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STUDYING THE PROPERTIES OF MASSIVE GALAXIES IN PROTOCLUSTERS USING MILLIMETRE-WAVELENGTH OBSERVATIONS

M. Zeballos,[1] D. H. Hughes,[1] I. Aretxaga,[1] and G. Wilson[2] on behalf of the AzTEC team

RESUMEN

Presentamos un análisis de densidad y distribución espacial de la población de fuentes milimétricas (MMGs) hacia 17 galaxias activas a altos corrimientos al rojo usando observaciones a 1.1 mm tomadas con la cámara AzTEC en los telescopios ASTE (Atacama Submillimeter Telescope Experiment) y JCMT (James Clerk Maxwell Telescope). La muestra nos permite estudiar las propiedades de las MMGs en ambientes protocumulares (sesgados) y compararlas con la población de campos blancos (sin sesgo). El objetivo es identificar si estos ambientes sesgados son responsables de las diferencias en el número y distribución de galaxias oscurecidas por polvo, y averiguar si estos cambios apoyan la sugerencia de que las MMGs pueden ser las progenitoras de las galaxias (elípticas) masivas que vemos hoy en día en el centro de los cúmulos más ricos.

ABSTRACT

We present an analysis of the number density and spatial distribution of the population of millimetre galaxies (MMGs) towards 17 high-z active galaxies using 1.1 mm observations taken with the AzTEC camera on the Atacama Submillimeter Telescope Experiment (ASTE) and the James Clerk Maxwell Telescope (JCMT). The sample allows us to study the properties of MMGs in protocluster environments and compare them to the population in blank (unbiased) fields. The goal is to identify if these biased environments are responsible for differences in the number and distribution of dust-obscured star-forming galaxies and whether these changes support the suggestion that MMGs are the progenitors of massive (elliptical) galaxies we see today in the centre of rich clusters.

Key Words: cosmology: observations — galaxies: high-redshift — galaxies: active — submillimeter: galaxies

1. INTRODUCTION

In the nearby universe clusters have been detected and extensively studied across the full multiwavelength spectrum. Their progenitors, however, have been very difficult to identify with traditional methods such as the detection of X-ray extended emission or the identification of galaxy overdensities. X-ray emission has a positive k-correction and little of it is expected from protoclusters beyond $z \sim 2$. While cluster detection by red sequence algorithms is observationally cheap for large sky areas, clusters are typically detected using this method up to $z = 1$.

An effective technique to identify protoclusters, which has already been used in narrow-emission-line surveys, consists of targeting high-z powerful radio galaxies (Miley & De Breuck 2008). These objects have a massive stellar component and very extended neutral gas reservoirs. In addition, low-z radio galaxies usually lie in moderately rich clusters. These reasons imply that active galaxies could signpost the location of peaks in the underlying matter density-field of the universe and hence, the location of young clusters in the process of formation.

The study of millimetre sources in protocluster regions is of special interest because these heavily obscured star-forming galaxies have rest frame far-infrared fluxes that imply intrinsic luminosities $>10^{12}\ L_\odot$, star formation rates $>100\ M_\odot$ (Blain et al. 2002), and halo masses $>10^{11}\ M_\odot$ (Capak et al. 2011). These estimations make them good candidates to be progenitors of the massive elliptical galaxies in the centre of rich clusters.

This work presents 1.1 mm observations obtained with AzTEC (Wilson et al. 2008) towards 17 powerful active galaxies in order to study the number density and spatial distribution of MMGs in protocluster fields. We analyze the influence of a biased environment on the formation and evolution of this dust-enshrouded galaxy population, and determine whether these galaxies could evolve into massive ellipticals.

Our sample is part of a larger project, the AzTEC Cluster Environment Survey (ACES), which studies

[1]Instituto Nacional de Astrofísica, Óptica y Electrónica, Luis Enrique Erro 1, Tonantzintla, Puebla, Mexico (zeballos, dhughes, itziar@inaoep.mx).

[2]University of Massachusetts, 710 North Pleasant Street, Amherst, MA 01003-9305, USA (wilson@astro.umass.edu).

not only protoclusters but also low-z (evolved) clusters of galaxies. It is the largest and most complete study of biased regions at mm wavelengths to-date.

2. OBSERVATIONS AND DATA ANALYSIS

We observed 17 fields centred on active galaxies over a redshift range of $0.5 < z < 6.3$. Sixteen of these targets are powerful radio galaxies with radio luminosities $>10^{27}$ W Hz^{-1} at a rest frequency of 500 MHz. The additional source is an optically luminous ($M_B = -27.7$) radio quiet quasar. All targets were observed during a pilot run of AzTEC on the 15 m JCMT (FWHM = 18″) in 2005, and two 6-month observing campaings in 2007 and 2008 on the 10 m ASTE(FWHM = 30″).

We reduced each 1.1 mm map in a manner similar to that described in Scott et al. (2008). This involved despiking and removing correlated sky noise from the time streams with a PCA cleaning technique. Source candidates were identified as local maxima above a signal to noise (S/N) threshold of 3 (3.5) for ASTE (JCMT) maps. Given the low S/N of the source candidates, we expected some fraction of them to be spurious. Source fluxes were corrected for flux boosting (Coppin et al. 2006), and their number density (number counts) was estimated by binning the sources in flux and correcting for incompleteness using a semi-Bayesian approach described extensively in Austermann et al. (2009). The central active galaxies that were detected at 1.1 mm were removed from the catalogues since they bias the number density results.

3. RESULTS

Figure 1 shows the cumulative number counts for the combined 17 protocluster fields and compares them to a blank field also observed with AzTEC and used as a reference (details in Zeballos et al., in preparation) Figure 1 also shows number counts determined in 2 concentric circles centred at the positions of the active galaxies and with radii of 1.5′ and 3′ respectively. A significant overdensity of ∼2 is observed in the inner area ($r < 1.5'$). Further out, the number counts decrease until they look like a blank field. The significance of this overdensity was determined using Monte Carlo simulations, where we inserted a blank field population of sources into synthetic noise maps with the same area and noise properties as the observed maps. These simulations found that the probability of detecting a number of sources in a blank field that equals or exceeds the number of sources observed in our maps inside a $r < 1.5'$ is less than 5%. This could be interpreted as a preference

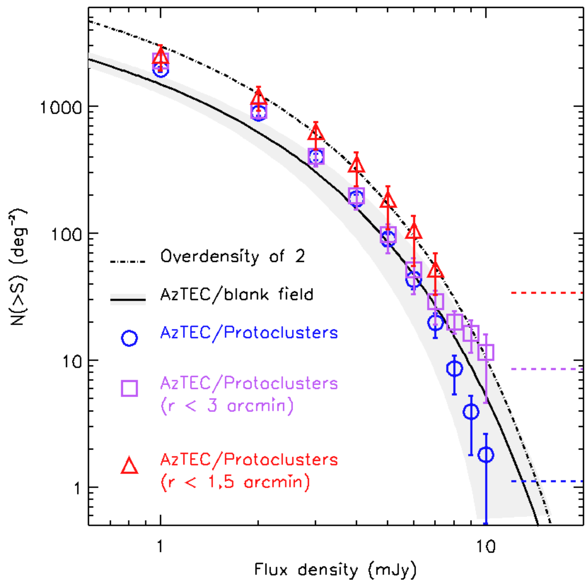

Fig. 1. Cumulative number counts for the combined protocluster sample (blue circles). The best fit to a modified Schechter function estimated from cumulative number counts of a blank field used as reference is also shown (black solid line). Red triangules (orange squares) represent the combined number counts for a 1.′5-radius (3′-radius) circular area centred on the active galaxies.

for MMGs to inhabit biased environments such as protoclusters, which supports the idea that MMGs are the progenitors of massive ellipticals since the latter are preferentially found in galaxy clusters.

We also analyzed if there was a preferred direction in which MMGs are aligned around active galaxies, and specifically if their distribution favoured the long axis of the asymetric radio emission of our radio galaxies. We rotated our 16 radio galaxy maps so that the preferred direction of their radio emission were aligned to each other. We then stacked the individual source distributions to enhance any possible alignment. The preferred direction of the MMG was calculated using the tensor of inertia of the source distribution (Zeballos et al., in prep.). We found that there is no alignment between the millimetre and radio emission.

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