1. Introduction

The formation and evolution of brown dwarfs (BD) is not well understood. While it seems clear that these objects are too massive to generally form by core-accretion in a circumstellar disk (Fig. 3 of Mordasini et al. 2009), a number of plausible formation theories have been advanced (see reviews by Whitworth et al. 2007, Luhman 2012), but the role each of them plays in the actual formation process is not clear. The small number of BD companions to solar-type stars prevents reliable statistical studies from being made, and although radial-velocity surveys have detected a few tens of objects with minimum masses in the BD regime (e.g. Sahlmann et al. 2011; Díaz et al. 2012), the inclinations from being made, and although radial-velocity surveys have detected a few tens of objects with minimum masses in the BD regime (e.g. Sahlmann et al. 2011; Díaz et al. 2012), the inclinations from being made, and although radial-velocity surveys have detected a few tens of objects with minimum masses in the BD regime (e.g. Sahlmann et al. 2011; Díaz et al. 2012), the inclinations from being made, and although radial-velocity surveys have detected a few tens of objects with minimum masses in the BD regime (e.g. Sahlmann et al. 2011; Díaz et al. 2012), the inclinations from being made, and although radial-velocity surveys have detected a few tens of objects with minimum masses in the BD

2. Description of the data

2.1. Kepler photometry

KOI-205 (KIC 7046804) was observed by Kepler from Quarters 1 through 13, i.e., between May 2009 and June 2012, with a sampling of one point every 29.4 minutes (Long Cadence data, LC). Although Short Cadence data are also available for some quarters, only LC data were used to reduce computation time, and because the transit shape is sampled well enough in the phasefolded data (Fig. 1). The light curve issued from the Photometric Analysis module of the Kepler pipeline was used. One-percent-deep transits are clearly visible by eye; they occur every 11.7 days. The typical uncertainty in individual LC points is around 230 ppm.

For the transit modeling only fragments of the light curve around each transit were considered. Each fragment was normalized with a parabolic fit to the out-of-transit part, and a sigma-clipping at 3σ was performed to reject outliers. The contamination by nearby stars was corrected using the crowding values.

SOPHIE velocimetry of *Kepler* transit candidates *

**VIII. KOI-205 b: a brown-dwarf companion to a K-type dwarf.**

R. F. Díaz¹, C. Damiani¹, M. Deléuil¹, J. M. Almenara¹, C. Moutou¹, S. C. C. Barros¹, A. S. Bonomo¹, F. Bouchy²,³, G. Bruno¹, G. Hébrard²,³, G. Montagnier²,³, A. Santerne¹

¹ Aix Marseille Université, CNRS, LAM (Laboratoire d’Astrophysique de Marseille) UMR 7326, 13388, Marseille, France
² Institut d’Astrophysique de Paris, UMR7095 CNRS, Université Pierre & Marie Curie, 98bis boulevard Arago, 75014 Paris, France
³ Observatoire de Haute-Provence, CNRS/OAMP, 04870 Saint-Michel-l’Observatoire, France
⁴ INAF - Osservatorio Astronomico di Torino, via Osservatorio 20, 10025, Pino Torinese, Italy

Received TBC; accepted TBC

**ABSTRACT**

We report the discovery of a transiting brown dwarf companion to KOI-205, a K0 main-sequence star, in a 11.720125-day period orbit. The transits were detected by the *Kepler* space telescope, and the reflex motion of the star was measured using radial velocity observations obtained with the SOPHIE spectrograph. The atmospheric parameters of the host stars were determined from the analysis of high-resolution, high signal-to-noise ratio ESPaDOns spectra obtained for this purpose. Together with spectrophotometric measurements recovered from the literature, these spectra indicate that the star is a mildly metallic K0 dwarf with *T* eff 5237 ± 60 K. The mass of the companion is 39.9 ± 1.0 *M* Jup and its radius is 0.81 ± 0.02 *R* Jup, in agreement with current theoretical predictions. This is the first time a *bona fide* brown dwarf companion is detected in orbit around a star of this type. The formation and orbital evolution of brown dwarf companions is briefly discussed in the light of this new discovery.

**Key words.** techniques: radial velocities – techniques: photometry – stars: brown dwarfs – stars: individual: KIC7046804
The **combined spectrum** has a $S + 3$. Host star ion hypothesis. Bisector measurements are also given in Table 2.

Kepler data, supporting the sub-stellar companion. Seven spectra of KOI-205 were obtained between February 2012 and June 2012 with the SOPHIE spectrograph (Perruchot et al. 2011). Exposure times ranging from 900 to 2700 seconds. The resulting radial velocities were fitted to a Keplerian orbit. The model SED was obtained using an interpolation of the PHOENIX/BT-Settl synthetic spectral library (Allard et al. 2012) for a given $T_{\text{eff}}$, [Fe/H], and log $g$ of the host star. The interpolated spectrum is scaled to a given distance and corrected from interstellar extinction. The distance $d$ and the color excess $E(B-V)$ were included as free parameters in our model.

The model therefore has 14 parameters, which are marked in Table 3. The mass ratio $q$ has only a slight effect on the model and because of the normalization procedure of the light curve described above, it is not constrained by these data. It was nevertheless included as a free parameter to take into account its effects on the error budget of the remaining parameters. Additionally, we included parameters describing the data: the out-of-transit flux of each of the two Kepler light curves, and a contamination factor for Season 2. Finally, the systematic errors in the radial velocities and in the light curves are modeled as an additional factor for Season 2. The parameters $\alpha_T$, $\beta_T$, and $\gamma_T$ were used to determine when each chain had reached a stationary point drawn from the joint prior, and 25 of them appeared to be appropriate. For $P$, $T_c$, and $E$, the determination by Batalha et al. (2012) was used, but the width of the distribution was increased by an order of magnitude to ensure that it would not bias the results.

Forty chains of 700,000 steps each were started at random points drawn from the joint prior, and 25 of them appeared to converge to the same solution. The remaining ones were stuck in regions of lower posterior probability, and were not considered further. A modified version of Geweke (1992) diagnostic was used to determine when each chain had reached a stationary state. To ensure that the samples used to estimate the parameters and their uncertainties are independent, the chains were thinned using their correlation length (e.g. Tegmark et al. 2004) before merging. In total, over 20,000 independent samples of the posterior distribution were obtained in this way. The formal 68.3%...

---

**Table 1. Target coordinates and apparent magnitudes.**

| Target ID | RA (J2000) | Dec. (J2000) | Parallax (mas) |
|-----------|------------|-------------|----------------|
| Kepler 7046804 | 19 41 59.20 | +42°32′16.4 ′ | 0.014          |
| 2MASS 19415919+4232163 | 19 41 59.20 | +42°32′16.4 ′ | 0.014          |

---

**Notes.** (a) From the Kepler Input Catalogue. (b) Cutri et al. (2003) (c) see Cutri et al. (2012)

from the **Kepler archive**. Due to the quarterly rotation of the spacecraft, the crowding value changes every three months, but recurs every four seasons. After contamination correction, it is obvious that transits from Season 2 are systematically deeper. We believe this is caused by an overestimation of the crowding factor, which is 12% in Season 2 and between 6 and 7% in the other seasons. We therefore decided to analyze the light curves from quarters belonging to Season 2 separately, and fit a contamination factor independently.

**2.2. SOPHIE velocimetry**

Seven spectra of KOI-205 were obtained during February 2012 and June 2012 with the SOPHIE spectrograph (Perruchot et al. 2008, Bouchy et al. 2013). Observations were performed in high-efficiency mode, with resolving power $R/\Delta R \approx 40,000$, and exposure times ranging from 900 to 2700 seconds. The resulting signal-to-noise ratios (S/N) per pixel at 550 nm are between 7 and 16.

The spectra were reduced and extracted using the SOPHIE pipeline (Bouchy et al. 2009), and the radial velocities were obtained from a Gaussian fit to the cross-correlation function with numerical masks corresponding to different spectral types. The charge transfer inefficiency (CTI) effect was corrected using the polynomial in Santerne et al. (2012). For faint targets such as these, the spectral orders at the edge of the wavelength range are usually too noisy, and adding them in the average cross-correlation function degrades the precision of the measurements. For KOI-205, 8 and 5 orders were discarded from the blue and red ends of the spectrum, respectively. The resulting radial velocities are plotted in Fig. 1 and listed in Table 2.

No bisector effect (Queloz et al. 2001) or mask effect were detected in the SOPHIE data, supporting the sub-stellar companion hypothesis. Bisector measurements are also given in Table 2.

---

**3. Host star**

The stellar atmospheric parameters were obtained using eight ESPaDOns spectra, acquired in service mode using the star + sky configuration, which provides a spectral resolution of 65,000 on the night of June 30 2012 (program 12AF05). The resulting combined spectrum has a $S/N \sim 90$ at 550 nm per resolution element. The method is described in Delorme et al. (2012) and yields the values $T_{\text{eff}} = 5210 \pm 70$ K, $[\text{Fe/H}] = 0.27 \pm 0.14$ dex, and log $g = 4.65 \pm 0.07$ [cgs]. The projected rotational velocity was determined to be $v \sin i = 2 \pm 1$ km s$^{-1}$. A comparison with StarEvolution tracks (Lagarde et al. 2012) indicates that the star is a K0 dwarf, with a wide range of allowed ages, because of the slow evolution of low-mass stars. However, its slow rotation suggests that the star is younger than the lower end of the range given in Table 3.

**4. Modeling of the data and parameter estimation**

The Kepler light curve and SOPHIE radial velocities were fitted together with the photometric measurements from Table 1 which provide a well-sampled spectral energy distribution (SED), to a model consisting of a star orbited by a dark companion of a given mass and radius. The model and the Markov Chain Monte Carlo algorithm used to take samples from the Bayesian posterior are implemented in the PASTIS package, which is described in detail in Díaz et al. (2013, in prep.). Basically, we modeled the light curves with the EBOP code (Etzel 1981, Popper & Etzel 1981) using a quadratically limb-darkened law with coefficients interpolated from the tables of Claret & Bloemen (2011). To deal with the distortion of the transit shape arising from the finite integration time (Kipping 2010) of LC data, we oversampled the model to five times the original sampling rate and re-binned to the LC sampling rate before comparing them to the data. The radial velocities were fitted to a Keplerian orbit. The model SED was obtained using an interpolation of the PHOENIX/BT-Settl synthetic spectral library (Allard et al. 2012) for a given $T_{\text{eff}}$, [Fe/H], and log $g$ of the host star. The interpolated spectrum is scaled to a given distance and corrected from interstellar extinction. The distance $d$ and the color excess $E(B-V)$ were included as free parameters in our model.

The model therefore has 14 parameters, which are marked in Table 3. The mass ratio $q$ has only a slight effect on the model and because of the normalization procedure of the light curve described above, it is not constrained by these data. It was nevertheless included as a free parameter to take into account its effects on the error budget of the remaining parameters. Additionally, we included parameters describing the data: the out-of-transit flux of each of the two Kepler light curves, and a contamination factor for Season 2. Finally, the systematic errors in the radial velocities and in the light curves are modeled as an additional source of Gaussian noise with zero mean and variance $\sigma_j$. The widths $\sigma_j$ of each dataset were also fitted.

Samples from the joint posterior distribution of the parameters were obtained using the Metropolis-Hastings algorithm (e.g. Geweke 1992), with an adaptive step size (Ford 2006), coupled with an adaptive principal component analysis to correctly sample the posterior even in the presence of non-linear correlations. Non-informative priors –i.e., uniform or Jeffreys distributions– were used for all parameters except for $T_{\text{eff}}$, $z$, $P$, and $T_c$, for which a normal distribution was deemed more appropriate. For $P$, and $T_c$, the determination by Batalha et al. (2012) was used, but the width of the distribution was increased by an order of magnitude to ensure that it would not bias the results.

Forty chains of 700,000 steps each were started at random points drawn from the joint prior, and 25 of them appeared to converge to the same solution. The remaining ones were stuck in regions of lower posterior probability, and were not considered further. A modified version of Geweke (1992) diagnostic was used to determine when each chain had reached a stationary state. To ensure that the samples used to estimate the parameters and their uncertainties are independent, the chains were thinned using their correlation length (e.g. Tegmark et al. 2004) before merging. In total, over 20,000 independent samples of the posterior distribution were obtained in this way. The formal 68.3%...
Our analysis shows that KOI-205 has a BD companion with a mass of \(40\, M_{\text{Jup}}\) and a radius of \(0.8\, R_{\text{Jup}}\), in a 11.7-day circular orbit. The position of KOI-205 in the mass-radius diagram (Fig. 2) agrees well with the theoretical isochrones by Baraffe et al. (2003) for a system with an age between 5 and 10 Gyr. If the age of the system were closer to 1 Gyr, which is permitted by the data, then the models would not reproduce the observed radius. However, given the slow rotation rate of KOI-205, it is likely that the age of the system is closer to 5 Gyr than to the lower end of the range reported in Table 3. Indeed, an analysis of the pipeline-corrected PDC Kepler light curve yields a rotational period of around 41 days, in agreement with the spectroscopic \(v \sin i\) value. Although KOI-205 b is the smallest BD detected as yet, its bulk density is similar to that of WASP-30 b (Triaud et al. 2013, Anderson et al. 2011) and lower than that of LHC6343 C (Johnson et al. 2011).

On the other hand, KOI-205 b is remarkable in two senses. First, it is the only object in the mass regime between massive BDs, such as WASP-30 b or CoRoT-15 b, and light BDs (or massive planets) such as KOI-423 b and CoRoT-3 b. Secondly, it is the only short-period (\(P \lesssim 10 - 15\) days) transiting BD known to date in orbit around a K-type star. Indeed, the second-most massive object orbiting around a similar star is HAT-P-20 b (Bakos et al. 2011), with a mass of \(7\, M_{\text{Jup}}\), i.e., almost six times less massive. Moreover, radial velocity surveys have discovered only four non-transiting objects with minimum masses above \(10\, M_{\text{Jup}}\) orbiting stars less massive than \(1\, M_{\odot}\) in short-period orbits.

Formation of BDs can proceed by gravitational collapse of a molecular cloud in a similar fashion as stellar objects form. Recent simulations (Base 2012) have shown that BDs can be formed in binaries with stellar primaries, and they reproduce quite naturally the paucity of BDs in close orbits. Another possible formation mechanism is disk fragmentation. Numerical simulations (e.g. Thies et al. 2010) have shown that numerous BDs can be formed in the outer regions of massive circumstellar disks. The mass spectrum of objects formed around a \(0.7\, M_{\odot}\) star has a maximum around the mass of KOI-205 b (Fig. 4 of Stamatellos & Whitworth 2009), so the measured mass is not only understood by but also expected from theoretical considerations. However, both processes form BDs no closer than \(10\) AU from the star, and therefore a mechanism is needed to migrate the newly-formed object to the inner system.

Scattering by other objects formed around the same star (e.g. Ford & Rasio 2008) or the Kozai mechanism (Kozai 1962) can bring the object to a closer orbit, possibly resulting in an eccentric and non-aligned orbit. Subsequent tidal dissipation is expected to have rapidly circularized the system (e.g. Matsumura et al. 2008). In these cases, the presence of at least one additional object in the system would be expected, but it is also reasonable to assume that these additional bodies are either very far out or have been ejected. Unfortunately, the time span of our current RV data is not sufficient to probe these possibilities.
Table 2. Radial velocity measurements for KOI-205

| BJD  | RV     | σ_RV  | BVS* | Exp. time | S/N/pix |
|------|--------|-------|------|-----------|---------|
| -2 450 000 | 5984.6759 | 12.144 | 0.054 | -0.386 | 1800 | 10 |
|      | 6015.6232 | 18.724 | 0.019 | -0.077 | 2700 | 16 |
|      | 6064.4682 | 16.055 | 0.061 | 0.193  | 1200 | 7  |
|      | 6071.5153 | 15.932 | 0.030 | 0.061  | 1371 | 11 |
|      | 6100.5669 | 14.414 | 0.038 | -0.035 | 1079 | 9  |
|      | 6103.3985 | 11.213 | 0.043 | -0.052 | 900  | 9  |
|      | 6105.5132 | 13.640 | 0.036 | 0.017  | 1200 | 11 |

Notes. (a) Bisector velocity span.

Fig. 3. Total angular momentum (top) and energy (bottom) of the system as a function of angular orbital frequency $n = 2\pi/P$, scaled to the critical values (see text). The solid curve is the corotation locus ($n = \Omega_c = 2\pi/P_{rot}$) for zero eccentricity, and the dashed and dot-dashed curves are the $n = 2\Omega_c$ and $n = 4\Omega_c$ loci, respectively. The green dashed curve is the constant total angular momentum locus. The position of the KOI-205 system as of today is marked by the square that is zoomed in the insets.

The fact that the orbit is nearly circular suggests that the tidal interactions are strong in the system, especially considering the spectral type of the star and the relatively high mass ratio. In fact, as mentioned in the introduction, close massive companions to late-type stars are not expected to survive engulfment. However, by taking the stellar spin rate from the spectroscopic ions to late-type stars are not expected to survive engulfment.

The orbital and physical parameters.

| Period $P$ [days] | 11.7201248 ± 2.1e-06 |
|------------------|------------------------|
| Midtransit time $T_{0}^{b}$ [BJD]$^a$ | 975.17325 ± 1.2e-04 |
| Eccentricity $e$ | < 0.031$^b$ |
| Argument of periastron $\omega$ [deg] | 263 ± 61$^c$ |
| Inclination $i$ [deg] | 88.456 ± 0.055 |
| Radial-velocity amplitude $K^*$ [km s$^{-1}$] | 3.732 ± 0.039 |
| Radius ratio $q = R_{J}/R^∗$ | 0.09849 ± 0.00049 |
| Mass ratio $q = M_{J}/M^∗$ | [0.0 - 0.02]$^d$ |
| Center-of-mass velocity $v^∗$ [km s$^{-1}$] | 15.057 ± 0.026 |
| Semi-major axis [AU] | 0.0987 ± 0.0013 |
| Transit duration [hours] | 3.07 ± 0.15 |
| Stellar density $\rho^∗$ [g cm$^{-3}$] | 1.550 ± 0.073 |
| Effective temperature $T^∗_{eff}$ [K] | 5237 ± 60 |
| Metallicity [Fe/H]$^∗$ [dex] | 0.14 ± 0.12 |
| Distance $d^∗$ [pc] | 585 ± 16 |
| E(B-V)$^∗$ [mag] | 0.040 ± 0.023 |
| Rotational velocity $v\sin i^∗$ [km s$^{-1}$] | 2.0 ± 1.0 |
| Rotation period [d] | 40.99 ± 0.50 |
| Stellar mass $M^∗$ [M$_{\odot}$] | 0.925 ± 0.033 |
| Stellar radius $R^∗$ [R$_{\odot}$] | 0.841 ± 0.020 |
| Age [$10^9$ yr] | [0.4 - 8.3]$^c$ |
| Companion mass $M_{c}$ [M$_{Jup}$] | 39.9 ± 1.0 |
| Companion radius $R_{c}$ [R$_{Jup}$] | 0.807 ± 0.022 |
| Companion density $\rho_{c}$ [ρ$_{Jup}$] | 75.6 ± 5.2 |
| Equilibrium temperature $T_{eq}$ [K] | 737 ± 31 |

Notes. (a) Fitted parameters in the MCMC algorithm (b) BJD,UTC - 2,454,000 (c) 99% upper limit (d) uniform distribution; not constrained. 68% 99% confidence interval expected to be stable on the scale of thousands of gigayears (Hut 1980). Furthermore, if KOI-205 were a more massive G-type star with a five-day rotational period, the system would still be stable over more than 10 Gyr.

This shows that stars with convective envelopes are capable of harboring massive companions in close orbits. Therefore, the lack of detections around late-type stars cannot be explained by their being doomed to fall into their stars. On the other hand, an inefficient formation process, selection biases, or insufficient statistics might be invoked. Whichever is the case, KOI-205 b will prove to be of great importance in constraining formation and evolution theories of brown dwarfs and massive extrasolar planets.

Acknowledgements. We thank the staff at Haute-Provence Observatory. We acknowledge the PNP of CNRS/INSU, and the French ANR for their support. This publication makes use of data products from the Wide-field Infrared Survey Explorer. RFD is supported by CNES.
References

Allard, F., Homeier, D., & Freytag, B. 2012, Royal Society of London Philosophical Transactions Series A, 370, 2765

Anderson, D. R., Collier Cameron, A., Hellier, C., et al. 2011, ApJ, 726, L19+

Bakos, G. Á., Hartman, J., Torres, G., et al. 2011, ApJ, 742, 116

Baraffe, I., Chabrier, G., Barman, T. S., Allard, F., & Hauschildt, P. H. 2003, A&A, 402, 701

Batalha, N. M., Rowe, J. F., Bryson, S. T., et al. 2012, ApJS

Bate, M. R. 2012, MNRAS, 419, 3115

Bouchy, F., Bonomo, A. S., Santerne, A., et al. 2011a, A&A, 533, A83

Bouchy, F., Deleuil, M., Guillot, T., et al. 2011b, A&A, 525, A68+

Bouchy, F., Díaz, R. F., Hébrard, G., et al. 2013, A&A, 549, A49

Bouchy, F., Hébrard, G., Udry, S., et al. 2009, A&A, 505, 853

Claret, A. & Bloemen, S. 2011, A&A, 529, A75

Cutri, R. M., Skrutskie, M. F., van Dyk, S., et al. 2003, 2MASS All Sky Catalog of point sources.

Cutri, R. M., Wright, E. L., Conrow, T., et al. 2012, Explanatory Supplement to the WISE All-Sky Data Release Products, Tech. rep.

Deleuil, M., Bonomo, A. S., Ferraz-Mello, S., et al. 2012, A&A, 538, A145

Deleuil, M., Deeg, H. J., Alonso, R., et al. 2008, A&A, 491, 889

Díaz, R. F., Santerne, A., Sahlmann, J., et al. 2012, A&A, 538, A113

Eisel, P. B. 1981, in Photometric and Spectroscopic Binary Systems, ed. E. B. Carling & Z. Kopal, 111

Ford, E. B. 2006, ApJ, 642, 505

Ford, E. B. & Rasio, F. A. 2008, ApJ, 686, 621

Geweke, J. 1992, in Bayesian Statistics 4, ed. A. D. J.M. Bernardo, J.O. Berger & A. Smith (Oxford University Press)

Grilliland, R. L., Chaplin, W. J., Dunham, E. W., et al. 2011, ApJS, 197, 6

Hellier, C., Anderson, D. R., Collier Cameron, A., et al. 2009, Nature, 460, 1098

Ho, S. & Turner, E. L. 2011, ApJ, 739, 26

Hut, P. 1980, A&A, 92, 167

Johnson, J. A., Apps, K., Gazak, J. Z., et al. 2011, ApJ, 730, 79

Kipping, D. M. 2010, MNRAS, 408, 1758

Kozai, Y. 1962, AJ, 67, 591

Lagarde, N., Dercins, T., Charbonnel, C., et al. 2012, A&A, 543, A108

Luhman, K. L. 2012, ARA&A, 50, 65

Matsumura, S., Takeda, G., & Rasio, F. A. 2008, ApJ, 686, L29

Mordasini, C., Alibert, Y., Benz, W., & Naef, D. 2009, A&A, 501, 1161

Perruchot, S., Kohler, D., Bouchy, F., et al. 2008, in SPIE Conference Series, Vol. 7014, SPIE Conference Series

Pont, F., Melo, C. H. F., Bouchy, F., et al. 2005, A&A, 433, L21

Pont, F., Moutou, C., Bouchy, F., et al. 2006, A&A, 447, 1035

Popper, D. M. & Eisel, P. B. 1981, AJ, 86, 102

Queloz, D., Henry, G. W., Sivan, J. P., et al. 2001, A&A, 379, 279

Sahlmann, J., Segransan, D., Queloz, D., et al. 2012, A&A, 549, A95+

Santerne, A., Díaz, R. F., Moutou, C., et al. 2012, A&A, 545, A76

Siverd, R. J., Beatty, T. G., Pepper, J., et al. 2012, arXiv:1206.1635

Spada, F., Lanzafame, A. C., Lanza, A. F., Messina, S., & Collier Cameron, A. 2011, MNRAS, 416, 447

Stamatellos, D. & Whitworth, A. P. 2009, MNRAS, 392, 413

Tegmark, M., Strauss, M. A., Blanton, M. R., et al. 2004, Phys. Rev. D, 69, 103501

Thies, I., Kroupa, P., Goodwin, S. P., Stamatellos, D., & Whitworth, A. P. 2010, ApJ, 717, 577

Triaud, A. H. M. J., Hebb, L., Anderson, D. R., et al. 2013, A&A, 549, A18

Whitworth, A., Bate, M. R., Nordlund, Å., Reipurth, B., & Zinnecker, H. 2007, Protostars and Planets V, 459

Winn, J. N., Holman, M. J., Torres, G., et al. 2008, ApJ, 683, 1076

Díaz et al.: KOI-205 b: a brown dwarf companion to a K-type dwarf.