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THE SEARCH FOR SYMBIOTIC STARS IN THE IPHAS SURVEY

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Abstract. We have started a project to search for symbiotic stars using the data from IPHAS, the Hα survey of the Northern Galactic plane. Candidates are selected from the IPHAS photometric catalogue based on their colors, combined with the information in the near-infrared from 2MASS. So far, follow-up spectroscopy allowed us to discover 14 new symbiotic stars, compared to the 10 systems previously known in the IPHAS survey area. Their general characteristics and the most notable cases are briefly presented. The spectroscopic campaign also allowed us to refine the selection criteria for symbiotic stars in IPHAS. Perspectives, which include the extension of the survey in the Southern Galactic plane and a portion of the bulge (VPHAS+), are discussed.

Key words: surveys – stars: binaries: symbiotic

1. INTRODUCTION

Since its design and implementation phase, IPHAS – the INT Hα photometric survey of the northern Galactic plane (Drew et al. 2005, see also *www.iphas.org*) – was seen as an opportunity to improve our knowledge of the total population of symbiotic stars in the Galaxy and their distribution. The issue is clearly relevant, as it would help to better understand their origin, predecessors, lifetimes and ability to evolve into SN Ia following mass accretion on their hot components (e.g., Munari & Renzini 1992). I review here the results obtained so far and the perspectives.

2. THE IPHAS SURVEY AND THE SEARCH FOR SYMBIOTIC STARS

The IPHAS observations were obtained between 2003 and 2009 using the prime focus Wide Field Camera (WFC) at the 2.5 m Isaac Newton Telescope (INT) of the Observatorio del Roche de los Muchachos, La Palma, Spain. The WFC consists of a mosaic of four 2k×4k EEV CCDs, providing in a field of view of 34×34 arcmin^2. The sampling is $0.33''$ per pixel, well matched to the typical image quality of the combination of the site and telescope (note that observations obtained with seeing worse than $1.7''$ FWHM were generally repeated). The area surveyed by IPHAS is the band of the Galactic plane between latitudes $-5°$ and $+5°$ visible from the Northern hemisphere ($35.5° \leq l \leq 215.5°$).

The IPHAS images are taken through three filters: a narrow-band Hα filter (λ_c = 6568 Å; FWHM = 95 Å) and two broad-band Sloan r and i filters, with matched 120, 30 and 10 s exposures, respectively. In this way, the magnitude range $13 \leq r \leq 20$ is covered for point sources (the fainter end at 10σ). Pipeline data reduction and data distribution are handled by the Cambridge Astronomical Survey Unit.

The use of a narrow-band Hα filter in a combination with two red broad-band filters is well suited to detect both the strong Hα emission which is typical of symbiotic stars, as well the continuum emission from their red giant component by highlighting its intrinsically red colors. However, given that the IPHAS observations are restricted to a narrow lane close to the Galactic plane, searching for symbiotic stars is a bit like searching for a needle in a haystack. The huge number of emission-line stars associated to young environments and star-forming regions are indeed expected to severely hamper the detection of symbiotic stars which instead belong to a relatively old stellar population (bulge/thick disk, see Munari & Renzini 1992) and thus are less concentrated in the Galactic plane. Therefore, defining searching criteria that successfully distinguish symbiotic stars from all other Hα emitting stars has been the main challenge of our project. A practical way to start is to combine the IPHAS photometry with the near-IR photometry from the 2MASS survey, whose detection limits ($K_s \sim 15$ mag) are well matched with IPHAS for the typical colors of symbiotic stars (Corradi et al. 2008).

As a first step, we have defined relatively broad selection boxes in the r–Hα vs. r–i and J–H vs. H–K_s color-color diagrams from IPHAS and 2MASS, respectively (Corradi et al. 2008). Such boxes were chosen in a way that they include the vast majority of the known symbiotic stars. The price, which we pay in order to be complete in the symbiotic star selection, is that the contamination from other sources, in particular from T Tauri stars and other young stellar objects, will be significant. The reason is that T Tauri stars not only show Hα in emission and contain a cool star like symbiotic binaries (mimicking their IPHAS colors), but also show some infrared excess by their dusty disks, which make their 2MASS colors to largely overlap with those of symbiotic stars of type D, which are the most affected by such a contamination. With these criteria, 337 candidate symbiotic stars of the S type, and 846 of the D type were selected from a preliminary list of IPHAS Hα emitters, being aware that the real symbiotic stars will be a small fraction of this sample (Corradi et al. 2008). The following step was to collect a significant number of spectra of these candidates in order to test the ability of IPHAS of finding new symbiotic systems, and at the same time estimate the contamination level in different regions of the color-color diagrams. This is discussed in Corradi et al. (2010b).

2. THE NEW IPHAS SYMBIOTIC STARS

The follow-up spectroscopy of a sub-sample of the $\sim$1100 symbiotic star candidates selected using our relatively loose criteria defined above, has led so far to the discovery of 14 new symbiotic stars. Before IPHAS, 10 symbiotic systems were known in this area of the Galactic plane[1]. The new IPHAS symbiotic stars are listed in Table 1 with reference to the discovery paper. The IPHAS r and 2MASS

[1]Excluding the additional source UV Aur that is included in Belczyński et al. (2000) but which may be not a genuine symbiotic star (e.g., see Herbig 2009).

Table 1. List of new symbiotic stars discovered by IPHAS to August 2011. The IAU-registered IPHAS name contains the J2000 coordinates of the sources.

No.	Name	r [mag]	K_s [mag]	Type	Reference
1	IPHAS J182906.08–003457.2	17.5	9.1	S	3
2	IPHAS J183501.83+014656.0	16.3	8.9	S	3
3	IPHAS J184446.08+060703.5	14.7	9.4	S	3
4	IPHAS J184733.03+032554.3	18.5	7.7	S	3
5	IPHAS J185323.58+084955.1	16.5	8.5	S	3
6	IPHAS J185704.44+002631.7	18.3	8.1	S	1
7	IPHAS J190832.31+051226.6	16.2	8.5		2
8	IPHAS J190924.64–010910.2	17.2	9.8	S	1
9	IPHAS J190926.60+120044.6	16.9	8.8	D	4
10	IPHAS J193436.06+163128.9	16.8	8.8	S	3
11	IPHAS J193501.31+135427.5	14.0	8.6	S	3
12	IPHAS J194607.52+223112.3	17.5	6.0	D	3
13	IPHAS J202510.58+435233.0	15.3	7.7	S	1
14	IPHAS J205836.43+503307.2	16.8	6.1	D	5

(1) Corradi et al. (2008)
(2) Corradi et al. (2010a)
(3) Corradi et al. (2010b)
(4) Corradi & Giammanco (2010)
(5) Corradi et al. (2011)

K_s magnitudes quoted in the table were not obtained at the same epoch and are just indicative of the brightness of the sources as it is known that these objects are highly variable. The first column of the table is only meant to be a reference number to the sources in this article.

In Figure 1, the distribution in Galactic coordinates of the new IPHAS symbiotic stars compared to all previously known systems from Belczyński et al. (2000) is presented. It can be seen that most of the new symbiotic stars are located toward the inner Galaxy, which together with their estimated distances (Corradi et al. 2010b) indicates that they may well belong to the bulge population.

In Figure 2, the r magnitudes of the new sources are compared to the magnitudes of the ten previously known systems in the IPHAS area. It is clear that IPHAS covers a magnitude range fainter than the sample of known objects. This is indeed one of the aims of the survey, which provides a deeper view into the Galaxy in terms of distances and amount of interstellar and circumstellar extinction. Of course, this also means that relatively large telescopes are needed to study these new systems in detail, which might be an obstacle for their future investigation.

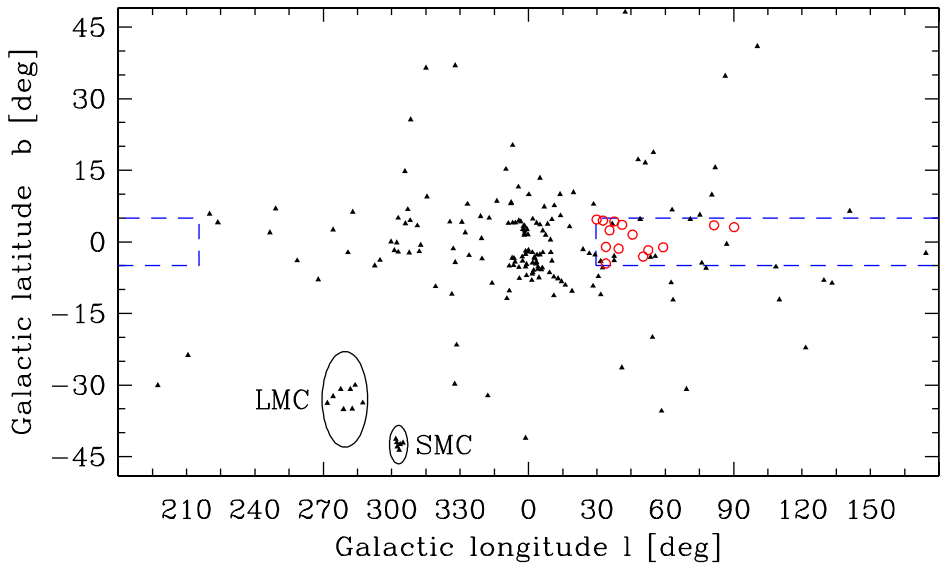


Fig. 1. Distribution of the new IPHAS symbiotic stars (empty circles), compared to the previously known systems (triangles). Three known objects with $|b| > 50°$ fall outside the graphic. The limits of the area surveyed by IPHAS are indicated by the dashed line.

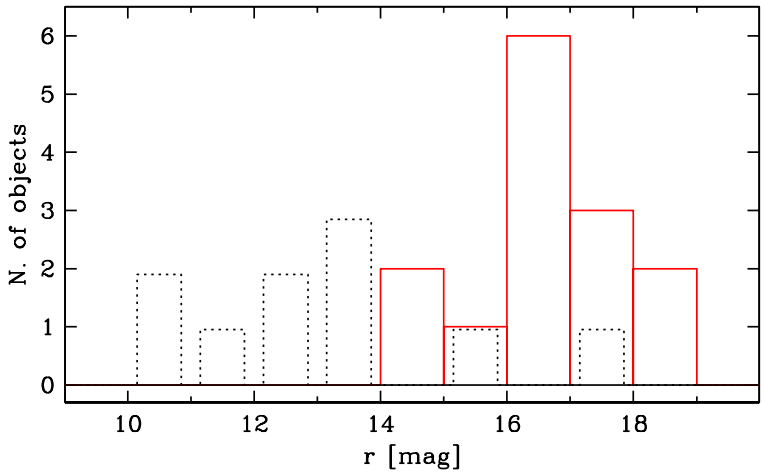


Fig. 2. Distribution of r magnitudes for the new IPHAS symbiotic stars (solid line histogram), compared to the systems previously known in the IPHAS survey area (dotted line).

3. CHARACTERISTICS OF THE IPHAS SYMBIOTIC STARS

Several of the new IPHAS symbiotic stars are classical "text-book" S-type symbiotic systems, showing the combination of a red continuum with the deep TiO absorption bands typical of an M giant, a strong Hα line in emission, and a number of high excitation emission lines such as He II, [O III], [Fe VII] and [Ca V]. These are the sources numbered as 1, 2, 3, 4, 5, 8, 10 in Table 1. In some other

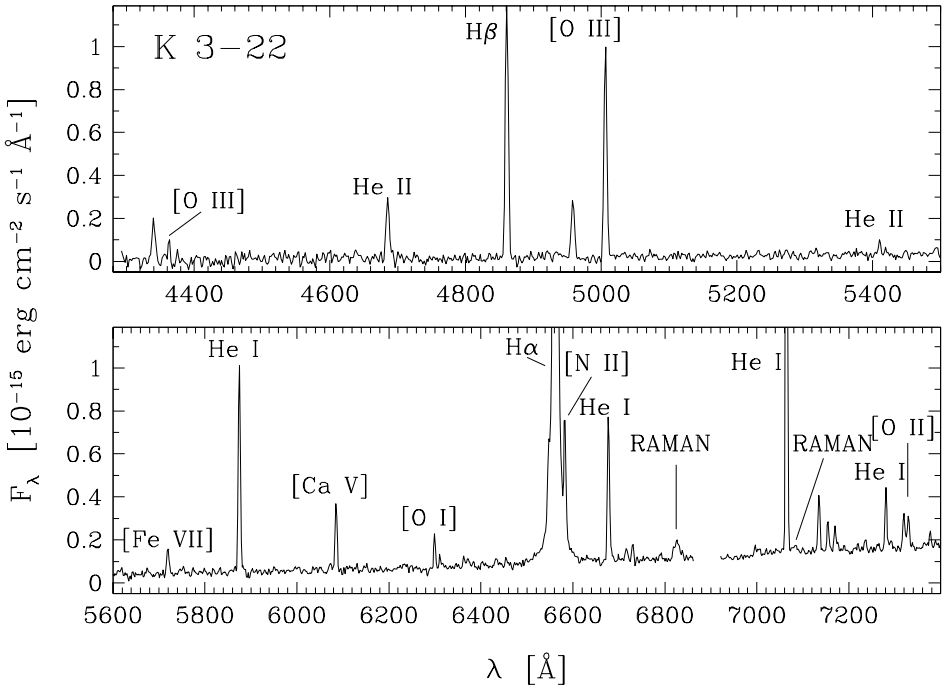


Fig. 3. The spectrum of the D-type symbiotic star IPHAS J194607.52+223112.3, previously catalogued as a possible planetary nebula and known as K 3-22 (figure adapted from Corradi & Giammanco 2010).

cases (Nos. 6, 11 and 13), the TiO bands are shallower and/or the high-excitation emission lines relatively fainter but still clearly detected. The Raman scattered broad emission feature at 6830 Å, typical of symbiotic stars, is detected in stars 3 and 5.

Three new D-type stars have been found. Two of them (Nos. 9 and 12) belong to the group of elusive D-type symbiotic stars in which in the optical range the red giant is not detected spectroscopically. Their spectra strongly resemble those of high-excitation planetary nebulae. Indeed No. 12 was previously included in catalogs of planetary nebulae. Their distinctive symbiotic features are the large Hα/Hβ and [O III] 4363/5007 line ratios indicating high densities and large optical thickness in the ionized gas, and most important the presence of the Raman scattered emission feature which indirectly points to the existence of a cool companion.

The third D-type system (No. 14, named IPHAS J205836.43+503307.2) is a very interesting new symbiotic star which contains a carbon star (Corradi et al. 2011). The system was found to be highly variable. As shown in Figure 4, upper panel, in 2006 the optical spectrum showed the combination of a number of emission lines, including the high-ionization species of He II, [O III], [Fe VII] and [Ca V], and a red continuum with the CN absorption bands of a star at the cool end of the carbon star sequence. In 2010 (lower panel of the figure), the giant star has significantly brightened, and now the optical spectrum is fully dominated by the carbon star continuum. The existing photometry indicates that the system

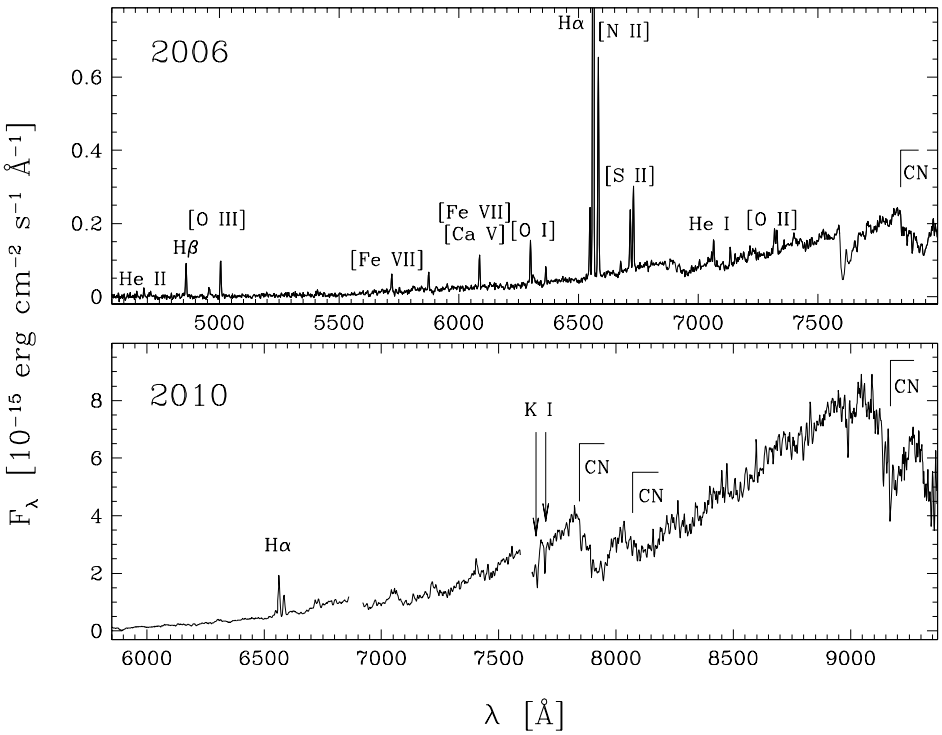


Fig. 4. The 2006 and 2010 spectra of the carbon symbiotic star IPHAS J205836.43+503307.2 (figure adapted from Corradi et al. 2011).

brightened by two to four magnitudes in the optical and near-IR regions sometime in the last decade. The near-IR excess, which was especially strong in 1999 (J–H = 3.0 and H–K_s = 2.3) and which is now more moderate (J–H = 2.1 and H–K_s = 1.6), indicates that a thick circumstellar dust shell was present in the system. Ongoing photometric monitoring from the ANS collaboration led by Munari (2012) shows additional photometric modulations that support the hypothesis that the carbon star is a Mira variable. Note that only two other symbiotic stars with a carbon Mira are known in the Galaxy (SS 38 and AS 210).

Finally, star No. 7 in Table 1 (IPHAS J190832.31+051226.6) was discovered and followed during the onset of an outburst (possibly of the symbiotic nova type) that is still in progress (Corradi et al. 2010a). Further monitoring of the system is needed to better understand its nature.

4. PERSPECTIVES

In addition to the fourteen new symbiotic stars, our follow-up spectroscopy has highlighted $\sim$150 emission-line stars, mainly young stellar objects like classical T Tauri stars but with some very interesting massive stars as well (Corradi et al. 2010b). These allow us to refine our search criteria for symbiotic stars and estimate the success rate as a function of the position in the IPHAS and 2MASS color-color diagrams. Once the final release of the fully-calibrated IPHAS photometric catalog will be available (expected for the end of 2011), this will also allow to estimate the

total number of symbiotic stars in the IPHAS survey area.

However, Figure 1 shows that most of Galactic symbiotic stars are likely to be located outside the IPHAS region. Therefore, our final goal of determining the total population of symbiotic stars in the Galaxy has to rely on future surveys which fortunately are under way. I mainly refer to VPHAS+, the IPHAS twin in the Southern hemisphere, which will be carried out with the one-square degree camera of the 2.6 m VLT Survey Telescope (VST) at ESO Paranal, Chile, starting at the end of 2011. Not only VPHAS+ will complete the coverage of the Galactic plane, but also it will survey a significant area in the bulge where we expect to detect a large number of symbiotic stars. Once VPHAS+ is completed, we will be able to derive a first reliable observational determination of the total number of symbiotic stars in the Galaxy. The ability of IPHAS of determining extinction distances (cf. Corradi et al. 2010b), will also help to investigate their 3D distribution. We expect to reach these goals on a timescale of three or four years from now, say around 2015.

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