PMAS-PPAK integral-field spectroscopy of nearby Seyfert and normal spiral galaxies

I. The central kiloparsecs of NGC 4138

Bartáková T.[1], **Jungwiert B.**[2,3], **Sánchez S. F.**[4,5], **Stoklasová I.**[2], **Emsellem E.**[6], **Ferruit P.**[7], **Jahnke K.**[8], **Mundell C.**[9], **Tacconi-Garman L. E.**[6], **Vergani D.**[10], **Wisotzki L.**[11]

1 Department of Theoretical Physics and Astrophysics, Faculty of Science, Masaryk University, Brno, Czech Republic;
2 Astronomical Institute, Academy of Science of the Czech Republic, Prague, Czech Republic; 3 Astronomical Institute of the Charles University in Prague, Czech Republic;
4 Centro de Estudios de Física del Cosmos de Aragón (CEFCA), Teruel, Spain; 5 Centro Astronómico Hispano-Alemán, Calar Alto, Almería, Spain;
6 European Southern Observatory, Garching, Germany; 7 CRAL-Observatoire de Lyon, Saint-Genis-Laval, France; 8 Max-Planck-Institut fur Astronomie, Heidelberg, Germany;
9 Astrophysics Research Institute, Liverpool John Moores University, United Kingdom; 10 INAF-Osservatorio Astronomico di Bologna, Italy; 11 Astrophysical Institute Potsdam, Germany.

email: `terka@physics.muni.cz`

Project overview

We study properties of ionized gas, gas/stellar kinematics and stellar populations in central regions (a few inner kiloparsecs) of four pairs of nearby Seyfert (*NGC 5194*, *NGC 4579*, *NGC 4151*, *NGC 4138*) and normal spiral galaxies (*NGC 5505*, *NGC 3351*, *NGC 2985*, *NGC 3245*).

While the key to the AGN fuelling and growth of the central supermassive black holes lies certainly closer to the nucleus than 1 kpc, establishing the connection between 100 pc and 1 kpc scale is one of unavoidable preliminary steps: the velocity field at 100 pc can be very complex and its modeling requires a prior understanding of larger scales. Also, signatures of past inflow can be expected in the kpc-scale radial gradients of stellar age, metallicity and velocity dispersion. Our main goals are to: **1.** look for systematic differences in central stellar populations and stellar/gaseous kinematics between Seyfert and non-active galaxies; **2.** estimate inflow/outflow to/from the central kpc; **3.** put constraints on the central kpc fuelling via stellar mass-loss. The sample is intended as a pilot study to demonstrate the efficacy of using the PMAS-PPAK integral field spectrograph for the study of active and inactive galaxies over a uniquely wide range of size scales.

Observations

Eight nearby ($0.001 < z < 0.005$) galaxies were observed with PMAS-PPAK IFU at the Calar Alto 3.5 m telescope with FOV of $74'' \times 64''$ (see Fig. 1) and spatial sampling of $2.68''$, i. e. $\sim 100 - 260$ pc. Our data were obtained in two setups: **1.** range $3600 - 7000$ Å with resolution of ~ 10.7 Å (FWHM); **2.** range $6200 - 6900$ Å with resolution of ~ 2.77 Å.

The spectra contain stellar absorption features, e. g. Balmer lines, MgI, Fe lines, CaII H and K lines, useful to constrain stellar populations and kinematics, as well as emission lines including Hα, Hβ, [OI], [OII], [OIII], [NI], [NII], [SII] for deriving gas kinematics and ionization sources, extinction, electron density and star formation rate. The range $6200 - 6900$ Å centered on Hα was chosen to get more precise gas kinematics.

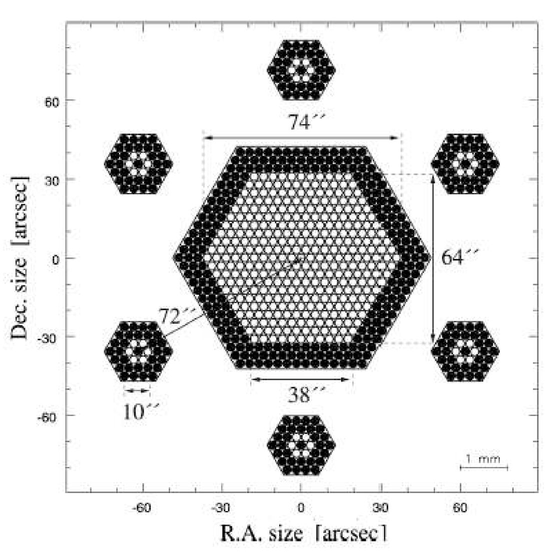

Figure 1: PPAK layout: 331 object fibers surrounded by 36 sky fibers. The black circles are just protective buffers. From Kelz el al. (2006).

2D maps of NGC 4138

Here we present 2D maps for a Seyfert 1.9 galaxy *NGC 4138* (d $\sim$ 16 Mpc, $1'' \sim 80$ pc). While it is morphologically classified as SA(r)0$^+$ and looks very regular on optical images, it displays major kinematical disturbances – two counterrotating stellar disks, a counterrotating gaseous disk and a gaseous warp (Jore et al., 1996) – as well as a chemically distinct core (Afanasiev & Silchenko, 2002). It also possesses a spectacular Hα ring (Pogge & Eskridge, 1987) at $R \sim 22''$ (~ 1.7 kpc) while it shows no large-scale bar.

These peculiarities are suspected to be related to a minor merger, however they could also be related to a destroyed bar, or a combination of both. New studies are necessary to understand the galaxy history and mass transfer within the inner kiloparsecs. Our new data bring, for the first time, the 2D spectroscopic coverage of the whole region encompassed by the ring.

We modelled the absorption features and slope of the spectra using the synthetic library of Bruzual & Charlot (2003) to derive LOS stellar velocities and continuum flux and to make correction for stellar absorption. Emission lines were fitted by simple Gaussian functions to obtain line intensities, mean LOS velocities and velocity dispersions. See Figs. 2. – 4. We also show spectral diagnostic diagrams in Fig. 5. to constrain ionization sources.

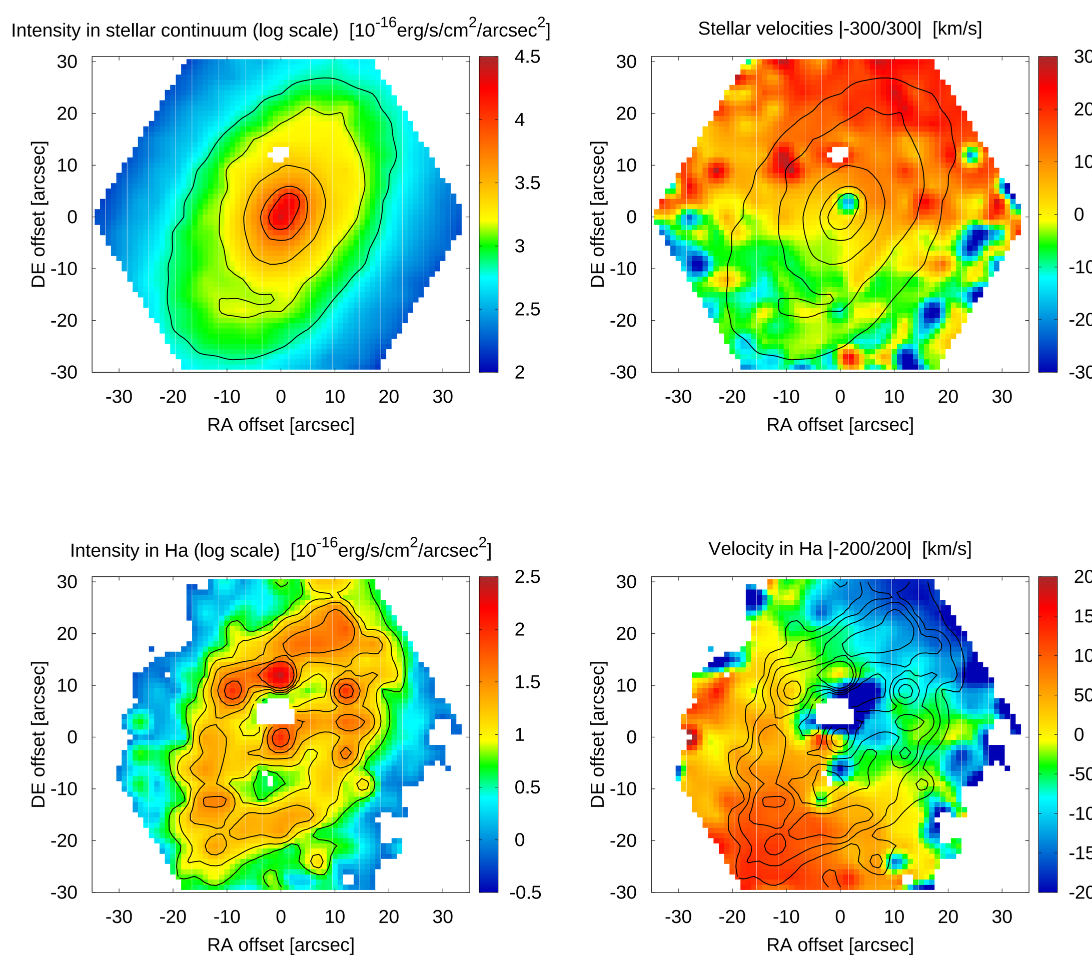

Figure 2: Intensity and mean LOS velocity of stars (*top*) and in Hα line (*bottom*). One can see very different morphologies – smooth stellar light, gaseous ring surrounding a gaseous mini-bar – and rotation in opposite directions.

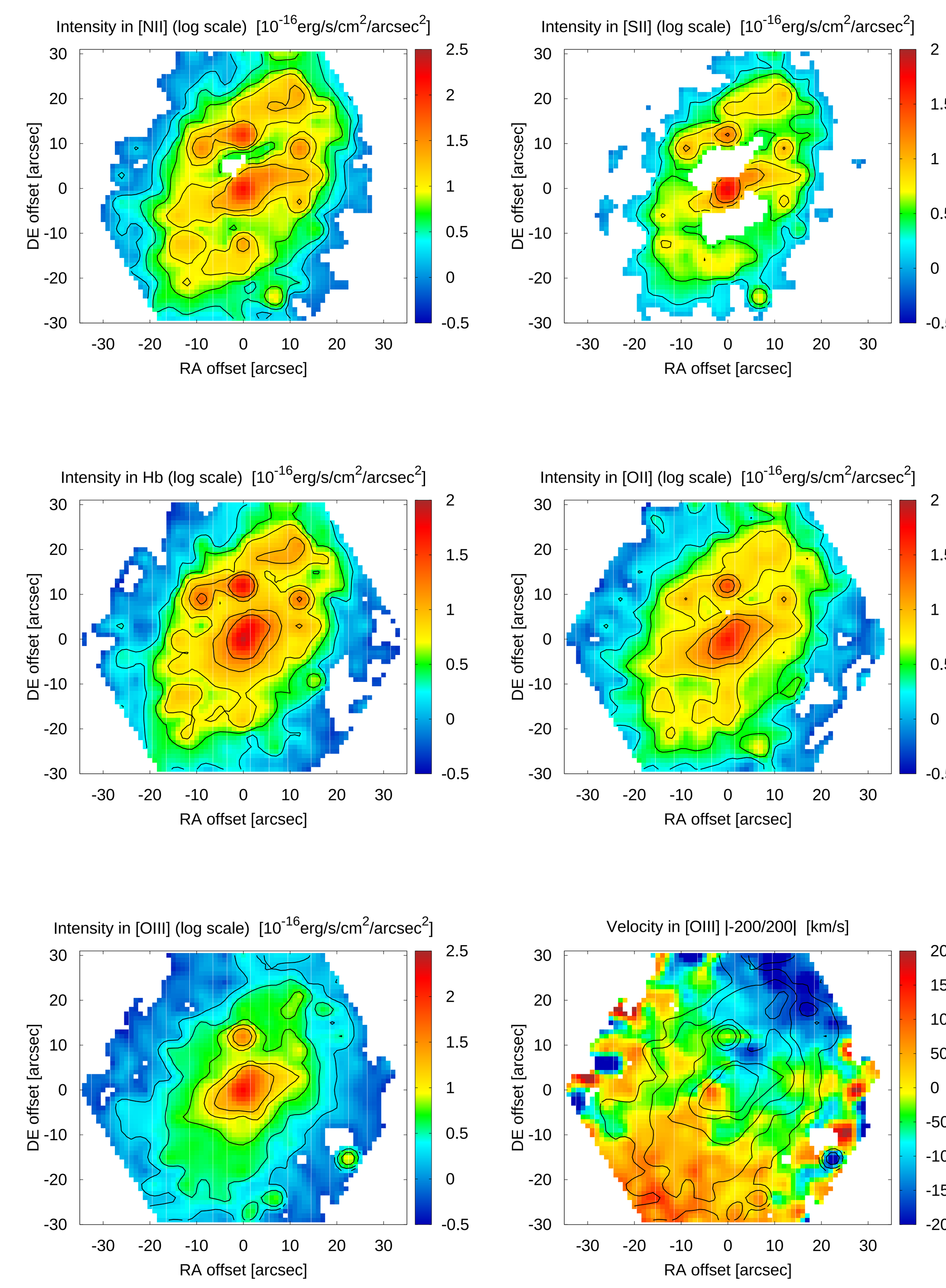

Figure 3: Intensity of [NII]6583Å, [SII]6731Å, Hβ, [OII]3727Å and [OIII]5007Å with mean LOS velocity field.

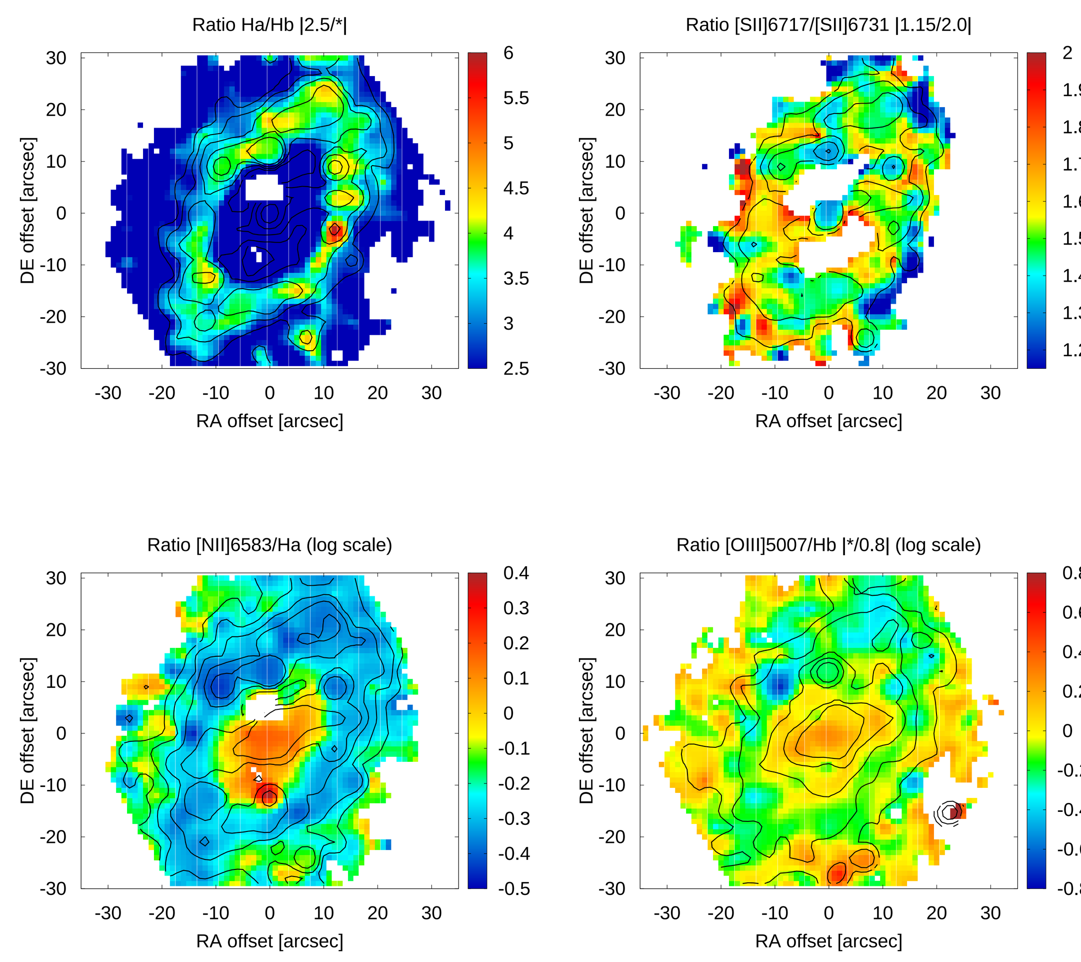

Figure 4: *Top left:* Map of Hα/Hβ intensity ratio tracing the interstellar redenning: the highest extinction follows the ring. *Top right:* Map of [SII]6717/[SII]6731 ratio, which is related to electron density distribution: highest ratio values correspond to lowest electron densities. *Bottom left* and *right:* Maps of [NII]/Hα and OIII/Hβ ratios show that gas in the inner region is most probably ionized by the AGN, while stars dominate the ionization of the ring.

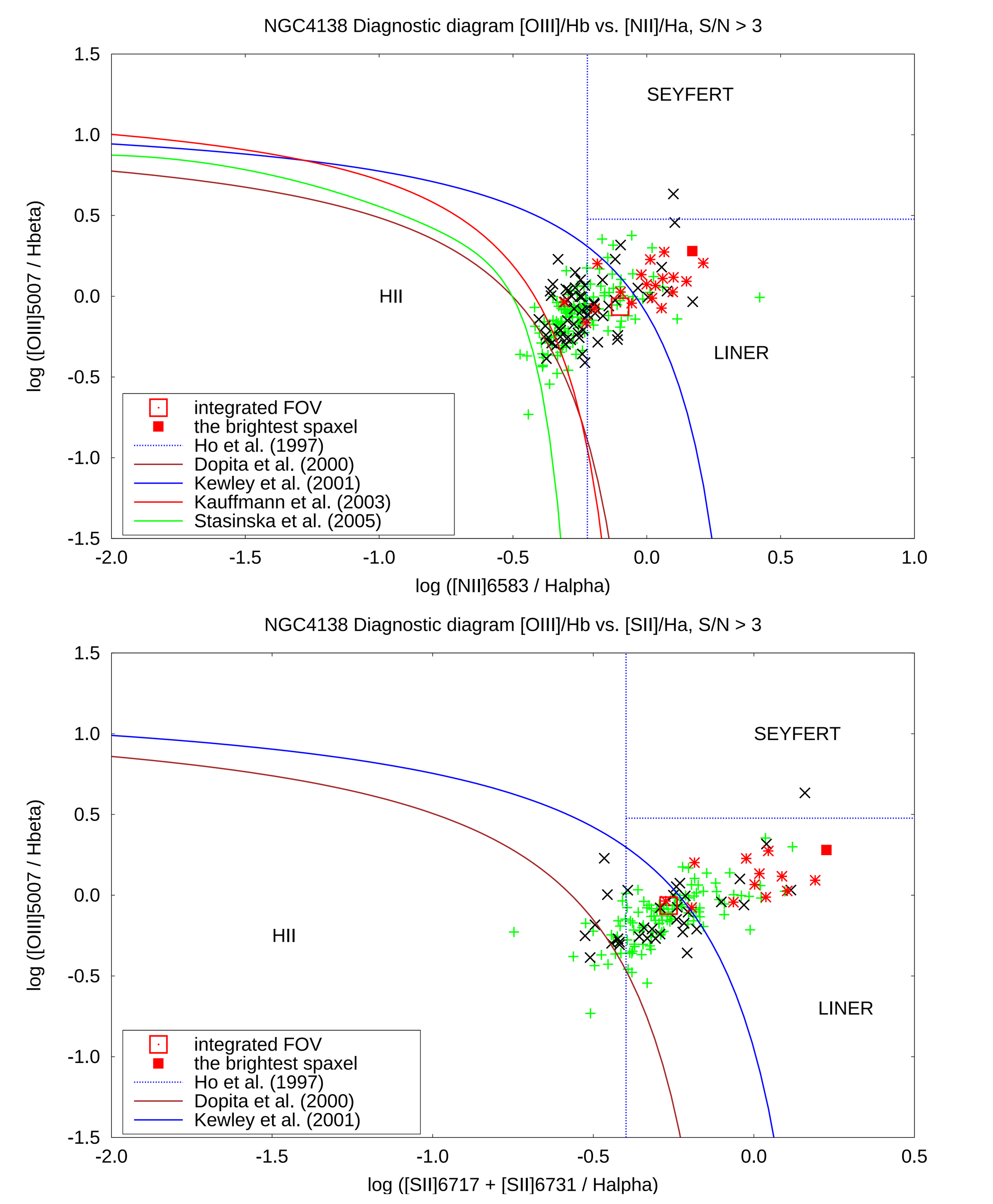

Figure 5: Spatialy resolved diagnostic diagrams; central spaxels with $R \leq 10''$ are *red*, those with $10'' < R \leq 25''$ are *green* and spaxels with $R > 25''$ are *black*.

Acknowledgements

This project is supported by grants No. 205/08/H005 (Czech Science Foundation), AV0Z10030501 (Academy of Sciences of the Czech Republic), LC06014 (Center for Theoretical Astrophysics, Czech Ministry of Education) and MUNI/A/0968/2009 (Masaryk University in Brno). The data were obtained under the EU Opticon Access Program following a proposal (PI: B. Jungwiert) submitted in the framework of the EU Research Training Network. “Euro3D - Promoting 3D Spectroscopy in Europe”.

References

[1] Afanasiev V. L. & Silchenko O. K., 2002, ApJ **124**, 706

[2] Bruzual G. & Charlot S., 2003, MNRAS **379**, 1000

[3] Jore K. P., Broeils A. H., & Haynes M. P., 1996, AJ **112**, 438

[4] Kelz A., Verheijen M. A. W., Roth M. M., Bauer S. M., Becker T., Paschke J., Popow E. & Sánchez S. F., 2006, PASP **118**, 129

[5] Pogge R. W., & Eskridge P. B., 1987, AJ **92**, 291

Poster presented at the conference “What drives the growth of black holes?”, Durham, England, July 26-29, 2010