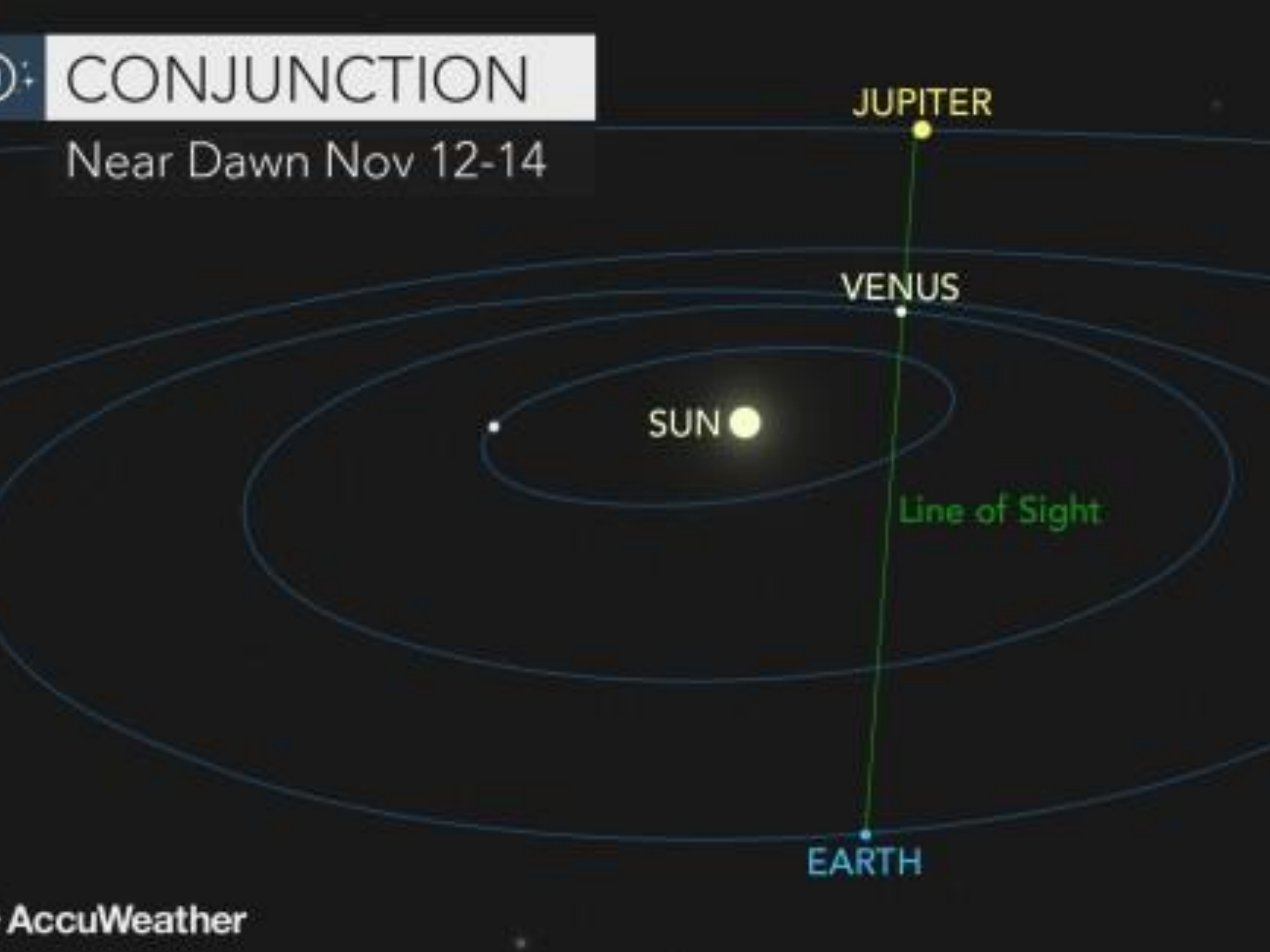
ASTR/GEOL-2040: Search for life in the Universe: Lecture 31

- Venus & Jupiter this a.m.
- Exoplanets: radial velocity
- Transit method → Kepler

Axel Brandenburg w/ Max Gilbraith
(Office hours: Mondays 2:30 – 3:30 in X590
and Wednesdays 11-12 in D230)


CONJUNCTION
Near Dawn Nov 12-14
JUPITER
VENUS
SUN
Line of Sight
EARTH
AccuWeather

Venus & Jupiter

A. Venus appears to move faster
B. Jupiter appears to move faster
C. Both move at the same speed

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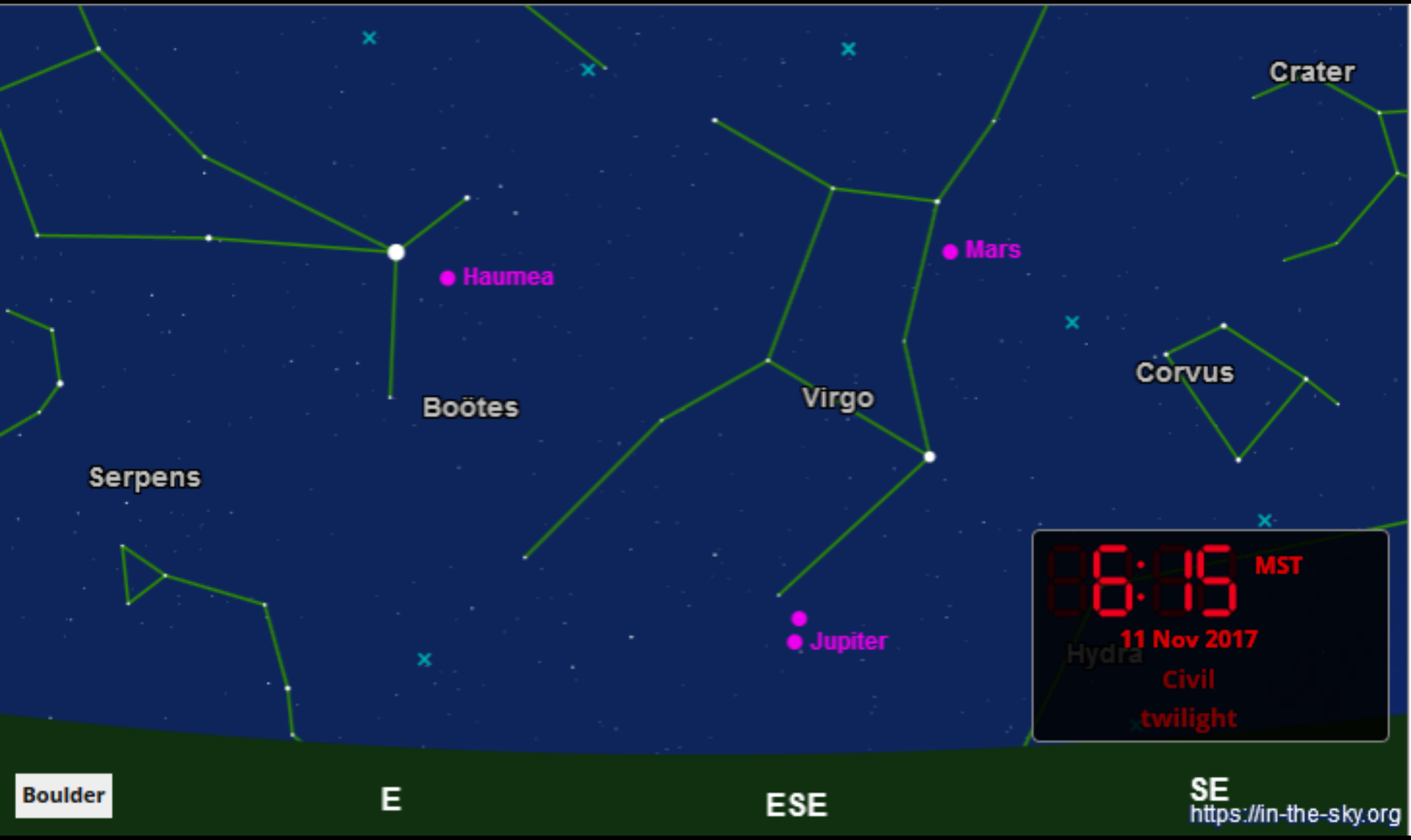
Crater
Haumea
Mars
Corvus
Boötes
Virgo
Serpens
Jupiter
Hydra
6:15 MST
11 Nov 2017
Civil
twilight
Boulder
E
ESE
SE
https://in-the-sky.org


Crater
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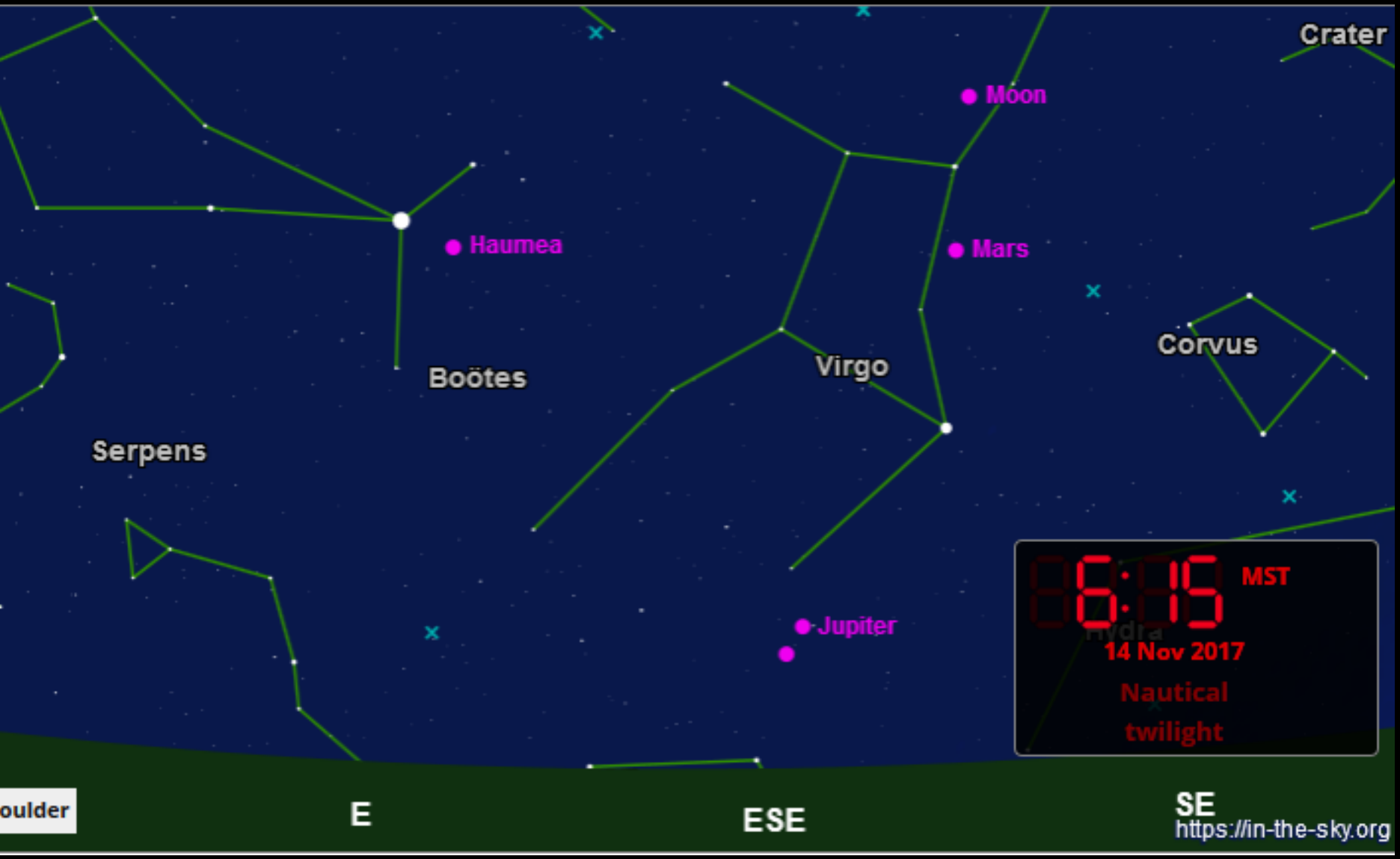
Crater
Moon
Haumea
Mars
Corvus
Boötes
Virgo
Serpens
Hydra
Jupiter
06:15 MST
14 Nov 2017
Nautical twilight
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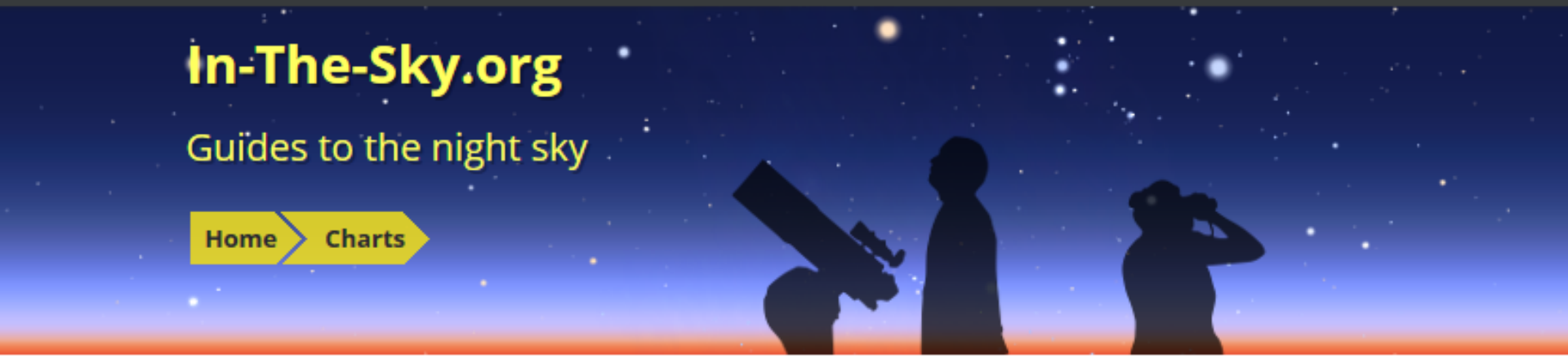


The In-The-Sky.org Planetarium

by Dominic Ford

Date

14 Nov 2017

Time

06 : 15

Time slider

04:15 05:15 06:15 07:15 08:15

Date slider

25 Sep 20 Oct 14 Nov 09 Dec 03 Jan

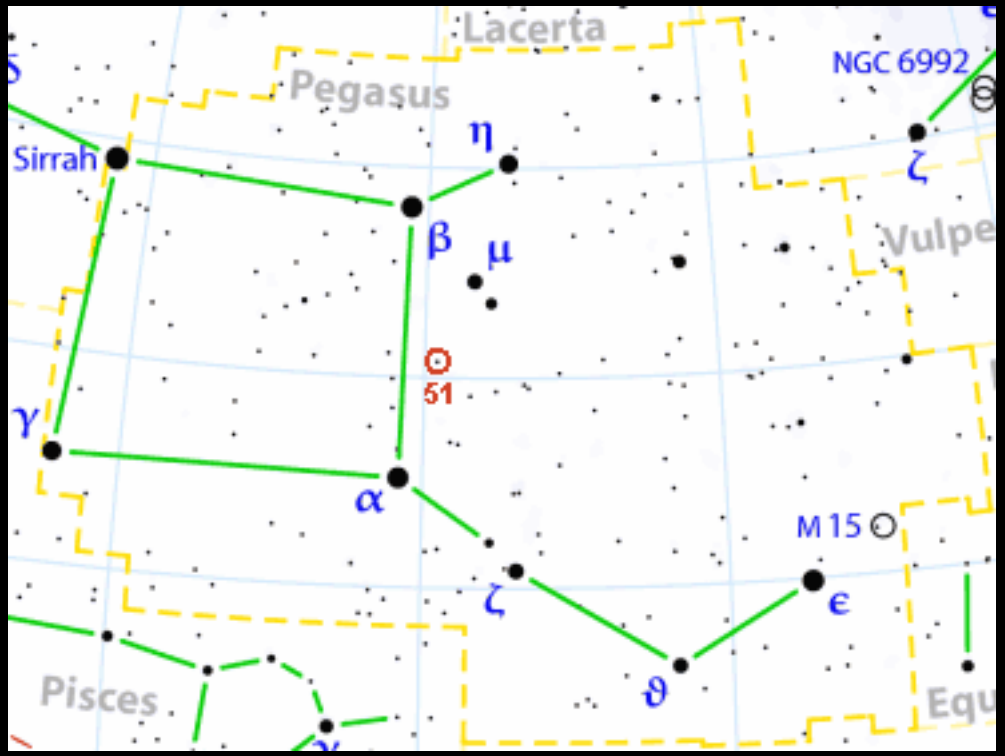
Limiting magnitude

Faint

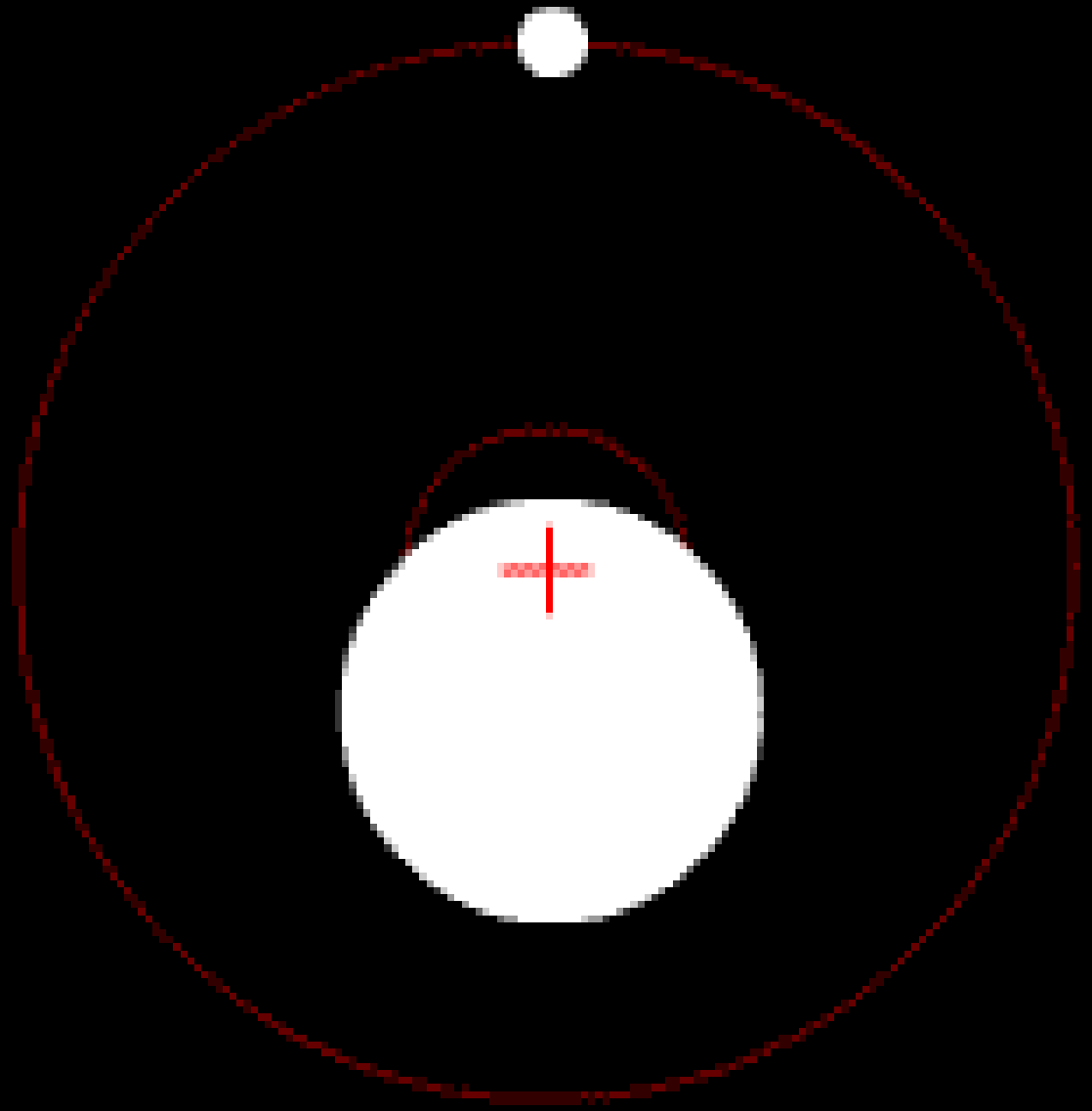
Showing stars down to mag 6.5

51 Pegasi b (=51 Peg b)

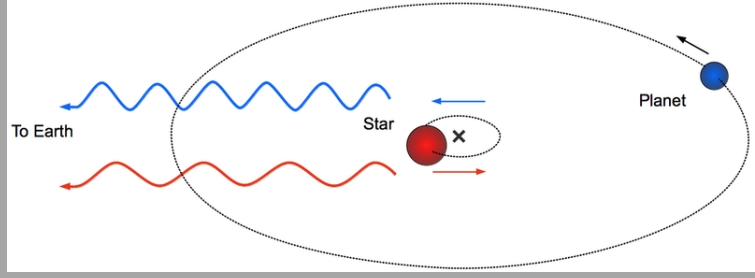
- First confirmed exoplanet discovery
- Hot Jupiter



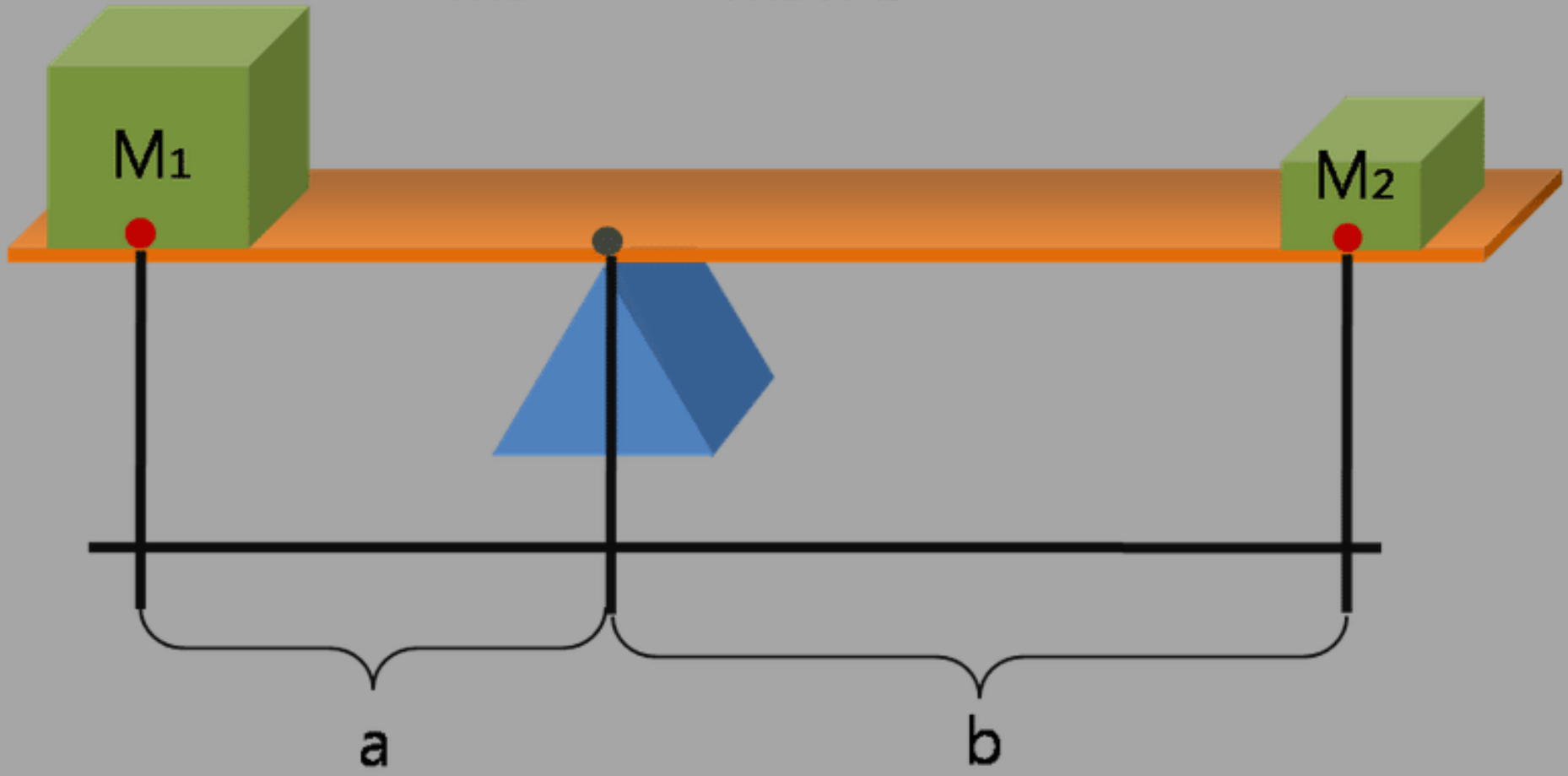
Find it in the sky!



Wobble of host star



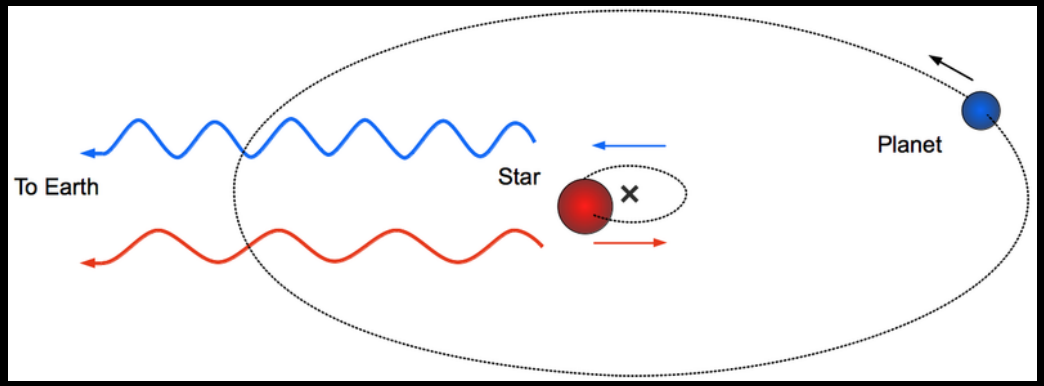
$$M_1 \times a = M_2 \times b$$



Example of last lecture

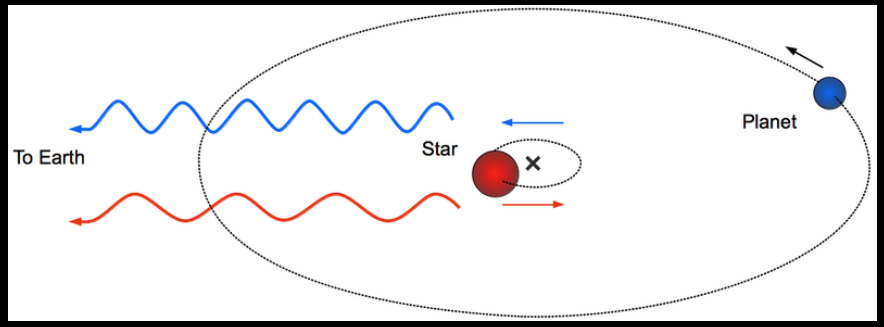
- Jupiter-mass planet around solar-mass star
- 10^{-3} M_{sun} around 1 M_{sun}
- at 0.1 AU
- Distance of star to center of mass?

A. 10^{-4} AU
B. 10^{-3} AU
C. 10^{-2} AU



$MR = mr$, so $R = r*m/M = 0.1*10^{-3}/1 = 10^{-4}$

Speed



- Circumference: $2\ \pi\ 10^{-4}$ AU = 6×10^{-4} AU
- Period $0.1^{3/2}$ yr = 0.03 yr ~ 10 days
- Speed = 6×10^{-4} AU / 10 d
  = 6×10^{-4} x 1.5e11 m/10^6s
  = $10^8/10^6$ m/s = 100 m/s

- But what if orbit tilted??

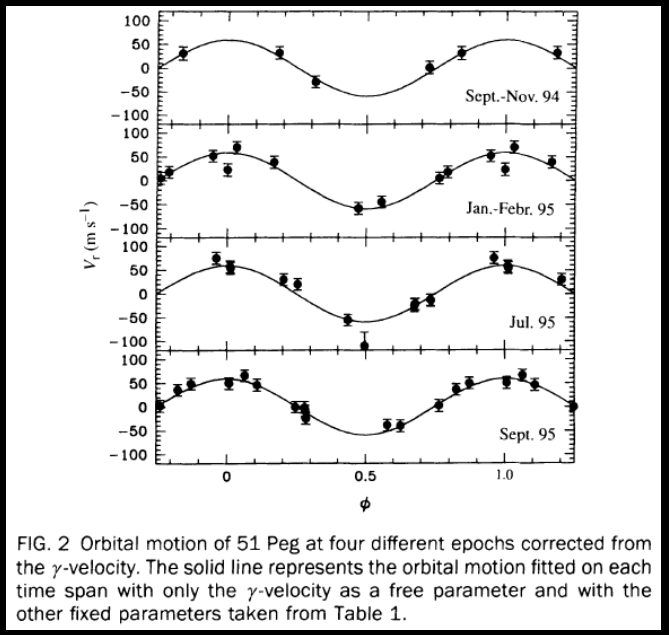
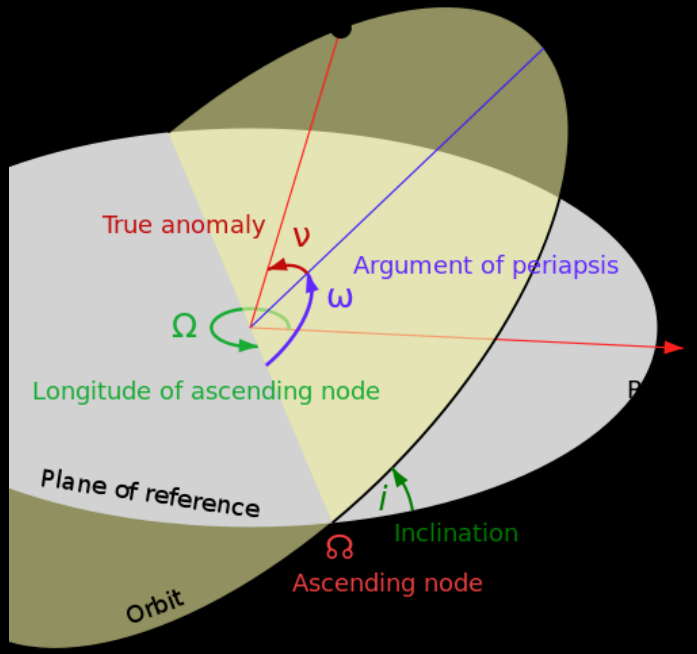


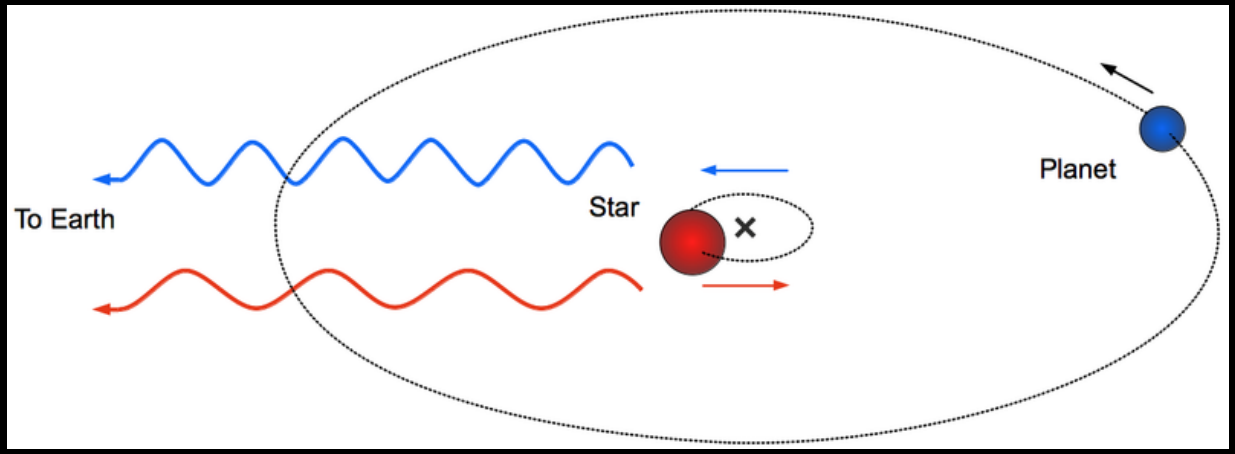
FIG. 2 Orbital motion of 51 Peg at four different epochs corrected from the γ-velocity. The solid line represents the orbital motion fitted on each time span with only the γ-velocity as a free parameter and with the other fixed parameters taken from Table 1.

Inclined orbit

A. Actual velocity larger?

B. Actual velocity smaller?





Inclined orbit

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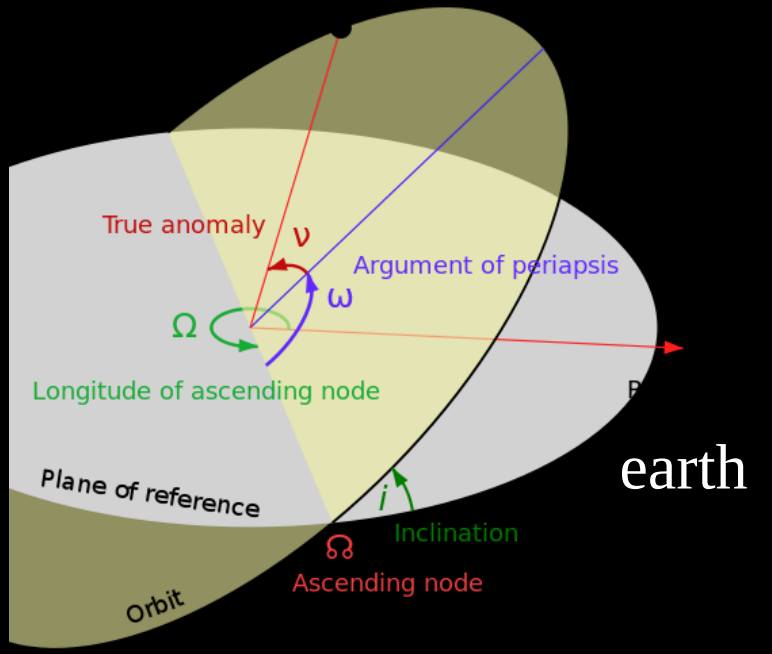
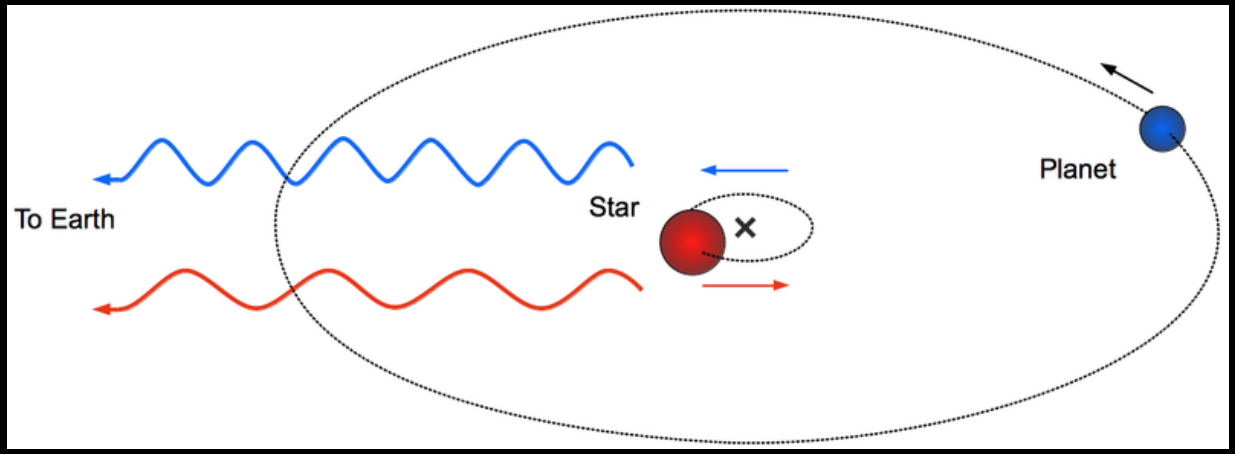
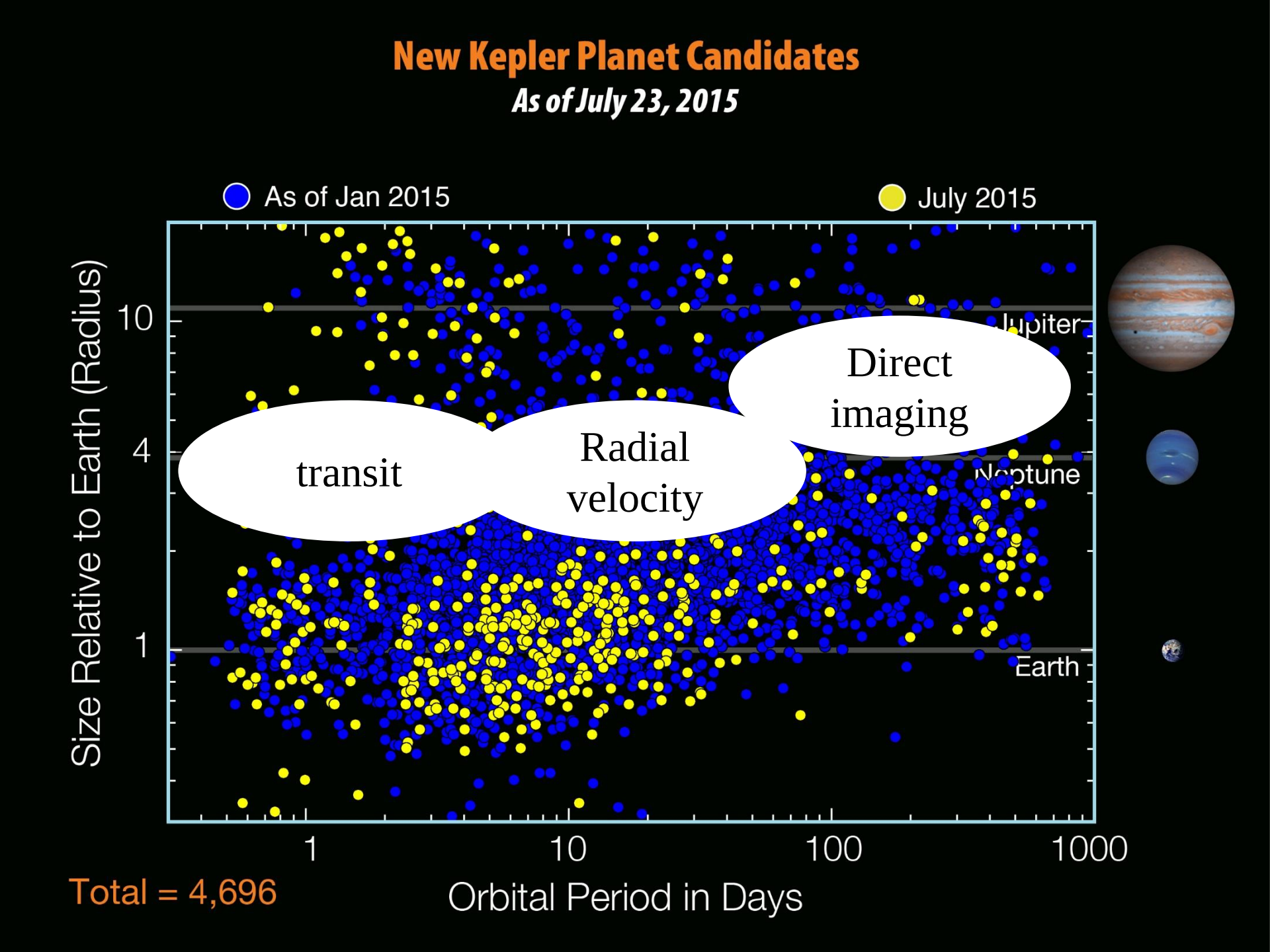




Larger wobble, larger mass

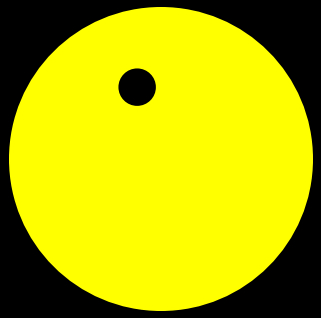
→ Only know minimal mass of the planet!!


New Kepler Planet Candidates
As of July 23, 2015
As of Jan 2015
July 2015
Size Relative to Earth (Radius)
10
4
1
Jupiter
Neptune
Earth
Direct imaging
transit
Radial velocity
1
10
100
1000
Orbital Period in Days
Total = 4,696

Transit method

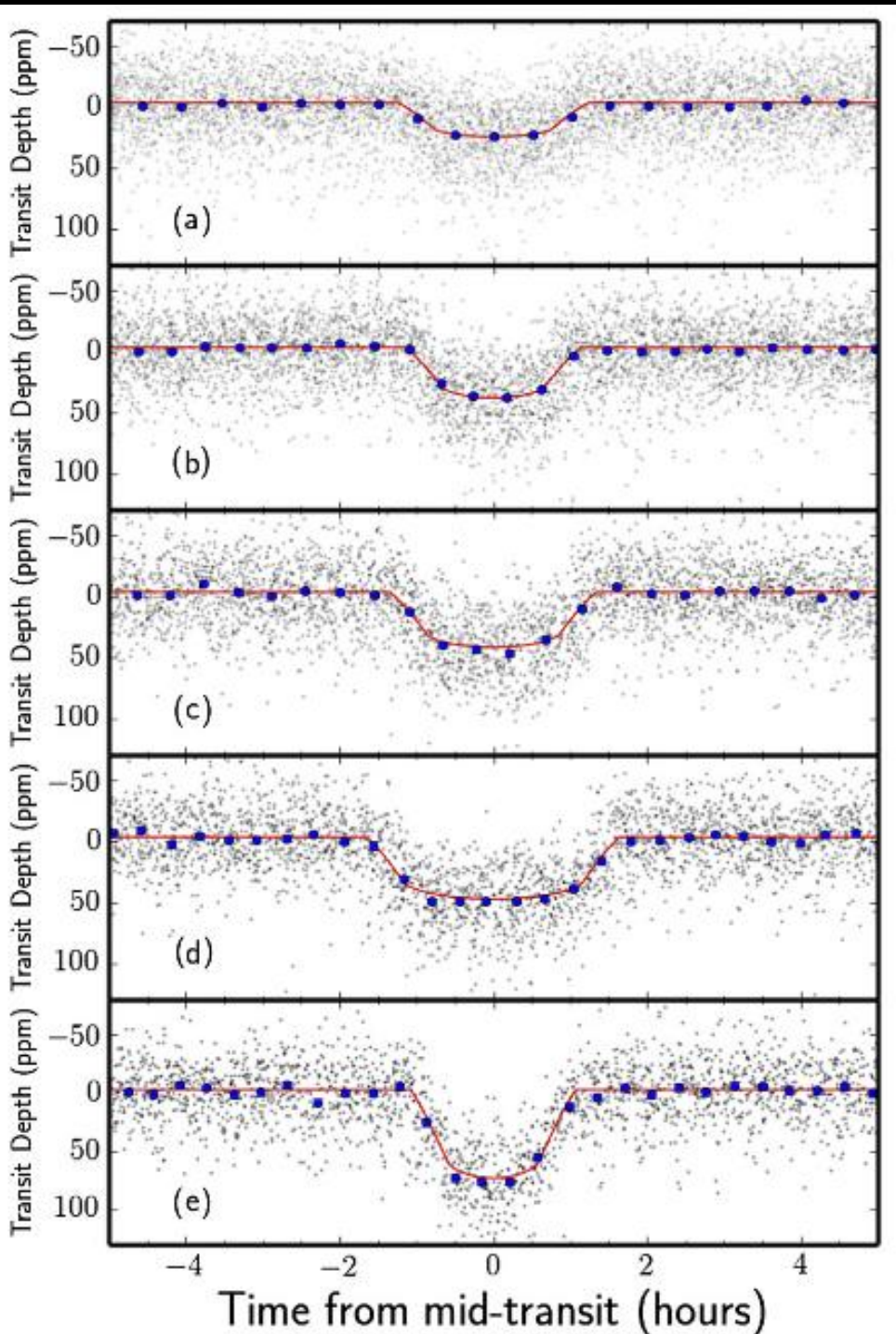
Kepler-444

- Actually 5 planets
- ~ 100 ppm

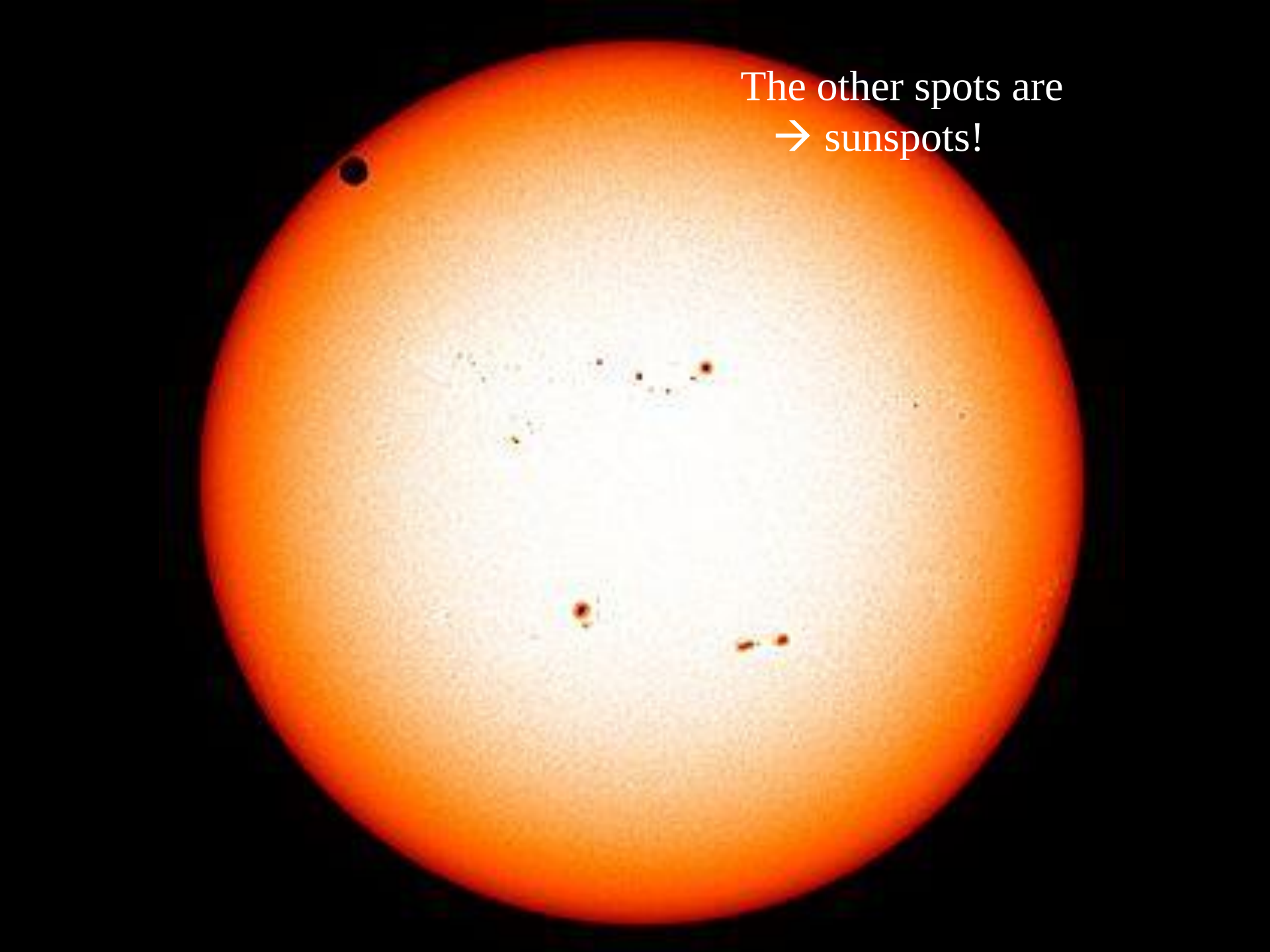


$$\frac{\Delta I}{I} = \frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2$$

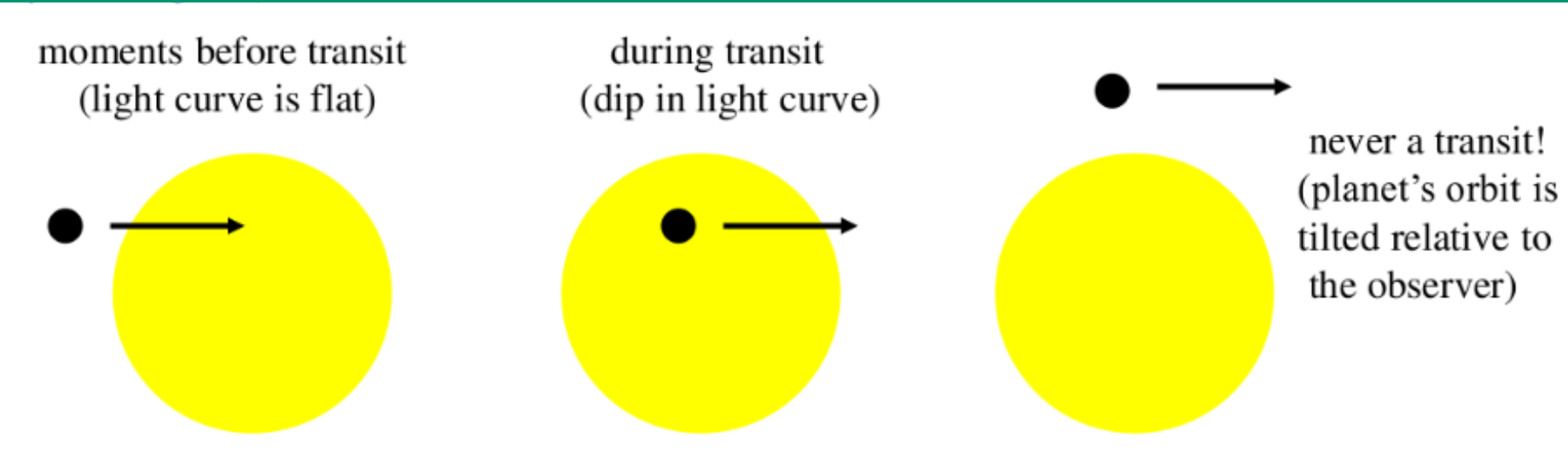
$$r / R = \left(10^{-4}\right)^{1/2} = 10^{-2}$$




23:36 UTC
8:36 JST


The other spots are
→ sunspots!

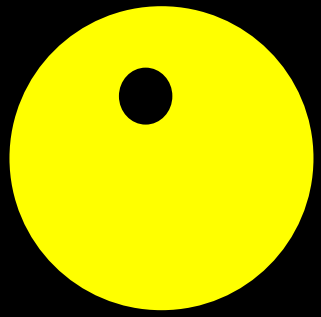
*We'll miss **most** of the planets!*



"Only" ~2% of all Kepler stars show transits

But: can "easily" observe Earth-sized planets → 100 ppm

Jupiter sized planet



$$\frac{\Delta I}{I} = \frac{\pi r^2}{\pi R^2} = \left(\frac{r}{R}\right)^2$$

A. 10%

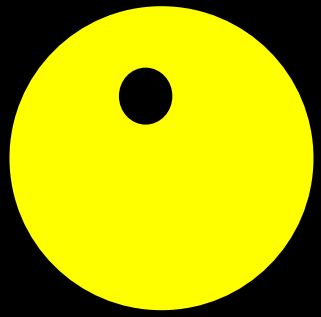
B. 1%

C. 1 permille

D. 100 ppm

E. 10 ppm

Jupiter sized planet



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A. 10%

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D. 100 ppm

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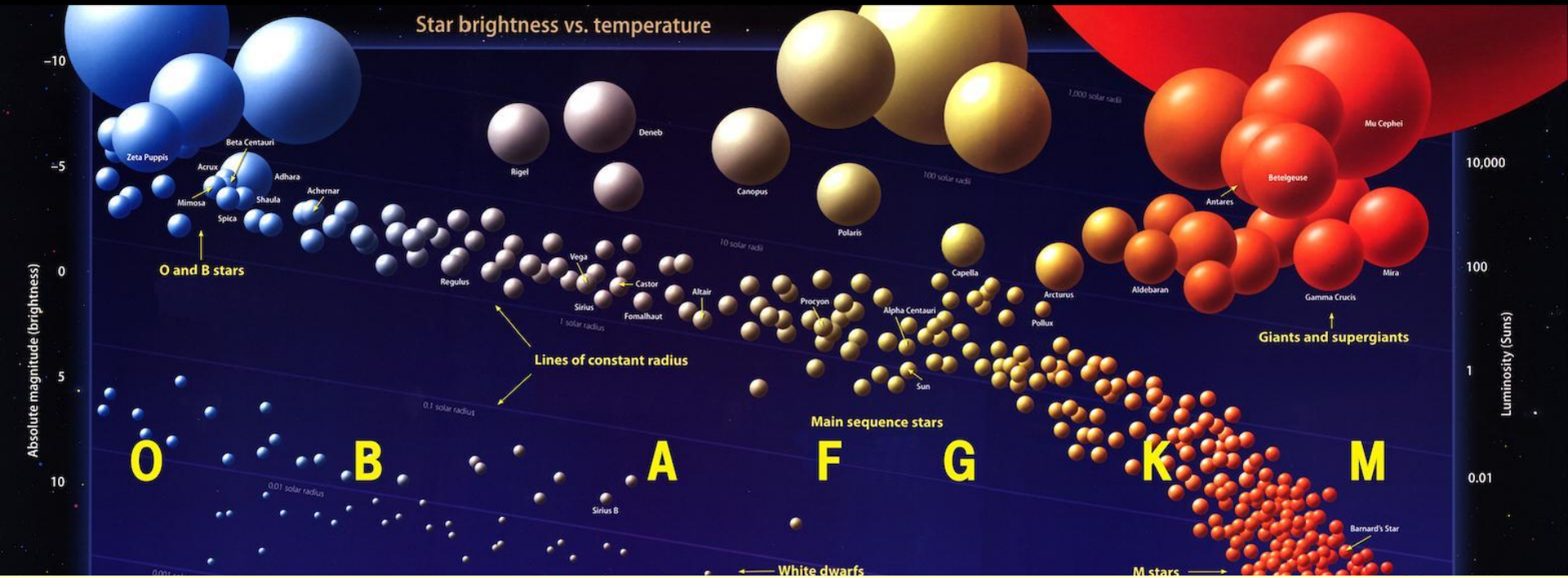
Jupiter's radius is 10% of the Sun's radius
→ it's area is therefore 1% of the solar disk

Which stars can host planets?

- Need long-term stability?
- Fraction of heavy elements?



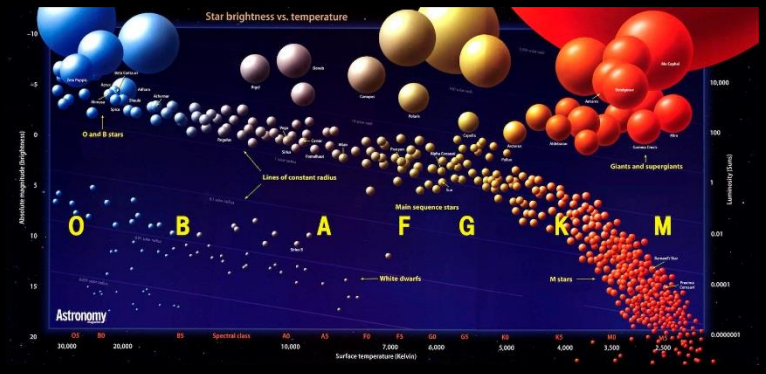
1. Oh Be A Fine [Guy/Gal/Girl] Kiss Me (Right Now [Smack/Sweetheart]).
2. Oh Begone, A Friend's Gonna Kiss Me (Right Now Smack).
3. Only Boys Accepting Feminism Get Kissed Meaningfully.

From classification to understanding

- Originally A, B, C, D, …
- Later reorganized by temperature

Cecilia Payne
(1900-1978)

Stars made of H & He



Annie Jump Cannon
(1863-1941) → 1901

"There is no joy more intense than that of coming upon a fact that cannot be understood in terms of currently accepted ideas."
—Cecilia Payne

What are the stars made of? The answer to this fundamental question of astrophysics was discovered in 1925 by Cecilia Payne and explained in her Ph.D. thesis. Payne showed how to decode the complicated spectra of starlight in order to learn the relative amounts of the chemical elements in the stars. In 1960 the distinguished astronomer Otto Struve referred to this work as "the most brilliant Ph.D. thesis ever written in astronomy."

Enough time for life?

Spectal Type	M/Msun	Life span [Gyr]	Percentage
O	60	0.0005	0.001
B	6	0.05	0.1
A	2	1	1
F	1.5	2	2
G	1	10	7
K	0.7	20	15
M	0.2	600	75

- Life might not emerge on O, B, and A stars
- But they make up small percentage

Kepler-444 is 11.2 Gyr old!
→ it was born when Universe was

A. 2% of its current age
B. 5%
C. 10%
D. 20%
E. 50%

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→ it was born when Universe was

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E. 50%

13.8 Gyr
-11.2 Gyr

2.6 Gyr

2.6/13.8 = 0.2 = 20%

Born when Universe was

A. 2% of its current age

B. 5%

C. 10%

D. 20%

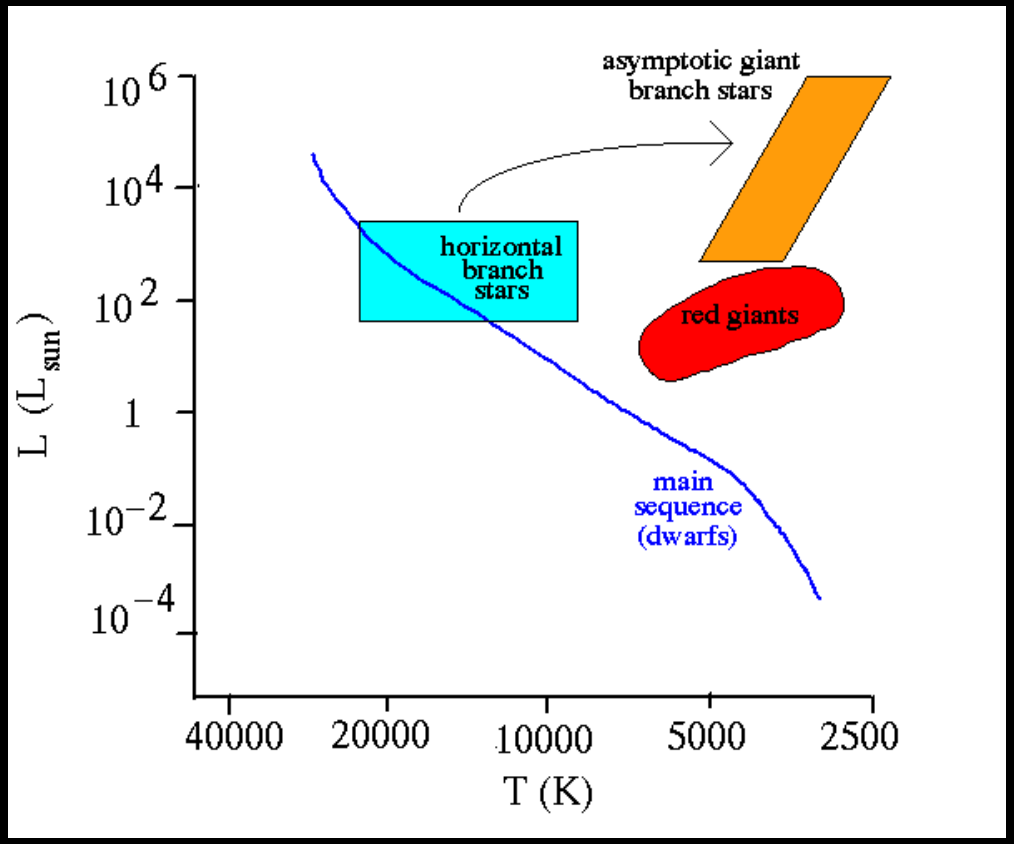
E. 50%

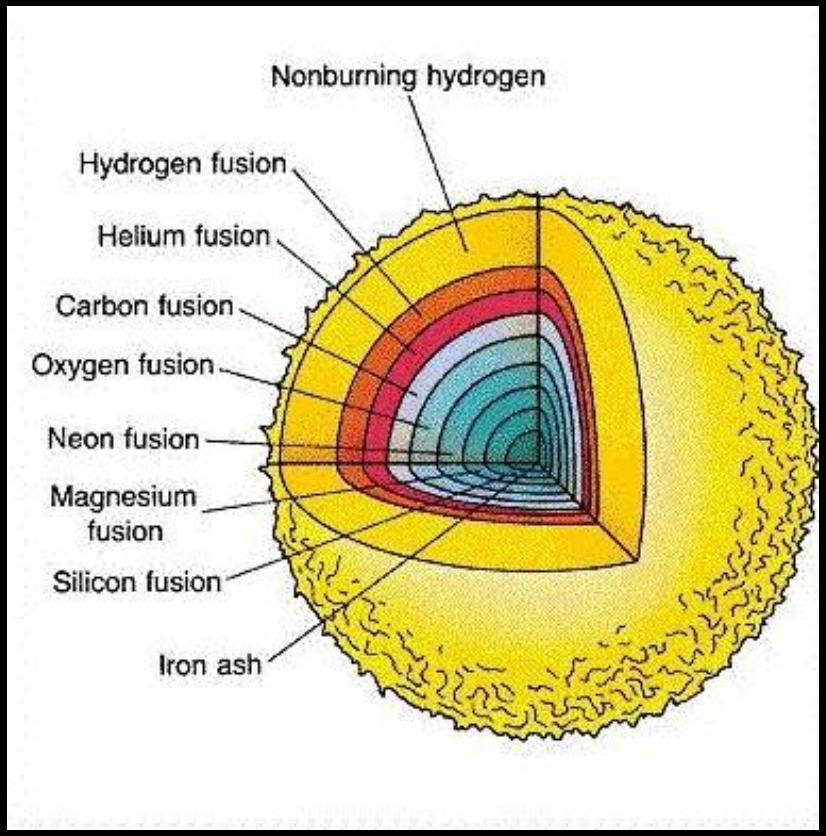
13.8 Gyr
-11.2 Gyr

2.6 Gyr

2.6/13.8 = 0.2 = 20%

Organic matter in the Universe





Quiz on Wednesday

- All topics will come up
- See sample example
  - And its model solutions
- 15 min Q/A before the quiz
- Friday: Carol Cleland:
  - shadow biosphere