Draft version October 7, 2017
Typeset using LaTeX **twocolumn** style in AASTeX61

PHASE CURVES OF WASP-103B

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Submitted to ApJ

ABSTRACT

WASP-103b is a short-period hot Jupiter.

Keywords: planets and satellites: individual (WASP-107b), planets and satellites: atmospheres

1. INTRODUCTION

It is a truism to say that planets are round. The. And yet planets' roundness gives rise to a host of complications: atmospheric circulation, variable , gradients in chemistry, cloud formation and evaporation, and time-dependent phenomena (weather).

It is a challenge is to reveal this structure at great distances, when we cannot spatially resolve the photosphere of the planet. Most observations of exoplanet atmospheres are sensitive to a single isolated region – either the terminator, for transmission spectroscopy, or the disk-integrated dayside, for emission spectroscopy. The solution to this problem is to observe phase curves of tidally-locked planets, which monitor the brightness of the planet over its entire orbit. As the orbital phase changes, the observer

The first phase curve was observed with *Spitzer* for the hot Jupiter HD 189733b by (**?**), and was followed by FIXME more (with IRAC). Several trends emerged from these measurements, including eastward shifted hotspots (which suggest super-rotating equatorial jets), larger day-night temperature contrast for shorter period planets (ref), . The first spectroscopic phase curve was measured with Hubble's Wide Field Camera 3 (WFC3) by (**?**) for the hot Jupiter WASP-43b. Found low albedo, offset hotspot, water visible at other phases,

In parallel with these observations, there have been major advances in the theory of exoplanet atmospheres in three-dimensions. Global circulation models (GCMs) are now capable of self-consistent radiative transfer and atmospheric dynamics (refs) and are beginning to include clouds (refs?).

In addition to GCMs, work on the inverse problem Cowan - how to get maps, . SPIDERMAN, an open-source Python package designed to take any temperature or brightness map of a planet and output the corresponding phase curve, so that we can readily connect GCMs to phase curve observations.

In this paper we present *HST* and *Spitzer* phase curve observations of WASP-103b, a hot Jupiter with a mass of X, radius of Y, period of Z (cite discovery paper). These properties are similar to WASP-43b, except that WASP-103b has a much (FIXME vs FIXME K) thanks to its hot F?? star host. By comparing the phase curves of these two planets, we can test the effect of irradiation on the climate of the planet.

The structure of the paper is as follows:

2. OBSERVATIONS AND DATA REDUCTION

We observed two full-orbit phase curves of WASP-103b with *HST*/WFC3 and one each with *Spitzer*/IRAC at 3.6 and 4.5 μm (from HST Program 14050 and Spitzer Program 11099). We also reduced two *HST*/WFC3 secondary eclipse observations of WASP-103b from *HST* Program 13660 (PI: M. Zhao).

2.1. *HST/WFC3*

The *HST* phase curve observations consisted of two visits on 26-27 February and 2-3 August 2015. Each visit was 15 orbits in duration and spanned 23 hours. We took a direct image of the star with the F126N filter at the beginning of each orbit to determine the wavelength solution zero-point. The remainder of the orbit consisted of time-series spectroscopy with the G141 grism ($1.1 - 1.7$ μm) and the 256 x 256 pixel subarray. We used the SPARS10/NSAMP = 15 read-out mode, which has an exposure time of 103 seconds. To optimize the duty cycle of the observations, we used the spatial scan observing mode with a scan rate of 0.03"/s, alternating between forward and backward scanning on the detector. The scan height was 25 pixels and the peak counts were 35k photoelectrons per pixel. We collected a total of 18 spatial scan exposures per orbit. The two eclipse observations from Program 13660 had a similar observing setup.

We reduced the data from both programs using a custom pipeline developed for past analyses of WFC3 data (for details see **???**). Briefly, we use the optimal extraction algorithm of **?** to extract each up-the-ramp sample (or "stripe") separately. The stripes are then summed to create the final spectrum. For each stripe, the extraction window is 24 pixels high and centered on the stripe midpoint. We estimate the background from the median of a region of the detector that is uncontaminated by the target spectrum (rows 5-50). The typical background counts are low (10-15 photoelectrons per pixel, roughly 0.03% of the peak counts from the target star). We note that the extracted spectrum includes flux from a nearby star, which is separated from WASP-103 by less than two pixels (0.2"; **?**). Our extracted spectrum includes flux from this star, which we account for later in the analysis.

2.2. *Spitzer*

The *Spitzer* observations had the following setup. Each phase curve observation consisted of 30 hours of time series photometry, beginning three hours prior to one secondary eclipse and ending three hours after a second eclipse. We used 12 s exposures to maximize the duty cycle without saturating the detector. The data volume is relatively low for this exposure time, so we read out the full array. To minimize the intrapixel effect (variations in flux caused by imprecise pointing), we did not dither and also used PCRS peak-up to improve the