

A new sky subtraction technique for low surface brightness data



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INTRODUCTION

Low-surface brightness ($\mu_B > 23$ mag/arcsec²) outer regions of galaxies contain crucially important information for understanding the properties of their extended discs and dark matter haloes. Analysis of absorption line spectra at such surface brightness levels is often hampered by systematic errors of the sky subtraction. Here we present a new approach to the sky subtraction for long-slit spectra based on the controlled reconstruction of the night sky spectrum in the Fourier space using twilight or arc-line frames as references.

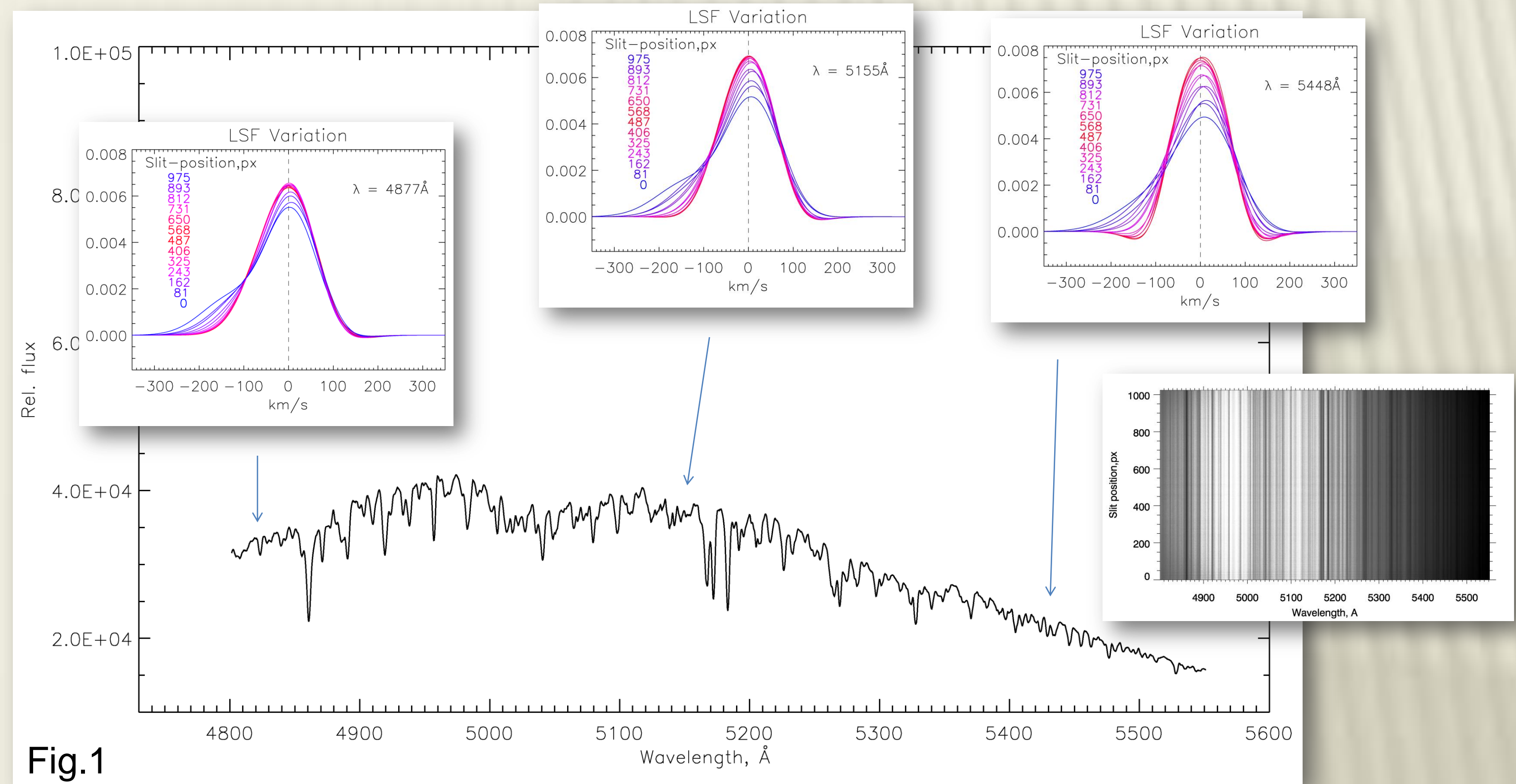


Fig.1

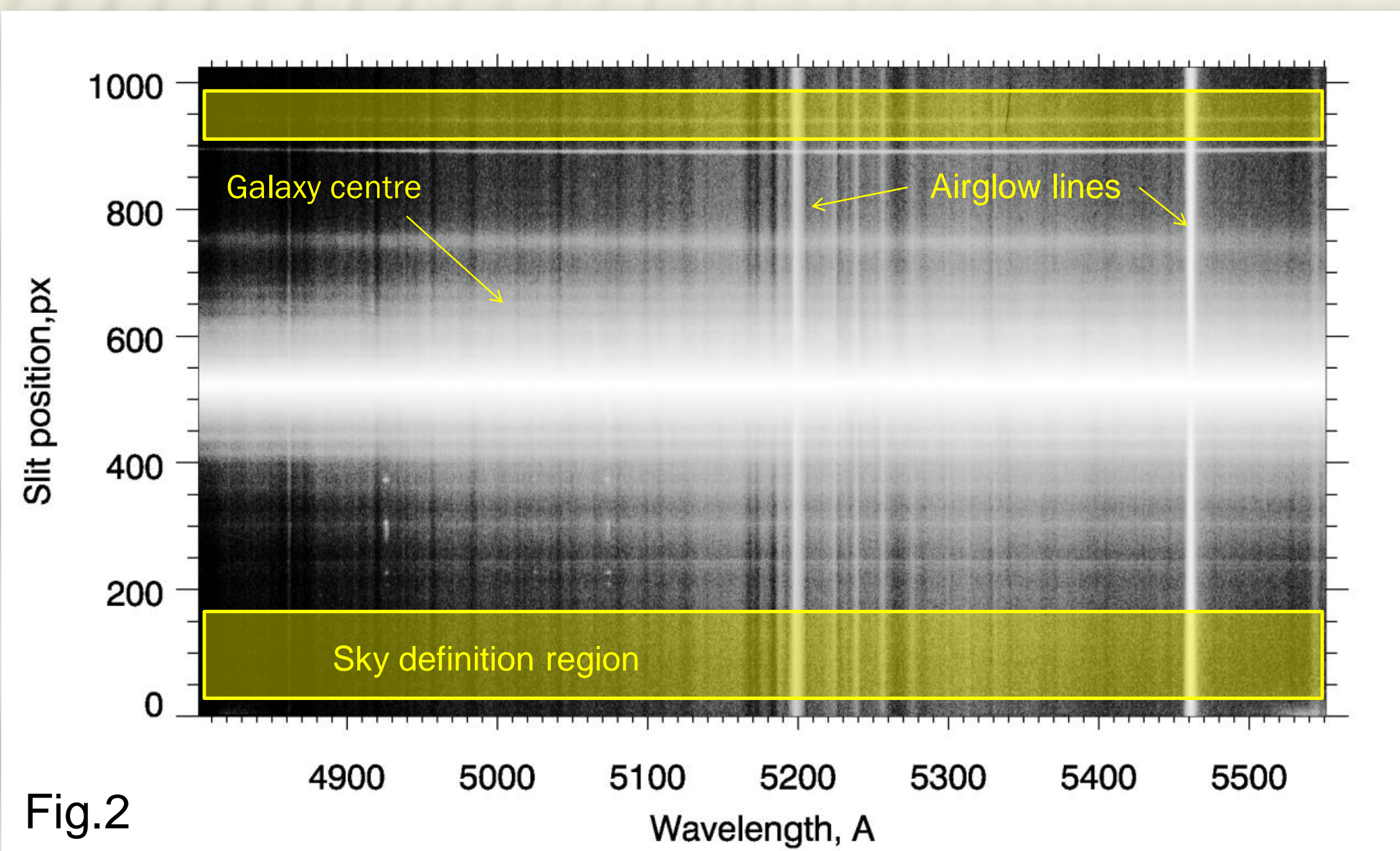


Fig.2

Due to optical distortions, the shape of the spectral line spread in a longslit spectrograph varies along the wavelength range as well as along the slit. In Fig.1, we provide an example of the LSF shape of the SCORPIO¹ universal spectrograph at the Russian 6-m telescope reconstructed from the twilight frame (i.e. the Solar spectrum). The LSF is slightly asymmetrical and cannot be described by the Gaussian function, a usual parametrization in most data reduction packages.

These LSF variations affect the night sky spectrum which is subtracted from science frames during the data reduction. On the Fig.2 we show a reduced long-slit spectrum of the spiral galaxy NGC 5440 before the sky subtraction step.

SKY SUBTRACTION

TRADITIONAL TECHNIQUE (Fig.3)

In the traditional sky subtraction technique implemented in most standard data reduction packages (IRAF, MIDAS), the night sky spectrum is constructed from the outer regions of the slit which are (supposedly) free of the galaxy light as a κ -sigma clipped average. Then it is subtracted at every slit position.

DECONVOLUTION TECHNIQUE (Fig.4)

Our sky subtraction technique includes several steps:

1. An oversampled sky spectrum is created from the non-linearized spectra using the wavelength solutions in order to perform the pixel-to-wavelength coordinate mapping. Then it is approximated using a b-spline. This approach was proposed by ²Kelson (2003) to improve the sky subtraction in undersampled datasets.
2. At every position along the slit, we change the LSF shape inside this night sky spectrum using a Fourier-based technique into the LSF at that slit position. Assuming that an observed sky spectrum is a convolution of a true spectrum with the LSF and according to the convolution theorem, the LSF difference can be accounted by multiplying the Fourier transform of the original dataset by the ratio between the Fourier transforms of a template spectrum (high signal-to-noise twilight frame) in the two positions along the slit: the sky definition region and the current position.
3. The b-spline parametrization provides the necessary regularisation for the numerical stability of this procedure

Traditional technique

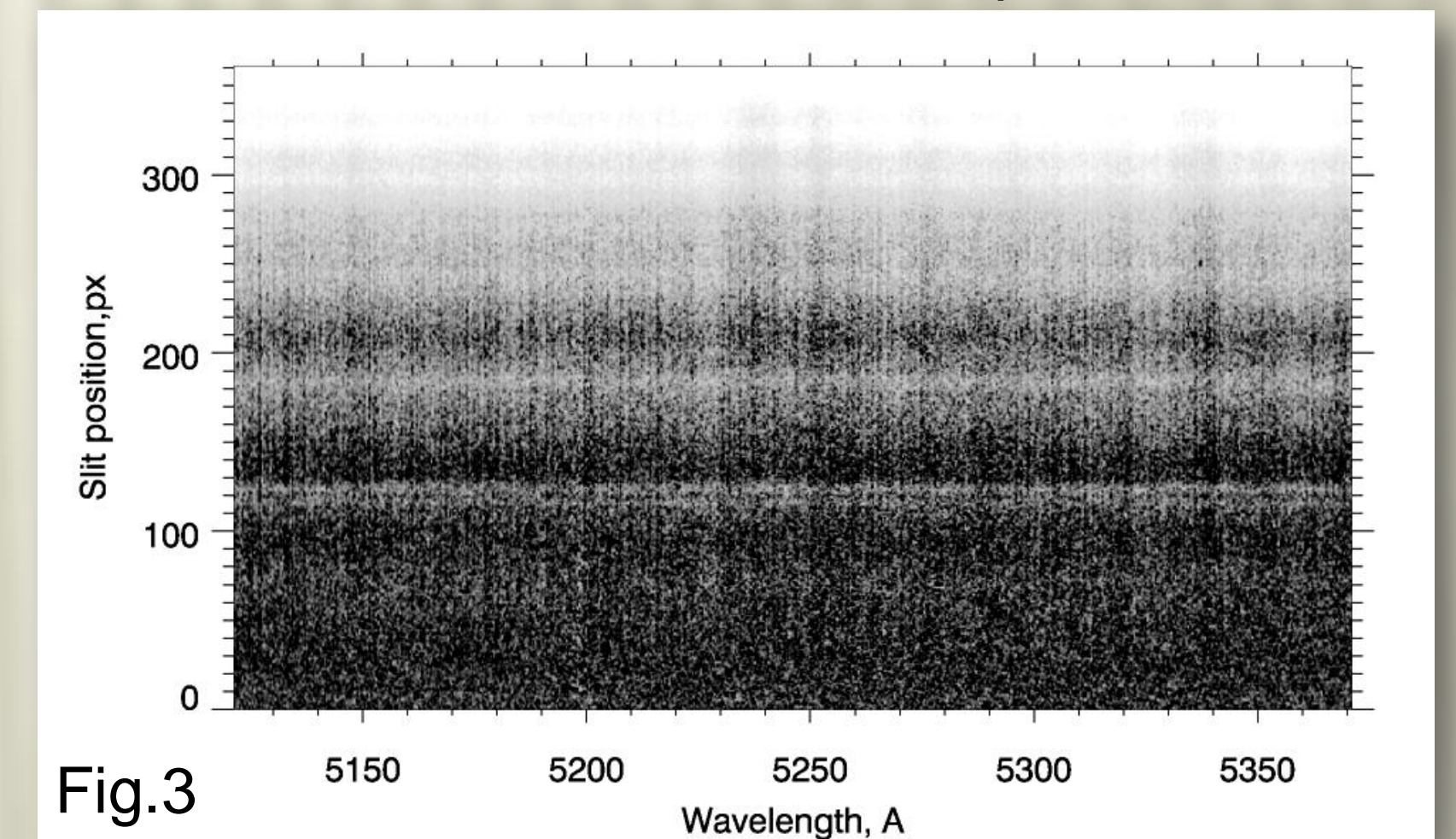


Fig.3

Deconvolution technique

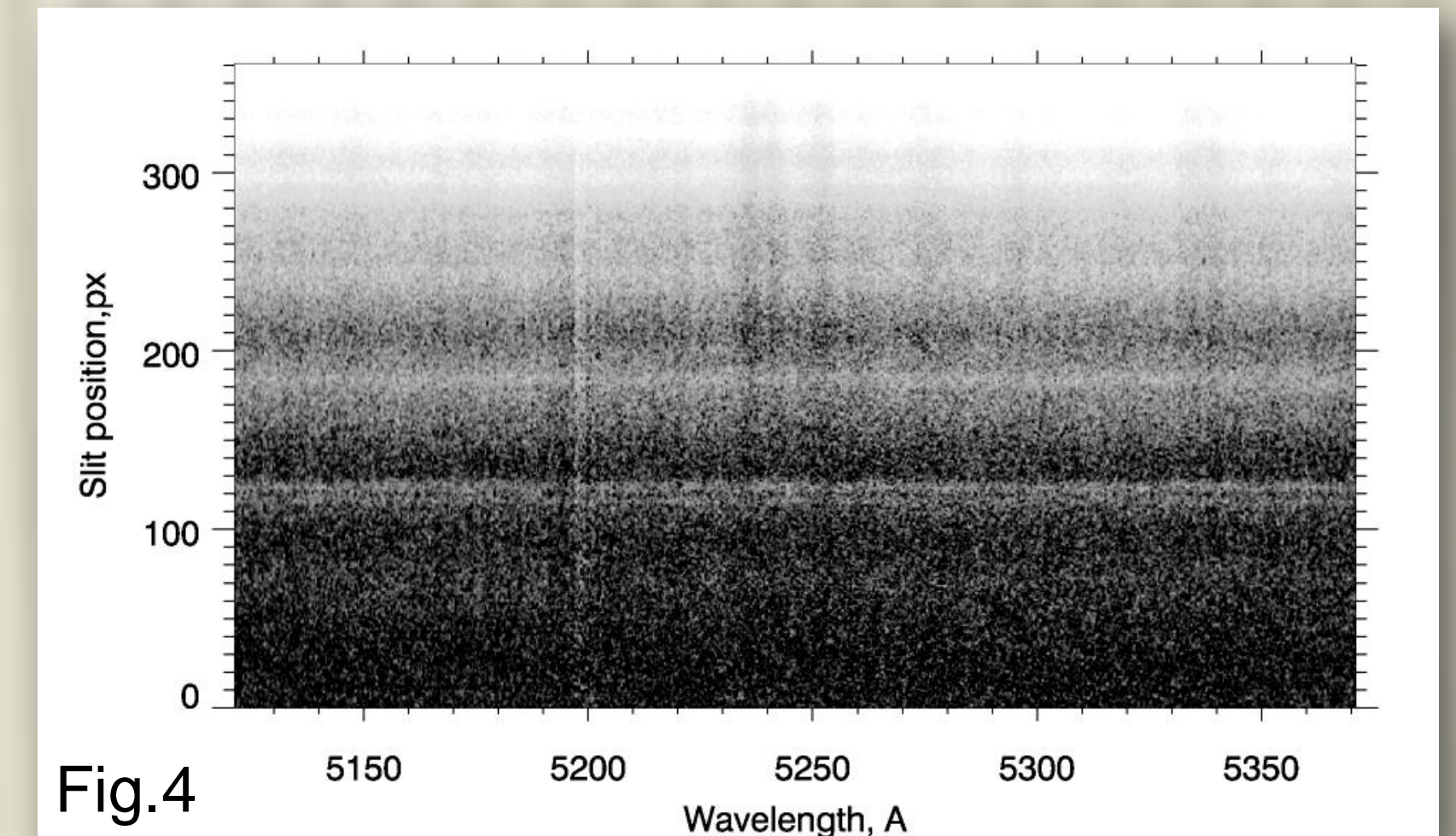


Fig.4

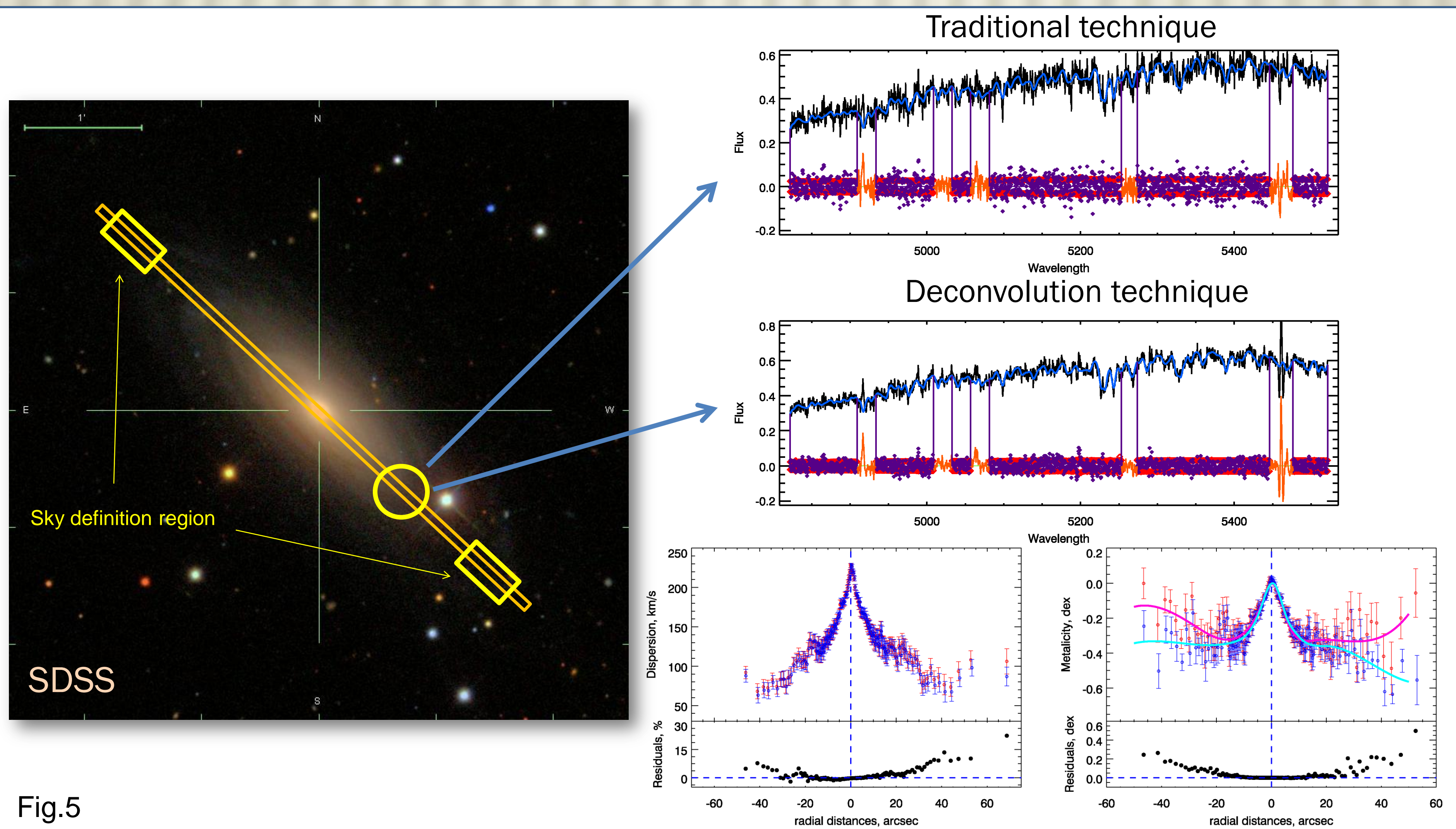


Fig.5

EXAMPLE : NGC 5440

Here we present the result of the data analysis of a longslit spectrum of NGC 5440 for the two sky subtraction techniques. We fitted the reduced sky subtracted spectra with high resolution stellar population models with the NBursts full spectral fitting technique³ and extracted kinematical (radial velocity and velocity dispersion) and stellar population (age and metallicity) parameters along the slit. The radial profiles of velocity dispersion and metallicity are shown in Fig.5. While the measurements are very similar near the galaxy centre, they differ notably in the peripheral regions. With the new sky subtraction technique the uncertainties are lower, and the general trend of the galaxy metallicity gradient correspond to the physical expectations. The traditional sky subtraction technique possesses systematic errors in the low surface brightness regime, which propagate to the data analysis and may result in misleading astrophysical conclusions.

ACKNOWLEDGEMENTS

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REFERENCES

- ¹Afanasiev & Moiseev, 2005
²Kelson, 2003 ³Chilingarian et al. 2007