


Extrasolar Planets

Gregory Laughlin
UC Santa Cruz

From: David Charbonneau
Subject: **Exoplanet Lunch: Oct 5 12:00-1:30pm**
Date: September 25, 2006 12:54:01 PM PDT

Dear Exoplaneteers,

Please join us for the next exoplanet lunch, which shall be held Thursday Oct 5 from 12:00-1:30pm in the Classroom.

Greg Laughlin will be visiting the CfA to present the colloquium later that day, and this will be an opportunity to hear the latest results that are [redacted] Moreover, we plan to ask several attendees of the Heidelberg Transiting Planet Worksh (Sept 25-28) to give us the lowdown on all the latest fashion trends relating to that beloved boxcar.

Please let me know if you would like to present some of your recent wor or to introduce and discuss the recent work of others in the field.

Best wishes,

Dave

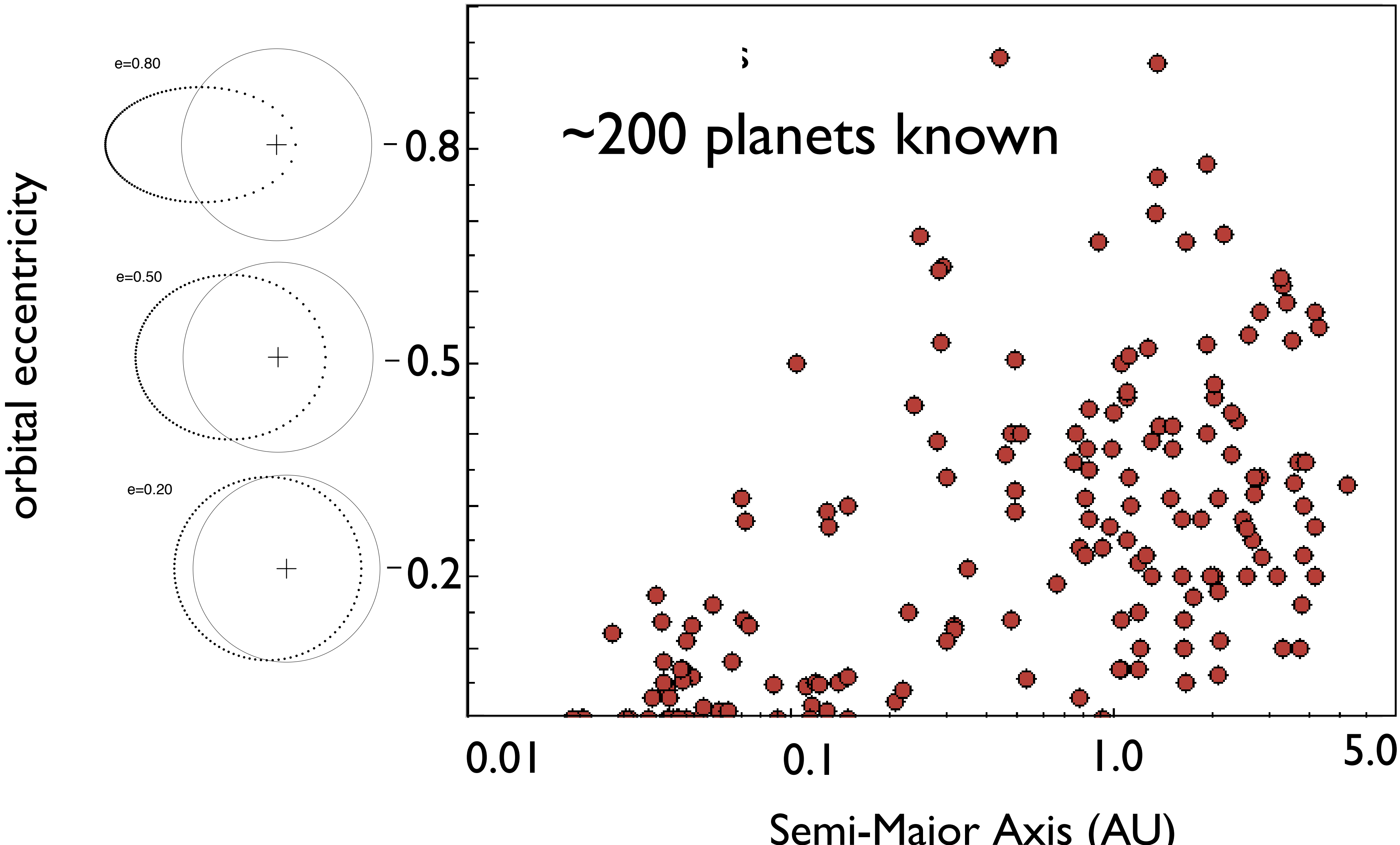
Talk Outline and Collaborators

1. Systemic - A public participation research project to understand the underlying statistics of the galactic planetary census. Collaborators: Aaron Wolf (Caltech), Eugenio Rivera (UCSC), Stefano Meschiari (Bologna)

2. The Computational Imaging of Extrasolar Planets - Hydrodynamical simulations to obtain appearances and IR light curves of extrasolar planets, with application to HD 209458b and HD 80606b . Collaborator: Jonathan Langton (UCSC)

3. Small Planets Transiting Red Dwarfs - The formation of habitable terrestrial-mass planets orbiting low-mass red dwarf stars. Collaborator: Ryan Montgomery (UCSC)

4. A Telescopic Mission to Alpha Centauri B - Scientific justification and simulations of a dedicated high-cadence radial velocity campaign to observe very low mass planets in the Alpha Centauri System. Collaborator: Debra Fischer(SFSU)



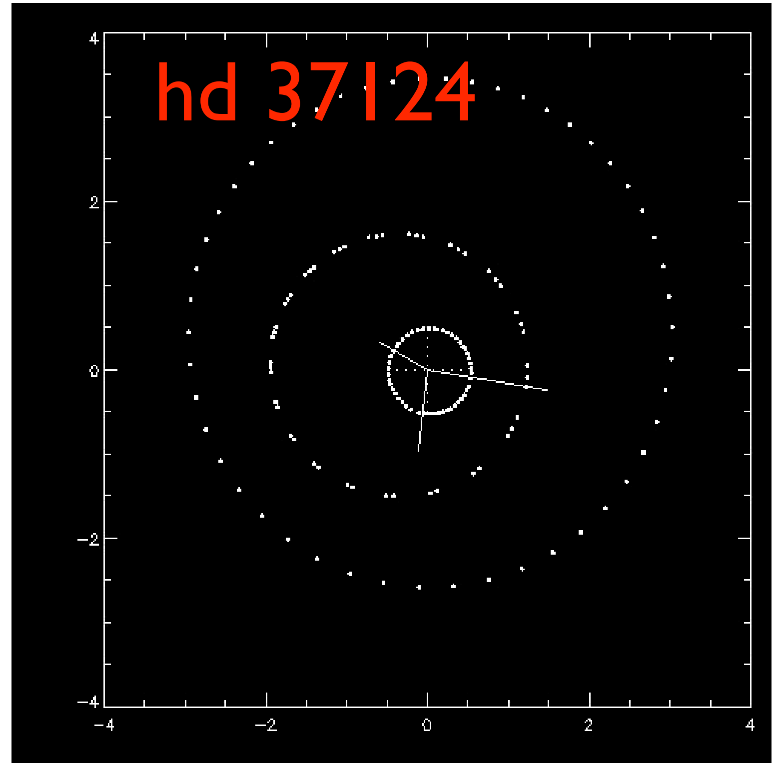
Nobody remembers who discovered the 200th asteroid, but we do remember and appreciate the Kirkwood Gaps.

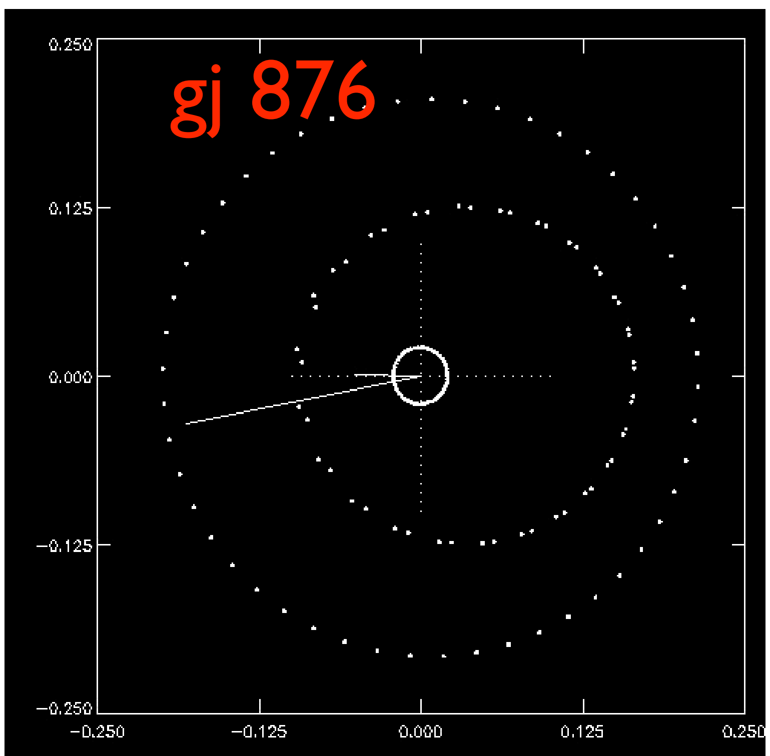
Interesting Questions

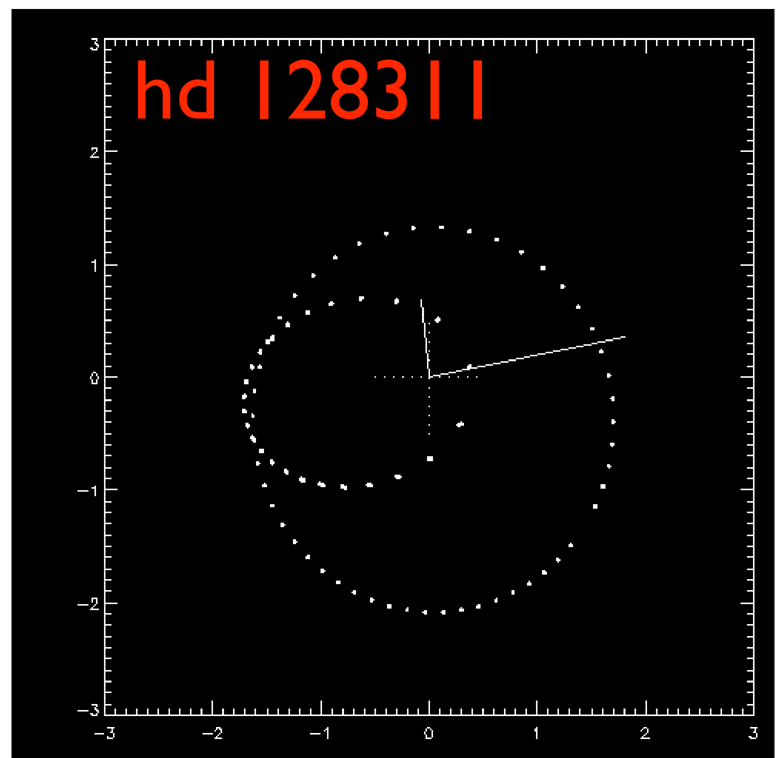
Can we develop better characterization of multiple-planet interacting systems?

What is the real a-e distribution?

When will we know how our solar system fits into the galactic planetary census?







Many of these questions can be addressed by a large-scale Monte Carlo simulation -- systemic

1. 100,000 star catalog based on Hipparcos. Take all known stellar properties, and scramble RA.

2. Create synthetic planetary systems for these stars. Try to be absolutely as creative as possible. Idea is to be able to draw subset distributions after the fact.

3. Integrate each system for one million years to sort out severe dynamical instabilities. (Assume Inelastic collisions).

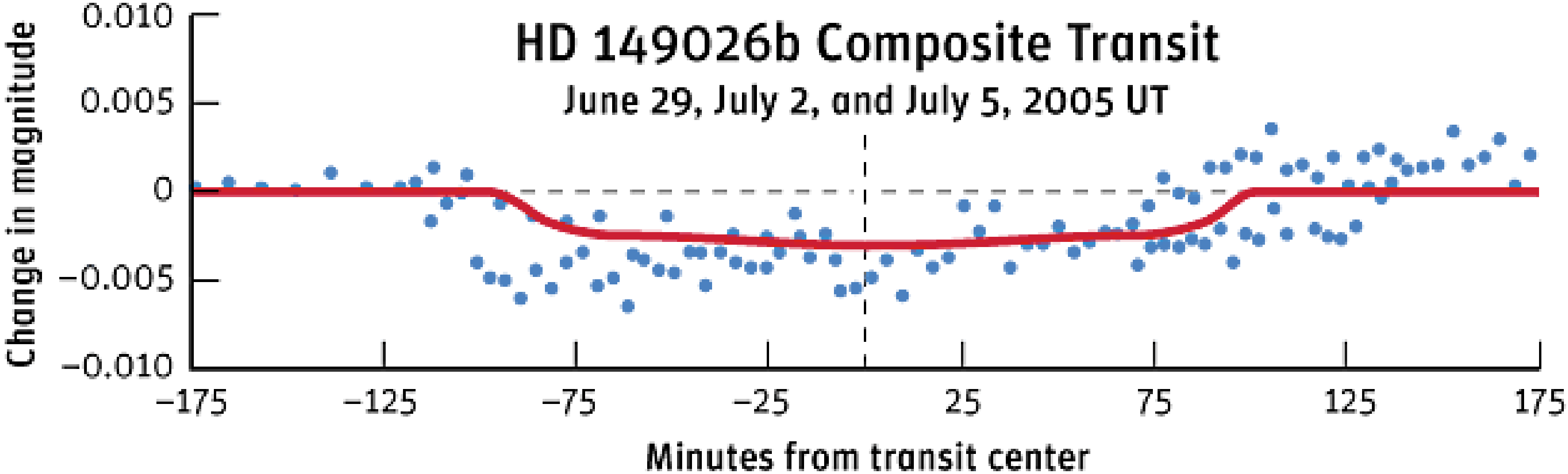
4. Observe these systems. Our "TAC" program uses realistic cadences, S/N, Earth location, weather, etc. to generate radial velocity data sets that are similar to those obtained by the major observatories and teams HARPS, Keck, HET, etc.

5. Provide interface and tools for public participation.

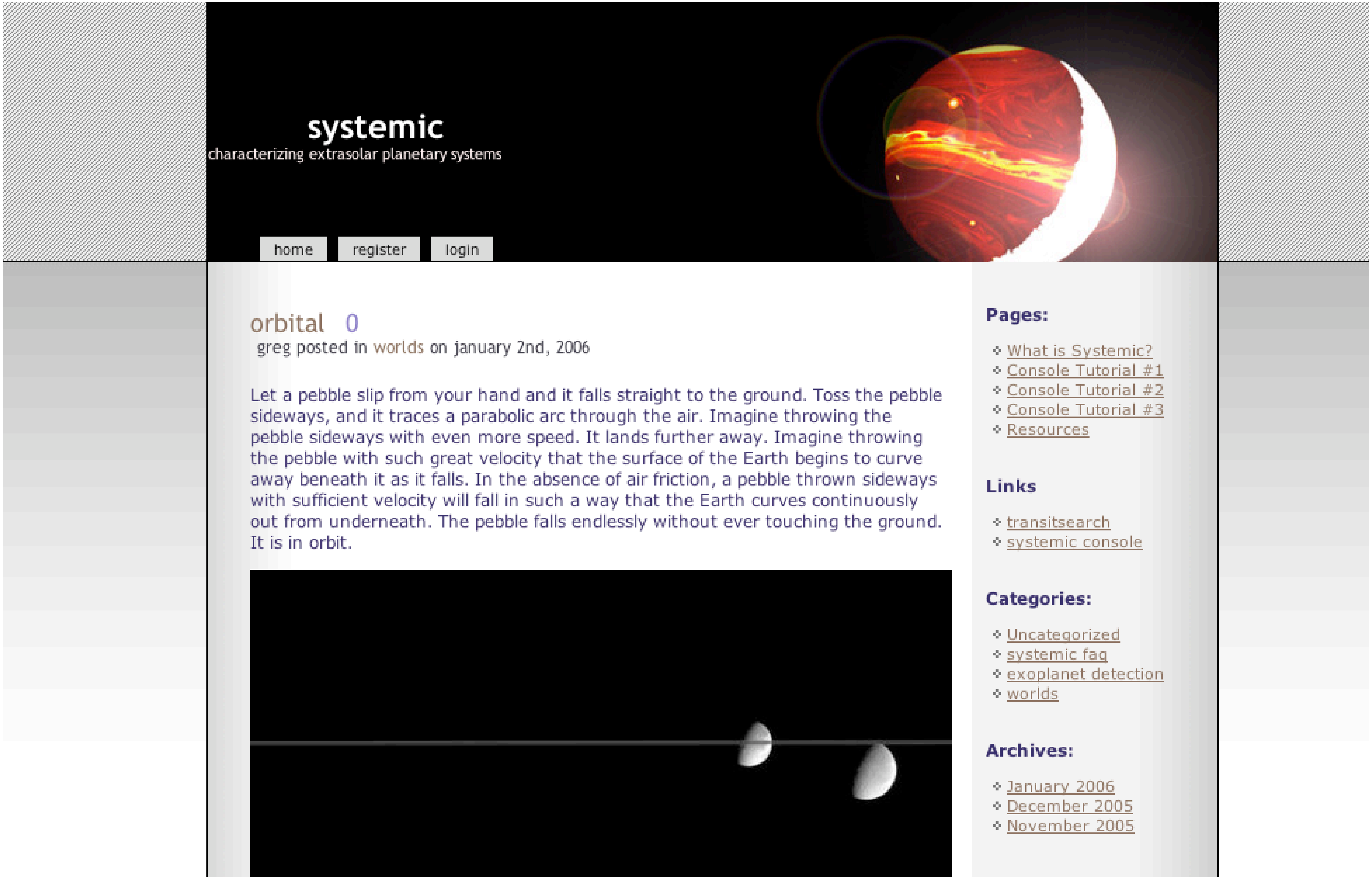

Transitsearch.org observer Ron Bissinger

Use the project to build on the ongoing transitsearch.org effort.

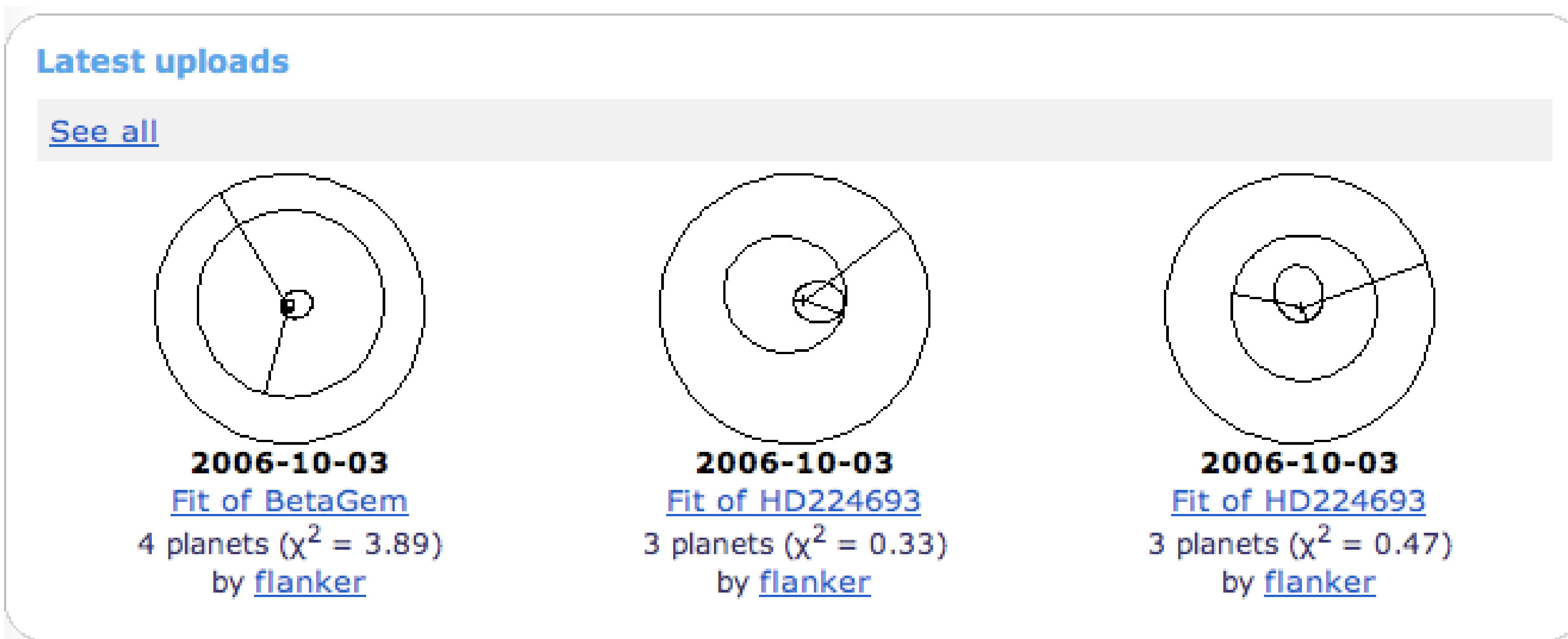
Allow analysis of published data for real stars as well. A wiki-based Major Planets Information Center.



www.oklo.org

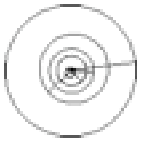

systemic
characterizing extrasolar planetary systems
home
register
login
orbital 0
greg posted in worlds on january 2nd, 2006
Let a pebble slip from your hand and it falls straight to the ground. Toss the pebble sideways, and it traces a parabolic arc through the air. Imagine throwing the pebble sideways 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

We have developed a collaborative "backend" for the systemic project website which aggregates the distributed effort. It's fully functioning, and has access to all of the published radial velocity data on which the known extrasolar planets are based.

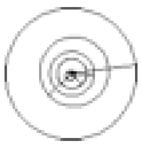


1500 fits to ~300 data sets

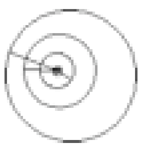
Latest comments



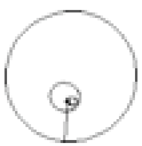
7-planets fit of HD13189 by bruce01
10.03.06, 07:56:51
bruce01 says: *A little research of the literature confirms that the short period radial velocity variations are likely due to stellar processes. This is a K giant star. Such stars are known to have radial velocity variations with periods of many days due to spots, rotation, and pulsations. So, all the short period "planets" in this fit are artifacts of the star.*



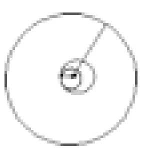
7-planets fit of HD13189 by bruce01
10.02.06, 07:04:24
bruce01 says: *This star is listed at 4.5 solar masses, somewhat more massive than most of the stars in the catalog. Does that explain the poor chi square? Are the short period velocity variations in the data due to planets or due to random motions of the stellar atmosphere?*



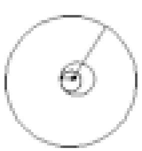
5-planets fit of HD168746_B06K by goldrake
09.30.06, 07:55:05
goldrake says: *A CPU error is occured*



4-planets fit of HD74156 by bruce01
09.28.06, 04:53:59
bruce01 says: *This upload exceeded 20% resource limit. Chi^2 is 1.01 not 0.*



5-planets fit of 47uma_4datasets by andy
09.27.06, 22:41:15
glenn says: *I uploaded a fit for HD10697 with a chi square of 1.38, but the upload listed it as a chi square of 20.98. Can this be corrected?*



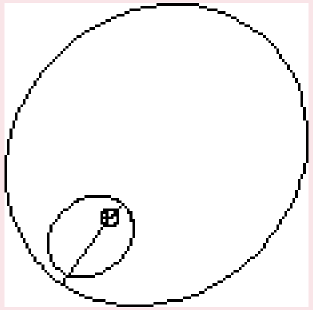
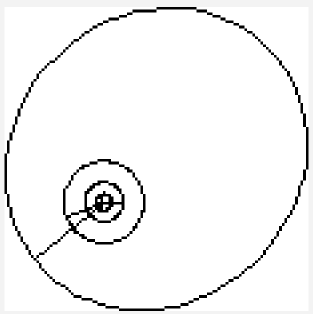
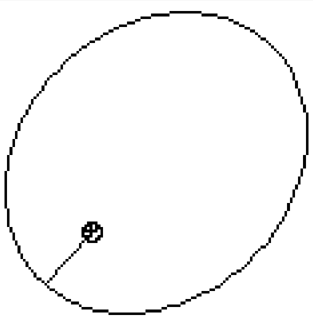
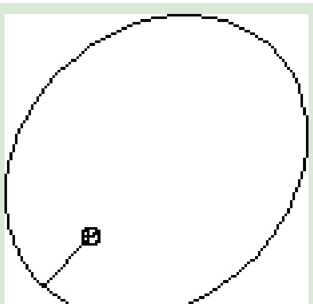
5-planets fit of 47uma_4datasets by andy
09.27.06, 08:03:37
andy says: *What with intersecting orbits and short-period eccentric planets, this one isn't looking too plausible I don't think.*

2-planets fit of rhoCrB by mikehall
09.26.06, 16:53:29
greg says: *That fit looks like it might be stabilized by 2:1 resonance. How does it sound? Greg*

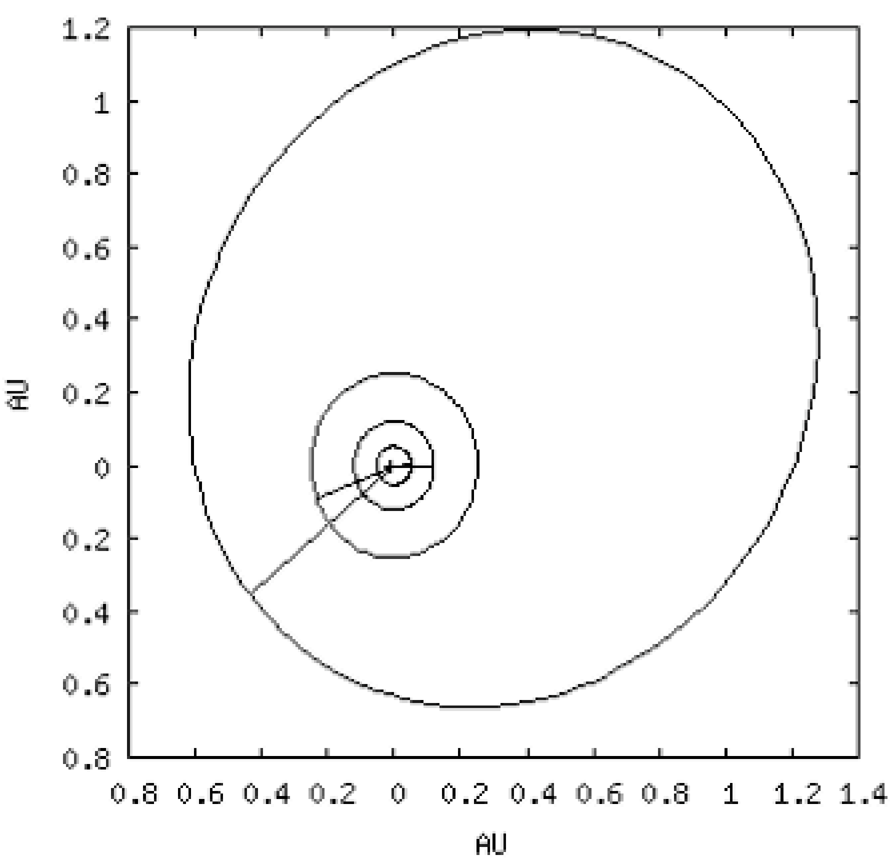
2-planets fit of rhoCrB by mikehall
09.26.06, 15:08:27
mikehall says: *I am not really happy with these osculating orbits, but the integrator says YES!*

All uploaded fits for 51peg_B06L

» Best fit » Most recent fit

	χ^2	Planets	Uploaded on	by	# comments
	1.48	3	2006-09-02, 07:09:49	bruce01	0
	1.48	4	2006-09-02, 07:11:15	bruce01	0
	1.58	2	2006-07-20, 18:52:18	greg	0
	1.58	2	2006-09-13, 20:23:56	mikevald	0

view | comments (0) | printable version



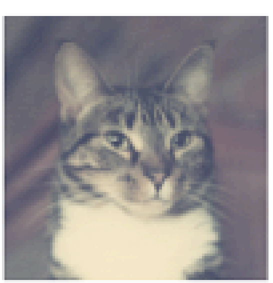
4-planets fit of [51peg_B06L](51peg_B06L) (Chi^2 = 1.48)

Download this fit
Add to My Favourites Library

Views: 14
Favourited: 0 times
Downloaded: 0 times
Rate: (rated 1 times)

Tags:

About this fit



Added on 2006-09-02, 07:11:15
From bruce01
URL http://www.oklo.org/php/

Fit parameters

Chi square	1.48
Rms	8.25
Jitter	4.42

greg's Messages:

Inbox (50)
Outbox (23)
Colleagues reqs

Tools:

My uploaded fits
Search
Gen. discussion f

Latest uploaded fi

Fit of BetaGem, 4 pl
χ^2 = 3.89
— by flanker

Latest comment:

About fit of HD131
uploaded by bruce
A little research of
literature confirms
the short period ra
velocity variations a
— by bruce01
More comments...

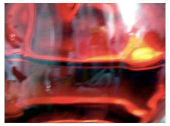
Pages:

- Acknowledgments
- What is Systemic?
- Console Tutorial #
- Console Tutorial #
- Console Tutorial #
- Resources

Computational "imaging" of extrasolar planets is very exciting and important.

1. Spitzer allows for observations of the infrared flux coming from these planets. Corot and Kepler should allow for optical reflection as a function of phase to be observed.

2. There's an intrinsic value to having the best possible views of these planets.



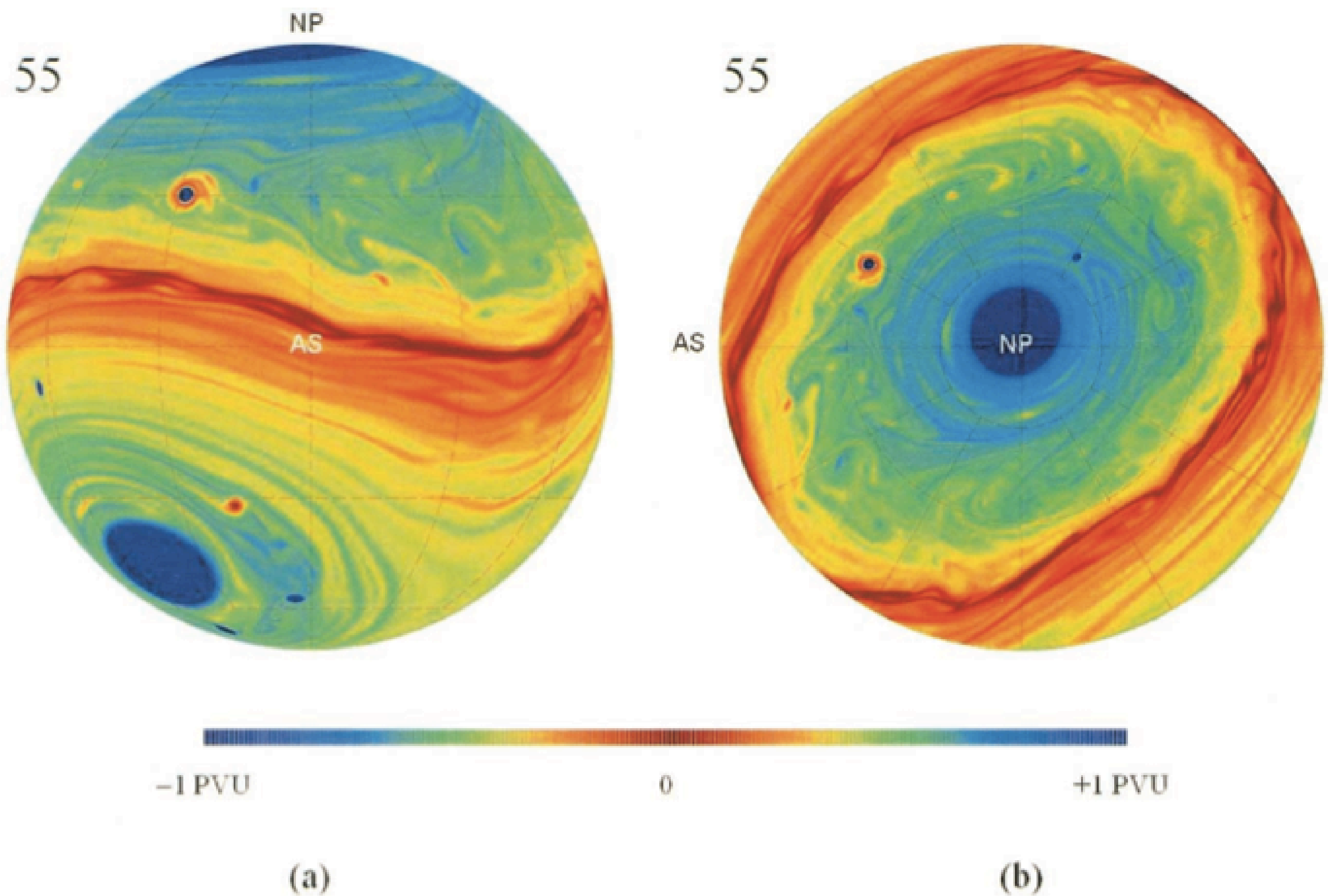
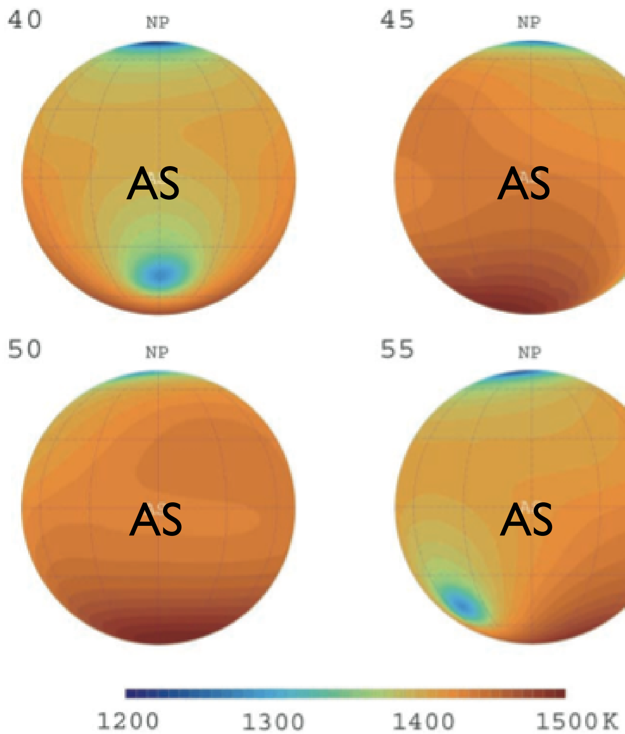
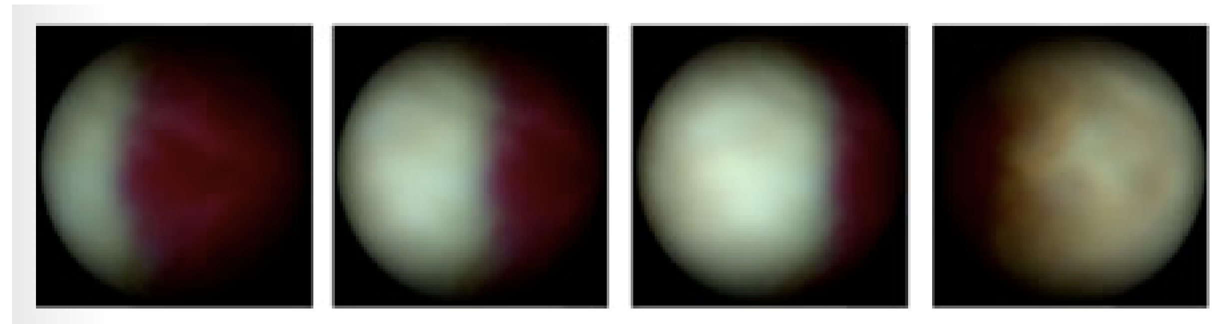


FIG. 1.—Two views of the dynamical flow tracer, potential vorticity (Holton 1992), at day (=year) 55 from our T341 (1024 × 512 grid resolution) simulation of the atmospheric circulation of HD 209458b: (*a*) orthographic projection centered at the antistellar (AS) point on the night side and (*b*) polar-stereographic projection centered at the north pole (NP). 1 PVU = 4×10^{-27} s^{-1} $\mathrm{m}^{1/K}$. The global flow is characterized by two circumpolar cyclonic (rotating in the same direction as the planet—counterclockwise in the figure) vortices at high latitudes and high-amplitude planetary waves at low latitudes.

Cho et al. 2003





Fortney et al. (Cooper-Showman Model)

Cho et al.

No consensus yet on what the flow patterns should look like at the photosphere of HD 209458b. Cho et al. with a high-resolution 2D "shallow water" model predict cold polar vortices and an equatorial jet. Cooper & Showman (2005) use lower-resolution full 3D model and predict a superrotating jet and a late afternoon "hotspot" at the photospheric level.

Our immediate goal is to get an understanding of why these simulations differ, and to do simulations for two other observationally testable scenarios.

Following Cho et al., model the dynamics using the so-called shallow water equations:

$$\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v} \cdot \nabla \mathbf{v} = -g\nabla h - f\mathbf{k} \times \mathbf{v}$$

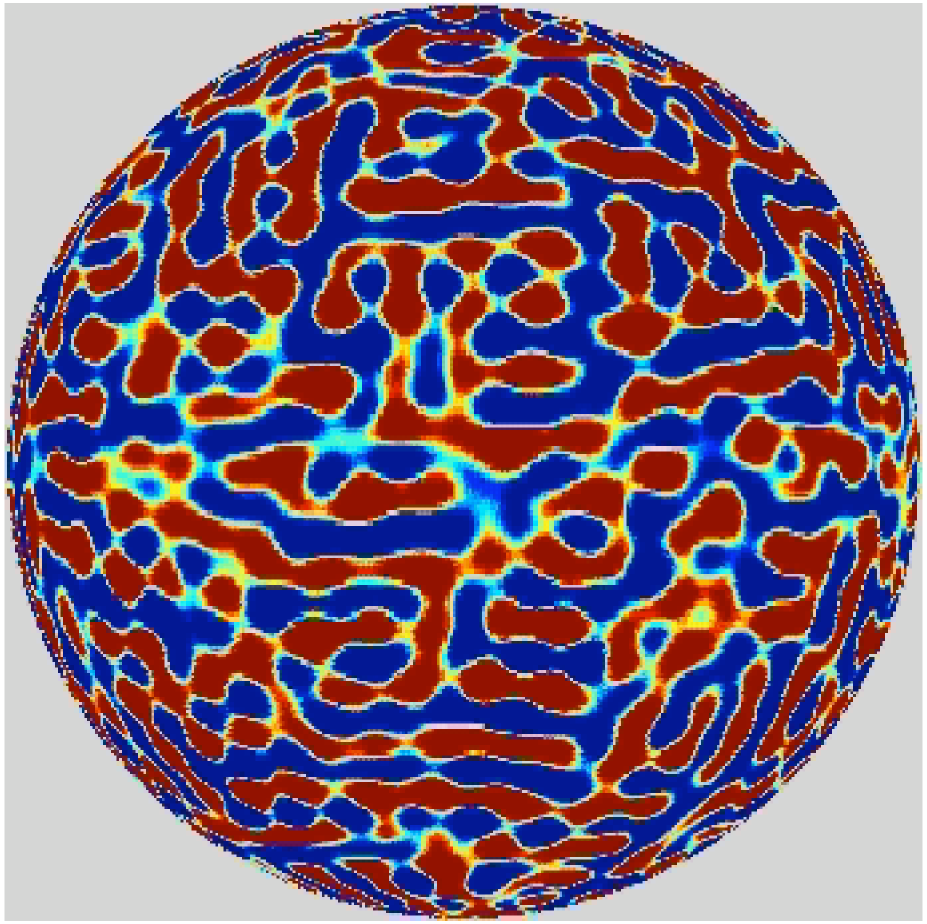
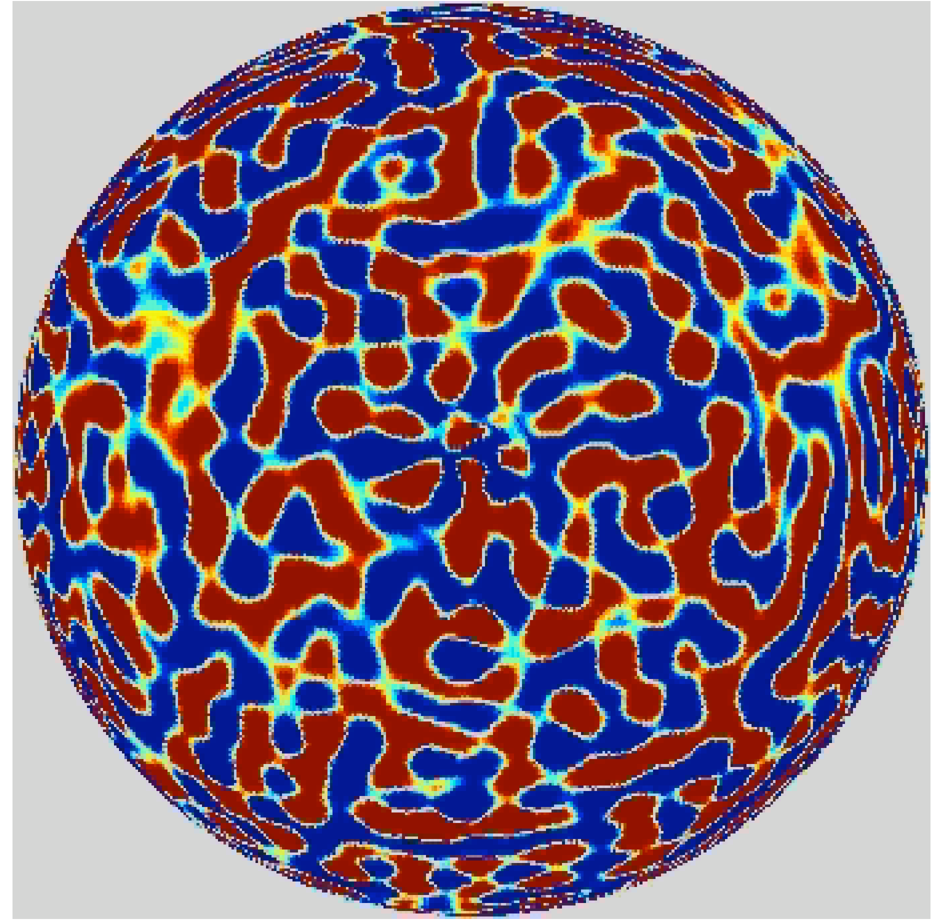
$$\frac{\partial h}{\partial t} + \mathbf{v} \cdot \nabla h = -\mathcal{K} h \nabla \cdot \mathbf{v} - (h - h_E)/\tau_d$$

Height, *h* of the fluid layer is proportional to temperature. Departures are from a forced equilibrium height profile across the planet, e.g. for synchronous rotation:

$$h_E = \eta \cos\phi \cos\lambda \qquad \mathcal{K} = R/c_p$$

τ_d = radiative time constant for "Newtonian" cooling

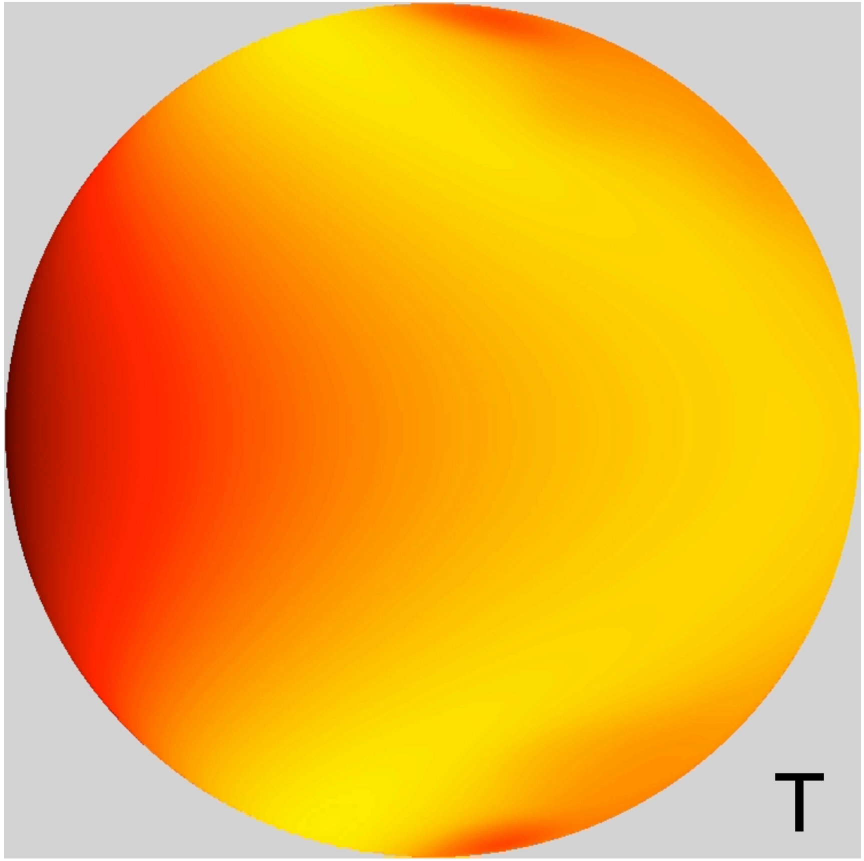
η = day-night equilibrium temperature difference

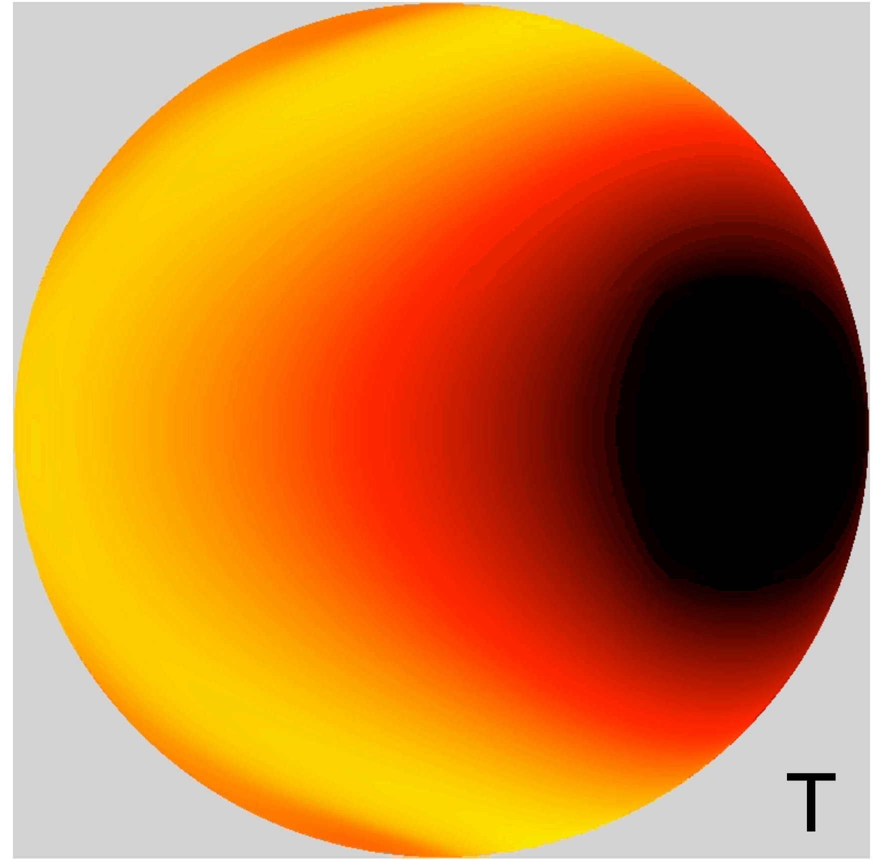
Equatorial View $\nabla \times \mathbf{v}$ Polar View

P=3.52 d, R=1.3 Rjup, M=0.69 Mjup, 384x193 res, t=40 rotations
Evolution of a random velocity field on a planet with no forcing.

Conclusion -- Cho simulations are largely driven by initial conditions. They use a radiative time constant of 10 days. Results of Iro et al. 2005 suggest 8 hours at photosphere is more realistic.

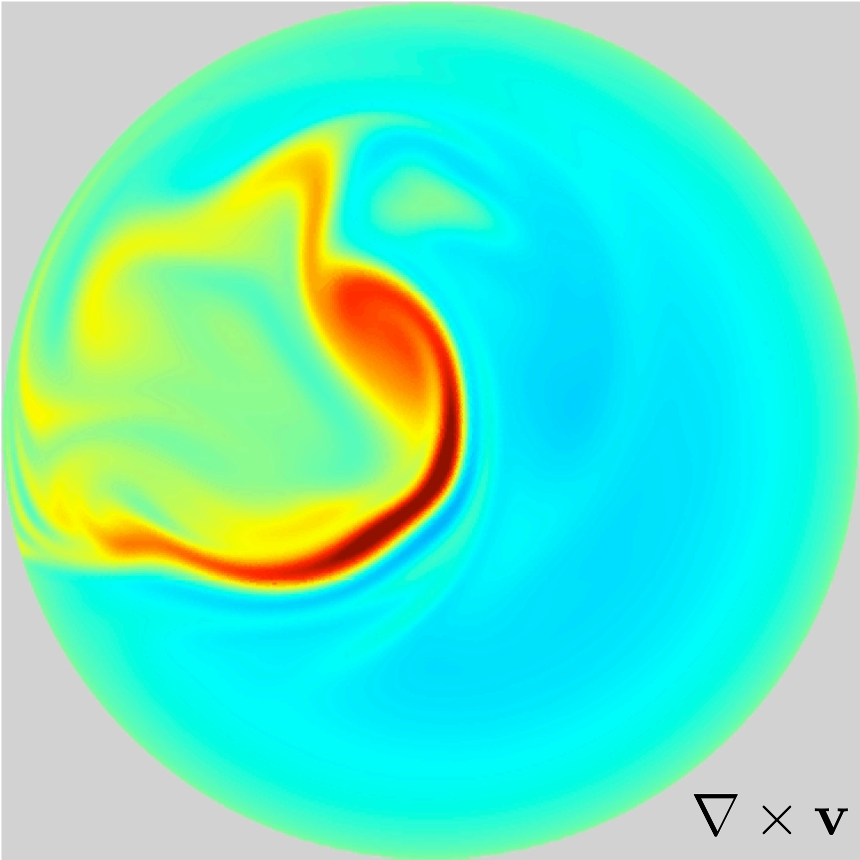


Dayside View

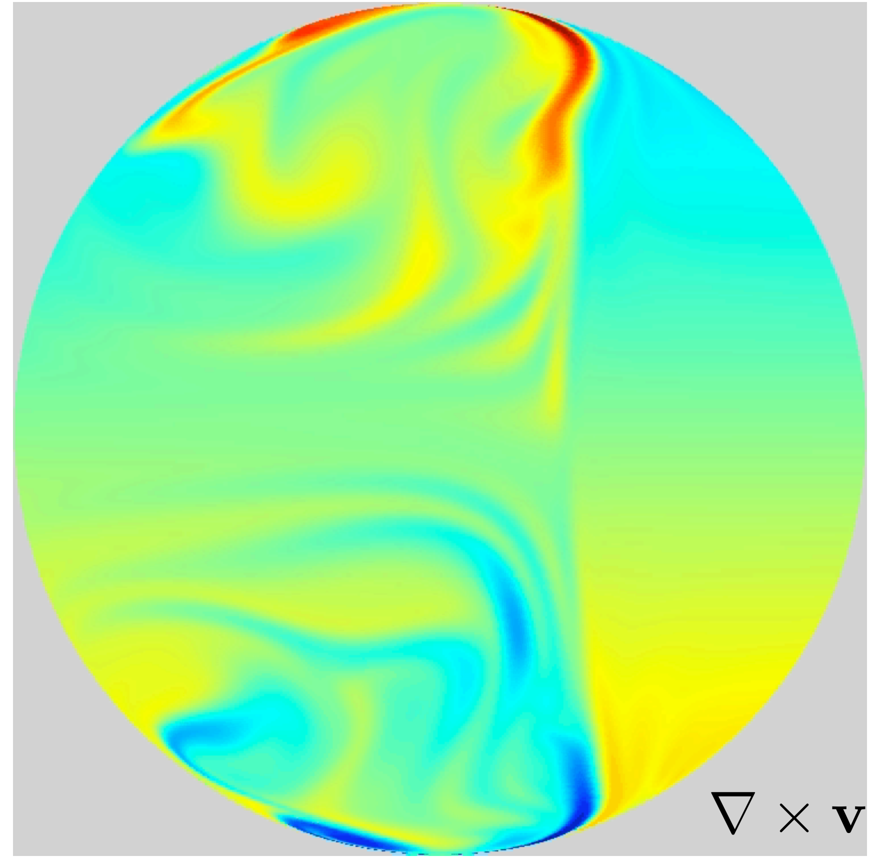


Nightside View

Based on the results of Iro et al. 2005, we assume a photospheric radiative time constant of 8 hours, and a day-night equilibrium temperature difference of 800K. The system is allowed to evolve for 250 rotational periods, and then plotted for 4 rotations.
Flow pattern is qualitatively similar to Cooper & Showman (2005).



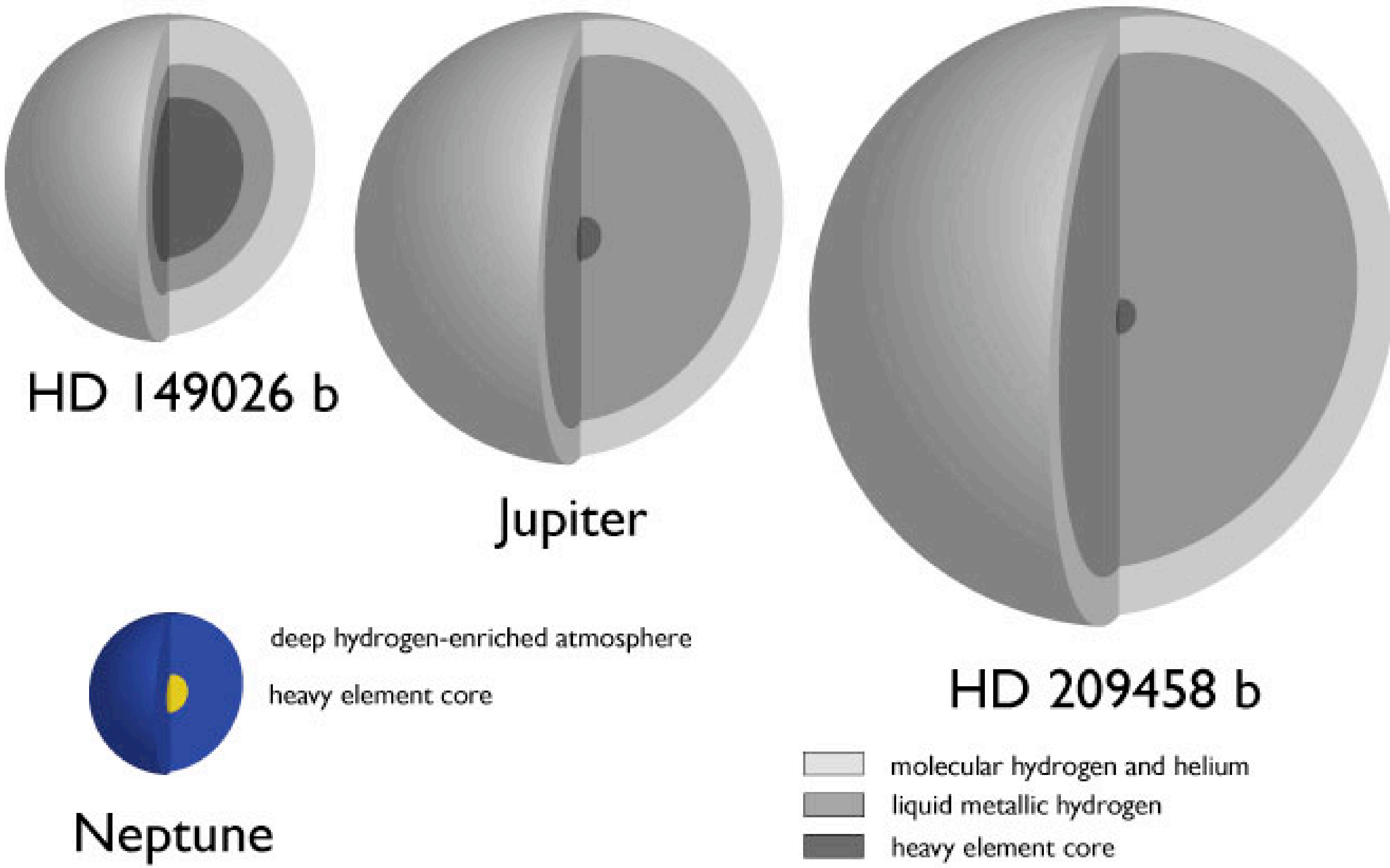
North Pole View



Equatorial View

Because of the radiative time constant used, our overall velocity flow pattern for HD 209458b is more similar to the Cooper Showman model, and predicts a significant day-night side variation.

The size of HD 209458 b and several other known transiting planets is a real problem.



OBLIQUITY TIDES ON HOT JUPITERS

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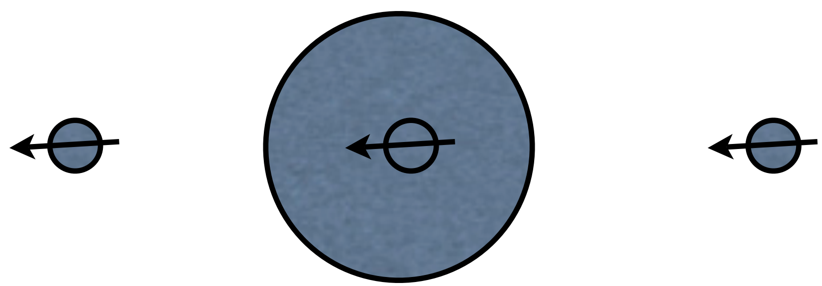
Received 2005 May 13; accepted 2005 June 20; published 2005 July 15

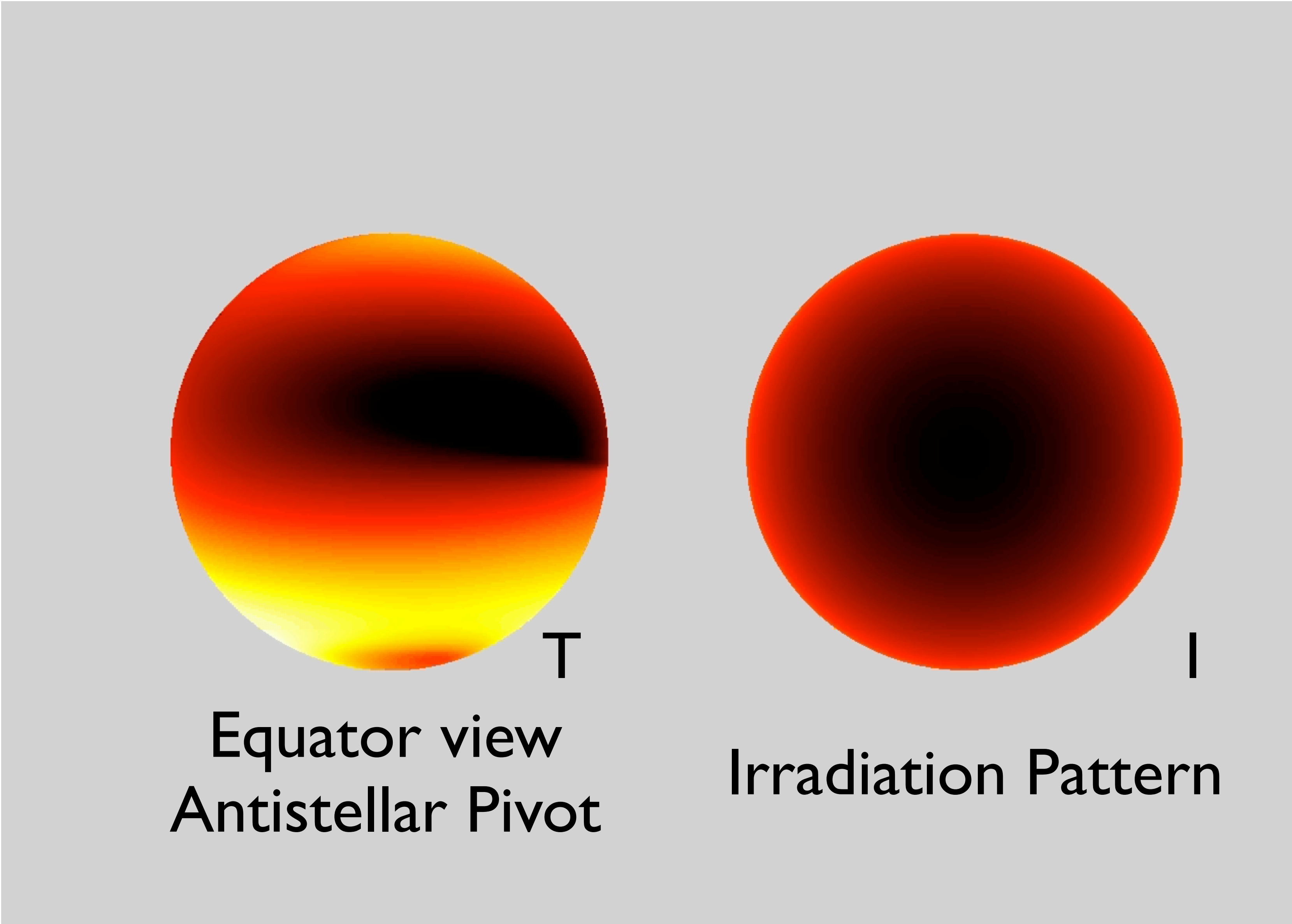
ABSTRACT

Obliquity tides are a potentially important source of heat for extrasolar planets on close-in orbits. Although tidal dissipation will usually reduce the obliquity to zero, a nonzero obliquity can persist if the planet is in a Cassini state, a resonance between spin precession and orbital precession. Obliquity tides might be the cause of the anomalously large size of the transiting planet HD 209458b.

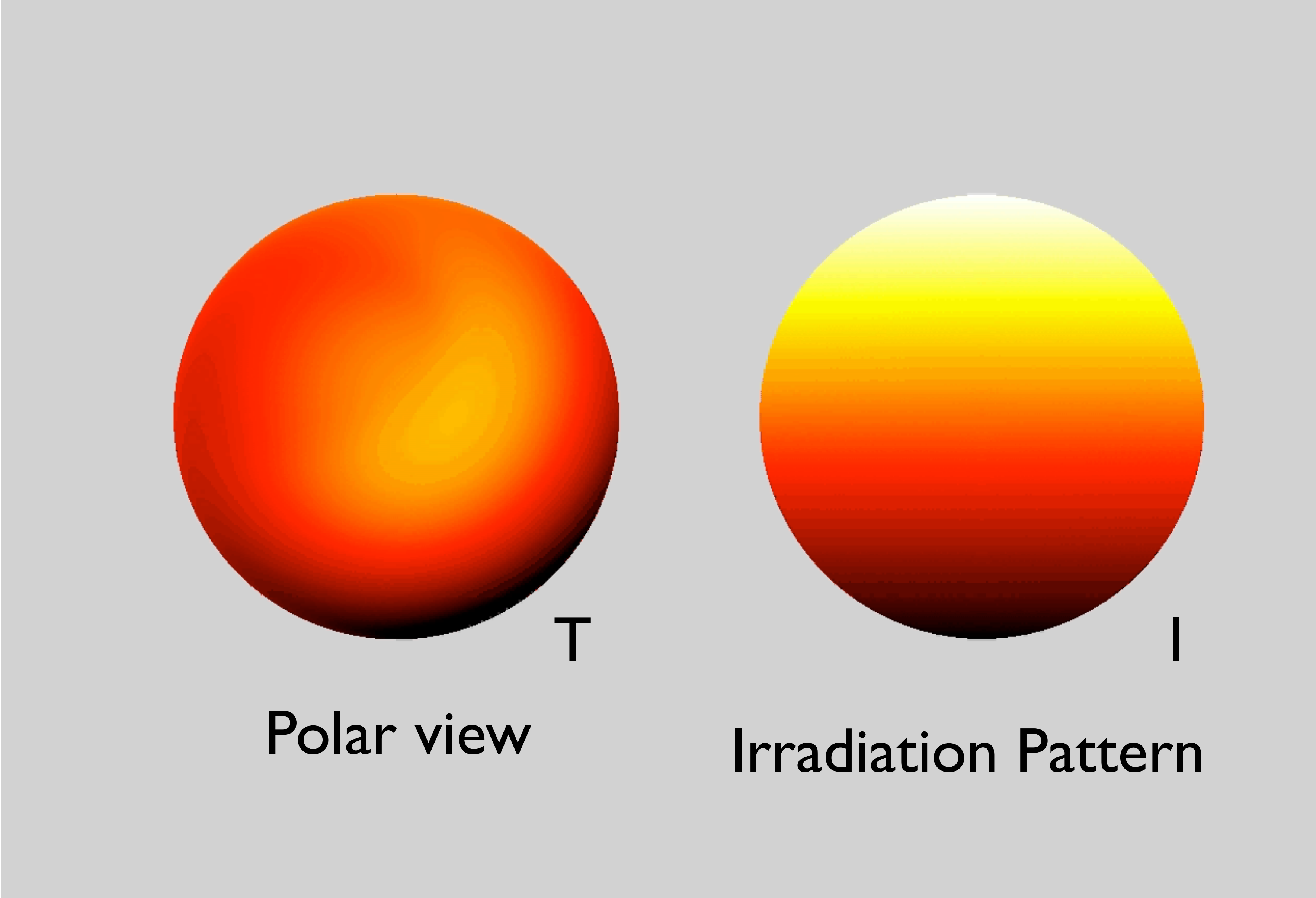
Subject headings: celestial mechanics — planetary systems: formation — planets and satellites: formation — stars: individual (HD 209458)



Spins once per orbit, but the rotation axis is tipped over.

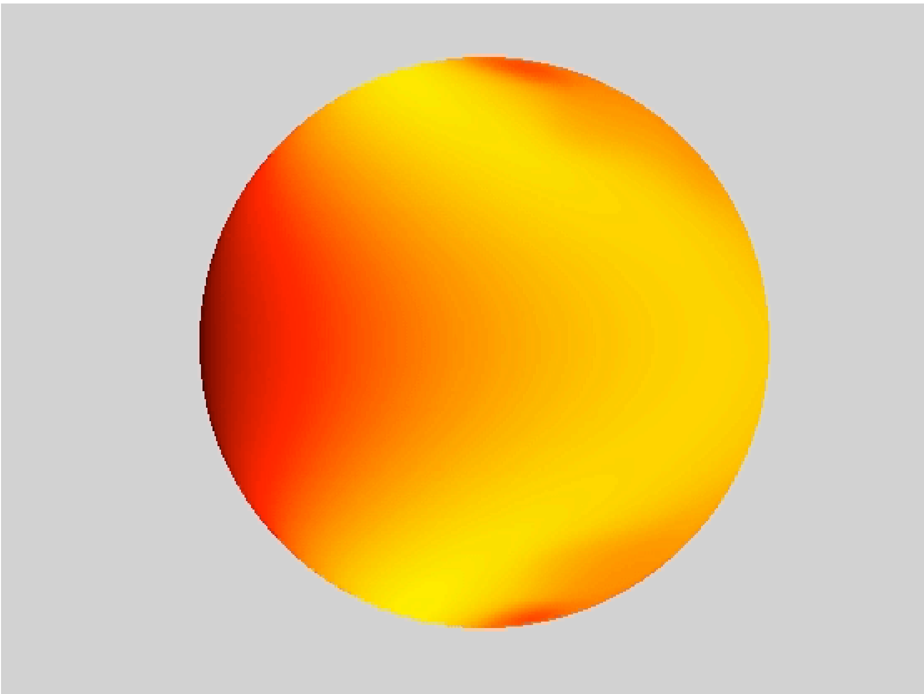


The irradiation pattern for a planet in Cassini State 2 is totally different, and leads to a different hydrodynamic response in the atmosphere.

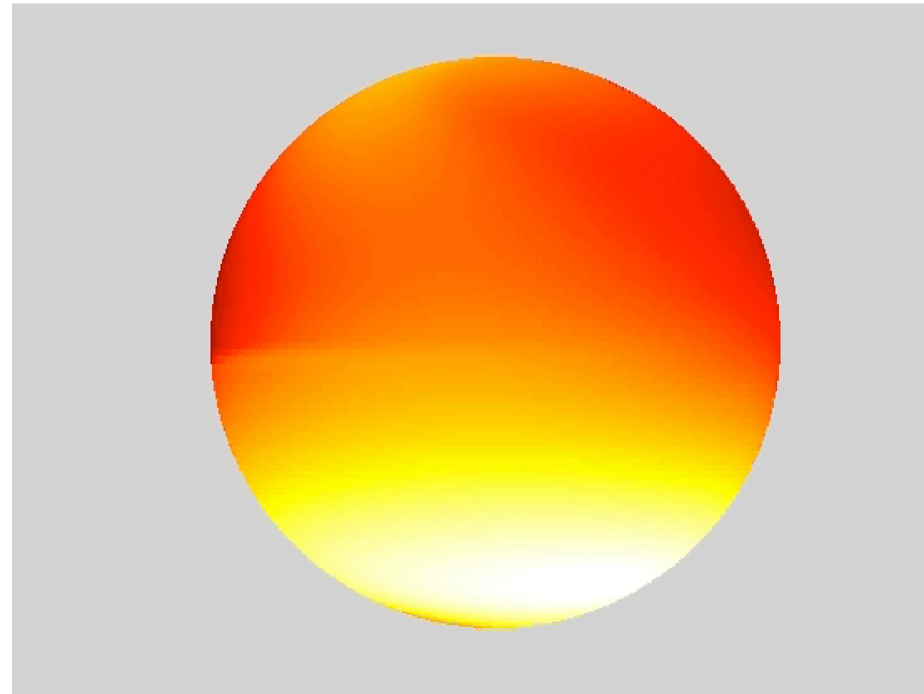


The irradiation pattern for a planet in Cassini State 2 is totally different, and leads to a different hydrodynamic response in the atosphere.

View from Earth

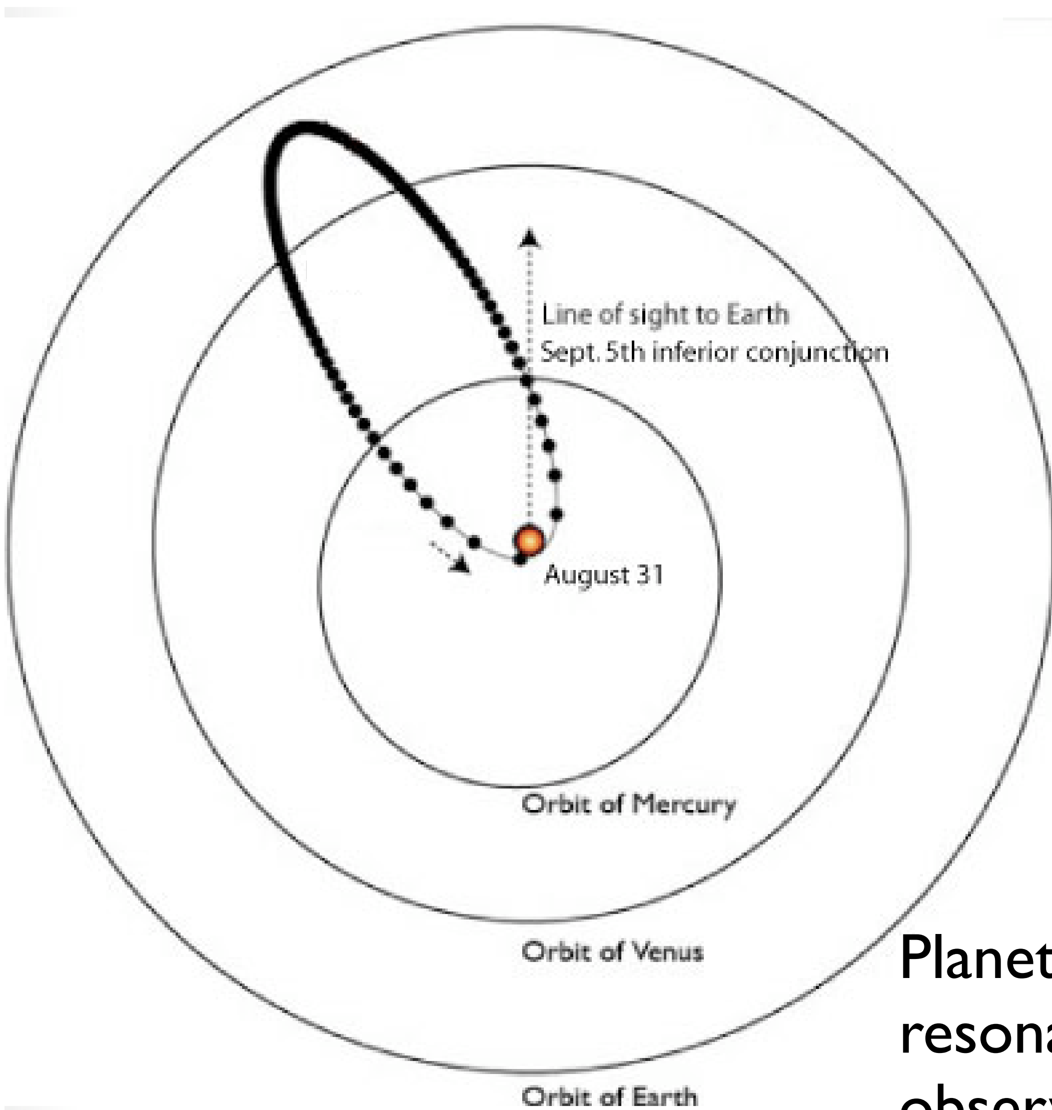


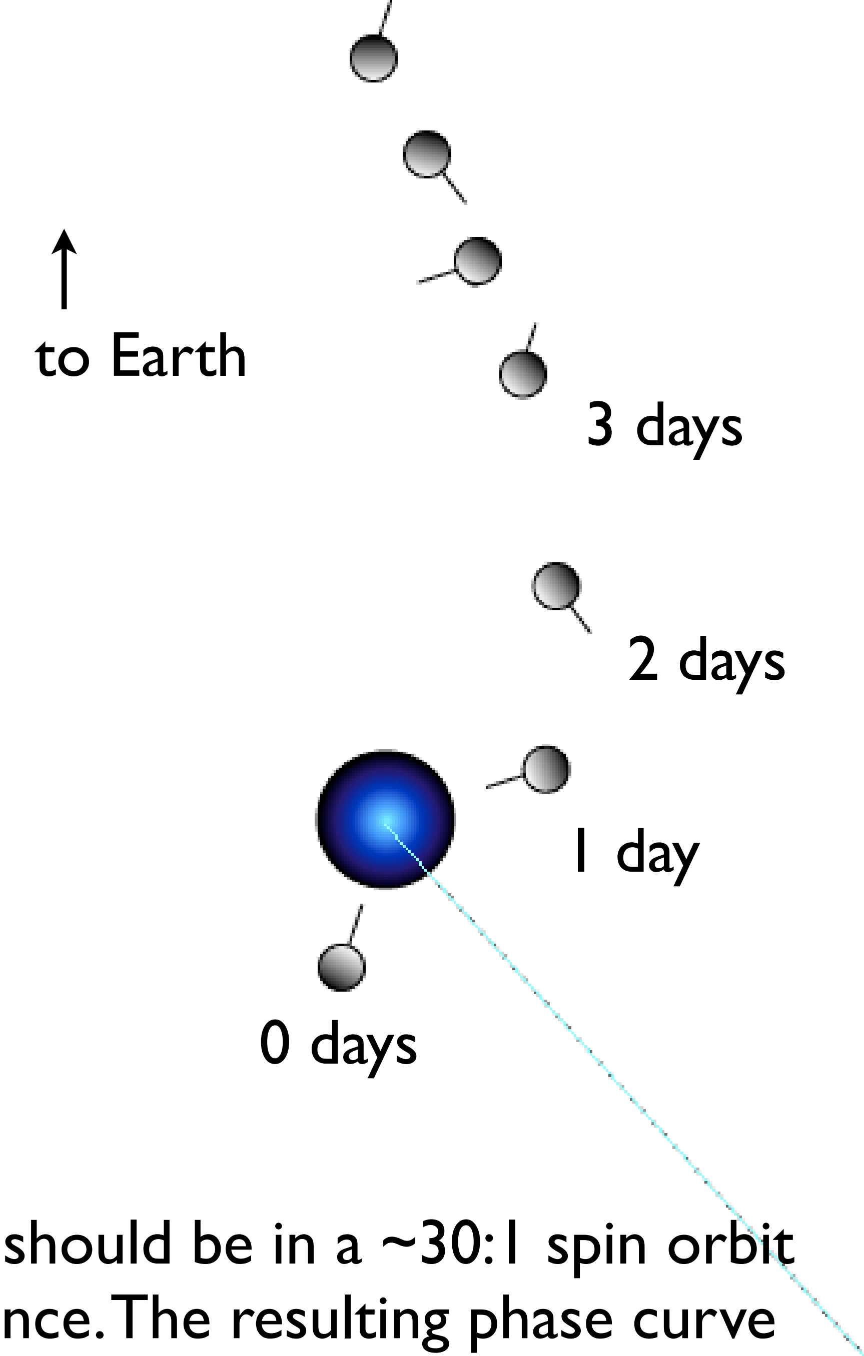
Cassini State 1



Cassini State 2
(equatorial alignment)

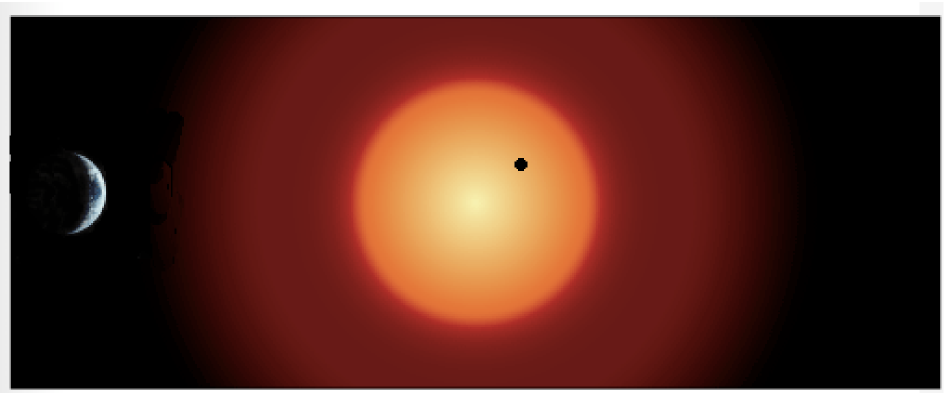
HD 80606 b

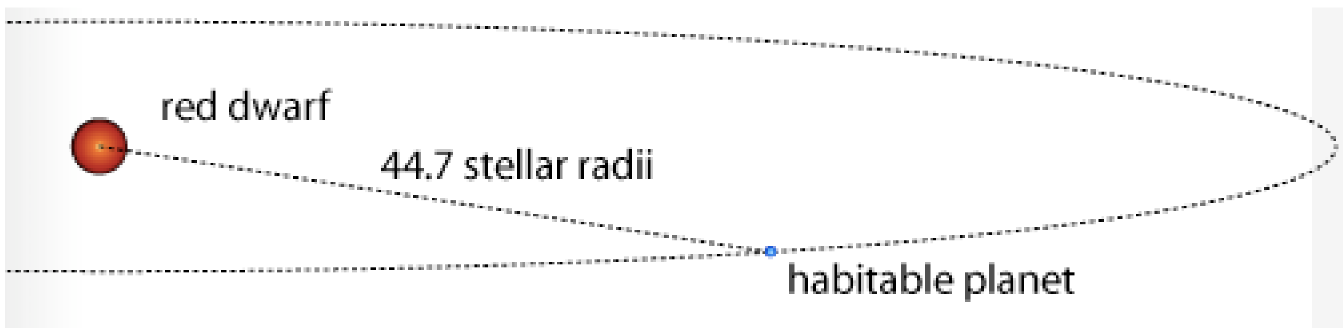




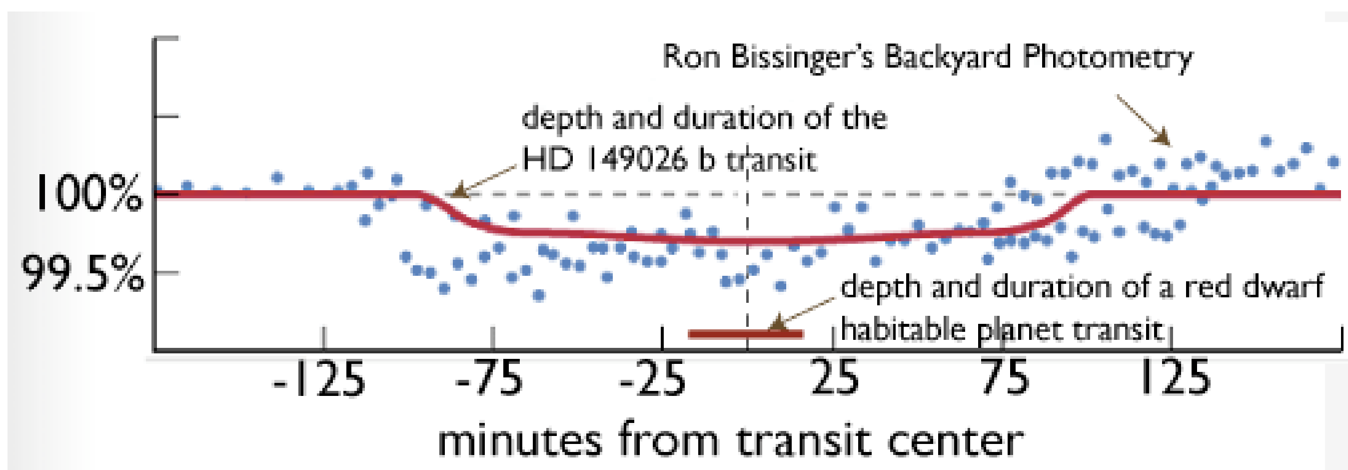
Planet should be in a ~30:1 spin orbit resonance. The resulting phase curve observable with Spitzer in Nov. 2007 will tell us about the radiative time constant of the atmosphere.

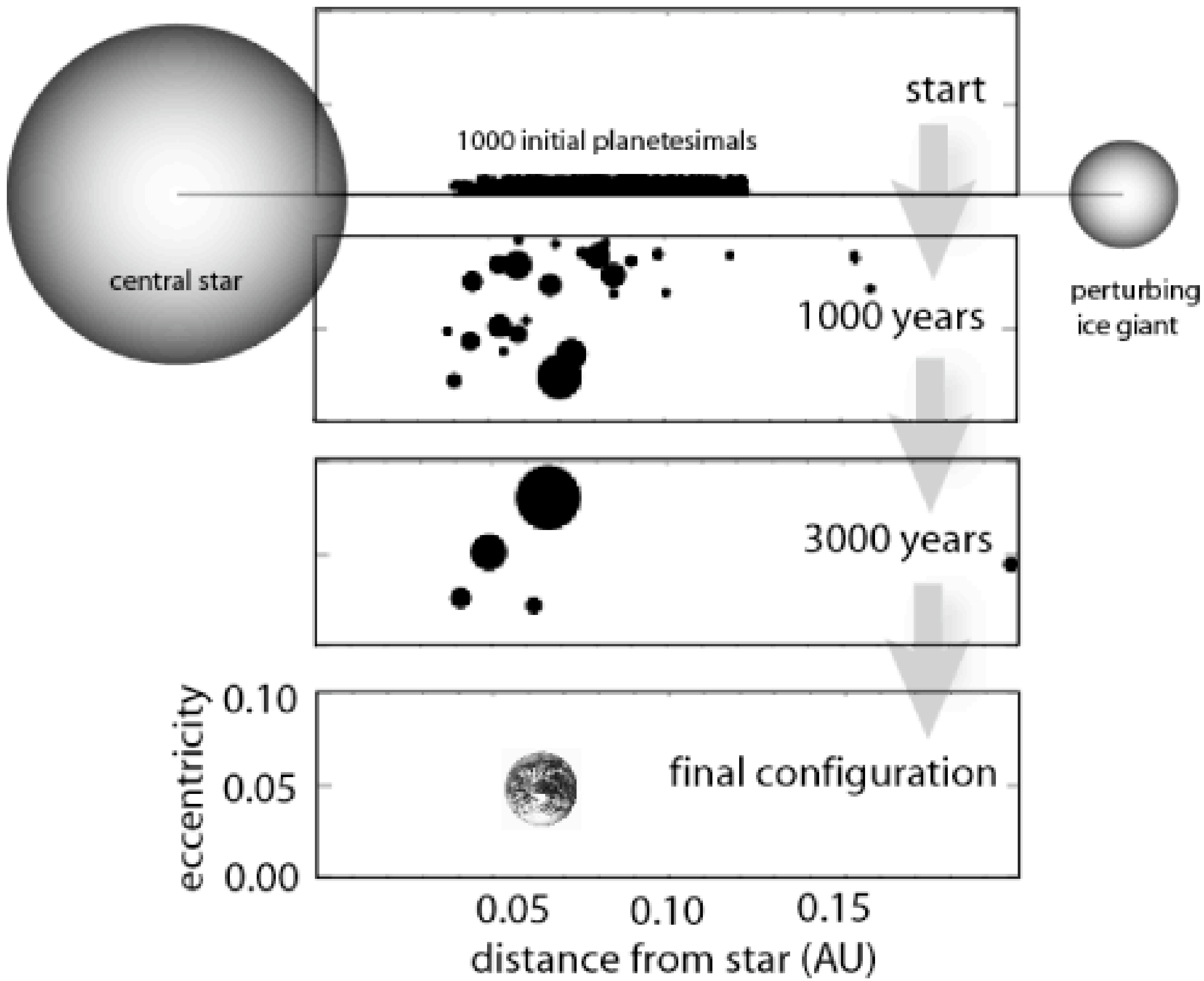
Switch topics: How can we find the first habitable extrasolar planet? (And how much will it cost?)



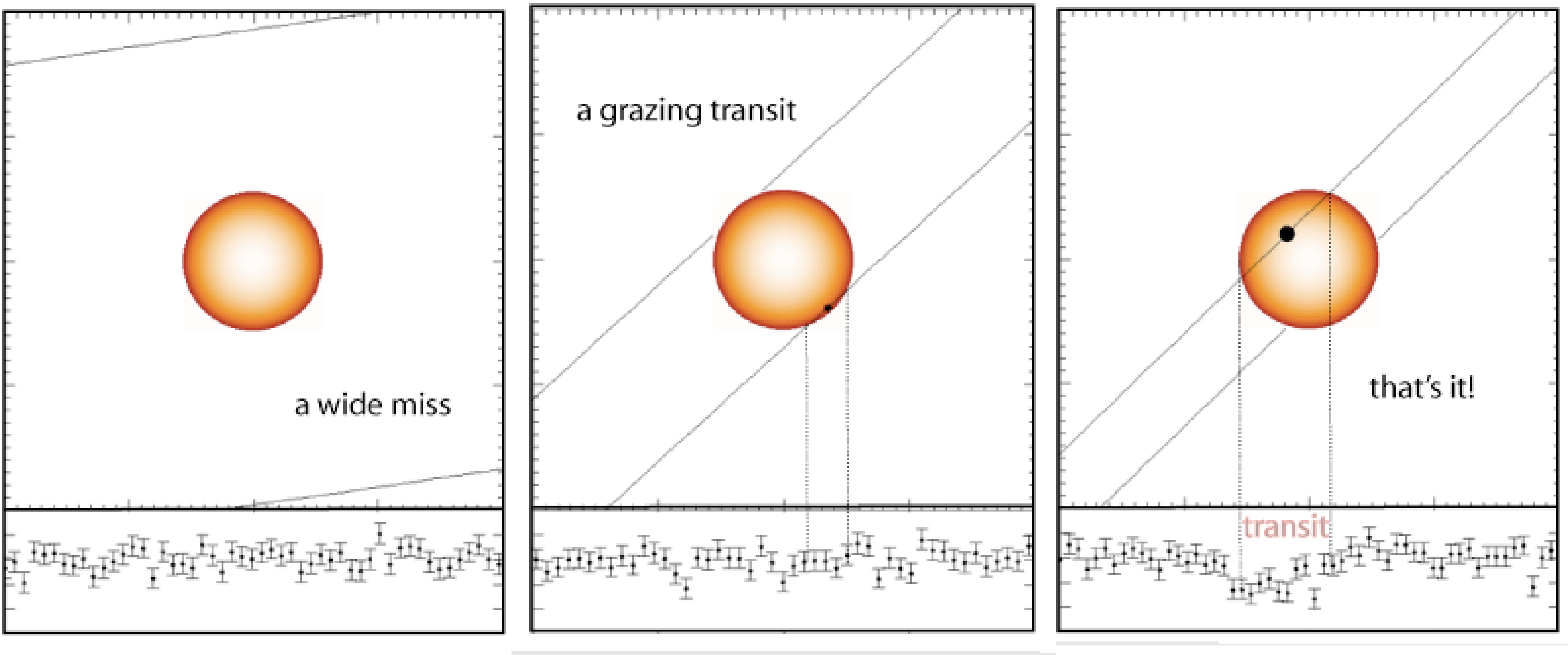


Cheapest possibility: If a habitable Earth-Mass planet is transiting Barnard's Star, it won't cost *anything* to detect.

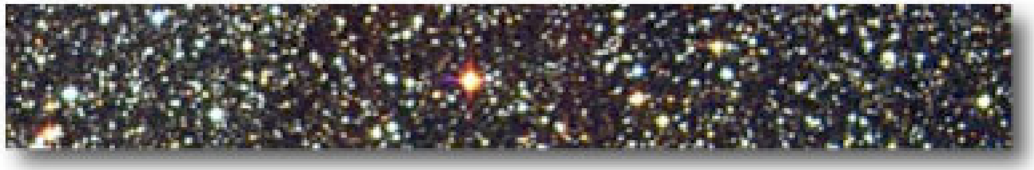




Our accretion simulations show that the formation of habitable planets around the lowest-mass stars is dependant on the initial planetesimal surface density in the protoplanetary disk. A targeted search of M-type dwarfs should be put at a very high priority.



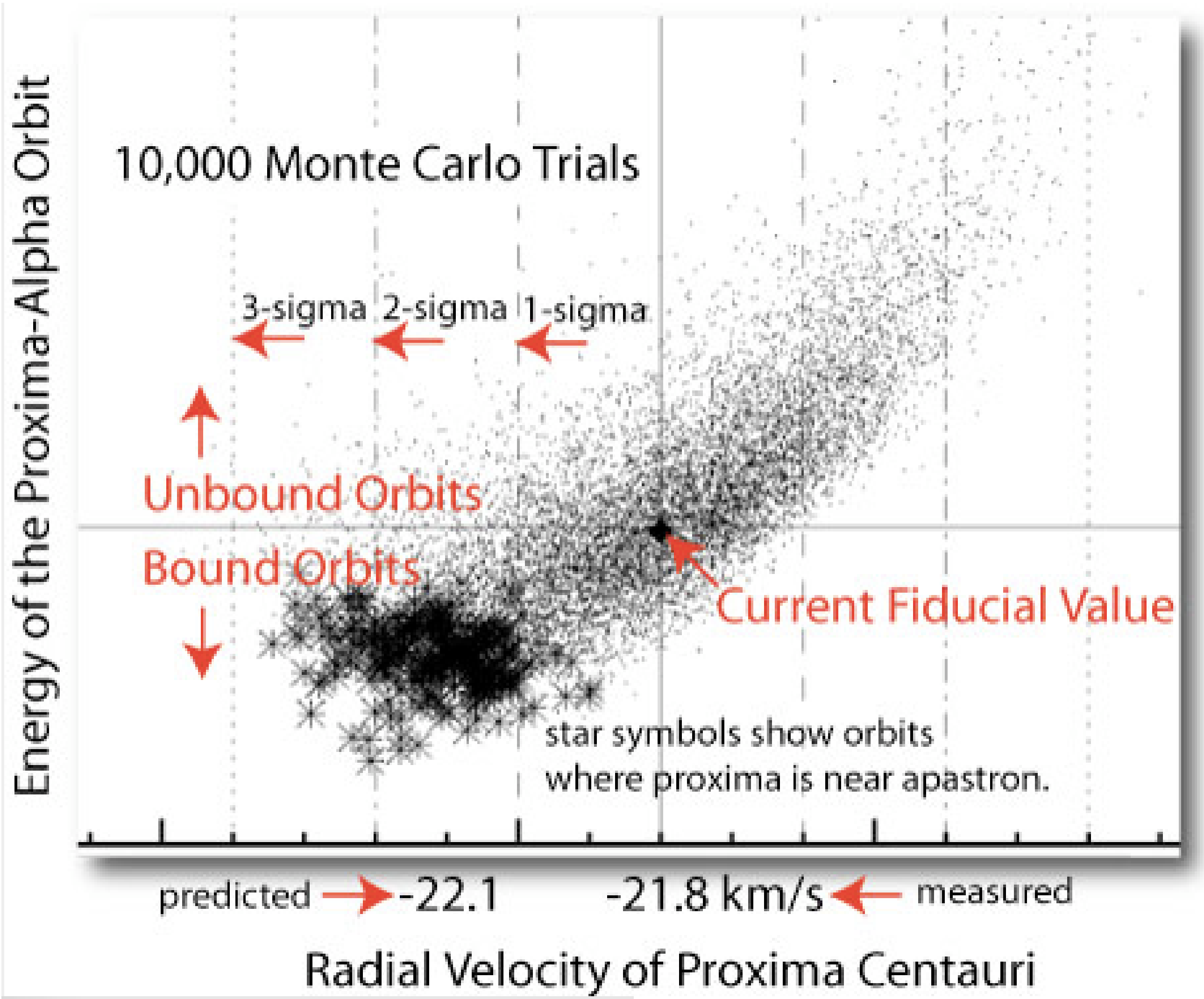
Monte-Carlo simulation using systems that come out of our planet accretion simulations. Photometric time-series have the characteristics of typical transitsearch.org data submitted by Ron Bissinger.

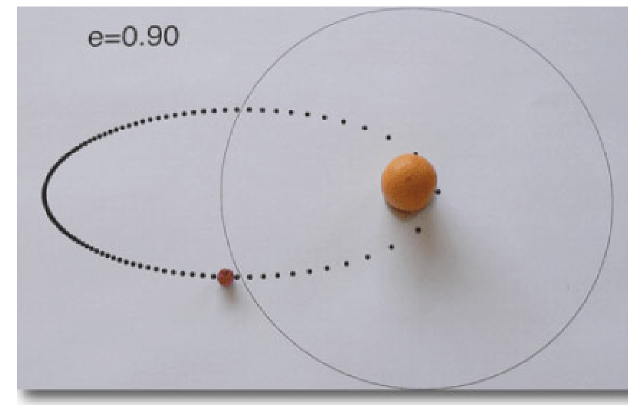


Proxima

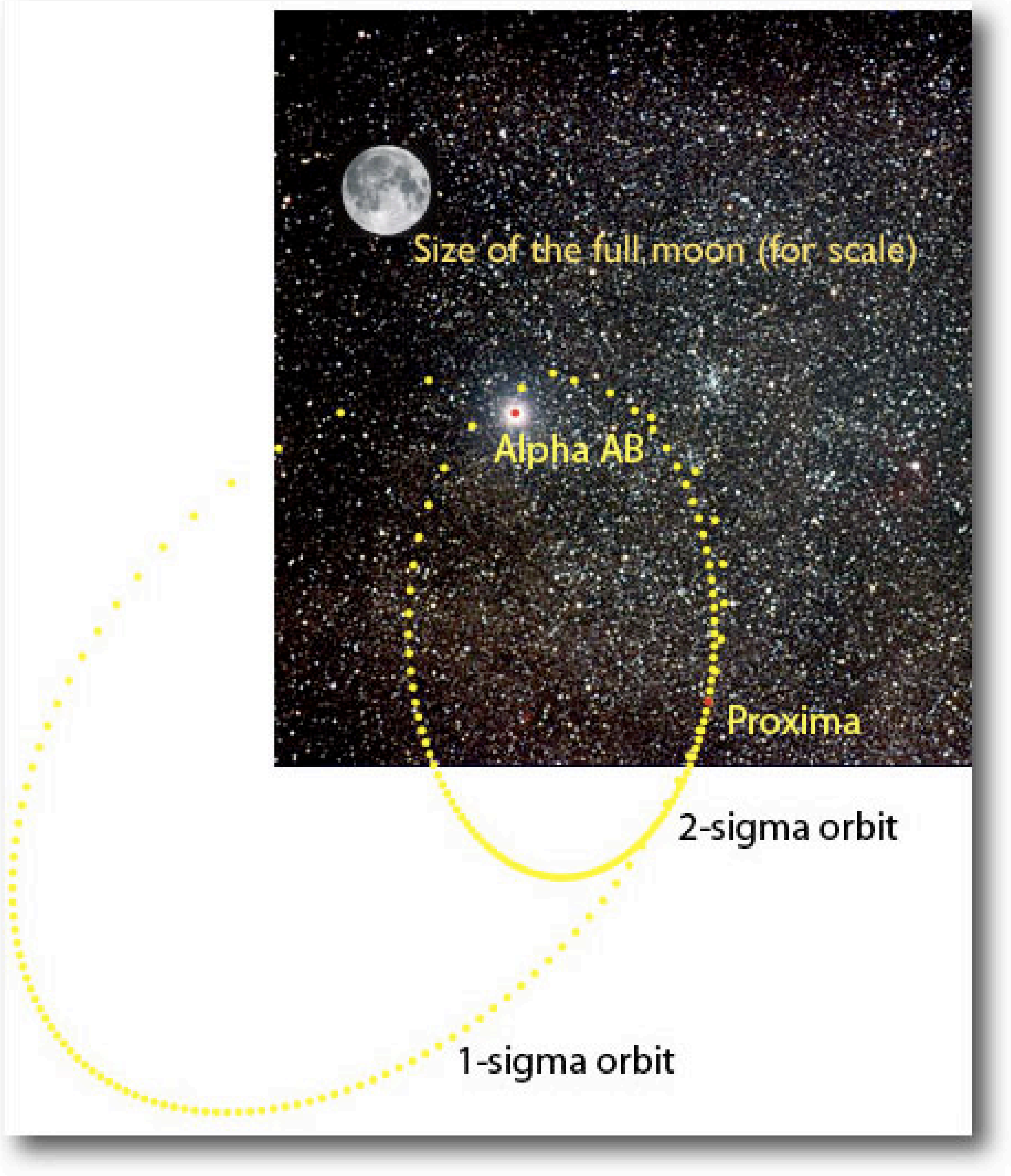
Anosova et al (1994) and Matthews and Gilmore (1993) using pre-Hipparcos astrometry both found that Proxima Centauri is unbound to Alpha Centauri AB. (Despite extremely similar space motion and distances). This seemed completely bizarre, and had been bothering me for the last 10 years.

UCSC student Jeremy Wertheimer reanalyzed the latest kinematic data for his class project in my AY212 class.





Using Hipparcos astrometry, and an updated radial velocity for Proxima, we found that Proxima is indeed likely bound to Alpha AB. Under the assumption that Proxima is most likely to be found near apastron, we predict a radial velocity of -22.1 km/s, which differs by 1.5 sigma from the current best value. (Wertheimer and Laughlin 2006, AJ in Press)



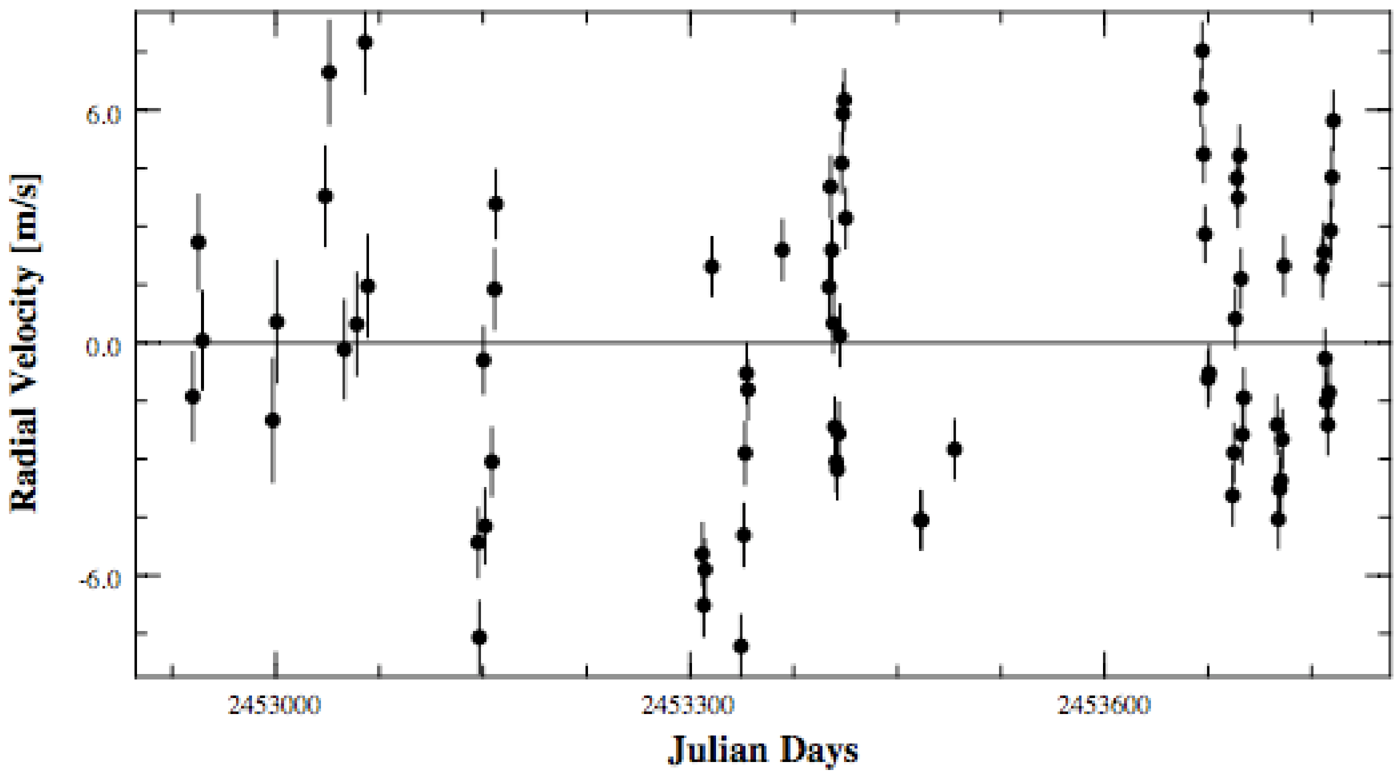
Having Proxima bound to Alpha AB yields some nice consequences

1. Metallicity should be the same for all three stars. Proxima is metal-rich. Only one red dwarf known to be richer. This is good for empirical calibrations.

2. Stars are co-eval (this calibrates red dwarf evolutionary models).

3. Proxima periodically stirs up Alpha AB circumbinary comet disk, delivering volatiles to circumprimary planets.

The HD 69830 Detection is a Groundbreaking Discovery



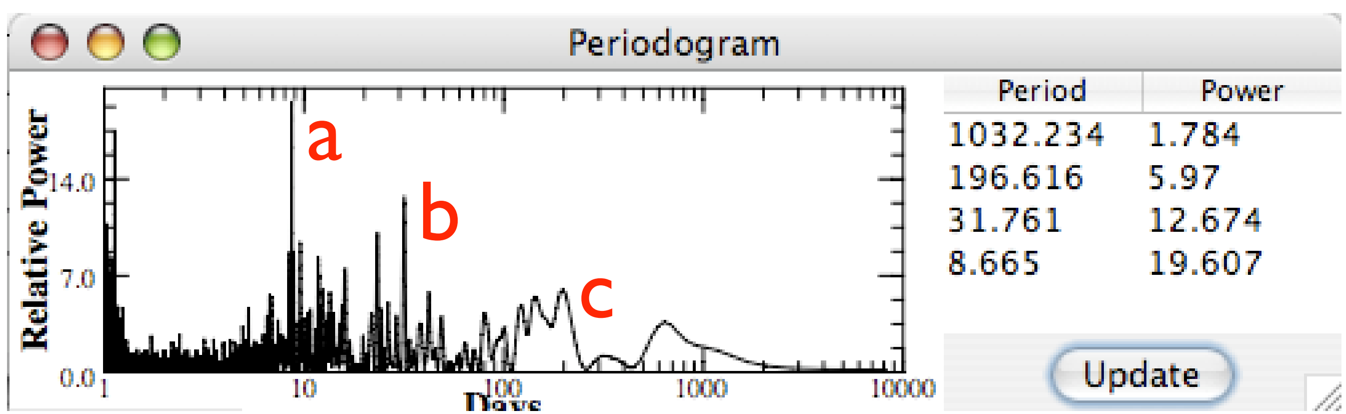
6 m/s

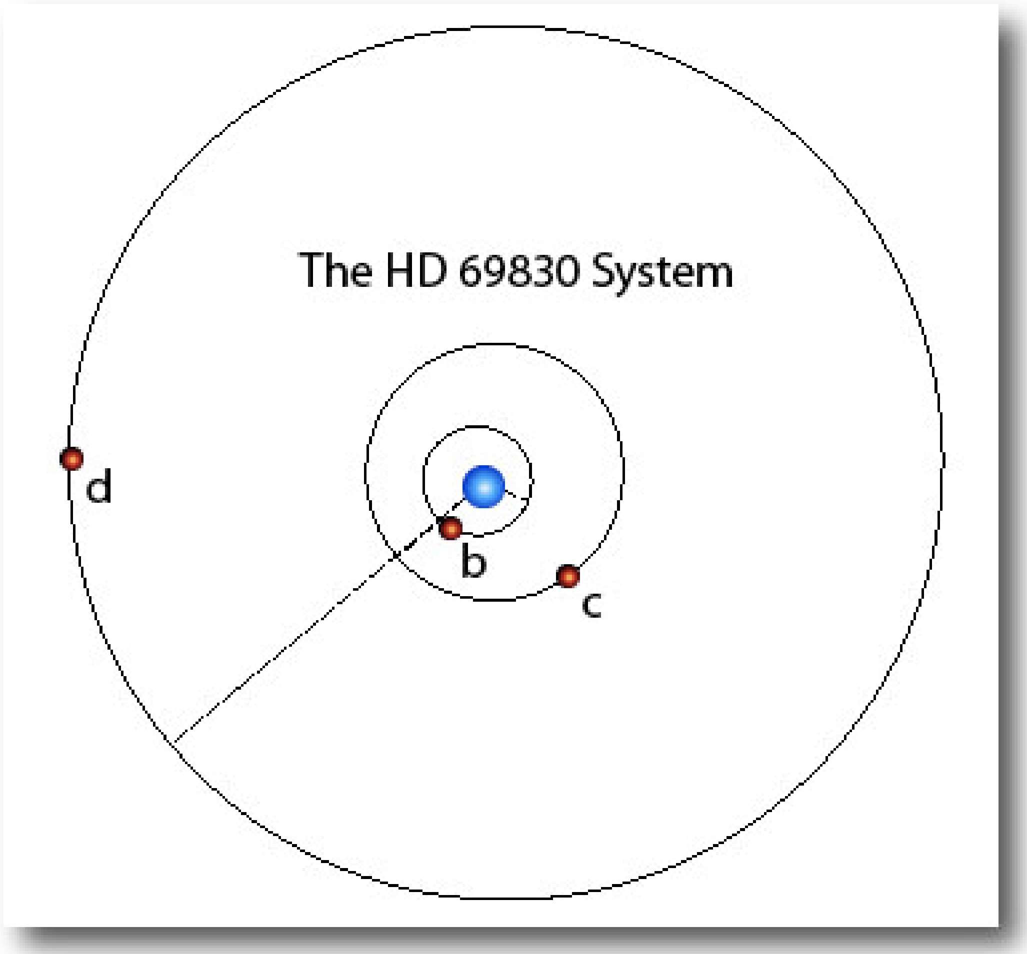
Type K0

0.86 Msun

V=5.95

<1 m/s “jitter”



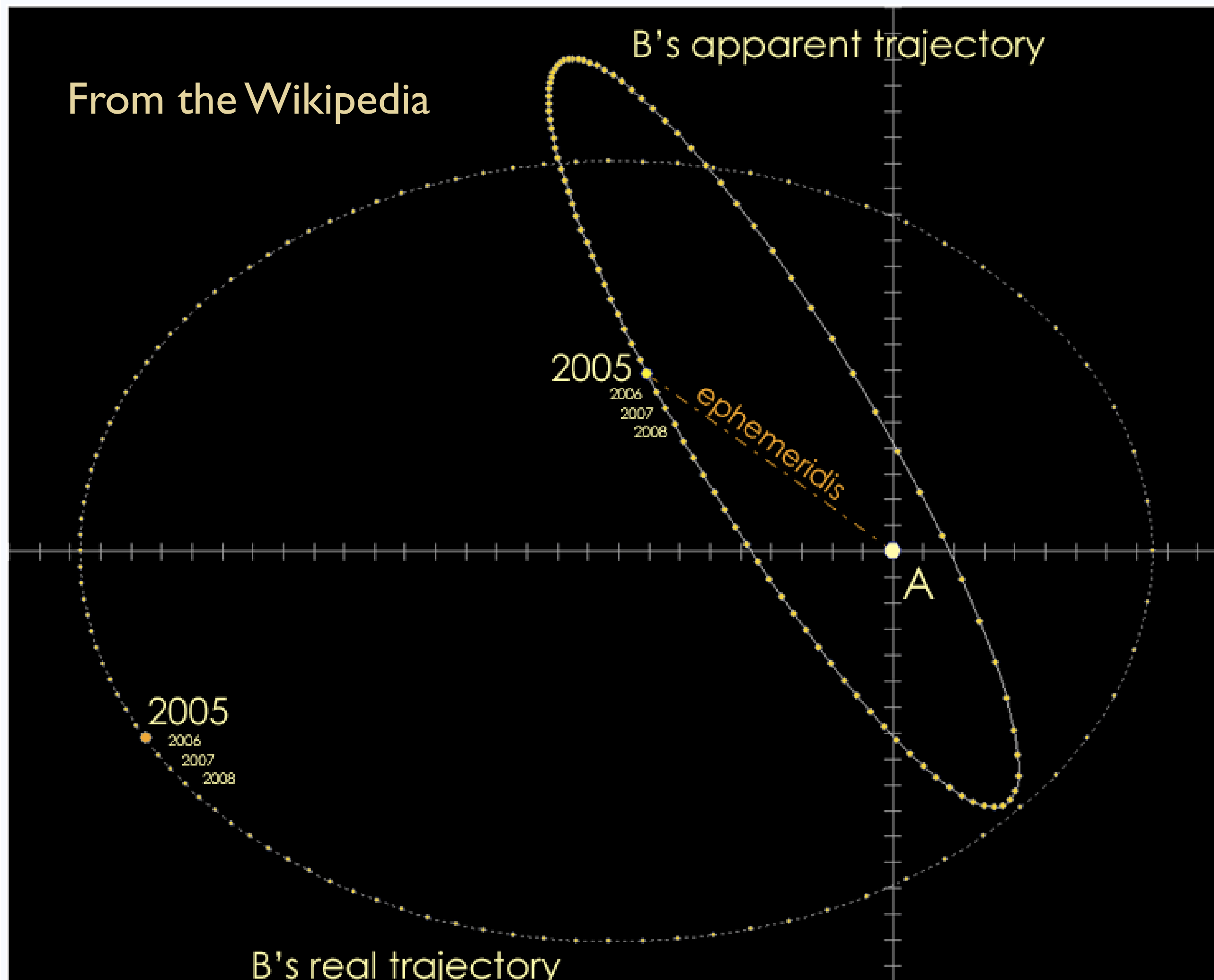


10.2 Earth Masses
11.8 Earth Masses
18.1 Earth Masses

The error on the half-amplitude, K, for planet b *is 0.2 m/s*

WANTED: High Quality RV Candidate star. A successful applicant should be old (6-8 Gyr) MS Dwarf, Med. to wide binary w/ orbital Plane: inclined by 11 degrees to line of sight or less pref.; Metallicity: >0.2 dex (plenty of planet-forming material); HZ: 0.7 AU, K=20 cm/sec for an Earth-mass planet; V mag=0.8 (100x brighter than typical high quality applicant) Spectral type K0. Dead quiet photosphere. No variables please. Near-twin of HD 69830 pref. No gas giants. Circumpolar in SH (Dec=-60), must be available nearly year round. Send HD or HIP number to: oklo@mac.com

Alpha Centauri B

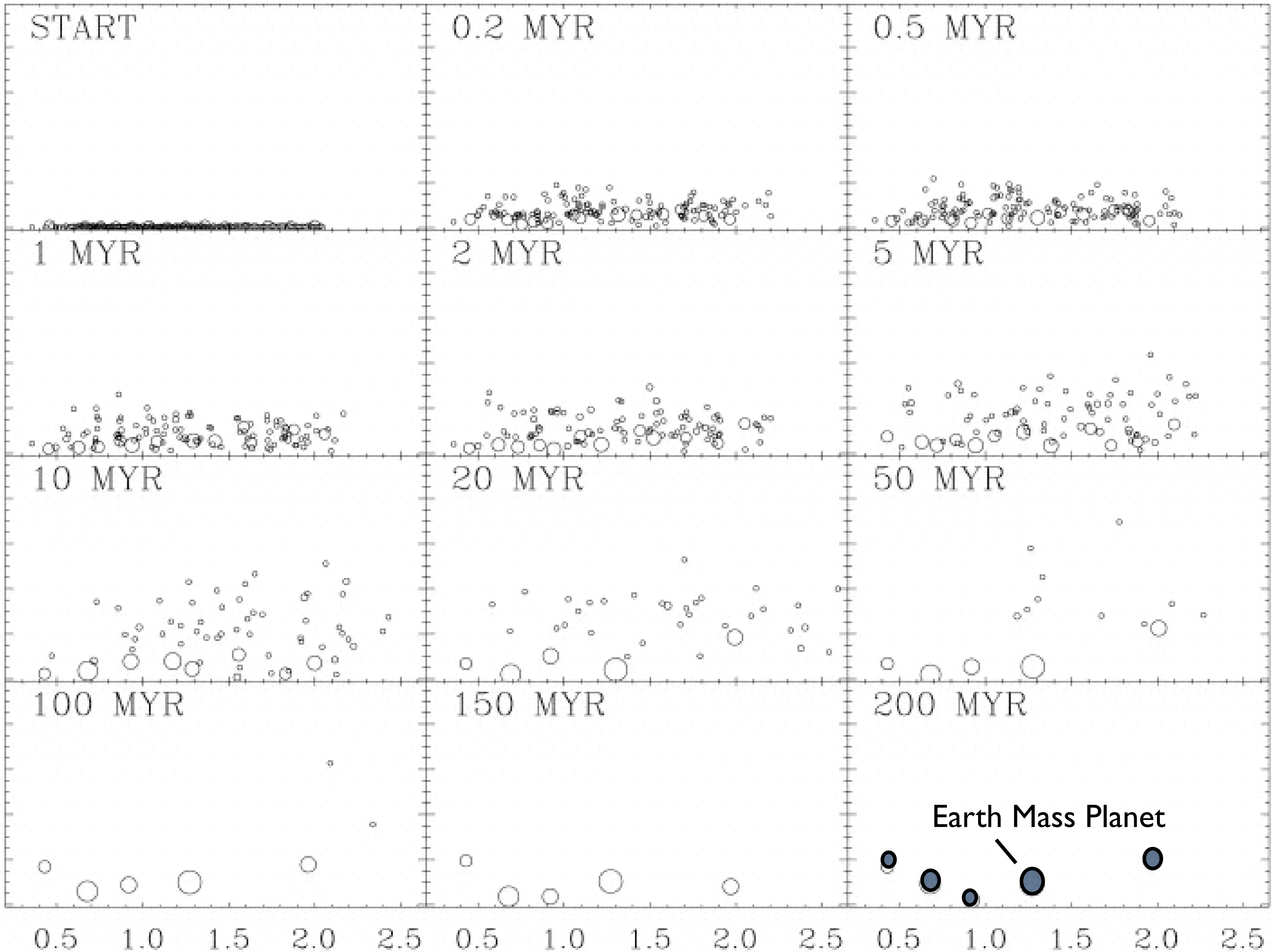


Terrestrial Planet Formation in the Alpha Centauri System
Quintana et al. (2002) ApJ, 576, 982

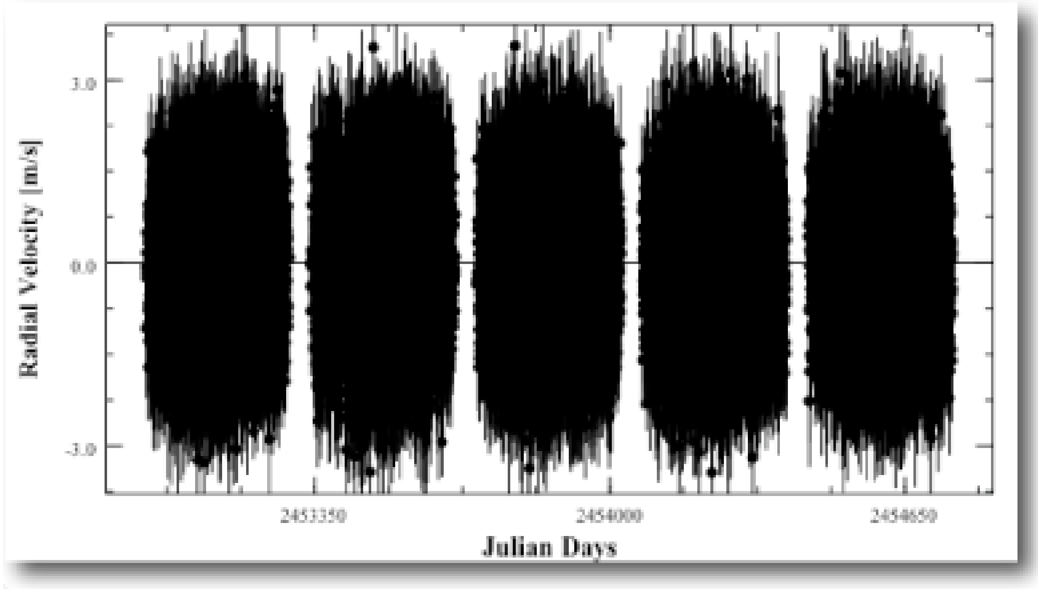
ABSTRACT

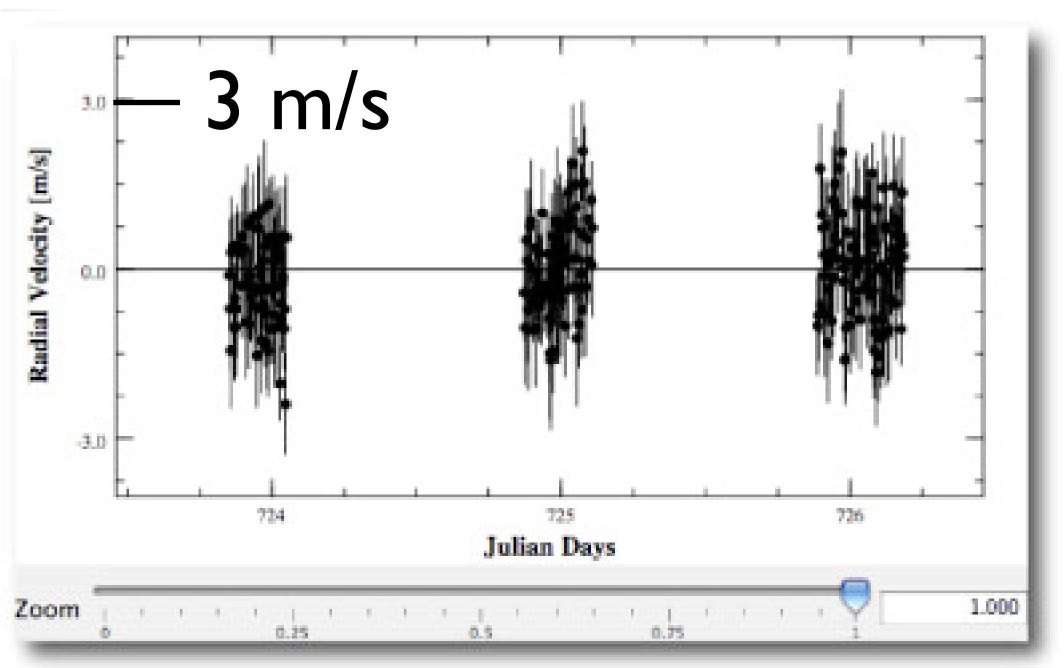
We examine the late stages of terrestrial planet formation around each star in the α Centauri A and α Centauri B binary system. Each integration begins with a "bimodal" mass distribution of 14 large embryos embedded in a disk of smaller planetesimals orbiting one of the stars. These initial conditions were chosen because when they are used in simulations about a single star with giant planets, they lead to systems most closely resembling our solar system. However, it is far from certain that such a planetesimal distribution actually occurs either in single or binary star systems. We follow the evolution of the accreting bodies at various values of the inclination of the midplane of the disk relative to the binary orbit for 200 Myr to 1 Gyr. In simulations in which the midplane of the disk was inclined $\leq 30°$ relative to the binary orbital plane, three to five terrestrial planets were formed around α Cen A. When the embryos in the disk were moving retrograde relative to the binary plane, four or five terrestrial planets formed [redacted] with α Cen A perturbing the system in the same plane. [redacted] In contrast, terrestrial planet growth around a star lacking both stellar and giant planet companions is slower and extends to larger semimajor axis for the same initial disk of planetary embryos. In systems with the accreting disk initially inclined at 45° relative to the binary star orbit, two to five planets formed despite the fact that more than half of the disk mass was perturbed into the central star [redacted]

We are currently running additional new simulations for Alpha Cen B with a finer resolution, wider parameter variations, and Fe/H~0.2



A Sample Calculation from Quintana et al.





Commandeer HARPS and use it to observe *only* Alpha Centauri B.

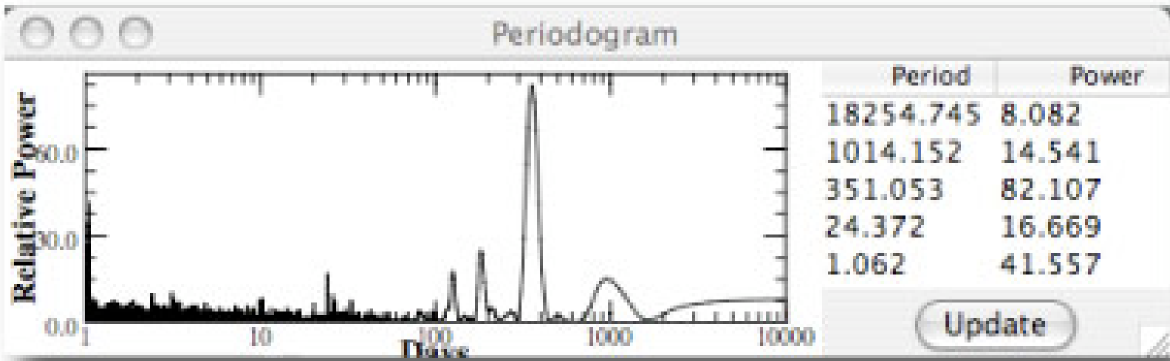
- 200 second cadence (completely readout limited)

- Realistic La Silla weather

- Observe whenever dark, clear, and when Alpha Centauri is at sec(z)<2.5

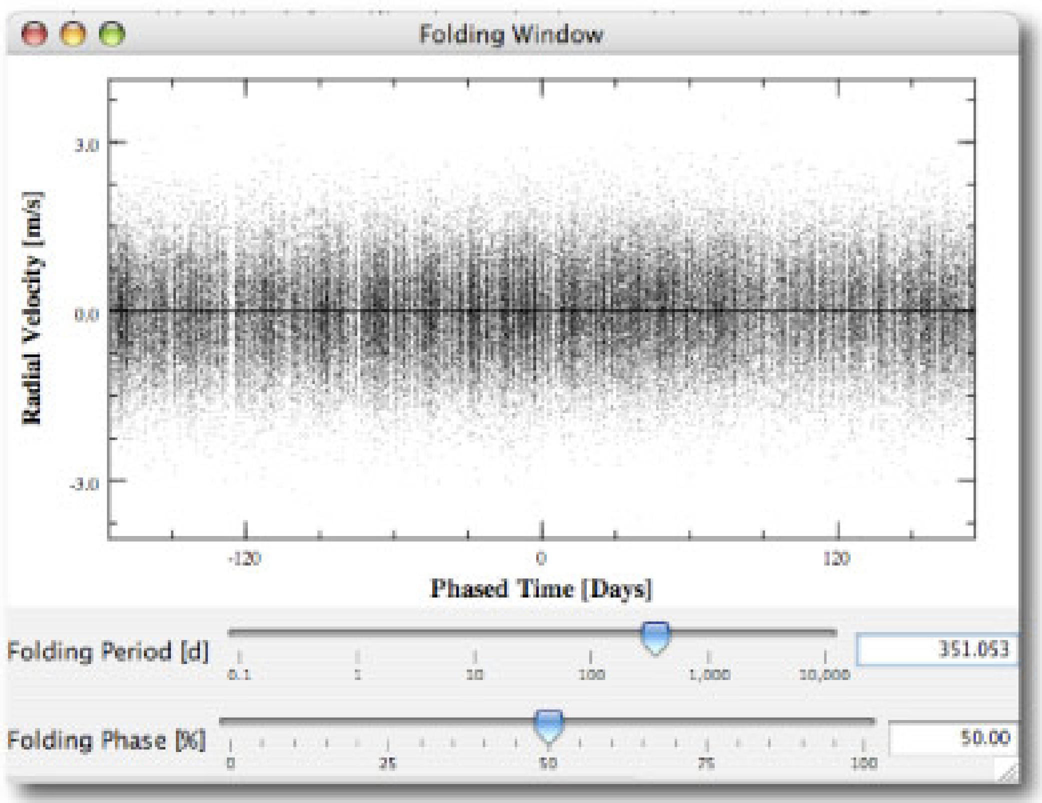
- Adopt HD 69830 error distribution

- In five years, obtain 96464 simulated velocities



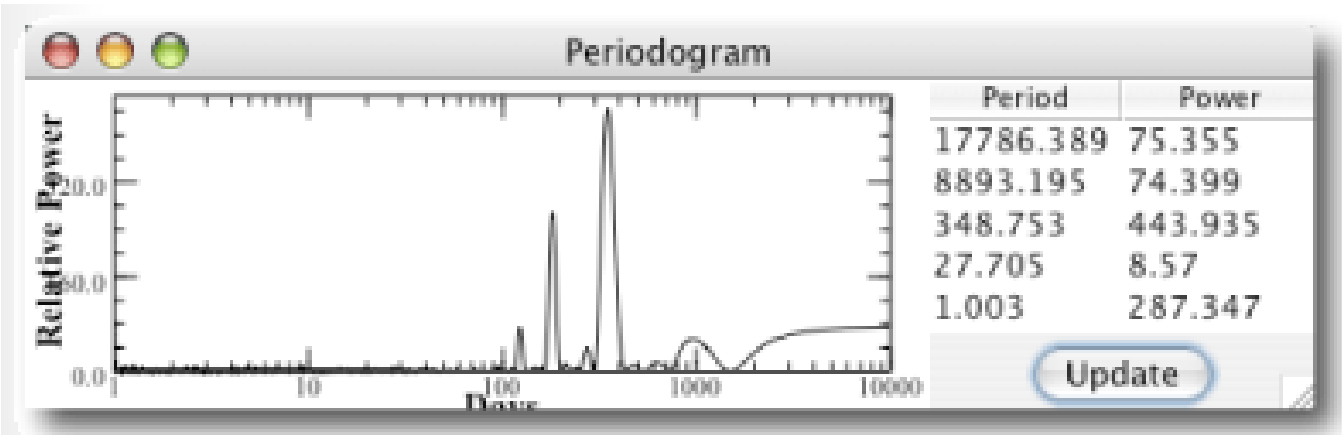
The periodogram shows a peak at 351 days with a vanishingly small false alarm probability.

This peak corresponds to a planet with a mass *one half* that of Earth. It is well outside the habitable orbit of ~270 days appropriate to Alpha Cen B. The second highest peak corresponds to a *Mars-mass* planet.

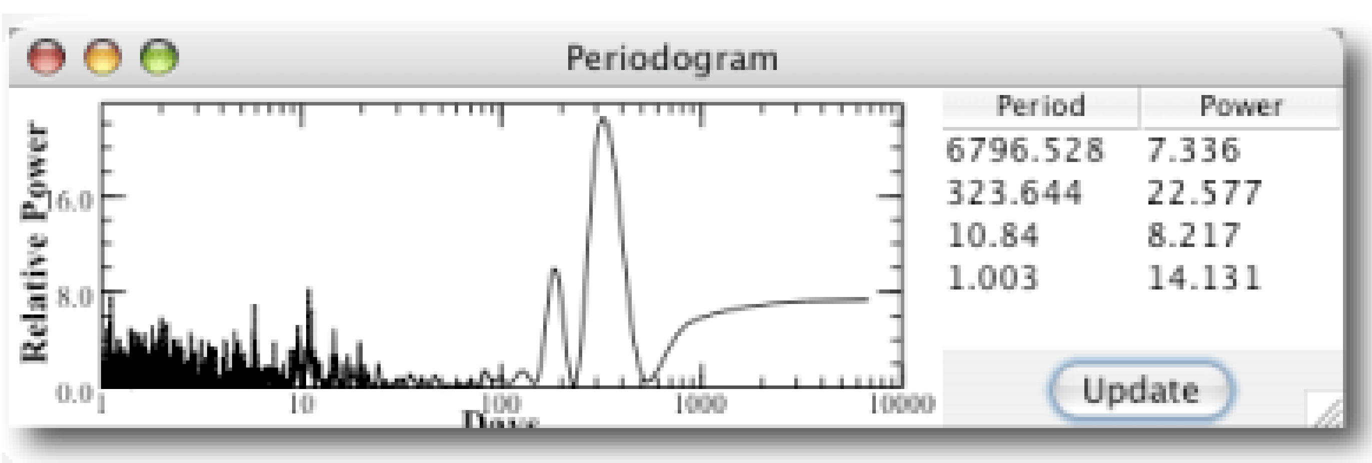


Note that the folded velocities don't show anything to the eye.

Here's the periodogram for a system with an Earth-mass planet. It's overwhelmingly detectable with 94,000 HARPs-quality RVs



Here's the same system observed for only 2 years with 3 m/s precision.



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