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<b>Authors</b>	Christiansen, J. L., Vanderburg, A., Burt, J., Fulton, B. J., Batygin, K., Benneke, B., Brewer, J. M., Charbonneau, D., Ciardi, D. R., Cameron, A. C., Coughlin, J. L., Crossfield, I. J. M., Dressing, C., Greene, T. P., Howard, A. W., Latham, D. W., MOLINARI, Emilio Carlo, Mortier, A., Mullally, F., Pepe, F., Rice, K., Sinukoff, E., SOZZETTI, Alessandro, Thompson, S. E., Udry, S., Vogt, S. S., Barman, T. S., Batalha, N. E., Bouchy, F., Buchhave, L. A., Butler, R. P., Cosentino, R., Dupuy, T. J., Ehrenreich, D., Fiorenzano, A., Hansen, B. M. S., Henning, T., Hirsch, L., Holden, B. P., Isaacson, H. T., Johnson, J. A., Knutson, H. A., Kosiarek, M., Lopez-Morales, M., Lovis, C., Malavolta, L., Mayor, M., MICELA, Giuseppina, Motalebi, F., Petigura, E., Phillips, D. F., Piotto, G., Rogers, L. A., Sasselov, D., Schlieder, J. E., Segransan, D., Watson, C. A., Weiss, L. M.
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<b>Journal</b>	VizieR Online Data Catalog



**J/AJ/154/122** Radial velocities for the HD 3167 system (Christiansen+, 2017)

Three's company: an additional non-transiting super-Earth in the bright HD 3167 system, and masses for all three planets.

Christiansen J.L., Vanderburg A., Burt J., Fulton B.J., Batygin K., Benneke B., Brewer J.M., Charbonneau D., Ciardi D.R., Cameron A.C., Coughlin J.L., Crossfield I.J.M., Dressing C., Greene T.P., Howard A.W., Latham D.W., Molinari E., Mortier A., Mullally F., Pepe F., Rice K., Sinukoff E., Sozzetti A., Thompson S.E., Udry S., Vogt S.S., Barman T.S., Batalha N.E., Bouchy F., Buchhave L.A., Butler R.P., Cosentino R., Dupuy T.J., Ehrenreich D., Fiorenzano A., Hansen B.M.S., Henning T., Hirsch L., Holden B.P., Isaacson H.T., Johnson J.A., Knutson H.A., Kosiarek M., Lopez-Morales M., Lovis C., Malavolta L., Mayor M., Micela G., Motalebi F., Petigura E., Phillips D.F., Piotto G., Rogers L.A., Sasselov D., Schlieder J.E., Segransan D., Watson C.A., Weiss L.M.  
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=[2017AJ....154..122C](#) (SIMBAD/NED BibCode)

**ADC\_Keywords:** Stars, nearby ; Exoplanets ; Radial velocities

**Keywords:** eclipses - stars: individual (HD 3167) - techniques: photometric - techniques: spectroscopic

**Abstract:**

HD 3167 is a bright ( $V=8.9$ ), nearby K0 star observed by the NASA K2 mission (EPIC 220383386), hosting two small, short-period transiting planets. Here we present the results of a multi-site, multi-instrument radial-velocity campaign to characterize the HD 3167 system. The masses of the transiting planets are  $5.02 \pm 0.38 M_{\text{earth}}$  for HD 3167 b, a hot super-Earth with a likely rocky composition ( $\rho_b = 5.60_{-1.43}^{+2.15} \text{ g/cm}^3$ ), and  $9.80_{-1.24}^{+1.30} M_{\text{earth}}$  for HD 3167 c, a warm sub-Neptune with a likely substantial volatile complement ( $\rho_c = 1.97_{-0.59}^{+0.94} \text{ g/cm}^3$ ). We explore the possibility of atmospheric composition analysis and determine that planet c is amenable to transmission spectroscopy measurements, and planet b is a potential thermal emission target. We detect a third, non-transiting planet, HD 3167 d, with a period of  $8.509 \pm 0.045$  d (between planets b and c) and a minimum mass of  $6.90 \pm 0.71 M_{\text{earth}}$ . We are able to constrain the mutual inclination of planet d with planets b and c: we rule out mutual inclinations below  $1.3^\circ$  because we do not observe transits of planet d. From  $1.3^\circ$  to  $40^\circ$ , there are viewing geometries invoking special nodal configurations, which result in planet d not transiting some fraction of the time. From  $40^\circ$  to  $60^\circ$ , Kozai-Lidov oscillations increase the system's instability, but it can remain stable for up to 100 Myr. Above  $60^\circ$ , the system is unstable. HD 3167 promises to be a fruitful system for further study and a preview of the many exciting systems expected from the upcoming NASA TESS mission.

**Description:**

The final data set includes observations obtained with Keck/HIRES, Automated Planet Finder (APF)/Levy, and HARPS-N.

Our observational setup for both Keck/HIRES and the APF/Levy was essentially identical to those described in Fulton et al. (2016, [J/ApJ/830/46](#)) and Burt et al. ([2014ApJ...789..114B](#)). We collected a total of 60 RV measurements using Keck/HIRES (Vogt et al. [1994SPIE.2198..362V](#)), and 116 measurements using the Levy Spectrograph on the APF (Radovan et al. 2014SPIE.9145E..2BR; Vogt et al. [2014PASP..126..359V](#)) at Lick Observatory between 2016 July 7 and 2016 December 2.

We also observed HD 3167 with the HARPS-N spectrograph (Cosentino et al. 2012SPIE.8446E..1VC) located at the 3.58 m Telescopio Nazionale Galileo on the island of La Palma, Spain. HARPS-N is a stabilized spectrograph designed for precise RV measurements. We observed HD 3167 76 times

between 2016 July 7 (independently beginning the same night as the HIRES/APF campaign) and 2016 December 7, obtaining high-resolution optical spectra with a spectral resolving power of  $R=115000$ .

#### Objects:

RA	(ICRS)	DE	Designation(s)
00 34 57.52		+04 22 53.3	HD 3167 = HIP 2736

#### File Summary:

FileName	lrecl	Records	Explanations
ReadMe	80	.	This file
<a href="#">table2.dat</a>	32	252	Radial Velocities for HD 3167

#### See also:

- [J/ApJ/829/L9](#) : K2 LC of HD 3167 and Robo-AO image (Vanderburg+, 2016)
- [J/ApJ/830/46](#) : Radial velocities of 3 Neptune-mass planet hosts (Fulton+, 2016)
- [J/AJ/153/208](#) : LCES HIRES/Keck radial velocity Exoplanet Survey (Butler+, 2017)
- [J/AJ/154/123](#) : Radial velocity follow-up of the HD 3167 system (Gandolfi+, 2017)

#### Byte-by-byte Description of file: [table2.dat](#)

Bytes	Format	Units	Label	Explanations
1- 11	F11.5	<a href="#">d</a>	HJD	[17576.70031/17728.4833] Heliocentric Julian Date (HJD-2440000) UTC
13- 20	F8.2	<a href="#">m/s</a>	RV	[-14.91/19534.88] Radial velocity <a href="#">(1)</a>
22- 25	F4.2	<a href="#">m/s</a>	e_RV	[0.52/2.73] Uncertainty in RV <a href="#">(2)</a>
27- 32	A6	---	Inst	Instrument (APF, HARPSN, HIRES or APFS)

**Note (1):** Zero point offsets between instruments have not been removed and must be fit as free parameters when analyzing this dataset.

System velocity:

$$V_{\text{HIRES}} = -0.9^{+0.46}_{-0.47}$$

$$V_{\text{APF}} = -0.51^{+0.36}_{-0.37}$$

$$V_{\text{HARPSN}} = -19528.8 \pm 0.23$$

**Note (2):** Stellar jitter has not been incorporated into the uncertainties.

#### History:

From electronic version of the journal

(End) Prepared by [AAS], Tiphaine Pouvreau [CDS] 06-Jun-2018

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