Multiple Intermediate-mass Black hole candidates in the local dwarf galaxy UGCA320

Xin LI

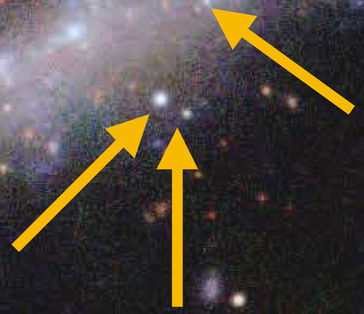
Nanjing University, China

ESO, Chile

Contact me: XinLi@smail.nju.edu.cn

Collabrators: Yong SHI (NJU), Fuyan Bian (ESO), Junfeng Wang (XMU), Zhiyuan Zheng (NJU),...

Multiple Intermediate-mass Black hole candidates in the local dwarf galaxy UGCA320



Xin LI

Nanjing University, China

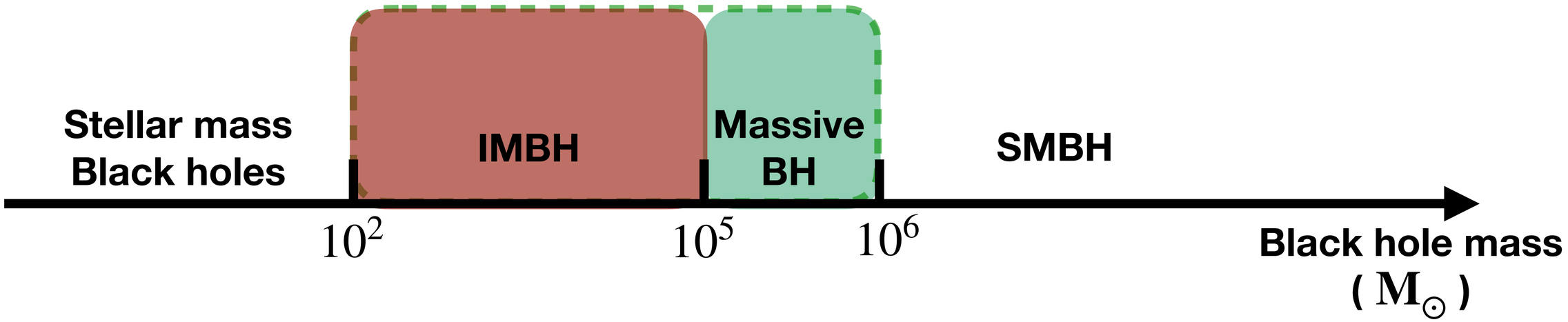
ESO, Chile

Contact me: XinLi@smail.nju.edu.cn

Collabrators: Yong SHI (NJU), Fuyan Bian (ESO), Junfeng Wang (XMU), Zhiyuan Zheng (NJU),…

Background

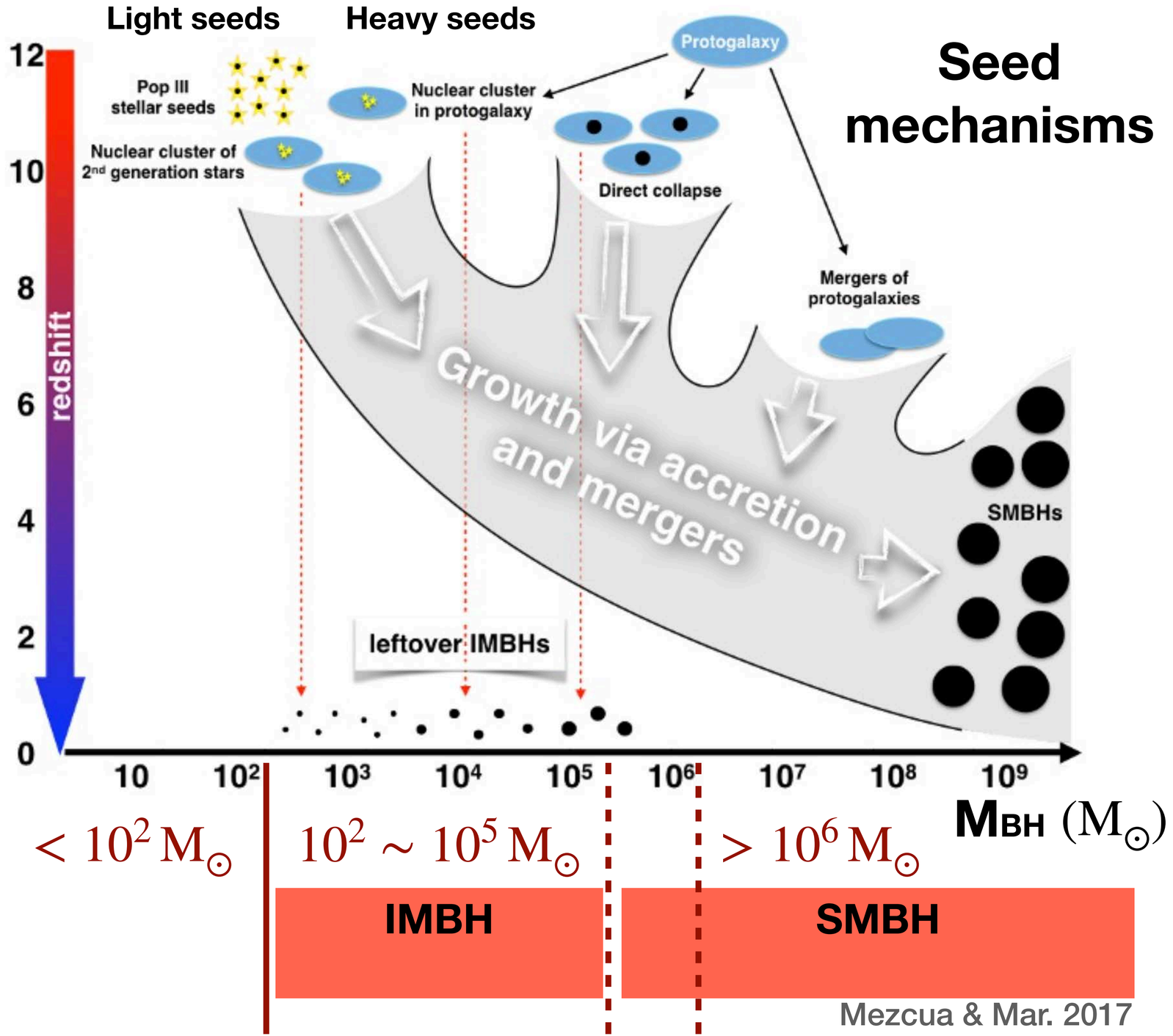
Intermediate-mass black hole (IMBH): $10^2 \sim 10^5\,M_\odot$



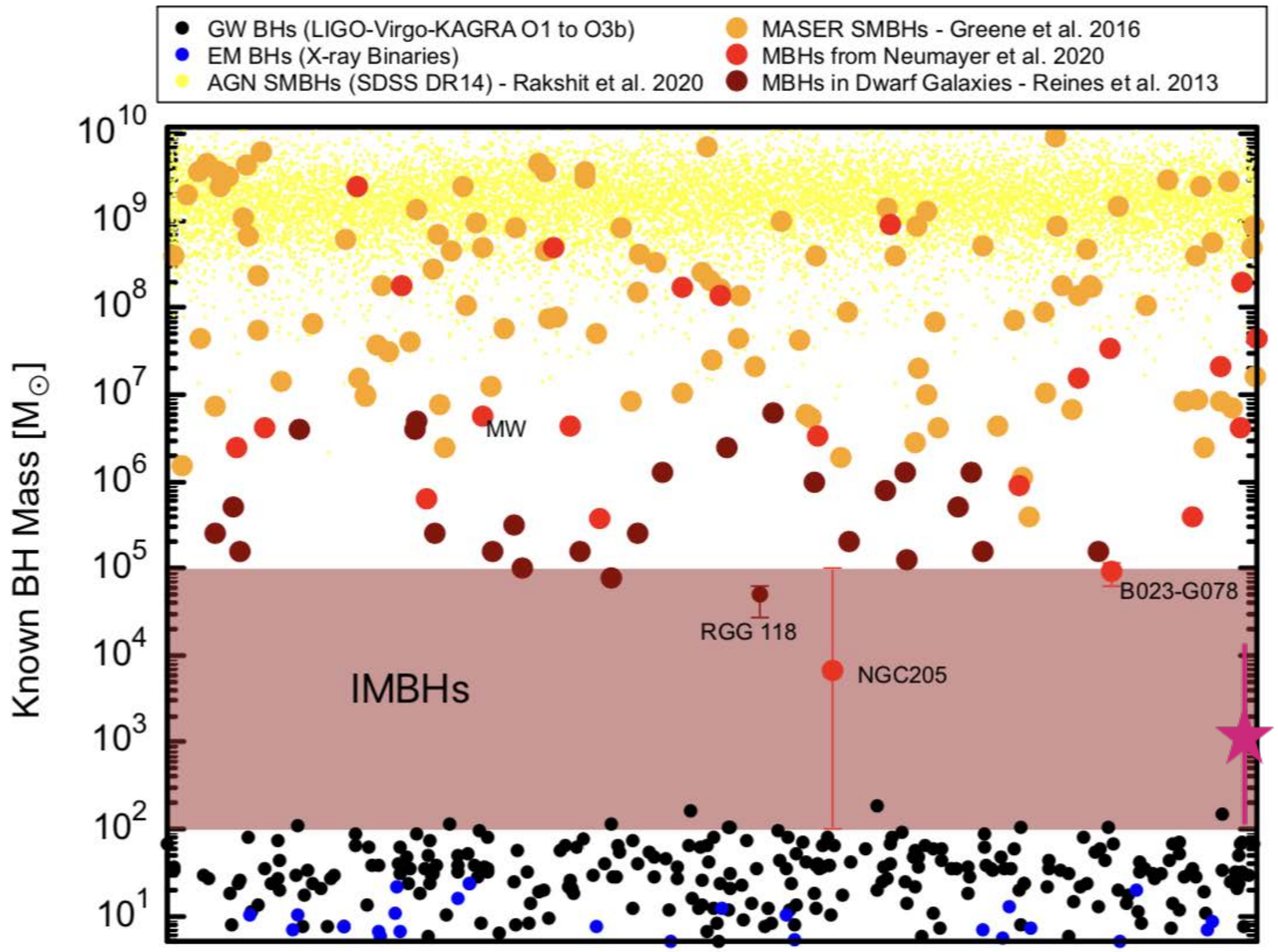
Background

Hierarchical evolution

- IMBHs as the seeds of SMBHs
- IMBHs retain more information about their childhood

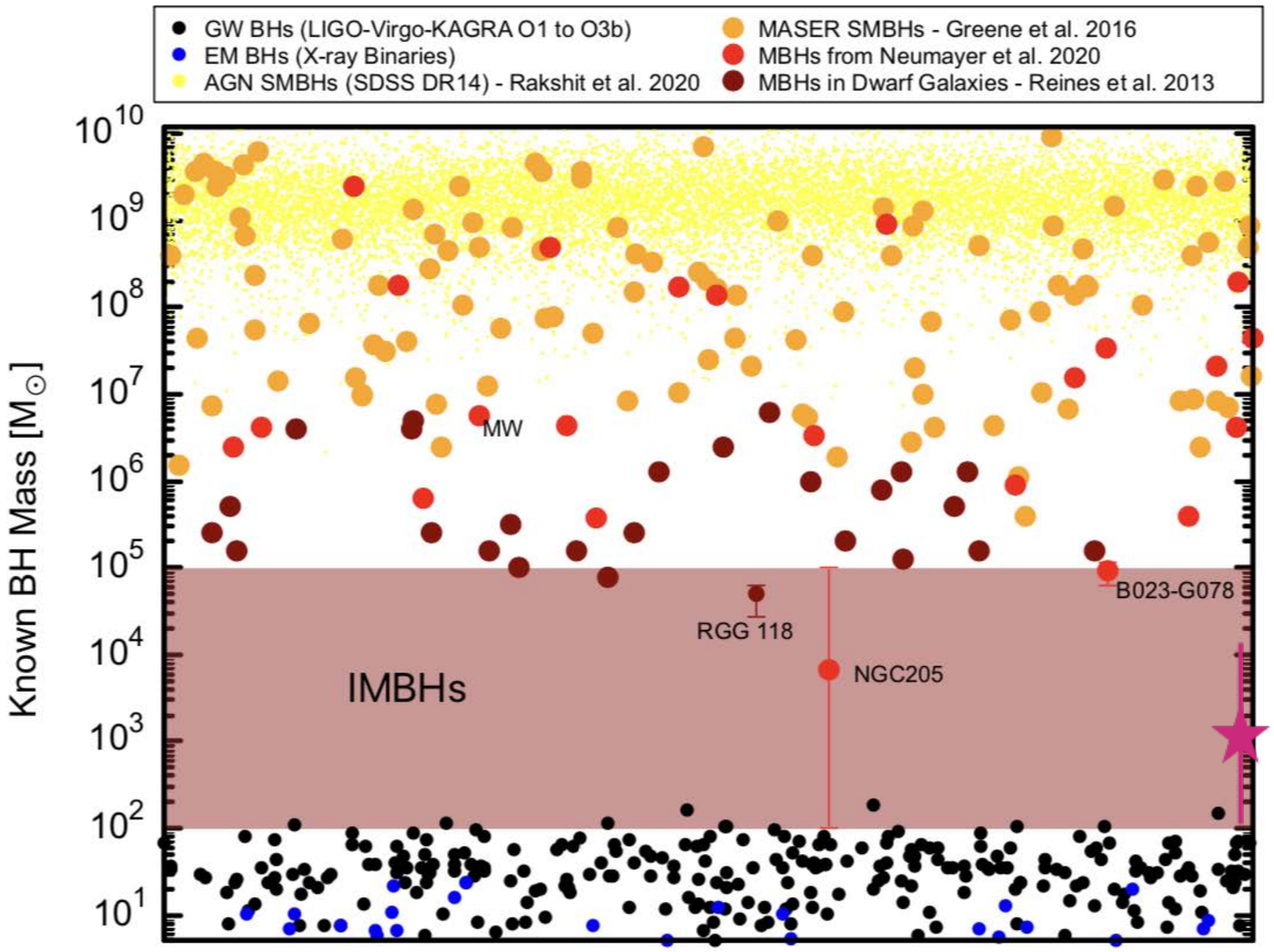


Background



Askar,Baldassare and Mezcua,2023

Background



Askar,Baldassare and Mezcua,2023

- **Hard to find:**
  - **Faint;**
  - **Less gas accretion;**
  - **Diluted by star forming signal**

★**Deep exposure, high spatial resolution.**

- **Hard to identify:**
  - **Confuse with other objects**

HXB;

Massive evolving stars;

Wolf-Rayet stars;

Supernova(SNe);

Supernova remnant (SNR);

…

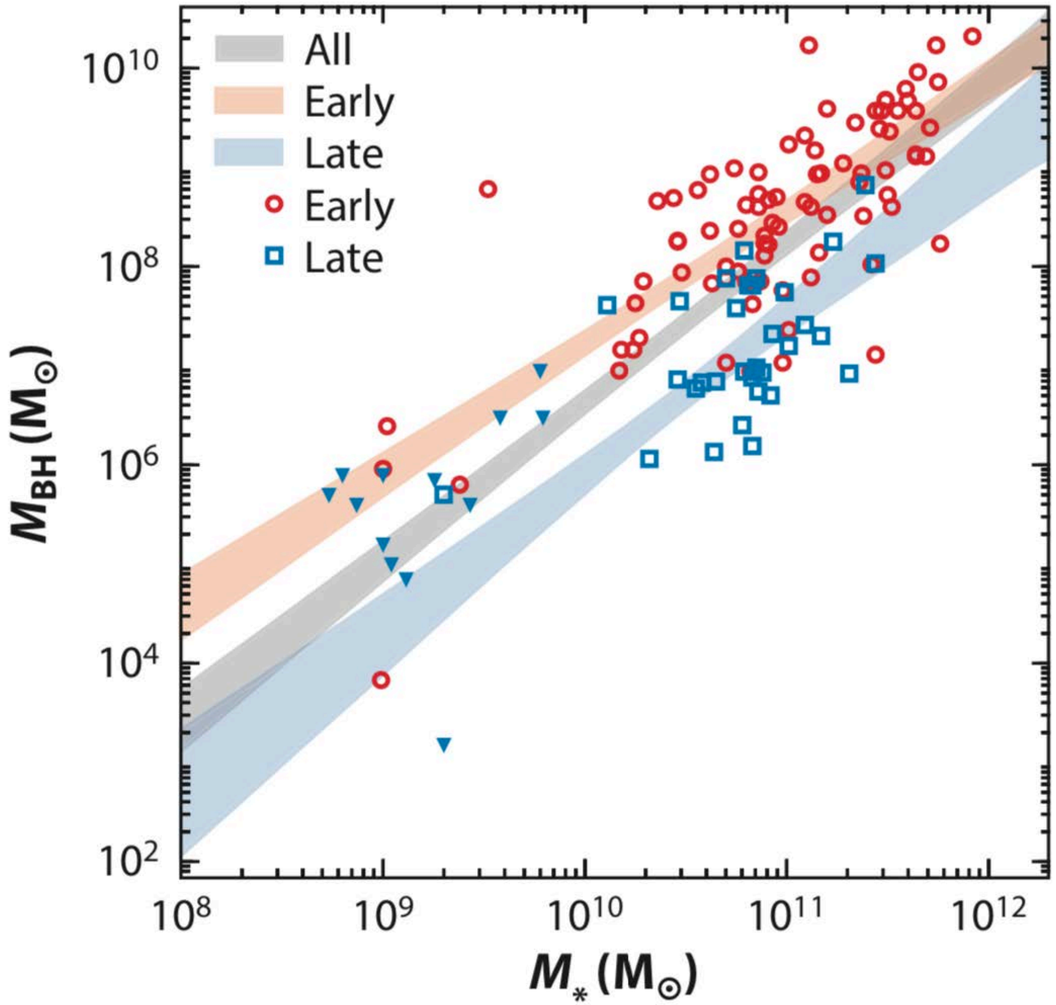
★**Multiple diagnostics.**

Background

Finding IMBHs in dwarf galaxies ($M_* < 10^9 M_\odot$)

- **Less gas accretions and mergers;**
- **Strong stellar feedback;**
- **Less efficient dynamic friction;**
- **Lower metallicity environment;**

Hamper IMBHs growth and sink to the center.



Greene, Strader, and Ho 2020

Observation

Dwarf Galaxy Integral-field Survey

DGIS: Dwarf Galaxy Integral-field Survey

PI: Yong Shi, co-PI: Fuyan Bian

https://www.dgisteam.com

Telescope: MUSE/VLT (45/63), ANU-2.3/WiFeS (18/63)

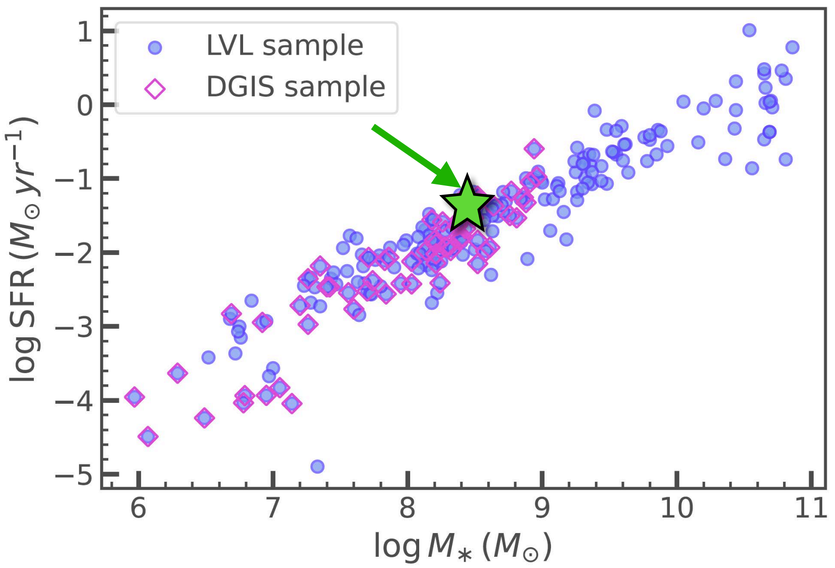
- Distance < 11 Mpc;
- Dec < 20° ;
- Stellar mass $< 10^9 M_\odot$

X.Li et al.
arxiv:2501.04943v1

	VLT/MUSE	ANU-2.3 m/WiFeS
Wavelength	4650-9350A	**3500-9000A**
PSF	**0.8 arcsec**	1.5 arcsec
FOV	**60”×60”**	25”×38”
Spectral resolution	2000~3000	**7000**
Exp time (single sources)	0.6~4 hr	3~13 hr
Total expose time	**80 hr**	**139.4 hr**

UGCA 320

DGIS: Dwarf Galaxy Integral-field Survey



arxiv:2501.04943v1

RA : 13:03:16.74

DEC: -17:25:22.9

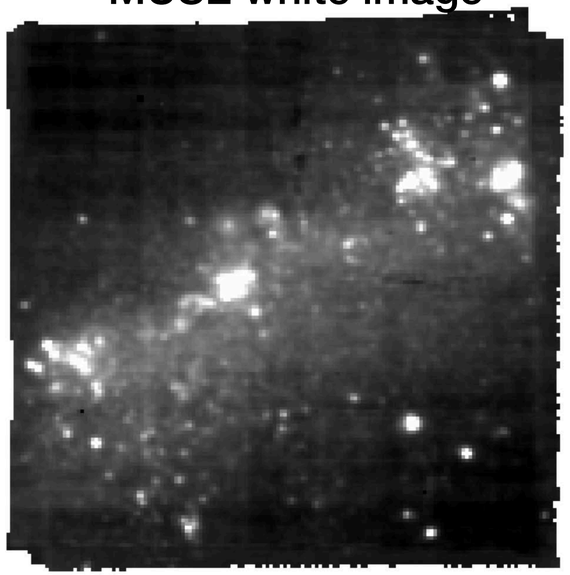
Distance: 6.03 Mpc

Inclination: edge on

Morphology Type: Sm

- LogM*: 8.52 $M_\odot$
- LogM$_{HI}$: 8.83 $M_\odot$
- LogSFR(UV): -1.24 $M_\odot yr^{-1}$
- LogSFR(Ha): -1.71 $M_\odot yr^{-1}$
- 12+log(O/H): 8.02

MUSE white image

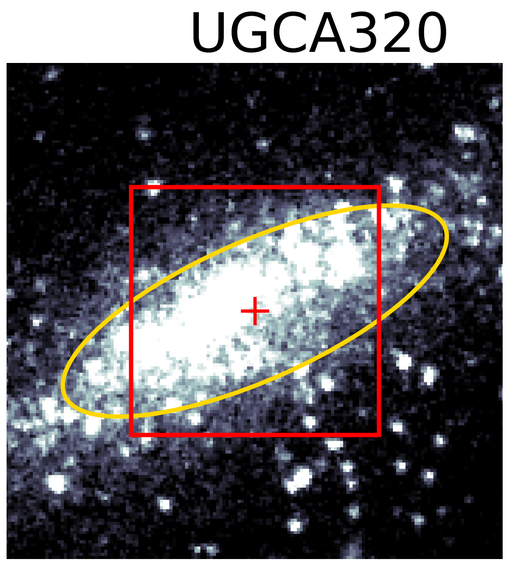


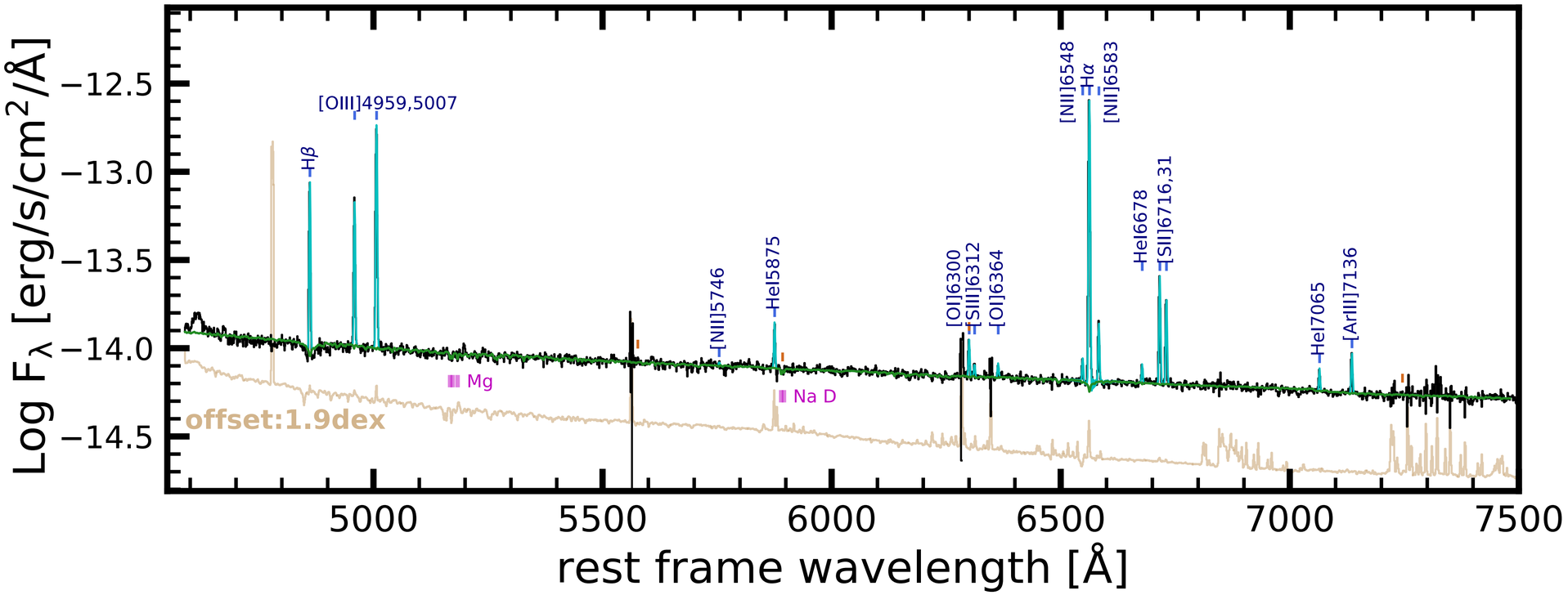
Telescope: MUSE

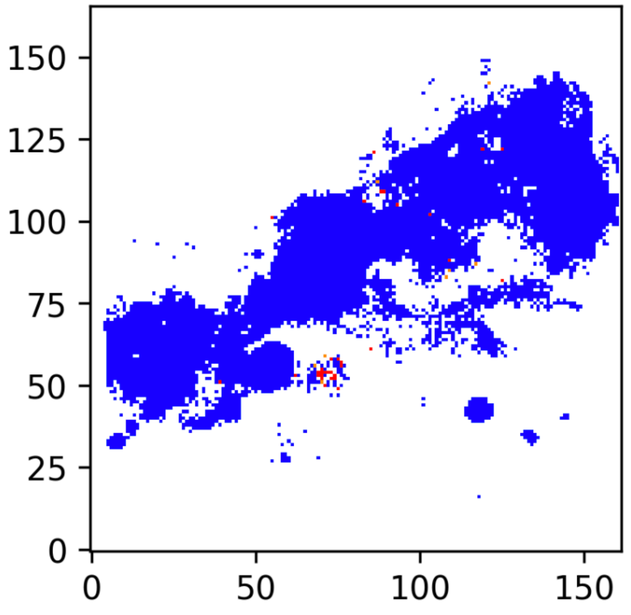
Exposure Time: 4480 s (2021-4-22)

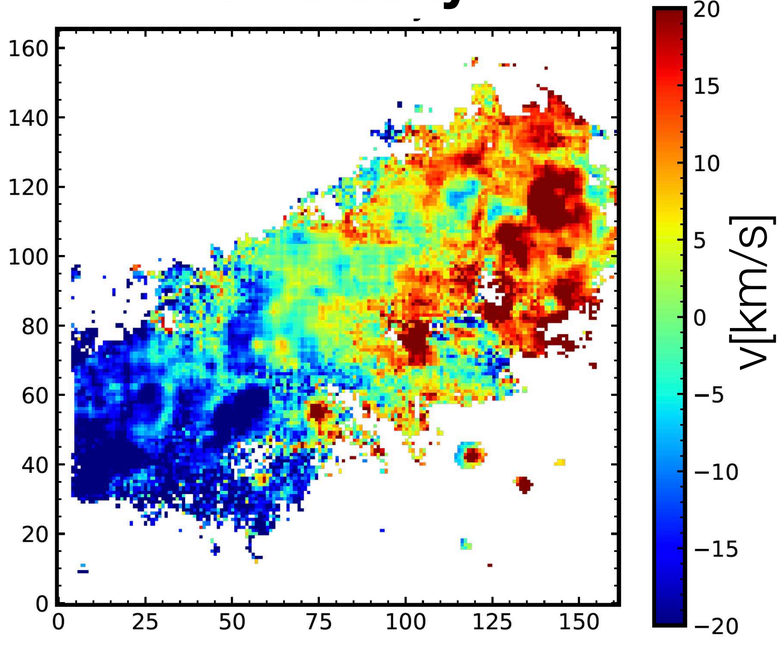
Pixel scale: 0.4” — — >11.7 pc

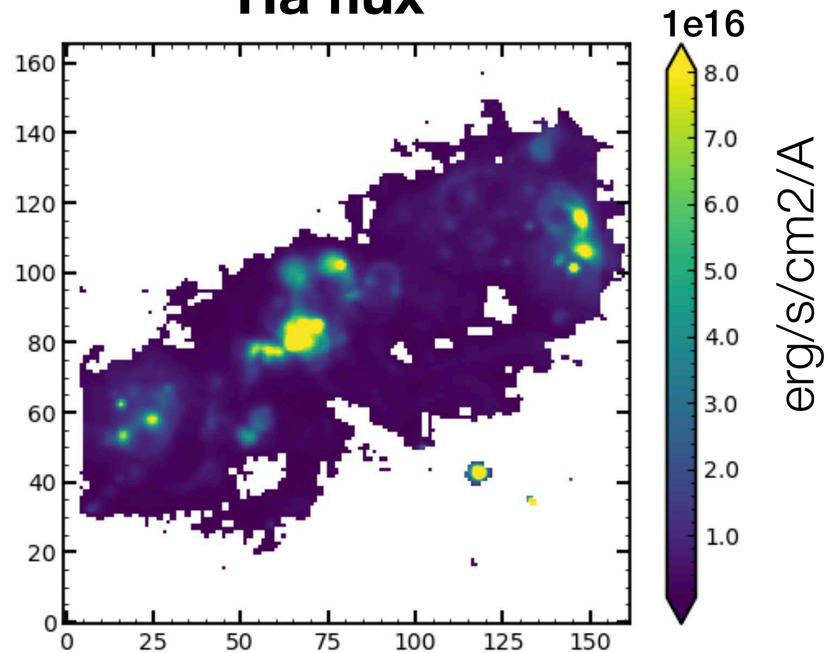
FWHM of PSF: 1.02” — —> 30 pc


UGCA320


Log F$_\lambda$ [erg/s/cm^2/Å]
−12.5
−13.0
−13.5
−14.0
−14.5
[OIII]4959,5007
Hβ
[NII]5746
HeI5875
[OI]6300
[SIII]6312
[OI]6364
[NII]6548
Hα
[NII]6583
HeI6678
[SII]6716,31
HeI7065
[ArIII]7136
Mg
Na D
offset:1.9dex
5000
5500
6000
6500
7000
7500
rest frame wavelength [Å]


SII-BPT
150
125
100
75
50
25
0
0
50
100
150


Ha velocity
160
140
120
100
80
60
40
20
0
0
25
50
75
100
125
150
20
15
10
5
0
−5
−10
−15
−20
v[km/s]


Ha flux
1e16
160
140
120
100
80
60
40
20
0
0
25
50
75
100
125
150
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
erg/s/cm2/A

UGCA 320

Two-Gaussian fittings

Ha narrow component

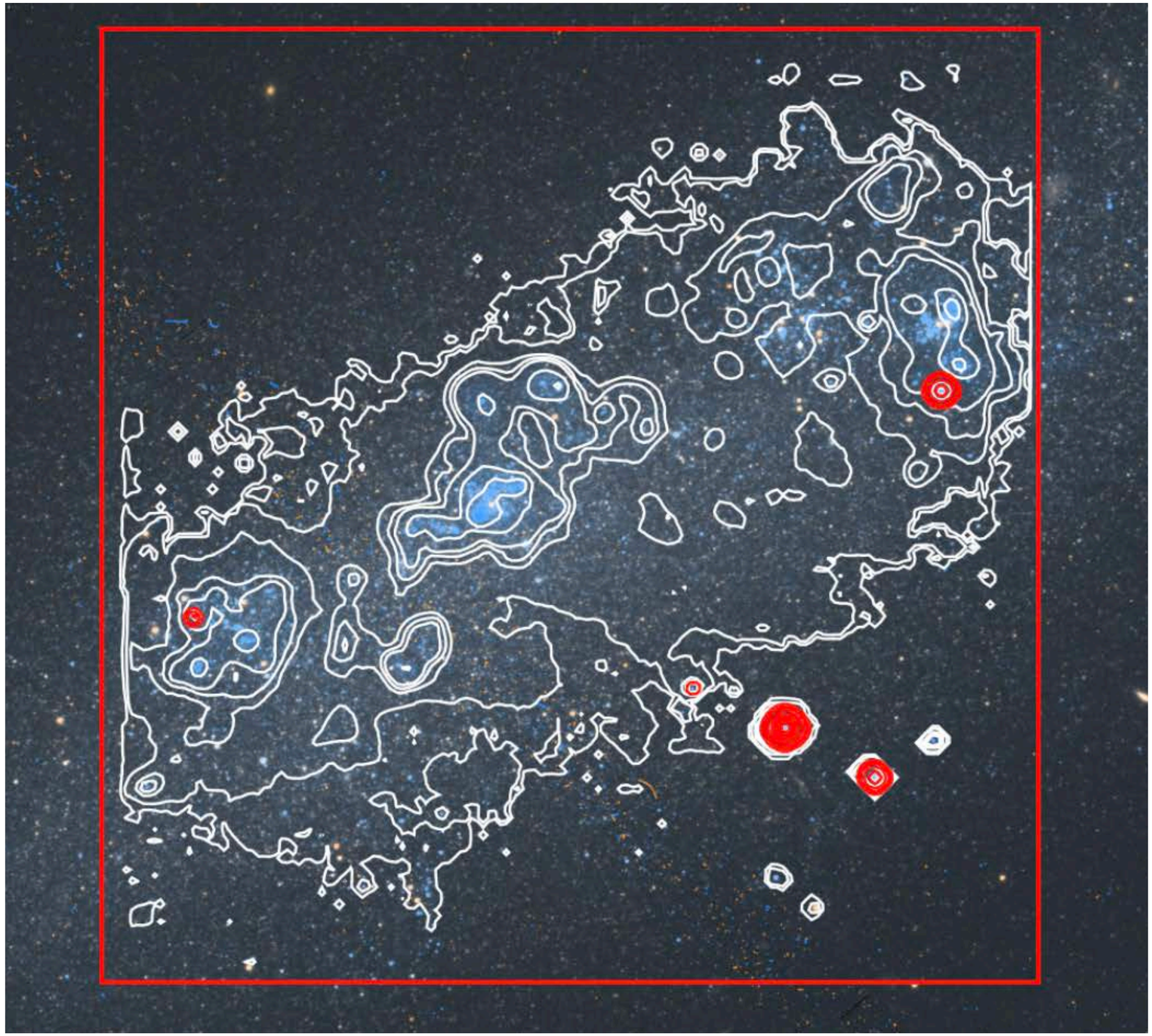
Ha broad component

★ **Five regions detected Ha broad emission line**

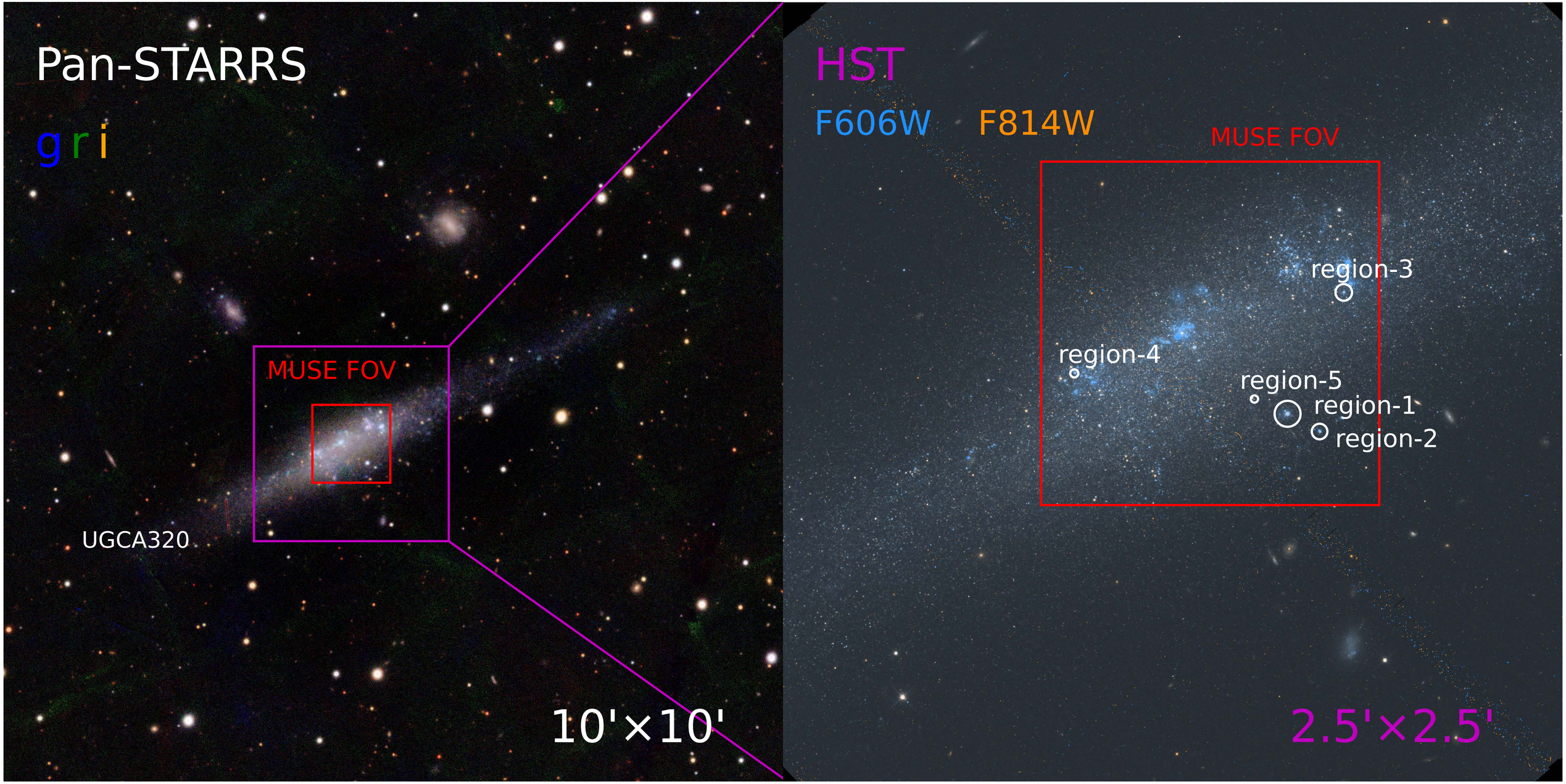
$$\log L_{H\alpha,br} = 36.4 \sim 38.0\ erg/s$$

$$\sigma_{H\alpha,FWHM} = 310 \sim 855\ km/s$$

SMBH: $\log L_{H\alpha,br} > 40\ erg/s$, $\sigma_{H\alpha,FWHM} > 1000\ km/s$



IMBH candidates



UGCA 320

Two-Gaussian fittings

Ha narrow component

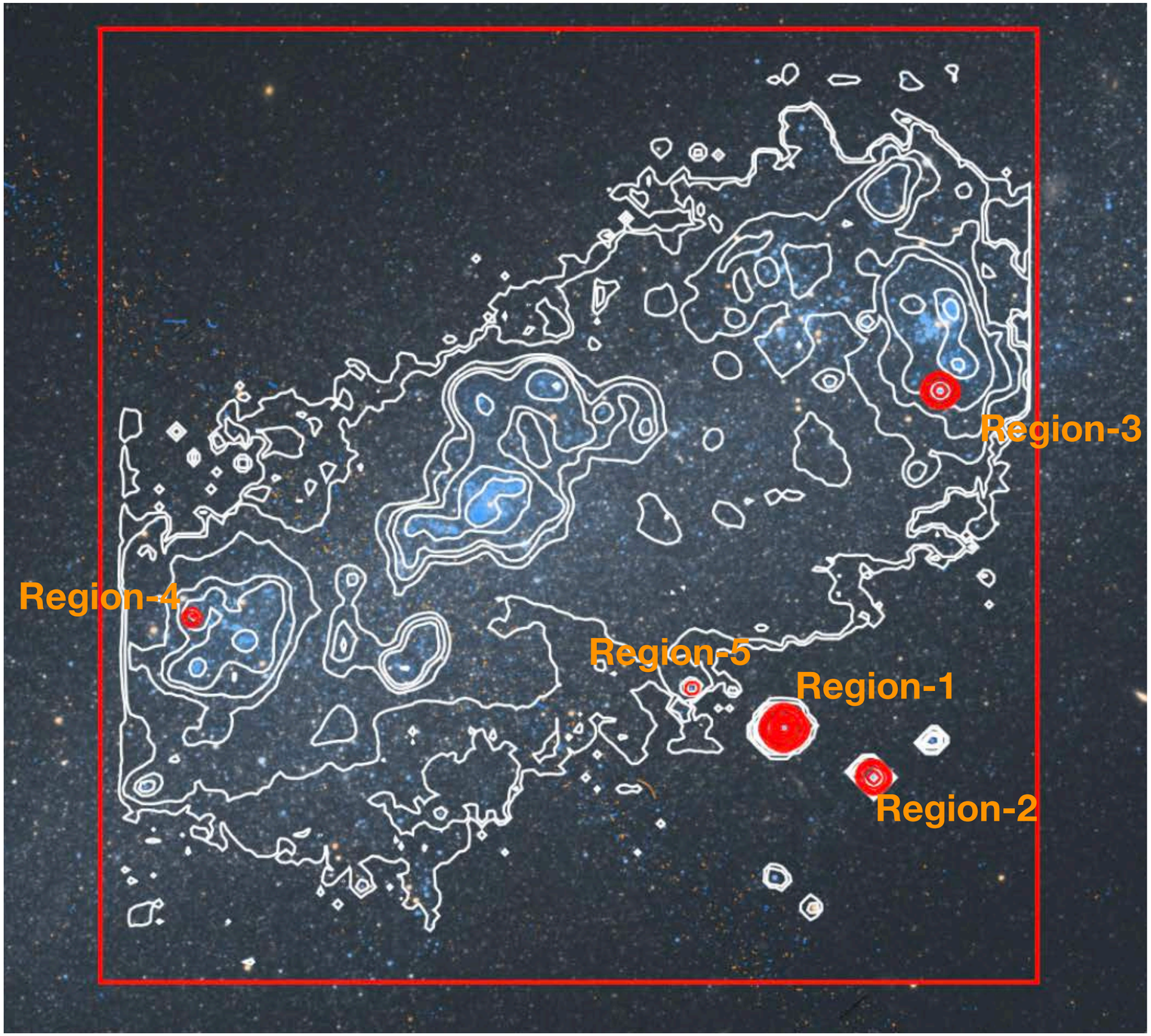
Ha broad component

★ Five regions detected
Ha broad emission line

$$\log L_{H\alpha,br} = 36.4 \sim 38.0\ erg/s$$

$$\sigma_{H\alpha,FWHM} = 310 \sim 855\ km/s$$

SMBH: $\log L_{H\alpha,br} > 40\ erg/s$, $\sigma_{H\alpha,FWHM} > 1000\ km/s$



Identification

Wolf Rayet (WR) Stars;

SN explosion;

SN remnant;

Massive O/B stars;

IMBH

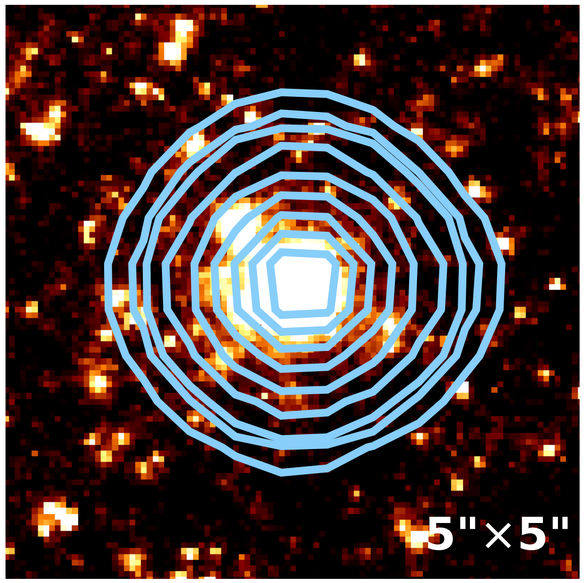
Identification

Background: HST F814W
Contours: Ha broad emissions

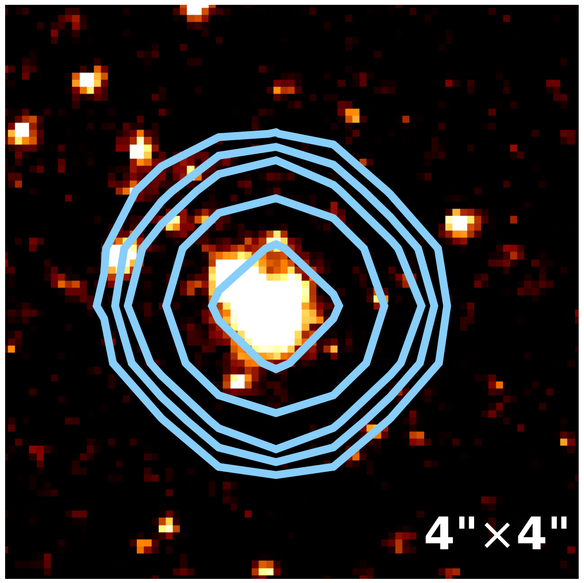
1” ~ 11 pc

★ **Having continuum point source counterparts**

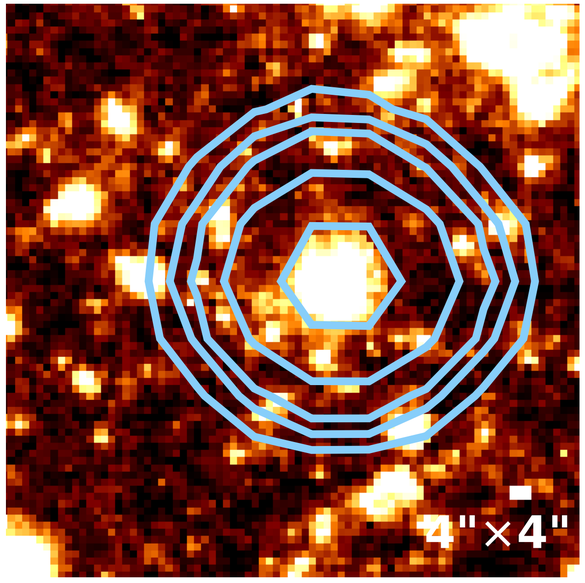
region-1



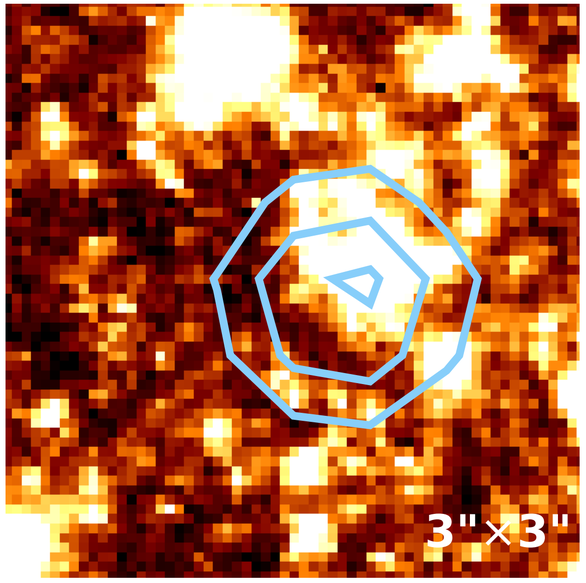
region-2



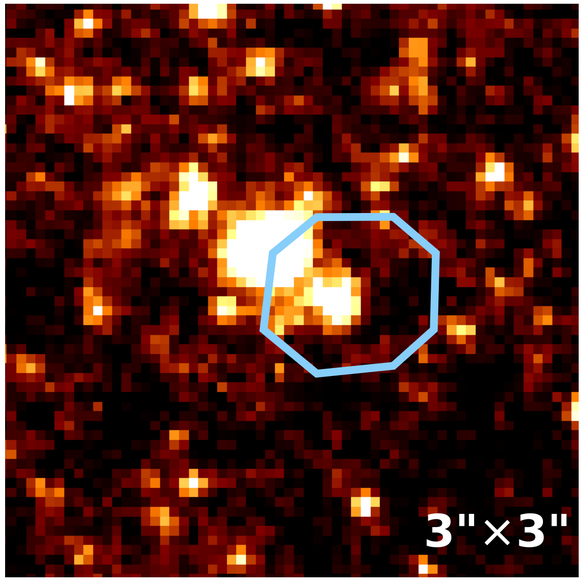
region-3



region-4



region-5



- **Identification**

Wolf Rayet (WR) Stars;

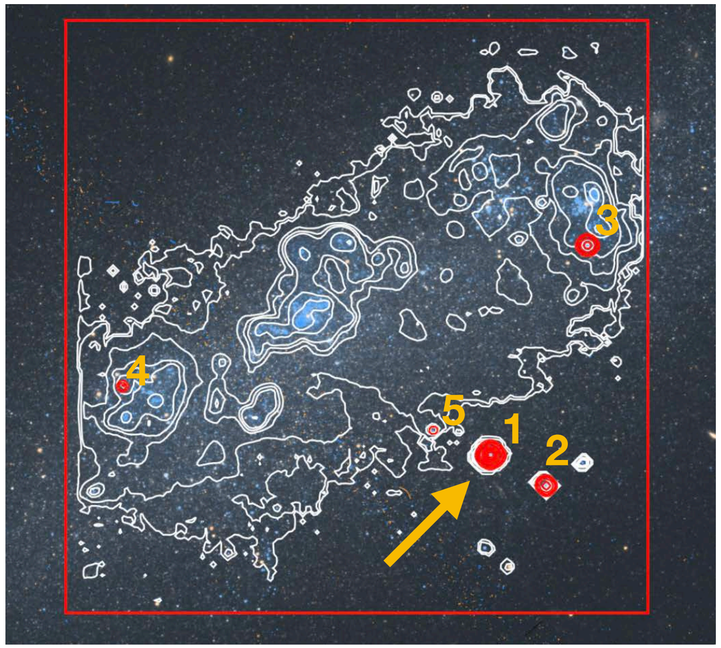
SN explosion;

~~**SN remnant;**~~

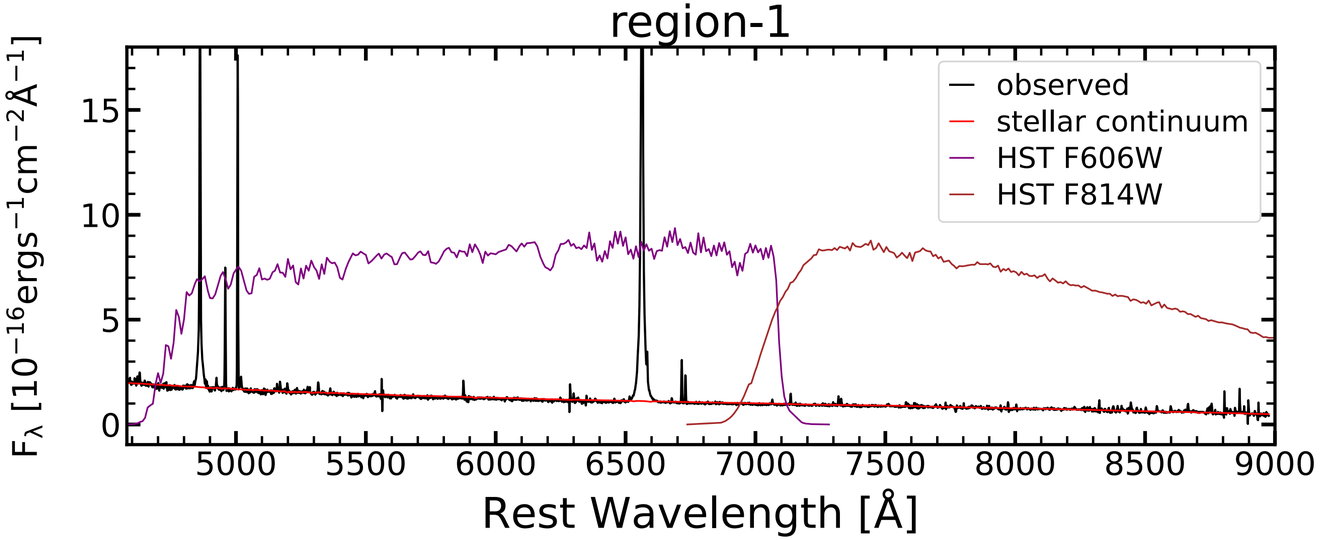
Massive O/B stars;

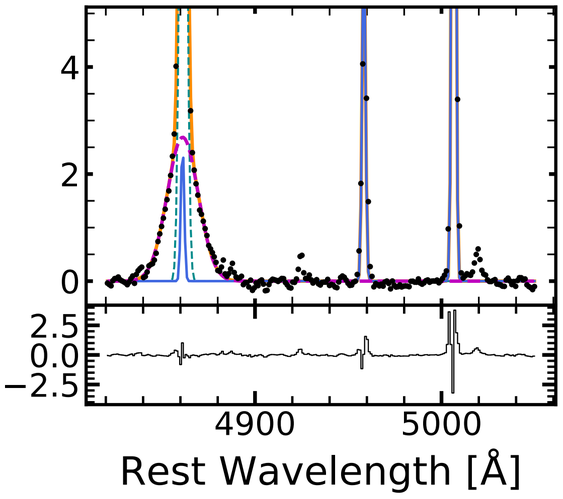
IMBH

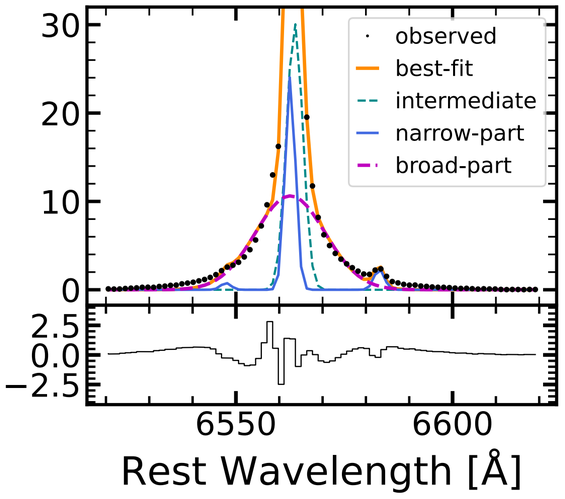
Identification—— spectra



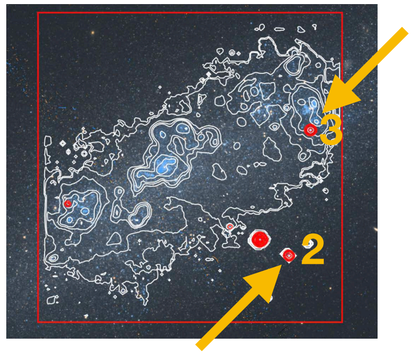
- **Outflows: [OIII], [SII] broad components**
- **Wolf Rayet stars: Bump around 4686 A;**
- **Massive stars: weak/without [OIII]; P-Cygni profiles**



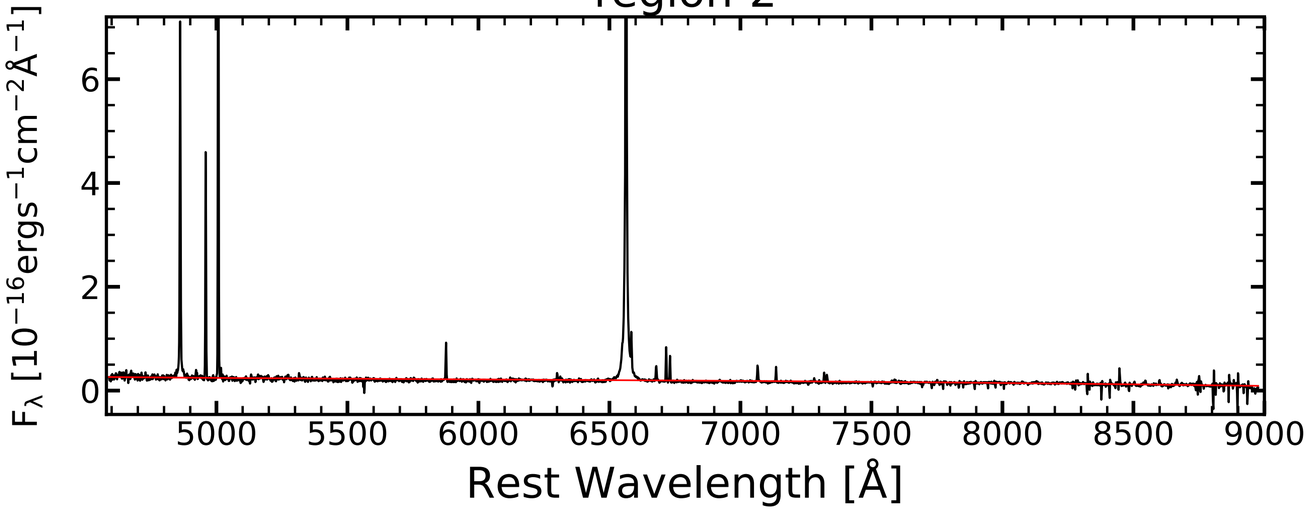


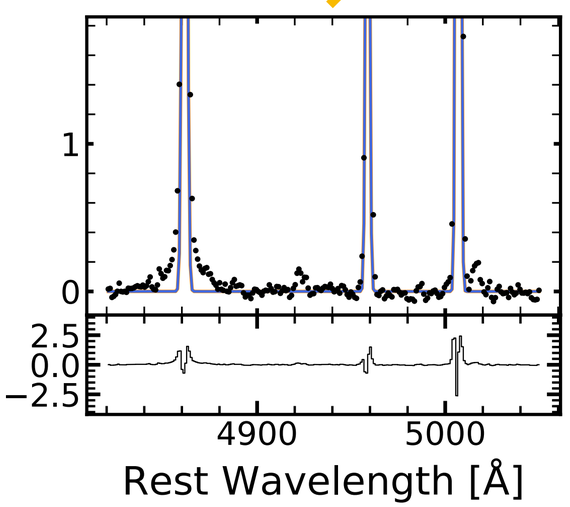


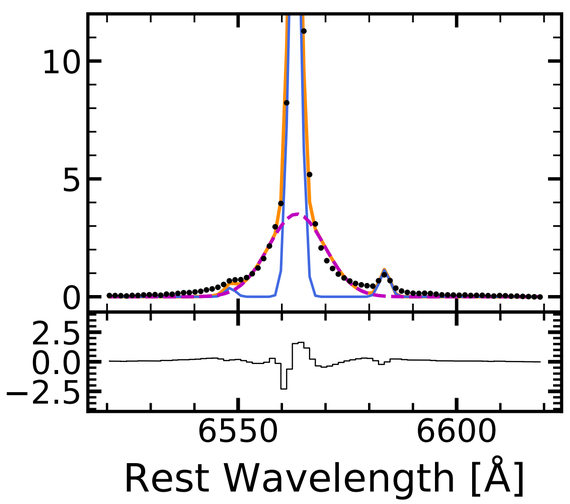
Identification—— spectra



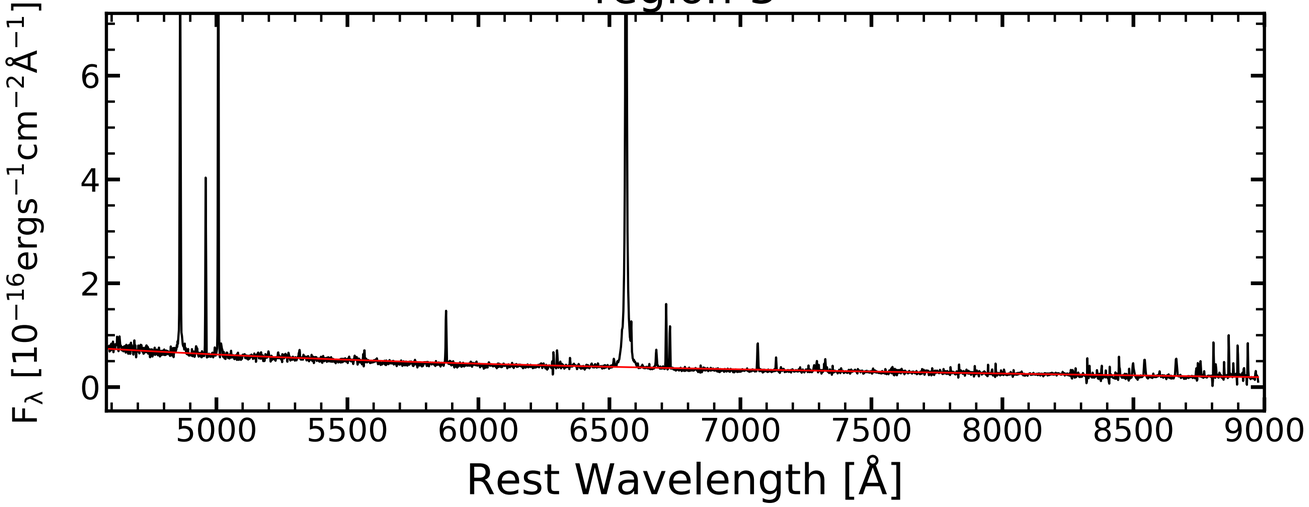
region-2

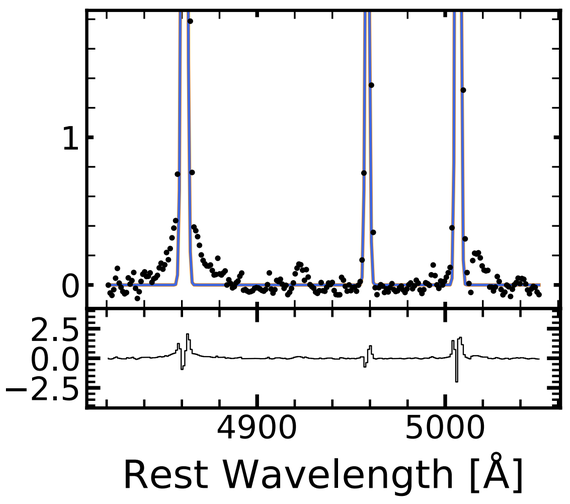


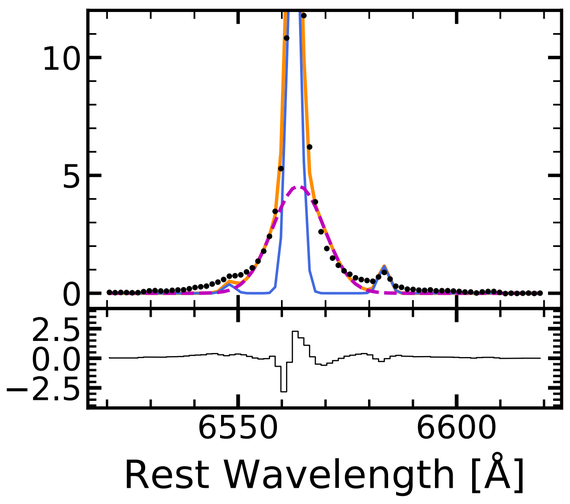




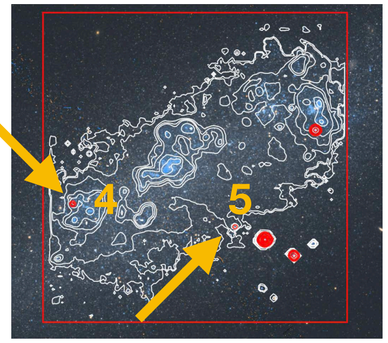
region-3



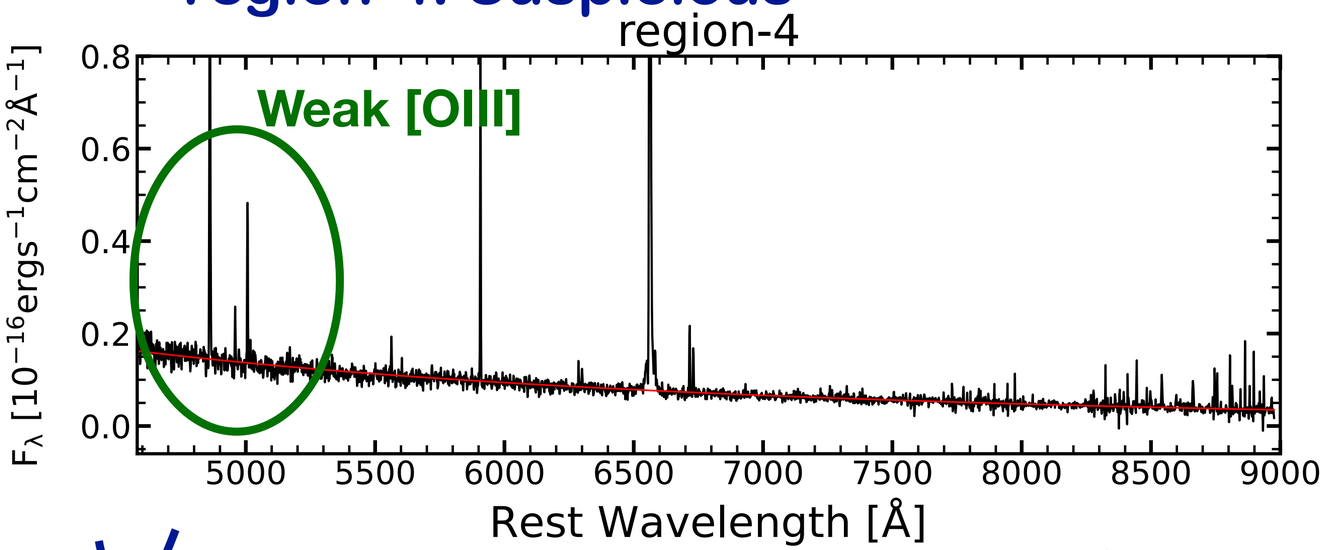


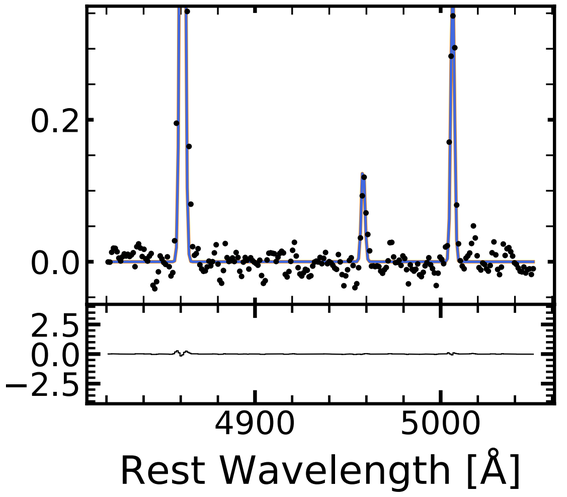


Identification—— spectra

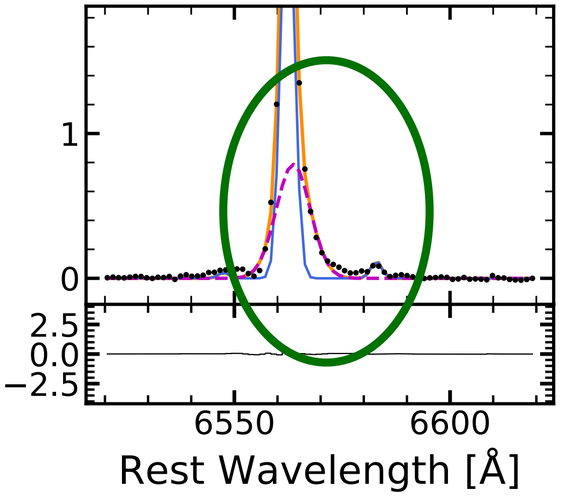


region-4: Suspicious

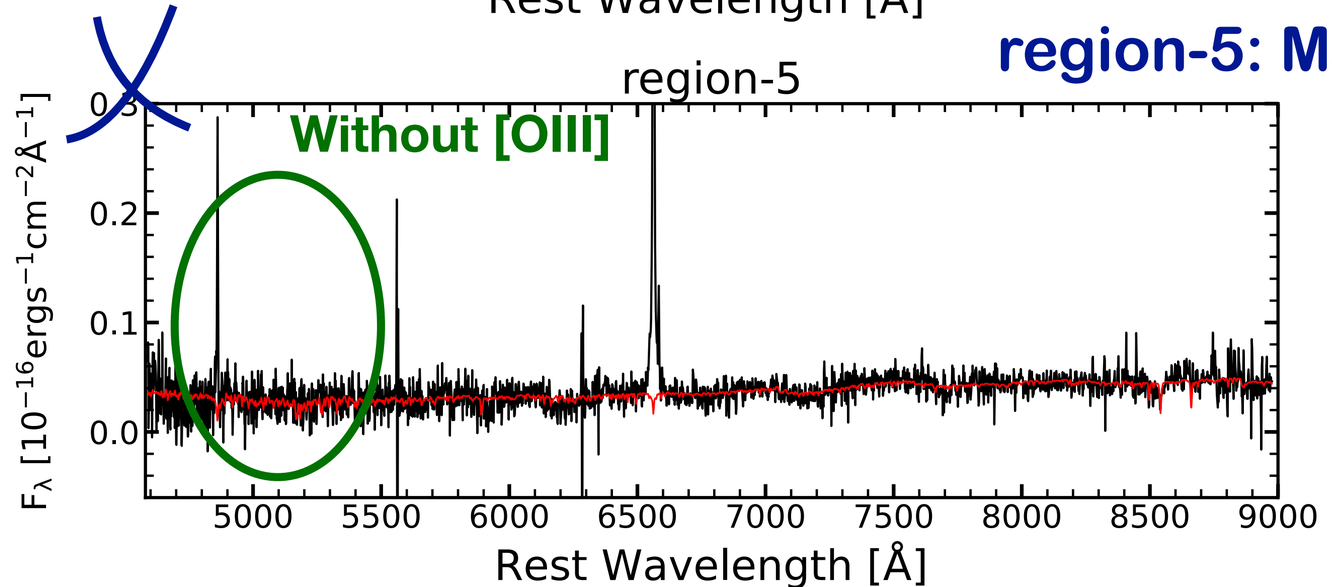


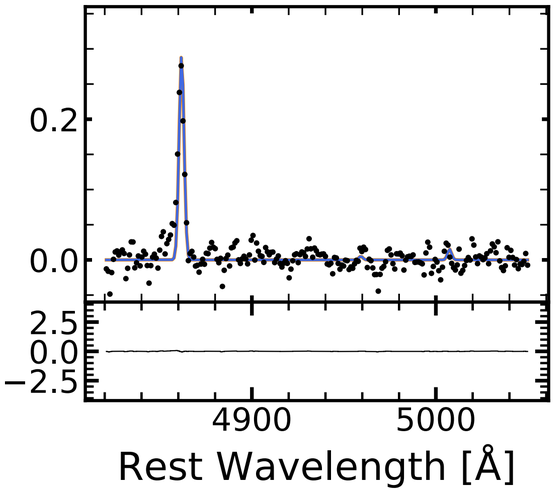


Red-shifted

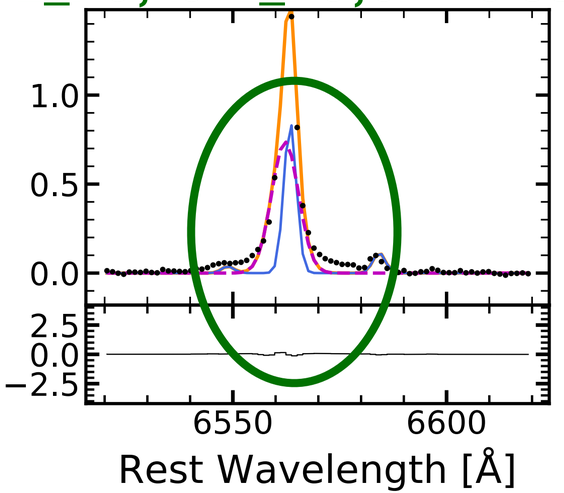


region-5: Massive star

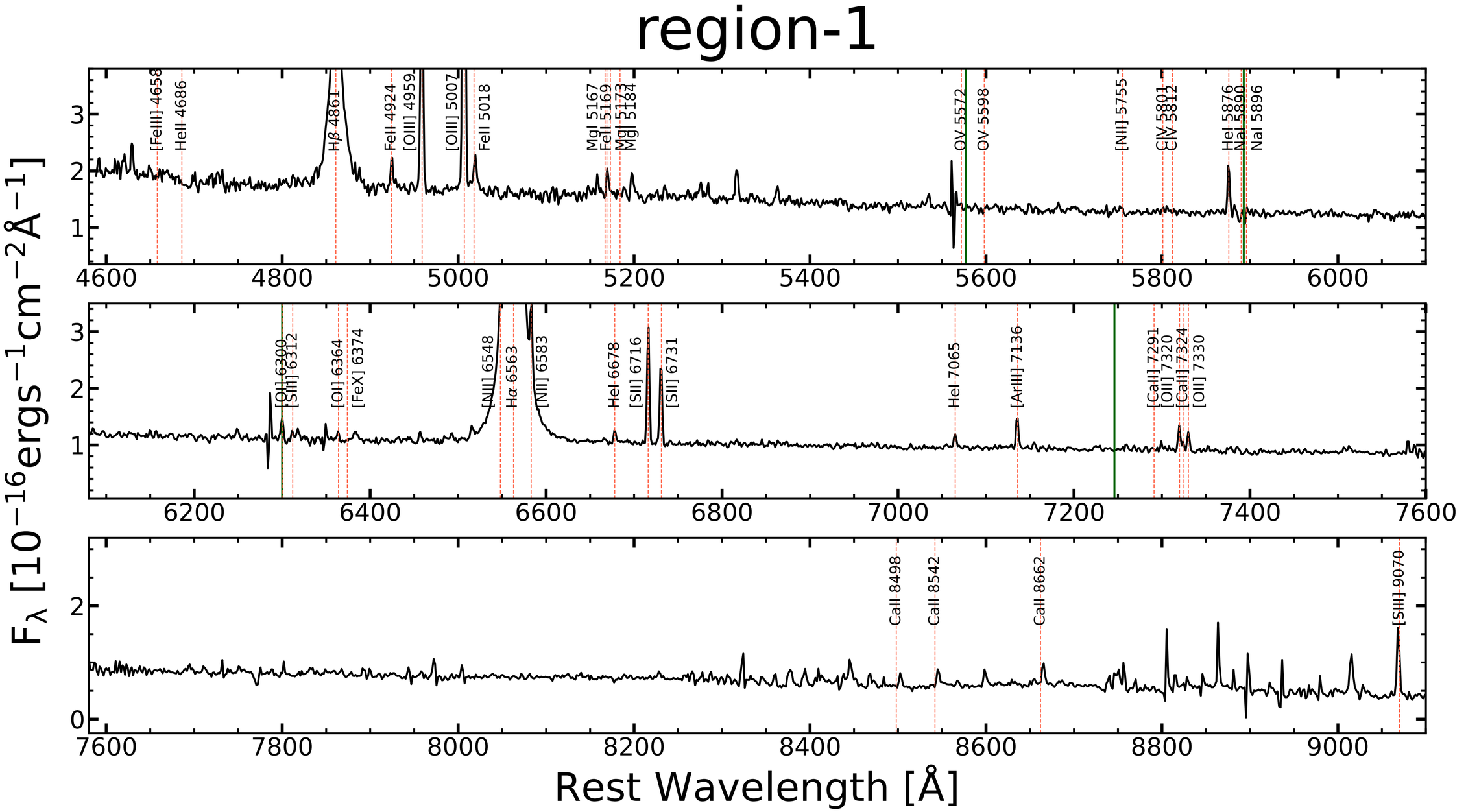




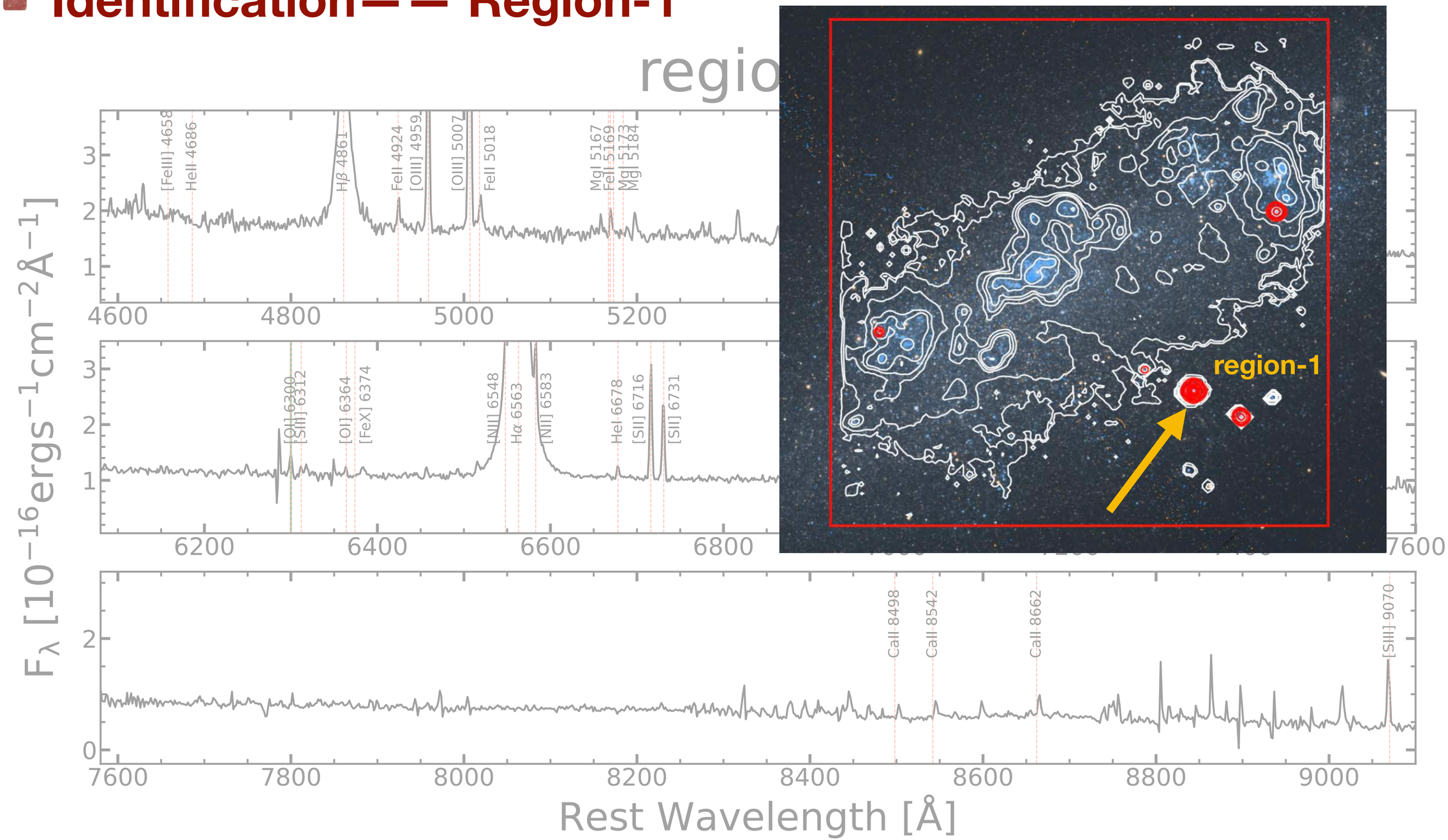
L_Ha,na/L_Ha,br = 0.53



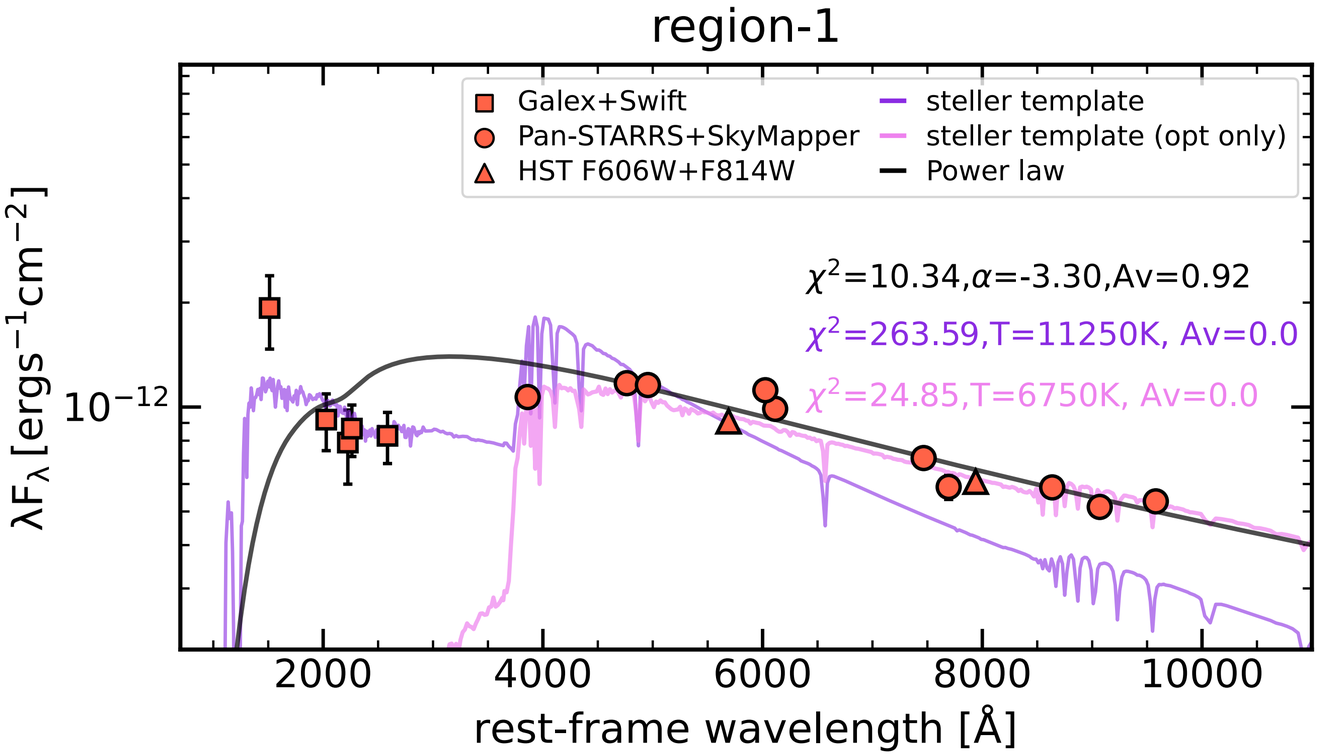
Identification—— Region-1



Identification—— Region-1

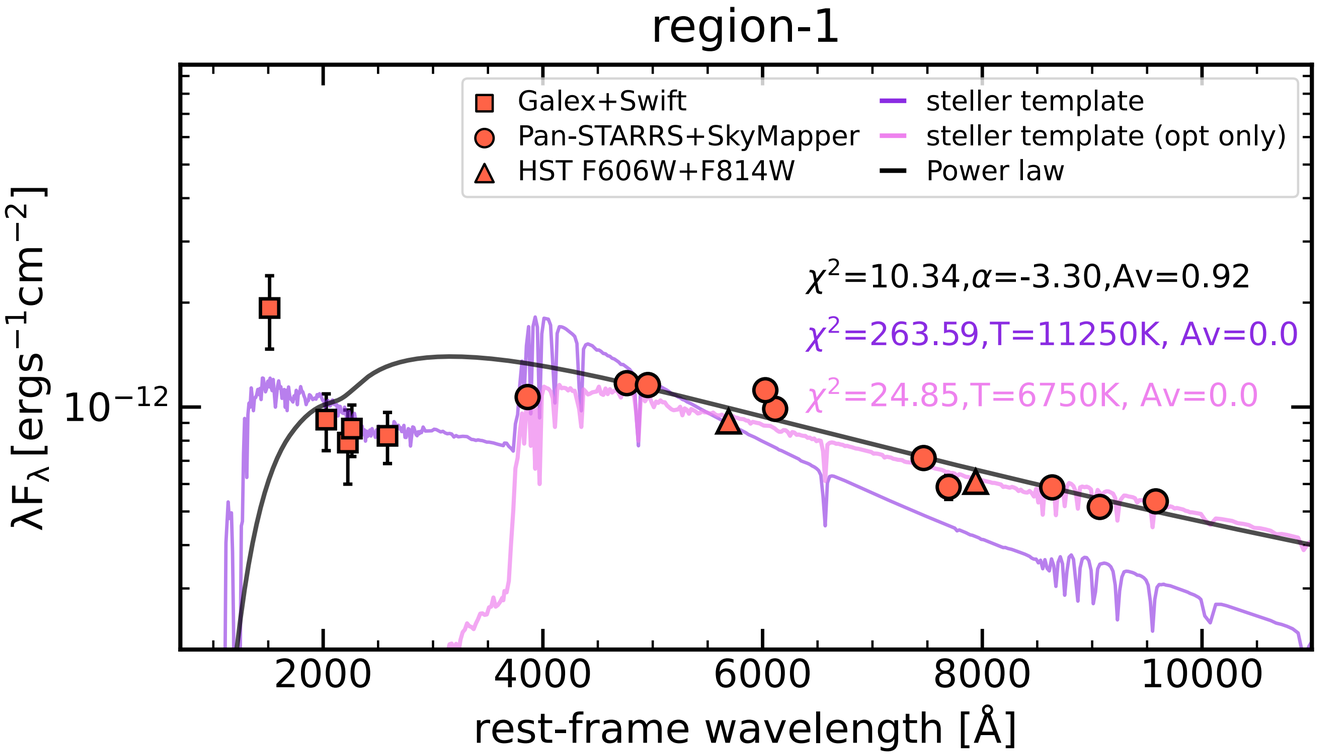


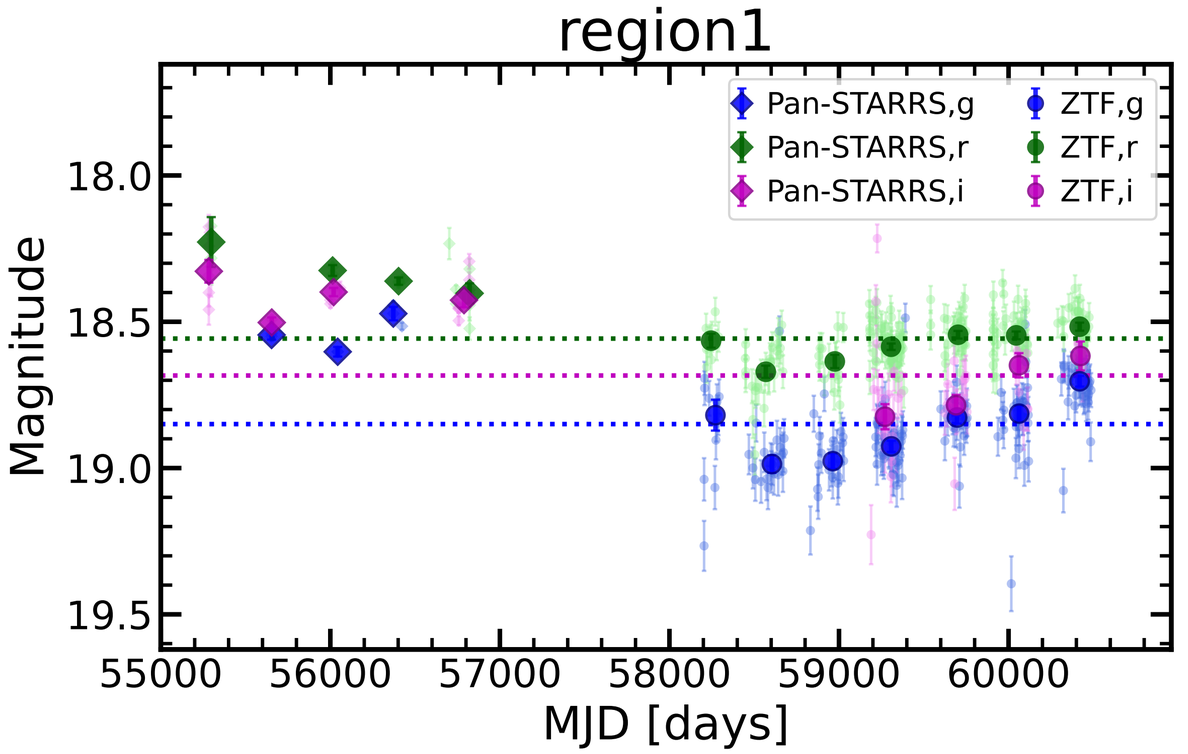
Identification—— Region-1



★ **UV-to-optical SED prefers AGN power-law with some extinction;**

Identification—— Region-1

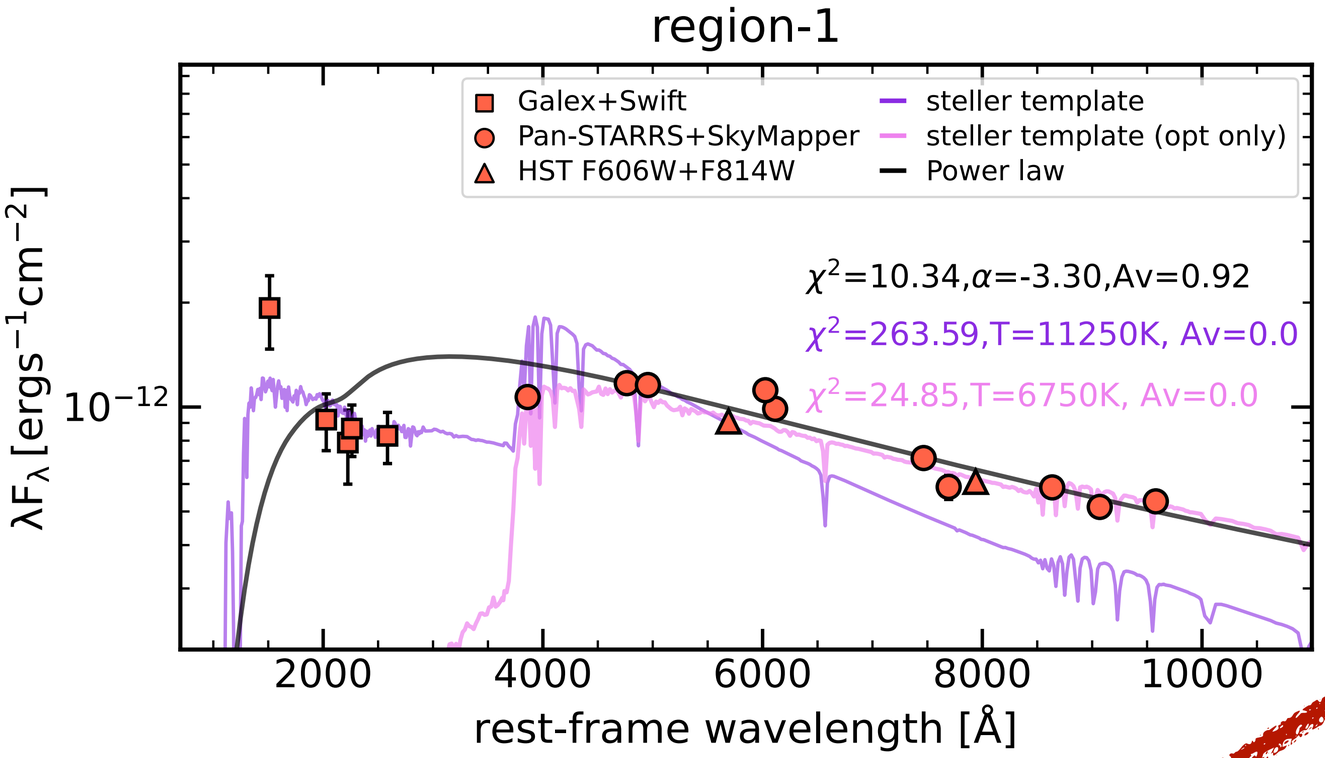


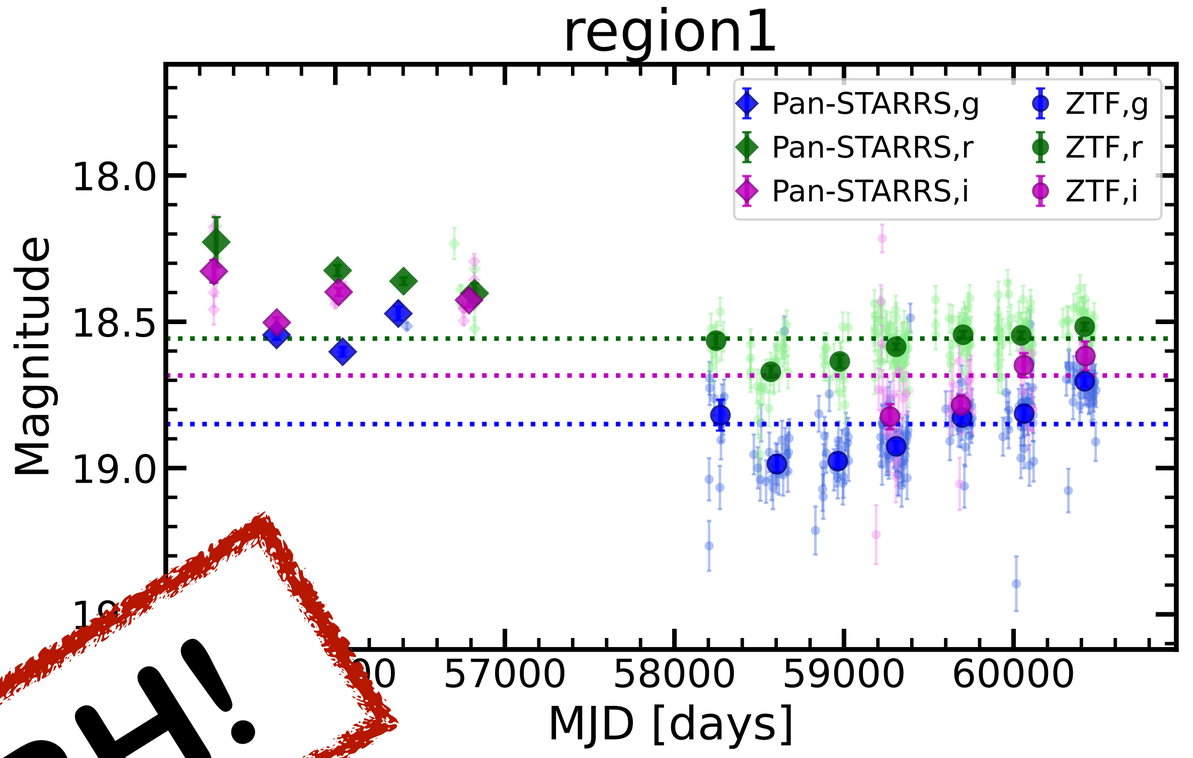


★ **UV-to-optical SED prefers AGN power-law with some extinction;**

★ **AGN-like light variabilities for 12-year monitor.**

Identification—— Region-1





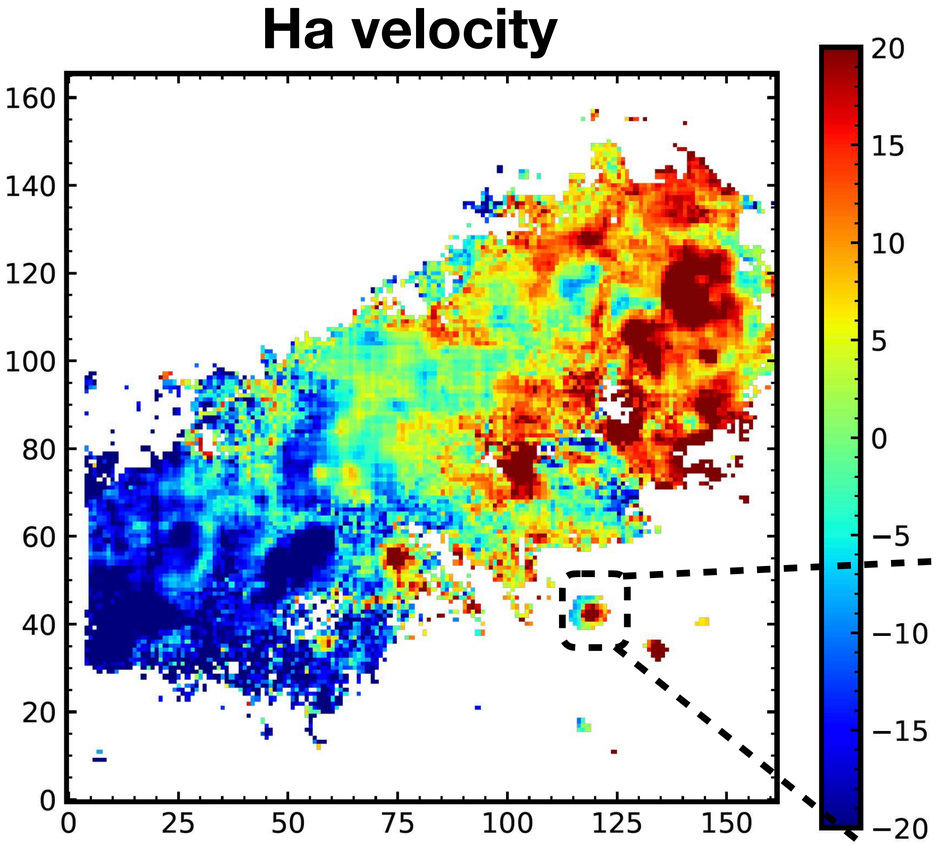
IMBH!

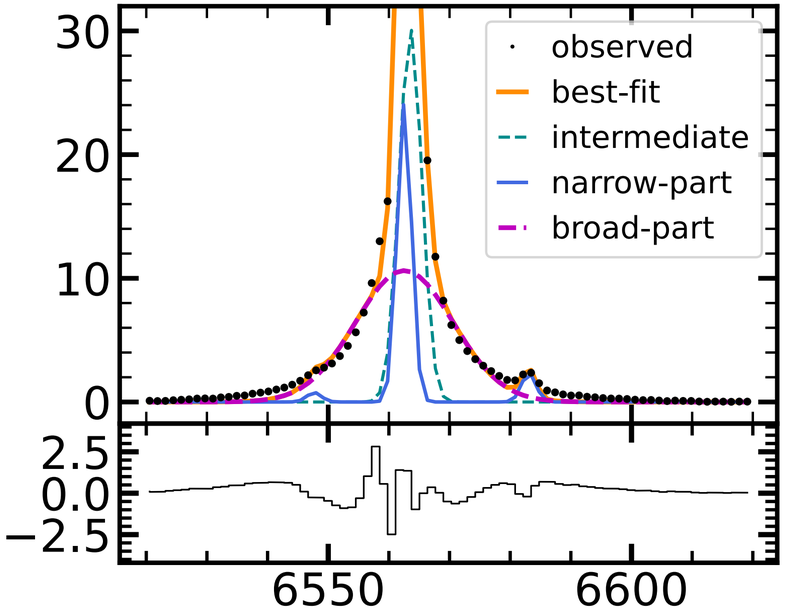
★ UV-to-optical SED prefers AGN ith some extinction;

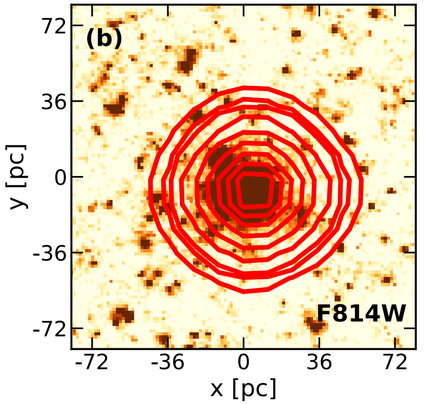
★ AGN-like light variabilities for 12 monitor.

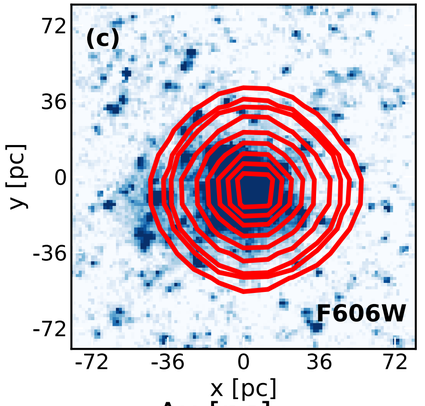
$$M_{\mathrm{BH}} = 3.47 \times 10^4\,\mathrm{M}_\odot$$

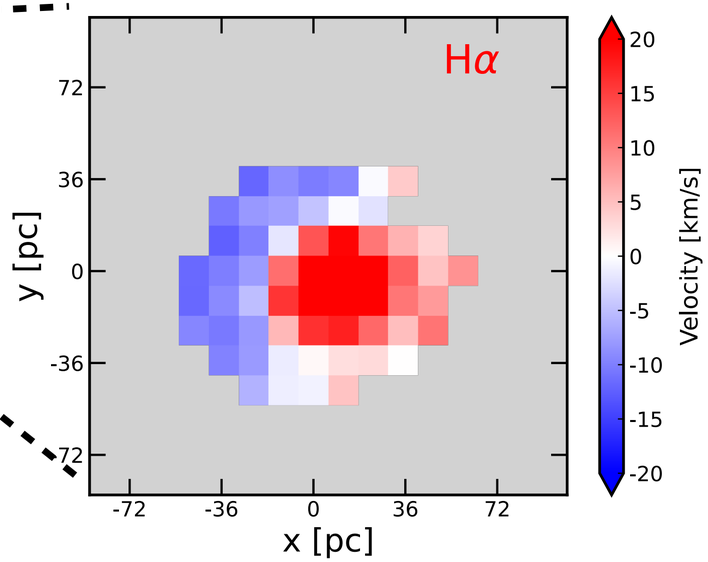
Properties—— Region-1

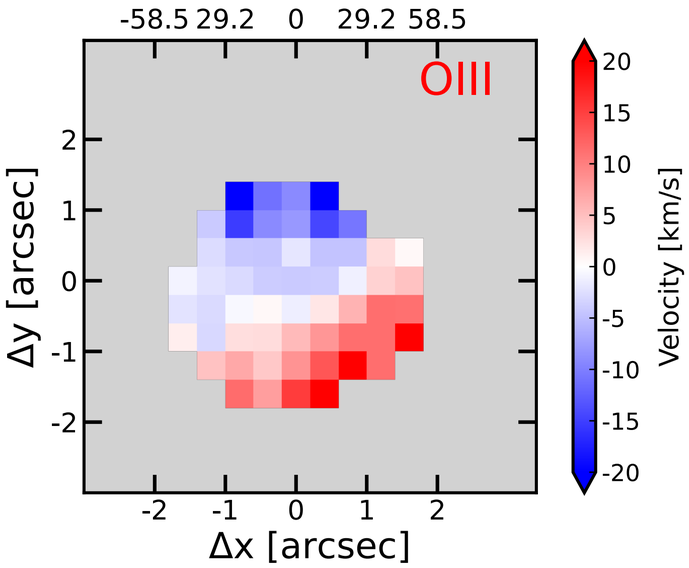








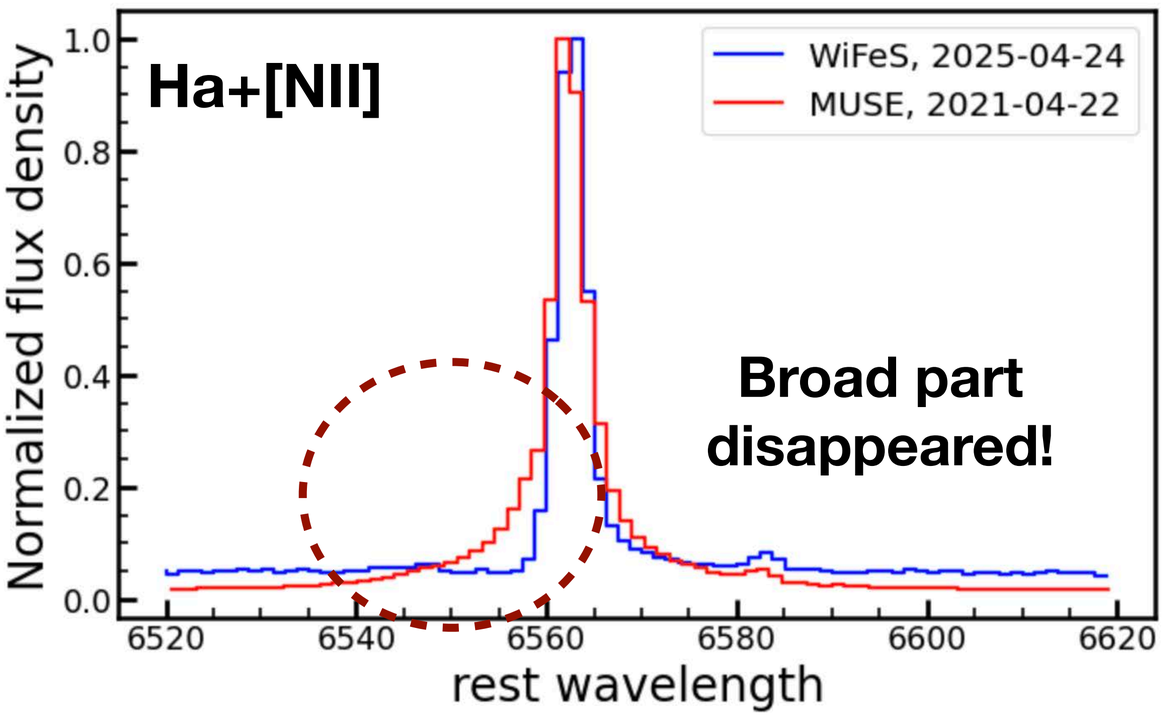


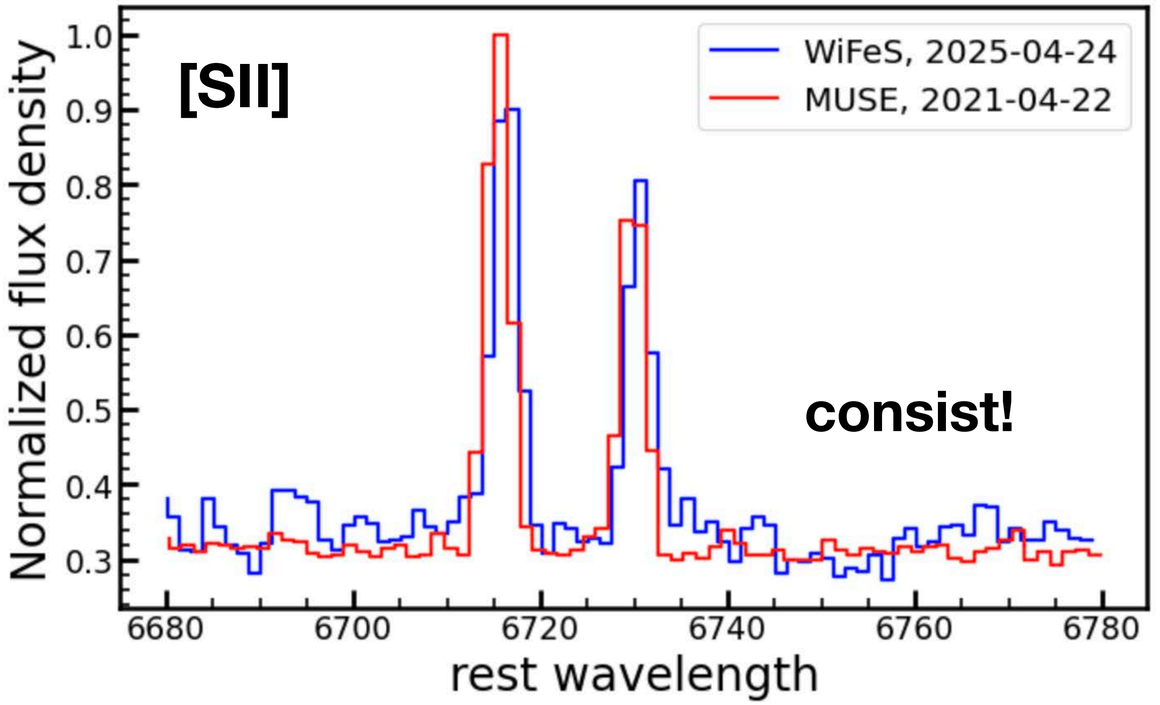


★ Get through gas accretion;

Properties—— Region-1

We carried out new observations with ANU-2.3m/WiFeS (R~3000) at April 2025

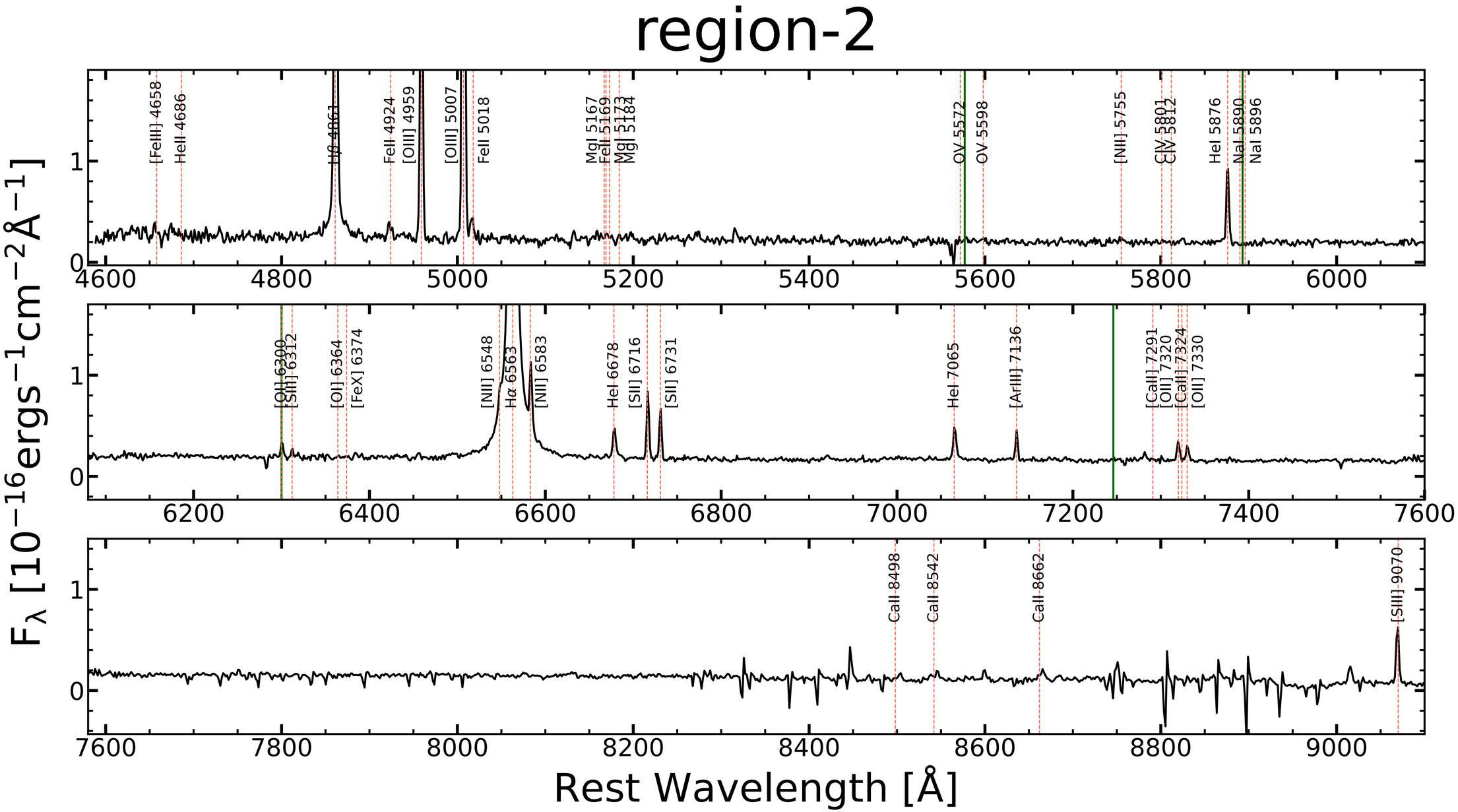




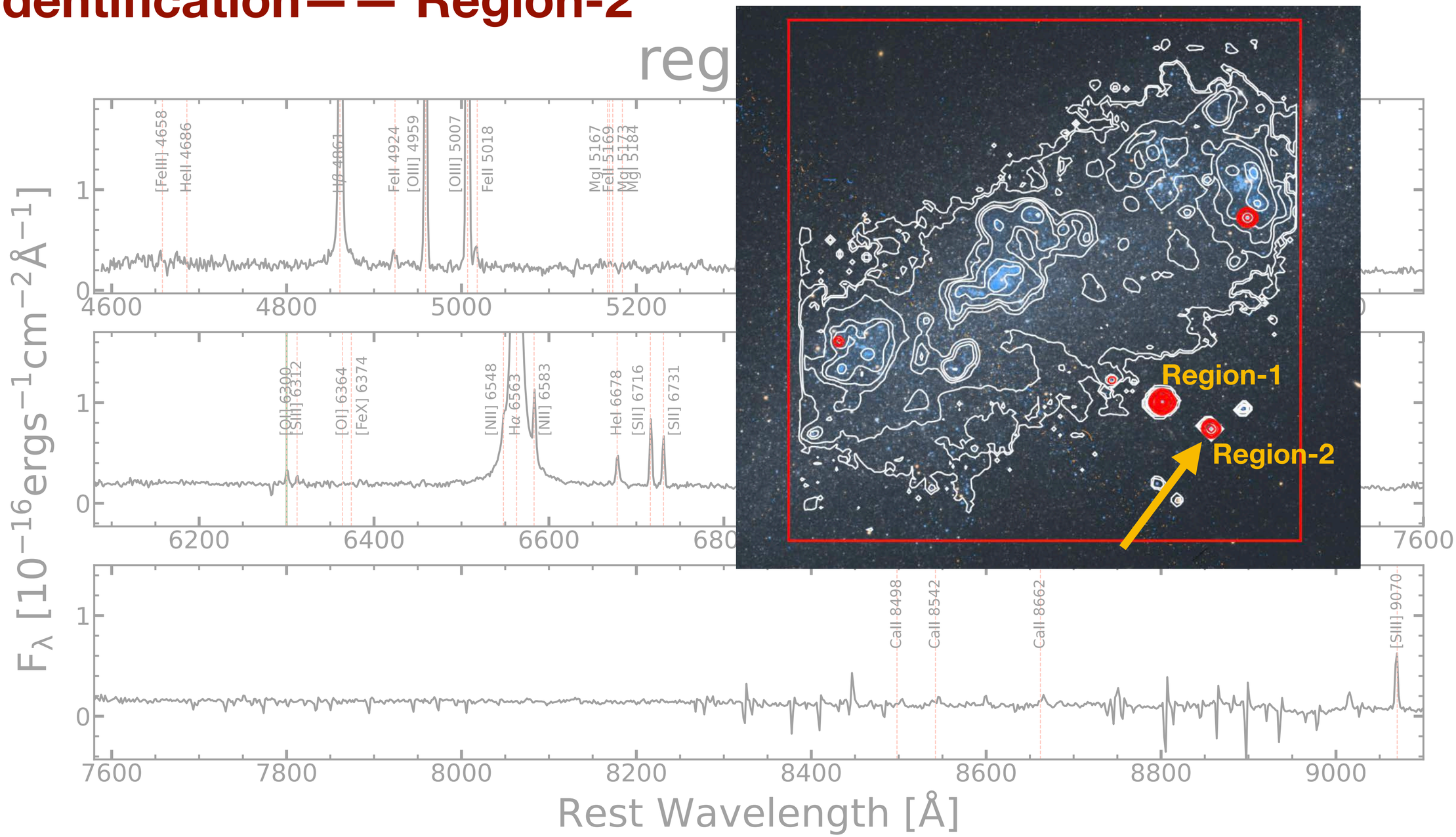
★ **Changing look AGN! Broad components are disappeared!**

X. Li et al. 2026, in prep

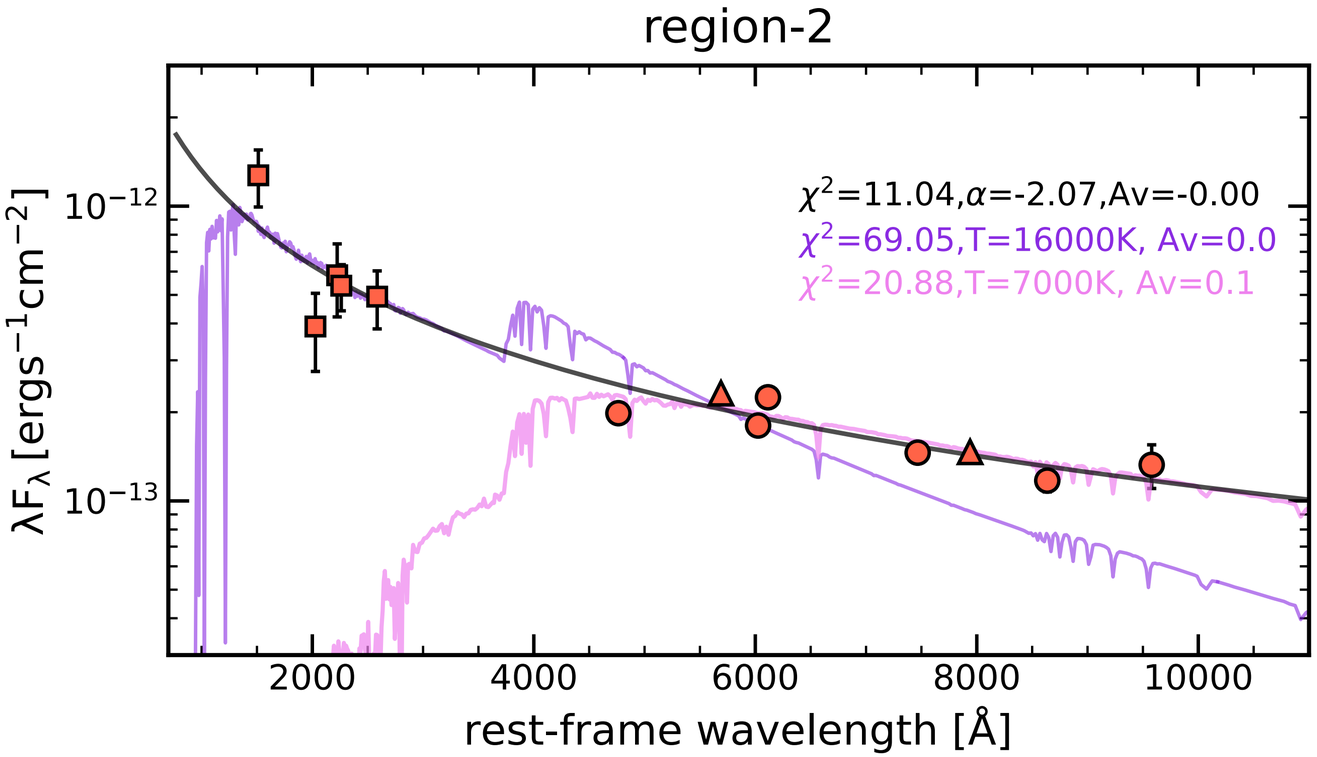
Identification—— Region-2

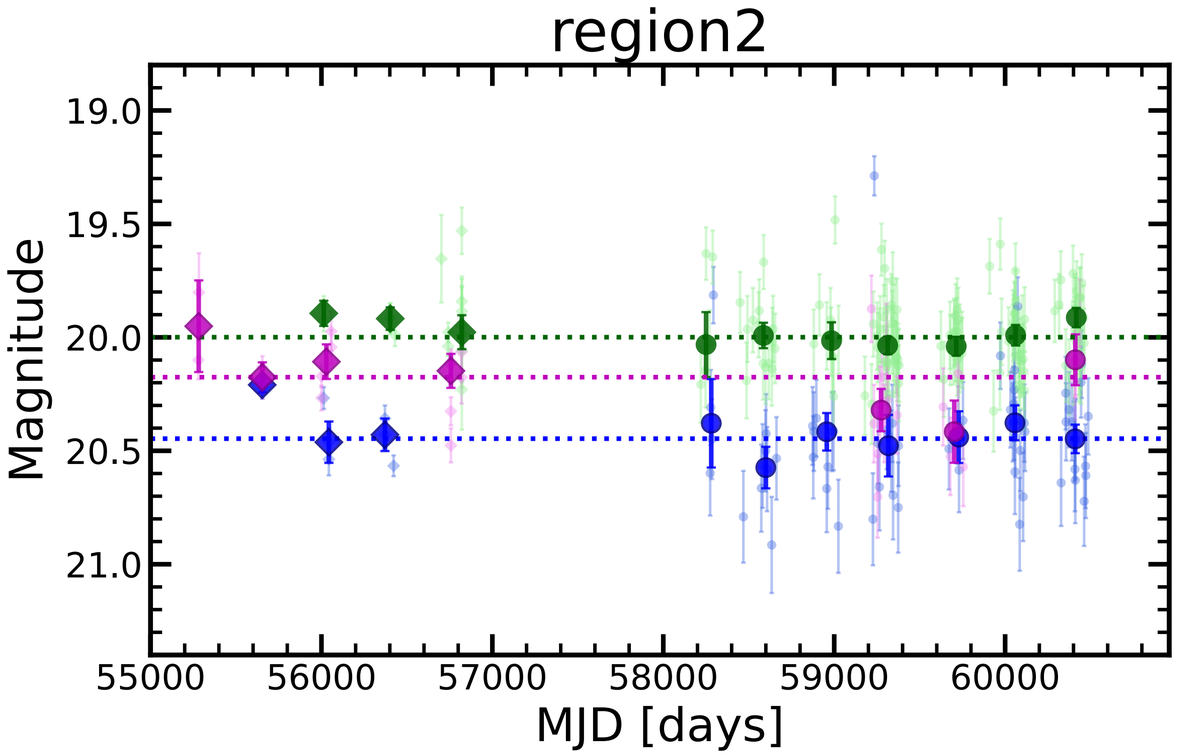


Identification—— Region-2



Identification—— Region-2

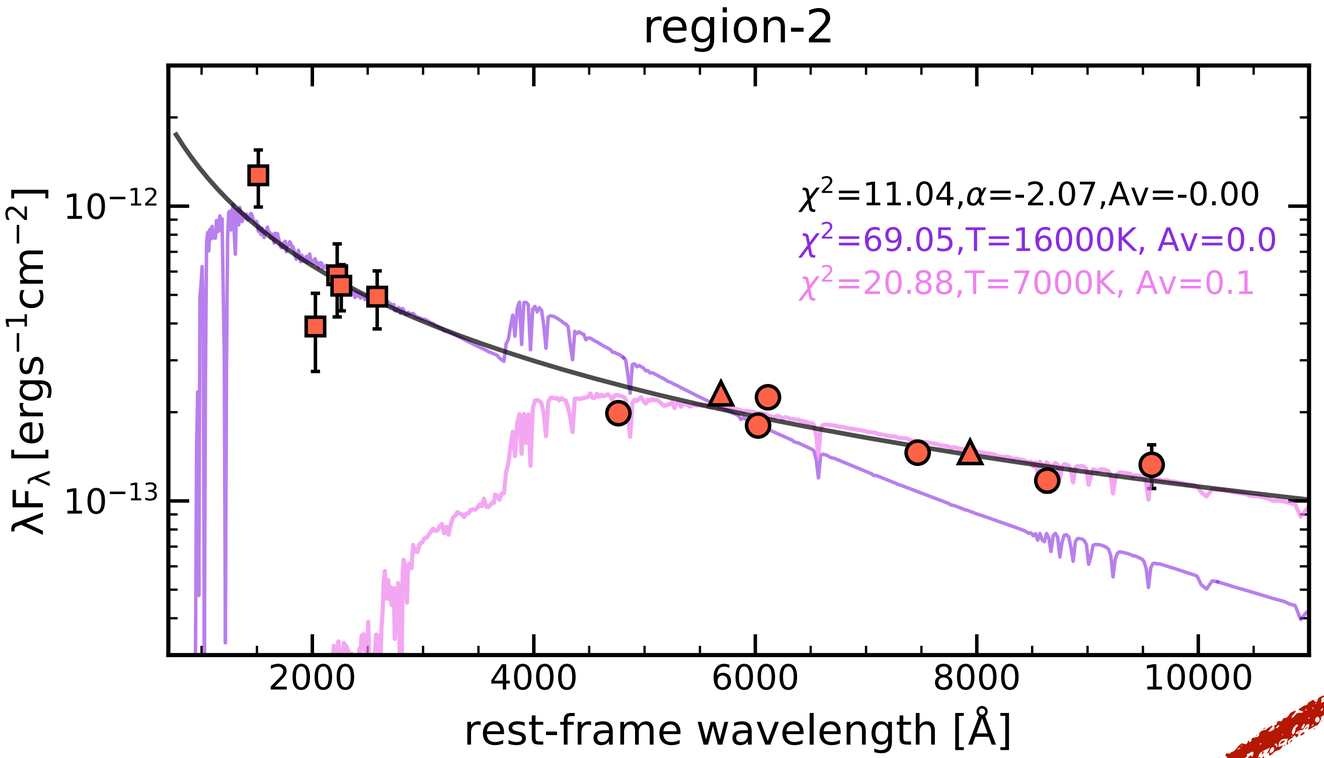


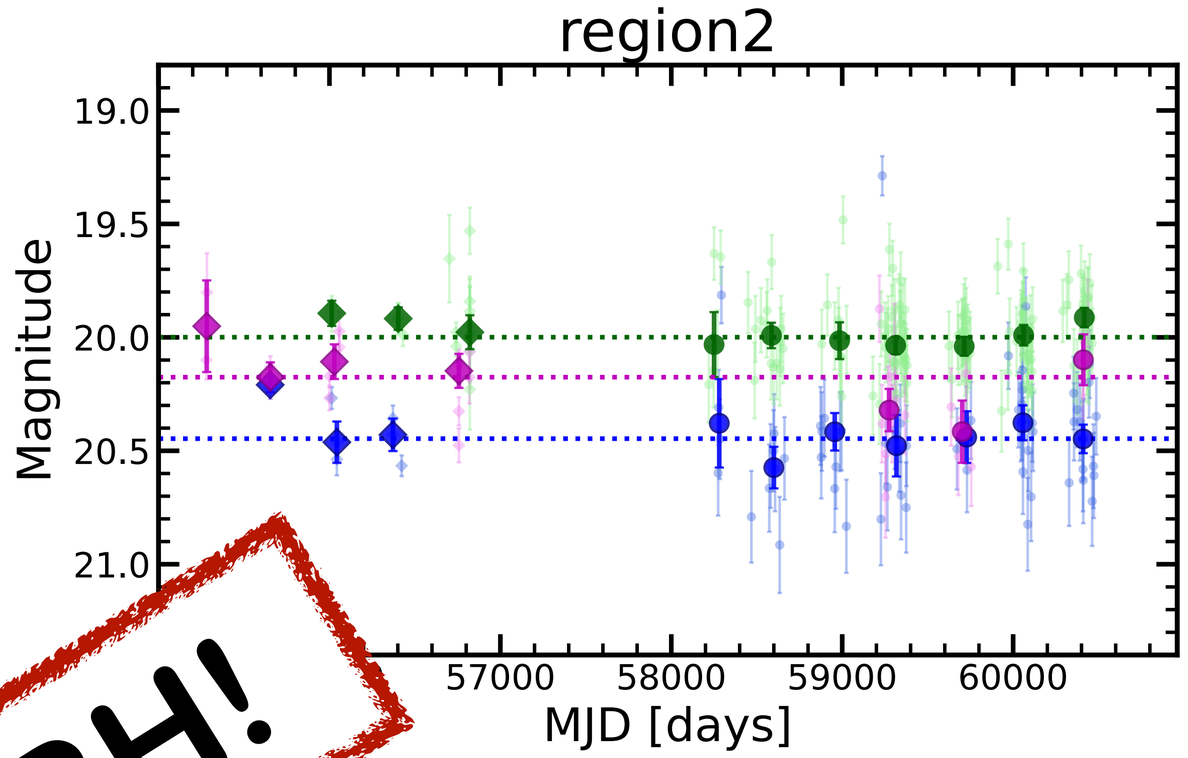


★ **UV-to-optical SED prefers AGN power-law without dust extinction;**

★ **Weak/Non light variabilities for over 12 years.**

Identification—— Region-2





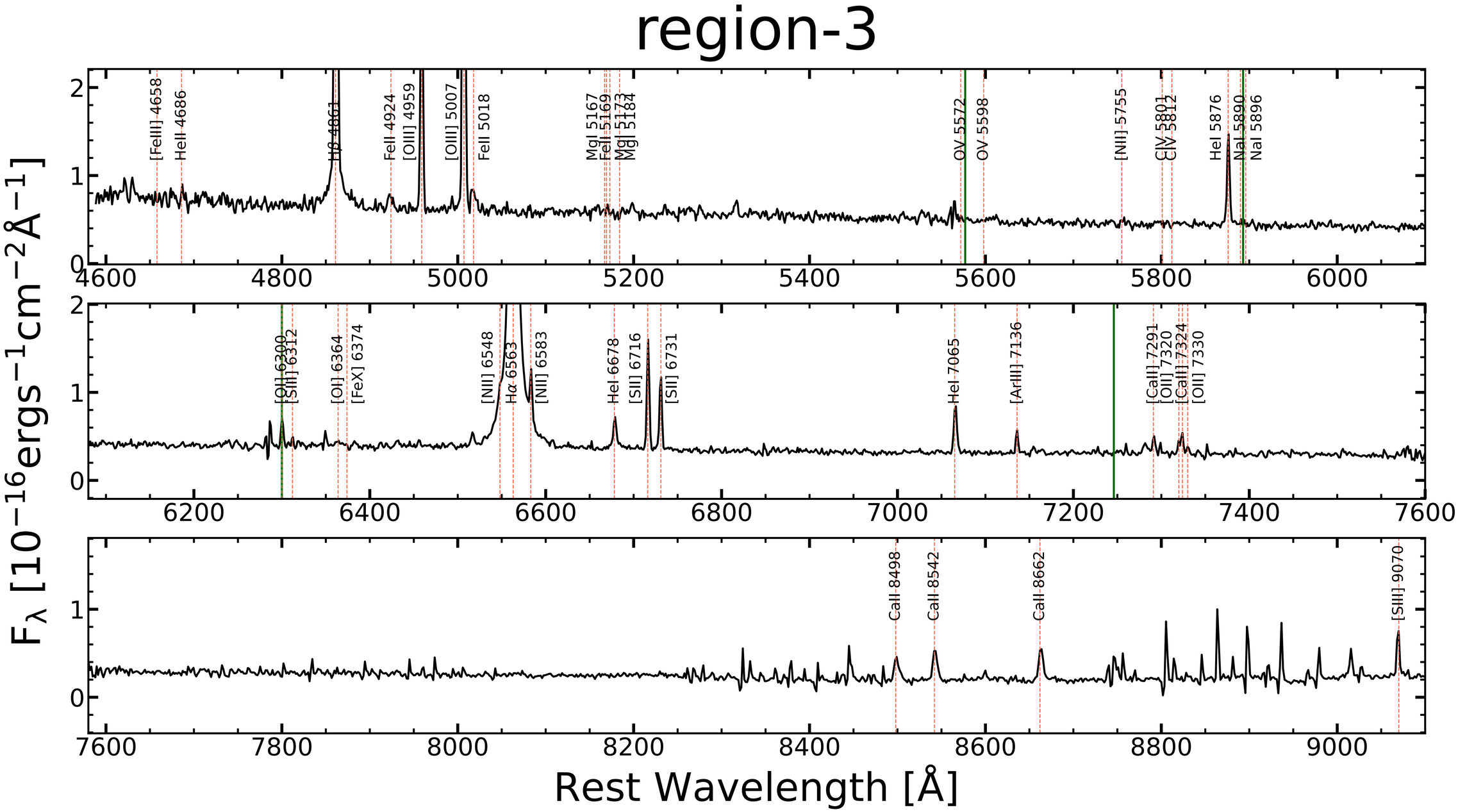
IMBH!

★ UV-to-optical SED prefers AGN ... without dust extinction;

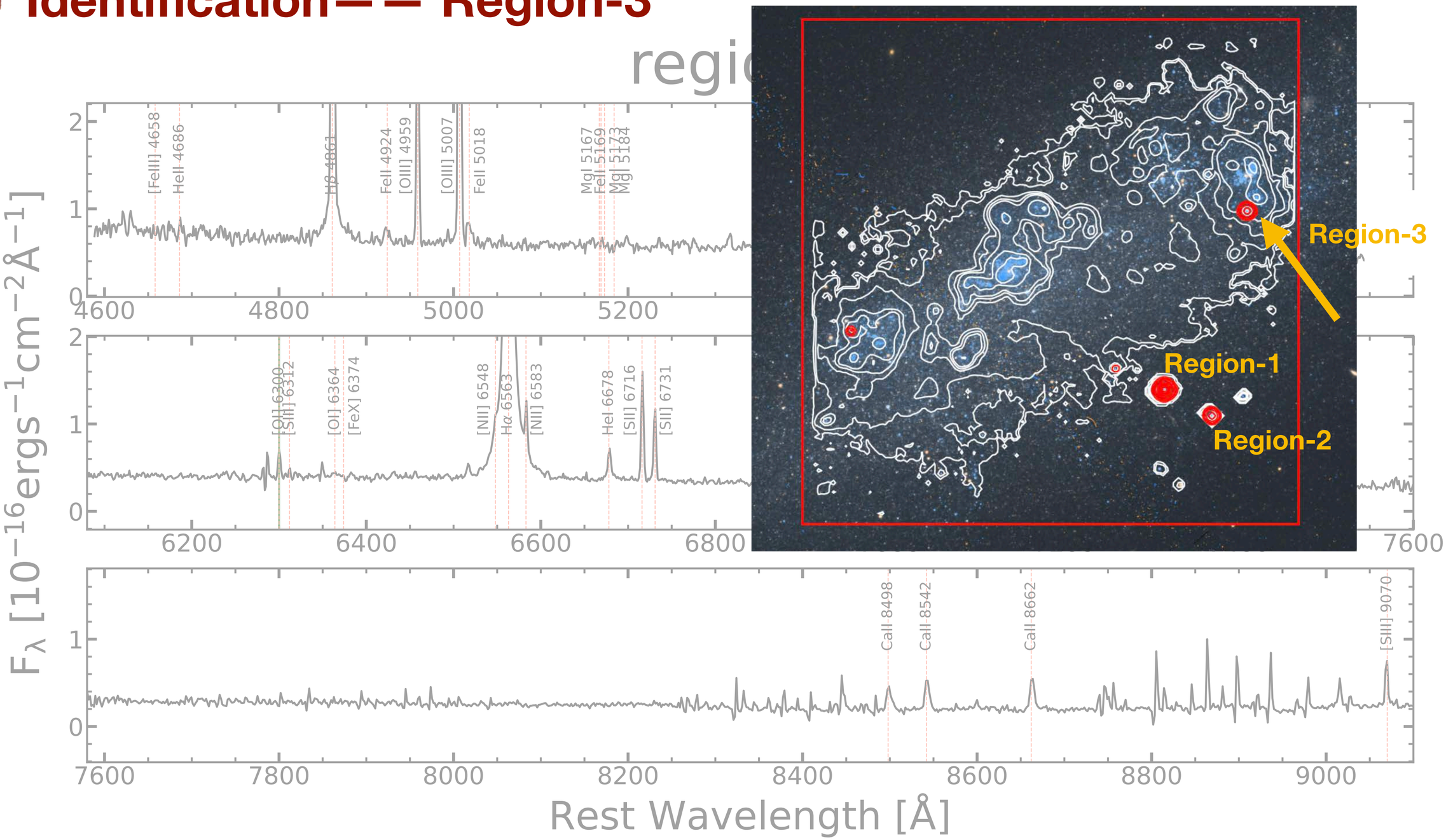
★ Weak/Non light variabilities for o... years.

$$M_{\mathrm{BH}} = 1.58 \times 10^{4}\,\mathrm{M}_{\odot}$$

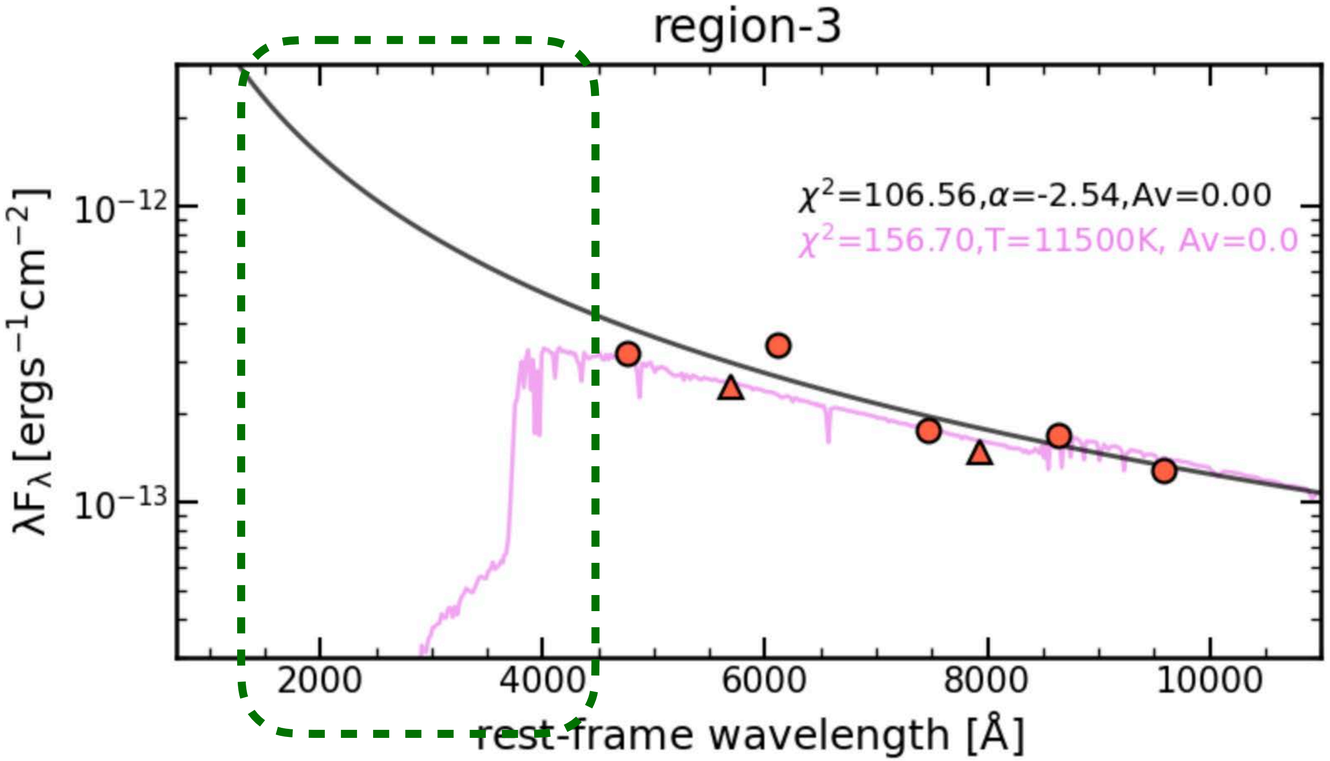
Identification—— Region-3

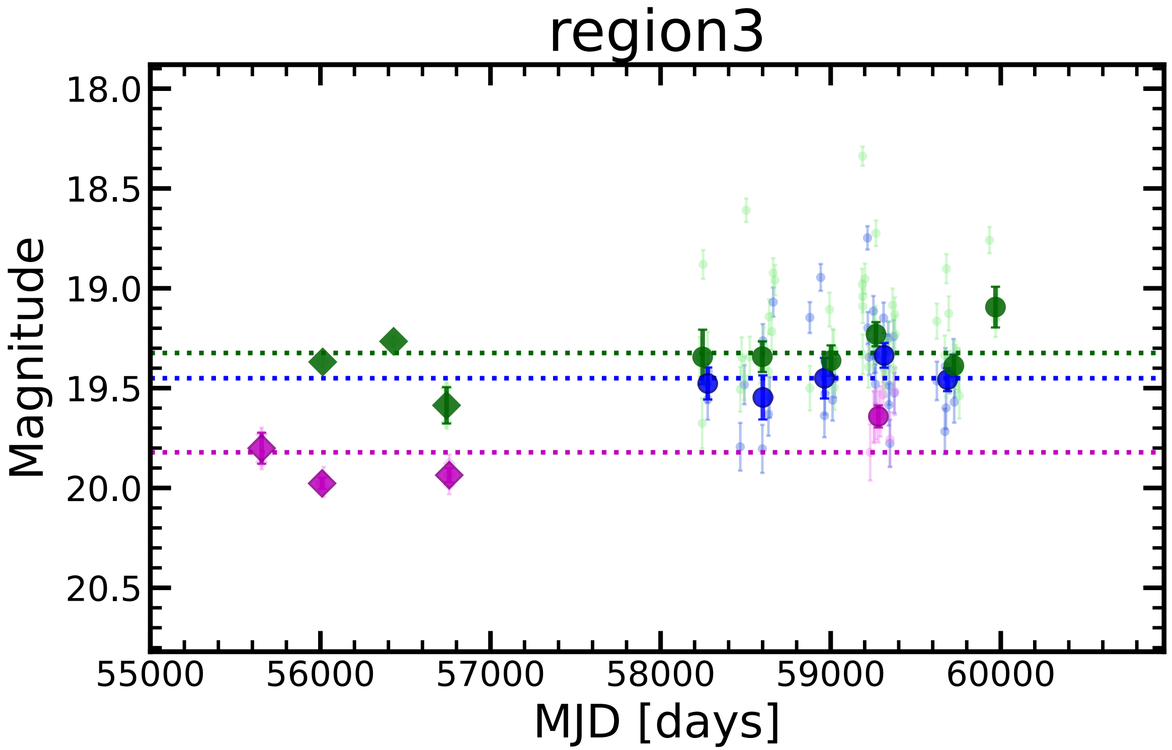


Identification—— Region-3



Identification—— Region-3

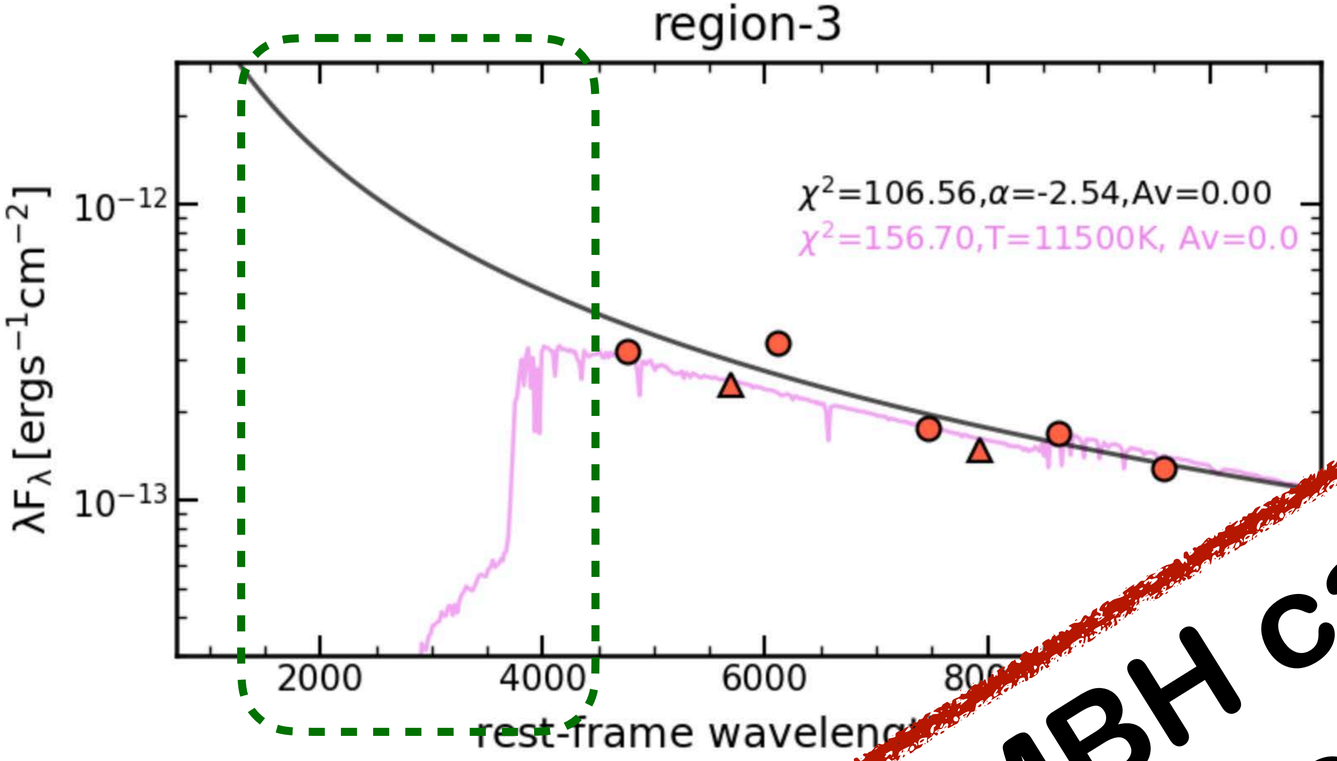


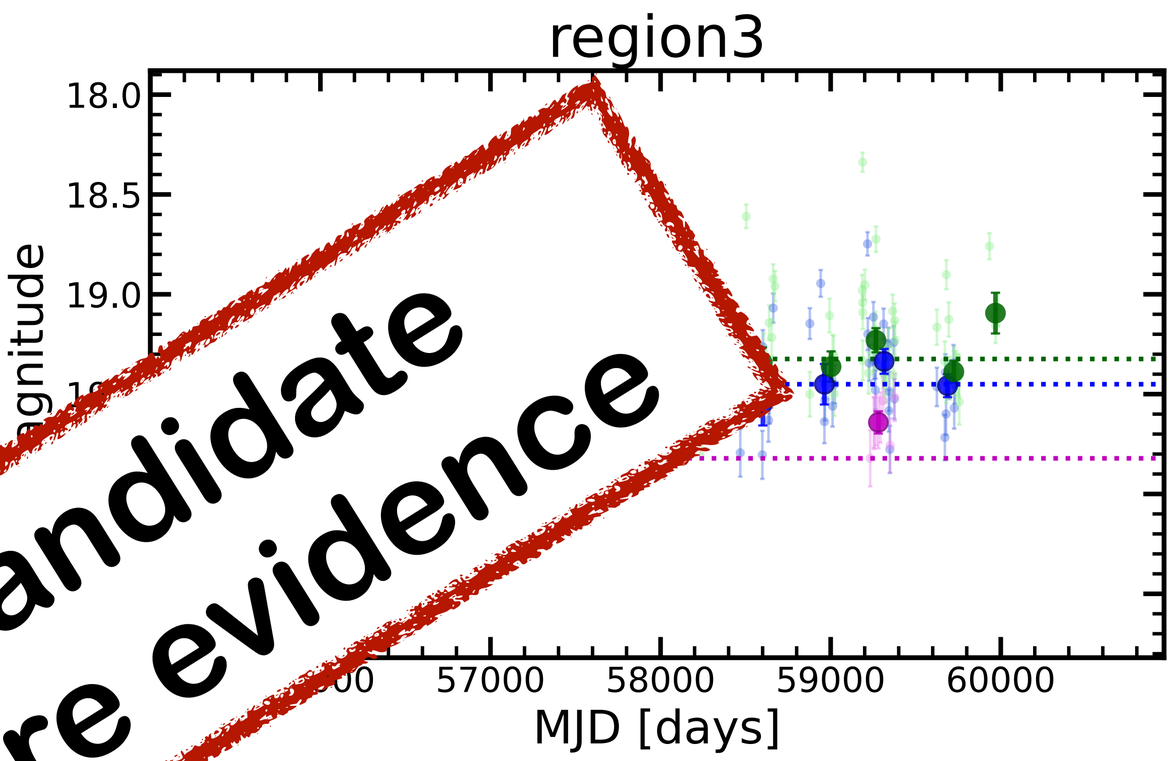


★ Can’t distinguish AGN and star;

★ SFR polluted light curve.

Identification—— Region-3





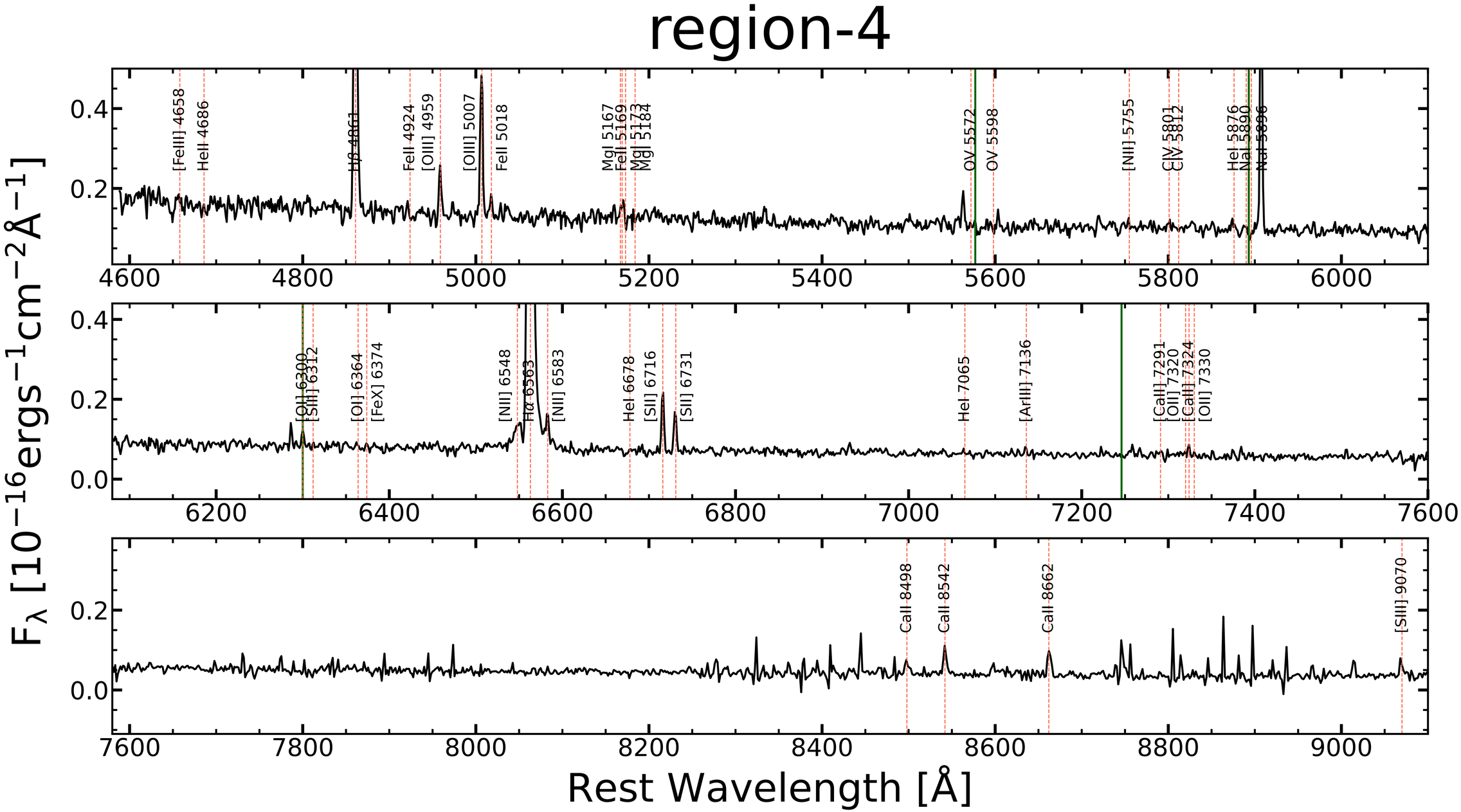
IMBH candidate
Need more evidence

★ Can't distinguish A

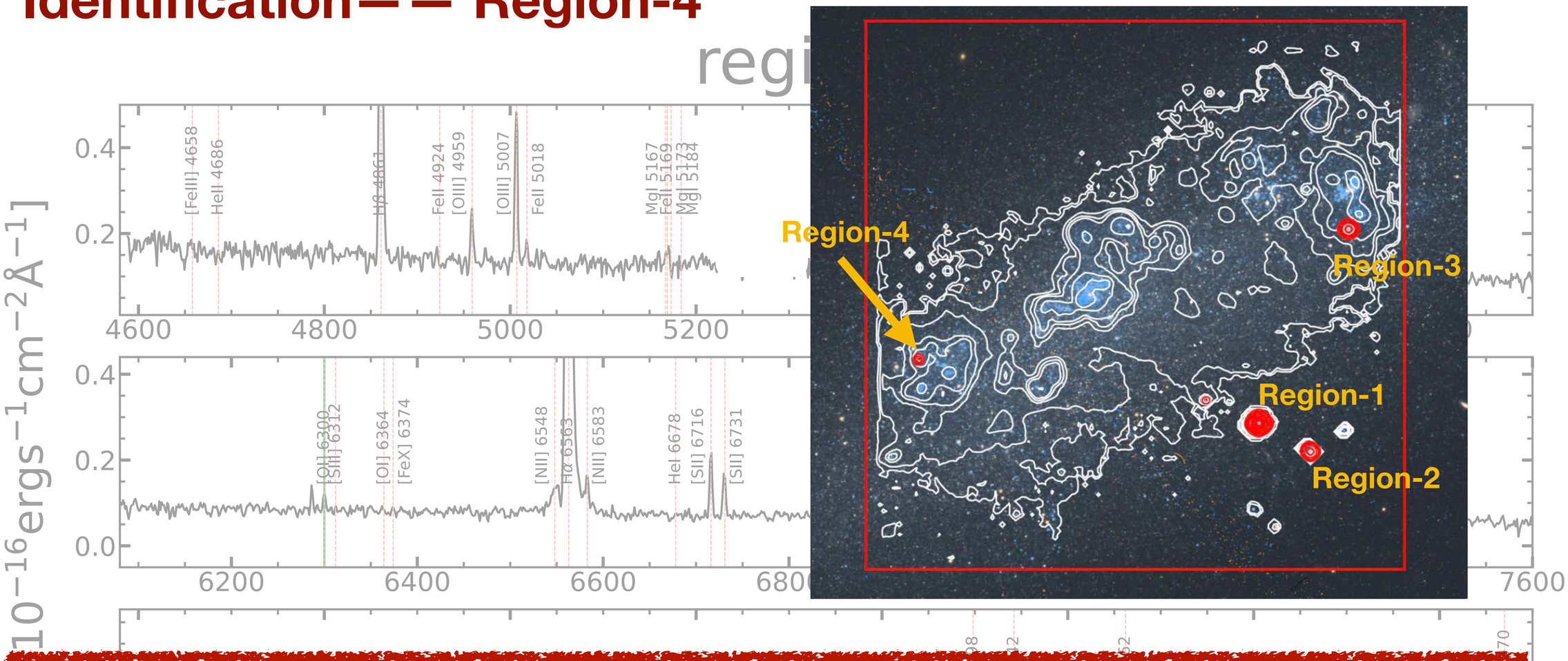
★ SFR polluted light cur

$$M_{\mathrm{BH}} = 1.7 \times 10^4\,\mathrm{M}_\odot$$

Identification—— Region-4



Identification—— Region-4



Lack additional data

More likely evolving star

Other observations

- X-ray ***Chandra*** 0.8~8 keV for 15k-s exposure: non detection (< 2e-15); PI: J. Wang

  — — Apply for XMM-Newton: Improve sensitivity

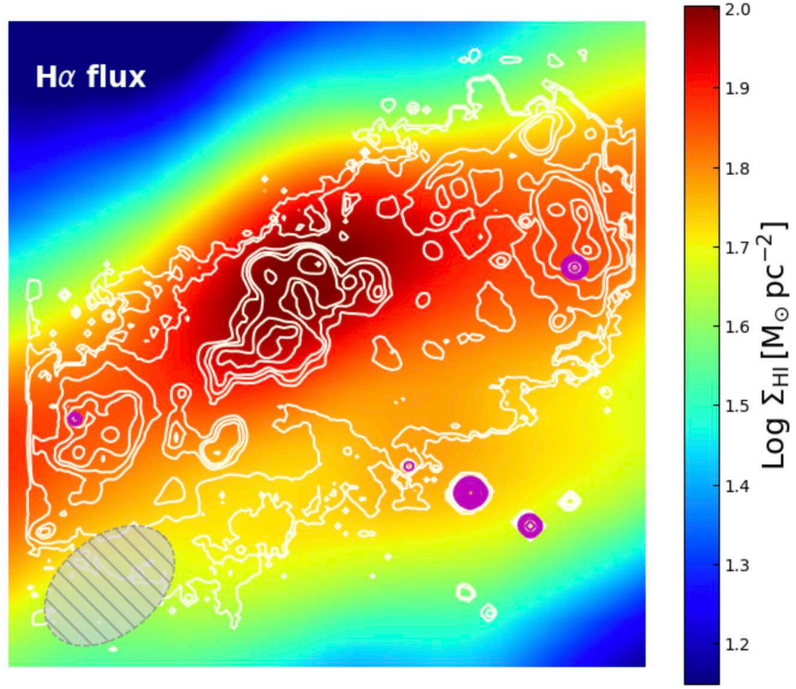
- Radio **MeerKat** K-band for ~50-hr exposure: non detected continuum; Archived data

  — — Apply for ALMA: Improved spatial resolution and sensitivity

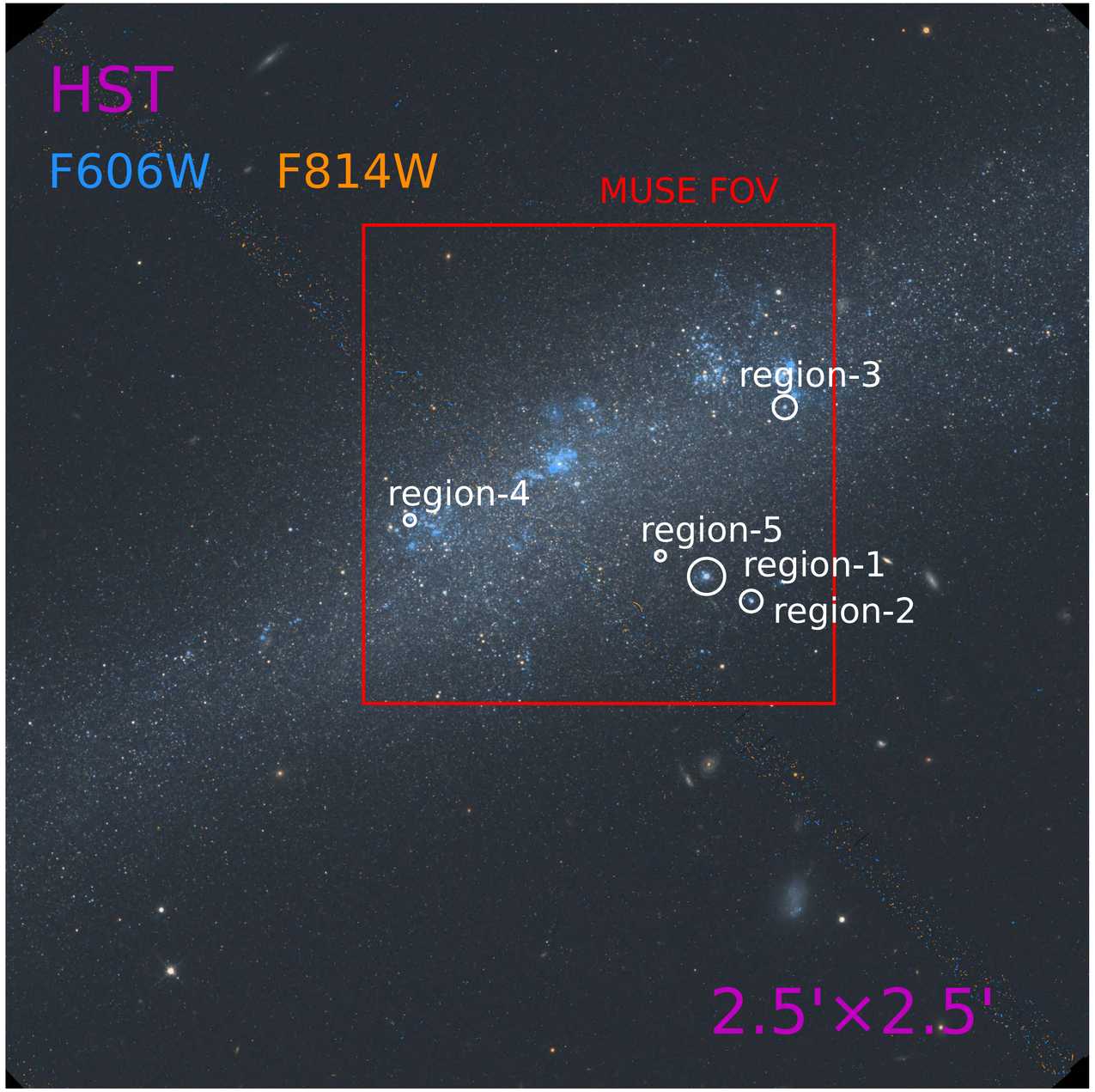
- u-band **CFHT** 0.6-hr exposure: data is under processing; PI: X.Li

- UV; **HST observation will be carried out at next year** PI: X.Li

- IR — — Apply for JWST



Summary



Region-1: IMBH with strong evidence

—— Spectrum, SED, light curve

Region-2: IMBH with medium evidence

—— Spectrum, SED, light curve;

Excluded Wolf Rayet stars, SNe, SNR, some type of massive stars

Region-3: possible IMBH candidate

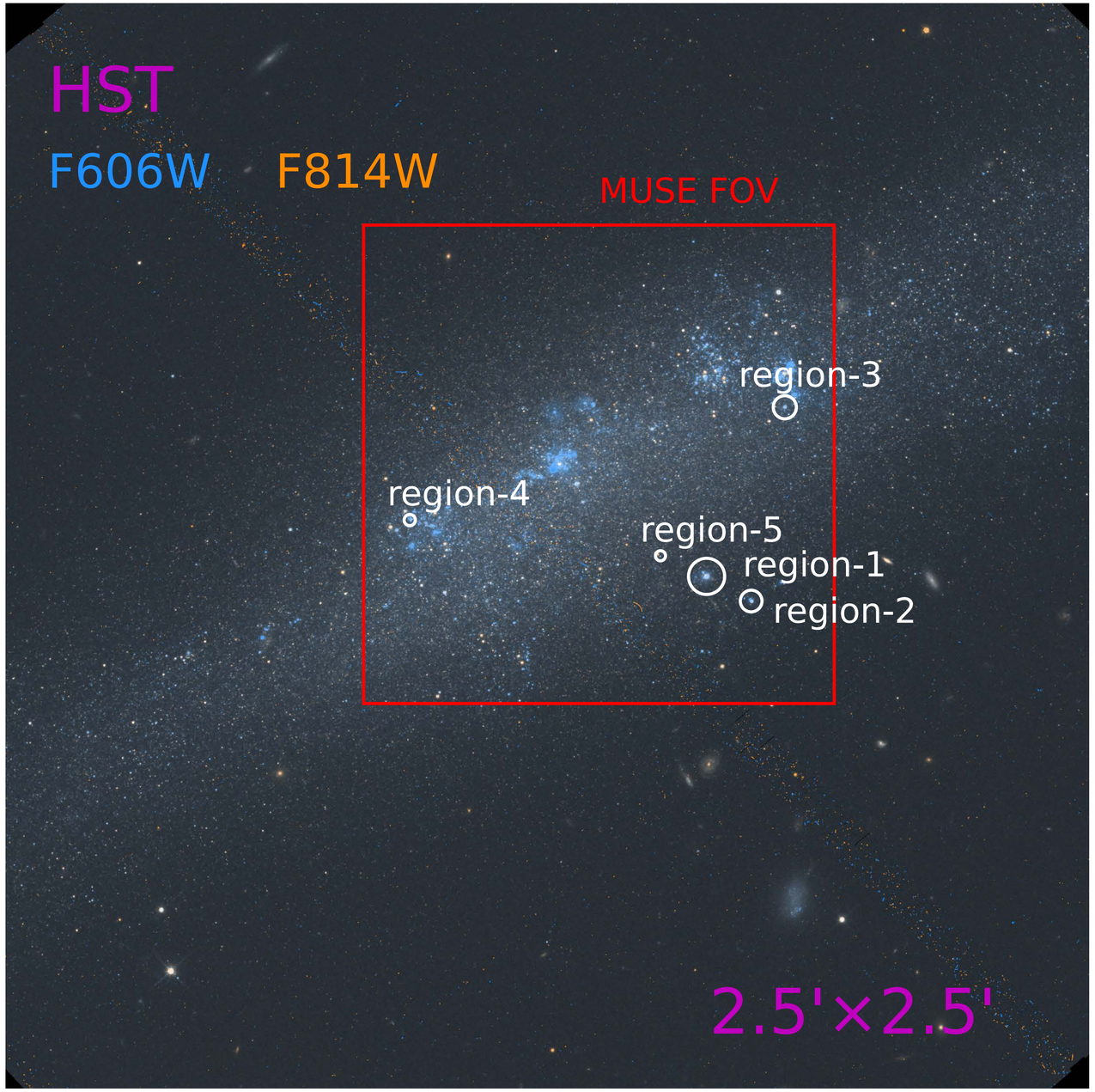
—— Spectrum

Star formation contamination

Region-4, region-5: Not IMBHs

—— Spectrum

Implication



How Do SMBHs Form

Simulations predict a large fractions of IMBHs not sink to galactic centers

$$M_{BH} \sim 10^4 M_\odot$$

IMBHs merger through dynamic friction

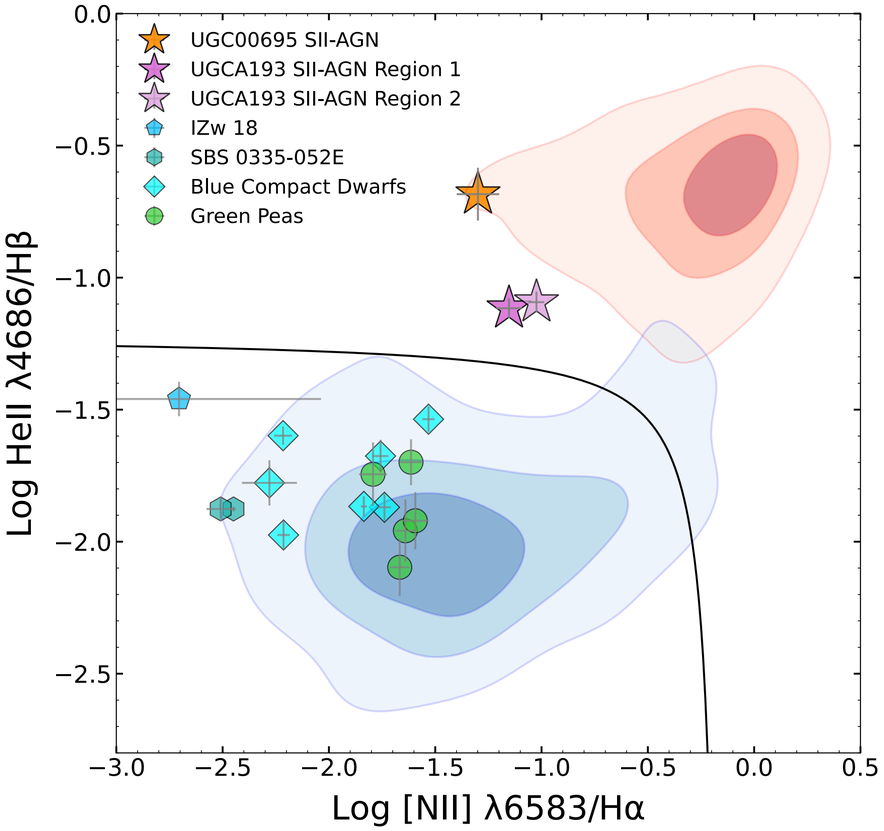
$$N \times 10^4 M_\odot \longrightarrow \textbf{SMBH}$$

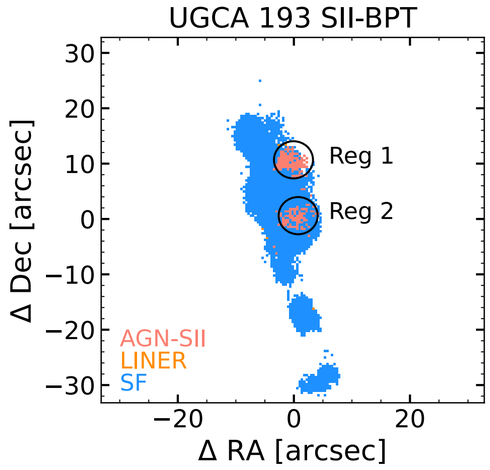
LGWA LISA ET …

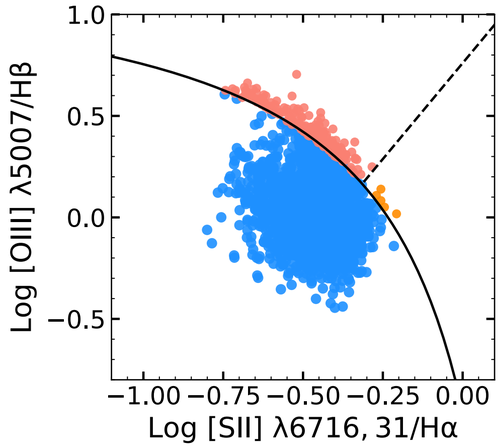
Implication

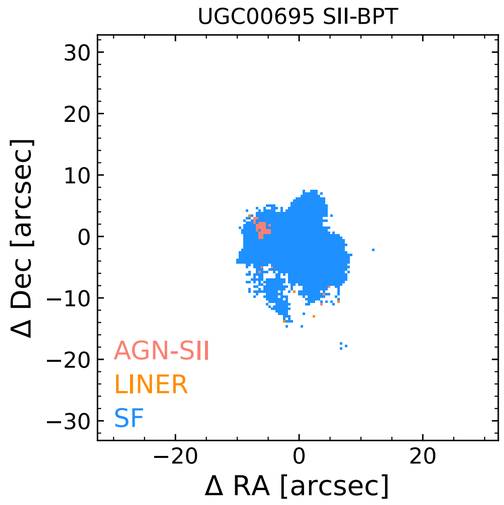
DGIS:

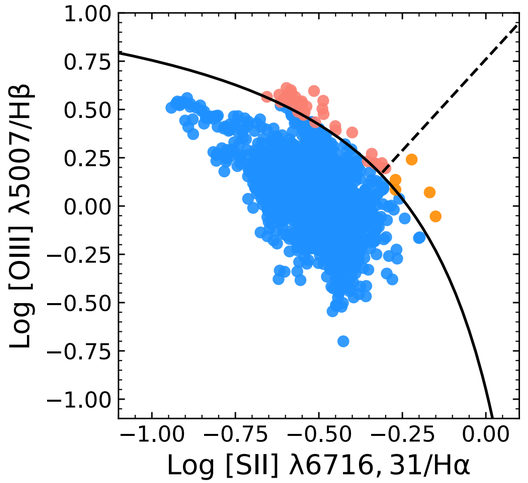
Searching IMBHs in dwarf galaxies with high spatial-resolution observations









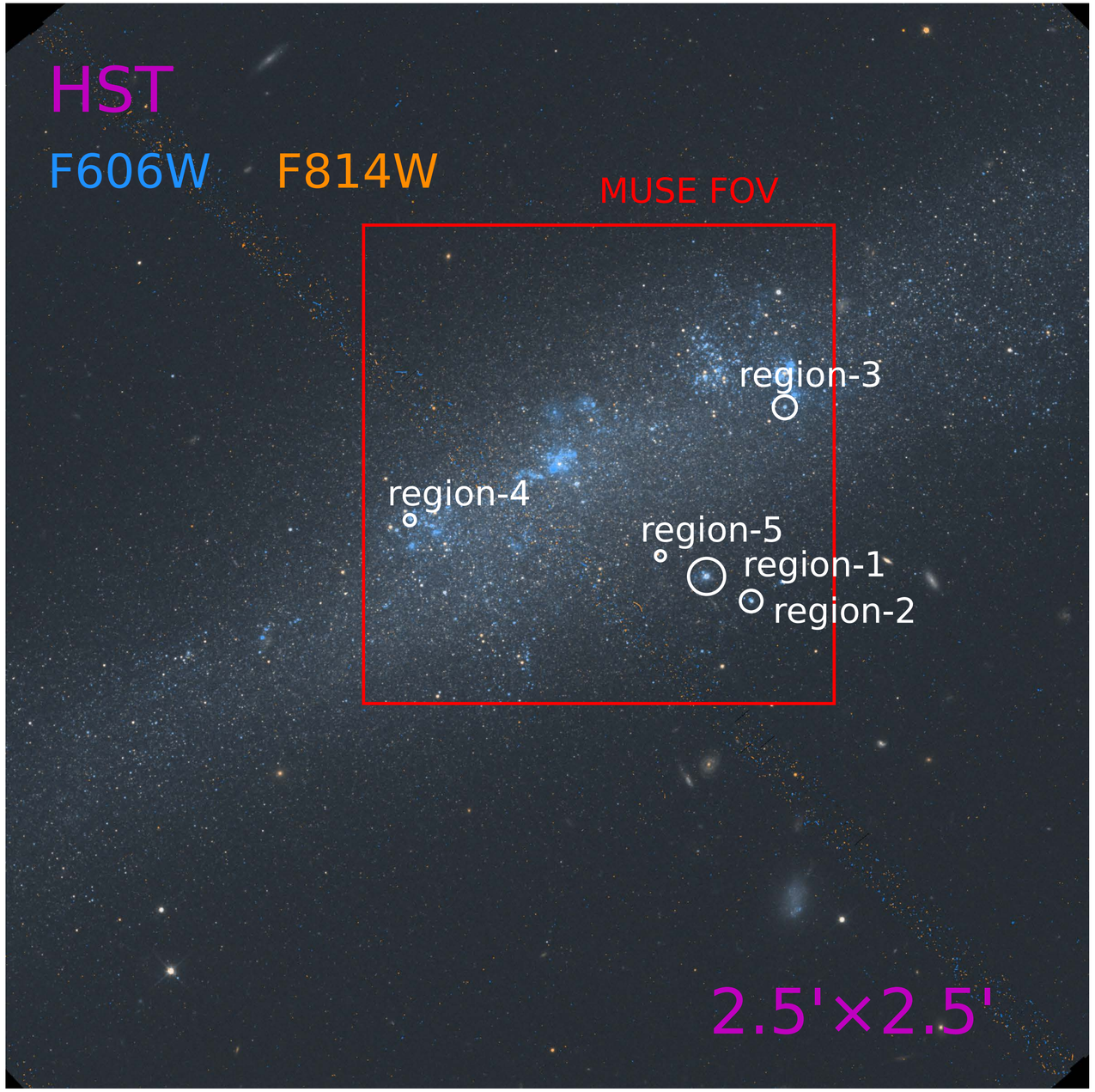


To be continue

ZY Zheng et al, 2025 in prep.

KY Liu et al, 2026 in prep.

Summary



Region-1: IMBH with strong evidence

—— Spectrum, SED, light curve

Region-2: IMBH with medium evidence

—— Spectrum, SED, light curve;

Excluded Wolf Rayet stars, SNe, SNR, some type of massive stars

Region-3: possible IMBH candidate

—— Spectrum

Star formation contamination

Region-4, region-5: Not IMBHs

—— Spectrum

Thank you!