Interaction between massive stars and ISM in metal-poor galaxies

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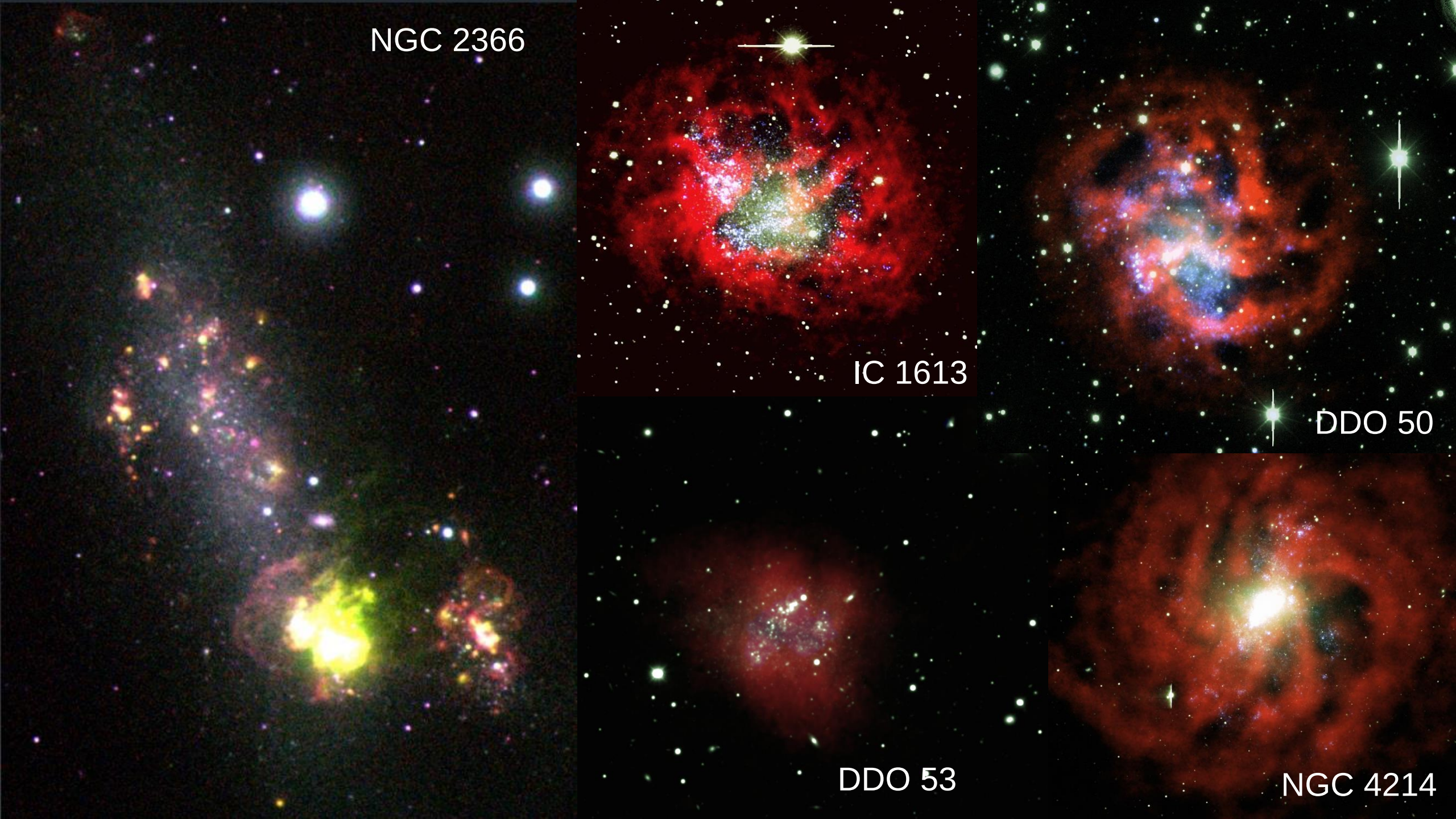
Plan

- Introduction
- Methods and instruments
- Studies of local galaxies, interesting results
  - Peculiar nebula in NGC 4068
  - Interaction between ISM and massive stars in IC 1613
- Conclusion and questions


NGC 2366
IC 1613
DDO 50
DDO 53
NGC 4214

The interaction between massive stars and the ISM in metal-poor galaxies can give rise to several astrophysical problems, including:

- Chemical enrichment
- Ionization and heating
- Galactic winds and outflows
- Stellar populations and feedback

Instruments

- 6-m telescope

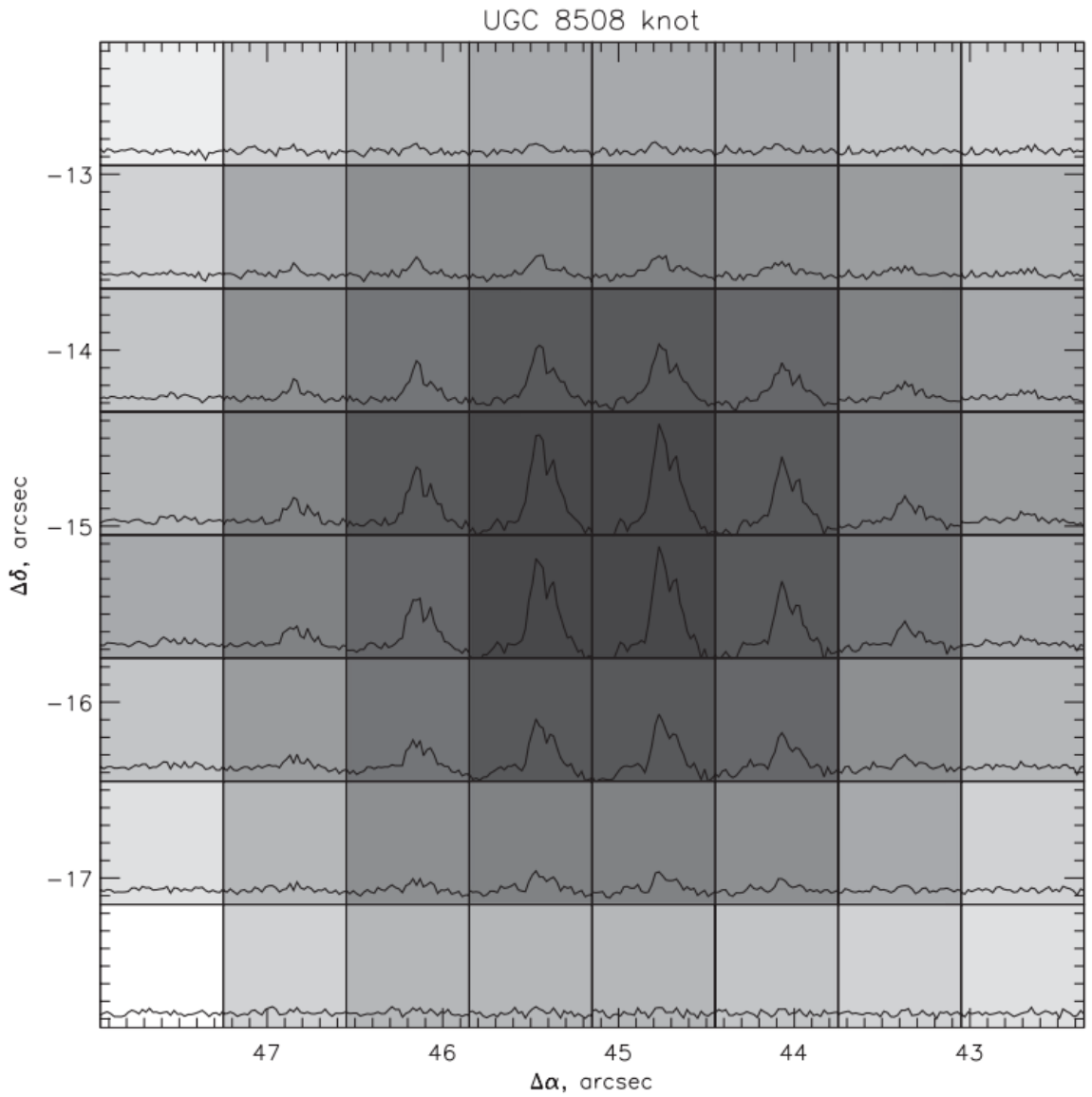
Focal reducer
Scorpio1/Scorpio-2:

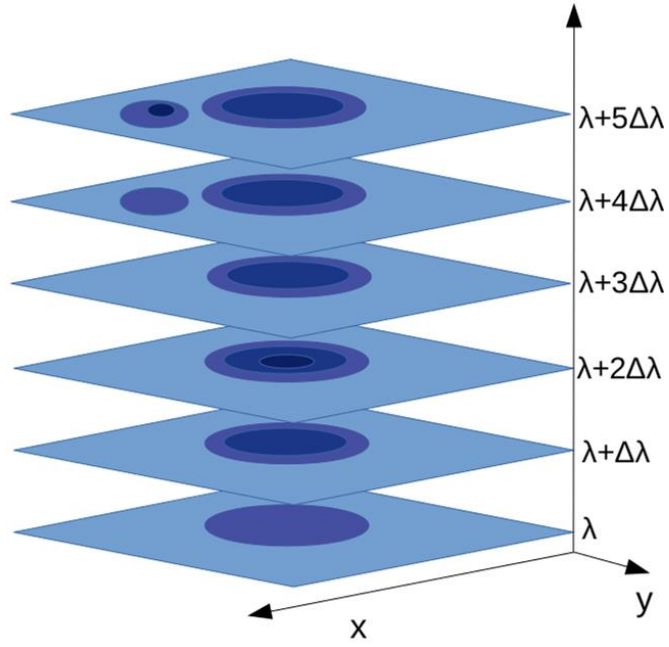
- Long-slit spectroscopy
- Fabry-Perot interferometry
- Optical photometry

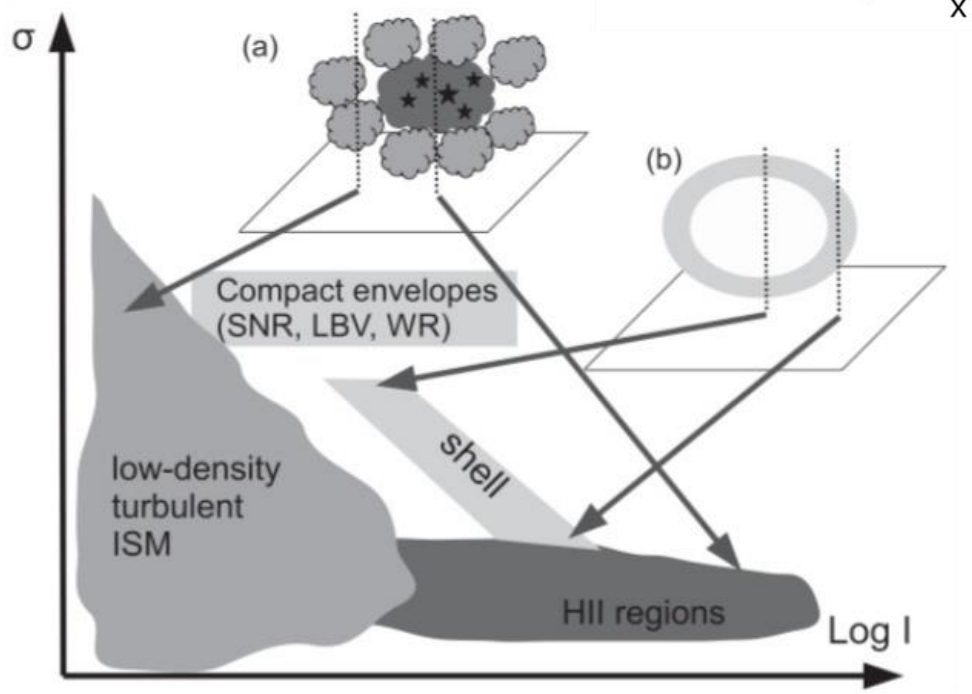
- 2.5-m telescope

- Long-slit spectroscopy
- NIR and optical photometry
- Mapper of Narrow Galaxy Lines (sessions)
- High resolution fiber echelle spectrograph
- Speckle polarimeter

3D-spectroscopy with Fabry-Perot interferometer

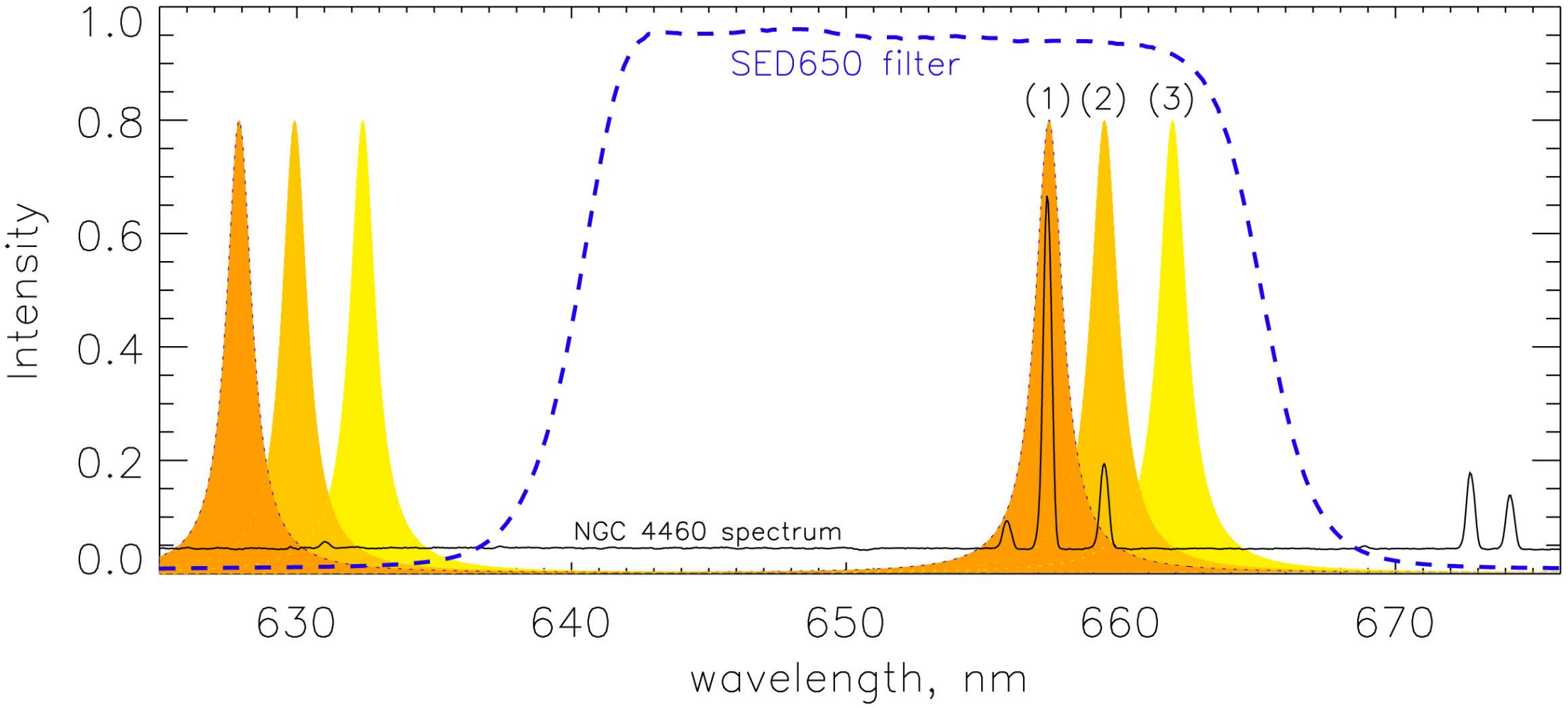






Moiseev, Lozinskaya, 2012

MaNGaL (Mapper of Narrow Galaxy Lines)



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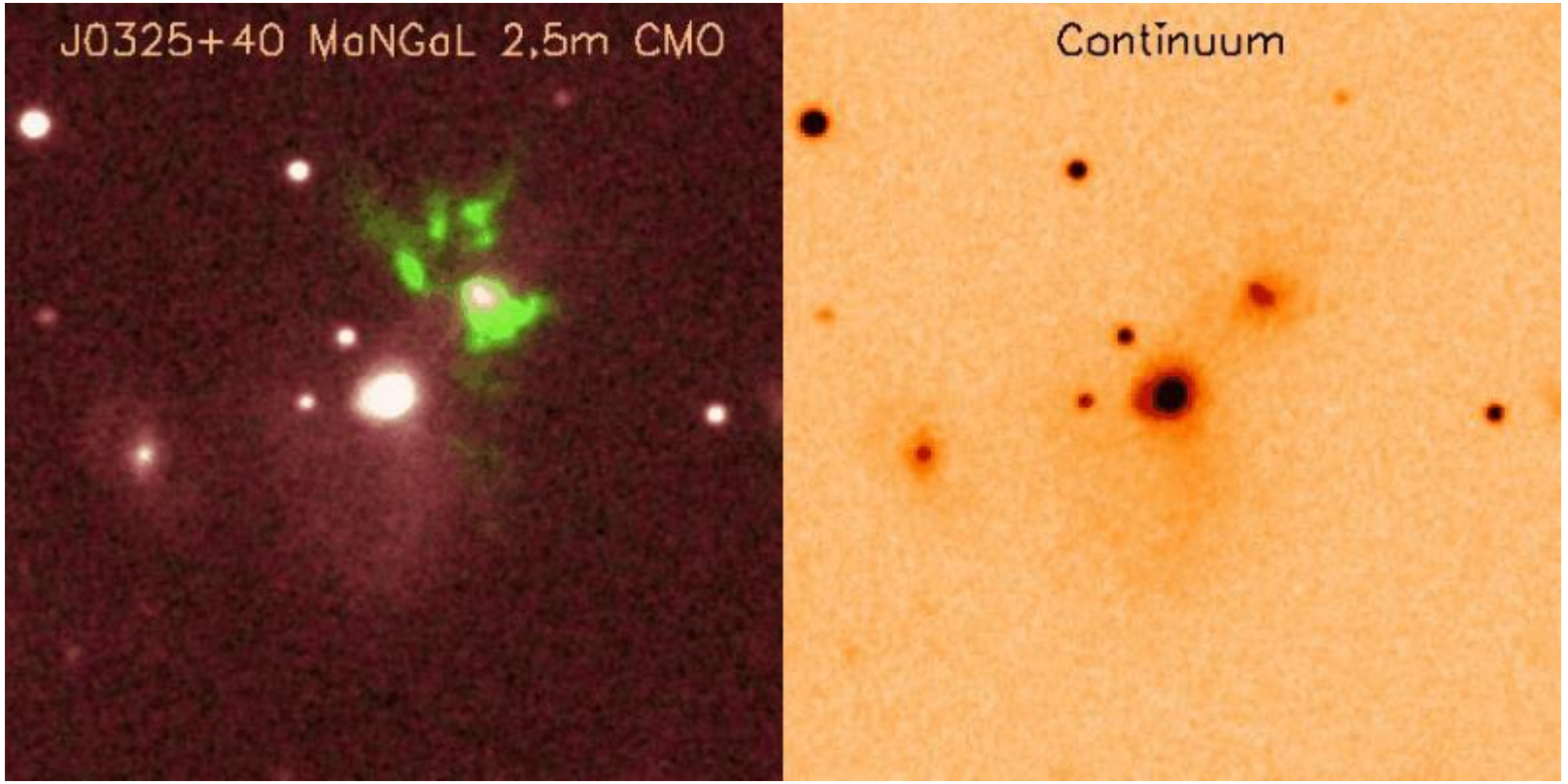
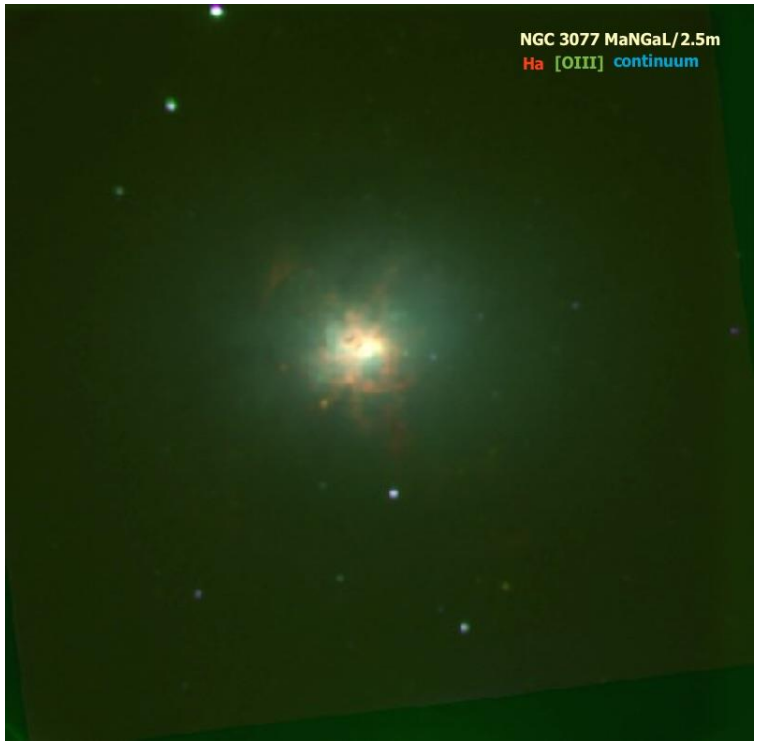


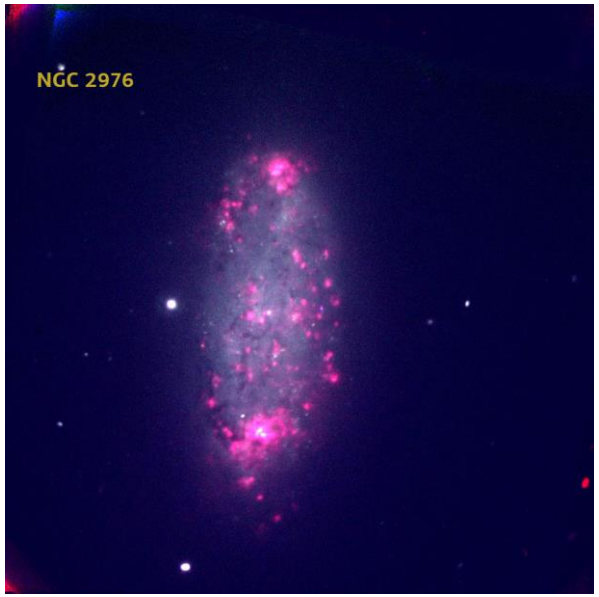
2020 Nov. *The result from 2.5-m telescope: tunable filter revealed an extended ionizing cone around active nucleus in the merging galaxies.*

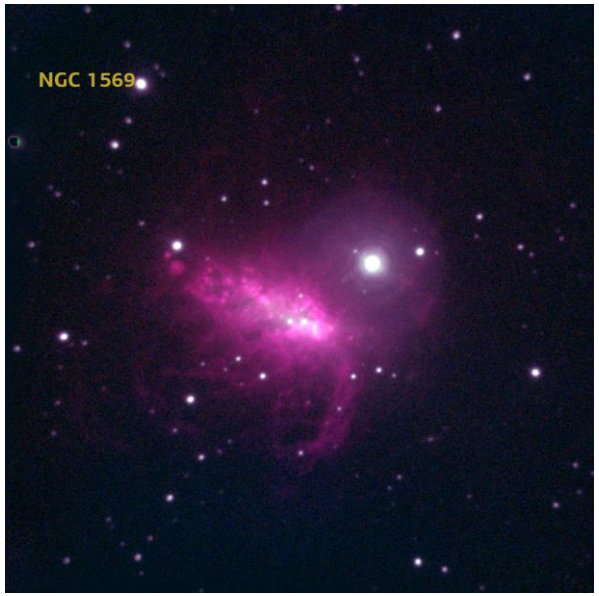
https://www.sao.ru/hq/lsfvo/devices/mangal/index.html

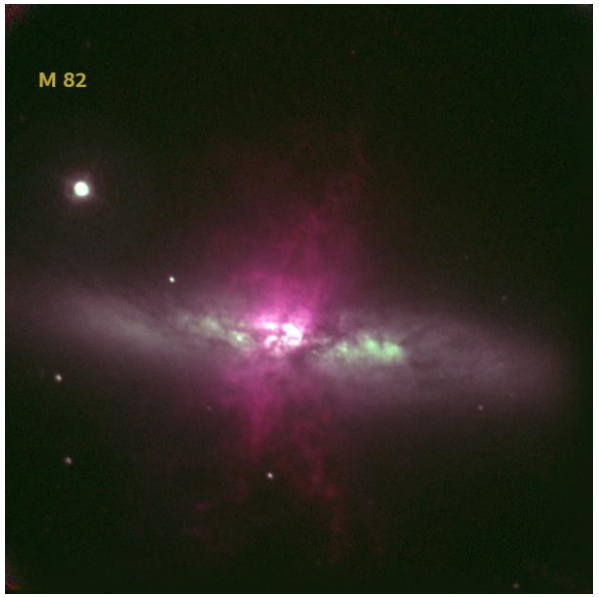

S255/257 MaNGaL/Zeiss-1000
[SII]
Ha
[OIII]

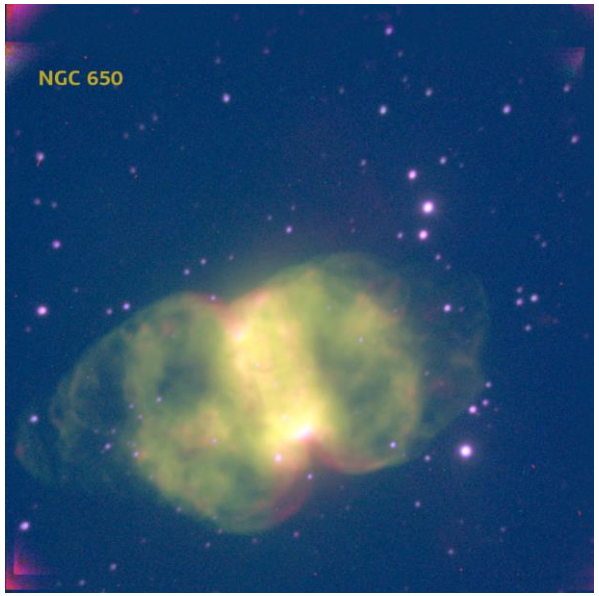

S201 MaNGaL/Zeiss-1000
[NII]
Ha
Continuum


NGC 3077 MaNGaL/2.5m
Ha [OIII] continuum

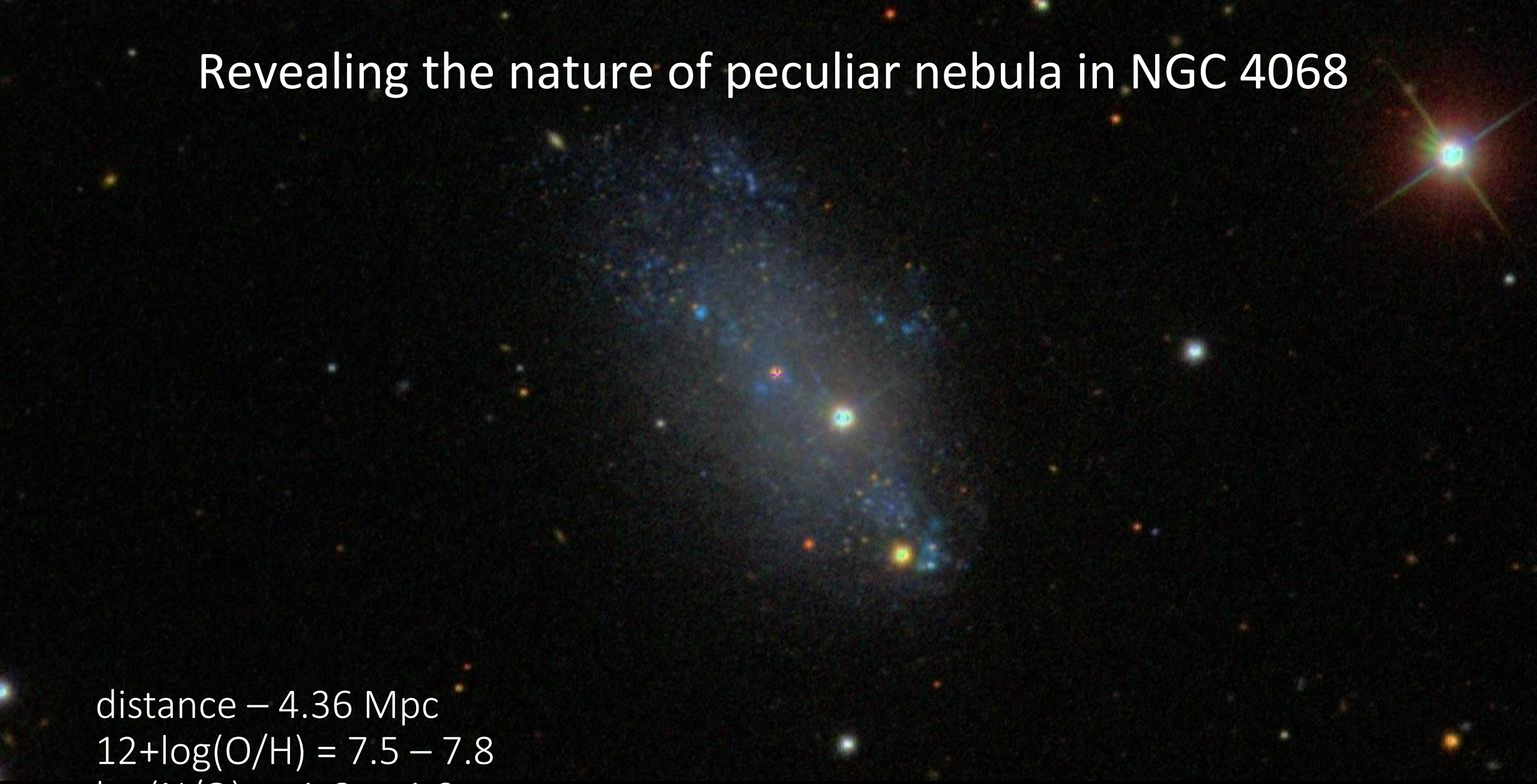

NGC 2976


NGC 1569


M 82

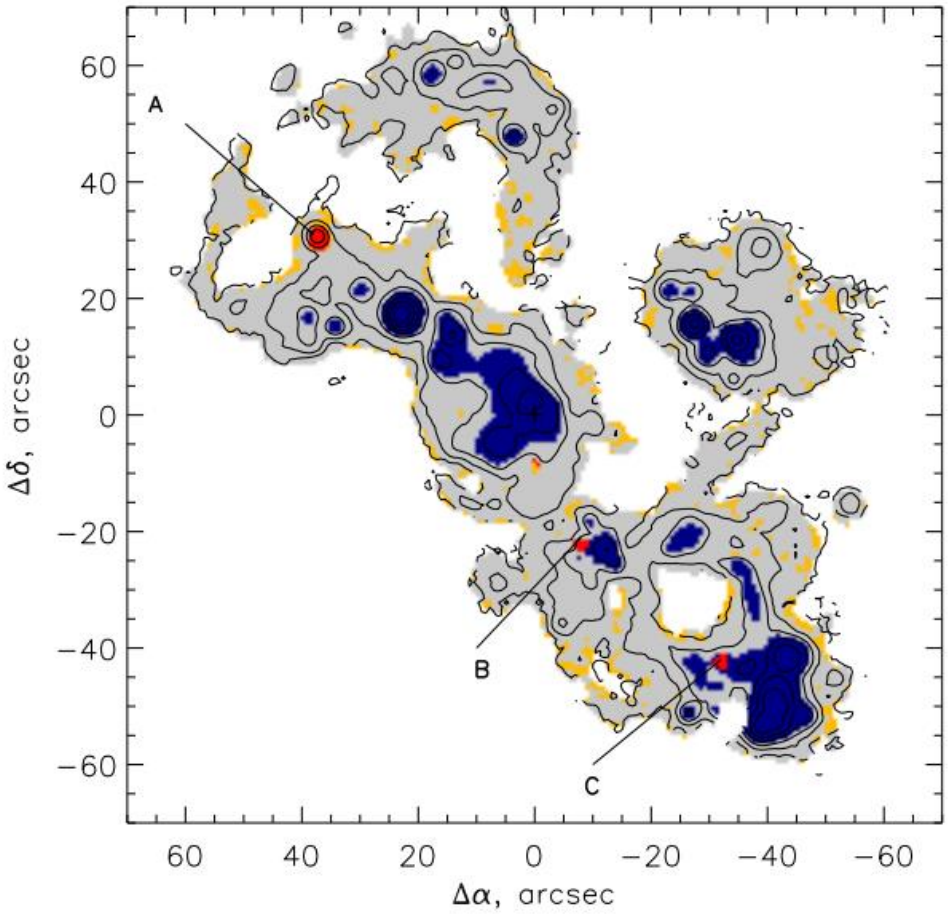

NGC 650

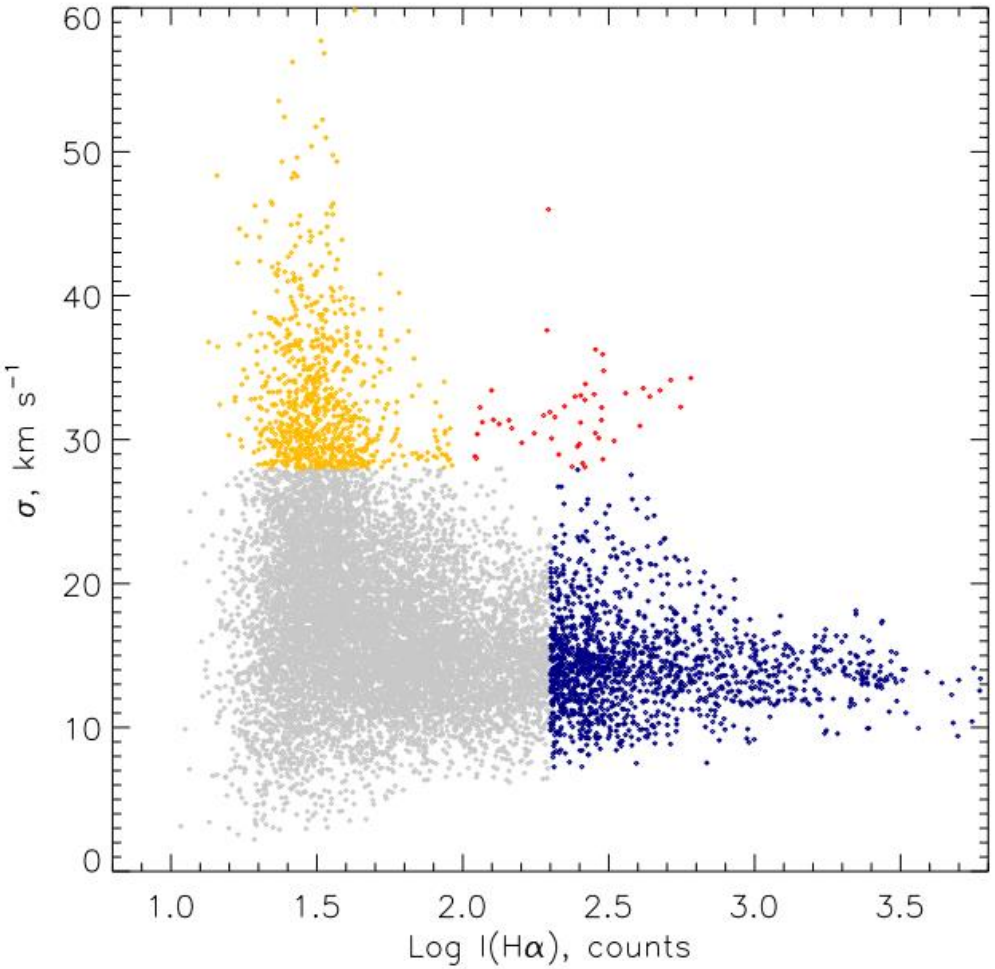
Revealing the nature of peculiar nebula in NGC 4068



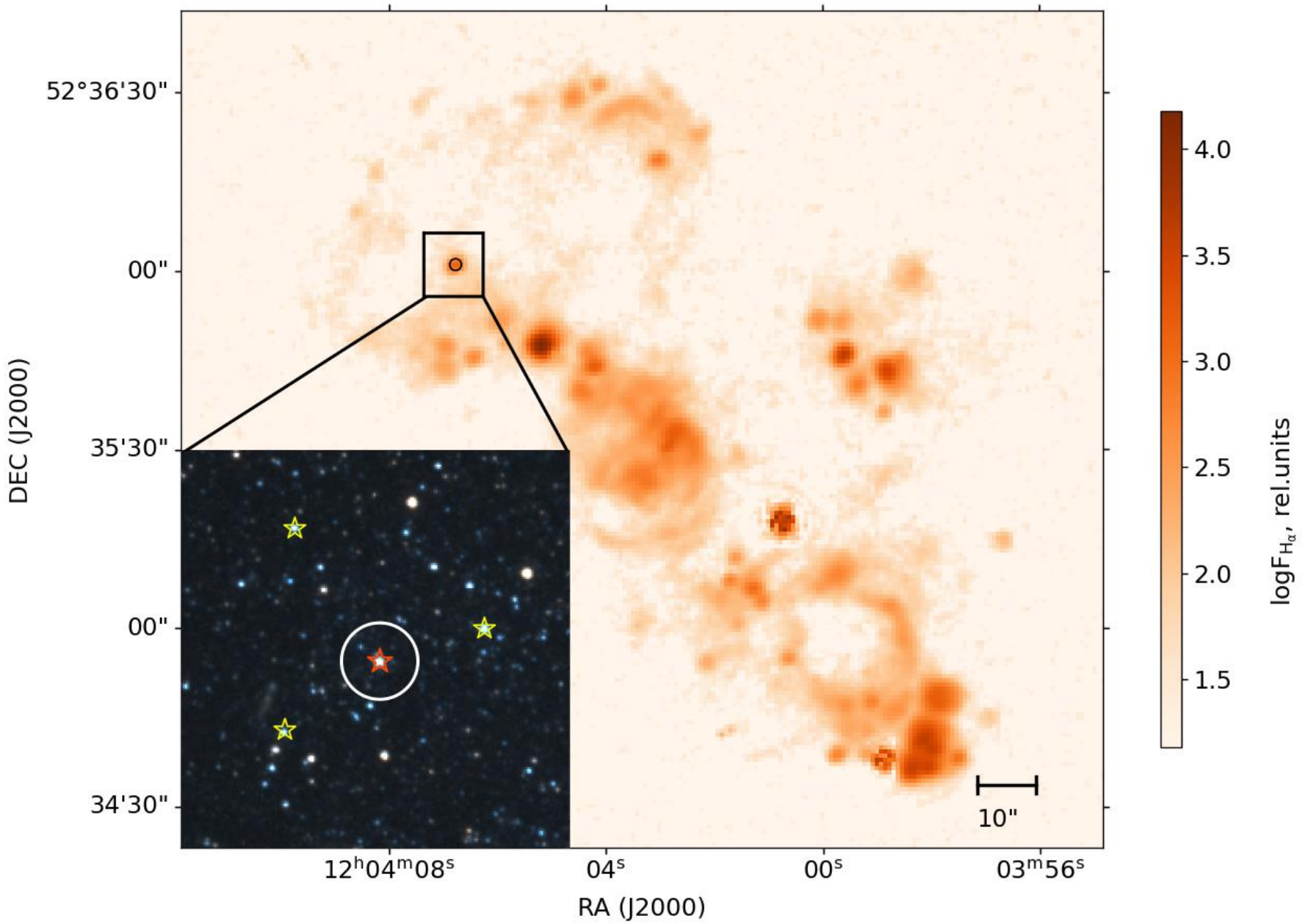
distance – 4.36 Mpc
12+log(O/H) = 7.5 – 7.8
log(N/O) = -1.6 – -1.3

I-sigma diagram for NGC 4068

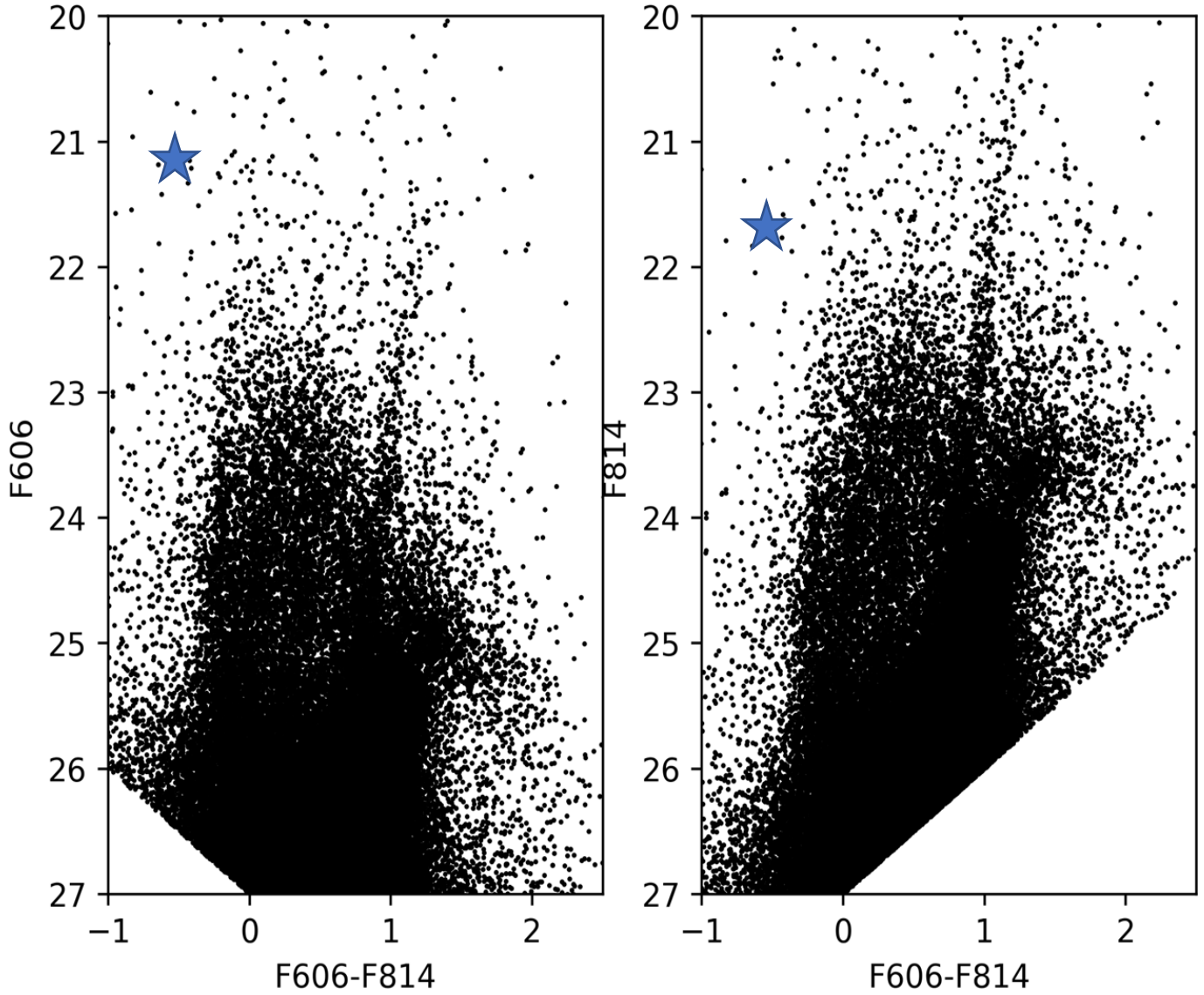




$H_\alpha + HST\ ACS(F606W + F814W)$

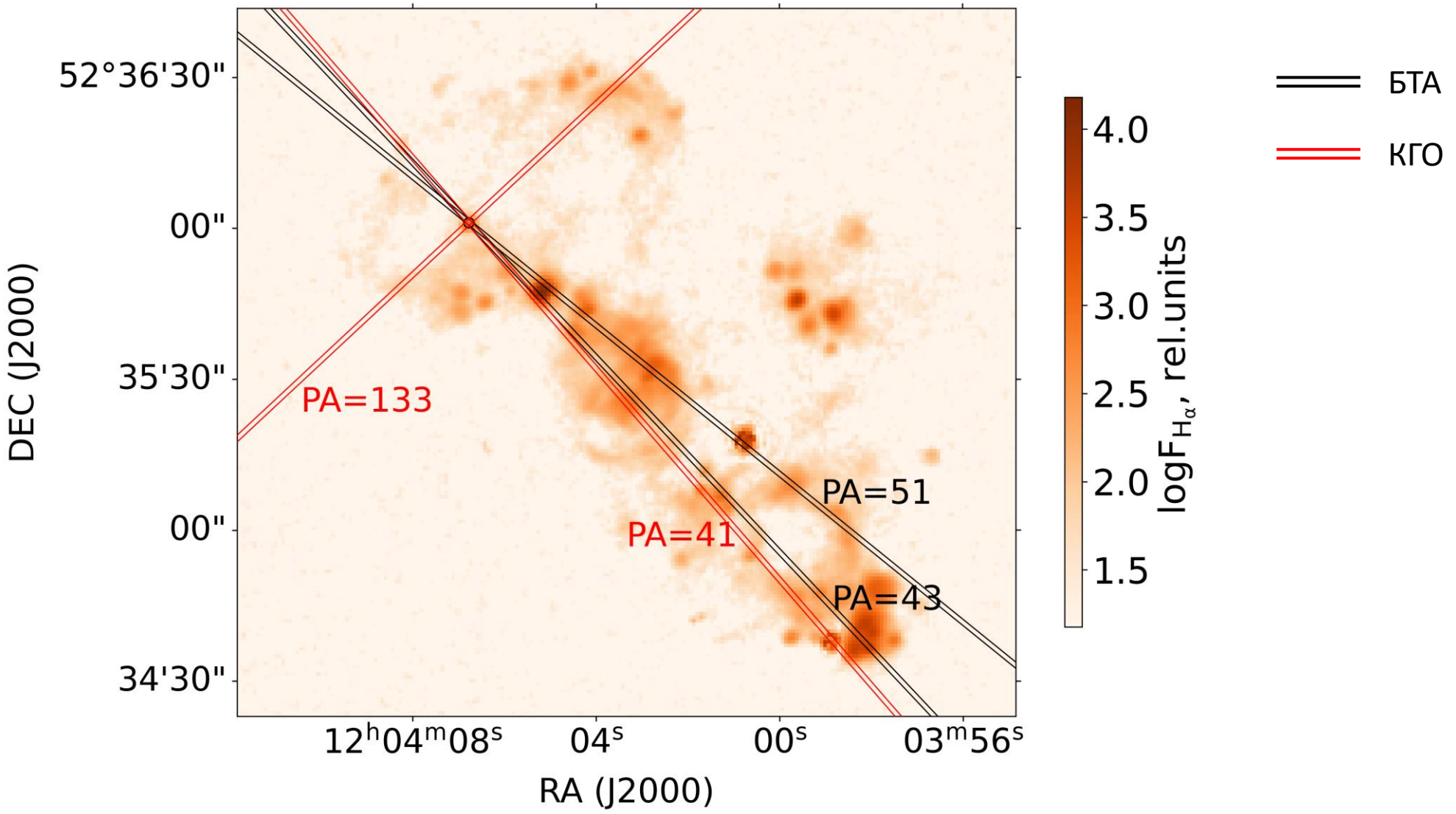


Color-Magnitude diagram

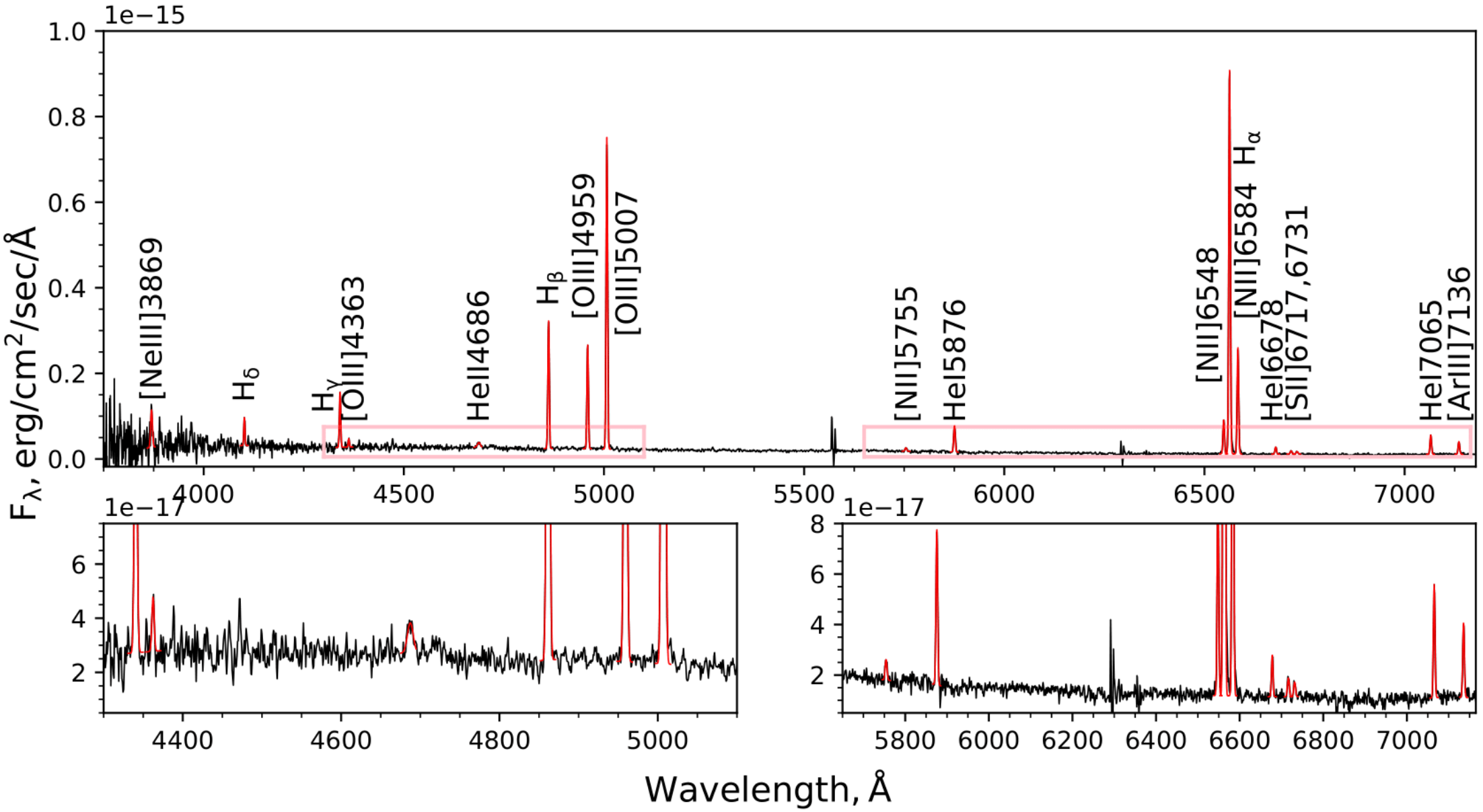


Photometry from NGC, Sharina et al., 2008

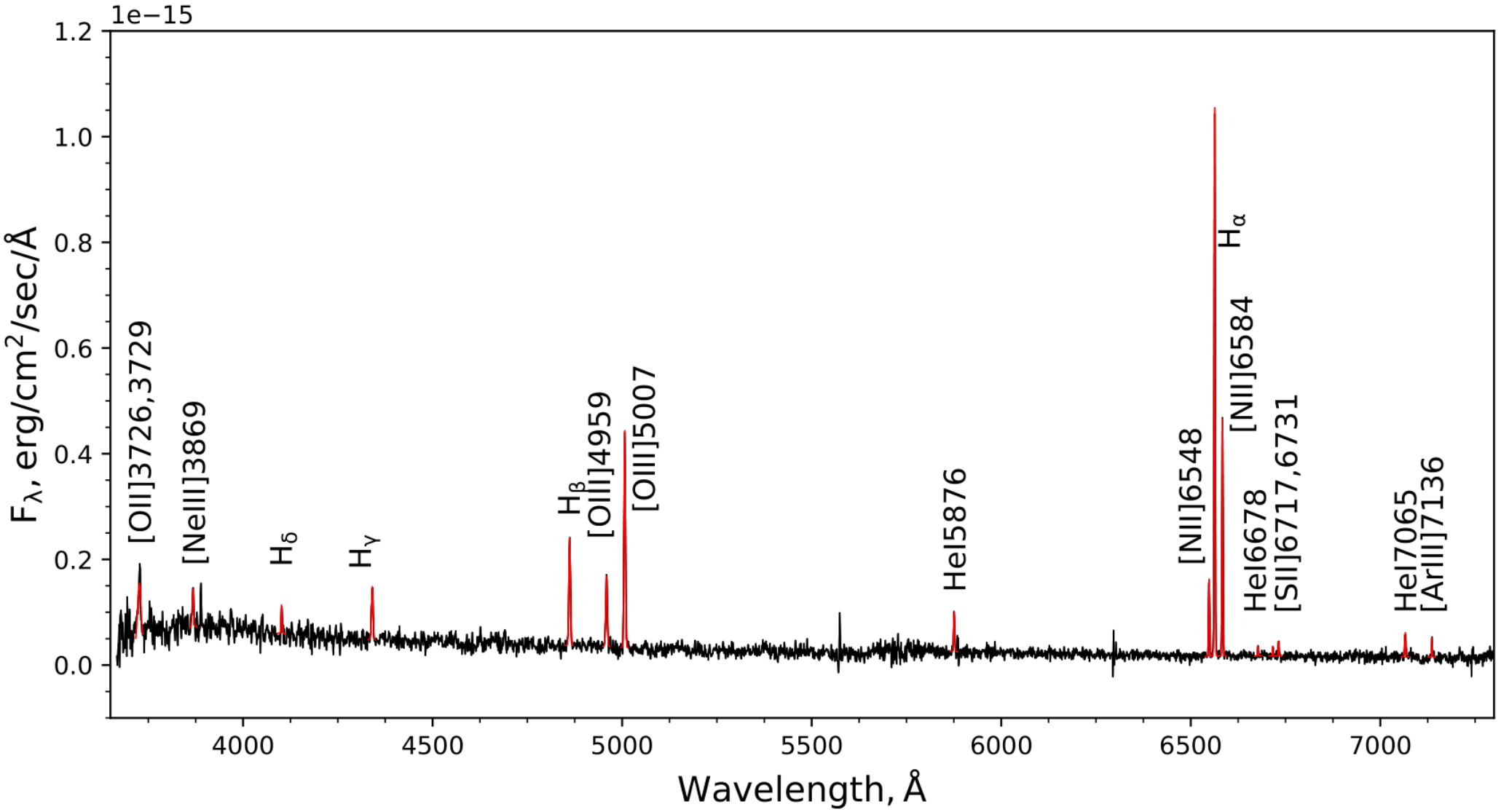
Long-slit spectroscopy



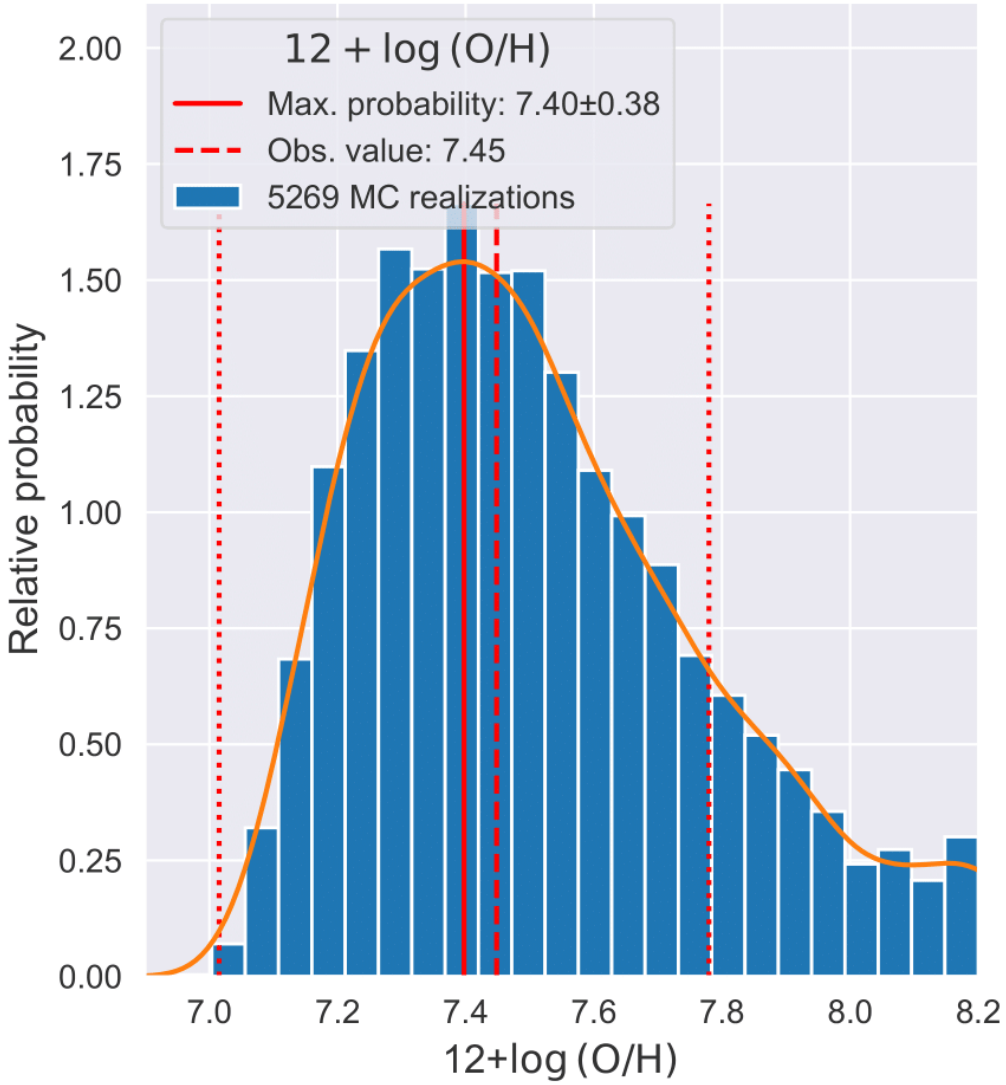
6-m telescope spectrum

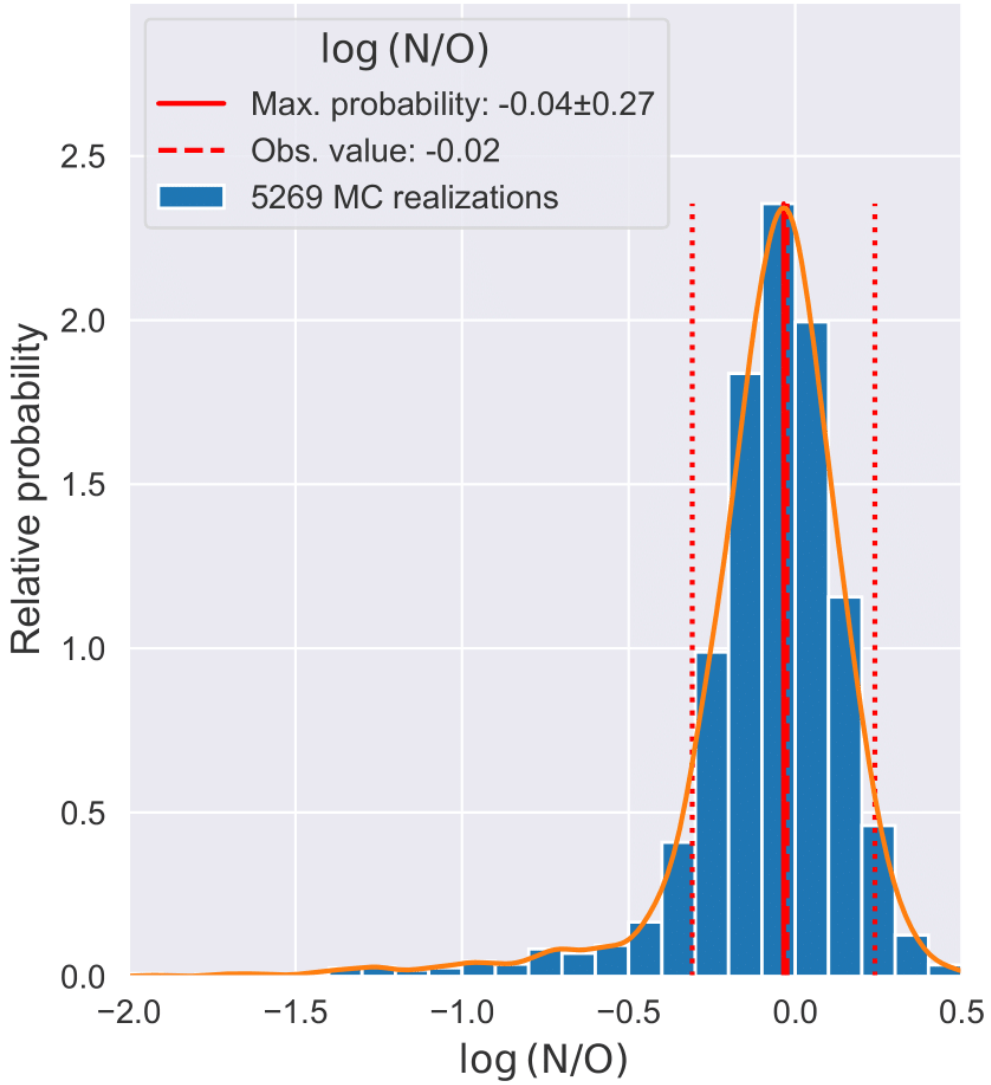


2.5-m telescope spectrum



Chemical composition of the nebula





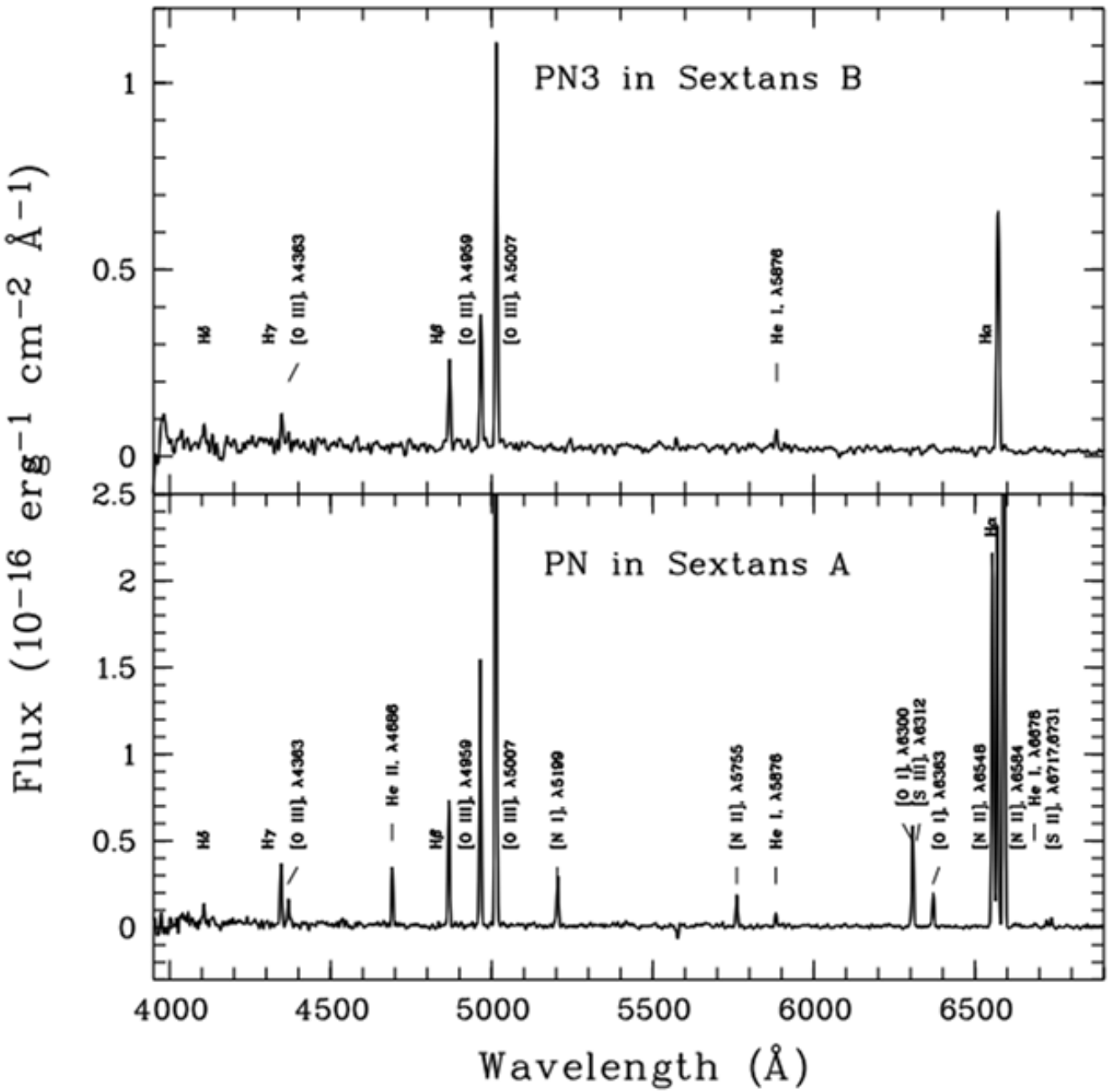
What could that object be?

- Planetary nebula

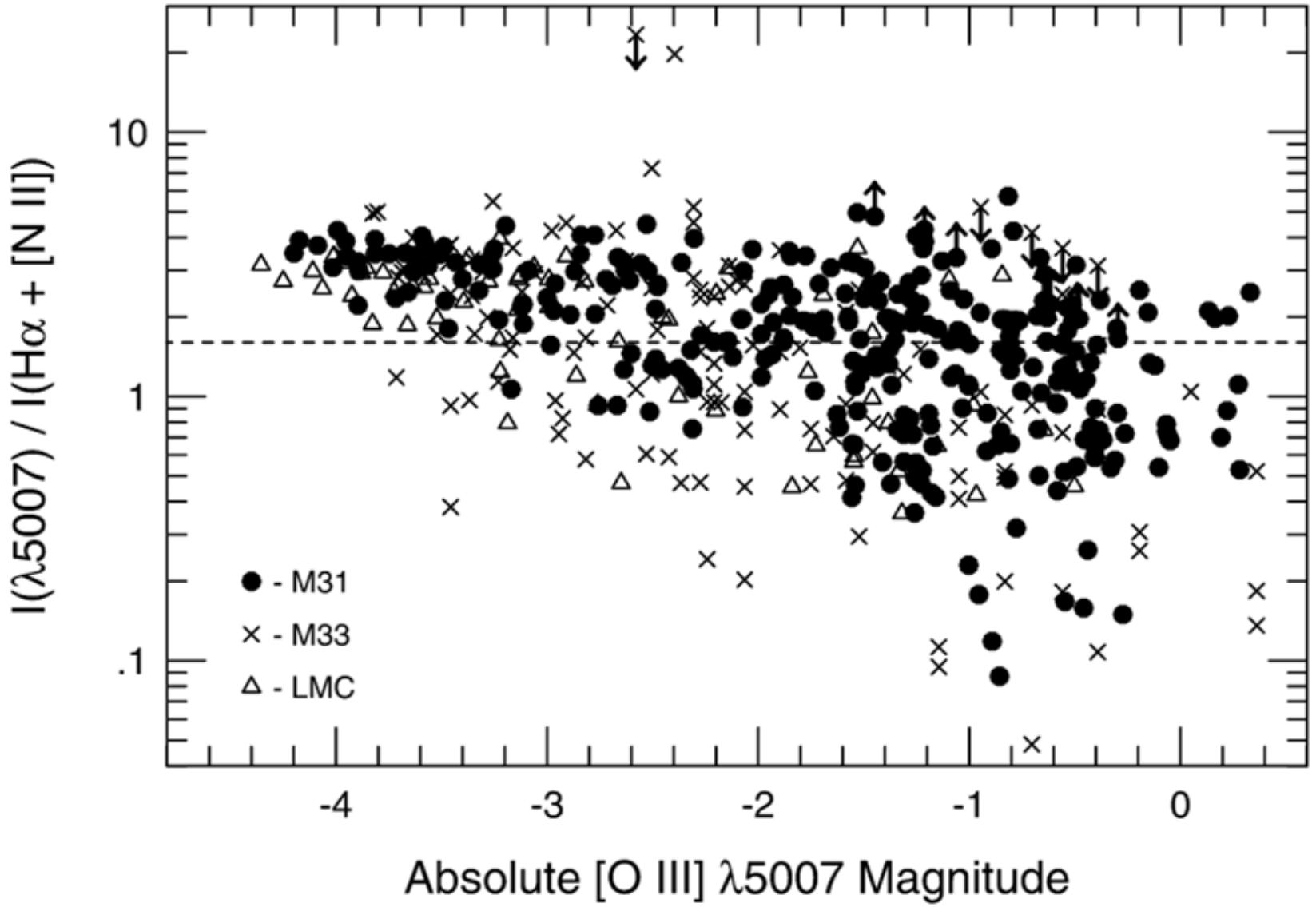
(then we have to check [OIII]5007 emission line flux)

- Very close group of O stars
- Nebula ionized by massive star (BSG, WR, LBV)

(then we have to check HeII 4686 line and possible variability)



Kniazev et. al., 2005



For our object

M([OIII]) = −5.42

(estimated from image in [OIII]5007 filter)

Ciardullo et.al., 2002

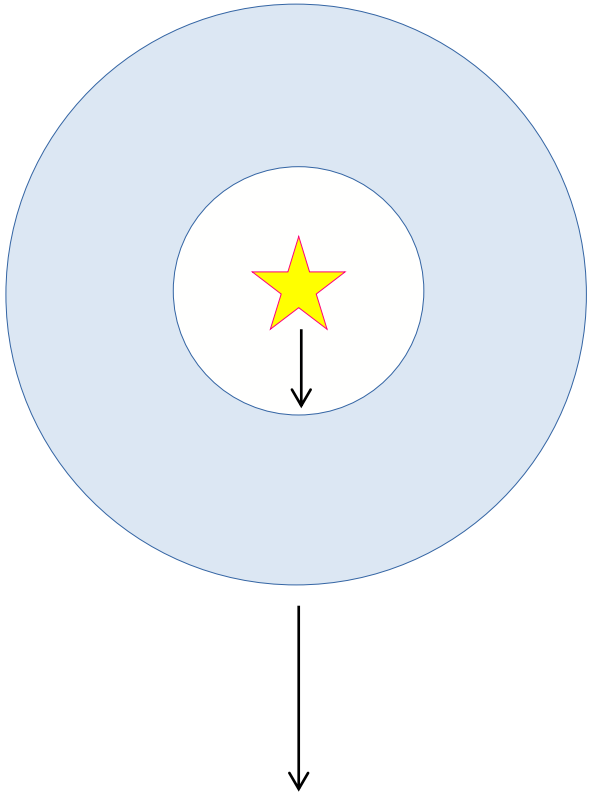
CLOUDY modelling of the nebula spectrum

Constant parameters:

Filling factor – 0.15
Geometry – close
Metallicity – 0.1 Z_{sun}
Inner radius – 3 pc

Variable parameters:

Outer radius – 4-30 pc
Density – 1-2 cm^{-1}
Nitrogen abundance I = 1-20 N/N_{ord}

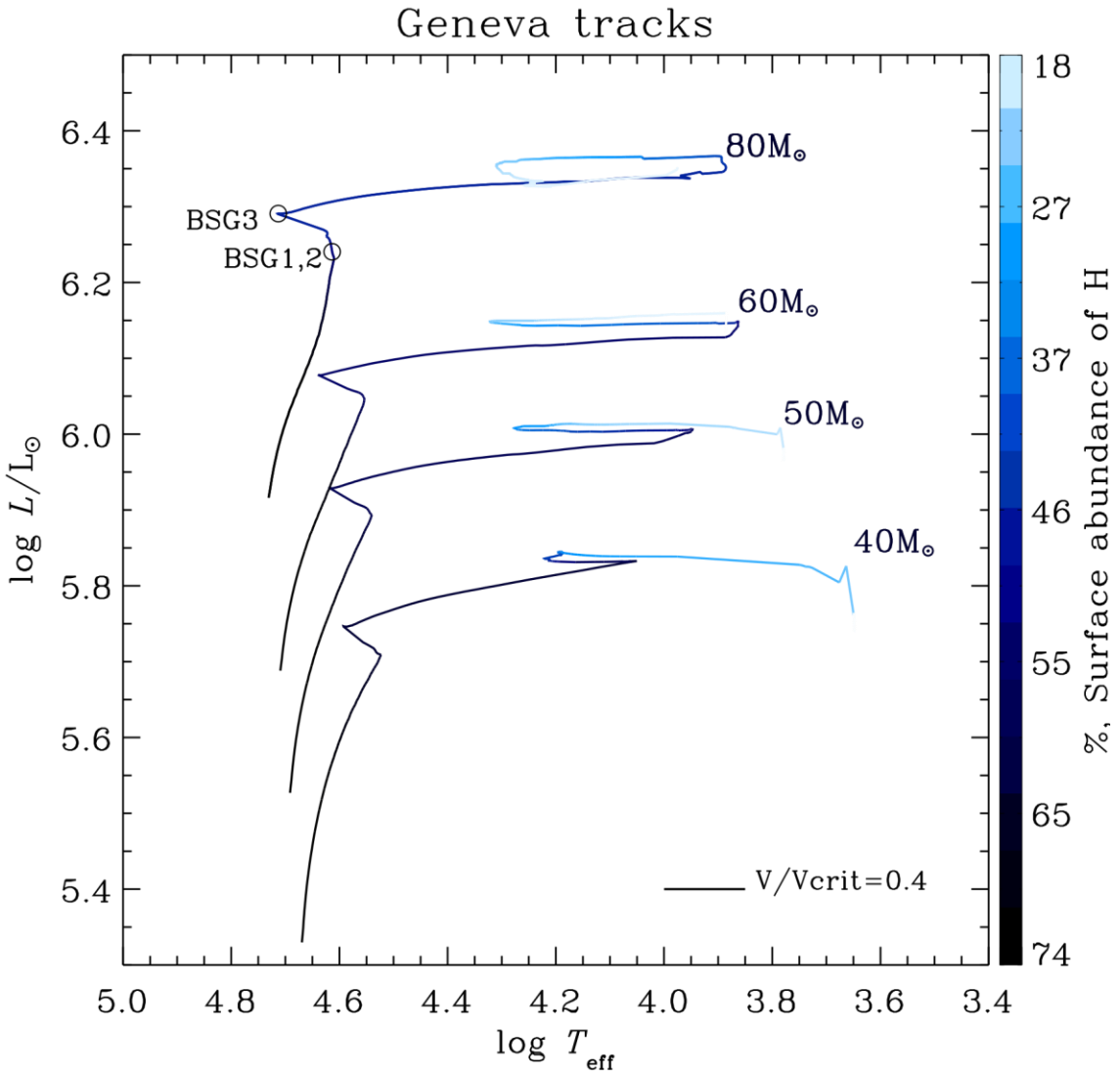


Solar element content scaled for metallicity of NGC 4068

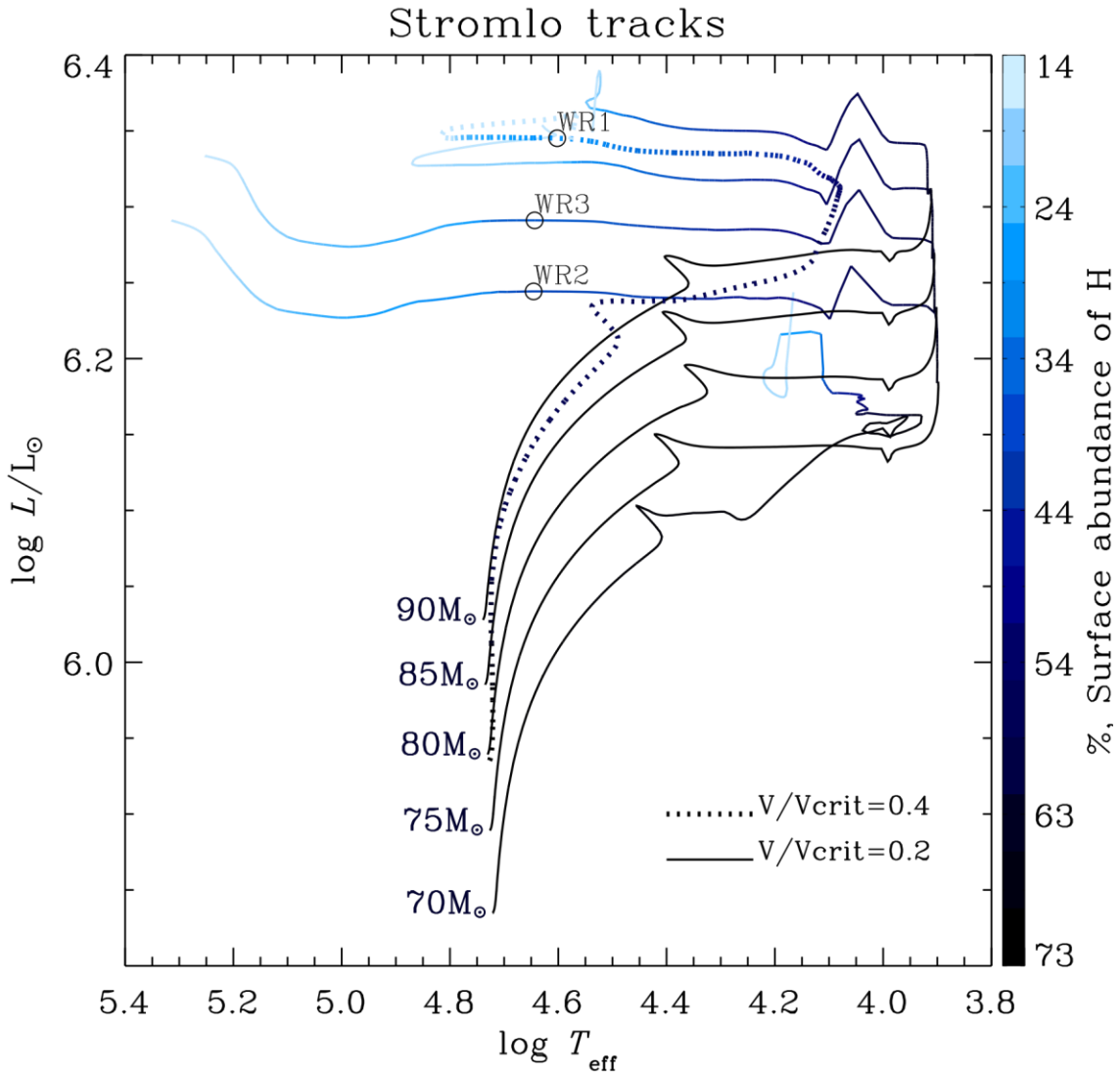
Nitrogen content varies (increases i times)

Spectrum of the nebula

Evolutionary tracks for Massive stars

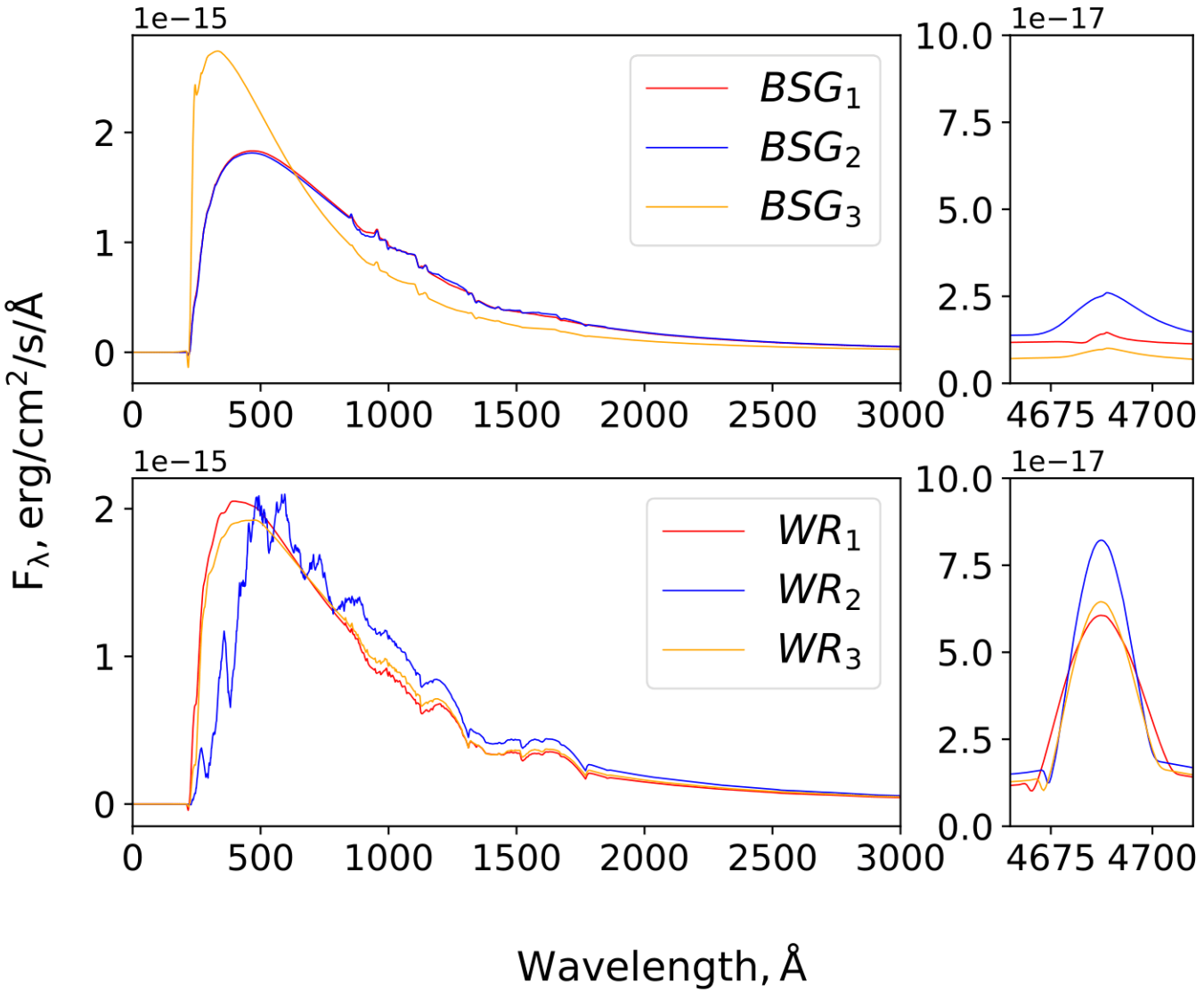


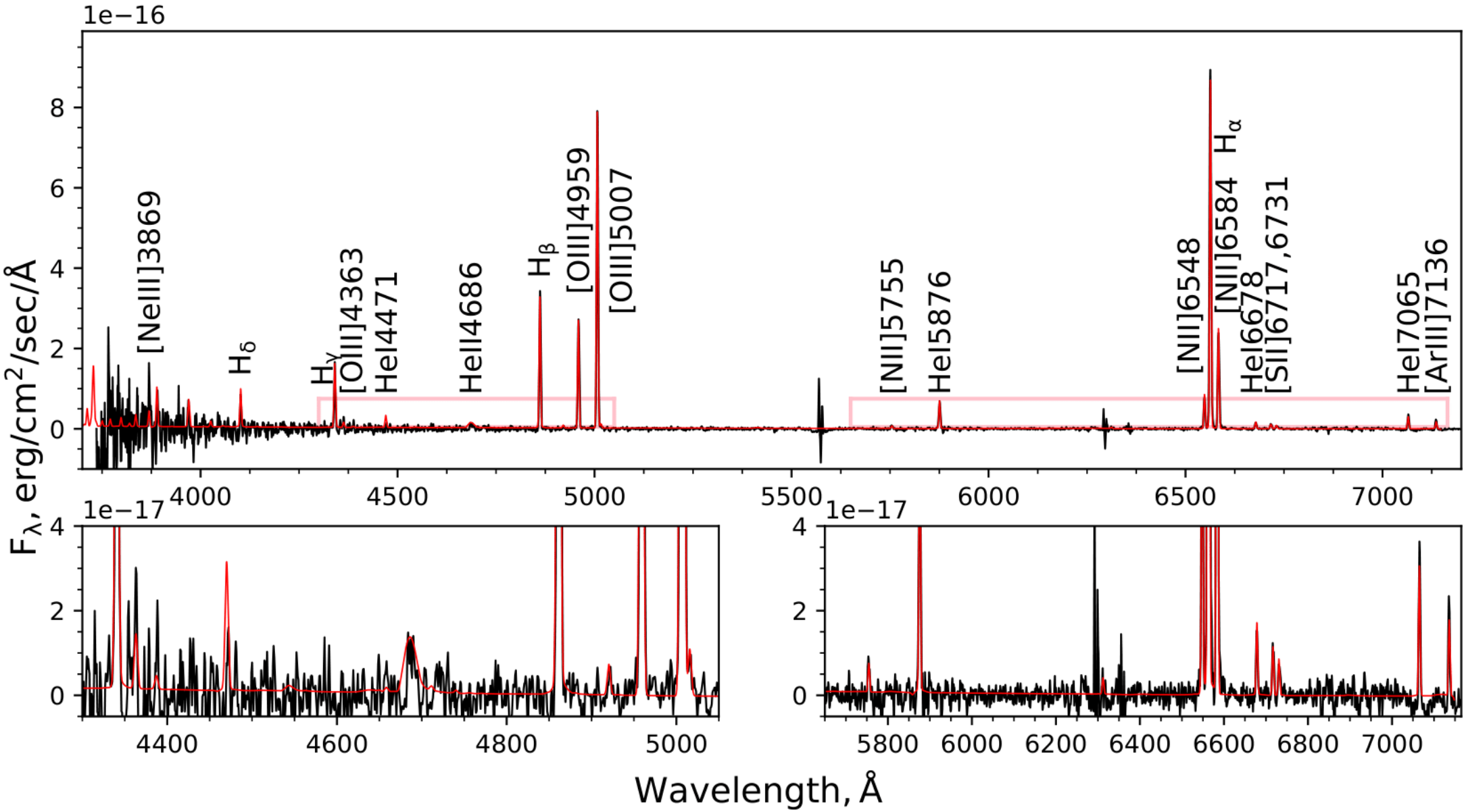
Georgy et al, 2013



Grasha et al, 2021

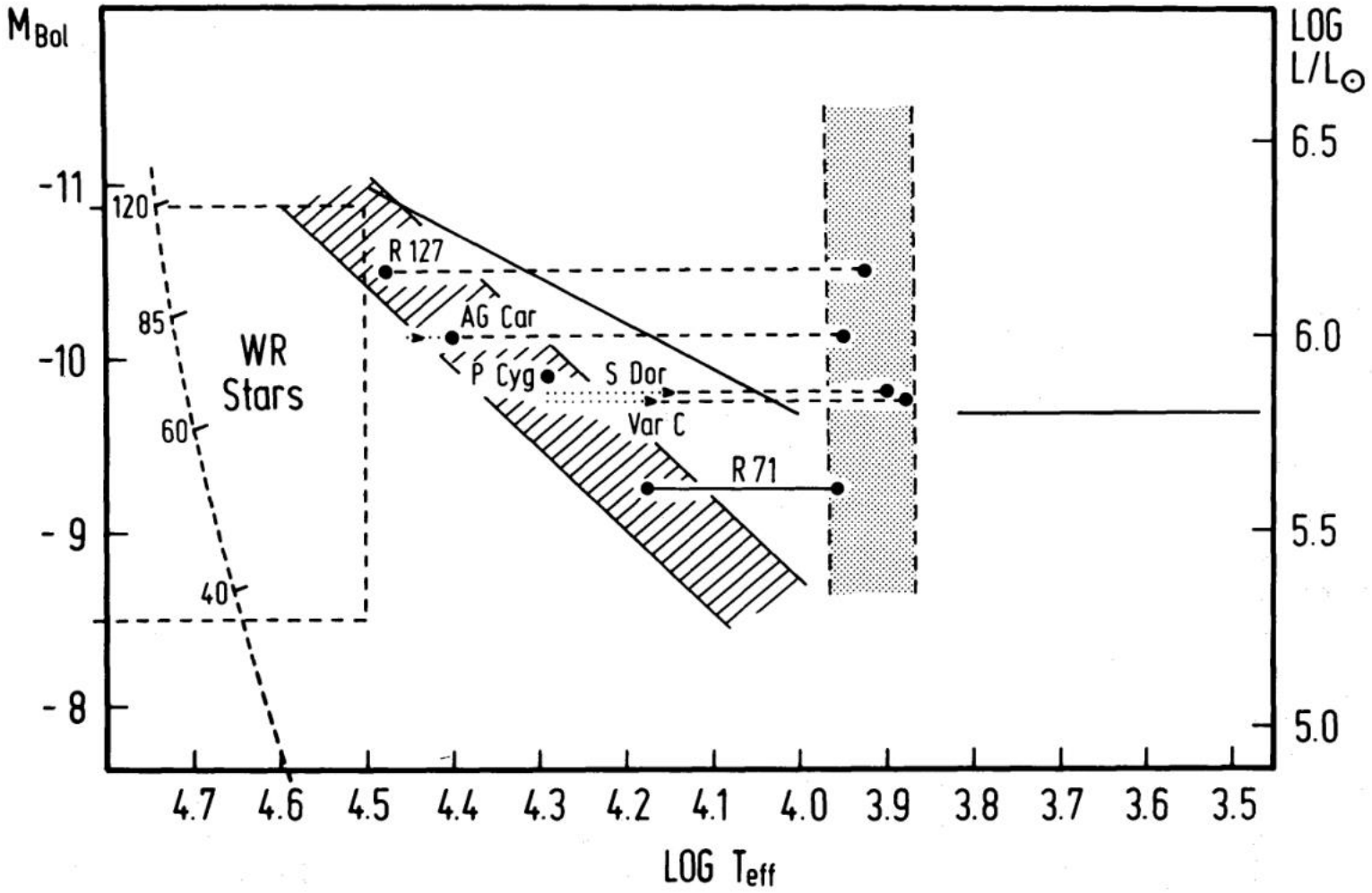
SED of model stars




1e−16
[NeIII]3869
Hδ
Hγ
[OIII]4363
HeI4471
HeII4686
Hβ
[OIII]4959
[OIII]5007
[NII]5755
HeI5876
[NII]6548
[NII]6584
Hα
HeI6678
[SII]6717,6731
HeI7065
[ArIII]7136
Fλ, erg/cm²/sec/Å
1e−17
1e−17
Wavelength, Å
BTA spectrum
Best-fit model spectrum

Our results

- Model WR stars built using tracks from (Grasha et. al. 2021) allow us to reproduce the main features of the spectrum, including the HeII line
- According to our models, HeII4686 is the line of a star (not of a nebula)
- The nebula is probably ionized by the radiation of a low-metal WR star with parameters T~40-50 kK, m~80 M_{sun}, L~$10^6 L_{sun}$. About ~0.5 Myr ago (upper estimate) the star ejected a large amount of nitrogen in the form of a stellar wind, which led to the currently observed ratio of the emission lines of the nebula and the increased velocity dispersion in the H_α line

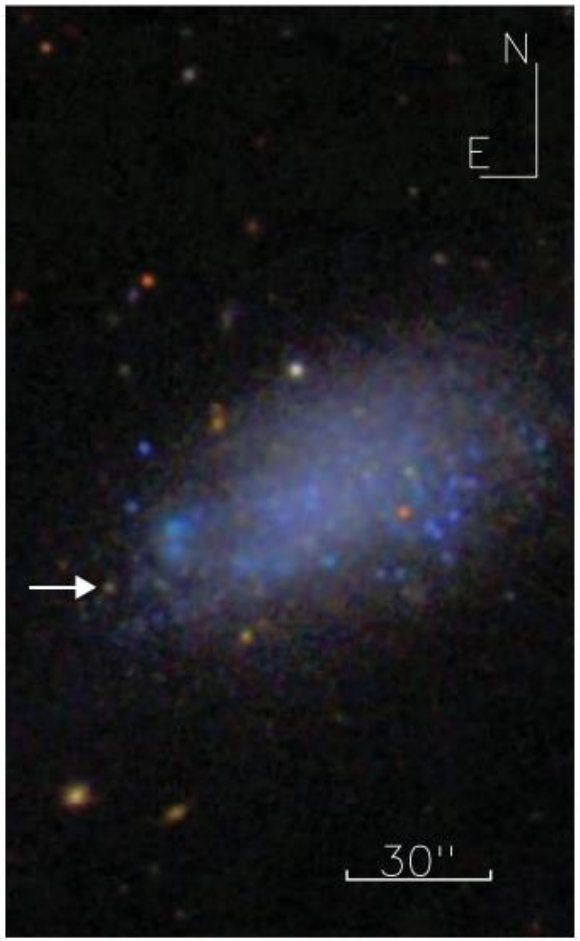


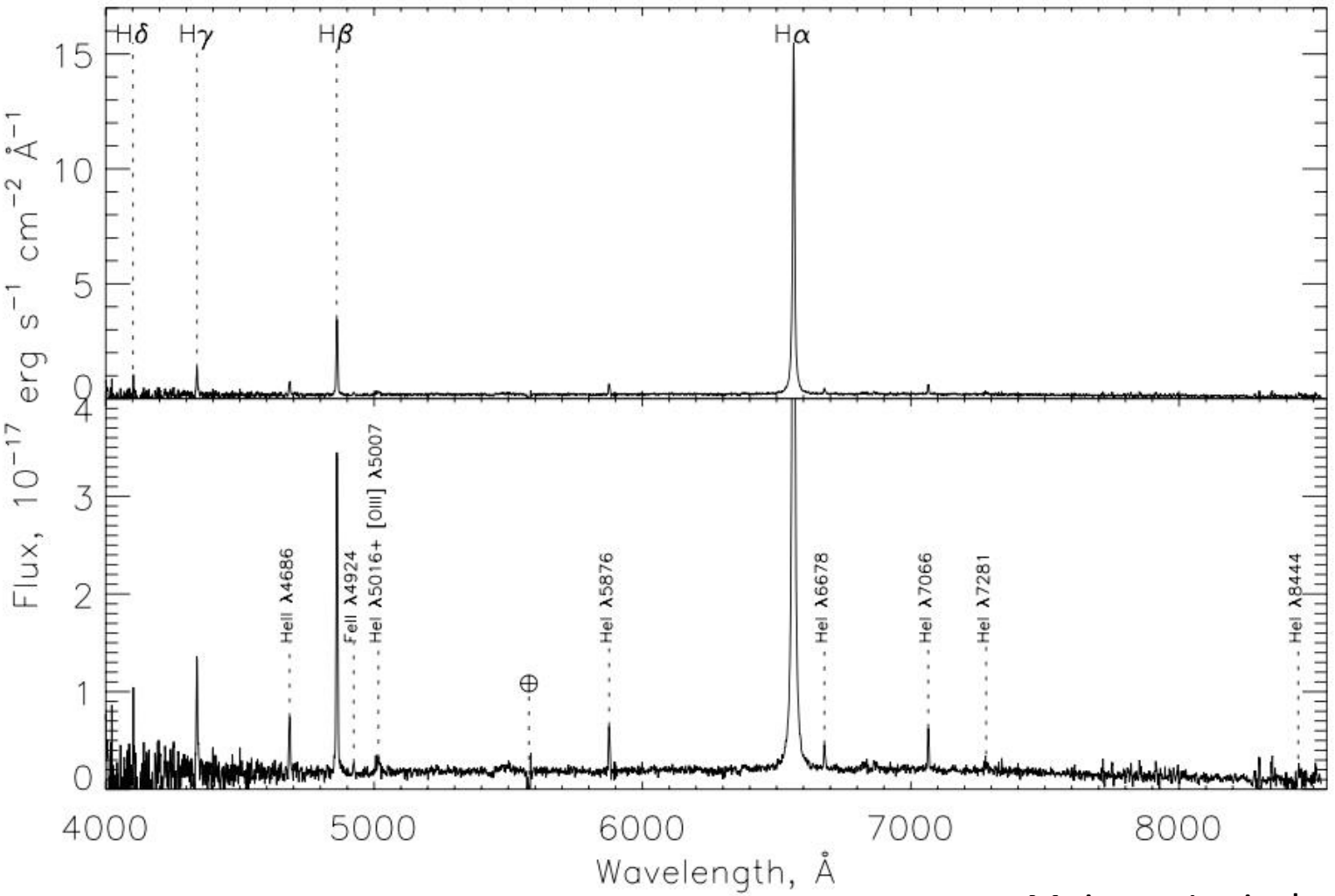
A significant number of LBVs have at least temporarily an Of/WN type spectrum indicating the presence of emission line and in particular a larger amount of nitrogen in their photosphere. The S Dor variability is the one and only clear distinction of LBVs from other massive evolved stars.

Weis, Bomans, 2020

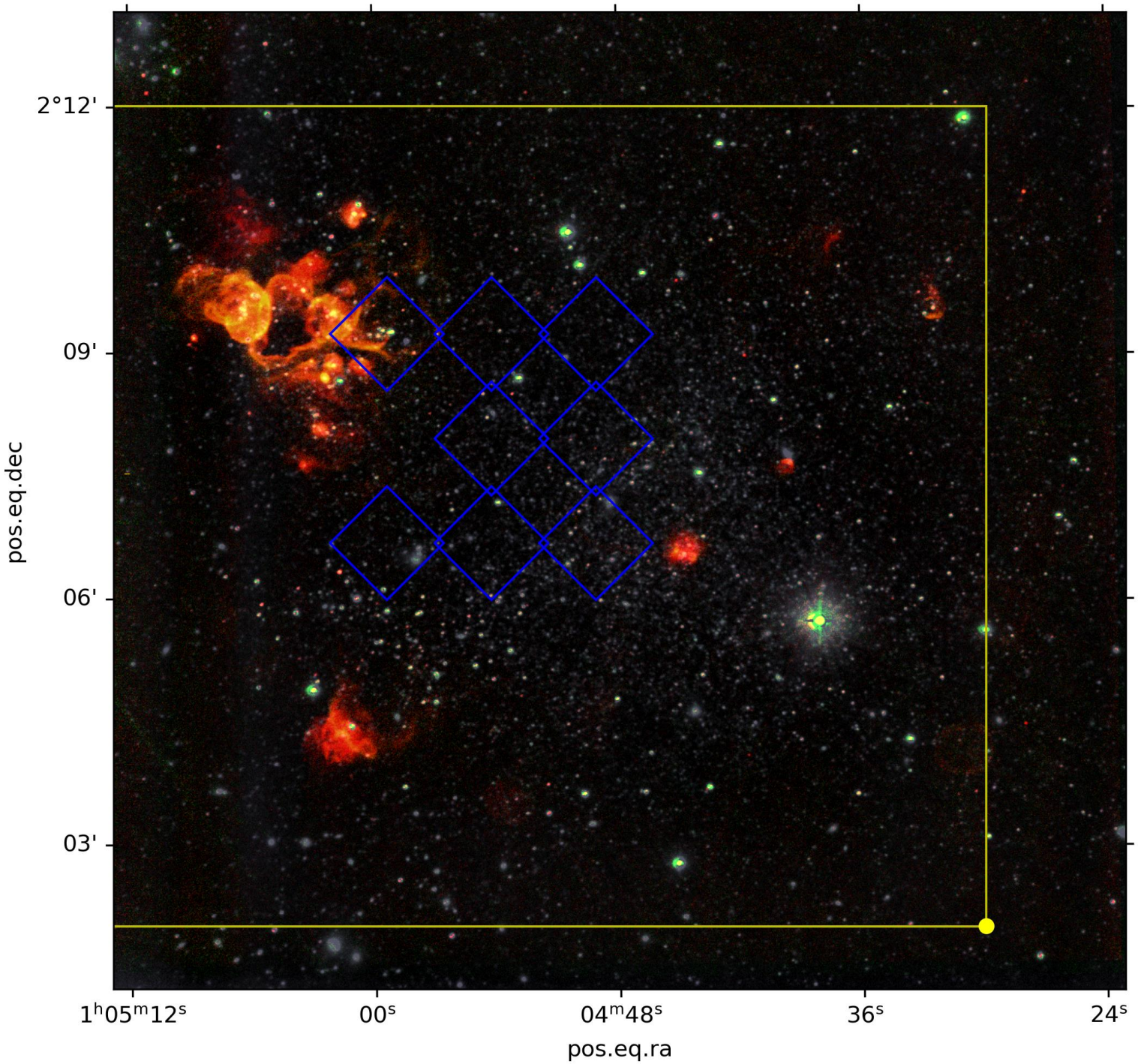
Further studies. Search for variability.

+ one more object in UGC 8508:





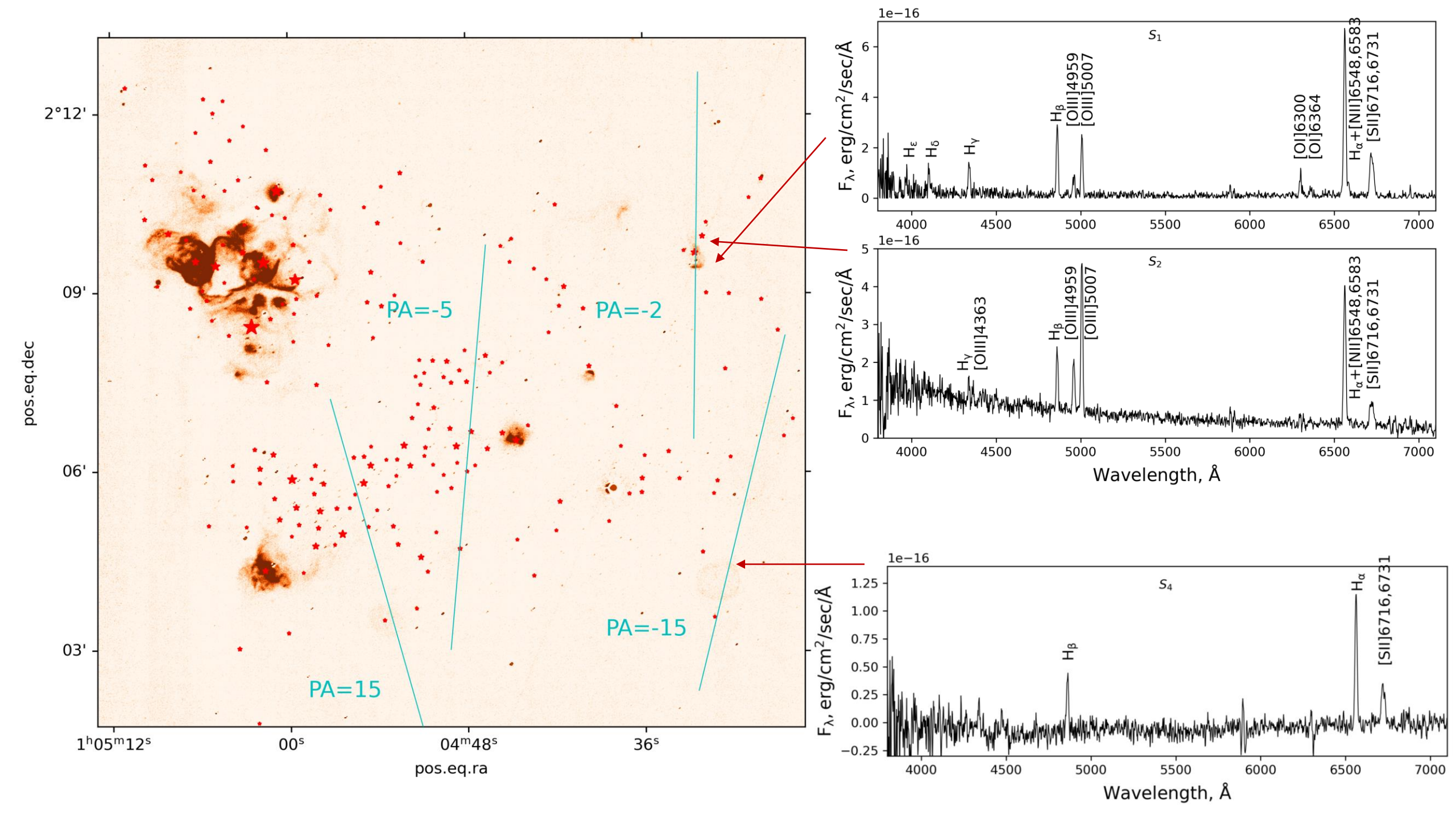
Moiseev, Lozinskaya, 2012



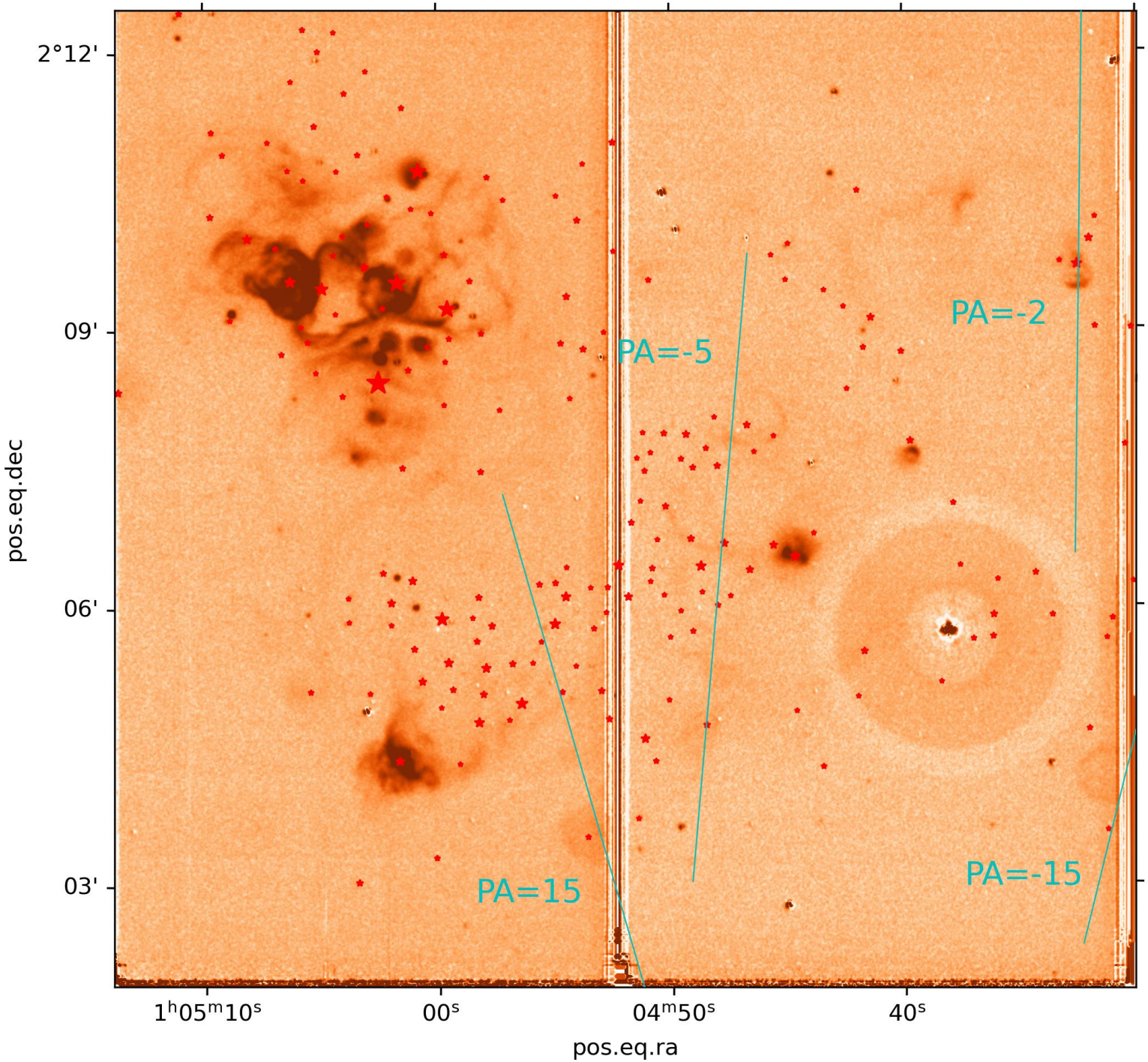
Massive stars studies in IC 1613

12’ field of star forming regions in IC 1613 from 1.5-m Russian-Turkish telescope

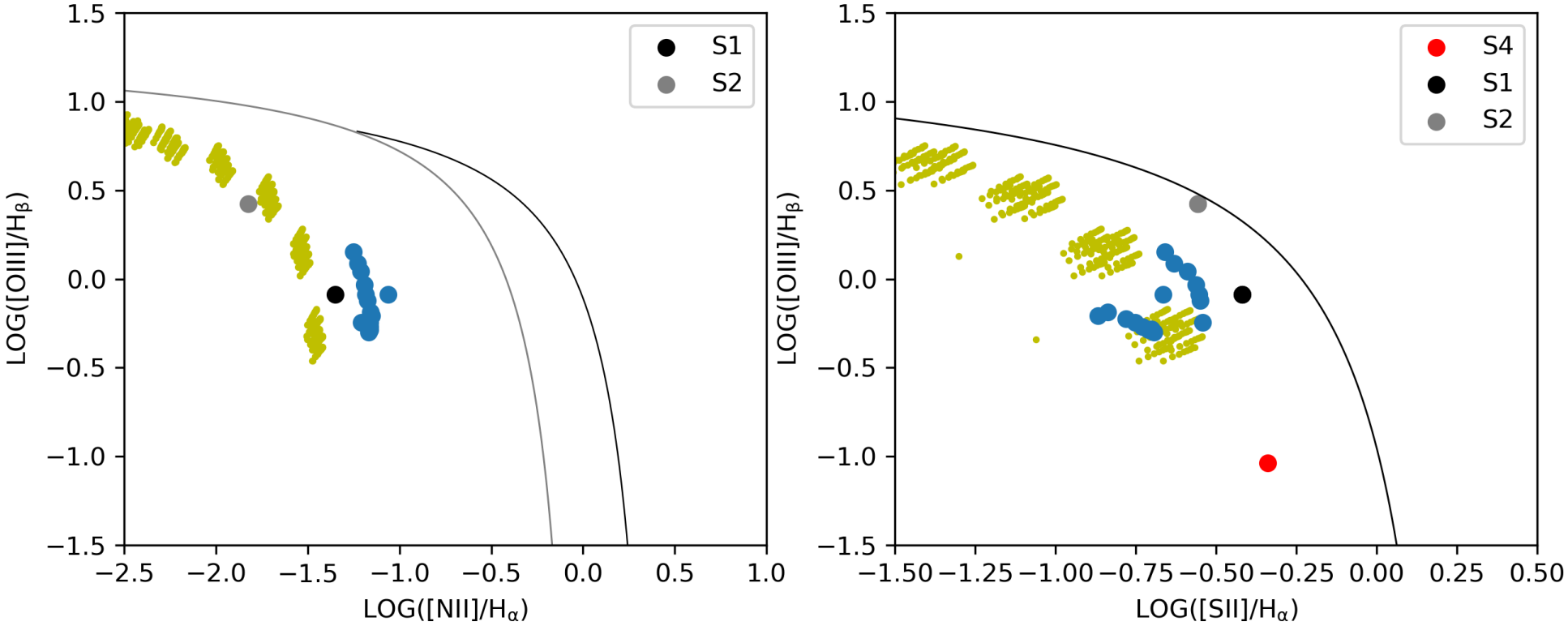
- 10’ field from 2.5-m Russian telescope
- 1’ field from MUSE, VLT


PA=-5
PA=-2
PA=-15
PA=15
2°12'
09'
06'
03'
pos.eq.dec
1h05m12s
00s
04m48s
36s
pos.eq.ra
1e−16
S1
Fλ, erg/cm2/sec/Å
Hε
Hδ
Hγ
Hβ
[OIII]4959
[OIII]5007
[OI]6300
[OI]6364
Hα+[NII]6548,6583
[SII]6716,6731
Wavelength, Å
S2
[OIII]4363
S4

…and we see even fainter details in H_α

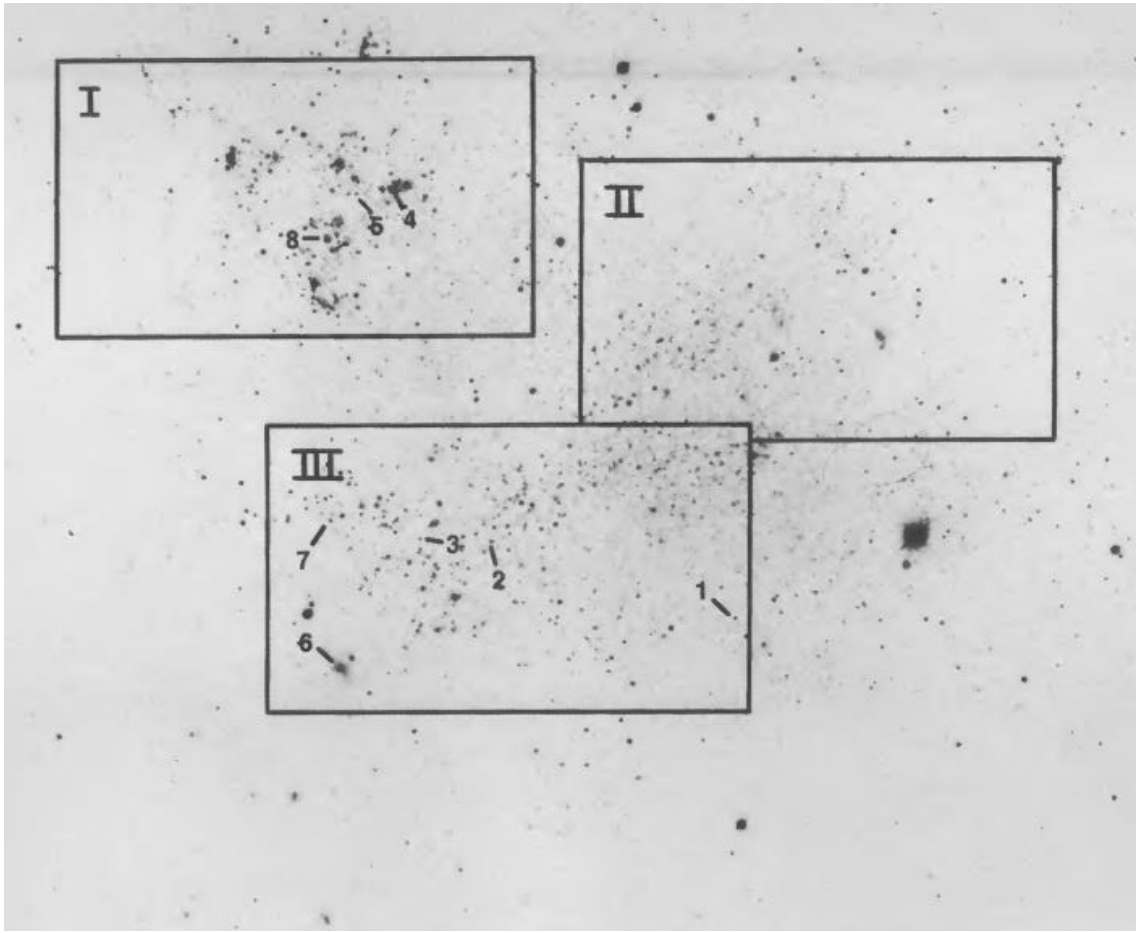


Diagnostic diagrams

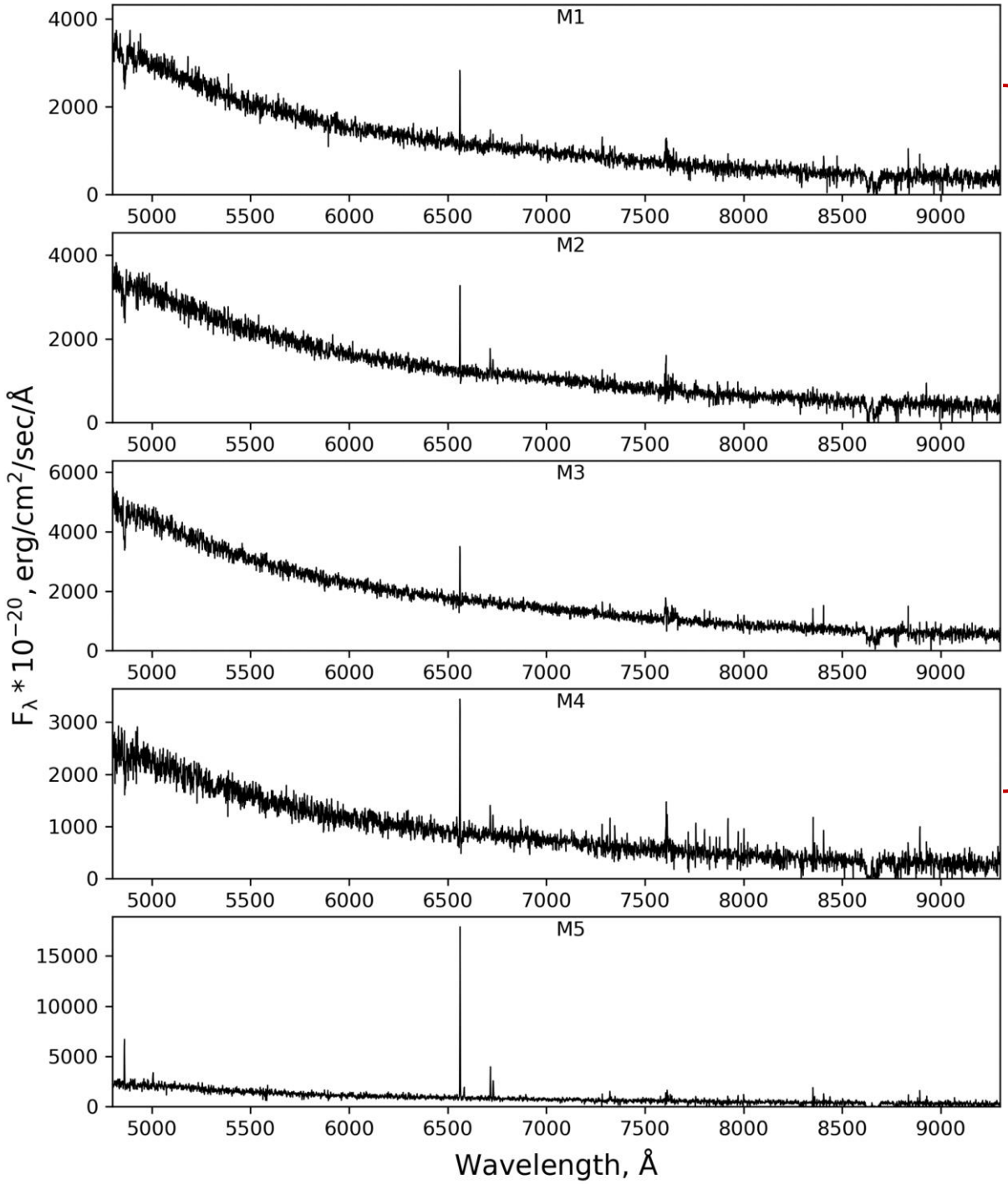


- - Photoionized regions of IC 1613
- - Models from Gutkin et.al., 2016 for metallicity Z=0.002

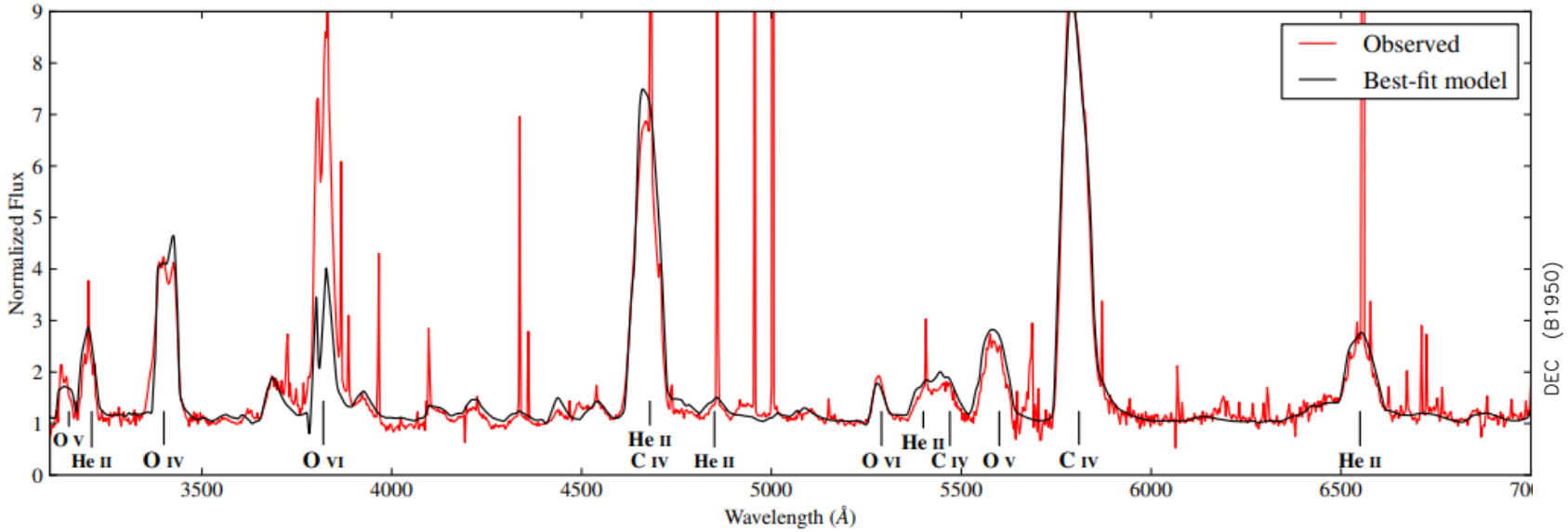
cWR stars in IC 1613

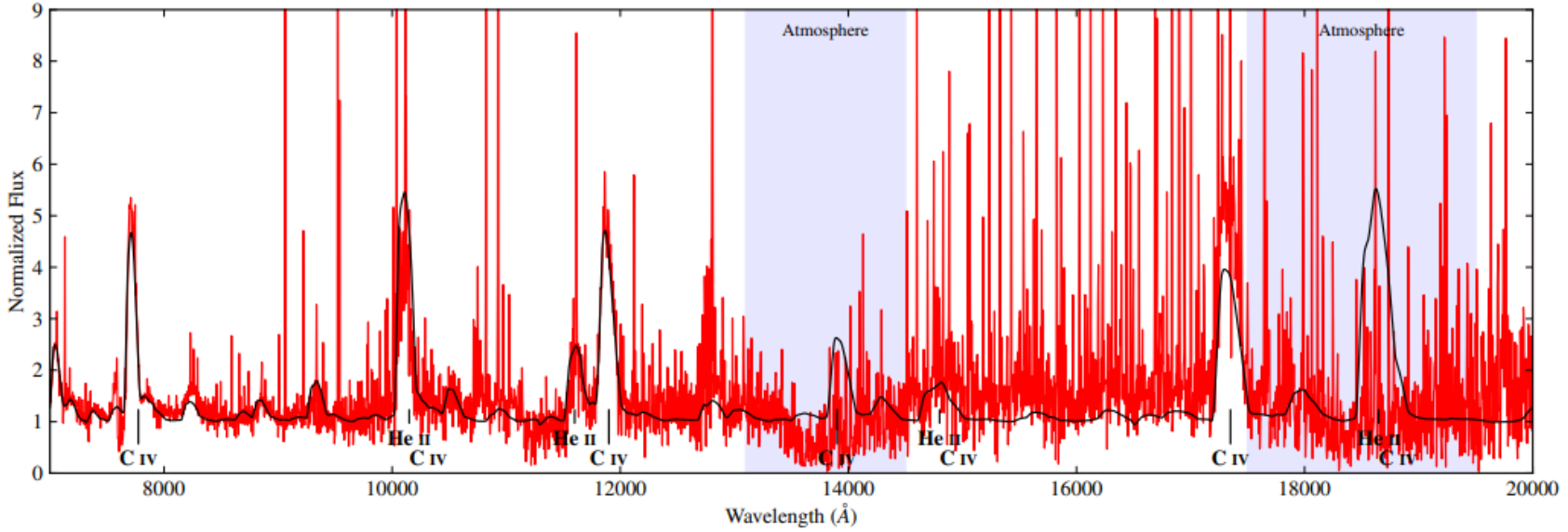


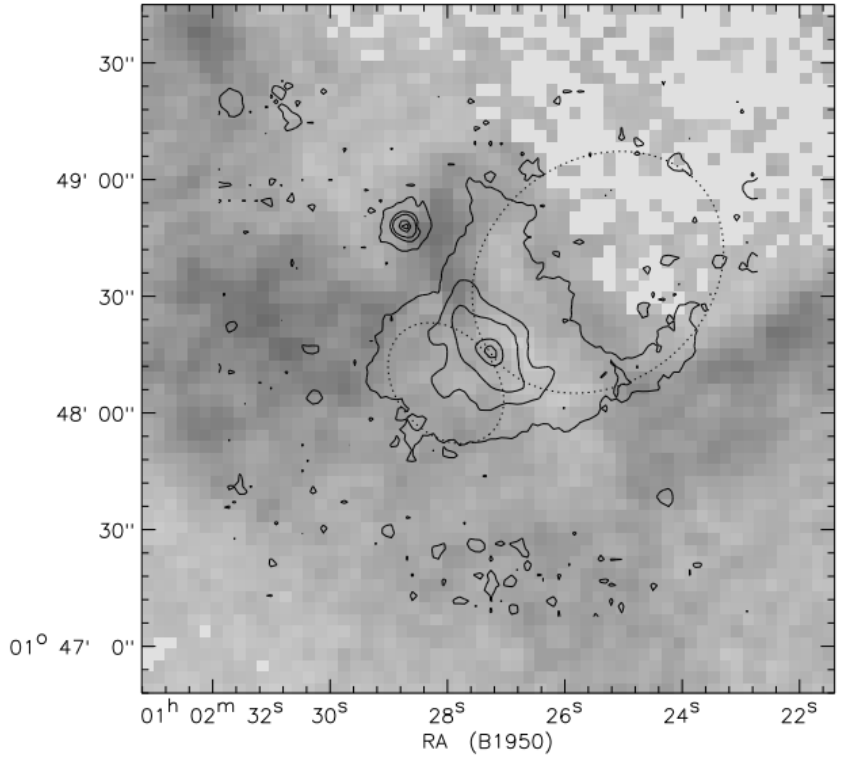
Armandroff, Massey, 1985



Rare WO-type star in IC 1613



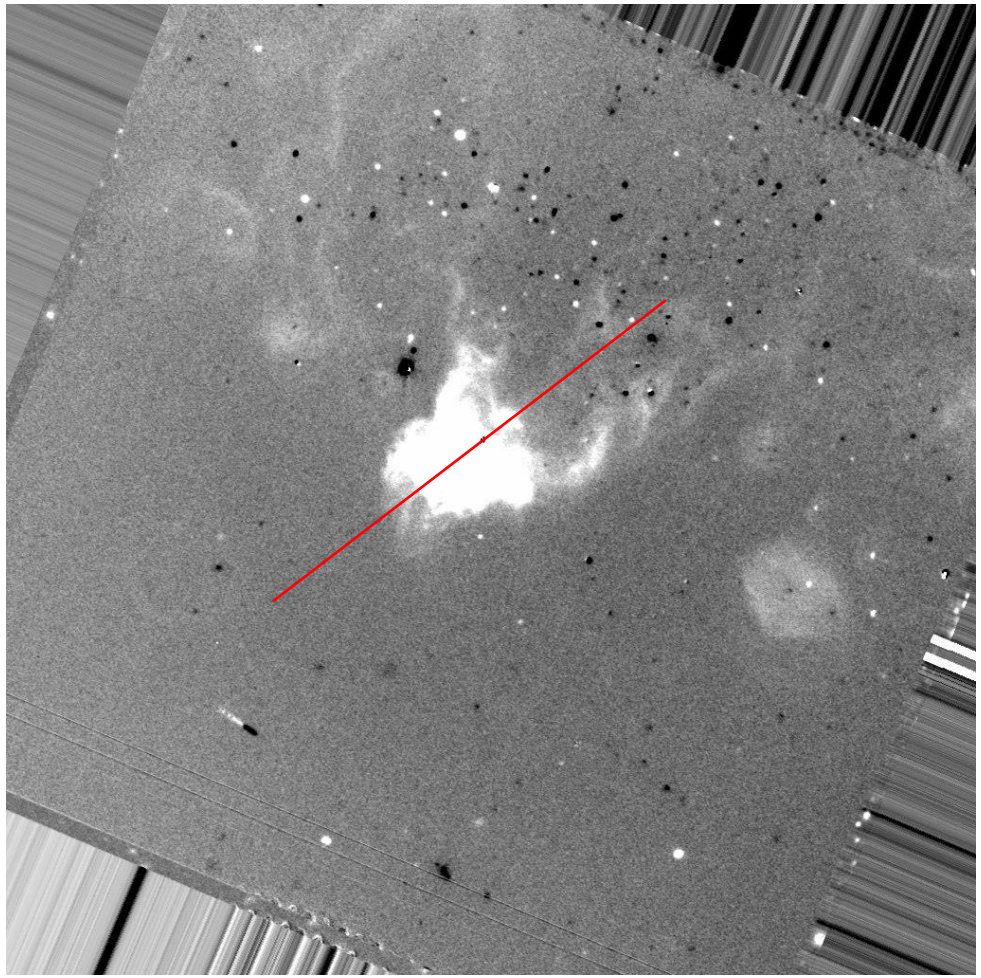




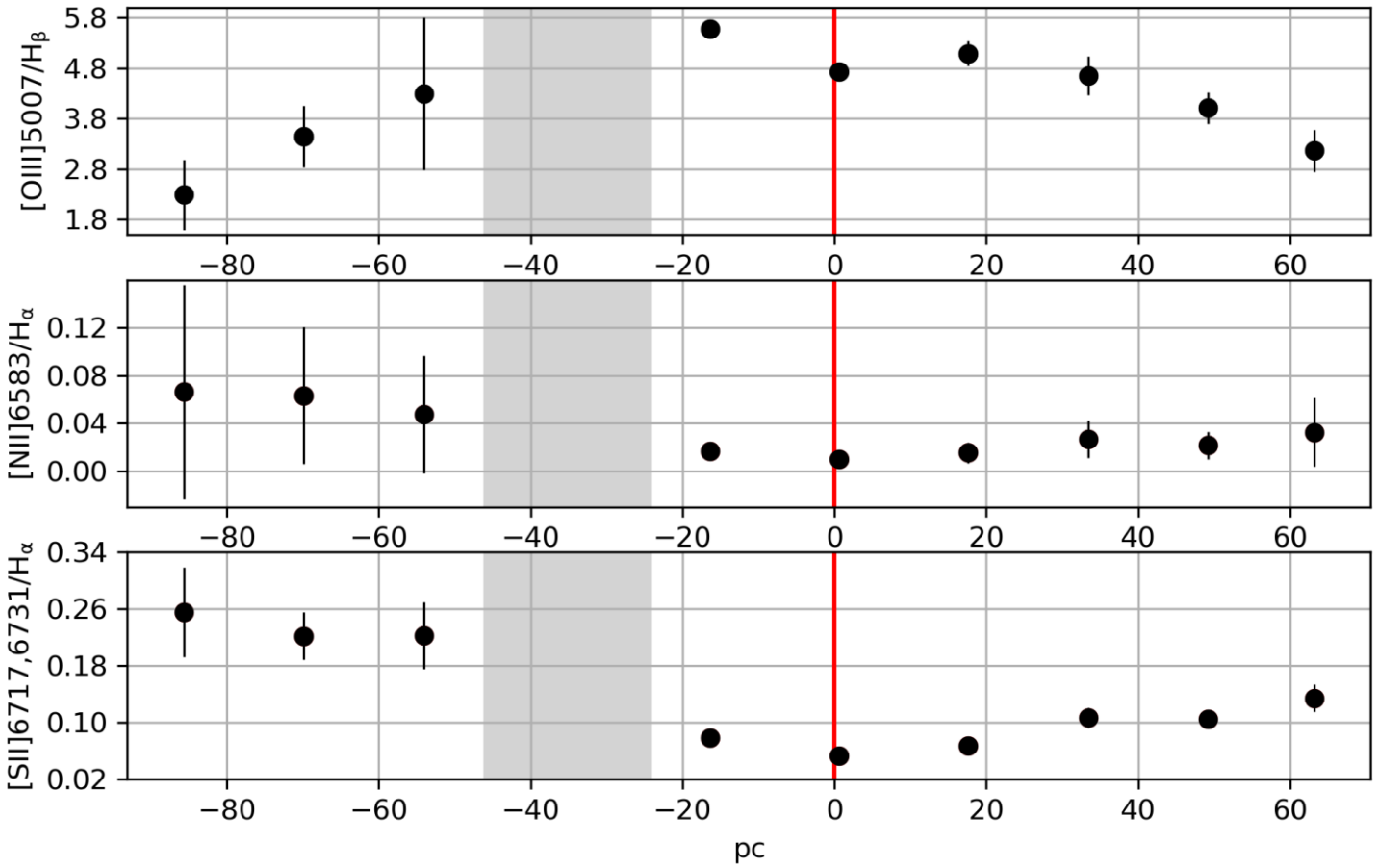
Left: optical and IR spectrum of the WO star, Tramper et.al., 2013

Up: HI image + H_α isophotes, Lozinskaya et.al., 2001

Deep H_α image of WO nebula



Emission lines ratio



Results and discussion

- Studying ISM together with stellar population in local dwarf galaxies can reveal rare and interesting types of objects (WR and LBV stars, SNr).
- With modern instruments we can effectively find faint shells and gaseous structures and analyze state of the ISM, making conclusions about galaxy evolution, feedback effect etc.
- Applications to observations on Russian 6-m and 2.5-m telescopes are welcome ☺

Thank you for your attention!