PROCEEDINGS OF SCIENCE

The starburst-AGN connection: A case study of SMMJ04135+10277 using MERLIN and HSA*

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One of the key outstanding questions in AGN astrophysics is the relation between the growth of super-massive black holes and massive galaxies. We have conducted a VLBI study using MERLIN C-band and HSA L-band radio continuum observations of the submillimetre selected type-1 quasar SMMJ04135+10277 (z=2.8) to address whether this particular quasar is a transition object between growth of the stellar mass and the super-massive black hole or not. CO data and submillimetre data indicate that the quasar host galaxy appears to be undergoing an intense episode of star formation. The VLA C-band flux is in good agreement with this and the MERLIN results show that at least half of the radio emission arises from an extended starburst region. SMMJ04135 is not detected in VLA L- and X-band data, yielding a rather peculiar radio continuum spectral energy distribution. We discuss the potential for using HSA and MERLIN observations for determining the relative contribution to the radio emission from the AGN and the starburst.

From Planets to Dark Energy: the Modern Radio Universe
October 1-5 2007
University of Manchester, Manchester, UK

*MERLIN is a national facility operated by the University of Manchester on behalf of the STFC. The National Radio Observatory is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities Inc. The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a cooperative agreement with the National Science Foundation. This work has benefited from research funding from the European Community's sixth Framework Programme under RadioNet R113CT20035058187.

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PoS(MRU)107

1. Introduction

It has been suggested that quasars, submillimetre galaxies (SMGs), and extremely red objects (EROs) form an evolutionary sequence and that the end product is a massive elliptical galaxy (e.g., [5]). Through studies of the submillimetre properties of EROs and distant red galaxies (DRGs) an overlap between EROs/DRGs and SMGs has been established ([10, 9, 4]). Additionally, several high-z quasars exhibit signatures of intense star formation (e.g. [8]).

In this project we have focused on the submm discovered type-1 quasar SMMJ04135+10277 ($z = 2.84$; [3]). SMMJ04135 has a lensing corrected 850μm flux of 19 mJy, making it one of the brightest SMGs. The submm spectral energy distribution (SED) suggests that the far-infrared emission is thermal dust emission. From the CO detection ([2]) the estimated H_2 mass is $\sim 10^{11}\,M_\odot$, which is one of the most massive reservoirs of molecular gas at high redshift, suggesting that it has a potential for undergoing intense star formation. As the redshift of SMMJ04135 makes near-IR observations of e.g. Hα or oxygen lines difficult, we have sought an alternative through high angular resolution radio continuum to be able to quantify the relative contributions of the AGN and the starburst.

2. Results

The observations were conducted using the High Sensitivity Array (which included the VLBA, VLA, GBT and Arecibo) at 1.4GHz L-band and MERLIN at 5GHz (C-band) reaching a sensitivity of 6μJy and 33μJy, respectively. The astrometry of the data was verified using the cD galaxy of the foreground cluster A478. SMMJ04135 was not detected in either data-set and so we place upper limits on the flux. The results are shown in Table 1. Additionally, we have used archival VLA C-band data, which yield a $\sim 7\sigma$ detection. Based on a typical spectral index as well as the radio-far-infrared correlation for starburst galaxies it was expected that SMMJ04135 would have been detected in the L-band VLA data that were obtained with the HSA observations and thus providing the total L-band flux, however, surprisingly it was not detected. For redshift 2.84, $1''$ corresponds to 7.9 kpc.

Table 1: The resolution and sensitivity of the existing data, as well as the flux or upper limits for SMMJ04135.

	band	FWHM	f [μJy]
HSA	L	$0.01'' \sim 80$ pc	< 18
MERLIN	C	$0.04'' \sim 320$ pc	< 100
VLA	C	$0.4'' \sim 3.2$ kpc	220$\pm$30
VLA	X	$0.7'' \sim 5.5$ kpc	< 15
VLA	L	$1.4'' \sim 11$ kpc	< 180

3. Discussion

3.1 Major starburst in the host galaxy?

The original goal of the project was to determine the fraction of radio emission arising from the AGN and from the starburst of SMMJ04135 and constrain the size of the starburst region, similar to

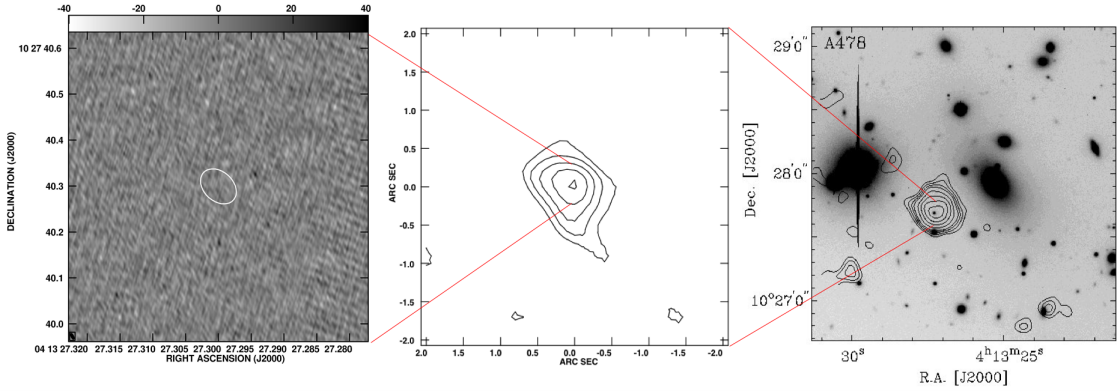

Figure 1: (left) The HSA map of SMMJ04135. The ellipse show the uncertainty in position based on the VLA C-band detection. The flux scale is in μJy/beam. The resolution corresponds to $\sim$ 80 pc. When tapering the data to a resolution of 25 milliarcsec ($\sim$ 200 pc), the radio source is still not detected. (middle) The VLA C-band detection; contours are 3 to 7. (right) A VLT I-band image of the cluster field A478 overlayed with SCUBA 850μm contours ([3]). The resolution of the SCUBA map is 15$''$.

the projects conducted for the quasars J1409+5628 ([1]), BR1202-0725 and BRI1335-0417 ([6, 7]). The C-band data are in good agreement with the predicted expectations from the radio-far-infrared correlation of starburst galaxies and hence the MERLIN results suggest that at least half of the radio emission arise from an extended starburst region (larger than 320pc). However, the non-detections at VLA L- and X-band yield a rather peculiar radio spectral energy distribution suggesting that SMMJ04135 is a unique object, making the HSA data inconclusive at this time. New observations have been proposed to confirm the VLA results.

3.2 The potential of VLBI observations for determining the relative contributions from AGN vs. starburst - HSA and MERLIN compared

Because of the extremely high resolution achieved with the High Sensitivity Array, such observations are ideal for determining the presence of a high brightness temperature source (typically a compact source like an AGN). Given the large sensitivity it is also possible, through tapering, to place a low limit on the size of an extended component (typically a circumnuclear starburst region).

The resolution achieved using MERLIN is somewhat less than that of the HSA, however, it is better matched to the angular extend of a high-redshift massive starburst at scales $\sim$ 1 kpc. With the upgrade of MERLIN to eMERLIN, which will be completed and operational in 2008 and with a sensitivity increase by a factor 20, eMERLIN will be an ideal instrument to study the radio continuum emission from high-z starbursts. Through eMERLIN the extended sources can be studied and the compact sources can be identified and followed-up using HSA – both instruments offering great potential for such projects.

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