Rejuvenated Early-type Galaxies at z~0.1

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What is the main result of this study?

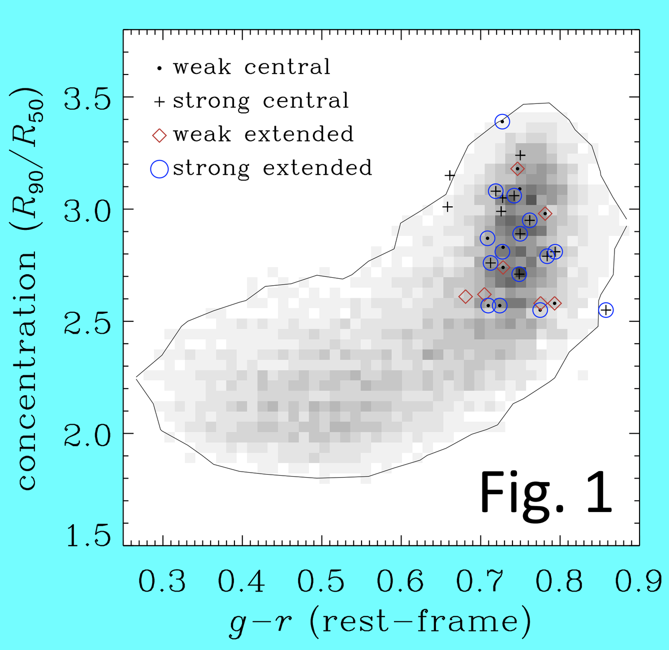
We find that early type galaxies (ETGs) with high far-UV excess owe that excess mostly to *extended star formation*, even when optical spectra and images show no obvious signs of SF.

How was the sample selected?

These galaxies were selected from the combination of SDSS spectroscopic sample and GALEX medium deep imaging, and are typically at z~0.1. We focus only on relatively massive ETGs (see Fig 2).

What makes them early-type (ETG)?

We selected galaxies with high concentration, typical of early types, and no emission lines in SDSS spectra. This resulted in a sample that lies fully on the optical red sequence (see Figure 1 below), though we didn't select explicitly by optical color. We discarded E+As which often have UV excess. In the end we got 30 ETGs with very strong UV excess and nothing too obvious going on in the optical images (see the left large panel) or spectra.

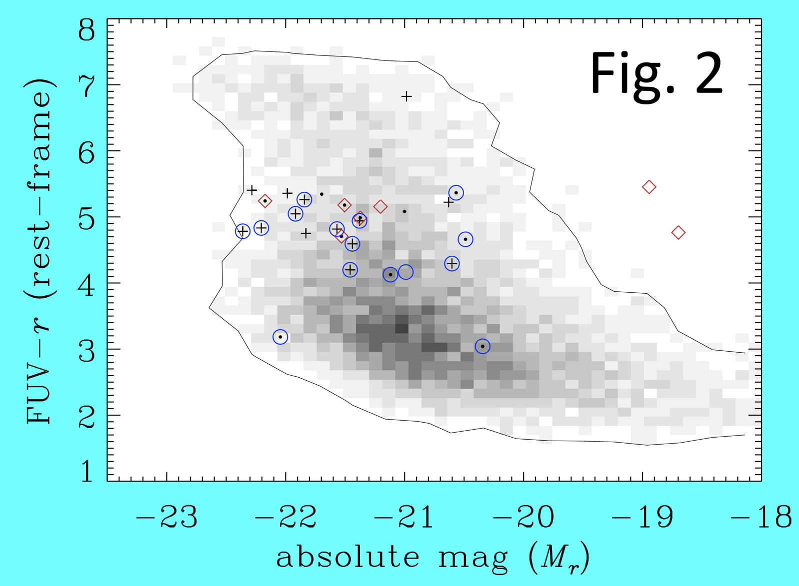


Could the UV excess in this sample simply be due to the old populations (UV upturn) or an AGN?

That's what we wanted to test. But it was unusual that the UV excess was much stronger than in any known local UV-upturn ETG. Likewise, we expected no AGN since we selected galaxies with basically no emission lines. Third possibility, SF, also didn't make sense since it would imply clearly detectable H alpha.

Are these galaxies the same as the green valley population?

The UV excess makes our sample acquire green-valley UV-optical colors (Fig. 2 or 3). However, the green valley is a heterogeneous mix and also contains dusty late types (e.g, edge-on spirals), passive late types (anemic spirals) and transitional ETGs such as E+As.

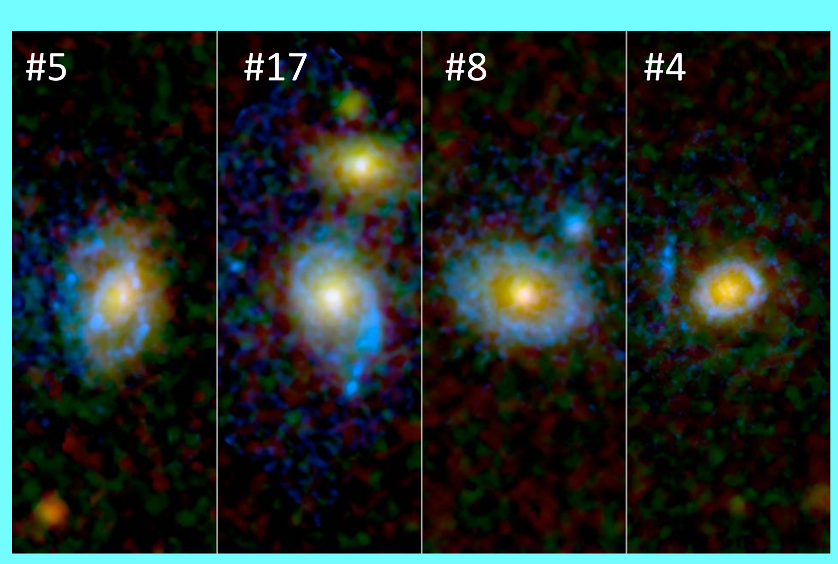


How do we test the origin of UV excess?

Far UV morphology. If it is the classical UV upturn, FUV coming from old stars would look smooth, an AGN would yield a central source, while SF would be extended and/or patchy. However, at these redshifts GALEX imaging (5" PSF) is of little help. We needed HST. It is only the SBC detector on ACS which can detect far UV, so we used one orbit per galaxy with the F125LP filter.

What did the HST UV images show?

See the large panel (right). Most galaxies (~3/4) turned out to have patchy and/or extended UV emission, so most of the UV is indeed from star formation, with typical SFR of around ~0.5 Ms per year. Here are several star-formers shown in optical/UV composite image:

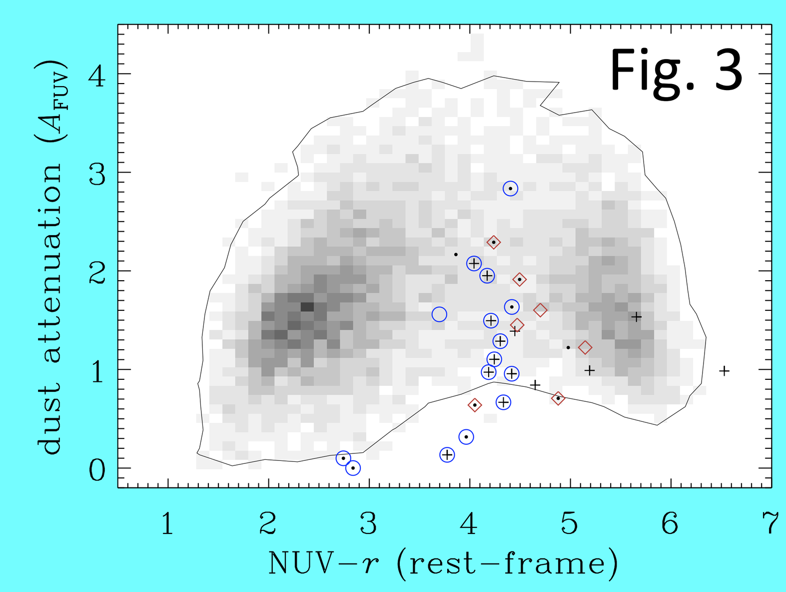


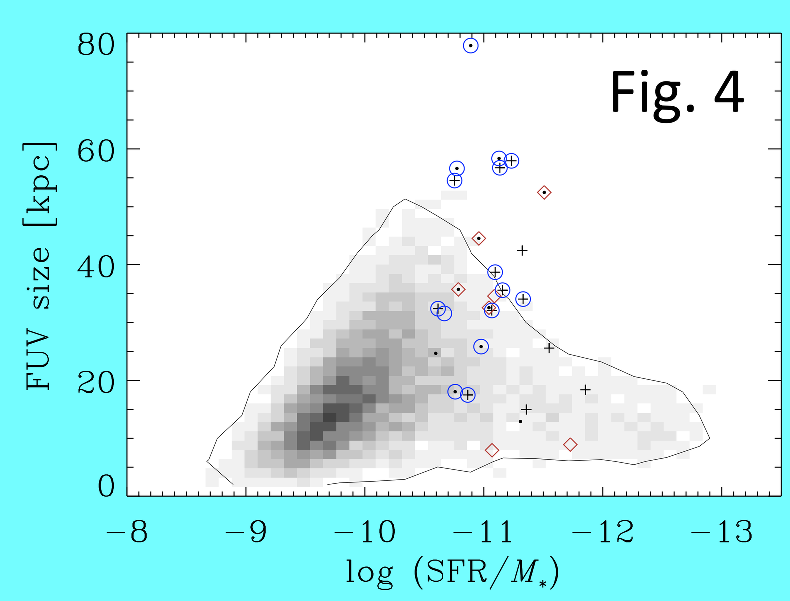
So why no Halpha in SDSS spectra?

Perhaps simply because the SDSS fiber covers only the central region (3"), where SF is mostly not present, as can be seen in the images. Alternatively, this galaxies could be post-starburst, so H alpha is gone, while UV lingers longer. We are acquiring H alpha narrow band images to check this.

Are these transitional galaxies that are shutting down their SF?

We believe that this is not the original star formation that is being shut down (which may be happening in other green valley galaxies), but that these were already quiescent (normal) ETGs that experienced a *new* episode of SF. We base this on the observation that most galaxies have little dust (Fig 3), similar to normal ETGs, and that the SF structures are very large (10-50 kpc, Fig 4), often much larger than normal SF disks, and in the form of rings, and not disks.





Where did the new gas come from?

We are not sure. One popular explanation for SF in ETGs is that it is due to minor gas-rich mergers. However, that would probably result in central bursts and less uniform structures, while we see mostly uniform extended structures (except in some cases that look more central, e.g, #13 or #19). Another possibility is that this is fresh accretion from the 'cosmic web', as predicted in cosmological simulations. But why would such accretion be episodic and why in these ETGs? Perhaps it is being regulated by an AGN. When AGN is off, as seems to be the case here, the accretion could continue.

Why so many rings?

Another unknown. These are certainly not collisional rings (those are eccentric, plus very rare). Locally, rings are mostly the result of bar resonances. We don't really see bars in SDSS optical images, though they may be present but weak. If it were the bars, here they would be too frequent. Perhaps accretion alone can form rings.

Are these ETGs predominantly ellipticals, or S0s?

We don't have high resolution optical imaging, so we don't know for sure. We suspect that these are mostly S0s since we never see such strong UV excess in the most massive ETGs (which are all Es). If rings need bars, those that have them would have to be S0s.

What about the central source visible in many images?

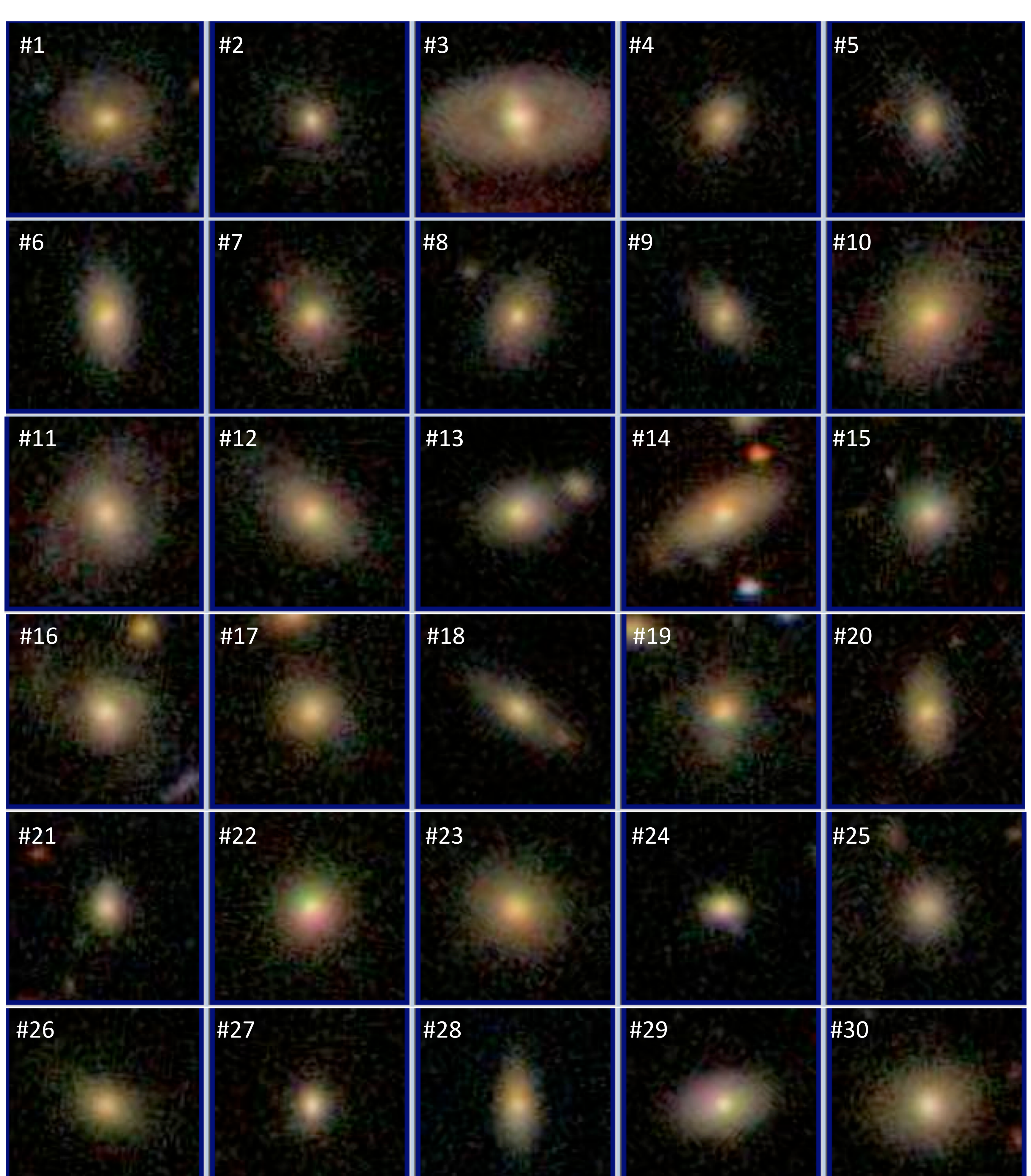
These could possibly be very weak AGN, or the core of the classical UV upturn. In couple of cases where only central source is visible (#22, #27), the UV color is very blue, indicative of an AGN.

Is there a full paper about this?

"Star Formation Signatures in Optically Quiescent Early-type Galaxies", Salim and Rich, 2010 ApJL, 714, 290.

What next?

High resolution WFC3 imaging from NUV to NIR could help determine the scenario for the origin of the star-forming gas. Alternatively, we could try to find more nearby examples showing similar phenomena.



25"x25"
50 kpc

← Optical (SDSS gri composite) ←

→ Far-UV (HST ACS/SBC) →