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CASE STUDIES OF INTERACTING QSO HOST GALAXIES[1]

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RESUMEN

La interacción putativa de fusiones de galaxias, actividad en brotes estelares y actividad nuclear es un ingrediente clave para la hipótesis de una secuencia evolutiva desde las galaxias infrarrojas ultra-luminosas (ULIRGs) a los objetos cuasi-estelares (QSOs). Resultados novedosos recientes del estudio de la galaxia huésped del QSO I Zw 1, basado en imágenes en el cercano infrarrojo y espectros obtenidos con ISAAC en el Very Large Telescope (VLT) del European Southern Observatory (ESO), y en imágenes ópticas complementarias del EFOSC2 en el telescopio de 3.6 m de ESO, apuntan a que está sucediendo una fusión menor entre I Zw 1 y su galaxia compañera del oeste. Los primeros resultados de SDSS J114203.40+005135.8 con ISAAC más el sistema de óptica adaptativa NAOS CONICA (NACO) con el Simultaneous Differential Imager (SDI) en el VLT muestran evidencia de una estructura doble en la región central.

ABSTRACT

The putative interplay of galaxy mergers, starburst activity, and nuclear activity is a key ingredient for the hypothesis of an evolutionary sequence from ultra-luminous infrared galaxies (ULIRGs) to quasi-stellar objects (QSOs). Recent results from a case study of the nearby QSO host I Zw 1, based on near-infrared (NIR) images and spectra taken with ISAAC at the Very Large Telescope (VLT) of the European Southern Observatory (ESO) and on complementary optical images from observations with EFOSC2 at the 3.6 m telescope of ESO, show new indications for an ongoing minor merger between I Zw 1 and the western companion galaxy. First results from NIR imaging of SDSS J114203.40+005135.8 with ISAAC and with the adaptive-optics assisted NAOS CONICA (NACO) Simultaneous Differential Imager (SDI) at the VLT give evidence for a double structure in the center.

Key Words: galaxies: interactions — quasars: individual (I Zw 1, SDSS J114203.40+005135.8)

1. INTRODUCTION

An evolutionary link between ULIRGs and QSOs was suggested by Sanders et al. (1988). The physical scenario proposed involves major galaxy mergers triggering the inflow of gas which serves as fuel for strong starburst activity and for the newly formed or already existing active galactic nucleus (AGN). At an early stage of the evolution, the object would appear as a ULIRG characterized by emission from the starburst and the dust-enshrouded AGN. At a later stage, when the starburst has subsided and the AGN is blown dust-free, the object would appear as a typical QSO. The validity of this evolutionary scheme is a matter of debate and might depend on the QSO sample. While an evolutionary relation between the hosts of the QSO sample of Dunlop et al. (2003) and ULIRGs seems doubtful (Tacconi et al. 2002), QSOs from the Palomar Green Bright Quasar Survey (Schmidt & Green 1983) might be candidates for a post-ULIRG stage (e.g. Dasyra et al. 2007).

Since galaxy mergers are a key ingredient of the ULIRG-to-QSO evolution, the case studies presented here concentrate on QSO hosts with indications of ongoing galaxy mergers. Results from an ongoing case study of the nearby QSO and minor merger candidate I Zw 1 are shown in § 2. First results from NIR imaging of the possible major merger remnant SDSS J114203.40+005135.8 are presented in § 3.

2. THE NEARBY QSO HOST I ZW 1

I Zw 1 was observed with ISAAC at the VLT of ESO. Complementary optical images from the ESO Science Archive Facility were observed with EFOSC2 at the 3.6 m telescope of ESO. A detailed

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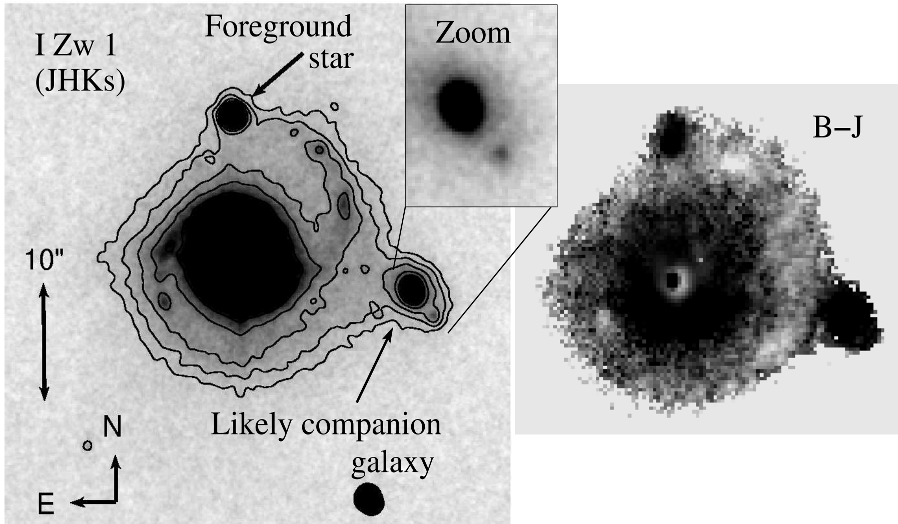

Fig. 1. Left panel: NIR image of I Zw 1 taken with ISAAC. The figure shows the average of the J-, H-, and Ks-band images. A zoom of the region around the likely companion highlights the separate object to the south-west of the companion. Right panel: $B-J$ image of I Zw 1 with light and dark grey indicating blue and red colors, respectively. The central part of the color image shows artifacts from saturation by the QSO nucleus.

discussion of the complete data set, including spectroscopy with ISAAC, has meanwhile been published (Scharwächter et al. 2007).

I Zw 1 is well known for its prototypical properties as a narrow-line Seyfert 1 galaxy (e.g. Boller et al. 1996; Gallo et al. 2004). It is also considered as one of the closest QSOs ($z = 0.0611$), (Condon et al. 1985). The object to the west of the I Zw 1 disk is a possible companion galaxy which has been found at approximately the same redshift as I Zw 1 (Canalizo & Stockton 2001). The ISAAC J-band image combined with the EFOSC2 B-band image (Figure 1, right panel) indicates a possibly interaction-driven star formation activity in the western part of the I Zw 1 host galaxy. This is suggested by a concentration of blue color extending along the north-western spiral arm of the host galaxy into the region adjacent to the companion galaxy. The extension of the likely companion galaxy to the south-west, which was previously suggested as a kind of tidal tail (Scharwächter et al. 2003), resolves into a separate source when combining the J-, H-, and Ks-band images (Figure 1, left panel). The companion itself is likely to be a gas-poor dwarf elliptical (Canalizo & Stockton 2001; Scharwächter et al. 2007).

3. A DOUBLE STRUCTURE IN THE CENTER OF SDSS J114203.40+005135.8

SDSS J114203.40+005135.8 was observed with ISAAC in the J- and H-bands and with the adaptive-optics assisted NACO SDI. SDSS J114203.40+005135.8 ($z = 0.245$) has been mentioned as a LINER (Kniazev et al. 2004) and as a radio source (17.68 mJy at 1.4 GHz), the optical counterpart of which shows emission lines characteristic of star formation activity (Magliocchetti et al. 2002). The SDSS image gives evidence for a low surface-brightness structure extending in the form of an arc about 6″ from the main body of the host galaxy to the south west.

The new H-band image of SDSS J114203.40+005135.8 (Figure 2, left panel) shows the faint arc-like extension of the host galaxy and reveals a double structure in the center. At high spatial resolution, this double structure is resolved in the NACO SDI observations (Figure 2, middle panel) although the S/N is too low to reliably provide detailed morphological information. The S/N of the image in Figure 2 has been enhanced by median-combining of the images taken simultaneously through the four NACO SDI filters (centered at 1.575, 1.600 micron and two at 1.625 micron). The morphology of SDSS J114203.40+005135.8 is likely to be the result of a major galaxy merger. The one-sided extension of the host galaxy and the double structure in the center remind of the radio-loud QSO 3C 48 (Figure 2, right panel). 3C 48 is known to display a second luminosity peak about 1″ north-east of the QSO. This peak has been discussed as a possible interaction of the

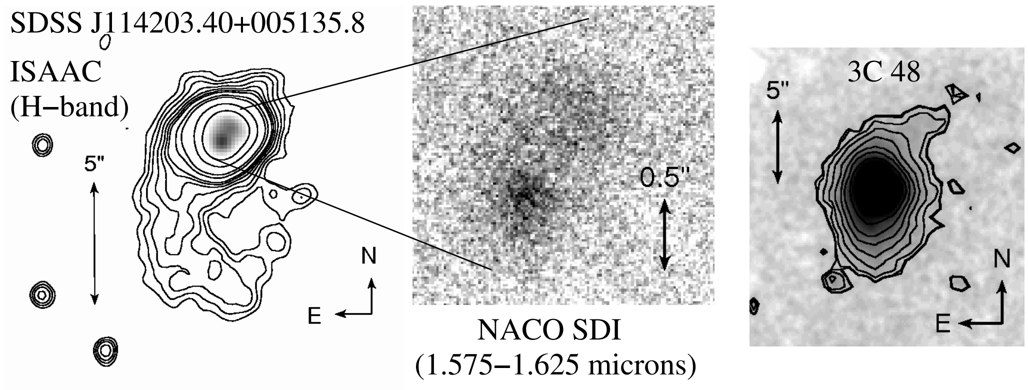

Fig. 2. Left panel: H-band ISAAC image of SDSS J114203.40+005135.8. The contours of the ISAAC image show the disturbed morphology of the QSO with the prominent extension to the south-west. The cuts of the underlying grey-scale image are adjusted to highlight the double structure in the center of the host galaxy. Middle panel: NACO SDI image of the central region. The plot shows a median of the four images taken simultaneously by the SDI at 1.575, 1.600, and 1.625 micron. Right panel: Averaged ISAAC J- and H-band image of the QSO 3C 48 for comparison (data published in Zuther et al. 2004).

radio-jet with the interstellar medium, or as the nuclear bulge of a second galaxy merging with 3C 48 (e.g. Stockton & Ridgway 1991; Chatzichristou et al. 1999; Canalizo & Stockton 2000; Zuther et al. 2004; Scharwächter et al. 2004; Krips et al. 2005). Multi-particle simulations for 3C 48 have shown that the one-armed tidal structure can be explained by projection effects during a major merger between two inclined disk galaxies (Scharwächter et al. 2004).

4. CONCLUSIONS

The data for I Zw 1 lend further support for an ongoing minor merger with the western companion galaxy. If not triggering the QSO activity, the minor merger process might be responsible for a rejuvenation or for an increase of the AGN activity from Seyfert- to QSO-levels (see Corbin 2000). The double structure revealed in the center of SDSS J114203.40+005135.8 and the clearly disturbed morphology of the host make this QSO an interesting target for a more detailed case study of a major merger candidate. The ongoing project with the NACO SDI aims at a detailed study of the morphology of the central region at improved S/N.

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