# IFU Spectroscopy of 10 ETG nuclei: Properties of the circumnuclear gas emission

T.V. Ricci[1*], J.E. Steiner[1] and R.B. Menezes[1]

1 - Instituto de Astronomia, Geofísica e Ciências Atmosféricas – Universidade de São Paulo, Brazil

* tvricci@iag.usp.br

Low-ionization nuclear emission regions (LINERs) are associated with objects whose spectra have a prominence of low ionization emission lines [1]. Several sources of ionization may be responsible for producing a LINER: low-luminosity active galactic nuclei (AGNs) [2,3]; shocks [1,4]; hot-old stellar populations(e.g. pAGB stars) [5].

Almost 50% of the Early-type galaxies (ETGs) in the local Universe has LINER-like emission in their centre [6]. In fact, the majority of ETGs has an extended emission of gas up to 1 kpc [7,8]. However, low-luminosity AGNs are unable to produce enough ionizing photons to explain such extended emission [8,9,10]. Thus, even when nuclear activity is clearly detected, an additional ionization source is necessary to explain the extended emission of gas in these objects.

In the present work, we have analysed a sample of 10 ETGs with the goal to detect and characterize the nuclear and circumnuclear (scales of 100 pc) regions of these objects. We found that all sample galaxies have an AGN in their centre [11,12]: in six objects, a broad component in the Ha line was detected [12]. In this poster, we show a summary of the analysis performed in the circumnuclear region of the sample galaxies after the subtraction of the stellar components from the sample galaxies. A more complete study is presented in Ricci, Steiner & Menezes (2015, MNRAS, 451, 3728 - all figures presented in this poster were taken from this paper).

## Methodology

- Data cubes – observed with GMOS – IFU in Gemini South Telescope [11].
- Basic reduction steps performed (bias, flat-field, wavelength calibration and flux calibration).
- High frequency artefacts removal - low-pass Butterworth filter.
- Removal of low frequency instrumental fingerprints: PCA Tomography [11, 13].
- Stellar spectral synthesis and subtraction - STARLIGHT code [14]. Applied to each spaxel of the data cubes. Results in a data cube of gas lines only.
- The broad component of the Ha line was removed from the gas cubes of all sample galaxies whose nuclear spectrum has such a feature.

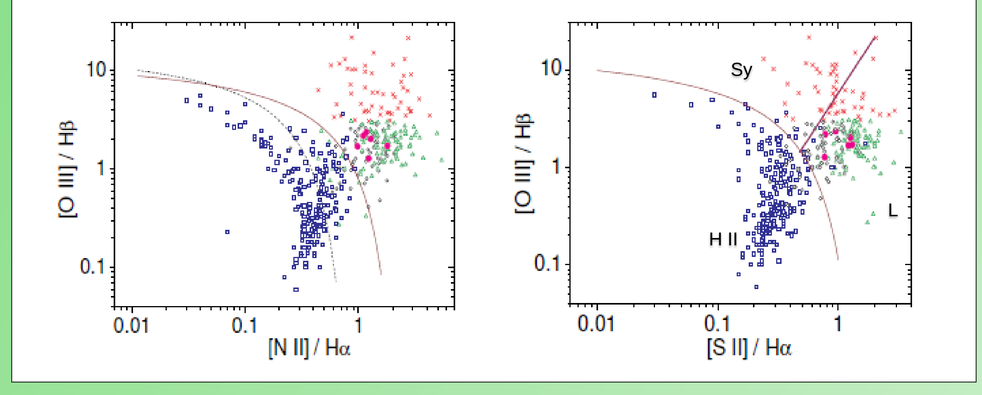


Figure 1: BPT Diagrams

- Emission line diagnostic: Seyfert (Sy); LINER (L); H II regions (H II)
- Two proposed separations:
  - Red (Sy), green (L) and blue (H II) points: data from Palomar survey [16]
  - Lines: brown is the maximum starburst line [15]; dashed black is the empirical separation between H II and AGNs [19]; purple is the L/Sy separation [15].
- Magenta points: Sample galaxies => Circumnuclear emission with LINER-like ratios


Figure 2 – RB => flux of the red and blue wings of the Ha emission line:
G => tip of PSF of the flux map of the Ha emission line (see Fig. 3)
pure gaseous discs (e.g. ESO 208 G-21, NGC 1380)
gaseous discs affected by outflows (e.g. IC 1459)

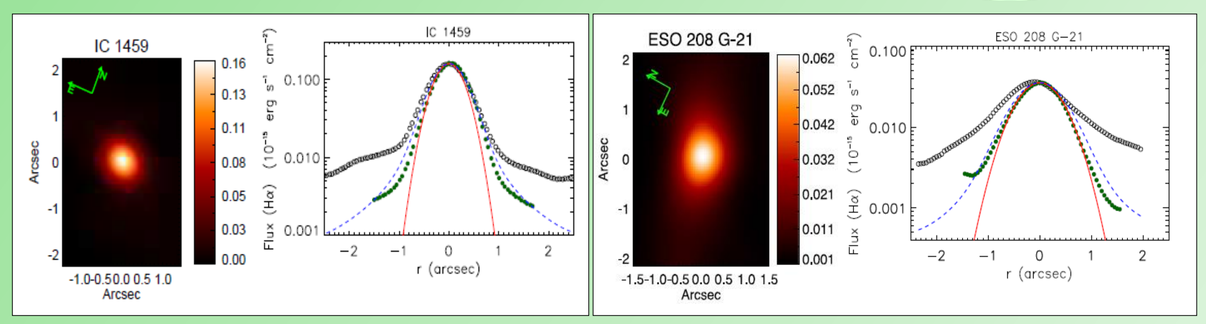


Figure 3 – Flux maps of the narrow component of the Ha line.

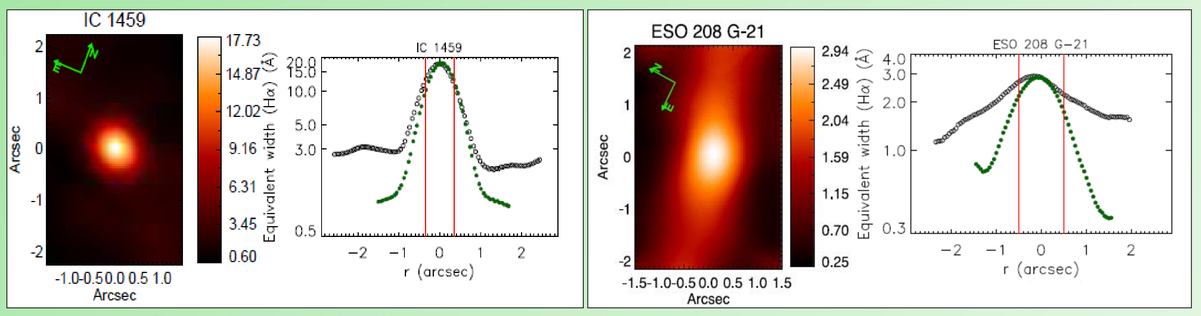


Figure 4 – Equivalent width of the Ha emission line.

1D profiles in Figs 3 and 4:
Hollow black circles => along the gaseous discs
Green filled circles => perpendicular to the gaseous discs
Red lines => PSF of the data cubes

## Is AGN photoionization enough to explain the circumnuclear emission of the sample galaxies?

### 1 - Photoionization models

1a - Simplistic flux model [9,10]:

- infinitesimally thin disc
- optically thin
- constant density and filling factor
- photoionized by an AGN
- decreases as $R^{-2}$ (Dashed blue lines in Fig. 3)
- AGN is responsible only for the photoionization along the direction perpendicular to the gaseous discs. It does not explain the emission along the gaseous discs.

1b – Nebular spectral simulation with CLOUDY [18]

- Plane parallel geometry
- AGN with ionization parameter log U = -3.4
- Power law: α = -1.5
- $n_e$ = 200 $cm^{-3}$; filling factor $10^{-3}$
- Lower cut energy ionizing photons: 27 eV
- Metallicity: 2.5 solar
- Explain emission line ratios of the circumnuclear region of the sample galaxies
- Results in a photon density of $n_\gamma$=0.079 $cm^{-3}$
- To maintain this $n_\gamma$ in a projected distance of ~ 2 arcsec => AGN with 10 times more ionizing photons than the observed for the sample galaxies.

### 2 - Equivalent width of Ha emission line (Figs. 4 and 5)

- EW(Ha) <~ 3Å along the gaseous discs => in accordance with photoionization caused by hot-old stellar populations (e.g. pAGB stars) [17]
- Correlation nuclear EW(Ha) and EW(Ha) along the direction perpendicular to the gaseous discs. => AGN photoionization

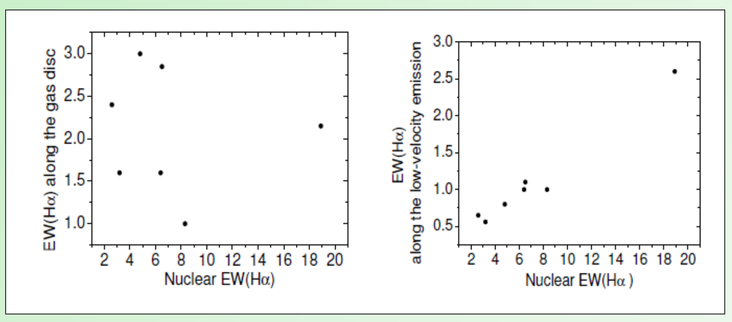


Figure 5 – Left: EW(Ha) along the gaseous disc x nuclear EW(Ha). Right: EW(Ha) along the direction perpendicular to the gaseous discs x nuclear EW(Ha).

## Conclusions

- We detected circumnuclear emission in seven galaxies of the sample. In all cases, it is a LINER-like emission (see Fig. 1).
- In six galaxies, kinematic bipolar structures are related to gaseous disc. In some cases, the gaseous disc is affected by outflows (see Figs. 2, 3 and 4).
- In the galaxies with a gaseous disc, we also detected an emission along the direction perpendicular to the discs (see Figs. 3 and 4).
- We propose that the emission along the disc-like structures is not photoionized by the AGN of the galaxies. Hot old stellar populations (e.g. pAGB stars) are the best candidate for the ionization source.
- On the other hand, the AGNs are probably the main source of photoionization of the region along the direction perpendicular to the gaseous discs.
- We propose a scheme for LINER-like circumnuclear emission where an ionization cone, perpendicular to a gaseous disc, is formed by the collimation of ionizing photons by some agent which is somehow aligned with the gaseous disc.

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