Wednesday/Thursday Summary

"*There's a lot of violence…*" (P. Hopkins)

Galaxy Game of Thrones

- Many unpleasant ways for galaxies to be quenched…
  - Starvation (Winter is coming…)
  - Strangulation
  - Ram pressure stripping
  - Exploding dwarfs
  - Secular processes
  - Collisions/mergers
  - Shocks
  - DrAGoNs
- Which one sits on the Iron Throne?

Stripping (z=<1 groups/clusters)

- Besla - quenched and unquenched dwarfs
  - Only quenching mechanism is becoming a satellite: tides, ram pressure and starvation.
  - Interactions speed stripping. Satellite-satellite encounters dominate gas removal.
- Rosenberg – groups and clusters
  - Only marginal evidence for depletion of gas in the largest mass haloes.
  - Gas removal probably a complicated process.
- Owers – clusters with SAMI
  - Star forming galaxies are infalling
  - But now decompose individual galaxies. See galaxies with PSB/HDS components within 0.5 Rvir
  - Consistent with ram pressure stripping - outside-in truncation.
- Noble – z~1 clusters
  - *R*v* gives you a proxy for accretion epoch, see quenching at z~1
  - Quenching after ~1st passage?
  - CO detections from ALMA - ~8 detections at z~1.6

“High-z” clusters (Starvation/strangulation? ram pressure?)

- Alberts – cluster evolution at z>1
  - SF fraction in cores of clusters at z>1; also AGN
  - z> 1; 1-4x10^{14} Msun in Bootes
  - More SF in cores at z>1.4; very rapid quenching comparable to field
  - AGN in excess at z>1 relative to field.
- Darvish – mass quenching and environmental quenching
  - Environmental quenching turns off at high-z, and is more effective in massive galaxies.
  - Environmental quenching happens on a short timescale at z<1
- Wilson – z>1 clusters
  - No difference in red sequences between samples – preprocessing in groups, or strangulation?
  - BCGs grow by factor ~2 by dry mergers at z<1; at z>1 some still starforming
  - Passive fraction evolves rapidly from z~1-2
  - Quenching timescales short at high-z -> starvation?

Collisions/shocks - I

- Kartaltepe – HLIRGs
  - Do galaxy mergers matter? If so, for what?
  - At least 50% of high-z ULIRGS are interactions/mergers
- Man – merger rates at z=0-3
  - Need to include both gas and stars when calculating mass ratio.
  - Seem to be not enough mergers to explain the "puffing up" of quiescent galaxies since z~2?
  - Need ALMA to find the gas-rich mergers
- Mei – protoclusters
  - z~1.8 protocluster in GOODS-S ~10^{14}Msun; 50% are ETGs but have [OII] "blue nuggets"; 50% disturbed/mergers
  - EUCLID/WFIRST will revolutionize the field.
- Hung – protoclusters
  - Pair fraction seems higher in protoclusters with overdensity of submm sources
- Stroe – cluster collisions
  - One system has excess of star forming galaxies, active for ~100Myr
  - Shock induced star formation?

Collisions/shocks – II (compact groups)
"IFUs are stronger together" – Appleton
"Can I see Phil's birth certificate?" - Privon

- Gallagher – compact groups overview
  - B-V vs V-I colors of star clusters; tag dynamical histories. Interaction started ~400Myr ago; big burst starting ~10Myr ago
  - Initial conditions matter
- Lisenfeld – galaxy transitions in compact groups
  - Objects move from the green valley to the IRTZ/canyon
  - Galaxies in the canyon have both SF suppression and less molecular gas
  - Consistent with turbulent energy from shocks
- Appleton – shocks in compact groups
  - Phase transition – shocks can form molecular gas
  - Both C-shocks and J-shocks needed; most of the cooling is from the slow shocks
  - Mid- and far-IR cooling carries away most of the shock energy.

Dwarfs

- Wetzel – dwarf galaxies and LCDM
  - Model thin disks well; no missing satellite problem.
  - Feedback important.
- Lelli – starbursting dwarf galaxies
  - Starburst dwarfs are highly concentrated and do not explode
  - Tidal dwarfs formed during major mergers.

AGN – *"AGN feedback is a "Thing""* – *Medling* (also galaxy mass quenching)

- Medling – AGN vs SF driven outflows with IFUs
  - Nuclear disks in nearly every ULIRG
  - Lower power jets avoid breakout, affect more material
  - Outflows multiphase. Are molecular clumps preserved, or reform after shocks?
- Kocevski – obscured BH growth
  - Most black hole growth occurs via major mergers, missing from X-ray surveys.
  - At z~2, AGN fraction of compact, blue galaxies is very high, probably transform to red compact galaxies.
- Nyland – radio AGN
  - Wimpy radio AGNs can affect their hosts
  - Alpha-z relation may be telling us about changes of environment with redshift.
- Tinker – what can scatter do for you?
  - Scatter in stellar mass at fixed halo mass is only ~0.16dex
  - Scatter is from star formation histories
  - "galaxy quenching" – galaxy hits fixed mass & quenches or it correlates strongly with halo formation history

AGN – accretion is messy and variable

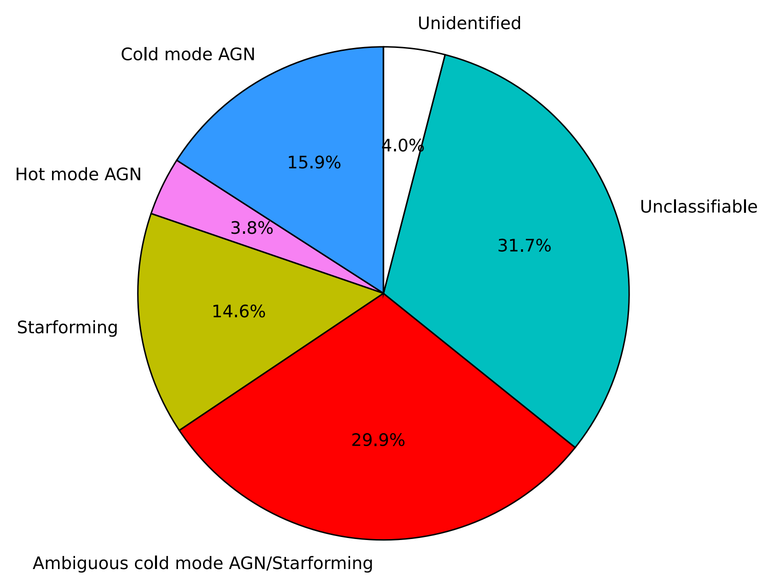
- Urrutia (fading type-1 AGN),
- Muller-Sanchez (NGC1068, H_2 and ALMA results)
- Aird (wide range of AGN properties for fixed galaxy properties)

Discussion questions - I

- Are the quenching mechanisms the same for the central galaxy in a dark matter halo and its satellites?
- Does the satellite quenching mode change with redshift?
- Positive Feedback
  - Some evidence that shocks can trigger stars
    - Infall (ram pressure)
    - Cluster collisions shocks (Stroe)
    - Jet induced star formation candidates (jet pressure)
  - Is positive feedback important or can we ignore it?
- What are the "Blue Nuggets" and why do we not see them below z~2?

Radio mode

- What can we say about radio/maintenance-mode feedback?
  - "Hot mode" AGN hard to pick up in optical/X-ray/IR surveys (very low accretion rates; no accretion disk/corona/torus).
  - Need expensive microJy radio surveys and corresponding deep IR/optical follow-up,ideally over several tens of square degrees (e.g. SERVS/DeepDrill). And they are still rare/hard to indentify.
- Low luminosity radio-loud AGN are exclusively found in massive hosts at all redshifts (e.g. Simpson et al. 2013; Luchsinger et al. 2015), and their numbers seem to be consistent with a high duty cycle in their massive hosts (~ few 10s of %).
- Low luminosity radio-loud AGN *are the only AGN to evolve "backwards"* – less common in the past than they are now (Best et al. 2014).
  - Consistent with the idea that their evolution is tied to the formation of the most massive galaxies

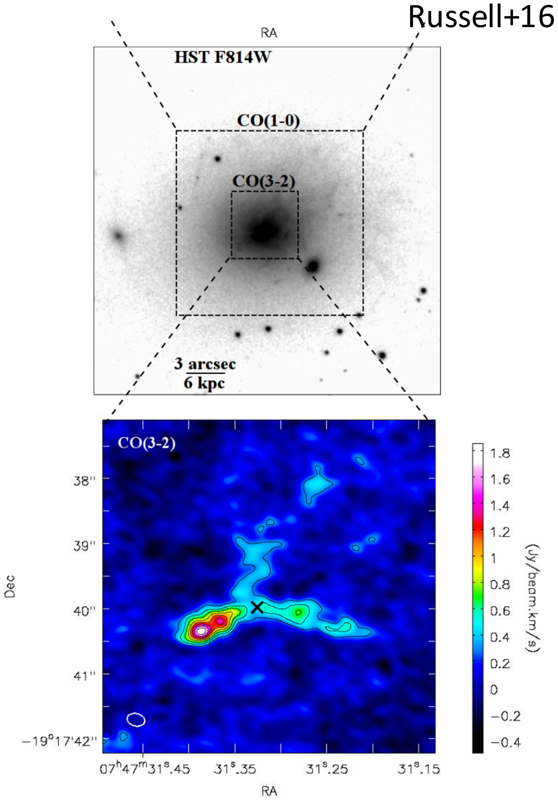


Luchsinger+SERVS 2015

How do radio jets couple to the gas?

- Uplift?
  - Russell et al. 2016; McNamara et al. 2016 - see CO filaments in PKS 0745-191 with ALMA that are behind X-ray cavities.
  - Dense gas uplifted by radio bubbles.
  - If so, needs to from and cool in situ or be coupled in some other way (magnetic fields?).
- Direct entrainment? –
  - do see evidence of shocks in H_2 (Lanz), but jet is “pencil beam”
- Jet triggered star formation?
  - Can form stars in gas clouds before they rain onto the central galaxy. Source of intracluster stars (>10% of cluster stars)?

Russell+16



The future…

- ALMA (& ultimately ngVLA) studies can be used to determine the location and dynamics of the molecular gas that does form.
- Deep radio surveys (MeerKAT, ASKAP, ultimately SKA) combined with IR and X-ray surveys will allow a complete census of low luminosity radio-loud AGN.
- Wideband polarization capabilities on the VLA can be used to dissect the interaction of jets with the intracluster/group medium.
- In general, IFUs are needed for emission line studies in the optical and near-IR - match ALMA capabilities for molecular lines.