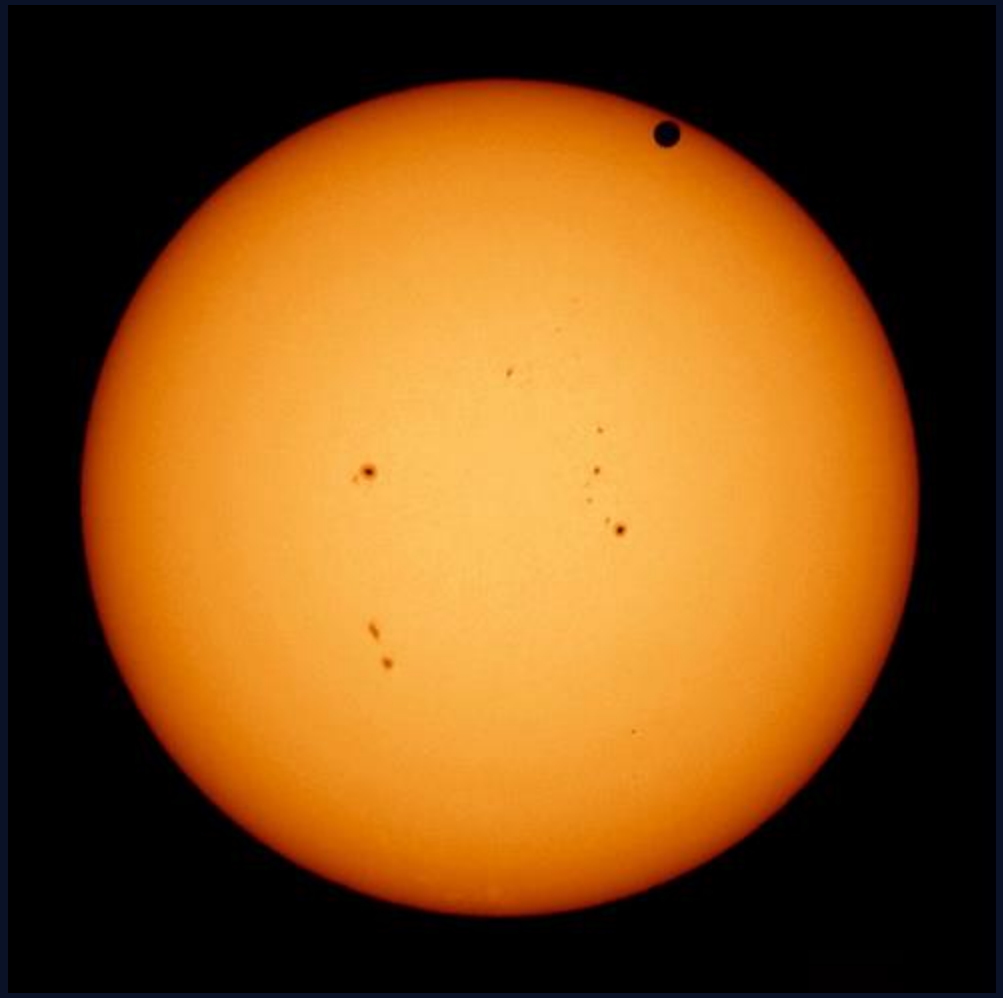
How dark is the edge of a star?

JWST tests simple limb-darkening laws against real stars and against stellar atmosphere models.

Based on Sing et al. (2026)



The image was taken during the 2012 transit of Venus (seen here as the dark spot at the upper right).

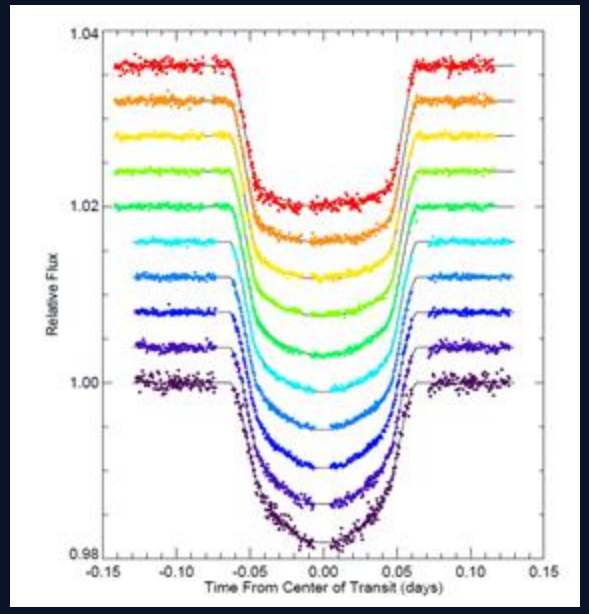
A planet’s shadow is measured against a star

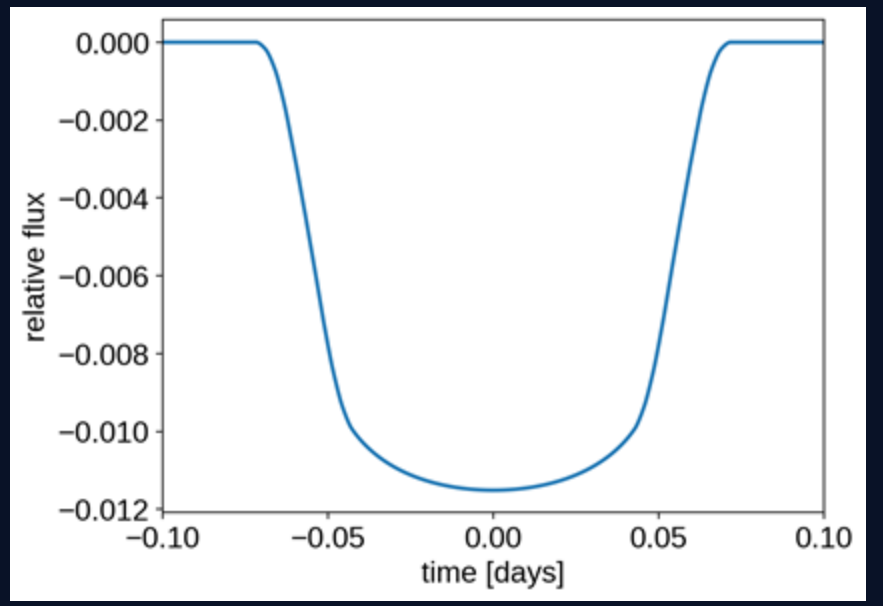
THE TRANSIT SIGNAL

A planet crossing its star blocks some of the star’s light. The light-curve shape is used to infer the planet-to-star radius ratio and, ultimately, its atmospheric properties.

THE HIDDEN COMPLICATION

The stellar disk is brighter at its center and dimmer near its edge. This is called **limb darkening**; it changes the transit light curve with wavelength.





How much complexity does the data actually require?

The paper tests two linked questions:

1 THE FITTING LAW

Can a simple quadratic law reproduce the observed stellar intensity profile well enough—or do higher-order laws materially improve the transit fit?

2 THE ATMOSPHERE MODELS

How well do theoretical stellar-atmosphere grids predict the limb darkening measured directly from JWST transits?

Core idea: test the assumptions against empirical, wavelength-resolved observations.

Seven transiting systems, one broad stellar sample

HOST-STAR TEMPERATURE RANGE

4,200–6,800 K

Seven FGK host stars
(F, G and K spectral types)

JWST INSTRUMENTS

NIRISS/SOSS

NIRSpec/PRISM

TARGETS IN THE PAPER'S SURVEY

WASP-121 b	6,770 K
WASP-12 A,b	6,380 K
WASP-94 A,b	6,140 K
WASP-6 b	5,380 K
HAT-P-11 b	4,840 K
WASP-107 b	4,425 K
WASP-80 b	4,210 K

All targeted stars sampled >95% of the stellar disk area.

From JWST photons to a model comparison

01

Reduce spectra

FIREFLy + JWST calibration; remove noise and extract stellar spectra.

→

02

Fit transit curves

Fit white-light curves with four limb-darkening laws; coefficients are free.

→

03

Compare models

Use BPICS, a Bayesian predictive model-selection statistic, to balance fit quality and complexity.

→

04

Test atmosphere grids

Compare empirical quadratic coefficients with PHOENIX, MPS-ATLAS and Stagger predictions.

Four laws tested: linear • quadratic • 3-parameter • 4-parameter nonlinear

The quadratic law is usually enough

6 OF 7 STARS

Favor the quadratic law.

4-PARAMETER LAW

Disfavored in the combined sample.

EXCEPTION

WASP-94 A prefers higher-order fits.

AGGREGATE MODEL COMPARISON | ΔBPICS RELATIVE TO QUADRATIC



The 3-parameter law is statistically comparable overall; the 4-parameter law adds complexity without a better predictive fit.

The practical bias in transit depth is small

14 ppm

1σ scatter in quadratic-law transit depth

for 6 of 7 targets, relative to model average

WHY THIS MATTERS

Typical one-scale-height transmission features are about 200 ppm in the paper's comparison.

RELATIVE SCALE (illustrative; ppm)



WASP-94 A: quadratic result differs by 73 ppm—still about one-quarter of a scale-height feature.

The models get the wavelength trend—but miss the baseline

WHAT MATCHES

Atmosphere models generally reproduce the wavelength-to-wavelength shape of the measured coefficient spectra.

WHAT DOESN'T

Models tend to predict stronger limb darkening and more curvature than the empirical data.

A more physical coefficient language

ℓ | LIMB INTENSITY

Intensity at the stellar edge (μ = 0). Higher ℓ means weaker overall limb darkening.

δ | CURVATURE

Departure from a straight-line intensity profile at μ = 0.5. Empirical values are generally δ ≤ 0.1.

A small edge correction makes model predictions more useful

The key adjustment is to exclude the extreme limb when calculating the model coefficients

μ_min = 0.2

Ignore intensities at μ < 0.2
when deriving model coefficients.



~4%

of stellar disk area is excluded—
only the outer edge.

Conclusion:

A simpler law, empirically tested, gives more reliable planet spectra

01 **Use quadratic as the starting point**

It is preferred for most stars and keeps transit-depth bias small.

02 **Keep the exception in view**

WASP-94 A shows that higher-order laws can matter for individual targets.

03 **Calibrate the atmosphere models**

Use μ_min = 0.2 and gray offsets; model predictions are useful but not exact.