New results on NGC7469 from high-resolution IFU spectroscopy with MEGARA@GTC

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We present our analysis of high-resolution (R ~ 20 000) MEGARA@GTC IFS observations of Hα-[NII] emission, obtained during commissioning, in the inner region (12.5"x11.3") of the active galaxy NGC7469, at spatial scales of 0.62" (Cazzoli et al. 2020). MEGARA observations reveal, for the first time, the presence of a very thin (20 pc) ionised gas disc supported by rotation, embedded in a thicker (222 pc), dynamically hotter one. These discs nearly co-rotate with similar peak-to-peak velocities, but with different average velocity dispersion. The kinematics of both discs may be perturbed by star-forming regions. We interpret the morphology and the kinematics of a third (broader) component (σ > 250 km/s) as suggestive of the presence of non-rotational turbulent motions possibly associated either to an outflow or to the lense. For the narrow component, the [NII]/Hα ratios point to star-formation as the dominant mechanism for ionisation, whereas ionisation from shocks seems to be favoured in the case of the intermediate component.

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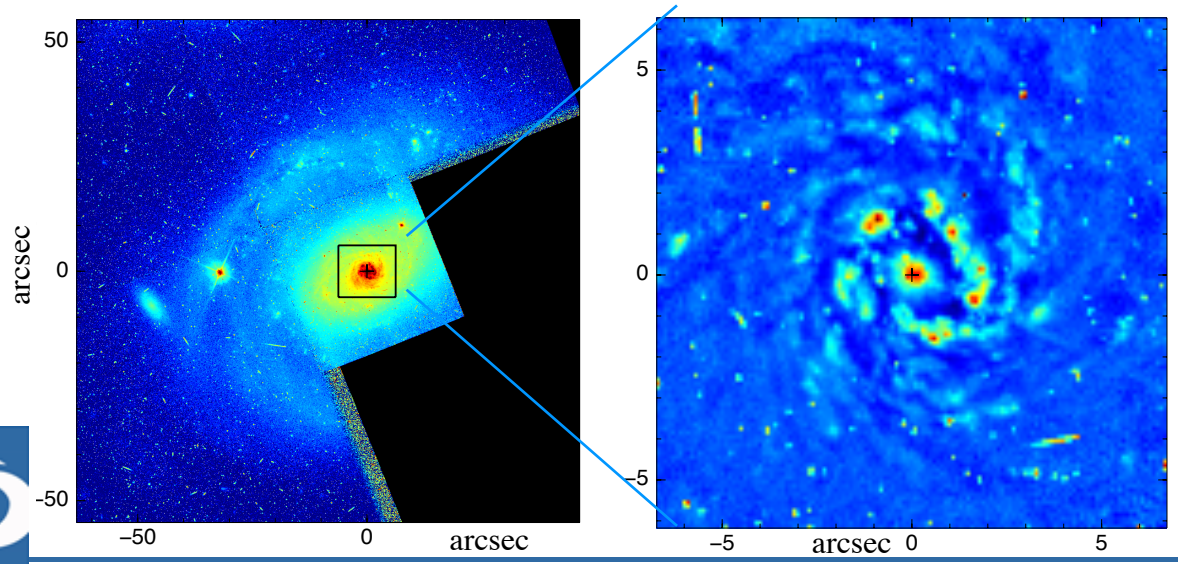
NGC7469 as seen by MEGARA

NGC7469

It is a nearby z~0.016, grand-design spiral galaxy hosting a Seyfert 1.5 AGN (Landt+2008). The powerful star formation (SF) activity, SFR = 48 Msun/yr (Pereira Santaella+2011), is mainly occurring in the circumnuclear star-forming ring bright at various wavelengths (e.g. Davies+2004, Colina+2007, Diaz-Santos+2007) and led NGC7469 to be enclosed among Luminous InfraRed Galaxies (LIRGs). The spatially resolved disc kinematic has been studied mainly through ALMA (Fathi+2015) and VLT/SINFONI (Müller-Sanchez+2011) observations of cold and warm molecular and ionised gas. Signatures of non-rotational motions, such as outflows, have been found at NIR and X-rays (e.g. Müller-Sanchez+2011, Blustin+2007).

MEGARA

The field of view (IFS mode) covers 12.5"x11.31" on the sky with a spaxel size of 0.6". We used the high resolution (R~20000) HR-R Volume Phase Holographic covering the 6406-6791 A spectral range. The dispersion is of ~0.097A/pixel, i.e. ~5km/s at the wavelength of Hα λ6563.



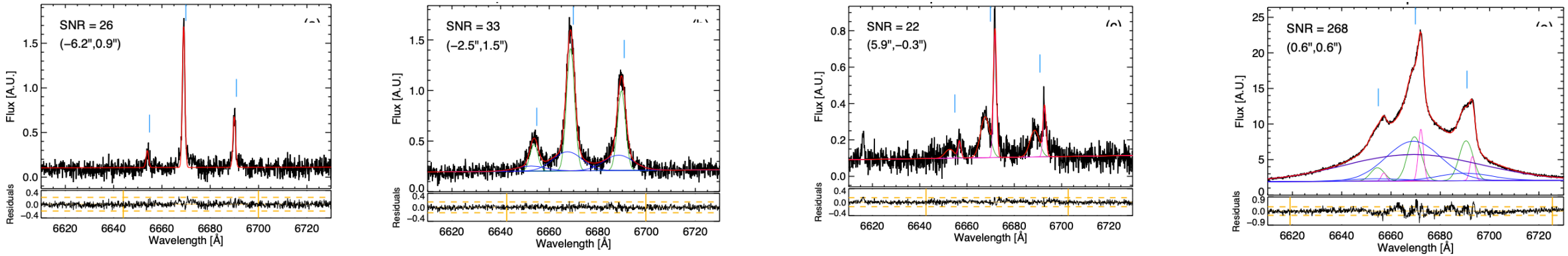
Optical images of NGC7469.
The left-hand panel shows the large-scale HST-WFPC2 image (F606W filter), whereas the right panel displays its sharp-divided image (Marquez+2003) with a zoomed-in view. The zoomed image matches the field of view of MEGARA observations marked with a black square in the left-hand panel.

METHODOLOGY

We explore the kinematics, dynamics, ionization mechanisms, and oxygen abundances of the ionized gas, by modelling the Hα-[NII] emission lines at high signal-to-noise (>15) with up to four Gaussian components: named as narrow, very-narrow, intermediate-width and broad. Finally, we model the disc kinematics with "kinemetry" (Krajnovic+2006).

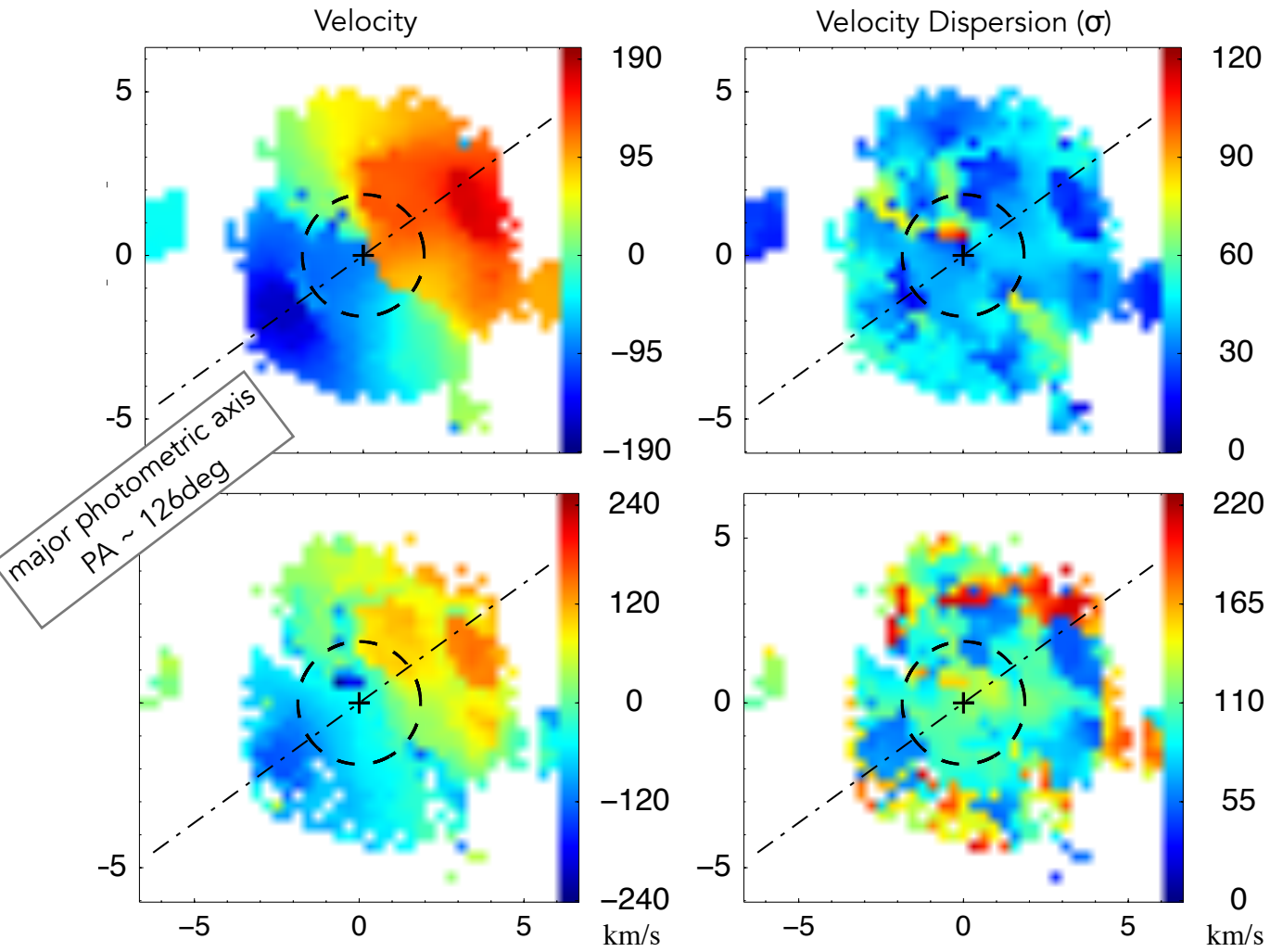
WORK FLOW

- ✤ Data reduction
- ✤ Emission line modelling and generation of the maps (velocity, velocity dispersion and flux)
- ✤ Analysis of the maps (e.g. Position-Velocity diagrams and line ratios)
- ✤ Disc modeling with "kinemetry"



Examples of line modeling. For each spaxel the modelled line profile (red continuous line) and the components (with different colours) are shown. Specifically, green, pink, blue Gaussian curves indicate: very-narrow, narrow, and intermediate-width components; in purple is marked the broad Hα component from the BLR not resolved at MEGARA spatial scales. Residuals from the fit (i.e. data model) are in the small lower panels in which orange dashed lines indicate the +/- 3×ε is the standard deviation of the residuals). Vertical orange continuous lines mark the wavelength range considered for calculating ε for the different cases. The coordinate labels indicate distance from the photometric centre.

Disc kinematics



Kinematic maps of the very-narrow (top) and narrow (bottom) components. The dashed circle with radius equal to the width at 5% intensity of the PSF radial profile is the "nuclear region"

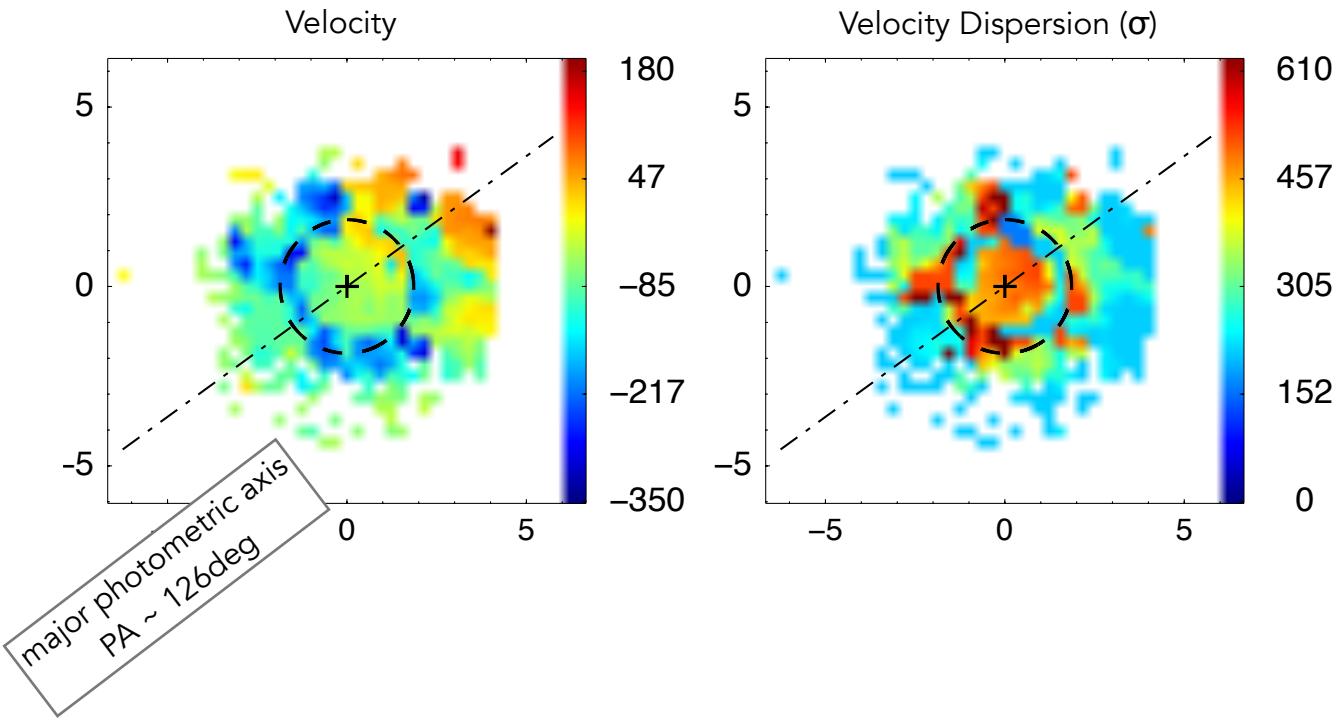
- **Very Narrow component**

The velocity field shows a pattern consistent with ordered rotational motions. The peak-to-peak semi-amplitude is 163 +/- 1 km/s, with the maximum velocity gradient oriented as the photometric major axis (~125deg). The σ-map is not centrally-peaked, contrary to what is expected for a rotating disc. The average velocity dispersion inside the nuclear region (40+/-1 km/s) is similar to that in the disc (38 +/- 1 km/s) that presents some perturbations (Cazzoli+20). The dynamical ratio (V/σ) is 4.3 indicating a rotation-dominated kinematics; using a thin-disc approximation (Cresci+09) the disc height hz is 20 pc.

- **Narrow component**

Kinematic maps reveal an irregular spider-pattern-like velocity field and non-centrally peaked σ-map. The disc has an increasingly larger random-motion component (V/σ = 1.3) with respect to the disc dominated by rotation. hz is 200 (500) pc as inferred with a thin (thick) disc approximation (Cresci+09)

Turbulent non-rotational motions



Kinematic maps of the intermediate-width components
The dashed circle with radius equal to the width at 5% intensity of the PSF radial profile is the "nuclear region"

The kinematics of the intermediate-width component lack of any rotating disc features, being irregular, chaotic with no peculiar morphology/orientation.

- **Outflow hypothesis:** a broad and blue-shifted component is indicative of outflows, even if not oriented perpendicular to the disc (e.g. García Burllo+14) The observed outflow-like kinematic agrees with that of the nuclear outflow of coronal gas (Muller-Sanchez+11) and partially with the X-rays flow (Blustin+07) on kpc-scales.
- **Lense hypothesis:** the ring-like emission with the highest turbulence could probe gas flows at the Inner Lindblad Resonance radius of the large-scale lens (Marquez+1994)
- **Gas out of the plane of the disc:** the gas with σ ~ 250 km/s could be associated to either disc-perturbations (with V > 0) or to diffuse and not virialized gas (with V ~ 0).

Main results

- ***DISCS KINEMATICS, DYNAMICAL SUPPORT AND HEIGHT***

The two discs, probed by the narrow and second components, nearly co-rotate with similar peak-to-peak velocities, 163 and 137 km/s , respectively, but with different velocity dispersion, i.e. 38 +/- 1 and 108 +/- 4 km/s, respectively. We found that the very thin (20 pc) ionized gas disc, mainly supported by rotation ($V/\sigma = 4.3$), is embedded in a thicker (222 –564 pc), dynamically hotter ($V/\sigma = 1.3$) one.

- ***TURBULENT MOTIONS***

The morphology and the kinematics of the intermediate-width component non-circular motions, possibly associated either to an ionized gas wide angle outflow (not perpendicular to the discs) or to gas flows related to the lens.

For more results about

e.g. "kinemetry" modelling, BLR properties (from the broad component) and ionisation mechanisms

see Cazzoli+2020

REFERENCES: Blustin et al. 2007 A&A, 466, 107; Colina et al. 2007 A&A 467, 559; Cresci et al. 2009 ApJ, 697, 115; Davies et al. 2004 ApJ, 602, 148; Diaz-Santos et al. 2007 ApJ, 661,149, Fathi et al. 2015 ApJ 806, L34; García Burillo et al. 2014 A&A, 567, A125; Landt et al. 2008 ApJS, 174, 282; Muller-Sanchez et al. 2011 ApJ, 739, 69; Marquez et al. 1994 AJ, 108, 90; Marquez et al. 2003 A&A, 409, 459; Krajnovic et al. 2006 MNRAS, 366, 787; Pereira Santaella et al. 2011 A&A 535, A93. **CAZZOLI et al. 2020 MNRAS 493, 3656-3757**