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# The impact of stellar spot-crossings on planet transmission spectra

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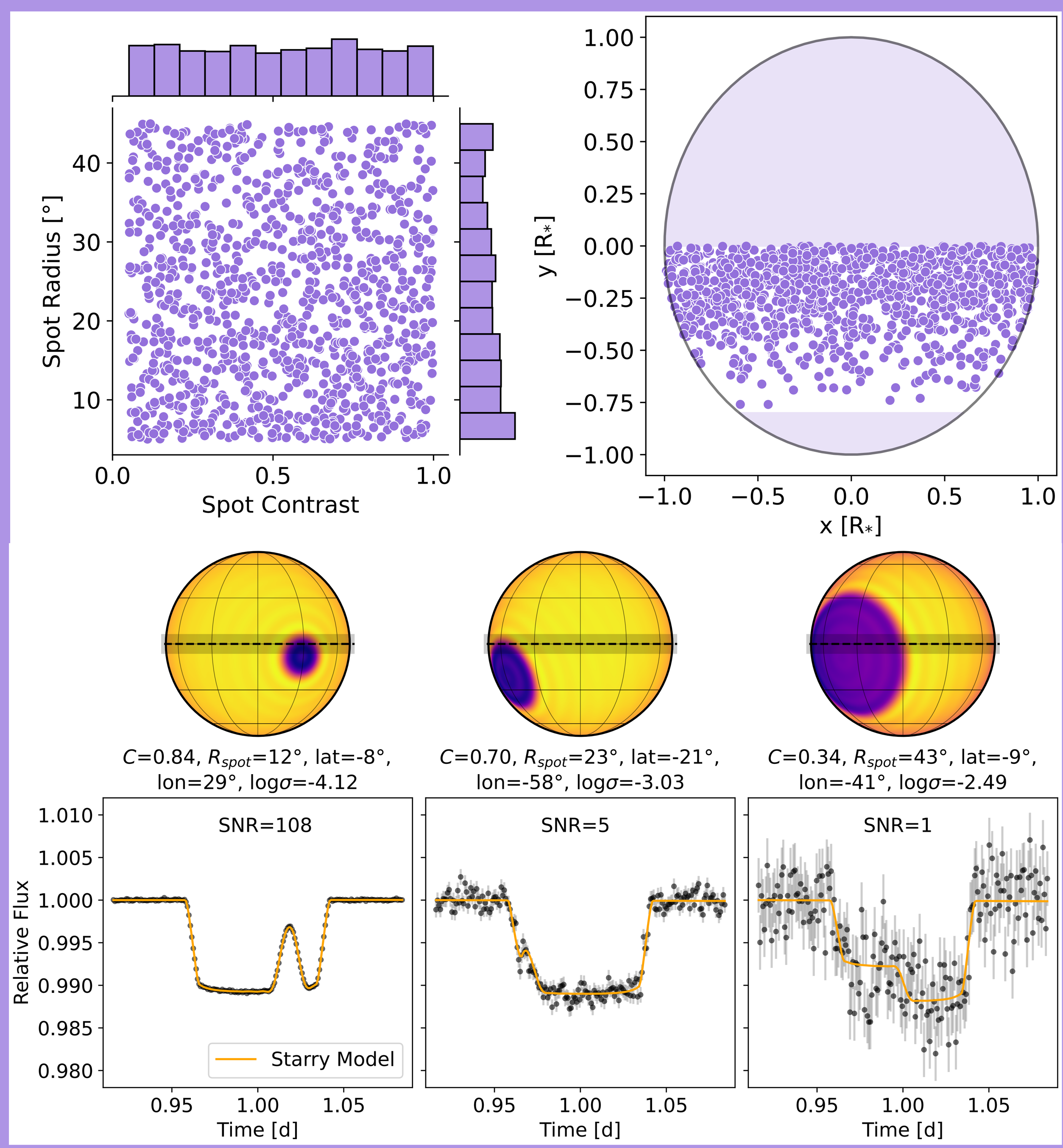
## Context for JWST

Spectral contamination from stellar heterogeneities is of major concern in this era of precise atmospheric characterization. Spot-crossing events have also been observed in recent JWST data [1]. Current approaches to correct for stellar contamination rely heavily on the fidelity of stellar models which has already proven problematic [2,3,4,5].

We aim to quantify how well stellar contamination can be constrained from spot-crossing events alone, without stellar model assumptions. Considering each transit in isolation is equivalent to fitting for spot properties from a single wavelength, or a white light transit.

## The Starspot-Crossing Sample

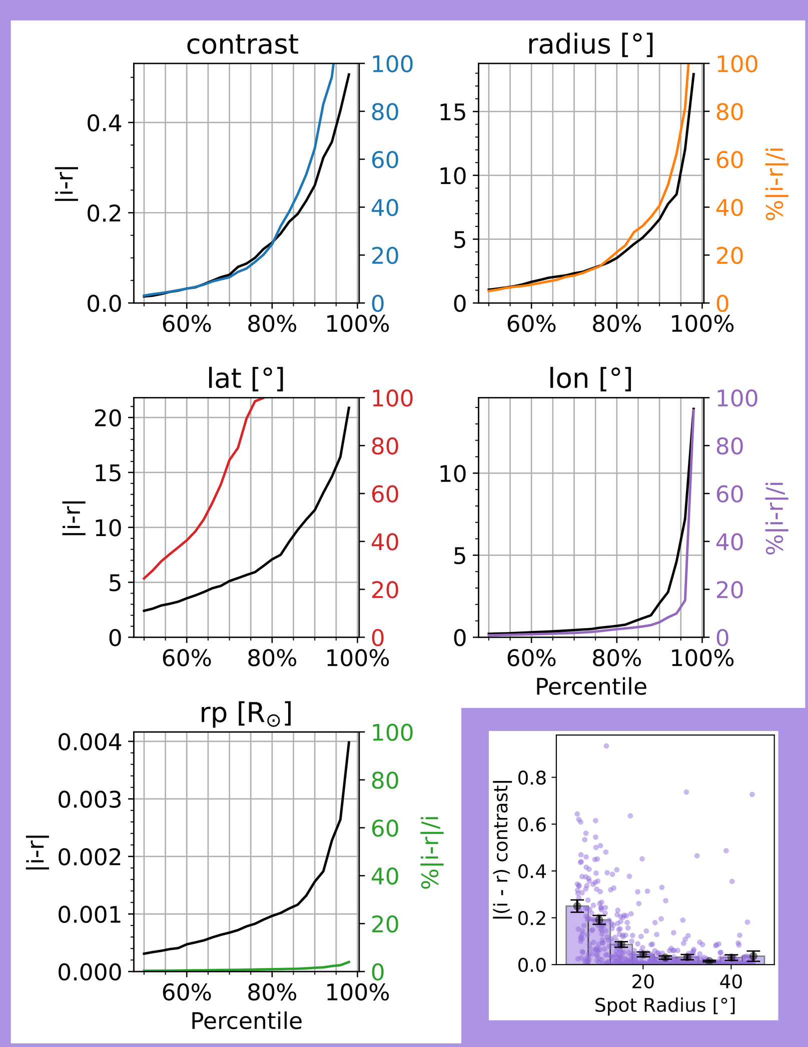



We created a large sample of 1000 spot-crossing events by generating a simple circular star-planet transiting system using ***starry***. We defined a transiting planet with radius R=0.1R*, an orbital period P=1d, and zero inclination.

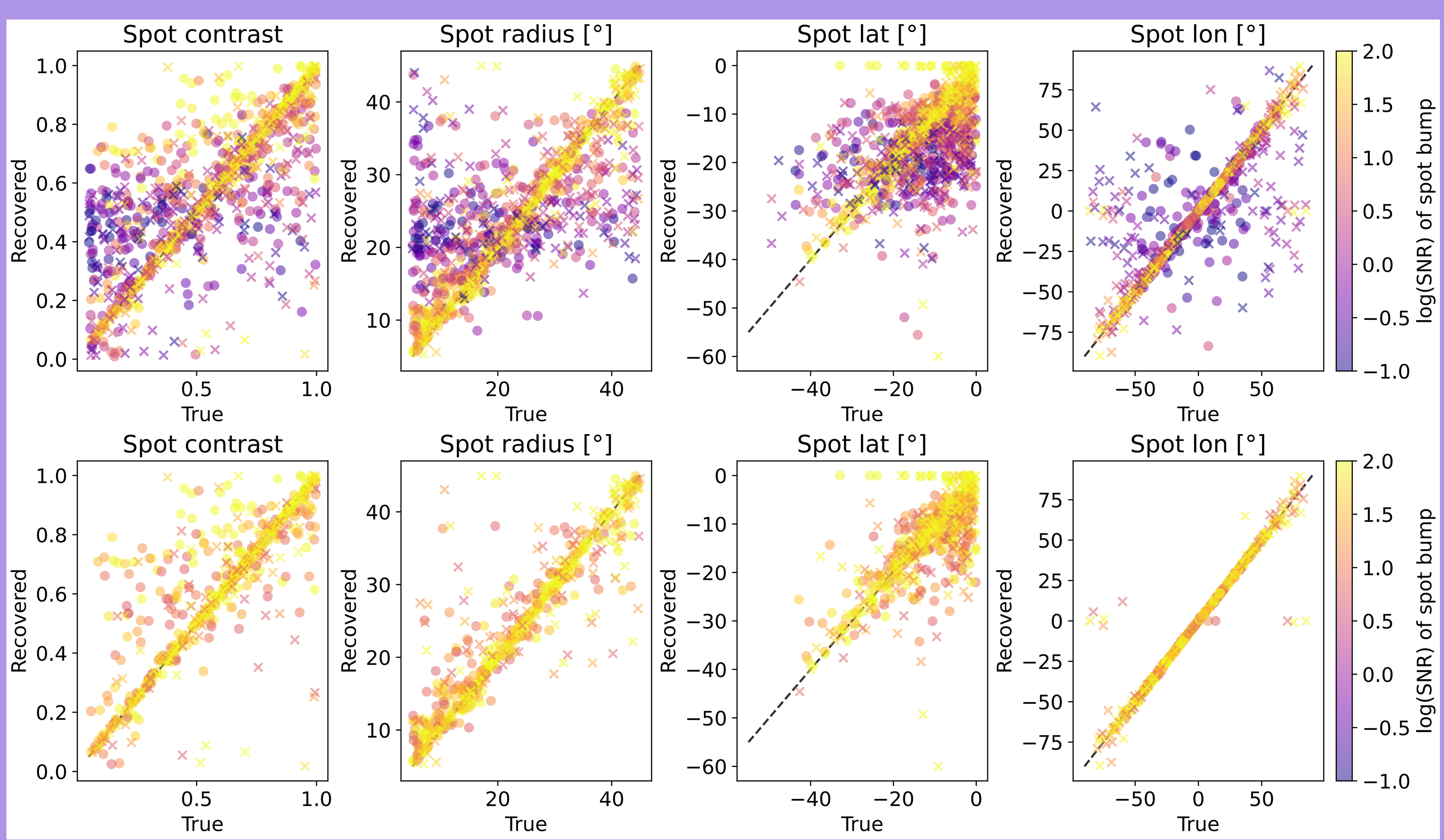
We simulated a 'typical' single transit light curve with 100 points in and out of transit. We then modified this transiting system to include 1000 simulated star spot-crossing events with a range of light curve uncertainties, spot contrasts, sizes, and locations.

## Spot and Planet Parameter Retrieval

We use ***chromatic_fitting*** to model the spot-crossing simultaneously with the planet parameters. We extract the MAP-optimized best-fit parameters for each of the 1000 samples. We are also performing MCMC sampling for a small subset.

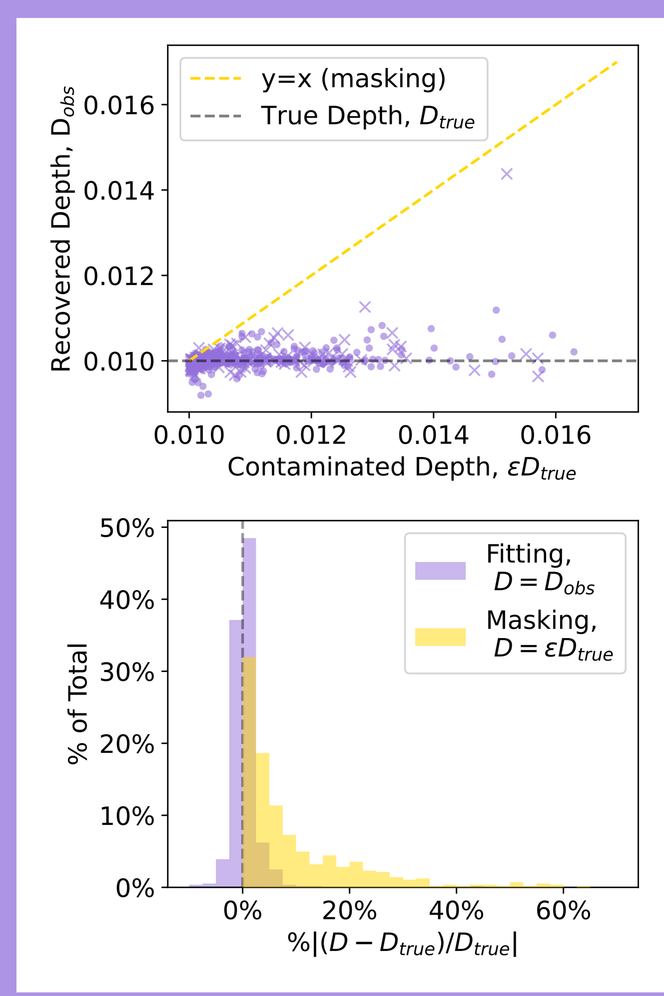



For SNR>5 of the spot signal in the light curve, 80% of the spot contrasts, radii, longitudes, and latitudes are recovered to within 0.13, 3.5°, 0.7°, and 7.1° respectively. Spot contrasts in particular are recovered very successfully for large spots (>15°). More than 80% of the time the planet radius is recovered to within 1%.

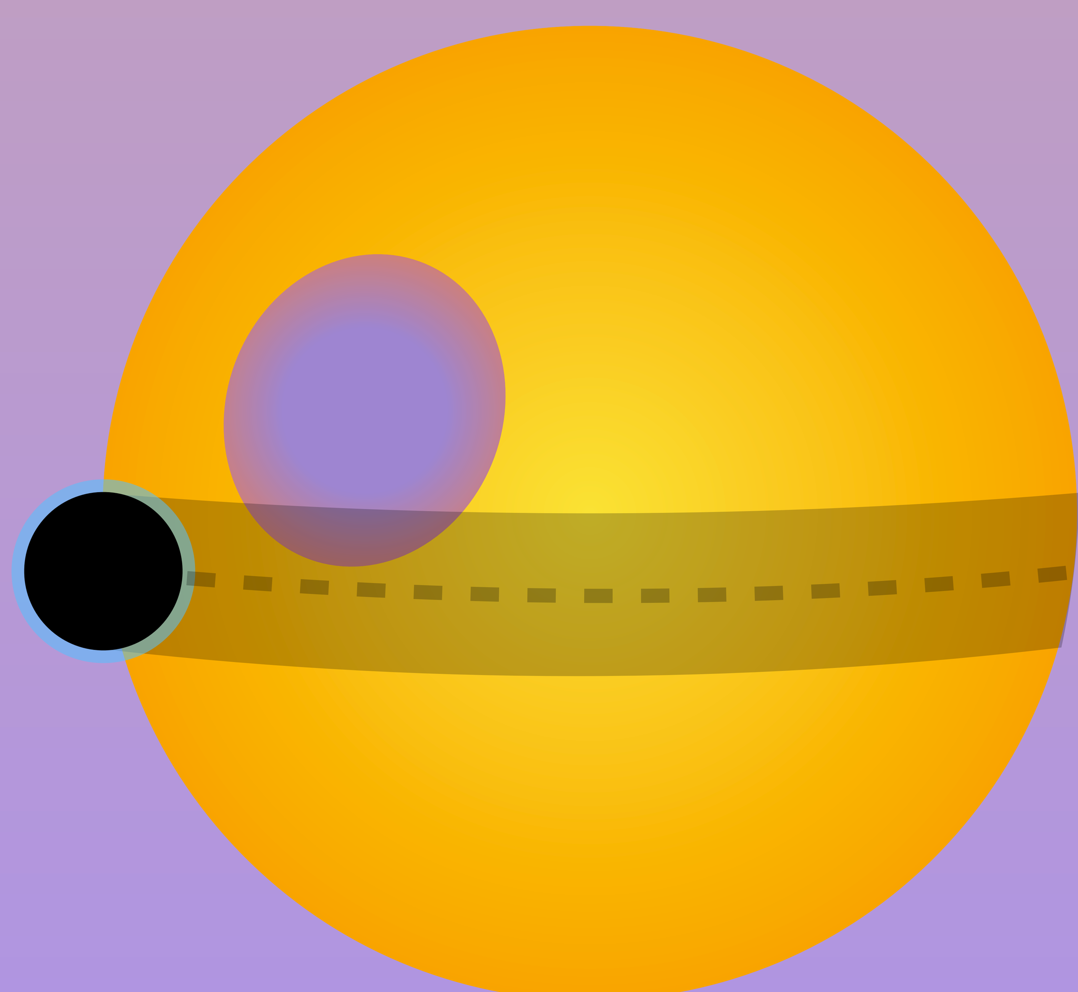



## Fitting vs. Masking

If we have broad multi-wavelength observations we could then correct for the Transit Light Source Effect (TLSE) in the transmission spectrum directly. However, in many cases we do not have sufficient resolution or coverage to bluer wavelengths.




By fitting for spot-crossings with SNR>5 we recover the true transit depth to within 1% (2%, 5%) in 79% (87%, 96%) of samples. We demonstrate that fitting for starspot-crossings is significantly more successful in recovering the true transit depths compared to simply masking, and can mitigate contamination from the TLSE. This also removes the complexities that arise from a lack of stellar model fidelity (with average transit depth errors of ~200ppt [4]).



[1] Fu+22, [2] Wakeford+19, [3] Garcia+22, [4] Rackham+23, [5] Lim+23