MORE GALAXIES IN THE LOCAL VOLUME IMAGED IN Hα

IGOR D. KARACHENTSEV AND SERAFIM S. KAISIN
Special Astrophysical Observatory, Russian Academy of Sciences, N. Arkhyz, KChR 369167, Russia; ikar@sao.ru

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ABSTRACT

We have carried out an Hα flux measurement for 52 nearby galaxies as part of a general Hα imaging survey for the Local Volume sample of galaxies within 10 Mpc. Most of the objects are probable members of the groups around Maffei 2/IC 342, NGC 672/IC 1727, NGC 784, and the Orion galaxy. The measured Hα fluxes corrected for extinction are used to derive the galaxy star formation rate (SFR). We briefly discuss some basic scaling relations between SFR, hydrogen mass, and absolute magnitude of the Local Volume galaxies. The total SFR density in the local (z = 0) universe is estimated to be \((0.019 \pm 0.003) M_\odot\text{ yr}^{-1}\text{Mpc}^{-3}\).

Key words: galaxies: evolution – galaxies: ISM – stars: formation

Online-only material: color figures, extended figures

1. INTRODUCTION

Systematic measurements of Hα fluxes in nearby galaxies within a fixed distance is one of the major techniques for determining the star formation rate (SFR) in the local universe. The presence of dwarf galaxies with extremely low luminosities in the Local Volume (LV), which are usually invisible at large distances, provides a unique opportunity for researching the SFR of a galaxy depending on its luminosity, structure, gas mass, and density of its environment in the broadest possible range of these characteristics. Thus it is essential that the observational program contains objects of all types and sizes in order to avoid the observational selection, distorting the interpretation of results.

Kraan-Korteweg & Tammann (1979) proposed to view an exemplary sample of 179 nearest galaxies with distances within 10 Mpc (the so-called LV sample). Later, Karachentsev (1994) replenished it with galaxies discovered from new redshift surveys. The updated sample constituted 226 galaxies. Later, Karachentseva & Karachentsev (1998, 2000) and Karachentseva et al. (1999) undertook the all-sky search for nearby galaxies using plates of the POSS-II and ESO-SERC survey. A large number of new nearby dwarf galaxies of low surface brightness were found. A limiting magnitude of the survey was \(B = 17\) mag providing an essential completeness of the LV sample up to absolute magnitude \(M_B \simeq -12.5\) mag within a distance of 8 Mpc. Their radial velocities were measured by Huchtmeier et al. (2000, 2001) during a subsequent H I survey. Distances to many of the LV galaxies were first measured with high accuracy on the Hubble Space Telescope (HST) using the tip of red giant branch (TRGB) method. The results of these international efforts were summarized in the Catalog of Neighboring Galaxies (CNG; Karachentsev et al. 2004), consisting of 451 galaxies with distance estimates within \(D < 10\) Mpc.

Different surveys of large areas of the sky in the optical and radio bands such as the Sloan Digital Sky Survey (SDSS; Abazajian et al. 2009), Two-Degree Field (Colless et al. 2001), Six-Degree Field (Jones et al. 2004), HIPASS (Zwaan et al. 2003), and ALFALFA (Giovanelli et al. 2005) have led to an essential increase of the LV sample. The second version of the CNG (I. D. Karachentsev et al. 2011, in preparation) contains \(N \simeq 790\) galaxies, i.e., more than four times that of the original list by Kraan-Korteweg & Tammann (1979). Such a representative sample, being registered in the Hα emission line, provides a detailed picture of star formation in the LV during the recent time interval of \(\sim 10\) Myr.

Measurements of Hα fluxes in nearby galaxies were performed by many authors. Their interest was normally fixed on objects of a certain type, for example, on spiral or irregular galaxies. A synopsis of publications, where the number of measured Hα fluxes for the LV galaxies was not less than 10, is presented in Table 1. The first column of the table contains a link to the paper, the second contains the number of LV galaxies imaged in Hα, and the third column reflects the nature of the sample (the morphological type of galaxies or their affiliation to a fixed group). The last row of the table summarizes the number of LV galaxies, which were observed in our program (Karachentsev et al. 2005; Kaisin & Karachentsev 2006, 2008; Kaisin et al. 2007; Karachentsev & Kaisin 2007), including the results of this paper. Unlike all previous observational programs, our Hα survey of LV galaxies does not imply any selection of objects by morphological type, or their affiliation to a group. This has led to some unexpected results, in particular, to the detection of circumnuclear emission in isolated E/S0 galaxies (Moiseev et al. 2010).

As follows from the data above, so far there are 692 measurements of the Hα flux available for 435 LV galaxies, i.e., a lot of galaxies were observed independently by different authors, which enables an estimate of the external error of the flux measurement. More than half of the Hα data were obtained within the framework of two programs: Kennicutt et al. (2008) and our survey.

The degree of completeness of the LV galaxy collection currently available remains quite ambiguous. New sky surveys reveal new nearby galaxies of both low and high surface brightness. Refinement of individual distances to galaxies leads to their inclusion or exclusion as LV members. Among \(\sim 790\) galaxies that are currently listed in the LV, there are objects with absolute magnitudes \(M_B\) ranging from \(-22\) mag to \(-4\) mag, i.e., their luminosities vary by more than seven orders of magnitude. Figure 1 presents the distribution of 572 galaxies situated within 8 Mpc according to their \(B\)-band absolute magnitude. The shaded areas on the left and right panels indicate numbers of galaxies that have been observed in Hα and H I, respectively. The median absolute magnitude of the LV galaxies is \(-14\) mag. Measurements of the Hα flux are carried out for 355 galaxies
or 62% of the sample. As one can see, the current Hα survey is almost complete on the bright half of the luminosity function, i.e., up to $M_B \approx -15$ mag. For a comparison, note that the completeness of the LV galaxy survey in the neutral hydrogen line $\text{H}\alpha$ is much higher, reaching 88%. A comparison of these panels indicates the need to speed up the survey of nearby galaxies in the Hα line to have a sufficiently complete picture of the SFR diversity in them.

2. OBSERVATIONS AND IMAGE PROCESSING

Below we present a survey of 52 nearby galaxies, most of which were observed in the Hα line for the first time. Some of these galaxies are likely members of the closest neighboring group Maffei 2/IC 342, poorly studied due to its location in the region of strong absorption in the Milky Way; the other part is a mixture of field galaxies and members of other small groups, in particular, around NGC 672, NGC 784, and in the Orion region.

CCD images of galaxies in the Hα line and in the continuum were obtained during observing runs from 2005 to 2009. An average seeing was 1′.8. All the observations were performed in the Special Astrophysical Observatory of the Russian Academy of Sciences (SAO RAS) with the Bol’shoi Teleskop Azimutal’nyi (BTA) 6 m telescope equipped with the SCORPIO focal reducer (Afanasiev et al. 2005). A CCD chip of $2048 \times 2048$ pixels provides a total field of view of about 6′1 with a scale of 0′.18 pixel$^{-1}$. The images in Hα+[N II] were obtained via observing the galaxies through a narrow-band interference filter $\text{H}α(\Delta \lambda = 75 \, \text{Å})$ with an effective wavelength $\lambda = 6555 \, \text{Å}$. In order to remove the stellar continuum contribution to these images, we also observed the same fields with two medium-band filters situated on both sides from Hα: SED607 with $\Delta \lambda$ = 6063 Å, $\Delta \lambda = 167$ Å, and SED707 with $\lambda = 7063$ Å, $\Delta \lambda = 207$ Å. Typical exposure times were $2 \times 600$ s in Hα and $2 \times 300$ s in the continuum. Since the range of radial velocities in our sample is small, we used the same Hα filter for all the observed objects. Our data reduction followed the standard practice and was performed within the MIDAS package. For all the data, bias was subtracted and the images were flat-fielded by twilight flats. Cosmic particles were removed and the sky background was subtracted. The next operation was to spatially align all the images for a given object. Then the images in the continuum were normalized to Hα images using 5–15 field stars and were subtracted. Hα fluxes were obtained for the continuum-subtracted images, using spectrophotometric standard stars from Oke (1990) observed during the same nights as the objects. The investigation of measurement errors, brought in by the continuum subtraction, flat-fielding, and scatter in the zero points, has shown that they have typical values within 15%. We did not correct Hα fluxes for the contribution of the [N II] lines, because it is likely to be small for the majority of low-luminosity galaxies in our sample. For instance, according to Equation (1B) in Kennicutt et al. (2008), a typical galaxy in our sample with the median absolute magnitude $M_B = -15$ mag has an [N II]/Hα ratio of $1/20$, which is lower than the accuracy of our measurements.

3. Hα FLUXES AND SFRs

The measured integrated flux of a galaxy in the Hα+[N II] lines, calibrated according to Oke’s spectrophotometric standards (and noted as $F$(Hα)), was expressed in units of erg cm$^{-2}$ s$^{-1}$. In each case, we tried to take into account
not only the sum of emission knots of the galaxy but also its
diffuse emission background insofar as it was not distorted by
the background subtraction errors, significant in large apertures.
Due to the width of the filter used, the measured galaxy fluxes
are also containing emission in the neighboring line doublet
[NII]. However, according to Kennicutt et al. (2008), relative
contribution of the doublet for the majority of galaxies is small,
especially for dwarf galaxies. The measured $F$(Hα) flux is then
corrected for light absorption in the Milky Way $A_G$ (MW) using
a technique by Schlegel et al. (1998), and for internal extinction
in the galaxy itself $A_B$(int), defined as

\[
A_B(\text{int}) = [1.6 + 2.8\times (\log V_m - 2.2)] \times \log(a/b),
\]

if $V_m > 42.7$ km s\(^{-1}\), and $A_{\text{int}} = 0$ otherwise. This ratio
corporated the known fact (Verheijen 2001) that internal
extinction depends not only on the inclination of the galaxy,
expressed in terms of its apparent axial ratio $a/b$, but also on its
luminosity, an indicator of which according to Tully & Fisher
(1977) is the amplitude of its rotation velocity $V_m$. Here, the
quantities $a/b$, $V_m$, and $A_B$(int) are taken from Tables 1 and 4
of the CNG. Absorption in the H\(\alpha\) line was adopted as
proportional to the absorption in the $B$ band:

\[
A(\text{H}\alpha) = 0.538[A_B(\text{MW}) + A_B(\text{int})].
\]

Following Gallagher et al. (1984), we calculated the
integrated SFR in the galaxy as

\[
\text{SFR}(M_\odot\,\text{yr}^{-1}) = 1.27 \times 10^9 \times F_\alpha(\text{H}\alpha) \times D^2,
\]

where $D$ is the distance to the galaxy expressed in Mpc.
The validity of the linear transition (3) from the flux $F_\alpha$ to
the SFR has recently been a subject of critical reviews. Pfennig-
Altenburg et al. (2007) and Pfennig-Altenburg & Kroupa (2009)
conclusively argued that the canonical relation (3) underesti-
mates the SFR value in dwarf galaxies, and that the weaker
the luminosity of the galaxy is, the stronger the difference (or
underestimation) will be. In dwarf systems with absolute mag-
itude $M_B \sim -10$ mag. $-12$ mag, an underestimation of
the SFR value may reach one to two orders of magnitude. To be

\begin{table}
| Name | R.A. decl. (2000.0) | $T$ | $V_{LC}$ (km s\(^{-1}\)) | $D_{FW}$ (Mpc) | $M_p$ (mag) | $\log M(H\alpha)$ ($M_\odot$) | $\log F(H\alpha)$ (erg cm\(^{-2}\) s\(^{-1}\)) | $\log F_c(H\alpha)$ (erg cm\(^{-2}\) s\(^{-1}\)) | $\log$ (SFR) ($M_\odot$ yr\(^{-1}\)) |
|------|--------------------|-----|----------------|----------------|----------|----------------|----------------|----------------|----------------|
| KKH5 | 010732.5+512625    | 10  | 304           | 4.26           | -12.27   | 6.87          | -13.31         | -13.05         | -2.69          |
| KKH6 | 013451.6+520550    | 10  | 270           | 3.73           | -12.38   | 7.12          | -13.78         | -13.42         | -3.18          |
| Cas1 | 020607.9+690036    | 10  | 284           | 3.3            | -16.70   | 8.11          | -12.32         | -11.37         | -1.24          |
| KKH11| 022435.0+560042    | 10  | 324           | 3.0            | -12.35   | 7.68          | -12.10         | -12.64         | -2.59          |
| KKH12| 022727.0+572916    | 10  | 303           | 3.0            | -13.03   | 7.53          | -13.11         | -12.37         | -2.32          |
| MB1  | 023535.6+592247    | 10  | 421           | 3.0            | -14.81   | 7.23          | -13.37         | -12.46         | -2.41          |
| Maffei 1 | 023635.5+593918  | -3  | 246           | 3.01           | -18.97   | 8.55          | -14.00         | -12.99         | -2.68          |
| Maffei 2 | 024154.5+593611  | 4  | 212           | 3.0           | -20.37   | 8.82          | -11.99         | -10.34         | -0.35          |
| Dwrig2| 025408.5+590019    | 10  | 316           | 3.0           | -14.55   | 8.30          | -13.52         | -12.42         | -2.36          |
| MB3  | 025543.6+585142    | 10  | 280           | 3.0           | -13.65   | 6.32          | -14.00         | -12.80         | -2.70          |
| Dwrig1| 025656.1+585442    | 4  | 333           | 3.0           | -18.93   | 8.63          | -12.22         | -10.81         | -0.81          |
| KK35 | 034512.6+675150    | 10  | 320           | 3.16           | -14.30   | 6.27          | -12.13         | -11.59         | -1.49          |
| UA86 | 035949.5+670731    | 8  | 275           | 2.96           | -17.95   | 8.79          | -11.94         | -11.06         | -1.02          |
| CamA | 042515.6+724821    | 10  | 164           | 3.93           | -14.06   | 8.22          | -13.19         | -12.99         | -2.70          |
| N1569| 043049.1+645053    | 9  | 88            | 3.36           | -19.36   | 8.29          | -10.59         | -9.94          | 0.21           |
| AU92 | 043200.3+633650    | 10  | 89            | 3.01           | -15.60   | 8.35          | -12.30         | -11.56         | -1.51          |
| N1569| 043249.9+715252    | 7  | 171           | 3.45           | -16.17   | 9.10          | -11.60         | -11.37         | -1.19          |
| CanB | 045306.9+670557    | 10  | 266           | 3.34           | -11.85   | 7.12          | -12.56         | -13.36         | -3.21          |
| UA105| 051415.4+623451    | 7  | 279           | 3.15           | -16.81   | 8.51          | -11.58         | -11.27         | -1.17          |

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4. COMMENTS ON INDIVIDUAL OBJECTS IN THE MAFFEI GROUP

The structure and kinematics of the binary association of
galaxies around the major spirals Maffei 2 and IC 342 as
subgroup centers were considered by Karachentsev et al. (2003a). Most of the galaxies presented in Table 2 are physical companions of either Maffei 2 or IC 342, judging from their radial velocities.

**KKH5, KKH6.** Both dIrr galaxies are peripheral members of the association that have probably not yet reached the virialized region around Maffei 2. Their distances are measured with an accuracy of $\sim 10\%$ from the TRGB detected on the images.
Figure 3. Hα and continuum-subtracted images of 33 galaxies in the field.
(An extended version of this figure is available in the online journal.)

derived with HST (Karachentsev et al. 2003b, 2006). Both galaxies show emission knots, which are more diffuse in the case of KKH6.

Cas1 = KK19. This dIrr galaxy is located in the zone of strong absorption ($A_B = 4.4$ mag), which remains inaccessible for determining the distance via the TRGB. Its distance as a
which is estimated by Fingerhut et al. (2003) from the central AB the total H galaxies are companions of Maffei 2. Each galaxy demonstrates ii from the residues of overexposed star images, there are no our image frame. Based on its apparent K luminosity appeared to be outside of our frame. KKH11, KKH12, MB1 = KK21. All three the irregular galaxies are companions of Maffei 2. Each galaxy demonstrates the presence of emission knots and filaments with the values of the total Hα flux close to one another.

Maffei 1. Maffei 1 is an elliptical galaxy, the distance to which is estimated by Fingerhut et al. (2003) from the central dispersion of radial velocities. Its angular sizes, corrected for absorption A_B = 5.05 mag, extend beyond our image frame, which created problems with background subtraction. Apart from the residues of overexposed star images, there are no visible traces of emission regions on the body of the galaxy. In the table, we indicate the upper limit of its possible Hα flux.

Maffei 2. This barred spiral (SBc) galaxy also extends beyond our image frame. Based on its apparent K magnitude (5.22 mag) from the Two Micron All Sky Survey (2MASS) and from the width of the Hα line (305 km s^{-1}), we estimated its distance as 3.1 Mpc using the infrared Tully–Fisher relation M_K = −9.35 log(W_{50}) + 0.75. We obtained the total Hα flux of Maffei 2 assuming that the Hα profile of the galaxy reproduces its brightness profile in the K band whereas about 50% of the luminosity appeared to be outside of our frame.

Dwingeloo2. Dwingeloo2 is an irregular galaxy in the region of strong absorption (A_B = 5.12 mag). A rather bright star is projected on it. The image of this star is likely screening a significant part of the galaxy’s Hα flux.

MB3 = KK22. For this dIrr galaxy, we estimated only the upper limit of its Hα flux.

Dwingeloo1 = KK23 = Cas2. This is a spiral SBbc-type galaxy, prone to strong absorption (A_B = 6.34 mag). For it we adopted the mean distance of the group 3.0 Mpc, although an individual assessment of the distance from the infrared Tully–Fisher relation gives (at K_s = 8.82 and W = 187 km s^{-1}) a distance of 4.7 Mpc. Approximately 20% of the luminosity of the galaxy is beyond the range of our image.

KK35. This object looks like an isolated spot of low surface brightness at the distance of 16 arcmin from the center of IC 342. It can be a dIrr galaxy in the process of merging with the giant spiral IC 342 or a stellar association on the outer spiral pattern of the galaxy. Its distance, 3.16 Mpc, determined via the TRGB, is consistent within errors with the distance of IC 342 itself, 3.28 Mpc, defined via the Cepheids. As the Hα image shows, KK35 is in a state of very active star formation.

UGC A86. This is an Sm/Im galaxy with a bright association of blue stars (VII Zw9) on the SE side. Its distance, 2.96 Mpc, measured via the TRGB (Karachentsev et al. 2006), confirms the affiliation of UGC A86 to the IC 342 companions. Compact emission knots and filaments are scattered throughout the galaxy disk, but more than half of the integrated Hα flux comes from a powerful site of star formation, VII Zw9.

CamA = KK41, CamB = KK44. Both are dIrr galaxies of low surface brightness that show the presence of a blue stellar population in the images obtained with the WFPC2 on the HST (Karachentsev et al. 2003a). Both galaxies show small compact
knots and a weak diffuse emission component in the Hα line, which indicates a sluggish process of star formation in these systems.

**NGC 1569.** Along with M82 and several Markarian galaxies, NGC 1569 belongs to the objects of the LV with the most active star formation per luminosity unit of the galaxy. An abundance of arc-like emission filaments in the periphery makes the galaxy resemble a crab. Due to significant absorption ($A_B = 3.02$ mag), the distance to NGC 1569 has long remained uncertain. Recently, Grocholski et al. (2008) determined its distance as 3.36 Mpc using the TRGB method.

**UGC A92.** This dIrr galaxy is located in the sky in the vicinity of the previous galaxy. Radial velocities and distances from the observer of UGC A92 and NGC 1569 are also close. These galaxies can form a bound pair on the outskirts of the group around IC 342, reminiscent of the famous pair of NGC 147 and NGC 185, which are dwarf galaxies in the neighborhood of M31. In the UGC A92 body there are groups of bright emission knots, and two arcs interlocking in the northern part of the galaxy.

**NGC 1560, UGC A105.** These are two galaxies of late Sd and Sm types, oriented at different angles to the line of sight. Their Hα fluxes are also approximately equal. Their characteristic features are ring-shaped HII regions, apart from which there are many compact emission knots.

### 5. COMMENTS ON INDIVIDUAL OBJECTS

**NGC 404.** This is the nearest isolated lenticular galaxy of moderate luminosity. In its central part small dust clouds are visible. Del Rio et al. (2004) found an extended H1 shell around NGC 404, and ultraviolet observations with GALEX have identified a ring-shaped structure of young stars (Thilker et al. 2010). On our Hα image one can see fairly bright emission in the circumnuclear region of the galaxy, as well as separate emission knots, scattered in the periphery. The integrated Hα flux of the galaxy, shown in Table 3, does not have any contribution of distant emission knots in the H1 region shell. Recently, Williams et al. (2010) presented HST/WFPC2 observations across the disk of NGC 404 and studied its star formation history in detail.

**AGC112521.** This dIrr galaxy of low surface brightness was detected in the “blind” H1 survey ALFALFA, performing with the Arecibo radio telescope (Saintonge et al. 2008). Our Hα image of the galaxy shows only one compact emission knot, which was previously spotted by Zitrin & Brosch (2008).

**KK13, KK14, KK15.** These are dwarf irregular companions of the spiral galaxy NGC 672, discovered by Karachentseva & Karachentsev (1998), and detected in the H1 surveys by Huchtmeier et al. (2000) and in the ALFALFA. All three objects have several compact emission knots, which were also noted by Zitrin & Brosch (2008).

**IC 1727, NGC 672.** These are a pair of spiral galaxies of late types (Sm, Sd). Their distance, 7.2 Mpc, was estimated by I. Drozdovsky (1999, private communication) from the luminosity of brightest stars. It is the distance we ascribed to the four remaining members of the NGC 672 group: AGC112521, KK13, KK14, and KK15. Hα images of both spirals exhibit many HII regions, typical for Sm and Sd galaxies. Integrated Hα fluxes of IC 1727 and NGC 672 are in good agreement with the fluxes previously measured by Kennicutt et al. (2008), but are nevertheless significantly (by two to three times) higher than the fluxes given by Zitrin & Brosch (2008).

**UGC 1281, KK16, KK17.** These three dwarf galaxies form a group along with a brighter Sd galaxy NGC 784. Their distances were measured by Tully et al. (2006) using the TRGB method. Zitrin & Brosch (2008) imaged all four galaxies in Hα. Their descriptions of emission components in these galaxies are consistent with what we see in Figure 3. However, in the case of KK16, where only a faint diffuse emission is visible, the Hα flux measured by us is five times higher than that obtained by Zitrin & Brosch (2008). The reason for this difference remains unclear to us.

**UGC 1703 = KKH9.** This is a dwarf spheroidal galaxy at a distance of 4.2 ± 0.3 Mpc estimated by Rekola et al. (2005) from the fluctuations of its surface brightness. Judging from this distance, UGC 1703 may either be associated with the far periphery of the dwarf galaxy group around NGC 784, or belong to the rare class of isolated dSph galaxies. Our Hα image of UGC 1703 does not show any signs of emission. Table 3 indicates the upper limit of its Hα flux.

**NGC 855.** This isolated elliptical galaxy is similar to NGC 404 in terms of luminosity and hydrogen mass. Its distance, 9.73 Mpc, was determined by Tonry et al. (2001) from fluctuations of surface brightness. Wallington et al. (1988) noted the presence of a ring-shaped H1 shell around it, which is atypical for E galaxies. Our snapshot of NGC 855 in the Hα line reveals bright emission in the circumnuclear area, external parts of which are extended in the polar directions. To understand the nature of this object with hybrid properties of E and S galaxies, it is necessary to investigate its kinematics in the H1 and Hα lines.

**AGES.** This dIrr galaxy was discovered as a result of the “blind” AGES survey in the H1 line of the vicinity of an isolated galaxy NGC 1156 (Minchin et al. 2010). Judging from its radial velocity, the AGES object is a dwarf companion of NGC 1156 at the projection distance of ~80 kpc, if we adopt for it the same distance as that of NGC 1156, 7.8 Mpc. Our image of AGES in the Hα line reveals two diffuse HII regions with a total SFR of ~1 × 10^-3 M⊙ yr^-1.

**KKH18.** KKH18 is an isolated dIrr galaxy, the distance to which, 4.43 Mpc, is determined via the TRGB (Karachentsev et al. 2003b). KKH18 and UGC 1703 are possibly forming the eastern extension of a filament of dwarf galaxies, the dense part of which is also hosting the group around NGC 784. A compact HII region and weak diffuse emission in the center are visible on the body of KKH18.

**UGC 2773.** This is an isolated BCD galaxy in the region of NGC 404 with significant ($A_B = 2.43$ mag) absorption. Its Hα image demonstrates many compact HII regions as well as a considerable diffuse emission. The distance to UGC 2773 is estimated by us simply from the radial velocity taking the Hubble parameter of $H_0 = 72$ km s^-1 Mpc^-1. Of course, in the local universe, peculiar motions can dominate over the systematic Hubble component. However, at present there is no generally accepted model that describes the local peculiar velocity field well while taking into account the Virgo-centric infall and the Local Velocity Anomaly (see details in Tully et al. 2008).

**UGC 2905.** UGC 2905 is an isolated dIrr galaxy on the southern part of which a background spiral neighbor is projected. The distance to UGC 2905, 5.8 Mpc, is estimated from the brightest stars (Georgiev et al. 1997). Its Hα image reveals several compact and diffuse HII regions.
UGC 3303. This is an isolated Sm galaxy with a bright star projected on its central part. The distance of UGC 3303 is estimated as 7.2 Mpc from the brightest stars (Makarova & Karachentsev 1998). It may be located in the periphery of a scattered association of galaxies, the brightest member of which is the Orion galaxy. The Hα image reveals a lot of small HII regions scattered across the disk of the galaxy.

KK49 = CGCG422–003. This is a BCD galaxy in the Orion complex. Its distance is evaluated from the radial velocity. The Hα image of the KK49 body looks granulated because of the tightly located emission knots.

Orion, Ant0554. These are two galaxies (Sm and dIrr) located in the Orion complex in the region of significant galactic absorption. Their distances (6.4 and 5.5 Mpc, respectively) are determined by Karachentsev & Musella (1996) from the luminosity of brightest stars. The HII regions, more abundant in the Orion galaxy in accordance with its morphological Sm type, are visible on their Hα images. Recently, Cannon et al. (2010) carried out Hα and VLA H I observations of the Orion galaxy and found the rotating H I disk extending far outside the optical boundary of the galaxy.

HIZOA J0630+08. This H I source detected in the survey by Donley et al. (2005) is located in a dense stellar region of the Milky Way at the galactic latitude \( b = -0.9 \). On the POSS-II blue and red images, not a single galaxy is seen within the radio telescope beam (\( \sim 15' \)). Our Hα image does not show an optical counterpart to this radio source either, which is most likely a dIrr galaxy of low surface brightness, weakened by absorption \(( A_v = 2.95 \) mag).

UGC 3476, UGC 3600, UGC 3698. These are three isolated dIrr galaxies, the distances to which are found from the brightest stars (Makarova & Karachentsev 1998). Each one of them demonstrates the presence of active star formation sites, which is characteristic of isolated irregular galaxies.

UGC 3755. This is a dIrr galaxy, the distance to which is measured by Tully et al. (2006) applying the TRGB. Its image in Hα indicates active star formation, most pronounced in the western part of the galaxy.

DDO47, KK65 = CGCG087-033. These two galaxies are dwarf galaxies forming an isolated pair with a difference in radial velocities of only 6 km s\(^{-1}\). The distances measured by Tully et al. (2006) via the TRGB confirm a physical compact emission regions.

KK69, KK70. KK69 and KK70 are two dwarf companions of the spiral galaxy NGC 2683. Both have low surface brightness. An irregular dwarf, KK69, is characterized by a very narrow H I emission with a line width of 16.5 ± 0.6 km s\(^{-1}\) (Huchtmeier et al. 2003). Our Hα image shows a very red or emission star-like object within its optical boundaries. The nature of this object can be clarified by spectral observations. The dwarf spheroidal system KK70 lacks any signs of Hα emission.

NGC 2787, NGC 4600. These are two isolated lenticular galaxies, the distances to which are determined from surface brightness fluctuations (Tonry et al. 2001). In both cases, the central parts of galaxies are over-exposed, which makes the assessment of the flux in Hα somewhat uncertain.

6. EXTERNAL COMPARISON OF Hα FLUXES

The accuracy of measurement of the Hα flux of a galaxy, and of the SFR value determined from it, depends on many factors. If variable atmospheric conditions were successfully monitored during the observations by regular calibration using the spectrophotometric standards, the main source of errors for the \( F(Hα) \) values is inaccurate subtraction of the sky background on the obtained images. For compact starburst galaxies these errors are negligible, but for the galaxies with weak and diffuse Hα emission, such errors appear to reach \( \sim 10\% - 20\% \). Note also that some authors determine the integrated flux of a galaxy as the sum of its separate HII regions, while others also take into account the general diffuse component, which also gives rise to differences in the data they provide.

We evaluated our typical accuracy of \( F(Hα) \) as \( \sim 15\% \), or \( \pm 0.06 \) dex in the logarithmic scale. However, this internal assessment needs to be subject to an independent external audit.

Among the 52 galaxies we observed there are 12 objects, in which the Hα fluxes were measured by Kennicutt et al. (2008), and 11 galaxies observed in Hα by Zitrin & Brosch (2008). The data on Hα fluxes in these galaxies are presented in Table 4. In the case of Kennicutt et al. (2008), we also cite the internal flux measurement errors indicated by them.

A comparison of our log \( F(Hα) \) values with the data by Kennicutt et al. (2008) yields the mean square difference \( \sigma(\Delta \log F) = 0.09 \) and the average difference \( \langle \log F_{KK} - \log F_{KK} \rangle = +0.004 \pm 0.03 \), which indicates a good agreement of independent measurements. The internal error of our measurements that we have estimated as \( \sigma(\log F) = 0.06 \) is approximately the same as in Kennicutt et al. (2008; 0.058), and their quadratic sum reproduces well the mean square difference \( \sigma(\Delta \log F) = 0.09 \). Note, however, that the agreement of our data with the Hα fluxes published by Zitrin & Brosch (2008) turned out to be much worse: \( \sigma(\Delta \log F) = 0.34 \) and \( \langle \log F_{KK} - \log F_{KK} \rangle = +0.10 \pm 0.11 \).

A transition from the measured Hα flux of a galaxy to the SFR value is accompanied by additional errors, which are usually systematic. These factors include the contribution of the emission line \([\text{NII}]\) in the total registered Hα + \([\text{NII}]\) flux, different methods of correction for internal absorption in a galaxy, uncertainty of the Galactic absorption value according to Schlegel et al. (1998) at low latitudes, underestimation of the diffuse emission component of very low surface brightness, and underestimation of possible HII regions in the distant periphery.

| Galaxy | This Paper | Zitrin & Brosch (2008) | Kennicutt et al. (2008) |
|--------|------------|------------------------|------------------------|
| A112521| −14.81     | −14.36                 | ...                    |
| KK13   | −13.77     | −13.41                 | ...                    |
| KK14   | −14.24     | −14.53                 | ...                    |
| KK15   | −14.52     | −14.48                 | ...                    |
| IC 1727| −11.94     | −12.27                | −11.96 ± 0.06         |
| N672   | −11.56     | −12.00                 | −11.49 ± 0.06         |
| U1281  | −12.46     | −12.65                 | −12.45 ± 0.07         |
| KK16   | −13.97     | −14.76                 | ...                    |
| KK17   | −13.96     | −14.03                 | ...                    |
| N784   | −11.95     | −11.66                 | −11.78 ± 0.04         |
| N855   | −12.14     | −12.29                 | −12.23 ± 0.04         |
| Maffei 2| −11.99     | ...                    | −11.95 ± 0.06         |
| UA86   | −11.94     | ...                    | −12.01 ± 0.07         |
| N1569  | −10.59     | ...                    | −10.62 ± 0.01         |
| UA92   | −12.30     | ...                    | −12.52 ± 0.03         |
| N1560  | −11.60     | ...                    | −11.54 ± 0.05         |
| UA105  | −11.58     | ...                    | −11.60 ± 0.03         |
| DDO47  | −12.57     | ...                    | −12.51 ± 0.06         |
of a galaxy (the case of NGC 404). Finally, as noted above, the transformation of $F(\text{H}\alpha)$ into the SFR via the linear relationship (3) can significantly (by one to two orders of magnitude) underestimate the true SFR due to the simplistic notions on the initial stellar mass function in dwarf systems (Pflamm-Altenburg & Kroupa 2009).

7. SOME BASIC SCALING RELATIONS

Estimates of the global SFR are currently obtained for 435 LV galaxies. As it is noted by many authors (Karachentsev & Kaisin 2007; James et al. 2008; Thilker et al. 2007; Lee et al. 2009) that the SFR value correlates with the integrated luminosity of a galaxy, its morphological type, color index, and hydrogen mass. The data on the dependence of an SFR of a galaxy on its environment are rather contradictory (Hunter & Elmegreen 2004; James et al. 2004), but the prevailing view is that such a dependence, if it exists, is weak, i.e., the process of star formation in the galaxy is more likely driven by its internal state than by external factors. Nevertheless, there are well-known cases where a close interaction or merger of galaxies leads to a spectacular burst of star formation or, the other way around, a passage of a dIrr galaxy close to a massive spiral suppresses star formation in the dwarf system due to gas stripping from its shallow potential well.

Figure 4 represents a relation between the global SFR and blue absolute magnitude for 435 LV galaxies. The galaxies of different morphological types are shown by characters of different colors. Empty symbols with arrows mark the instances when only the upper limit of the SFR of a galaxy is known, determined from Equation (3). The straight line in the figure corresponds to a constant SFR per unit luminosity.

Corresponding to the constant specific SFR (SSFR) per luminosity unit, $SSFR = 7.0 \times 10^{-10} \, M_\odot \, yr^{-1} \, L_\odot^{-1}$. Evidently, dwarf galaxies are systematically located below this line. According to Pflamm-Altenburg & Kroupa (2009), their deviation from the linear relation is leveled if the transition from the measured H$\alpha$ flux to the SFR is made in the light of modern ideas on the initial stellar mass function in dwarf systems. The galaxies from Tables 2 and 3 do not noticeably stand out among the rest of the objects. A distinctive feature of the $\{\text{SFR}, M_B\}$ diagram is the presence of a rather sharp upper boundary, $SSFR = 4.3 \times 10^{-10} \, M_\odot \, yr^{-1} \, L_\odot^{-1}$, which is mainly traced by dIrr, BCD, and Sm–Sc galaxies. Of the galaxies listed in Tables 2 and 3, UGC 2773, KK35, and NGC 1569 present examples of such cases. The existence of a critical upper value for the SSFR is obviously an important universal parameter characterizing the process of conversion of gas into stars.

Figure 5 represents a relation between the global SFR and neutral hydrogen mass for 435 LV galaxies. The objects with an upper limit of SFR or $M_{\text{HI}}$ are indicated by open symbols. The dashed line corresponds to a fixed SFR per unit hydrogen mass and the solid line traces the relationship $\text{SFR} \propto M_{\text{HI}}^{3/2}$.

(A color version of this figure is available in the online journal.)
distance-independent parameters

\[
P = \log(\text{[SFR]} \times T_0/L_K). \quad F = \log(1.85M_H/\text{[SFR]} \times T_0)
\]

show which part of the observed stellar mass of the galaxy can be reproduced at the now observed SFR during the cosmological time \(T_0\), and for how long the star formation can continue there with the present gas reserves of \(M_{\text{gas}} = 1.85M_H\). Here the factor 1.85 gives a correction for the average abundance of helium and molecular gas in the galaxy (Fukugita & Peebles 2004). For the \(P\) parameter in expression (4), we use a known fact that the infrared \(K\)-band luminosity \(L_K\) of a galaxy reproduces its stellar mass at \(M_* \sim L_K = 1M_\odot/L_\odot\) (Bell et al. 2003; Karachentsev & Kutz'kin 2005). We adopted \(K\)-band magnitudes for 122 LV galaxies from the 2MASS survey (Jarrett et al. 2003). For the remaining objects, we transferred their \(B\) magnitudes into the \(K\) ones, using the empirical relations between the average color index \((B-K)\) and the morphological type of a galaxy, discussed by Jarrett et al. (2003) and Karachentsev & Kutz’kin (2005):

\[
\langle B - K \rangle = 4.10 \quad \text{for} \quad T \leq 2
\]
\[
\langle B - K \rangle = 4.60 - T/4 \quad \text{for} \quad T = 3-8
\]
\[
\langle B - K \rangle = 2.35 \quad \text{for} \quad T = 9, 10.
\]

The distribution of 435 LV galaxies on the “Past–Future” plane is presented in Figure 6, where galaxies of different types, (E, S0, dSph), (Sa, Sab, Sb, Sbc), (Sc, Scd, Sd, Sdm, Sm), and (Irr, BCD), are given in four separate panels. As above, open symbols with arrows indicate objects with only the upper limit of SFR or H\(_\alpha\) flux. Here, we omitted 41 galaxies with the upper limit of both SFR and H\(_\alpha\) flux because of their uncertain position on the \(F\) scale.

It is easy to see that the galaxies of different morphological types occupy different regions on the \(\{P, F\}\) plane, demonstrating the expected evolutionary segregation. The evolutionary trend according to galaxy types is also reflected in the data of Table 5. Its columns indicate (1) morphological type, (2) number of galaxies of this type in the LV with measured SFRs, and (3, 4) median values of the \(P\) and \(F\) parameters. We can draw the following conclusions from these data.

1. The current SFRs in the E, S0, and dSph galaxies can reproduce only about 2% of their stellar mass; therefore in the past their average SFR was significantly higher. Typical gas reserves in the E, S0, and dSph galaxies are rather uncertain, and their typical gas consumption timescale remains uncertain too.

2. According to the median parameters \(P\) and \(F\), the spiral galaxies of early types, dominated by the bulges, have already passed the peak of their evolution. The past SFR was an order of magnitude higher than the present one and the current gas reserves can support the SFRs during merely 28% of the cosmological timescale.

3. In disk-like galaxies of the late Sc–Sd types, the current SFR is only slightly lower than it was in the past. The resources of gas in Sc–Sdm galaxies are supplying their observed SFRs during almost another Hubble time.

4. The population of Irr and BCD galaxies had almost the same mean SFR in the past as it does now. Their gas reserves are sufficient for further star formation on a timescale of around \(1.8T_0\). The diagonal character of the distribution of these galaxies on the \(\{P, F\}\) plane obviously points to the variability of SFR in galaxies of low masses. Facing periodic bursts, dIrr galaxies are moving from the top left to the bottom right quadrant, acquiring the signs of BCD galaxies. Note that Stinson et al. (2007) simulated the evolution of dIrr galaxies taking into account effects of gas outflow due to the wind from SNe, and found cyclic bursts of star formation on a scale of \(~0.3\) Gyr with an amplitude of \(~(2-3)\) mag for dwarf systems of very low masses.

5. Scattering of the LV galaxies on the \(\{P, F\}\) diagram is quite high, reaching two to four orders of magnitude depending on the morphological type. As we already noted, the H\(_\alpha\) flux measurement error normally does not exceed \(~0.1\) dex, although near the detection limit these errors can be much higher. The uncertainty of transformation of \(F(H\alpha)\) into [SFR] discussed by Pflamm-Altenburg & Kroupa (2009) also affects the parameter spread, but it shifts the galaxies exactly arriswise \(F = -P\). Thus, much of the galaxy dispersion in Figure 6 does not have an instrumental origin, but a cosmic one. The smallest dispersion, \(\sigma(P) = 0.4\), \(\sigma(F) = 0.6\), is observed for the population of late-type spirals, Sc–Sdm. It is most likely that the rotation of Sc–Sdm galaxies and the stimulation of star formation it causes in gas-rich disks makes this process fairly regular.

### 8. The Present Cosmic SFR Density

As demonstrated by Madau et al. (1996), Villar et al. (2008), Gonzalez et al. (2010), Westra et al. (2010), and other authors, the average SFR in previous epochs \(\sim 1-2\) was an order of magnitude higher than nowadays. Analyzing the change in the average SFR density from redshift \(\rho_{\text{SFR}}(z)\), it is important to reliably fix the current value of \(\rho_{\text{SFR}}(0)\) from the observations of nearby galaxies.

To this end, we used all available data on the SFR of galaxies situated within 8 Mpc at galactic latitudes \(|b| > 10^\circ\). We did not consider more distant objects because the present completeness of the H\(_\alpha\) survey drops appreciably beyond 8 Mpc. The integrated SFR for the 8 Mpc sample amounts to 53 \(M_\odot\) yr\(^{-1}\). As is seen from Figure 1, the present H\(_\alpha\) survey is quite complete up to \(M_B = -15\) mag. Based on the relation “SFR versus \(M_B\)” in Figure 4, we estimate that the integrated contribution of dwarf galaxies still unobserved in H\(_\alpha\) adds about 4 \(M_\odot\) yr\(^{-1}\) to the total amount. Therefore, the mean SFR density within 8 Mpc turns out to be \(\rho_{\text{SFR}}(0) = 0.032 M_\odot\) yr\(^{-1}\) Mpc\(^{-3}\). As was noted by Karachentsev & Kutz’kin (2005), the mean stellar mass density within 8 Mpc, estimated from the \(K\)-band luminosity density \(j_K(L|8\ Mpc) = 6.8 \times 10^L_\odot\ Mpc^{-3}\), appeared to be \((1.7 \pm 0.2)\) times higher than the mean cosmic density \(j_K(L|\text{cosmic}) = (3.8 \pm 0.6) \times 10^L_\odot\ Mpc^{-3}\) obtained by Cole et al. (2001) and Bell et al. (2003) from 2MASS. Reducing for the local overdensity yields the mean cosmic density of SFR in the present epoch:

\[
\rho_{\text{SFR}}(0) = (0.019 \pm 0.003) M_\odot\ yr^{-1}\ Mpc^{-3}.
\]

Table 6 gives a comparison of our estimate with the data obtained by other authors based on the samples of different types.
depths and different compilation methods. As one can see, the agreement of independent estimates of $\rho_{\text{SFR}}(0)$ is quite satisfactory.

The data from Table 7, gathering the values of some basic cosmic parameters describing the star formation within 1 Mpc$^3$ at $z = 0$ and $h = 0.72$ can be useful to validate various models of galaxy evolution. The rows of the table present (1) the critical density of matter, (2) the luminosity density in the $K$ band (also evaluating the mean density of stellar mass at $M_\star/L_K = 1 M_\odot/L_\odot$), (3) the mean density of hydrogen mass according to HIPASS (Zwaan et al. 2003), (4) the mean density of SFR, and (5, 6) the mean density of the dimensionless parameters $P$ and $F$, derived from the quantities of rows (2)–(4) via Equations (4). The value $\rho(P) = -0.17$, actually averaged

![Figure 6](image-url)

**Figure 6.** LV galaxies of different morphological types on the diagnostic diagram “Past–Future.” The objects with an upper limit of SFR or $M_{\text{HI}}$ are shown by open symbols with arrows.

| $\log(\rho_{\text{SFR}})$ ($M_\odot\,\text{yr}^{-1}\,\text{Mpc}^{-3}$) | Reference | Note |
|----------------|-------------|-------|
| $-1.95 \pm 0.04$ | Gallego et al. (1995) | Emission line galaxies |
| $-1.73 \pm 0.07$ | Tresse & Maddox (1998) | $I$-band survey |
| $-1.64 \pm 0.02$ | Perez-Gonzalez et al. (2003) | Optically selected |
| $-1.66 \pm 0.08$ | Brinchmann et al. (2004) | SDSS-based |
| $-1.81 \pm 0.03$ | Hanish et al. (2006) | $\text{H}_\alpha$-selected |
| $-1.75 \pm 0.03$ | Salim et al. (2007) | UV-based |
| $-1.72 \pm 0.08$ | James et al. (2008) | $\text{H}_\alpha$ Local universe |
| $-1.72 \pm 0.06$ | This paper | $\text{H}_\alpha$ Local Volume |

**Table 6**

Total SFR Density in the Local Universe ($z = 0, H_0 = 72$ km s$^{-1}$ Mpc$^{-1}$, Extinction Corrected)
with the galaxy masses proportional to their $K$ luminosity, means
that the current SFR in a unit volume is only 1.5 times lower than
the average SFR in past epochs. This result looks significantly
at odds with the notion that the characteristic SFR in the
average SFR in past epochs. This result looks significantly
that the current SFR in a unit volume is only 1.5 times lower than
intergalactic space.

under the condition that the bulk of gas is located in the volume
formation. It is needless to stress that this assertion is true only
this process immediately after the era of peak intensity of star
gone more than halfway in the history of transformation of

to maintain the average present rate of star formation in them
limits of $\rho_{c}$

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9. CONCLUDING REMARKS

The program of our massive Hα survey of galaxies in the
neighboring volume a the radius of 10 Mpc allows us to
determine some basic cosmic parameters, characterizing the
rate and resource of star formation in the local universe. An
important prerequisite for this is an exclusion of deliberate
selection in the choice of objects for the observational program
by morphological type and/or other features. A simple principle
is evident here: the lower the selectivity of objects is for
observations, the simpler the interpretation of the data obtained
will be. The lack of accurate distance measurements to a part
of nearby galaxies somewhat ruins this ideal situation. It should
be noted, however, that positions of galaxies in the diagnostic
diagram $\{P, F\}$ (Figure 6) do not depend on the errors of
distance finding.

Keeping the E, S0, and dSph galaxies, which are not expected
to have Hα emission, in our sample we found surprisingly
that in some of them the process of star formation goes on at a fairly high rate. For example, spheroidal galaxies
KDG61, DDO44, and KKR25 indicate the presence of active
emission knots in which a young stellar population is
arising intergalactic gas into these galaxies (Moiseev et al. 2010).

there are reasons to assume that a population of young semi-
formed dwarf galaxies, similar to the H I clouds in the Virgo
(122746.2+013601) and CVN1 (122043.4+461233) clusters, or
to the HIJASS (102100.2+684200) and Leib (AGC219303) ob-
jects in the M81 and LeoI groups, is located in the upper right
quadrant of the diagnostic diagram (Figure 6). To clarify the
nature of such objects with masses comparable to the masses of
dwarf galaxies, much deeper observations are needed with flux
limits of $F(H\alpha) \sim 10^{-16}$ erg cm$^{-2}$ s$^{-1}$ and $F(H1) \sim 10^{-2}$Jy km s$^{-1}$.

Such observations would obviously require a significant amount
of time on large telescopes. This demand should be related to the
predictions of modern scenarios of galaxy evolution. So far,
the existing shallow Hα survey of nearby dwarf galaxies is suc-
cessfully competing with another survey of these galaxies in the
ultraviolet range on GALEX (Gil de Paz et al. 2003) due to
weaker absorption in the Hα line and higher angular resolution.

Table 7

| Parameter | Quantity | Reference |
|-----------|----------|-----------|
| $\rho_{c}$ | $1.43 \times 10^{11} M_{\odot}$ Mpc$^{-3}$ | Spergel et al. (2007) |
| $j_{K}(L)$ | $3.8 \times 10^{8} L_{\odot}$ Mpc$^{-3}$ | Cole et al. (2001); Bell et al. (2005) |
| $\rho(H\alpha)$ | $0.44 \times 10^{8} M_{\odot}$ Mpc$^{-3}$ | Zwaan et al. (2003) |
| $\rho(SFR)$ | $0.019 M_{\odot}$ yr$^{-1}$ Mpc$^{-3}$ | This paper |
| $\rho(F)$ | $-0.17$ | This paper |
| $\rho(F)$ | $-0.50$ | This paper |
MORE GALAXIES IN THE LOCAL VOLUME IMAGED IN Hα

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