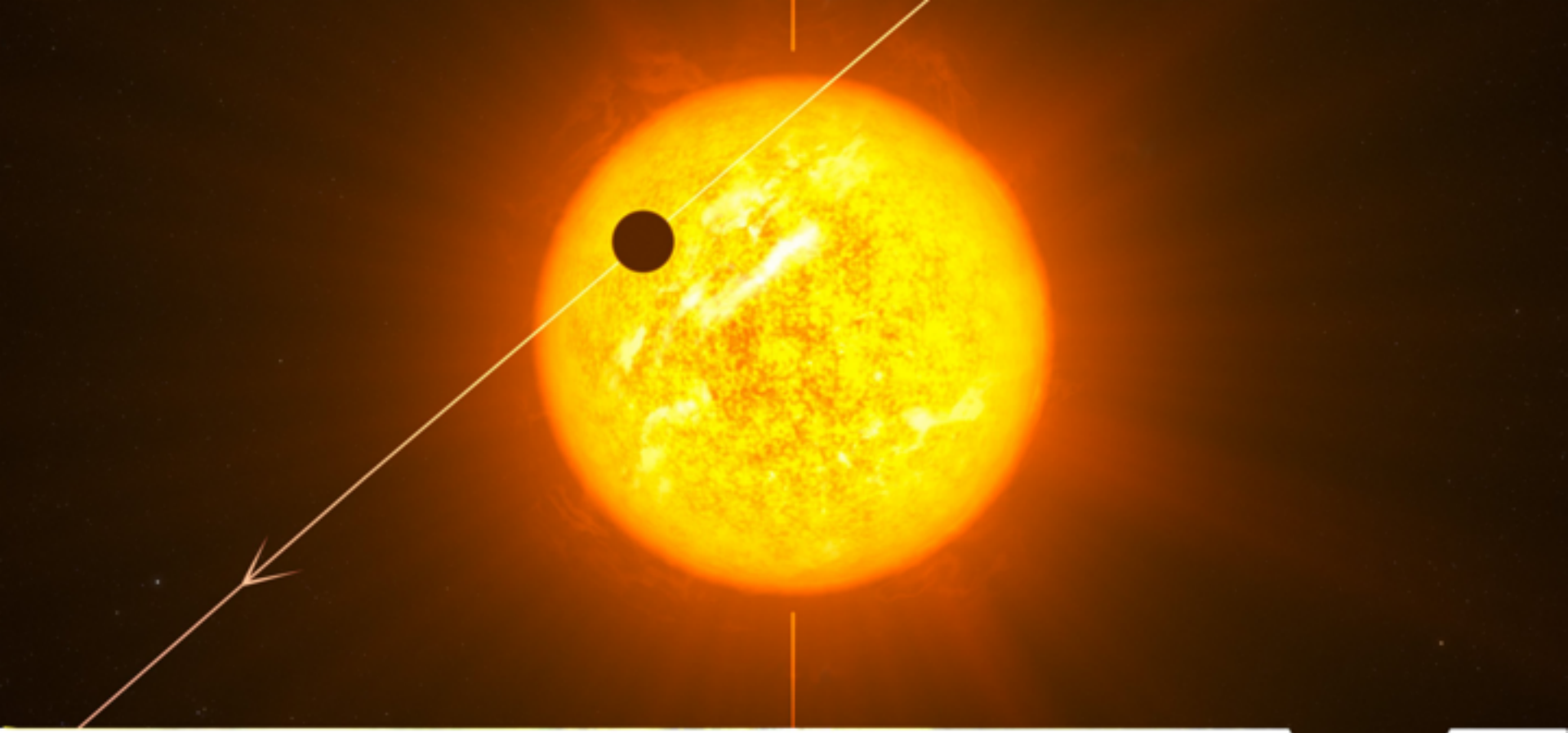

WARWICK

Exoplanets and me

Hugh Osborn

@HughO2

Outline

- A bit about me
- The basics
- How we find planets
- EPIC-1166
- The future of exoplanets

WARWICK

How I got here

WARWICK

How I got here.

WARWICK

How I got here

WARWICK

ASTRONOMY &
ASTROPHYSICS

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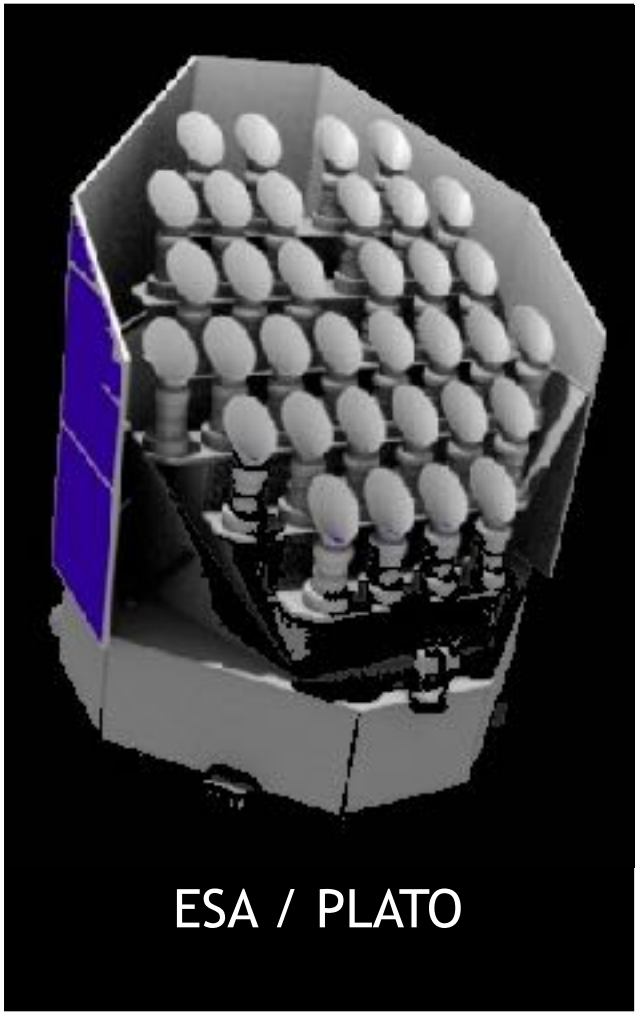
Future:



ESA / PLATO

LAM

LABORATOIRE D'ASTROPHYSIQUE
DE MARSEILLE

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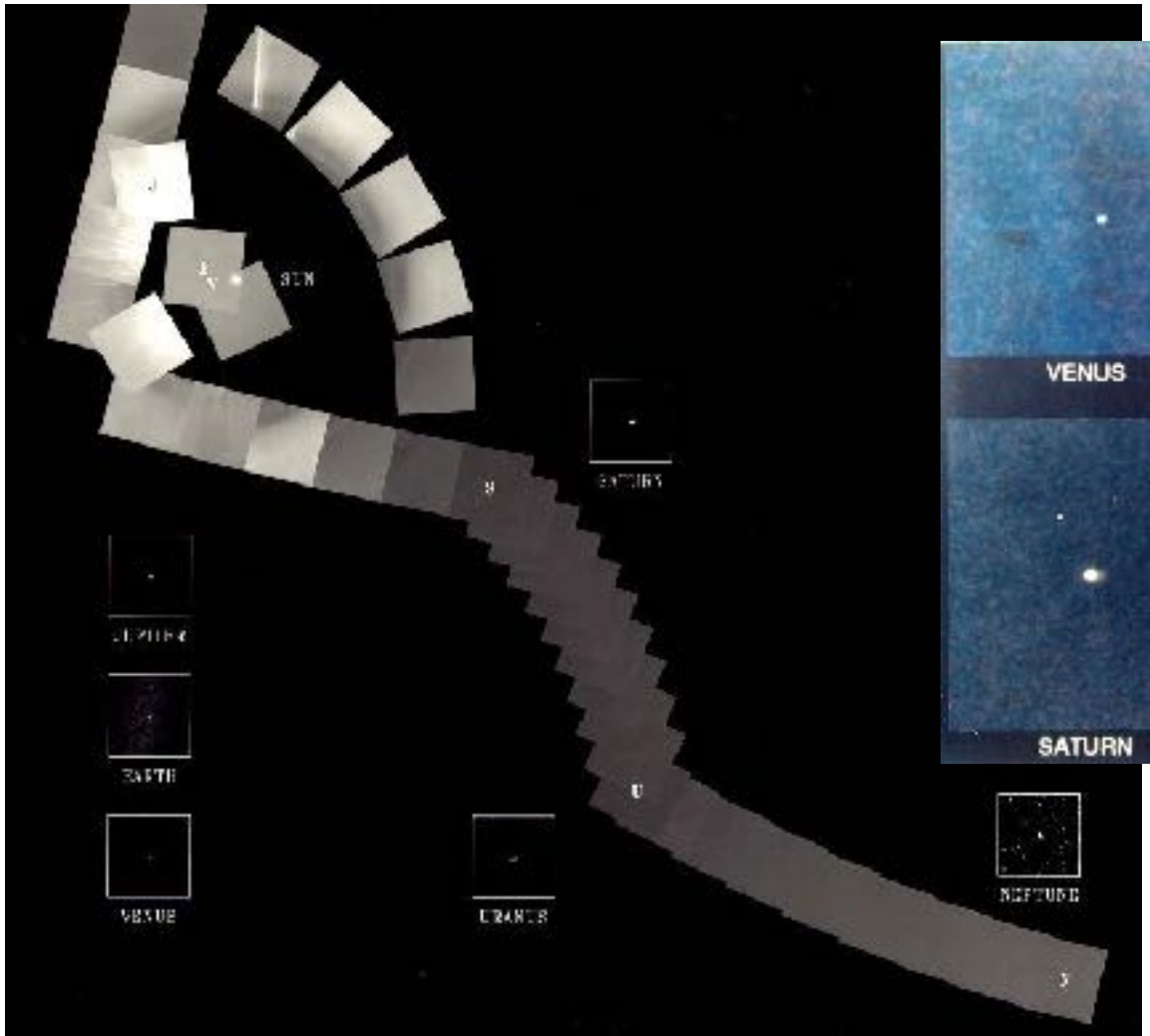
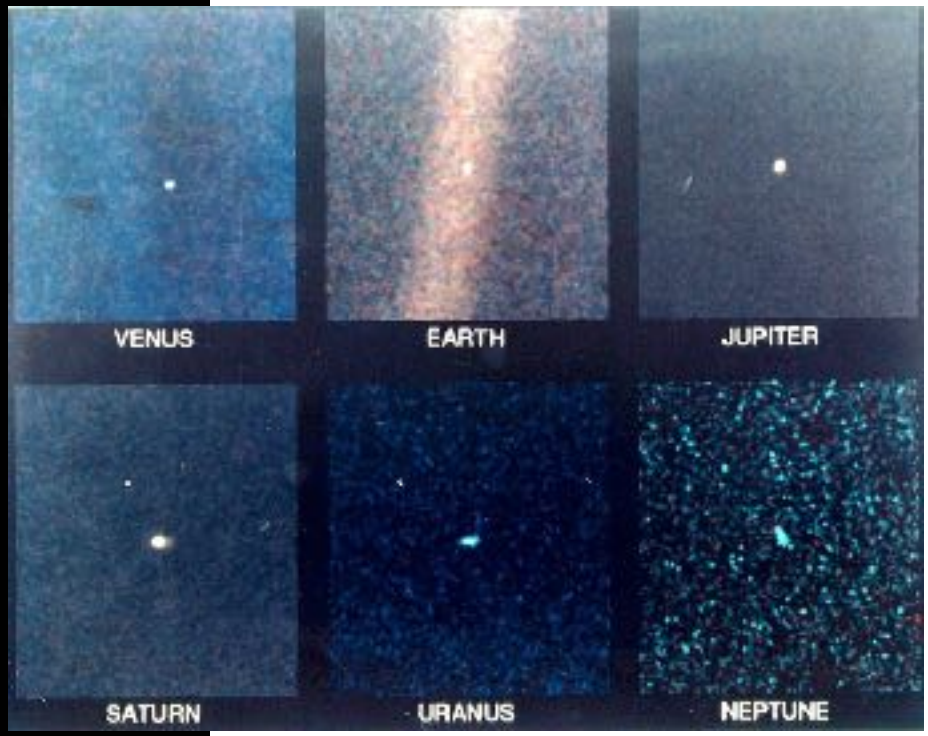
What are exoplanets?





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Ancient History of Exoplanets

Epicurus and Aristarchus

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Ancient History of Exoplanets

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History of Exoplanets

Bruno

Huygens

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History of Exoplanets

Capt WS Jacob (1855)

Peter Van de Kamp (20th C)

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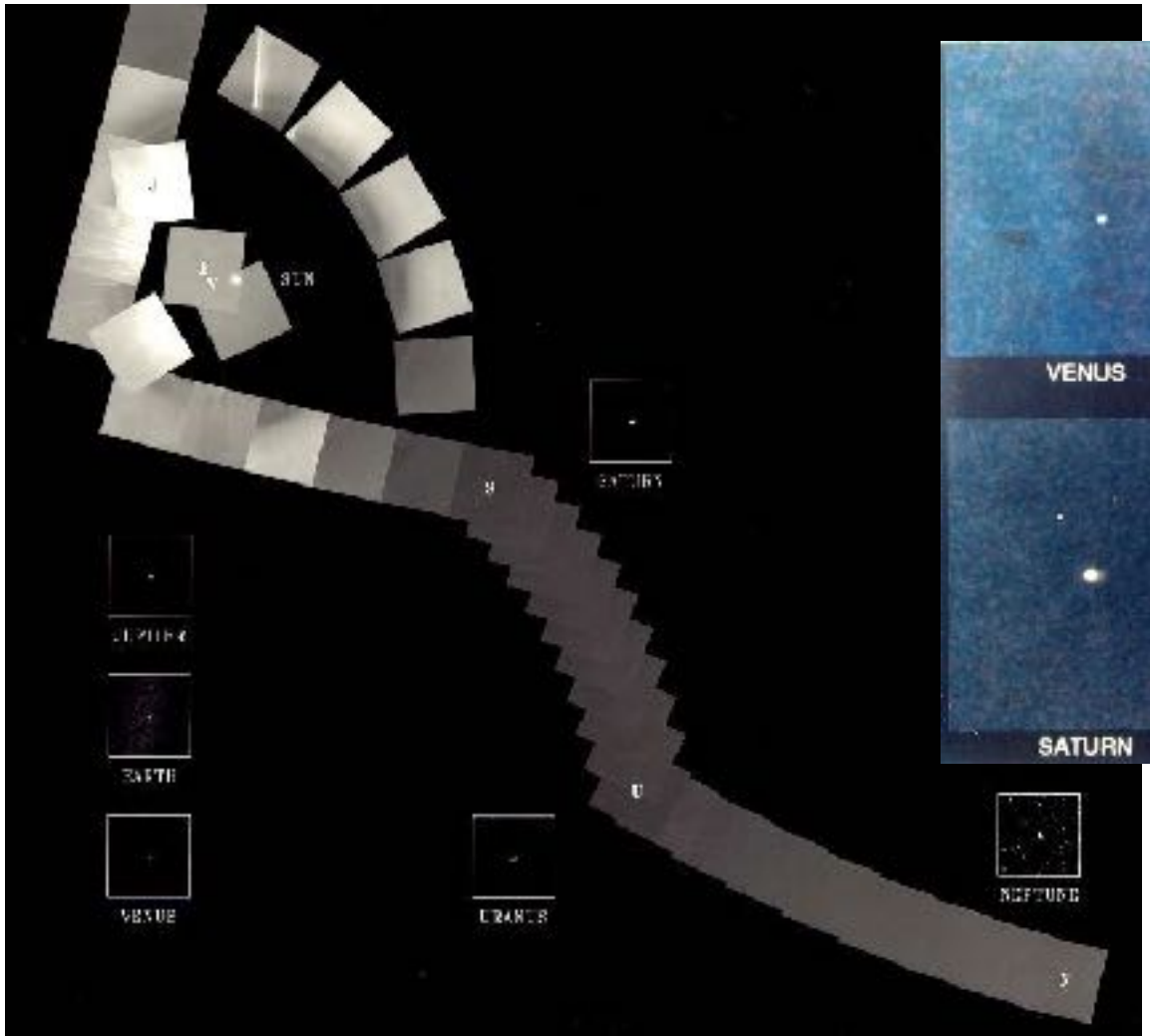
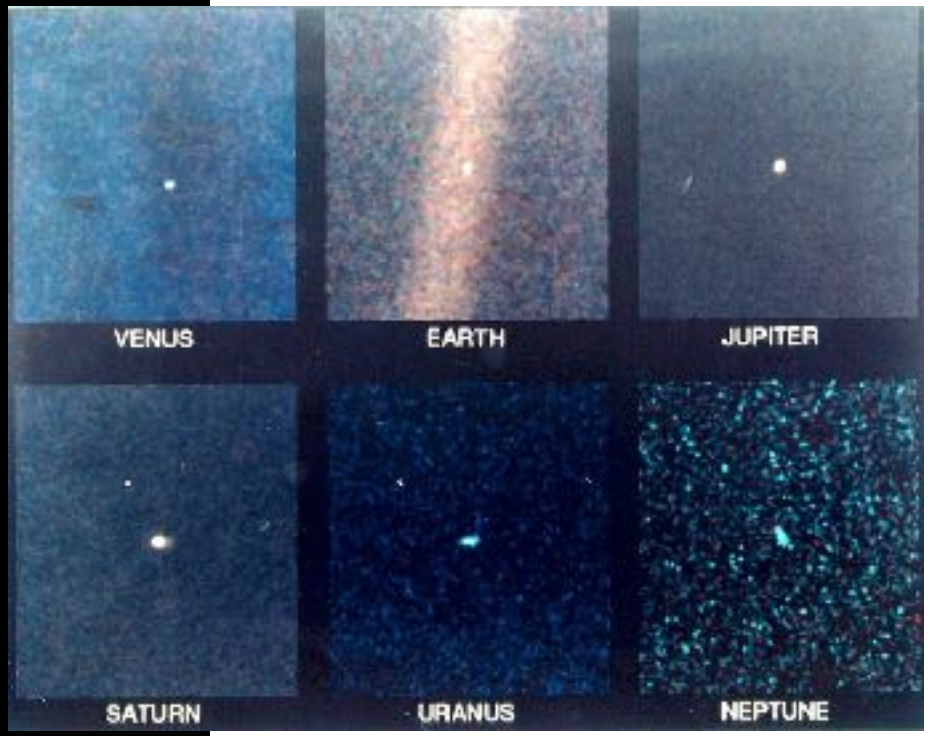
Finding exoplanets





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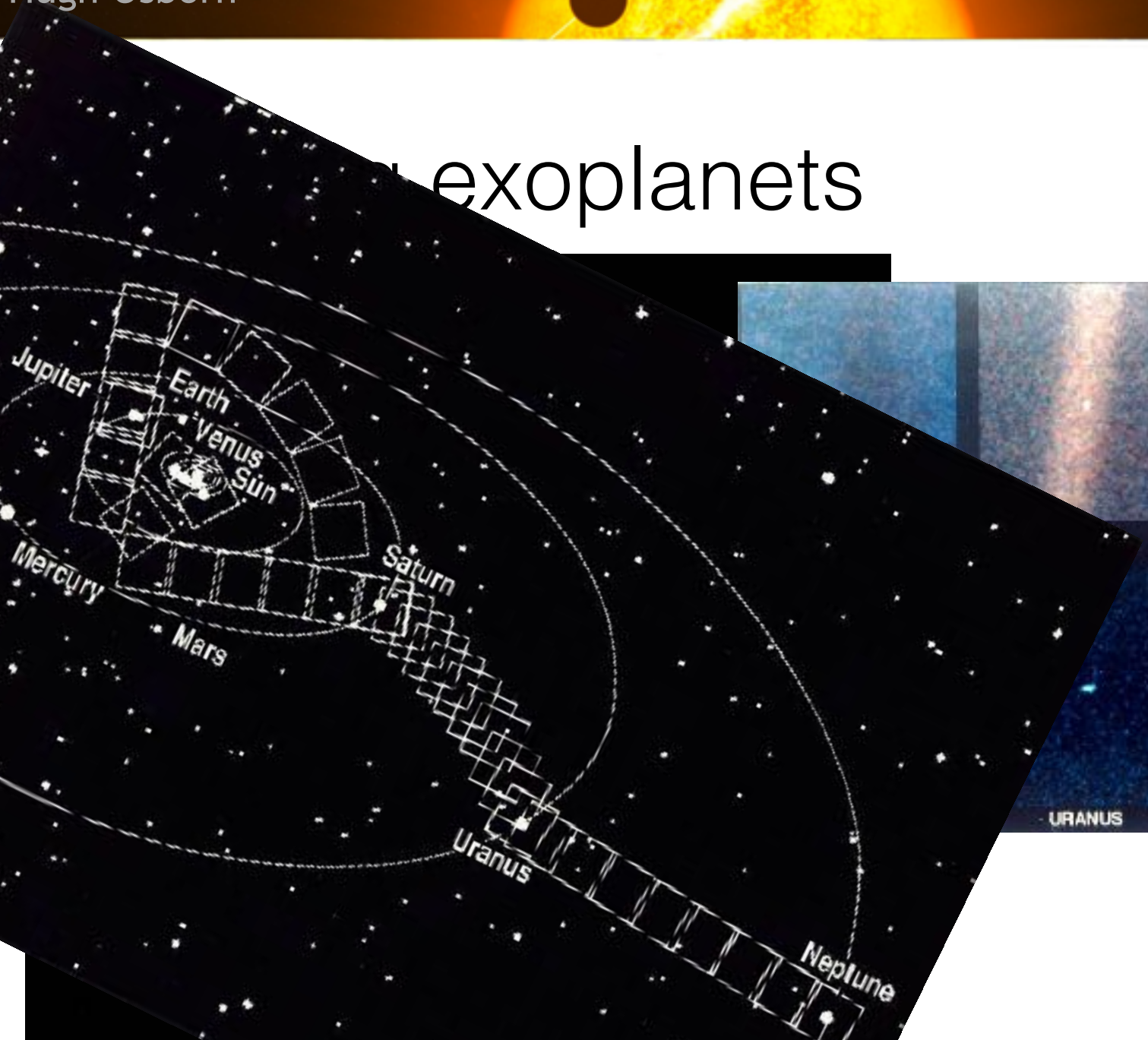
exoplanets




So how can we find planets at all?

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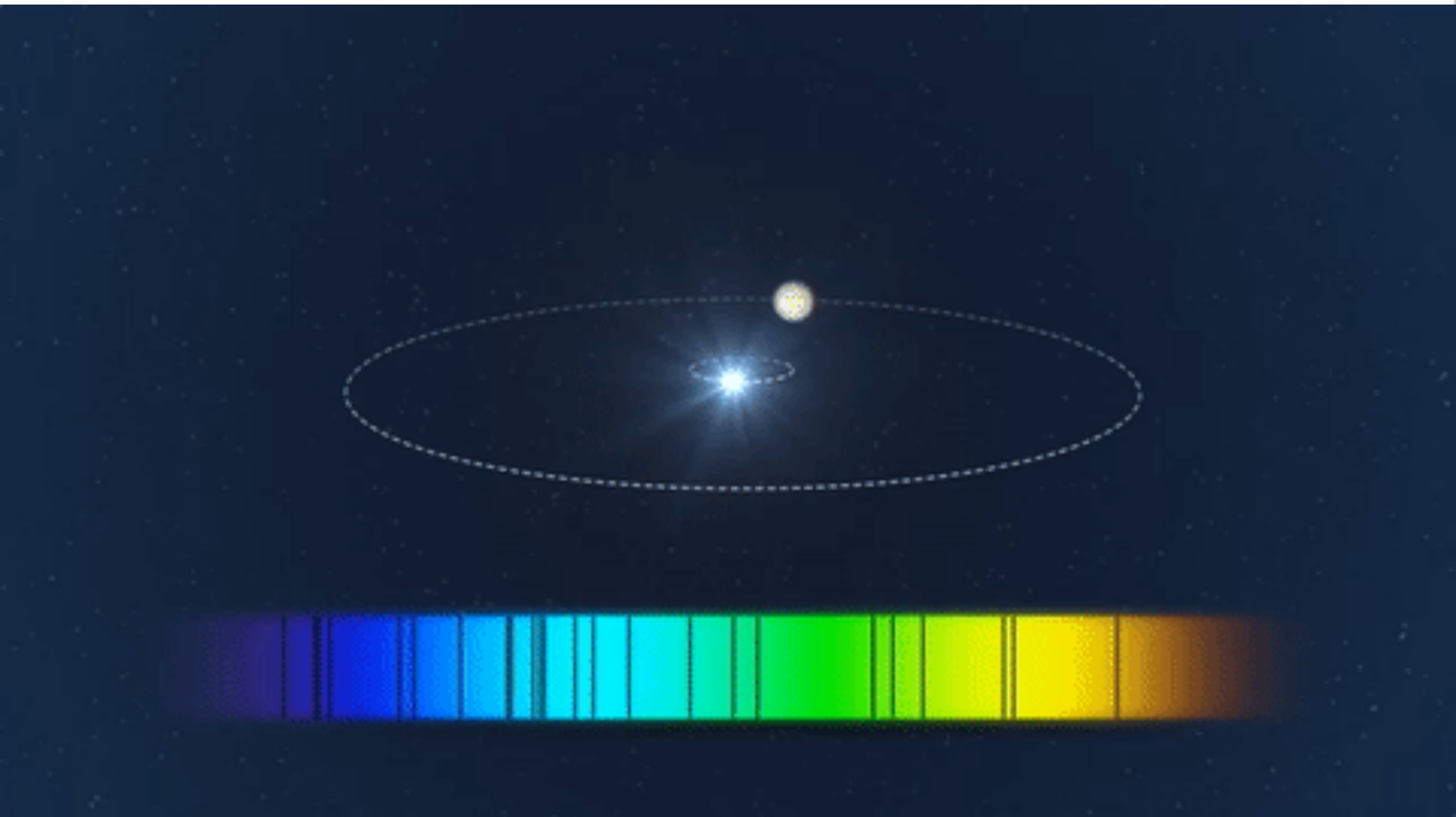
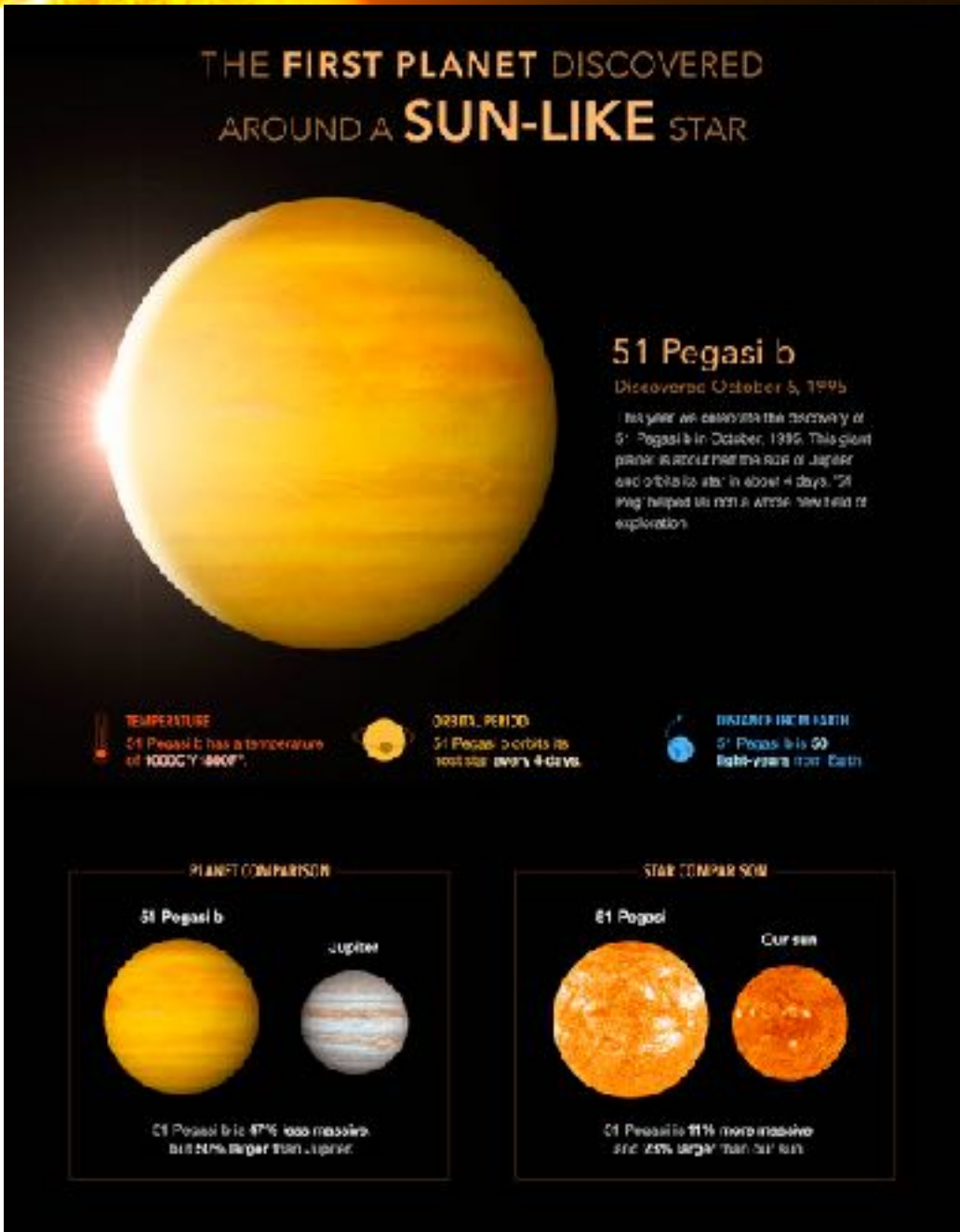
Radial Velocity

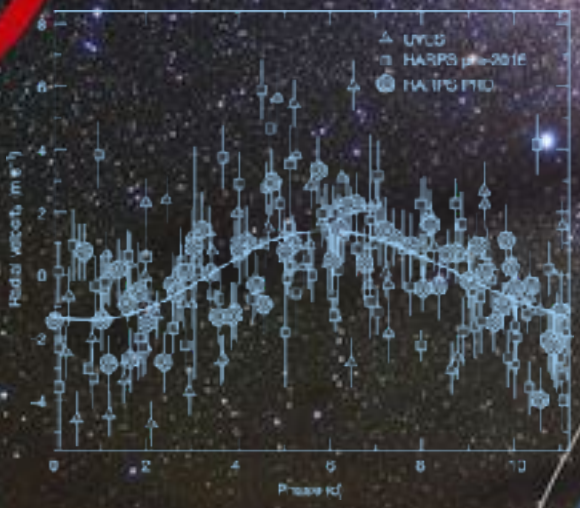


Radial Velocity

- First exoplanet – 51 Pegasi b found in 1995
- “Hot Jupiter” class
- 4 day orbit
- 0.5 Jupiter mass



PALE RED DOT



6 LIGHT YEARS

4 LIGHT YEARS

2 LIGHT YEARS

ALPHA CENTAURI A

PROXIMA CENTAURI

ALPHA CENTAURI B

OORT CLOUD

SUN

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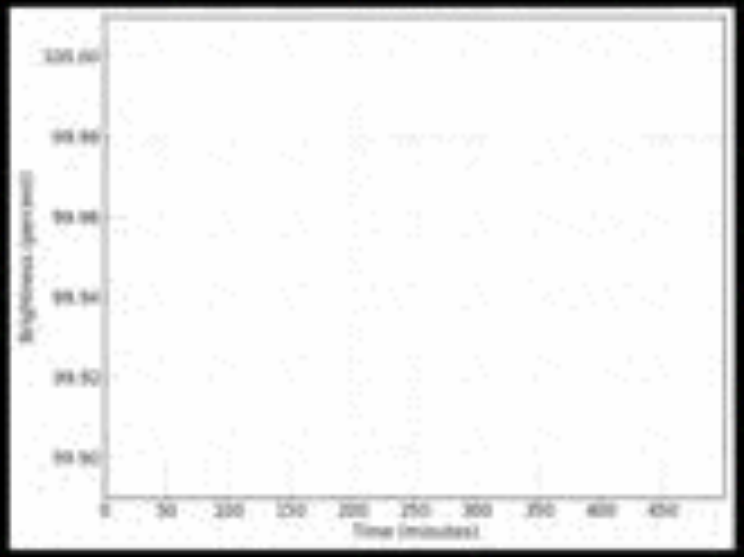
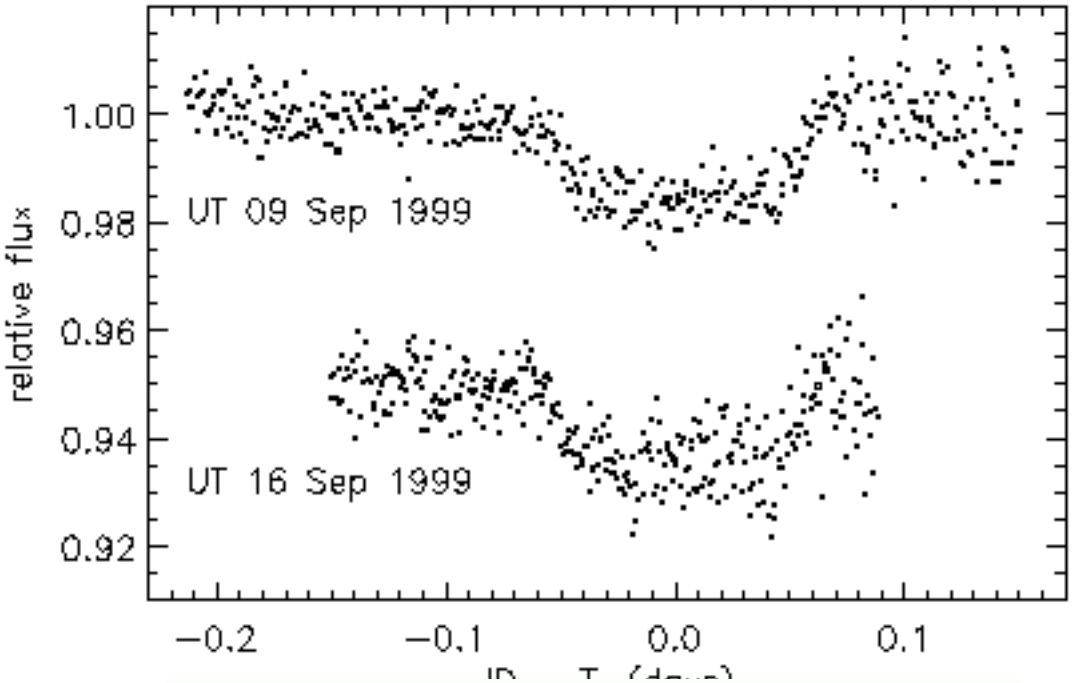
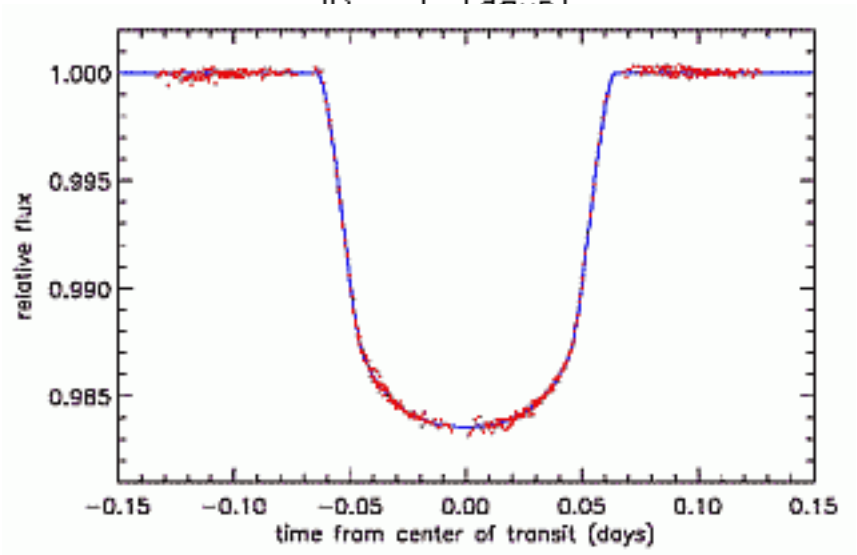
Transits



Transits

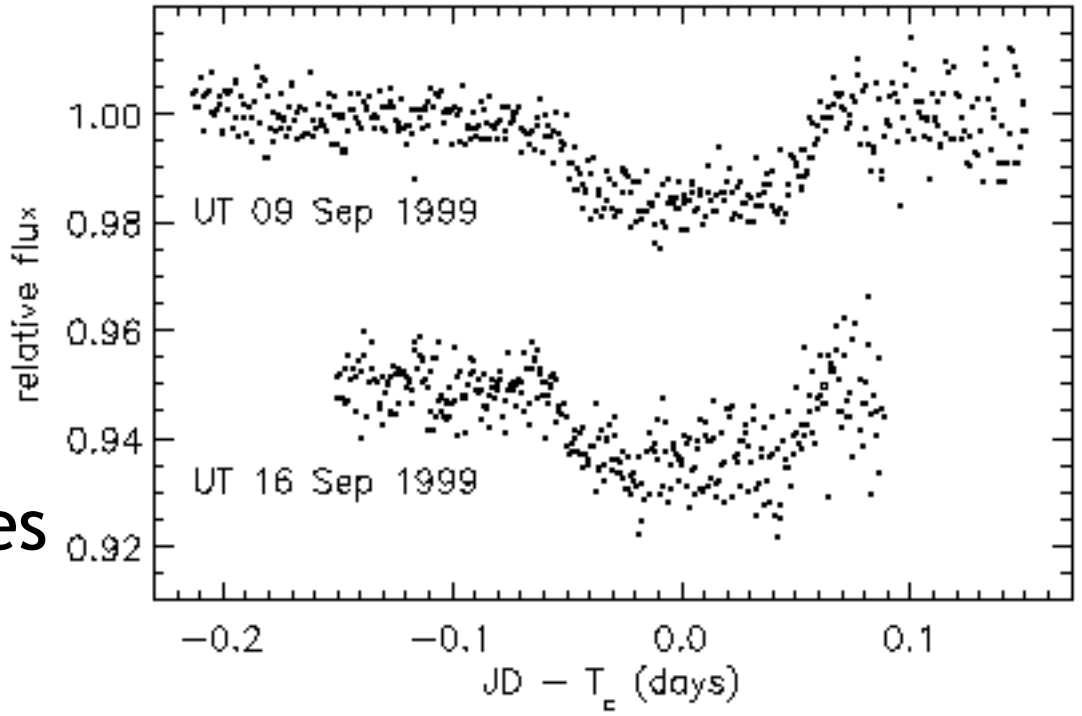
- First transiting planet: HD 209458b in 1999
- Confirmed with Hubble in 2000

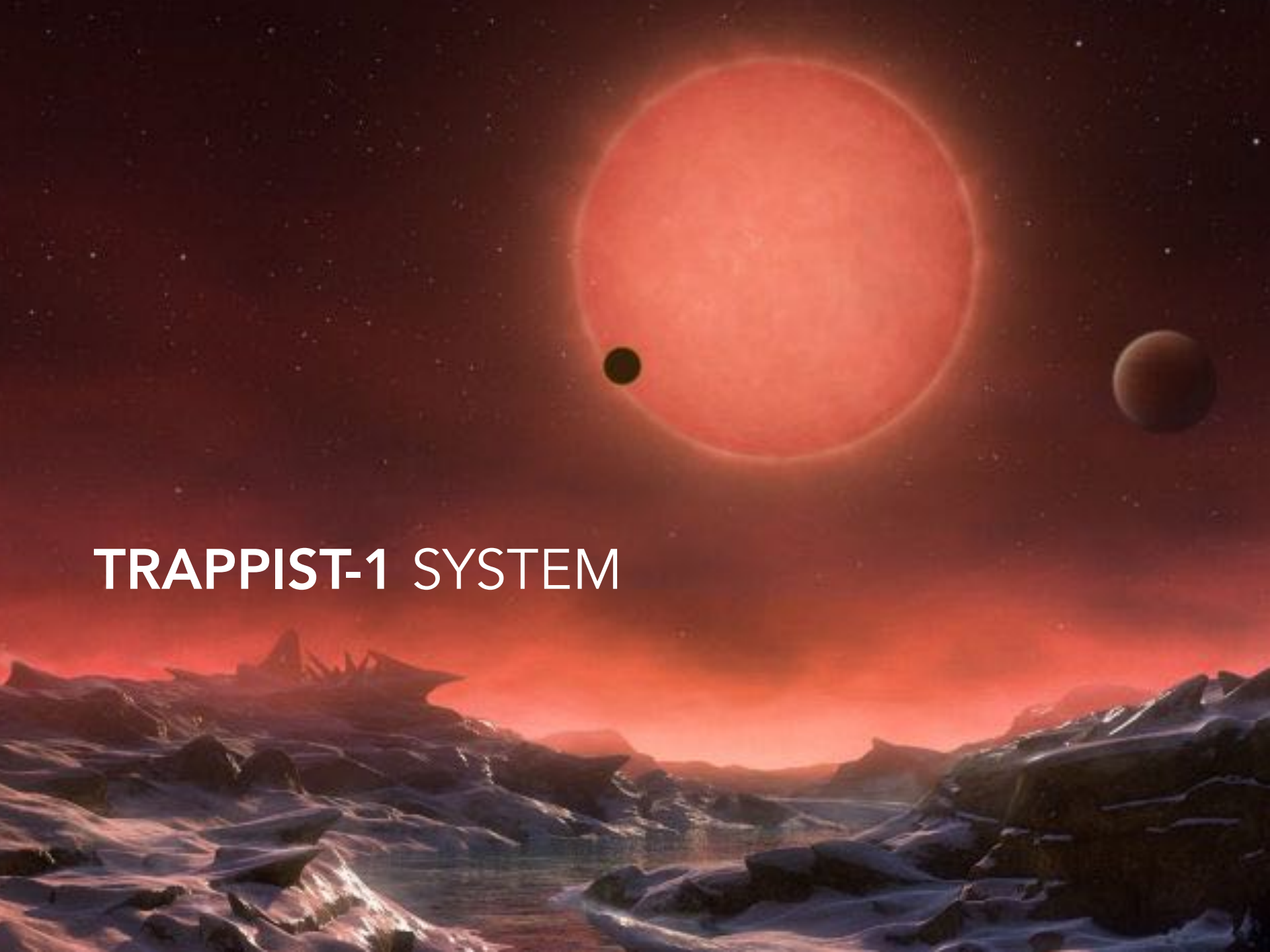




Transits

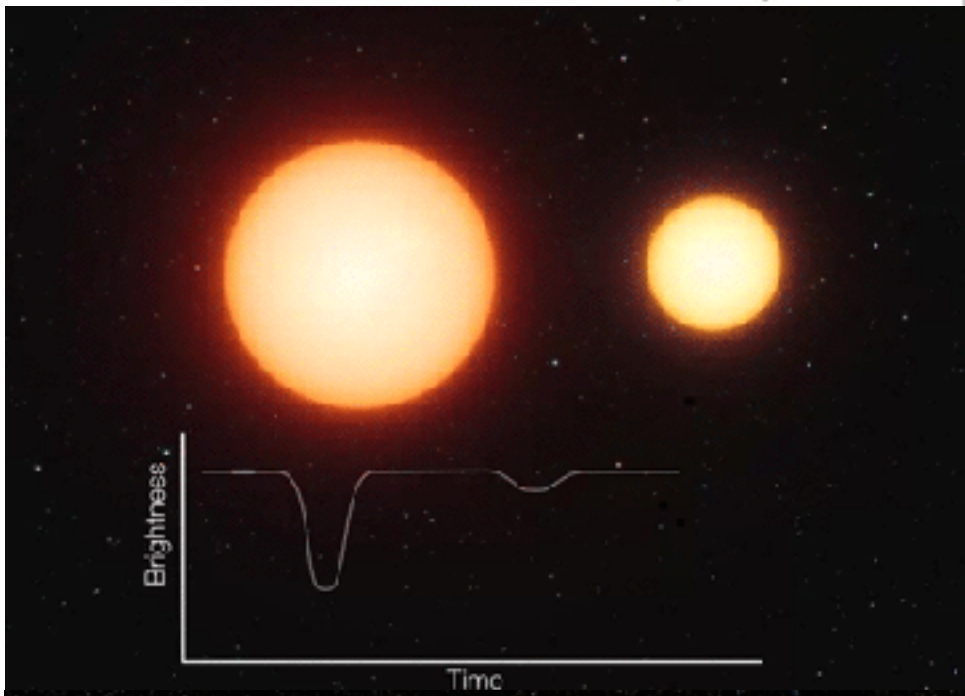
- First exoplanet surveys in ~2003
- Found 1500 candidates and ~200 planets

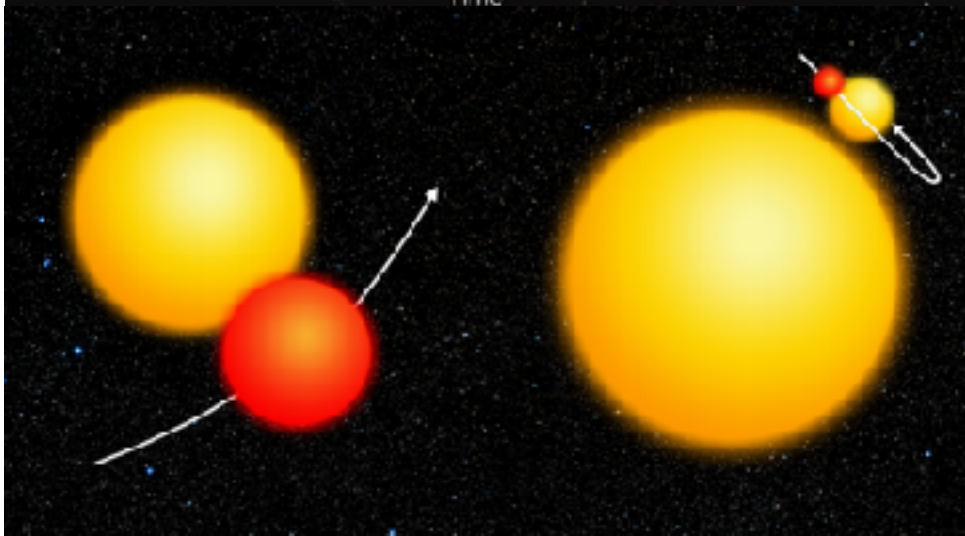



TRAPPIST-1 SYSTEM

Transits

- >80% of transit signals from ground-based surveys are imposters
- Eclipsing binaries more likely
- Need to confirm with Radial Velocities





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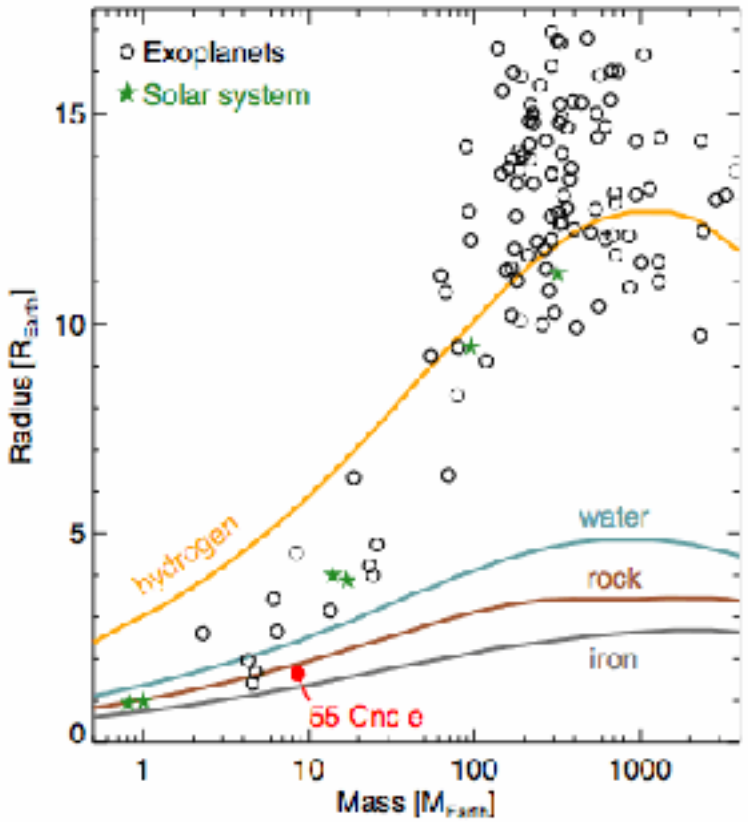
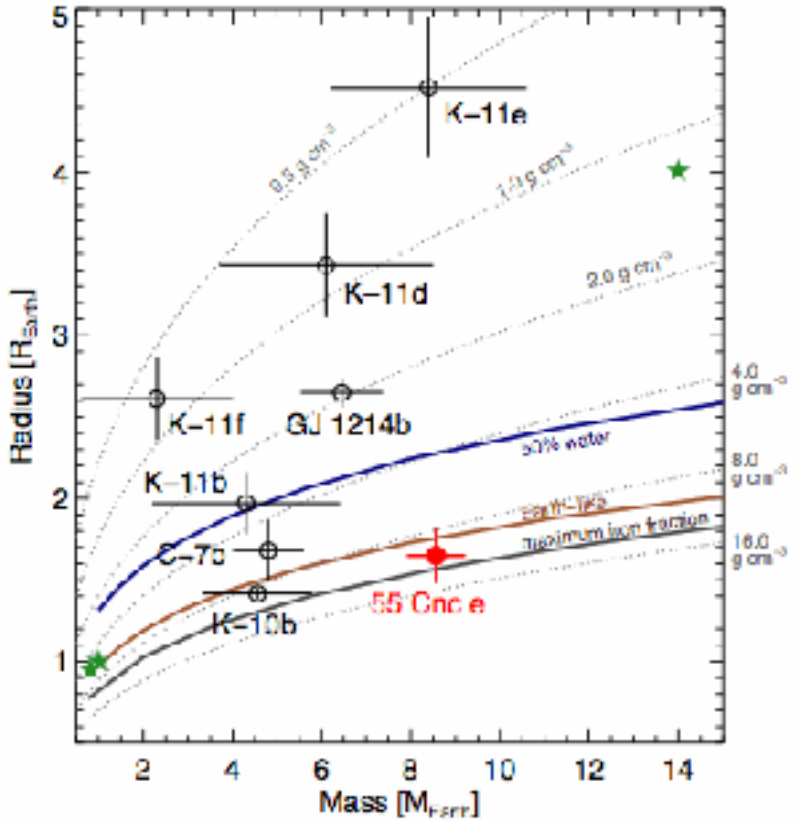
Transits = Densities

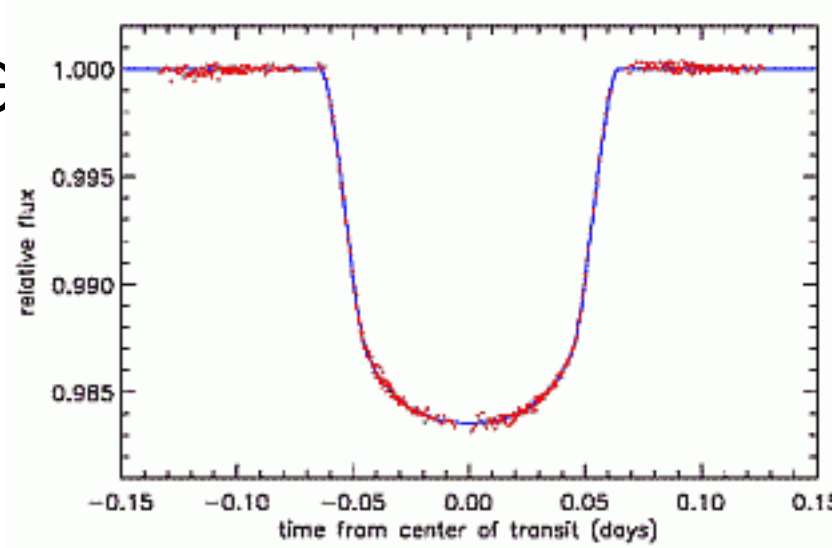
- RVs (mass) + Transit (Radius) = Density

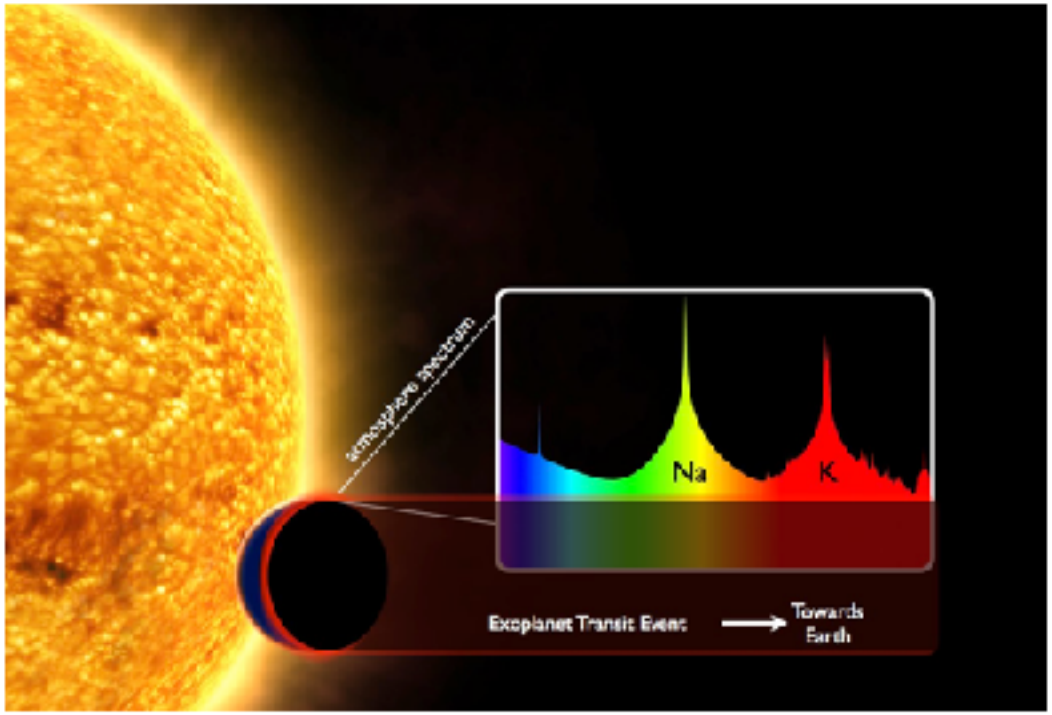


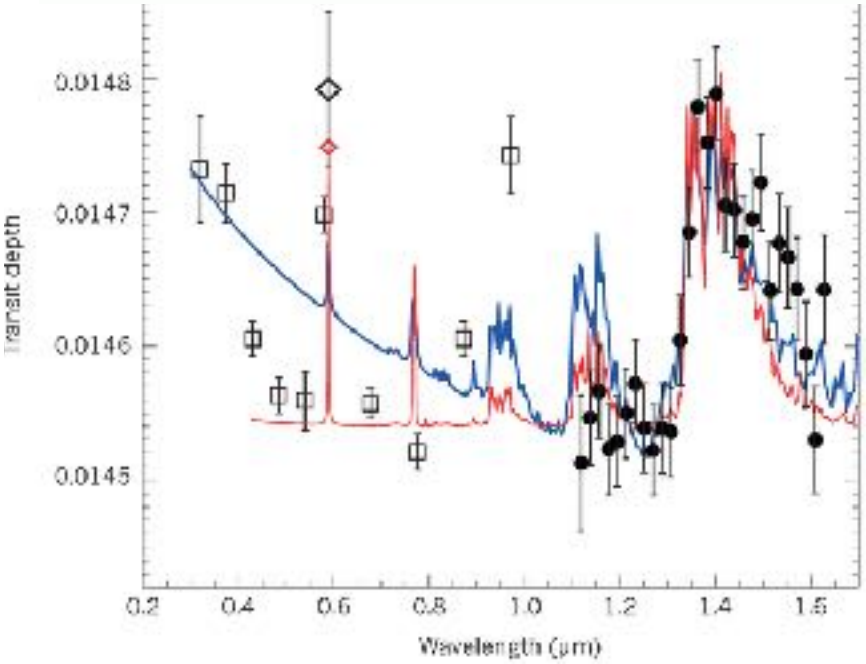


Transits = Atmosphere

- Signal of planetary atmosphere imprinted in starlight during transit







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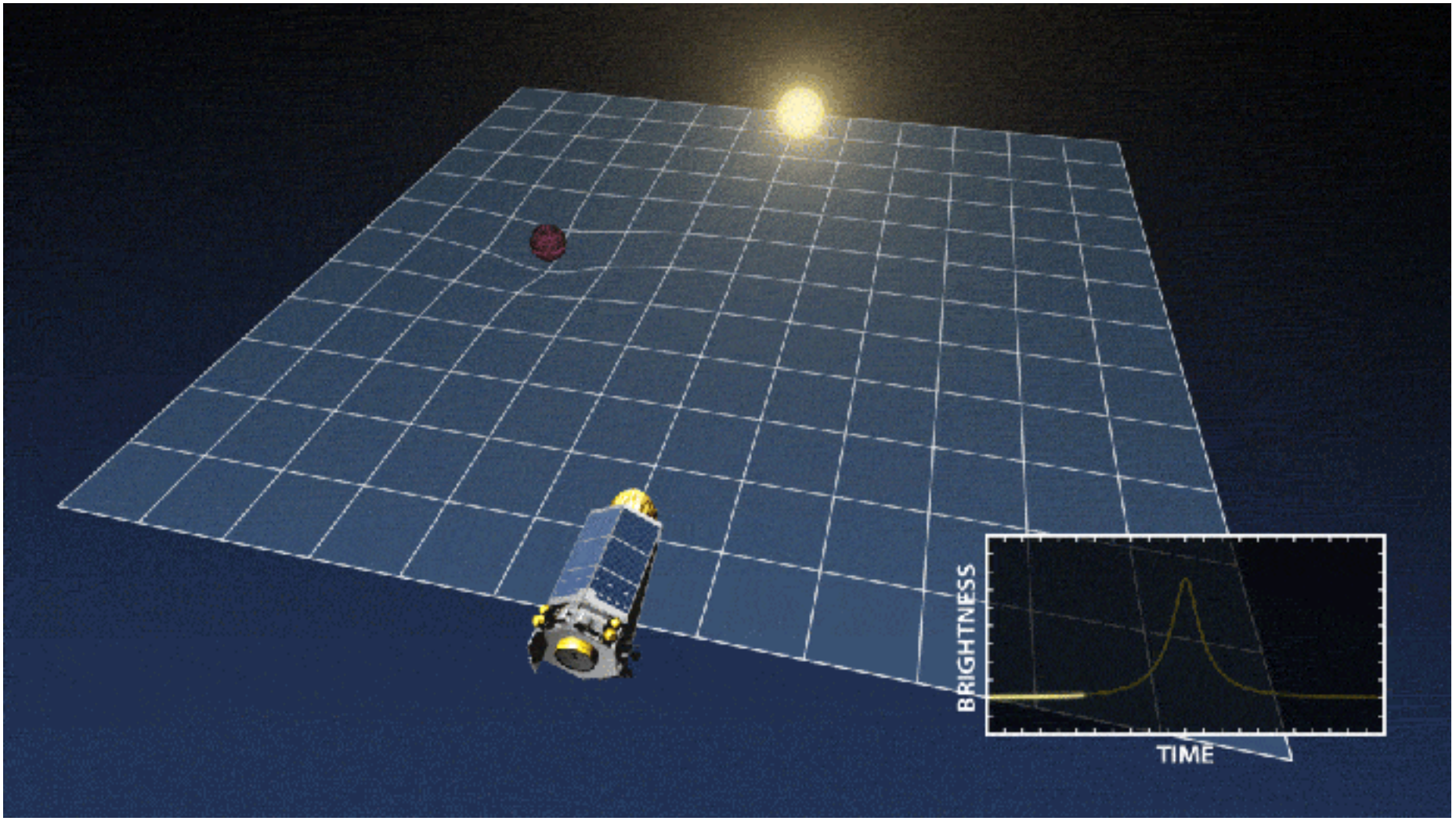
Microlensing



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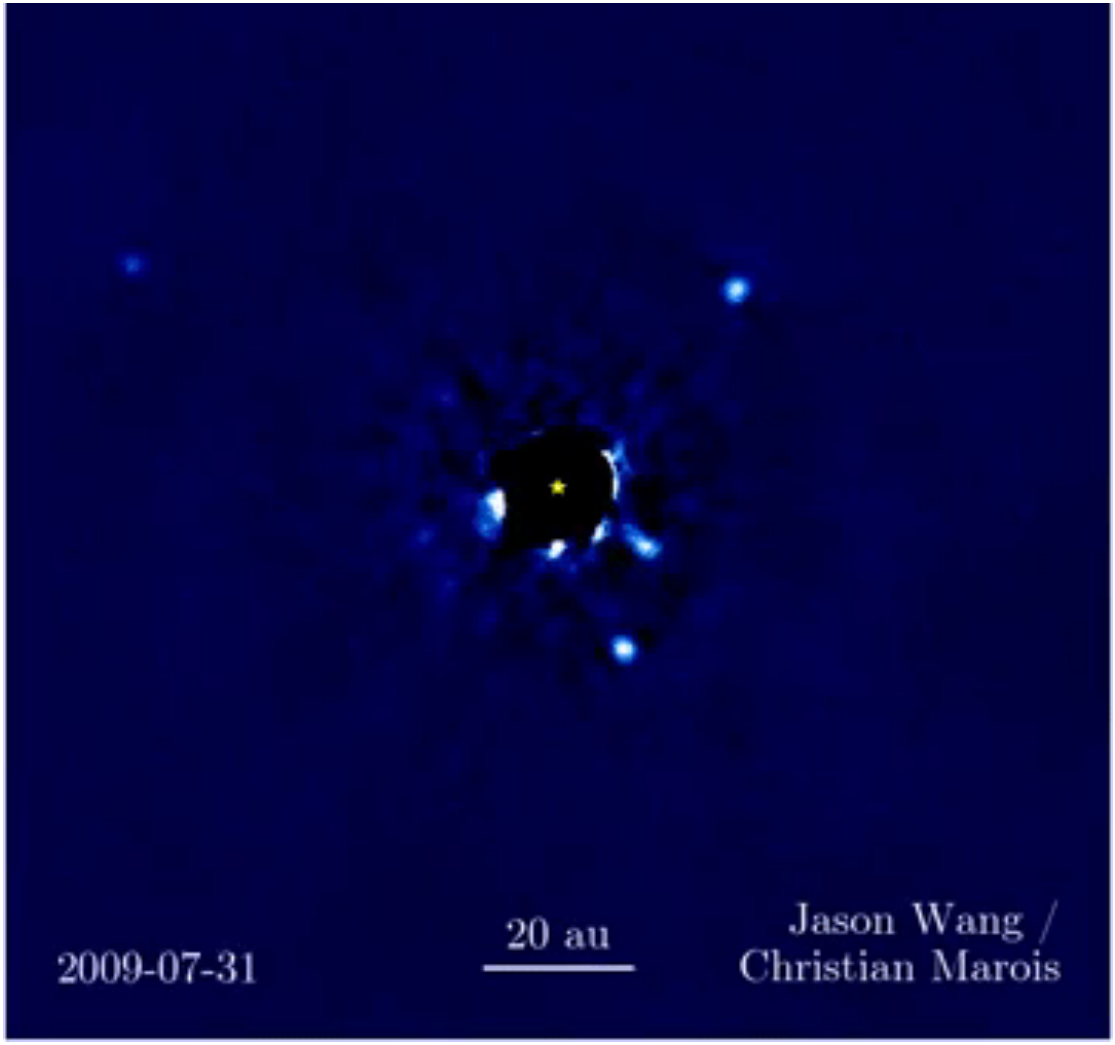
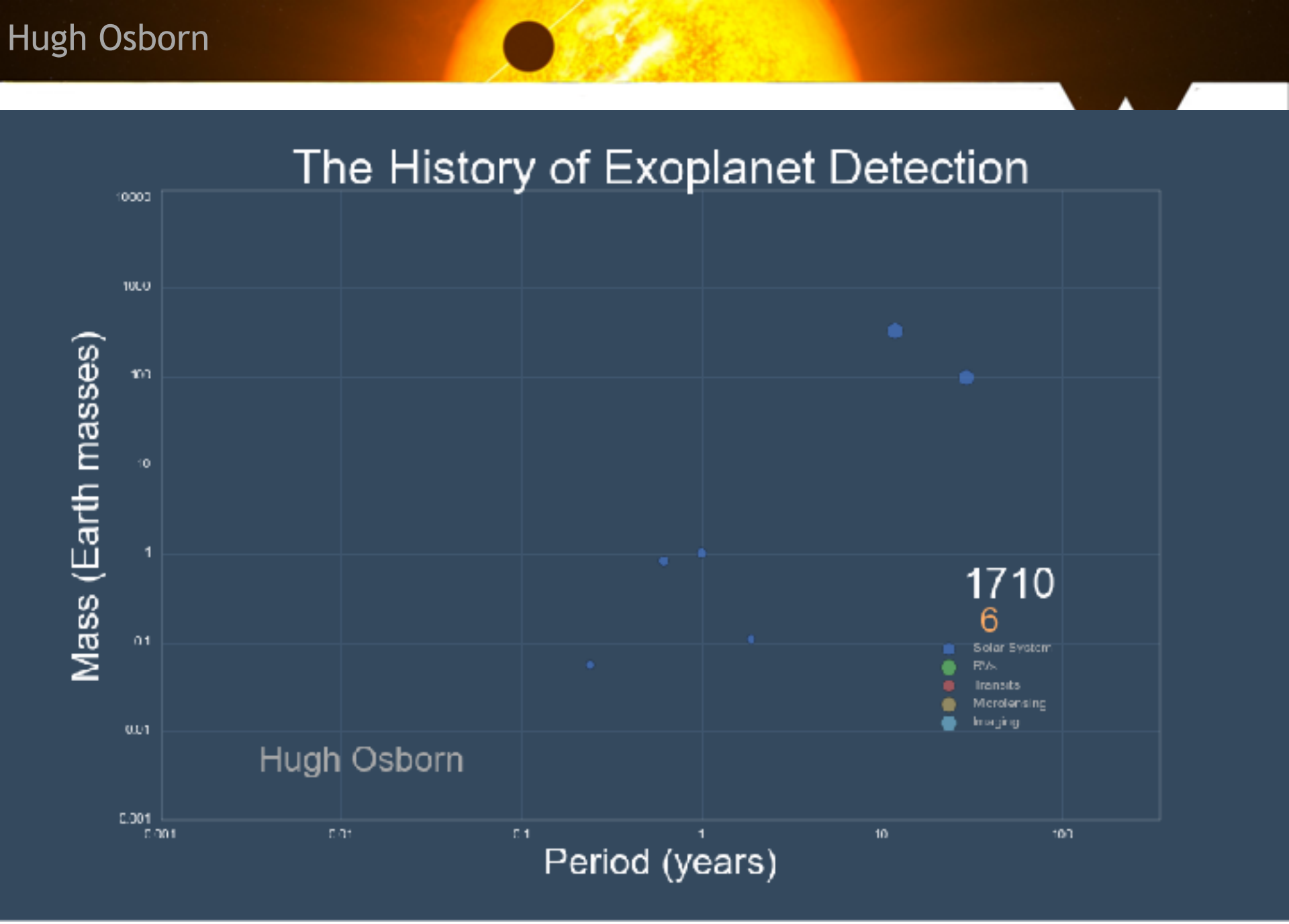
Direct Imaging

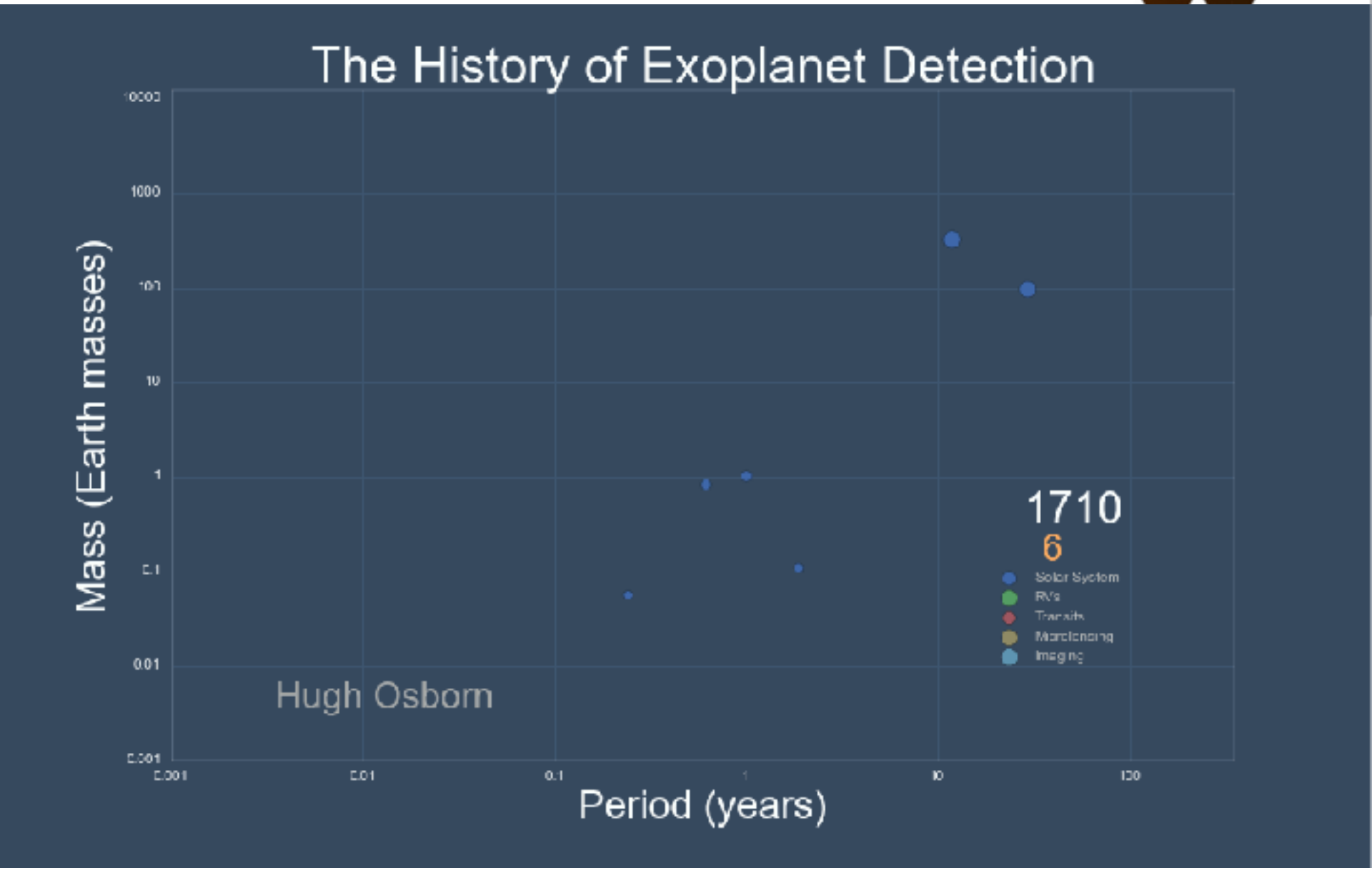
Sphere at the



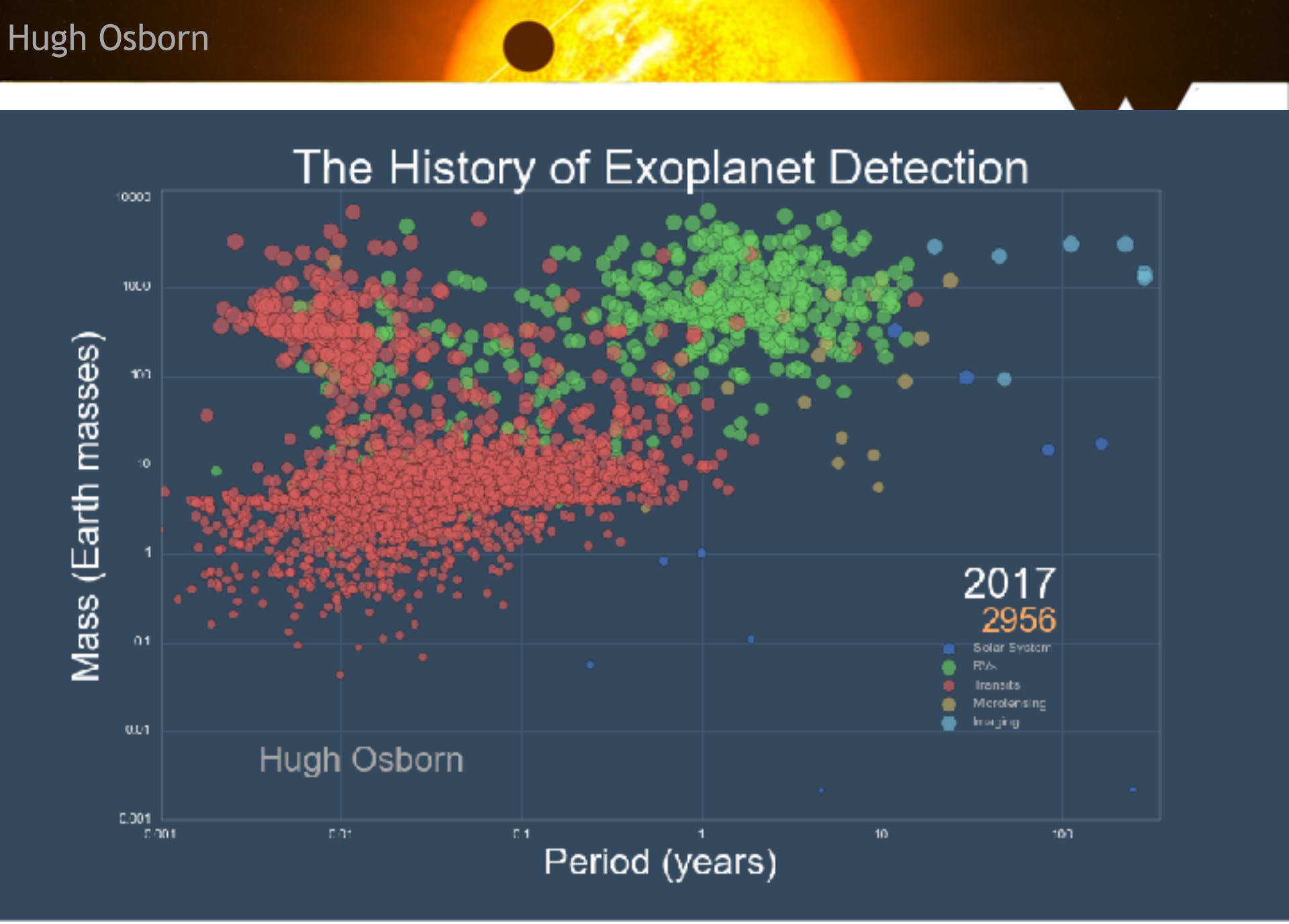
Hugh Osborn


The History of Exoplanet Detection
Mass (Earth masses)
Period (years)
1710
6
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn

Hugh Osborn


The History of Exoplanet Detection
Mass (Earth masses)
10000
1000
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10
100
Period (years)
1710
6
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn

Hugh Osborn


The History of Exoplanet Detection
Mass (Earth masses)
Period (years)
2017
2956
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn

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Kepler

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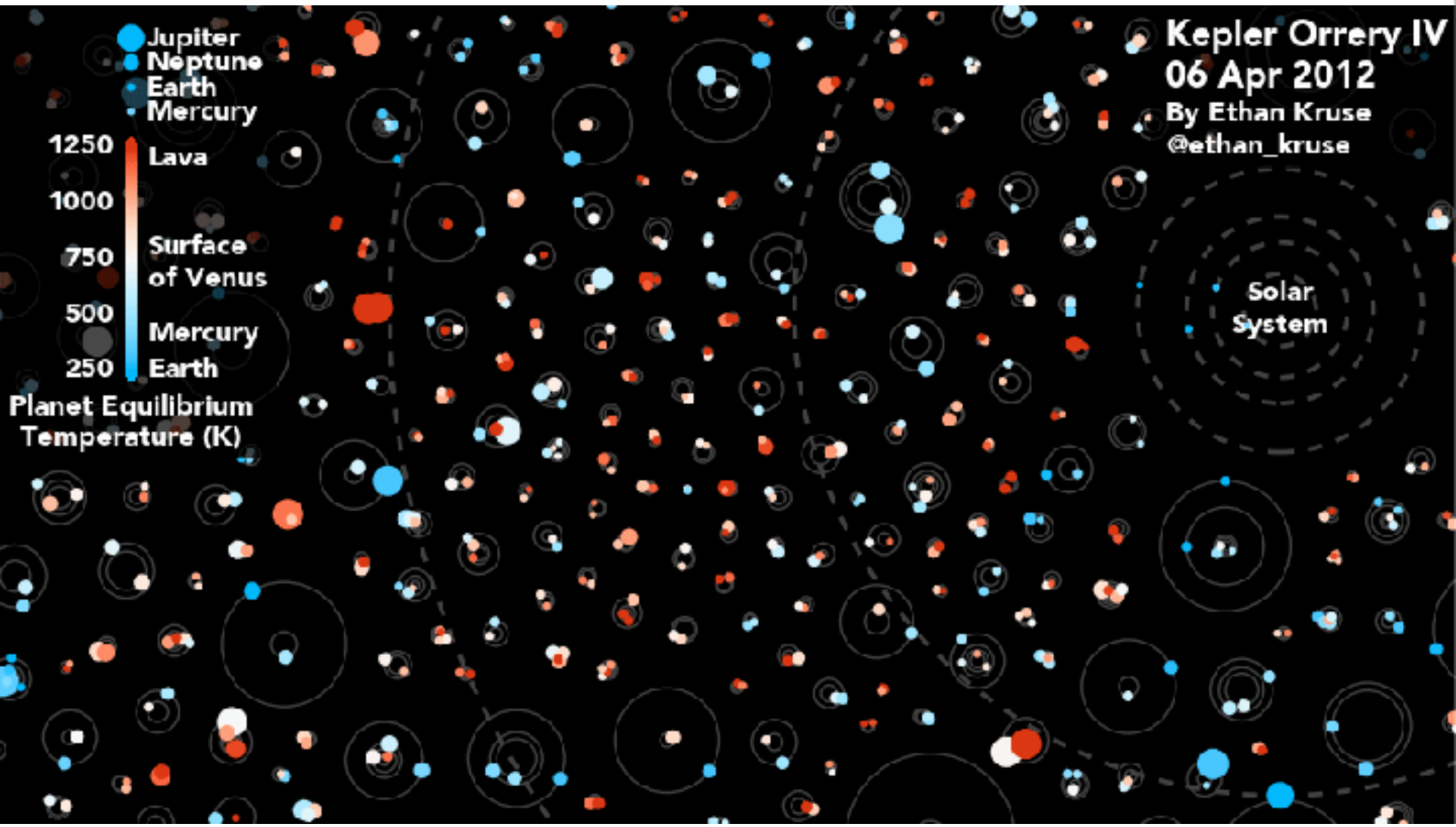
Jupiter
Neptune
Earth
Mercury
1250
Lava
1000
750
Surface of Venus
500
Mercury
250
Earth
Planet Equilibrium Temperature (K)
Kepler Orrery IV
06 Apr 2012
By Ethan Kruse
@ethan_kruse
Solar System

Kepler Highlights

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- Kepler-37b: the smallest exoplanet ever found

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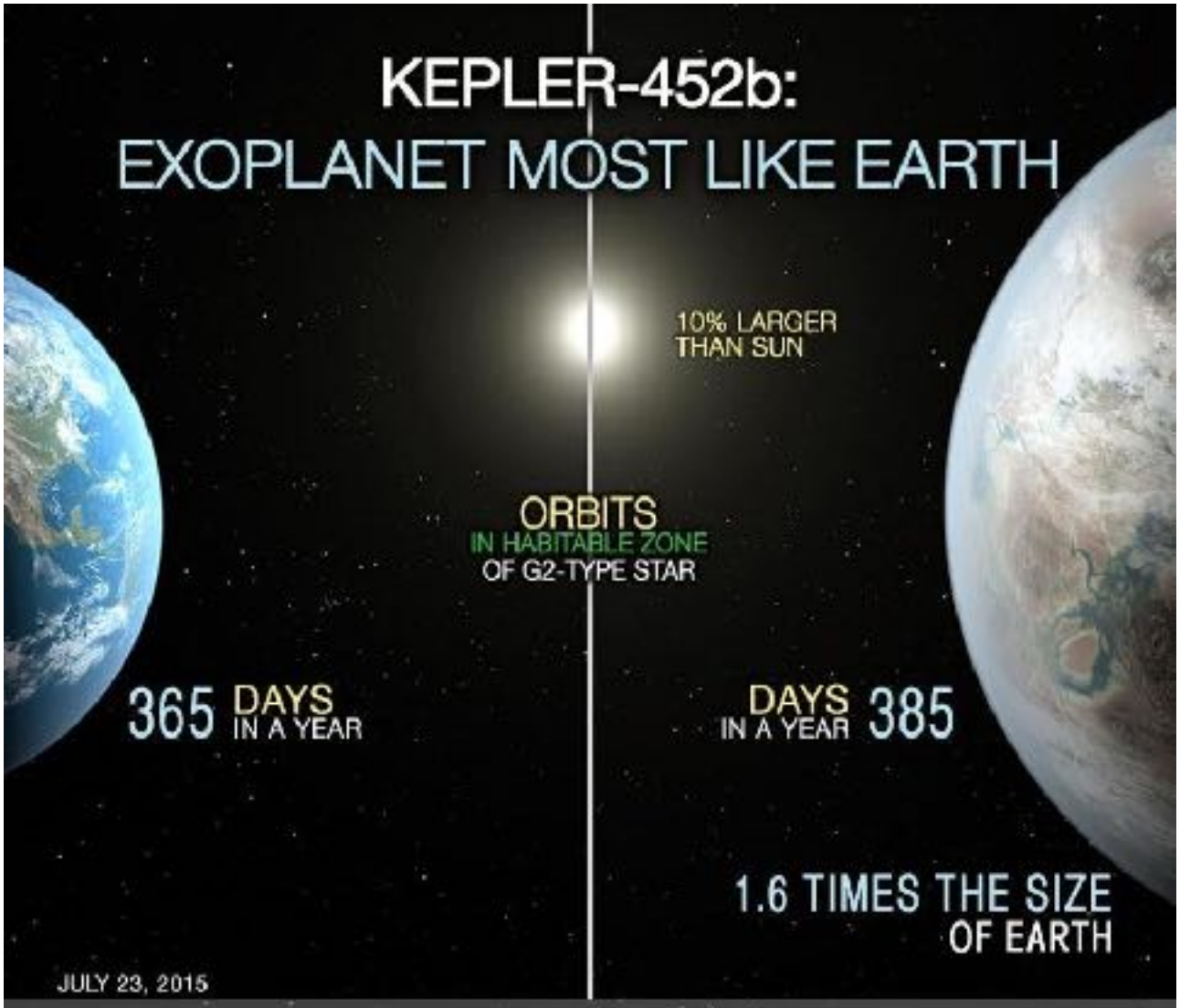
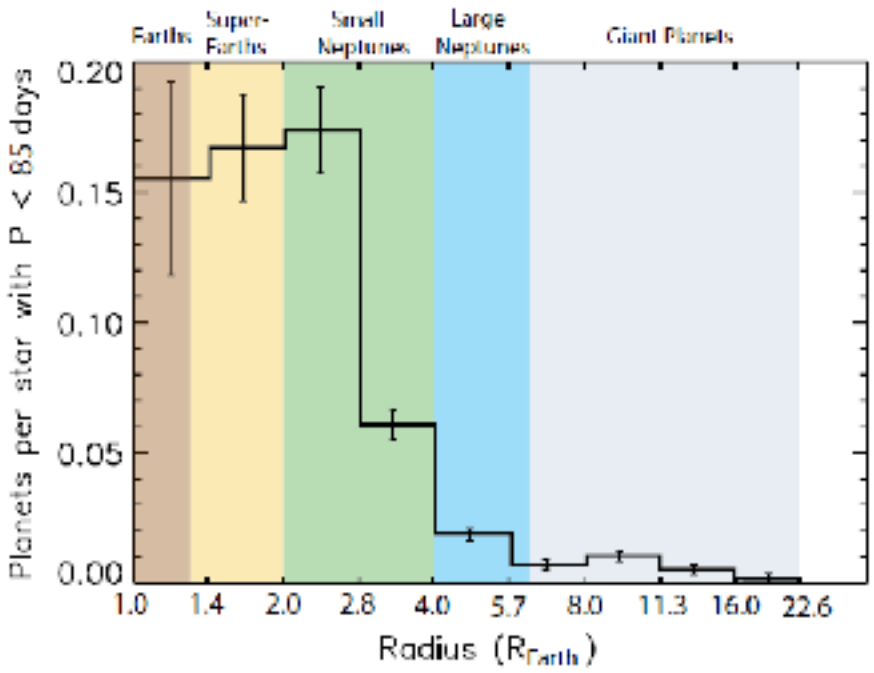
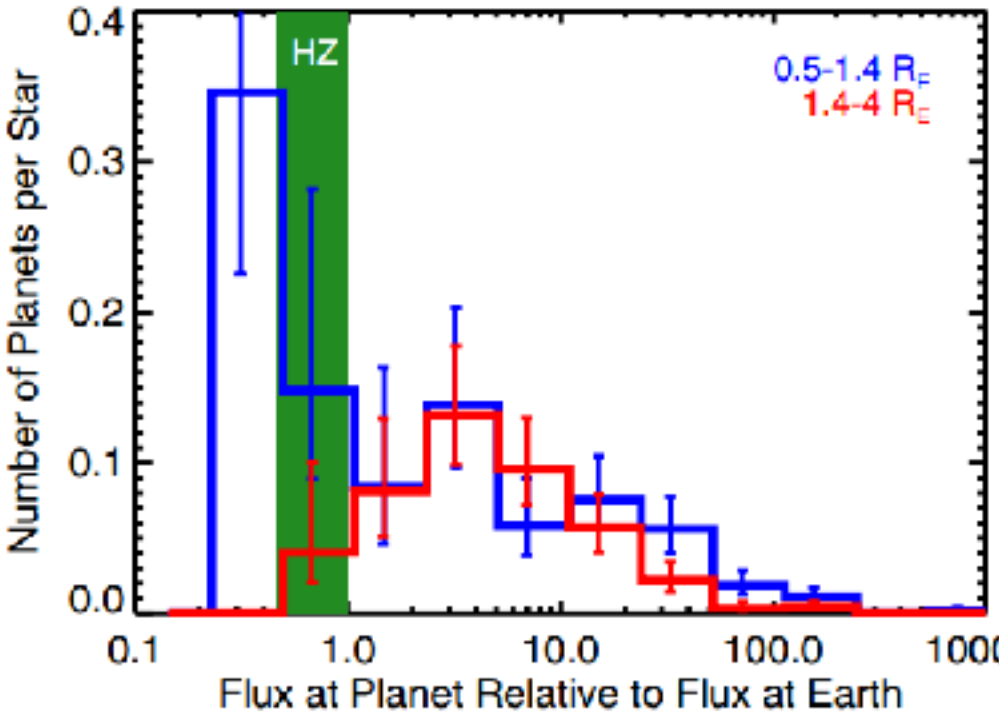

KEPLER-452b:
EXOPLANET MOST LIKE EARTH
10% LARGER
THAN SUN
ORBITS
IN HABITABLE ZONE
OF G2-TYPE STAR
365 DAYS
IN A YEAR
DAYS
IN A YEAR 385
1.6 TIMES THE SIZE
OF EARTH
JULY 23, 2015

WARWICK





Earthlike planets are common

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Kepler

But…

- Most Kepler systems extremely faint (~14th magnitude).
- Cannot study atmospheres, masses, compositions, etc.

The Demise of Kepler

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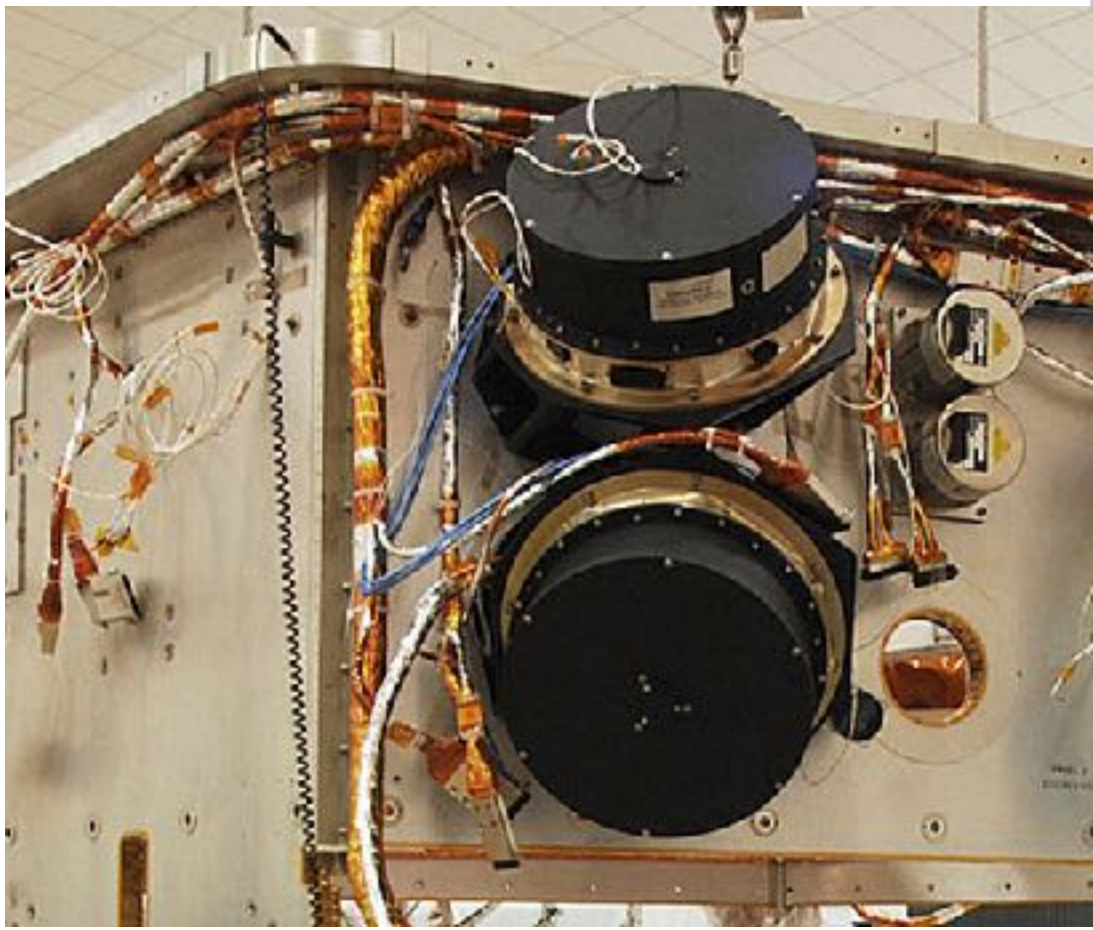
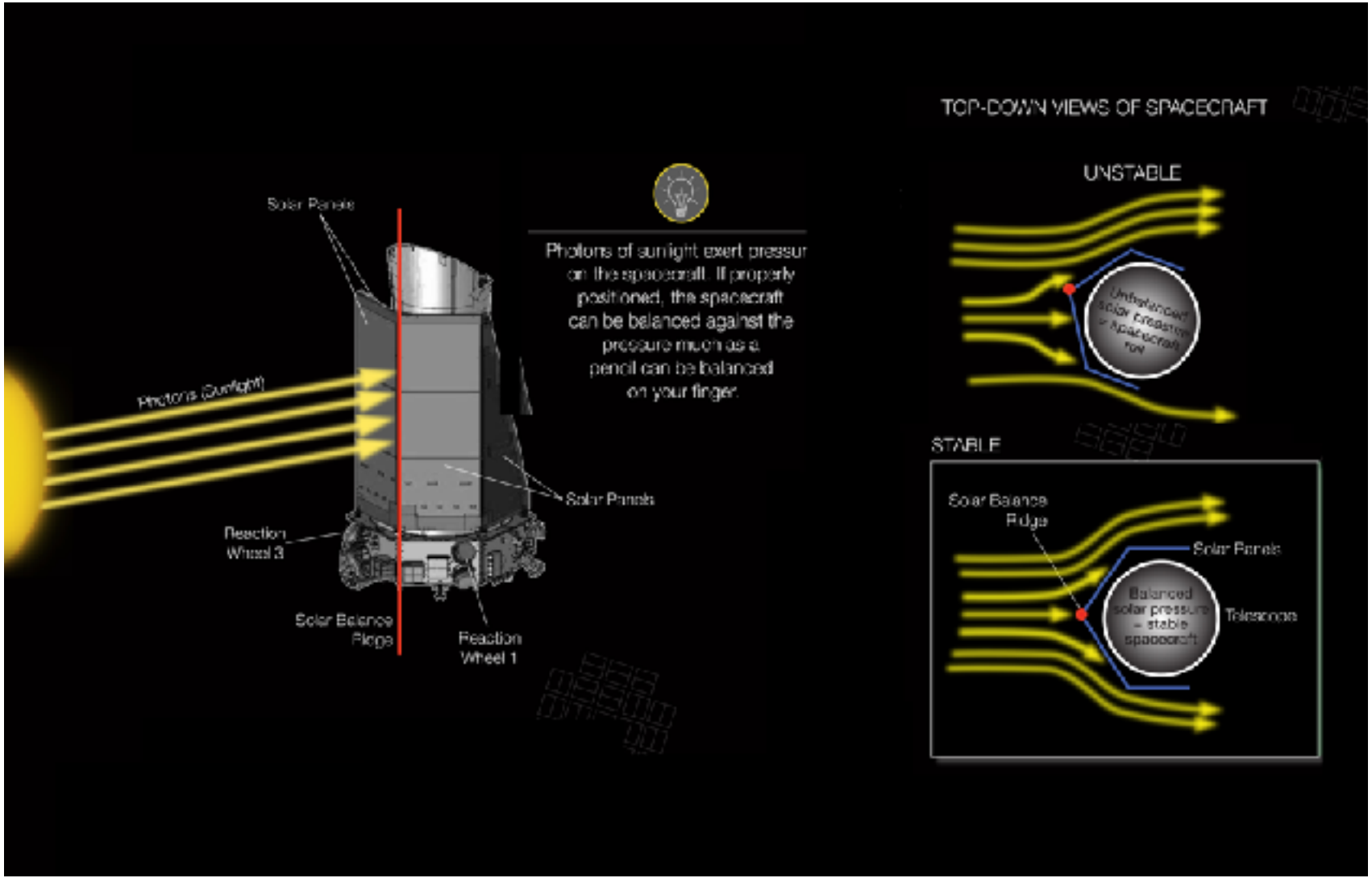
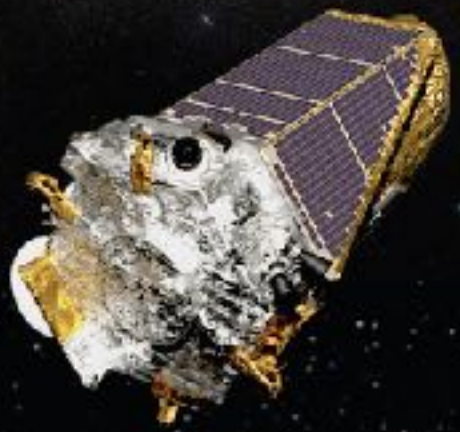


K2

WARWICK


Solar Panels
Photons (Sunlight)
Reaction Wheel 3
Solar Balance Flaps
Reaction Wheel 1
Solar Panels
Photons of sunlight exert pressur on the spacecraft. If properly positioned, the spacecraft can be balanced against the pressure much as a pencil can be balanced on your finger.
TOP-DOWN VIEWS OF SPACECRAFT
UNSTABLE
STABLE
Solar Balance Flaps
Solar Panels
Telescope

K2



- 80 days per field
- ~20,000 stars per field

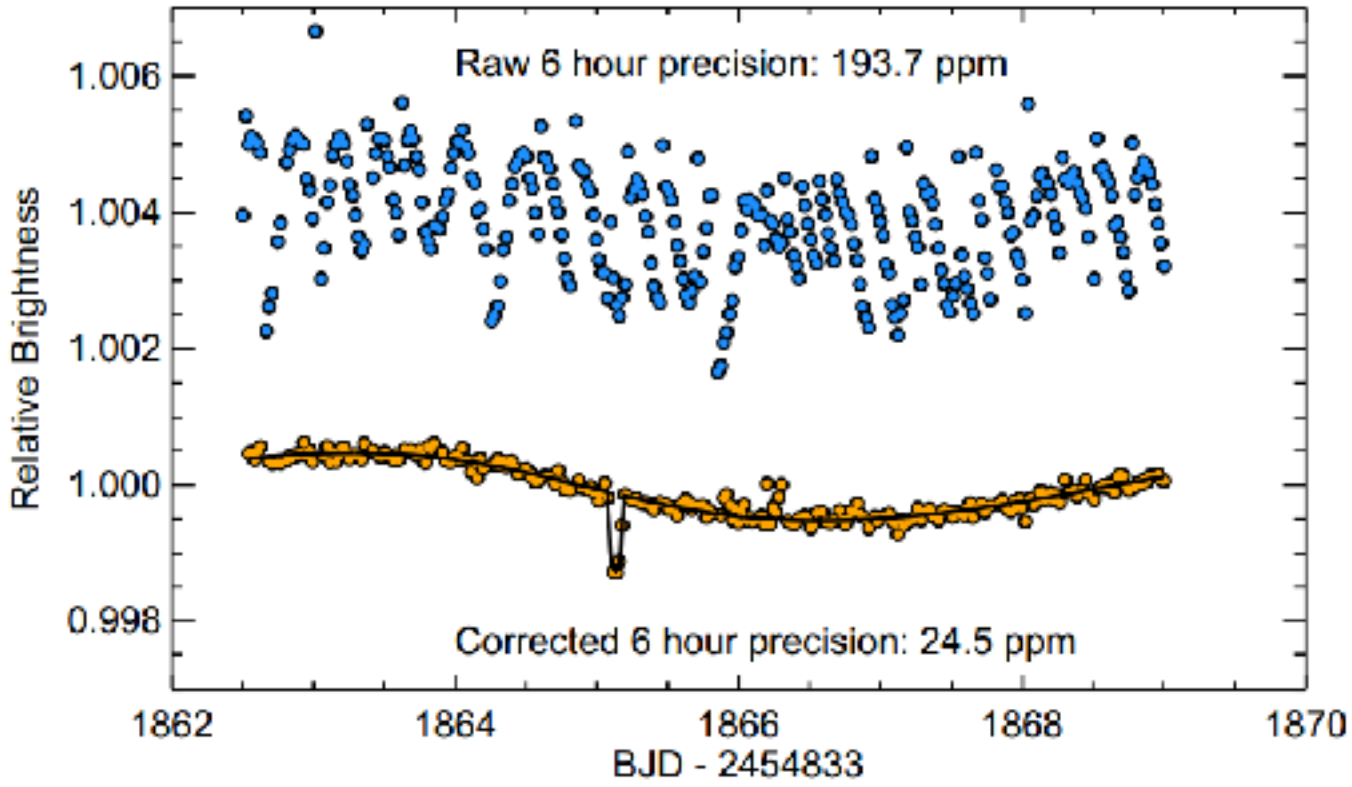
Hugh Osborn

Europe-wide collaboration
~20 people
across 7 countries

WARWICK

1) The Data

- Lightcurve detrending



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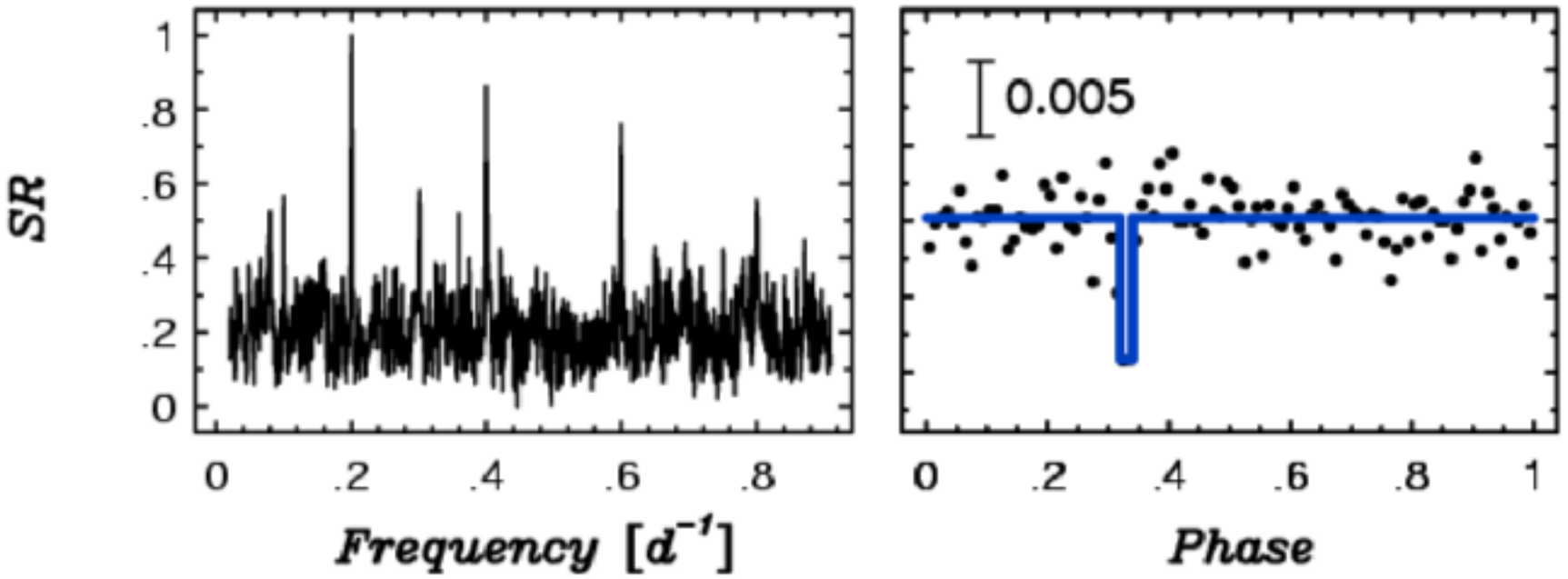
2) The Search

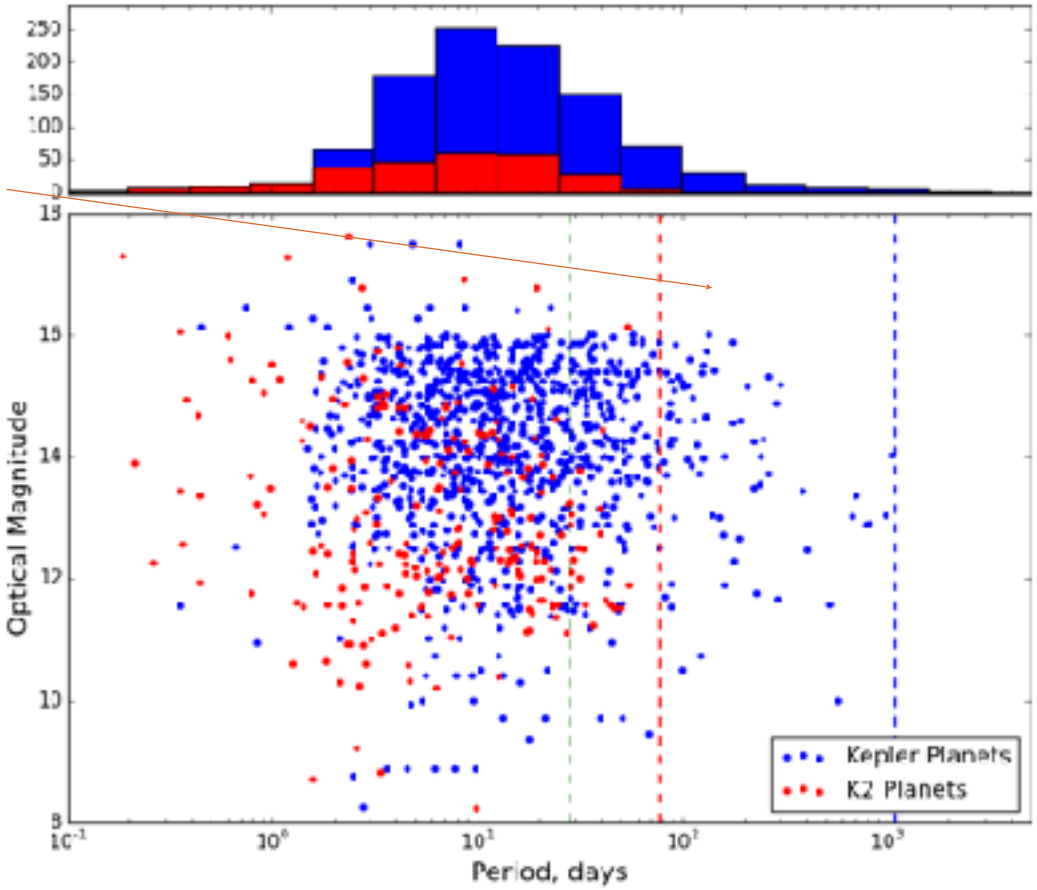
- Automated search of all lightcurves for transits
- Looks for multiple transits.



WARWICK

(Long-period planets)

- Lots of planets found by Kepler beyond 50 days
- Should detect some of these with K2



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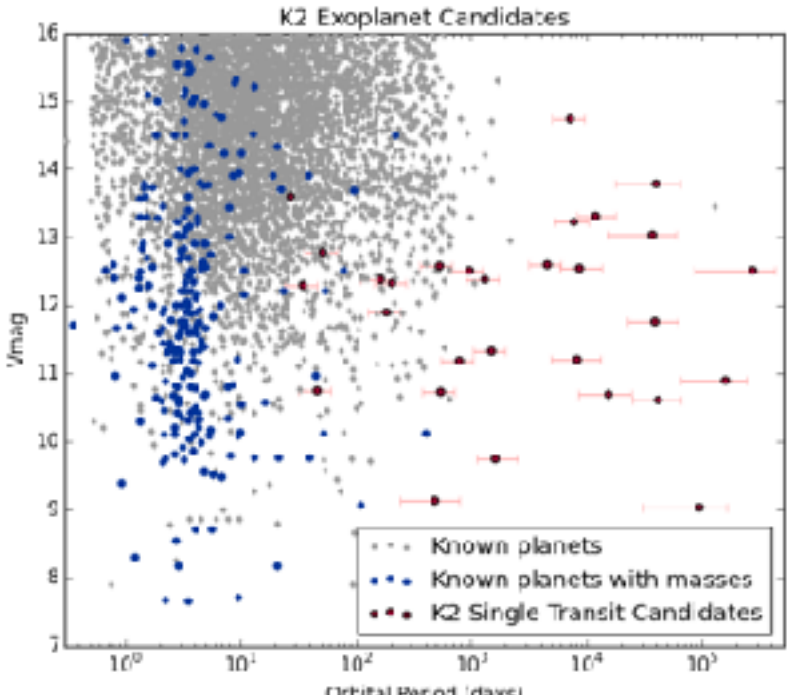
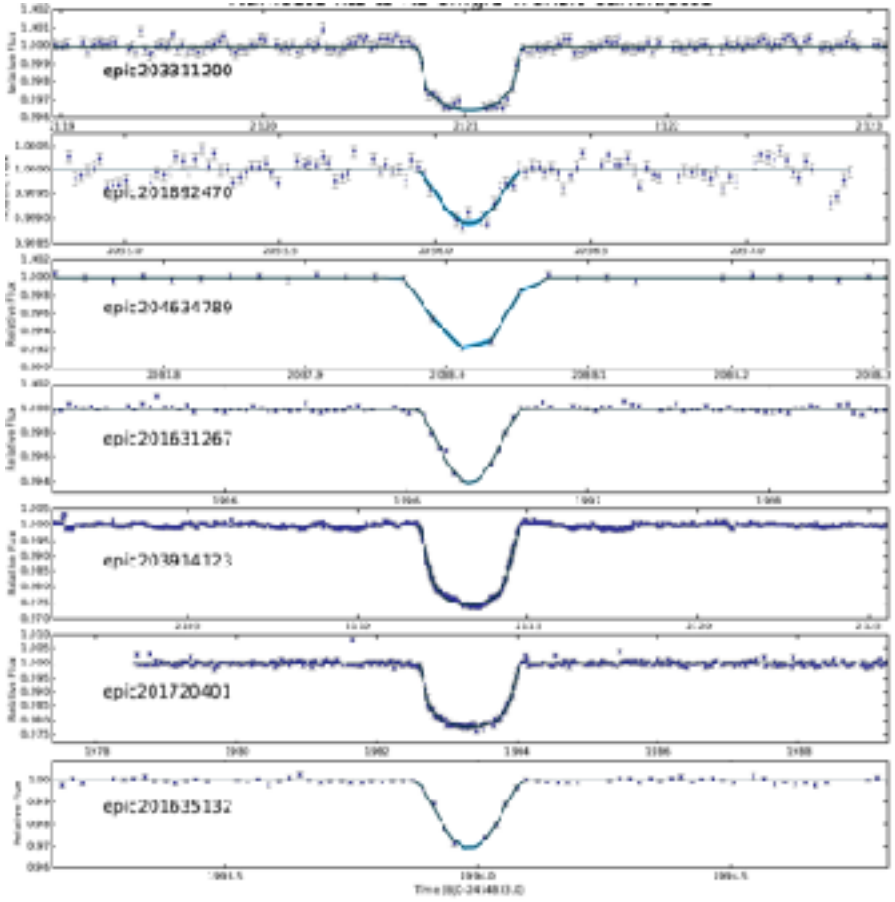
(Long-period planets)

- 40 candidate planets on longer periods

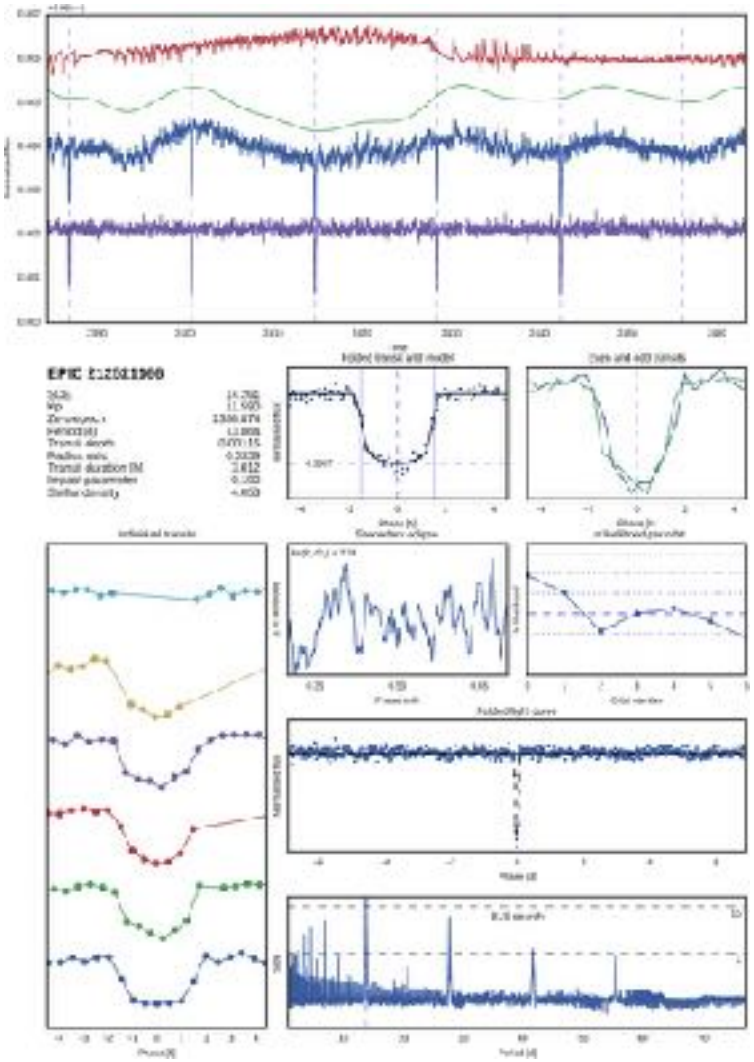




WARWICK

3) The Candidates

- Look at the candidates by eye.
- Discard false positives
- Rank and send best ones on to follow-up
- My job at Warwick is to run this step.



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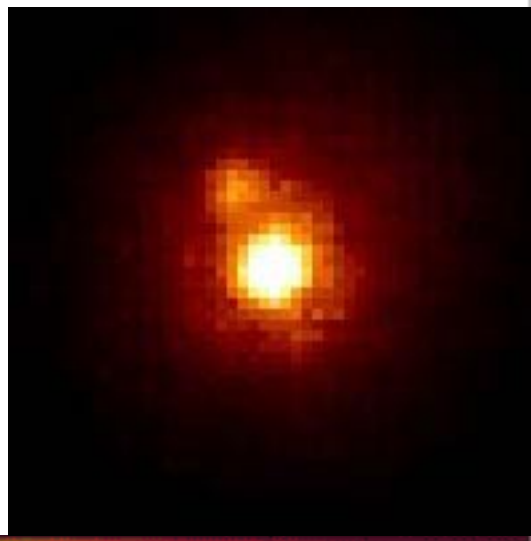
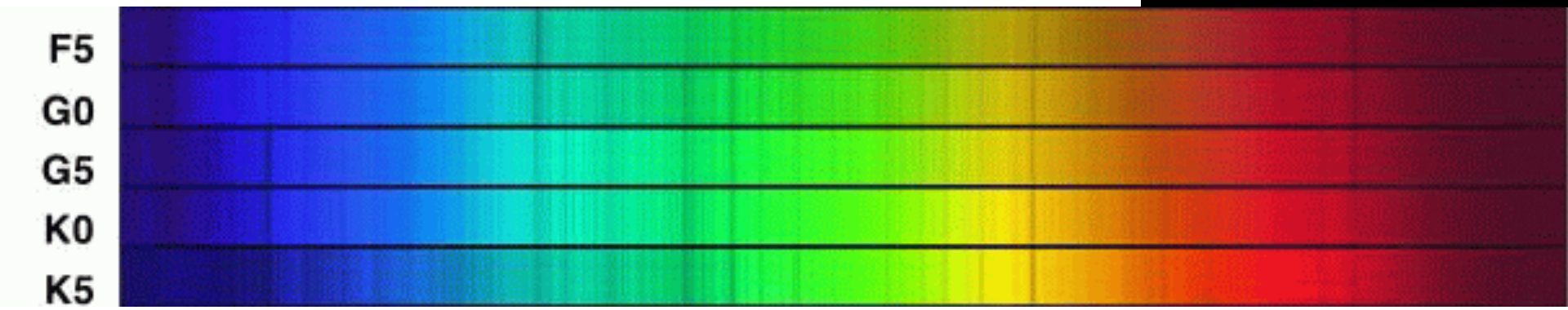
4) The Star

- Spectroscopy to estimate stellar parameters.
- High-resolution images to check for nearby stars





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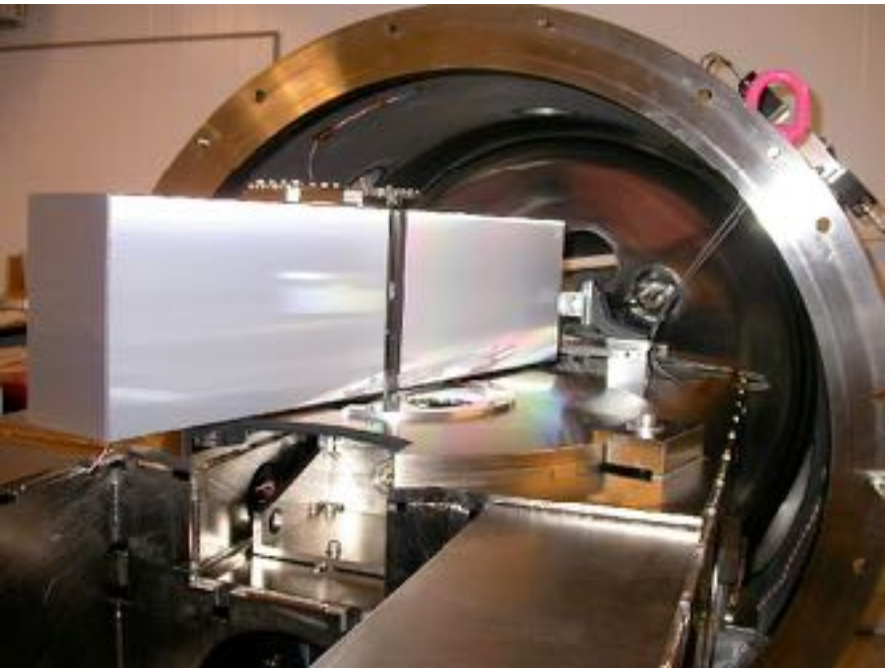
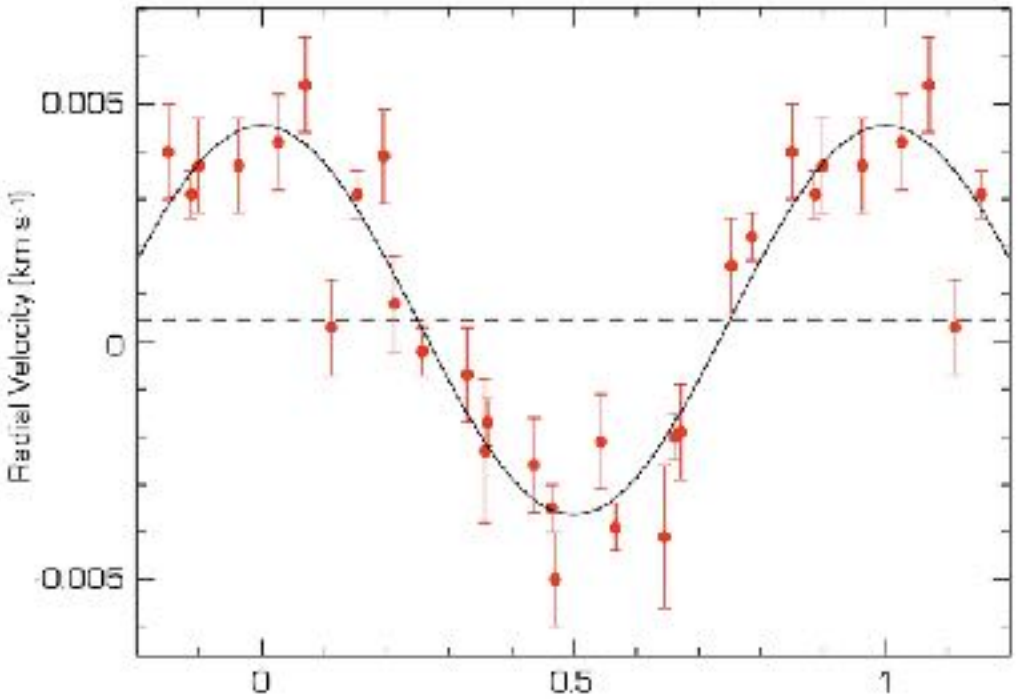
5) Radial Velocities

- Use RVs to detect the mass of the planet





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6) Publish

- 7 publications and 20+ citations so far
- More on the way
- Some examples…

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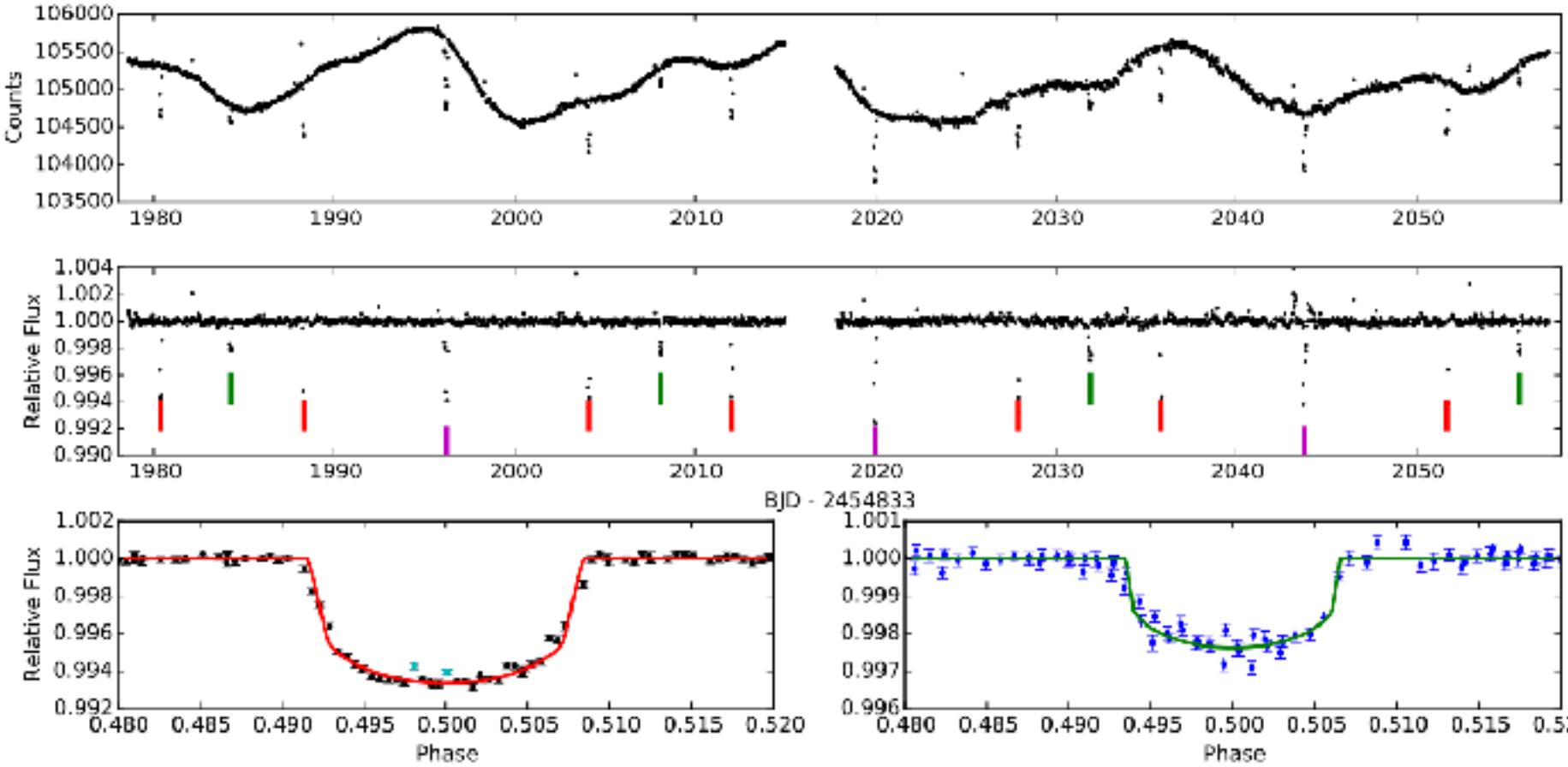
K2-19b and c



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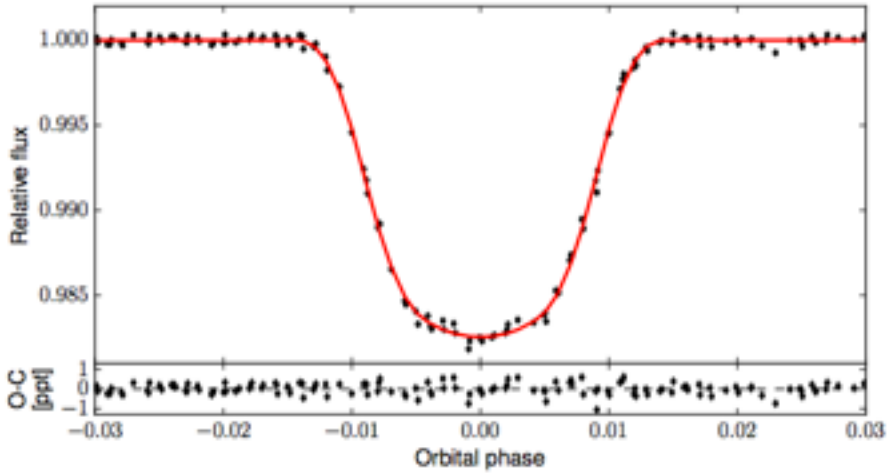
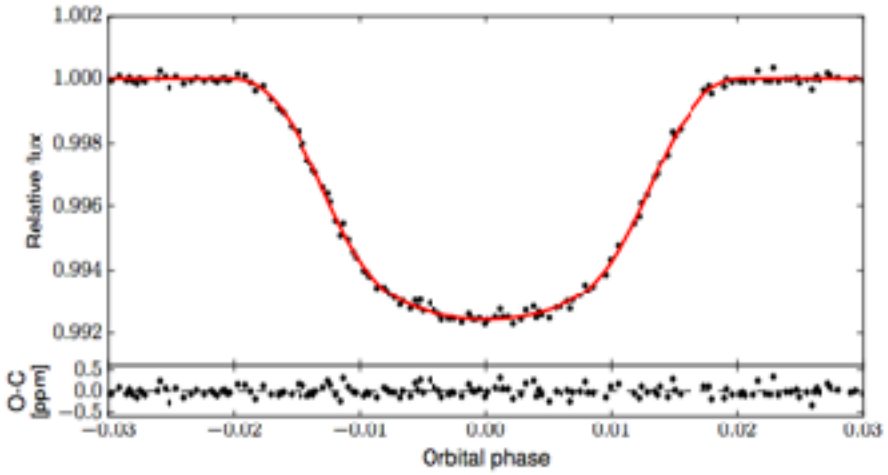
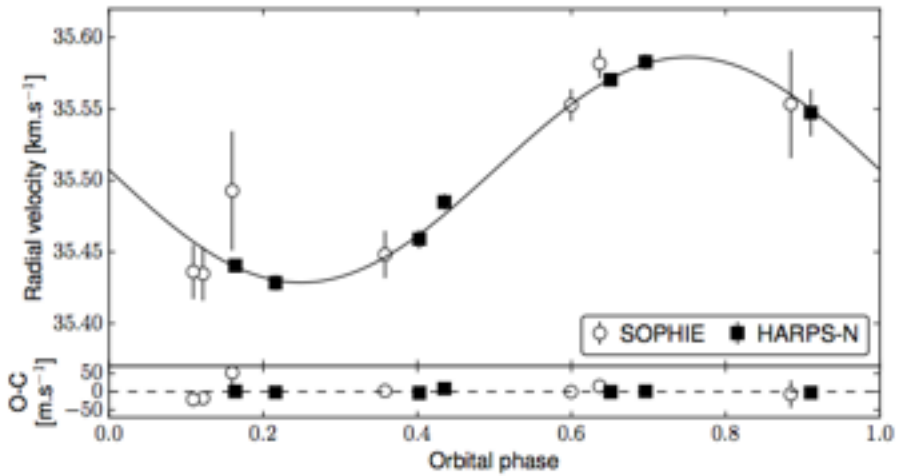
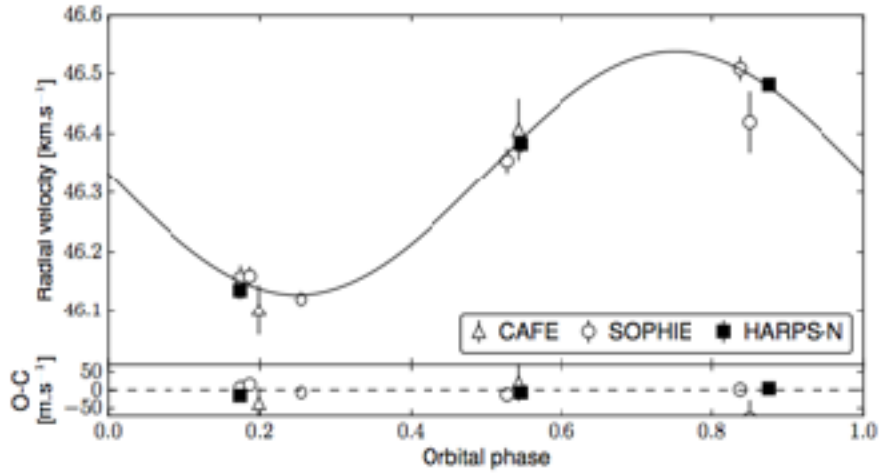
K2-30b and K2-34b









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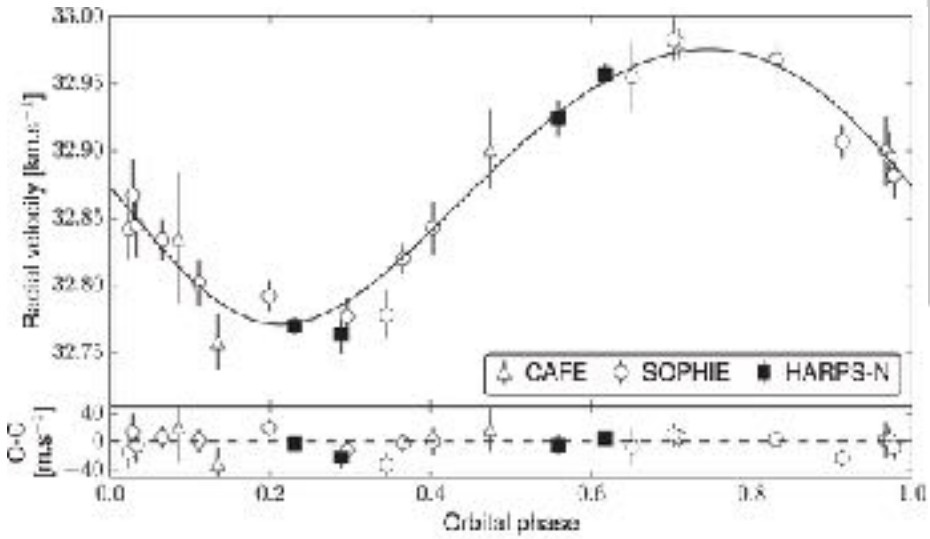
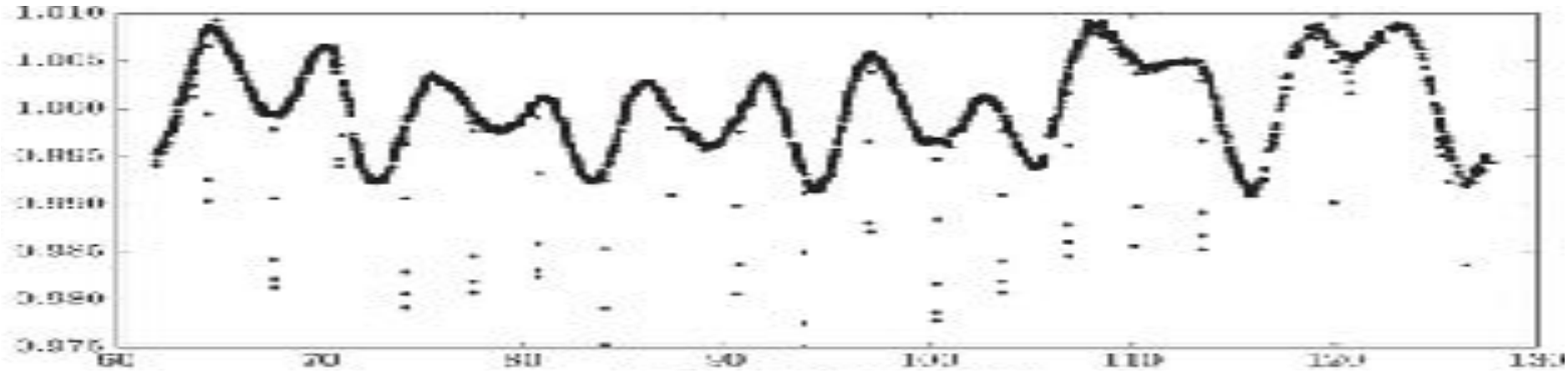
K2-29b

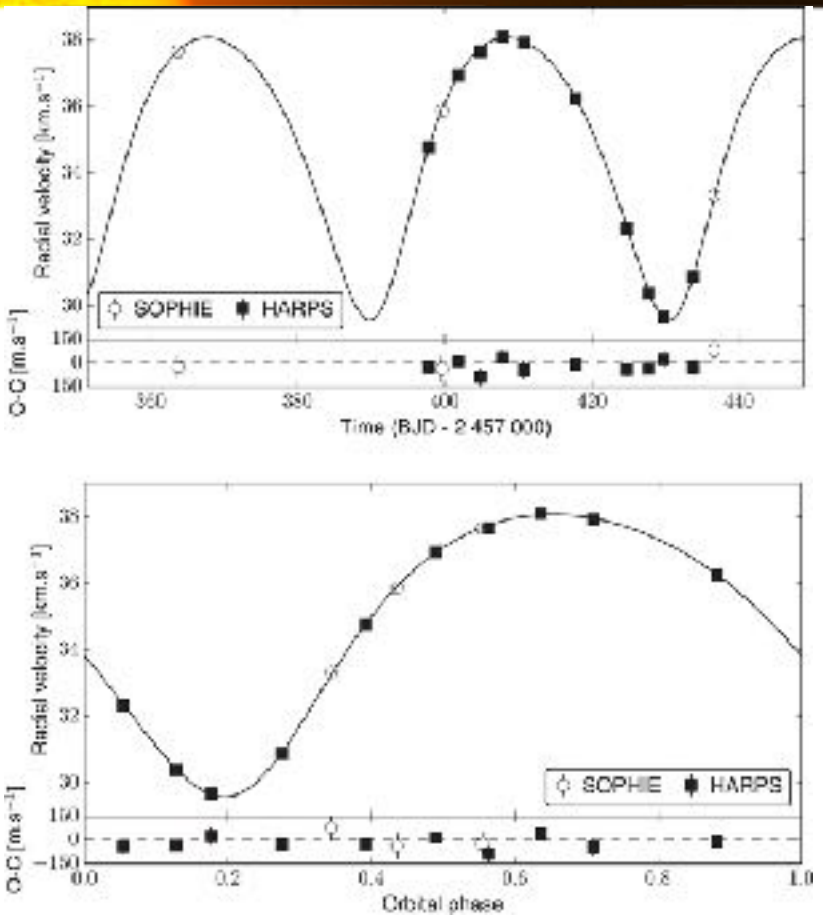
- Young star (400Myr)
- Low-density hot Jupiter

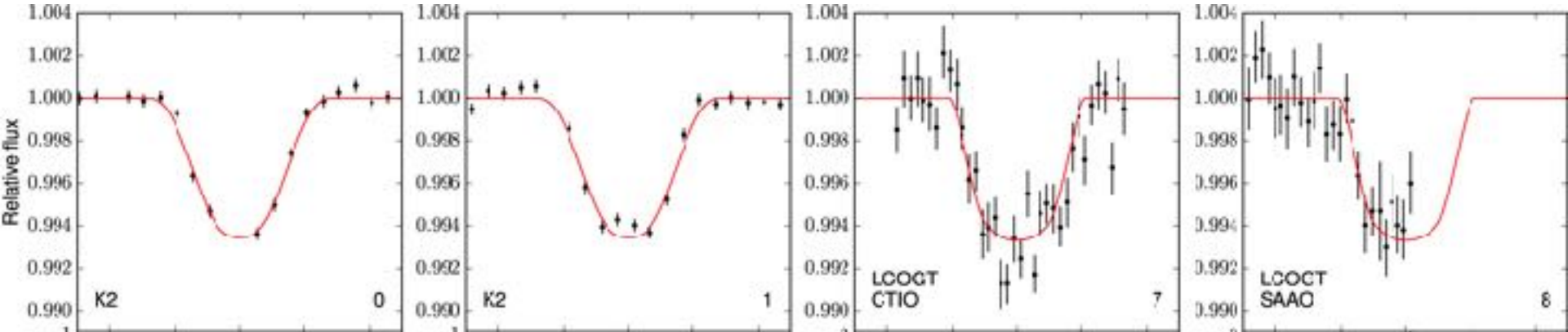




EPIC 201702477b

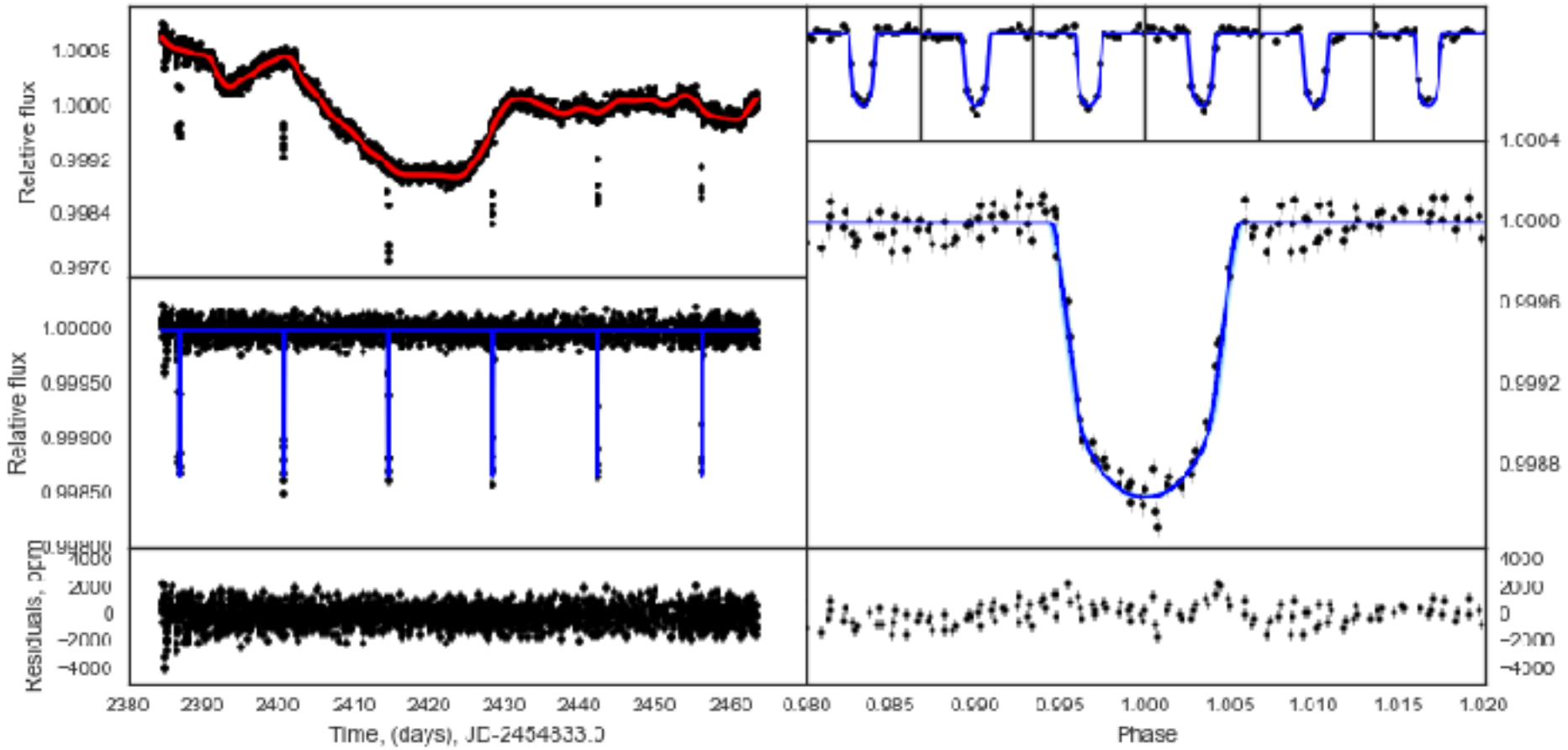
- 8 earth radii... ($0.76R_{Jup}$)
- 21,000 earth masses.
- Brown dwarf (failed star)





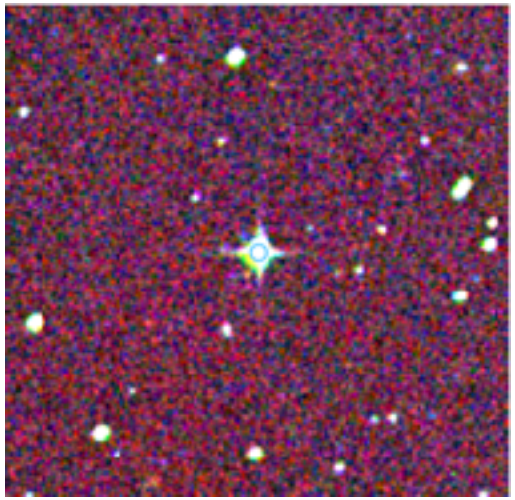
WARWICK

EPIC212521166b

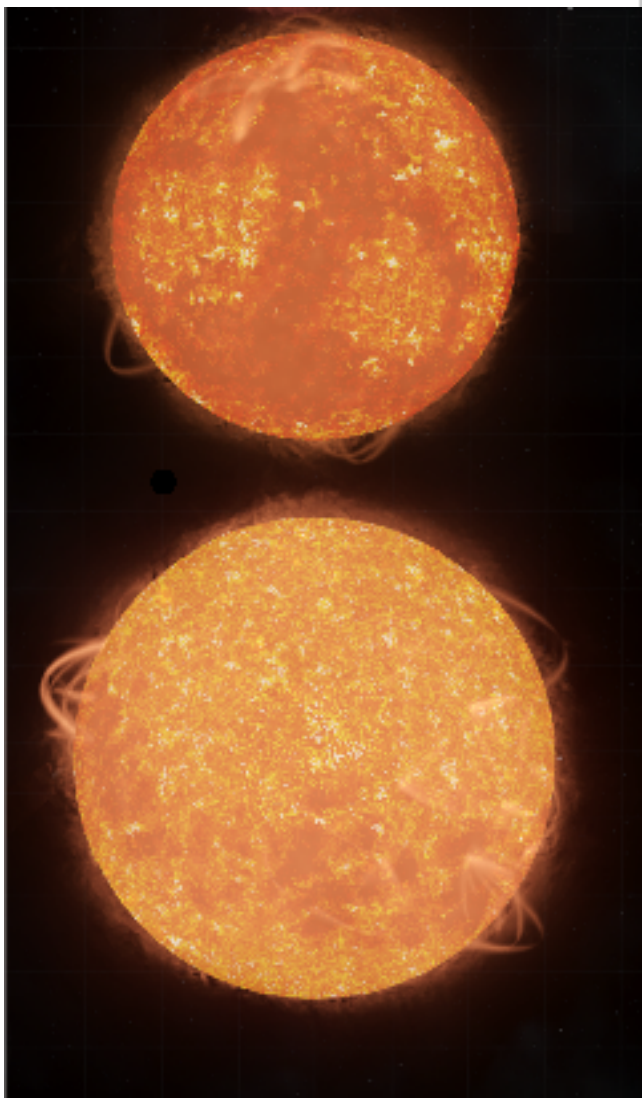


EPIC-1166

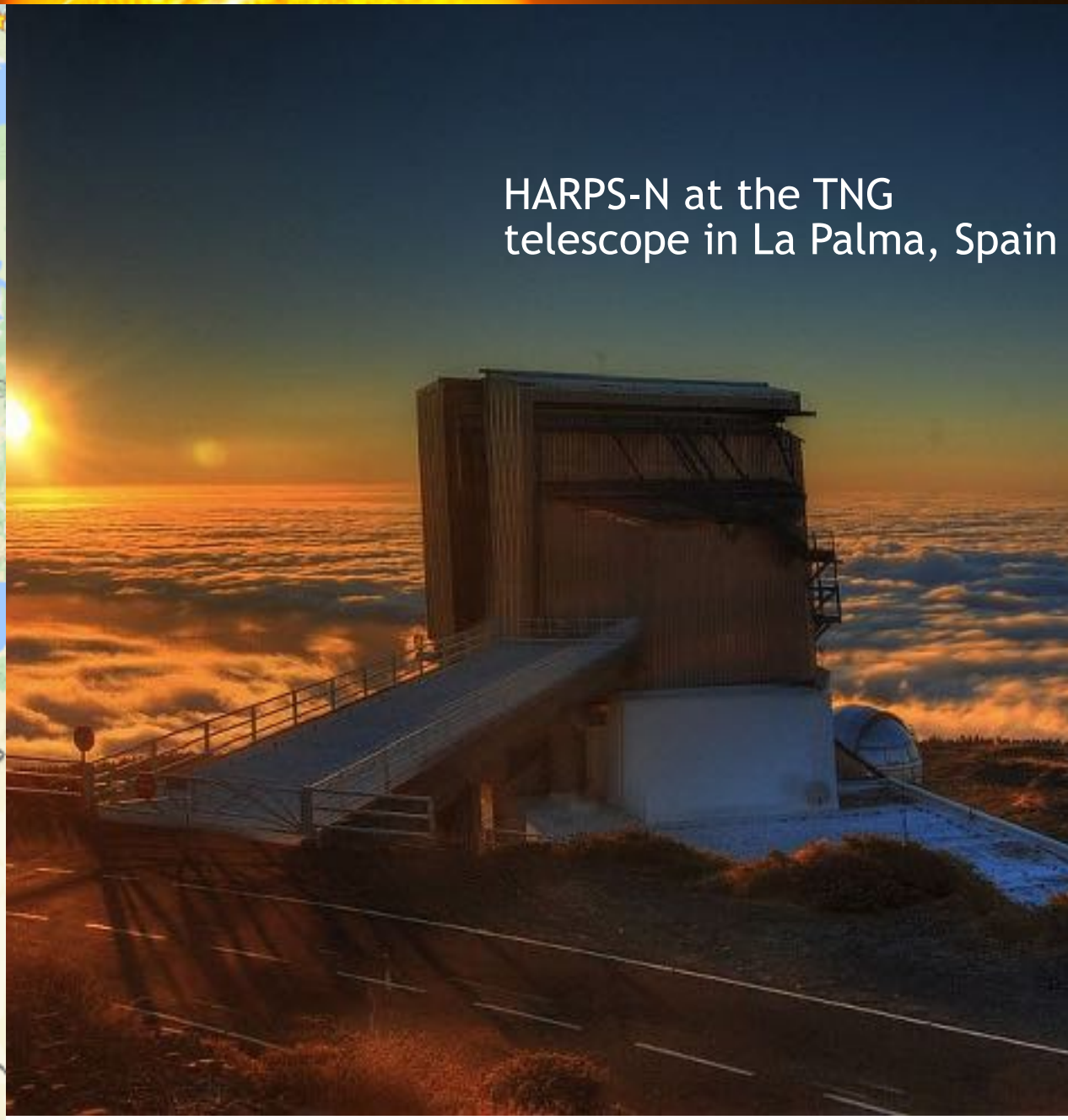
- K-type star
- Old – around 8.5Gyr
- Depleted in metals



- No nearby stars



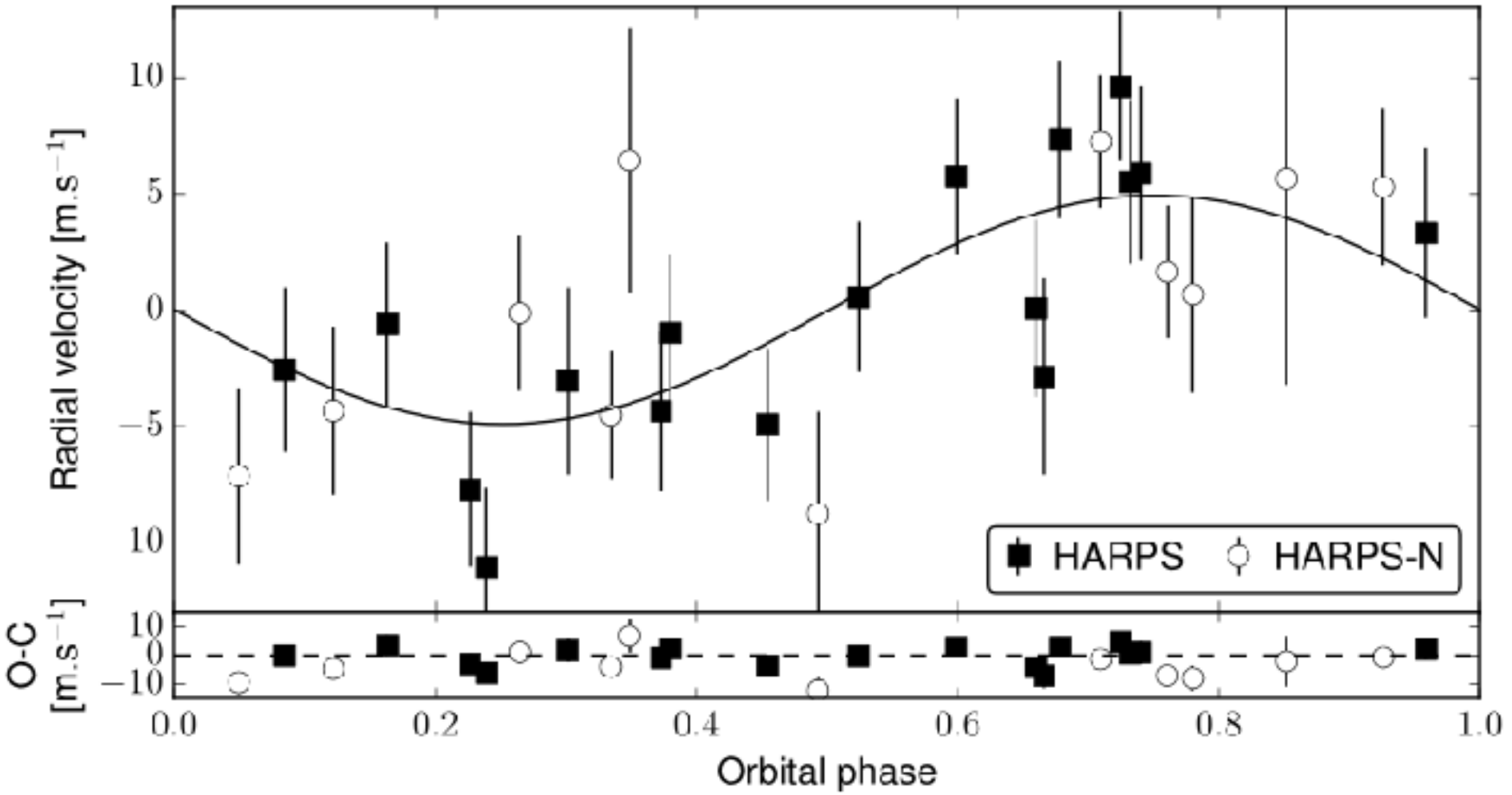
HARPS-S at the 3.6m telescope in La Silla, Chile



HARPS-N at the TNG telescope in La Palma, Spain

WARWICK

EPIC-1166b



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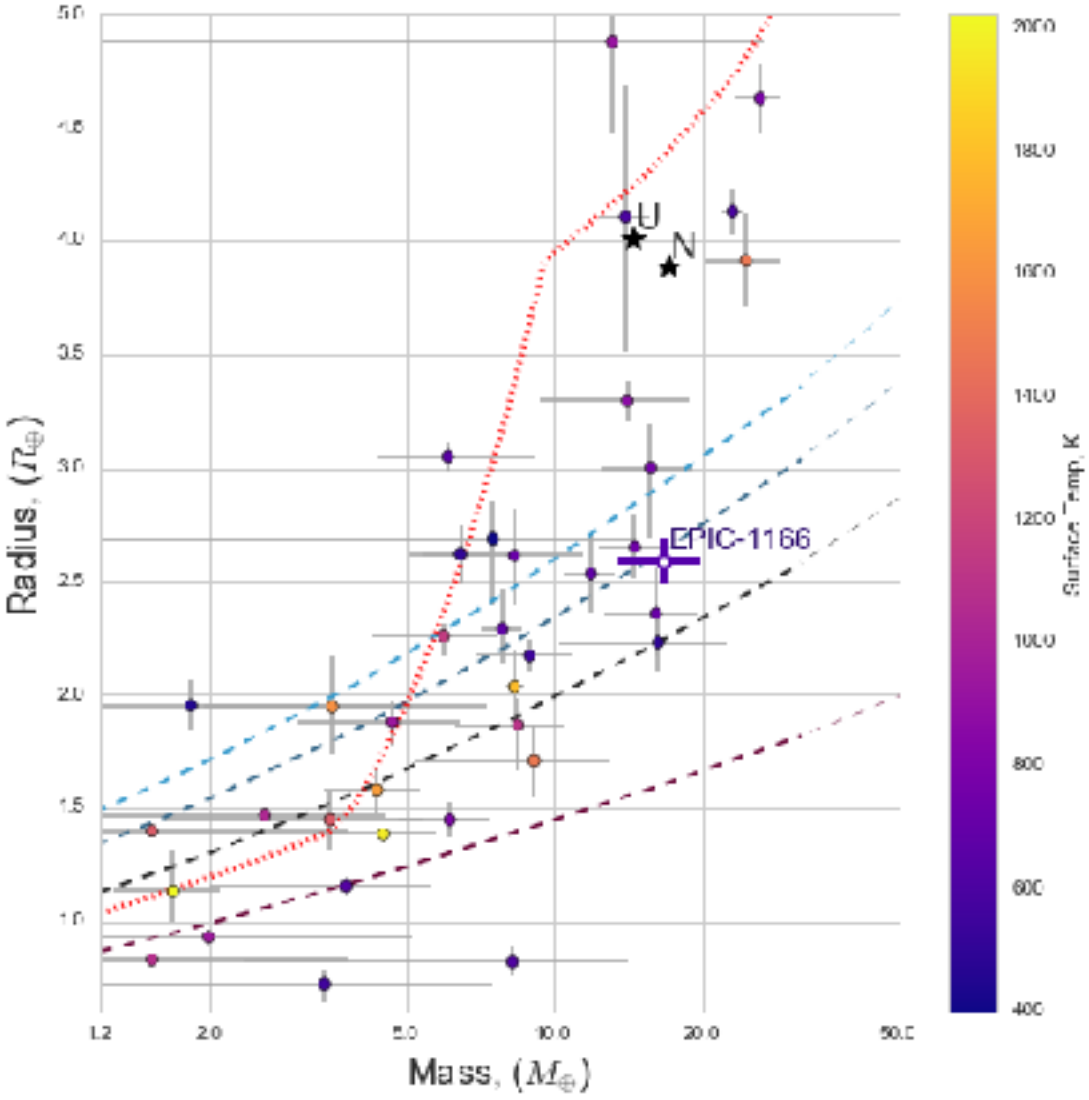
Density

- Radius = 2.6 earths
- Mass = 18 earths
  - gives a density.
- Can explore what it it made of…



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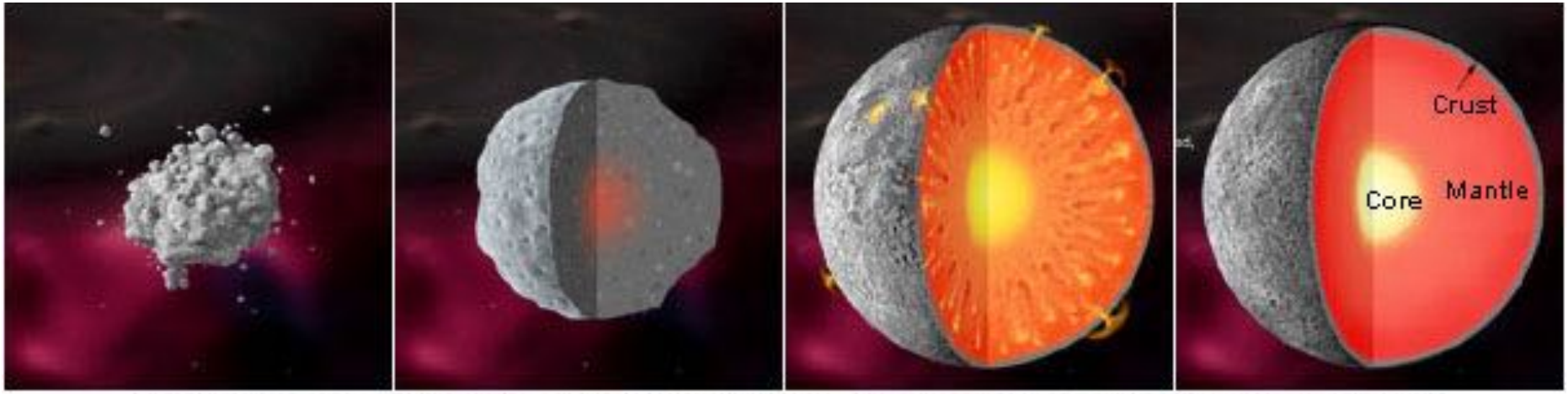
Composition

- More massive planets are gravitationally compressed
- 18 earth mass body has density 50% higher than Earth



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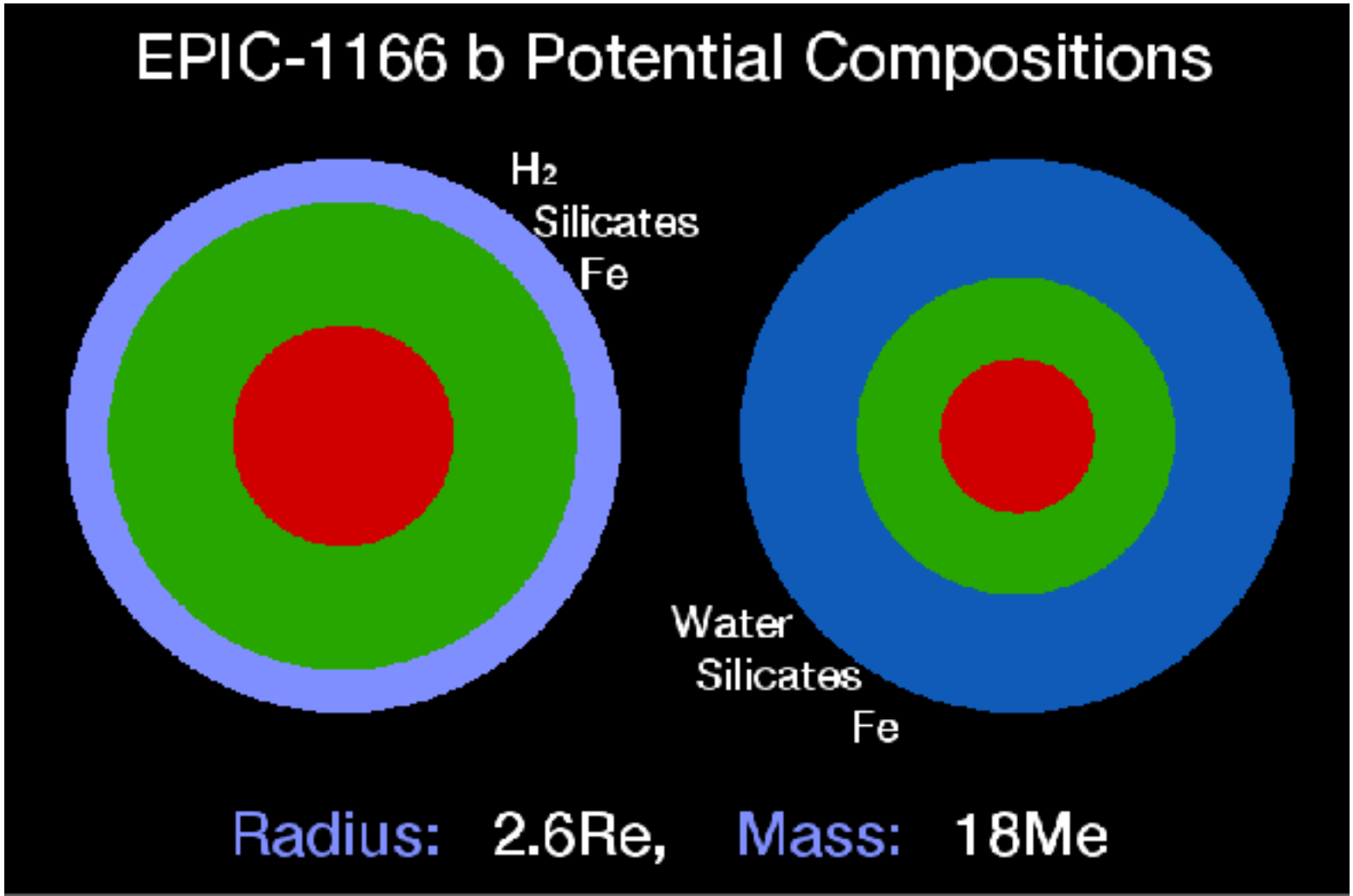
Composition



EPIC-1166b

- How could it have grown so big?
- Collisions could explain size, lack of thick atmosphere and eccentricity

The future is bright

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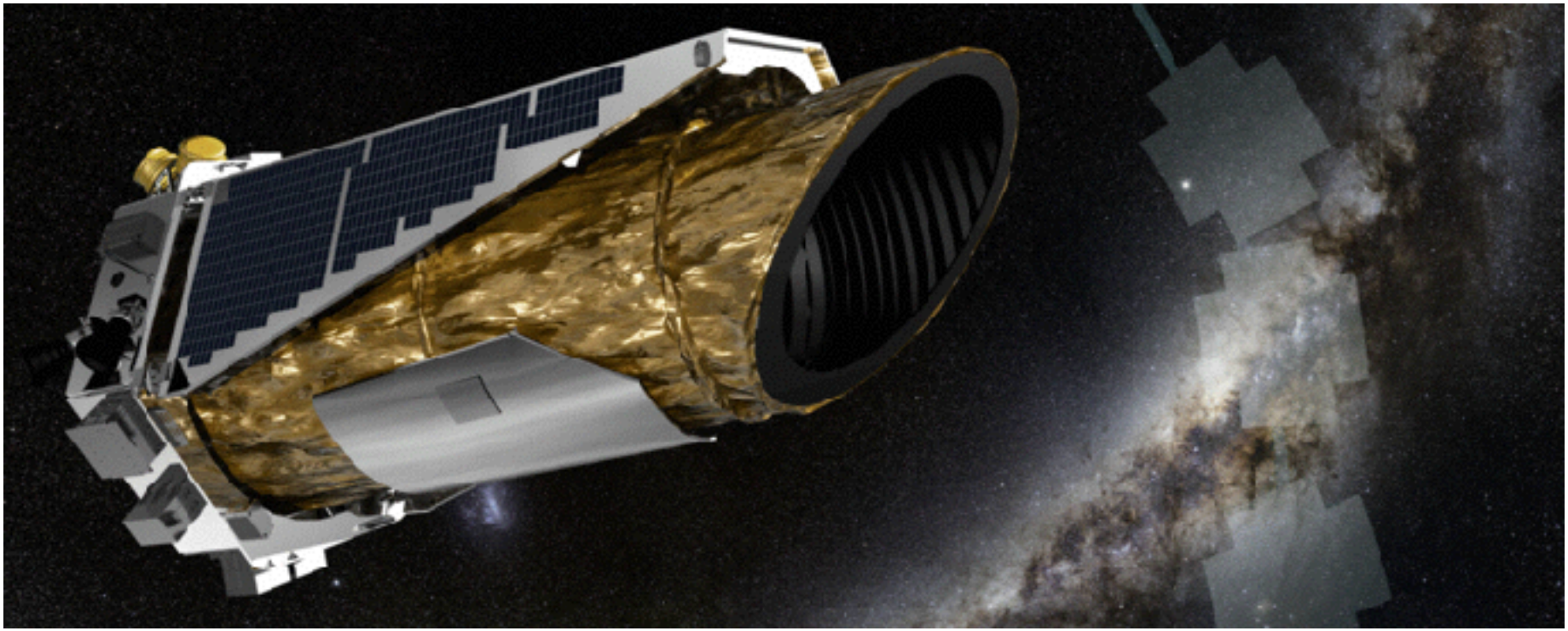
K2



- 2 more years (160,000 more stars) of K2

NGTS

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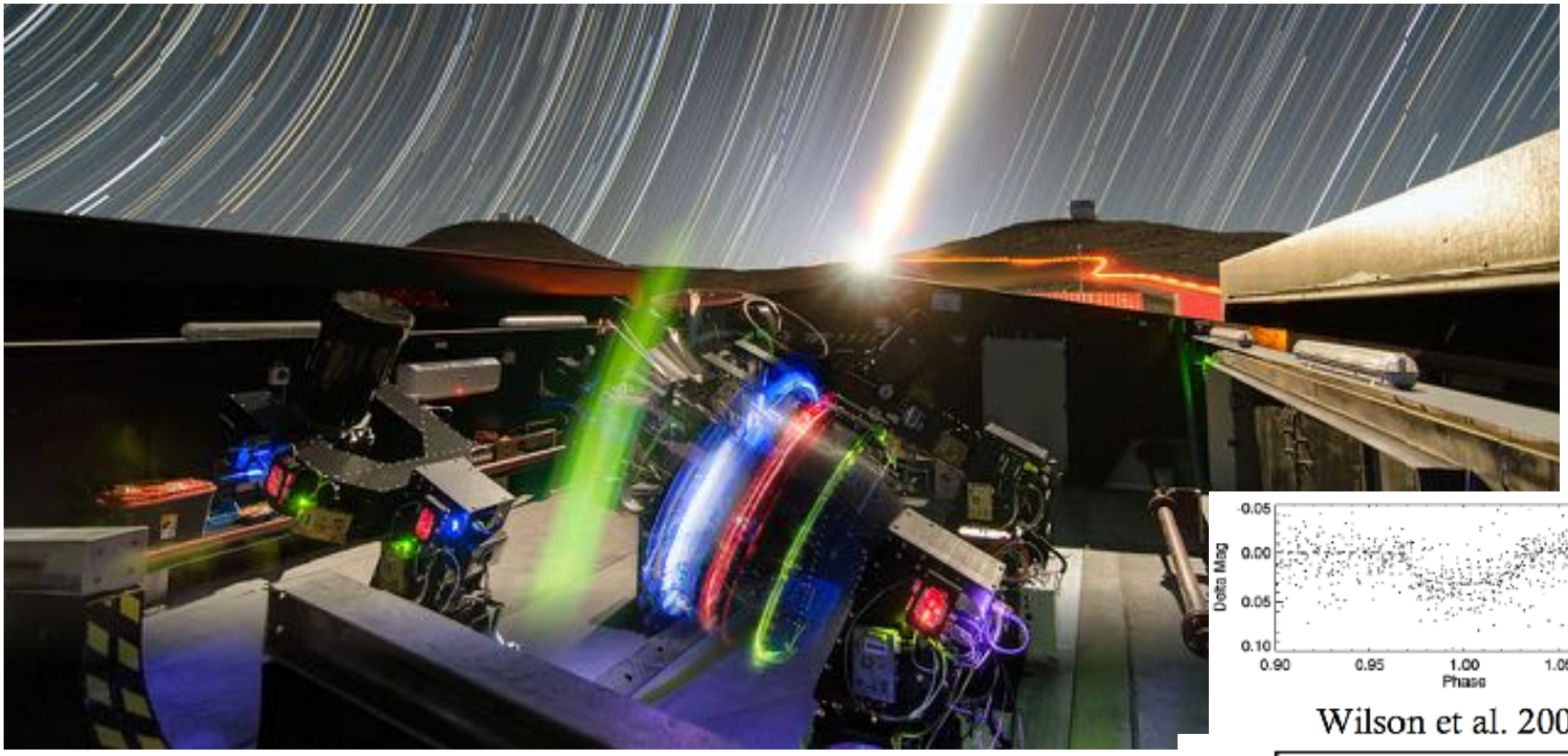
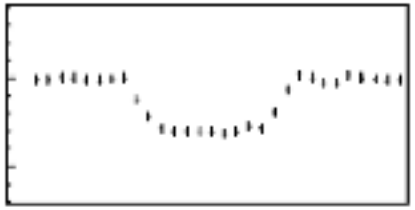


Wilson et al. 2008,



- Warwick-led transit survey in Chile.
- Will find Neptunes & super-Earths

NGTS Single event

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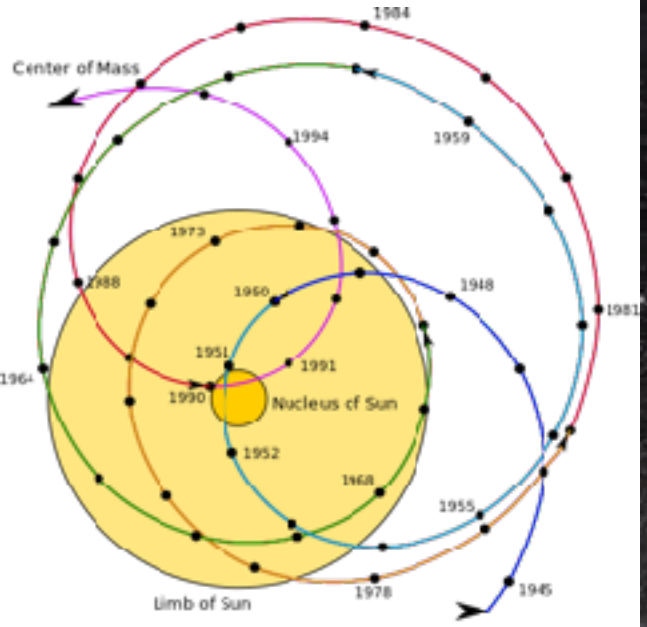
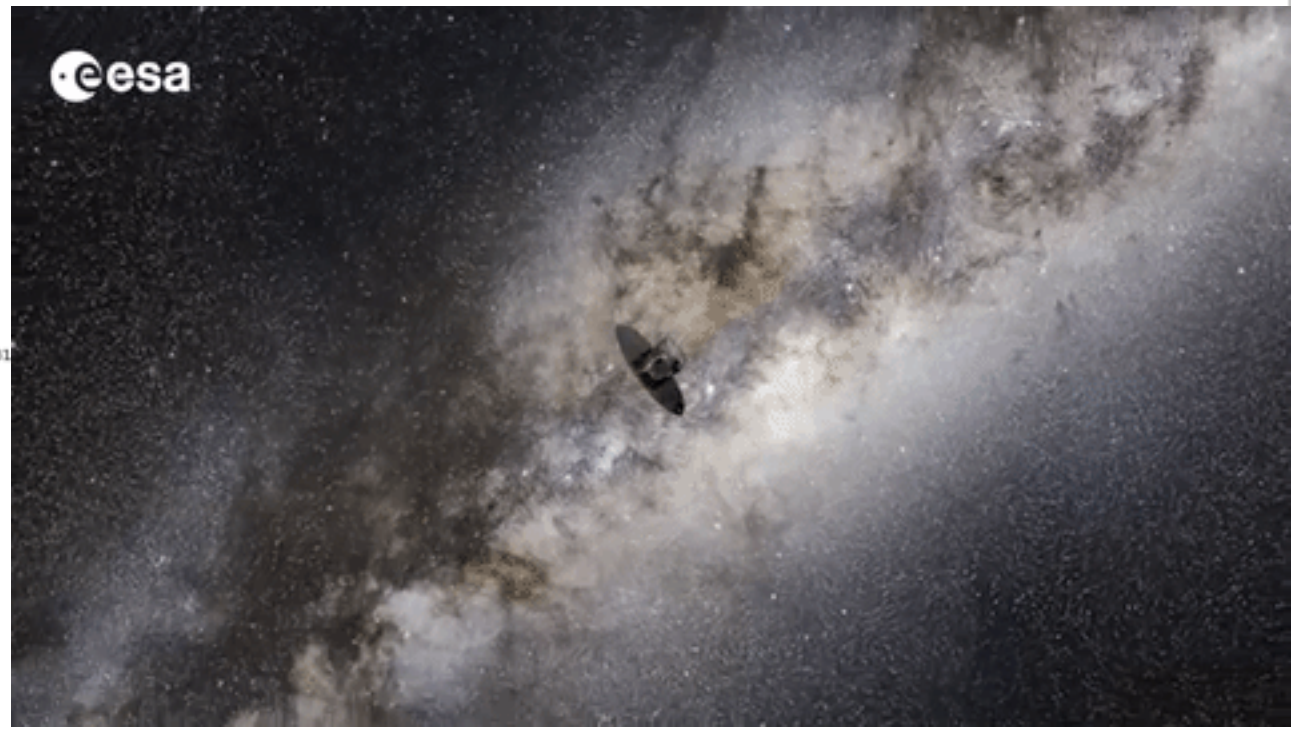
Gaia





- Launched in 2012 to survey positions of 1billion stars.
- ~20,000 new giant planets (from 1 to 5AU).

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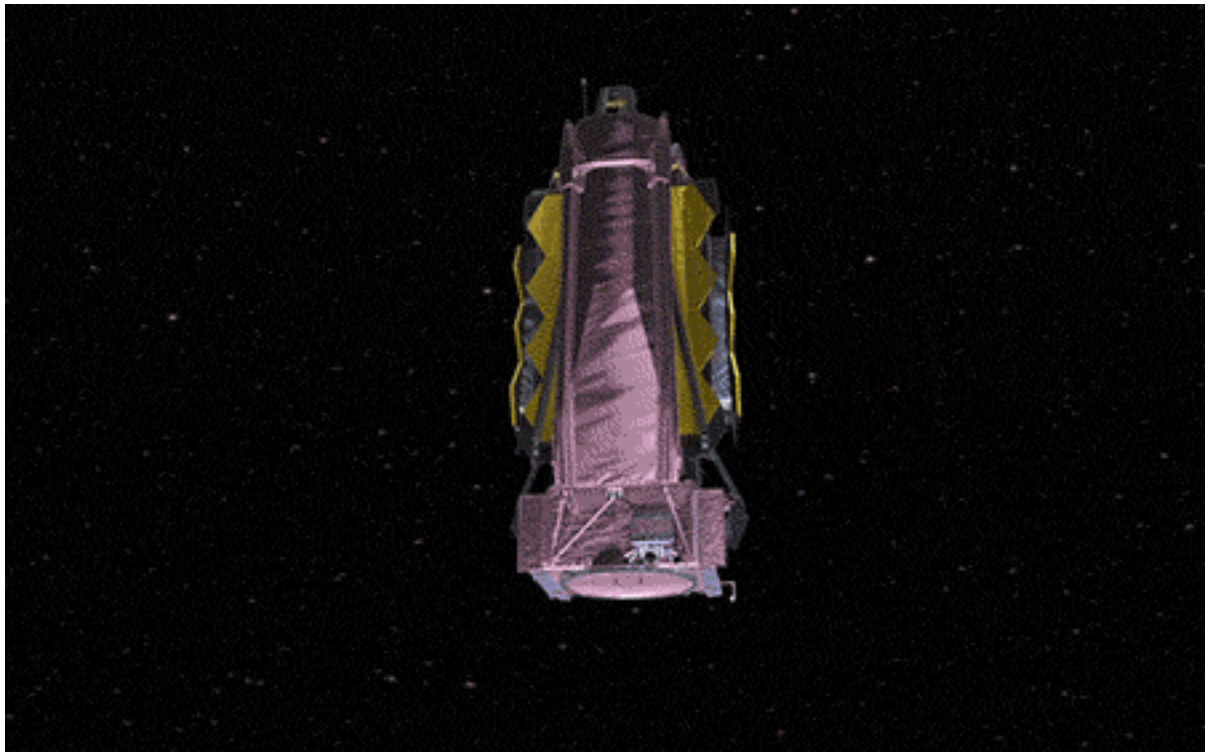
JWST



- 8m space telescope. Launches 2017
- Will probe atmospheres of exoplanets in amazing detail

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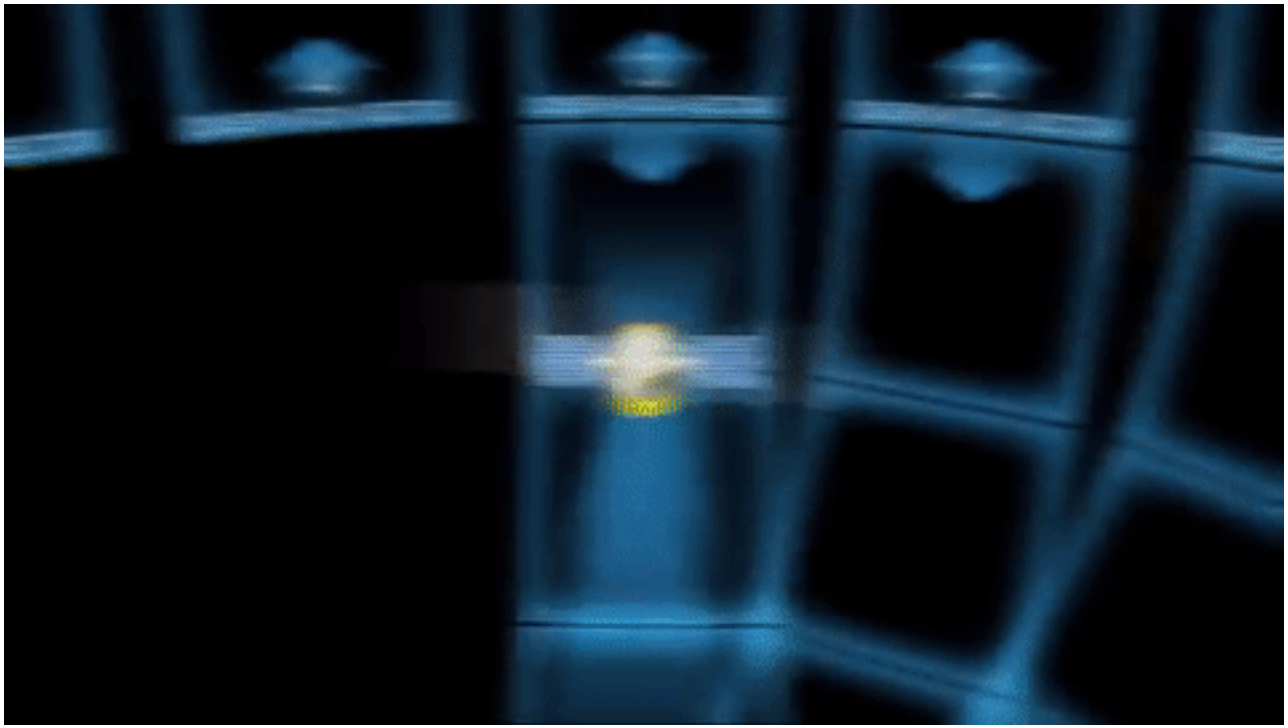
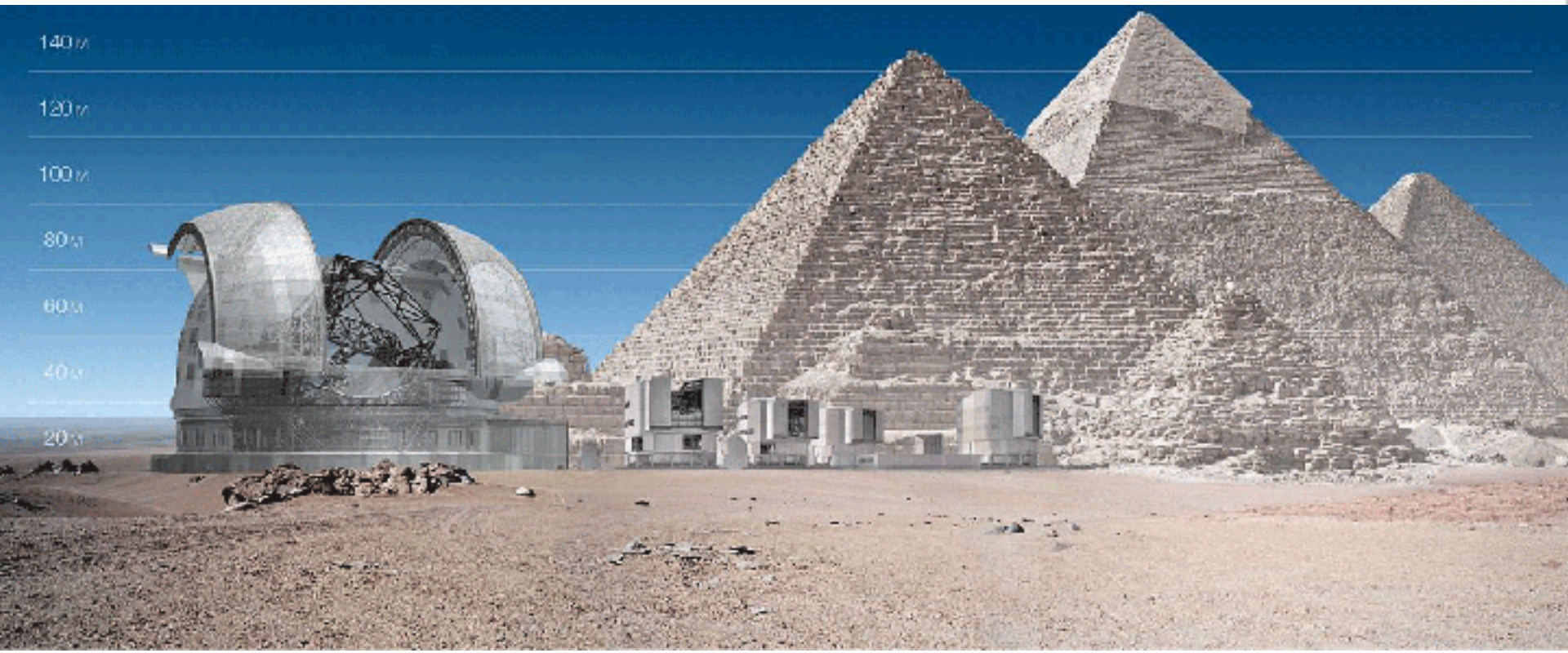
TESS



- Transit detecting telescope launching in 2018
- 20,000 new giant planets & 500 small (<2R_e) planets

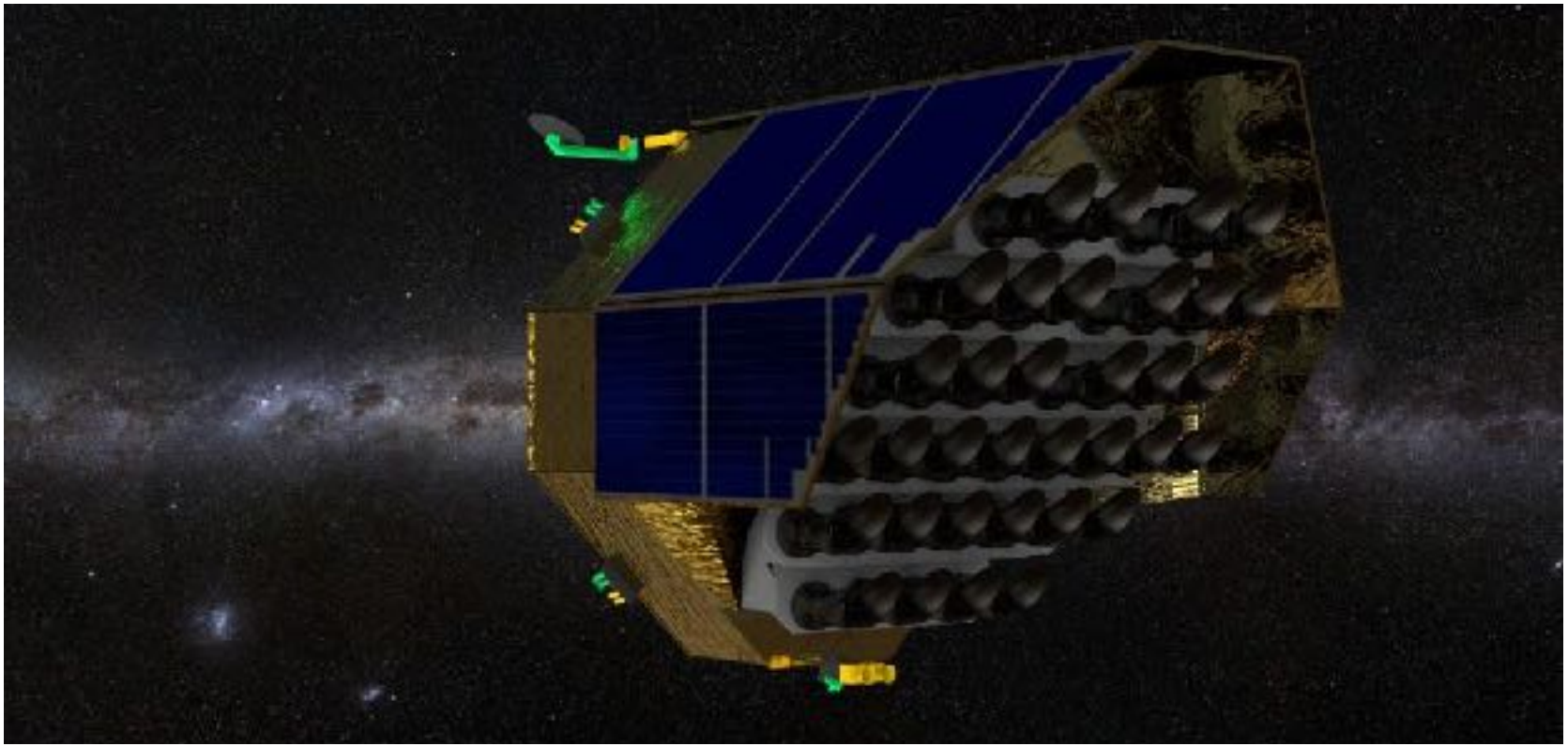
WARWICK

E-ELT



- 39m telescope in Chile. Completed ~2024
- Will directly image nearby exoplanets at ~1AU

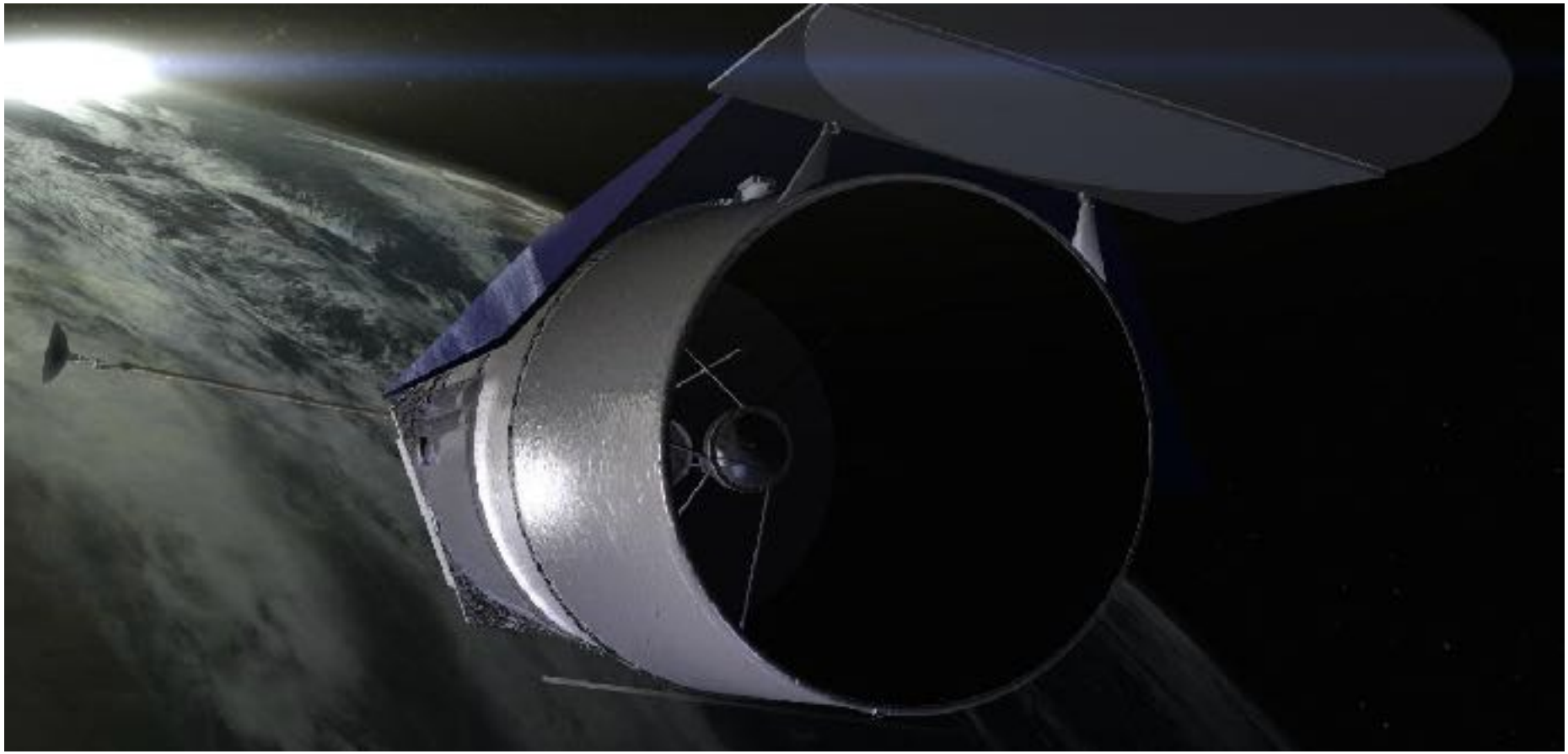
PLATO



- 28 telescopes in space. Launch ~2026
- RV and Asteroseismology follow-up part of mission

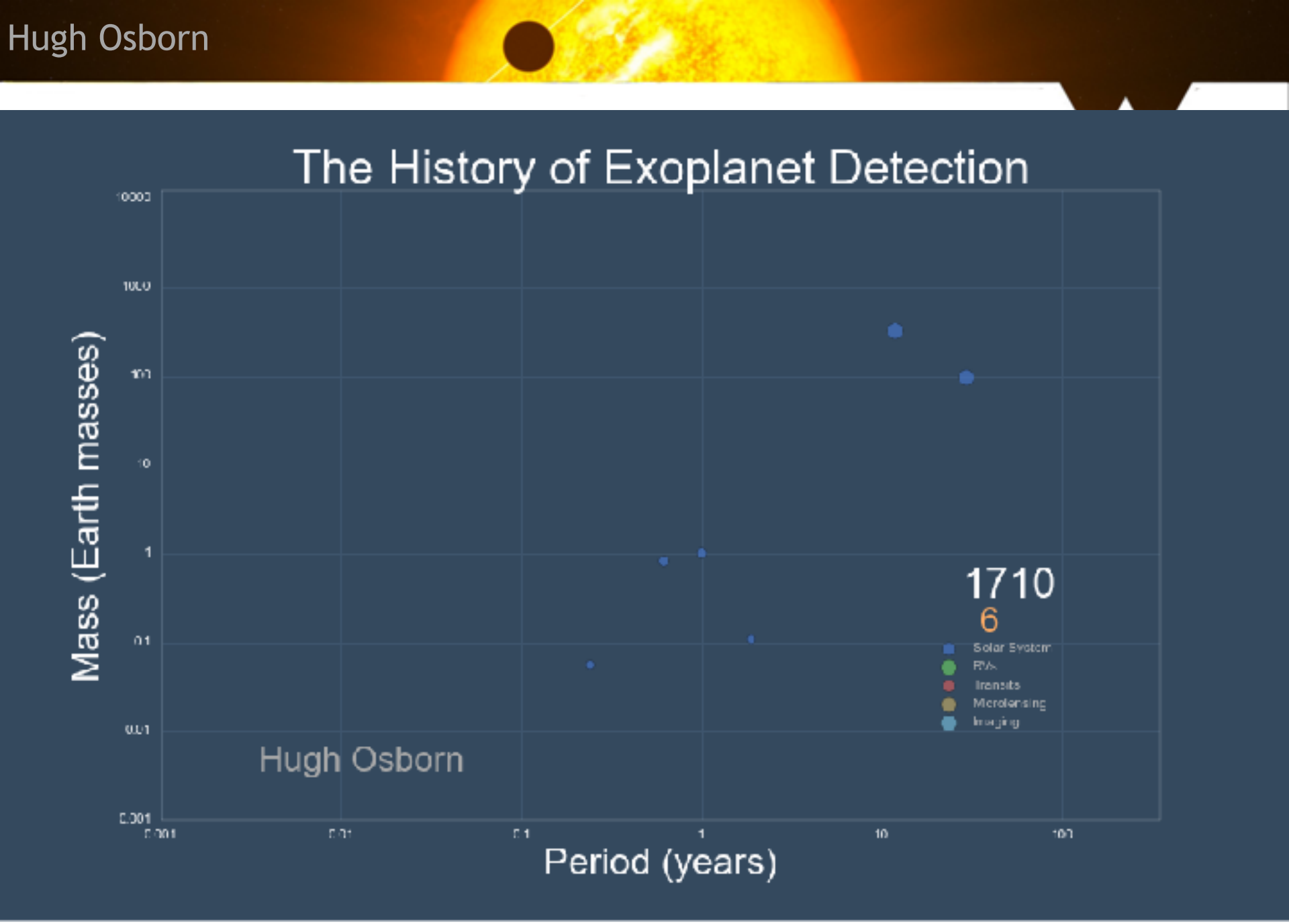
WFIRST

WARWICK



- Microlensing & transit mission launching ~2027
- Give occurrence rates of planets down to Mars mass

Hugh Osborn


The History of Exoplanet Detection
Mass (Earth masses)
Period (years)
1710
6
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn

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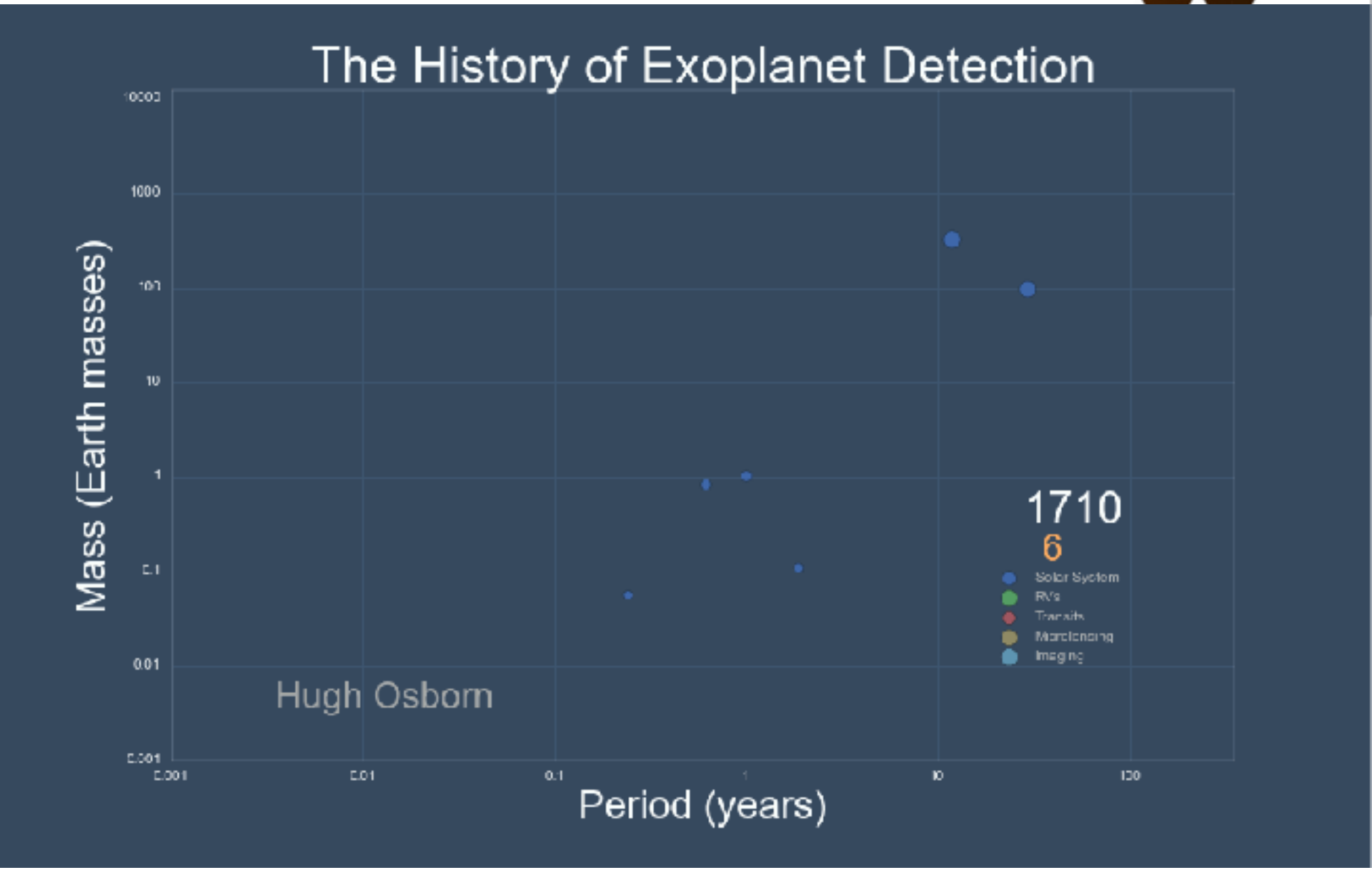
The History of Exoplanet Detection
Mass (Earth masses)
10000
1000
100
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
10
100
Period (years)
1710
6
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn

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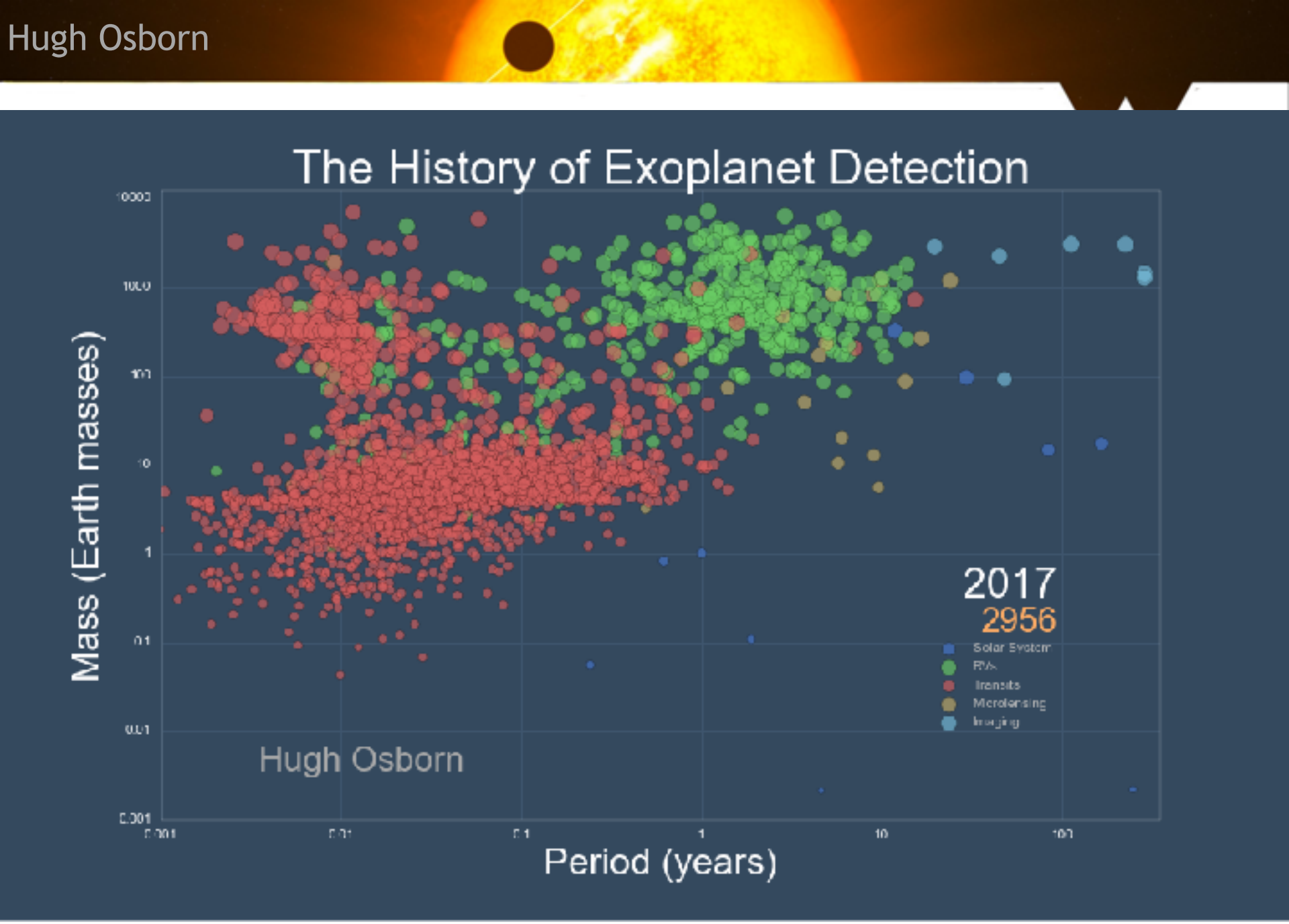
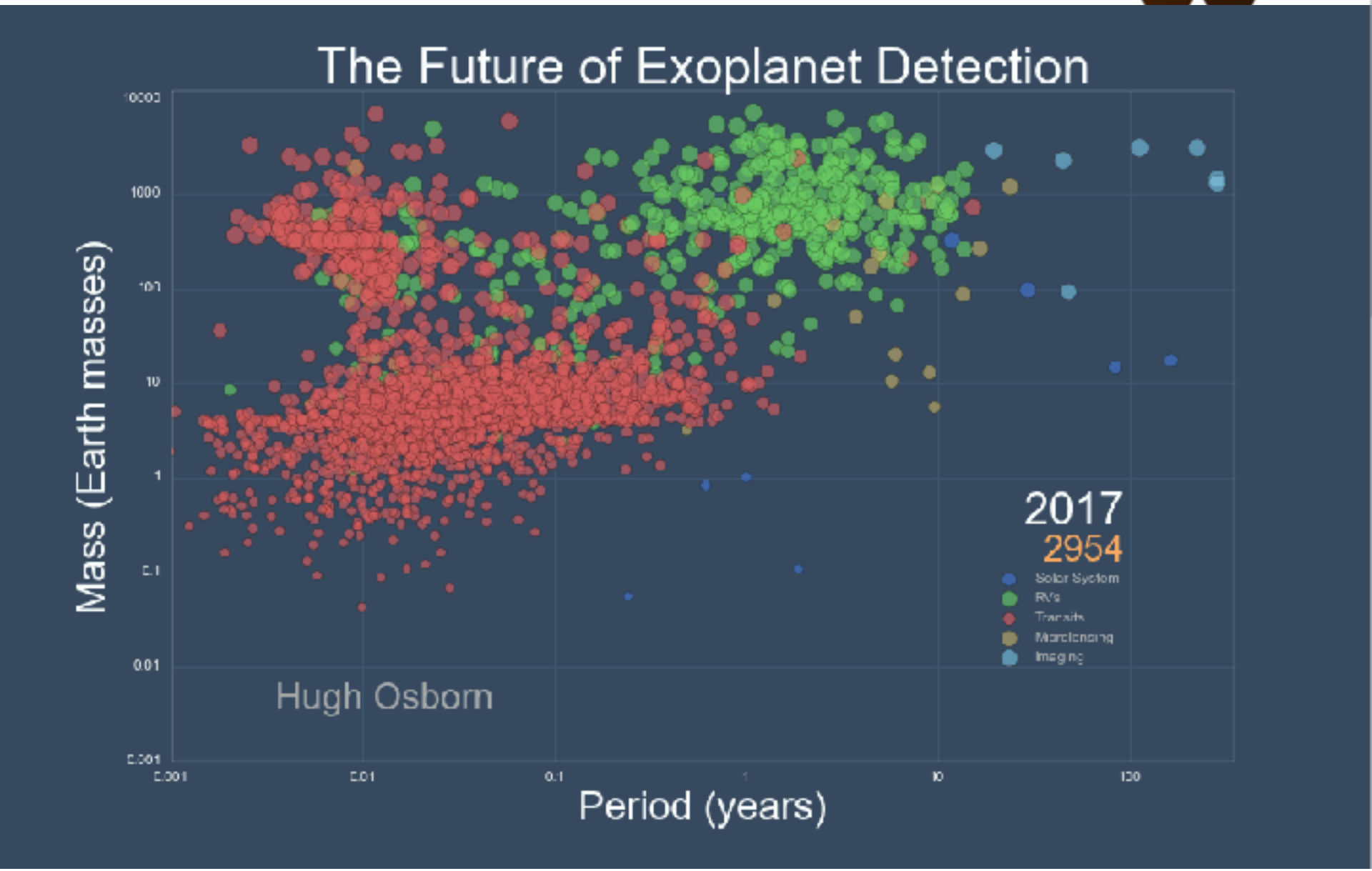
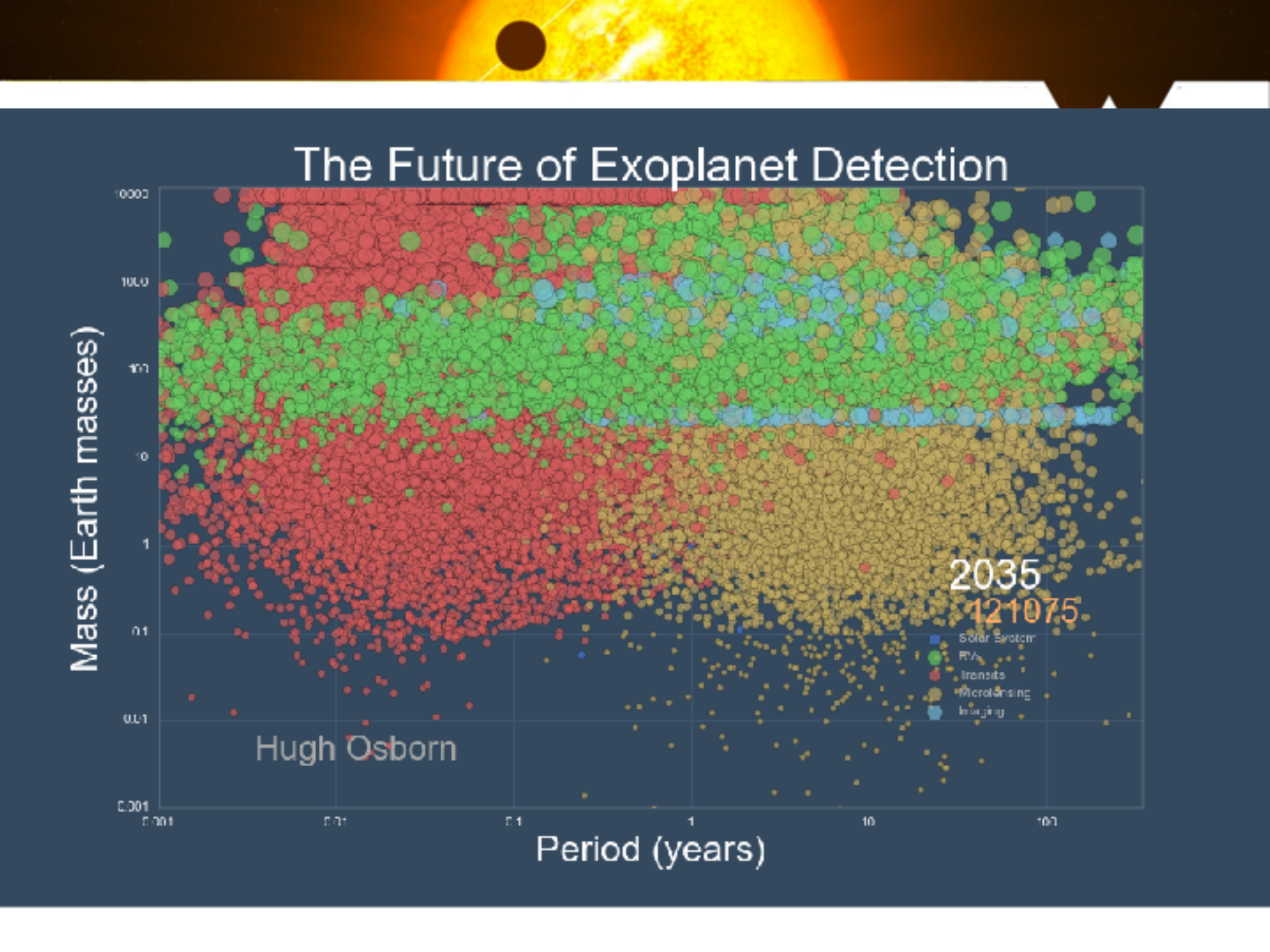

The History of Exoplanet Detection
Mass (Earth masses)
Period (years)
2017
2956
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn

Hugh Osborn


The Future of Exoplanet Detection
Mass (Earth masses)
Period (years)
2017
2954
Solar System
RVs
Transits
Microlensing
Imaging
Hugh Osborn


The Future of Exoplanet Detection
Mass (Earth masses)
Period (years)
2035
121075
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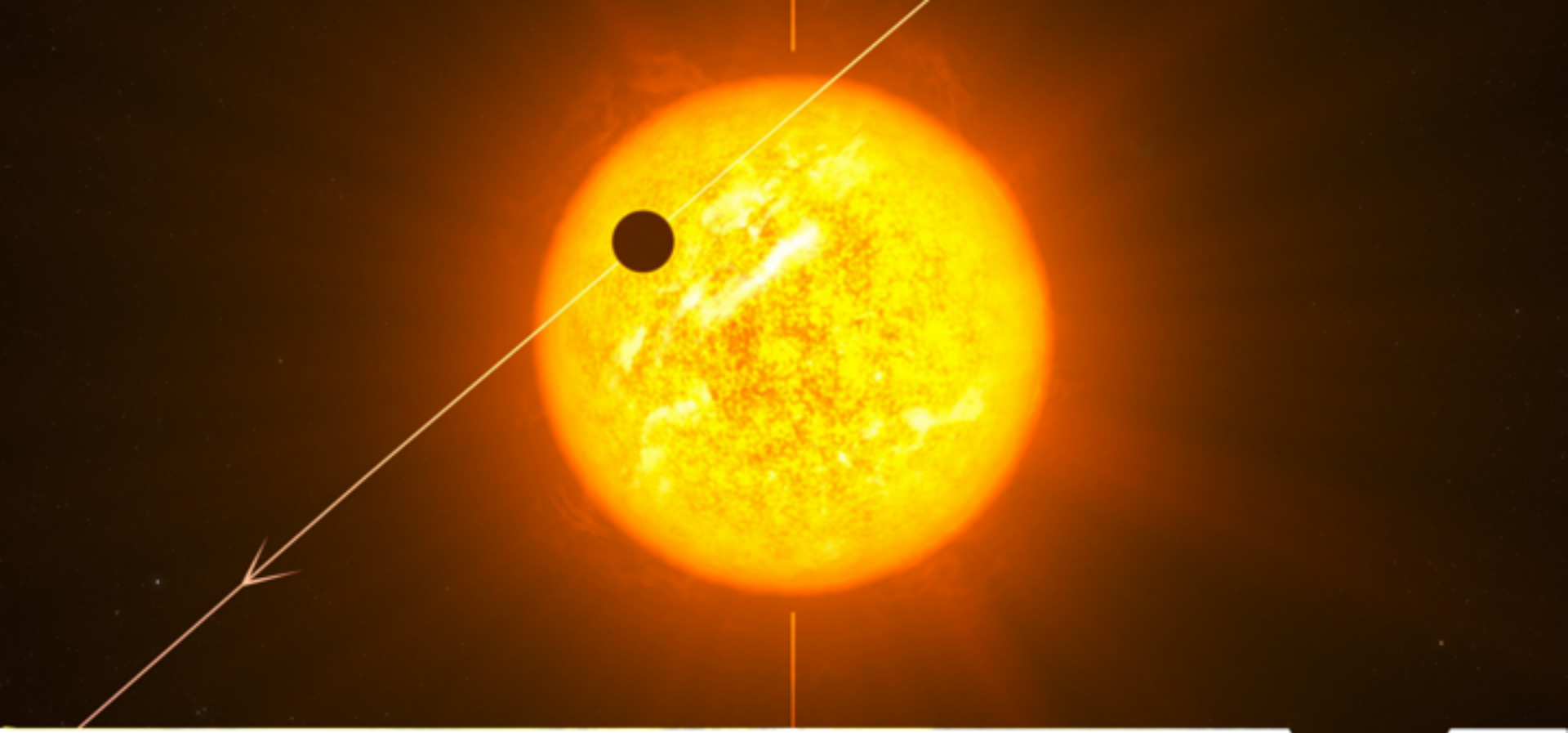

Any Questions?

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Hugh Osborn

@HughO2