The Fueling Diagram: Linking Galaxy H_2/HI Ratios and Bulge/Disk Assembly to Interactions and Accretion

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See also Stark et al., 2013, ApJ, 769, 82

I. Introduction

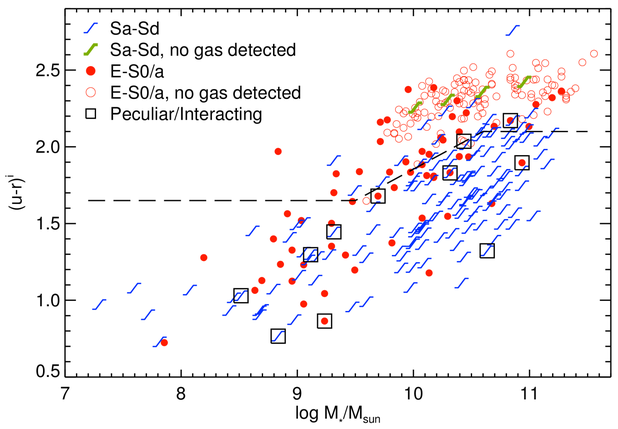
We analyze how external factors such as galaxy interactions and gas accretion influence the ISM and bulge/disk growth of galaxies. We show that z=0 galaxies occupy several loci in a ``fueling diagram" that plots H_2/HI vs. mass-corrected blue-centeredness, a metric tracing the degree to which galaxies have bluer centers than the average galaxy at their stellar mass. Spiral galaxies show a positive correlation between H_2/HI and mass-corrected blue-centeredness, which we use to argue for a systematic link between galaxy interactions and gas inflows/bulge growth. We also identify a population of blue-sequence E/S0 galaxies that define a separate regime in the fueling diagram. This population appears to be composed of low-mass, gas rich merger remnants currently in late- or post-starburst states. Trends in color and total gas-to-stellar mass ratios suggest that this population eventually migrates back towards the spiral locus while accreting fresh gas, leading to stellar disk regrowth. We discuss plans to use existing Herschel and eventually ALMA data to reconstruct a fueling diagram using dust continuum emission to track dense star-forming gas using the volume-limited RESOLVE Survey, allowing a statistical view of accretion and HI-to-H_2 conversion.

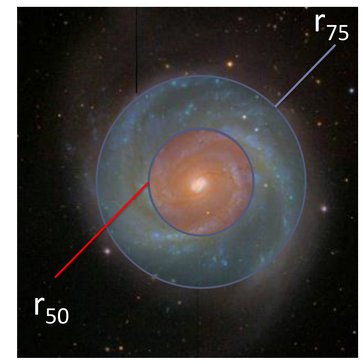
II. Data

- Representative subset of Nearby Field Galaxy Survey (Jansen et al. 2000ab, Wei et al. 2010, Kannappan et al. 2013) supplemented by extensive literature search (see Stark et al. 2013 and references therein)
- Final sample of 323 galaxies with good photometric, HI, and CO data (Fig. 1)

III. Methods

- 21cm + CO(1-0) emission → HI + H_2 mass
  - CO flux beam corrected, but reject galaxies with correction > 50%
- Recent interactions/minor mergers traced using mass-normalized color gradients, $\Delta(g\text{-}r)^m$ (Fig. 1)
  - Blue-centered color gradients previously linked to external perturbations (Kannappan et al. 2004)





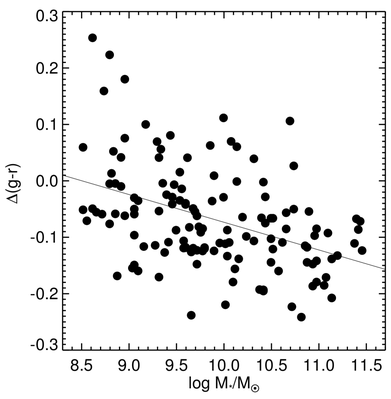


Figure 1: ***(top)*** Final sample of 323 galaxies spanning a large range of masses, morphologies, and evolutionary states. ***(top-right)*** Illustration of blue-centeredness diagnostic, defined as the color from the half-light radius (r_{50}) to the 75% light radius (r_{75}) minus the color from the center to r_{50}. ***(right)*** Linear fit between blue-centeredness and stellar mass. Residuals of this fit yield *mass-corrected blue-centeredness,* $\Delta(g\text{-}r)^m$, indicating the degree to which galaxies have bluer centers than the average galaxy at their stellar mass (tracing recent excess central star formation).

IV. Results

- The ***fueling diagram*** links global galaxy H_2/HI and mass-corrected blue centeredness ($\Delta(g\text{-}r)^m$)
- Galaxies cluster in 3 main loci that show distinct galaxy populations (Fig 2,3,4)

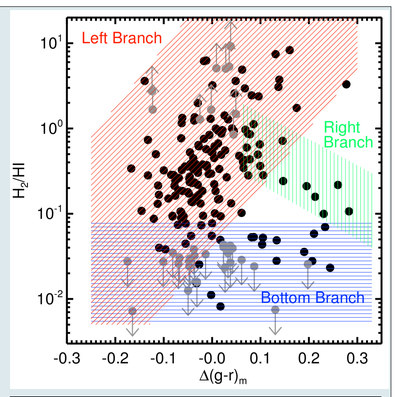


Figure 2: The fueling diagram and branches

Left branch:

- Home to most spiral galaxies
- Linear correlation between log H_2/HI and $\Delta(g\text{-}r)^m$
- Consistent with picture where interactions/minor mergers drive gas inflows, leading to HI →H_2 conversion and bulge growth
- No clear sign that bars drive this relation

Right & Bottom branches:

- Primarily low mass, gas-rich, blue-sequence E/S0 galaxies
- Colors indicate galaxies move right-to-left on bottom branch
- Gas content grows as galaxies evolve on bottom branch
- Consistent with picture where right/bottom branches formed from gas-rich major mergers which then regrow disks as their central starbursts fade

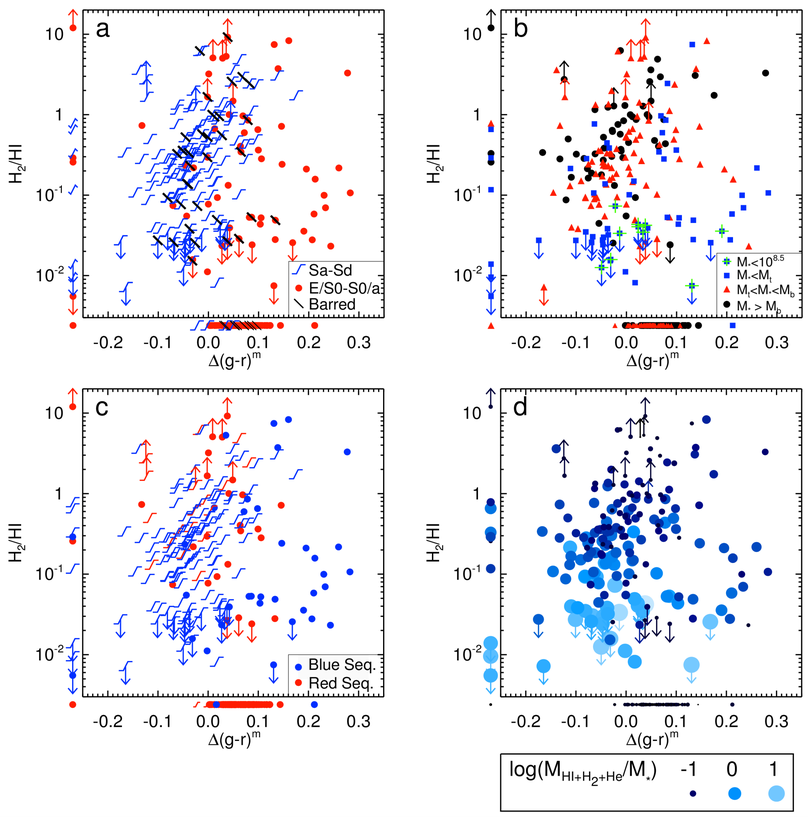


Figure 3: The *fueling diagram* (H_2/HI vs. mass-corrected blue-centeredness) with symbols representing (a) morphology, (b) stellar mass, (c) red/blue-sequence, (d) gas-to-stellar mass ratio. Galaxies with highly peculiar morphologies are shown left of the y-axis, while quenched galaxies (lacking detected HI or CO) are shown below the x-axis.

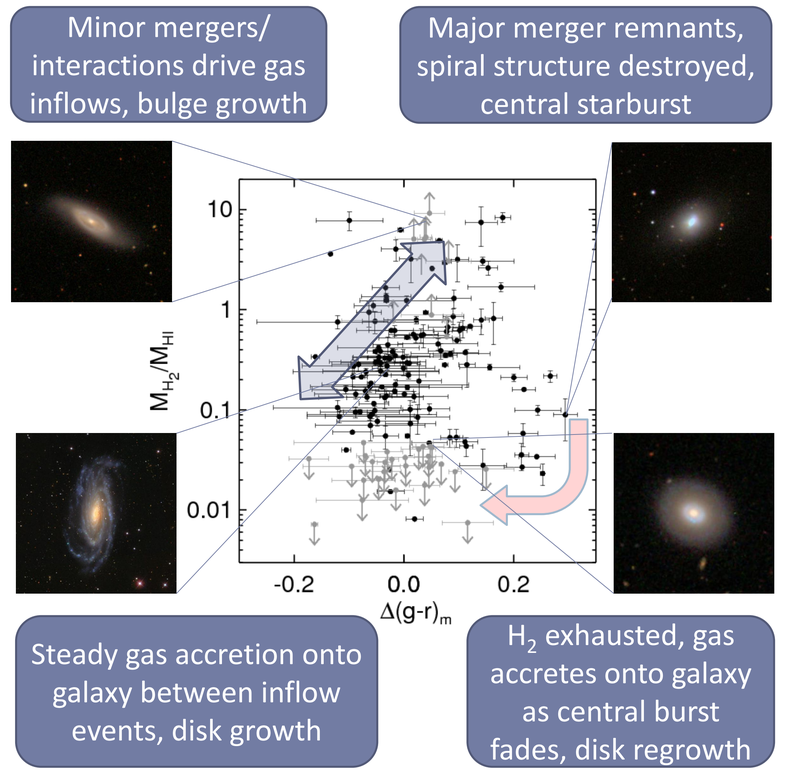


Figure 4: Illustration of the key stages of evolution in the fueling diagram. Arrows indicate the direction that galaxies evolve.

V. Open Questions

- How common are galaxies on the different branches of the fueling diagram?
- How fast do galaxies evolve through the branches of the fueling diagram?
- Does environment affect the distribution of galaxies on the fueling diagram?

To answer these questions, we need a statistically fair sample of the galaxy population that probes a diverse range of environments.

VI. The RESOLVE Survey

- RESOLVE (Resolved Spectro--scopy Of a Local VolumE) is a ~1500 galaxy volume-limited survey
- Complete into the dwarf regime (baryonic mass > 10^9 M_{sun})
- Spans diverse large-scale structures (filaments, walls, clusters, voids)

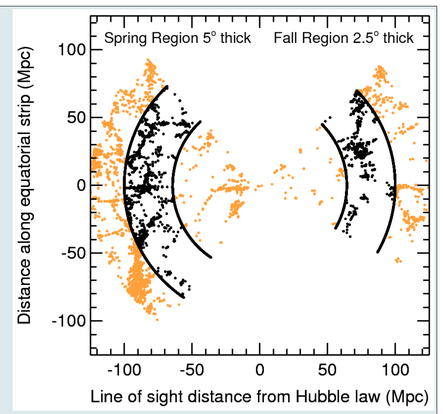


Figure 5: The RESOLVE footprint (black) within the SDSS redshift survey

- Complete optical/NIR photometry plus ongoing 21cm and optical spectroscopic census
- Overlap with Herschel surveys (Helms, HERS, H-Atlas) allows alternative way to account for H_2 using dust continuum
- Herschel supplemented with ALMA CO/sub-mm observations will yield a view of the fueling diagram using a fair subset of the galaxy population, allowing a statistical view of how interactions and accretion drive bulge and disk growth in different environments

VII. Conclusions

- Spirals (and some E/S0s) show a positive correlation between blue-centered color gradients and H_2/HI. Combined with previous results that blue-centered color gradients correlate with external perturbations, this suggests external perturbations play key role in H_2 replenishment and help drive bulge growth.
- Blue-sequence E/S0 galaxies define loci offset from spirals in the fueling diagram. Multiple lines of evidence suggest these are gas-rich merger remnants in a late/post star forming stage.
- Blue E/S0 merger remnants evolving back towards red-centered color gradients show signs of fresh gas accretion and disk regrowth.
- The RESOLVE Survey combined with FIR/sub-mm/CO information from Herschel and ALMA will allow study of the fueling diagram in a statistically fair way, illuminating how the frequency of bulge and disk growth varies across cosmic environments.

References & Acknowledgements

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