

# Internal kinematics of giant H II regions in M101 with the Keck Cosmic Web Imager

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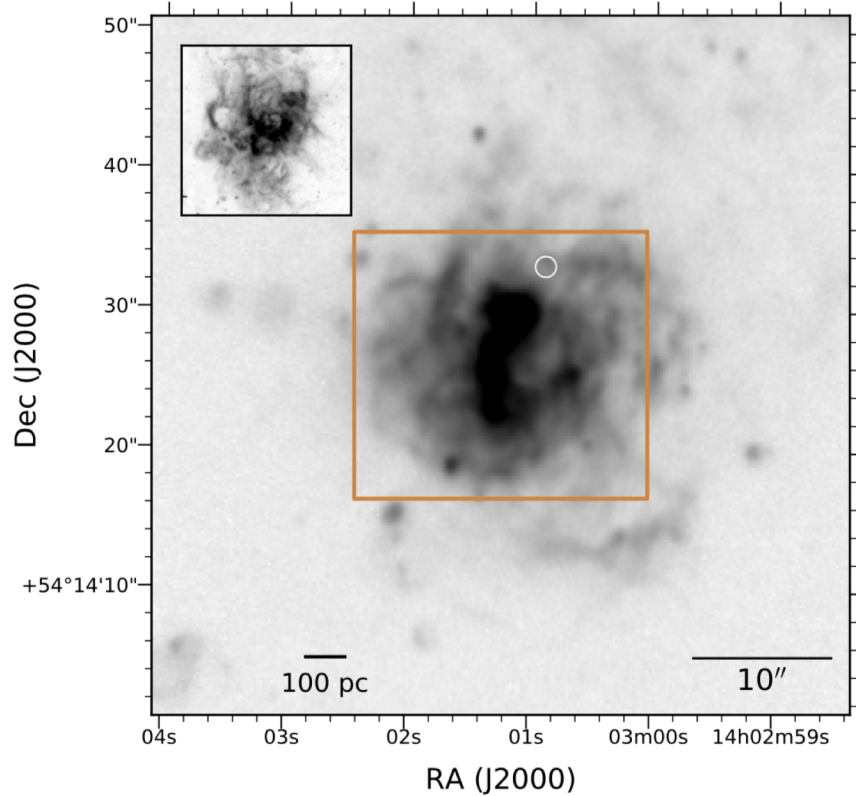
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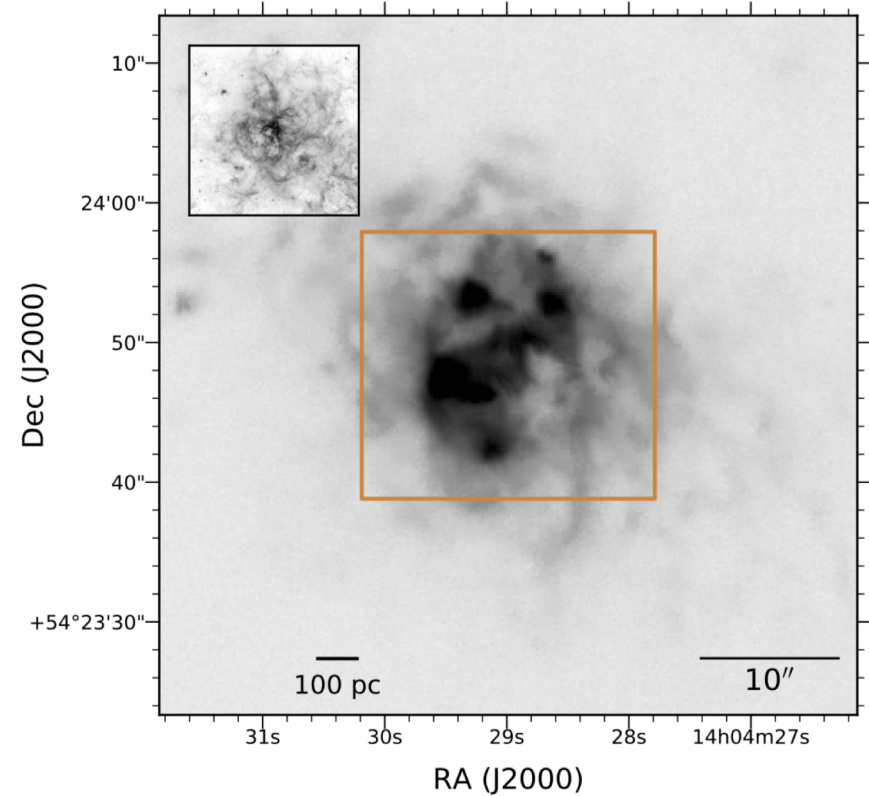
22 May 2020

## ABSTRACT

We study the kinematics of the giant H II regions NGC 5455 and NGC 5471 located in the galaxy M101, using integral field observations that include the H $\beta$  and [O III]  $\lambda$ 5007 emission lines, obtained with the Keck Cosmic Web Imager. We analyse the line profiles using both single and multiple Gaussian curves, gathering evidence for the presence of several expanding shells and moving filaments. The line decomposition shows that a broad ( $\sigma \simeq 30\text{--}50\text{ km s}^{-1}$ ) underlying component is ubiquitous, extending across hundreds of pc, while a large fraction of the narrow components have subsonic line widths. The supersonic turbulence inferred from the global line profiles is consistent with the velocity dispersion of the individual narrow components, i.e. the global profiles likely arise from the combined contribution of discrete gas clouds. We confirm the presence of very extended ( $400\text{--}1200\text{ km s}^{-1}$ ) low-intensity line components in three bright star-forming cores in NGC 5471, possibly representing kinematic signatures of supernova remnants. For one of these, the known supernova remnant host NGC 5471 B, we find a significantly reduced [O III]/H $\beta$  line ratio relative to the surrounding photoionized gas, due to the presence of a radiative shock at low metallicity. We explore the systematic width discrepancy between H I and [O III] lines, present in both global and individual spaxel spectra. We argue that the resolution of this long-standing problem lies in the



**Figure 1.**  $H\alpha$  image of NGC 5455 (extracted from the CFHT Science Archive) with overlay of the field observed with KCWI (rectangle). In the inset at the upper left the giant H II region NGC 604 in the galaxy M33 is shown at the same physical scale, for comparison. The circle indicates the position of SN 1970G (Dittmann et al. 2014) for reference.



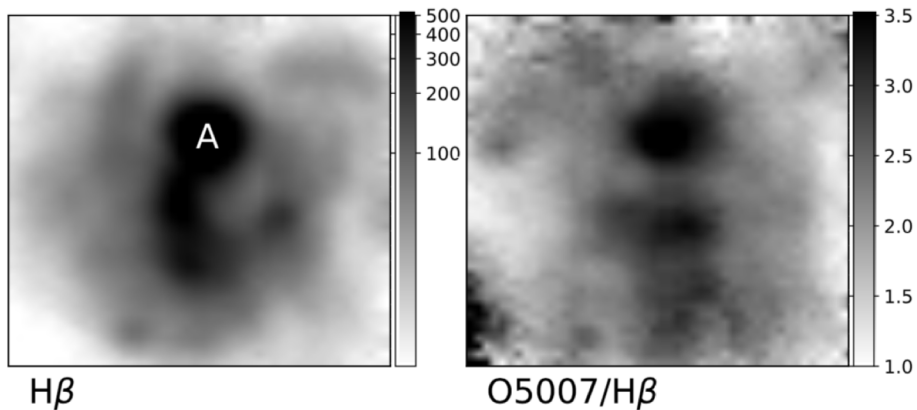
**Figure 2.**  $H\alpha$  image of NGC 5471 (extracted from the CFHT Science Archive) with overlay of the field observed with KCWI (rectangle). In the inset at the upper left the giant H II region 30 Dor in the LMC is shown at the same physical scale, for comparison (image from the ESO archive).

Keck Cosmic Web Imager (Morrissey et al. 2018)

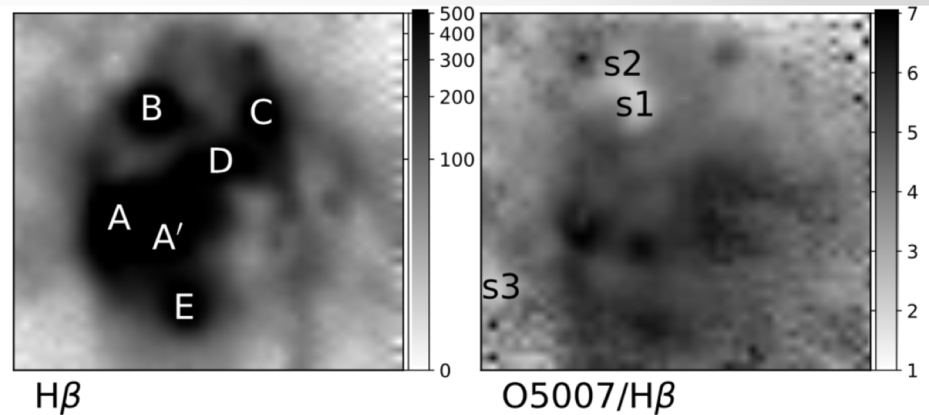
Щель 0.35"; Поле зрения 8.4x20.4"; Пиксель 0.146 "/px; R~16700 (18 км/с)

Полное поле зрения 21.4x20.4"

$$\sigma = (\sigma_{obs}^2 - \sigma_{instr}^2 - \sigma_{th}^2 - \sigma_{fs}^2)^{1/2}.$$

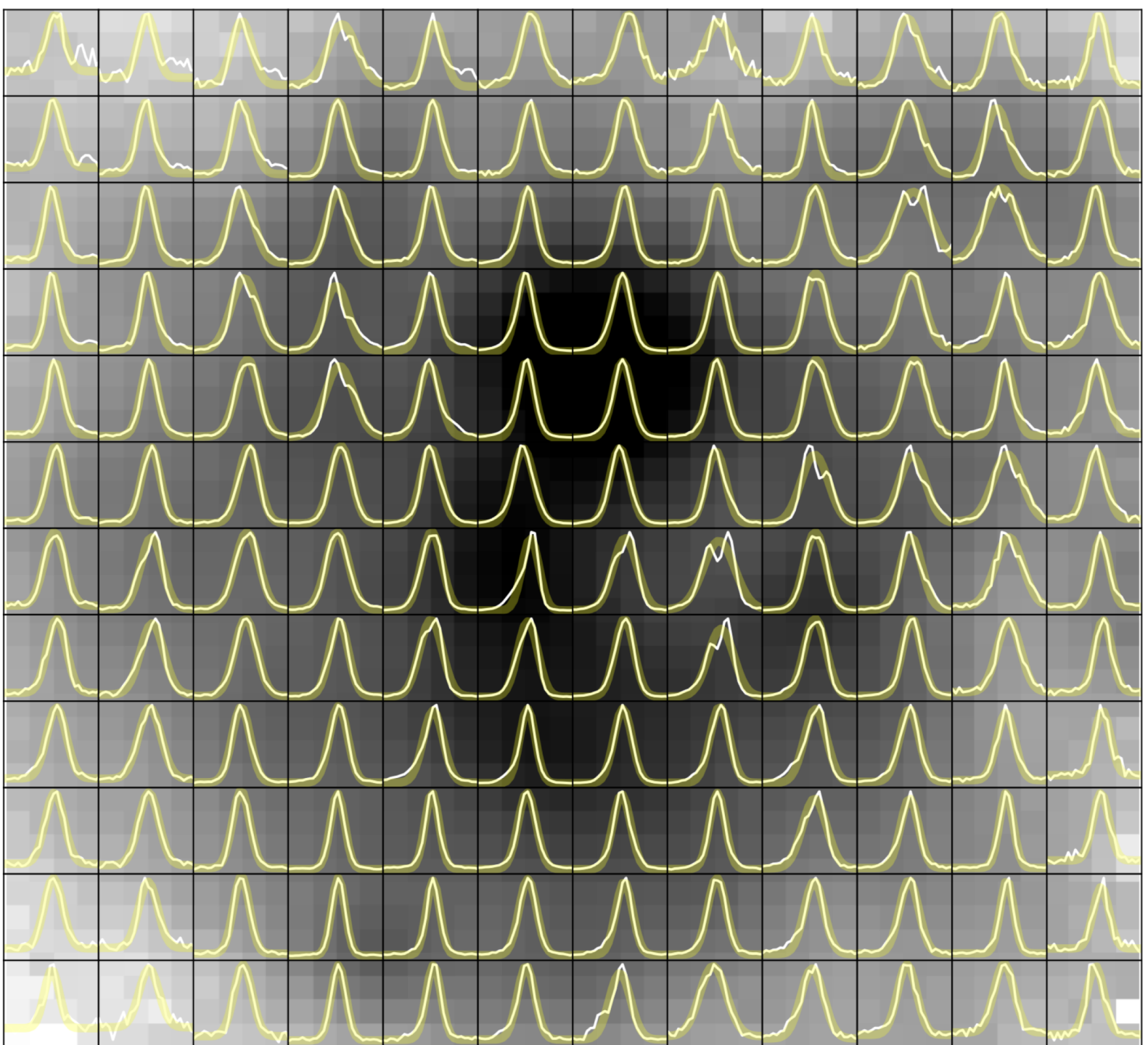


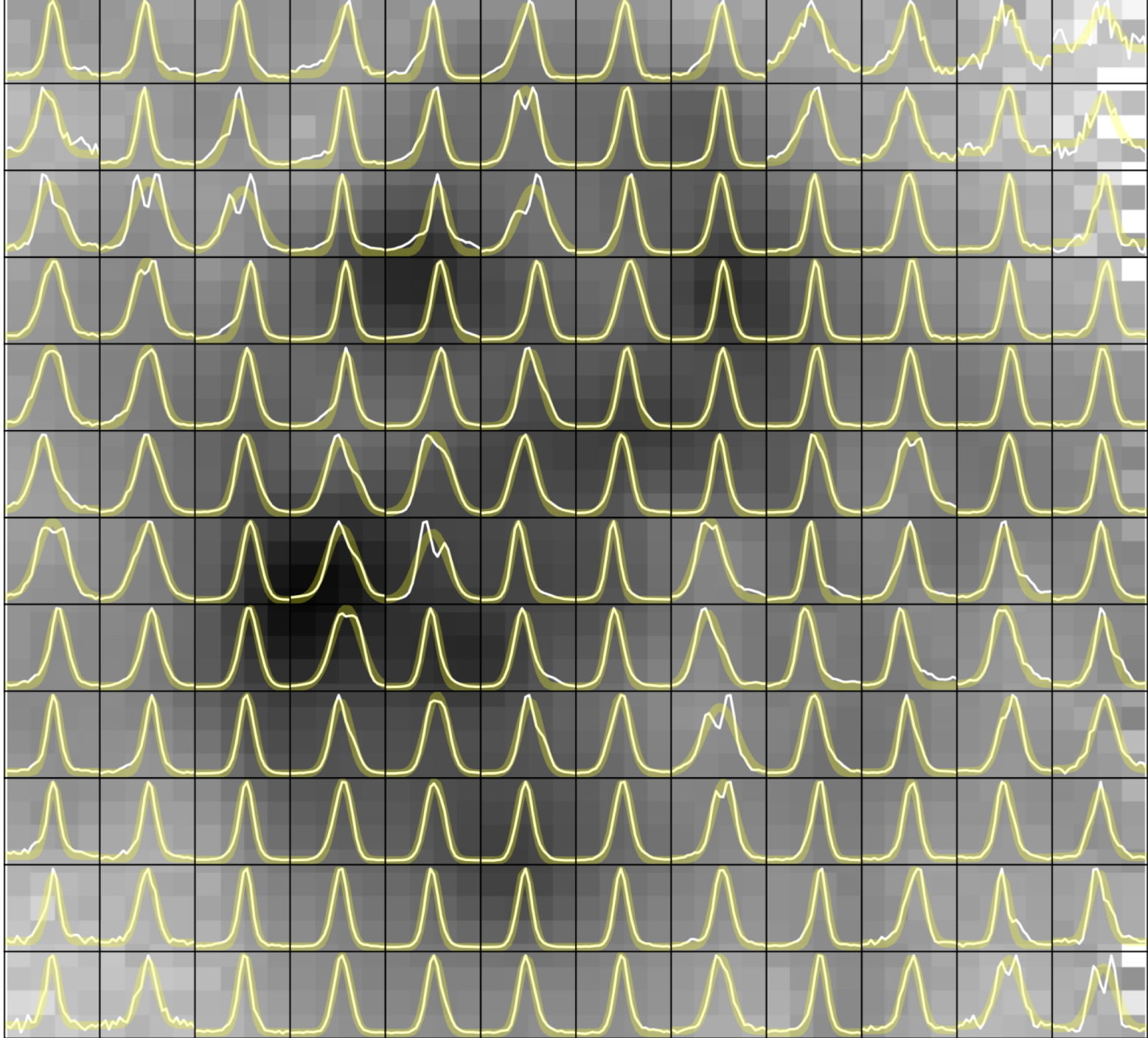
**Figure 3.** (Left) Continuum-subtracted  $H\beta$  image of NGC 5455 derived from the KCWI data cube. The spot with the brightest emission is labelled as A. (Right) The  $[\text{O III}] \lambda 5007/H\beta$  emission line ratio image. In this and subsequent figures we refer to  $[\text{O III}] \lambda 5007 \equiv O5007$ .

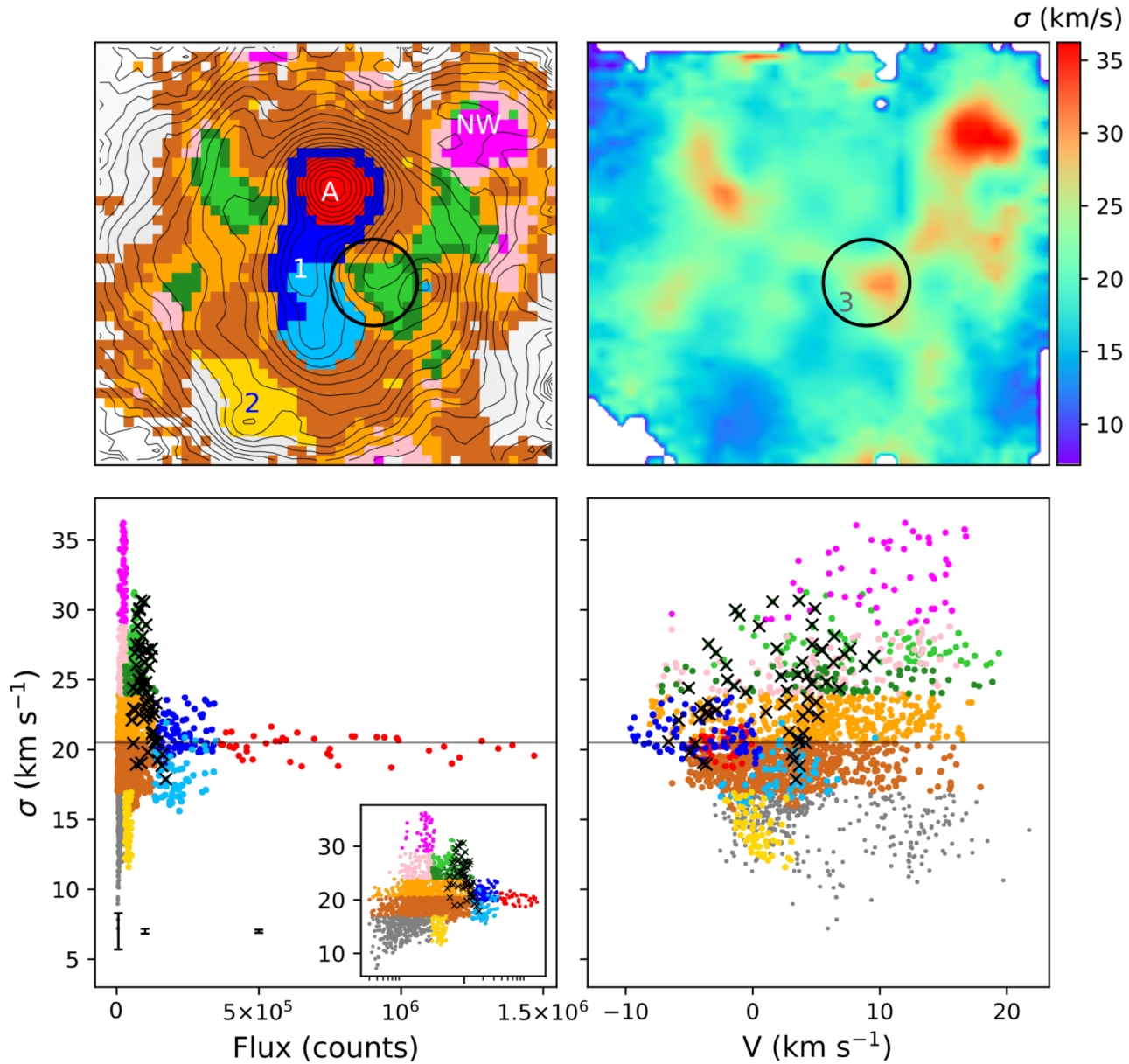


**Figure 4.** (Left) Continuum-subtracted  $H\beta$  image of NGC 5471 derived from the KCWI data cube. The letters A–E refer to the emission peaks identified by Skillman (1985), while A' follows from Muñoz-Tuñón et al. (1995). (Right) The  $[\text{O III}] \lambda 5007/H\beta$  emission line ratio image. The letters s1–s3 refer to the emission peaks identified by Chen

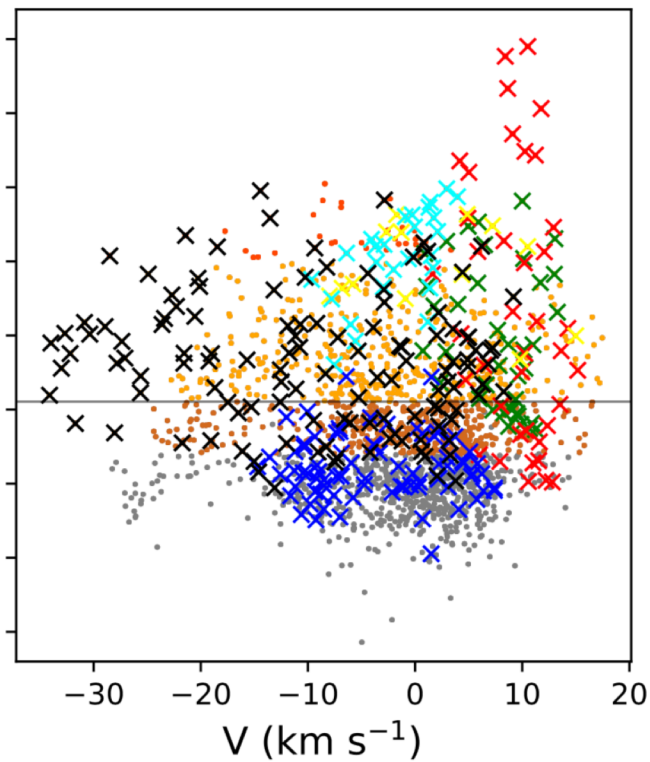
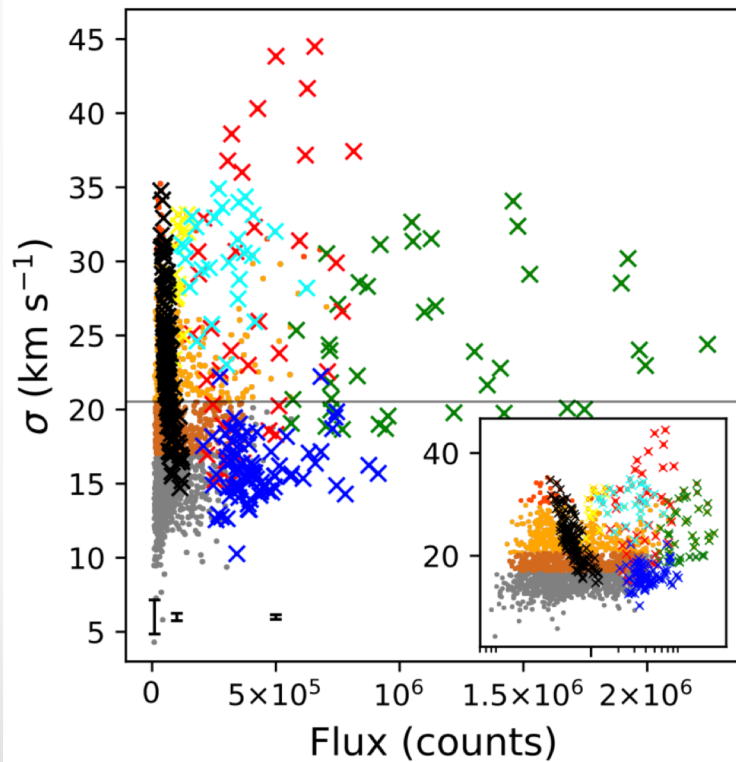
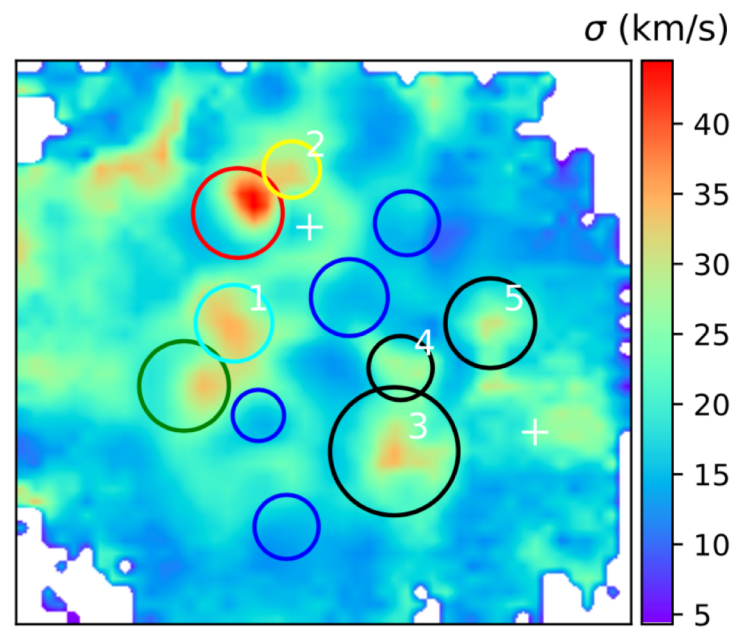
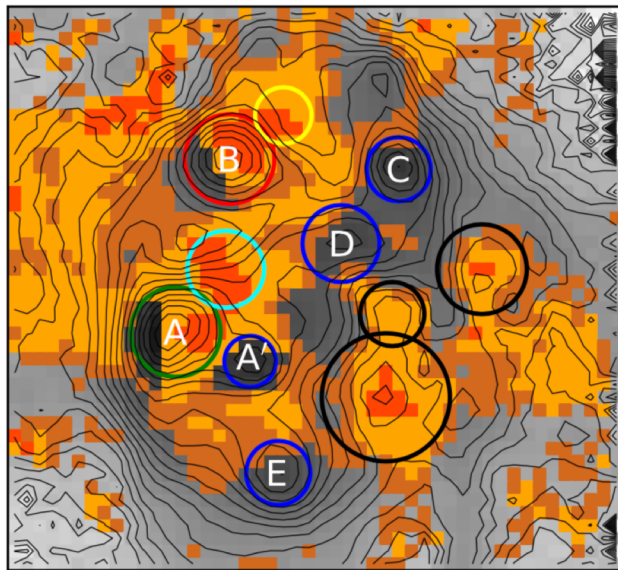


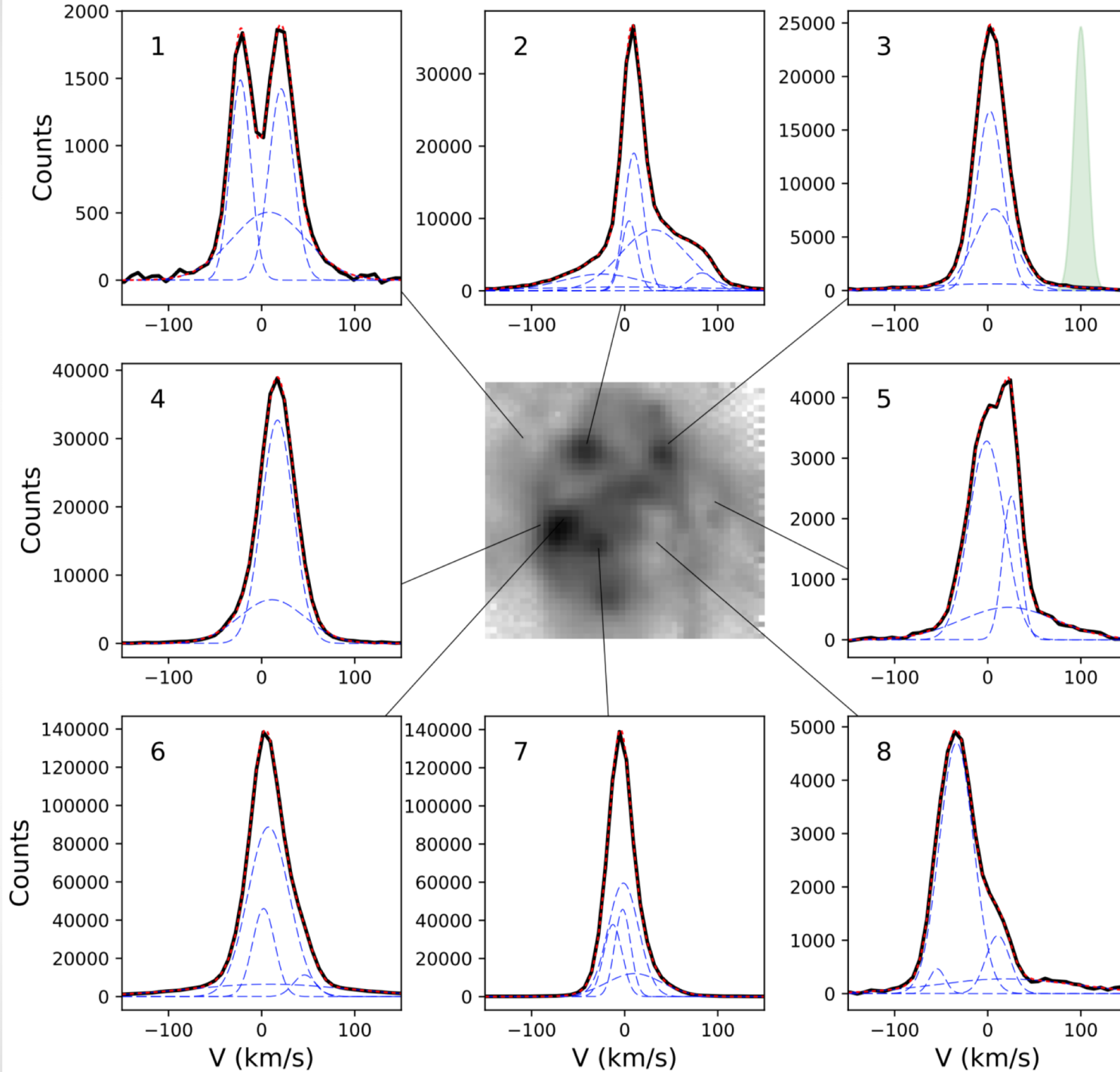




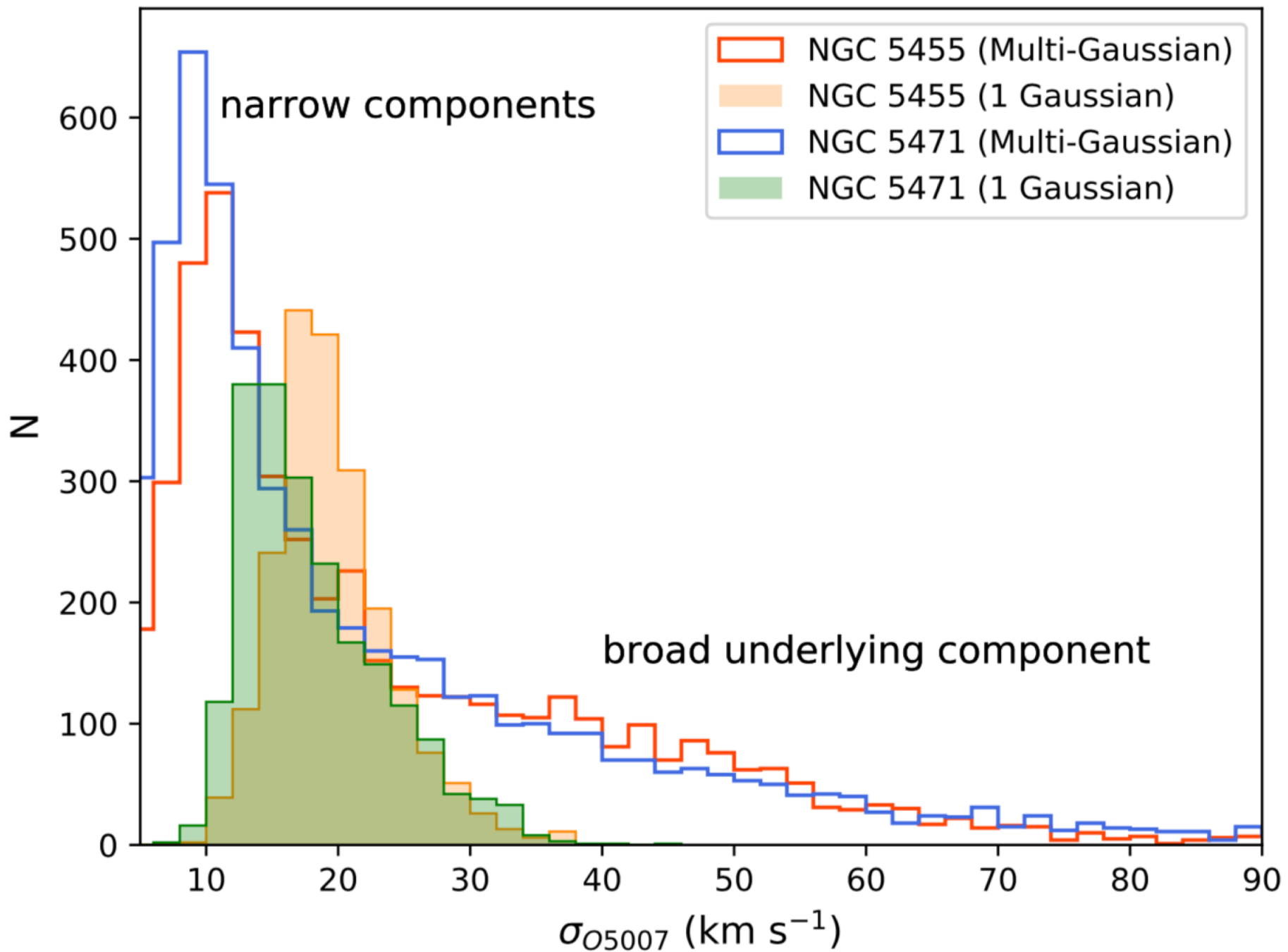


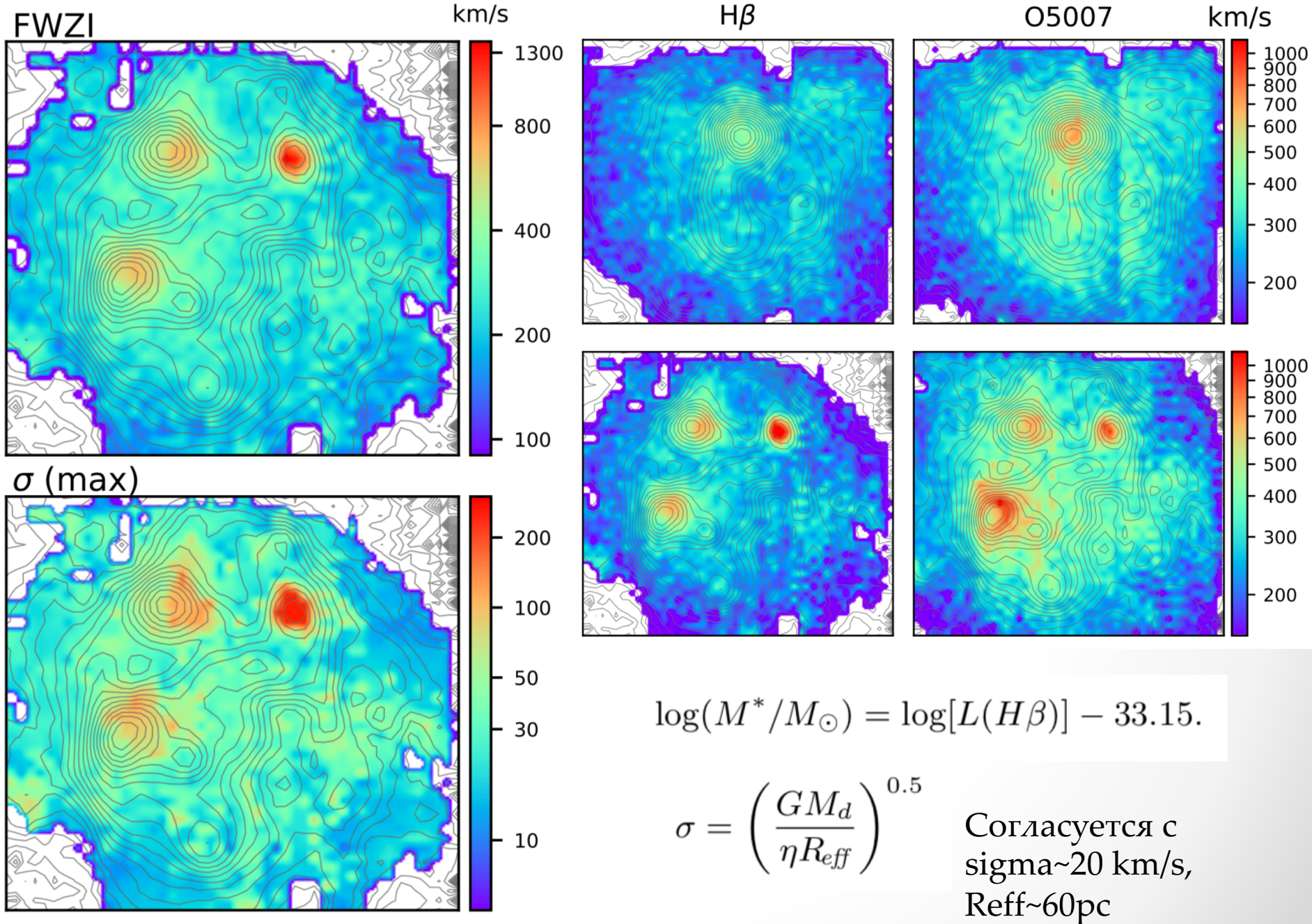
**Figure 9.** Results from single Gaussian fits for NGC 5455. (Top left): Isocontours of the H $\beta$  flux distribution (arbitrary level spacing). The colored areas represent regions selected in the  $I-\sigma$  diagram shown in the panel below. (Top right): velocity dispersion map, smoothed with a bilinear interpolation. (Bottom left):  $I-\sigma$  diagram, where we use different colors to isolate portions that are mapped onto the top left panel. The error bars represent the uncertainties estimated by comparing the widths of the two [O III] lines,  $\lambda 4959$  and  $\lambda 5007$ . The inset uses the logarithmic scale for the flux. (Bottom right):  $V-\sigma$  diagram, using the same colour code. The horizontal line in the two bottom plots represents the flux-weighted average  $\sigma$  value. The circle in the top row identifies the location of slit profiles with a maximum in  $\sigma$ , that we associate with the presence of a shell.



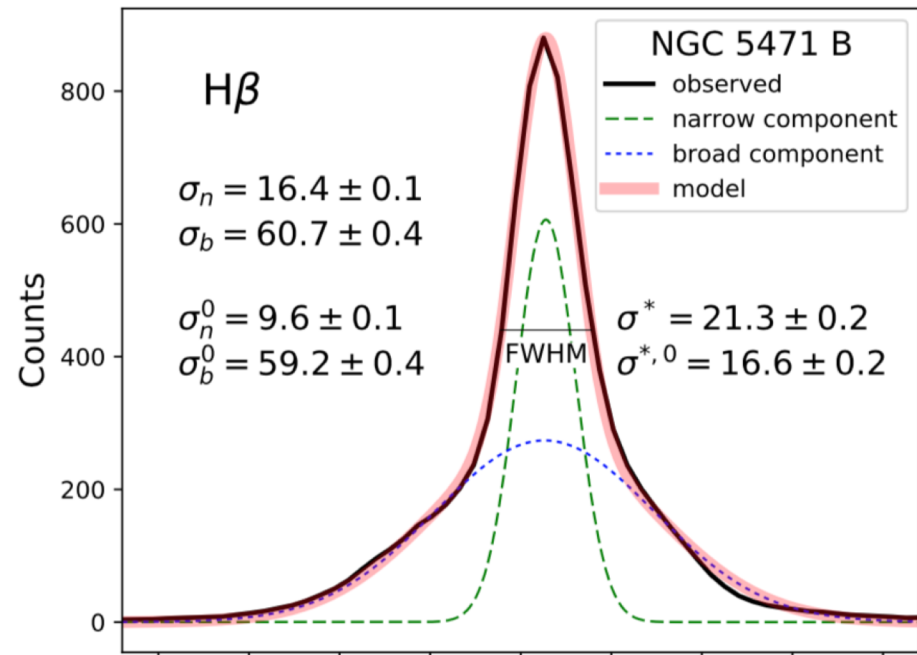




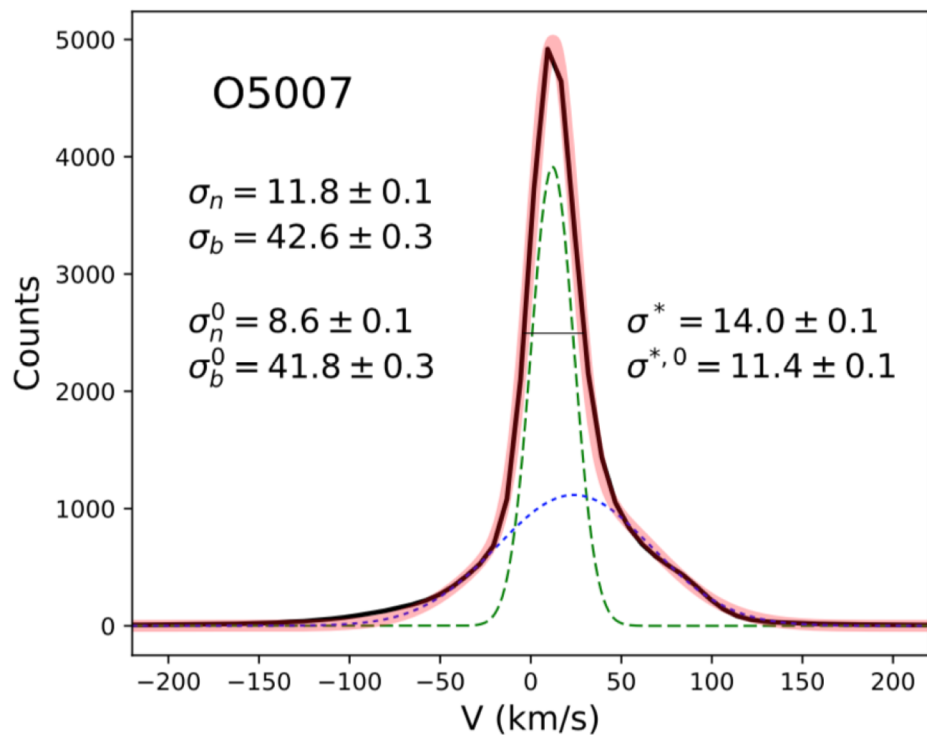


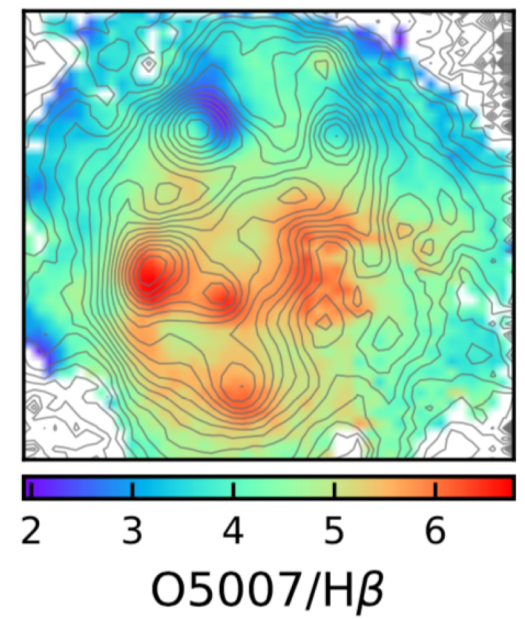
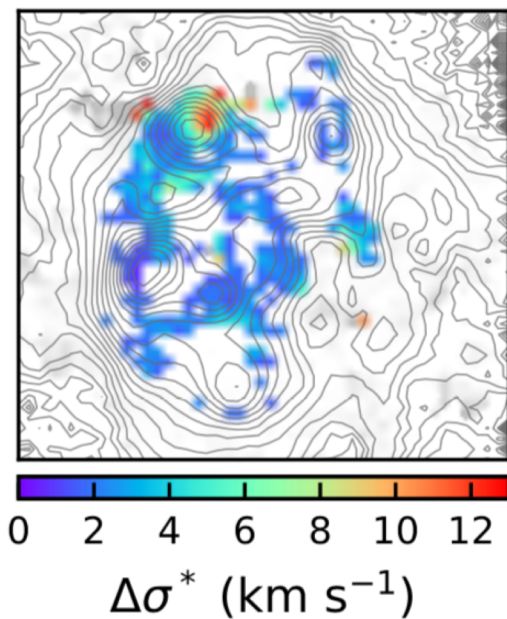
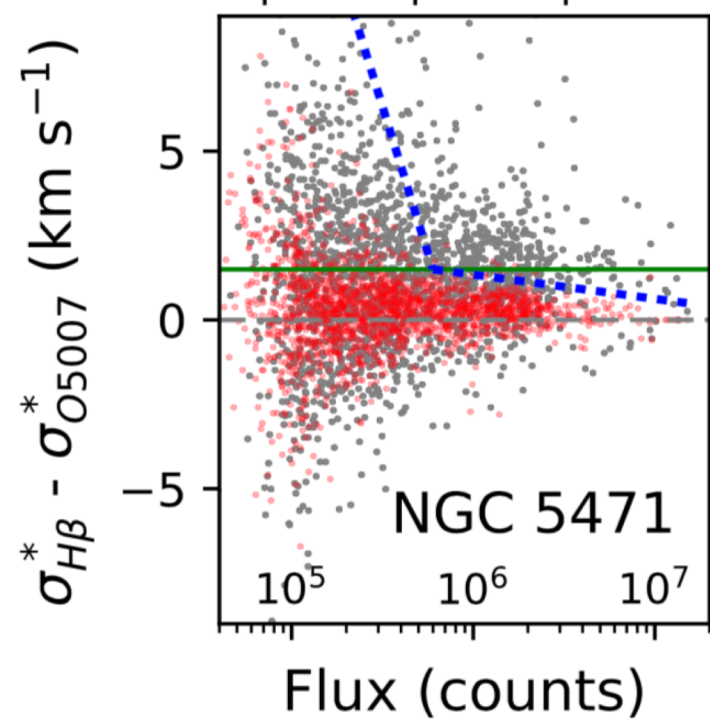
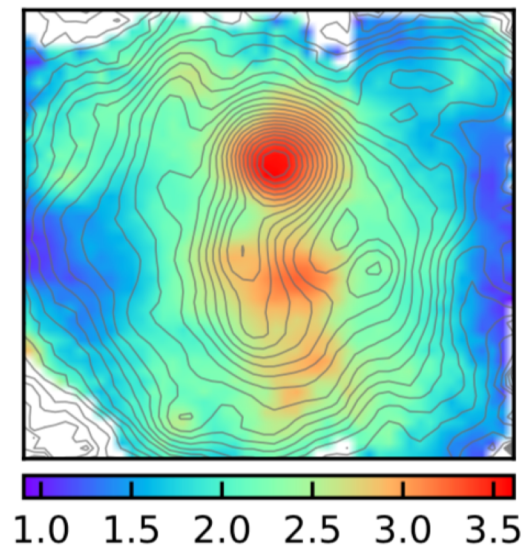
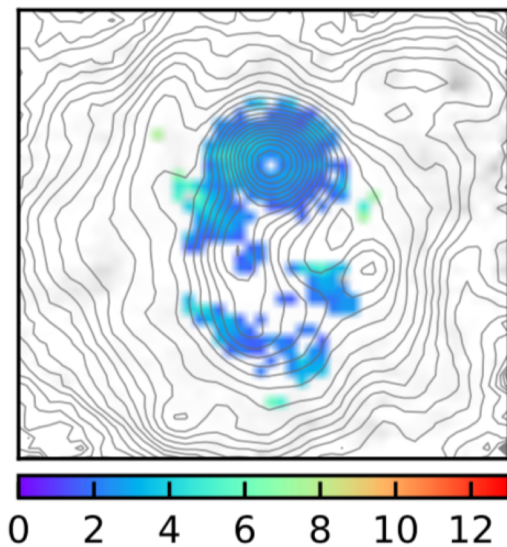
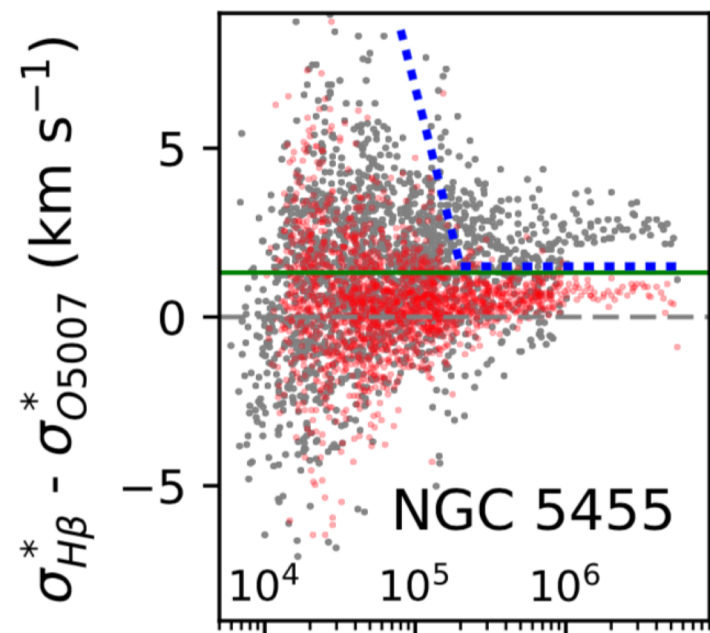


**Figure 14.** Spatial distribution of the FWZI (top) and maximum velocity dispersion (bottom) of the H $\beta$  line for NGC 5471.



В среднем, разница по дисперсии скоростей между [OIII] и Hbeta  $\sim 2$  km/s





$\Delta\sigma^*$  (km s $^{-1}$ )

O5007/H $\beta$