Proposed acronyms:
E-WASP
EEW - STYLE

Group 2: Effect of wavelengths and spectral type on light curves

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https://github.com/lundmb/Sagan2016

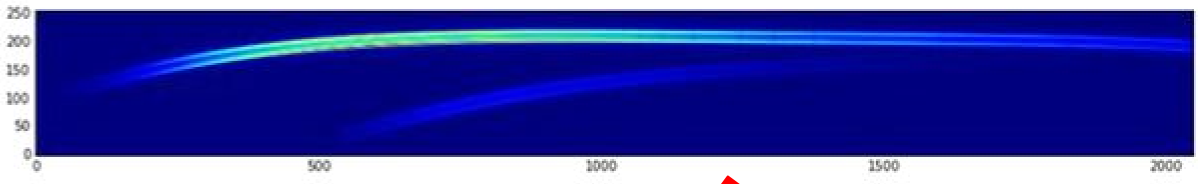
<u>Project Goal</u> - *How does transit shape change with wavelength?*

We will consider the following:

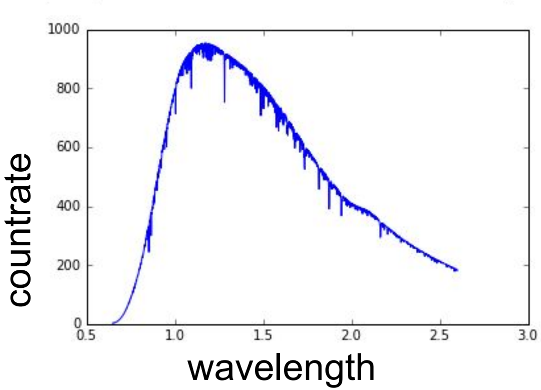
1. Using the 1D stellar spectra as a function of time, derive a white-light (summed over all wavelength) light curve (as a function of time)
2. Estimate the depth of the transit
3. Given that the transit depth is $(R_p/R_*)^2$, roughly estimate the planet radius (using the stellar spectrum as a guide for the stellar type/size)
4. The combinations of stellar types and planets that might give a similar transit depth
5. Describe why small stars (M dwarfs) make advantageous host stars
6. Create light curves for spectral resolutions ($R \sim \lambda/\Delta\lambda$) of roughly 10 and 100
7. Investigate how the transit shape/depth changes as a function of wavelength
8. Consider at which wavelengths the limb-darkening effect is strongest

1. Using the 1D stellar spectra as a function of time, we derived a white-light light curve (as a function of time)

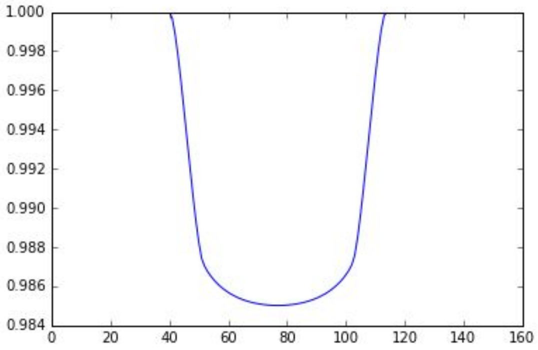
Inputs from JWST……



2D SOSS trace images as a function of time



White-light transit curve
(summed over all wavelengths)



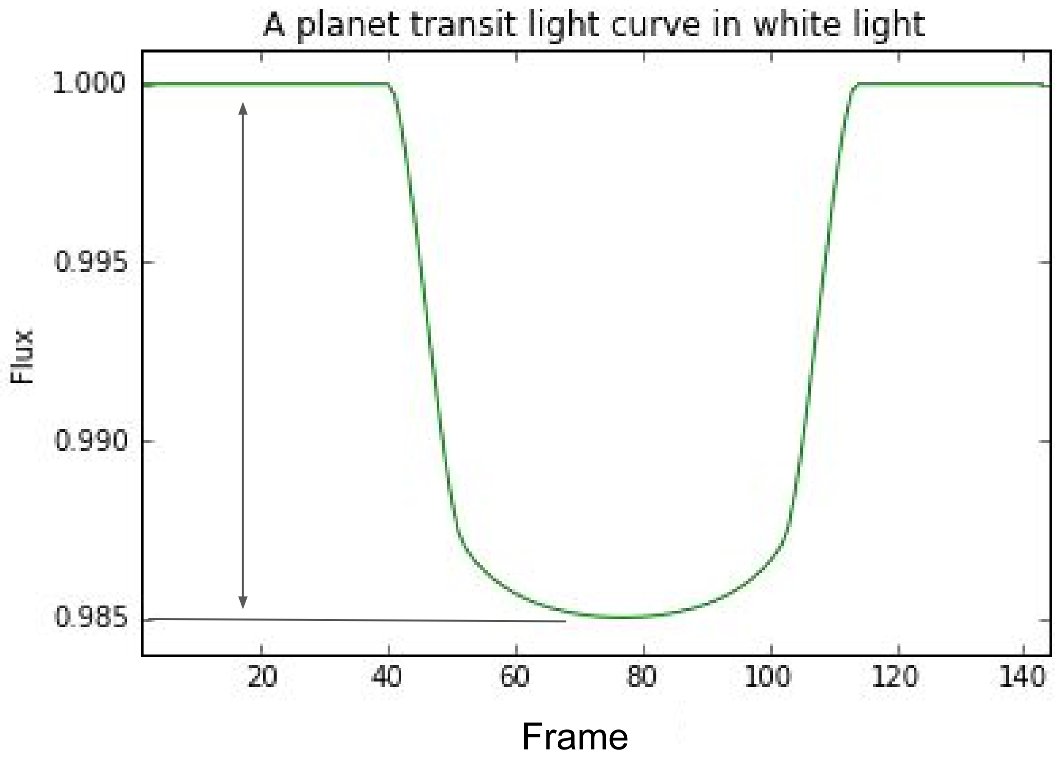
To do your own… http://maestria.astro.umontreal.ca/niriss/simu1D/simu1D.php

2. We then estimate the depth of the transit

We can observe that this is a 1.5% flux transit event

$(R_p/R_*)^2 = 0.015$

$R_p = 0.12\ R_*$



3. Given that the transit depth is $(R_p/R_*)^2$, we estimate the planet radius

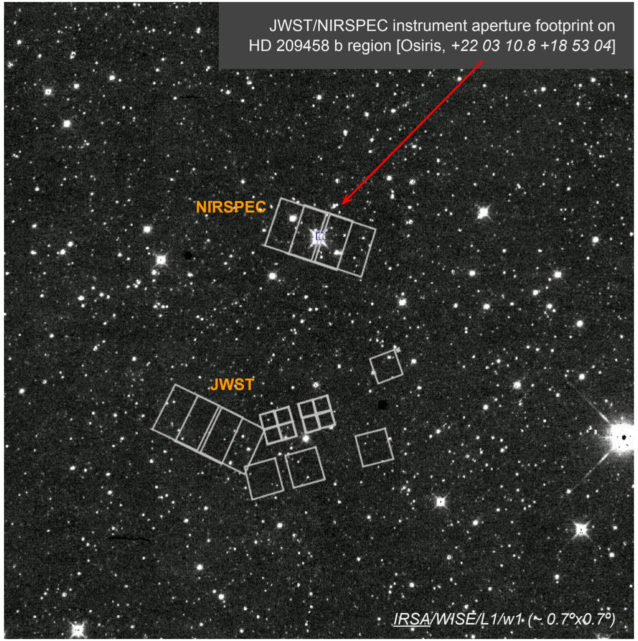
Using the stellar spectrum as a guide for the stellar type/size:

- Stellar type = G0V (HD 209458b)
- Stellar radius = 1.14 R_{sun}

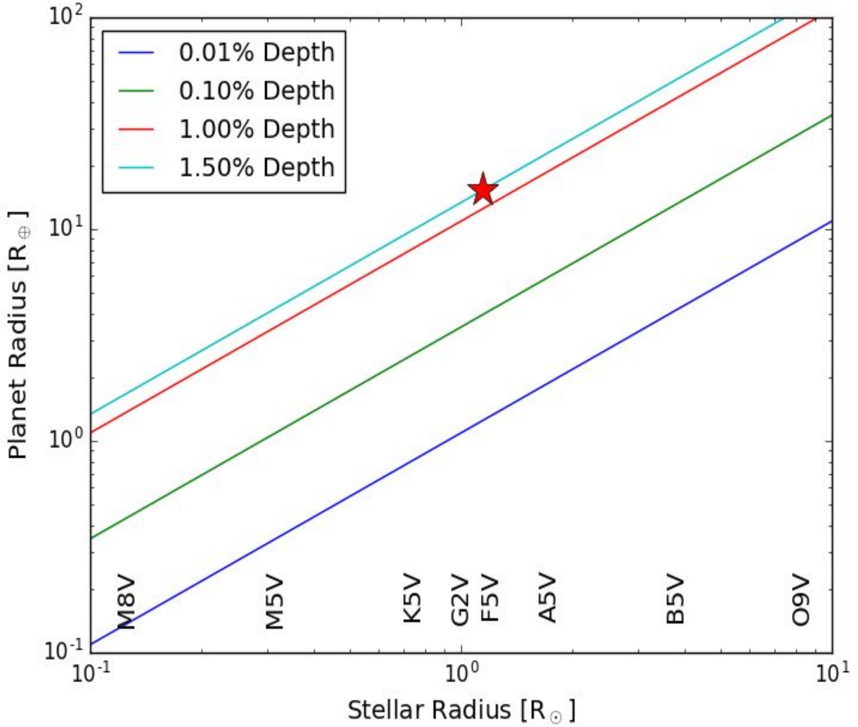
$$Planet\ radius = \sqrt{transit\ depth} * stellar\ radius$$

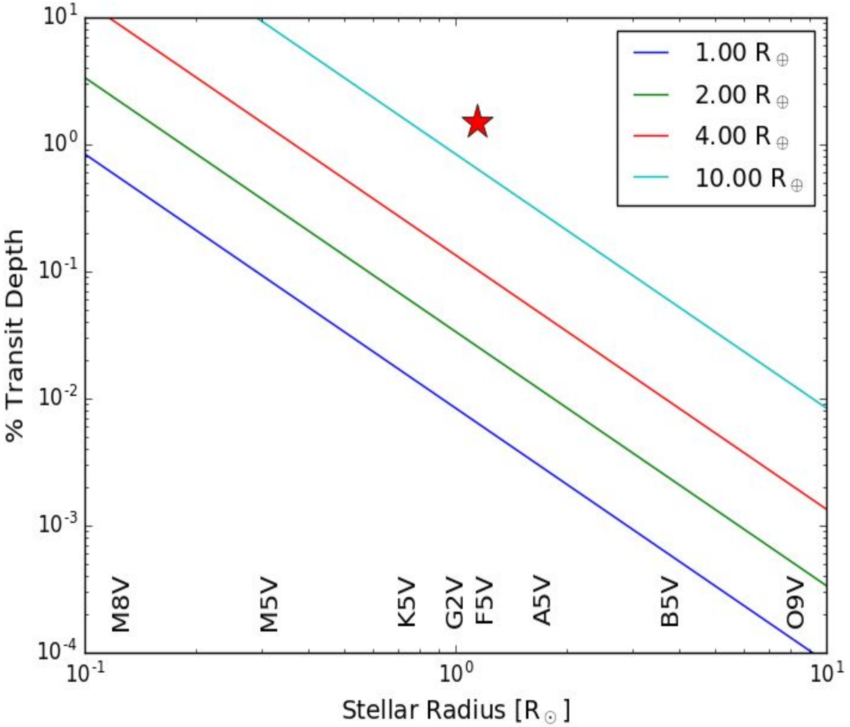
$$= 0.12 * (1.14\ R_{sun})$$

$$\sim 1.35\ R_{jup}$$



4. What combination of stellar types and planets give similar transit depths?





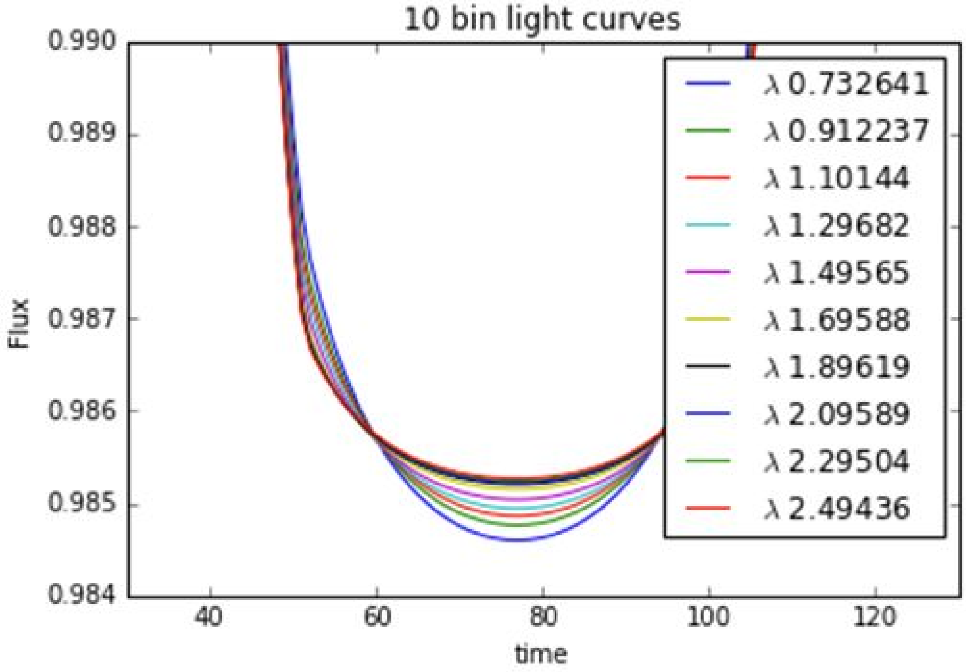
5. Why do small stars (M dwarfs) make advantageous host stars?

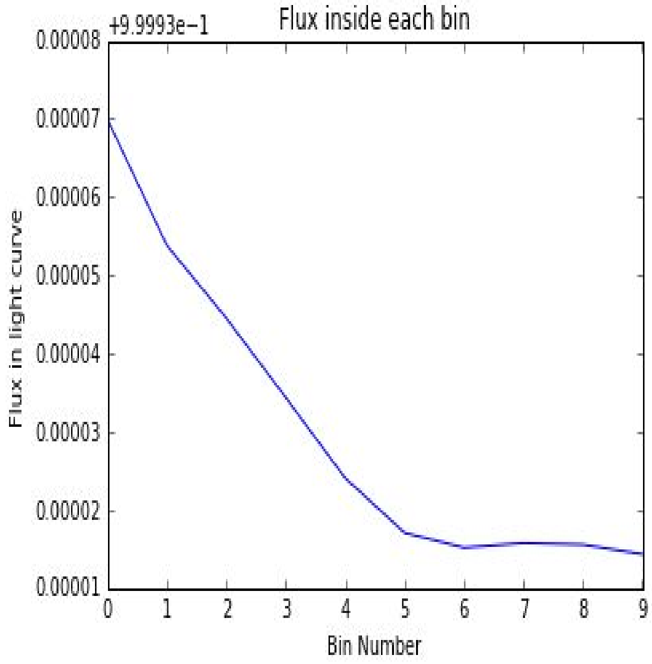
- M - dwarfs are small, therefore the same physically sized planet transit will block a larger fraction of such a star, making a deeper transit, than for an earlier type star
  - Also allows for the detection of smaller planets
- M - dwarfs are common (making up approximately 70 percent of all the stars in our galaxy)
  - more targets

But…

- M dwarfs have very narrow habitable zones, close to the star (which could lead to tidal locking)

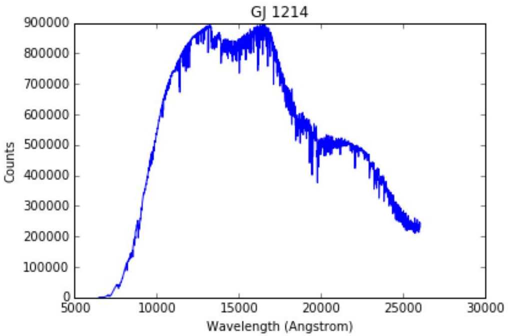
6. We consider how the light curve changes at different wavelengths

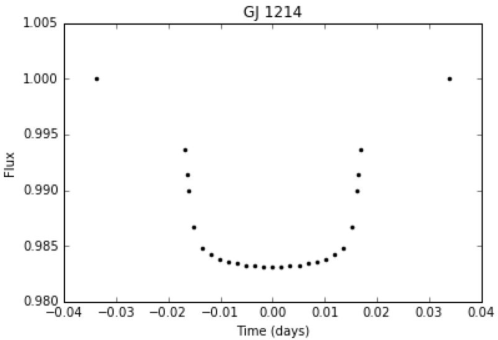


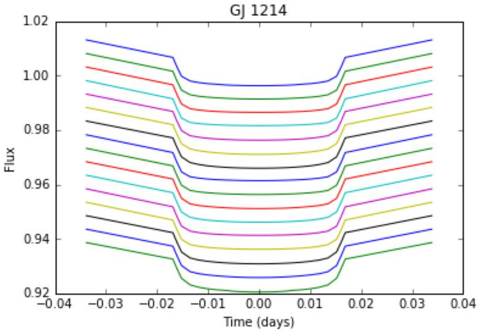


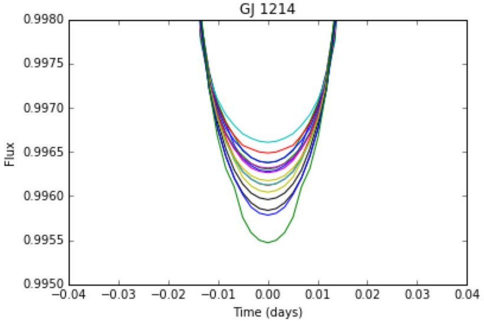
Observation wavelength affects transit depth (short is deeper), so we will see "wider" planets…
Flux appears to be redistributed, area under the curves appears to be the same (right chart)

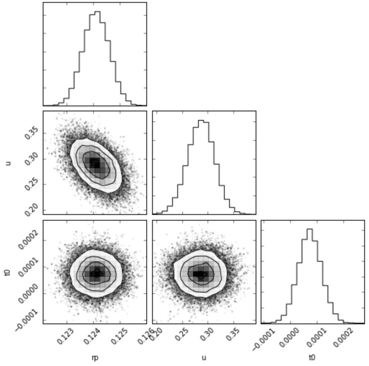
Bonus slide: Example of a Super-earth around an M-dwarf





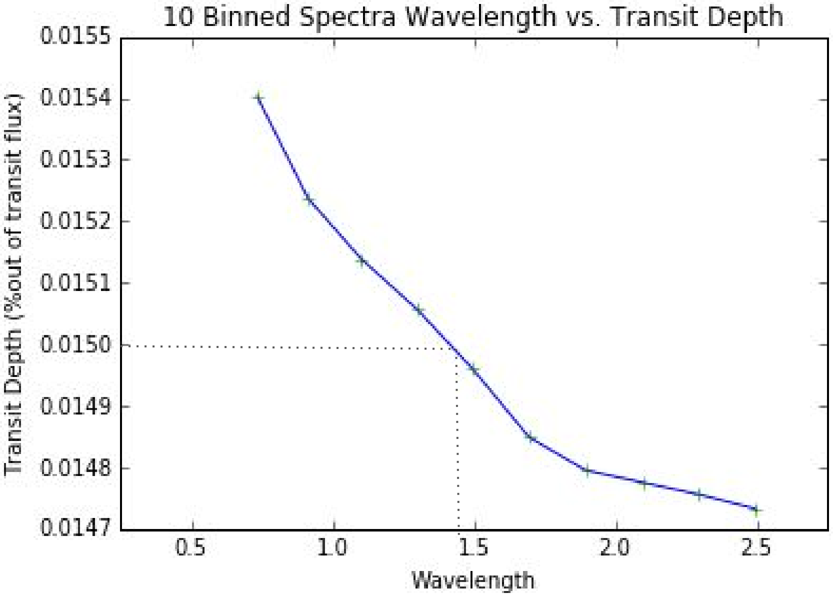


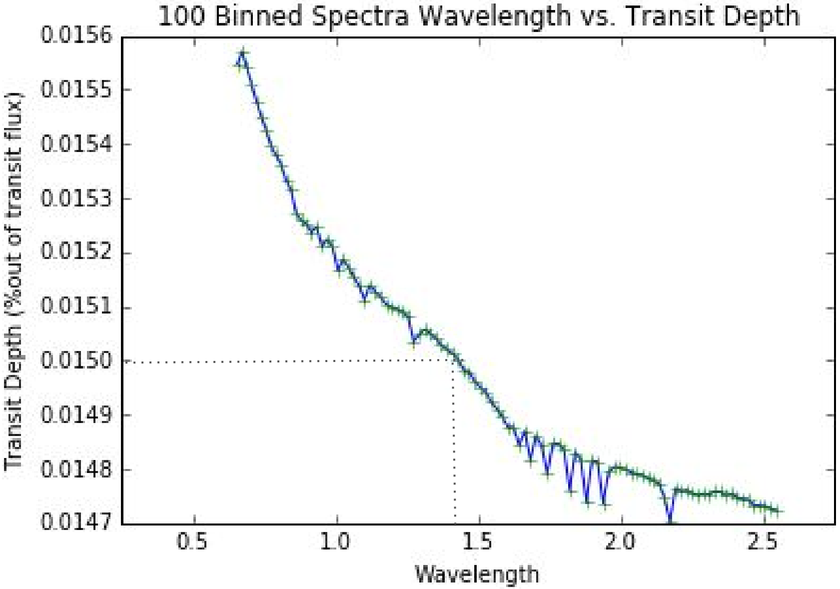




(missing steps)
→ Clouds!!!

7. How does transit shape and depth change as a function of wavelength?

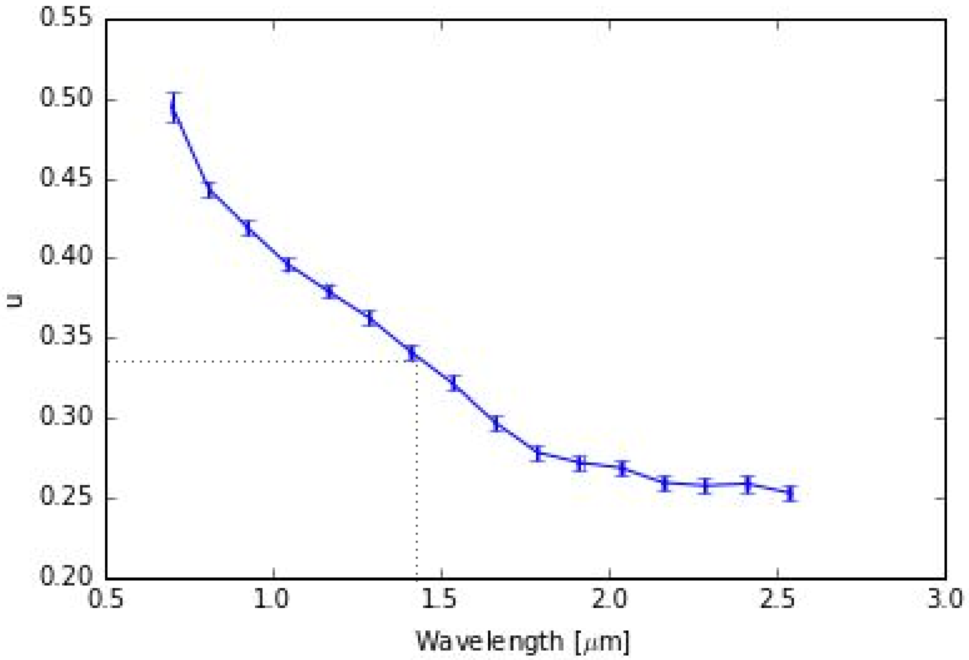




We binned up the spectra and looked at the transit depths by wavelength. Depth varied by approx 4% from max to min, or some 8% using the formula above for planetary radius. Woah!

8. At which wavelengths is the limb-darkening effect strongest?

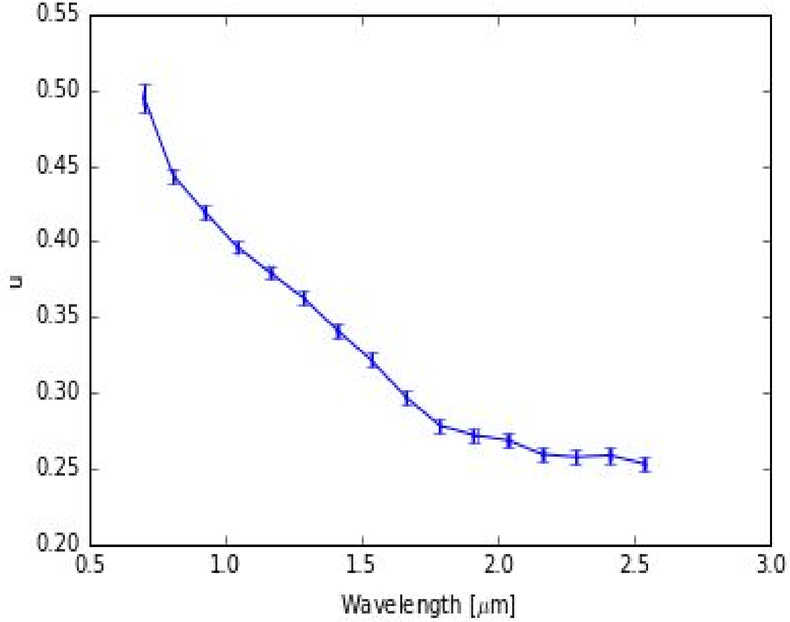
- The limb darkening decreases with increasing wavelength

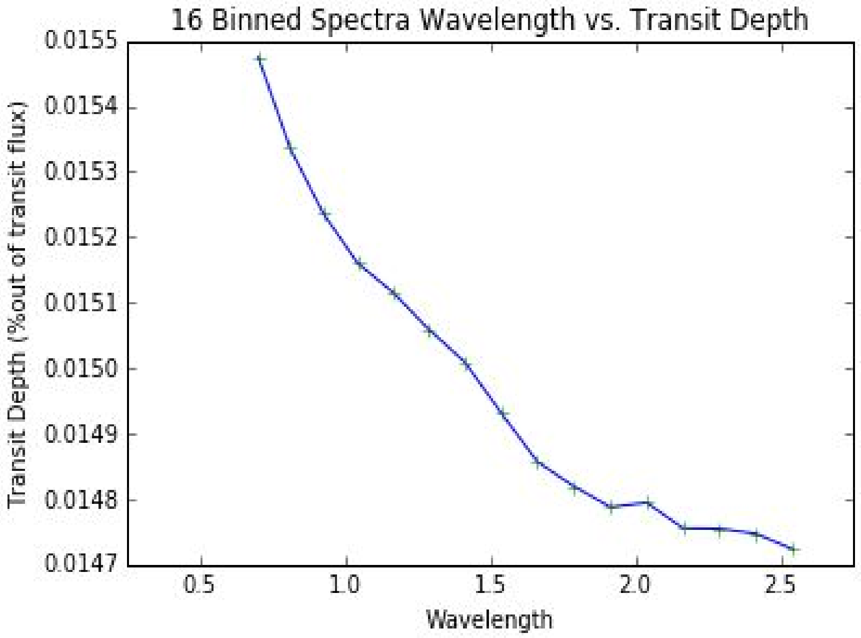


Using MCMC, we fitted the light curve for all 16 bins, including the limb darkening coefficient

Assume: <u>linear</u> limb darkening

Wavelength dependence due to limb darkening?





The gradient of u is approximately 4 times transit depth gradient. Correlation analysis would be interesting. Flux being redistributed inside the star

Conclusions

- Yes, there was a planet in our data
- Taking maximum transit depth, planet radius is 12% that of its star
- Assuming star is ‘typical’ G0V (from spectra) then this is 1.35 Jupiter radii so not a brown dwarf
- But if star is larger or smaller in reality, then so is the planet as we’re just looking at geometry so far
- Do we see an effect with wavelength? Yes, via limb darkening


Any Questions?