Ultracool Dwarfs in deep extragalactic surveys using the Virtual Observatory: ALHAMBRA and COSMOS

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ABSTRACT

Ultracool dwarfs encompass a wide variety of compact stellar-like objects with spectra classified as late-M, L, T and Y. Most of them have been discovered using wide-field imaging surveys. The Virtual Observatory has proven to be of great utility to efficiently exploit these astronomical resources. We aim to validate a Virtual Observatory methodology designed to discover and characterize ultracool dwarfs in deep extragalactic surveys like ALHAMBRA and COSMOS. Three complementary searches based on parallaxes, proper motions and colours, respectively were carried out. A total of 897 candidate ultracool dwarfs were found, with only 16 previously reported in SIMBAD. Most of the new UCDs reported here are likely late-M and L dwarfs because of the limitations imposed by the utilization of optical (Gaia DR2 and r-band) data. We complement ALHAMBRA and COSMOS photometry with other catalogues in the optical and infrared using VOSA, a Virtual Observatory tool that estimates effective temperatures from the spectral energy distribution fitting to collections of theoretical models. The agreement between the number of UCDs found in the COSMOS field and theoretical estimations together with the low false negative rate (known UCDs not discovered in our search) validates the methodology proposed in this work, which will be used in the forthcoming wide and deep surveys provided by the Euclid space mission. Simulations of Euclid number counts for UCDs detectable in different photometric passbands are presented for a wide survey area of 15,000 square degrees, and the limitations of applicability of Euclid data to detect UCDs using the methods employed in this paper are discussed.

Key words: astronomical data bases: surveys – astronomical data bases: virtual observatory tools – stars: low-mass – stars: brown dwarfs.

1 INTRODUCTION

Ultracool dwarfs (UCDs) are defined as objects with spectral types M7V or later and comprise very low mass stars, brown dwarfs (BDs) and planetary-mass objects. They represent about 15% of the stellar population in the solar neighbourhood (Henry et al. 2006) and their lifetimes make them the longest-lived not evolved objects of the universe. The M7V spectral type is just below the substellar boundary in the benchmark Pleiades cluster (e.g. Martin et al. 1996; Rebolo et al. 1996), and it marks the beginning of a variety of changes that are seen to happen with decreasing effective temperature, in particular the appearance of dust clouds and the marked increase of pressure-broadened neutral atomic lines of alkali elements (e.g. Jones & Tsuji 1997; Martin et al. 1997; Helling et al. 2008; Kirkpatrick et al. 1999).

In addition to be key elements to properly understand the physical processes at the stellar/substellar boundary, UCDs are excellent candidates for exoplanet searches. As they are much fainter and smaller than solar-like stars, it is much easier to detect low-mass rocky planets orbiting around them (Martin et al. 2013). TRAPPIST-1 (Gillon et al. 2017) has been the first successful example of this type of planetary system.

Not many studies of stellar and substellar objects in extragalactic surveys can be found in the literature. The search of brown dwarfs in the UKIDSS DXS and UDS surveys by Lodieu et al. (2009) and the pioneering work by Cuby et al. (1999) using the NTT Deep Field and Liu et al. (2002) using the IFA Deep Survey are some of the few exceptions to this. In fact, UCDs are normally treated as contaminants
since, at high-redshift, galaxies and ultracool dwarfs show similar
colours in the near infrared (Wilkins et al. 2014; Ryan & Reid 2016).
This, together with the photometric depth of the extragalactic surveys,
makes them very interesting niches for the discovery of UCDs. In this
paper we use the ALHAMBRA and COSMOS surveys to discover and
characterize new UCDs. These two extragalactic surveys have a
relatively large field of view and low extinction, which facilitates
the discovery a significant number of UCDs and the determination of
their physical parameters. Our main goal is to assess the effectiveness
of a Virtual Observatory (VO)-based methodology that could be
used in future, deeper and larger surveys like those planned with the
Euclid space mission.

ALHAMBRA (Advance Large Homogeneous Area Medium-Band
Redshift Astronomical, Moles et al. 2008) is a deep photometric
survey aimed at providing precise photometric redshifts and
information on the Spectral Energy Distributions (SEDs) of thou-
sands of galaxies and active galactic nuclei. ALHAMBRA was
conducted in eight different regions of the sky, covering a total area
of 4 deg$^2$ and including overlapping sections of COSMOS, DEEP2,
ELAIS, GOODS-N, SDSS and Groth survey fields. Observations
were made at Calar Alto Observatory with the 3.5 m telescope using
LAICA (optical) and Omega-2000 (near-IR) instruments. These
observations provided photometric information in 20 contiguous,
equal-width, medium-band filters from 3500 to 9700 Å plus the stan-
dard J, H and Ks near-infrared bands. The ALHAMBRA filter set
and associated limiting magnitudes are given in Table 3 of Molino
et al. (2014).

The COSMOS project pioneered the study of galactic structures at
intermediate to high redshifts as well as the evolution of the galaxy
and AGN populations, thanks to the unique combination of a large
area and precise photometric redshifts. In this work we made use of
the COSMOS2015 catalogue, which contains photometric infor-
mation for 1.182,108 sources over the 2 deg$^2$ COSMOS field. This
version of the COSMOS catalogue was improved from previous
versions by the addition of new Y JHKs images from the UltraVISTA-
DR2 survey, Y-band images from Subaru/Hyper-Suprime-Cam, and
infrared data from the Spitzer Large Area Survey with the Hyper-
Suprime-Cam Spitzer legacy program. The COSMOS photometric
bands and the averaged limiting magnitudes are given in Table 1 of
Laigle et al. (2016). All ALHAMBRA and COSMOS magnitudes
are given in the AB system.

This article is organized as follows: In Sect. 2, we describe the
methodology we have followed to separate stars from galaxies and
to identify candidate UCDs among the stellar sources. In Sect. 3 we
assess the robustness of our methodology by studying the fraction
of known UCDs that have been recovered. Sect. 4 presents the spec-
trosopic analysis made to confirm the UCD nature of some of our
candidates. Sect. 5 deals with simulations of UCD number counts in
the Euclid surveys and how the lessons learnt from this work may be
used to optimize the identification of UCDs in those fields, and,
finally, Sect. 6 contains the conclusions of this work.

2 METHODOLOGY

2.1 Sample selection

The ALHAMBRA final catalogue provides astrometric, morpho-
metric, photometric, redshift and quality information for 438,661
sources (see the Documentation section for a detailed description of
the catalogue contents).

We first applied a morphometric filter to keep only stellar objects.
For this, we made use of the stell and Stellar-Flag parameters with the
conditions stell≥0.5 and Stellar_Flag≥0.5 (Molino et al. 2014).
stell is the stellarity parameter implemented in Sextractor with values
ranging from 0 (galaxy) to 1 (star). Stellar_Flag represents a
source-by-source statistical classification among stars and galaxies
as described in Molino et al. (2014). Later, we used a photometric
flag to remove saturated objects (Satflag=0), and, finally, we
discarded bona-fide extragalactic objects by keeping sources with
values in the redshift column (zb_1) smaller than 0.5. This parameter
can have associated large uncertainties so, in order not to loose any
potential candidate UCD, we decided to adopt this very conservative
criterion. This gave us a list of 54,611 objects.

In the COSMOS catalogue we applied a morphometric filter using
the keyword TYPE set to 1 and zphot equal to 0 or -99.9. This way
we ended up with 37,069 objects.

2.2 Hertzsprung–Russell diagram

We cross-matched the 54,611 ALHAMBRA objects with Gaia DR2
using a 3 arcsec radius. We kept only counterparts with relative errors
of less than 10 percent in G and GRP and less than 20 per cent in
parallax. The absolute Gaia magnitude in the G band for individual
stars was estimated using

$$M_G = G + 5 \log \varpi + 5,$$

where $\varpi$ is the parallax in arcseconds. In our case, the inverse of
the parallax is a reliable distance estimator because we kept only sources
with relative errors in parallax lower than 20 per cent (Luri et al.
2018).

After the crossmatch we ended up with 1,548 stellar sources. A
preliminary selection of UCDs was done using the updated version
of Table 5 in Pecaut & Mamajek (2013) taking a conservative value
of G-GRP > 1.3 (corresponding, according to this table, to M5 V).
This gave us 119 candidate UCDs. These candidates were plotted on
top of a Hertzsprung–Russell diagram (HRD) built with all the Gaia
DR2 objects at less than 100 pc and good G,GRP photometry (Fig. 1).
This diagram is similar to that shown in fig. 6 of Gaia Collaboration
et al. (2018).

We made use of VOSA (Bayo et al. 2008) to estimate effective
temperatures of these 119 objects. VOSA computes physical parameters
by fitting the observational Spectral Energy Distribution (SED)
to different collections of theoretical models. In our analysis we made
use of the BT-Settl collection (Allard et al. 2012). Gravity and metal-
licity were restricted to the ranges logg: 4.5 – 6 and [M/H]: -0.5 –
+0.5, respectively. No extinction correction was used as low extinc-
tion was the first and basic criterion to select the ALHAMBRA fields
(Moles et al. 2008). An example of a VOSA SED fitting can be found
in Fig. 2.

1 http://sci.esa.int/euclid/
2 http://cdsarc.u-strasbg.fr/viz-bin/cat/J/ApJS/224/24
3 http://svo2.cab.inta-csic.es/vocats/alhambra/
4 https://www.pas.rochester.edu/~emamajek/
5 http://svo2.cab.inta-csic.es/theory/vosa/
According to this table we adopt for UCDs a conservative value of spectral type as well as the standard deviations are given in Table 1. The mean effective temperature as a function of the spectral type of the objects given in (West et al. 2011). The list of spectroscopically confirmed M dwarfs compiled by West et al. (2011). The mean effective temperature as a function of the spectral type as well as the standard deviations are given in Table 1. According to this table we adopt for UCDs a conservative value of $T_{\text{eff}} \leq 2900$ K. Only sources with good SED fitting ($\text{vgfb} < 15$) were kept. $\text{vgfb}$ is a modified chi2, calculated by forcing $\Delta F_{\text{obs}}$ to be larger than 0.1×$F_{\text{obs}}$, where $\Delta F_{\text{obs}}$ is the error in the observed flux ($F_{\text{obs}}$). This parameter is particularly useful when the photometric errors of any of the catalogues used to build the SED are underestimated. $\text{vgfb} < 15$ is a reliable indicator of good fit. After applying these conditions we ended up with 30 sources.

Similarly, we cross-matched the 37 069 objects in the COSMOS sample with Gaia DR2 using a 3 arcsec radius. We found 207 fulfilling the conditions on parallaxes and photometry, out of which only one (COSMOS 998096) has $T_{\text{eff}} \leq 2900$ K.

A mean value of $\sim 170$ pc was obtained for the 31 sources (30 ALHAMBRA + 1 COSMOS) with good parallaxes, with the closest and farthest objects at 70 and 350 pc, respectively.

### 2.3 Proper motions

Proper motions can be used to discriminate between galaxies and stars because extragalactic objects must have negligible values. For instance, M31, the nearest galaxy to the Milky Way, has a proper motion of just a few tenths of microarcseconds (van der Marel et al. 2019). Taking the remaining 53 063 (54 611 - 1 548) ALHAMBRA sources, we found 5 102 sources having Gaia counterparts in a 3 arcsec radius, out of which 3 774 are sources with non-zero proper motions, defining as such those sources fulfilling that, at least, one of the proper motion components is larger (in absolute value) than three times the associated error. Among them, 1 733 sources also fulfilled the conditions of having relative errors of less than 10 per cent in $G$ and $G_{\text{RP}}$ and less than 20 per cent in both proper motion components.

To discriminate between stars and galaxies in the remaining list of 51 330 (54 611 - 3 281) sources, we used the ALHAMBRA photometric information. We assigned a "true galaxy" status to all objects with Stellarsel/~flag with Stellar_Flag in the range 0.0 – 0.1, and a "true galaxy" status to all objects with Stellar_Flag in the range 0.0 – 0.1.
3 Known UltraCool Dwarfs in the ALHAMBRA and COSMOS Fields

In this section we assess the fraction of known UCDs that have been recovered using our methodology. In particular we looked for UCDs in SIMBAD (Wenger et al. 2000).

Using the SIMBAD TAP service\(^6\), we chose objects having spectral types later than M7V or labelled as "brown dwarfs." A total of 13329 objects fulfilled these conditions.

To know how many of them lie in the region of the sky covered by ALHAMBRA and COSMOS, we took advantage of Aladin and the Multi-Object Coverage\(^7\) VO standard. Regarding ALHAMBRA, a total of 193 SIMBAD UCDs lie in its field of view, but only 10 were really included in the ALHAMBRA catalogue. For COSMOS, there were 15 sources in the field of view, out of which 12 were in Laigle et al. (2016).

The efficiency of our search was estimated using the false negative rate (number of known UCDs in SIMBAD that were not rediscovered in our search). For ALHAMBRA, nine of the objects were recovered by us. The remaining object (ALHAMBRA 81441106044) escaped from our search because of its low \( \text{stellar} \) value (0.1). For COSMOS, seven objects were recovered while the remaining five escaped from our search due to different reasons: \( \text{TYPE} \) value different from 1 (2 sources), lack of \( Ks \) photometry (1 source) and \( J-Ks \) colour slightly higher than 0.15 (2 sources).

4 Spectroscopic Follow-Up

Another way to confirm the validity of our methodology to find new UCDs is to look for available spectroscopic information in public

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\(^6\) [http://simbad.u-strasbg.fr:80/simbad/sim-tap](http://simbad.u-strasbg.fr:80/simbad/sim-tap)

\(^7\) [http://ivoa.net/documents/MOC/index.html](http://ivoa.net/documents/MOC/index.html)
archives. We found spectra for 11 ALHAMBRA candidate UCDs in the SDSS DR16 archive\(^8\) using a 10 arcsec search radius. SDSS spectra cover the optical range (\(\sim 3800 - 9200 \ \text{Å}\)) with a resolving power \(\lambda/\Delta\lambda = 1800\). Spectra were automatically reduced and assigned a spectral type by the SDSS pipeline software following Bolton et al. (2012). In all cases the sources were classified as "stars" with spectral types M5 (4), M6 (5), and M7 (2). We can see how the conservative value of \(T_{\text{eff}}\) adopted to select UCDs has a clear impact on the non-negligible number of contaminants (i.e., objects with spectral types earlier than M7 V). Two of the M6 objects (ALHAMBRA 81461309369 and ALHAMBRA 81473108856) were classified in SDSS as M6III. However, the position of the first source in the HRD clearly indicates that this object is a dwarf. The second target was photometrically selected and we cannot conclude about its dwarf/giant nature. Regarding COSMOS we found spectroscopic information for two objects, COSMOS 247323 and COSMOS 601887, classified as M9 V and M6 V, respectively (Fig. 7). The list of objects with spectral type in SDSS are given in Table 2. One more object (ALHAMBRA 81422407651, classified as a M3 star) was found in LAMOST DR5.

Additionally, we got service mode time with LIRIS\(^9\) (Manchado et al. 1998) for two ALHAMBRA objects at the 4.2 m William Herschel Telescope (WHT) in La Palma Observatory. The spectra of ALHAMBRA 81473108856 and ALHAMBRA 81473110590 were obtained on 25–27th June 2018 with a clear sky and a seeing of 0.9 arcsec for 81473108856 and 0.7 arcsec for 81473110590, respectively. The observations were reduced in the standard way (sky subtraction, flat-field division, extraction of the spectra and wavelength

\(^8\) https://dr16.sdss.org

\(^9\) https://www.ing.iac.es/Astronomy/instruments/liris/
of filter transmission passbands. We used a service of the Spanish Virtual Observatory to gather observational and theoretical templates covering the M6 – L8 spectral range. These templates were used to assess the UCD nature of the candidates. In particular, we used the NIRSPEC library (McLean et al. 2003, 2007). The templates were first convolved to match the LIRIS spectral resolution and the comparison was done by visual inspection.

For visual comparison, we plot the LIRIS spectra together with those of the NIRSPEC library in the Y and J-bands, which is where our targets have the best signal to noise ratio ranging from ∼30 to ∼40 (Fig. 8). The presence of the $K_1$ doublet at 1.168 $\mu$m and 1.177 $\mu$m clearly indicates that our targets are UCDs. We defer to a later paper the detailed analysis of these spectra and additional follow-up spectra of UCDs that we plan to obtain for preparation of the Euclid mission.

5 SIMULATIONS OF ULTRACOOL DWARF DETECTIONS IN THE EUCLID WIDE SURVEY

This decade the Euclid Space Mission will cover 15,000 square degrees of the extragalactic sky with just one single epoch (the Euclid wide survey) and 40 square degrees in three selected regions that will be observed repeatedly during the lifetime of the mission (six years).

The COSMOS field is likely to be selected as a calibration field for Euclid, and hence the analysis of UCDs considered in this work could be used as reference.

The requirements for Euclid were stated in the Red Book (Lauriejs et al. 2011). In this work an updated version of the Euclid filter transmission passbands has been adopted as follows: photometric sensitivity 24.5 mag. (AB) in VIS passband (0.55–0.9 $\mu$m), and 24 mag. (AB) in three NIR passbands, Y (0.945–1.231$\mu$m), J (1.159–1.587$\mu$m), and H (1.510–2.000$\mu$m), and slit-less spectroscopic sensitivity of 21 mag. (AB) at spectral resolution of 250 over the wavelength range 1.25 – 1.85$\mu$m. The corresponding sensitivities for the deep survey are 2 mag. deeper.

The simulation parameters are the following: Log-normal mass function with $\alpha$ parameter =0.5 (Chabrier 2005), star-formation rate from Aumer & Binney (2009), evolutionary models from Burrows et al. (1993), spectral type versus absolute magnitudes and Teff from Pecaut & Mamajek (2013), disk scale heights from 250 to 450 pc (Ryan & Reid 2016), although a value around 450 pc appears more likely from recent results by Sorahana et al. (2019) and Carnero Rosell et al. (2019), and constant galactic latitude at 45 degrees for all objects and total survey area of 15,000 square degrees.

The most sensitive filter to UCDs in the Euclid wide survey will be the J-band as shown in Fig. 9. About two million L dwarfs, one million T dwarfs and a handful of Y dwarfs are expected to be detected in the thin disk for a scale height of 450 pc (green line). The corresponding numbers are about a factor of 2 lower for a scale height of 250 pc (blue line), about a factor of 10 lower for the thick disk population (red line), and about a factor of 500 lower for the halo (purple line). For comparison, simulations of UCD number counts in the Y-band and H-band are shown in Fig. 10 and Fig. 11, respectively. A very large number of UCDs (of order of 1 million objects) are expected to be detected in the three NISP passbands. This is important because, as shown in this work and in other works such as Deacon (2018); Holwerda et al. (2018), it is not enough to detect a UCD in one or two filters to identify it as such. Parallaxes, proper motions and/or multi-colors are needed. Ideally all of them are required for secure identification.

The VIS instrument will provide higher spatial resolution than NISP, which will allow to resolve hundreds of UCD binaries. Simulations of UCD number counts in the VIS filter are shown in Fig. 12. The numbers of UCDs expected to be detected in the VIS-band are more than a factor of 100 less than in the J-band, particularly for late-T dwarfs.

In the Euclid photometric catalogs, the availability of colors for UCDs is going to be provided mainly by the NISP instrument. The color-method will be based on Y-J versus J-H color color diagrams. The UCDs identified in this work will be useful to calibrate those diagrams with known UCDs. It will also be useful to cross identify Euclid point sources detected in the J band with the NEOWISE catalog in the W1 and W2 bands to find T and Y dwarfs.

The proper motion and parallax methods of UCD identification can be applied in the Euclid deep fields and in the calibration fields. In Fig. 13 the predicted number counts of UCDs in the total area expected to be covered by the deep fields are presented. The number of T dwarfs that could be identified in the Euclid deep fields by proper motions in the J-band may be of order of a few thousands. These objects will be selected independently from their colors, and hence they will provide useful feedback to the color methods used to select UCDs in the wide field survey.

6 CONCLUSIONS

Using a Virtual Observatory methodology we have built a catalogue of 897 candidate UCDs found in the ALHAMBRA and COSMOS extragalactic surveys. Sixteen of them were already known in SIMBAD. Our primary goal in this paper was not to carry out a detailed analysis on the properties of the found candidates but to define and assess a search methodology to be used for deeper and larger surveys like Euclid, whose excellent sensitivity makes it an ideal resource for the discovery of new UCDs, including brown dwarfs with very low effective temperatures.

The use of different approaches based on parallaxes, proper motions and colours tends to minimize the drawbacks and biases associated to the search of ultracool objects: photometric-only selected samples may leave out peculiar UCDs not following the canonical trend in colour-colour diagrams and they can also be affected by extragalactic contamination. Proper motion searches may ignore objects with small values of projected velocity in the plane of the sky. Regarding parallax-based searches, they will be limited to the brightest objects with parallax values from Gaia.

With the help of the VOSA we estimated effective temperatures for our candidate UCDs. They range from 1 100 K to 2 900 K with the great majority of the objects in the 2 600 – 2 900 K range. We also compared the number of candidate UCDs found in the COSMOS field with theoretical estimations (Ryan & Reid 2016), finding a good agreement. The high success ratio recovering known UCDs demonstrates the robustness of our procedure, and the consistency with predicted counts of UCDs in the COSMOS fields indicates that the VO-based procedures described in this paper are reliable to efficiently mine forthcoming wide and deep surveys for new UCDs.

We found that our choice of 2 900 K as an upper effective temperature limit in our selection is not restrictive enough to prevent somewhat
Figure 7. SDSS spectra of COSMOS 247323 (M9V). Together with the rest of SDSS spectra (12), it is available from the SVO archive (see Appendix).

Table 2. Candidate UCDs with SDSS spectral types. The column method indicates whether the candidate has been selected using their position in the HR diagram (HRD) or their colours (PHOT).

| RA (ICRS, deg) | DEC (ICRS, deg) | Survey | Source_id | \( \sigma \) | \( \mu_\alpha \cos \delta \) | \( \mu_\delta \) | Gmag | Method | \( T_{\text{eff}} \) | Sp. Type |
|---------------|----------------|--------|-----------|----------|----------------|----------------|-----|--------|-------------|---------|
| 37.0651       | 0.6742         | ALHAMBRA | 81421305057 | 5.96     | 21.60          | -8.08          | 18.80 | PHOT   | 2600        | M7      |
| 37.3364       | 0.5783         | ALHAMBRA | 81422407651 | 7.43     | 84.99          | -16.34         | 18.46 | HRD    | 2900        | M5      |
| 37.3496       | 0.6364         | ALHAMBRA | 81422405585 | 14.22    | -36.03         | -20.49         | 18.75 | HRD    | 2900        | M5      |
| 139.4752      | 45.9878        | ALHAMBRA | 81431401913 | 26.00    | 76.46          | -34.27         | 18.98 | HRD    | 2900        | M7      |
| 37.3364       | 0.7832         | ALHAMBRA | 81422407651 | 7.43     | 84.99          | -16.34         | 18.46 | HRD    | 2900        | M5      |
| 37.3496       | 0.6364         | ALHAMBRA | 81422405585 | 14.22    | -36.03         | -20.49         | 18.75 | HRD    | 2900        | M5      |

Table 3. COSMOS UCDs number counts. Ryan & Reid (2016) estimations have been computed considering both the thin and thick disc components and an sky area of 2 deg\(^2\).

| Spectral type | Ryan & Reid (2016) | This work |
|---------------|---------------------|-----------|
| M8–M9         | 100                 | 120       |
| L0–L9         | 72                  | 43        |
| T0–T5         | 1–2                 | 1         |

Earlier M dwarfs (M4–M6 V) from contaminating the sample of UCD candidates and will be taken into account in subsequent studies.

Last but not least, we present simulated number counts of UCDs detected in the Euclid wide and deep fields, and we discuss the applicability of the methods of UCD detection used in this work.

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Figure 8. Comparison of the LIRIS spectra of two of our ALHAMBRA UCD candidates with template spectra from the NIRSPEC library.

Figure 9. Simulated number counts of UCDs detected by the Euclid wide survey (15,000 square degrees) in the NISP J-band for a constant galactic latitude of 45 degrees for all objects.

Figure 10. Same as Figure 9, but for the NISP Y-band.

Figure 11. Same as Figure 9, but for the NISP H-band.

Figure 12. Same as Figure 9, but for the Euclid VIS-band.

7 DATA AVAILABILITY STATEMENT

The data underlying this article are available at http://svo2.cab.inta-csic.es/vocats/alhambra_cosmos/
Figure 13. Same as Figure 9 but for the Euclid deep surveys (40 square degrees) in the NISP J-band.

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APPENDIX A: VIRTUAL OBSERVATORY COMPLIANT, ONLINE CATALOGUE

In order to help the astronomical community on using our catalogue of candidate UCDs, we developed an archive system that can be accessed from a webpage\textsuperscript{15} or through a Virtual Observatory Cone-Search.

The archive system implements a very simple search interface that allows queries by coordinates and radius as well as by other parameters of interest. The user can also select the maximum number of sources (with values from 10 to unlimited) and the number of columns to return (minimum, default, or maximum verbosity). The result of the query is a HTML table with all the sources found in the archive fulfilling the search criteria (Fig. A1). The result can also be downloaded as a VOTable or a CSV file. Detailed information on the output fields can be obtained placing the mouse over the question mark located close to the name of the column. The archive also implements the SAMP\textsuperscript{16} (Simple Application Messaging) Virtual Observatory protocol. SAMP allows Virtual Observatory applications to communicate with each other in a seamless and transparent manner for the user. This way, the results of a query can be easily transferred to other VO applications, such as, for instance, Topcat.

This paper has been typeset from a \TeX/\LaTeX\ file prepared by the author.

\textsuperscript{15} http://svo2.cab.inta-csic.es/vocats/alhambra_cosmos/
\textsuperscript{16} http://www.ivoa.net/documents/SAMP
The SVO archive of ultracool dwarfs identified in ALHAMBRA and COSMOS.

| RA (J2000) (deg) | DEC (J2000) (deg) | RA (J2000) (millsec) | DEC (J2000) (millsec) | Survey (1) | Source_ID (1) | Gaia_ID (1) | Parallax (1) | Parallax_error (1) | posx (1/2) | posy (1/2) | pmra_error (1/mas/yr) | pmra (1/mas/yr) | pmdec_error (1/mas/yr) | pmdec (1/mas/yr) |
|------------------|------------------|----------------------|----------------------|-------------|---------------|-------------|-------------|-------------------|------------|-----------|---------------------|----------------|------------------------|------------------|
| 121.4720 | 50.2879 | 09:16:16.05 | 50:50:16.08 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 121.1638 | 48.4855 | 09:16:17.52 | 48:20:16.36 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 121.2669 | 52.0166 | 09:13:29.35 | 52:40:29.41 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 121.5959 | 52.3289 | 09:14:44.21 | 52:19:28.00 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 121.9511 | 61.1680 | 12:34:21.86 | 61:50:24.05 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 121.3904 | 52.1722 | 12:30:22.26 | 52:20:01.06 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 121.0850 | 54.6876 | 10:14:23.88 | 54:15:24.43 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 120.3920 | 53.6629 | 02:28:58.32 | 52:19:52.32 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |
| 120.0940 | 53.6629 | 02:28:58.32 | 52:19:52.32 | ALHAMBRA | 84021403933 | 80952731925739028 | 14.229 | 0.279 | -0.012 | 0.370 | -20.588 | 0.653 |

You can send these results to other VO applications if they are already open in your computer. Maybe you could want to take a look to TOPCAT, Aladin, SPLIT-VO or other interesting VO applications.

Figure A1. Result from a query in the SVO archive of ultracool dwarfs identified in ALHAMBRA and COSMOS.