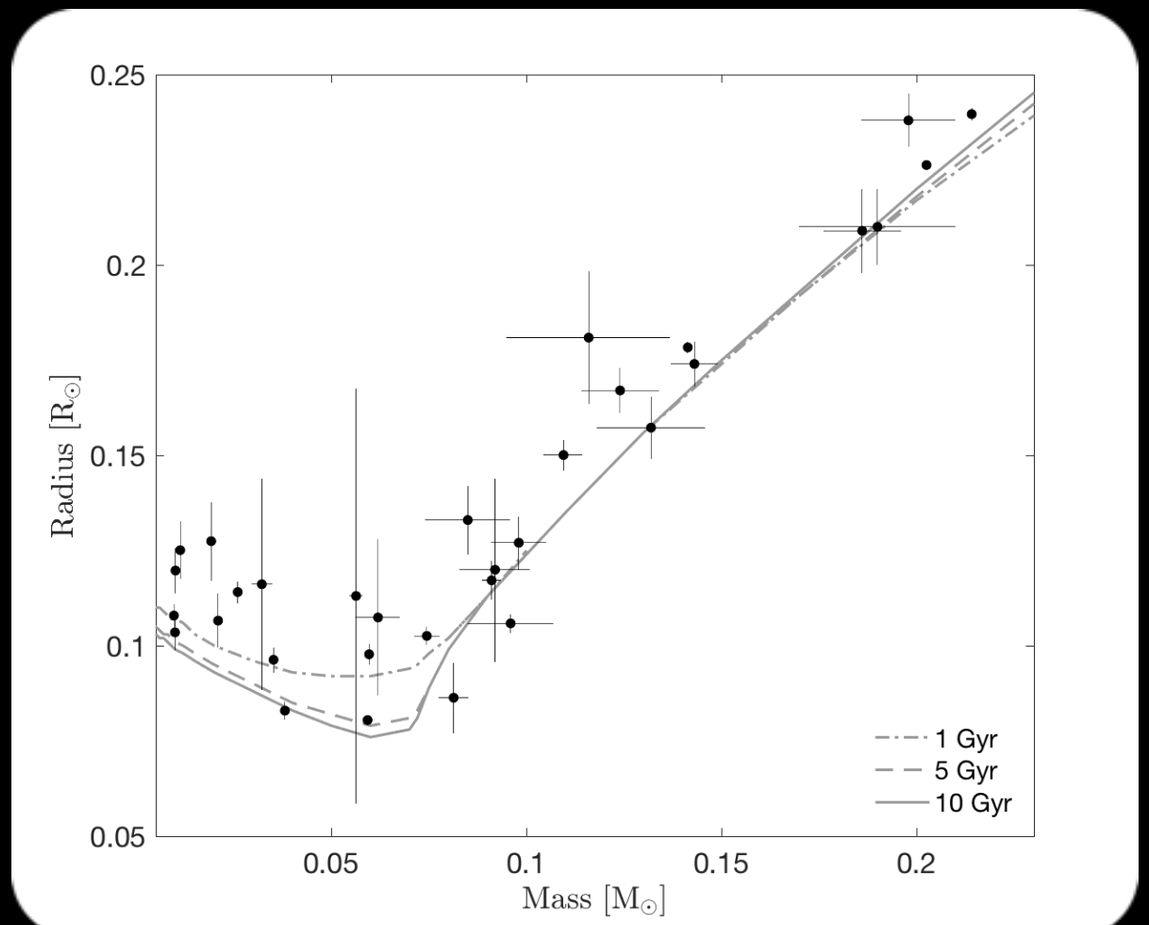
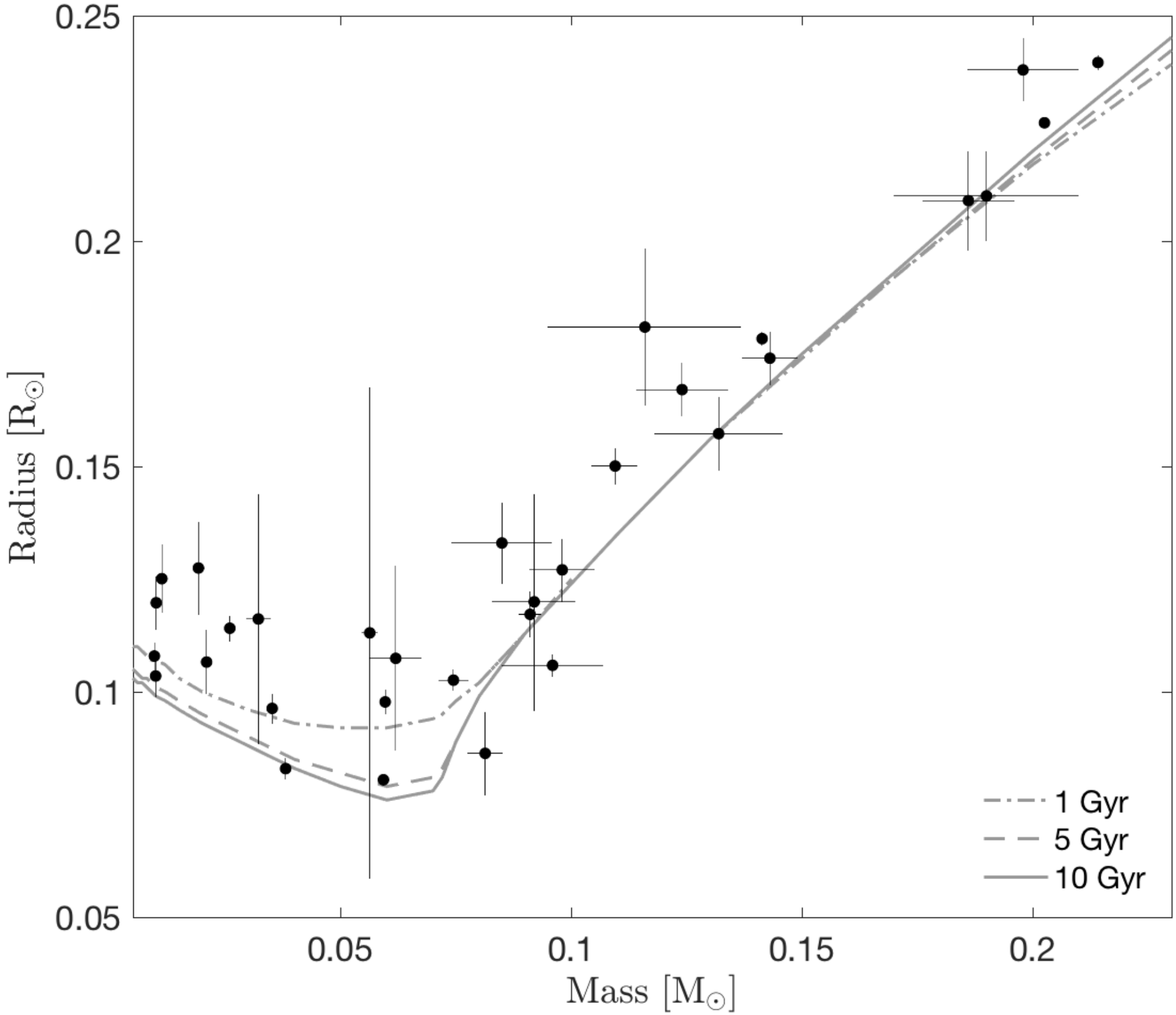
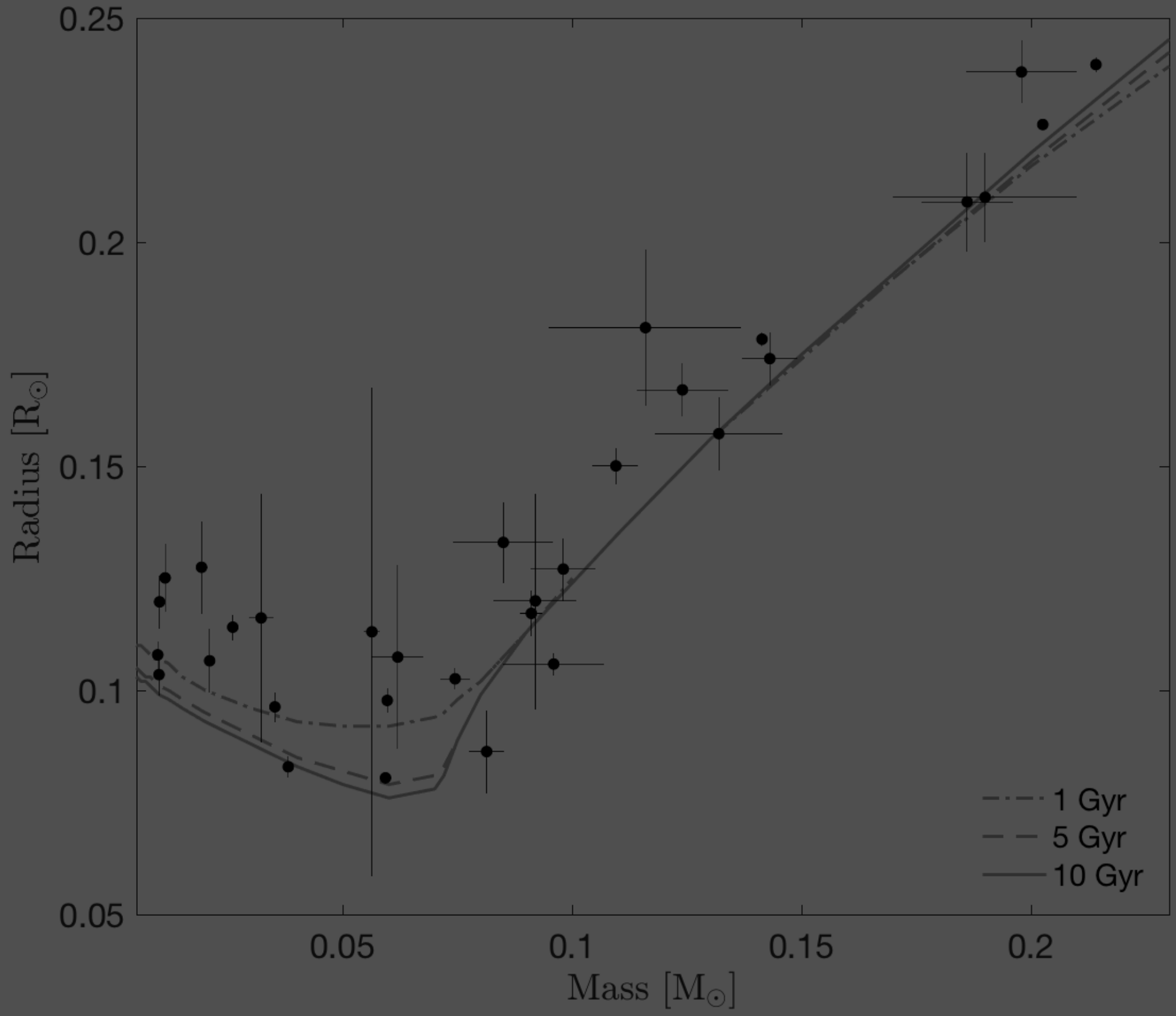
Measuring the radius and mass of the smallest stars



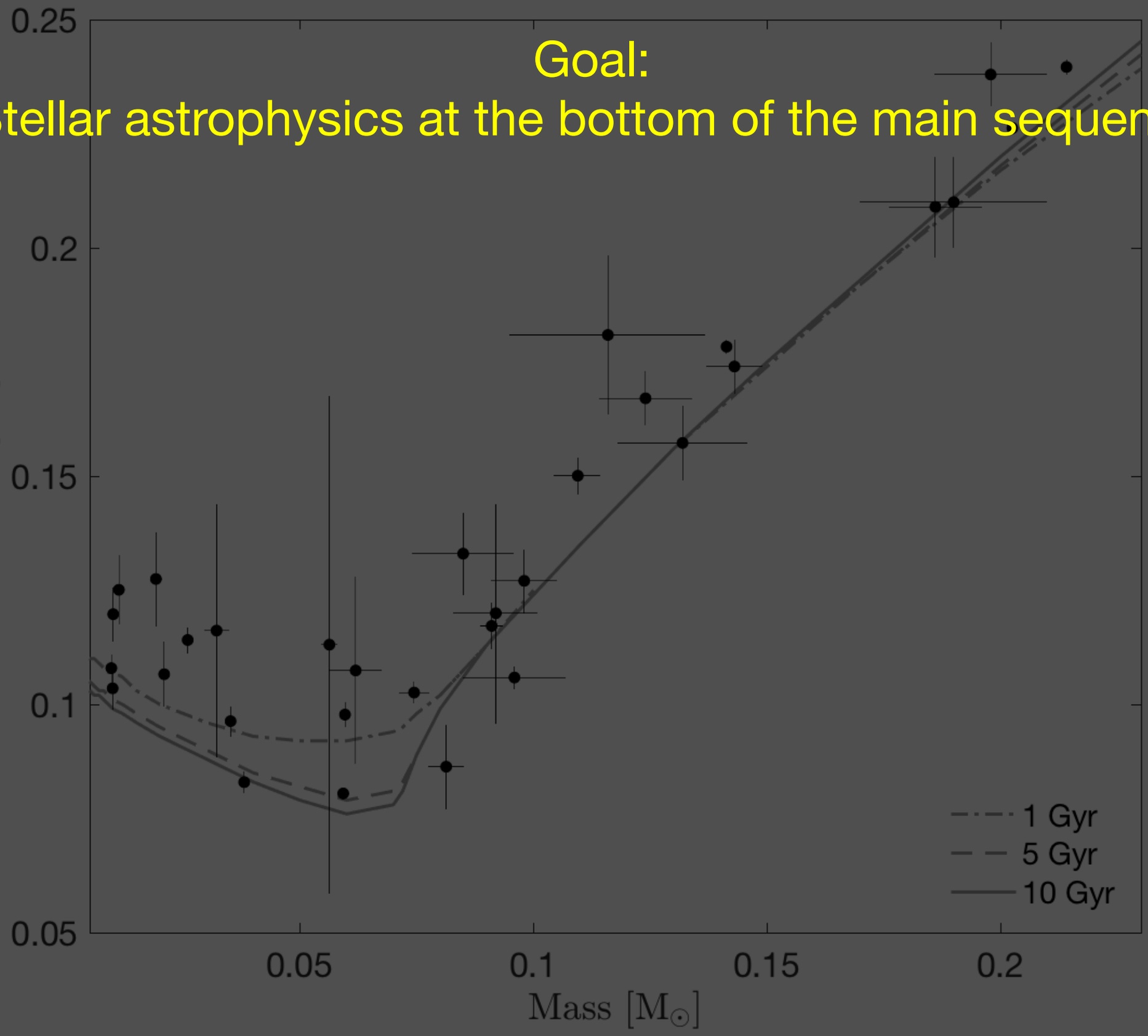
Avi Shporer
MIT

Collaborators: George Zhou, Andrew Vanderburg, Howard Isaacson, BJ Fulton, Allyson Bieryla, Rob Siverd, Guillermo Torres, Tim Morton, Joao Bento, Andrew Howard, Dave Latham, Dan Stevens


0.25
0.2
0.15
0.1
0.05
Radius [R⊙]
0.05
0.1
0.15
0.2
Mass [M⊙]
1 Gyr
5 Gyr
10 Gyr


0.25
0.2
0.15
0.1
0.05
Radius [R⊙]
0.05
0.1
0.15
0.2
Mass [M⊙]
1 Gyr
5 Gyr
10 Gyr

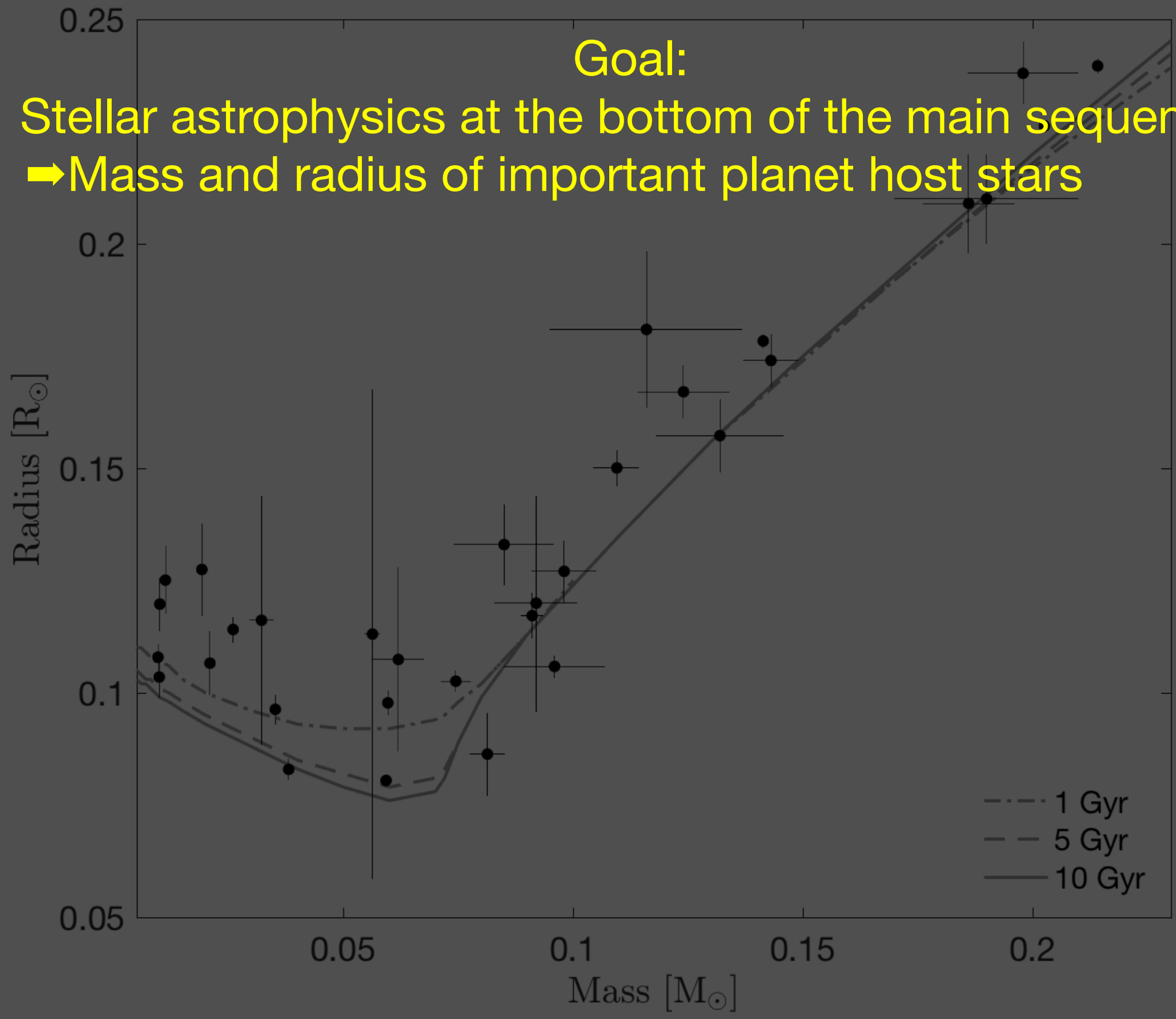
Goal:
Stellar astrophysics at the bottom of the main sequence



Goal:

Stellar astrophysics at the bottom of the main sequence

➡Mass and radius of important planet host stars



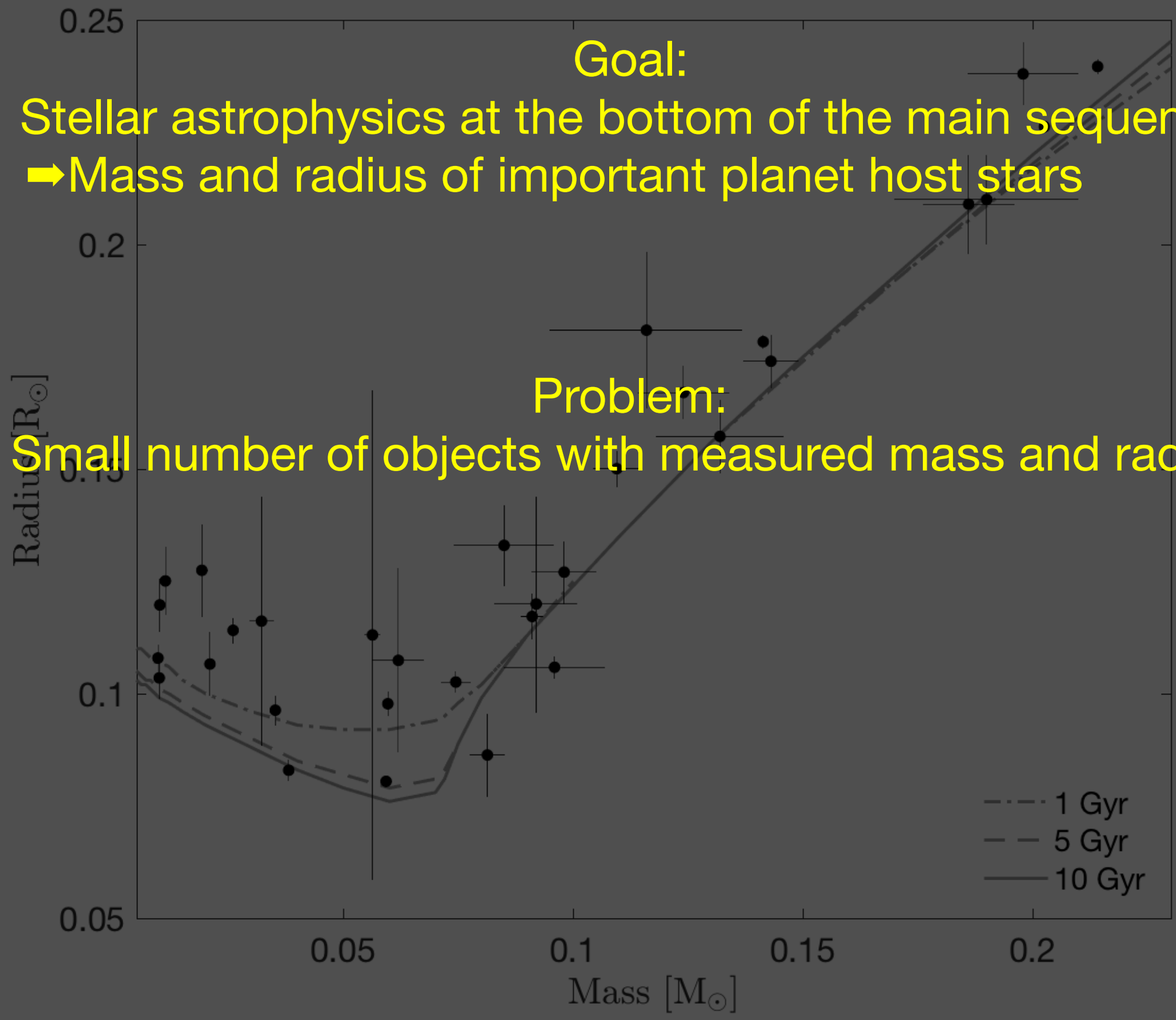
Goal:

Stellar astrophysics at the bottom of the main sequence

➡Mass and radius of important planet host stars

Problem:

Small number of objects with measured mass and radius



Goal:

Stellar astrophysics at the bottom of the main sequence

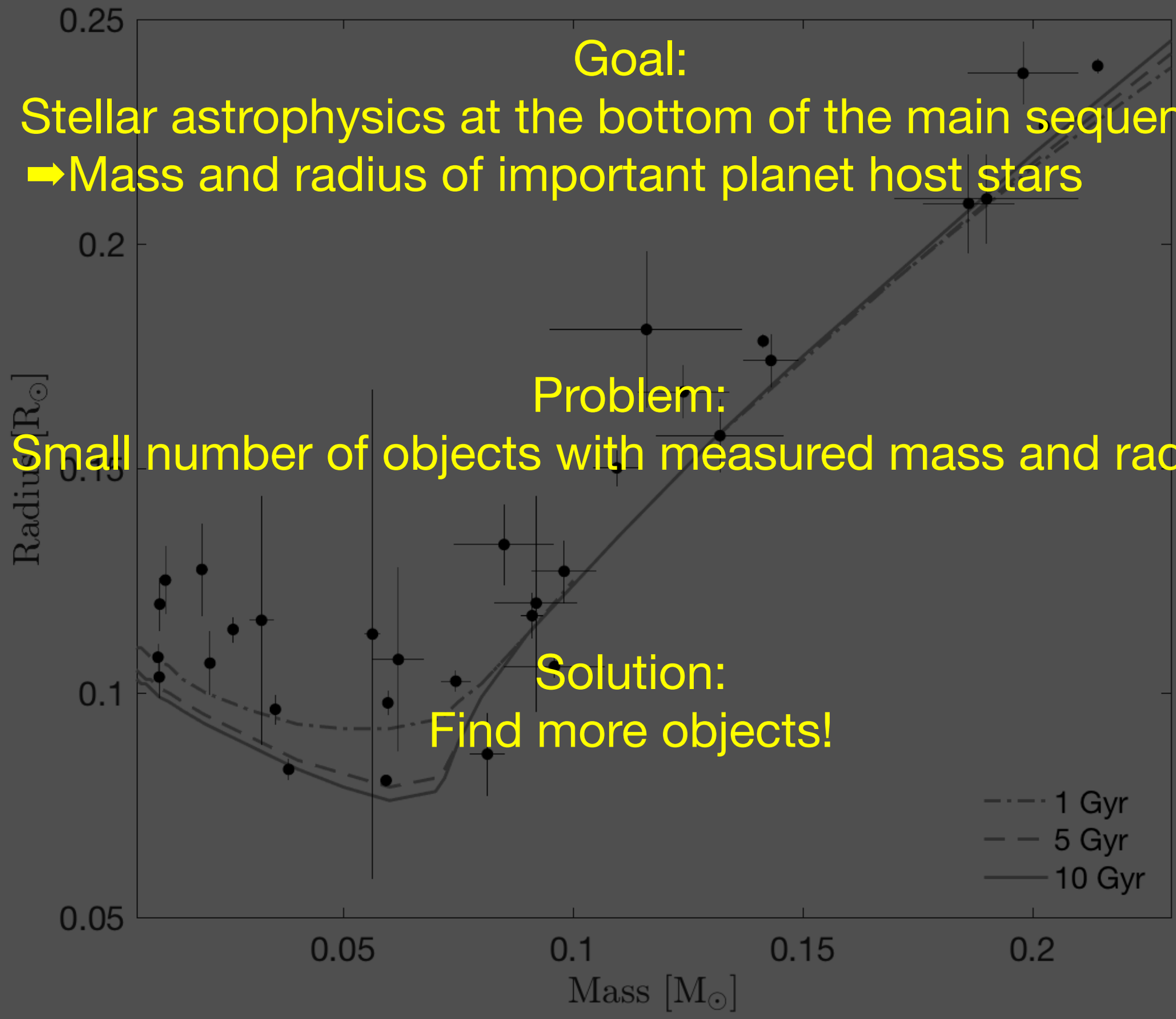
➡Mass and radius of important planet host stars

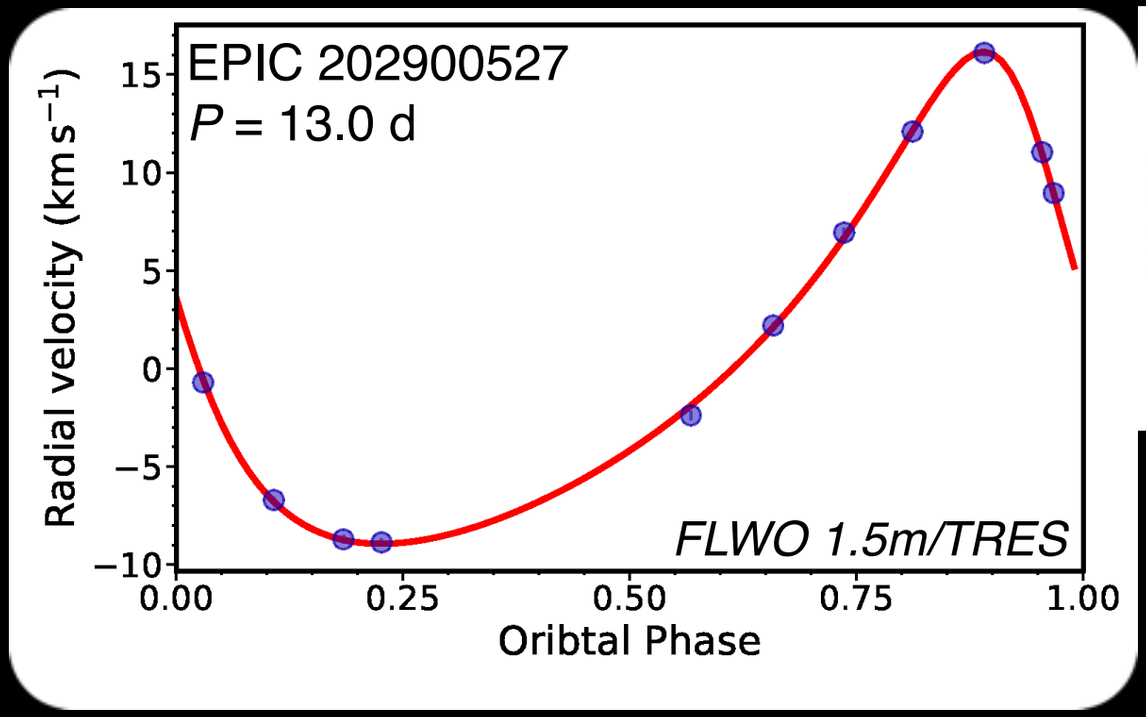
Problem:

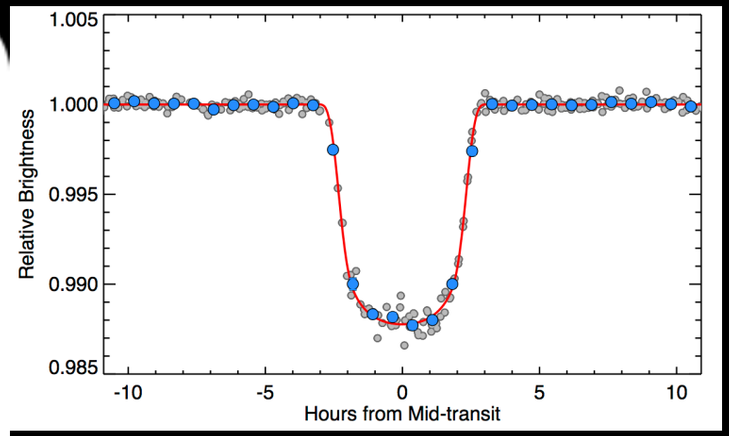
Small number of objects with measured mass and radius

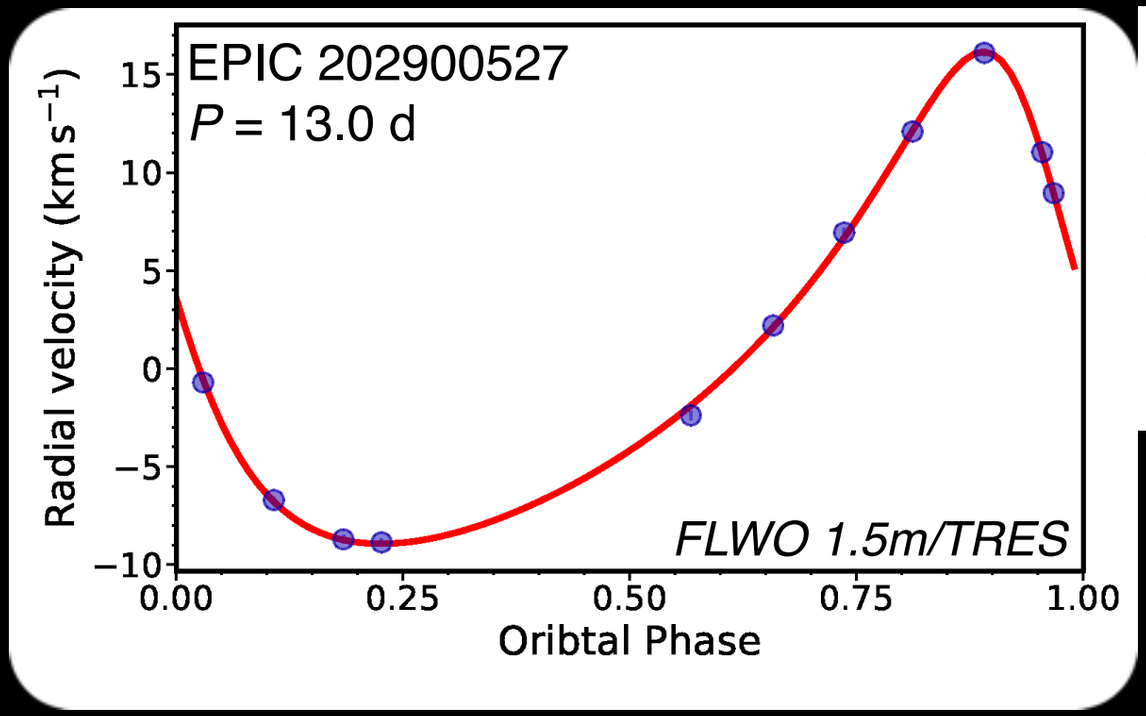
Solution:

Find more objects!




EPIC 202900527
P = 13.0 d
FLWO 1.5m/TRES
Radial velocity (km s−1)
Oribtal Phase
15
10
5
0
−5
−10
0.00
0.25
0.50
0.75
1.00


Relative Brightness
Hours from Mid-transit
1.005
1.000
0.995
0.990
0.985
-10
-5
0
5
10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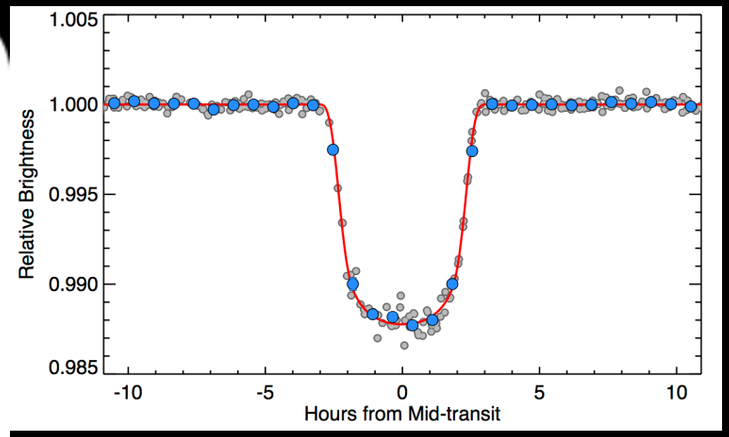
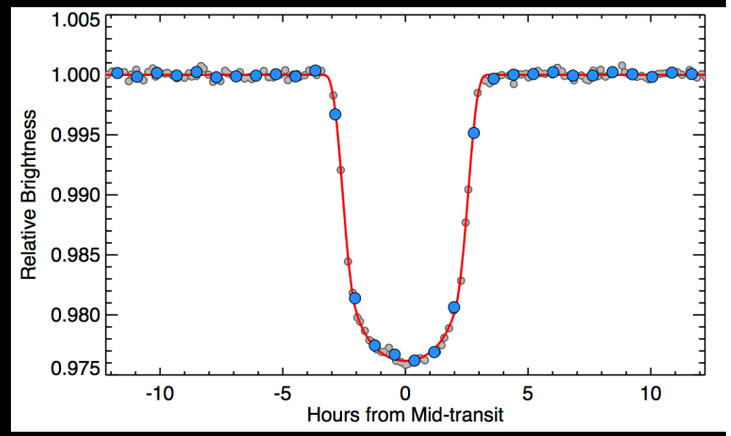
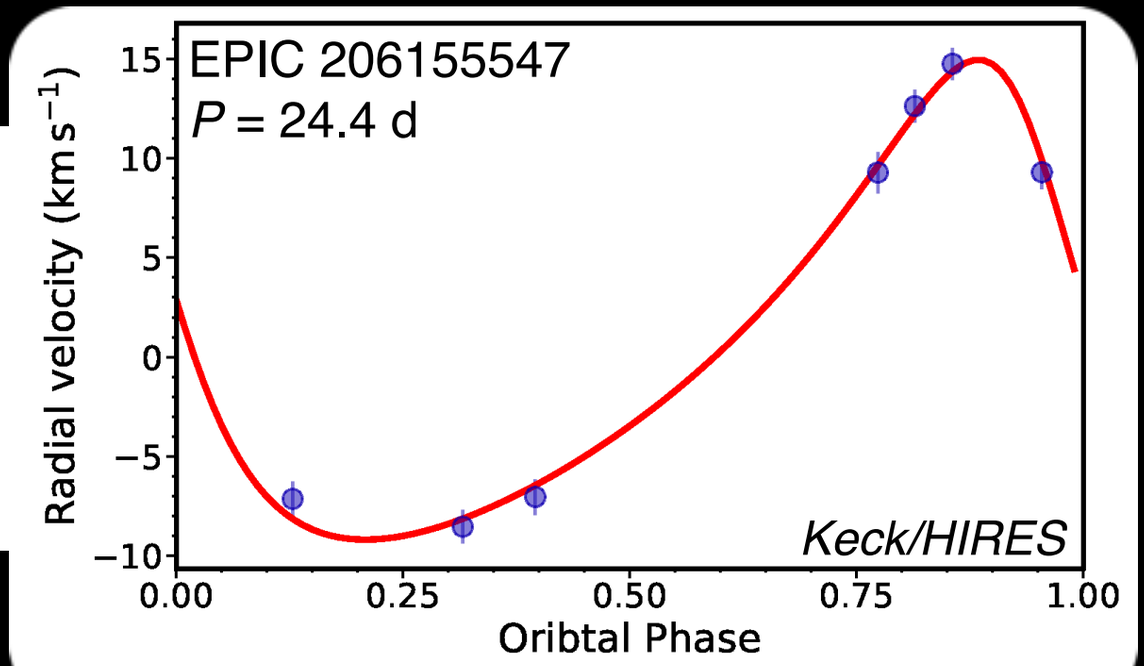
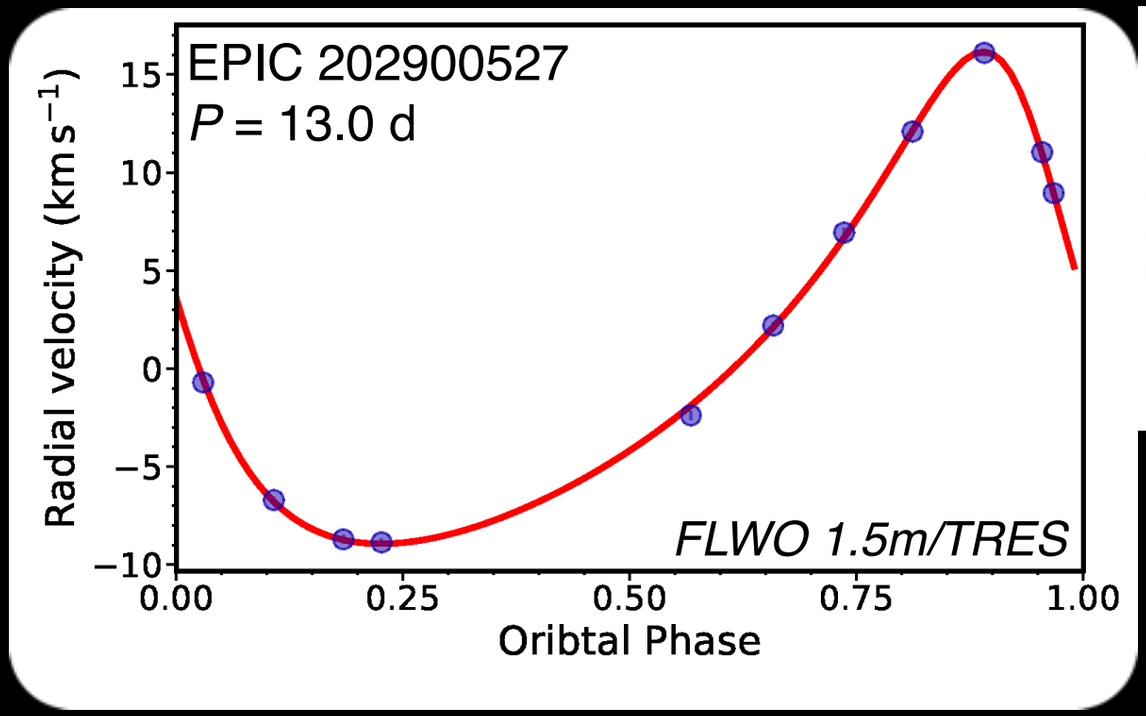
P = 13.0 d
FLWO 1.5m/TRES
Radial velocity (km s−1)
Oribtal Phase

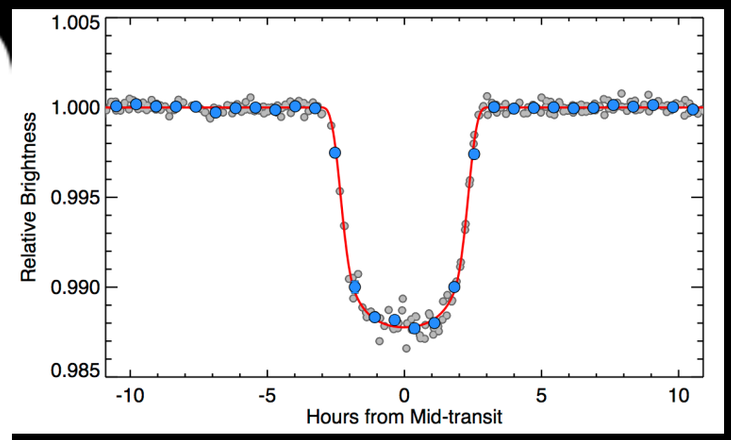

Relative Brightness
Hours from Mid-transit

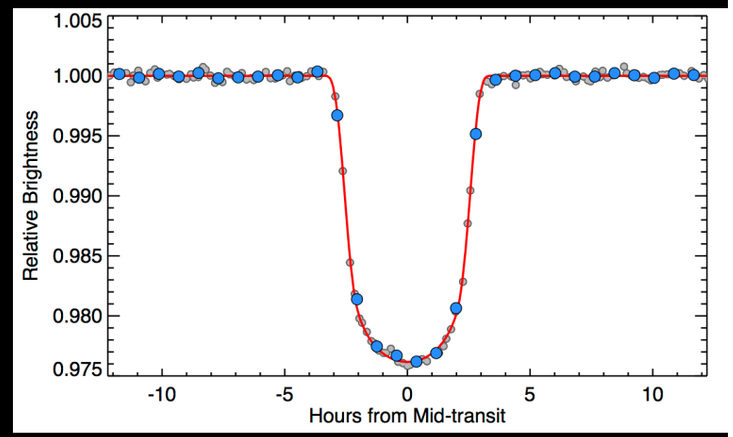

Relative Brightness
Hours from Mid-transit

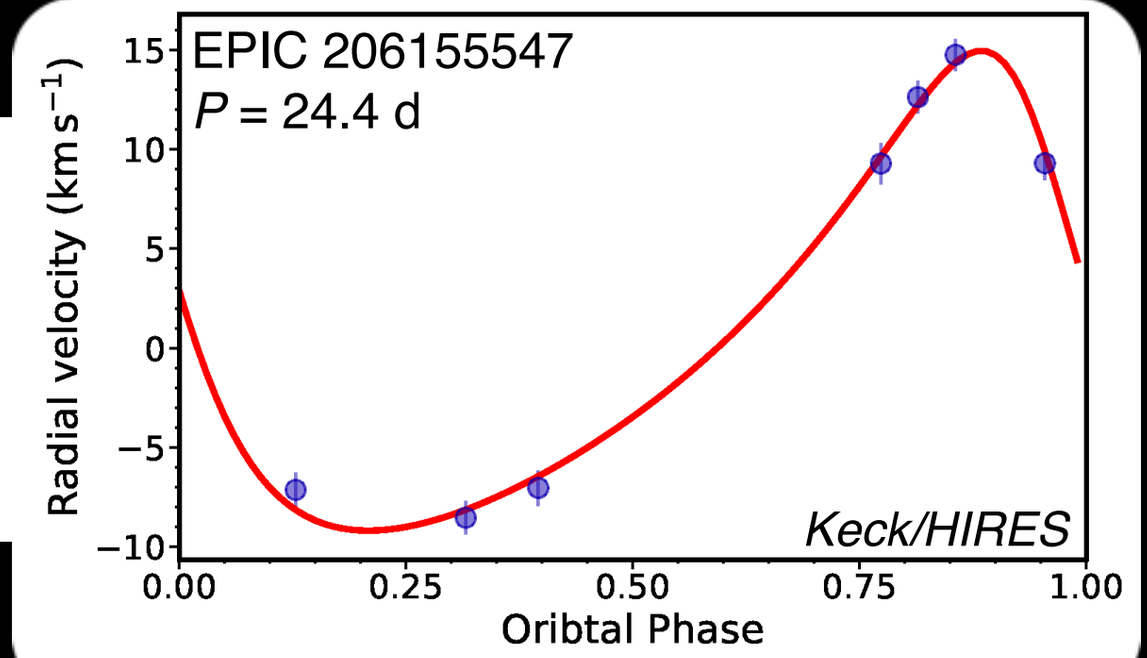

EPIC 206155547
P = 24.4 d
Keck/HIRES
Radial velocity (km s−1)
Oribtal Phase

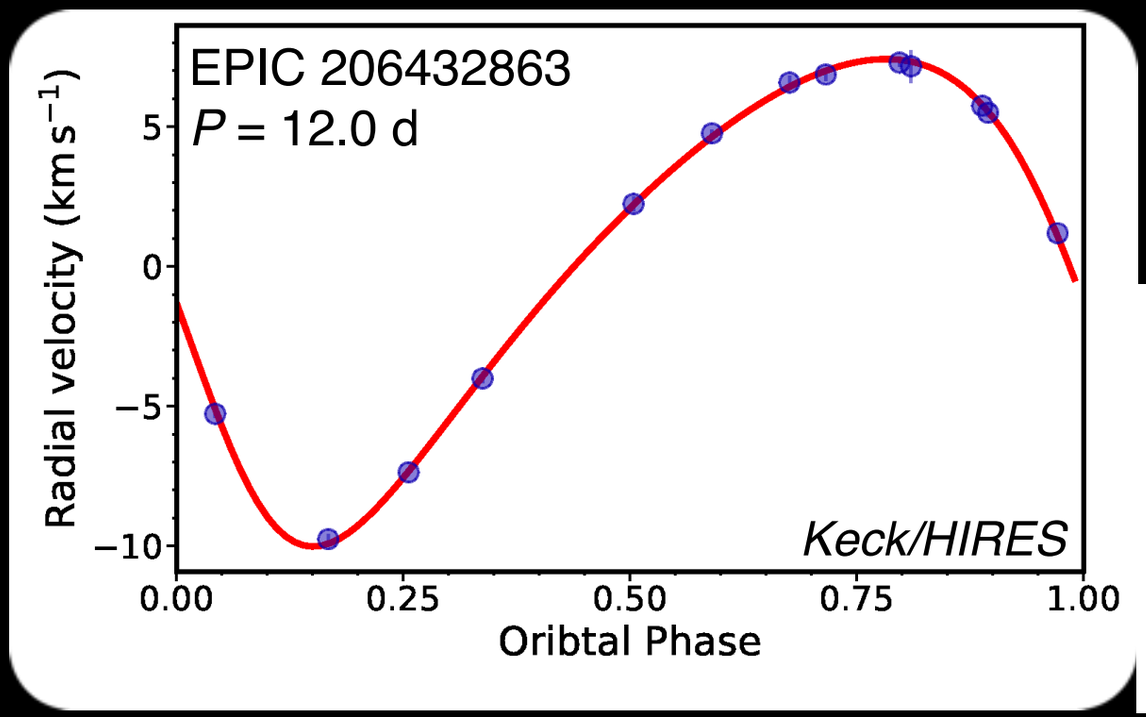
Shporer et al. 2017

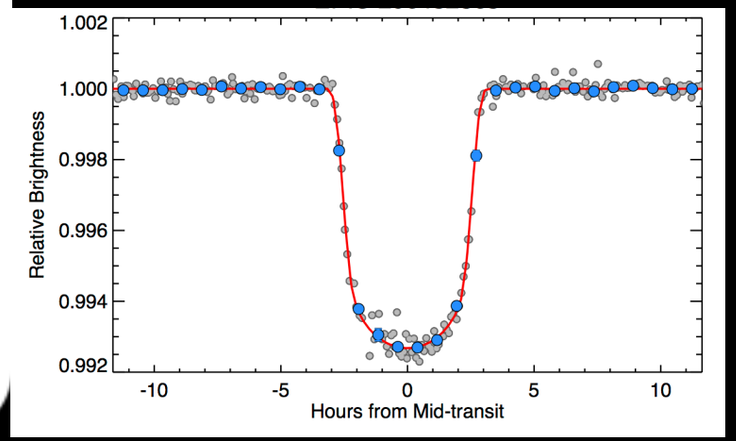


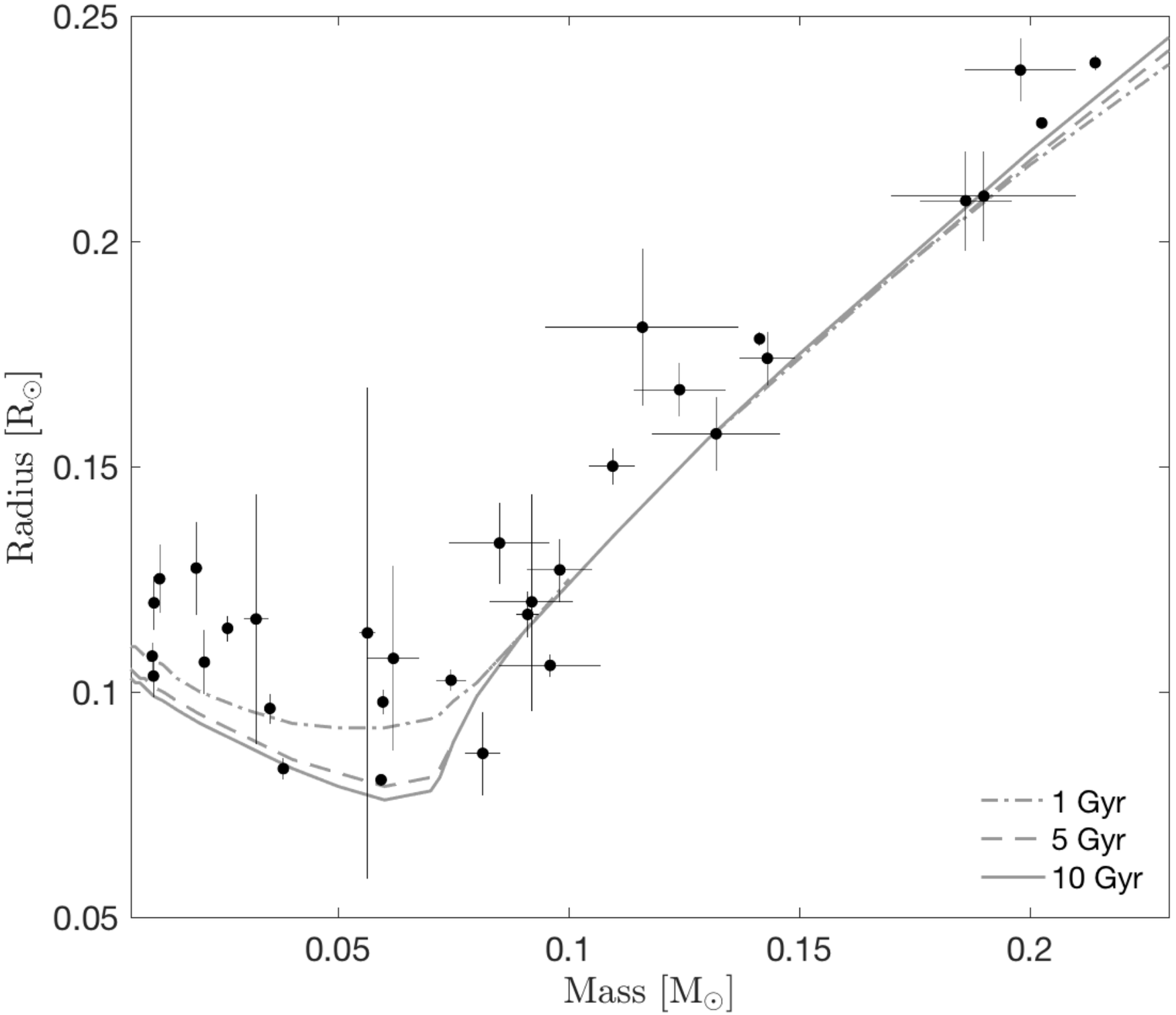












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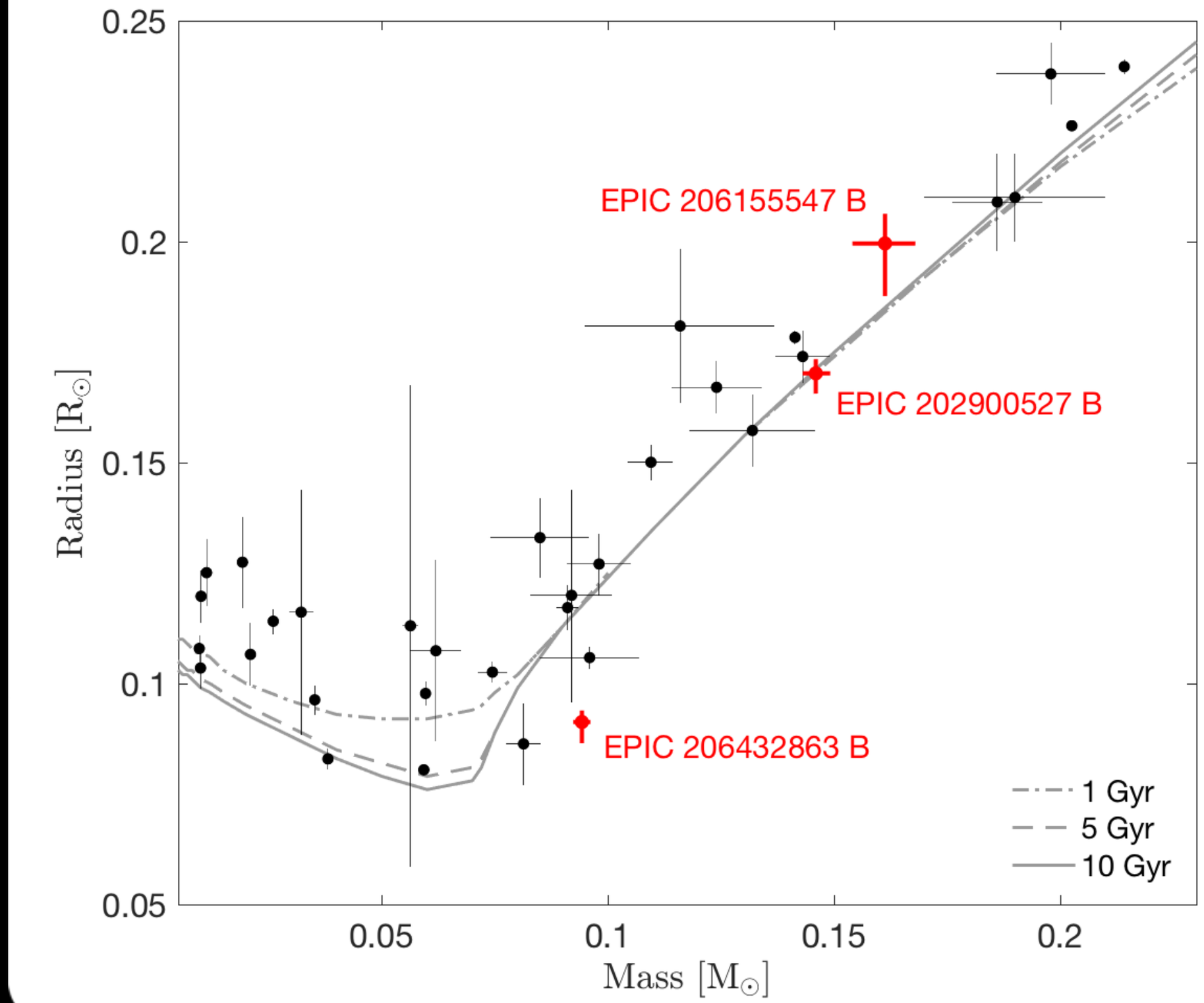

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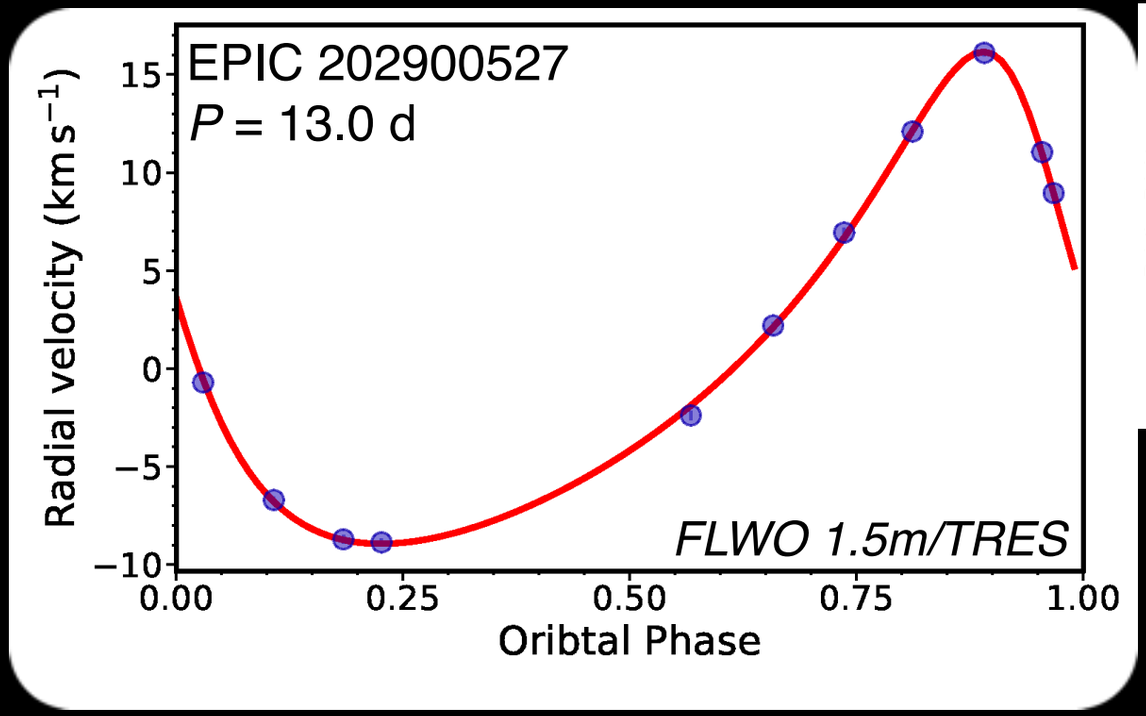

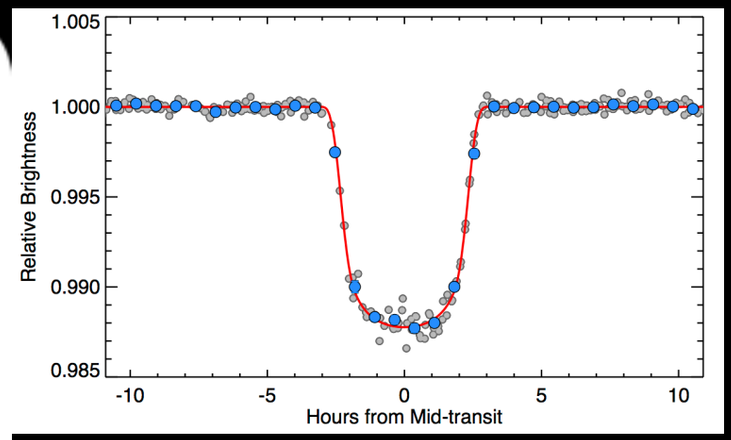

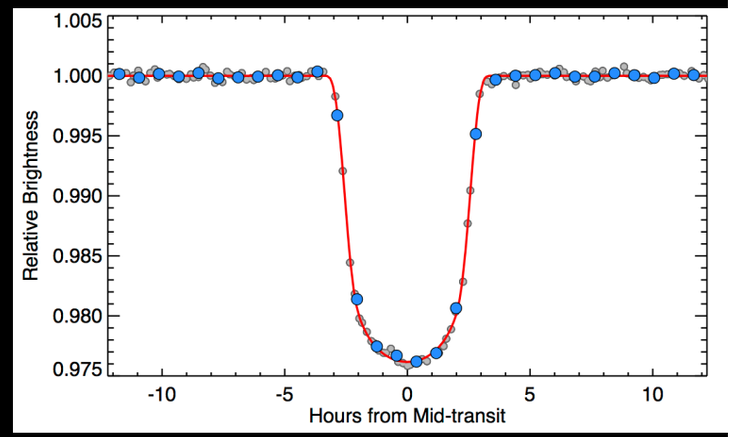

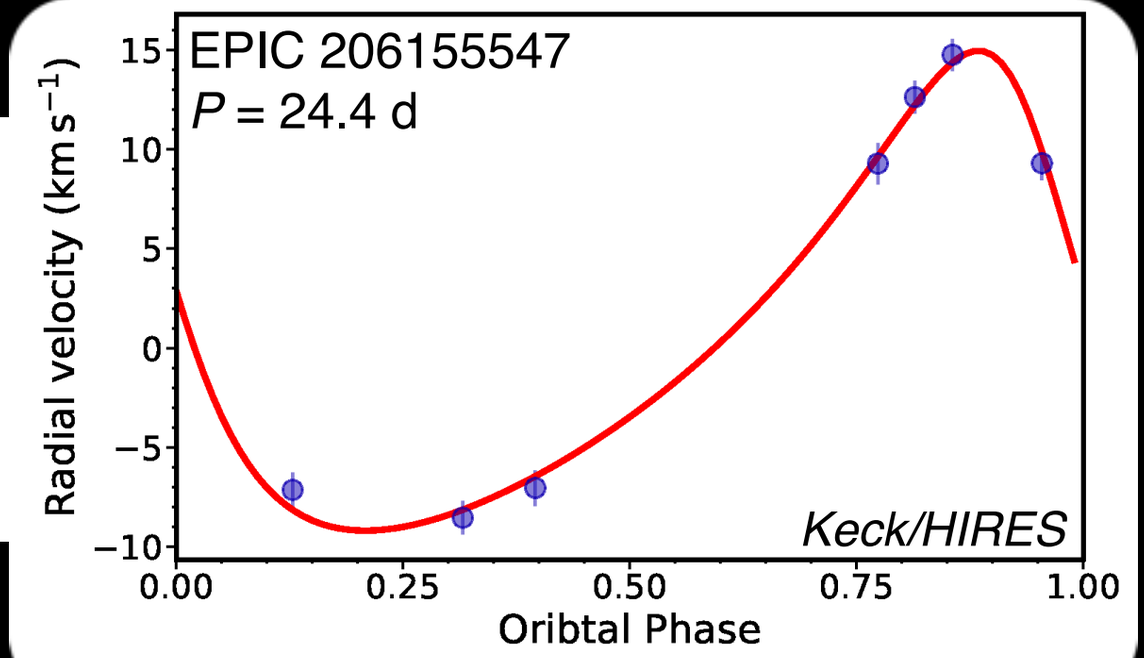

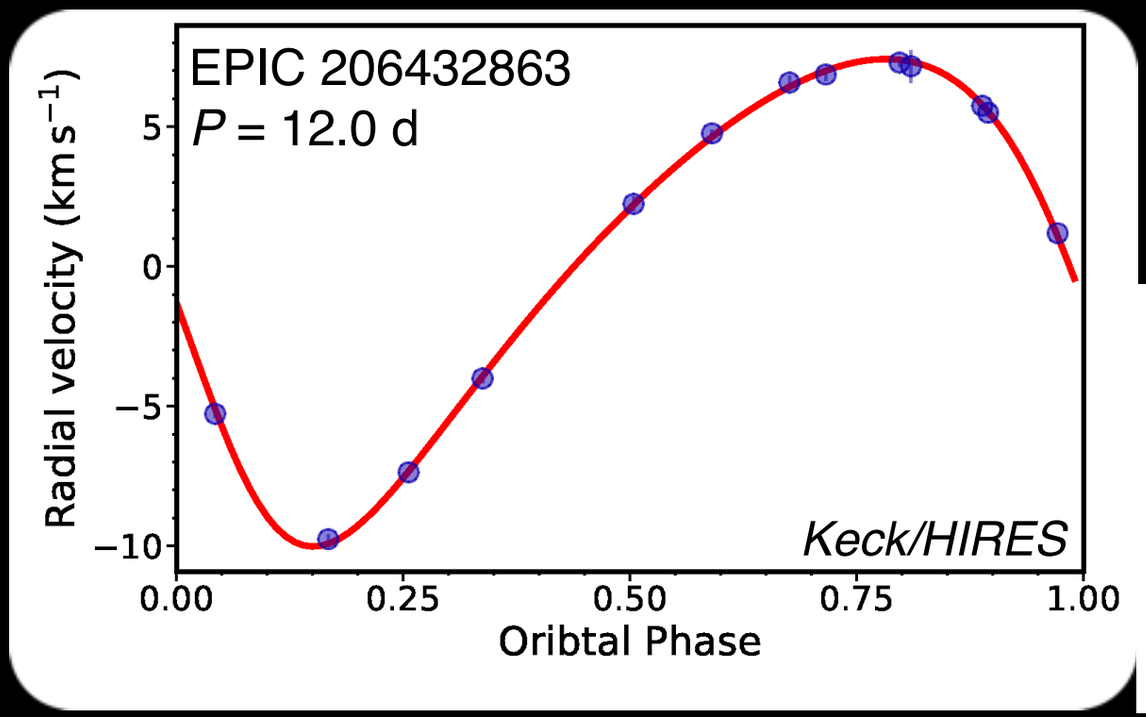

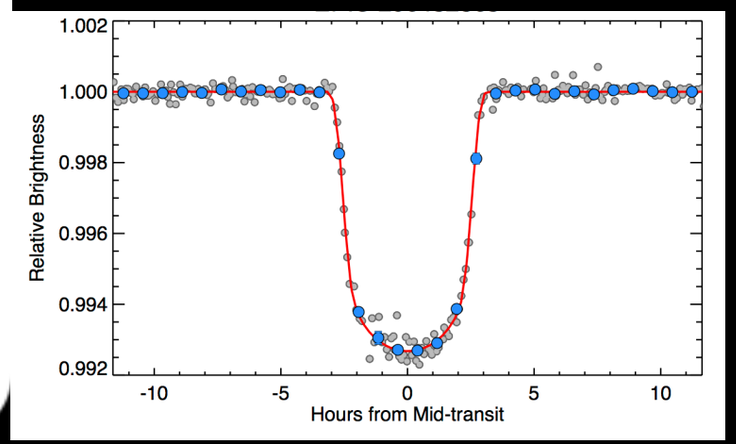

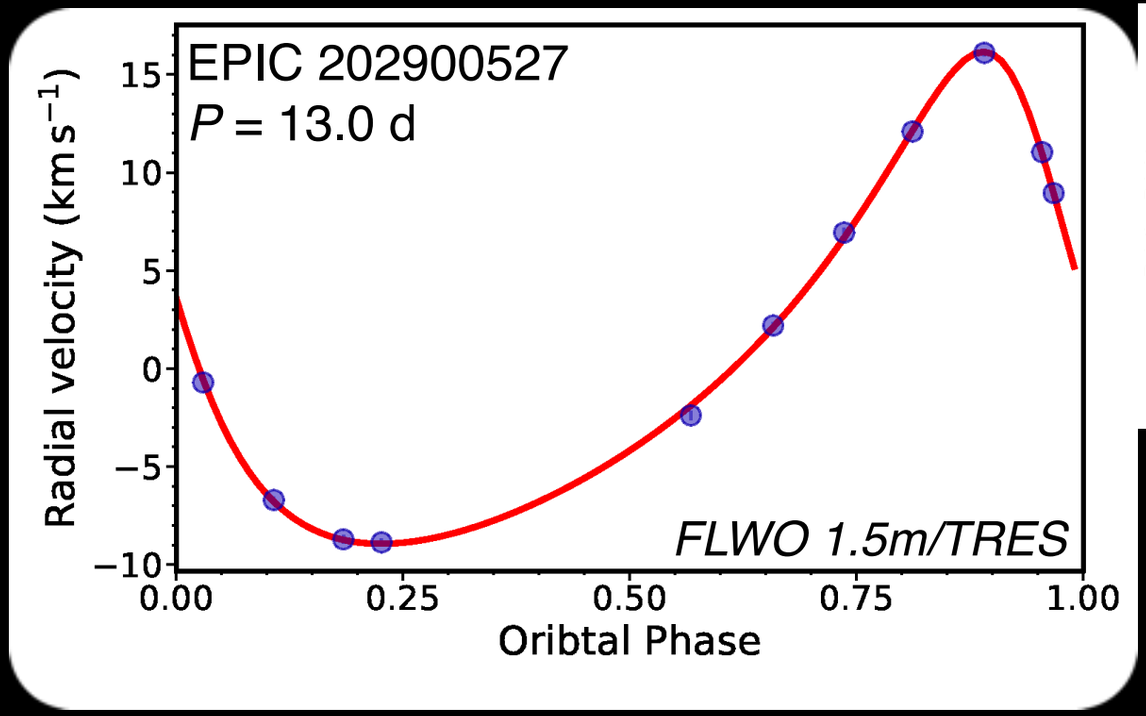

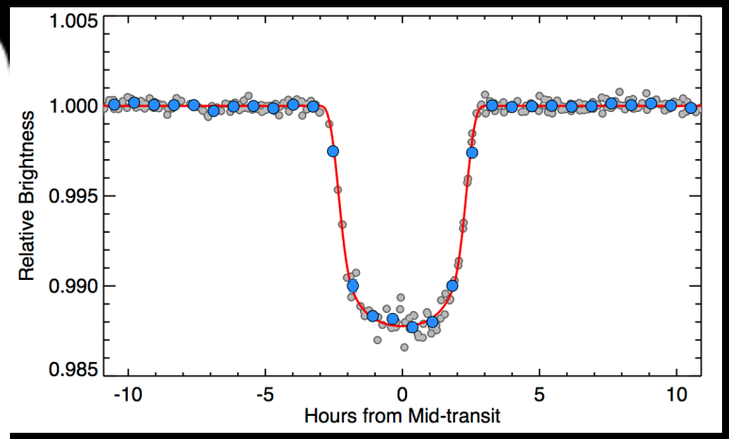

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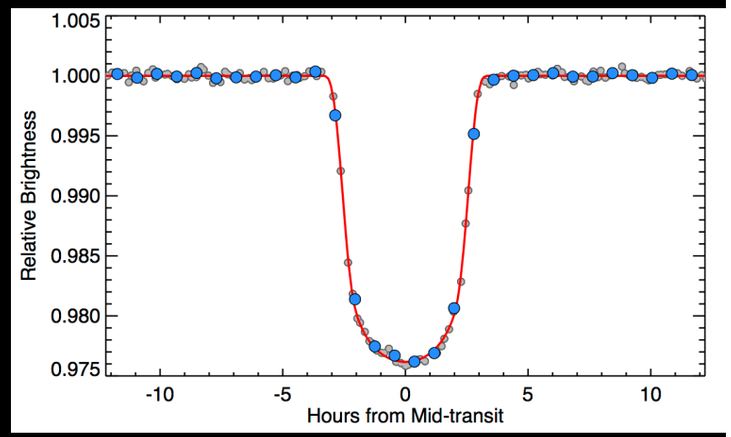
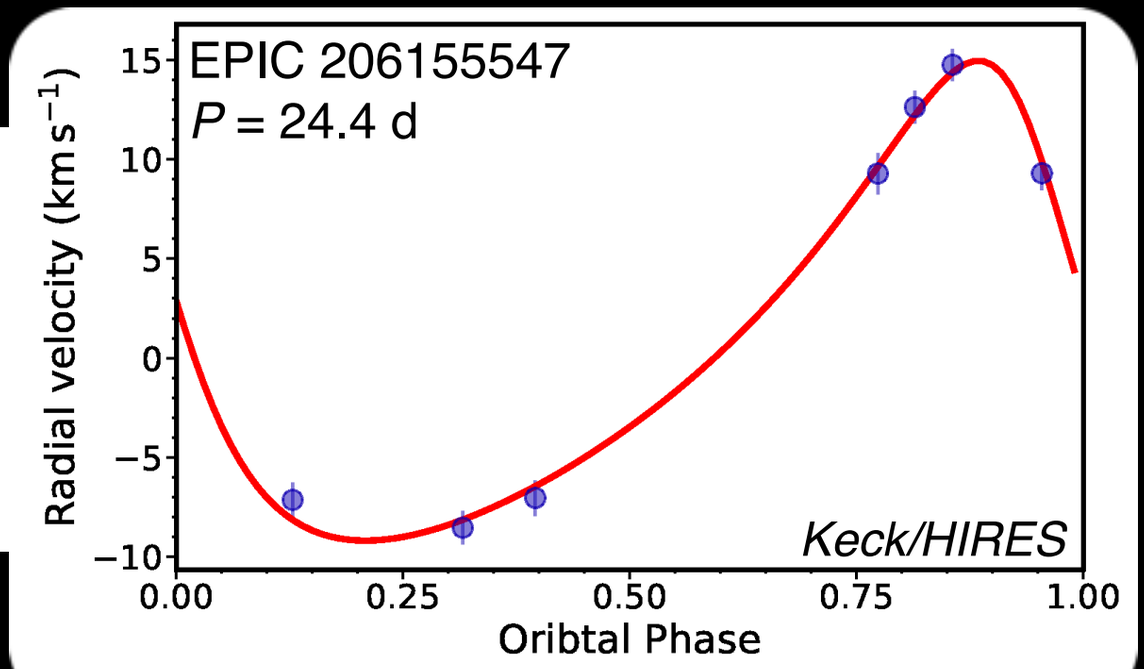
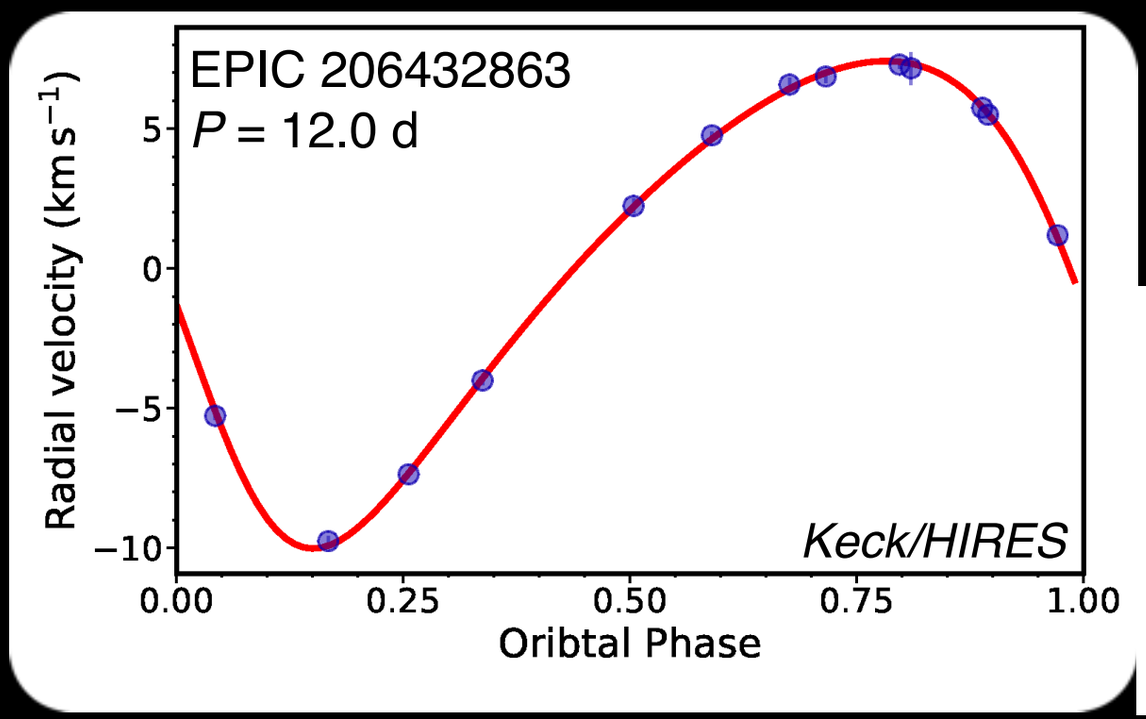
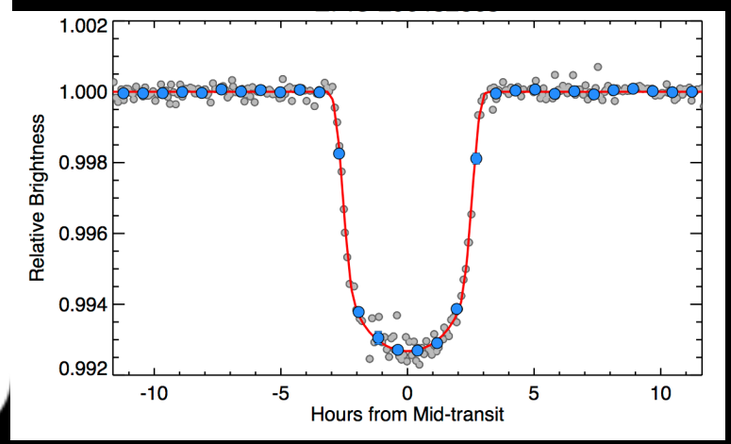
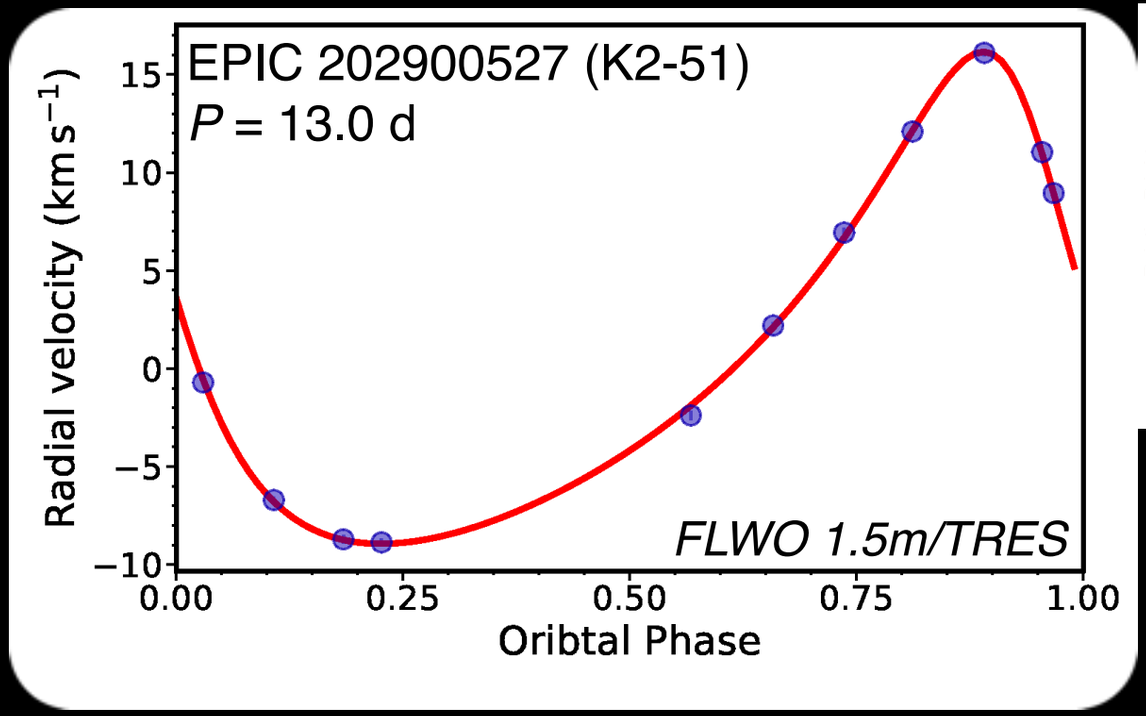
Misclassified statistically validated K2 planets

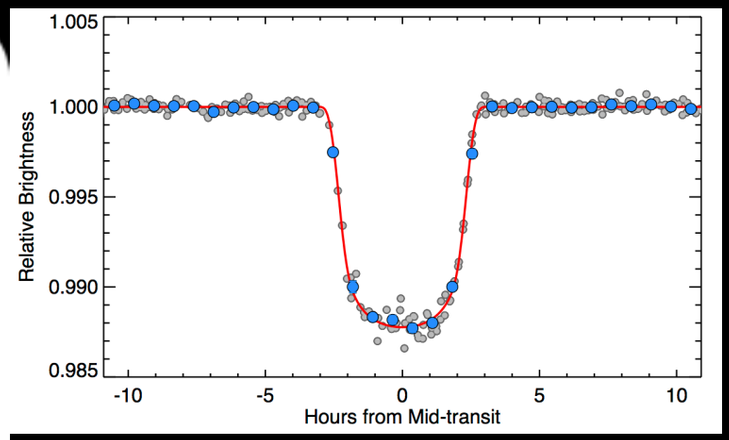












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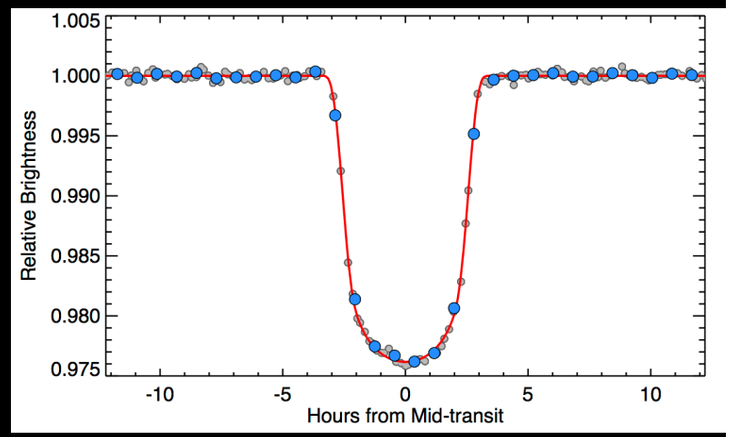
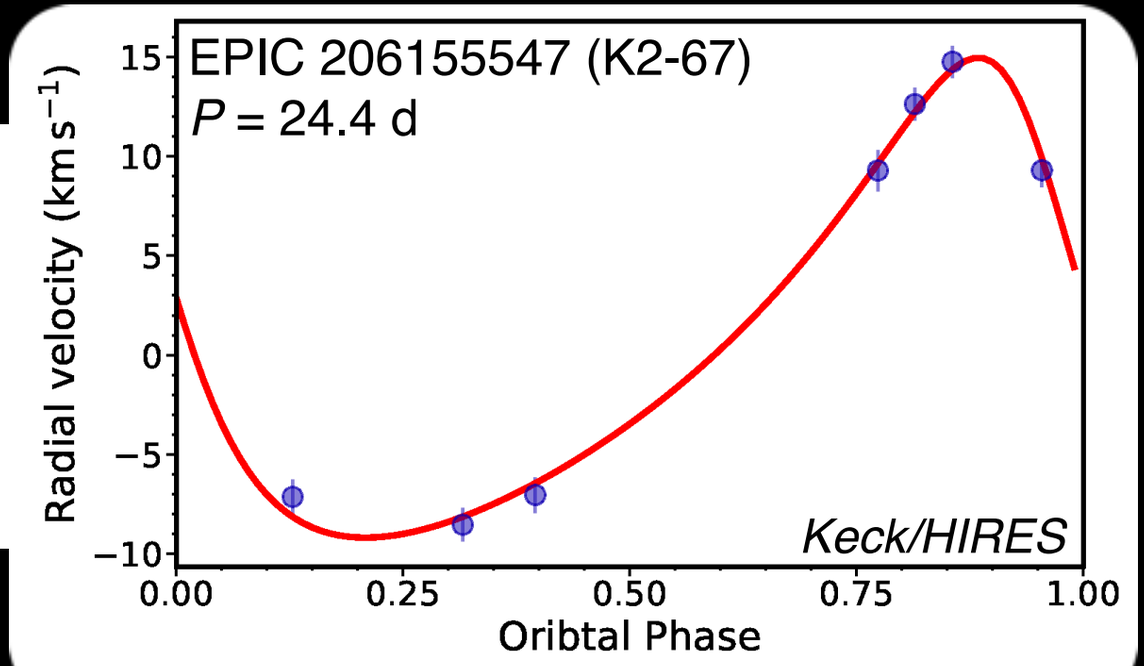
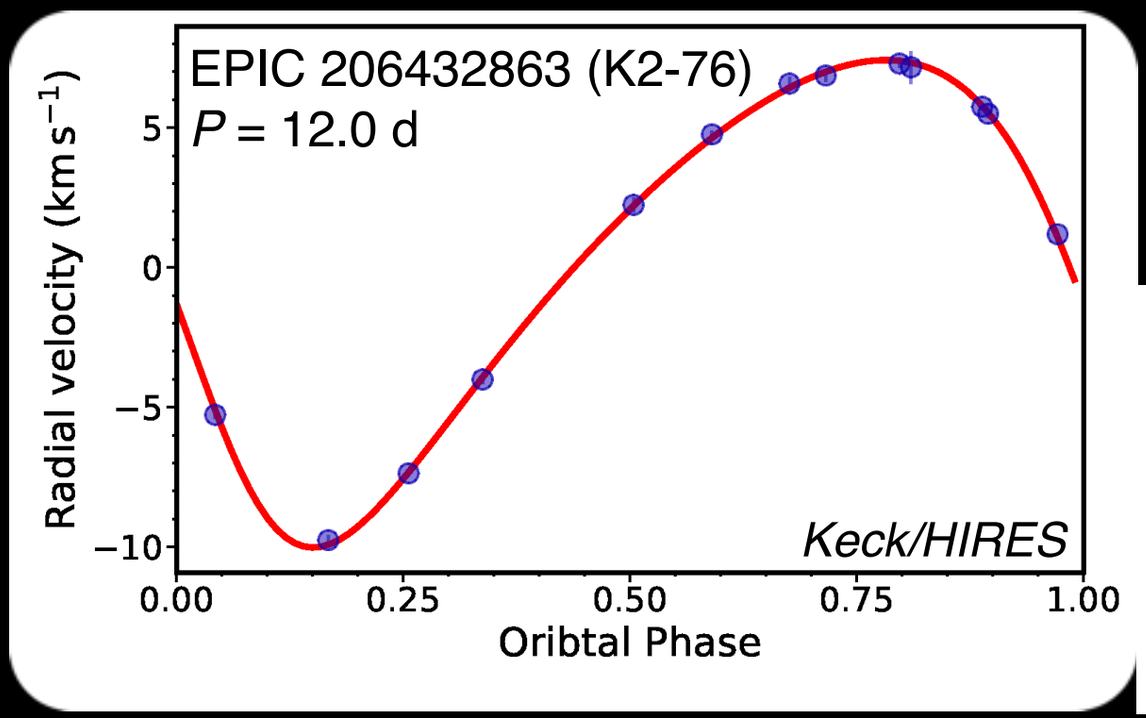
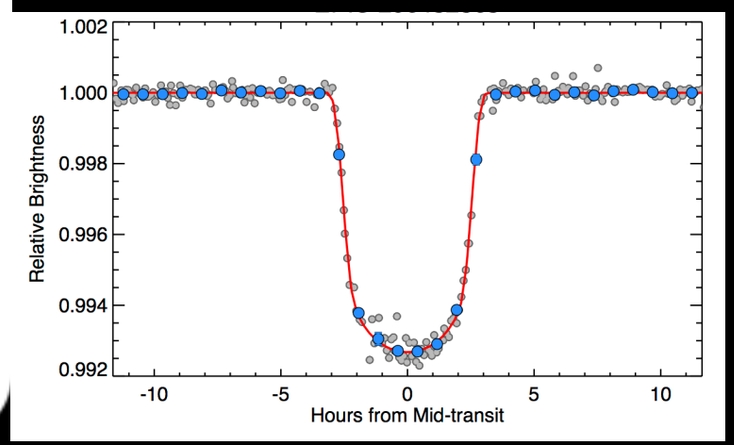
Misclassified statistically validated K2 planets

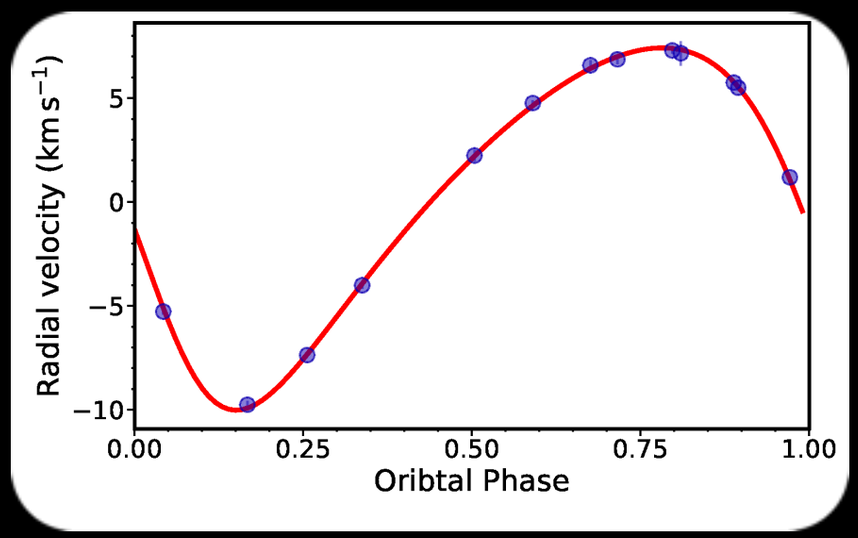






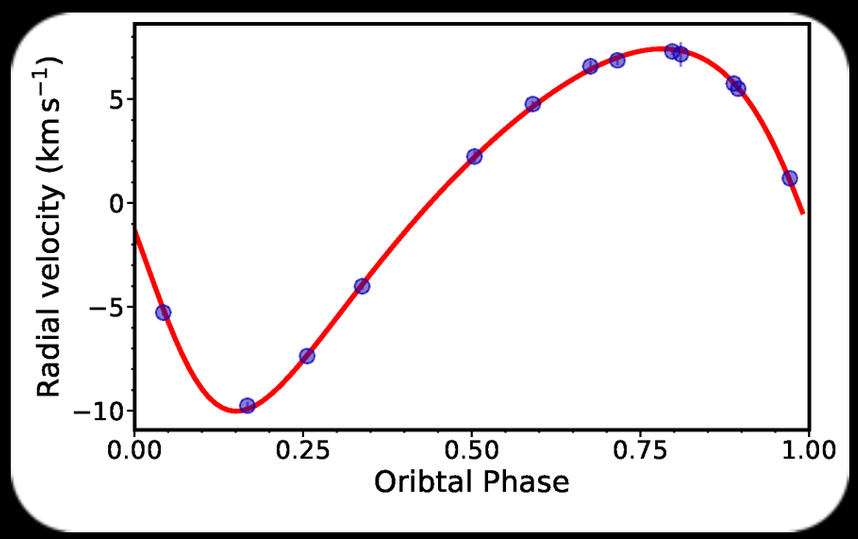


$$\frac{M_1}{M_2} \sim 10$$



$$\frac{M_1}{M_2} \sim 10$$

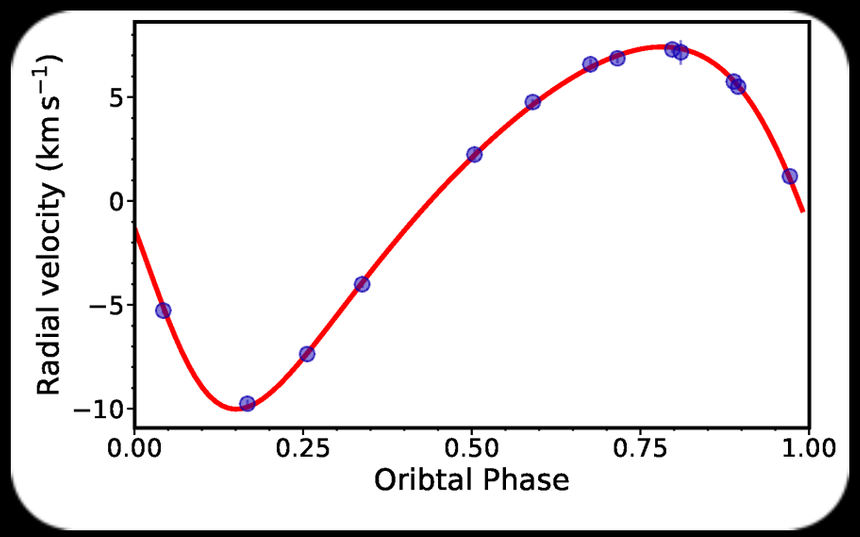
$$\frac{a^3}{G(M_1 + M_2)} = \frac{P^2}{4\pi^2}$$

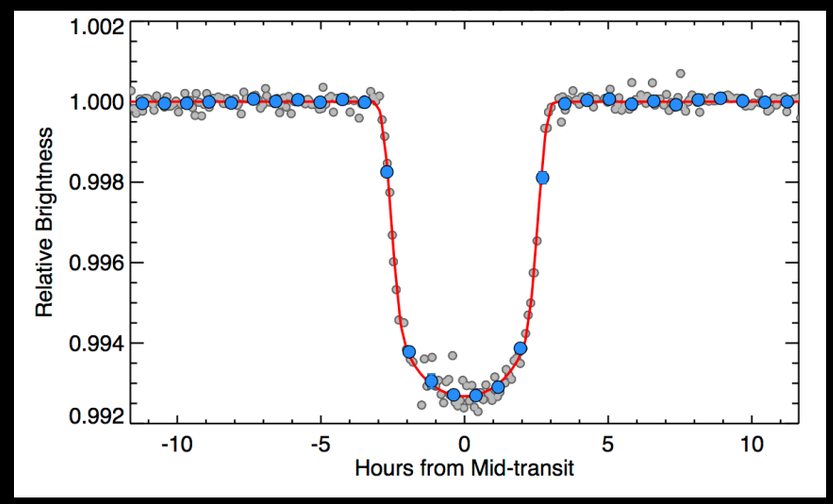


$$\frac{M_1}{M_2} \sim 10$$

$$\frac{F_1}{F_2} \sim 10^3 - 10^4$$
(In the optical)

$$\frac{a^3}{G(M_1 + M_2)} = \frac{P^2}{4\pi^2}$$



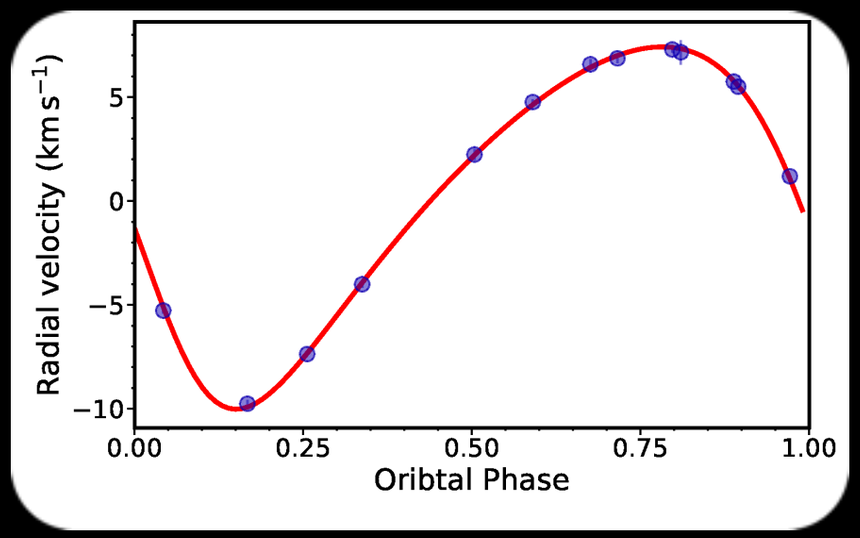


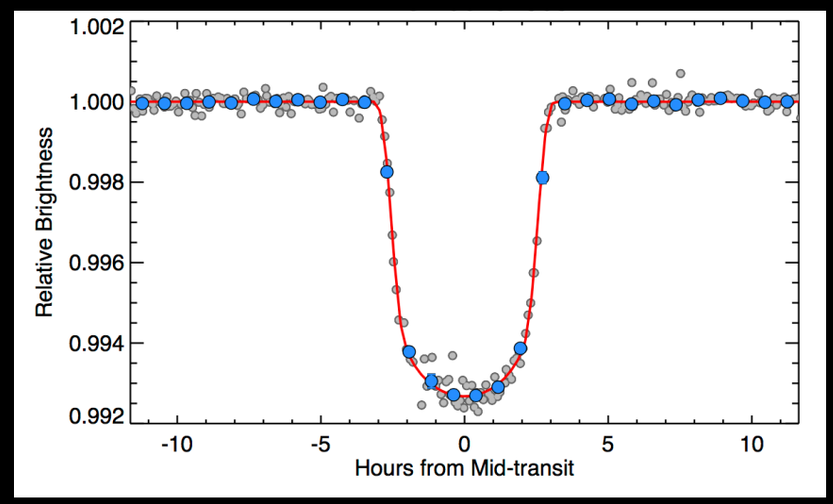
$$\frac{M_1}{M_2} \sim 10$$

$$\frac{F_1}{F_2} \sim 10^3 - 10^4$$
(In the optical)

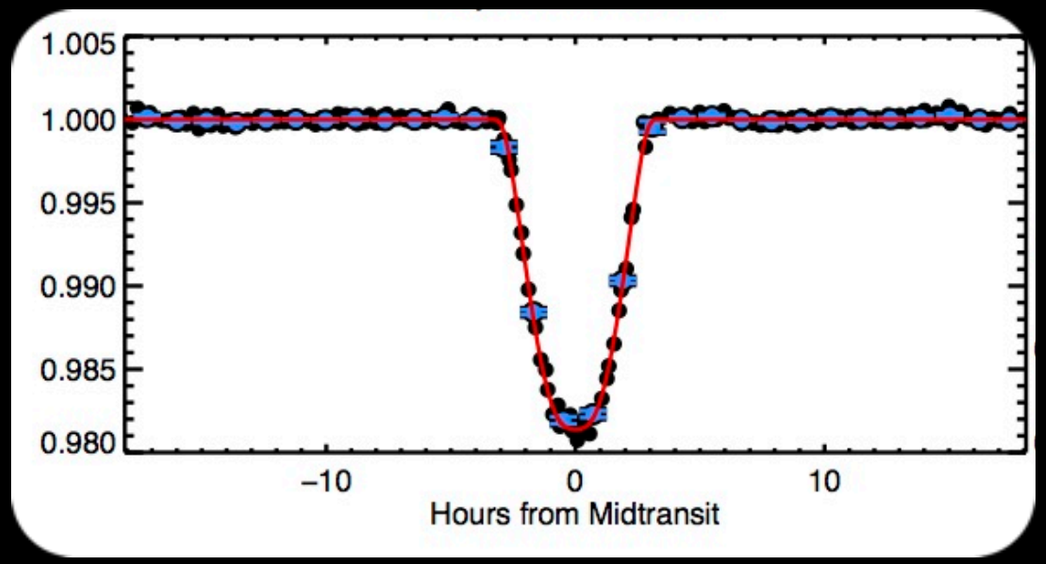
$$\frac{a^3}{G(M_1 + M_2)} = \frac{P^2}{4\pi^2}$$

Eclipse depth $\longrightarrow$ $\frac{R_2}{R_1}$

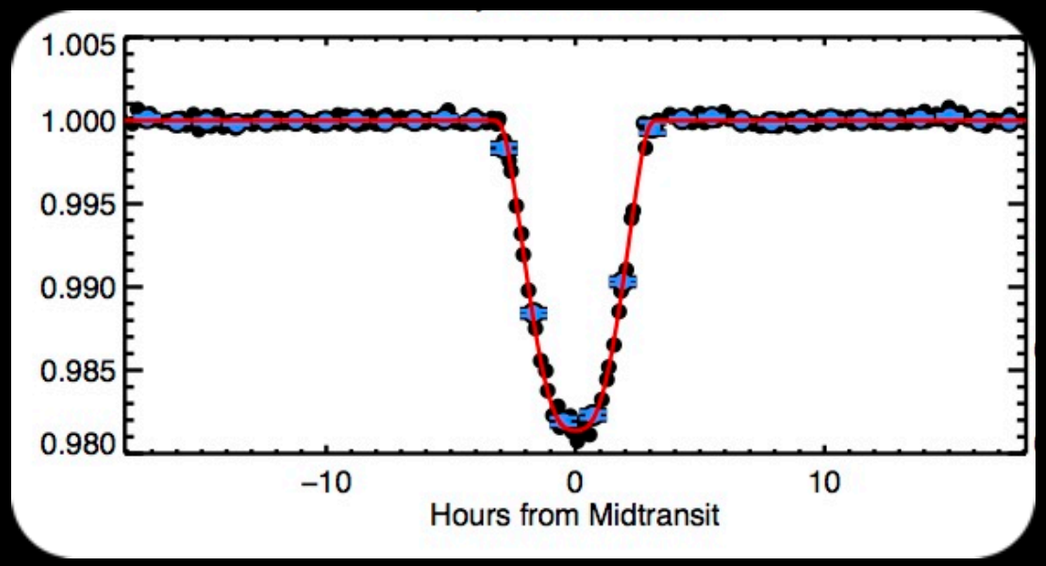




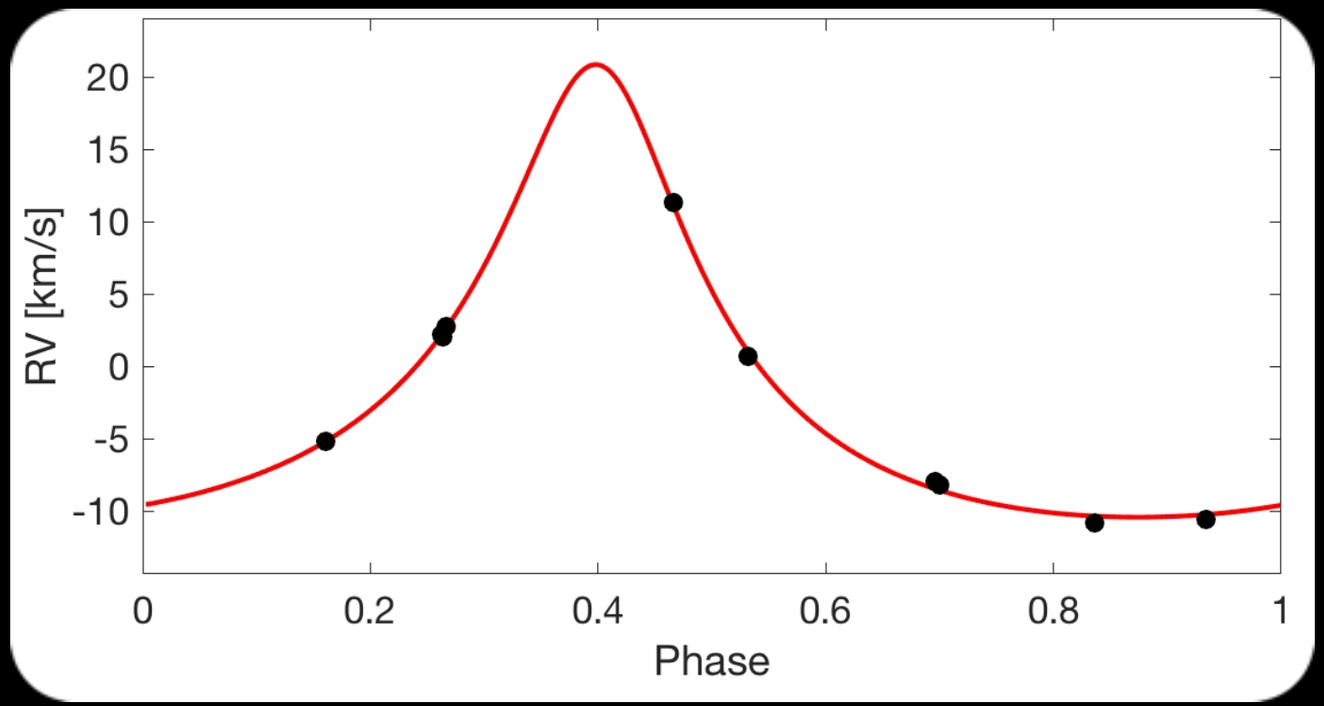
K2



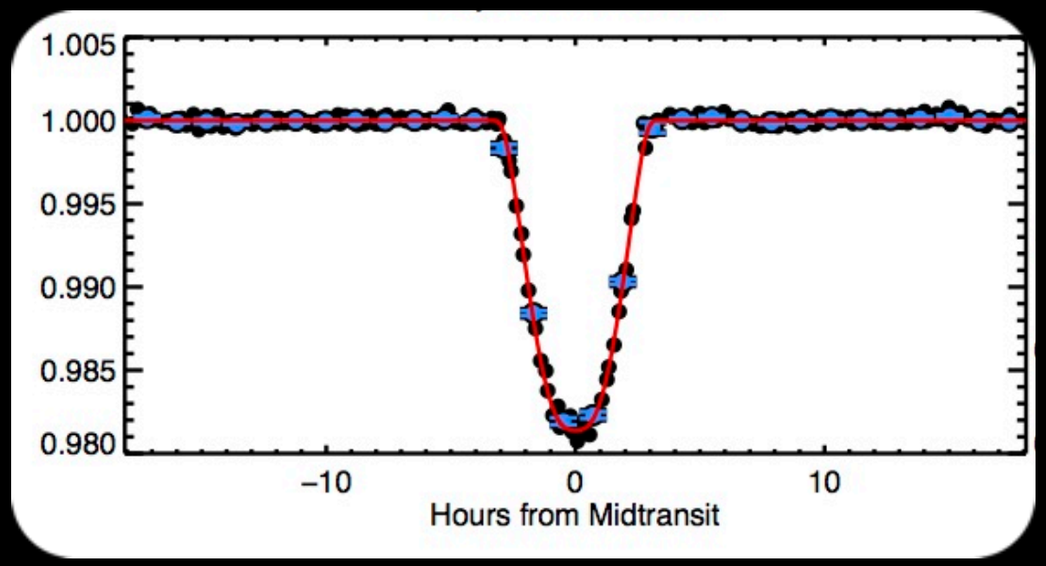
K2

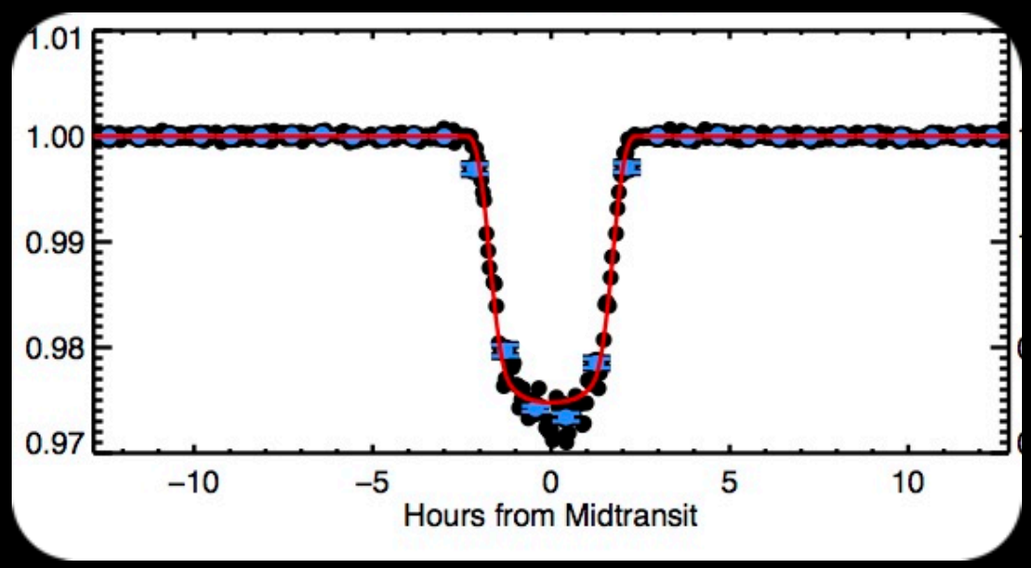


Keck/HIRES



K2





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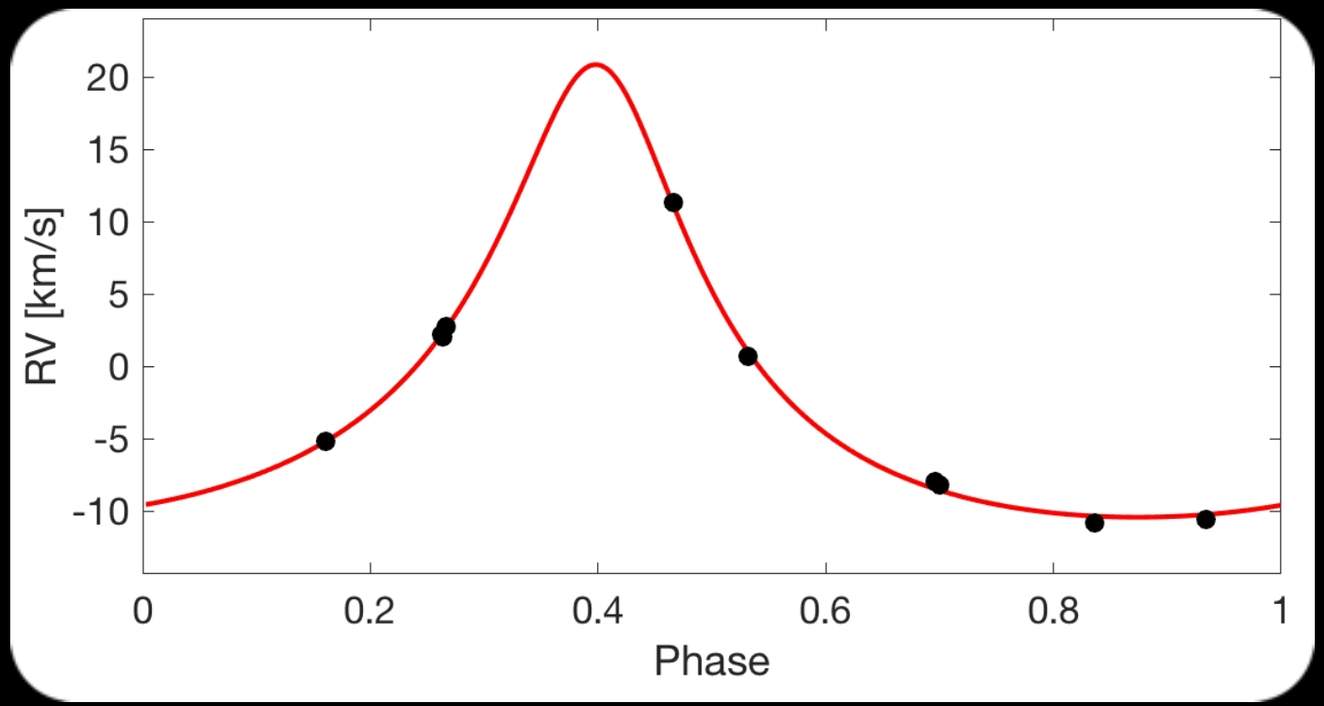
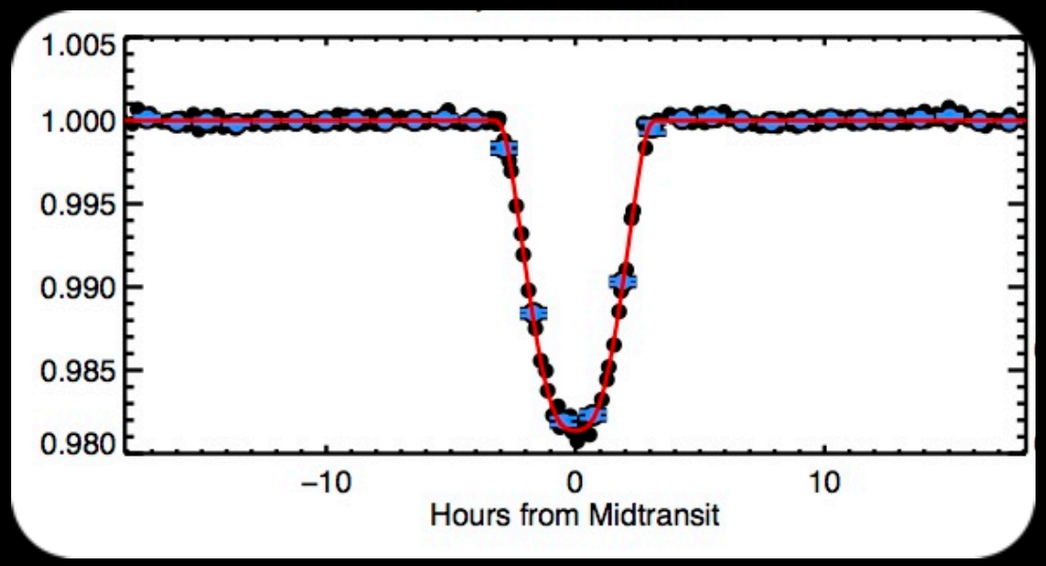
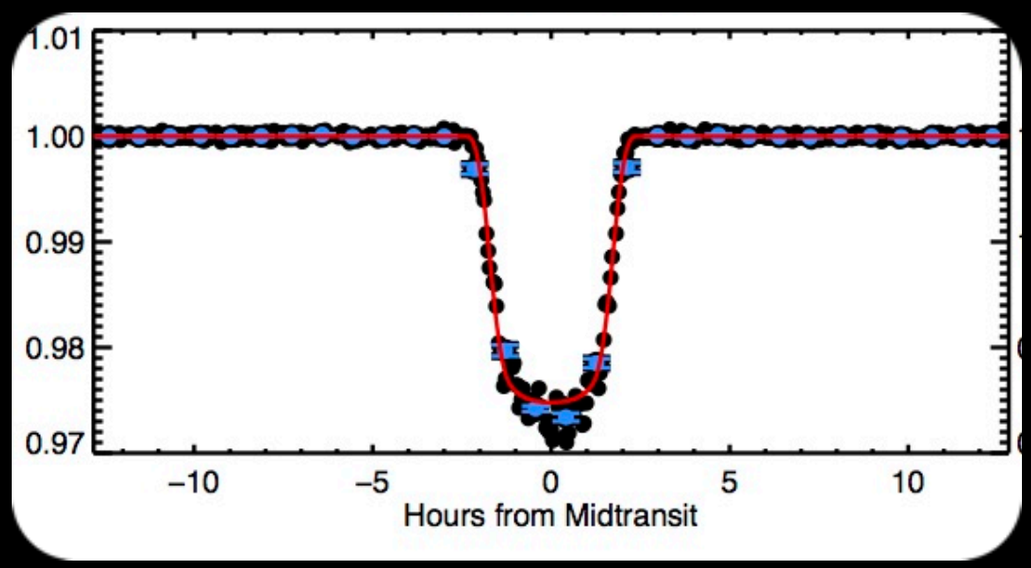


K2





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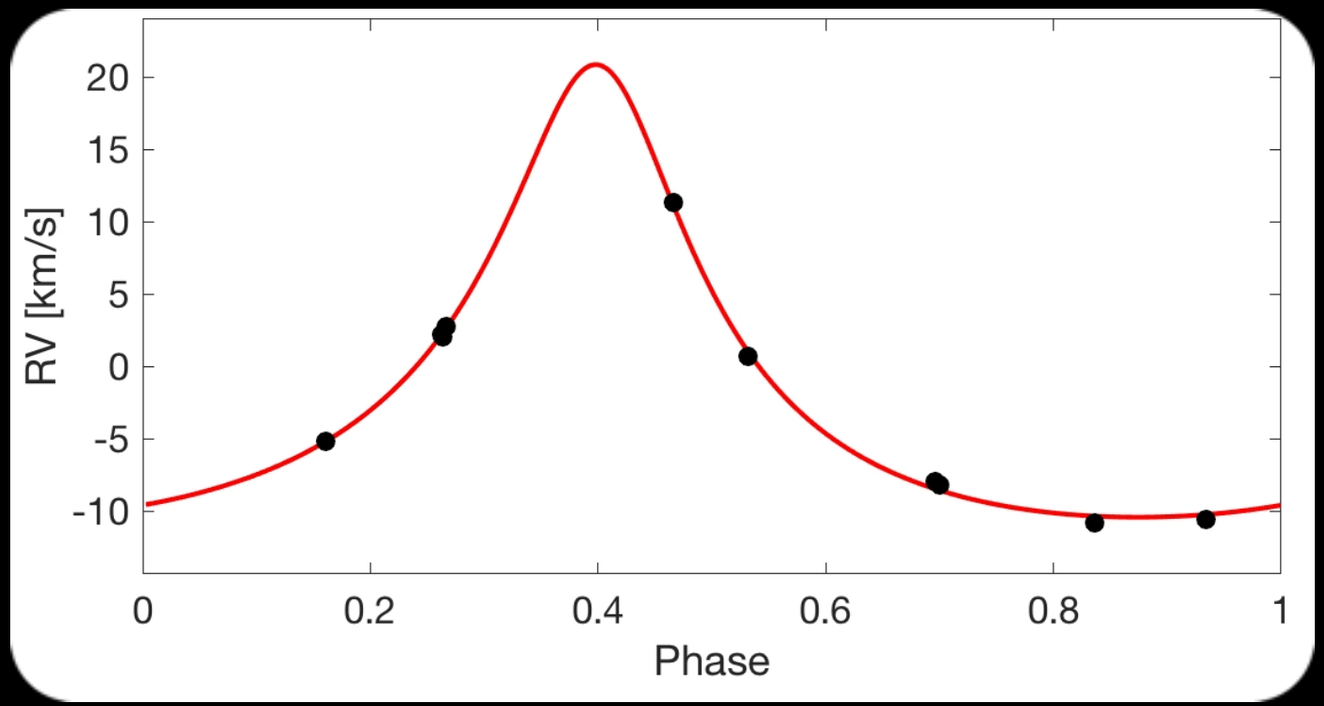
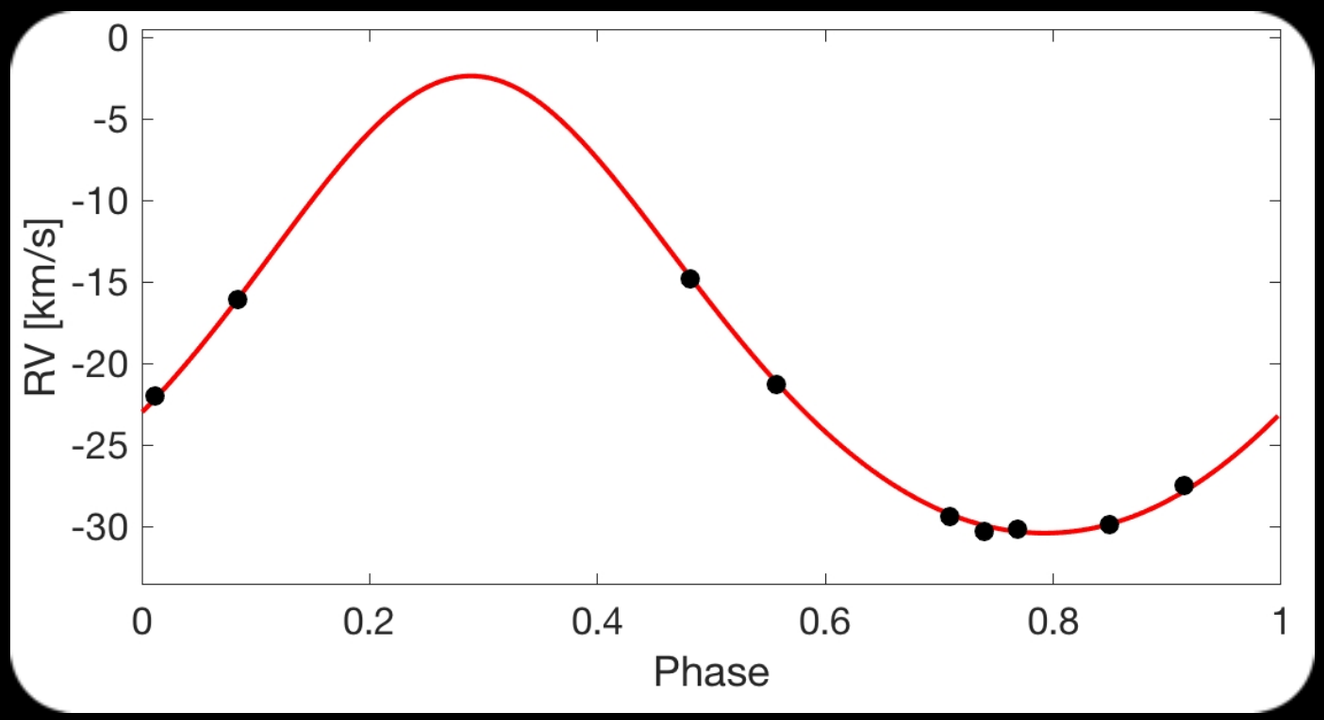
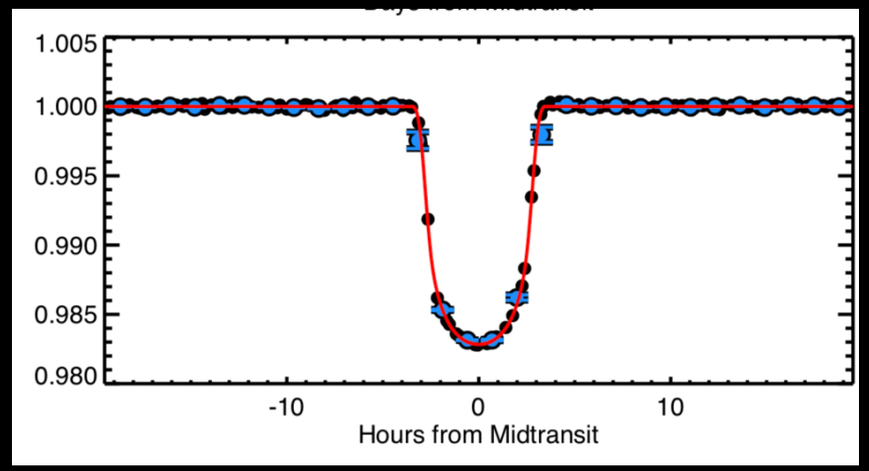


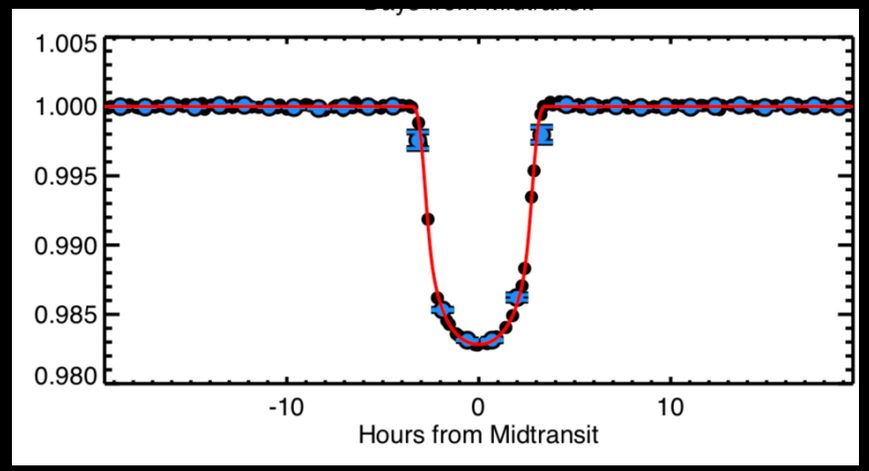


K2

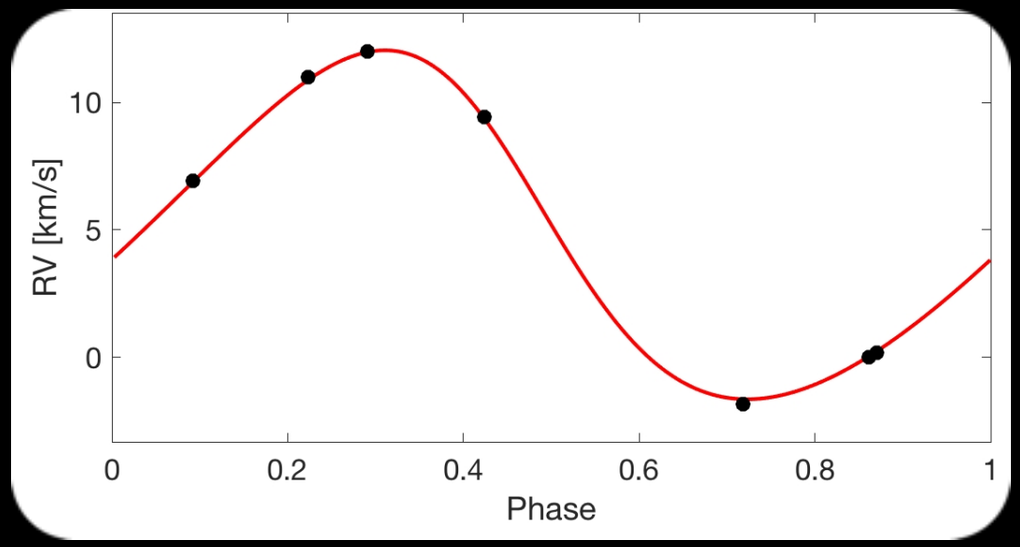
K2



K2



FLWO 1.5m/TRES



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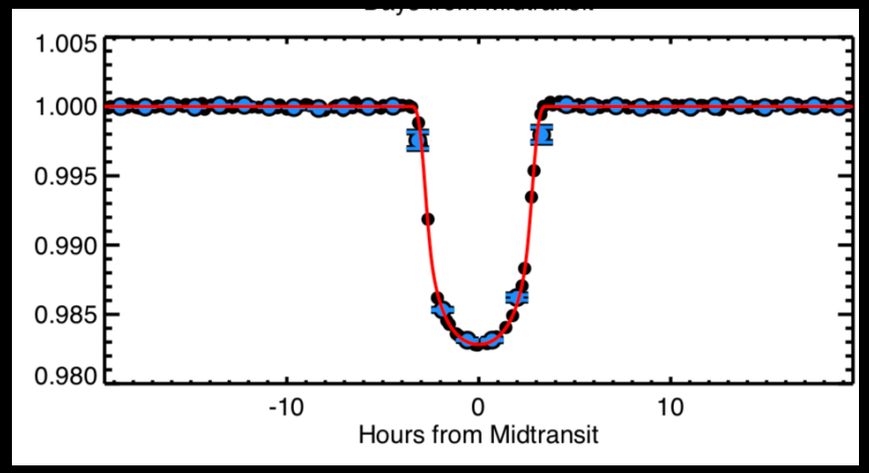

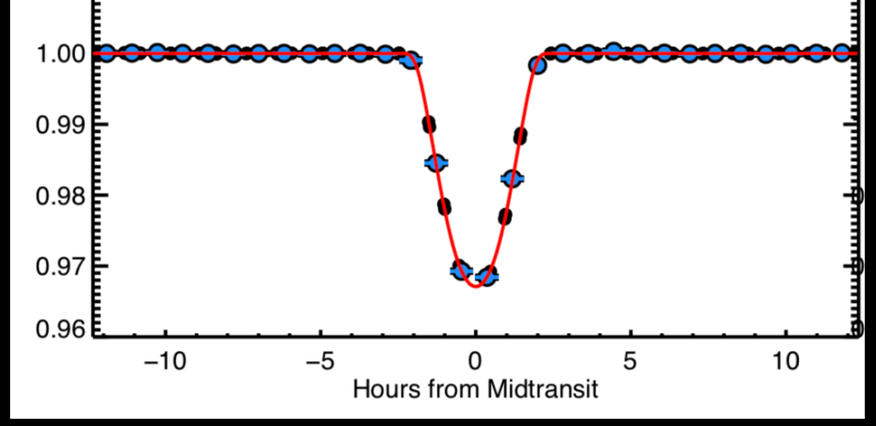

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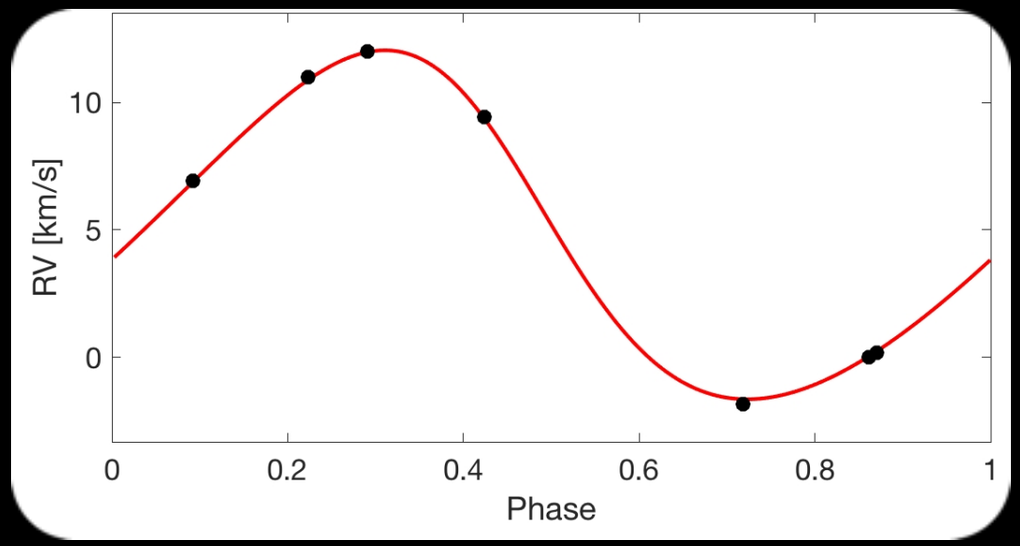

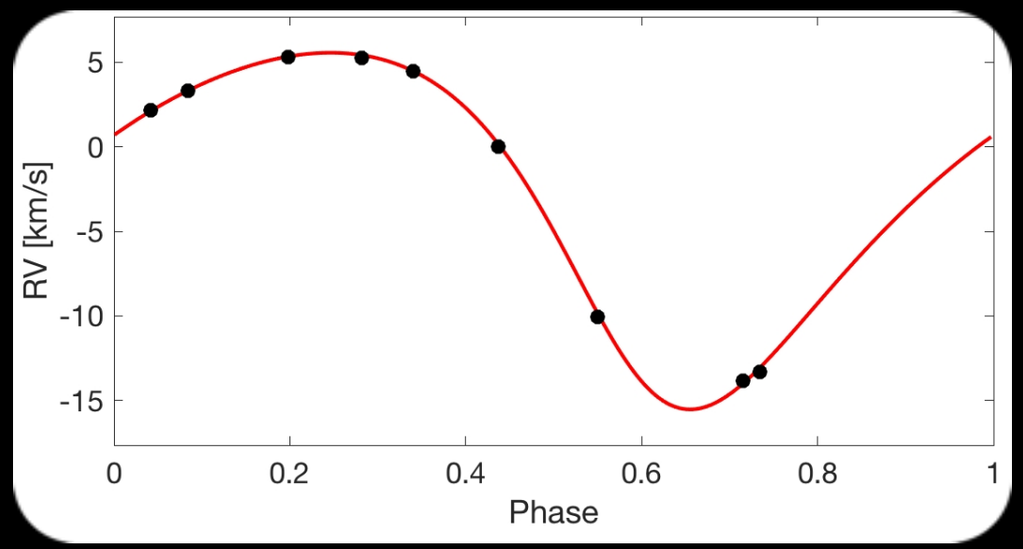

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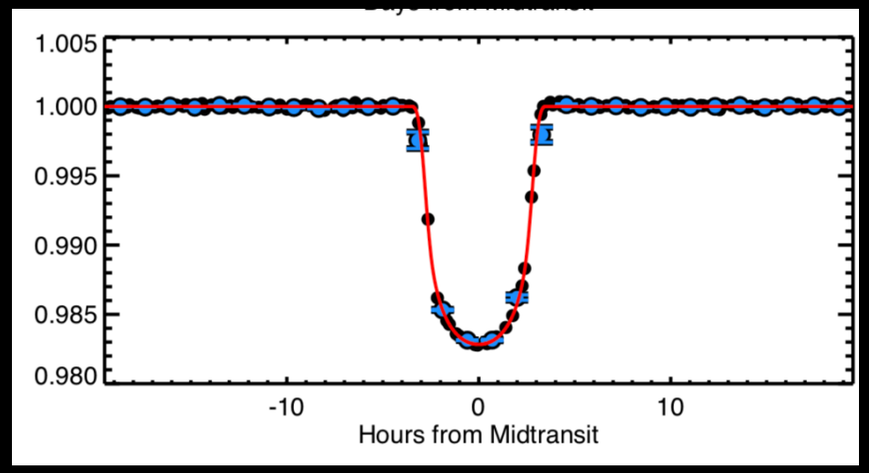
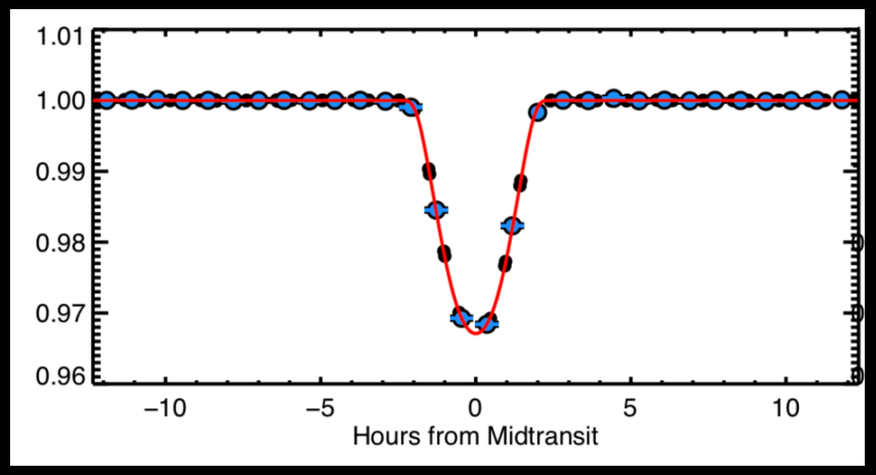
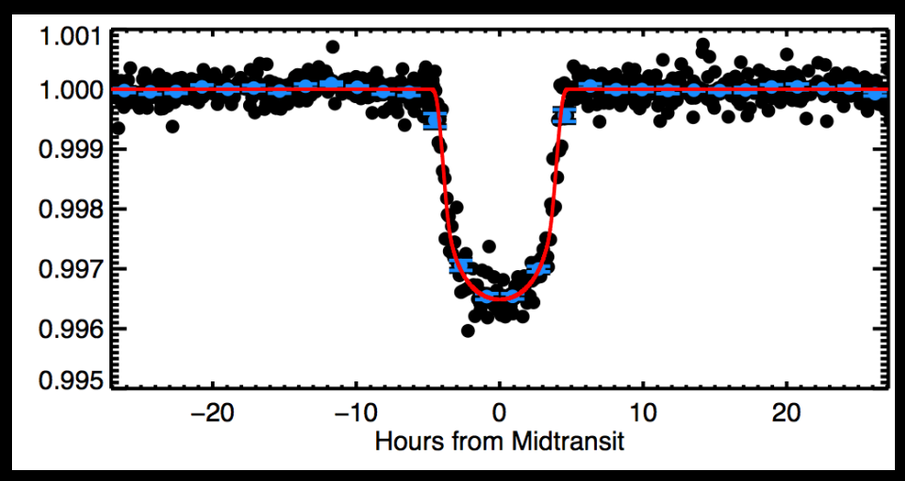
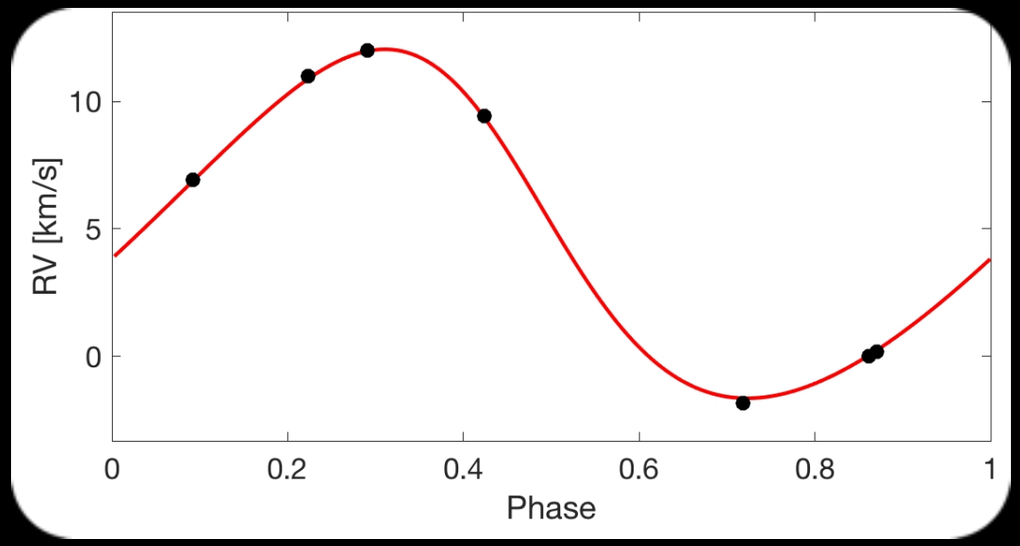
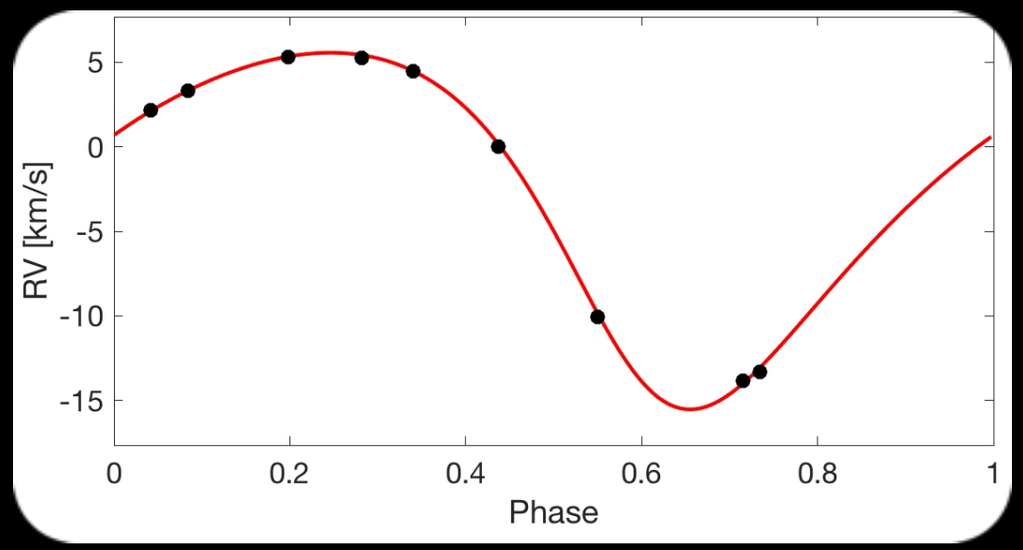


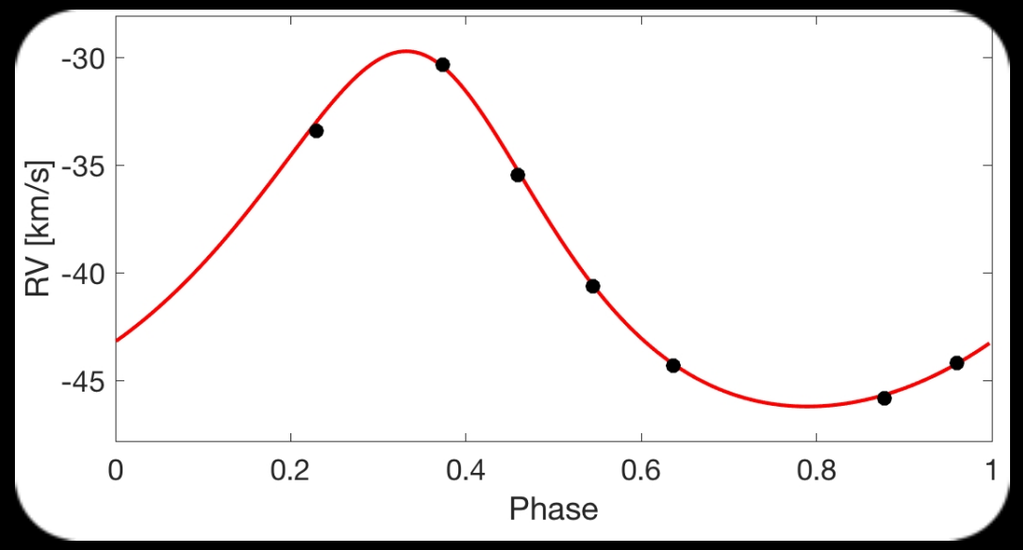




FLWO 1.5m/TRES

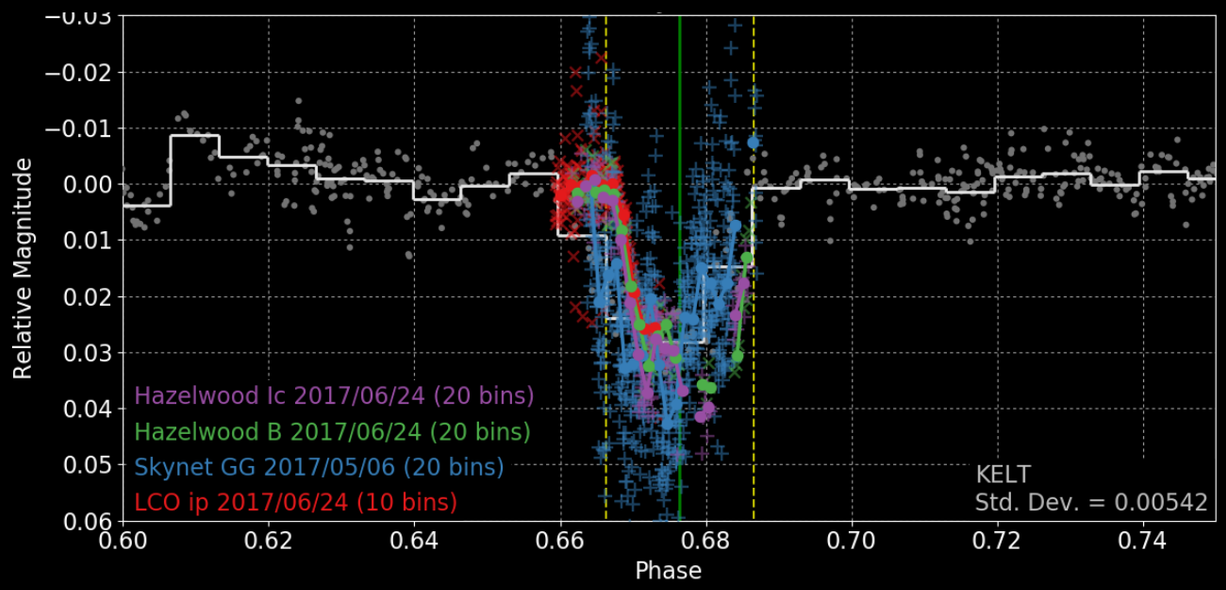






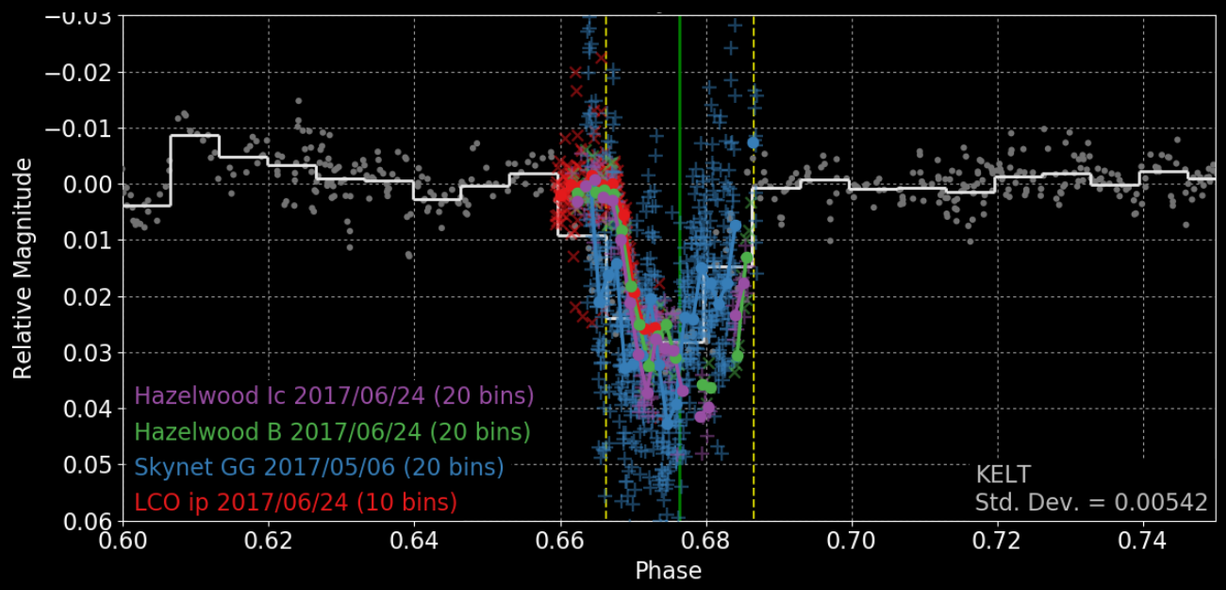
KELT

KELT


−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Relative Magnitude
0.60
0.62
0.64
0.66
0.68
0.70
0.72
0.74
Phase
Hazelwood Ic 2017/06/24 (20 bins)
Hazelwood B 2017/06/24 (20 bins)
Skynet GG 2017/05/06 (20 bins)
LCO ip 2017/06/24 (10 bins)
KELT
Std. Dev. = 0.00542

KELT

LCO/NRES



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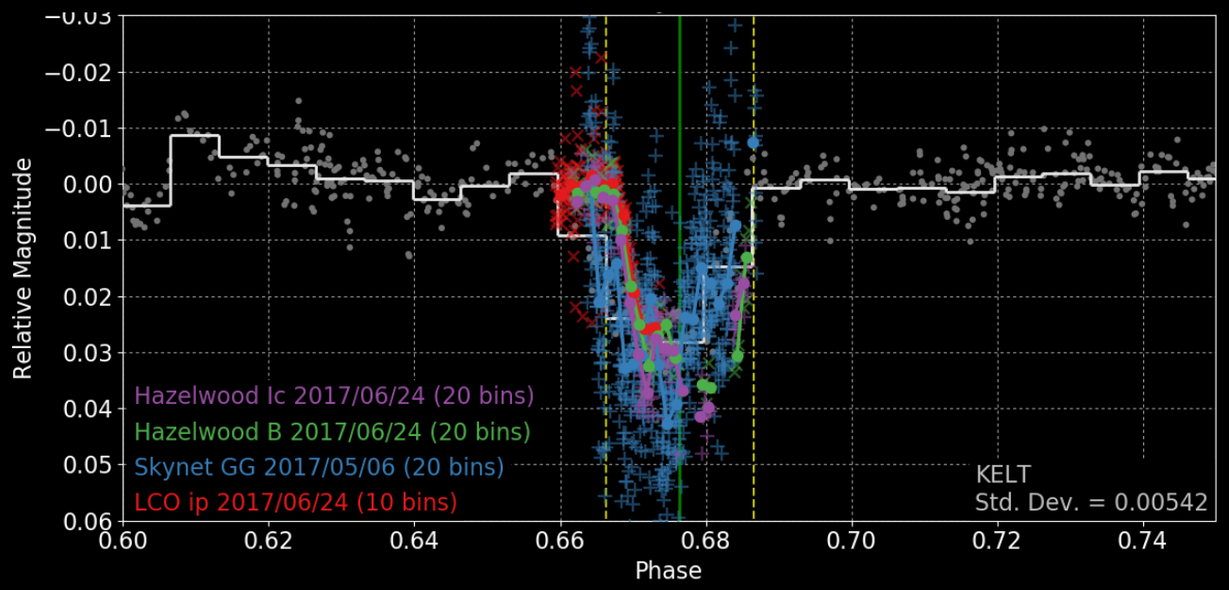
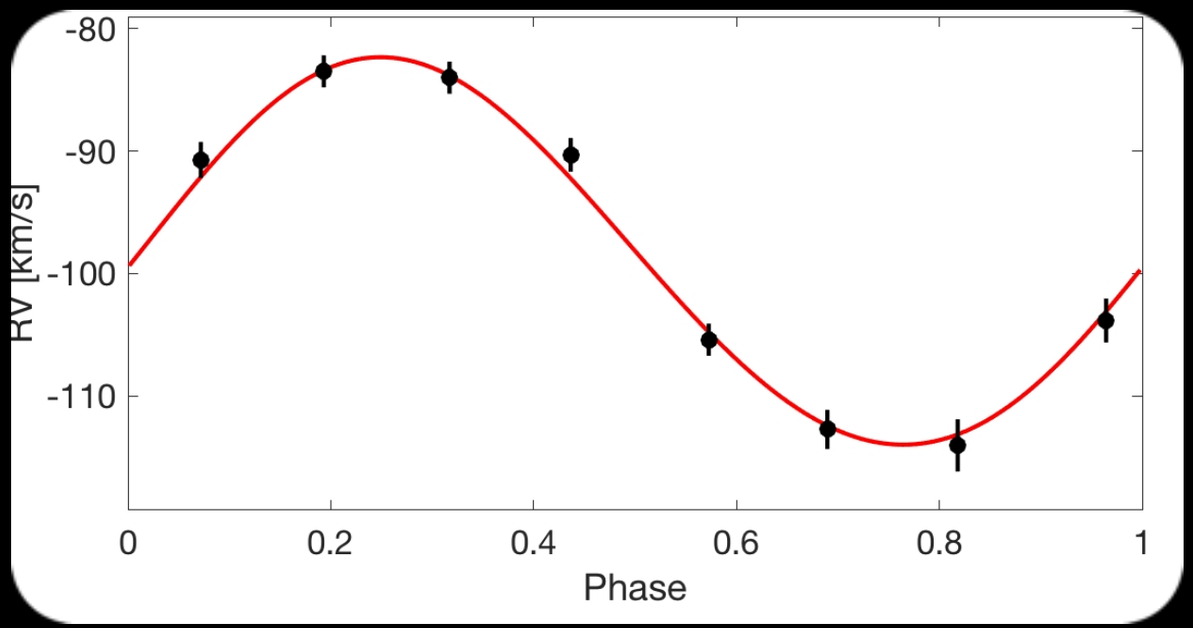
LCO/NRES





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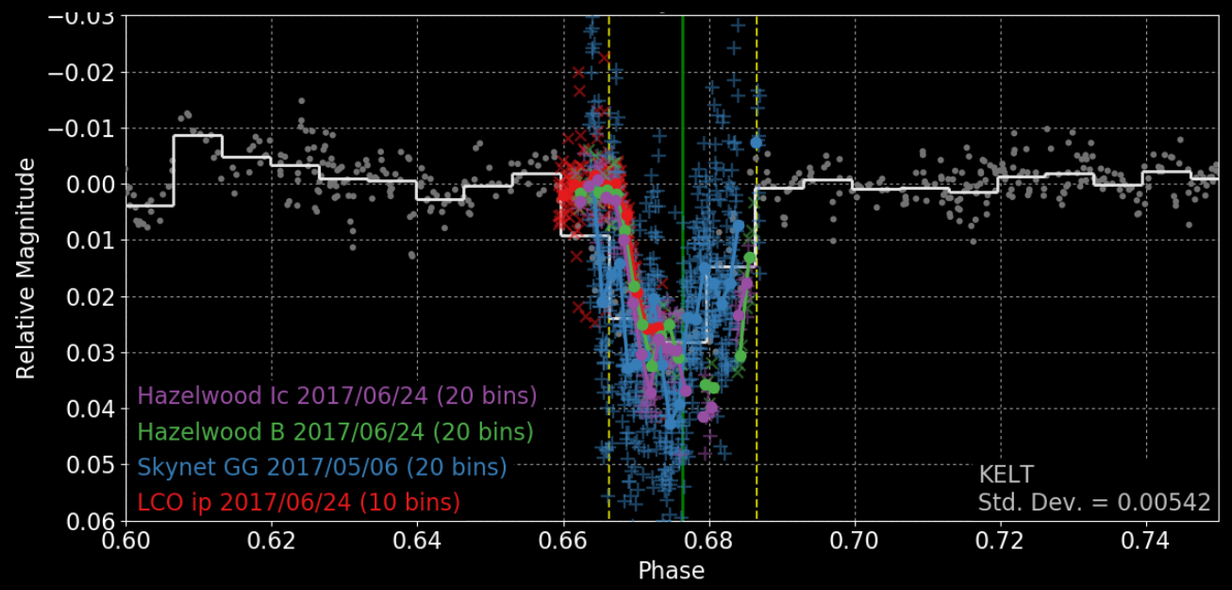
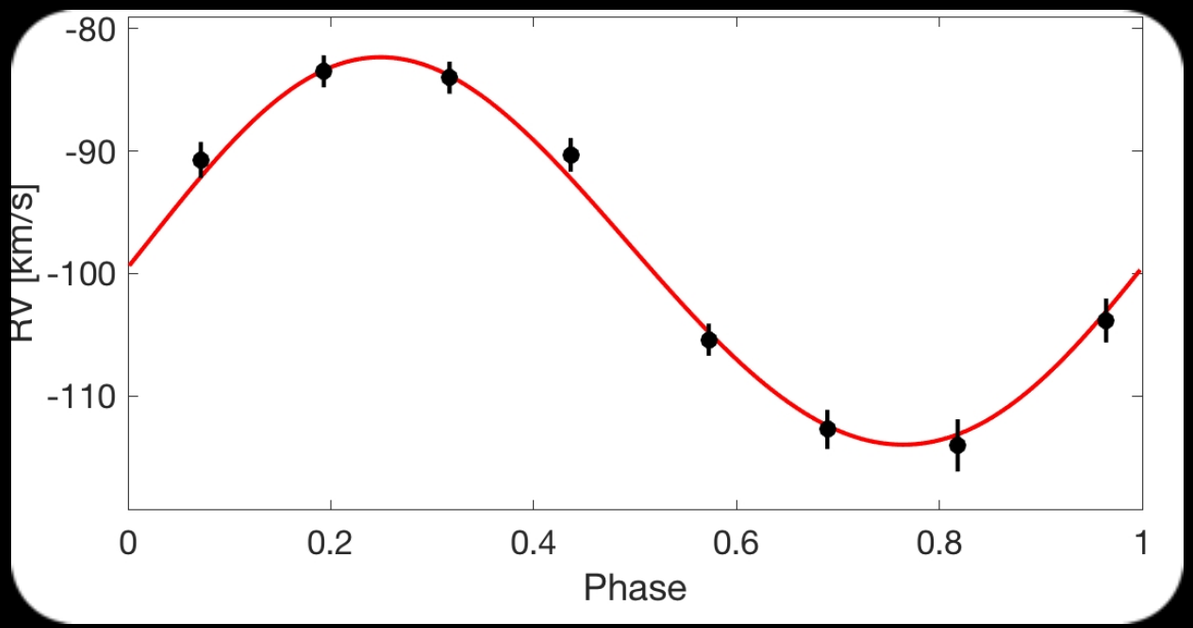
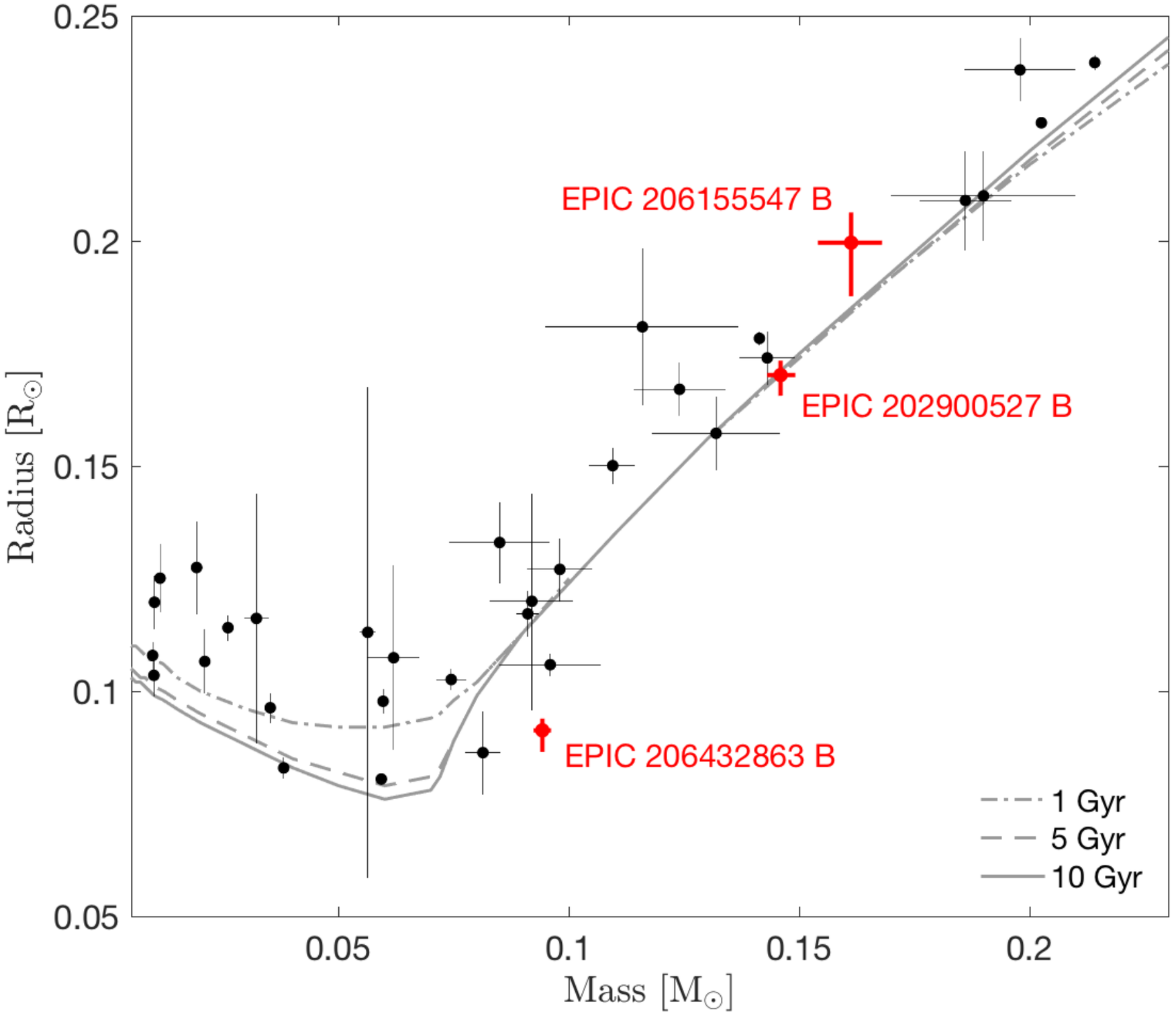


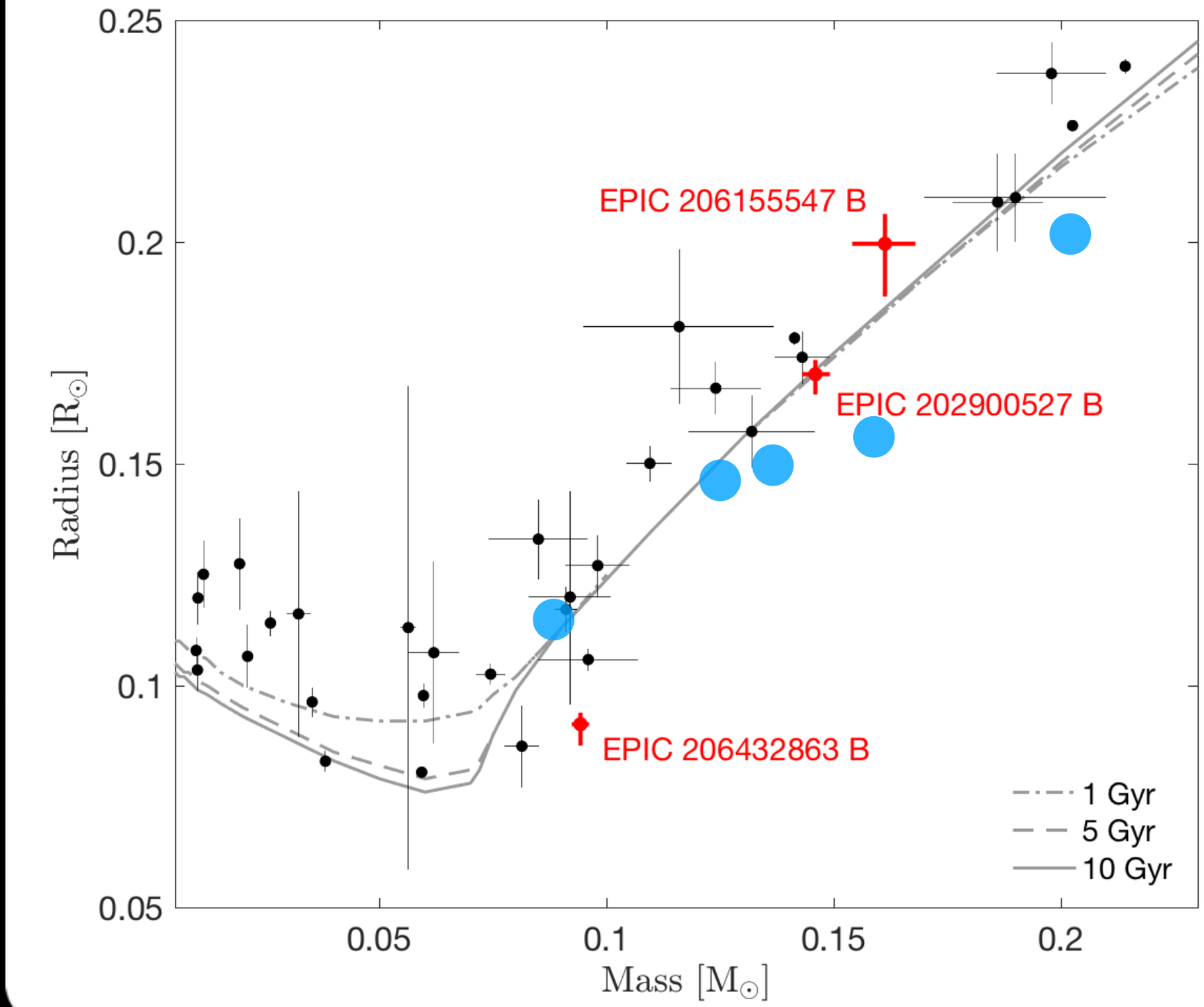
LCO/NRES



Many more to
come from TESS!



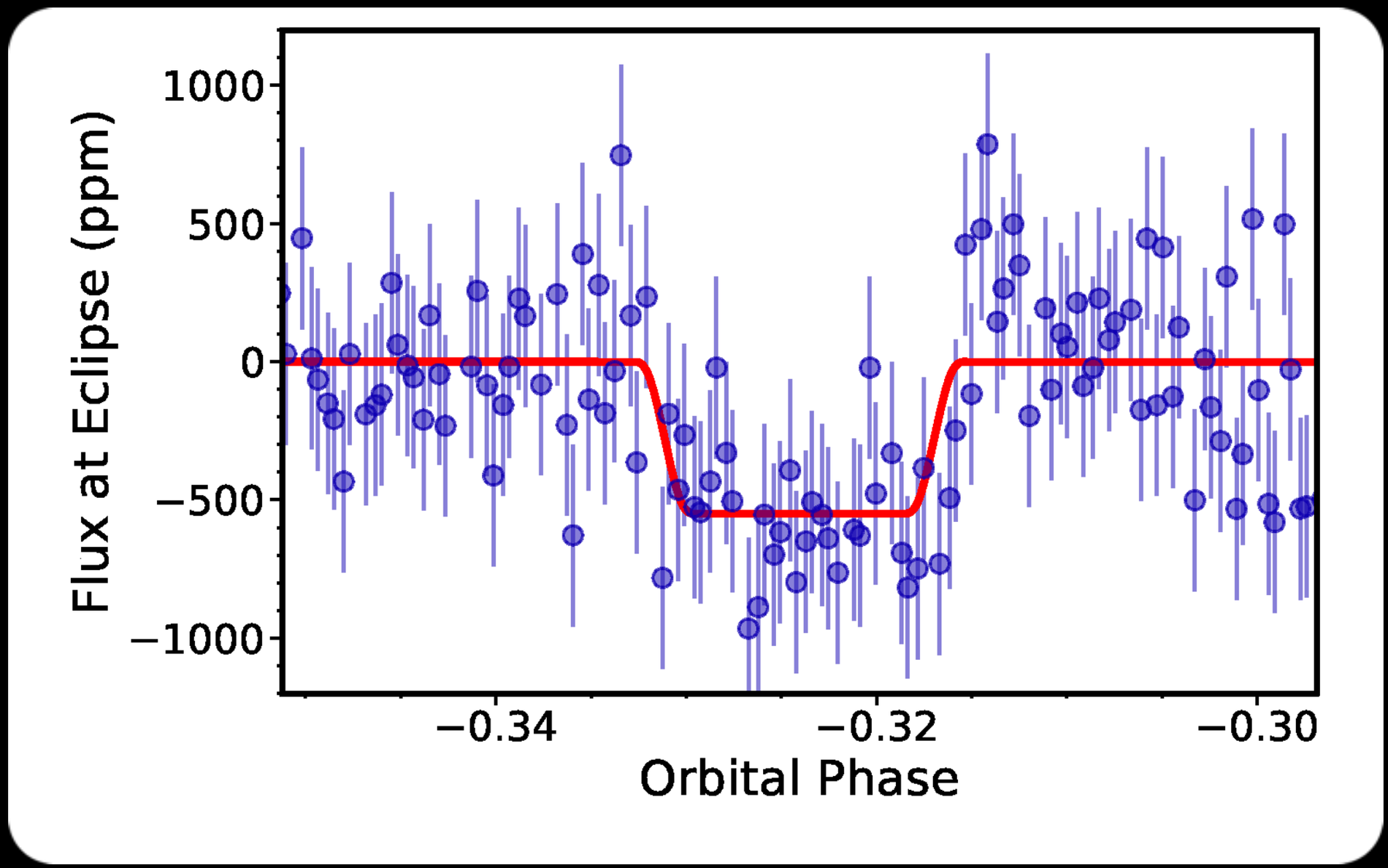
Shporer et al. 2017



Shporer et al. 2017

Additional slides

EPIC 206155547 (K2-67) secondary eclipse



TESS + LCO

TESS + LCO

TESS: All-sky bright-stars survey

TESS + LCO

TESS: All-sky bright-stars survey

➡ Need all-sky RV follow-up machine

TESS + LCO

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➡ LCO's Network of Robotic Echelle Spectrographs (NRES)

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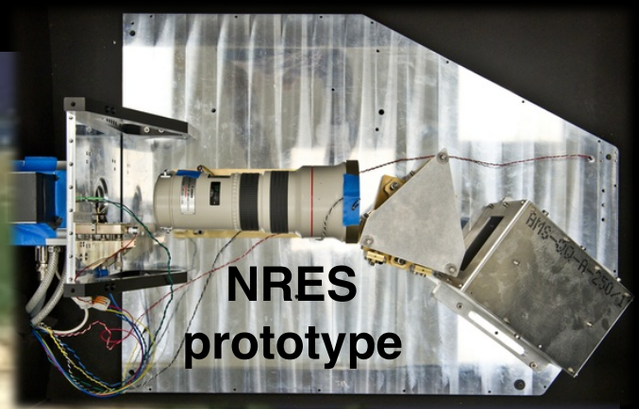
R ~ 53,000, σ_{RV} = 3 m/s, 3,800 – 8,600 Å



Haleakala
2x0.4m
1x2m

McDonald
1x1m

Teide
2x0.4m

Wise
1x1m (2017)

Ali
2x1m (2018)

Cerro Tololo
1x0.4m
3x1m

Sutherland
3x1m

Siding Spring
2x0.4m
2x1m
1x2m

TESS + LCO

TESS + LCO

TESS: All-sky bright-stars survey

TESS + LCO

TESS: All-sky bright-stars survey

➡ Need all-sky follow-up machine

TESS + LCO

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➡ Las Cumbres Observatory (LCO) network of robotic telescopes

TESS + LCO

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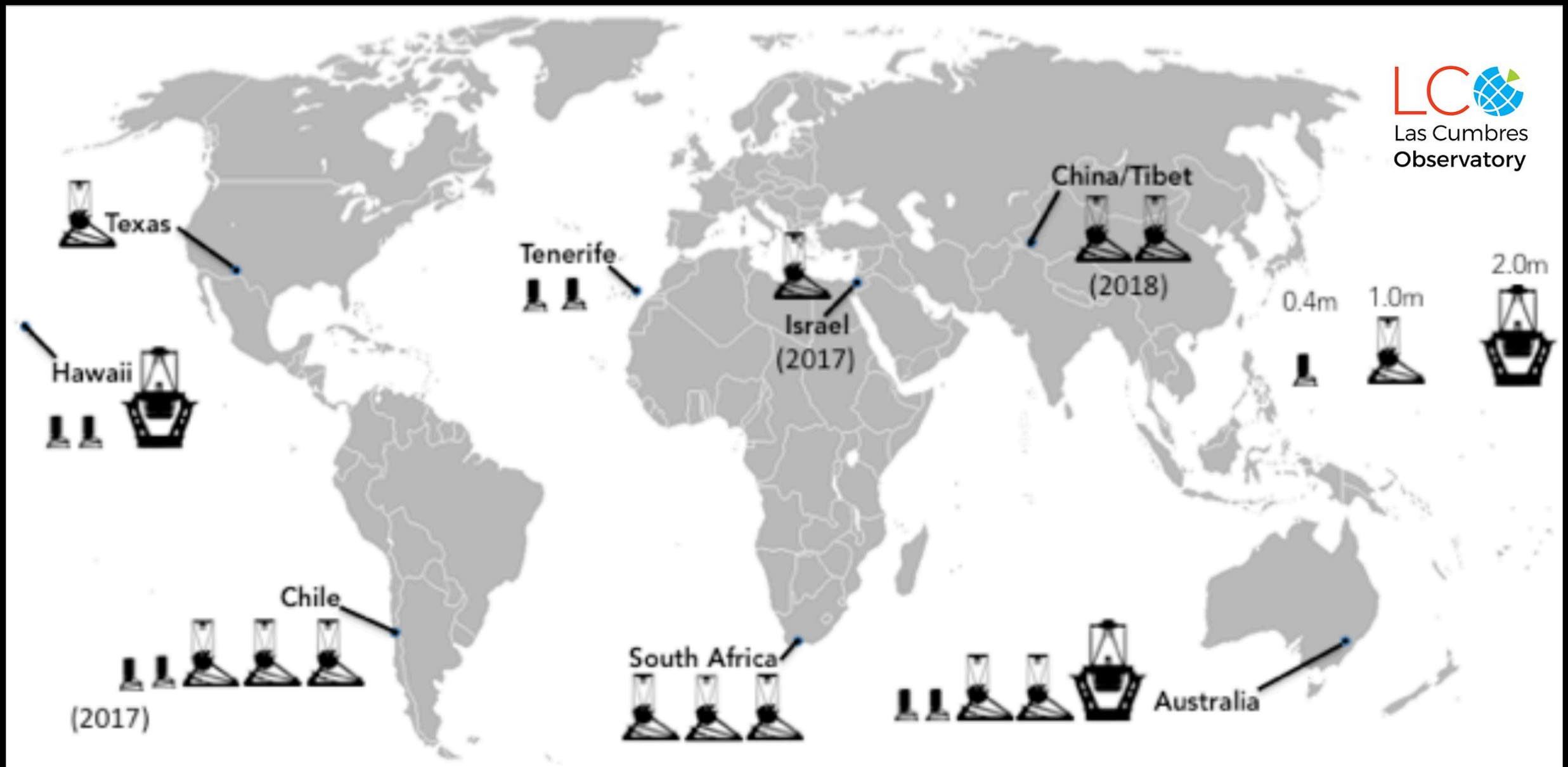
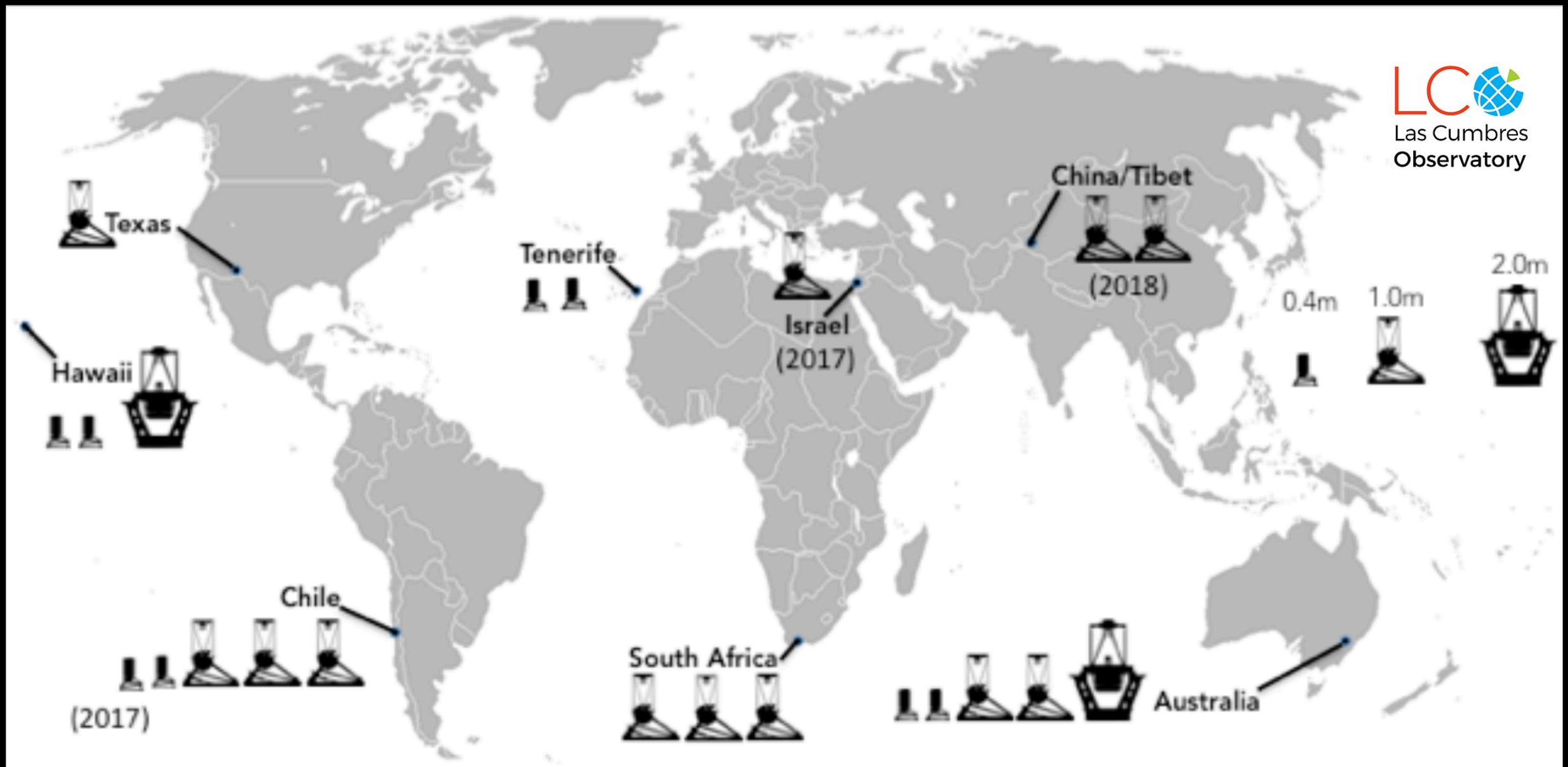


TRANSITING EXOPLANET WITH LCO -

THE NETWORK AWAKENS



TRANSITING EXOPLANET WITH LCO -

THE NETWORK AWAKENS

LCO Key Project: ≈3,600 hours, April 2017 - May 2019, PI: Avi Shporer

73% Photometry
27% Spectroscopy ⟹ Echelle Spectrographs, NRES: σ_{RV} = 3 m/s