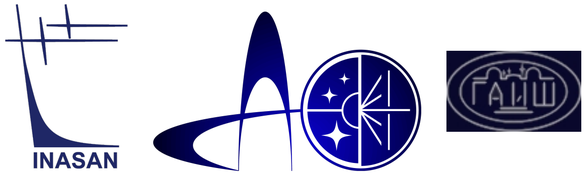
3D structure of expanding HII regions

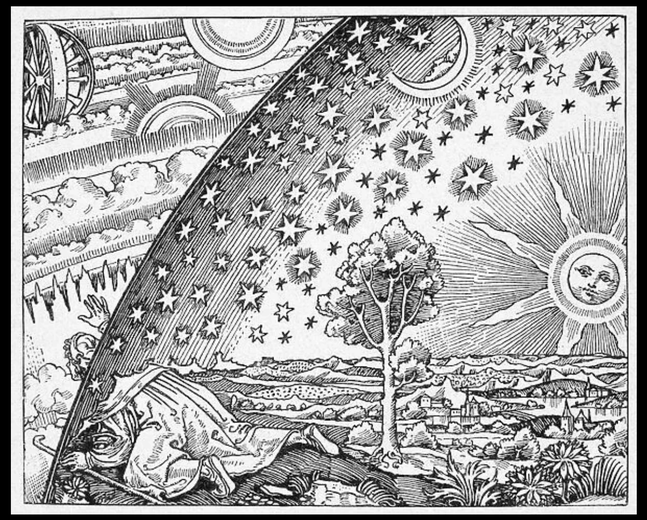
Maria S. Kirsanova
Alexey V. Moiseev, Paul A. Boley, Andrey M. Tatarnikov

Institute of Astronomy, Russian Academy of Sciences
Special Astrophysical Observatory
Moscow State University

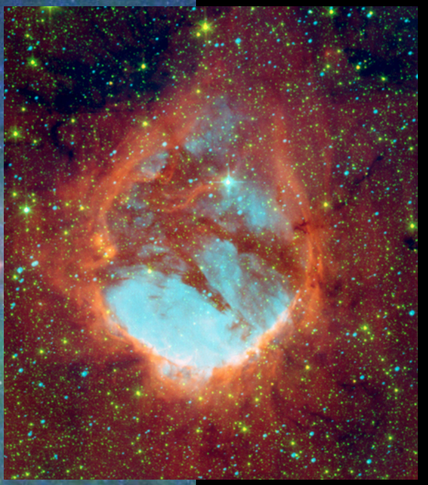


14th SCSLSA conference, June 2023

Astronomers can only observe but not 'touch' cosmic objects or make experiments with them



Spitzer and WISE found more than 5000 infrared bubbles, most of them are related with HII regions



8 um H α

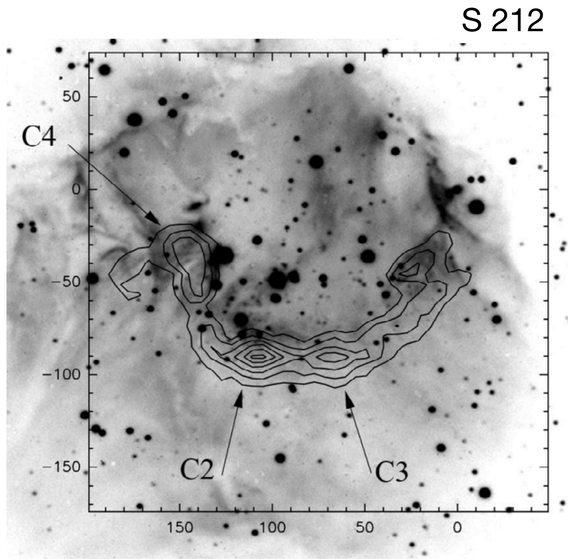
Deharveng et al, 2005, 2009
Zavagno et al., 2006, 2007

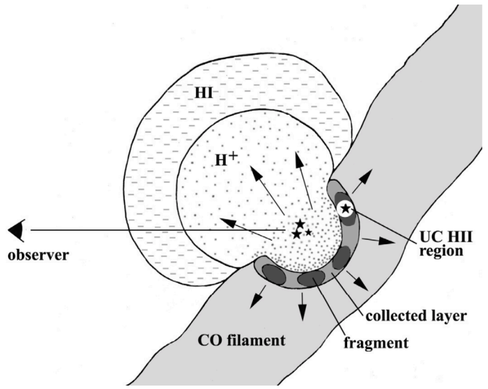
3.6um 8um 24um

images from NASA/JPL

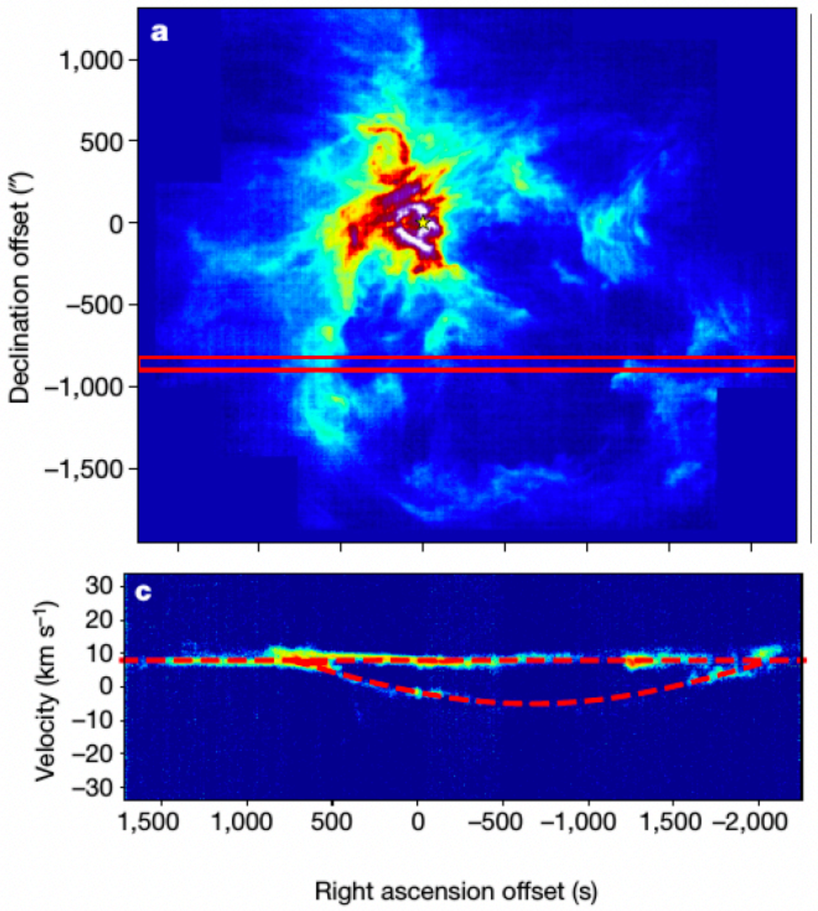
3D structure using velocity information

Radial velocity as a third coordinate





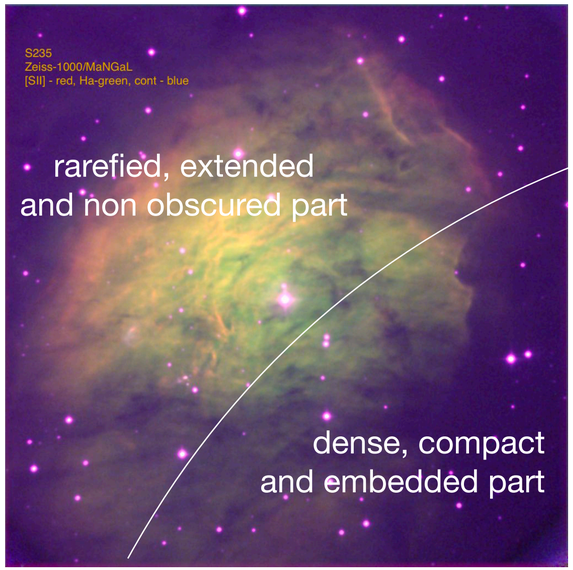
Deharveng et al, 2005, 2006



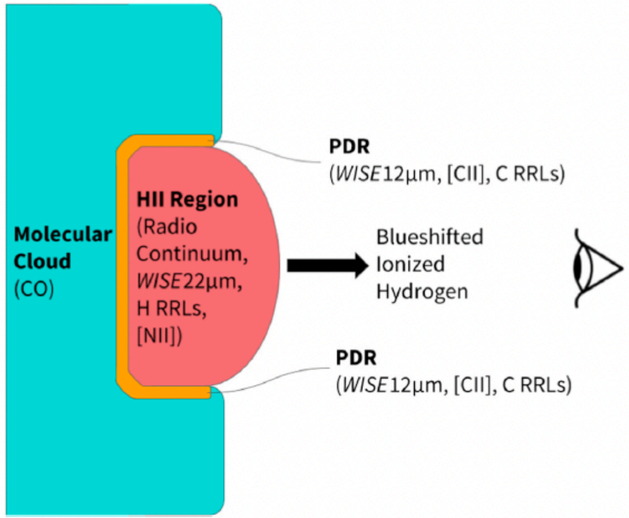
[CII] position-velocity diagram
Pabst et al, 2019, 2020

3D structure using combinations of images

Optical + infrared images confirmed results from spectroscopy

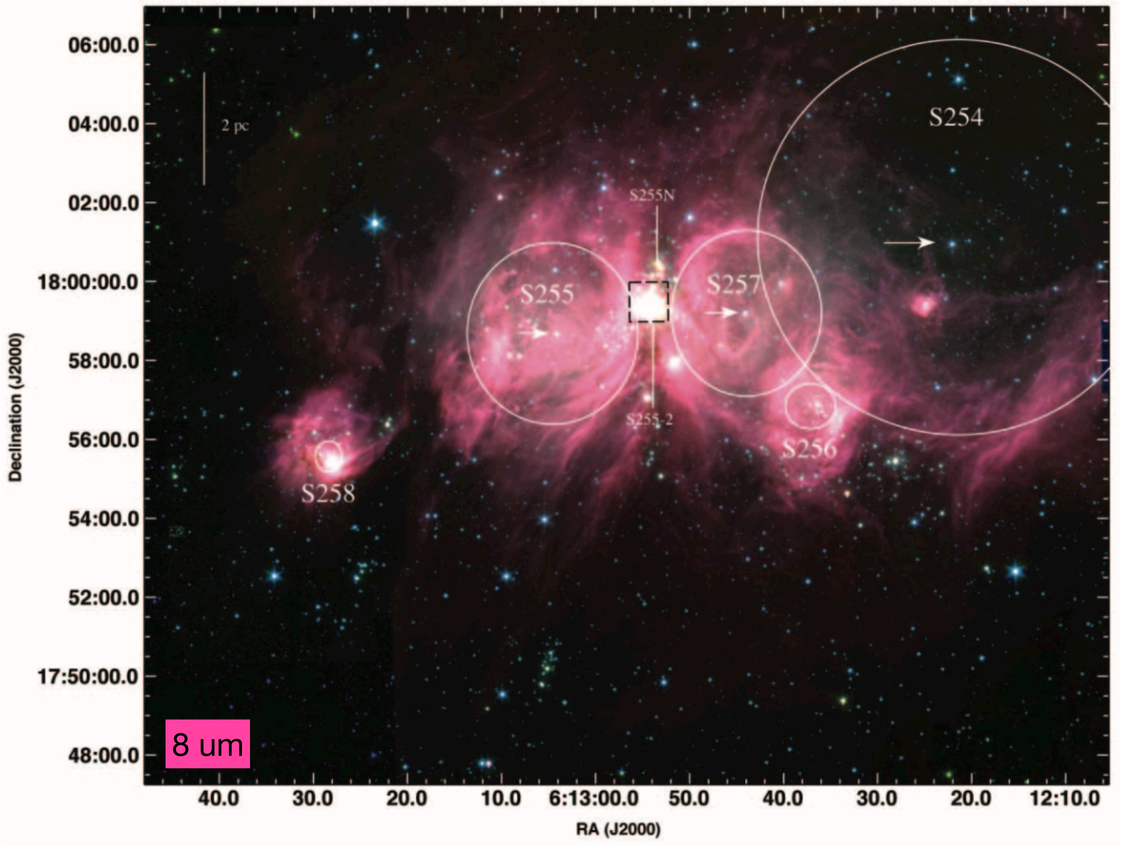


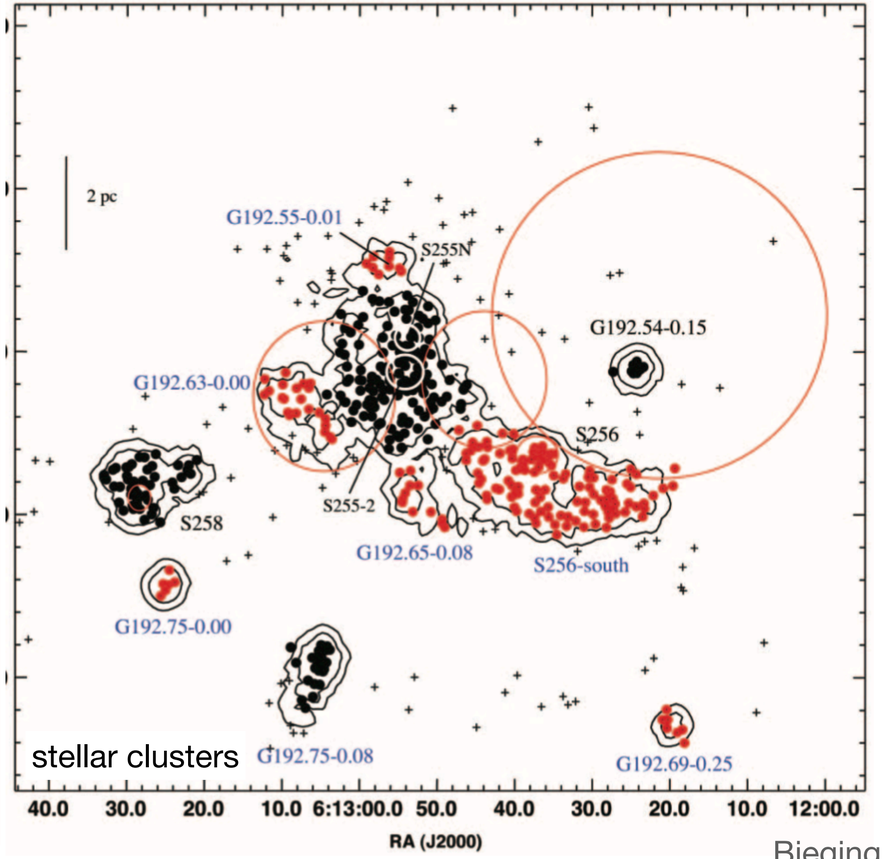
Kirsanova et al, 2020



Anderson et al., 2019

Star-forming complex S254-S258





Bieging et al, 2009
Chavarria et al., 2008, 2014
Ojha et al., 2011
Samal et al., 2015
Zinchenko et al., 1997, 2009, 2012
Ladeyshikov et al., 2022
and many others

Observations

Zeuss-1000

tunable-filter
photometer MaNGaL

6m BTA

long-slit spectroscopy
SCORPIO-2

2.5m SAI

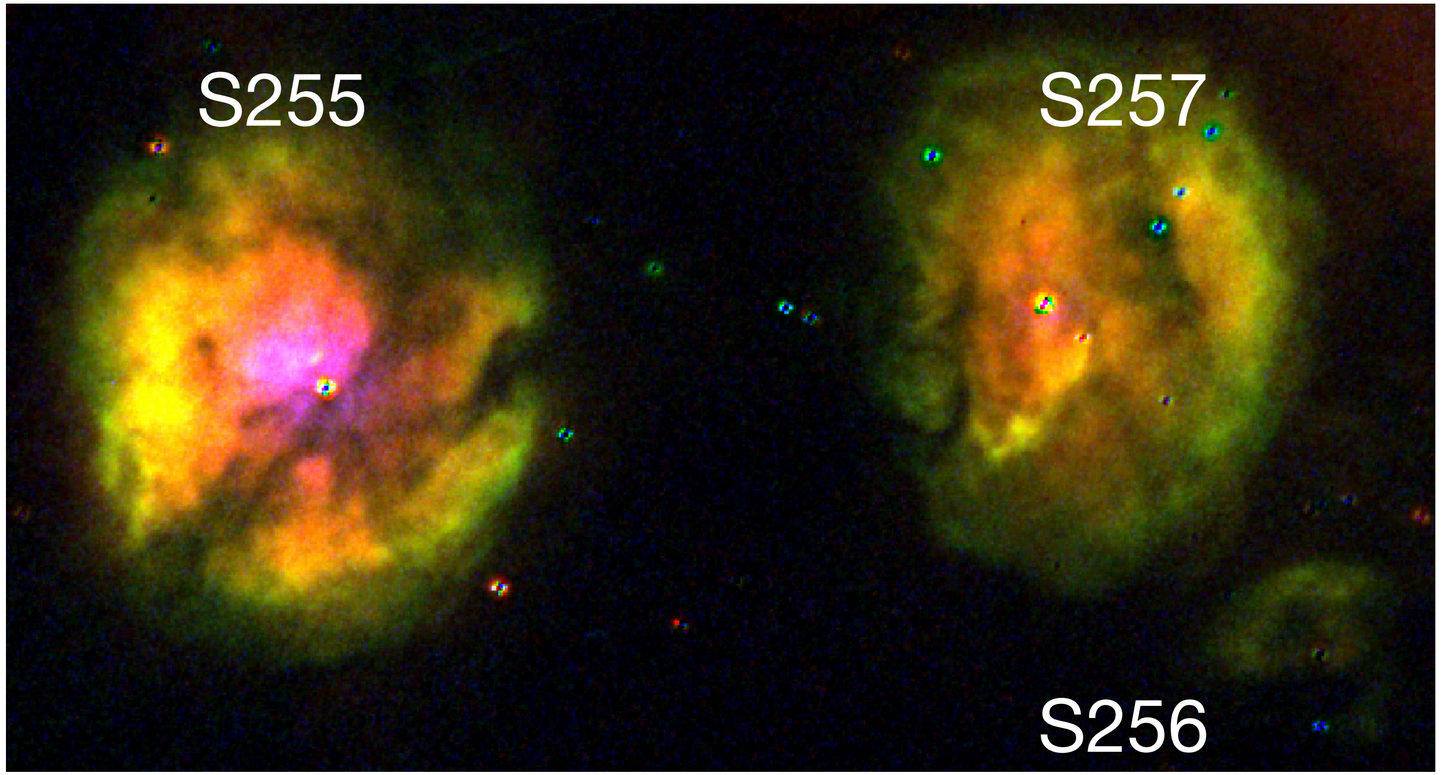
near-inrfared camera
ASTRONIRCAM

Observations with MaNGaL @ Zeiss 1000

images of HII regions

Zeuss-1000

tunable-filter photometer MaNGaL

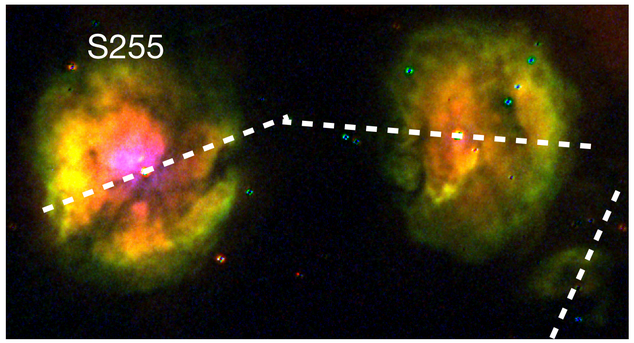


Colour composite image: Hβ, [SII], [OIII]

Kirsanova, Moiseev, Boley, submitted

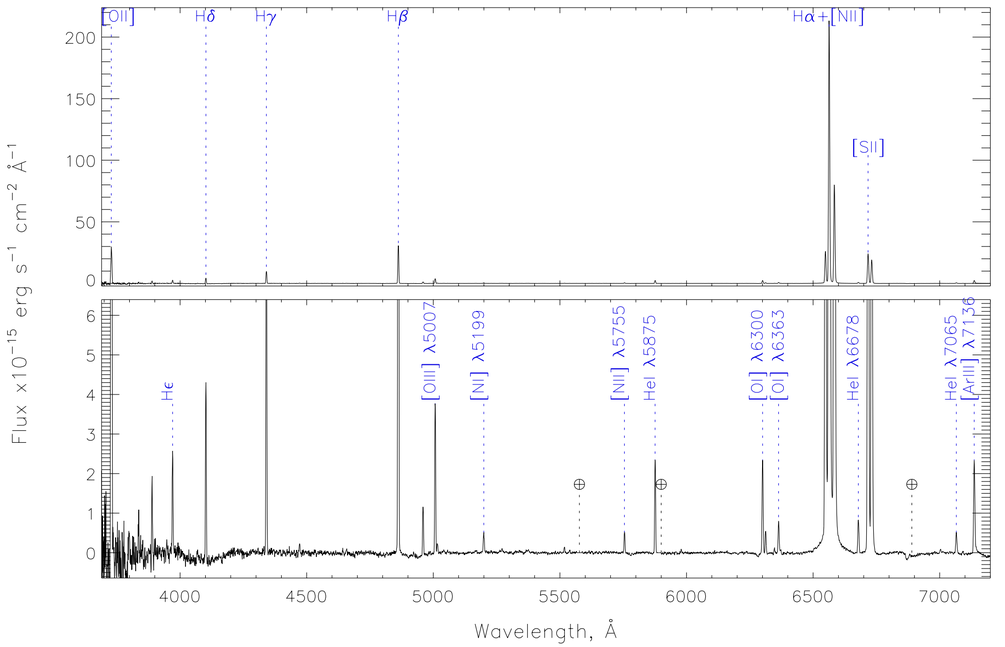
Observations with the 6m BTA telescope

long-slit spectroscopy

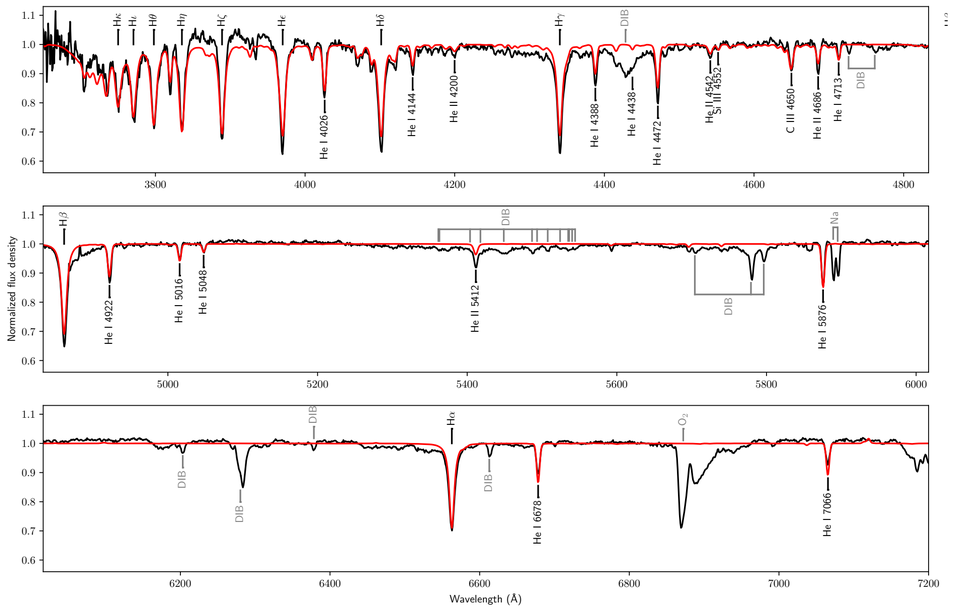


6m BTA

long-slit spectroscopy
SCORPIO-2



Emission spectrum of S255

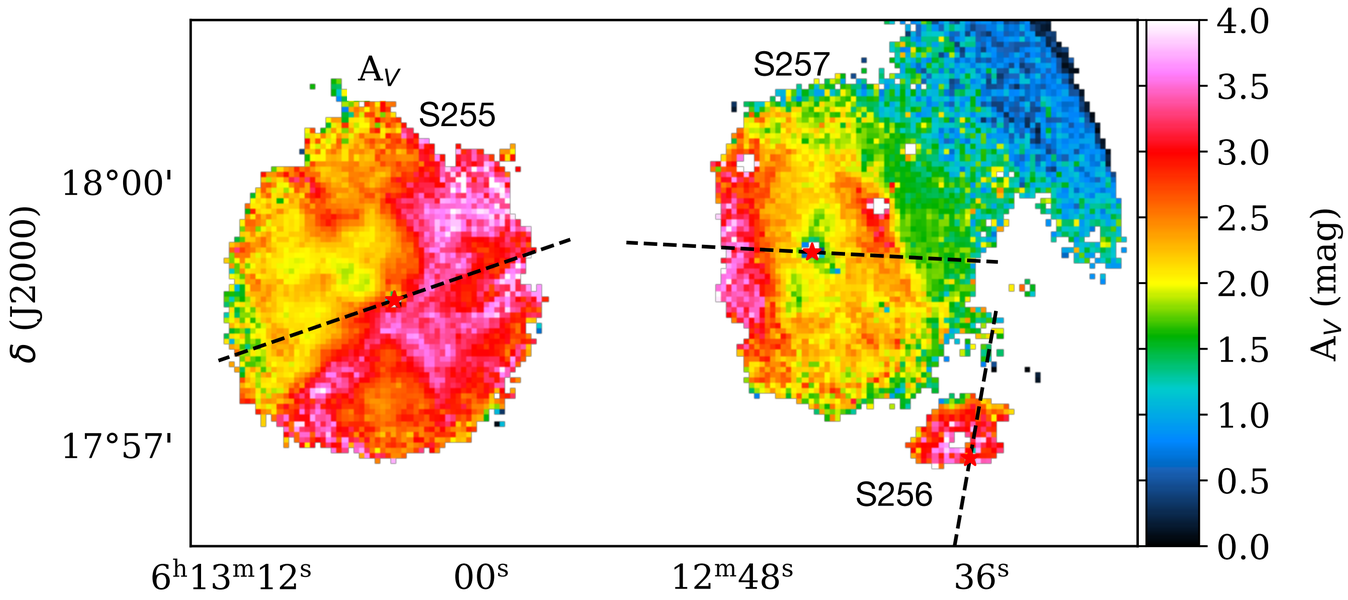


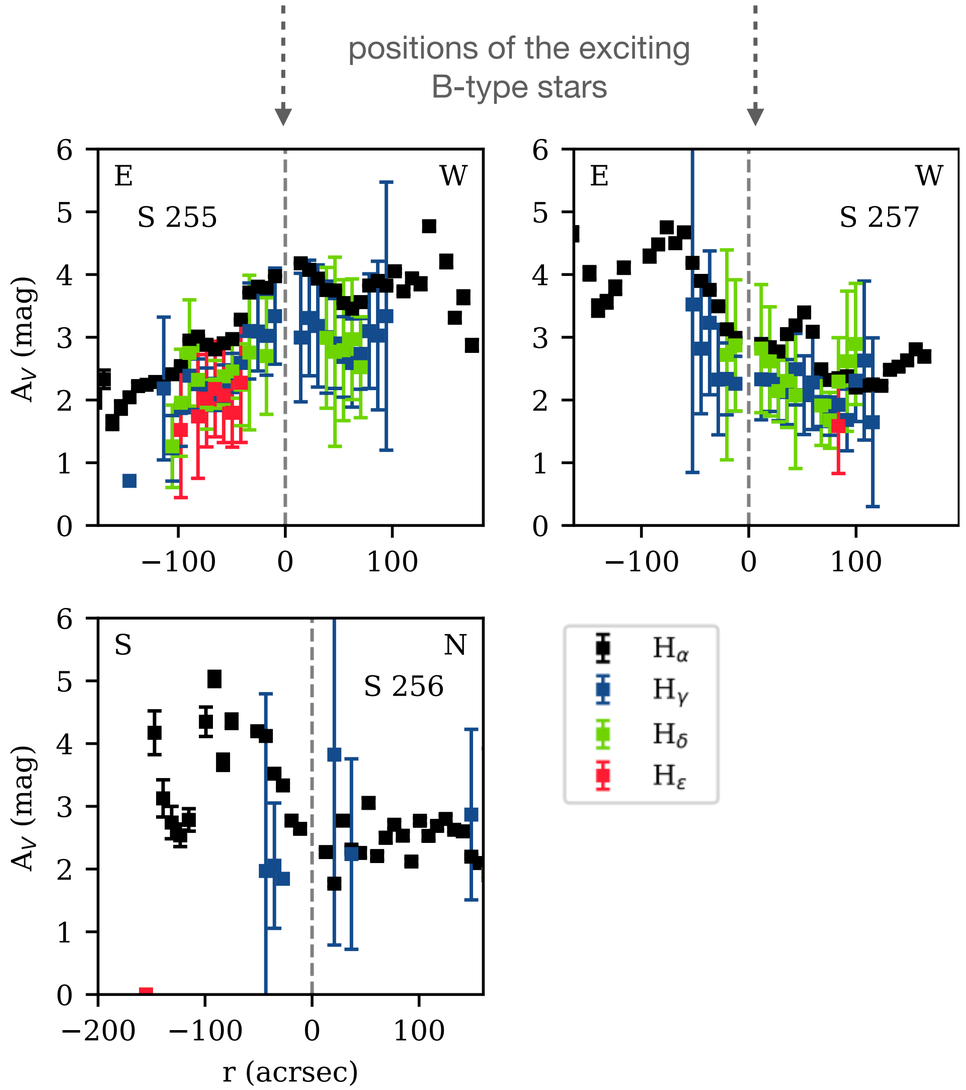
Emission spectrum of the
B-type exciting star in S255

Kirsanova, Moiseev, Boley, submitted

Maps of the foreground extinction

using the ratio of Hα to Hβ

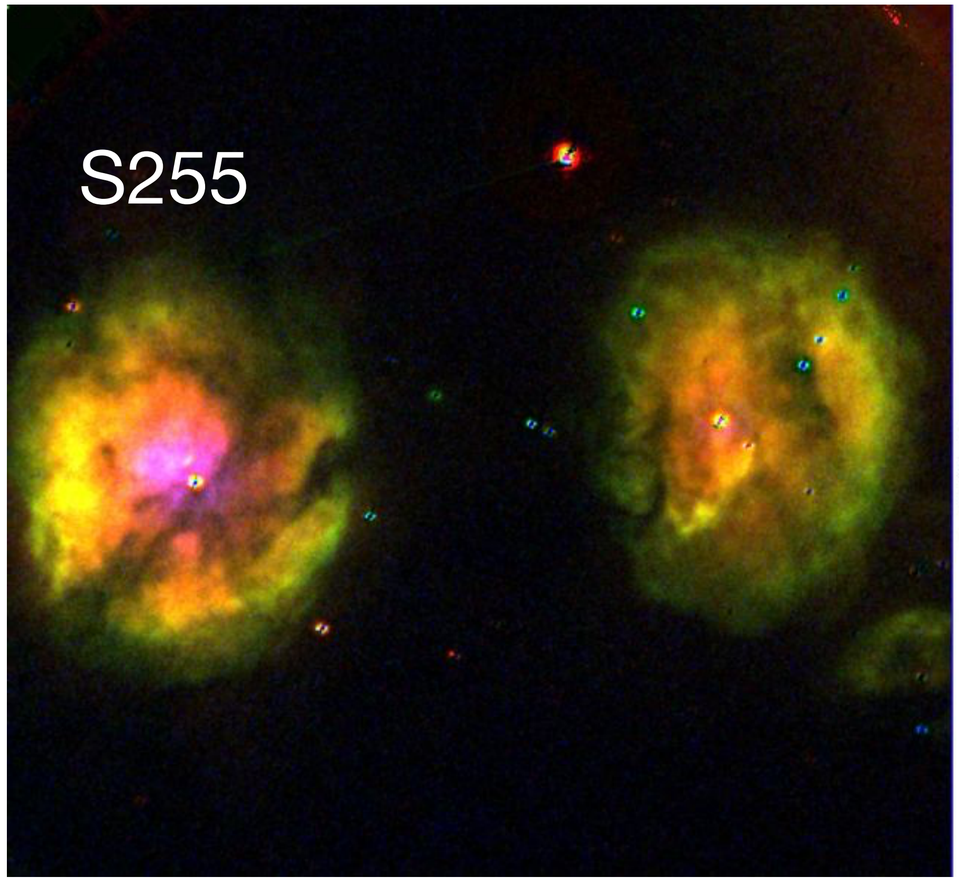


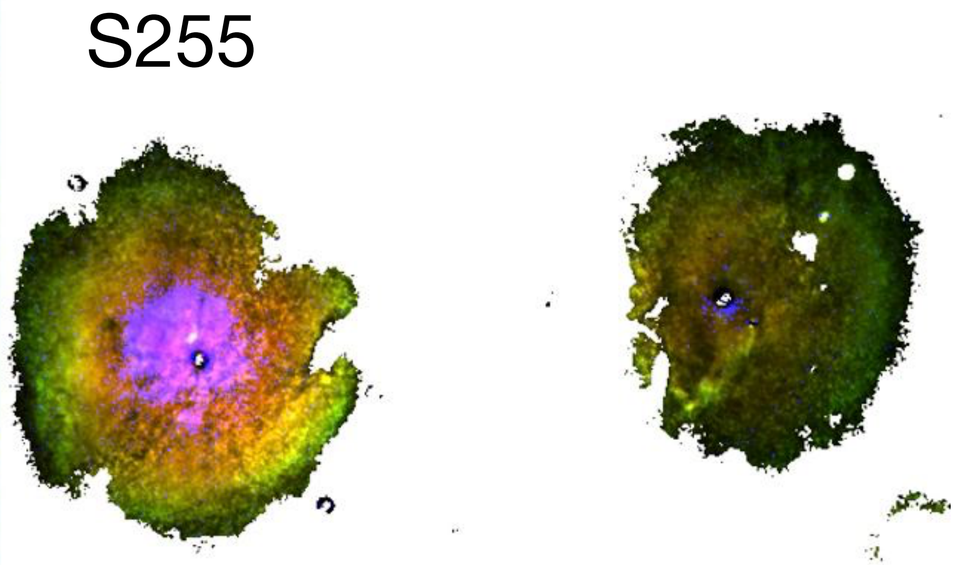


Kirsanova, Moiseev, Boley, submitted

S255 looks as 'classical' spherical HII region

Original VS dereddened



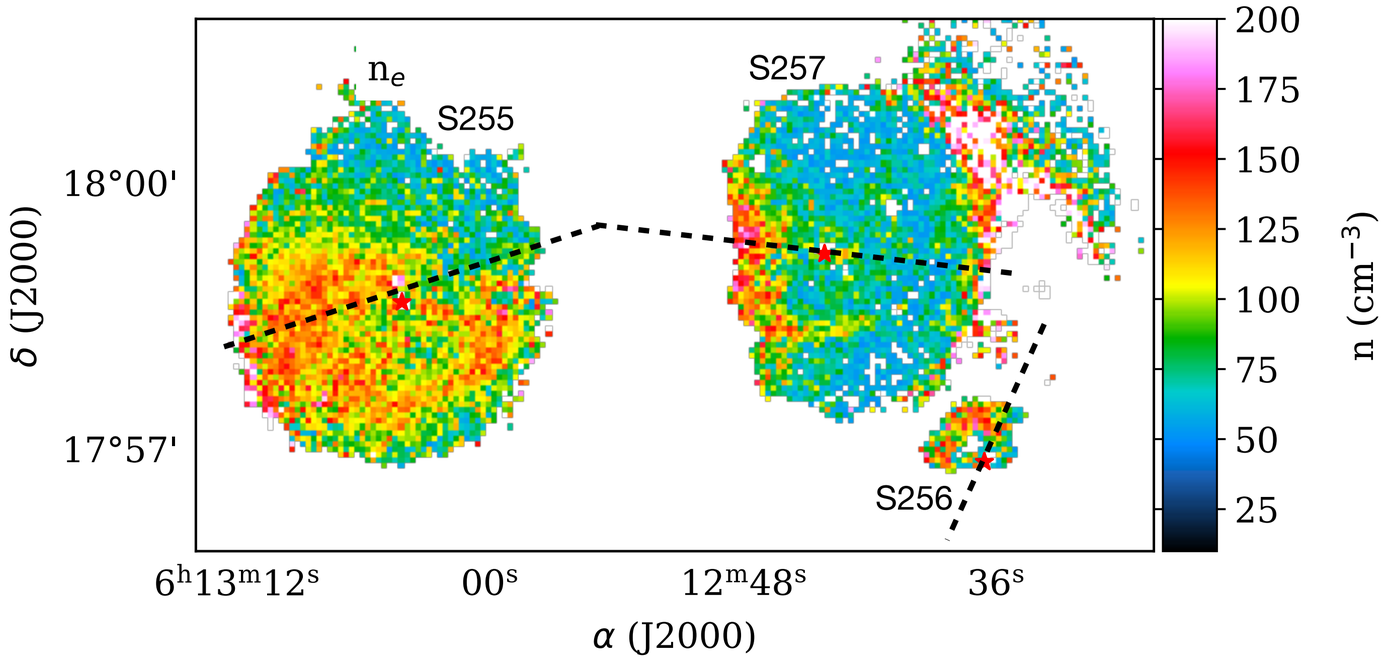


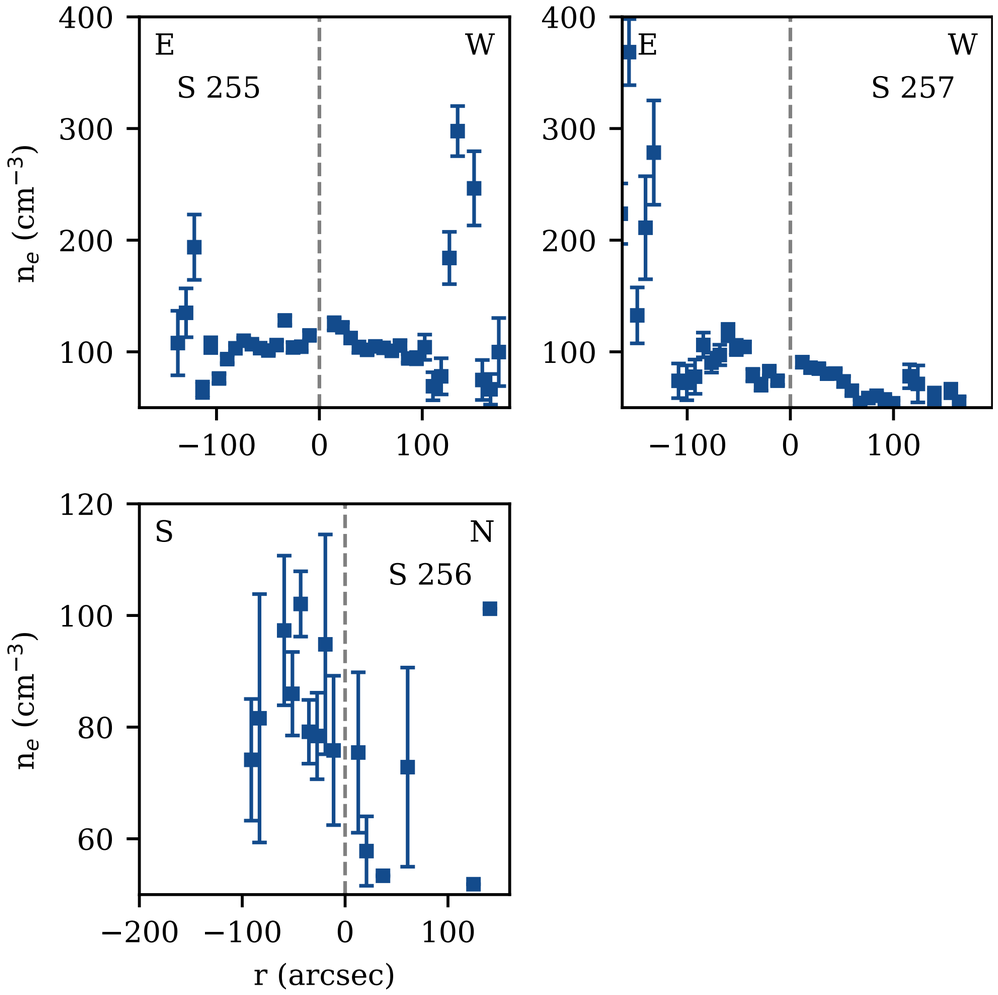
Colour composite image: Hβ, [SII], [OIII]

Kirsanova, Moiseev, Boley, submitted

Maps of electron density

using the [SII] lines λ6716/λ6731

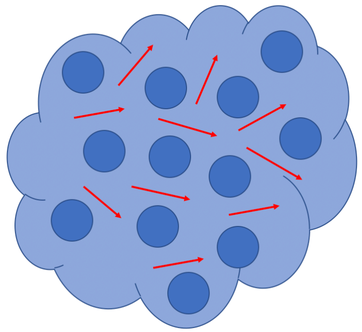




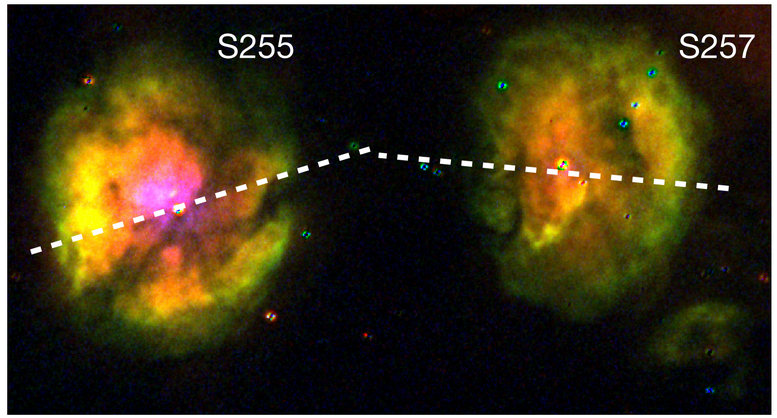
Kirsanova, Moiseev, Boley, submitted

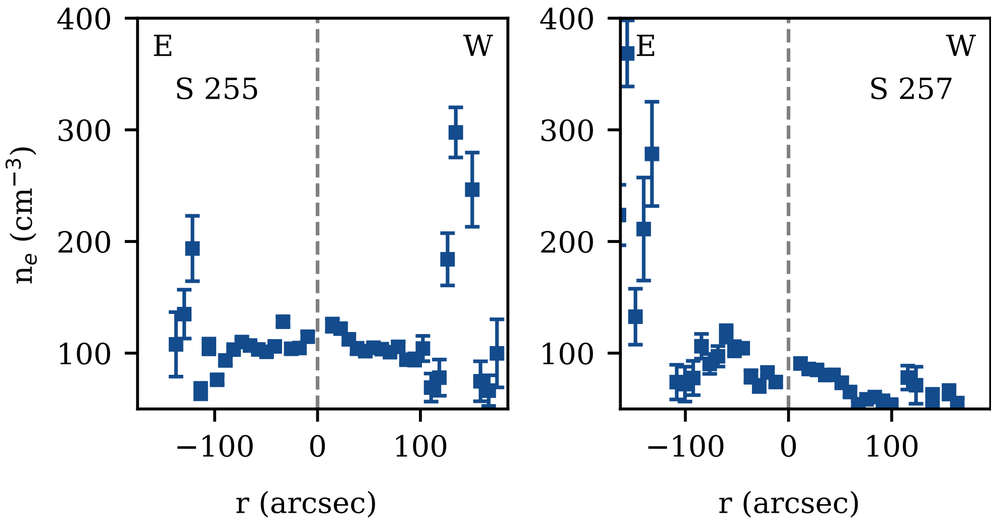
Enhancements of electron density on the borders of HII regions

- diffuse UV photons, which penetrate through a clumpy dense neutral medium and ionize it



- evacuation of the ionized gas from the vicinity of the massive stars by stellar wind



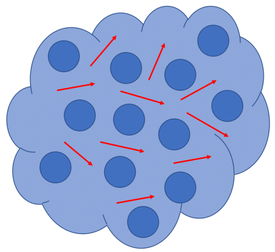


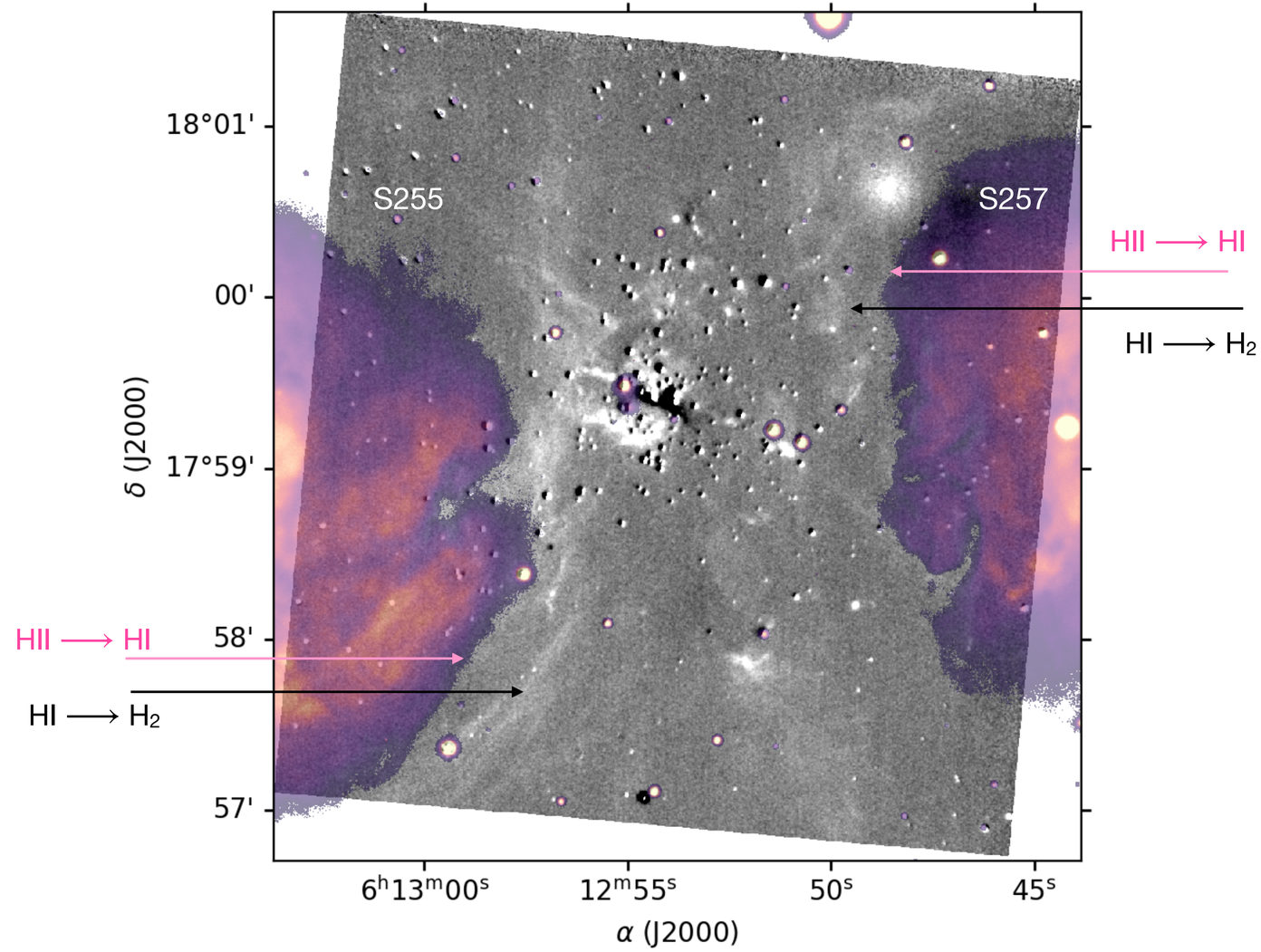
Kirsanova, Moiseev, Boley, submitted

Ro-vibrational emission of H_2, excited by FUV photons

appears near the H_2 dissociation front

- projected distances between the ionization and dissociation fronts Δ=0.3 pc
- simulations with uniform density distribution: $\Delta \ll 0.1$pc
- *we need clumpy medium to obtain this thick HI layer*





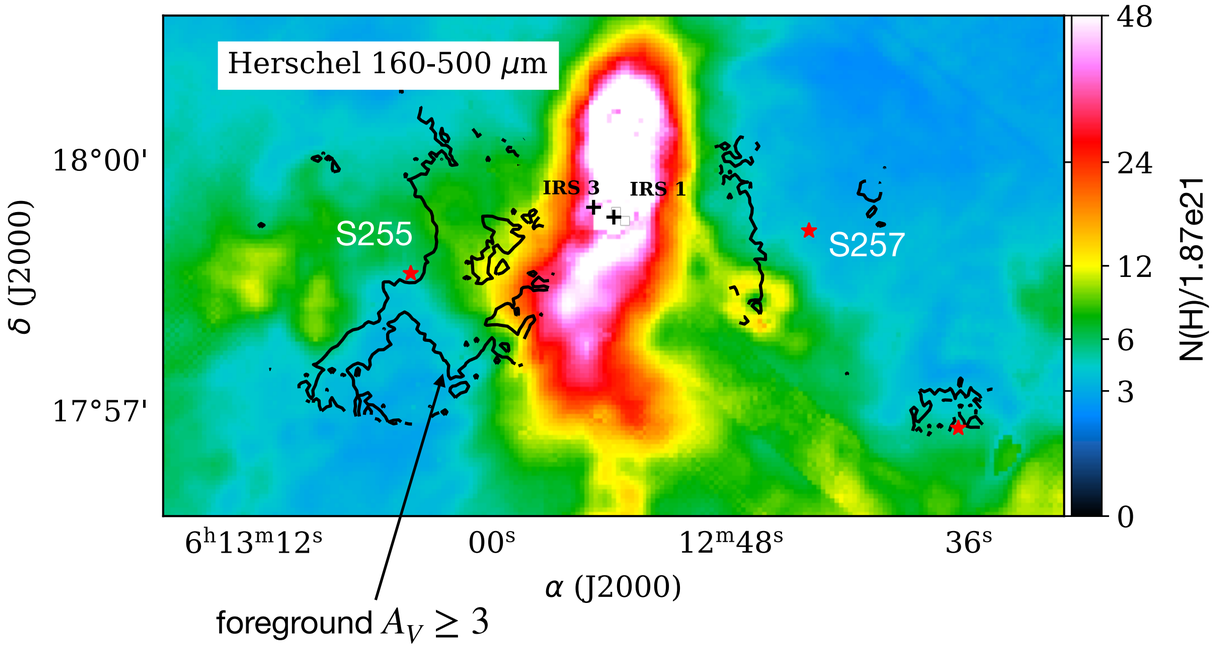
Colour composite image: Hα, ro-vibrational H_2 @ 2 μm

Kirsanova et al., 2023

3D structure of the HII regions

Foreground extinction and total column density of neutral material

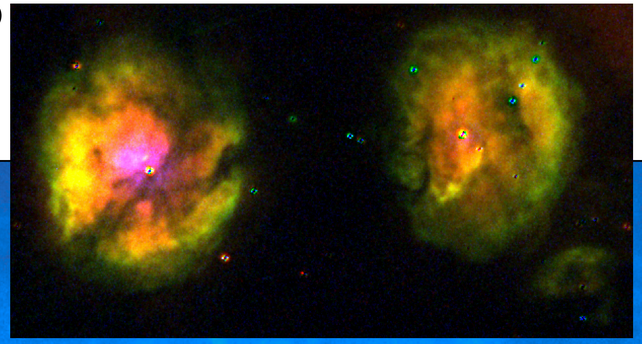
- $A_V = \frac{H(\mathrm{H})}{1.87 \times 10^{21}}$ (Bohlin et al. - 1978)
- S255 is partly surrounded by dense neutral gas from all sides
- S257 is situated on the border of a molecular cloud and does not have dense front and back walls
- compact HII region S256 is deeply embedded into molecular cloud



Kirsanova, Moiseev, Boley, submitted

3D structure of the HII regions

star-forming complex S254-258



optical image

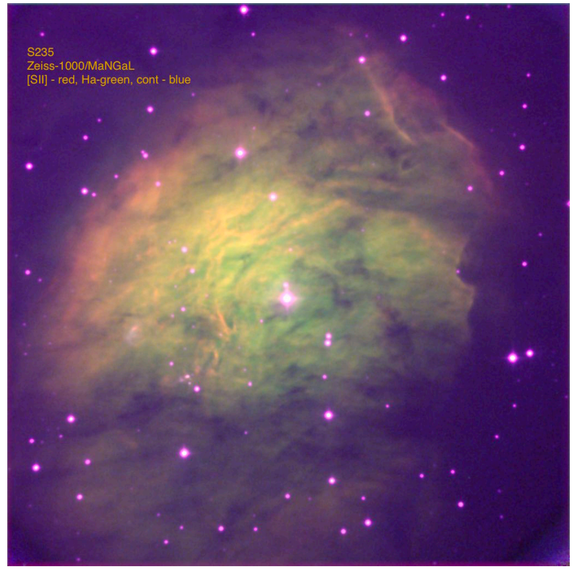
Kirsanova, Moiseev, Boley, submitted

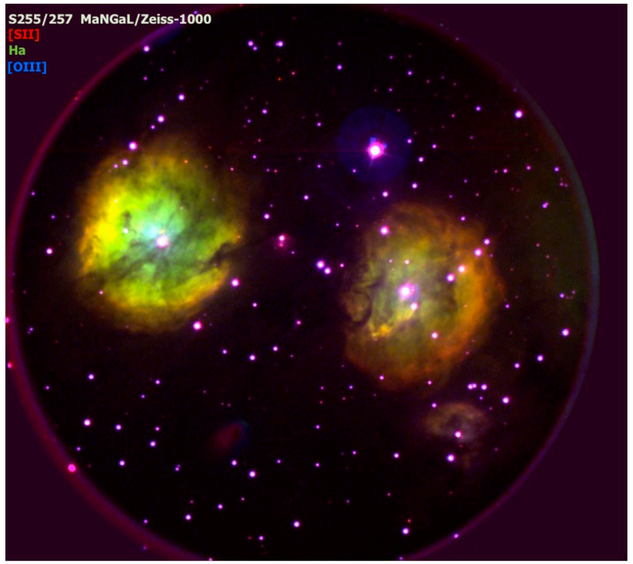
Conclusion

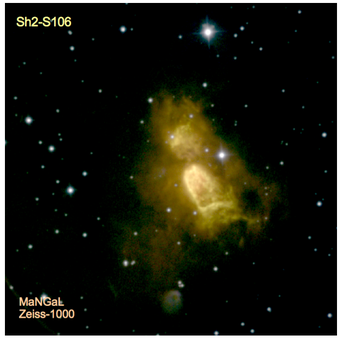
- The three-dimensional structure of the observed HII regions is varied:
- S255 is surrounded by the dense gas from all sides
- S257 does not have dense front and back walls
- S256 is deeply embedded into molecular cloud.
- In spite of the different spatial distribution of the atomic and molecular gas, the clumpy structure of the medium can explain the observed electron density distribution and the broad layers of atomic hydrogen around the ionized gas.

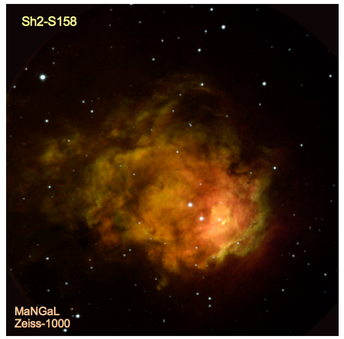
Conclusion

This study is a part of a large project









- and many more HII regions!
- MaNGaL gallery https://www.sao.ru/hq/lsfvo/devices/mangal/gallery_sky.html

This study is supported by Russian Science Foundation, grant 21-12-00373