Precision Photometry for Exoplanet Atmospheric Characterization with WIRC-POL

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Why do we need high precision photometry?

Detecting shallower transits and eclipses

Measuring better transit and eclipse parameters

Enabling reliable ground based follow-up

Breaking model degeneracies

WIRC-POL

Newly commissioned instrument on the Hale Telescope

Diffuser-mode	Broadband photometry J, H, K diffuser-assisted
Grism-mode	Spectroscopy J, H, K with R~200
Polarizing Grating-mode	Spectro-polarimetry J, H with R~100-150 Simultaneous Stokes Q, U measurements

Why WIRC-POL?

Wide field: 8.4 arcmin by 8.4 arcmin
(more comparison stars)

Novel diffuser-assisted photometry
(smoother and steadier images)

Large telescope size: 5m telescope
(smaller photon-noise limit)

Ways to improve photometric precision

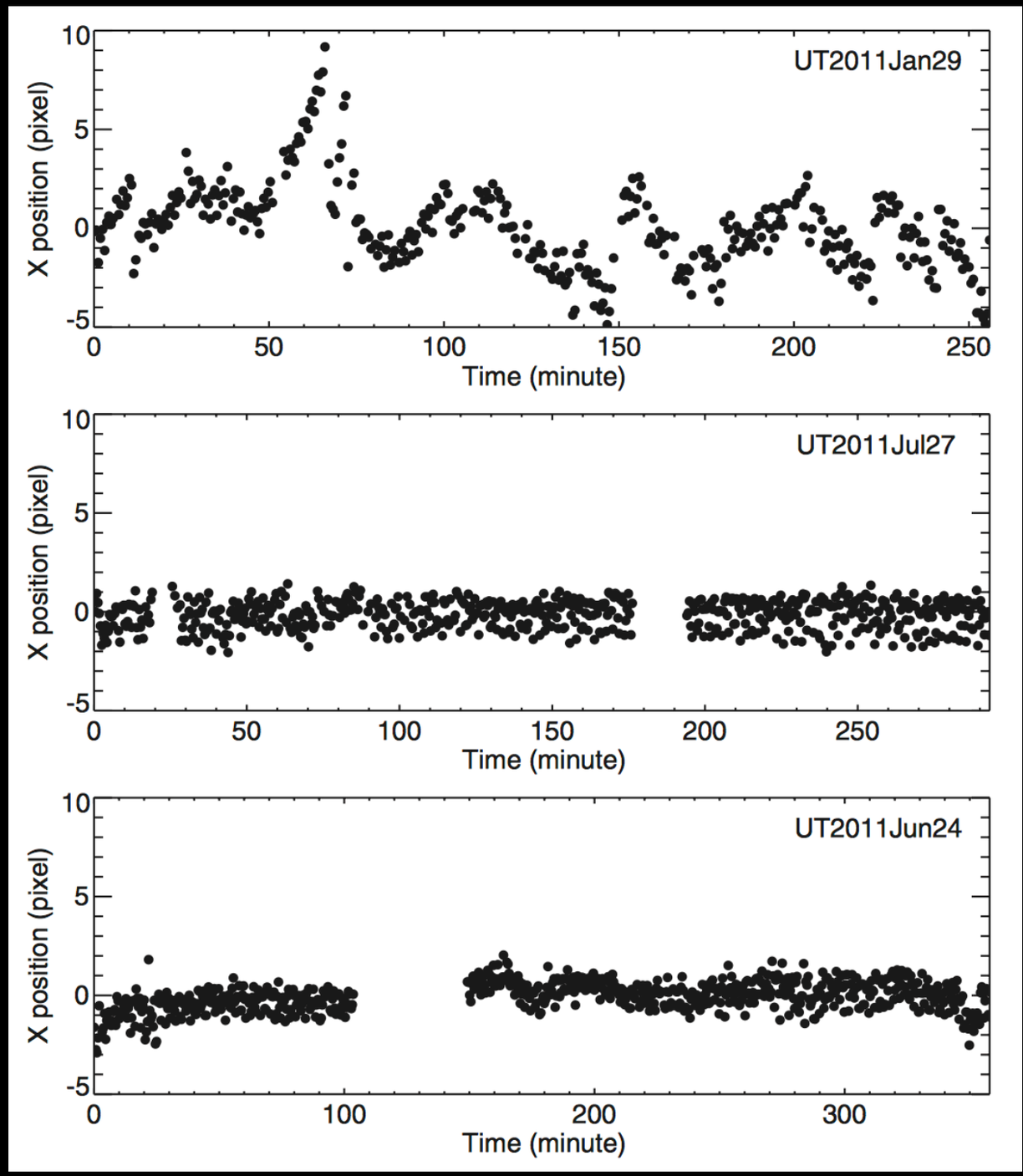
Better guiding

Better detector calibration

Steadier PSF

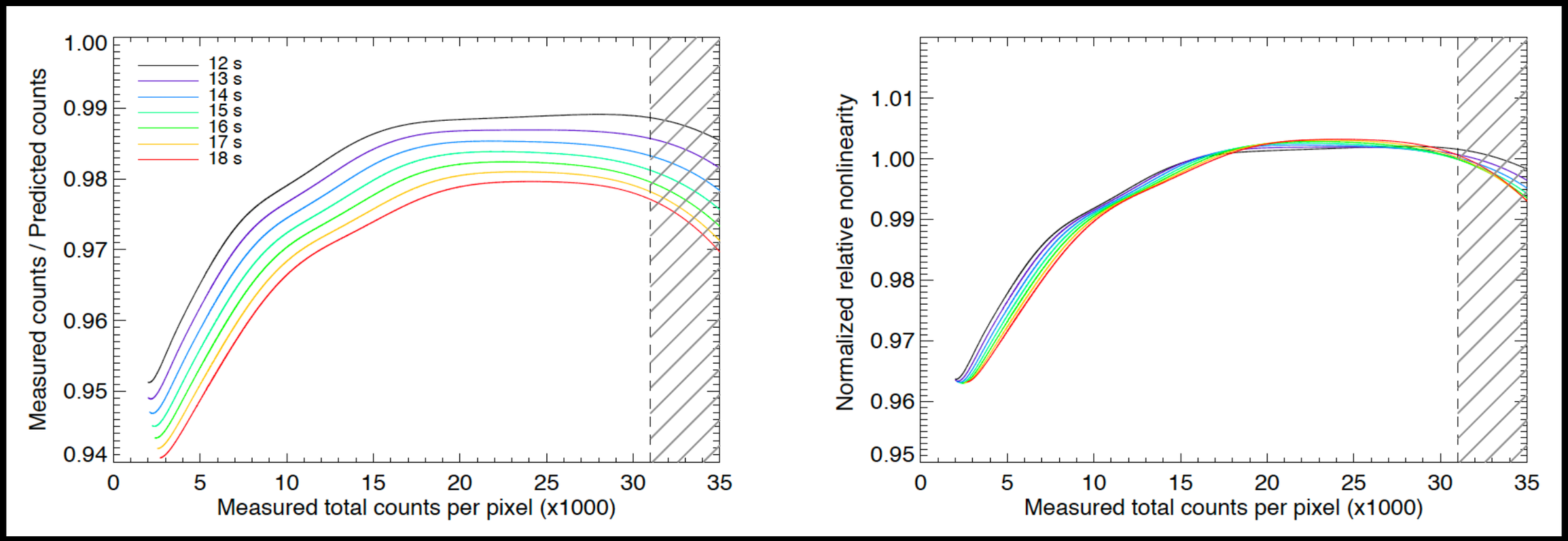
Guiding

Need precise guiding
to minimize pointing errors



(Zhao et al. 2012)

Detector Calibration

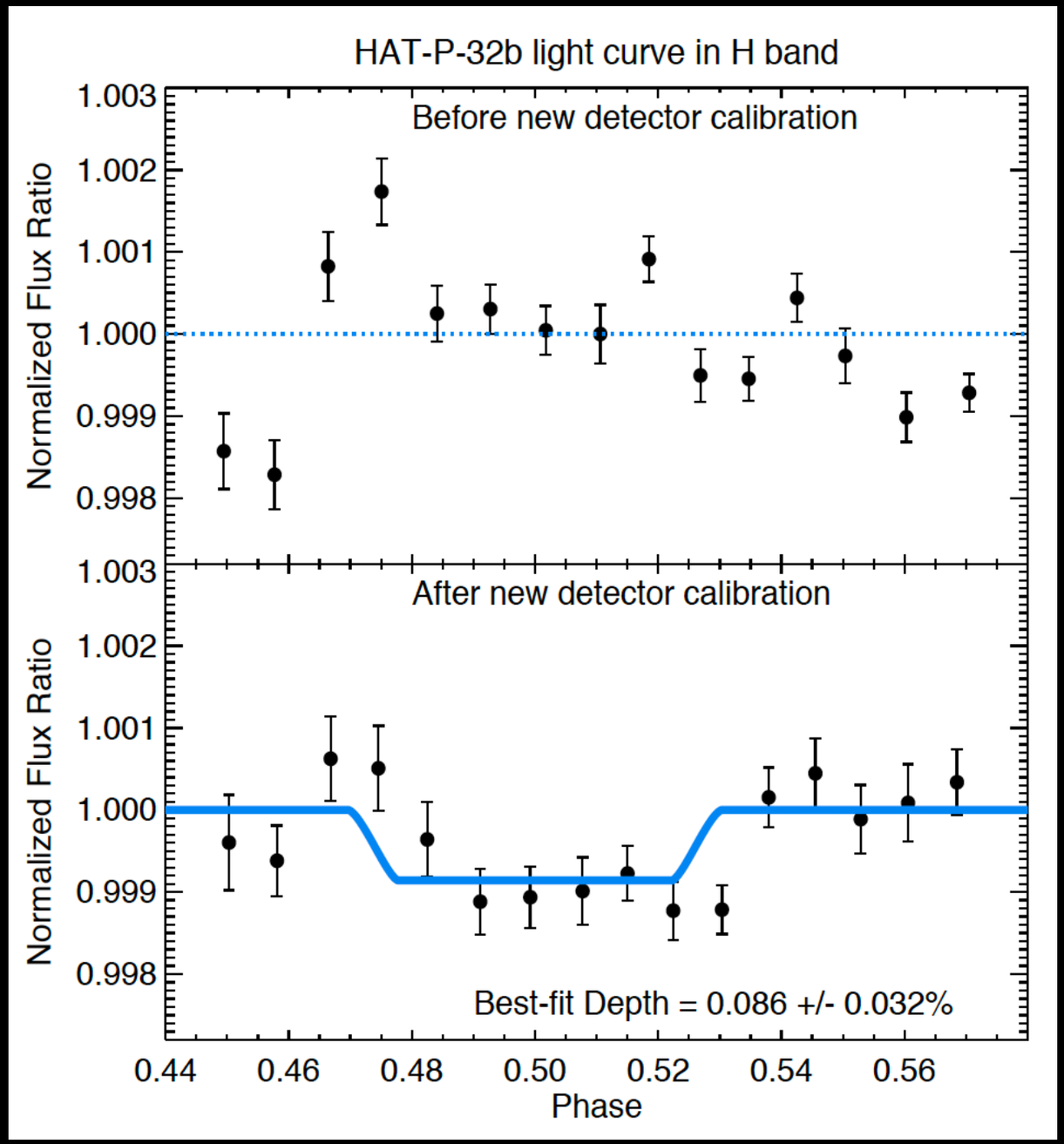


(Zhao et al. 2014)

In NIR detectors, nonlinearity is both count-dependent and flux-dependent.

Detector Calibration

Shallow transits (<1000 ppm) will be much harder to detect if the nonlinearity effect is not corrected.



(Zhao et al. 2014)

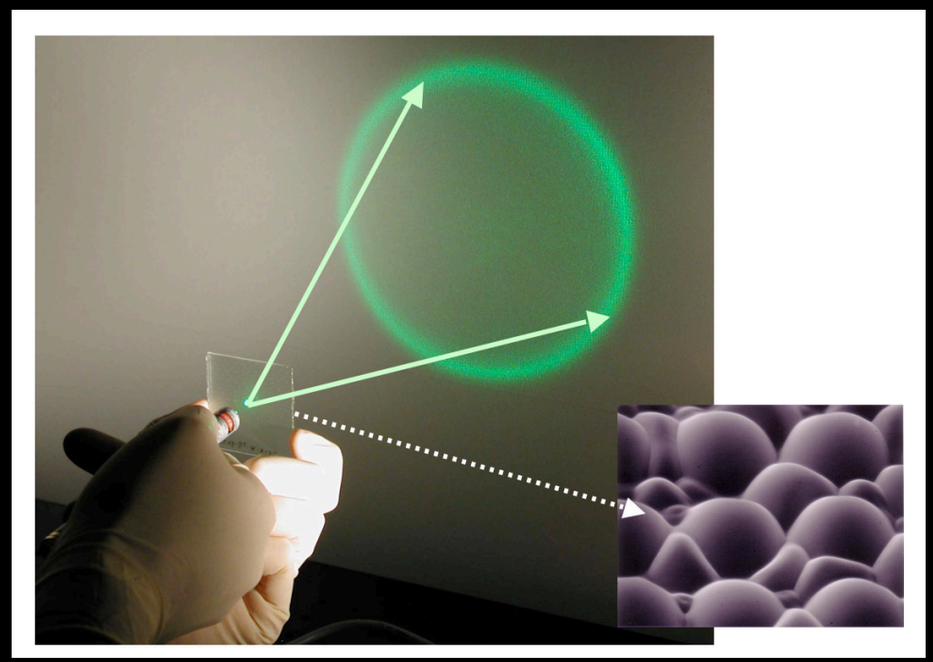
Stable PSF

Advantages of diffuser

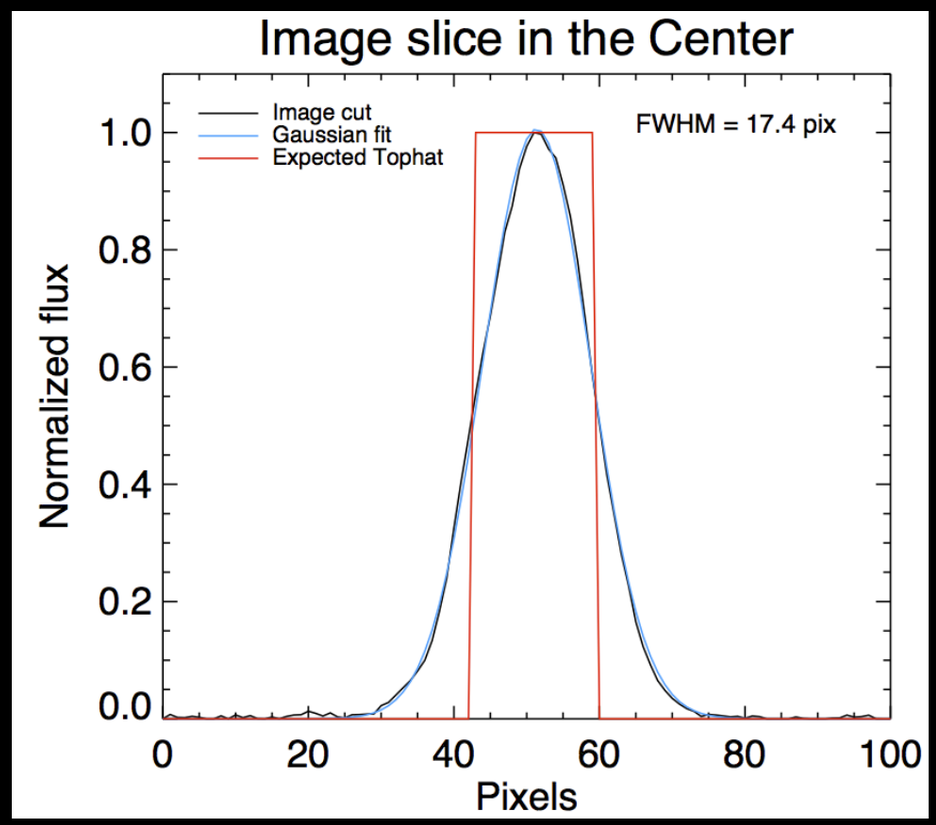
Stabilize the PSFs of targets

Improve the observing efficiency

Minimize the flat-fielding error

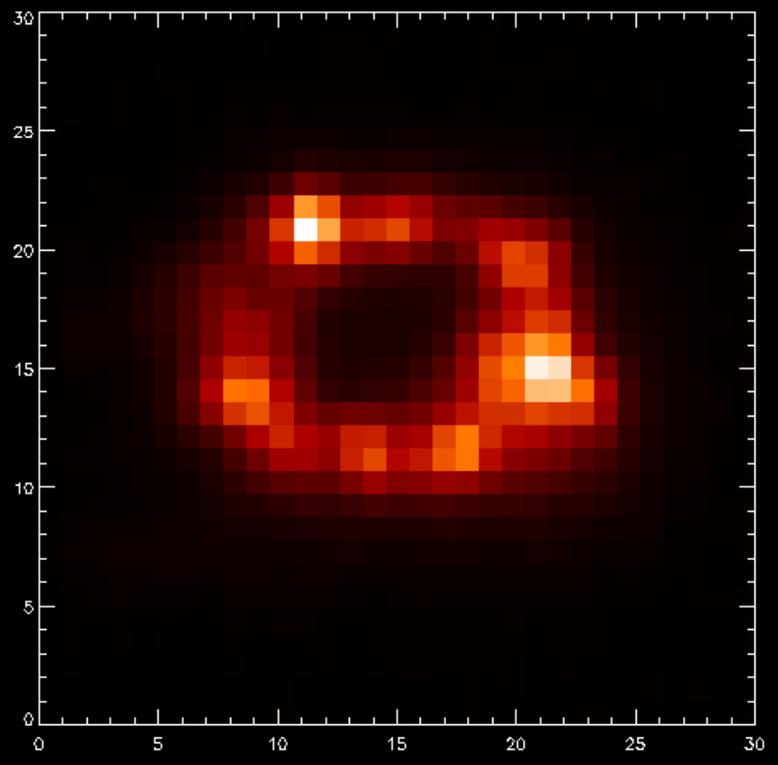


(credit:
RPC photonics)

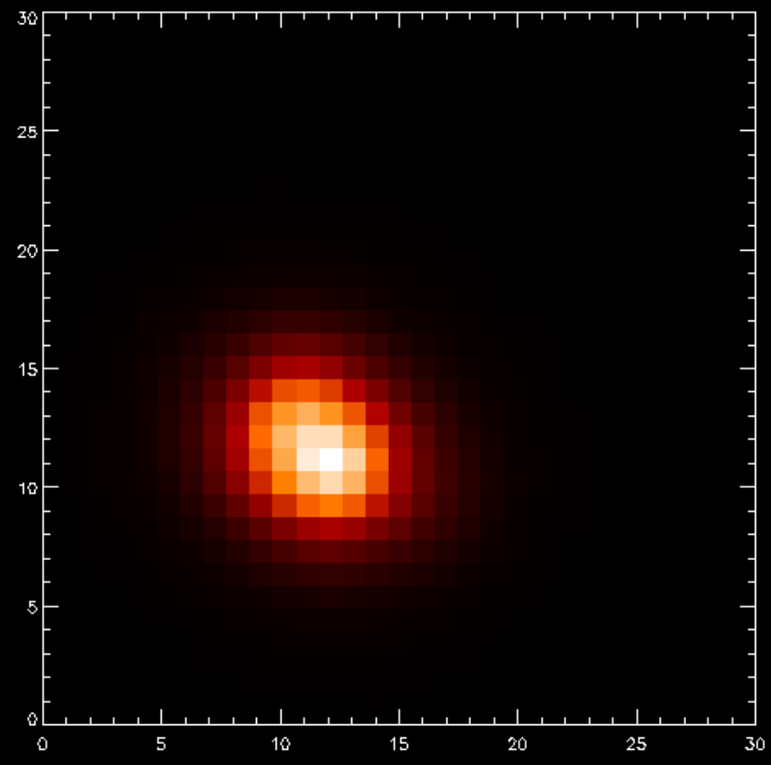


(credit:
Ming Zhao)

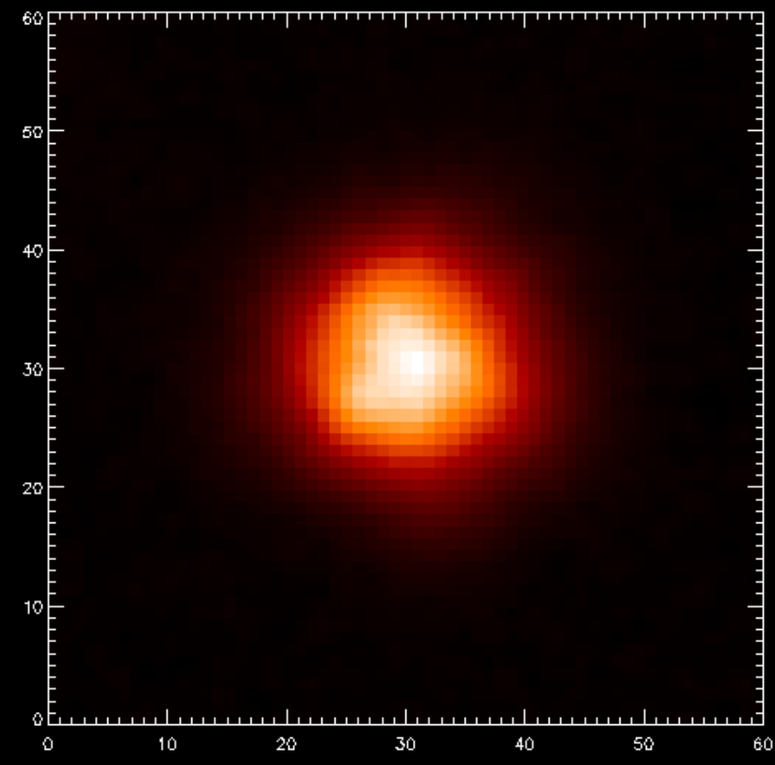
Stable PSF



defocused



focused
without diffuser



focused
with diffuser

(credit: Ming Zhao)

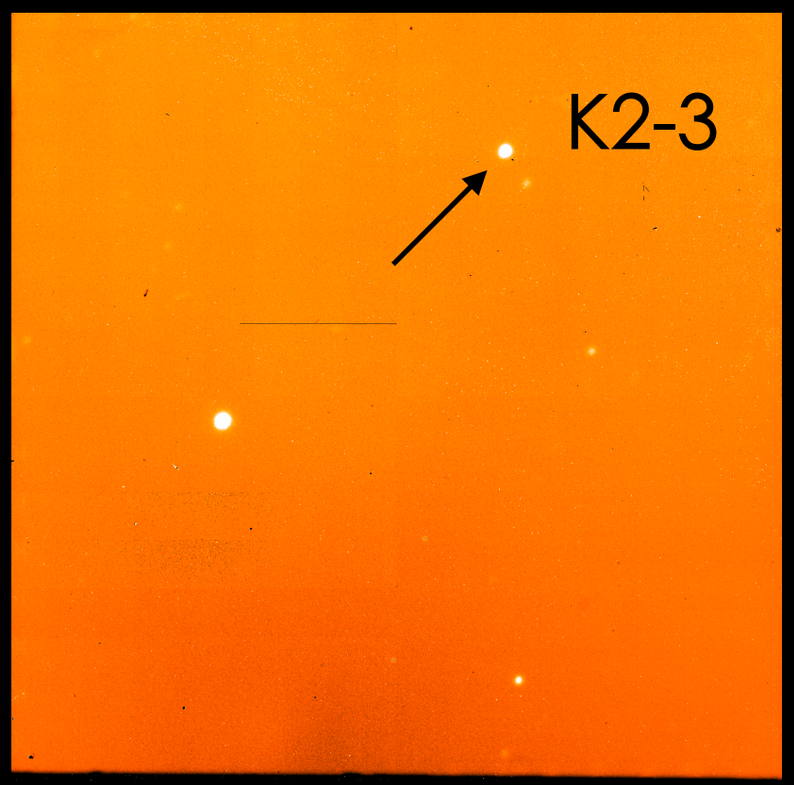
Diffuser stables the PSF much better than the other two techniques.

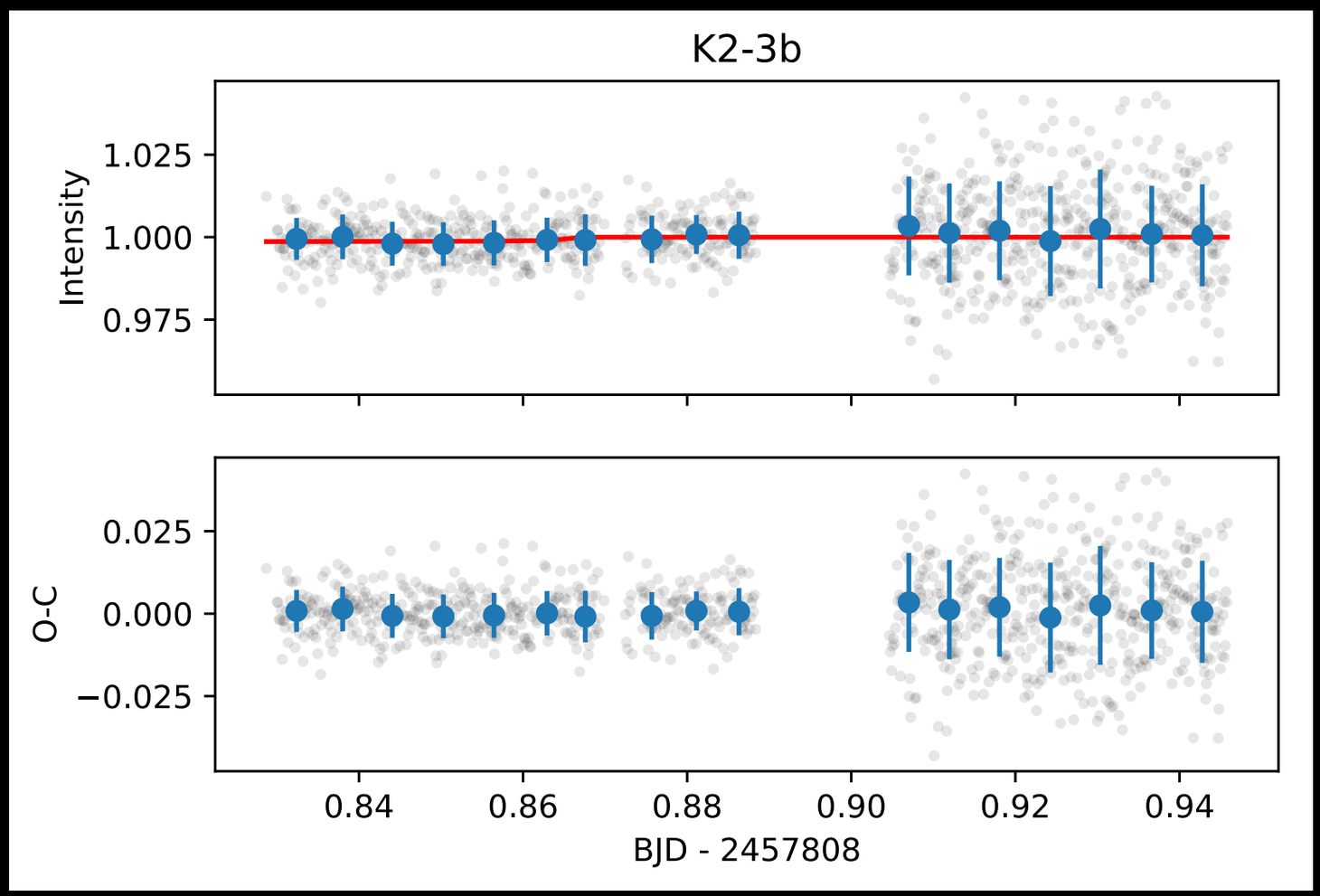
K2-3b (J band, 1.1 to 1.4 micron)

super-Earth
transiting a nearby
M dwarf

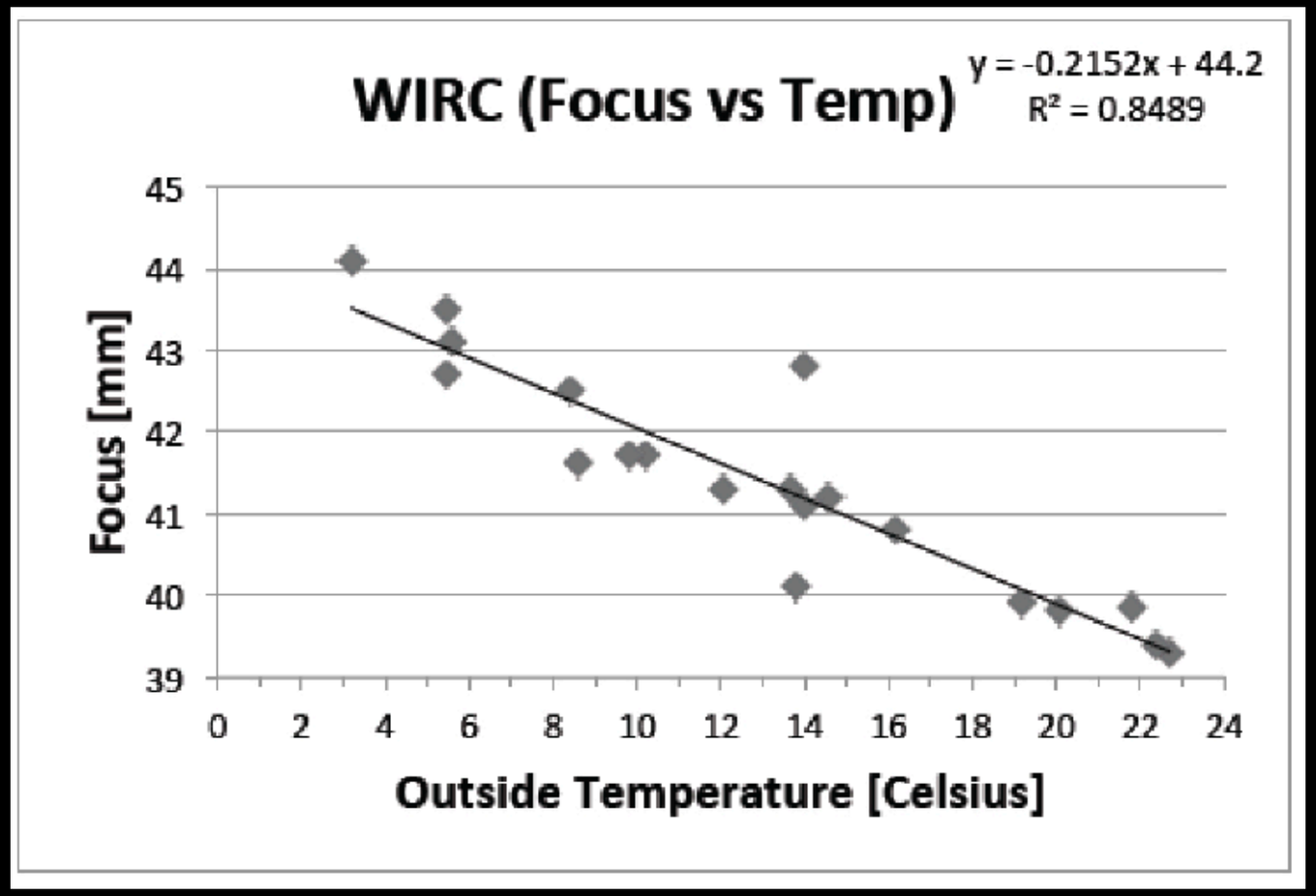
transit depth: ~1200 ppm

ingress not observed





Lessons learned

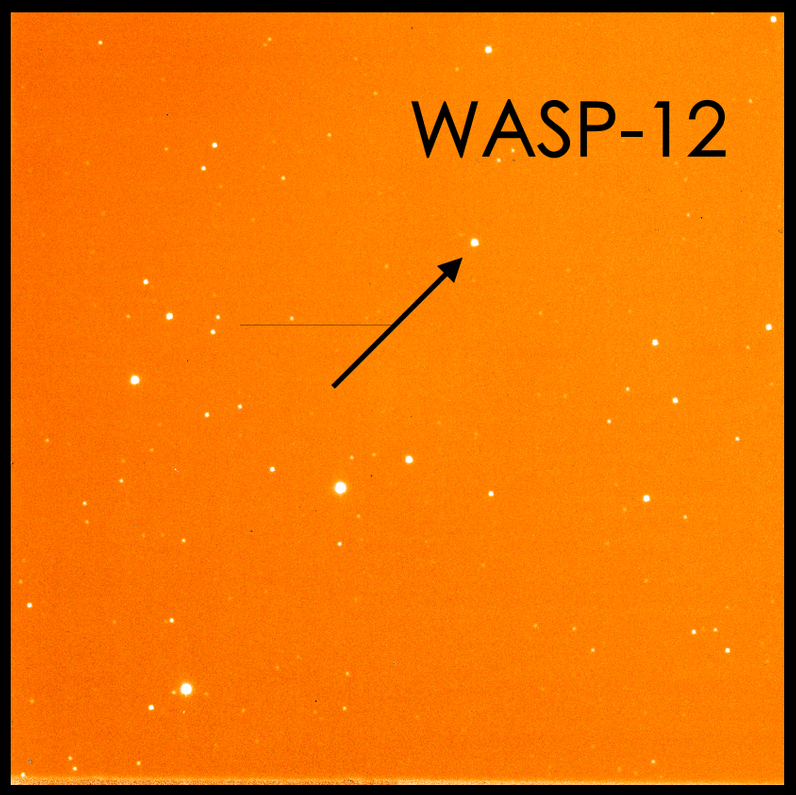


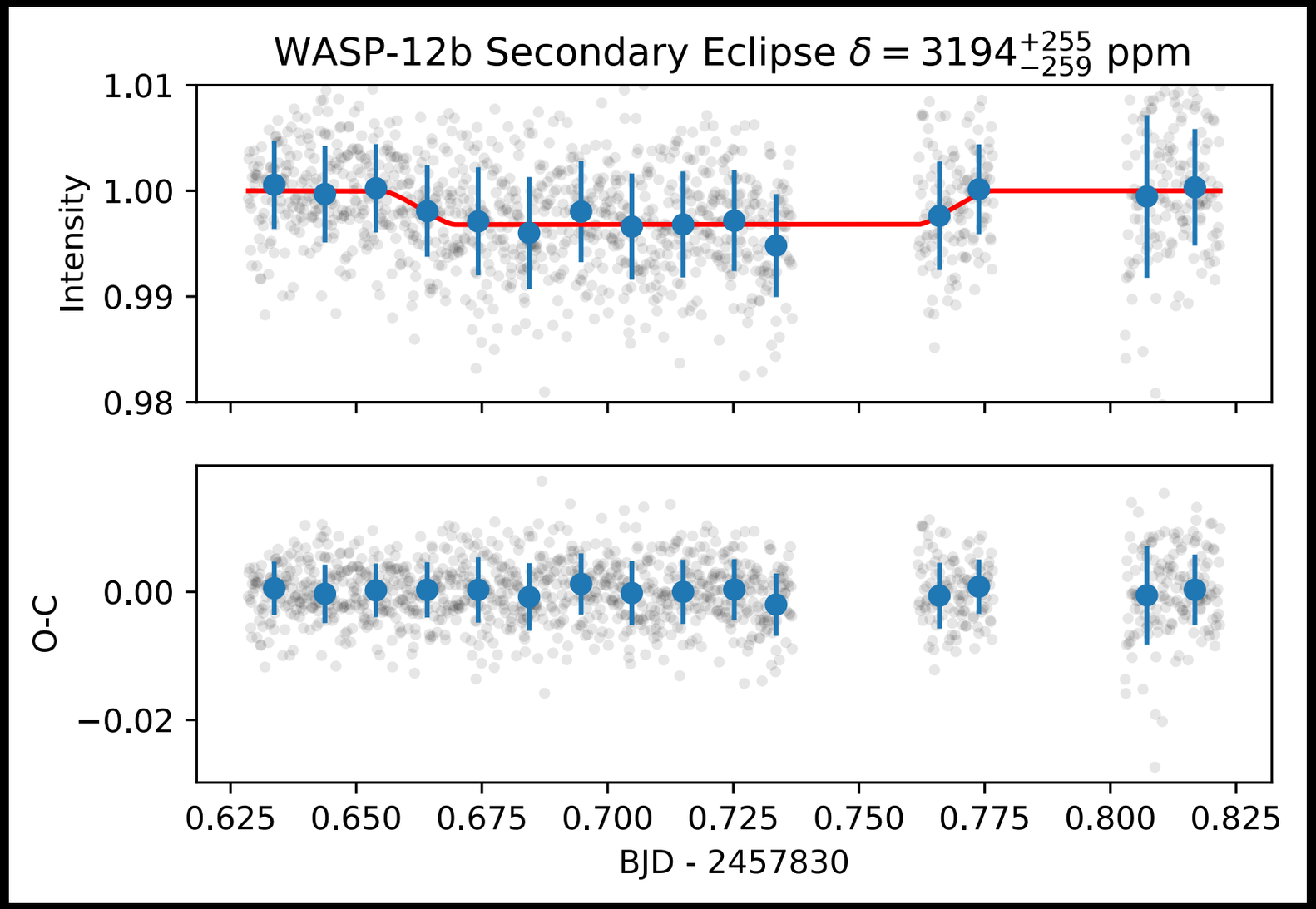
Refocus the telescope
when the outside temperature changes by a lot.

WASP-12b (Ks band, 2.0 to 2.4 micron)

Ks band observations useful for determining water presence

3090 ppm in Ks (Croll et al. 2011)

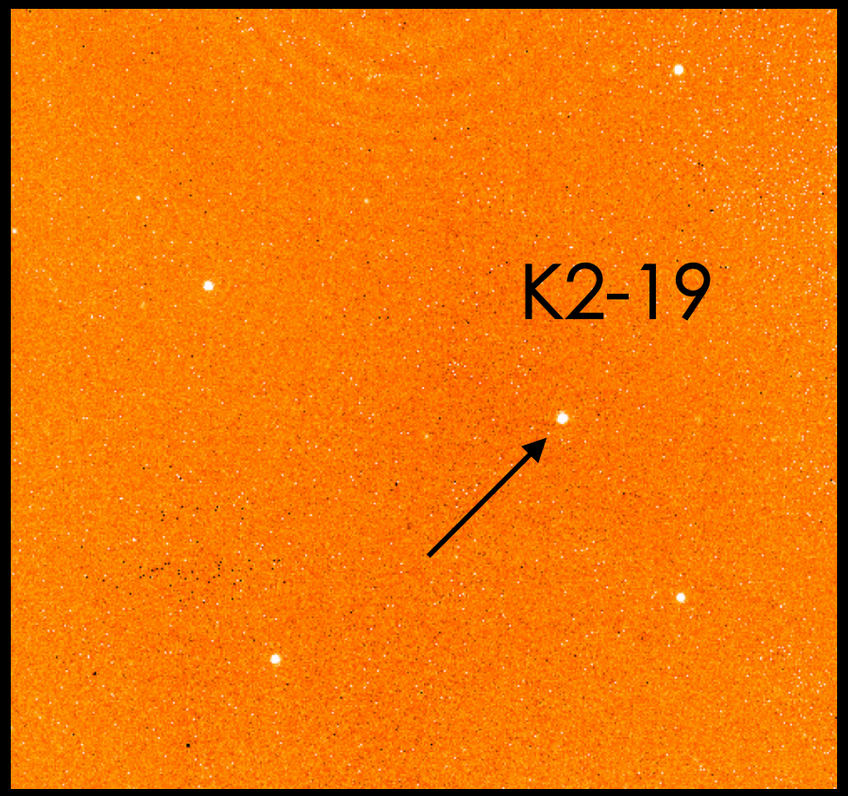


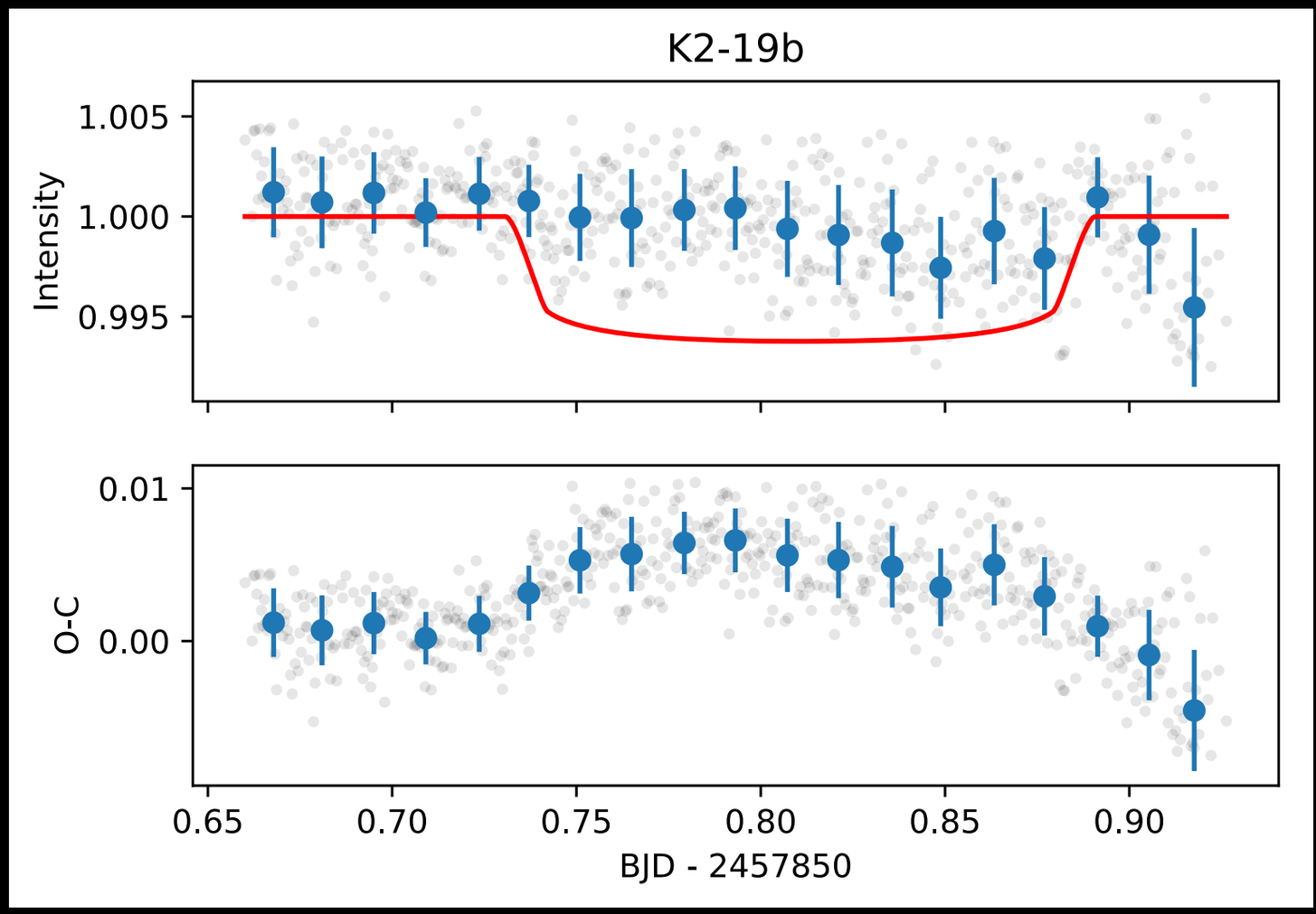


K2-19b (J band, 1.1 to 1.4 micron)

K2-19b/c
close pair of exoplanets
in a 3:2
mean motion resonance

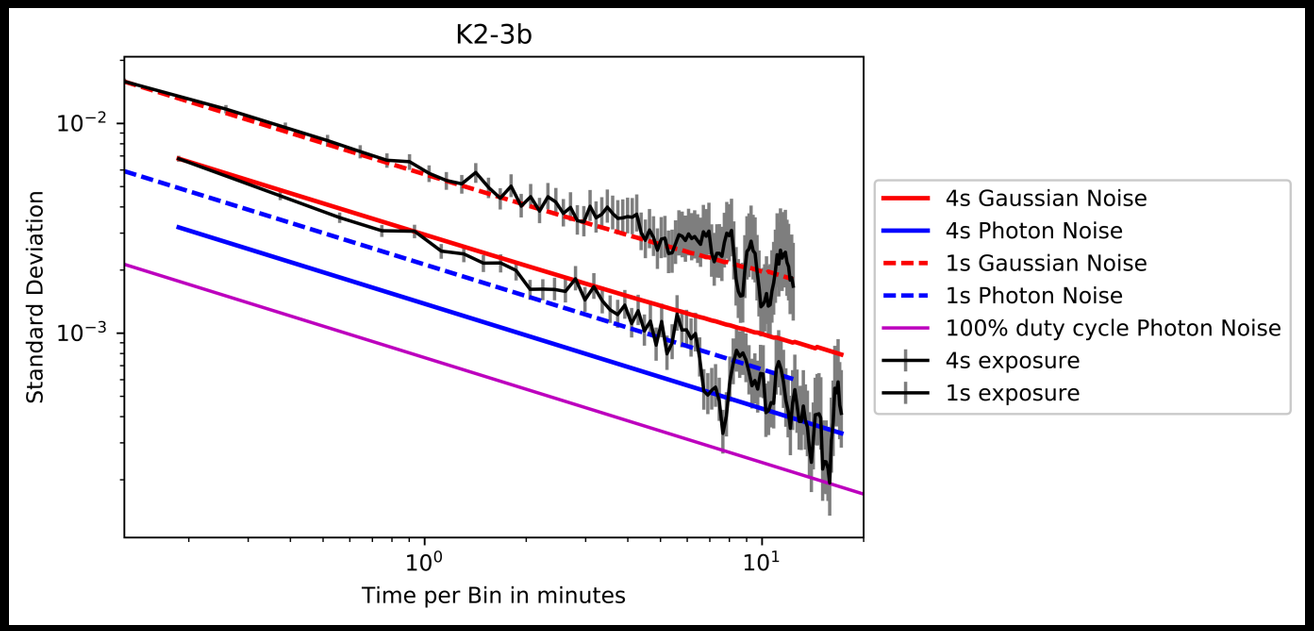
TTV detections could
constrain the masses
better

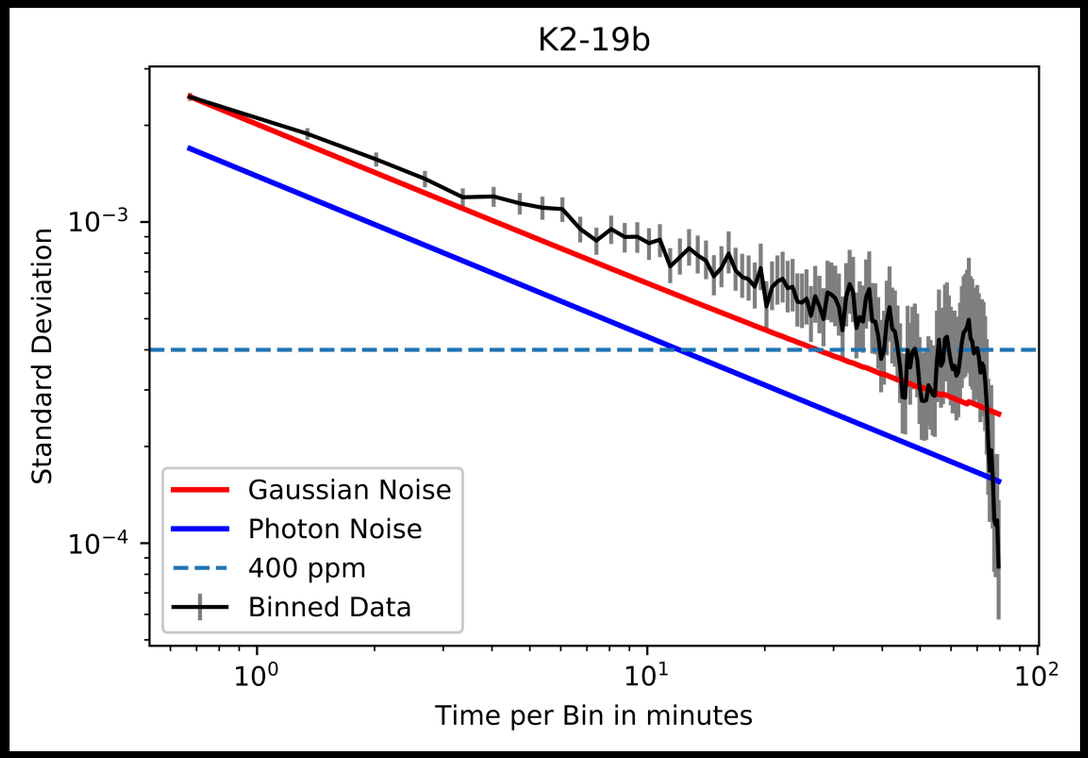


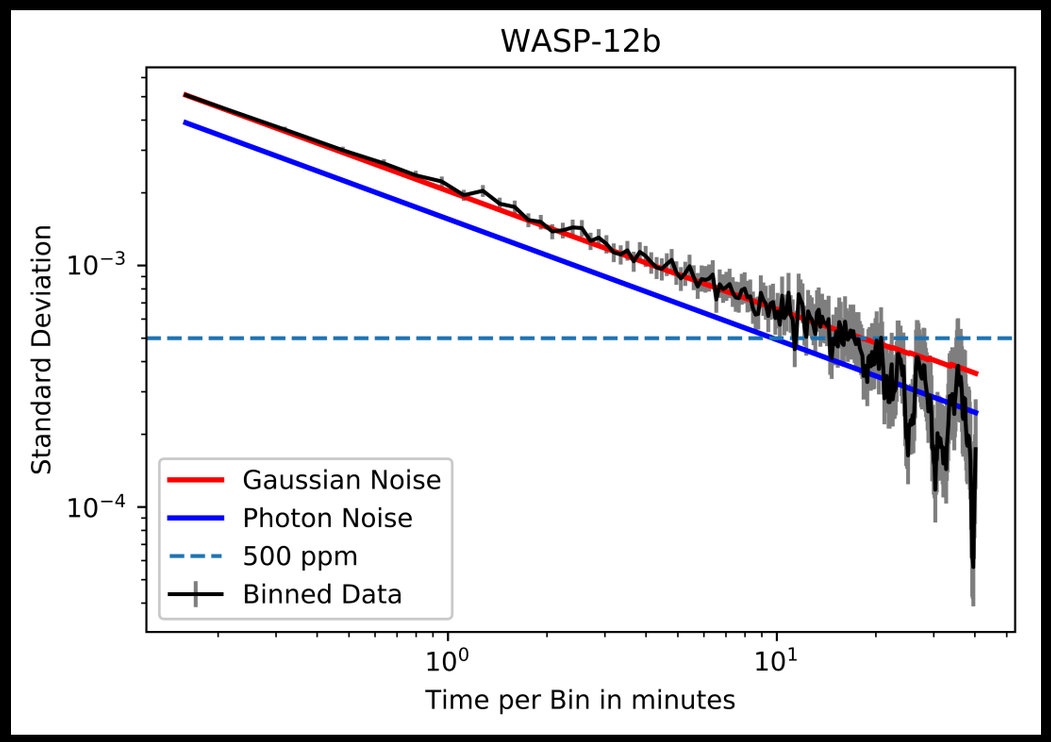


completely missed the transit
due to large TTV ~5 hours

Precision achieved



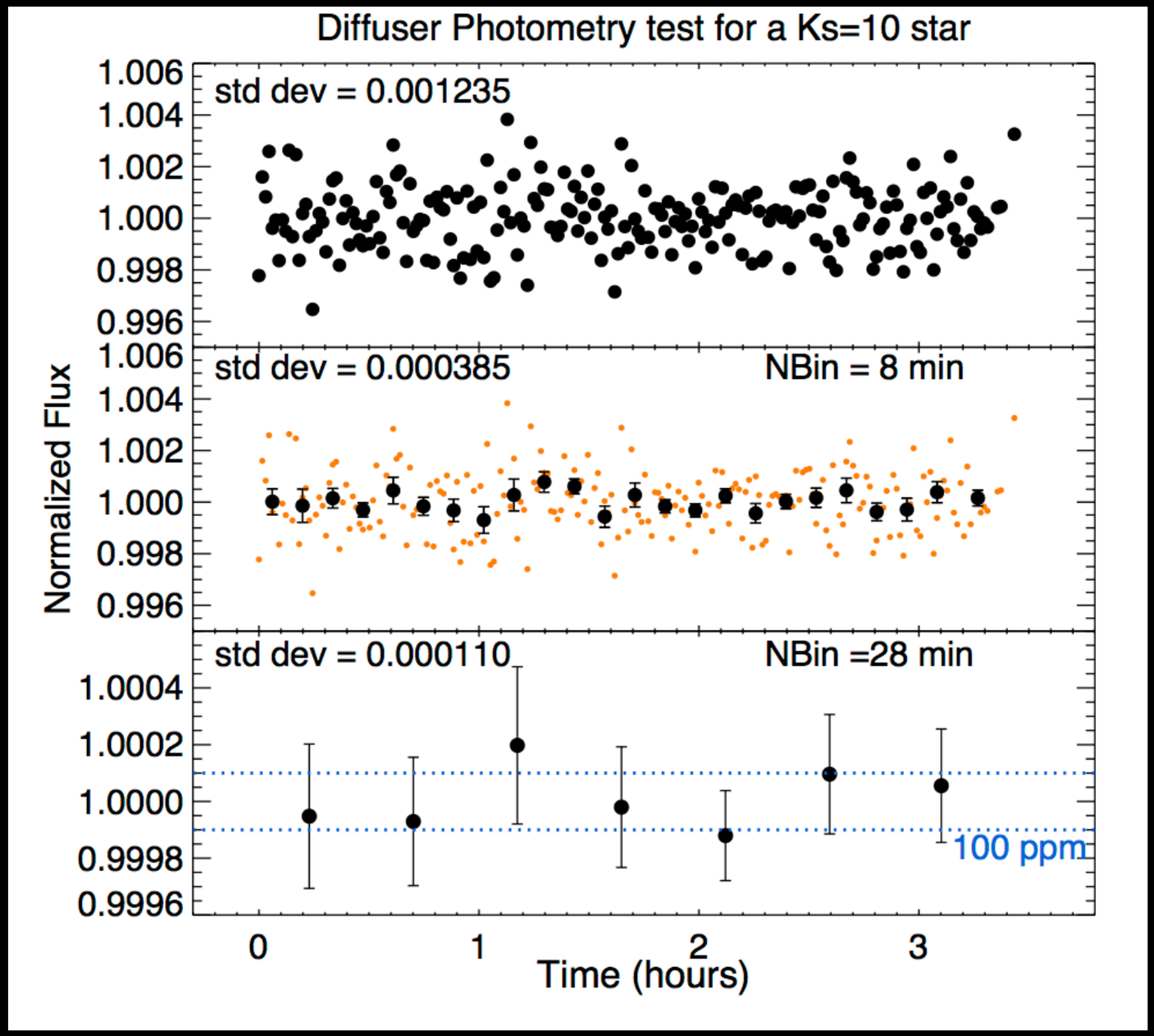




400 ppm in 30 min

1.4 times above the photon-noise limit in Ks (WASP-12b)

Comparison to the old WIRC



WIRC 2013
(before explosive debonding
credit: Ming Zhao)

100 ppm in 30 min

Comparable to
Spitzer precision
for a Ks = 10 star

Future perspectives

- Characterizing the nonlinearity
    - Improve the precision even better
- Observe more targets (summer and fall)
    - WASP-103b, WASP-69b, WASP-74b, TRAPPIST-1b, c, d, e, Kepler-29b and Kepler-36c
- WIRC-POL will be a prime ground based facility for TESS/ JWST follow-up in the near future