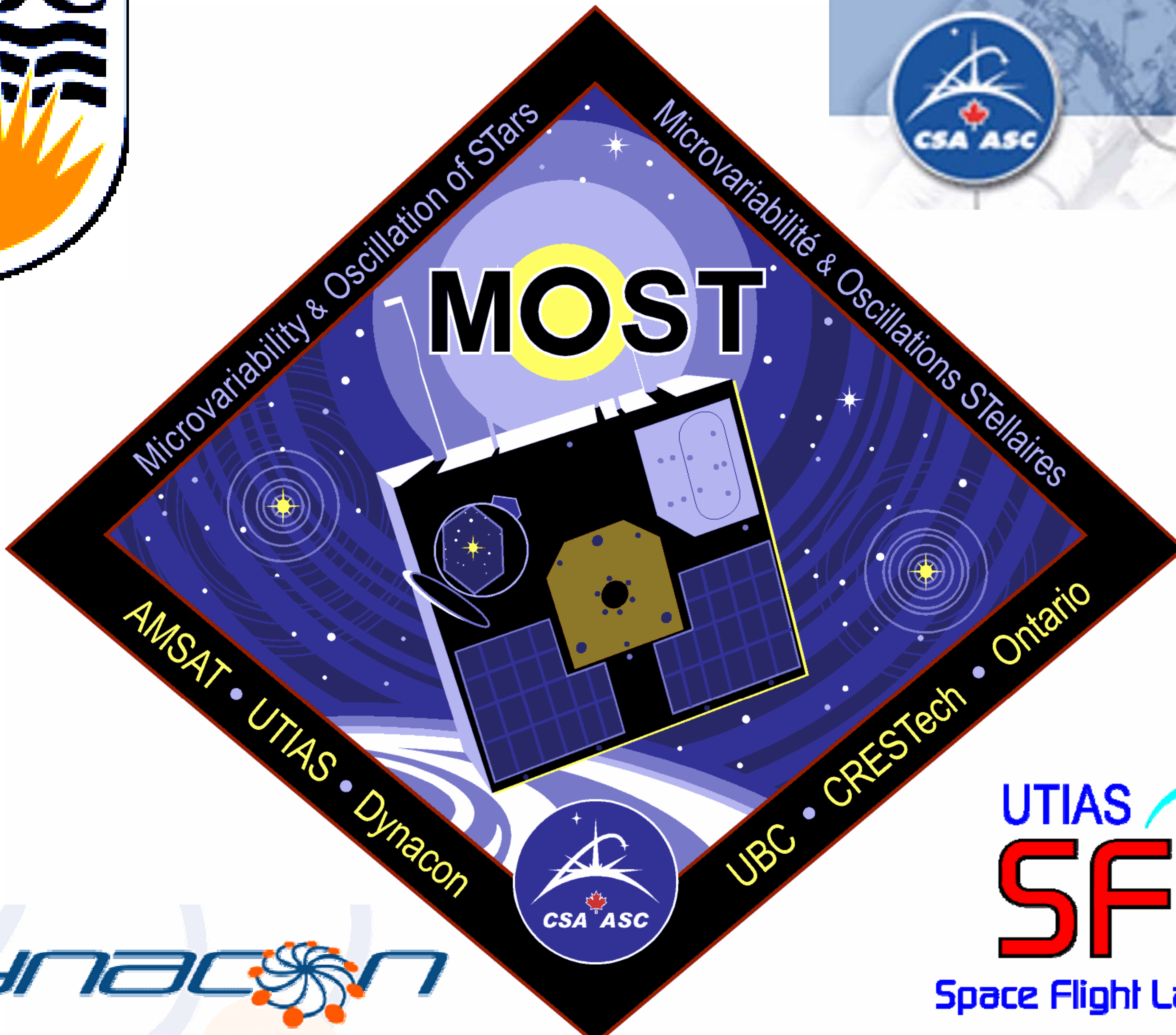
UBC

Agence spatiale canadienne

Canadian Space Agency

CSA ASC



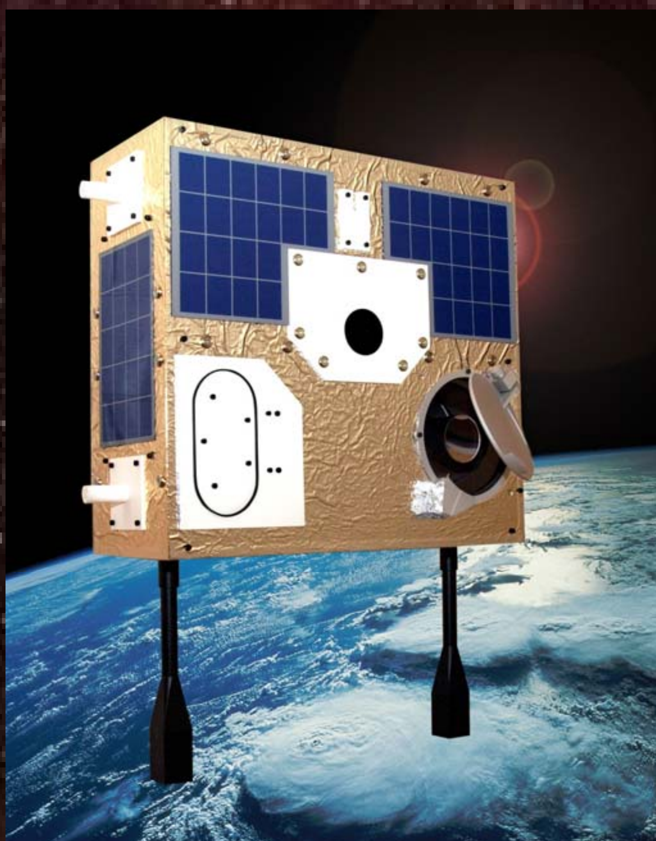
dynacon

UTIAS SFL

Space Flight Laboratory

MOST exoplanet system photometry

Transit timing and searches; eclipse analyses
Star-exoplanet interactions



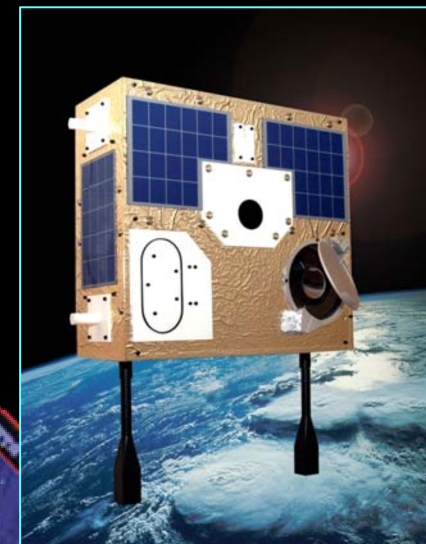
Jaymie M. Matthews
MOST Mission Scientist
Department of Physics & Astronomy
University of British Columbia
Vancouver, Canada

Jason Rowe, Chris Cameron
Bryce Croll, Rainer Kuschnig
Dimitar Sasselov, Eliza Miller-Ricci

MOST at a glance

Mission

- **M**icrovariability and **O**scillations of **ST**ars / **M**icrovariabilité et **O**scillations **ST**ellaire
- First space satellite designed for *asteroseismology*
  - Small optical telescope & ultraprecise photometer
  - precision: *~ few ppm = μmag*
- Canada’s first space telescope



Canadian Space Agency (CSA)

Agence spatiale canadienne — Canadian Space Agency

CSA ASC

MOST at a glance

Satellite

- 54 kg, 60×60×30 cm
- Power: solar panels
  - peak ~ 38 W
- Attitude Control System:
  - reaction wheels
  - pointing accuracy ~ 1″
- Communication: S-band
  - frequency ~ 2 GHz
- 8 Lifetime: 4 – 7 years +?

CONTRACTORS: Dynacon Inc.
U of T Institute for Aerospace Studies

MOST at a glance

Mission Scientist

- > 54 kg, 182 cm high
- Power: hydrocarbons
  - peak ~12 MW at disco/pub
- Attitude uncontrolled
  - reactions slow
  - doesn't always have point
- Communication: loud
  - high-frequency
- Lifetime: fun while it lasts

***CONTRACTORS:** my parents*

MOST at a glance

Instrument

- Maksutov telescope
  - aperture = 15 cm
  - field of view = 2° diameter
- single broadband filter
  - $380 \leq \lambda \leq 750$ nm
- twin E2V 47-20 CCDs
  - Science and Startracker
  - Fabry microlenses produce pupil images of star and sky

University of British Columbia
CRESTech, Spectral Applied Research

MOST at a glance

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  - aperture = 15 cm
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- single broadband filter
  - 380 ≤ λ ≤ 750 nm
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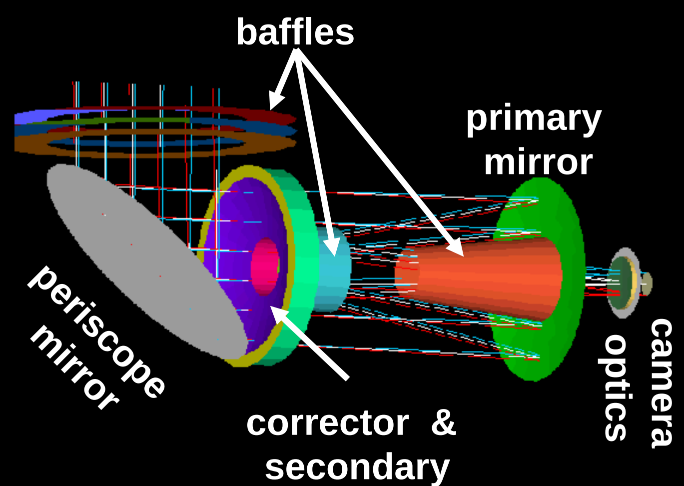
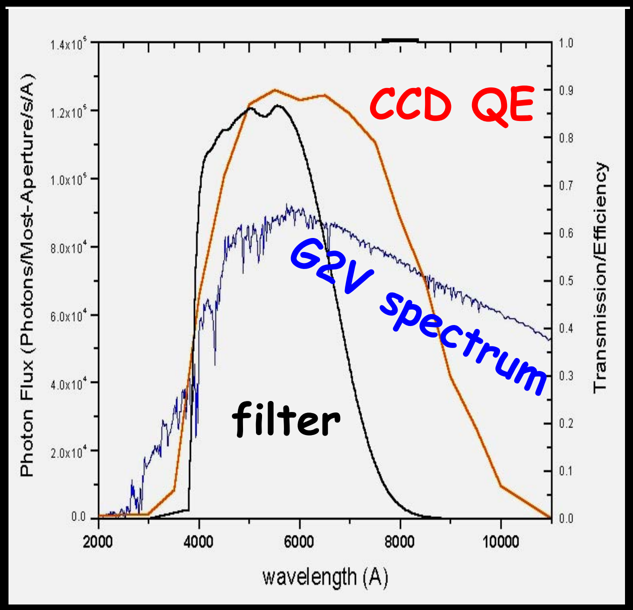
  - Science and Startracker
  - Fabry microlenses produce pupil images of Primary Star and sky backgrounds

Ceravolo Optical Systems (Ottawa)
Custom Scientific (Phoenix)





MOST at a glance

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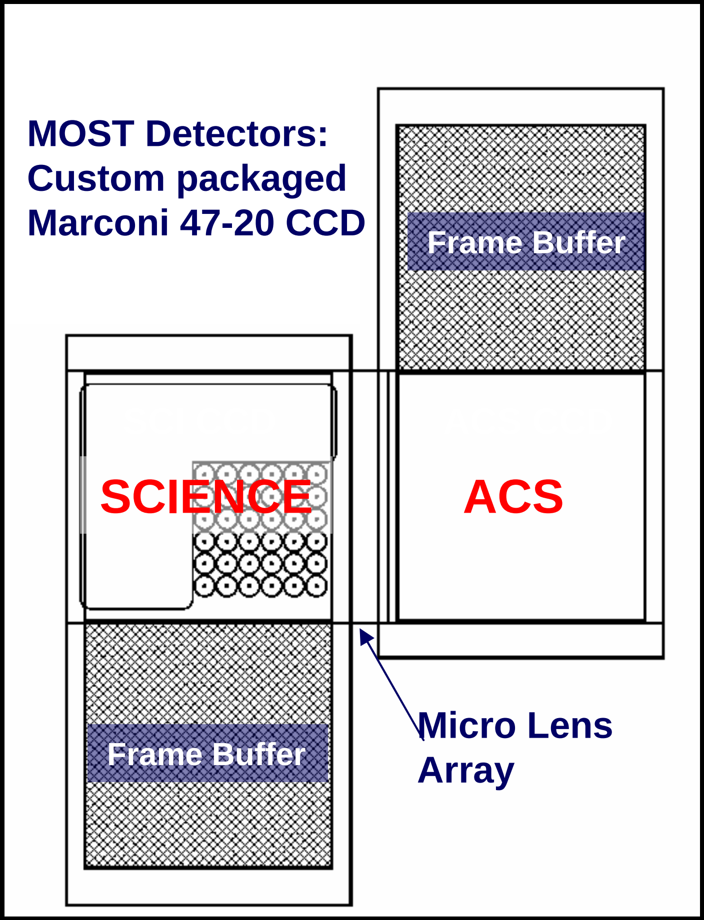

E2V Technologies (formerly Marconi) Chelmsford, UK

MOST at a glance

Instrument

- Maksutov telescope
  - aperture = 15 cm
  - field of view = 2° diameter
- single broadband filter
  - $380 \leq \lambda \leq 750$ nm
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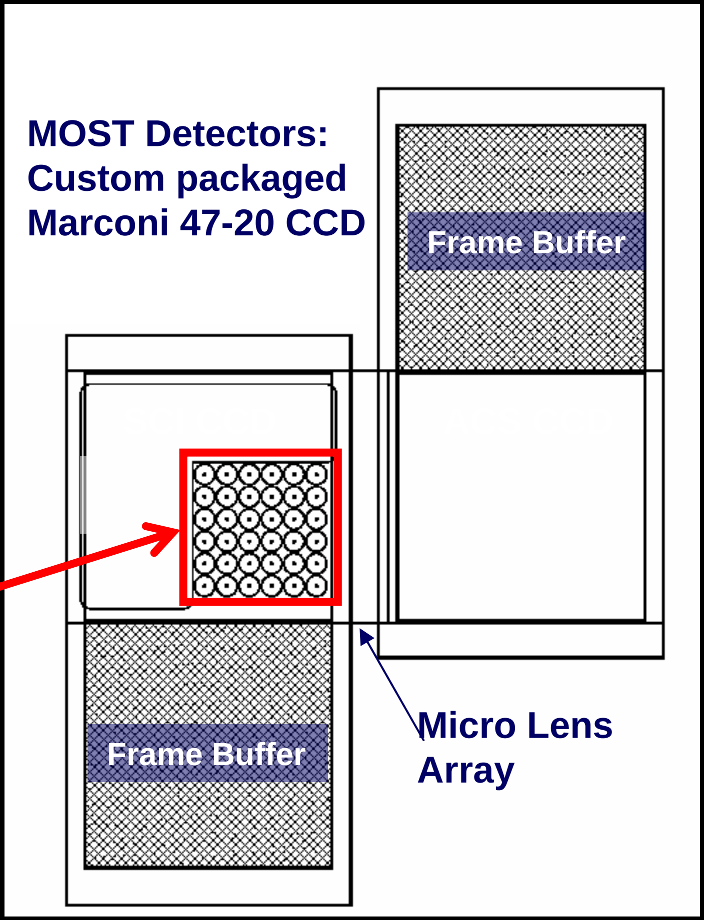
  - Science and Startracker
  - Fabry microlenses produce pupil images of Primary Star and sky backgrounds

Advanced Microoptic Systems (Saarbrücken, Germany)



MOST at a glance

Instrument

- Maksutov telescope
  - aperture = 15 cm
  - field of view = 2° diameter
- single broadband filter
  - $380 \leq \lambda \leq 750$ nm
- twin E2V 47-20 CCDs
  - Science and Startracker
  - Fabry microlenses produce pupil images of Primary Star and sky backgrounds

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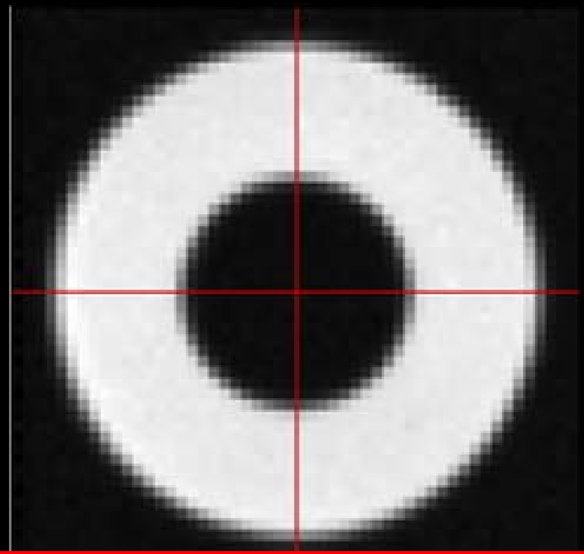
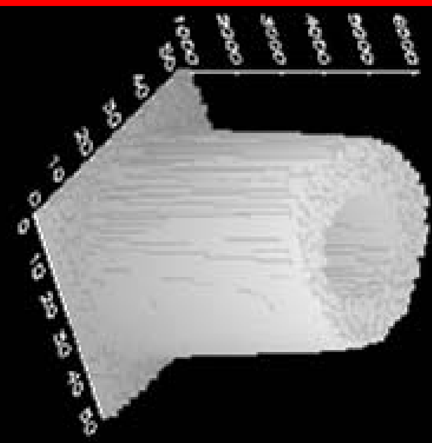


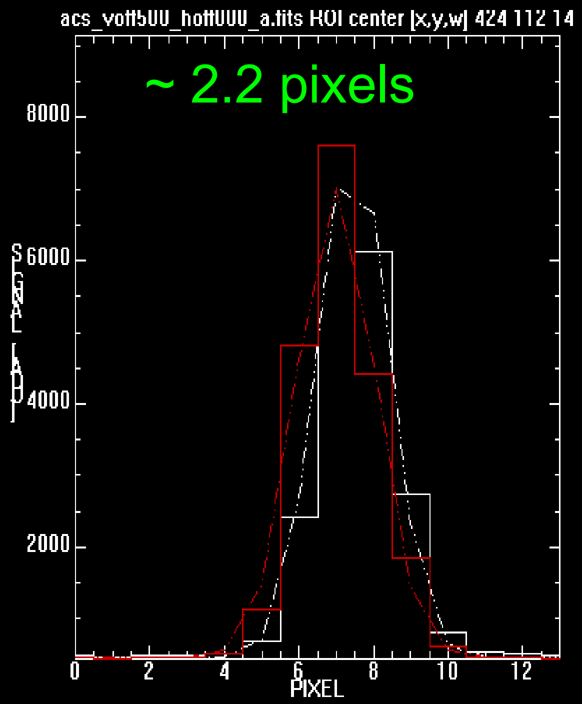
~1500 lit pixels fixed on CCD; insensitive to flatfielding errors

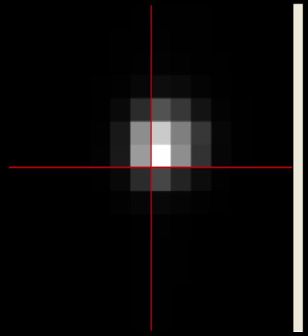


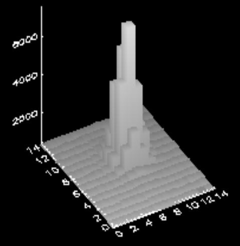
MOST at a glance

Instrument

- 15-cm Maksutov telescope
- single broadband filter
  - 380 ≤ λ ≤ 750 nm
- twin 47-20 CCD detectors
  - Science and Startracker
    - 1K × 1K; 3 arcsec/pixel
  - Fabry microlenses produce pupil images of 1 Primary Star and sky backgrounds
  - Direct Imaging field for PSF photometry of 3-6 stars
  - Startracker photometry of up to 30 stars

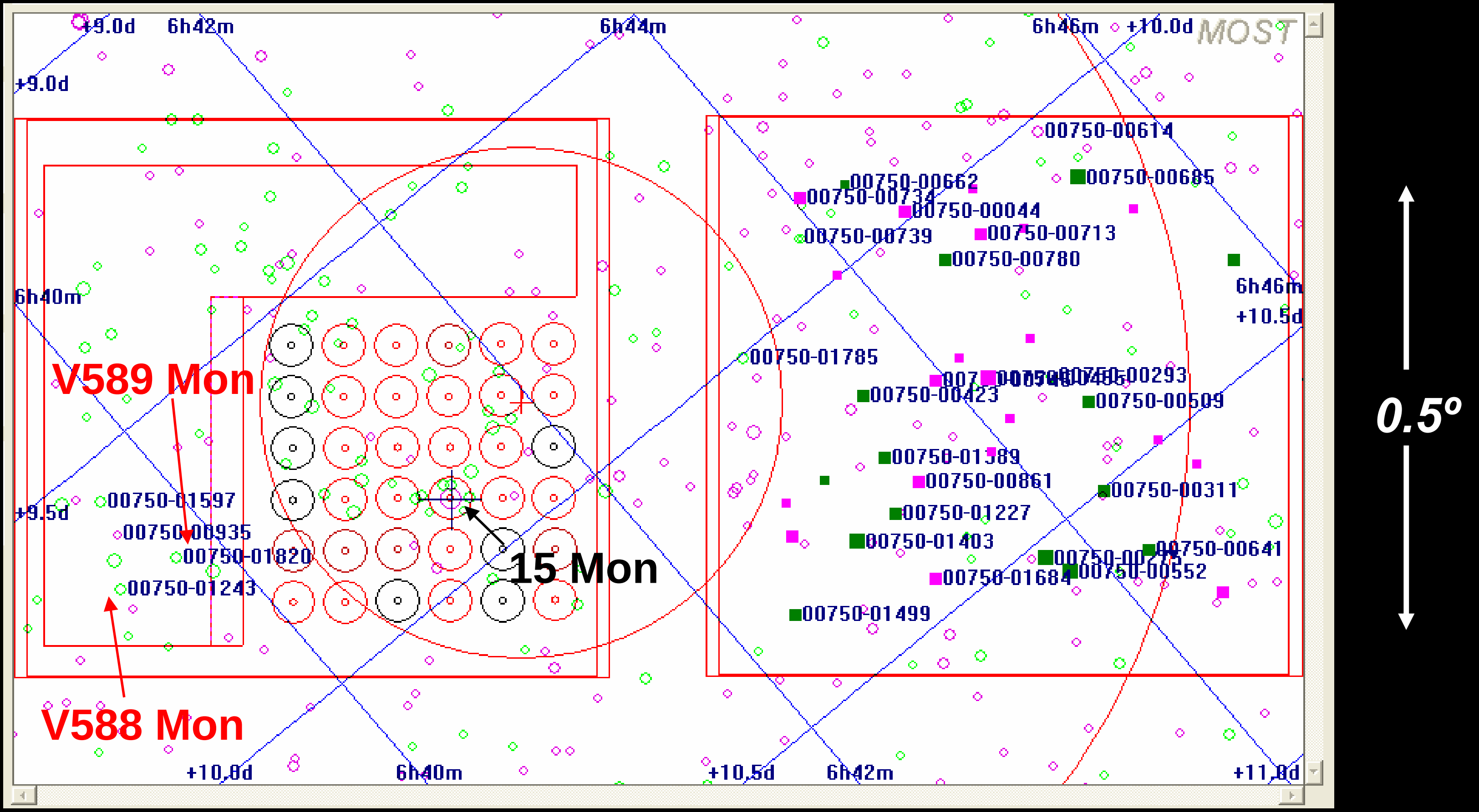






MOST at a glance

Focal plane



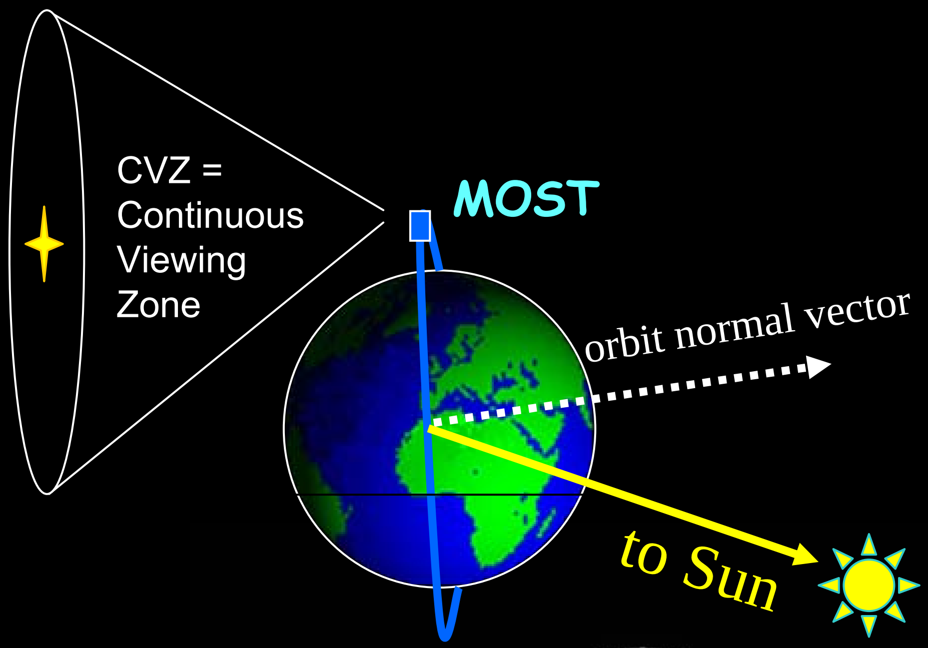
- Startracker photometry of up to 30 stars

NGC 2264

MOST at a glance

Orbit

- circular polar orbit
  - altitude *h = 820 km*
  - period *P = 101 min*
  - inclination *i = 98.6º*
- Sun-synchronous
  - *stays over terminator*
- CVZ ~ 54° wide
  - -18º < δ < +36º
  - *stars visible for up to 8 wks without interruption*

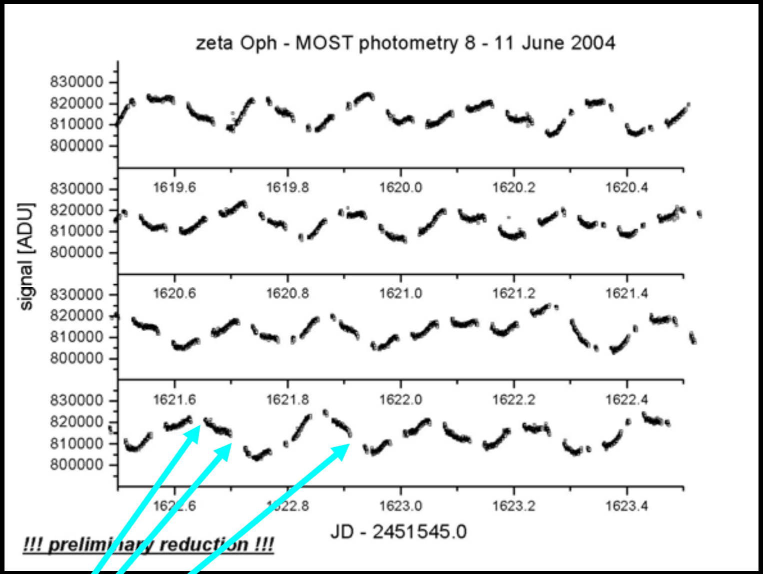


Sun-synchronous, dawn-dusk orbit

MOST at a glance

Performance

- Sampling: *up to 10×/min*
- Fabry Imaging
  - *targets: 0.3 < V < 7.0*
  - *S/N per exposure ~ 6000*
- Long time coverage
  - *record to date: 50 days*
- High duty cycle *up to 99%*
  - *sometimes outages per orbit due to extreme stray light*

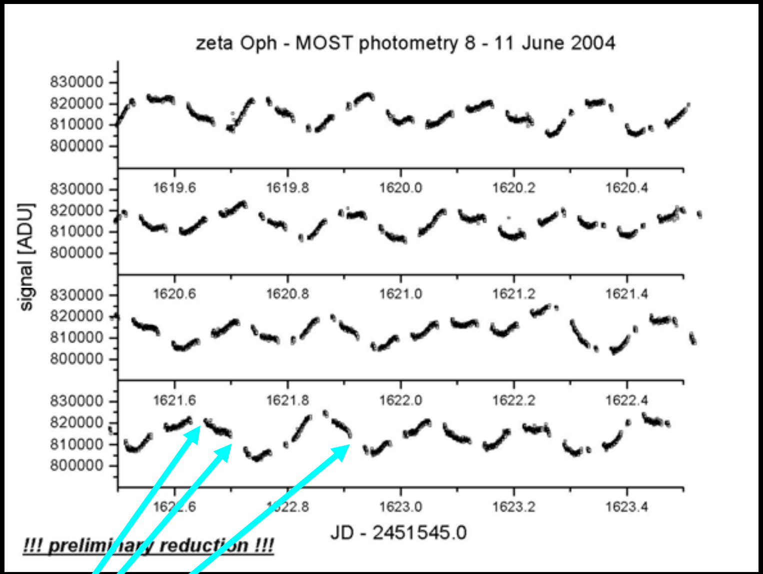


e.g., 4 days of ζ Oph
Walker et al. 2005 ApJL

MOST at a glance

Performance

- Sampling: *up to 10×/min*
- Fabry Imaging
  - *targets: 0.3 < V < 7.0*
  - *S/N per exposure ~ 6000*
- Long time coverage
  - *record to date: 50 days*
- High duty cycle *up to 99%*
  - *sometimes outages per orbit due to extreme stray light*
  - *very clean spectral window*
    - *sometimes aliases at MOST orbital frequency of 165 μHz*
    - *not 1 cycle/day = 11.56 μHz*



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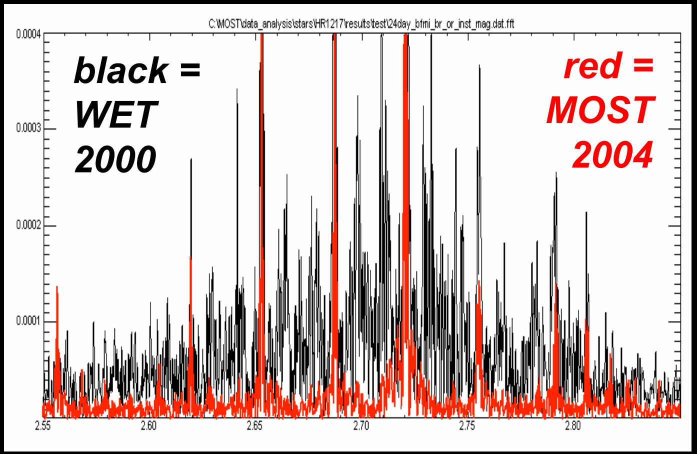
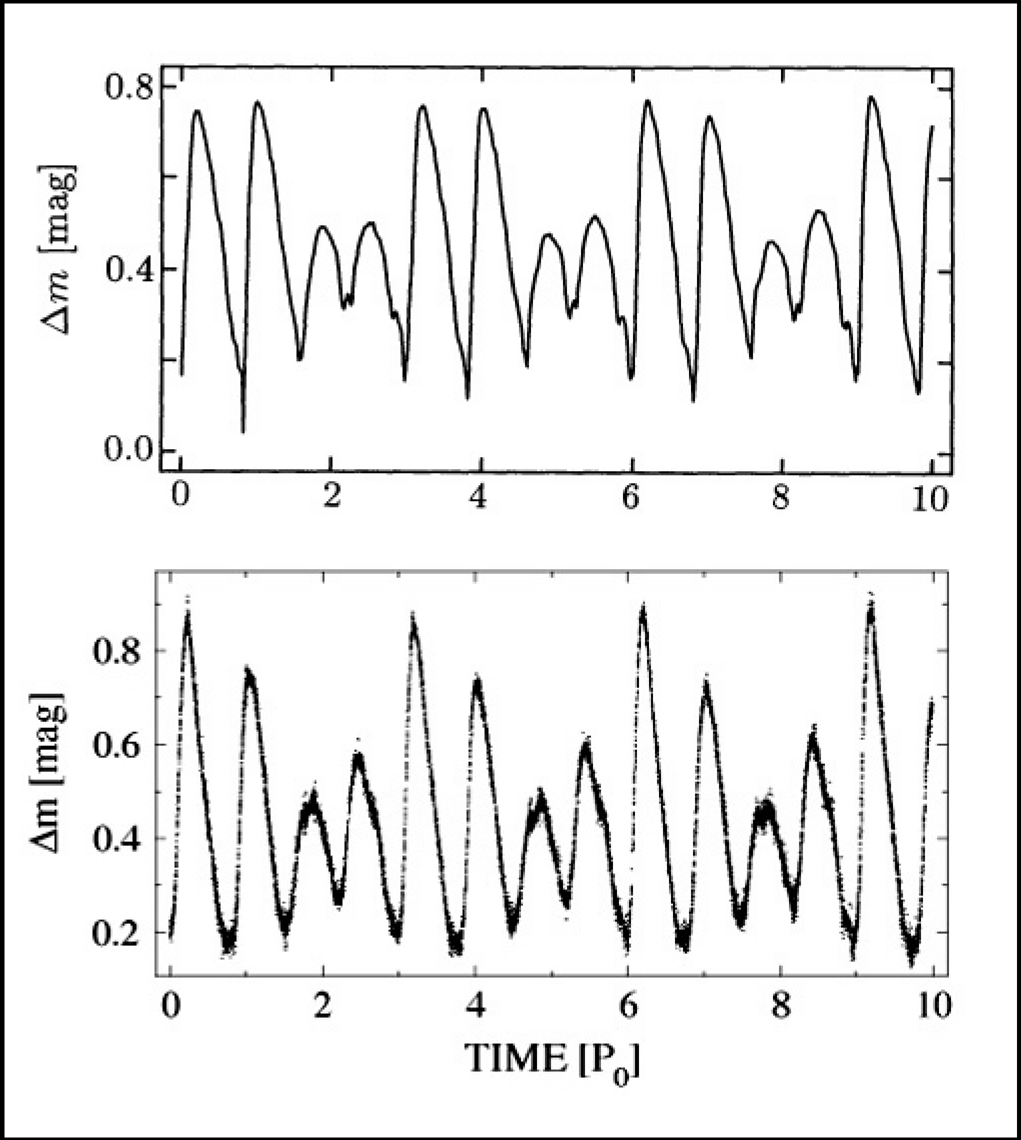


e.g., roAp HD 24712

MOST at a glance

Performance



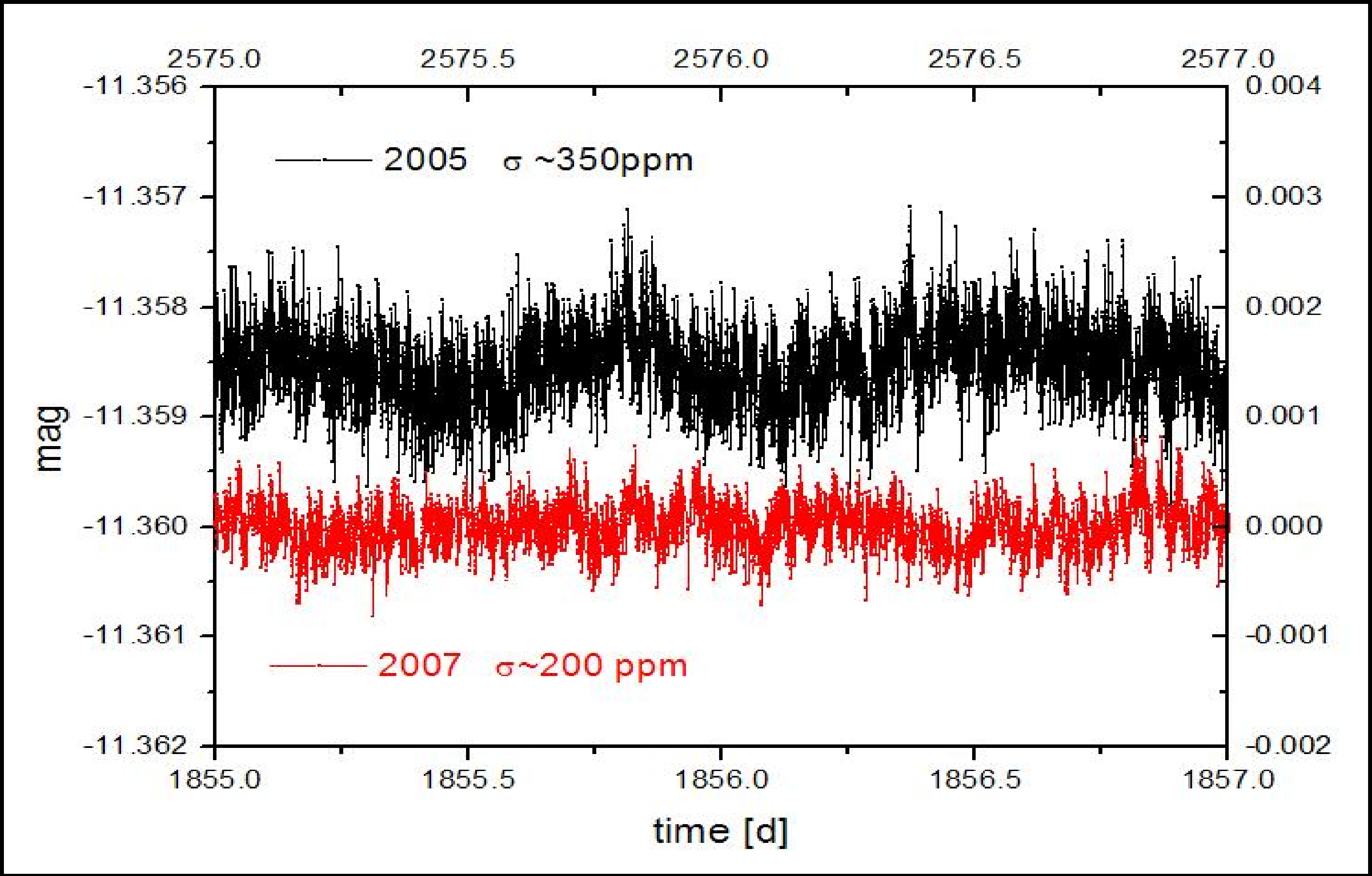
RRd star AQ Leo

V = 12.7

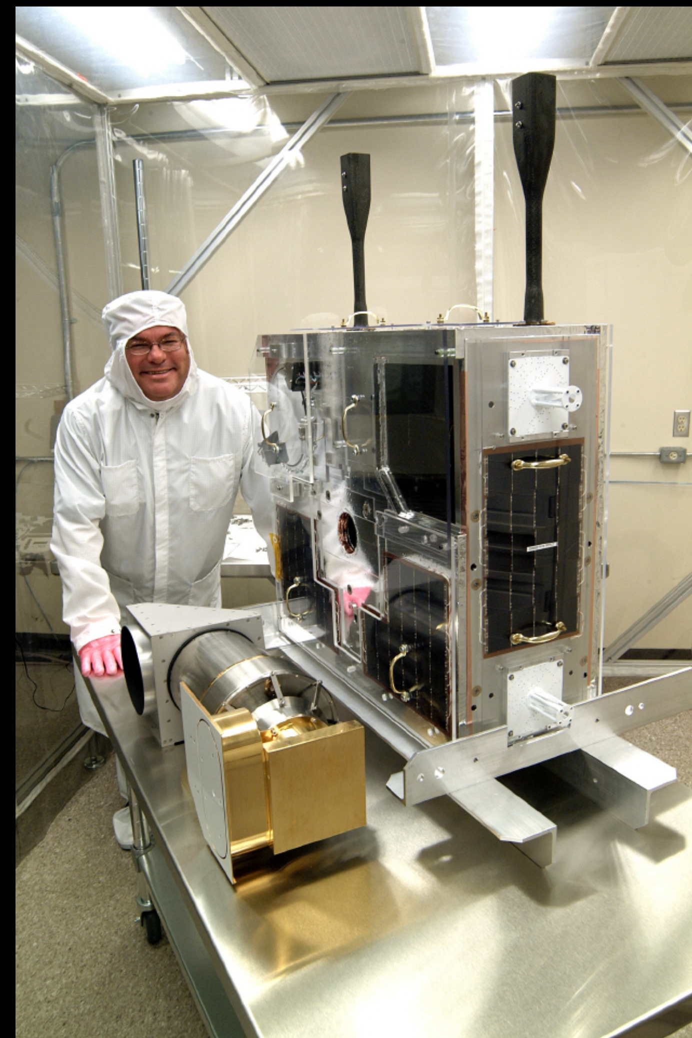
MOST at a glance

Performance

Procyon



MOST science

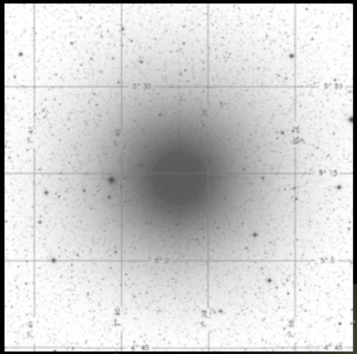


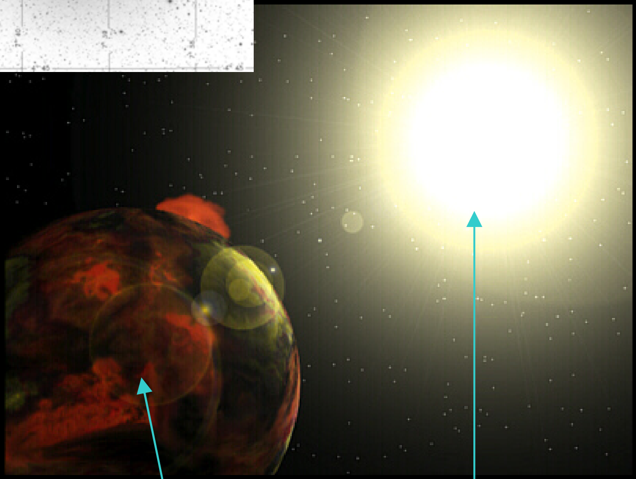
MOST science

Science Targets

- Sun-like stars
  - asteroseismology
  - surface spots, activity
- ancient halo intruders
- magnetic (Ap) stars
- massive evolved stars
  - wind turbulence
  - pulsations
- exoplanet systems
- pulsating protostars
- red giants

Procyon





51 Peg b　*51 Peg a*

MOST science

Science Targets

- Sun-like stars
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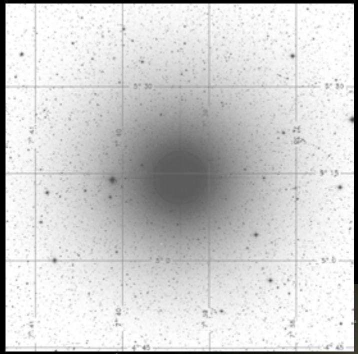
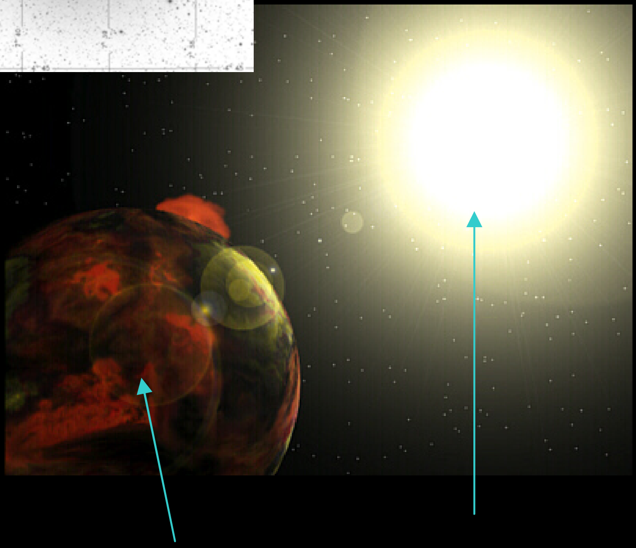
Procyon





51 Peg b *51 Peg a*

Differential rotation

kappa 1 Ceti

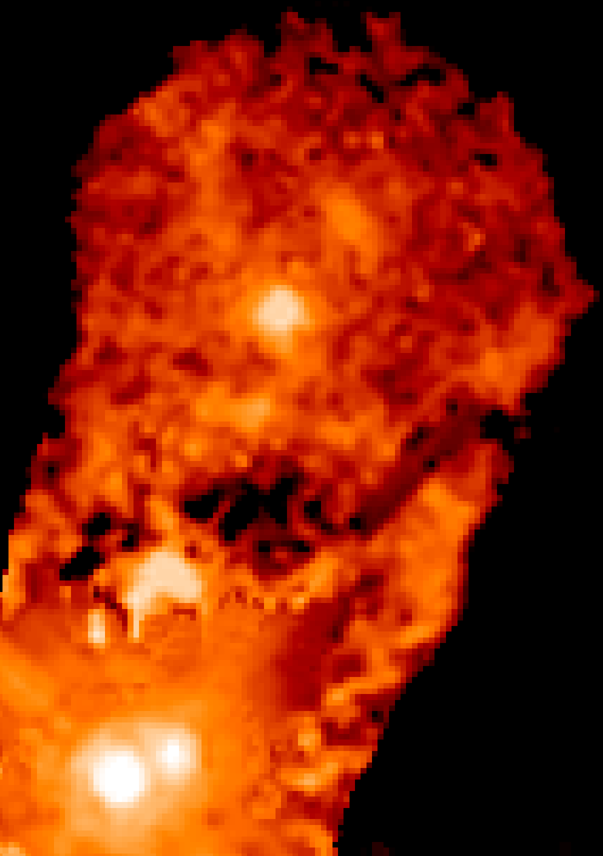
- "pre-teen" version of Sun
  - G5Ve   age ~ 0.6 - 0.8 Gyr

(Guinan et al. 1999)

kappa 1 Ceti — *Differential rotation*

- "pre-teen" version of Sun
  - G5Ve   age ~ 0.6 – 0.8 Gyr

    (Guinan et al. 1999)

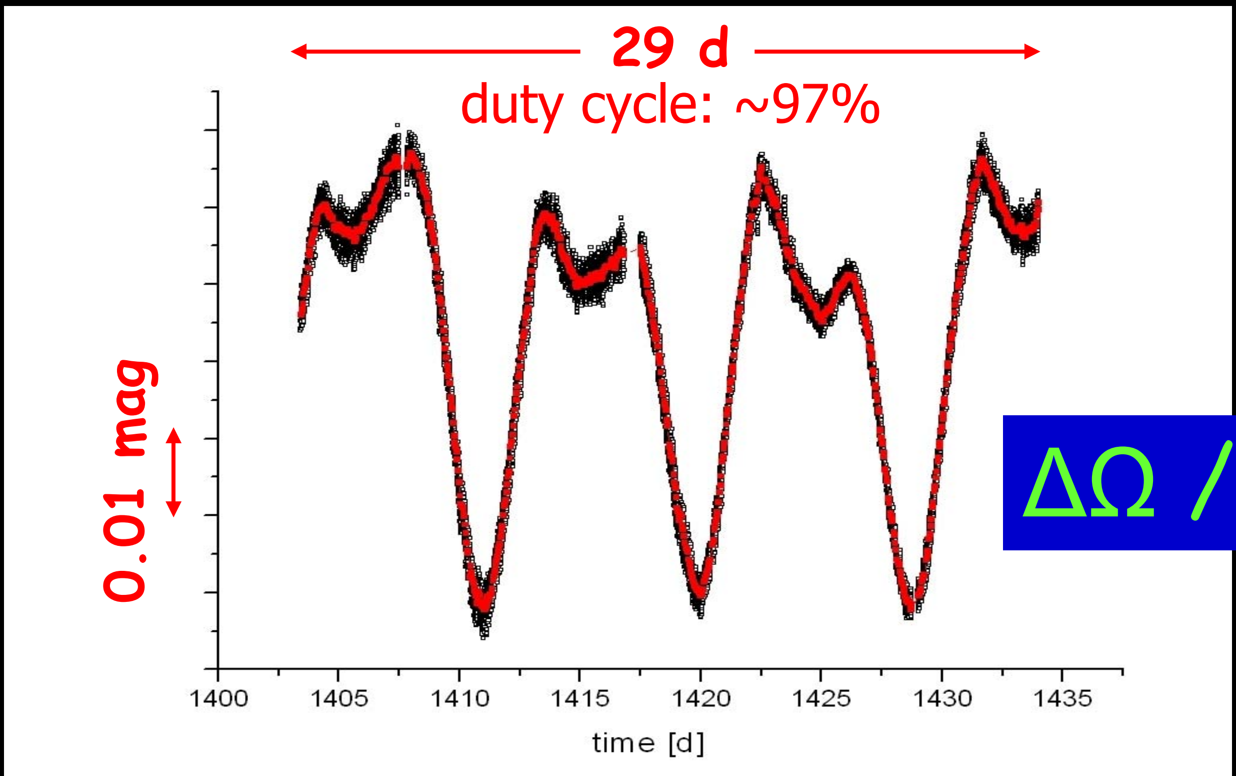


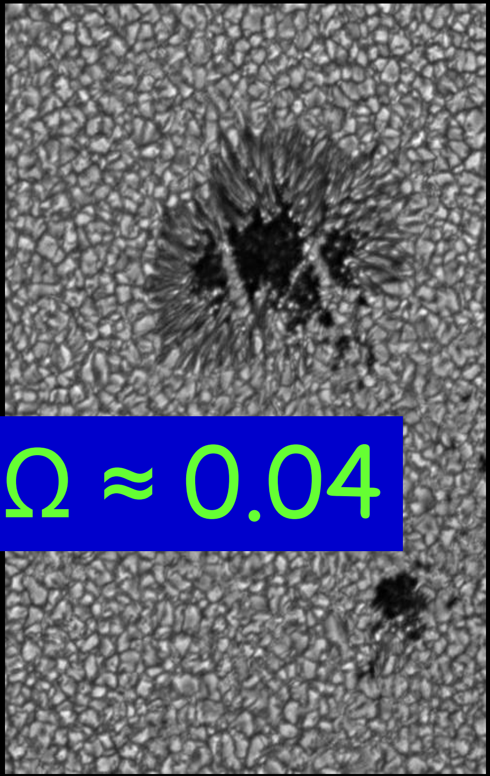
- hyperactive
  - fast rotator: P ~ 9 d
  - "superflares"? *(Schaeffer et al. 2000)*
- Doppler exoplanet searches
  - no companions found

    (Walker et al. 1995; Cumming et al. 1999)

kappa 1 Ceti

Differential rotation





$\Delta\Omega / \Omega \approx 0.04$

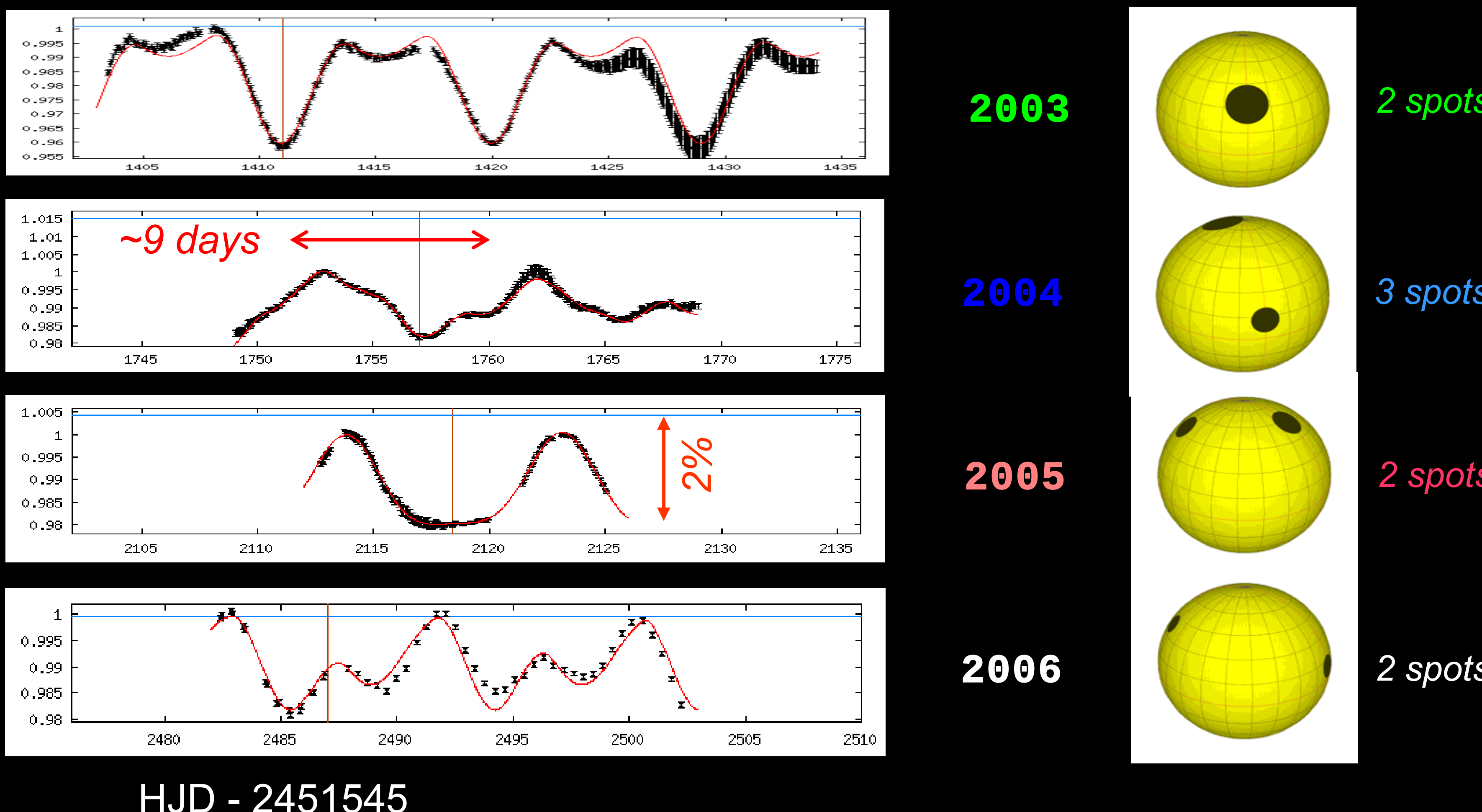
- kappa 1 Ceti light curve modeled by *differentially rotating* starspots at different latitudes

Rucinski, Walker, Matthews et al. 2004 PASP

kappa 1 Ceti

Differential rotation

MOST light curves and best-fitting spot models



Walker, Croll, Matthews et al. ApJ 2007

kappa 1 Ceti

Differential rotation

A rotation profile
for a star other than the Sun

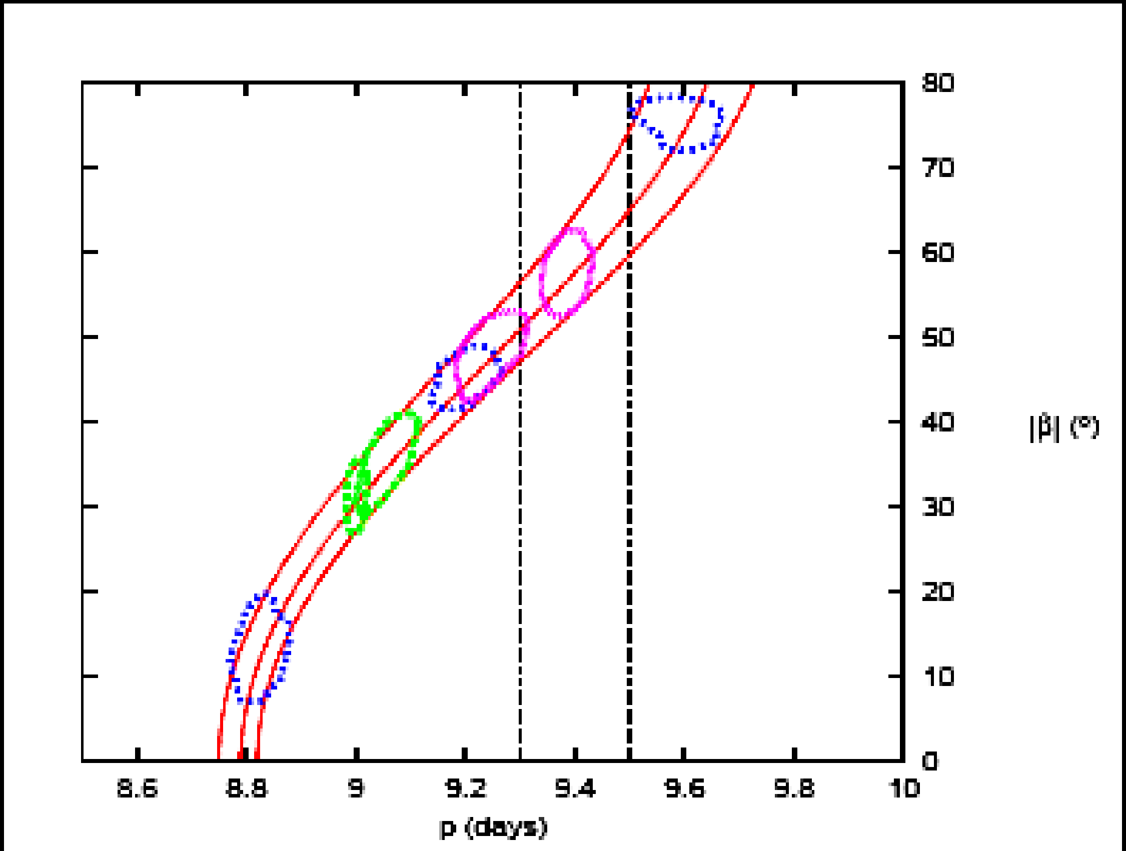
Best-fitting periods vs. star spot latitudes for three epochs.

Ellipses indicate 68% confidence limits

Red curves indicate solar period-latitude relation:

$$P_\beta = P_{eq} / (1 - k \sin^2 \beta)$$

for the confidence limits on P_{eq} and k



Walker, Croll, Matthews et al. ApJ 2007

MOST science

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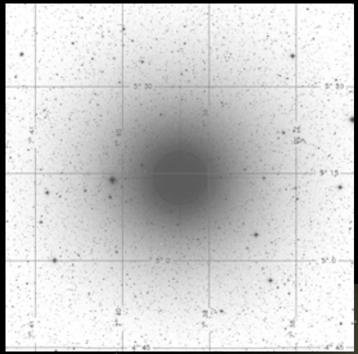
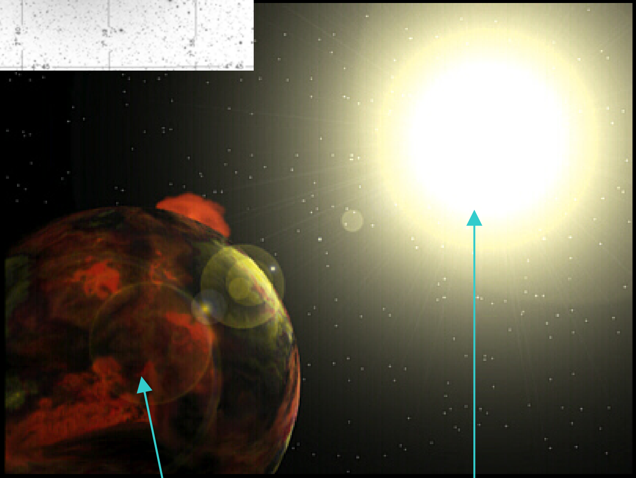
Procyon

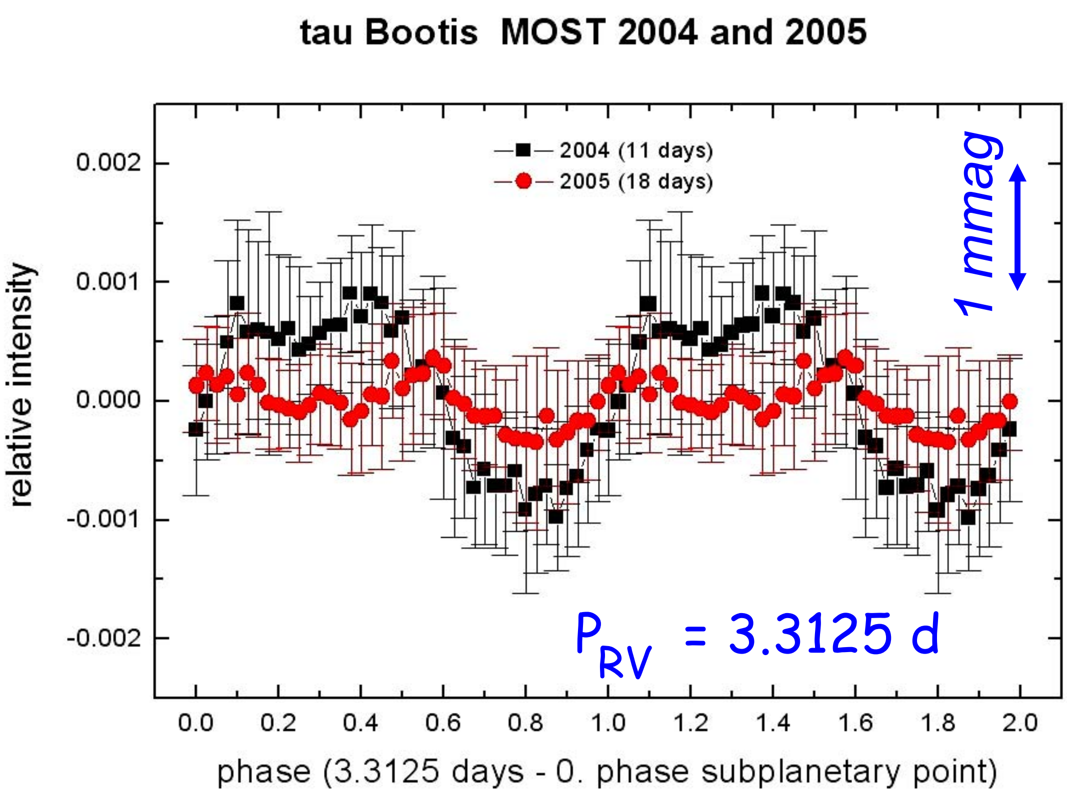


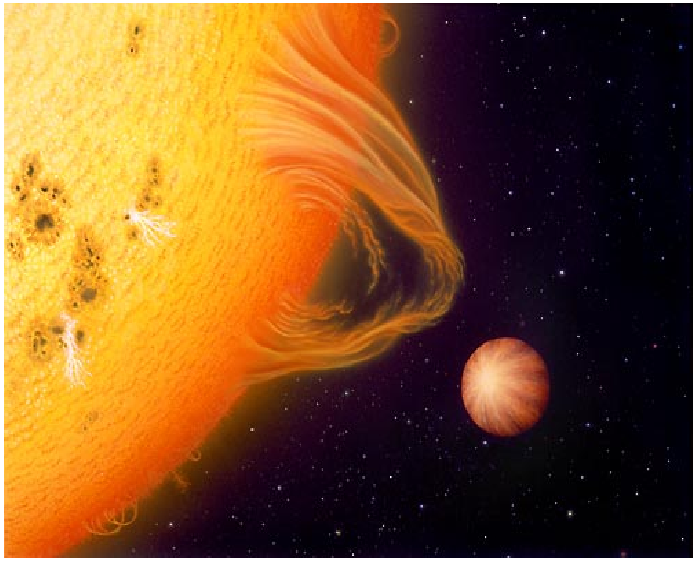


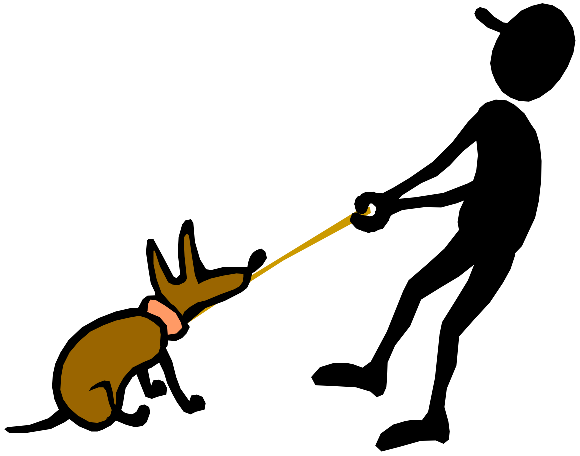
51 Peg b 51 Peg a

MOST exoplanet science

Star-exoplanet coupling





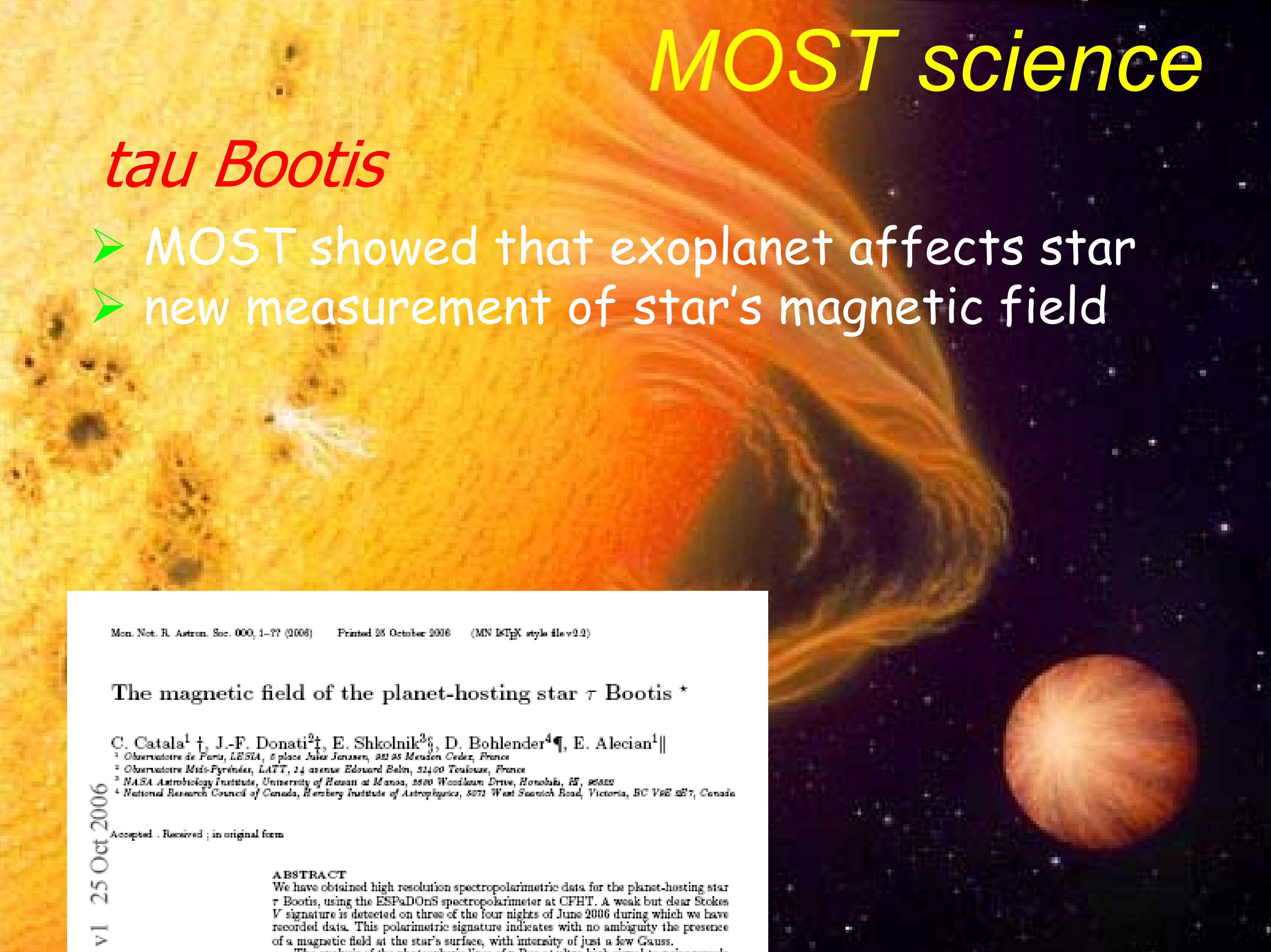


Tail wags dog!

MOST science

tau Bootis

- MOST showed that exoplanet affects star
- new measurement of star's magnetic field



Mon. Not. R. Astron. Soc. 000, 1–?? (2006) Printed 26 October 2006 (MN LaTeX style file v2.2)

The magnetic field of the planet-hosting star τ Bootis *

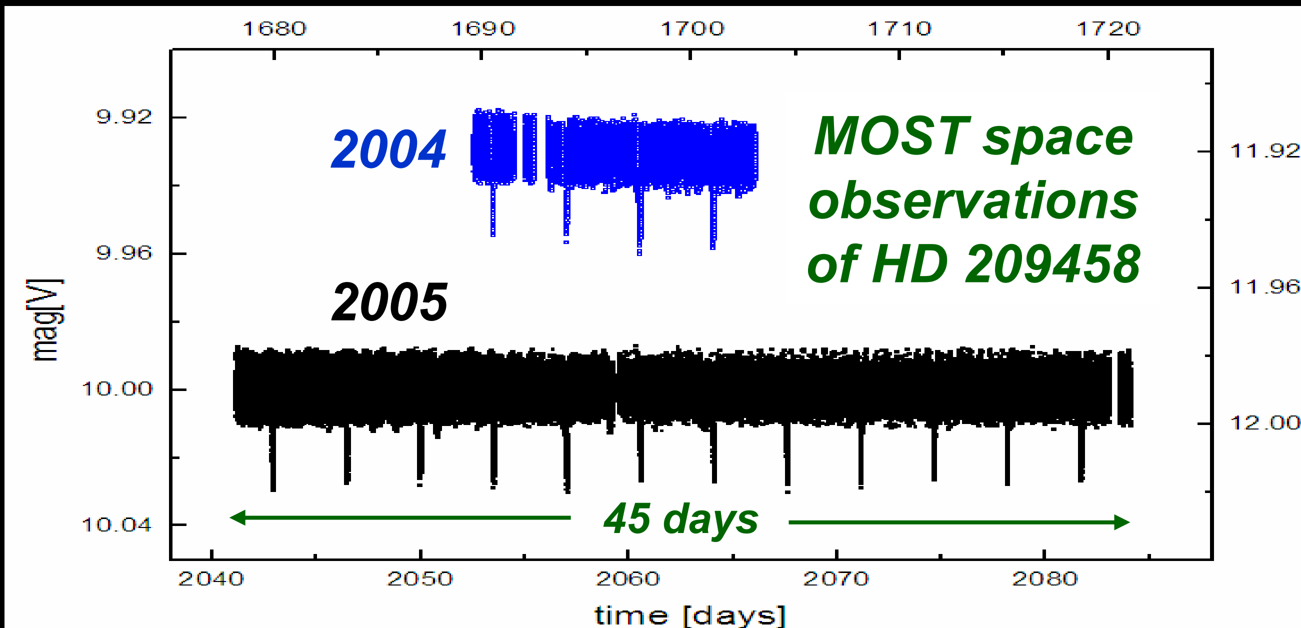
C. Catala[1] †, J.-F. Donati[2]‡, E. Shkolnik[3]§, D. Bohlender[4]¶, E. Alecian[1]||
[1] *Observatoire de Paris, LESIA, 5 place Jules Janssen, 92195 Meudon Cedex, France*
[2] *Observatoire Midi-Pyrénées, LATT, 14 avenue Edouard Belin, 31400 Toulouse, France*
[3] *NASA Astrobiology Institute, University of Hawaii at Manoa, 2680 Woodlawn Drive, Honolulu, HI, 96822*
[4] *National Research Council of Canada, Herzberg Institute of Astrophysics, 5071 West Saanich Road, Victoria, BC V9E 2E7, Canada*

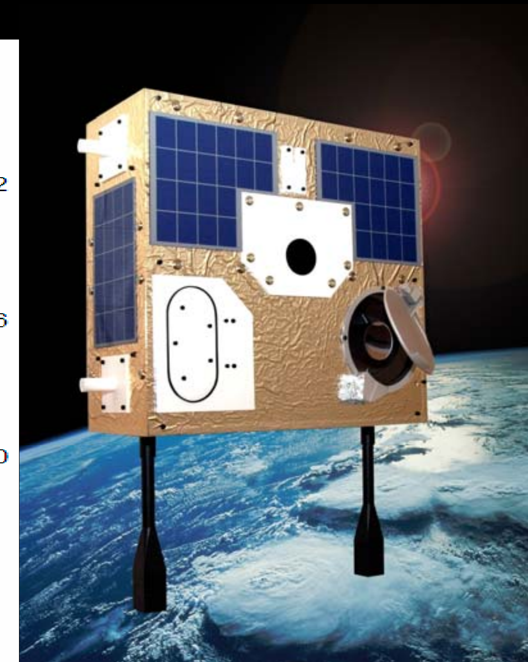
v1 25 Oct 2006

Accepted . Received ; in original form

ABSTRACT
We have obtained high resolution spectropolarimetric data for the planet-hosting star τ Bootis, using the ESPaDOnS spectropolarimeter at CFHT. A weak but clear Stokes V signature is detected on three of the four nights of June 2006 during which we have recorded data. This polarimetric signature indicates with no ambiguity the presence of a magnetic field at the star's surface, with intensity of just a few Gauss.

HD 207458

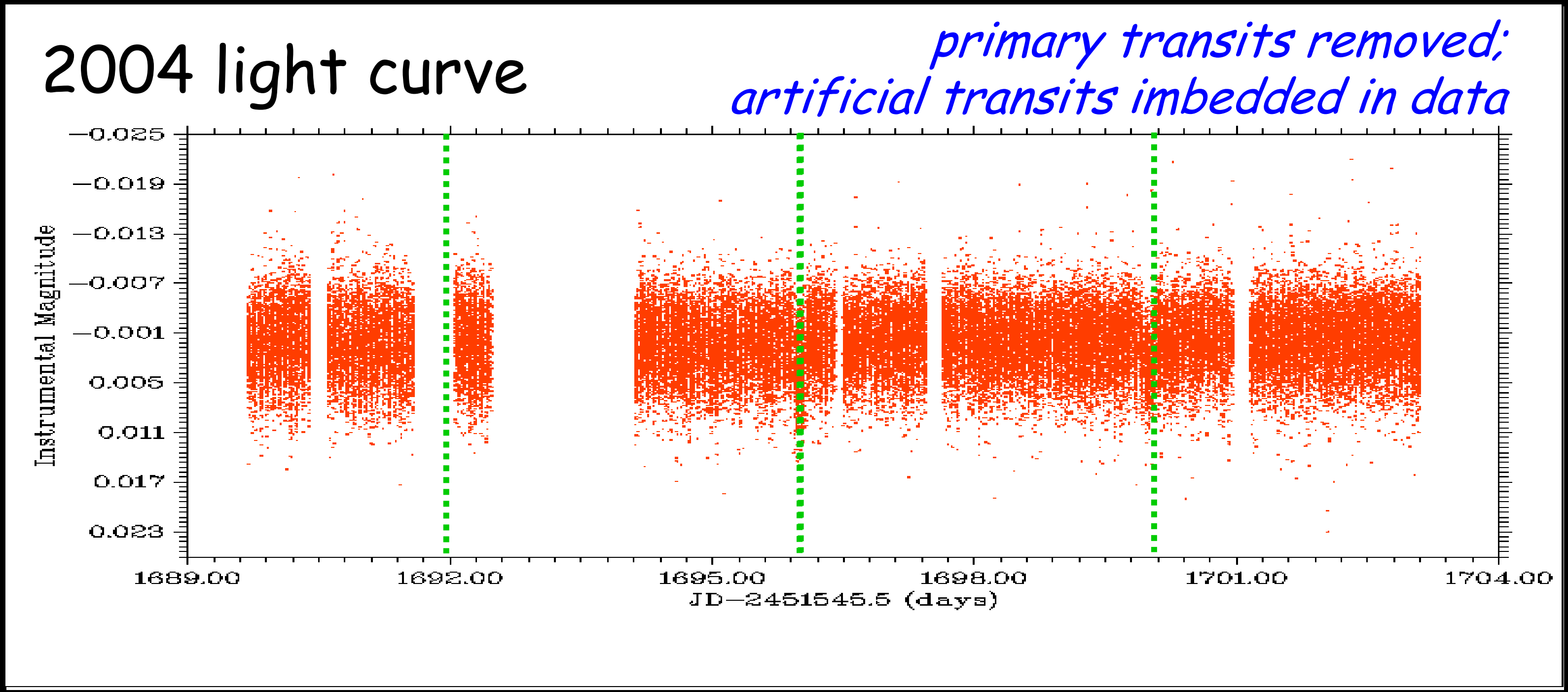




- search for transits at other periods → *eccentricity, moons?*
- timing of successive transits → *Earth-sized planets?*

HD 207458

- MOST Direct Imaging photometry

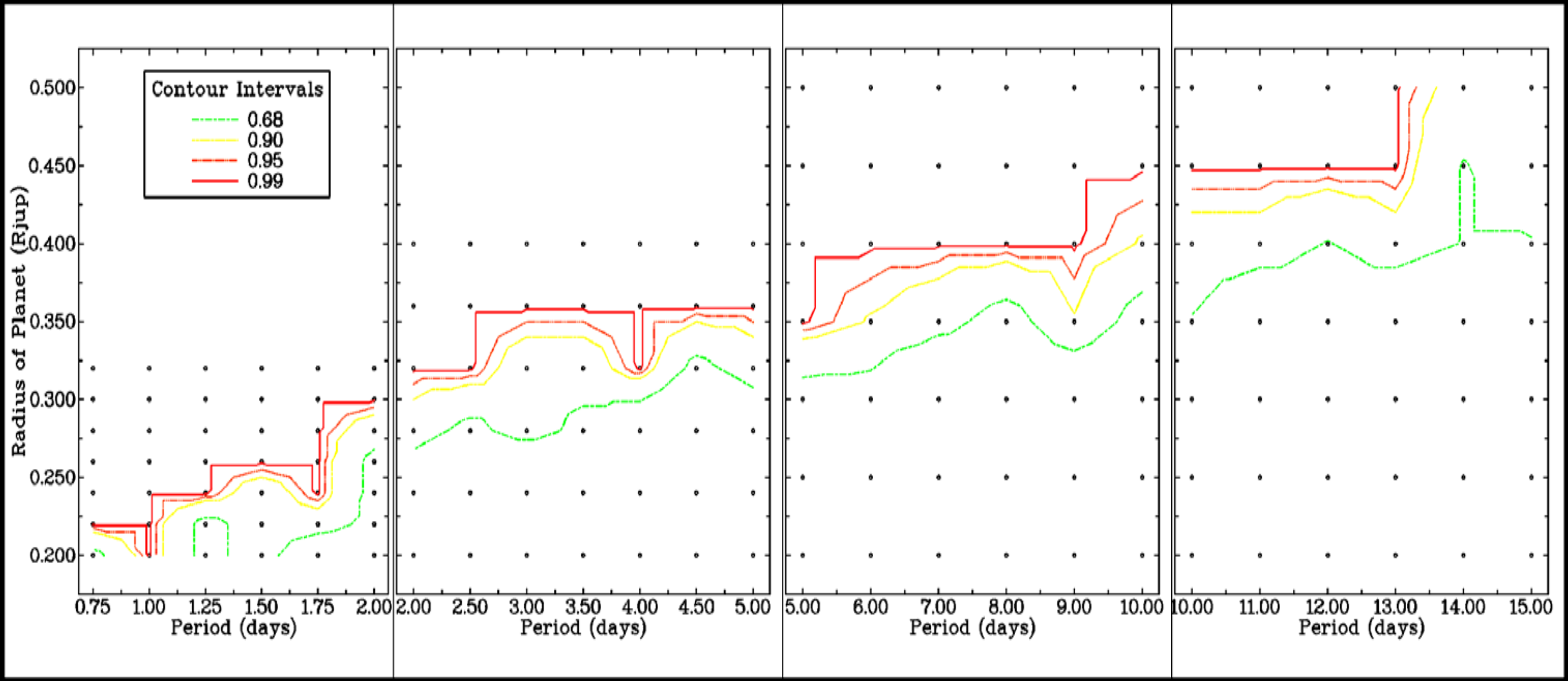


- search for transits at other periods

Croll, Matthews et al. 2007, ApJ, in press

HD 207458

- MOST Direct Imaging photometry



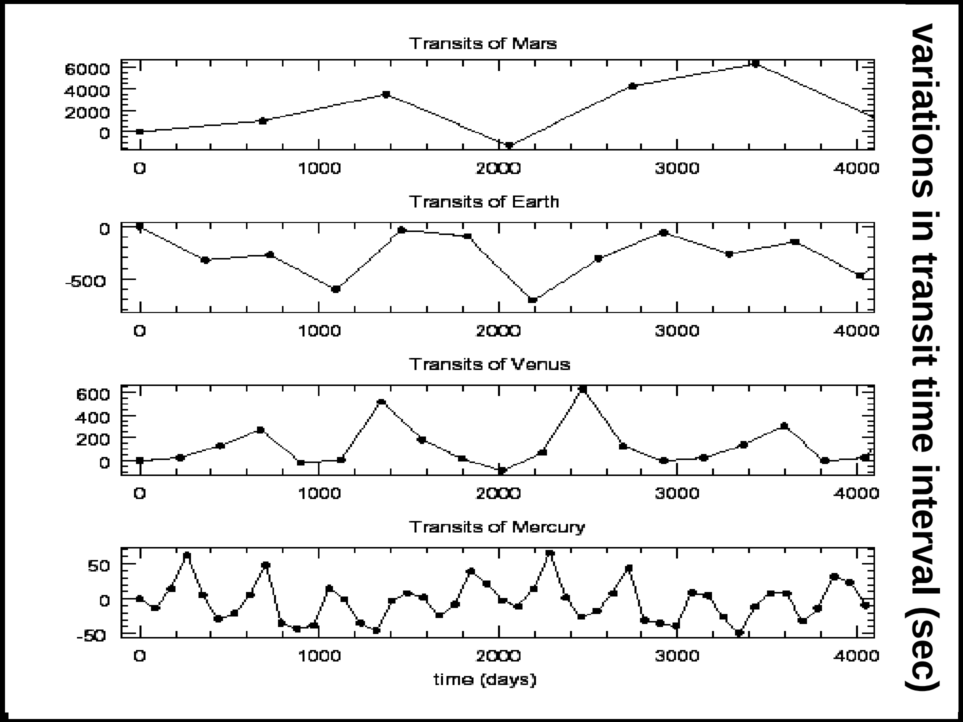
- search for transits at other periods

Croll, Matthews et al. 2007, ApJ, in press

HD 207458

- Variations of transit times in Solar System

Holman & Murray 2005
Science 307, 1288



- search for transits at other periods
- timing of successive transits

HD 207458

- Variations of transit times in HD 209458: *predicted*

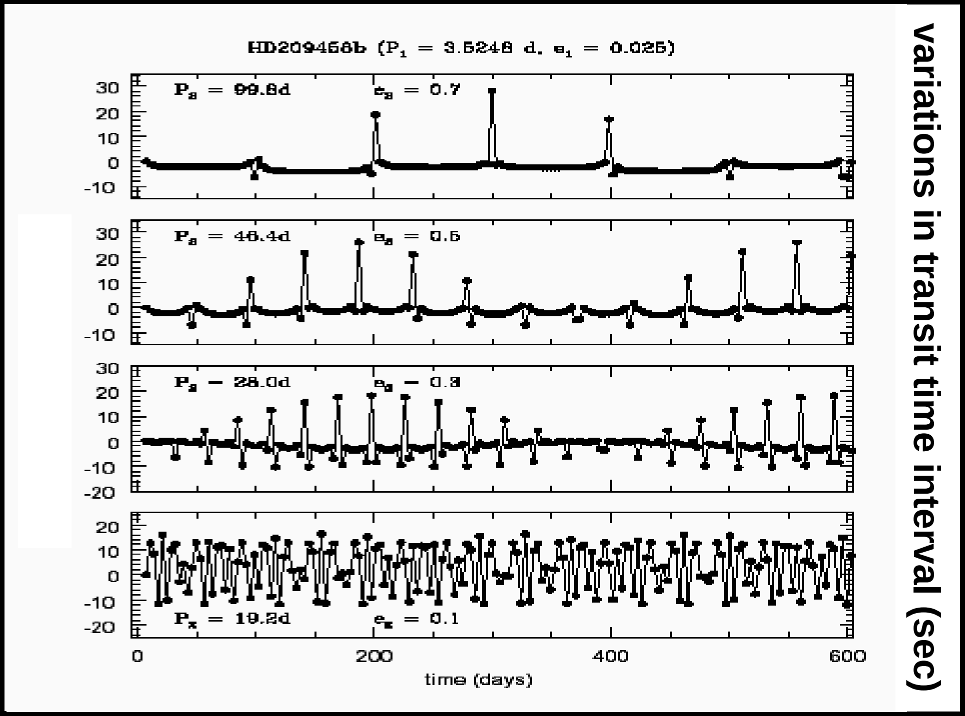
Holman & Murray 2005
Science 307, 1288

P = 99.8 d

P = 46.4 d

P = 28.0 d

P = 19.2 d



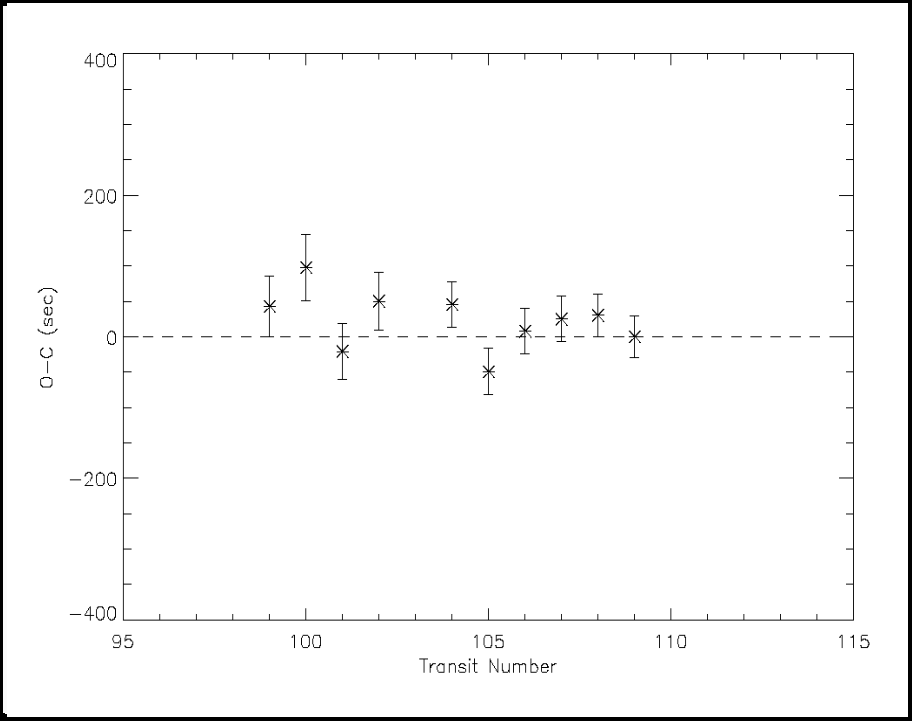
- search for transits at other periods
- timing of successive transits

Miller-Ricci, Sasselov, Matthews et al. 2007, ApJ, in press

HD 207458

- Variations of transit times in HD 209458: *observed*

transits in 2005
(preliminary reduction)



- search for transits at other periods
- timing of successive transits

Miller-Ricci, Sasselov, Matthews et al. 2007, ApJ, in press

HD 207458

- Variations of transit times in HD 209458: *observed*

  … can already exclude:

  - Earth in an outer 2:1 resonance (based on Holman's model)
  - Earth-like planets with $e > 0.15$ near 3:1 and 4:1 resonances
  - sub-Earth planet in an inner 1:2 resonance
    - eliminating one of the options for obliquity tides on HD 209458b *(Winn & Holman 2005)*

- search for transits at other periods
- timing of successive transits

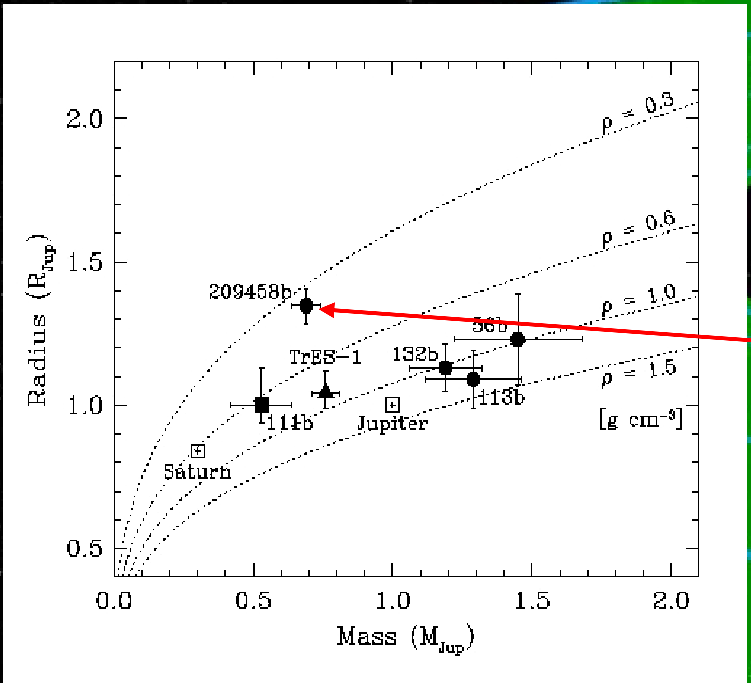
Miller-Ricci, Sasselov, Matthews et al. 2007, ApJ, in press

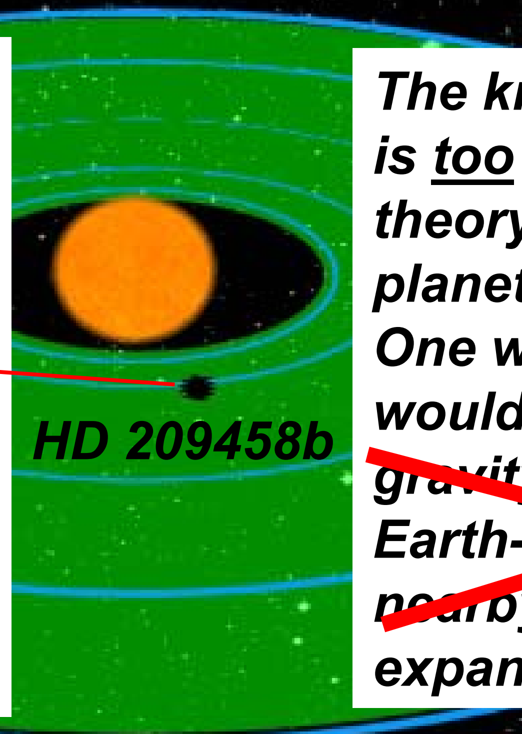
HD 209458

So what?

No Earth-mass planets in these orbits

No 2 - 5 Earth-radius planets here



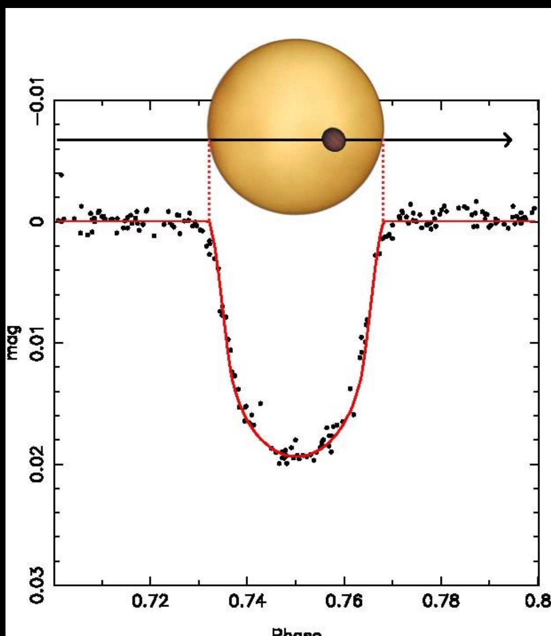


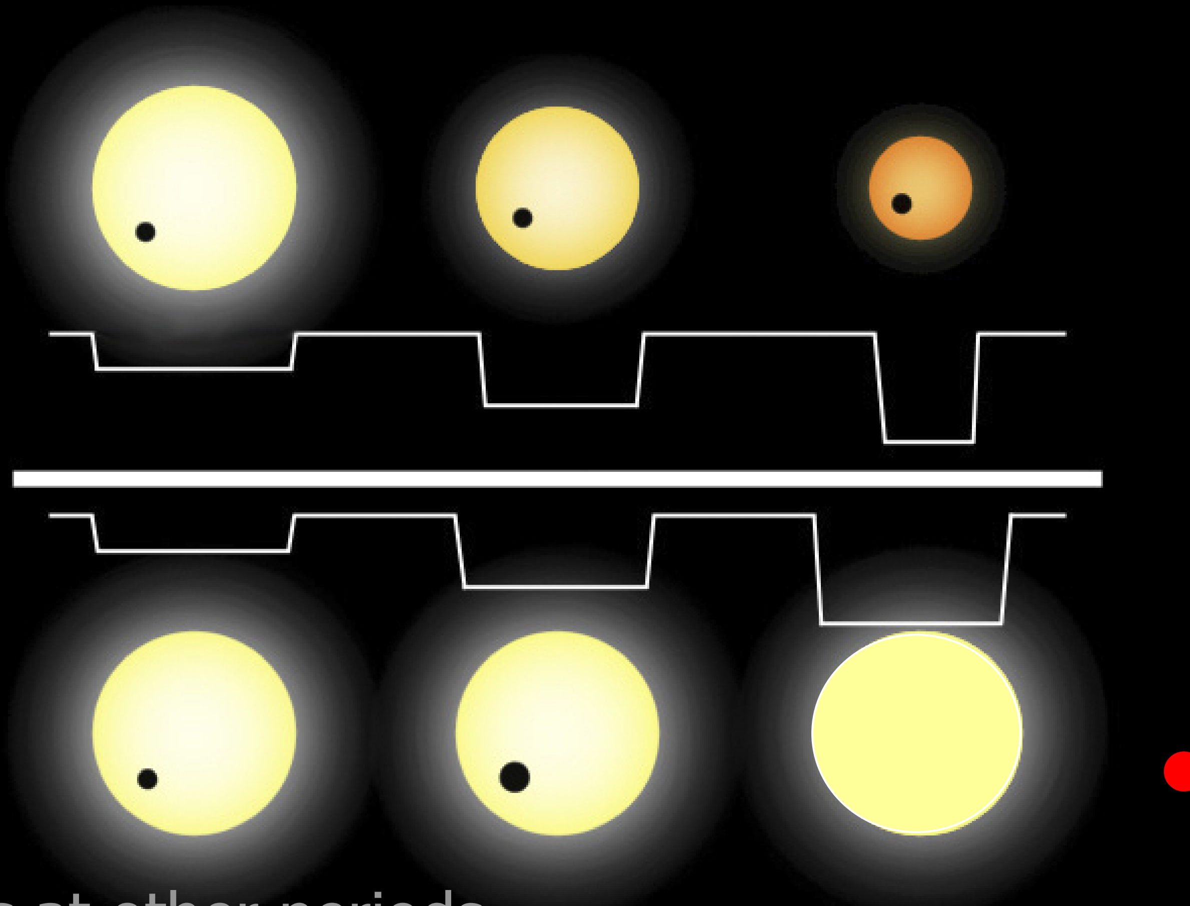
The known giant planet is <u>too</u> giant – larger than theory and data on other planets predict.

One way to explain this would have been the ~~gravity of an undetected Earth-mass planet in a nearby orbit tidally~~ expanding HD 209458b.

< ------------ 34 million km ------------ >

Clouds on HD 209458



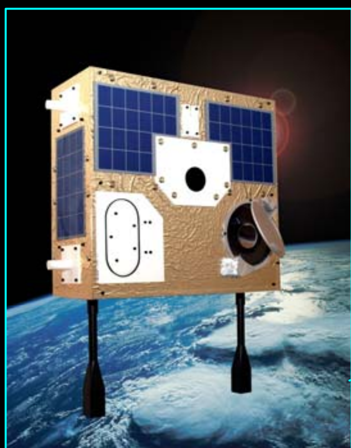


- search for transits at other periods
- timing of successive transits
- measurement of eclipse of giant planet

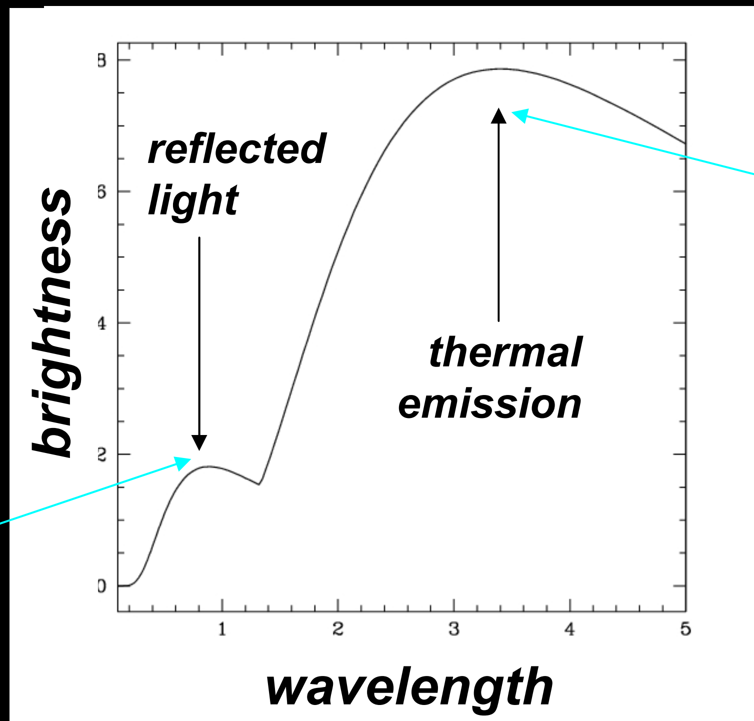
Rowe, Matthews et al.

Clouds on HD 209458

MOST
optical



Rowe et al. 2006
ApJ



emergent light from planet

Spitzer
infrared

Deming et al. 2005
Nature 111, 111

- search for transits at other periods
- timing of successive transits
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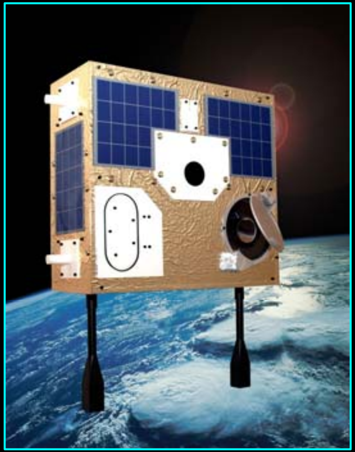
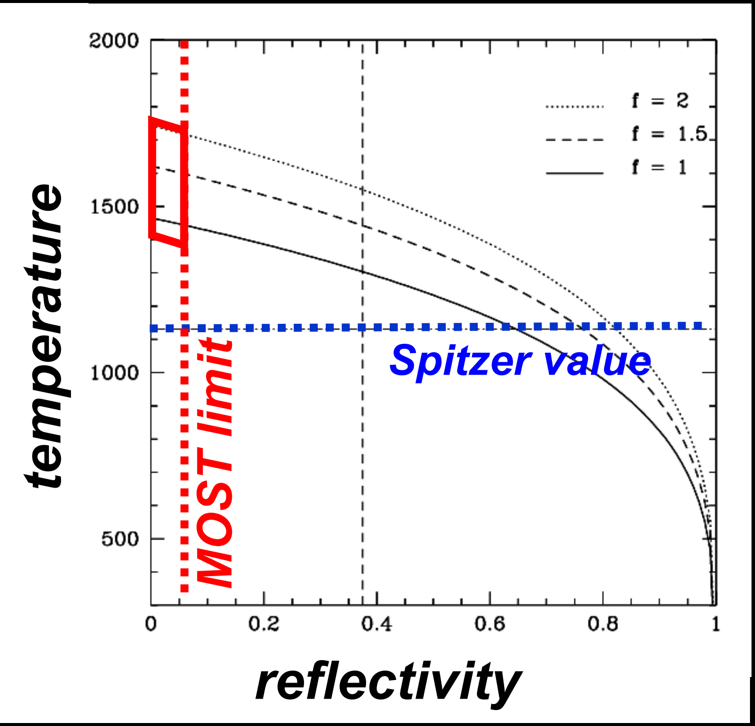
Rowe, Matthews et al.

Clouds on HD 209458

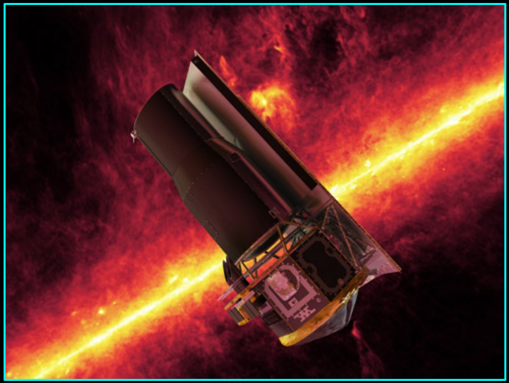
MOST
optical



Rowe et al. 2006
ApJ



models of planet atmosphere



Spitzer
infrared

Deming et al. 2005
Nature 111, 111

- search for transits at other periods
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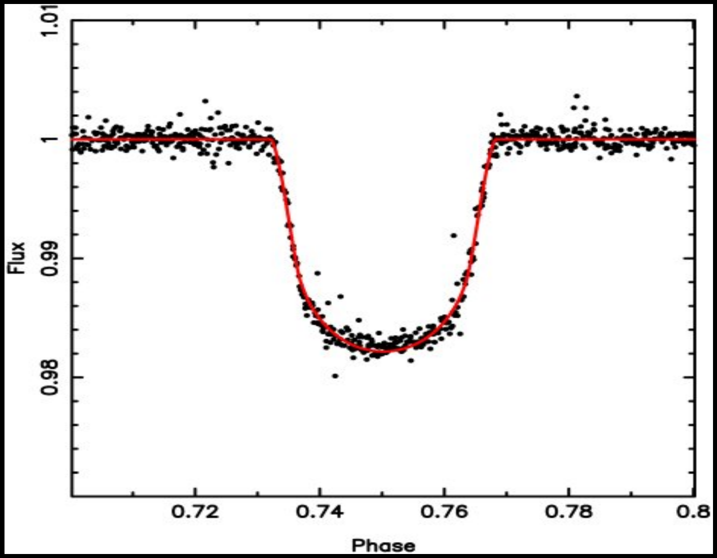
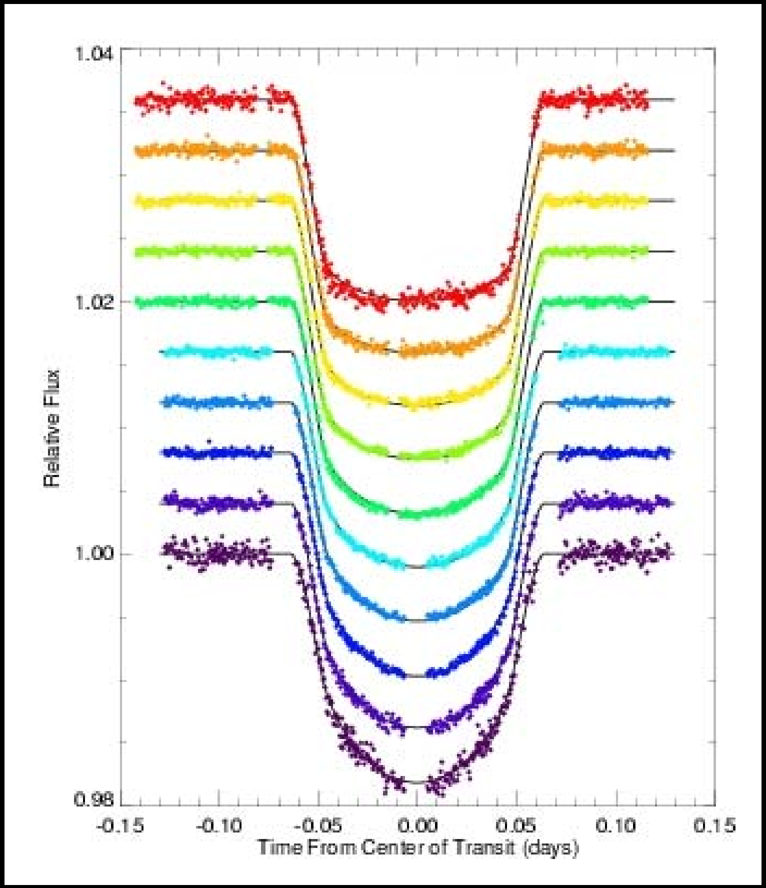
- measurement of eclipse of giant planet

Rowe, Matthews et al.

Clouds on HD 209458

- MOST vs. HST in transit monitoring





Clouds on HD 209458

- MOST vs. HST in transit monitoring

Knutson et al. 2006

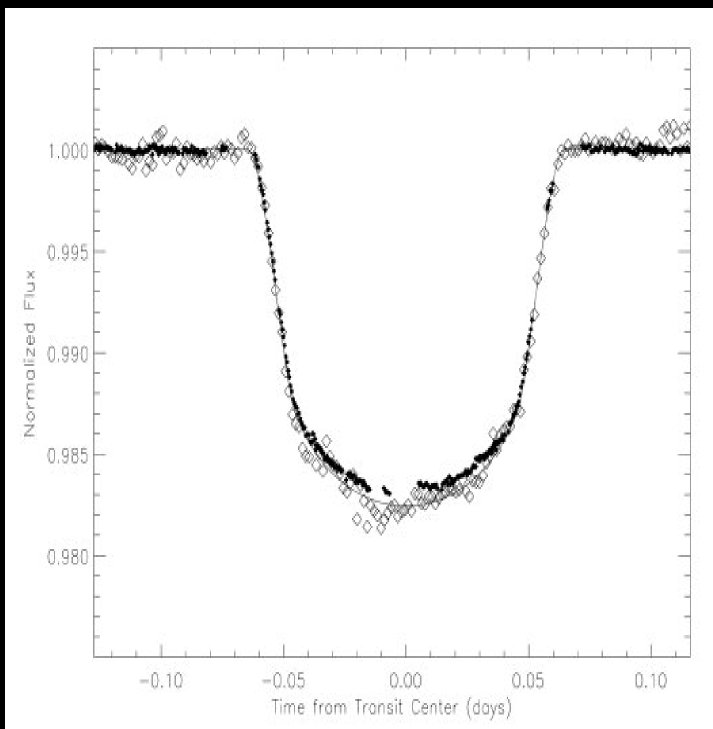


Table 4. Comparison between best-fit values and results from previous works

Study	R_P (R_{Jup})	Inclination (°)	$M_\star$ ($M_\odot$)	$R_\star$ ($R_\odot$)
Wittenmyer et al. (2005)	1.35 ± 0.07	86.668	1.09 ± 0.09^a	1.15 ± 0.06^a
Winn et al. (2005)	1.35 ± 0.06	86.55 ± 0.03	1.06 ± 0.13^b	$1.15^{+0.05}_{-0.06}$
This Work	$1.320^{+0.024}_{-0.025}$	$86.929^{+0.009}_{-0.010}$	$1.101^{+0.066}_{-0.062}$ a	$1.125^{+0.020}_{-0.023}$ a

[a] Used stellar mass-radius relation from Cody & Sasselov (2002)

[b] Assumed value for the stellar mass from Cody & Sasselov (2002)

- nonlinear limb-darkening
  - Kurucz models
  - specific to MOST bandpass
- stellar radius:
  - $1.121 \pm 0.003\ R_{Sun}$
- planetary radius:
  - $1.346 \pm 0.002\ R_{Jup}$

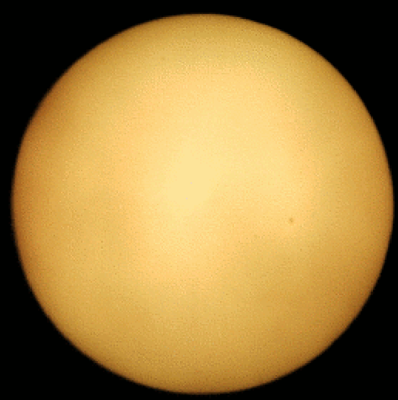
- *MOST transit data leads to slightly larger radius than HST but agrees with independent groundbased measurements*

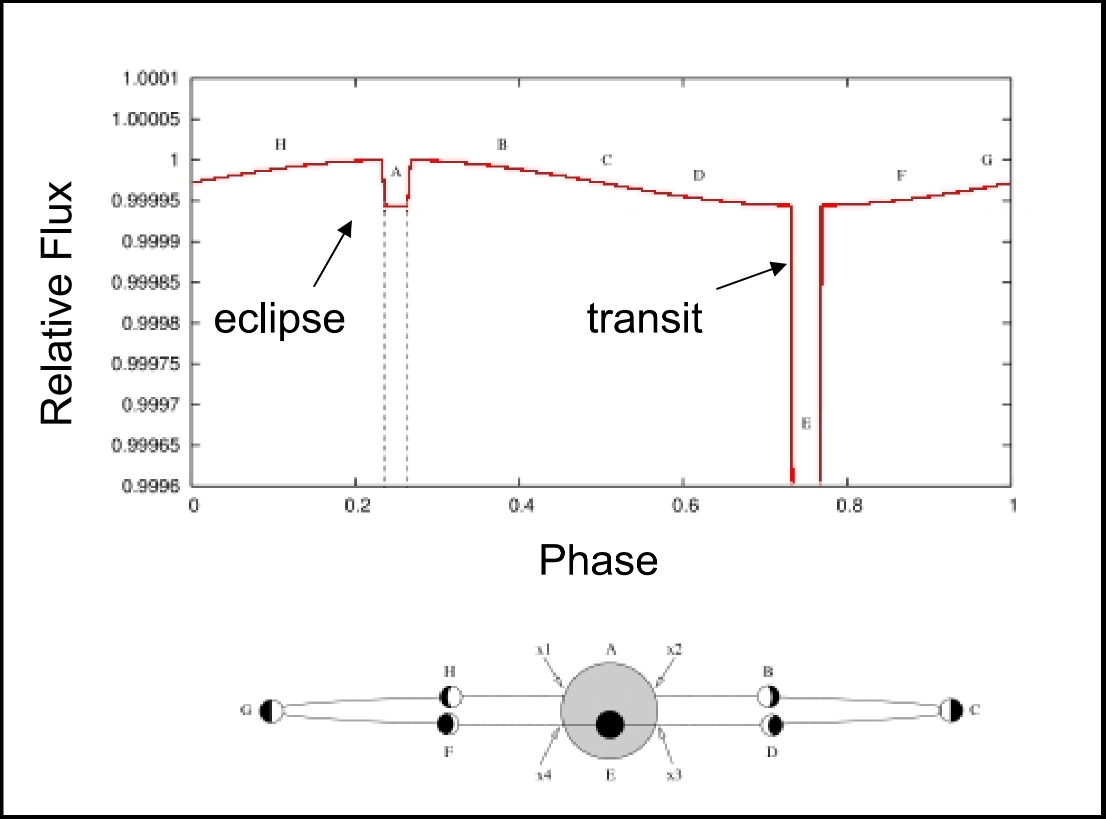
Clouds on HD 209458

- eclipsed exoplanet

V = 7.5
G0 V

P_{orb} = 3.52 days
M_p = 0.68 $M_{Jupiter}$
R_p = 1.35 $R_{Jupiter}$
T_p = 1130 K





Clouds on HD 209458

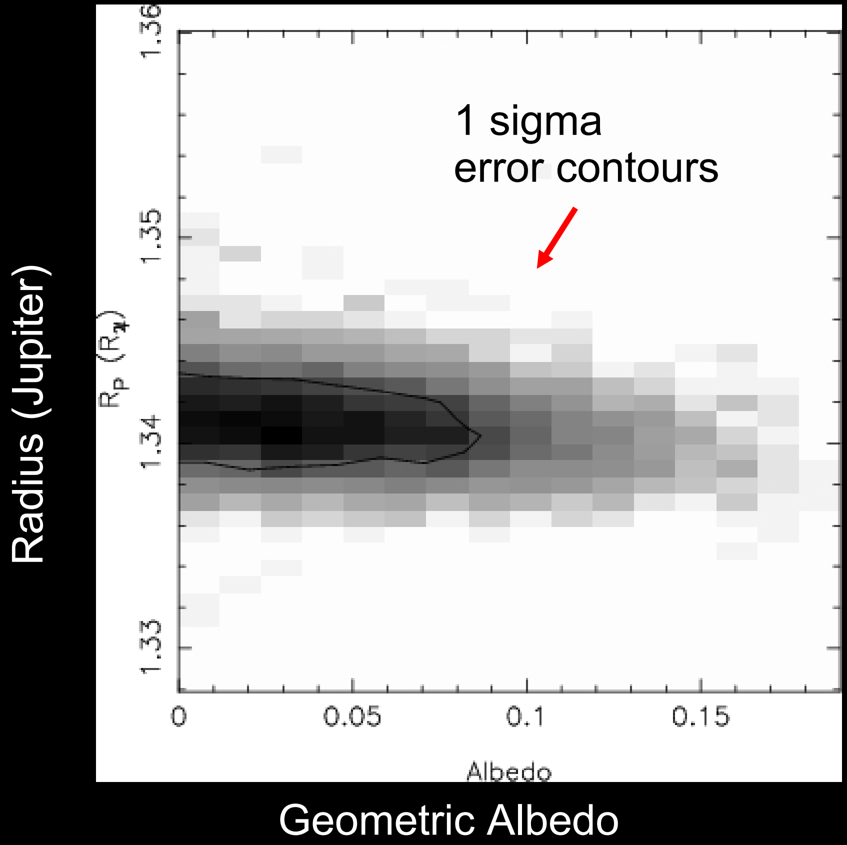
- eclipsed exoplanet gives albedo and atmosphere / cloud conditions
  - Sudarsky Planet types
    - I : Ammonia Clouds
    - II : Water Clouds
    - III : Clear
    - IV : Alkali Metal
    - V : Silicate Clouds
  - Predicted Albedos:
    - IV : 0.03
    - V : 0.50

Simulated image of class IV planet generated using Celestia Software

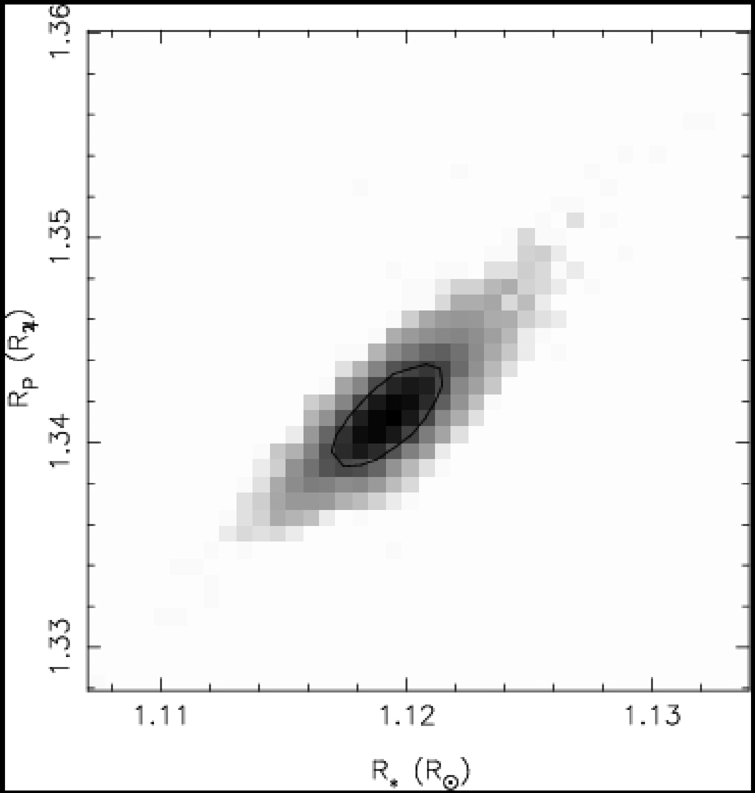
Clouds on HD 209458

- Best fit parameters:
  - *albedo : 0.04 ± 0.04*
  - stellar radius :
    1.339 ± 0.001 R_{Jup}
  - stellar mass
    1.084 ± 0.005 M_{Sun}

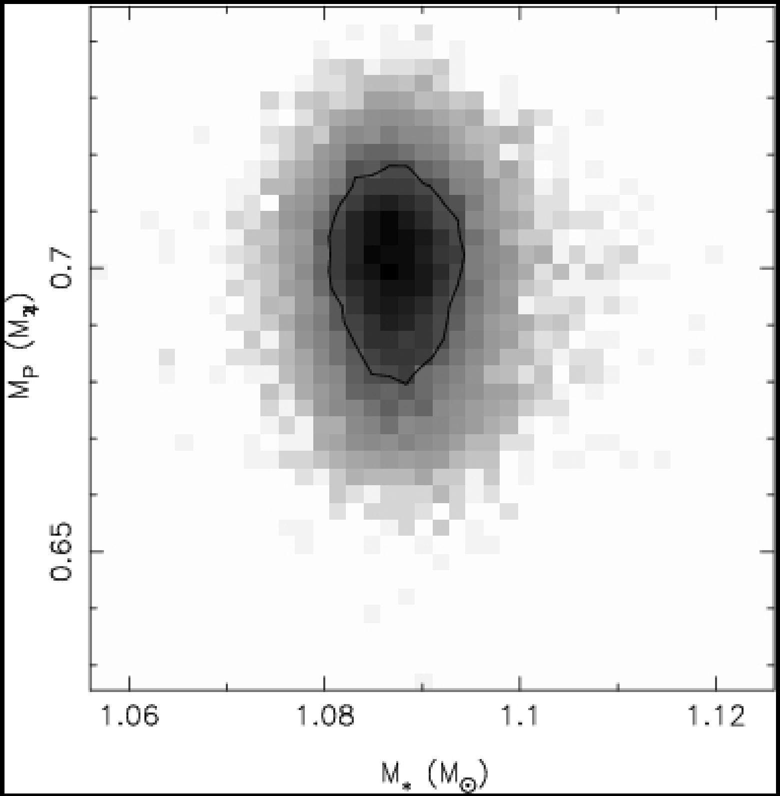
  i = 86.937° ± 0.003°
  P = 3.5247489 d



Clouds on HD 209458



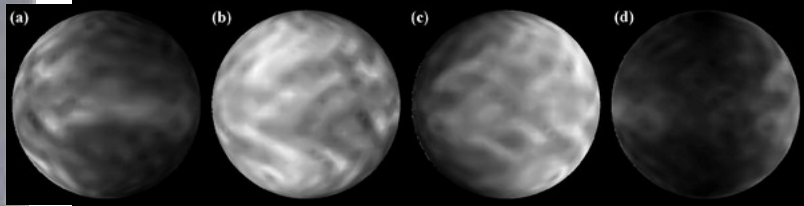
stellar and planetary radii



stellar and planetary masses

Weather on HD 209458

MOST upper limit on reflectivity already eliminates a range of potential models for the atmosphere and nature of the cloud cover of exoplanet HD 209458b



Thermal flow models of HD209458b

Rowe, Matthews et al. 2007, in preparation

HD 189733

- transiting exoplanet

V = 7.6

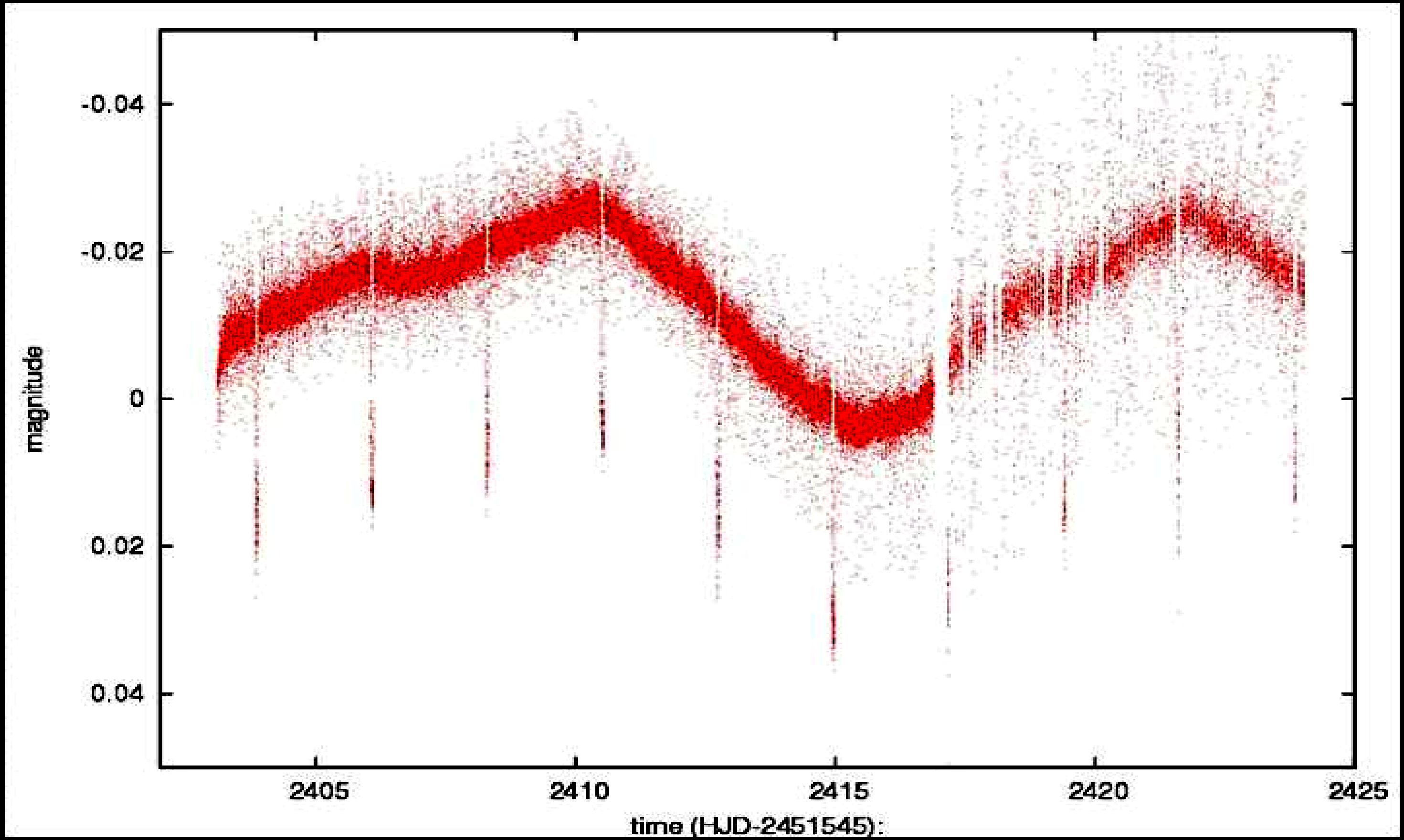
K1 V, M_{star} = 0.82 M_{Sun}

P_{orb} = 2.22 days

M_p = 1.15 $M_{Jupiter}$

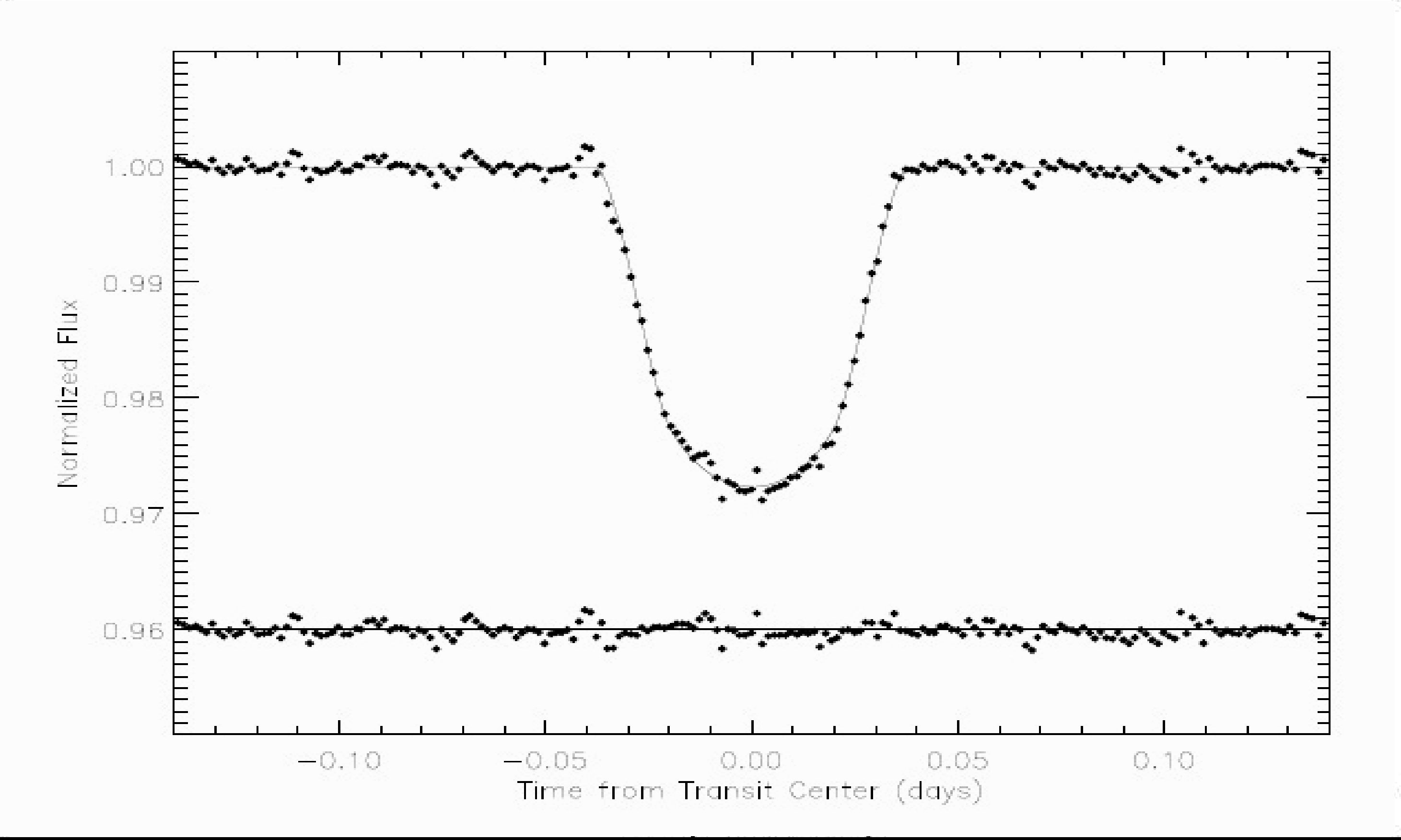
HD 189733

- transiting exoplanet, with <u>starspots</u>



HD 189733

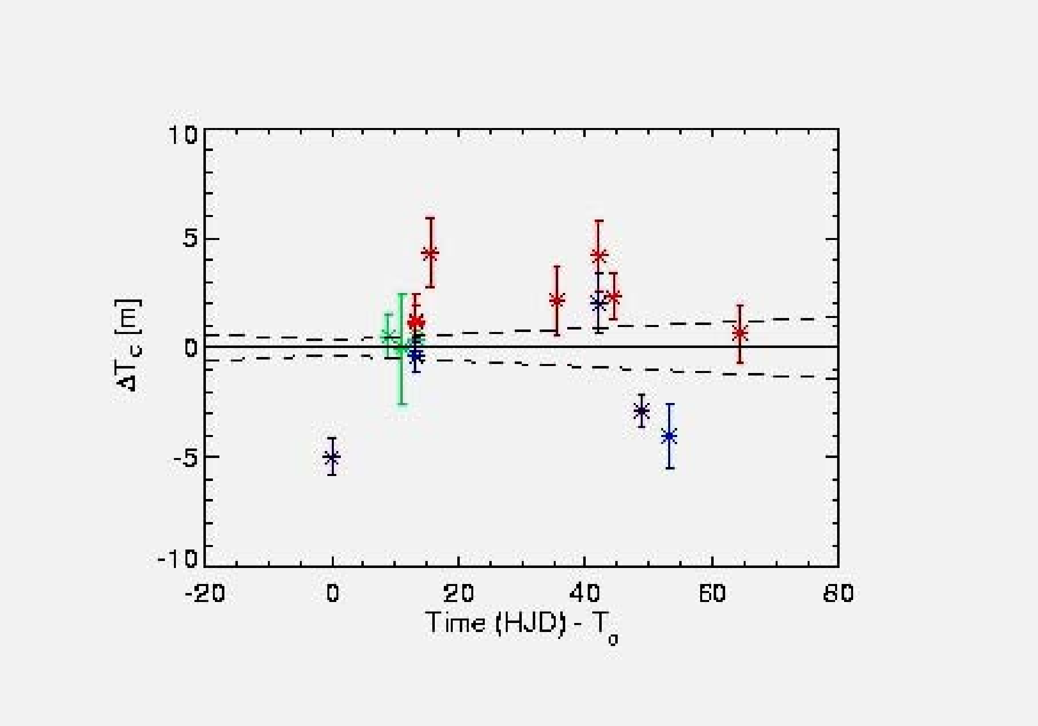
- transiting exoplanet, with <u>starspots</u>



HD 189733

Are there hot "Earths" in this system?

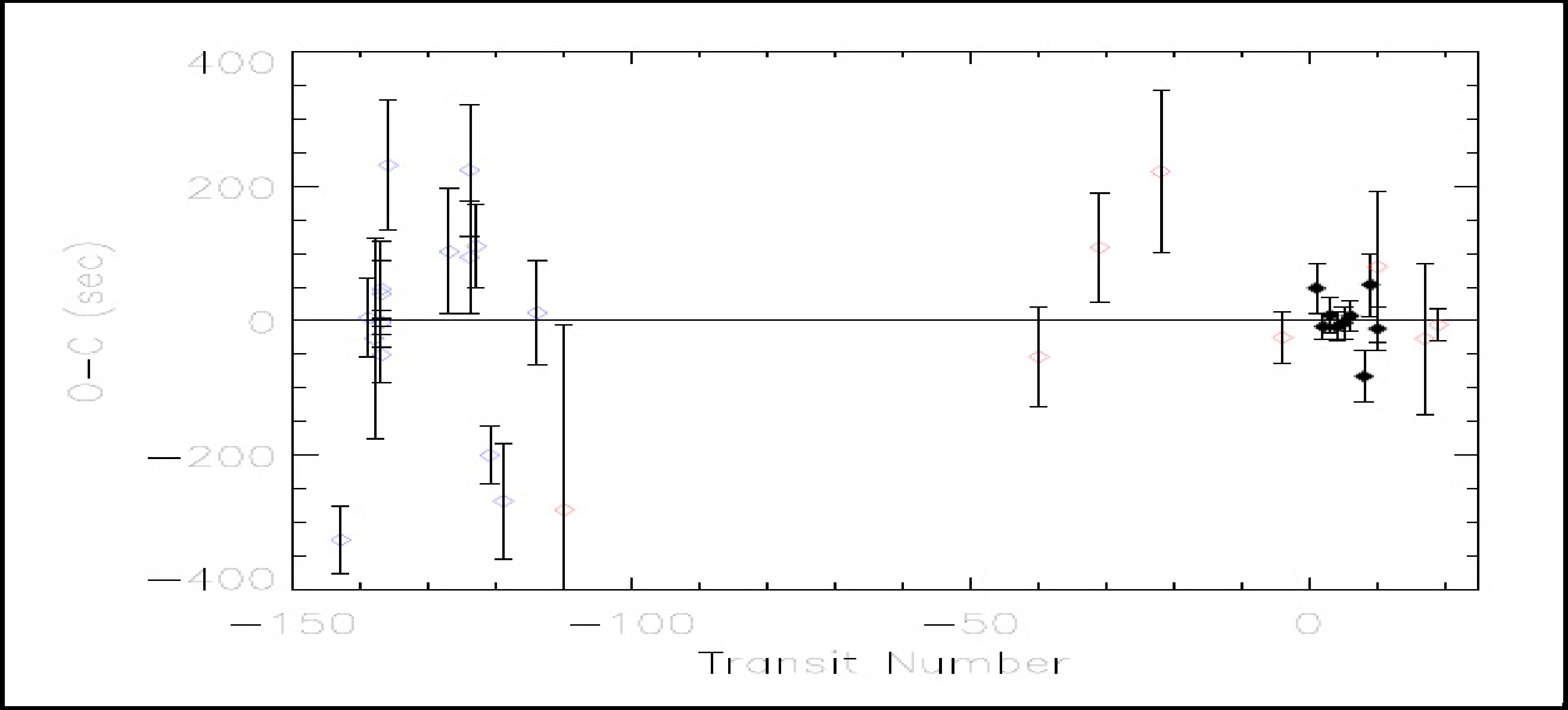
Timing measurements of groundbased photometry *(Bakos et al. 2006)* *(scatter across 10 min)*:



HD 189733

Are there hot "Earths" in this system?

Timing measurements of MOST photometry *(Miller-Ricci et al. 2007)* *(no variations above 30 s)*:



HD 189733

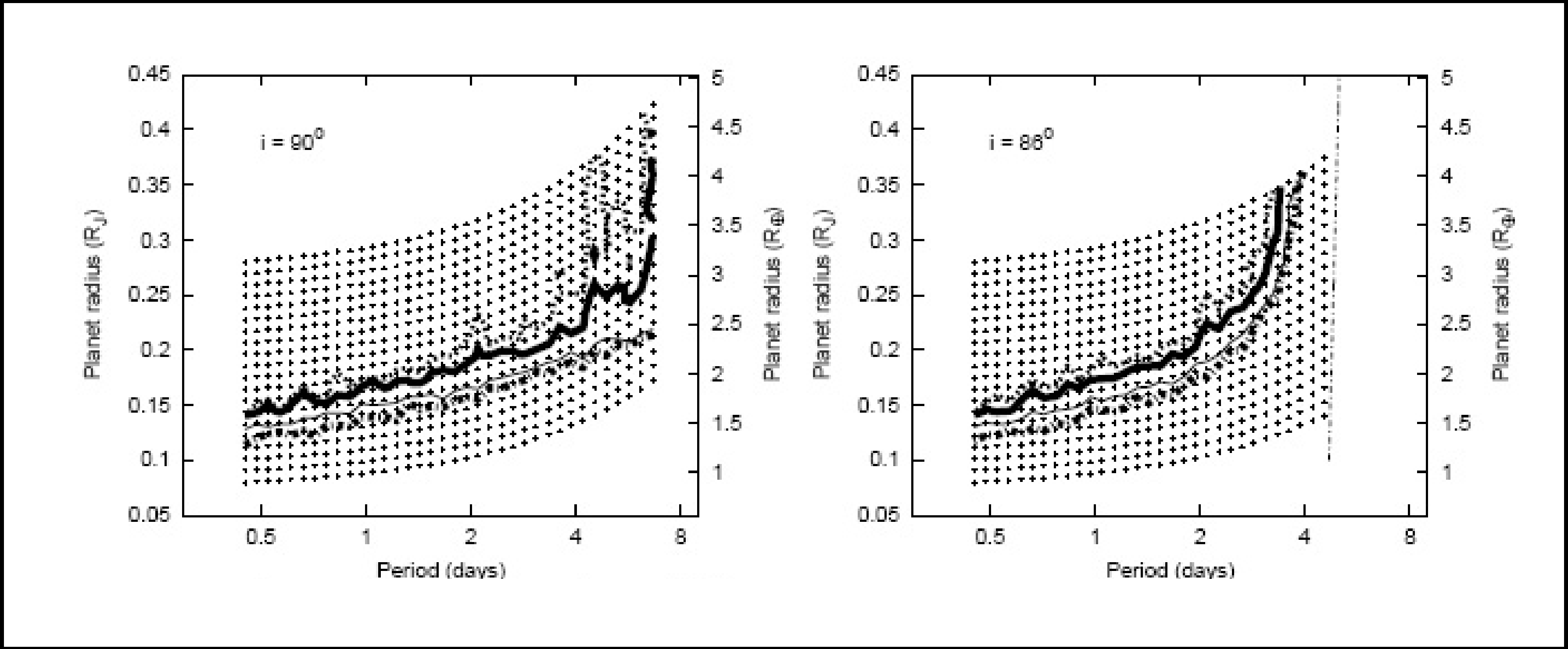
Are there hot "Earths" in this system?

MOST timing measurements of 10 consecutive complete transits *(Δt = 0 within 30 sec)* already exclude:

- planets of 3 Earth masses in an outer 2:1 resonance
- Super-Earth planets greater than 13 Earth masses with eccentrcities *e > 0.15* near the 3:1 resonance

HD 189733

Are there hot "Earths" in this system?

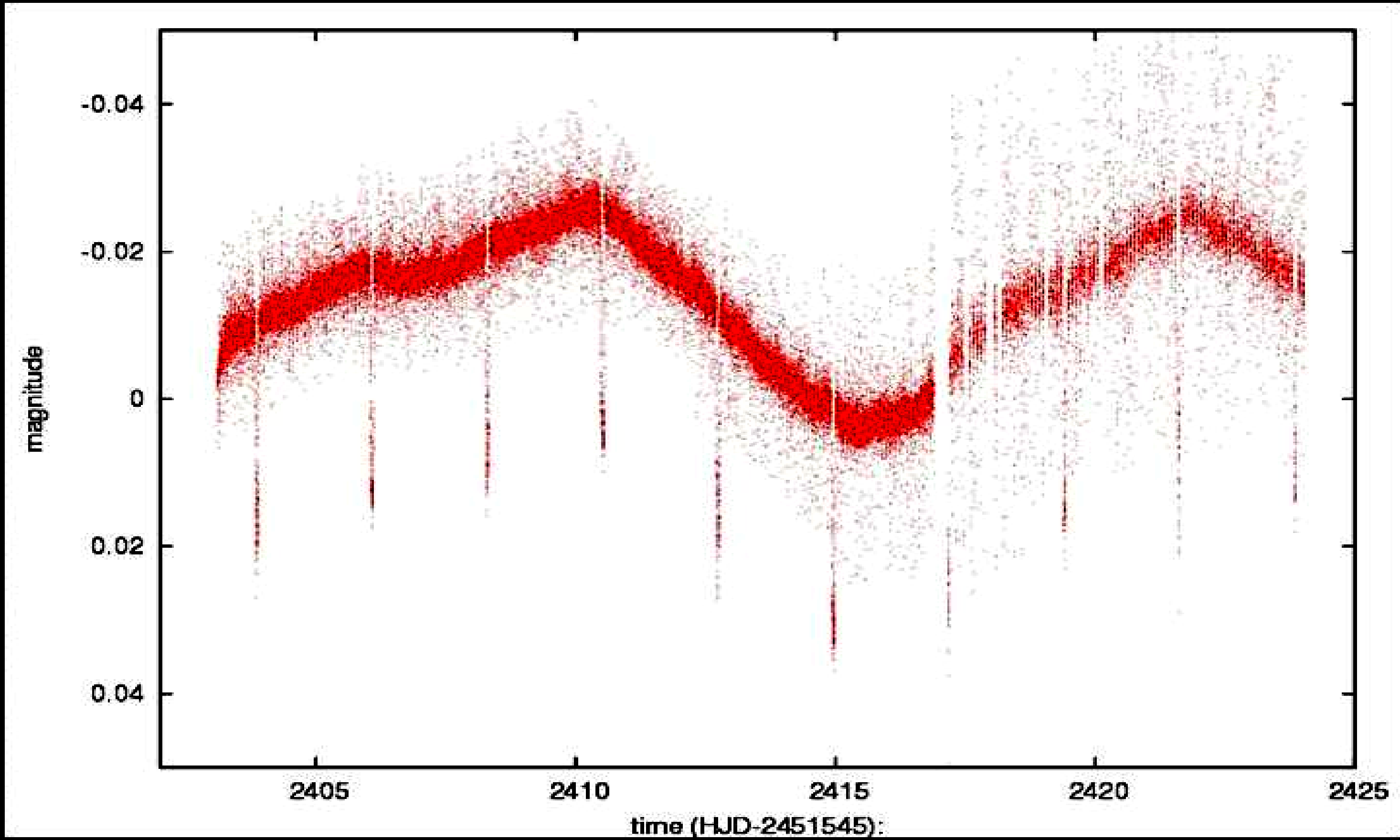


No planets from 1.6 – 3.5 Earth radii

HD 189733

HD 189733

- transiting exoplanet, with starspots

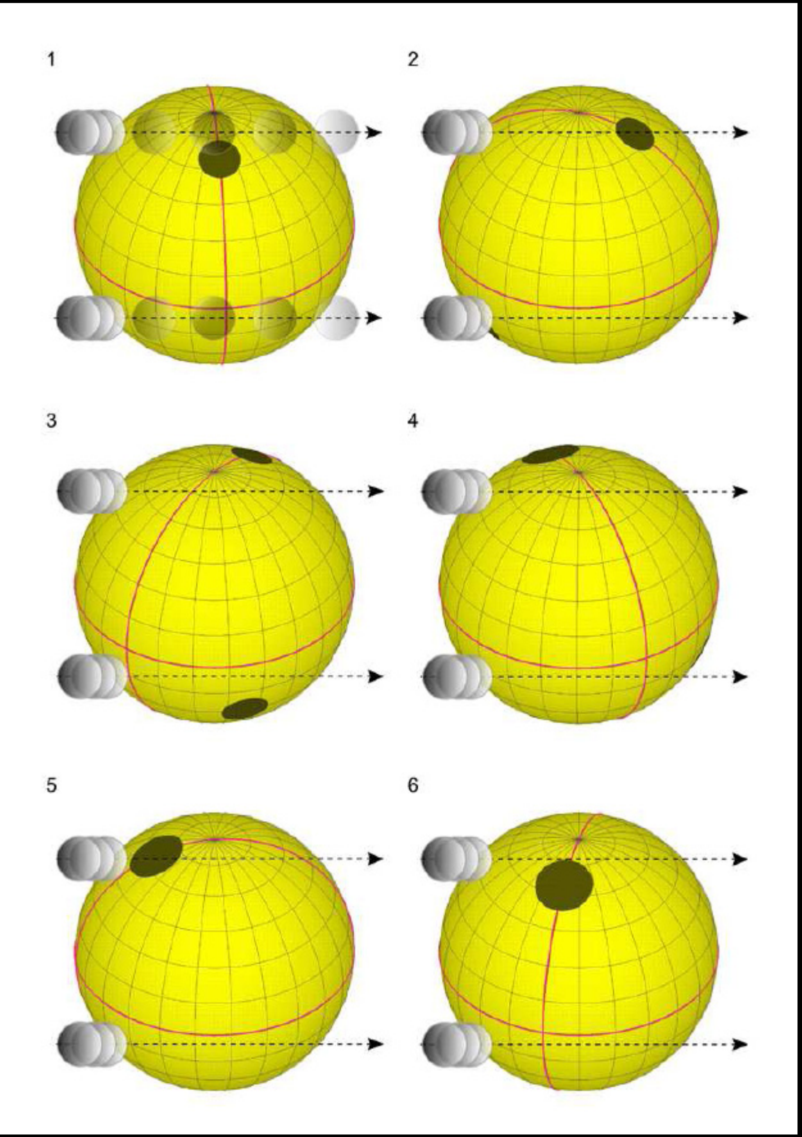


HD 189733

- transiting exoplanet with <u>starspots</u>

(Miller-Ricci et al. 2007)

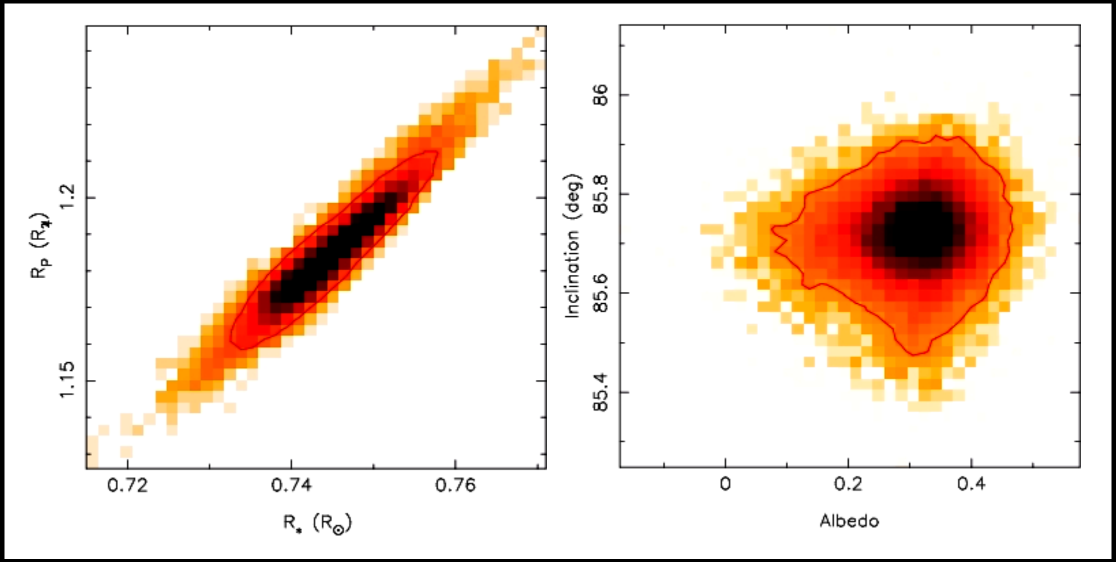
(Croll, Matthews et al. 2007)

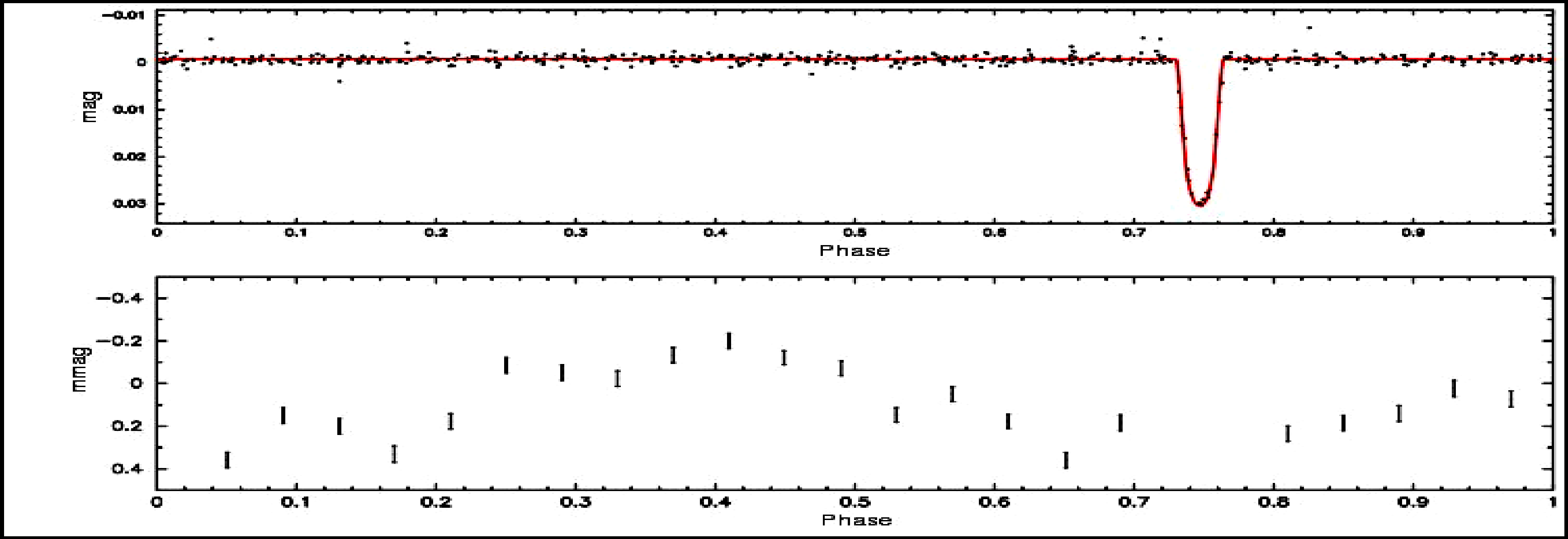


HD 189733

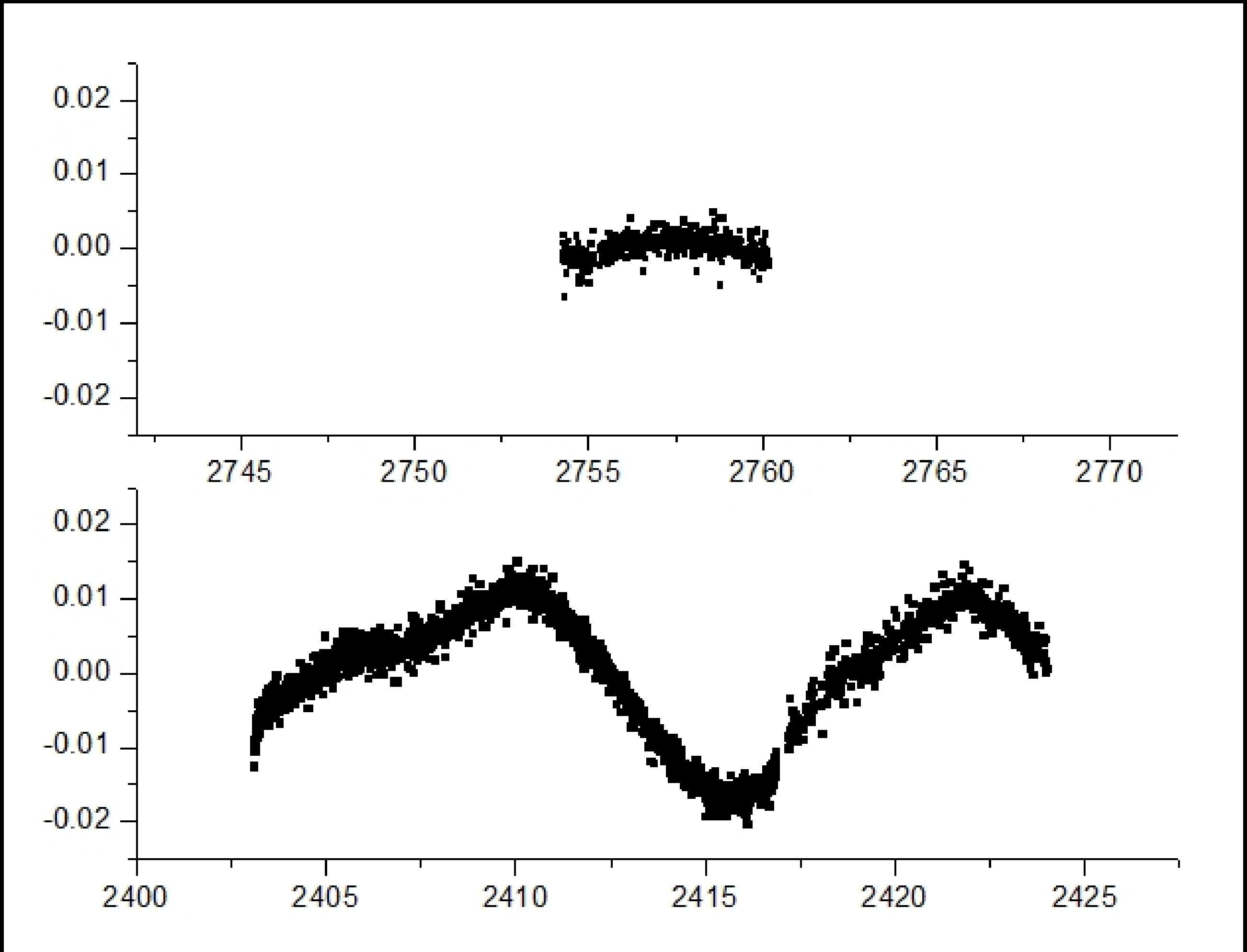
- modeling the light curve

(Rowe, Matthews et al. 2007)





HD 189733



0.02
0.01
0.00
-0.01
-0.02
2745
2750
2755
2760
2765
2770
0.02
0.01
0.00
-0.01
-0.02
2400
2405
2410
2415
2420
2425

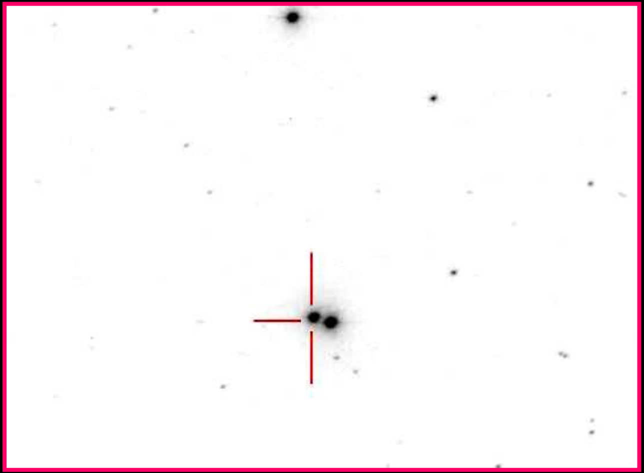
Other exoplanets

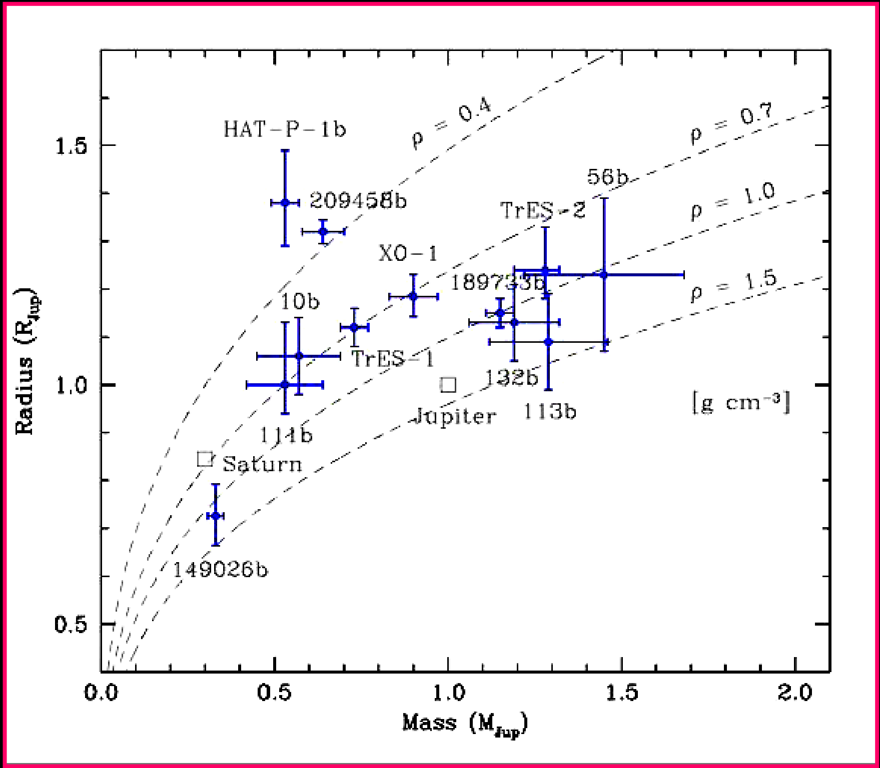
HAT-P-1

- the 'lightest' exoplanet yet

V = 9.6
G0 V, M_{star} = 1.12 M_{Sun}

P_{orb} = 4.46 days
M_p = 0.53 $M_{Jupiter}$



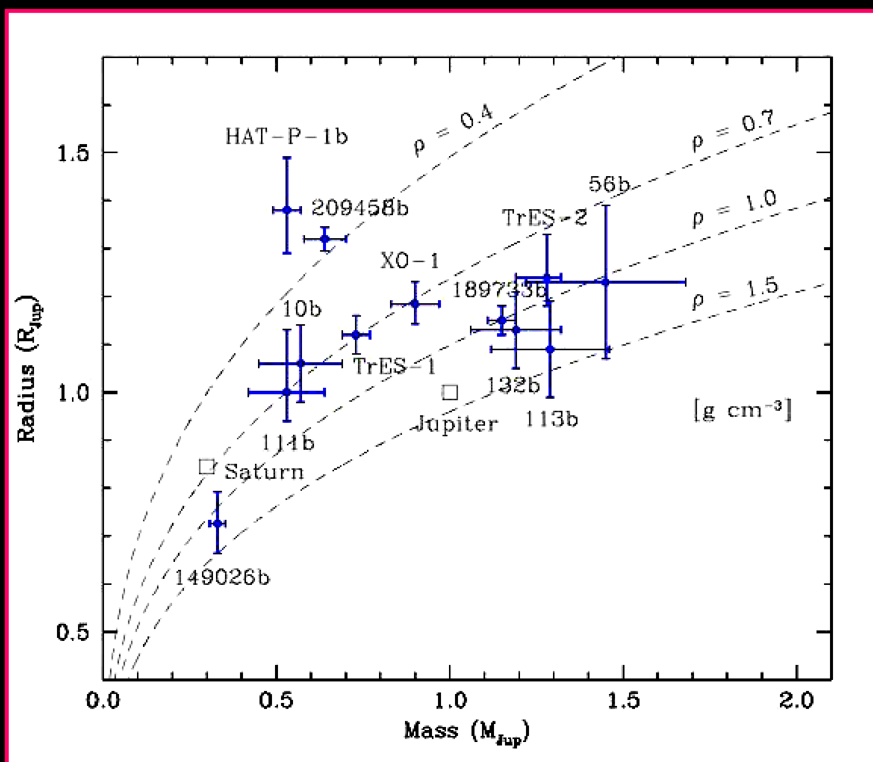


transiting giant extrasolar planets - mean densities

Other exoplanets

HAT-P-1

The first question to be answered by MOST is simple:
Is there another undetected planet capable of gravitationally "puffing up" HAT-P-1? *A planet of at least 8 Earth masses*

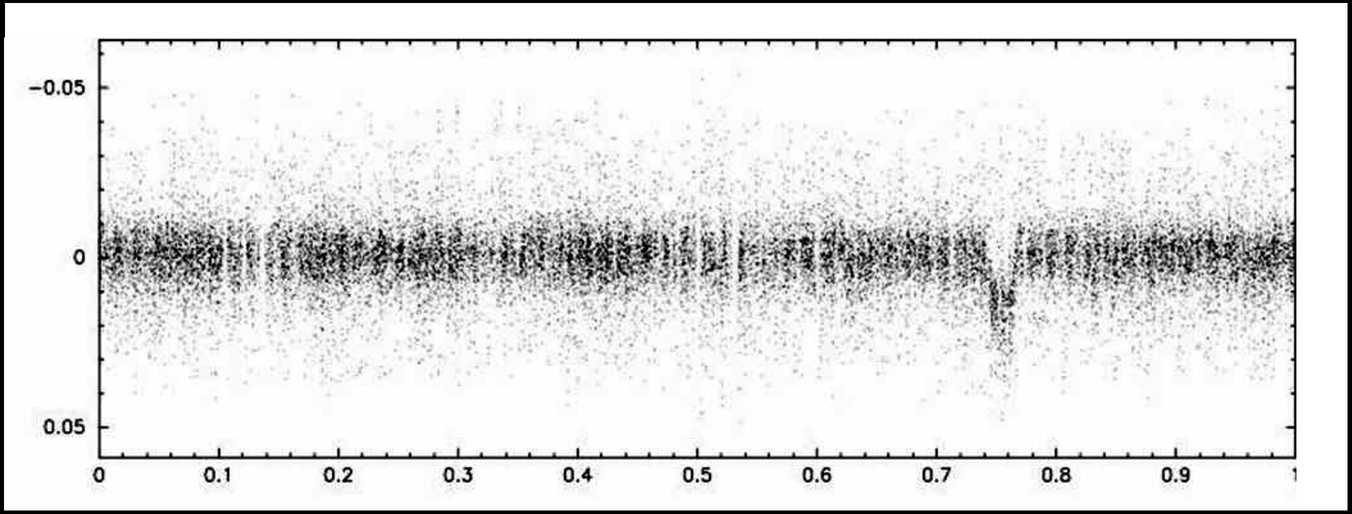


transiting giant extrasolar planets - mean densities

Other exoplanets

HAT-P-1

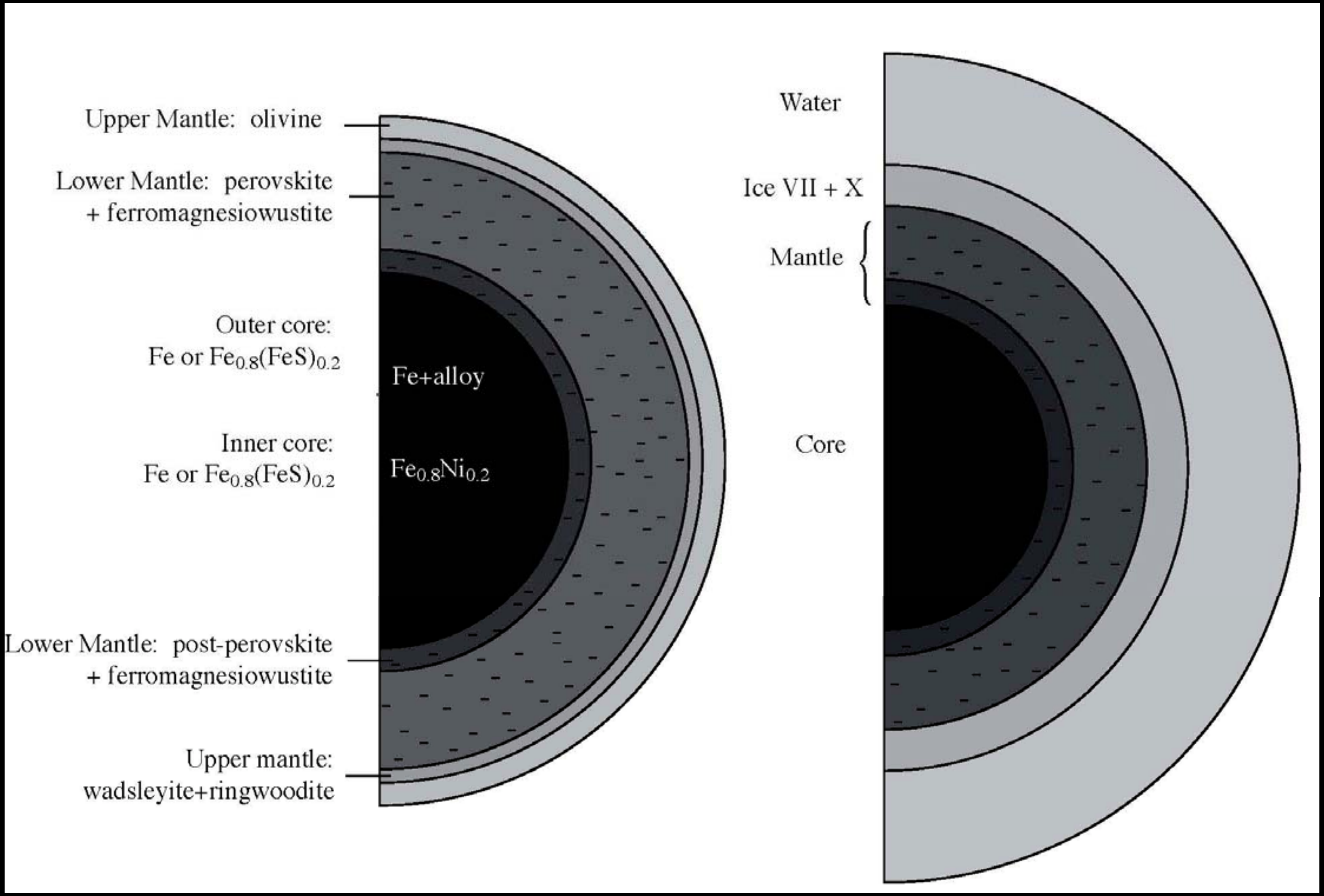
The first question to be answered by MOST is simple:
Is there another undetected planet capable of gravitationally "puffing up" HAT-P-1? *A planet of at least 8 Earth masses*



The answer: *No*
MOST transit timing data is able to say this.

Other exoplanets

Super-Earths



Earth-like **Ocean Planet**

Valencia, Sasselov, O'Connell (2006)

Other exoplanets

Super-Earths

e.g. HD 69830b

Could MOST measure the density of a super-Earth?

Yes!

Planet Transit Depths:

- For a Super-Earth model: *455 ppm*
- For a 20% Ocean Planet: *540 ppm*
- For a 40% Ocean Planet: *600 ppm*
- For a Super-Mercury model: *380 ppm*

MOST will be able to tell the difference !

Other exoplanets

Super-Earths

e.g. HD 69830b

Could MOST measure the density of a super-Earth?

Yes!

- Super-Earths discovered in close orbits around bright stars (V= 5 - 7 mag) with HARPS spectrograph:
  - *expect ~10 in next 2 years*

MOST may be able to measure the mean density of a terrestrial planet outside the Solar System

Internal and public data archives

- ongoing efforts to optimize groundbased software for handling MOST photometry
- internal archiving formats modified for consistency with reduction and processing software
- "secondary" target IDs now included in headers

- new formats established to anticipate when data released to MOST Public Data Archive
  - UBC software consultant Andrew Walker (Sumus Technology Ltd.)
  - Heather King, undergrad student assistant (UBC ground station operations, data archiving, MOST web site management)


Did I leave
any time for
questions?
www.astro.ubc.ca/MOST

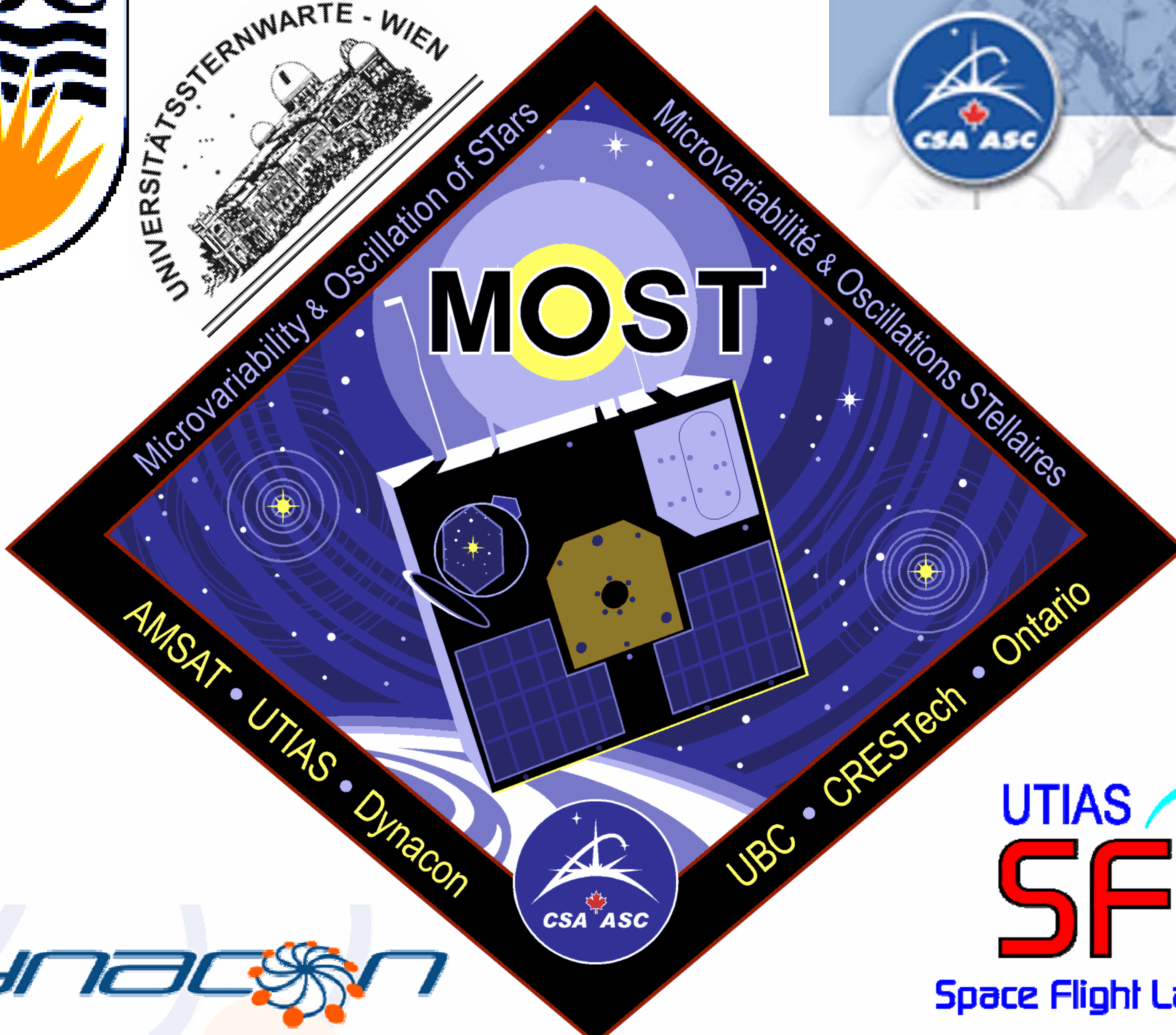
UBC

UNIVERSITÄTSSTERNWARTE - WIEN

Agence spatiale canadienne

Canadian Space Agency

CSA ASC



dynacon

UTIAS SFL

Space Flight Laboratory

The bad news for you:

This part of the talk will be boring

The good news for Glieseans:

This part of the talk will be boring

UFO sightings increase near concerts and honky-tonks!

SPACE ALIENS LOVE COUNTRY MUSIC

VISITORS from other planets may be attracted to the particular vibrations of Western melodies.

sightings had in common with one another," says the 34-year-old researcher. "We didn't know exactly what we were looking for.

"We fed information into our computer from over 700 reports of alien activity over the last 15 years — everything from what time of day the sighting occurred to what color clothes the witnesses were wearing.

"We even logged in what thoughts the people were thinking just before they encountered the aliens.

"The only factor that came up with regularity was country music."

Amazingly, Dr. Simms'

most country and Western songs," says Lebow. "They have a certain 'feel' or 'vibration' that no other kind of music on earth has.

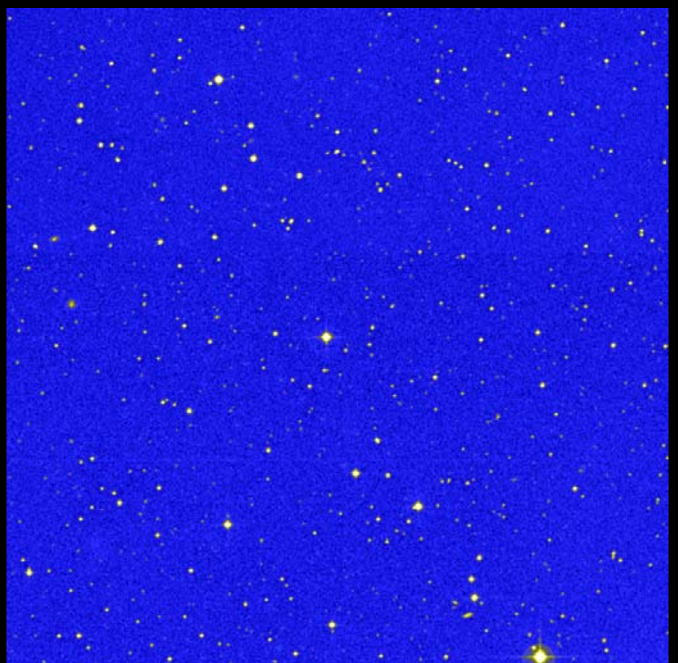
"It could be that these creatures are somehow attuned to that particular vibration — that they're drawn to it as moths are drawn to bright light."

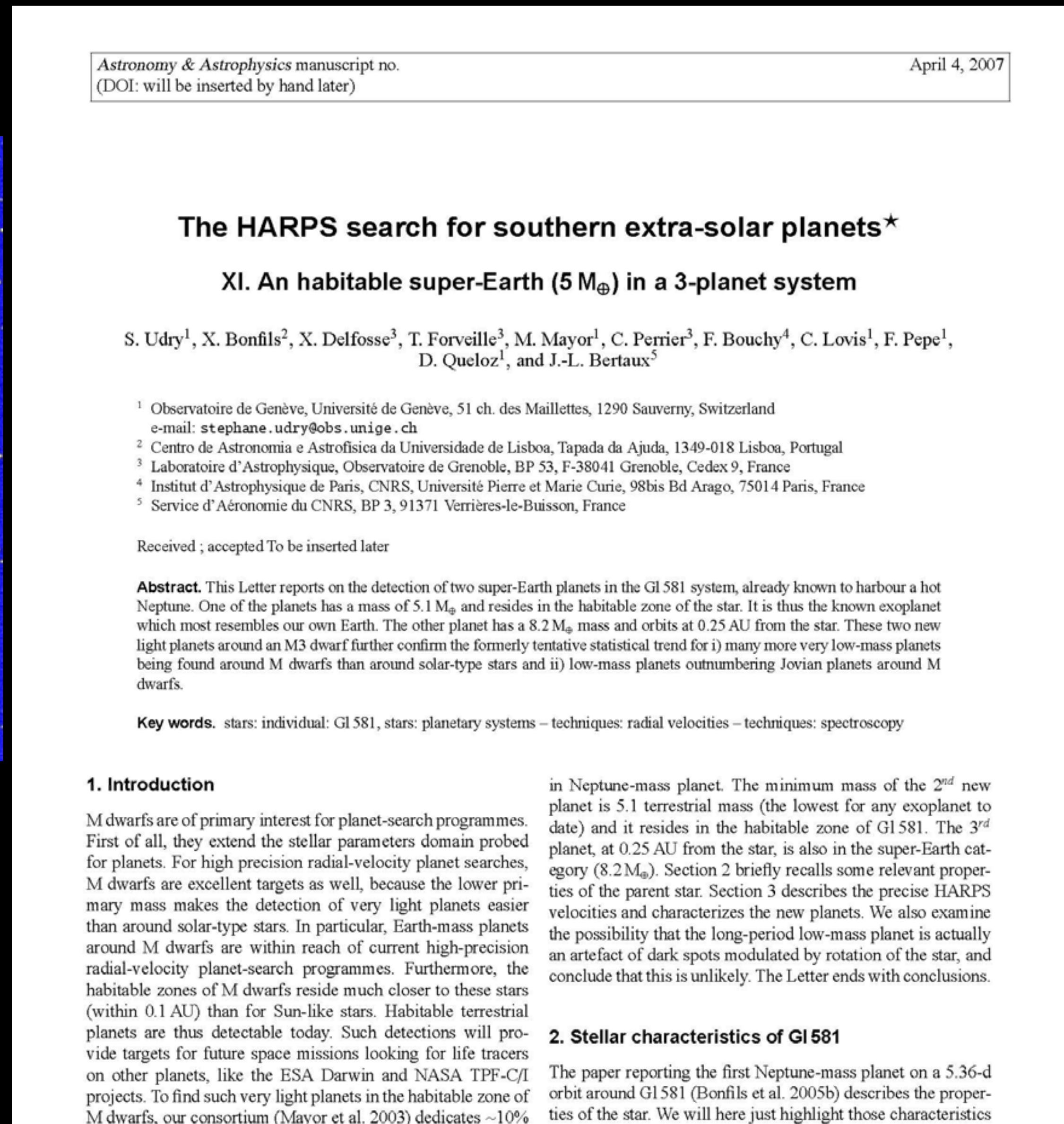
How to attract space aliens to your own backyard! Turn to Pages 24-25.

Possible Gliesean sightings

Habitable exoplanets?

Gliese 581





Astronomy & Astrophysics manuscript no.
(DOI: will be inserted by hand later)

April 4, 2007

The HARPS search for southern extra-solar planets★

XI. An habitable super-Earth (5 $M_\oplus$) in a 3-planet system

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2 Centro de Astronomia e Astrofísica da Universidade de Lisboa, Tapada da Ajuda, 1349-018 Lisboa, Portugal
3 Laboratoire d'Astrophysique, Observatoire de Grenoble, BP 53, F-38041 Grenoble, Cedex 9, France
4 Institut d'Astrophysique de Paris, CNRS, Université Pierre et Marie Curie, 98bis Bd Arago, 75014 Paris, France
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Received ; accepted To be inserted later

Abstract. This Letter reports on the detection of two super-Earth planets in the Gl 581 system, already known to harbour a hot Neptune. One of the planets has a mass of 5.1 $M_\oplus$ and resides in the habitable zone of the star. It is thus the known exoplanet which most resembles our own Earth. The other planet has a 8.2 $M_\oplus$ mass and orbits at 0.25 AU from the star. These two new light planets around an M3 dwarf further confirm the formerly tentative statistical trend for i) many more very low-mass planets being found around M dwarfs than around solar-type stars and ii) low-mass planets outnumbering Jovian planets around M dwarfs.

Key words. stars: individual: Gl 581, stars: planetary systems – techniques: radial velocities – techniques: spectroscopy

1. Introduction

M dwarfs are of primary interest for planet-search programmes. First of all, they extend the stellar parameters domain probed for planets. For high precision radial-velocity planet searches, M dwarfs are excellent targets as well, because the lower primary mass makes the detection of very light planets easier than around solar-type stars. In particular, Earth-mass planets around M dwarfs are within reach of current high-precision radial-velocity planet-search programmes. Furthermore, the habitable zones of M dwarfs reside much closer to these stars (within 0.1 AU) than for Sun-like stars. Habitable terrestrial planets are thus detectable today. Such detections will provide targets for future space missions looking for life tracers on other planets, like the ESA Darwin and NASA TPF-C/I projects. To find such very light planets in the habitable zone of M dwarfs, our consortium (Mayor et al. 2003) dedicates ~10%

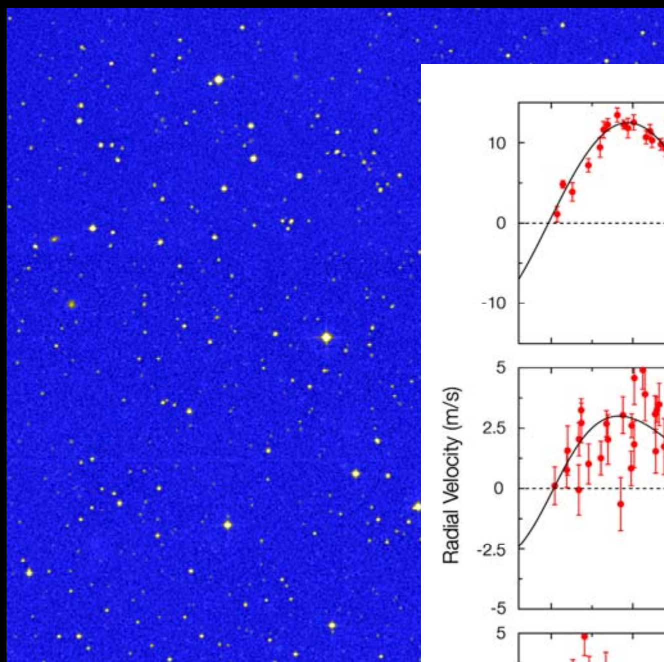
in Neptune-mass planet. The minimum mass of the 2nd new planet is 5.1 terrestrial mass (the lowest for any exoplanet to date) and it resides in the habitable zone of Gl 581. The 3rd planet, at 0.25 AU from the star, is also in the super-Earth category (8.2 $M_\oplus$). Section 2 briefly recalls some relevant properties of the parent star. Section 3 describes the precise HARPS velocities and characterizes the new planets. We also examine the possibility that the long-period low-mass planet is actually an artefact of dark spots modulated by rotation of the star, and conclude that this is unlikely. The Letter ends with conclusions.

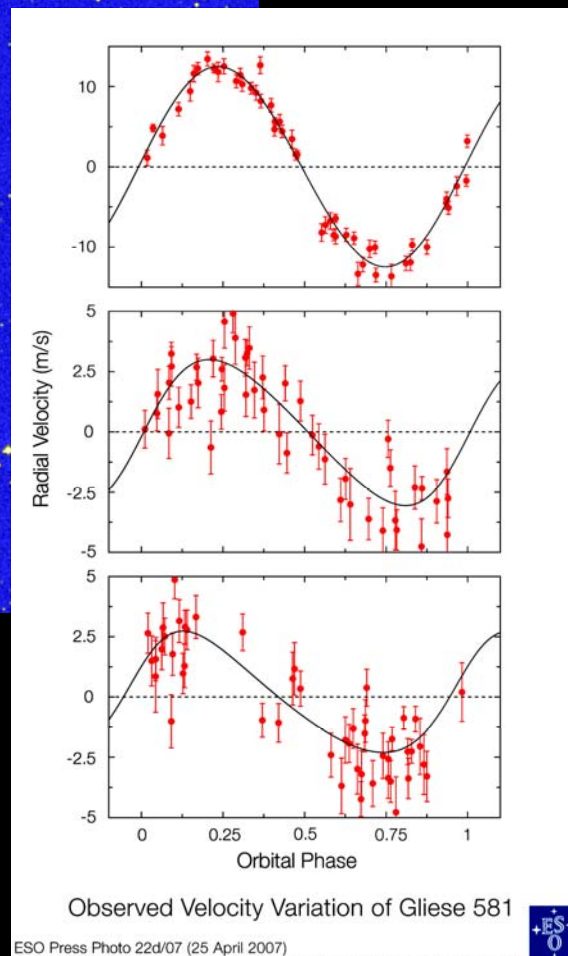
2. Stellar characteristics of Gl 581

The paper reporting the first Neptune-mass planet on a 5.36-d orbit around Gl 581 (Bonfils et al. 2005b) describes the properties of the star. We will here just highlight those characteristics

Habitable exoplanets?

Gliese 581 system





HARPS data

Udry et al. 2007

3 planets around
an M dwarf

Habitable exoplanets?

Gliese 581 system

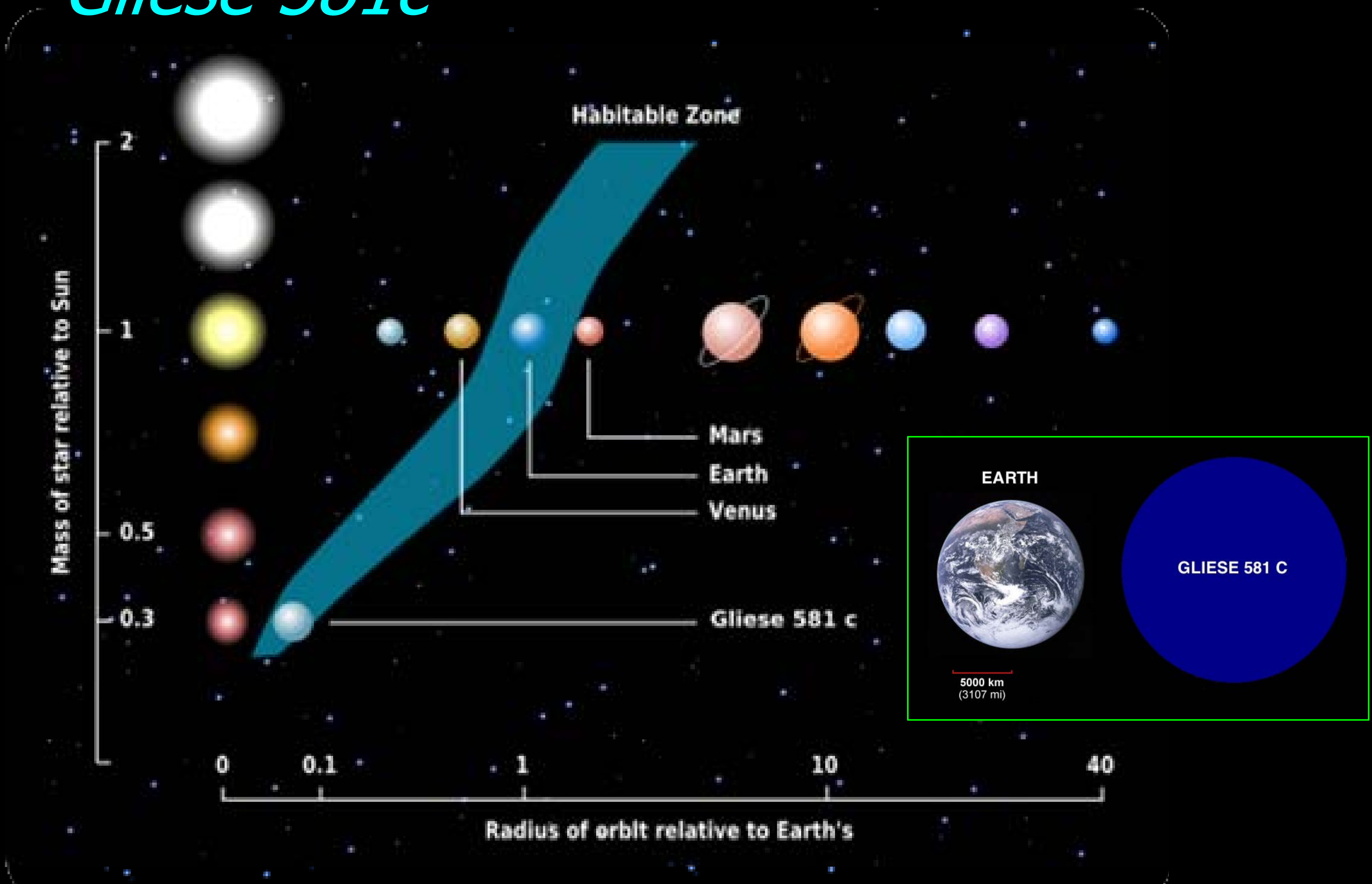
star

Gliese 581a M3V (V ~ 10.5) $L = 0.013 \pm 0.002\ L_\odot$

exoplanets	P (d)	a (AU)	(M sin i) / M_{Earth}
Gliese 581b	5.36	0.041	15.7
Gliese 581c	12.91	0.073	5.1
Gliese 581d	84.4	0.25	8.2

Habitable exoplanets?

Gliese 581c

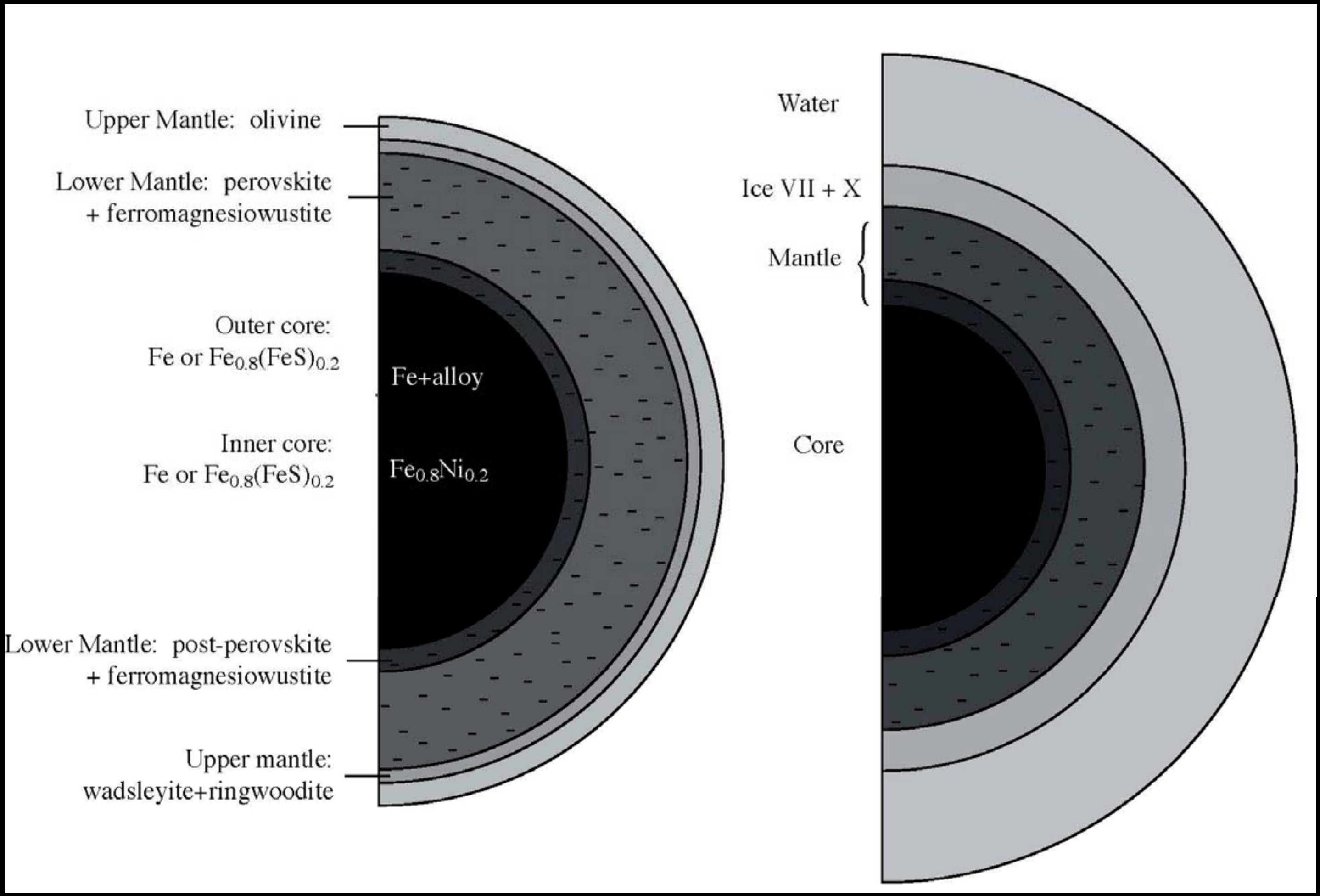


Habitable exoplanets?

Gliese 581c:
Super-Earth

Habitable exoplanets?

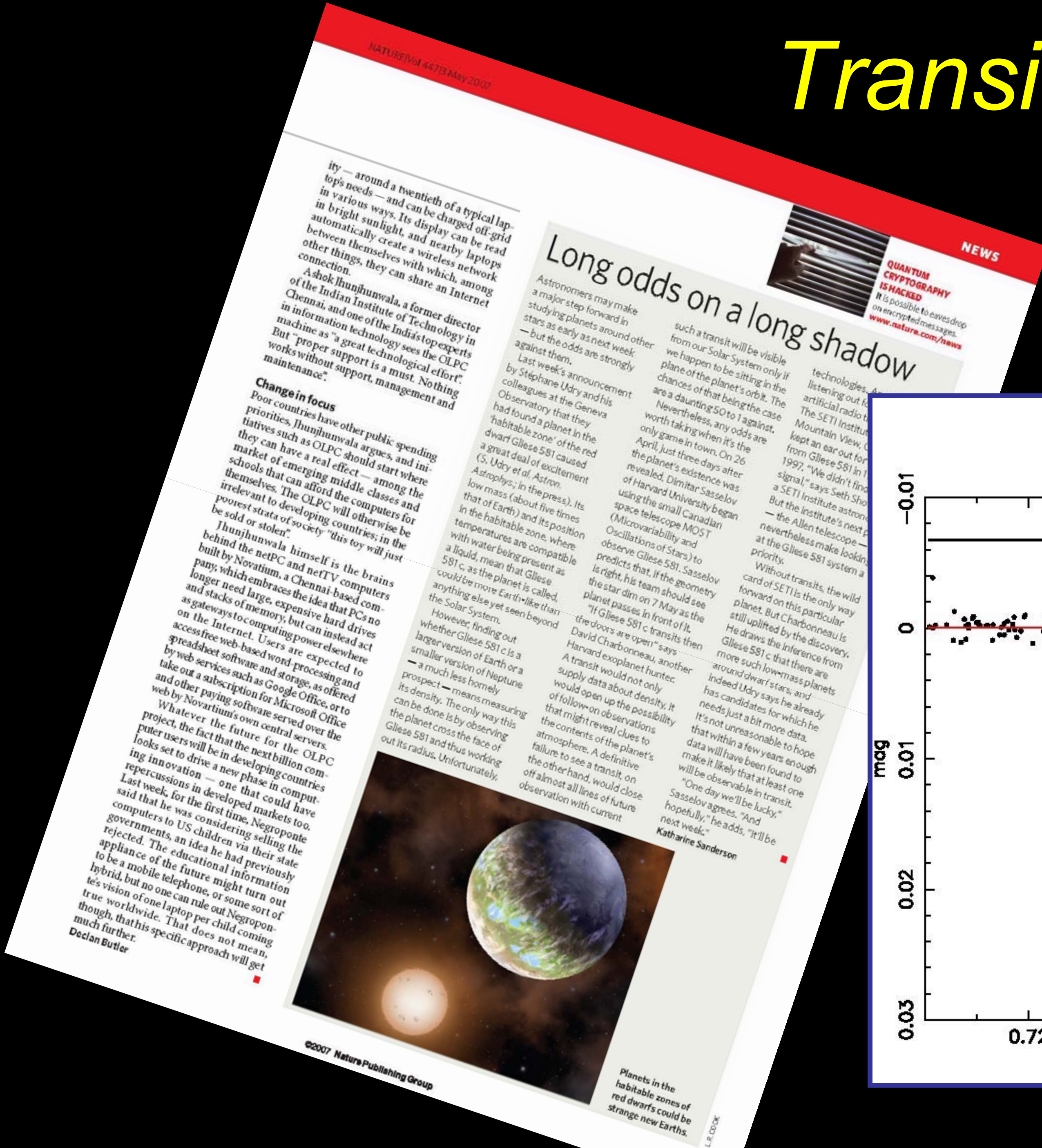
Super-Earths



Earth-like **Ocean Planet**

Valencia, Sasselov, O'Connell (2006)

Transit search



ity — around a twentieth of a typical laptop's needs — and can be charged off-grid in various ways. Its display can be read in bright sunlight, and nearby laptops automatically create a wireless network between themselves with which, among other things, they can share an Internet connection.

Ashok Jhunjhunwala, a former director of the Indian Institute of Technology in Chennai, and one of the India's top experts in information technology sees the OLPC machine as "a great technological effort". But "proper support is a must. Nothing works without support, management and maintenance".

Change in focus

Poor countries have other public spending priorities, Jhunjhunwala argues, and initiatives such as OLPC should start where they can have a real effect — among the market of emerging middle classes and schools that can afford the computers for themselves. The OLPC will otherwise be irrelevant to developing countries; in the poorest strata of society "this toy will just be sold or stolen".

Jhunjhunwala himself is the brains behind the netPC and netTV computers built by Novatium, a Chennai-based company, which embraces the idea that PCs no longer need large, expensive hard drives and stacks of memory, but can instead act as gateways to computing power elsewhere on the Internet. Users are expected to access free web-based word-processing and spreadsheet software and storage, as offered by web services such as Google Office, or to take out a subscription for Microsoft Office and other paying software served over the web by Novatium's own central servers.

Whatever the future for the OLPC project, the fact that the next billion computer users will be in developing countries looks set to drive a new phase in computing innovation — one that could have repercussions in developed markets too.

Last week, for the first time, Negroponte said that he was considering selling the computers to US children via their state governments, an idea he had previously rejected. The educational information appliance of the future might turn out to be a mobile telephone, or some sort of hybrid, but no one can rule out Negroponte's vision of one laptop per child coming true worldwide. That does not mean, though, that this specific approach will get much further.

Declan Butler

QUANTUM CRYPTOGRAPHY IS HACKED
It is possible to eavesdrop on encrypted messages.
www.nature.com/news

Long odds on a long shadow

Astronomers may make a major step forward in studying planets around other stars as early as next week — but the odds are strongly against them.

Last week's announcement by Stéphane Udry and his colleagues at the Geneva Observatory that they had found a planet in the 'habitable zone' of the red dwarf Gliese 581 caused a great deal of excitement (S. Udry et al. Astron. Astrophys.; in the press). Its low mass (about five times that of Earth) and its position in the habitable zone, where temperatures are compatible with water being present as a liquid, mean that Gliese 581 c, as the planet is called, could be more Earth-like than anything else yet seen beyond the Solar System.

However, finding out whether Gliese 581 c is a larger version of Earth or a smaller version of Neptune — a much less homely prospect — means measuring its density. The only way this can be done is by observing the planet cross the face of Gliese 581 and thus working out its radius. Unfortunately, such a transit will be visible from our Solar System only if we happen to be sitting in the plane of the planet's orbit. The chances of that being the case are a daunting 50 to 1 against.

Nevertheless, any odds are worth taking when it's the only game in town. On 26 April, just three days after the planet's existence was revealed, Dimitar Sasselov of Harvard University began using the small Canadian space telescope MOST (Microvariability and Oscillations of Stars) to observe Gliese 581. Sasselov predicts that, if the geometry is right, his team should see the star dim on 7 May as the planet passes in front of it.

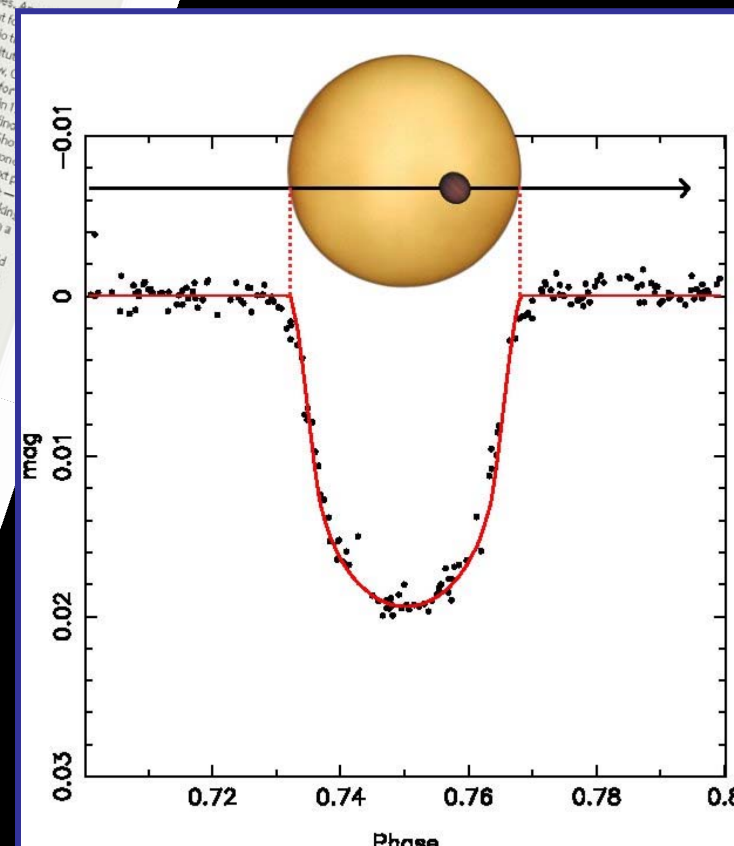
"If Gliese 581 c transits then the doors are open" says David Charbonneau, another Harvard exoplanet hunter. A transit would not only supply data about density, it would open up the possibility of follow-on observations that might reveal clues to the contents of the planet's atmosphere. A definitive failure to see a transit, on the other hand, would close off almost all lines of future observation with current technologies. A... listening out fo... artificial radio t... The SETI Institut... Mountain View, C... kept an ear out for... from Gliese 581 in 1... 1997. "We didn't fin... signal," says Seth Sho... a SETI Institute astron... But the institute's next p... — the Allen telescope — ... nevertheless make looking at the Gliese 581 system a priority.

Without transits, the wild card of SETI is the only way forward on this particular planet. But Charbonneau is still uplifted by the discovery. He draws the inference from Gliese 581 c that there are more such low-mass planets around dwarf stars, and indeed Udry says he already has candidates for which he needs just a bit more data. It's not unreasonable to hope that within a few years enough data will have been found to make it likely that at least one will be observable in transit.

"One day we'll be lucky," Sasselov agrees. "And hopefully," he adds, "it'll be next week."

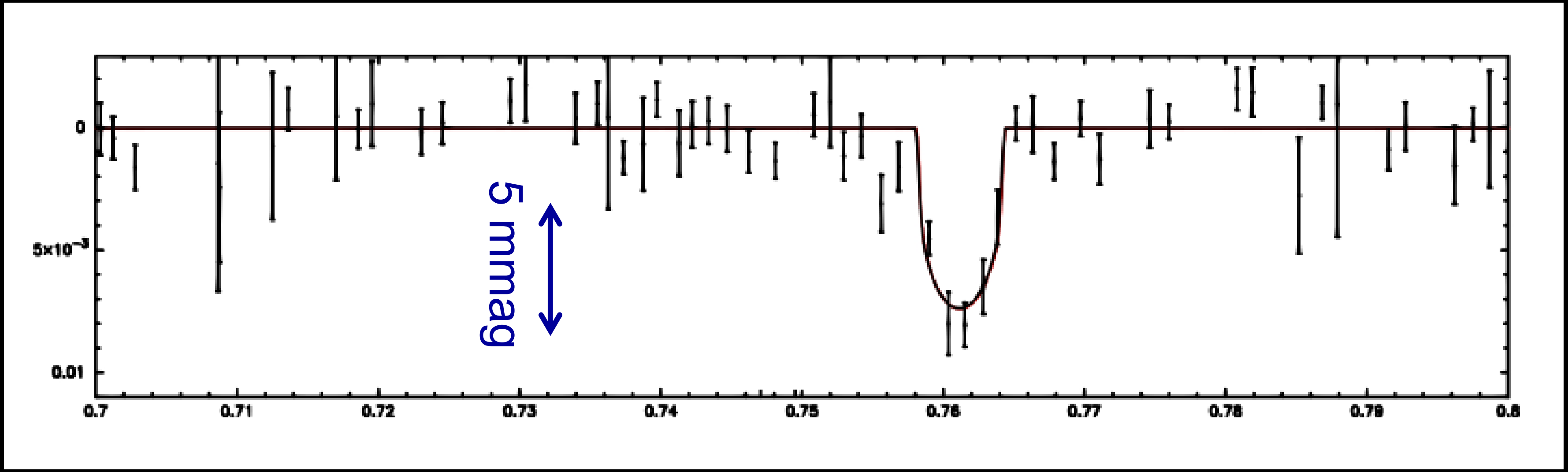
Katharine Sanderson

Planets in the habitable zones of red dwarfs could be strange new Earths.



Transit search

$2.2\ R_{Earth}$

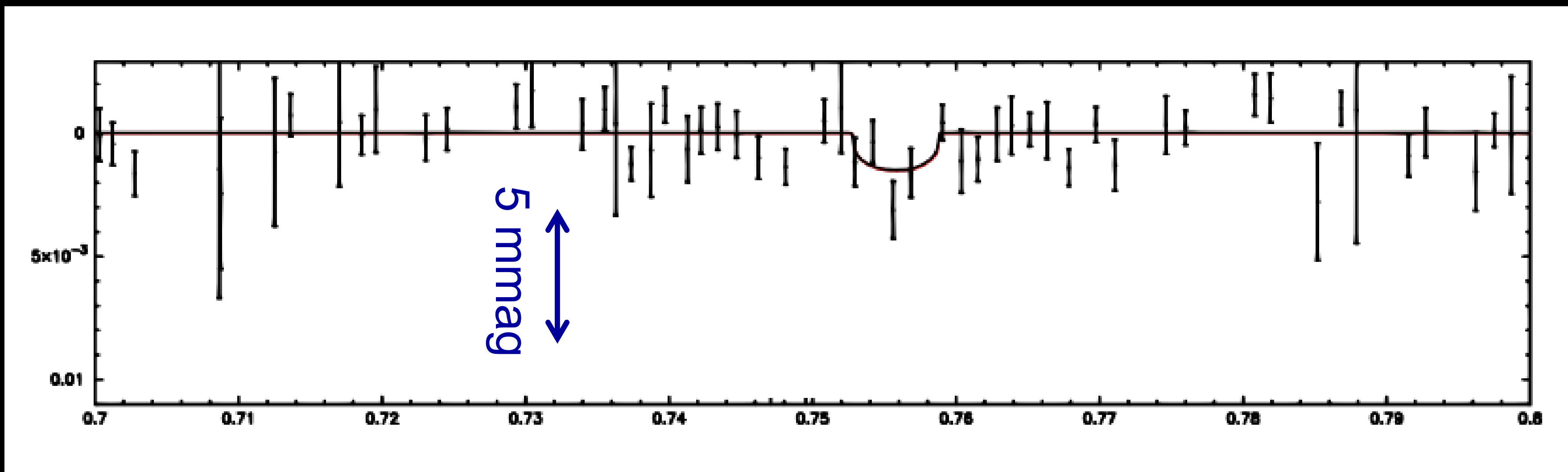


0.7 Phase 0.8

30 hrs

Transit search

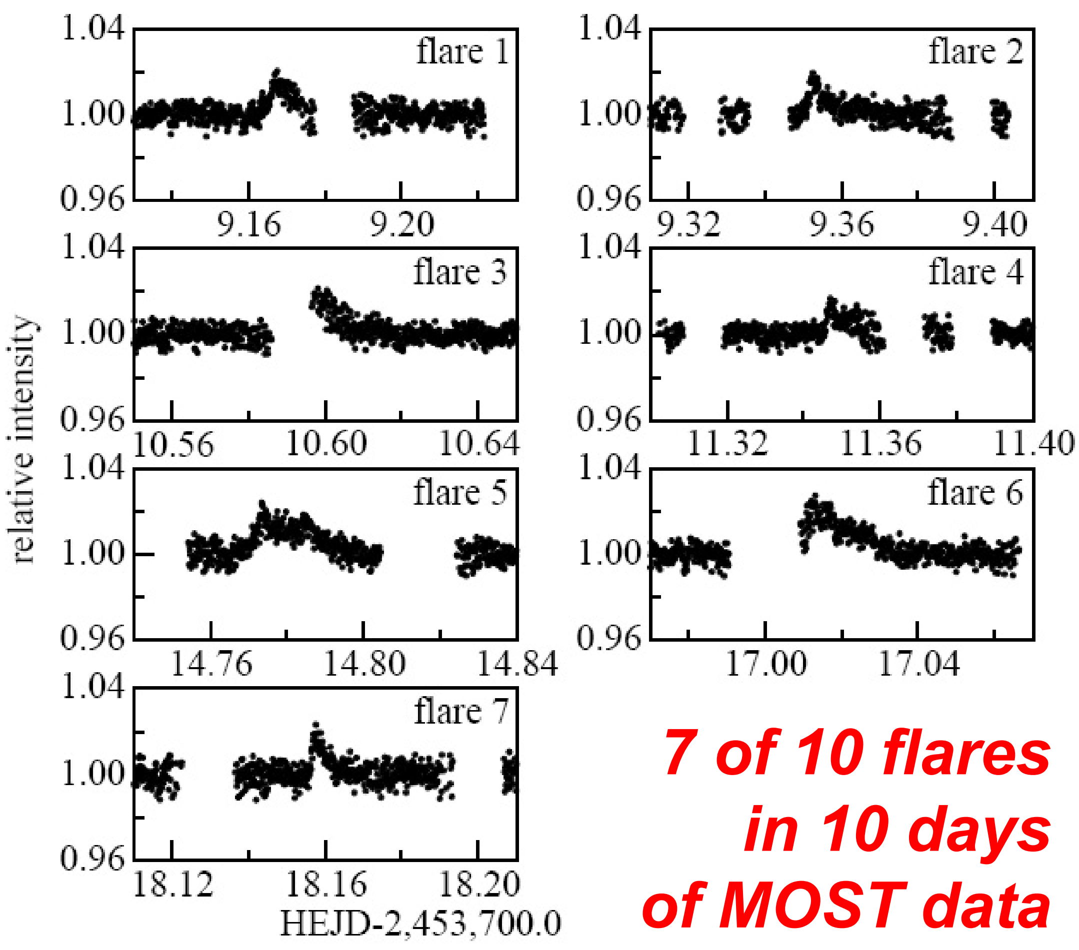
1.1 R_{Earth}



0.7 Phase 0.8

30 hrs

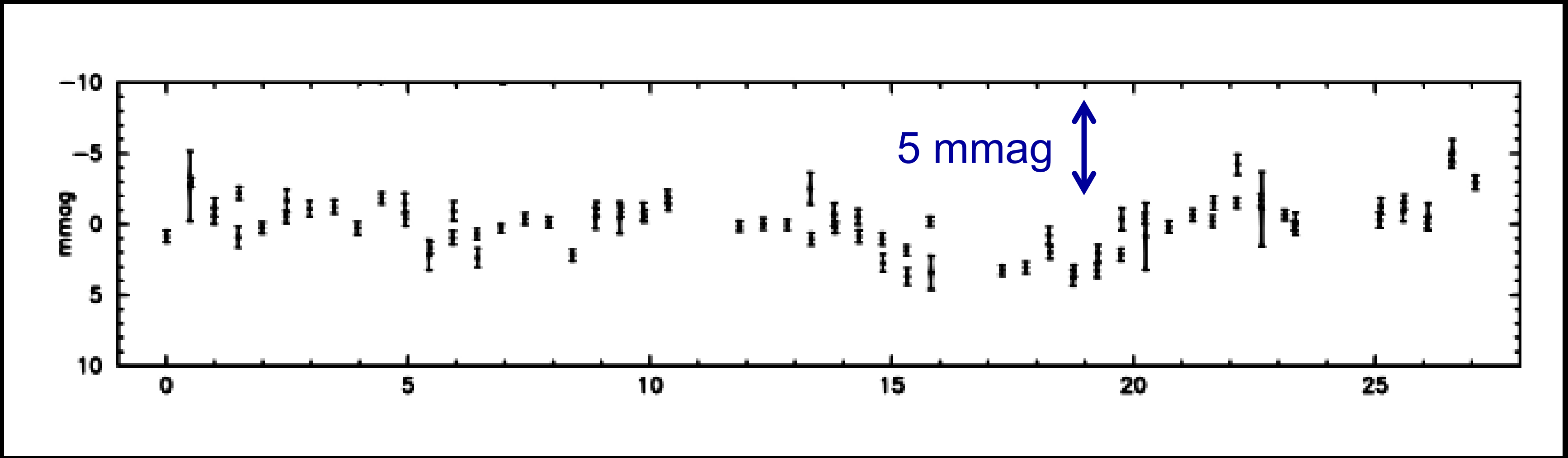
V471 Tau: An unboring M star



7 of 10 flares in 10 days of MOST data

Kaminski, Rucinski et al. 2007

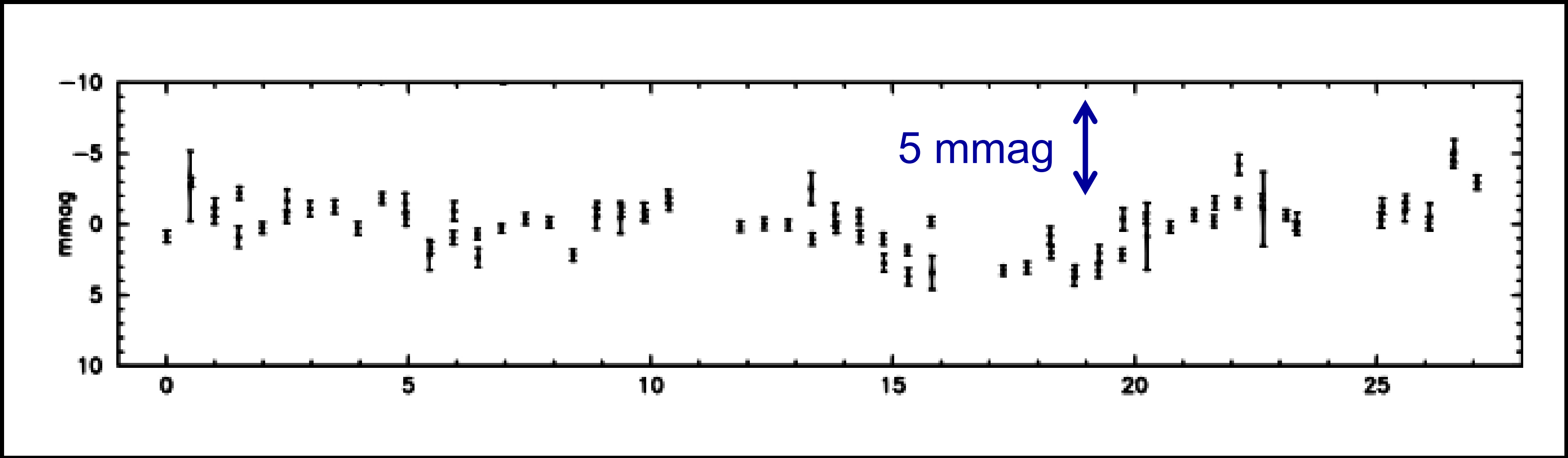
Gliese 581a: A boring M star



Matthews, Rowe, Sasselov et al. 2007, in prep.

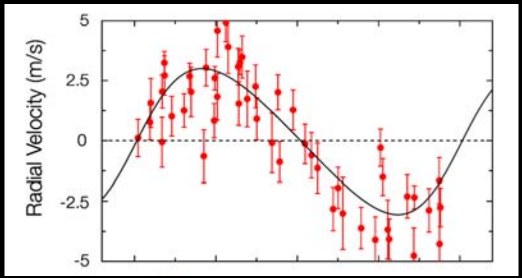
✓ *peak-to-peak variability over 6 weeks < 5 mmag*

Gliese 581a: A boring M star

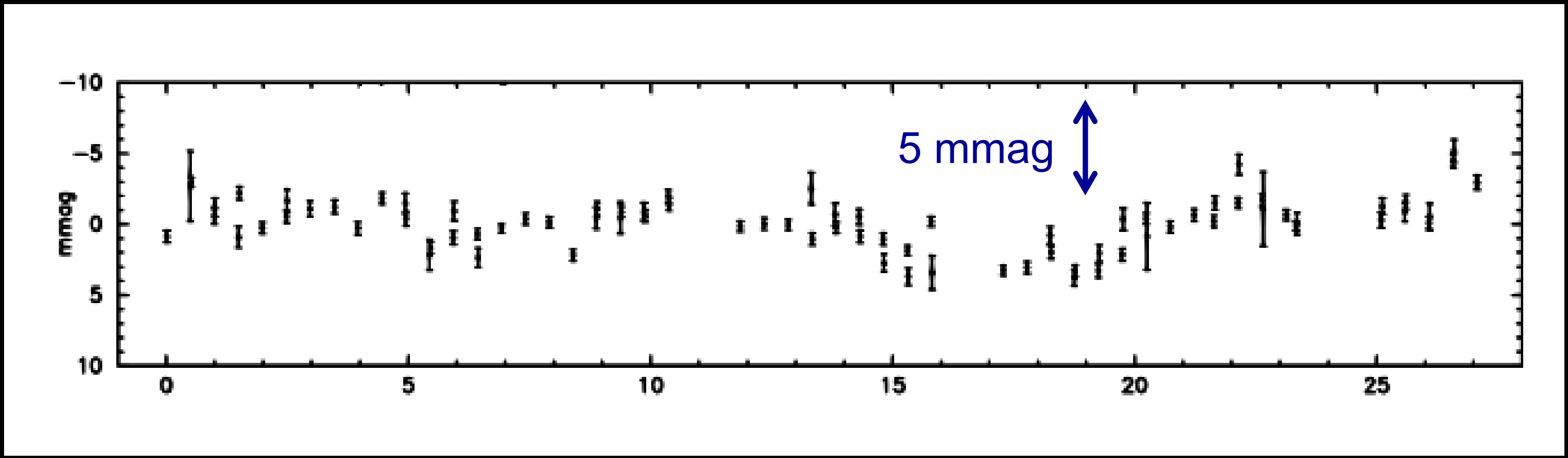


Matthews, Rowe, Sasselov et al. 2007, in prep.

- ✓ *peak-to-peak variability over 6 weeks < 5 mmag*
- ✓ *no coherent variations in phase with 12.9-d period*
  - ➢ *RV signal not due to rotational modulation due to spots or granulation patches*



Gliese 581a: A boring M star



Matthews, Rowe, Sasselov et al. 2007, in prep.

- ✓ *peak-to-peak variability over 6 weeks < 5 mmag*
- ✓ *no coherent variations in phase with 12.9-d period*
  - ➢ *RV signal not due to rotational modulation due to spots or granulation patches*

- ✓ *old star, probably age > 3 Gyr*


Did I leave time for any questions?
www.astro.ubc.ca/MOST