Unexplored outflows and feedback in low-luminosity AGNs: the case of NGC1052

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Multiphase-outflows play a central role in galaxy evolution shaping the properties of galaxies and regulating their nuclear activities through feedback. Understanding outflows and their feedback effects in low luminosity AGNs as LINERs is essential, as they bridge the gap between starburst and active galaxies, being the most numerous local AGN population.

For the prototypical nearby low luminosity AGN NGC1052, we recently obtained new IFS observations at high spatial (~40pc scale) and spectral (R~6000) resolution, with MUSE@VLT and MEGARA@GTC, respectively. These data sets will allow us to map, for the first time, the kinematics and spatial distribution of both ionised and neutral gas in NGC1052 up to ~5kpc. The preliminary results of this study (Cazzoli et al. in preparation), that sets the ground for exploring outflows and feedback in LINERs, will be presented.

Outflows and Feedback

Outflows, produced by AGNs and intense star-formation, have been proposed to play a crucial role in regulating (feedback) the stellar mass and black-hole mass growth (Kormendy & Ho +13). The different gas phases of outflows have been widely studied in different galaxies populations (Veilleux+05). ***For low luminosity AGNs as LINERS*** (low-ionization nuclear emission line regions) ***outflows and feedback effects are still largely unexplored***. This is specially relevant, since LINERs are thought to be the most numerous local AGN population (Ho+08).

Except for individual discoveries (e.g. Dopita+15) the only systematic studies of outflows in LINERs are by Cazzoli+18 and Hermosa-Muñoz+20 based on optical long-slit spectroscopy. Among the explored LINER population (30 sources), outflows seem common in type-1 LINERs (detection rate: 60%) also showing a large-scale biconical or bubble-like ionised gas morphology along with sub-structures as gas clumps of sizes ~ 20-70 pc in their HST-Hαλ6563 image (Masegosa +11).

The case of NGC1052

We obtained both MUSE and MEGARA IFS data, for this prototypical LINER (type-1 AGN) hosted by an elliptical galaxy,

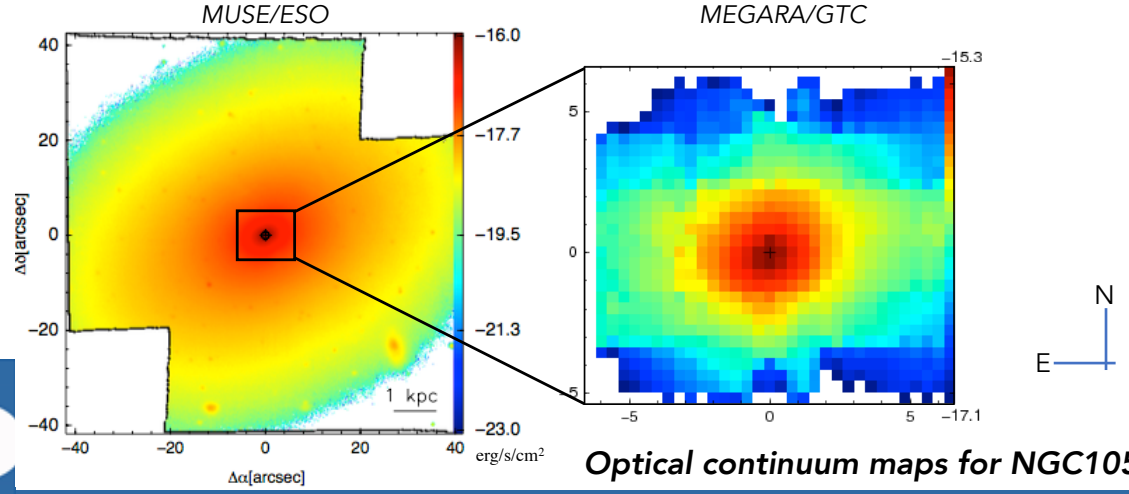
There are two previous integral field spectroscopy (IFS) studies by Sugai+05 and Dopita+15 focussing on NGC1052, but they are limited either in spectral range or in field of view (FoV) and in spatial sampling.

METHODOLOGY

We aim to use the unrivalled features of the MUSE and MEGARA IFU to map the kinematics and spatial distribution of both ionized and neutral gas in low luminosity AGNs selected to show strong evidence for outflows on the basis of slit spectroscopy. These datasets will allow us to: (i) detected and map simultaneously two different phases of outflows at subkpc scale; (ii) unveil their ionization structure and identify outflowing gas clumps; ascribe to outflows the capability of (iii) regulating nuclear activities and/or (vi) forming stars, contributing substantially to the evolution of their host.

WORK FLOW

- ✤ Data reduction
- ✤ Voronoi binning by Cappellari & Chopin +04, S/N thresholds 40 (MUSE) and 20 (MEGARA)
- ✤ Stellar continuum modelling / subtraction with pPXF (penalized pixel fitting) and GIST (Cappellari+17; Bittner+19)
- ✤ Modeling of emission line and NaDλλ5890,5896 and generation of the maps (velocity, velocity dispersion and flux)
- ✤ Analysis of the maps (e.g. kinematics line ratios); estimate of outflow properties and feedback



Optical continuum maps for NGC1052.

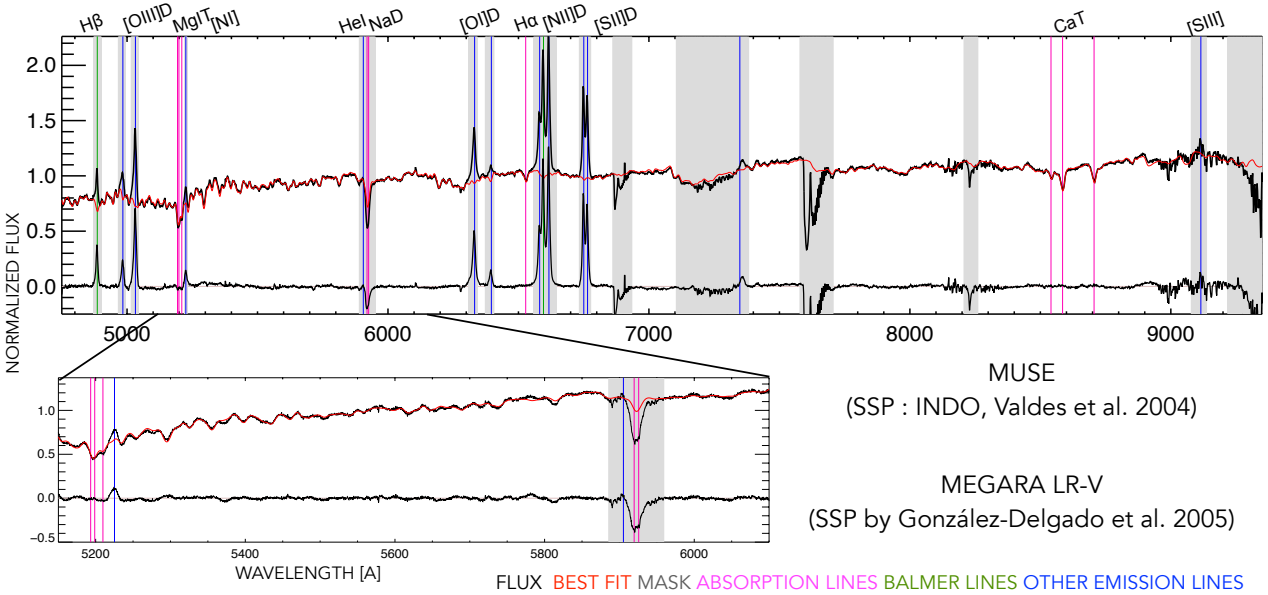
MUSE @ 8.2m Very Large Telescope

- Δλ = 4750-9350 A; R~4000
- Spaxel size: 0.2" FoV: 1'x1'(WFM);
  mosaic of two pointings for total FoV of ~80"x80"

MEGARA IFU @ 10.4m Gran Telescopio Canarias:

- Δλ = 5143-6164 A (LR-R) & 6094-7300 A (LR-V); R~6000
- Spaxel size: 0.6" FoV: 12.5"x11.3"

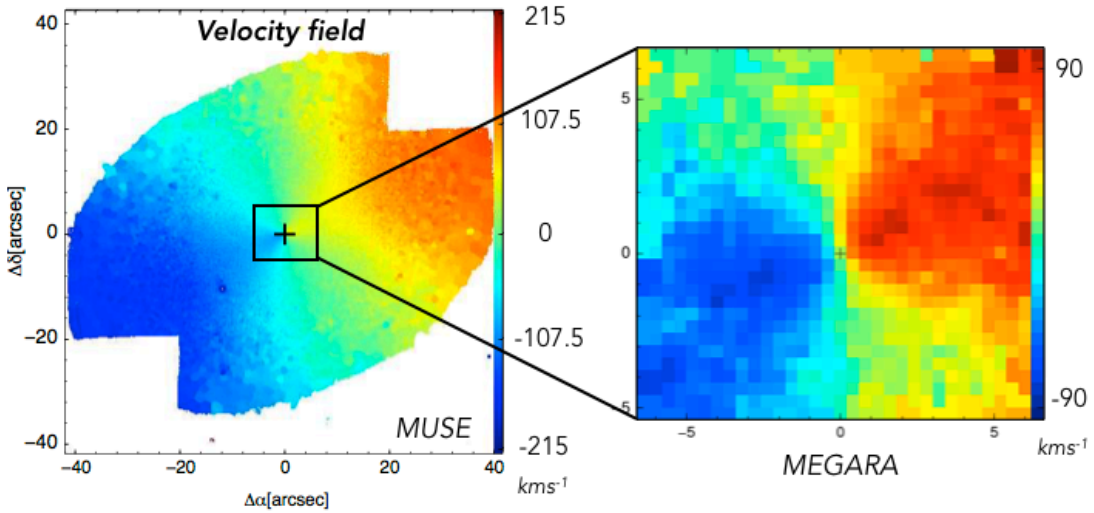
Stellar kinematics

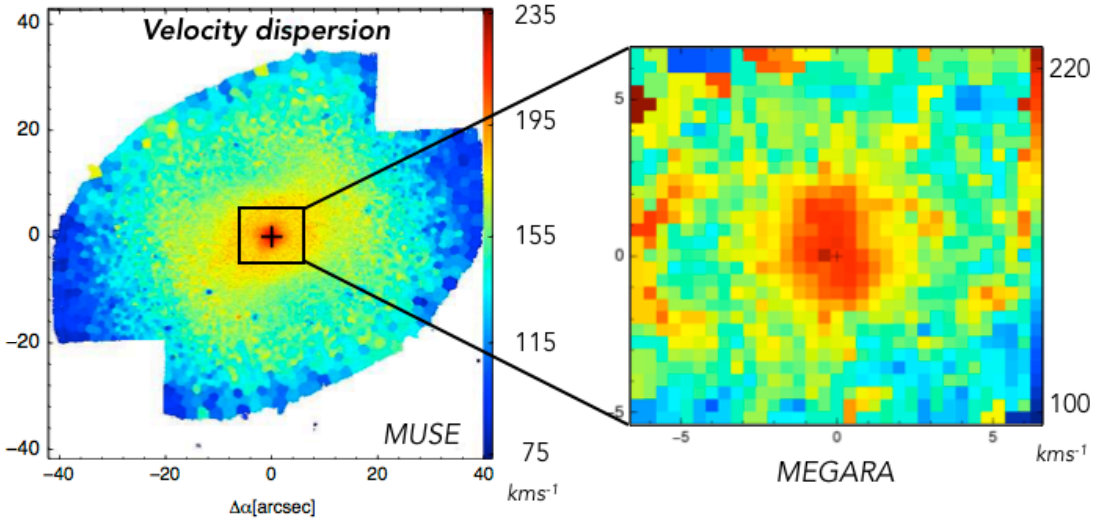


After producing high S/N cubes (Voronoi Tesselation), we applied the pPXF analysis for the recovery of the shape of the stellar continuum and extract its kinematics.

Stellar kinematics

The velocity field presents a pattern consistent with a rotating disc. The major kinematic axis (PA = 115) is well aligned with the photometric one (PA = 113, Hyperleda). The velocity dispersion map shows a centrally peaked pattern with its maximum value, 220 km/s in positional agreement the photometric center.





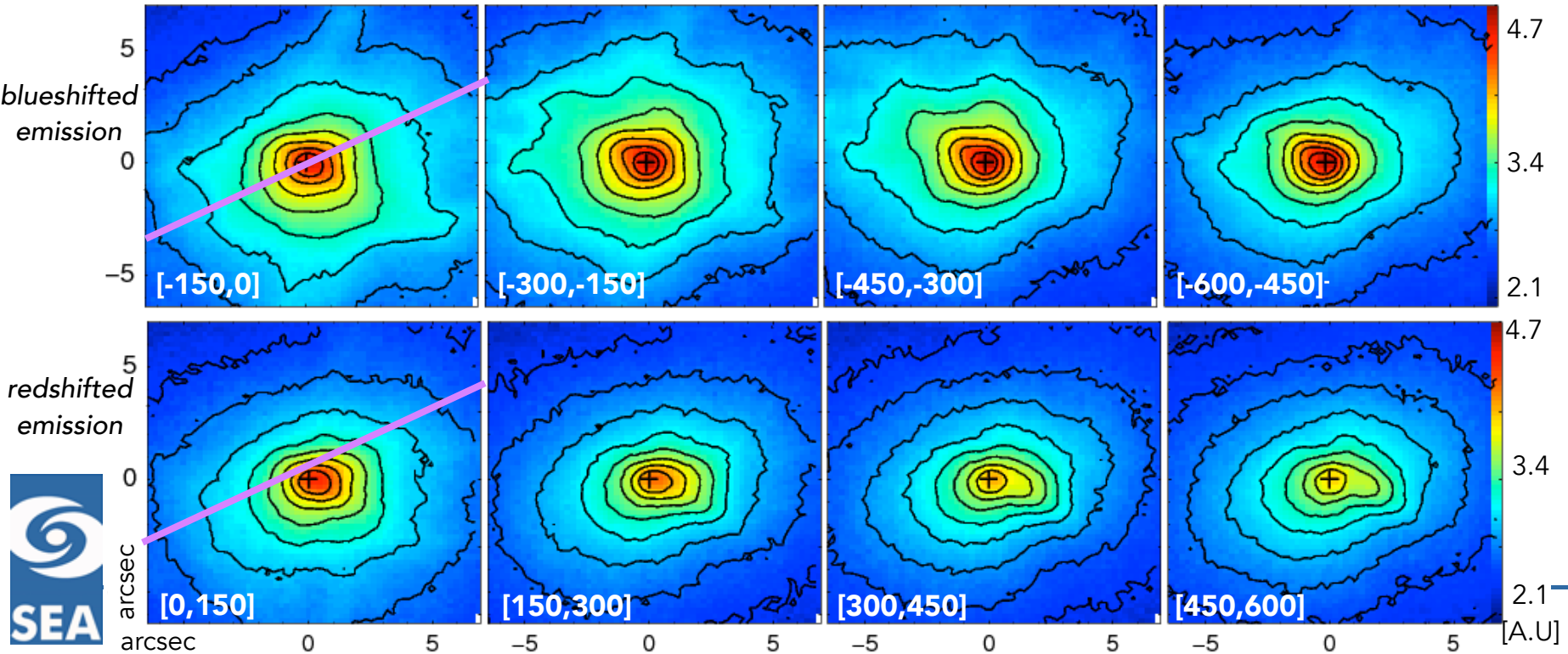
Example of stellar continuum modelling/subtraction (top) and stellar velocity and velocity dispersion maps (bottom).

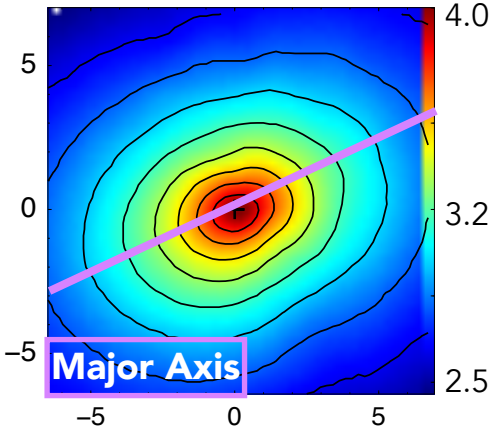
Tomography of the [OIII]λ5007 line

We present [OIII] channels maps in the central 12”x12” of NGC1052 providing hints of the kinematics and spatial distribution of the different components, prior an accurate multi Gaussian modeling (*ongoing)*.

The spatial distribution of the high velocity emission is different from that of the continuum. Specifically:

- *Blueshifted* emission (top): At velocities of |V|<150 km/s some ‘filaments’ are present e.g. towards the North. At their locations, lines profiles are generally double-peaked. At higher velocities, a bubble-like emission arises toward the North-East, roughly aligned with the minor kinematic axis. There, the line profiles show broad wings.
- *Redshifted emission* (bottom): The emission of the bubble seems dominant (no filaments) and somehow collimated as seen at the highest velocities displayed.





Continuum emission shown as reference

***Channels maps* of the [OIII] line**.
The channel width is 150 kms/s. Ten isocontours are overlaid to highlight the morphology; the cross marks the photometric center.

Preliminary results

- ***STELLAR KINEMATICS***

The velocity field presents a pattern consistent with a large (kpc-scale) rotating disc. The major kinematic axis (PA = 115deg) is well aligned with the photometric one (PA = 113deg, Hyperleda). The velocity dispersion map shows a centrally peaked pattern with its maximum value, 220 km/s in positional agreement the photometric center.

- ***[OIII] TOMOGRAPHY***

Channel maps reveal a bubble emission at high velocities along the minor axis of rotation, in positional agreement with the outflow seen in past works (Sugai+03, Dopita+15).

¿ WHAT NEXT ?

For NGC1052 (Cazzoli in prep)

- Modeling emission lines with multiple Gaussian components as well as the NaD absorption (as in Cazzoli+16,+20) in order to map the multiphase outflow in NGC1052 up to its full extent
- Study the morphology, clumpiness, gas density, mass-velocity distribution and energetics of the outflow of the feedback
- Comparison with the properties of outflows in different galaxy populations (e.g. Fiore et al. 2017)

For the local LINER AGN-population

- Systematic exploration of the outflow/feedback phenomenon via imaging and MEGARA-IFS (Hermosa-Muñoz in prep)

REFERENCES: Bittner et al. 2109 A&A 628, A117; Cappellari & Chopin 2003, MNRAS 342, 2; Cappellari 2017, MNRAS 466,1; Cazzoli et al. +2016 A&A, 590, A125, +2018 MNRAS 488, 1106; +2020 MNRAS 493, 3656-3757, Dopita et al. 2015 Apj 801,42; Fiore et al. 2017 A&A 601,143 González-Delgado et al. 2005 MNRAS 357, 3; Hermosa-Muñoz et al. (2020), A&A 635, A50; Ho 2008, ARA&A 46, 75; Kormendy & Ho 2013 ARA&A 51,1; Masegosa et al. 2011, A&A 527,A23; Sugai et al. 2005 Apj 629, 131; Valdes et al. 2004 ApJS 152, 251; Veilleux et al. 2005 ARA&43, 769. **CAZZOLI IN PREP.**