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THE WARM INTERSTELLAR GAS IN STARBURSTS AND AGNS

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RESUMEN

Estudiar la relación entre formación estelar violenta y el fenómeno AGN es crucial para entender la formación y evolución de las galaxias y los agujeros negros supermasivos. El gas ionizado es un trazador excelente de los procesos de retroacción entre las poblaciones estelares y el gas en AGNs y Starbursts. Imágenes profundas de AGNs (Seyferts, Radio Galaxias y QSOs) y Starbursts (ULIRGs-VLIRGs) en las líneas de emisión Lyα, CIV, HeII, Hα, y líneas colisionales en el óptico ([OIII], [NII], ...) tomadas con OSIRIS serán imprescindibles para determinar si existe un vínculo evolutivo entre galaxias con formación estelar violenta y actividad nuclear.

ABSTRACT

Elucidating the relationship between intense star-formation and the AGN phenomenon is crucial to our understanding of the formation and evolution of galaxies and their SMBHs in the early universe. The warm interstellar gas is an excellent probe of the feedback processes taking place in galaxies, in particular in AGNs and starbursts. Deep imaging taken with OSIRIS tuned at the emission lines Lyα, CIV, HeII, Hα, and optical collisional lines of AGNs (Seyferts, Radio Galaxies and QSOs) and Starbursts (ULIRGs-VLIRGs) will help to determine whether there is an evolutionary link between star-formation and nuclear activity.

Key Words: **GALAXIES: ACTIVE — GALAXIES: EVOLUTION — GALAXIES: STARBURSTS — ISM**

1. INTRODUCTION

Today there is increasing evidence that the evolution of massive galaxies is linked to their nuclear activity. This evidence is supported by: 1) the similarities between the evolution of the QSO luminosity density and the star formation rate (Boyle & Terlevich 1998); 2) the tight correlation between the black hole mass and the bulge stellar velocity dispersion (Ferrarese & Merrit 2000). These results imply that the creation and evolution of a BH (pressumably associated to a QSO) is intimately connected to that of the galaxy bulge. Furthermore, they also suggest a Starburst-AGN connection due to the coexistence in a galaxy of circumnuclear starbursts and QSO activity. However, it is uncertain, whether the star formation and AGN activity are always coeval.

In the last decade we have found evidence of the Starburst-AGN connection through the identification of circumnuclear starbursts in nearby Seyfert 2 galaxies (González Delgado et al. 1998a, 2001; Cid Fernandes et al. 2001). The bolometric luminosities of these starbursts are similar to the estimated bolometric luminosities of their Seyfert nuclei, suggesting that more powerful AGNs may be related to more powerful central starbursts. Young and intermediate age populations have also been detected in SDSS luminous AGN (e.g. Kauffmann et al. 2003), Low-Luminosity AGN (González Delgado et al. 2004) and Radio Galaxies (Tadhunter et al. 2005). Circumnuclear starbursts have also been found in surveys of QSO host galaxies (Canalizo & Stockton 2001; Sánchez et al. 2004). They have revealed that the host galaxy colors are significantly bluer than those of elliptical galaxies. The colors and stellar lines are consistent with an intermediate age population, that was probably associated to a starburst triggered 1 Gyr ago. These QSOs show merger/interaction features in their hosts. A major merger between two/several gas-rich galaxies can induce major and extended starburst as well as QSO activity, for example in ultraluminous infrared galaxies (ULIRGs) (Veilleux et al. 2002). Strong evidence has been found connecting nuclear activity and merger in these objects because the fraction of Seyfert nuclei increases with the far-infrared luminosity (Veilleux et al. 1999). These results suggest that mergers can drive an evolutionary sequence from cool ULIRGs to warm ULIRGs on their way to becoming QSOs (Sanders et al. 1988; Canalizo & Stockton 2001).

The extended warm gas is a very useful tracer of the kinematics, the metallicity and the star formation rate in galaxies. Furthermore, it is an excellent probe of the feedback processes taking place in galax-

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ies, in particular in AGNs and starbursts. Outflows of ionized gas that are driven by the evolution of the massive stars in starbursts or AGNs, or the interaction of the radio-jet with the interstellar medium are well traced by the extended warm gas. In addition, the morphology of the ionized gas can also trace the leftover debris products of the interaction and/or merger processes in these galaxies. Thus, observations of the warm extended ionized gas are essential to determine whether there is an evolutionary link between star-formation and nuclear activity in AGNs. For this propose we have selected several samples of Starbursts (ULIRGs and VLIRGs, with log $L_{IR} \geq 12.0$ and 11.0-12.0 L⊙, respectively) and AGNs (Seyferts, Radio Galaxies and QSOs), at high- ($2 \leq z \leq 4$) and low-redshift ($z \leq 0.4$) to be observed with OSIRIS. Deep images at Lα, CIV λ1550, HeII λ1640, Hα, and optical collisional lines (such as [OIII] λ5007,4959, [NII] λ6584,6548, [OI] λ6300, [SII] λ6717, 6732, etc) of AGNs and Starbursts will provide crucial information about the feedback processes taking place in these galaxies.

2. HIGH-Z GALAXIES: Lα EMISSION

Lyα in emission can be produced by recombination of hydrogen photoionized by the starbursts and AGN. Massive stars in the starbursts provide enough ionizing photons to produce a large Lyα flux. However, the Lyα line has a complex structure because: a) is affected by dust more than any Balmer recombination line since extinction curves peak in the FUV; b) Lyα photons are attenuated by dust as a result of multiple resonant scatterings by hydrogen atoms that increase the path length of the Lyα photons and thus the probability that they will be absorbed by dust. On the other hand, the visibility of the Lyα line depends on the distribution and kinematics of the neutral gas. However, the Lyα line is a good tracer of the large-scale outflows that are expected to be a common phenomenon in Starbursts (González Delgado et al. 1998b). These Lyα outflows have been detected extended up to 10 Kpc in nearby starbursts (Mas-Hesse et al. 2003).

The Lyα line is very important for studying the star formation processes at redshift z≥ 2, when the line becomes accesible at optical wavelengths. Narrow band images of Lyman break galaxy fields have reported the detection of Lyα blobs (Steidel et al. 2000; Matsuda et al. 2004). The origin of these blobs is still unclear. They could be associated to shock heating gas by starbursts-driven superwinds, but they could be produded by cooling radiation from gravitationally heated gas in collapse halos. Because these halos are in protocluster regions, the phenomenon could be related to early galaxy formation.

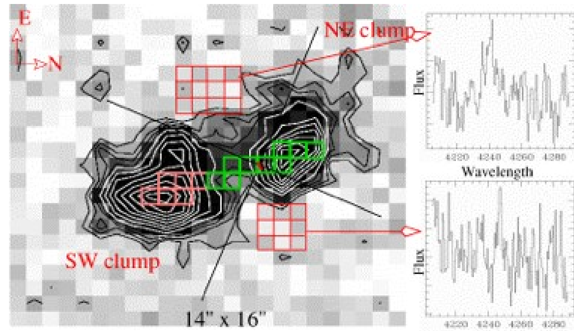

Fig. 1. Lyα halo of the radio galaxy MRC 2104-242 (z=2.49) obtained with VIMOS+VLT (taken from Villar-Martín et al. 2006). The nebula is extended about 120 Kpc and it is tracing a very massive rotating disk.

Lyα halos have been detected in Radio Galaxies. In addition to Lyα emission aligned with the radio-jet, the line is detected very extended, up to more than 100 Kpc (Villar-Martín et al. 2003; van Breugel et al. 2006). They have very low surface brightness, and Lyα luminosities of 10^{44} erg s^{-1}. The morphology in some cases suggests that the Lyα halo is associated with superwinds (Reuland et al. 2003). However, in other radio galaxies, the kinematic information suggests that the line is tracing a rotating disk of gas with 10^{11} M⊙ (Villar-Martín et al. 2005; Figure 1).

OSIRIS is an ideal instrument to detect Lyα halos in a sample of Radio Galaxies and QSOs with 2≤z≤4 because it will be able to detect easily a surface brightness of 10^{-17} erg s^{-1} cm^{-2} $Å^{-1}$, typical of Lyα halos and blobs. Its tunable filters allow us to observe other emission lines, such as HeII and CIV, providing information about the ionization mechanism of these halos. These studies will tell us about how the star formation proceeds in massive galaxies and in consequence about the formation of galaxies.

3. LOW-Z GALAXIES: BALMER AND COLLISIONAL LINES

Are QSOs and Radio Galaxies part of a post-merger evolutionary sequence between VLIRGs-ULIRGs and elliptical galaxies? At what stage during the merger sequence do the radio jet and QSO activity occur? To answer these two questions we have selected several samples of VLIRGs-ULIRGs, Radio galaxies and QSOs at low redshift ($z \leq 0.4$). The proposal is:

a) To study the spatial distribution of the properties of the host stellar populations. The high-order

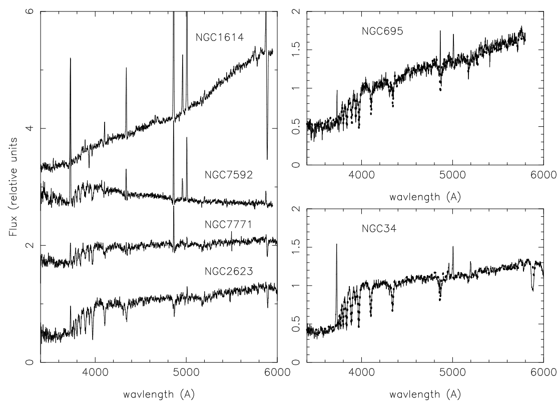

Fig. 2. Spectra of VLIRGs-ULIRGs obtained at the WHT. The spectra are fitted using evolutionary models (right pannel). The age, extinction, luminosity and mass are determined. This analysis together with QSOs data will allow us to investigate whether there is an evolutionary link between VLIRGs-ULIRGs, QSOs and ellipticals.

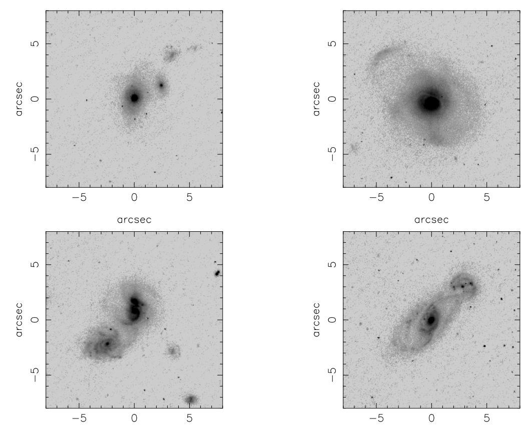

Fig. 3. HST+ACS(F606w) images of Post-Starburst QSOs. The SDSS spectra show broad Hα emission line characteristic of classical QSOs plus high-order Balmer lines and CaII K and H in absorption as in post-starbursts. The images show features of merger systems, such as long tidal tails. They may represent transition objects between ULIRGs and classical QSOs.

Balmer lines, the CaII H and K, G band, Mgb and the Balmer break, together with evolutionary synthesis models (González Delgado et al. 2005) and spectral synthesis techniques, are used to determine the stellar properties (age, mass, luminosities, extinction) of the AGN hosts and VLIRGs-ULIRGs. In particular, ages can be used as a clock to set the possible evolution between ULIRGs, QSOs and elliptical galaxies. Furthermore, the determination of the relative ages of the different stellar components within the same host, along with dynamical ages can put constrains on the timescale for concentrating material in the nucleus. This study requires long-slit or integral field spectroscopy in the rest-frame optical range at intermediate spectral resolution. For the nearby galaxies, the observations can be done with an intermediate size telescope (see Figure 2); however, a large collecting area, such as GTC has, and a sensitive instrument (e.g. OSIRIS or ELMER) is needed to obtain the stellar population properties in the QSO hosts (see some examples in Figure 3).

b) To study the spatial distribution of the extended ionized gas. OSIRIS is essential to map the extended ionized gas by means of the most important emission lines, such as Hα, Hβ, [NII] λ6584, [OIII] λ5007, [OII] λ3727, [OI] λ6300 and [SII] λ6717,6732. The morphology of these regions together with the emission line ratios will be used to distinguish between gas photo-ionized by the AGN or by young stellar components. The OSIRIS tunable filters are crucial to probe the feedback processes taking place in these galaxies, such as outflows associated to the starbursts, as well as to find out very far-away filaments and arcs that could be associated to tidal debris from recent mergers (see Tadhunter et al. 2000).

These studies enable us to find out whether there is an evolutionary link between powerful AGNs (Radio Galaxies and QSOs) and starbursts (ULIRGs and VLIRGs), and to study the role of mergers in triggering the AGN activity and the formation of galaxies.

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