

Goals:

- Map the gas excitation and kinematics in the inner kiloparsec of the radio galaxy Arp 102B, at a distance 105 Mpc. Although classified as an E0 galaxy, narrow-band HST ACS H α images showed the presence of nuclear spiral arms (Fathi et al. 2011).
- Investigate the nature of the spiral arms, which seem to correlate with a curved radio jet (imaged at 8.4 GHz).

Data:

Optical Integral Field Spectroscopy obtained at Gemini North Telescope with the GMOS IFU with spectral resolution of 1.8Å, a spectral coverage from $\lambda 4400\text{\AA}$ to $\lambda 7300\text{\AA}$ and angular resolution of 0.6 arcsec or 294 pc. The field of view covers $3.9'' \times 5.5''$ (1.9kpc \times 2.7kpc) and is oriented along position angle PA=65°. Flux maps, velocity dispersions, and centroid velocities were obtained in the narrow emission lines.

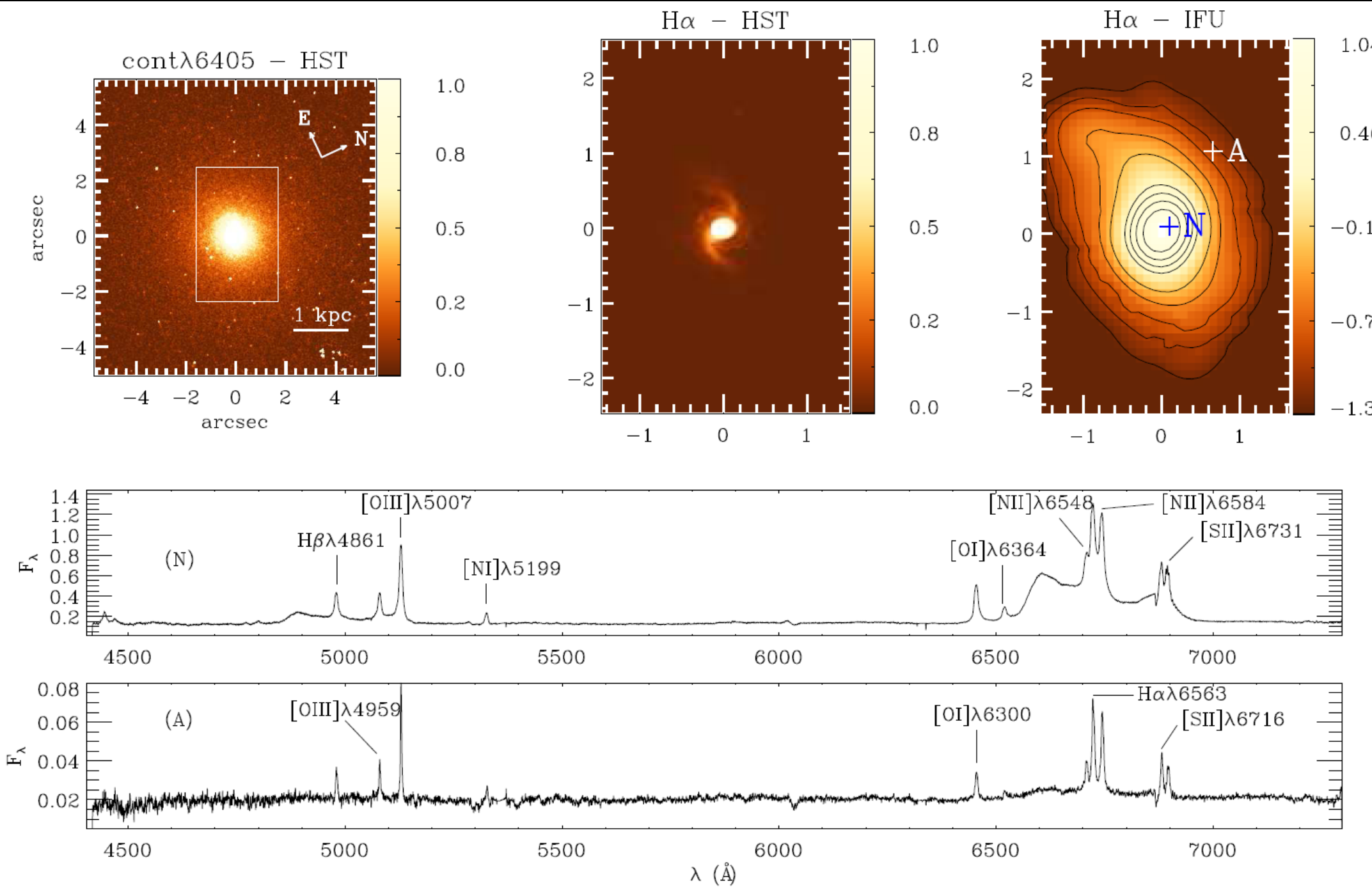


Fig. 1. **Top Left:** HST H α image within the IFU FOV, showing the E and W spiral arms extending to ~ 500 pc from the nucleus. **Top Right:** H α flux map from our IFU spectroscopy, showing that the E arm extends up to 1 kpc from the nucleus. Flux maps in other narrow emission lines are similar. A 8.4 GHz VLA radio image (see Fig. 3) correlates with the E spiral arm. Flux units are 10^{-15} erg cm $^{-2}$ s $^{-1}$ spaxel $^{-1}$ and are shown in a logarithmic scale. **Bottom:** Spectra extracted at the positions N and A marked in the top right panel, showing the double-peaked H α and H β at the nucleus (N).

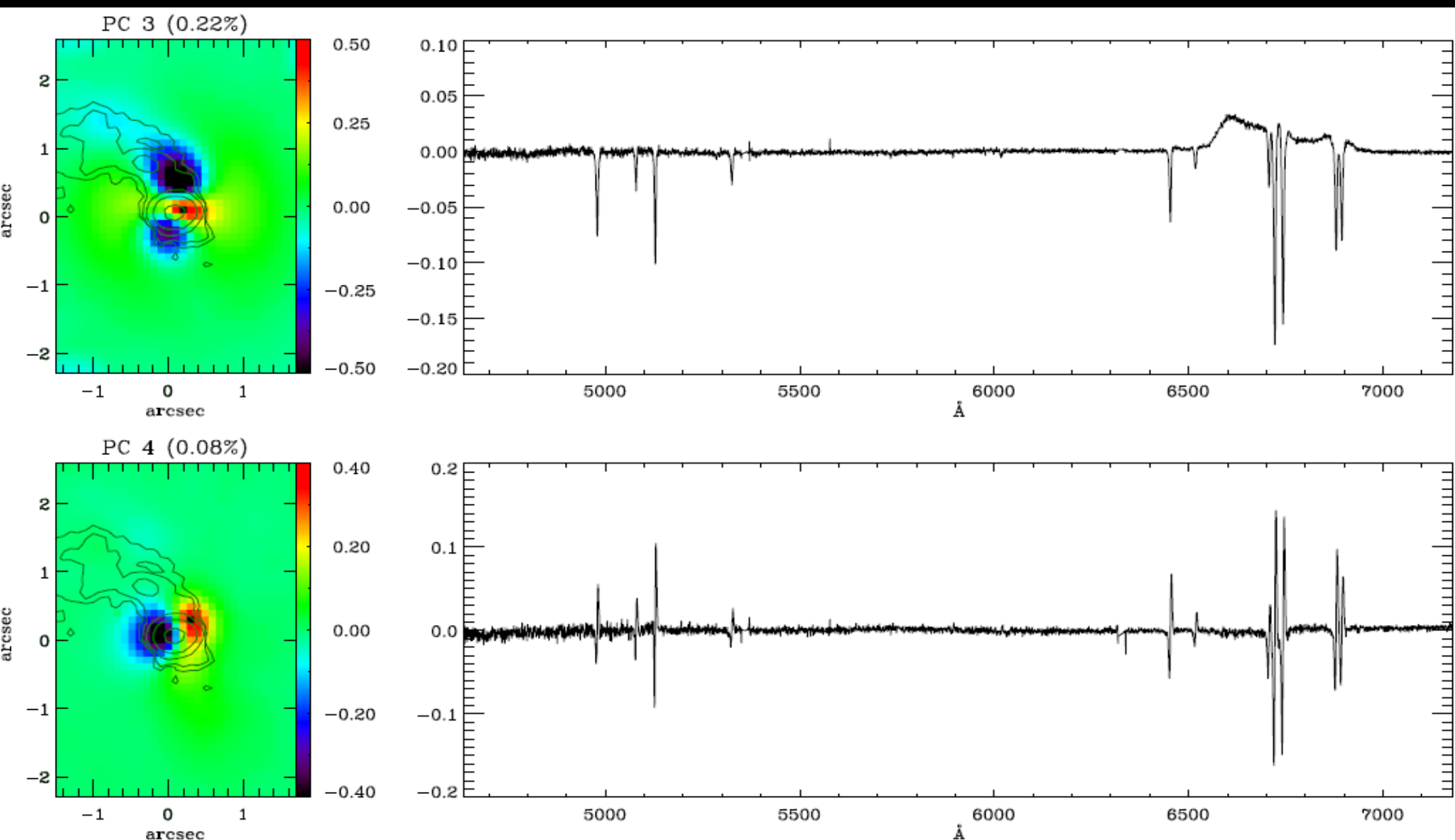


Fig. 2. Principal Component Analysis (PCA) was applied to the data in the search for small scale structures. The result is the separation of the information in a system of non-correlated coordinates, called "eigenspectra", which reveal spatial correlations and anti-correlations in the data. The projection of eigenspectra on the data cubes are called "tomograms" and map their spatial distribution. Left panels show tomograms PC3 and PC4, and right ones show the respective eigenspectra. **PC3 component (Variance 0.22%):** narrow line emission shows an inverse correlation with the broad component of H α (red in the tomogram). Narrow line emission (blue) are approximately co-spatial with the radio jet. **PC4 component (Variance 0.08%):** narrow line emission shows redshifts anti-correlated to blueshifts, possibly due to a bipolar outflow.

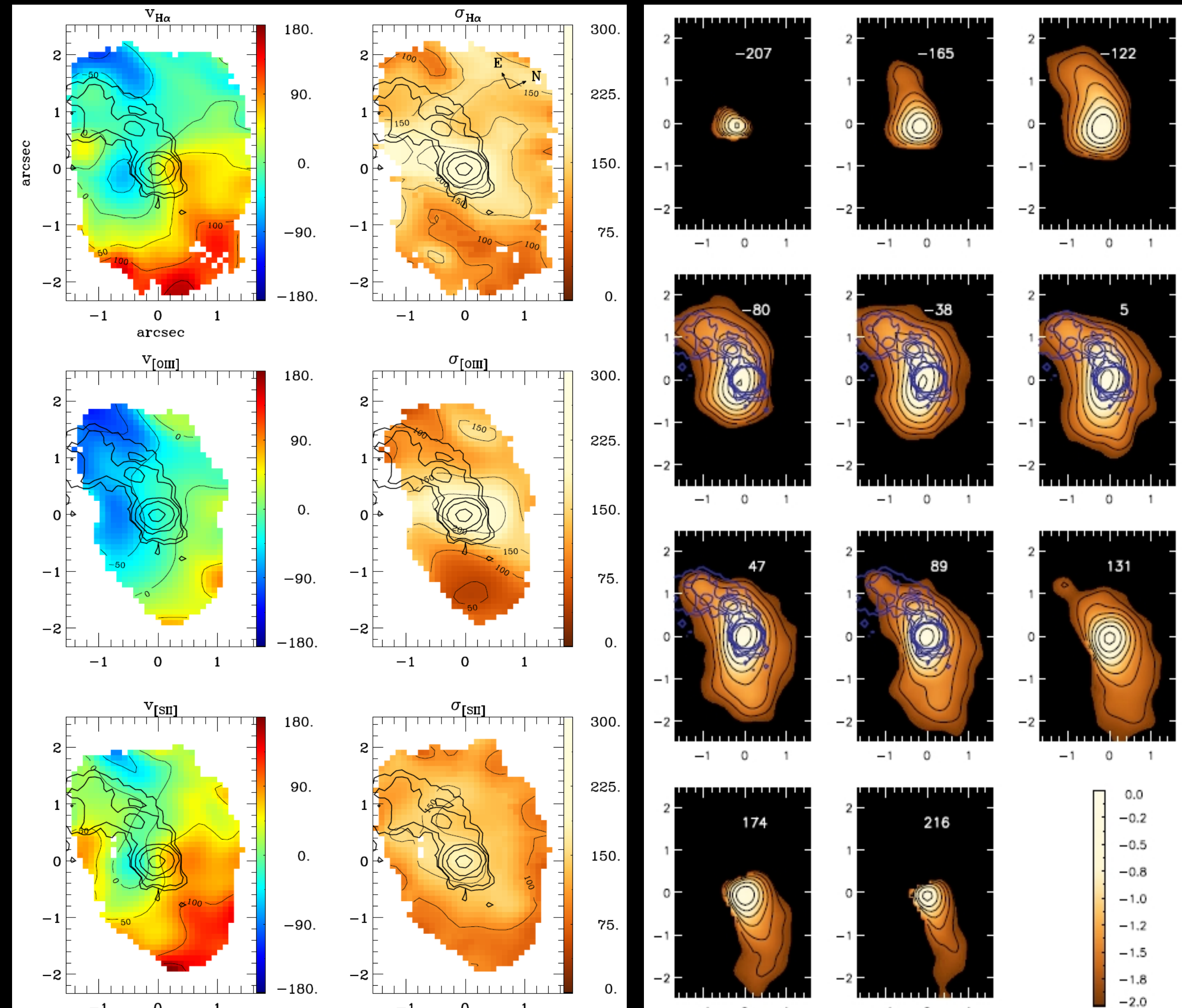


Fig. 3. **Left:** Centroid velocity maps showing redshifts to W and blueshifts to E, in a distorted rotation pattern, which can be due to the combination of rotation and outflows. **Right:** Velocity dispersion maps. Highest dispersions (~ 270 km/s) are observed around the nucleus and extending to the SE and NW. Black contours show the radio structure in 8.4 GHz (jet), along which there is a decrease in the blueshift values of the gas emission.

Fig. 4. Channel Maps along H α , with velocities indicated at the top right corner of each panel, in km/s. Flux units are 10^{-15} erg cm $^{-2}$ s $^{-1}$ spaxel $^{-1}$, in logarithmic scale. Blue contours delineate the radio structure which correlates with the E spiral arm, along which both blueshifts and redshifts are observed. We interpret this as a signature of an outflow close to the plane of the sky, related to the radio jet. The emitting gas to the W shows only redshifts.

Fig. 5. **Left:** Reddening map, with E(B-V) obtained from H α /H β . Highest reddenings (E(B-V) ~ 0.4) are observed at the nucleus and to SE and NW. **Right:** Gas densities, in cm $^{-3}$, derived from the [SII] ratio. Highest densities (~ 900) are observed at the nucleus and at the northern border of the E arm (~ 500), particularly in a knot located in the region where the radio jet bends to the S.

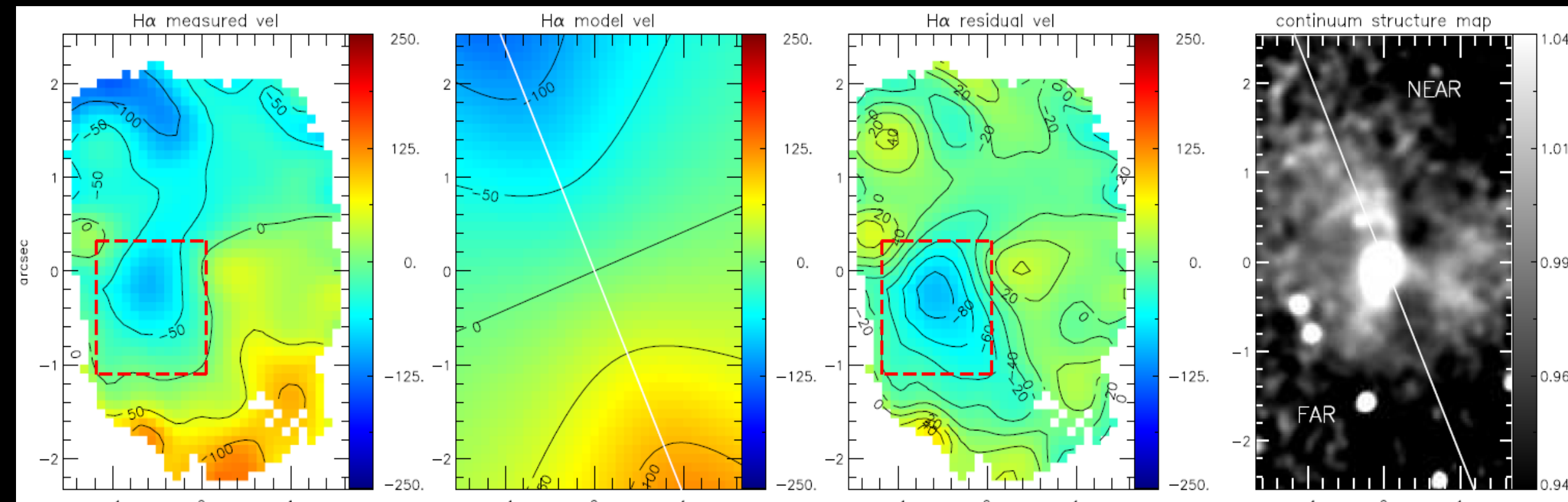
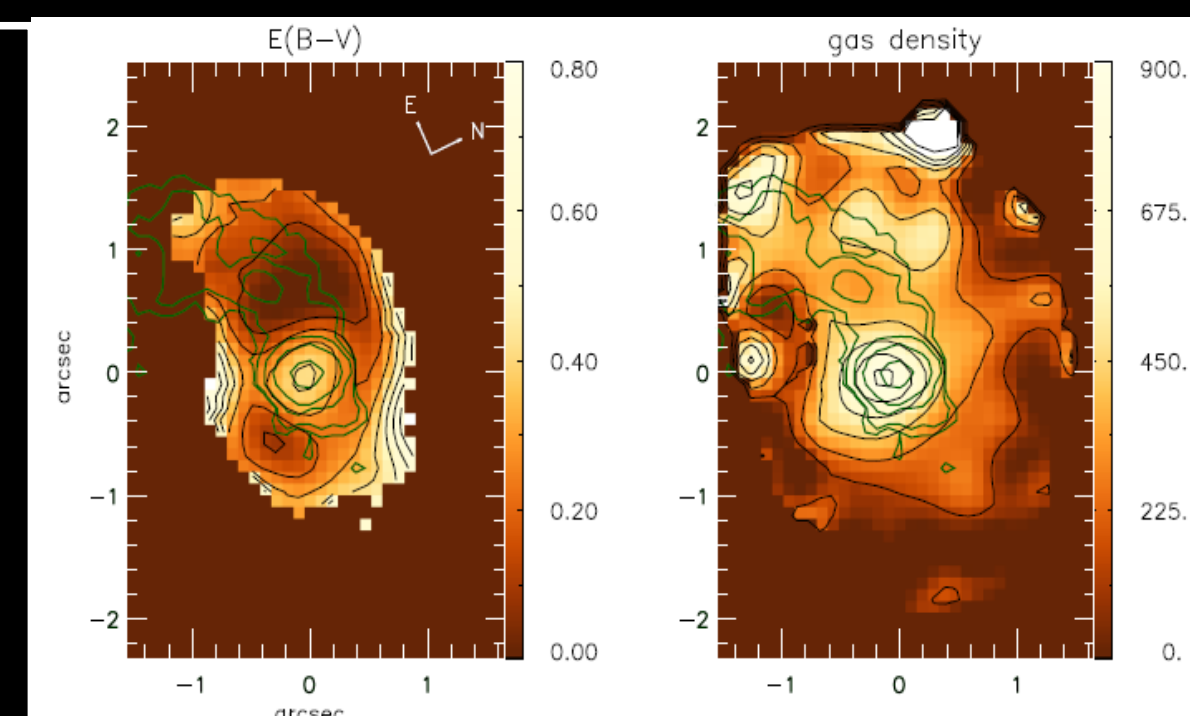


Fig. 6. Gas rotation model for H α , assuming circular orbits in a plane. **Left:** centroid velocity map. **Middle left:** rotation model. **Middle right:** residual map. **Right:** structure map from HST ACS continuum image. The red dashed box illustrates the masked region due to high residual velocities, from a possible outflow. The white line displays the line of nodes. Velocities are in km s $^{-1}$. The disk inclination is 79°. A dust lane revealed by the structure map supports a high inclination.

Main conclusions:

- We propose a scenario (Couto et al., in preparation) in which the gas observed in the inner kiloparsec of Arp 102B was captured in an interaction with its companion, Arp 102A and settled in a rotating disk in the inner kiloparsec. The inflow of this gas towards the nucleus ignited the nuclear activity, giving origin to a radio jet launched close to the plane of the sky. Interaction of the jet with the rotating gas gave origin to the arms which are regions of enhanced emission due to compression by the radio jet. The jet, launched approximately along the line of nodes of the rotating disk, gets deflected to high disk latitudes in a high density gas knot, dragging along gas located in the disk, forming the spiral arms. The E arm is deflected towards us and the W arm is deflected away from us. Besides the outflow along the radio jet, we found another outflow, more compact and probably more recent, oriented approximately perpendicular to the previous one.