



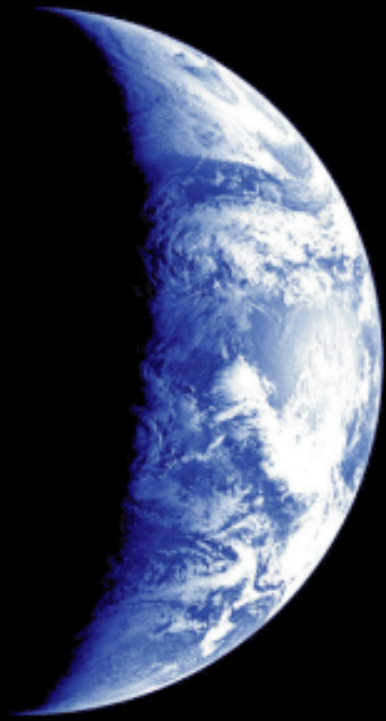
Extrasolar Planets

Gregory Laughlin

UC Santa Cruz



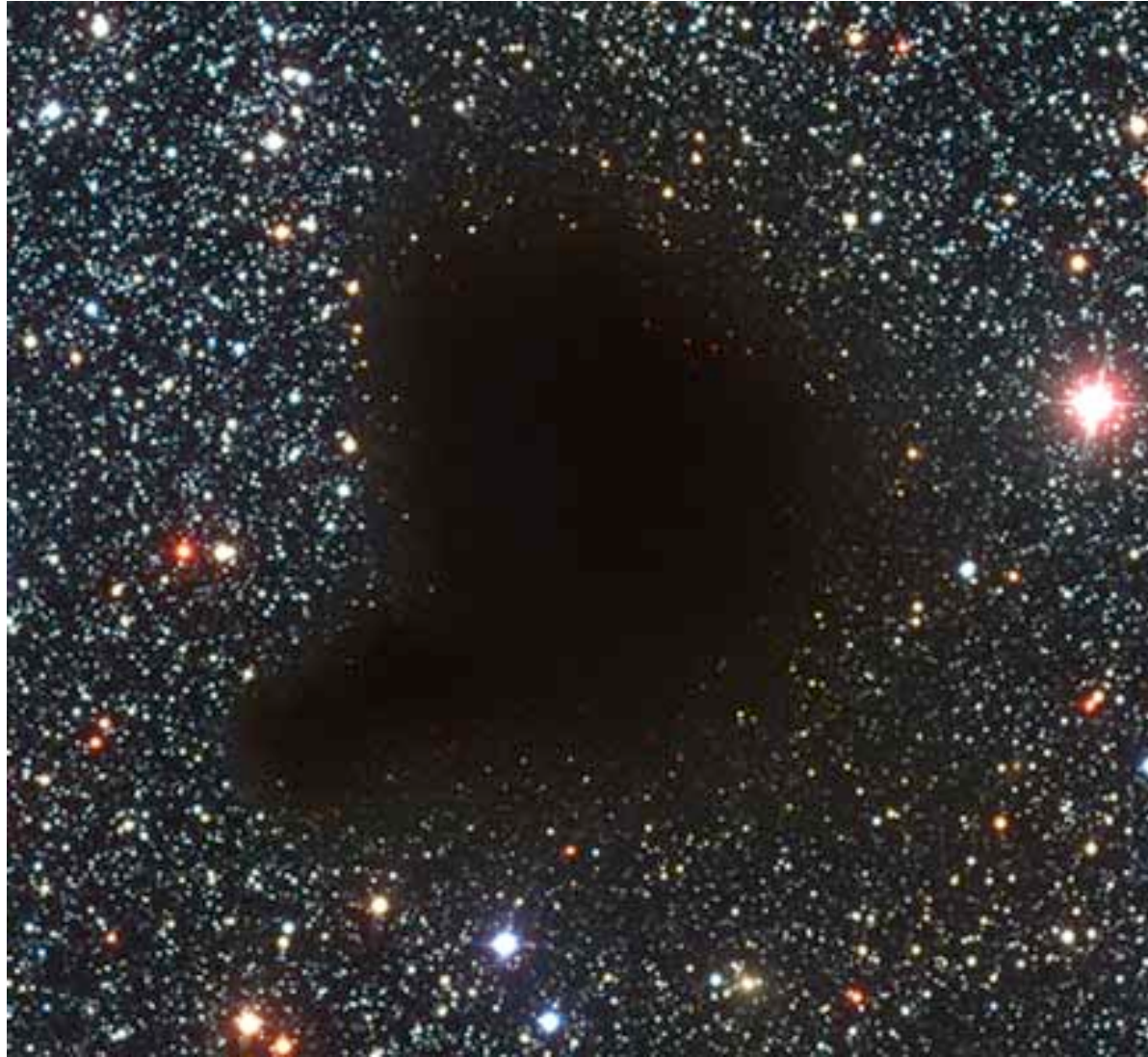












This is how our solar system looked
4.57 Billion Years Ago

The Encounter Hypothesis

Physical *cosmogony*, the idea that the Earth and the other planets arose through natural processes, dates to the 18th century

- Buffon, in 1742, advanced the hypothesis that the planets in our solar system arose from the close encounter of another star, which pulled out a stream of material from the sun that later condensed to form the planets.



G.L.L.C. Buffon

The Nebular Hypothesis

Our current theory of how planets form can be traced directly back to the ideas of Immanuel Kant and Pierre Simon de Laplace

- In 1748, Kant suggested that the planets formed from a spinning disk of gas and dust.
- In 1782, Laplace developed a mathematical theory that argued that the planets arose from the cooling of gaseous rings in a nebular disk surrounding a contracting central sun



P. S. de Laplace

“Dreams about the modes of creation, inquiries whether our globe has been formed by the agencies of fire or water, how many millions of years it has cost Vulcan or Neptune to produce what the fiat of the creator would effect by a single act of will are too idle to be worth a single hour of any man’s life.”

-Thomas Jefferson

(Writing on the topic of Laplace’s Nebular Hypothesis for the formation of the Solar System.)

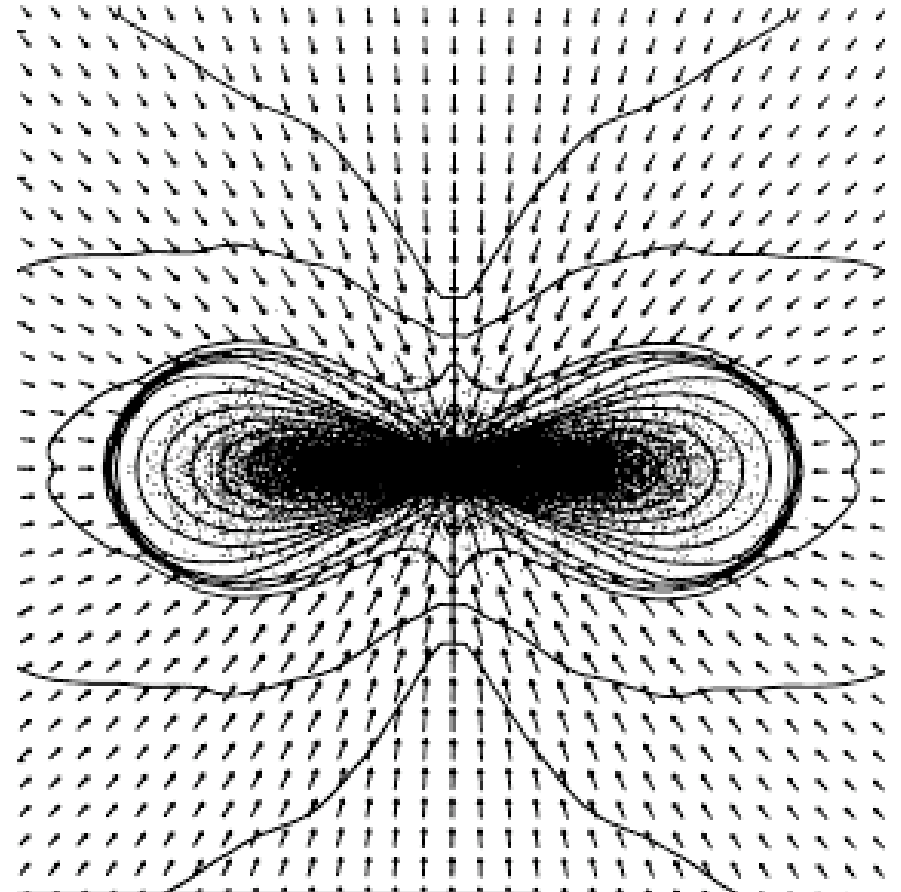
Source: Ronald Numbers, 1977, “Creation by Natural Law -- Laplace’s Nebular Hypothesis in American Thought”, University of Washington Press



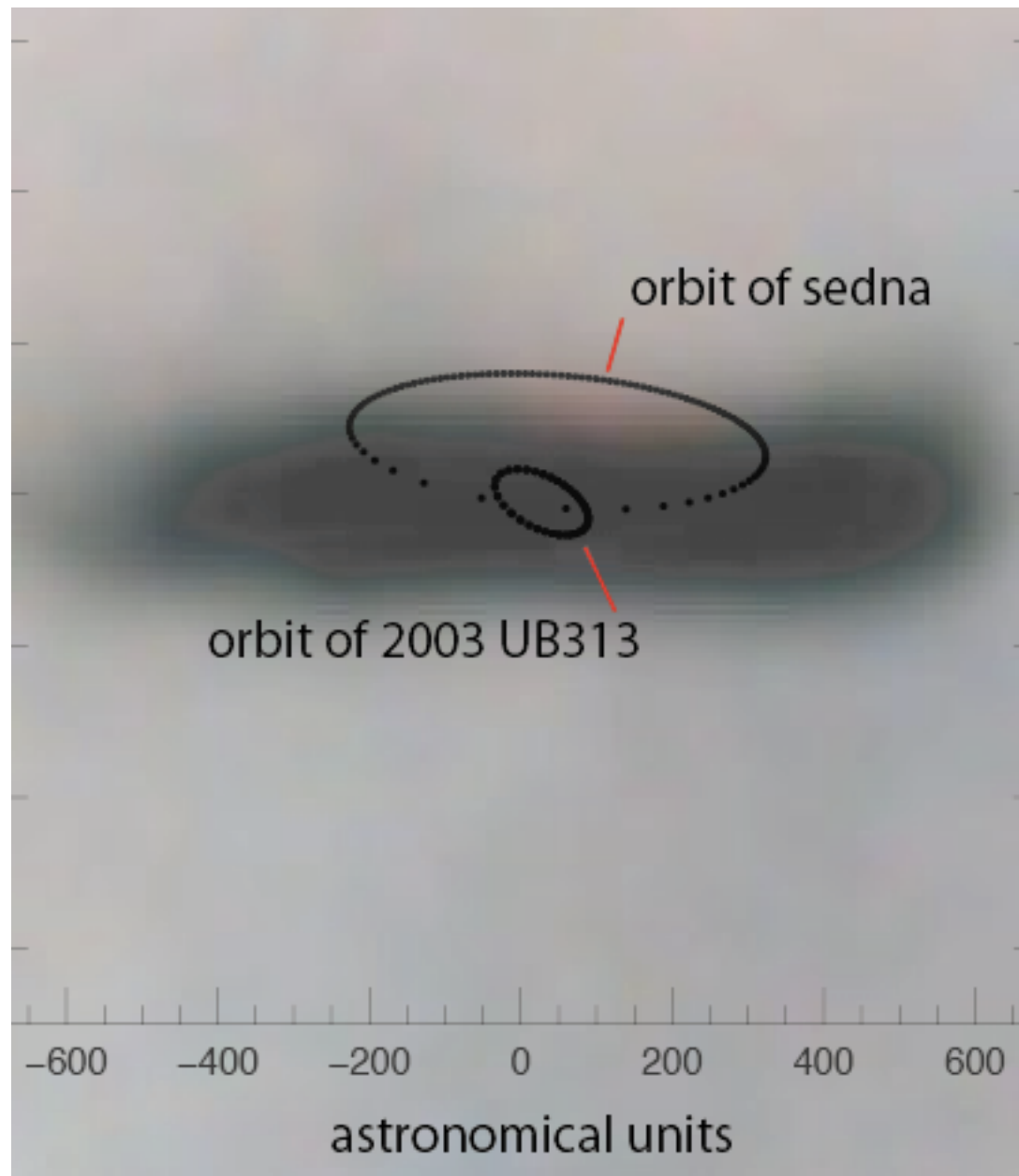
The cloud of gas and dust that gave rise to the solar system was unstable, and began to collapse under its own weight

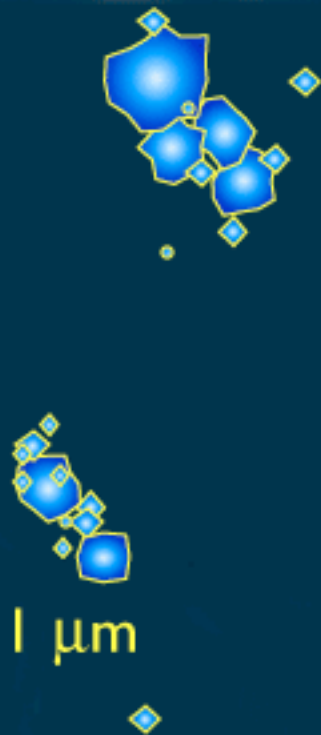


Hubble Space
Telescope image

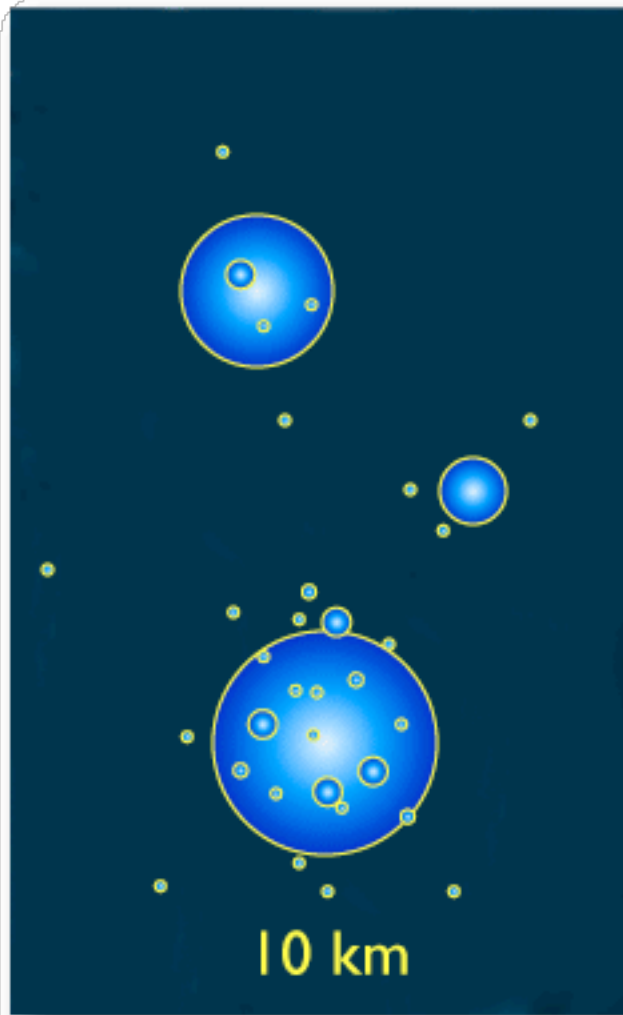


A computer simulation

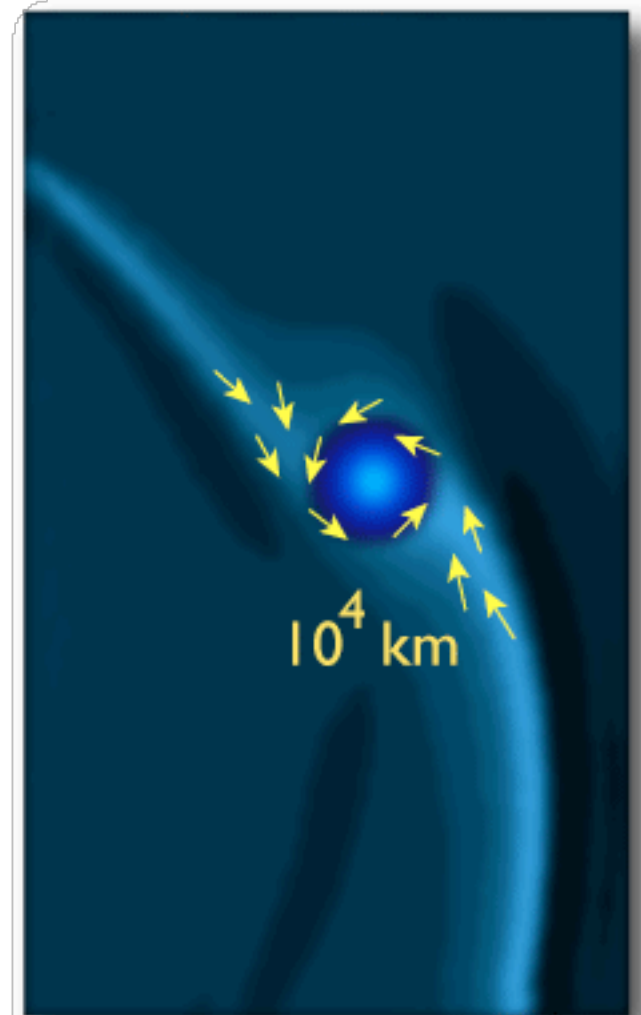




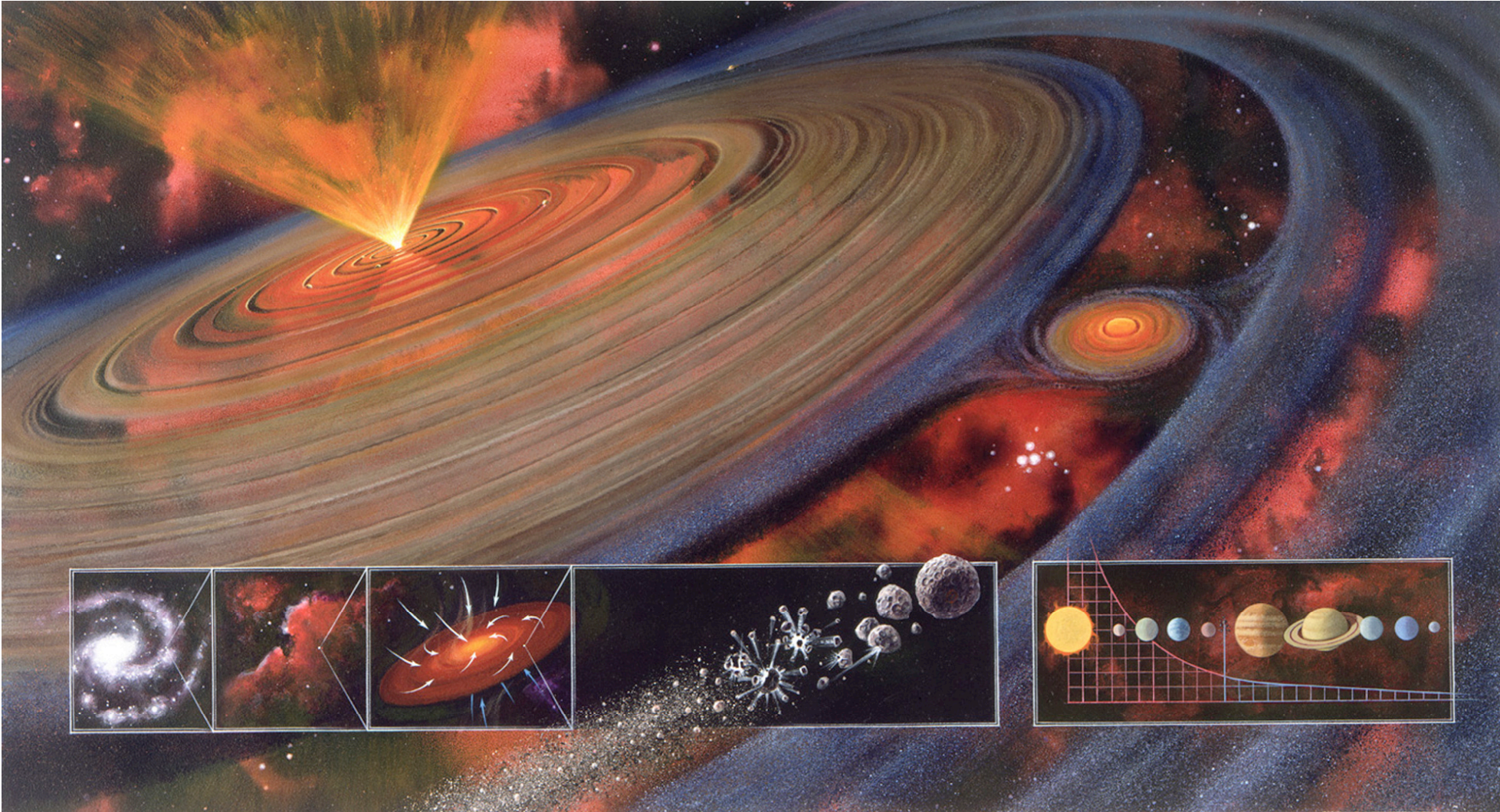
Early growth:
Sticking and Coagulation

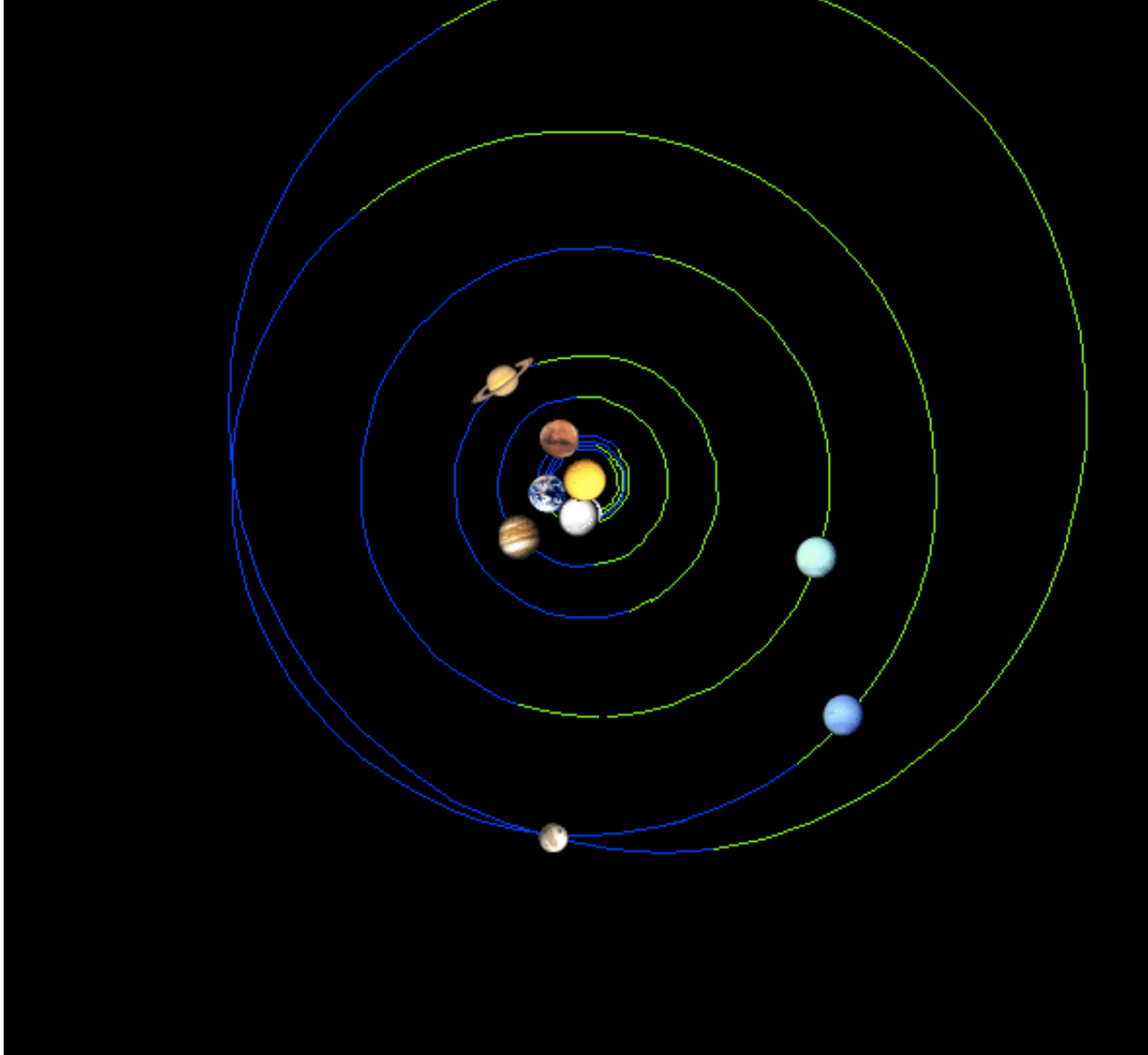


Mid-life growth:
Gravitational Attraction



Late growth:
Gas Sweeping



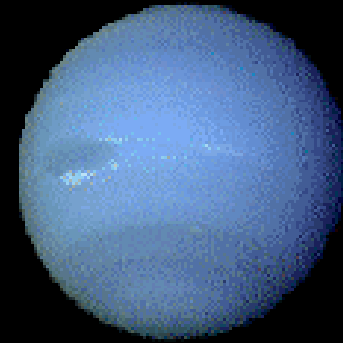


The positions of the planets at 7:30 PM, April 13, 2006, CDT
(Julian Day 2453839.52118)

<http://www.fourmilab.ch/cgi-bin/uncgi/Solar>



Gas Giants



Ice Giants



Terrestrial Planets



Icy Outer "Planets"

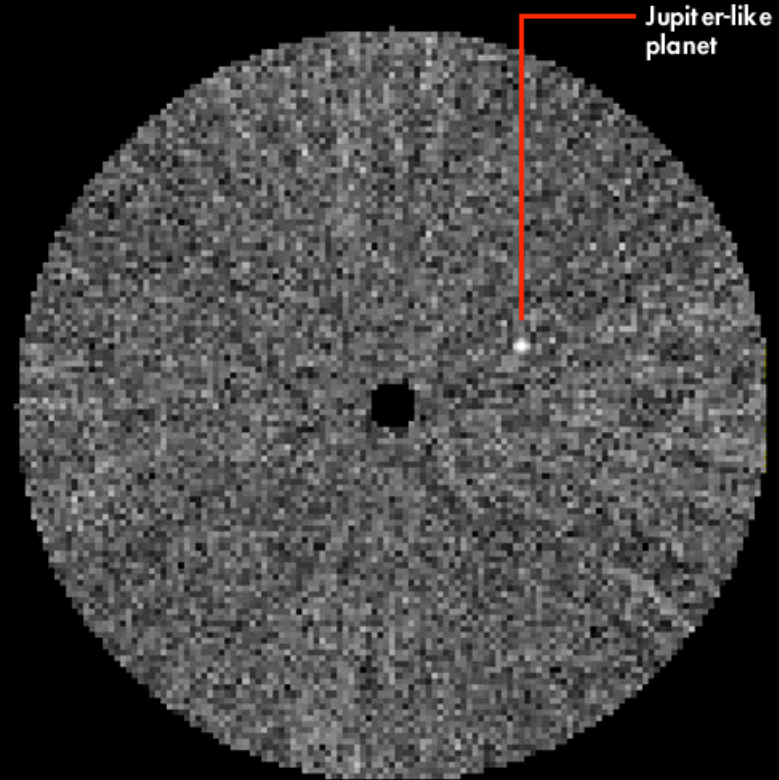


How Can We Detect Extrasolar Planets?

The most straightforward approach to finding extrasolar planets is **direct imaging**. The first known search for extrasolar planets using this method was carried out by Huygens in 1698.

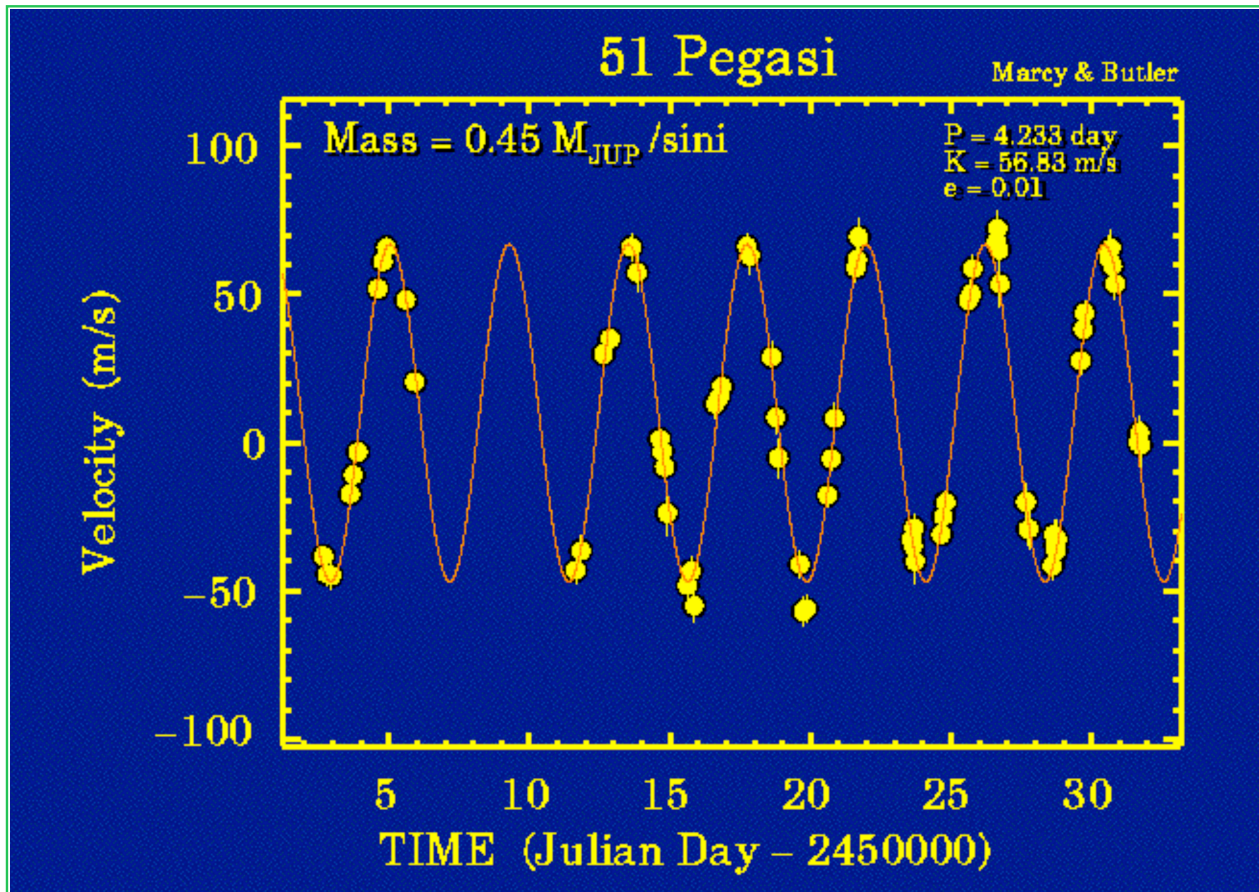
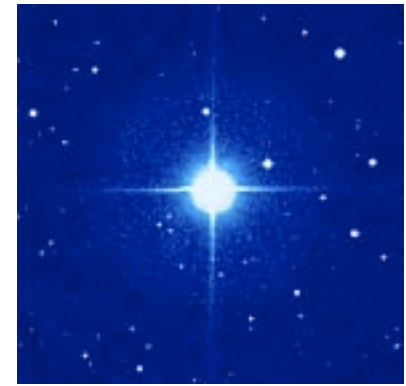


This HST image was initially thought to show a young Jupiter-like planet at ~40 Pluto distances from a young star. It was later discovered to be a background star.

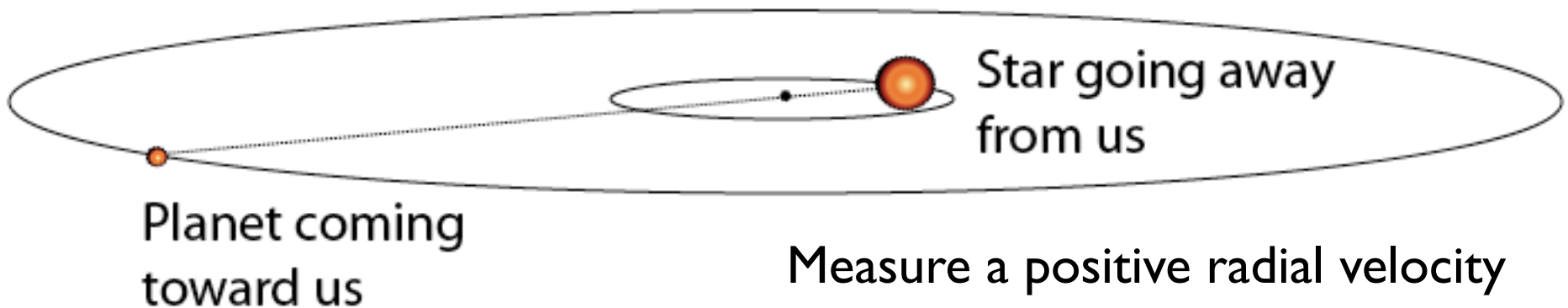


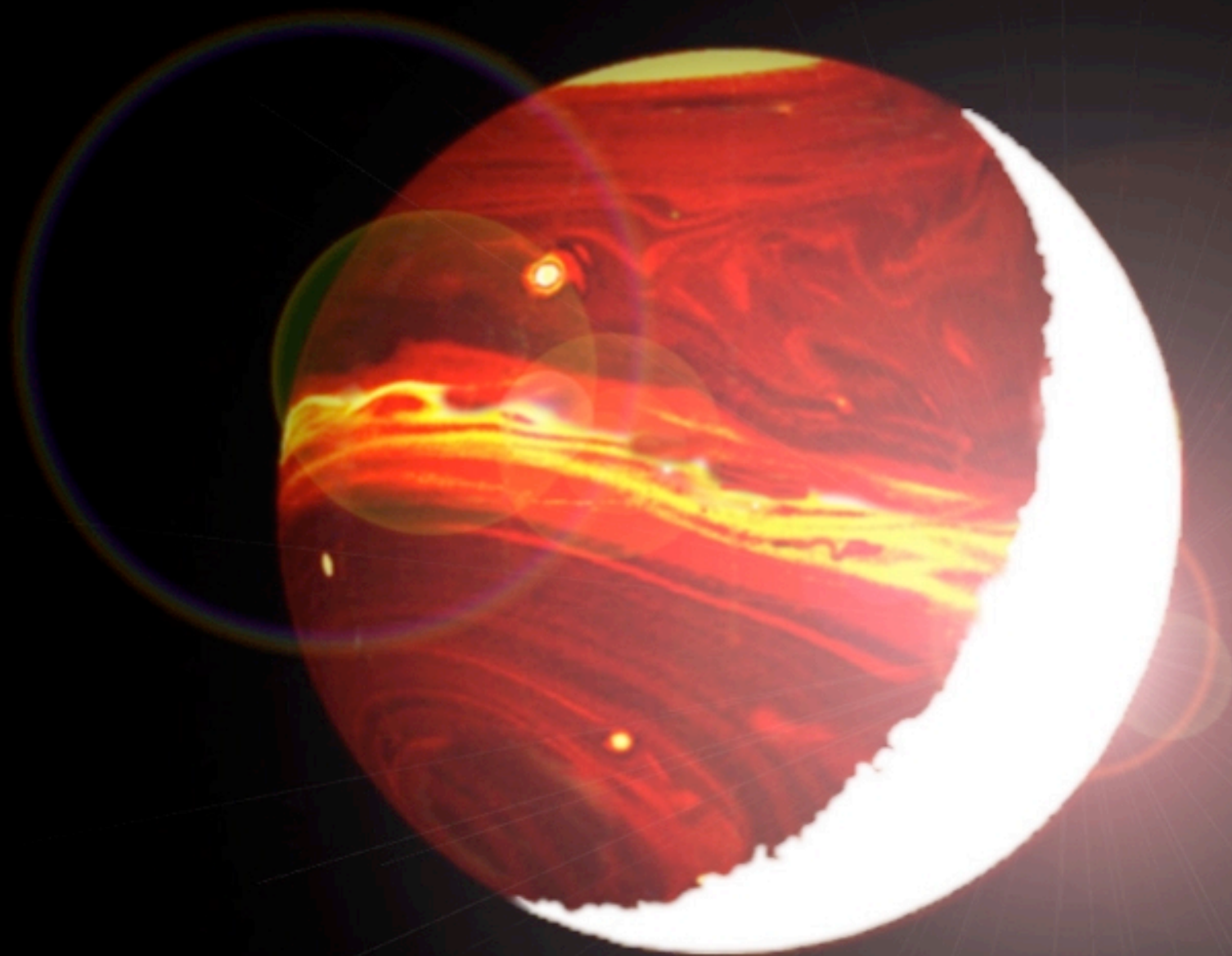
Simulated image from a super-Adaptive Optics system on an 24-foot telescope.

51 Pegasi b was discovered in 1995

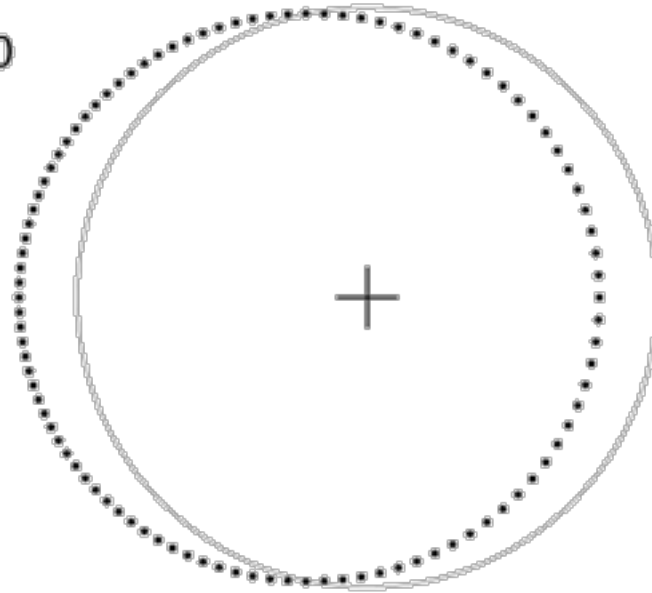


Mayor and Queloz

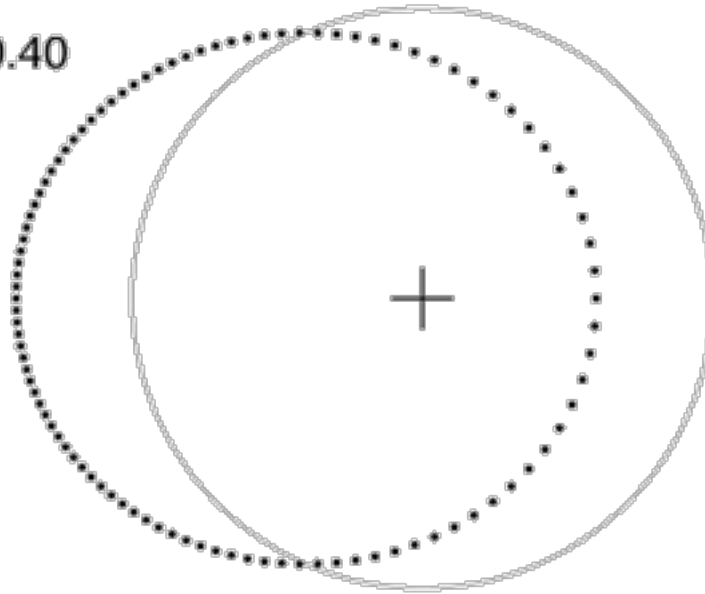




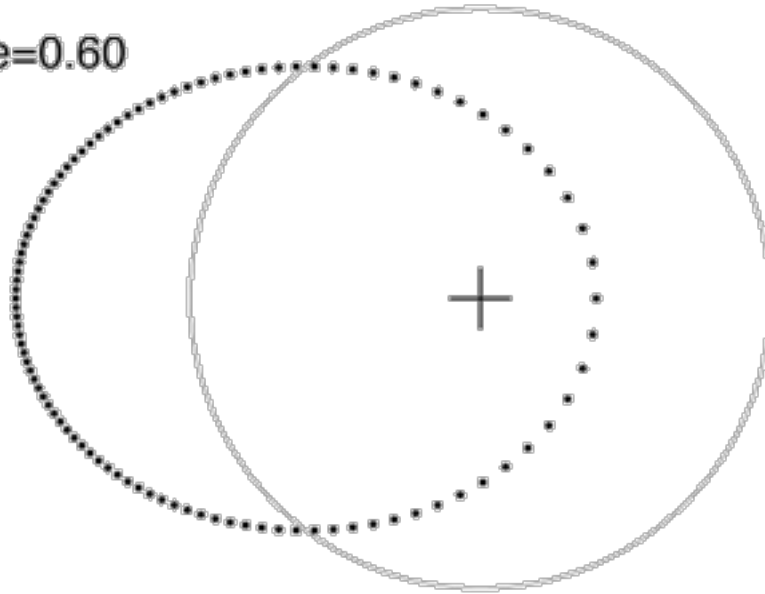
$e=0.20$



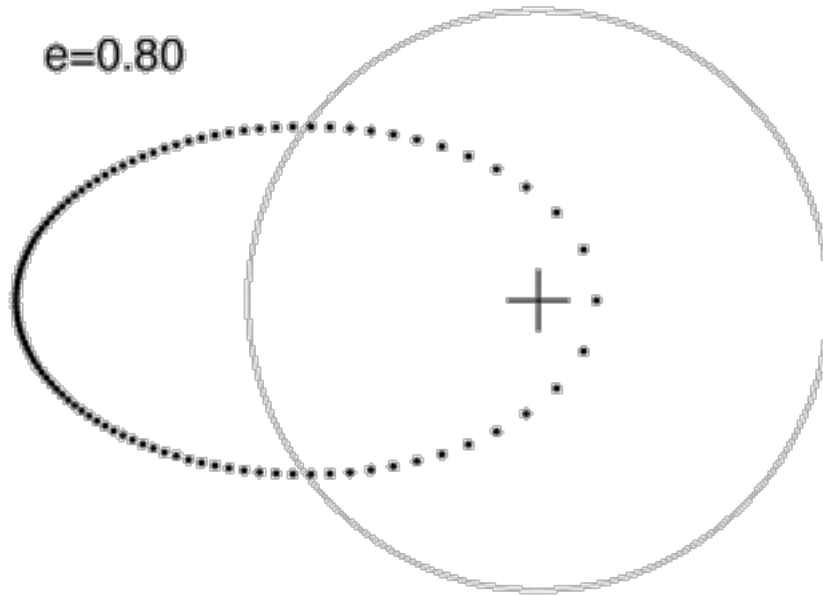
$e=0.40$

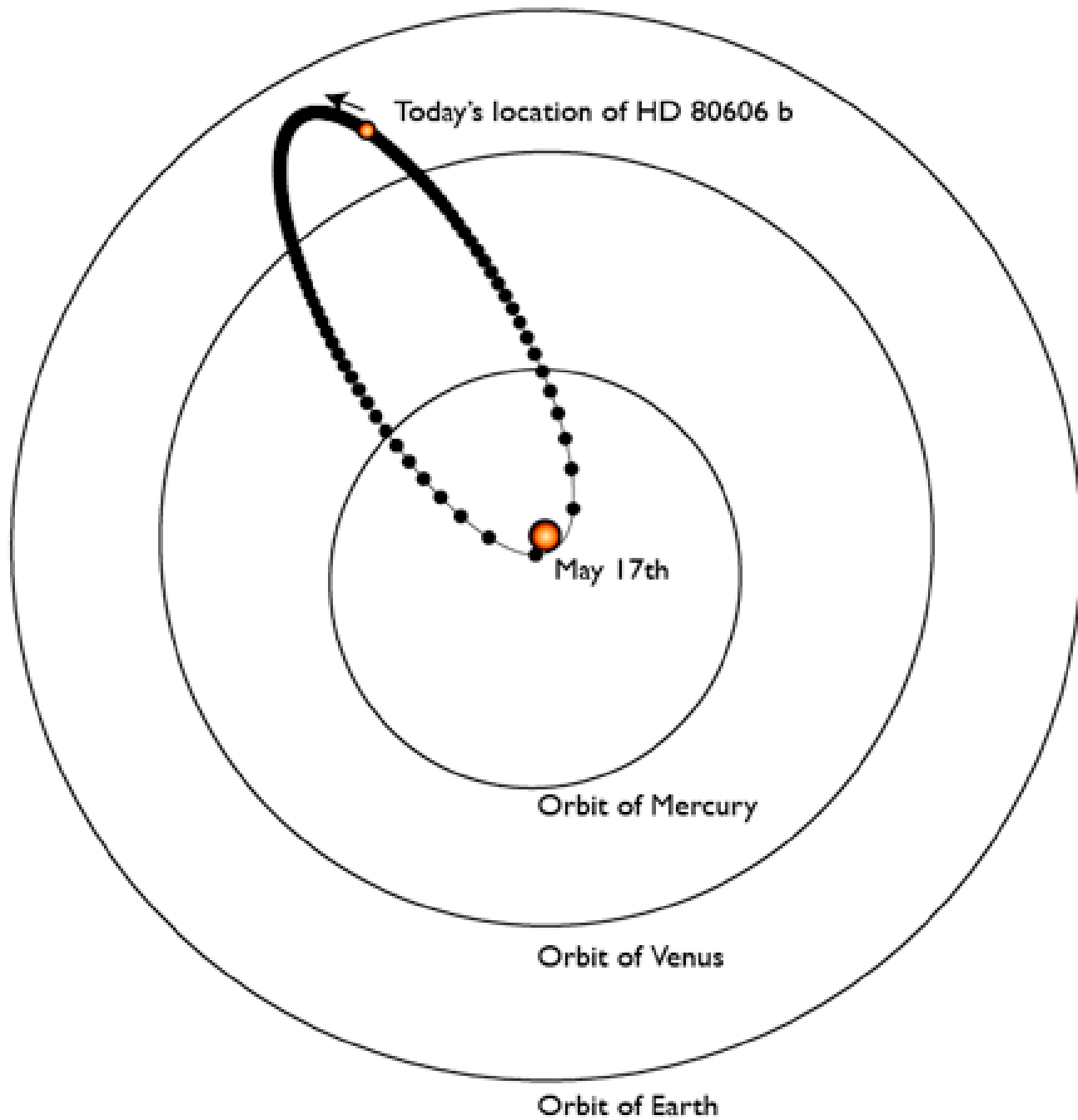


$e=0.60$



$e=0.80$





Today's location of HD 80606 b

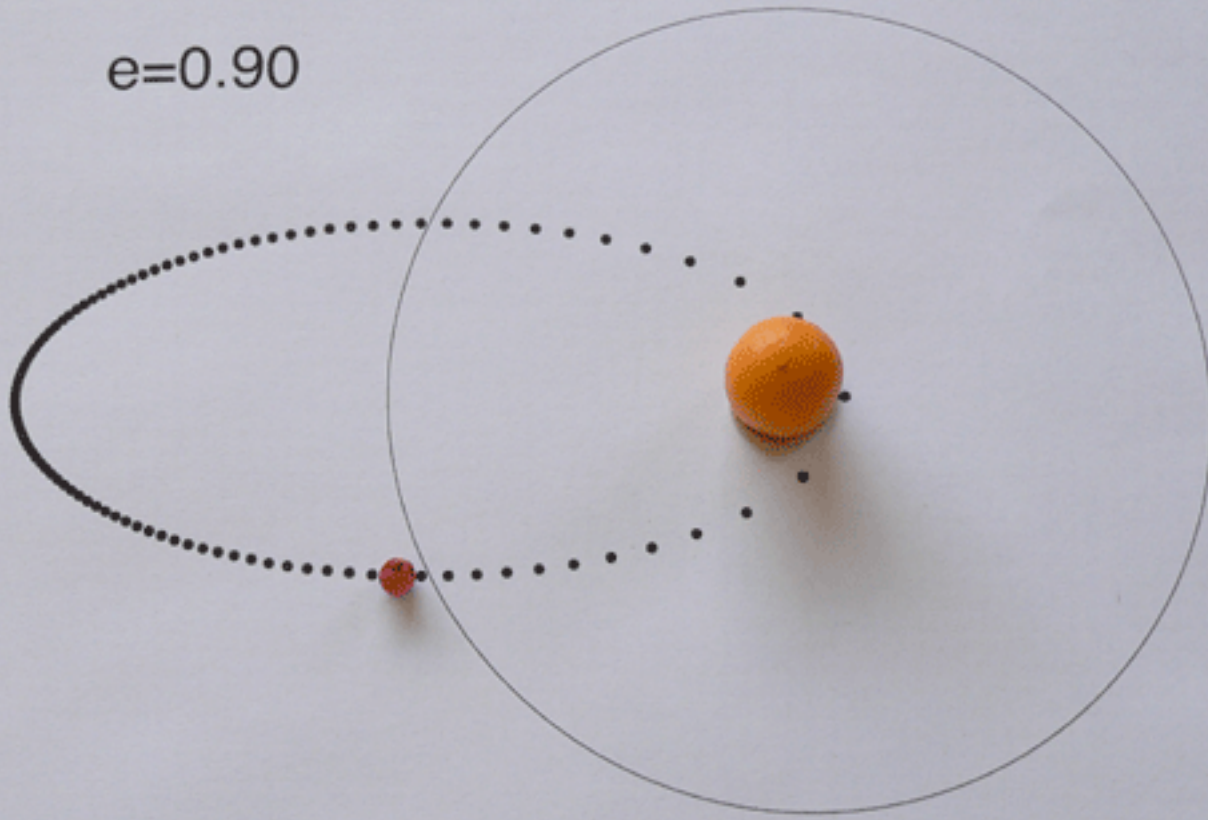
May 17th

Orbit of Mercury

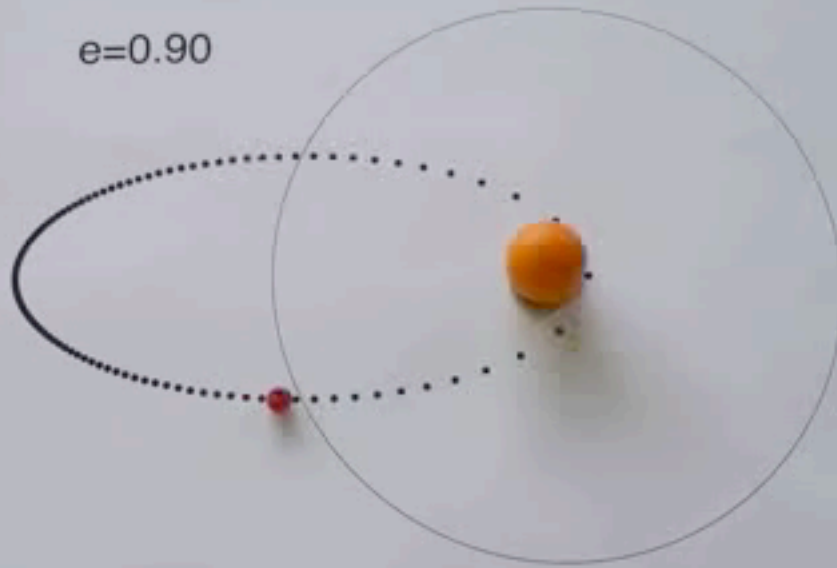
Orbit of Venus

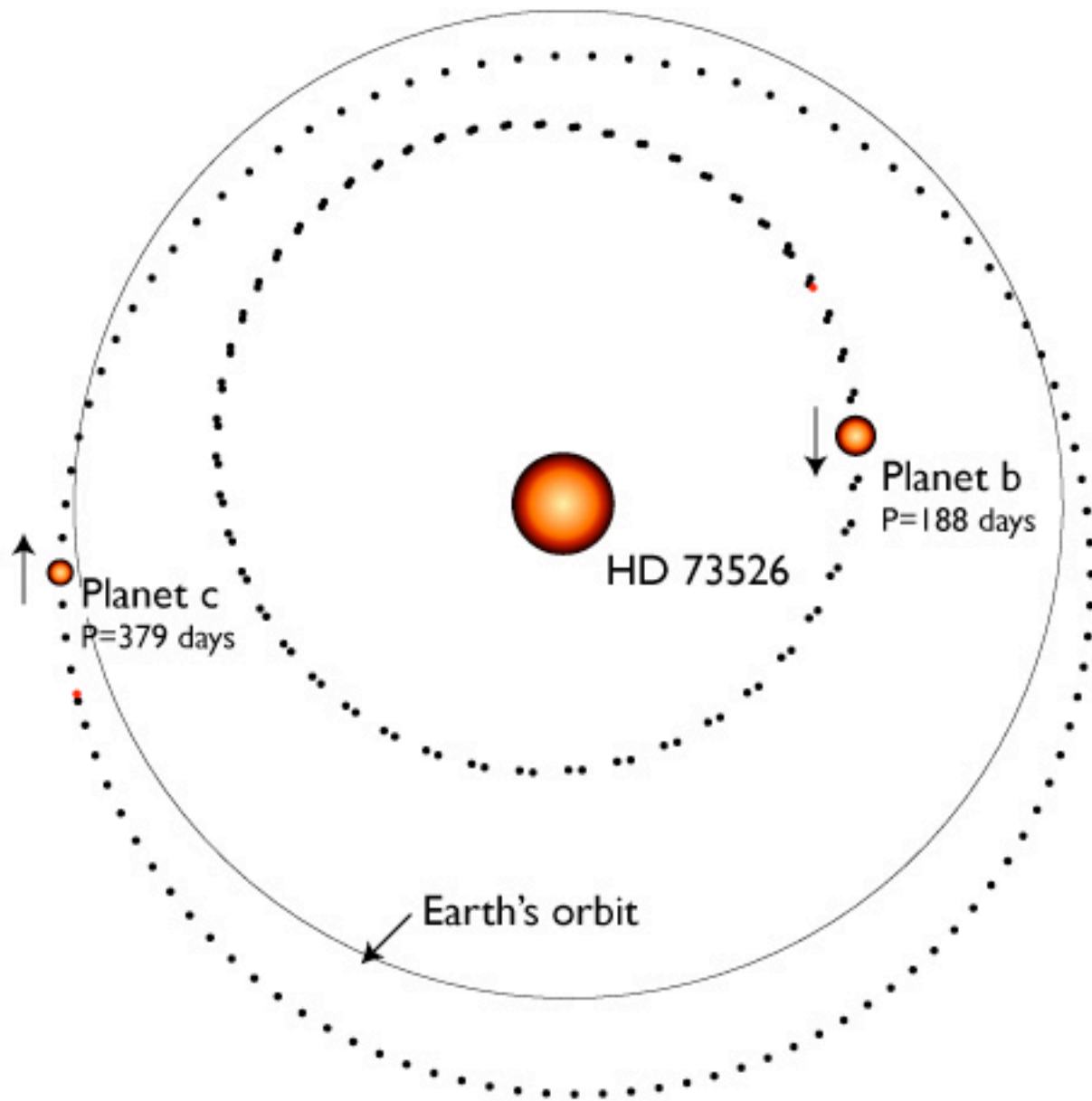
Orbit of Earth

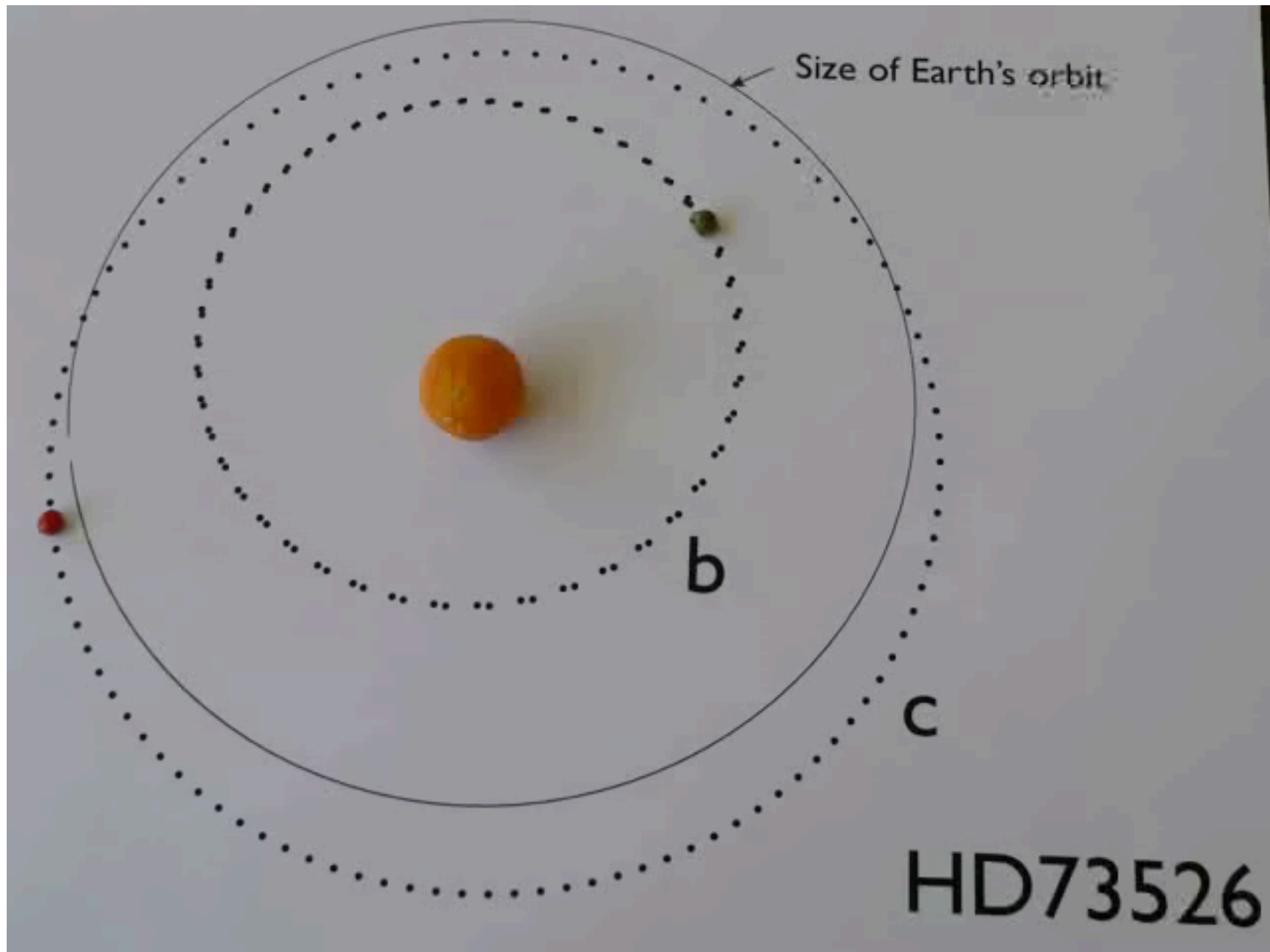
$e=0.90$



$e=0.90$





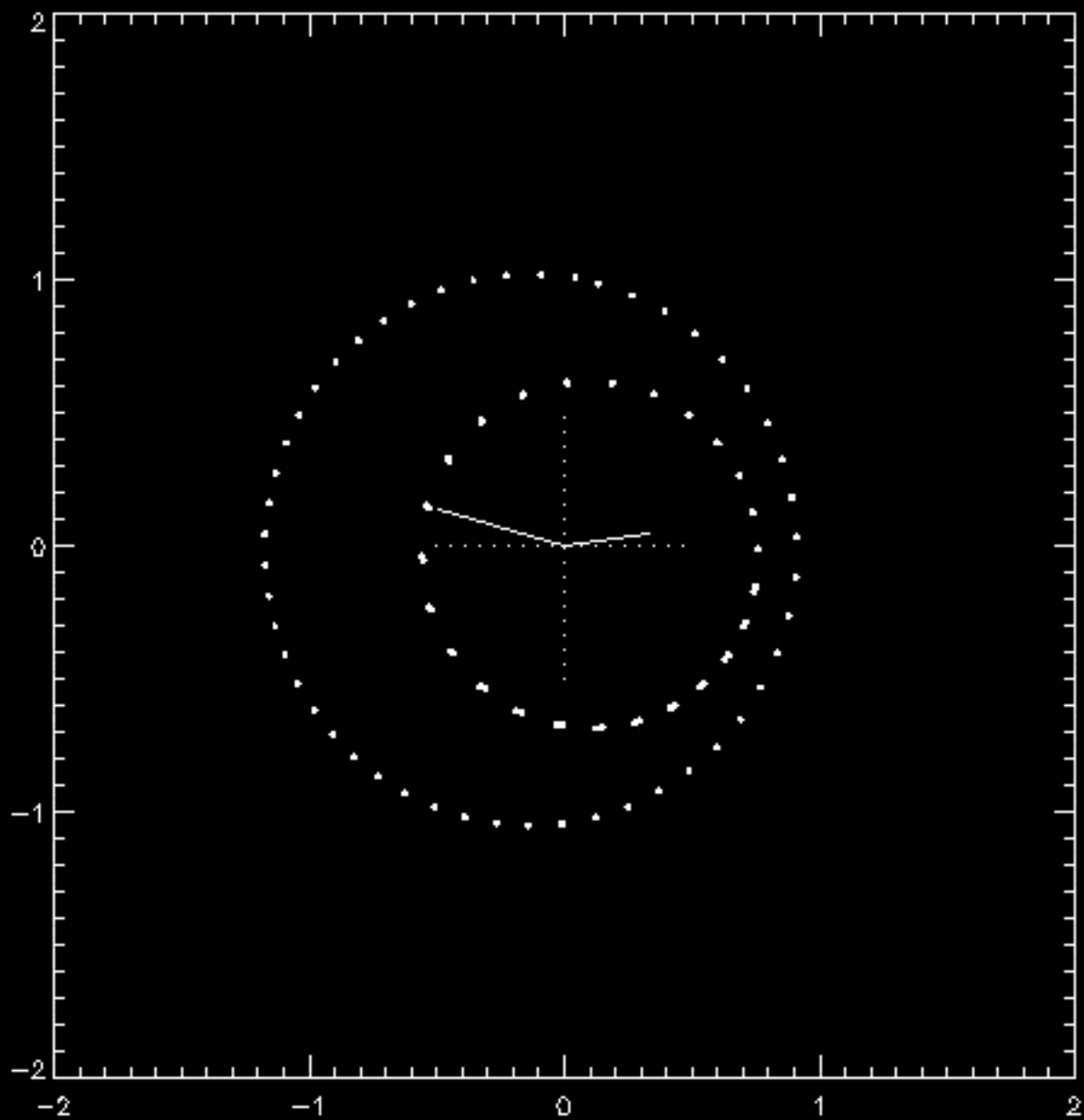


Size of Earth's orbit

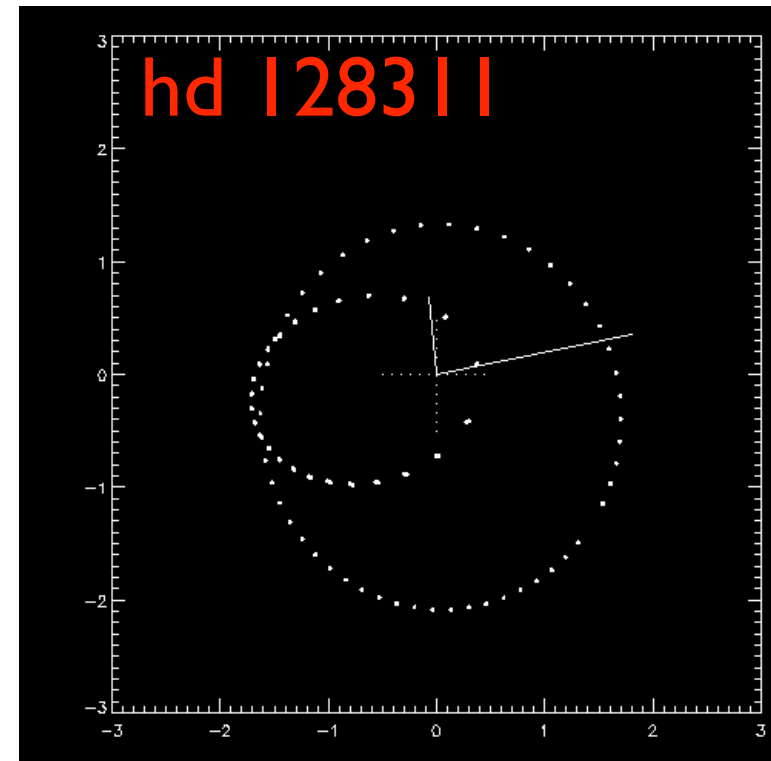
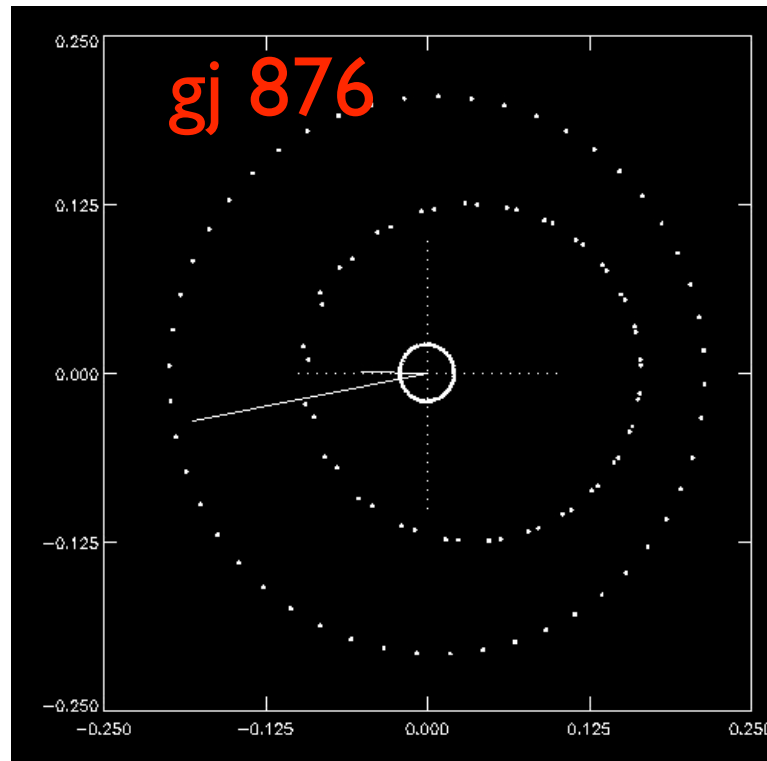
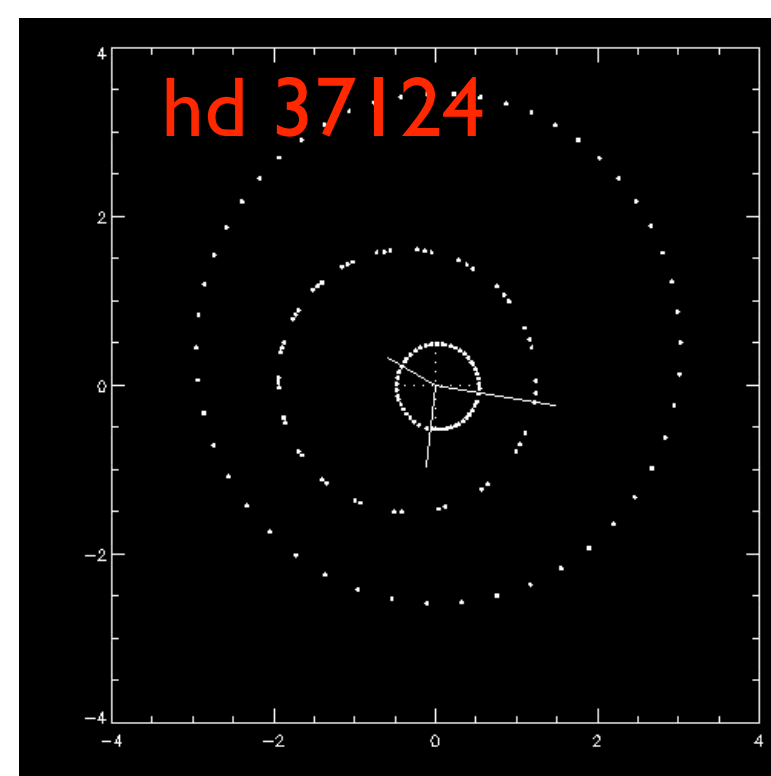
b

c

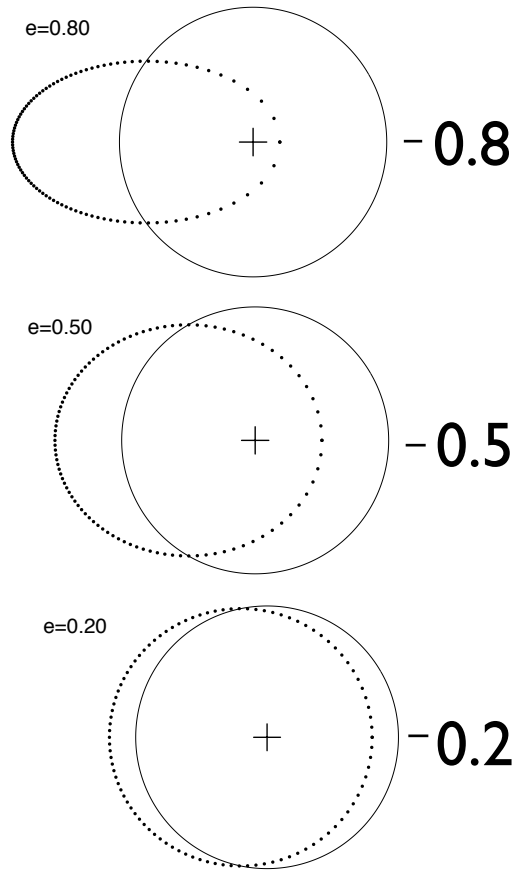
HD73526



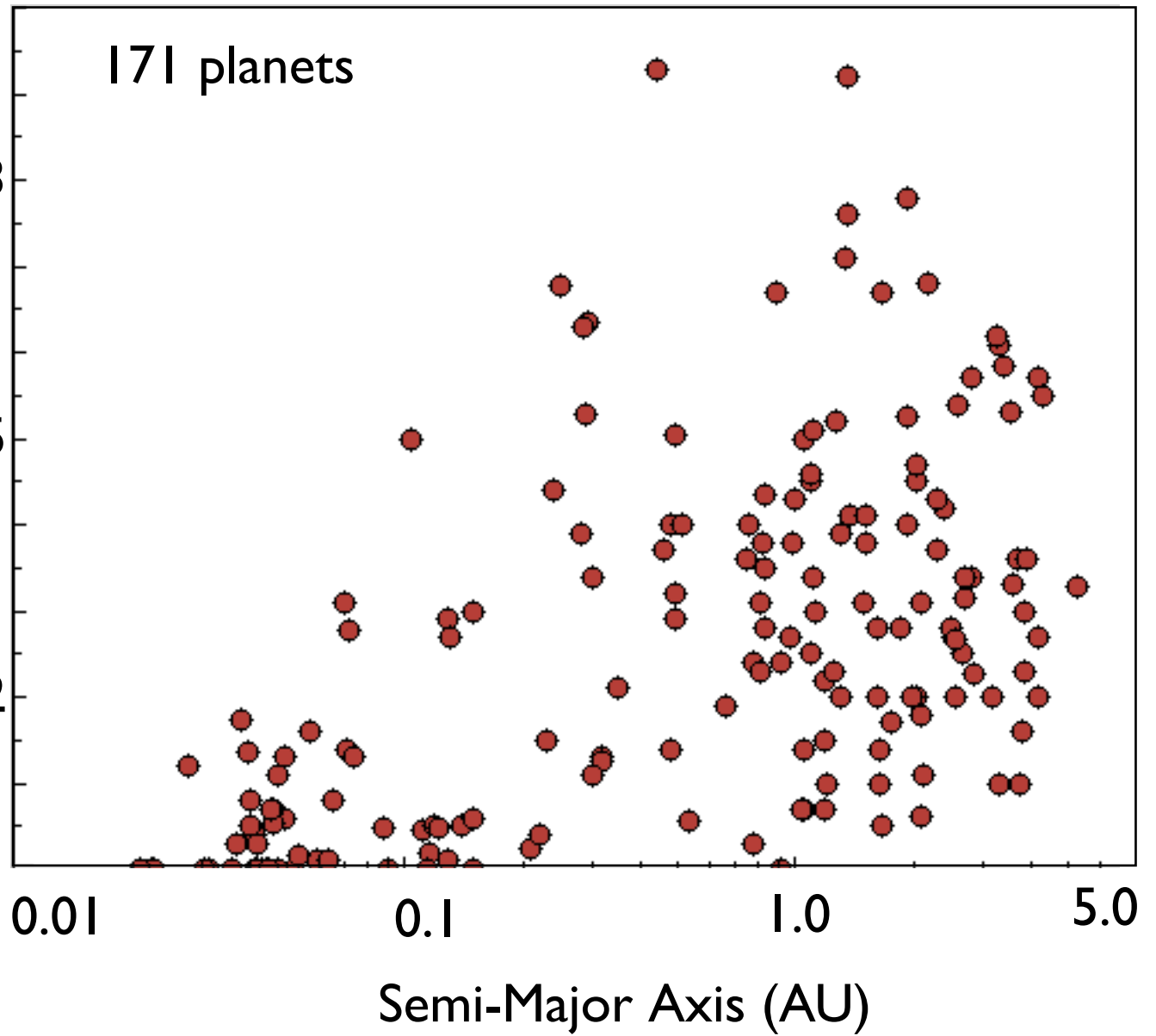
The multiple planetary systems that have been discovered often show strong gravitational pulls between the planets, which causes the orbits to evolve with time

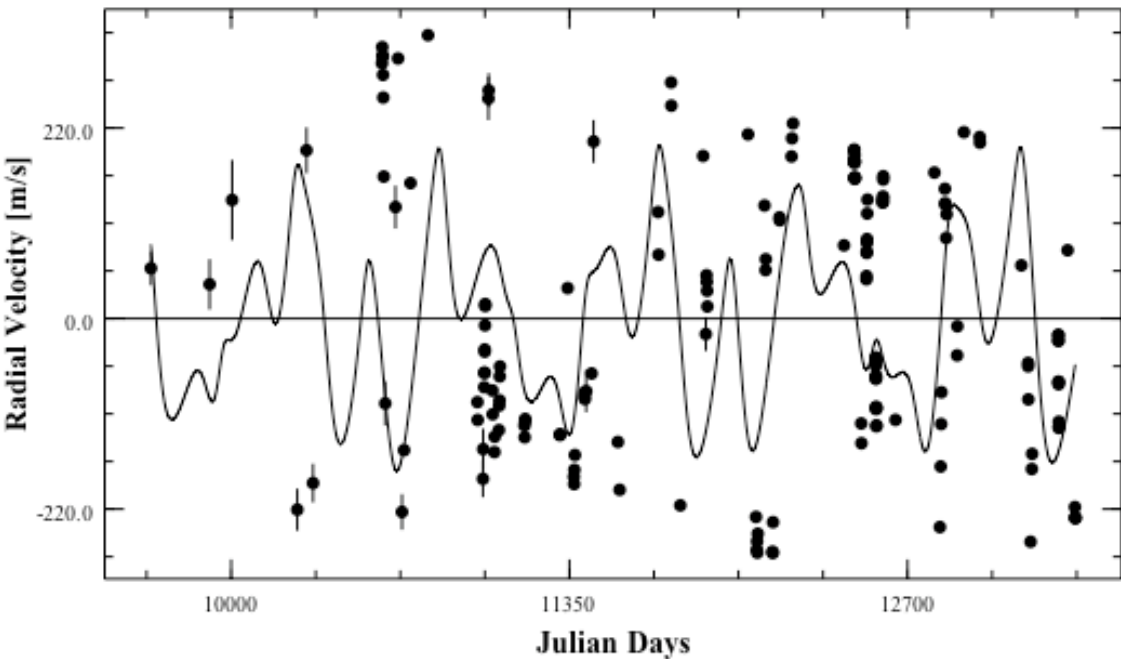


orbital eccentricity



171 planets





System: **gj876**

Fit:

Integrate

Orbital View:

Periodogram: periodogram of residuals:

ChiSq =

RMS = Req. Jitter =

Velocity Offsets
(Telescopes relative to: gj876_2.vels)

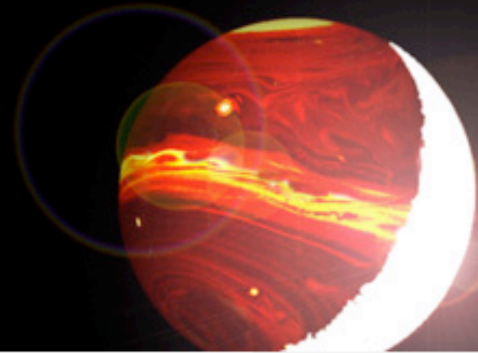
Stellar Offset

gj876_1.vels

Parameter	Value
Period [days]	289.4010
Mass [MJupiter]	1.0000
Mean Anomaly [deg]	0.000
Eccentricity	0.3254
Long Peri [deg]	0.000
Period [days]	235.9391
Mass [MJupiter]	1.0000
Mean Anomaly [deg]	0.000
Eccentricity	0.1243
Long Peri [deg]	102.249
Period [days]	701.7784
Mass [MJupiter]	1.8463
Mean Anomaly [deg]	83.077
Eccentricity	0.0000
Long Peri [deg]	0.000
Period [days]	10.0000
Mass [MJupiter]	1.0000
Mean Anomaly [deg]	0.000
Eccentricity	0.0000
Long Peri [deg]	0.000

systemic

characterizing extrasolar planetary systems

[home](#)[register](#)[login](#)

orbital 0

greg posted in [worlds](#) on january 2nd, 2006

Let a pebble slip from your hand and it falls straight to the ground. Toss the pebble sideways, and it traces a parabolic arc through the air. Imagine throwing the pebble sideways with even more speed. It lands further away. Imagine throwing the pebble with such great velocity that the surface of the Earth begins to curve away beneath it as it falls. In the absence of air friction, a pebble thrown sideways with sufficient velocity will fall in such a way that the Earth curves continuously out from underneath. The pebble falls endlessly without ever touching the ground. It is in orbit.



Pages:

- ❖ [What is Systemic?](#)
- ❖ [Console Tutorial #1](#)
- ❖ [Console Tutorial #2](#)
- ❖ [Console Tutorial #3](#)
- ❖ [Resources](#)

Links

- ❖ [transitsearch](#)
- ❖ [systemic console](#)

Categories:

- ❖ [Uncategorized](#)
- ❖ [systemic faq](#)
- ❖ [exoplanet detection](#)
- ❖ [worlds](#)

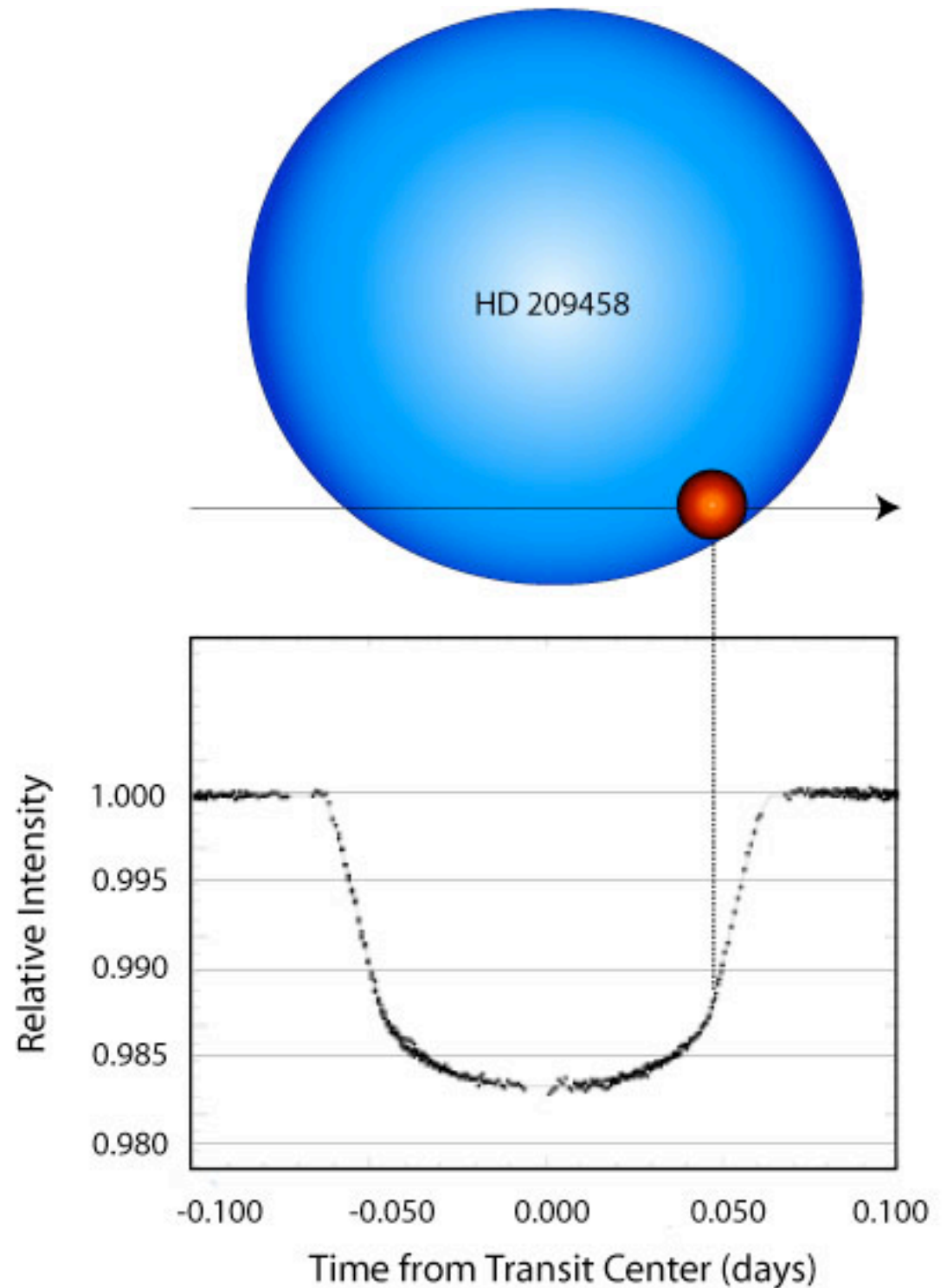
Archives:

- ❖ [January 2006](#)
- ❖ [December 2005](#)
- ❖ [November 2005](#)

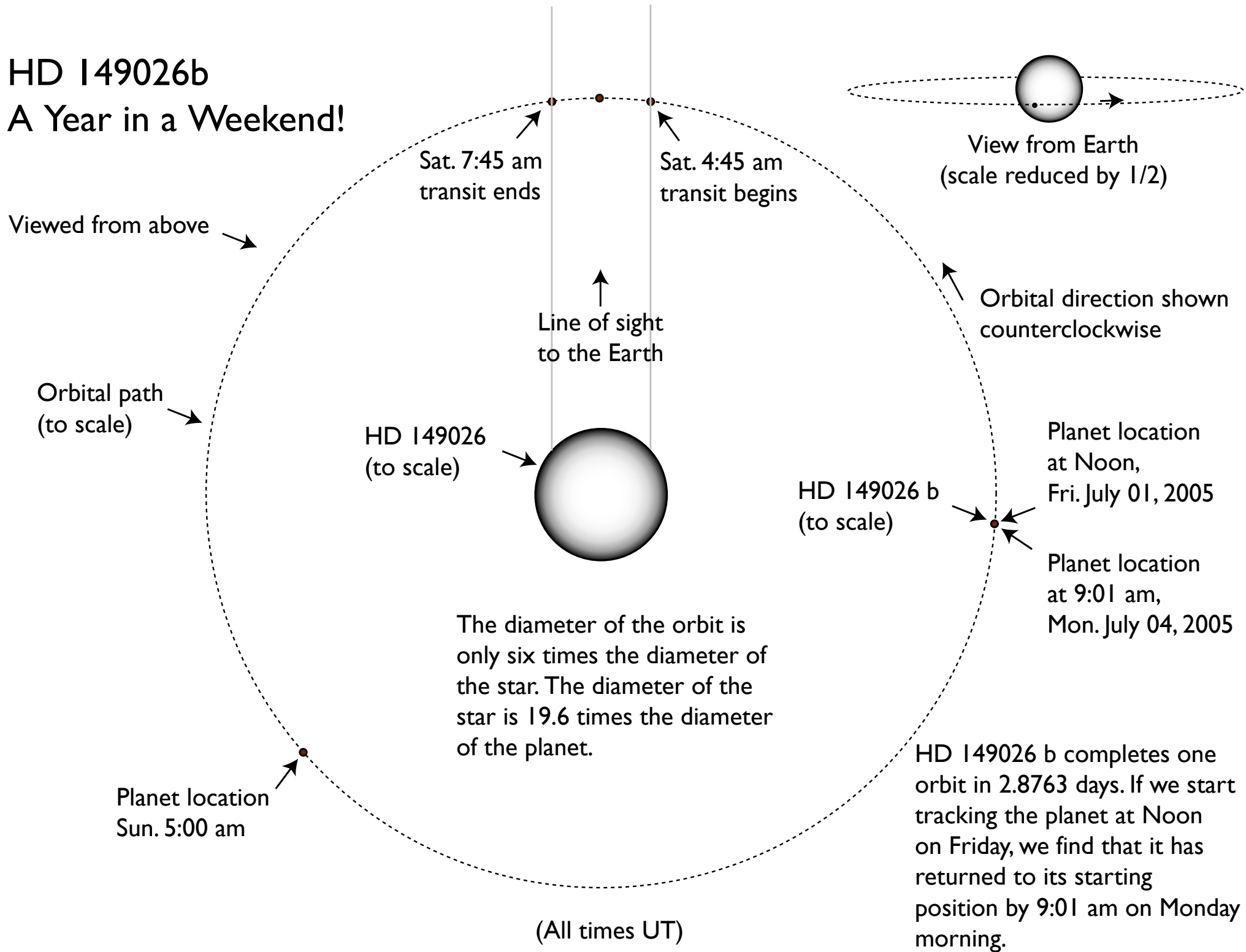
Transits have also been used to discover extrasolar planets.



Transit of Venus
June 2004



HD 149026b A Year in a Weekend!



Sat. 7:45 am
transit ends

Sat. 4:45 am
transit begins

View from Earth
(scale reduced by 1/2)

Viewed from above

Orbital direction shown
counterclockwise

Orbital path
(to scale)

Line of sight
to the Earth

HD 149026
(to scale)

Planet location
at Noon,
Fri. July 01, 2005

HD 149026 b
(to scale)

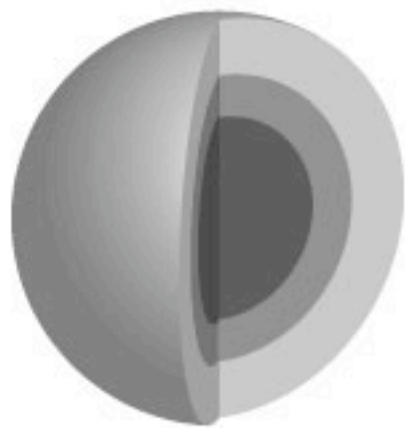
Planet location
at 9:01 am,
Mon. July 04, 2005

The diameter of the orbit is
only six times the diameter of
the star. The diameter of the
star is 19.6 times the diameter
of the planet.

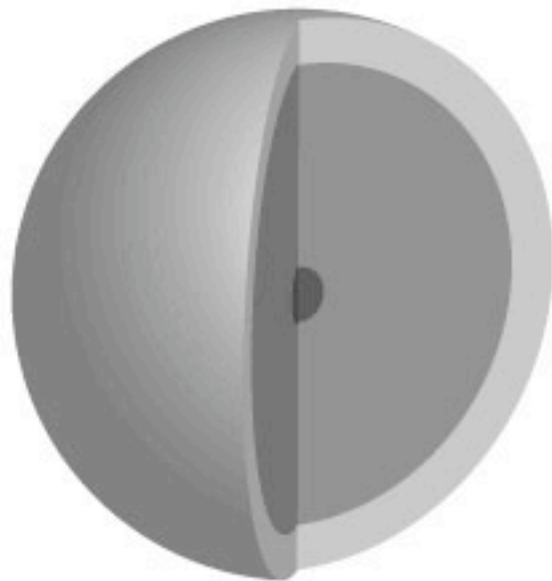
Planet location
Sun. 5:00 am

HD 149026 b completes one
orbit in 2.8763 days. If we start
tracking the planet at Noon
on Friday, we find that it has
returned to its starting
position by 9:01 am on Monday
morning.

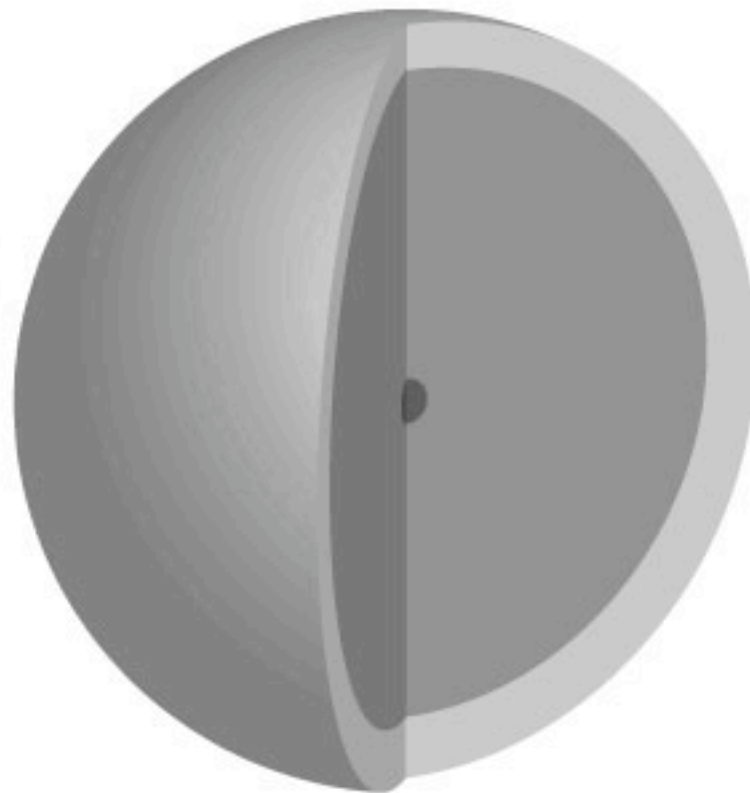
(All times UT)



HD 149026 b



Jupiter






HD 209458 b



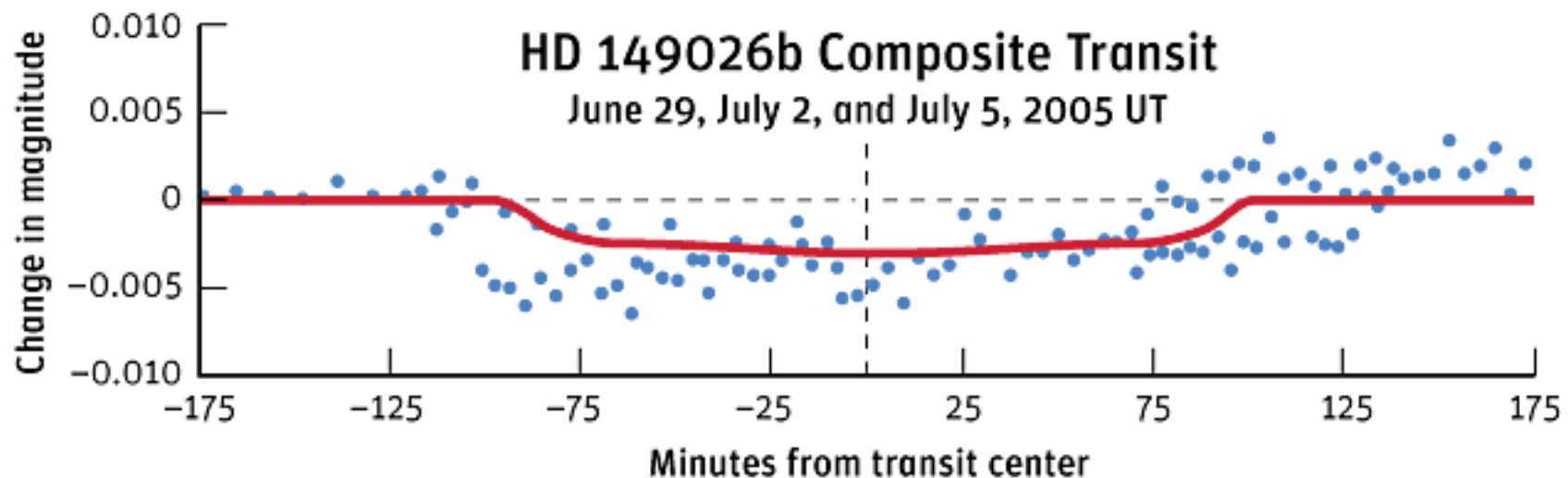
Neptune

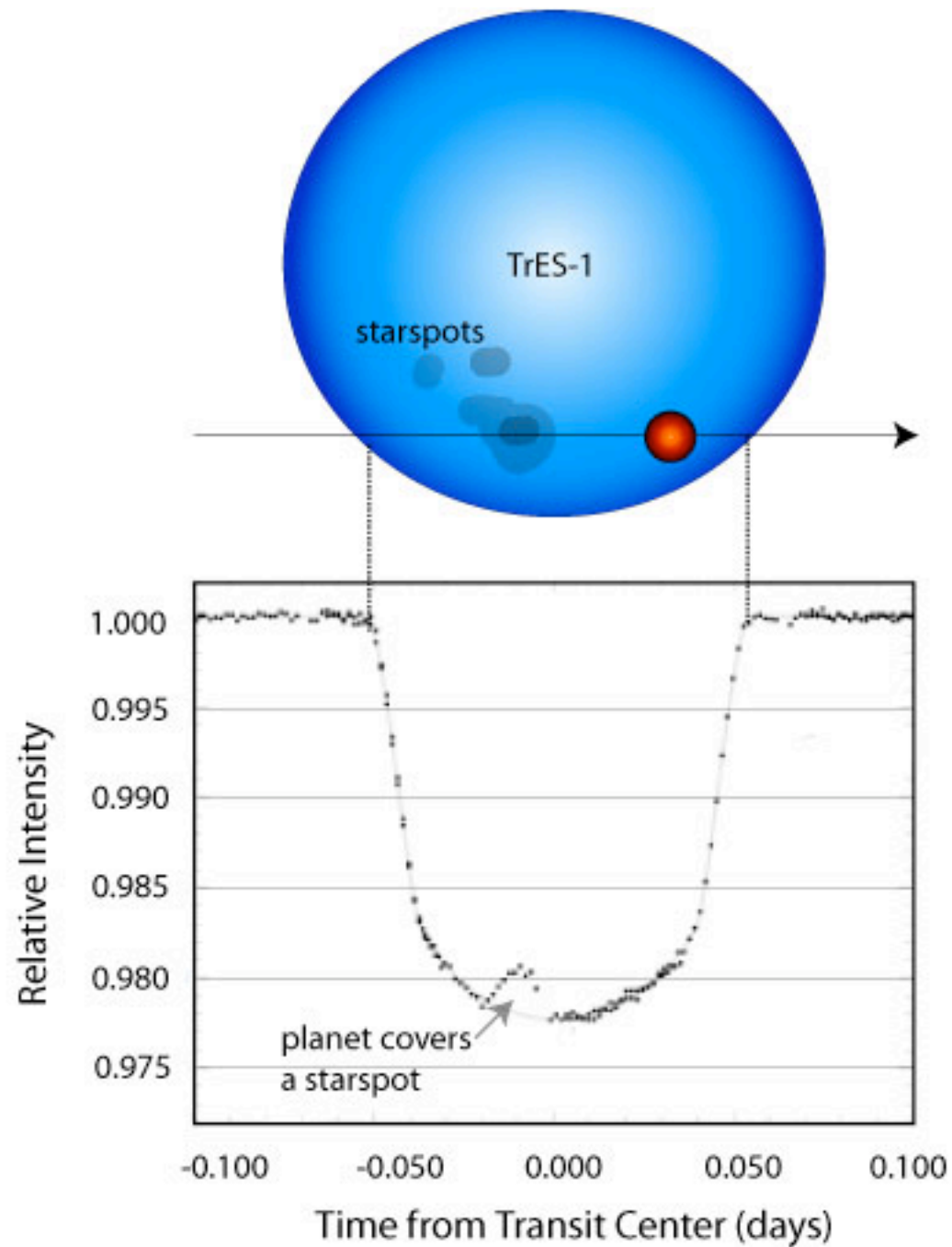
deep hydrogen-enriched atmosphere
heavy element core

-  molecular hydrogen and helium
-  liquid metallic hydrogen
-  heavy element core



Amateur astronomer Ron Bissinger observed the transit from his backyard in Pleasanton as soon as we announced the discovery

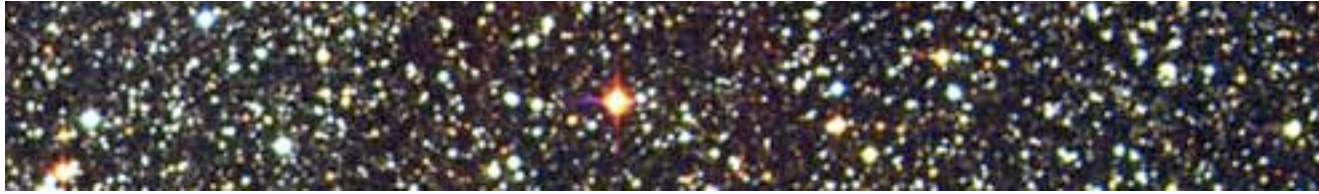




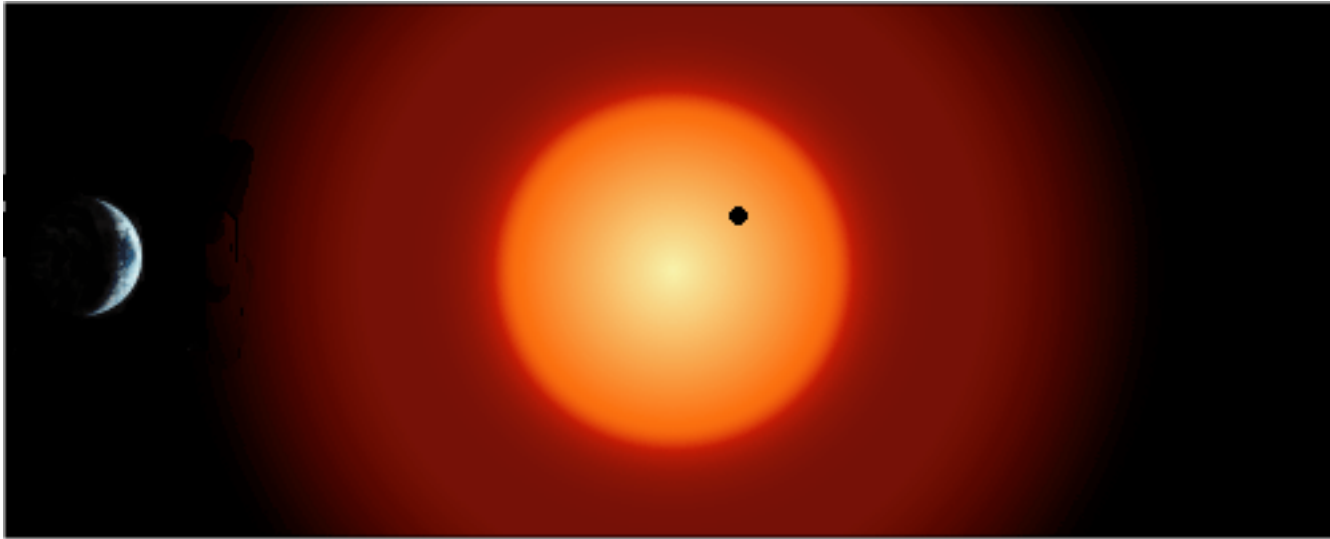
HST showed that the amateurs were indeed seeing something interesting -- starspots!



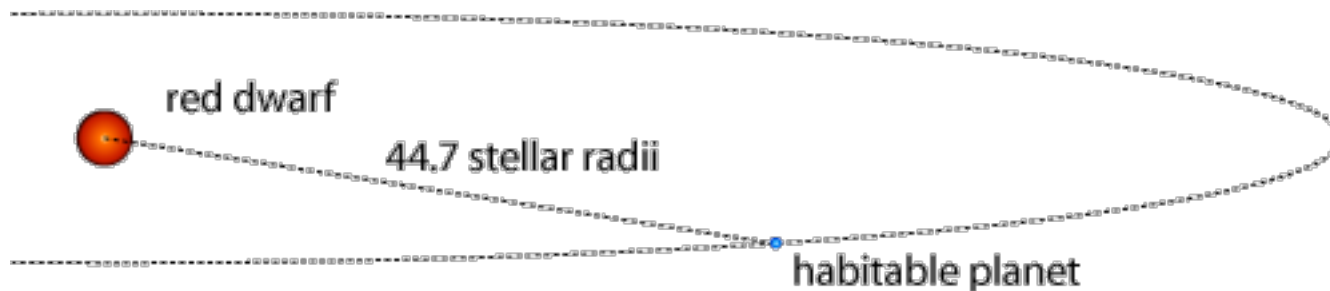
The Kepler Mission is scheduled to launch in 2008. It will look for transits of Earth-sized planets, using a 30-inch telescope in space.



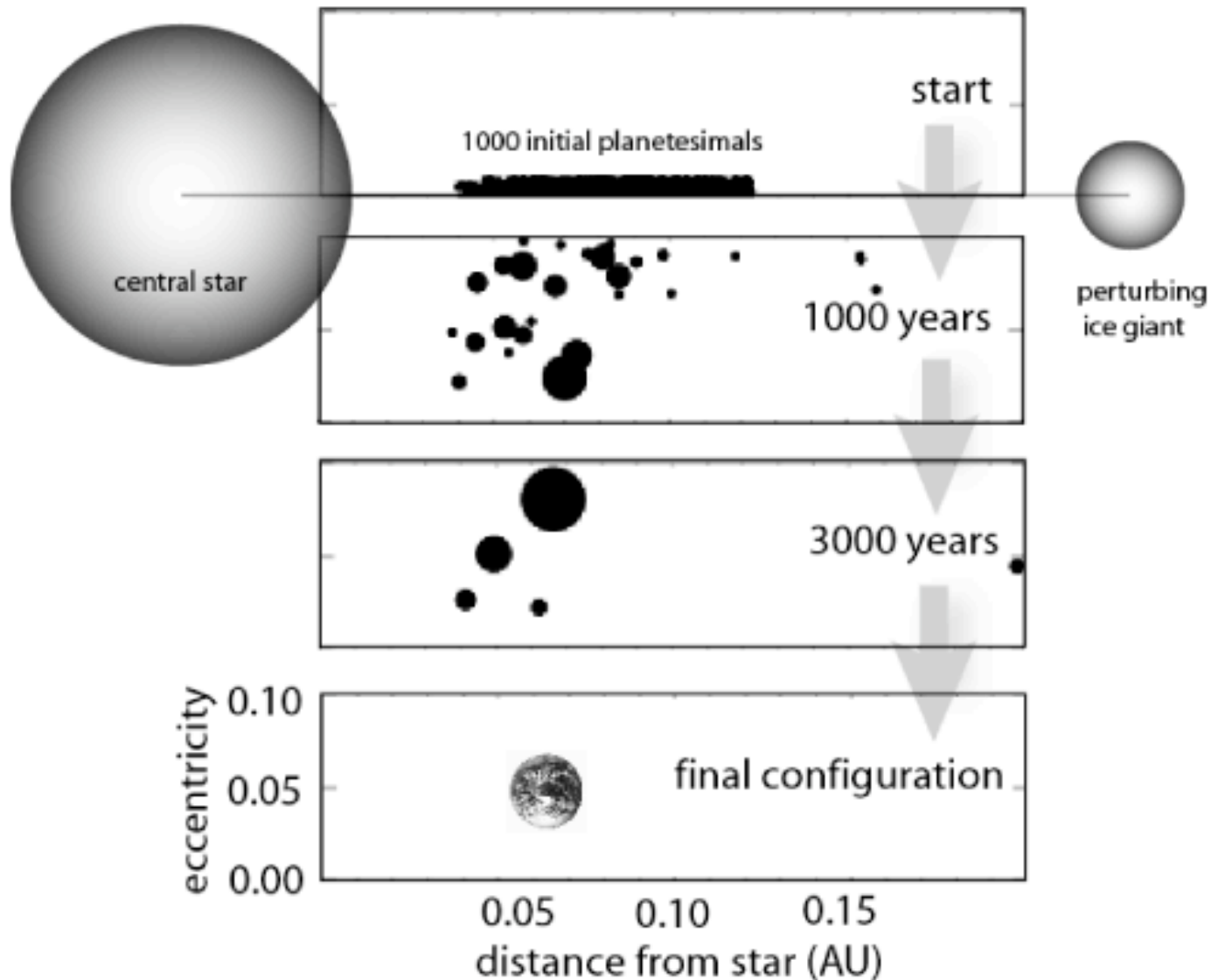
Red dwarf stars are the most numerous type of star in the Galaxy



A habitable planet orbiting a red dwarf has a ~ 3 day orbit



If such planets exist, they could be discovered with small telescopes



Our simulations of planet formation are indicating that it's quite likely that such planets exist.

www.oklo.org