# Nucleation fraction in field versus cluster environment


Vivienne Baldassare, Elena Gallo

Department of Astronomy, University of Michigan


## NSCs and SMBHs in early-type galaxies

- Investigate how nuclear activity, occurrence/properties of NSCs, coexistence of NSCs/SMBHs vary with environment
- Studying NSCs across environment can help us understand how NSCs form and evolve
- NSC formation – two prevalent theories
  - **Dissipative (in situ):** gas flows to center of galaxy, stars form in nucleus
  - **Dissipationless:** globular clusters inspiral to center of galaxy through dynamical friction
- Unclear when/to what degree each mechanism contributes to mass assembly in nucleus

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- **Goal: Explore whether nucleation fraction for early-type galaxies is affected by environment in which a galaxy lives**
- Connect results to study of nuclear X-ray activity in cluster versus field galaxies (Gallo et al. 2008, 2010; Miller et al. 2012a, 2012b, 2014)

## Optical + X-ray Data

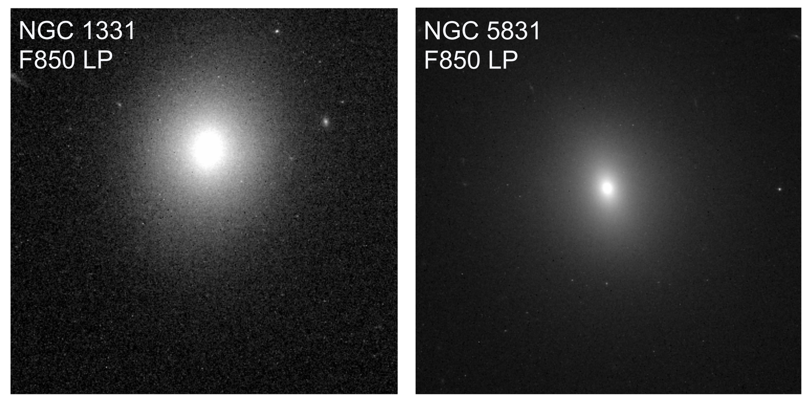


**Figure 1. HST/ACS F850LP images of two early-type galaxies in the Field sample**

- **Total sample:** 103 Field and 100 Virgo early-type galaxies
- **Data:**
  - X-ray: Chandra X-ray data obtained for 100 Virgo and 103 field early-type galaxies.
  - Optical Imaging: Dual-band HST imaging (F475W + F850LP) for 100 Virgo galaxies, 28 field galaxies.
- **Sample properties:**
  - Galaxies are all nearby (distance < 30 Mpc)
  - Masses range from $8.6 < \log(M_*/M_\odot) < 11.4$
  - Eddington-scaled luminosities range from $-9 < \log(L_X/L_{Edd}) < -4$
  - 25/28 field galaxies had nuclear Chandra X-ray detections

## Detection and characterization of NSCs

- Use IRAF *ellipse* to extract azimuthally averaged surface brightness profiles, GALFIT to model 2D surface brightness profiles
- We identify NSCs as nuclear light excesses with respect to a Sèrsic profile fit to the outer galaxy (e.g. Côté et al. 2007)

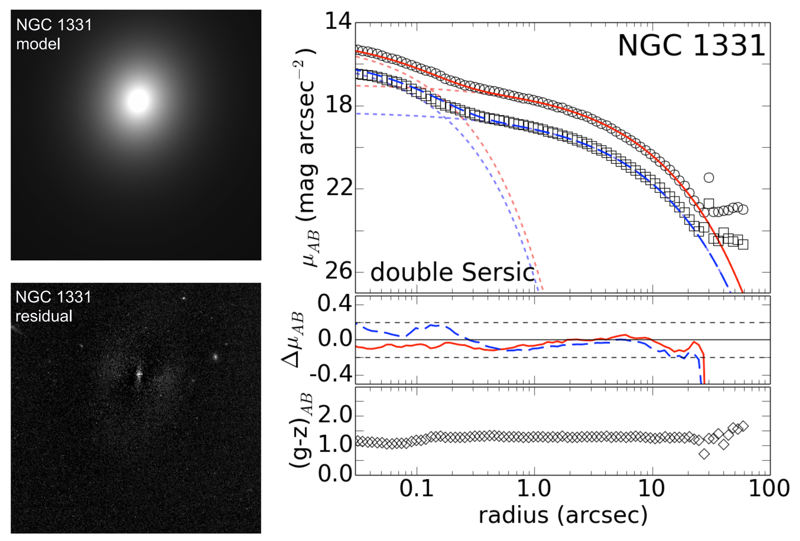


Figure 2. Left: GALFIT model and residuals for NGC 1331. Right: The surface brightness profile of NGC 1331 is well fit by two Sèrsic components. We find NGC 1331 to be nucleated.

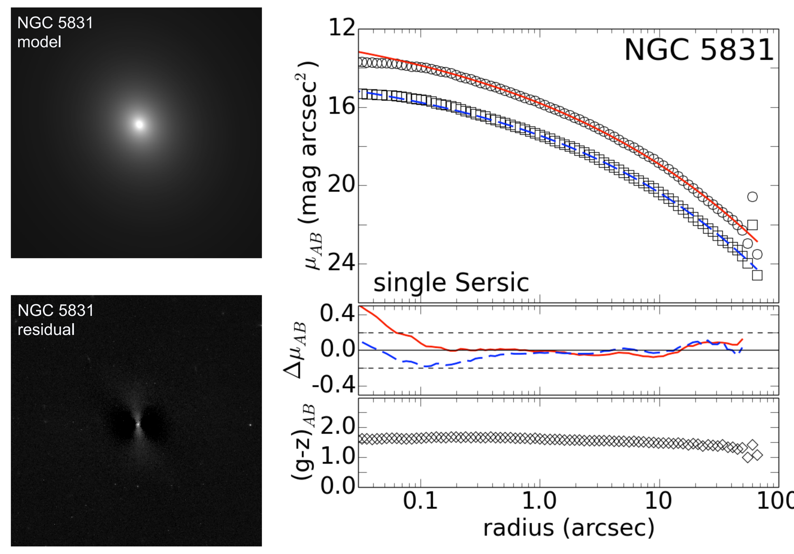


Figure 3. Left: GALFIT model and residuals for NGC 5831. Right: The surface brightness profile of NGC 5831 is well fit by a single Sèrsic component. We do not find NGC 5831 to be nucleated.

## Nucleation fraction does not depend on environment

- We found that 6/23 field early-type galaxies hosted NSCs
- Field nucleation fraction = 27% (Baldassare et al. 2014)
- Virgo cluster nucleation fraction for mass-matched subsamples = 36% (Côté et al. 2006)
- **No statistically significant difference in nucleation fraction between field and cluster environments**
- Argues for main process by which NSCs form being intrinsic to the galaxy itself, i.e. not strongly affected by environment

## Future work: properties of NSCs across environment

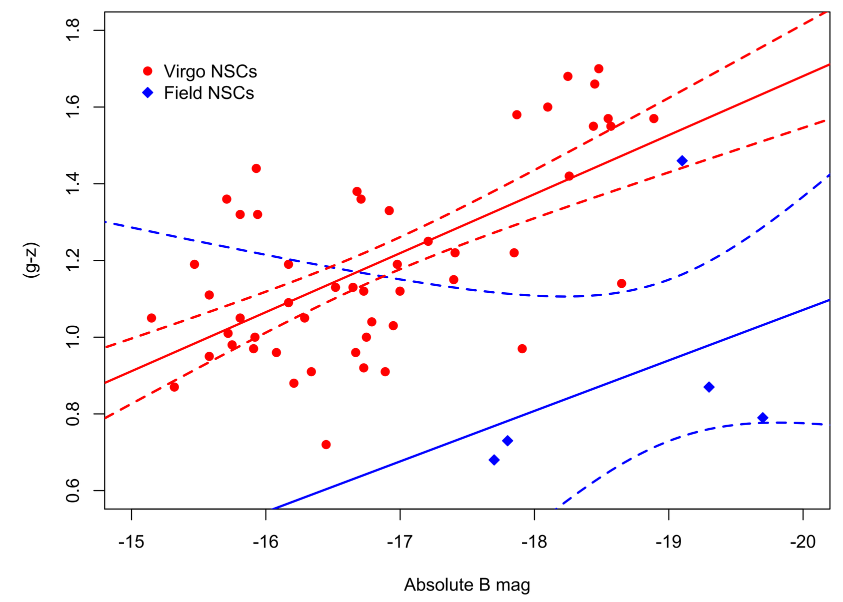


Figure 4. $(g-z)$ color versus absolute B-magnitude for Virgo (red circles) and Field (blue diamonds) NSCs. We carried out a linear regression analysis for the Virgo and Field NSCs to test for the presence of a relation of the form $(g-z) - 1.2 = a + b \times (M_B)$. No statistically significant correlation was found for the Field sample.

- We were unable to discern an environmental dependence of NSC properties due to small sample size
- Virgo NSCs redden with increasing NSC mass/luminosity
  - The extremely red colors of massive NSCs are evidence for NSCs in massive galaxies growing further through accretion of enriched gas (Turner et al. 2012)
  - Single stellar population models show that colors are still reflective of old (> 1 Gyr; $\approx t_{dyn}$ for Virgo Cluster) stellar population
- X-ray results
  - Incidence/intensity of nuclear X-ray activity is enhanced in the field – nucleus has more present-day access to gas
  - Possible interpretation: gas has been stripped more effectively from Virgo Cluster galaxies since the last epoch of nuclear star formation
- Based on X-ray results, might expect to see difference in NSC colors/metallicities with environment (e.g. more recent star formation for field NSCs)
  - Bigger field sample would allow us to identify environmental dependence of $M_B - (g-z)$ relation.

## Acknowledgements


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## References


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