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Summary of Research

Introduction

The general process of galaxy cluster formation through hierarchical merging is well understood, but many details, such as the impact of feedback sources on the cluster environment and radiative cooling in the cluster core are not. My research has focused on studying these details via X-ray properties of the ICM in clusters of galaxies. I have paid particular attention to ICM entropy distribution, the process of virialization, and the role of AGN feedback in shaping large scale cluster properties.

My primary research makes use of a 350 observation sample (276 clusters) taken from the *Chandra* archive. This massive undertaking necessitated the creation of a robust reduction and analysis pipeline which 1) interacts with mission specific software, 2) utilizes analysis software (i.e. `XSPEC`, `IDL`), 3) incorporates calibration and software updates, and 4) is highly automated. Because my pipeline is written in a very general manner, adding pre-packaged analysis tools from missions such as *XMM*, *Spitzer*, and *VLA* will be straightforward. Most importantly, my pipeline deemphasizes data reduction and accords me the freedom to move quickly into an analysis phase and generating publishable results.

The picture of the ICM entropy-feedback connection emerging from my work suggests that cD radio luminosity and Hα emission are anti-correlated with cluster central entropy. I have explored these relations with my thesis sample and am finding a trend of high central entropy favoring low $L_{H\alpha}$ and low L_{Radio}. I am following up these results by examining the distribution of central cooling times as a window onto the timescale of AGN feedback. In addition, I am exploring the dependence of the X-ray loud AGN distribution on redshift and amount of cluster substructure.

This work has been very fruitful thus far: I am a co-author for two refereed journal papers ([**?**], [**?**]), generated new and unique work each year ([**?**], [1], [2], [3], [4], [5]), a first author paper which is in draft, and another first author paper in preparation containing my thesis results. I have also contributed to several successful *Chandra*, *XMM*, *Suzaku*, and *Subaru* proposals in addition to writing my own high scoring – although unsuccessful – *Chandra* proposal for time observing an amazing ULIRG. I am also planning Hα imaging observations for several previously unobserved clusters with MSU's SOAR telescope.

In another part of my thesis research I have studied bandpass dependence in determining X-ray temperatures and what this dependence tells us about the virialization state of a cluster. The ultimate goal of this project is to find an aspect-independent measure for a cluster's dynamic state. Prompted by the work of [6] I have investigated the net temperature skew in my sample of the hard-band (2.0_{rest}-7.0 keV) and full-band (0.7-7.0 keV) temperature ratio for core-excised apertures. I have found this temperature ratio is statistically connected to mergers and the presence of cool cores. This work has produced a first author paper which is near ApJ submission and was used in a successful *Chandra* theory proposal.

Looking ahead, the natural extension of my thesis is to further study questions regarding details of feedback and galaxy formation. What are the micro-physics of ICM heating, including the thermalization

of mechanical work done by bubbles and the effect of non-thermal sources like cosmic rays. How prevalent are cold fronts and do they play a role in galaxy and star formation? Also of interest are how accretion onto the cD SMBH is regulated by large-scale ICM properties and what the AGN energy injection function looks like and how it correlates with cluster environment.

There are also exciting theoretical cluster feedback model developments on the horizon which will need observational investigation, and for which I am well positioned to study. Developments such as: how exactly are AGN fueled? Does accretion of the hot ICM/ISM proceed via Bondi-eque flows? What is the efficiency of the accretion? Why do we see metallicity gradients in the ICM/ISM when some amount of mixing should take place? How is feedback energy distributed symmetrically throughout the ICM?

References

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