Detecting Nuclear Star Clusters in Coma Cluster Dwarf Elliptical Galaxies

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Abstract

- A new method for detecting Nuclear Star Clusters (NSCs) is presented
- The method is based on measuring the deviation from the best fit light profile of individual galaxies
- This is a robust way to measure the luminosity of a galaxy nucleus with only basic photometry
- The technique is tested and characterised on 3000 model galaxies
- The method is then used to detect Nuclear Star Clusters (NSCs) in dwarf Elliptical (dE) galaxies in the Coma cluster
- Relationship between NSCs and Super-Massive Black Holes (SMBH) is examined

Coma Cluster and the HST Treasury Survey

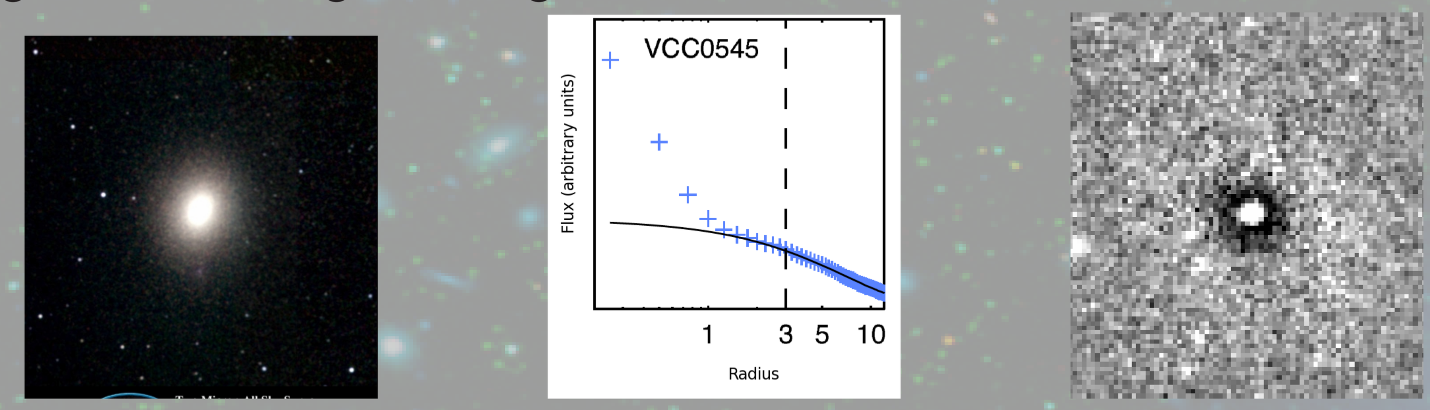
- The Hubble Space Telescope (HST) offers unrivalled resolution and sensitivity making it ideal for studying the structural properties of faint, diffuse dEs
- The Coma cluster is a rich dense cluster of galaxies at a distance of 100Mpc containing thousands of dEs
  - Background image: Multi-wavelength image of the Coma cluster
  - Each green point represents a dE galaxy!
- The properties and location of the Coma cluster are ideal to study galactic structure and evolution

Nuclear Star Clusters

- What are Nuclear Star Clusters?
  - Dense star clusters located at the centre of most galaxies. Recent studies find NSCs in as much as ∼60% of galaxies[1].
  - All dE galaxies contain NSCs
  - Figure 1. shows the nearby, featureless dE galaxy, M32. This galaxy contains a NSC, however, without analysing the image this is impossible to tell! (see next section!)
- Why are Nuclear star clusters important?
  - Central regions of galaxies are key in galactic evolution
  - Studying the difference between nucleated and non-nucleated galaxies is important in understanding clustering processes
  - Central clusters are closely related central to SMBH

How are Nuclear Star Clusters detected?

- Light profiles are used to model galaxies
- At small radii extra light is detected beyond the smooth light profile. Figure 2. centre: galaxy flux against radius. Solid black line is the model profile. Blue points show the galaxy profile.
- Subtracting galaxy image (Figure 2. left) from model profile leave a bright nucleus. Figure 2. right



Galaxy Image | Galaxy profile | Blue – Black lines

Nuclear Excess Index

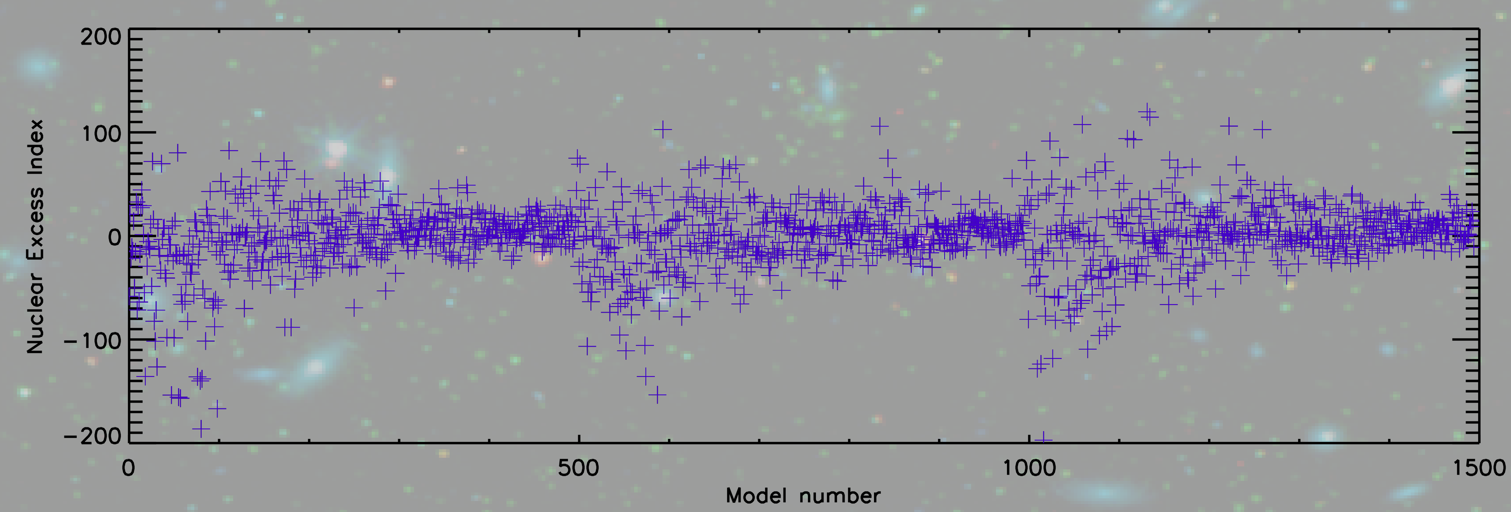
- The index is designed to search for excess light in the galaxy centre
- After model subtraction the index compares the nuclear flux (F(r<2pix)) with the flux just outside the nucleus (F(r<7pix)):

$$\mathrm{NEI} = \frac{2 \times \mathrm{F}(\mathrm{r} < 2.0\mathrm{pix}) - \mathrm{F}(\mathrm{r} < 7.0\mathrm{pix})}{< \sigma_{\mathrm{img}} >}$$

- NEI (Nuclear Excess Index) defines the degree of galaxy nucleation
- $< \sigma_{\mathrm{img}} >$ is the average value of the noise on each pixel within the galaxy area

Model galaxies: Characterisation of the Nuclear Excess Index

- The NEI index has been tested on various model galaxies
- Simulated galaxies without a NSC define the not nucleated range
- Figure 3. shows the distribution of galaxies without a NSC

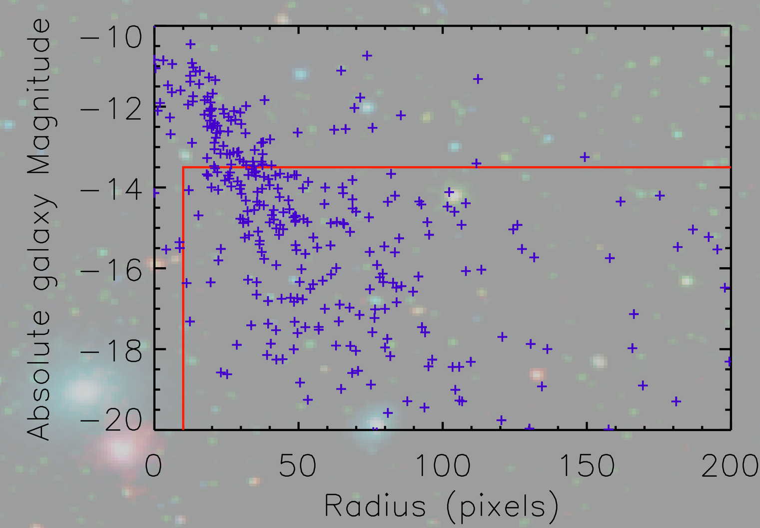


- From Figure 3. four regions are defined:

Region	Range of NEI values
Definitely nucleated	NEI > 125
Possibly nucleated	75 < NEI < 125
Not nucleated	-125 < NEI < 75
Undefined	NEI < -125

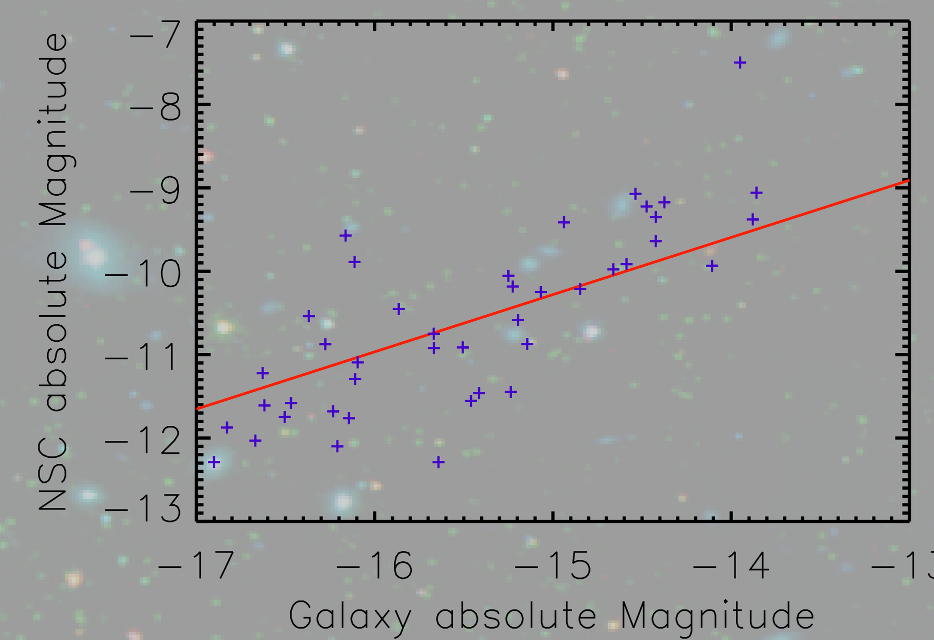
Model galaxies: What can be detected?

- Simulated galaxies with a NSC define what can be detected
- The index cannot detect the very faint galaxies or galaxies with a very small radius
- Figure 4. absolute galaxy magnitude (**M**) vs. radius for the sample for Coma cluster galaxies
- The red lines mark what can be detected by the NEI (i.e. **M** <-13.5 & r> 10 pix)



Real Galaxies

- The NEI detects 139 galaxies in the Definitely nucleated region
- There exists a relationship between host galaxy and NSC luminosity (Figure. 5)



- From Figure. 5 we can see that brighter galaxies (lower **M**) on average contain brighter NSCs
- This transforms into a luminosity relation:

$$\mathrm{L_{host}} = 10^{3.2\pm1.0} (\mathrm{L_{NSC}})^{0.69\pm0.22}$$

- This relation is significantly different to the relation predicted if SMBHs and NSCs are two stages in one evolutionary series[3]
- Our results do not rule out a relation between the two objects but clearly show that it is more complex

Future Work

- The NEI requires more model galaxies and more in depth analysis to fully characterise the limitations
- The index should be tested on published data (e.g. the HST Virgo cluster survey) to reproduce results adding confidence to the NEI
- Test the index on other types of galaxies in other clusters to increase the increase the versatility of the NEI

References: 1. Cote, P. et al.2006.ApJS,166,57. 2. Figure 1: Atlas Image mosaic courtesy of 2MASS/UMass/IPAC-Caltech/NASA/NSF 3. Balcells, M. et al.2007.ApJ,665,1084