WASP-120b, WASP-122b, and WASP-123b: Three Newly Discovered Planets from the WASP-South Survey

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Abstract

We present the discovery by the WASP-South survey of three planets transiting moderately bright stars (V ≈ 11). WASP-120 b is a massive (4.85 M_Jup) planet in a 3.6-day orbit that we find likely to be eccentric (e = 0.059±0.025) around an F5 star. WASP-122 b is a hot Jupiter (1.28 M_Jup, 1.74 R_Jup) in a 1.7-day orbit about a G4 star. Our predicted transit depth variation caused by the atmosphere of WASP-122 b suggests it is well suited to characterization. WASP-123 b is a hot Jupiter (0.90 M_Jup, 1.32 R_Jup) in a 3.0-day orbit around an old (~7 Gyr) G5 star.

Key words: planets and satellites: individual (WASP-120b, WASP-122b, WASP-123b)

Online material: color figures

1. Introduction

The Wide Angle Search for Planets (WASP) survey is a prolific contributor to the field of exoplanet science having published the discovery of 104 planets to date. Our effective magnitude range of 9 < V < 13 means that WASP systems are conducive to further study. Examples from the extremes of this range are the bright WASP-33 (V = 8.3; Collier Cameron et al. 2010) and WASP-18 (V = 9.3; Hellier et al. 2009) and the relatively dim WASP-112 (V = 13.3; Anderson et al. 2014).

Here, we present the discovery of WASP-120 b, a system with a star showing variable activity and a possibly eccentric planet orbit, WASP-122 b, which offers a good opportunity for atmospheric study, and WASP-123 b, which orbits an old star, ~7 Gyr.

2. Observations

The transits of these planets were discovered in photometry gathered from the WASP-South installation hosted by the South African Astronomical Observatory. The WASP-South instrument is an array of 8 cameras using 200 mm f/1.8 lenses to survey the sky at a cadence of ~10 minutes. For more information on the WASP instrument, see Pollacco et al. (2006). The data were processed and searched for transits, as described in Collier Cameron et al. (2006), with candidate selection following the procedure in Collier Cameron et al. (2007a). Details of observations for each star in this paper can be found in Table 1. The phase-folded WASP data are displayed in the top panels of Figures 1, 2, and 3. We used the method of Maxted et al. (2011) to search the WASP photometry for modulations caused by star spots. We detected no rotational modulation above 2 mmag that suggests that the hosts are inactive.

We obtained spectra of the three stars with the CORALIE spectrograph on the 1.2 m Swiss telescope as outlined in Table 1. We used these data to measure radial velocity (RV) variations and confirm the planetary nature of the candidates (Table 2; bottom panels of Figures 1, 2, and 3). We obtained nine of the WASP-120 spectra after the spectrograph was upgraded in November of 2014. The lack of correlation between the bisector spans and RVs (Figure 4) indicate that the RV variations are not a result of blended eclipsing binaries. For example, Santos et al. (2002) found a brown dwarf mass
companion that produces a correlation between the RVs and bisector spans with a gradient of 0.67. The largest gradient from among our planets is an order of magnitude smaller and not significant, $0.06 \pm 0.07$ for WASP-120. While we cannot strictly rule out the case of blended planet-hosting stars, we can eliminate brown dwarf blends and more massive objects.

We acquired the follow-up photometry needed to accurately determine the system parameters from the 0.6 m TRAPPIST telescope (Gillon et al. 2011) and EulerCam (Lendl et al. 2012) on the Swiss telescope at La Silla, Chile. The TRAPPIST telescope’s equatorial mount requires a meridian flip when the target culminates during an observation. These occurred at BJD = 2456609.725 during the transit of WASP-120 on 2013 November 12 and at BJD = 2456644.758 during the transit of WASP-122 on 2013 December 17. We account for any offsets introduced by treating them as two separate data sets during our analysis. The photometric data are presented in Table 3. This follow-up revealed a star within 2.2 of WASP-120, which is $4.35 \pm 0.02$ magnitudes fainter in the I band and $3.89 \pm 0.02$ magnitudes fainter in the z band. CORALIE’s fibers are 2" in diameter, and the RVs were obtained in good seeing, so the star is sufficiently distant that it did not contaminate the observations and thus could not cause a false positive.

### 3. Analysis

#### 3.1. Stellar Parameters

We determined the atmospheric parameters of each host star by analyzing the co-added CORALIE spectra after correcting them for shifts due to the radial motion of the star using the measured RVs. Our spectral analysis followed procedures given in Doyle et al. (2013). For each star we obtained the effective temperature, $T_{\text{eff}}$, using the Hı line, log g from the Na...
D and Mg b lines and iron abundances from the analysis of equivalent width measurements of several unblended Fe i lines. We found the projected rotation velocity, $V \sin i$, by fitting the profiles of the Fe i lines after convolving with the instrumental

**Figure 2.** Discovery data for WASP-122 b. Top panel: phase-folded WASP photometry for WASP-122. Middle panel: WASP discovery photometry (gray), TRAPPIST (blue), and EulerCam (green) follow-up photometry with our transit model overplotted. The meridian flip in the TRAPPIST data has been corrected for and marked with a vertical dashed line. All photometric data have been binned with a duration of 2 minutes for clarity. Bottom panel: CORALIE radial velocity data, overplotted with our circular solution.

**Figure 3.** Discovery data for WASP-123 b. Caption as for Figure 2.
resolution \((R = 55,000)\) and a macroturbulent velocity adopted from the calibration of Doyle et al. (2014).

### 3.2. System Parameters

We used a Markov Chain Monte Carlo (MCMC) code to determine the system parameters using the discovery and follow-up photometry with RVs as described by Collier Cameron et al. (2007b) and Anderson et al. (2015).

For each system we modeled our transit light curves using the formulation of Mandel & Agol (2002) and accounted for limb-darkening using the four-parameter nonlinear law of Claret (2000, 2004). The photometric bands and limb-darkening coefficients used in the light curve models are detailed in Table 4.

We used BAGEMASS (Maxted et al. 2015) to compare \(\rho_s\), determined from the transit light curves coupled with the spectroscopic values of \([\text{Fe}/\text{H}]\) and \(T_{\text{eff}}\), to stellar models in order to estimate the mass of the star. BAGEMASS also gives an estimate of the age of the system.

To calculate the distance, we use the apparent K \(s\)-band magnitude from Skrutskie et al. (2006), the radius of the star from Table 5, and the angular diameter of the star based on the calibration of the K-band surface brightness–effective temperature relation from Kervella et al. (2004). We assume that interstellar reddening is negligible and that \(K = K_s + 0.044\).

The free parameters in our MCMC analysis were \(T_0\), \(P\), \((R_P/R_*)^2\), \(T_{14}\), \(b\), \(K_1\), \([\text{Fe}/\text{H}]\), and \(T_{\text{LD}}\). Here, \(T_0\) is the epoch of mid-transit, \(P\) is the orbital period, \((R_P/R_*)^2\) is the planet-to-star area ratio, \(T_{14}\) is the total transit duration, \(b\) is the impact parameter of the planet’s path across the stellar disk, \(K_1\) is the reflex velocity semi-amplitude, \(\gamma\) is the systemic velocity, \([\text{Fe}/\text{H}]\) is the stellar metallicity, and \(T_{\text{LD}}\) is the limb-darkening temperature. \(T_{\text{LD}}\) and \([\text{Fe}/\text{H}]\) were constrained by the spectroscopic values of \(T_{\text{eff}}\) and \([\text{Fe}/\text{H}]\). \(T_{\text{LD}}\) was used by

| HJD  | RV (km s\(^{-1}\)) | Error (km s\(^{-1}\)) | BS (km s\(^{-1}\)) | Target Name |
|------|---------------------|------------------------|-------------------|-------------|
| 6552.902673 | 19.30305 | 0.05043 | -0.27331 | WASP-120 |
| 6572.735422 | 20.41666 | 0.03569 | 0.03952 | WASP-120 |
| 6573.843533 | 19.62050 | 0.03173 | -0.01785 | WASP-120 |
| 6871.746191 | 16.99747 | 0.00673 | -0.01808 | WASP-123 |

**Note.** Data available in this format at ADS. The data are provided to the full precision used in our calculations but times are only accurate to a few seconds at best.
the MCMC to interpolate limb-darkening coefficients at each step from the Claret limb-darkening tables for the appropriate photometric band of each light curve. At each step of our MCMC, these values were perturbed by a small random value and the $\chi^2$ of the model based on the new values was calculated. If this leads to a lower $\chi^2$, the step was accepted while a larger value would be accepted with a probability proportional to $\exp(-\Delta\chi^2/2)$. Our final values were calculated from the medians of the posterior distributions with uncertainties corresponding to the 1σ confidence intervals. When we allow the MCMC to explore eccentric solutions, we fit $\sqrt{e} \cos \omega$ and $\sqrt{e} \sin \omega$ to ensure a uniform probability distribution. Our results for each system are in the lower part of Table 5 and corner plots of the jump parameter posterior distributions of each analysis in Figures 5, 6, and 7.

We checked for trends in the derived transit depths with respect to the color of the observational band for each star by running each light curve through our MCMC separately. The depths for WASP-122 and WASP-123 agree to within 1σ of the depth derived from the combined analysis. The depths from this analysis of the two complete light curves of WASP-120 show a slight difference of $(1.2 \pm 0.4) \times 10^{-3}$, which could be accounted for by a low level of inherent stellar variability in either the host star or faint, nearby companion.

4. WASP-120

WASP-120 b is a 4.85–$M_{\text{Jup}}$, 1.73–$R_{\text{Jup}}$ planet orbiting a moderately bright ($V = 11.0$) F5 star. The effective temperature of WASP-120 places it in the lithium gap (Böhm-Vitense 2004), so we cannot estimate the age of this star based on the lithium abundance. Using the star’s Tycho B-V color and rotation period from its $V \sin i$ and the radius from our MCMC, we use gyrochronology calibration of Barnes (2007) to estimate an age of 0.7 ± 0.6 Gyr. For comparison, the calibration of Mamajek & Hillenbrand (2008) gives 1.0 ± 1.8 Gyr. We cannot apply the calibration of Meibom et al. (2009) as the star’s color results in a term requiring the logarithm of a negative value. Using BAGEMASS, we find an age of 2.6 ± 0.5 Gyr, which is consistent with that of the Mamajek & Hillenbrand calibration.

The FWHM of the lines in the spectra and the bisector spans show more scatter in the later data, after the CORALIE upgrade (Figure 8), suggesting that the star may have become more active, and therefore have variable activity like the Sun. It is unlikely that the increased scatter is caused by the change to CORALIE since data sets on other stars do not show an increased scatter (e.g., recent RV data taken of WASP-47; Neveu-VanMalle et al. 2015).

Table 3
Follow-up Photometry from TRAPPIST and EulerCam

| HJD$_{UTC}$ | Norm. Flux | Error | $\Delta X$ Position | $\Delta Y$ Position | Airmass | Target | Sky Bkg. (Counts) | Exp. Time (s) | Target Name | Instrument | Band |
|------------|------------|-------|---------------------|---------------------|--------|--------|--------------------|--------------|-------------|------------|------|
| 6887.720753 | 0.990347 | 0.002159 | -1.91 | -2.21 | 2.64 | 11.12 | 71.30 | 50.00 | WASP-120 | EulerCam | IC |
| 6887.721534 | 0.996407 | 0.002145 | 0.25 | -1.40 | 2.62 | 12.18 | 70.00 | 50.00 | WASP-120 | EulerCam | IC |
| 6887.722324 | 0.994713 | 0.002114 | 0.06 | -1.04 | 2.60 | 10.85 | 68.82 | 50.00 | WASP-120 | EulerCam | IC |

Note. Data available in this format at ADS. The data are provided to the full precision used in our calculations, but times are only accurate to a few seconds at best.

Table 4
Limb-darkening Parameters Extrapolated Using the $T_{\text{LD}}$ Resulting from Each Analysis

| Planet | Instrument | Instrument Band | Claret Band | $a_1$ | $a_2$ | $a_3$ | $a_4$ |
|--------|------------|-----------------|-------------|-------|-------|-------|-------|
| WASP-120 | WASP | Broadband (400–700 nm) | Cousins R | 0.136 | 1.286 | -1.188 | 0.391 |
|         | TRAPPIST | I + z | Sloan z | 0.221 | 0.827 | -0.760 | 0.226 |
|         | EulerCam | Cousins I | Cousins I | 0.200 | 0.951 | -0.863 | 0.263 |
| WASP-122 | WASP | Broadband (400–700 nm) | Cousins R | 0.799 | -0.503 | 1.076 | -0.515 |
|         | TRAPPIST | z | Sloan z | 0.717 | -0.743 | 1.095 | -0.492 |
|         | EulerCam | Gunn R | Cousins R | 0.717 | -0.503 | 1.076 | -0.515 |
| WASP-123 | WASP | Broadband (400–700 nm) | Cousins R | 0.683 | -0.405 | 0.957 | -0.473 |
|         | TRAPPIST | z | Sloan z | 0.766 | -0.664 | 1.010 | -0.462 |
|         | EulerCam | Cousins I | Cousins I | 0.763 | -0.639 | 1.059 | -0.491 |
Table 5
Stellar and Planetary Parameters Determined from Spectra and MCMC Analysis

| Spectroscopic Parameter | WASP-120 | WASP-122 | WASP-123 |
|-------------------------|----------|----------|----------|
| Tycho-2 ID              | 8068-01208-1 | 7638-00981-1 | 7427-00581-1 |
| USNO-B ID               | 0441-0033568 | 0475-0113097 | 0571-1147509 |
| RA (J2000)              | 04:10:27.85 | 07:13:12.34 | 19:17:55.04 |
| Dec (J2000)             | -45:53:53.5 | -42:24:35.1 | -32:51:35.8 |
| V Magnitude             | 11.0      | 11.0      | 11.1      |
| Tycho (B-V) color       | 0.523 ± 0.083 | 0.78 ± 0.11 | 0.48 ± 0.17 |
| Spectral Type           | F5        | G4        | G5        |
| Distance (pc)           | 437 ± 21  | 266 ± 10  | 214 ± 11  |
| BAGEMASS Age (Gyr)      | 2.6 ± 0.5 | 5.11 ± 0.8 | 6.9 ± 1.4 |
| Stellar Effective Temp., T_{eff} (K) | 6450 ± 120 | 5720 ± 130 | 5740 ± 130 |
| Stellar Surface Gravity, log g_e | 4.3 ± 0.1 | 4.3 ± 0.1 | 4.3 ± 0.1 |
| Stellar Metallicity, [Fe/H] | -0.05 ± 0.07 | 0.32 ± 0.09 | 0.18 ± 0.08 |
| Projected Rot. Vel., V sin i (km s^{-1}) | 15.1 ± 1.2 | 3.3 ± 0.8 | 1.0 ± 0.7 |
| Stellar Lithium Abundance, log A(Li) | <1.2 | <1.0 | <0.5 |
| Micro turbulence (km s^{-1}) | 1.5 ± 0.1 | 0.9 ± 0.1 | 1.0 ± 0.1 |
| Macro turbulence (km s^{-1}) | 6.0 ± 0.8 | 3.4 ± 0.5 | 3.4 ± 0.5 |

MCMC Parameter | WASP-120 | WASP-122 | WASP-123 |
|---------------|----------|----------|----------|
| Period, P (d) | 3.6112706 ± 0.0000043 | 1.7100566 ± 0.0000002 | 2.9776412 ± 0.0000023 |
| Transit Epoch, T_0 | 6779.43556 ± 0.00051 | 6665.22401 ± 0.000021 | 6845.17082 ± 0.000039 |
| Transit Duration, T_{14} (d) | 0.1483 ± 0.0016 | 0.09117 ± 0.00082 | 0.1289 ± 0.0014 |
| Scalded Semi-major Axis, a/R_s | 5.90 ± 0.33 | 4.248 ± 0.072 | 7.13 ± 0.25 |
| Transit Depth, (R_p/R_s)^2 | 0.00655 ± 0.00016 | 0.01386 ± 0.00029 | 0.01110 ± 0.00027 |
| Impact Parameter, b | 0.78 ± 0.02 | 0.8622 ± 0.0071 | 0.530 ± 0.049 |
| Orbital Inclination, i (°) | 82.54 ± 0.78 | 78.3 ± 0.3 | 85.74 ± 0.55 |
| Eccentricity, e | 0.057^{+0.023}_{-0.018} | 0 (adopted; <0.08 at 2σ) | 0 (adopted; <0.12 at 2σ) |
| Argument of Periastron, ω(°) | -27^{±18}_{±28} | - | - |
| Systemic Velocity, γ (km s^{-1}) | 19.836 ± 0.013 | 34.5934 ± 0.0017 | 16.9344 ± 0.0017 |
| Semi-amplitude, K_1 (ms^{-1}) | 509 ± 17 | 185.1 ± 2.3 | 114.2 ± 2.2 |
| Semi-major Axis, a (AU) | 0.0514 ± 0.0007 | 0.03005 ± 0.00031 | 0.04263 ± 0.00074 |
| Stellar Mass, M_*(M_{Sun}) | 1.393 ± 0.057 | 1.239 ± 0.039 | 1.166 ± 0.061 |
| Stellar Radius, R_*(R_{Sun}) | 1.87 ± 0.11 | 1.52 ± 0.03 | 1.285 ± 0.051 |
| Stellar Density, \rho_*(\rho_{Sun}) | 0.212^{±0.041}_{-0.031} | 0.351 ± 0.018 | 0.548 ± 0.059 |
| Stellar Surface Gravity, log(g_*) (cgs) | 4.035 ± 0.049 | 4.166 ± 0.016 | 4.286 ± 0.032 |
| Limb-Darkening Temperature, T_{LD} (K) | 6440 ± 120 | 5750 ± 120 | 5740 ± 130 |
| Planet Mass, M_p(M_{Sun}) | 4.85 ± 0.21 | 1.284 ± 0.032 | 0.899 ± 0.036 |
| Planet Radius, R_p(R_{Sun}) | 1.473 ± 0.096 | 1.743 ± 0.047 | 1.318 ± 0.065 |
| Planet Density, \rho_p(\rho_{Sun}) | 1.51^{±0.3}_{-0.26} | 0.243 ± 0.019 | 0.393 ± 0.056 |
| Planet Surface Gravity, log(g_p) (cgs) | 3.707 ± 0.056 | 2.985 ± 0.022 | 3.07 ± 0.04 |
| Planet Equilibrium Temperature, T_{eq} (K) | 1880 ± 70 | 1970 ± 50 | 1520 ± 50 |

Note. Spectral parameters have formal uncertainties while parameters found via MCMC are the median values of the posterior distributions with an uncertainty corresponding to the 1σ confidence interval.

Due to the upgrade to CORALIE, we partitioned the data into two sets. We added jitter of 5.1 ± 0.2 m s^{-1} to the older data and 6.3 ± 0.8 m s^{-1} to the newer data. These values were adopted such that both data sets gave reduced χ² values of one compared to a circular orbit solution and are in keeping with jitter determined for similar stars by Wright (2005). The uncertainties were estimated using a jackknife resampling. The difference between the jitter values of 0.8 ± 0.8 is consistent with zero; thus, the jitter values are consistent to 1σ.

Our resulting orbital solution had an eccentricity of 0.057^{+0.023}_{-0.018}. This is significantly non-zero at 3.3σ, while a Lucy-Sweeney test (Lucy & Sweeney 1971) gives a probability of only 0.1% that the orbit is circular. We note, though, that this result is somewhat dependent on the jitter values used. Fitting with no jitter increased the eccentricity to 0.068 ± 0.014. This led to a higher apparent significance (4.9σ), though the Lucy-Sweeney test no longer excluded the circular solution since neither solution is a good fit to the data. We thus adopt the
value of eccentricity with jitter added but regard this as needing confirmation.

More massive planets, such as WASP-120 b at 5.0 $M_{\text{Jup}}$, often have eccentric orbits (Figure 10), though it is unclear if the correlation is due to a real phenomenon or observation bias, as the eccentricities of more massive planets are easier to detect from RVs. A conclusive determination of this system’s eccentricity would come from the observation of an occultation that we expect to be delayed by 2.6 ± 1.1 hours if our eccentricity value is accurate. Based on the equilibrium
temperature of the planet, we estimate occultation depths in the Spitzer 3.6 \( \mu \)m and 4.5 \( \mu \)m bands of approximately 780 and 960 ppm, respectively. Recent observations with Spitzer (Zhao et al. 2014; Deming et al. 2015) show detecting such an occultation is easily achievable.

The faint star close to WASP-120 may provide evidence in support of the planet having undergone high-eccentricity migration due to Kozai-Lindov cycles. According to Dotter et al. (2008), the companion’s color is consistent with a 0.6 \( M_\odot \), K9 star at the same distance as WASP-120. Assuming this

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**Figure 6.** Caption as for Figure 5. As we enforced a circular orbit, we did not fit \( \sqrt{e} \cos \omega \) and \( \sqrt{e} \sin \omega \).
to be the case, the on-sky separation gives a minimum separation of 950 AU. Using the equations of Fabrycky & Tremaine (2007), a star of this mass could induce Kozai-Lindor cycles if the planet’s original orbital distance was 14.5 AU or greater. As the periodogram of the RVs for WASP-120 show no significant peaks beyond that of the planet (Figure 9), we checked for the presence of an additional, long-period object in the system by fitting a linear trend to the residuals of the RVs. The result was an RV drift, $\gamma$, of $(84 \pm 73)$ m s$^{-1}$ yr$^{-1}$, which is consistent with zero at $\sim 1.2\sigma$. 

Figure 7. Caption as for Figure 6
Following Montet et al. (2014), for a planet on a circular orbit:

\[ \dot{\gamma} = (6.57 \text{ m s}^{-1} \text{ yr}^{-1}) \left( \frac{M_2}{M_{\text{rup}}} \right) \left( \frac{a_2}{5 \text{ AU}} \right)^{-2} \sin i_2. \]  

(1)

Therefore, if there is an additional object in the system it has a mass, \( M_2 \), semimajor axis \( a_2 \), and inclination, \( i_2 \), such that \( M_2 \sin i_2/a_2^2 \lesssim 0.51 M_{\text{rup}} \text{ AU}^{-2} \).

Notable examples of massive planets with confidently detected eccentricities are HAT-P-16 b (Buchhave et al. 2010), HAT-P-21 b (Bakos et al. 2011), WASP-14 b (Joshi et al. 2009), and WASP-89 b (Hellier et al. 2014). All of these are in sub 7-day orbits with masses > 4 \( M_{\text{Jup}} \). Also notable are HAT-P-20 b (Bakos et al. 2011), which has the smallest eccentricity of the group, and Kepler-14 b, with the longest orbital period at 6.79 days (Buchhave et al. 2011). Like WASP-120, three of these six systems are known to have other stars nearby: HAT-P-16, WASP-14, and Kepler-14 (Wöllert et al. 2015; Wöllert & Brandner 2015; Ngo et al. 2015; Buchhave et al. 2011). However, this sample is too small to draw conclusions about a link between orbital eccentricity and the presence of a stellar-mass neighbor.

It is thought that stars with effective temperatures cooler than 6200 K have convective envelopes that enhance orbit circularization/realignment (Winn et al. 2010). This could erase any correlation between the type of orbit a planet is in and the presence of a further companion.

In a study on the prevalence of multiple stars in planetary systems, Ngo et al. (2015) found that of their sample of hot-
host stars \((T_{\text{eff}} > 6200K)\) with evidence of misaligned or eccentric planet orbits, 59% ± 17% had companions, while 83% ± 14% of their well-aligned/circular orbit sample had companions. When Ngo et al. (2015) considered just the spin–orbit alignment of these systems, 73% ± 15% of misaligned systems had companions as opposed to 53% ± 14% of well-aligned systems. They concluded that there is no evidence for a link between multiplicity and orbital eccentricity/alignment, though so far the sample is just 18 hot stars, fewer when just those systems with measured spin–orbit alignments are used.

The typical timescale of orbital circularization is expected to be shorter than that of tidal realignment, meaning that observations of spin–orbit misalignment may provide a better record of migration pathway than eccentricity. Therefore, increasing the number of hot-host star systems with measured spin–orbit alignment that have been evaluated for stellar multiplicity could change the current picture.

5. WASP-122

WASP-122 b is a 1.28 \(M_{\text{Jup}}\), 1.74 \(R_{\text{Jup}}\) planet orbiting a moderately bright \((V = 11.0)\), metal-rich \([\text{Fe/H}] = +0.32 \pm 0.09\), G4 star. WASP-122 is depleted in lithium \((\log A(Li) < 1.0)\) and so must be several Gyr old (Sestito & Randich 2005). Using the star’s color and rotational period from its \(V\ sin i\), we calculate gyrochronological ages of 2.3 ± 1.4 Gyr (Barnes 2007), 2.8 ± 1.4 (Mamajek & Hillenbrand 2008), and 2.9 ± 4.8 (Meibom et al. 2009). Using BAGEMASS, we find two possible solutions. Approximately 75% of the Markov chain output by BAGEMASS favors a mass of 1.24 ± 0.04 \(M_\odot\) and an age of 5.11 ± 0.80 Gyr. The other 25% of the output prefer a solution giving a mass of 1.10 ± 0.03 \(M_\odot\), and an age of 8.67 ± 1.05 Gyr. The favored, younger, higher-mass solution is a better match to, though is still older than, the gyrochronological ages.

WASP-122 b presents a good target for atmospheric characterization via transmission spectroscopy. Assuming the atmosphere is isothermal and adequately described as an ideal gas, we can calculate the atmospheric scale height, \(H\), using

\[
H = \frac{kT_{\text{eq}}}{g\mu}
\]  

(2)

Here, \(k\) is Boltzmann’s constant, \(T_{\text{eq}}\) is the planetary equilibrium temperature, \(g\) is the planetary surface gravity, and \(\mu\) is the mean molecular mass of the atmosphere. We can use \(H\) to predict the transit depth variation due the addition of one atmospheric scale height to the planetary radius. In the case of WASP-122 b this is 142 ppm. The same calculation for the well-studied HD209458b yields a variation of \(\approx 200\) ppm. Deming et al. (2013) found evidence for water absorption on this scale in HD209458b. While WASP-122 is dim by comparison to HD209458, constraints have been put on the atmospheric compositions of planets with similarly bright hosts. For example, studies of WASP-12 \((V = 11.6,\) ) show evidence of aerosols and a lack of TiO (Sing et al. 2013) as well as placing constraints on the C/O ratio of the planet (Kreidberg et al. 2015), which has been suggested may be an indicator of formation environment. We predict occultation depths in 3.6 \(\mu\)m and 4.5 \(\mu\)m Spitzer bands of 2100 and 2500 ppm, respectively. In the K-band we predict a depth of 1000 ppm. Similar K-band depths have been detected, for example, that of WASP-10b (Cruz et al. 2015), making ground-based follow-up possible. Such observations of WASP-122 b stand to shed light on our understanding of atmospheric albedo and opacity sources as well as its formation history.

6. WASP-123

WASP-123 b is a 0.90 \(M_{\text{Jup}}\), 1.32 \(R_{\text{Jup}}\) planet orbiting a moderately bright \((V = 11.1)\), G5 star with a super-solar metal abundance \(([\text{Fe/H}] = +0.18 \pm 0.08)\). WASP-123 is depleted in lithium \((\log A(Li) < 0.5)\) suggesting an age of several Gyr. This star falls into an area of parameter space for which gyrochronology is poorly calibrated (Jeffries 2014). The Barnes calibration gives an age greater than the present age of the universe, and Mamajek and Meibom calibrations are not applicable as the star’s color results in the calibrations requiring the logarithm of a negative value. The age we derive using BAGEMASS, 6.9 ± 1.4 Gyr, supports an advanced age. Planets of similar mass and radius are not uncommon and are frequently found in orbits \(\sim 3\) days around such host stars. This makes WASP-123 a typical example of a hot-Jupiter system. However, even these can prove surprising (e.g., WASP-47;
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Becker et al. 2015; Neveu-VanMalle et al. 2015) and/or contribute as vital controls to other studies.

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