Horologium I

Fabrizio Muratore

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1 Introduction

One of the primary quests of astronomy is understanding the formation of structure in the universe. In this regard, the Λ Cold Dark Matter (ΛCDM) cosmological model is consistent with many observable phenomena, but there are discrepancies at small scales (Kauffmann et al. 1993). Specifically ΛCDM predicts many more dark-matter sub-halos than the number observed as dwarf galaxies, this is called the "missing satellite" problem. Many astronomers think that reionization could have suppressed star formation in the smallest DM sub-halos. Therefore, the dearth of stars would then make these sub-halos difficult or impossible to detect.

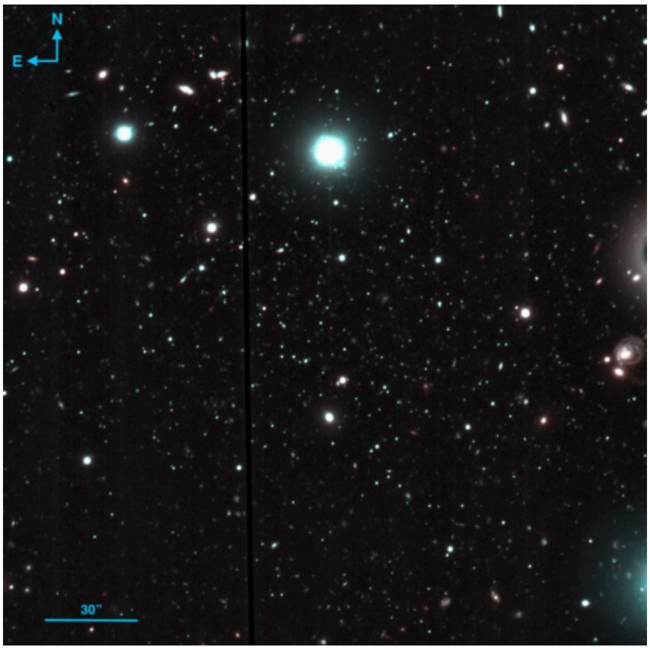

Figure 1: Horologium I from Jerjen et al. 2018 (2018arXiv180902259J)

Given their low metallicities, old ages, faint luminosities, and high M/L_V ratios, the Ultra faint dawrf galaxies (UFDs) are an excellent laboratory to search for reionization signatures in the star formation history (SFH) of small DM sub-halos, and to assess the possible solutions to the missing satellite problem. Brown et al. (2014) analysed six UFDs to solve the missing problem. In particular they were searching for a true fossil galaxy, whose existence could demonstrate that the reionization had interrupt the star formation in DM sub-halos.

In this work I analysed the color-magnitude diagram of Horologium I, a UFD galaxy, which could be a true fossil galaxy. To answer this question I compare the characteristics of Horologium I with ones of the six UFDs analysed by Brown et al. (2014). Using the isochrone I derive also estimations of age, reddening and distance.

2 Ultra faint dwarf galaxy

The dwarf galaxies could follow one of three evolutionary paths: "true fossils" that formed most of their stars prior to reionization, "polluted fossils" with star formation continuing beyond reionization, and "survivors" that largely formed their stars after reionization.

The ultra-faint dwarf (UFD) galaxies have luminosities of $M_V > -8$ mag. Thus most of them are fainter than the typical globular cluster. Photometric and spectroscopic observations of the UFD galaxies have shown that they are excellent candidates for demonstrating the existence of fossil galaxies. Color-magnitude diagrams (CMDs) indicate the UFDs are generally dominated by old ($> 10Gyr$) populations, while spectroscopy of their giant stars indicates low metallicities (Brown et al. 2014). The internal kinematics from such spectroscopy also imply large mass-to-light ratios ($M/L_V \sim 100$), that is one of the characteristics that marks them as galaxies, instead of star clusters, despite their low luminosities.

3 Color-magnitude diagrams by Brown et al.

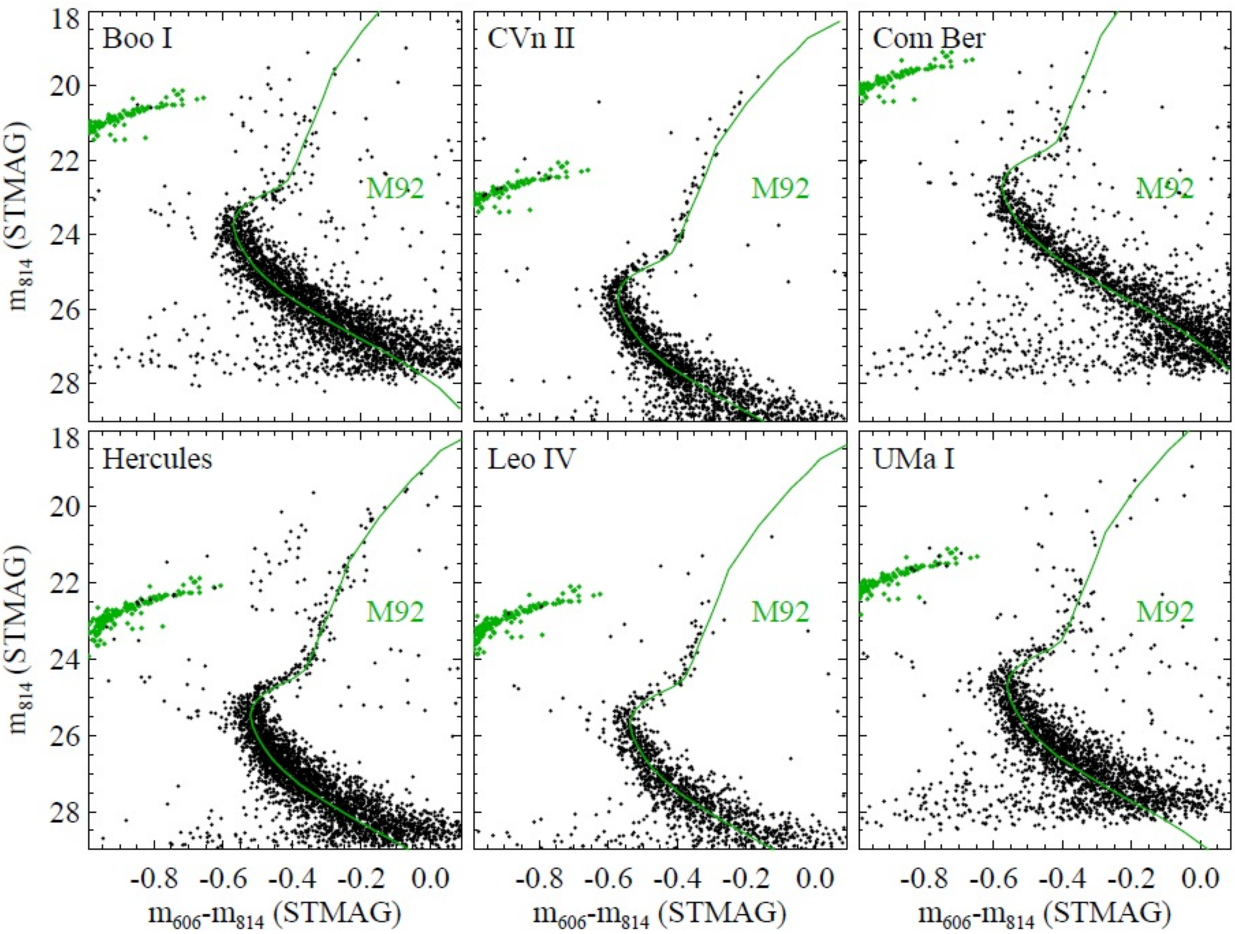

Figure 2: CMDs derived by Brown et al. (2014).

Brown et al. studied these six UFWs galaxies: Bootes I, Canes Venatici II, Coma Berenices, Hercules, Leo IV, Ursa Major I. The CMDs are shown in figure 2. The characteristics discovered are:

- The CMDs are very similar to ones of globular clusters.
- The CMDs are all similar each others, this means that the populations have same parameters as ages and metallicities.
- The ages are all around 13-14 Gyr, very ancient populations.

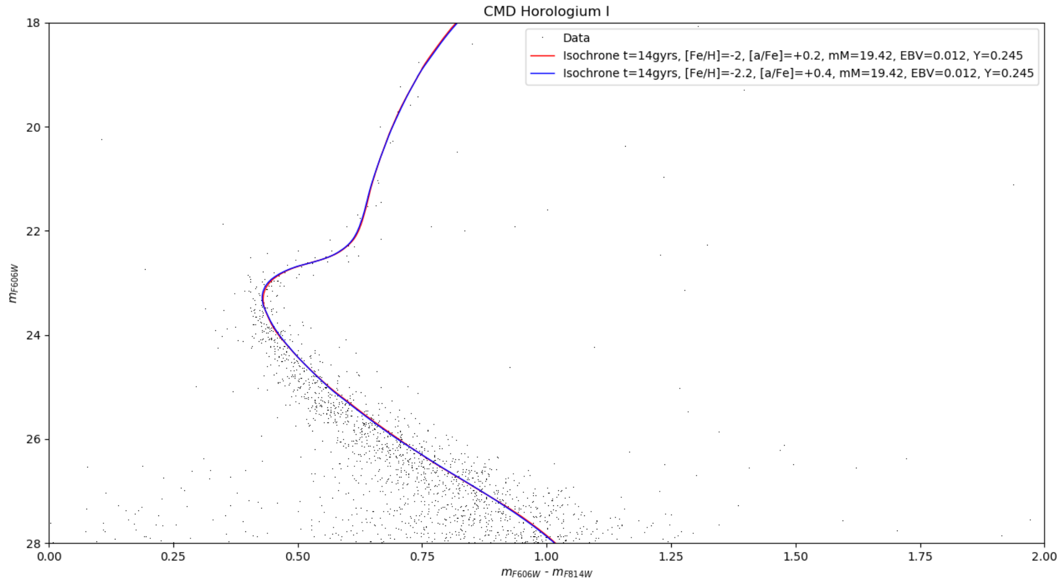

Figure 3: CMD of Horologium I.

- The metallicity are very low, the populations are extremely metal poor with a $-1 < [Fe/H] < -4$
- The abundance of α-element is: $[\alpha/Fe] = +0.4$, an appropriate value for an old and metal poor population.
- From the diagrams is visible that in the red giant branch stars are more blue than the green line that is the isochrone of M92, an ancient globular cluster. This means that the UFDs are more metal poor that M92.

4 The color-magnitude diagram of Horologium I

I built the CMD of Horologium I using the photometry of Hubble space telescope, in particular it is obtained with the Wide Field Channel (WFC) of the Advanced Camera for Surveys (ACS). The filters used are 'F606W' and 'F814W'. In figure 3 there is the CMD derived and in the legend we can see the parameters of the two isochrones.

Parameters	Values 1st isochrone	Values 2nd isochrone
Y	0.245	0.245
$(m - M)_0$ [mag]	19.42	19.42
Age [Gyrs]	14.0	14.0
E(B-V) [mag]	0.012	0.021
[Fe/H]	-2.2	-2.0
[α/Fe]	+0.4	+0.2

Table 1: Parameters from the fitting with two isochrones.

5 Conclusion

From the comparison with the isochrones, reliable values were derived for age, metallicity, alpha enrichment, distances, reddening, helium abundance. It is observed how Horologium I is a very faint system, very ancient (14Gyr) and extremely metal poor. These are the main characteristics of a UFD.

Furthermore, from the CDM it is clear how the fit is acceptable for two two alpha enrichment values. From Brown's work we know that UFDs are expected to have an enrichment of +0.4, in accordance with the red isochrone. Assuming that the six Brown galaxies are true fossils, and comparing of parameters with those found by Brown, we can say that Horologium I could actually be a true fossil. For a certain answer, Horologium I should be studied in more detail with spectroscopic measurements or the star formation history could be derived with measurements of the infrared bolometric luminosity.