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VOLGA View On the Life of GAlaxies

Star formation triggering and its influence on ISM: multiwavelength view on the nearby galaxies.

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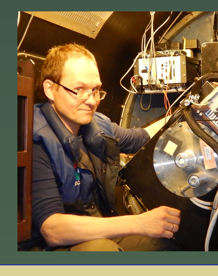

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Abstract

We report the results of our study of the ionized and neutral gas morphology and kinematics in the regions of triggered star formation in nearby galaxies. The main goal of our study was to find an answer to the questions: which processes are responsible for the triggering of star formation at global scale and how the feedback from new regions of star formation influences on ISM for each individual galaxy studied.

In this poster we mostly focus on our recent findings about two galaxies: IC 2574 and Holmberg II.

Stellar feedback and multiple superbubbles in dIrr galaxies

Stellar feedback is very important for the regulation of ISM structure and the whole galaxy evolution as well, especially for Irr galaxies. Stellar winds and supernovae explosions create complexes of shells and supershells of ionized and neutral gas; e.g. Bagetakos et al. (2011) analysed the HI distribution in 20 nearby galaxies and revealed about 1000 cavities in their discs with sizes from 80 pc to 2.6 kpc, expansion velocities from 4 to 64 km/s (typically 10-20 km/s) and ages from 2 to 150 Myr.

The origin of the largest kpc-sized HI holes and shell-like structures (so-called supergiant shells, SGS) has been the subject of debate for more than two decades. Recent studies have found that multiple star formation events over the age of the hole do provide enough energy to drive HI SGS formation (see e.g. Weisz et al., 2009a,b).

The regions of ongoing star formation in Irr galaxies usually located at the rims of HI supergiant shells. Despite the large amount of HI superbubbles in galaxies, only a small part of them exhibits the ongoing star formation.

Triggered star formation in superbubbles: the best examples.

A number of supergiant shells in nearby galaxies exhibit signs of expansion-triggered star formation at their periphery. In Fig.1 we selected several galaxies which ISM represents a lot of superbubbles, but the ongoing star formation has place only in the rim of the largest kpc-sized supergiant shell.

Weisz et al. (2009a,b) showed that the star formation in IC 2574 and Holmberg II galaxies was triggered by the previous episode of star formation that took place in the centre of supergiant shells studied.

The distribution of star formation in selected galaxies allows us to suppose its different nature. For example, intense star formation in IC 2574 take place over the whole HI supergiant shell, but in Holmberg II and IC 1613 it take place only at one side of superbubble - at the place of its possible collision with the adjacent supershells. Star formation in Holmberg II occupies the most of the central part of the galaxy, while in IC 2574 and IC 1613 it take place only at the small part of the galaxy disc at its periphery. The Holmberg I galaxy is an example of a galaxy-sized supergiant shell – the whole galaxy is almost one kpc-sized supershell with a relatively weak star formation it its walls.

A special interest consists in a detailed analysis of the interaction of stars and gas in the region of new sites of star formation in the walls of SGS, which can elucidate the process of their evolution.

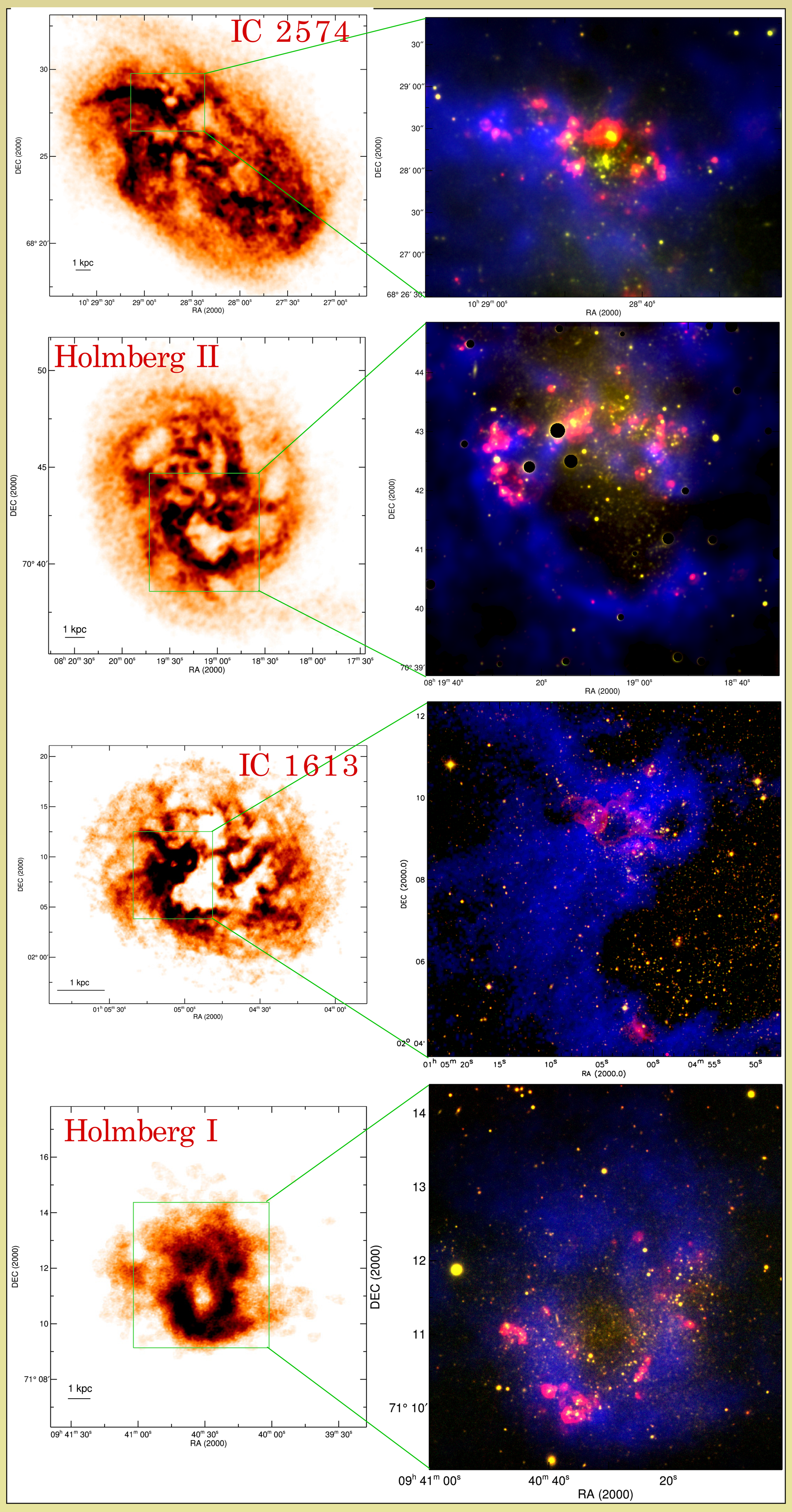


Fig.1: Examples of the galaxies with ongoing star formation regions in the rim of the kpc-sized HI supergiant shell. Left: HI column density distribution; Right: False-colour image of the part of the galaxy inside the green rectangle. Red colour corresponds to H-alpha emission distribution; yellow -- to the stellar population (continuum image); blue -- HI 21 cm distribution.

Observation

Our study based on the observations performed at the 6-m telescope of Special Astrophysical Observatory of Russian Academy of Science with SCORPIO-2 (Afanasiev & Moiseev, 2011) multi-mode focal reducers. We used a scanning Fabry–Perot interferometer (FPI) mode to obtain the H-alpha data cubes for the study of the ionized gas kinematics, while the observed narrow-band H-alpha direct images were used for analysis of the ionized gas morphology. Neutral gas distribution and kinematics were studied using the data of archival VLA HI 21 cm observations from THINGS (Walter et al., 2008) and LITTLE THINGS (Hunter et al., 2012) surveys. The detailed description of the observational settings are shown in the corresponding papers for each galaxy discussed.

Star formation triggering at the scales of individual giant HII regions

Stewart & Walter (2000) and Stewart et al. (2000) compared their UV and H-alpha observation in order to highlight the star formation triggering in IC 2574 and Holmberg II galaxies. We applied the same method using the data of our H-alpha and archival GALEX FUV observations to Holmberg II and NGC 4068 galaxies.

FUV and H-alpha emission are both the tracers of the young stellar population, but the timescale at which they appear are different. H-alpha emission is a good tracer of the current star formation (age < 10 Myr) while FUV emission traces the recent star formation took place at the longer timescale (age < 100 Myr). Fig.2 demonstrates the dependence of H-alpha and FUV fluxes ratio as well as their difference on the age according to the STARBURST99 simulations (Leitherer et al., 1999) for metallicity Z = 0.2 Zsun. The normalized difference between H-alpha and FUV fluxes should be positive for the regions with the age less than about 9 Myr and negative for the older one.

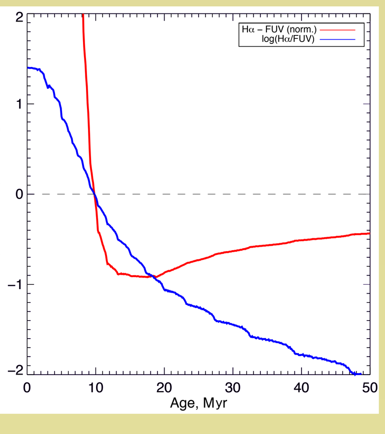


Fig.2: Evolution of H-alpha and FUV fluxes logarithm ratio (blue curve) and normilized difference (red curve) with the age of the cluster according to STARBURST99 model.

In Fig. 3 we plot the regions with negative value of Ha-FUV (older than 9 Myr) in blue colors and with positive value (younger than 9 Myr) in red for two galaxies – NGC 4068 and Holmberg II. In this figure one may observe that at the scales of individual giant HII regions the current star formation (red) closely related to the bright in FUV blue regions where the active star formation recently occurred. We may consider this map as an evidence of the star formation triggering there.

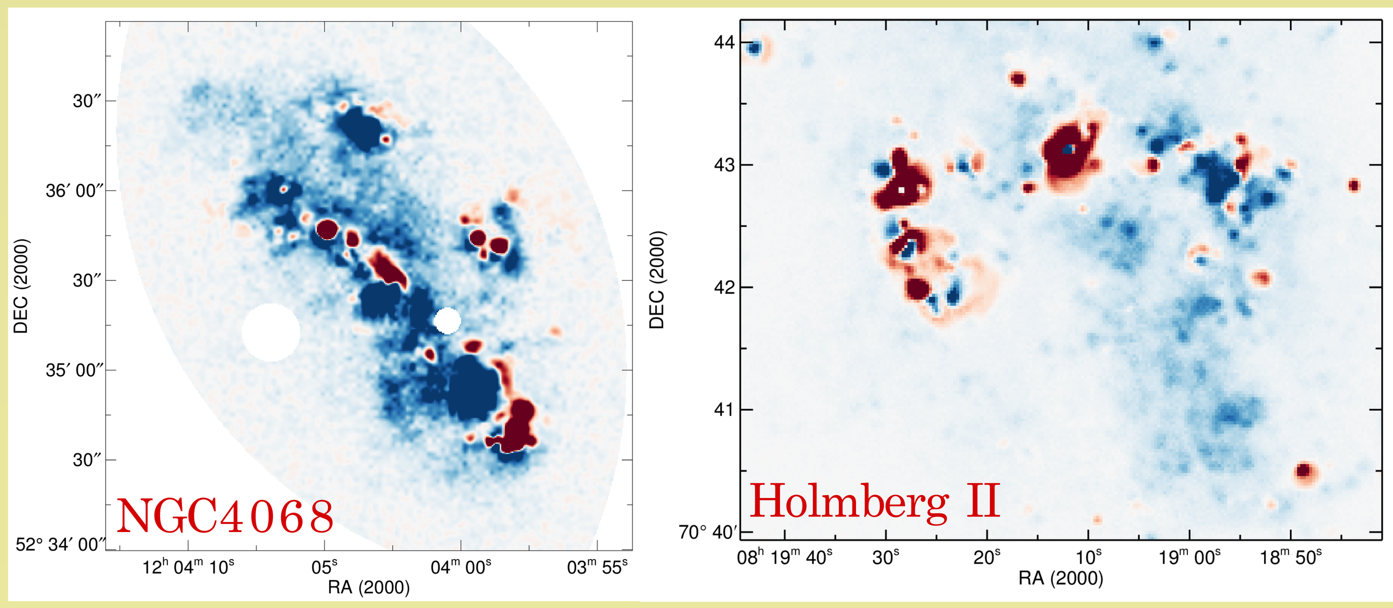
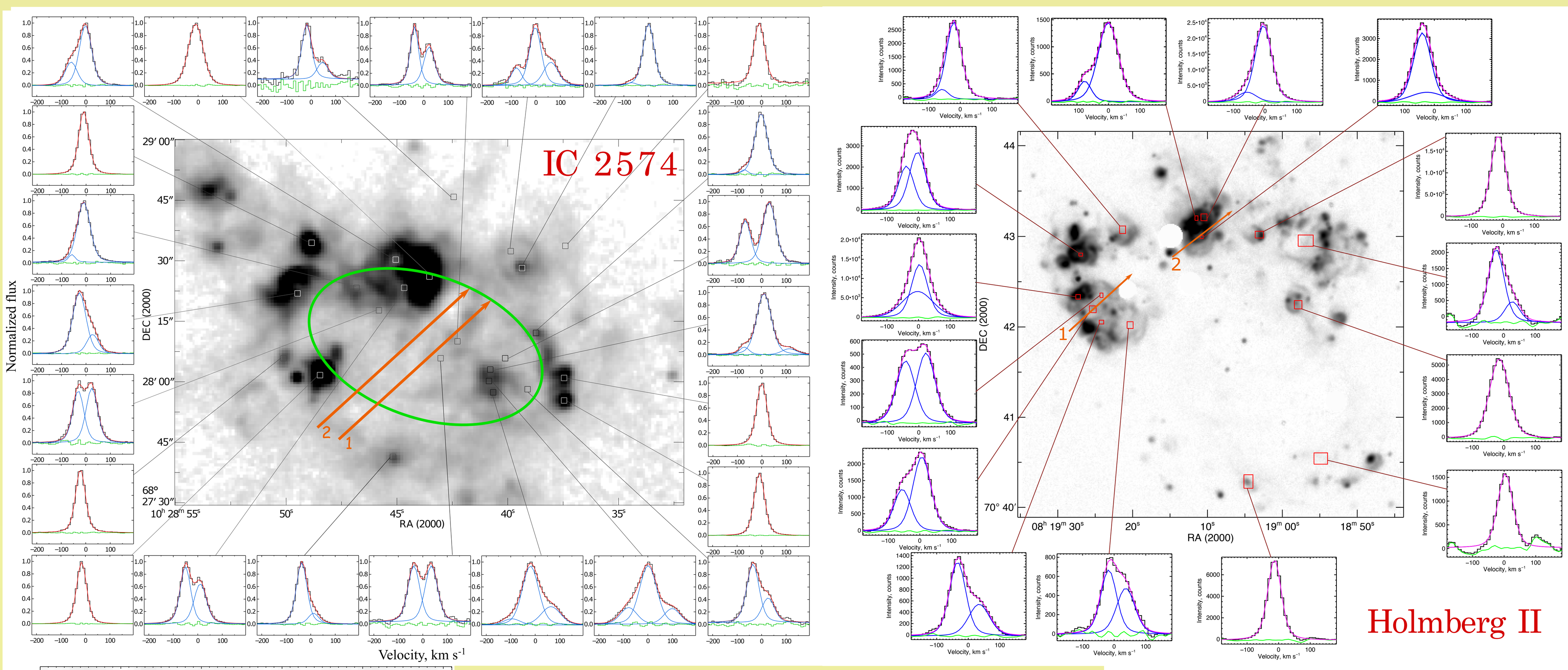


Fig.3: Map of the H-alpha and FUV fluxes difference for NGC 4068 and Holmberg II galaxies. Red color denotes the regions with dominated H-alpha emission while blue color traces the ones with suppressing contribution of FUV emission.

Ionized gas kinematics in IC 2574 and Holmberg II: how ongoing star formation influences to "parrent" HI supergiant shell?

The ionized gas kinematics is very perturbed in overall regions of ongoing star formation in both galaxies. Perfomed analysis of H-alpha data cubes obtained with scanning Fabry-Perot interferometer revealed that two- or three-component H-alpha line profile is a common feature for many ionized structures in these galaxies. We found clear evidences of expansion with velocities up to 80 km/s for 6 relatively bright HII regions in IC 2574 galaxy and for 22 faint shell-like emission structures in Holmberg II.

How the ongoing star formation influence to the "parrent" HI supergiant shell, where it took place? Qualitively, we may propose that stellar feedback from the new sight of star formation should destroy the integrity of giant HI structure that will lead to dissolution of HI there. Deep H-alpha images of both galaxies reveals a lot of faint arcs of ionized gas, which extended outside of the HI SGS. Our data reveal the very faint H-alpha superbubbles at the internal wall of the "parrent" HI supergiant shells. Most probably we observe the part of SGS ionized by escaped ionizing quanta from the bright HII regions. All these observational facts support the idea about further destruction of HI SGS at the places of ongoing star formation, but the theoretical modeling is needed to confirm that.



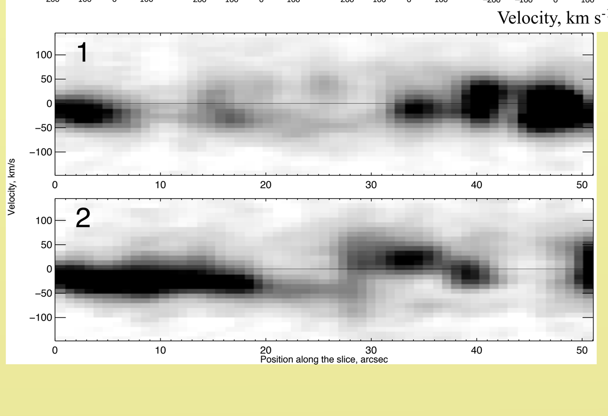
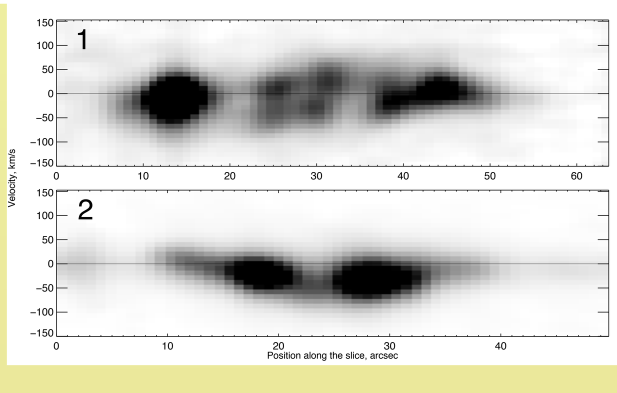


Fig.4: H-alpha distribution of IC 2574 and Holmberg II galaxies and examples of H-alpha line profiles decomposition. Red arrows denote the location of shown examples of "position-velocity" diagrams. Green ellipse on the IC 2574 image shows the border of HI SGS.



Superbubbles collision as a trigger of star formation.

The distribution of H-alpha in Holmberg II galaxy along the "parent" HI supergiant shell is not homogeneous. Most intensive star formation takes place at the north part of the SGS, while at the southern part there are only few compact HII regions. It allows us to propose that star formation at the north side of SGS was triggered by its collision with adjacent supergiant shells. One of the best examples where the superbubbles collision led to the burst of star formation is IC 1613 (see Fig.1 and the evidence of that in Lozinskaya, 2002).

In Fig. 5 we checked how the velocity dispersion of HI depends on H-alpha flux along the giant supershell in Holmberg II and IC 2574. In the case of IC 2574 velocity dispersion of HI does not depend on H-alpha flux, while for the Holmberg II galaxy there is a clear trend to increase of HI dispersion with F(Ha). Probable explanation of the dependence in the case of Holmberg II is that the supergiant shells collision have led to increase of the turbulence of neutral hydrogen, that in turn triggered star formation.

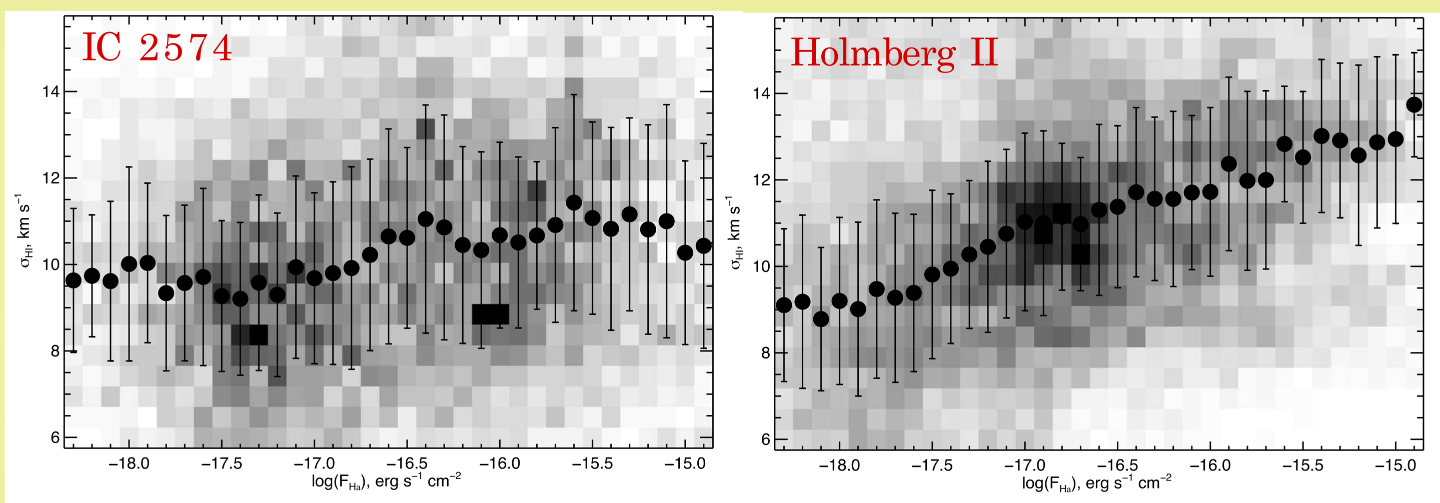


Fig.5: HI velocity dispersion vs H-alpha flux for IC 2574 and Holmberg II galaxies

Summary

Star formation in the rims of HI supergiant shells is a common for many nearby galaxies. We suppose that supershells collision might be an important to trigger star formation there. In turn, feedback from new sights of star formation influences to ISM and probably leads to partial destruction of HI supergiant shell. Here we present some of observational results that support these idea. For more details about the study of IC 2574 and Holmberg II galaxies please see our recent paper Egorov et al. (2014) and forthcoming paper Egorov et al. (2016).

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