Tracing Outflows and Shocked Disk Gas in an Assembling Galaxy Cluster

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We directly study the progenitors of cluster galaxies while still in the group environment and find:

- An enhancement of low-mass star forming galaxies, radio AGN, and X-ray AGN
- Outflows are common among strongly star-forming galaxies
- Composite galaxies show evidence for shock heating throughout their disks – they may be galaxies in transition
T = 2.2 keV
\( \sigma = 303 \text{ km/s} \)

T = 1.7 keV
\( \sigma = 406 \text{ km/s} \)

T = 1.8 keV
\( \sigma = 580 \text{ km/s} \)

T = 3.0 keV
\( \sigma = 567 \text{ km/s} \)

Gonzalez+2005, Tran+2009
The early-type galaxy fraction is consistent with clusters at comparable redshift.

Kautsch+2008
Central galaxy mass is increasing by $\geq 40\%$ through merging and with no sign of current (or recent) star formation.
There are four times as many radio-active galaxies as field and cluster environments at similar redshift.

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≥ 18% of galaxies with SFR > 8 M_☉/ yr show ionized gas characteristics indicative of outflows.
A fast outflow is observed from a ULIRG.

Freeland+2011
Warm extraplanar gas is seen in two edge-on galaxies whose SFR ~ $10 \, M_\odot / \text{yr}$.
We use MEx & BPT diagrams to classify galaxies as star forming or composite systems.
Disk gas in composite galaxies is heated compared to disk gas in purely star-forming galaxies.

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The observed properties are consistent with shock heating which has implications for AGN selection.

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U/LIRGS with widespread shock ionization can be classified as composites despite having no AGN contribution (Rich+14). Our composite galaxies extend this to sub-LIRGs.
What process is responsible for the shocks in these galaxies? Interactions?

Scale bar is 25 kpc.

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AGN prefer group centers, composites prefer outskirts.

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