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Recent star formation in nearby 3CR radio-galaxies

Abstract

We analyzed HST images of 25 nearby 3CR radio-galaxies. We compared their UV and optical images in order to recognize the presence of recent star formation. Having subtracted the emission from their nuclei and/or jets, 12 of the remaining 25 objects present an UV/optical color (NUV - r < 5.4) that must be ascribed to a young stellar population. The fraction of "blue" 3CR host galaxies (48 %) is higher than observed in quiescent early-type galaxies, implying a physical link between star formation and nuclear activity.
We then considered the radio-galaxies separating them on the basis of the radio-morphology, radio power and diagnostic optical line ratios (into low and high excitation galaxies, LEG and HEG). While there is no connection between the FR type (or radio power) and color, this is clearly related to the spectroscopic type. In fact, the fraction of "blue" HEG is 100 % (6/6) and most objects present morphologically evidence of recent star formation in UV compact knots, extended over 5-20 kpc. Conversely, there are only 6 "blue" LEG (out of 19, i.e. ~32 %). With only one exception, LEG display star formation only spatially coincident with their circum-nuclear dusty disk, extended on a scale of 0.5-1 kpc.
The picture that emerges, considering color, UV and optical morphology, is that only in HEG the star formation is associated to a recent major merger that is also responsible for the triggering of these relatively powerful AGN. In LEG galaxies the fraction of actively star forming objects is similar to what is observed in quiescent galaxies.

Scientific background, Aims of the analysis and Data reduction

In the last decade observational as well as theoretical studies have supported the idea of a co-evolution between supermassive black holes (SMBH) and their host galaxies (Fig. 1).
According to this common evolutionary process, both SMBH and the host grow up together. In this framework, nuclear activity (i.e. the manifestation of gas accretion onto a SMBH) and star formation are expected to be related, and for both processes mergers, as triggering process of SMBH/galaxies co-evolution, are likely to play a crucial role.

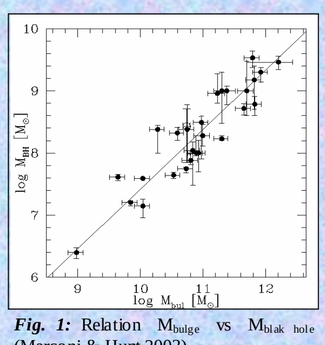

Fig. 1: Relation M_{bulge} vs $M_{blak\ hole}$ (Marconi & Hunt 2003).

What is the fraction of nearby radio-galaxies showing evidence for young stars? Is there a relationship between the AGN properties and the star formation characteristics? What is the role of mergers in the triggering of AGN activity and star formation in radio-galaxies?

We analyzed images of 3CR radio galaxies for which both optical and UV HST images are available. The sample is composed of 31 radio-galaxies, all but one with z < 0.1.
We have excluded six objects since they are very highly nucleated or have too low signal-to-noise ratio, finally remaining with 25 objects. We masked the UV emission from nuclei and/or jets. We also estimated that emission line contamination to the UV fluxes is negligible. We then measured UV and optical fluxes within a set of concentric apertures.
In order to perform a proper comparison with previous studies, we derived a cross-calibration between GALEX, SDSS, and HST data with models of stellar population synthesis. We conservatively estimated the error associated with this procedure to be < 0.2 mag.

Results

The NUV-r color can be used as discriminant (Schawinski et al. 2006) , adopting a threshold at NUV-r < 5.4 to separate "red" quiescent galaxies from "blue" galaxies with active star formation, see also Lee et al. (2005).
On the basis of this criterion on the integrated colors and on the UV morphology, the galaxies of the sample can be divided in 3 main categories (see Fig. 2):

a. ***quiescent red galaxies*** (14 objects) have red and essentially flat color profiles (Fig. 3), with only diffuse UV emission, tracing the optical light;

b. ***blue UV-clumpy galaxies*** (7 objects) show a clumpy UV morphology (extended over 5-20 kpc) usually associated to dust lanes structures. They have monotonous color profiles (Fig. 4);

c. ***UV-disky galaxies*** (4objects) have UV emission confined co-spatially with their circum-nuclear (on a scale of 0.5-1 kpc) dusty disks; only in 2 of these objects the UV excess is sufficient to produce a "blue" color (Fig. 5).

Fig. 2

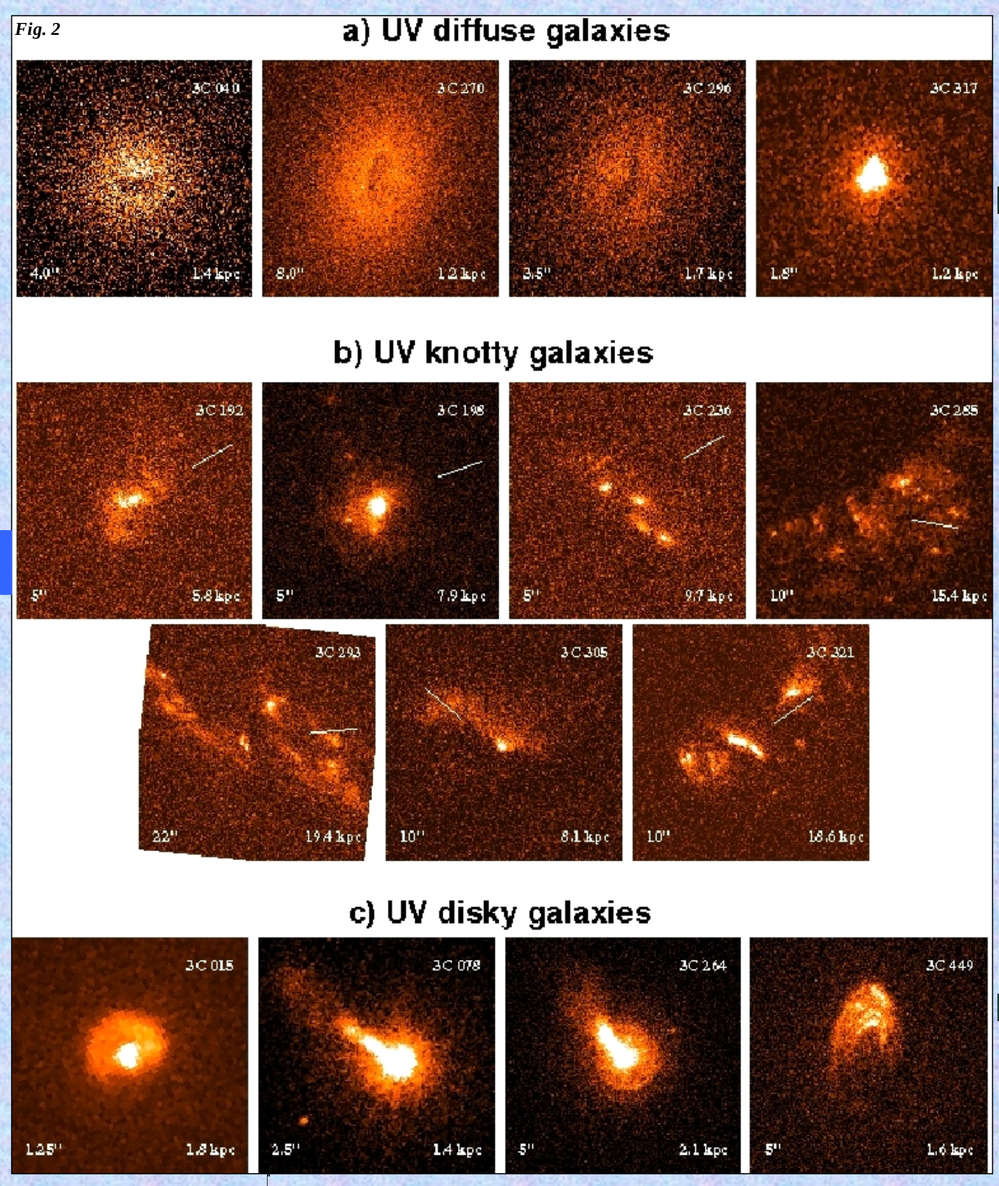

Fig. 3

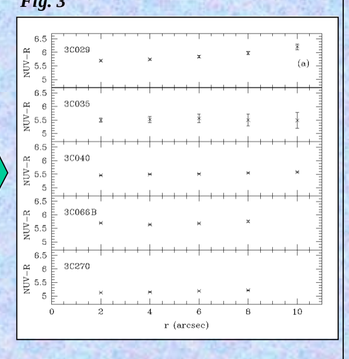

Fig. 4

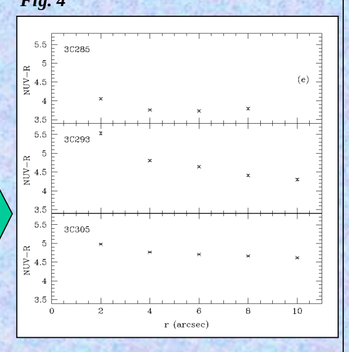

Fig. 5

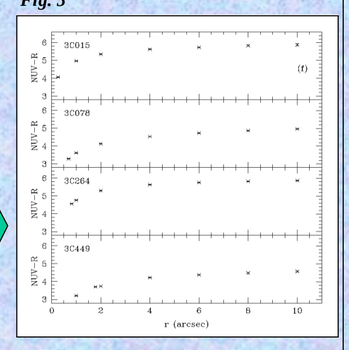

Fig. 3, 4, 5: NUV-R color (HST based) profiles of the sample

Discussion

The NUV-r color distribution of our sample (see Fig. 6) is peaked at NUV-r ~5.9 but with a substantial blue tail, very similar to those found by Kauffmann et al. 2006 (including only AGN).

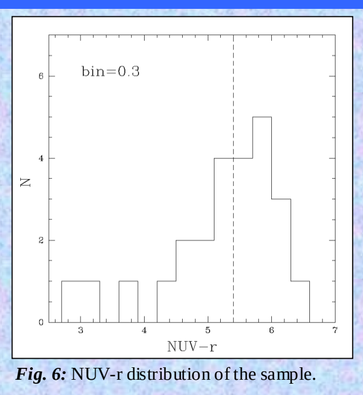

Fig. 6: NUV-r distribution of the sample.

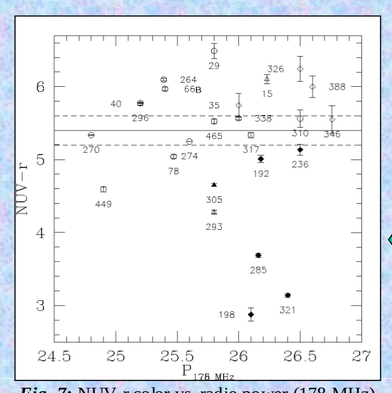

Fig. 7: NUV-r color vs. radio power (178 MHz) for the sample.

The fraction of the blue galaxies (NUV-r < 5.4) among the 3CR galaxies (see Fig. 7) is 48^{+16}_{-12} %. These values are substantially higher than ~20 - 25 % the fraction of recent star forming (RSF) galaxies in the sample of non-active early-type galaxies studied by Schawinski et al. 2006.
The higher fraction of "blue" 3CR host galaxies implies a physical link between star formation and nuclear activity.

We then considered the radio-galaxies separating them on the basis of :

1. radio power: no clear connection (Fig. 7). While the bluest galaxies are all at relatively large values of $P_{178\ MHz}$, at the high end of radio luminosities we also find many of the reddest galaxies;

2. radio morphology (into FRI and FRII): no clear connection, since we find an almost equal share of "blue" and "red" galaxies in all;

3. on the diagnostic optical line ratios (into low and high excitation galaxies, LEG and HEG): there is a clear association between galaxy color and optical spectroscopic classification. In fact, all six HEG are blue, while there are only 32^{+21}_{-16} % (6^{+4}_{-3} /19) blue LEG, a fraction of RSF galaxies consistent with that observed in the non-active population of early-type galaxies.

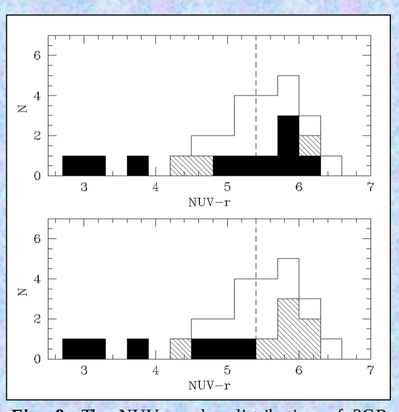

Fig. 8: The NUV-r color distribution of 3CR galaxies. In the upper panel we point out the FR-morphological separation: the FRII distribution is black, the FRI one is empty and the FRI/II intermediate one is shaded. In the lower panel we point out the excitation level classification: the HEG distribution is black, the FRII-LEG one is shaded and the distribution of the FRI objects is empty (for simplicity we sorted the FRI/II intermediate-LEG objects as FRII-LEG).

Summary and Conclusion

The general link between star formation and AGN in 3CR hosts is actually driven only by the presence of high excitation galaxies.
The results obtained, concerning the properties of HEG and LEG can be summarized as follows:

1. All HEG have a blue NUV-r color, while the fraction of blue LEG is similar to the non-active population of early-type galaxies;

2. UV, optical, and dust morphology in HEG are highly chaotic and unsettled morphologies, while they are more regular, arranged in disk structures, in LEG;

3. HEG have a higher dust content;

4. HEG have higher nuclear luminosity.

All these findings can be explained if in the case of HEG we are seeing the effects of a recent major, "wet" merger (Fig. 9). The fresh input of gas and dust causes both the higher star formation rate and stronger nuclear activity. Conversely, in LEG the interstellar medium appears to be able to provide sufficient fuel for star formation activity (localized in their central regions) and for the AGN itself, without need for an external gas supply.

Fig. 9: image of a merger of two galaxies.