1. Introduction

We discuss observations of the submm-selected galaxy, SMM J02399−0136, and what has been learnt about it during the year following its discovery. SMM J02399−0136 was the first distant galaxy detected in submm surveys with SCUBA. Its association with a massive, gas-rich starburst/AGN at z = 2.8 has lead to suggestions that the prevalence of AGN in the early Universe may be high (Ivison et al. 1998) and that these AGN may account for a significant fraction of the far-IR background.

2. Discovery

The discovery of SMM J02399−0136 (Ivison et al. 1998) came as a surprise to all concerned, with the possible exception of Andrew Blain who had been a long-time proponent of submm imaging of the distant Universe using massive cluster lenses (Blain 1997). The discovery images were obtained with SCUBA during uncharacteristically good weather in the summer of 1997 by Smail, Ivison & Blain (1997). As often seems to happen, SMM J02399−0136 was seen in the first map, behind the z = 0.37 massive cluster, Abell 370. The area covered during that first night has since
increased by two orders of magnitude, with the completion of the SCUBA Lens Survey (Smail et al. 1998; Blain et al. 1999; Smail et al., these proceedings) and the commencement of several large, conventional blank-field surveys (e.g. Eales et al. 1999) but SMM J02399−0136 remains the brightest submm-selected galaxy, by virtue of its amplification by the foreground cluster (a factor 2.4 ± 0.3). This amplification aids us in the follow-up of SMM J02399−0136 at all wavelengths, and when combined with the lavish archival datasets available for this field, has allowed a detailed view of the nature of this source to be achieved relatively quickly.

3. New and archival data

Fortuitously, a deep (10 µJy beam−1) 1.4-GHz map of A 370 obtained some years ago by Frazer Owen and K.S. Dwarakanath revealed a weak, extended radio counterpart within the error box of the submm position of SMM J02399−0136 (Fig. 1). A pair of optical counterparts, resolved in archival CFHT images (Kneib et al. 1994), are within 1″ of the radio source. L1, the compact component, is marginally resolved with an intrinsic FWHM of 0.3″. L2 has a more complex morphology than L1, showing a ridge of emission to the north and a diffuse region extending south and west towards L1. L1 and L2 are separated by ~ 3″ (~ 9 kpc after correcting for tangential amplification).

The swift provision of near- and mid-IR images from UKIRT and ISO by
Figure 2. Optical spectra of L1 and L2 (Ivison et al. 1998). L1 shows a number of narrow emission lines at $z = 2.803$ superimposed on a blue continuum, with hints of broad absorption features on the blue wings of some lines. The substantially fainter L2 shows only Ly$\alpha$ and Si$\text{II}$/O$\text{I}$ at a similar redshift to that of L1. The lower spectrum in each panel is an arbitrarily scaled sky spectrum; the hatched regions are strongly affected.

Tim Naylor and Leo Metcalfe showed that at least one of the two counterparts possessed a spectral energy distribution (SED) whose broad features were consistent with those expected for a submm-bright galaxy.

Since the optical counterparts were relatively bright ($I_{\text{total}} \sim 20.5, 22.7$), we added a slit to a mask being used for multi-object spectroscopy of A 370 with the CFHT and obtained high-quality optical spectra (Fig. 2). These clearly show that both counterparts are at the same redshift, $z = 2.803 \pm 0.003$. Both have faint continua with narrow lines in emission: L1 shows strong, narrow Ly$\alpha$, N$\text{V}$ and C$\text{IV}$, hints of weak Si$\text{II}$, Si$\text{IV}$, He$\text{II}$ and possibly a broad C$\text{III}$] line; L2 shows only weak, narrow Ly$\alpha$ and Si$\text{II}$/O$\text{I}$, with the Ly$\alpha$ emission extending over at least 8$''$.

The 1.4-GHz radio emission covers 7.9$''$$ \times$ 2.2$''$, with a position angle (PA) of 71$^\circ$, a maximum surface brightness of 221 $\mu$Jy beam$^{-1}$ and an integrated flux density of 526±50 $\mu$Jy. This is below the detection thresholds of most radio surveys, even after lens amplification. The rest-frame far-IR-to-5 GHz flux ratio is similar to that seen in nearby starbursts (Condon et al. 1991), which could be taken as evidence that a starburst is the dominant contributor to the far-IR luminosity; however, a recent 5-GHz map shows a PA closer to the optical/IR morphology, which suggests that the 1.4-GHz emission may be from the AGN.

Near-IR spectra of [O$\text{III}$] and Balmer $\alpha$ were also obtained. Observa-
Figure 3. SED of SMM J02399−0136 (filled circles). The right-hand scale gives the flux densities for this galaxy. For comparison, we have plotted the SEDs of the only other reliably identified submm galaxy, SMM J14011+0252 at $z = 2.6$ (Ivison et al. 1999), several IRAS galaxies, and the $z = 4.25$ radio galaxy, 8C1435+635, with units of luminosity density on the left-hand scale. Amplification corrections have been applied. For SMM J02399−0136, data were taken from Ivison et al. (1998), A. Cooray, K. Dwarakanath, L. Metcalfe and F. Owen (priv. comm.) and Frayer et al. (1998).

The most recent observational success was a search for molecular gas in the system (Frayer et al. 1998). The search began at the optical redshift, using the Owens Valley Millimeter Array. After 38 hr of integration time, a weak signal with coherent phases was found at the reddest velocities. A further 16 hr was spent at a lower frequency to obtain the complete...
line profile shown in Fig. 4. The CO emission is unresolved (< 5″) and positionally coincident with L1. It is redshifted by 400 km s\(^{-1}\) with respect to the optical lines, with \(z_{\text{CO}} = 2.808\). The line is broad (710 \(\pm\) 80 km s\(^{-1}\)), with an apparent double-peaked profile.

The high molecular gas mass implied by the data (\(\sim 10^{11} M_\odot\)) lends weight to arguments that a significant fraction of the immense far-IR luminosity is due to star formation. Such a mass is not unique for high-redshift systems but it is several times higher than the most luminous low-redshift IRAS galaxies, implying that SMM J02399−0136 will evolve into a massive galaxy. The large gas mass, compared to the dynamical mass, suggests that the gas is a dynamically important component of this galaxy and points to its relative youth. On the other hand, the gas-to-dust ratio (400 for \(T_{\text{dust}} = 50 K\)) is similar to that found for other high-redshift CO sources, suggesting that like many other high-redshift massive galaxies, SMM J02399−0136 is already chemically evolved.

SMM J02399−0136 is one of two galaxies from the SCUBA Lens Survey to be detected in CO to date, the other being SMMJ14011+0252 at \(z = 2.6\) (Ivison et al. 1999; Frayer et al. 1999). These are the first two members of the submm field population to be investigated in detail. Their optical emission-line characteristics are radically different, with one showing strong AGN signatures, the other an apparently pure starburst spectrum;
however, both are found to be associated with gas-rich, massive galaxies, which supports the idea that a significant proportion of the submm galaxy population is made up of proto-ellipticals.

In summary, SMM J02399−0136 shows clear signs of the presence of an AGN, both in its optical emission-line properties and its radio morphology. However, there are also indications of an on-going starburst: extended optical emission, narrow and strong Hα emission, a large mass of dust and a dynamically significant gas reservoir. If asked the question: “Is SMM J02399−0136 an AGN or a starburst?”, we’d probably have to answer: “Both”. Critical tests of the relative luminosity of the AGN and the starburst include the identification in polarized light of hidden broad-line components to the rest-frame UV/optical emission lines, a search with AXAF for hard X-ray emission (which should escape an obscured active nucleus), and high-resolution 1.4-GHz images to look at the radio emission characteristics in more detail.

We must wait and see whether a significant fraction of submm-selected galaxies resemble SMM J02399−0136. A large AGN contribution to the far-IR background would certainly resolve potential problems concerning over-production of metals, though there are other solutions — modifying the IMF, for example (Blain et al. 1999). A decisive test of the contribution of AGN-powered emission to the extragalactic background awaits the detailed study of a representative sample of the submm-selected galaxies that dominate the submm background emission. The faintness of these sources in the optical/near-IR and millimetre wavebands compared to the sensitivities of current instrumentation means that the advantages of using lens amplification will probably remain clear for these important studies.

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