# Introducing the Seyfert-LINER Index (SLI): High Resolution ($< 100$ pc) Ionization Structures in the ISM of AGN ESO 137-G34

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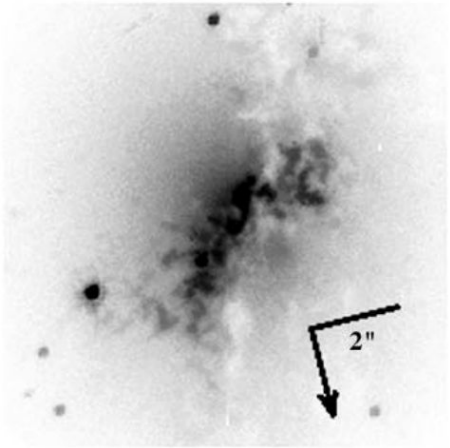



ESO 137-G34 (261 pc/")

Malkan et al. 1998

arXiv:2510.22447

# AGN feedback

Основные механизмы:

1. фотоионизация: рентгеновское и УФ излучение АЯГ ионизирует газ на сотни пк
2. джеты и крупномасштабные ветра: создают ударные волны, которые нагревают МЗС

Классификации основаны на сравнении отношений эмиссионных линий:

[O III]/Hβ и [S II]/Hα (S-BPT), [N II]/Hα (N-BPT) или [O I]/Hα (O-BPT).

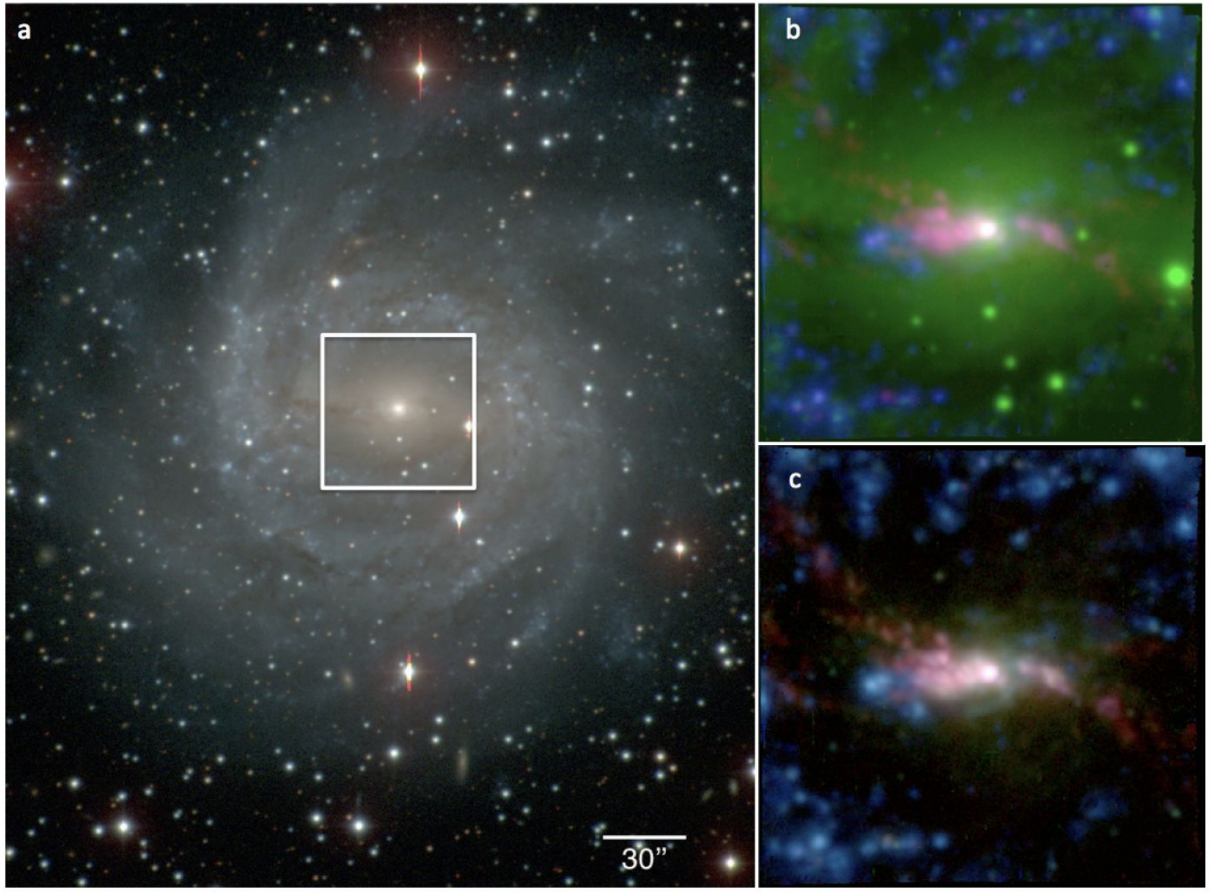



**Fig. 1.** Galaxy NGC 5643. Panel **a)** three-color (blue: *B* band; green: *V* band; red: *I* band) image of the galaxy obtained with the 2.5 m du Pont Telescope for the Carnegie-Irvine Galaxy Survey (CGS, Ho et al. 2011). The MUSE field of view is shown with a white square. North is up and east is left. Panel **b)** three colors MUSE map, showing H$\alpha$ emission in blue, [OIII]$\lambda$5007 emission in red, and the integrated continuum emission from 5200 to 6000 Å in green. The tip of the dust lane in the bar, visible on larger scale in Panel a, is evident next to the blue clump east of the nucleus as a gap in the continuum emission. Panel **c)** three-color MUSE maps, showing H$\alpha$ in blue and [OIII]$\lambda$5007 in red as before, and [NII]$\lambda$6584 emission in green. The two-sided AGN ionization cone traced by the filamentary [OIII] emission is prominent, as well as the strongly H$\alpha$ emitting clumps between the two eastern lobes of the cone. North is up and east is left.

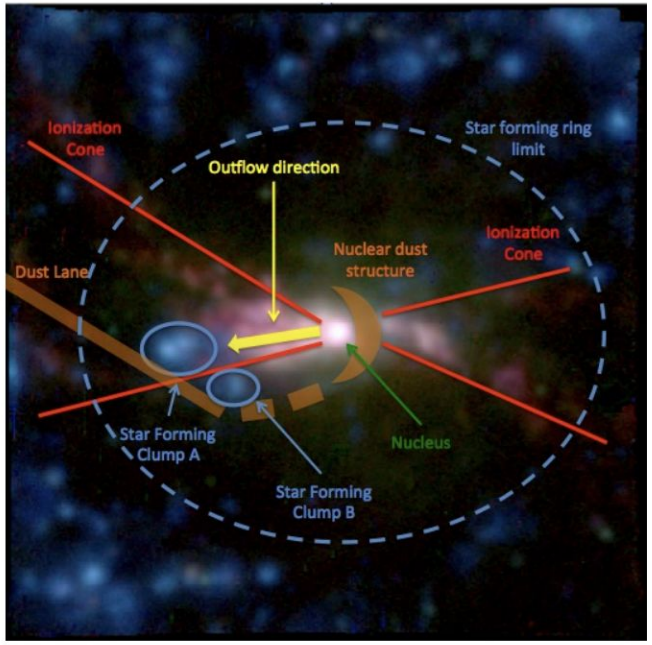



**Fig. 7.** Schematic view of the main structures revealed by MUSE in the central region of NGC 5643, drawn over the three-color image from Fig. 1, panel **c)**. The ionization cone borders are highlighted with red lines, the dust lane and nuclear dust structure location in brown. The two star-forming clumps A and B are marked with blue circles, and the dashed blue ellipse, corresponding to a circle with the same inclination of the galaxy, shows the inner radius of the star-forming ring around the nuclear region of the galaxy.

Cresci et al. 2015

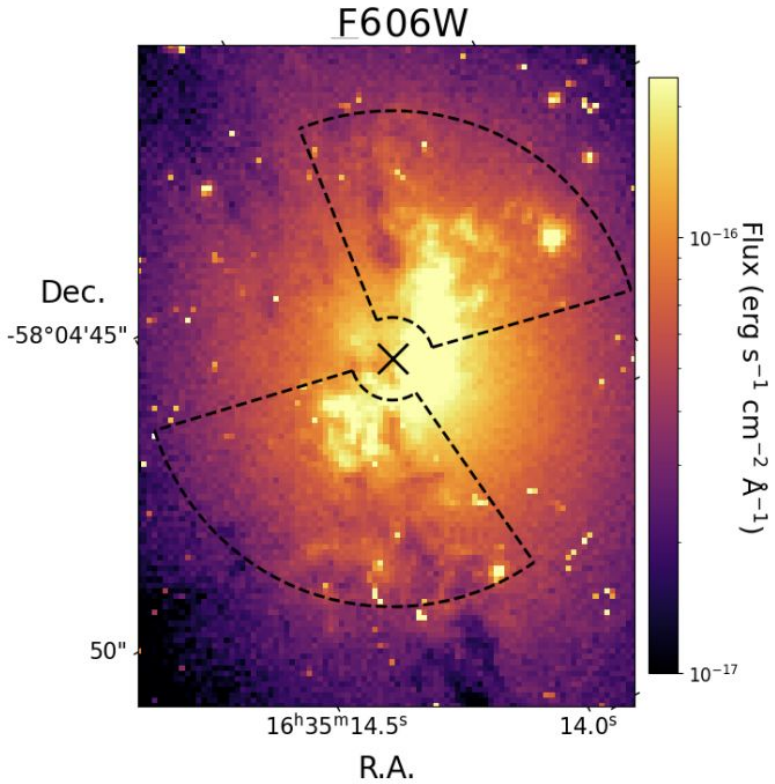



**Figure 1.** HST/F606W image of ESO 137-G034 (Malkan et al. 1998). Dashed black lines mark the ionization cones, as defined by the diffuse X-ray emission (Paper I). The black "X" marks the position of the nucleus, defined as the centroid of the [O III] continuum emission.

# HST data

| Instrument | Filter | Proposal ID | $t_E$ [s] | Note |
|---|---|---|---|---|
| WFPC2 | FR533N | 6419 | 1600 | [O III]$\lambda$5077 |
| WFPC2 | F547M | 6419 | 200 | [O III] continuum |
| WFPC2 | FR680P15 | 6419 | 1400 | H$\alpha$+[N II] |
| WFPC2 | F791W | 6419 | 200 | H$\alpha$ continuum |
| WFC3 | F673N | 16841 | 2000 | [S II]$\lambda$6716,31 |
| WFC3 | F763M | 16841 | 262 | [S II] continuum |
| WFC3 | FQ492N | 16841 | 2000 | H$\beta$ |
| WFC3 | F547M | 16841 | 254 | H$\beta$ continuum |

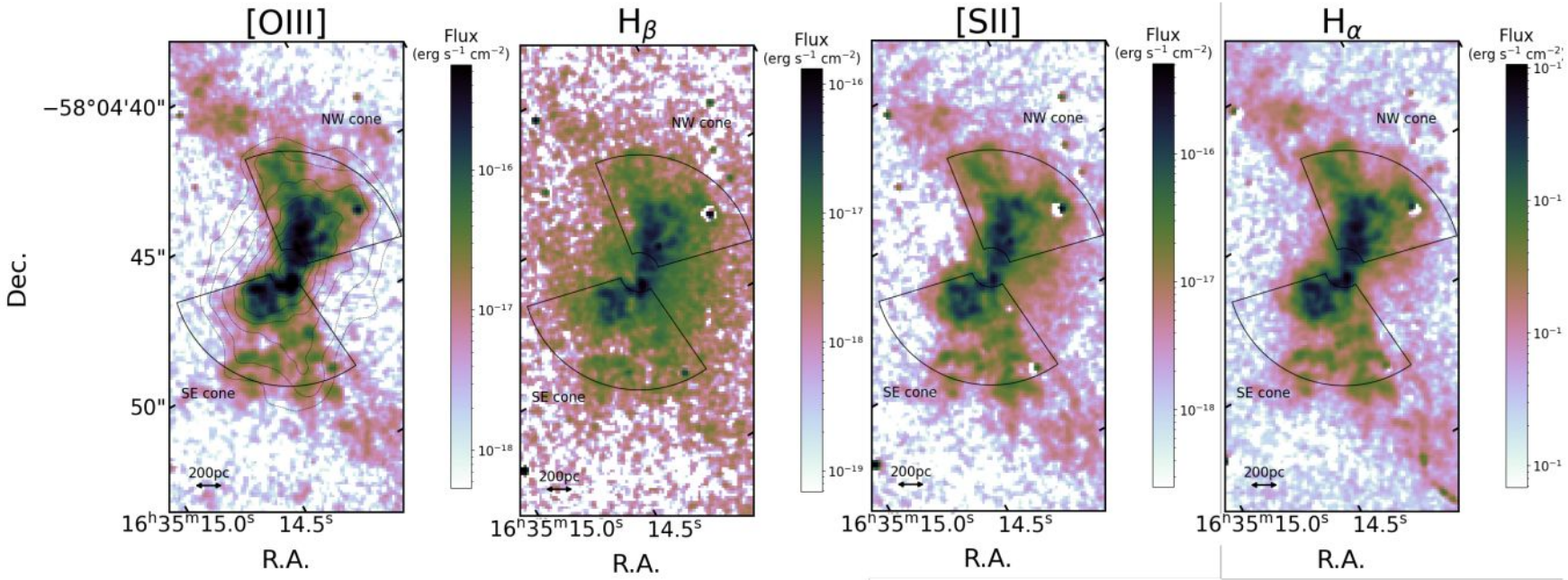



**Figure 2.** Continuum-subtracted narrow-line emission images of the ESO 137-G034 in [O III], H$\beta$, [S II], and H$\alpha$, from left to right. Dashed black contours on the leftmost panel trace the extended, smoothed X-ray emission, while the cones marked on all panels were obtained based on the azimuthal profile of the diffuse X-ray emission (Paper I). The black "X" marks position of the nucleus, defined as the centroid of the [O III] continuum emission.

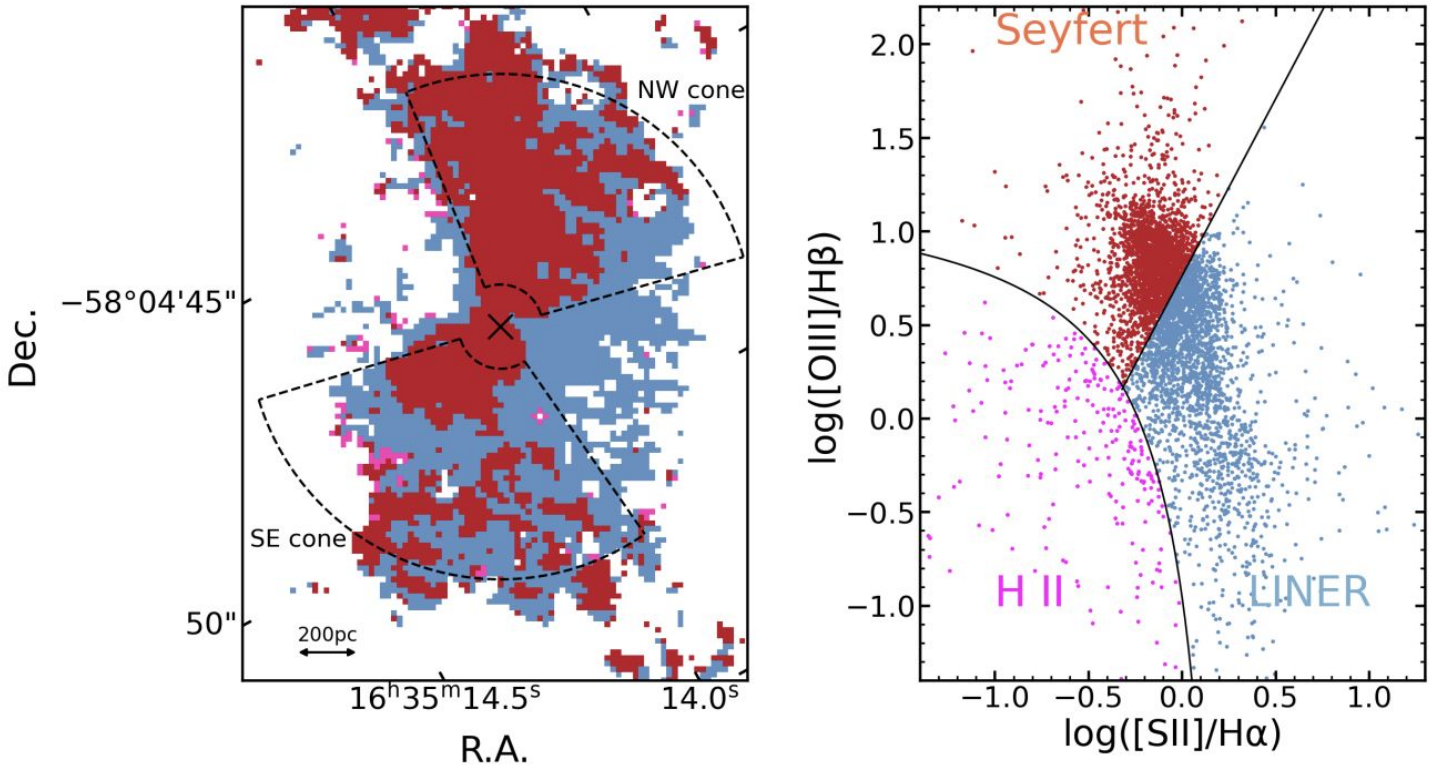



**Figure 3.** Left panel: BPT map of ESO 137-G034. Colors indicate the ionization classification based on line ratios: red for Seyfert-like points, blue for LINER-like points, and magenta for H II region-like points. The dashed outlines mark the ionization bicone defined by the extended X-ray emission (see Paper I for details). The black "X" marks position of the nucleus. Right panel: corresponding BPT diagram, with the same color scheme representing the classification of individual pixels.

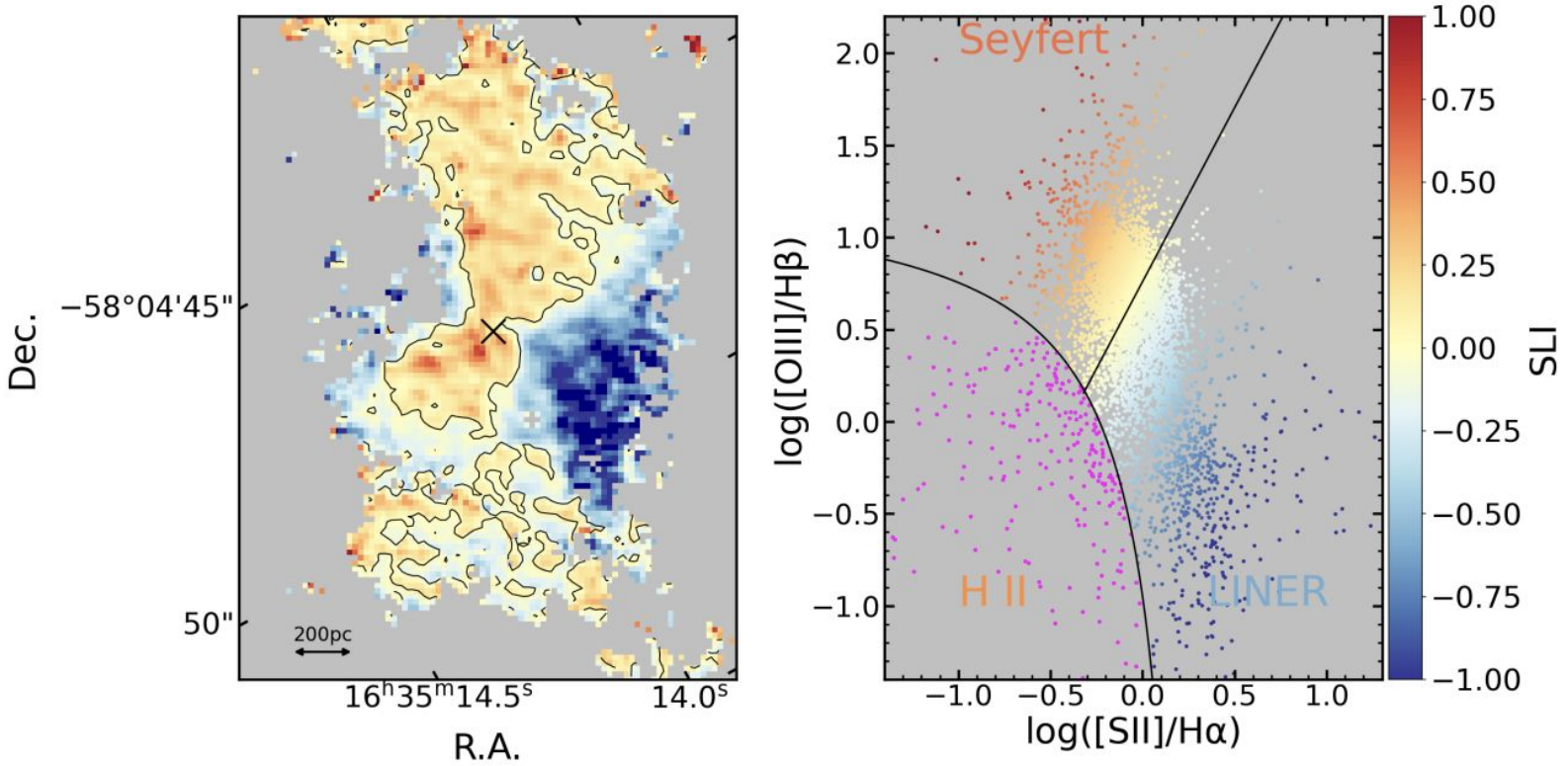
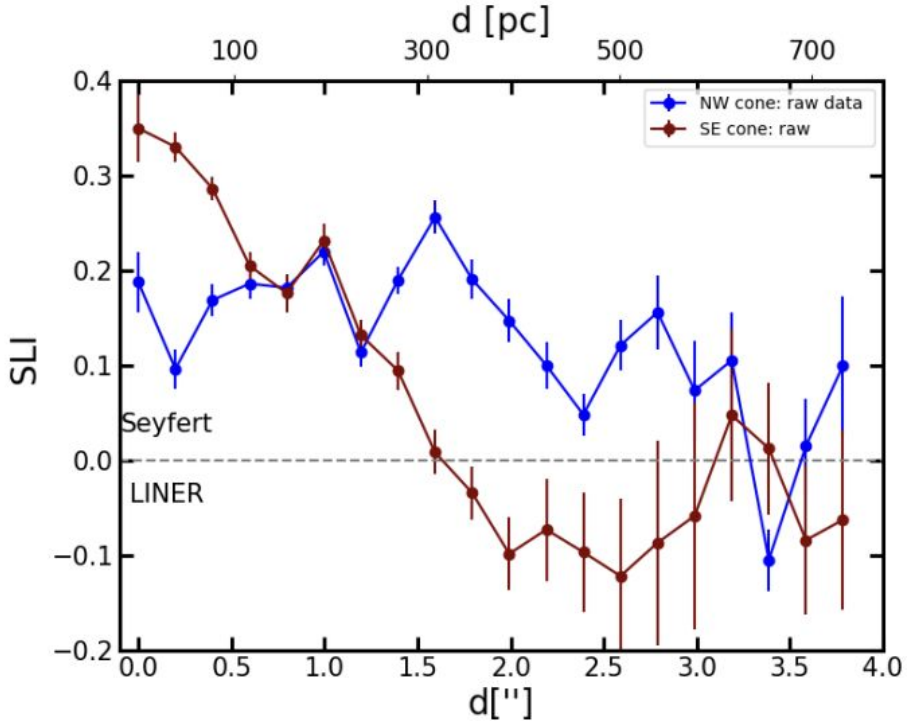



**Figure 4.** Left panel: BPT map showing Seyfert- and LINER-type points, color-coded by value of SLI, which quantifies the distance from the Seyfert/LINER division line in the BPT diagram. Black contours trace points on the Seyfer/LINER division line. The black "X" marks the position of the nucleus. Right panel: Corresponding BPT diagram, with magenta points representing H II region–like line ratios, red indicating Seyfert-like excitation, and blue denoting LINER-like excitation. For Seyfert and LINER points, the color intensity scales with the SLI value.



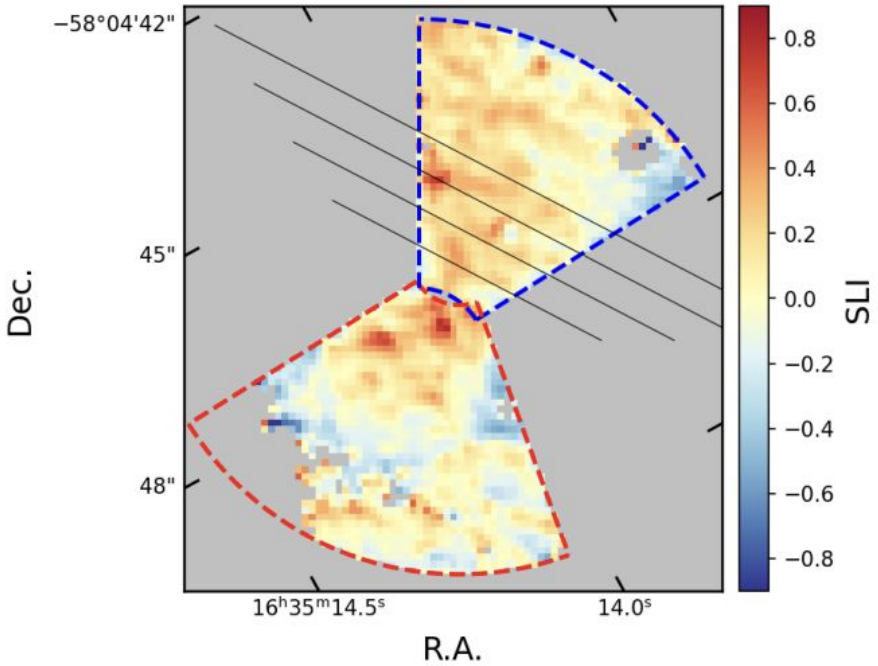




**Figure 8.** Radial profile of the SLI index for the bi-cone regions of ESO 13734. Left panel: radial profile of the average SLI value for the points in the SE (red) and NW (blue) ionization cones. Right panel: SLI map of regions mapped into the radial profile with contour colors corresponding to the curve colors. The black lines indicate the positions of the cross-sections shown in Fig. 9.

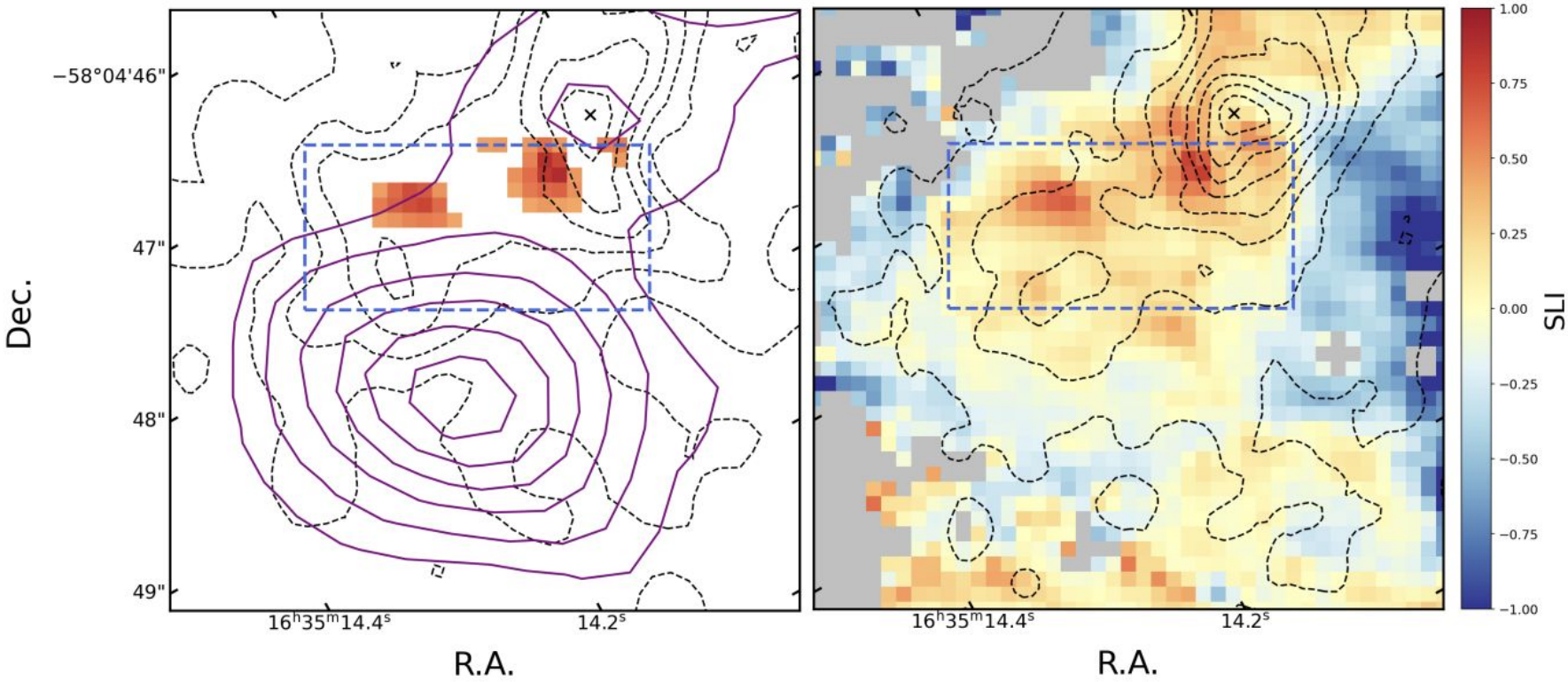
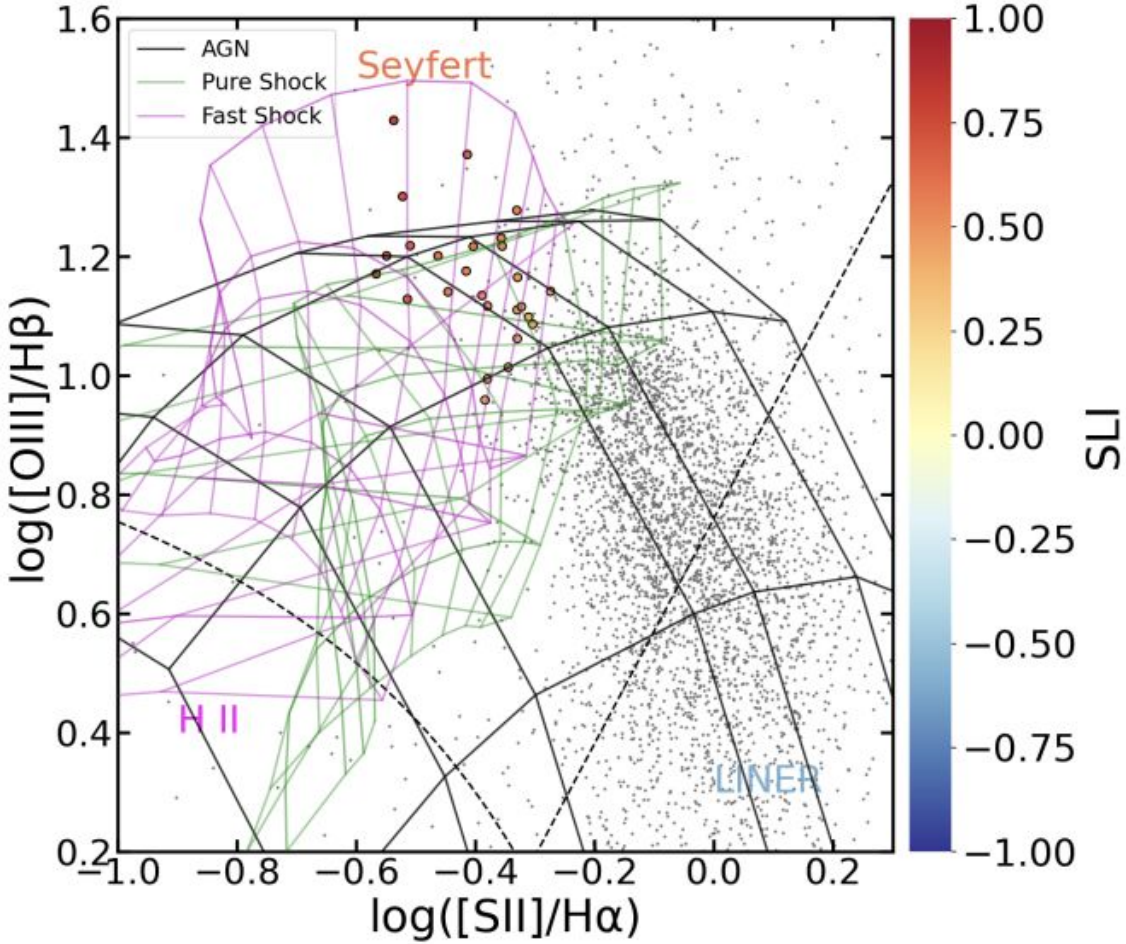
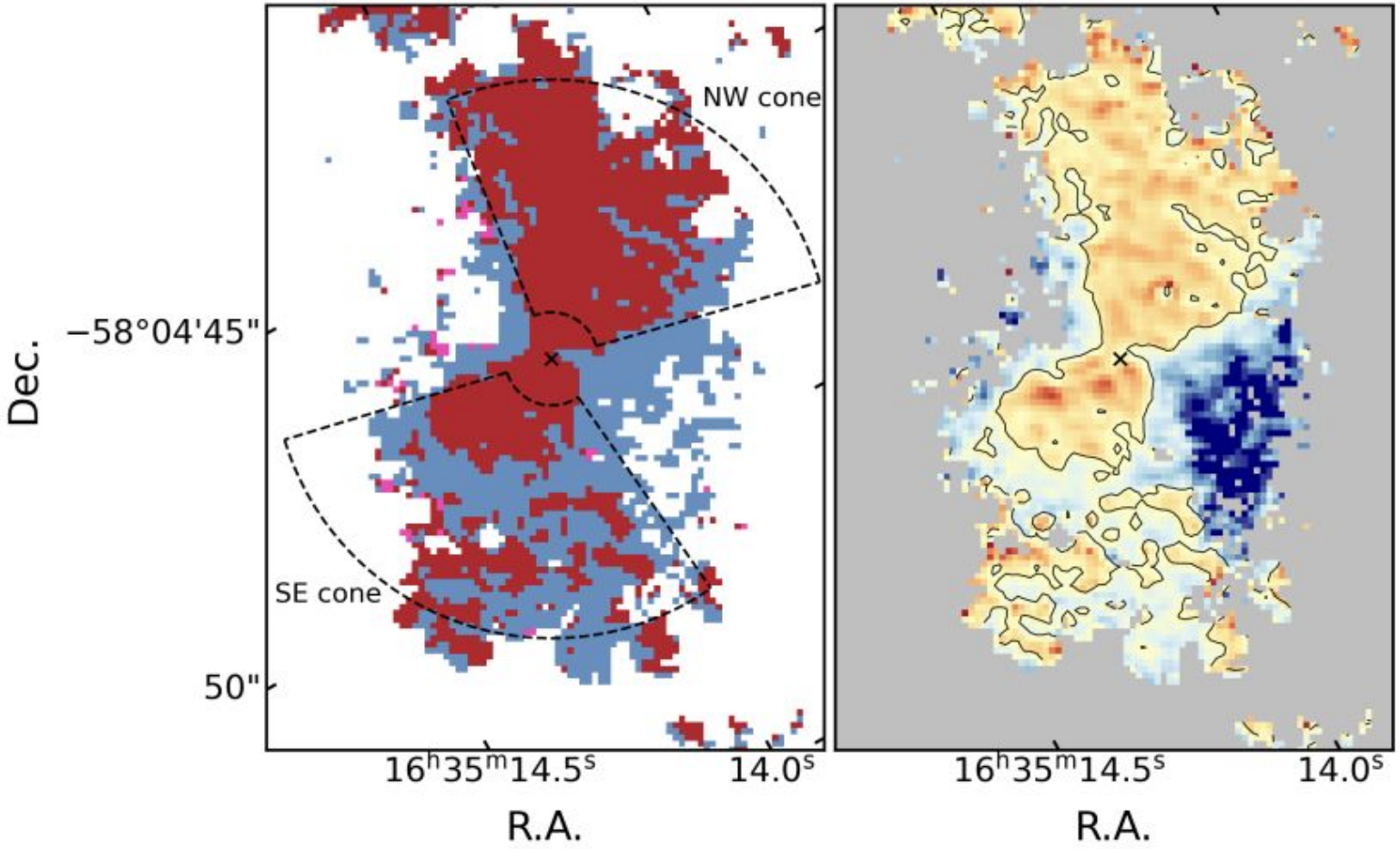
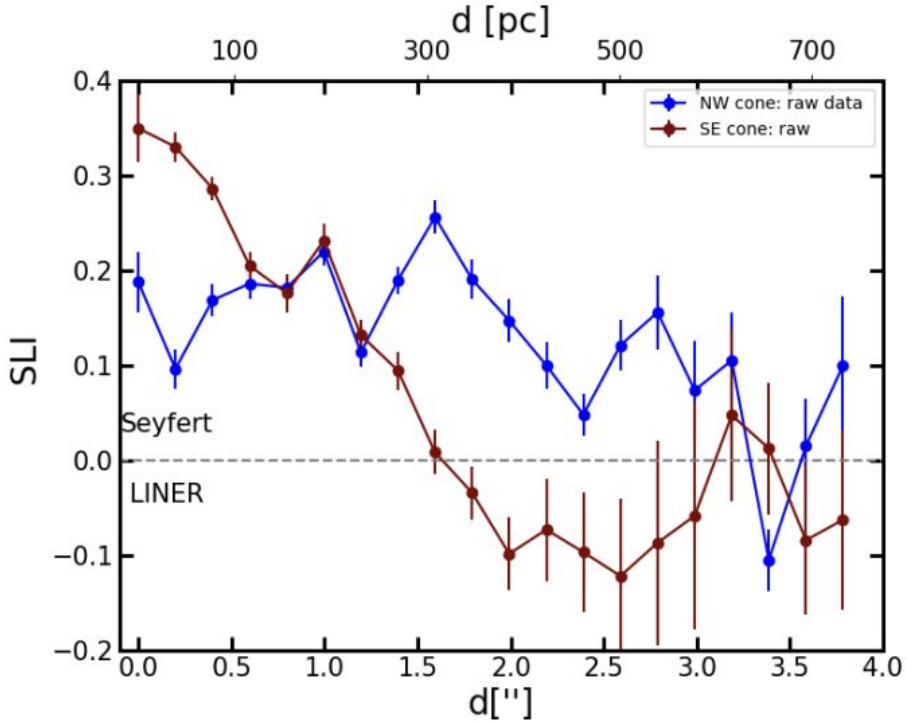
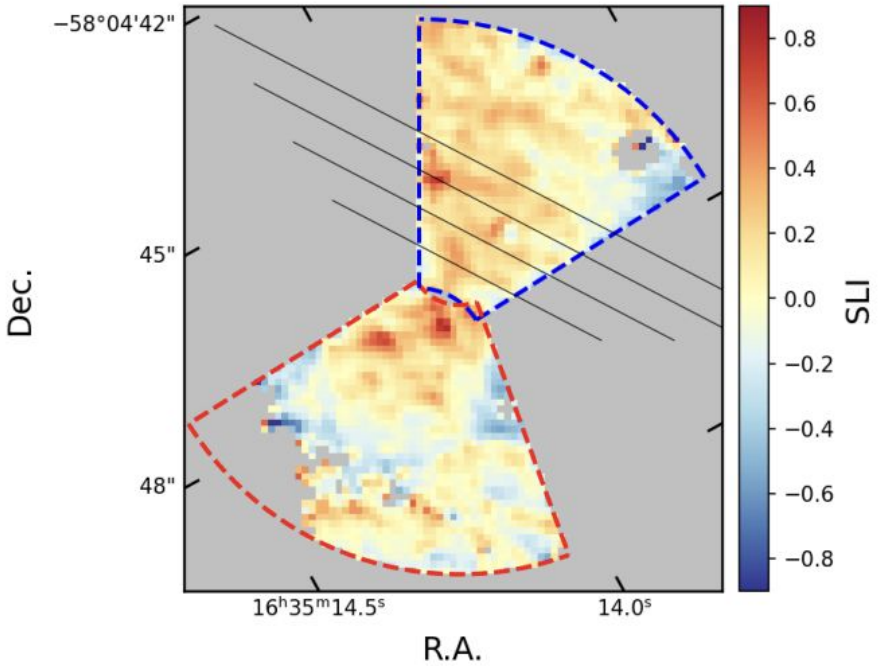



**Figure 5.** ESO137-G034 maps illustrating the high-excitation region within the SE cone. Black dashed contours trace soft ($0.3 - 1.5$ keV) X-ray emission (Paper I) and the blue dashed rectangle marks the region discussed in the context of excitation models. Left panel: red contours indicate the 3 cm radio emission (Morganti et al. 1999). Here only points with SLI$>0.4$ within the blue dashed box are marked in color. They correspond to colored points in Fig. 6. Right panel: BPT map of ESO137-G034 with colors defined as in Fig. 4.


AGN
Pure Shock
Fast Shock
Seyfert
H II
LINER
log([OIII]/Hβ)
log([SII]/Hα)
SLI
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
−1.0
−0.8
−0.6
−0.4
−0.2
0.0
0.2
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00


NW cone
SE cone
Dec.
−58°04'45"
50"
16h35m14.5s
14.0s
R.A.
16h35m14.5s
14.0s
R.A.

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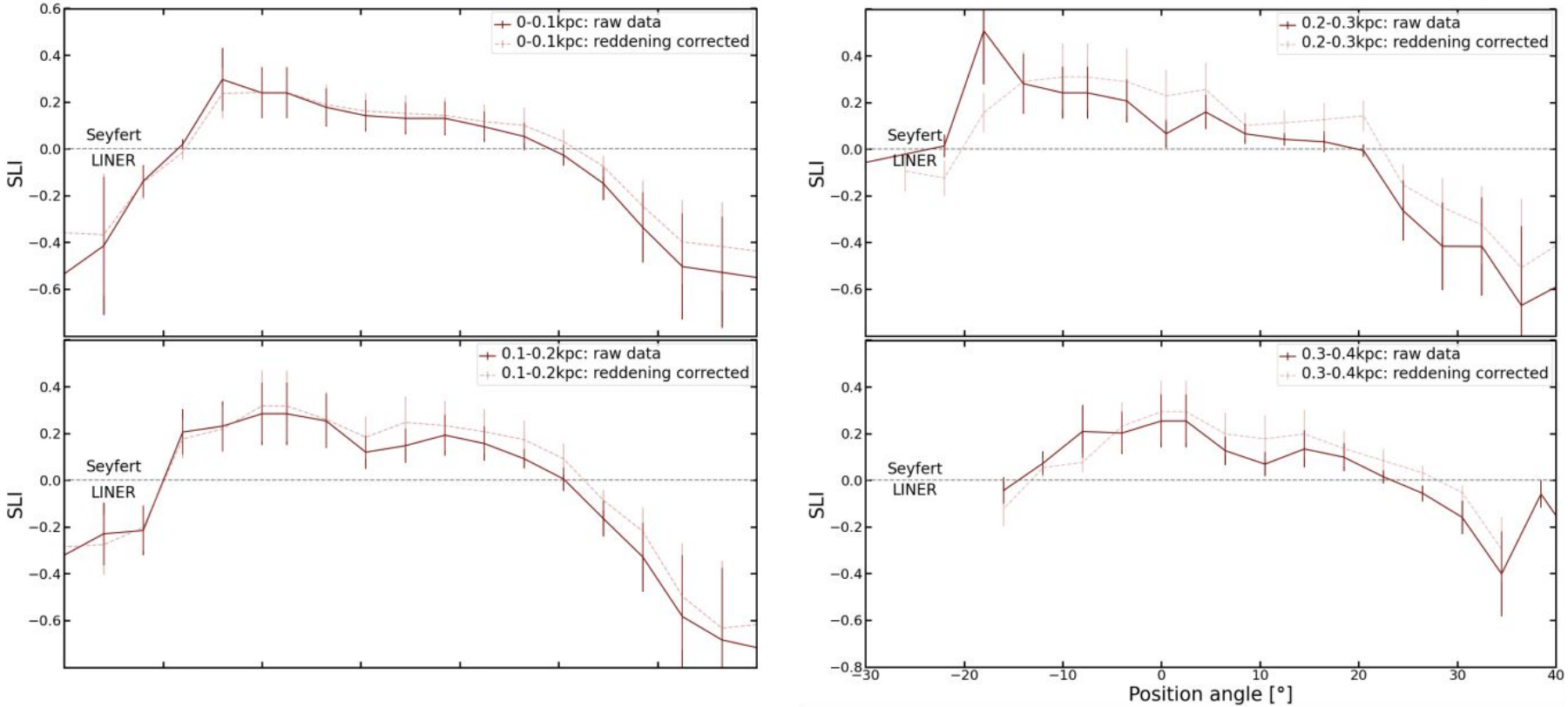
0-0.1kpc: raw data
0-0.1kpc: reddening corrected
0.1-0.2kpc: raw data
0.1-0.2kpc: reddening corrected
0.2-0.3kpc: raw data
0.2-0.3kpc: reddening corrected
0.3-0.4kpc: raw data
0.3-0.4kpc: reddening corrected
Seyfert
LINER
SLI
Position angle [°]

# Summary

1. излучение в линиях [O III], [S II], Hα и Hβ имеет двуконическую морфологию с удлинением в NW и SE направлениях и близко соответствует диффузному рентгеновскому излучению, наблюдаемому в рентгене на Chandra
2. большая часть излучения внутри конусов имеет сейфертовский тип и характеризуется умеренными значениями SLI (60% сейфертовских пикселей имеют SLI < 0,5)
3. NW и SE конусы демонстрируют четкие различия

# Summary

4. в NE конусе обнаружены 3 дуги с более высокими значениями SLI, эти хребты могут отражать прошлые циклы активности АЯГ с предполагаемыми временными масштабами ~ (1–2) × $10^3$ лет при времени распространения света, и до ~ (5–10) × $10^3$ лет при скорости распространения джета 0.2c или (3 – 7) × $10^5$ лет при типичных скоростях истечения [OIII], но эти особенности могут быть связаны с неоднородным профилем МЗС
5. в конусе SE неоднородности в значениях SLI: точки с высоким значением SLI (SLI $\gtrsim$ 0,4) сгруппированы во внутренней области ($\lesssim$ 200 пк от ядра). Эти точки перекрываются областью избытка мягкого рентгеновского излучения и внутренним краем радиолепестка, их положение на диаграмме BPT согласуется с возбуждением быстрыми ударными волнами ($\gtrsim$ 1000 км с−1), остальные сейфертовские пикселы в конусе SE, имеющие более низкие значения SLI (< 0,4), согласуются с фотоионизацией активного ядра
6. постепенный переход SLI через границы конуса указывает на слоистую ионизационную структуру, сформированную взаимодействием ветров АЯГ с МЗС, затенённым излучением АЯГ ударными волнами с меньшей скоростью или их комбинацией