Connections between Galaxy Morphology and Star Cluster Populations in Nearby Spirals

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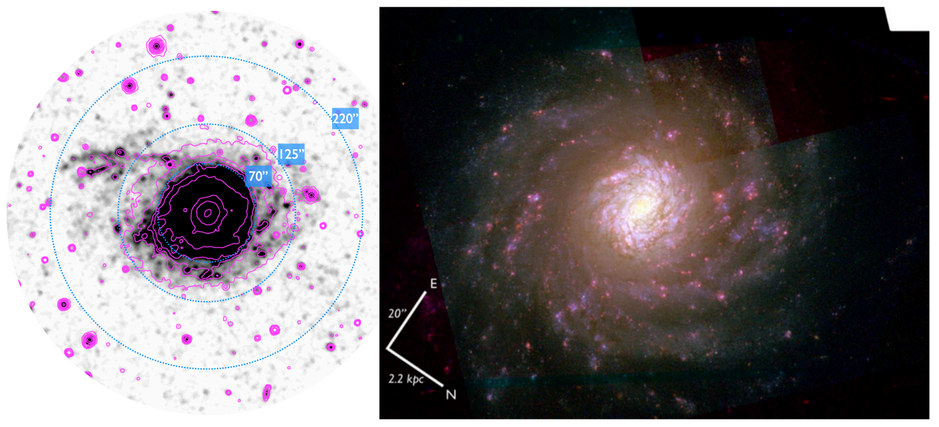
Introduction

All star-forming galaxies host populations of young and intermediate-age star clusters. By obtaining luminosities, ages, masses, extinctions, and sizes of hundreds of star clusters in each galaxy, we can 'map' each galaxy spatially and temporally over ~1 Gyr. and probe the events that resulted in the current morphology. Here we present three galaxies of dissimilar morphology for which we have found connections between the host galaxy structure and the star cluster population. We also construct SEDs of our galaxies across the UV-IR baseline, and compare to model SEDs corresponding to each system's visual morphological type.

Snapshot Hubble U-band Cluster Survey

The Snapshot Hubble U-band Cluster Survey (SHUCS) aims to characterize the young star cluster populations of a sample of 10 nearby spiral galaxies (see Konstantopoulos et al. 2013). We obtained U-band images to complement archival BVI from *HST*. With the sub-arcsecond spatial resolution of *HST*, the surface brightness profiles of individual star clusters in each galaxy are slightly resolved. We can therefore measure the luminosities and sizes of large numbers of clusters. We fit the SED of each cluster over the UBVI baseline with evolutionary synthesis models to obtain its age, mass, and extinction. With hundreds of clusters in each galaxy, we can study the cluster population itself, including the mass function, mechanisms for disruption, efficiency of cluster formation, as well as how each relates to the environment.

NGC 4041

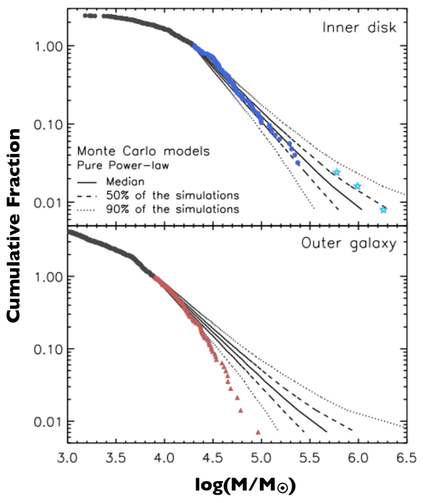


Basic Properties

- NED Homogenized Classification: SA(rs)bc?
- D = 22.7 Mpc, i ~ 0°
- Group member: 5 companions

Visual Appearance

- *HST* UBVI+Hα image shows two-step disk structure: bright inner disk and dimmer outer disk with tightly wound spiral arms
- *GALEX* FUV+NUV image reveals far outer structure, including faint clumpy emission and a fork-like tidal feature
- Hints at a recent interaction or accretion event



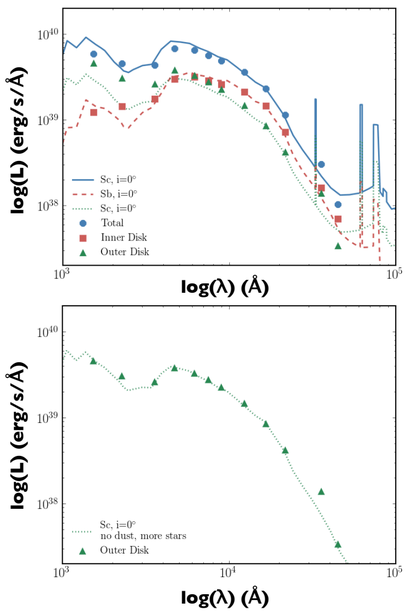
Konstantopoulos et al. (2013)

Cluster Properties

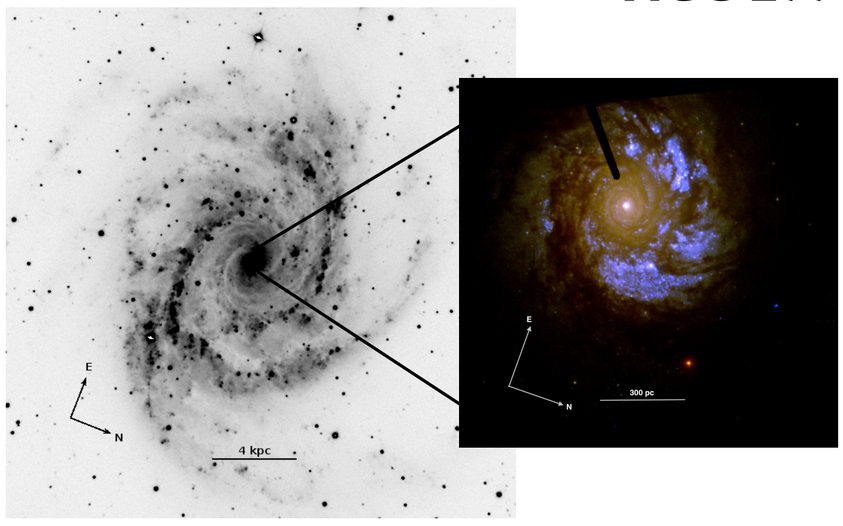
- Compared properties of star clusters in the two disks
- Find inner disk is redder in color on average and hosts more massive clusters than outer disk
- Cluster mass function of inner disk is consistent with a power-law, can form clusters as massive as ~10^6 $M_\odot$
- Outer disk mass function has a cutoff around 3×10^4 $M_\odot$, cannot produce very massive clusters

Galactic SED

- SED of entire disk consistent with Sc template
- Inner disk shows lower UV luminosity, more consistent with Sb template
- Outer disk shows more UV and less 8.0μm luminosity than Sc
- Adjusted components of Sc model to match observed SED of outer disk
- Removed all diffuse dust emission and added 50% more starlight extincted by molecular clouds only



NGC 2997



Basic Properties

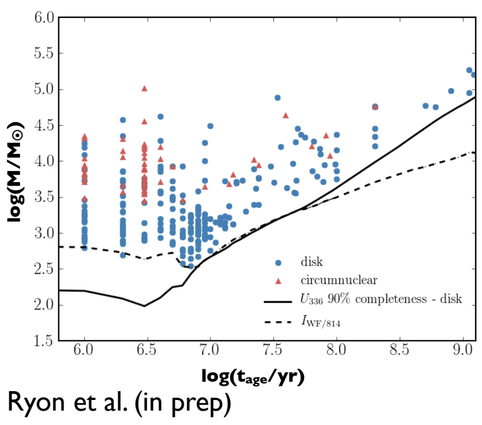
- NED Homogenized Classification: SAB(rs)c
- D = 9.5 Mpc, i ~ 45°
- Relatively isolated, few nearby low-mass galaxies

Visual Appearance

- B band image from Larsen & Ritchler (1999) shows grand design spiral structure
- High-resolution *HST* NUV+UVI image reveals star-forming circumnuclear ring
- No hints of recent interactions or merger events

Galactic SED

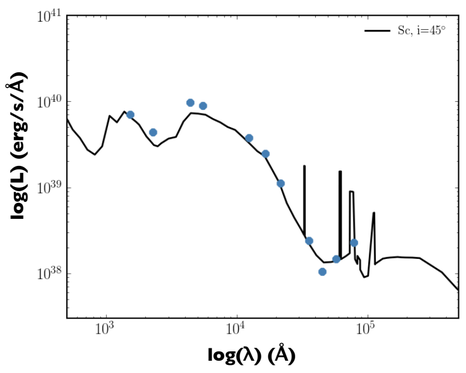
- SED of entire disk consistent with an Sc template with i ~ 45°
- Slightly higher optical and UV luminosity, slightly lower IR luminosity
- May be consistent with more starlight/less dust, but not significant



Ryon et al. (in prep)

Cluster Properties

- Separated clusters in circumnuclear ring from those in the rest of the disk
- Age-mass plot shows circumnuclear clusters may be slightly more massive on average, but this could be selection bias
- No significant differences seen in age or mass distributions of two samples
- Effects of environment may be too subtle to see in our cluster samples



Comparing Galactic SEDs to GRASIL Models

To understand if the visual morphological classifications of our galaxies properly describe their integrated properties, we constructed SEDs using data from *GALEX*, SDSS, 2MASS, *Spitzer*, and optical data from the Danish 1.54-m (Larsen & Ritchler 1999) and Kitt Peak 0.9-m telescopes (Cheng et al. 1997). We used apertures of radius 80", 170.4", and 152.7" for NGC 4041, NGC 2997, and NGC 2146, respectively. For the inner disk of NGC 4041, an aperture radius of 22" was used. We compared our empirical SEDs with GRASIL templates of similar morphological types and inclination angles as our galaxies (Silva et al. 1998). We scaled each model to our observed 2MASS K_s luminosities. In cases where the shapes of the model and empirical SEDs did not match, we adjusted the amplitudes of model components to better correspond to the observed properties.

Conclusions

Star clusters can be used to probe the recent SFHs of their host galaxies at a much finer spatial and temporal resolution than broadband metrics.

- NGC 4041: More massive cluster formation in the older, inner disk. A recent interaction may be funneling gas to the center of the galaxy and driving enhanced star formation.
- NGC 2997: Circumnuclear ring and disk have similar cluster properties, and the SED matches an Sc. Despite its spectacular central ring, this galaxy may be a normal, undisturbed spiral.
- NGC 2146: A cluster age gradient in the tidal stream is clearly observed. The SED suggests enhanced star formation and dust attenuation than a typical Sb, which is consistent with a LIRG.

NGC 2146

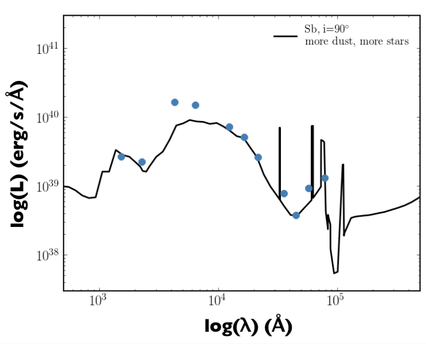
Adamo et al. (in prep)

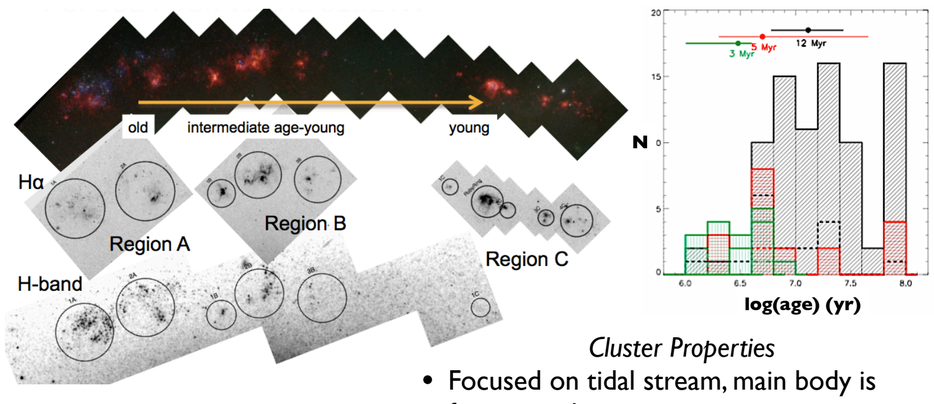
Basic Properties

- NED Homogenized Classification: SB(s)ab pec
- D = 17.2 Mpc, i ~ 90°
- Isolated, few to no companions
- Luminous IR Galaxy (LIRG)

Visual Appearance

- *HST* UBVI+Hα image shows highly obscured edge-on disk and tidal stream projected above the disk
- Highly disturbed morphology
- Suggests recent or ongoing merger event





Galactic SED

- As expected, SED of entire disk not fully consistent with the Sa or Sb template, higher UV and IR luminosity
- Increased diffuse and molecular cloud dust emission by a factors of 10 and added 10% more starlight extincted by molecular clouds only
- Large dust emission bump and increased star formation expected for LIRGs

Cluster Properties

- Focused on tidal stream, main body is future work
- Increase in Hα emission seen from Region A to Region C
- Decrease in red supergiants (bright sources in H-band) follows Hα trend.
- Histograms of cluster ages show that clusters in Region A are older than those in Region B, which are older than those of Region C
- All these signs point to an age gradient in star formation along the tidal stream

References

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