27/04/2015

EXOPLANETARY DETECTION AND CHARACTERISATION

TOMAS JAMES

SUPERVISOR: DR E. L. GOMEZ

IMAGE SOURCE: HTTP://UPLOAD.WIKIMEDIA.ORG/WIKIPEDIA/COMMONS/9/9B/PLANETS_EVERYWHERE_(ARTIST'S_IMPRESSION).JPG

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)

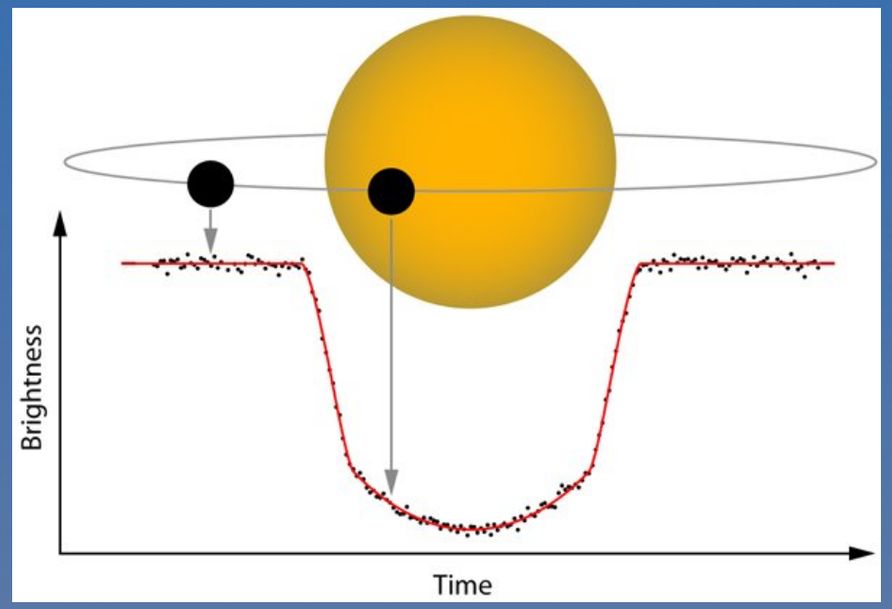
THE HUNT FOR EXOPLANETS

Exoplanets first theorised by Newton, but first detected orbiting a Pulsar in 1992 (Wolszszan and Frail, 1992). Since then, multiple high profile exoplanet missions have been launched.

EXOPLANET DETECTION

Transit Method

- Utilises the fraction of stellar flux blocked by a non-luminous exoplanet to suggest exoplanet companion
- Multiple observed transit events required for statistical significance (e.g. to exclude false positive)
- Biased towards ‘hot-Jupiters’: Jupiter sized planets orbiting at very small semi-major axes



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° 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

MATHEMATICAL CONSIDERATION

Flux ratio

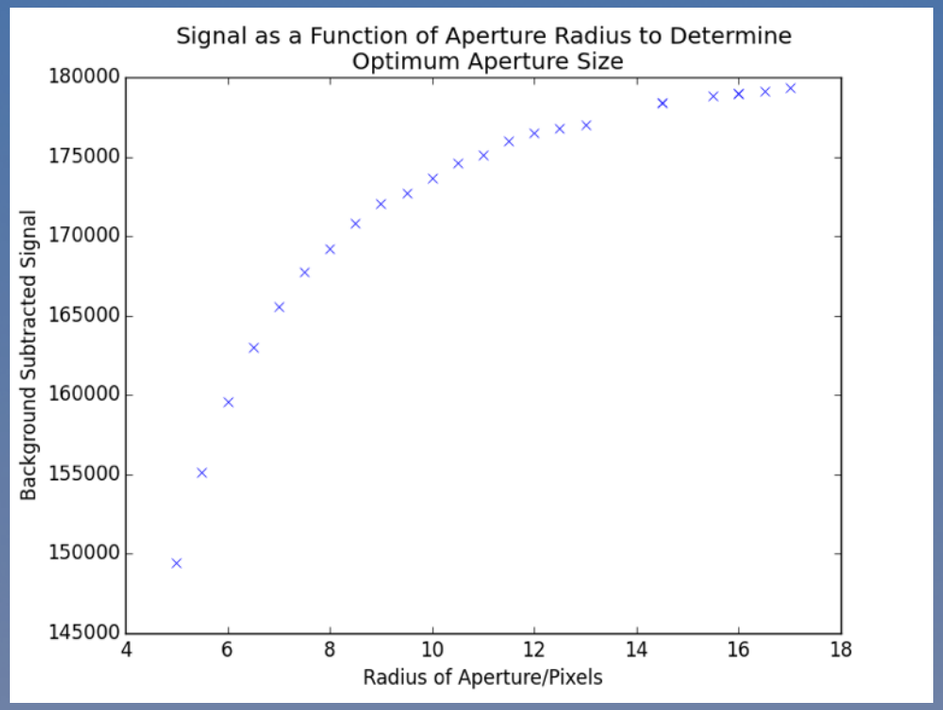
$$\frac{\Delta F}{F} = \frac{{R_{exo}}^2}{{R_{star}}^2}$$

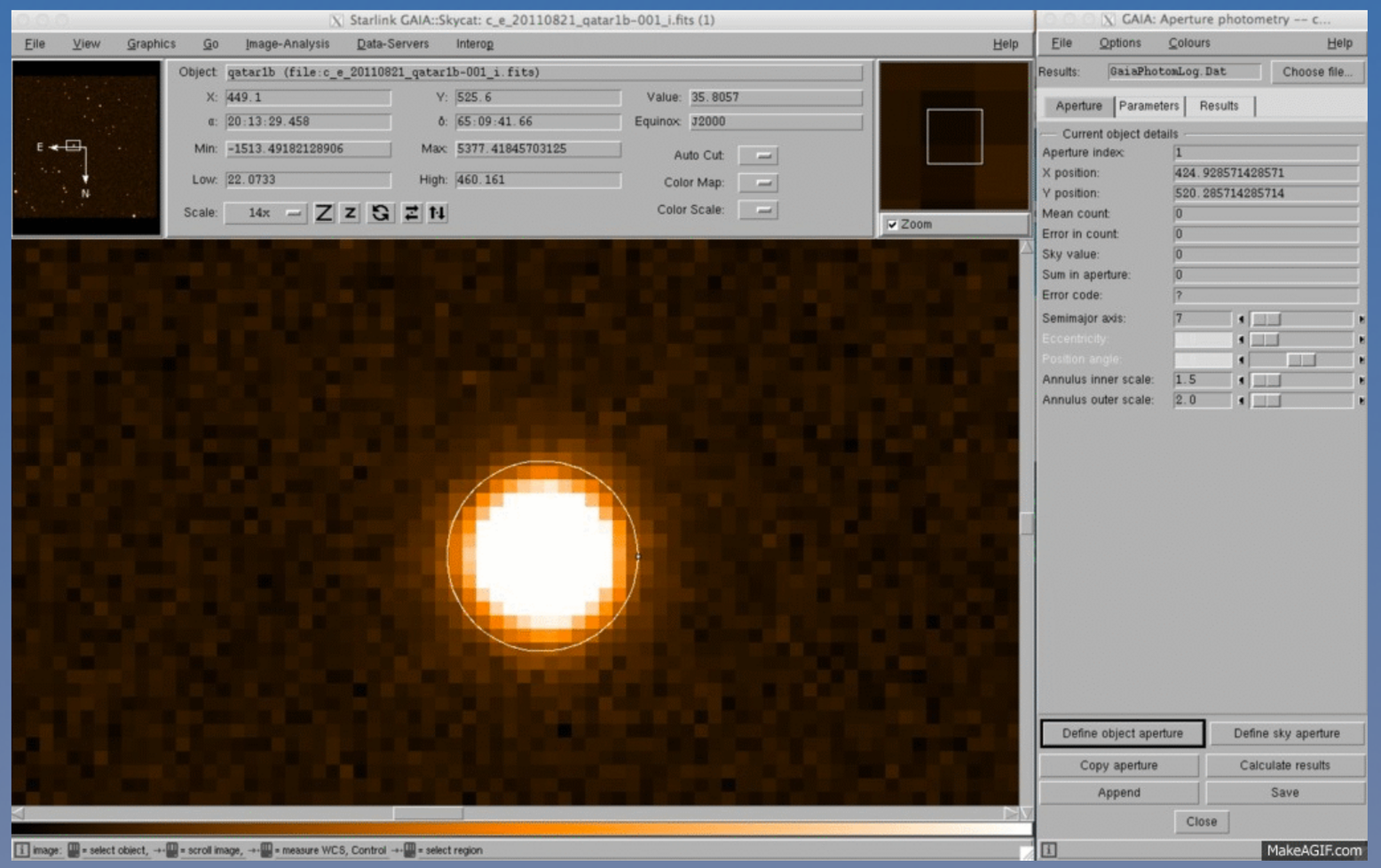
EPTM flux blocked (Addison, Durrance and Schwietermann, 2010)

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

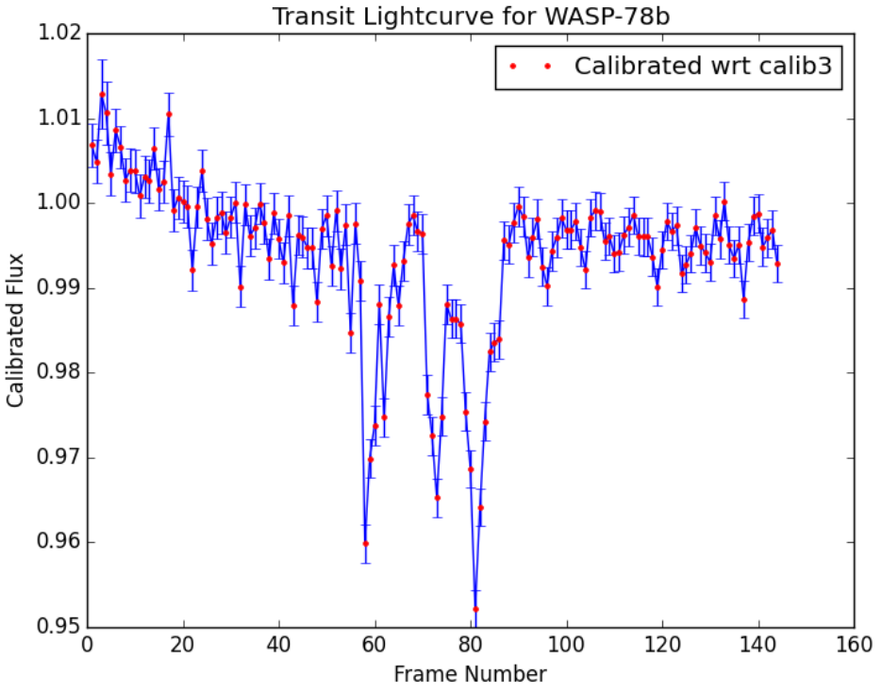
APERTURE PHOTOMETRY

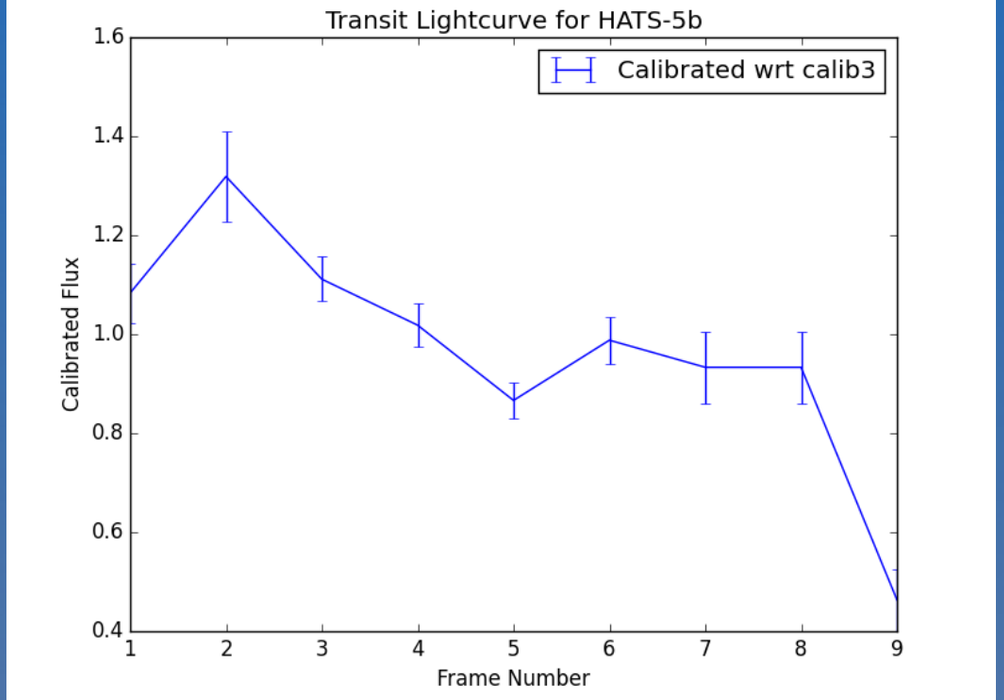
- Photometry technique practiced on Qatar-1b dataset (provided by Dr. E. L. Gomez)
- Need to determine optimum aperture size - plot background subtracted signal as a function of aperture radius
- Constant gradient represents point at which all stellar flux has been captured - this is the optimum aperture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

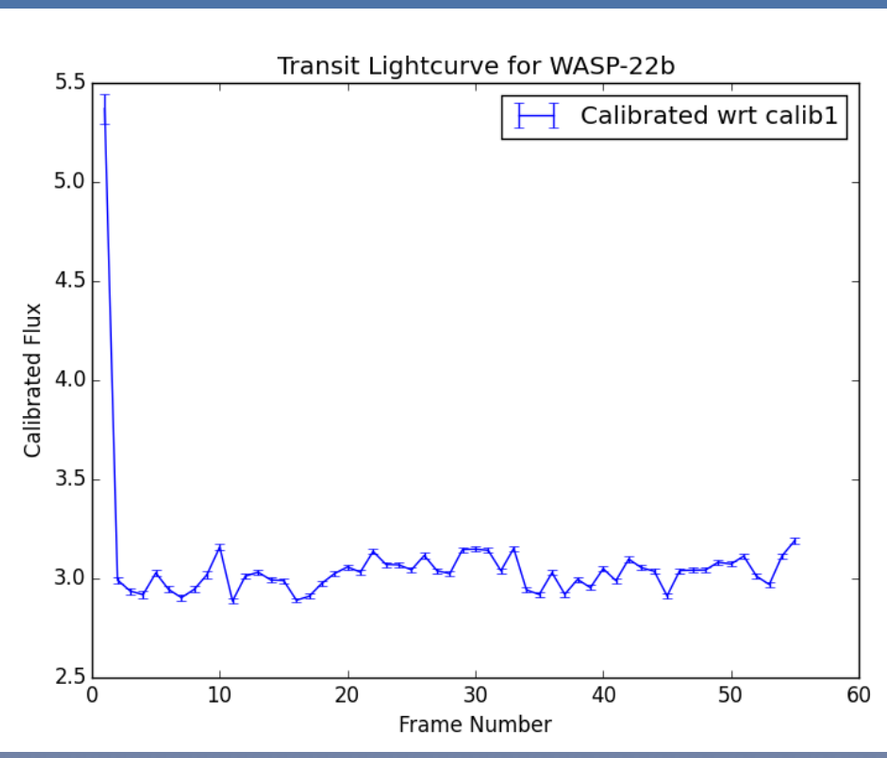




RESULTS

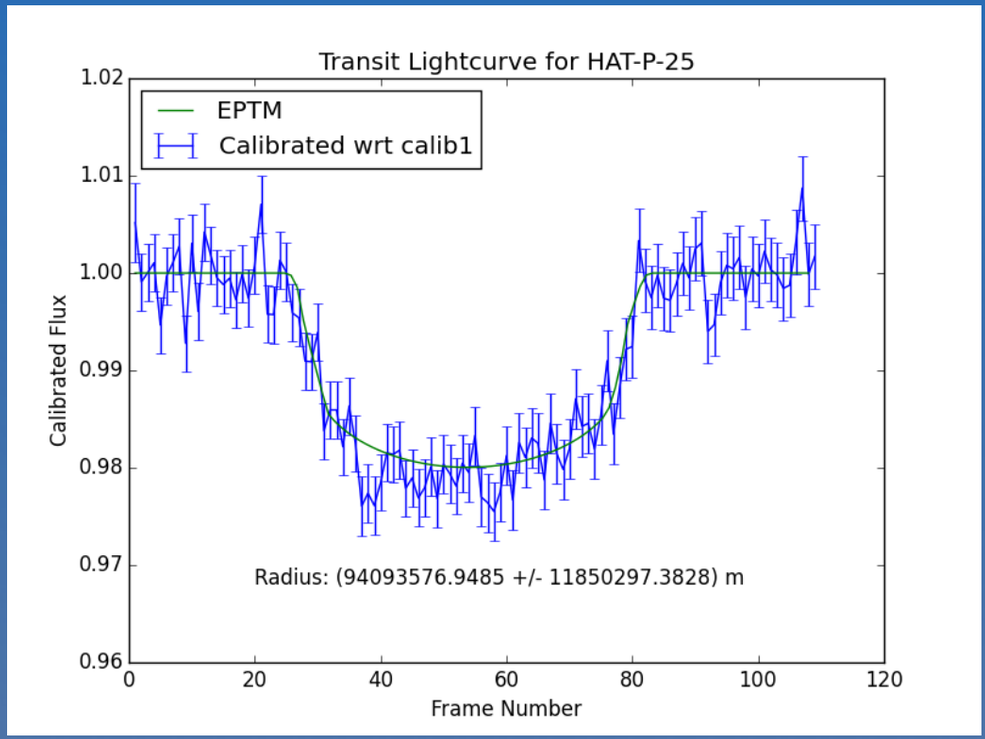


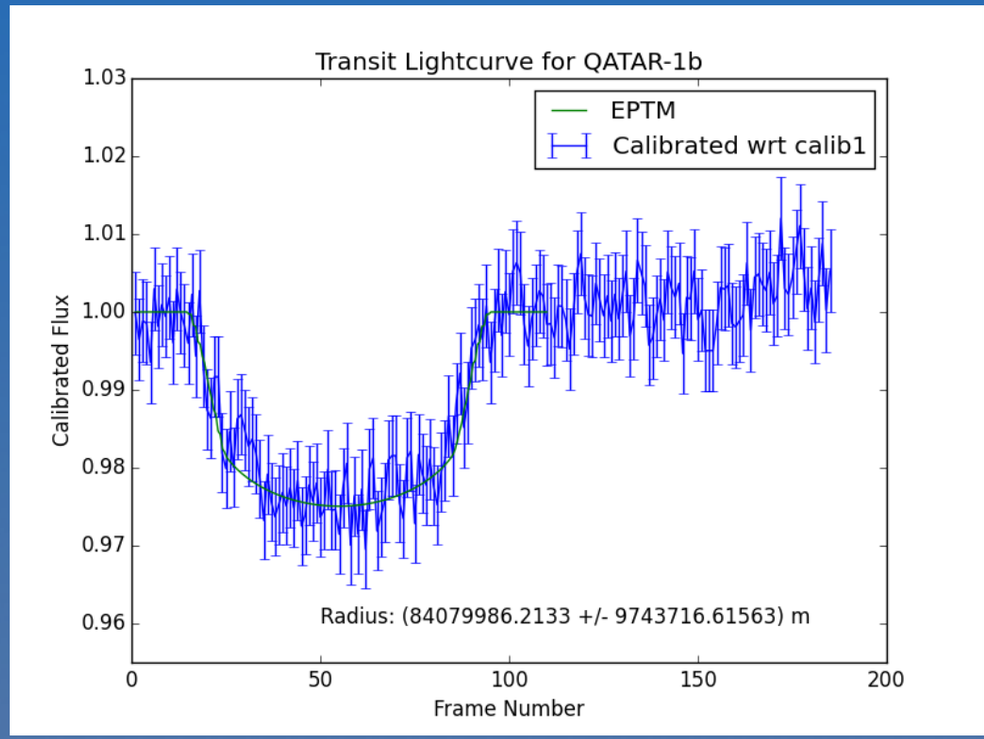


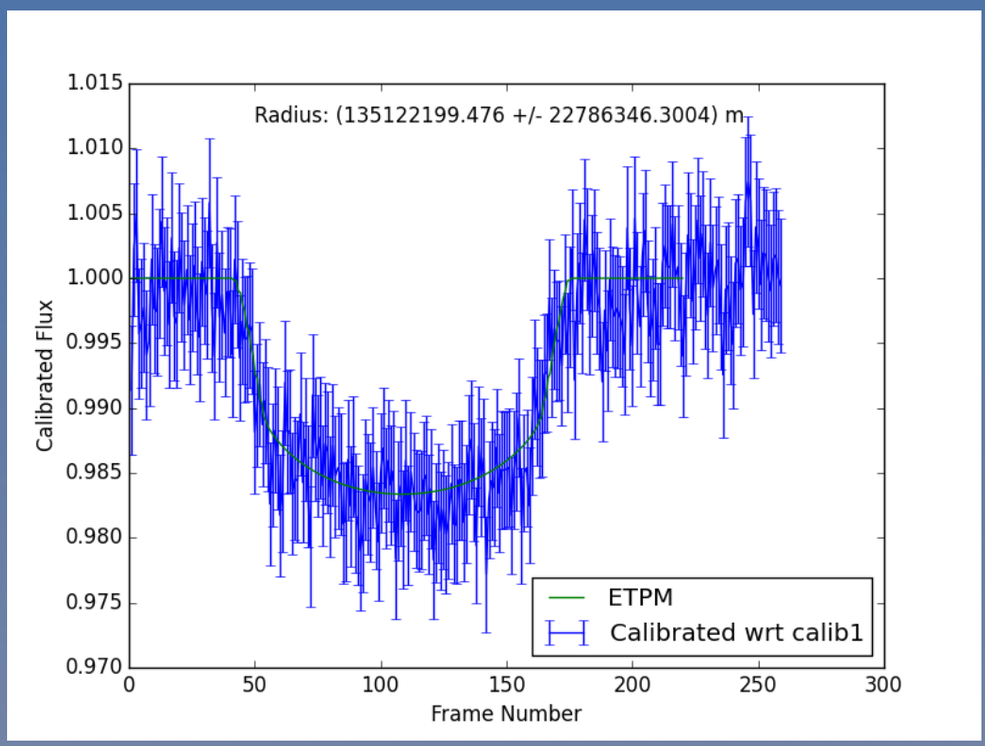


- HATS-5b and WASP-22b data not usable
- WASP-78b shows evidence of transit, but bad weather obscures dip

RESULTS







EXOPLANET	CALCULATED RADIUS	EPTM RADIUS	KNOWN RADIUS
HAT-P-25 B	$(9.4 \pm 1.2)\times10^7$ m	9.4×10^7 m	8.31×10^7 m
QATAR-1B	$(8.4 \pm 0.97)\times10^7$ m	9.0×10^7 m	$(8.14 \pm 0.3)\times10^7$ m
WASP-12B	$(13.5 \pm 2.2)\times10^7$ m	14.3×10^7 m	$(12.13 \pm 0.6)\times10^7$ m

CONCLUSIONS

- Observed results close to known values
- Results match known values within error ranges (QATAR-1b just outside of error range)
- Further pixelisation could lead to more accurate results

FUTURE WORK

- Implement Sextractor for automatic source detection
- Use Lemon to grade results against
- Further code optimisation to fit EPTM model automatically and not by eye
- Consider further datasets on more varied systems

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.