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White Dwarfs in the European Galactic Plane Surveys (EGAPS)

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Abstract. The space density of white dwarfs is highly uncertain even nearby. This results from the fact that the known sample of white dwarfs is largely incomplete in part because most white dwarfs have been discovered as by-products in non-dedicated surveys. In order to obtain more accurate white dwarf space densities and scale heights we must build up a complete sample of white dwarfs. The European Galactic Plane Surveys (EGAPS) are the best database to search for white dwarfs as they will provide broad band (U, g', r', i') and narrow band (Hα and HeI) measurements for one per cent of all the stars in the Galaxy. By looking at the Galactic Plane, where most stars are, we ensure that we are obtaining a complete sample. The space densities obtained from EGAPS can then be compared with those found in high latitude surveys such as the Sloan Digital Sky Survey (SDSS). The methods used to identify white dwarfs using the colours available in EGAPS are described and some preliminary results presented.

1. European Galactic Plane Surveys: EGAPS

The space density of white dwarfs is not well known even in the solar neighbourhood (Schröder, Pauli, & Napiwotzki 2004). There is also a deficit of bright white dwarfs in the Galactic Plane, compared to high Galactic latitudes, due to the fact that most white dwarfs have been discovered out of the Plane as by-products of extra-galactic surveys. The best way to obtain a complete sample of white dwarfs, and thus compute accurate space densities, is to search for them in the Galactic plane, where most of them reside. The use of a multi-band Galactic Plane Survey will greatly facilitate this task.

EGAPS is the combination of a number of Galactic Plane surveys in several passbands. The main aim of EGAPS is to obtain broad band (U, g', r', i', Z, Y, J, H, K_s) and narrow band (Hα and HeI) photometry of a 10 degree latitude strip centred in the Plane all along the Galaxy, i.e. covering the Northern and Southern Galactic Planes, and going down to 21st magnitude in the optical bands. Most of the stars in the Galaxy lie in the plane. Thus, by surveying a 10 degree-wide strip we are gathering photometry for 1 billion stars, one per cent of the total number of stars in the Milky Way. These large numbers are required to study statistically the different stellar populations.

The surveys that make up EGAPS (on-going, approved and proposed) are shown, together with their coverage, filters and limiting magnitudes, in Table 1. IPHAS, UVEX and VPHAS+ are all double pass surveys and include re-observations at intervals of at least two years to determine proper motions of all targets. ΩWhite overlaps in area with VPHAS+ and includes observations in the HeI narrow-band filter and 25 observations of selected fields in a two hour interval. This will allow the detection and study of HeI emission sources such as AM CVn systems and of short period variables such as AM CVns, magnetic cataclysmic variables (CVs), post-bounce CVs and other ultra-compact binaries and fast pulsators.

Table 1. IPHAS: INT/WFC photometric Hα survey of the Northern Galactic Plane (Drew et al. 2005). UVEX: Northern Galactic Plane UV-excess survey. VPHAS+: VST/OMEGACAM photometric Hα survey of the Southern Galactic Plane. ΩWhite: VST/OMEGAWHITE variability survey. VVV: VISTA variables in the Vía Láctea.

Survey	Area (deg^2)	Filters	Limit mag
	Northern hemisphere		
IPHAS	10×180	Hα,r',i'	$r' = 21$
UVEX	10×180	U,g',r',HeI	$g' = 22$
	Southern hemisphere		
VPHAS+	10×180	u',g',r',i',Hα	$r' = 21$
ΩWhite	400	u',g',r',i',Hα,HeI	$g' = 22$
VVV	520	Z,Y,J,H,K_s	

The science drivers for EGAPS are very broad and range from the study of proto-stars, interacting binaries, planetary nebulae and stellar remnants, such as white dwarfs, to the study of Galactic structure and dust. IPHAS will most probably be complete by the end of 2007. The completion date for UVEX is still uncertain. Both VST programs (VPHAS+ and ΩWhite) will probably start at the end of 2007/beginning of 2008 and will be complete by 2010. The VVV survey has yet to be approved. Up to date information on EGAPS and its constituent surveys will be posted during and after the data taking at: `http://www.egaps.org`.

2. Searching for White Dwarfs in EGAPS

White dwarfs are a galactic population and yet have mostly been found at high latitudes. As mentioned above, the two main reasons for this are: 1) they have been found as interlopers in the search for blue extragalactic sources, 2) the plane presents a challenge to observe due to the vast number of sources and the high extinction. As most of the white dwarfs in the Galaxy will be in the plane, it is definitely worth looking for them there. From simulations of the distribution of objects with Galactic latitude, using a galactic model based on Boissier & Prantzos (1999) and including extinction towards the Galactic plane according to the Sandage model, Nelemans (private communication) finds that 12 (40) per cent of old (young) white dwarfs, i.e. with $M_V = 15$ (10), are concentrated within $|b| < 5°$. Reddening turns out not to be such a tough problem to go around as it is only severe within the first two degrees in latitude.

Synthetic spectra for six hydrogen-rich white dwarfs with temperatures of 10,000, 20,000, 30,000, 40,000, 50,000 and 60,000 K are shown in Fig. 1 together with the passbands of broad band filters used in EGAPS and the passband of the Hα narrow band filter. The Hα narrow band filter allows us to search for both Hα emission and absorption stars, this last group includes white dwarfs. The Hα equivalent width of hydrogen-rich white dwarfs scales with temperature, being larger for temperatures between 10,000 and 20,000 K (see Fig. 2) which means that the IPHAS survey on its own is most sensitive to white dwarfs in that temperature range. This temperature range is particularly interesting as it overlaps with the hydrogen-rich white dwarf instability strip, $11,000 - 12,500$ K (Mukadam et al. 2006).

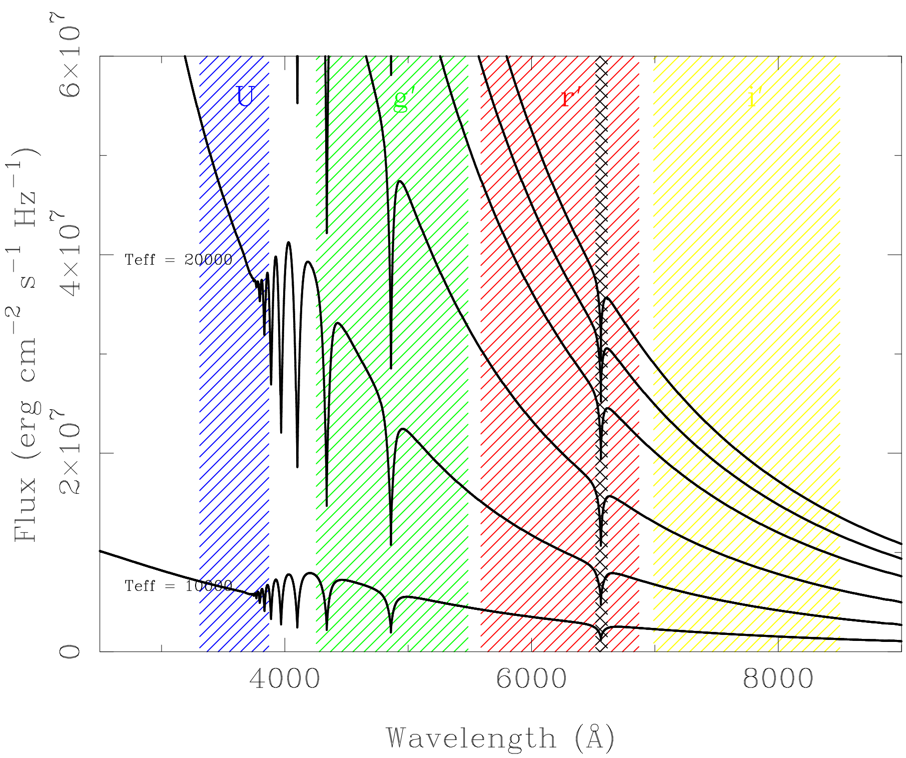

Figure 1. Synthetic spectra of six hydrogen-rich white dwarfs of different temperatures (10,000 to 60,000 K in 10,000 K steps) obtained with TLUSTY. Note that the flux increases with temperature. Also plotted (hatched) are the band passes of the broad band filters U, g', r', and i', and the the band pass of the narrow band filter Hα (cross-hatched).

2.1. The IPHAS Colour–Colour Space

Fig. 3 shows an example of the IPHAS colour space for a given field in Cassiopeia. The position where the un-reddened hydrogen-rich white dwarfs lie is marked with a box. The position of this box was calculated by convolving the IPHAS

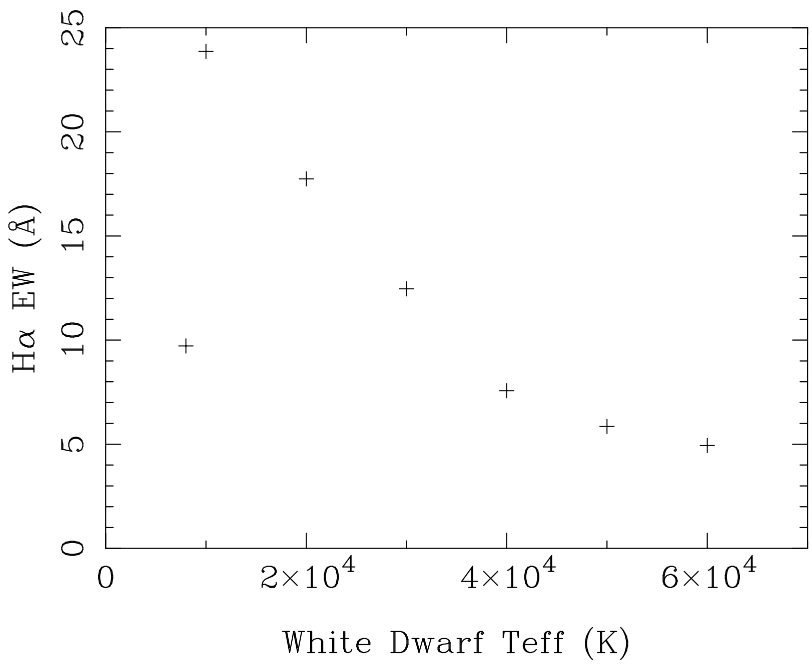

Figure 2. Equivalent width (EW) of the Hα absorption line for hydrogen-rich white dwarfs of different temperatures. Note that the EW is larger for white dwarf with temperatures between 10,000 and 20,000 K.

band passes with a set of SDSS hydrogen-rich white dwarfs. For this given field, we find one white dwarf candidate. The rest of the stars in the field outline the main sequence, as well as the giant and supergiant sequences (see Drew et al. 2005, for a description of the positions of the un-reddened and reddened main sequence, the giant and the supergiant sequences in the IPHAS colour space).

White dwarfs in the IPHAS colour space lie away from the main sequence and therefore are easy to pick out.

3. Preliminary Results

We performed a search for white dwarfs by looking for candidates in the colour box presented in the previous section in the first IPHAS data release, which comprises ten observing epochs between August 2003 and 2004. As IPHAS is a double pass survey, all fields are observed twice with only a small region of non-overlap between the two fields. We only selected candidates that appeared in both fields and whose positions differed, from one field to its overlap, by one arcsec at the most.

The densities of white dwarfs found vary considerably from epoch to epoch and are given in Table 2. These discrepancies cannot be explained only by the different area in the sky that each epoch covers, or by contamination of the white dwarf box due to different reddening in different fields. The result of reddening would be to move white dwarfs to larger values of $(r'-i')$ and $(r'-\mathrm{H}\alpha)$ out of the

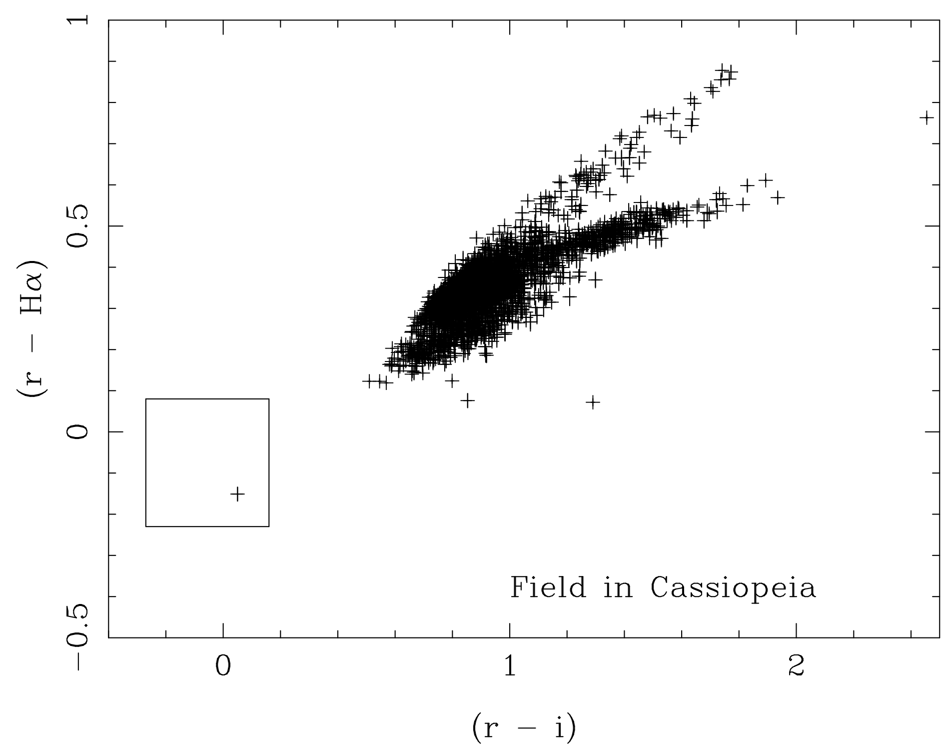

Figure 3. IPHAS colour space indicating the position of hydrogen-rich white dwarfs with respect to the main sequence and the giant and supergiant sequences

box, thus the white dwarf density would decrease. No other objects would fall in the white dwarf box to increase the number of false detections so this cannot explain the large value seen, for example in June 2004. The most probable causes for the discrepancies are: the fact that not all the data is of the same quality and only a seeing cutoff has been applied in this search, and that there is not, as yet, a global photometric solution for the survey, which translates in offsets between colours for different fields.

Table 2. Density of white dwarf candidates found for the first ten epochs of observations of IPHAS

Epoch	Area (deg^2)	Density (deg^{-2})	Epoch	Area (deg^2)	Density (deg^{-2})
Aug 2003	72	0.26	Sep 2003	14	4.6
Oct 2003	145	1.6	Nov 2003	199	0.6
Dec 2003	118	0.8	Jun 2004	96	12.2
Jul 2004a	71	4.6	Jul 2004b	99	2.2
Aug 2004a	58	0.76	Aug 2004b	146	2.18

If we only make use of the data presented by Drew et al. (2005) (seven fields, 1.86 deg^2), which has been checked for quality and calibration, we find one un-reddened hydrogen-rich white dwarf, giving a density of 0.6 deg^{-2}. The theoretical prediction is of 0.8 white dwarfs per deg^2 (assuming all spectral types and temperatures). From follow up spectroscopy using the multi-object spectrograph HECTOSPEC mounted on the 6.5 m MMT (Steeghs et al., in preparation), we also find an average of one hydrogen-rich white dwarf per deg^2.

Preliminary follow-up of UVEX sources shows them to be white dwarfs at a density of $1-2$ per pointing ($4-8$ per deg^2).

4. Conclusions

EGAPS will constitute the perfect collection of surveys to obtain a complete sample of white dwarfs, determine their space densities and their scale height. On their own, some of the surveys that make up EGAPS, e.g. IPHAS, will also provide the data to find white dwarfs, targeting systems in specific temperature ranges. The temperature range that IPHAS is sensitive to includes the instability strip allowing us to find pulsating white dwarfs in large numbers. Following up of these objects can lead to asteroseismological studies to determine their internal structure and to search for planets around them.

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