Extrasolar Planets & The Power of the Dark Side

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Fermilab – 24 April 2002

Gravitational Wobble

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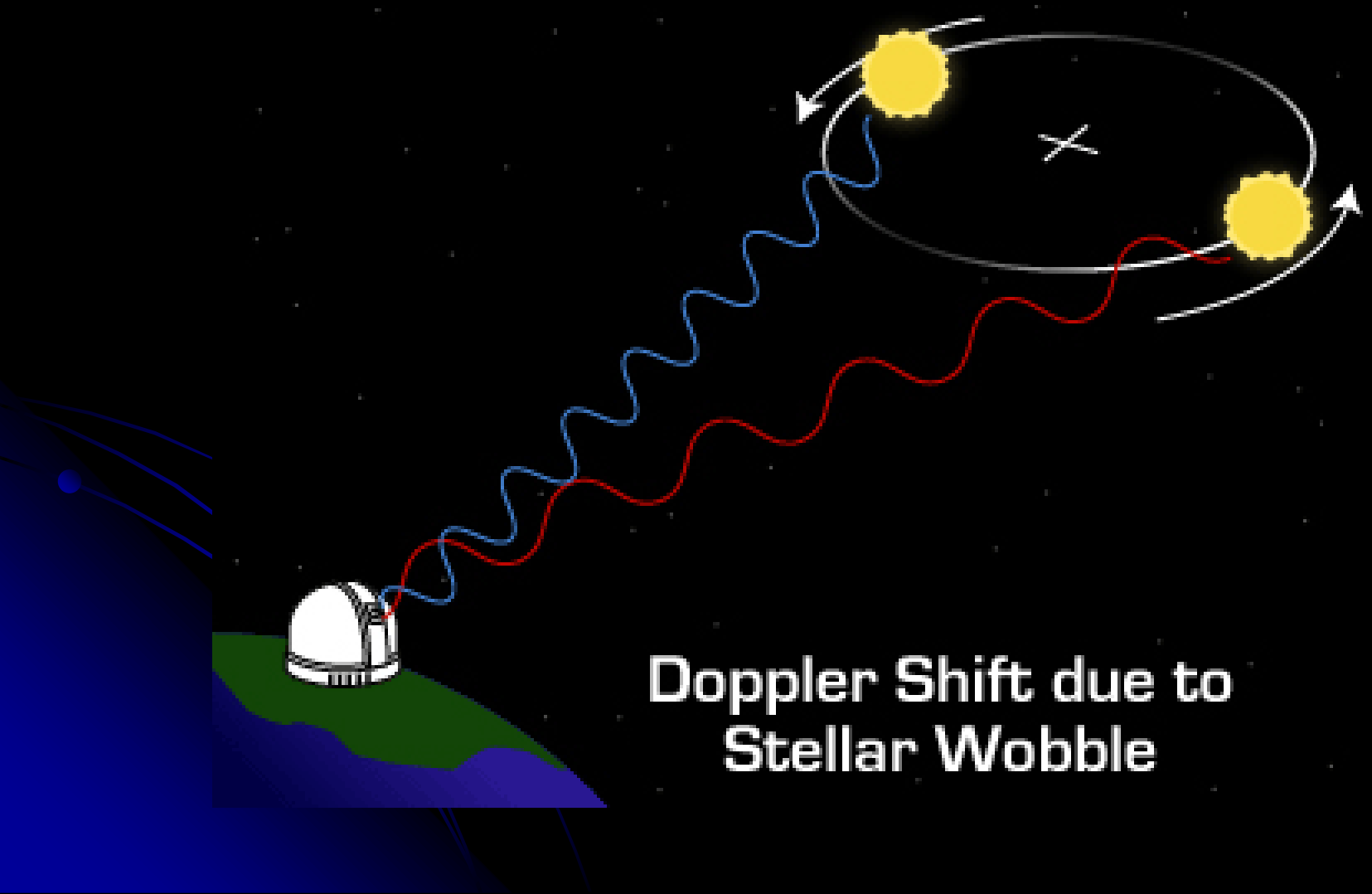
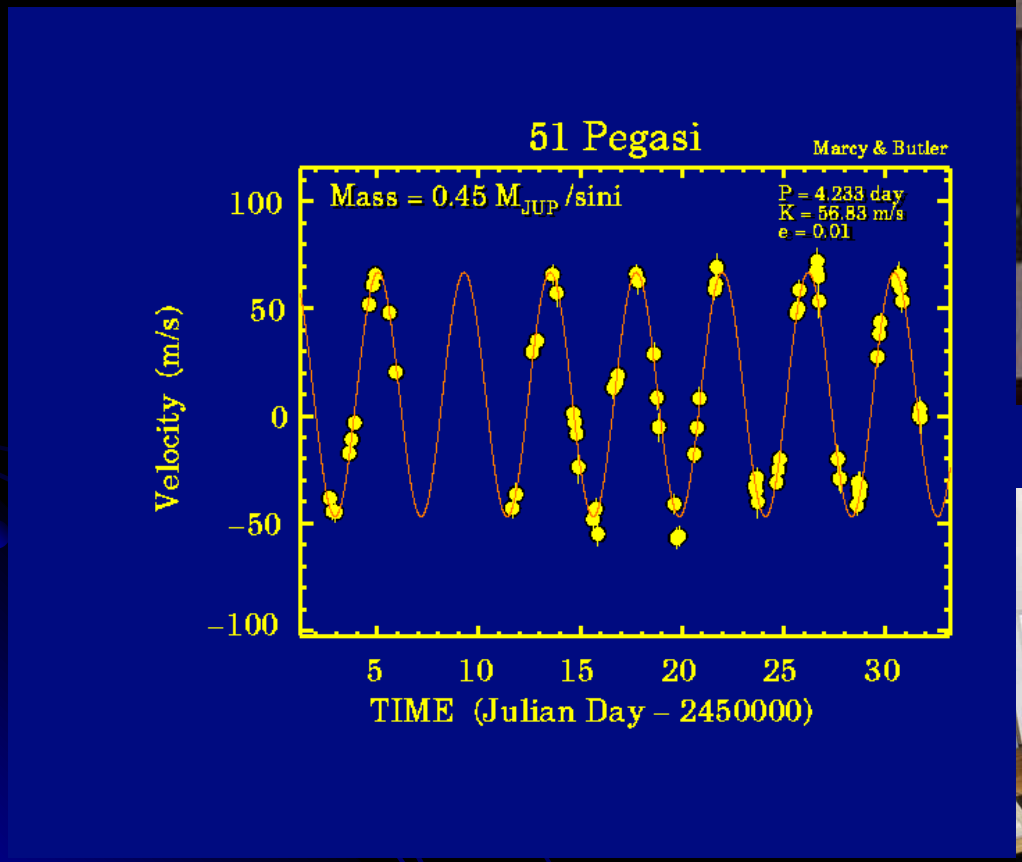
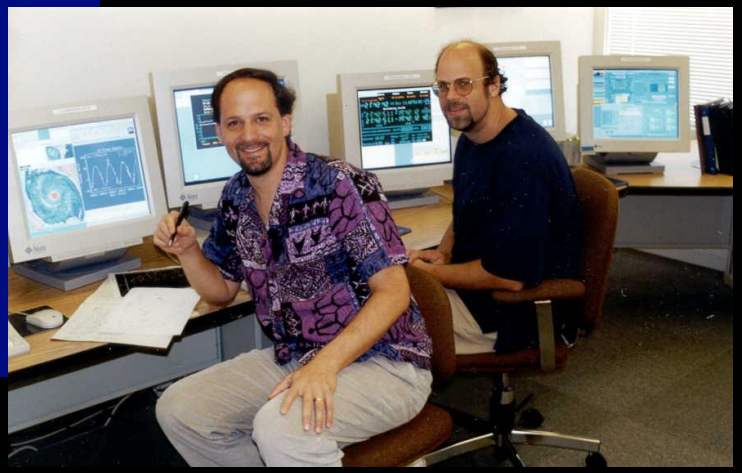
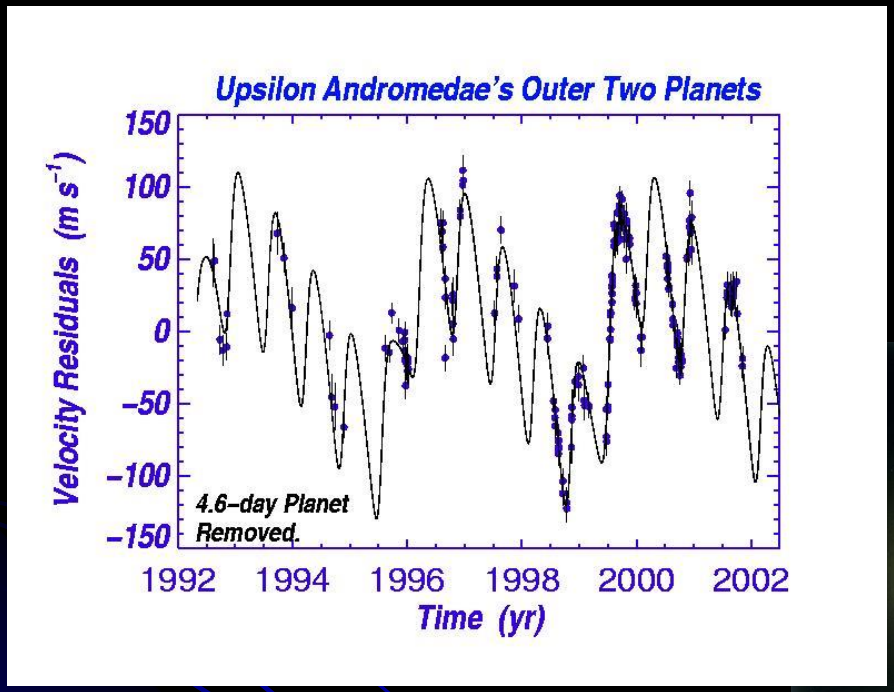


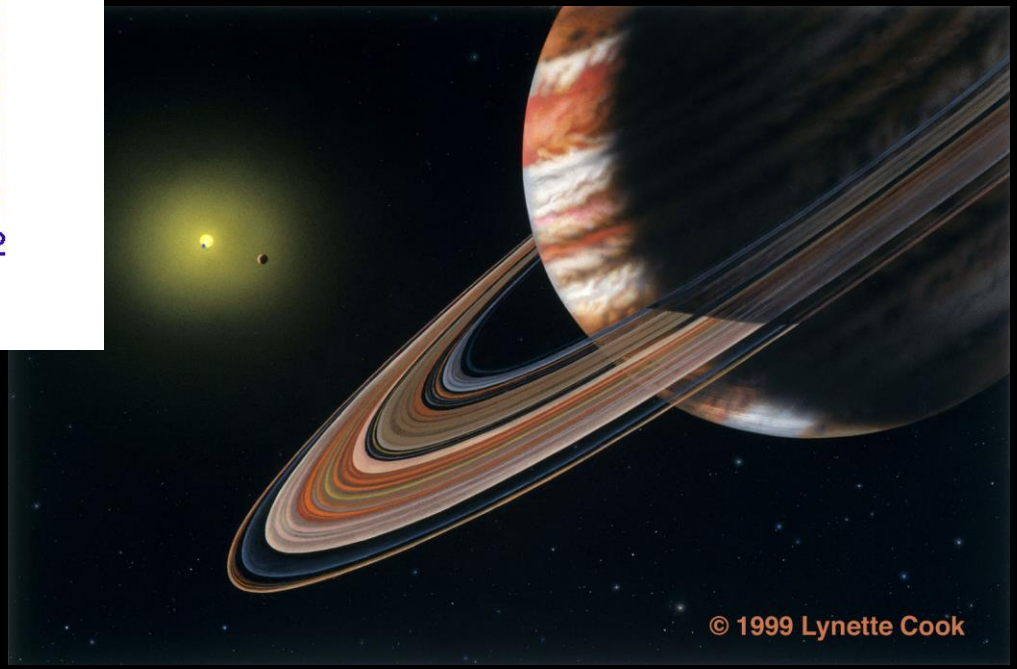
First Planet Detected
51 Pegasi – November 1995





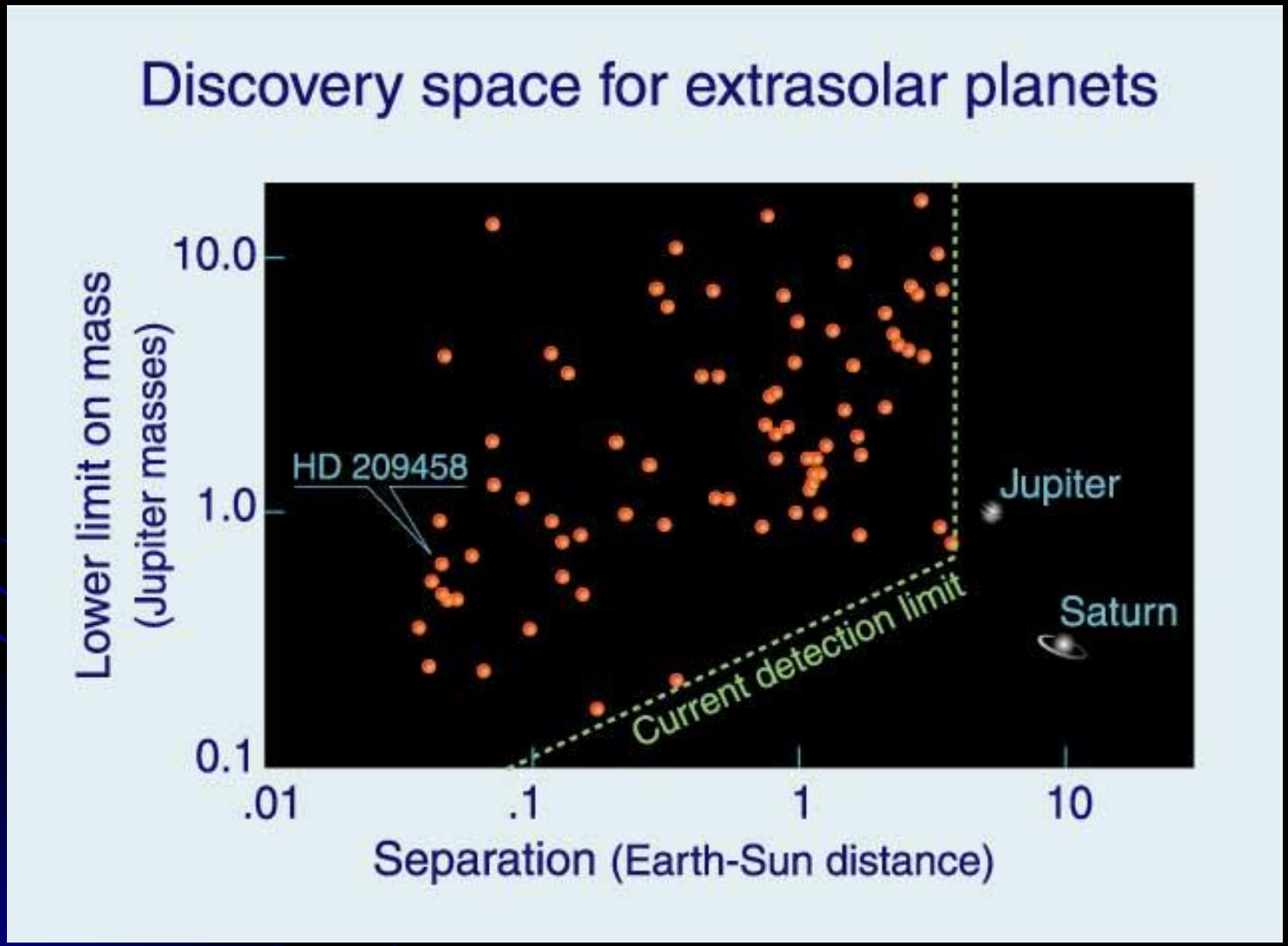
First Planet System Detected Upsilon Andromedae – April 1999



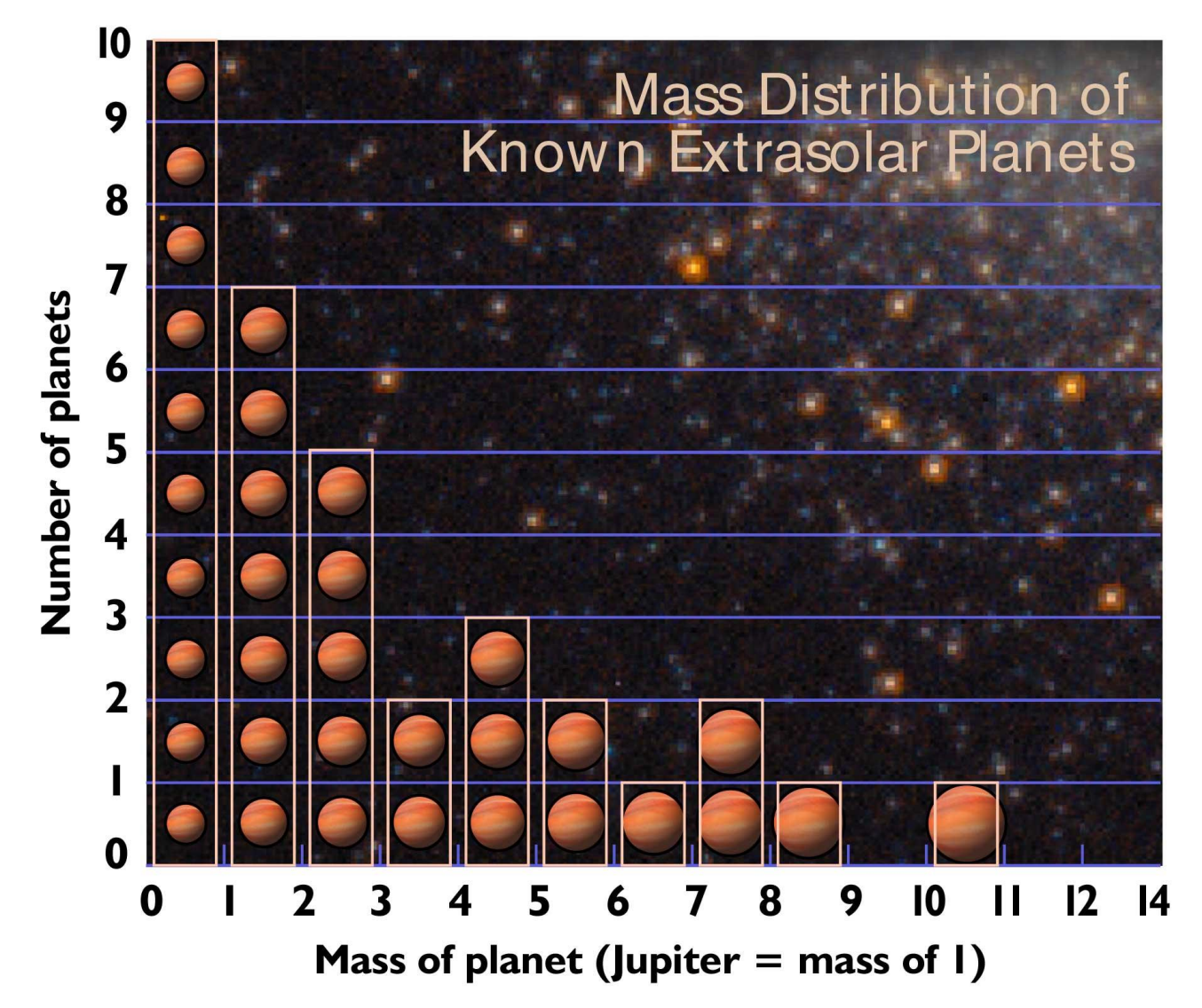


Used with permission of the artist.

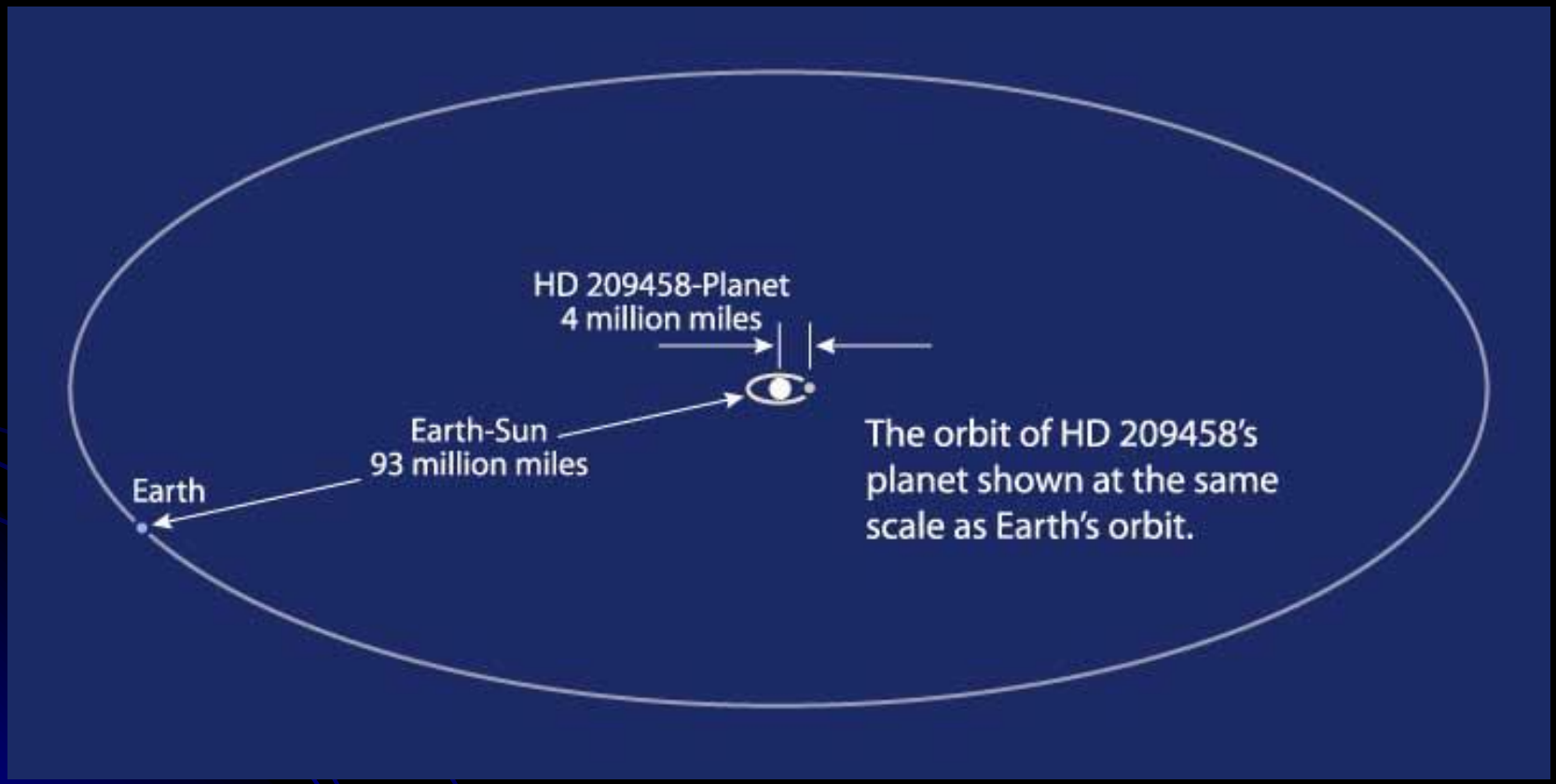
The Radial Velocity Surveys



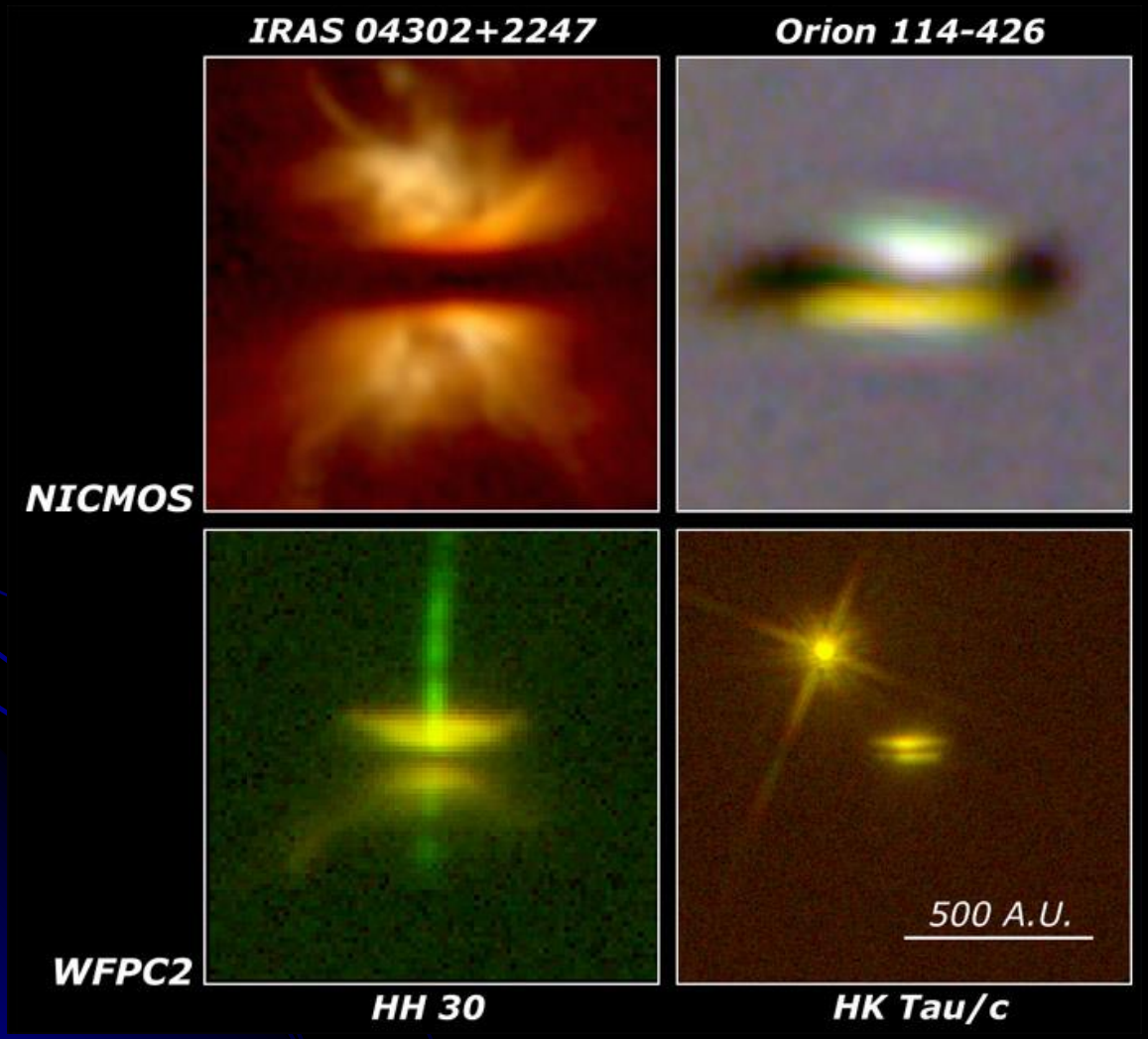
Masses of Extrasolar Planets



Close-In Extrasolar Giant Planets and Planetary Migration



Protoplanetary Disks Around Young Stars



D. Padgett (IPAC/Caltech), M. McCaughrean (A I Potsdam), C. Burrows (STScI), K. Stapelfeldt (JPL/Caltech)

Transits:
A Little Closer To Home…

Where will you be June 8, 2004?

Transit Characteristics

- Probability

  $p_t = R_{star} / a$

  $= 0.1$

- Depth

  $\delta I / I = (R_{pl} / R_{star})^2$

  $= 0.01$

- Period

  P = 3 – 7 days

- Duration

  t = 3 hours

The Observational Challenge

The fraction of stars with transits is:

$$f = f_s \, f_{MS} \, f_{CEGP} \, p_t$$

f_s	= fraction of stars that are single	= 0.5
f_{MS}	= fraction of those on the main sequence	= 0.5
f_{CEGP}	= fraction of those that have a close-in planet	= 0.01
p_t	= fraction of those with an inclination to transit	= 0.1

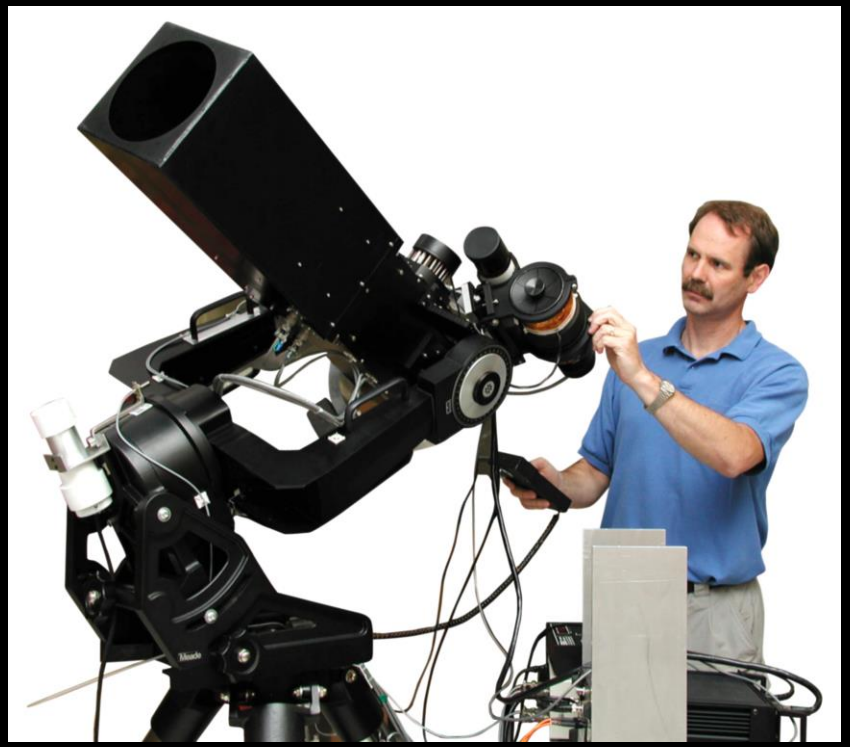
- Need to look at 4000 stars to find 1 that transits.
- Need to sample often compared to transit duration.
- Need 1% accuracy for a 3σ detection of a 2 hour transit.
- Need to look on sky for at least 1 orbital period.

Require 1,000,000 15-minute samples with 1% accuracy to detect one transit.

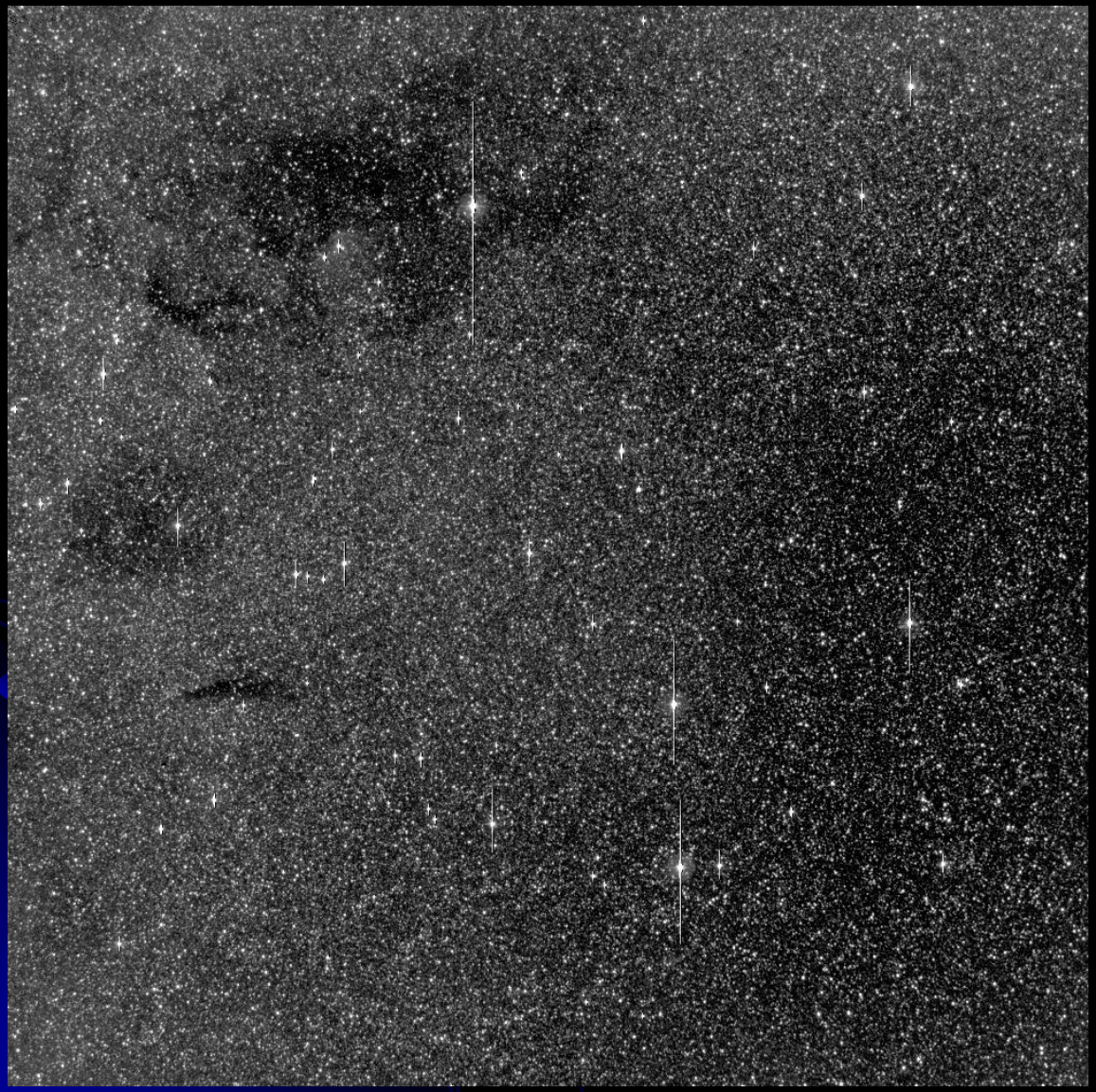
The STARE Project

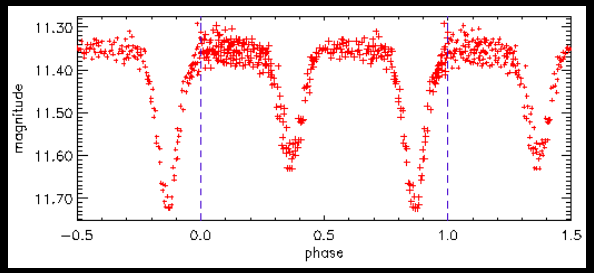
Delivers high-cadence time series photometry on roughly 30,000 stars ($9 < V < 13$) in a typical field centered on the galactic plane.

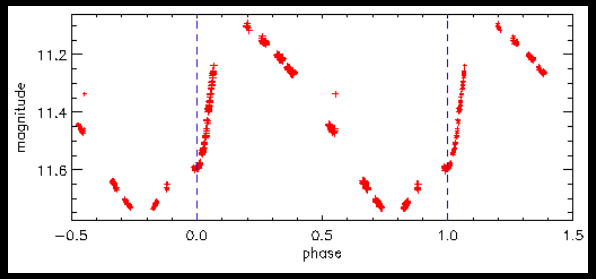
We obtain sufficient precision on 5,000 stars to detect a close-in Jupiter-sized companion.

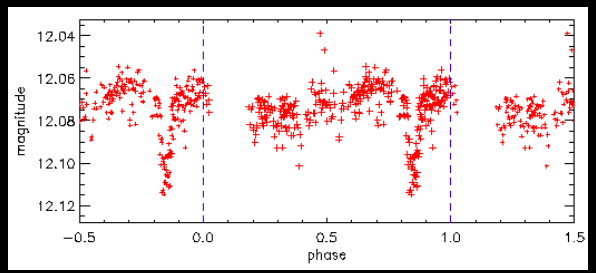


The Search Is On!

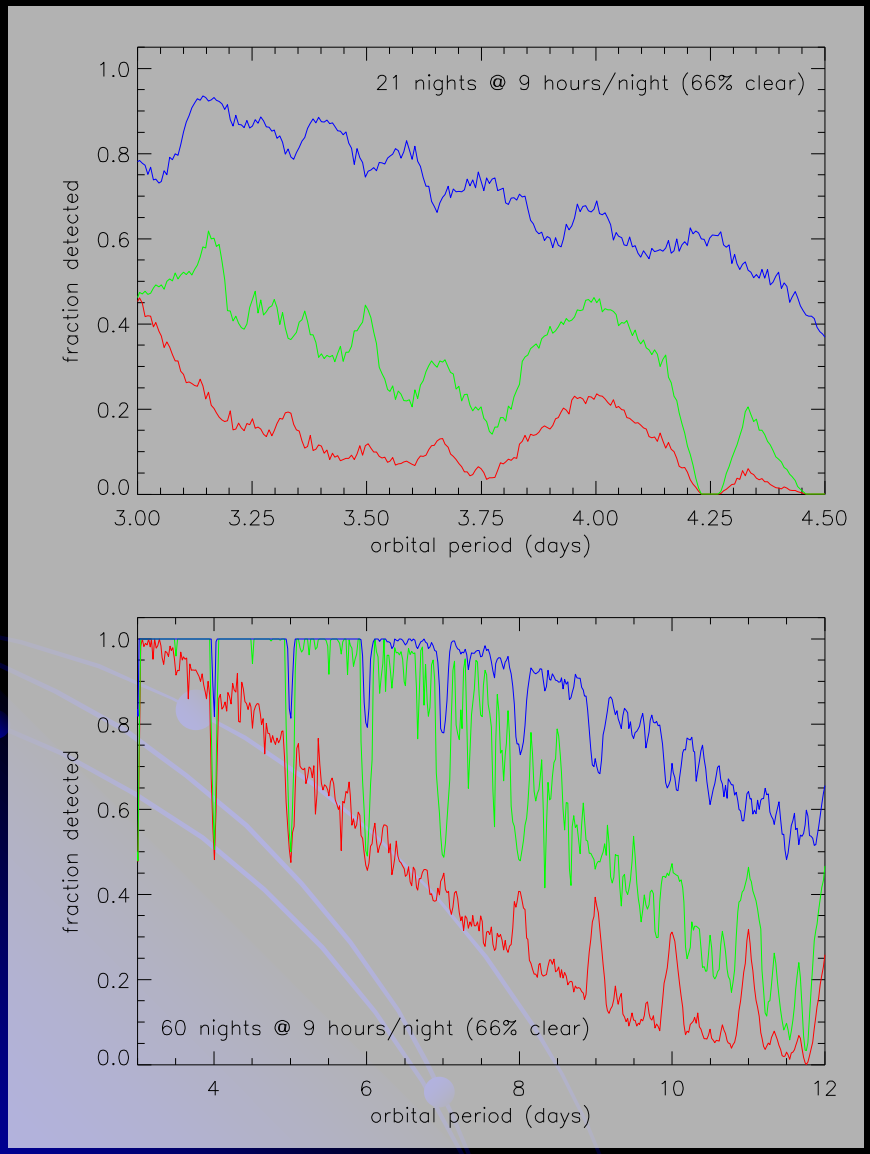




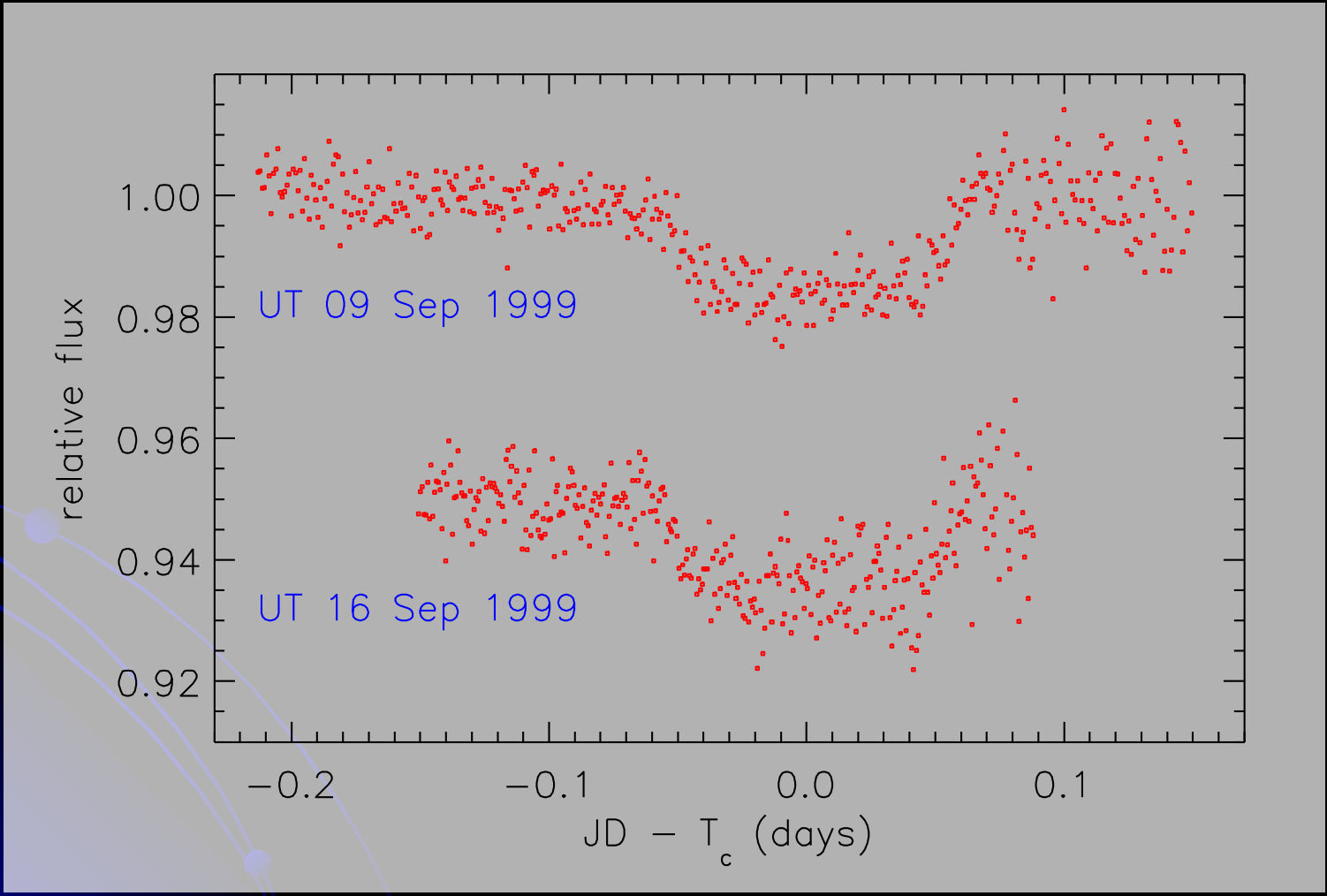




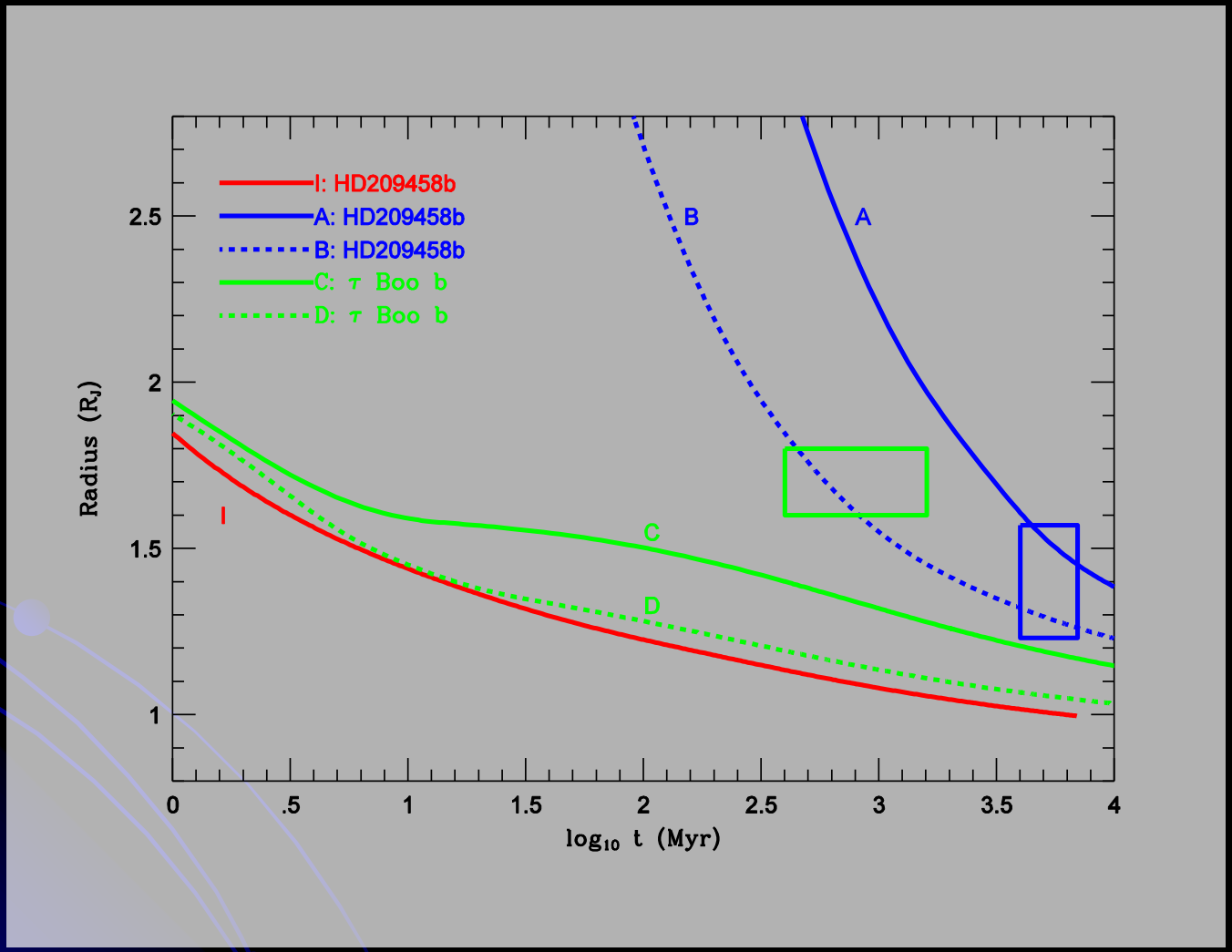
The Benefits of a Network



HD 209458 b
The First Transiting Planet

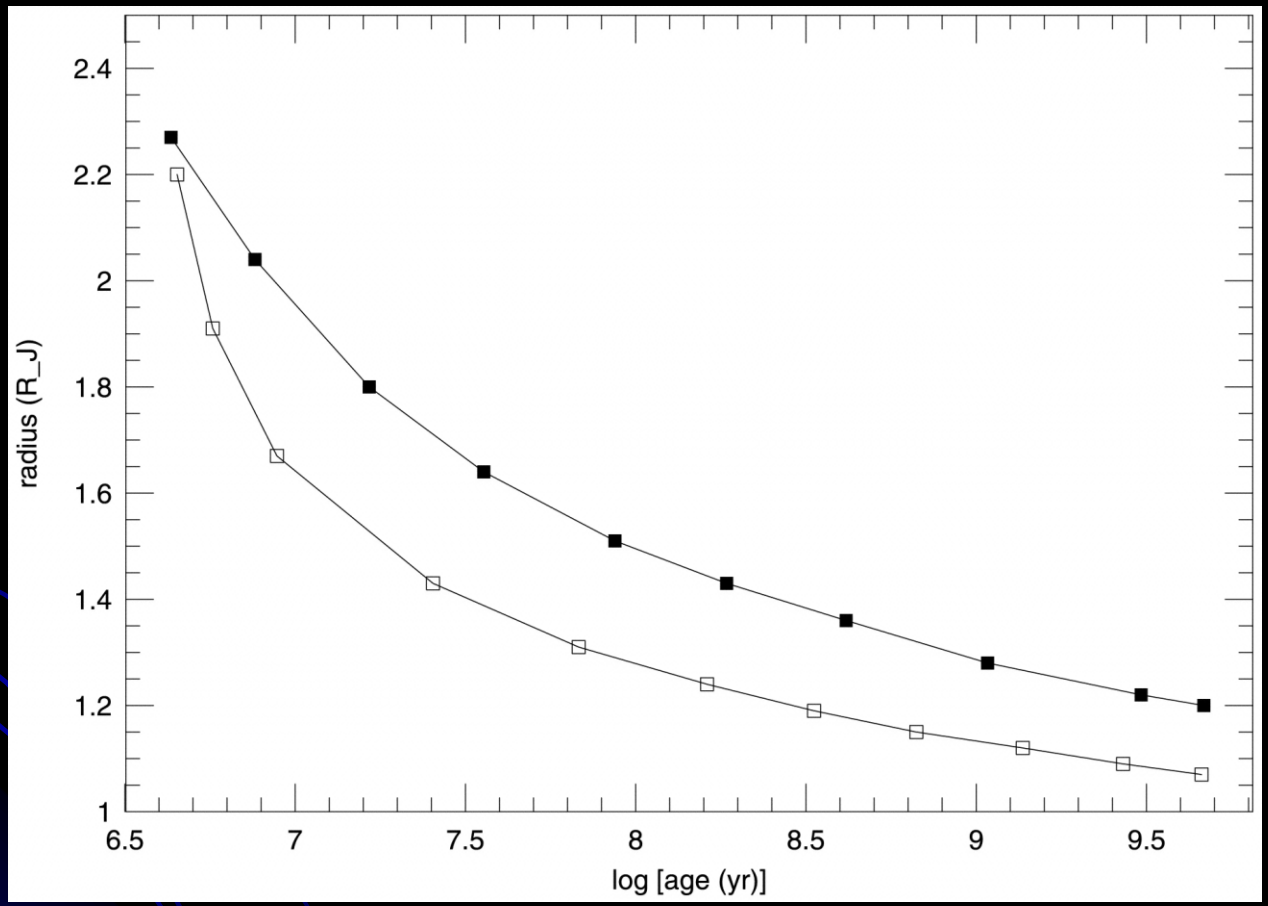


The Effects of Stellar Insolation



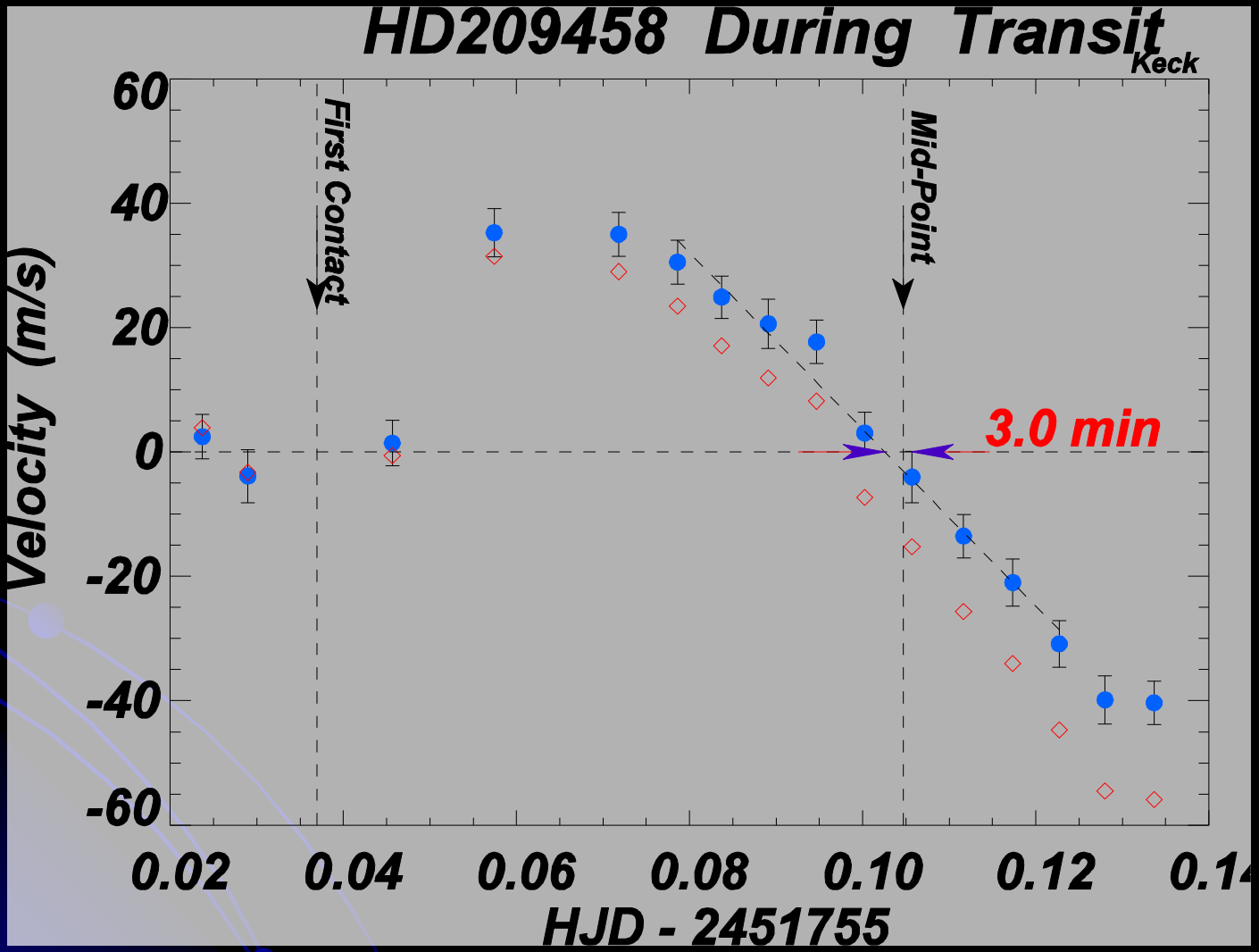
Burrows et al. (2000)

The Effects of a Planetary Core and Tidal Dissipation



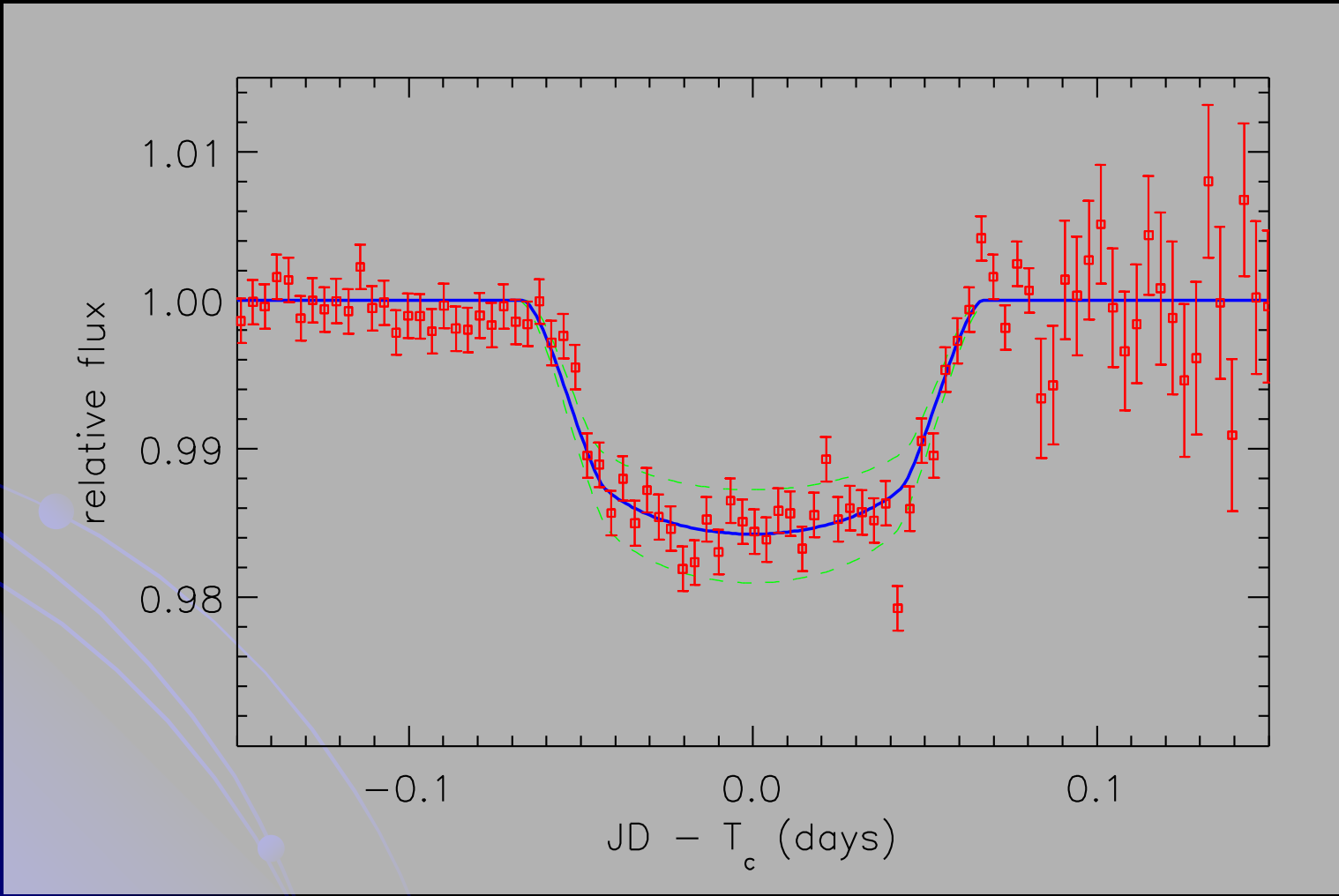
Bodenheimer et al. (2001)

Radial Velocity with Orbit Removed

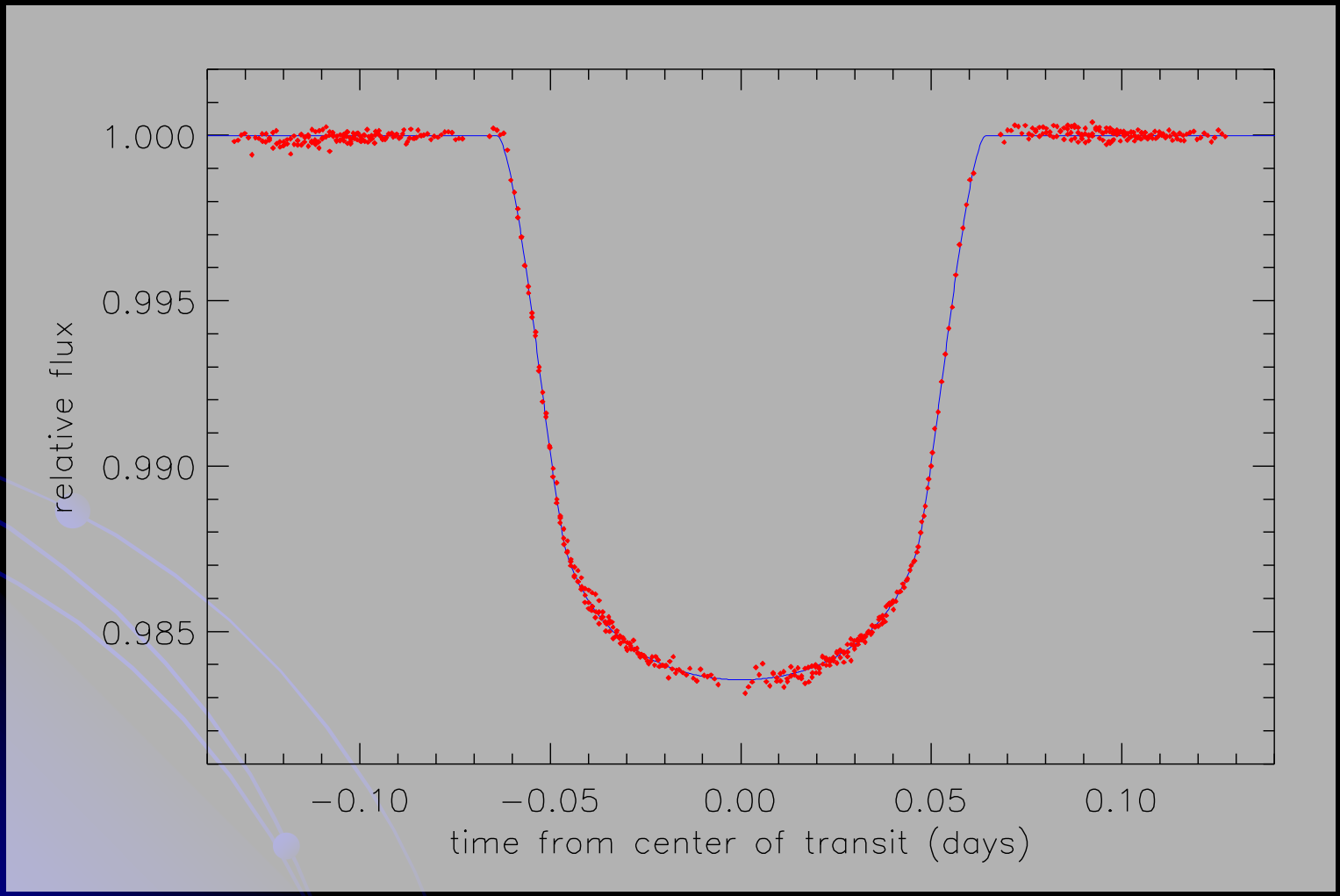


G. Marcy et al. (2000)

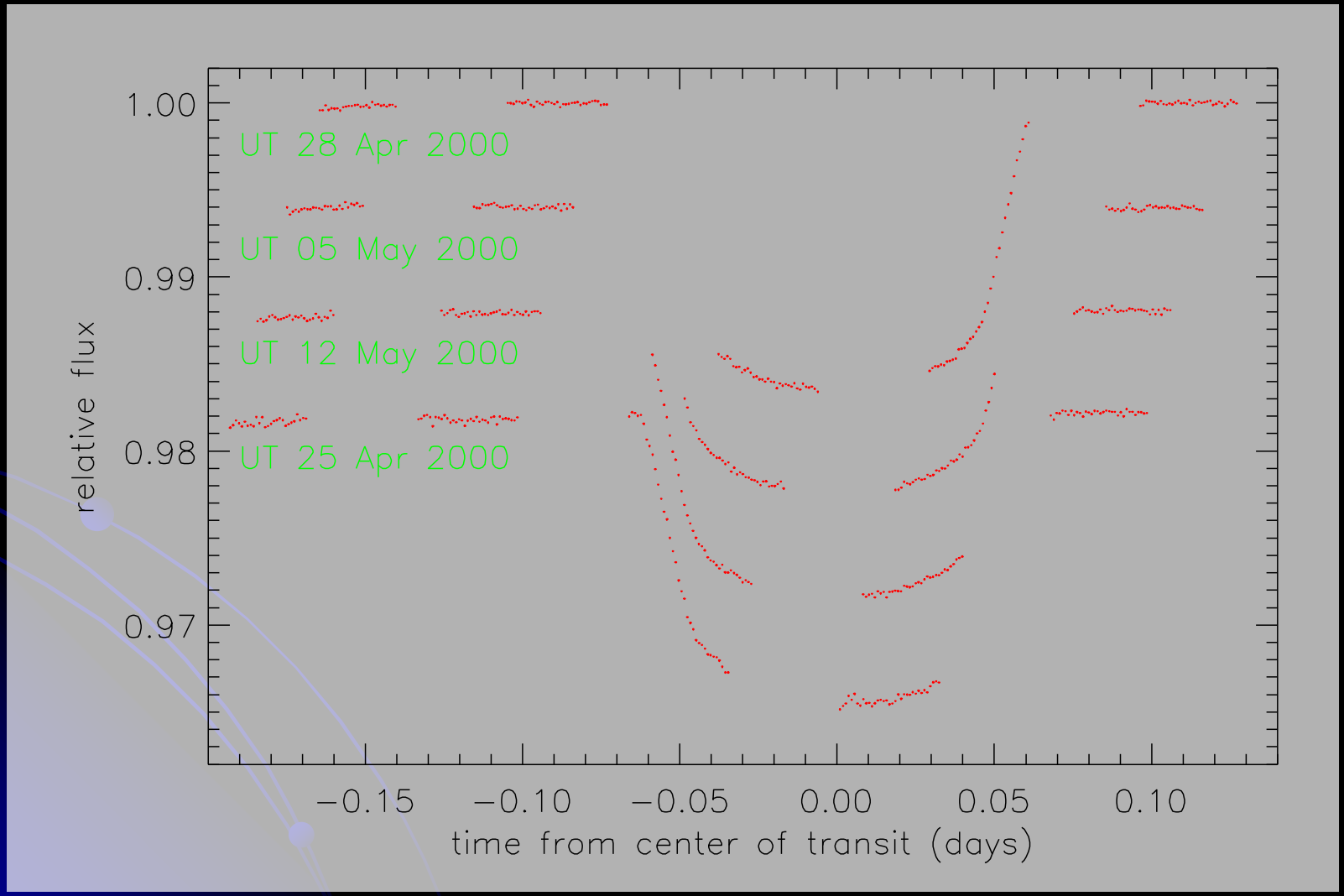
STARE Photometry of HD 209458



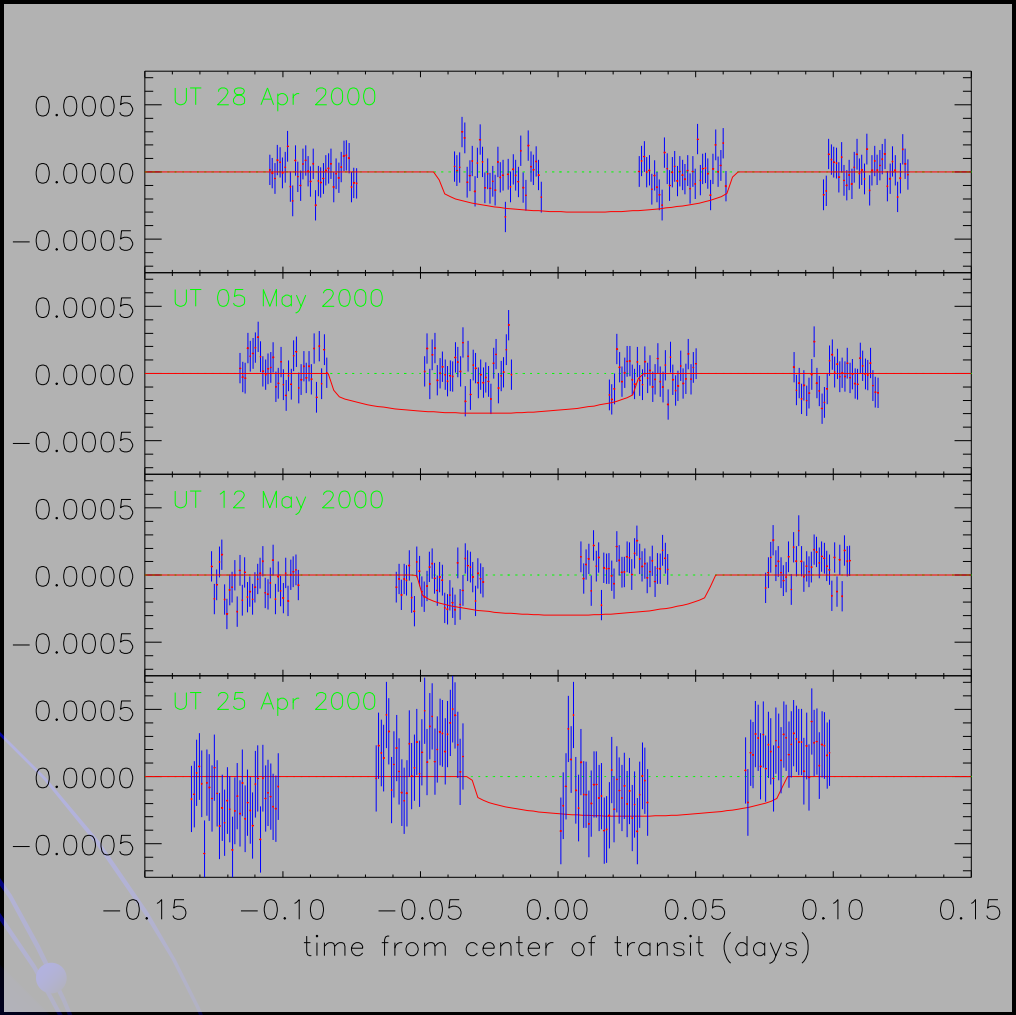
HST STIS Photometry of HD 209458



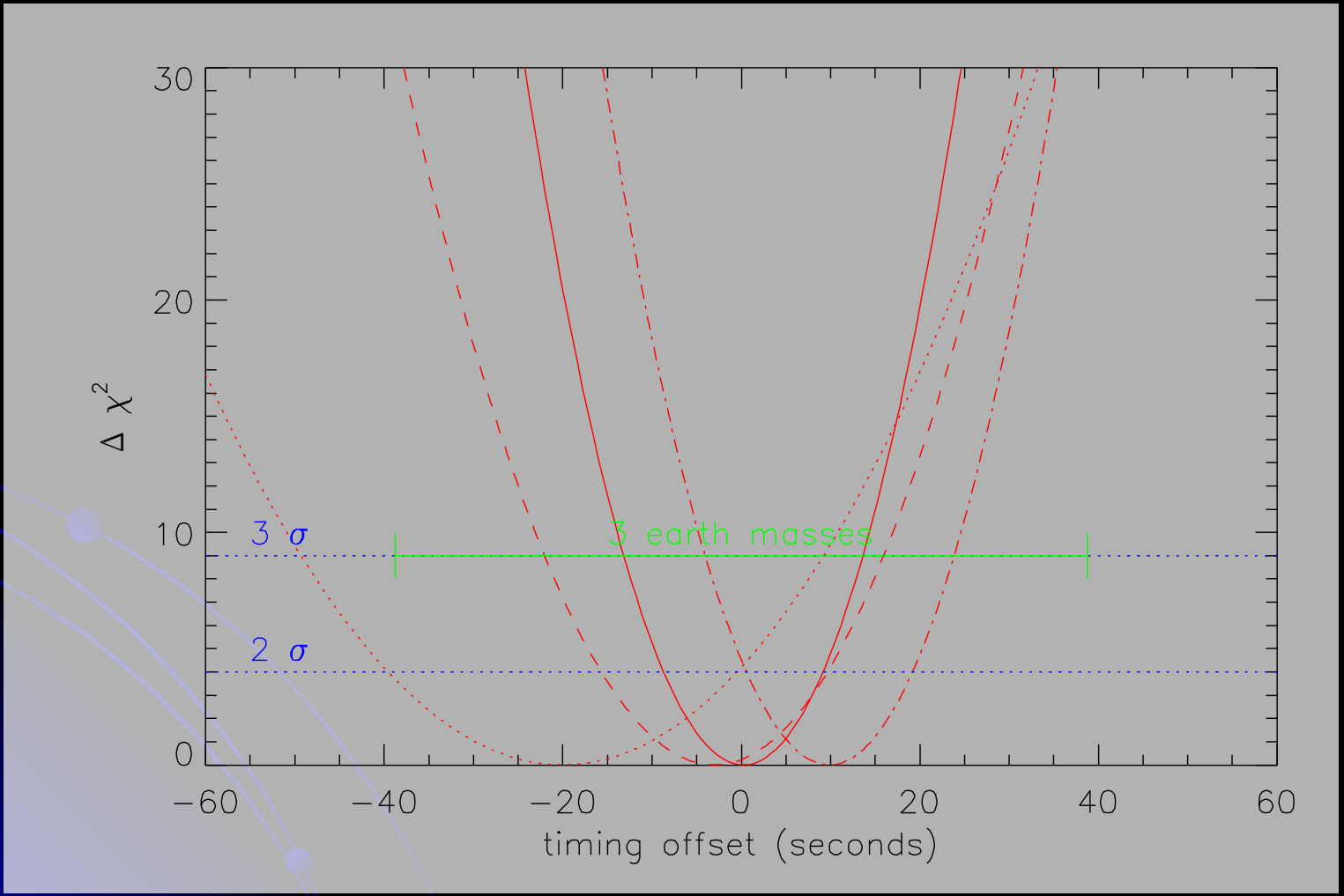
Unphased HST STIS Photometry of HD 209458



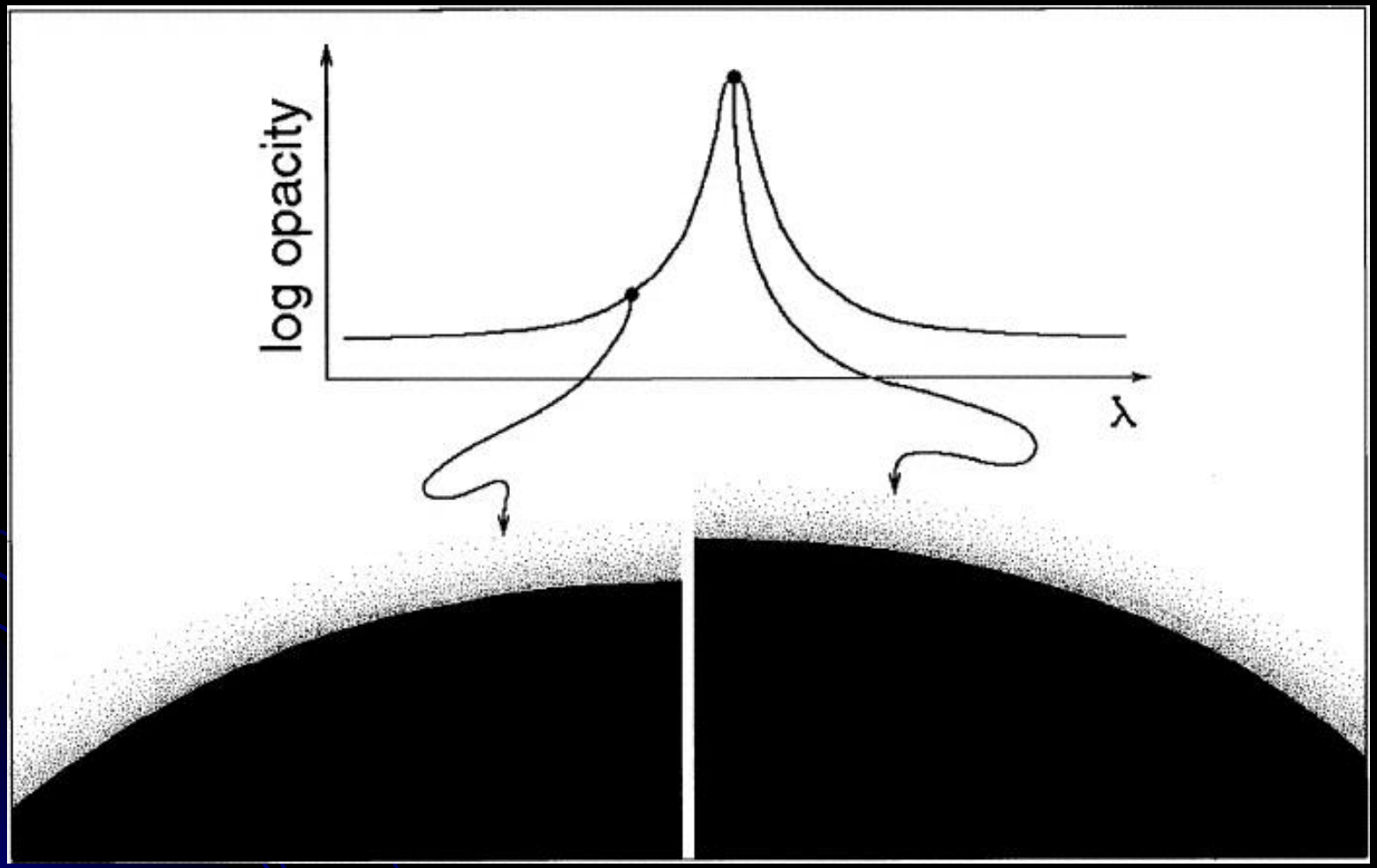
Planetary Satellites from Photometric Residuals



Planetary Satellites from Transit Timing

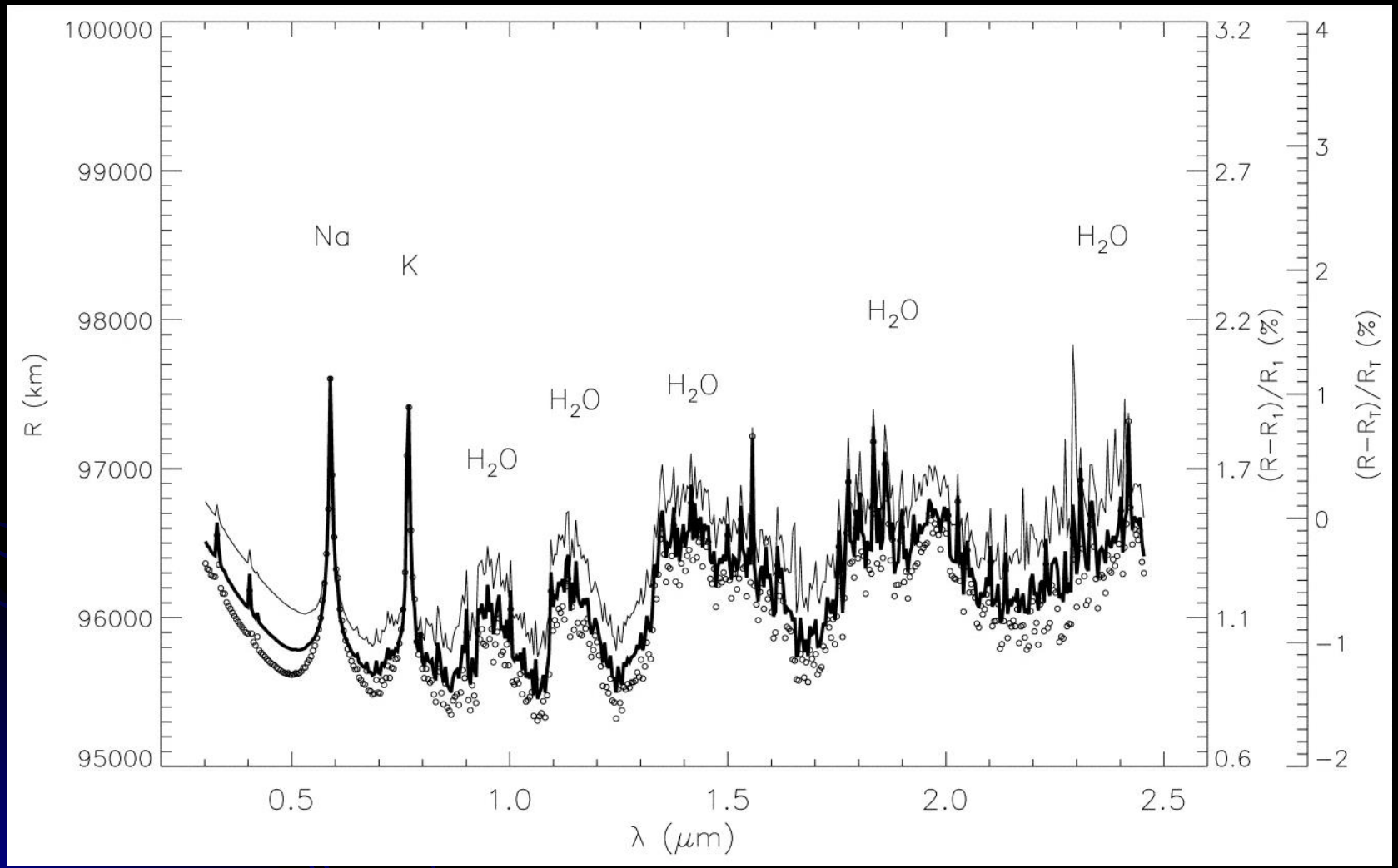


Transmission Spectroscopy



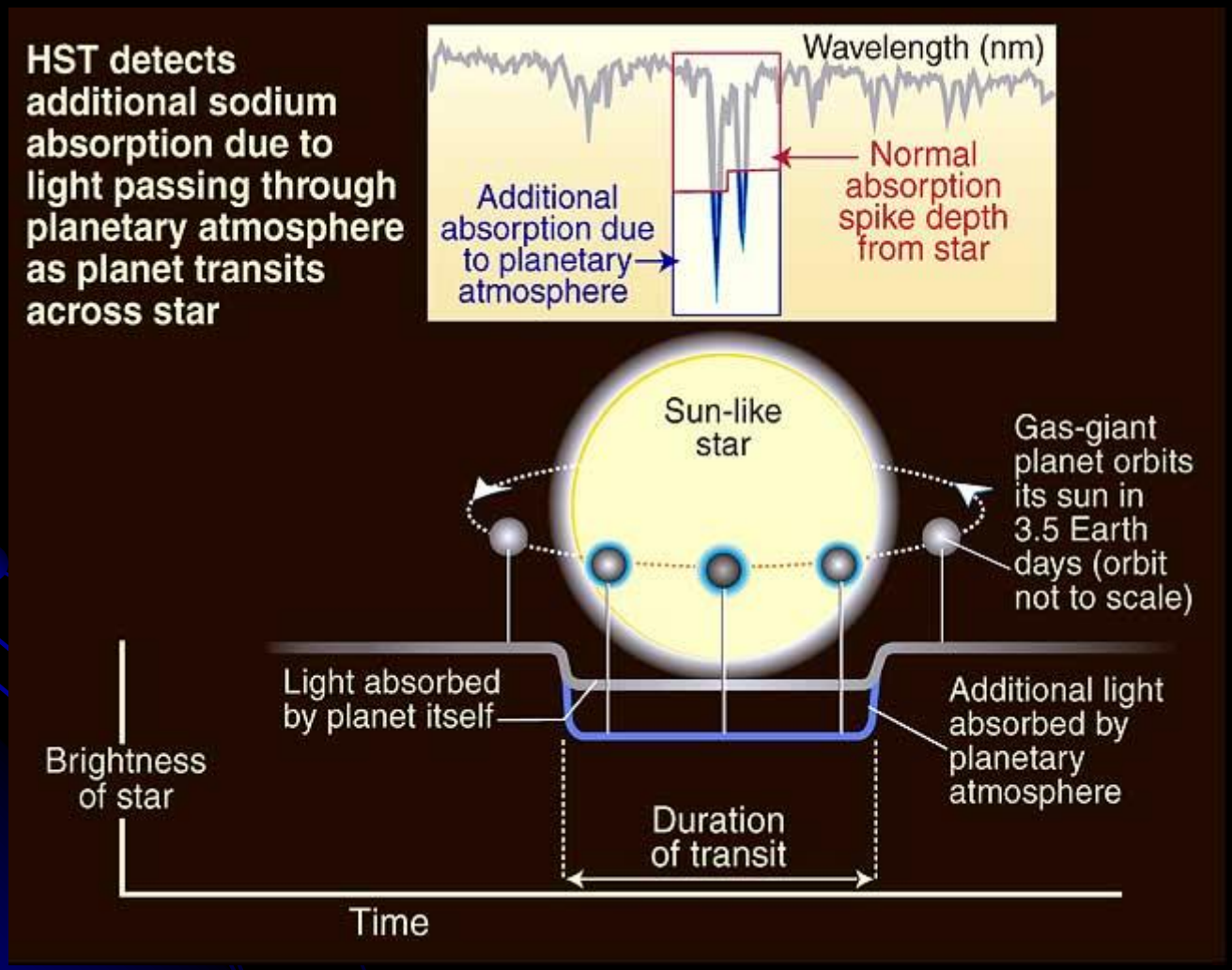
Brown (2001)

A Prediction of Sodium Absorption

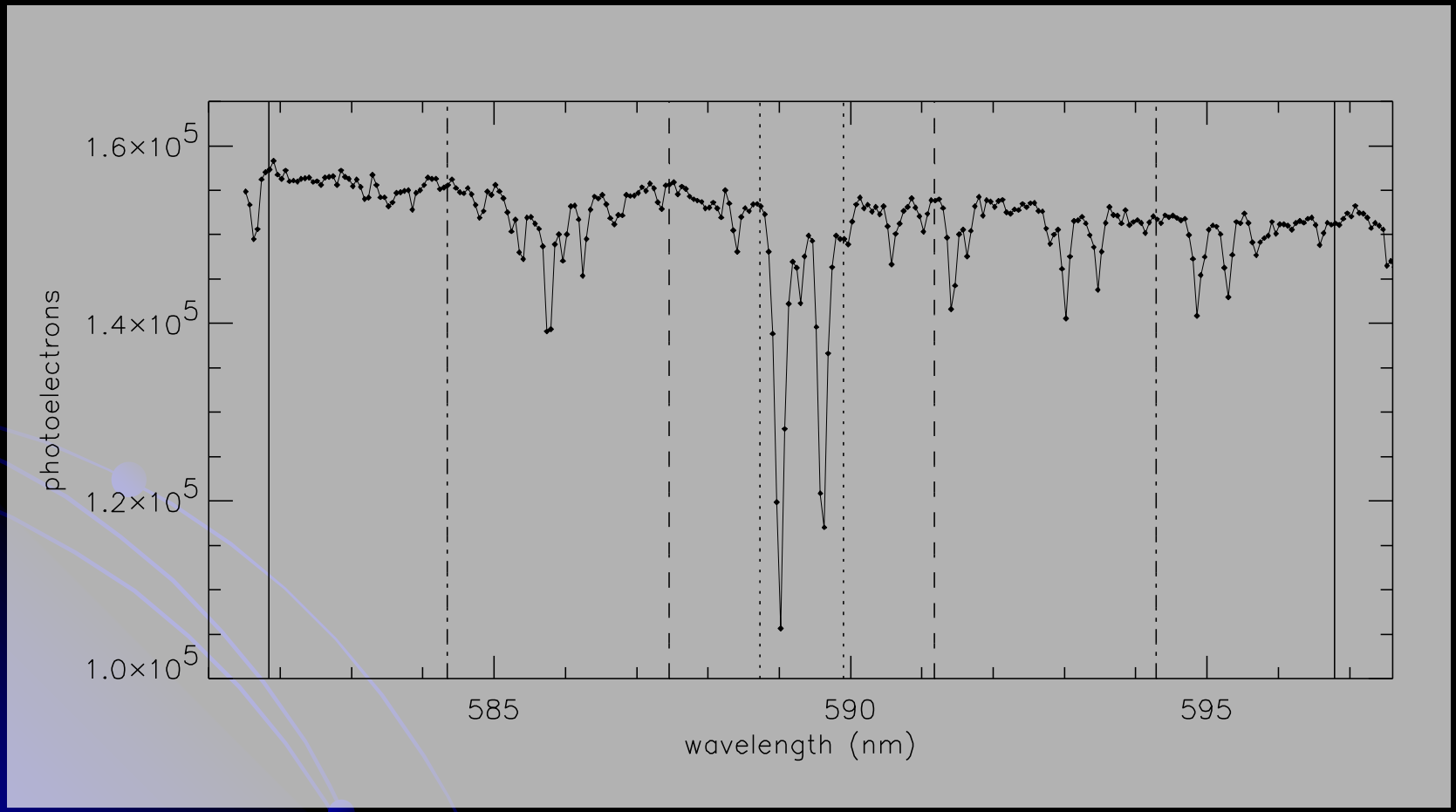


Hubbard et al. (2001)

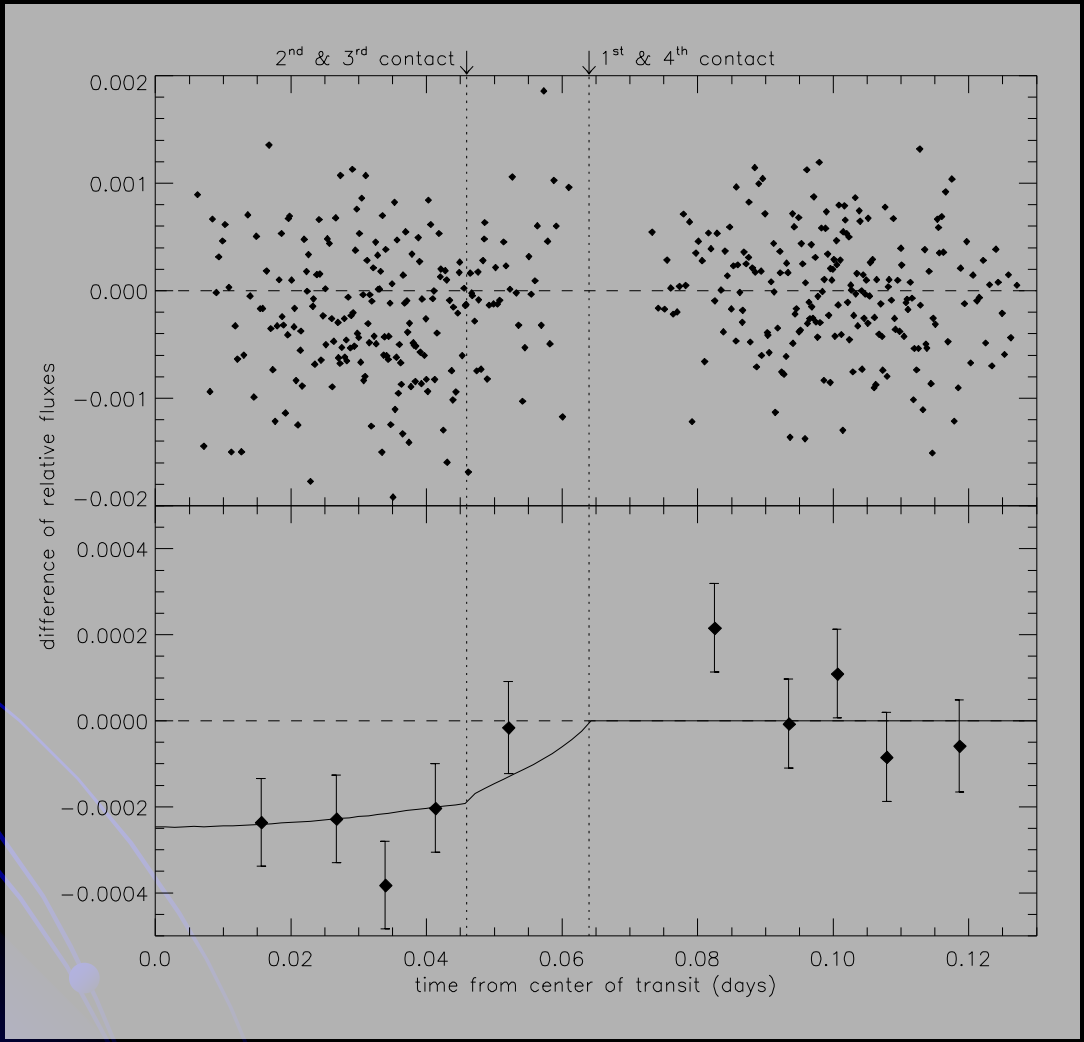
Detection of an Extrasolar Planet Atmosphere



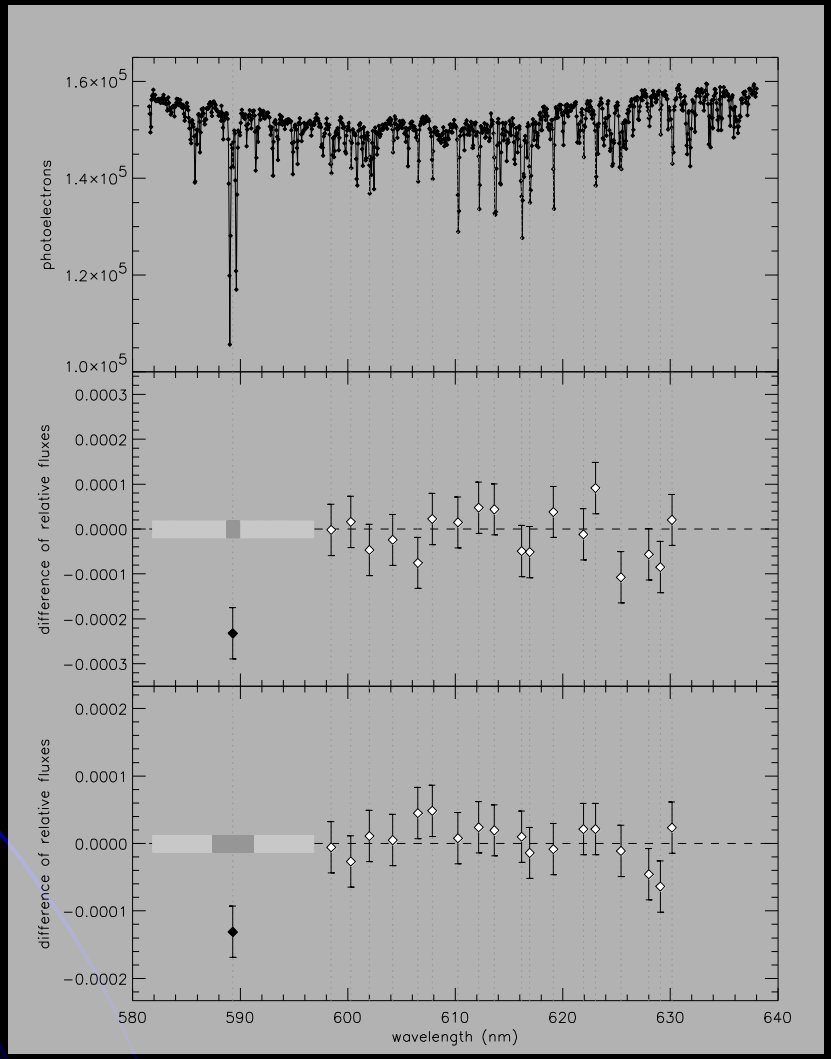
STIS Transmission Spectrum BANDPASSES



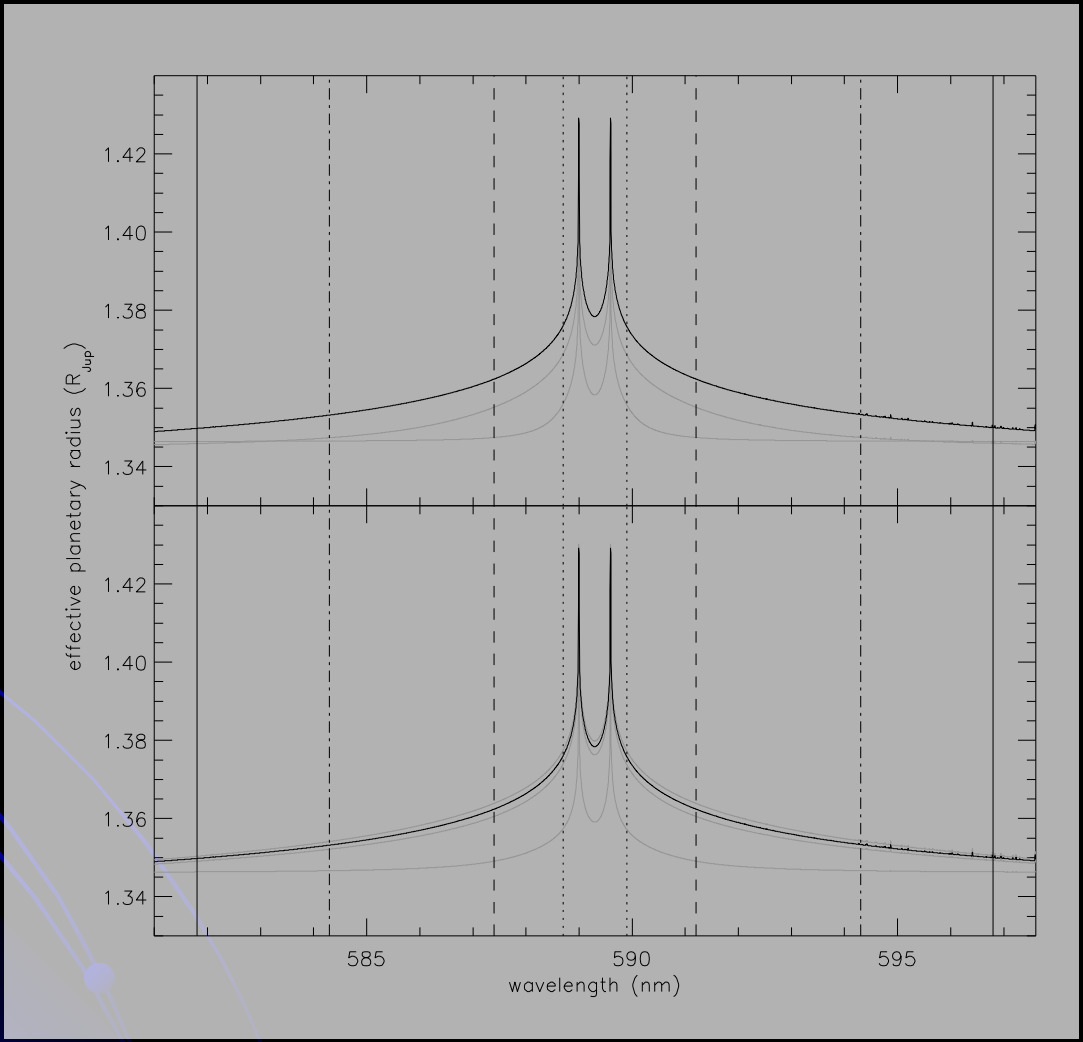
STIS Transmission Spectrum DATA



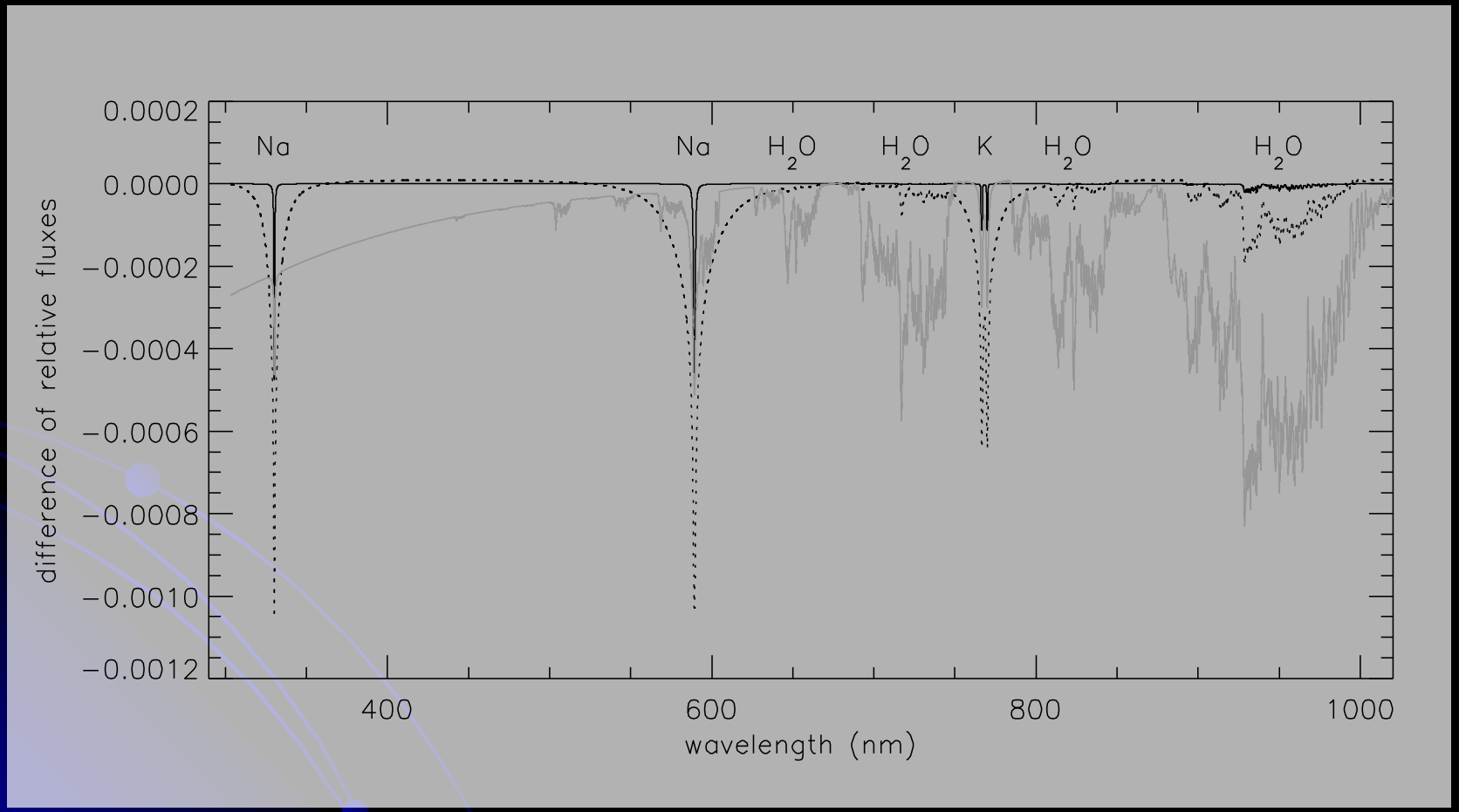
STIS Transmission Spectrum DATA



STIS Transmission Spectrum THEORY



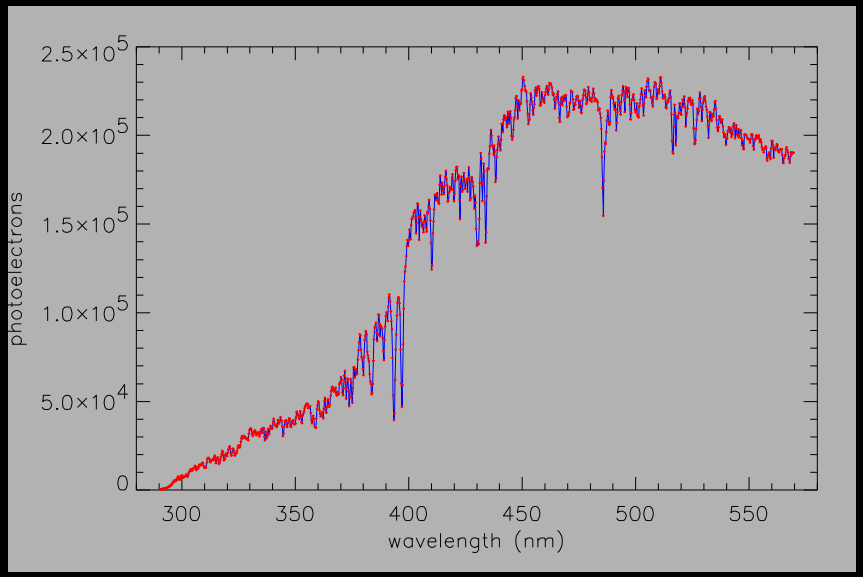
STIS Transmission Spectrum NEAR FUTURE



Reflected Light

Combination of:

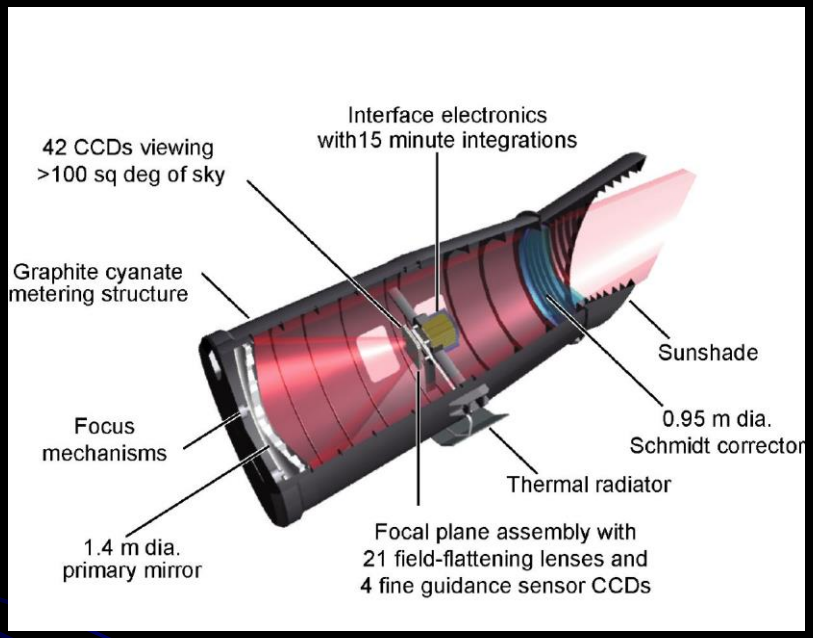
- Transiting planet with a well-determined value for the radius
- Excellent photometric precision with STIS
- Desire to measure the planetary albedo, p

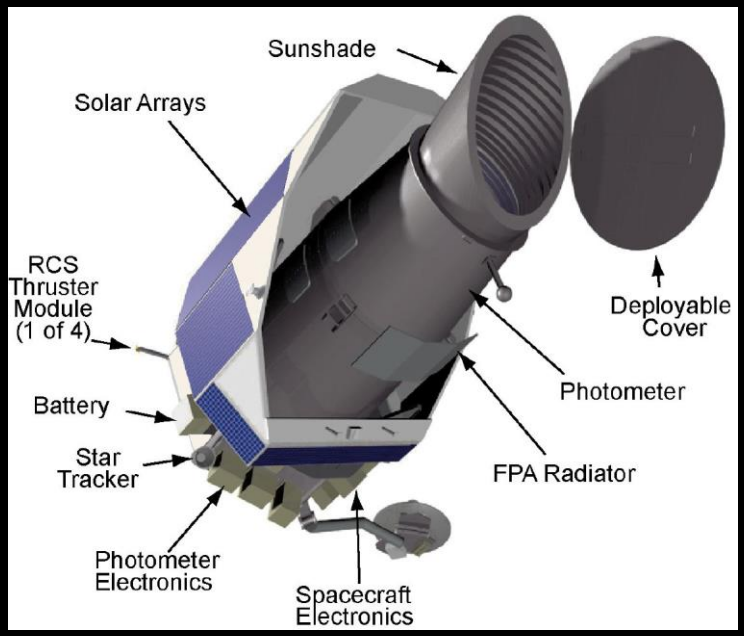


We have 20 orbits of STIS data (290 – 1030 nm) spanning 4 times of secondary eclipse. The photon noise limit of these data would permit a detection threshold of p = 0.1, averaged over the entire bandpass.

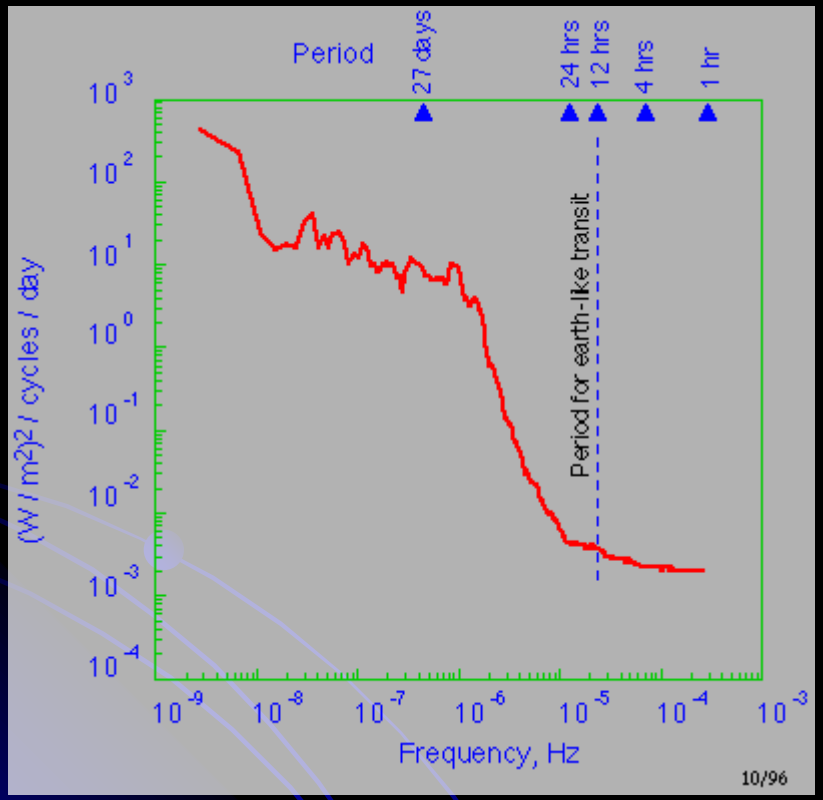
These data will allow us to quantify the net energy deposition into the planet.

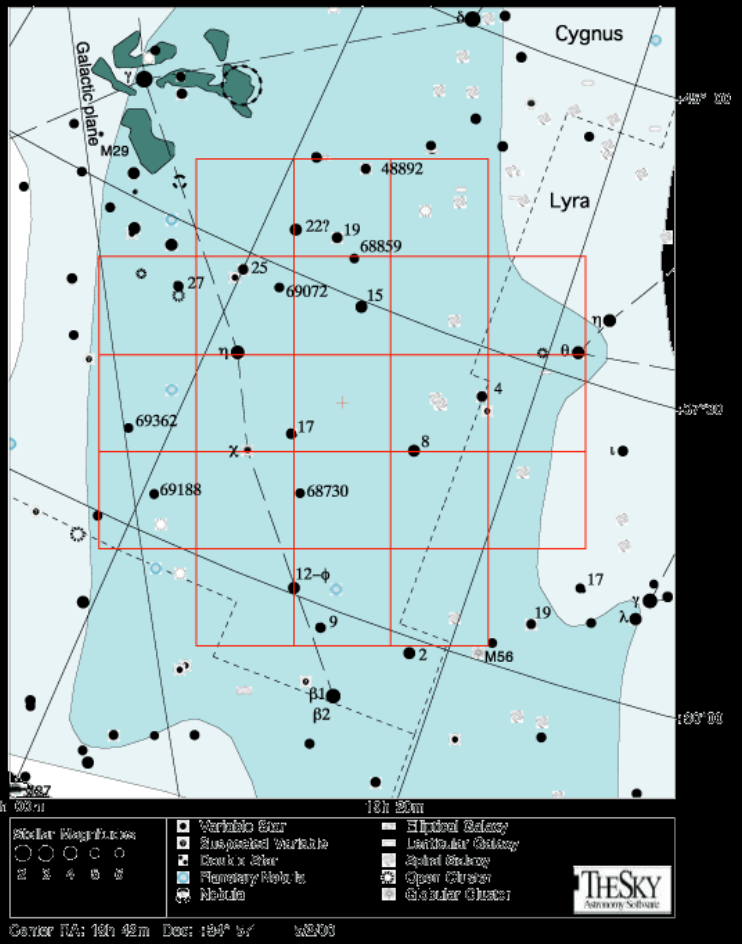
The Kepler Project



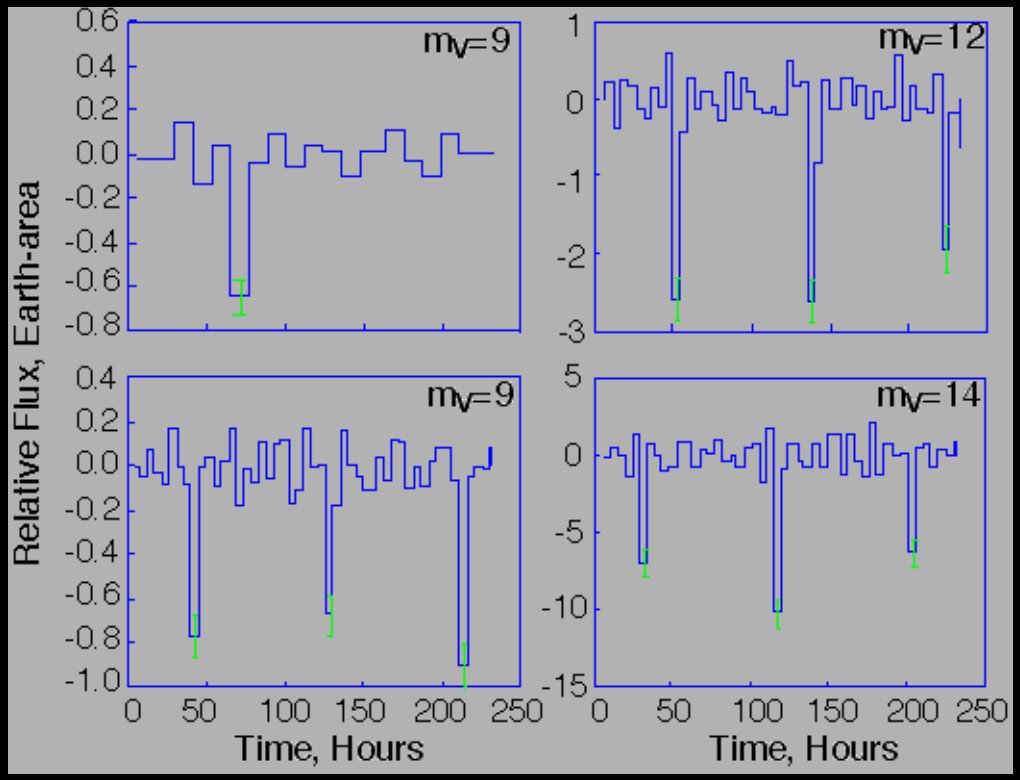


The Kepler Project Parameter Space





The Kepler Project Technology Demonstration



The Kepler Project