Star Formation Activity of Brightest Cluster Galaxies

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Abstract

We cross checked Brightest Cluster Galaxies (BCG) with both infrared sources and x-ray cluster in an attempt to find BCGs with enhanced star formation rates. The BCG sample comes from the Sloan Digital Sky Survey (SDSS), containing 13823 samples between a redshift of 0.1 to 0.3 while the infra red sources are from the IRAS faint source catalogue with 174033 objects, and for the x-ray clusters catalogue is from the NORAS survey of extended x-ray sources. The cross match results show 46 potential candidates of IRAS-BCG and x-ray-BCGs, which were later narrowed down to 2 positive IRAS-BCGs and 7 x-ray-BCGs. The final results suggests that within the local universe, the mechanism which allows for enhanced star formation rates of BCGs has not yet started, and only occur in galaxies at higher redshift.

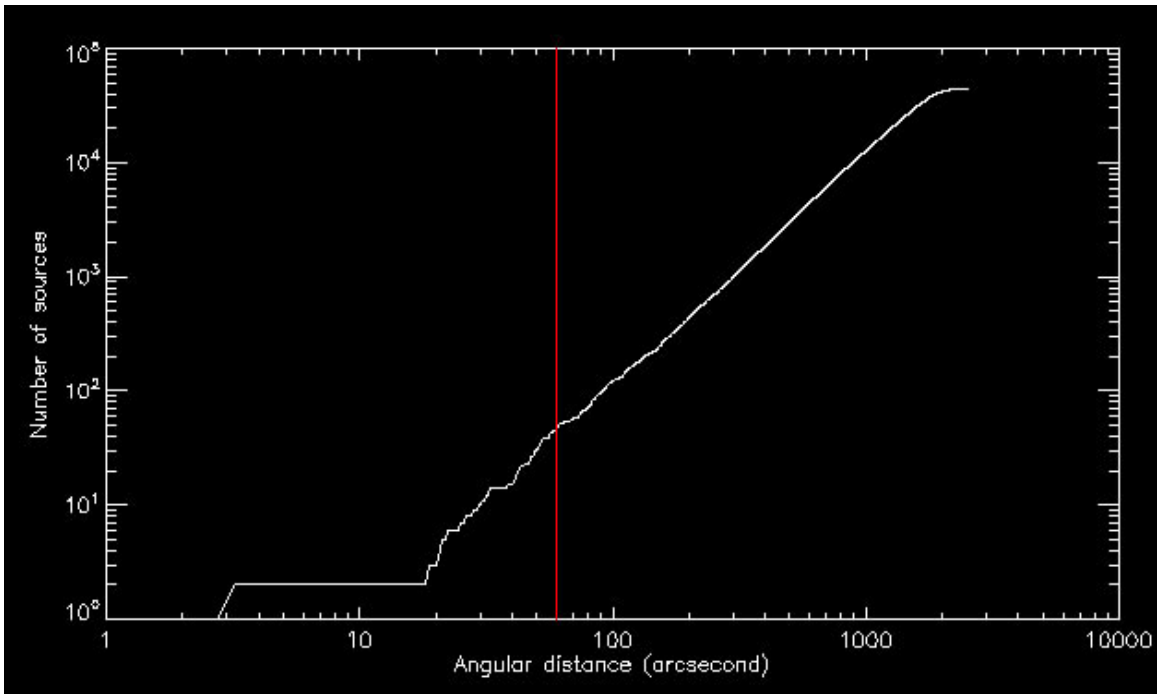
Introduction

It is conventionally thought that galaxies with enhanced star formation rates are usually due to galaxy - galaxy interactions and mergers. However, observations of some Brightest Cluster Galaxies, BCG in short, show that some BCGs have enhanced star formation rate without obvious signs of mergers (McDonald et al. 2012). This leads to the theory that there exists an alternative mechanism which for such enhanced star formation rates in BCGs.

Method

To find such BCGs with high star formation activity, a cross match of BCGs with other sources which may indicate star formation was performed using the IDL programming software. A large sample of 13823 BCGs with a redshift range of 0.1 to 0.3 was selected and the data was derived from the Sloan Digital Sky Survey (Koester et al. 2007). The other sources include far infra red sources which we use to give an indication of the SFR of the BCG and x-ray clusters to see if the BCG is within a cooling ICM which forms cooling flow, which we believe is a key factor of the mechanism which allows for high SFR. The far infrared sources were from the IRAS faint source catalogue, which includes 174033 sources, with the sources across the galactic plane removed. The x-ray cluster data comes from the NORAS catalogue from the Rosat satellite and contains 369 sources.

The coordinates of each IRAS and x-ray cluster sources were cross matched to each BCG, and the angular separation of each pair were recorded. To define an IRAS source as a counterpart of a BCG, we used the criteria of 60 arcseconds, due to the angular resolution of the IRAS satellite, and 30 arcseconds for the x-ray cluster sources. Also, to investigate whether the far infrared luminosity of the surroundings of a BCG affects the SFR of the BCG. For the criteria of an IRAS source being a member of the BCG, we selected 0.5 Mpc as the maximum distance between the sources.



The results show that there were 46 potential candidates for both the IRAS-BCGs and the x-ray-BCGs which fitted the criteria stated. However, they did not match together, so they may not affect one another for galaxies in the local region. The result were then analysed further.

Analysis

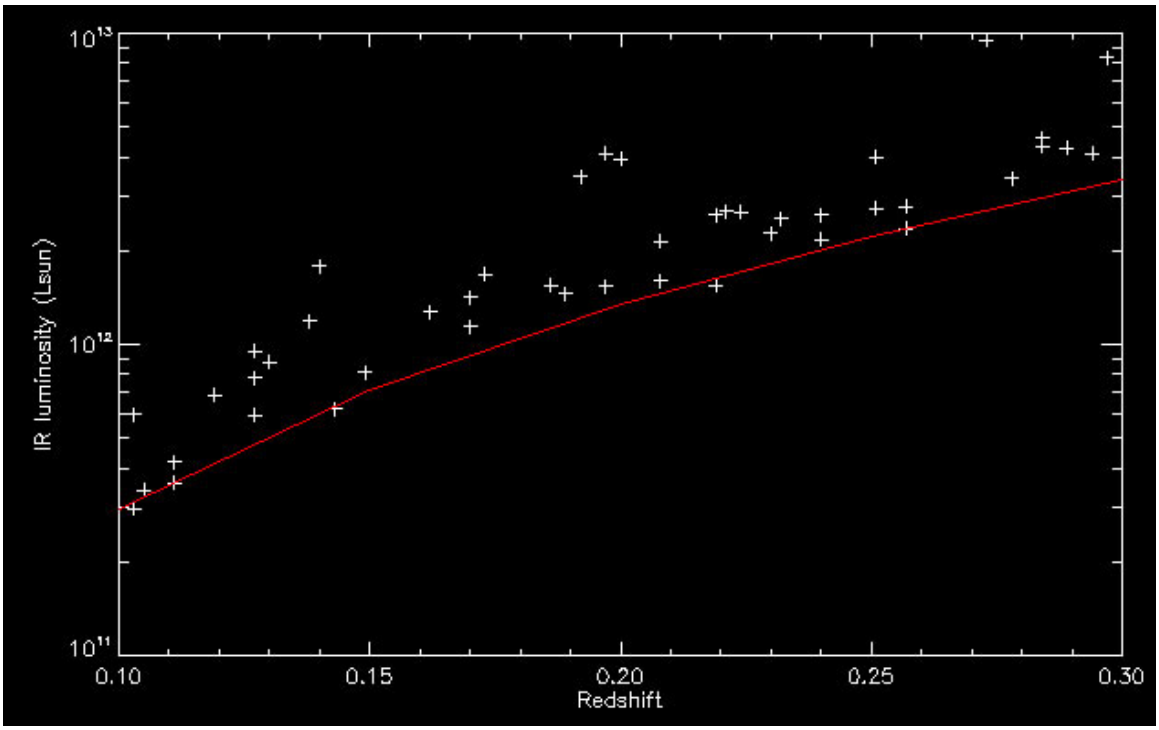
The four far infrared fluxes from the IRAS channels were converted to the $Flux_{(8\text{-}1000\mu m)}$ in Wm^{-2} using the conversion of

$$1.8x10^{-14} (13.48 \times f_{12} + 5.16 \times f_{25} + 2.58 \times f_{60} + f_{100})$$ (Sanders & Mirabel, 1996)

where the f_x is the flux at the certain wavelength. This was further converted into far infrared luminosity using the equation

$$L_{FIR} (W) = Flux_{(8\text{-}1000\mu m)} 4\pi d^2$$

where the d is the distance of the source from Earth. The luminosity distribution of the 46 sources was plotted, which shows a strong positive correlation.

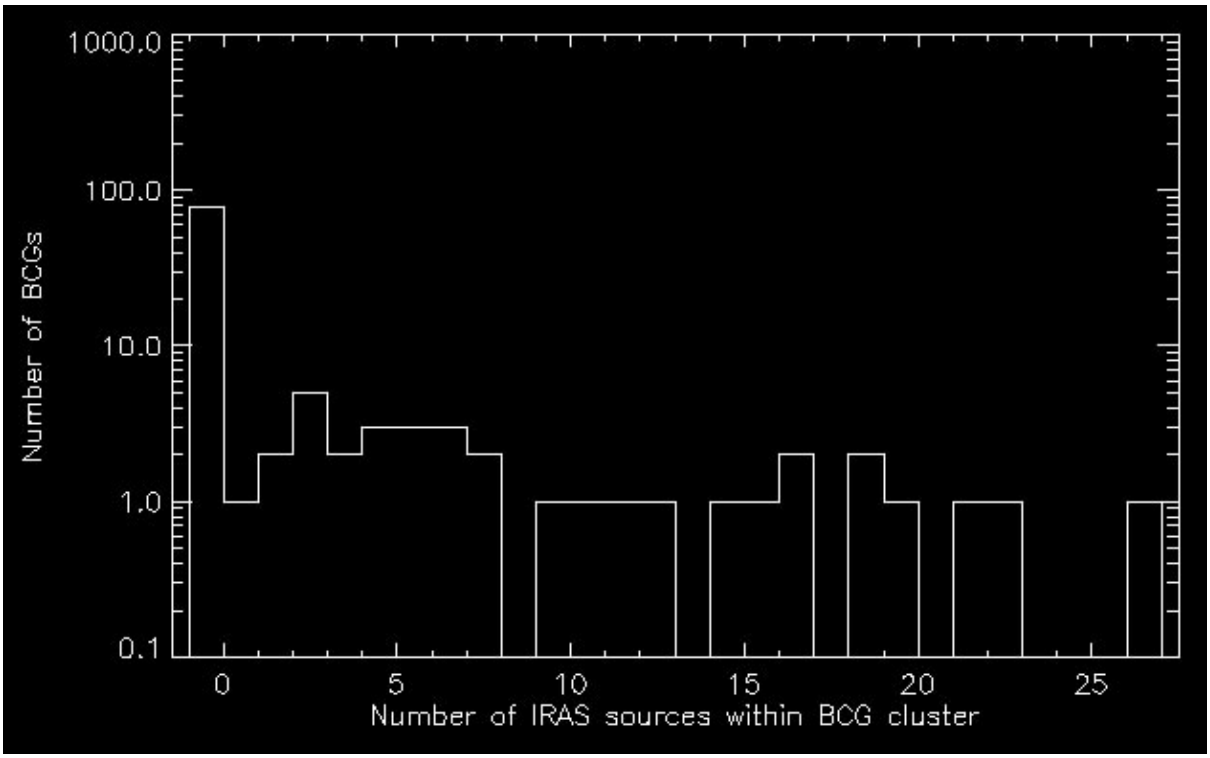


Although the results seem like it is biased, one can argue that there seem to be missing ULIRGs and HLIRGs at low redshift (z=0.1), and HLIRGs are also missing at moderate redshift (z=0.2). All the sources were later individually checked using the NED database to see if the counterparts from my results are actually counterparts of the BCG. The final result was that there were only 2 IRAS-BCGs and 7 x-ray-BCGs. Some data from the 2 IRAS-BCG sources are included in the table below.

Object Name	Ra	Dec	sep(arcsec)	z	L(Lsun)	SFR(My-1)
F10196+4853	155.694	48.6366	2.354	0.138	5.95e+11	102
MaxBCG J155.69355+48.63712	155.694	48.6371				
F13599+1038	210.607	10.4050	3.353	0.103	1.19e+12	205
MaxBCG J210.60818+10.40563	210.608	10.4056				

where the SFR equation: SFR ($M_{solar}year^{-1}$)= 4.5 x 10^{-44} L_{FIR} ($ergs^{-1}$) (Kennicutt, 1998).

For the IRAS-BCG members, due to the IRAS catalogue not including redshift for the sources, the probability of projection was taken into account. First of all, we considered the fact that the number of sources would be proportional to the galactic latitude. So samples of the number of sources within 10 degrees of galactic a latitude was found, and so the number of projections as a function of latitude was found. This, coupled with the surface number density and area of sky, the number of IRAS sources within the BCG cluster was found.



This data is useful in determining whether the environment of the BCG could affect the star formation properties. However, due to time constraints, we have more discussion on this in the "Future Work" section.

Conclusions

From the luminosity distribution function, it could be that BCG LIR evolution is as indicated, backed up by the absence of expected ULIRGs at lower redshift, which may be due to the combined effects of ICM feedback and galaxy mergers. Also, the luminosity distribution graph can provide an upper limit for the infrared luminosity of IR-BCGs, which can stretch to millimeter or sub-millimeter ranges, so that any future ALMA observations targeting BCGs or even SMGs at higher redshifts, can at least work with the results to better fine tune theoretical models.

Discussions

BCGs with enhanced SFR at higher redshift have previously been observed (McDonald et al. 2012), where as the enhancements in local BCGs are low, which could possibly be due to an alternative mechanism which allows for efficient star formations from gases. This leads to speculations that the SFR enhancements would be correlated to the redshift of the galaxy. This new speculation, coupled with the assumption that the number of mergers which occur between galaxies is also a function of redshift and that the cooling ICM from cool core clusters is involved, then the first two can be found from observations and the effects of cooling ICM on the SFR of galaxies could be better understood.

Future Work

The Observations of BCGs or sub-millimeter galaxies at higher redshift can provide valueble data to allow further analysis of a possible alternate mechanism for triggering such high starbursts in galaxies. Also, to continue on the research to find if the infrared richness is correlated to the star formation activity of BCGs, as well as whether galaxies in the central region have AGN feedback, and determine the relationship between AGN activity with the dusty gas from cooling flow and, ultimately, whether they would also fuel star formation too. Finally, to compare the differences between cool core BCGs and non-cool core BCGs and see how SFR is related to the cooling ICM with more emphasis to the mechanism itself.