The SECCO survey: hunting for extremely dark dwarf galaxies with LBT

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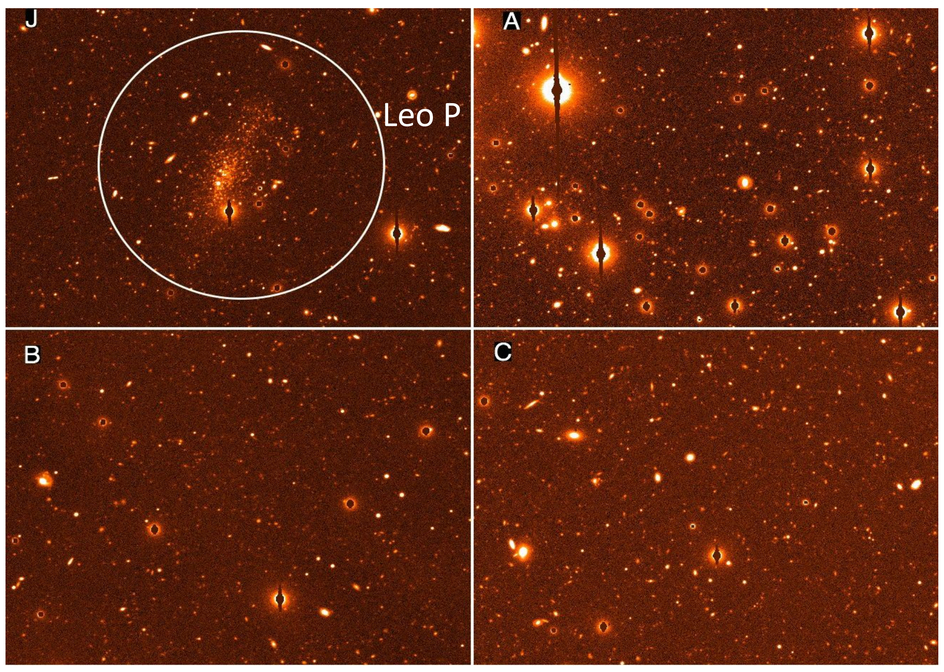
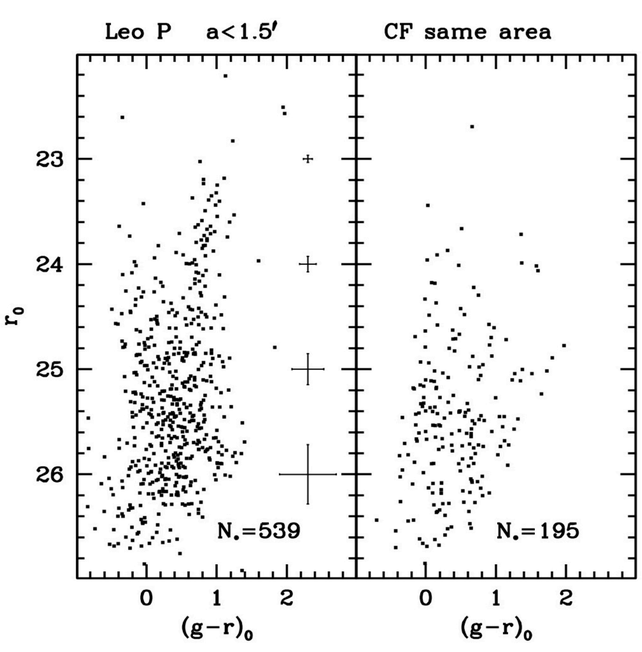
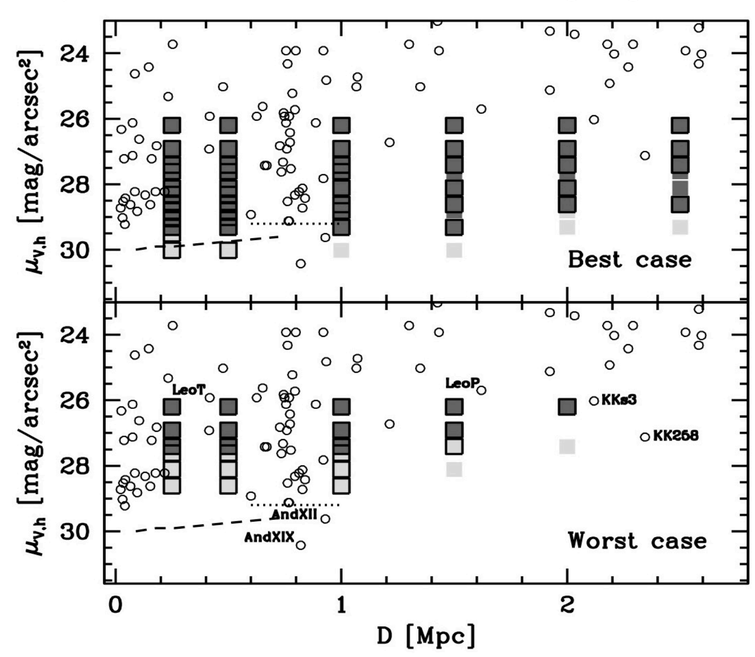
SECCO (*StEllar Counterparts of COmpact high velocity clouds*; Bellazzini et al. 2015a, A&A, 575, 126; hereafter B15a) is a survey aimed at searching for stellar counterparts of ultra-compact high-velocity clouds (UCHVCs) of neutral hydrogen that have been recently proposed by different teams as candidate mini-haloes residing in the Local Group or its surroundings ($D \lesssim 3.0$ Mpc; Saul et al. 2012, ApJ, 758, 44; Adams, Giovanelli & Haynes 2013, ApJ, 768, 77; GALFA-H I and ALFALFA surveys, respectively). The only way to confirm the nature of UCHVCs as small gas-rich dwarf galaxies is to identify a concomitant stellar population that can allow us to constrain the distance to the system. Several groups have attempted this search, mainly using public archive data. On the other hand, SECCO is based on very-deep, homogeneous, wide-field imaging obtained with the Large Binocular Telescope (MtGraham, AZ), allowing a full quantitative characterization of non-detections (Beccari et al. 2016, A&A, 591, 56; hereafter B16).

We obtained deep g,r images of wide fields centered on the best 25 ALFALFA candidates with **LBC in binocular mode**. With 2 × 300s exposures per filter, under good seeing conditions, we reach r=26.5 (B15a). We are looking for stellar systems resolved into stars. In the fields where the available observational material is of top quality (≃36% of the SECCO fields), we detect synthetic galaxies as ≥5σ over-densities of resolved stars down to $\mu_{V,h} \simeq 30.0$ mag/arcsec^2, for D ≤ 1.5 Mpc, and down to $\mu_{V,h} \simeq 29.5$ mag/arcsec^2, for D ≤ 2.5 Mpc. In the field with the worst observational material of the whole survey, we detect synthetic galaxies with $\mu_{V,h} \leq 28.8$ mag/arcsec^2 out to D ≤ 1.0 Mpc, and those with $\mu_{V,h} \leq 27.5$ mag/arcsec^2 out to D ≤ 2.5 Mpc. Dwarf galaxies with $M_V = -10.0$, with sizes in the range spanned by known dwarfs, are detected by visual inspection of the images up to D = 5 Mpc independent of the image quality (B16). The faint star-forming dwarf Leo P provide a test case: it is detected as a > 30σ overdensity. We found only one stellar counterpart in 25 UCHVC and it has D≈17 Mpc. ***Preliminary conclusion:*** **it is unlikely that ALFALFA UCHVC are local mini-halos.** The analysis of 18 GALFA-HI UCHVCs is ongoing.



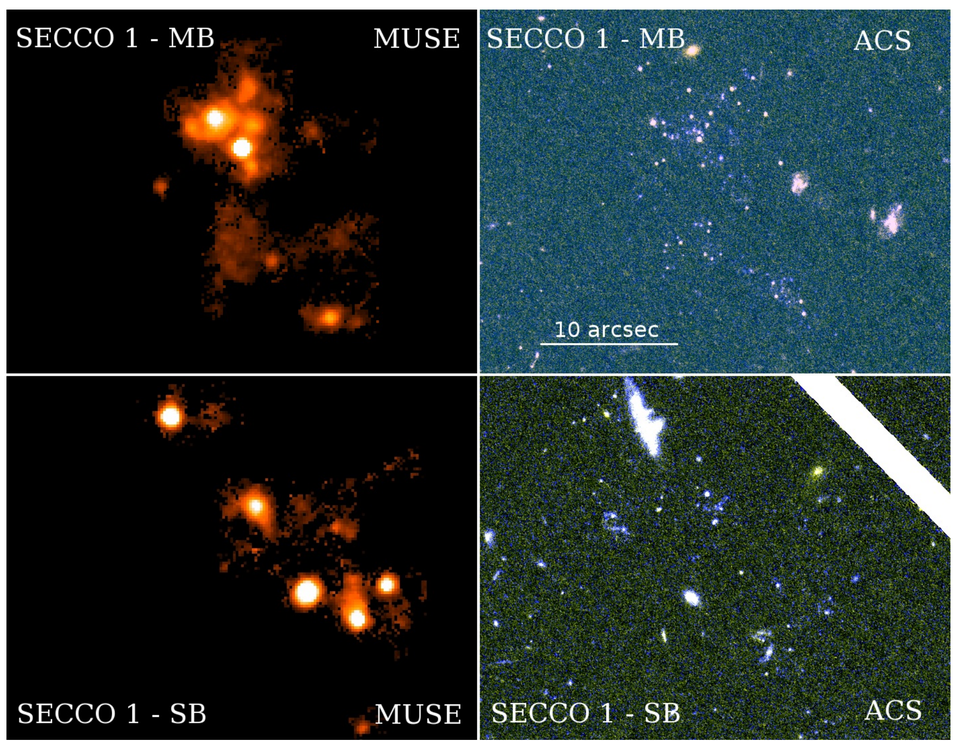


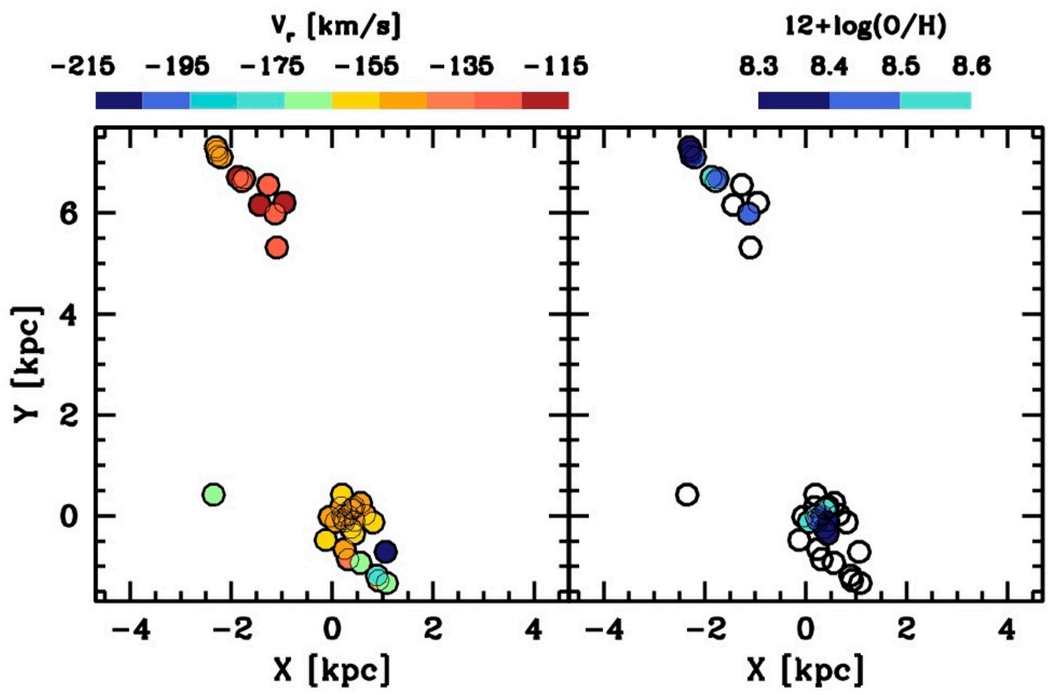


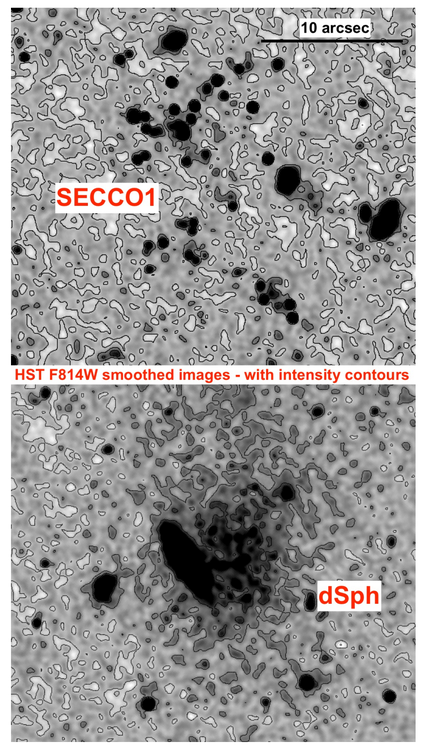
Left panel: *inner portion of r-band images of four random SECCO fields, including Leo P.* *Central panel:* *SECCO color-magnitude diagram of Leo P and of an adjacent Control Field.* *Right panel:* *filled squares are the synthetic galaxies that are successfully detected in our suite of experiments to measure the sensitivity of the survey (light grey >5σ, dark grey >10σ detections) . Open circles are real dwarf galaxies in the Local Volume, from McConnachie (2012, AJ, 144, 4). Dashed line: SDSS detection limit. Dotted line: PAndAS detection limit. Upper panel: top quality data. Lower panel: worst quality data.* ***For D≥1 Mpc SECCO probes the Local Volume for LSB dwarfs with unprecedented sensitivity.***

We followed up the only stellar counterpart with **MODS@LBT** spectra confirming that it is indeed physically associated with the surveyed UCHVC: **we have discovered a new very faint ($L_V \approx 1.6 \times 10^6 L_{V,\odot}$) star-forming stellar system: SECCO1**. It is located into a substructure of the Virgo cluster of galaxies (the so called LVC, see, e.g., Boselli et al. 2014, A&A, 570, 69) and it is composed of two subsystems separated by ~ 6 kpc (projected), the Main Body (MB) and Secondary Body (SB). Subsequent MUSE@VLT observations (Beccari et al. 2017, MNRAS, 465, 2198) revealed that the two subsystems host several HII regions having very similar velocity and metallicity. The metallicity is quite uniform over the whole system, with a dispersion lower than the uncertainty on individual metallicity estimates. The mean abundance, $\langle 12 + \log(O/H) \rangle = 8.38$, is much higher than the typical values for local dwarf galaxies of similar stellar mass. This strongly suggests that the SECCO1 stars were born from a pre-enriched gas cloud, possibly stripped from a larger galaxy. However any possible parent galaxy lies more than 350 kpc apart, in projection, implying a long travel time before the beginning of star formation, that seems to have occurred only in the last 50 Myr. We are performing hydro-dynamical simulations to follow the evolution of such a small gas cloud in the Virgo environment.

The total stellar mass of SECCO1 is ≃1.6×10^5 $M_\odot$: it has a very high H I-to-stellar mass ratio for a dwarf galaxy, $M_{HI}/M_* \sim 100$, it is among the darkest stellar systems ever observed. The star formation rate, derived from the H_α flux, is 0.7×10^{-3} $M_\odot$ yr^{-1}, quite typical of star-forming dwarfs of comparable luminosity.







Left panels: *H_α emission from the Main and Secondary body of SECCO1, from MUSE observations, is compared with HST-ACS images of the same fields.* *Central panels:* *radial velocity and metallicity maps of individual HII regions identified in the MUSE datacube.* *Right panels:* *the HST view of SECCO1-MB is compared with a Virgo low-SB dwarf spheroidal galaxy serendipitously found in the same image, whose Red Giant Branch Tip is resolved. A 7 px gaussian smoothing kernel has been applied to both and intensity contours are drawn. The dark elongated blob on the left side of the dSph is a background galaxy. It is clear that in SECCO1 there is no detectable trace of the old stellar population that dominates the dwarf spheroidal. Any old population in SECCO1 should have $\mu_V \gtrsim 28$ mag/arcsec^2.*

We have also discovered several new LSB dwarfs in the Virgo cluster (B16) as well as two isolated star forming Ultra Diffuse Galaxies (UDG, Bellazzini et al. 2017, MNRAS, 467, 3751), one of them having $M_{HI}/M_\star \sim 90$: the first almost-dark UDG.