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Cluster Difference Imaging Photometric Survey. III. Subtitle.

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ABSTRACT

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1. INTRODUCTION

Lorem ipsum.

Section 2 describes the identification of the candidate, and our follow-up observations. Section 3 combines the available data to assess the system's false positive probability, and validates TOI 1937b as a planet. Section 4 presents our knowledge of the cluster (Section 4.1), the star (Section 4.2) and the planet (Section 4.3). We conclude by discussing avenues for confirmation and improved characterization in Section 5.

2. IDENTIFICATION AND FOLLOW-UP OBSERVATIONS

2.1. *TESS Photometry*

2.2. *Gaia Astrometry and Imaging*

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2.3. *High-Resolution Imaging*

2.4. *Ground-based Time-Series Photometric Follow-up*

2.5. *Spectroscopic Follow-up*

2.5.1. *SMARTS 1.5 m / CHIRON*

2.5.2. *FEROS*

2.5.3. *Veloce*

3. ASSESSMENT OF FALSE POSITIVE SCENARIOS

3.1. *Constraints on False Positive Scenarios*

3.2. *False positive probability*

4. SYSTEM MODELING

4.1. *The Cluster*

4.1.1. *Physical Characteristics*

4.1.2. *HR Diagram*

4.2. *The Star*

4.2.1. *Membership of TOI 1937 in NGC 2516*

4.2.2. *Rotation*

4.2.3. *Lithium*

4.2.4. *Stellar Parameters*

4.3. *The Planet*

5. DISCUSSION

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This research was based in part on observations obtained at the Southern Astrophysical Research (SOAR) telescope, which is a joint project of the Ministério da Ciência, Tecnologia e Inovações (MCTI/LNA) do Brasil, the US National Science Foundation's NOIRLab, the University of North Carolina at Chapel Hill (UNC), and Michigan State University (MSU).

This research made use of the Exoplanet Follow-up Observation Program website, which is operated by the California Institute of Technology, under contract with the National Aeronautics and Space Administration under the Exoplanet Exploration Program.

This research made use of the SVO Filter Profile Service (http://svo2.cab.inta-csic.es/theory/fps/) supported from the Spanish MINECO through grant AYA2017-84089.

Resources supporting this work were provided by the NASA High-End Computing (HEC) Program through the NASA Advanced Supercomputing (NAS) Division at Ames Research Center for the production of the SPOC data products.

Software: `arviz` (Kumar et al. 2019), `astrobase` (Bhatti et al. 2018), `AstroImageJ` (Collins et al. 2017), `astropy` (Astropy Collaboration et al. 2018), `astroquery` (Ginsburg et al. 2018), `ceres` (Brahm et al. 2017), `cdips-pipeline` (Bhatti et al. 2019), `corner` (Foreman-Mackey 2016), `exoplanet` (Foreman-Mackey et al. 2020), and its dependencies (Agol et al. 2020; Kipping 2013; Luger et al. 2019; Theano Development Team 2016), `IPython` (Pérez & Granger 2007), `matplotlib` (Hunter 2007), `numpy` (Walt et al. 2011), `pandas` (McKinney 2010), `pyGAM` (Servén et al. 2018), `PyMC3` (Salvatier et al. 2016), `radvel` (Fulton et al. 2018), `scipy` (Jones et al. 2001), `tesscut` (Brasseur et al. 2019), `wotan` (Hippke et al. 2019).

Facilities: *Astrometry*: Gaia (Gaia Collaboration et al. 2016, 2018). *Imaging*: Second Generation Digitized Sky Survey, SOAR (HRCam; Tokovinin 2018). *Spectroscopy*: CTIO1.5 m (CHIRON; Tokovinin et al. 2013), PFS (**CITE**), AAT (Veloce; Gilbert et al. 2018). *Photometry*: El Sauce:0.356 m, TESS (Ricker et al. 2015).

Table 1. Literature and Measured Properties for TOI 1937A

Parameter	Description	Value	Source
Other identifiers			
	TIC 268301217		
	GAIADR2 5489726768531119616		
	GAIAEDR3 5489726768531119616		
$\alpha_{J2016.0}$	Right Ascension (deg)	116.3707 ± 0.0109	1
$\delta_{J2016.0}$	Declination (deg)	-52.3833 ± 0.0097	1
$l_{J2016.0}$	Galactic Longitude (deg)	265.3082	1
$b_{J2016.0}$	Galactic Latitude (deg)	-13.5487	1
V	Johnson V mag.	13.18 ± 0.10	2
G	Gaia *G* mag.	13.005±0.003	1
Bp	Gaia *Bp* mag.	13.417 ±0.003	1
Rp	Gaia *Rp* mag.	12.421±0.004	1
T	TESS mag.	12.493±0.006	2
J	2MASS J mag.	11.717 ± 0.020	3
H	2MASS H mag.	11.324 ± 0.026	3
K_S	2MASS K_S mag.	11.226 ± 0.021	3
W1	WISE1 mag.	11.135 ± 0.023	4
W2	WISE2 mag.	11.155 ± 0.020	4
W3	WISE3 mag.	11.160 ± 0.086	4
W4	WISE4 mag.	9.246 ± N/A	4
π	Gaia EDR3 parallax (mas)	2.411 ± 0.011	1
d	Distance (pc)	414.7 ± 1.9	1
$\mu_{\alpha'}$	Gaia EDR3 proper motion in RA (mas yr^{-1})	-5.627 ± 0.013	1
μ_{δ}	Gaia EDR3 proper motion in DEC (mas yr^{-1})	11.309 ± 0.013	1
RUWE	Gaia EDR3 renormalized unit weight error	0.908	1
RV	Gaia EDR3 systemic radial velocity (km s^{-1})	17.44 ± 0.64†	1
RV	Adopted systemic radial velocity (km s^{-1})	17.44 ± 0.64†	1
$v \sin i_\star$	Rotational velocity (km s^{-1})	– ± –	5
$v_{\rm mac}$	Macroturbulence velocity (km s^{-1})	– ± –	5
[Fe/H]	Metallicity	– ± –	5
$T_{\rm eff}$	Effective Temperature (K)	—- ± —	6
$\log g_\star$	Surface Gravity (cgs)	x.xxx ± 0.049	6
Li EW	6708Å Equiv. Width (mÅ)	< 30	7
$P_{\rm rot}$	Rotation period (d)	6.5 ± $X.X$	8
Age	Adopted stellar age (Myr)	—	9
Spec. Type	Spectral Type	G2V	5
$R_\star$	Stellar radius ($R_\odot$)	X.XXX±X.XXX	6
$M_\star$	Stellar mass ($R_\odot$)	1.XXX±X.XXX	6
A_V	Interstellar reddening (mag)	0.XX±0.XX	10

NOTE— † Systemic RV uncertainty is the standard deviation of single-transit radial velocities, as quoted in Gaia DR2. **FIXME** Provenances are: [1]Gaia Collaboration et al. (2018), [2]Stassun et al. (2019), [3]Skrutskie et al. (2006), [4]Wright et al. (2010), [5]CHIRON spectra, [6]Method 2 (cluster isochrone, Section 4.2.4), [7]FEROS spectra, [8]TESS light curve, [9]IC 2602 ages from isochrone & lithium depletion analyses (Section 4.1.1), [10]Method 1 (photometric SED fit, Section 4.2.4).

Table 2. Literature and Measured Properties for TOI 1937B

Parameter	Description	Value	Source
Other identifiers			
	TIC 766593811		
	GAIADR2 5489726768531118848		
	GAIAEDR3 5489726768531118848		
$\alpha_{J2016.0}$	Right Ascension (deg)	116.3706 ± 0.0098	1
$\delta_{J2016.0}$	Declination (deg)	-52.3826 ± 0.0753	1
G	Gaia G mag.	17.653±0.003	1
Bp	Gaia Bp mag.	17.950 ±0.098	1
Rp	Gaia Rp mag.	16.246 ±0.015	1
T	TESS mag.	16.86±0.08	2
ΔI_C	SOAR Cousins-I mag diff.	4.3±0.X	2
π	Gaia EDR3 parallax (mas)	2.351 ± 0.089	1
d	Distance (pc)	425.3 ± 16.1	1
$\mu_{\alpha'}$	Gaia EDR3 proper motion in RA (mas yr^{-1})	-5.387 ± 0.104	1
μ_δ	Gaia EDR3 proper motion in DEC (mas yr^{-1})	11.349 ± 0.096	1
RUWE	Gaia EDR3 renormalized unit weight error	1.120	1
[Fe/H]	Metallicity	– ± –	5
$T_{\rm eff}$	Effective Temperature (K)	—- ± —	6
$\log g_\star$	Surface Gravity (cgs)	x.xxx ± x.xx	6
Li EW	6708Å Equiv. Width (mÅ)	NaN	7
$P_{\rm rot}$	Rotation period (d)	NaN	8
Age	Adopted stellar age (Myr)	—	9
Spec. Type	Spectral Type	M1V**FIX**	5
$R_\star$	Stellar radius ($R_\odot$)	0.XXX±X.XXX	6
$M_\star$	Stellar mass ($R_\odot$)	0.XXX±X.XXX	6
A_V	Interstellar reddening (mag)	0.XX±0.XX	10

NOTE— **FIXME** Provenances are: [1]Gaia Collaboration et al. (2018), [2]Stassun et al. (2019), [3]Skrutskie et al. (2006), [4]Wright et al. (2010), [5]CHIRON spectra, [6]Method 2 (cluster isochrone, Section 4.2.4), [7]FEROS spectra, [8]TESS light curve, [9]IC 2602 ages from isochrone & lithium depletion analyses (Section 4.1.1), [10]Method 1 (photometric SED fit, Section 4.2.4).

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