Limb-Darkening of WASP-55

Kezman Saboi, Edgar Escalante, and Tiancheng Gong

Abstract

Various discoveries of transit exoplanets have led to increased understanding of important features of host stars such as their limb-darkening. Limb-darkening, in simple terms, refers to a phenomenon that is observed about a star that indicates that the star's brightness reduces radially with increasing distance from its center. This implies that the star's limb (edge) tends to appear relatively dark. This is generally assumed for all stars in the known cosmos, WASP-55 inclusive. WASP-55 is a star found in the WASP-55 system that mainly comprises the star itself and a planet currently referred to as WASP-55 b. This research primarily focuses on studying limb-darkening of WASP-55 through observations of light curves generated as WASP-55 b transits across it's surface. From data obtained, the surface brightness of WASP-55 with respect the it radius will be analyzed.

Approach

This project will be implemented through the use of a carefully developed Python algorithm and relevant physics equations among which are briefly outlined below.

To understand how stellar flux evolves during each transit, it is important to take into consideration the fractional flux deficit ΔF that is given by the equation;

$$\Delta F = \frac{Rpl^2}{R*^2} \quad (1)$$

where R_{pl} is the radius of WASP-55 b and R_* is WASP-55's radius.

The duration of each transit hugely depends on the impact parameter b defined by;

$$b = \frac{a(cos(i))}{R*} \quad (2)$$

where *a* is the semi-major axis and *i* the angle of inclination of WASP-55 b with respect to WASP-55. Refer to Figure 1 below to visualize b in the planetary system.

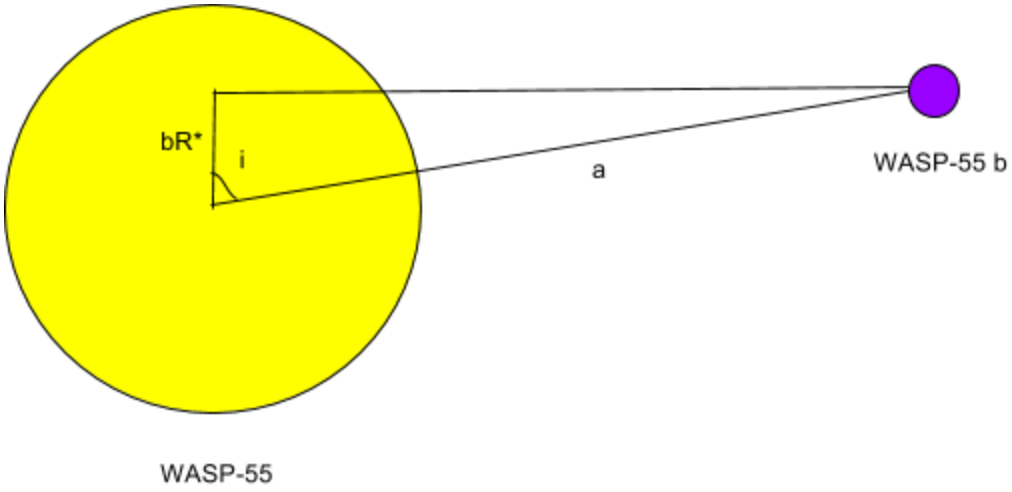

Figure 1.
Based on the impact parameter and the semi-major axis, the transit duration is defined as;

$$T_{duration} = \frac{P}{\pi} \sin^{-1}\left(\frac{\sqrt{(R* + Rpl)^2 - (bR*)^2}}{a} \right) \quad (3)$$

where P is the orbital period of WASP-55 b.

For our algorithm, the following non-linear limb-darkening equation:

$$I(\mu) = I_0[1 - c_1(1-\mu^{\frac{1}{2}}) - c_2(1-\mu) - c_3(1-\mu^{\frac{3}{2}}) - c_4(1-\mu^2)] \quad (4)$$

where I_0 is specific intensity at the center of WASP-55, $\mu = \cos(\theta)$ (Note that θ is the angle between the line of observation and WASP-55's surface), and where c_1, c_2, c_3, and c_4 are all coefficients that are particular to WASP-55.

μ can also be defined as $\mu = \sqrt{1 - x^2}$, given that $0 \leq x \leq 1$ for normalized radial coordinate.

Input parameters that will be used include;

1. Radius of WASP-55 b $\approx 1.3R_J$, where R_J is the radius of Jupiter
2. Radius of WASP-55 $\approx 1.011R_{SUN}$, where R_{SUN} is the radius of the Sun
3. Effective temperature of WASP-55 $\approx$ 5900 K
4. Distance of WASP-55 from Earth = 330 pc
5. Inclination of WASP-55 b $\approx 89.2^o$
6. Mass of WASP-55 $\approx 1.013M_{SUN}$, where M_{SUN} is the mass of the Sun
7. Mass of WASP-55 $\approx 0.57M_J$, where M_J is the mass of the Jupiter

Goals of Project

1. Simulate transit of WASP-55 b across the surface of WSP-55 and plot the flux evolution with respect to time.
2. Plot the surface brightness of WASP-55 versus positions of its radius
3. Plot relative flux of WASP-55 with respect to its radius
4. Modify surface of WASP-55 by including relatively cold spots (regions) and making plot ot light curve to analyze effects of stellar spots.

References

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