Bright Opportunities for Atmospheric Characterization of Small Planets

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University of California, Santa Cruz
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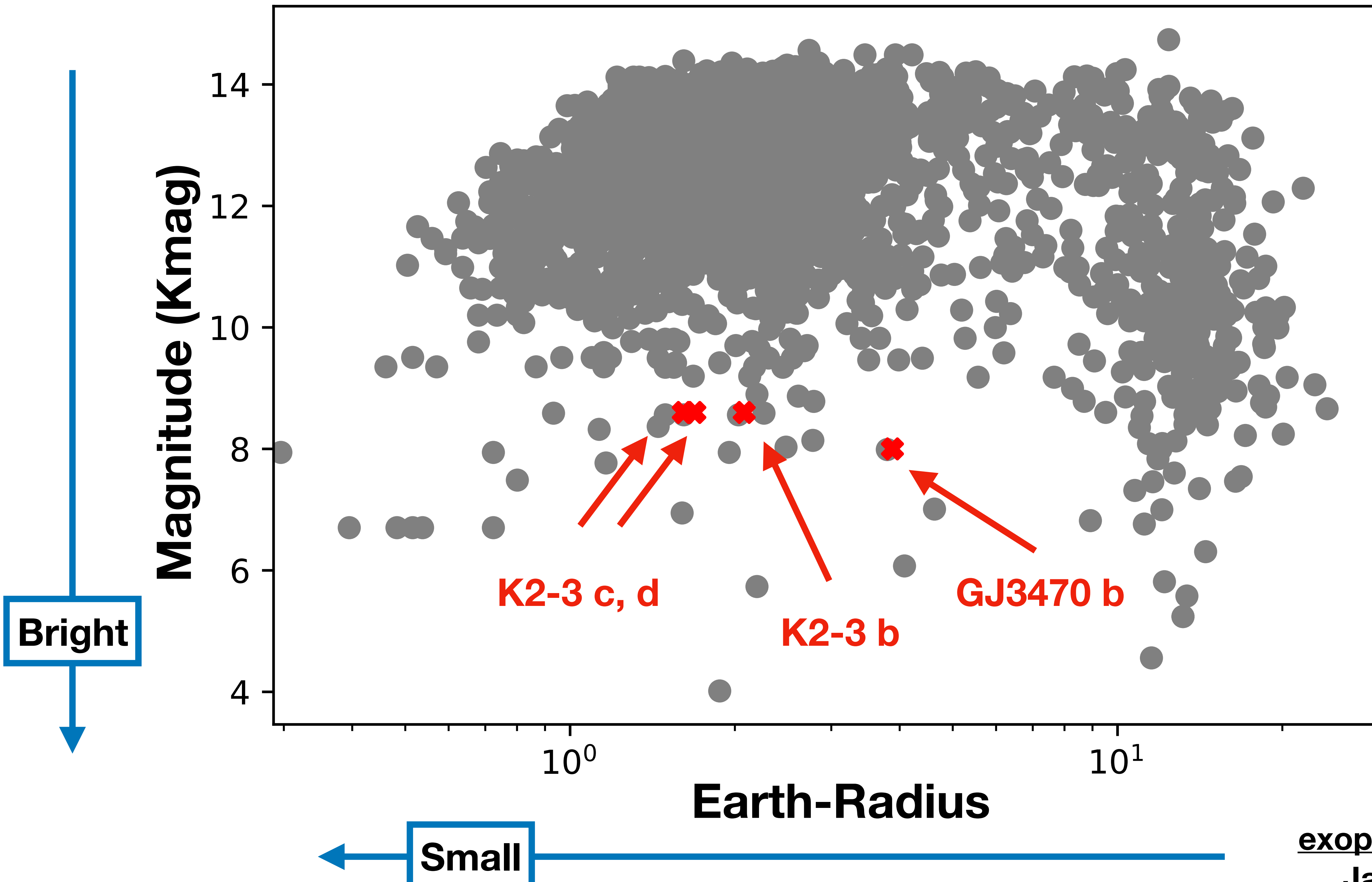
Advisors: Ian Crossfield + Andrew Howard

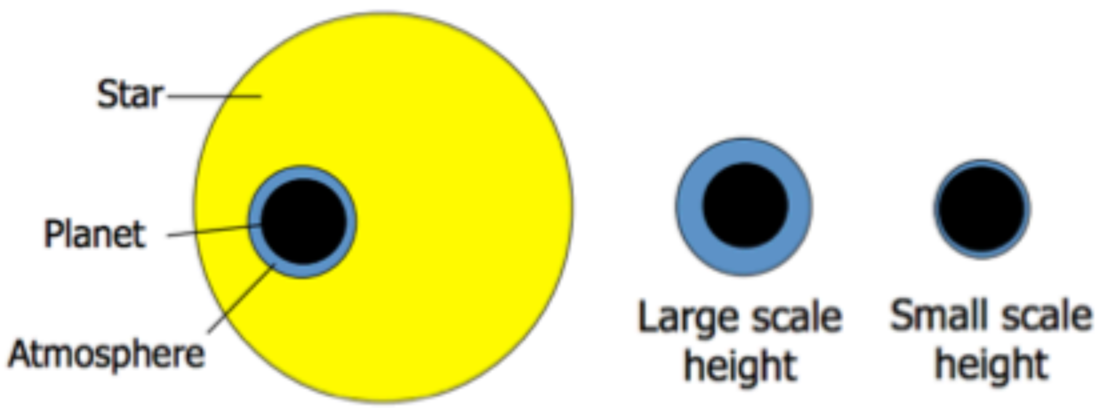
Kevin Hardegree-Ullman, John Livingston, Gregory Henry, Ward Howard, Bjorn Benneke, Heather Knutson, Courtney Dressing, Joshua Schlieder, and more
California Planet Search Team, HARPS Team, Evryscope Team.

We observed GJ3470 and K2-3, two of the brightest M dwarfs hosting small planets.



exoplanets.org
Jan 2018

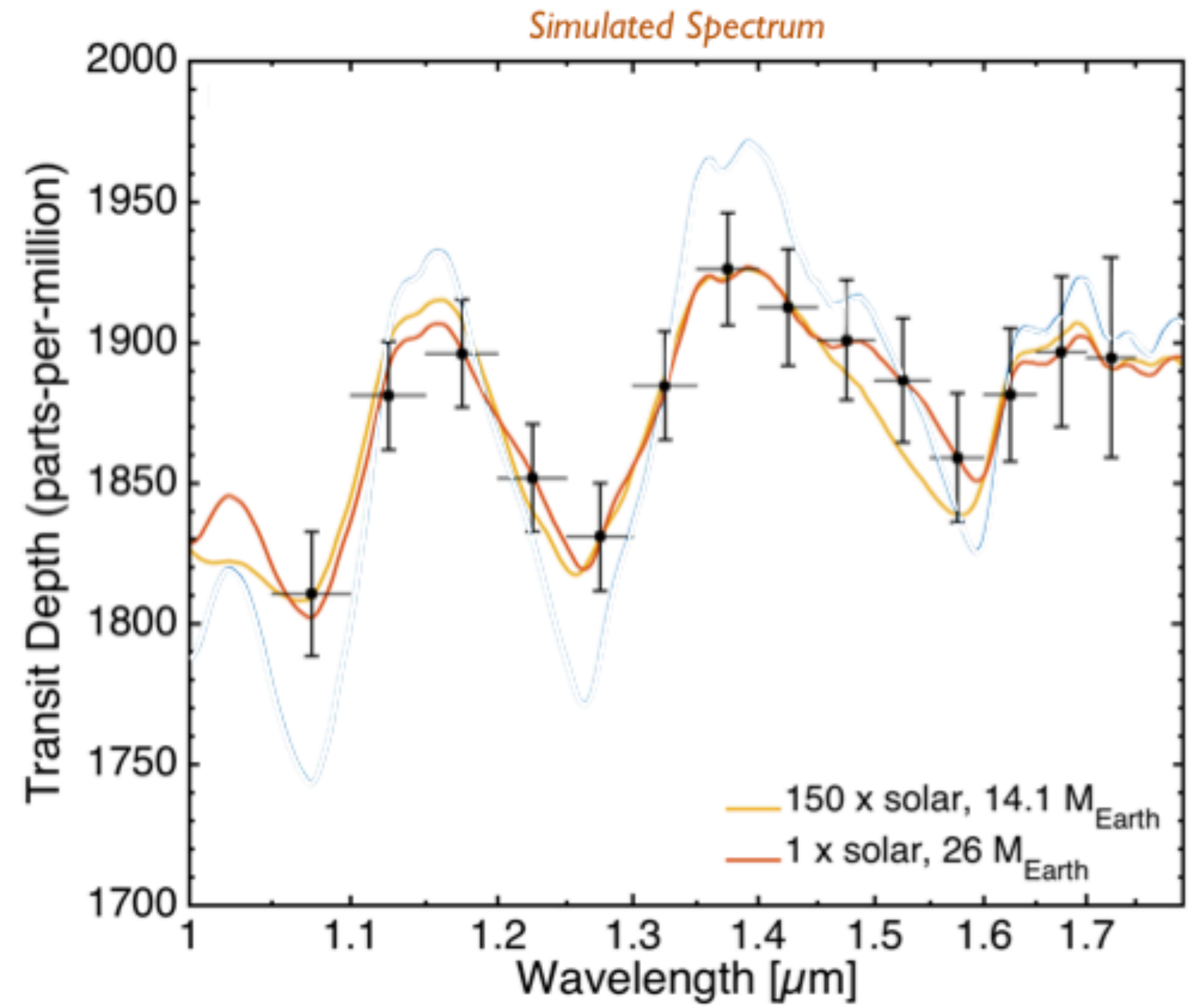
Planet Mass and Atmosphere Composition are Fundamentally Degenerate



Measure Atmospheric Scale Height

$$H = \frac{kT}{\mu g} \propto \frac{1}{\mu M_{\mathrm{pl}}}$$

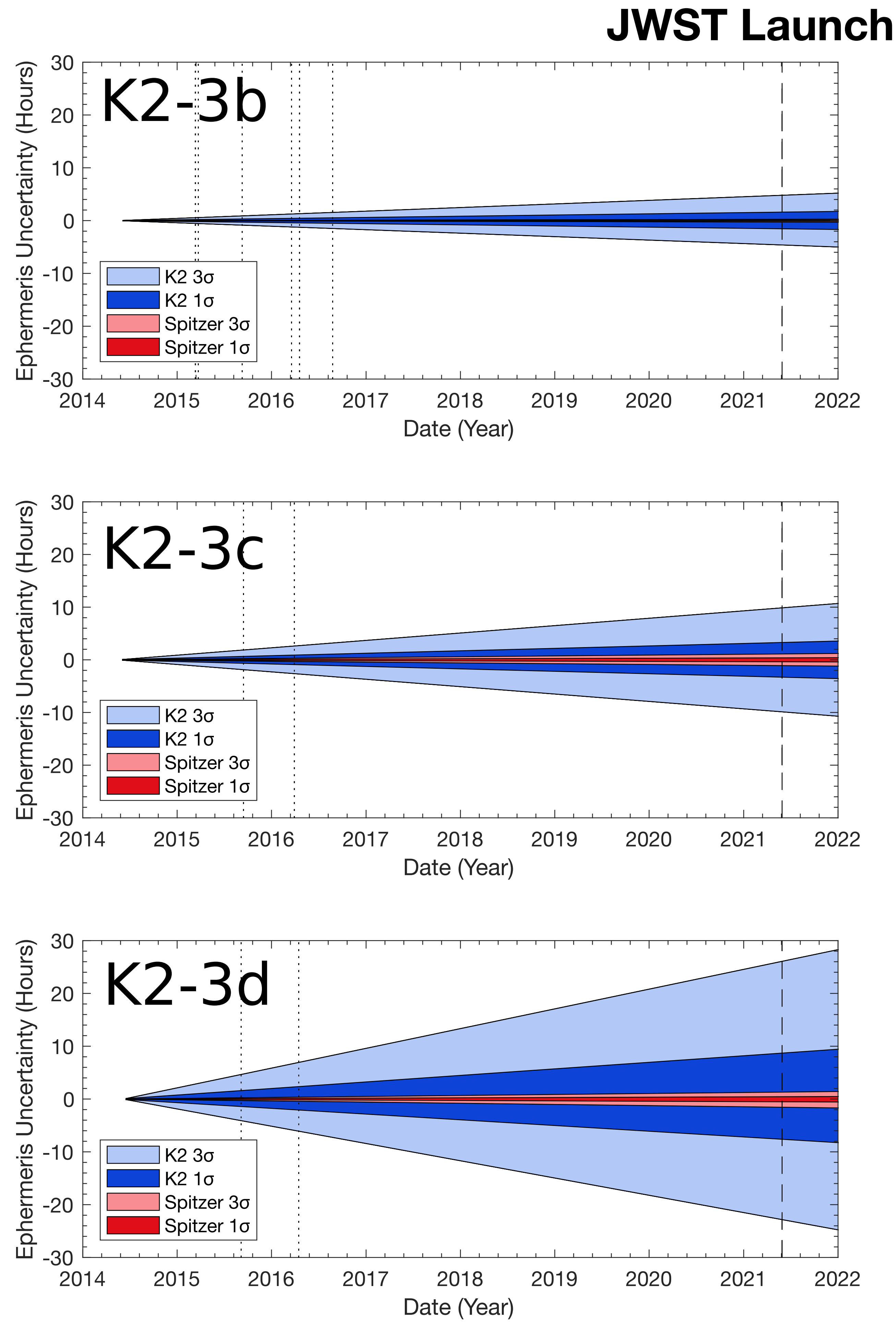
Mean molecular weight **Planet Mass**



Simulation by Bjoern Benneke

Slide by Andrew Howard

Spitzer transit follow-up of K2-3 planets



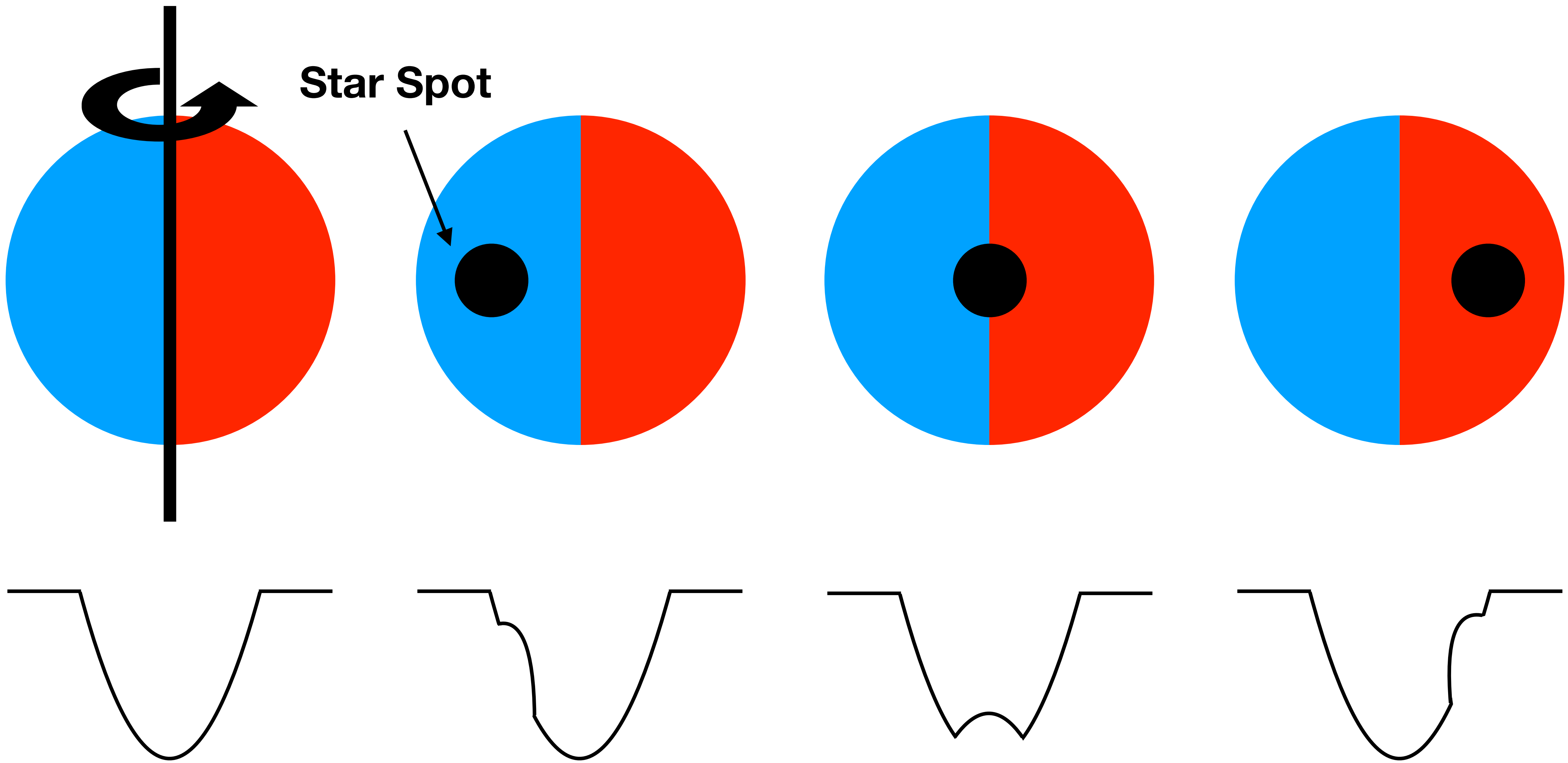
- 2 - 6 transits of each planet
- Transit ephemerides uncertainty decreased by more than 10x

We collected new radial velocity (RV) measurements of K2-3 and GJ3470 on Keck and HARPS.

www.keckobservatory.org

Kosiarek et al. 2018
Dai et al. 2016
Almenara et al. 2015
Damasso et al. 2018
Bonfils et al 2012

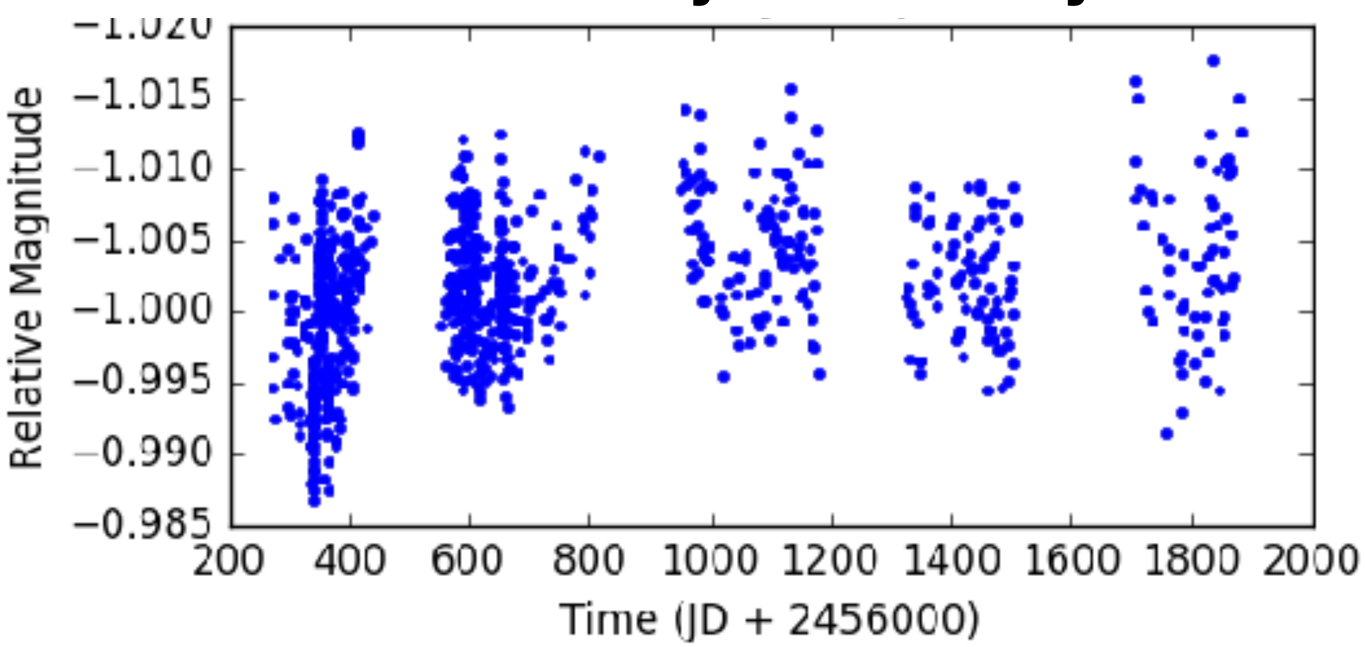
Magnetic activity on the stellar surface can induce planet-like signals in RV data.

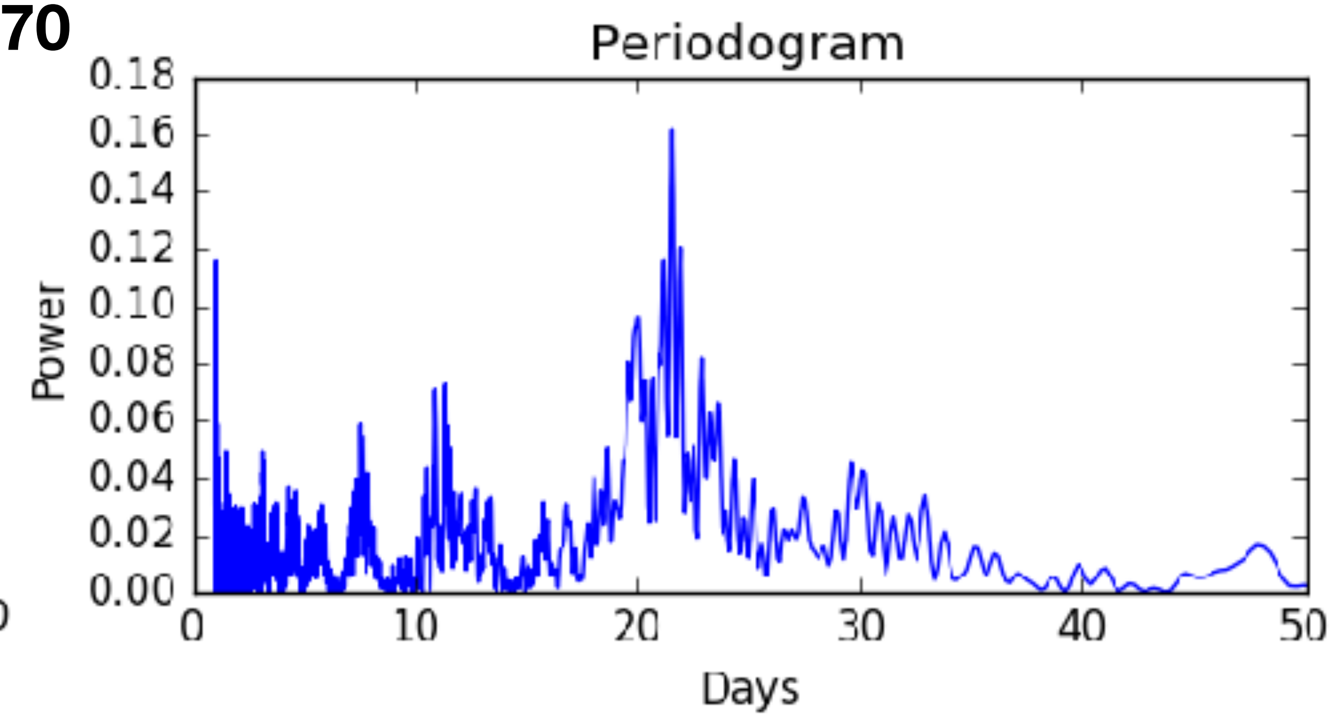


We modeled our RVs with Gaussian processes trained on photometry

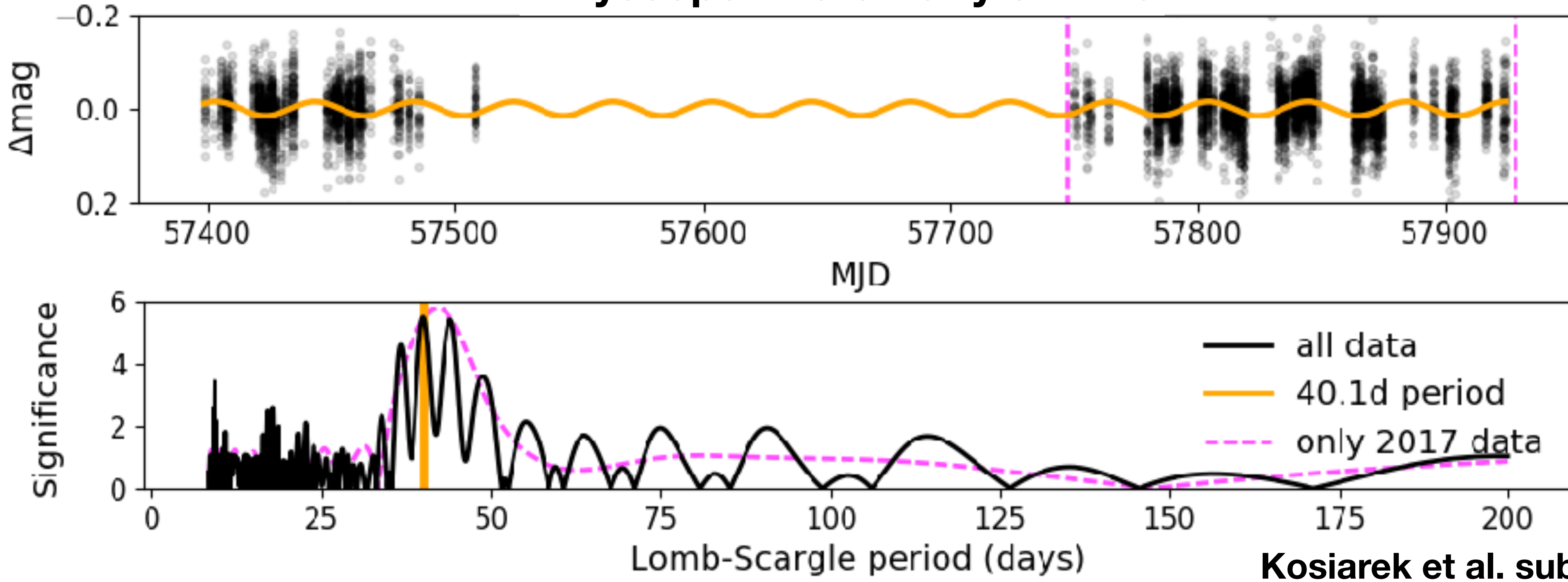
Photometry training of GP hyper parameters

Fairborn Observatory Photometry of GJ3470



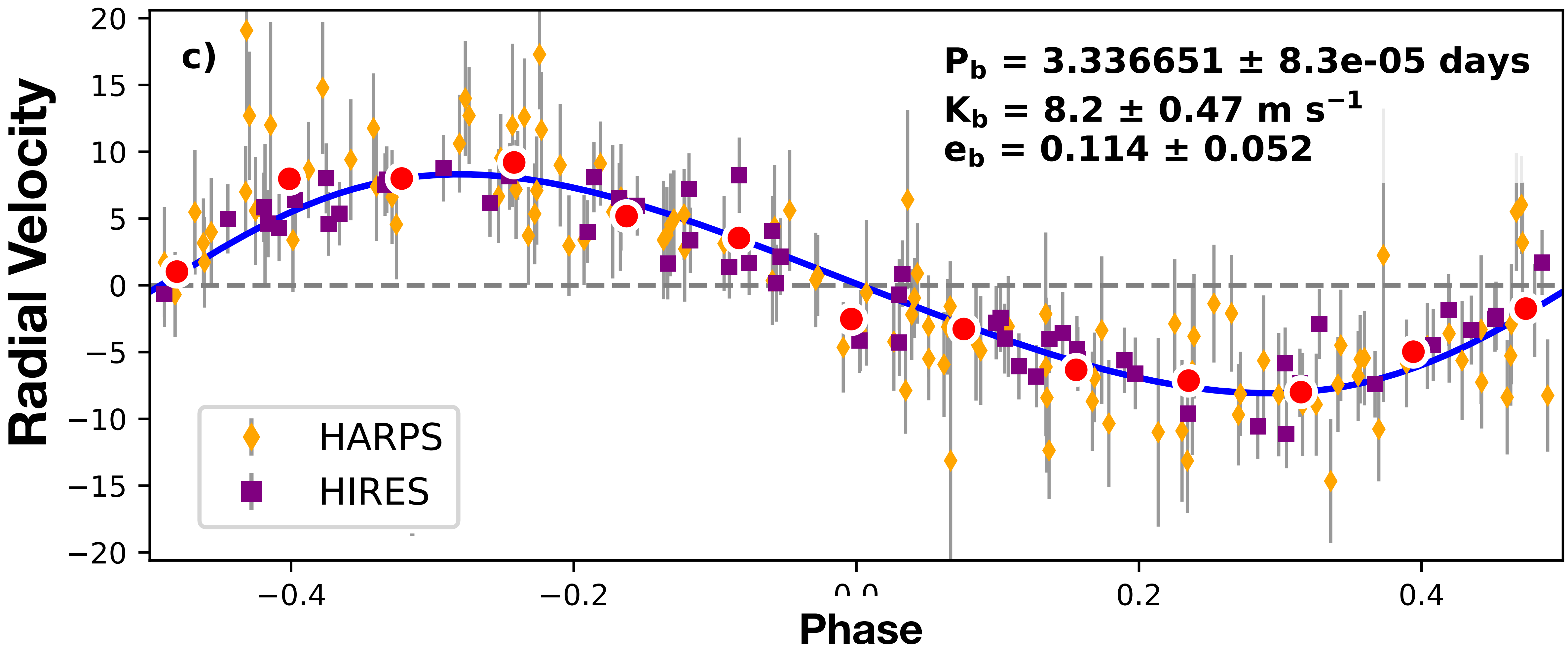


Evryscope Photometry of K2-3



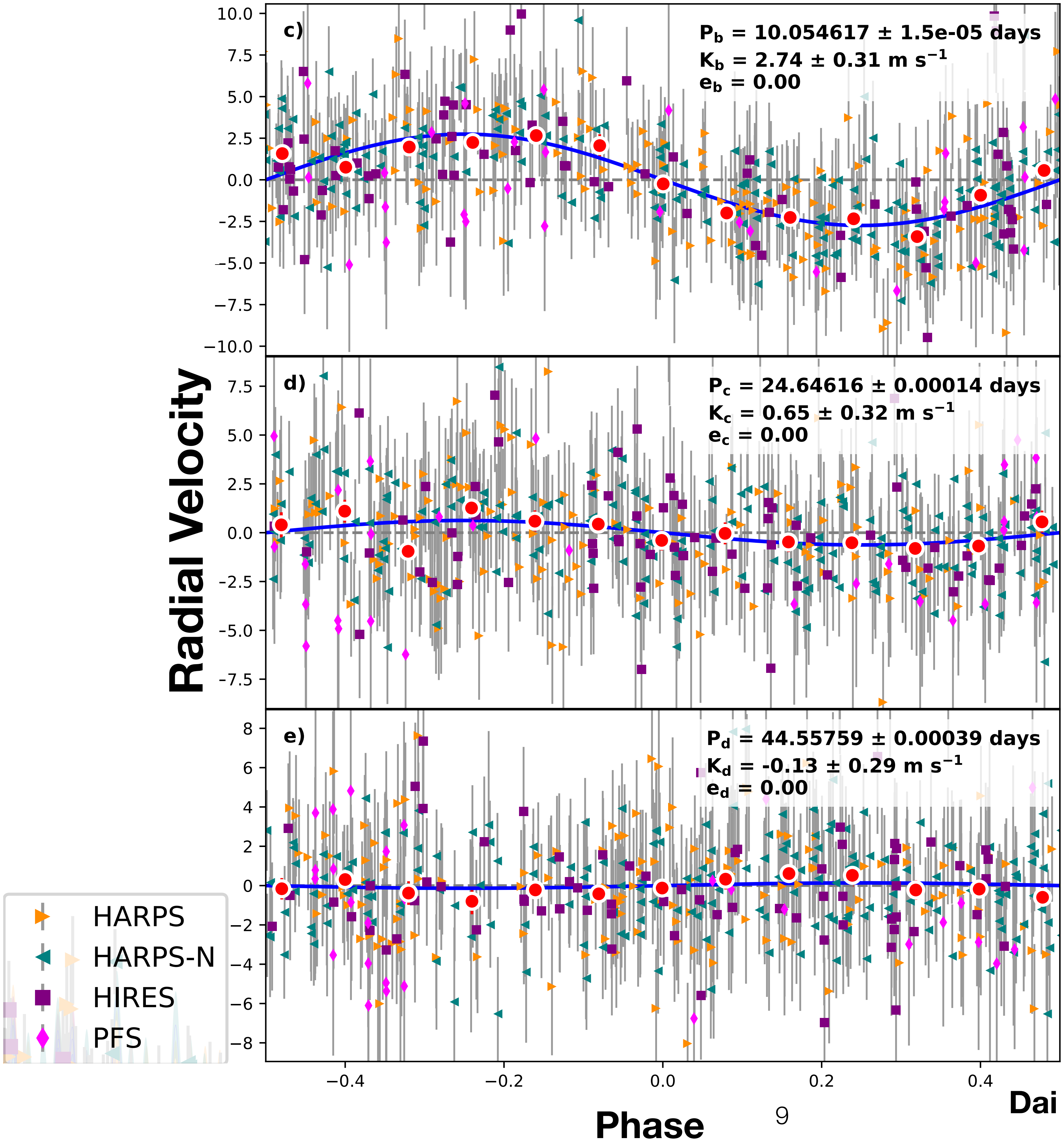
Kosiarek et al. submitted.

GJ3470: Radial Velocity fit including 57 HIRES and 113 HARPS measurements spanning 8 years.



Mass = 12.57 ± 1.3 M_{Earth}

Kosiarek et al. submitted



6.5 ± 1.0 M_{Earth}

2.1 ± 1.1 M_{Earth}

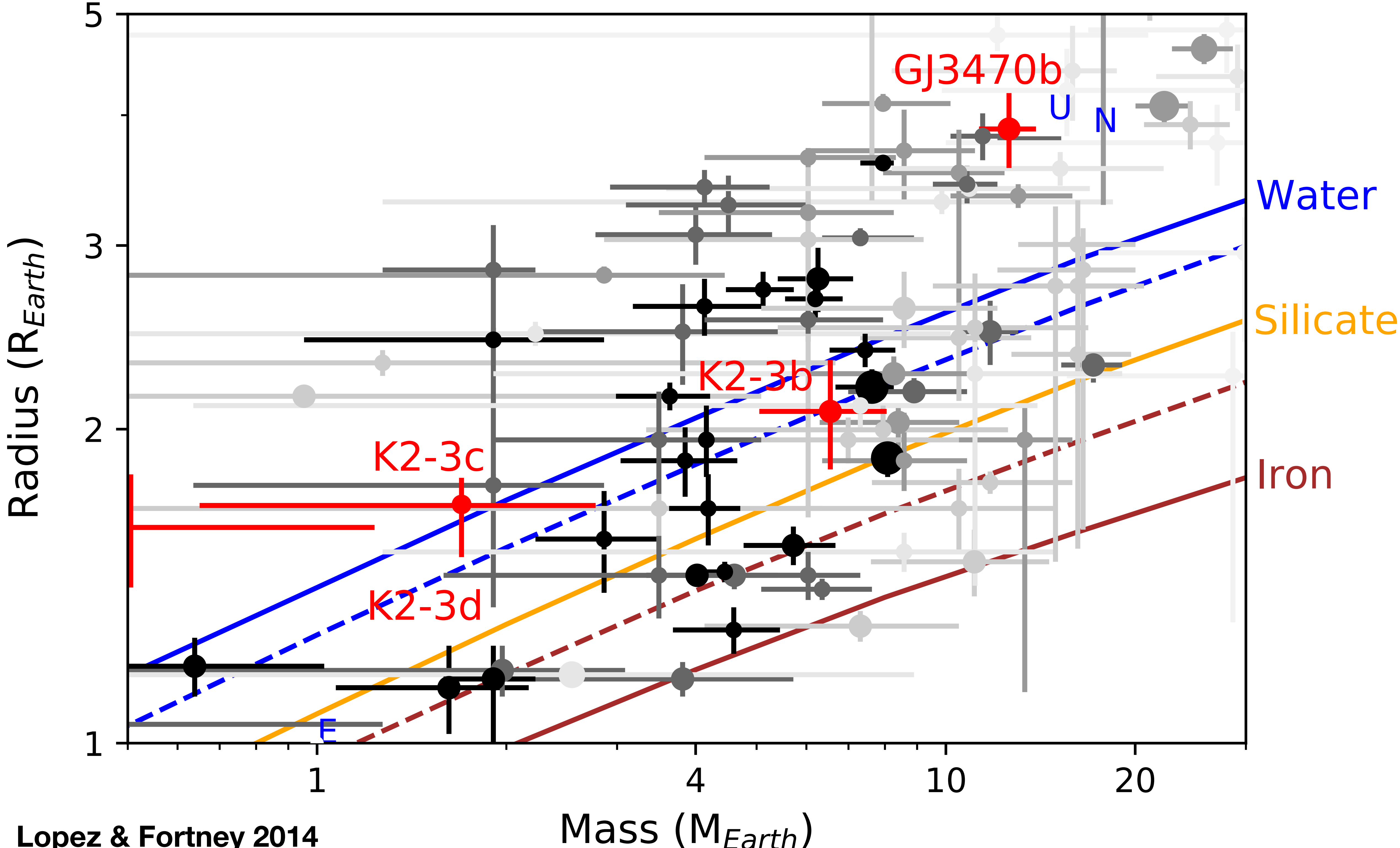
1-σ upper limit: 0.5 M_{Earth}

Kosiarek et al. submitted

Damasso et al. 2018

Dai et al. 2016 Almenara et al. 2015

GJ3470 has between 4% and 13% H/ He depending on the core composition.



Lopez & Fortney 2014
Zeng et al. 2016

Kosiarek et al. submitted

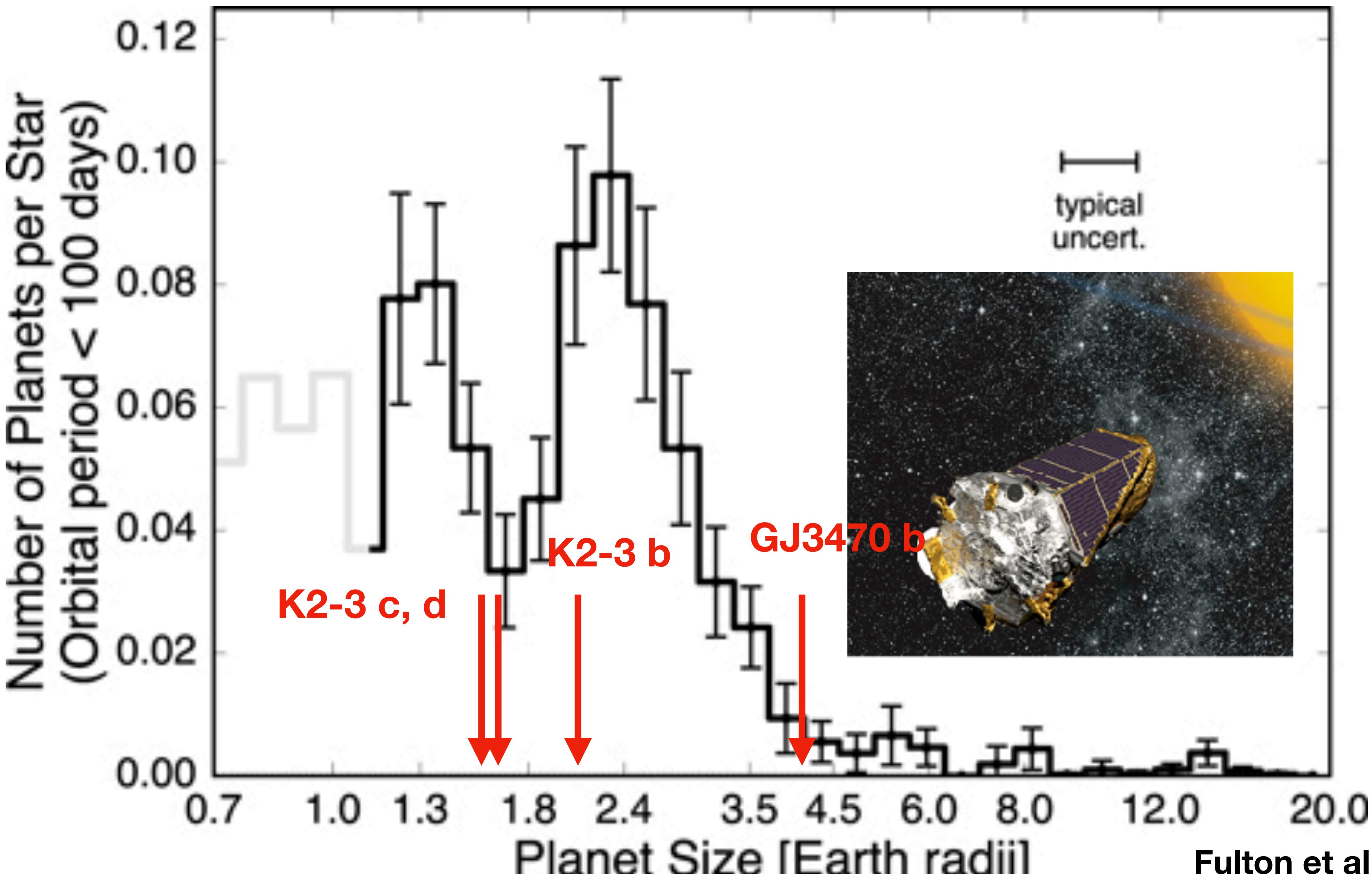
Key Points

- We measured the masses of GJ3470 b and K2-3 b, c, d, crucial for transit spectroscopy measurements.
- The mass of K2-3 d is not well constrained due to the similarities in stellar rotation period and planet orbital period.
- We used a Gaussian process trained on photometry to model correlated noise from stellar activity in our RV fits.
- We refined the periods and radii of K2-3 b, c, and d from Spitzer transits. This ephemeris refinement is essential for future JWST transmission spectroscopy measurements.

See Kosiarek et al. submitted. for more information.
Coming to an arxiv near you soon!

Backup Slides

Our four targets span the Fulton gap.



Fulton et al. 2017
California Kepler Survey

We modeled our RVs with Gaussian processes trained on photometry

Amplitude of the covariance function

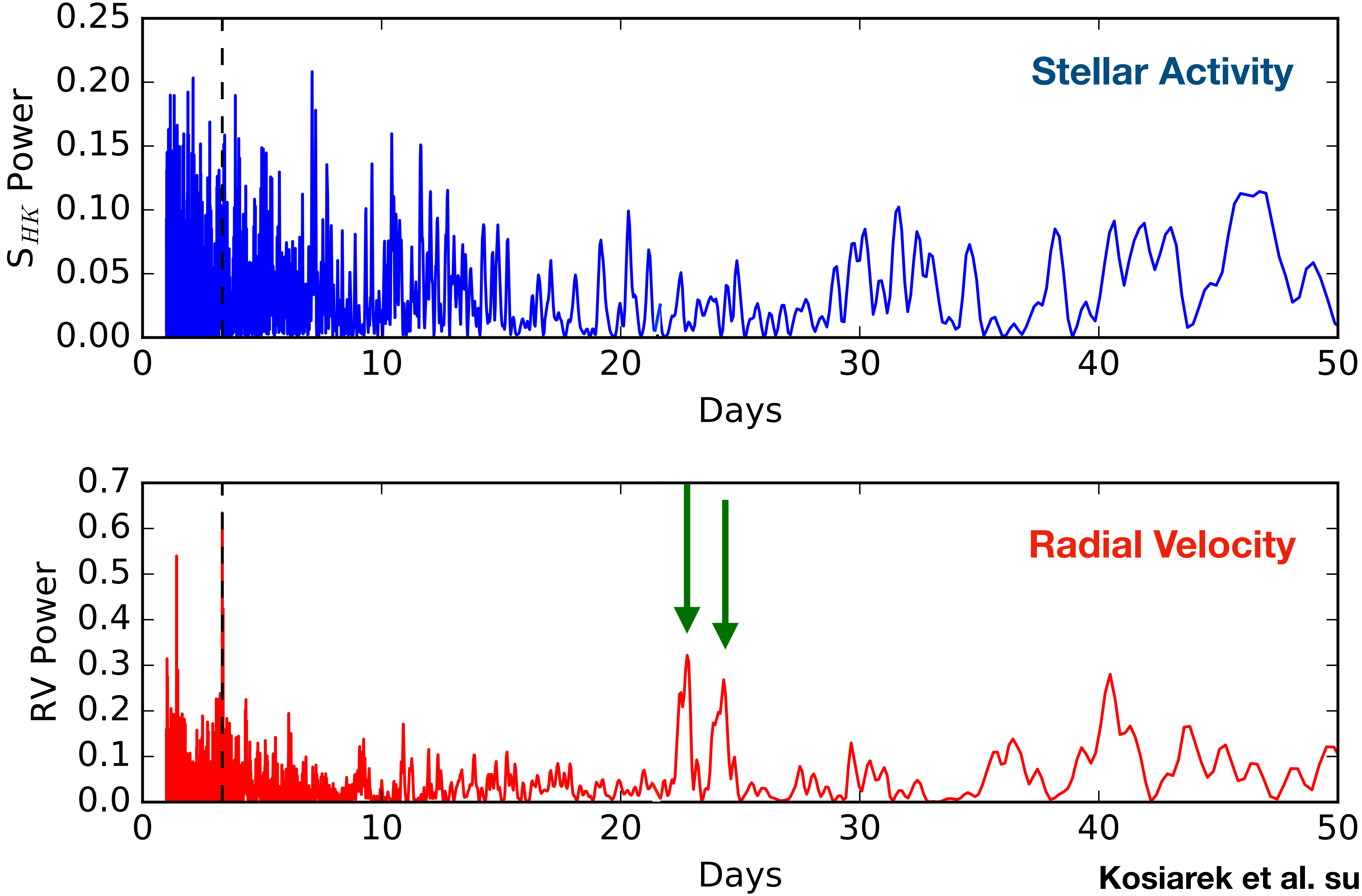
Period of correlated signal (stellar rotation period)

$$k(t,t') = \eta_1^2 \exp\left[-\frac{(\mathrm{t}-\mathrm{t}')^2}{\eta_2^2} - \frac{\sin^2\left(\frac{\pi(\mathrm{t}-\mathrm{t}')}{\eta_3}\right)}{\eta_4^2}\right]$$

Active region evolutionary timescale (spot decay lifetime)

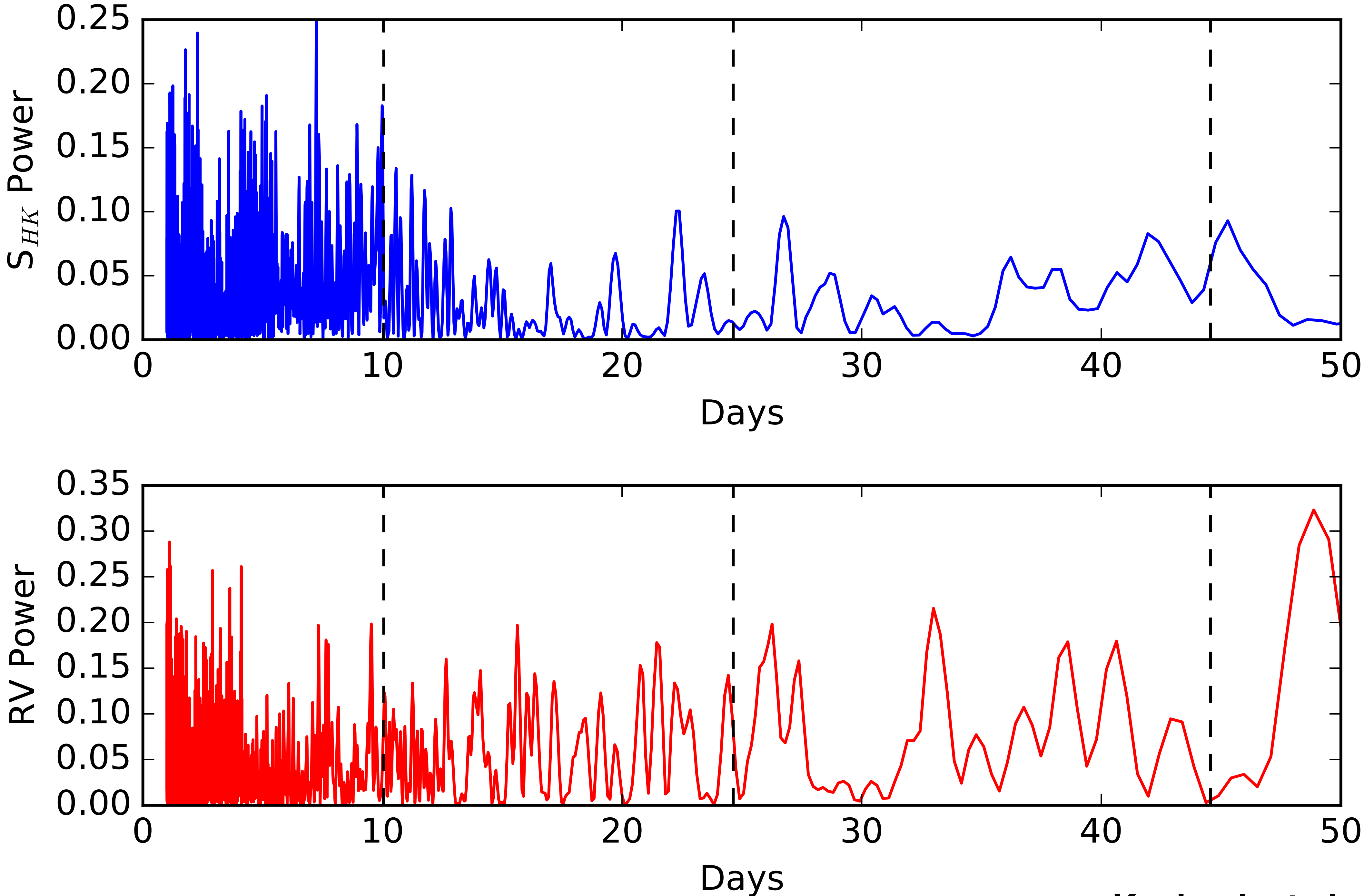
Length scale of the periodic component

GJ3470: There are stellar activity signals in the RV data.



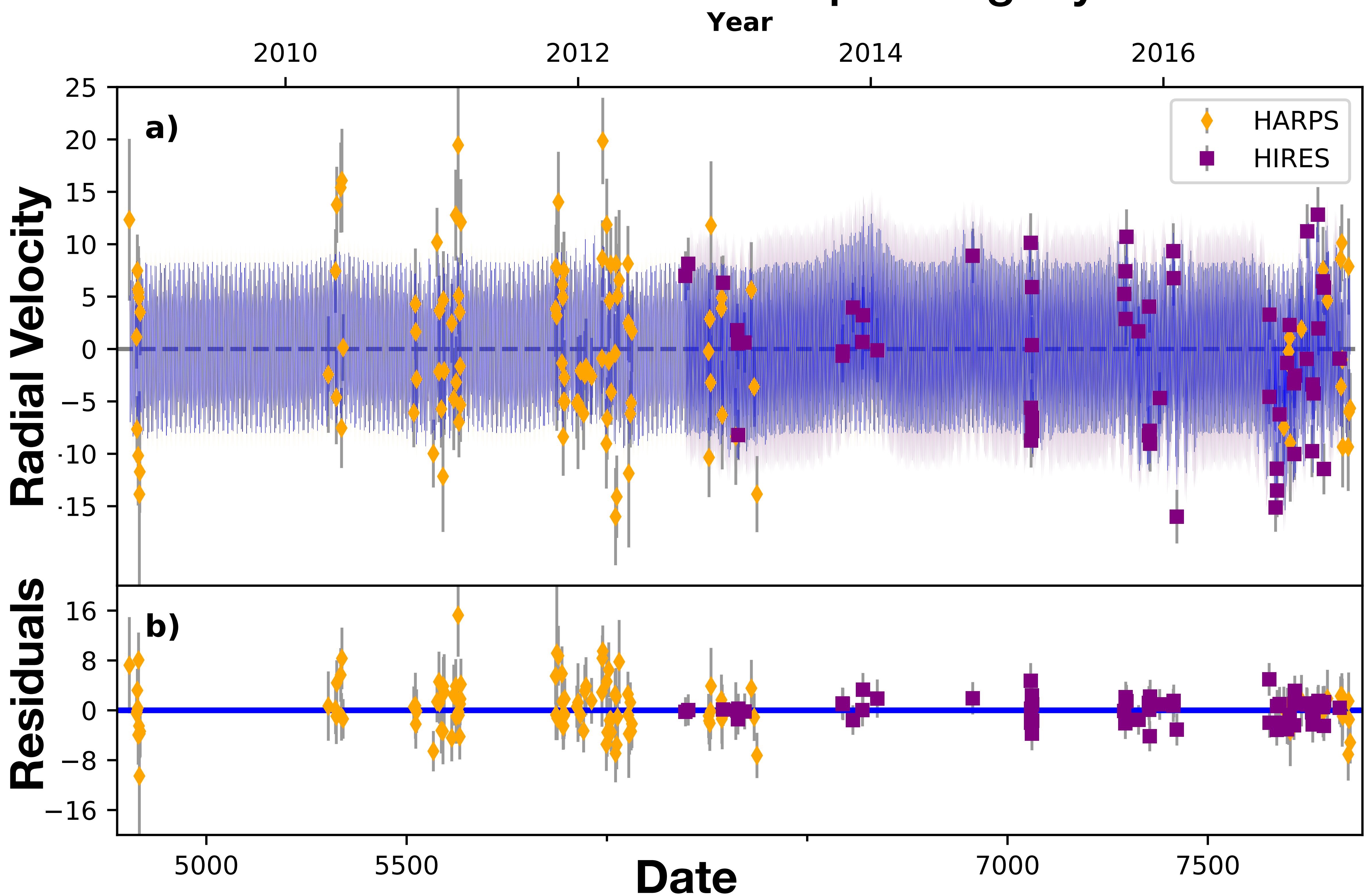
Kosiarek et al. submitted

K2-3: There are no clear stellar activity signals in the RV data or the S_{HK} data.



Kosiarek et al. submitted

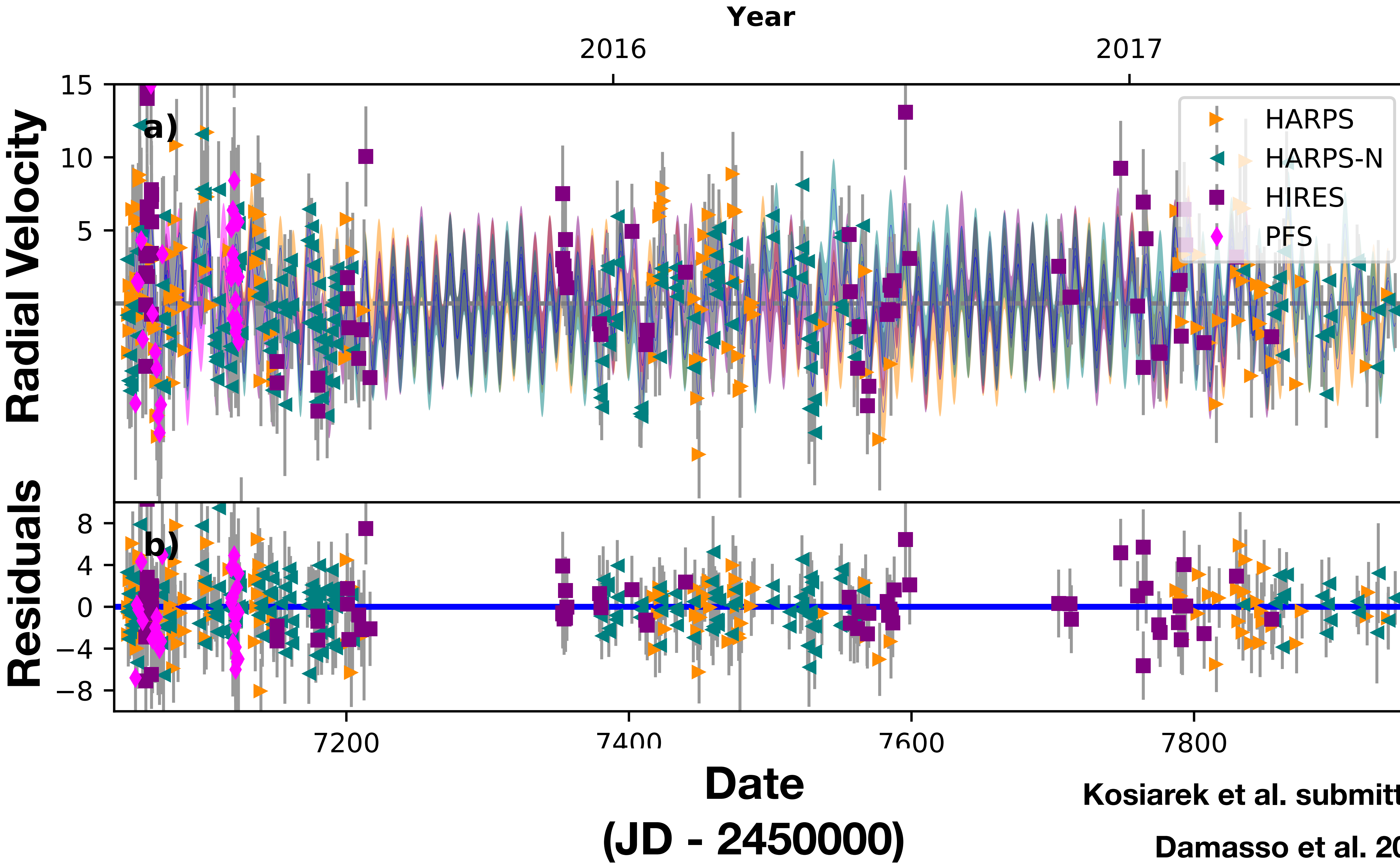
GJ3470: Radial Velocity fit including 57 HIRES and 113 HARPS measurements spanning 8 years.



Kosiarek et al. submitted

Bonfils et al. 2012

K2-3: Radial Velocity fit with Gaussian Processes.

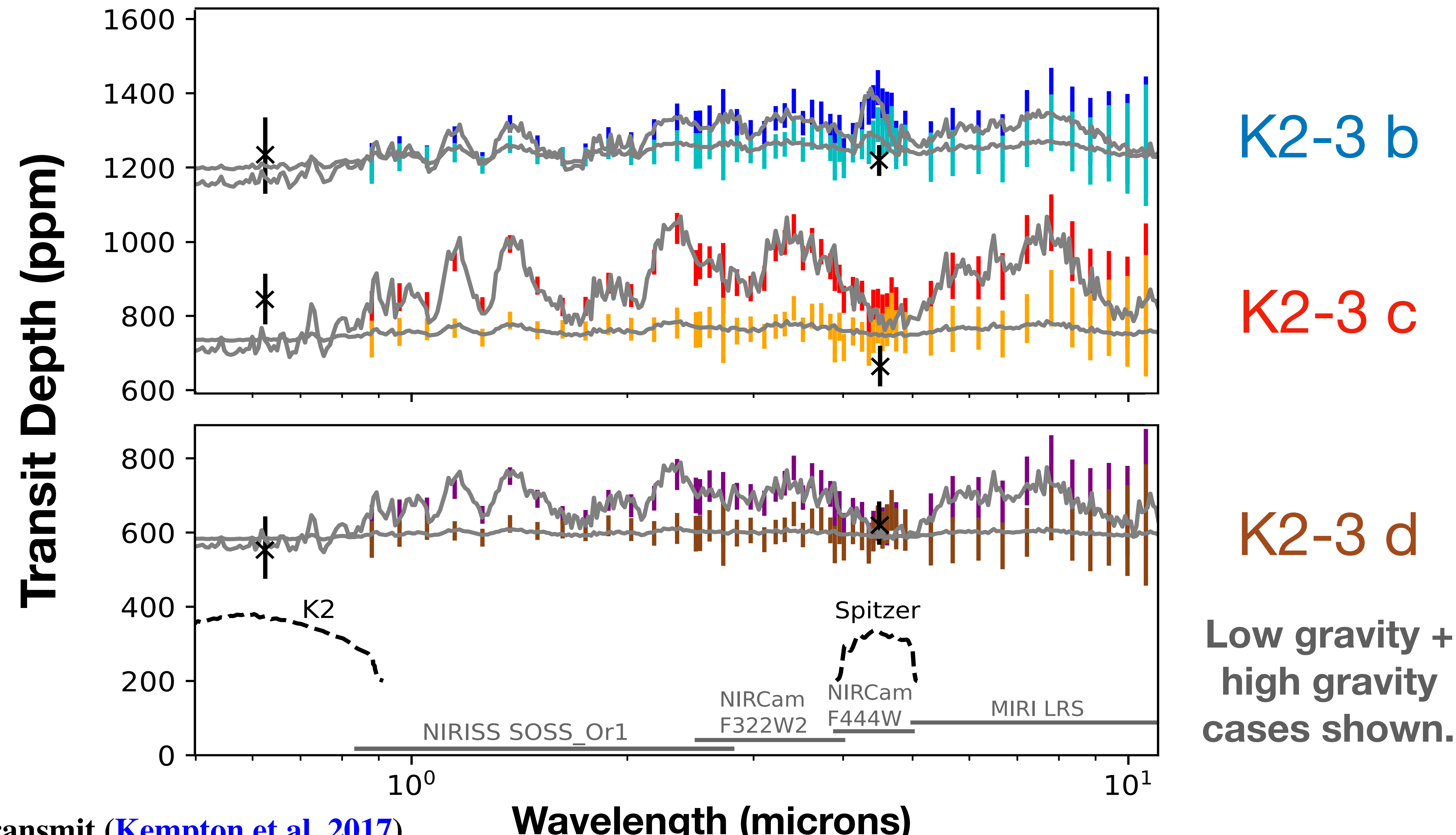


Kosiarek et al. submitted

Damasso et al. 2018

Dai et al. 2016 Almenara et al. 2015

K2-3: JWST transmission spectroscopy can determine atmospheric composition.



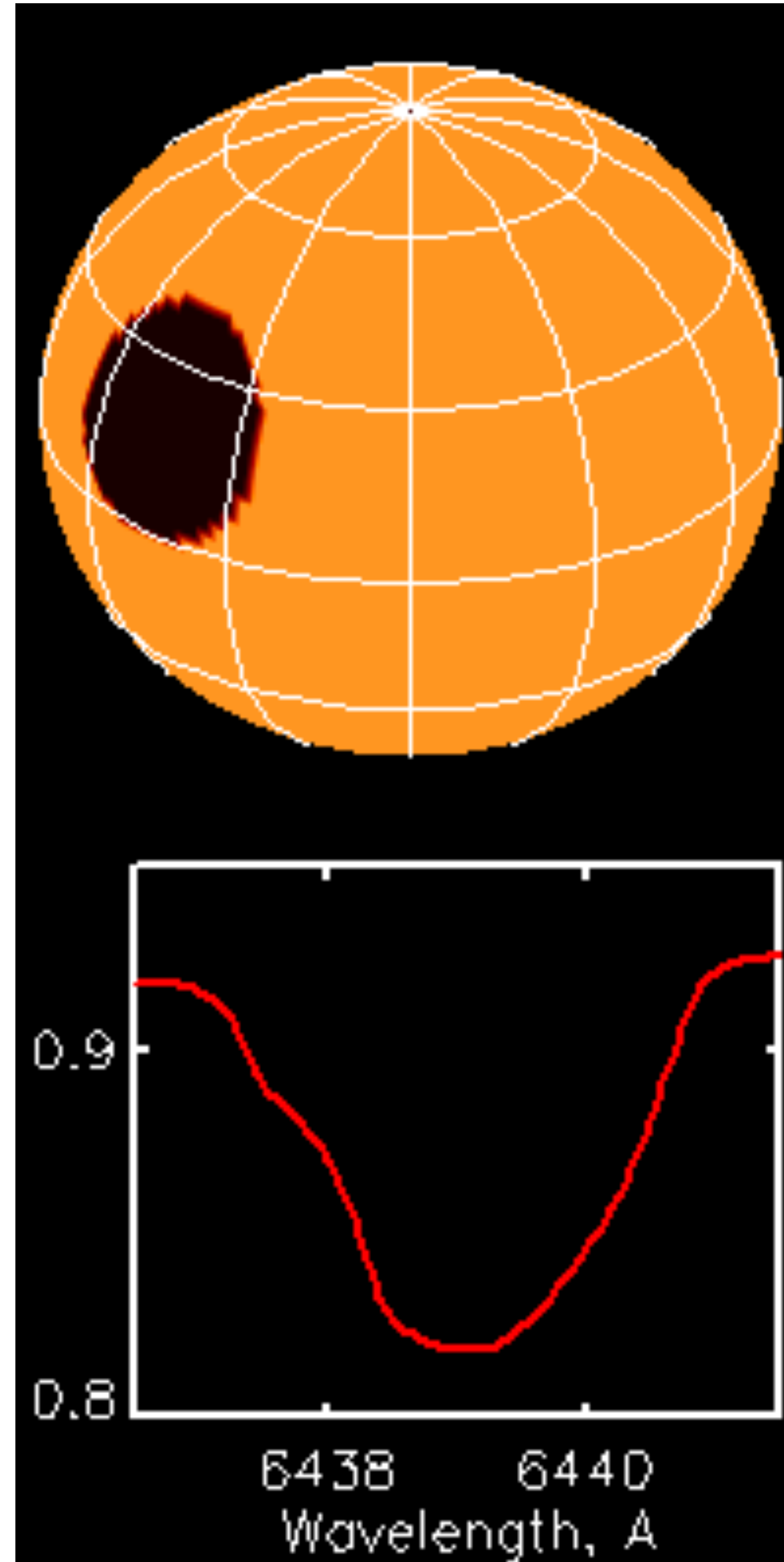
ExoTransmit (Kempton et al. 2017)

PandExo (Greene et al. 2016; Batalha et al. 2017b)

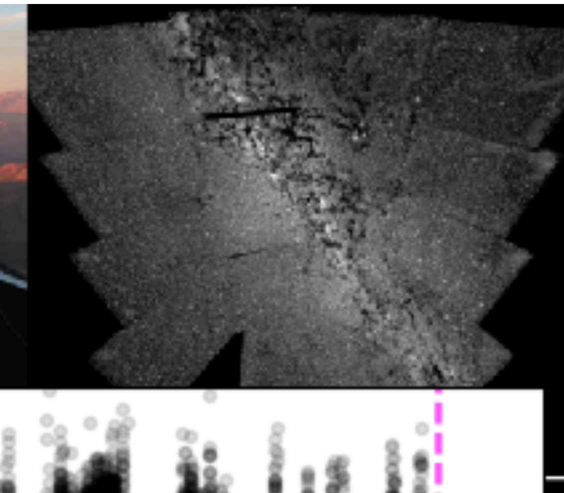
Kosiarek et al. submitted.

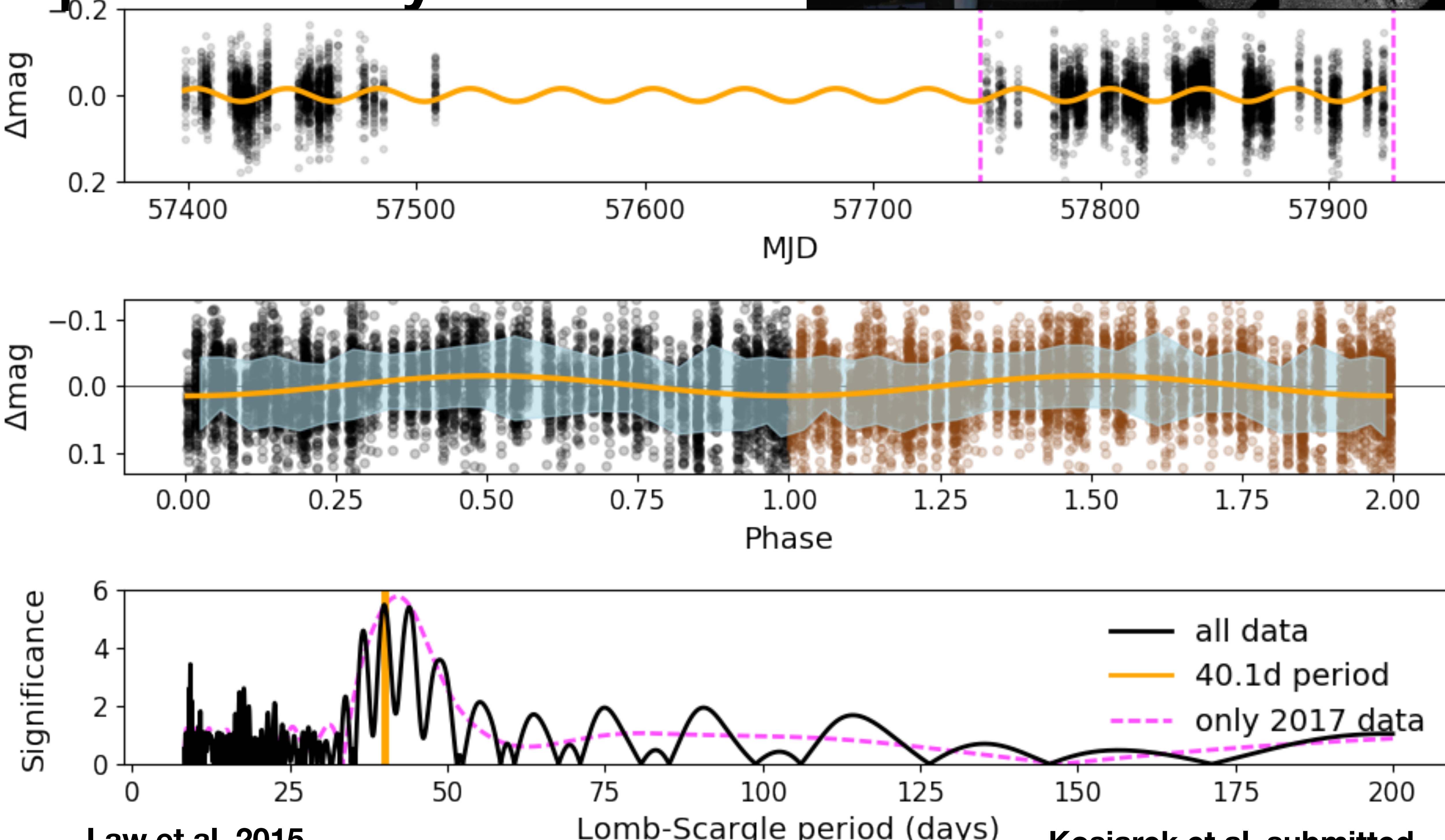
Magnetic activity on the stellar surface can induce planet-like signals in RV data.

We modeled our RVs with Gaussian processes trained on photometry



Evryscope Ground-based photometry of K2-3





Law et al. 2015

Kosiarek et al. submitted