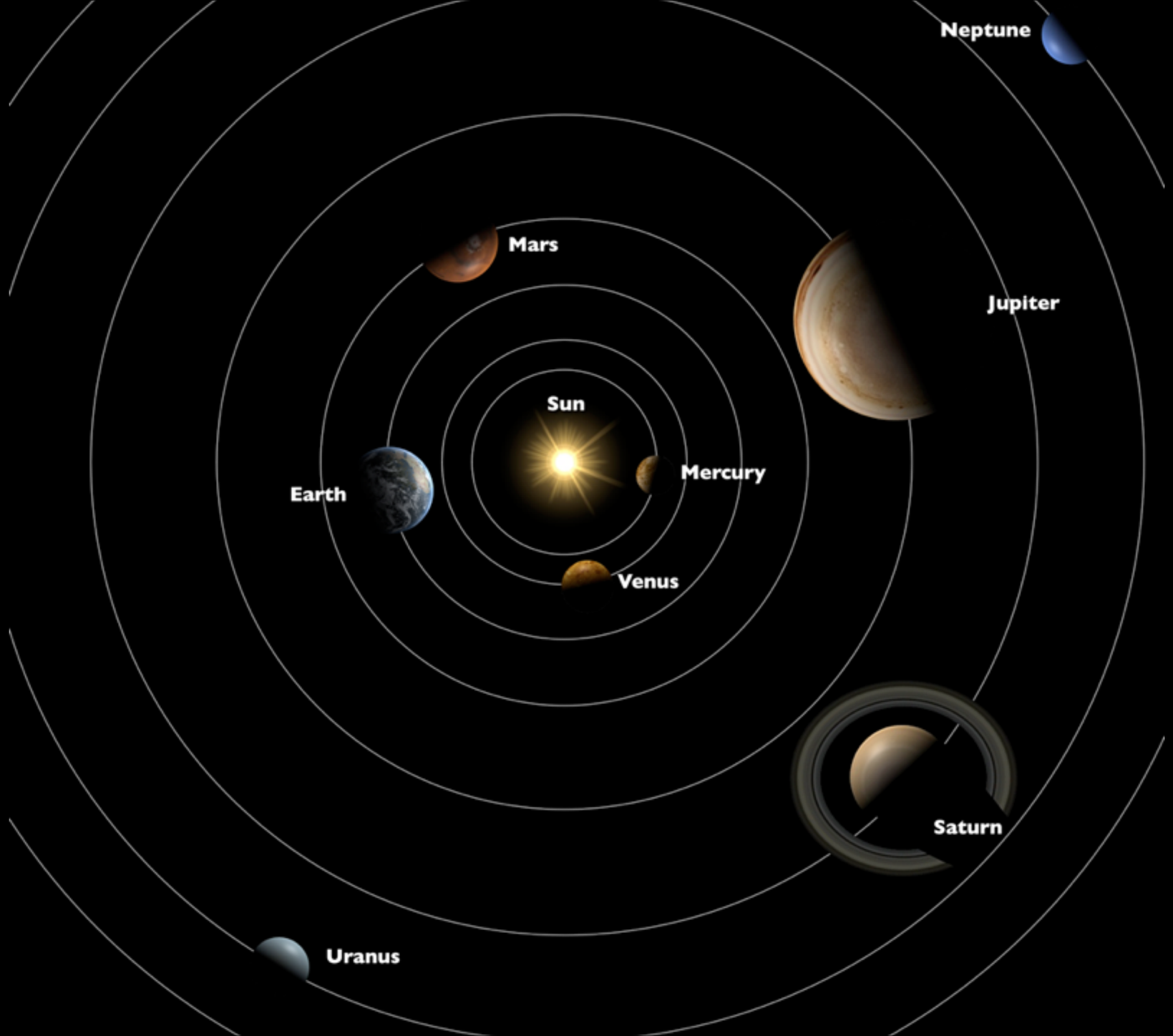
Winks, Blips and Wobbles

Extra-solar planets and how to find them

Dr Edward Gomez & Dr Haley Gomez
Cardiff University & Las Cumbres Observatory

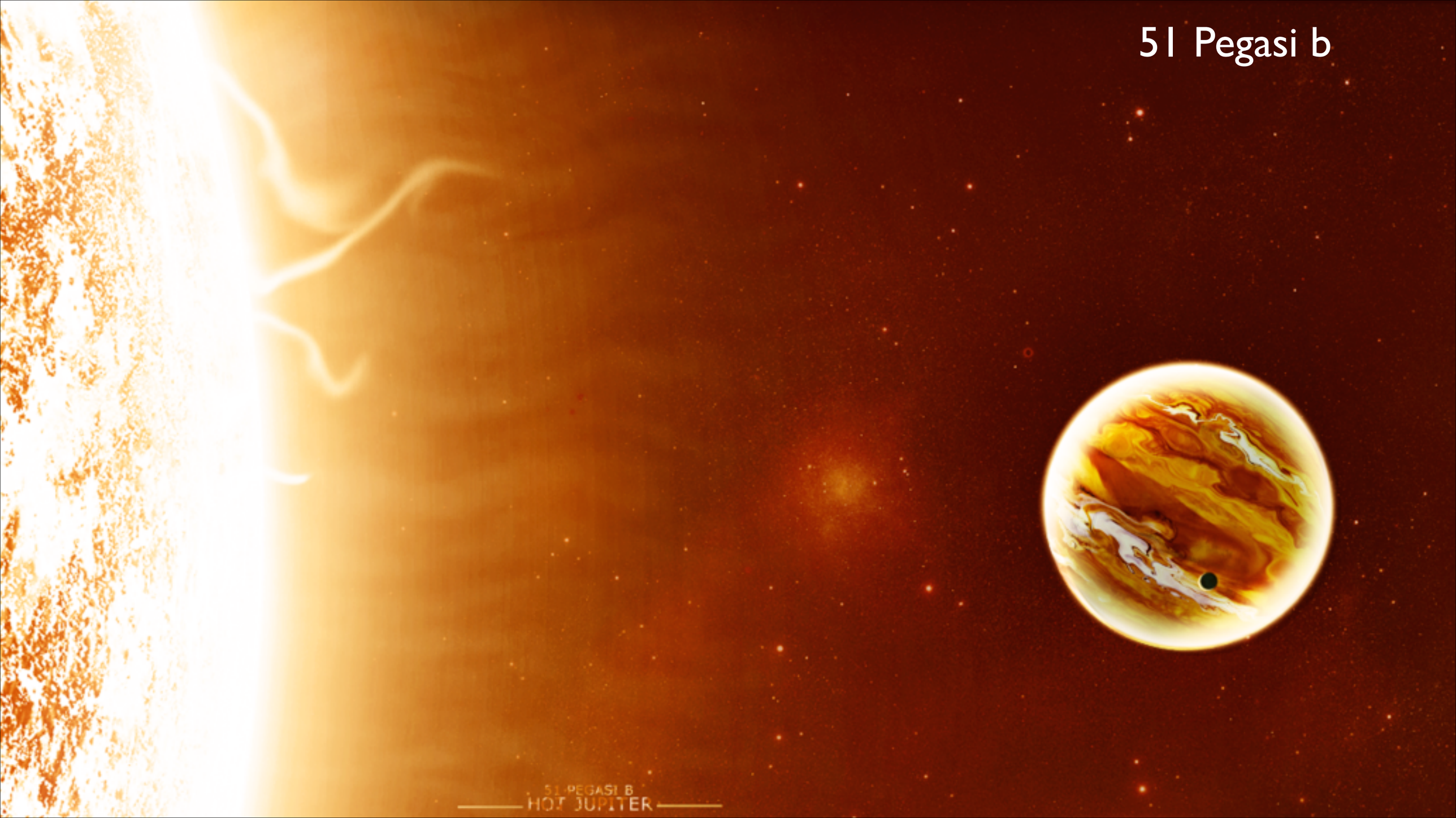
What?


Neptune
Mars
Jupiter
Sun
Mercury
Earth
Venus
Saturn
Uranus

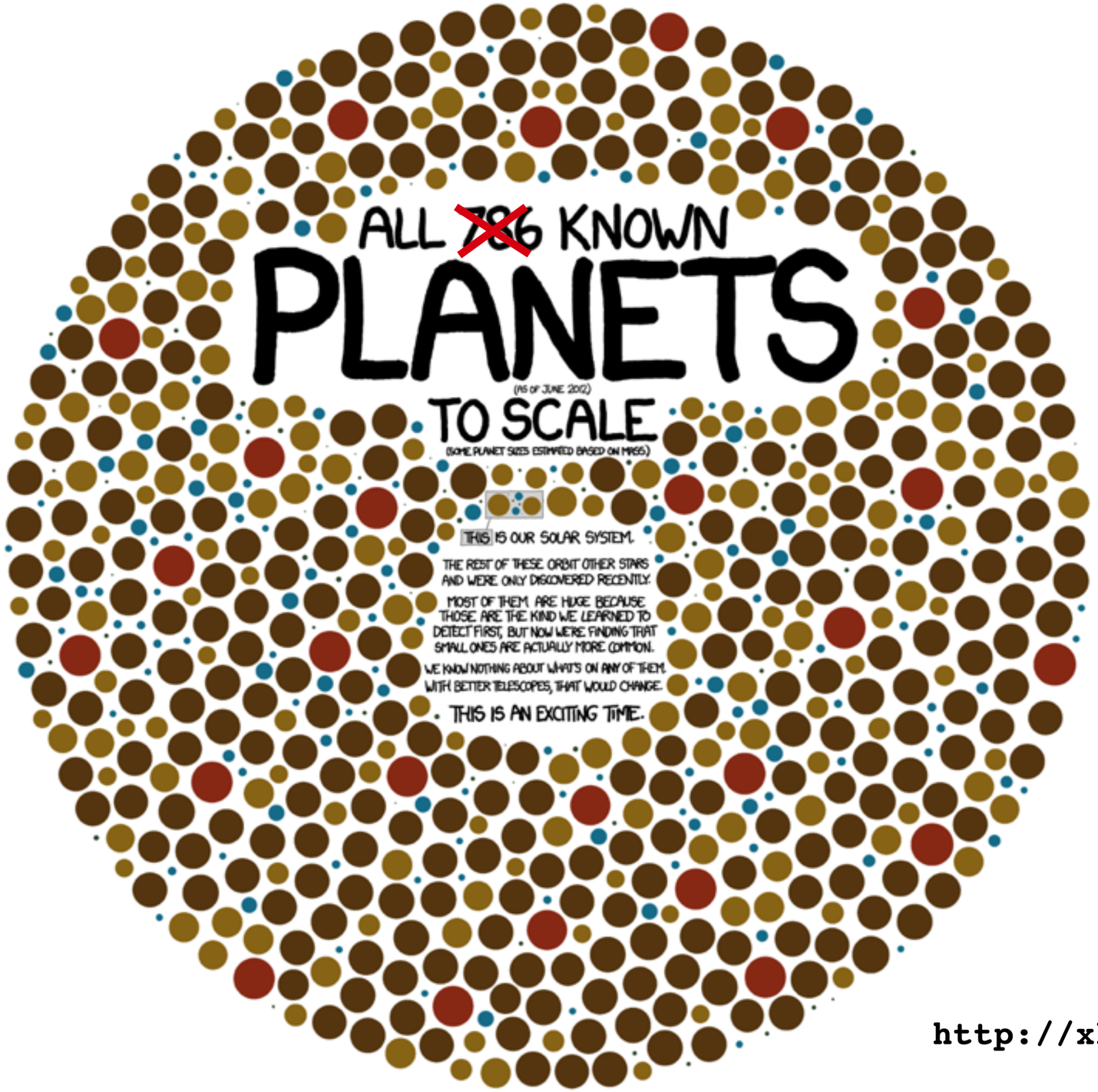
Milky Way Over Crater Lake with Airglow - John H. Moore - APOD

Pulsar PSR B1257+12
Wolszczan & Frail
NASA/JPL-Caltech/R. Hurt (SSC)

51 Pegasi b

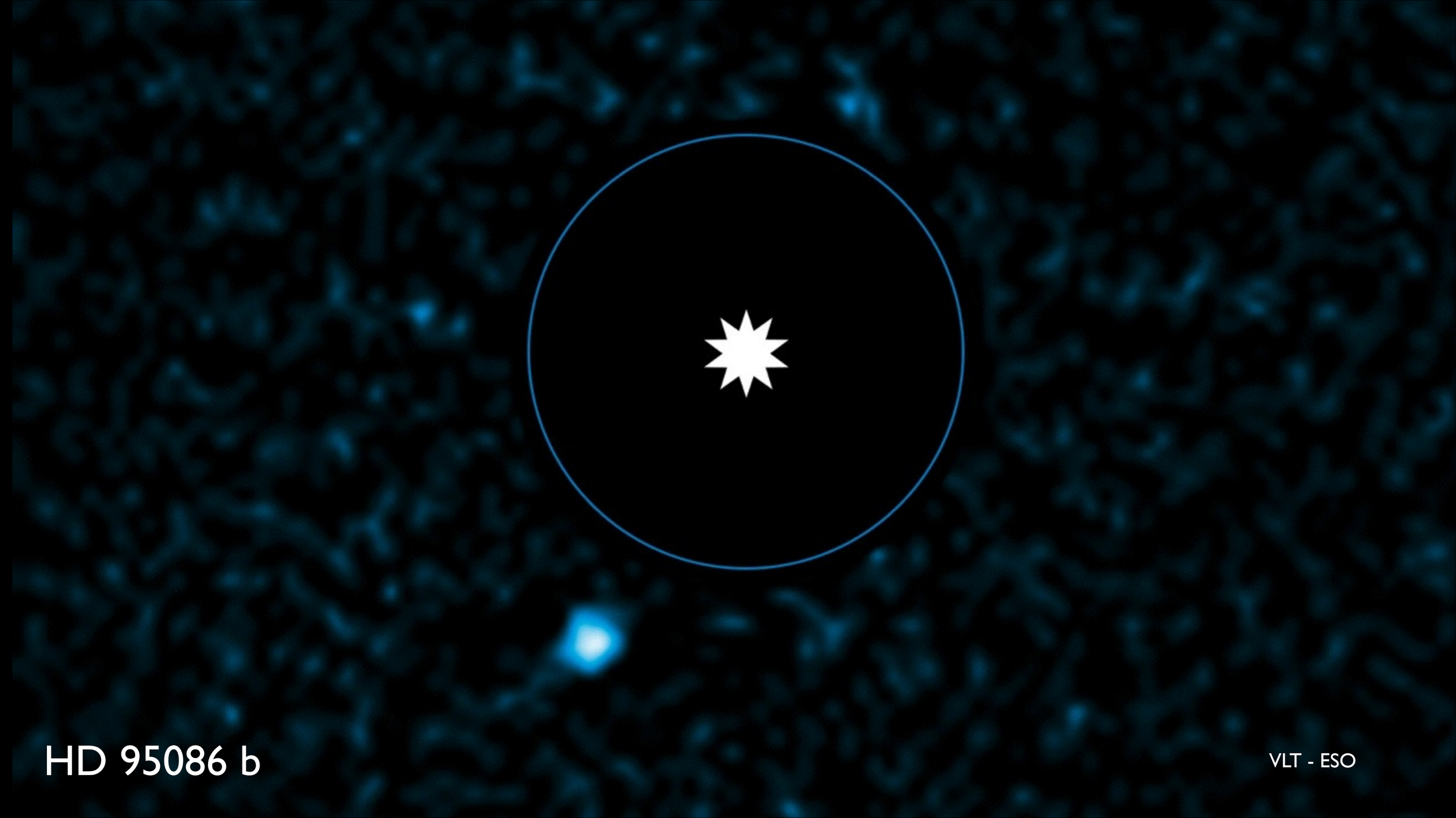


Now 1050!

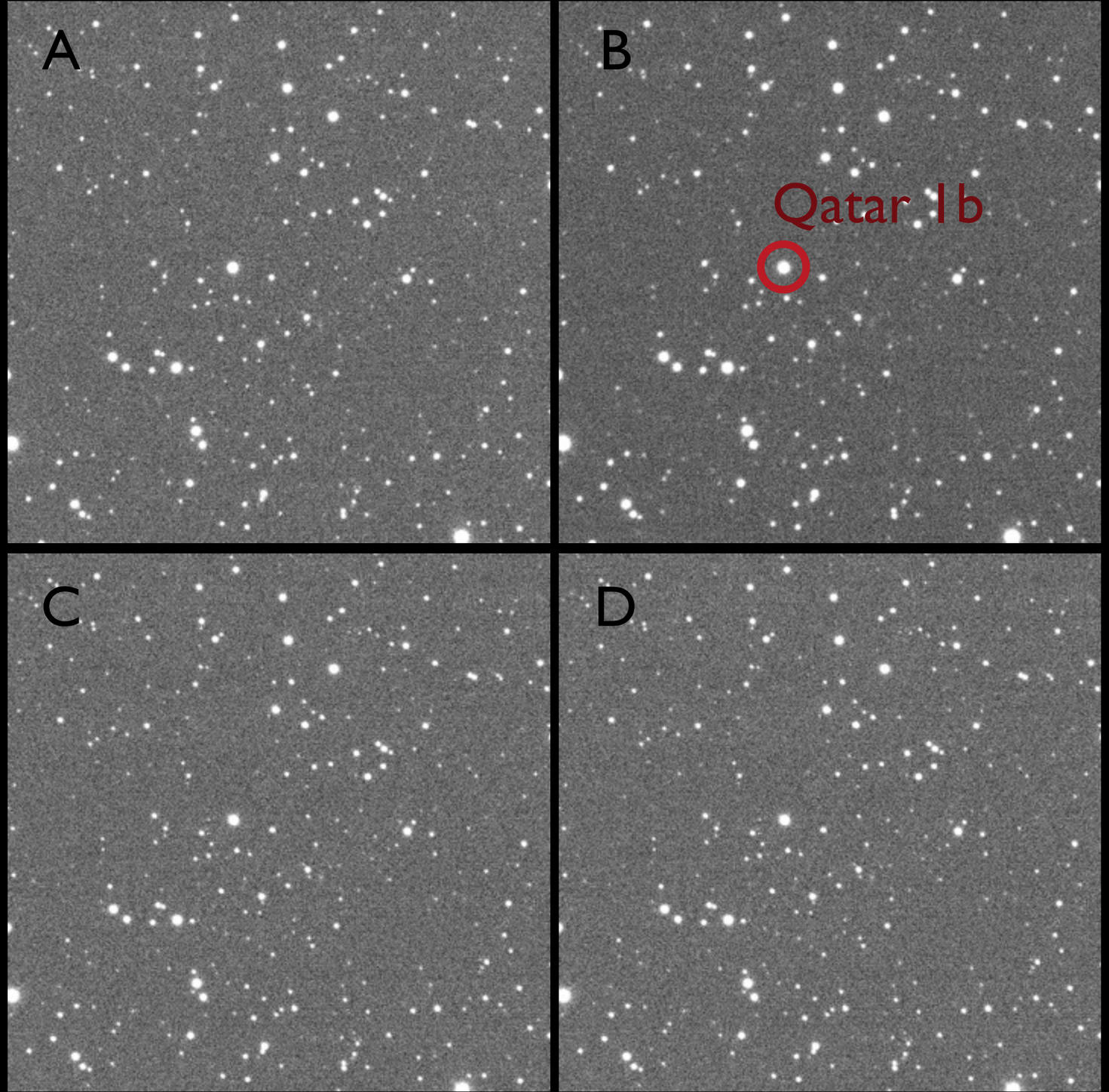


http://xkcd.com/1071/

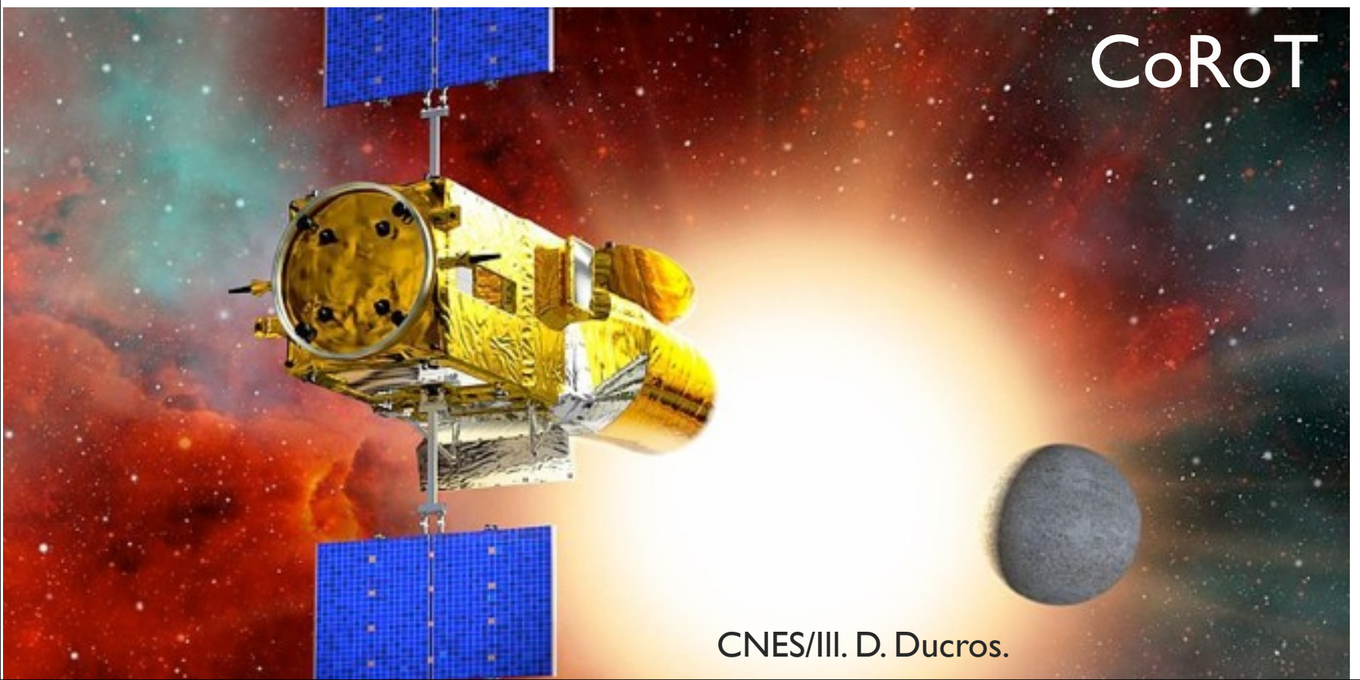
How?

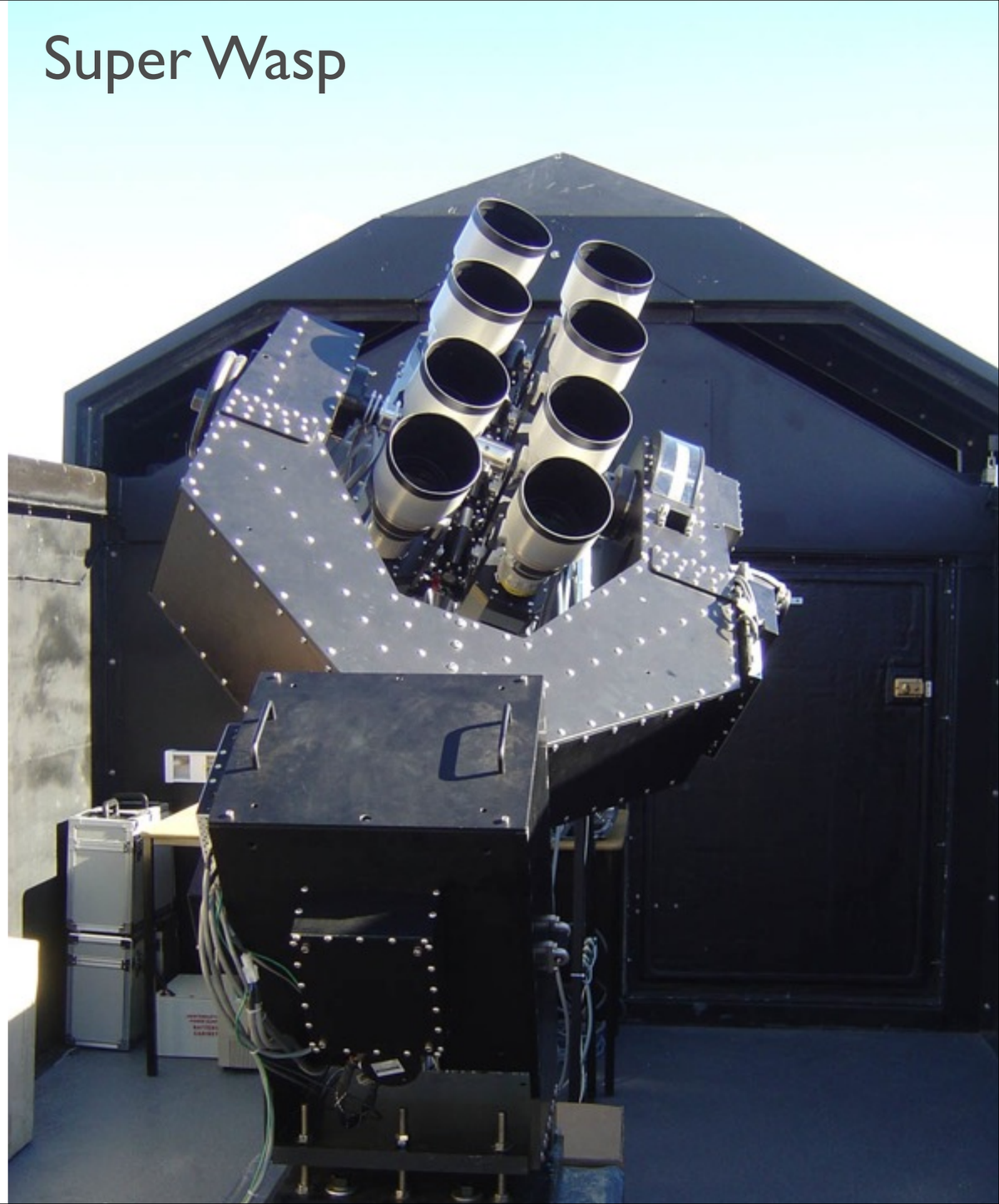

HD 95086 b
VLT - ESO

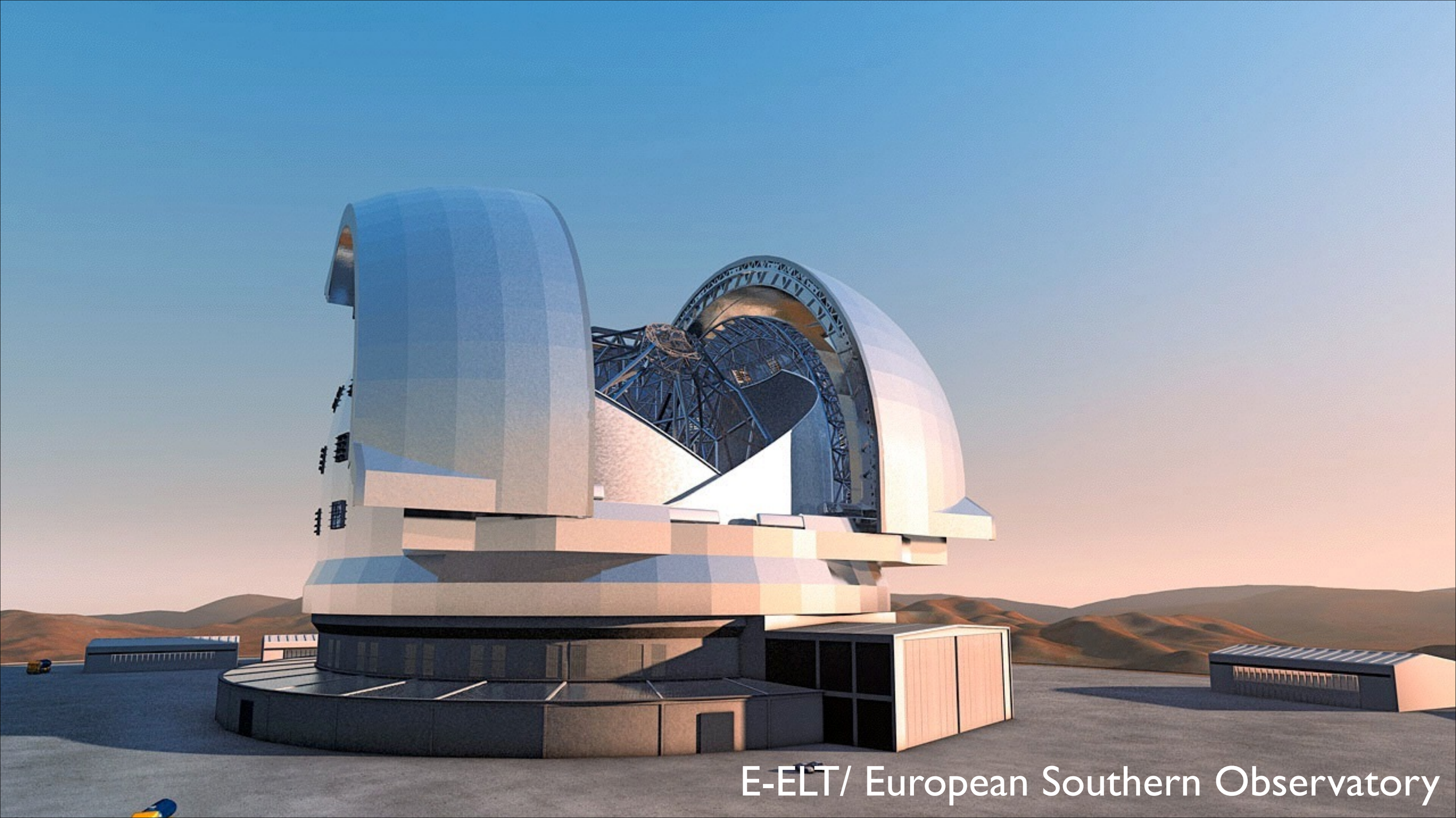
Can you find the exoplanet?



NASA/Ames/JPL-Caltech
Kepler


CoRoT
CNES/Ill. D. Ducros.

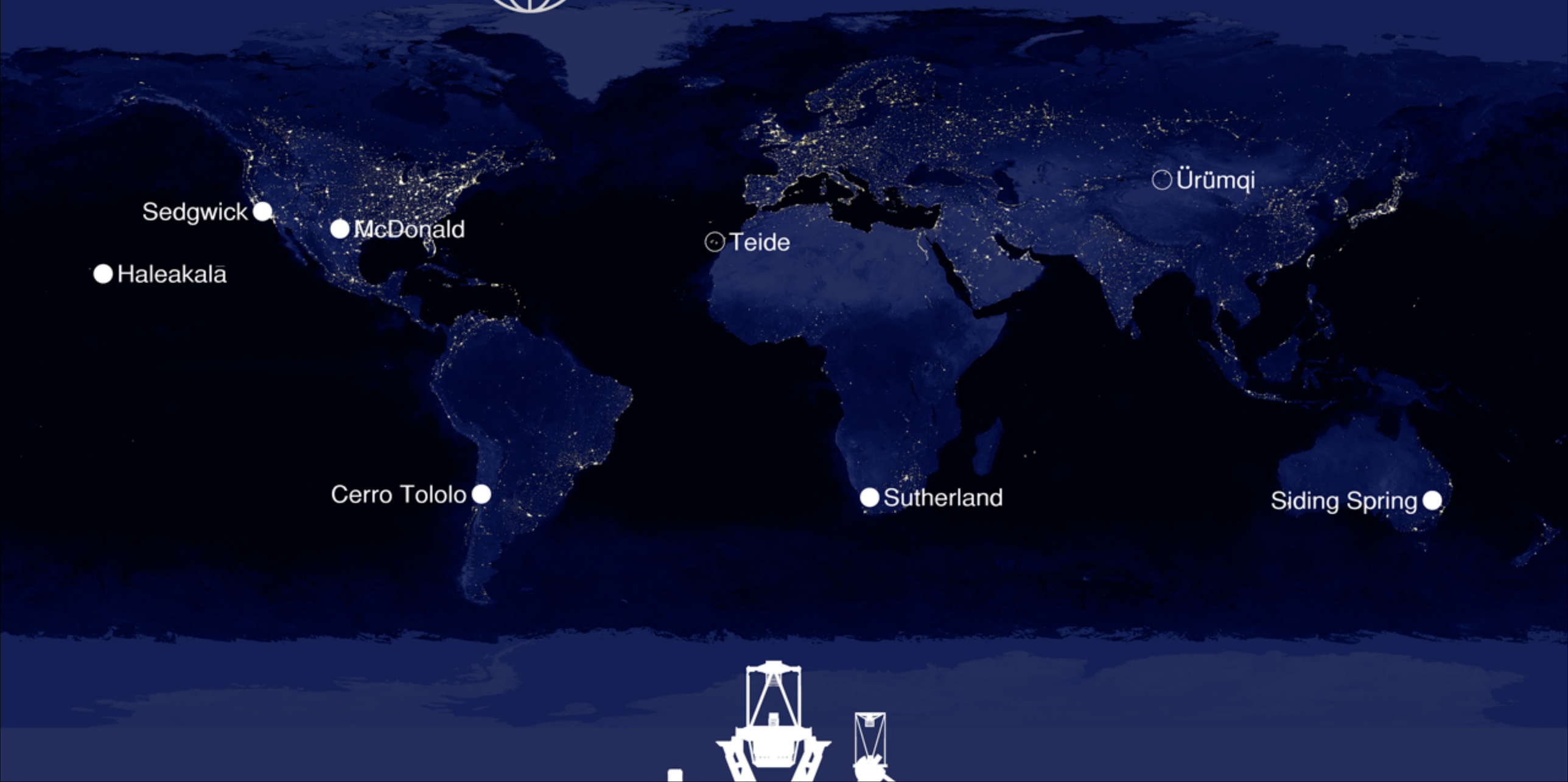

Super Wasp


E-ELT/ European Southern Observatory

DANGER

Las Cumbres Observatory

Global Telescope Network



How do we find them?

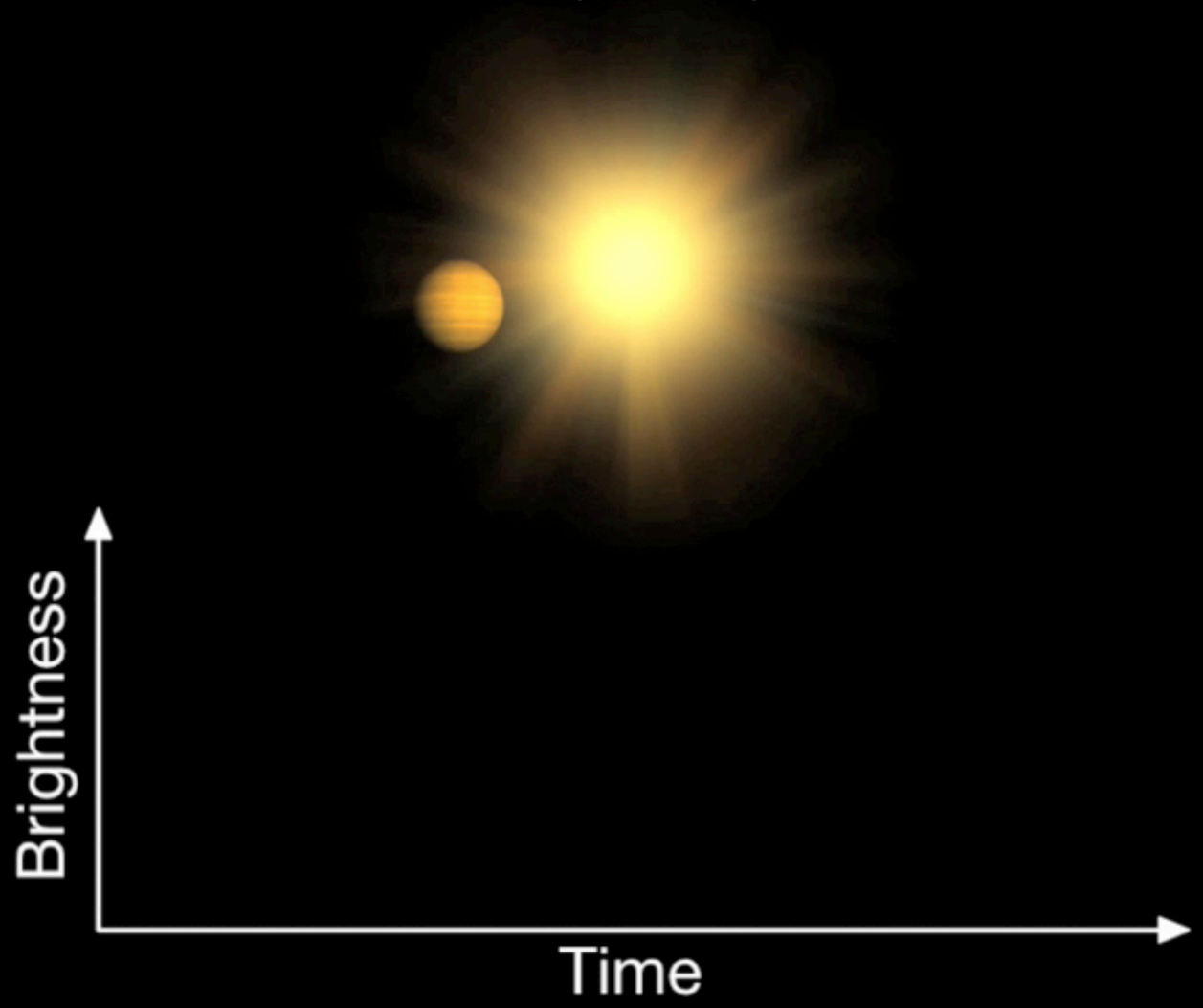
- Wink — Transit method
- Blip — Microlensing method
- Wobble — Radial velocity method

Transit method

(winks)

Transit method

(winks)



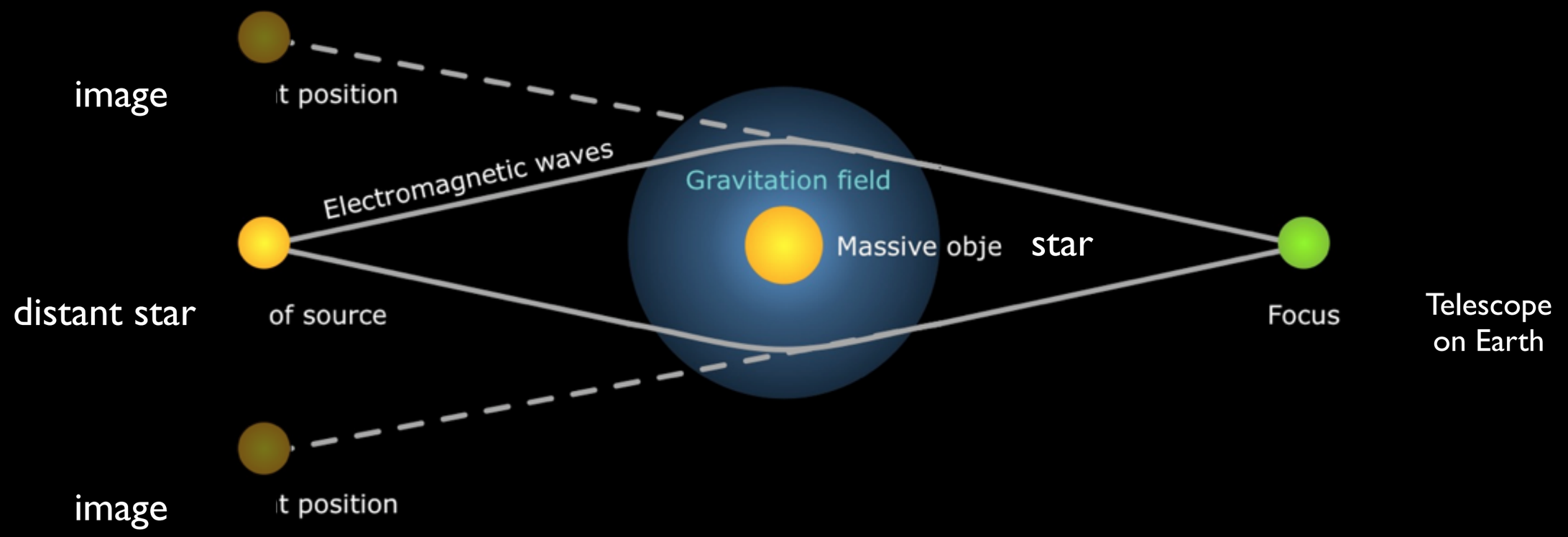
Transit method

(winks)

- Faint planet passes in front of a bright star
- Star's light dims
- Finds big planets (large diameter)

Microlensing
(blips)

Gravitational Lens



Microlensing

(blips)

Microlensing

(blips)

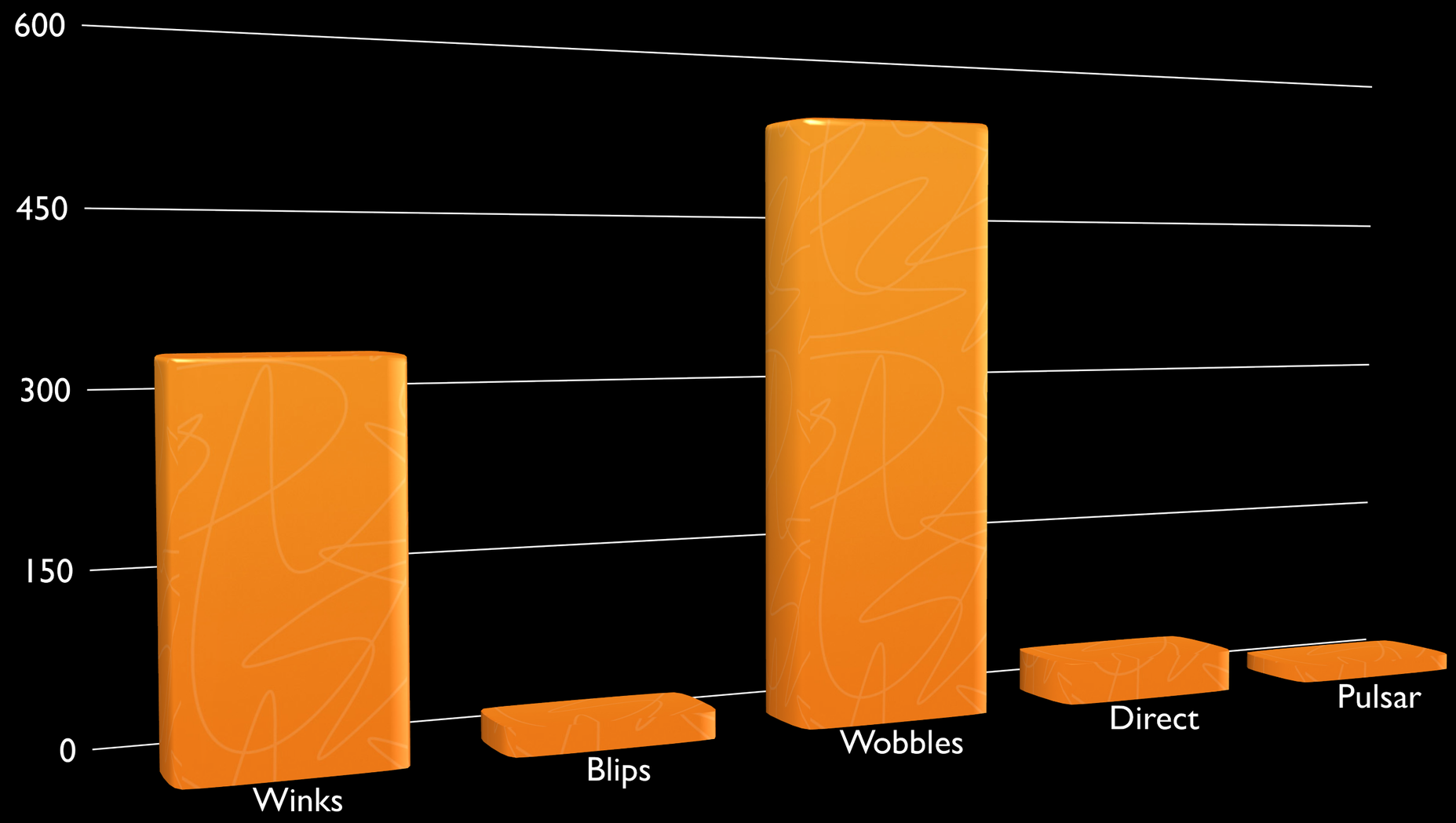
- Chance alignment, never seen again
- Found in galactic bulge where there are lots of stars

Radial velocity

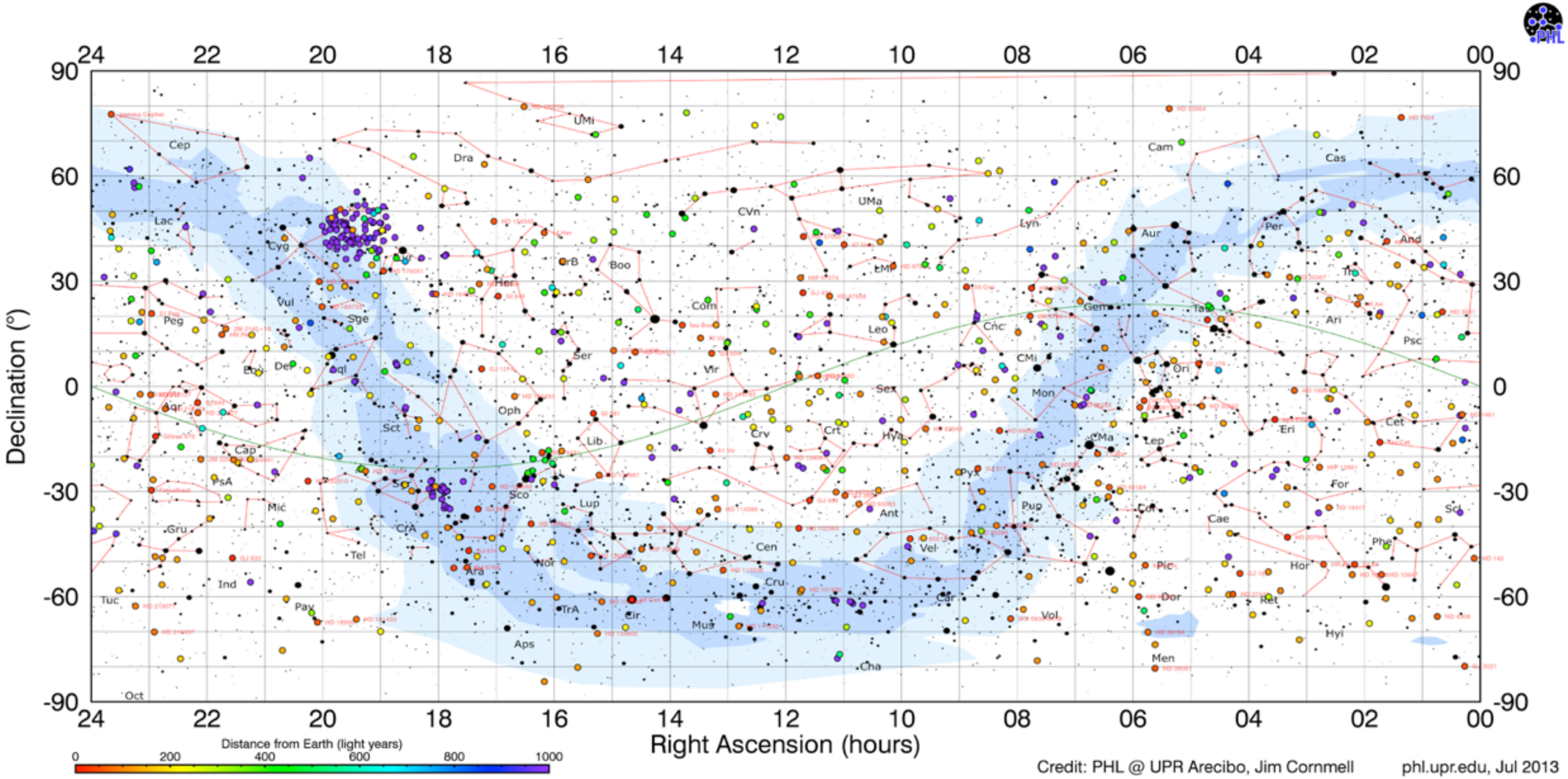
(wobbles)

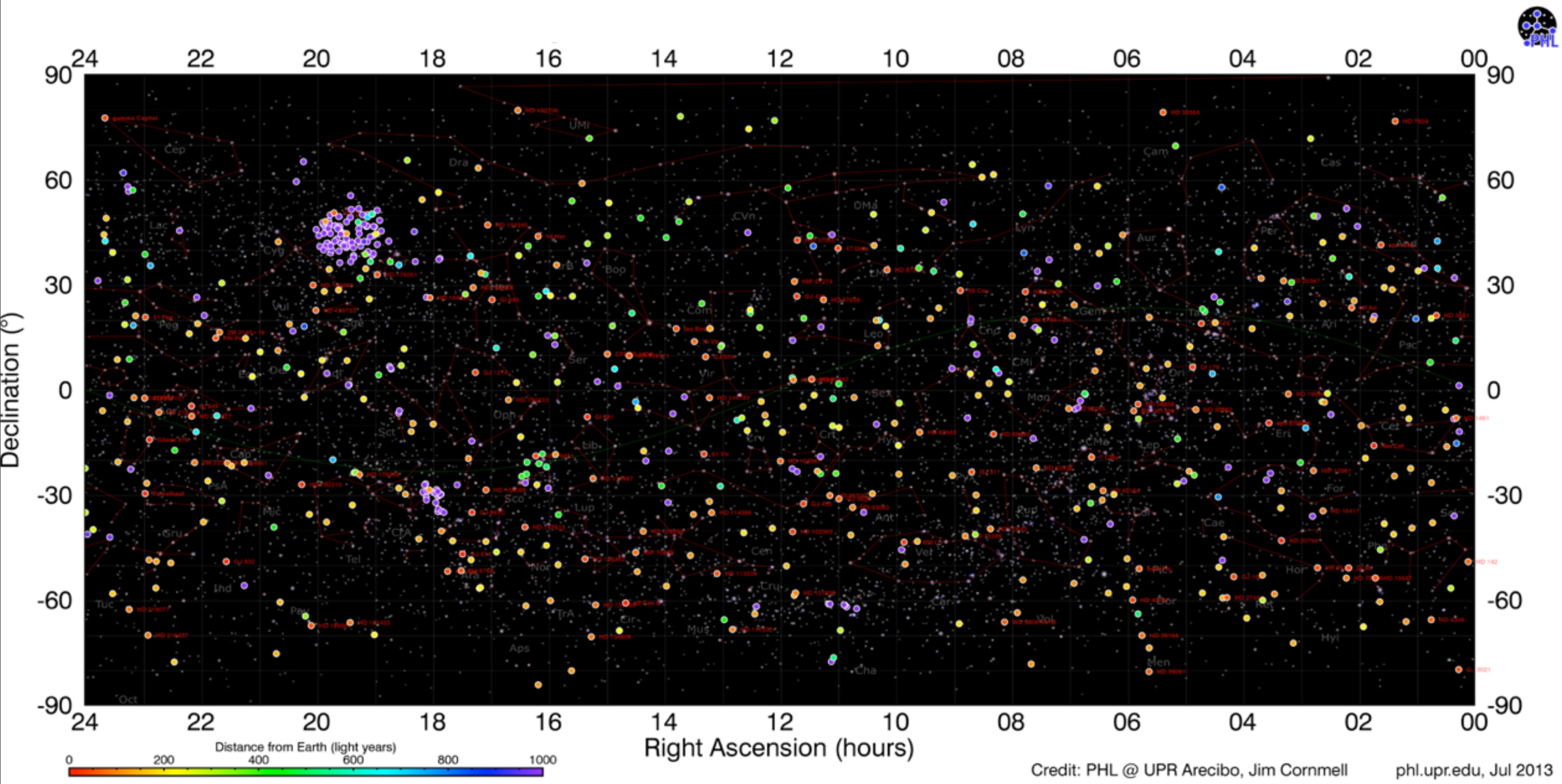
- Stars and planets orbit around a common centre of mass
- Only see star wobbling
- Finds massive planets

Who wins?



Where?


Declination (°)
Right Ascension (hours)
Distance from Earth (light years)
0
200
400
600
800
1000
Credit: PHL @ UPR Arecibo, Jim Cornmell
phl.upr.edu, Jul 2013


Declination (°)
Right Ascension (hours)
Distance from Earth (light years)
0
200
400
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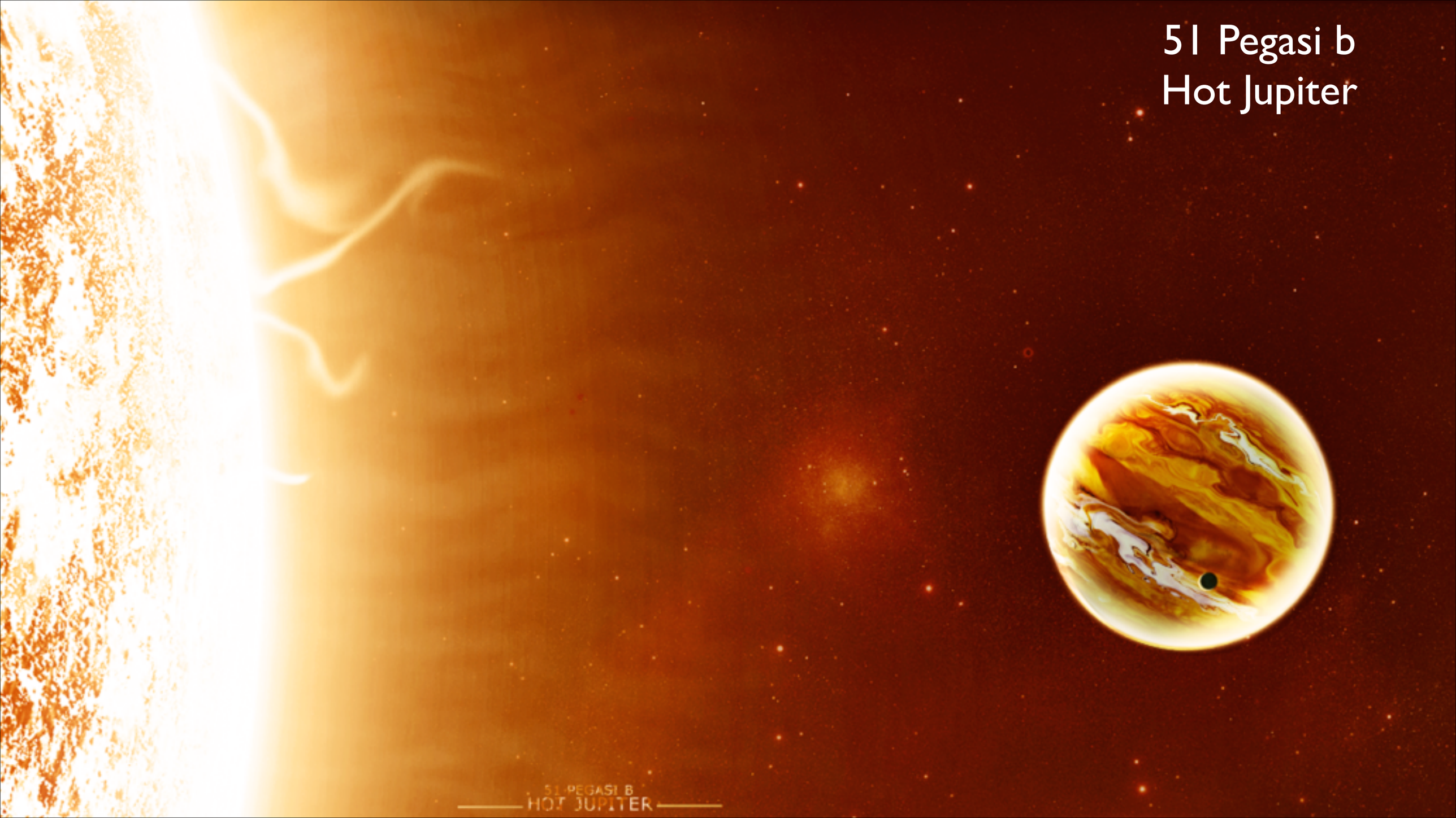
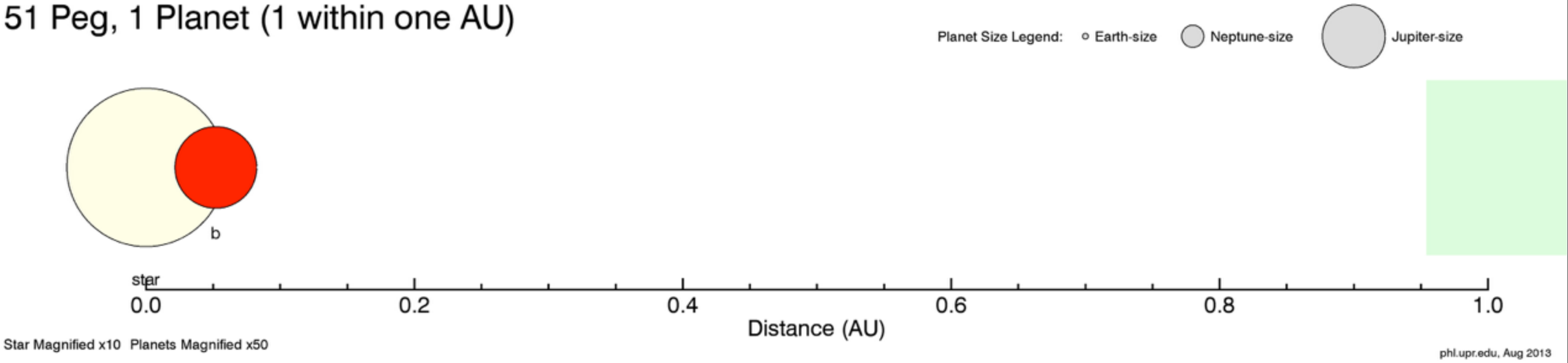
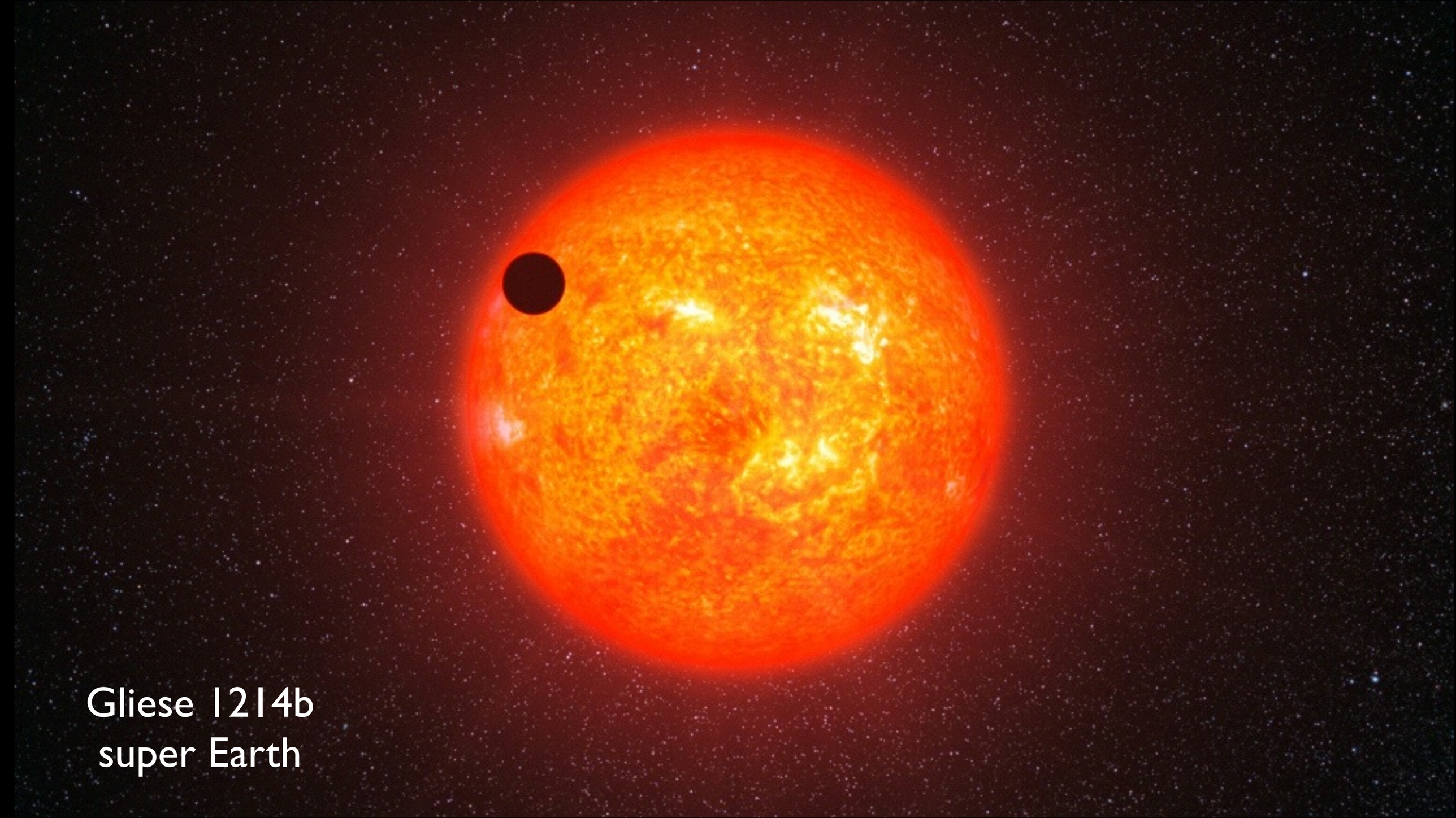
Credit: PHL @ UPR Arecibo, Jim Cornmell
phl.upr.edu, Jul 2013

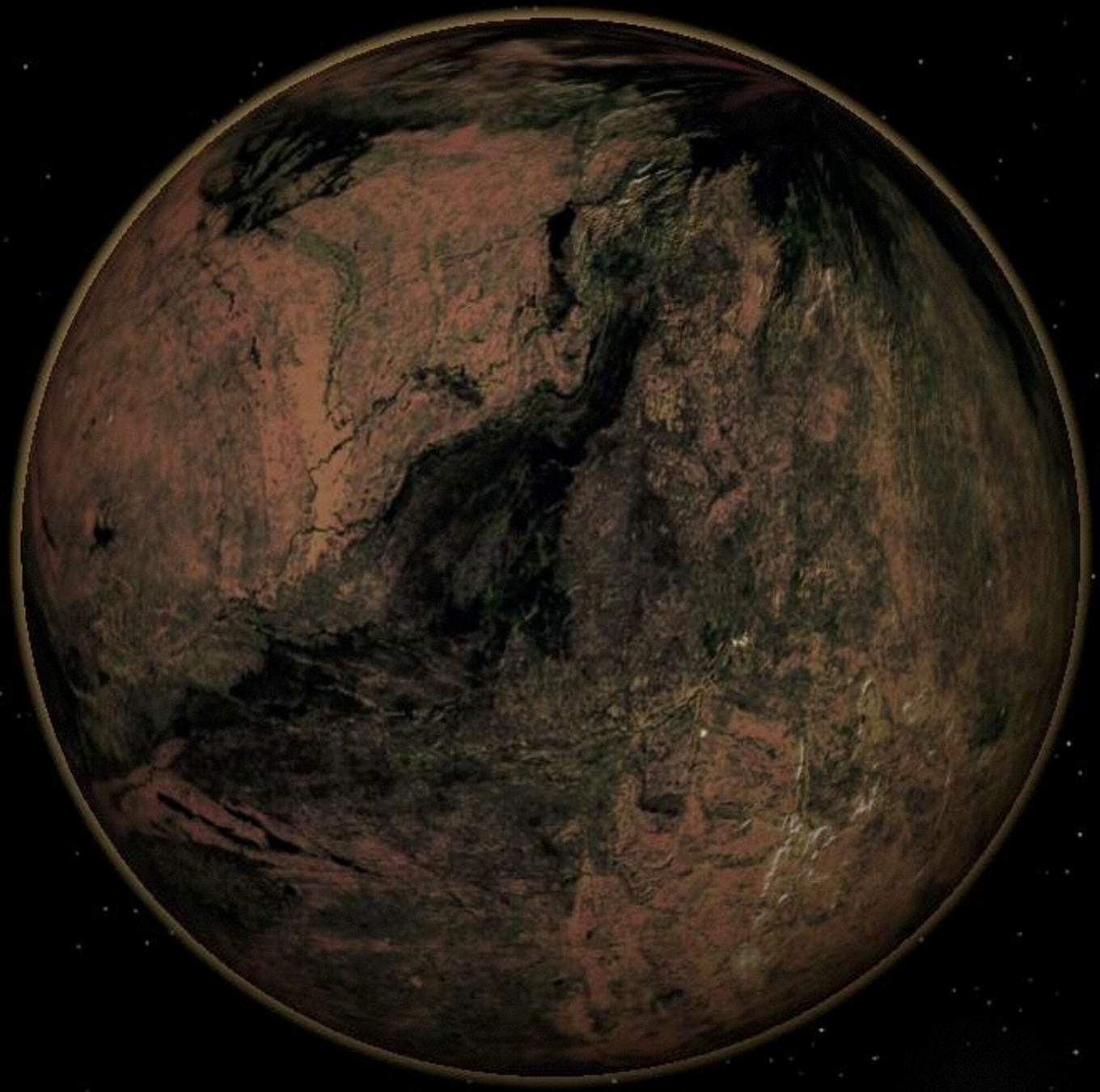

51 Pegasi b
Hot Jupiter
51-PEGASI B
HOT JUPITER

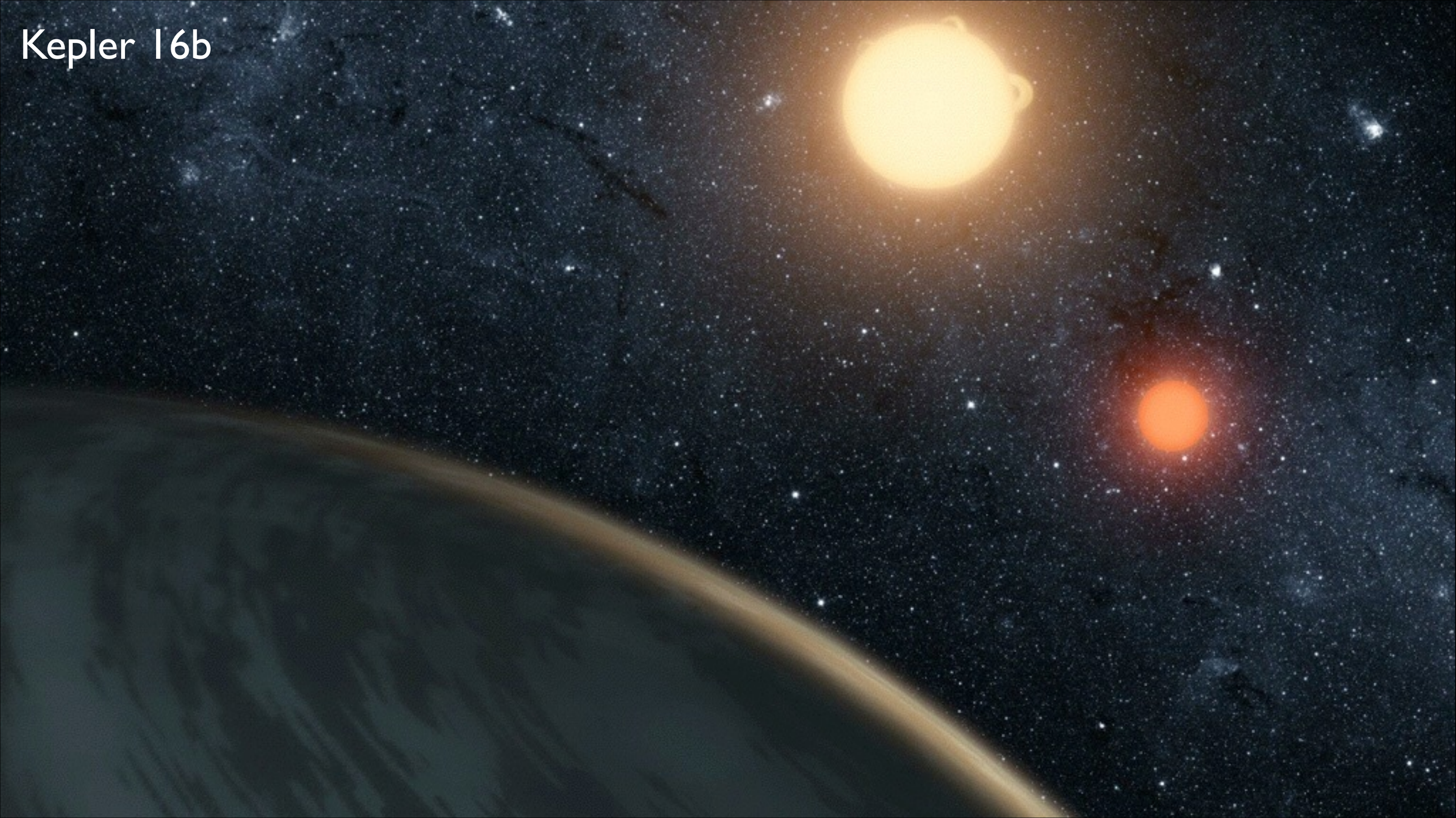
51 Peg, 1 Planet (1 within one AU)

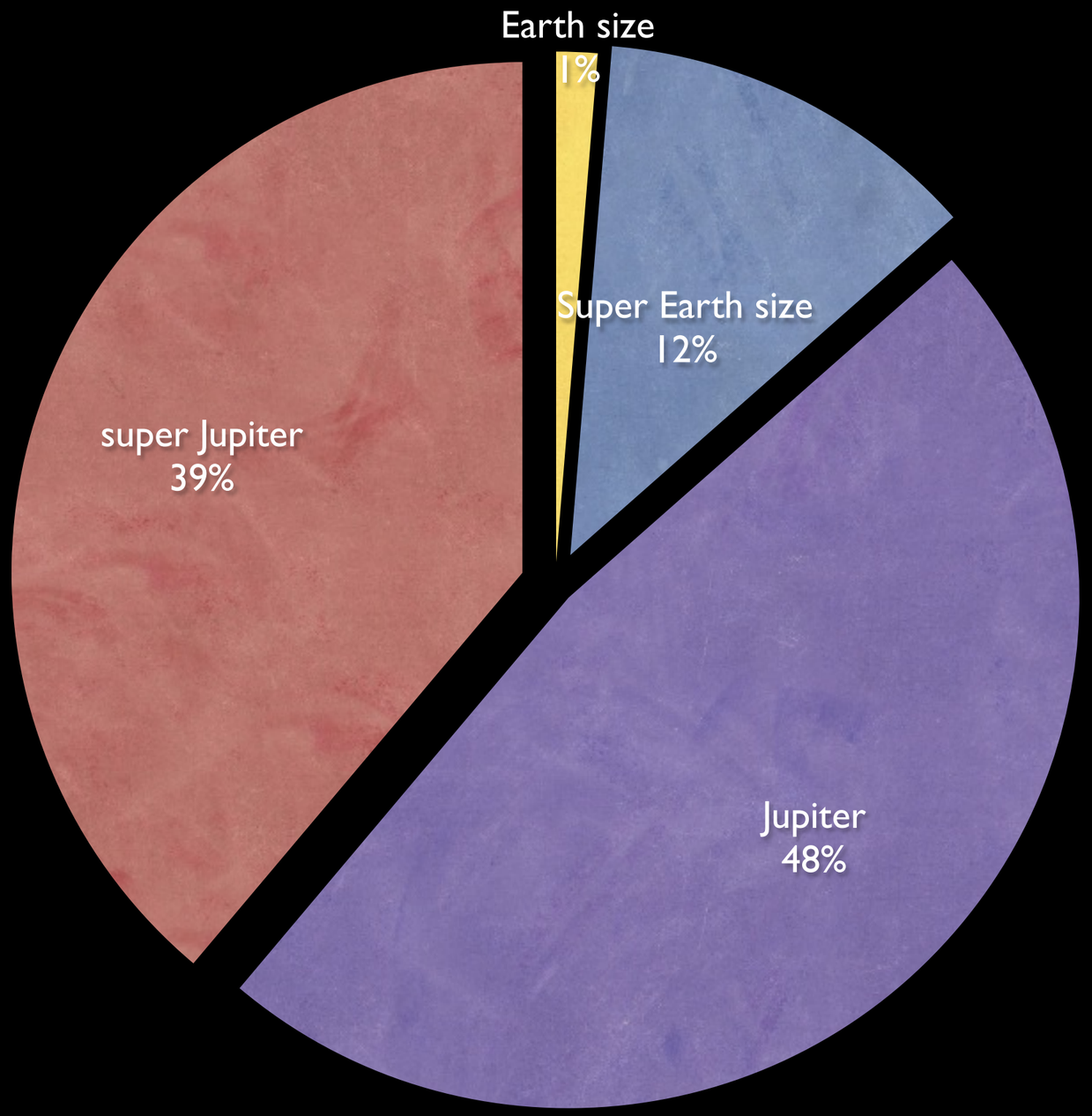



Gliese 1214b
super Earth

55 Cancri e
Carbon planet




Kepler 16b

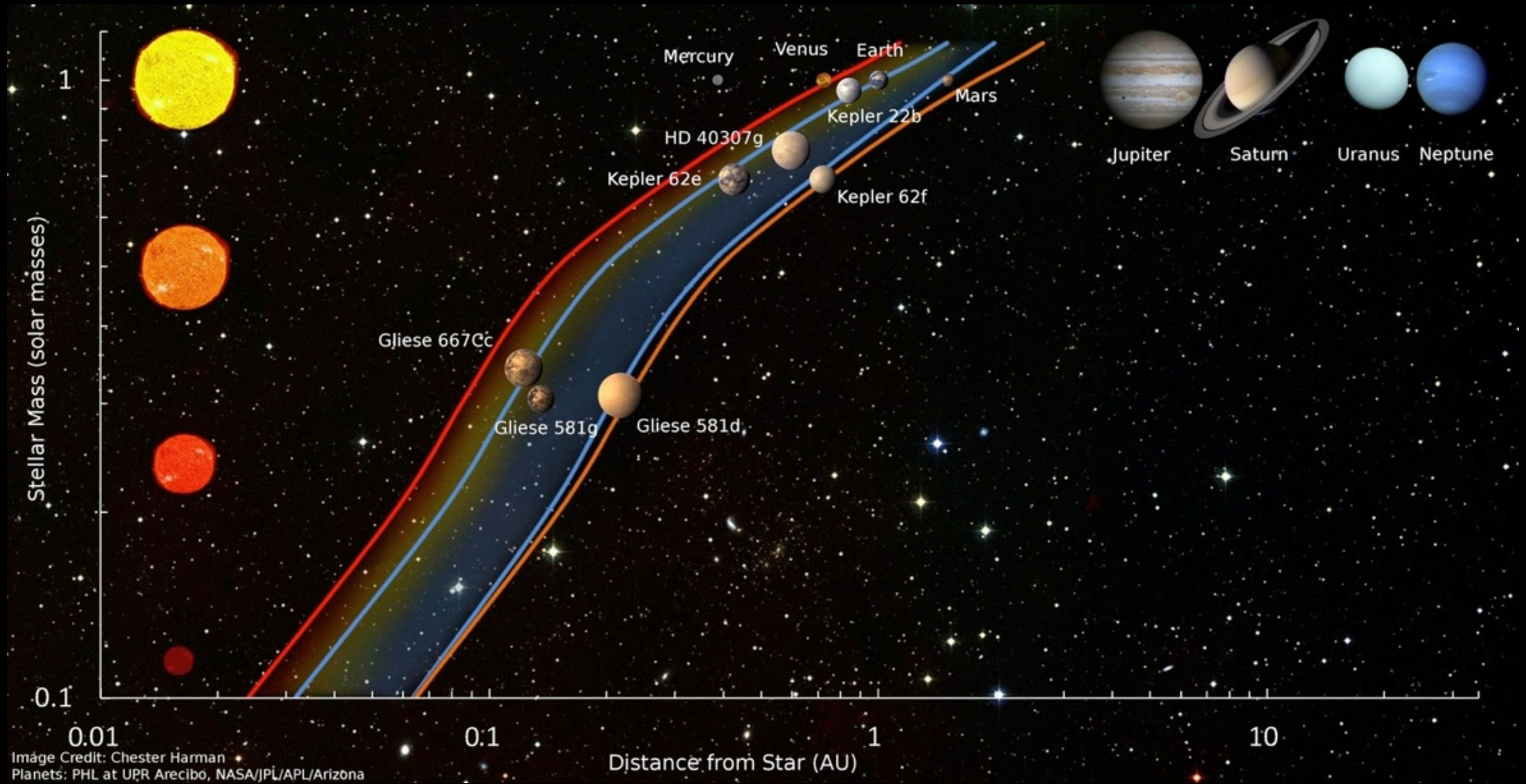


1050 exoplanets discovered

797 extra-solar systems

Why?

Habitable Zone

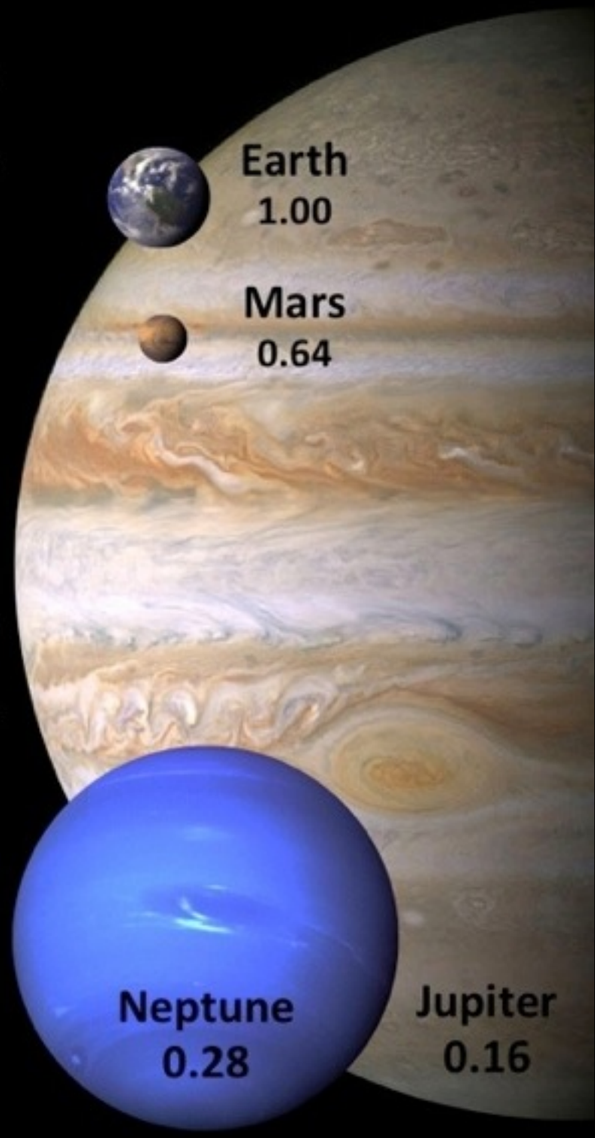


Current Potentially Habitable Exoplanets

Ranked in Order of Similarity to Earth

#1	#2	#3	#4	#5	#6
Kepler-62 e 0.83	Gliese 667C c 0.82	Gliese 581 g* 0.82	Tau Ceti e* 0.77	Gliese 667C f 0.76	Kepler-22 b 0.75

#7	#8	#9	#10	#11	#12
Gliese 163 c 0.74	Kepler-61 b 0.73	HD 40307 g* 0.72	Kepler-62 f 0.67	Gliese 667C e 0.60	Gliese 581 d 0.53

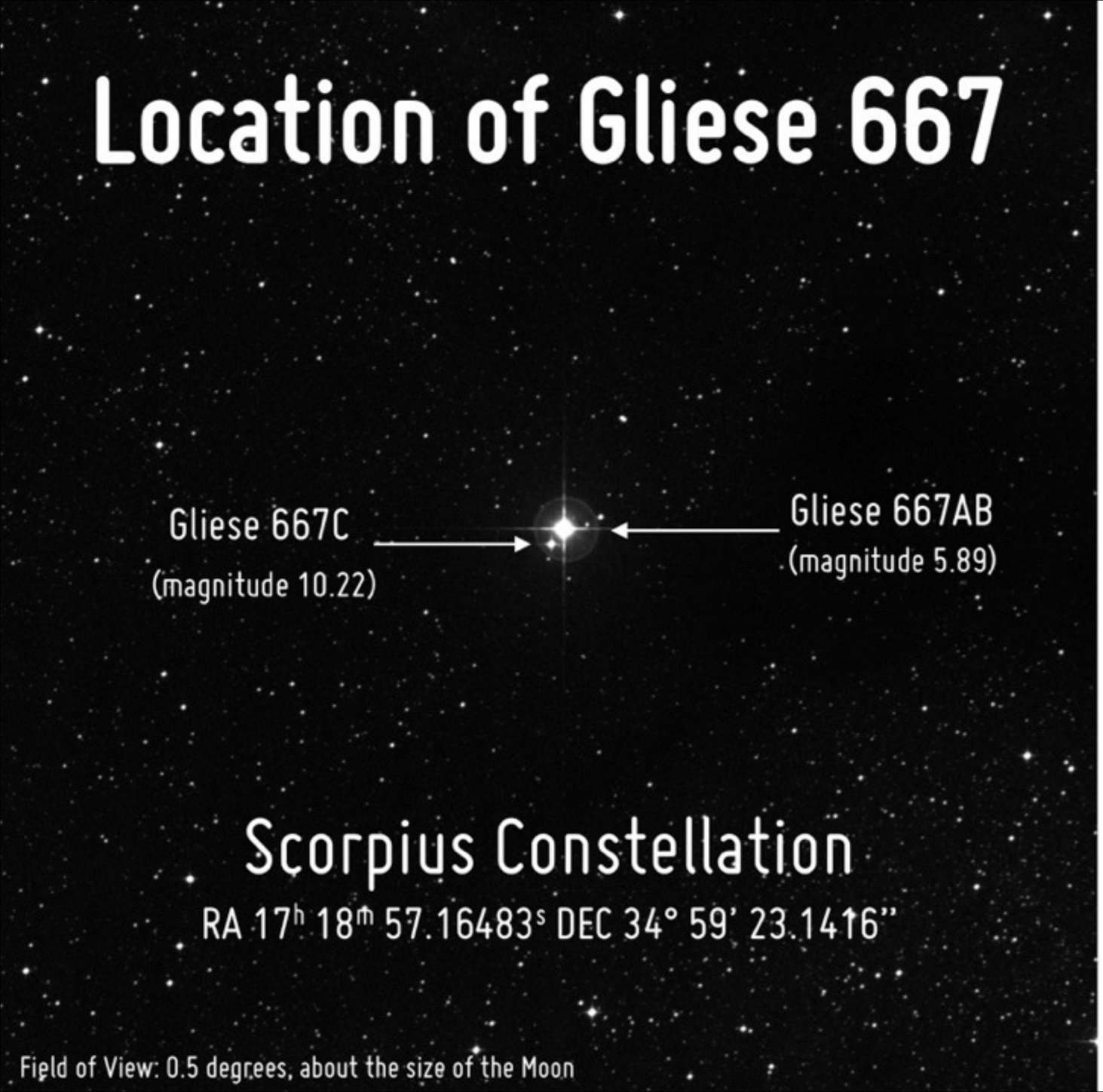


*planet candidates

Number below the names is the Earth Similarity Index (ESI)

CREDIT: PHL @ UPR Arecibo (phl.upr.edu) July 29, 2013

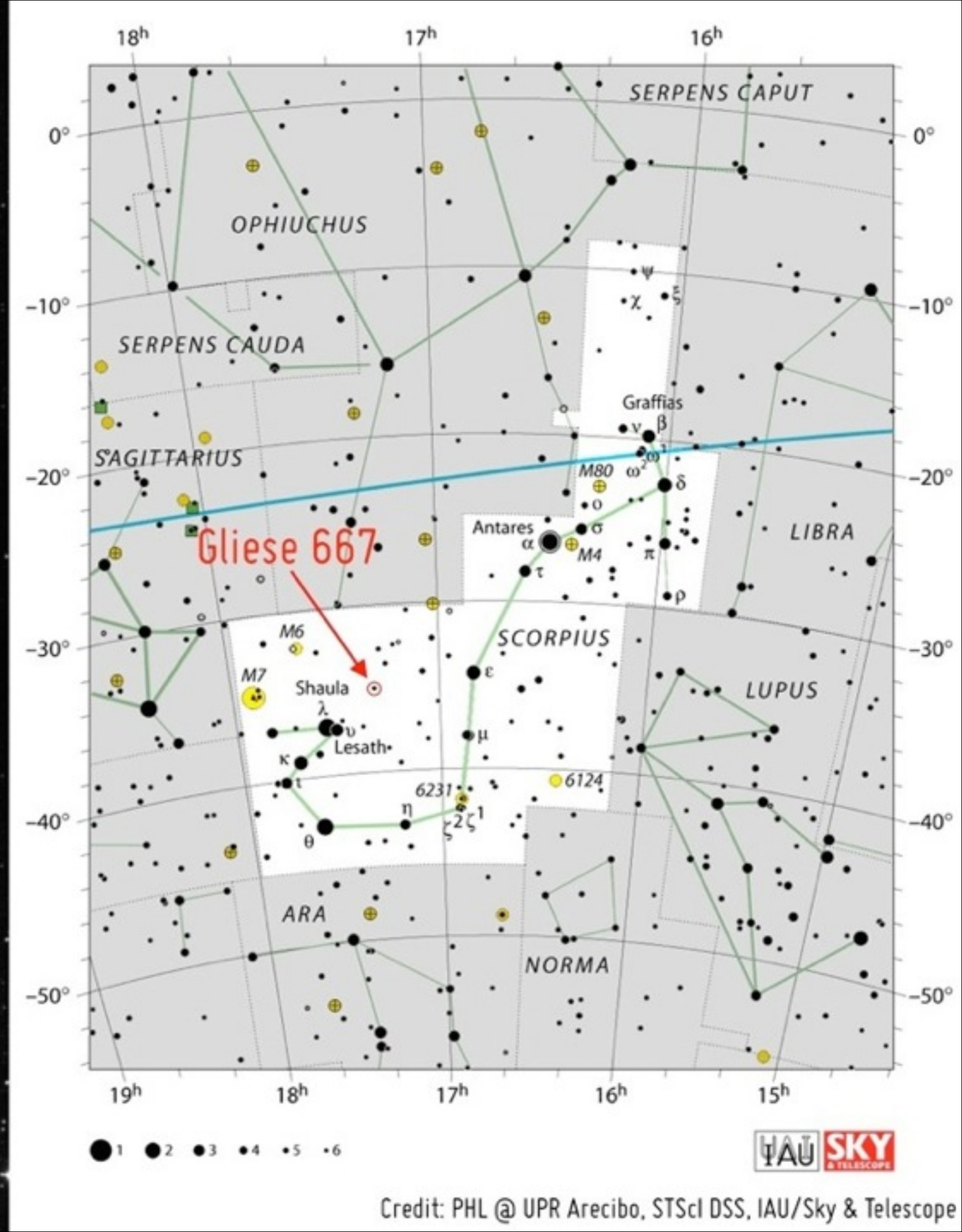
Location of Gliese 667



Scorpius Constellation

RA 17h 18m 57.16483s DEC 34° 59' 23.1416"

Field of View: 0.5 degrees, about the size of the Moon

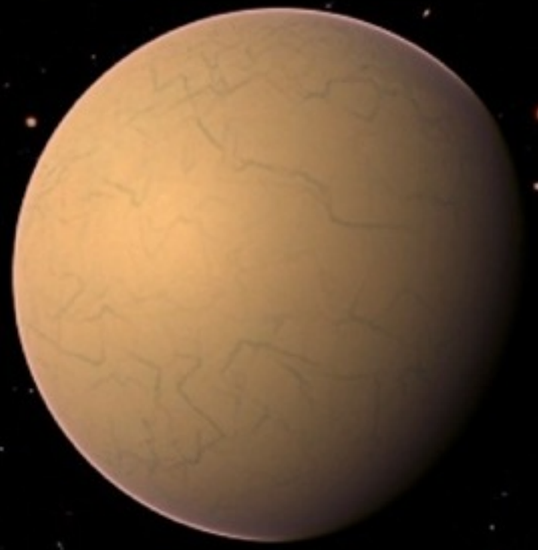


Credit: PHL @ UPR Arecibo, STScI DSS, IAU/Sky & Telescope

Three Potentially Habitable Worlds Around Gliese 667C

Gliese 667C c

Gliese 667C f

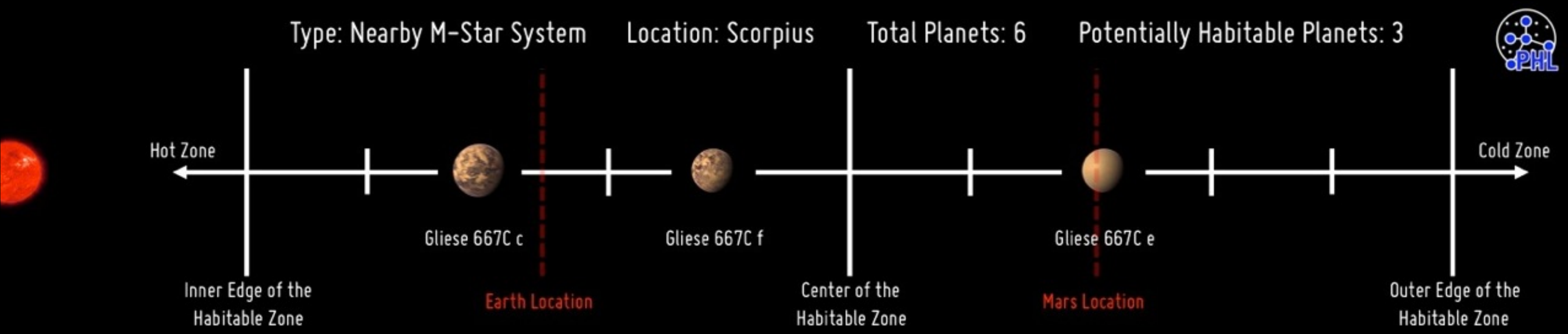


Gliese 667C e

Earth

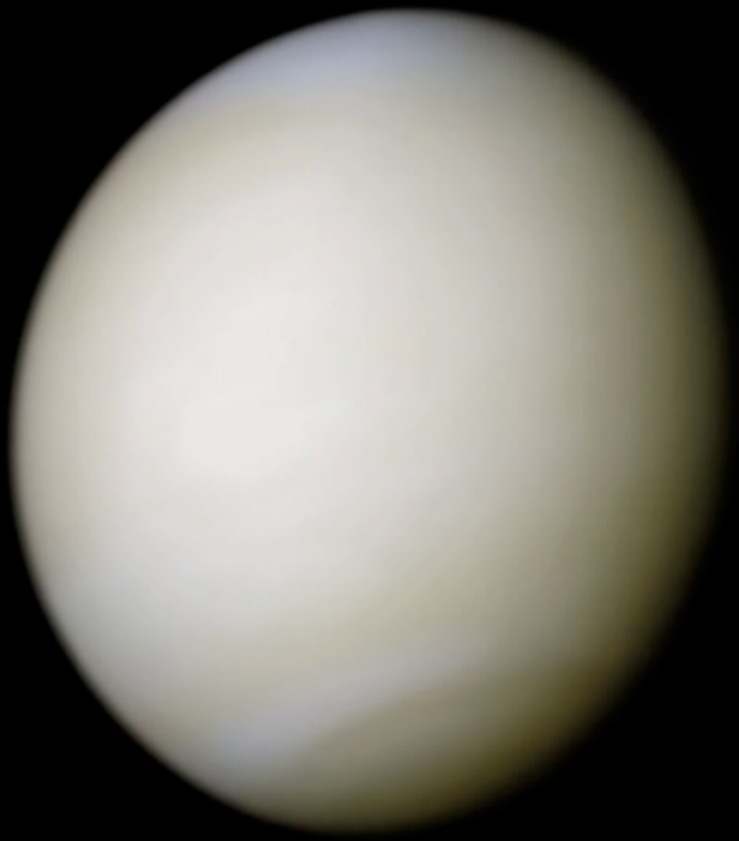
CREDIT: PHL @ UPR Arecibo, NASA

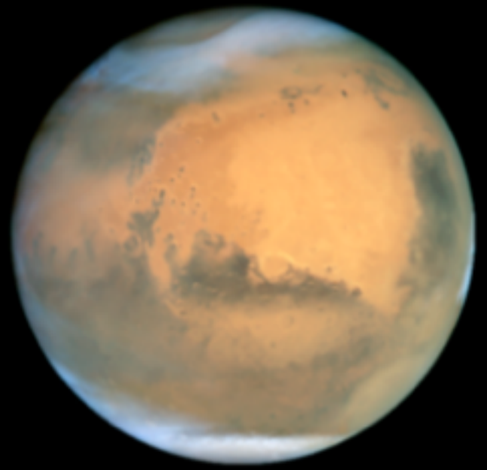
Gliese 667C

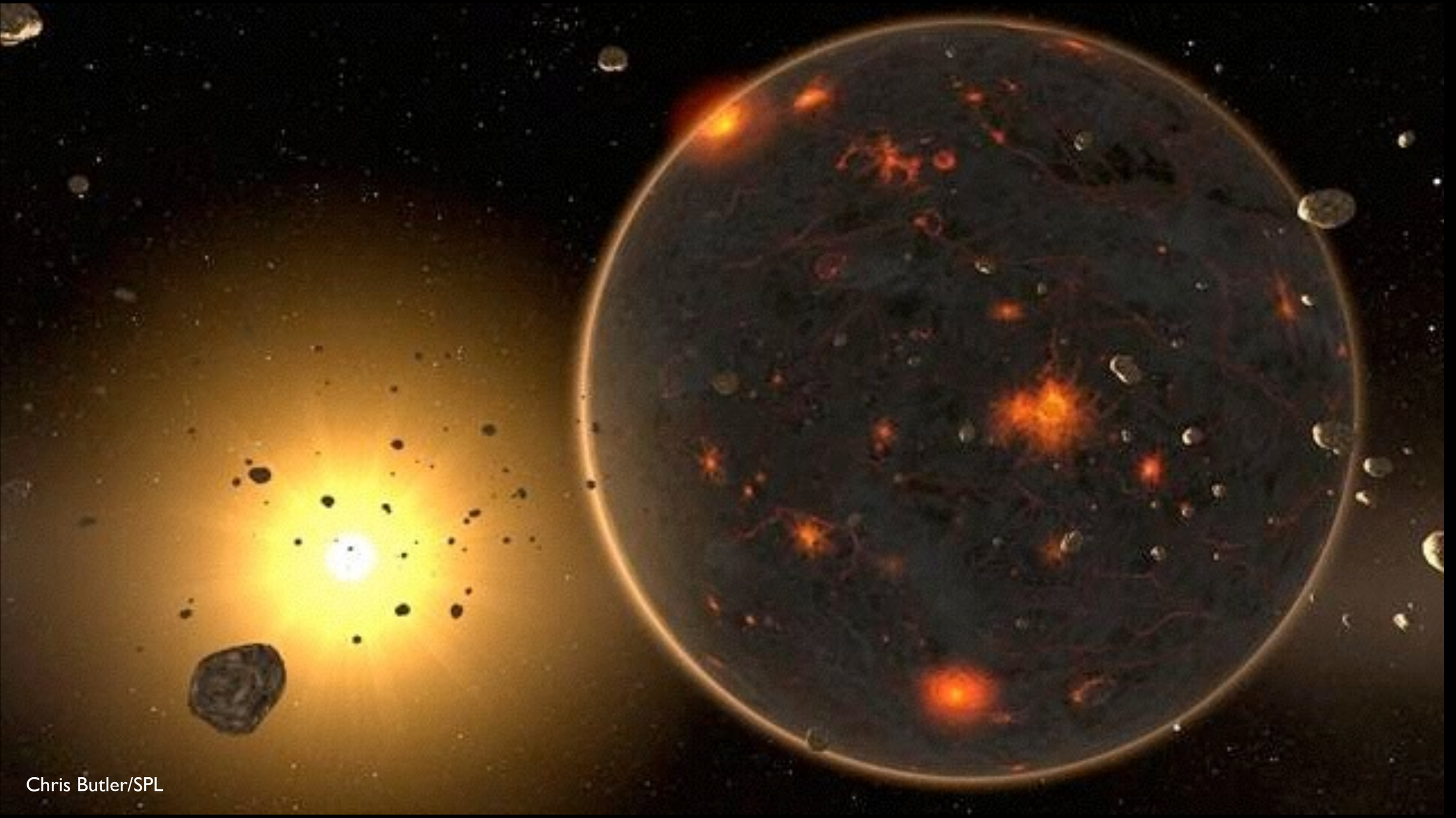

Type: Nearby M-Star System
Location: Scorpius
Total Planets: 6
Potentially Habitable Planets: 3
PHL
Hot Zone
Cold Zone
Gliese 667C c
Gliese 667C f
Gliese 667C e
Inner Edge of the Habitable Zone
Earth Location
Center of the Habitable Zone
Mars Location
Outer Edge of the Habitable Zone

Sunset of Gliese 667C
Earth
Gliese 667C c
Gliese 667C f
Gliese 667C e
CREDIT: PHL @ UPR Arecibo

The End?







Chris Butler/SPL

goran-d, environaut

THE HUNT FOR EXOMOONS

→ Edge-on system view: Giant planet with a highly-inclined moon

→ Simulated transit lightcurve of both planet and moon

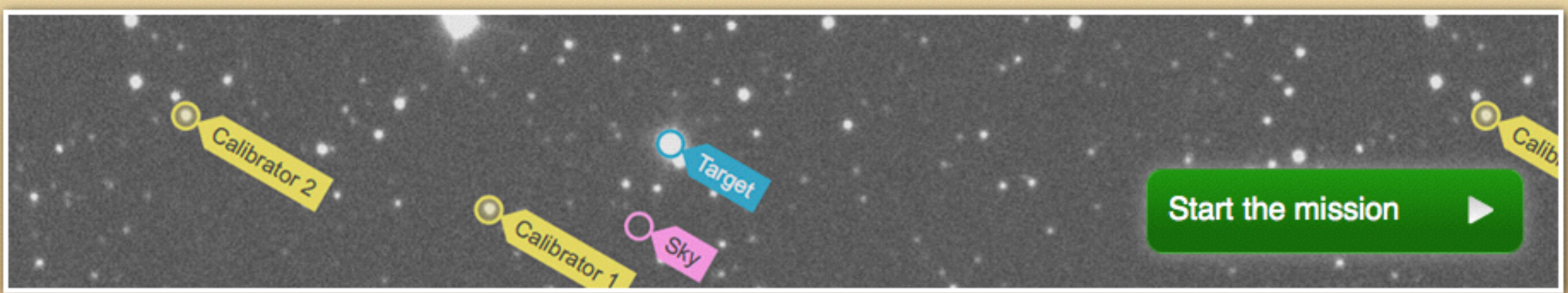
alex parker creative commons

AGENT EXOPLANET

http://lcogt.net/agentexoplanet

AGENT EXOPLANET

Powered by LCOGT.net



Mission Brief

Welcome Edward.

Astronomers at Las Cumbres Observatory are investigating exoplanets - planets which orbit stars other than our Sun - and you can too.

Joining Agent Exoplanet you will study known exoplanets using images taken by LCOGT's telescopes. You'll measure the brightness of a star while a planet moves between it and our viewpoint.

You can examine as many images, from as many exoplanet transit events, as you like and contribute to understanding the properties of each exoplanet.

Find out more...

Briefing Video

AGENT EXOPLANET

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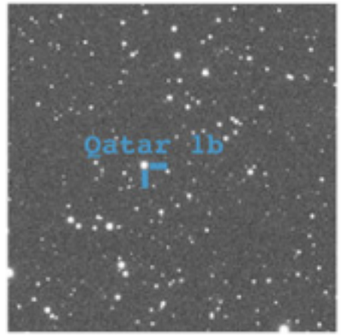


Finder chart

Add calibrator

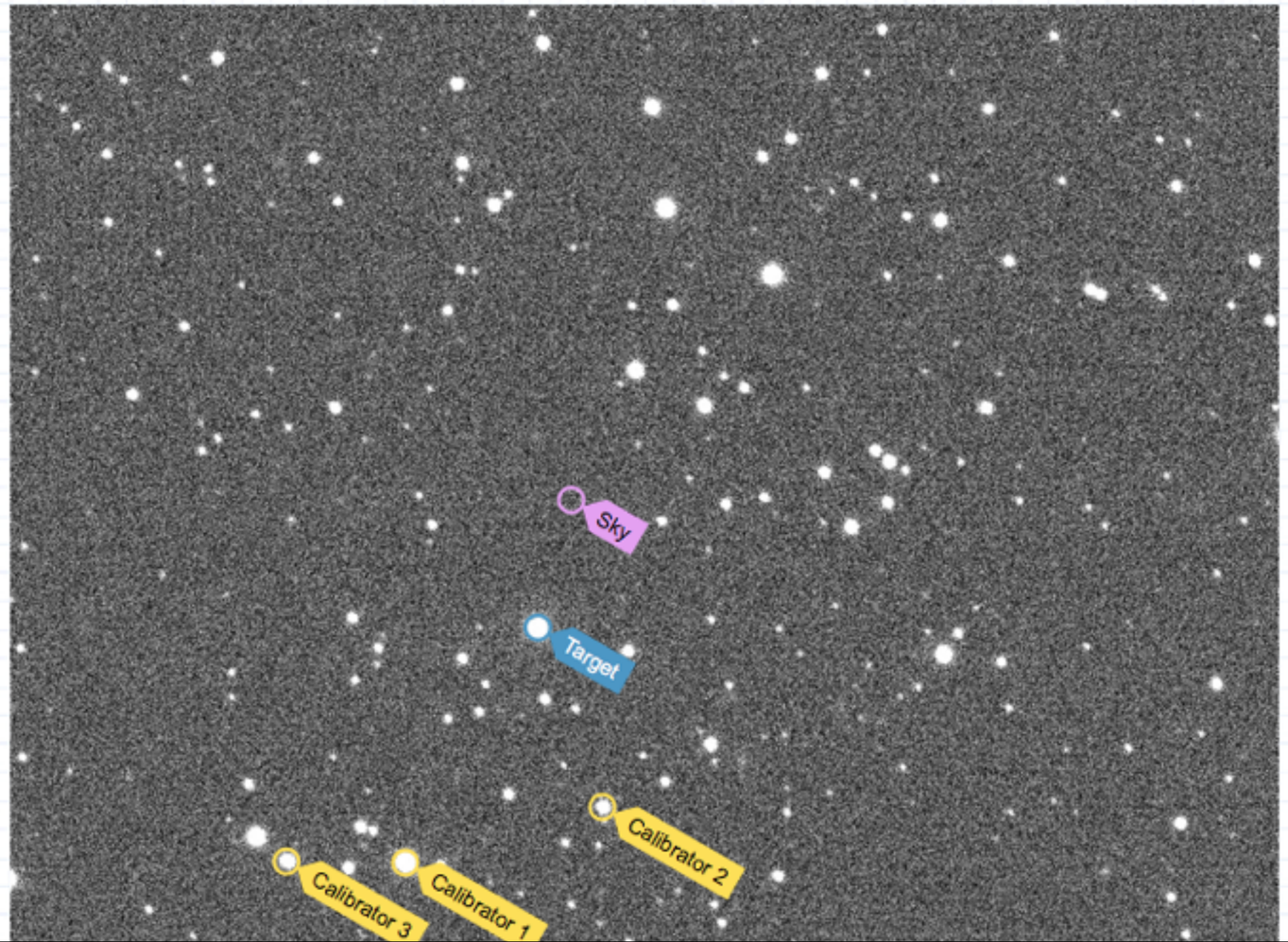
Analyze image

Next image

Light Monitor: Qatar-1b

AUG. 23, 2011, 5:27 A.M.

You've completed 21 of 130 frames (16%)



AGENT EXOPLANET

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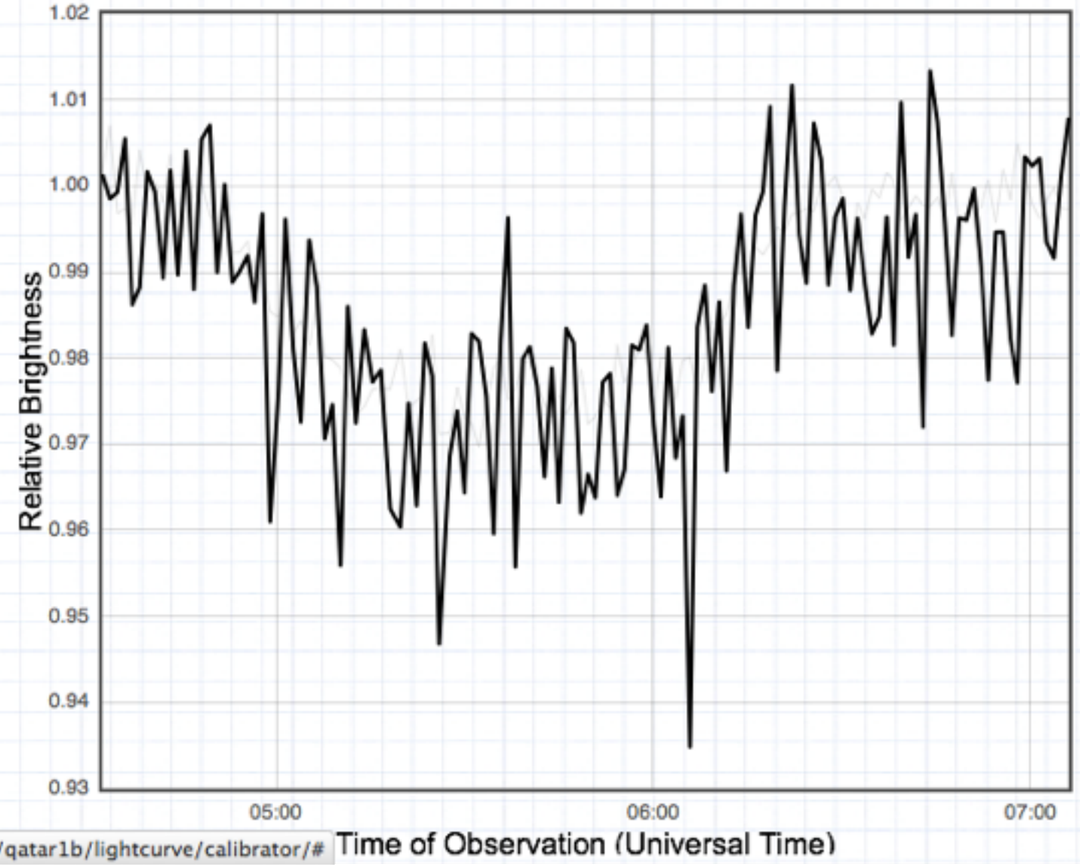
Step 2: Classify Lightcurves for Qatar-1b

Here are complete lightcurves made by combining your measurements with those of volunteers who used the same calibrators. The graphs below show the average values per calibrator and may look different from the previous graph, which contained only your values.

You have analyzed 16% of the images for Qatar-1b. Continue analysing?. You have classified 1 out of 2 calibrators which have full datasets that you have contributed to.



Classify Calibrator 2

(USNO-A2.0 1551-0215373)

Select the picture which is the closest match for this graph.

Dip | No dip | Other

Step 3: Final lightcurve

AGENT EXOPLANET

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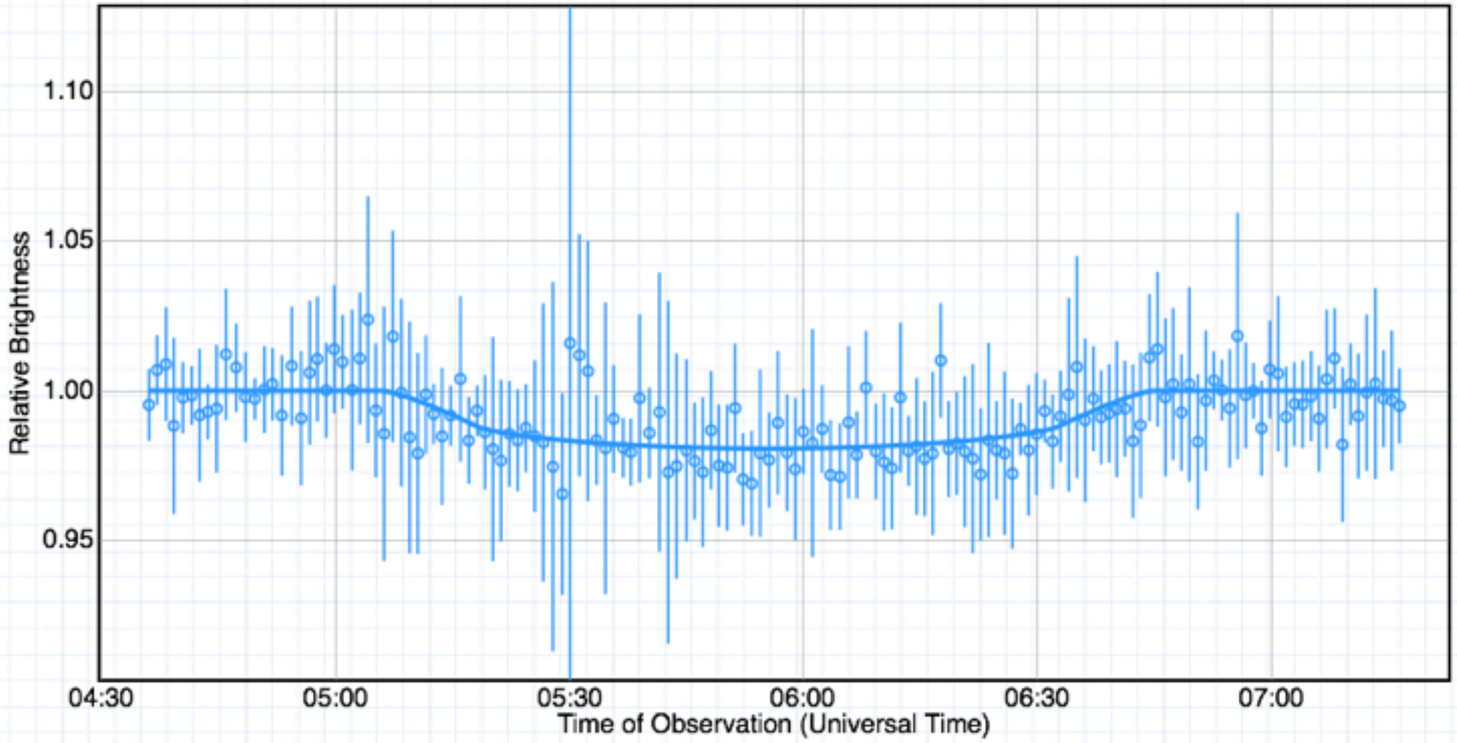
Step 3: Final Lightcurve for WASP-2b

Measurements with 13 calibrators were combined to make the final, combined, lightcurve. With more calibrators the lightcurve should improve.



Relative sizes

This cartoon shows the relative sizes of the star, planet and orbit based on the transit above. It assumes that we are seeing WASP-2b's orbit edge on. The dip in brightness happens when the planet blocks the star.

Relative sizes

This cartoon shows the relative sizes of the star, planet and orbit based on the transit above. It assumes that we are seeing WASP-2b's orbit edge on. The dip in brightness happens when the planet blocks the star.

How we worked this out

The orbital period for WASP-2b is known to be 2.152 days. Through either the star's stellar type or radial velocity measurements, we can infer a mass for the star of 0.84 times that of the Sun. With Kepler's third law of planetary motion we can then calculate the orbital radius to be about 4604000 km (0.031 AU).

From the graph we estimate the transit to take 1.435 hours (we will call this t_{trans}) with a dip in brightness of 1.93%. The dip in brightness is related to the relative sizes of planet and star - the bigger the planet, compared to the star, the bigger the dip in brightness when it passes in front. Your measurements suggest the planet has a diameter roughly 0.14 times that of the host star. The duration of a transit is related to the orbital period P, the star's radius R_*, the orbital radius a and the inclination of the orbit i. These are all related by the formula:

$$t_{trans} = \frac{P}{\pi}\sqrt{\left(\frac{R_*}{a}\right)^2 - cos^2(i)}$$

If we assume an edge-on orbit, like in the cartoon above, the inclination (i) is zero and this becomes the more straightforward:

$$t_{trans} = \frac{P\,R_*}{\pi\,a}$$

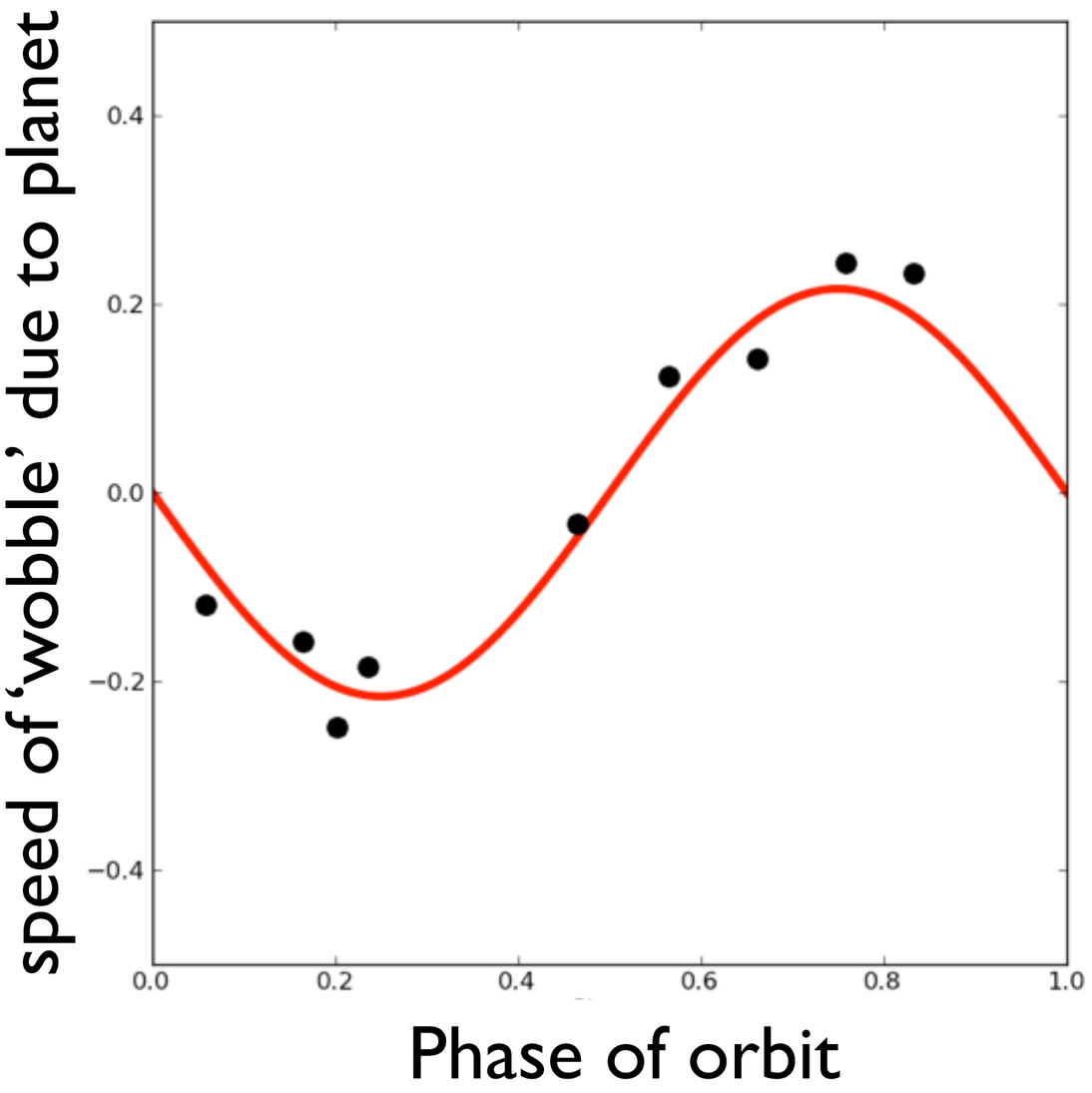
Using all the values we've measured, calculated or inferred the planet is then estimated to have a radius of 55900 km.

Property	Value	Note
Star mass	0.84 solar	inferred
Orbital period	2.152 days	measured
Orbital radius	4604000 km	inferred

Getting the mass

Qatar 1b

Phase of orbit	speed of wobble due to planet
0.201	-0.248
0.832	0.233
0.565	0.123
0.235	-0.185
0.661	0.143
0.058	-0.118
0.758	0.244
0.465	-0.033
0.167	-0.159


speed of 'wobble' due to planet
0.4
0.2
0.0
−0.2
−0.4
0.0
0.2
0.4
0.6
0.8
1.0
Phase of orbit

Iron
Density: 7874 kg/m^3

Metamorphic Rock
Density: 2650 kg/m^3

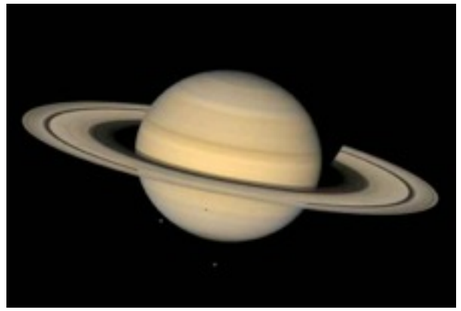
Sedimentary Rock
Density: 2500 kg/m

Ice
Density: 917kg/m^3

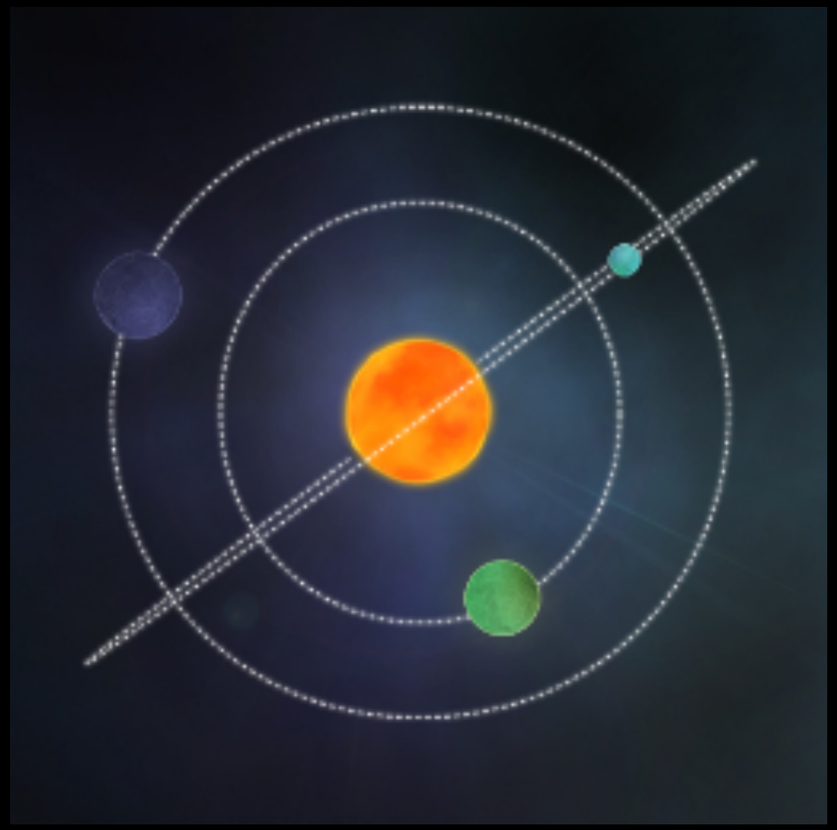
Mars
Density: 3940 kg/m^3

Earth
Density: 5155 kg/m^3

Jupiter
Density: 1330 kg/m^3



Saturn
Density: 700kg/m^3



Planet Hunters

http://planethunters.org