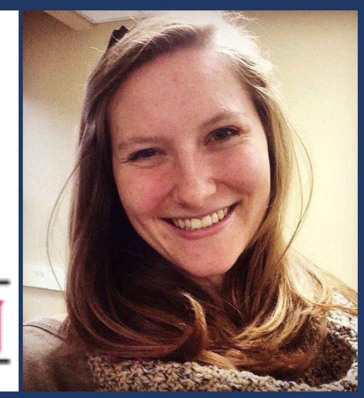
The Virgo Cluster: SED Fitting and Evidence for Enhanced Star Formation due to Accretion



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Abstract

Using UV-through-FIR data in matched apertures, we modeled the spectral energy distributions (SED) of 49 Virgo cluster spiral galaxies with the modeling program Magphys (da Cunha+ 2008). We used the results from these models to explore the relationships between the stellar masses (M*), specific star formation rates (sSFR), and HI properties in our sample. This poster highlights one initial result from these comparisons: supportive evidence for gas accretion in the outskirts of the Virgo cluster. The galaxies with the highest sSFRs in the mass range 10^9-10^{10} M_{sun} are all HI-rich, have extended irregular HI envelopes, and lie in the outskirts of the cluster. We propose that these galaxies are accreting gas onto their disks, a process which enhances their SFRs. By confirming these systematic trends in the stellar properties of Virgo galaxies due to accretion, we can gain a more thorough understanding of the processes by which galaxy in clusters evolve.

Introduction

Various evolutionary mechanisms affect the star formation rates (SFR) in galaxies. Environmental changes in gas abundance or density can enhance or quench star formation. Accretion of gas onto a galaxy's disk can trigger star formation by providing new material and increasing the gas density (Sánchez Almeida + 2014). Alternatively, removal of a galaxy's ISM via ram pressure stripping may reduce or cease star formation by depriving the galaxy of the raw material for star formation (Bekki 2009). Gravitational interactions may induce star formation by increasing gas concentrations, or reduce star formation by tidally stripping gas (as well as stars and dark matter) from the galaxy's halo (Sanders+ 1988). Gas removed from the halo by either ram pressure stripping or tidal stripping is considered starvation. This poster will focus on the connection between gas accretion and heightened star formation in Virgo cluster galaxies.

SED Modeling

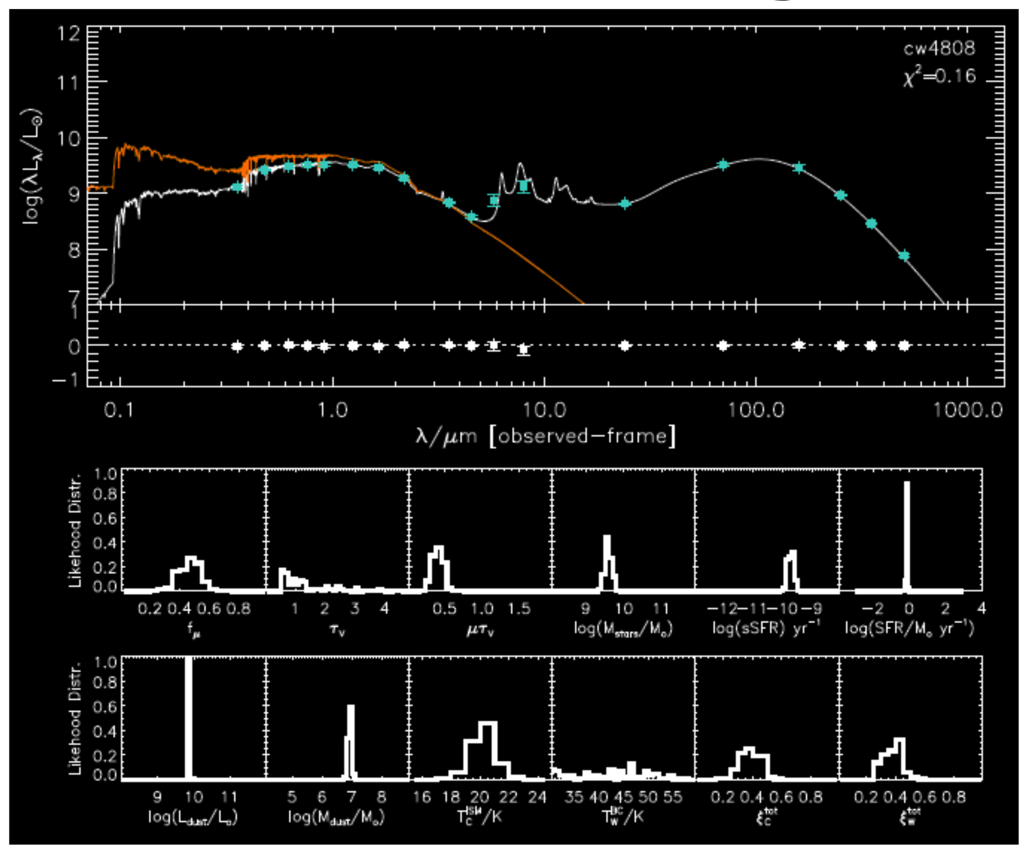


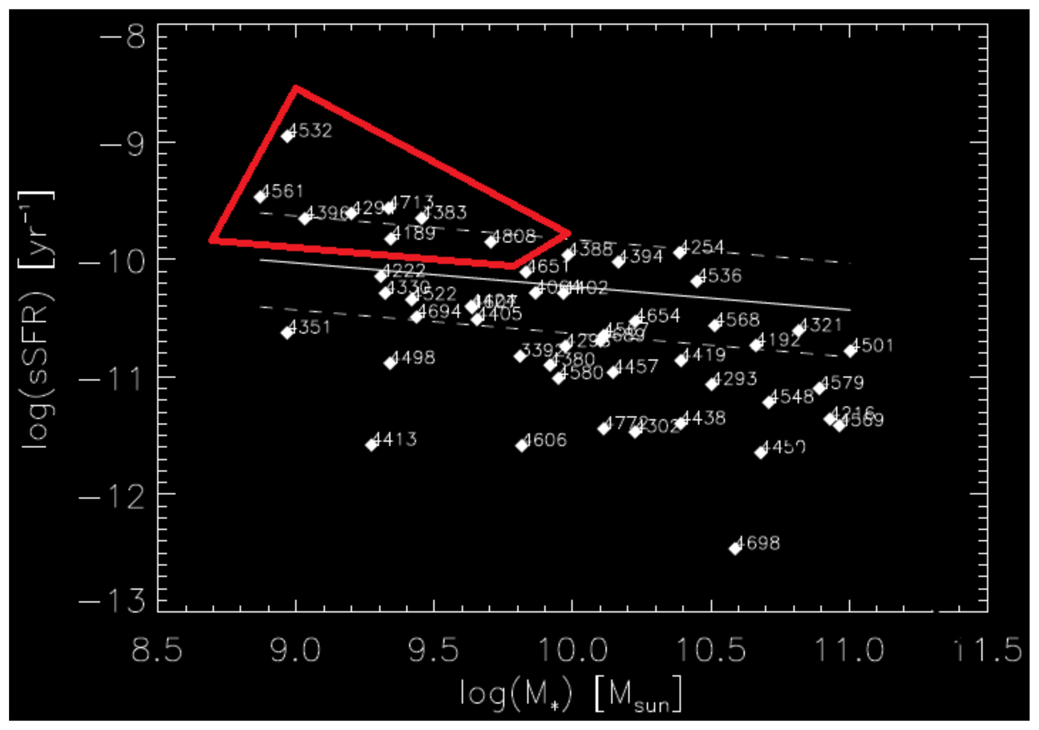
Figure 1 (above): An example of the Magphys output for the Virgo spiral galaxy NGC 4808. The uppermost panel displays the input data (cyan), the final optical – IR combination fit to stars plus dust (white), and the stellar component corrected for dust extinction (orange). The bottom two panels describe probability distributions of all the input parameters based on the goodness-of-fit.

We modeled photometric data using the robust SED-modeling program Magphys. Magphys employs 50,000 optical stellar population spectra (Bruzual & Charlot 2003) in combination with 50,000 infrared models (daCunha+ 2008) that incorporate dust emission from both birth clouds and the ambient ISM. After a X^2 best-fit model is selected by fitting a linear combination of these 100,000 models to the observed galaxy, Magphys reports the parameters that were applied to create that particular model along with a probability distribution for each of these values. In this example, the narrow probability distributions for stellar mass and SFR indicate that both parameters are robustly fit in NGC 4808. The photometric data set consists of optical data from SDSS, NIR from 2MASS, IR from Spitzer, and FIR from Herschel.

Accretion in High-sSFR Virgo Galaxies

After modeling the sample with Magphys SEDs, I extracted the SFR and M* input parameters that Magphys employed in its best-fit models of each galaxy's SED. The following analysis of these data provides an extensive visualization of star formation trends within the Virgo cluster, allowing us to identify and understand the specific Virgo galaxies which exhibit high rates of star formation.

Figure 2 (right): A comparison of sSFR vs. stellar mass for the VIVA galaxy sample. The solid line denotes the star-forming "main sequence" at z=0.0 (Chang+ 2015). The main sequence refers to the median sSFR of all nearby star-forming galaxies. The dotted lines mark +/-1σ range and enclose ~$^2/_3$ of all nearby SF galaxies. The red polygon indicates galaxies with sSFR > 1.4×10^{-10} yr^{-1}.



By first identifying which galaxies exhibit heightened sSFRs, we can begin to trace the source of increased star formation within the Virgo cluster by evaluating shared properties among these galaxies. In the mass range 10^9-10^{10} M_O, the galaxies with the highest sSFRs are all HI-rich and show evidence for gas accretion.

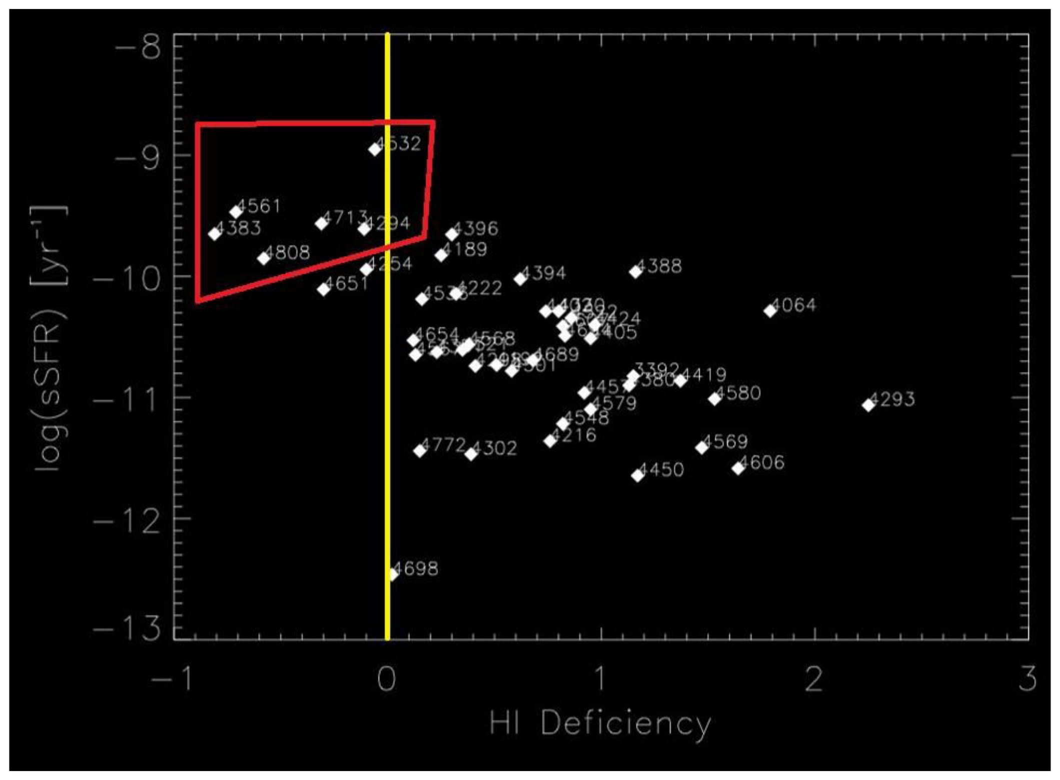


Figure 3 (left): A comparison of sSFR vs. HI deficiency. Galaxies with an HI deficiency less than zero are seen as HI rich, as shown with the yellow vertical line. The red polygon highlights the same high-sSFR galaxies as in Figure 2.

Further analysis of HI deficiency in our sample reveals that all high-sSFR galaxies are HI rich. This correlation may result from systematic causation: These galaxies may have become HI rich due to accretion, thus triggering their star formation.

HI Deficiency Calculation:

HI Def = log M(HI expected) – log M(HI)

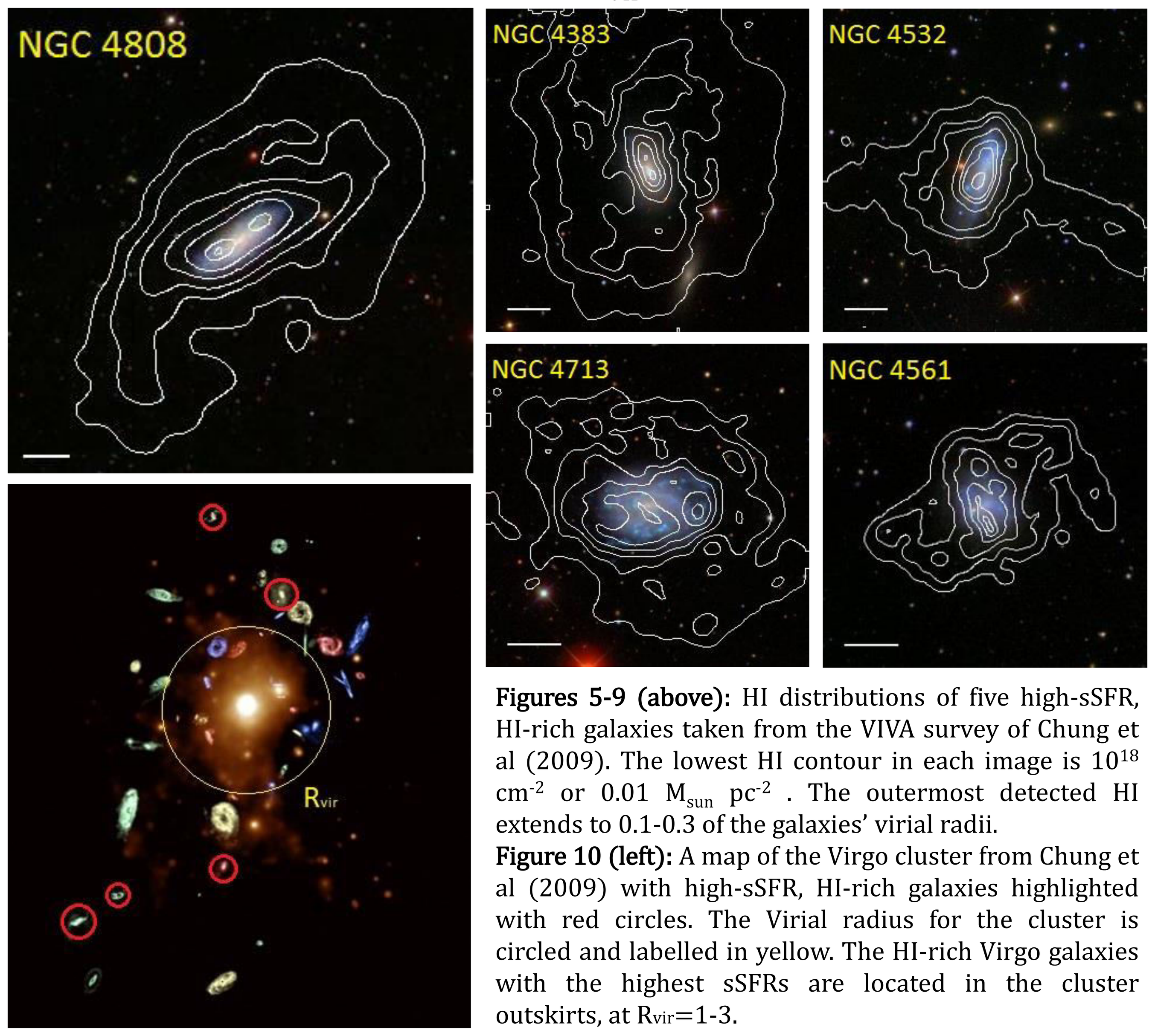
HI Def = =0.0 indicates normal isolated galaxy

HI Def << 0.0 indicates HI-rich galaxy

Figure 4 (above): The equation for calculating HI deficiency in our sample of Virgo galaxies and parameters for "normal" and "HI-rich" galaxies.

HI Distributions and Cluster Locations of HI-Rich Galaxies

An evaluation the HI maps of the selected high-sSFR, HI-rich galaxies from the VIVA survey of Chung et al (2009) reveal very extended, disturbed, and warped gas distributions (Figures 5-9). Such abnormal distributions are indicative of recent gas accretion. Furthermore, all selected galaxies lie in the outskirts of the cluster (> R_{vir}), as shown in Figure 10.



Figures 5-9 (above): HI distributions of five high-sSFR, HI-rich galaxies taken from the VIVA survey of Chung et al (2009). The lowest HI contour in each image is 10^{18} cm^{-2} or 0.01 M_{sun} pc^{-2} . The outermost detected HI extends to 0.1-0.3 of the galaxies' virial radii.

Figure 10 (left): A map of the Virgo cluster from Chung et al (2009) with high-sSFR, HI-rich galaxies highlighted with red circles. The Virial radius for the cluster is circled and labelled in yellow. The HI-rich Virgo galaxies with the highest sSFRs are located in the cluster outskirts, at R_{vir}=1-3.

Conclusions

- Several low-mass spirals (M* = 10^9-10^{10} M_O) in the Virgo cluster outskirts (~1-3 R_{vir}) are HI-rich and have very extended, disturbed and/or warped HI gas distributions.
- These galaxies have the highest sSFRs in the cluster in this mass range, with sSFRs 2-10 times higher than the star formation "main sequence" line.
- We propose that the outer disks of these are accreting gas from the inner halo of the galaxy (0.1-0.3 R_{vir}), thus fueling or triggering star formation.

References & Acknowledgements

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