Starspots in WFC3 transmission spectroscopy: the case of WASP-52 b

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Know thy star, know thy planet - Pasadena, CA
October 12, 2017

Starspots and

the exoplaneteer

the stellar physicist

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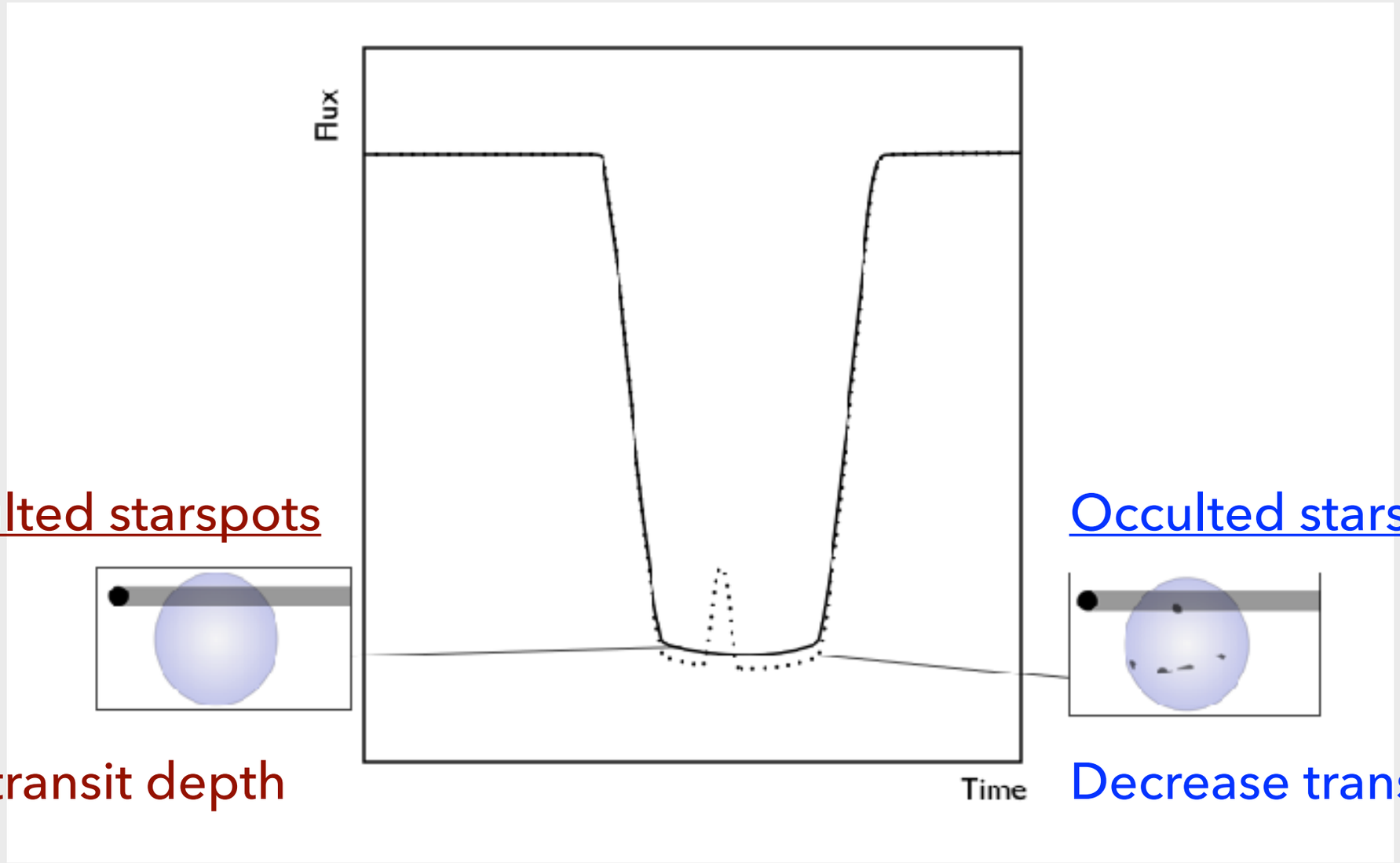
the exoplaneteer

the stellar physicist

Starspots affect transit depth measurements



Non occulted starspots

Increase transit depth

Occulted starspots

Decrease transit depth

Pont et al. 2013

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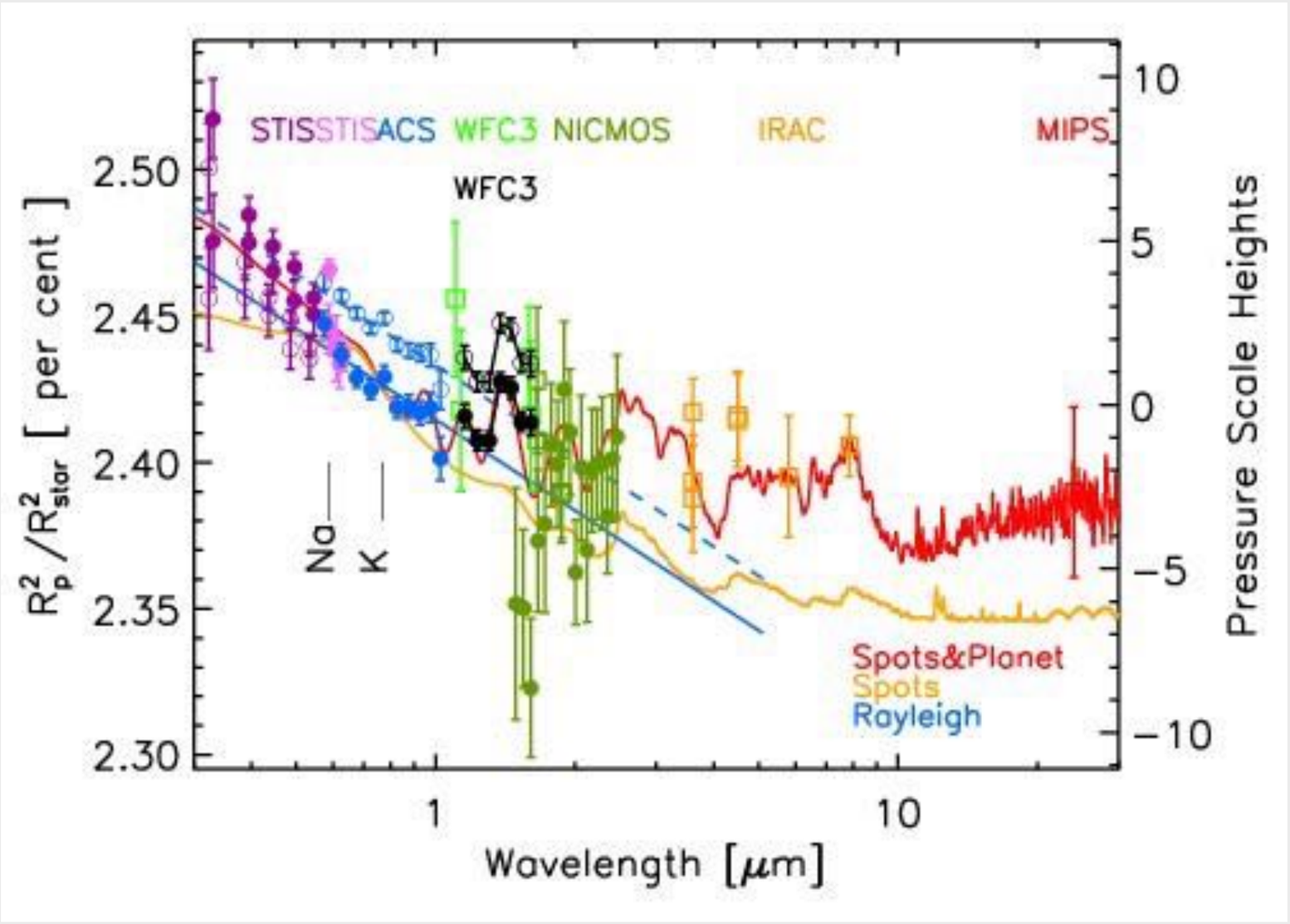
Transmission spectroscopy: wavelength dependence

- Starspots OUT of transit:
  R_p blue > R_p red

  ~ Rayleigh scattering

- Water vapor in very (very) cool starspots?

HD189733b



McCullough et al. 2014

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Transmission spectroscopy: wavelength dependence

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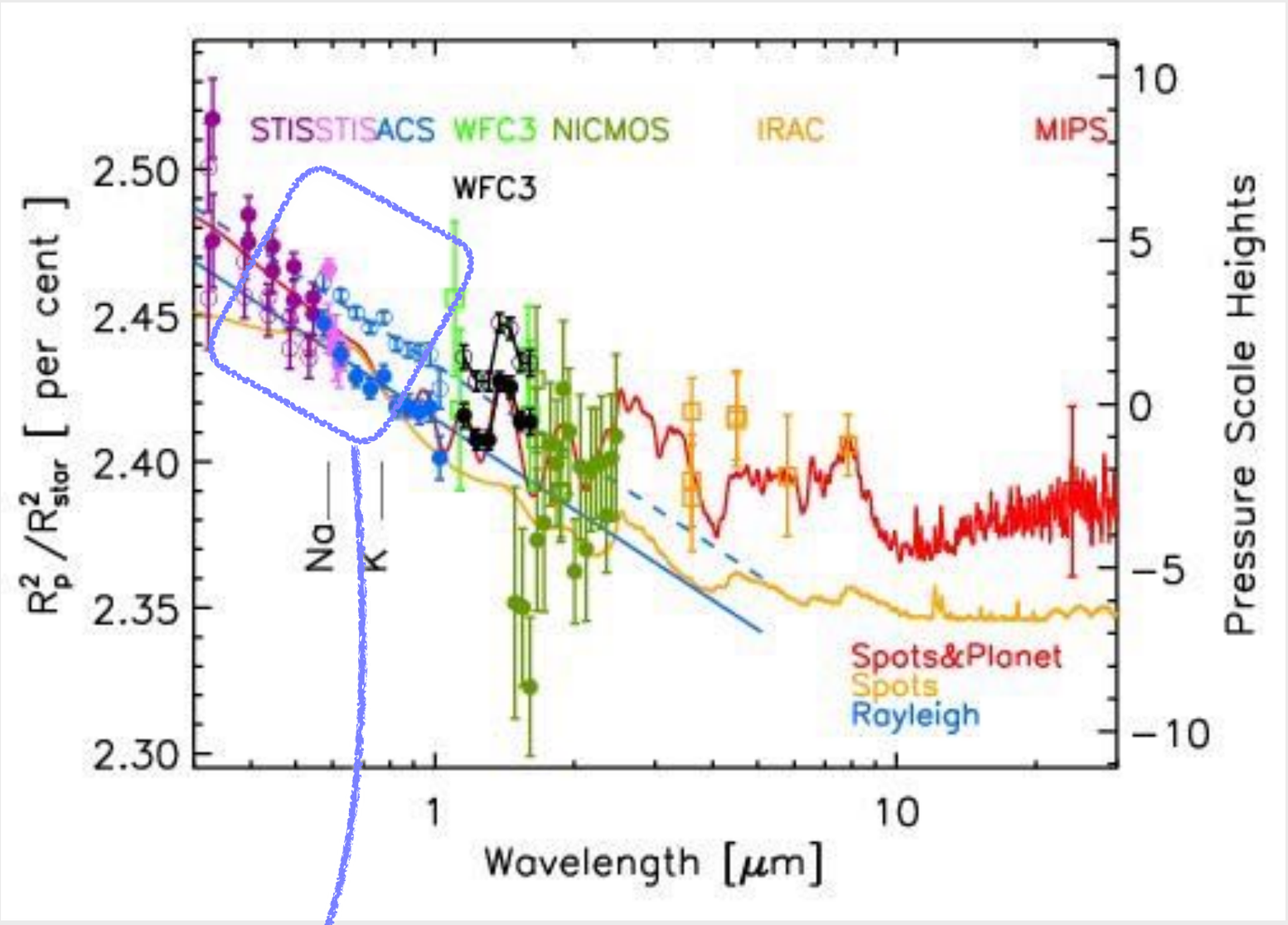
Stellar atmosphere models to compute contrast

HD189733b



McCullough et al. 2014

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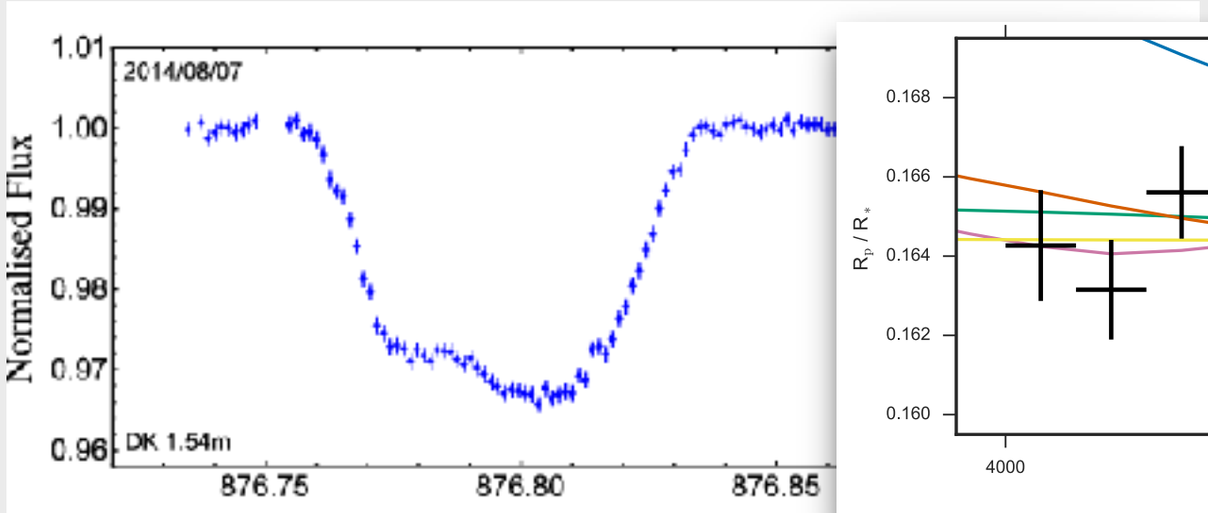
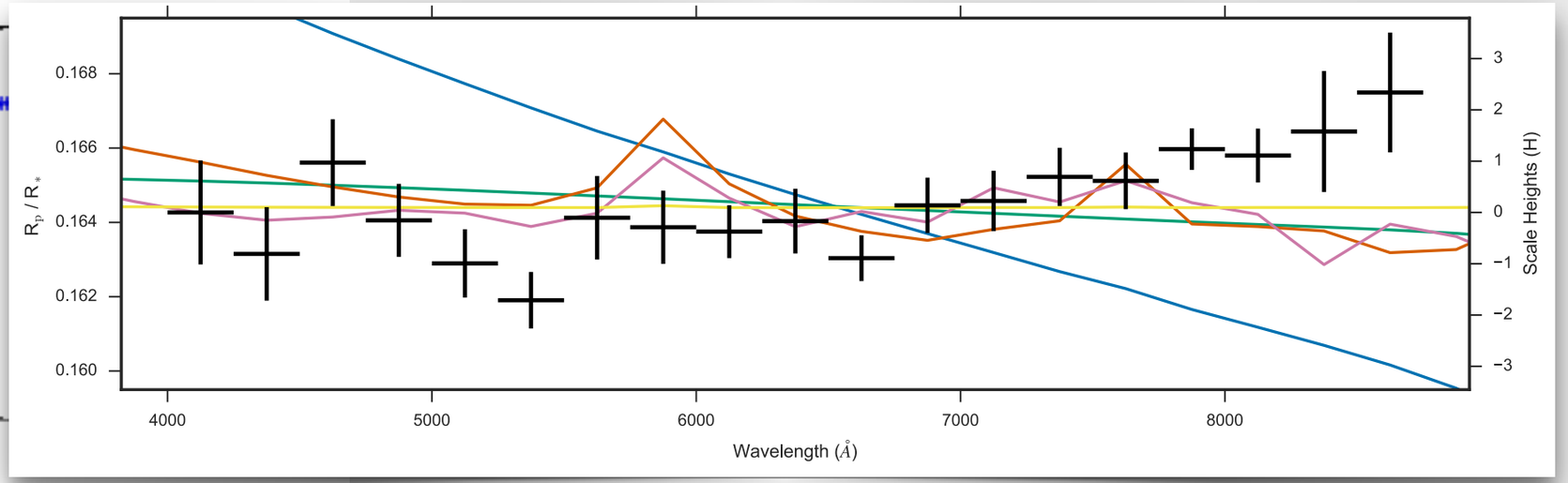
WASP-52b – A variety of scenarios

- Active star, inflated planet (Hébrard et al. 2012)
- Flat transmission spectrum 350-900 nm
  (Mancini et al. 2016, 2017, Kirk et al. 2016, Louden et al. 2017)

T_{eff} ~ 5000 K
log g ~ 4.5 [cgs]
vsini ~ 3.6 km/s



Mancini et al. 2017



Louden et al. 2017

- Starspots/faculae
- No Rayleigh scattering
- Grey cloud 0.1 mbar?

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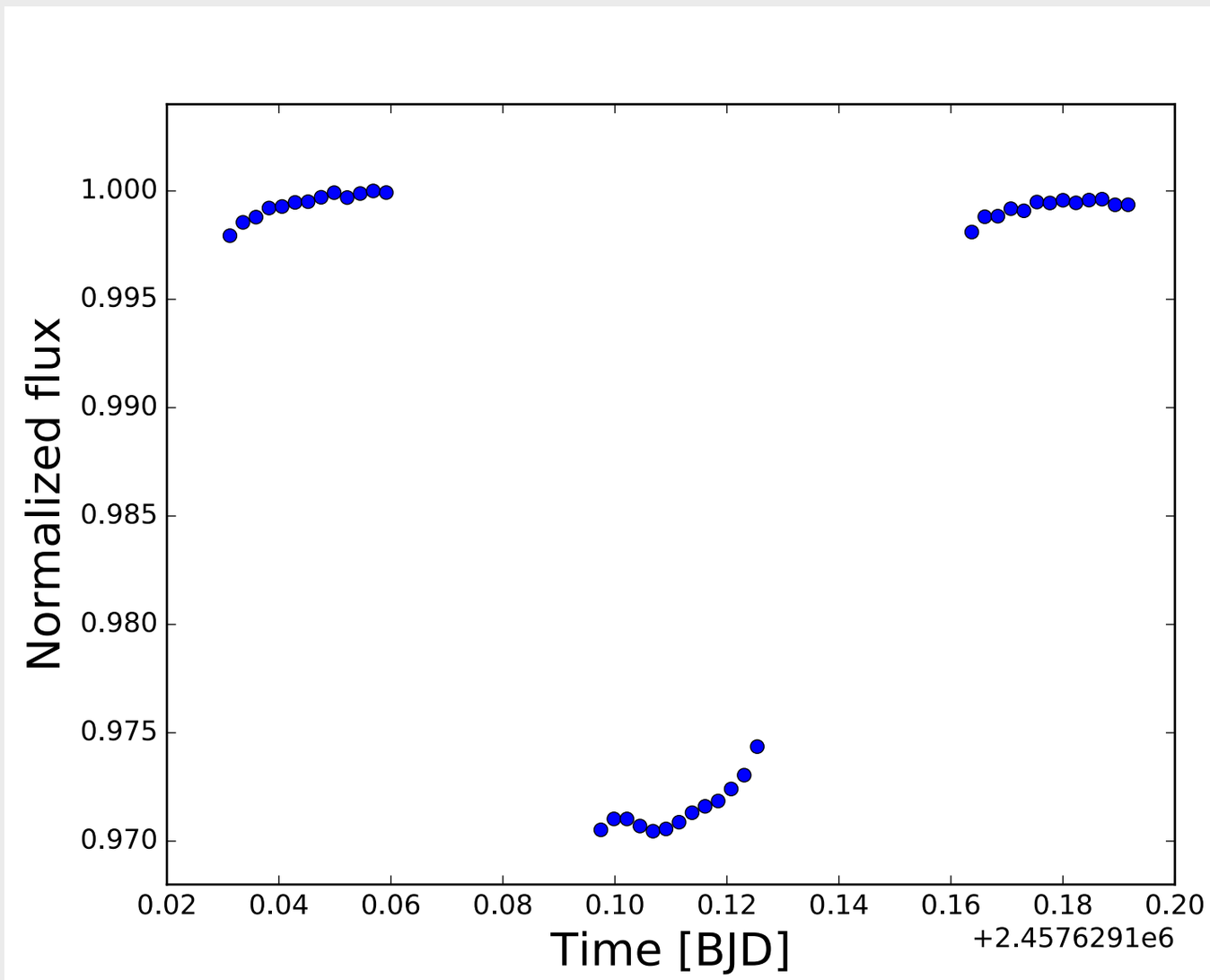
Focus on HST/WFC3 spectra (1.1-1.7 microns)

WASP-52 b



- Single transit (no out-of-transit constraint)
- One or two starspot crossing events?
- HST systematics

HST Cycle 23 (PI Deming)

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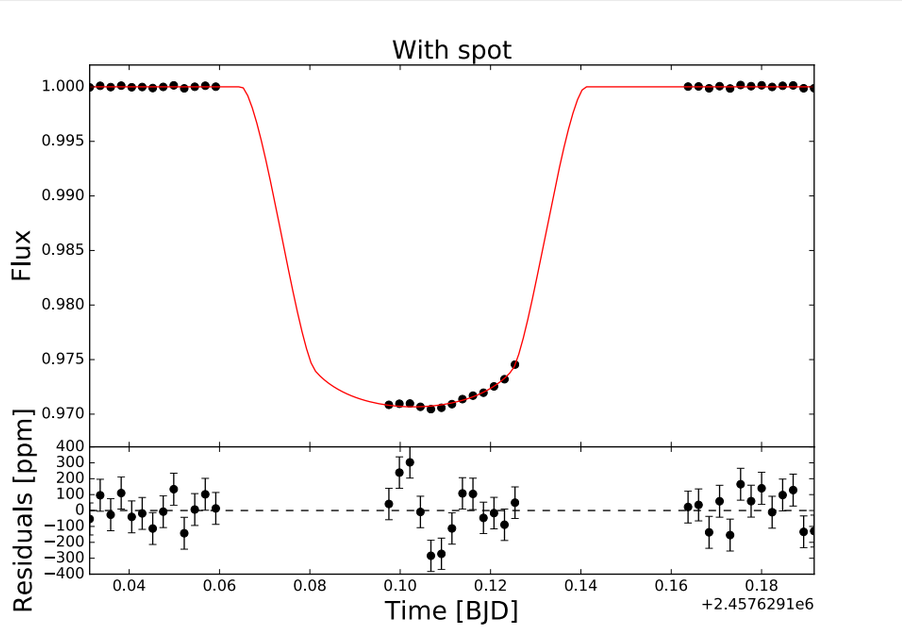
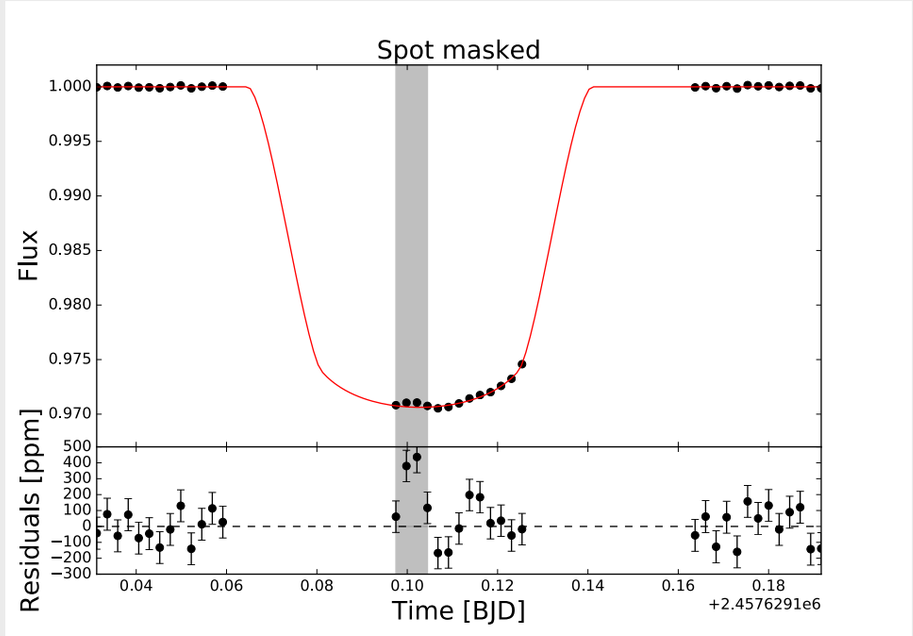
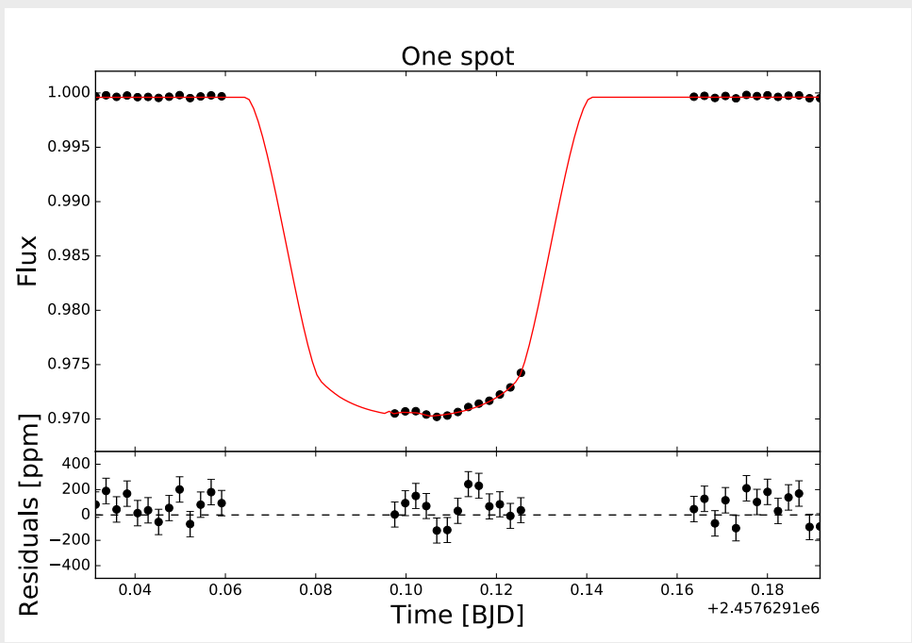
How do different approaches compare?

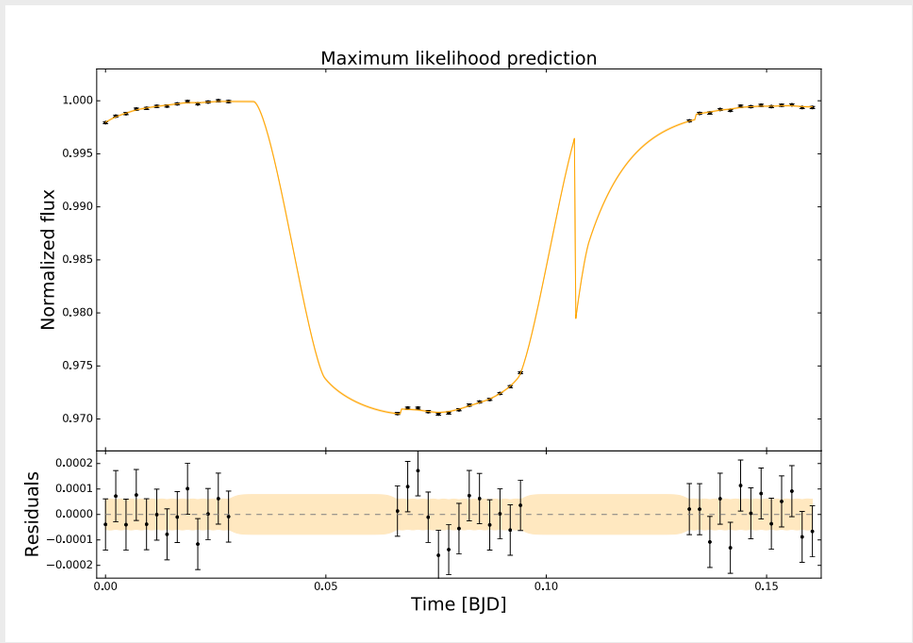




Standard - no masking

Standard - masking



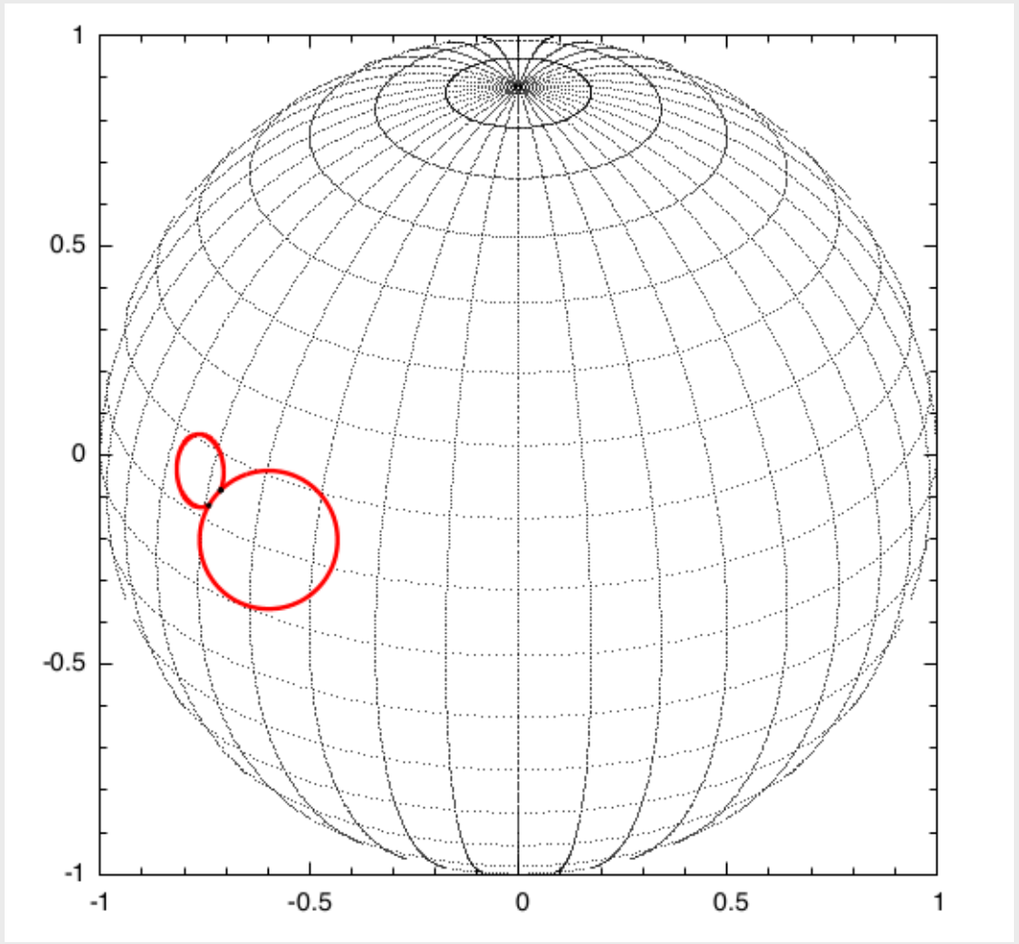


Spot modeling

Gaussian processes

Bruno et al., in prep.

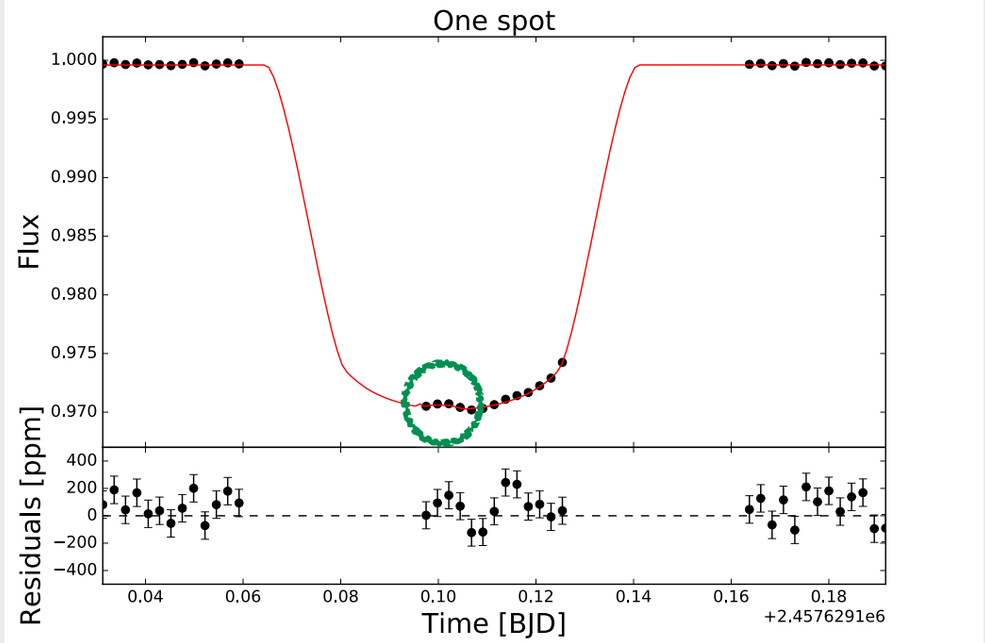
Starspot(s) + HST systematics model



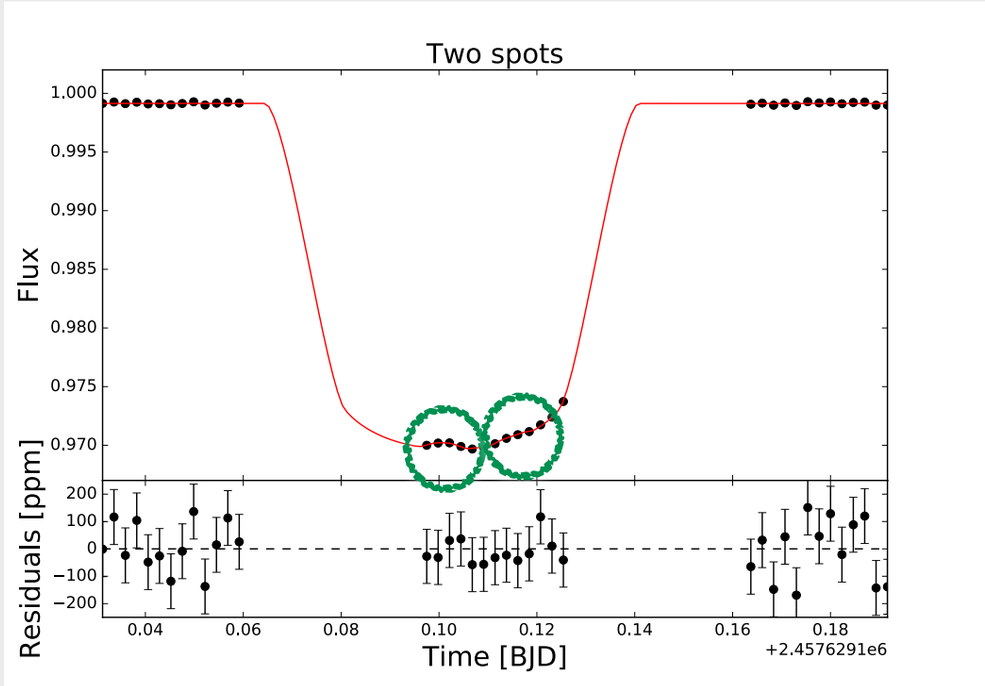
KSint (Montalto et al. 2014)

- Geometric configuration
- Analytic starspot modeling - fast!
- Implemented in MCMC software (MC^3, Cubillos et al. 2016)

1)

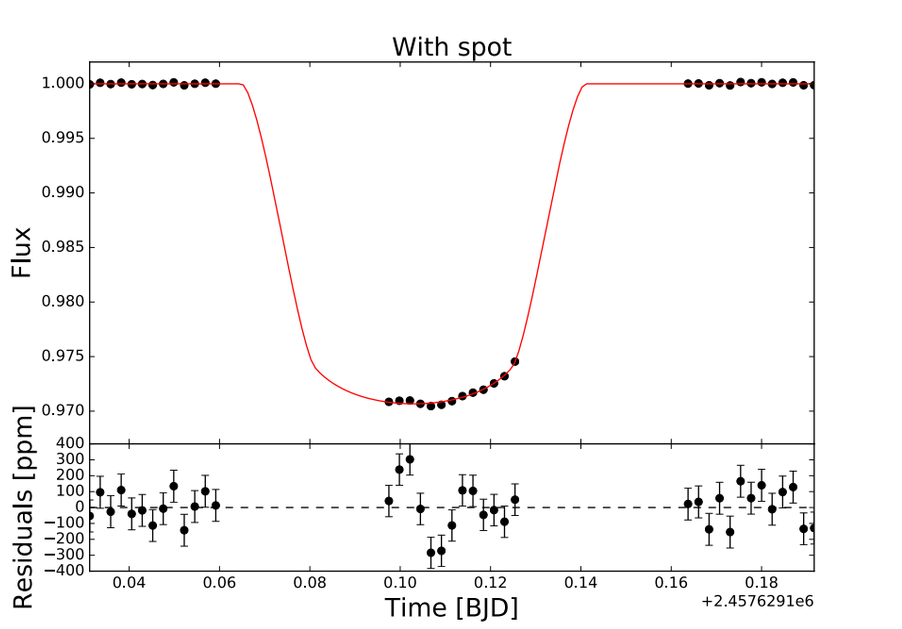


2)

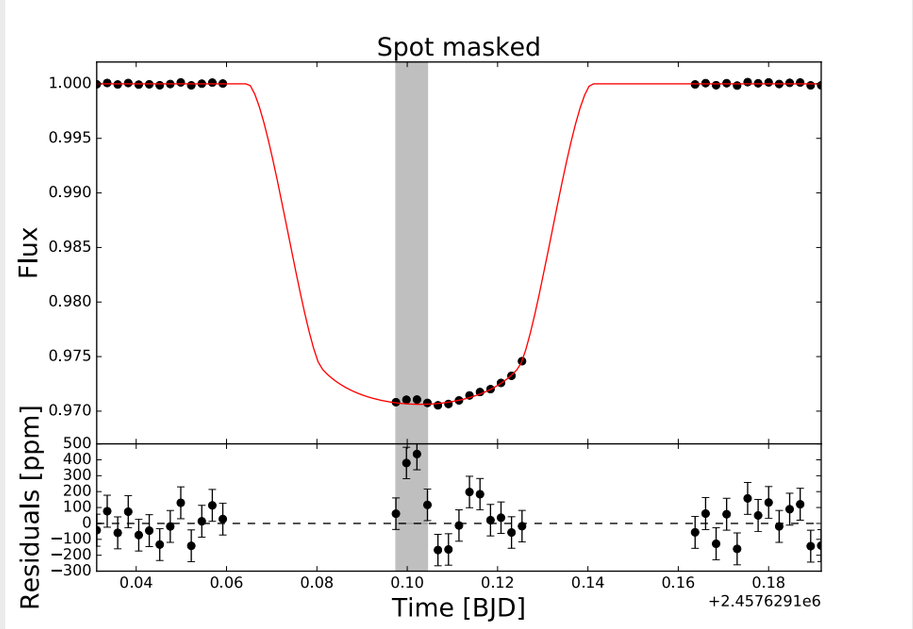


Bruno et al., in prep.

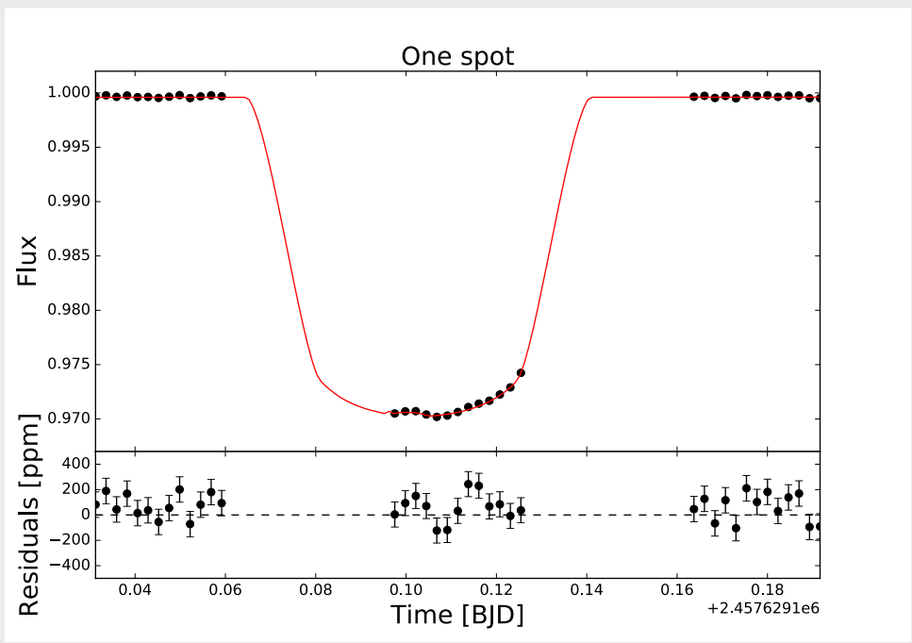
Spot modeling helps for band-integrated transit



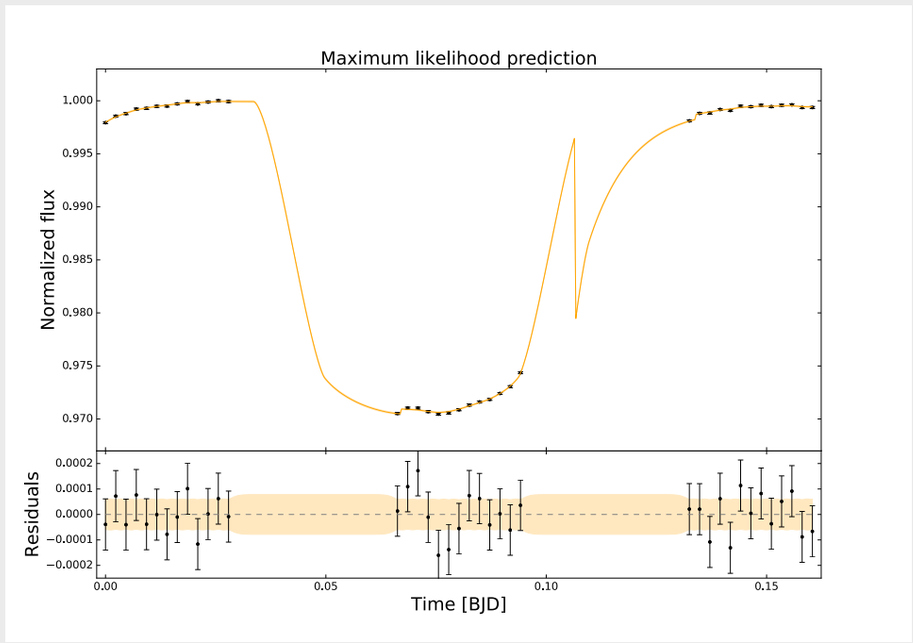
1.96



1.43



1.37-1.13

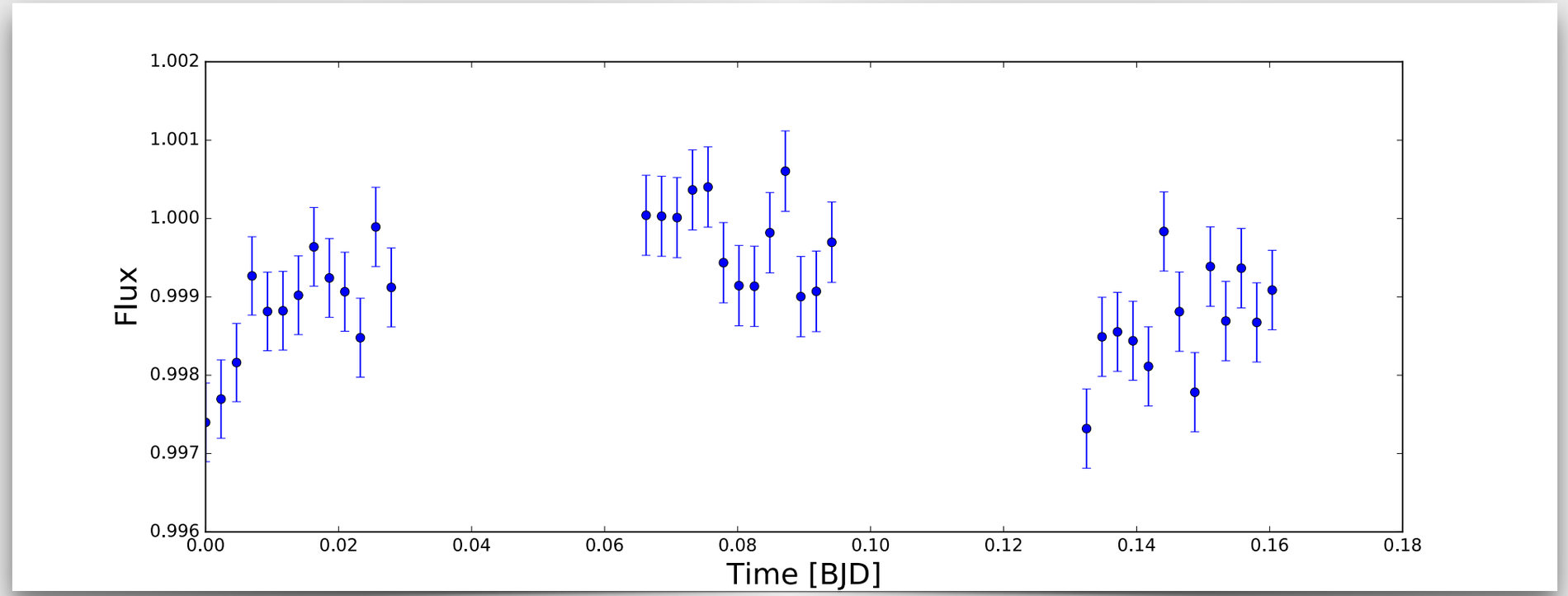


1.13?

Bruno et al., in prep.

Varying contrast and limb darkening coefficients

Common-mode correction



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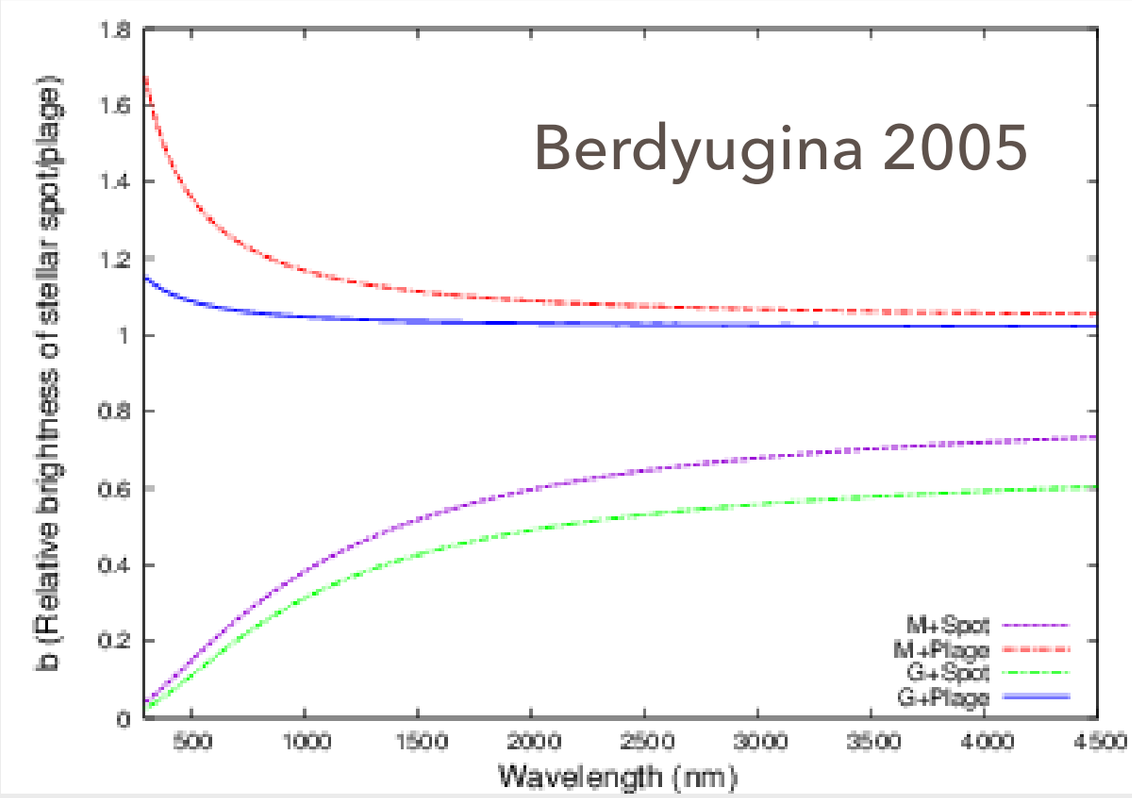
Varying contrast and limb darkening coefficients

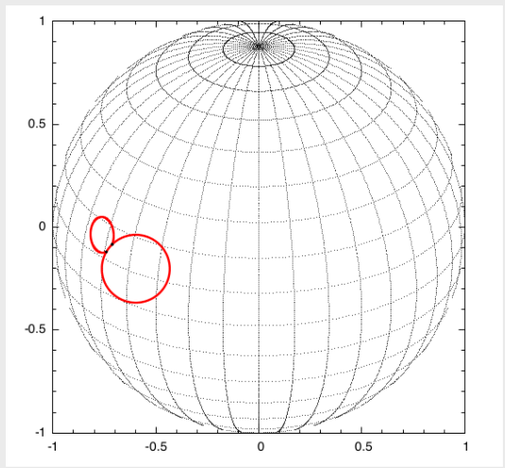
Common-mode correction

or



Oshagh et al. 2014

Free parameter



PHOENIX stellar models

Exoplanet Characterization Toolkit

ExoCTK

https://exoctk.stsci.edu/

Fixed

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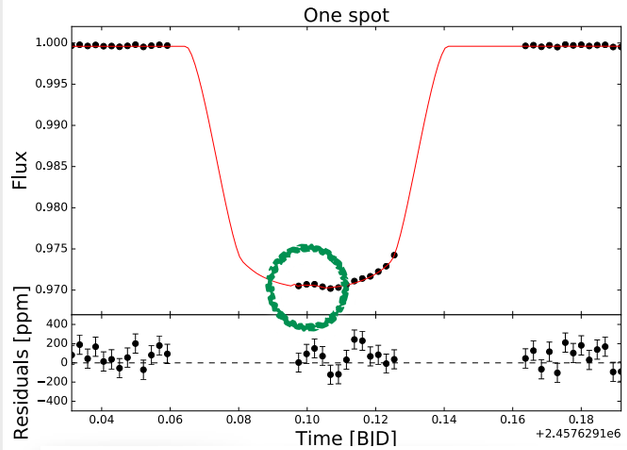
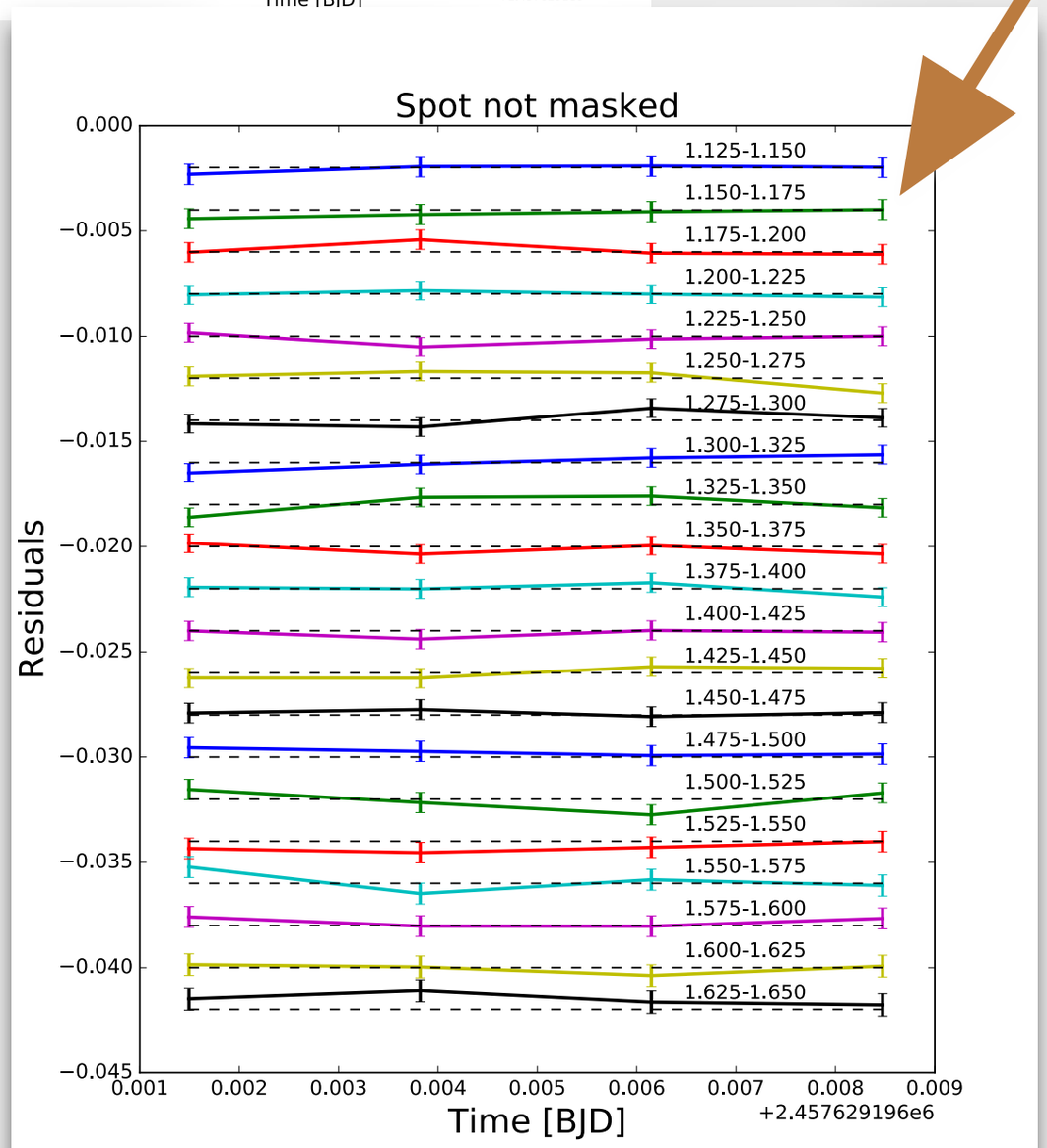
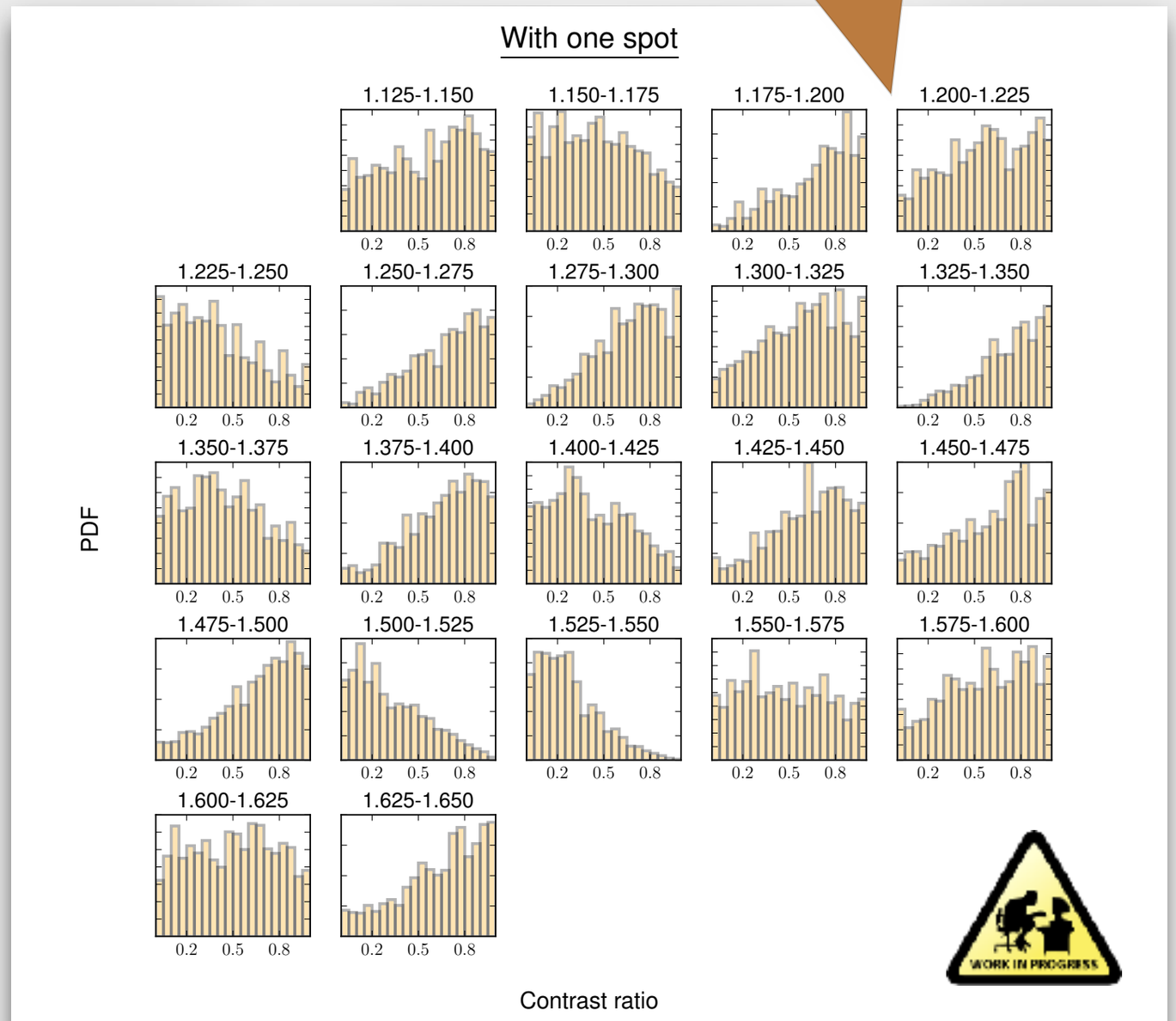
Does spot modeling for every channel help?



Residuals - no spot model



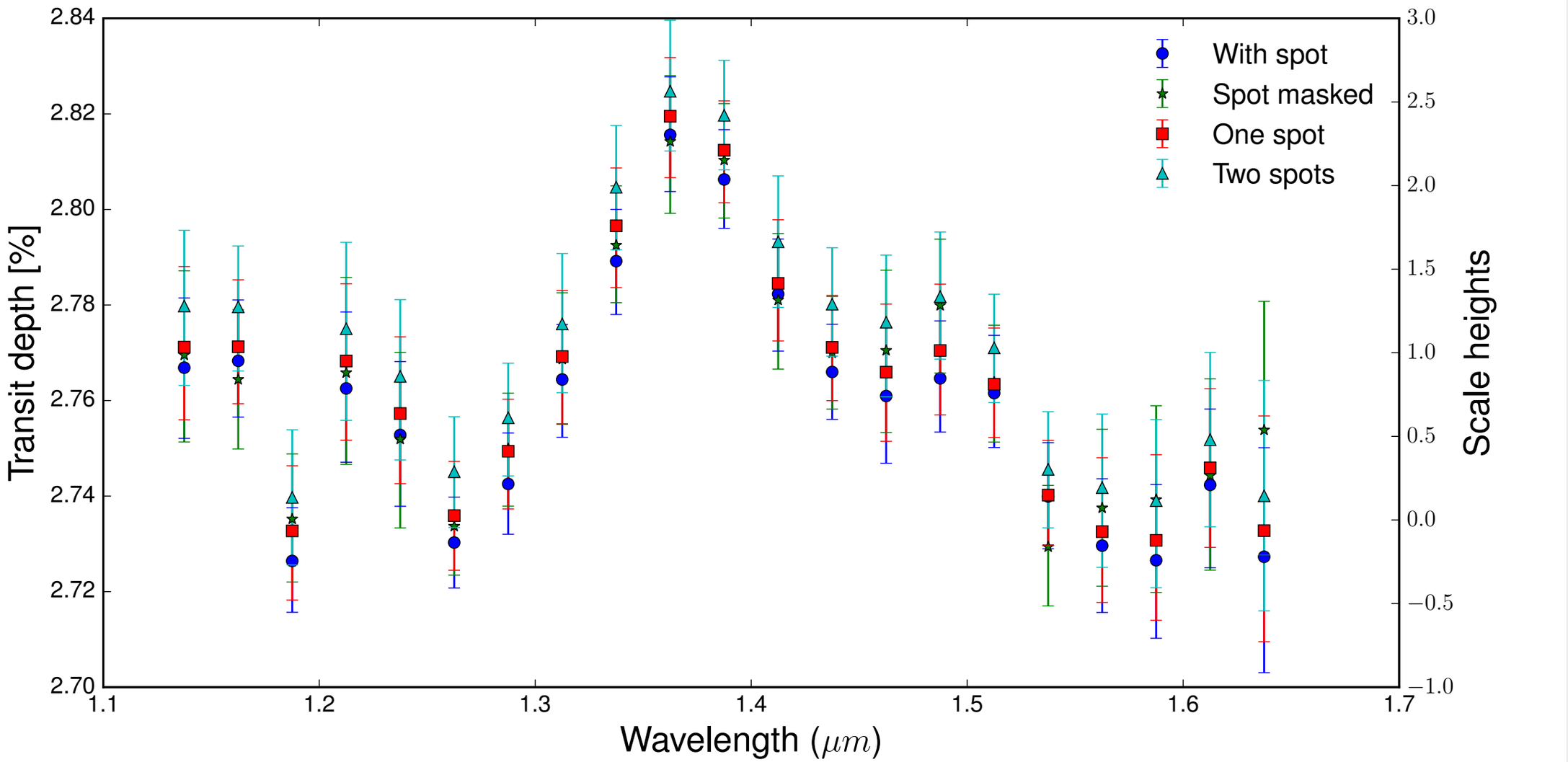
Contrast posteriors



Spot contribution ~ noise

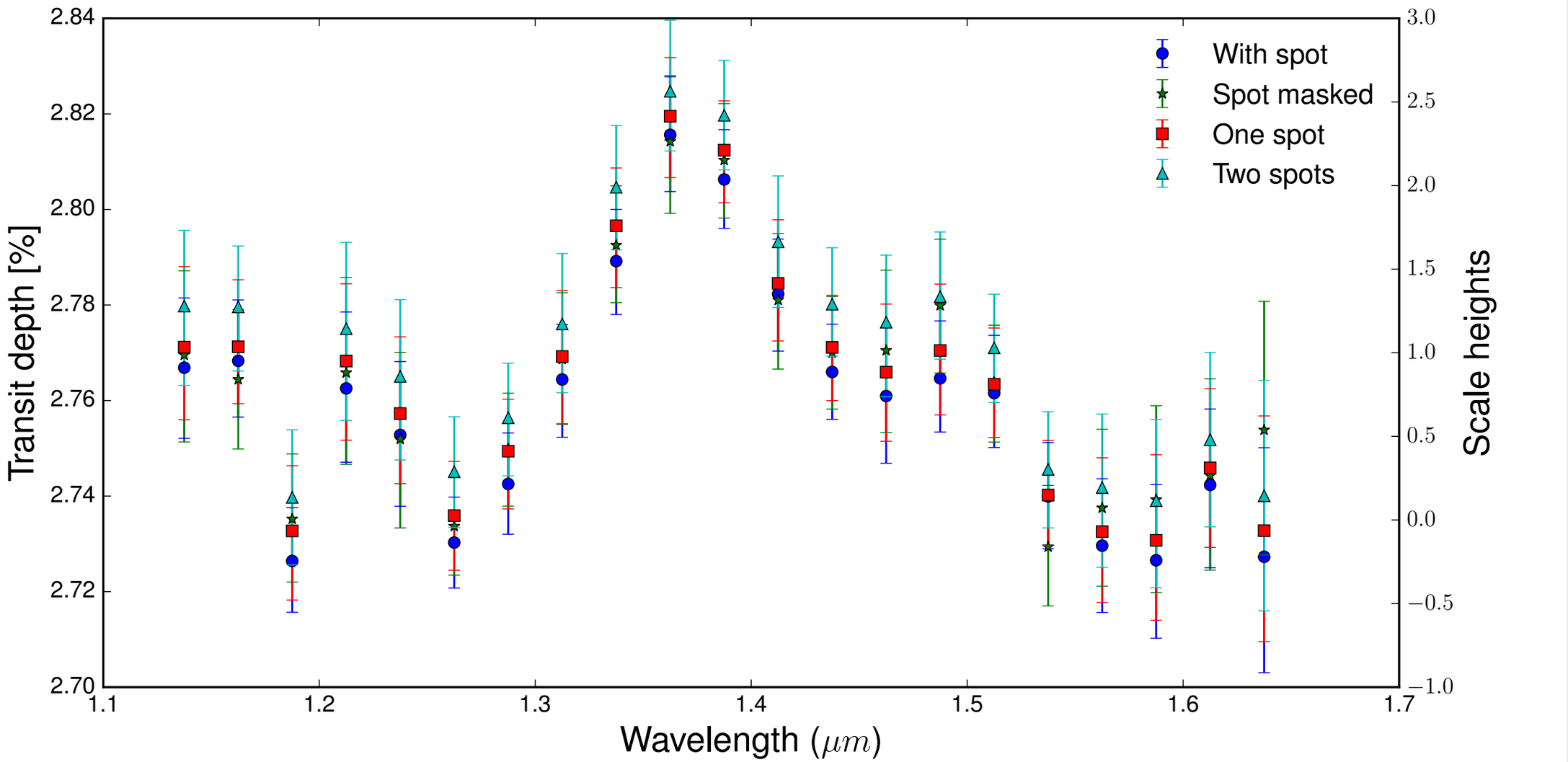
Bruno et al., in prep.

Common mode correction, enough for this dataset?

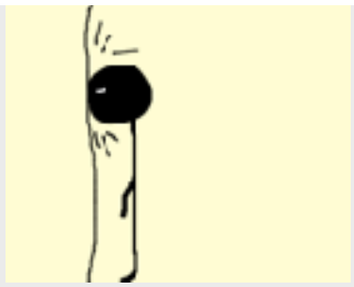


Bruno et al., in prep.

Common mode correction, enough for this dataset?



GP coming soon (hopefully)



Bruno et al., in prep.

Conclusions

- Common-mode correction robust against starspots?
- Other stars, general test on synthetic data
- Prepare for JWST observations of active stars
- HST/STIS data – Retrievals on WFC3 + STIS (Alam et al. in prep.)

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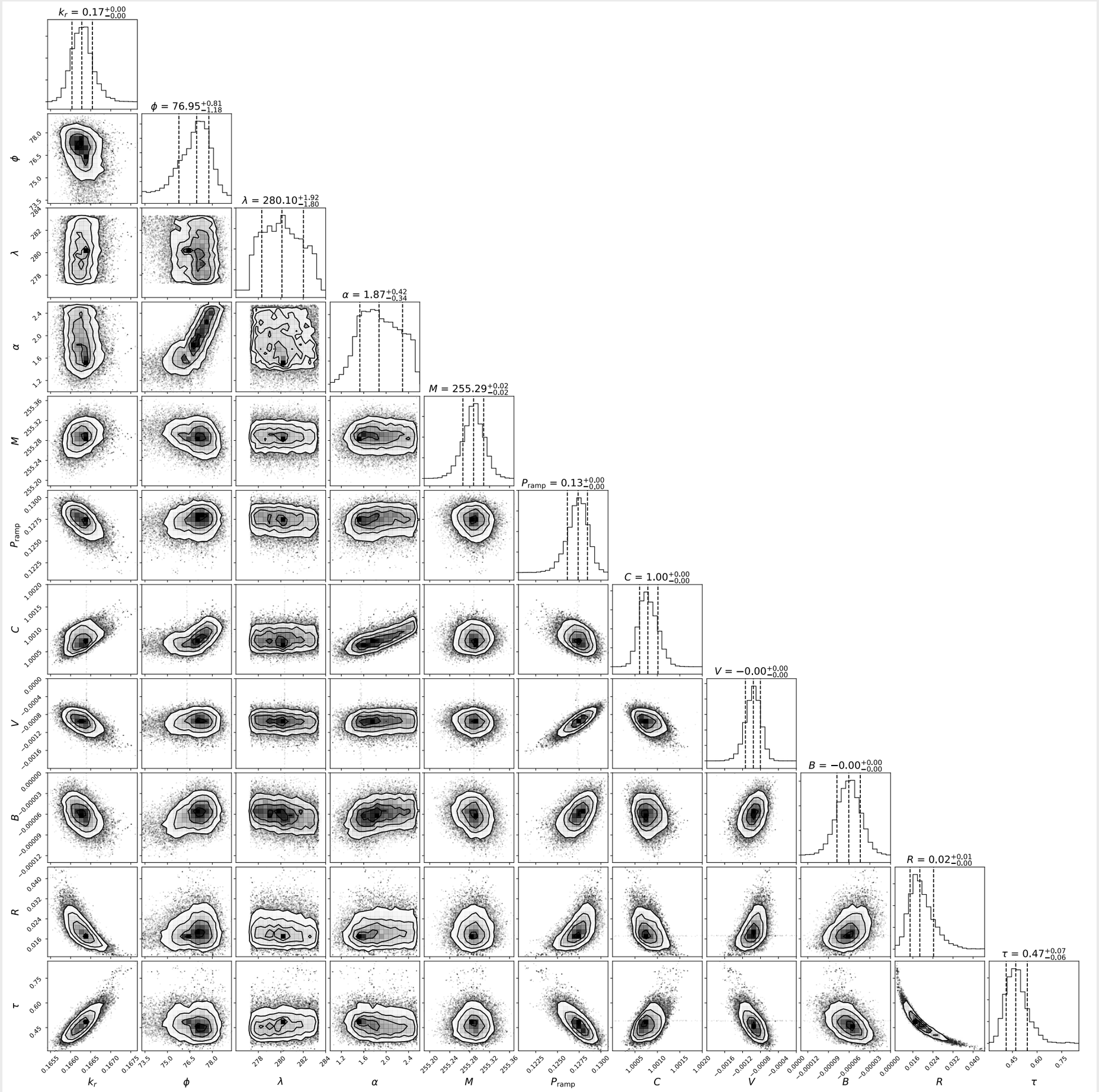
$k_r = 0.17^{+0.00}_{-0.00}$
$\phi = 76.95^{+0.81}_{-1.18}$
$\lambda = 280.10^{+1.92}_{-1.80}$
$\alpha = 1.87^{+0.42}_{-0.34}$
$M = 255.29^{+0.02}_{-0.02}$
$P_{\mathrm{ramp}} = 0.13^{+0.00}_{-0.00}$
$C = 1.00^{+0.00}_{-0.00}$
$V = -0.00^{+0.00}_{-0.00}$
$B = -0.00^{+0.00}_{-0.00}$
$R = 0.02^{+0.01}_{-0.00}$
$\tau = 0.47^{+0.07}_{-0.06}$
k_r
ϕ
λ
α
M
P_{ramp}
C
V
B
R
τ