The Ying and Yang of M83 nucleus

D. Mast[1,2], R. J. Díaz[3] H. A. Dottori[4] , M. P. Agüero[1], I. Rodrigues[5], J. F. Albacete-Colombo[6]

1 Observatorio Astronómico de Córdoba, Universidad Nacional de Córdoba, Argentina
2 Calar Alto Observatory, Almería, Spain
3 Gemini Observatory, Southern Operations Center, Chile
4 IF/UFRGS
5 Universidade do Vale de Paraiba, UNIVAP, São José dos Campos, SP, Brazil
6 CURZA - Univ. del Comahue, Argentina

Abstract

The spiral galaxy M83, an SB(rs)b at only 4.5 Mpc, harbors the nearby starburst nucleus. Its proximity makes it a privileged case to study the microphysics in detail, at spatial scales of tenth of parsecs. At the same time, it shows a morphological complexity very difficult to fit in classical studies of starburst galaxies. Studying the physical properties of gas and stars, we will try to bring some light to this scenario where dust and interactions play a main role. With 3D spectroscopy observations using CIRPASS from Gemini-S, we studied the ionized gas properties in J-band with a spatial resolution of 0."5. Paβ velocity field showed two dynamical centers, neither of them coincident with the bulge center, identified with the optical nucleus and the hidden nucleus, with masses of ~10^7 M⊙. We proposed the hypothesis of satellite capture into the 100 inner parsecs of M83 as the responsible mechanism for triggering the starburst, in the Aztec model frame proposed by Taniguchi et al. Adding complexity to this scenario, we present GMOS+Gemini imaging and spectroscopy of the radio source J133658.3--295105. The detected Hα emission at the position of this source, redshifted by ~130 km s^{-1} with respect to an M 83 HII region, leads us to face the possibility of witnessing the ejection of an object by gravitational recoil from M 83 nucleus. The X spectrum fit supports the association between this source and the disk of M 83 by the detection of the FeK 6.7 KeV line.

Introduction

In its visit to Gemini South (March 2003), we used the Cambridge Infrared Panoramic Survey Spectrograph (CIRPASS, Parry et al. 2000), to obtain spectra of M83 central region in the near IR, minimizing dust efects. Paβ emission, a powerful age indicator, and [FeII], allowed us to analyze the age and the physical properties on three fields covering both mass concentrations. In our previous work Díaz et al. (2006), we analyzed one of the CIRPASS fields and established the satellite capture and the star formation triggering scenario. We present here the complete analysis of the mosaiced radial velocity field containing both mass concentrations.

Observations

The observations were taken with an Integral Field Unit (IFU) sampling of 0".36 (7.2 pc) in an elliptical arrangement with a size of 13" x 5". The array has 490 hexagonal doublet lenses attached to fibers and provides an area filling factor near 100%. The IFU was oriented at PA 120°(Figure 1) and was centered in a point midway between the optical nucleus position and the possible position of the hidden nucleus previously determined from our optical 2D kinematics (Mast et al. 2006). We observed three fields superposed in order to construct the mosaiced field. Between each observed galaxy field, we took a spectra of the sky in order to make the telluric subtraction. The set of 490 spectra covers the spectral range 1.2-1.4 μm, including the emission lines Paβ 1.3 μm and [Fe II] 1.26 μm, and the spectral resolution is ~3200.

Data Reduction

The data were reduced using IRAF, ADHOC (2D kinematics analysis software developed by Marseilles Observatory), SAO (spectra processing software developed by the Special Astrophysical Observatory, Russia), and standard worksheets and image processing software. The first stage of the reduction process was made using CIRPASSOFT, developed to be used inside IRAF for CIRPASS data reduction (Sharp, R. 2003)1. In Figure 2 we can see an extracted spectrum. After the extraction of the spectra from the MEF files, we used standard worksheets and visual basic macros to calibrate and construct the final IFUs. Splot task inside IRAF was used to measure the intensity, FWHM, and equivalent width (W), of the emission lines. We fit gaussians to the Paβ and Fe[II] emissions of each spectrum, as well as to the three most prominent sky emission lines near Paβ *for* use them as wavelength and profiles references.

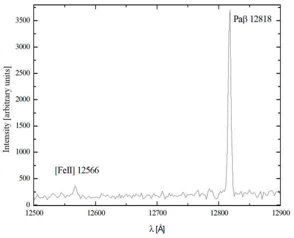

Figure 2: Extracted spectrum with Paβ and Fe[II] emissions indicated.

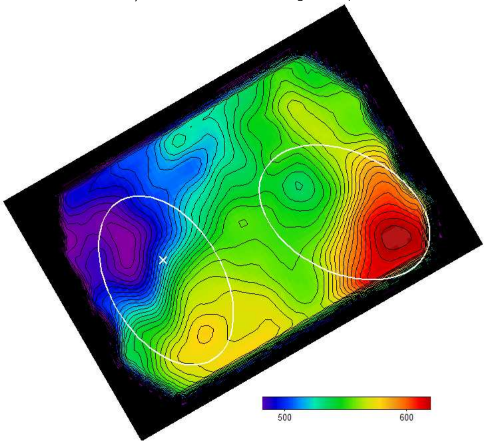

Figure 3: Radial velocity field of the ionized gas constructed from Paβ emission. The isovelocity lines are traced each 5 km sec^{-1} . The field was smoothed with a gaussian of 0".9. The white cross marks the optical nucleus (ON) position. The scale bar is in Km sec^{-1}. North is up, East left.

Results

In Figure 3 we can see the radial velocity field of the ionized gas constructed from Paβ emission. The spider diagram centered in the ON clearly shows rotation around this mass concentration. In the west part of the field, another spider diagram can be seen, what indicates disk-like rotation around what we called the hidden nucleus (HN, Díaz et al. 2006; Mast et al. 2006). The regions where the mentioned disk-like rotation is detected are indicated with ellipses.
The Paβ FWHM map can be seen in Figure 4 (left). Two crosses indicate nucleus position. Around ON we can see a ring of radius ~1" with average value of 170 km sec^{-1}. ON FWHM goes down to 122 km sec-1. The value for the HN is (118 ± 9) km sec-1. In Figure 4 (right) we can see the same field smoothed with a 0".9 gaussian. Neither of the nuclei coincides with the FWHM local maximums.

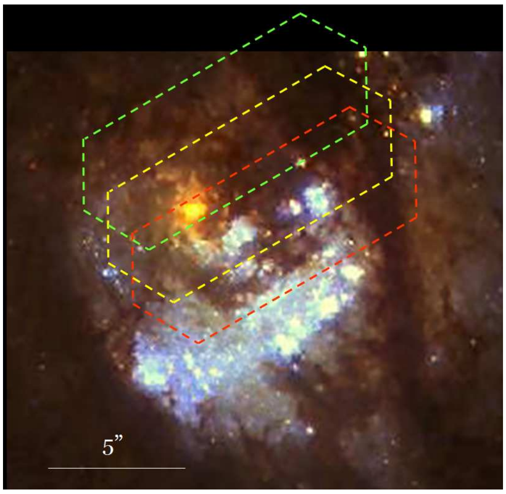

Figure 1: False color HST image constructed from the filters F300W, F547M, and F814W, with the three CIRPASS fields indicated (PA120º). North is up, East left.

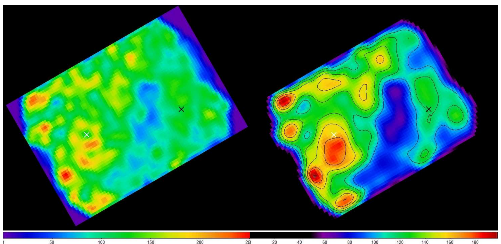

Figure 4: Left: Paβ FWHM map. Right: Smoothed Paβ FWHM map (gaussian of 0".9). The white cross marks the optical nucleus (ON) position, and the black cross marks the HN. The scale bar is in Km sec^{-1}. North is up, East left.

The [FeII]/Paβ ratio (Figure 5) is related to the transition from shock ionization due to supernovas and pure photoionization (Moorwood & Oliva 1988; Simpson et al. 1996; Rodríguez-Ardila et al. 2004). In Figure 5 we can see that around ON values are 2 - 2.5 and fall to 0.5 while we approach HN from the East. Those values are the expected for HII regions. All the above indicates, by one hand, that [FeII] emission surrounding ON is excited by SN. It remains unveiled if these SN are from the current starburst, or debris from past starbursts in M83 nuclear region. Most probably, it comes from a combination of both phenomena. If we move to the West of ON, we enter a region of the field where photoionization predominates. The region of possible shocks producing [FeII] emission would be on the opposite side of the dust lane that intersects M83 central region, ruling out any possibility of shock effect on the dust lane, disturbing the radial velocity field and mimicking a disk-like rotation.

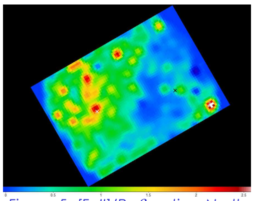

Figure 5: [FeII]/Paβ ratio . North is up, East left.

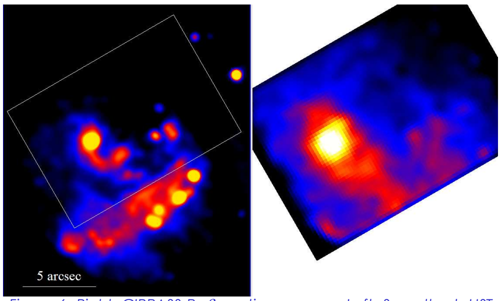

Figure 6: Right: CIRPASS Paβ continuum map. Left: Smoothed HST image (F814W). Same scale. North is up, East left.

The Paβ continuum map is shown in Figure 6 (right), together with a smoothed HST image for comparison.

The equivalent widths of hydrogen recombination lines, are powerful age indicators (Dottori 1981; Stasińska & Leitherer 1996). We made a polynomial fit to the SB99 model (instantaneous star formation, Z=2Z⊙, Salpeter IMF with limits 1 and 100 M⊙) and obtained an equation that allowed us to calibrate our W(Paβ) map in age. The resulting map is shown in Figure 7. A white cross indicates the postion of ON. It has an age, according to our determination, of 8 x 10^6 years, and appears to be the oldest region of the field. In a ring-like structure around ON, with radius ~ 1"-2", age values fall to 7.5 x 10^6 years. Moving to the West in PA 90° from the ON, there is a region with values closer to 4 x 10^6 years, that extends to the North more than 6" without surpassing 6.5 x 10^6 years. The HN is in a region between (6.5 - 7) x 10^6 years.

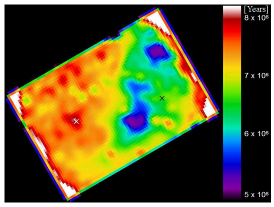

Figure 7: Age distribution obtained from W(Paβ) and SB99 model. North is up, East left.

We can estimate the enclosed mass within a 10 pc radius around each nucleus, using a keplerian approximation, obtaining: M_{ON} = (1.8 ± 0.4) x 10^{7}M⊙ and M_{HN} = (1.0 ± 0.4) x 10^{7}M⊙. Our new determination implies that the ON mass would be slightly greater than HN mass. For the bulge center we have, inside a 54 pc radius, MKC = (4 ± 2) x 10^7 M⊙.

Kicked-off from M83?

The correlation between the bulge mass and that of central SMBH in spiral galaxies points to a strong interplay between these systems in a hierarchical scenario of disk-galaxies formation. A paradigmatic byproduct of a black holes merger is the recoil of the resulting black hole as a response to the anisotropic emission of gravitational waves. In a triple black holes system one of them can be ejected from the galactic center before the merger of the other two occurs. The search for kicked-off black holes has been unsuccessful up to now. Supermassive binary black holes systems should also be common objects, but they are elusive as well.

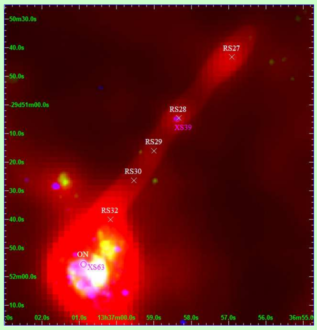

Figure 8: Blow-up along a line through ON and J 133658.3–295105. The radio map (red) is superposed detaching the radio sources 28, 27 and 29.

J 133658.3–295105 is the X-ray source No 39 in Soria & Wu list (Soria & Wu 2003). They argue that XS39 is a background source because it is coincident with an inverted spectrum radio source, No 28 in Maddox et al. (2006) list, though to be the core of a FRII radio-galaxy. In addition to the flat-spectrum radio core RS28 also present two distinct radio lobes with clear effects of relativistic boosting, at ≈ 25" north-west (RS27) and south-east (RS29) of the core (Figure 8). Soria & Wu estimated a distance z>1 arguing that known FRII radio-galaxies always have a lower limit of their L_6cm and L_20cm.

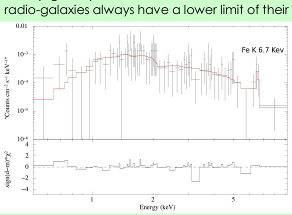

Figure 9: Spectra of J 133658.3–295105.

The curious on-the-sky projected distribution of the radio sources RS27, RS28 and RS29 with respect to the optical nucleus of M 83 lead Dottori et al. (2008) to try to detect J 133658.3–295105 through GEMINI+GMOS Hα spectroscopy and multi-band imagery. The authors detected Hα in emission, thought with low S/N, with Vr=130±40 km sec^{-1} with respect to M83 optical nucleus (z= 0.00152), which indicates that it is a nearby source and it is receding with respect to the galaxy. Looking for Fe-Ka emission line to better constrain the distance to the source, we reanalyze *Chandra* observations previously discussed by Soria & Wu. Figure 9 shows the spectra of J 133658.3–295105. With the type of binning we used the Fe-Ka line, though noisy, is clearly visible. The model of J 133658.3–295105 is composed of a thermal component (apec) and a disk-blackbody (diskline), this one, specifically models the Fe-Ka line, which shows a redshift z=0.021(+0.008-0.004). We can conclude that RS28 is associated with M83.

References

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