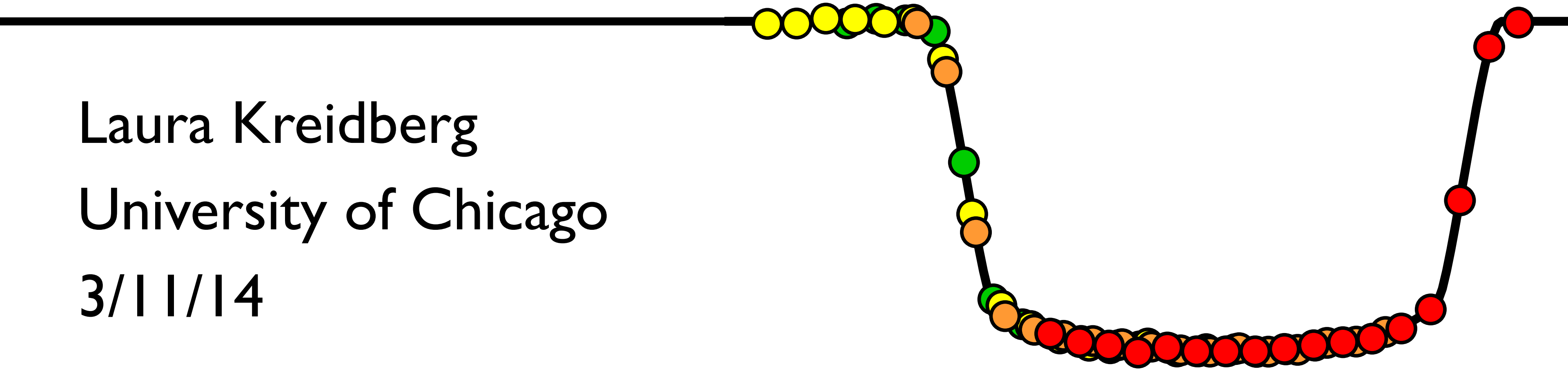
Frontiers of Precision Exoplanet Atmosphere Characterization with HST



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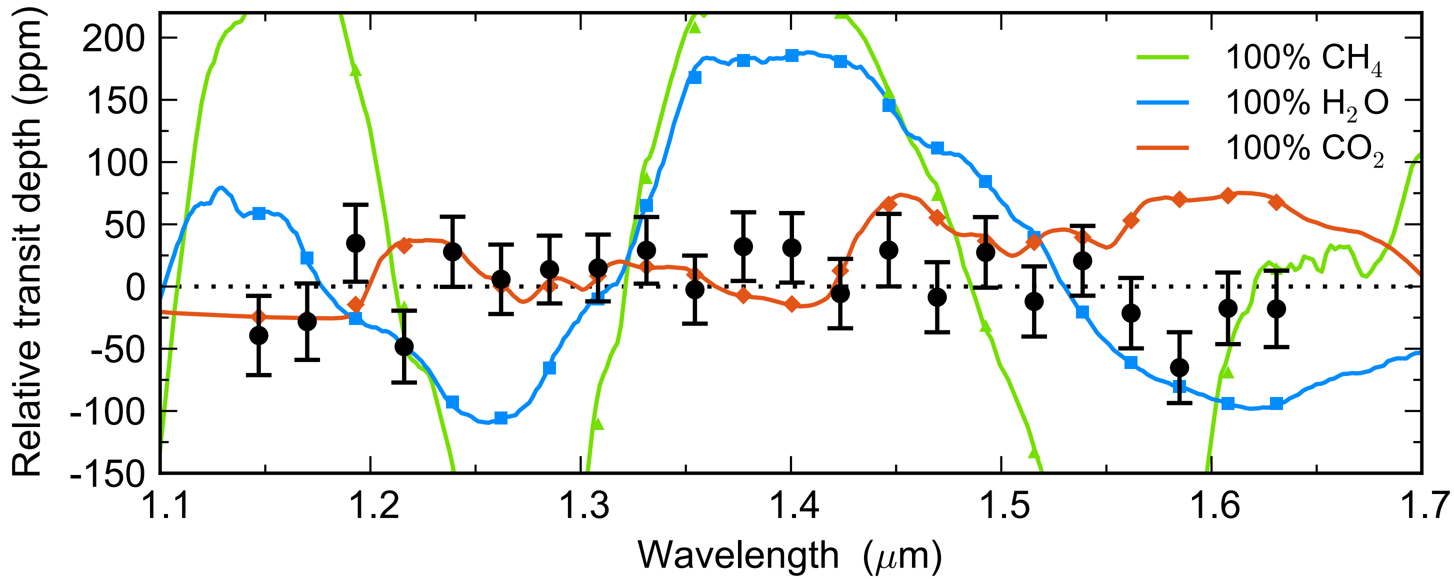
University of Chicago
3/11/14

Special thanks to:
Jacob Bean, Kevin Stevenson, Heather Knutson

Frontier #1:
Stacking Many Transit Observations (GJ 1214b)



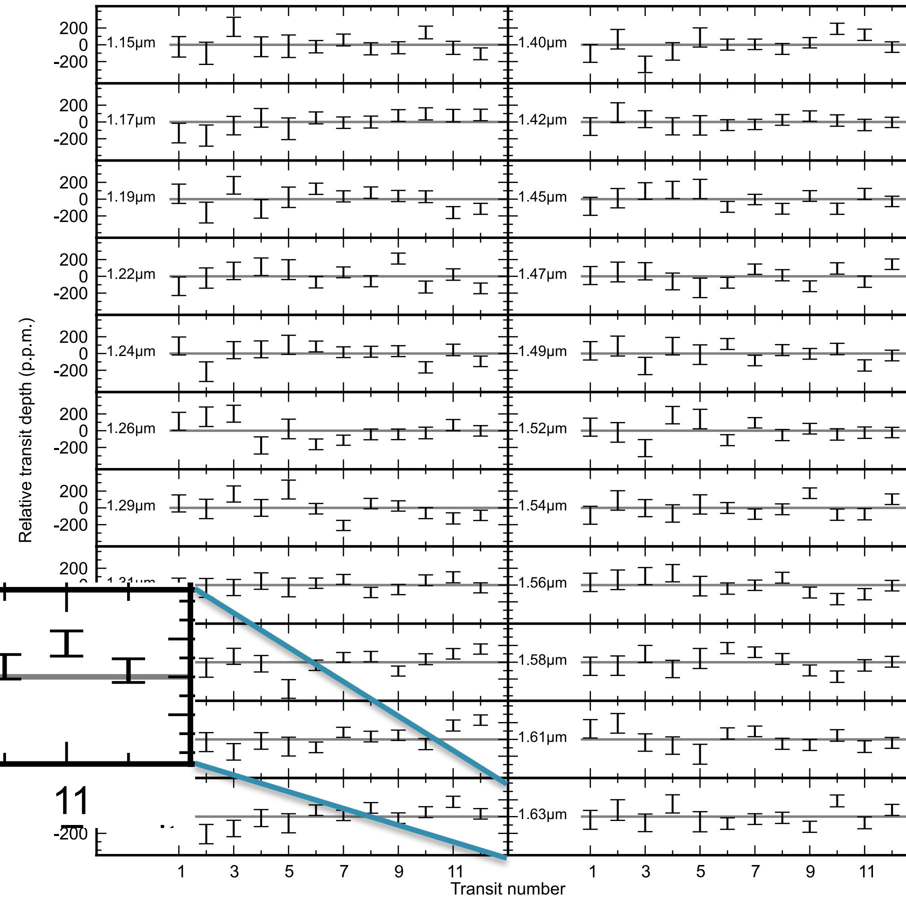
Kreidberg et al. 2014, Nature, 505, 69

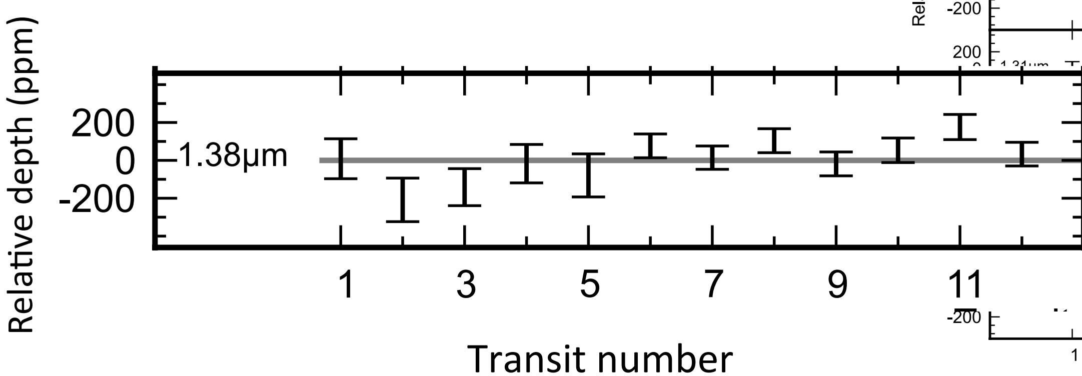
- Observed a record 15 transits of the planet with WFC3
- High-altitude clouds are required to explain the transmission spectrum
- We rule out cloud-free compositions at very high confidence (e.g., H_2O at 16 σ)

Enabling a Definitive Result

1. Repeatability

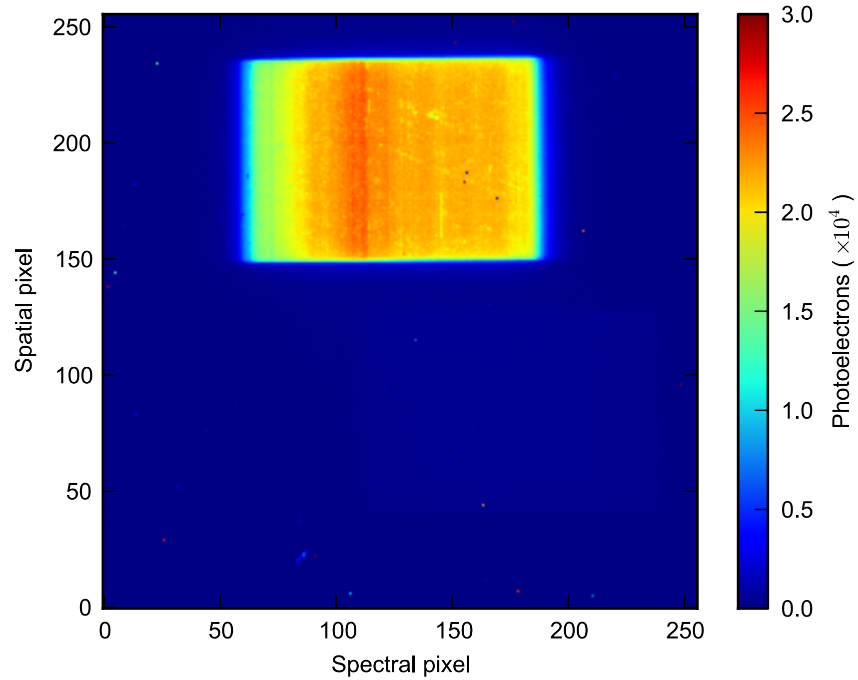
   Transit depths measurements are consistent over the full year of observations in all spectral channels





Enabling a Definitive Result

2. Spatial scanning
   a) Not ideal for instrument systematics
   b) Improves the duty cycle to 60%, a factor of 5 increase over previous observations
   c) Careful modeling of instrument systematics yields light curve residuals which are Gaussian, uncorrelated in time, and within 10% of the photon noise limit



An example raw data frame.
- 90s exposure
- peak fluence ~20,000 e-/pixel

Enabling a Definitive Result

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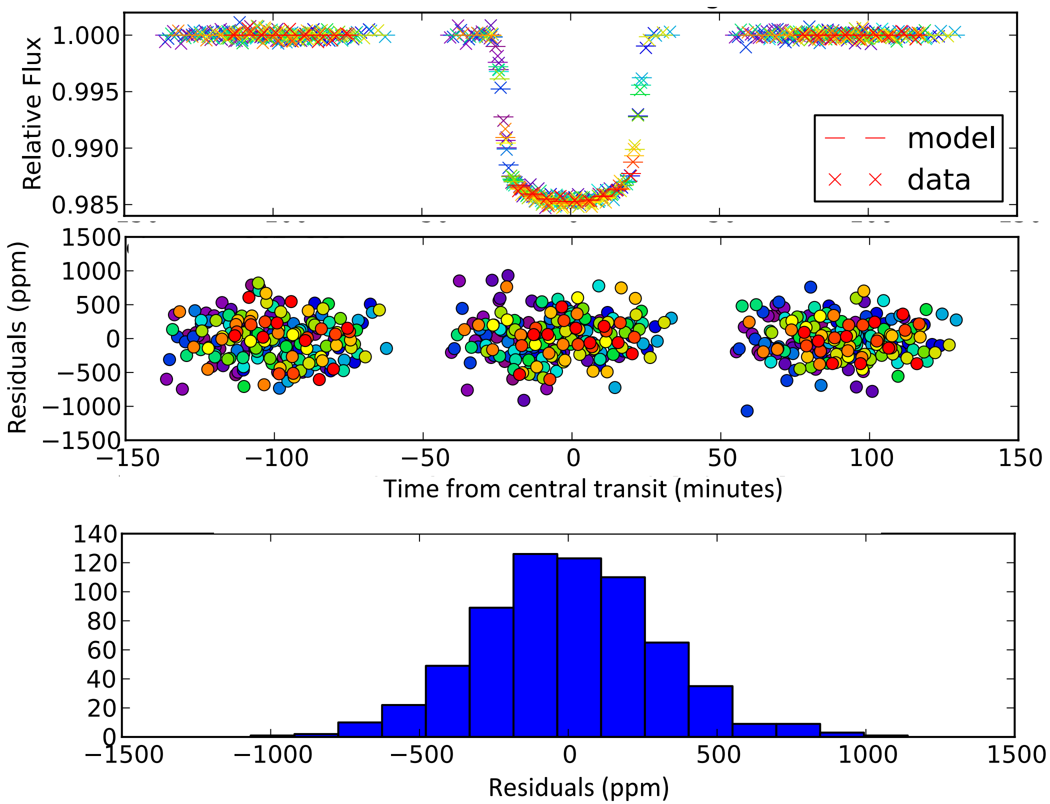
1.40 µm channel fit



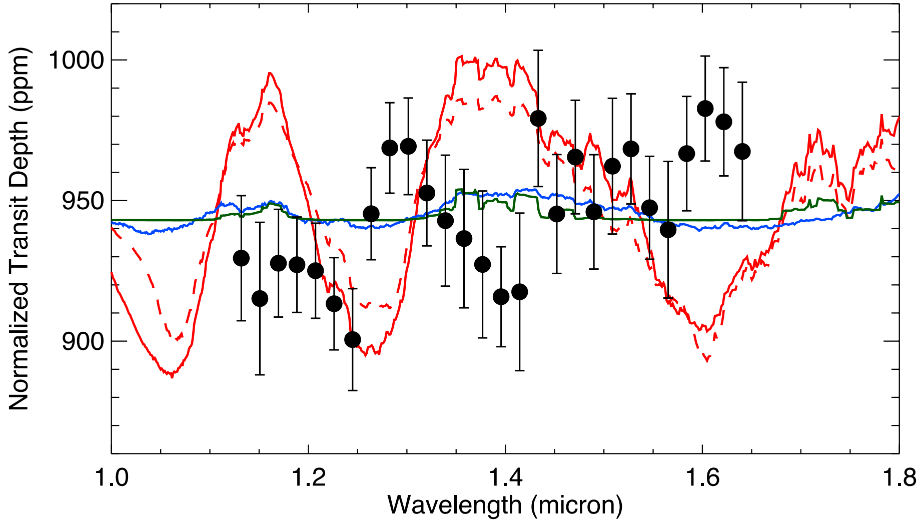
Frontier #2:
Making the Most of Big Signals (WASP-43b)

- Time series spectroscopy of the hot Jupiter WASP-43b over three full planetary orbits
- Observed an additional 3 transits and 2 eclipses

[REDACTED]

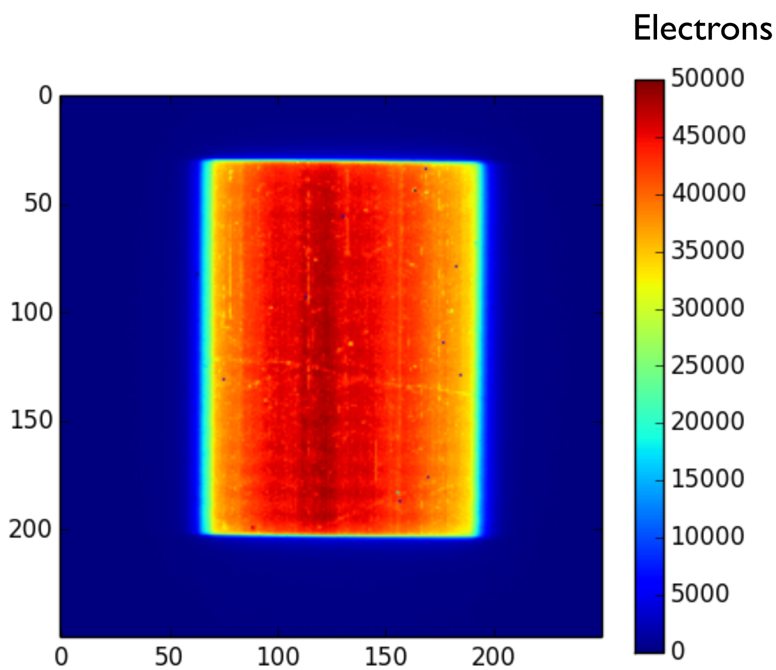
Frontier #3:
Observing the Brightest Targets (HD 97658b)

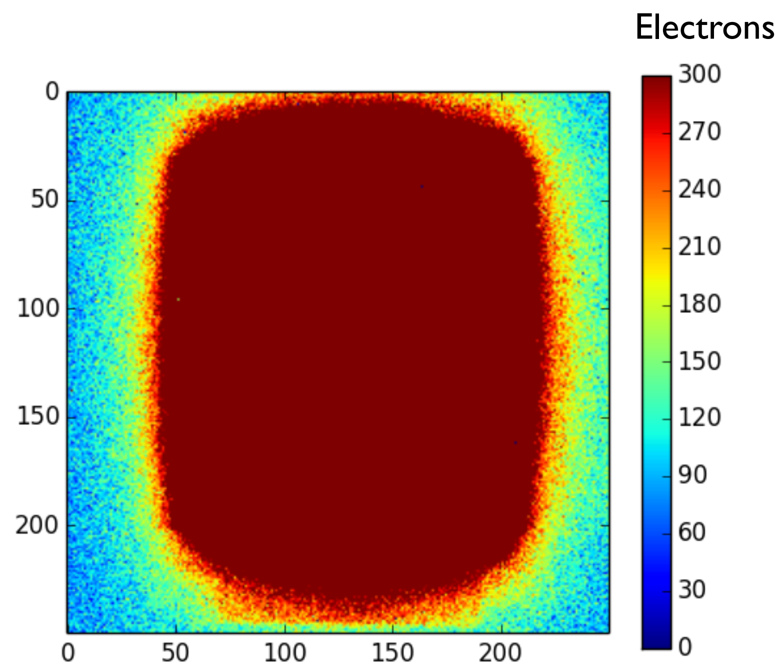
- HD 97658b is a super-Earth recently confirmed to be transiting
- Host star H-band magnitude = 5.8
- Two WFC3 transit observations (PI: H. Knutson)
  - most precise near-IR transmission spectrum to date (20 ppm uncertainty on transit depth)
  - rules out a cloud-free hydrogen-rich atmosphere (red line)



Knutson et al., in prep

Challenges of Observing Bright Targets

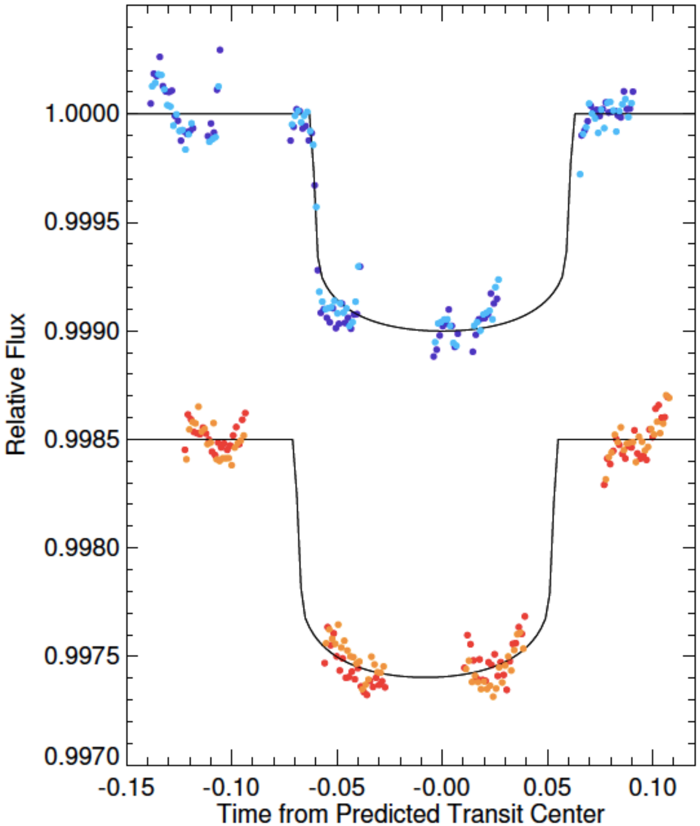




- Loss of flux at detector edges
- Difficult to estimate background
- Fast scan rate → spectrum drifts with time

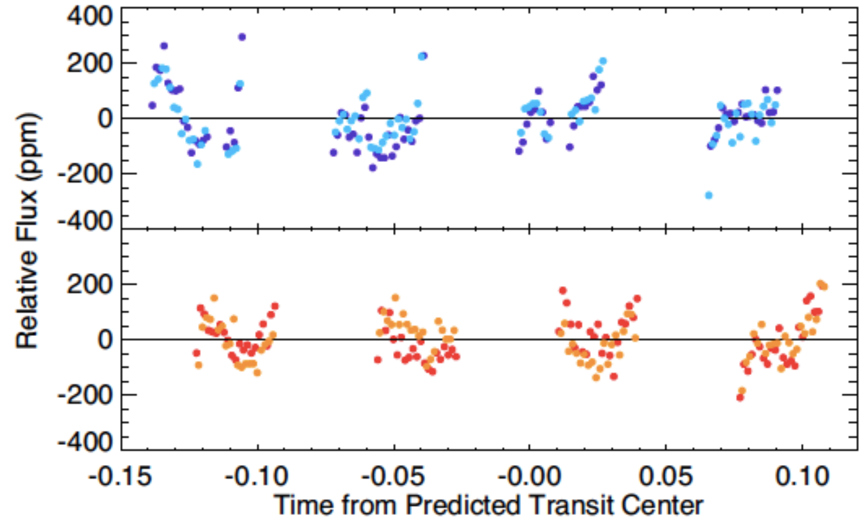
Challenges of Observing Bright Targets

Best fit broadband light curve



Knutson et al., in prep

Residuals



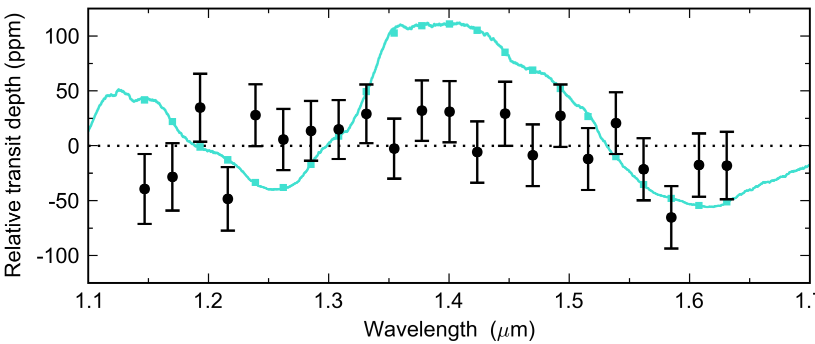
Best-fit rms is 2-3x the photon limit of 30 ppm
Systematic noise floor near 75 ppm

Looking Forward

GJ 1214b

$R_p = 2.7\ R_E$
$R_s = 0.2\ R_\odot$
$T = 580$ K
H mag = 9.1

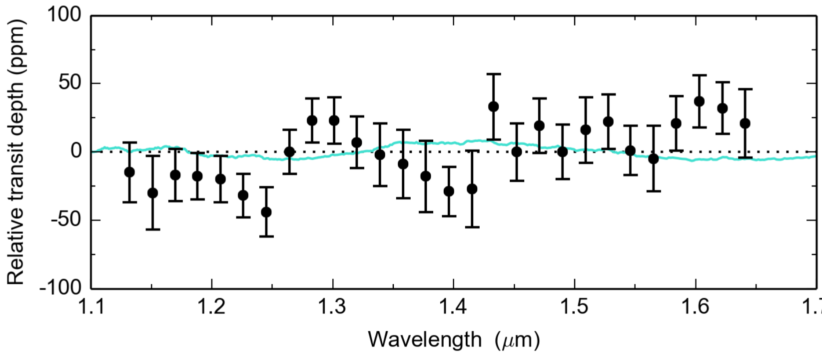
2014
Kreidberg et al.
precision = 30 ppm



HD 97658b

$R_p = 2.3\ R_E$
$R_s = 0.74\ R_\odot$
$T = 800$ K
H mag = 5.8

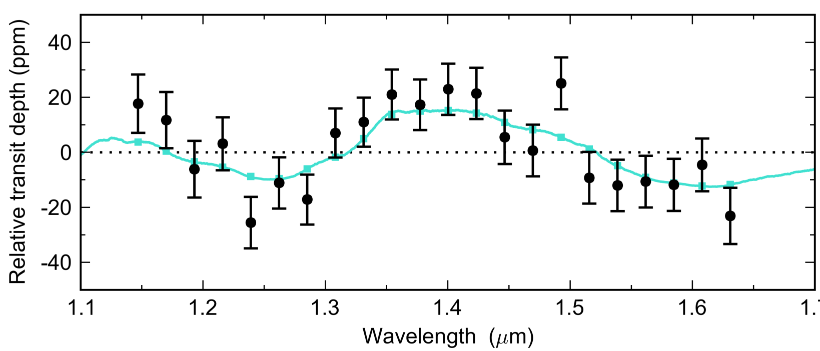
2014
Knutson et al.
precision = 20 ppm



Earth 2.0

$R_p = 1.0\ R_E$
$R_s = 0.2\ R_\odot$
$T = 300$ K

201?
precision = 10 ppm



N_2-rich, trace H_2O atmosphere

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