Searching for White and Brown Dwarfs in the frame of the MUSYC/CYDER survey

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Abstract. MUSYC (MUltiwave-length Survey by Yale and Chile), and its predecessor, the CYDER (Calán Yale Deep Extragalactic Research) survey are both deep multiwavelength surveys mainly aiming at extragalactic issues; however they were both designed with a strong Galactic component in mind. Therefore they consist not only of multipassband imaging ($UBVRIzJK$) and wide field multi object spectroscopy - it is also foreseen to create a multi-epoch dataset, thus allowing proper motions to be derived using data of 1 and 4-5 years baseline. This enables us to identify fast moving objects, and derive tangential velocities of nearby and intrinsically faint objects, such as White Dwarfs (especially cool WDs) and Brown Dwarfs (BDs). For the former, we will be able to study the faint end of the halo-field luminosity function and determine the fraction of baryonic dark matter consisting of WDs. We will be able to put constraints on the volume density of BDs, and determine whether this density actually meets expectations. Here we give a report of work in progress.

1. Introduction

With the advent of large CCD mosaic detectors it has become feasible to undertake surveys of selected parts of the sky of various field size, depth, and spectral coverage, some including spectra and/or proper motions. In empty, dust free fields of moderate to high Galactic latitude, which are mostly the subject of these surveys, most objects to interest are faraway galaxies and galaxy clusters. However there are plenty of stellar objects which are of interest to Galactic and stellar astronomy. Among these are old objects, such as White Dwarfs (WDs), Horizontal Branch Stars of various types or Pop II Subdwarfs (metalpoor main sequence stars), and faint but nearby stars, e.g. M Dwarfs and Brown Dwarfs (BDs). We will be able to detect BDs up to a distance of 100 pc using proper motions and NIR photometry. White Dwarfs (see e.g. Pauli et al., 2003), especially the cooler objects, are important tracers of the older populations of our Galaxy, i.e. Thick Disk and Halo. With this study, we will be able to study the faint end of the Halo WD luminosity function, by using the oldest WDs in the data set. This will allow us to constrain the fraction of WDs in baryonic dark matter, a long standing mystery. Other hot stars - intrinsically much brighter than WDs - may help us to constrain the extent of the Galactic Halo.
Table 1. Celestial and Galactic coordinates and interstellar extinction of the selected MUSYC (first four lines) and CYDER (lower part) fields

| Field      | RA           | DEC          | b   | l   | $E_{B-V}$ |
|------------|--------------|--------------|-----|-----|-----------|
| CDF-S      | 03:32:29     | -27:48:47    | 224 | -54 | 0.01      |
| SDSS 1030  | 10:30:27     | +05:24:55    | 239 | +50 | 0.02      |
| Cast 1256+01 | 12:55:40    | +01:07:00    | 306 | +64 | 0.01      |
| HDFS-Ext   | 22:32:35     | -60:47:12    | 328 | -49 | 0.03      |
| CYDER-A2   | 00:36:58     | -34:41:07    | 321 | -82 | 0.01      |
| CYDER-A4   | 02:16:37     | -40:28:50    | 255 | -68 | 0.01      |
| CYDER-D3   | 03:37:44     | -05:02:39    | 238 | -44 | 0.04      |
| CYDER-C5   | 11:30:07     | -14:49:27    | 276 | +44 | 0.04      |
| CYDER-C2   | 12:52:48     | -09:24:30    | 305 | +53 | 0.04      |
| CYDER-C3   | 14:00:00     | -10:00:00    | 330 | +49 | 0.04      |
| CYDER-D1   | 22:01:38     | -31:46:30    | 16  | -54 | 0.02      |
| CYDER-A1   | 22:44:22     | -40:07:49    | 359 | -61 | 0.01      |

For the Galactic part of this project, we employ all four 30' × 30' MUSYC fields, as well as a selection of the preceding CYDER survey (see Table 1). The former have full $UBVRIzJK$ coverage, but are more recent than the CYDER fields (which mostly have $UBVI$); these allow us to determine proper motions accurate to ~5 mas/yr. The MUSYC fields have a baseline of (currently) only 1-2 years. This forces us to use two different approaches to retrieve BD/WD candidates. For MUSYC, we preselect targets using multi-colour photometry to be followed up by multi object spectroscopy - proper motions will be added later to determine the kinematics (“Spectroscopy first”, see Sect. 2.1). For CYDER, we first isolate the high proper motion targets, and then classify them using spectra and photometry (“Proper motions first”, see Sect. 2.2).

The optical imaging data was mostly obtained with the 4 m Blanco+MOSAIC II telescope on Cerro Tololo, supplemented by data taken with WFI (ESO, La Silla), and KPNO, the MOS spectroscopy is being done at Magellan/IMACS and VLT/FORS+VIMOS, the NIR imaging with Blanco+ISPI and the DuPont telescope on Las Campanas. Source extraction, photometry and star/galaxy separation was done using SExtractor (Bertin & Arnouts 1987).

2. Strategy

2.1. Spectroscopy first

For some fields, especially the MUSYC fields, the observations of multi object spectra has already started, long before we could think of deriving proper motions. Therefore our WD/BD candidates were preselected using multi-passband photometry. In order to keep the number of false candidates as low as possible while keeping the completeness as high as possible, our methods of preselection are being continuously refined. Employing the CLASS parameter of SExtractor, we selected a sample of point sources. In the beginning, we used simple colour
cuts, such as $B - V < 0$ to isolate blue objects from the sample. However this still keeps a large number of misidentifications in the selected subsamples. A second step is to select samples of targets using colour trends, as can be seen in Fig. 1. This figure shows two different selections, one subsample of hot stellar targets, another one of cool WD candidates. Also shown are the main sequence (e.g. Baraffe et al. 1997, and taken from Landolt Boernstein Vol. 2) and WD cooling tracks (Chabrier et al. 2000). This already gives us a high confidence in most samples. Additional methods, which are under consideration use fluxes in multiple passbands of template model and standard star spectra to make the preselection, either by fitting the templates to the measured spectra (Hatziminaoglou et al. 2000) or by using neural networks (Willemse, priv. comm.). Finally, the derivation of proper motions, to gain access to the full kinematics if possible, will be done after the identification process.

2.2. "Astrometry first": Proper motions

For the proper motions we need data from at least two epochs. The datasets of MUSYC/CYDER are almost ideal for our purposes, because, they are 3 epoch data, with one baseline being short (i.e. 1 year), and the other significantly longer (4-5 years). For the CYDER fields the third epoch is currently being obtained. The short baseline allows us to account for high proper motion targets, i.e stars that move faster than $0.25''$/yr - when using longer baseline data these objects could be lost during the registration.

Figure 1. Example of colour preselection (field HDFS-E). Note the prominent distribution of main sequence stars. This plot shows two colour selections. The line going from the upper left to the lower right separates hot stars, such as WDs and BHB/EHB stars; the other isolates cool WD candidates. The selected stars are depicted by bigger dots. Also shown are WD cooling tracks and a template main sequence.

Figure 2. One of the faint ($V \simeq 26$ mag) fast moving objects found by image blinking in field CYDER-C2. The images were taken $\sim 1$ year apart; a crude estimate leads to a proper motion of 0.5" for this particular object.
However there might be objects with proper motions in excess of 1" (which corresponds to 4 pixels in our data) - these might even be missed using the 1 yr baseline. To isolate these, we use several methods, one of which is the classical blinking of the two epochs by eye. The field CYDER-C2 has been blinked, revealing about 20 mostly very faint objects with detectable motion, one of which is shown in Fig. 2. The 3rd epoch will be needed to verify these proper motions and to rule out other effects, which could mimic such motions, such as distant supernovae, etc. Unfortunately, given their faintness, most of them cannot be observed spectroscopically. Therefore photometry will have to provide us the information needed to classify these elusive objects. The combination of faintness and large proper motion restricts the number of possible object types to two intrinsically faint types of objects: White and Brown Dwarfs. The latter will reveal itself by the very red colours, recently formed WDs due to their blue colour, and old WDs due to their rather unique spectral energy distribution.

The final accuracy of the proper motions (using all three epochs) is estimated to be in the order of 5 mas/yr. The nominal margins - as shown in an analysis of data from the 2.5 m DuPont telescope (which has an almost identical image scale) are even smaller for all but the faintest stars - however we keep to this rather conservative estimate.

### 3. Discussion and outlook

Upto now we have the result of one spectroscopic campaign (CYDER-D1 & D3). We found about 25 mostly late M stars, and several hot stars, some even of spectral type B, as can be seen by the presence of He-lines. Since many spectra were of relatively low S/N it is hard to tell at first glance, some could be HB-like stars. Since the target selection of this campaign was done with the most primitive method we will be more efficient in later campaigns. The field CYDER-C2 has been checked for objects of extremely high proper motion - about 20 candidates were found. This can only be a report on work in progress: However, with the spectroscopy of the MUSYC fields being well underway, and the 3rd. epoch observations of the CYDER fields coming up soon\(^1\) we expect to be able to come to more significant results in the very near future.

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\(^1\)Unfortunately the first campaign to secure the 3rd epoch data in August 2004 was lost completely due to inclement weather conditions.