Boletim da Sociedade Astronômica Brasileira, **30**, no. 1, 176-177

Panchromatic stellar populations in early type galaxies: NGC 1052

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Abstract. We map the gas excitation and kinematics, and the stellar population properties of the elliptical NGC 1052 both in the optical and in the J and K Near Infrared bands. Emission-line flux distributions reveal, beside a rotation component, two double peaked regions along the radio jet. The flux-ratios show extended LINER emission throughout the 5.0 × 3.0" optical field of view. These regions are found to be compatible with inflows/outflows. Principal component analysis (PCA) reveal an unresolved broad line region centered at the nucleus, consistent with a low luminosity active galactic nucleus (LLAGN). This scenario is found to be compatible with a X-ray source located in the same point. In the near infrared, the emission lines are much weaker, with only the [FeII] and H_2 lines displaying extended emission. Also, for the first time in the literature, we combine optical and NIR datacubes and perform stellar population synthesis. By using the optical alone, we find only contribution from old stellar populations. When adding the NIR, in the other hand, we detect a featureless continuum in the nucleus, associated with the LLAGN and compatible with the PCA results.

Resumo. Nós mapeamos a excitação e a cinemática do gás, além das propriedades da população estelar da galáxia elíptica NGC 1052, tanto no óptico quanto nas bandas infravermelhas J e K. As distribuições de fluxos das linhas de emissão revelam, além de uma componente de rotação, duas regiões com duplo pico ao longo do jato em rádio. As razões de fluxo mostram emissão LINER extendida ao longo do campo de visão óptico de 5.0 × 3.0". Estas regiões são compatíveis com *inflows/outflows*. Análise das componentes principais revela uma linha larga não resolvida centrada no núcleo, consistente com um núcleo ativo de baixa luminosidade. Este cenário é compatível com uma fonte em raios-X localizada no mesmo ponto. No infravermelho próximo, as linhas de emissão são muito mais fracas, com apenas as linhas de [FeII] e H_2 apresentando emissão extendida. Pela primeira vez na literatura, nós combinamos dados ópticos e infravermelhos e realizamos síntese de população estelar. Usando apenas dados ópticos, nós encontramos apenas contribuição de populações velhas. Por outro lado, ao incluir dados infravermelhos, nós detectamos um *featureless continuum* no núcleo, associado com o núcleo ativo e compatível com os resultados PCA.

Keywords. Galaxies: stellar content – Galaxies: elliptical and lenticular, cD – Galaxies: active

1. Introduction

NGC 1052 is an E4 galaxy located in the constellation Cetus, the nearest radio-loud AGN. On radio wavelengths, it displays two jets with slightly different orientations (Wrobel 1984, Fey & Charlot 1997). It also has AGN properties reported in X-rays (Kadler et al. 2004), with emissions from an absorbed power law, various jet-related emissions and an extended region, also aligned with the radio synchrotron jet-emission. Also, in the optical, both Barth et al. (1999) and Sugai et al. (2005) found a broad line region in the Hydrogen emission lines.

Regarding the stellar population of NGC 1052, Fernández-Ontiveros et al. (2011) found 15 compact sources exhibiting Hα luminosities an order of magnitude above the estimate for an evolved population of extreme horizontal branch stars. Their Hα equivalent widths and optical-to-NIR spectral energy distributions are consistent with them being young stellar clusters aged <7 Myr. According to them, this is probably related with the merger event that occurred ~1 Gyr ago (van Gorkom et al. 1986)

2. Data

The optical data was obtained with Gemini South Multi Object Spectrograph (GMOS) on Integral Field Unit (IFU) mode. Near Infrared (NIR) data was obtained using the Near-Infrared Integral Field Spectrometer (NIFS) from Gemini North. Both data were reduced using Gemini IRAF package, which included trimming of the images, flat fielding, sky subtraction, wavelength and s-distortion calibrations and remotion of the telluric absorptions.

3. Results and Discussion

To study the stellar population, we used the STARLIGHT code (Cid Fernandes et al. 2004, 2005), who fits the observed spectrum with Simple Stellar Populations (SSPs) in different proportions. To reproduce extragalactic dust, we used the Calzetti et al. (2000) reddening law. As a library of models, we used the Röck et al. (2016) library. This library was chosen because it covers a wavelength range from 3500 to 50000 Å. Also, the high resolution it offers on the NIR is essential for a proper classification of the stellar population (Dahmer-Hahn et al. 2017, submitted).

By using the optical alone, STARLIGHT found only old stellar populations. This result was already expected, since NGC 1052 is an elliptical galaxy whose last major merging event happened ~ 1Gyr ago. On the other hand, when using only NIR data, we found high (>90%) intermediate populations on the whole

cube but the nucleus. However, these populations came along a high (>1.0) extinction, which is in contrast with other results, that found that dust extinction in elliptical galaxies is negligible (Padilla & Strauss 2008). The divergence between optical and NIR results was already reported by (Dahmer-Hahn et al. 2017, submitted), which found that stellar population synthesis in the NIR, as long as the dust extinction cannot be constrained by other methods, produce unreliable results.

For an improved characterization of the stellar population, we combined optical and NIR data in a panchromatic, spatially resolved datacube. For the full optical+NIR spectral range, the code was able to detect a Featureless Continuum (FC) in the nucleus of the galaxy.

After subtracting the stellar population, we fitted the emission lines with Gauss-Hermite polynomials. All emission lines displayed nearly identical profiles, with an emission peak in the nucleus and two double-peaked regions located along the radio jets, suggesting regions with a kinematic component that deviates from the gas rotation. Since they are located along the radio jet, they are probably generated by inflows/outflows.

Also, the kinematics of the gas is decoupled from the kinematics of the stars, presenting different inclinations. This result has already been reported by Dopita et al. (2015), and implies different origins for the gas and the stars.

We also followed Steiner et al. (2009) and used Principal Component Analysis (PCA) on the optical datacube to disentangle the main emissions from the datacube. The eigenvector 1, as expected, reflects the emission from the stellar continuum and the gas that is spread along the galaxy. Eigenvector 2, on the other hand, reflects a punctual emission centered in the nucleus, co-spatial with the obscured AGN detected in X-rays. On this eigenvector, it is possible to see a correlation between the emission-line fluxes and the stellar absorptions of FeI λ5270 and NaD λ5893. As pointed out by Ricci, Steiner & Menezes (2014), this is an indicative of a power-law, since a featureless continuum decreases the equivalent width of the stellar lines on the nuclear region. This result is in direct agreement with the Featureless Continuum detected by the panchromatic synthesis. These two results together can be taken as strong evidence of the LLAGN behind the broad lines detected by Barth et al. (1999), Sugai et al. (2005) and eigenvector 2 of the PCA.

Also, eigenvectors 3 and 6 find components oriented along the radio jets. While eigenvector 3 seems to be a kinematic component (e.g. inflows/outflows), eigenvector 6 resembles a ionization cone.

The NIR emission lines, on the other hand, are much weaker if compared to the optical ones, with only Paβ, [FeII] λ12570Åand H_2 λ21218Åabove the signal-to-noise threshold. From these three lines, only [FeII]λ12570Å and $H_2\lambda$21218Å display extended emission, with Paβ having only nuclear emission.

4. Final Remarks

We present here, for the first time, panchromatic spatially resolved data of the elliptical galaxy NGC 1052. We mapped the stellar population and emission lines. Our main results can be summarized as follows:

- When using the optical alone, STARLIGHT finds only contributions from old stellar populations. On the other hand, when adding the NIR to the synthesis, the code is able to detect a featureless continuum in the nucleus.
- Optical emission line fluxes reveal a rotation component and two double peaked regions located along the radio jets, probably generated by inflows/outflows.
- The stellar and gas rotations are decoupled, implying different origins for the stars and the gas.
- PCA find a broad Hα component centered in the nucleus, co-spatial with a Featureless Continuum. It also detects two components associated with the radio jets.
- Near Infrared emission lines are much weaker, with only [FeII] λ12570Å and H_2 λ21218Å displaying extended emission.

Acknowledgements. LGDH agradece ao CNPq

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