The peculiar(?) case of [BHF2008] 19 -

an extremely compact and massive elliptical galaxy

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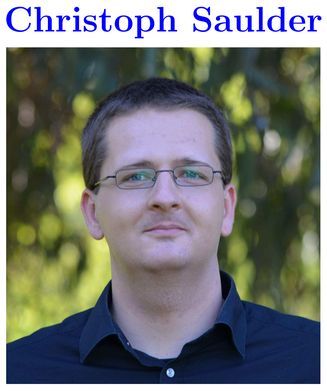

Abstract

We investigate the case of the allegedly peculiar galaxy [BHF2008] 19 (short b19). It is very compact elliptical galaxy with an outstandingly high central velocity dispersion. This galaxy is believed to have either an extraordinarily massive central black hole or an unusual initial mass function (IMF). We try to find more galaxies with similar overall properties to provide a large sample for further studies. Therefore, we select define a sample of about 50 galaxies consisting the most compact and most massive (highest central velocity dispersion) of more than 100000 SDSS galaxies which were classified by GalaxyZoo to be early type. We study how well these galaxies fit on well-known relations of elliptical galaxies such as the fundamental plane or the red sequence. We also use Sersic fits in addition to the de Vaucouleurs fits provided by SDSS in order to better understand possible peculiarities of the global parameters of these galaxies. Our investigation yields that b19 is not unique and that b19-like objects just form the most massive and most compact tail of the general distribution of elliptical galaxies and that they are that distinct after all. The main objective of this work is to establish the correct framework for understanding b19 and similar galaxies.

The suspect

[BHF2008] 19 (short b19) is a very compact and massive early type galaxy. It was investigated in great detail in Läsker et al. (2013). b19 either shows signs of an unexpectedly high stellar mass-to-ratio and a bottom-heavy IMF or it may have an extremely massive black hole in its centre and a normal IMF.
Its characterizing parameters using the de Vaucouleurs (dV) fit from SDSS DR10 are:

- redshift (CMB-corrected): 0.117
- dV radius (r band): 2.2 kpc/h_{70}
- central velocity dispersion: 371 km/s
- corrected apparent magnitude (r band with dV profile): 16.9 mag
- absolute magnitude (r band with dV profile): $-21.8\,\mathrm{mag} + 5\log_{10}(h_{70})$
- (g-r) colour: 0.80 mag.

The values we derived from SDSS are compatible with the ones presented in Läsker et al. (2013).

FIGURE 1: [BHF2008] 19 aka. SDSS J151741.75-004217.6

Accomplices

The first question was, if b19 was a unique object or not. To this end, we defined several criteria to select similar objects from our dataset. We consider galaxies with small scale radii R_0 as compact and in a first approximation, galaxies with high central velocity dispersions σ_0 as massive. For a galaxy to be considered similar to b19 it must fulfil the following criteria:

- $\log_{10}(R_0) < \overline{\log_{10}(R_0)}$ - $\sigma_{\log_{10}(R_0)}$
- $\log_{10}(\sigma_0) < \overline{\log_{10}(\sigma_0)}$ - $\sigma_{\log_{10}(\sigma_0)}$
- more than 3-σ off from the $\log_{10}(R_0) - \log_{10}(\sigma_0)$ relation

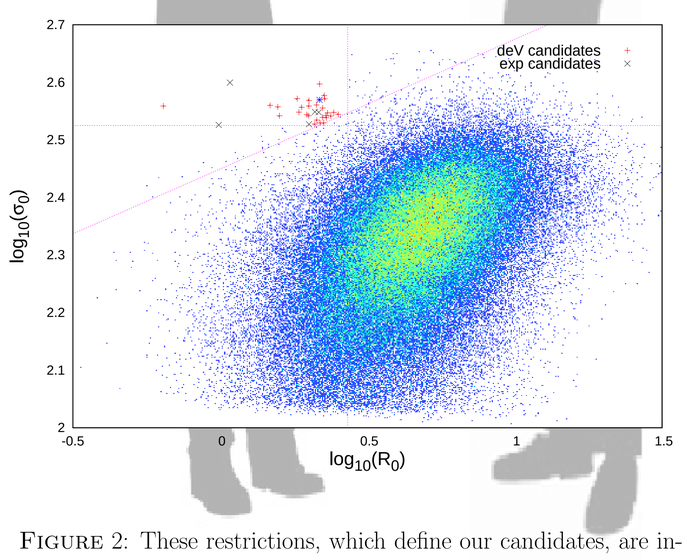

FIGURE 2: These restrictions, which define our candidates, are indicated by the dashed magenta lines. b19 is represented by a blue star in the plot.

Aside from b19, we find 28 early type galaxies (according to GalaxyZoo classification) with a greater likelihood for a dV-profile than for an exponential that fulfil our criteria. In addition to that we also find 5 galaxies with a greater likelihood for an exponential profile than for an dV-profile that fulfil our criteria.

Accusation

Taking b19 and galaxies located in the same corner of the $\log_{10}(R_0)$-$\log_{10}(\sigma_0)$ diagram, we ask the following questions:

- Is b19 unique or part of a special class of early type galaxies?
- How peculiar is b19?
- Are b19-like objects just the compact-massive tail of the general distribution of elliptical galaxies?
- In which aspects do b19-like objects differ from other ellipticals?
- Are b19-like galaxies really outliers?
- Do they have an usual IMF or an extremely massive central black hole?

So far, very little work has been done on these kind of galaxies and therefore, it is important to see how the fit in the bigger picture first. There are also a couple of galaxies known, which may fall into the same category, but are not part of our sample such as NGC 1277 (R. van den Bosch et al., 2012) or NGC 4486B (Magorrian et al., 1998).

Evidence

According to Läsker et al. (2013), b19 is a clear outlier of the fundamental plane of Bernardi et al. (2003). We find that b19 is only about a little bit more than 1-σ off the fundamental plane, which we derived in Saulder et al. (2013). Furthermore, all other b19-like galaxies are clearly within 3-σ of the fundamental plane (see Figure 3), although basically all of them are located on the same side above the fundamental plane.

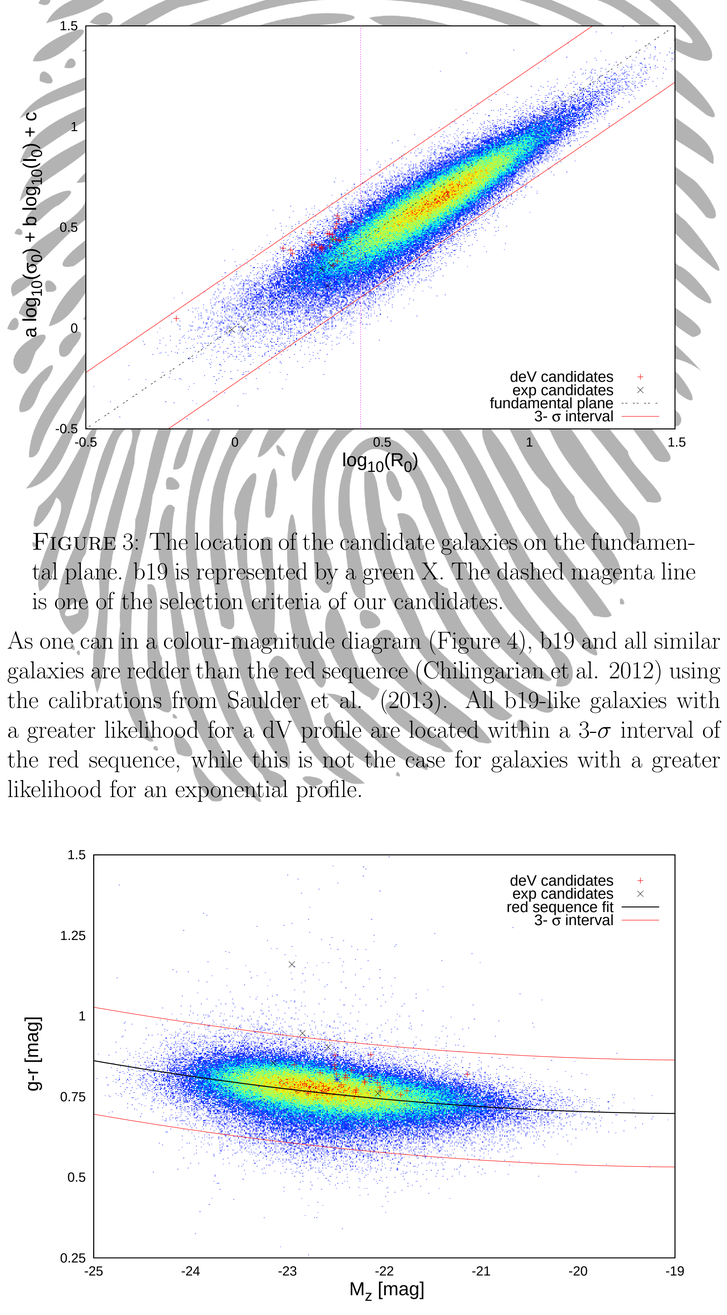

FIGURE 3: The location of the candidate galaxies on the fundamental plane. b19 is represented by a green X. The dashed magenta line is one of the selection criteria of our candidates.

As one can in a colour-magnitude diagram (Figure 4), b19 and all similar galaxies are redder than the red sequence (Chilingarian et al. 2012) using the calibrations from Saulder et al. (2013). All b19-like galaxies with a greater likelihood for a dV profile are located within a 3-σ interval of the red sequence, while this is not the case for galaxies with a greater likelihood for an exponential profile.

FIGURE 4: The location of the candidate galaxies in a colour-magnitude diagram. b19 is represented by a green X.

More Evidence

In addition to the basic SDSS dV fits, we use the Sersic fits of the SDSS DR7 data of Simard et al. (2011). In Figure 5, we compare the Sersic parameters of the b19-like galaxies with the overall distribution of the Sersic parameters of all SDSS galaxies and all galaxies classified as early type by GalaxyZoo. We find that there is no significant difference in the distribution of elliptical galaxies and the b19-like galaxies, except that the clumping (due to the fit algorithm used in Simard et al. (2011)) at a Sersic index of 8 is more prominent for the compact galaxies.

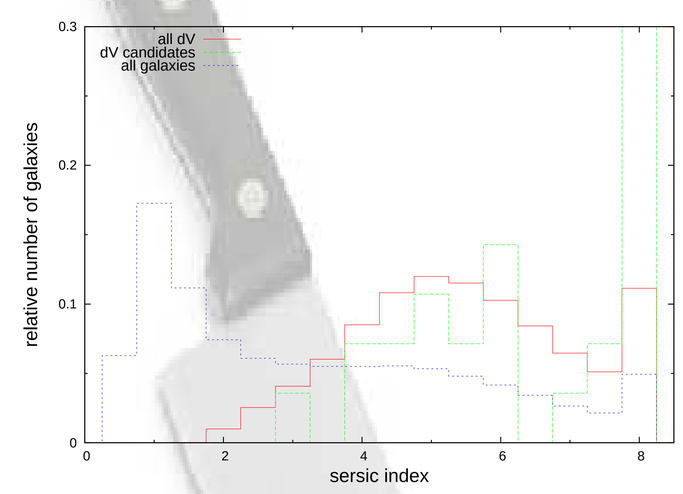

FIGURE 5: The distribution of the Sersic parameter of all SDSS galaxies, all elliptical galaxies and the candidate galaxies.

Redoing the plot of Figure 2 with the values from the Sersic fits instead of the dV, it becomes clear that all b19-like galaxies that have a greater likelihood for a dV profile are still located in the same corner of the plot, while those that have a greater likelihood for an exponential profile can be now found in a different part of the plot (see Figure 6), which means that the later category, was just located in the compact massive corner due to bad fitting and not because of the actually properties of those galaxies.

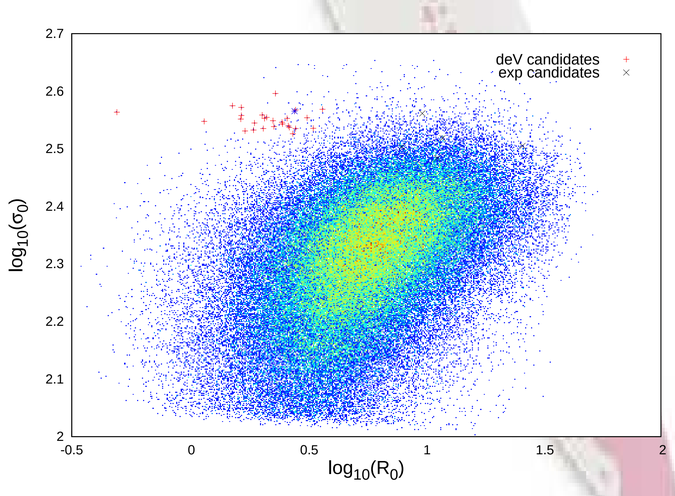

FIGURE 6: $\log_{10}(R_0) - \log_{10}(\sigma_0)$ plot using the values from the Sersic fits from Simard et al. (2011). b19 is represented by a blue star in the plot.

Judgement

Based on the gathered data, we conclude that

- b19 is not unique
- galaxies, which can be found in the same corner as b19 in a $\log_{10}(R_0) - \log_{10}(\sigma_0)$ plot and classified as early type by GalaxyZoo show similar properties, except those that have according to SDSS a greater likelihood for an exponential fit than for a dV fit (due to poor fitting).
- all b19 like galaxies deviate from known relations for elliptical galaxies slight and in the same direction
- all deviations are still well within 3-σ limits and the overall scatter of those relations. (the galaxies are a part of the cloud and no outliers)
- b19 and similar galaxies just form the compact and massive tail of the general distribution of elliptical galaxies and are not distinct after all

The only peculiar galaxy we find in all the plots is SDSS J105612.22+051544.6, which definitely deserve some further investigation. However, the SDSS photometry of this object may be unreliable.