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Spectrophotometry with low and moderate spectral resolution for the blue compact galaxies

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Abstract. In this paper we compare the results of spectral observations for the blue compact galaxies from the Second Byurakan Survey (SBS) carried out with the scanner spectrograph (nearly 400 objects) and echelle spectrograph (40 objects) on the 6 m telescope of the Special Astrophysical Observatory. The comparison was aimed to study systematic errors of the scanner spectrograph. The study of these errors made it possible to improve the accuracy of determination of physical conditions and chemical content of BCGs using low spectral resolution spectra. This includes the correction for the nonlinear photon counting rate for strong lines and the necessity of taking into account the underlying absorption. A comparison of line intensities, electron temperatures and equivalent widths obtained from the scanner and echelle observations showed their good agreement.

A method is proposed for definition of galaxies belonging to the low branch of the dependence of the oxygen abundance versus the total intensity of the oxygen lines [OII] + [OIII]. The low branch is used to derive the oxygen abundance in galaxies with low metallicity in the case when the [OIII] 4363 Å emission line is not detected. Blue compact galaxies are generally located on the low branch and therefore Pagel's (1979) method can not be used for them. The low branch is plotted using the spectral data obtained with the echelle spectrograph for the galaxies with the observable [OIII] 4363 Å line.

No correlation is found between the absolute magnitude and oxygen abundance for the sampled objects (blue compact galaxies) with the use of the reliable data.

Key words: star burst galaxies: spectrophotometry – chemical abundance estimation: methods

1. Introduction

Blue compact galaxies (BCGs) have been known since the 70s as gas–rich and heavy elements poor objects. Spectra of these objects are similar to those of giant high excitation HII regions with bright emission lines against weak continua, which suggest intensive star formation processes. However, in comparison with ordinary HII regions in spiral galaxies they are observed as metal–defficient with oxygen abundance from 1/2 to 1/40 of solar abundance. There are some extreme cases when BCGs consist of one supergiant zone HII (Puche and Westpfahl, 1993). Such properties suggest that blue compact galaxies are evolutionary young (some galaxies are likely to undergo the first star formation burst). Observations of BCGs give the most precise estimates for primary helium abundance, chemical evolution, evolution of the most massive stars of chemical composition different from solar and to study problems of galaxy origin.

The SBS is one of the deepest surveys, which contains a great number of blue compact galaxies. The basic criterion of selecting BCG candidates from the Second and partly from the First Byurakan Survey (Markarian et al., 1989) was the presence of very strong emission lines superimposed on the comparative weak continua. With this criterion the sample includes only those dwarf systems, in which the current star formation is observed. The list of such galaxies contained over 400 BCG candidates. The observation of the full list of galaxies was conducted at the 6 m telescope using a TV scanner. Because of the small dynamic range of the detector the authors faced with the effect of non–linearity for strong lines, so for the most BCGs with high excitation HII zones the strongest lines are observed in a non–linear mode. Since for determining physical conditions and chemical abundances in HII regions it is necessary to obtain intensities of some weak lines and weak continuum, apart from strong lines, then the common used technique of observation with an attenuator is insufficient in this case. The character and values of the errors introduced have not been previously investigated for the given objects. Part of the galaxies from the complete sample with the extremely low abundance of heavy elements have been observed also with the echelle spectrograph of the 6 m telescope, for which the non–linearity effects are not so large thank to higher spectral resolution and 2D acquisition system. Thus, it is possible to study the errors of estimation of chemical abundances caused by the scanner spectrograph and compare the results obtained using the two instruments. The second source of errors in determination of element abundances is the difference in the methods of determination of physical conditions and chemical composition of galaxies. When the [OIII] 4363 Å line is absent in the spectra of number of galaxies abundances are estimated empirically. In the present paper is shown the accuracy of different calibrations in determination of element abundances. The known sources of errors and the application of more reliable methods enable confident results to be obtained from low and moderate resolution spectra.

2. Observations and processing

The program of observations of blue compact objects from the Second and partly from the First Byurakan Survey with the 6 m telescope scanner was started in 1988. Spectra were obtained with the 2×1000–channel TV scanner attached at the Nasmyth–1 focus. Diffraction gratings giving dispersions 100 and 200 Å/mm were used, the spectral resolution was 5–8 Å. For some individual galaxies ($\sim$ 30) spectra were obtained in blue, 3700–5600 Å and red 5400–7200 Å spectral ranges. For the rest of the galaxies ($\sim$ 360) only the blue spectra were obtained. Since the object and background channels are somewhat different in sensitivity, for the correct night sky subtraction the spectra of galaxies were taken replacing an object and the sky in the two channels with equal or close exposures and combined when being processed. To correct for the non–linearity effects, sometimes the cases of short exposures of several minutes with a special attenuator were used for very bright lines. In the spring of 1991 about 200 remaining sample galaxies were observed with the TV scanner in a snapshot mode of search with short exposures (3÷5 min). The main objective of the program accomplished with the scanner was the search for BCGs from the candidates selected from the Second Byurakan Survey as well as the rough classification of the found objects. The classification is based on the power of star formation burst and possible content of heavy elements in the medium. We tried to avoid mixing of any AGN nuclear star–burst bright galaxies in the sample. All the objects are separated into four classes:

- Class A: equivalent width EW([OIII] 50 Å)$\geq$ 100 Å, a very weak blue continuum, as a ru high excitation spectra, with a low signal/noise rat (S/N), there are no signs of the [NII] 6584 Å line.
- Class B: EW([OIII] 5007 Å) = 50–80 Å, a wea blue or flat continuum.
- Class C: EW([OIII] 5007 Å) = 20–50 Å, a n ticeable blue or flat continuum, Balmer absorptio lines can be observed, beginning with Hγ; Hβ show frequently an underlying absorption.
- Class D: EW([OIII] 5007 Å) = 0–20 Å, we [OII] 3727 Å are often observed, a strong blue or fl continuum, Balmer absorption lines, usually Hβ Hγ are observed, H and K Ca II moderate absorpti lines may be present.

Thus, the scanner data are quite inhomogeneo in both the type of objects and the quality of spect The quality of the scanner spectra has been scored a four–point scale:

"1": the galaxy was observed with a long exposu ($\sim$30 min), in both the object and sky channels, in linear range, with a seeing of $\approx 3''$.

"2": the galaxy was observed with a long exposu only in the object channel, with a seeing of $\approx 3''-5$

"3": the galaxy was observed either with a long e posure but in a non–linear mode and with a po seeing or with a short exposure but in a linear mo and with a good seeing.

"4": short exposure (3–5 min), non–linear conditio poor seeing.

Some results of the scanner observations we published in the paper by Izotov et al. (1993). Su sequent observations of some selected objects ha been conducted on the echelle spectrograph "Z BRA" (SP–161) attached at the Nasmyth–2 focus the 6 m telescope with the 2D TV counting syste "QUANTUM". Two–dimensional spectrum images 512 × 512 pixels (13 orders) were transformed in 1D spectra and processed as described by Izotov al. (1990). The spectral resolution was 1.7–2.5 Å. the present paper 40 echelle spectrograms of gala ies with the lowest heavy element abundances fro the total list of about 360 blue compact galaxies ob served with the scanner are used. First of all compac galaxies with strong star–formation bursts, in whic the [OIII] 4363 Å line is reliably measurable, are in cluded in the program of echelle observations. For th echelle the spectral sensitivity, S/N, spectral resolu tion and dynamic range are better than for the scan ner. The echelle observations were intended to yiel high–quality observational data, that included goo seeing, long exposures, and observing in the linea mode. The Fig. 1 represents the quality of spectr taken for SBS 1037+494 with both instruments, T scanner and echelle.

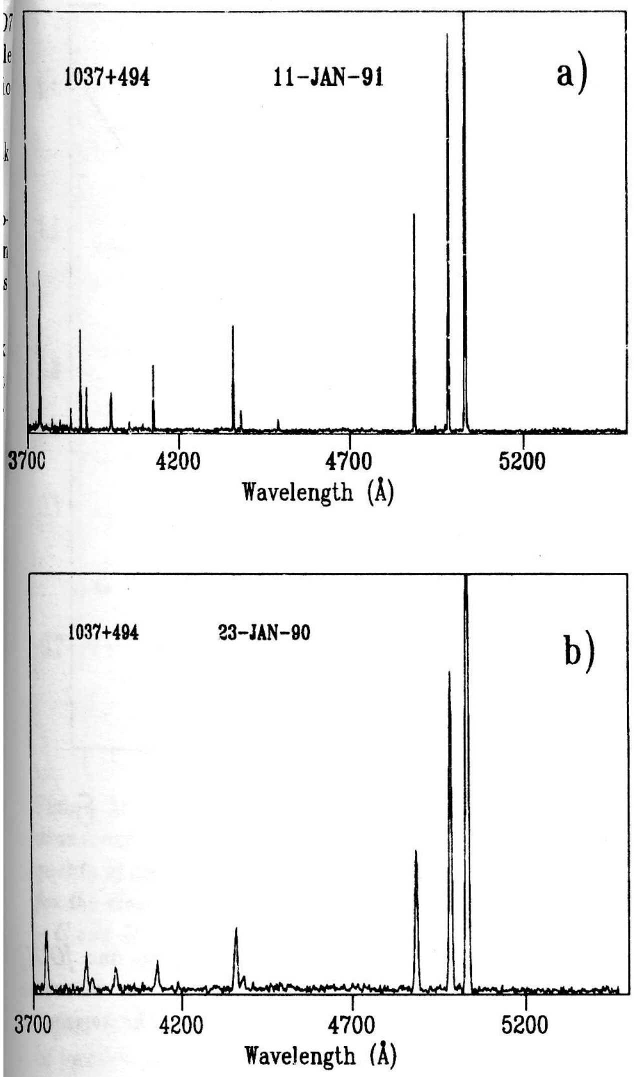

Figure 1: *Spectra of the galaxy SBS 1037+494 obtained with the scanner and echelle spectrograph of the 6 m telescope.*

For a short slit of the echelle the night–sky spectrum was taken as an isolated exposure. In processing it was calibrated to the same exposure time and subtracted, dispersion curves for the galaxies and standard stars were calculcated, the spectra were rebinned and after correction for the spectral sensitivity the spectra of different orders were pasted, when necessary. Then the emission line intensities were corrected for absorption underlying continua and internal extinction.

2.1. Correction for the non–linear photon counting mode

First of all the emission lines in the spectra taken with the scanner were tested for the effect of non–linearity during observations. Under the non–linear condition the characteristic curve becomes saturated and as a result, the intensities of the brightest lines turn out to be underestimated. To estimate the errors introduced in the intensities of the brightest lines by the non–linearity of a signal, 200 spectra obtained during snapshot mode on February 11 and 12, 1991 with short exposures were taken. Assuming that the line N2 [OIII] 4959 Å has been obtained in all the spectra in the linear mode, theoretical values of intensities of the line N1 [OIII] 5007 Å with a coefficient of 2.88 have been calculated (Aller, 1984) and a comparison of the intensities of the lines N1 obtained in this mode with the observed ones has been made. In Fig.2 the abscissa is the photon counting rate for the line N1, while the ordinate is the difference between the theoretical and observed photon counting rates for the integral line intensities (we used the raw data before any correction for the spectral sensitivity).

As follows from Fig.2 the line intensities begin to deviate strongly from the theoretical value at photon counting rates > 2.5 counts/s. The intensities of all the lines, in which the photon counting rate values in the spectra were higher than 2.5 counts/s, have been corrected by means of the curve in Fig.2 $\Delta = -2.31182 - 0.824327 counts/s + 0.680672 (counts/s)^2$.

2.2. Correction for interstellar extinction and underlying absorption lines

The equivalent width of absorption lines of the Balmer series observed in the stellar population of galaxies is accepted normally to be 1.9 Å and is taken into account prior to the correction for interstellar extinction in the following manner:

$$I(\lambda) = F(\lambda)\left(1 + \frac{EW_{abs}}{EW_{em}}\right), \quad (1)$$

where EW_{abs} is the equivalent width of absorption lines of the Balmer series, EW_{em} is the equivalent width of emission lines of the Balmer series, $F(\lambda)$ and $I(\lambda)$ are the observed and corrected line intensities.

To correct the line intensities for interstellar extinction theoretical intensity ratio $I(H\alpha)/I(H\beta)=2.85$ has been adopted for the photoionized HII zone (case B) with the electron temperature $T_e = 10^4 K$ and $N_e = 10^2$ cm^{-3} (Aller, 1984); the absorption coefficient C ($H\beta$) at the wavelength of the line $H\beta$ is found from all observable Balmer lines in each galaxy. For each pair of Balmer lines $H\alpha/H\beta$, $H\gamma/H\beta$, etc. the coefficient C($H\beta$) is determined by the formula:

$$c(H\beta) = \frac{1}{f(\lambda)}\left[lg\left(\frac{I(\lambda)}{I(H\beta)}\right) + lg\left(\frac{F(\lambda)}{F(H\beta)}\right)\right], \quad (2)$$

where $I(\lambda)/I(H\beta)$ is the theoretical value of the Balmer decrement, $F(\lambda)$ is the observed Balmer line intensity corrected for the atmospheric extinction and equivalent width of absorption of the Balmer series arose in stellar composition of galaxies, $f(\lambda)$ is the

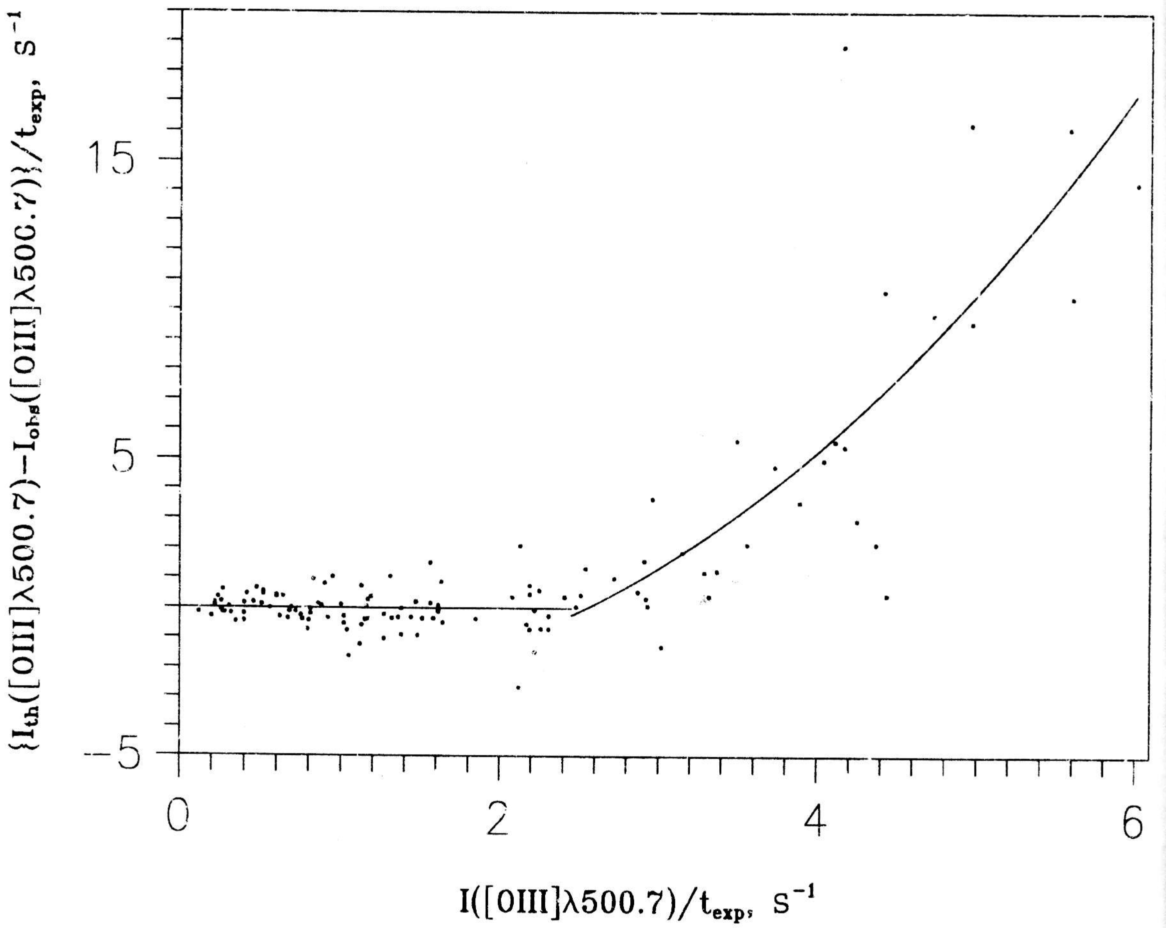

Figure 2: *Difference between the theoretical and the observed photon counting rate in the line [OI 5007 Å vs the observed counting rate. The theoretical photon counting rate is derived from the ra $I([OIII]5007)/I([OIII]4959) = 2.88$. The solid line is an approximation of the observed data. The horizon portion of the approximation curve corresponds to the linear photon counting condition.*

reddening function normalized to the value at the wavelength of the line Hβ and determined from the normal reddening law (Whitford, 1958).

Due to the large variety of galaxies at different stages of star formation burst in them, represented in the complete sample of BCGs, EW_{abs} may differ from 1.9 Å. The equivalent width of absorption EW_{abs} was determined simultaneously with c(Hβ) in such a way that the difference between the Balmer decrement, obtained as a result of correction for the two effects, and theoretical value is minimal. If several lines of the Balmer series are present in the spectra, the resulted c(Hβ) is obtained by averaging isolated estimates taken with weights proportional to intensities of lines.

In the spectra of some galaxies, besides the narrow emission lines, broad absorption lines of the hydrogen series are visible. It is possible to measure the equivalent widths of hydrogen absorption lines provided that the absorption lines of the hydrogen series turn out to be broader relative to the emission lines, which occurs in the case of large dispersion of velo ities of stars in the galaxy. Since no measureme of absorption lines have been made for the scan observations, and EW_{abs} has been determined by t procedure described above, for several galaxies galaxies with c(Hβ) > 1.0) the equivalent width the absorption lines of the hydrogen series EW_{abs} most likely not to have been fully taken into accou For the higher members of the hydrogen series this fect is stronger, which results in a very large amou c(Hβ). For some objects the absorption has not be determined at all because of the low–quality spe trum or weak emission lines of the galaxy, when t Hγ line can not be measured, and the red portion the spectrum has not been observed.

As is seen from Fig.3, there is no correlation b tween the absorption coefficient c(Hβ) and the oxyge abundance for galaxies with strong lines, the reliab intensity estimates and the low oxygen abundan $(12 + \log(O/H) < 8.3)$. A large part of the gala ies with excess absorptions are concentrated in th

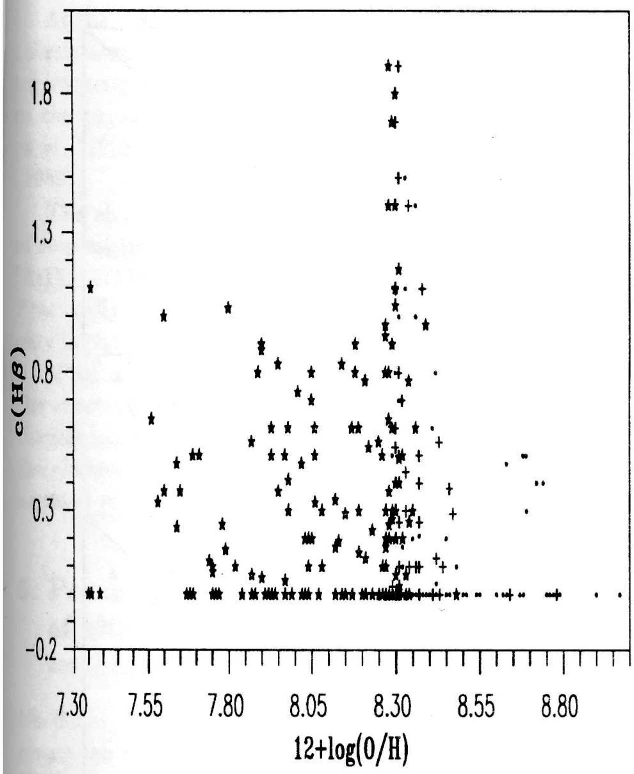

Figure 3: *Absorption coefficient c(Hβ) vs. oxygen abundance for all the galaxies of the sample with a quality of spectral data from "1" to "4". Designations for the class of galaxies: stars – A, crosses – B, dots – C and D.*

region $12 + \log(O/H) = 8.3 - 8.4$, i.e. in the region of location of galaxies with weak emission lines. The extinction coefficient c(Hβ) depends on the number of dust particles in the line of sight. The last value, in turn, is associated with the abundance of heavy elements in the galaxy and is larger in the galaxies with higher metallicity. In this case the strong absorptions may also be due to observational errors. The quality of the spectra of the galaxies with c(Hβ) > 1.1 is 3 or 4, they all are located in the region of small equivalent widths of Hβ lines.

For some galaxies from the Michigan survey (UM) (Salzer et al., 1989), after the correction for the extinction, anomalously high line intensity values I([OII]λ 372.7)/I(Hβ) > 10 were obtained, which is not typical of the regions with a photoionization excitation mechanism. Apparently, this is associated with the fact that in determination of c(Hβ) in the UM sample the absorption lines of the stars have been taken into account.

For the same reason (underestimation of the absorption lines of the hydrogen series) part of the SBS galaxies have also an anomalously large value of line intensities, which can be tested readily by the intensities of the oxygen lines. Absorption underestimation in Hβ line and hence the underestimated Hβ intensity lead to enhancement of I(OII)/I(Hβ) and I(OIII)/I(Hβ), where I(OIII) denotes I([OIII]) 4959 Å+ I([OIII]) 5007 Å. From all the known calibration curves used to dètermine oxygen abundance from the sum of intensities of oxygen lines it follows that the values of $\log([(OII + OIII)/H\beta]) > 1.05$ are not realized (McGaugh, 1991; Skillman, 1988). The theoretical calculations performed by McGaugh (1991) suggest that under no conditions in the HII region the values of $\log([(OII+OIII)/H\beta]) > 1.05$ are possible. For 13 SBS galaxies, for which $([OII] + [OIII]/\beta > 12.0$, the spectrum is of low quality. Part of the galaxies with $(OII + OIII)/H\beta > 9.5$ with the apparent absence of absorption lines of the hydrogen series are distinguished by unusually broad lines of doubly ionized oxygen [OIII] and occasionally by the presence of a broad low–intensity component in these lines.

3. Comparison of line intensities

Comparison of the corrected line intensities for the galaxies, observed with both instruments, and in whose spectra the intensity of the line [OIII] 4633 Å has been measured (28 galaxies), allows us to estimate systematic errors in the line intensities for spectra taken with the scanner. Fig.4 presents a comparison of line intensities [OII] 3727, [OIII] 4363, [OIII] 4959 and [OIII] (4959+5007).

The intensities of [OIII] 4959 and [OIII] 5007 lines have no systematic differences. The intensities of [OIII] 4363 in the scanner spectra are systematically stronger, and hence the electron temperature derived from the ratio of [OIII] line intensities is higher as well, and the oxygen abundance is accordingly lower. The systematic deviation in [OIII] 4363 Å line intensities with the scanner observations has been taken into account in determination of oxygen:

$$O_{cor} = O + (-0.33117O) + 2.66406, \qquad (3)$$

where $O = 12 + \log(O/H)$ is the oxygen abundance from the scanner data with the measured intensity of the line [OIII] 4363 Å.

The large systematic deviation of the intensity of the line [OII] 3727 Å and its large dispersion are evident. Since this line is observed on the UV side of the spectrum, the dependence of the difference $\Delta = [OII]_{ech} - [OIII]_{sc}$ on the redshift, i.e. on the position of the line [OIII] with respect to the edge of the spectrum was studied. The large spread in Δ values at small z and the decrease in this scatter with increasing z may be explained as the result of atmospheric dispersion influence when the program galaxies and the standard stars are observed. The echelle observation are free from these effects since the 1D spectra are extracted from the intensity maximum in 2D spectra. When plotting the spectral sensitivity

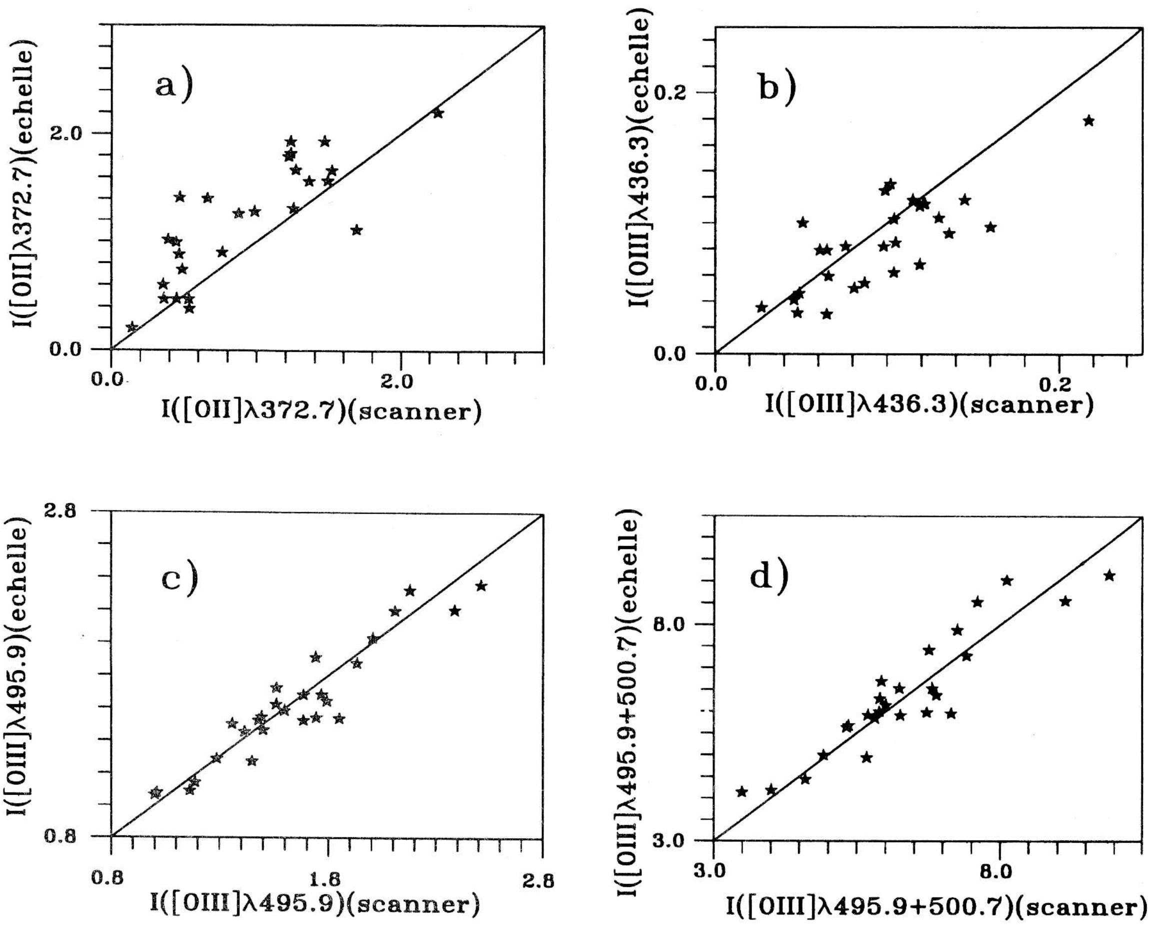

Figure 4: *Relation between emission line intensities obtained with the scanner and echelle spectrograph solid lines correspond to I(scanner)=I(echelle).*

curve considerable errors are also possible due to the sharp drop in the distribution of energy in the spectra of many standard stars in the region of the line [OII] 3727 Å. The large scatter of points is partially accounted for by the errors in plotting the dispersion curve: there are no strong lines in the comparison spectra (the spectrum of neon for the scanner and the spectrum of Ne+Ar+He for the echelle) in the region 3727 Å. Because of these effects, which are difficult to define unambiguously, no corrections of the intensity of [OII] have been made. The comparison of the equivalent widths of [OII] 3727 Å lines does not show systematic differences.

4. Definition of physical conditions in the regions of ionized hydrogen

The most sensitive to the electron temperature T_e is the intensity ratio of the forbidden lines of doubly ionized oxygen [OIII]: the auroral line 4363 Å to the sum of the nebular lines 4959+5007. In all the cases when the line 4363 Å was observed the electron temperature was determined from the following relation (Aller, 1984):

$$T_e = \frac{14320}{\log(I_{4959+5007}/I_{4363}) - 0.881}.$$

In connection with the essential errors in deterr nation of [OII] line intensities the differences in t estimates of the oxygen ion 0^+ abundances using two–zone model in the ionization structure of the H region turn out to be less affected by the errors in th intensities of the line [OII]. That is why even in th cases when the electron temperature for the zone high degree ionization was determined using the lin [OIII] 4363 Å, T_e for the zone of low degree ionizatio was not determined in the processing of the scanne spectra. Moreover T_e for the low–excitation zone i impossible to determine because the red region of th spectra and hence [NII] lines are missing for part o the galaxies, and also because of the weak lines [NII in the galaxies with low heavy element abundance.

When the line [OIII] 4363 Å was not observed, T_e was computed from the empirical relation of Pagel (1979):

$$T_e = 3570 + 7940 \log[(I_{3727} + I_{4959+5007})/I(H_\beta)]. \quad (5)$$

At the present time there are a number of empirical relations to determine the abundance from the total intensity of oxygen lines (OII+OIII), for instance, in the papers of Evans and Dopita (1985), McCall et al. (1985), Pagel (1979), Torres–Peimbert et al. (1989).

The electron density N_e is found from the ratio of sulphur lines [SII] 6717/6730, and also argon lines [ArIV] 4711/4740 or the doublet [OII] 3727/3726. Practically all the scanner spectra have been obtained only in the blue region of the spectrum, in the majority of the spectra no [ArIV] lines have been registered, the spectral resolution is insufficient for the lines of the oxygen doublet [OII] to be separated. That is why the electron density N_e for all the galaxies has been adopted to be $100 cm^{-3}$, which is typical of BCGs.

5. Procedures of determination of chemical abundances in galaxies: oxygen and neon

No doubt, the abundance of oxygen and other elements can be estimated most reliably using the temperature determined from the lines [OIII] 4363 Å and [OIII] (4959+5007) Å. Unfortunately, in most of the cases the intensity of the line [OIII] 4363 Å turned out impossible to be measured. On the one hand, with metallicities comparable to solar ($Z > 0.5 Z_\odot$) the line [OIII] 4363 Å is weak, and such objects are rather numerous. On the other hand the typical intensity value of [OIII] 4363 Å is not large (0.05–0.1), and in the spectra of quite a few galaxies with spectra of not very high quality (quality class "3", "4") we are unable to measure the line [OIII] 4363 Å even in the galaxies where it is bound to be observed. Indeed, part of the galaxies with the abundance found from the empirical relation of Pagel (1979) have too large oxygen abundance values with large values of $EW(H\beta)$. In Fig.5, prior to the correction, these objects were located in the region marked with the square. Using the investigation of HII regions in spiral galaxies, Edmunds and Pagel (1984) have demonstrated the bifurcation of the curve in determining the oxygen abundance from the intensities of the lines [OIII] 4959+5007, [OIII]/[NII] and [OII]+[OIII]. For $\log([OII] + [OIII]) < 1$ there is an ambiguity in the determination of oxygen abundance associated with the fact that when passing to the HII regions with a smaller number of heavy elements, first of all oxygen, which is the main coolant, the electron temperature T_e and therefore the [OII]+[OIII] line intensity increase. However with the further decrease in oxygen abundance ($12 + \log(O/H) < 8.1 - 8.2$ the cooling efficiency of the nebula by doubly ionized oxygen is reduced since other mechanisms of heat abstraction come to be effective, and the intensity of oxygen lines drops again. T_e rises to a degree, but there become effective the cooling mechanisms at free–free transitions as well as the mechanism of two–photon continuum radiation with the further decrease in oxygen abundance. The combined action of these mechanisms leads in the long run to an ambiguity in determining the oxygen abundance from the sum of the oxygen lines [OII]+[OIII]. The branches of the bifurcated curve, which refer to large and small oxygen abundances are called upper and lower, respectively. Thus, it is necessary to have additional criteria for the objects to belong to the lower branch.

In the present paper two criteria are used: the Hβ line equivalent width and the line intensity ratio $[OIII]/[OII]$, which is the level of nebula ionization and hence proportional to T_e. The Hβ line equivalent width defines the time from the start of a star–formation burst and therefore the measure of enrichment of the nebula with heavy elements. In Fig.6 is displayed the dependence of EW(Hβ) versus [OIII]/[OII] for 40 high excitation echelle spectra as well as for all the scanner observed galaxies (34) with the spectrum quality "1", in which the line 4363 Å has not been measured. All the scanner spectra of class "A" are located in the region of echelle objects, above and to the right of the solid line, which separates clearly the objects of the upper and lower branches. For all the galaxies situated above and to the right of the solid line the abundance, in the absence of the line 4363 Å in the spectrum, is defined from the lower branch. Skillman (1989) has constructed the empirical relation between the oxygen abundance and the sum of intensities of oxygen lines for the lower branch from the data for 23 galaxies, taken from different papers (Campbell et al., 1986; Davidson and Kinman, 1985; Kinman and Davidson, 1981; Kunth and Sargent, 1983; Peimbert et al., 1986; Skillman et al., 1988, 1989a,b).

In the present paper we use our own calibration curve, $\log(OII + OIII)$ as a function of oxygen abundance, plotted for 40 echelle spectra with a low heavy element abundance and readily measurable 4363 Å line. The lower branch is approximated by the expression $\log(OII + OIII) = 5.71b - 4.32$, where $b = 12 + \log(O/H)$, which is used to determine the oxygen abundance. Thus, to determine the abundance of heavy elements three procedures have been applied: the most reliable is the technique using the line [OIII] 4363 Å (corrected for the systematic deviation by formula (3)), evaluation of the abundance from the lower branch for the galaxies with low abundance of heavy elements, and the method of Pagel (1979) for the galaxies of high heavy element abundance. Let us call these methods: the 4363 method, the lower branch method, and Pagel method, respectively. It is seen in Figs. 2, 5, 7, and 8 that reliable conclusions can be drawn provided the results have

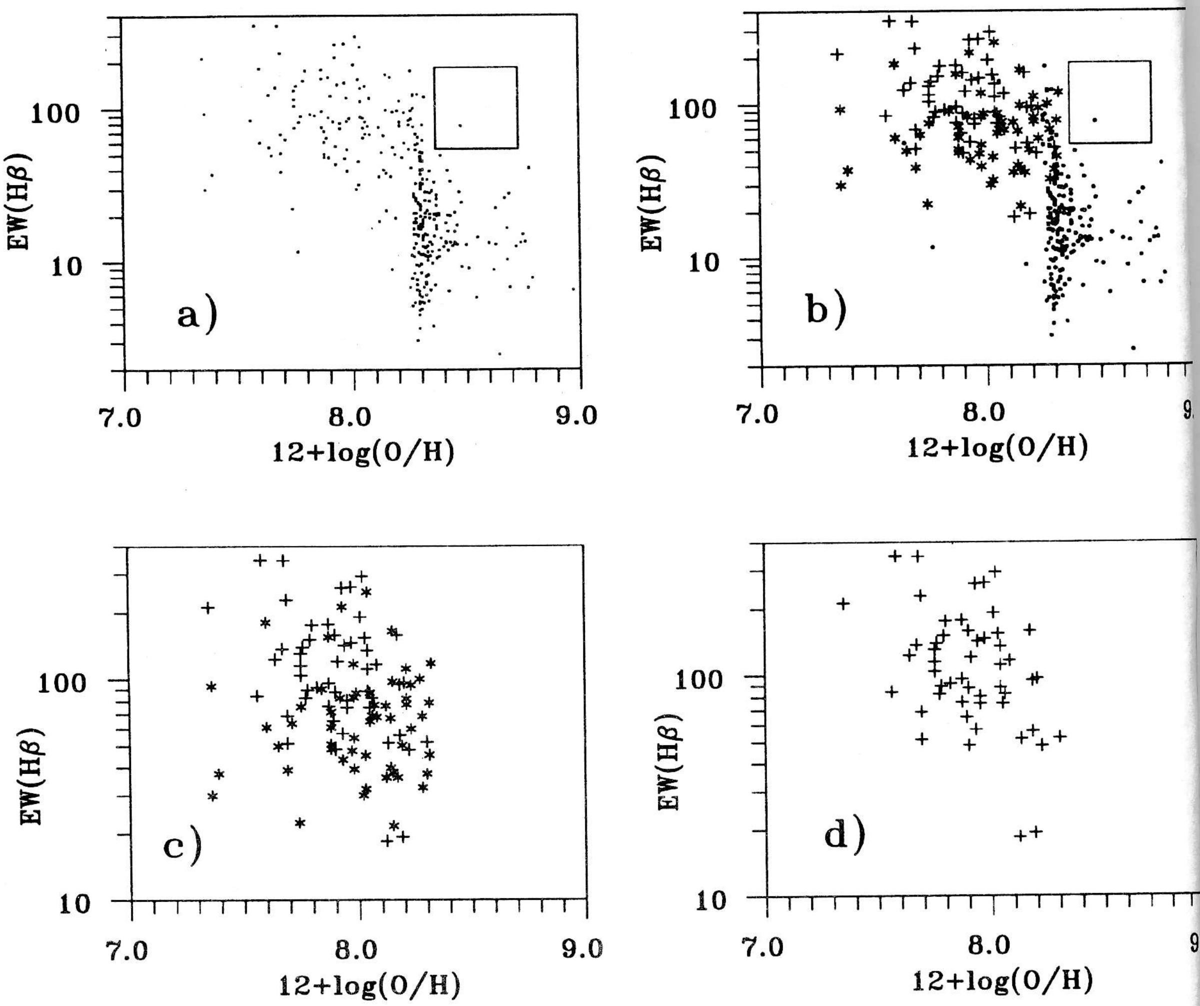

Figure 5: *Equivalent width of the line Hβ as a function of oxygen abundance. (a) all galaxies, (b) the cro[…] indicate the galaxies for which the oxygen abundance was determined by the 4363 method, asterisks – b[…] lower branch method, dots – by the Pagel method; (c) and (d): the symbols are the same as in (b). […] large square denotes the original location of the galaxies with large Hβ equivalent width values at large ox[…] abundance values found by the Pagel method. The abundance is redetermined by the lower branch metho[…]*

been obtained by the 4363 method, and somewhat less certain from the lower branch. The results obtained by the Pagel method are rather different because of the less reliable T_e estimates. For the galaxies with T_e estimated by the methods of 4363 and Pagel the relative concentration of oxygen ions O^+ and O^{++} and Ne^{++} has been calculated by the formulae of Aller (1984). The total abundances of oxygen and neon, with allowance made for the unobserved ionization states, have been found using the expressions of French (1981); Gonzales–Riestra et al. (1988); Perrinotto (1983):

$$\frac{O}{H} = \frac{O^+ + O^{2+}}{H^+}, \quad (6)$$

$$\frac{Ne}{H} = \frac{Ne^{2+}}{H^+}\frac{1}{1.2(O^{2+}/O) - 0.2}. \quad (7)$$

For the galaxies in which the oxygen abundance has been estimated from the lower branch the elec[…] temperature T_e has been evaluated from the dep[…] dence of $12 + \log(O/H)$ on T_e constructed from[…] echelle spectra.

In Fig.7 is shown Ne/O plotted as a func[…] of oxygen abundance, obtained by the three pro[…] dures. From the data of two methods, 4363 and lo[…] branch, i.e. for the high excitation HII regions, th[…] is no relation between Ne/O and oxygen abundan[…] The mean value Ne/O = 0.15, that is in good agr[…] ment with the data for the echelle spectra as w[…] as with the results of Masegosa et al. (1991), wh[…] Ne/O = 0.17 ± 0.04.

The distribution of absolute magnitude vers[…] oxygen abundance for the blue compact galaxies fr[…] the SBS with the abundance found by the meth[…] 4363 and lower branch is presented in Fig.8a. T[…] straight line represents the relationship obtained[…]

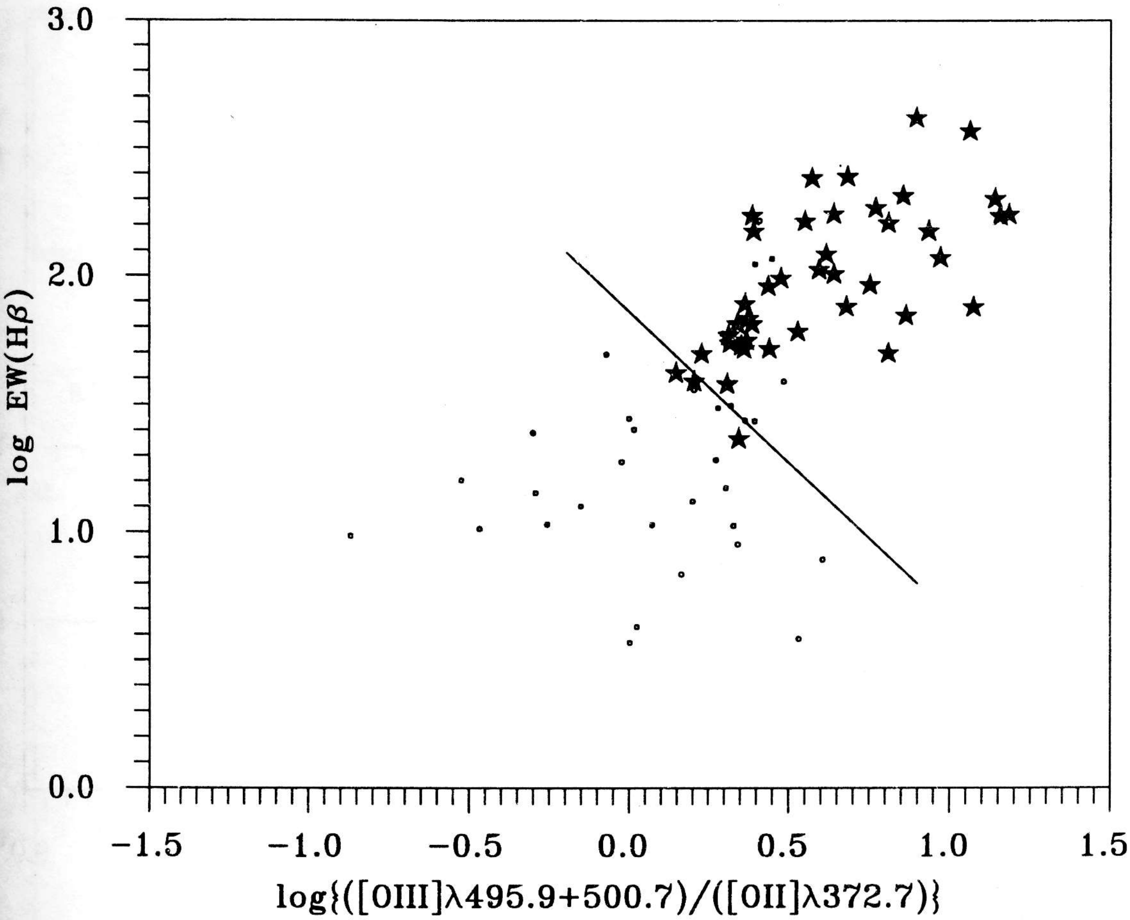

Figure 6: *Equivalent width of the Hβ line vs the level of ionization of [OIII]/[OII] in the HII region. The stars indicate the data for the high excitation HII regions, which were obtained with the echelle spectrograph, the dots are for the galaxies observed with the scanner spectrograph with the best spectrum quality "1". The solid line separates the lower and upper branch objects. For all the galaxies above and to the right of the solid line the oxygen abundance, when [OIII] 4363 Å line is absent in the spectrum, is found by the lower branch method.*

Skillman et al. (1989a) for different types of galaxies. On the basis of this relationship the absolute magnitude criterion is frequently taken into account when selecting BCG galaxies with low abundance of heavy elements. As is seen in Fig.8a, the SBS galaxies do not show correlation between absolute magnitude and oxygen abundance, but shifted systematically towards higher luminosities. This is due to the fact that during a star formation burst the galaxy may increase its brightness by 3–4 magnitudes with almost unaffected oxygen abundance. Then the oxygen abundance increases rapidly with a comparatively slow drop in brightness. In Fig.8b is presented the same relationship, but here are included the galaxies with high heavy element abundance (Pagel method). These galaxies are located higher and to the left. One can conclude that there is no relationship between absolute magnitude and abundance of heavy elements for the blue compact objects with low heavy element abundance — a reliably isolated homogeneous class of objects. The relationship derived by Skillman et al. (1989a) can be regarded to be a classifying relationship for different types of galaxies: irregular, spiral, elliptical, etc.

6. Conclusion

In the present paper a comparison is made of the results of the spectral observations of the blue compact galaxies from the Second Byurakan Survey, performed with the scanner and echelle spectrograph of the 6 m telescope of SAO RAS. The comparison permits the systematic errors of the TV scanner to be investigated, allowance for which enables the accuracy of determination of physical conditions and chemical analysis of HII regions from low resolution spectra to be improved.

As a result the following has been ascertained.

1. The most essential systematic error in the observations of HII regions with strong emission lines

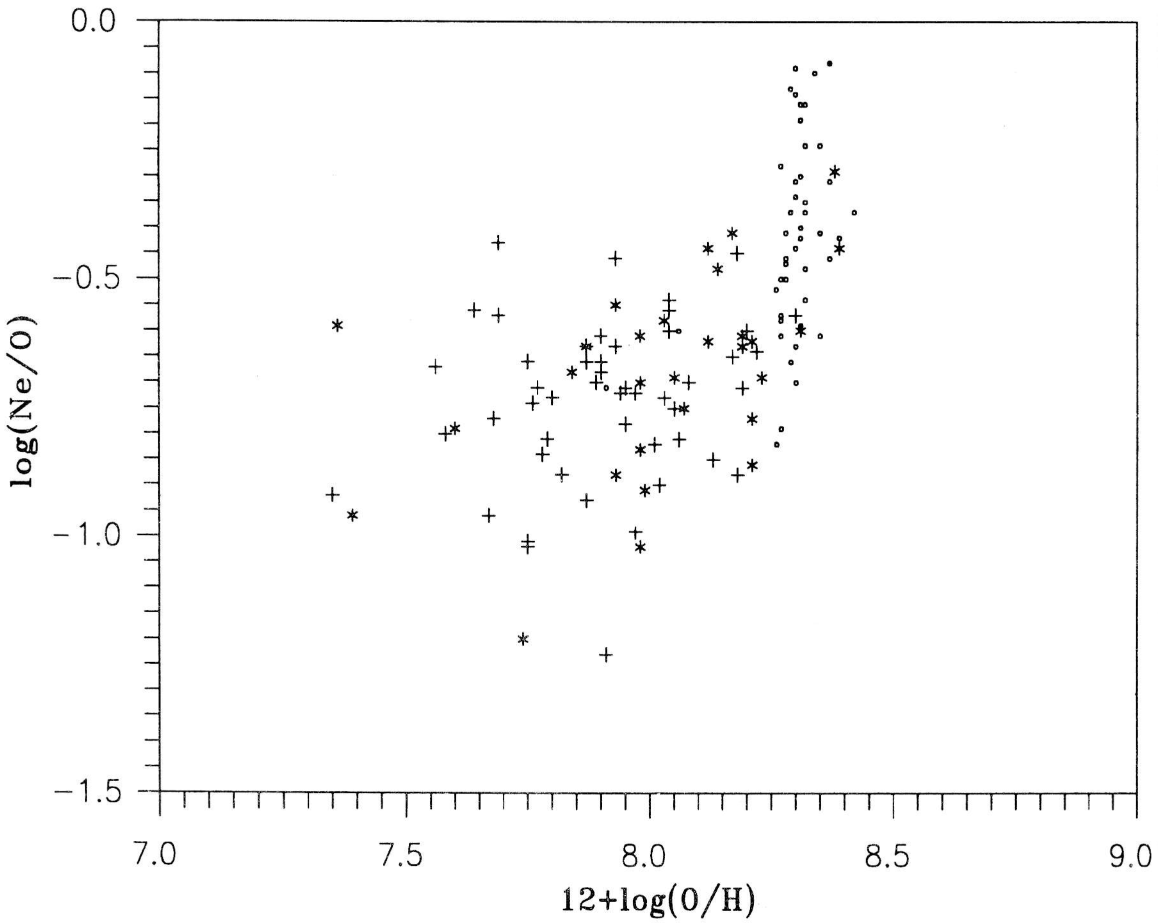

Figure 7: *Relationship between logarithm of the neon/oxygen ratio and oxygen abundance O/H. The syml are the same as in Fig. 8.*

on the scanner of the 6 m telescope is the non–linear mode of photon counting in strong lines, especially in the line [OIII] 5007 Å. Neglect of this effect results in overestimated electron temperature values T_e in the region HII and hence in underestimated values of oxygen and other heavy element abundances.
A comparison of the observed and theoretical line intensity ratio [OIII] 5007/4959 has shown that the non–linearity in the intensities of lines becomes considerable for a photon count rate higher than 2.5 counts/s.

2. Correction of spectra for interstellar extinction with allowance for the contribution of absorption lines of stellar origin to the overall intensity of emission lines of the Balmer hydrogen series is shown to be of necessity. The equivalent width of absorption lines is not constant but varies from galaxy to galaxy, and for HII regions at late stages of star formation burst it can reach values comparable to the equivalent width of the emission line Hβ. The extinction coefficient c(Hβ) derived without taking into account hydrogen absorption lines turns out to be overestimated. This leads to erroneous correction of spectra for extinction, and in a number of cases the int sity of the emission line [OII] 3727 Å proves to too high and cannot be explained within the scope photoionization models.

3. A comparison of intensities of different em sion lines in the spectra of the galaxies observed w both the scanner and the echelle spectrograph of 6 m telescope showed them to be in good agreeme The line [OII] 3727 Å, which is systematically less tensive in the scanner spectra, is an exception. Mo likely this effect is associated with the loss of lig flux at the edge of the spectrum, where the line [O 3727 Å is located, due to the atmospheric dispersio

4. The method of Pagel (1979) for determinati of oxygen abundance in blue compact galaxies fro the total intensity of lines of singly and doubly ioniz oxygen is shown to be inapplicable because of the e istence of two branches in the relation between tot intensity of oxygen lines and oxygen abundance. T Pagel method corresponds to the branch for high ox gen abundances (upper branch), while blue compa objects are located mainly on the lower branch. the paper a procedure is proposed that makes it po

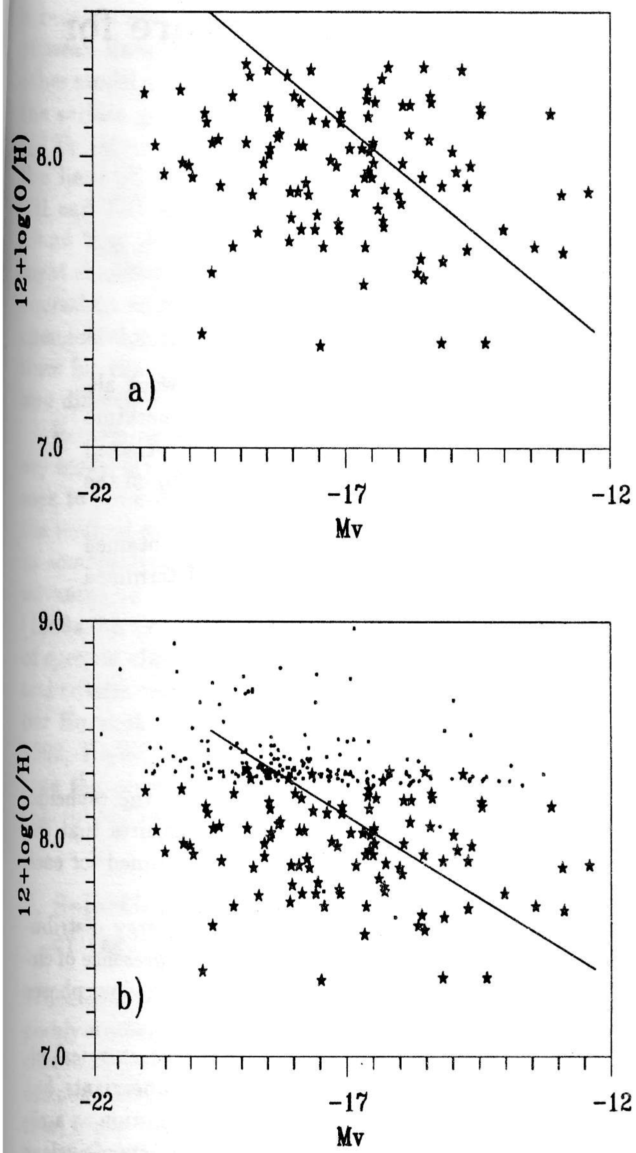

Figure 8: *Oxygen abundance 12+log (O/H) as a function of absolute magnitude M_v. (a) the galaxies for which the oxygen abundance was determined by the 4363 and lower branch methods; (b) the same, but the galaxies with the abundances found by the Pagel method (dots) were added.*

sible to select which branch (upper or lower) a galaxy belongs to, using the equivalent width of Hβ line and nebula ionization degree [OIII]/[OII]. On the basis of spectral observations with the echelle spectrograph of the 6 m telescope of galaxies with the observed auroral line [OIII] 4363 Å a calibration relation between total intensity of oxygen lines, referred to as the lower branch, has been constructed.

5. It is shown that blue compact galaxies have no noticeable correlation between oxygen abundance in HII regions and integral absolute magnitude of the galaxy and are systematically displaced towards the region of lower abundances and higher luminosities as compared with the relationship obtained by other authors for other types of galaxies.

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