

# Transit timing variation and transmission spectroscopy studies of transiting exoplanet with 0.7m class Thai telescopes

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in collaborated with

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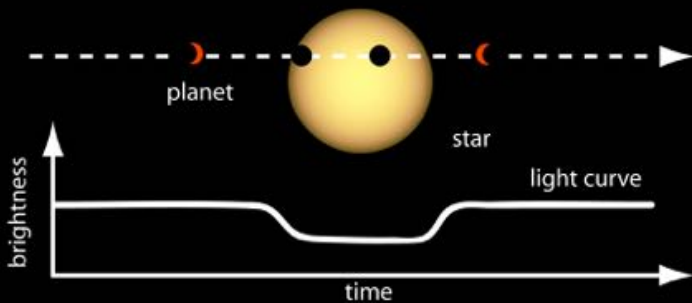
# Transmission spectroscopy

- **Transit**

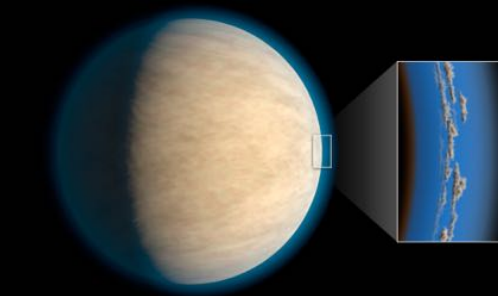
- A periodic dip in the stellar light curve which occurs when the orbit of one of the planet passes in front of the star.

- **Transmission spectroscopy**

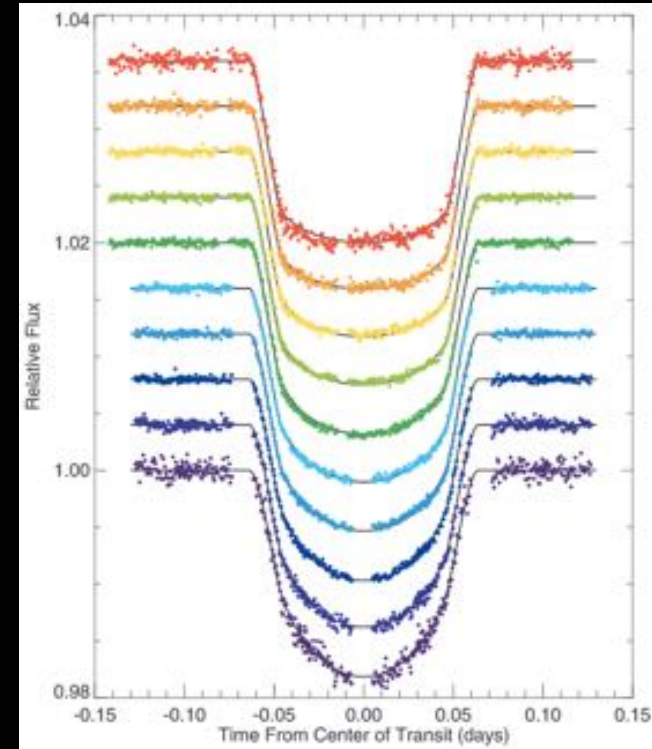
- Chemical compositions of the atmosphere of a transiting exoplanet.
- Light from the host star passes through the planetary atmosphere, some of the light is absorbed by the atoms, molecules or grains present in the atmosphere.
- Planet bigger in some wavelengths.



Credit: NASA

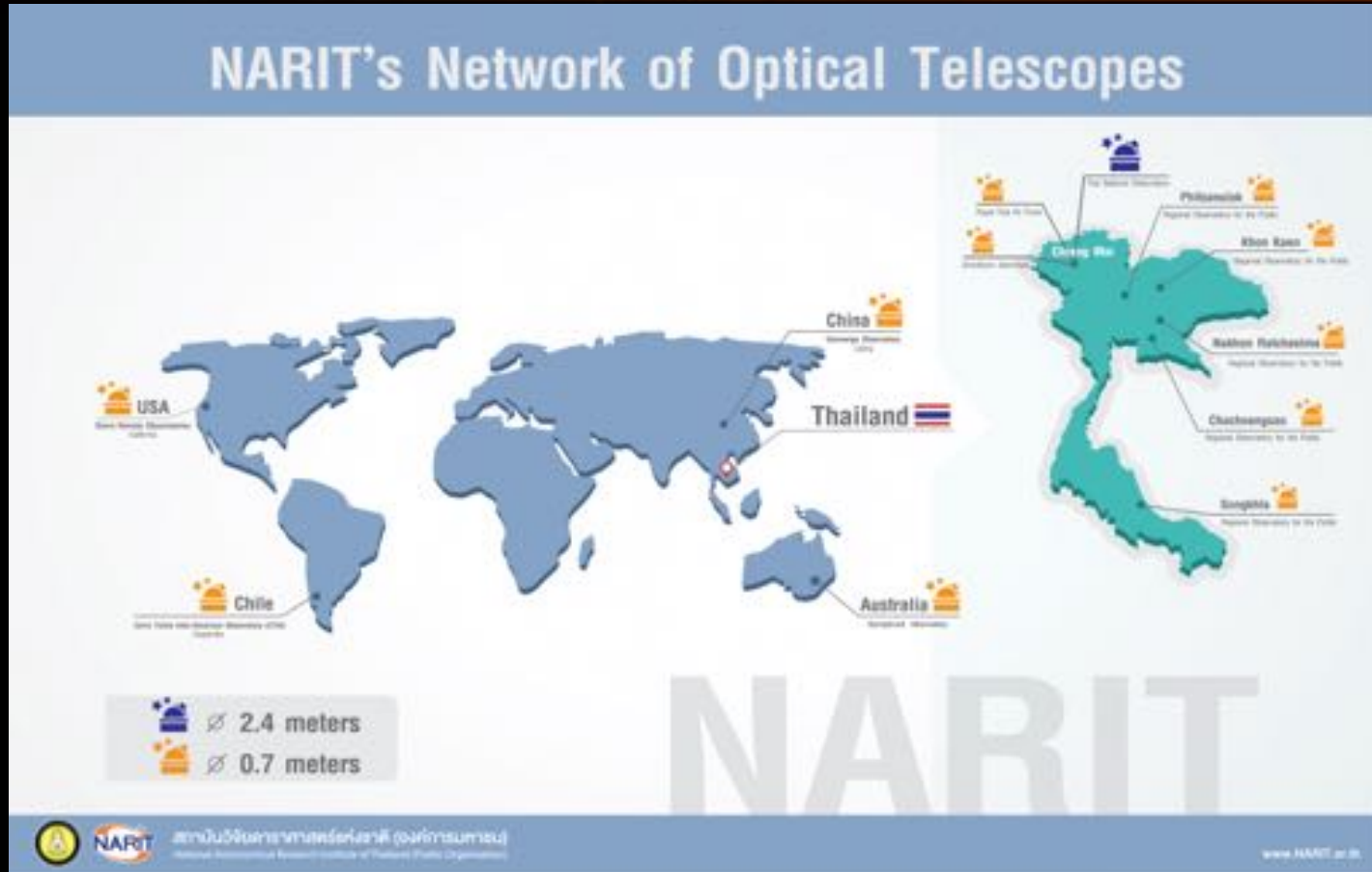


Credit: NASA



HD 209458b light curves in 10 bandpasses (290-1030 nm) (Knutson et al. 2009)

# NARIT's Network of optical telescopes



Credit: NARIT

Supachai Awiphan

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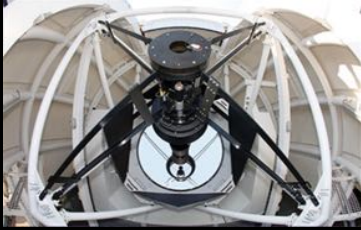
Taipei, Taiwan

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# NARIT's Network of optical telescopes

- 2.4 m Thai National Telescope, Thailand



- Lat 18°34'25" N
- Long 98°28'56" E
- Altitude 2457 m

- 0.7 m TRT-GAO, China



- Lat 18°34'25" N
- Long 98°28'56" E
- Altitude 2457 m

- 0.5 m TRT-TNO, Thailand



- Lat 18°34'25" N
- Long 98°28'56" E
- Altitude 2457 m

- 0.7 m Nakhon Ratchasima telescope, Thailand



- Lat 14°52'25" N
- Long 102°01'44" E
- Altitude 250 m

- 0.6 m PROMPT-8 telescope, Chile



- Lat 30°10'11" S
- Long 70°48'23" W
- Altitude 2201 m

- 0.7 m Chachoengsao telescope, Thailand

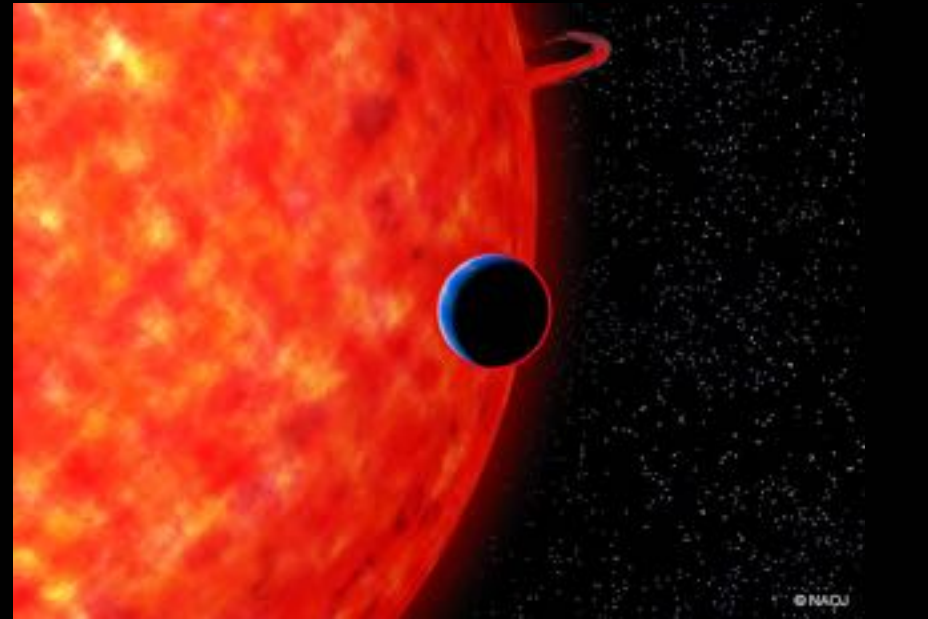


- Lat 13°35'37" N
- Long 101°15'22" E
- Altitude 10 m



# GJ3470b: Hot Neptune-like exoplanet

- The planet GJ3470b is a transiting hot Neptune-like exoplanet orbiting a nearby M-dwarf (V=12.3).
- The planet was originally seen in HARPS radial velocity data and then confirmed to be a transiting planet (Bonfils et al. 2012).
- The first sub-Jovian planet to exhibit Rayleigh scattering atmosphere (Nascimbeni et al. 2013).
- 10 nights photometric observations were conducted between 2013 and 2016
  - 2.4 m TNT with ULTRASPEC (4 nights)
  - 0.5 m TRT-TNO (2 nights)
  - PROMPT-8 telescope (2 nights)

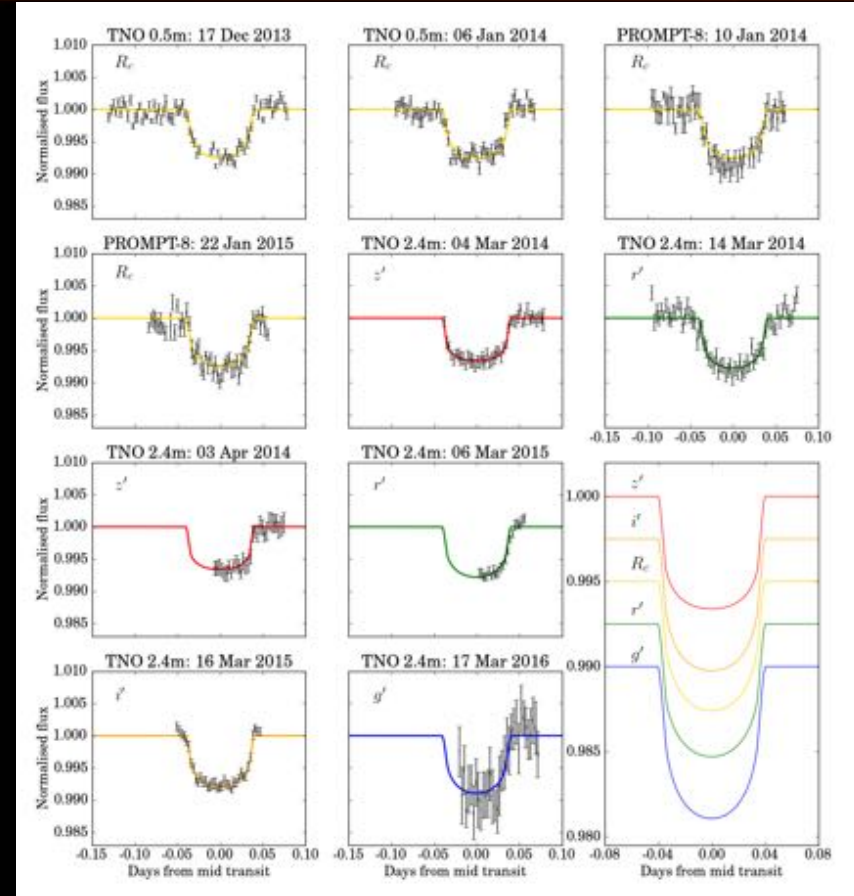


Credit: NAOJ

# GJ3470b: Planetary parameters

- 4 minutes binned light curves with best fit model from TAP (Gazak et al. 2012) analysis
  - Filter  $R_c$ ,  $z'$ ,  $i'$ ,  $r'$  and  $g'$
- Using Radial-velocity semi-amplitude  $13.4 \pm 1.2 \text{ ms}^{-1} d^{1/3}$  from Demory et al. (2013)

Parameter	Value
Period (day)	$3.33665^{+0.00001}_{-0.00001}$
Inclination (degree)	$89.13^{+0.26}_{-0.34}$
Radial ( $R_{\oplus}$ )	$4.57 \pm 0.18$
Mass ( $M_{\oplus}$ )	$13.9 \pm 1.5$
Mean density ( $\text{g cm}^{-3}$ )	$0.80 \pm 0.13$
$T_p$ (K)	497-690
- Bond albedo = 0-0.4	
- Heat redistribution factor = 0.25-0.5	

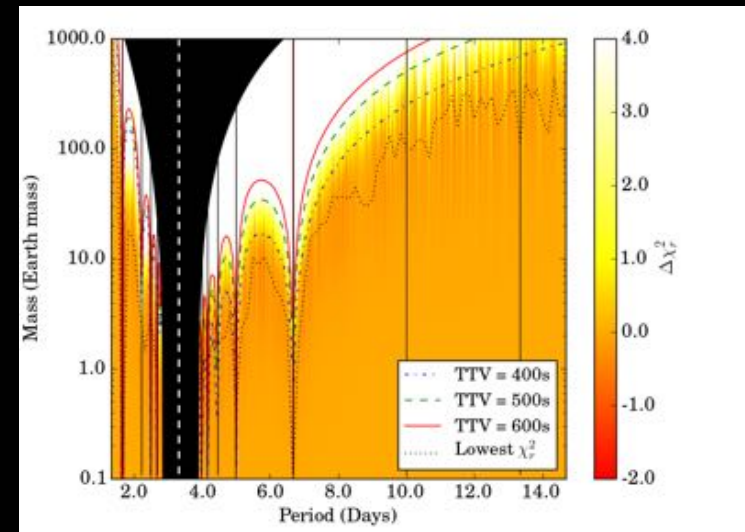
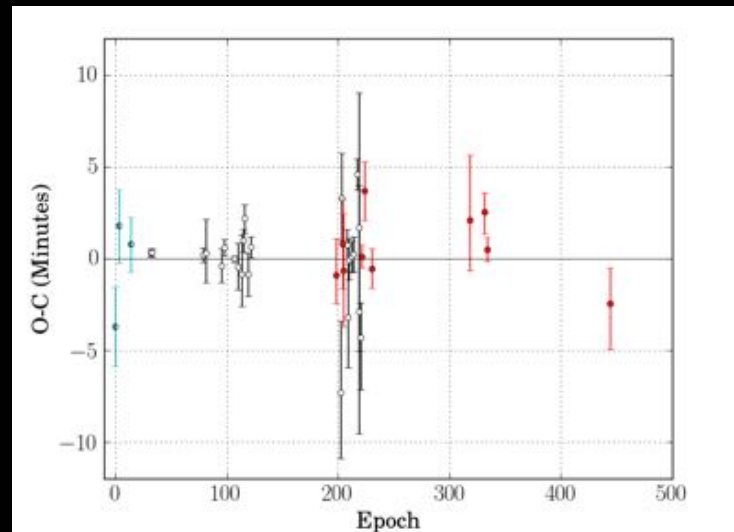


# GJ3470b: Transit timing variation

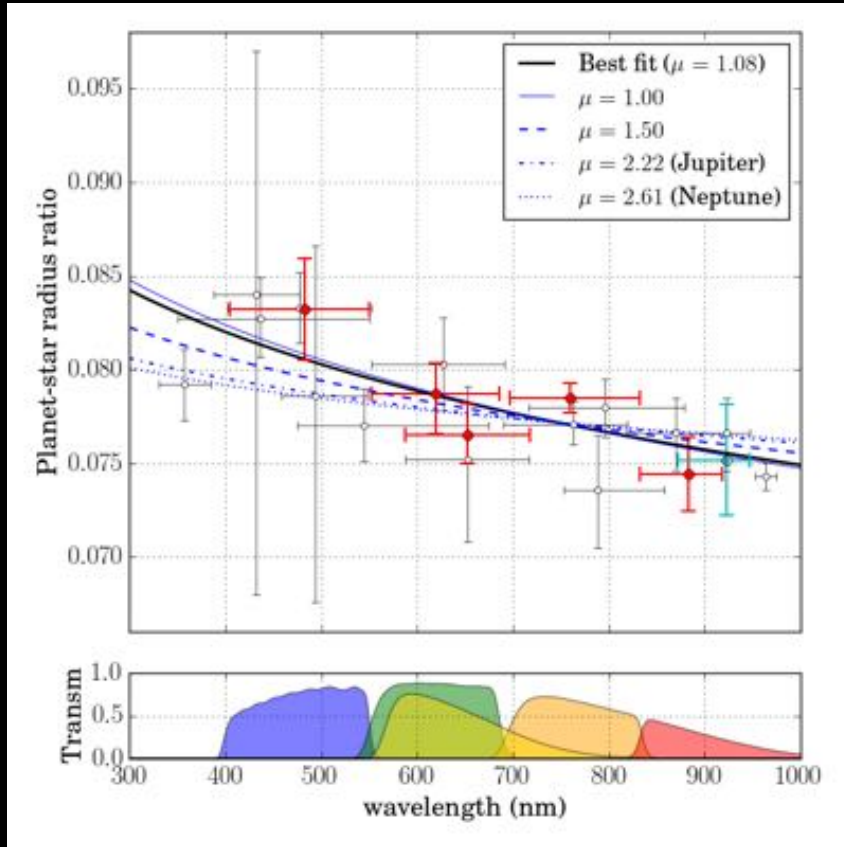
- Linear fit to the O-C diagram to correct GJ3470b's ephemeris

$$T_0(E) = 2,455,983.70421 + 3.33665 E$$

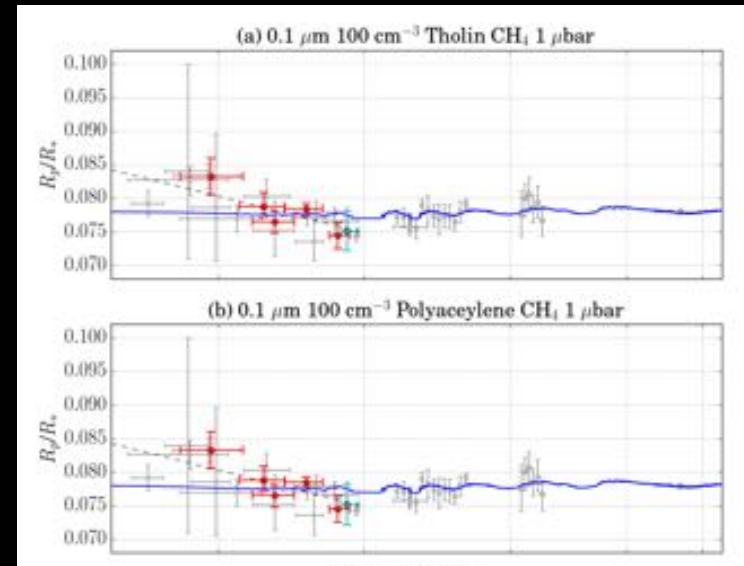
- No significant TTV signal
- Upper mass limit of the second planet
  - Ruled out a nearby second planet with period between 2.5 and 4.0 d from the mutual Hill sphere.
  - Excluded a Jupiter-mass planet with period less than 10 d



# GJ3470b: Transmission spectroscopy



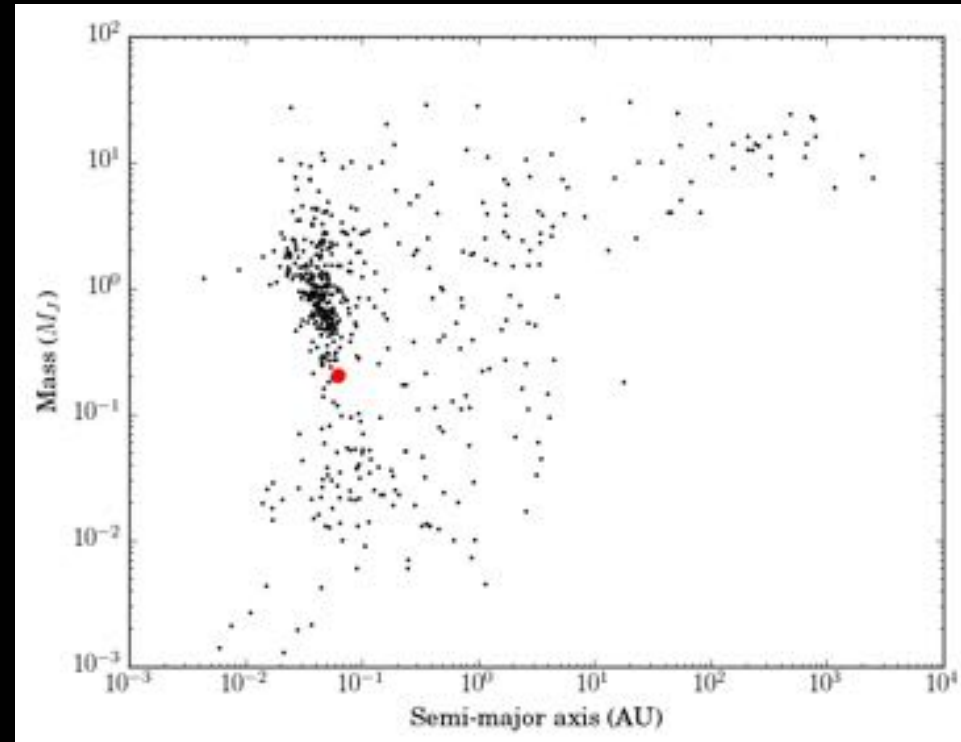
- Broadband optical transmission spectroscopy
- GJ3470b atmosphere mean molecular weight 1.08
- Use Howe & Burrows (2012) planetary atmosphere model
- A methane atmosphere with high particle ( $100 \text{ cm}^{-3}$ ) abundance haze (tholin or polyacylen) at high altitude (1-1000 $\mu$ bar) provide the best fit with  $\chi^2 = 1.38$  to 1.40





# HAT-P-47b: Low density sub-Saturn mass exoplanet

- HAT-P-47b is a transiting low density hot sub-Saturn mass exoplanet orbiting a moderately bright F-type star ( $V=10.7$ ) (Bakos et al. 2016).
- HAT-P-47b is one of the lowest mass exoplanet with radius greater than Jupiter radius.
- It falls in the desert between hot Jupiters and hot super Earth in the semi-major axis-mass plane.
- Two nights photometric observations were conducted in 2016
  - 2.4 m TNT with ULTRASPEC (1 night)
  - 0.7 m TRT-GAO (2 nights)

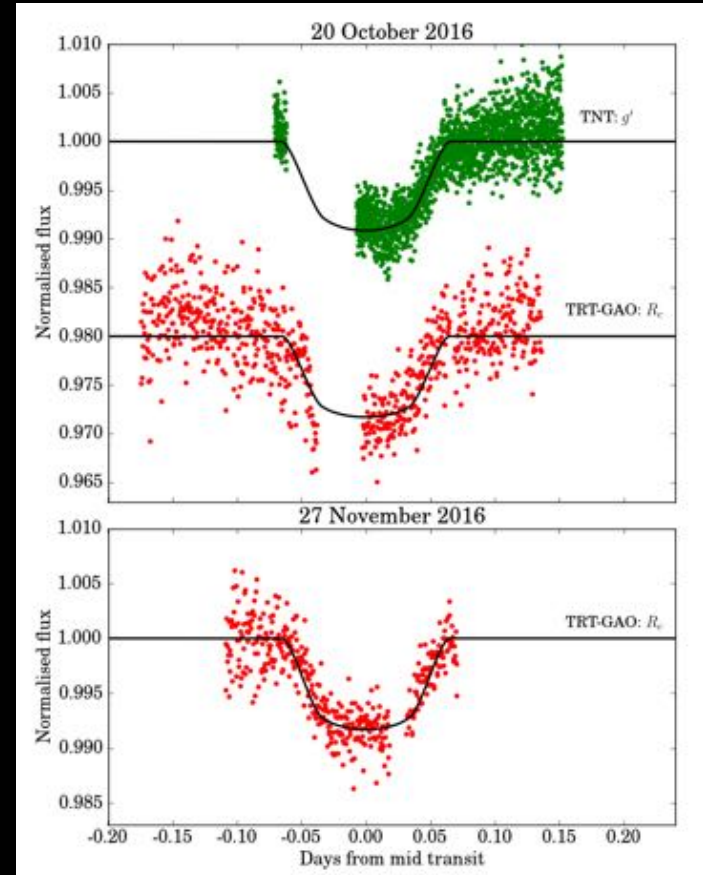


Data retrieved from <https://exoplanetarchive.ipac.caltech.edu/> on 22th May 2017

# HAT-P-47b: Planetary parameters

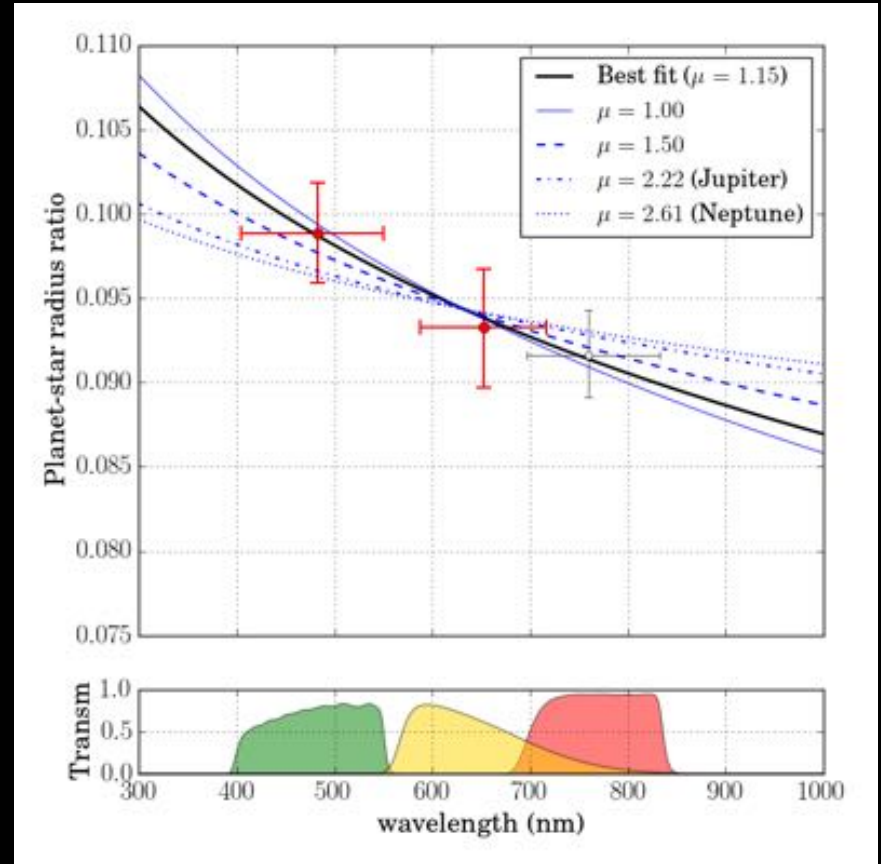
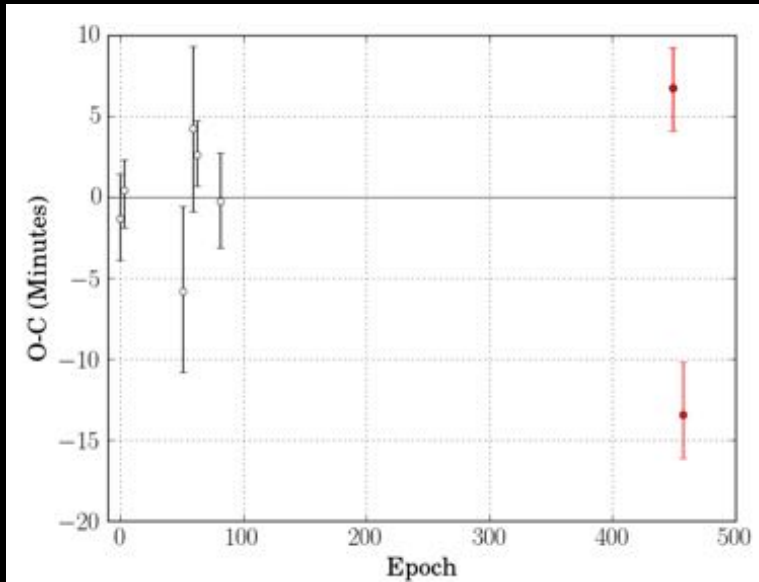
- Light curves with best fit model from TAP analysis
  - Filter  $R_c$  and  $g'$
- Using Radial-velocity semi-amplitude  $19.9 \pm 3.8 \text{ ms}^{-1}$  from Bakos et al. (2016)
- The largest sub-Saturn mass exoplanet.

Parameter	Value
Period (day)	$4.73214^{+0.00068}_{-0.00065}$
Inclination (degree)	$84.47^{+0.30}_{-0.30}$
Radial ( $R_J$ )	$1.42 \pm 0.07$
Mass ( $M_J$ )	$0.205 \pm 0.039$
Mean density ( $\text{g cm}^{-3}$ )	$0.095 \pm 0.023$
$T_p$ (K)	1190-1640
- Bond albedo = 0-0.4	
- Heat redistribution factor = 0.25-0.5	



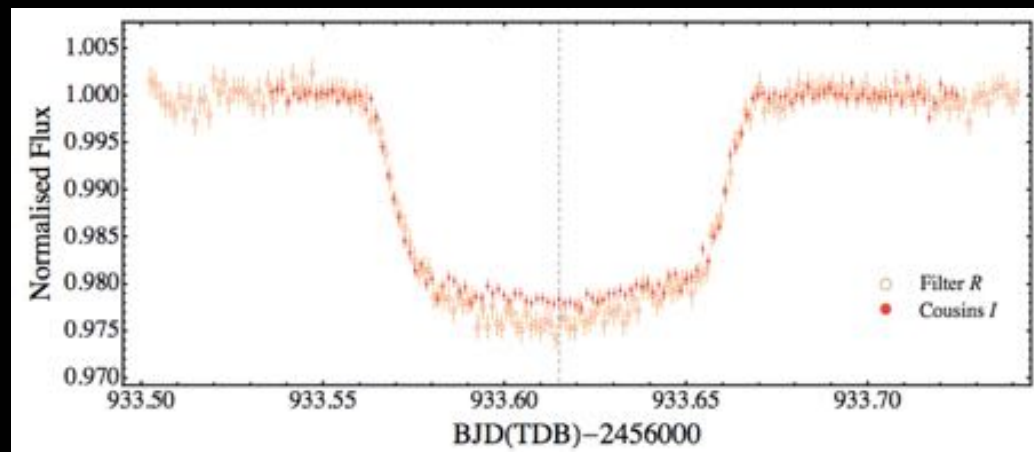
# HAT-P-47b: TTV and transmission spectroscopy

- Corrected HAT-P-47b's ephemeris
$$T_0(E) = 2,455,557.52879 + 4.73217 E$$
- Broadband optical transmission spectroscopy
- HAT-P-47b atmosphere mean molecular weight 1.15



# WASP-11/HAT-P-10b: Inflated sub-Saturn mass exoplanet

- WASP-11/HAT-P-10b is an inflated sub-Saturn mass exoplanet orbiting a K-type star ( $V=11.9$ ) (West et al. 2008 and Bakos et al. 2009).
- A transit event of WASP-11/HAT-P-10b was observed simultaneously with the CA 1.23m (Red,  $R_c$ ) and the IAC 80cm (Orange,  $I_c$ ) telescopes. The light curves show the difference in transit depth (Mancini et al. 2015).
- Three nights photometric observations were conducted between 2016 and 2017
  - 0.5 m TRT-TNO (1 night)
  - 0.7 m TRT-GAO (2 nights)
  - 0.7 m Nakhon Ratchasima (2 nights)
  - 0.7 m Chachoengsao (1 night)



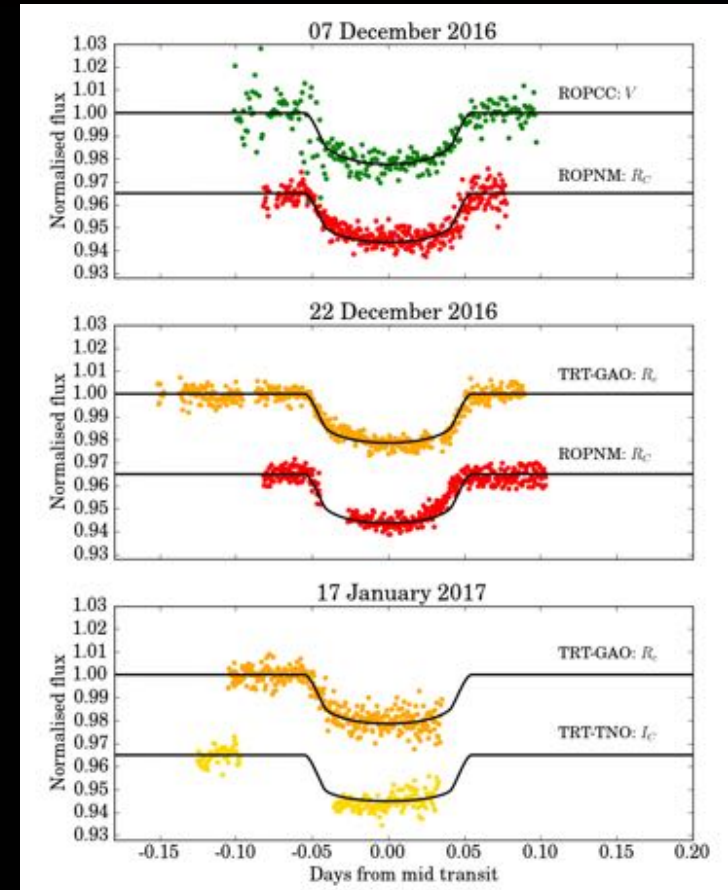
WASP-11/HAT-P-10b light curves with the CA 1.23m and the IAC 80cm telescopes (Knutson et al. 2009)



# WASP-11/HAT-P-10b: Planetary parameters

- Light curves with best fit model from TAP analysis
  - Filter  $V$ ,  $R_c$  and  $I_c$
- Using Radial-velocity semi-amplitude  $82.7 \pm 4.2 \text{ ms}^{-1}$  from Mancini et al. (2015)

Parameter	Value
Period (day)	$3.82246^{+0.00001}_{-0.00001}$
Inclination (degree)	$88.67^{+0.26}_{-0.34}$
Radial ( $R_j$ )	$1.04 \pm 0.03$
Mass ( $M_j$ )	$0.547 \pm 0.033$
Mean density ( $\text{g cm}^{-3}$ )	$0.653 \pm 0.075$
$T_p$ (K)	735-1010
- Bond albedo = 0-0.4	
- Heat redistribution factor = 0.25-0.5	

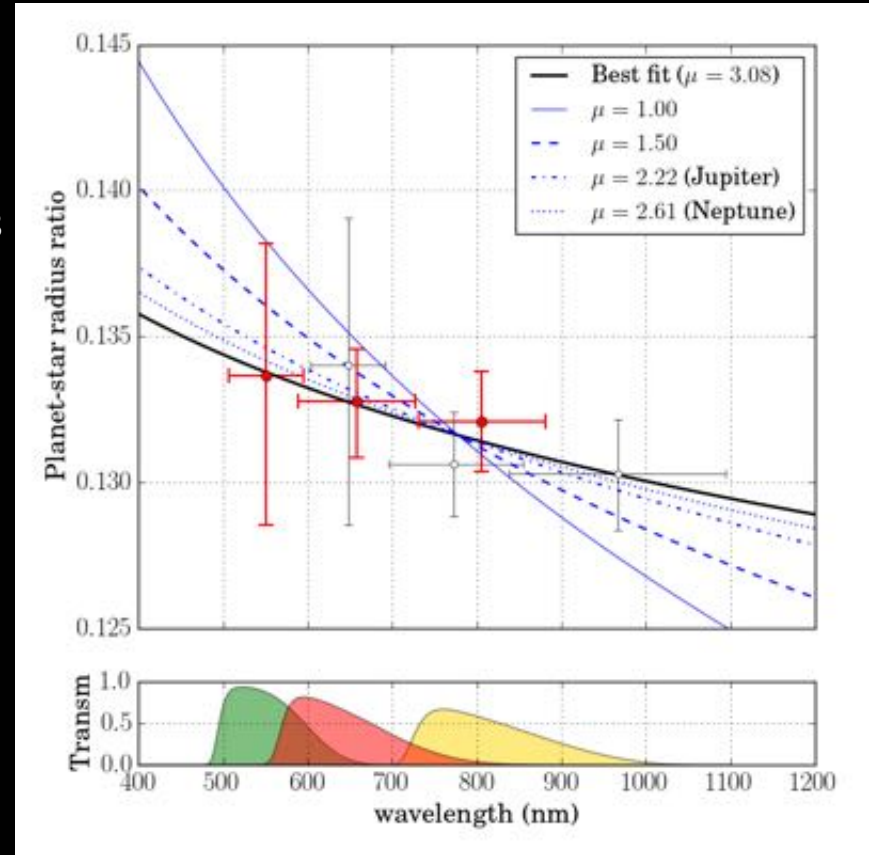
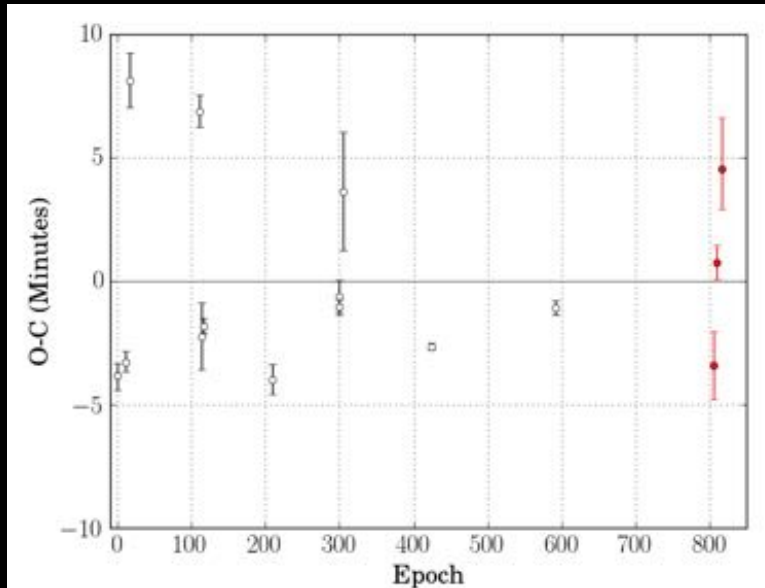


# WASP-11/HAT-P-10b: TTV and transmission spectroscopy

- Corrected WASP-11/HAT-P-10b's ephemeris

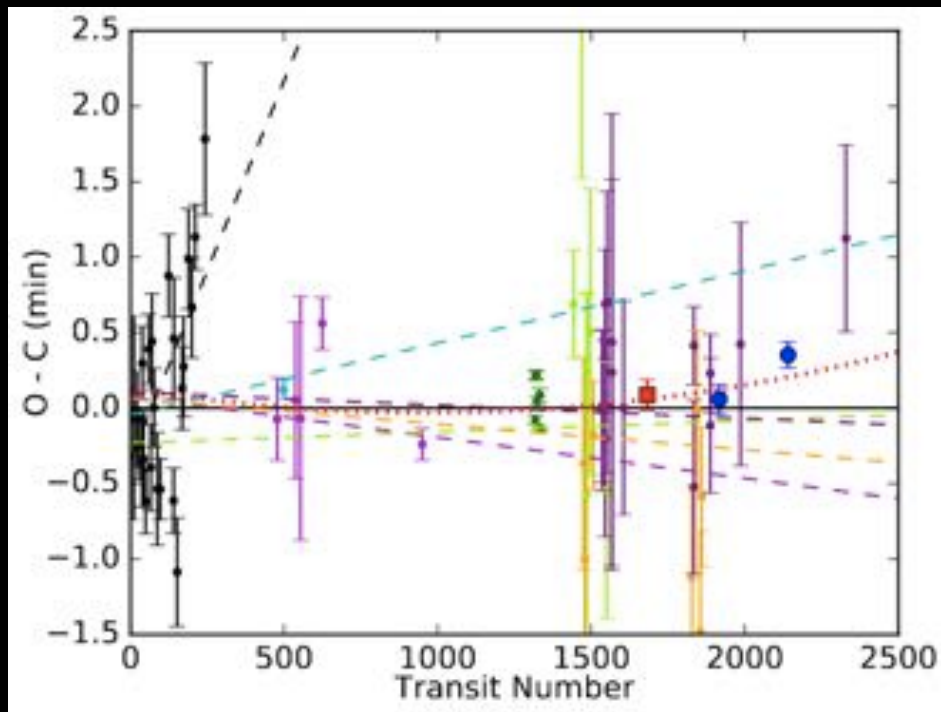
$$T_0(E) = 2,454,729.90915 + 3.72248 E$$

- Broadband optical transmission spectroscopy
- WASP-11/HAT-P-10b atmosphere mean molecular weight 3.08



# WASP-43b: hot Jupiter with possible orbital decay

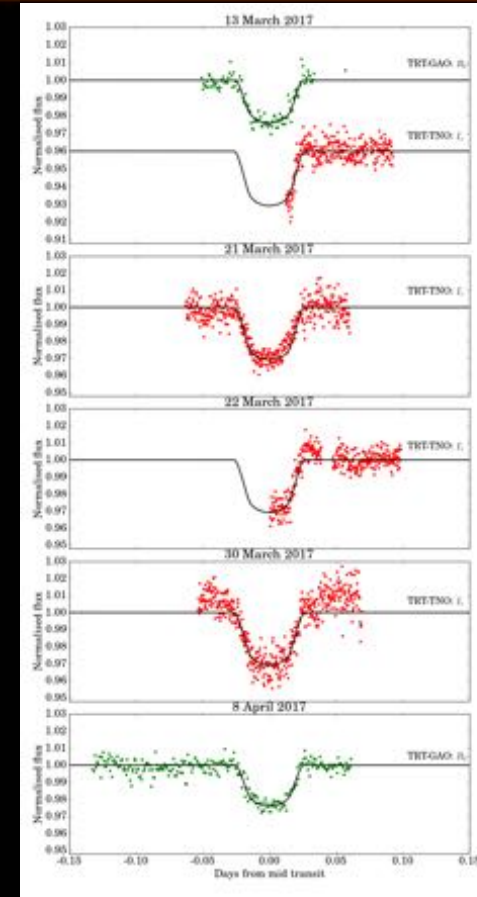
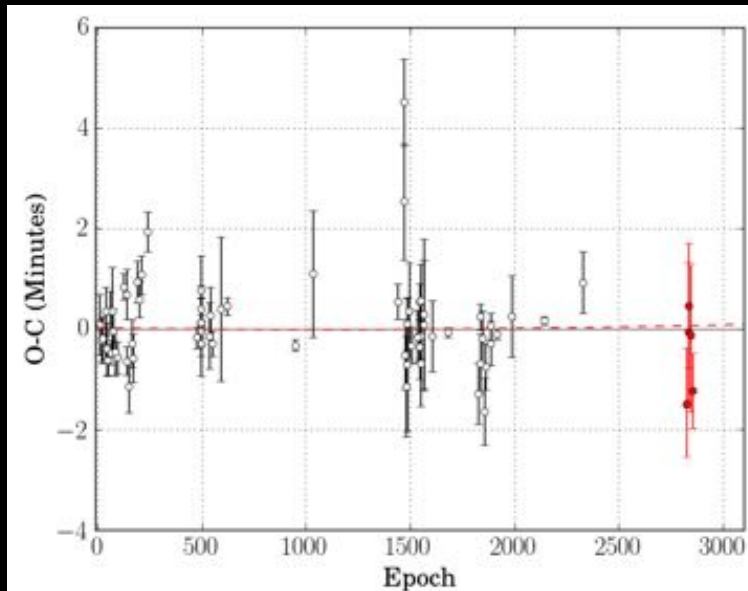
- WASP-43b is a hot-Jupiter exoplanet orbiting a K-type star ( $V=12.4$ ) (Hellier et al. 2011).
- Blecic et al. (2014), Murgas et al. (2014) and Jiang et al. (2016) proposed an orbital decay of the WASP-43b
- Hoyer et al. (2016) and Stevenson et al. (2017) ruled out the orbital decay of the WASP-43b
- Five nights photometric observations were conducted in 2017
  - 0.5 m TRT-TNO (4 nights)
  - 0.7 m TRT-GAO (2 nights)



Observed TTV of WASP-43b (Stevenson et al. 2017)

# WASP-43b: Orbital decay

- WASP-43b orbital period change rate 0.0013 sec/year
  - Blecic et al. (2014) -0.095 sec/year
  - Murgas et al. (2014) -0.15 sec/year
  - Jiang et al. (2016) -0.029 sec/year
  - Hoyer et al. (2016) -0.001 sec/year
  - Stevenson et al. (2017) 0.009 sec/year





# Conclusions

- Follow-up observations of exoplanets using 0.7m class Thai telescopes and 2.4m Thai National Telescope to study their transit timing variations and atmospheres.
  - GJ3470b, HAT-P-47b, WASP-11/HAT-P-10b, WASP-43b, WASP-107b , WASP-127b, HAT-P-26b, HAT-P-33b and KELT-3b
- **GJ3470b**
  - From TTV analysis, we can exclude a Jupiter-mass planet with period less than 10 days in the system.
  - GJ3470b atmosphere mean molecular weight 1.08.
  - A methane atmosphere with high particle ( $100 \text{ cm}^{-3}$ ) abundance haze (tholin or polyacetylen) at high altitude (1-1000 $\mu$ bar) provide the best fit with  $\chi^2 = 1.38$  to 1.40.
- **HAT-P-47b**
  - The largest sub-Saturn mass exoplanet.
  - HAT-P-47b atmosphere mean molecular weight 1.15.
- **WASP-11/HAT-P-10b**
  - WASP-11/HAT-P-10b atmosphere mean molecular weight 3.08.
- **WASP-43b**
  - WASP-43b orbital period change rate 0.0013 sec/year.

# Thank you

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