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Feeding and feedback in the nucleus of NGC 613

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Abstract. Active Galactic Nuclei (AGN) are objects in which a supermassive black hole is fed by gas and, as this generates energy, can ionise the environment and interact with it by jets and winds. This work is focused on the processes of feeding and feedback in the nucleus of NGC 613. This object is a case in which both phenomena can be studied in some detail. The kinematics and morphology of the molecular gas trace the feeding process while the ionization cone, seen in [OIII]λ5007 and soft X-rays, as well as the radio jet and wind/outflows are associated with feedback processes. In addition, we see 10 HII regions, associated with nuclear and circumnuclear young stellar populations, dominant in the optical, that makes the analysis complicated, though more interesting. For all these phenomena, NGC 613 nucleus is a vibrant example of the interplay between the AGN and the host galaxy.

Keywords. galaxies: active, galaxies: individual: NGC 613, galaxies: nuclei

1. Introduction

NGC 613 is an SB(rs)bc galaxy located at 26 ± 5 Mpc (Nanosova *et al.* 2011). It contains a very rich nucleus, composed by a circumnuclear ring of star formation (Hummel & Jorsater 1992; Böker *et al.* 2008; Fálcon-Barroso *et al.* 2014), a nuclear spiral of molecular gas (Audibert *et al.* 2019) and an obscured Active Galactic Nucleus (AGN, Castangia *et al.* 2013; Asmus *et al.* 2015) with a Low Ionization Emission-Line Region (LINER) emission (Audibert *et al.* 2019).

For more details about this work, see da da Silva *et al.* (2020a).

2. Metodology

The observations were taken with the Integral Field Unit (IFU) of Gemini Multi-Object Spectrograph (GMOS) of Gemini South Telescope and with the SOAR Integral Field Spectrograph (SIFS) from the SOAR telescope. We also analysed the data of public archives from the Chandra Space Telescope, the Hubble Space Telescope (*HST*) and the Atacama Large Millimeter/Submillimeter Array (ALMA) and SINFONI from the Very Large Telescope (VLT).

The treatment of SIFS and GMOS data cubes was performed using scripts developed by our group and its reduction and observational information is described in da Silva *et al.* (2020a). For more details on treatment processes, see Menezes *et al.* (2014, 2015) and Menezes *et al.* (2019).

3. Results

The difference of F475W–F814W filters from *HST* (*B-I* in magnitude scale) shows the inner morphology of the bar of NGC 613 (Fig. 1). The streams of gas and dust

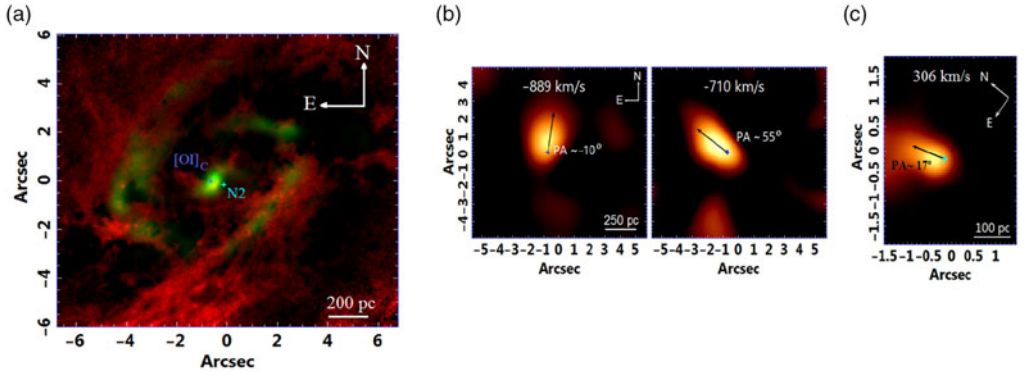

Figure 1. (a) RB composition of F475W–F814W filters from *HST* (*B-I* in magnitude scale) in red and CO(3-2) from the ALMA data cube in green. The purple and cyan crosses represent the position of the centroid of the [OI]λ6300 emission line and the center of N2 (referential point for the superposition of the data –see da Silva *et al.* 2020a for more details), respectively, and its size the uncertainty of 3σ, considering the size of the pixel of the HST images. Outflows of [OIII]λ5007 (b) and Hα (c) observed in the GMOS data cube. The cross reprents the position of the AGN.

are connected to the circumnuclear ring in two opposite points. This is compatible with the findings of Böker *et al.* (2008), that suggest that the ring is being fed by the bar through these two points. By its turn, the nuclear spiral is also connected to the bar in two nearby points. The kinematics of the nuclear spiral (da Silva *et al.* 2020b) reveals that this structure is directly injecting gas and dust to the center.

The AGN, which is located in the center of the nuclear spiral (see da Silva *et al.* 2020a), is highly obscured and the nuclear spiral is responsible for this obscuration, since the optical image of the nucleus is composed by two sources (which we called N1 and N2, see Fig. 9 of da Silva *et al.* 2020a) separated by the nuclear spiral. The Chandra data present an extended soft X-ray emission, which delineates the ionization cone observed in [Oiii]λ5007 (see Fig. 15 of da Silva *et al.* 2020a). Two outflows were detected in [Oiii]λ5007, one of them in blueshift ($v \sim -710$ km s^{-1}) with a PA compatible with the one of the ionization cone axis. The Hα emission also presented an outflow with redshift emission ($v \sim 306$ km s^{-1}) with PA compatible with the one of the radio jet observed by Hummel & Jorsater (1992).

The AGN interacts with the environment by outflows of gas and the ionization cone, and the galaxy interacts with it by feeding it through the nuclear spiral that is connected to its bar.

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