

27/04/2015

# EXOPLANETARY DETECTION AND CHARACTERISATION

TOMAS JAMES

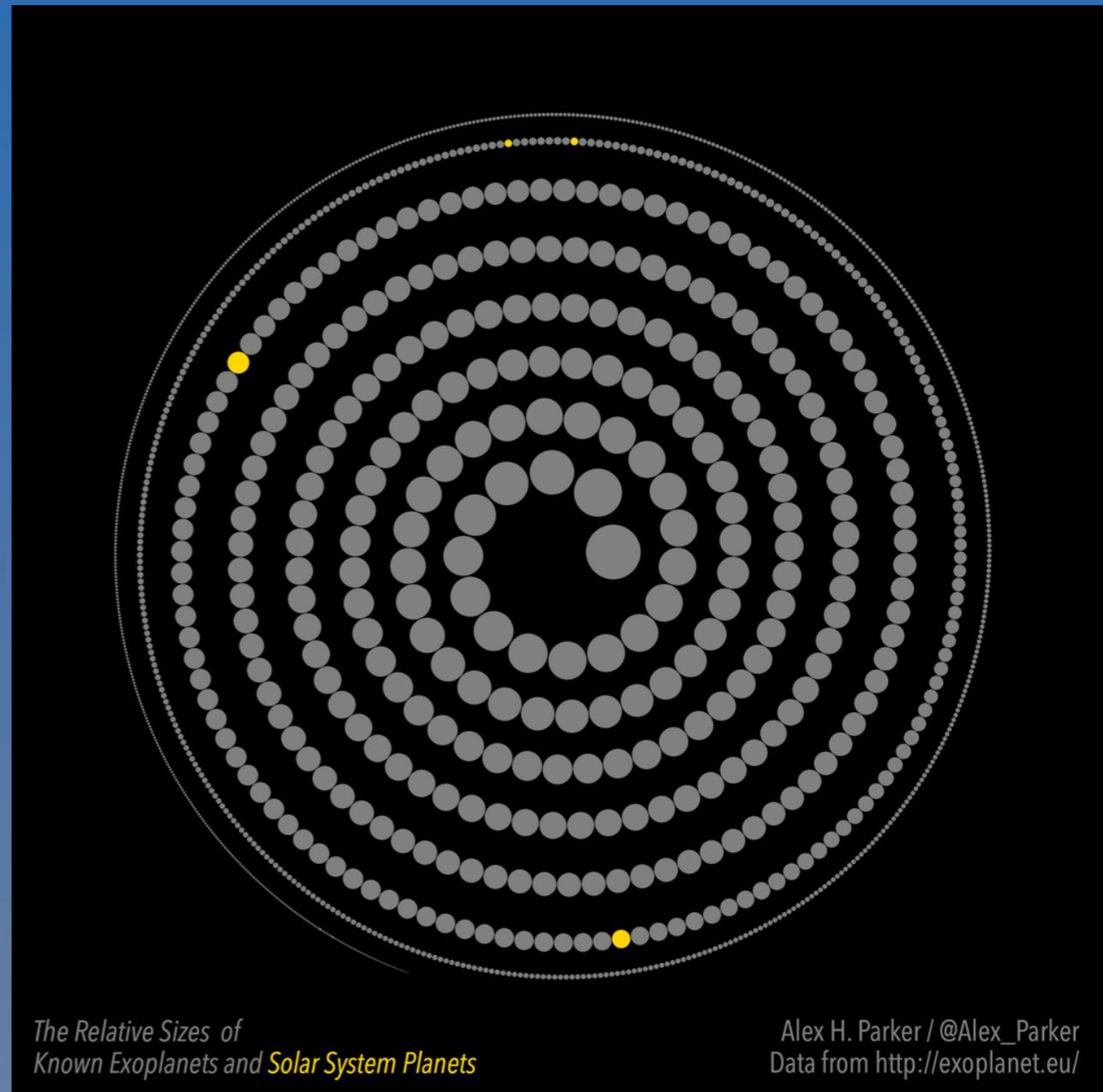
SUPERVISOR: DR E. L. GOMEZ

# PROJECT AIMS

- To survey the data on known exoplanets
- Select 3 transiting exoplanets for observation and observe using the Southern Hemisphere LCOGT network
- Analyse data using GAIA aperture photometry to plot lightcurves using Python
- Use lightcurves to extrapolate exoplanet radius
- Adapt and fit Exoplanetary Pixelisation Transit Model (Addison, Durrance and Schweitermann, 2010) in Python to compare radius to data analysis lightcurves and known values

# WHAT ARE EXOPLANETS?

- Planets that orbit stars outside of the Solar System
- Extensive range of physical and orbital parameters
- Formation theory is still highly debated
- Number of exoplanets detected today: 1911  
(Extrasolar Planets Encyclopaedia, 2014)

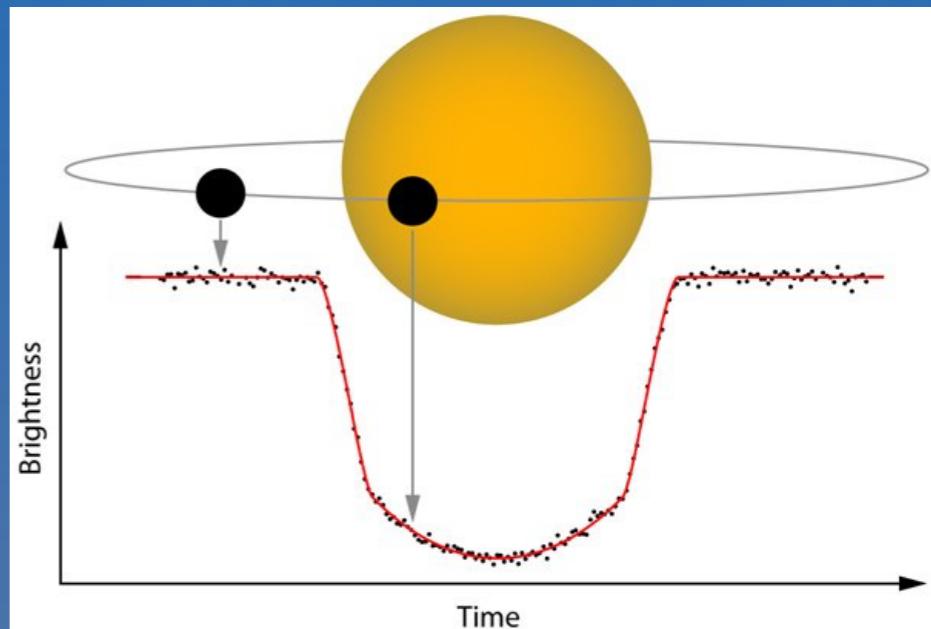


Alex H. Parker / @Alex\_Parker  
Data from <http://exoplanet.eu/>

# EXOPLANET DETECTION

## Transit Method

- Utilises the fraction of stellar flux blocked by an exoplanet to suggest exoplanet companion
- Flux blocked is directly related to square of the radii ratio
- Biased towards larger planets



$$\frac{\Delta F}{F} = \frac{R_{exo}^2}{R_{star}^2}$$

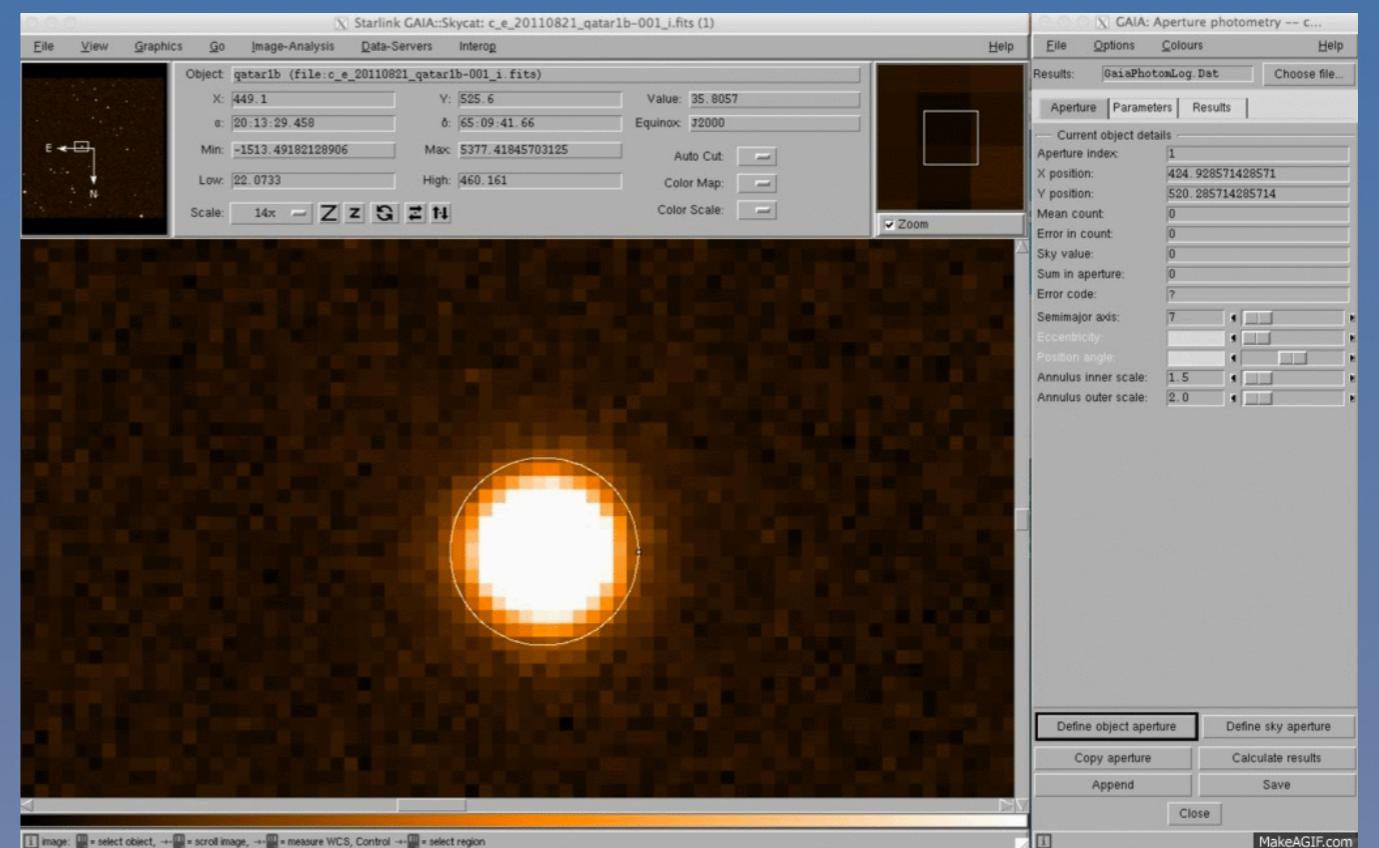
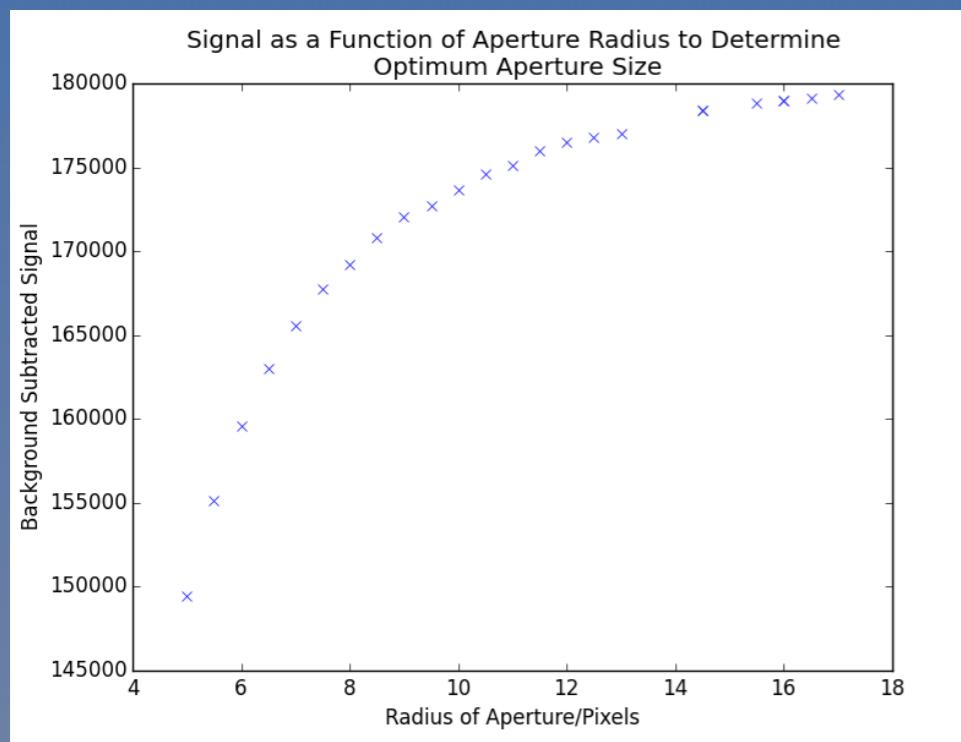
# EXOPLANETS CONSIDERED

- Only transiting exoplanets were considered in this project
- Exoplanet had to be observable during window October 2014 - December 2014
- Observations had to be above at least  $30^{\circ}$  above the horizon for the entirety of the observation window

EXOPLANET	RA	DEC	DATE
WASP-22 B	03H 31M 16.3S	-23° 49' 11"	09/11/2014
WASP-78 B	04H 15M 02.0S	-22° 06' 59.1"	30/11/2014
HATS-5 B	04H 28M 53.47S	-21° 28' 54.0"	01/12/2014

# DIFFERENTIAL APERTURE PHOTOMETRY

- Photometry technique practiced on Qatar-1b dataset (provided by Dr. E. L. Gomez)
- Need to determine optimum aperture size - plot background subtracted signal as a function of aperture radius
- Constant gradient represents point at which all stellar flux has been captured - this is the optimum aperture size
- Analyse multiple stars in the field of view - those with constant flux were used as calibrators

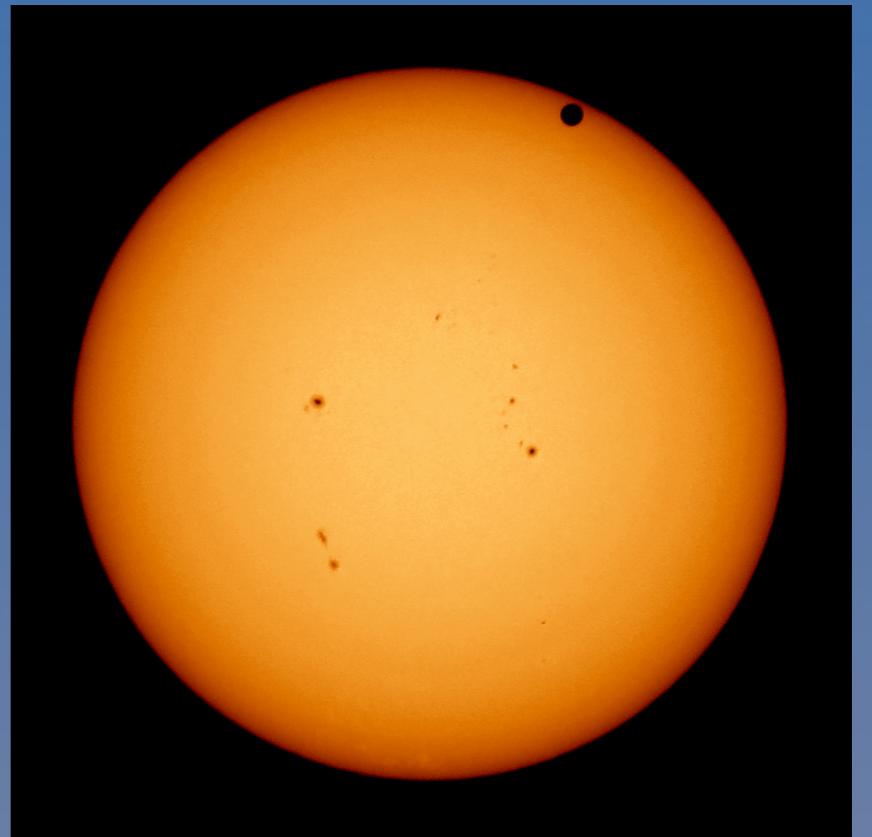


# EXOPLANETARY PIXELISATION TRANSIT MODEL

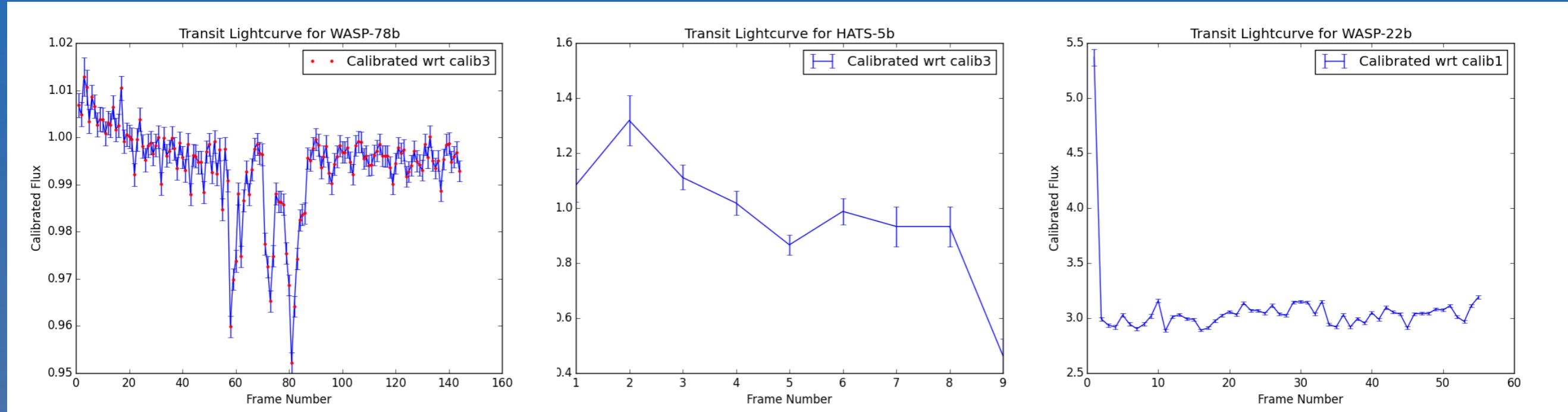
$$F_b = \Delta\Omega_{\text{pix}} \sum_{\text{pixels}} I_o \left[ 1 - \mu \left( 1 - \sqrt{1 - \left( \frac{d_{\text{pix}}}{R_\star} \right)^2} \right) \right]$$

(Addison, Durrance and Schwietermann, 2010)

- Splits the exoplanet into a 2D grid of pixels
- Determines flux blocked for each pixel in the stellar radius
- $\mu$  dependent on effective temperature of star
- Crucial as exoplanet blocks less flux when crossing the limb
- Values of  $\mu$  taken from Van Hamme (1993)



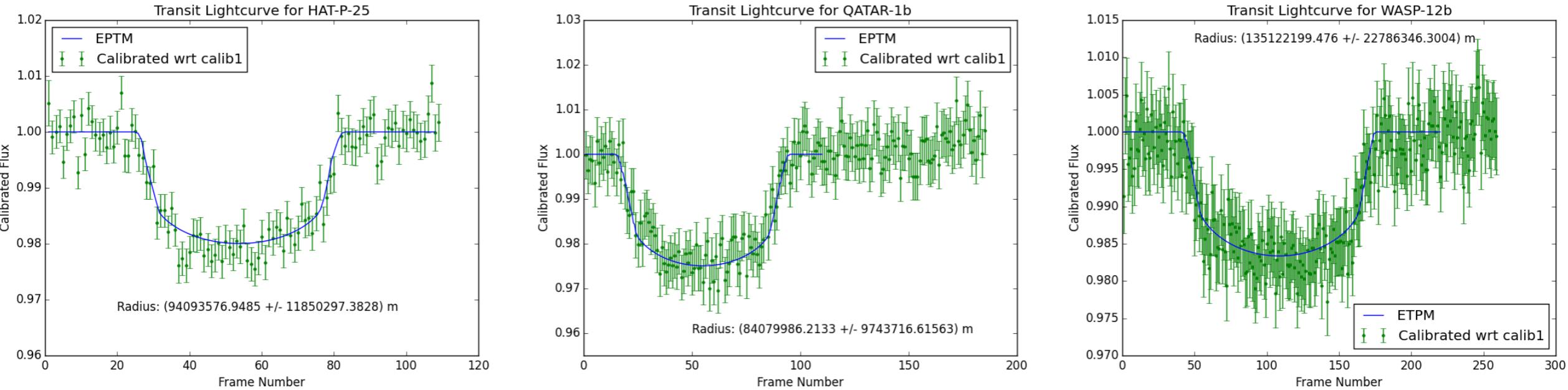
# RESULTS



- HATS-5b and WASP-22b data not usable
- No visible transit in either
- WASP-78b shows evidence of transit, but bad weather obscures dip
  
- Known transiting datasets (provided by Dr. E. L. Gomez) analysed in replacement

(\*): no error value quoted

# RESULTS



EXOPLANET	CALCULATED RADIUS	EPTM RADIUS	KNOWN RADIUS	CALCULATED DENSITY	KNOWN DENSITY
HAT-P-25 B	$(9.4 \pm 1.2) \times 10^7$ m	$(9.42 \pm 1.03) \times 10^7$ m	$8.31 \times 10^7$ m (*)	$(308 \pm 110)$ kg m $^{-3}$	$(420 \pm 70)$ kg m $^{-3}$
QATAR-1B	$(8.4 \pm 0.97) \times 10^7$ m	$(9.03 \pm 0.79) \times 10^7$ m	$(8.14 \pm 0.3) \times 10^7$ m	$(832 \pm 296)$ kg m $^{-3}$	$(690^{+98}_{-84})$ kg m $^{-3}$
WASP-12B	$(13.5 \pm 2.2) \times 10^7$ m	$(14.3 \pm 1.78) \times 10^7$ m	$(12.1 \pm 0.6) \times 10^7$ m	$(258 \pm 132)$ kg m $^{-3}$	$(240^{+30}_{-20})$ kg m $^{-3}$

# CONCLUSIONS

- Results (observed and model) are overestimated, but close to known values
- Results match known values within error ranges
- Larger error ranges than known values - reflects 'by-eye' nature of model fit
- Further exoplanet pixelisation could lead to more accurate results
- Further code optimisation to fit EPTM by an automated routine could enhance accuracy

# QUESTIONS

# REFERENCES

- Addison B. C., Durrance S. T., and Schwieterman E. W. (2010). "Modeling and Observing Extrasolar Planetary Transits". *Journal of the Southeastern Association for Research in Astronomy* 3, pp. 45–51.
- Van Hamme W. (1993). "New Limb Darkening Coefficients for Modeling Binary Star Light Curves". *The Astronomical Journal*, 106.5, pp. 2096–2117.
- Extrasolar Planets Encyclopaedia (2014). Extrasolar Planets Encyclopaedia. url: <http://www.exoplanet.eu>.