SDSS-IV MaNGA: the physical origin of off-galaxy Hα blobs in the local Universe

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ABSTRACT

Hα blobs are off-galaxy emission-line regions with weak or no optical counterparts. They are mostly visible in Hα line, appearing as concentrated blobs. Such unusual objects have been rarely observed and studied, and their physical origin is still unclear. We have identified 13 Hα blobs in the public data of MaNGA survey, by visually inspecting both the SDSS optical images and the spatially resolved maps of Hα line for $\sim$ 4600 galaxy systems. Among the 13 Hα blobs, 2 were reported in previously MaNGA-based studies and 11 are newly discovered. This sample, though still small in size, is by far the largest sample with both deep imaging and integral field spectroscopy. Therefore, for the first time we are able to perform statistical studies to investigate the physical origin of Hα blobs. We examine the physical properties of these Hα blobs and their associated galaxies, including their morphology, environments, gas-phase metallicity, kinematics of ionized gas, and ionizing sources. We find that the Hα blobs in our sample can be broadly divided into two groups. One is associated with interacting/merging galaxy systems, of which the ionization is dominated by shocks or diffuse ionized gas. It is likely that these Hα blobs used to be part of their nearby galaxies, but were stripped away at some point due to tidal interactions. The other group is found in gas-rich systems, appearing as low-metallicity star-forming regions that are visually detached from the main galaxy.

- Звездная составляющая на далекой периферии галактик и в приливных структурах может иметь слишком низкую яркость, чтоб быть обнаружимой. Наблюдаемые изолированные области HII выявляют наличие островков плотного газа или маломассивных спутников.

Возможные механизмы ионизации:

- Молодые звезды
- Ударные волны
- УФ излучение ядра

Наиболее впечатляющий пример

The Astrophysical Journal, 837:32 (13pp), 2017 March 1 Lin et al.

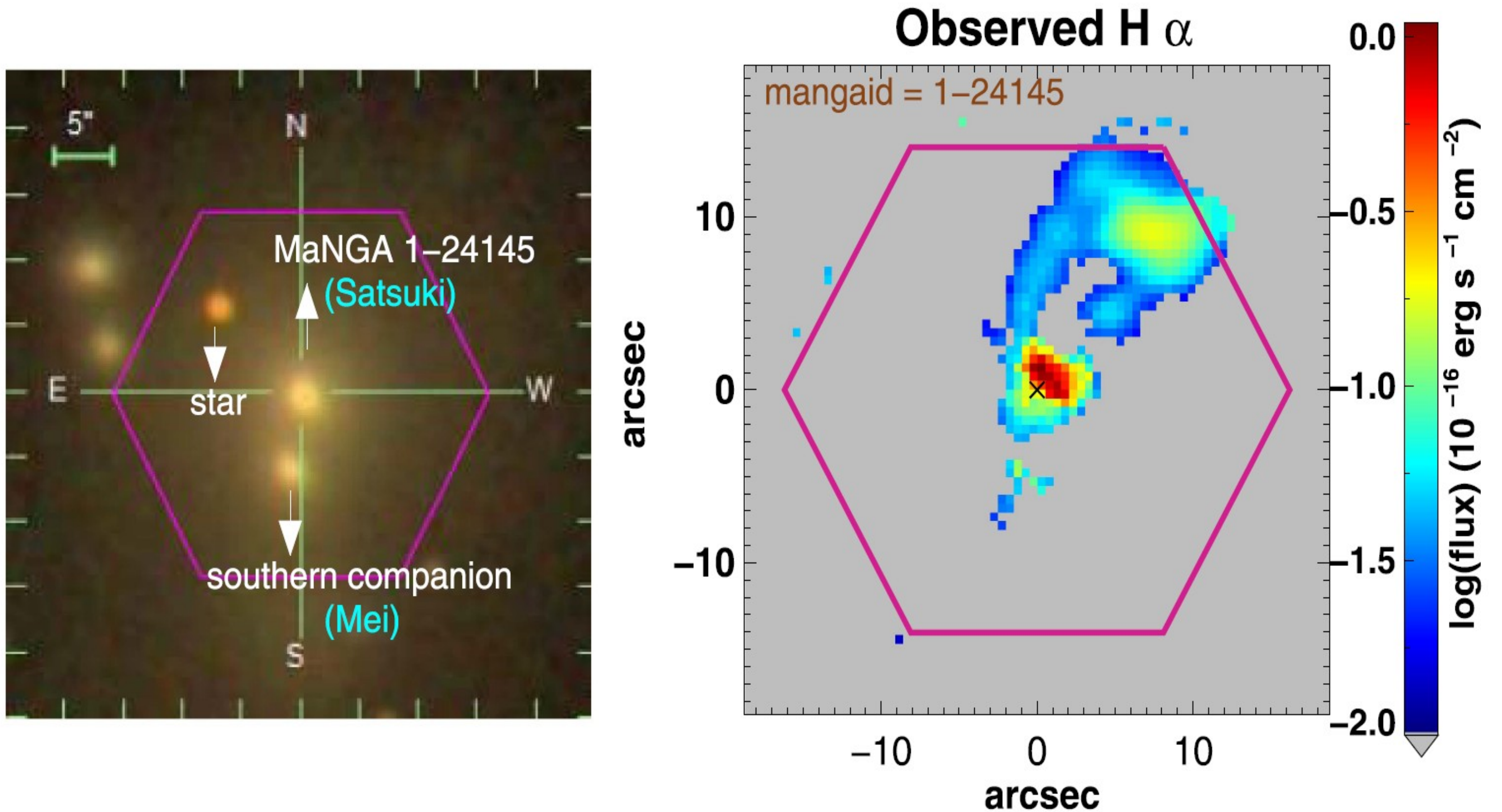


Figure 1. Left: the SDSS *gri* composite image of MaNGA 1-24145 with the MaNGA hexagonal bundle field of view (FoV) overlaid. This system was observed with the 127 fiber bundle of MaNGA, so this hexagon is ~32.″5 in diameter. The data extend to regions just outside the hexagon because of the dithering. Three distinct objects are visible within the bundle, including two elliptical galaxies (Satsuki and Mei) and one foreground star. Right: the observed Hα flux map from the MaNGA observations.

Возможная интерпретация

(i) It is a gas cloud stripped out from the galaxy due to ram pressure, as the host system falling towards the center of the host cluster of galaxies.

(ii) It is a tidal remnant produced by the merger of two galaxies in this system.

(iii) It is an UDG, disturbed by the dry-merger system.

(iv) It is a transient gas blob expelled and possibly also illuminated by the AGN inside the central galaxy.

(v) It is formed by the cooling of the intragroup medium (IGM).

In this work we identify off-galaxy Ha blobs by visually inspecting the two-dimensional maps of both the flux of the Ha line and the integrated flux in g-band for all 4639 galaxies in the MaNGA DR15 sample.

We will require extended structures in the Ha maps to have on-sky sizes larger than the PSF (or equivalently 5 spaxels), in order for them to be distinguished from pointlike sources.

Table 1. Global properties of the sample galaxies

No.	MaNGA ID	IAU name	z	$NUV - r$ (mag)	$\log(\frac{M_\star}{M_\odot})$	R_e (kpc)	ΔRA † ($''$)	ΔDEC † ($''$)	Δz † (10^{-3})	$\frac{r_p}{R_e}$	$\Sigma_{\mathrm{H}\alpha}^{\mathrm{peak}}$ (10^{39}erg/s/kpc^2)
1	1-114129	J213405.08+102518.5	0.0774	4.595	10.3	15.6***	-5.51	-13.00	0.40	1.32	1.02
2	1-24145*	J171523.26+572558.3	0.0322	10.554**	10.5	11.4***	-8.06	8.68	-0.07	0.67	0.74
3	1-36779	J023750.73+003428.6	0.063	4.464	10.2	3.7	3.49	-4.50	0.40	1.89	0.97
4	1-52637	J040723.52-064111.1	0.038	1.945	8.9	3.6	6.01	-10.51	0.31	2.51	0.90
5	1-282600	J122642.32+434704.0	0.1115	5.409	10.9	14.1***	-7.99	-3.49	0.85	1.26	1.11
6	1-207914	J144934.69+525802.2	0.0577	3.568	10.1	5.3	-2.99	8.50	-0.03	1.90	1.40
7	1-339300	J075437.32+465917.5	0.0172	3.484	8.8	1.9	-5.00	8.50	0.15	1.78	0.78
8	1-564242	J084746.76+540136.0	0.0469	7.337	9.8	2.9	6.01	-6.01	1.12	2.66	0.87
9	1-148597	J110038.83+501205.1	0.0232	2.956	9.0	1.0	-1.48	-6.01	0.08	2.95	0.91
10	1-247975	J160224.40+424525.4	0.0399	2.410	9.3	4.7	-11.01	2.99	-0.15	1.93	0.15
11	1-71869	J075837.71+372859.1	0.0401	4.981	10.3	9.4	4.00	11.02	0.28	0.98	1.49
12	1-122361	J080931.34+394806.7	0.0639	4.553	10.2	4.2	6.48	-5.51	-0.09	2.46	0.23
13	1-230052	J081542.55+255755.2	0.0393	2.307	9.2	7.1	-12.53	1.01	-0.16	1.37	2.30

* This is the galaxy system with an Hα blob discovered by Lin et al. (2017).
** This value is not reliable as the *NUV* magnitude of this galaxy provided by NSA has an uncertainty comparable to the value.
*** These galaxy systems appear as late-stage mergers and thus the measurement of the effective radius might not be reliable.
† The differences are defined as Parameter(Hα blob) − Parameter(galaxy).

Две группы галактик:

Низкой и высокой светимост

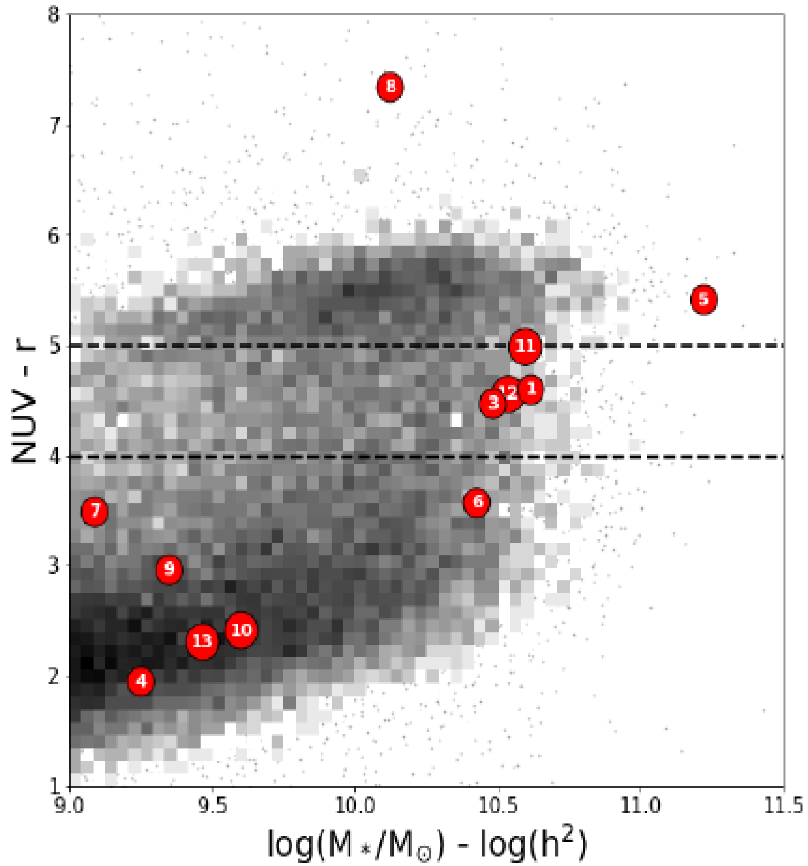


Figure 1. Sample galaxies are plotted as red circles with corresponding serial numbers in the stellar mass versus $NUV - r$ color plane. A representative, volume-limited sample of NSA galaxies are plotted in grey as background. The two dashed lines indicate $NUV - r$ colors of 4 and 5 respectively, commonly used as demarcation lines to separate red-sequence, green-valley and blue-cloud galaxies. For galaxy system **ga12** (MaNGA ID: 1-24145), its $NUV - r$ color is not reliable due to the large measurement error in its NUV magnitude. Thus it is not shown in the figure.

- SDSS gri
- Размеры blobs –
от 1.5 до 16 kpc
(большинство –
 3-6 kpc)

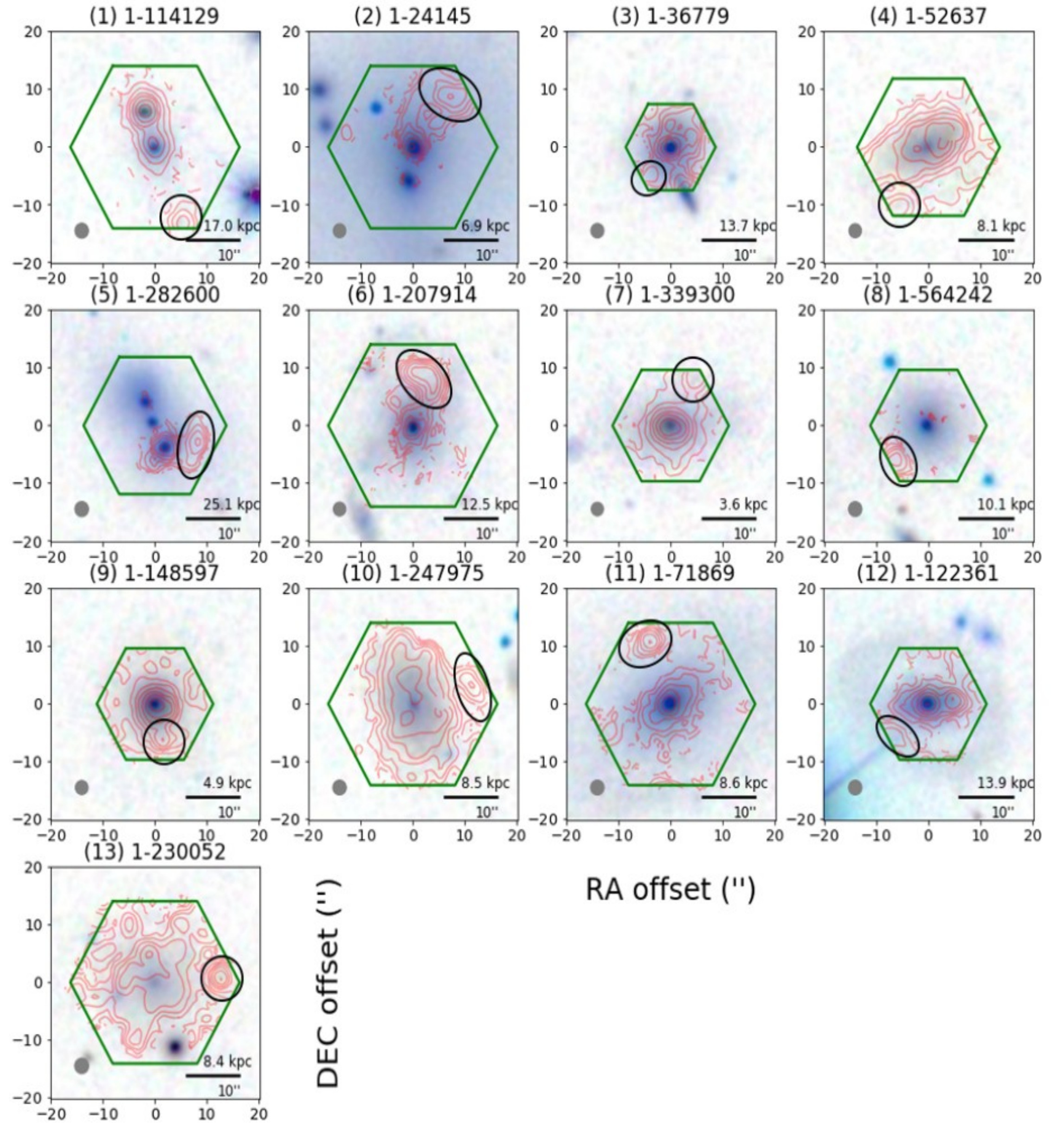


Figure 2. Color-inverted SDSS *gri* composite images with contours of Hα fluxes. Each set of contours has eight equally spaced levels in logarithmic scale, from the lowest value to the highest value in the system. For system 13, we have masked the foreground star in the south before making the contours. Boundaries of MaNGA's fields of view are shown as green hexagons. For each system, the location of the Hα blob is marked with a black ellipse. A scale bar indicating the physical scale of 10 arcsecs is shown for reference, and the FWHM of MaNGA's PSF is indicated by the grey circle. The MaNGA ID and serial number is displayed above.

Глубокая
фотометрия.
В основном,
это взаимодействук
или merging систем
Blobs – в пределах
звездных гало.

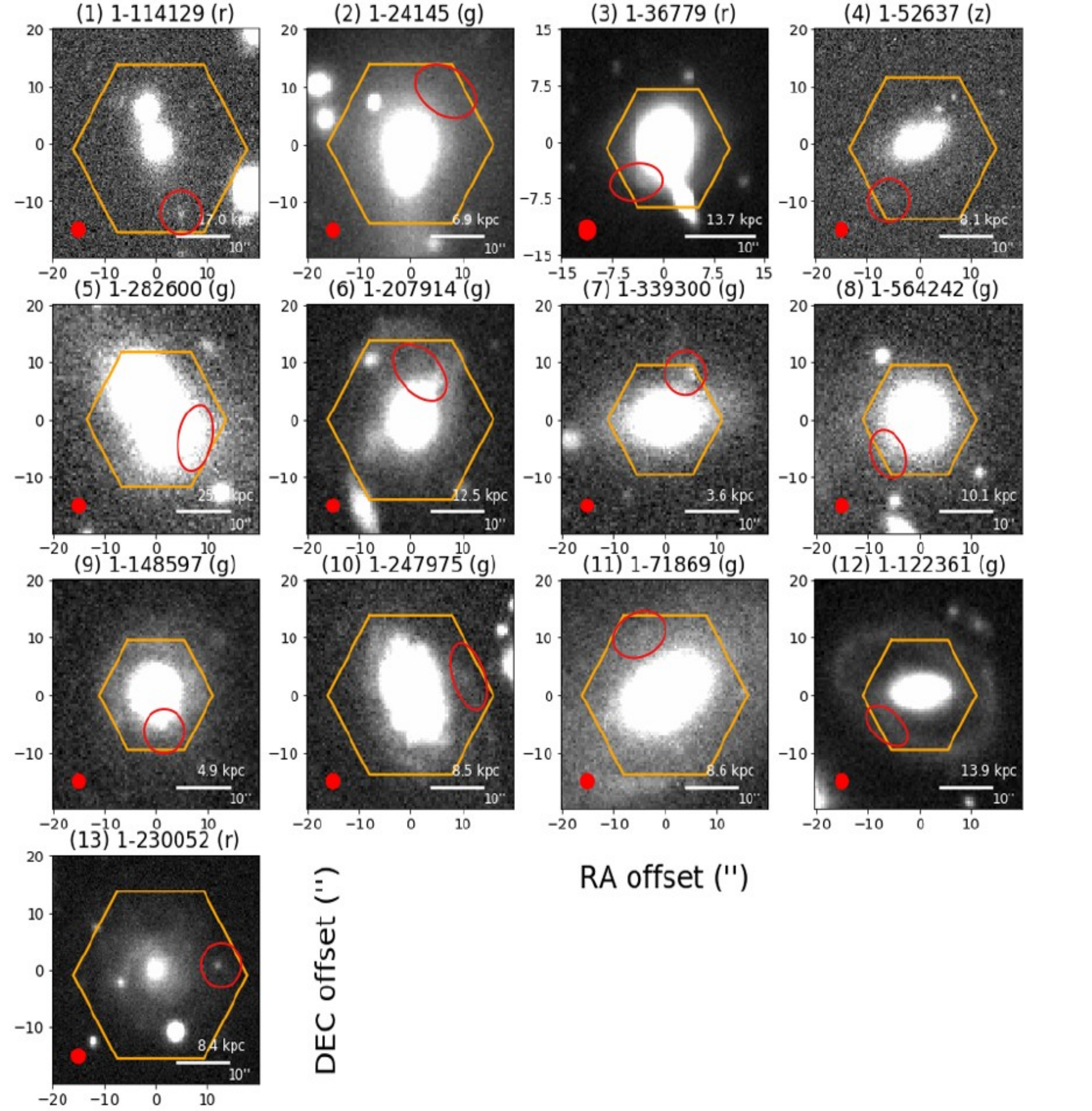
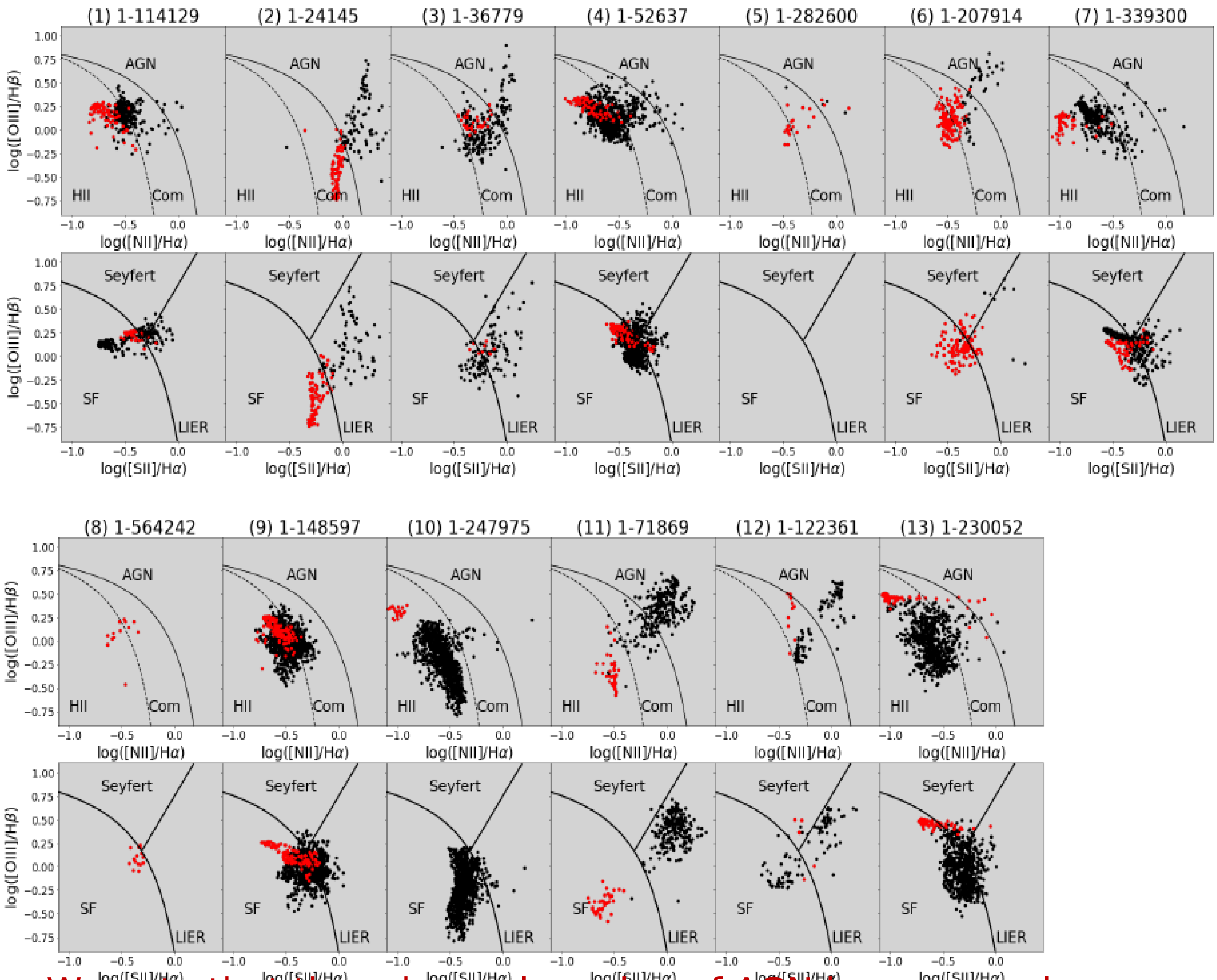


Figure 4. Contrast-enhanced optical images of our sample galaxies from BASS, DECaLS and MzLS surveys. The footprints of MaNGA's fiber bundles are shown as orange hexagons, and the locations of Hα blobs are marked with red open elipses. We use g-band images for most of the galaxies. For some galaxies, the r-band images better reveal the faint optical structures and thus are displayed instead. In the case of galaxy system 4, only the z-band image is available. For each system, the location of the Hα blob is marked with a red ellipse. A scale bar indicating the physical scale of 10 arcsecs is shown for reference, and the MaNGA PSF is shown as the red circle.



We note that there is no clear sign of AGN in our sample.

Figure 5. Distribution of our sample spaxels in [N II] and [S II] BPT diagrams. Red points correspond to spaxels inside Hα blobs, and black points correspond to spaxels belong to the host galaxies.

- It is clear that the spaxels inside the H blobs are mostly classified as star-forming (SF) regions, while the spaxels of the host galaxies are a mix of SF regions and low-ionization (nuclear) emission line regions.

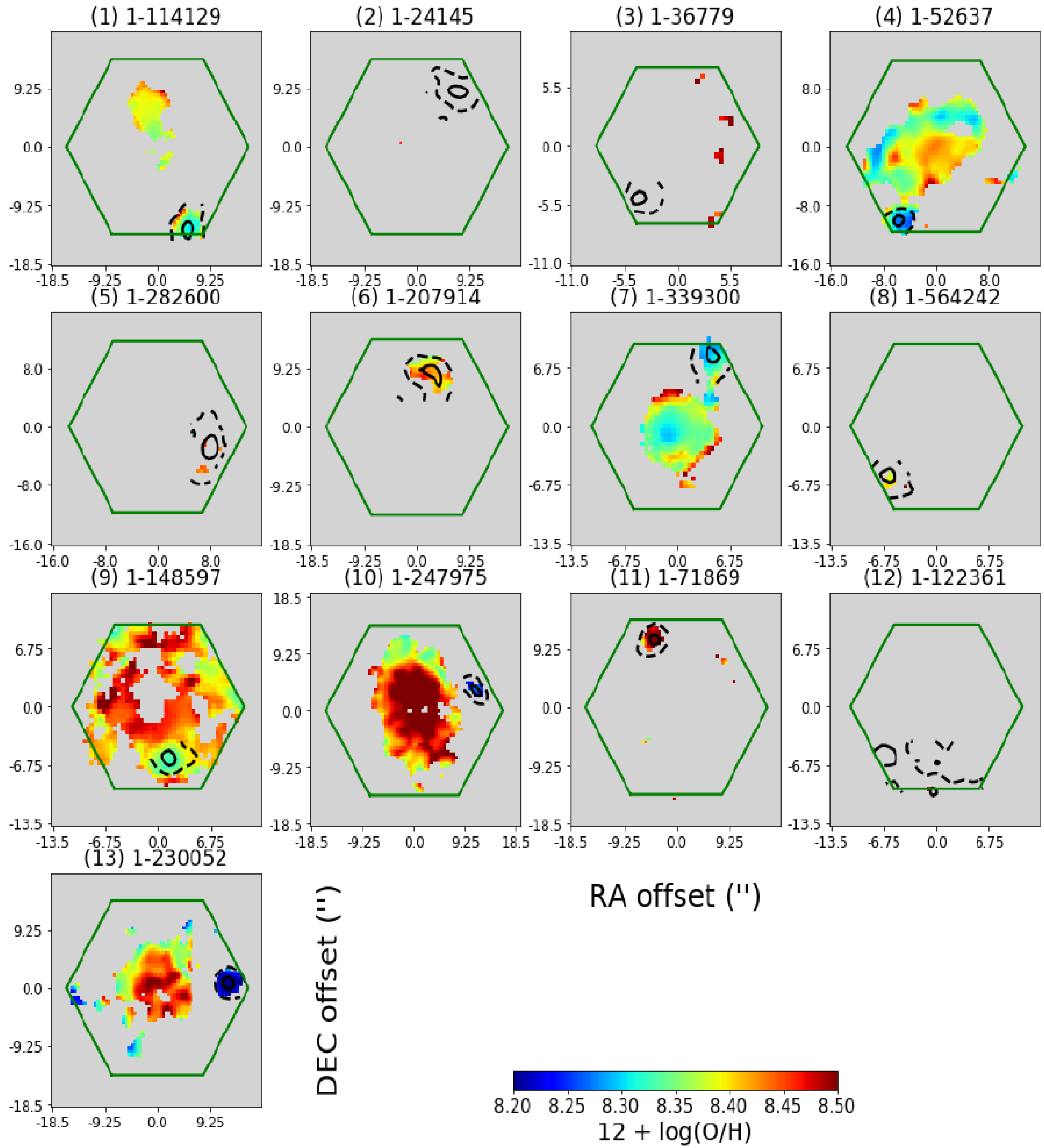


Figure 7. Spatially resolved gas-phase metallicity maps of H II regions in the sample galaxies. The locations of Hα blobs are indicated by black contours. The solid and dashed contours correspond to the 95th and 63rd percentiles of the Hα surface brightness in Hα blobs.

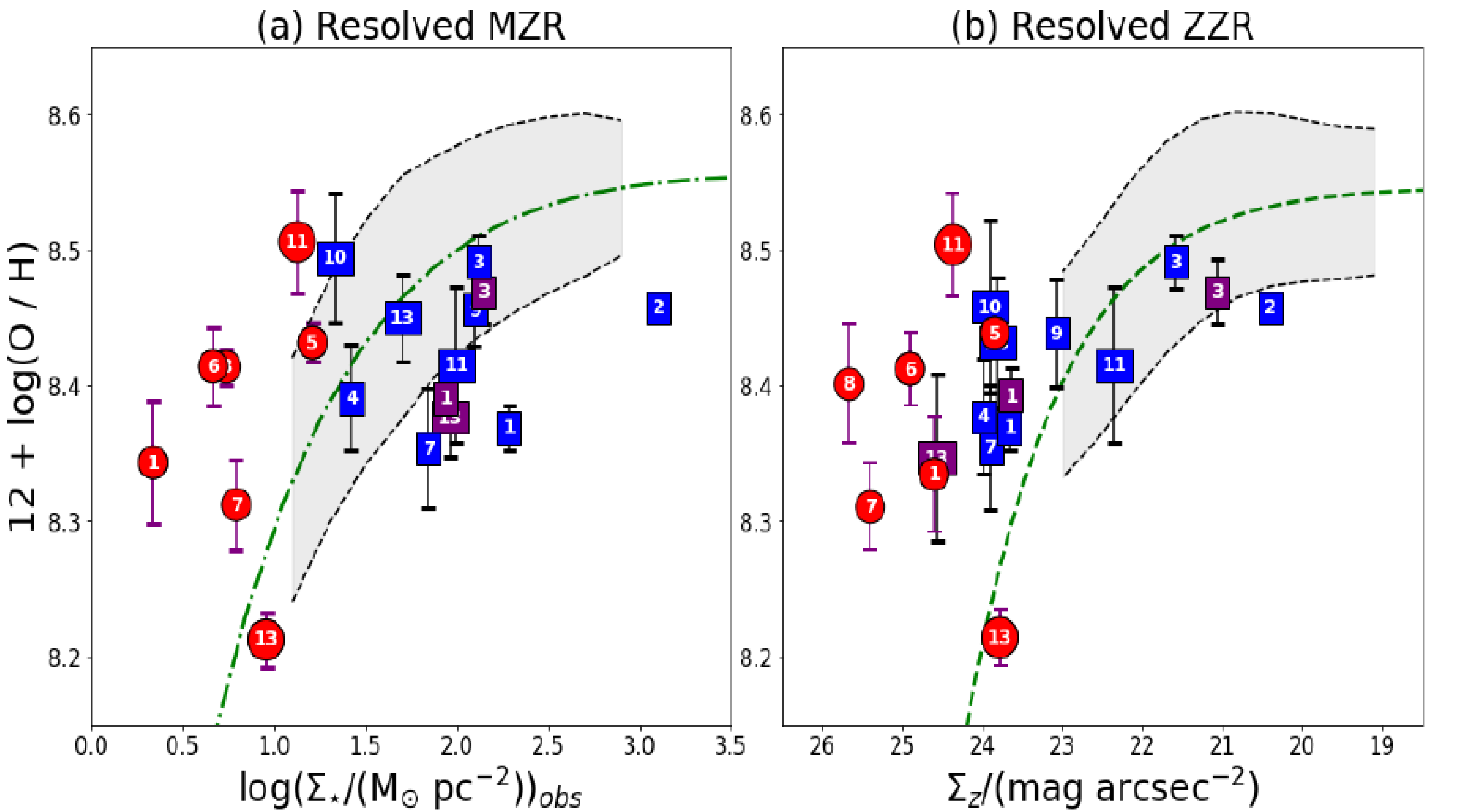


Figure 8. Left panel: resolved mass-metallicity relation of Hα blobs and their host galaxies. The red circles are Hα blobs and the blue boxes are their host galaxies. Purple boxes are other galaxy members observed inside the MaNGA IFU bundles. Galaxies/Hα blobs that belong to the same system are marked with the same serial number. Error bars indicate the 1σ variations of the metallicity inside the blobs/galaxies. The green dashed-dot line shows the fitted median trend with extrapolations at low and high surface mass density ends. The two sets of black dashed lines enclose spaxels within one standard deviation from the median along the vertical axis. Right panel: resolved metallicity - z-band surface brightness relation of Hα blobs and their host galaxies. Only the Hα blobs that have median z-band fluxes greater than zero are plotted.

The galaxies and the Ha blobs as a whole cover a relatively narrow range of metallicity, limited to intermediate low values. In contrast, their surfac mass-densities and flux densities s several orders of magnitude, indic attening of radial metallicity prole sample galaxies, as compared to Galaxies.

The seemingly pre-enriched metall of H blobs is again consistent with picture where they were originally of the nearest galaxies. An alterna explanation is the inflow of low-m gas diluting the metallicity in the which could also be result of the interaction between galaxies.

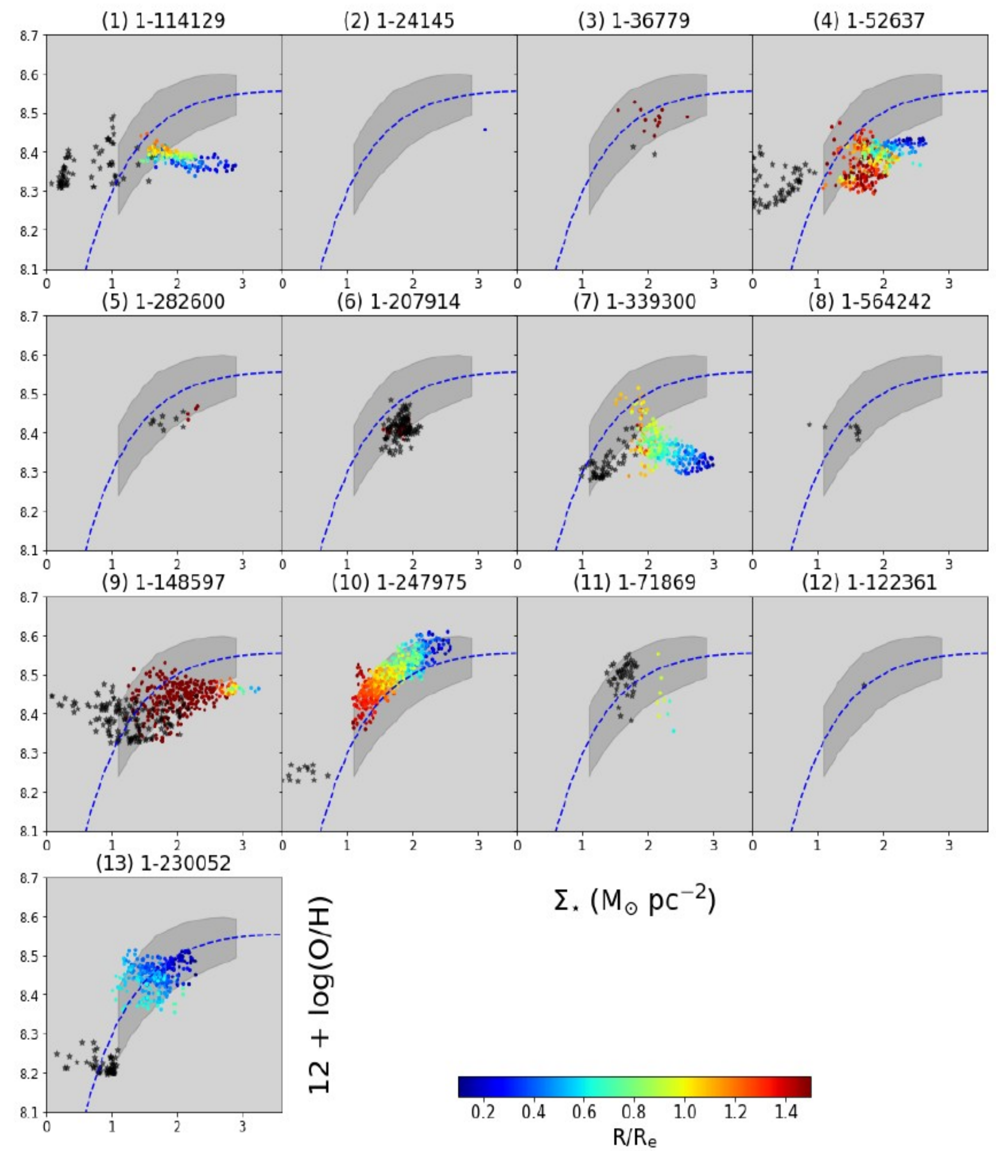


Figure 9. Spatially resolved MZR of our sample spaxels. While the host galaxy spaxels are color-coded according to their radial positions, R/R_e, the Hα blob spaxels are colored in black. The blue dashed lines represent the extrapolated median trend in Figure 8, and the shaded region on the background is the same as that in Figure 8, which describes 1σ variation in metallicity.

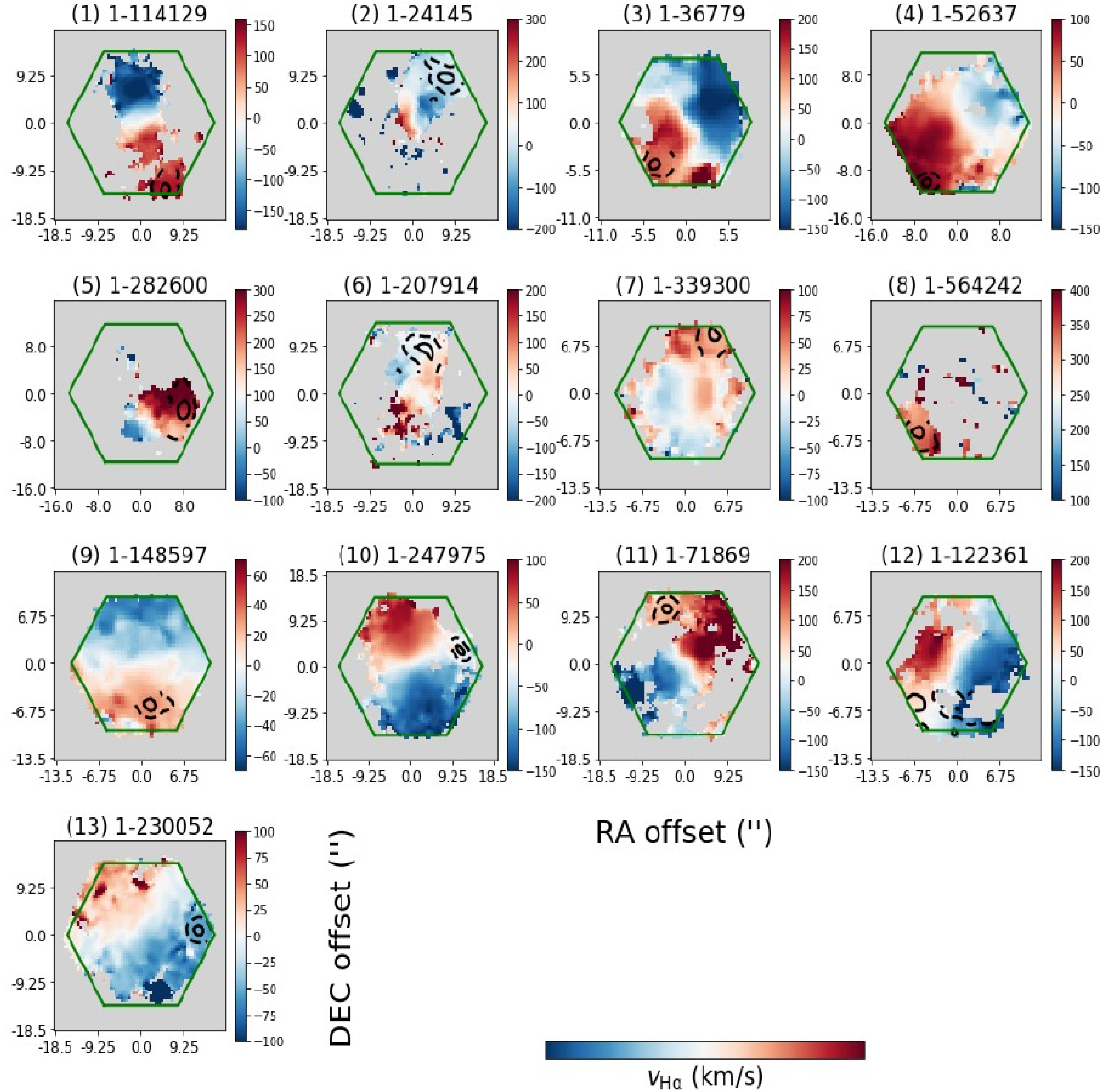


Figure 10. Velocity fields traced by the Hα line in the sample galaxy systems. The locations of Hα blobs are indicated by black contours. The solid and dashed contours correspond to the 95$^{\rm th}$ and 63$^{\rm rd}$ percentiles of the Hα surface brightness in Hα blobs.

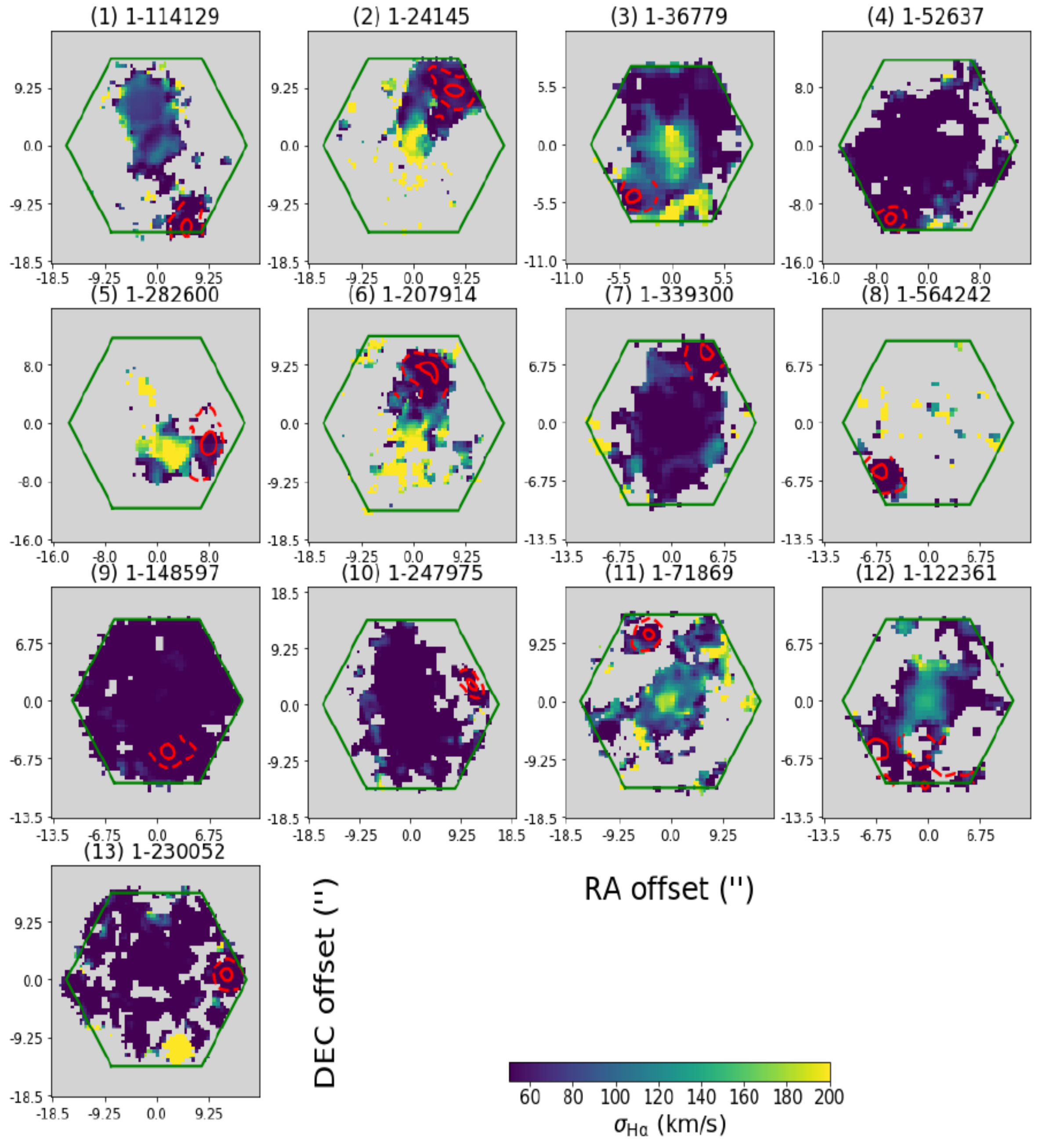


Figure 11. Velocity dispersion maps traced by the Hα line in the sample galaxy systems. The locations of Hα blobs are indicated by red contours. The solid and dashed contours correspond to the 95th and 63rd percentiles of the Hα surface brightness in Hα blobs.

Итоговая таблица

Table 2. Derived properties of Hα blobs

No.	Morphology*	No. of companion galaxies	BPT classification	12 + log(O/H) (via O3N2)	$\log(\Sigma_*)$** ($\log(M_\odot\ pc^{-2})$)	Σ_z** (mag arcsec^{-2})	$\Delta v_{H\alpha}$ (km/s)	$\sigma_{H\alpha}$ (km/s)
1	spot	2	H II	8.33 ± 0.04	0.34 ± 0.40	24.6 ± 0.6	123 ± 17	33 ± 20
2	/	2	composite	/	/	/	-12 ± 30	58 ± 24
3	ring	2	composite	/	0.48 ± 0.63	26.6 ± 1.2	124 ± 18	81 ± 36
4	tail/spiral	1	H II	8.31 ± 0.04	/	/	94 ± 8	28 ± 8
5	/	3	H II	8.44 ± 0.01	1.21 ± 0.79	23.8 ± 0.7	268 ± 60	58 ± 33
6	tail/spiral	1	H II	8.41 ± 0.03	0.66 ± 0.80	24.9 ± 1.0	-9 ± 32	47 ± 29
7	spot	1	H II	8.31 ± 0.03	0.80 ± 0.88	25.4 ± 0.9	39 ± 12	38 ± 12
8	/	2	H II	8.40 ± 0.04	0.74 ± 0.74	25.7 ± 1.0	331 ± 23	32 ± 31
9	faint disk	1	H II	8.40 ± 0.03	/	/	25 ± 8	28 ± 8
10	tail/spiral	1	H II	8.26 ± 0.01	/	/	-38 ± 23	28 ± 33
11	faint disk	1	H II	8.50 ± 0.04	1.13 ± 0.77	24.4 ± 0.8	82 ± 18	50 ± 33
12	ring	1	composite	/	/	/	-11 ± 69	42 ± 34
13	spot	1	H II	8.21 ± 0.02	0.96 ± 0.15	23.8 ± 0.2	-51 ± 12	23 ± 22

* This is the morphology of the underlying optical structures at the locations of the Hα blobs revealed by the deep images, which are not necessarily the optical counterparts of these Hα blobs.

** These are the model subtracted values (except for hab1 and hab13).

Основные выводы

- Первая группа – маломассивные галактики (logM<10)с активным SF. Blobs - либо области SF на периферии, либо близкие карлики. Нет признаков взаимодействия
- Вторая группа – массивные галактики. У них blobs - продукт приливного взаимодействия, области SF во внешних частях галактик. Большой вклад DIG.
- Кинематически blobs – это продолжение галактик, а не независимые галактики..
- По металличности blobs не сильно отличаются от MZR, однако у некоторых host galaxies металличность понижена (аккреция?).