

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



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co-authors:

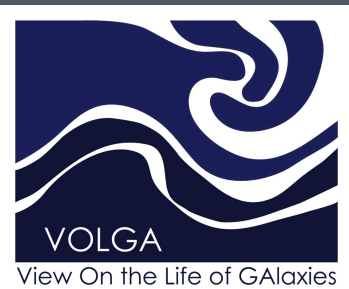
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# dlrr galaxies as a good laboratory

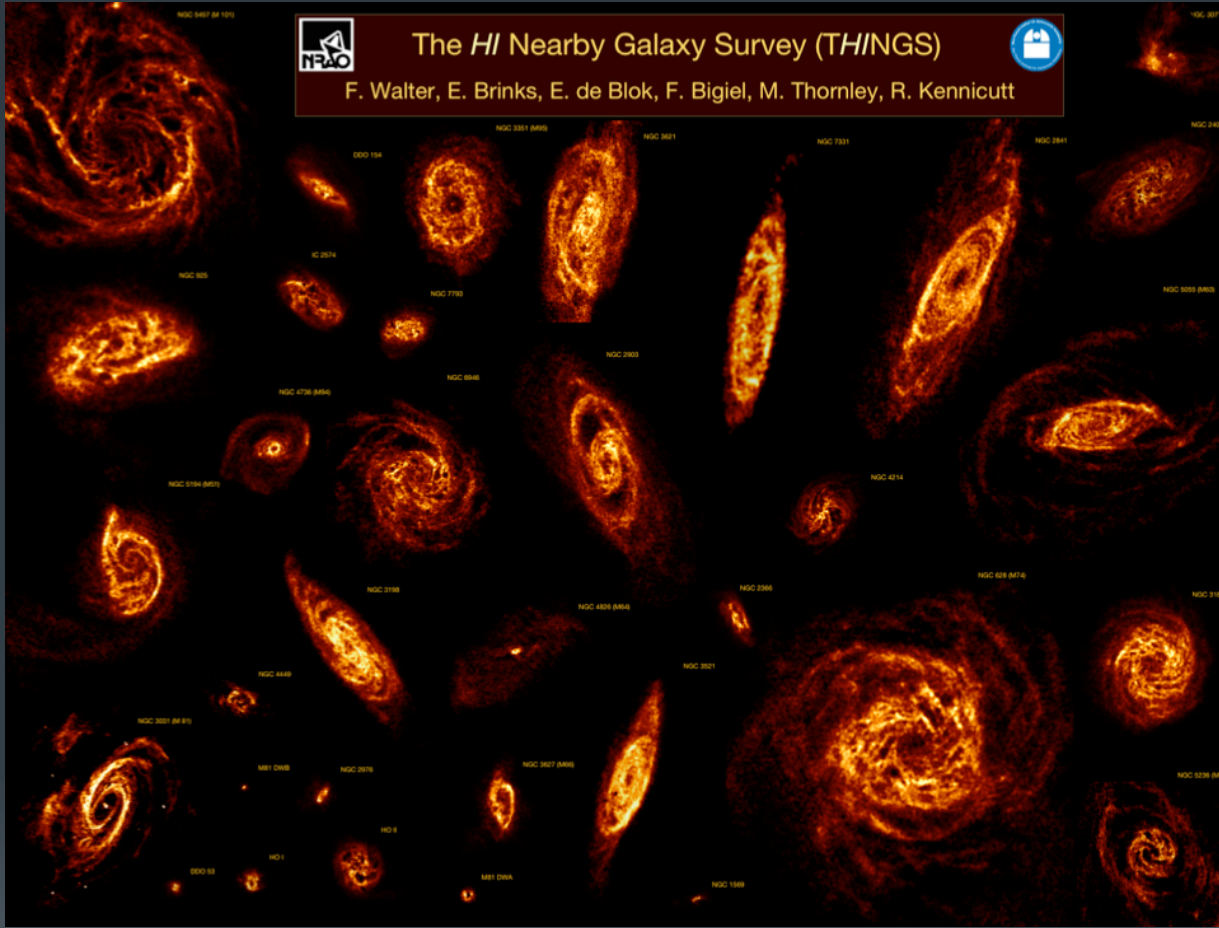
- They are gas rich
- Have a thick gas disc
- ... a shallow potential
- ... and a lack of spiral density waves.

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

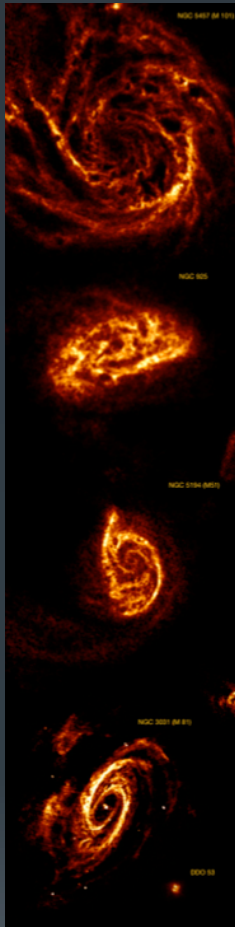
- We study how the ongoing star formation influences to the gas and dust components of ISM using multiwavelength observations of nearby dlrr galaxies.

# You may find dlrr galaxies in a lot of things...

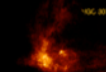




# You may find dlrr galaxies in a lot of things...



The *HI* Nearby Galaxy Survey (*THINGS*)

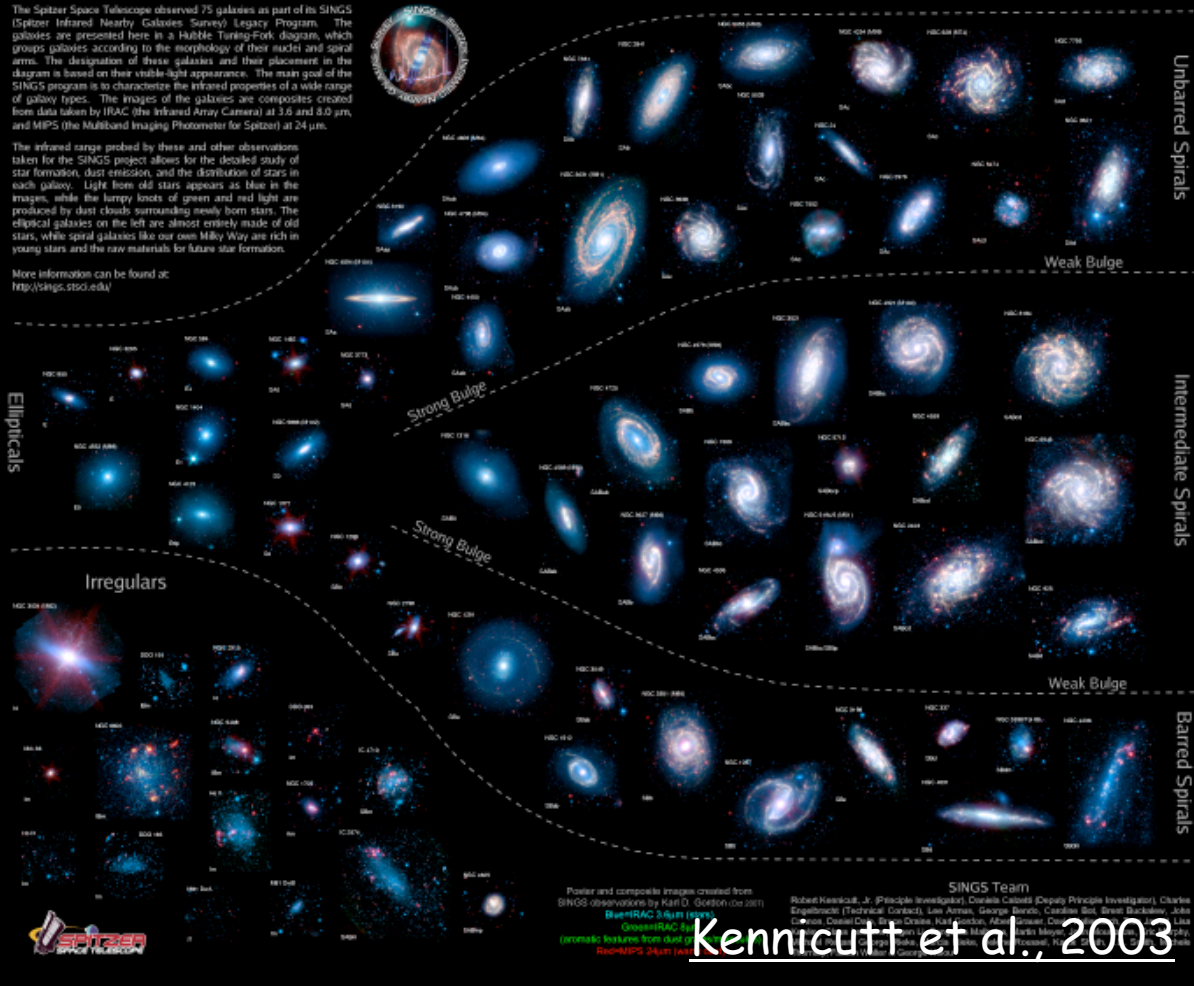


## The *Spitzer* Infrared Nearby Galaxies Survey (*SINGS*) Hubble Tuning-Fork

The *Spitzer* Space Telescope observed 75 galaxies as part of its *SINGS* (*Spitzer* Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the *SINGS* program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0  $\mu\text{m}$ , and MIPS (the Multiband Imaging Photometer for *Spitzer*) at 24  $\mu\text{m}$ .

The infrared range probed by these and other observations taken for the *SINGS* project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.


More information can be found at: <http://sings.stsci.edu/>




Poster and composite images created from *SINGS* observations by Karl D. Gordon (co PI) **Kennicutt et al., 2003**  
SINGS Team: Robert Kennicutt, Jr. (Principal Investigator), Daniela Calzetti (Deputy Principal Investigator), Charles Engelbracht (Technical Contact), Lise Amis, George Barlow, Caroline Beu, Steve Beckwith, John C. Becher, Doreen Cavaletto, Brian Ogle, Karl Gordon, Alan Goetz, Lisa Harbeck, David Hogg, Brian Ogle, Hal Weaver, John Wiseman, Carl Zuckerman, Robert Kennicutt, Jr., Daniela Calzetti, Charles Engelbracht, Lise Amis, George Barlow, Caroline Beu, Steve Beckwith, John C. Becher, Doreen Cavaletto, Brian Ogle, Karl Gordon, Alan Goetz, Lisa Harbeck, David Hogg, Brian Ogle, Hal Weaver, John Wiseman, Carl Zuckerman.




# You may find dlrr galaxies in a lot of things...



The *HI* Nearby Galaxy Survey (*THINGS*)





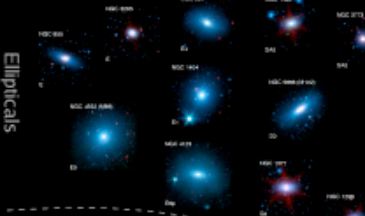
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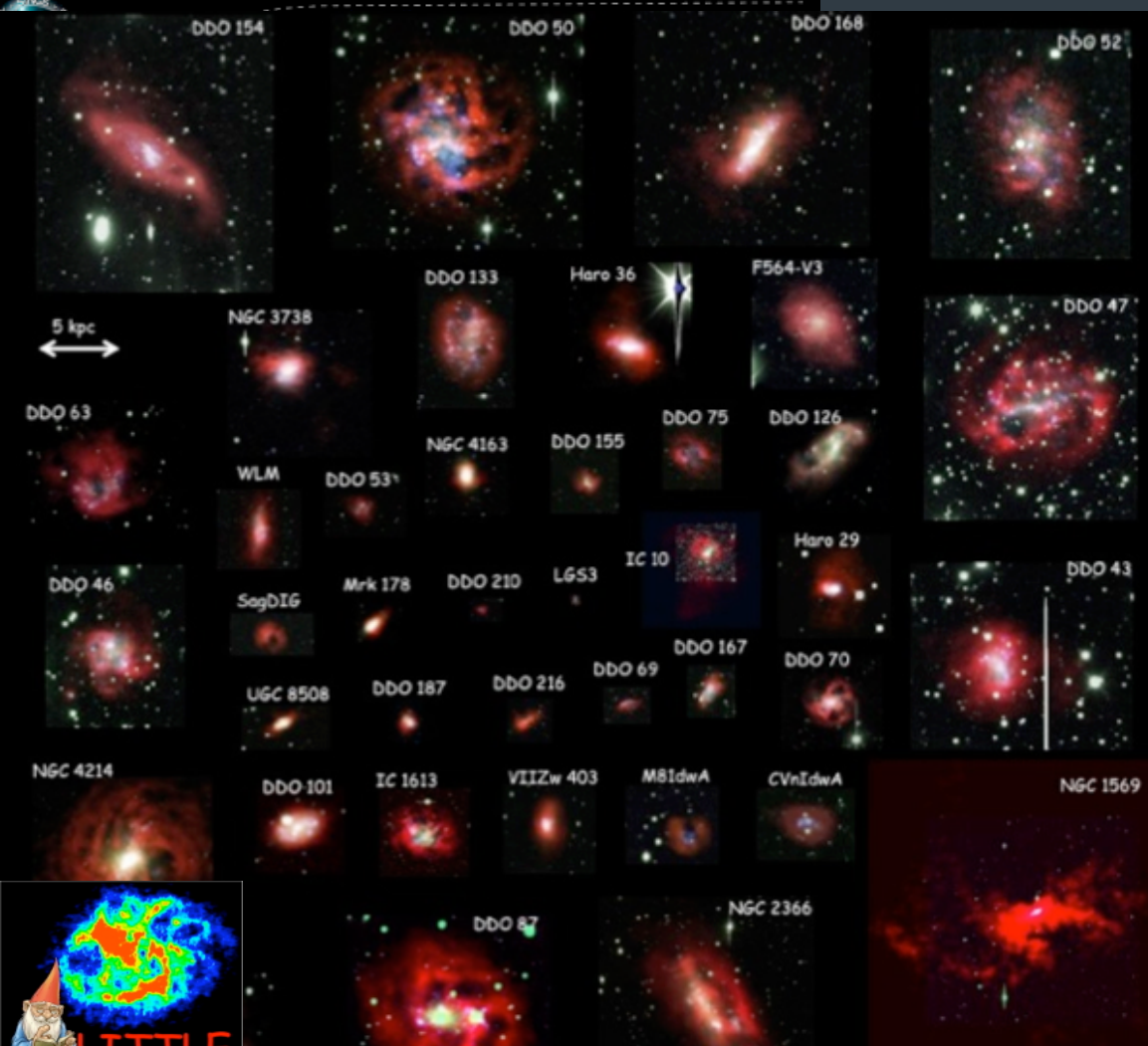
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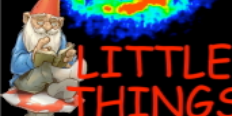
Ellipticals



Irregulars





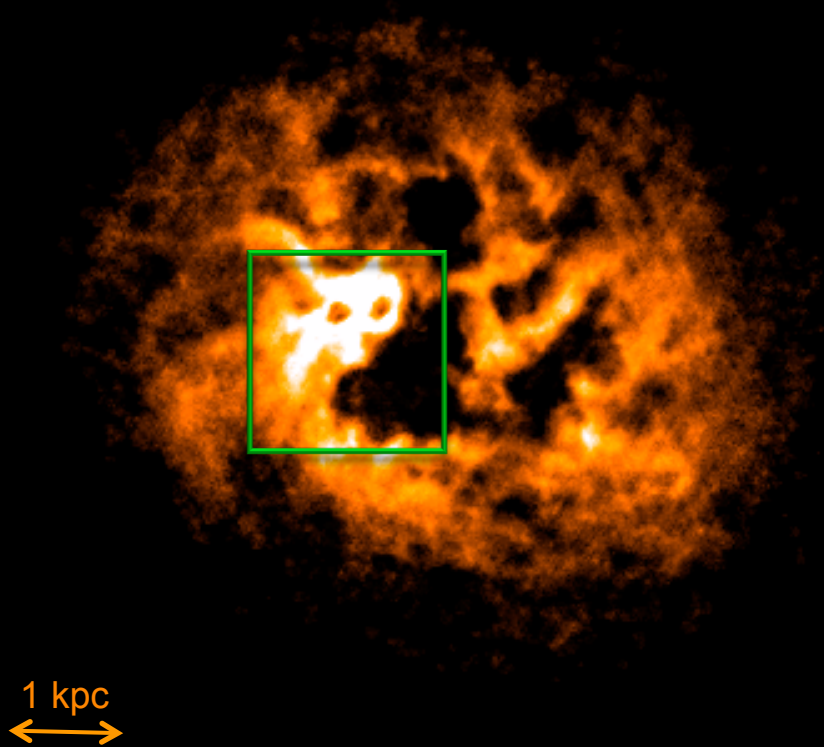


LITTLE THINGS

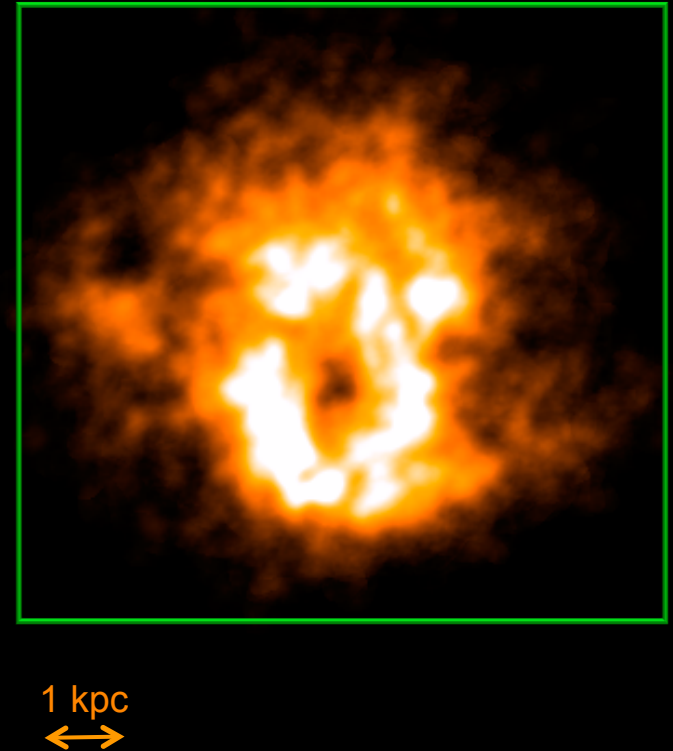
Hunter et al., 2012

# HI 21 cm distribution in dIrr galaxies

IC 1613



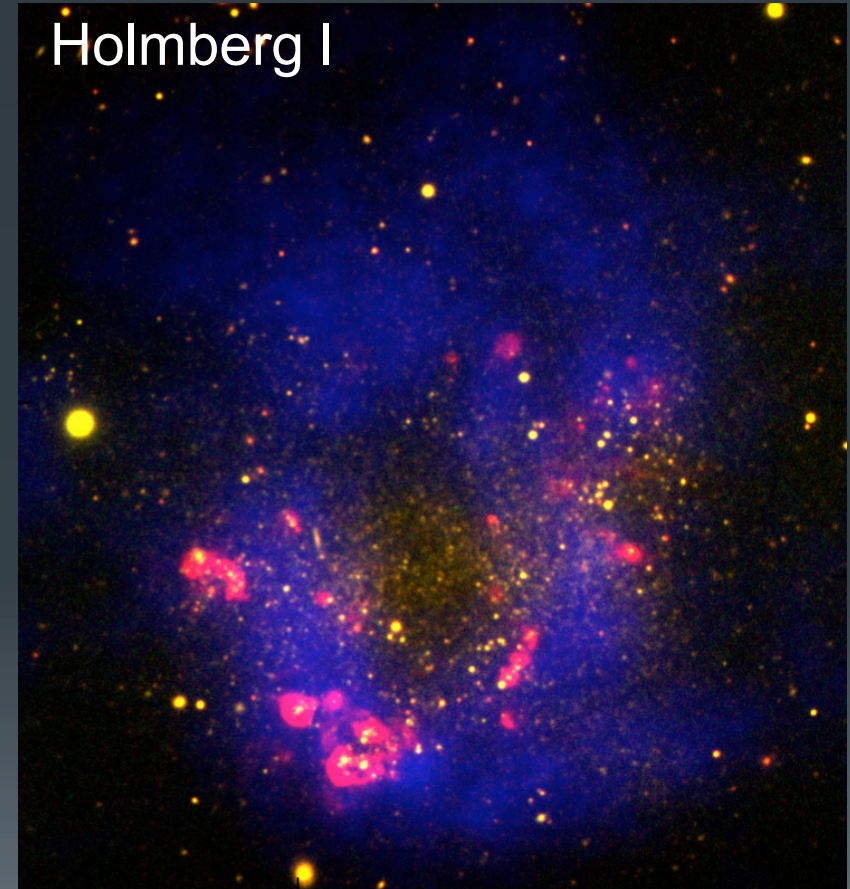
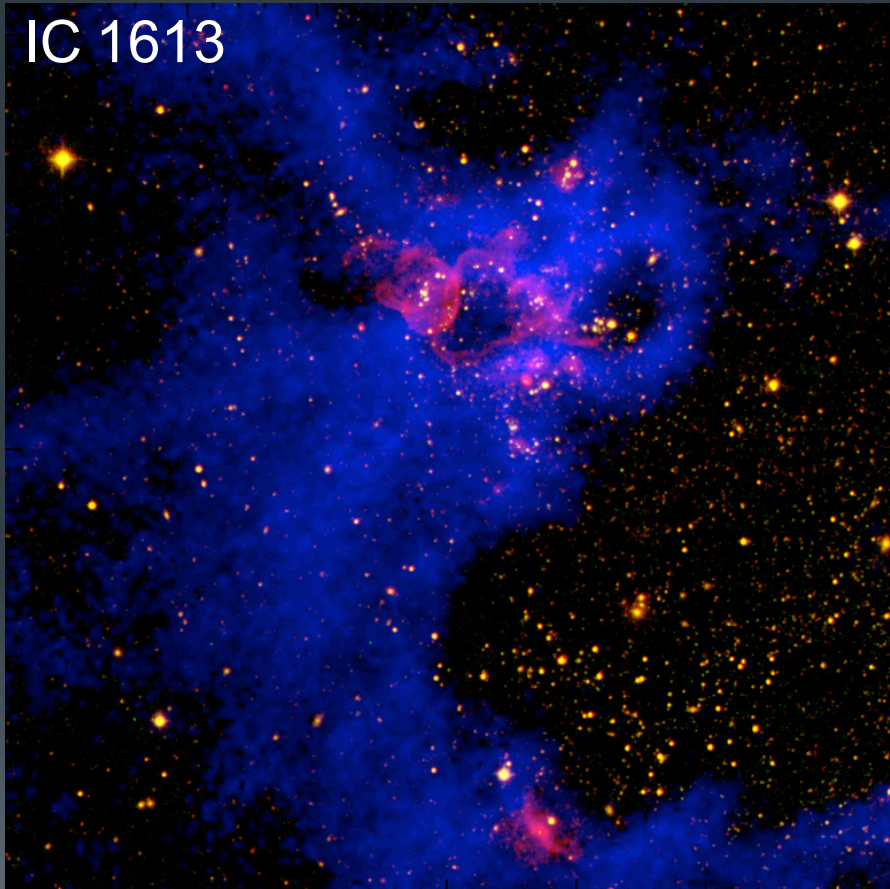
Holmberg I



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



# Multiwavelength view on dlrr galaxies



H-alpha + HI 21cm + stars

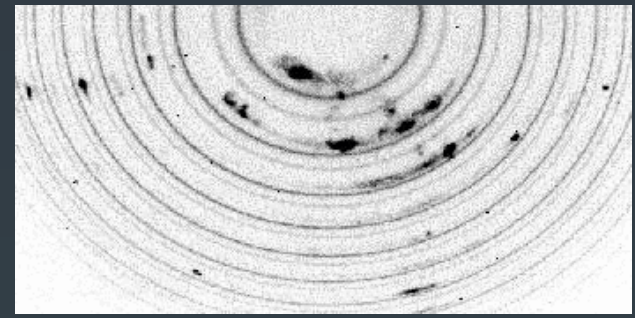
Ongoing star formation is often observed in the rims of giant HI shells.



# Observations with scanning Fabry-Perot Interferometer

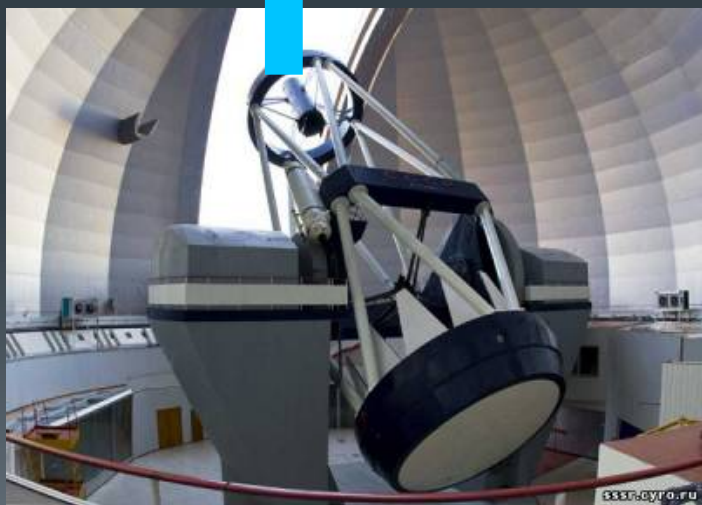
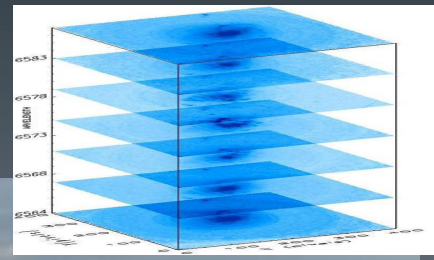


**SCORPIO & SCORPIO-2** multi-mode focal reducers with scanning FPI (Afanasiev & Moiseev, 2005, 2011)



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

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

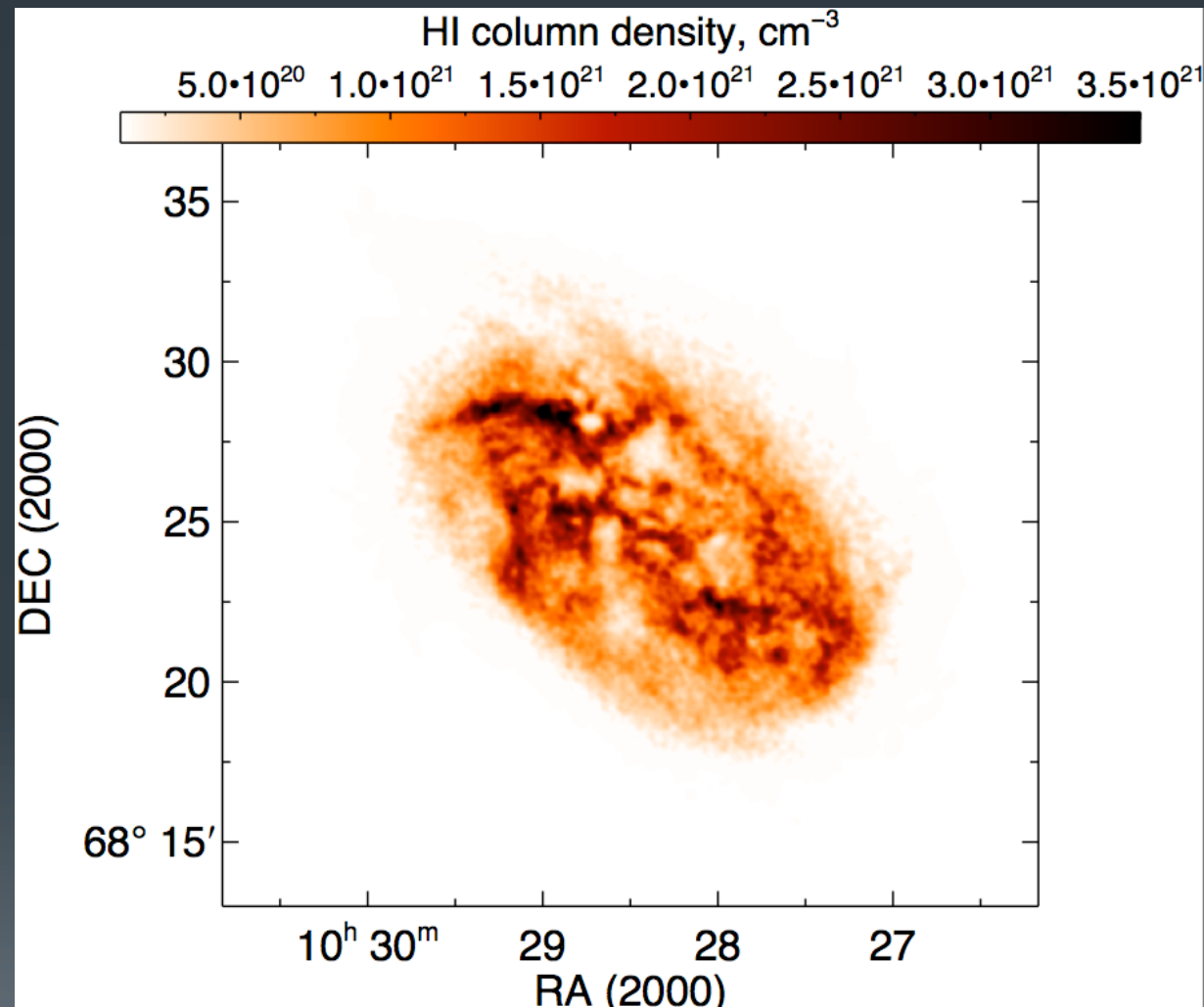


**6-m telescope : [www.sao.ru](http://www.sao.ru)**

# IC 2574: Supergiant shell (SGS)

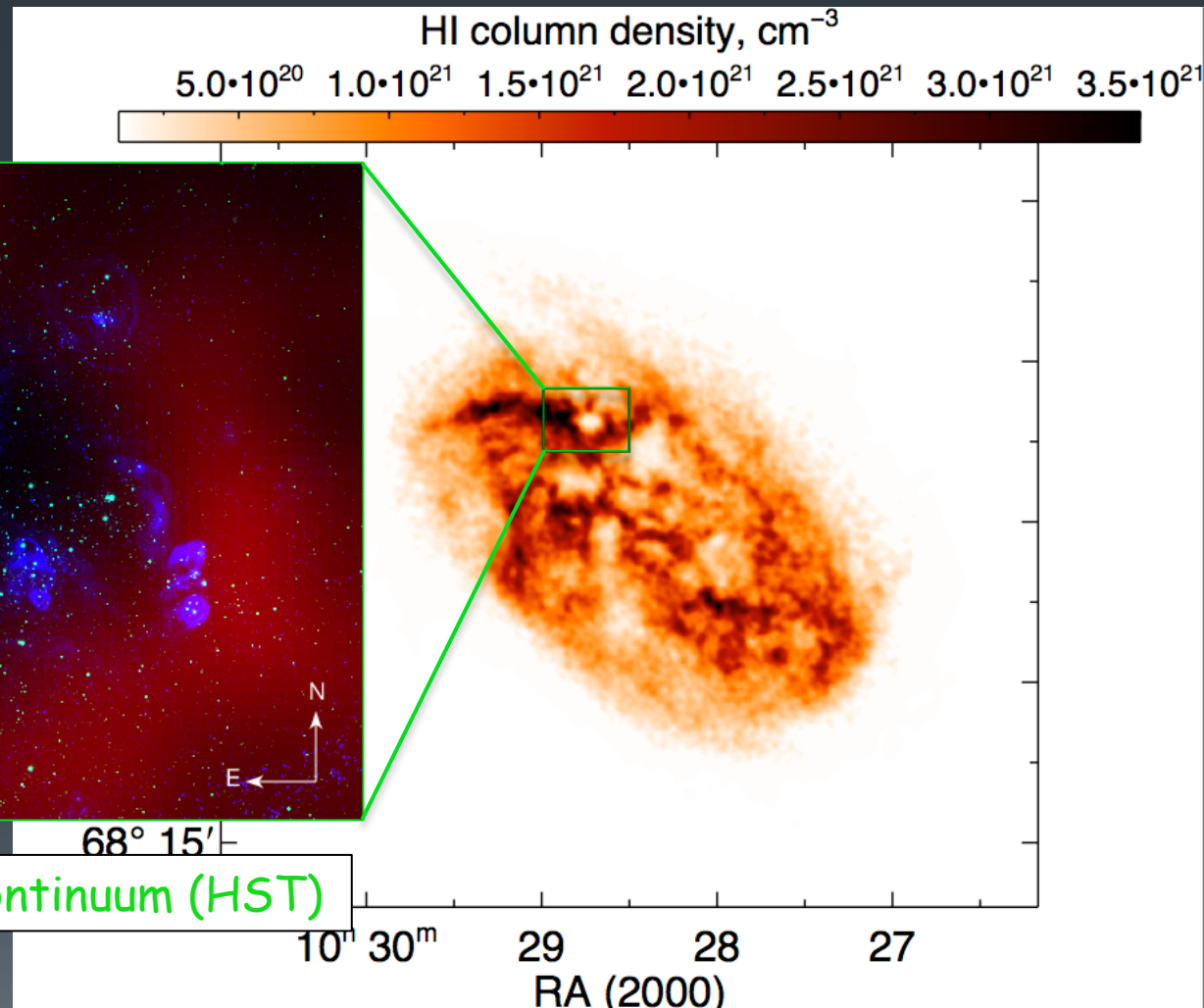
9

- 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



# IC 2574: Supergiant shell (SGS)

10

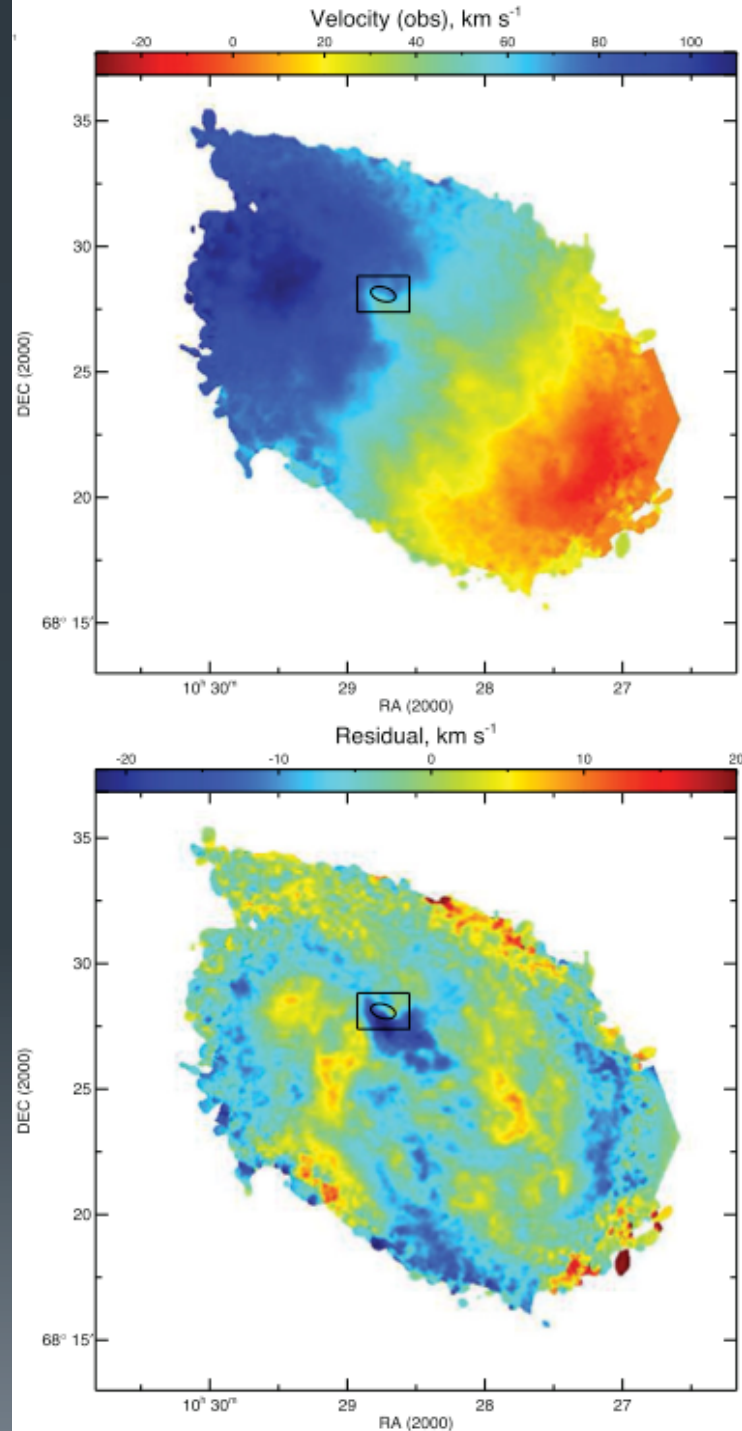


H-alpha (HST) + HI 21 cm + continuum (HST)



# IC 2574: SGS

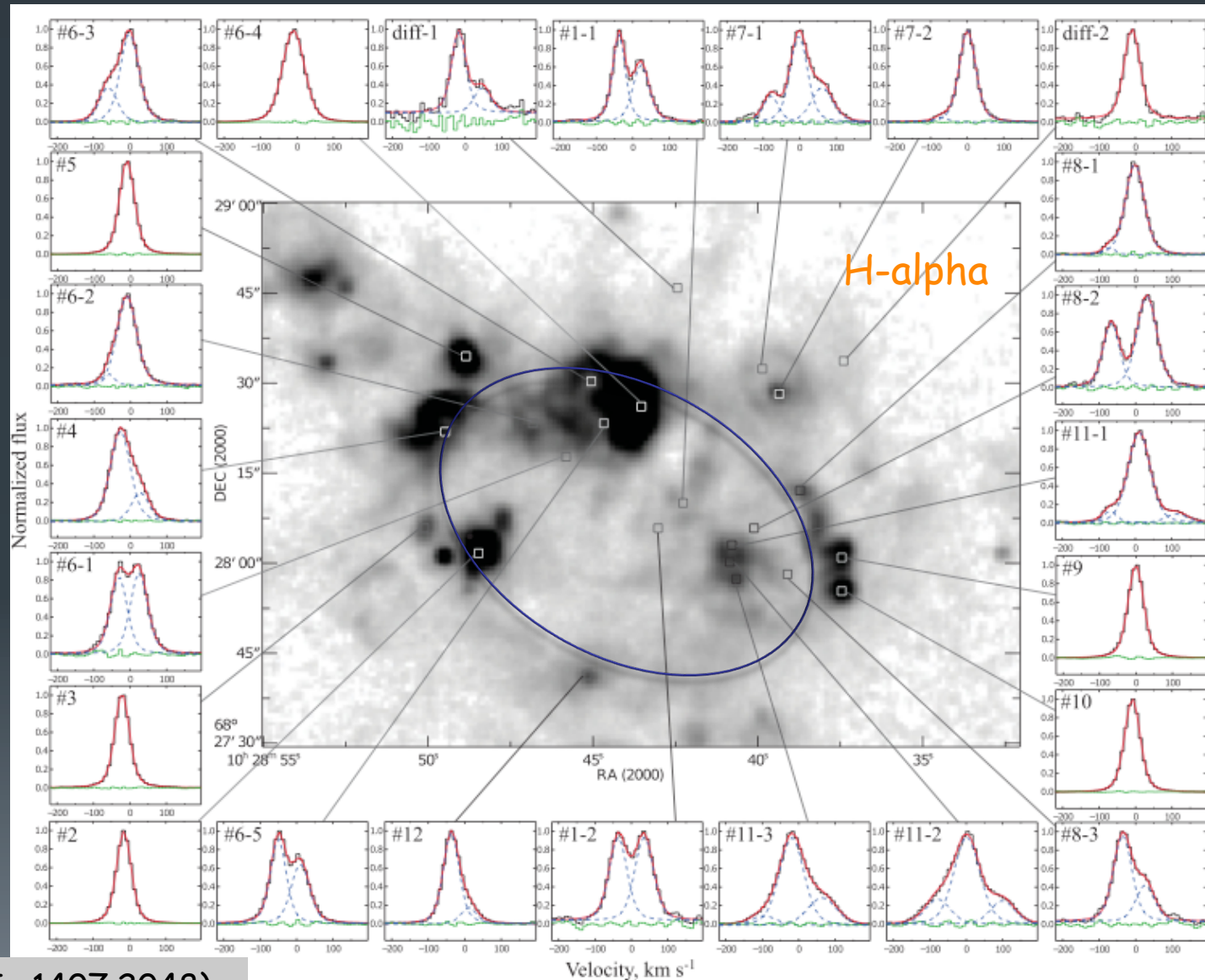
The largest perturbations of gas velocity field is observed in the direction of the region of ongoing star formation



# IC 2574: SGS

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

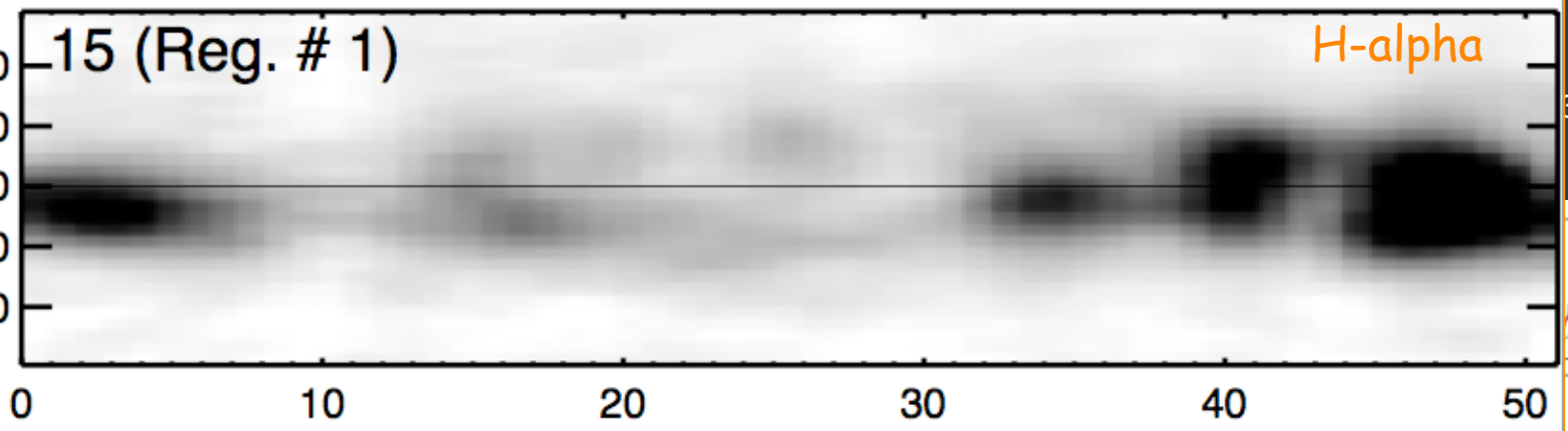
- We detected the faint expanding H-alpha supershell never seen before in the interior of SGS



Velocity, km/s

H-alpha

15 (Reg. # 1)

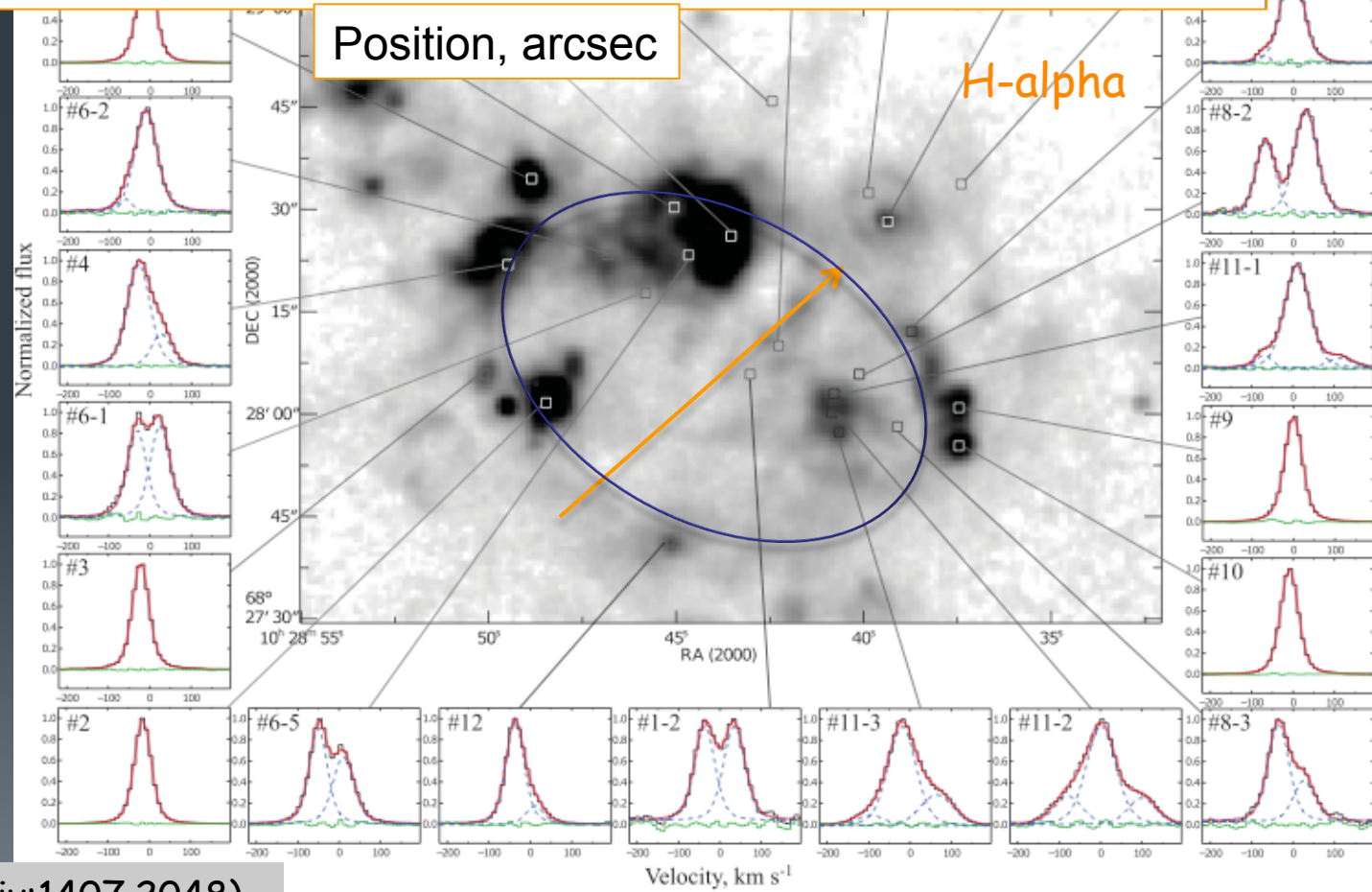


- Percent of ionized and neutral gas kinematics observed in overall star formation region

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

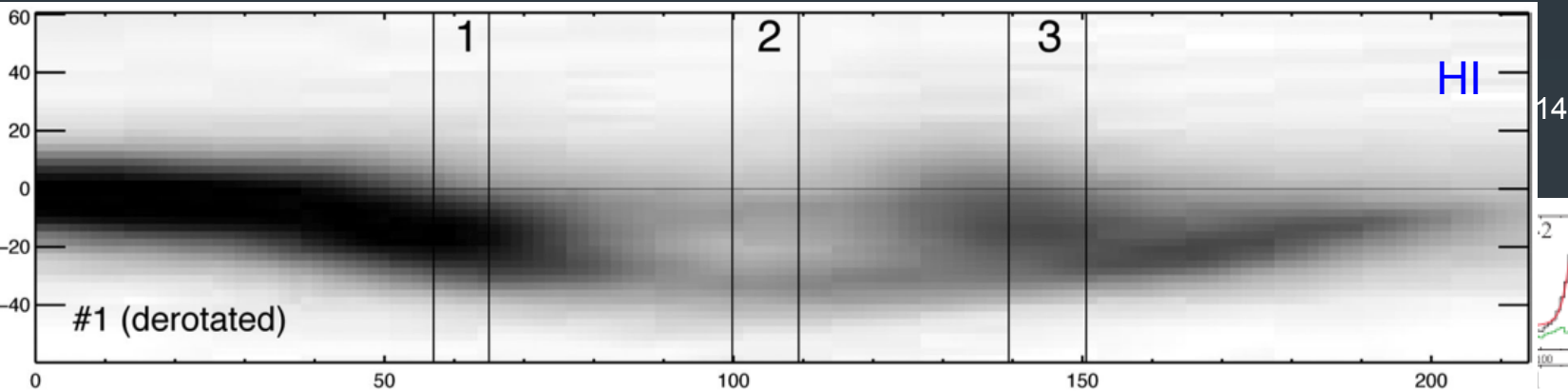
Position, arcsec

H-alpha



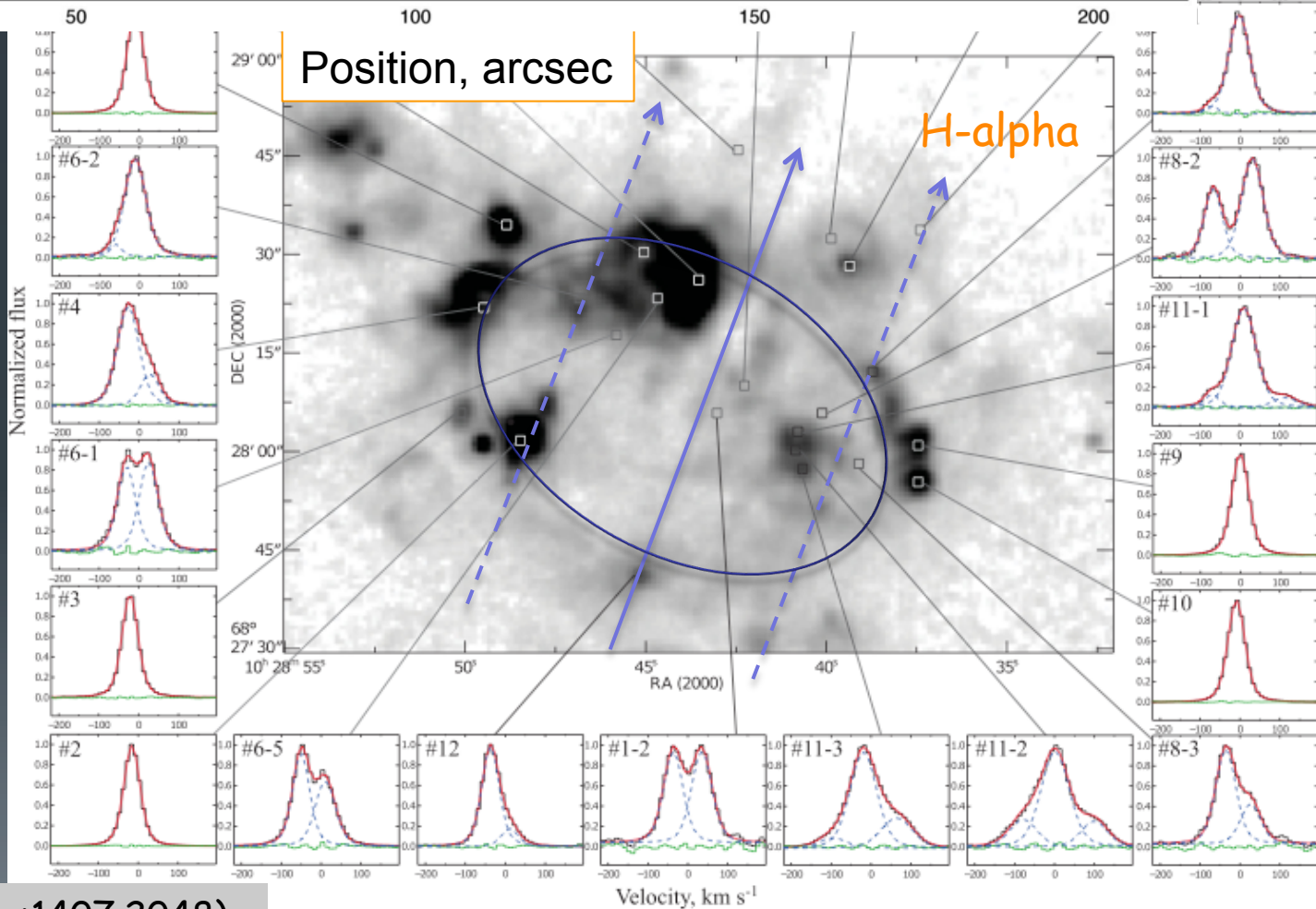


Velocity, km/s



- Perimeter 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



# IC 2574: SGS

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

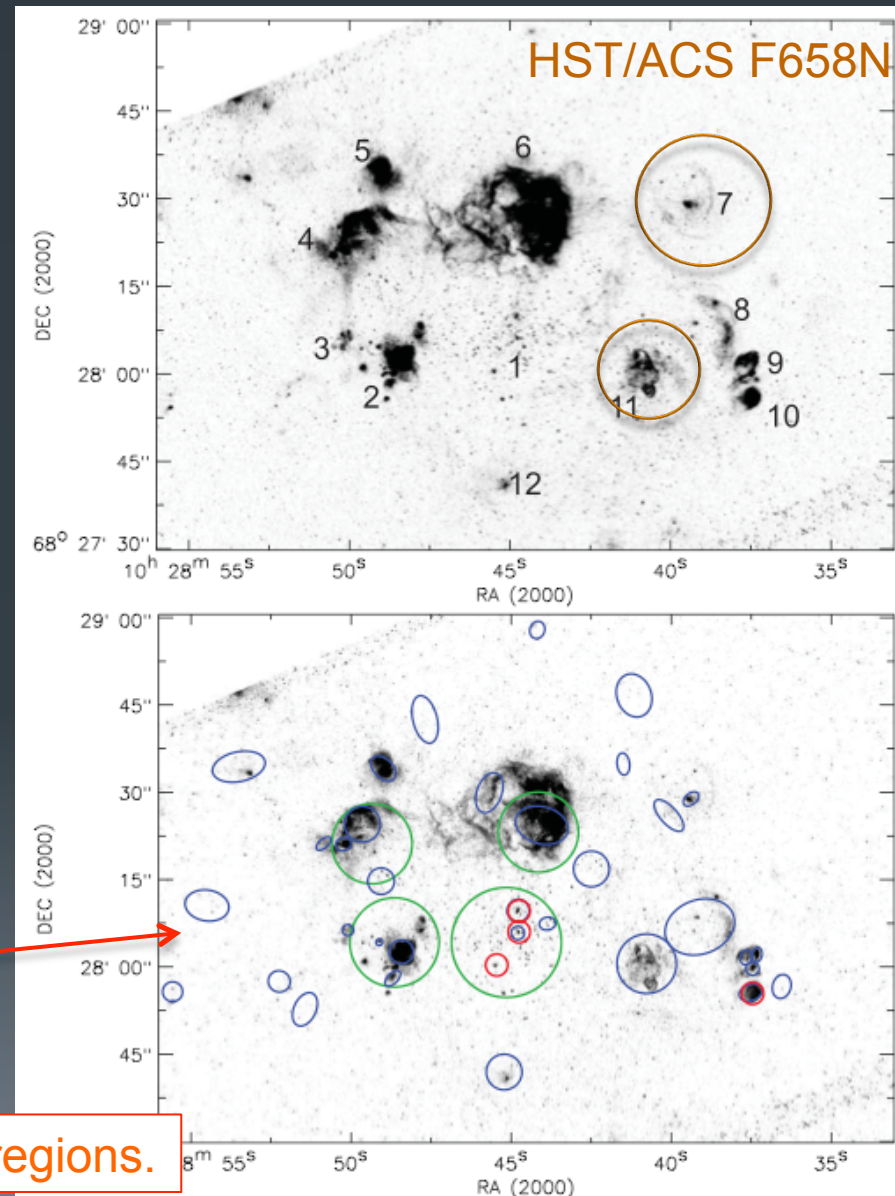
According to Mac Low & McCray (1988):

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

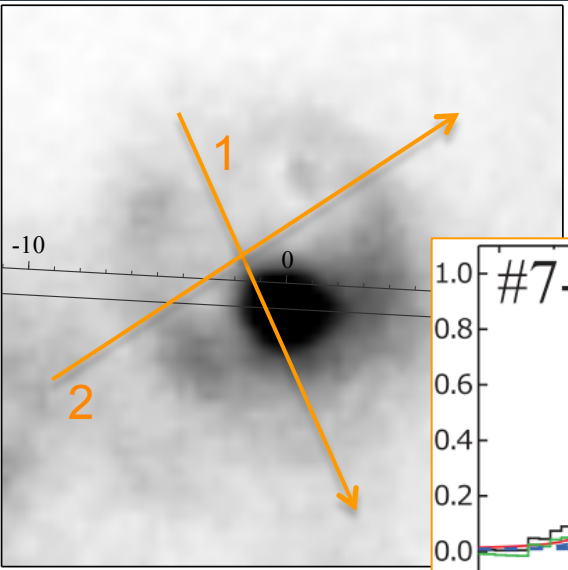
$$v_{\text{exp}}(t) = \frac{0.6R_s}{t} = 39.4 \left( \frac{L_{38}}{n_0} \right)^{1/5} t_6^{-2/5} \text{ km s}^{-1}.$$

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) =>

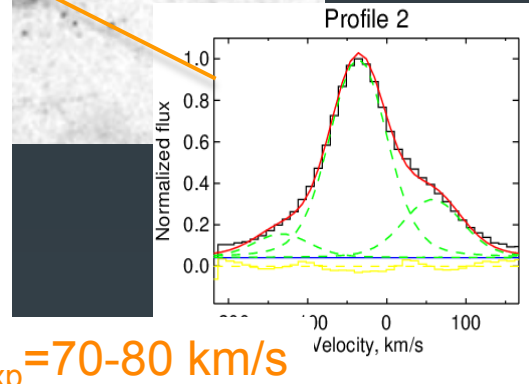
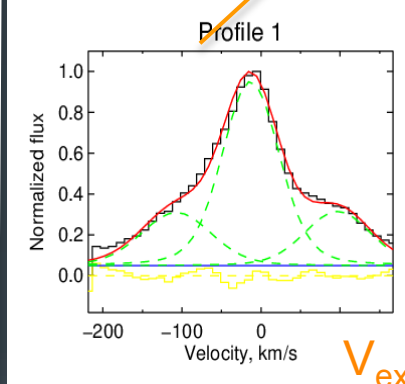
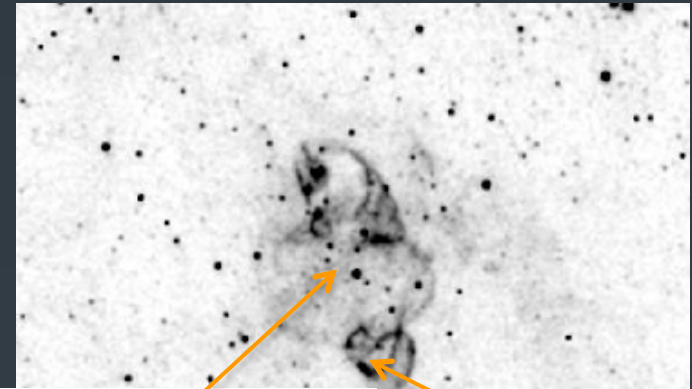
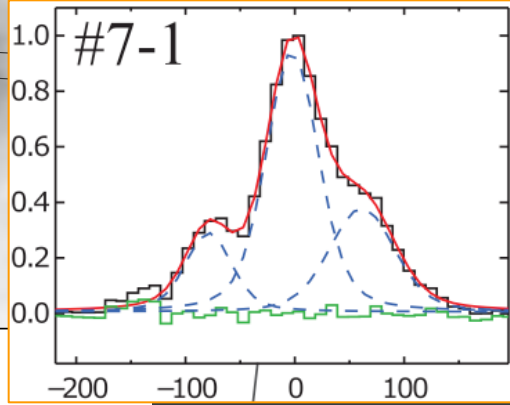
Yes, except two regions.



# IC 2574: SGS



The youngest region in the area  
 $t_{kin} = 1 \text{ Myr}$   
 $V_{exp} = 65 \text{ km/s}$   
 Size = 210 pc



$V_{exp} = 70-80 \text{ km/s}$

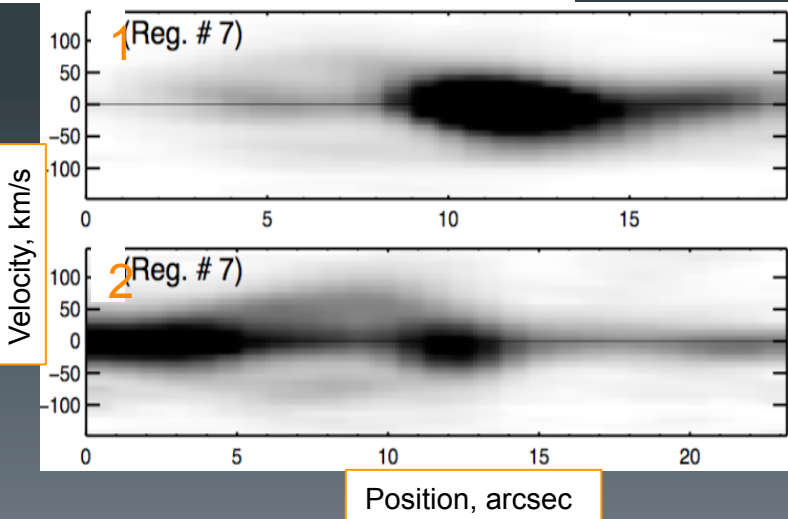
Supernova remnant.

Following Sedov (1946) self-similar solution

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

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

Age = 0.3 Myr

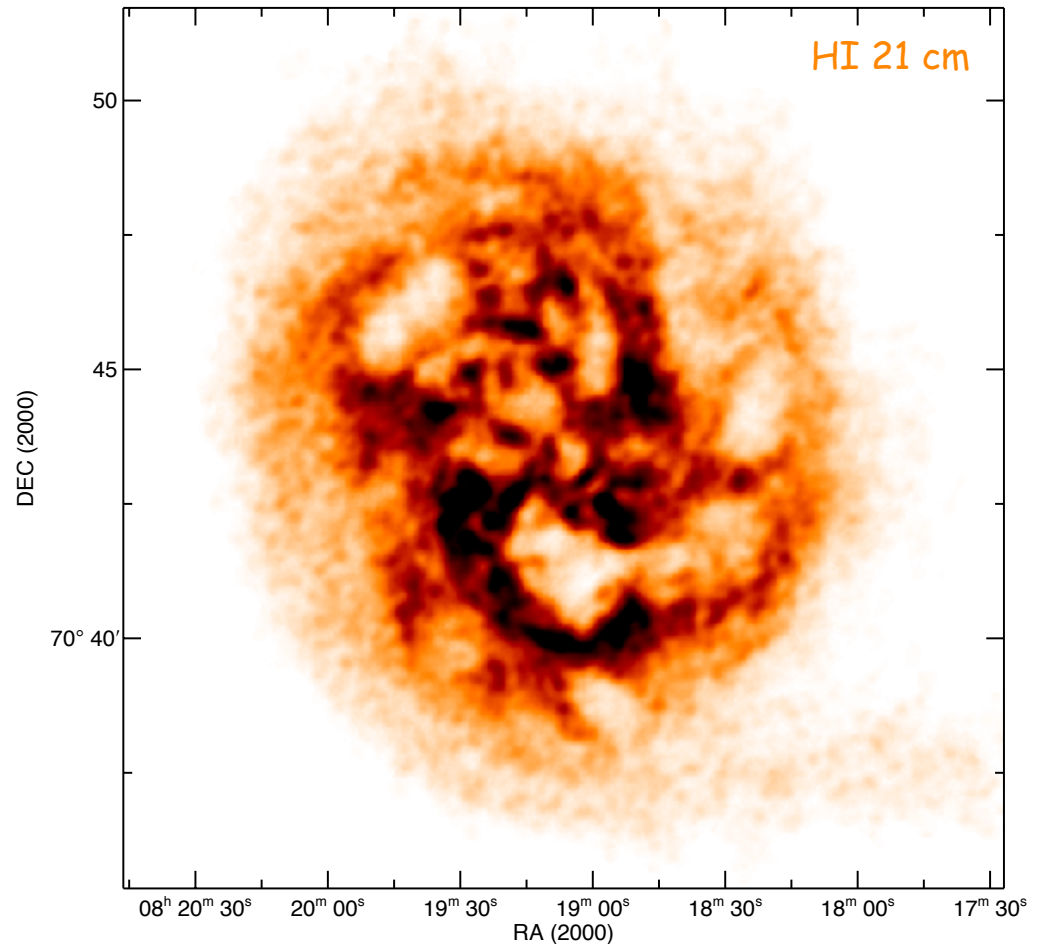




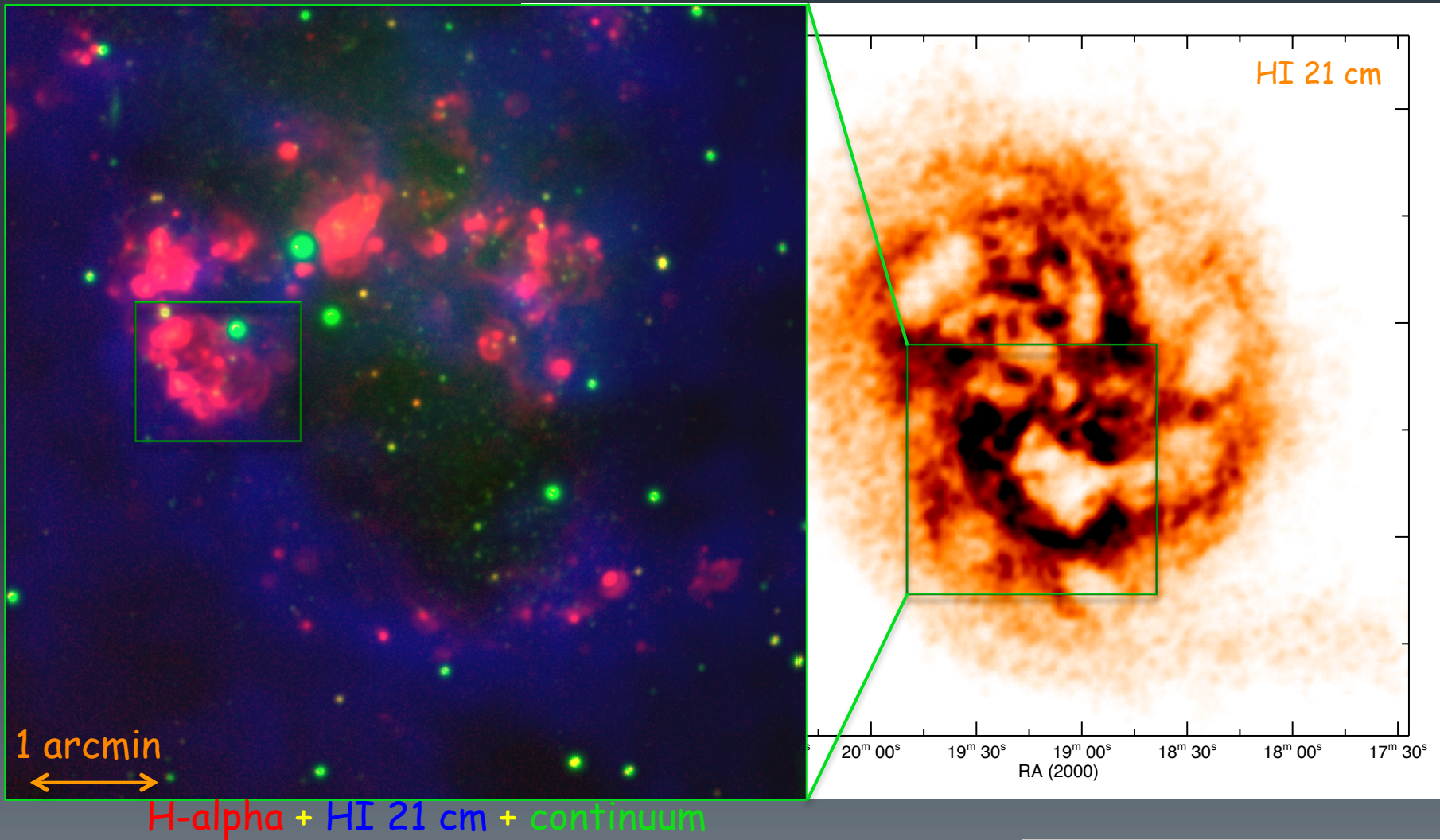
# Holmberg II

17

- 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.



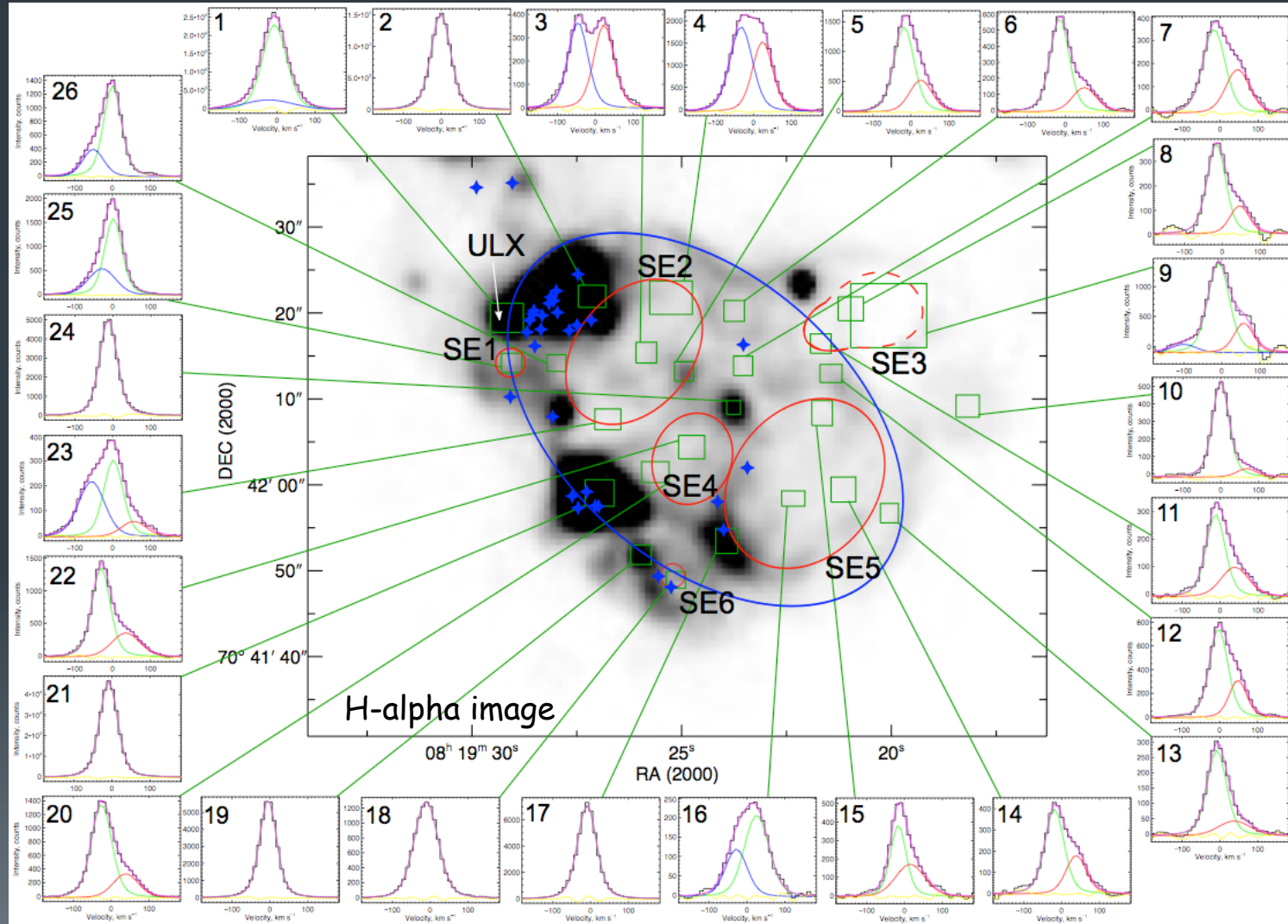
# Holmberg II



# Holmberg II

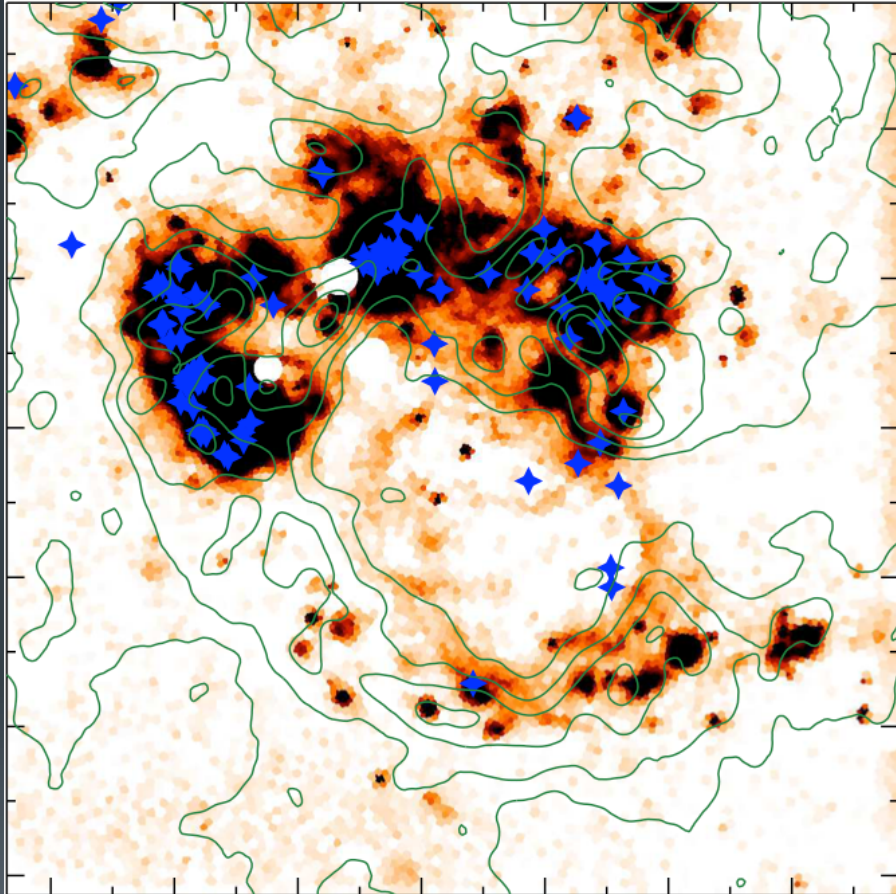
We found a lot of faint expanding ionized shell-like structures with sizes  $\sim 100\text{-}400$  pc as well as the signs of HI expanding shells around star formation complexes.

It 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.



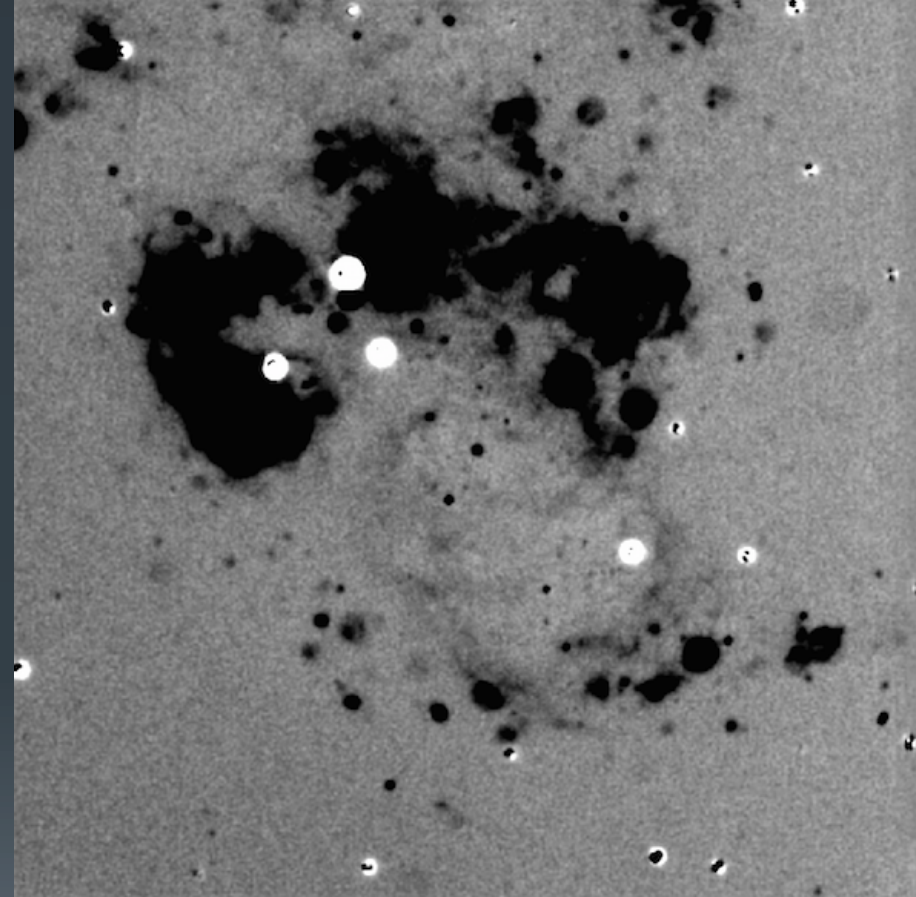


# Holmberg II



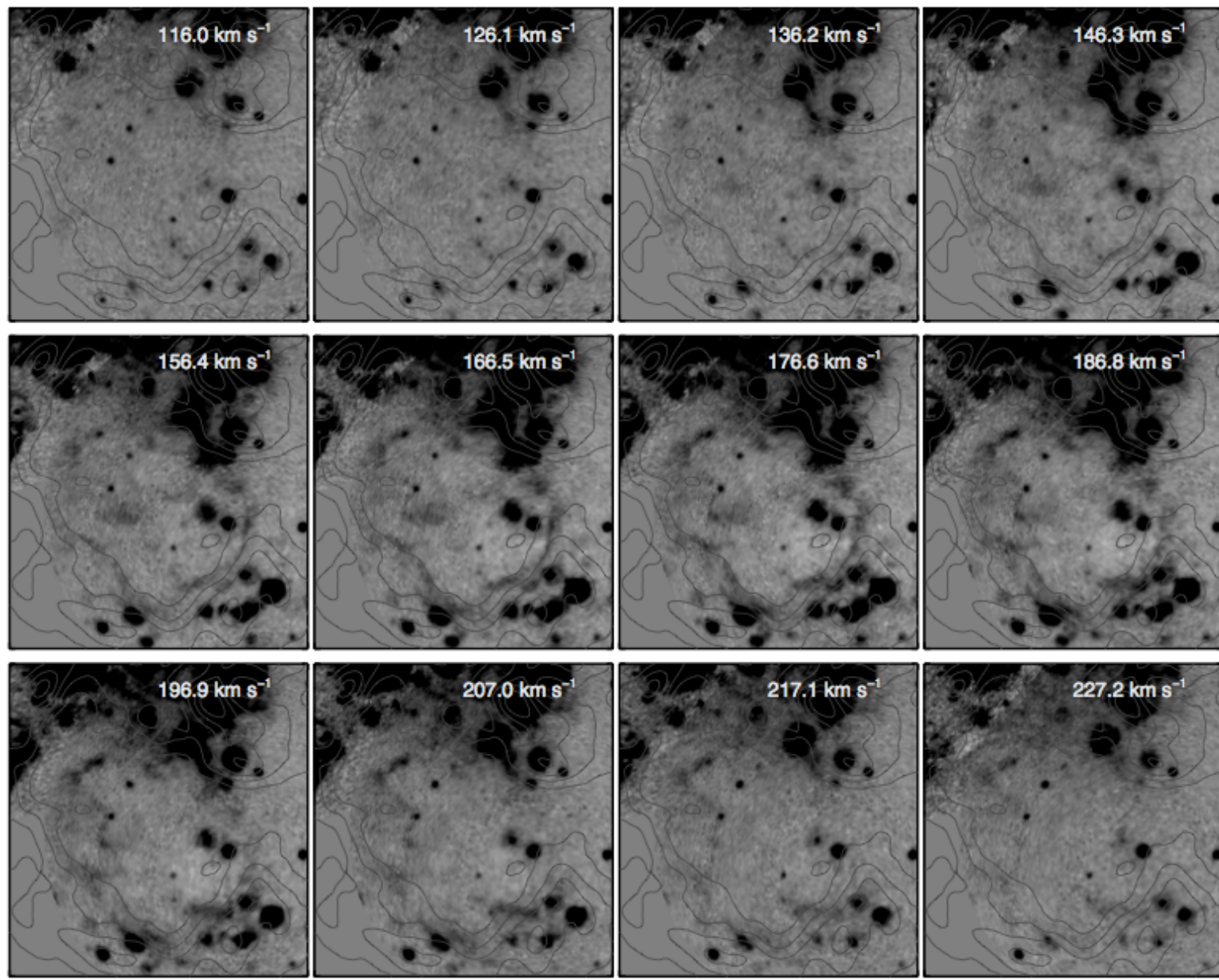
H-alpha + OB-stars + HI 21 cm

$$I_{\text{H}\alpha} \sim 5 \times 10^{-19} \text{ erg/s/cm}^2/\text{arcsec}$$



H-alpha

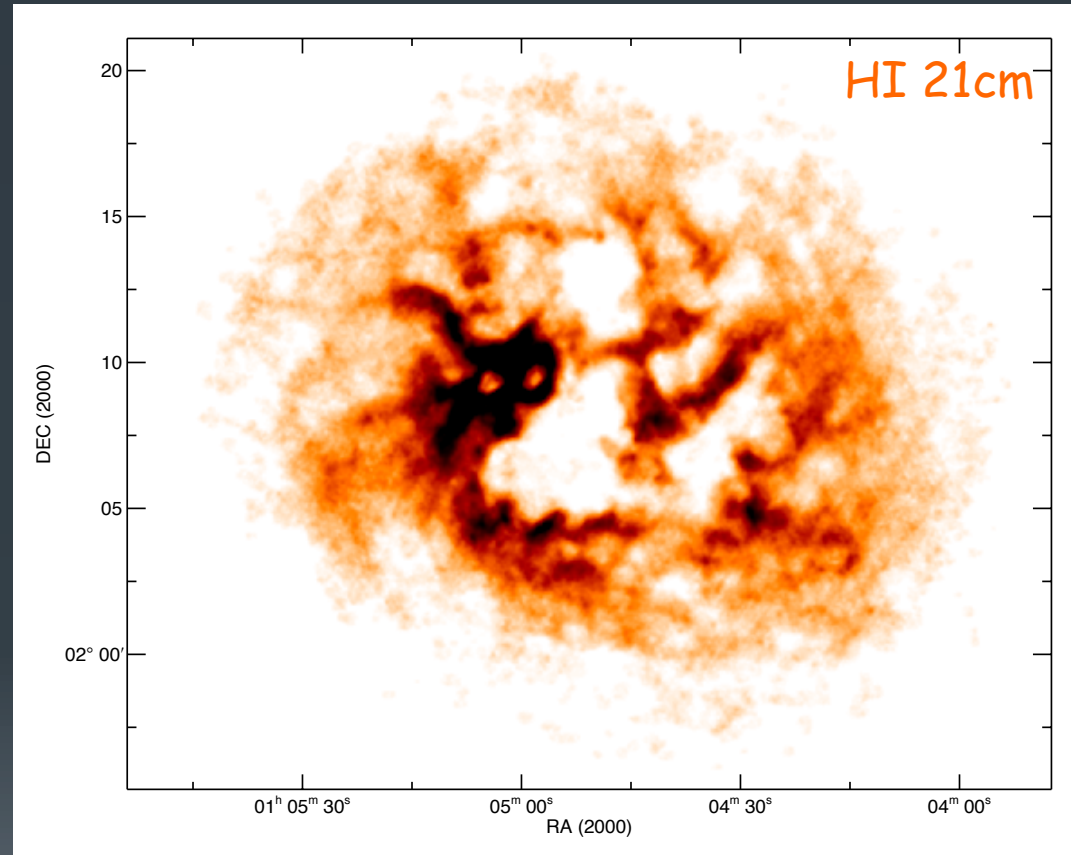
There are only few OB stars located inside the structure. Possibly, they are sources of this kpc-size ionized structure formation. Another possible mechanism of its formation is ionizing quanta leakage from the bright HII regions.



FPI channel maps in H-alpha of discovered giant ionized shell. Its expansion velocity is no more than  $\sim 10$  km/s (the same as for parent H I supershell)

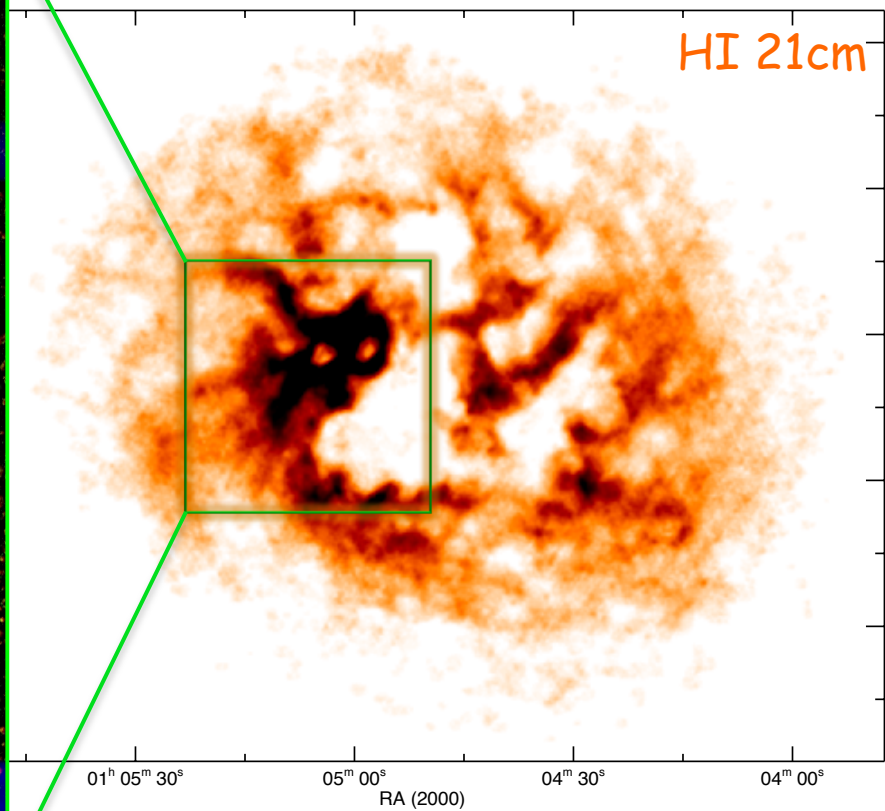
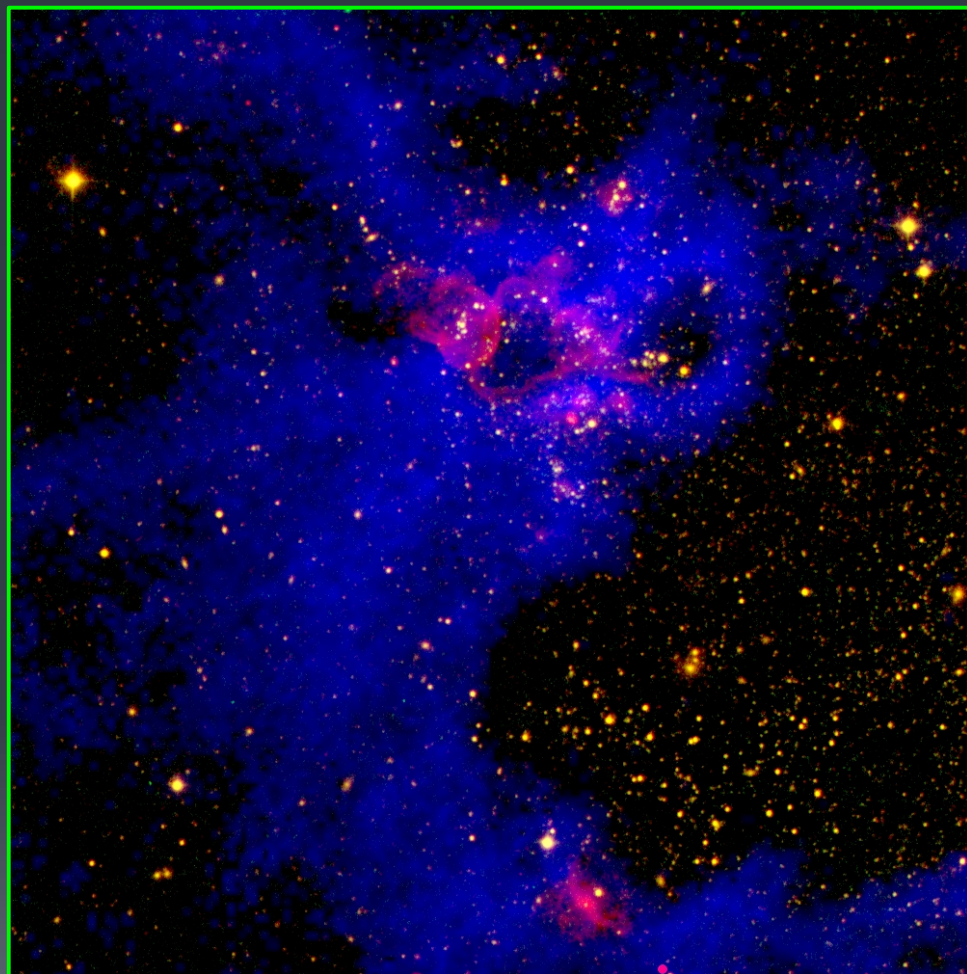
# IC1613

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



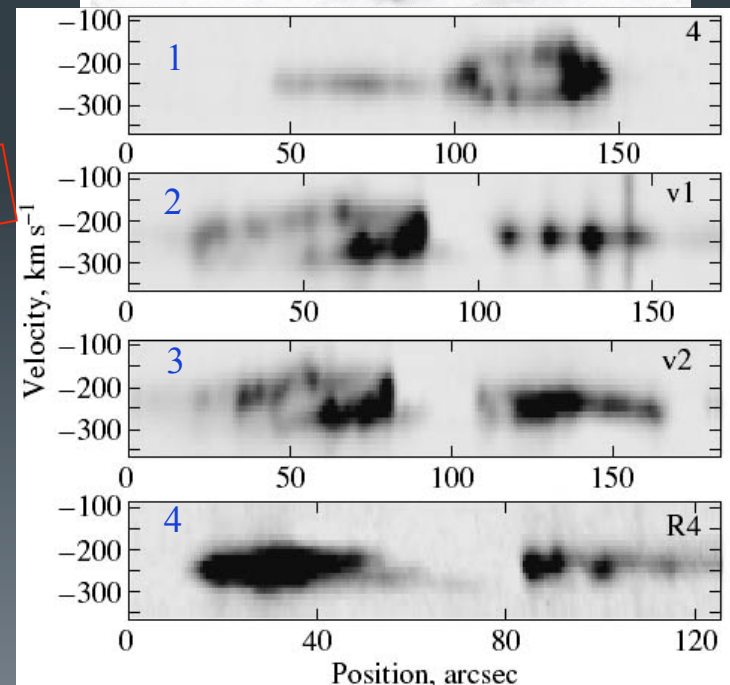
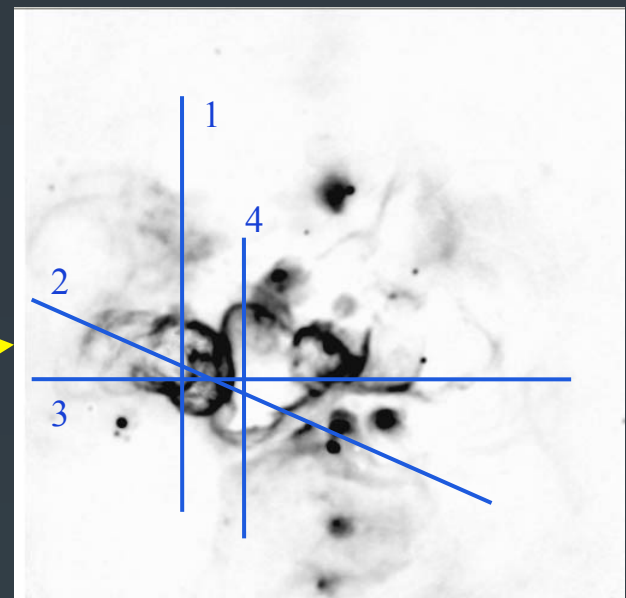
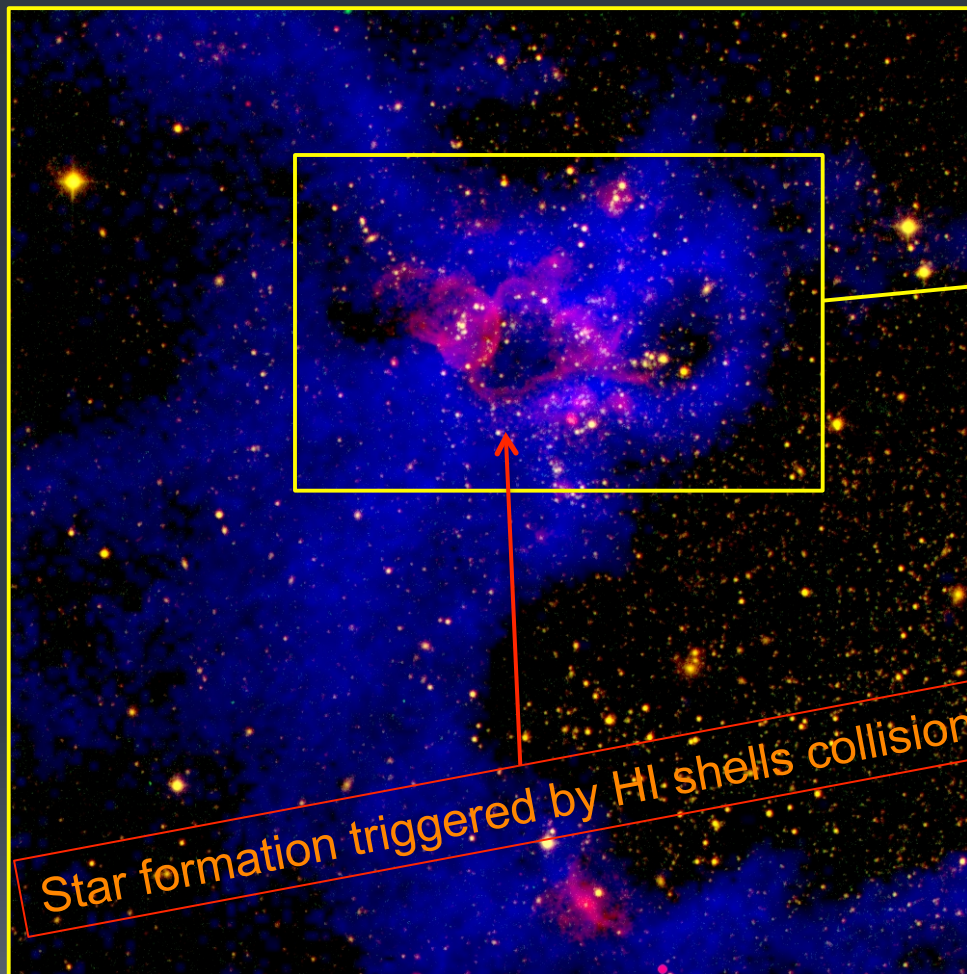


# IC1613



H-alpha + HI 21 cm + continuum

# IC1613



H-alpha + HI 21 cm + continuum

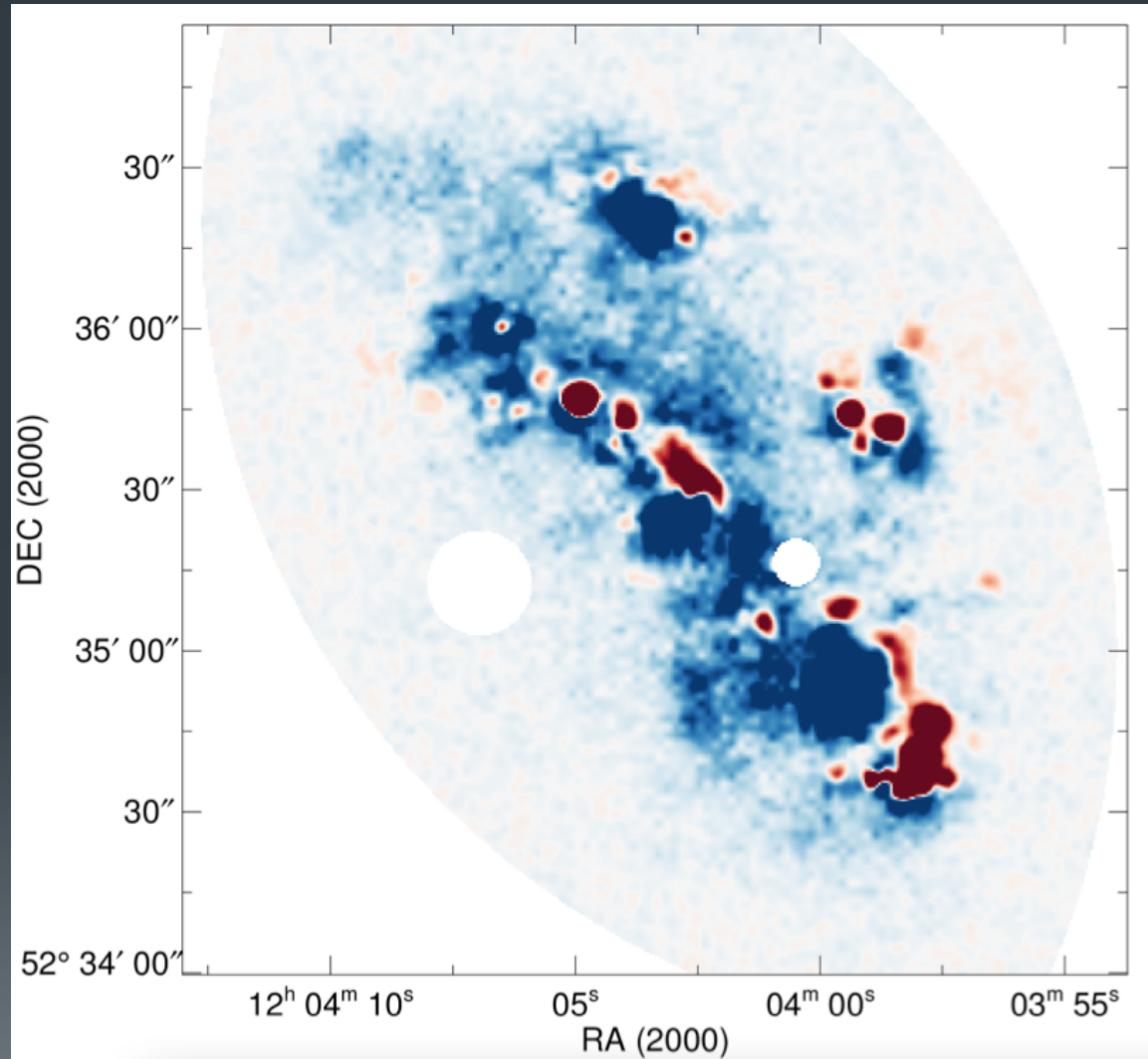
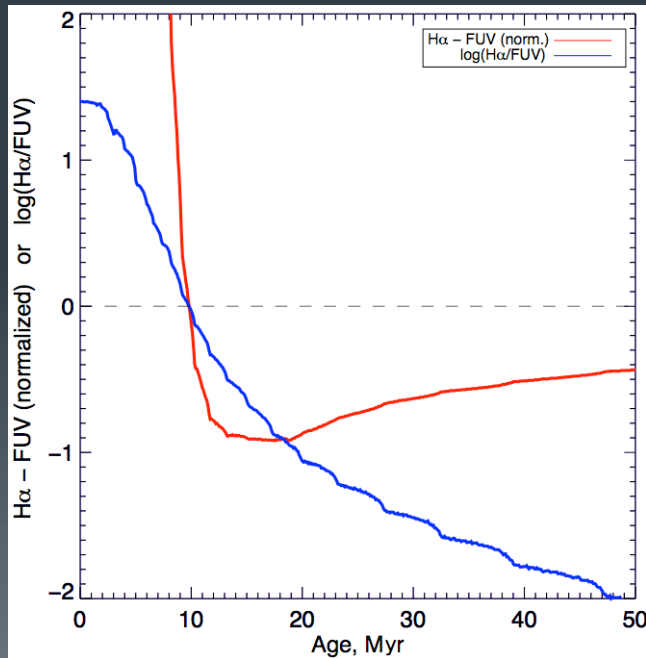
Age of shells  
HI: 5.3-5.6 Myr,  
HII: 0.6-2.2 Myr



# NGC 4068: Triggered star formation

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

Starting from age  $\sim 9$  Myr FUV becomes brighter than H-alpha.



Regions of **ongoing** and **recent** star formation



# IC 2574 & Holmberg II: Triggered star formation

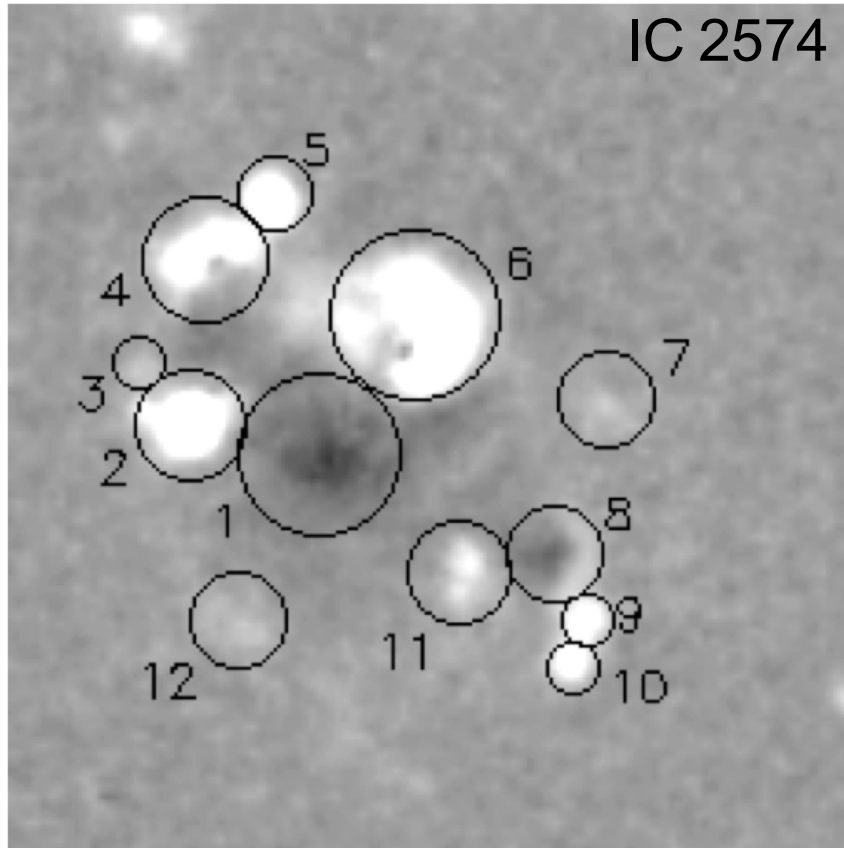
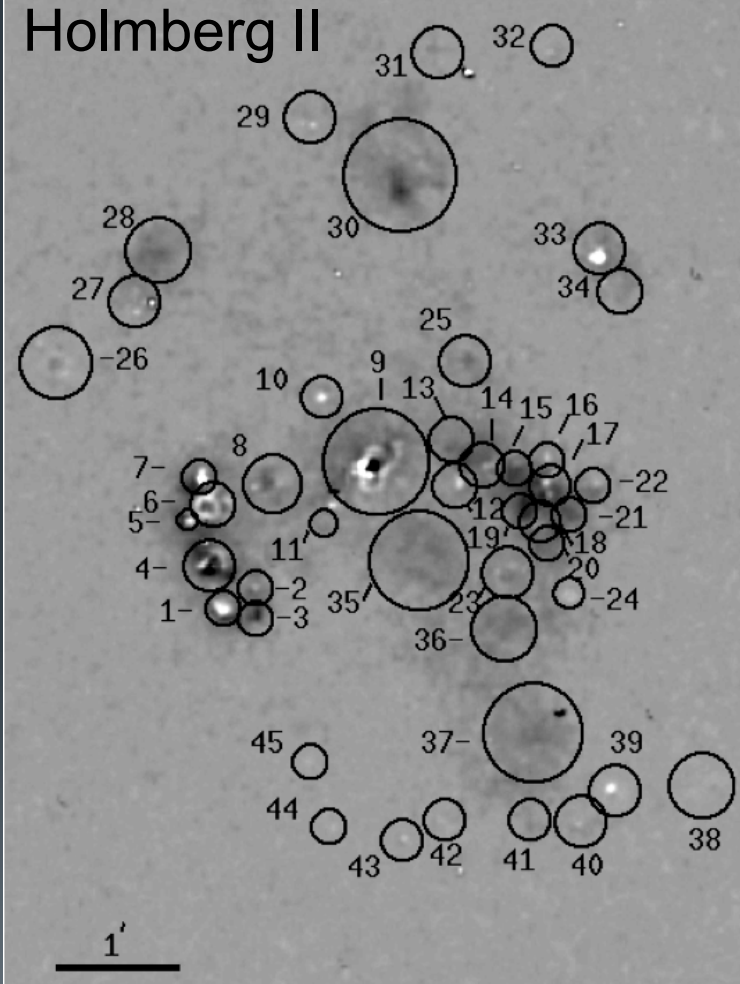


FIG. 3.—FUV, H $\alpha$  difference image with apertures indicating the regions defined by us. The image is displayed so that areas containing FUV and no H $\alpha$  are black and areas containing H $\alpha$  and no FUV are white. The orientation is the same as in Fig. 1.



The same as in the left image

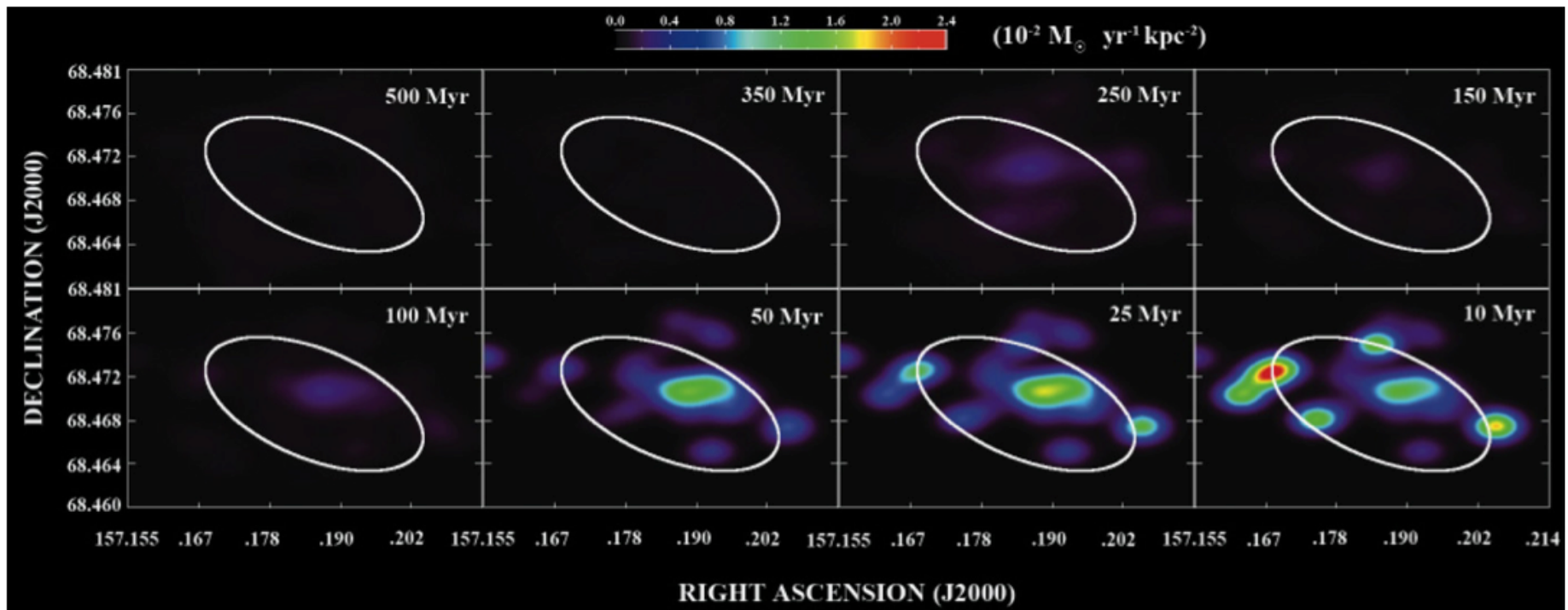
# IC 2574: Triggered star formation

27

No. 1, 2009

TRIGGERED STAR FORMATION AND THE CREATION OF THE SGS IN IC 2574

L61

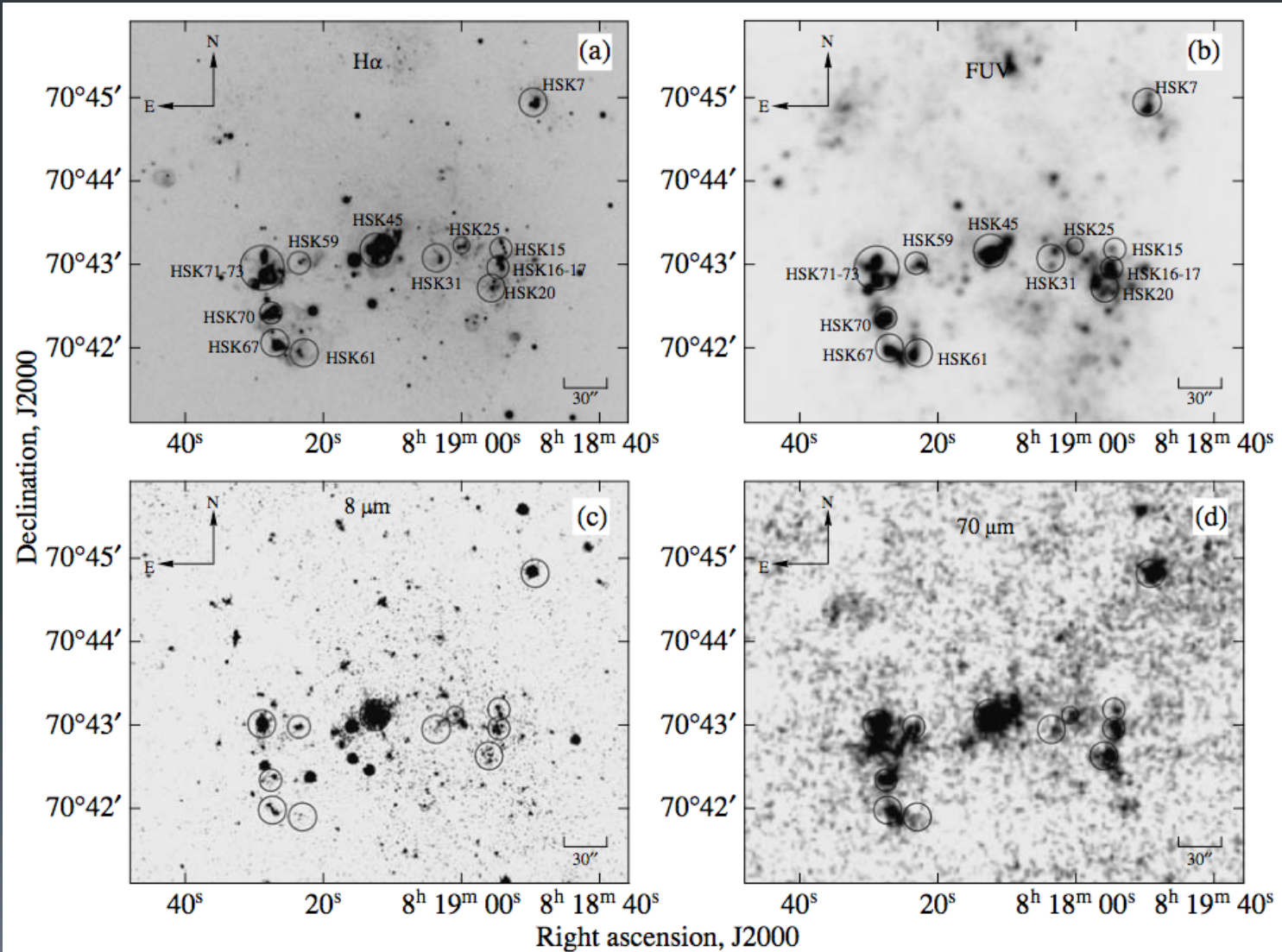


**Figure 4.** Selected still frames from the spatially resolved recent SFH of the SGS region. The white ellipse corresponds to the elliptical outline of the SGS itself shown in Figure 1. The spatial resolution of the images is  $\sim 8''$ , similar to that of the HI observations. The movie can be seen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

# Very shortly about the dust

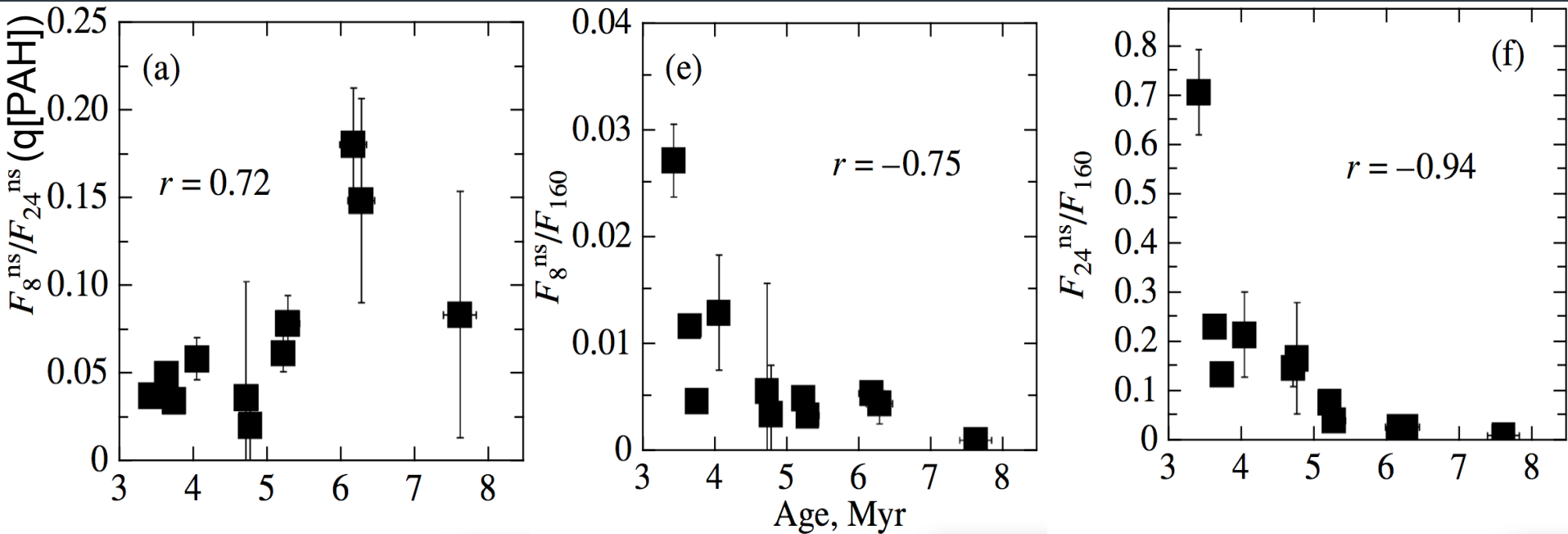
Holmberg II:

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



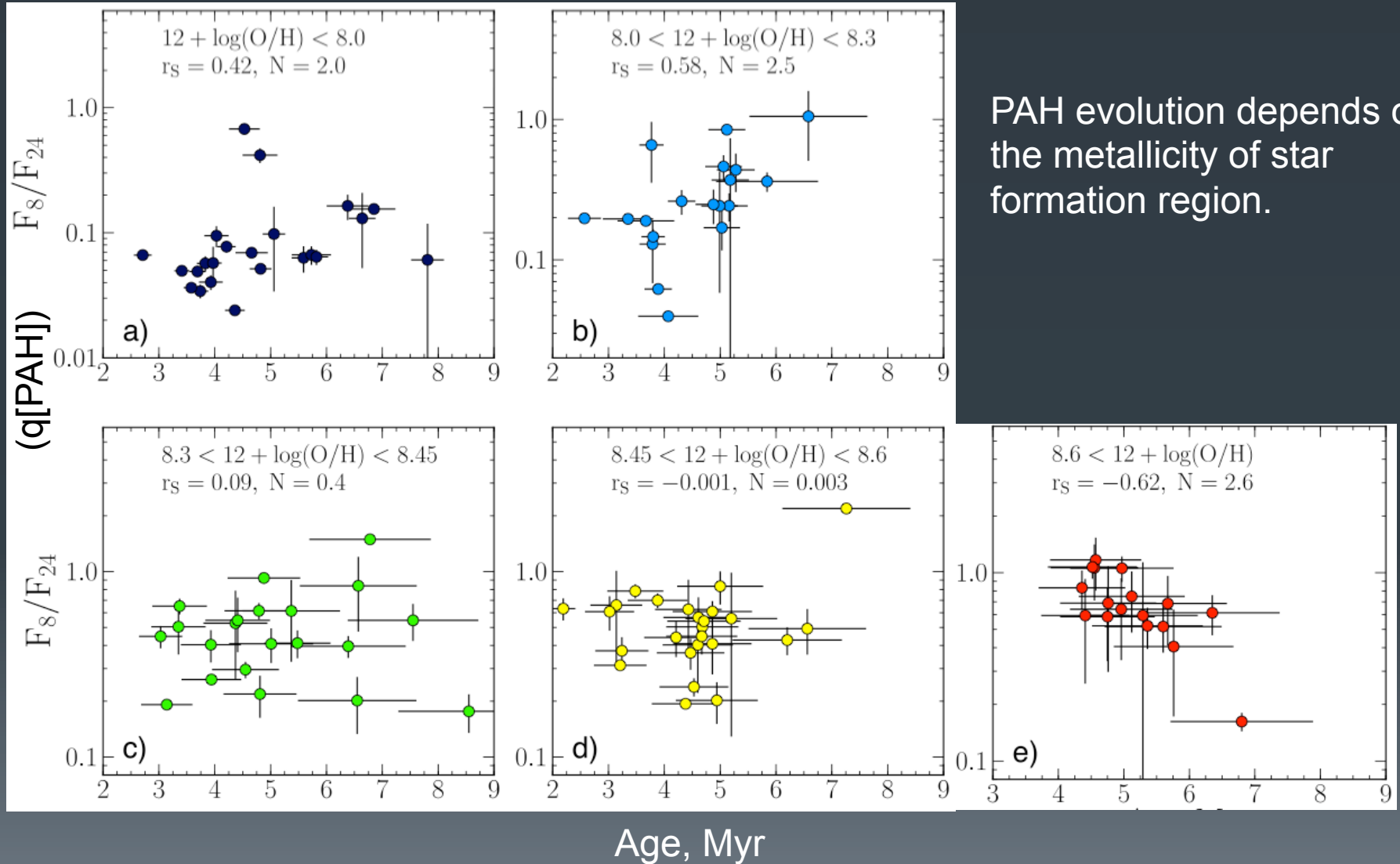


# PAH evolution in star formation regions



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 24 $\mu$  emission) and the formation of PAH from them.

# PAH evolution in star formation regions



PAH evolution depends on the metallicity of star formation region.

# Summary

31

- 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!