The Search for Evidence of Tidal Orbital Decay in Hot Jupiters

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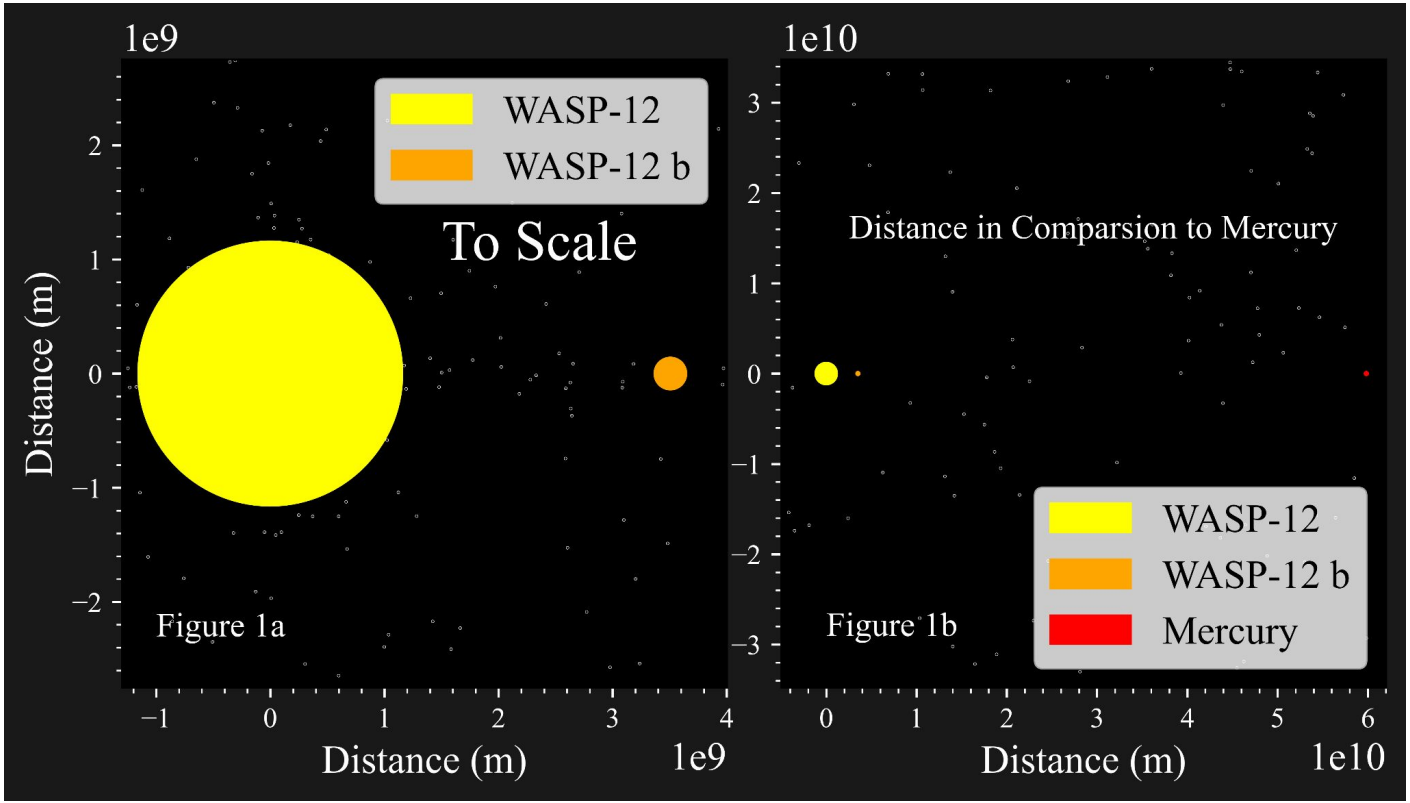
(in prep.)

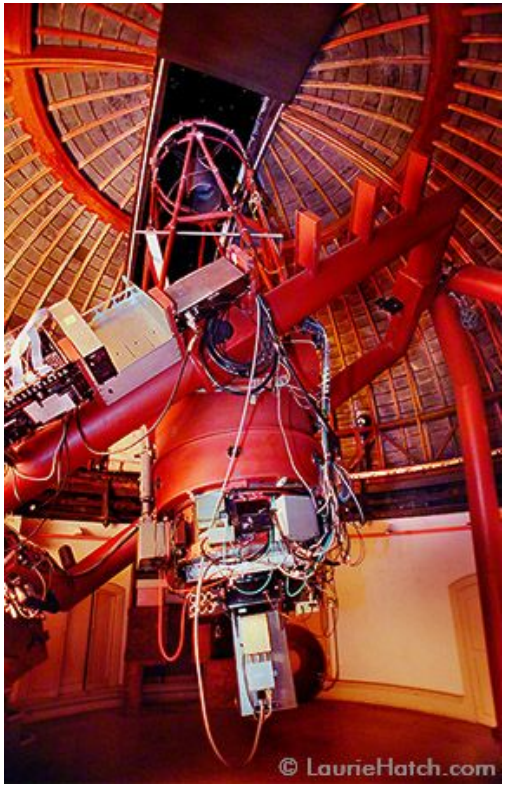
Outline

- Background
- Data Acquisition
- Timing and Radial Velocity Analysis
- Results
- Conclusions

Background: Hot Jupiters



Data Acquisition



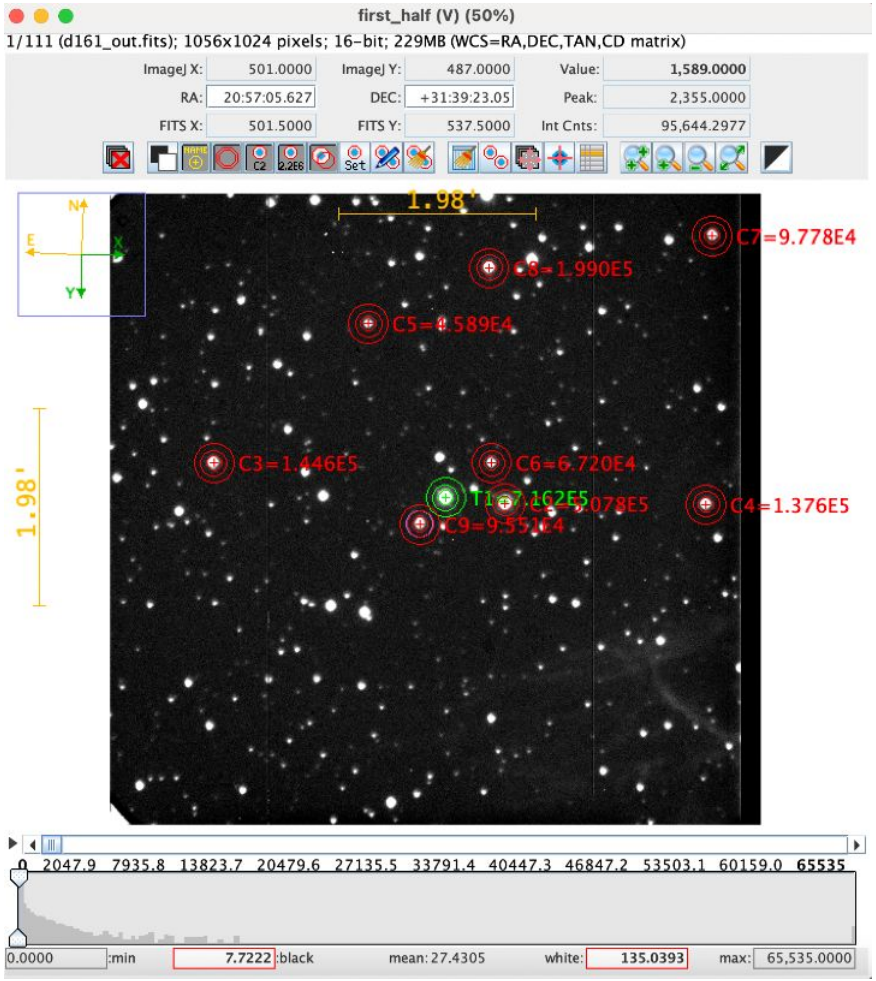
The systems we studied:

- HAT-P-23
- KELT-16
- WASP-12
- WASP-43
- WASP-103
- WD-1856+534 (WD 1856)
- WTS-2

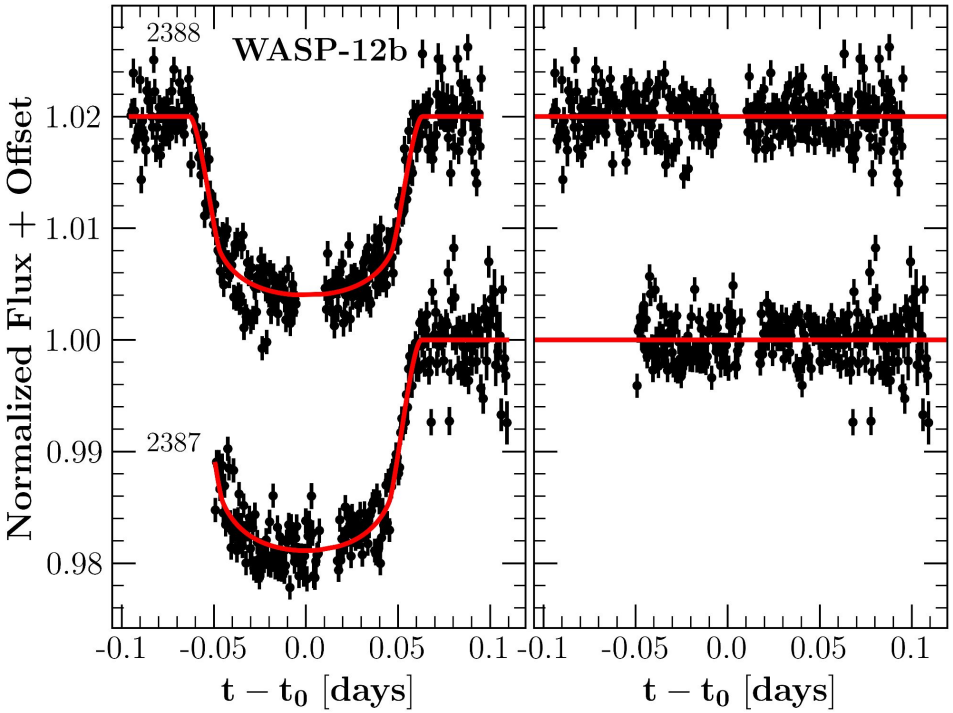
Data Acquisition

Used AstroImageJ for:

- Calibration (flat field corrections and bias reduction)
- Aperture Photometry
- Calculates the time stamp (BJD_TDB) for each frame



Data Analysis



We fit a theoretical lightcurve to the data (Mandel & Agol 2002). We also corrected for airmass by adding a linear function.

Timing Analysis

$$\textbf{Constant Period: } t(E) = t_0 + PE$$

$$\textbf{Orbital Decay: } t(E) = t_0 + PE + \frac{1}{2}\frac{dP}{dE}E^2$$

Where P is the orbital period, E is the epoch,

t_0 is the mid-transit time at the zeroth epoch, and $\frac{dP}{dE}$ is the change of period per epoch.

$$\frac{dP}{dt} = \frac{1}{P}\frac{dP}{dE}$$

Timing Analysis

Orbital Acceleration: $t(E) = t_0 + PE + \frac{1}{2}\frac{dP}{dE}E^2 + \frac{1}{6}\frac{d^2P}{dE^2}E^3$

$$\frac{d^2P}{dt^2} = \frac{1}{P^2}\frac{d^2P}{dE^2}$$

Where $\frac{d^2P}{dE^2}$ is the derivative for the change of period per epoch.

Radial Velocity Analysis

Constant Period

$$\mathrm{RV}(t) = K \sin\left(\frac{2\pi}{P}t + \phi\right) + c$$

$$K = m_p \sin(i)(m_\star + m_p)^{-2/3} P^{-1/3}$$

P is the orbital period, ϕ is the phase angle, and c is a constant offset.
K is the velocity semi-amplitude velocity is a function of:
orbital inclination (i),mass of the planet (m_p), and mass of the host star ($m_\star$).

Radial Velocity Analysis

Orbital Decay

$$\mathrm{RV}(t) = K(t) \sin\left(\frac{2\pi}{P(t)} + \phi\right) + c$$

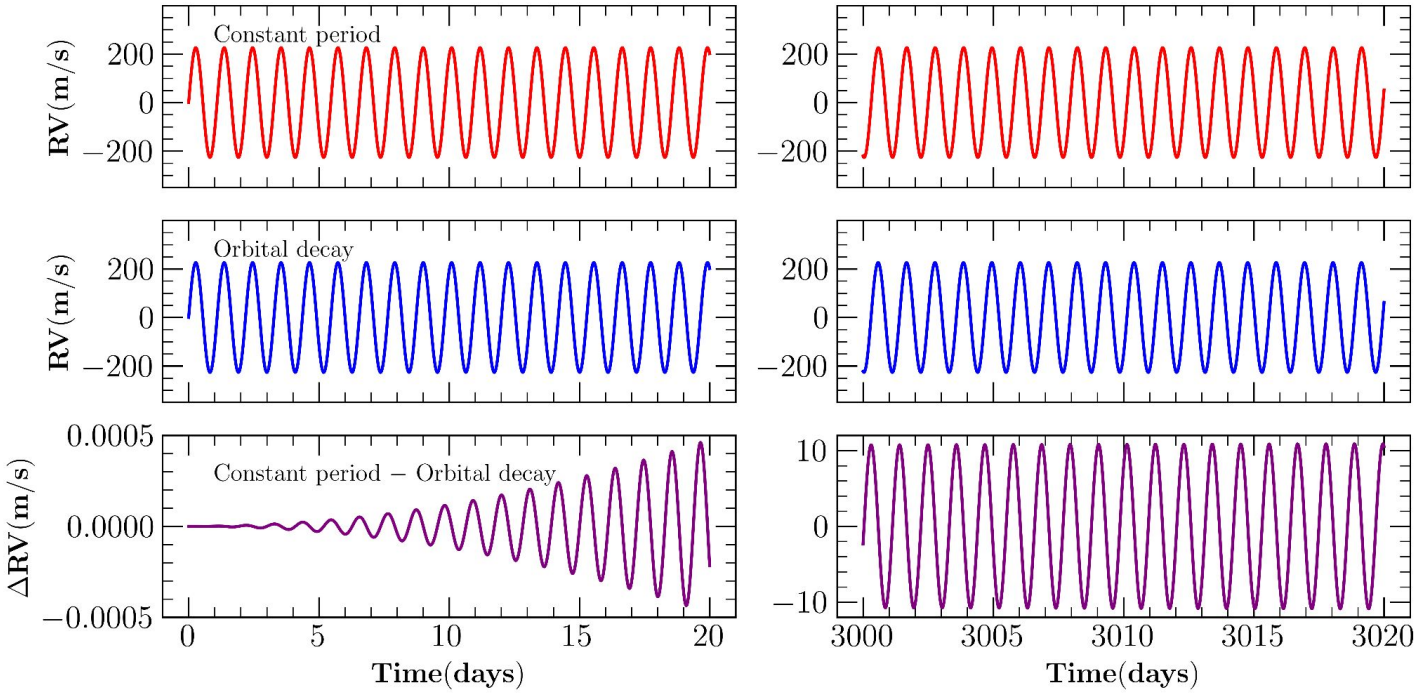
$$K(t) = m_p sin(i)(m_\star + m_p)^{-2/3} P(t)^{-1/3}$$

where

$$P(t) = P_0 + \frac{dP}{dt}$$

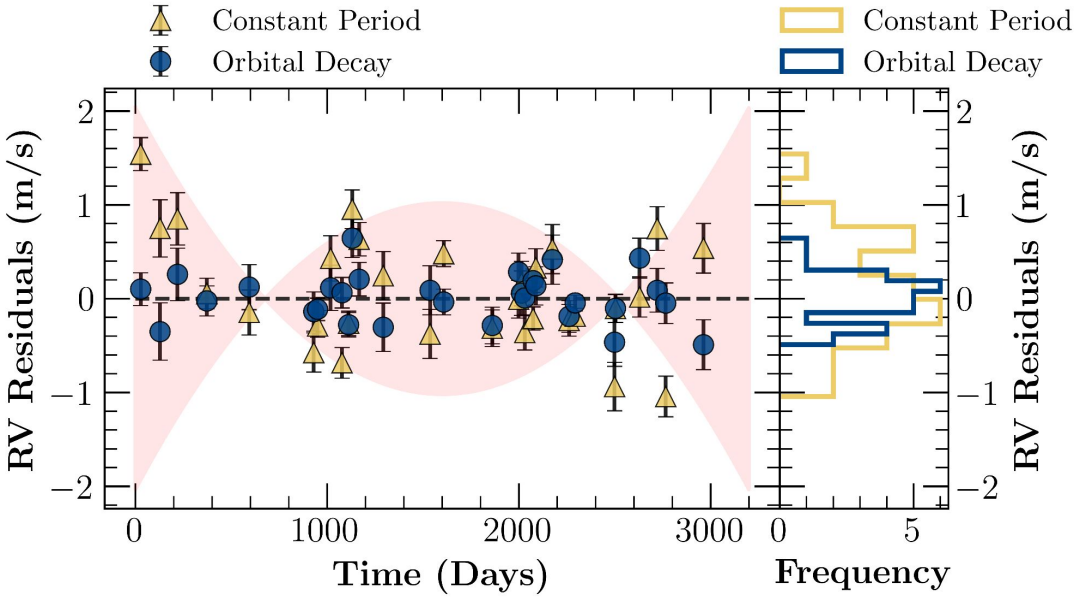
Here P_0 is the orbital period at $t = 0$

Radial Velocity Analysis

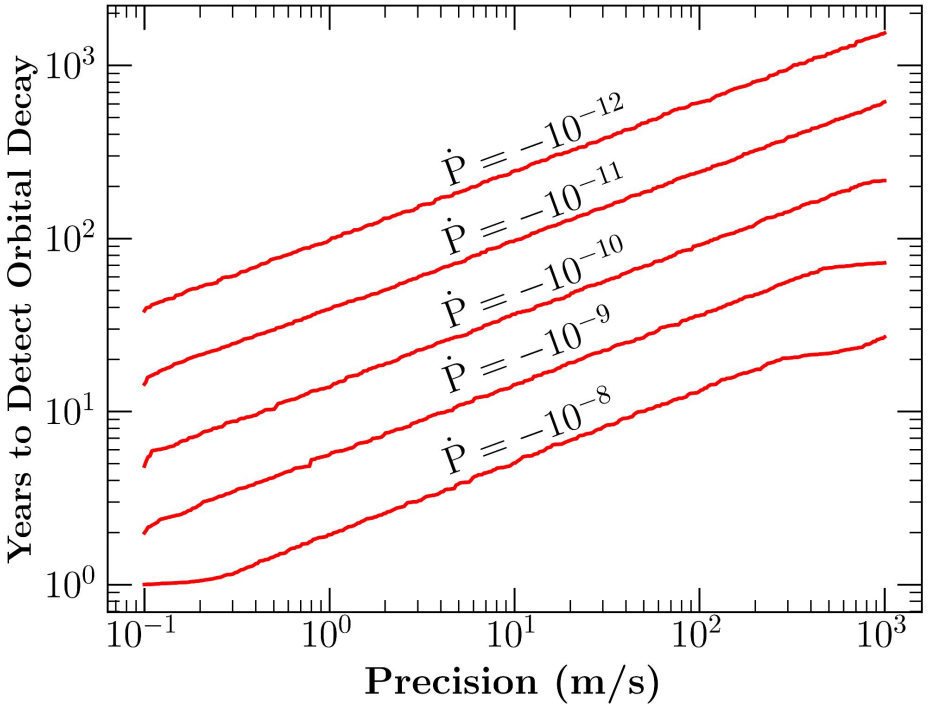


Radial Velocity Analysis

We simulated data after the WASP-12 system.



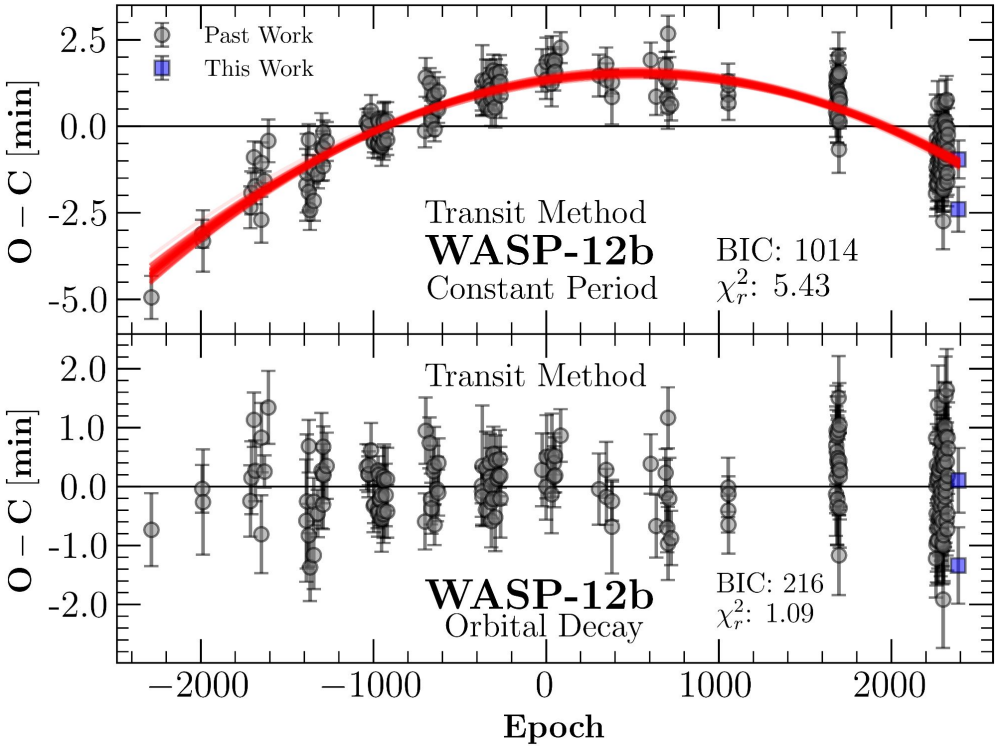
Radial Velocity Analysis



We wanted to predict the timescale of detecting orbital decay based on the average precision.

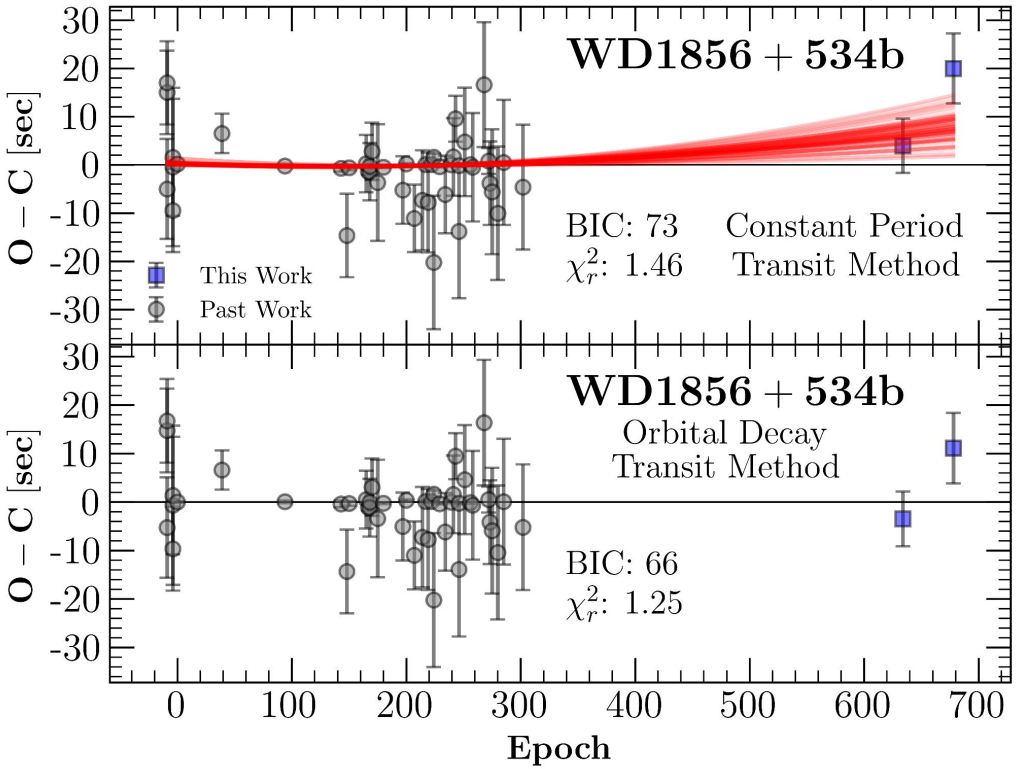
Timing Results

No detection of orbital decay with any of the systems that were studied- with the exception of the well studied **WASP-12b.**



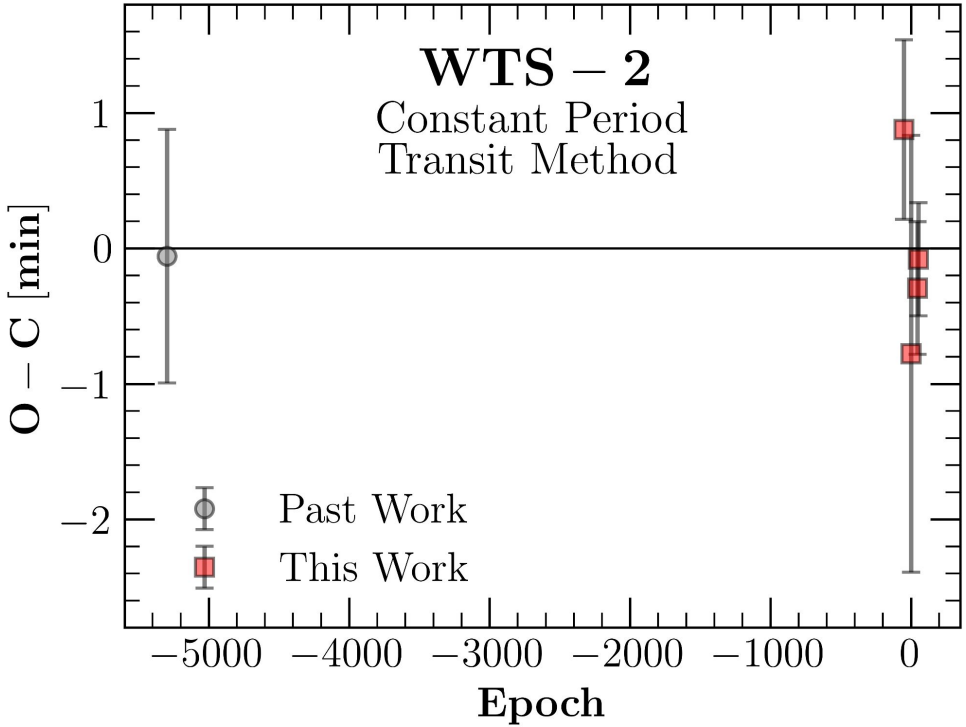
Timing Results

No detection of orbital decay with any of the systems that were studied- with the exception of the well studied WASP-12b. However, there is a tentative detection of **orbital growth** for the **WD-1856+534 system.**

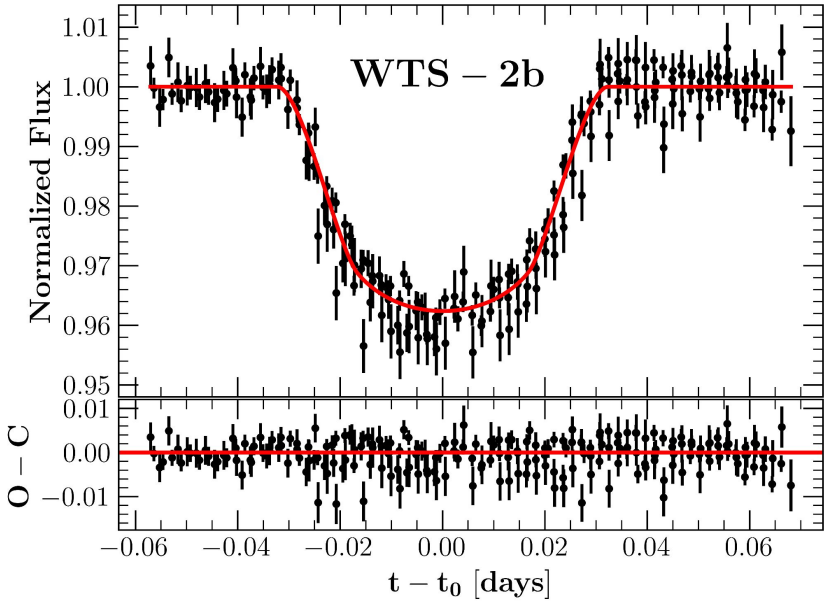


Timing Results

No detection of orbital decay with any of the systems that were studied- with the exception of the well studied WASP-12b. However, there is a tentative detection of orbital growth for the WD-1856+534 system. **WTS-2** is an understudied system thus the **change of period cannot be measured** at the moment.



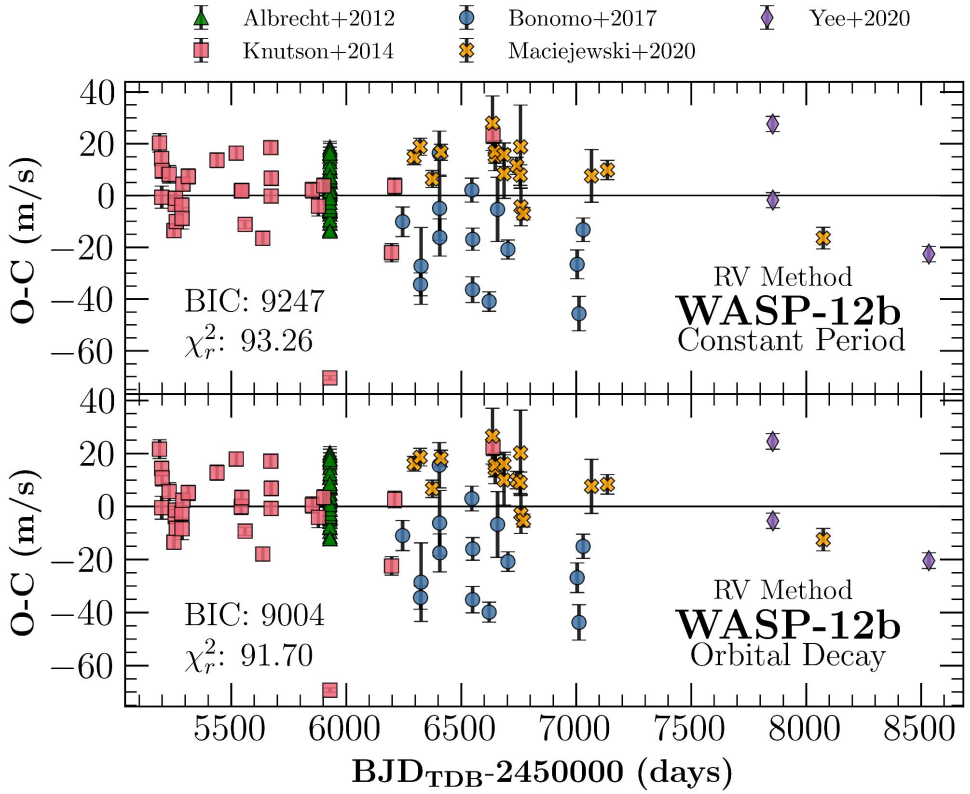
Timing Results



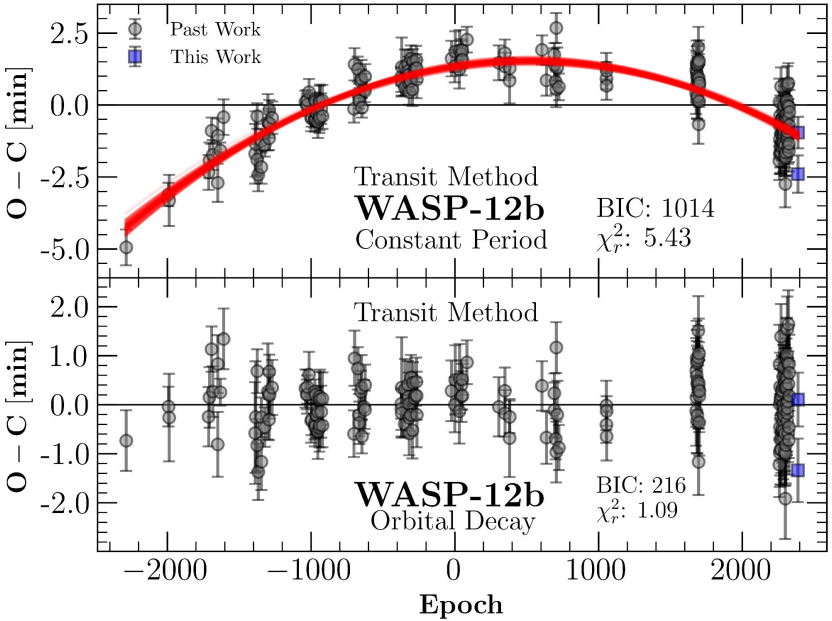
	Discovery	vs.	This Work
Period:	$\left(1.0187068 \pm 6.5 \times 10^{-7}\right.$		$\left.1.01870539 \pm 1.2 \times 10^{-8}\right)$ days
b:	0.597 ± 0.032		0.611 ± 0.045
$R_p/R_\star$:	0.1755 ± 0.0018		0.1849 ± 0.0028
$R_\star/a$:	0.1885 ± 0.0102		0.1924 ± 0.0064

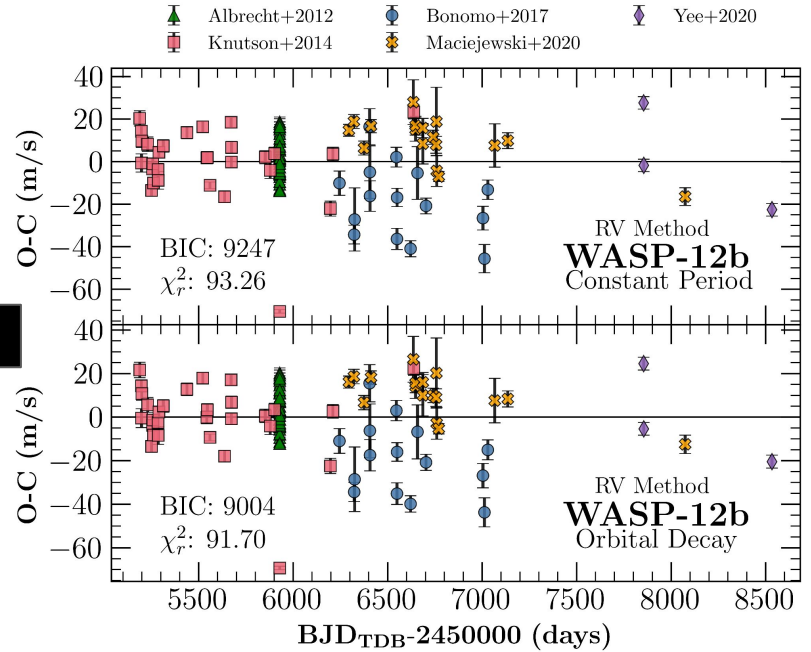
Results from Radial Velocity Analysis

From the RV-fitting, we determine that dP/dt is similar for the WASP-12 system. However, the uncertainty is large to be considered not a detection. Similar results were found for the other systems that were studied.



Joint Fit of Timing and RV Data





Conclusions

There is no **detection of orbital decay** for any systems that we were studied other than **WASP-12.** For WASP-12, we attempt to detect **acceleration of orbital decay**, and find that it is **(-7 ±8)x10^(-14) 1/s**. We see a **tentative detection** of **orbital growth** in the **WD-1856+534** system. **WTS-2b** is an understudied system so we provided newer transit parameters and a **tighter constraint on the orbital period**.

Conclusions

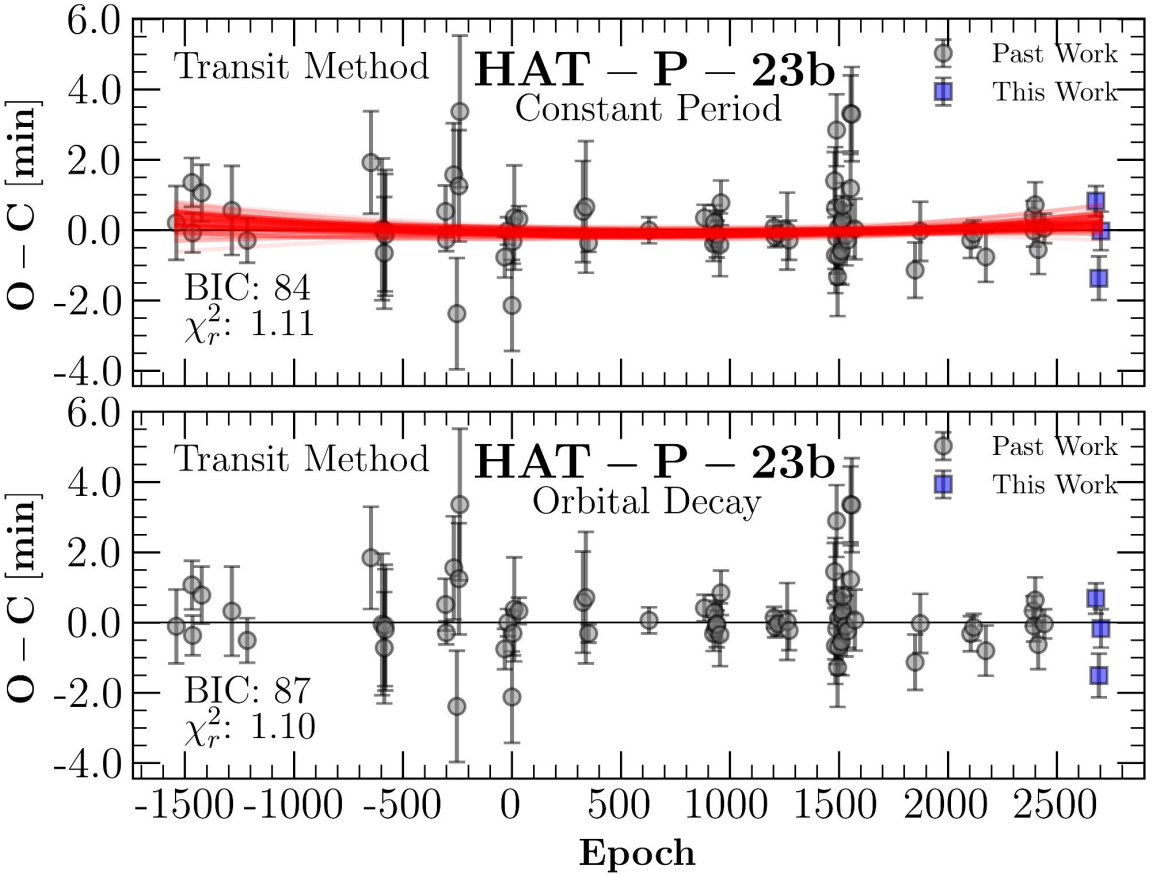
We provide a **new method** of determining orbital decay **using RV data**. In theory, the **RV method can detect orbital decay quicker,** but needs smaller error bars on RV data**.** We **cannot conclusively determine** whether (**WASP-43b, WASP-103b, and HAT-P-23b**) are **undergoing orbital decay** with the **exception of WASP-12b.**

By **joint-fitting both sets of data**, constraining the rate of orbital decay does help assist the RV data. However, there is still **no detection** for any system that we studied.

Acknowledgements

EA would like to thank the CaI NERDS and UC LEADS for the funding of this project.

Extra Slides



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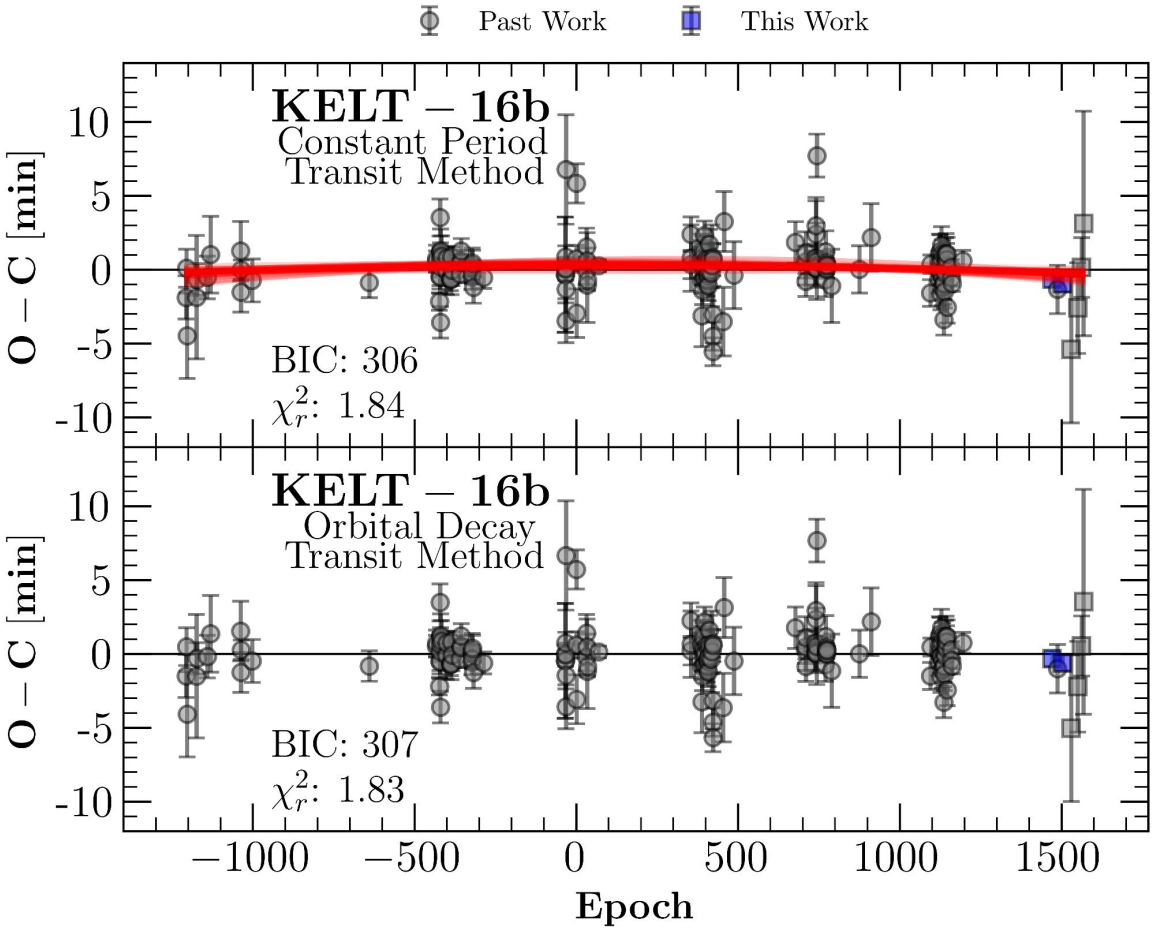

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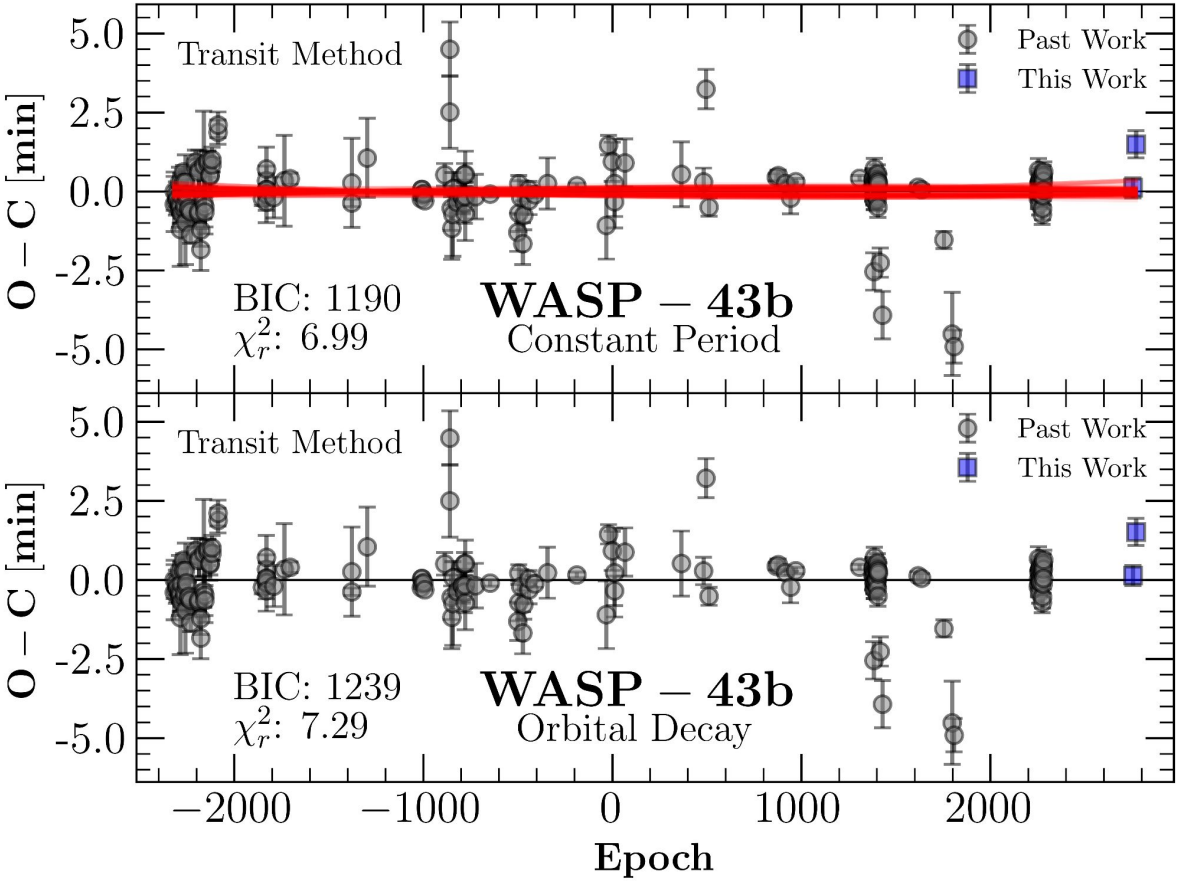

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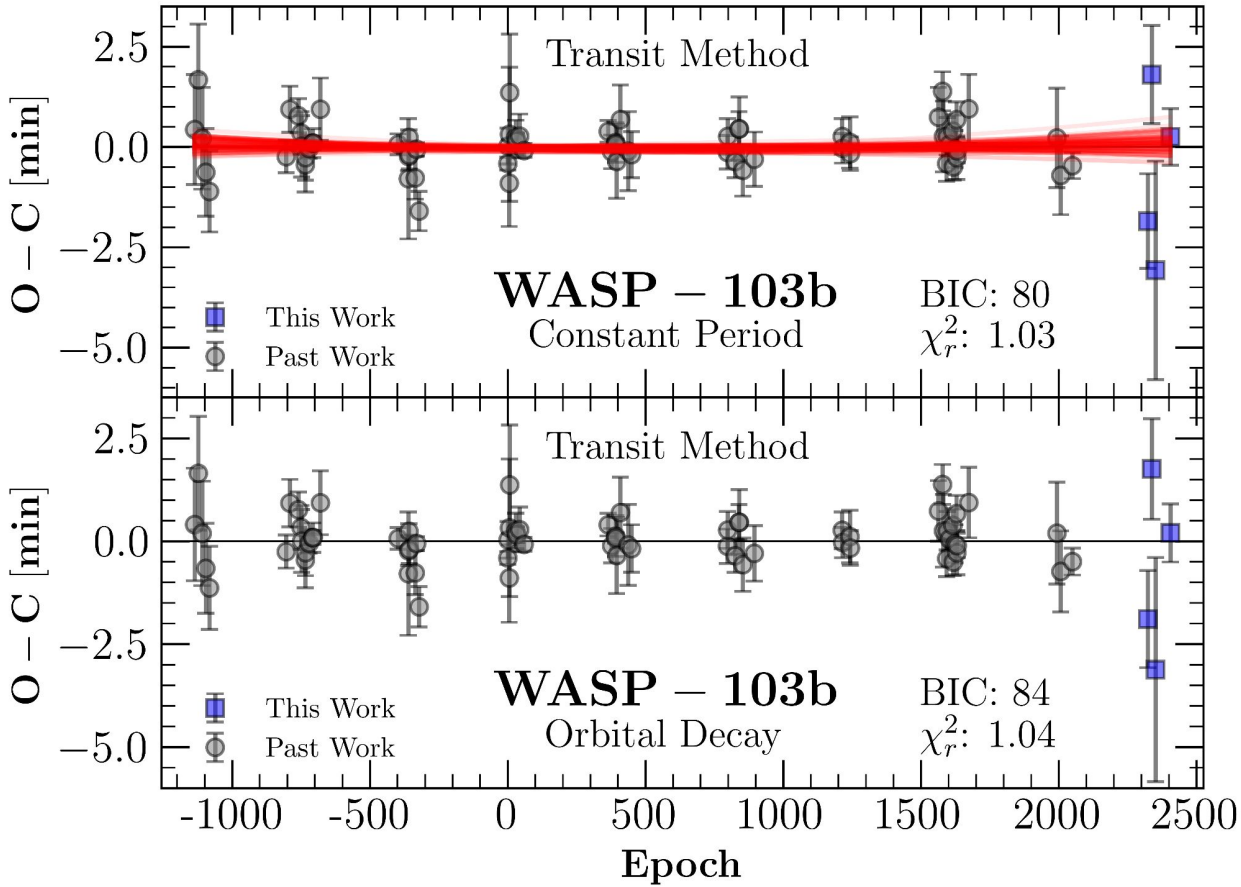

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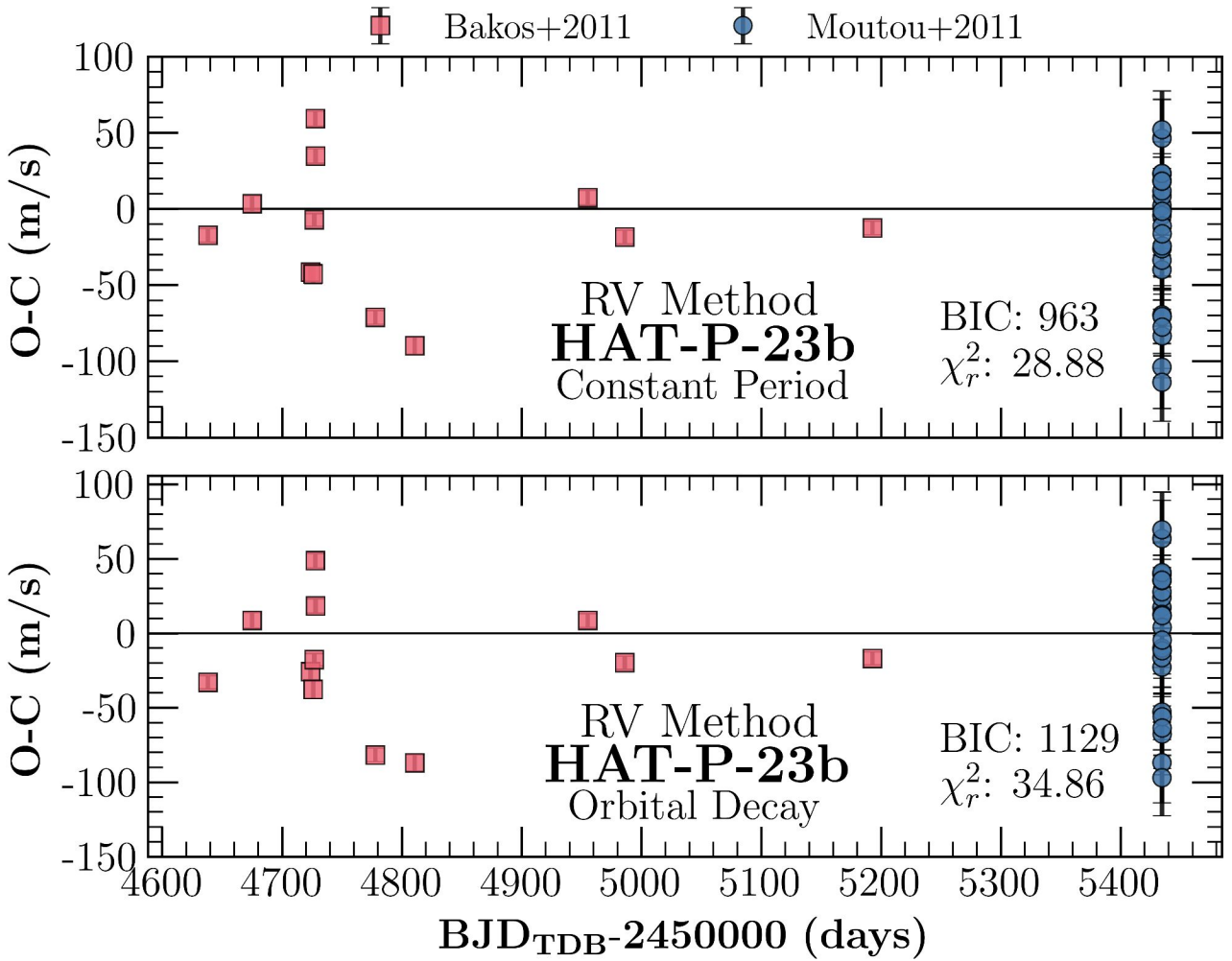

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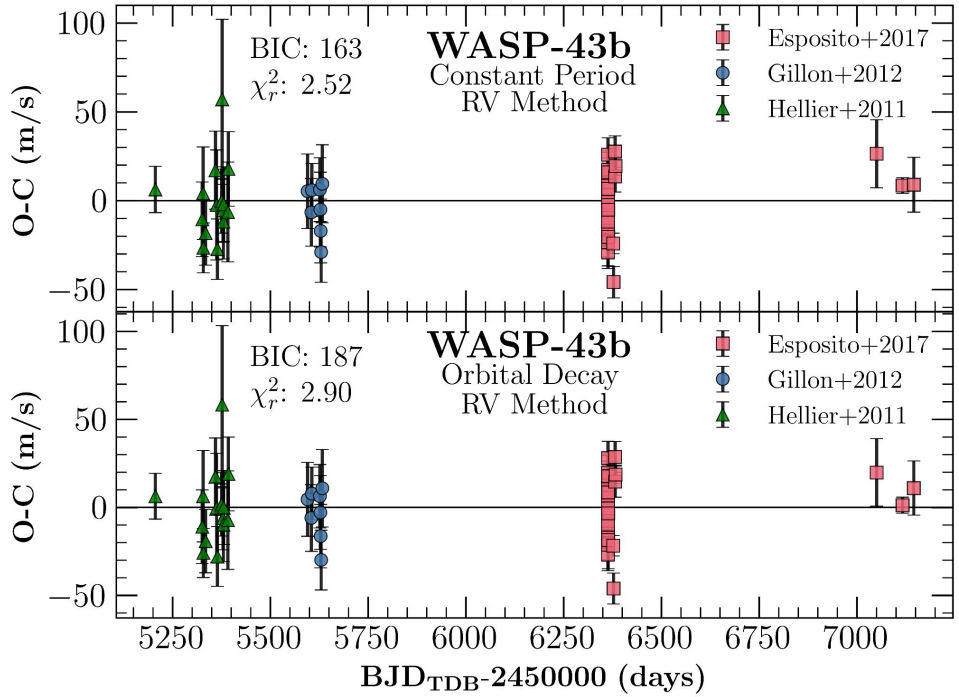

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