Lecture 16 – 24th March 2009

HOMEWORK 05: due tonight, 11:59pm
HOMEWORK 06: Out now, due next Tuesday, 30th March, 11:59pm
***COMPREHSION 02:* This Thursday, 26th March**

- **SCIENCE TOPICS**:
  Extrasolar Planets (cont.)
  How the Sun shines
- **READING**
  Ch 4, sec 4.4: Planets Beyond the Solar System
  Ch 9, sec 9.1, 9.2, 9.5
  Beware of excessive detail

PRACTICE:

Chp. 9: Review: 1-3, 5,8,11, 13, 15
Chp. 9. Self-test: 1, 3, 6, 13, 14, 15;
Chp. 9. Problems: 8, 9

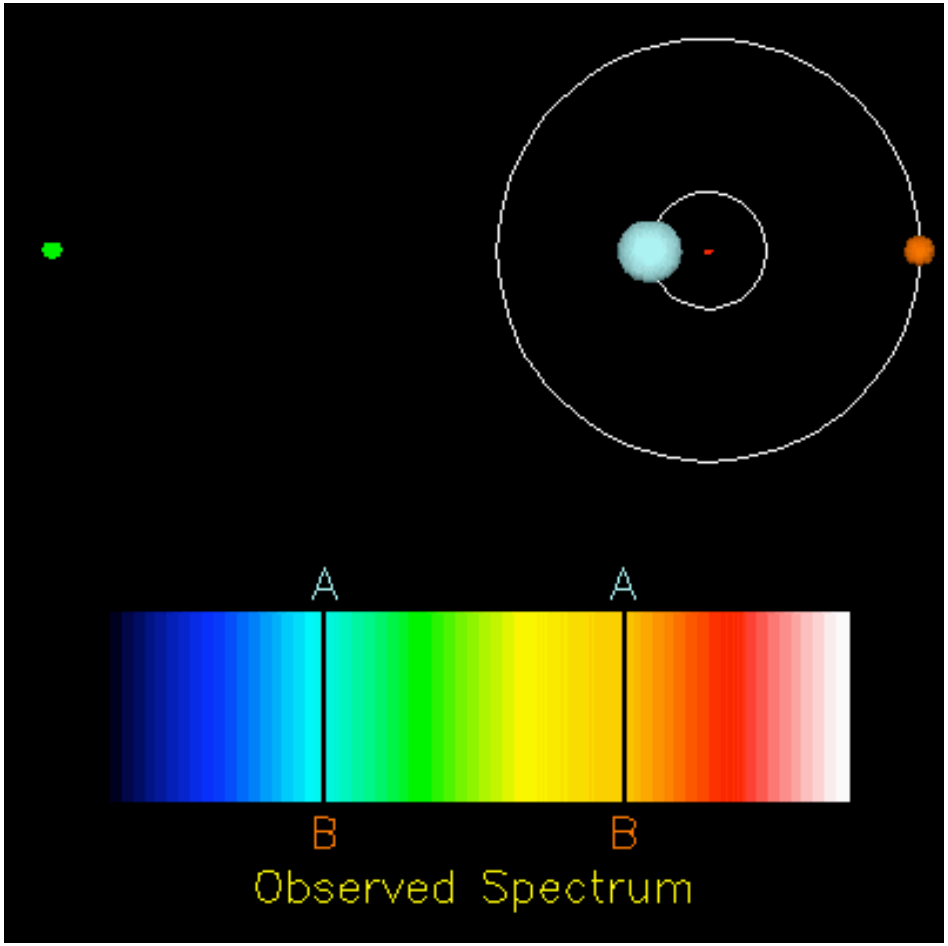
About Comprehension 2

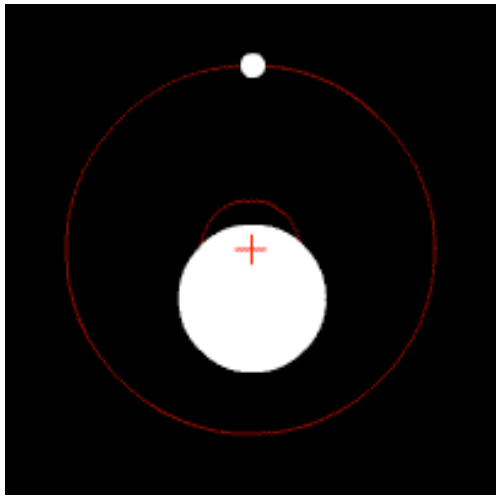
- ***When and Where***: **Thursday**, 26 March 2009 in this classroom, during regular class time
- ***Format and Time Limit:***
  A passage of unseen text relevant to the course. 20 multiple choice questions; 1 mark per question. ***ALL*** the information you need to answer the questions will be provided in the text.
- ***What to Bring:***
  - **your PSU ID card**
  - #2 pencils and eraser
  - a calculator
- ***Other Rules and Regulations:***
  - closed book, closed notes
  - work on your own
  - items other than the above out of sight (*especially* cellphones)

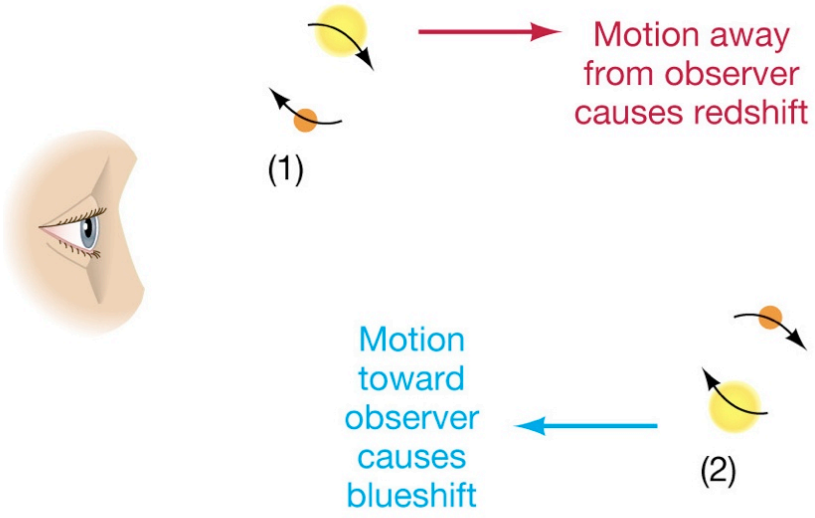
About Comprehension 2

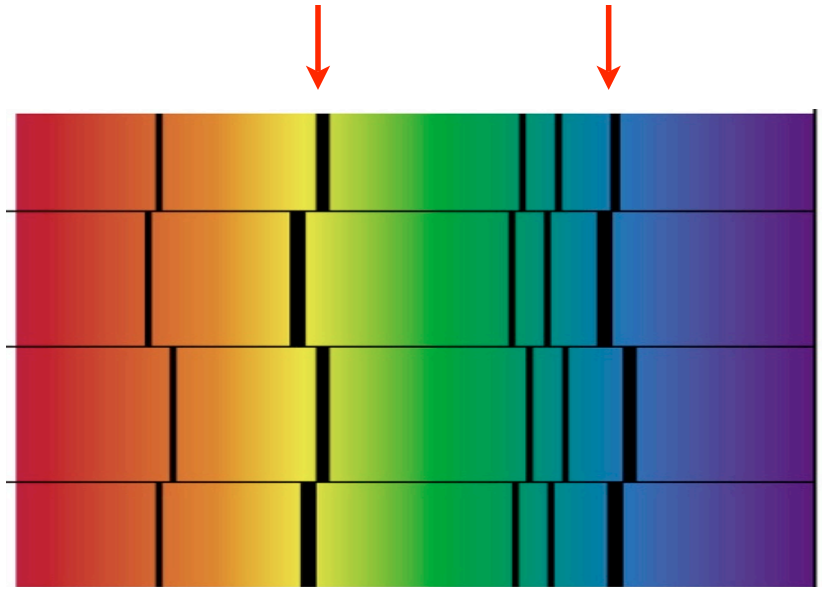
- ***TIPS:***
  - Don't be scared by the "jargon"
    - Maybe think of this more as an English test rather than as an Astronomy (science) exam
  - Read the question carefully!!
  - "There's not enough information in the text" is (sometimes) the correct answer.
  - 2 or 3 questions require a (small) calculation. It's assumed you now know about "Powers of Ten", and that e.g. 1 trillion = 1×10^9

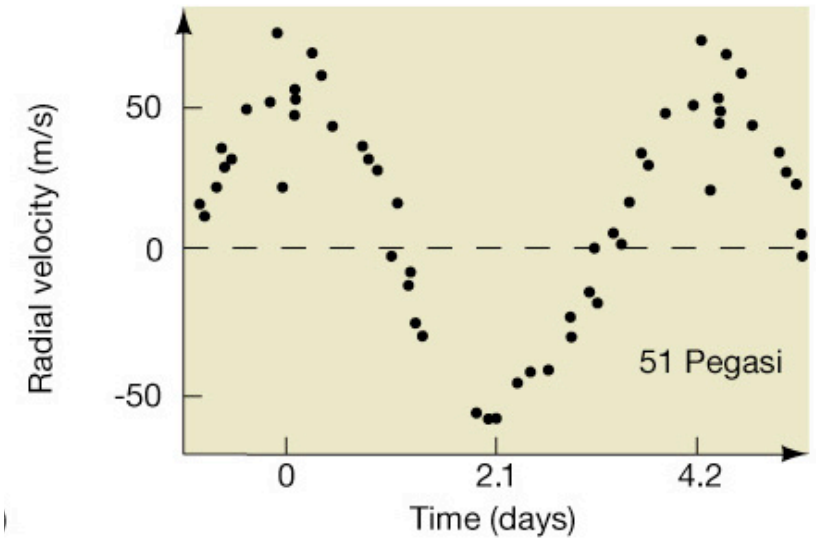
Extra-solar Planets ("Exoplanets")

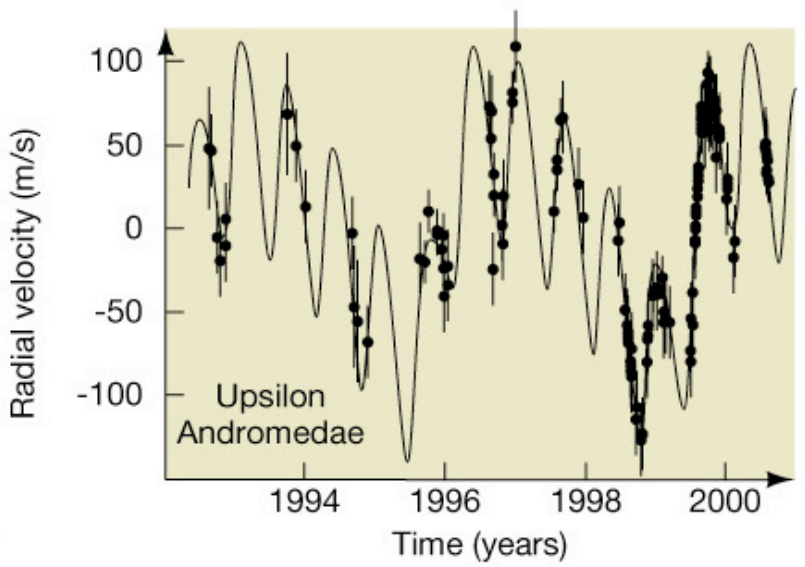

A
A
B
B
Observed Spectrum

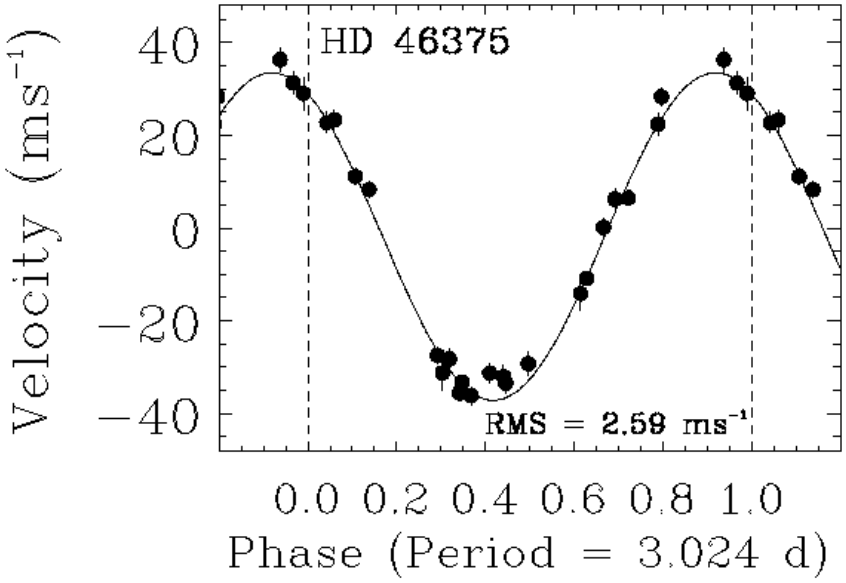


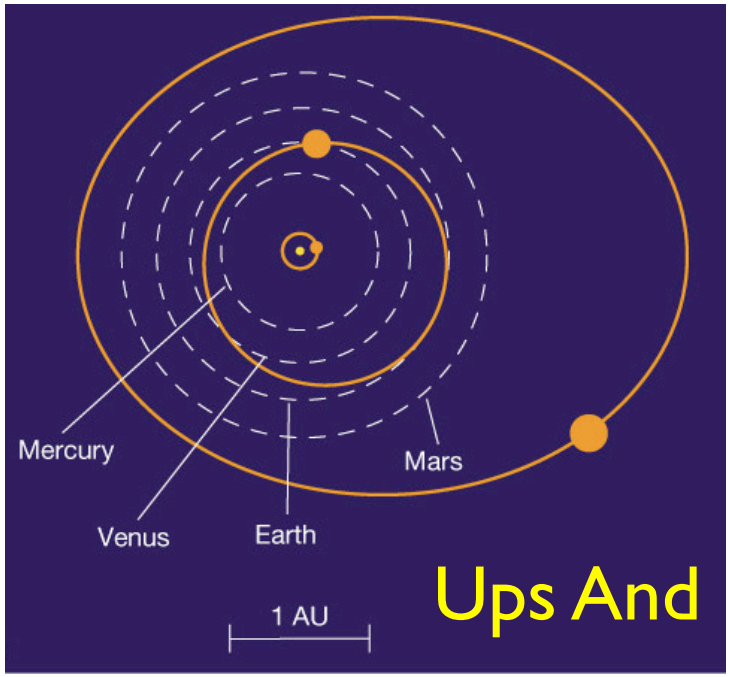

Motion away
from observer
causes redshift
(1)
Motion
toward
observer
causes
blueshift
(2)

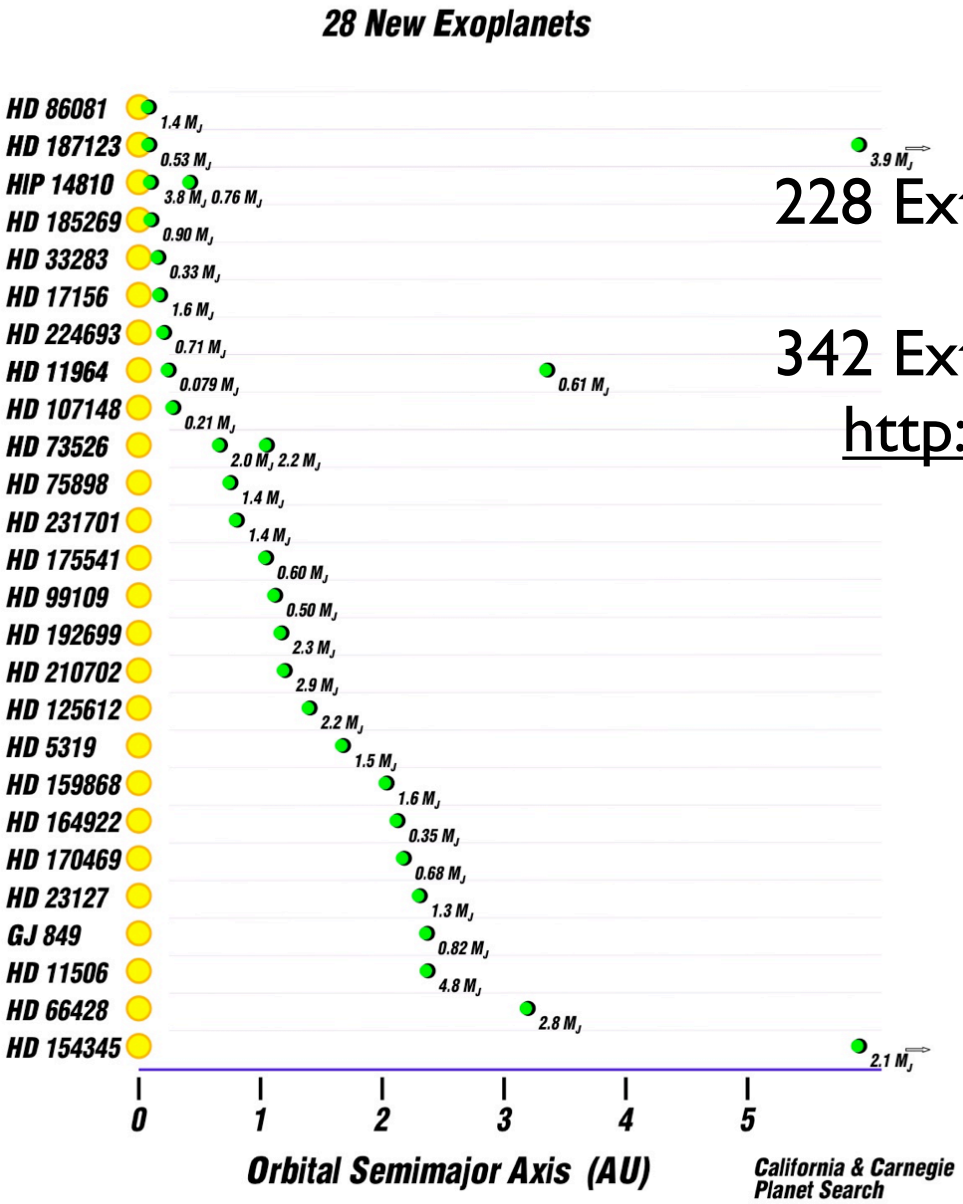



Radial velocity (m/s)
50
0
-50
51 Pegasi
0
2.1
4.2
Time (days)


Radial velocity (m/s)
100
50
0
-50
-100
Upsilon
Andromedae
1994
1996
1998
2000
Time (years)


Velocity (ms⁻¹)
40
20
0
−20
−40
HD 46375
RMS = 2.59 ms⁻¹
0.0 0.2 0.4 0.6 0.8 1.0
Phase (Period = 3.024 d)


Mercury
Venus
Earth
Mars
1 AU
Ups And



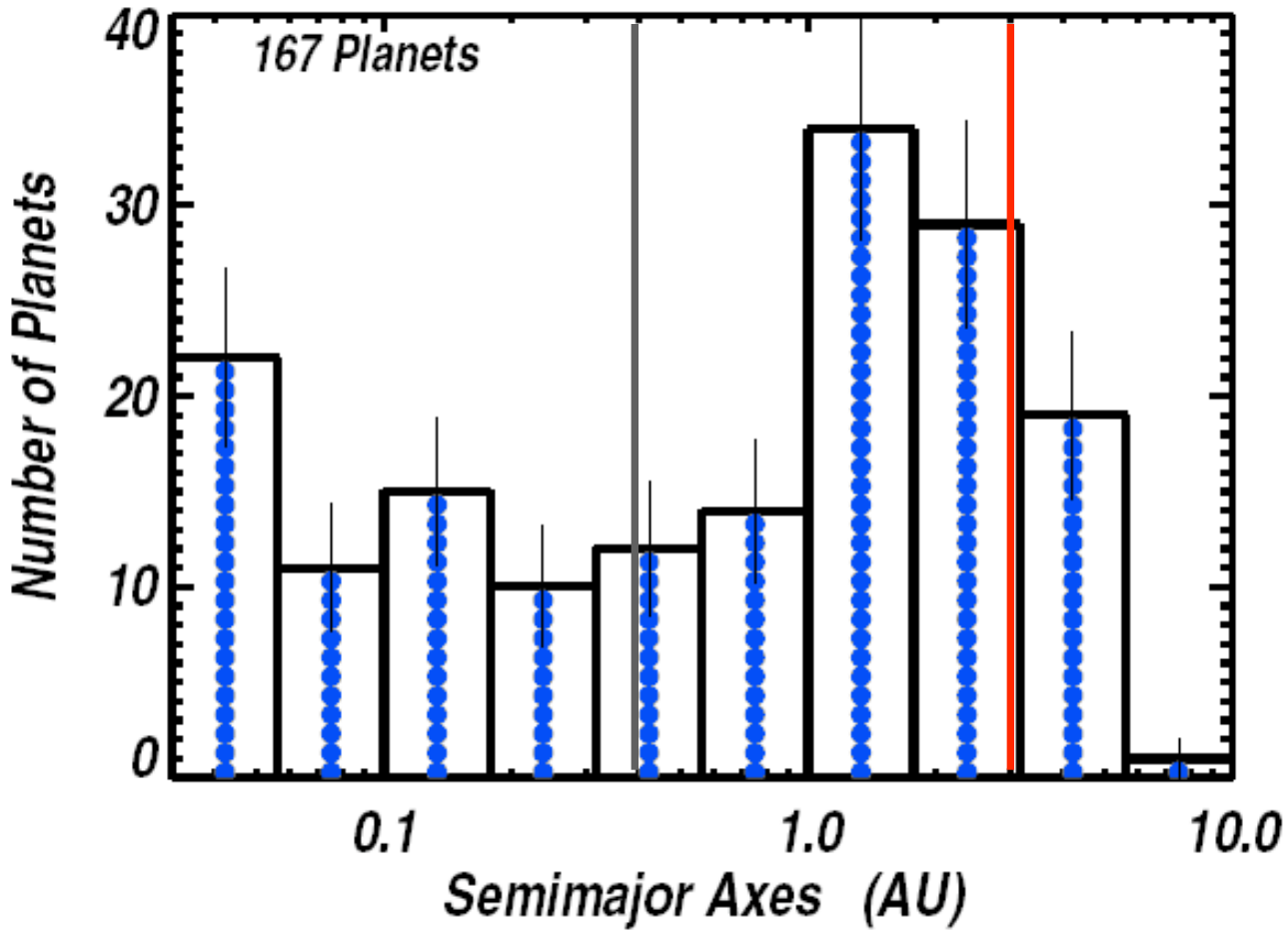
228 Extrasolar planets found so far
http://exoplanets.org
342 Extrasolar planets found so far
http://planetquest.jpl.nasa.gov/

(as of March 2009)

smallest extrasolar planets known: 6-8 Earth masses

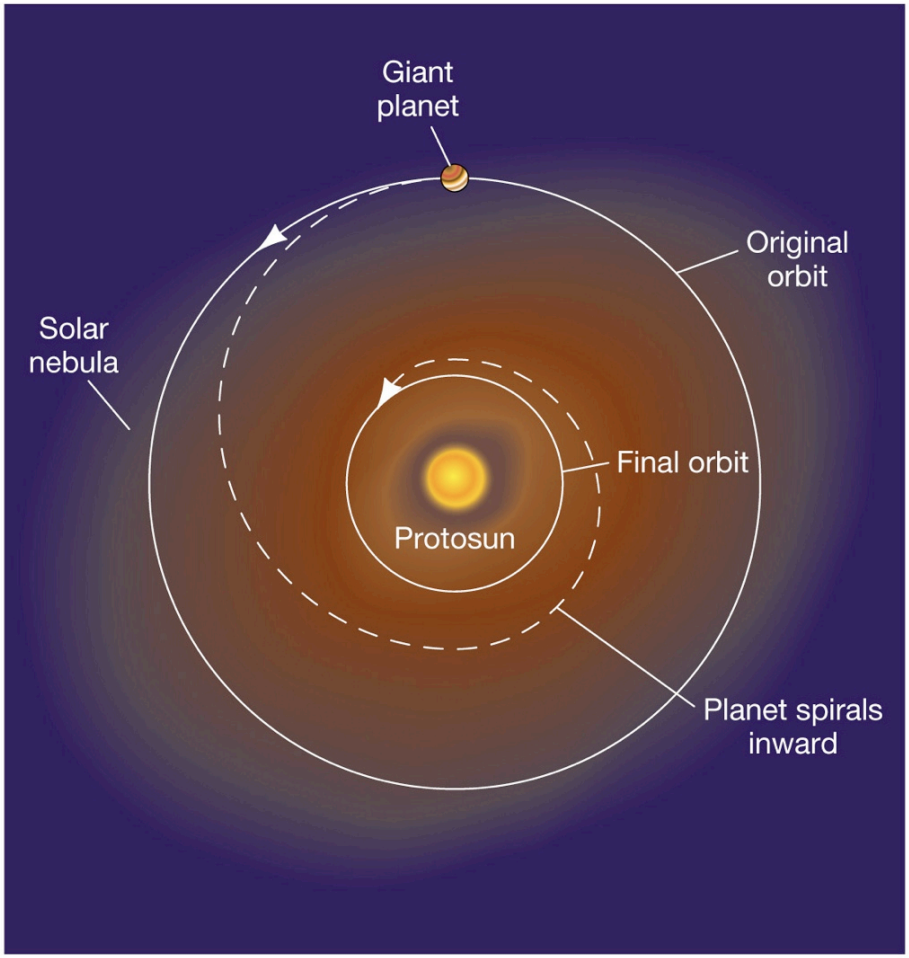
("super-Earths")

88% within 3 AU



"Hot Jupiters"

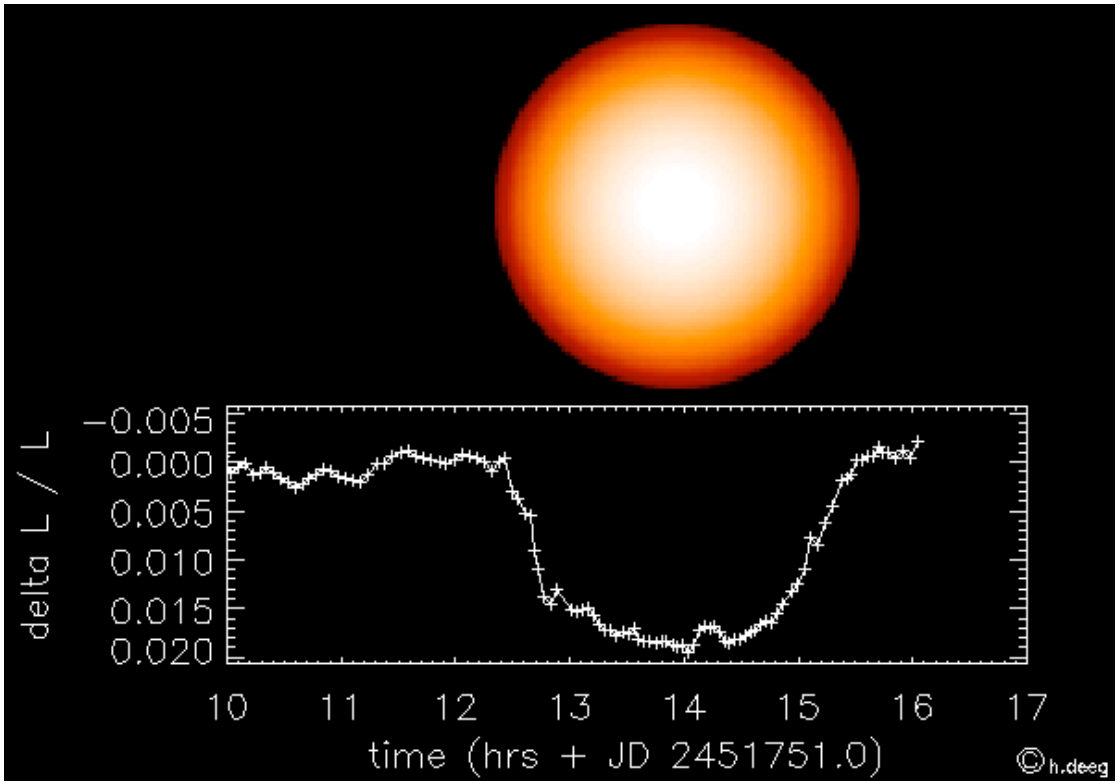
The missing ingredient from the planet formation scenario: Planetary Migration



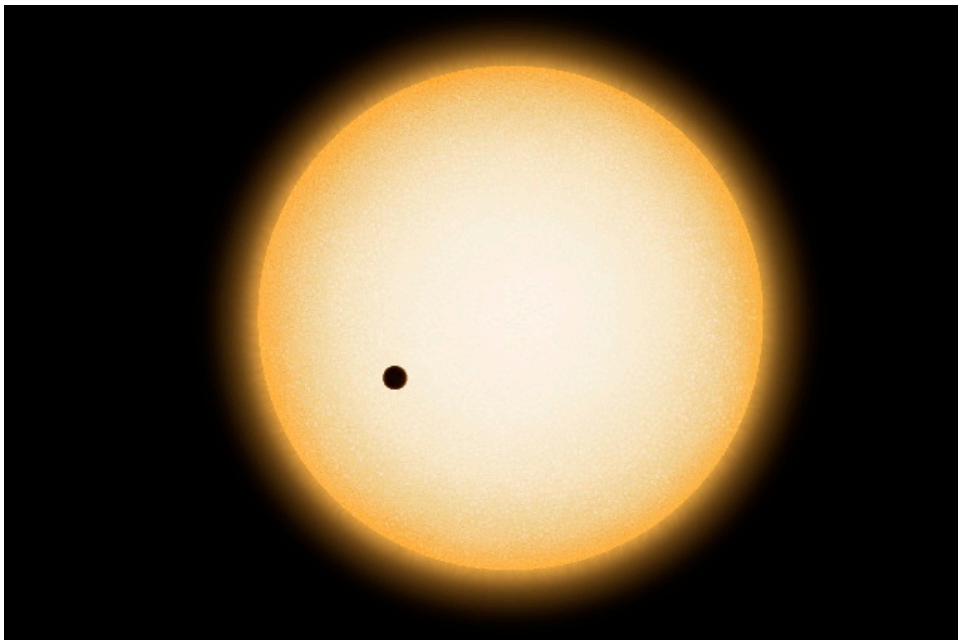
Methods for finding exoplanets

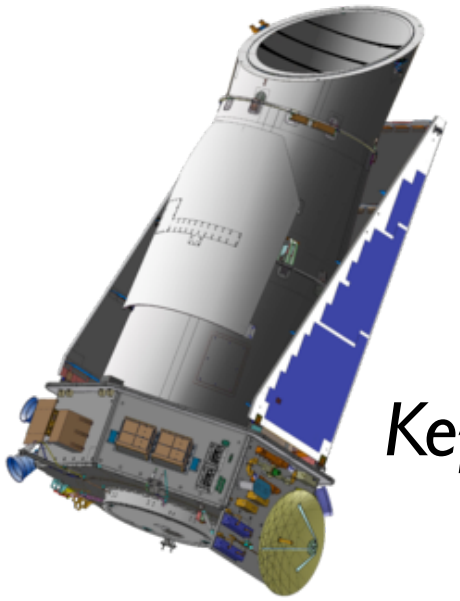
- Radial Velocities
- Transits
  - COROT, Kepler satellites
- Gravitational Lensing
- Interferometry
- Direct Imaging

Alternative Method: Transits



Notice that the dimming is 2% or less.
Therefore, very accurate measurements are needed.
4 planets discovered this way prior to 2006.





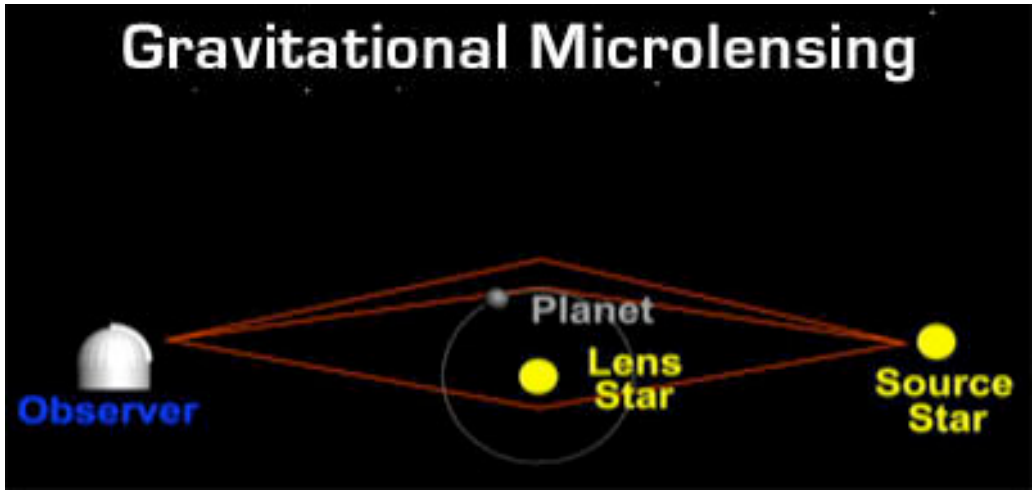
Kepler

7 more since Dec. 2006 by the satellite ***COROT***
incl. a 1.7 Earth-radius planet: COROT-Exo-7b

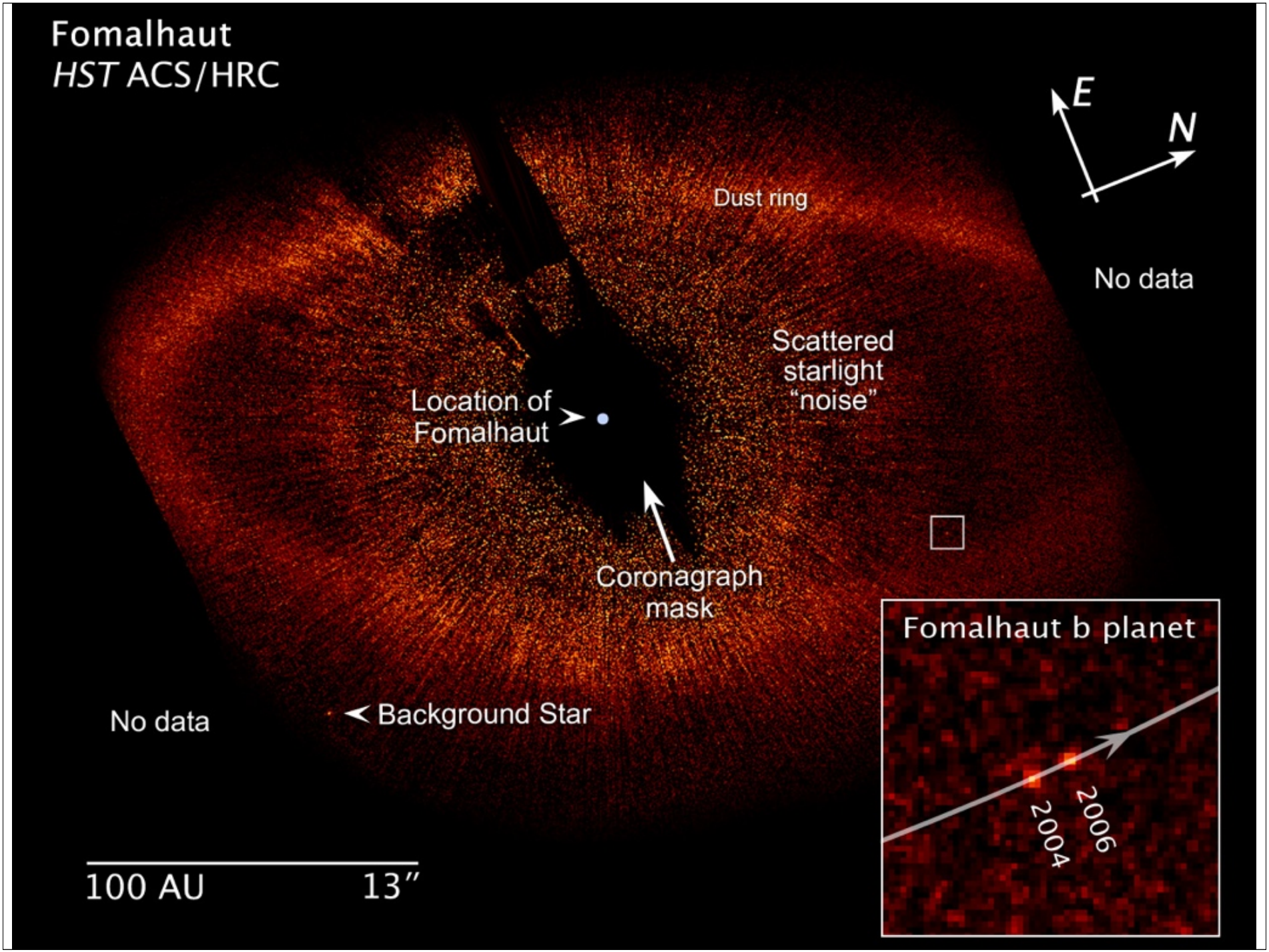
Kepler Mission: Just launched.
Aim: repeatedly observe the brightness of over 100,000 stars over 3.5 years to detect periodic transits

More Methods:

- Gravitational Microlensing
  A handful of planets discovered this way so far

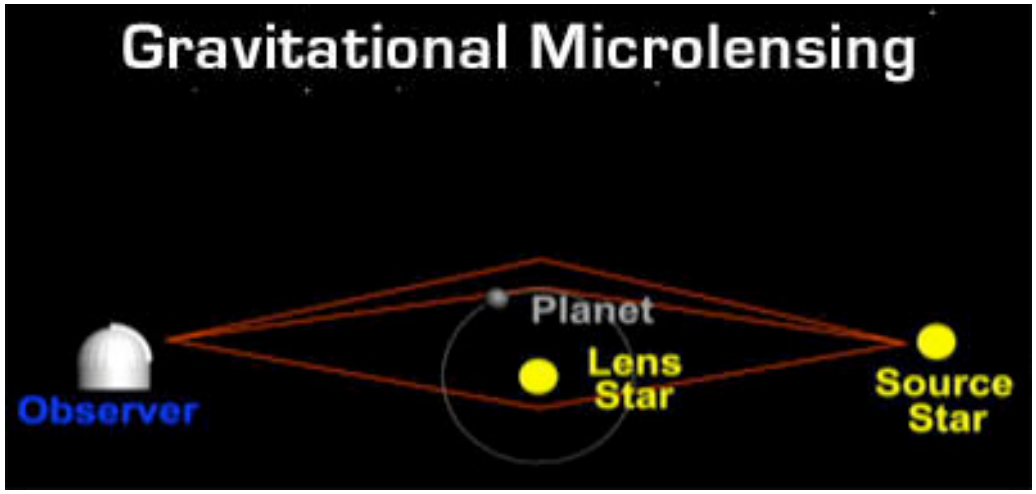


- Direct imaging: "coronography" (**happening NOW!!)**


Fomalhaut
HST ACS/HRC
E
N
Dust ring
No data
Scattered
starlight
"noise"
Location of
Fomalhaut
Coronagraph
mask
Fomalhaut b planet
2006
2004
No data
Background Star
100 AU
13″

More Methods:

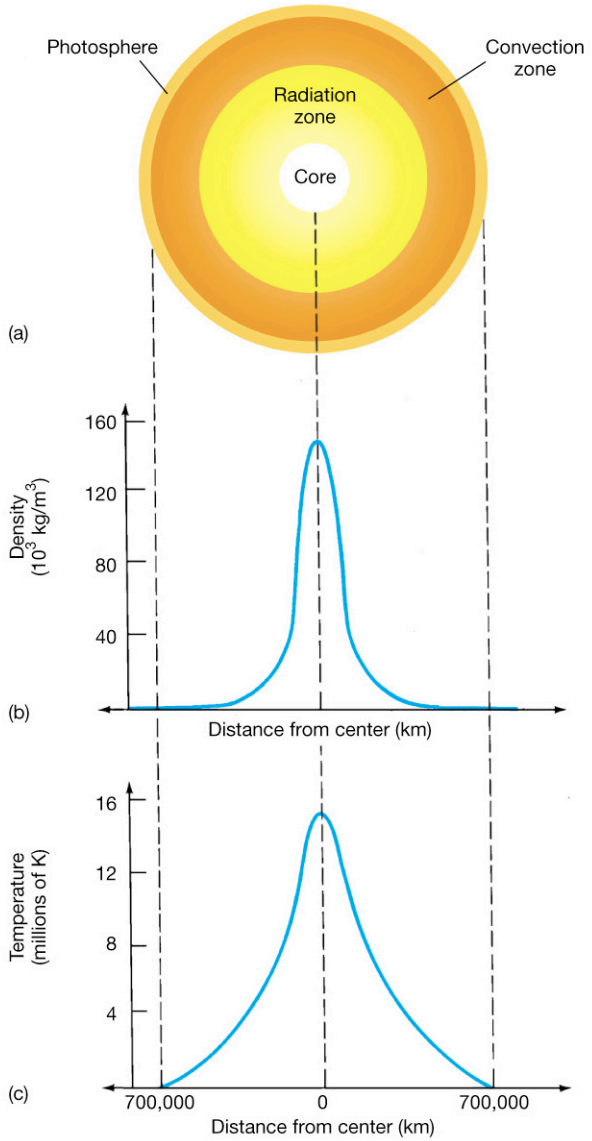
- Gravitational Microlensing
  A handful of planets discovered this way so far

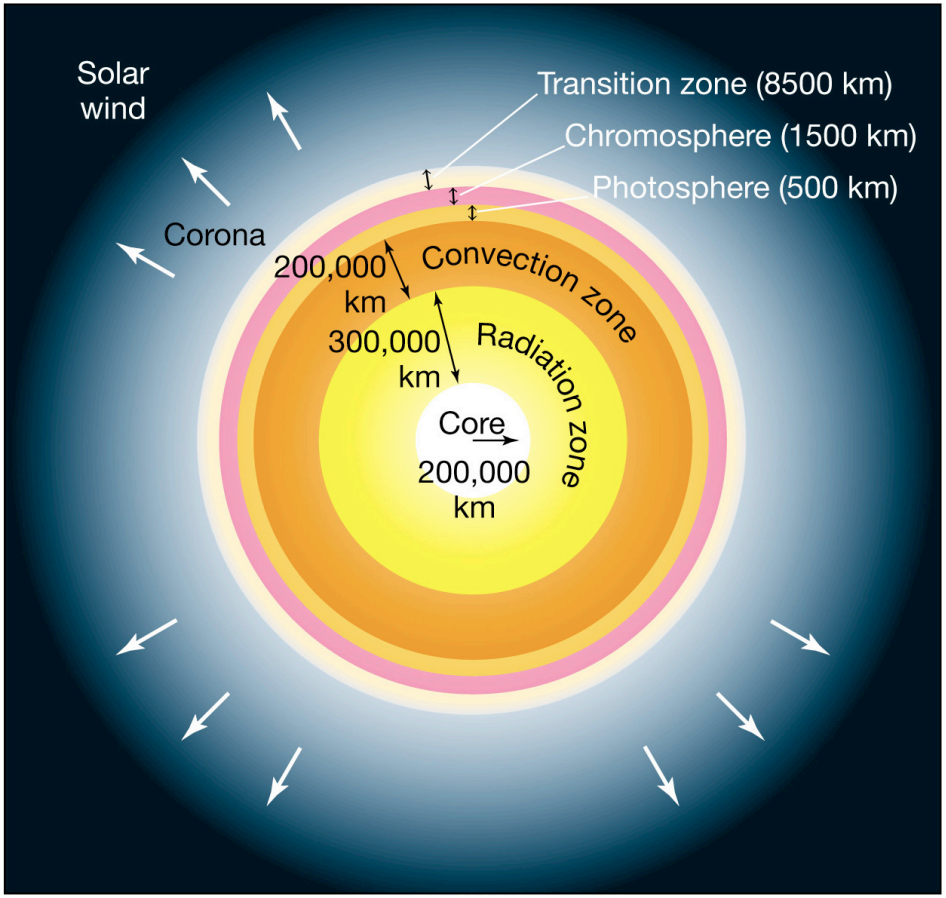


- Direct imaging: "coronography" (**happening NOW!!)**
- Interferometry ("Darwin" or "New Worlds"): stay tuned...

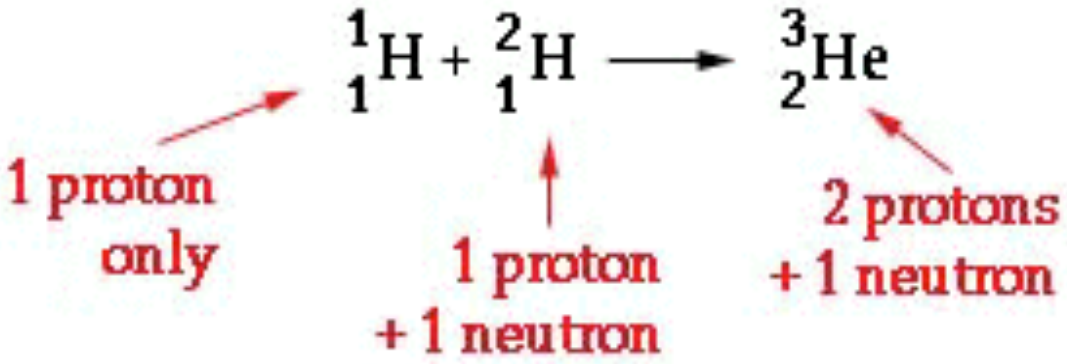
The Sun and How it Shines

Quick Anatomy of the Sun





Example of a Nuclear Reaction



We add the mass numbers and the atomic numbers of the ingredients to get the product.