Statistical Computing: Assignment 1

Investigating Globular Clusters and Galaxies

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Introduction

Background

A globular cluster is a spherical collection of stars that orbits a galactic core as a satellite. The catalog we will be investigating (@catalog) is based on a literature survey to the end of 2012 and consists of 422 galaxies with published measurements of their globular cluster (GC) populations. The galaxy morphological classification of these consist of 248 E galaxies, 93 S0 galaxies, and 81 spirals or irregulars. [@1_harris_harris_alessi_2013] To gain some insight into these morphological classification types we take a look at how the types look in Figure , @hubbleClassificationScheme.

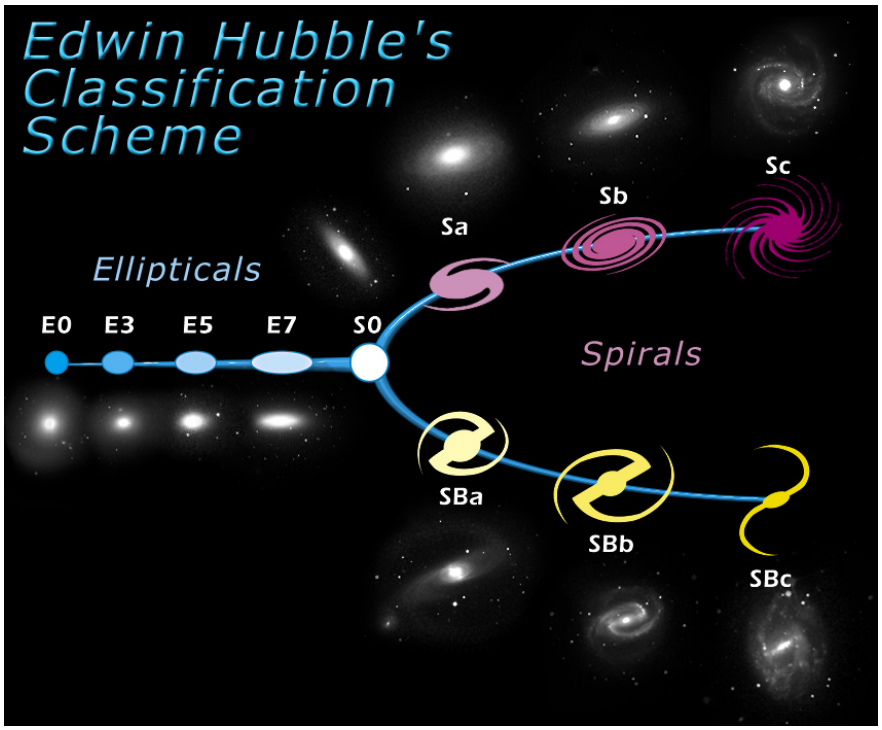

Figure 1: Galaxy Morphological Classification a.k.a. Hubble Tuning Fork

The majority of GCs, in both the Milky Way and other galaxies, contain primarily old stars. Their metallicities range from extremely metal-poor (less than 1/100th of the solar value) up to values close to what we see in the Sun. It is this variation in metallicity that gives rise to the two distinct types of GC in galaxies. In the Milky Way at least, the redder GCs are more metal-rich and associated with the galactic bulge, while the bluer GCs are more metal-poor and tend to be associated with the halo. @2_stellar_populations_of_globular_clusters_cosmos_2017

Data Gathering And Cleaning

```
## [1] >3
## 296 Levels: 0.0 0.6 1.0 1.8 10.0 10.2 10.4 10.8 10.9 100.0 ... 3
```

Data cleaning is done in dataCleaning.R

1. `read.table` from website
2. define headers as below
3. convert `nid` to `NA`
4. convert `nd` to `NA`
5. detected `>3` in NGC column and forced to 3
6. convert factors that will be used numerically to numbers

Use grep to convert types to S, E and L

Analysis

M_V, M_V, T

sigma, sigma, T

M_BH, M_BH, T

M_dyn, M_dyn, T

M_V, sigma M_V, M_BH M_V, M_dyn

M_V, sigma, M_BH M_V, sigma, M_dyn M_V, sigma, T M_V, M_BH, M_dyn M_V, M_BH, T M_V, M_dyn, T

M_V, sigma, M_BH, M_dyn M_V, sigma, M_BH, T M_V, sigma, M_dyn, T M_V, M_BH, M_dyn, T

M_V, sigma, M_BH, M_dyn, T

sigma, M_BH sigma, M_dyn

sigma, M_BH, M_dyn sigma, M_BH, T sigma, M_dyn, T

sigma, M_BH, M_dyn, T

M_BH, M_dyn

M_BH, M_dyn, T

1. Plot first and see if linear assumption is valid, if not we transform
2. Multiple R-squared - tells us in percentage how much of variation in our input varables tells us about our estimation.

Parameter	Definition
N_{GC}	Number of Globular Clusters
T	Galaxy Type E, S or I
M_V	Absolute visual magnitude
σ	Bulge velocity dispersion
M_{BH}	Central black hole mass
M_{dyn}	Dynamical mass
$\varepsilon_{N_{GC}}$	Uncertainty in NGC
ε_{M_V}	Uncertainty in MV
ε_{σ}	Uncertainty in σ
$\varepsilon_{M_{BH}}$	Uncertainty in MBH

```
str(GCs)
```

```
## 'data.frame':    422 obs. of  49 variables:
##  $ name                      : Factor w/ 420 levels "A1644-1","A1689-BCG",..: 120 420 348 311 158 166
##  $ id                        : Factor w/ 180 levels "A1016-1","A1177-1",..: NA 27 NA NA NA NA 67 69 68
##  $ fac.right.ascension.hr    : Factor w/ 419 levels "0.0328381","0.0541441",..: NA 1 2 3 4 5 6 7 8 9
##  $ fac.declination.deg       : Factor w/ 419 levels "-01.3380556",..: NA 10 264 106 354 353 345 341 34
##  $ type                      : Factor w/ 69 levels "E","E/S0","E/cD",..: 44 22 41 38 11 7 11 6 43 28
##  $ fac.dist                  : Factor w/ 342 levels "0.03","0.05",..: NA 11 46 183 7 6 9 7 8 265 ...
##  $ fac.dist.o                : Factor w/ 207 levels "0.00","0.01",..: NA 9 59 7 9 2 4 6 3 12 ...
##  $ dist.method               : Factor w/ 21 levels "Cepheids","Cepheids/RRL",..: 21 17 10 17 19 19 16
##  $ fac.foreground.extinction: num  0 0.088 0.147 0.036 0.475 0.5 0.17 0.17 0.17 0.05 ...
##  $ fac.vis.mag               : Factor w/ 335 levels "-11.170","-11.510",..: 254 31 200 144 40 38 78 71
##  $ fac.vis.mag.o             : Factor w/ 34 levels "0.200","0.210",..: 11 1 9 1 11 1 1 2 1 1 ...
##  $ fac.k.band.mag            : Factor w/ 341 levels "-14.510","-14.954",..: NA NA 182 78 9 13 41 50 17
##  $ fac.k.band.mag.o          : Factor w/ 75 levels "0.100","0.101",..: NA NA 4 12 18 13 11 2 2 18 ...
##  $ fac.N.GC                  : Factor w/ 296 levels "0.0","0.6","1.0",..: 57 3 51 171 5 272 14 1 202 1
##  $ fac.N.GC.o                : num  10 0 40 15 2 1 3 1 100 30 ...
##  $ lit.source                : Factor w/ 109 levels "1","10","100a",..: 50 58 41 92 104 30 29 109 93 9
##  $ fac.vel.dispersion        : Factor w/ 258 levels "10.40","101.20",..: 6 NA 56 NA 104 77 183 242 45
##  $ fac.vel.dispersion.o      : Factor w/ 118 levels "0.70","1.10",..: 53 NA 97 NA 79 47 75 59 103 NA
##  $ fac.radius.half           : Factor w/ 274 levels "0.13","0.29",..: 23 NA 178 154 17 4 21 1 231 203
##  $ fac.radius.half.o         : Factor w/ 91 levels "0.01","0.02",..: 10 NA 19 9 8 4 3 1 12 20 ...
##  $ fac.dyn.mass              : Factor w/ 246 levels "10.001","10.005",..: 238 NA 63 NA 186 185 190 191
##  $ fac.dynl.mass.o           : Factor w/ 88 levels "0.008","0.010",..: 78 NA 26 NA 80 55 64 28 21 NA
##  $ fac.mass.cluster          : Factor w/ 258 levels "10.01","10.10",..: 148 9 141 100 53 46 61 61 178
##  $ fac.mass.cluster.o        : Factor w/ 44 levels "0.00","0.01",..: 4 1 11 16 12 6 11 11 10 19 ...
##  $ fac.mass.CBH              : Factor w/ 43 levels "0.00","10.32",..: 4 NA NA NA NA NA 1 3 16 NA ...
##  $ fac.mass.CBH.upper.o      : Factor w/ 40 levels "0.03","0.04",..: 2 NA NA NA NA NA 22 6 17 NA ...
##  $ fac.mass.CBH.lower.o      : Factor w/ 26 levels "0.00","0.03",..: 3 NA NA NA NA NA 1 9 9 NA ...
##  $ right.ascension.hr        : num  NA 0.0328 0.0541 0.2482 0.5533 ...
##  $ declination.deg           : num  NA -15.5 16.1 -39.2 48.5 ...
##  $ dist                      : num  NA 1 13.18 2.09 0.76 ...
##  $ dist.o                    : num  NA 0.1 0.88 0.08 0.1 0.01 0.04 0.07 0.02 0.2 ...
##  $ foreground.extinction     : num  0 0.088 0.147 0.036 0.475 0.5 0.17 0.17 0.17 0.05 ...
##  $ vis.mag                   : num  -21.3 -14.8 -20.2 -18.8 -15.5 ...
##  $ vis.mag.o                 : num  0.3 0.2 0.28 0.2 0.3 0.2 0.2 0.21 0.2 0.2 ...
##  $ k.band.mag                : num  NA NA -23.5 -20.4 -17.3 ...
##  $ k.band.mag.o              : num  NA NA 0.103 0.111 0.118 0.112 0.11 0.101 0.101 0.118 ...
##  $ N.GC                      : num  160 1 150 36 10 8 11 0 450 60 ...
##  $ N.GC.o                    : num  10 0 40 15 2 1 3 1 100 30 ...
##  $ vel.dispersion            : num  105 NA 169 NA 22 ...
##  $ vel.dispersion.o          : num  20 NA 7.2 NA 5 2.4 4.7 3 8 NA ...
##  $ radius.half               : num  0.7 NA 2.84 2.31 0.57 0.35 0.66 0.13 4.66 3.64 ...
##  $ radius.half.o             : num  0.1 NA 0.19 0.09 0.08 0.04 0.03 0.01 0.12 0.2 ...
##  $ dyn.mass                  : num  9.86 NA 10.88 NA 8.41 ...
##  $ dynl.mass.o               : num  0.116 NA 0.037 NA 0.13 0.069 0.086 0.039 0.032 NA ...
##  $ mass.cluster              : num  7.66 5.14 7.57 6.87 6.16 6.07 6.26 6.26 8.14 7.09 ...
##  $ mass.cluster.o            : num  0.03 0 0.1 0.15 0.11 0.05 0.1 0.1 0.09 0.18 ...
##  $ mass.CBH                  : num  6.61 NA NA NA NA NA 0 6.46 8.18 NA ...
##  $ mass.CBH.upper.o          : num  0.04 NA NA NA NA NA 4.58 0.08 0.2 NA ...
##  $ mass.CBH.lower.o          : num  0.04 NA NA NA NA NA 0 0.1 0.1 NA ...
```

central black hole mass

dynamical bulge mass

bulge velocity dispersion

absolute visual magnitude and type of galaxy

Interaction Questions:

1. Does this interaction make sense conceptually?
2. Is the interaction term statistically significant? are the slopes that differnt? summary(m1), p value of interaction term

Needs to be yes for both questions to include.

Extra

Look at dSph KKS-55 at MVT = ???11.2 holding a single GC, while the largest are cD/BCG supergiants with MVT ??????24andholdingupto30,000GCseach. they are the smallest and largest

One notorious outlier is our own Milky Way galaxy, for which there are far too many globular clusters given the mass of its central super- massive black hole, despite the fact that both are accurately measured. @1_de souza_hi lbe_buelens_riggs_cameron_ishida_chies-santos_killedar_2015

Conclusions

Check that you get the values in Table 2 @1_harris_harris_alessi_2013

Look at NGC221 M32 as N(GC) = 0 - An exception is the Local Group elliptical M32, which we include for historical reasons though it has no clearly identified clusters.

References