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# Longslit spectroscopy of the starburst galaxy HRG 02041


**Vera Ap. F. Martin[1], Max Faúndez-Abans[2], Paulo C.R. Poppe[1]**
**Mariângela de Oliveira-Abans[2], Iranderly F. de Fernandes[2]**

UEFS – Departamento de Física/Observatório Astronômico Antares – Brazil[1]
MCT/Laboratório Nacional de Astrofísica – Brazil[2]



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## I - INTRODUCTION

Galaxies with unusually high levels of star formation are referred to as starburst galaxies. They were first identified by their strong optical emission lines. The term "starburst" was originally coined by Weedman et at. (1981, ApJ, 248, 105) to indicate qualitatively that a galaxy is undergoing a period of intense star formation. It still lacks a precise definition and provides a blanket covering for all regions that have an above normal star formation rate. In particular, for interacting galaxies it includes star formation enhanced by any process ranging from a mild pertubation to a collision.

In this work we present the first optical longslit spectroscopy for the galaxy HRG 02401, an SB...(according to the NASA/IPAC Extragalactic Database) type peculiar galaxy seen face-on with an asymmetrical elliptical structure. The aim of the current study is to describe the main physical properties of this object. The spectra obtained with the 1.6m telescope of the Observatório do Pico dos Dias (OPD)-MCT/LNA-Brazil, shows a variety of interesting features and we have used diagnostic diagrams to classify this object as a Starburst galaxy, at a redshift of 5206.24 ± 13.01, corresponding to a distance of 71.32 Mpc ($H_0$ =73 km $s^{-1}$ $Mpc^{-1}$).

## II – OBSERVATION AND DATA REDUCTION

The optical spectrum was obtained using the Boller and Chivens spectrograph attached on the 1.6-m OPD Telescope on 2006 June 28 with a 1200-s integration. The configuration was a 3.0-arcsec-wide longslit centred on the optical peak and oriented at position angle $68^0$, shown schematically in Fig. 1. The detector used was CCD WI-105 with 2048x2048 pixels, and a 600 lines $mm^{-1}$ grating, blazed at 5850Å, which provides a dispersion of 88.75 $Åmm^{-1}$.

The scale of the frames on the spatial direction was 0.56 arcsec $pixel^{-1}$, although the PSF of the standard star showed that the seeing was about 1.5 arcsec. The spectral resolution was matched to the 1.2 Å $pixel^{-1}$, yielding an effective resolution of about 3.74 Å (FWHM) and covering the 4623-7077 Å. The Table 1 gives some informations about the HRG 02401 galaxy.

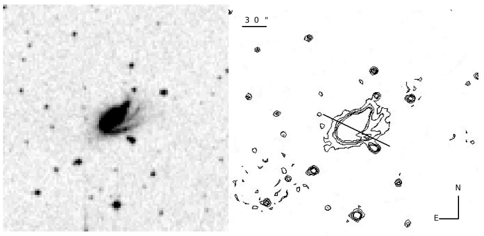



Fig.1 Contour plot of HRG 02401 galaxy in the optical from DSS, showing the orientation of the 3 arcsec wide longslit. Near names: AM 1740-790, ESO 024-IG 009.

Table 1a. Observational caracteristics (OPD/LNA)

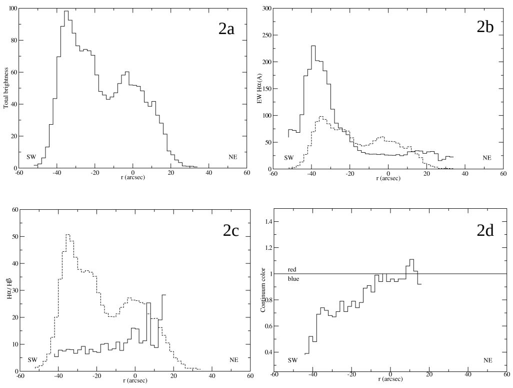
| OPD/LNA | Exp. Time (s) | PA ($^0$) | Seeing (arcsec) | Airmass | S/N | Window centre |
|---|---|---|---|---|---|---|
| 2006, June 28 | 1200 | 68 | 1.5 | 1.358 | 16 | Nucleus |

Table 1b. Basic parameters (NASA/IPAC Extragalactic Database)

| Galaxy (near names) | α (h m s) | δ (° ´ ") | v (km $s^{-1}$) | D, d (arcmin) | Mag (Filter) | Type |
|---|---|---|---|---|---|---|
| HRG 02401 | 17 49 16.25 | –79 02 03 | 5384 ± 29 | 1.0, 0.5 | 14.8 (b) | SB... |

## III – SPATIAL MAPPING

In order to make the most use of the spatial information that a longslit affords, the central 50.4" was divided into a series of 1.12" (390.9-pc) apertures. For each of resulting spectra, measurements were made of the total integrated flux of the spectrum, the slope of the continuum, the Hα line flux and equivalent width ($EW_{H\alpha}$), and where possible the Hβ line flux (see Fig. 2).



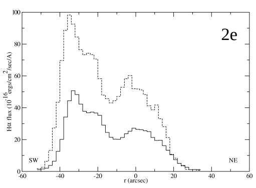




Fig. 2. Mapped region of the longslit showing the variation along the slit. The individual frames (described in the text in more detail) are (a) total optical brightness, (b) observed Hα flux, (c) ratio Hα/Hβ, (d) continuum colour, and (e) Hα equivalent width.

Fig. 2(a) shows the total brightness, computed as simply the total flux detected in each aperture, and Fig. 2(d) shows the continuum colour, i.e., the ratio of the continuum flux density at Hα to that at Hβ, with the dotted line representing a flat continnum. The Fig. 2(a) shows clearly that along the slit there is a bimodality observed in the region within ±20 arcsec (about 7kpc across, central and southwest peak), brighter and bluer, indicative of a starburst nucleus.

## IV – SPECTRAL ANALYSIS

This galaxy includes some of the most important emission lines for ionization diagnostics: Hβ, [OIII]λ5007, [OI]λ6300, Hα, [NII]λ6583, [SII]λλ6716,6731. The strengths of the detectable emission lines after appropriate dereddening, as well as their equivalent widths, are presented in Table 2.

This object is a Starburst with narrow emission lines and λ6583/Hα = 0.22. The ratio of the sulfur lines in the doublet can be used as a density diagnostic. We find that [S II] (λ6716/λ6731) = 1.0–1.4, typical densities 100–500 $cm^{-3}$.

The nuclear spectrum and others ones for different regions are presented in Fig. 3 on the same scale to allow direct comparison. Figure 4 gives the heliocentric velocities and an asymmetric feature can be observed in the rotaion curve.

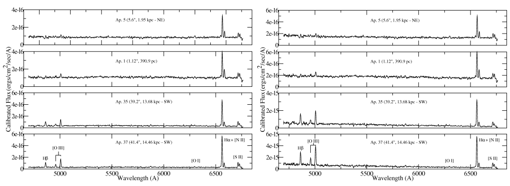



Fig. 3. Spectra of the Starburst: left (not correted) and right (correted for extinction – only Galactic reddening for the apertures 1 and 5).

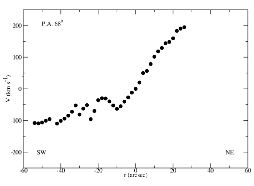



Fig. 4. Heliocentric velocities. 1.12 arcsec = 390.9 pc

Table 2. Emission-lines intensities. Reddening-corrected fluxes in units of $10^{-16}$ erg $cm^{-2}$ $s^{-1}$ $Å^{-1}$.

| Ion | Ap.1 (EW Å) | Ap. 5 (EW Å) | Ap. 35 (EW Å) | Ap. 37 (EW Å) |
|---|---|---|---|---|
| Hβ λ4861 | – | – | 98.3±7.52 (16.99) | 166.0±11.09 (17.72) |
| [O III] λ4959 | – | – | 33.6±2.15 (5.89) | 91.7±7.80 (11.29) |
| [O III] λ5007 | – | – | 122.0±10.01 (21.66) | 294.0±21.56 (36.32) |
| [O I] λ6300 | – | 1.05±0.66 (1.37) | 4.67±1.65 (1.63) | 6.08±2.09 (1.75) |
| [N II] λ6548 | 2.89±0.97 (2.07) | 1.76±0.74 (2.40) | 16.2±3.33 (8.70) | 19.7±3.00 (7.82) |
| Hα λ6563 | 26.4±4.07 (26.17) | 21.3±3.82 (24.9) | 286.0±18.05 (153.7) | 499.0±27.85 (200.1) |
| [N II] λ6583 | 8.72±2.48 (8.70) | 5.32±1.98 (6.24) | 46.0±3.63 (24.85) | 69.1±5.65 (28.03) |
| [S II] λ6716 | 4.98±2.65 (4.96) | 4.51±2.71 (5.36) | 51.5±5.18 (31.41) | 75.5±5.92 (35.89) |
| [S II] λ6731 | 4.07±2.98 (4.04) | 3.08±2.27 (3.66) | 37.5±4.87 (24.51) | 62.1±5.18 (30.05) |

Table 3. Emission-lines ratios.

| | Hα / Hβ | [O III] / Hβ | [N II] / Hα | [O I] / Hα | [S II] / Hα |
|---|---|---|---|---|---|
| Aperture 1 | – | – | 0.82 | – | 0.34 |
| Aperture 5 | – | – | 0.10 | 0.05 | 0.36 |
| Aperture 35 | 2.91 (7.04) | 1.24 | 0.16 | 0.02 | 0.31 |
| Aperture 37 | 2.94 (8.39) | 1.77 | 0.14 | 0.01 | 0.28 |

## V – DISCUSSION AND CONCLUSION

The Hα flux and equivalent width, in Figs. 2(b) and (e) respectively, show that this is not the complete picture. In both diagrams the optical brightness has been overplotted with a dashed line for comparison. Both peaks are very close but not in the same position. This feature can suggest that the nucleus host a cluster of hot young OB stars which are producing a large ionizing flux. In such a situation we might expect $EW_{H\alpha}$ to change more slowly, which is the case, as further from the nucleus the continuum becomes more dominated by older redder stars. However, to the northeast (positive offset) the Hα flux decreases in the same way, while the optical brightness decreases abruptly. In the case of $EW_{H\alpha}$, we can see a small cut–off (±10 arcsec) suggest that the stellar population changes from hot OB stars to cooler non-ionizing ones, but this cannot be correct because the continuum colour shows that the stars are still blue.

To understand it further, we need to know how the extinction varies across the nucleus. Since this can be calculated from the Balmer decrement, we have shown the ratio Hα/Hβ in Fig. 2(c), although it could be measured for some apertures in which Hβ was strong enough to detect. The Hα flux has been overplotted (dotted line) to show that it is strongest were the extinction is lowest ($A_V$ ≈3 mag), and that the cut–off occurs where the extinction increases 3–5 mag.