Vancouver 2010

skepticamp

be the candle in the dark

An informal, community-organized conference borne from the desire for people to share and learn in an open environment. Everyone from casual skeptics to the experienced participate, give talks, and get to know each other.

Completely Free

10am-6pm
Saturday, March 20, 2010
Victoria Learning Theatre (Room 182)
Irving K. Barber Learning Centre
1961 East Mall, UBC, Vancouver

http://vancouver.skepticamp.org/

vancouver.skepticamp.org

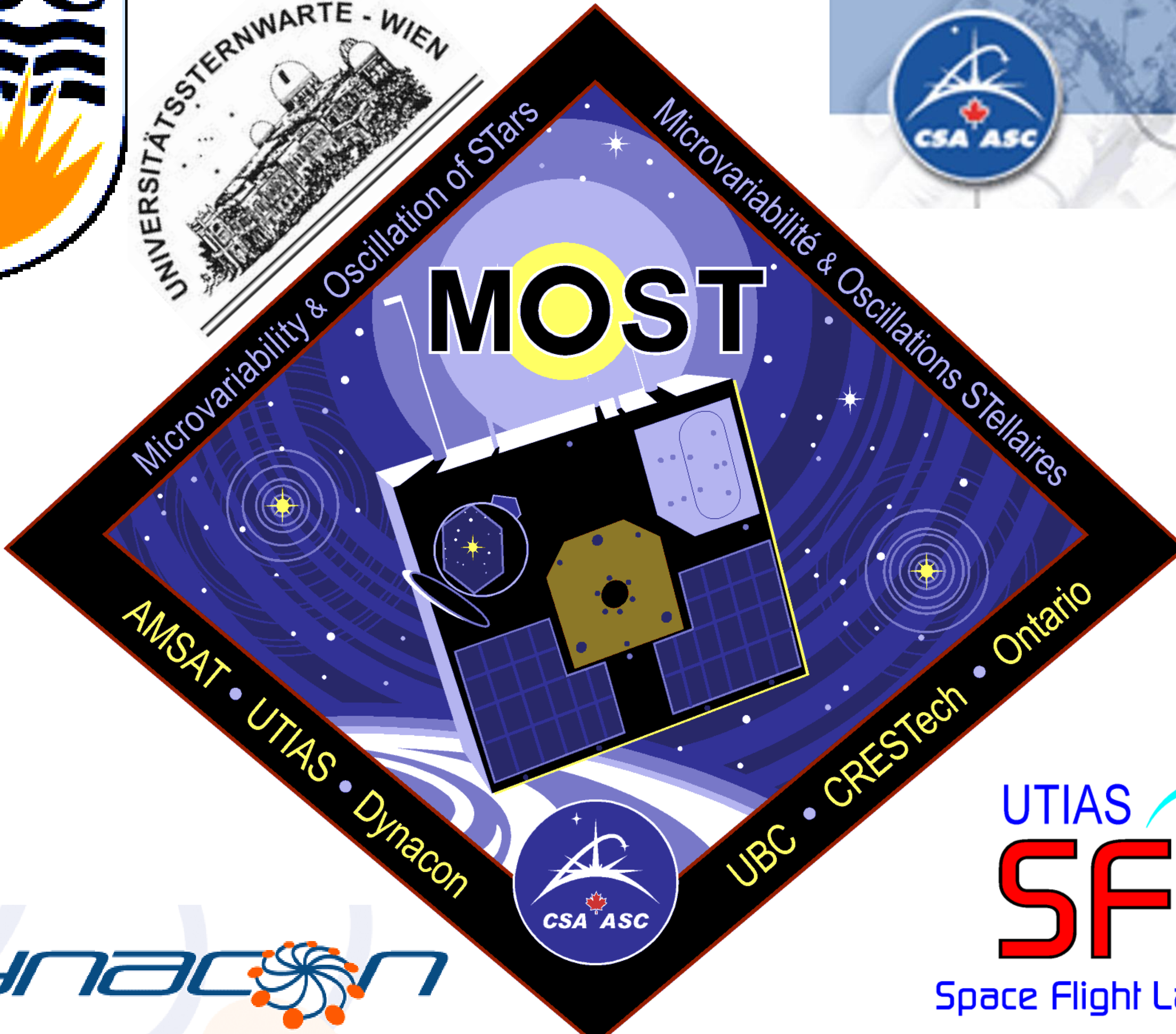
UBC

UNIVERSITÄTSSTERNWARTE - WIEN

Agence spatiale canadienne

Canadian Space Agency

CSA ASC



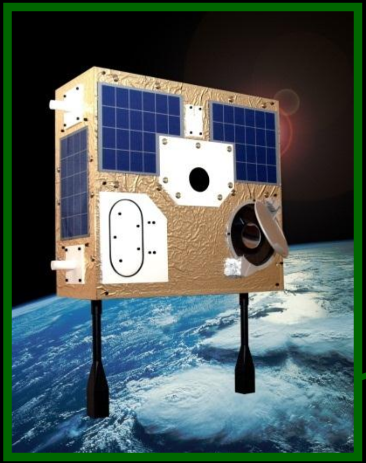
dynacon

UTIAS SFL

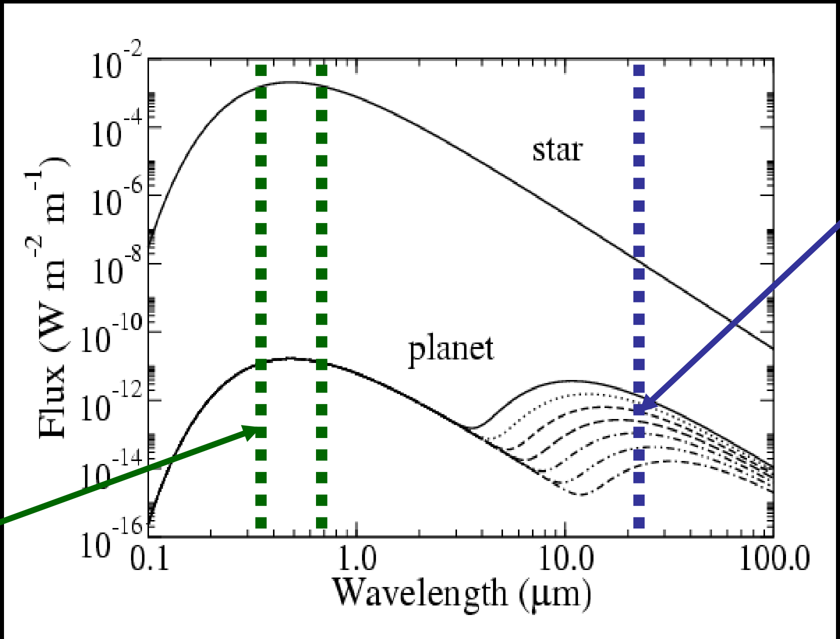
Space Flight Laboratory

HD 209458

MOST optical



Rowe et al. 2008
Astrophysical Journal

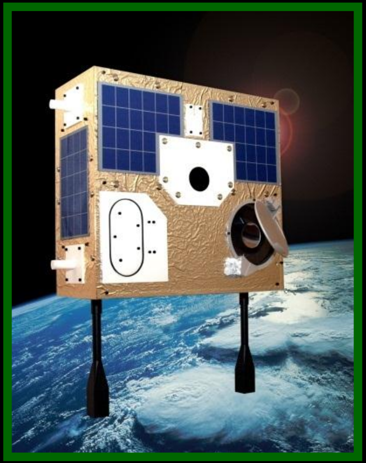


Spitzer infrared

Deming et al. 2005
Nature 111, 111

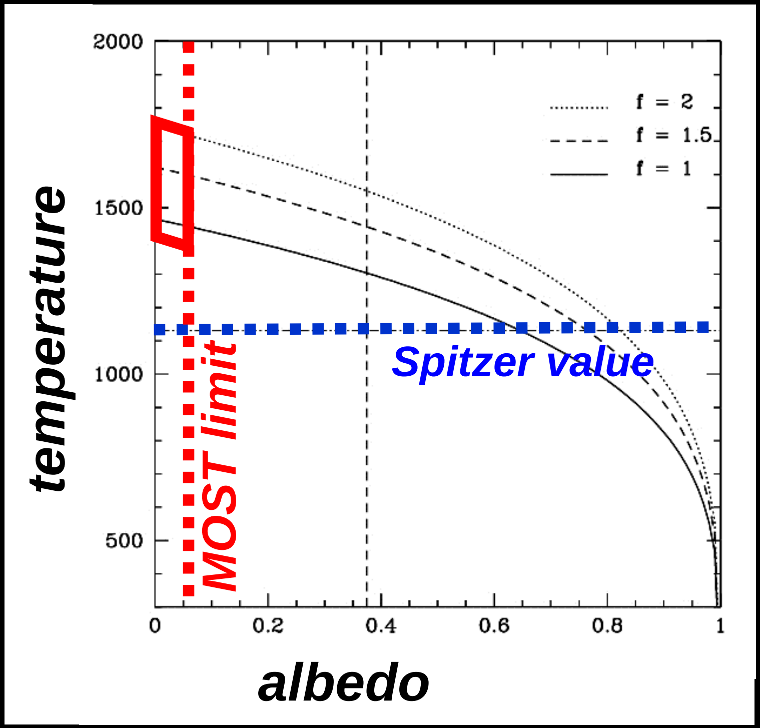
HD 209458

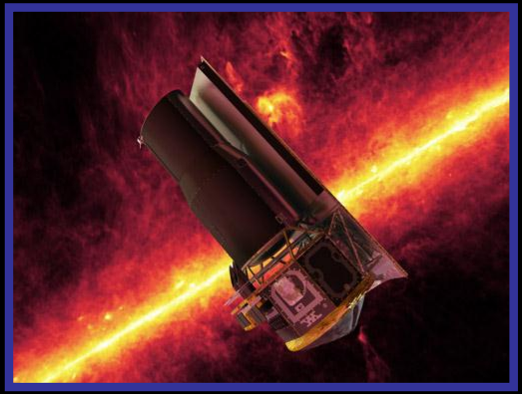
MOST
optical



Rowe et al. 2008
Astrophysical Journal

models of planet atmosphere





Spitzer
infrared

Deming et al. 2005
Nature 111, 111

HD 209458

Best fit parameters:

albedo = *0.04 ± 0.04*

stellar radius :

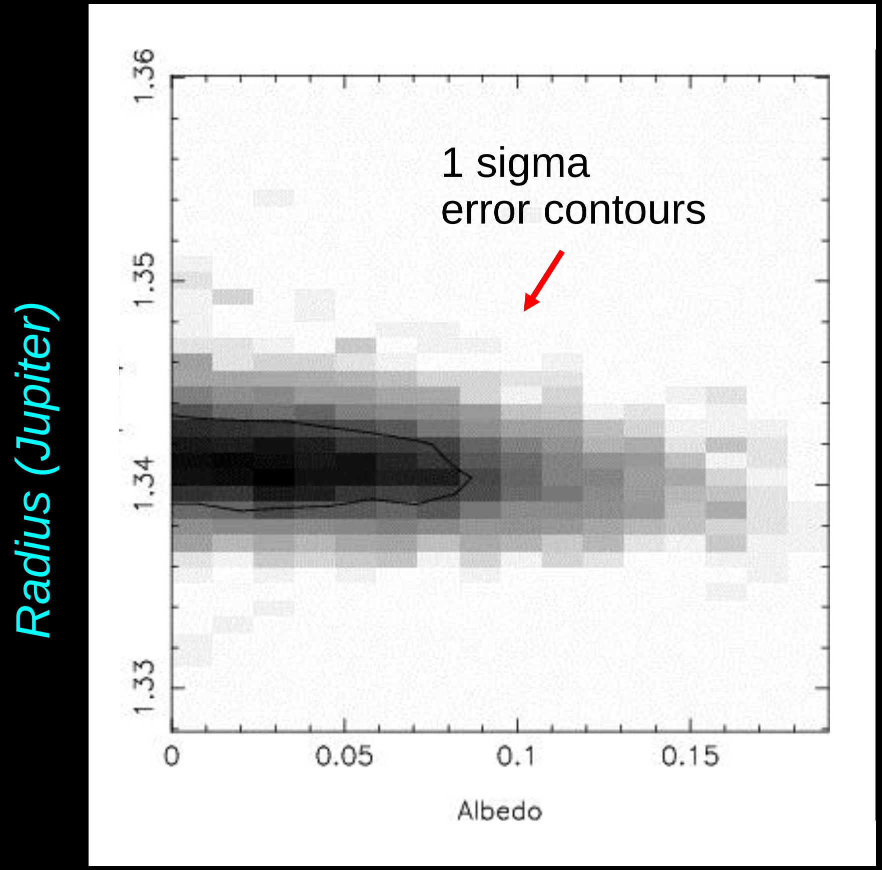
$1.339 \pm 0.001\ R_{Jupiter}$

stellar mass

$1.084 \pm 0.005\ M_{Sun}$

$i = 86.937° \pm 0.003°$

$P = 3.5247489$ d



Geometric Albedo

Exoplanetometeorology

MOST data are helping us understand the weather and clouds on a planet you can't even see around a star 160 light years away!?!

Changing channels

Exoplanetometeorology

Conception of a Sudarsky Class IV planet generated using Celestia Software

I : Ammonia Clouds
~~II : Water Clouds~~
III : Clear
IV : Alkali Metal ✓
~~V : Silicate Clouds~~

Predicted Albedos:
IV : 0.03 ✓
~~V : 0.50~~

Sudarsky Planet Classes

Exoplanetometeorology

Numerical simulations of atmospheric flow

✓ no vertical motion
radiative zone approximation
256 × 128 element grid
✓ forced thermal heating from star (f_{rad})
Newtonian heating / cooling

$$\frac{\partial T}{\partial t} = -\mathbf{v}\cdot\nabla T - (\gamma - 1)T\nabla\cdot\mathbf{v} + f_{rad}$$

$$\frac{\partial \mathbf{v}}{\partial t} = -\mathbf{v}\cdot\nabla\mathbf{v} - \frac{RT}{\rho}\nabla\rho - R\nabla T - 2\Omega_{rot}\sin\theta(\hat{n}\times\mathbf{v})$$

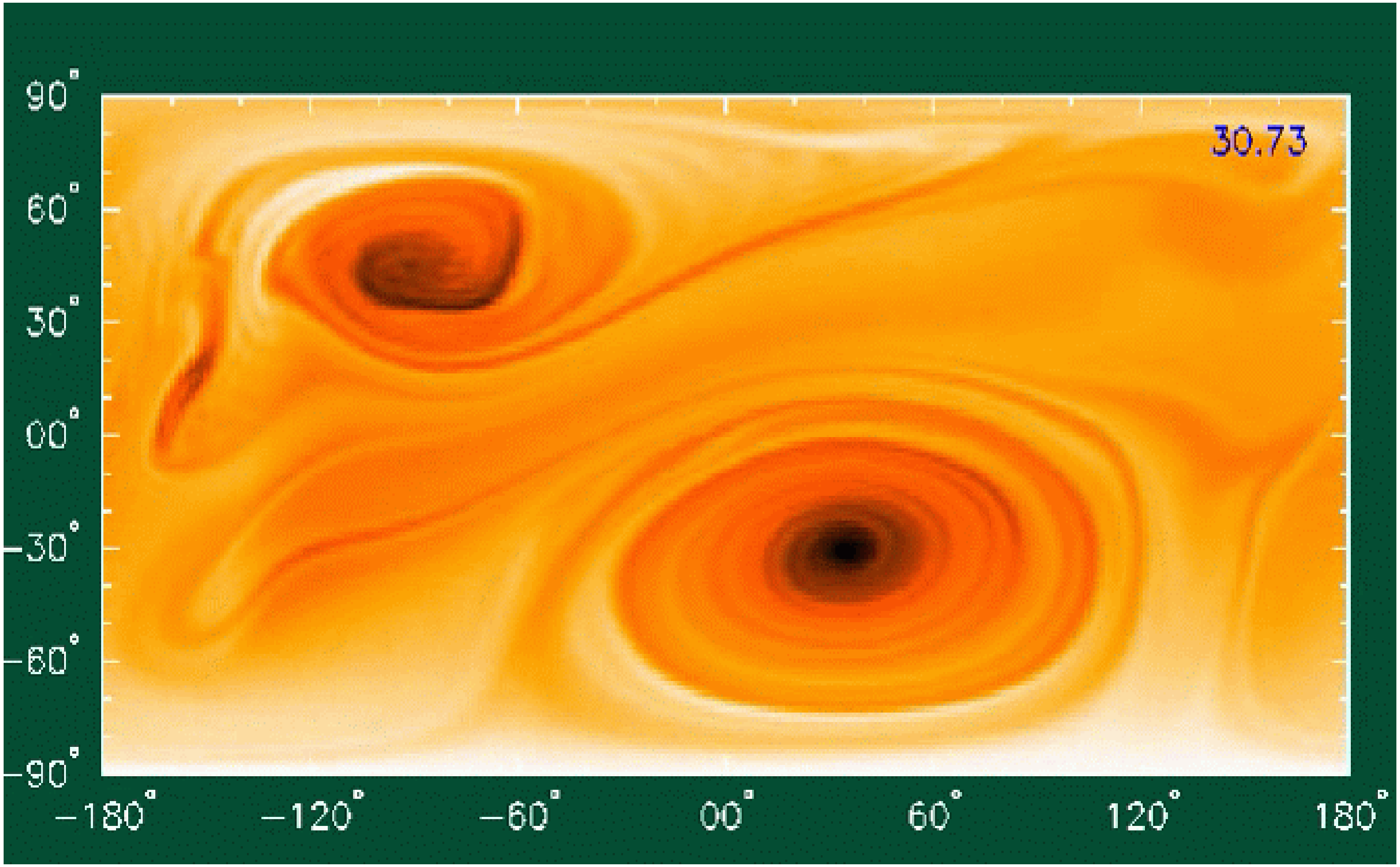
$$\frac{\partial \rho}{\partial t} = -\mathbf{v}\cdot\nabla\rho - \rho\nabla\cdot\mathbf{v},$$

Rowe & Matthews
2009 in preparation

Exoplanetometeorology

HD 189265b P_{rot} = 4.61 d T_{night} = 720 K

M = 4.18 $M_{Jupiter}$ P_{orbit} = 6.83 d a = 0.0766 AU e = 0.280



HD 209458 b atmosphere

- ✓ *Hubble Space Telescope (NICMOS)* programme ‘visited’ transiting exoplanet system HD 209458 *once in June 2008* and *twice in August 2008*
  - ✓ *infrared observations of transits and eclipses*

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  - *largest source of systematic error in their modeling*

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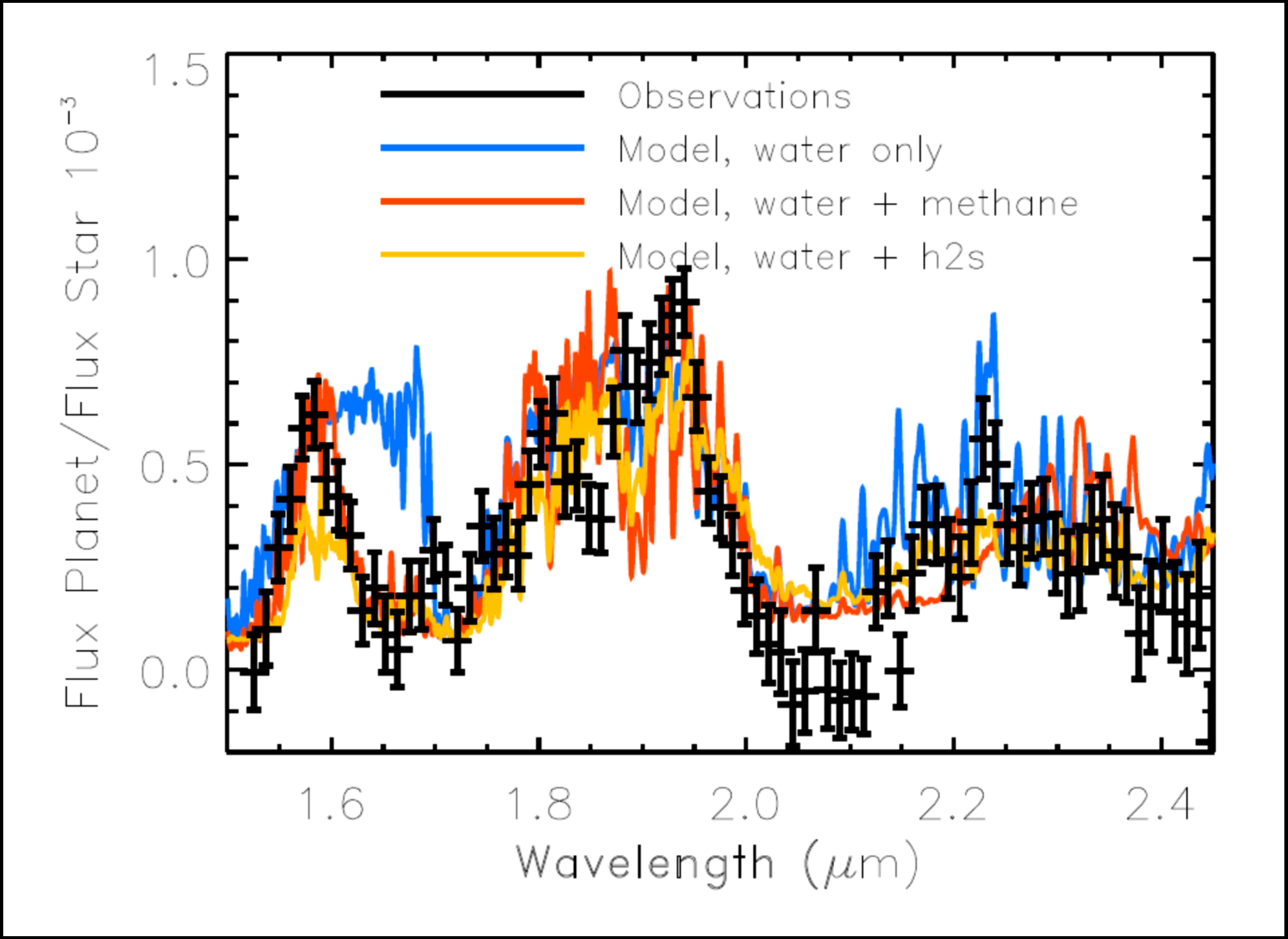
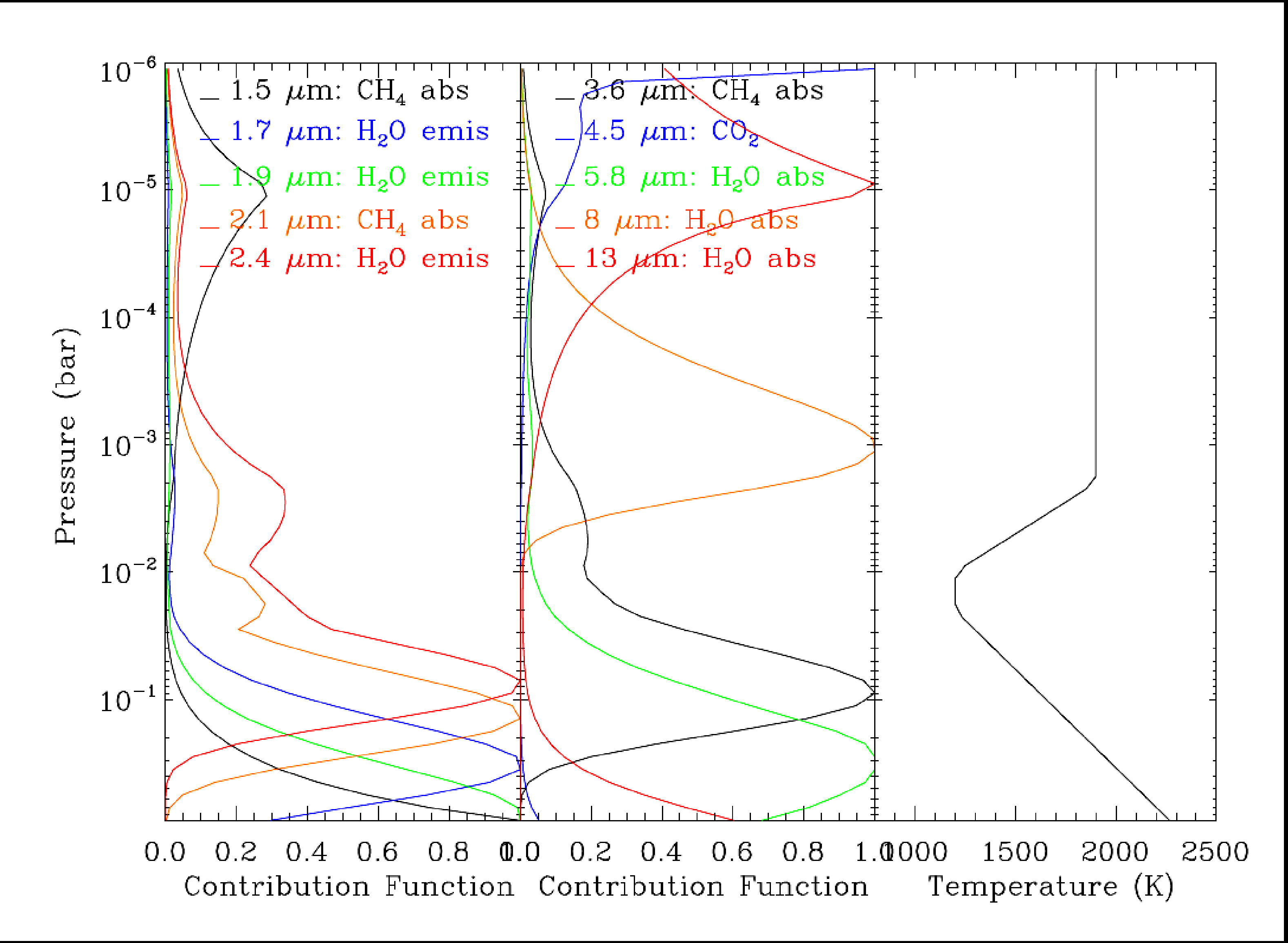
- PI Mark Swain (JPL) requested that MOST observe the star to calibrate the mean light level of the star from HST visit to HST visit
  - *largest source of systematic error in their modeling*
- Five successful 'visits' by MOST in June 2009
  - *Ability to observe a target long before it enters the CVZ by timing visits to coincide with solar eclipses*
- Paper published in Science – *Swain et al. 2009*

HD 209458 b atmosphere



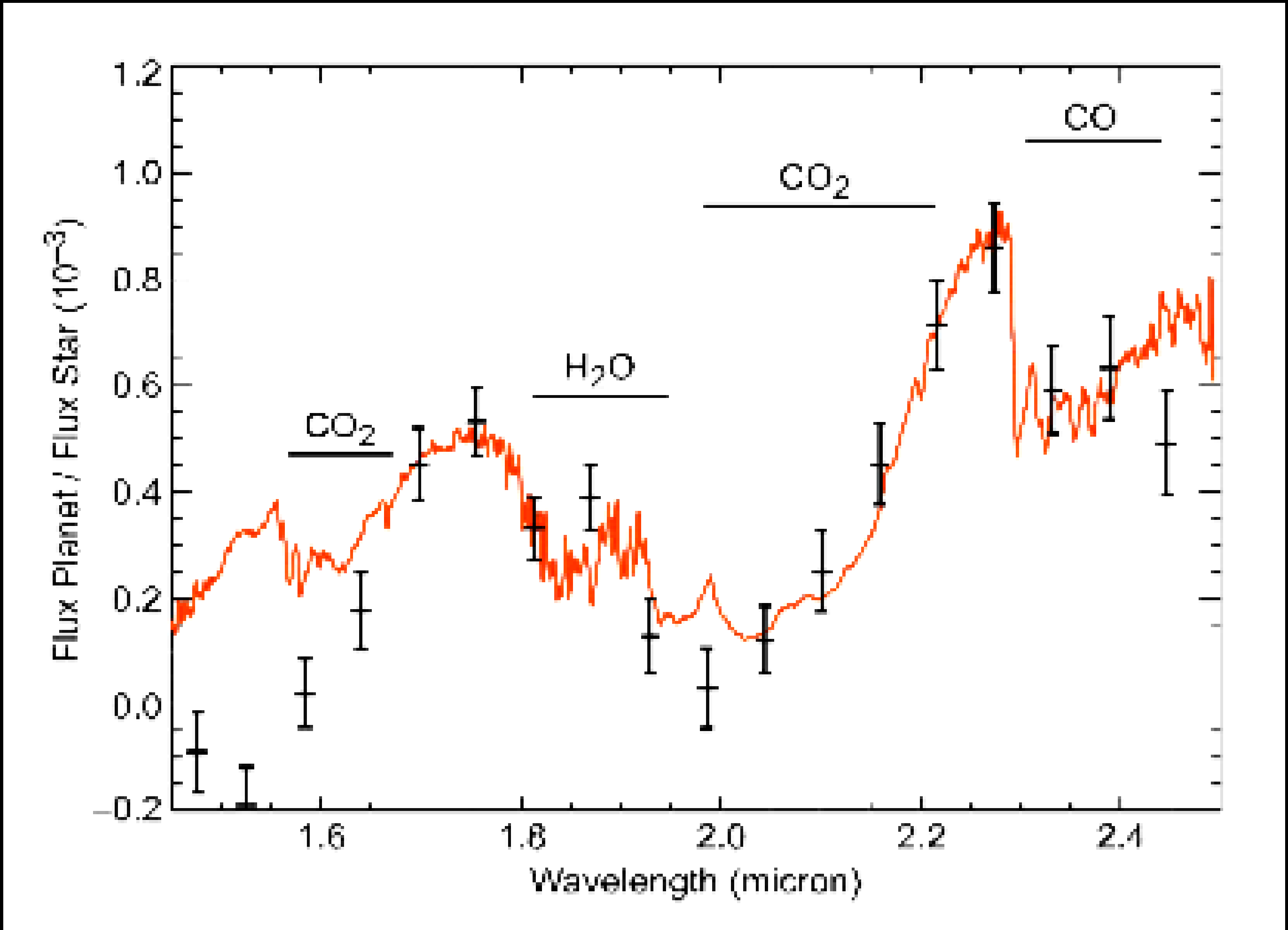
Swain et al. 2009

HD 209458 b atmosphere



Swain et al. 2009

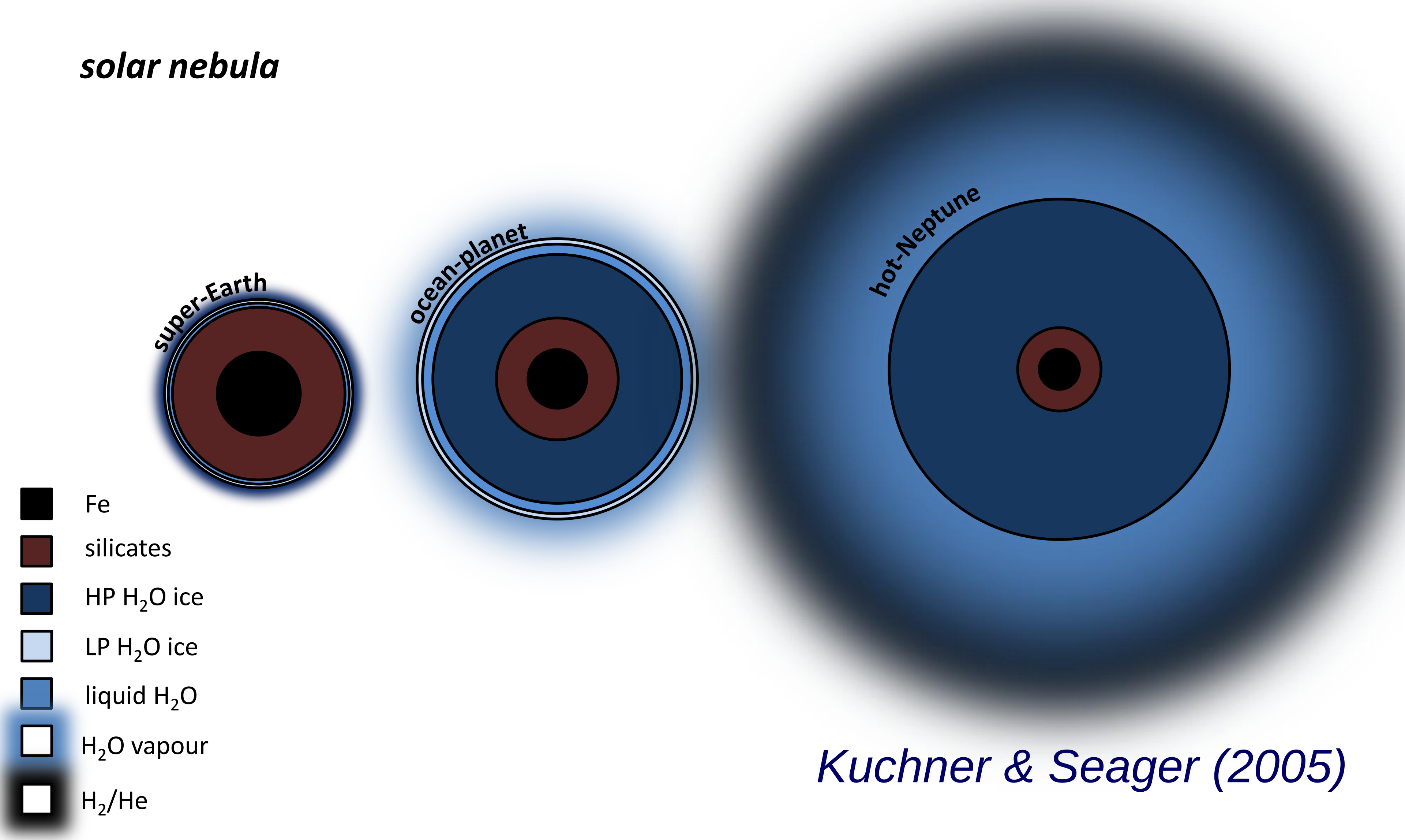
HD 189733 b atmosphere



Swain et al. 2008 Science

mini-Neptune vs. superEarth

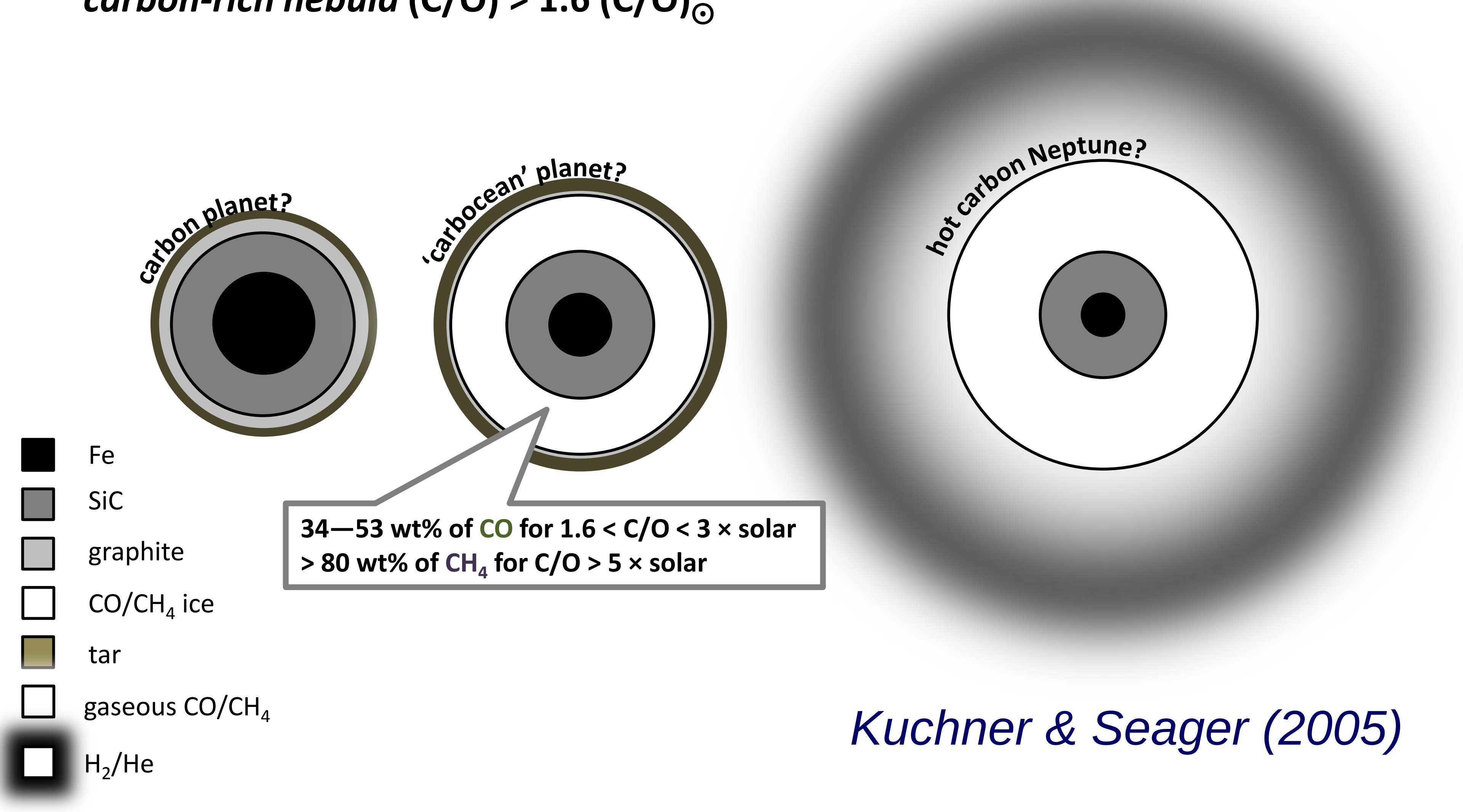
solar nebula



Kuchner & Seager (2005)

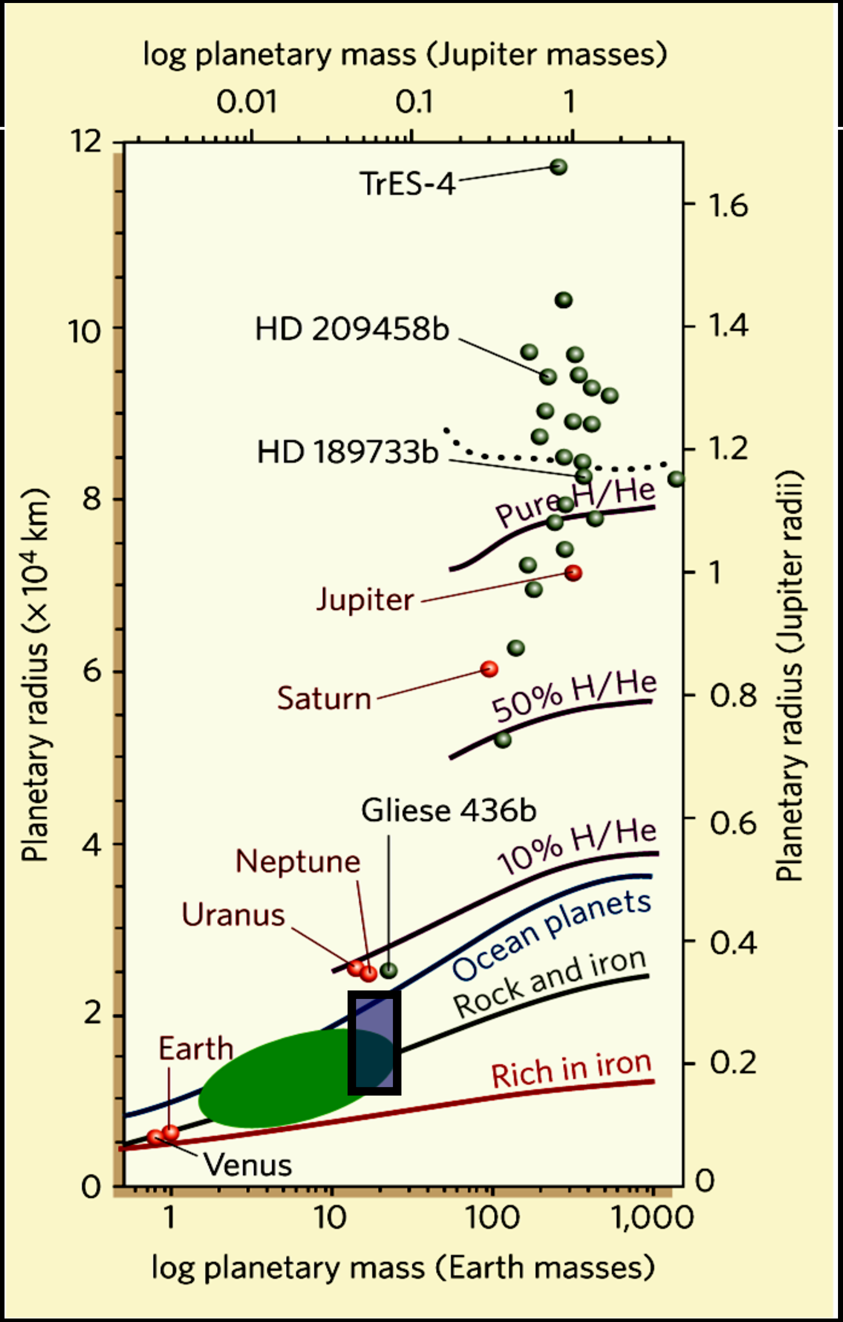
mini-Neptune vs. superEarth

carbon-rich nebula **(C/O) > 1.6 (C/O)$_\odot$**



Kuchner & Seager (2005)

superEarths

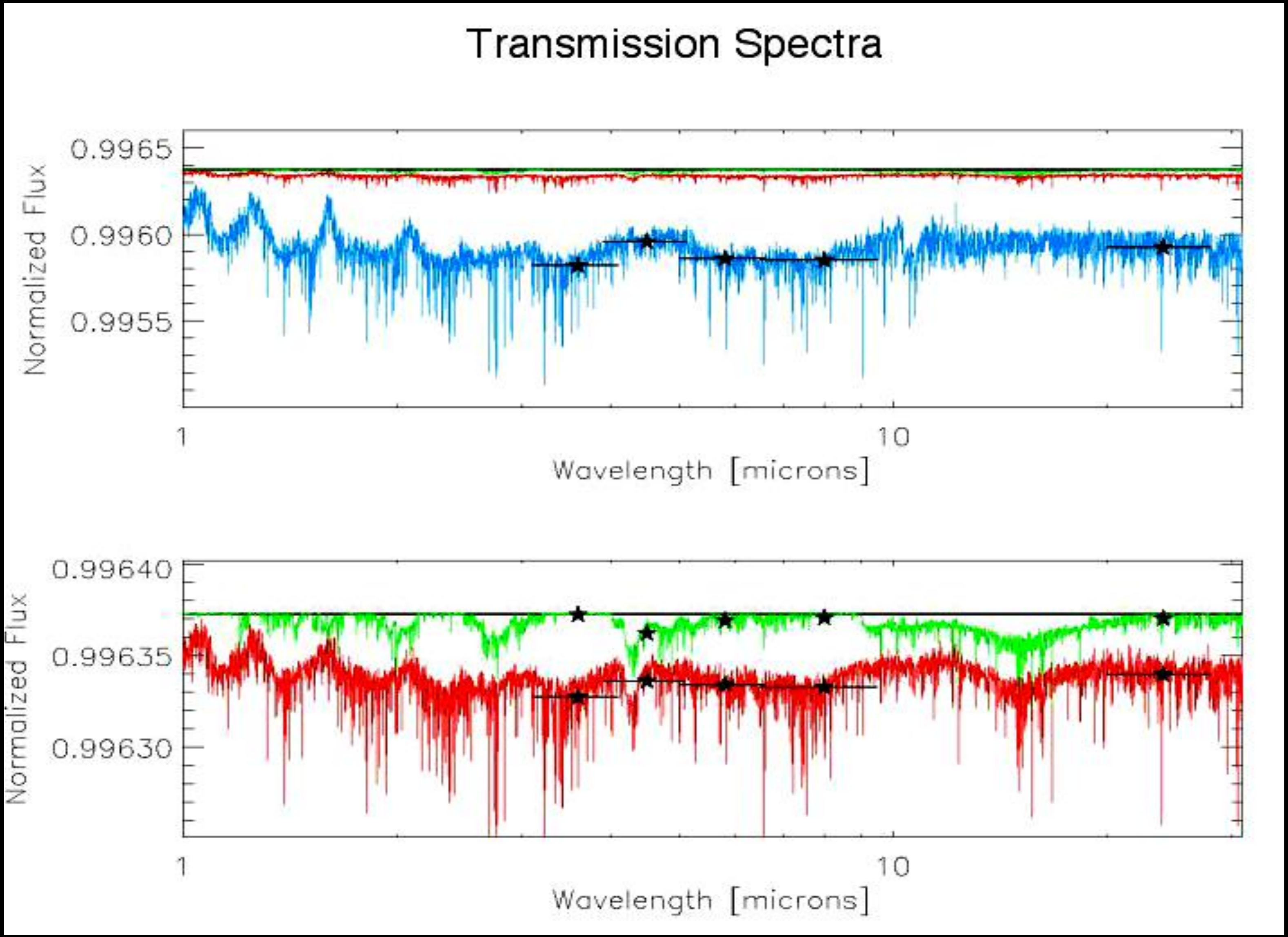


$M \sim 2 - 20\ M_{Earth}$

- ✓ Mass range is somewhat arbitrary
  - ✓ upper limit → a core that can accrete H_2 gas from the disk
- ✓ Two generic families
  - ✓ depends on H_2O content
- ✓ None in Solar System

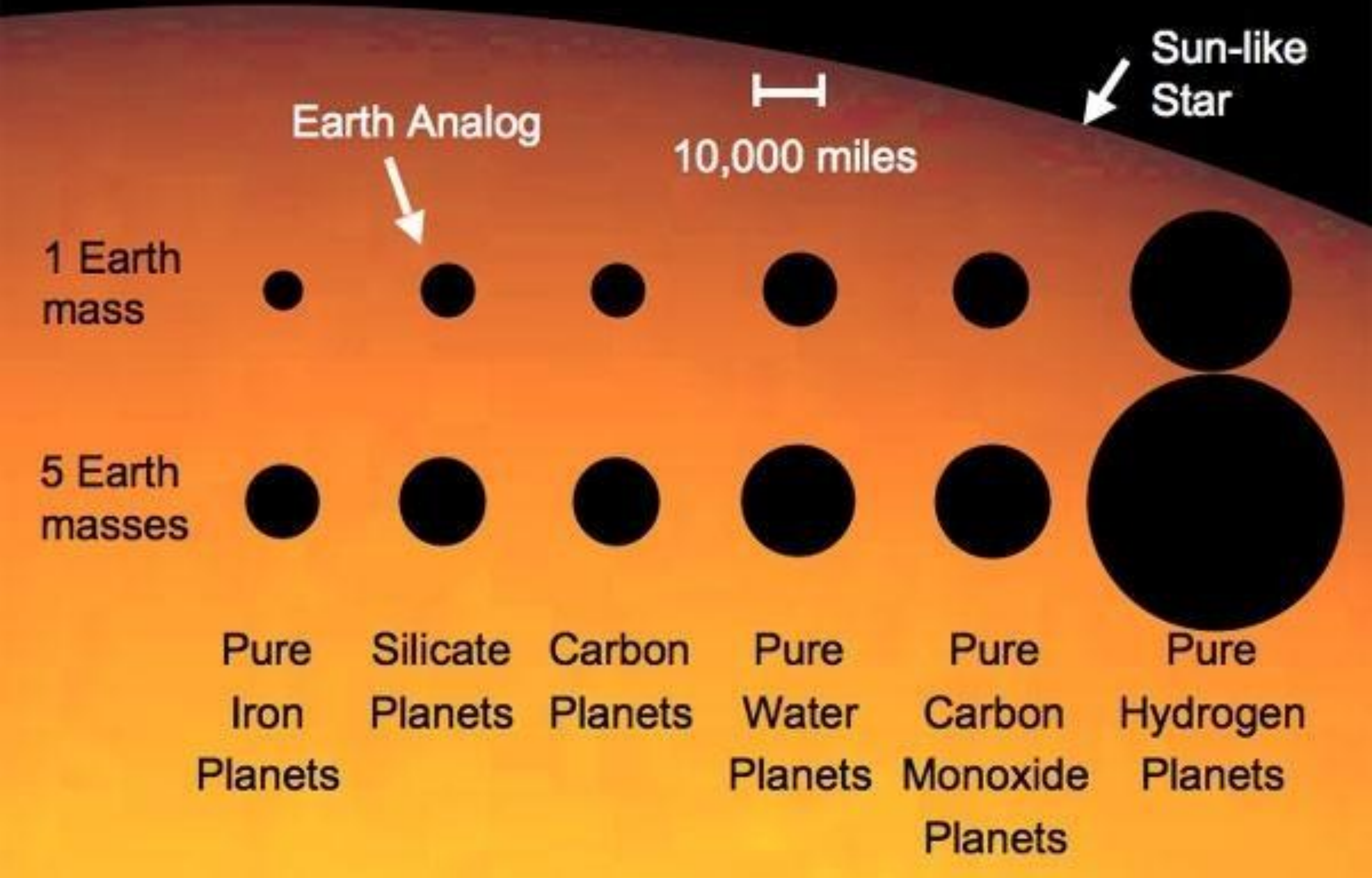
"confusion region"

mini-Neptune vs. superEarth



Miller-Ricci, Seager, Sasselov 2008

Predicted Sizes of Different Kinds of Planets



Questions?

Spin-orbit alignment

The Rossiter-McLaughlin Effect

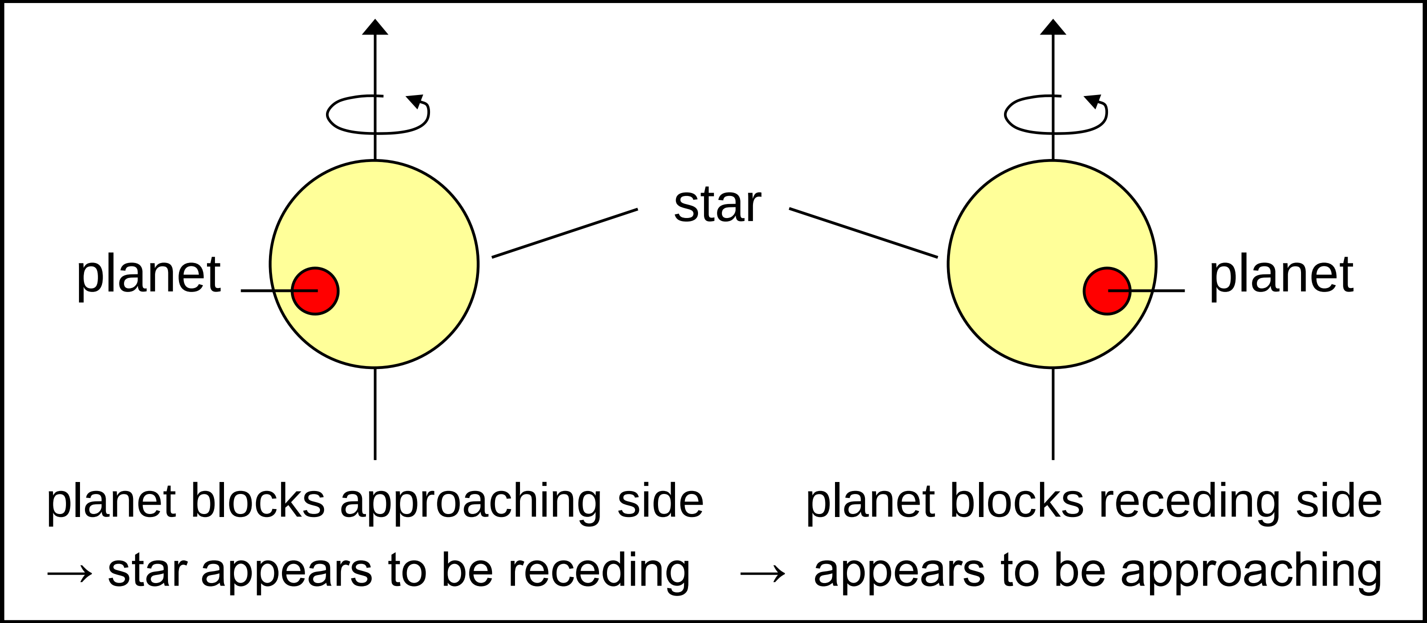
When a planet transits the Sun
or an exoplanet transits a star
there is more than just
a brief dip in observed flux

Spin-orbit alignment

The Rossiter-McLaughlin Effect

When a planet transits the Sun or an exoplanet transits a star there is more than just a brief dip in observed flux

The planet filters the integrated rotation profile of the visible disk of the star that broadens spectral lines



Spin-orbit alignment

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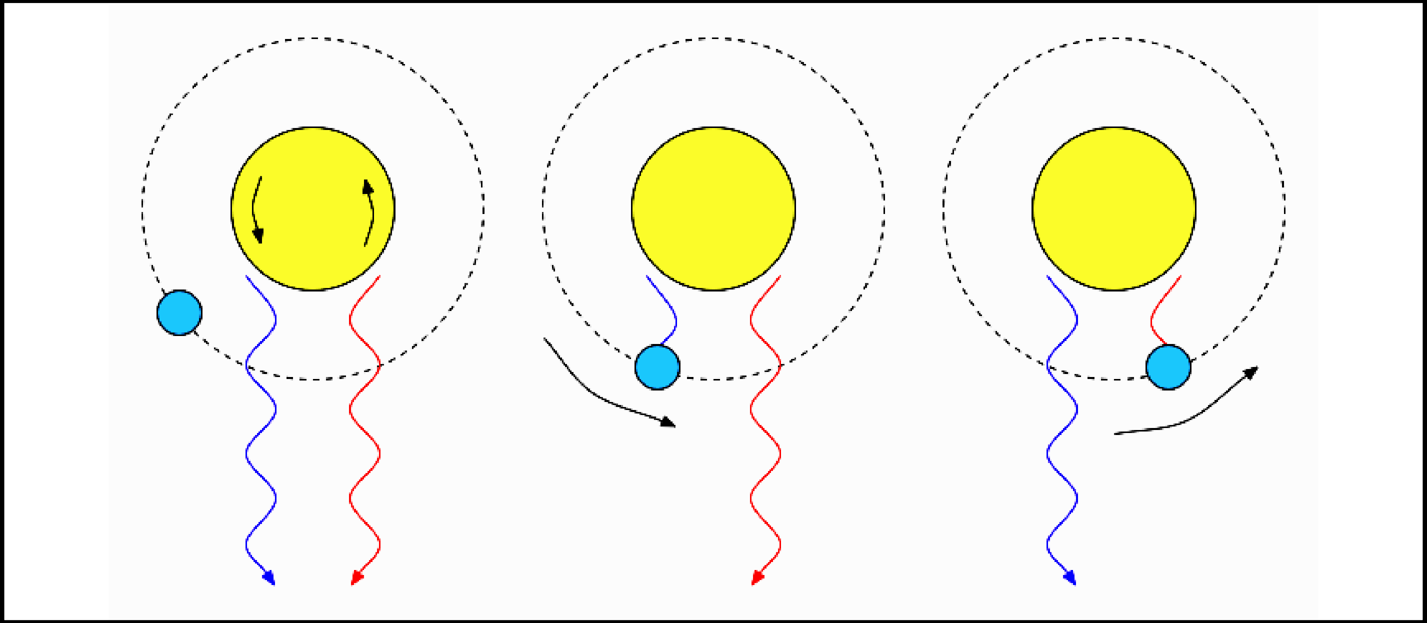
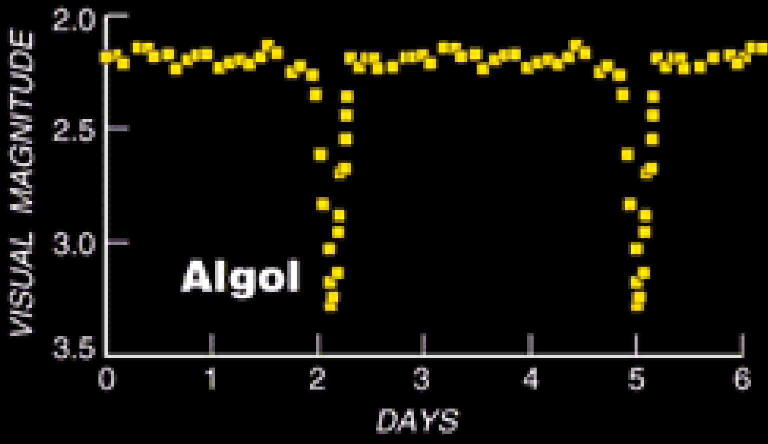


Spin-orbit alignment

The Rossiter-McLaughlin Effect

The effect was first observed in the eclipsing binary systems β Lyrae and β Persei (Algol)

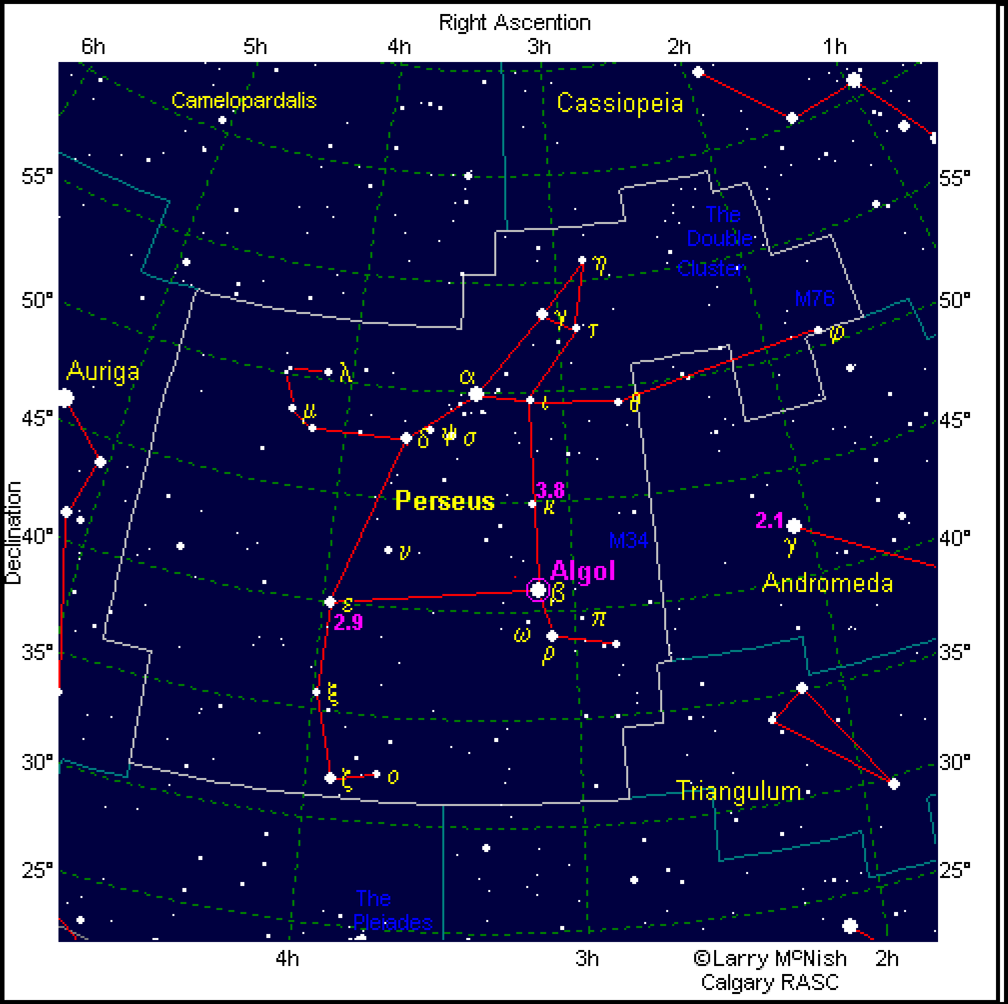


Spin-orbit alignment

The mystery of The Demon

Spin-orbit alignment

The mystery of The Demon



The second brightest star in the constellation Perseus (β Persei) would dim and brighten and was thought of by Arabic astronomers as the blinking red eye of a demon

They named it
Ra's Al Ghul
"The Head of the Ghoul"
now written *Algol*

Spin-orbit alignment

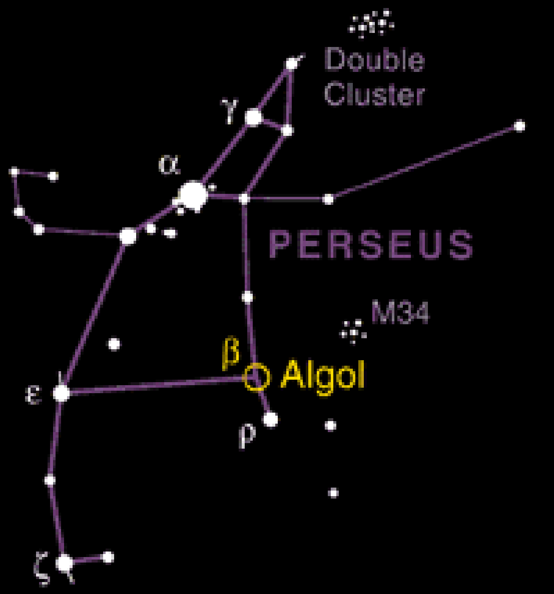
The mystery of The Demon

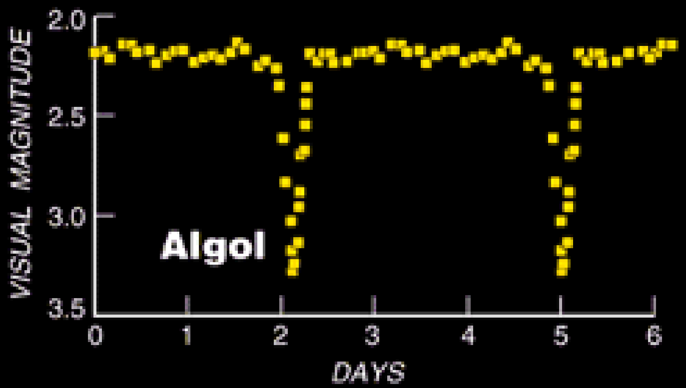
This even became the name of a supervillain that clashed with Batman

They named it
Ra's Al Ghul
"The Head of the Ghoul"
now written *Algol*

Spin-orbit alignment

The mystery of The Demon





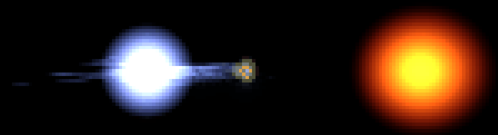
The second brightest star in the constellation Perseus (β Persei) would dim and brighten and was thought of by Arabic astronomers as the blinking red eye of a demon

The blinking is due to the fact that *Algol* is an <u>eclipsing binary system</u> *(orbital period ~ 3 days)*

Spin-orbit alignment

The mystery of The Demon

Algol is an eclipsing binary with a *3.7 M_{Sun}* main-sequence star and a *0.8 M_{Sun}* red giant



Spin-orbit alignment

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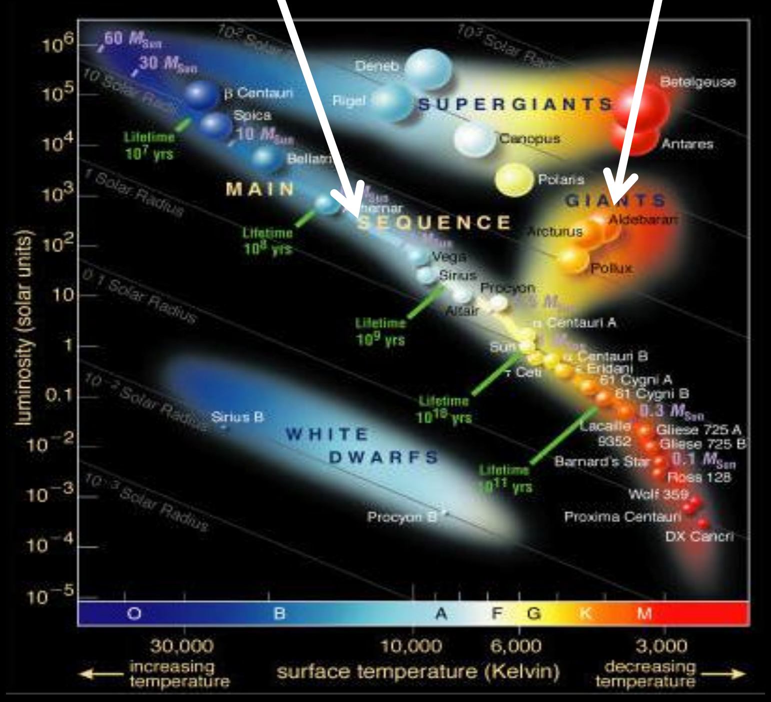
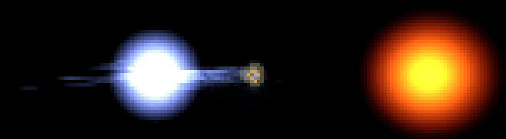


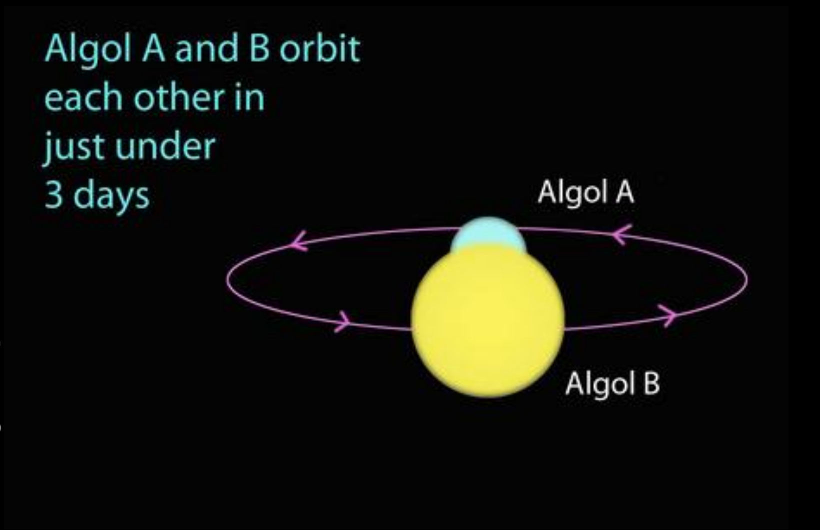


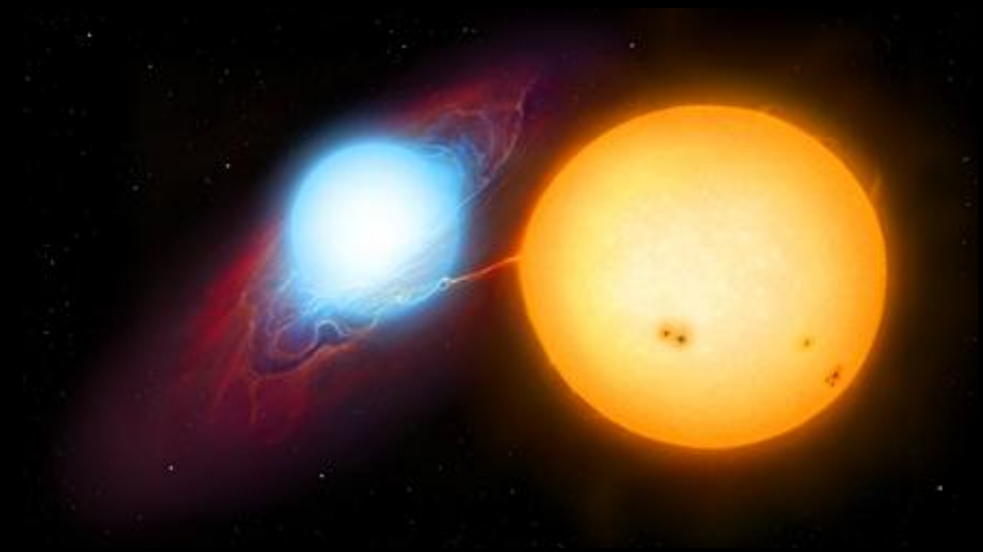
Spin-orbit alignment

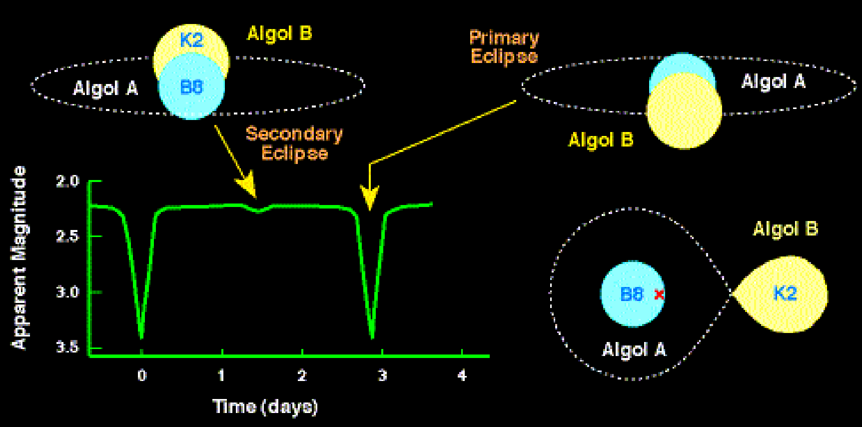
The mystery of The Demon

Algol is an eclipsing binary with a *3.7* M_{Sun} main-sequence star and a *0.8* M_{Sun} red giant

This was a mystery *Why?*







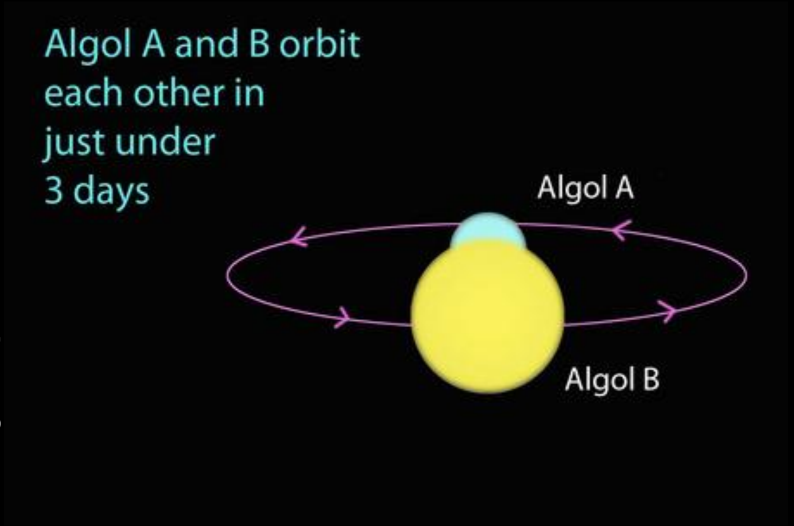
Spin-orbit alignment

The <u>mystery</u> of The Demon

Algol is an eclipsing binary with a *3.7* M_{Sun} main-sequence star and a *0.8* M_{Sun} red giant

This was a mystery *Why?*

Because a more massive star has a shorter main sequence lifetime than a less massive star



How did a star less massive than the Sun become a red giant <u>before</u> a star of greater mass when both stars were born at the same time?

Spin-orbit alignment

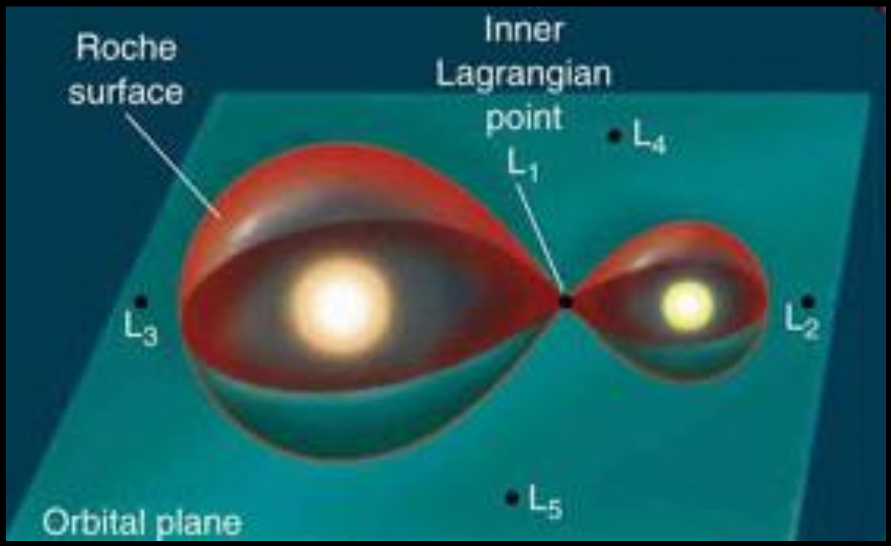
Close binaries and mass transfer

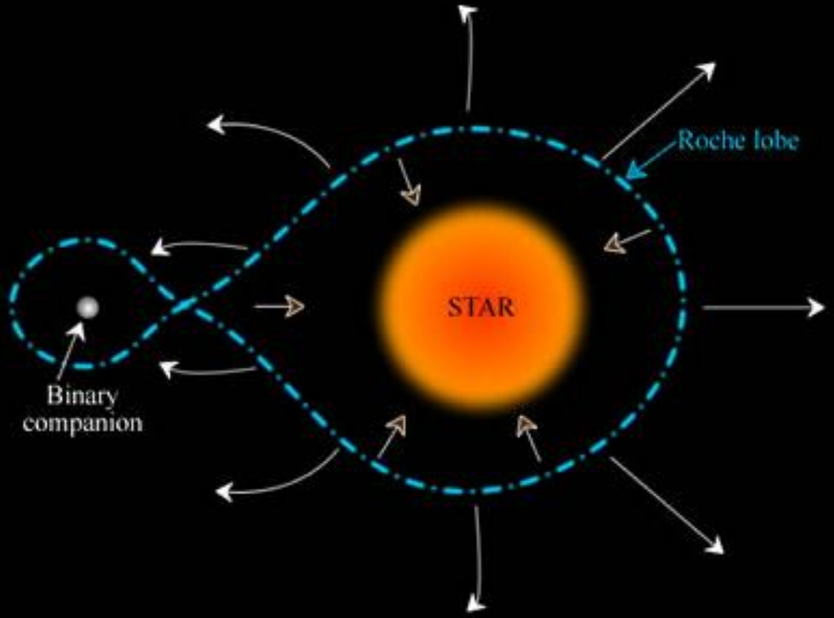
The two stars in the Algol system are so close together that they exchange gas from one to the other

Spin-orbit alignment

Roche lobes

When two stars are close enough, their gravitational fields interact to define surfaces of constant gravitational potential which are no longer spheres centred on each star



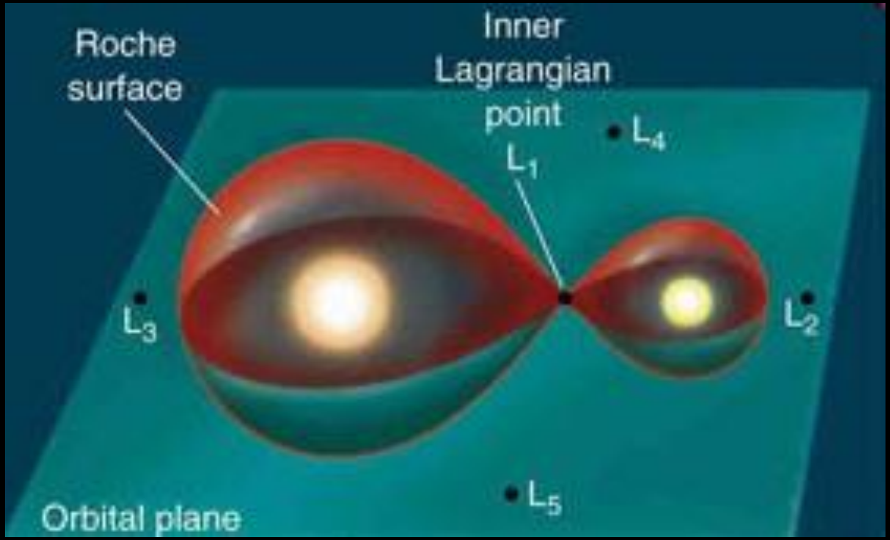


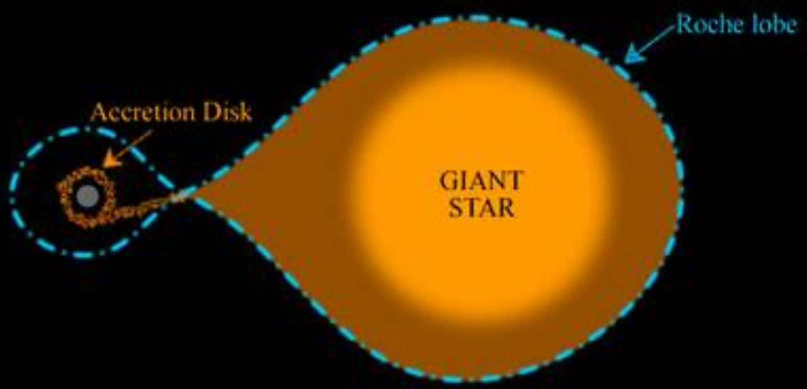
The surfaces connect and look like two balloons tied together

Spin-orbit alignment

Roche lobes and binary evolution

The higher-mass star in the Algol binary
evolved more quickly, exhausting its core hydrogen
and expanding into a red giant, overflowing its Roche lobe





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Spin-orbit alignment

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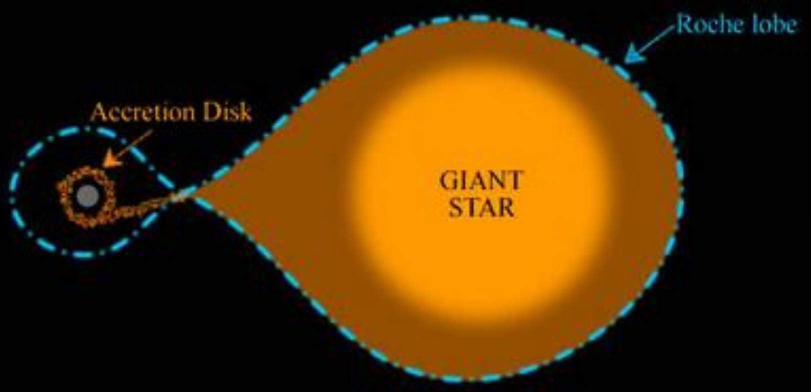
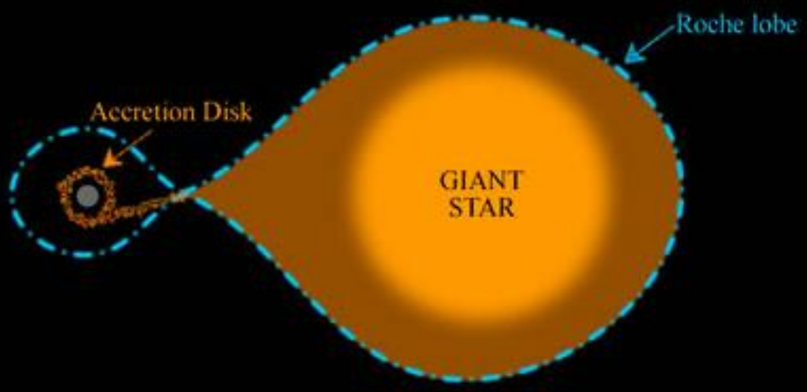


Gas begins to flow across the connection onto the other star

Spin-orbit alignment

Roche lobes and binary evolution

The red giant loses mass and the main-sequence star gains (so it starts evolving more rapidly but still hasn't reached the end of its core hydrogen burning and turned into a red giant)



Gas begins to flow across the connection onto the other star

Spin-orbit alignment

The life of Algol so far

beginning of
main sequence life

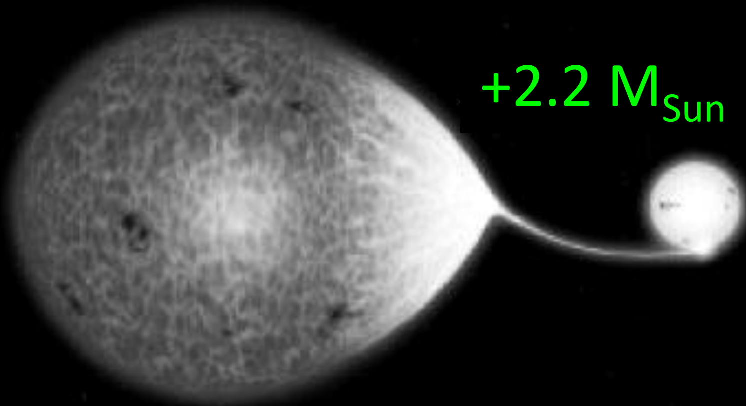
$3.0\ M_{Sun}$ $1.5\ M_{Sun}$

Spin-orbit alignment

The life of Algol so far

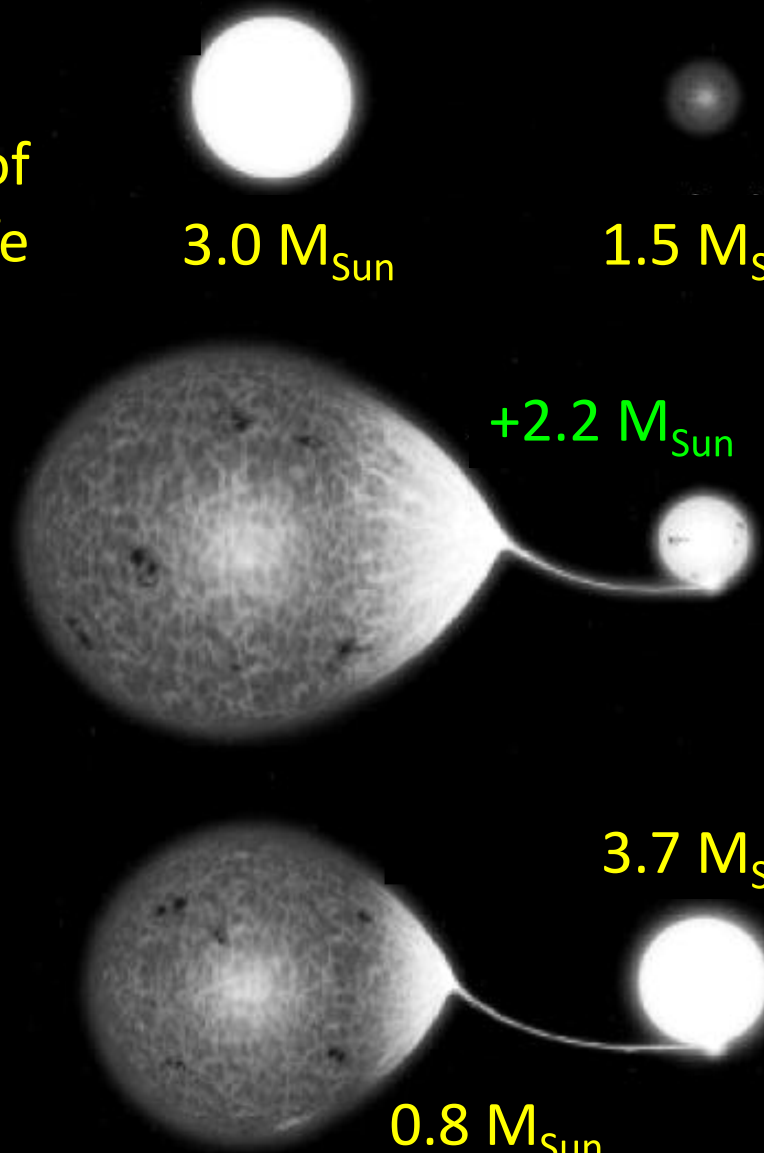
beginning of
main sequence life

$3.0\ M_{Sun}$ $1.5\ M_{Sun}$



Spin-orbit alignment

The life of Algol so far



Spin-orbit alignment

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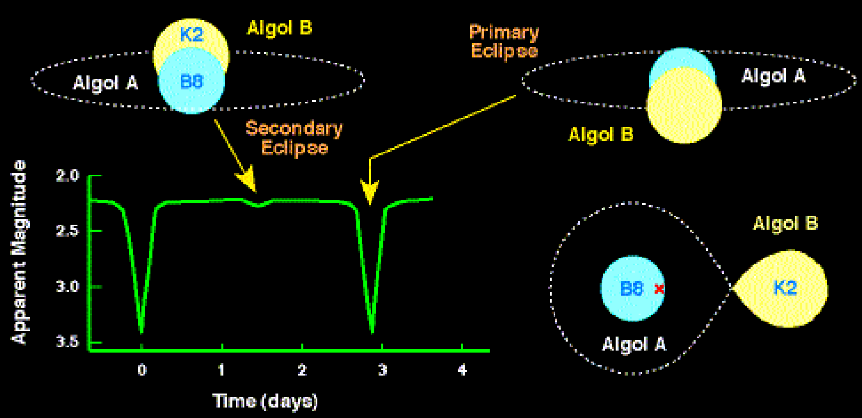


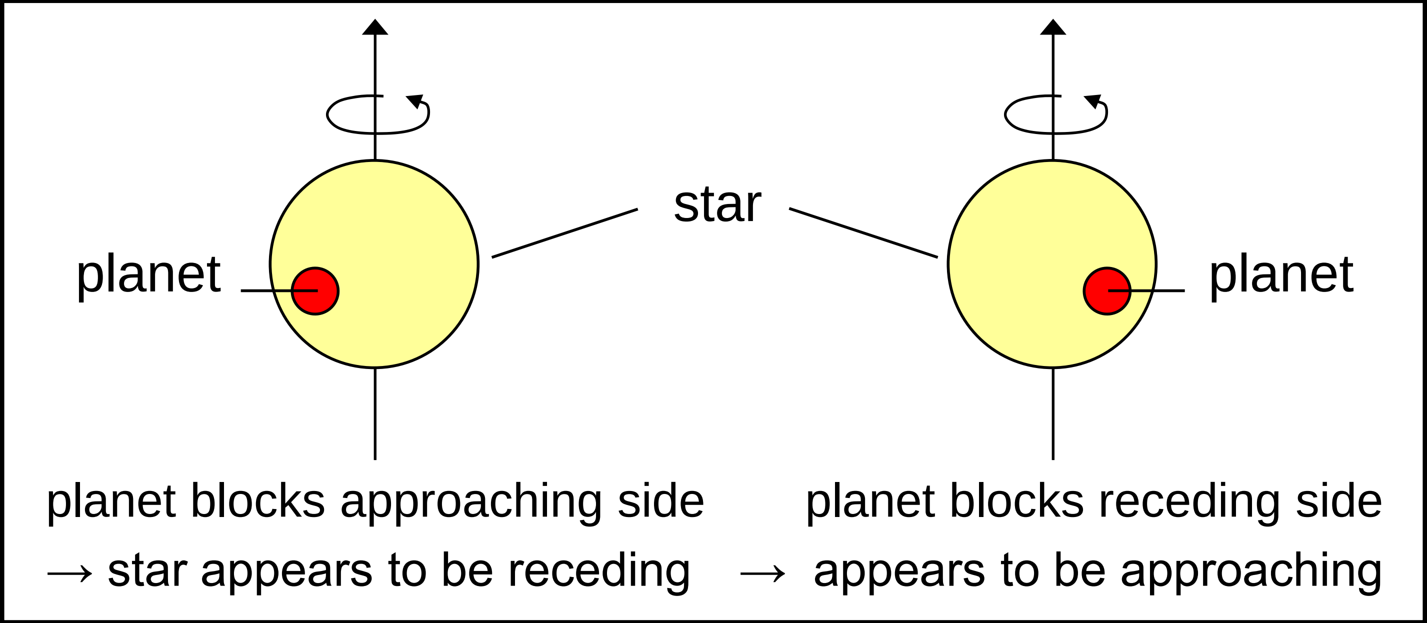
There are many other *mass-transfer binary* systems like Algol

Spin-orbit alignment

The Rossiter-McLaughlin Effect

When a planet transits the Sun or an exoplanet transits a star there is more than just a brief dip in observed flux

The planet filters the integrated rotation profile of the visible disk of the star that broadens spectral lines



Spin-orbit alignment

The Rossiter-McLaughlin Effect

The effect was first observed in 1924
in the eclipsing binary system
β Lyrae by Rossiter

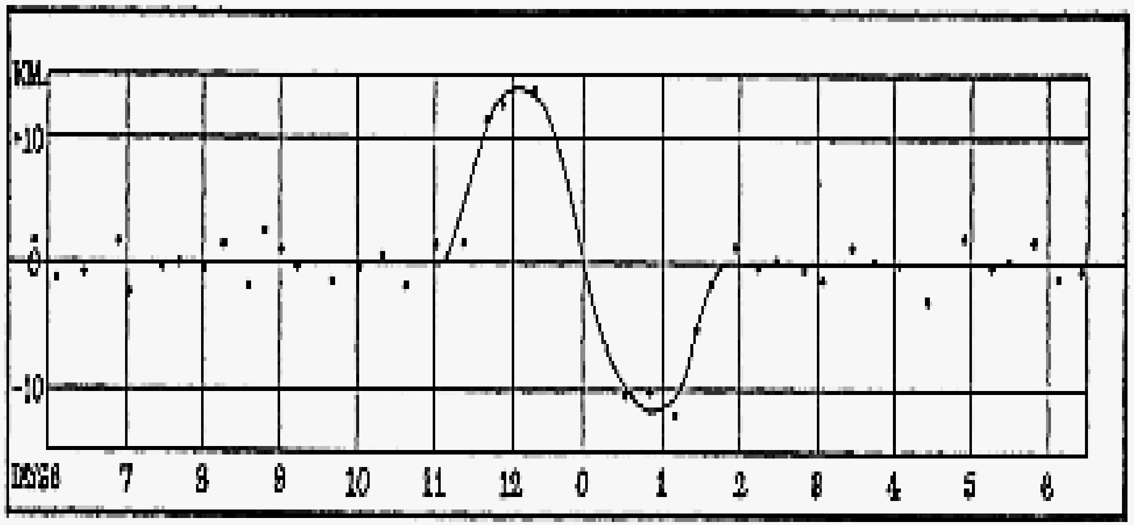


FIG. 2

Spin-orbit alignment

The Rossiter-McLaughlin Effect

The effect was first observed in 1924 in the eclipsing binary systems β Lyrae by Rossiter and β Persei (Algol) by McLaughlin

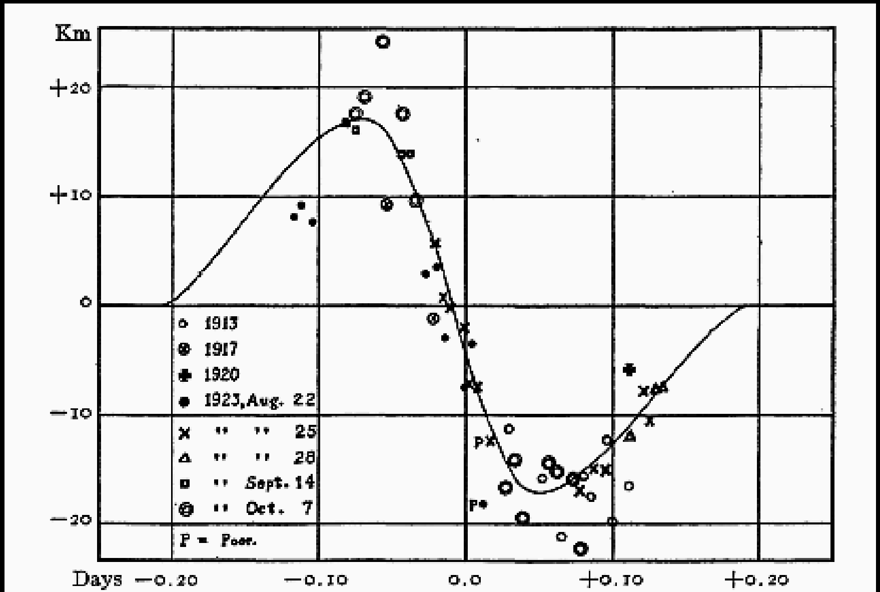
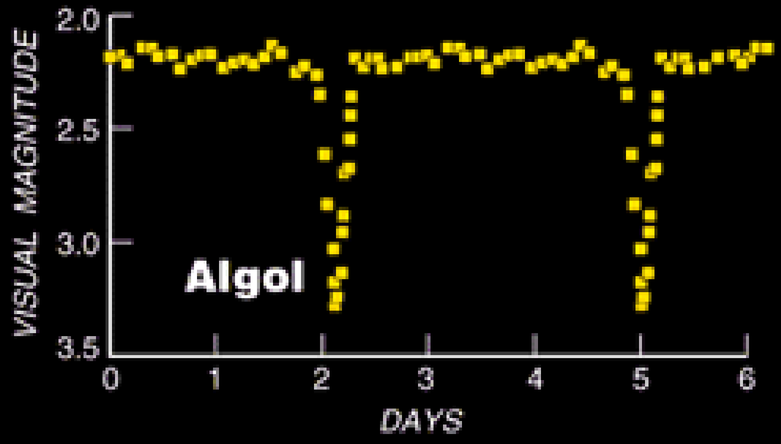


FIG. 1.—Curve of the rotational effect in Algol

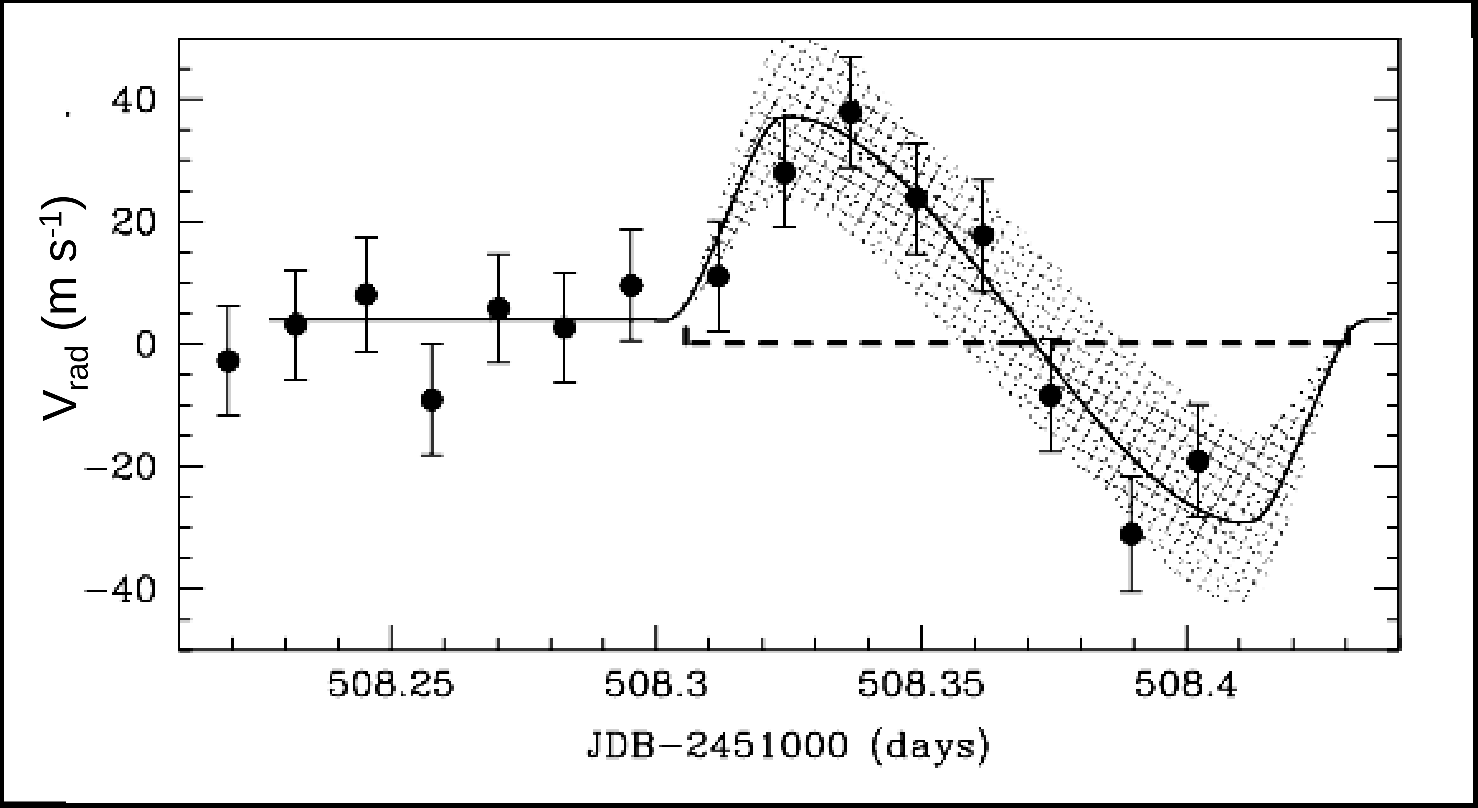


Spin-orbit alignment

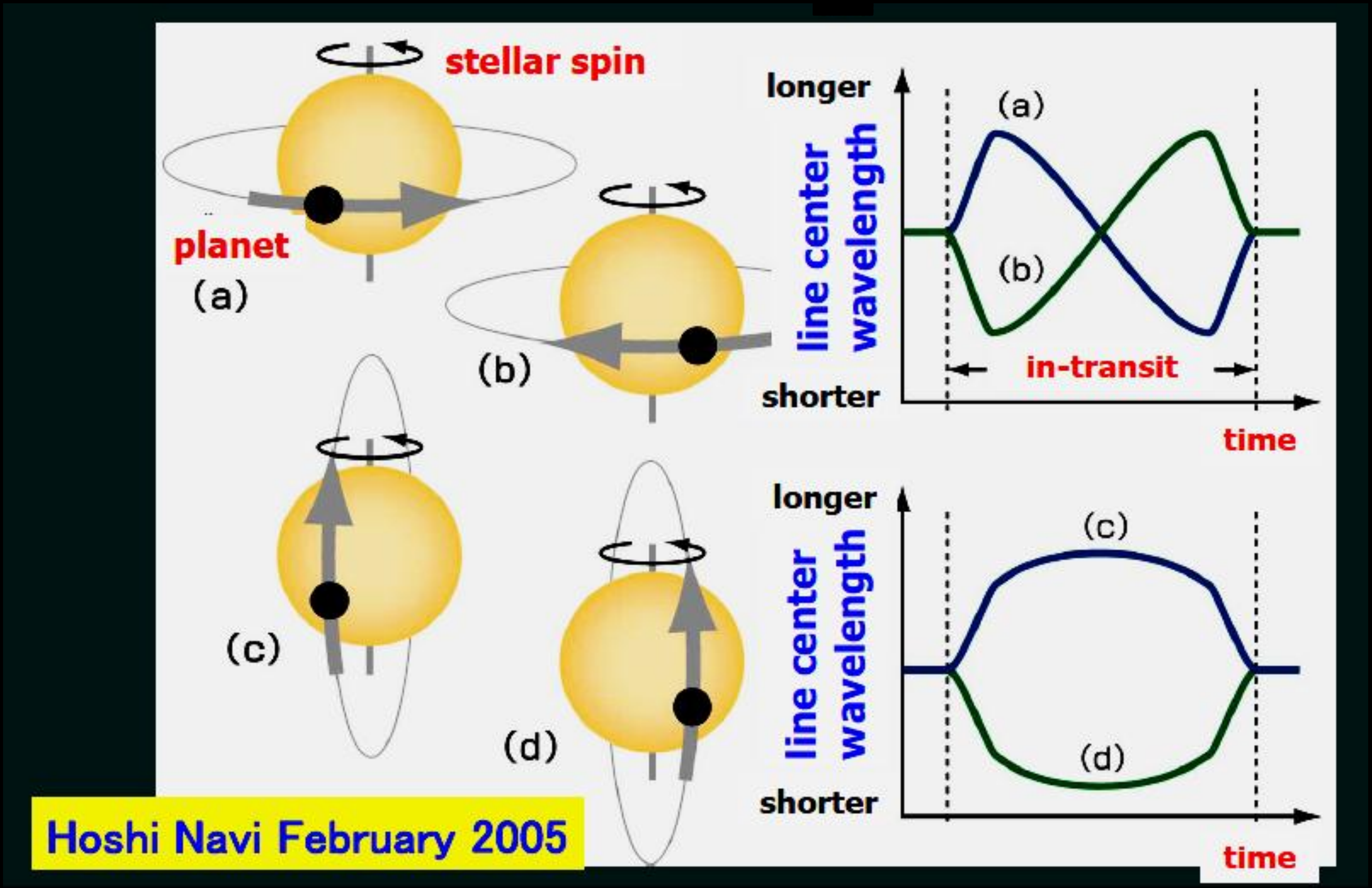
The Rossiter-McLaughlin Effect

The effect was first observed in 2000
in an exoplanet system by Queloz et al.

HD 209458



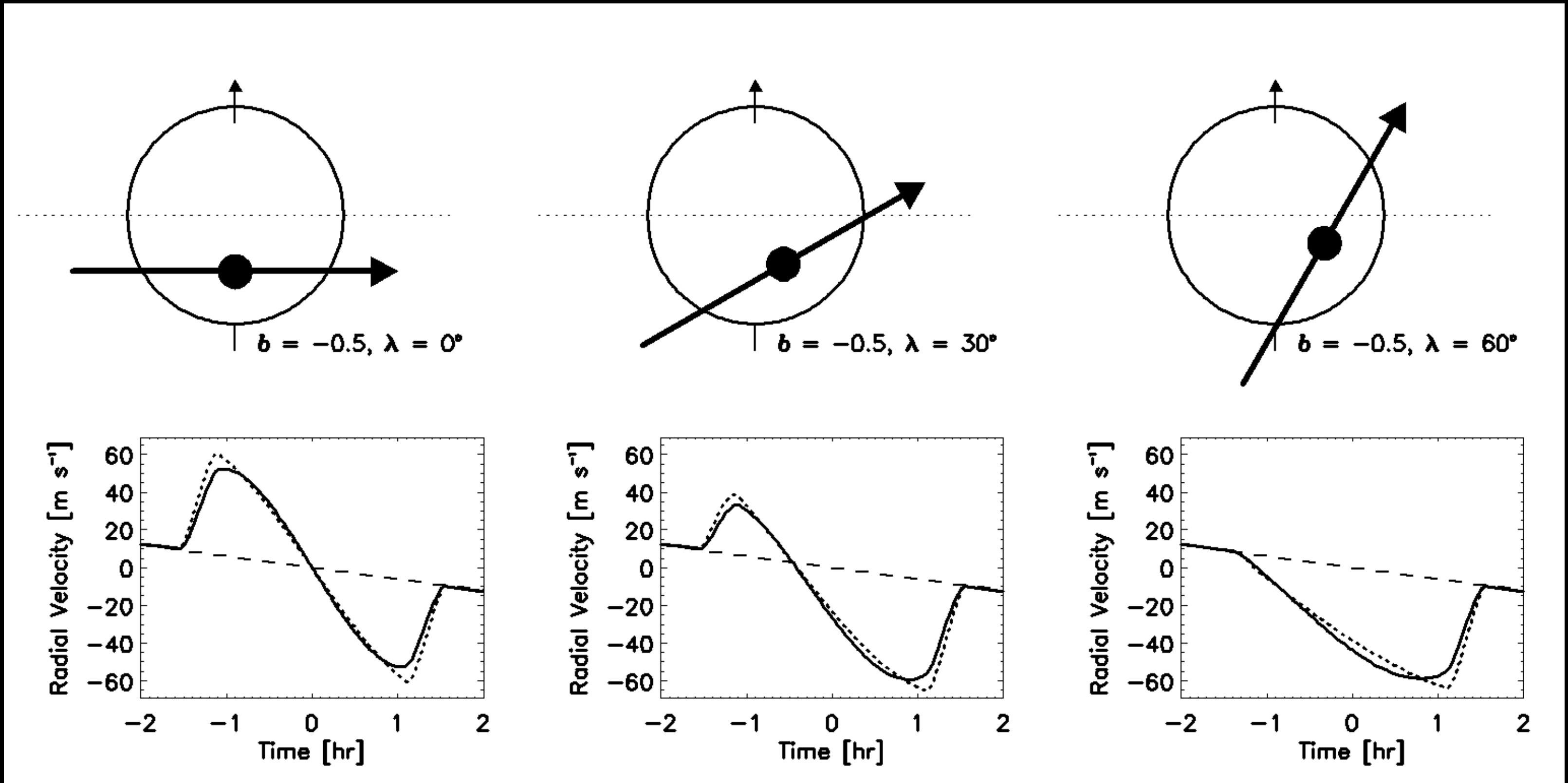
Spin-orbit alignment



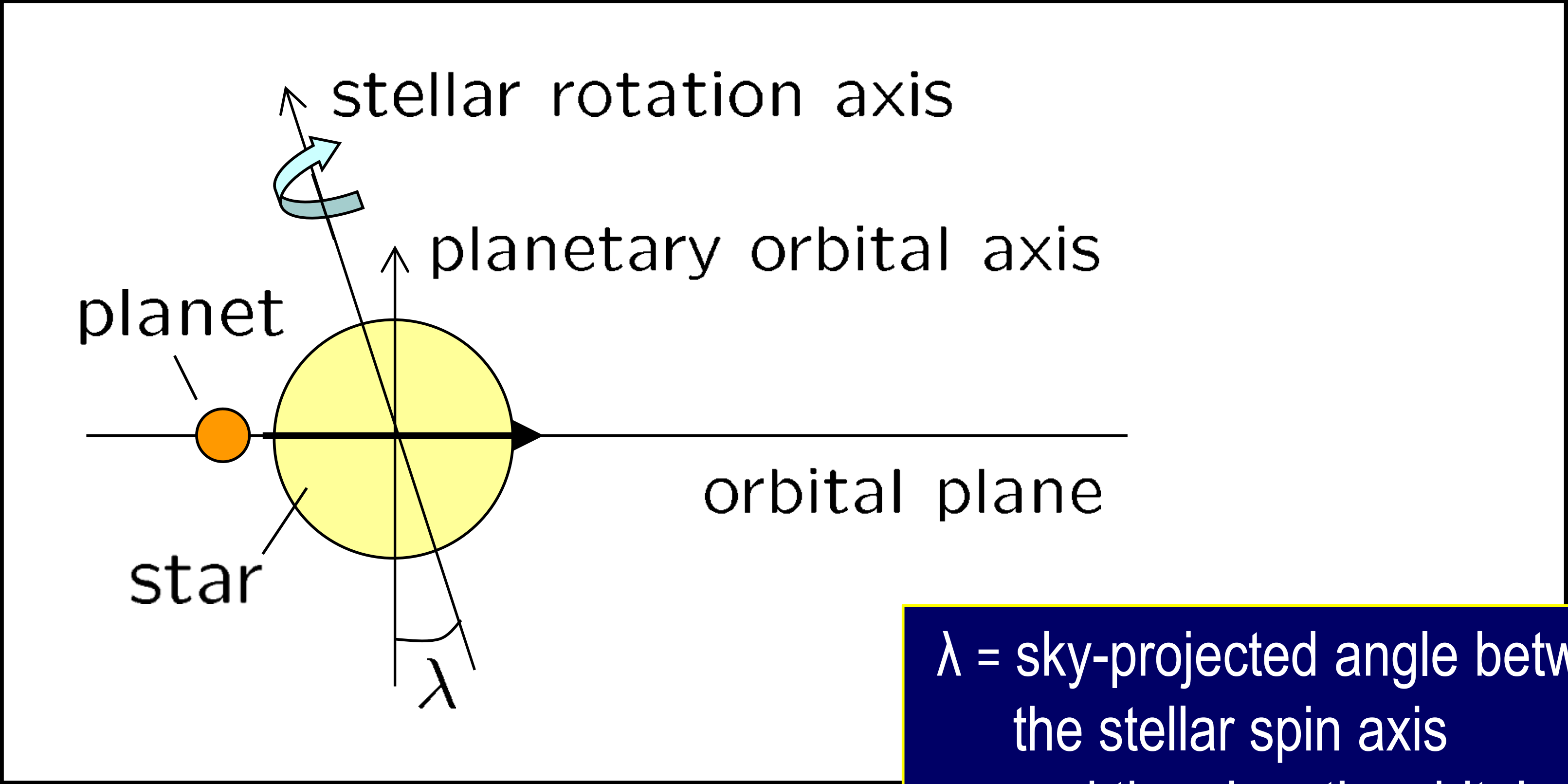
Spin-orbit alignment

The Rossiter-McLaughlin Effect

The shape of the velocity anomaly depends on the details of the transit trajectory of the exoplanet (Gaudi & Winn 2000)



Spin-orbit alignment



λ = sky-projected angle between
the stellar spin axis
and the planet's orbital axis

e.g., Ohta et al. 2005,
Gimentz 2006,
Gaudi & Winn 2007

Spin-orbit alignment

The Rossiter-McLaughlin Effect

λ can be affected by various exoplanetary migration models

e.g.,

- ✓ Type II migration

  planetary disk and planet interaction

- ✓ Planet-Planet interaction

  multiple-planet interaction and scattering

- ✓ Kozai migration

  perturbation by a binary companion

Spin-orbit alignment

The Rossiter-McLaughlin Effect

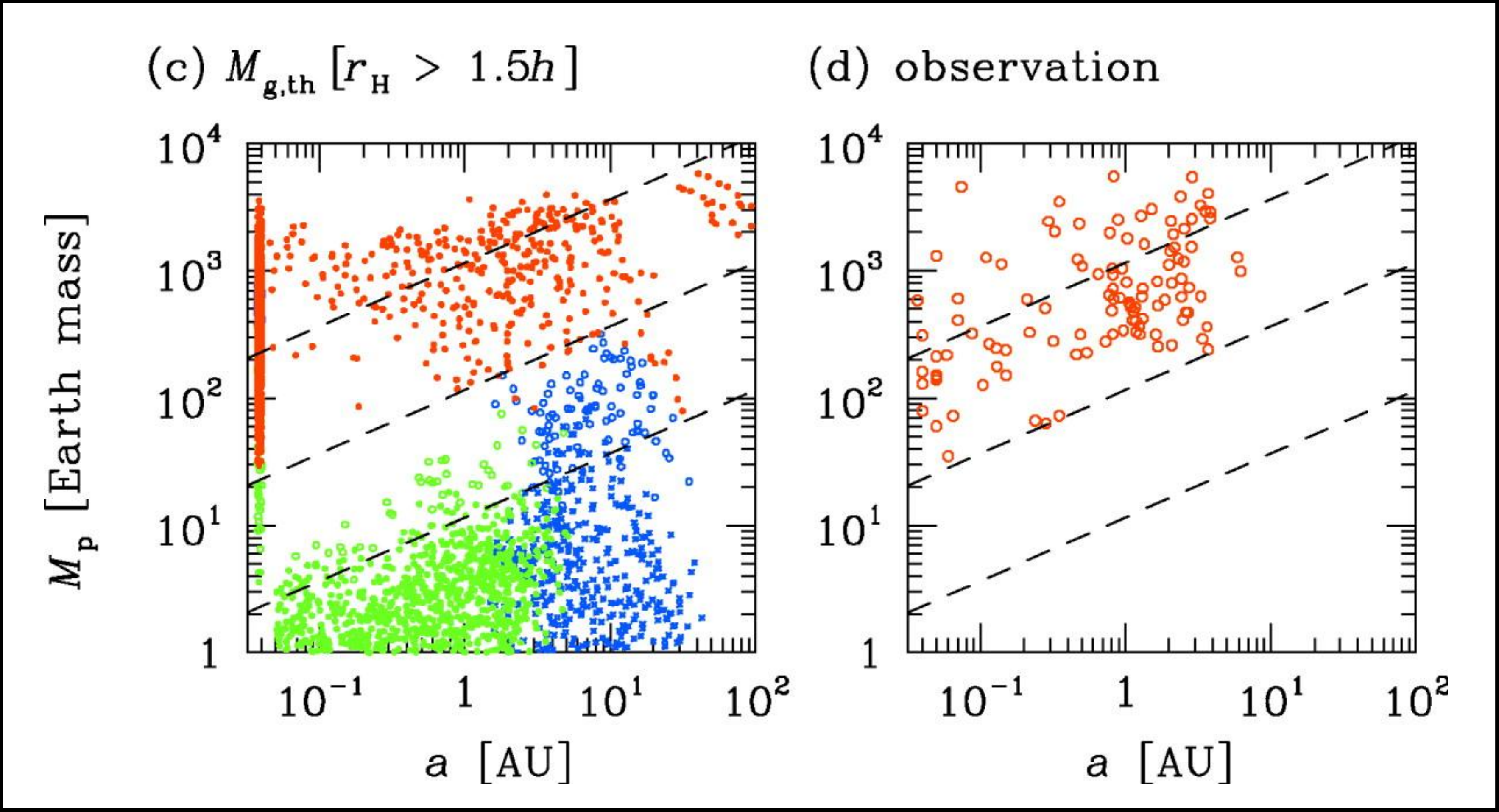
Type II migration

- ✓ *small eccentricity and inclination*
- ✓ can roughly explain semi-major axis distribution (Ida & Lin 2004)
- ✓ but cannot explain eccentric planets

Spin-orbit alignment

Type II migration

Ida & Lin (2004)



Spin-orbit alignment

The Rossiter-McLaughlin Effect

Type II migration

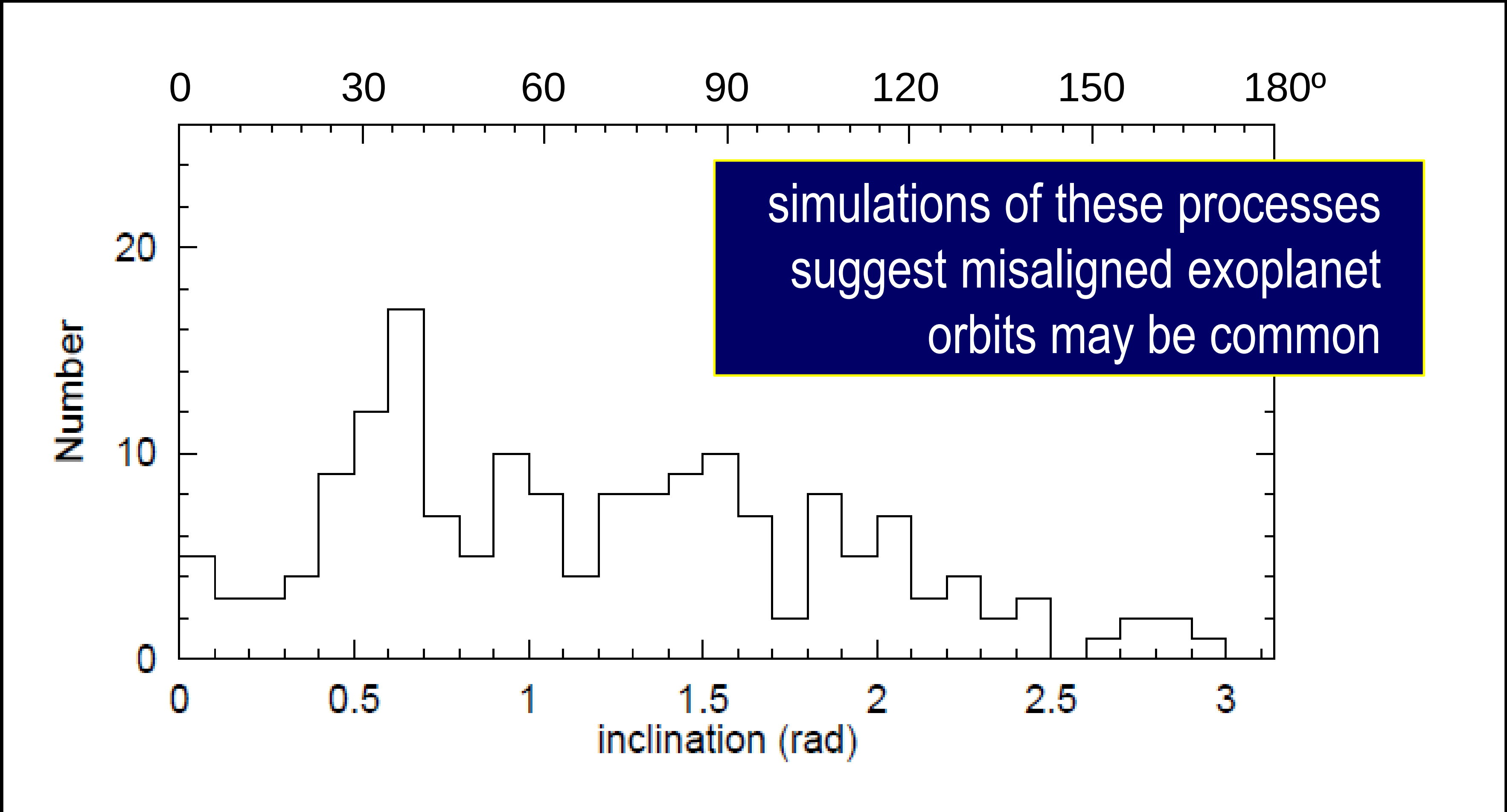
- ✓ *small eccentricity and inclination*
- ✓ can roughly explain semi-major axis distribution (Ida & Lin 2004)
- ✓ but cannot explain eccentric planets

Planet-Planet interaction / Kozai migration

- ✓ *possible large eccentricity and inclination*
- ✓ would explain eccentricity distribution when combined with Type II migration models

Spin-orbit alignment

Planet-planet interaction *Nagasawa et al. (2008)*



Spin-orbit alignment

Other exoplanetary RM Effect detections

• HD209458	Queloz et al. 2000, Winn et al. 2005
• HD189733	Winn et al. 2006
• TrES-1	Narita et al. 2007
• HAT-P-2	Winn et al. 2007, Loeillet et al. 2008
• HD149026	Wolf et al. 2007
• HD17156	Narita et al. 2008
• TrES-2	Winn et al. 2008
• CoRoT-Exo-2	Bouchy et al. 2008
• HAT-P-1	Johnson et al. 2008
• XO-3	Hebrard et al. 2008

Spin-orbit alignment

Other exoplanetary RM Effect detections

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Spin-orbit alignment

HD 17156

- Reported by Fischer et al. (May 2007)
- Transit was detected by Barbieri et al. (October 2007)
  - magnitude: $V \sim 8.2$ *(bright!)*
  - planet mass: $M_{planet} \sim 3.1\ M_{Jupiter}$ *(massive!)*
  - eccentricity: $e \sim 0.67$ *(eccentric!)*
  - period: $P \sim 21.2$ days *(long!)*

Spin-orbit alignment

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Narita et al. (2008)

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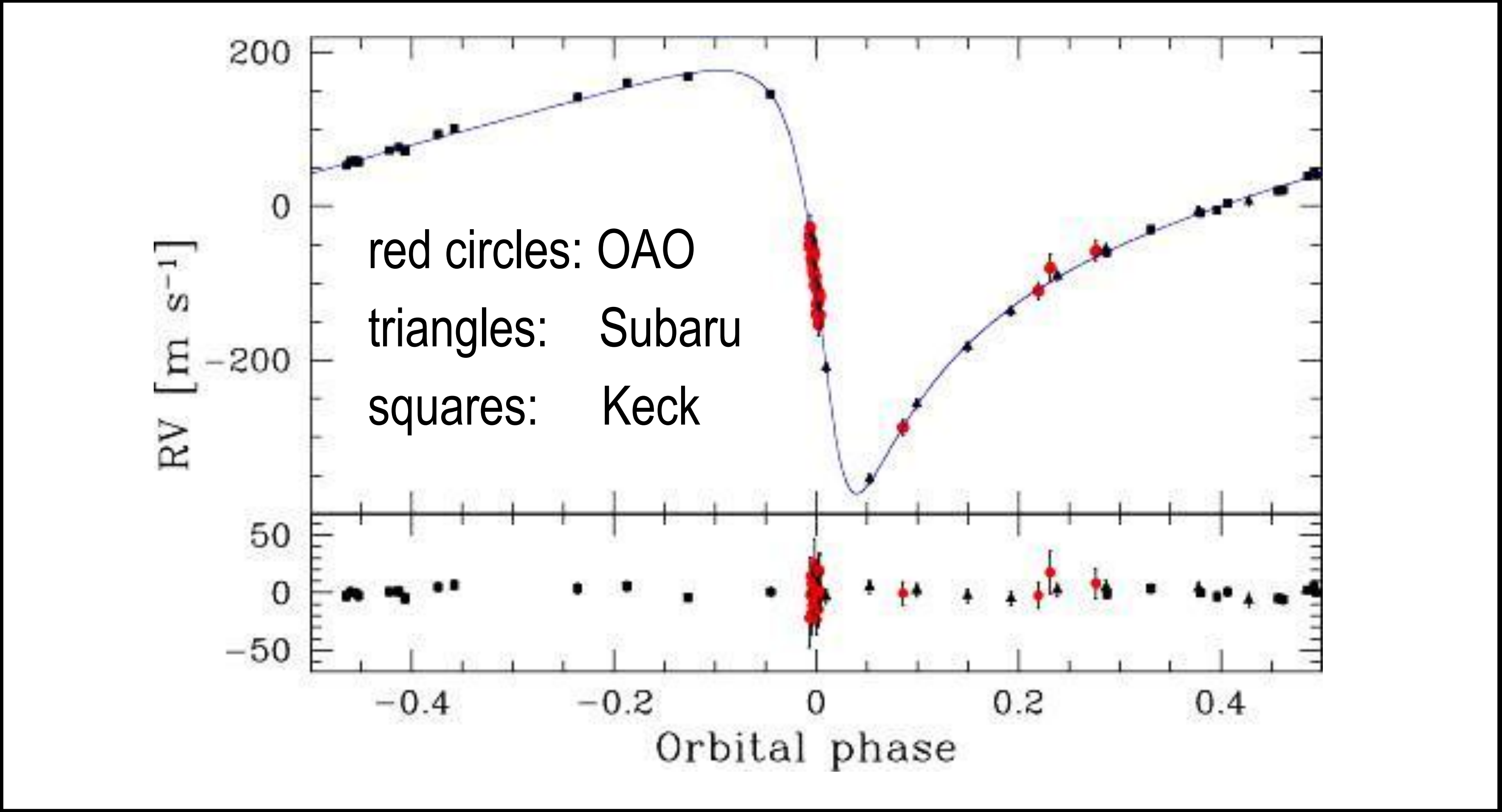
- Narita et al. (2008) obtained simultaneous spectroscopic and photometric observations in November 2007
  - Okayama Astrophysical Observatory (OAO) 1.88-m telescope
  - Japanese Transit Observation Network (amateur astronomers)

Spin-orbit alignment

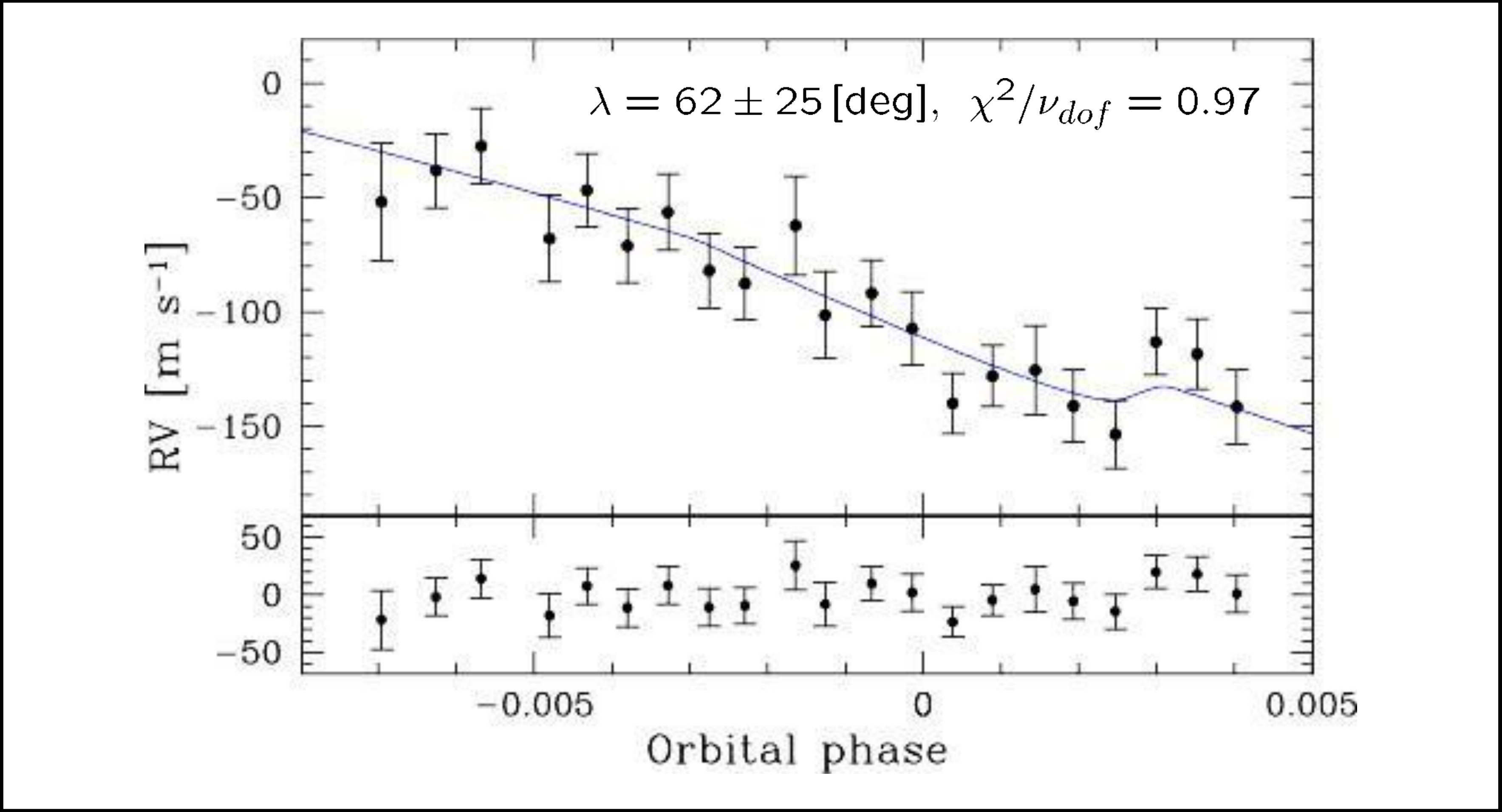
HD 17156

Narita et al. (2008)



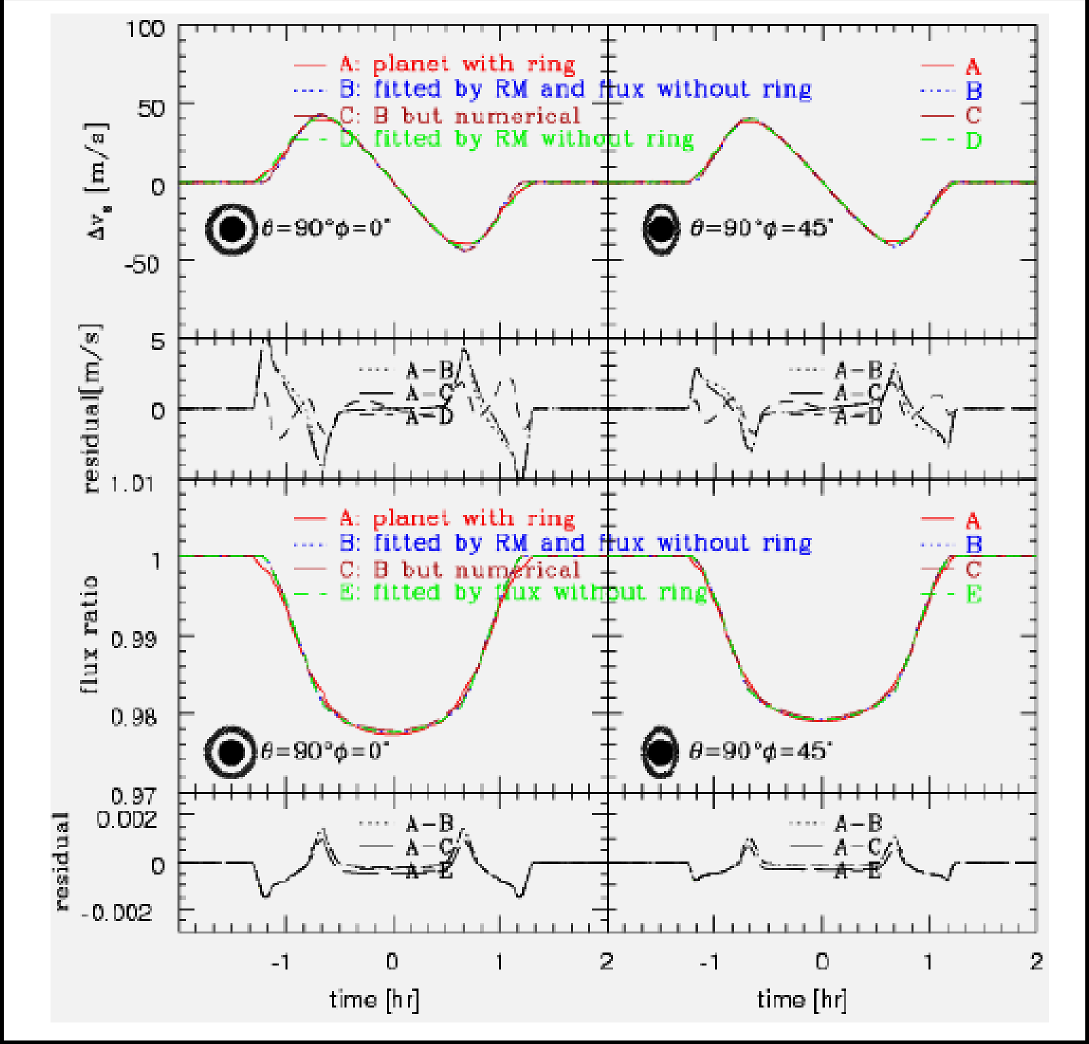
Spin-orbit alignment

Close to phase of transit — *Narita et al. (2008)*



Spin-orbit alignment

Looking for rings around exoplanets



A model search for a characteristic RM anomaly due to an exoplanetary ring in the photometric and spectroscopic data during a transit

δv ~ a few m/s
δF/F ~ 0.1%

Ohta (2005, PhD thesis)
Ohta, Taruya & Suto (in preparation)

What if Earth had rings?

You Tube user Roy Prol has imagined what it would look like if Earth had rings like Saturn, as seen from space and from cities around the world

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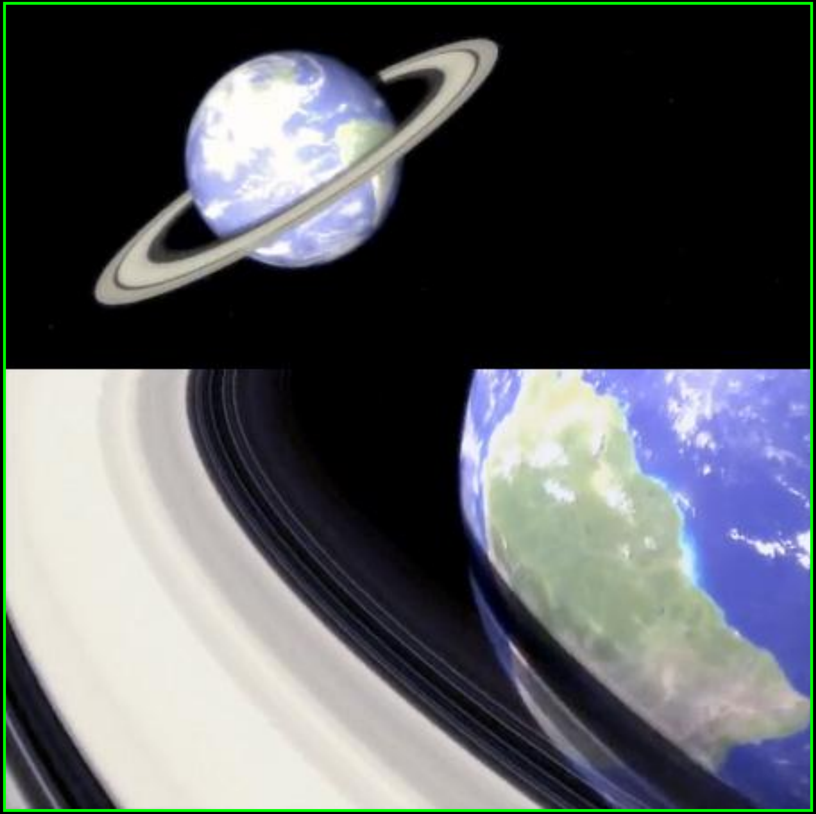
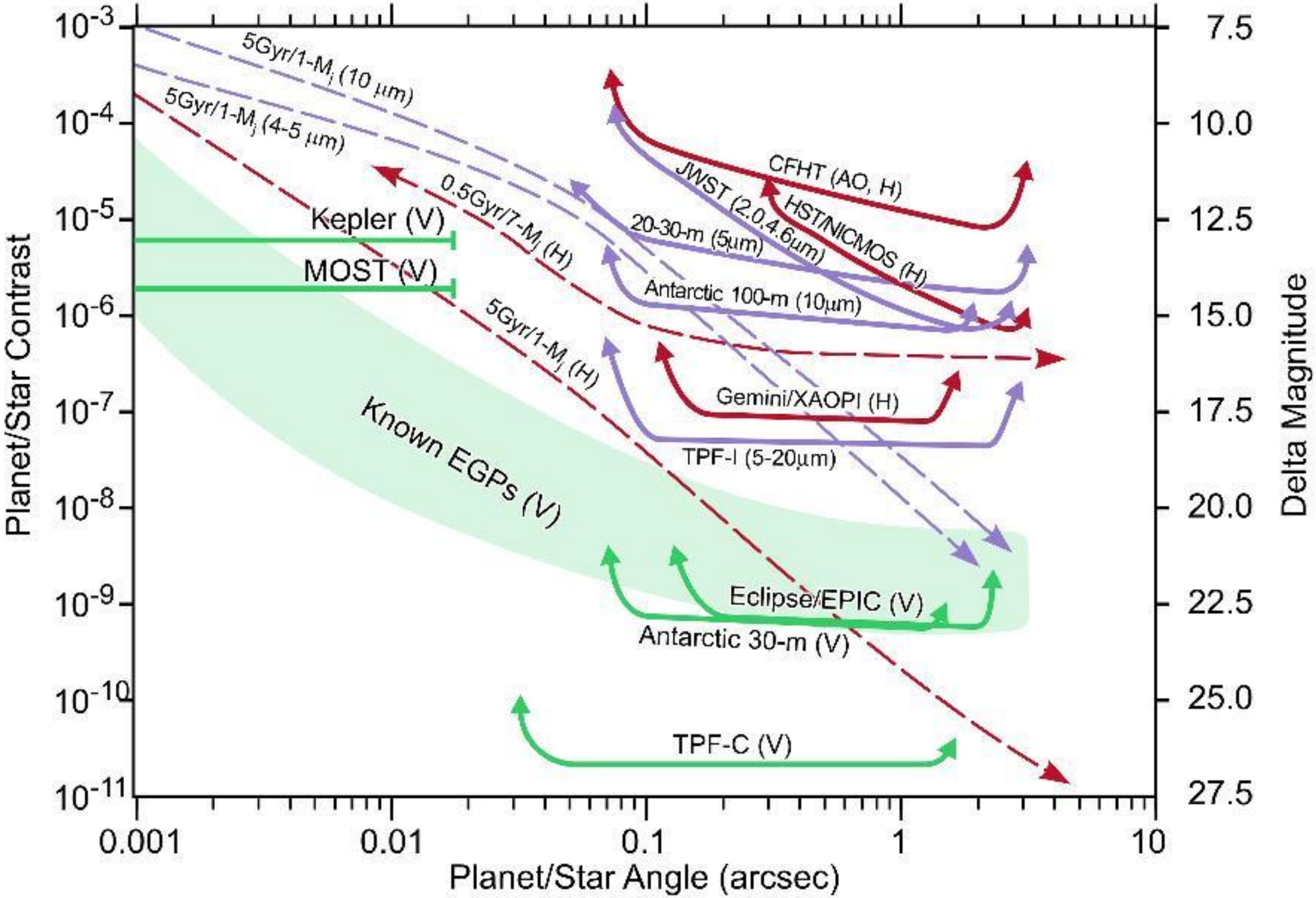


Questions?



Nature review article, 2005, Adam Burrows