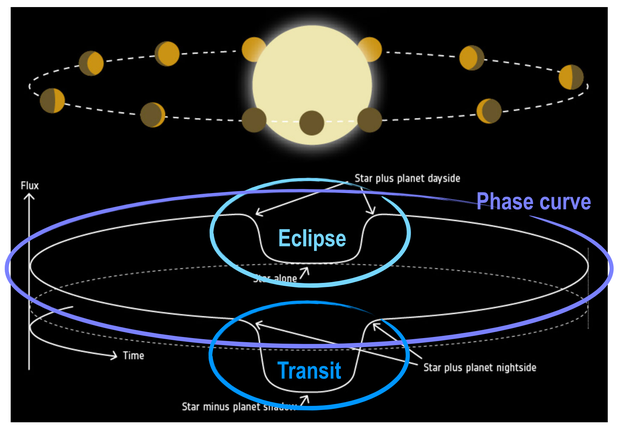
Preparing for Transiting Exoplanet Atmosphere Studies with the *Nancy Grace Roman Space Telescope*

Yiwei Chai [1], Néstor Espinoza [2,1], Robby Wilson [3] and the Transits in the Roman galactic EXoplanet Survey (TRExS) Team

[1] *Johns Hopkins University, Baltimore, MD, USA,* [2] *Space Telescope Science Institute, Baltimore, MD, USA* [3] *Goddard Space Flight Center, Greenbelt, MD, USA*

Roman is projected to detect ~100,000 transiting exoplanets…



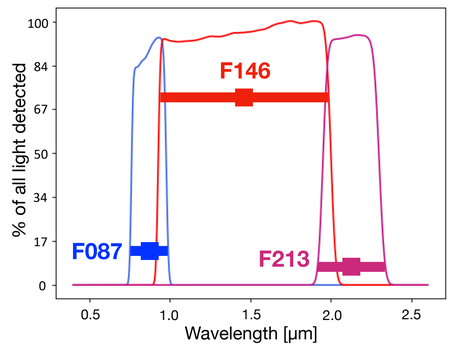
What can this wealth of multi-band primary transits, secondary eclipses, and phase curves teach us about…

1. Trends in broad **atmospheric composition** and **cloudiness**?
2. Trends in **planet dayside fluxes** and **orbital eccentricities**?
3. **Atmospheric circulation** and **cloud distributions**?

…with the Galactic Bulge Time-Domain Survey

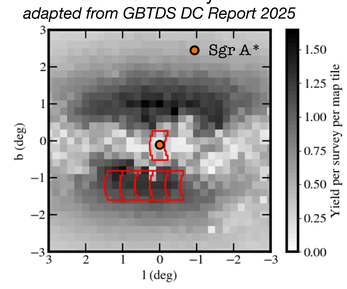
Roman's GBTDS will observe 6 fields over ~440 days

1 image every ~12 mins with the **F146 broadband filter** + narrow secondary filter at longer cadence

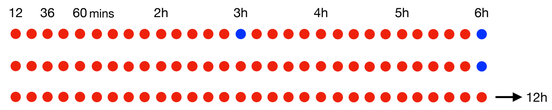


WFI F146 primary filter + 2 potential secondary filters: Z (F087) and K (F213)

GBTDS field layout
adapted from GBTDS DC Report 2025

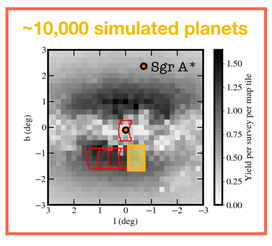


Potential secondary filter cadences at 3, 6, or 12 h

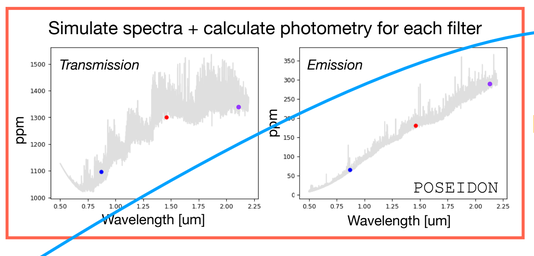


Building an end-to-end simulation to explore atmosphere science yields

~10,000 simulated planets



Simulate spectra + calculate photometry for each filter

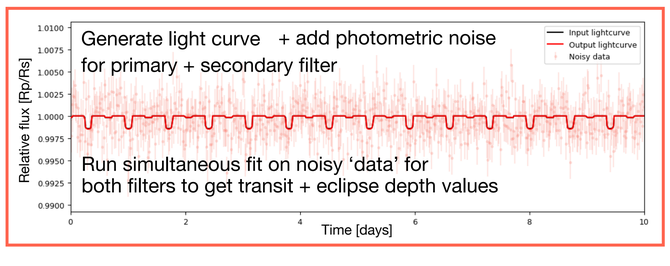


How does it compare?

What is the **expected 3-σ yield?** (from analytic estimates)

Generate light curve + add photometric noise for primary + secondary filter

Run simultaneous fit on noisy 'data' for both filters to get transit + eclipse depth values

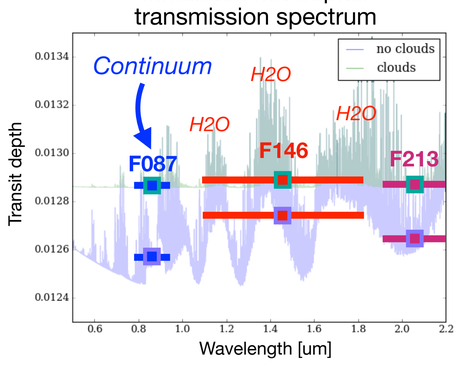


What actual **% transit + eclipse detections** do we recover?

What **% chromatic variations** in transit + eclipse depths?

Why do we care about secondary filters?

Simulated hot-Jupiter transmission spectrum



Different filters **trace different features** of the spectrum

This enables us to do transmission + emission 'spectrophotometry'

Secondary filter observing cadence particularly affects our ability to **constrain multi-band transits**

Choice of secondary filter/s + cadence could still be tweaked pre-launch to maximise atmosphere science!

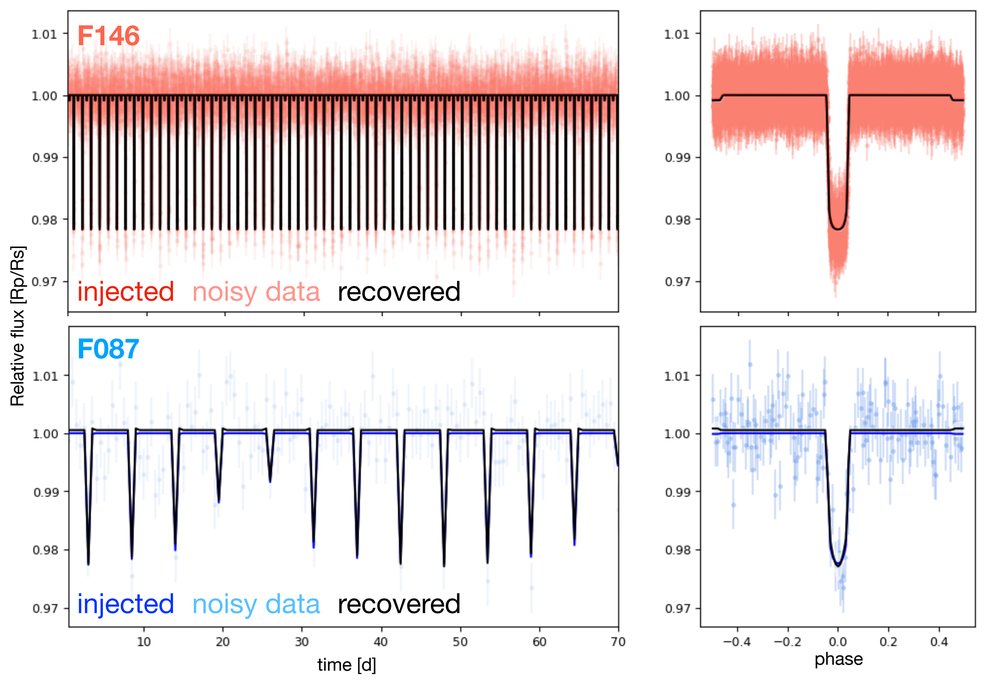
Example fit

Planet parameters:

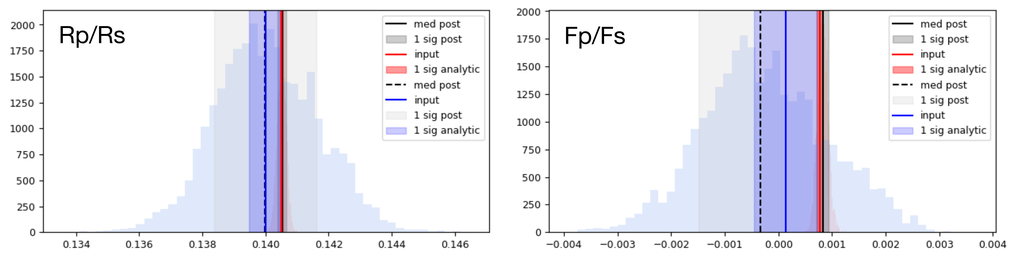
T_{eq} = 554 K
R_p = 0.9 R_J
M_p = 3.7 M_J

Set up:

12-hour cadence over 1 70-day season with F087 secondary filter



Transit + eclipse depth posteriors show good agreement with input values



How many secondary eclipses could *Roman* detect?

For 10,000 planets in 1 GBTDS field (assuming cloudy, solar atmospheric composition), we repeat our end-to-end simulations over each possible secondary filter + secondary filter cadence combination

Analytical estimates

	F146	F087	F213
3 hour	166	0	5
6 hour	173	0	1
12 hour	175	0	1

Simulation yields

	F146	F087	F213
3 hour	150	0	1
6 hour	159	0	0
12 hour	164	0	0

Extrapolating over 6 total fields gives

~900+
secondary eclipse detections

at a ~90% recovery rate from best-case scenario

Eclipse yields are not significantly affected by choice or cadence of secondary filter, as the high cadence of secondary filter observations limits our ability to constrain the secondary filter light curve

How many chromatic transits could *Roman* detect?

For chromatic transit yields, **choice of secondary filter + cadence *does* matter!**

Analytical estimates

	F087-F146	F146-F213
3 hour	90	0
6 hour	49	0
12 hour	23	0

Simulation yields

	F087-F146	F146-F213
3 hour	79	0
6 hour	41	0
12 hour	18	0

Extrapolating over 6 total GBTDS fields gives

~100-500
chromatic transit detections

at a ~80% recovery rate from best-case scenario

Higher photometric filter noise in F213 results in no chromatic transit detections for F146-F213 case — **chromatic transits are only detectable with F087**

Summary

1. Compared to other missions, ***Roman's* power for exoplanet characterisation will be in large sample statistics** that can help reveal population-level trends
2. Optimal GBTDS design to **maximise atmosphere science yield** is with an **F087 secondary filter at a shorter cadence** (e.g. 3 hours)
3. Simulations of GBTDS data with photometric filter noise recover ~80-90% of best-case analytical yield estimates: **100s of chromatic transits** & **~900+ eclipses!**

Stay tuned for…constraints on orbital eccentricities
…the problem of false positive eclipsing binaries
…phase curve simulations!

References

Buchner 2016, S&C, 26, 383B
Espinoza et al. 2019, MNRAS, 490, 2262
Kreidberg 2015, PASP, 127, 1161
MacDonald & Madhusudhan 2017, MNRAS, 469, 2
MacDonald 2023, JOSS, 8, 4873
Montet 2017, PASP, 129, 947
Speagle 2020, MNRAS, 493, 3132
Wilson et al. 2023, ApJS, 269, 5
Winn 2014, arXiV:1001:2010
Zasowski et al. 2025, ROTAC Final Report and Recommendations

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Contact Yiwei Chai at **mchai3 [at] jhu [dot] edu**