The secular evolution of M83 central bulge

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Abstract. The luminosity profile of M 83 bulge can be traced by a de Vaucouleurs' law between ≈ 200 pc and ≈ 800 pc. The inner part can be fitted by a $n = -1/2$ Sérsic profile. Also the IR $(J - K)$ color shows difference between the periphery and the central part of the bulge, both properties indicating the presence of a pseudobulge. Previous Gemini-S 3-D, Paβ spectroscopy of the central $\approx 5'' \times 13''$ revealed spider like diagrams indicating disk like motion around three extended masses identified respectively with the optical nucleus (ON), with the center of the bulge isophotes, similar to the CO kinematical center (KC), and with a condensation hidden at optical wavelengths (HN), coincident with the largest lobe in $10\,\mu m$ emission, most probably a cannibalized satellite. Numerical simulations show that they suffer strong evaporation and they would merge engulfing also the star forming arc in few hundred Myr, increasing the mass at the kinematical center by a factor o five or more. Upper mass limit of putative Black Holes associated to ON, KC and HN are a few ten thousand to a million solar masses. GMOS+Gemini imaging and spectroscopy of a chain of radio sources has yield no optical high redshift counterparts. This radio sources are aligned with ON, neither associated to SN nor to HII regions and might point to an older similar phenomenon, which left behind a kick-off spur.

Keywords. galaxies: individual (M83), galaxies: kinematics and dynamics, black hole physics

1. Introduction

M 83 and Cen A are the largest galaxies in one of the most active regions in the nearby sky, the Hydra-Centaurus group. Processes of mergers as well as galactic inner build-up are evident in both galaxies. M 83 is a unique case for this type of studies, because of the richness of phenomena occurring at the bulge center. Indeed, the condensation traditionally recognized as its nucleus (ON) is observable at optical wavelengths and is off-centered by $4''$ to the NE with respect to the center of the external K band isophotes of the bulge which can be fitted by a de Vaucouleurs' law in an annular region between $\approx 10''$ and $40''$ (Jensen *et al.* 1981). Thatte, Tecza & Genzel (2000) demonstrated that the bulge center host an obscured condensation (KC). Assuming a virialized system, they derived comparable masses $M_{KC} \approx M_{ON} \approx 13.2 \times 10^6 \, M_\odot$ inside 5.4 pc in a cluster or a super massive core. From CO interferometry Sakamoto *et al.* (2004) found steep velocity gradients across ON, and determined a mass of $3 \times 10^8 \, M_\odot$ within a radius of 40 pc, nevertheless, the spatial resolution in CO observations is of the order of $3''$ and inhibits conclusions about the precise position of the rotation center (see Diaz *et al.* 2006). Elmegreen *et al.* (1997) determined for ON a photometric mass of $M_{ON} \approx 4 \times 10^6 \, M_\odot$ (Hot Spot 1 in their table 4). More recently, Mast, Diaz & Aguero (2006) demonstrated the existence of a third condensation (HN), also hidden at optical wavelengths, which
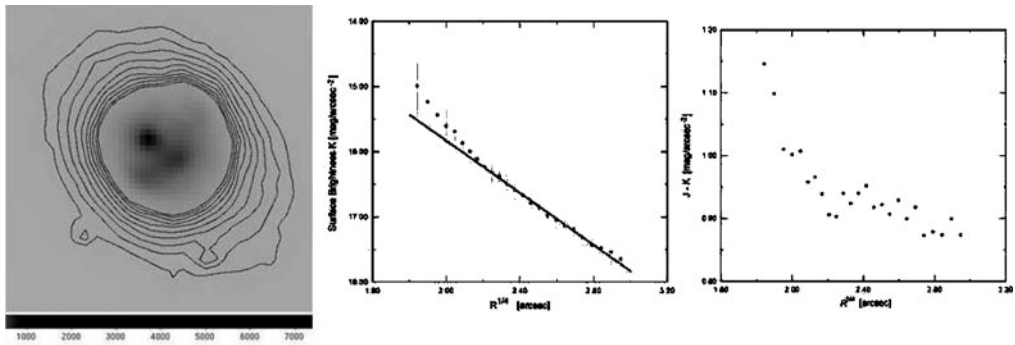
Figure 1. a) 2-mass K band $67'' \times 69''$ central field showing external bulge isophotes. b) de Vaucouleurs fit well inside $10'' < R < 40''$. c) $(J - K)$ color inside $R < 40''$. Note the change in K and $(J - K)$ inside $R < 10''$.

coincides with the maximum of continuum emission at $6\,\text{cm}$ and $10\,\mu\text{m}$ of a giant cloud (Telesco 1988) $7''$ to the WSW of KC. Diaz *et al.* (2006b) propose that HN is a small galaxy been cannibalized.

We discuss here in more detail the IR structure and colors of M83 central Kpc, as well as the effort made in detecting spurs of previous episodes similar to the undergoing merge inside the central $300\,\text{pc}$ of this interesting bulge.

2. Observations

K and J images of the 2-MASS Large Galaxies Atlas (Jarret et al. 2003) have been used to study K brightness and $(J - K)$ color profiles, with better spatial resolution than previous studies. The kinematics at the bulge center was studied at excellent conditions and with high spatial resolution 2-D spectroscopy with CIRPASS, (Parry *et al.* 2004) installed on the GEMINI-S telescope in March 2003. The IFU data, (partially presented by Diaz *et al.* 2006 and Dottori *et al.* 2007) have got a sampling of $0.36''$ ($7.8\,\text{pc}$) in an elliptical array with size $4.7'' \times 13''$.

On June 2007 GMOS-S at GEMINI-S has been used to check for the true nature of the radio source Maddox 28: is it at the distance of M83 or is it a QSR at $z = 2$, as suggested by Maddox *et al.* (2006). We performed broad and narrow band imaging in the range $500\,\text{nm}$ to $950\,\text{nm}$ centered at the position of radio-source 28 and with average seeing of $0.8''$. Spectroscopy in the same range spectral was performed with a $1.5''$ long slit along the line of radio sources shown in Figure 2 with similar seeing and in poor weather queue, being $3600\,\text{s}$ the approximate effective exposure time. The observation details will be presented elsewhere (Dottori *et al.*, in preparation).

3. Bulge and pseudobulge brightness and color

As already determined by Jensen *et al.* (1981) and Adamson, Adams & Warwick (1987), higher resolution 2-mass photometry shows that a de Vaucouleurs' law can be traced to the external part of the M83 bulge in the interval $200 < R < 800\,\text{pc}$ (Figure 1). The color $(J - K)$ is also uniform in this region, becoming redder inside $R = 200\,\text{pc}$. The isophotes of the de Vaucouleurs' bulge are circular at $R \approx 200\,\text{pc}$ but they become elliptical outwards, with major axis aligned with the bar. In spite of the non-regular light distribution, the inner region can be described by a Sérsic profile $n = -1/2$. This region with characteristic of pseudo-bulge is suffering a process of merger that in few hundred
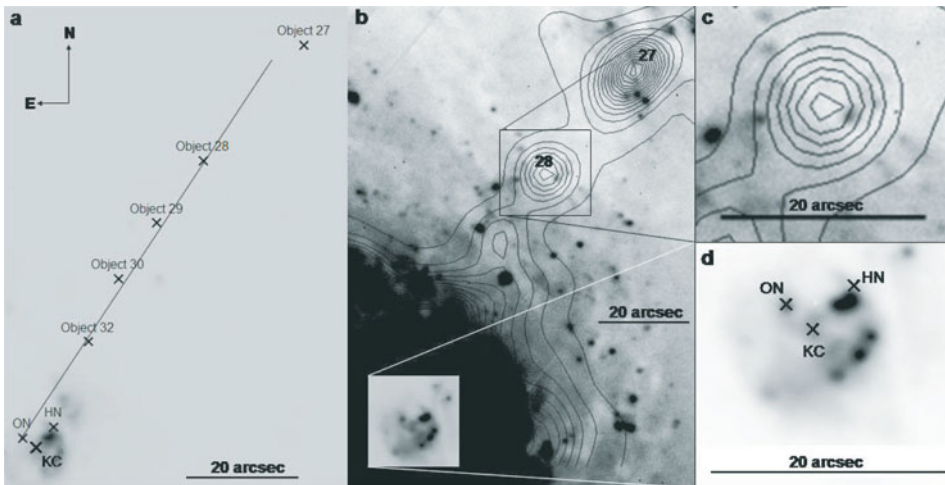
Figure 2. a) Chain of radiosources aligned with ON. b) Radiomap superposed to the 500 nm to 950 nm co-added image. c) Object 28 detail: no optical counterpart is found, and the nearest objects depict local HII region line emission. d) Bulge center map showing ON, KC and HN.

Myr will multiply by a factor of five or so the mass of KC, by adding the ones of ON, the intruder HN and that of the arc of HII regions.

4. Pseudobulge kinematics

Three spider diagrams can be well differentiated on the complex 2-D Paβ isovelocity contours. They identify the optical nucleus (ON), the bulge center (KC) and the strongly absorbed hidden nucleus (HN). A detailed description of the M 83 central region astrometry can be found in Diaz *et al.* (2006a). KC shows an inclination of $68° \pm 10°$ and the HN inclination is $50° \pm 10°$. The masses derived by Dottori *et al.* (2007) are $\approx 4 \times 10^6$ M$_\odot$, 60–70×10^6 M$_\odot$ and 30–40×10^6 M$_\odot$, respectively.

Upper mass limit for putative BH associated to each one of the condensations are (ON) $\sim 10^6 / \sin(i)$ M$_\odot$, and for (KC) and (HN) 0.2–$1.0 \times 10^6 / \sin(i)$ M$_\odot$. The kinematical data allowed also to constrain the knots relative motion. Numerical simulations, show that ON, KC and HN will merge, forming a single massive core in 50-100 Myr, an that the HII regions will also be swallowed in a few hundred Myrs.

The short dynamical timescales of this merger make of this phenomenon a unique one (probability less than 1% per galaxy). Since the Centaurus-Hydra Group to which M 83 belongs together with Cen A is so rich in activity, it is natural to rise the question on why should not have previously occurred a similar phenomenon in M 83.

5. A signature of a previous accretion?

The FII type radio-source 28 in Maddox *et al.* (2006) list, projected onto M 83 disk, presents boosted radio-lobes (objects 27 and 29) strongly aligned with the galactic bulge and other radio-sources at a projected distance between 1 and 2 kpc (Figure 2). The radio-source 28 has been proposed as a $z = 2$ radio-galaxy (Maddox *et al.* 2006), although no radial velocity measurements have been made up to now. We see other two possible scenarios for this radio-source namely it might be (a) a massive binary derived microquasar with superluminal jets; or (b) a kicked-off object (e.g. Gualandris & Merrit

2007; Bonning, Shields & Salviander 2007) associated to a past BHs quasi-merger event at the bulge center of M83.

The 12 minutes co-added image from the observed GMOS-S bands V, [OIII], [OIII]C, Hα, HαC, [SII], z, i, and CaT is shown in Figure 2. With an average seeing of $0.8''$ and considering the background noise from M 83 disk, the approximate detection limit is $m_i = 23.5 \pm 0.5$ at $S/N \sim 3$. Although the faintest expected i band apparent magnitude of a radio galaxy at $z = 2$ is $m_i \sim 18.5$ nothing is detected as can be seen in Figure 2. Then, a $z = 2$ galaxy have to be absorbed by about 5 magnitudes or more in order to avoid detection in this co-added image. Such level of extinction is not usually expected in the interarm region where the object appears projected.

In the co-added spectra, the detection limit for the continuum of an elliptical galaxy at redshift 2 was $m_i = 20.5 \pm 0.8$ ($S/N \sim 3$), and it was $m_i = 22.2 \pm 0.8$ considering the detection of H$_\gamma$ in a QSO at $1 < z < 2$. Therefore, optical spectroscopy does not confirm too that radio source 28 is a quasar at $z = 2$.

6. Conclusions

- The luminosity profile of M 83 bulge can be traced by a de Vaucouleurs' law and the inner part can be fitted by a $n = -1/2$ Sérsic profile. This characteristic and the IR $(J - K)$ color difference between the periphery and the central part of the bulge, would indicate the presence of a pseudobulge.

- High resolution 3D spectroscopy observations constrain the masses of possible central very dense objects in the ON and KC, ruling out the presence of a BH more massive than $10^6 \, M_\odot$ within these condensations. Our numerical simulations show that ON, KC and HN will merge forming a single massive core in less than 50 Myr.

- Deep optical imaging and spectroscopy on the location of the source Maddox 28 do not confirm the high redshift nature of the source and leave open the question of a possible kick-off remnant pointing to the bulge center.

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