The Hamburg/SAO survey for emission–line galaxies

II. The second list of 128 galaxies

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Abstract. We present the second part¹,² of the Hamburg/SAO Survey for Emission-Line Galaxies (HSS therein, SAO – Special Astrophysical Observatory, Russia) which is based on the digitized objective-prism photoplates database of the Hamburg Quasar Survey (HQS). The main goal of the project is the search for emission-line galaxies (ELG) in order to create a new deep sample of blue compact/HII galaxies (BCG) in a large sky area. Another important goal of this work is to search for new extremely low-metallicity galaxies. In this paper we present new results of spectroscopy obtained with the 6 m Russian telescope. The main ELG candidate selection criteria applied are blue or flat enough continuum (near λ4000 Å) and the presence of strong or moderate [OIII]λλ4959, 5007 Å emission lines recognized on digitized prism spectra of galaxies with the survey estimated B-magnitudes in the range 16.5 to 19.5. No other criteria were applied. The spectroscopy resulted in detection and quantitative spectral classification of 134 emission-line objects. For 121 of them the redshifts are determined for the first time. For 13 ELGs known before emission line ratios are presented at first time. 108 of 134 emission-line objects are classified as BCG/HII galaxies and probable BCGs, 6 – as QSOs, 1 – as Seyfert galaxy, 1 – as super-association in a dwarf spiral galaxy, 2 – as probable LINERs, 14 are low excitation objects – either of starburst nuclei (SBN), or dwarf amorphous nuclei starburst galaxy (DANS) type, and 2 – nonclassified. 23 galaxies did not show significant emission lines. The five most metal-deficient BCGs discovered have oxygen abundances log(O/H)+12 in the range 7.4 to 7.7, similar to the most metal-deficient BCGs known before.

Key words: surveys — galaxies: distances and redshifts — galaxies: starburst — galaxies: compact

1. Introduction

The studies of various types of galaxies with strong current star formation (SF) are among the most popular in extragalactic astronomy. For many purposes in this work it is very important to deal with large enough and well selected samples of such objects. In particular, the authors are involved in studies of SF bursts in low-mass galaxies (HII-galaxies, or blue compact galaxies - BCGs), and thus are interested in dealing with large samples of BCGs. There are three such large BCG/HII galaxy samples on the northern sky, each covering about 1000 square degrees. The first one is situated in the zone of the Second Byurakan Survey (Markarian et al. 1983; Stepanian 1994) (α = 7h40m – 17h20m, δ = +49° – +61°). It is described partly by Izotov et al. (1993a, 1993b); Thuan et al. (1994) and Pustilnik et al. (1995). The second one is under completion (Salzer et al. 1995; Ugryumov 1997; Ugryumov et al. 1998) and is situated in a region, which is a part of the Case objective prism survey (α = 8h00m – 16h20m, δ = +29° – +38°) (Pesch et al. 1995). The third one, the Heidelberg void survey (Popescu et al. 1996, 1998), is located in two separated regions. The new Hamburg/SAO Survey for Emission-Line Galaxies is intended to cover the
gap between the regions of the SBS and the Case survey and to create a new BCG/HII galaxy sample in that region. It covers the region between 7h20m to 17h40m in right ascension and between +35° to +50° in declination. This is the second article of the series devoted to follow-up spectroscopy results of preselected ELG Hamburg/SAO candidates. The basic ideas of the Hamburg/SAO survey and the selection methods of ELG candidates are described along with the first results of follow-up spectroscopy in Ugryumov et al. (1999) (Paper I).

This article is organized as follows. In Sect. 2 we give the details of the 6 m telescope spectroscopic observations and of the data reduction. In Sect. 3 the results of the observations are presented in several tables. Along with general parameters for emission-line galaxies and several quasars the parameters of the strongest emission lines are summarized in a separate table. The information on several non emission-line galaxies is presented as well. In Sect. 4 we briefly discuss the new data and summarize the current state of the Hamburg/SAO survey. Throughout this paper a Hubble constant $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$ is used.

### 2. Spectral observations and data reduction

All results presented below were obtained by observations with the Russian 6 m telescope, mainly in the snapshot mode during 16 runs between December 1995 and June 1998. The spectrograph SP-124 attached to the Nasmyth-1 focus of the telescope and equipped with a new Photometrix CCD-detector PM1024 (with $24 \times 24$ μm pixel size) was used in most of the runs. We used the gratings either with 300 grooves/mm or with 600 grooves/mm (see journal of observations in Table 1). Due to an experimental set-up of the CCD detector, it was not properly optimized, and significant vignetting prevented us in several runs in 1995 and early 1996 to get spectra in the UV ($\lambda \leq 4000$ Å). Various spectral set-ups were used with dispersions from 2.4 to 5.5 Å/pixel. The long slit with a length of 40″ was used. The slit width was 2″ in almost all observations. The scale along the slit was 0.4″ or 0.5″/pixel. Normally, short exposures were used (2 − 5 min) in order to detect strong emission lines, to measure redshifts and make some crude classification. Several spectra were taken with the Long Slit spectrograph (LSS in Table 1) (Afanasiev et al. 1995) at the 6 m telescope prime focus equipped with a CCD-detector on base of an ISD015A chip (530 × 580 pixels, with rectangular pixel size $18 \times 24$ μm), produced at SAO RAS. Long slit spectra ($2″ \times 180″$) were obtained with the grating having 650 grooves/mm and a dispersion 3.1 Å/pixel, and a scale along the slit of 0.41″/pixel. Reference spectra of an Ar–Ne–He lamp were recorded before or after each observation to provide a wavelength calibration. The spectrophotometric standard stars from Massey et al. (1988) were observed for flux calibration at least twice a night.

All observations and data acquisition with the spectrograph SP-124 have been conducted under software package NICE in MIDAS, described by Kniazev & Shergin (1995).

#### 2.1. Data reduction

The data reduction was done at SAO with the MIDAS software package. The context LONG was adapted to the SAO data formats to perform an automatic reduction.
3. Results of follow-up spectroscopy

In total 196 new candidates and 13 known ELGs have been observed. Among them 128 are new or confirmed emission line galaxies, 6 are quasars (all with redshifts in the range 2.93 to 3.35) and 23 are galaxies without emission lines (only 5 of them have good enough S/N ratio to identify absorption features and to measure redshifts). The remaining 52 objects appeared to be either stars with characteristic absorption lines or stellar objects with featureless spectra mainly due to insufficient signal-to-noise ratio to identify weak lines.

3.1. Emission-line galaxies

The new emission line galaxies are listed in Table 2 containing the following information:

| Column 1: | The object’s IAU-type name with the prefix HS. |
| Column 2: | Right ascension for epoch B1950. |
| Column 3: | Declination for epoch B1950. The coordinates were measured on direct plates of the HQS and are accurate to $\sim 2''$ (Hagen et al. 1995). |
| Column 4: | Heliocentric velocity and its rms uncertainty in km s$^{-1}$. |

| Column 5: | Apparent B-magnitude obtained by calibration of digitized photoplates with photometric standard stars, mainly Feige 34 and HZ 44. |
| Column 6: | Apparent B-magnitude obtained by calibration of digitized photoplates with photometric standard stars, mainly Feige 34 and HZ 44. |
| Column 7: | Apparent B-magnitude obtained by calibration of digitized photoplates with photometric standard stars, mainly Feige 34 and HZ 44. |
| Column 8: | One or more alternative names, according to the information from NED$^3$. |

Below we give notes on several individual objects in Table 2.

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$^3$ The NASA/IPAC Extragalactic Database (NED) is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.
HS0737+4011 This is a comet-like galaxy. The spectrum is shown for its head. HS0811+4913 This is a probable super-association (SA) at 75″ to NEE from the nucleus of the SA(s)cd galaxy NGC 2541 ($M_B = -17.5$) with a radial velocity 556 km s$^{-1}$. HS1035+4758 Nearby BCG with a recent supernovae type IIIP (SN1998bw, Kniazev et al. 1998; Merlino et al. 1998; Pustilnik et al. 1999). HS1057+4632 KUG 1047+465 is at 67″ to NNE. HS1102+4120 An object resembling on the Digital Sky Survey (DSS) an elliptical galaxy with a size 15″ × 12″. Elongated NE-SW. Due to strong [S$\text{ii}$] lines the galaxy is classified as LINER in diagnostic diagrams involving this line. But its luminosity is untypically low for a LINER. An alternative classification is therefore an Hii galaxy with some enhanced [S$\text{ii}$] shock excitation (post-merger starburst?). HS1457+4458AB Two ELGs with close redshifts at $\approx 20″$ from each other (15 kpc in projection). Interacting pair? HS1542+4116 Seemingly a dwarf companion of the SB(r)b galaxy NGC 5993, which is at 52″ to the west. This SB galaxy is a component of the pair KPG 471. HS1604+4127 Seemingly a dwarf companion of a barred dwarf spiral CGCG 1604.0+4127 at 41″ to NE. The latter is a component of the galaxy pair KPG 482. HS1614+4709 Probable companion of the face-on dwarf spiral UGC 10310=Arp 2. HS1643+4015 This is a disturbed galaxy of about 24″ in extent with two knots in the central part. The spectrum is shown for the brighter eastern one. HS1717+4955 Seemingly a dwarf companion of the SB(s)dm galaxy UGC 10806 ($M_B = -17.8$) with a radial velocity of $\approx 927$ km s$^{-1}$ (see for details Kniazev et al. 1999).

Several new BCGs from this paper were reobserved with higher S/N ratio in order to measure the flux of the [O$\text{ii}$] 4363 line, necessary to determine unambiguously the electron temperature $T_e$([O$\text{ii}$]) of the Hii-region and the oxygen abundance. A preliminary determination according to the procedure decribed by Izotov et al. (1997) shows a log(O/H)+12 for the five most metal-deficient BCGs HS 0822+3542, HS 0837+4717, HS 1013+3809, HS 1033+4757 and HS 1442+4250 to be 7.4, 7.68, 7.63, 7.7 and 7.7, respectively. A more detailed presentation of their spectroscopy will appear in forthcoming publications.

3.2. Quasars

In the course of our follow-up spectroscopy six QSOs were discovered with a strong emission line in the wavelength region between 5000 Å and the sensitivity break of the Kodak IIIa-J photoemulsion near 5400 Å. For all of them it was Ly$α$ 1216 redshifted to $z \approx 3$. This strong line produces an easily visible emission peak in the digitized prism spectra even for very faint objects ($B \sim 19^m0 - 20^m0$) which is hard to distinguish from low-redshifted [O$\text{ii}$] features. In other cases QSOs normally were not selected as candidates for follow-up spectroscopy.

The data for these six new high-redshift quasars are presented in Table 3. Their finding charts and plots of spectra can be found on www-site of the Hamburg Quasar Survey (http://www.hs.uni-hamburg.de/hqs.html).

3.3. Non emission-line objects

In total for 75 candidates no (trustworthy) emission lines are detected. We divided them into three categories.

3.3.1. Absorption line galaxies

For five bright non-ELG galaxies the signal-to-noise ratio of our spectra was sufficient to detect absorption lines, allowing the determination of redshifts. The data are presented in Table 5.

3.3.2. Stellar objects

To separate the stellar objects among all objects without emission lines we used a list of the most common stellar features as a template, and cross-correlated this list with observed the spectra. As a result we found 31 objects with definite stellar spectra and redshifts close to zero. Three of them are obvious M-stars. The rest were classified roughly in categories from definite A-stars to definite G-stars, with most of them G-type, and intermediate between F and G. The data for these stars are presented in Table 6.

3.3.3. Non-classified objects

39 non emission-line objects are hard to classify. Their continuum have too low signal-to-noise ratio to detect trustworthy absorption features, or small EW emission lines. 18 of them are certainly non-stellar on DSS images. For half of these galaxies we have spectra only in the range $\approx 4000$ to $\approx 5400$ Å, and they could have emission in H$\alpha$. For the other half we have spectra in the range $\approx 4000$ to $\approx 7000$ Å, and we can exclude the presence of strong H$\alpha$. The remaining 21 objects are indistinguishable from stellar ones, and we suggest that most of them are galactic stars.

4. Discussion

Altogether we have observed 209 objects preselected as ELG candidates on HQS objective prism plates, of which 196 had no previous spectroscopic information. 134 (64%) are found to be either ELGs, or
quasars. Of 128 detected ELGs 108 were classified on the character of their spectra and their absolute magnitudes as BCGs or probable BCGs. One galaxy showing broad Hα ($FWHM = 1800 \text{ km s}^{-1}$) and Hβ ($FWHM = 1400 \text{ km s}^{-1}$) and wide and strong HeII $\lambda 4686$ ($I(\text{HeII})/I(\text{H}\beta) \sim 0.7$) is a Seyfert galaxy (HS 1057+4632). One very faint object (HS 0811+4913) of absolute magnitude $M_B = −11.4$ is probably a superassociation in the dwarf spiral NGC 2541. Two galaxies show emission line ratios characteristic for LINERs. Two are difficult to classify. The remaining 14 ELGs are objects of lower excitation: either Starburst Nuclei galaxies (SBN) or their lower mass analogs Dwarf Amorphous Nuclear Starburst galaxies (DANS) (Salzer et al. 1989). Since the main goal of the HSS is an efficient search for new BCGs, the fraction of this type among all new detected ELGs $\sim 84\%$, or $80\%$ among all emission-line objects, is very encouraging.

It is worth to note that after the analysis of the results of pilot part of the HSS (see Paper I), the selection algorithm was improved in order to clean the candidate lists for follow-up spectroscopy from the majority of stellar-like and second priority objects. The majority of the former have been found as blue stars, and the latter are either low excitation ELG or galaxies without emission lines. The overall detection efficiency of emission-line objects has grown significantly, up to $64\%$ for this second part of the HSS.

The distributions of the new HSS ELGs in the line-ratio diagrams $[\text{OIII}] \lambda 5007/H\beta$ versus $[\text{NII}] \lambda 6583/H\alpha$ and $[\text{OIII}] \lambda 5007/H\beta$ versus $[\text{OIII}] \lambda 3727/[\text{OII}] \lambda 5007$ (see Baldwin et al. 1981; Veilleux & Osterbrock 1987, for details) in general are similar to those shown in Paper I. Several new high excitation BCGs are discovered or rediscovered. Follow-up spectroscopy with high signal-to-noise of these prominent galaxies resulted in the discovery of new very metal-poor galaxies. This data will appear in separate papers currently in preparation.

One more immediate conclusion comes from the absolute magnitudes of new the ELGs in Table 2. Even with some reservations concerning the accuracy of the apparent magnitudes, the Hamburg/SAO Survey picks up well objects with $M_B \geq −15$. Thus, with additional photometry to improve the accuracy of $B$-magnitudes, this sample will serve as an important instrument to study the still poorly known faint end of the ELG luminosity function.

Altogether in Paper I and in the present paper we discovered 176 new emission-line objects (10 of them QSOs), and for 32 more galaxies we got quantitative data for their emission lines. Preliminary classification of the 198 ELGs yields 155 confident or probable blue compact/low-mass HII-galaxies. Thus a large fraction of BCGs relative to all ELGs is found ($\sim 78\%$) demonstrating the high efficiency of this survey to find on the Hamburg Quasar Survey photoplates namely galaxies with HII-type spectra. A statistical analysis of this BCG sample, supplemented with galaxies from the next parts of the survey is underway.

5. Conclusions

We conducted follow-up spectroscopy for the second part of candidates from the Hamburg/SAO Survey for ELGs. Summarizing the results presented, the analysis of the content of various types of objects, and the discussion above, we draw the following conclusions:

- The intended methods to detect ELG candidates on the plates of the Hamburg Quasar Survey give a reasonably high detection rate of emission-line objects ($\sim 64\%$) (134 objects of 209 observed in this second part). Additional selection criteria applied in comparison to the first, pilot part increased the efficiency of follow-up spectroscopy by a factor of about two.
- Besides of ELGs we found also 6 new quasars, all with Lyes in the wavelength region $5000 − 5300 \text{ Å}$ (i.e. with $2.9 < z < 3.35$) near the red boundary of the IIIa-J photoplates.
- The high fraction of BCG/HII galaxies among all newly discovered ELGs (about $84\%$) is in line with our main goal — to pick up a deep BCG sample in the sky region under analysis.

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