SPECTROSCOPIC SURVEYS OF STELLAR POPULATIONS

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ABSTRACT

Here we summarise some of the on-going photometric surveys in the Galactic Plane under the umbrella of the European Galactic Plane Surveys (EGAPS). We pay particular attention to IPHAS, the Hα survey of the Northern Galactic Plane being carried out on the Isaac Newton Telescope which is due to be completed in 2007. We discuss the survey and its current large-scale spectroscopic follow-up campaign and we illustrate the need for VO tools with examples of some specific use cases. We emphasise the need for general purpose classification tools, and the ability to interface with models.

Key words: Galaxy: disk; Surveys; Technique: spectroscopy; Virtual Observatory.

1. INTRODUCTION

Stellar spectroscopy is now dealing with large scale surveys of stellar populations in the Milky Way and even within Local Group galaxies. This huge influx of data is being enabled largely by wide-field multi-object spectrographs on 4-8m telescopes, spectrographs such as FLAMES on the VLT, HECTOSPEC on the MMT, AAOMEGA on the AAT and WYFFOS on the WHT. This approach is required to tackle important scientific questions by finding rare but important objects, or through investigating stellar groups rather than just a few individual stars, for example to study the dynamics, structure and star-formation histories of our own and nearby galaxies. Here we summarise some of the ongoing Galactic Plane photometric surveys, and use one example to illustrate the kind of large-scale spectroscopic follow-up which is taking place, and the problems which ensue from dealing with the resulting data. I suggest some areas where the VO could make an important contribution.

2. EUROPEAN GALACTIC PLANE SURVEYS (EGAPS)

The European Galactic Plane Surveys (EGAPS) are a loose association of Galactic Plane Surveys comprising

- IPHAS: 300 million point sources in Hα, r' and i' in the northern Galactic plane being carried out with the INT on La Palma. At the time of writing a total of 95% of the survey area has been observed, of which 70% has passed data quality control checks, an Early Data Release is expected soon. (P.I.: Janet Drew, web site is www.iphas.org)
- UVEX-N is a u', g' and HeI 5876Å survey of the north Galactic plane currently underway on the INT (P.I. Paul Groot; www.egaps.org)
- VPHAS+ is the southern counterpart of IPHAS and UVEX-N to be carried out on the VST and expected to produce a catalogue of 600 million point sources.
- There also exist infrared Galactic plane and bulge surveys, UKIDSS-GPS being performed on UKIRT, and VVV to be carried out on VISTA (P.I.s P. Lucas and D. Minniti)

3. THE IPHAS SPECTROSCOPIC FOLLOW-UP

IPHAS, or the INT photometric Hα Survey of the North Galactic Plane, is almost complete, and has a vigorous on-going spectroscopic program. The survey has several objectives dealing with both nebulae and point sources, but essentially aims to search for all classes of Hα emitting stars and nebulae. Hα is a strong signature of active stars, interacting binaries, very massive stars (especially supergiants, Luminous Blue Variables and Wolf-Rayet stars), Be stars, post-AGB stars, pre-main-sequence stars

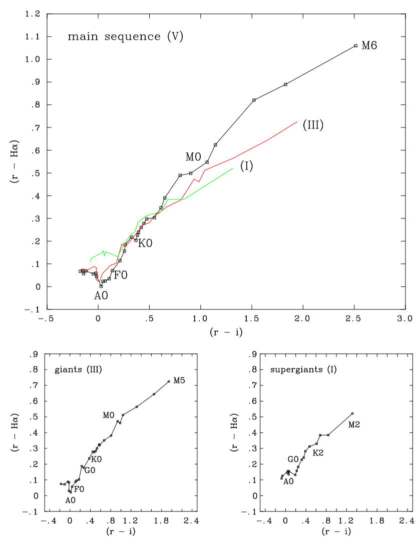

Figure 1. Here we see the simulated positions of unreddened dwarf, giant and supergiant stars in the (r'-i',r'-Hα) plane according to spectral type. The extinction vector drives stars diagonally right and upwards in this plot. Hα emission drives sources almost vertically upwards, while unusually strong absorption, such as in white dwarfs, drives them downwards. Note that the A-type stars occupy a rather easily isolated portion of the plane due to the fact that the Balmer lines reach their maximum strength at this spectral type.

and so on. These objects represent important evolutionary phases which are generally short lived, and are therefore few in number and often difficult to find. Strong Hα emission line stars are reasonably easily selected from the sample since they are well separated from the bulk population in the (r'-Hα, r'-i') diagram (Fig.1). Such a selection of strong emitters has already been made, resulting in several thousand sources, and subsequent follow-up spectroscopy of about 2000 of these sources has revealed the vast majority of these to be classical Be stars, with a sprinkling of CVs, compact PN, potential luminous blue supergiants and the occasional QSO (see Drew et al. 2005 for an overview of IPHAS and preliminary results).

Not all emission line objects are as easily discovered however due to extinction issues and weak emission. Furthermore there is great interest in selecting other interesting non-emission line objects such as white dwarfs, extremely red objects (EROs) and so on. Thus some effort has been put into understanding the IPHAS colour-colour plane in order that future object selections can be made with some confidence. This problem has been attacked on two fronts; through the construction of synthetic photometry using a library of observed flux-calibrated stellar spectra (Fig.1), and by conducting spectroscopic surveys of selected fields as a visual check on predicted spectral types. The survey has been carried out on two multi-fibre spectrographs; HECTOSPEC on the Multi-Mirror Telescope (MMT) and AF2/WYFFOS on the William Herschel Telescope (WHT). The spectra have been taken at moderate resolution and some AF2/WYFFOS data are illustrated in Fig.2. To date there are 15,000 spectra from HETOSPEC in the database and 2,000 from AF2/WYFFOS.

4. INFORMATION CONTENT OF SPECTRA

Before discussing the issues involved in dealing with the data it's worth considering the question of information content of spectra versus photometry. Hafner & Wehrse (1994) defined a quantitative method for estimating the information content of a stellar spectrum. They refer to this as the apparent spectral information (ASI) and their technique is based on the derivative of the flux with wavelength and is a function of wavelength coverage and resolution. In principle signal-to-noise can be considered as the effect of changing resolution. Using their formalism one can estimate that a typical AF2/WYFFOS spectrum referred to above has 300 times the information of the photometry for the same source (treating the photometry as a low resolution spectrum). Considering the existing IPHAS spectroscopic data we find that its ASI is already approximately 0.6Mbits compared to the photometric ASI of around 30Mbits. Therefore one can see that in terms of information content, spectroscopic surveys can grow very quickly and will eventually rival that of photometric surveys.

5. REQUIREMENTS FOR THE VO

As mentioned above, one of the objectives of the spectroscopic survey was to characterise the IPHAS colour-colour plane. To this end 2000 HECTOSPEC spectra were classified by eye using a rather crude classification scheme, the results are illustrated and summarised in Fig.3. Clearly a classification tool within the VO would be of enormous value in completing this work and on refining the classifications previously carried out by eye. There are difficulties which need to considered, for example Galactic Plane sources are subject to high and highly variable extinction, variations in signal-to-noise, artifacts and sky-lines. While the bulk of the data are obtained in a uniform manner, there is still a substantial part of it which has been obtained with many different instruments, resolutions and wavelength regions (i.e. the strong emission line sources). One should also consider the next step which is to measure quantities from the spectra, for example radial velocities, emission and absorption line strengths, and potentially interface the data with models. Combining spectroscopic and photometric data is also essential, for example one might wish to make colour selections followed up by interrogations based on spectroscopic properties of the sample.

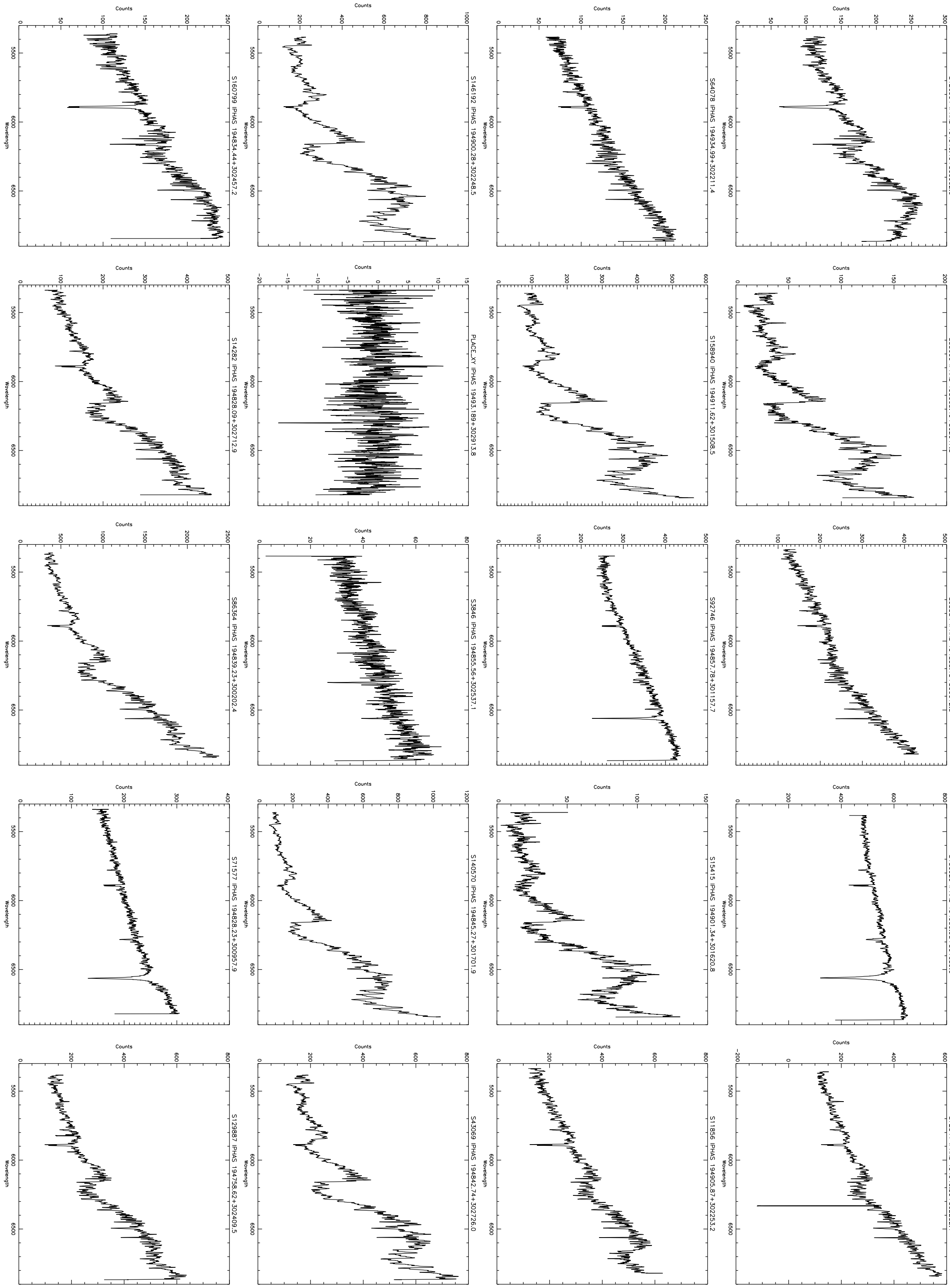

Figure 2. Typical cross-section of spectra obtained using the multi-object spectrograph AF2/WYFFOS on the WHT as part of a spectroscopic campaign designed to characterise the colour-colour plane of the IPHAS survey. The spectra cover the whole of HR diagram from early-type spectra to M-type stars, with the occasional Carbon star or exotic object; strong Hα absorption and NaI D-line absorption can be seen in the earlier spectral types in the panels above.

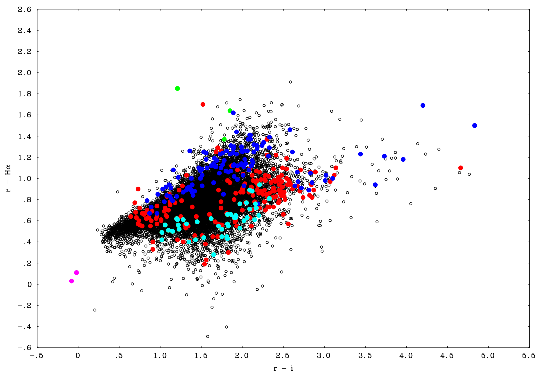

Figure 3. This illustrates the IPHAS colour-colour plane for a field in the Cygnus region where the small points are the photometric data. Larger points represent sources which have been classified by eye as early-type stars, G-K stars, M-type stars, white dwarfs and Be stars. The central gap in the spectroscopic sample is a selection effect due to the target selection algorithm. Approximately 2 000 spectra have been roughly catalogued by eye, addressing the full sample, currently close to 20 000 sources, would benefit greatly from suitable VO tools.

We illustrate these issues with a specific task which has been discussed within the IPHAS consortium; that of constructing a map of Galactic structure using A-type stars. A-type stars have strong Hα absorption (see Fig.1) and candidates can be pre-selected for spectroscopy using the colour-colour diagram. Subsequent spectral classification and combination with a calibration of Balmer-line equivalent width with absolute magnitude, derived extinction (from intrinsic colours), and radial velocities and astrometry could in principle then be used to construct a picture of the structure of the Galaxy. Much of this work could be carried out within the VO with the appropriate applications.

ACKNOWLEDGMENTS

IPHAS is being carried out with the Isaac Newton Telescope at the Roque de los Muchachos Observatory on the island of La Palma in the Canary Islands. This article is based on the collaborative efforts of the IPHAS consortium.

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