A Decade of Multi-band Observations of WASP-43 b Focused on Transit Timing and Atmospheric Characterization

N. A-thano[1], S. Awiphan[1], E. Kerins[2], A. Priyadarshi[2], O.Tasuya[1],Ing-Guey Jiang[3]

[1] National Astronomical Research Institute of Thailand, Thailand

[2] The University of Manchester, UK

[3] Institute of Astronomy, National Tsing-Hua University, Taiwan

EAMA11, Niigata, Japan, December 8-12, 2025

CONTENTS

Introduction
- WASP-43 b
- TTV of Exoplanets
- Transmission spectroscopy

Observations & Data Reductions

Transit Modelling

Timing Variation Modeling
- Detecting orbital decay

WASP-43 b Planetary Atmosphere

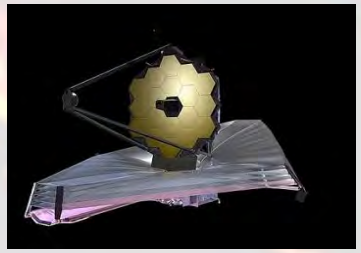
Conclusions

Introduction

The Hot Jupiter WASP-43 b



Hellier et al. 2011 The Wide-Angle Search for Planets survey (WASP)
A Hot Jupiter Orbiting a host K7 dwarf, P= 0.81 day. (V = 12, M_p = 1.99M_{Jup}, Rp = 1.04R_{Jup} T_{eq} = ~1300 K)



2011

Gillon et al. (2012)
- The first TTV study.
- TRAPPIST survey
- O-C diagram
- No sign of TTVs

2012

Blecic et al. (2014)
- dp/dt rate = −0.095 s/year.

Murgas et al. (2014)
- dp/dtrate = −0.15 s/year.
- Indicated to the orbital decay
- Needs to be made confirmation.

2014

Kreidberg et al. 2014
- HST/WFC3 First transmission spectrum
- Initial detection of H_2O.

2016

Jiang et al. 2016
- O-C diagram + 1849 epochs.
- Orbital decay rate = −0.03 s/year.
- Could be signals of a slow orbital decay.

2018

Tsiaras et al. (2018)
- HST reanalysis
- H_2O detection

2020

Weaver et al. (2020)
- ACCESS; no Na/K/Hα

Chubb et al. (2020)
- HST reanalysis; >5σ AlO detection

2021

Garai et al. (2021)
- MuSCAT2 + TESS
- Confirm no detection of orbital decay.

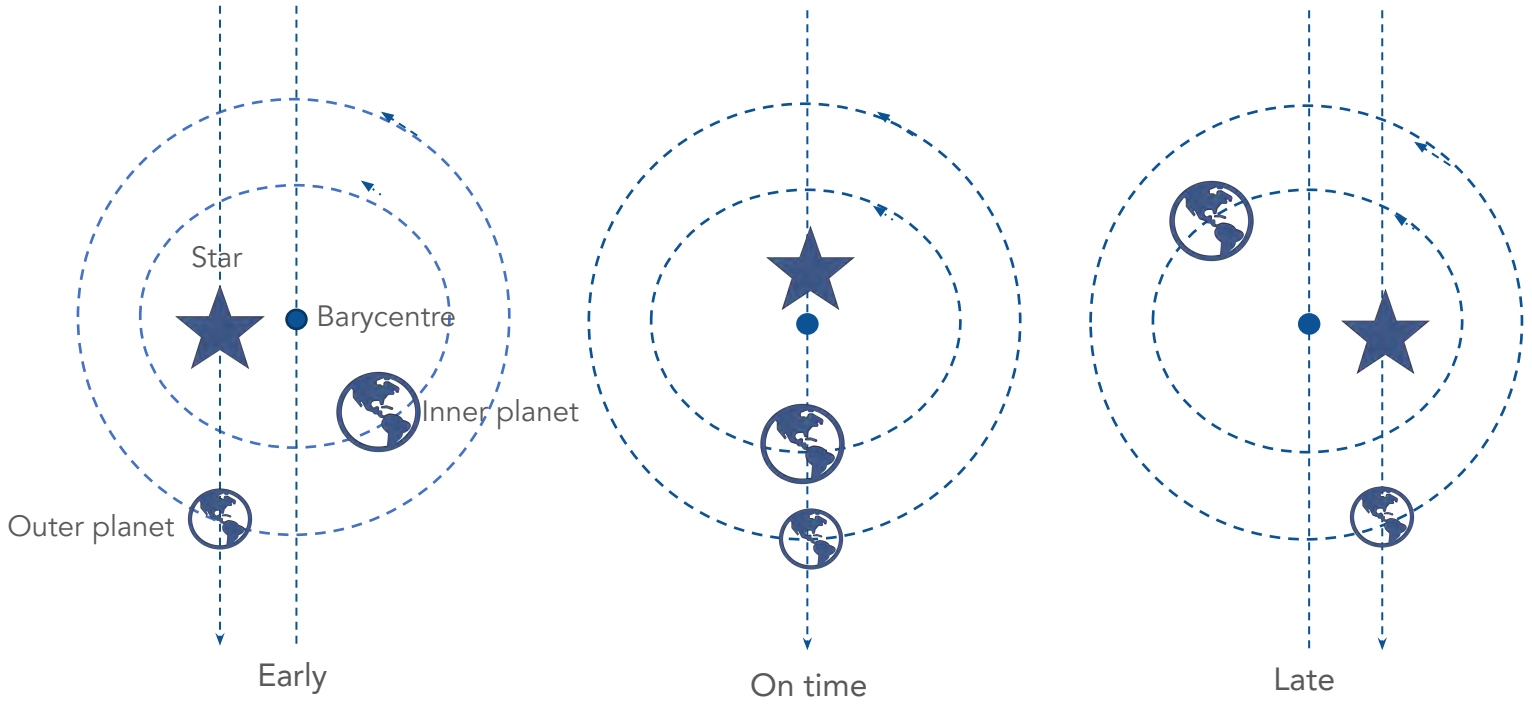
2023 2024

Bell et al. (2023–2024)
- JWST/MIRI phase curve strong day–night contrast & H_2O at all phases

The orbital decay with unsettled conclusions ???

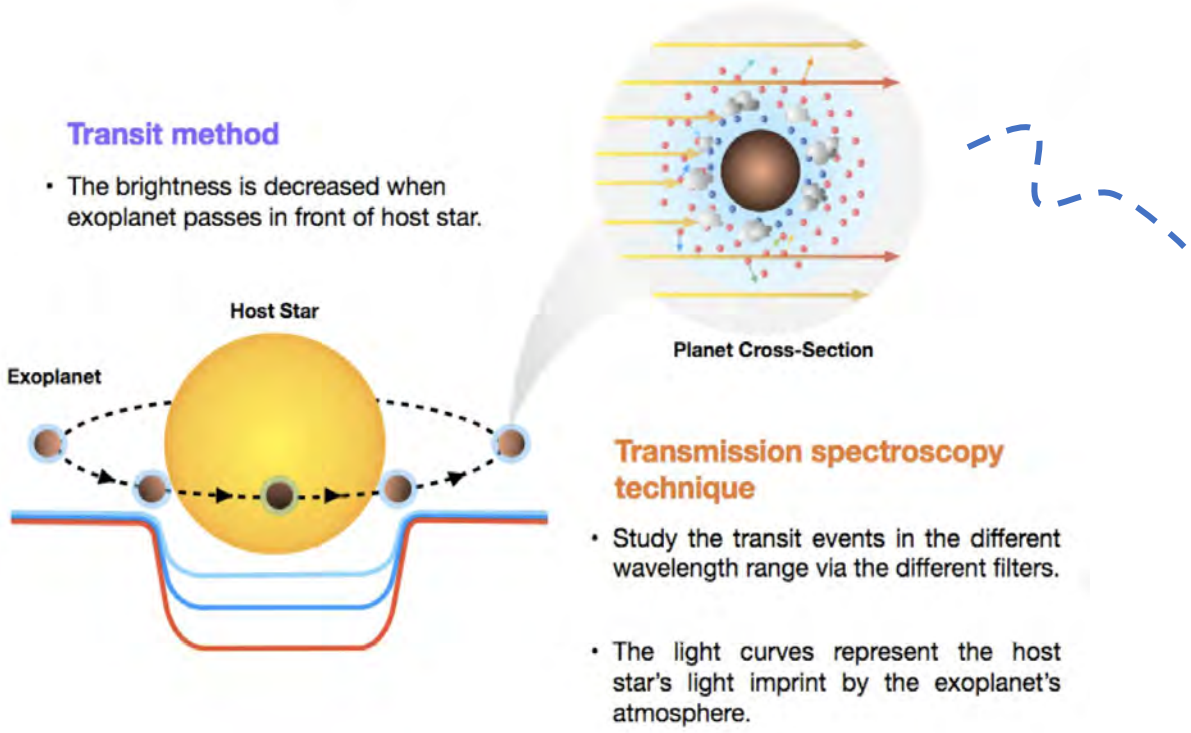
Transit Timing Variation (TTV) of Exoplanets

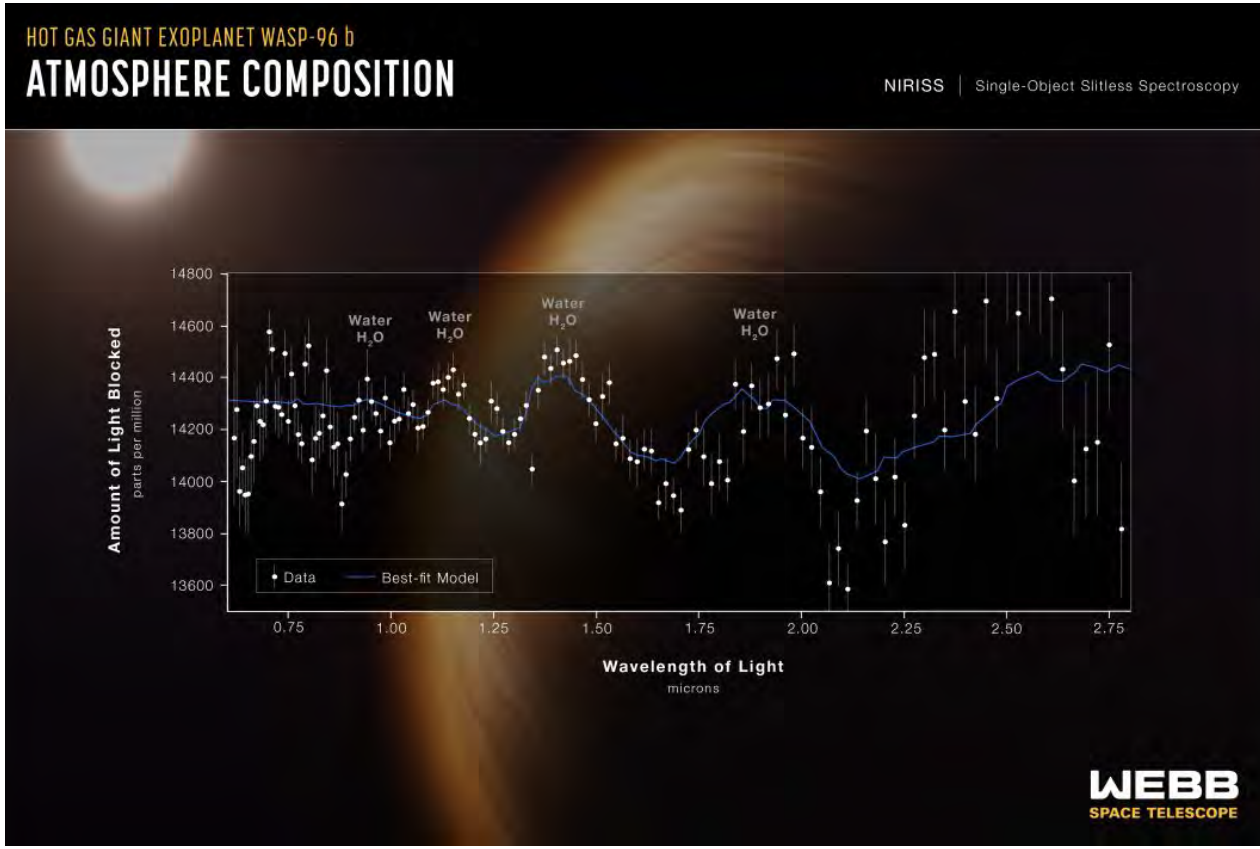
The variation of mid-transit time ($t_m - t_0$) from the linear ephemeris in Keplerian orbit, which may be caused by gravitational interactions from a third body.



The diagram shows the change in transit times in a 3-body system. The additional planet is the outer planet in a 2-planet system. Transit times are affected by the changing position of the host star with respect to the barycentre due to the other planet. (Agol et at. 2005)

Detection of Exoplanet Atmosphere by using Transmission spectroscopy



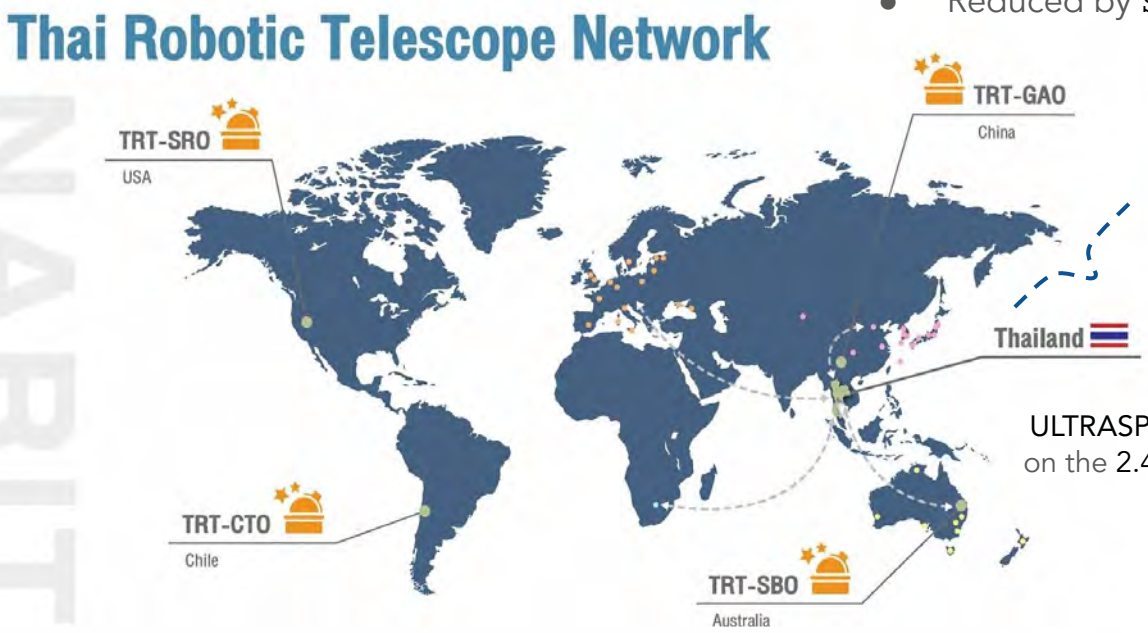


Illustrating of a transiting exoplanet, transmission spectroscopy technique and a transmission spectrum made from the JWST observation using Webb's Near-Infrared Imager and Slitless Spectrograph (NIRISS) reveals atmospheric characteristics of WASP-96 b (Credit:JWST).

Observation & Data Reduction

SPEARNET Observations

- Multi-bands photometry (2017-2022)
- Reduced by `SPEARNET` pipeline reduction.



The locations and sizes of the SPEARNET telescope network.

Image Credit : NARIT



ULTRASPEC, a high-speed EMCCD camera on the 2.4-m Thai National Telescope (TNT).



The 0.7-meter Thai Robotic Telescopes (TRTs)



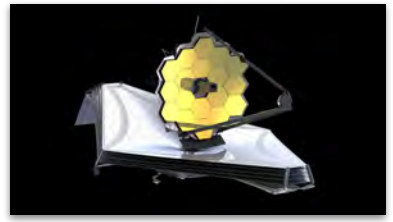


Image Credits : NASA

TESS

- Sector 9,35,62 & 89 (Feb 2019-March 2025)
- Produced the light curves by `SPOC` pipeline.

HST/WFC3 : Kreidberg et al. 2014

- G141 grism [25 wavelength bins (1.1 - 1.7 μm)]
- Reduced using `Iraclis` (Tsiaras et al. 2016).

JWST : Taylor J. Bell (Bell et al. 2024)

- JWST's Mid-Infrared Instrument (MIRI)
- 5 – 12 μm

Transit Modelling

The best-fit LCs

`TransitFit` (Hayes et al., 2021)

+ Transiting model [batman (Kreidberg 2015)
+ Dynamic nested sampling [dynesty (Speagle 2020)]

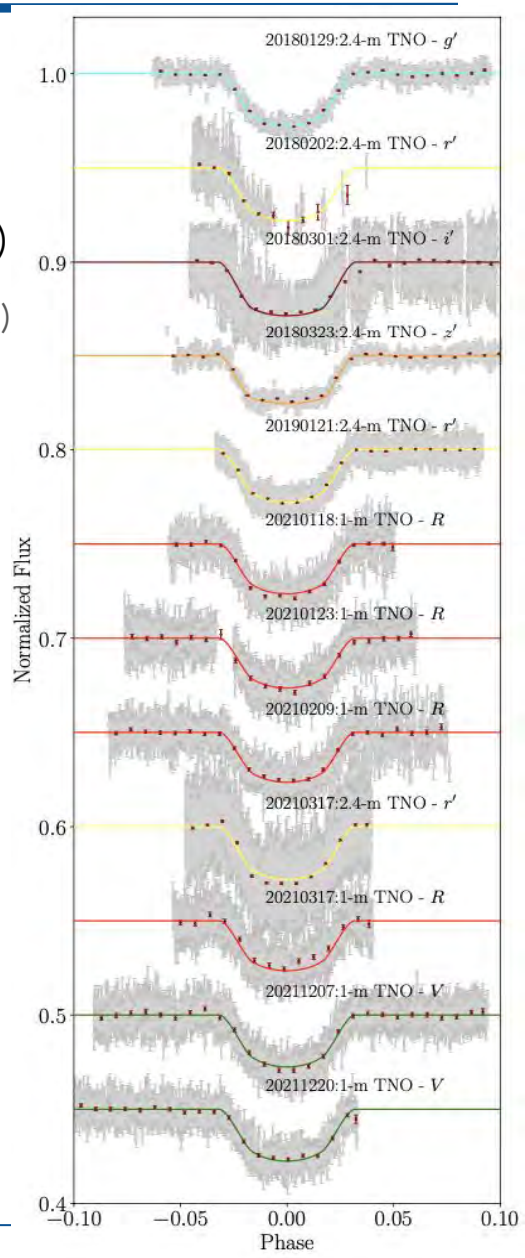
→ Ground+TESS+JWST LCs detrended by the 2nd polynomial function.

→ HST LCs detrended (Kreidberg et al. 2018)

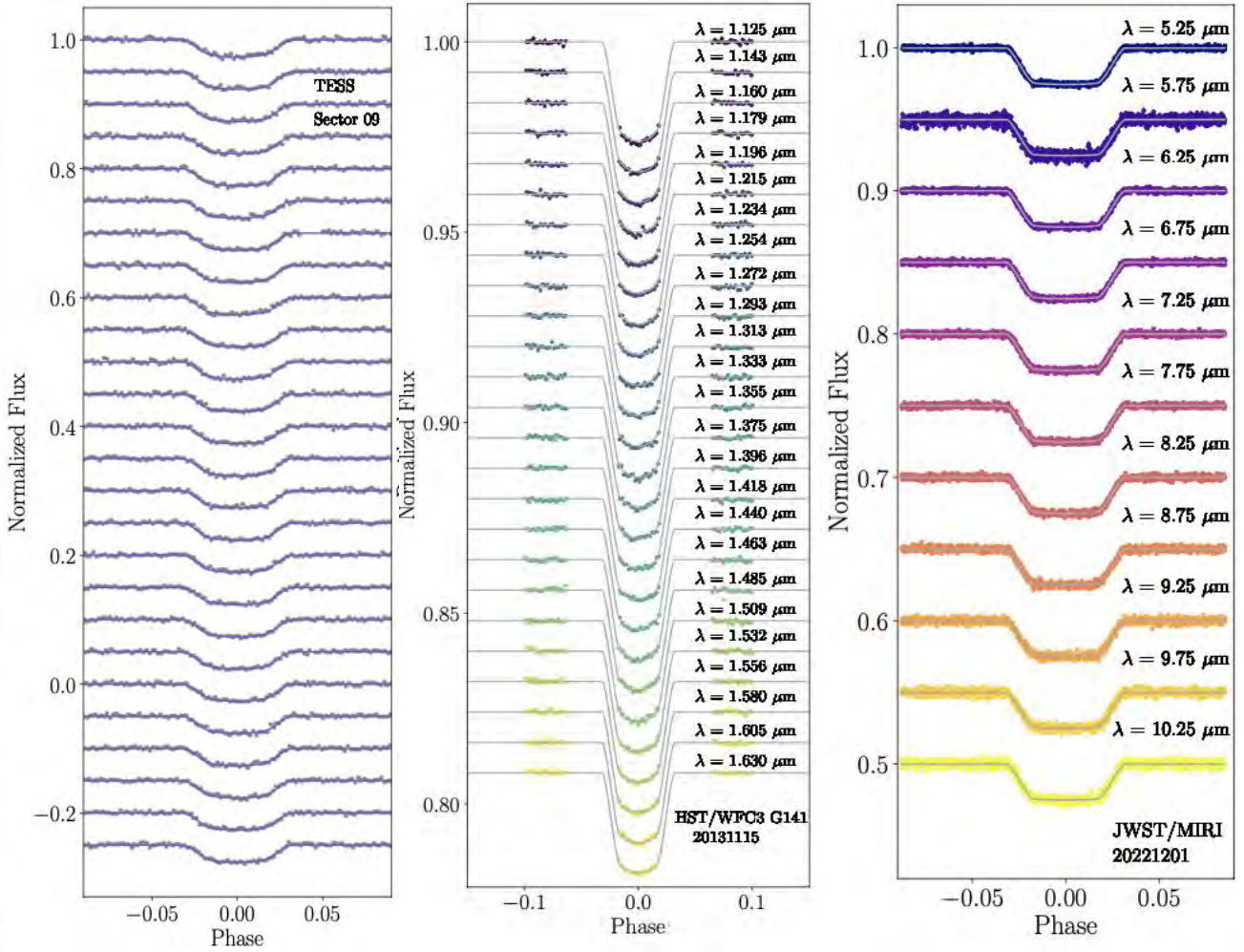
$$F_{sys} = (S + v_1 t_{visit} + v_2 t_{visit}^2)(1 - e^{-a t_{orb} - b})$$

Planetary parameters

- Period (day) = 0.813474131 ± 7×10^{-9}
- Inclication (degree) = 82.12 ± 0.01
- Radial ($R_p/R_\star$) = 0.1597 ± 0.0001
- Semi-Major Axis ($a/R_\star$) = 4.845 ± 0.003

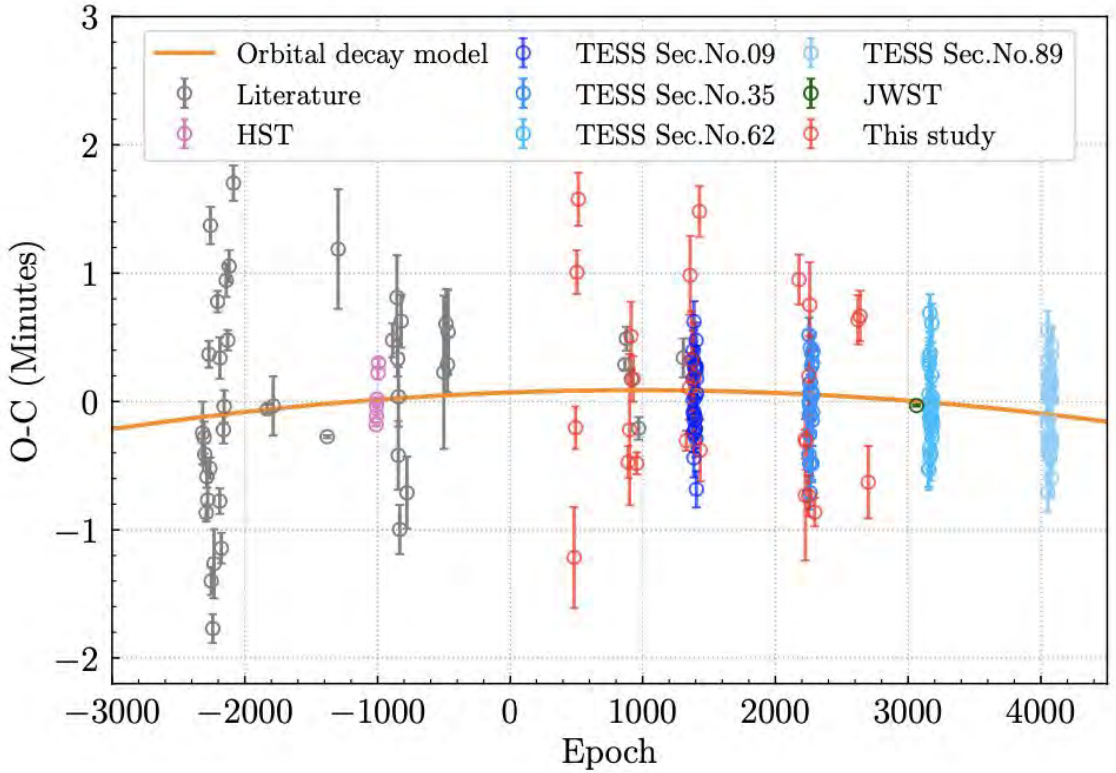


Phased-folded LCs fitting of WASP-43bb from Ground-Based,TESS, HST and JWST.



Timing Variation Modeling

Detecting orbital decay



O-C diagram and best fitting orbital decay model for WASP-43 b

$$t(E) = T_{0,d} + E \times P_d + \frac{1}{2}\frac{dP_d}{dE}E^2$$

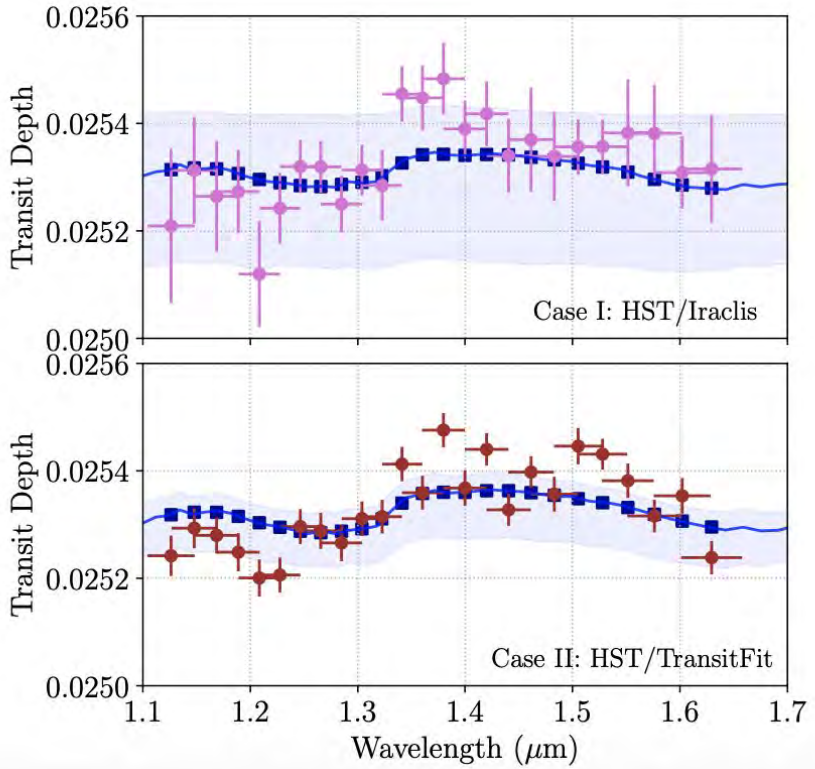
Orbital decay rate
= (-3 ± 1)x 10^{-11} day/orbit

Garai et al. (2021)
Orbital decay rate = (-5.09 ± 1.79) x 10^{-11}day/orbit

WASP-43 b's Planetary Atmosphere

→ The transmission spectrum of WASP-43 b modelled by **TauREx3** (Al-Refaie et al. 2021)

\+ Nested sampling + Molecular line lists from the ExoMol (Tennyson et al. 2016).



Limb Darkening Coefficients (LDCs)

Iraclis
- LDCs, the non-linear four-coefficient law [(Claret (2000).]

TransitFit
-LDCs derived from ExoCTK

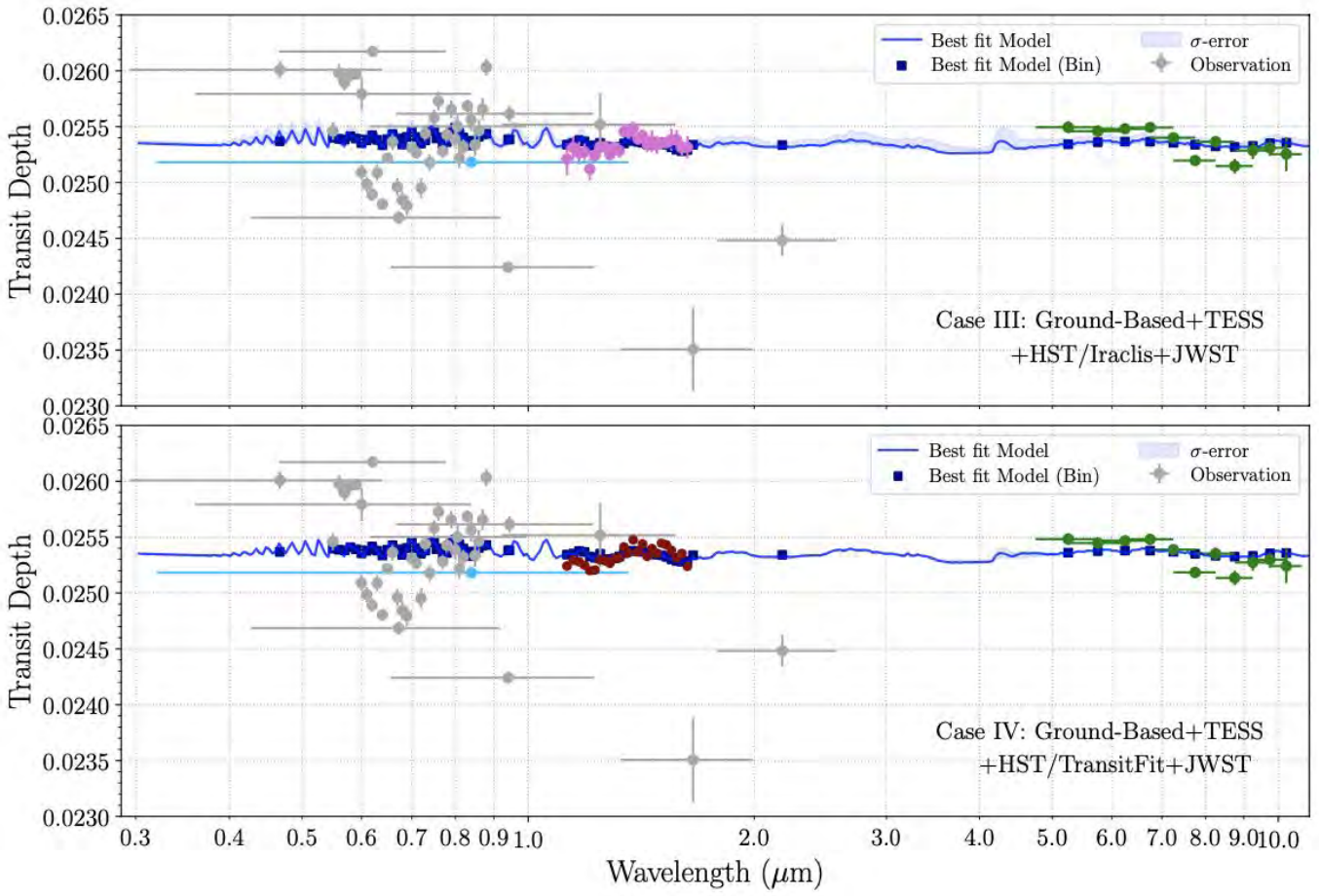
The best-fit transmission spectrum model of WASP-43 b derived from HST data.

HST/WFC3 G141 Transmission Spectrum

Parameter	Retrieved Values	
	Case I	Case II
T (K)	900^{+500}_{-400}	1200^{+200}_{-100}
H_2O	$-0.5^{+0.3}_{-2.3}$	$-0.5^{+0.1}_{-0.1}$
CH_4	-6^{+3}_{-3}	-6^{+3}_{-2}
CO	-6^{+3}_{-3}	-6^{+3}_{-3}
CO_2	-6^{+3}_{-3}	-6^{+3}_{-3}
TiO	-6^{+3}_{-3}	-6^{+2}_{-2}
VO	-8^{+2}_{-1}	-8^{+1}_{-1}
AlO	-6^{+2}_{-2}	-7^{+2}_{-2}
$\log(P_{\text{clouds}})$ (Pa)	4^{+1}_{-2}	$2.7^{+2.0}_{-0.8}$

*T presented in linear scale.
All chemical composition presented in log scale.

WASP-43 b's Planetary Atmosphere



Optical - Near IR Transmission Spectrum

Parameter	Retrieved Values	
	Case III	Case IV
T (K)	400^{+100}_{-20}	400^{+20}_{-40}
H_2O	$-2.8^{+0.5}_{-1.2}$	$-2.1^{+0.3}_{-0.4}$
CH_4	-7^{+2}_{-2}	-8^{+2}_{-1}
CO	-7^{+2}_{-2}	-4^{+1}_{-3}
CO_2	-6^{+2}_{-3}	-6^{+2}_{-2}
TiO	$-9.5^{+0.7}_{-0.4}$	$-9.5^{+0.7}_{-0.4}$
VO	$-6.2^{+0.4}_{-1.1}$	$-6.1^{+0.4}_{-0.4}$
AlO	$-6.6^{+0.7}_{-0.8}$	-8^{+1}_{-1}
$\log(P_{\text{clouds}})$ (Pa)	$5.1^{+0.5}_{-0.6}$	-5^{+1}_{-1}

*T presented in linear scale.
All chemical composition presented in log scale.

The best-fit transmission spectrum model of WASP-43 b,for the combined dataset:Ground-based (grey), TESS (light-blue), HST processed with Iraclis (pink), HST processed with TransitFit (dark-red), and JWST (green).

Conclusions

- Using our SPEARNET observational data + HST + TESS + JWST + published data, the planetary parameters of WASP-43 b are refined.
- Detecting of orbital decay model >> Orbital decay rate is consistent with the value from Garai et al. (2021)

  >> Confirm No detection of orbital decay.
- Atmospheric retrievals of WASP-43 b shows a distinct dependency of the retrieved parameters on wavelength coverage and data reduction.

  >> HST-only data give high temperatures with higher H_2O abundances, consistent with previous studies.

  >> Combining optical to mid-IR data yields a cooler with $\log_{10}(H_2O)$ between -2.8 and -2.1, consistent within 1σ of previous work, but the H_2O detection becomes non-significant.

  >> No other species (TiO, VO, AlO) are robustly detected.

Thank You !!