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Dusty Star Formation in Extreme Environments: Galaxies and Galaxy Clusters in the Distant Universe

Stacey Alberts, *University of Massachusetts - Amherst*

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Abstract
In this thesis, we present a comprehensive study of the dust-obscured star formation (SF) activity in galaxy clusters out to high redshift using infrared (IR) imaging. Using hundreds of galaxy clusters and wide-field far-IR imaging across nine square degrees, we quantify the average star formation rates (SFRs) out to the distant Universe for mass-limited cluster galaxy samples using stacking. We compare the evolution of this SF activity to field galaxies, finding that the evolution in clusters occurs more rapidly than in the field and clusters have field-like SF approximately nine billion years ago, during an epoch before SF quenching becomes effective in massive clusters.

Building on this result, we present new, deep far-IR imaging of 11 spectroscopically-confirmed clusters at high redshift, which allows us to examine the SFRs of individual IR-luminous cluster galaxies as a function of environment. We find a transition from field-like SF to quenching of IR-luminous galaxies in the cluster cores over the redshift range probed. We present the first UV-to-far-IR spectral energy distributions (SEDs) of high redshift cluster galaxies, quantify the cluster-to-cluster variations in SF properties, and compare cluster galaxies to star forming galaxies in the field. In addition, we examine the SEDs of cluster galaxies with measurable emission from black hole accretion and quantify the fraction of these galaxies as a function of environment and redshift, finding an excess at high redshift in the cluster cores. Lastly, we compare dust-obscured SFRs from far-IR to unobscured SFRs from optical emission lines.

In the last section, we present new submillimeter imaging of a massive cluster in the distant Universe. We characterize the FIR/submillimeter SED of IR-luminous cluster galaxies, finding dust temperatures similar to that in field galaxies in the same epoch. We use imaging of dust emission in the optically thin regime to derive the interstellar medium (ISM) masses of cluster galaxies. Through this analysis, we determine that IR-luminous cluster galaxies at high redshift have comparable ISM masses, gas fractions, and gas depletion timescales as field galaxies.

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