The N_{GC} vs. $M_\bullet$ relation for spiral galaxies: N4258

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Abstract

▶ We explore the relationship in spiral galaxies between the total number of globular clusters, N_{GC}, and the mass of the central black hole, $M_\bullet$, and how it compares with the correlation recently established for elliptical galaxies. We investigate whether the $N_{GC} - M_\bullet$ relation in spirals seems connected to the disk or only to the bulge properties, and its implications for galaxy formation theories. We present results for the Sbc galaxy NGC 4258, from u , g , i , and Ks data obtained with the Canada France Hawaii Telescope (CFHT). The GC selection is based on the (i' - Ks) vs. (u*- i') diagram, which is a superb tool to disentangle GCs, foreground stars, background galaxies, and young stellarclusters, even if the galaxy is not completely edge-on. N4258 has SN = 0.3-0.4, and falls right on the elliptical relation.

Introduction: scaling relations

▶ All massive galaxies contain central black holes. In spheroidal systems, $M_\bullet$ correlates with the bulge luminosity, L_{bulge}, mass, M_{bulge}, and stellar velocity dispersion, σ_* (Magorrian et al. 1998; Ferrarese & Merrit 2000; Gebhardt et al. 2000). Such correlations point toward a fundamental connection between black hole and spheroid evolution. It is unclear whether spiral galaxies fall on these relations. Recently, Burkert & Tremaine (2010) and, with more data, Harris & Harris (2011) have shown that, in elliptical galaxies, $M_\bullet$ increases almost exactly proportionally to N_{GC}. The correlation is tighter than the $M_\bullet - \sigma$ relation.

▶ A sample of spiral galaxies of diverse Hubble types, with precise measurements of both $M_\bullet$ and N_{GC}, would allow us to determine whether spirals as a whole show the same correlation between these quantities as do ellipticals and early-type spirals; whether they follow a separate correlation or just scatter around the elliptical relation; if spirals show differences due to the bulge/pseudobulge dichotomy. From this study, we will be able to draw conclusions about the co-evolution timescales and formation mechanisms of GC systems and central massive black holes.

This project

▶ Up until now, there were only 4 spiral galaxies with measurements of both M and N_{GC}: the Milky Way (MW), M 31, M 81, and M 104. There are only 23 more with precise black hole measurements (McConnell & Ma 2013; Kormendy & Ho 2013). Including NGC 4258, we will study 9 galaxies that are closer than 16 Mpc, and that span Hubble types Sab through Sm. Figure 1 shows i-band images of the sample galaxies taken from the NASA Extragalactic Database (NED).

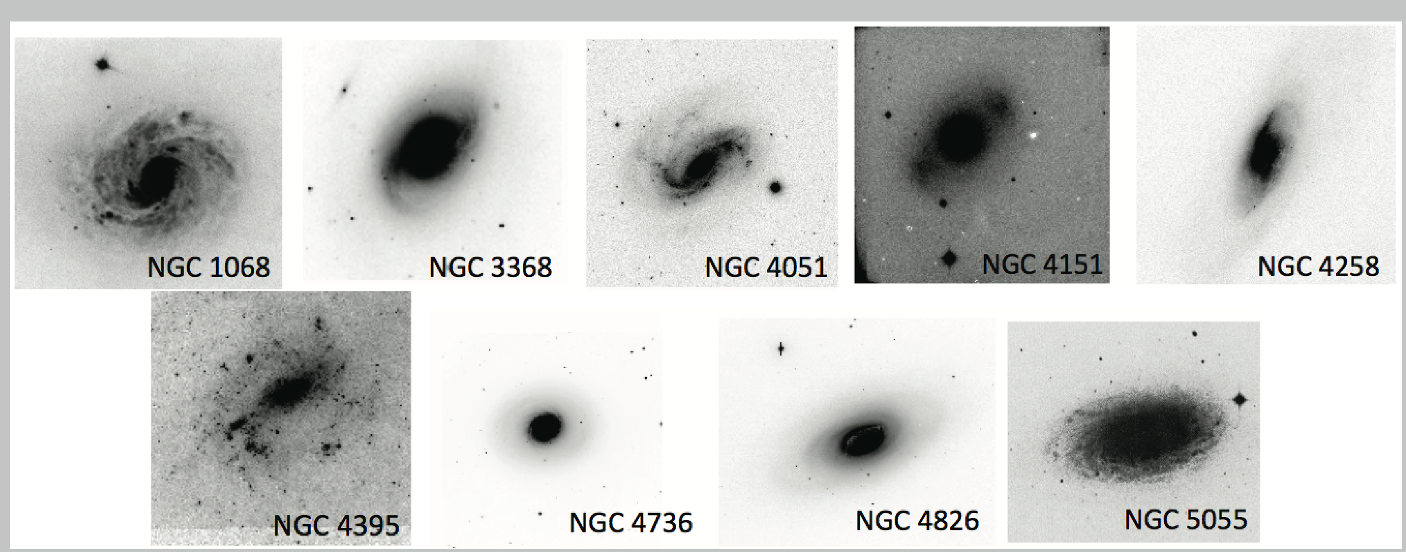

Figure 1: i-band images of the sample, from NED.

Conclusions and future work

▶ N4258 is consistent with the elliptical relation in the NGC vs. MBH plane.

▶ Spectroscopic analysis of the GC candidates will allow us to study their kinematics.

▶ The (i'-Ks) vs. (u* - i') DCC is the most efficient tool to disentangle GC candidates from foreground stars, background galaxies, and young stellar clusters, even in face-on spiral disks. Should be a boon for studies of GC systems in spirals.

▶ Through the study of the whole sample, we will investigate if the correlation is influenced by Hubble type, presence of bulge or pseudobulge, mass concentration, and whether in spirals it relates to the disk, or only to the bulge properties..k

▶ This, in turn, will have important implications for theories of galaxy/blackhole formation, black hole mass prediction based on scaling relations, and connection with nuclear star clusters, among others.

Methodology: (i'-Ks) vs. (u*-i') CCD + cluster-like decontamination

▶ The (i'-Ks) vs. (u*-i') CCD yields the best total number counts of GCs, virtually free of contamination from foreground stars and background galaxies, *without the need to resolve the targets or to obtain radial velocity measurements* (Munoz et al. 2014; Gonzalez-Lopezlira et al. 2016, in prep.). A check decontamination was performed by comparing the density of sources in the CCDs of N4258 and the Groth Strip (GS), respectively. The control field need not be contiguous or obtained simultaneously, since corrections for area, depth, completeness, seeing, and cosmic variations are straightforward. Sources without counterparts in the GS CCD are deemed associated to the galaxy. The detection of GCs in spirals has been a challenge so far, due to their more complex structure, compared to the smoothness of ellipticals.

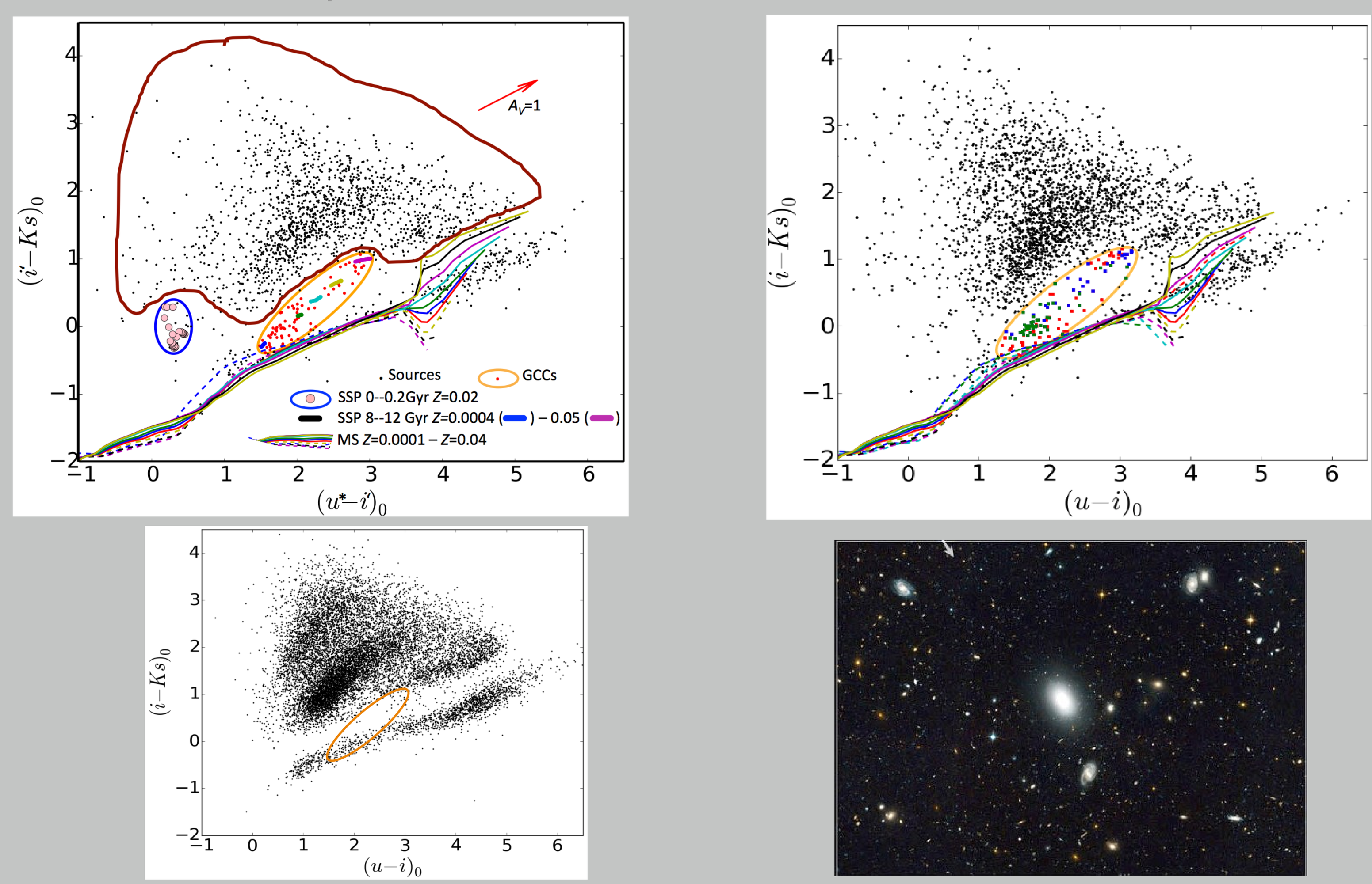

Figure 2: *Top left:* (u*-i') vs. (i'-Ks) color-color plot of N4258. GC candidates (red dots in orange ellipse) are well separated from foreground main sequence (MS) stars (black dots under thin lines), background galaxies (black dots enclosed by dark red curve), and young clusters (pink dots in blue ellipse). *Bottom left*: although the CCD of the Groth Strip (fragment in *bottom right*) is much denser, the orange selection ellipse is basically empty. *Top right:* inside orange ellipse, green dots: most robust GC candidates; blue dots: associated to NGC 4258, but likely dwarf galaxies from light concentration diagnostics; red dots: eliminated by comparison with Groth Strip. Photometry with PSFEx (Bertin 2011).

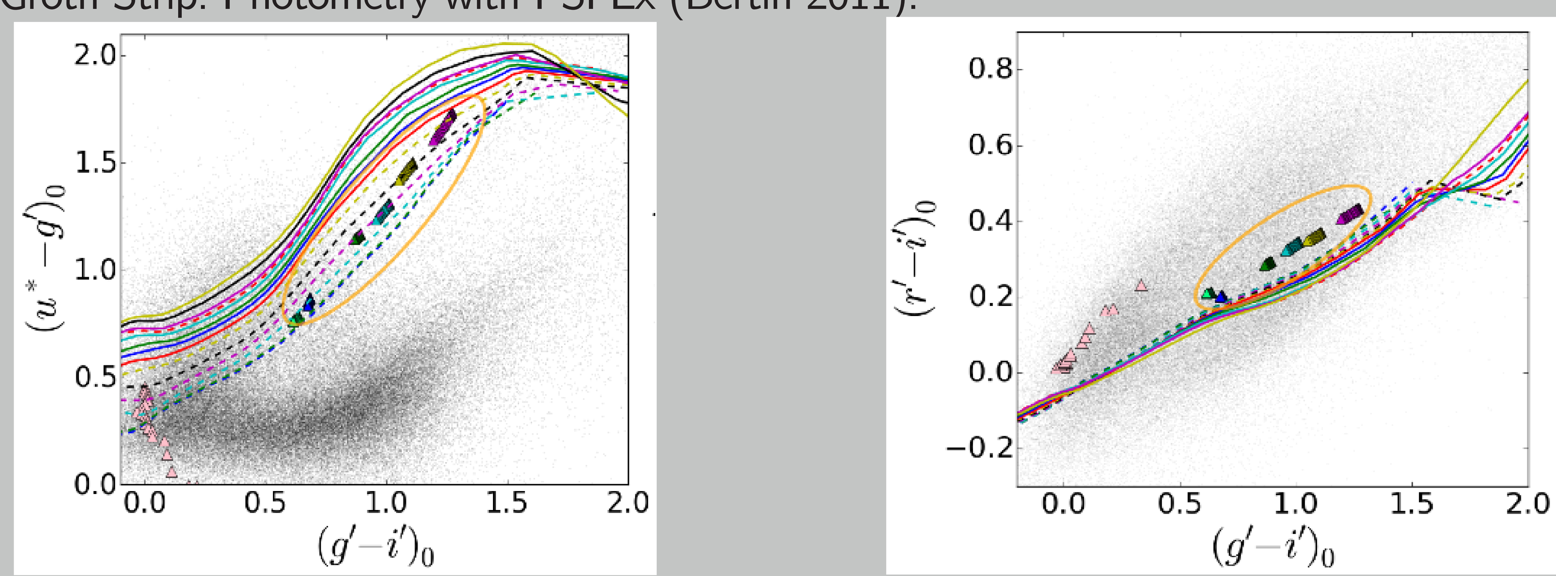

Figure 3: For contrast, other commonly used CCDs of N4258 data. *Left:* (u*-g') vs. (g'-i'). The orange selection ellipse, defined by old (8-12 Gyr), single burst populations (green, blue, and purple triangles), overlaps Galactic MS stars (lines). The locus of young, solar metallicity populations is also shown (pink triangles). *Right*: in the (r'-i') vs. (g'-i') plot, the selection region avoids the MS, but is densely occupied by a very large number of background galaxies.

K-band GCLF and location in the N_{GC} vs. $\log(M_\bullet)$ plane

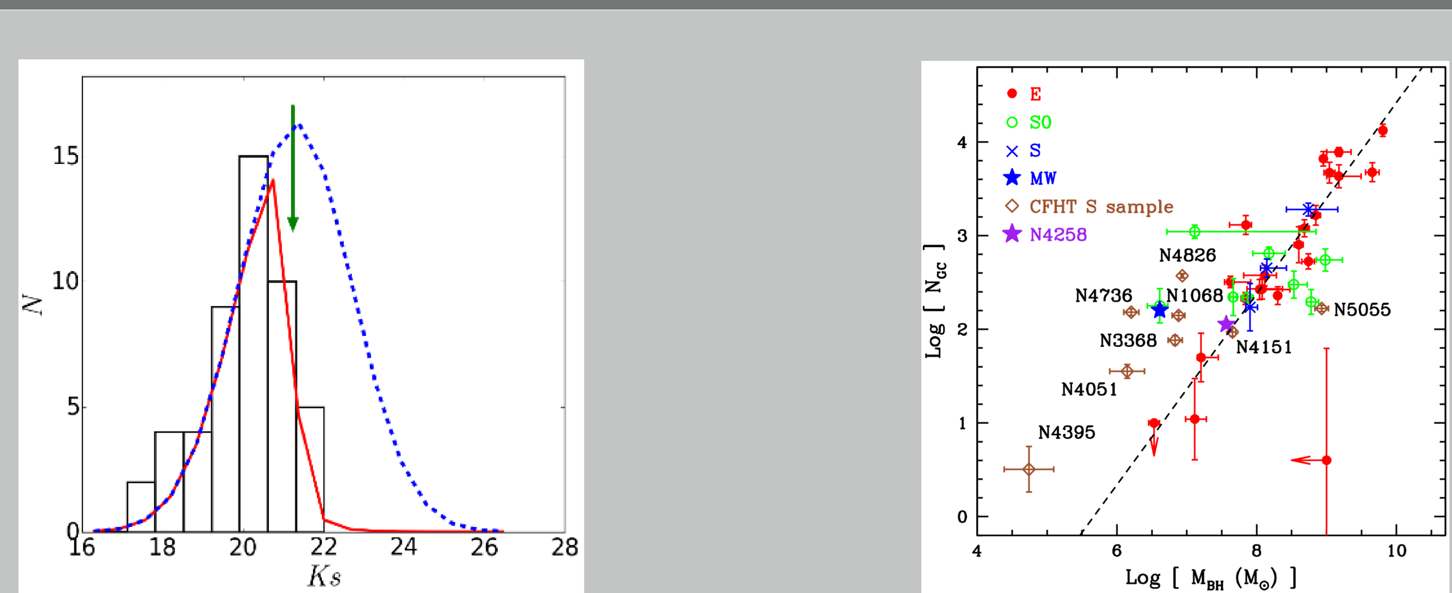

Figure 4: *Left:* Ks band luminosity function of most likely GC candidates. Blue dotted line: Gaussian fit; red solid line: Gaussian×Pritchet fit; green arrow: 50% completeness. *Right:* **log**(N_{GC}) vs. **log**($M_\bullet$). Red, green, and blue symbols represent observed values of, respectively, elliptical, lenticular, and spiral galaxies in the Harris & Harris (2011) sample; the dashed line is their fit to the ellipticals only. Purple star: NGC 4258, with 80–145 GC candidates after completeness and LF corrections, and S_N = 0.3-0.4. Brown open diamonds show the expected location of the rest of our proposed spiral sample, where N_{GC} is derived from their absolute V magnitude, M_V, through $N_{GC} = S_N \times 10^{-0.4[M_V+15]}$. S_N = 0.2 f or NGC 4395, 0.5 for all the rest (Georgiev et al. 2010).

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