Multiwavelength view on stellar feedback and gas kinematics in nearby dwarf galaxies

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VOLGA
View On the Life of GAlaxies

dIrr galaxies as a good laboratory

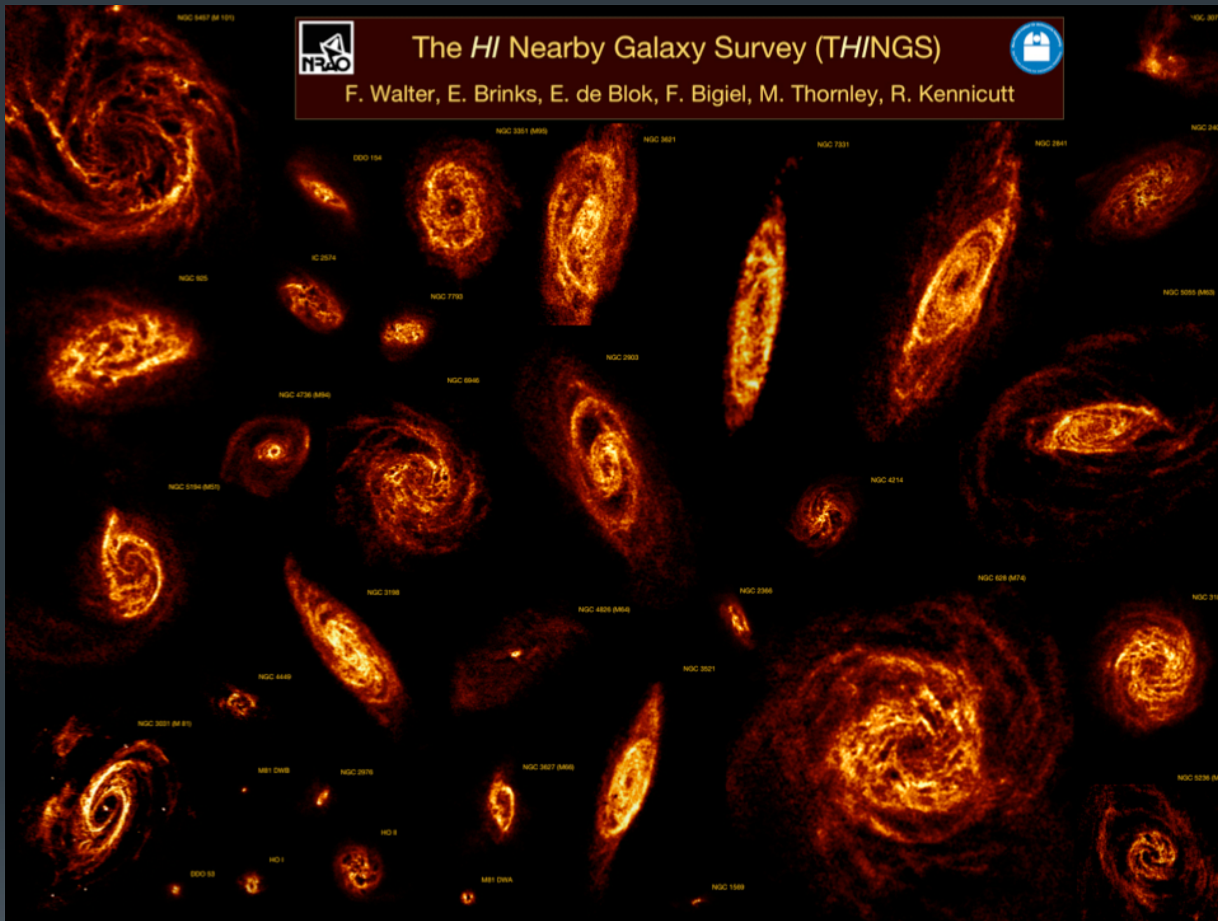
- They are gas rich
- Have a thick gas disc
- … a shallow potential
- … and a lack of spiral density waves.

Due to that the stellar winds and supernovae may create a large (up to several kpc sized) long-lived complexes of multiple shells, supershells and filaments.

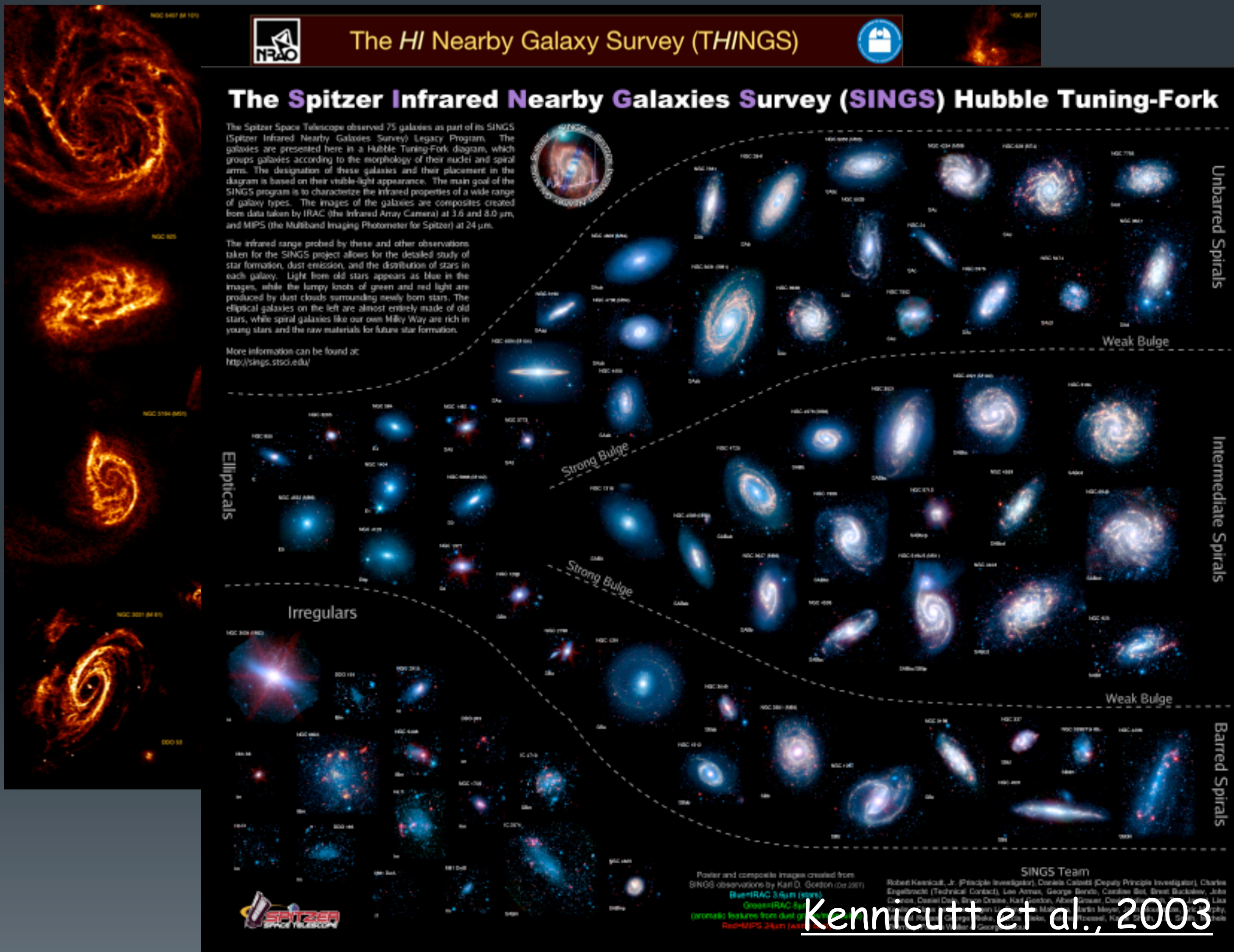
Hence dIrr galaxies provide a good opportunity to study the stellar feedback influence to ISM.

- We study how the ongoing star formation influences to the gas and dust components of ISM using multiwavelength observations of nearby dIrr galaxies.

You may find dIrr galaxies in a lot of things…

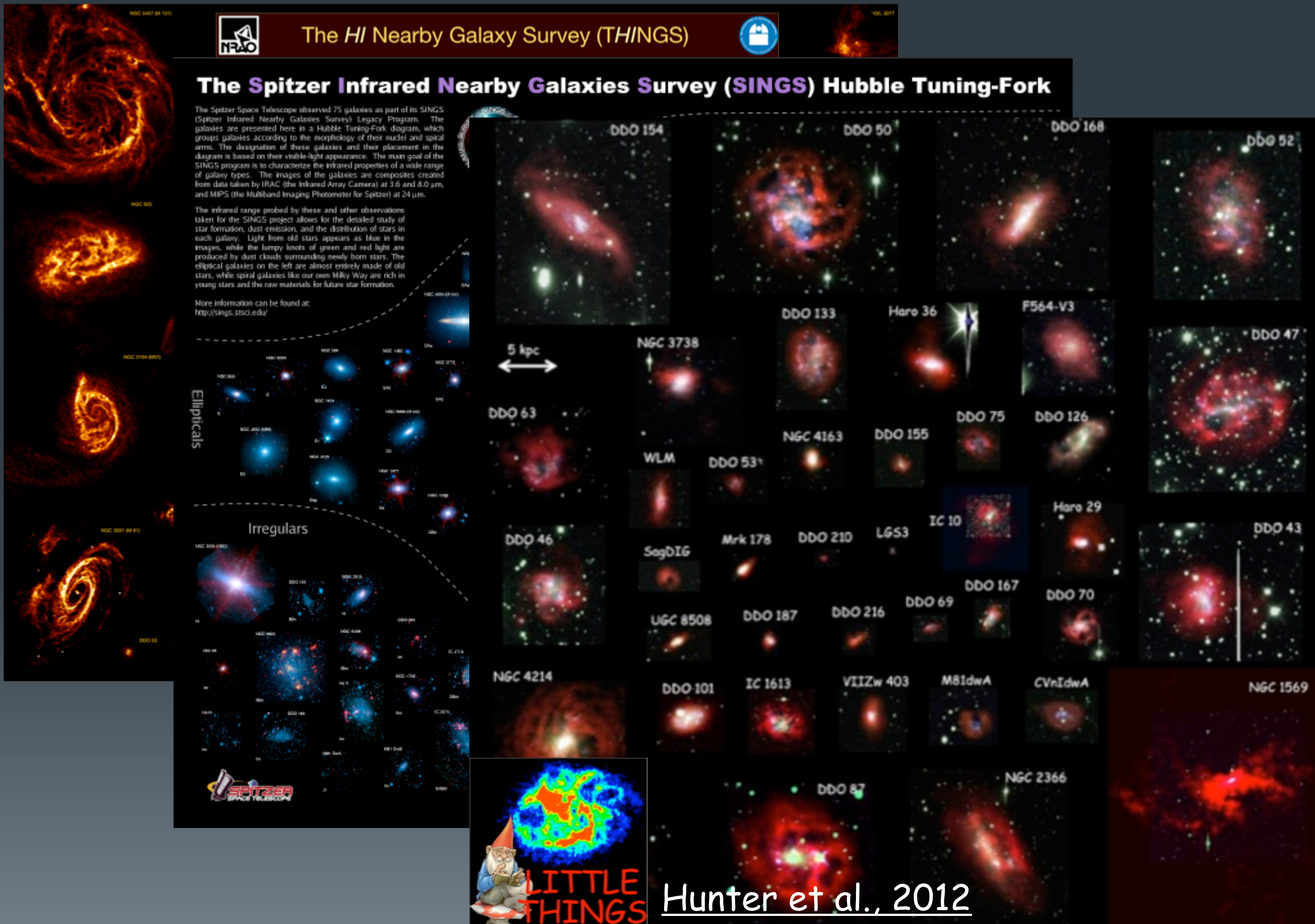


You may find dIrr galaxies in a lot of things…



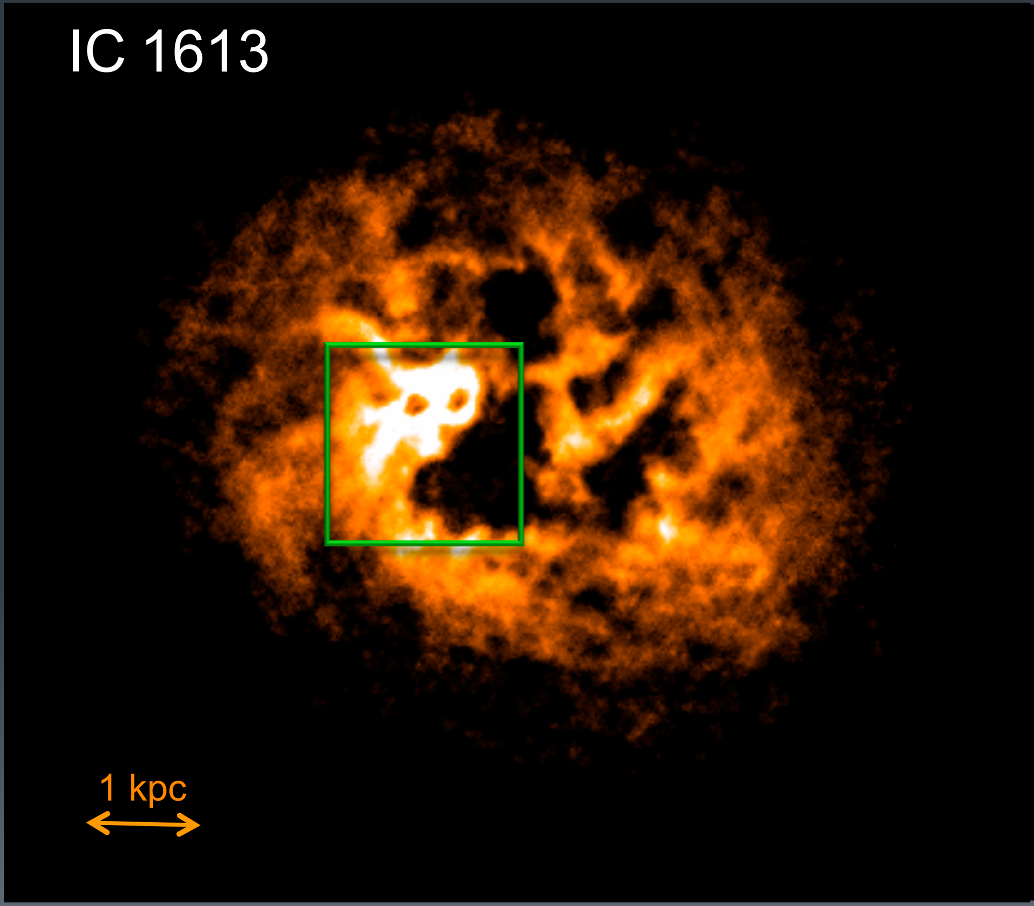
Kennicutt et al., 2003

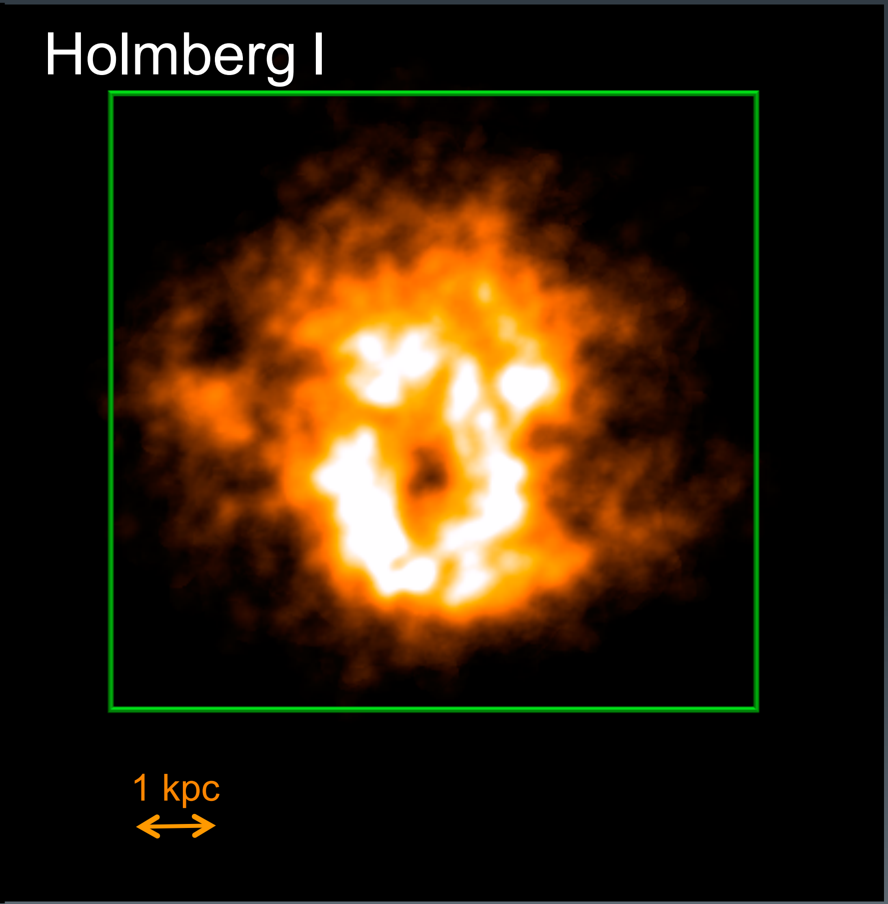
You may find dIrr galaxies in a lot of things…



Hunter et al., 2012

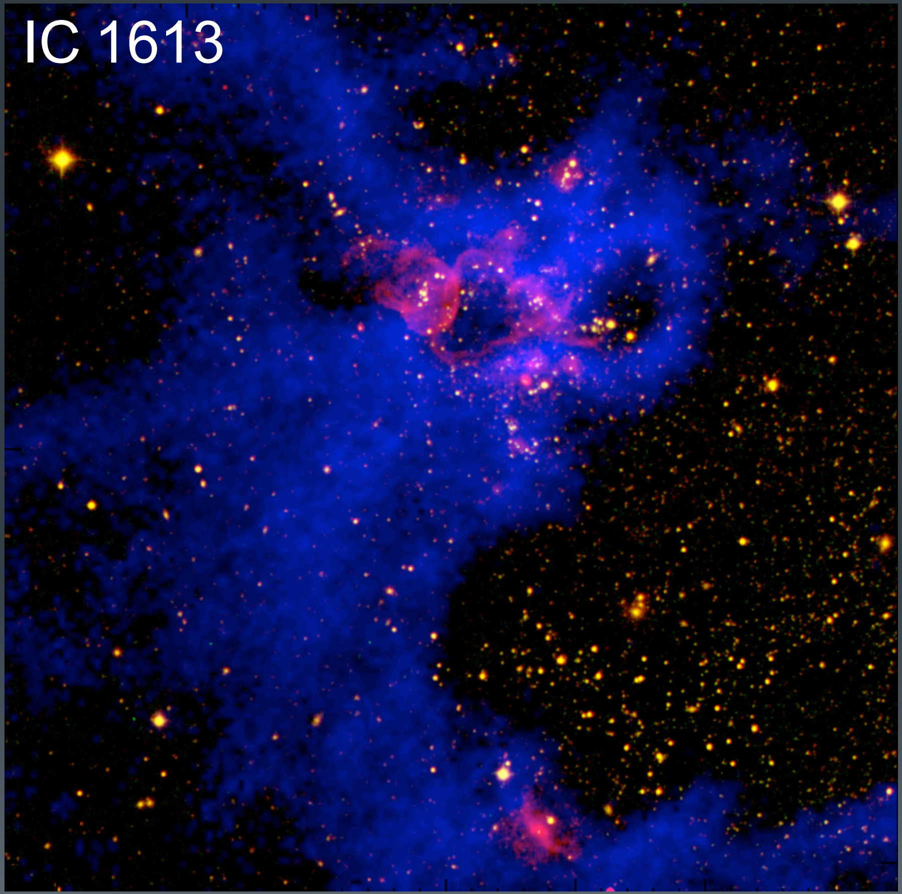
HI 21 cm distribution in dIrr galaxies

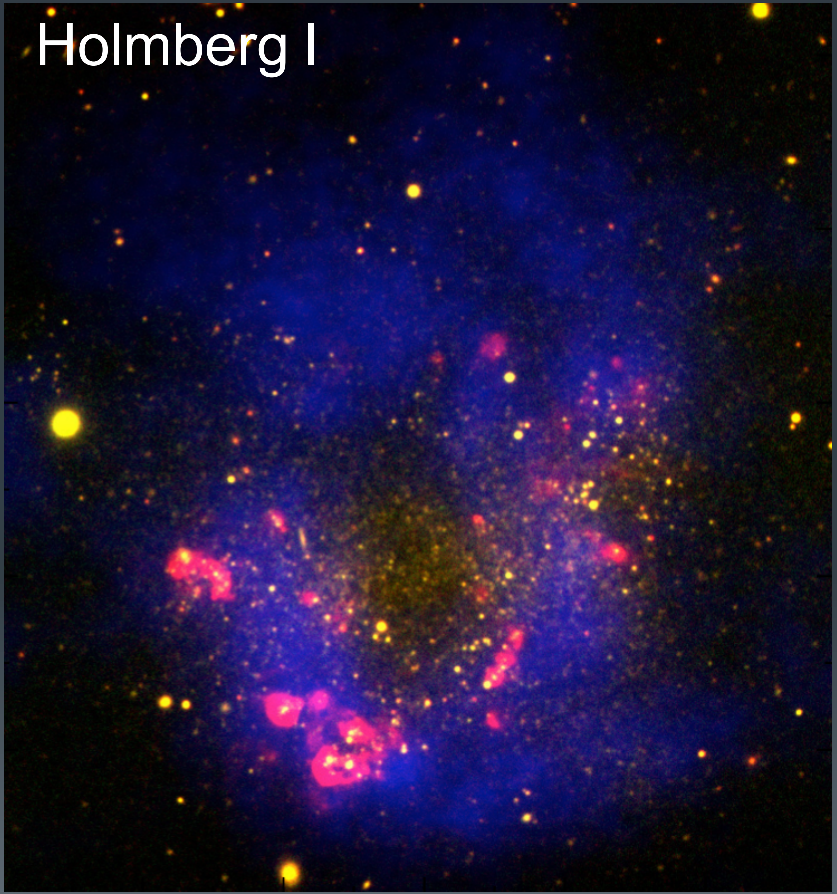




HI images reveal a lot of shell-like structures with sizes up to 1-2 kpc

Multiwavelength view on dIrr galaxies



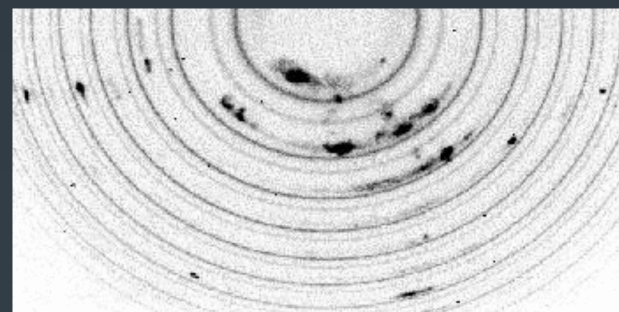


H-alpha + HI 21cm + stars

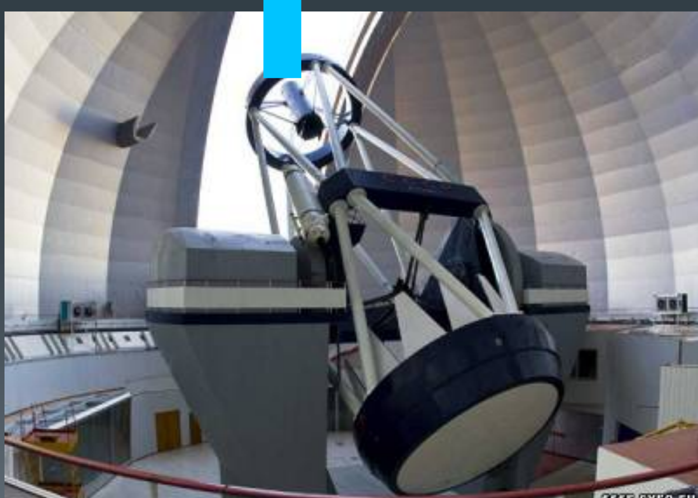
Ongoing star formation is often observed in the rims of giant HI shells.

Observations with scanning Fabry-Perot Interferometer

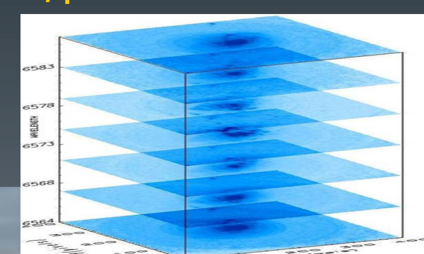
SCORPIO & SCORPIO-2 multi-mode focal reducers with scanning FPI (Afanasiev & Moiseev, 2005, 2011)



Data reduction:
Moiseev (2002)
Moiseev, Egorov (2008)
Moiseev (2015)

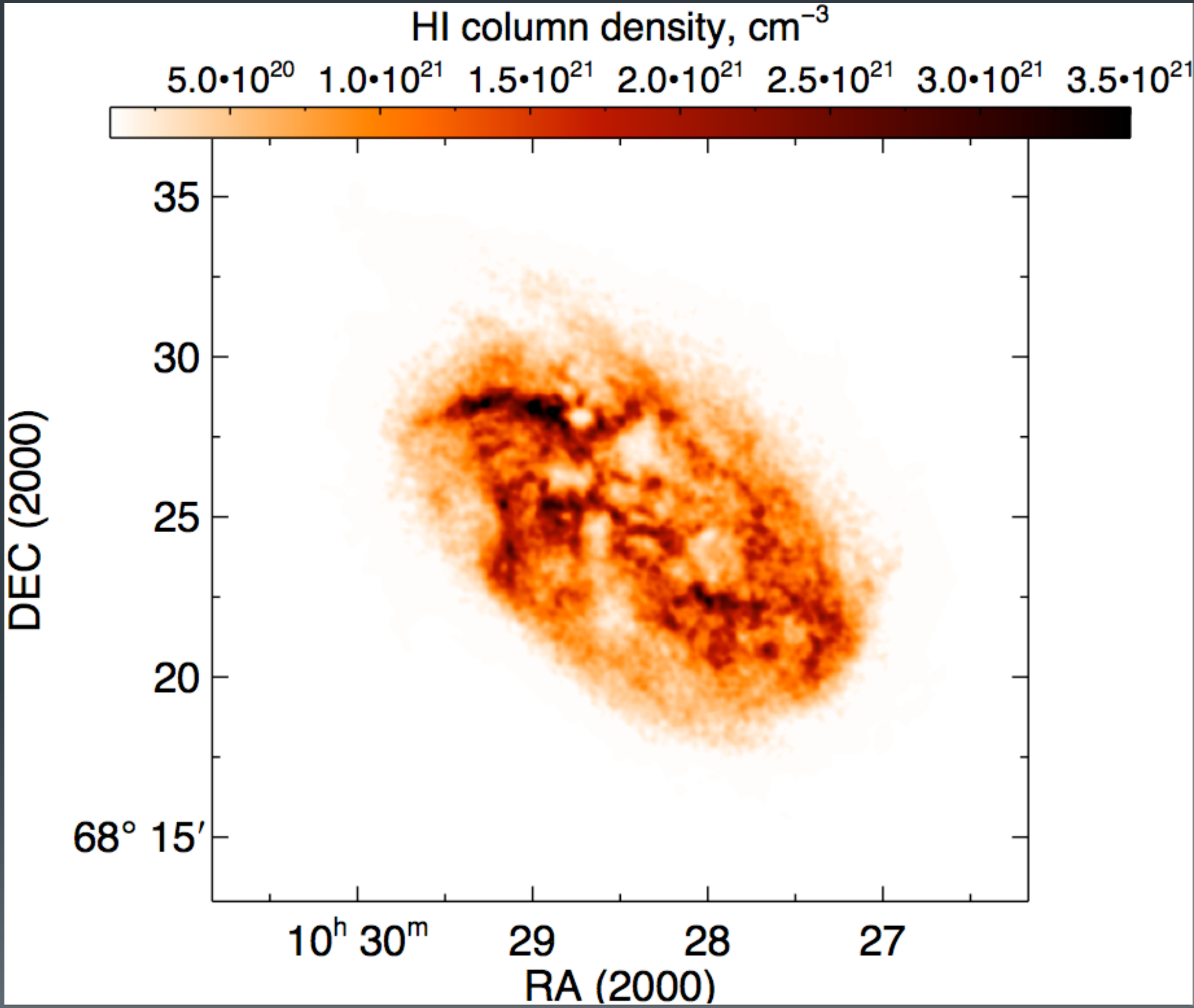


Field of view: 6.1x6.1 arcmin
Spectral range: Hα, [NII], [OIII] and [SII] emission line
Spatial sampling: 0.35-0.70 arcsec/px
Spectral resolution:
R=4000 - 15000
σ= 8.5 - 30.0 km/s



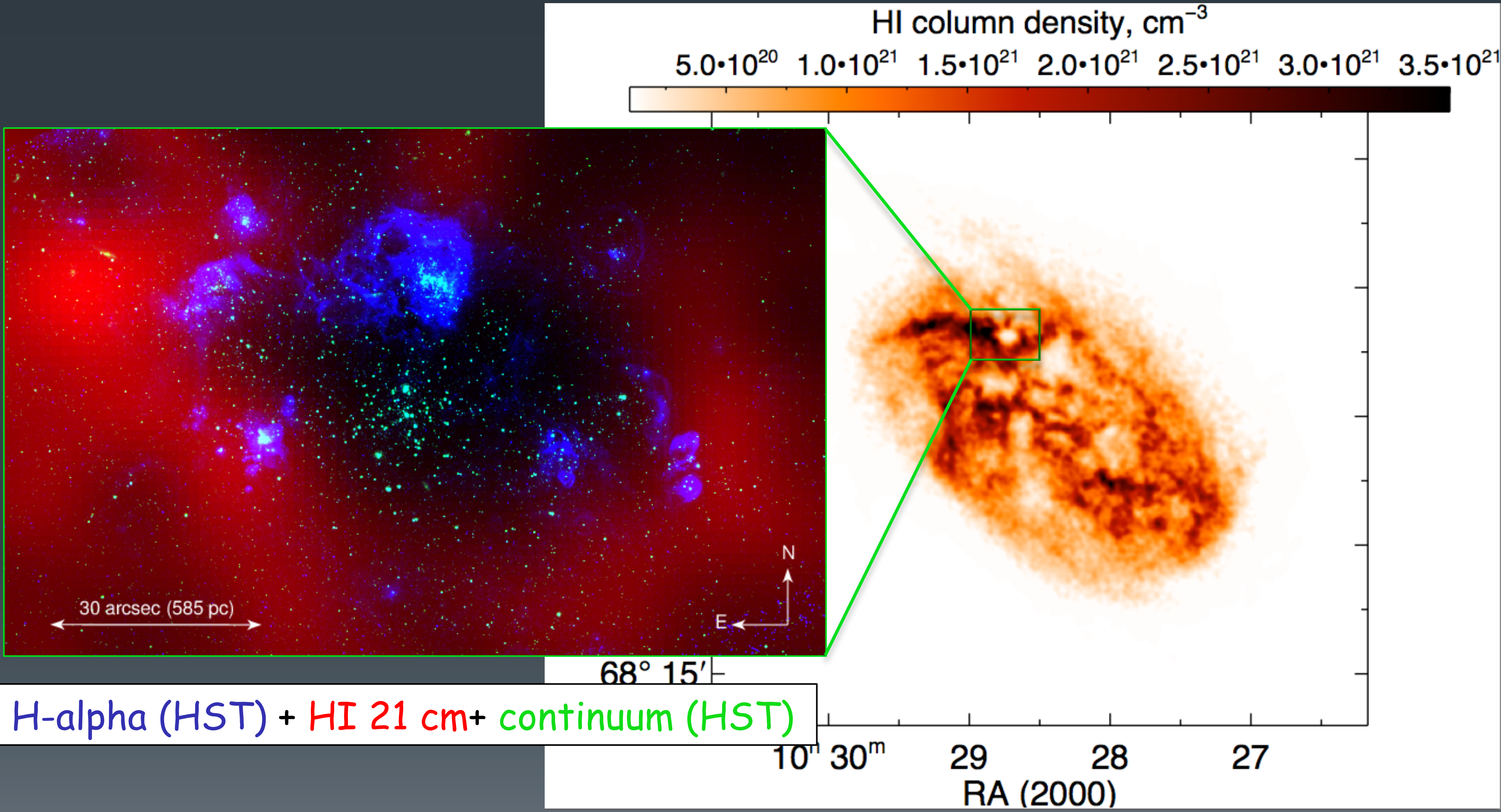
IC 2574: Supergiant shell (SGS)

- The member of M81 group
- Distance = 4 Mpc
- A lot of HI holes and supershells in neutral gas distribution
- Ongoing star formation observed only in the rim of one SGS



Egorov et al. (2014; arXiv:1407.2048)

IC 2574: Supergiant shell (SGS)

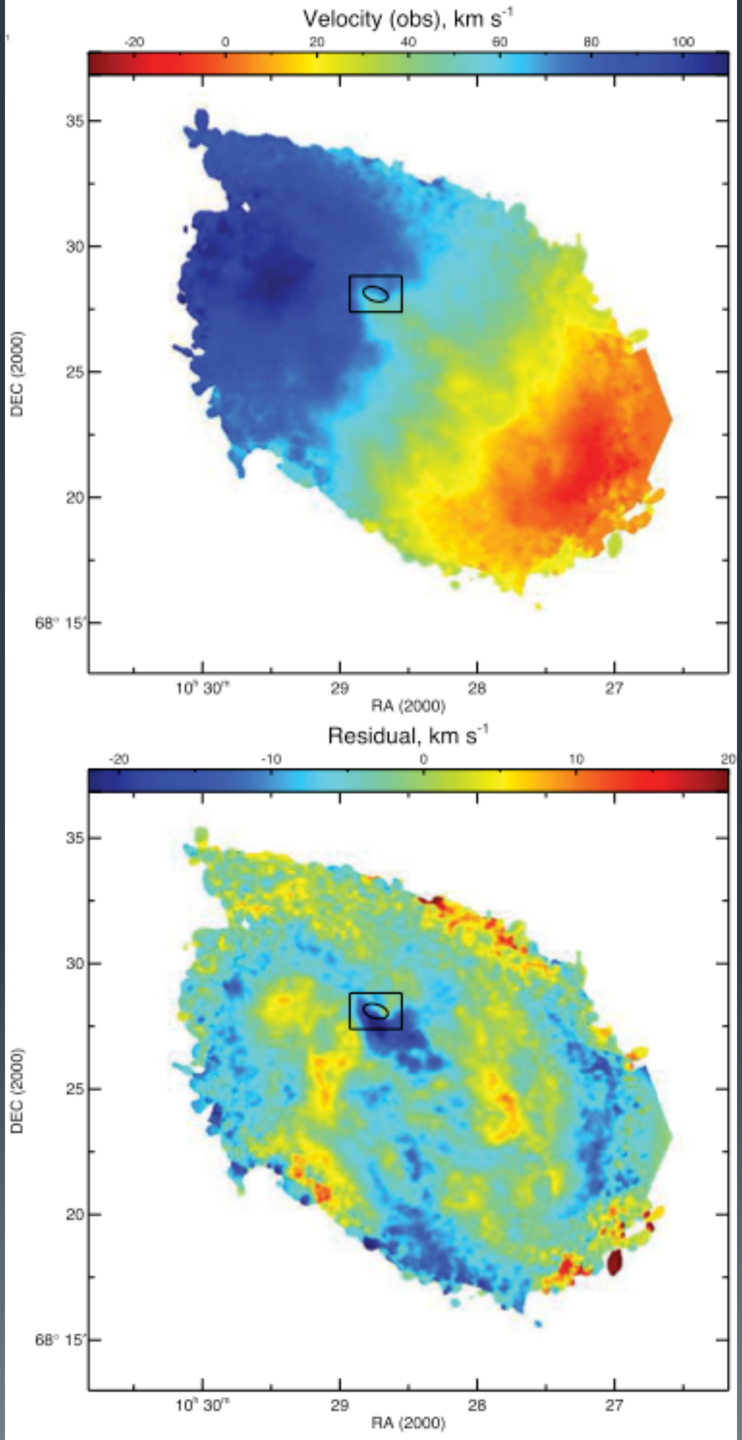


H-alpha (HST) + HI 21 cm+ continuum (HST)

Egorov et al. (2014; arXiv:1407.2048)

IC 2574: SGS

The largest perturbations of gas velocity field is observed in the direction of the region of ongoing star formation

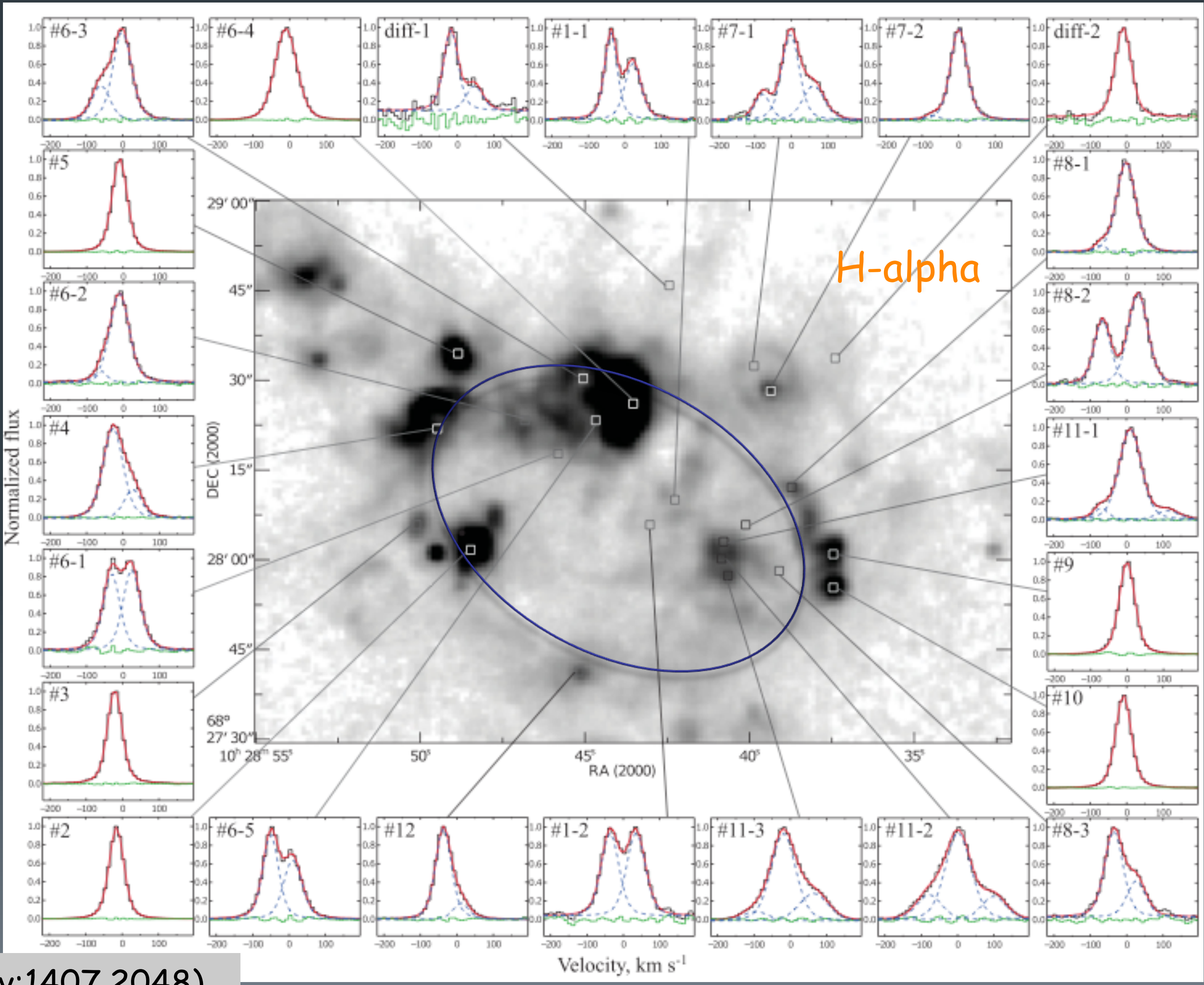


Egorov et al. (2014; arXiv:1407.2048)

IC 2574: SGS

- Perturbed complex of ionized and neutral gas kinematics observed in overall star formation region

- We detected the faint expanding H-alpha supershell never seen before in the interior of SGS



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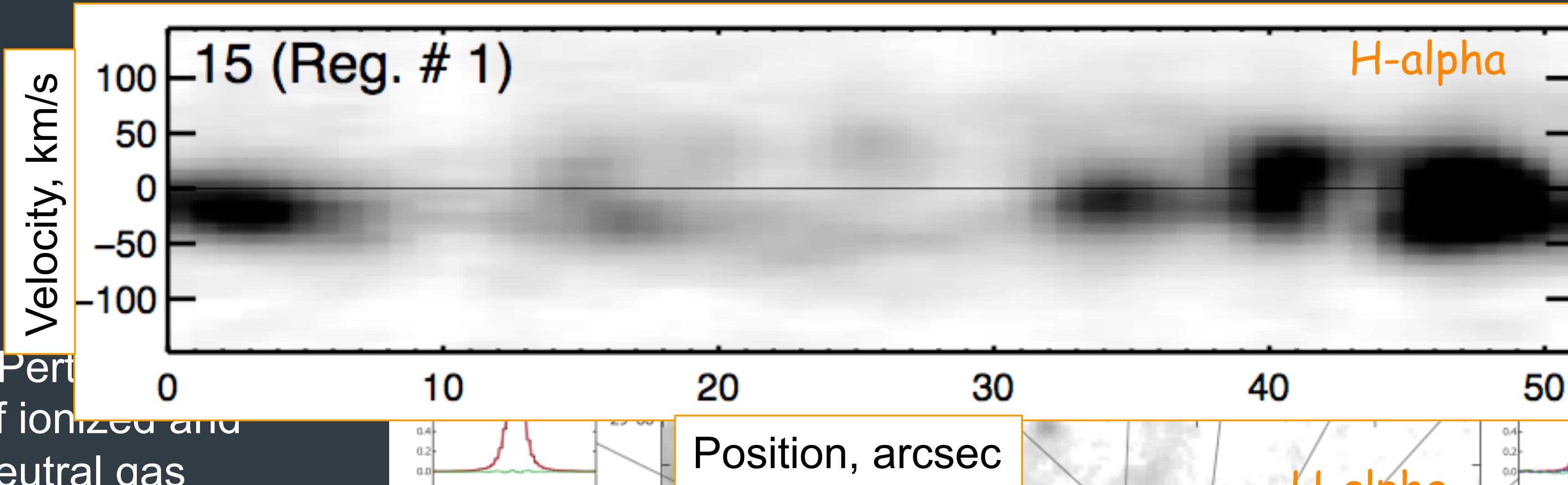
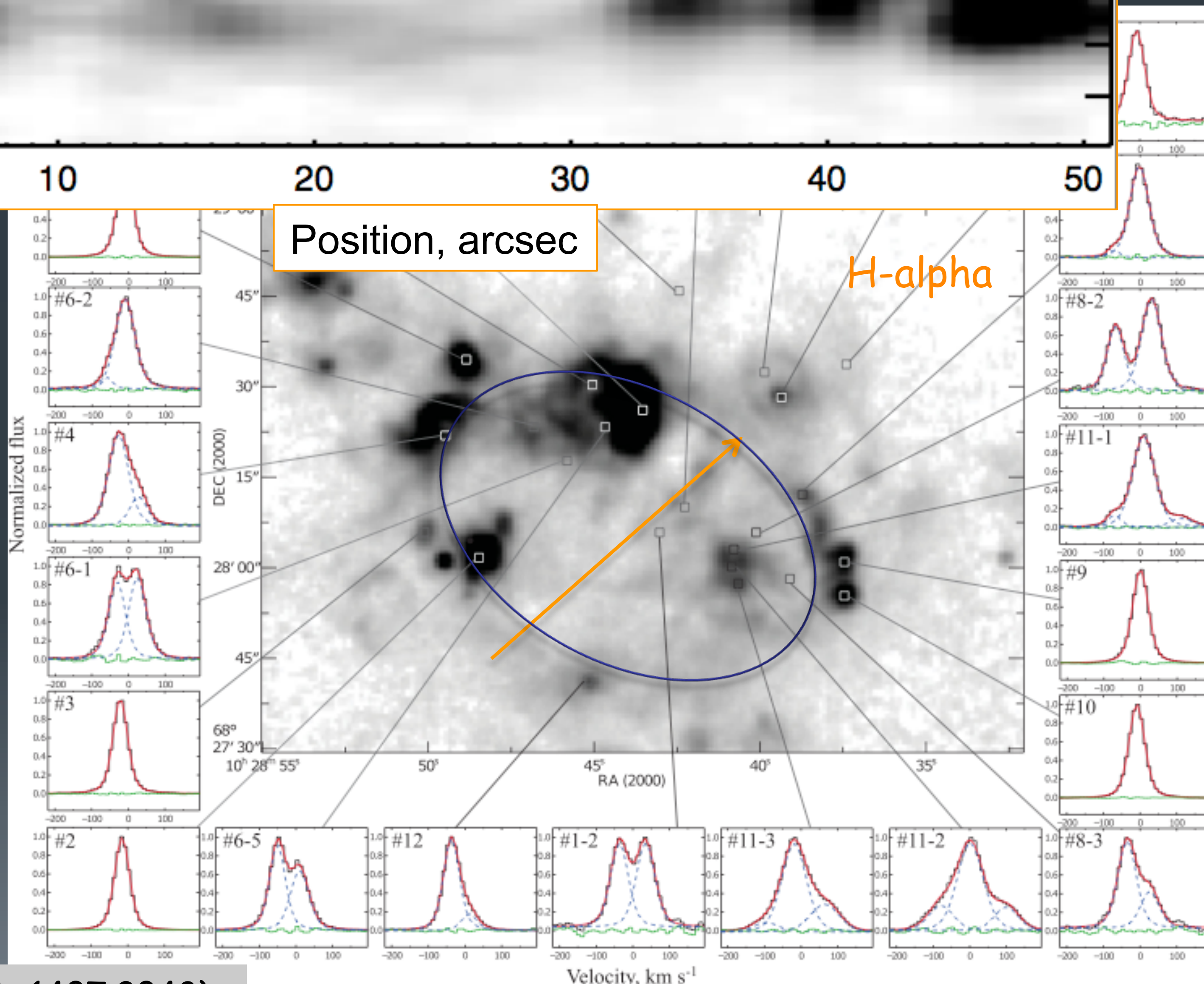
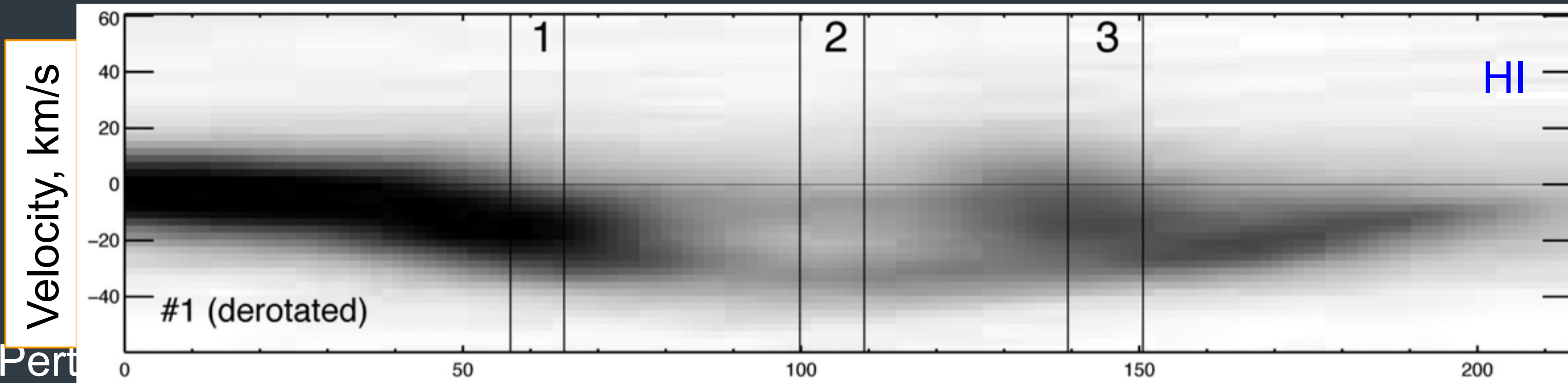




Egorov et al. (2014; arXiv:1407.2048)



- Pert
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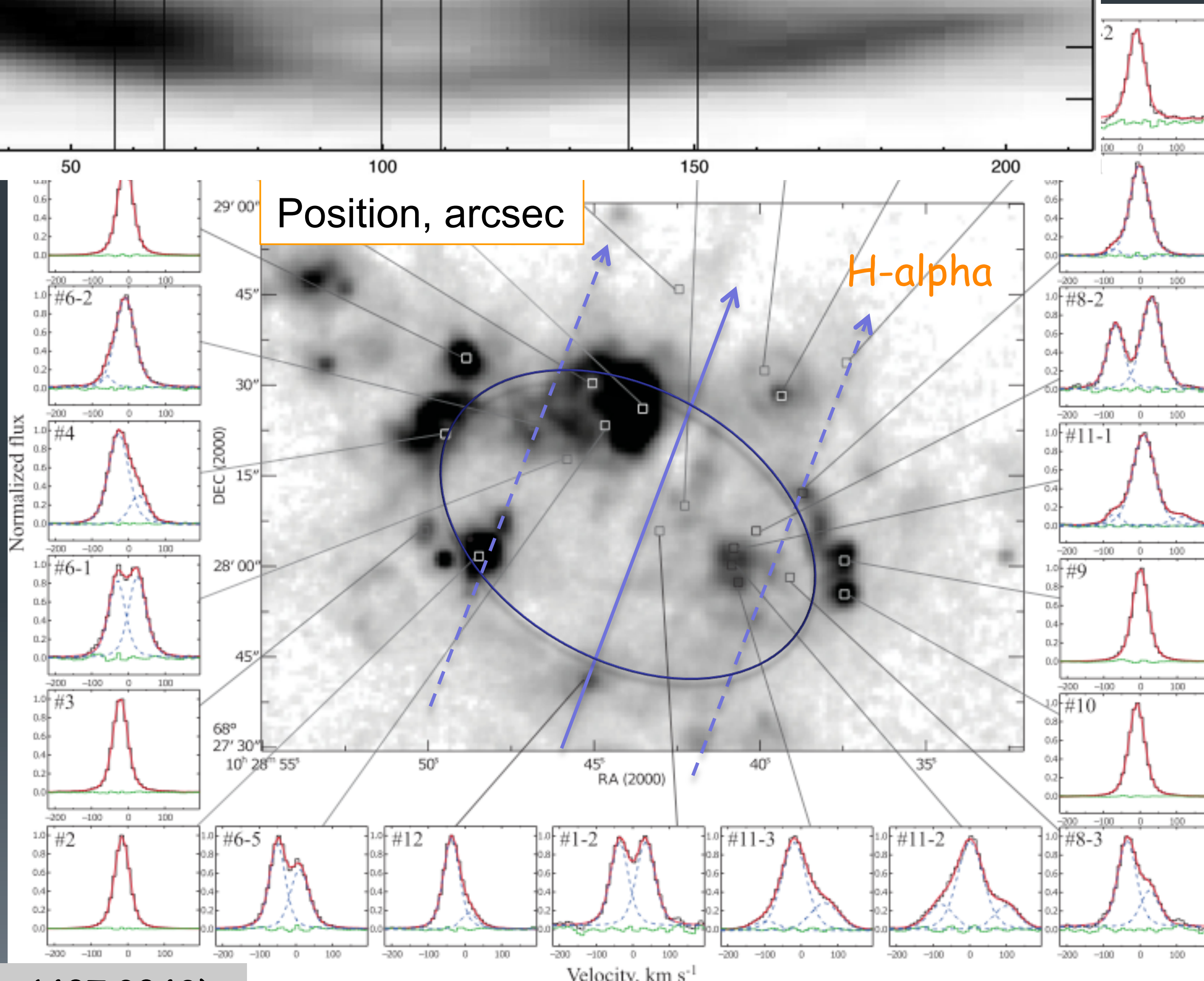


Egorov et al. (2014; arXiv:1407.2048)

IC 2574: SGS

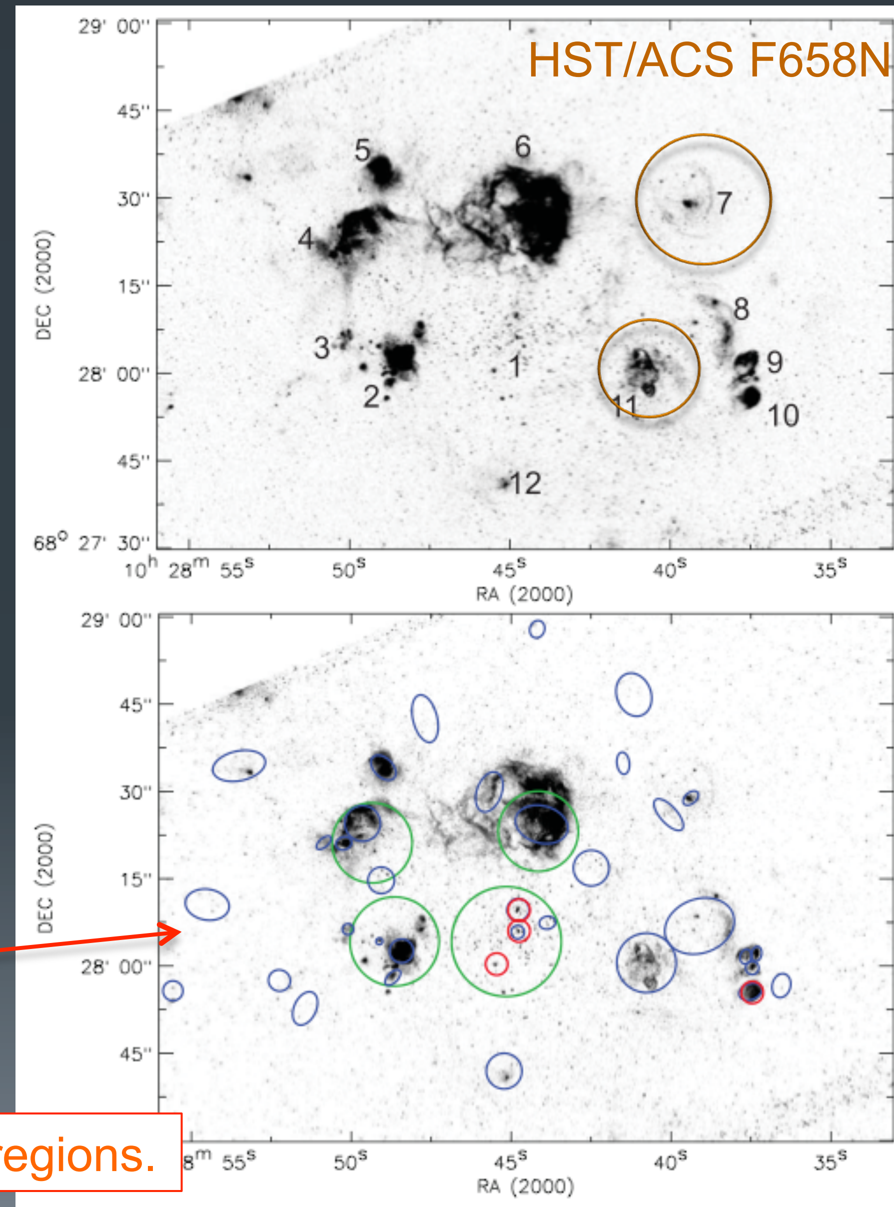
Whether the energy of winds from stellar population is sufficient for creation and driving the expansion of observed ionized shells?

According to Mac Low & McCray (1988):

$$R_s(t) = \left(\frac{125 L_w}{154\pi\rho_0}\right)^{1/5} t^{3/5} = 67 \left(\frac{L_{38}}{n_0}\right)^{1/5} t_6^{3/5}\ \mathrm{pc}$$

$$v_{exp}(t) = \frac{0.6 R_s}{t} = 39.4 \left(\frac{L_{38}}{n_0}\right)^{1/5} t_6^{-2/5}\ \mathrm{km\ s^{-1}}.$$

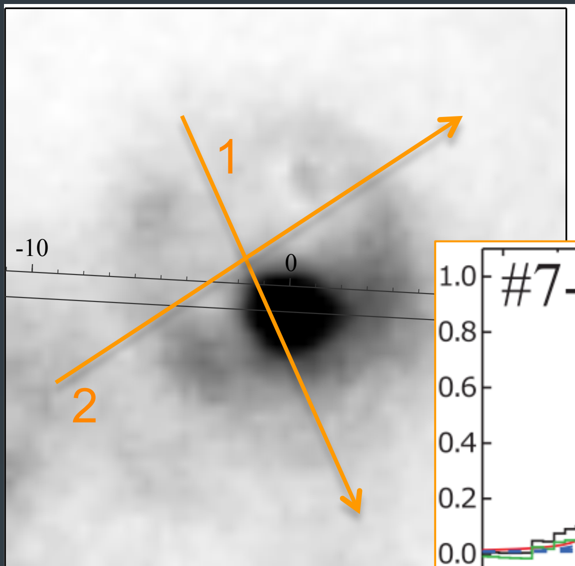
Using our FPI observations we estimated kinematic age and necessary energy input. Comparing it with the energetics of star clusters from Stewart & Walter (2000) and Yukita & Swartz (2012) =>



Yes, except two regions.

Egorov et al. (2014; arXiv:1407

IC 2574: SGS

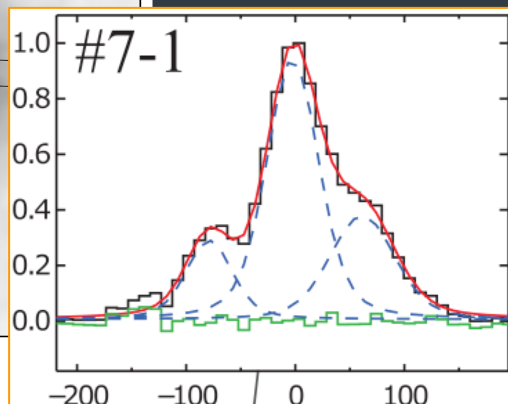


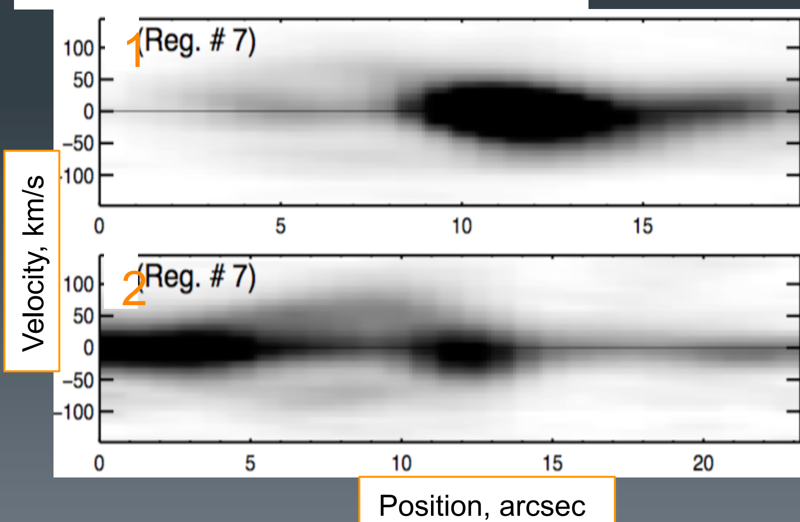
The youngest region in the area

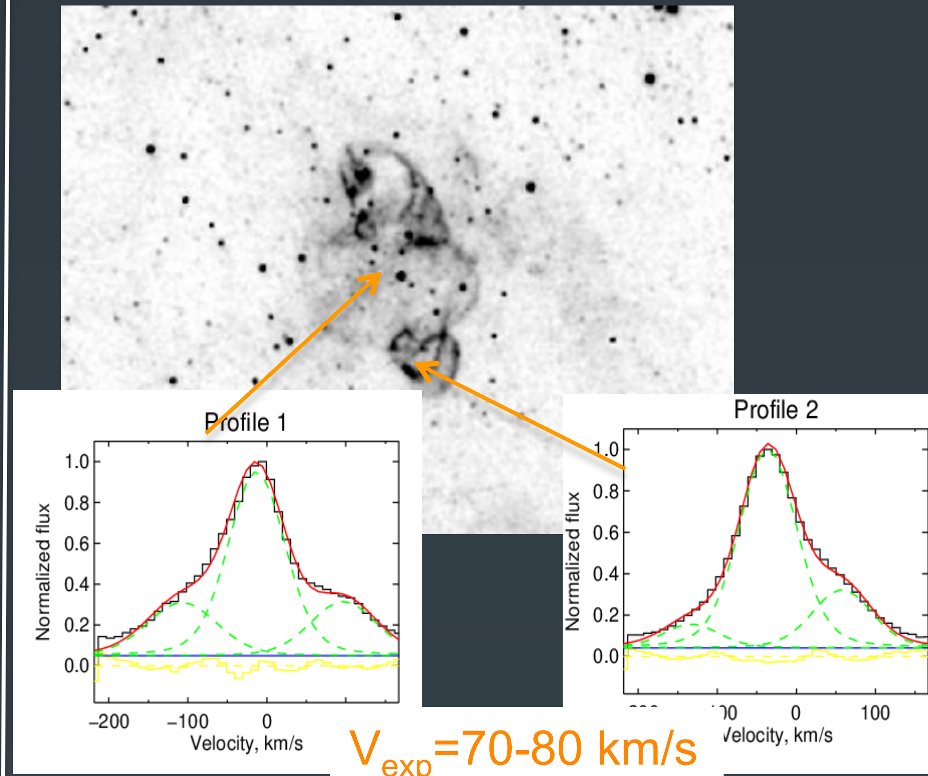
t_{kin} = 1 Myr

V_{exp} = 65 km/s

Size = 210 pc







Supernova remnant.

Following Sedov (1946) self-similar solution

$$R_s = 13.5(E_{51}/n_0)^{0.2}(t/10^4\ \mathrm{yr})^{0.4}\ \mathrm{(pc)}$$

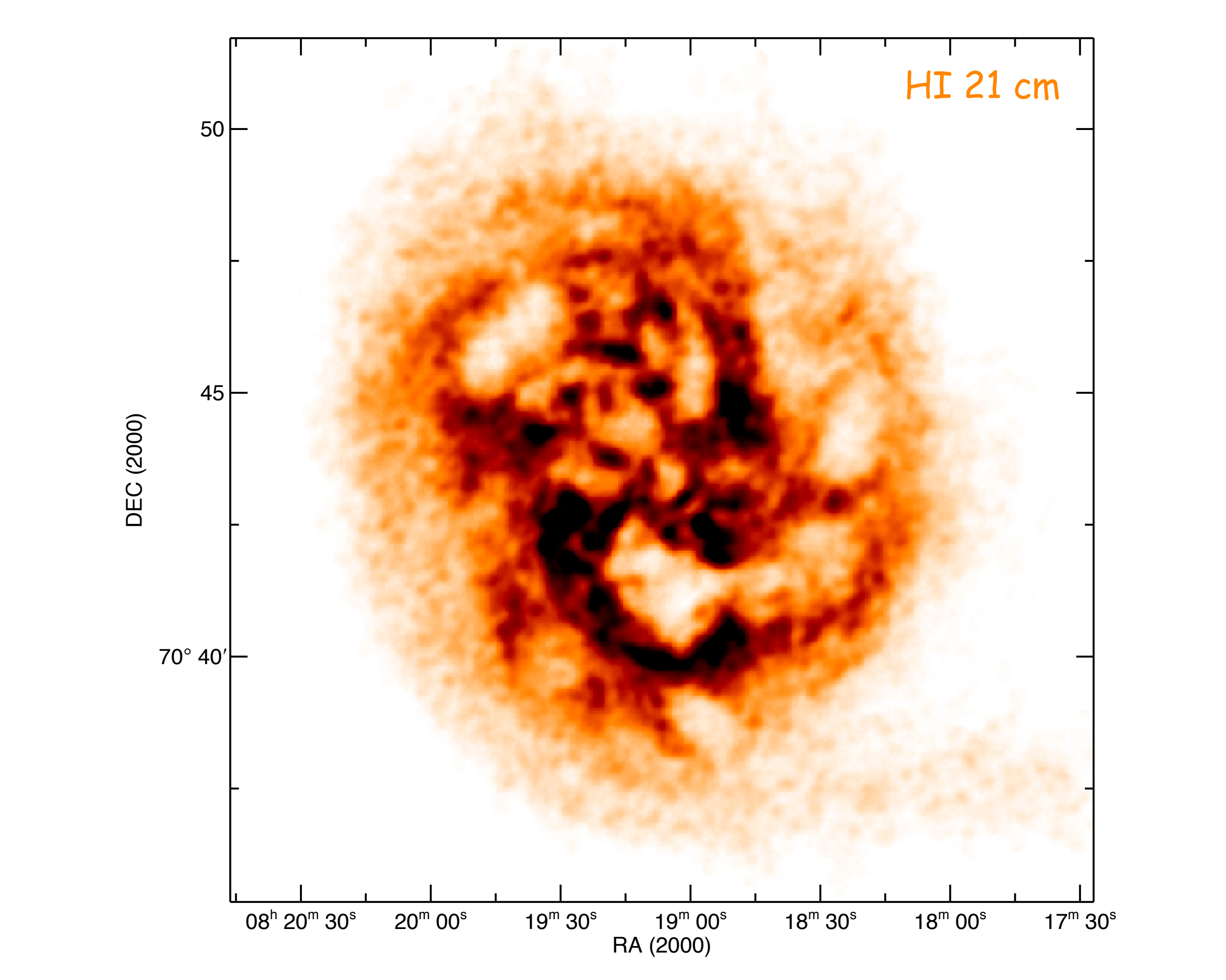
$$v_{exp} = 0.4 R_s/t,$$

Age = 0.3 Myr

Egorov et al. (2014; arXiv:1407.2048)

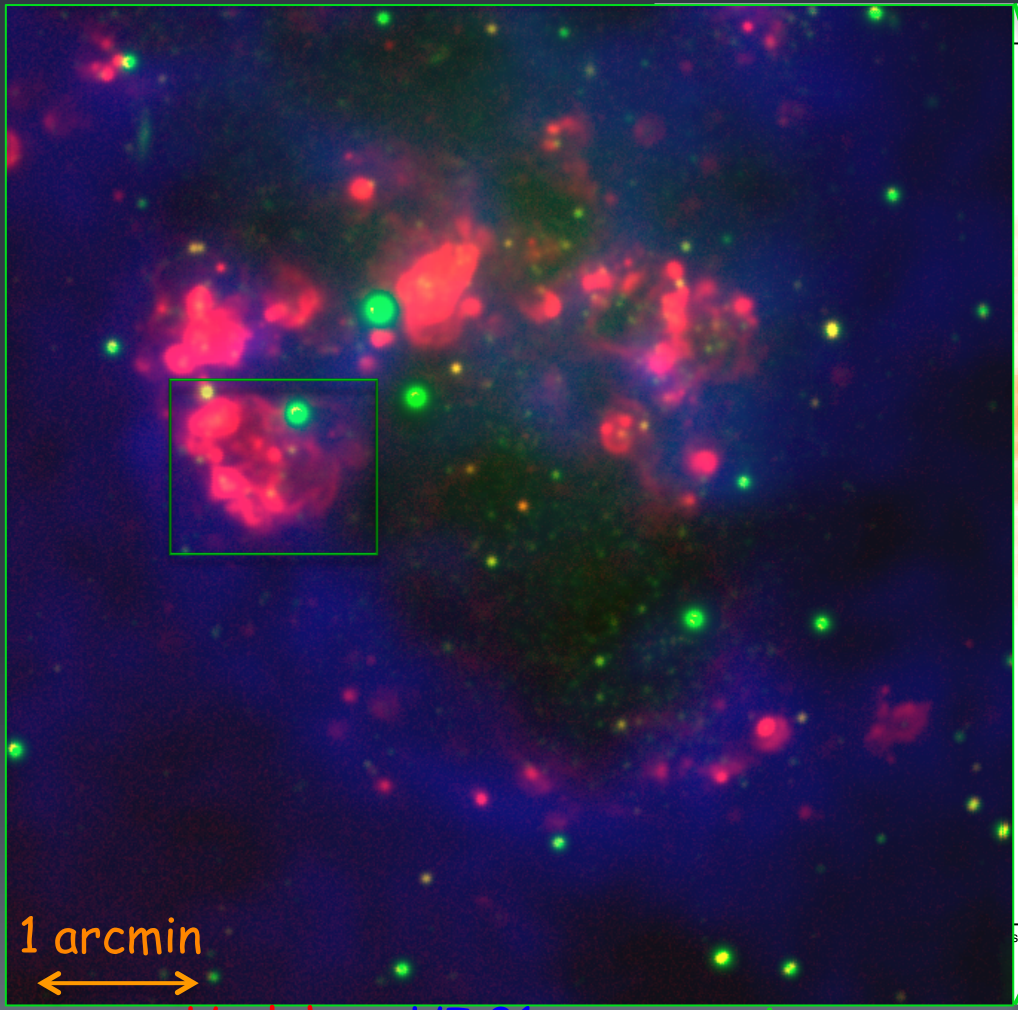
Holmberg II

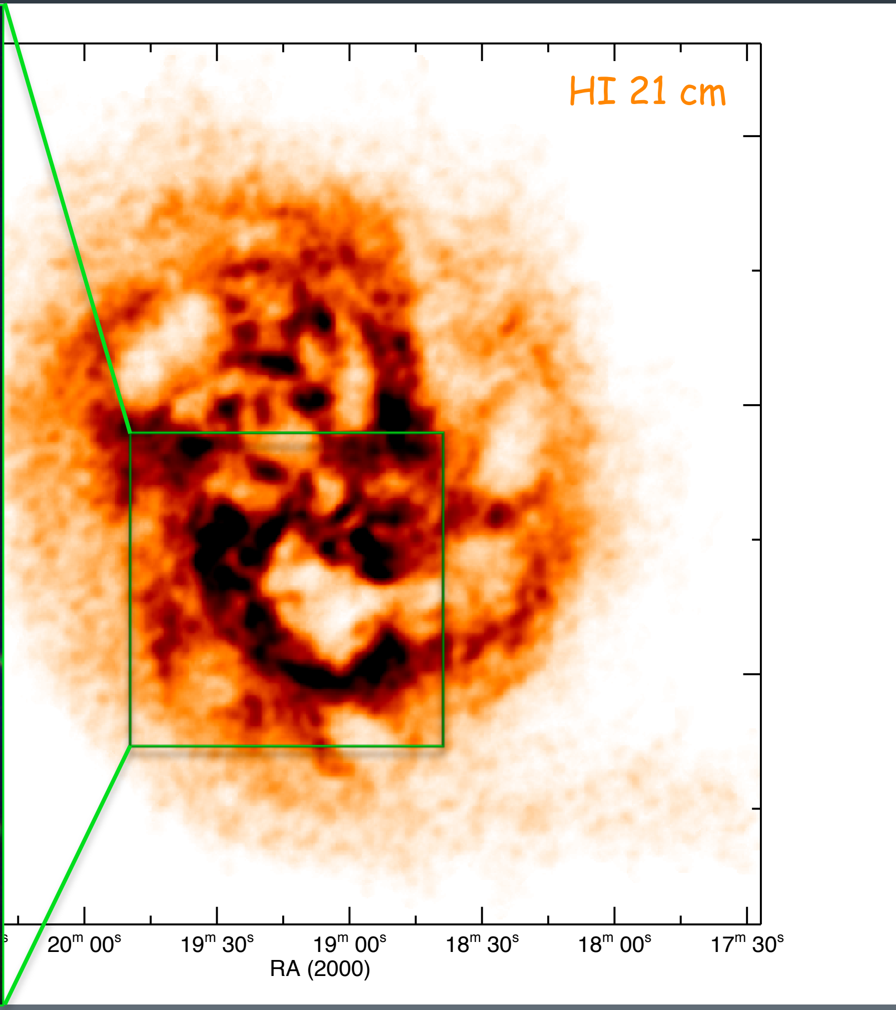
- M81 group member
- Distance 3.4 Mpc
- 51 giant HI holes and slowly expanding supershells (with sizes 1-2 kpc)
- Star formation region located in the rim of the largest HI supershell
- One of the known ULX sources is there.



Egorov et al. (in preparation)

Holmberg II



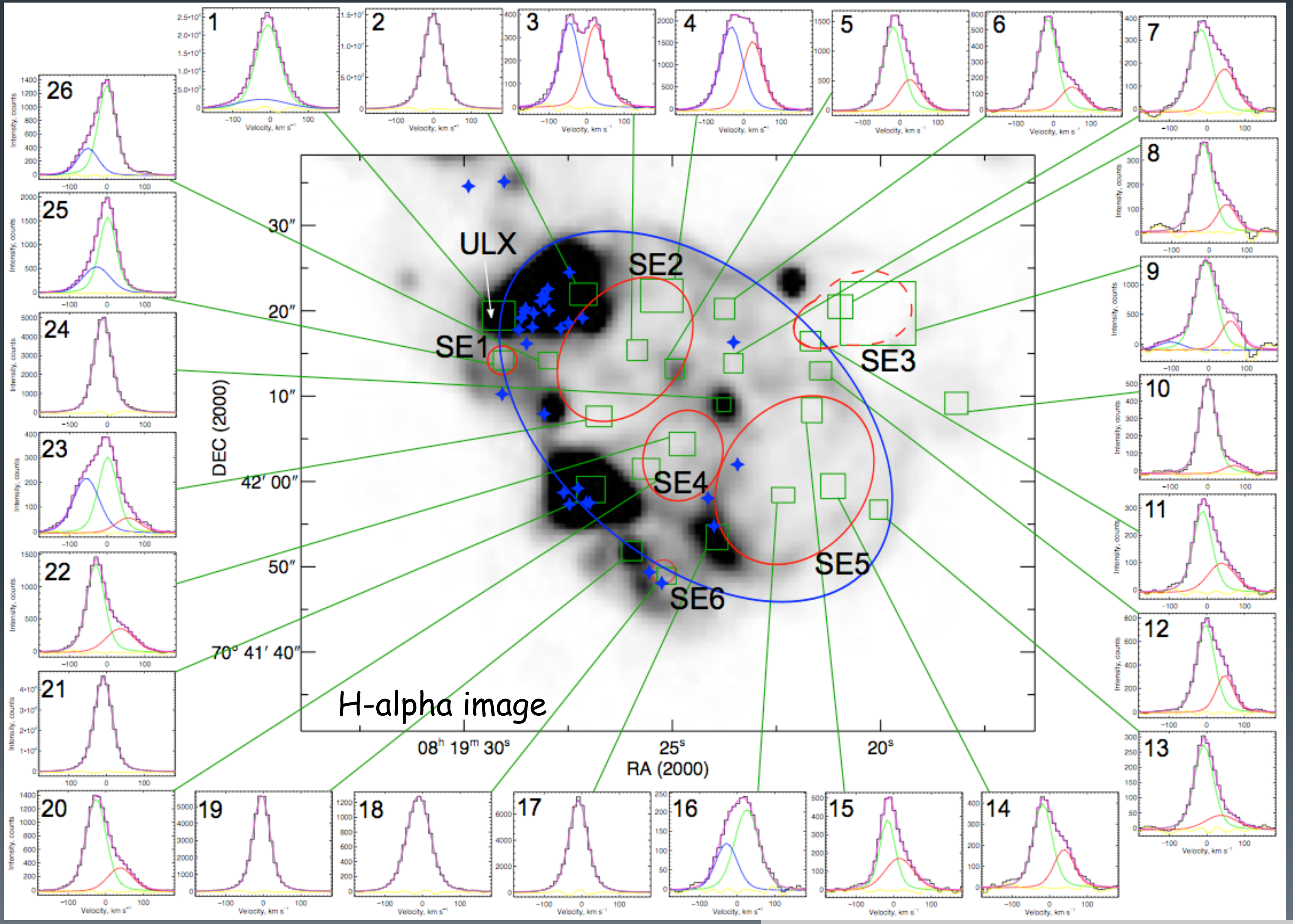


Egorov et al. (in preparation)

Holmberg II

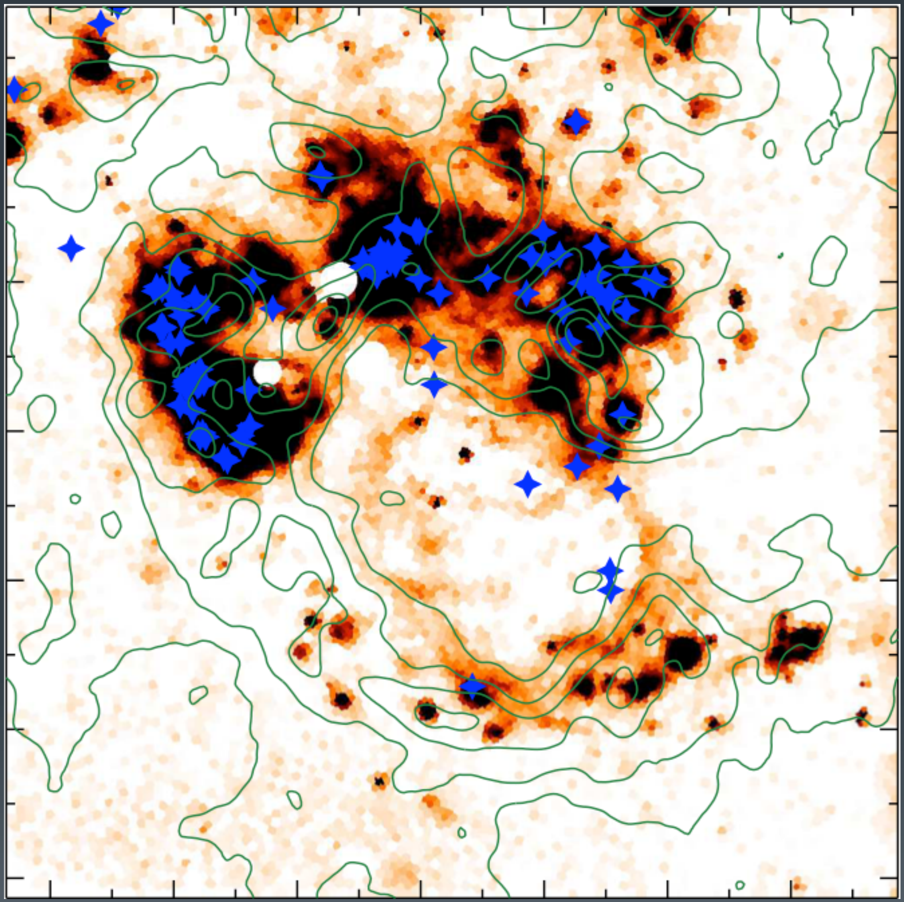
We found a lot of faint expanding ionized shell-like structures with sizes ~100-400 pc as well as the signs of HI expanding shells around star formation complexes.

It is seems that star formation in Holmberg II occurred in giant kpc-sized complexes where individual bright HII regions tied one each other with faint ionized filaments.

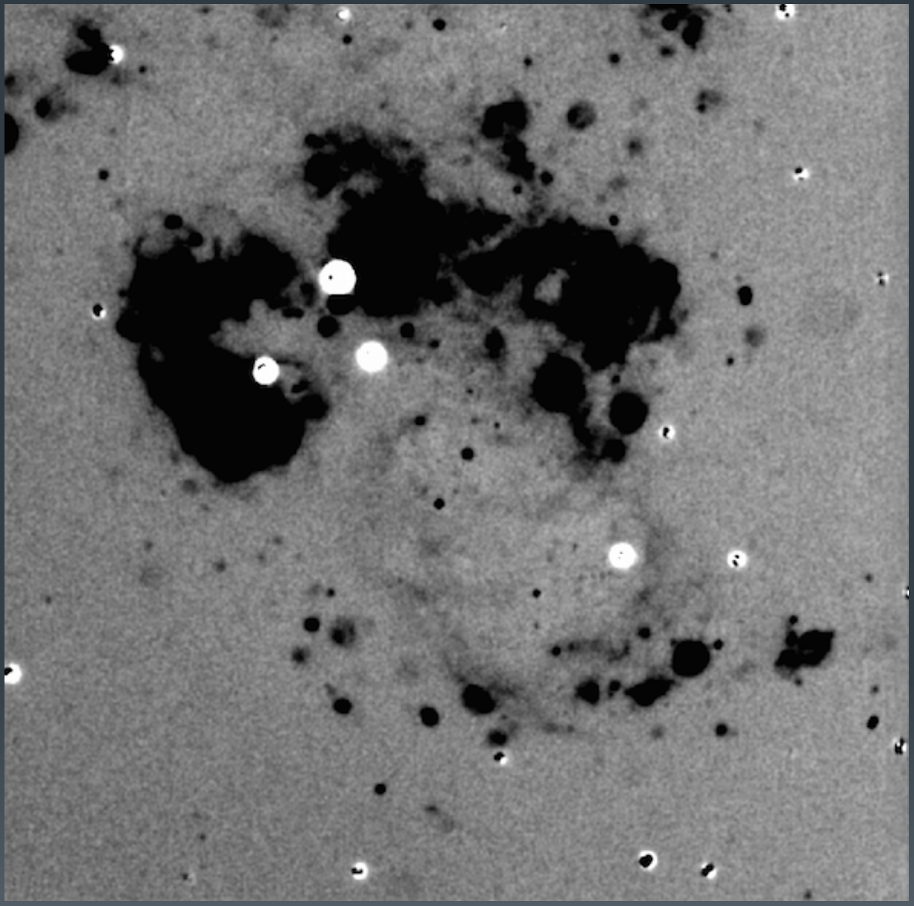


Egorov et al. (in preparation)

Holmberg II



H-alpha + OB-stars+ HI 21 cm

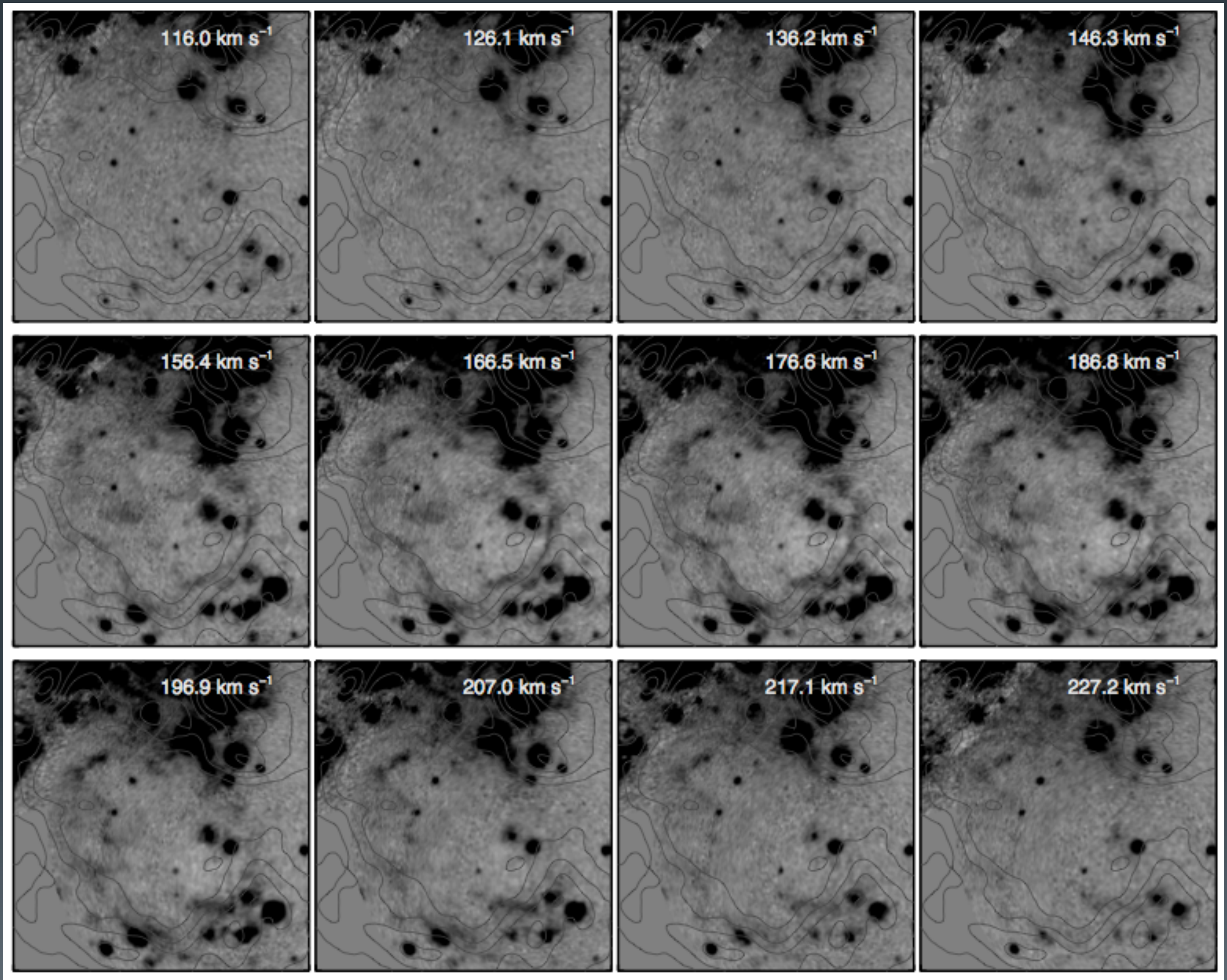


H-alpha

$I_{H\alpha} \sim 5\times10^{-19}$ erg/s/cm^2/arcsec

There are only few OB stars located inside the structure. Possibly, they are sources of this kpc-size ionized structure formation. Another possible mechanism of its formation is ionizing quanta leakage from the bright HII regions.

Egorov et. al (in preparation)

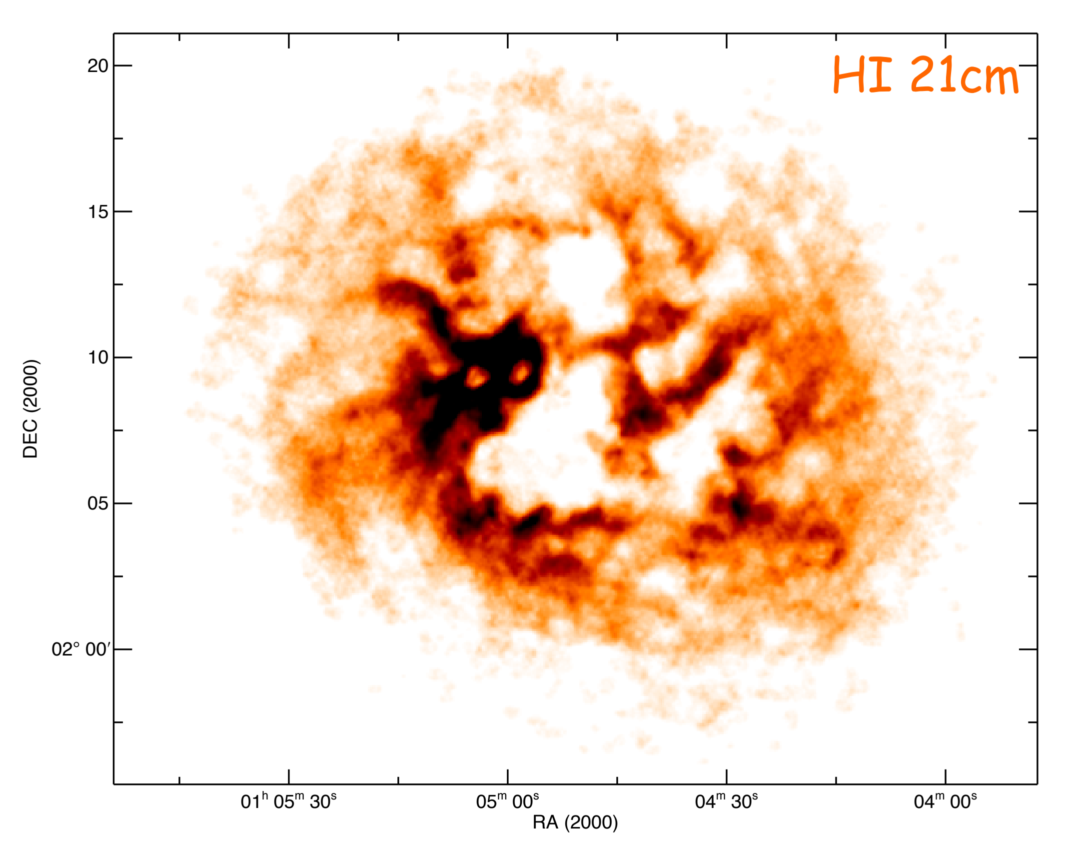


FPI channel maps in H-alpha of discovered giant ionized shell. Its expansion velocity is no more than ~10 km/s (the same as for parrent HI supershell)

Egorov et. al (in preparation)

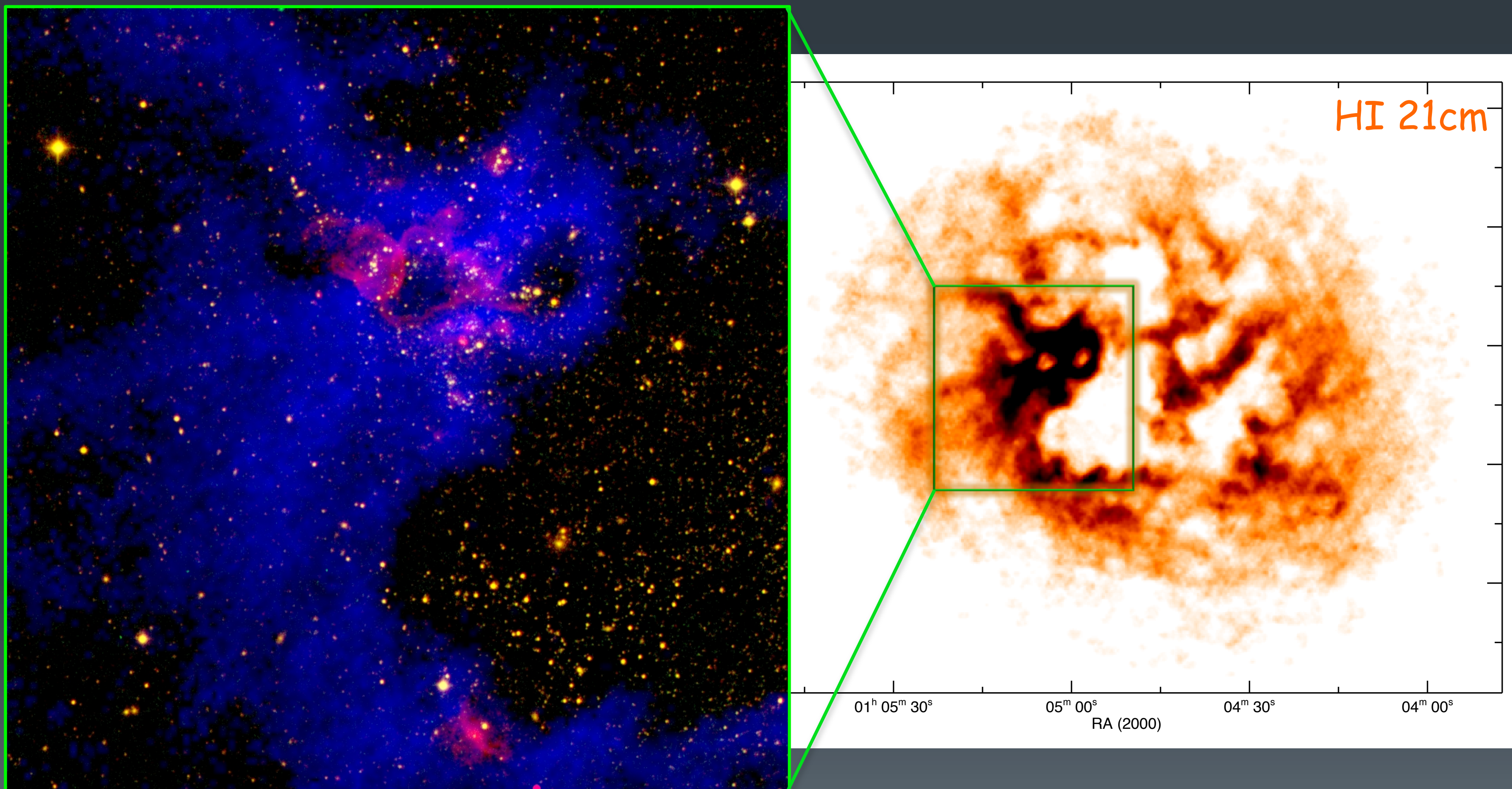
IC1613

- Local Group member
- D = 730 kpc
(3.5 pc/arcsec)
- Reveals a number of HI holes and supershells



Lozinskaya et al. (2003; arXiv:0301214)

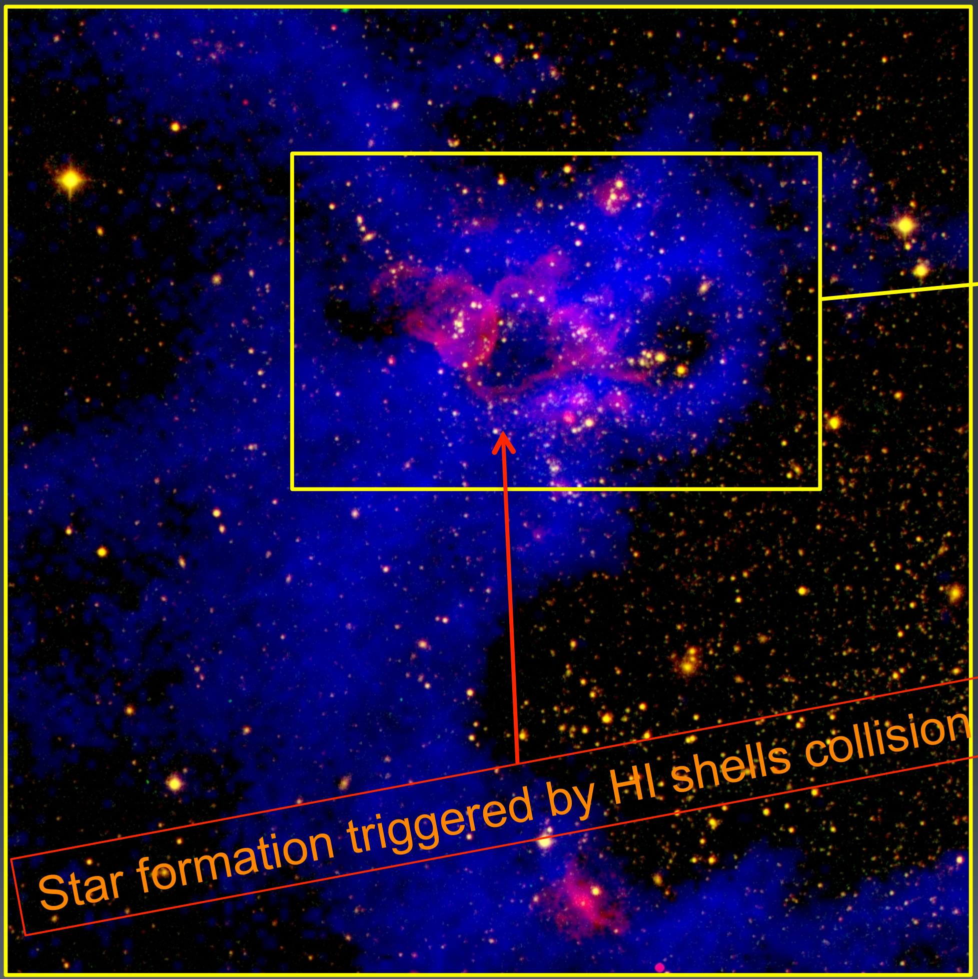
IC1613



H-alpha + HI 21 cm + continuum

Lozinskaya et al. (2003; arXiv:0301214)

IC1613



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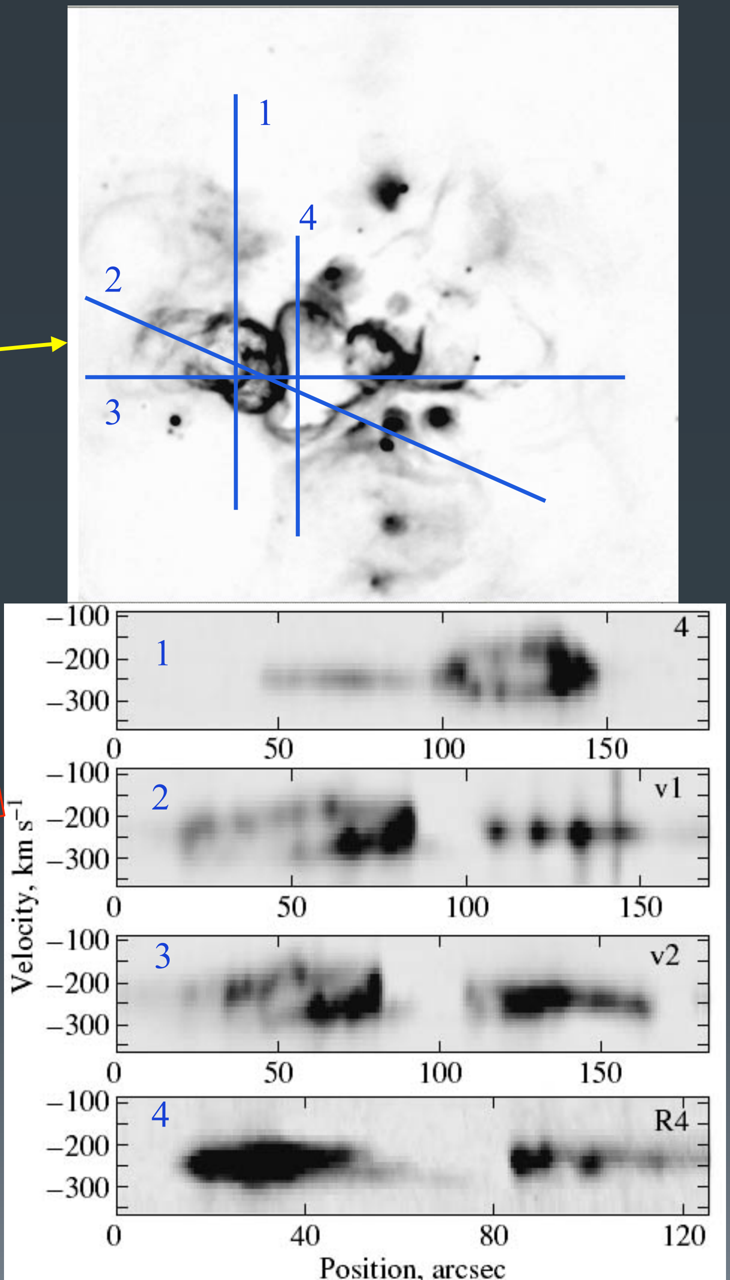


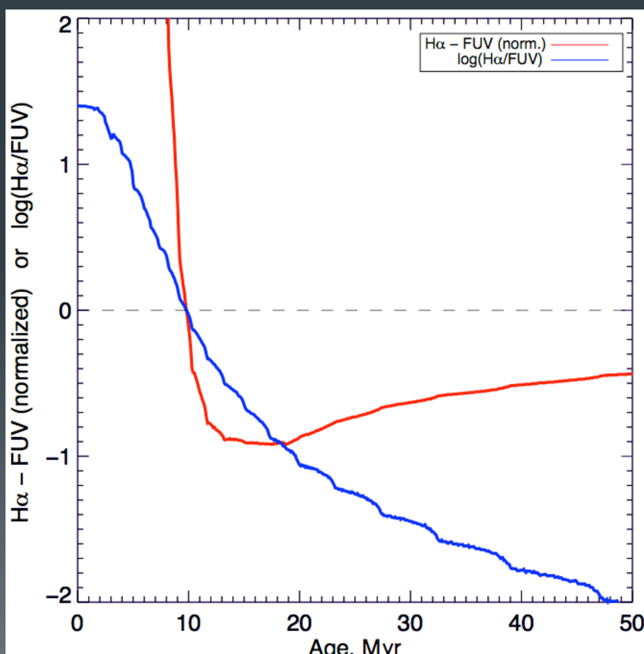
Age of shells
HI: 5.3-5.6 Myr,
HII: 0.6-2.2 Myr

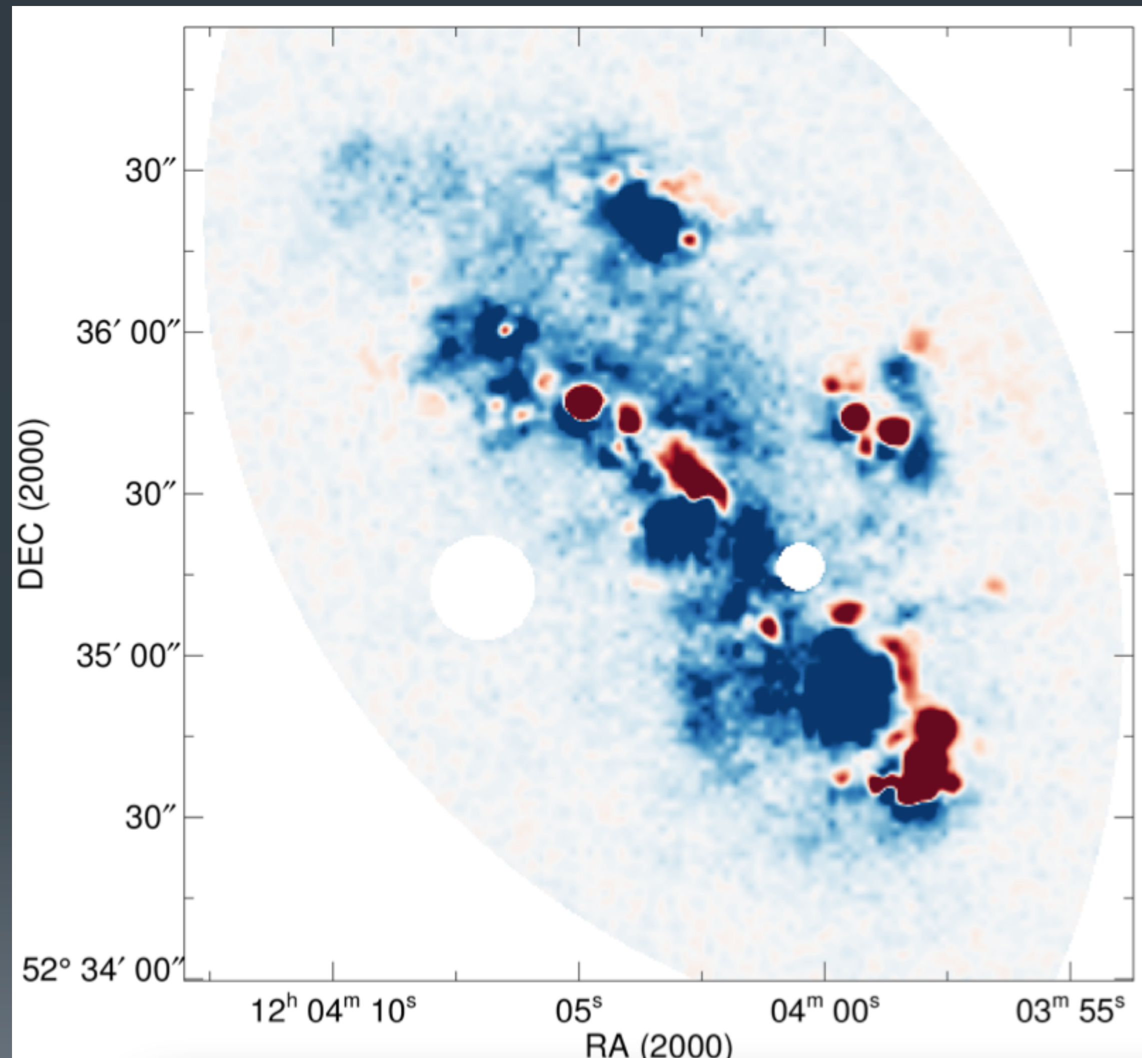
Lozinskaya et al. (2003; arXiv:0301

NGC 4068: Triggered star formation

FUV and H-alpha both are tracers of star formation, but H-alpha observed at timescale ~10 Myr while FUV ~100 Myr.

Starting from age ~9 Myr FUV becomes brighter than H-alpha.





Regions of ongoing and recent star formation

Moiseev et al. (in prep.)

IC 2574 & Holmberg II: Triggered star formation

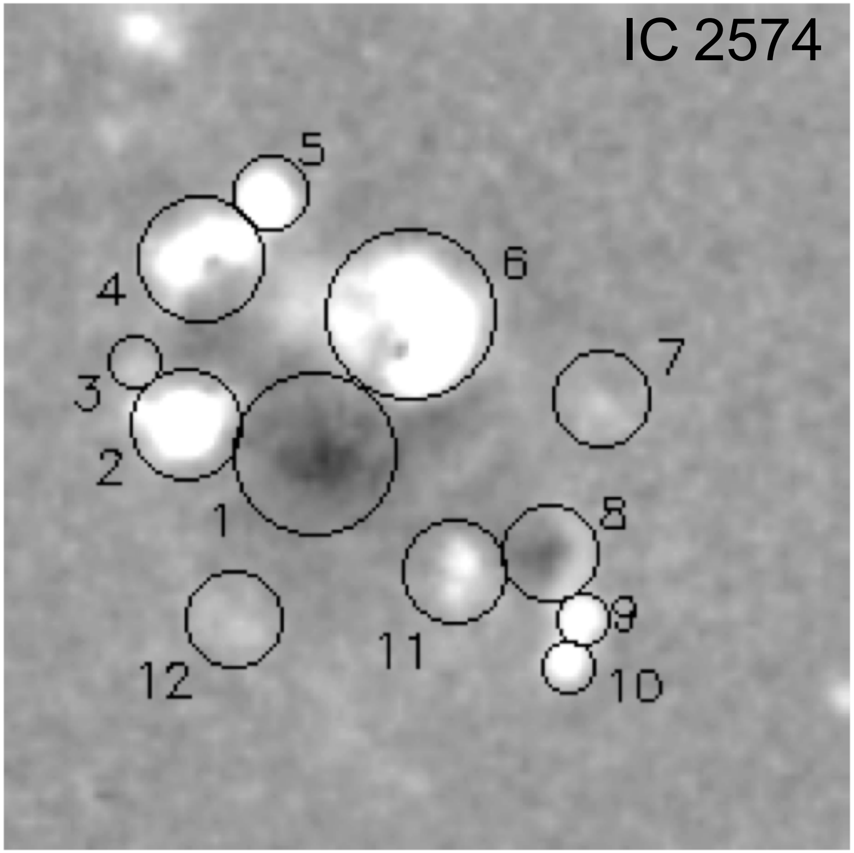
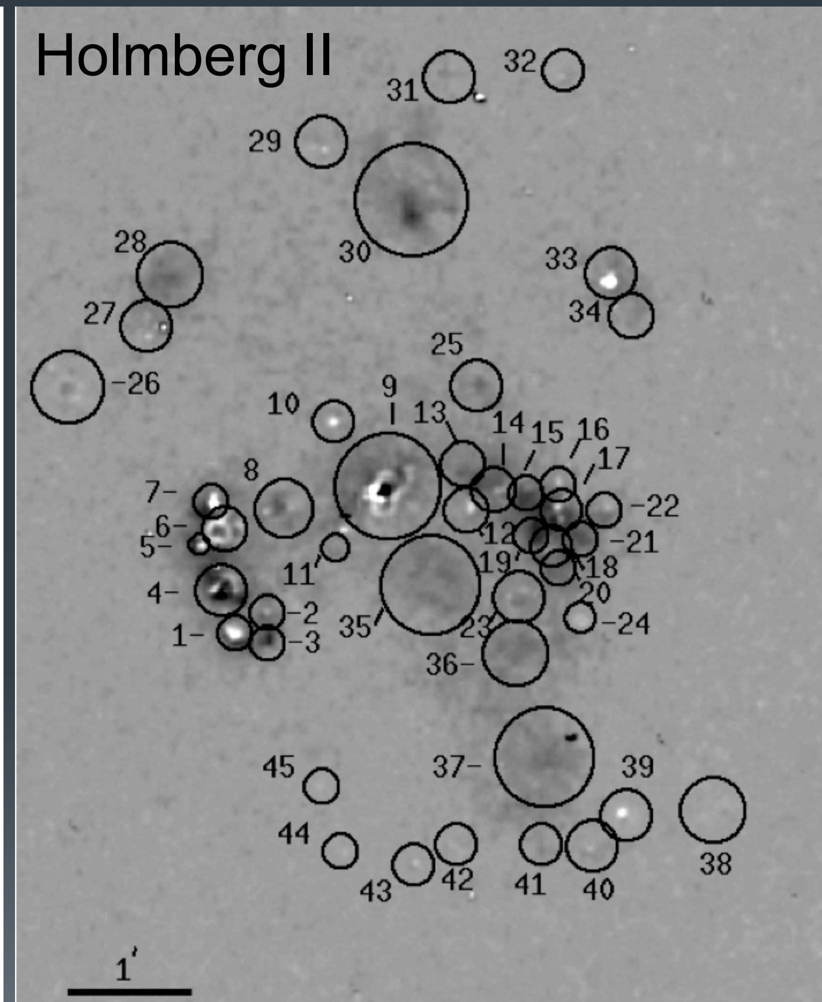


FIG. 3.—FUV, Hα difference image with apertures indicating the regions defined by us. The image is displayed so that areas containing FUV and no Hα are black and areas containing Hα and no FUV are white. The orientation is the same as in Fig. 1.



The same as in the left image

Stewart & Walter (2000)

Stewart et al. (2000)

IC 2574: Triggered star formation

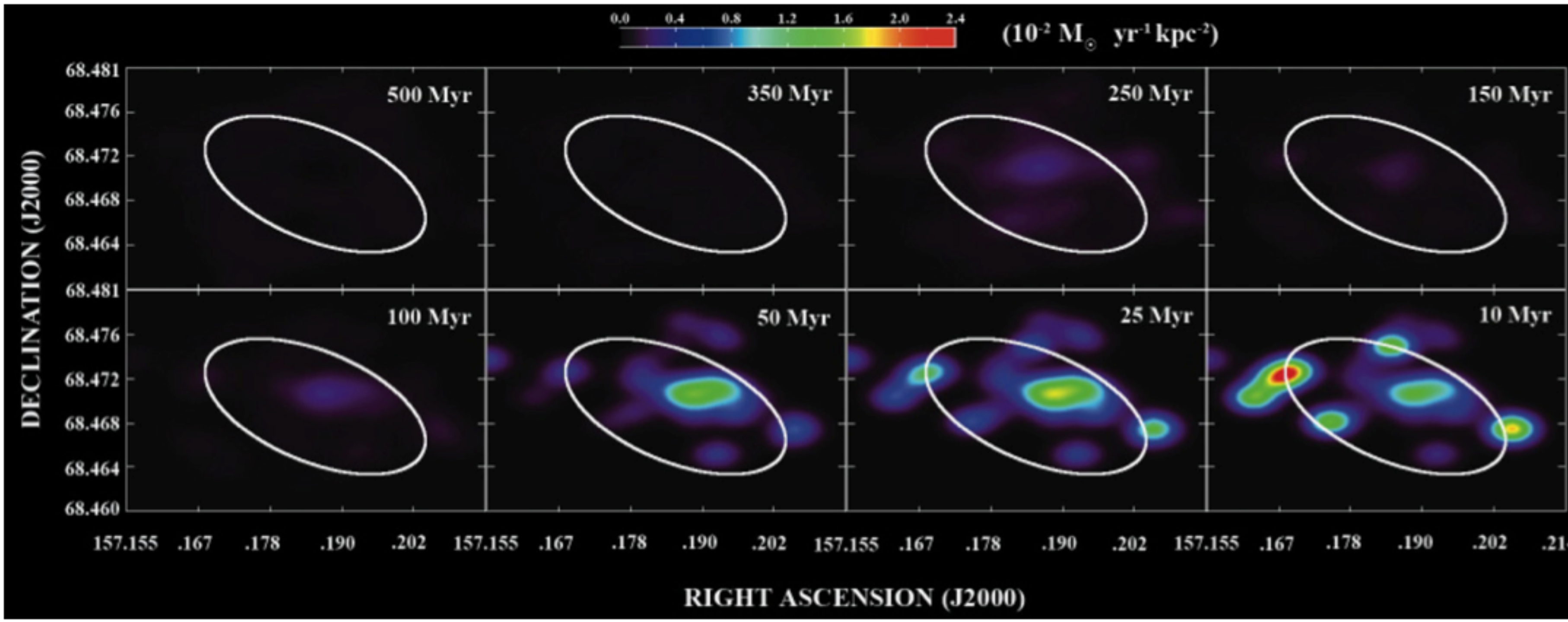


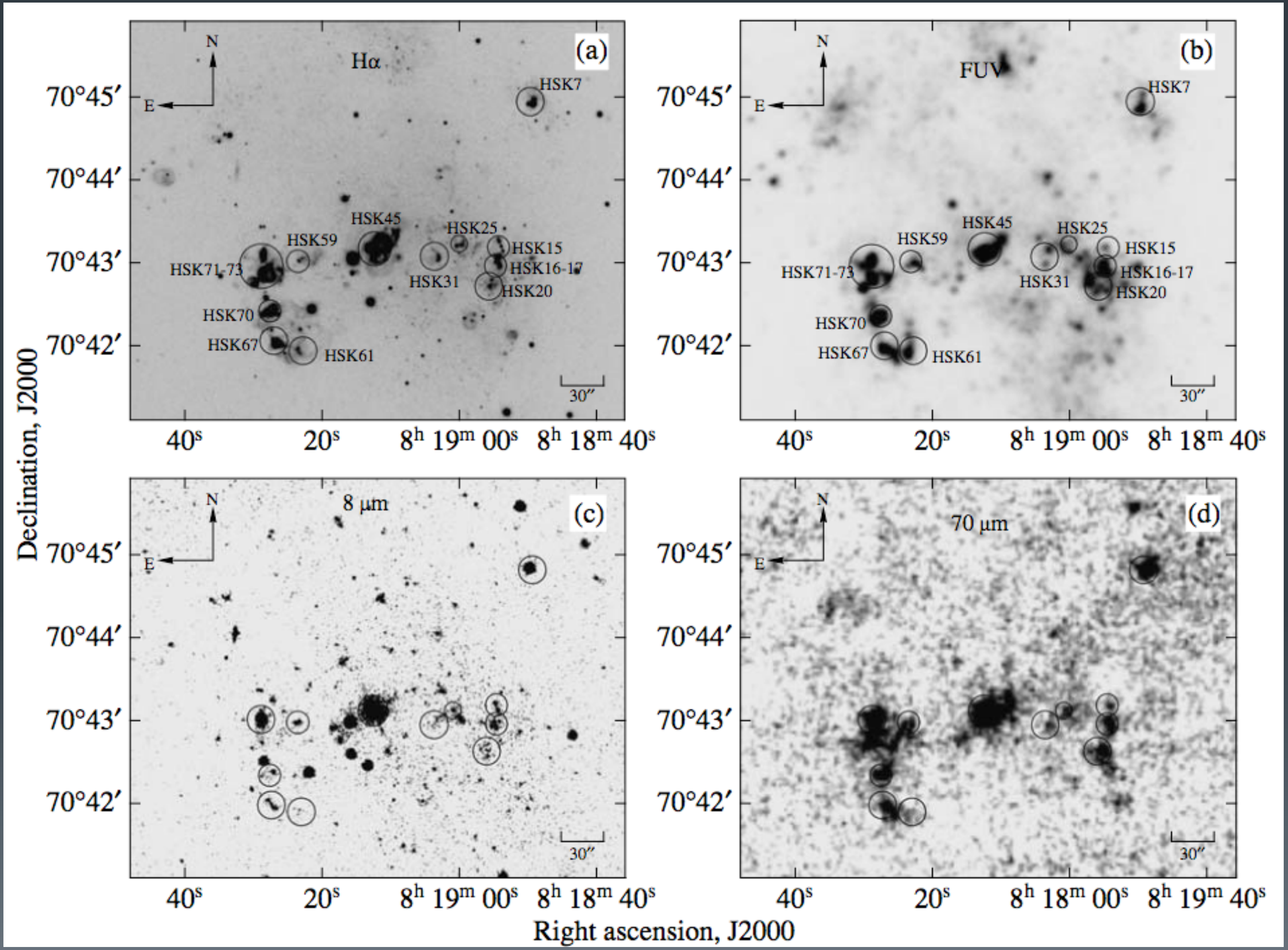
Figure 4. Selected still frames from the spatially resolved recent SFH of the SGS region. The white ellipse corresponds to the elliptical outline of the SGS itself shown in Figure 1. The spatial resolution of the images is ∼8″, similar to that of the H I observations. The movie can be seen at http://www.astro.umn.edu/~dweisz/2574/sgs.mov.

Weisz et al. (2009)

Very shortly about the dust

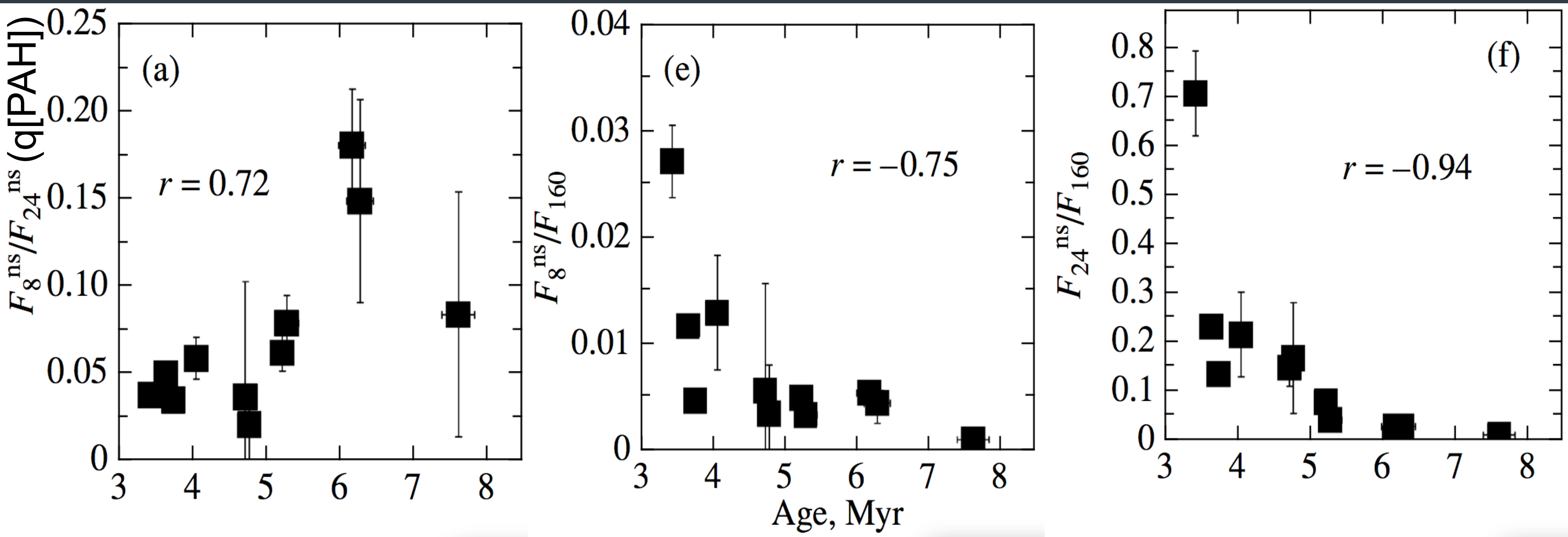
Holmberg II:

Results of aperture photometry in Spitzer and Herschel bands were compared with the information about radiation hardness, metallicity, ages of HII regions etc.



Wiebe et. al (2014; arXiv:1407.3065)

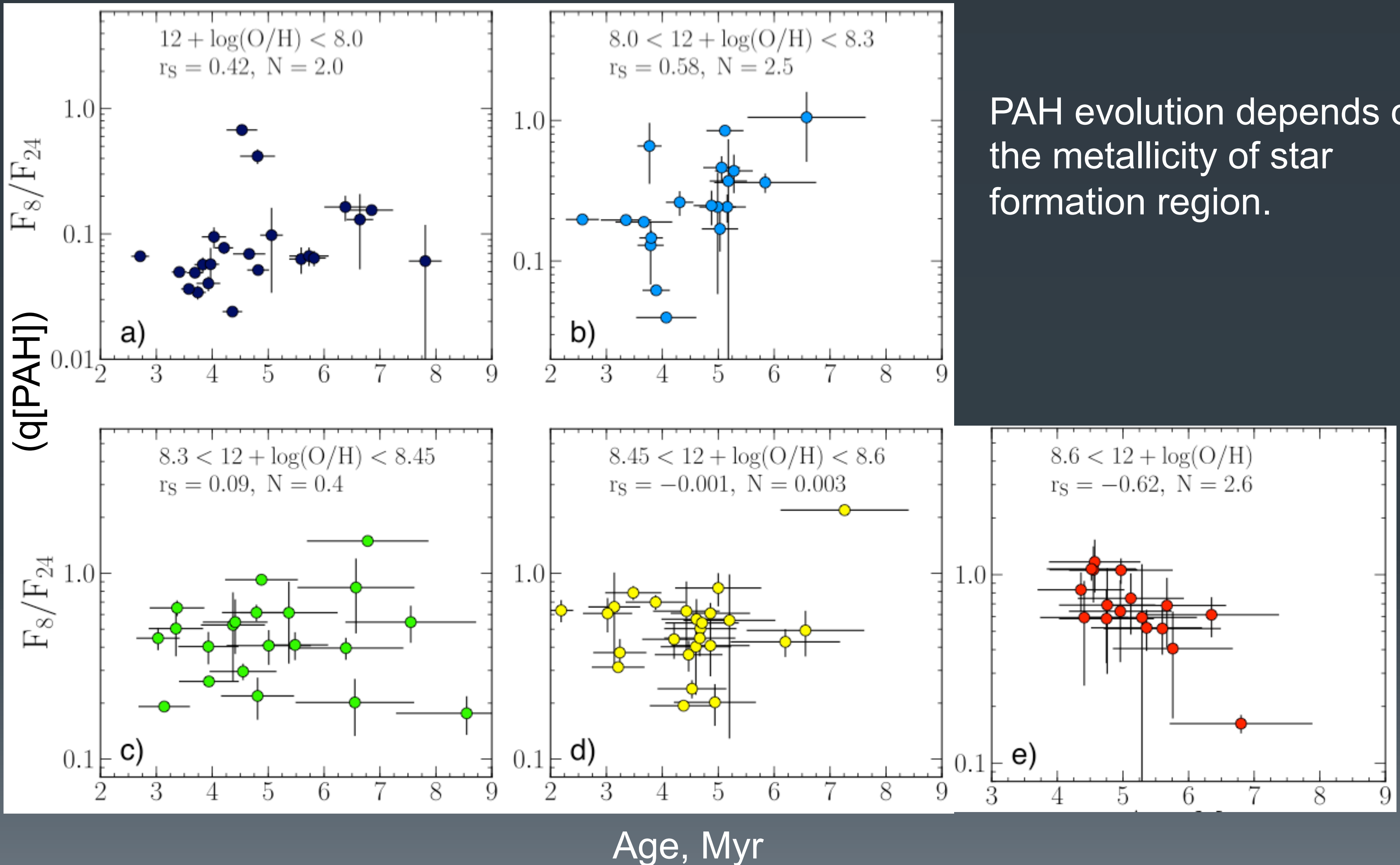
PAH evolution in star formation regions



Relative fraction of PAH molecules in dust in Holmberg II galaxy increases with the age of star formation region. Possible explanation is the destruction of very small grains (the main sources of 24μ emission) and the formation of PAH from them.

Wiebe et. al (2014; arXiv:1407.3065)

PAH evolution in star formation regions



PAH evolution depends on the metallicity of star formation region.

Khramtsova et. al (2014; arXiv:1407.8307)

Summary

- The energy balance between bright HII complexes and young stellar population is usually take a place (except several cases).

- A lot of faint expanding ionized (and several neutral) gas shells observed in star formation regions.

- We detected for the first time kpc-sized faint ionized supershell inside the HI holes in Holmberg II and IC 2574 galaxies.

- The signs of the triggering of star formation due to HI shells collisions were observed.

- Stellar feedback influence to the dust: PAH fraction in ISM of the star formation regions increases with the age for low-metallicity galaxies and decreases for high-metallicity galaxies.

- Wide field and high spectral and spatial resolution are making the scanning Fabry-Perot interferometer a very useful instrument to global and detailed gas kinematics study.

Thanks for your attention!