

## Simulation and Modeling of Transit Eclipses by Planets

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**Abstract.** Light curve analysis by MDW of the photometry and RV data accumulated to date on HD 209458 has made use of a simulations database created for an 8-day HST observing project led by RLG to look for transits in 47 Tuc. We report progress in developing a consistent set of parameters obtained with our versions of the Wilson-Devinney program, WD98 and wd98k93, specially

modified to treat large grid sizes, corresponding to objects with radii exceeding  $0.7R_J$  and masses greater than  $0.1M_J$ .

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## 1. Introduction

A July 1999, 8.3 day HST experiment (*Taking the measure of Planets in the Globular Cluster 47 Tuc*), organized and described by R. L. Gilliland, et al., (2000), was designed to search for transits by objects as small as Saturn in a densely crowded star field. The globular cluster 47 Tucanae, a rich, bright cluster, was selected to give the highest probability of finding transiting planets. The time-series data extraction, described by Brown, et al. (2000), has produced to present writing 75 variables. Only one of these seemed to offer promise as planetary transit candidate: WF2-V02, but this has now proven to be an artifact of the processing.

While 10's of planets were expected to be discovered in 47 Tuc by means of transit technique, the first discovery of a photometric planetary transit was reported instead by Henry, et al., (2000), and by Charbonneau, et al, (2000), following radial velocity work which identified a planet in this system. Consequently, Williams added the latter to his program of modeling based on planetary transit work carried out for the 47 Tuc project. As well as fitting model curves to data, predicted light curves in the infrared have also been produced by Williams. The density of the planet is found to be  $399 \frac{kg}{m^3}$  and the planetary albedo was assumed to be 0.52. The best results for each system are shown in table 1.

## 2. Analysis Procedure

The programs used for the analyses are the latest University of Calgary versions of the Wilson-Devinney program. WD98 and wd98k93d (see Milone, et al., 2000), developed over the past two years by Josef Kallrath from the WD95 package (Kallrath, et al., 1998; Kallrath & Milone 1999), and the more recent base code provided by Wilson (1998). WD98 is a self-iterating damped-least squares package, with Kurucz atmospheric models, and with all the upgrades of Wilson's code.

The initial parameters for the HD209458 modeling came from Charbonneau, et al., (2000) and Henry, et al., (2000). The initial values of the mass, temperature,  $M_V$ , log g, and radius of the dominant star in the 47 Tuc eclipsing systems were obtained from the nearest 47 Tuc isochrone (D. VandenBerg, 1999) point beneath the CMD position of the system. Iterations were performed until the parameter corrections were exceeded by the m.s.e.s and where possible, the p.e.s. The final error of the best fit (the m.s.e. of a single observation of average weight) appears in the last column of the results, table 1.

### 3. Results

Further examination of the data has shown the variability in WF2-V02 to be due to contamination from a saturated blue straggler variable, adjacent to it. The WF2-V02 results show that the search did have the sensitivity to find transits with a depth similar to that expected for giant planets. That the modeling largely ruled out the possibility of a planet in this case demonstrates the need for detailed modeling of suspected planetary transits.

The conclusion to be drawn from the 47 Tuc experiment is that there is a significant shortfall in the number of gas giant planets with periods less than a week in 47 Tucanae. There are two possible explanations: either higher metallicity is required for planetary formation; and/or such objects cannot survive the dynamical interactions in the cluster. In any case, there is an absence of 'hot Jupiters' in the fields surveyed in 47Tuc.

Table 1. M and R are in solar units except noted otherwise.  $\Omega$  is the modified Roche potential. T is the mean effective temperature.

System	Star/Planet	HD 209458	HD209458b
System Elements	P (days)		3.524779(295)
	epoch (245...)		1254.5857(148)
	a( $R_{\odot}$ )		9.925(744)
	i		86.32(10)
	q = $M_2/M_1$		0.00059(2)
Star/Planet Parameters	$\Omega$	8.772(41)	1.5432(6)
	M	1.06	0.655 $M_J$
	R	1.13	1.27 $R_J$
	T (K)	6037(70)	998(531)
	$M_{bol}$	4.33	16.76
Fit Error	$\sigma_1$ (av, wt)		$\pm 0.00153$

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