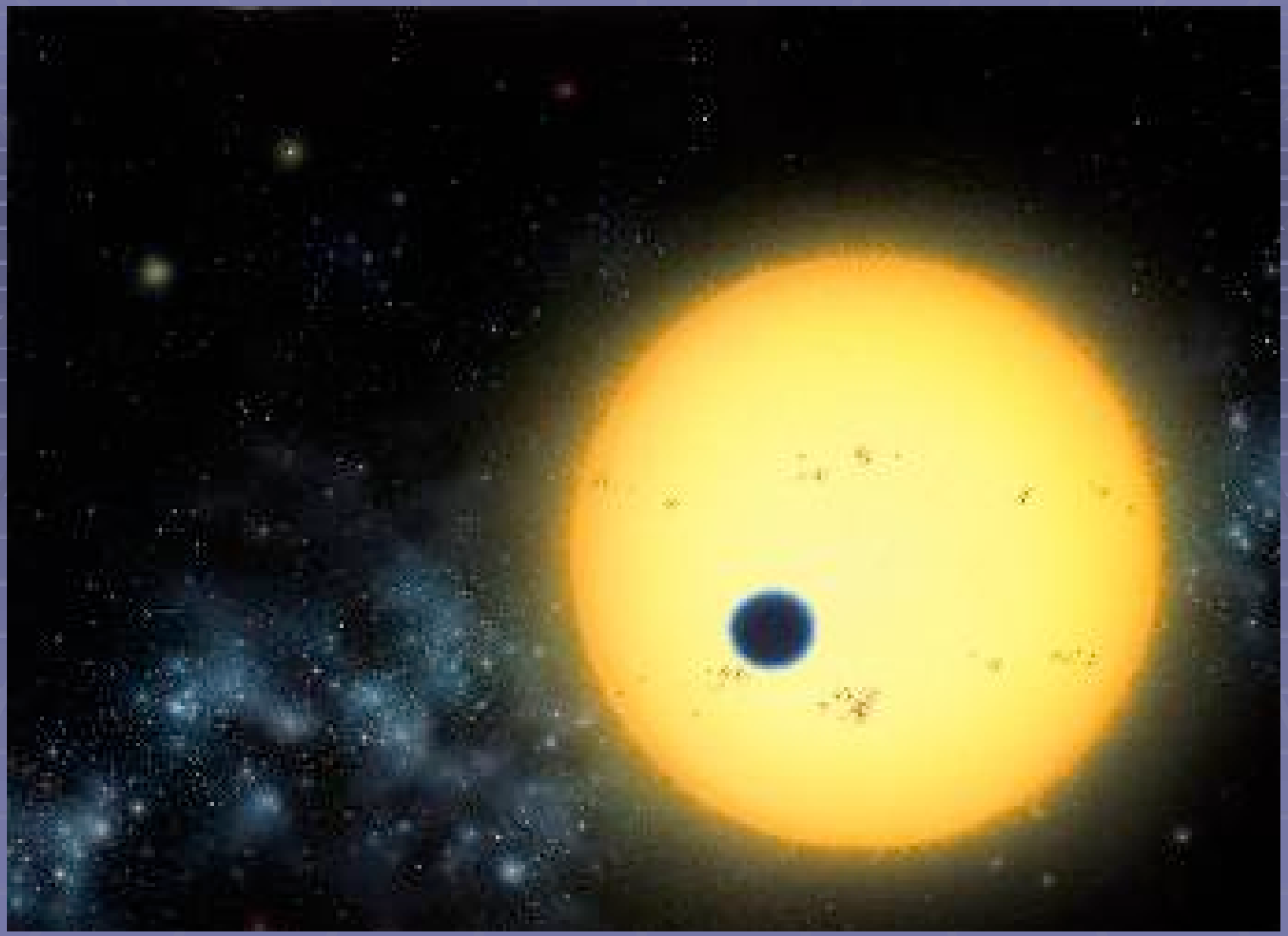
AST 205 Lecture

October 15, 2003



# Outline

- The Transit of Venus

http://www.dsellers.demon.co.uk/venus/ven_ch_frames.htm

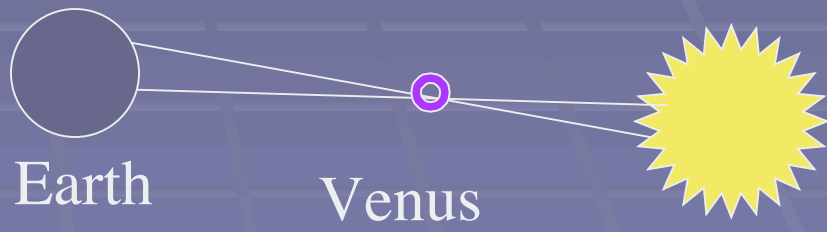
*The Transit of Venus,* D. Sellars

  - Measuring the size of our Solar system
- "The Royal Road to the Stars"
  - Determining stellar distances and masses
- Eclipsing Planets
  - HD 209458: The Best Known Stellar System outside our own
  - Terrestrial Searches: OGLE search
  - Space Missions

# Transits of Venus

| |
|---|
| 1631 December 7 |
| 1639 June 6 |
| 1761 June 4 |
| 1769 June 3 |
| 1874 December 9 |
| 1882 December 6 |
| 2004 June 8 |
| 2012 June 6 |

- 1677: 21 year old Edmond Halley sees transit of Mercury during stay at St. Helena-- recognizes that transits can be used for measuring size of solar system
- 1761/1769: Great Eclipse Expedition
- Able to get a 2.5% measurement of the distance to the Sun



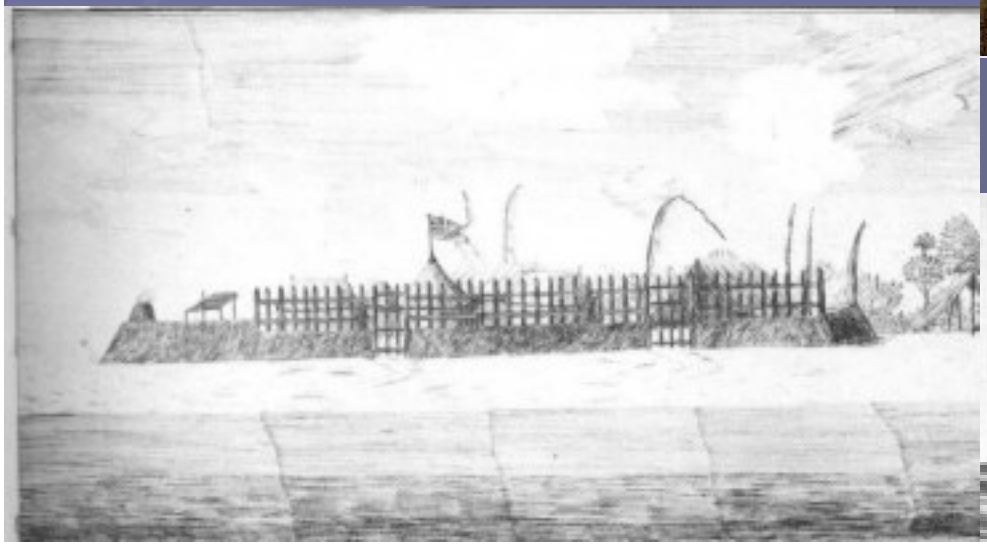
# Measuring the Solar System

- Kepler's laws
  - Given the period of Venus and Earth, we can work out the ratio of the Venus/Earth distance
- Parallax:
  - Given the starting time of the eclipse at different locations on the Earth's surface, we measure the angle in the Venus/Earth system
- This yields a measurement of the AU--- our first step in measuring the distance to the stars.

# The Transit of Venus

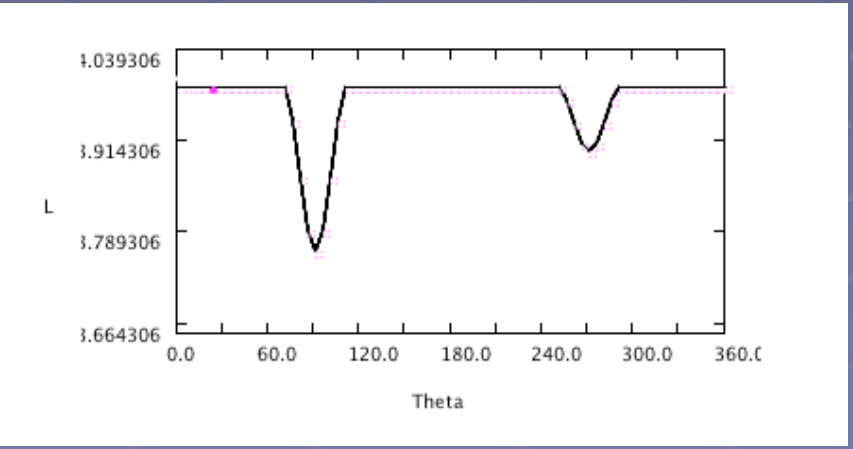
The Royal Society sent Captain Cook along with Joseph Banks to Tahiti to observe a transit of Venus on June 3, 1769 to set the scale of the Solar System

*Fundraising: Cook, Joseph Banks, and Lord Sandwich.*



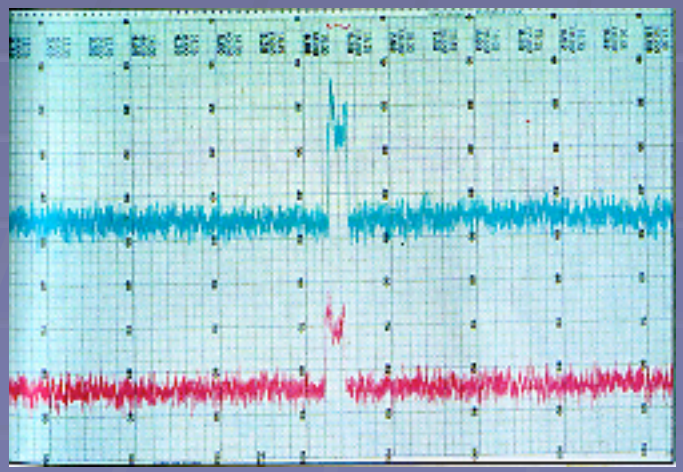
# Eclipsing Double Spectroscopic Binaries

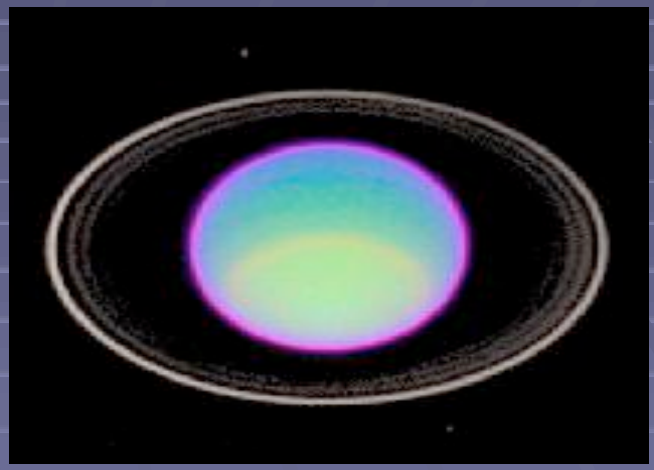
http://instruct1.cit.cornell.edu/courses/astro101/java/eclipse/eclipse.htm



# Stellar Occultations by Solar System Planets

- Discovery of Uranian Rings (1977)
  - 5 narrow rings seen as star flickered in brightness as it passed by Uranus

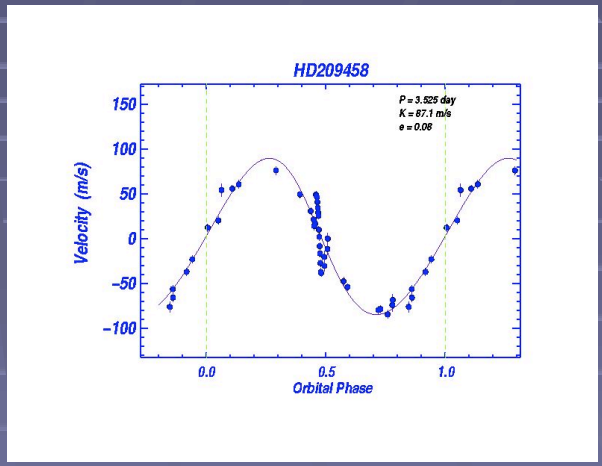


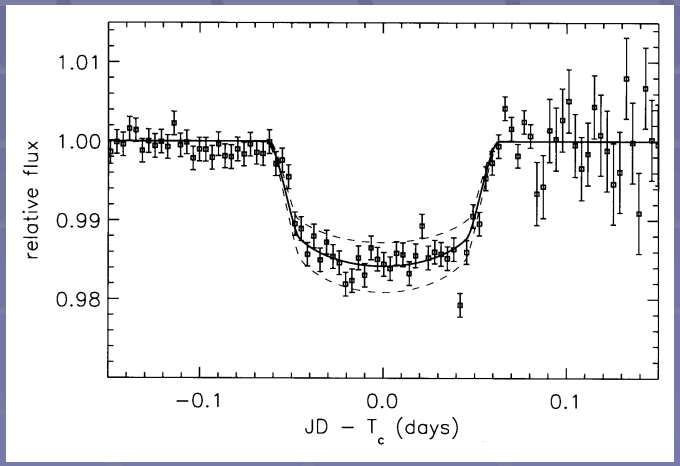


Voyager (1986)

# HD209458

- "Almost" naked eye-star with known planet (detected by radial velocity search)
  - 0.63 MJ planet in 3.5 d orbit around solar class star
- Brown and Charboneau monitor star and detect transit from parking lot
- 20+ groups start transit search



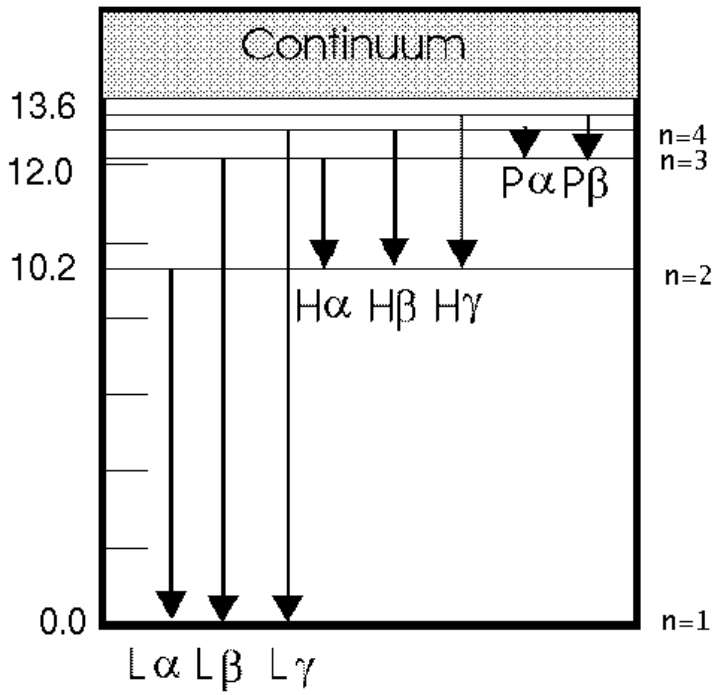
# Transit Determines Planet's Properties

- Transits of HD 209458 determine properties of another Solar System
  - Confirmation of planet interpretation
  - Inclination= 85.9°
  - Mass= 0.69 ± 0.07 $M_{jup}$
  - Radius =1.35 ± 0.06 $R_{jup}$
  - Density= 0.35 g/cc <Saturn
- Spectroscopy probes atmosphere
  - Cloud heights, heavy-element abundances, temperature and vertical temperature stratification, and wind velocities

# Atomic Spectroscopy

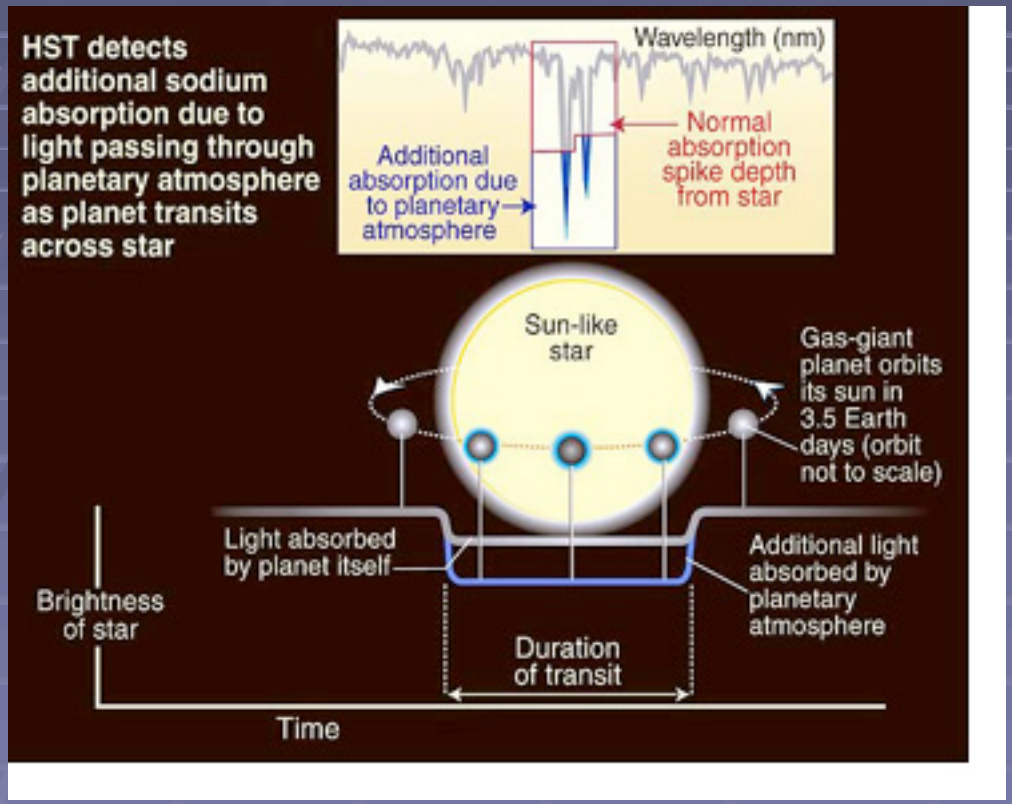
- Quantum Mechanics:
  - Electrons in an atom (or molecule) can only occupy discrete configurations (energy levels)
  - Each atom has its own distinctive set of energy levels
- In a cold gas, most of the atoms are in the ground state

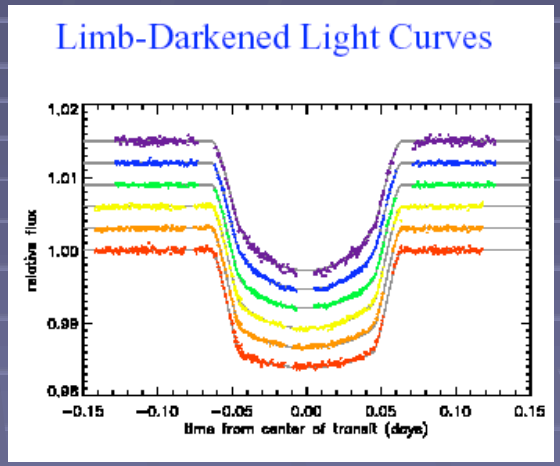
$$E = -\frac{13.6}{n^2}\ eV$$

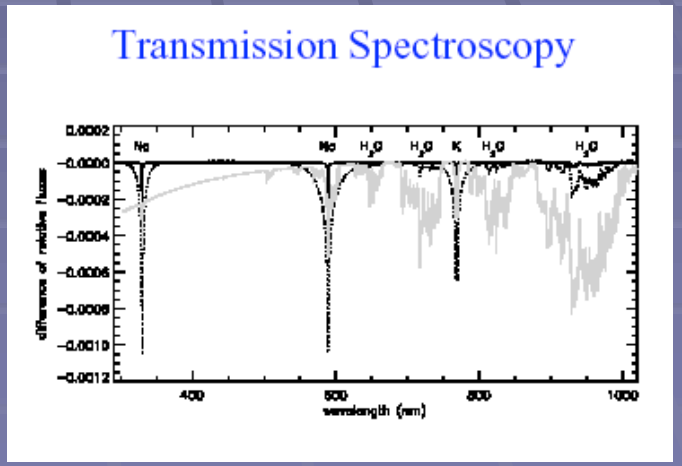



Energy levels in the Hydrogen atom. The scale on the left gives energies in electron volts above the ground level.

# Neutral Na seen in Atmosphere



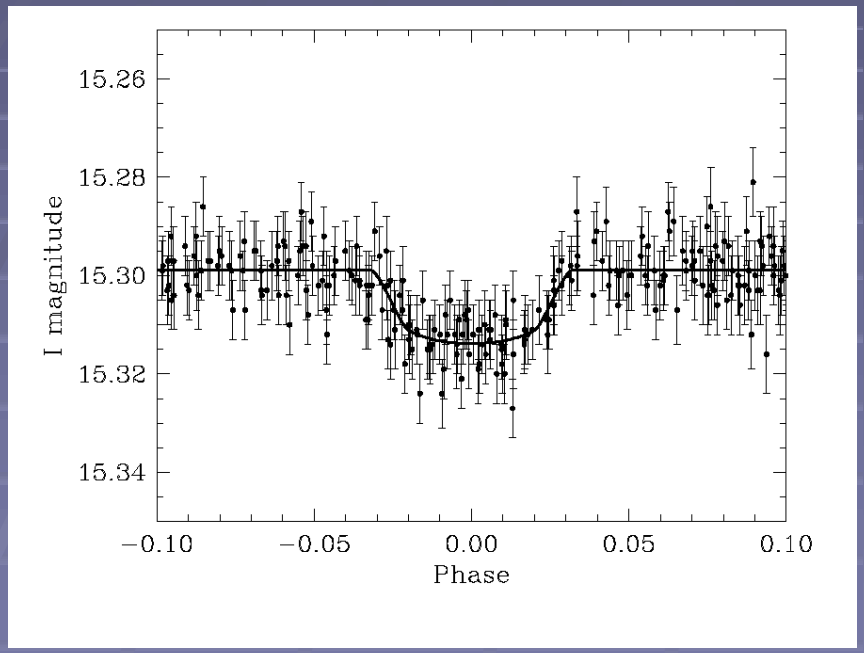




Less than expected: clouds in atmosphere?

# Evaporating Planetary Atmosphere

Astronomers detect an extended neutral hydrogen wind (Lyman )

# OGLE TR-56b




- First planet found by transit search
- OGLE telescope (Princeton/Poland/Chile)
- Just observed at Keck
- HST observations soon

# Cullen Blake '03 Search

- Can we find Earth size planets?
- Solution: Make the star smaller
- Brown Dwarfs are the size of Jupiter. Earth-size planets produce $10^{-3}$ amplitude occultation events.

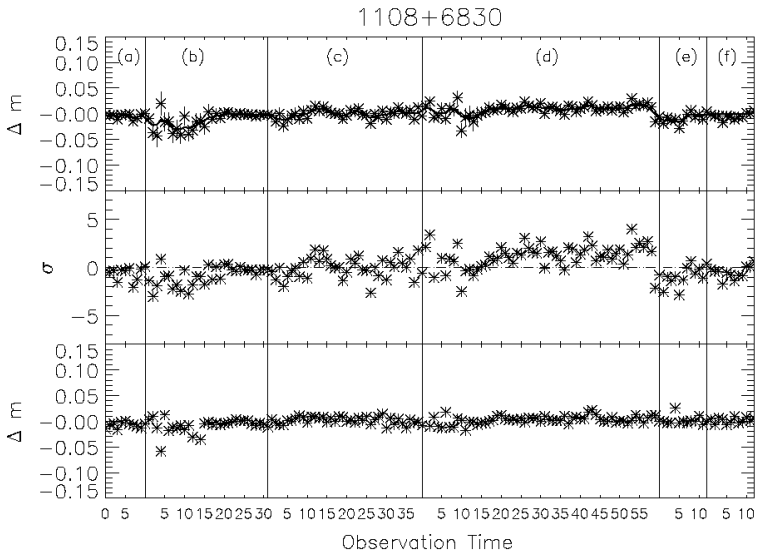



Fig. 3.— Each point represents an individual 300s BD filter observation. The top panel shows the differential photometry for 1108+6830 with the heavy line representing the data averaged in bins of 2 observations. The middle panel shows the error-normalized deviations from the mean. The bottom panel shows the photometry for a nearby comparison star. The vertical lines delineate observing nights. Observing times are JD+0.004·X. Panel (a) begins at JD=2452654.9136, panel (b) at JD=2452655.8192, panel (c) at JD=2452656.7914, panel (d) at JD=2452657.8084, panel (e) at JD=2452658.8039, and panel (f) at JD=2452659.8110

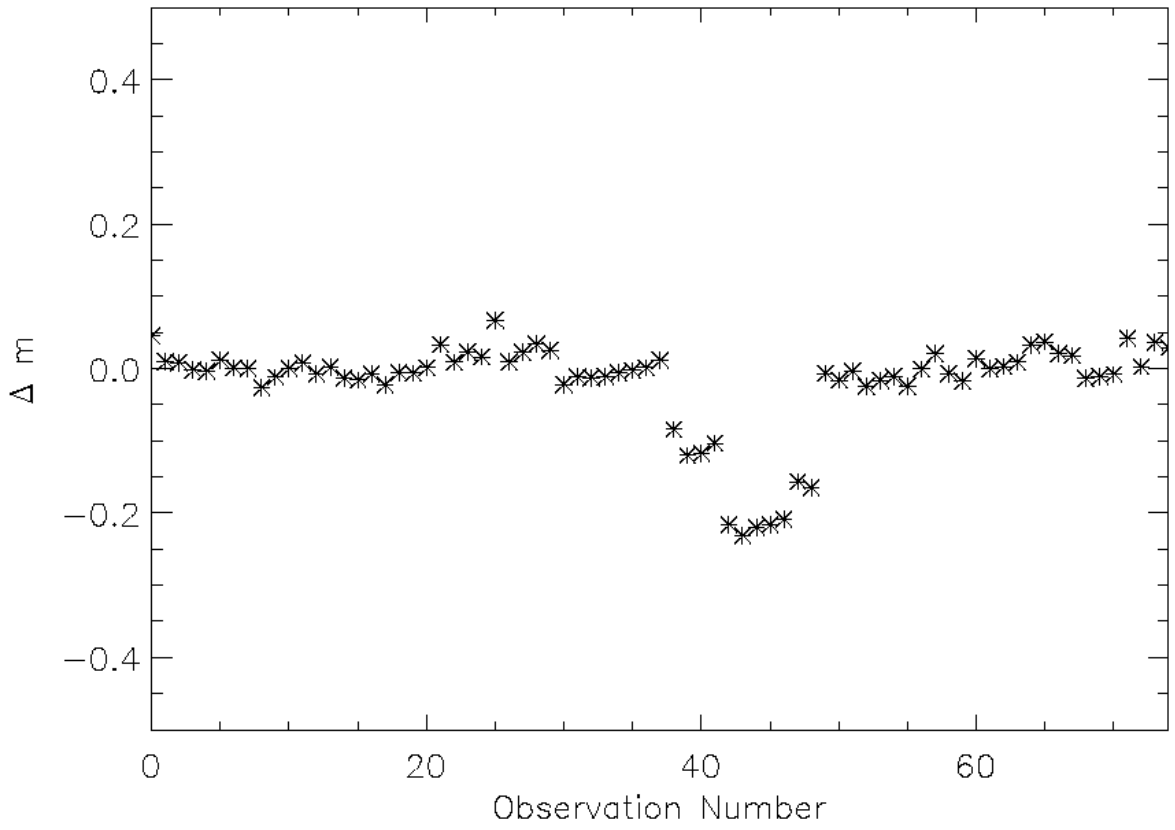



Fig. 9.— An example of an interesting eclipsing feature which was unfortunately found to be due to a small charge trap in the CCD array. A wide variety of difficult to diagnose errors may take a form similar to that of an eclipse.

# MOST

- Canadian Space Agency
- Jaymie Mathews (UBC)
- ``Humble Space Telescope" ($10M)
  - 15 cm aperture
  - 20 stars monitored per year
- Microsatellite

Just Launched

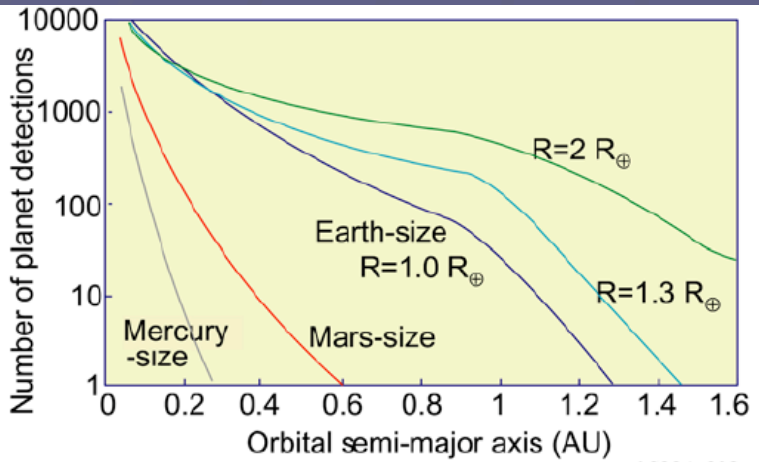
# COROT

- CNES/ESA
- Search 500,000 stars
- Expected to detect 10-40 super-Earths
- Helioseismology
- 2.8$^{o}$ x 2.8$^{o}$ FOV

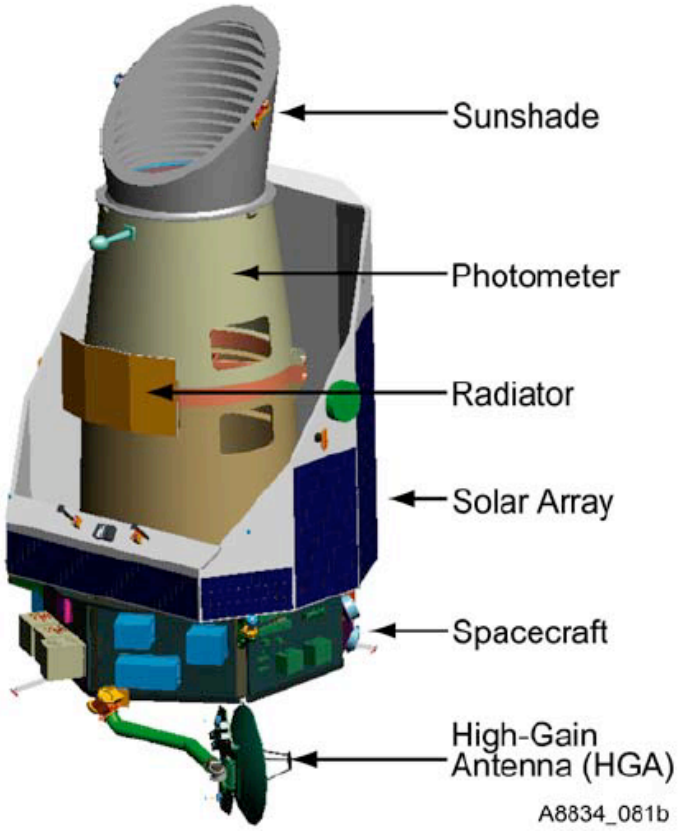
*Late 2005*

# KEPLER

- Discovery Mission
- Late 2006 launch




***Expected number of planetary discoveries.*** *The curves show the expected results based on monitoring 100,000 dwarf stars and a four-year mission and if most stars have terrestrial planets. The mission is sensitive to a large number of planets even smaller than Earth in short period orbits as a result of the larger number of observed transits.*




***Kepler Flight Segment*** **12/01**

# Eddington

- ESA
- Astroseismology
- Planet Occultation

2008 launch