Boletim da Sociedade Astronômica Brasileira, **30**, no. 1, 101-102

Identification and spectral classification of brown dwarfs in the Dark Energy Survey data

M. Dal Ponte[1,2], B. X. Santiago[1,2], A. Carnero Rosell[2], B. Burningham[3], & L. N. da Costa[2]

[1] Departamento de Astronomia (UFRGS) e-mail: marina.ponte@ufrgs.br, e-mail: basilio.santiago@ufrgs.br
[2] Laboratório Interinstitucional de e-Astronomia (LIneA) e-mail: carnero@linea.gov.br, e-mail: ldacosta@linea.gov.br
[3] University of Hertfordshire e-mail: burninghamster@gmail.com

Abstract. Brown dwarfs are low-mass, cool and intrinsically very faint sources compared to H-burning main-sequence stars. Here present our the first attempts to draw a sample of LT dwarf candidates using Dark Energy Sruvey (DES) data in conjunction with near and mid infrared surveys. We devise cuts in colour space and test them using known MLT dwarfs and QSOs. We also develop a simulation tool that generates synthetic samples of MLT dwarfs, against which to test our selection criteria. Finally, we briefly describe a simple likelihood analysis tool to further refine the sample of LT dwarfs.

Resumo. As anãs marrons são objetos de baixa massa, frios e instrinsicamente muito fracos quando comparadas com estrelas de sequência principal. Aqui apresentamos as primeiras tentativas de selecionar uma amostra de candidatas a anãs LT usando os dados DES em conjunto com surveys no infraverelho próximo e médio. Nós analisamos cortes no espaço cor-cor e os testamos usando anãs MLT conhecidas e QSOs. Nós também desenvolvemos uma ferramenta de simulação que gera amostras sintéticas de anãs MLT, novamente para testar nossos critérios de seleção. Finalmente, descreveremos brevemente uma ferramenta simples de análise de verossimilhança para aperfeiçoar a amostra de anãs LT.

Keywords. brown dwarfs – stars: low-mass – surveys

1. Introduction

The search for substellar objects, with masses that bridge the gap between H-burning low mass stars and giant planets, has led to the identification of over a thousand of sources classified as being of LTY spectral types. For instance, the Dwarf Archives (http://dwarfarchives.org/) lists 1281 known LTY dwarfs up to 2012. The more recent compilation by J. Gagné (https://jgagneastro.wordpress.com/list-of-ultracool-dwarfs/) reaches over 1700 sources later than an L0. Brown Dwarfs are supposed to be among the most common objects in the Milky Way, but their very low masses and temperatures, and hence luminosities, also rank them among the hardest sources to detect. Deep photometric surveys covering infrared filters, such as the 2MASS (Skrutskie et al 2006), UKIDSS (Lawrence et al 2007), and WISE (Wright et al 2010) have been responsible for the systematic increase to the census of brown dwarfs experienced in recent years. Optical surveys are also useful for probing such cool objects, specially L dwarfs, as is the case of the SDSS (York et al 2000), and more recently, the Dark Energy Survey (DES; The Dark Energy Survey Collaboration 2005).

In this contribution, we describe our initial efforts towards: i) selecting a sample of LT dwarfs using DES photometry coupled with near and mid-infrared from VHS (Emerson et al 2004) and WISE, respectively. ii) assessing the contamination of such a sample, mostly by M dwarfs, high-redshift QSOs, and very red galaxies; iii) photometrically classifying our candidate sources.

Our ultimate goal is to use this relatively deep sample of LT dwarfs to better constrain the spatial distribution of these objects away from the immediate solar neighbourhood, estimating their scale height and scale length on the disk, and assessing any possible contribution by thick disk LT dwarfs.

2. The Data

We have used internal releases of the first and third year by the DES collaboration, Y1A1 and Y3A2, respectively. Y1A1 is described in detail by Drlica-Wagner et al (2017) and provides reliable magnitudes down to $\simeq$ 23 mag in gr, $\simeq$ 22.5 mag in i, $\simeq$ 22 mag in z, and $\simeq$ 20 mag Y over $\simeq$ 2000 sq. deg. Y3A2 covers the full 5.000 sq. deg expected for the survey and is currently being characterized in terms of depth, star-galaxy separation, and other issues.

With the goal of identifying LT candidates and performing their spectral classification, we added more photometric bands to our data. We matched our DES sources to those from two infrared surveys: VISTA Hemisphere Survey (VHS) and Wide-Field Infrared Survey Explorer (WISE). The VHS and WISE were chosen because, besides complementing the DES photometry with infrared bands, they have a large overlap area with DES. We also compiled samples of known LT dwarfs (from J. Gagné's compilation), M dwarfs (West et al 2011), and quasars (Flesch 2015) that fall in the DES footprint, and identified these sources in the DES catalogues. They are very useful to test and validate our selection criteria, and to quantify contamination.

3. LT Selection

We looked at the color distributions of known LT dwarfs together with the known contaminant sources. We also developed a code, which we call Galmod-BDs, that computes expected counts of LT dwarfs, both as a function of magnitude and colour, using empirically determined space densities, absolute magnitudes (and hence colours) as a function of spectral type, and a model of Galactic structure. Galmod-BDs also creates synthetic samples of MLT dwarfs, with true and observed magnitudes in izY(DES)+JHK(VHS)+W1W2W3(WISE) filters. The observed magnitudes are determined according to input uncertainty curves for the filters and assuming Gaussian errors. The local space densities we use come from Marocco et al (2015) and references therein. The reference absolute magnitudes were empirically determined for the DES filters using the known MLT sources that fall in the DES Y1 and Y3 footprints. They have been cross-checked against estimates from Dupuy & Liu (2012) and Knapp et al (2004), and inconsistencies of the order of 0.1-0.2 mags were found, specially for izY, as the result of unaccounted for differences in the passbands.

After inspecting these distributions in colours, both of real and simulated sources, we were able to define a LT candidate selection based on cuts applied to the colour-colour diagrams. Figure 1 shows one of the main colour-colour planes we used and the selection adopted. We show both real and simulated LTs in the figure. The red dashed zone delimits our current colour selection. We estimated the completeness and purity of our selected sample, again for both real and artificial objects. We define completeness as c = (# of actual LT dwarfs selected as such) / (total # of actual LT dwarfs), and purity as p = (# of actual LT dwarfs selected as such) / (total # of selected LT dwarfs). Experiments with the latest simulated set yields values of $c = 0.94$ and $p = 0.64$ based on the colours alone.

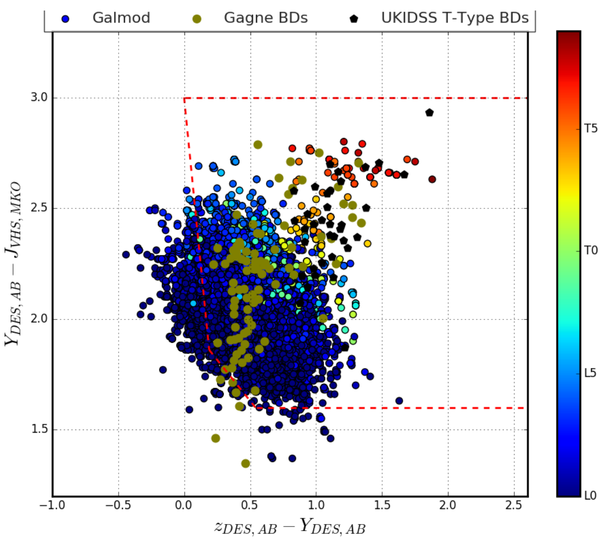

FIGURE 1. $Y(DES)-J(VHS)$ *vs.* $z-Y(DES)$ colour-colour diagram. The olive green circles come from Gagné's compilation and as measured by DES. The black hexagons are from UKIDSS (Burningham et al, 2010, MNRAS,406, 1885), converted from SDSS z and MKO Y and J. The slightly smaller circles are simulated LTs from Galmod-BDs (see text for a brief description of the code) and are colour coded according to their spectral type. The red dashed lines show our colour selection of LT dwarfs.

In brief, our approach to select the data is: i) use colour-colour cuts to find a sample that is complete in LT dwarfs, but that may be somewhat contaminated by galaxies, high-z QSOs and M dwarfs; ii) use the classification code described below to refine our sample in order to keep sources which are LT dwarfs and eliminate as many contaminants as possible. The final product will be a sample with high completeness and purity of LT dwarfs in DES+VHS+WISE data.

4. Classification Code

We have developed a simple algorithm that uses measured colours for the i-th source ($c_{ik}, k = 1, Ncols$) and their associated uncertainties ($\sigma_{c_{ik}}, k = 1, Ncols$) and compares them to reference colours ($c_{jk}, k = 1, Ncols$) from the j-th spectral type, this latter ranging from M1 up to T8. The reference colours we used are the same ones which were empirically determined and adopted by Galmod-BDs to predict LT counts and create synthetic MLT samples. With the measured and reference colours, we can build a Gaussian likelihood L_{ij} that the data for the i-th star come from the j-th model.

$$L_{ij} = \prod_{k}^{Ncols} \frac{1}{\sqrt{(2\pi)}\sigma_{c_{ik}}} \exp \frac{(c_{ik} - c_{jk})^2}{2\sigma_{c_{ik}}^2} \qquad (1)$$

The product above is over all available *Ncols* colours for each candidate LT source. Our algorithm currently finds the particular model that yields the largest likelihood value and tags each star to that model. We tested it against real MLTs of known spectral type and simulated sets. The accuracy depends on the number of colour indices available. This simple likelihood analysis is being used to further refine our colour selected sample. In particular, sources whose likelihood corresponds to colour deviations by 3σ or more from the reference values are discarded as non MLTs.

A more detailed description of the data, colour cuts, Galmod-BDs simulations, likelihood classification and modeling of the spatial distribution of LTs will be presented in a full journal paper (Carnero et al., in preparation).

Acknowledgements. MDP and BXS were supported by CNPq grant 473352/2013-3. MDP is also supported by CAPES Master fellowship. BXS is also supported by CNPq fellowship 304639/2013-3. The authors are grateful to the entire DES collaboration, specially the Milky-Way science working group, for all the support and useful discussions.

References

Burningham et al, 2010, MNRAS,406, 1885
The Dark Energy Survey Collaboration 2005, arXiv:astro-ph/0510346
Drlica-Wagner, A. et al. 2017, arXiv:1708.01531
Dupoy, T and Liu, M. 2012, ApJS, 201, 19
Emerson, J. P., Sutherland, W. J., McPherson, A. M., et al. 2004, The Messenger, 117, 27
Flesch E., 2015, PASA, 32, 10
Knapp, G. et al. 2004, AJ, 127, 3553
Lawrence, A., Warren, S. J., Almaini, O., et al. 2007, MNRAS, 379, 1599
Marocco, F. et al. 2015, MNRAS, 449, 3651
Skrutskie, M. F., Cutri, R. M., Stiening, R., et al. 2006, AJ, 131, 1163
West, A., et al. 2011, AJ, 141, 97
Wright, E. L., Eisenhardt, P. R. M., Mainzer, A. K., et al. 2010, AJ, 140, 1868
York, D. G., Adelman, J., Anderson, Jr., J. E., et al. 2000, AJ, 120, 1579