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Poster No.: D4
Name: Arsen Levitskiy
University No.: 3035445106
Students Major: Astronomy

Nature of the compact UV emission in Brightest Cluster Galaxies

Arsen Levitskiy, Dr. Jeremy J L Lim
Department of Physics

ABSTRACT

We address whether the circum-nuclear UV from giant elliptical galaxies at the centers of galaxy cluster observed in the CLASH program[1] is associated with recent star formation. By plotting the spectral energy distribution of these galaxies as a function of radius, we examined whether the UV to near IR emission of these galaxies changes from center outwards – as would be expected if galaxies exhibit circum-nuclear star formation. No change is detected in fourteen galaxies, suggesting that their UV emissions is produced by an evolved stellar population; the remaining two galaxies, however, show an excess emissions in UV to optical emission at the centers consistent with recent star formation. Using the stellar population synthesis code, BAGPIPES[2], we demonstrate that the SEDs of non-star forming galaxies are indeed characterizes of old stellar populations, whereas that of the star forming galaxies includes an additional young component.

Background

(a) MACSJ 0329 (b) MS2137

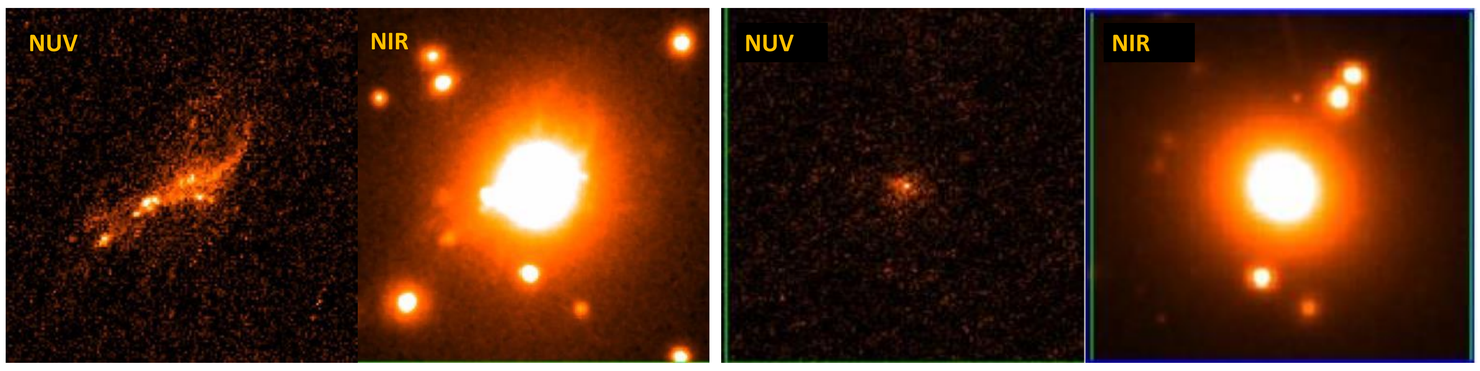

Figure 1: (a) MACSJ0329 in NUV and NIR filters, exhibiting spatially extended UV emission; **(b)** MS2137 in NUV and NIR filters, exhibiting compact UV emission

The most massive and luminous galaxies in the Universe inhabit the centers of galaxy clusters – referred to as Brightest Cluster Galaxies (BCGs). How these galaxies attained their enormous sizes and masses remain poorly understood: do they grow solely by cannibalizing lower- mass galaxies, or do they continue to form star from gas accreted from the surrounding intracluster medium. BCGs residing in galaxy centers whereby the intracluster gas is inferred to cool most strongly have been found to preferentially exhibit recent star formation, suggesting that their star formation is indeed fueled by the accretion of intracluster gas rather than the cannibalism of gas-rich galaxies[3].

Here we address the nature of UV emission from the BCGs observed in CLASH program. In this program, twenty-five galaxy clusters were observed with the Hubble Space Telescope (HST) in sixteen wavelength bands spanning the UV to the near – IR. The BCGs in nine of these galaxy exhibit spatially complex UV emission (e.g Fig 1a) from newly-formed stars[4]. The BCGs in the remaining sixteen galaxy cluster exhibit apparently compact UV emission from their centers (circum-nuclear UV emission; e.g. Fig 1b): is this emission also associated with newly-formed stars? If so, then their brightness as a function of wavelength – spectral energy distribution, or SED – should be different between their centers and further outwards. By comparing their SEDs with that predicted by theoretical models for the spectrum of different stellar population.. We can also quantify physical properties (e.g age and mass) of any young stellar population in addition to an old stellar population.

Results and future work

- In the fourteen of the sixteen BCGs exhibiting circum-nuclear UV emissions, their SEDs can be modelled by a 8-10 Gyr old stellar population (e.g Fig 4a)
- Two of sixteen BCGs, Ms2137 and MACSJ1206, showed excess UV to optical emission in circum –nuclear.
- The outer regions of these two BCGs resembles 8 – 10 Gyr stellar population, where the central region contain recent star formation, resembling a combined ~5 Myr young and 8-10 Gyr old stellar population (e.g Fig 4b)
- When not associated with recent star formation, the UV emission of all these galaxies presumably originate from a evolved stellar population – Sun like stars that have evolved away from the main sequence. In our galaxy such stars known to exhibit UV emission owing to shocks in their atmosphere generated by pulsation.
- For future work, a more detailed look at the possible evolved stellar population can studied through modeling and by further incorporating GALEX data.

Acknowledgments

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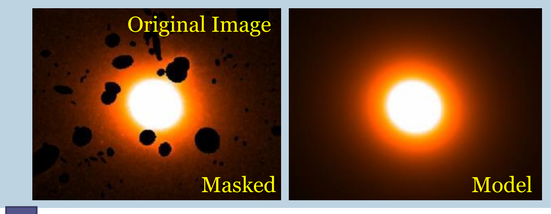
Methodology

To study the SEDs of the individual BCGs, we first mask you neighboring galaxies. We then fit a 2-dimentional Sersic function to the remaining galaxy light to determine the orientation of its major axis and its ellipticity. The SEDs are determined over elliptical annular regions from the center of BCGs outwards after imposing the same angular resolution to all images from UV to near-IR

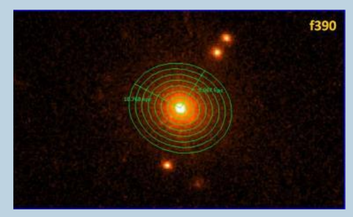
Step 1

Masking neighboring galaxies, and determine orientation of major axis and ellipticity of BCG.



Step 2 and 3

Convolve images at all wavelengths to a common angular resolution. Divide BCGs into elliptical annular regions with width of 0.3” about three times the angular resolution



Step 4

Generate SEDs for each annular region, normalized in brightness's at 10500A. Found fourteen of the BCGs to not exhibit detectable variations in SED between different annular regions (e.g Fig 2a), whereas two BCGs exhibit entirely different SEDs between their central and outer regions (e.g Fig 2 b,c)

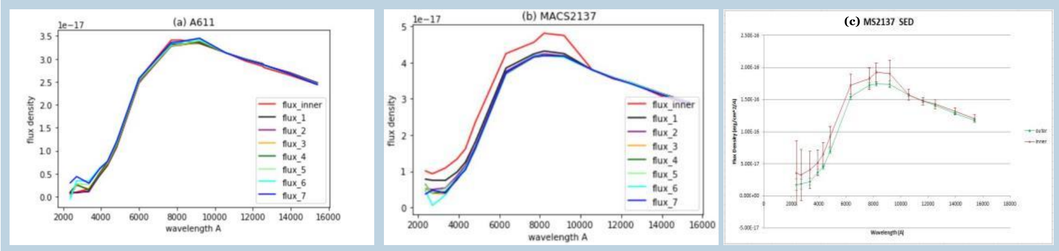


Figure 2: Representative normalized SEDs of BCGs, where different colors in first two panels indicate the SEDs at different radii from the center of the galaxy (flux_inner, flux_1, … flux_7 from the center outwards). **(a):** Similar SEDs as a function of radius, indicating no appreciable star formation. **(b):** excess emission at UV to optical wavelengths from the central region of MS2137. **(c):** Combined outer region SED, with UV to optical excess from the central region of MS2137

Step 5

Used BAGPIPES[3] to fit model stellar population to SED. Except in central regions of two BCGs, all other SEDs characteristic of an old stellar population. Two BCGs have, in addition a stellar population with ages ~5 Myr at their centers (Fig 3b).

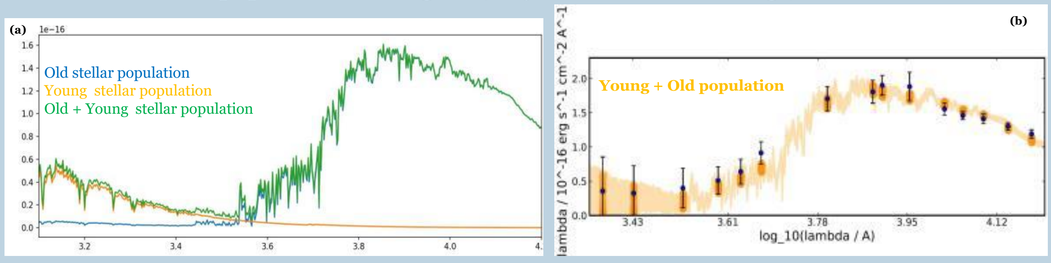


Figure 3: (a) SEDs of Old (blue), Young (orange) and Combined (blue) stellar populations (left); **(b):** Fitted SED of combined stellar population (orange line), with observed photometric measurements (blue points)

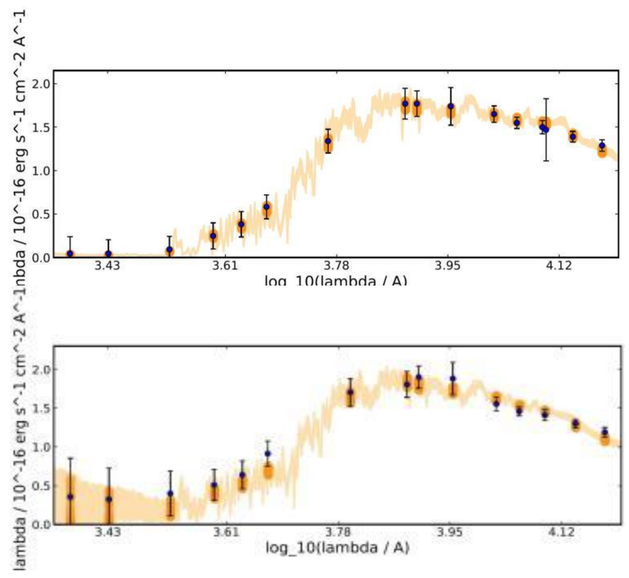


Figure 4: **(a)** Fitted 8-10 Gyr population to SED of circum-nuclear of A611, one of fourteen BCGs. **(b)** Fitted combined stellar population of ~5 Myr with 8-10 Gyr population to circum nuclear region of MS2137, one of two galaxies exhibit recent star formation

References

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2. Carnall, A., et al. 2017, MNRAS, 000, 1-27
3. Lim, J., et al. 2020, Nat Astron 4, 153–158
4. Donahue, M., et al. 2015, ApJ, 805, 177