Lab-03R

36-290 – Statistical Research Methodology

Week 3 Thursday – Fall 2021

Preliminaries

Goal

The goal of this lab is apply K-means and hierarchical clustering.

Note that this lab may have, in your view, relatively few instructions. That's in part because the labs at the back of each chapter in ISLR (the class textbook) provide details about packages and useful "starter code." You should look through (if not work through) these labs either before doing this lab or for extra practice. However, note that the ISRL labs use neither `dplyr` nor `ggplot` (which is fine).

If you are confused: that's what office hours are for.

Data

We'll begin by importing the stellar data you worked with on Tuesday:

```
rm(list=ls())
file.path = "https://raw.githubusercontent.com/pefreeman/36-290/master/EXAMPLE_DATASETS/DRACO/draco_photometry.Rdat
a"
load(url(file.path))
df = data.frame(ra,dec,velocity.los,log.g,mag.g,mag.r,mag.i)
rm(file.path,ra,dec,velocity.los,log.g,temperature,mag.u,mag.g,mag.r,mag.i,mag.z,metallicity,signal.noise)
objects()
```

```
## [1] "df"
```

If everything loaded correctly, you should see one variable in your global environment: `df`. `df` is a data frame with 2778 rows and 7 columns. See this README file (https://github.com/pefreeman/36-290/tree/master/EXAMPLE_DATASETS/DRACO) for a full description of the data and its variables. Note that I have removed `signal.noise`, `metallicity`, `temperature`, and two of the magnitudes from the data frame, to reduce the dimensionality.

Questions

To answer the questions below, it will help you to refer to Sections 10.3 and 10.5 of ISLR; it might also help you to refer to your previous lab work (and, as always, to Google).

Question 1

Filter the data frame such that it only contains values of `dec` > 56, values of `ra` < 264, and values of `velocity.los` between -350 and -250. Mutate the data frame to have g-r and r-i colors, then delete the magnitudes and `velocity.los`. (Pro tip: you can "negatively select" columns by putting minus signs in front of the column names.) Save the resulting data frame as `df.new`.

```
library(magrittr)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
df.new<- df %>% filter(., dec>56, ra< 264, velocity.los > -350 & velocity.los < -250) %>% mutate(., "g-r"=mag.g-mag
.r, "r-i"= mag.r-mag.i ) %>% select(.,-mag.g,-mag.r,-mag.i, -velocity.los)


df.new
```

```
##            ra      dec log.g         g-r         r-i
## 1    260.0115 57.81589   3.7  0.62614059  0.25812721
## 2    259.9352 57.79092   4.5  0.59450150  0.26698685
## 3    259.9352 57.79092   2.1  0.59450150  0.26698685
## 4    260.0805 57.85542   1.2  0.57201767  0.31466866
## 5    260.0039 57.75311   3.7  0.61961746  0.26855469
## 6    260.0039 57.75311   1.2  0.61961746  0.26855469
## 7    260.0039 57.75311   3.2  0.61961746  0.26855469
## 8    259.8828 57.55964   1.1  0.80937195  0.37376595
## 9    259.8828 57.55964   1.1  0.80937195  0.37376595
## 10   259.8828 57.55964   1.9  0.80937195  0.37376595
## 11   259.8828 57.55964   1.3  0.80937195  0.37376595
## 12   259.8828 57.55964   1.6  0.80937195  0.37376595
## 13   260.0880 57.82422   2.6  0.96387672  0.42143631
## 14   260.0880 57.82422   0.7  0.96387672  0.42143631
## 15   260.1038 57.81189   2.0  0.61110306  0.28328514
## 16   260.1038 57.81189   3.2  0.61110306  0.28328514
## 17   260.0775 57.76697   2.0  0.64290047  0.29775810
## 18   260.0775 57.76697   1.2  0.64290047  0.29775810
## 19   259.9794 57.55006   3.0  0.62359238  0.27491951
## 20   259.9794 57.55006   2.6  0.62359238  0.27491951
## 21   260.1319 57.84864   1.0  0.78652000  0.36330795
## 22   260.2132 57.63728   1.4  0.70061493  0.31844902
## 23   260.2313 57.74289   1.6  0.70239830  0.29327965
## 24   260.1729 57.79911   2.6  0.64671707  0.30360222
## 25   260.1729 57.79911   1.2  0.64671707  0.30360222
## 26   260.2654 57.66506   3.3  0.60568810  0.31266022
## 27   260.2654 57.66506   2.0  0.60568810  0.31266022
## 28   260.2654 57.66506   3.0  0.60568810  0.31266022
## 29   260.2654 57.66506   2.1  0.60568810  0.31266022
## 30   260.2654 57.66506   2.1  0.60568810  0.31266022
## 31   260.2654 57.66506   2.8  0.60568810  0.31266022
## 32   260.2654 57.66506   1.8  0.60568810  0.31266022
## 33   260.2507 57.77714   1.6  0.72683525  0.31524849
## 34   260.2507 57.77714   1.4  0.72683525  0.31524849
## 35   260.1754 57.82486   1.3  0.65998459  0.26937866
## 36   260.1754 57.82486   1.1  0.65998459  0.26937866
## 37   260.1754 57.82486   1.3  0.65998459  0.26937866
## 38   260.1754 57.82486   1.5  0.65998459  0.26937866
## 39   260.6283 57.59617   2.2  0.60172272  0.26959038
## 40   260.4140 57.77781   1.1  0.84945488  0.39056396
## 41   260.5150 57.75200   1.4  0.76242065  0.29623032
## 42   260.5150 57.75200   1.8  0.76242065  0.29623032
## 43   260.5150 57.75200   1.3  0.76242065  0.29623032
## 44   260.5150 57.75200   1.2  0.76242065  0.29623032
## 45   260.5150 57.75200   1.2  0.76242065  0.29623032
## 46   260.5150 57.75200   1.0  0.76242065  0.29623032
## 47   260.1807 57.84522   3.4  0.68673515  0.29483795
## 48   260.1807 57.84522   1.6  0.68673515  0.29483795
## 49   260.1807 57.84522   1.1  0.68673515  0.29483795
## 50   260.1807 57.84522   1.6  0.68673515  0.29483795
## 51   260.1807 57.84522   1.9  0.68673515  0.29483795
## 52   260.1807 57.84522   1.3  0.68673515  0.29483795
## 53   260.1807 57.84522   1.9  0.68673515  0.29483795
## 54   260.1807 57.84522   1.3  0.68673515  0.29483795
## 55   260.1807 57.84522   1.2  0.68673515  0.29483795
## 56   260.1807 57.84522   1.4  0.68673515  0.29483795
## 57   260.7745 57.73142   2.9  0.56448746  0.22020149
## 58   260.3762 57.83786   2.9  0.93719101  0.43173409
## 59   260.3762 57.83786   1.3  0.93719101  0.43173409
## 60   260.4182 57.79222   1.5  1.00365067  0.42736816
## 61   260.4182 57.79222   0.8  1.00365067  0.42736816
## 62   260.4182 57.79222   0.9  1.00365067  0.42736816
## 63   260.4182 57.79222   0.8  1.00365067  0.42736816
## 64   260.2685 57.89661   1.1  0.68200874  0.34345627
## 65   260.3975 57.91644   1.0  0.74408150  0.28389740
## 66   260.3975 57.91644   1.6  0.74408150  0.28389740
## 67   260.3975 57.91644   2.0  0.74408150  0.28389740
## 68   260.5253 58.00328   1.3  0.64132118  0.34874535
## 69   260.5253 58.00328   1.4  0.64132118  0.34874535
## 70   260.5253 58.00328   2.0  0.64132118  0.34874535
```

```
## 71   260.5253 58.00328   1.6  0.64132118  0.34874535
## 72   260.5253 58.00328   1.4  0.64132118  0.34874535
## 73   260.4242 57.93075   1.1  0.65962029  0.33335876
## 74   260.4242 57.93075   1.2  0.65962029  0.33335876
## 75   260.7778 58.17011   5.1  0.70701408  0.33314896
## 76   260.7778 58.17011   4.5  0.70701408  0.33314896
## 77   260.7778 58.17011   4.8  0.70701408  0.33314896
## 78   260.7778 58.17011   5.2  0.70701408  0.33314896
## 79   260.7778 58.17011   4.7  0.70701408  0.33314896
## 80   260.4074 58.01450   1.4  0.65087891  0.31983376
## 81   260.4074 58.01450   1.1  0.65087891  0.31983376
## 82   260.4074 58.01450   3.2  0.65087891  0.31983376
## 83   260.4074 58.01450   1.6  0.65087891  0.31983376
## 84   260.4074 58.01450   1.6  0.65087891  0.31983376
## 85   260.4074 58.01450   1.2  0.65087891  0.31983376
## 86   260.4074 58.01450   1.2  0.65087891  0.31983376
## 87   260.4074 58.01450   1.7  0.65087891  0.31983376
## 88   260.4074 58.01450   1.3  0.65087891  0.31983376
## 89   260.4074 58.01450   3.7  0.65087891  0.31983376
## 90   260.4074 58.01450   1.5  0.65087891  0.31983376
## 91   260.1864 57.91650   1.0  0.67800140  0.34913635
## 92   260.1864 57.91650   1.5  0.67800140  0.34913635
## 93   260.3528 58.09669   1.7  0.59618187  0.26110268
## 94   260.3528 58.09669   1.8  0.59618187  0.26110268
## 95   260.3033 58.07806   1.3  0.69382286  0.25196648
## 96   260.3033 58.07806   1.3  0.69382286  0.25196648
## 97   260.2553 57.96206   1.4  0.75049400  0.33977890
## 98   260.2357 58.04308   1.4  0.67816162  0.34037399
## 99   260.2357 58.04308   1.2  0.67816162  0.34037399
## 100  260.2124 58.08033   4.0  0.65240097  0.26616859
## 101  260.2124 58.08033   1.4  0.65240097  0.26616859
## 102  260.2124 58.08033   2.8  0.65240097  0.26616859
## 103  260.1513 57.92750   1.6  0.62690926  0.30303574
## 104  260.1339 58.09442   2.7  0.59506798  0.23877335
## 105  260.1201 57.89253   1.9  0.76747322  0.38023376
## 106  260.1606 58.00681   1.5  0.64848328  0.33205986
## 107  260.1606 58.00681   1.8  0.64848328  0.33205986
## 108  260.1606 58.00681   1.8  0.64848328  0.33205986
## 109  260.0436 58.04428   3.0  0.62620735  0.33057404
## 110  260.0436 58.04428   1.2  0.62620735  0.33057404
## 111  260.0673 58.06800   1.1  0.79477501  0.39331818
## 112  260.0673 58.06800   1.3  0.79477501  0.39331818
## 113  260.0673 58.06800   1.0  0.79477501  0.39331818
## 114  260.0673 58.06800   1.6  0.79477501  0.39331818
## 115  260.0673 58.06800   0.8  0.79477501  0.39331818
## 116  260.0673 58.06800   0.9  0.79477501  0.39331818
## 117  260.0253 58.04725   2.5  0.67266083  0.30711365
## 118  260.0253 58.04725   1.1  0.67266083  0.30711365
## 119  260.0253 58.04725   1.2  0.67266083  0.30711365
## 120  260.0605 58.21428   1.1  0.77185440  0.35449791
## 121  260.0605 58.21428   2.1  0.77185440  0.35449791
## 122  260.0605 58.21428   1.5  0.77185440  0.35449791
## 123  260.0605 58.21428   0.9  0.77185440  0.35449791
## 124  260.0605 58.21428   1.0  0.77185440  0.35449791
## 125  259.9743 58.11225   1.4  0.79516411  0.36142159
## 126  259.9743 58.11225   0.9  0.79516411  0.36142159
## 127  259.9743 58.11225   1.3  0.79516411  0.36142159
## 128  259.9743 58.11225   1.8  0.79516411  0.36142159
## 129  259.9743 58.11225   1.9  0.79516411  0.36142159
## 130  259.8226 58.17783   0.9  0.85223389  0.37253761
## 131  259.9909 58.01431   1.1  0.67015457  0.32089233
## 132  259.9909 58.01431   3.3  0.67015457  0.32089233
## 133  259.9909 58.01431   2.4  0.67015457  0.32089233
## 134  259.9909 58.01431   1.8  0.67015457  0.32089233
## 135  260.1006 57.89789   2.4  0.57964325  0.32260704
## 136  259.9850 57.98778   1.2  0.78502083  0.35390091
## 137  259.9850 57.98778   1.1  0.78502083  0.35390091
## 138  259.6910 58.12581   2.4  0.69365501  0.29061317
## 139  259.6910 58.12581   2.5  0.69365501  0.29061317
## 140  259.6910 58.12581   1.4  0.69365501  0.29061317
## 141  259.6910 58.12581   1.9  0.69365501  0.29061317
## 142  259.8570 58.01669   1.8  0.71711349  0.30902290
## 143  259.8570 58.01669   1.5  0.71711349  0.30902290
## 144  259.8570 58.01669   2.7  0.71711349  0.30902290
## 145  259.4933 58.09978   1.2  0.81982231  0.34882164
## 146  259.4933 58.09978   1.2  0.81982231  0.34882164
## 147  259.4933 58.09978   1.8  0.81982231  0.34882164
## 148  259.4933 58.09978   1.1  0.81982231  0.34882164
## 149  259.4933 58.09978   1.4  0.81982231  0.34882164
```

```
## 150  259.4933 58.09978   1.1  0.81982231  0.34882164
## 151  259.8270 57.99017   1.2  0.78361702  0.36230850
## 152  259.6487 58.01400   1.0 -0.41802216  1.51001358
## 153  259.6487 58.01400   1.2 -0.41802216  1.51001358
## 154  259.4108 58.07753   0.9  0.97565079  0.42773056
## 155  259.8121 57.94772   1.2  0.67067528  0.33325386
## 156  259.7452 57.90594   1.7  0.70814705  0.30191803
## 157  259.5743 57.93811   1.9  0.65812111  0.28248024
## 158  259.9244 57.87200   0.7  1.02595711  0.41595840
## 159  259.9244 57.87200   0.8  1.02595711  0.41595840
## 160  259.2317 57.78800   2.4  0.86960793  0.32014465
## 161  259.8867 57.83022   1.1  0.73410606  0.32433128
## 162  259.8867 57.83022   1.3  0.73410606  0.32433128
## 163  259.8867 57.83022   1.3  0.73410606  0.32433128
## 164  259.8867 57.83022   1.9  0.73410606  0.32433128
## 165  259.7649 57.77844   0.8  0.96249199  0.38521004
## 166  259.7649 57.77844   0.9  0.96249199  0.38521004
## 167  259.4127 57.72144   2.0  0.57760239  0.24916840
## 168  259.8945 57.80139   1.3  0.63693237  0.29554176
## 169  259.7428 57.81600   0.8  0.96922874  0.42019081
## 170  259.7428 57.81600   0.7  0.96922874  0.42019081
## 171  259.4698 57.59956   3.9  0.41514778  0.22108841
## 172  259.4698 57.59956   4.6  0.41514778  0.22108841
## 173  259.7337 57.72925   3.4  0.68342018  0.35063744
## 174  259.7337 57.72925   1.2  0.68342018  0.35063744
## 175  259.7119 57.69372   2.9  0.64774513  0.29898834
## 176  259.7119 57.69372   1.9  0.64774513  0.29898834
## 177  259.7119 57.69372   2.7  0.64774513  0.29898834
## 178  259.7119 57.69372   1.3  0.64774513  0.29898834
## 179  259.7119 57.69372   2.4  0.64774513  0.29898834
## 180  259.7119 57.69372   1.3  0.64774513  0.29898834
## 181  259.7119 57.69372   1.7  0.64774513  0.29898834
## 182  259.7119 57.69372   2.2  0.64774513  0.29898834
## 183  259.8932 57.76989   1.7  0.69008446  0.31264114
## 184  260.1893 57.81669   2.3  0.79253197  0.33104897
## 185  260.0485 57.82678   3.4  0.82755470  0.35683632
## 186  260.0485 57.82678   1.0  0.82755470  0.35683632
## 187  260.2122 57.85269   3.0  0.79199219  0.38150978
## 188  260.1830 57.86258   2.3  0.63456154  0.27474976
## 189  260.1830 57.86258   2.4  0.63456154  0.27474976
## 190  260.3890 57.77447   1.7  0.59533882  0.28391075
## 191  260.6396 57.80106   1.4  0.62971687  0.35889435
## 192  260.6396 57.80106   1.7  0.62971687  0.35889435
## 193  260.6396 57.80106   2.6  0.62971687  0.35889435
## 194  260.6396 57.80106   1.6  0.62971687  0.35889435
## 195  260.6396 57.80106   1.5  0.62971687  0.35889435
## 196  260.6396 57.80106   1.2  0.62971687  0.35889435
## 197  260.6396 57.80106   1.5  0.62971687  0.35889435
## 198  260.6396 57.80106   1.7  0.62971687  0.35889435
## 199  260.6396 57.80106   1.5  0.62971687  0.35889435
## 200  260.3218 57.79653   3.7  0.66572571  0.27662849
## 201  260.3218 57.79653   1.6  0.66572571  0.27662849
## 202  260.7551 57.78225   1.5  0.60741806  0.27507973
## 203  260.7551 57.78225   1.4  0.60741806  0.27507973
## 204  260.7551 57.78225   1.6  0.60741806  0.27507973
## 205  260.7551 57.78225   1.5  0.60741806  0.27507973
## 206  260.7551 57.78225   1.8  0.60741806  0.27507973
## 207  260.7621 57.45814   2.3  0.73789024  0.34158707
## 208  260.7621 57.45814   1.3  0.73789024  0.34158707
## 209  260.7621 57.45814   1.3  0.73789024  0.34158707
## 210  260.9679 57.97544   1.9  0.68560028  0.20579910
## 211  260.6343 58.29636   3.6  0.77193260  0.34259987
## 212  260.6343 58.29636   1.3  0.77193260  0.34259987
## 213  260.6343 58.29636   1.1  0.77193260  0.34259987
## 214  260.6343 58.29636   1.0  0.77193260  0.34259987
## 215  260.6343 58.29636   2.1  0.77193260  0.34259987
## 216  260.6343 58.29636   1.6  0.77193260  0.34259987
## 217  260.6343 58.29636   1.2  0.77193260  0.34259987
## 218  260.6343 58.29636   2.1  0.77193260  0.34259987
## 219  260.6343 58.29636   1.2  0.77193260  0.34259987
## 220  260.4273 58.24250   3.6  0.77323914  0.33361053
## 221  260.4273 58.24250   1.2  0.77323914  0.33361053
## 222  260.4273 58.24250   1.0  0.77323914  0.33361053
## 223  260.4273 58.24250   1.3  0.77323914  0.33361053
## 224  260.4273 58.24250   1.4  0.77323914  0.33361053
## 225  260.6216 58.08617   1.8  0.64653778  0.27412415
## 226  260.6216 58.08617   1.5  0.64653778  0.27412415
## 227  260.6216 58.08617   2.1  0.64653778  0.27412415
## 228  260.6216 58.08617   3.0  0.64653778  0.27412415
```

```
## 229  260.7431 58.02064   1.5  0.62214661  0.27225494
## 230  260.5120 58.14322   1.3  0.64719772  0.22807312
## 231  260.5120 58.14322   3.4  0.64719772  0.22807312
## 232  260.5120 58.14322   2.2  0.64719772  0.22807312
## 233  260.7860 58.01647   3.6  0.66232109  0.31045914
## 234  260.5221 58.02969   1.3  0.66675568  0.30817223
## 235  260.5221 58.02969   1.3  0.66675568  0.30817223
## 236  260.5221 58.02969   2.2  0.66675568  0.30817223
## 237  260.5221 58.02969   3.3  0.66675568  0.30817223
## 238  260.6820 57.95853   1.7  0.66039467  0.36691475
## 239  260.6820 57.95853   0.9  0.66039467  0.36691475
## 240  260.6820 57.95853   1.5  0.66039467  0.36691475
## 241  260.6820 57.95853   1.6  0.66039467  0.36691475
## 242  260.6820 57.95853   1.1  0.66039467  0.36691475
## 243  260.6520 58.05097   2.3  0.57285881  0.31044960
## 244  260.6520 58.05097   1.3  0.57285881  0.31044960
## 245  260.6520 58.05097   2.4  0.57285881  0.31044960
## 246  260.6520 58.05097   1.1  0.57285881  0.31044960
## 247  260.6520 58.05097   2.5  0.57285881  0.31044960
## 248  260.6520 58.05097   2.3  0.57285881  0.31044960
## 249  260.4033 57.97694   2.0  0.65513992  0.28785133
## 250  260.4873 57.99272   2.9  0.87588501  0.41214752
## 251  260.4873 57.99272   0.9  0.87588501  0.41214752
## 252  260.4873 57.99272   1.0  0.87588501  0.41214752
## 253  260.5467 57.94253   1.8  0.77202034  0.37130356
## 254  260.5467 57.94253   1.7  0.77202034  0.37130356
## 255  260.3428 58.03764   1.3  0.76146507  0.28060913
## 256  260.3428 58.03764   1.3  0.76146507  0.28060913
## 257  260.3428 58.03764   1.3  0.76146507  0.28060913
## 258  260.3428 58.03764   1.4  0.76146507  0.28060913
## 259  260.3428 58.03764   1.0  0.76146507  0.28060913
## 260  260.2169 57.99661   1.0  1.02651596  0.45251083
## 261  260.2634 57.93314   5.1  0.80955887  0.37194824
## 262  260.2634 57.93314   1.0  0.80955887  0.37194824
## 263  260.2634 57.93314   1.6  0.80955887  0.37194824
## 264  260.2648 57.95228   1.5  1.01665497  0.44452667
## 265  260.2648 57.95228   1.0  1.01665497  0.44452667
## 266  260.1908 57.92811   4.4  0.79371834  0.39380836
## 267  260.1421 57.97292   4.1  0.77004433  0.36049271
## 268  260.5446 57.89928   1.5  0.94838524  0.42973518
## 269  260.5446 57.89928   1.0  0.94838524  0.42973518
## 270  260.5446 57.89928   1.0  0.94838524  0.42973518
## 271  260.5446 57.89928   0.8  0.94838524  0.42973518
## 272  260.0634 58.00972   3.2  0.72179794  0.36255264
## 273  260.0563 57.86644   1.2  0.95328522  0.42140388
## 274  259.8488 57.78967   3.1  0.66842270  0.31089211
## 275  259.8488 57.78967   1.9  0.66842270  0.31089211
## 276  259.8383 57.75828   2.9  0.66142654  0.31783485
## 277  259.8383 57.75828   1.7  0.66142654  0.31783485
## 278  259.7370 57.77458   1.7  0.62735176  0.30803108
## 279  259.7370 57.77458   1.7  0.62735176  0.30803108
## 280  259.7370 57.77458   1.9  0.62735176  0.30803108
## 281  260.0222 57.83839   1.5  0.78962517  0.33624268
## 282  259.6790 57.64714   0.8  0.91941643  0.36170197
## 283  259.6790 57.64714   1.3  0.91941643  0.36170197
## 284  260.0405 57.77483   1.1  0.91461945  0.40106964
## 285  260.0405 57.77483   1.1  0.91461945  0.40106964
## 286  260.0073 57.77961   2.3  0.71872902  0.32018280
## 287  260.0073 57.77961   2.5  0.71872902  0.32018280
## 288  260.0073 57.77961   1.6  0.71872902  0.32018280
## 289  260.2525 57.82258   1.4  0.76394081  0.32650757
## 290  260.2525 57.82258   1.7  0.76394081  0.32650757
## 291  260.3372 57.87675   1.4  0.62346268  0.24774361
## 292  260.4686 57.87689   1.5  0.80035591  0.38510323
## 293  260.4686 57.87689   1.9  0.80035591  0.38510323
## 294  260.4686 57.87689   1.2  0.80035591  0.38510323
## 295  260.4686 57.87689   1.3  0.80035591  0.38510323
## 296  260.3106 57.90322   1.0  0.73062706  0.32913017
## 297  260.4721 57.93328   2.4  0.65659332  0.33173370
## 298  260.4721 57.93328   1.6  0.65659332  0.33173370
## 299  260.4721 57.93328   1.5  0.65659332  0.33173370
## 300  260.2610 57.87908   1.1  0.67741203  0.31748009
## 301  260.2610 57.87908   1.4  0.67741203  0.31748009
## 302  260.2610 57.87908   1.7  0.67741203  0.31748009
## 303  260.2610 57.87908   2.3  0.67741203  0.31748009
## 304  260.2610 57.87908   2.0  0.67741203  0.31748009
## 305  260.5412 57.96550   2.7  0.63335800  0.34818077
## 306  260.5188 57.95417   0.9  0.72203255  0.35994148
## 307  260.5188 57.95417   1.4  0.72203255  0.35994148
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## 308  260.5188 57.95417   1.1  0.72203255  0.35994148
## 309  260.3612 57.92339   3.2  0.52577400  0.26405525
## 310  260.2208 57.94103   1.2  0.63055611  0.30821991
## 311  260.2208 57.94103   1.9  0.63055611  0.30821991
## 312  260.2208 57.94103   1.5  0.63055611  0.30821991
## 313  260.2208 57.94103   1.2  0.63055611  0.30821991
## 314  260.2208 57.94103   1.3  0.63055611  0.30821991
## 315  260.2208 57.94103   1.0  0.63055611  0.30821991
## 316  260.2208 57.94103   1.0  0.63055611  0.30821991
## 317  260.2208 57.94103   1.8  0.63055611  0.30821991
## 318  260.2208 57.94103   1.6  0.63055611  0.30821991
## 319  260.2208 57.94103   1.6  0.63055611  0.30821991
## 320  260.3229 57.99703   1.6  0.57400703  0.26868248
## 321  260.3229 57.99703   2.0  0.57400703  0.26868248
## 322  260.1664 57.89328   2.2  0.54646492  0.25322151
## 323  260.1482 57.93553   1.1  0.68523979  0.23547173
## 324  260.2344 58.00739   1.7  0.64023209  0.27405739
## 325  260.2344 58.00739   2.3  0.64023209  0.27405739
## 326  260.2344 58.00739   1.3  0.64023209  0.27405739
## 327  260.3399 58.10231   3.4  0.63226128  0.27136612
## 328  260.3399 58.10231   2.0  0.63226128  0.27136612
## 329  260.3399 58.10231   2.2  0.63226128  0.27136612
## 330  260.3399 58.10231   1.4  0.63226128  0.27136612
## 331  260.3399 58.10231   3.9  0.63226128  0.27136612
## 332  260.3399 58.10231   2.3  0.63226128  0.27136612
## 333  260.3399 58.10231   1.7  0.63226128  0.27136612
## 334  260.1449 57.99911   0.9  0.99771500  0.43732452
## 335  260.1440 57.97017   2.0  0.64493752  0.29993439
## 336  260.1570 57.87128   1.6  0.69632149  0.25707054
## 337  259.8205 58.26414   2.5  0.75408936  0.37342072
## 338  259.8205 58.26414   2.4  0.75408936  0.37342072
## 339  259.8205 58.26414   1.3  0.75408936  0.37342072
## 340  260.0499 57.94144   1.6  0.63504791  0.30876160
## 341  260.0064 57.96650   2.0  0.70879936  0.32893562
## 342  260.0585 57.90694   3.1  0.56356239  0.28113174
## 343  259.9774 57.95186   1.9  0.72803116  0.35299492
## 344  259.9774 57.95186   1.5  0.72803116  0.35299492
## 345  259.9774 57.95186   1.8  0.72803116  0.35299492
## 346  259.5240 58.18958   1.9  0.76180458  0.34614372
## 347  259.5240 58.18958   1.1  0.76180458  0.34614372
## 348  259.5240 58.18958   1.6  0.76180458  0.34614372
## 349  259.5240 58.18958   2.0  0.76180458  0.34614372
## 350  259.5240 58.18958   1.2  0.76180458  0.34614372
## 351  259.5240 58.18958   1.4  0.76180458  0.34614372
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## 353  259.5240 58.18958   1.2  0.76180458  0.34614372
## 354  259.5240 58.18958   1.3  0.76180458  0.34614372
## 355  259.9575 58.00742   2.0  0.63817024  0.32404137
## 356  259.9575 58.00742   1.3  0.63817024  0.32404137
## 357  259.9575 58.00742   1.4  0.63817024  0.32404137
## 358  259.9575 58.00742   2.2  0.63817024  0.32404137
## 359  259.9575 58.00742   1.1  0.63817024  0.32404137
## 360  259.9575 58.00742   1.6  0.63817024  0.32404137
## 361  259.9575 58.00742   1.5  0.63817024  0.32404137
## 362  259.9108 57.96700   2.4  0.66644859  0.31198120
## 363  259.9108 57.96700   1.3  0.66644859  0.31198120
## 364  259.9108 57.96700   2.4  0.66644859  0.31198120
## 365  259.9108 57.96700   2.7  0.66644859  0.31198120
## 366  259.9108 57.96700   3.2  0.66644859  0.31198120
## 367  259.9108 57.96700   1.3  0.66644859  0.31198120
## 368  259.9108 57.96700   3.4  0.66644859  0.31198120
## 369  259.9108 57.96700   2.4  0.66644859  0.31198120
## 370  259.9108 57.96700   1.2  0.66644859  0.31198120
## 371  259.9108 57.96700   4.2  0.66644859  0.31198120
## 372  259.9108 57.96700   3.6  0.66644859  0.31198120
## 373  259.9989 57.91831   2.6  0.71777153  0.34057426
## 374  259.9989 57.91831   1.7  0.71777153  0.34057426
## 375  259.9989 57.91831   1.8  0.71777153  0.34057426
## 376  259.9989 57.91831   1.6  0.71777153  0.34057426
## 377  259.7951 57.98814   0.9  1.10619354  0.48713112
## 378  259.7951 57.98814   0.7  1.10619354  0.48713112
## 379  260.0082 57.90619   1.7  0.61191177  0.31828308
## 380  259.7228 57.97389   2.4  0.68795204  0.32641792
## 381  259.7228 57.97389   0.9  0.68795204  0.32641792
## 382  259.7228 57.97389   1.2  0.68795204  0.32641792
## 383  259.5262 58.03206   2.9  0.60417175  0.27368927
## 384  259.5262 58.03206   2.0  0.60417175  0.27368927
## 385  259.5262 58.03206   3.0  0.60417175  0.27368927
## 386  259.5262 58.03206   2.7  0.60417175  0.27368927
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## 387  259.8394 57.92711   2.6  0.72007179  0.29329491
## 388  259.8394 57.92711   1.0  0.72007179  0.29329491
## 389  259.8394 57.92711   1.6  0.72007179  0.29329491
## 390  259.8394 57.92711   1.0  0.72007179  0.29329491
## 391  259.7066 57.91686   1.6  0.63170433  0.27126884
## 392  259.7066 57.91686   3.0  0.63170433  0.27126884
## 393  259.9406 57.90772   1.2  0.76116753  0.31388092
## 394  259.9092 57.89747   4.0  0.77436256  0.29494858
## 395  259.7733 57.89950   2.5  0.63308525  0.29092979
## 396  259.7733 57.89950   1.6  0.63308525  0.29092979
## 397  259.2749 57.99264   2.6  0.64298248  0.27224922
## 398  259.2749 57.99264   3.4  0.64298248  0.27224922
## 399  259.2749 57.99264   1.2  0.64298248  0.27224922
## 400  259.2749 57.99264   1.4  0.64298248  0.27224922
## 401  259.5930 57.89639   1.9  0.65405655  0.27203560
## 402  259.5930 57.89639   2.3  0.65405655  0.27203560
## 403  259.2486 57.82600   1.8  0.58484459  0.30554199
## 404  259.2486 57.82600   2.7  0.58484459  0.30554199
## 405  259.2486 57.82600   4.1  0.58484459  0.30554199
## 406  259.2486 57.82600   3.8  0.58484459  0.30554199
## 407  259.2486 57.82600   4.6  0.58484459  0.30554199
## 408  260.0503 57.88369   2.2  0.68775940  0.34340096
## 409  259.9071 57.82181   3.0  0.69783211  0.32522011
## 410  259.9071 57.82181   1.0  0.69783211  0.32522011
## 411  259.9071 57.82181   1.8  0.69783211  0.32522011
## 412  259.4423 57.70608   1.3  0.83641624  0.37218094
## 413  259.4423 57.70608   1.1  0.83641624  0.37218094
## 414  259.4423 57.70608   0.8  0.83641624  0.37218094
## 415  259.4423 57.70608   0.9  0.83641624  0.37218094
## 416  259.4423 57.70608   1.1  0.83641624  0.37218094
## 417  259.4423 57.70608   0.9  0.83641624  0.37218094
## 418  259.4423 57.70608   0.8  0.83641624  0.37218094
## 419  259.1384 57.31642   4.6  0.59676933  0.35510635
## 420  259.1384 57.31642   5.0  0.59676933  0.35510635
## 421  260.2688 57.84661   1.6  0.61370850  0.28304863
## 422  260.2688 57.84661   4.8  0.61370850  0.28304863
## 423  260.2688 57.84661   3.3  0.61370850  0.28304863
## 424  260.3107 57.87053   1.0  0.75825310  0.32711983
## 425  260.3107 57.87053   1.1  0.75825310  0.32711983
## 426  260.3107 57.87053   1.1  0.75825310  0.32711983
## 427  260.3107 57.87053   1.7  0.75825310  0.32711983
## 428  260.2574 57.83317   1.5  0.63025284  0.32482338
## 429  260.2574 57.83317   1.3  0.63025284  0.32482338
## 430  260.1551 57.85797   1.5  0.58897018  0.25032234
## 431  260.1634 57.87633   1.5  0.70726967  0.29137230
## 432  260.1634 57.87633   1.4  0.70726967  0.29137230
## 433  260.1634 57.87633   1.9  0.70726967  0.29137230
## 434  259.9300 57.87631   1.5  0.66589928  0.29356194
## 435  259.9300 57.87631   1.8  0.66589928  0.29356194
## 436  259.9300 57.87631   3.0  0.66589928  0.29356194
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## 438  259.9300 57.87631   2.7  0.66589928  0.29356194
## 439  259.9300 57.87631   2.5  0.66589928  0.29356194
## 440  259.9300 57.87631   1.6  0.66589928  0.29356194
## 441  259.9300 57.87631   2.8  0.66589928  0.29356194
## 442  259.9300 57.87631   2.2  0.66589928  0.29356194
## 443  260.1635 57.95742   1.6  0.70577812  0.31727791
## 444  260.1635 57.95742   2.5  0.70577812  0.31727791
## 445  260.2005 57.91569   1.3  0.70849419  0.36137390
## 446  260.2005 57.91569   3.6  0.70849419  0.36137390
## 447  260.0432 57.88681   1.2  0.71508217  0.36018753
## 448  260.0432 57.88681   1.1  0.71508217  0.36018753
## 449  259.9348 58.01619   1.6  0.61033249  0.29049683
## 450  259.9348 58.01619   1.7  0.61033249  0.29049683
## 451  259.7847 57.96406   1.4  0.66015434  0.29979706
## 452  259.7847 57.96406   1.6  0.66015434  0.29979706
## 453  259.7994 57.90778   1.5  0.62765121  0.25020981
## 454  259.7994 57.90778   1.2  0.62765121  0.25020981
## 455  259.3902 57.68389   1.6  0.63056946  0.31432533
## 456  259.3902 57.68389   1.9  0.63056946  0.31432533
## 457  259.3902 57.68389   1.8  0.63056946  0.31432533
## 458  259.3902 57.68389   2.4  0.63056946  0.31432533
## 459  260.2437 57.85067   1.4  0.54475594  0.32139969
## 460  260.2466 57.79481   1.0  0.62258530  0.30206108
## 461  260.2466 57.79481   1.0  0.62258530  0.30206108
## 462  260.2819 57.87169   2.2  0.42939568  0.16246796
## 463  260.2819 57.87169   1.4  0.42939568  0.16246796
## 464  260.2819 57.87169   2.1  0.42939568  0.16246796
## 465  260.0818 57.90061   2.3  0.63245392  0.30830383
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## 466  260.0539 57.90083   1.1  0.62733459  0.33697128
## 467  260.0539 57.90083   1.4  0.62733459  0.33697128
## 468  260.0452 57.88264   1.6  0.62601089  0.31031418
## 469  260.0452 57.88264   3.0  0.62601089  0.31031418
## 470  260.0236 57.88436   1.5  0.67884254  0.32177162
## 471  260.0236 57.88436   1.5  0.67884254  0.32177162
## 472  260.0236 57.88436   2.1  0.67884254  0.32177162
## 473  259.7400 57.90394   1.3  0.93774223  0.40473557
## 474  259.7400 57.90394   1.3  0.93774223  0.40473557
## 475  259.9298 57.88367   1.8  0.68304634  0.24545670
## 476  259.3427 58.12372   1.4  0.85257149  0.37278748
## 477  259.3427 58.12372   2.6  0.85257149  0.37278748
## 478  259.3427 58.12372   1.4  0.85257149  0.37278748
## 479  259.3427 58.12372   1.5  0.85257149  0.37278748
## 480  259.3427 58.12372   1.3  0.85257149  0.37278748
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## 484  259.3088 58.18014   2.3  0.62198830  0.30615044
## 485  259.3088 58.18014   2.2  0.62198830  0.30615044
## 486  259.3088 58.18014   2.7  0.62198830  0.30615044
## 487  259.3088 58.18014   1.2  0.62198830  0.30615044
## 488  259.3088 58.18014   1.2  0.62198830  0.30615044
## 489  259.3088 58.18014   1.8  0.62198830  0.30615044
## 490  259.7493 58.10814   1.1  0.68716621  0.29767799
## 491  259.7493 58.10814   2.1  0.68716621  0.29767799
## 492  259.7493 58.10814   1.8  0.68716621  0.29767799
## 493  259.7493 58.10814   1.7  0.68716621  0.29767799
## 494  259.7493 58.10814   1.1  0.68716621  0.29767799
## 495  259.6760 57.98611   1.0  1.07271004  0.45840263
## 496  259.6760 57.98611   0.8  1.07271004  0.45840263
## 497  259.6760 57.98611   0.8  1.07271004  0.45840263
## 498  259.6760 57.98611   0.8  1.07271004  0.45840263
## 499  259.6760 57.98611   0.8  1.07271004  0.45840263
## 500  259.6760 57.98611   0.9  1.07271004  0.45840263
## 501  259.6760 57.98611   1.0  1.07271004  0.45840263
## 502  259.7923 58.13517   1.9  0.66993141  0.29729462
## 503  259.7923 58.13517   0.9  0.66993141  0.29729462
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## 505  259.7923 58.13517   1.2  0.66993141  0.29729462
## 506  259.7923 58.13517   1.7  0.66993141  0.29729462
## 507  259.9045 58.08892   2.2  0.73962975  0.33312607
## 508  259.8405 58.01125   1.0  0.80222321  0.33128548
## 509  259.9545 58.07556   0.9  0.97982979  0.43522835
## 510  260.2742 58.08192   1.4  0.61819839  0.24216843
## 511  260.2701 58.03364   1.0  0.85757065  0.35140991
## 512  260.2701 58.03364   1.3  0.85757065  0.35140991
## 513  260.2701 58.03364   1.1  0.85757065  0.35140991
## 514  260.2701 58.03364   1.1  0.85757065  0.35140991
## 515  260.2701 58.03364   1.2  0.85757065  0.35140991
## 516  259.6241 58.74625   4.4  0.56004715  0.24069023
## 517  259.6241 58.74625   3.6  0.56004715  0.24069023
## 518  259.6241 58.74625   4.8  0.56004715  0.24069023
## 519  259.1422 58.49883   2.2  0.70405388  0.29853630
## 520  260.6130 57.76511   1.1  0.72609329  0.32887840
## 521  260.6130 57.76511   1.3  0.72609329  0.32887840
## 522  260.1618 57.95681   3.5  0.56601906  0.26107216
## 523  262.9388 58.15181   1.7  0.54786873  0.24131775
## 524  263.3082 57.99483   2.8  0.52812576  0.27068710
## 525  263.0446 58.57925   5.1  0.69111252  0.28586006
## 526  262.7600 58.53464   5.2  1.13136482  0.45215034
## 527  262.6916 58.50639   4.9  0.70119095  0.19633865
## 528  262.8125 58.42494   3.2  0.57629776  0.24762154
## 529  260.0210 57.93847   1.7  0.74253464  0.33747101
## 530  260.1982 57.90236   2.2  0.64394760  0.29740715
## 531  260.1982 57.90236   1.4  0.64394760  0.29740715
## 532  260.1982 57.90236   1.4  0.64394760  0.29740715
## 533  260.1982 57.90236   1.1  0.64394760  0.29740715
## 534  260.1982 57.90236   1.3  0.64394760  0.29740715
## 535  260.1982 57.90236   1.8  0.64394760  0.29740715
## 536  260.1982 57.90236   1.4  0.64394760  0.29740715
## 537  260.1982 57.90236   1.2  0.64394760  0.29740715
## 538  261.9098 58.26308   0.9  0.82099915  0.36653709
## 539  261.9098 58.26308   1.2  0.82099915  0.36653709
## 540  261.9098 58.26308   1.0  0.82099915  0.36653709
## 541  259.9954 57.95581   1.1  1.08310699  0.48179054
## 542  259.3372 58.03258   1.7  0.74643326  0.34269524
## 543  259.3372 58.03258   1.9  0.74643326  0.34269524
## 544  259.3372 58.03258   1.5  0.74643326  0.34269524
```

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## 545  259.4220 58.01219   1.6  0.74535942  0.31901741
## 546  259.4108 57.98183   2.3  0.74553680  0.34949684
## 547  259.4108 57.98183   1.9  0.74553680  0.34949684
## 548  259.4108 57.98183   1.0  0.74553680  0.34949684
## 549  259.2333 57.97672   3.0  0.52561378  0.23605347
## 550  260.0297 57.88264   1.2  0.58193398  0.32453728
## 551  259.3576 57.68792   5.3  0.62726593  0.25207901
## 552  259.3576 57.68792   5.2  0.62726593  0.25207901
## 553  259.3576 57.68792   3.7  0.62726593  0.25207901
## 554  259.3576 57.68792   4.3  0.62726593  0.25207901
## 555  259.3576 57.68792   4.2  0.62726593  0.25207901
## 556  259.8333 57.81803   1.6  0.77812576  0.32898903
## 557  259.7138 57.70444   1.2  0.74328423  0.33575439
## 558  259.7138 57.70444   1.6  0.74328423  0.33575439
## 559  260.0029 57.89628   0.7  1.17779922  0.34352684
## 560  260.0029 57.89628   0.7  1.17779922  0.34352684
## 561  259.9488 57.81017   0.8  1.09977531  0.46011353
## 562  259.9488 57.81017   0.8  1.09977531  0.46011353
## 563  259.8745 57.80464   1.2  0.66836166  0.42993736
## 564  259.8745 57.80464   1.3  0.66836166  0.42993736
## 565  259.8745 57.80464   1.3  0.66836166  0.42993736
## 566  259.9903 57.83486   0.9  1.26946259  0.28682327
## 567  259.9903 57.83486   0.8  1.26946259  0.28682327
## 568  259.9404 57.67847   3.6  0.52985191  0.22843170
## 569  259.9404 57.67847   4.8  0.52985191  0.22843170
## 570  260.0310 57.90908   1.4  0.69892883  0.37666321
## 571  260.2209 57.57933   4.3  0.43150902  0.23762894
## 572  260.1452 57.64656   4.8  0.56062889  0.23902893
## 573  260.1397 57.83878   0.8  1.20415115  0.34327316
## 574  260.1397 57.83878   0.8  1.20415115  0.34327316
## 575  260.0672 57.88222   2.0  0.88617516  0.40797615
## 576  260.0672 57.88222   1.4  0.88617516  0.40797615
## 577  260.1660 57.85425   1.1  0.81424904  0.36982155
## 578  260.1660 57.85425   1.0  0.81424904  0.36982155
## 579  260.5157 57.69128   1.3  0.90903664  0.41003227
## 580  260.5157 57.69128   0.8  0.90903664  0.41003227
## 581  260.5157 57.69128   1.1  0.90903664  0.41003227
## 582  260.1368 57.86219   0.7  1.28071213  0.54098606
## 583  260.1368 57.86219   0.7  1.28071213  0.54098606
## 584  260.6843 57.74056   3.5  0.58113098  0.26688004
## 585  260.1425 57.89219   0.9  1.05431366  0.44012451
## 586  260.1425 57.89219   0.7  1.05431366  0.44012451
## 587  260.0655 57.90767   2.8  0.55338097  0.34054565
## 588  260.1856 57.86100   2.1  0.69007874  0.32097244
## 589  260.1856 57.86100   1.5  0.69007874  0.32097244
## 590  260.3694 57.86731   2.1  0.58229637  0.29008865
## 591  260.2462 57.89297   1.6  0.62918854  0.34782791
## 592  260.1026 57.92078   1.5  0.68630409  0.36199379
## 593  260.1026 57.92078   1.2  0.68630409  0.36199379
## 594  260.1026 57.92078   1.6  0.68630409  0.36199379
## 595  260.4549 57.89364   1.4  0.79345512  0.36337090
## 596  260.4549 57.89364   1.0  0.79345512  0.36337090
## 597  260.2208 57.93272   0.8  1.20451164  0.53052521
## 598  260.2208 57.93272   0.7  1.20451164  0.53052521
## 599  260.4110 57.92778   1.7  0.63887215  0.33641624
## 600  260.4110 57.92778   1.3  0.63887215  0.33641624
## 601  260.1854 57.91989   2.7  0.58320999  0.32003593
## 602  260.1854 57.91989   1.4  0.58320999  0.32003593
## 603  260.1135 57.93667   1.1  0.80827332  0.37705231
## 604  260.1677 57.95914   0.7  1.23710251  0.54184914
## 605  260.0842 57.94875   1.2  0.68194199  0.30609131
## 606  260.0842 57.94875   1.1  0.68194199  0.30609131
## 607  260.0709 57.93675   0.8  0.82075882  0.37384033
## 608  260.0709 57.93675   0.9  0.82075882  0.37384033
## 609  260.0709 57.93675   0.8  0.82075882  0.37384033
## 610  260.1991 57.99875   0.8  1.05961609  0.47470284
## 611  260.1991 57.99875   0.7  1.05961609  0.47470284
## 612  260.1742 58.00689   0.8  1.13911438  0.50286293
## 613  260.1742 58.00689   0.7  1.13911438  0.50286293
## 614  260.1742 58.00689   0.9  1.13911438  0.50286293
## 615  260.1559 57.98681   0.8  1.12903595  0.50153542
## 616  260.1559 57.98681   0.7  1.12903595  0.50153542
## 617  260.0985 57.98558   1.4  0.71974564  0.27238655
## 618  260.0985 57.98558   1.6  0.71974564  0.27238655
## 619  260.0985 57.98558   1.8  0.71974564  0.27238655
## 620  260.0750 58.01997   1.6  0.67246246  0.35323524
## 621  260.0750 58.01997   1.4  0.67246246  0.35323524
## 622  260.0750 58.01997   1.2  0.67246246  0.35323524
## 623  260.0750 58.01997   1.2  0.67246246  0.35323524
```

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## 624  260.0709 57.98389   0.8  0.95550919  0.41358757
## 625  260.0709 57.98389   0.8  0.95550919  0.41358757
## 626  260.2593 58.26064   0.7  1.09017181  0.46837807
## 627  260.2593 58.26064   0.7  1.09017181  0.46837807
## 628  260.2593 58.26064   0.7  1.09017181  0.46837807
## 629  260.2593 58.26064   0.8  1.09017181  0.46837807
## 630  260.0393 57.95886   1.7  0.63201332  0.25955772
## 631  260.0301 58.01794   2.1  0.59333992  0.29533386
## 632  260.0301 58.01794   1.3  0.59333992  0.29533386
## 633  259.9480 58.09764   2.9  0.59700012  0.28761482
## 634  259.9118 58.08044   1.6  0.53486633  0.29297066
## 635  259.7339 58.16869   2.9  0.58029938  0.23647499
## 636  259.7339 58.16869   2.2  0.58029938  0.23647499
## 637  259.7339 58.16869   1.9  0.58029938  0.23647499
## 638  259.7339 58.16869   2.6  0.58029938  0.23647499
## 639  259.9453 57.99892   1.4  0.65270996  0.33425522
## 640  259.9453 57.99892   1.3  0.65270996  0.33425522
## 641  259.5980 58.33522   4.7  0.56457710  0.21496201
## 642  259.5980 58.33522   3.0  0.56457710  0.21496201
## 643  259.5980 58.33522   3.4  0.56457710  0.21496201
## 644  259.5980 58.33522   4.9  0.56457710  0.21496201
## 645  260.0066 57.95128   0.9  0.85631752  0.39903259
## 646  259.9266 57.97714   0.8  1.21147919  0.35274506
## 647  259.9266 57.97714   0.8  1.21147919  0.35274506
## 648  259.7171 58.07025   0.7  1.09725380  0.47684479
## 649  259.7171 58.07025   0.7  1.09725380  0.47684479
## 650  259.8192 57.96911   1.4  0.66361618  0.32110405
## 651  259.8192 57.96911   1.9  0.66361618  0.32110405
## 652  259.9585 57.94464   1.4  0.83659554  0.37846756
## 653  259.9588 57.95289   2.1  0.60571289  0.30308533
## 654  259.9588 57.95289   3.6  0.60571289  0.30308533
## 655  259.5336 58.02969   0.9  1.04967690  0.44288445
## 656  259.5336 58.02969   0.7  1.04967690  0.44288445
## 657  259.5336 58.02969   0.7  1.04967690  0.44288445
## 658  259.8333 57.99531   1.7  0.77765465  0.36267281
## 659  259.8333 57.99531   1.2  0.77765465  0.36267281
## 660  259.5174 58.10214   2.5  0.60016251  0.20530128
## 661  259.5174 58.10214   1.6  0.60016251  0.20530128
## 662  259.5174 58.10214   1.8  0.60016251  0.20530128
## 663  259.5174 58.10214   1.3  0.60016251  0.20530128
## 664  259.6401 57.97689   1.1  0.68356323  0.27622604
## 665  259.6401 57.97689   1.4  0.68356323  0.27622604
## 666  259.8569 57.95156   1.8  0.59211349  0.32613754
## 667  259.7911 57.95297   1.8  0.62965202  0.30999184
## 668  259.7911 57.95297   2.5  0.62965202  0.30999184
## 669  259.4853 57.90019   2.2  0.62713432  0.33653069
## 670  259.4853 57.90019   2.3  0.62713432  0.33653069
## 671  259.9595 57.92228   2.6  0.70989037  0.29889870
## 672  259.9595 57.92228   1.4  0.70989037  0.29889870
## 673  259.1685 57.91889   1.2  0.78536606  0.33626938
## 674  259.1685 57.91889   1.6  0.78536606  0.33626938
## 675  259.8233 57.90892   1.3  0.88127136  0.36108971
## 676  259.9242 57.91261   1.5  0.70073509  0.31628609
## 677  259.9242 57.91261   2.1  0.70073509  0.31628609
## 678  259.6369 57.84897   1.1  0.88242531  0.32355118
## 679  259.6369 57.84897   1.1  0.88242531  0.32355118
## 680  260.1444 58.01061   2.4  0.55973434  0.24748611
## 681  259.9927 57.90878   2.5  0.53423691  0.39769745
## 682  259.3584 57.73817   4.1  0.61712456  0.26510811
## 683  259.3584 57.73817   5.2  0.61712456  0.26510811
## 684  259.3584 57.73817   4.3  0.61712456  0.26510811
## 685  259.8277 57.85097   2.8  0.68043900  0.29622269
## 686  259.8277 57.85097   1.4  0.68043900  0.29622269
## 687  259.8277 57.85097   1.7  0.68043900  0.29622269
## 688  259.8277 57.85097   1.5  0.68043900  0.29622269
## 689  259.8277 57.85097   1.2  0.68043900  0.29622269
## 690  259.8277 57.85097   2.0  0.68043900  0.29622269
## 691  259.8277 57.85097   1.2  0.68043900  0.29622269
## 692  259.8277 57.85097   1.0  0.68043900  0.29622269
## 693  259.8277 57.85097   1.1  0.68043900  0.29622269
## 694  259.8277 57.85097   2.1  0.68043900  0.29622269
## 695  259.8277 57.85097   1.1  0.68043900  0.29622269
## 696  259.8277 57.85097   1.1  0.68043900  0.29622269
## 697  259.8439 57.83694   2.5  0.72731400  0.34049797
## 698  259.8439 57.83694   1.6  0.72731400  0.34049797
## 699  259.8439 57.83694   2.3  0.72731400  0.34049797
## 700  259.8439 57.83694   1.9  0.72731400  0.34049797
## 701  259.8439 57.83694   1.6  0.72731400  0.34049797
## 702  259.8439 57.83694   1.2  0.72731400  0.34049797
```

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## 703  259.8439 57.83694   1.9  0.72731400  0.34049797
## 704  259.8439 57.83694   1.3  0.72731400  0.34049797
## 705  259.8439 57.83694   1.1  0.72731400  0.34049797
## 706  259.8439 57.83694   1.2  0.72731400  0.34049797
## 707  259.9858 57.87858   1.5  0.75032425  0.37416267
## 708  259.8614 57.72925   2.5  0.33573151  0.23366547
## 709  259.7432 57.62431   1.9  0.66363525  0.26537704
## 710  259.7432 57.62431   1.2  0.66363525  0.26537704
## 711  259.7432 57.62431   2.9  0.66363525  0.26537704
## 712  260.0081 57.85844   1.6  0.69916534  0.35058784
## 713  260.0081 57.85844   1.7  0.69916534  0.35058784
## 714  260.0081 57.85844   1.7  0.69916534  0.35058784
## 715  260.0081 57.85844   1.2  0.69916534  0.35058784
## 716  260.0081 57.85844   1.4  0.69916534  0.35058784
## 717  260.0081 57.85844   1.4  0.69916534  0.35058784
## 718  259.8347 57.48056   2.2  0.67216682  0.28468513
## 719  259.8347 57.48056   2.2  0.67216682  0.28468513
## 720  259.8347 57.48056   1.8  0.67216682  0.28468513
## 721  259.8347 57.48056   1.2  0.67216682  0.28468513
## 722  260.0403 57.58261   2.4  0.56398773  0.24963570
## 723  260.0285 57.58608   2.7  0.54113197  0.25257111
## 724  260.0707 57.88675   0.8  0.88976097  0.39765930
## 725  260.1820 57.81228   0.7  1.21088409  0.51776028
## 726  260.2419 57.77442   1.7  0.62962532  0.33442307
## 727  260.1675 57.78528   1.5  0.89750481  0.38560677
## 728  260.2619 57.83336   1.2  0.67802620  0.30929184
## 729  260.2619 57.83336   1.2  0.67802620  0.30929184
## 730  260.2619 57.83336   1.6  0.67802620  0.30929184
## 731  260.2619 57.83336   2.1  0.67802620  0.30929184
## 732  260.2619 57.83336   1.5  0.67802620  0.30929184
## 733  260.2619 57.83336   1.4  0.67802620  0.30929184
## 734  260.2619 57.83336   1.2  0.67802620  0.30929184
## 735  260.2619 57.83336   1.4  0.67802620  0.30929184
## 736  260.2619 57.83336   1.8  0.67802620  0.30929184
## 737  260.5672 57.83428   4.7  0.24710846  0.15508842
## 738  260.1472 57.90206   1.3  0.69250679  0.31763649
## 739  260.1472 57.90206   1.9  0.69250679  0.31763649
## 740  260.1472 57.90206   1.7  0.69250679  0.31763649
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## 744  260.1472 57.90206   2.3  0.69250679  0.31763649
## 745  260.1472 57.90206   1.6  0.69250679  0.31763649
## 746  260.1472 57.90206   1.3  0.69250679  0.31763649
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## 748  260.1680 57.93836   0.9  0.73916435  0.36306381
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## 750  260.1141 57.94789   0.8  0.91623688  0.41305351
## 751  260.1008 58.18900   1.4  0.64580917  0.30917168
## 752  260.1008 58.18900   2.1  0.64580917  0.30917168
## 753  260.1008 58.18900   2.2  0.64580917  0.30917168
## 754  260.1502 58.39472   4.8  0.75388336  0.30025101
## 755  260.1502 58.39472   5.5  0.75388336  0.30025101
## 756  260.1502 58.39472   5.4  0.75388336  0.30025101
## 757  259.9820 58.19147   1.8  0.43862152  0.17453766
## 758  259.9820 58.19147   2.2  0.43862152  0.17453766
## 759  259.8455 58.39475   1.4  0.68060493  0.31580353
## 760  259.8455 58.39475   3.1  0.68060493  0.31580353
## 761  259.8455 58.39475   1.9  0.68060493  0.31580353
## 762  259.8455 58.39475   2.3  0.68060493  0.31580353
## 763  259.8455 58.39475   1.8  0.68060493  0.31580353
## 764  260.0459 57.94603   1.8  0.73183060  0.32106590
## 765  259.9912 58.02225   2.2  0.68133163  0.31516266
## 766  259.9438 58.10925   2.8  0.70810127  0.32063484
## 767  259.7811 58.09694   1.7  0.34258080  0.17839622
## 768  259.8924 58.00867   2.8  0.66328239  0.32960320
## 769  259.8924 58.00867   2.1  0.66328239  0.32960320
## 770  259.8924 58.00867   1.8  0.66328239  0.32960320
## 771  259.8924 58.00867   2.0  0.66328239  0.32960320
## 772  259.8924 58.00867   1.3  0.66328239  0.32960320
## 773  259.8924 58.00867   2.0  0.66328239  0.32960320
## 774  259.8924 58.00867   1.6  0.66328239  0.32960320
## 775  259.8924 58.00867   1.9  0.66328239  0.32960320
## 776  259.8924 58.00867   1.0  0.66328239  0.32960320
## 777  259.8924 58.00867   1.0  0.66328239  0.32960320
## 778  259.8924 58.00867   1.3  0.66328239  0.32960320
## 779  259.8924 58.00867   2.0  0.66328239  0.32960320
## 780  259.6144 58.01275   3.1  0.35403442  0.13943672
## 781  259.9360 57.95600   3.8  0.66447830  0.32501602
```

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## 782  259.7822 58.00547   3.1  0.65384674  0.26908493
## 783  259.7822 58.00547   2.1  0.65384674  0.26908493
## 784  259.7822 58.00547   2.3  0.65384674  0.26908493
## 785  259.7822 58.00547   1.0  0.65384674  0.26908493
## 786  259.7822 58.00547   1.2  0.65384674  0.26908493
## 787  259.7822 58.00547   1.1  0.65384674  0.26908493
## 788  259.7822 58.00547   1.8  0.65384674  0.26908493
## 789  259.7822 58.00547   1.4  0.65384674  0.26908493
## 790  259.7822 58.00547   1.6  0.65384674  0.26908493
## 791  259.7822 58.00547   1.6  0.65384674  0.26908493
## 792  259.8455 57.92517   1.2  0.74969101  0.31601143
## 793  259.8019 57.93969   2.5  0.69118118  0.25874329
## 794  259.8019 57.93969   3.3  0.69118118  0.25874329
## 795  259.8019 57.93969   3.0  0.69118118  0.25874329
## 796  259.8019 57.93969   2.2  0.69118118  0.25874329
## 797  259.8019 57.93969   2.3  0.69118118  0.25874329
## 798  259.8019 57.93969   2.0  0.69118118  0.25874329
## 799  259.8019 57.93969   1.4  0.69118118  0.25874329
## 800  259.8019 57.93969   1.1  0.69118118  0.25874329
## 801  259.8019 57.93969   2.1  0.69118118  0.25874329
## 802  259.8019 57.93969   2.1  0.69118118  0.25874329
## 803  259.2925 57.97347   1.5  0.54086113  0.30587578
## 804  259.6273 57.86297   1.7  0.75760269  0.30782890
## 805  259.6273 57.86297   0.9  0.75760269  0.30782890
## 806  259.3702 57.82206   2.2  0.45999146  0.33425331
## 807  259.9852 57.51992   3.9  0.30888939  0.10193253
## 808  259.9852 57.51992   4.0  0.30888939  0.10193253
## 809  260.0642 57.89175   2.0  0.64952850  0.30388069
## 810  260.0687 57.81122   1.8  0.63745880  0.28117180
## 811  260.2459 57.80447   4.1  0.63836288  0.26327133
## 812  260.1655 57.84725   1.2  0.75899506  0.23909950
## 813  260.2258 57.86653   3.6  0.69325066  0.24668884
## 814  260.3112 57.86953   1.2  0.88734055  0.35954475
## 815  260.8801 57.74172   3.9  0.59706497  0.24794960
## 816  260.3076 57.87939   1.1  0.71434593  0.30902100
## 817  260.3076 57.87939   1.3  0.71434593  0.30902100
## 818  260.1004 57.92094   1.4  0.68084526  0.31323624
## 819  260.1004 57.92094   1.4  0.68084526  0.31323624
## 820  260.1004 57.92094   1.3  0.68084526  0.31323624
## 821  260.1004 57.92094   1.2  0.68084526  0.31323624
## 822  260.1004 57.92094   1.4  0.68084526  0.31323624
## 823  260.1004 57.92094   1.5  0.68084526  0.31323624
## 824  260.1004 57.92094   1.0  0.68084526  0.31323624
## 825  260.1004 57.92094   1.6  0.68084526  0.31323624
## 826  260.7913 58.01172   4.4  0.37700844  0.14198303
## 827  260.1008 57.94053   1.4  0.69291687  0.35286331
## 828  260.1267 57.96817   1.1  0.65781403  0.32453346
## 829  260.4432 58.12575   4.3  0.26459503  0.05171585
## 830  260.2817 58.28281   4.6  0.62628174  0.26019287
## 831  260.2817 58.28281   5.4  0.62628174  0.26019287
## 832  260.2467 58.08964   3.4  0.19587135  0.08532524
## 833  260.0988 58.09006   1.4  0.69013023  0.31249237
## 834  260.0988 58.09006   0.9  0.69013023  0.31249237
## 835  260.2166 58.25044   1.6  0.24480057  0.05775642
## 836  260.0437 57.97244   1.0  0.77676010  0.36155319
## 837  260.0389 58.13117   2.5  0.45859528  0.22583199
## 838  259.9302 58.16614   2.1  0.38453102  0.15693092
## 839  259.8380 58.13106   3.8  0.65280533  0.30008888
## 840  259.7522 57.99328   1.7  0.65457344  0.28711319
## 841  259.8417 57.98408   1.6  0.58363914  0.30987740
## 842  260.0280 57.93103   1.7  0.56468582  0.31917572
## 843  259.6530 58.04522   3.2  0.63303757  0.29171371
## 844  259.2945 57.99469   3.4  0.65475845  0.25393677
## 845  259.3325 57.96094   2.1  0.63900948  0.28240204
## 846  259.3325 57.96094   1.2  0.63900948  0.28240204
## 847  259.3325 57.96094   1.0  0.63900948  0.28240204
## 848  259.8736 57.90983   2.3  0.71291733  0.26021767
## 849  259.5033 57.85661   2.5  0.40353203  0.18432426
## 850  259.7212 57.92208   1.8  0.67902565  0.30389023
## 851  259.8078 57.86528   3.0  0.67094612  0.32512474
## 852  259.8078 57.86528   2.2  0.67094612  0.32512474
## 853  259.8078 57.86528   1.4  0.67094612  0.32512474
## 854  259.8078 57.86528   1.1  0.67094612  0.32512474
## 855  259.8078 57.86528   1.5  0.67094612  0.32512474
## 856  259.8078 57.86528   1.6  0.67094612  0.32512474
## 857  259.8078 57.86528   2.3  0.67094612  0.32512474
## 858  259.5448 57.84194   2.1  0.70445061  0.23017311
## 859  259.5448 57.84194   2.6  0.70445061  0.23017311
## 860  259.5448 57.84194   1.2  0.70445061  0.23017311
```

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## 861  259.2740 57.70583   4.6  0.39105034  0.18604469
## 862  259.2740 57.70583   4.8  0.39105034  0.18604469
## 863  259.2740 57.70583   4.8  0.39105034  0.18604469
## 864  259.2740 57.70583   2.9  0.39105034  0.18604469
## 865  259.5542 57.71294   2.0  0.77323532  0.35245705
## 866  259.5542 57.71294   2.0  0.77323532  0.35245705
## 867  259.5542 57.71294   1.0  0.77323532  0.35245705
## 868  259.5542 57.71294   1.2  0.77323532  0.35245705
## 869  259.7680 57.78575   1.9  0.64435768  0.30017662
## 870  259.7684 57.74744   3.6  0.32037735  0.14903831
## 871  259.7684 57.74744   3.0  0.32037735  0.14903831
## 872  260.0023 57.88239   2.5  0.70261383  0.36455154
## 873  260.0023 57.88239   2.4  0.70261383  0.36455154
## 874  260.0023 57.88239   2.5  0.70261383  0.36455154
## 875  260.0023 57.88239   3.0  0.70261383  0.36455154
## 876  260.0023 57.88239   2.7  0.70261383  0.36455154
## 877  260.0023 57.88239   2.2  0.70261383  0.36455154
## 878  260.0023 57.88239   2.1  0.70261383  0.36455154
## 879  260.0309 57.88669   1.8  0.64813042  0.31763077
## 880  258.2805 57.65767   5.0  0.65117645  0.24465752
## 881  258.7510 57.70108   4.8  0.58491707  0.08936119
## 882  258.9002 57.80956   2.7  0.64855003  0.24356270
## 883  258.9002 57.80956   1.6  0.64855003  0.24356270
## 884  259.3232 57.52461   3.0  0.72328949  0.26914978
## 885  259.3232 57.52461   3.5  0.72328949  0.26914978
## 886  259.3232 57.52461   3.5  0.72328949  0.26914978
## 887  259.3232 57.52461   3.4  0.72328949  0.26914978
## 888  259.1158 57.80239   1.1  1.12220955  0.47173691
## 889  259.5665 57.80322   3.0  0.37009048  0.15006828
## 890  259.5665 57.80322   4.7  0.37009048  0.15006828
## 891  259.5433 57.86917   1.3  1.12893677  0.46115494
## 892  259.5433 57.86917   0.7  1.12893677  0.46115494
## 893  259.6898 58.08231   4.2  0.66475105  0.34161758
## 894  259.6898 58.08231   1.5  0.66475105  0.34161758
## 895  259.6898 58.08231   1.2  0.66475105  0.34161758
## 896  259.6898 58.08231   1.5  0.66475105  0.34161758
## 897  259.0066 57.98864   1.1  0.68592644  0.31751060
## 898  258.5245 57.99161   3.8  0.46386337  0.38745308
## 899  261.7186 57.74378   4.6  0.64982224  0.26944733
## 900  261.7355 58.22667   3.1  0.31047440  0.09817505
## 901  261.2838 57.92397   4.4  0.37801933  0.19719887
## 902  261.2838 57.92397   3.0  0.37801933  0.19719887
## 903  261.5455 58.18492   3.1  0.42830467  0.21959686
## 904  261.3912 58.11586   2.9  0.39737892  0.19390678
## 905  261.2232 58.29106   1.3  0.67101097  0.28913307
## 906  261.2232 58.29106   2.0  0.67101097  0.28913307
## 907  261.2232 58.29106   3.3  0.67101097  0.28913307
## 908  261.1889 57.91392   4.2  0.28682137  0.09980011
## 909  261.1889 57.91392   4.3  0.28682137  0.09980011
## 910  260.5272 57.93617   1.2  0.64906311  0.30994797
## 911  260.7033 57.52231   4.4  0.30264854  0.12710953
## 912  260.7033 57.52231   2.1  0.30264854  0.12710953
## 913  260.6995 57.49989   3.4  0.40157700  0.23290443
## 914  260.0660 57.91744   1.9  0.57993126  0.33145714
## 915  260.0519 57.91453   1.2  0.55691528  0.29848099
## 916  260.1271 57.91756   3.0  0.68851662  0.33779144
## 917  260.1150 58.33094   2.8  0.65543365  0.28870773
## 918  260.5075 58.06383   2.1  0.55888176  0.27929115
## 919  260.8550 58.43894   3.4  0.34402084  0.10863304
## 920  260.8550 58.43894   2.1  0.34402084  0.10863304
## 921  259.5267 58.51378   4.9  0.57157135  0.23225594
## 922  259.4585 58.15000   2.6  0.32727432  0.07814789
## 923  259.4585 58.15000   3.6  0.32727432  0.07814789
## 924  259.9035 58.23400   1.7  0.32727623  0.14416504
## 925  259.9035 58.23400   2.3  0.32727623  0.14416504
## 926  259.8153 58.02825   2.2  0.43884659  0.12522125
## 927  260.6877 57.34681   4.5  0.67435646  0.22110367
## 928  260.6877 57.34681   5.2  0.67435646  0.22110367
## 929  260.5654 57.48831   4.2  0.23467827  0.17725182
## 930  260.3208 57.85831   4.7  0.59104919  0.24678040
## 931  260.2582 57.88056   1.4  0.60839844  0.29500771
## 932  260.2351 57.65772   2.9  0.42682457  0.12015915
## 933  260.2351 57.65772   4.0  0.42682457  0.12015915
## 934  260.2351 57.65772   4.7  0.42682457  0.12015915
## 935  260.2351 57.65772   4.6  0.42682457  0.12015915
## 936  260.2351 57.65772   3.3  0.42682457  0.12015915
## 937  260.1551 57.79089   1.7  0.51238823  0.28207397
## 938  260.0288 57.87697   1.0  0.83531189  0.38803101
## 939  259.8980 57.90311   3.4  0.64473534  0.18689346
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## 940  259.3305 57.71600   1.7  0.57158661  0.29011917
## 941  259.5107 57.44872   4.2  0.53791809  0.26216125
## 942  259.1983 57.32761   4.2  0.41134453  0.01573181
## 943  259.7024 57.21461   4.6  0.39676666  0.20845032
## 944  259.7024 57.21461   3.8  0.39676666  0.20845032
## 945  259.5411 57.00942   5.1  0.65652466  0.25141335
## 946  259.5411 57.00942   4.9  0.65652466  0.25141335
## 947  259.7330 57.08486   4.6  0.29359627  0.07704926
## 948  259.8066 57.89994   2.2  0.41400146  0.17473412
## 949  259.7928 57.91042   1.5  0.70243073  0.29490471
## 950  259.7928 57.91042   1.4  0.70243073  0.29490471
## 951  259.7928 57.91042   1.3  0.70243073  0.29490471
## 952  259.7928 57.91042   1.1  0.70243073  0.29490471
## 953  259.7928 57.91042   0.9  0.70243073  0.29490471
## 954  259.7928 57.91042   3.8  0.70243073  0.29490471
## 955  259.7928 57.91042   1.1  0.70243073  0.29490471
## 956  259.6687 57.91092   2.4  0.66754532  0.23920250
## 957  259.6687 57.91092   1.2  0.66754532  0.23920250
## 958  259.7271 57.83486   2.0  0.59272957  0.25916672
## 959  259.7271 57.83486   1.8  0.59272957  0.25916672
## 960  259.7531 57.84806   4.8  0.38560677  0.13603210
## 961  259.9737 57.89419   2.2  0.62891006  0.32492828
## 962  259.7912 57.70417   1.6  0.27634811  0.16134071
## 963  259.9207 57.80094   3.6  0.38419151  0.18757820
## 964  259.9981 57.61608   4.9  0.28702736  0.09173584
## 965  260.0683 57.71772   3.7  0.57129860  0.27518272
## 966  260.0683 57.71772   5.0  0.57129860  0.27518272
## 967  260.0683 57.71772   5.0  0.57129860  0.27518272
## 968  260.0683 57.71772   5.0  0.57129860  0.27518272
## 969  260.2248 57.79981   2.2  0.60174751  0.27832413
## 970  260.2248 57.79981   1.7  0.60174751  0.27832413
## 971  260.2933 57.79814   1.2  0.78612709  0.32612038
## 972  260.2933 57.79814   1.3  0.78612709  0.32612038
## 973  260.2978 57.74103   1.6  0.35596848  0.17537498
## 974  260.2978 57.74103   2.6  0.35596848  0.17537498
## 975  260.1100 57.90286   1.2  0.35443687  0.20000648
## 976  260.1100 57.90286   1.5  0.35443687  0.20000648
## 977  260.3795 57.88081   2.1  0.41489601  0.18414879
## 978  260.5975 57.97425   4.2  0.54207802  0.30227852
## 979  260.6562 57.99314   4.8  0.54243851  0.26979446
## 980  260.6562 57.99314   5.0  0.54243851  0.26979446
## 981  260.6562 57.99314   4.7  0.54243851  0.26979446
## 982  260.1845 57.92397   1.9  0.56791496  0.31138039
## 983  260.5095 58.02147   2.0  0.61325836  0.28640556
## 984  260.1711 57.97378   2.0  0.69469070  0.33794022
## 985  260.1711 57.97378   1.1  0.69469070  0.33794022
## 986  260.0844 57.93589   2.8  0.56522942  0.31495667
## 987  260.1335 58.01767   2.5  0.37483025  0.17300987
## 988  260.2139 58.09458   1.9  0.54262352  0.25244141
## 989  260.0830 57.98817   2.0 -0.10404587  1.12239647
## 990  260.0830 57.98817   1.2 -0.10404587  1.12239647
## 991  260.0830 57.98817   1.2 -0.10404587  1.12239647
## 992  260.0830 57.98817   1.7 -0.10404587  1.12239647
## 993  260.0830 57.98817   1.9 -0.10404587  1.12239647
## 994  260.0830 57.98817   1.2 -0.10404587  1.12239647
## 995  260.0830 57.98817   2.6 -0.10404587  1.12239647
## 996  260.0830 57.98817   1.2 -0.10404587  1.12239647
## 997  260.0558 57.99569   4.3  0.61482239  0.29531479
## 998  260.0235 57.96625   3.6  0.65643883  0.27931213
## 999  260.0220 57.98997   2.1  0.44140244  0.23306274
## 1000 259.9742 57.99992   2.7  0.61164856  0.30754852
## 1001 259.9742 57.99992   1.1  0.61164856  0.30754852
## 1002 259.9017 58.02433   2.3  0.28576660  0.12979126
## 1003 259.8447 58.02025   1.8  0.52378845  0.34444237
## 1004 259.8885 57.94389   2.4  0.81486130  0.14576530
## 1005 259.4997 57.94492   2.9  0.73783493  0.14740944
## 1006 259.4997 57.94492   2.6  0.73783493  0.14740944
## 1007 260.0683 57.91578   2.0  0.56536102  0.35795212
## 1008 260.0683 57.91578   1.8  0.56536102  0.35795212
## 1009 260.0683 57.91578   2.1  0.56536102  0.35795212
## 1010 260.4801 57.94981   2.1  0.59368706  0.34624100
## 1011 260.4801 57.94981   2.0  0.59368706  0.34624100
## 1012 260.4801 57.94981   1.6  0.59368706  0.34624100
## 1013 260.0631 57.94303   2.0  0.59064674  0.25499344
## 1014 260.0631 57.94303   1.3  0.59064674  0.25499344
## 1015 260.1134 57.95944   2.1  0.35802078  0.25939560
## 1016 260.1134 57.95944   2.5  0.35802078  0.25939560
## 1017 260.0153 57.96386   2.0  0.28926659  0.23263359
## 1018 259.6468 57.86325   2.7  0.38429832  0.15165138
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## 1019 259.7591 57.79844   1.9  0.22505760  0.13043213
## 1020 260.0924 57.69775   2.0  0.29605865  0.17872047
## 1021 260.1153 57.85019   3.8  0.45790672  0.15989876
## 1022 260.0893 57.79619   3.2  0.24893761  0.13834381
## 1023 260.0893 57.79619   3.1  0.24893761  0.13834381
## 1024 260.2239 57.82503   1.7  0.62083054  0.29404068
## 1025 260.2239 57.82503   1.4  0.62083054  0.29404068
## 1026 260.1253 57.89636   1.6  0.36626816  0.23325729
## 1027 260.5997 57.76808   3.0  0.42317963  0.13891220
## 1028 260.5997 57.76808   3.2  0.42317963  0.13891220
## 1029 260.1651 57.88547   1.4  0.55125427  0.28437042
## 1030 260.4622 57.91058   2.1  0.62071228  0.32551193
## 1031 260.4622 57.91058   2.7  0.62071228  0.32551193
## 1032 260.4622 57.91058   2.4  0.62071228  0.32551193
## 1033 260.4581 57.97142   2.5  0.55478287  0.25774574
## 1034 260.2032 57.95406   1.5  0.59352875  0.27423096
## 1035 260.1952 57.96064   2.5  0.23233604  0.10155296
## 1036 260.2008 57.98472   1.5  0.27241707  0.13571930
## 1037 260.2008 57.98472   1.9  0.27241707  0.13571930
## 1038 260.2008 57.98472   2.7  0.27241707  0.13571930
## 1039 260.1597 57.97419   1.3  0.40634537  0.21530151
## 1040 260.1536 57.98214   2.2  0.56649208  0.28084183
## 1041 260.0833 58.01503   1.7  0.57629967  0.30526161
## 1042 260.0770 58.07667   1.5  0.34995842  0.16117096
## 1043 260.0770 58.07667   3.8  0.34995842  0.16117096
## 1044 260.0770 58.07667   4.3  0.34995842  0.16117096
## 1045 260.0275 58.07686   1.8  0.57716751  0.27949715
## 1046 260.1074 58.21339   4.1  0.60159683  0.21574020
## 1047 260.0245 57.99731   1.2  0.31882286  0.17905617
## 1048 260.0360 57.99919   1.2  0.57121658  0.28748131
## 1049 259.9609 57.98036   2.3  0.59111023  0.30720711
## 1050 259.9497 57.93744   2.2  0.44920349  0.18783569
## 1051 259.9894 57.94114   2.0  0.67632484  0.25411224
## 1052 259.6923 57.93522   3.2  0.62956238  0.19920349
## 1053 259.6462 57.94847   3.6  0.40685272  0.21672249
## 1054 259.6462 57.94847   2.1  0.40685272  0.21672249
## 1055 259.8515 57.92164   2.4  0.66430855  0.25372314
## 1056 259.9212 57.90936   2.4  0.48513222  0.16385841
## 1057 260.0267 57.92619   2.2  0.63691711  0.25628853
## 1058 259.7843 57.88011   2.8  0.38228989  0.13451576
## 1059 259.9830 57.85681   3.0  0.59696198  0.26942635
## 1060 259.9830 57.85681   1.3  0.59696198  0.26942635
## 1061 259.9830 57.85681   2.0  0.59696198  0.26942635
## 1062 259.9830 57.85681   1.6  0.59696198  0.26942635
## 1063 259.9891 57.84919   1.6  0.45102692  0.05237579
## 1064 260.1185 57.94686   1.6  0.63111877  0.19229507
## 1065 260.1185 57.94686   2.2  0.63111877  0.19229507
## 1066 260.1619 57.78356   2.6  0.61648941  0.26922989
## 1067 260.1191 57.86044   2.1  0.57334137  0.23367119
## 1068 260.2188 57.91961   1.9  0.57575798  0.35272598
## 1069 260.2188 57.91961   2.2  0.57575798  0.35272598
## 1070 260.2188 57.91961   3.3  0.57575798  0.35272598
## 1071 260.3526 57.88153   2.3  0.35070610  0.11173630
## 1072 260.1633 57.93264   1.8  0.50252533  0.30117798
## 1073 260.1597 57.92564   1.5  0.60785294  0.29214287
## 1074 260.4126 57.96533   1.1  0.54673195  0.31341171
## 1075 260.2243 57.96183   2.6  0.25314522  0.08857918
## 1076 260.7650 58.12217   4.8  0.38500214  0.15085793
## 1077 260.7650 58.12217   3.6  0.38500214  0.15085793
## 1078 260.7650 58.12217   3.2  0.38500214  0.15085793
## 1079 260.2821 58.00583   2.4  0.57438850  0.25391769
## 1080 260.1103 57.99369   4.0  0.40599251  0.16079140
## 1081 260.1153 58.01653   2.4  0.43230438  0.21142197
## 1082 260.0748 57.99661   2.2  0.58058357  0.28410721
## 1083 260.0217 57.95622   2.1  0.63084030  0.25372314
## 1084 260.0239 57.93597   2.0  0.37366867  0.15577126
## 1085 259.5131 57.94331   1.8  0.67380714  0.29069328
## 1086 259.5131 57.94331   1.0  0.67380714  0.29069328
## 1087 259.6423 57.92403   2.2  0.62027168  0.21966934
## 1088 259.6855 57.91061   2.0  0.81442451  0.35430908
## 1089 259.9807 57.91650   1.3  0.62768936  0.29724693
## 1090 259.9764 57.85622   2.7  0.56783676  0.25516129
## 1091 260.0332 57.89794   1.4  0.53702164  0.36382675
## 1092 259.9356 57.81419   4.1  0.68092346  0.08615875
## 1093 260.2258 57.92219   1.7  0.63592911  0.29500961
## 1094 260.2238 57.97017   1.3  0.86620140  0.39246368
## 1095 259.9674 57.98586   2.7  0.24750900  0.10113335
## 1096 259.8409 58.03117   0.9  0.84214973  0.34986115
## 1097 259.8409 58.03117   1.4  0.84214973  0.34986115
```

```
## 1098 259.8191 57.98894   1.3  0.55300713  0.27350426
## 1099 259.7285 57.92064   2.9  0.23566437  0.13267136
## 1100 259.1486 57.83381   4.9  0.66750908  0.30338097
## 1101 259.8522 57.89336   3.3  0.30833054  0.10630798
## 1102 260.0405 57.91383   2.6  0.53311348  0.33549309
## 1103 260.1237 57.87275   2.1  0.42195129  0.20590782
## 1104 260.1997 57.86058   2.3  0.69148064  0.27349663
## 1105 260.3222 57.77581   3.8  0.39308357  0.16311264
## 1106 261.3758 57.68950   3.1  0.55866051  0.17373466
## 1107 261.1615 58.20194   4.6  0.58983994  0.16581535
## 1108 260.9440 58.38806   3.4  0.28084373  0.05775070
## 1109 260.7145 58.33981   3.1  0.52088165  0.31396484
## 1110 260.3083 58.42139   4.8  0.48251915  0.17665672
## 1111 259.9591 58.15167   4.9  0.32332611  0.22837639
## 1112 259.9152 57.93081   1.9  0.64923096  0.28376770
## 1113 259.9970 57.95050   2.5  0.60677910  0.34574318
## 1114 259.7048 57.75819   3.4  0.45602036  0.12701416
## 1115 260.0998 57.92681   1.7  0.64742279  0.30416489
## 1116 259.8809 57.91767   2.0  0.63536835  0.25561523
## 1117 260.1594 57.91342   1.6  0.56780434  0.34091568
## 1118 260.1594 57.91342   1.6  0.56780434  0.34091568
## 1119 259.8107 57.92294   2.1  0.40620995  0.09693146
## 1120 259.9639 57.88908   4.6  0.22575569  0.17029572
## 1121 259.9699 57.98158   1.5  0.47586632  0.38547897
## 1122 259.9460 57.96411   2.1  0.38063049  0.22287941
## 1123 259.8011 58.04939   0.9  1.01479721  0.44245529
## 1124 259.8011 58.04939   0.9  1.01479721  0.44245529
## 1125 259.8011 58.04939   1.0  1.01479721  0.44245529
## 1126 259.4481 57.90778   1.7  0.29578018  0.24941444
## 1127 259.4807 57.93308   1.1  0.77624893  0.36446762
## 1128 259.4807 57.93308   1.0  0.77624893  0.36446762
## 1129 259.4807 57.93308   1.2  0.77624893  0.36446762
## 1130 259.4311 57.95431   2.4  0.56394768  0.32387543
## 1131 259.2446 58.24353   2.5  0.41235542  0.20008278
## 1132 258.6842 57.82433   2.9  0.39476585  0.08314705
## 1133 258.6842 57.82433   4.2  0.39476585  0.08314705
## 1134 258.9248 57.61819   2.8  0.60663223  0.26401520
## 1135 258.9248 57.61819   2.4  0.60663223  0.26401520
## 1136 259.0511 57.49600   4.9  0.46627235  0.11617661
## 1137 260.7901 57.14606   5.3  0.62637520  0.25293541
## 1138 260.9027 57.20306   4.9  0.75873947  0.28132820
## 1139 261.0488 57.29119   4.4  0.40688705  0.20491409
## 1140 260.6603 57.41731   2.9  0.36276817  0.18904305
## 1141 259.8843 56.83700   5.3  0.59798241  0.29902840
## 1142 260.1042 57.74194   3.7  0.33727837  0.19704628
## 1143 260.1042 57.74194   2.8  0.33727837  0.19704628
## 1144 260.2686 57.78828   2.3  0.38417435  0.20376587
## 1145 260.3275 57.79547   3.7  0.13426971  0.02471924
## 1146 260.3275 57.79547   4.0  0.13426971  0.02471924
## 1147 260.1872 57.84294   2.0  0.44603539  0.14810753
## 1148 260.1872 57.84294   1.2  0.44603539  0.14810753
## 1149 260.7812 57.89872   2.2 -0.03148460 -0.15444946
## 1150 260.3992 57.91831   1.7  0.71808624 -0.30500221
## 1151 260.3992 57.91831   2.9  0.71808624 -0.30500221
## 1152 260.1970 57.92300   2.1  0.08450699  0.05980492
## 1153 260.1970 57.92300   2.0  0.08450699  0.05980492
## 1154 260.3849 58.16272   2.3  0.21219635 -0.08361053
## 1155 260.3849 58.16272   2.2  0.21219635 -0.08361053
## 1156 260.1718 58.01047   2.0  0.35376549  0.25533867
## 1157 260.0845 57.97750   2.2  0.05682755  0.46294594
## 1158 260.0845 57.97750   1.9  0.05682755  0.46294594
## 1159 260.0900 57.90853   2.0  0.19952583  0.10103989
## 1160 259.8727 57.97372   4.8  0.14979172  0.11343002
## 1161 259.7707 58.05833   5.0  0.18426895  0.12249756
## 1162 259.5430 58.02989   4.6  0.20358849  0.13452339
## 1163 259.9274 57.91375   2.4  0.37978363  0.15625381
## 1164 259.8454 57.90322   3.2  0.23659706  0.01949692
## 1165 260.6431 58.80189   2.0  0.31889915  0.11069870
## 1166 260.0397 58.86397   4.9  0.70664406  0.25094414
## 1167 260.0397 58.86397   4.9  0.70664406  0.25094414
## 1168 259.8745 58.91147   4.7  0.36922646  0.14573669
## 1169 259.8598 58.91150   4.7  0.58654976  0.22848129
## 1170 259.8453 58.72089   4.6  0.44983292  0.33148003
## 1171 259.5552 59.00986   4.4  0.26750755  0.16476631
## 1172 259.1689 58.70806   4.9  0.66275597  0.25877762
## 1173 259.4759 58.49194   4.0  0.46578407  0.27298546
## 1174 260.1585 57.96267   2.0  0.45788765  0.09116936
## 1175 260.1289 57.96492   2.3  0.59844589  0.26576042
## 1176 260.1289 57.96492   2.6  0.59844589  0.26576042
```

```
## 1177 260.0617 57.94042   1.6  0.70018578  0.33297539
## 1178 260.0617 57.94042   1.2  0.70018578  0.33297539
## 1179 260.1198 58.06639   2.3  0.62122917  0.23801422
## 1180 260.1198 58.06639   1.7  0.62122917  0.23801422
## 1181 260.0260 57.93836   1.5  0.55934715  0.23203278
## 1182 259.8539 58.04147   1.9  0.59129333  0.29318619
## 1183 259.8539 58.04147   2.3  0.59129333  0.29318619
## 1184 259.9758 57.96239   3.4  0.52045250  0.31942177
## 1185 259.9162 57.92372   3.2  0.56167984  0.17427254
## 1186 260.0029 57.90850   3.1  0.43910980  0.23629189
## 1187 260.0442 57.89656   3.6  0.51138306  0.34735680
## 1188 260.0715 57.91272   3.1  0.55453491  0.32967949
## 1189 260.1480 57.88722   2.4  0.59227943  0.28591347
## 1190 260.1480 57.88722   2.3  0.59227943  0.28591347
## 1191 260.1991 57.89006   2.2  0.62764931  0.29909515
## 1192 260.1991 57.89006   2.4  0.62764931  0.29909515
## 1193 260.0589 57.88039   2.8  0.55864525  0.29206085
## 1194 260.1135 57.91564   1.6  0.58540154  0.29883194
## 1195 260.3576 57.97186   1.4  0.59562302  0.26181030
## 1196 260.0063 58.02594   1.3  0.69054222  0.31860924
## 1197 259.2860 57.99742   4.6  0.56952667  0.26376534
## 1198 259.9678 57.88625   2.3  0.38060760  0.18442535
## 1199 259.2777 57.12828   5.2  0.72578049  0.25544357
## 1200 260.4824 58.03522   2.6  0.56866455  0.31271935
## 1201 261.6599 58.32167   3.2  0.44890022  0.11002159
## 1202 261.6599 58.32167   4.7  0.44890022  0.11002159
## 1203 262.0058 58.41808   5.2  0.60265732  0.29080391
## 1204 262.0058 58.41808   4.2  0.60265732  0.29080391
## 1205 262.2543 58.49175   3.2  0.69636917  0.20091248
## 1206 262.0333 58.88564   3.1  0.40287590  0.13957214
## 1207 262.0333 58.88564   3.7  0.40287590  0.13957214
## 1208 261.2489 58.79769   2.1  0.35200691  0.02413177
## 1209 261.5601 58.45803   5.1  0.64811707  0.23630142
## 1210 261.5108 58.37542   4.8  0.56845856  0.24068069
## 1211 261.5755 58.37083   3.3  0.65147591  0.24575806
## 1212 261.5755 58.37083   2.6  0.65147591  0.24575806
## 1213 258.7928 57.27197   3.6  0.65340996  0.25830650
## 1214 259.0558 57.75422   2.2  0.60552788  0.27838516
## 1215 258.9083 57.75117   1.7  0.56382751  0.25949669
## 1216 259.0976 57.83408   4.7  0.43459702  0.17978668
## 1217 257.7619 57.78469   3.5  0.51648521  0.31920433
## 1218 258.1173 57.26142   4.0  0.43073463  0.19822502
```

```
#df %>% mutate(.,mass.linear=10^mass) %>% select(.,mass,mass.linear) %>% arrange(.,mass) %>% head(.,3)
```

Question 2

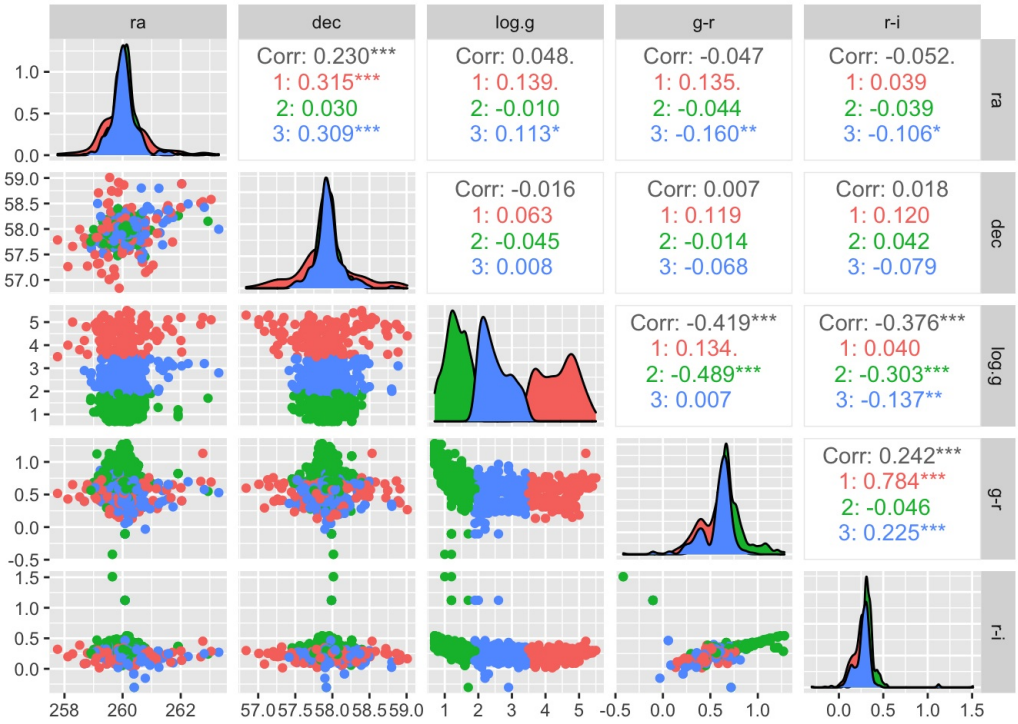
Use the `kmeans()` function to cluster the data in your data frame. Try different values for K, and finally display results for what *you* would choose as its optimal value. The default for `nstart` is 1; that should be increased to something larger…play with the values for this argument. Display the results using `ggpairs()`, and briefly comment on your interpretation of the results. Pass this argument to `ggpairs()`: `mapping=aes(color=factor(km.out$cluster))`, where `km.out` is the output from K-means, and `cluster` is the number of the cluster to which a datum has been assigned. Hint: if it looks like there are "strips" in `log.g`, you have probably done something wrong. Ruminate on what that might be. Finally ask me if you cannot figure out what might be wrong. Also, note that `kmeans()` utilizes random sampling, so you should absolutely set a random number seed immediately before calling `kmeans()` to enforce reproducibility!

```
library(ggplot2)
library(GGally)
```

```
## Registered S3 method overwritten by 'GGally':
##   method from
##   +.gg   ggplot2
```

```
set.seed(101)
km.out <- kmeans(df.new,3,nstart=20)
color = km.out$cluster

ggpairs(df.new,mapping=aes(color=factor(km.out$cluster)), progress=FALSE )
```




```
It seems there are three clusters
```

Question 3

For your final run of K-means, what are the number of groups and the number of data in each group? Also, what is ratio of the between-cluster sum-of-squares to the total sum-of-squares? (This is a measure of the total variance in the data that is “explained” by clustering. Higher values [closer to 100%] are better, but beware: the larger the value of \(K\), the higher the ratio is going to be: you will be getting into the realm of overfitting.) (Hint: `print()` your saved output from `kmeans()`.)

```
print(km.out)
```

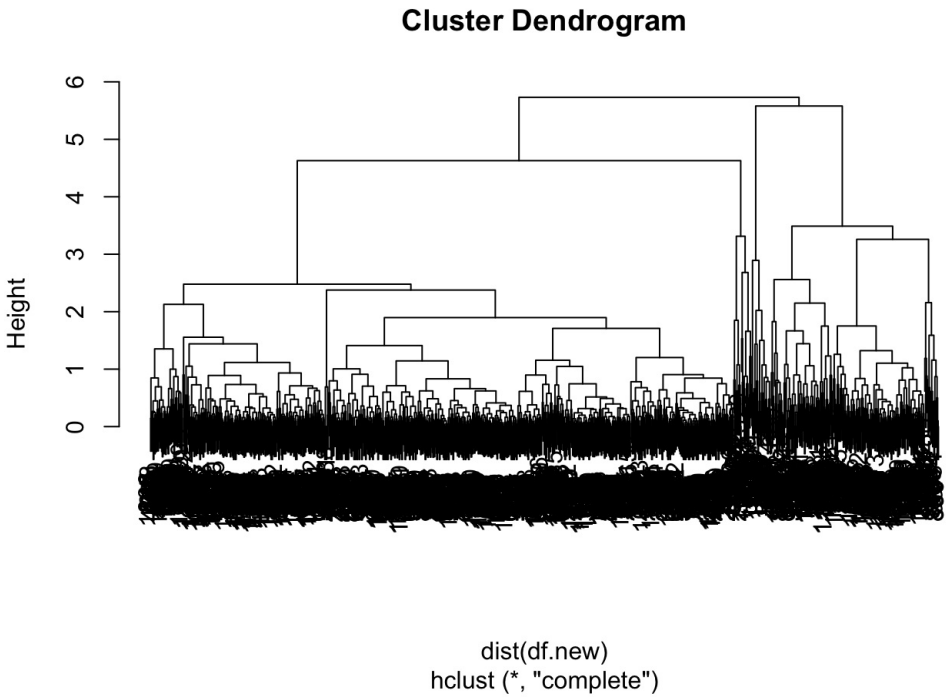
```
## K-means clustering with 3 clusters of sizes 162, 687, 369
##
## Cluster means:
##         ra      dec    log.g       g-r       r-i
## 1 260.0697 57.91672 4.387654 0.5392276 0.2328581
## 2 260.0433 57.93668 1.336536 0.7218806 0.3394231
## 3 260.0686 57.94690 2.515989 0.5725193 0.2676616
##
## Clustering vector:
##    [1] 1 1 3 2 1 2 3 2 2 2 2 2 3 2 3 3 3 2 3 3 2 2 2 3 2 3 3 3 3 3 3 2 2 2 2 2 2
##   [38] 2 3 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 2 2 3 3 2 2 2 2 2 2 2 2 3 2 2 3 2 2 2 2
##   [75] 1 1 1 1 1 2 2 3 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 1 2 3 2 3 2 2 2 2 3 2 2
##  [112] 2 2 2 2 2 3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 3 3 2 3 2 2 3 3 2 2 2 2 3 2 2 2 2
##  [149] 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 3 2 2 2 1 1 3 2 3 2 3 2 3 2 2 3 2 3 3
##  [186] 2 3 3 3 2 2 2 3 2 2 2 2 2 2 1 2 2 2 2 2 2 3 2 2 2 1 2 2 2 3 2 2 3 2 1 2 2
##  [223] 2 2 2 2 3 3 2 2 3 3 1 2 2 3 3 2 2 2 2 2 3 2 3 2 3 3 3 3 2 2 2 2 2 2 2 2 2
##  [260] 2 1 2 2 2 2 1 1 2 2 2 2 3 2 3 2 3 2 2 2 2 2 2 2 2 2 2 3 3 2 2 2 2 2 2 2 2
##  [297] 3 2 2 2 2 2 3 3 3 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 3 3 2 2 3 2 3 3 3 2 1 3 2
##  [334] 2 3 2 3 3 2 2 3 3 2 2 2 2 2 2 3 2 2 2 2 2 3 2 2 3 2 2 2 3 2 3 3 3 2 3 3 2
##  [371] 1 1 3 2 2 2 2 2 2 3 2 2 3 3 3 3 3 2 2 2 2 3 2 1 3 2 3 3 2 2 2 3 2 3 1 1 1
##  [408] 3 3 2 2 2 2 2 2 2 2 2 1 1 2 1 3 2 2 2 2 2 2 2 2 2 2 2 2 3 3 3 3 2 3 3 2 3
##  [445] 2 1 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 3 2 3 3 2 2 2 3 2 2 3 2 2 2 2 3 2 2 2 2
##  [482] 2 2 3 3 3 2 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 2 1 1 1
##  [519] 3 2 2 1 2 3 1 1 1 3 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 3 2 2 3 2 1 1 1 1 1 1
##  [556] 2 2 2 2 2 2 2 2 2 2 2 2 1 1 2 1 1 2 2 3 2 2 2 2 2 2 2 2 1 2 2 3 3 2 3 2 2
##  [593] 2 2 2 2 2 2 2 2 3 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [630] 2 3 2 3 2 3 3 2 3 2 2 1 3 3 1 2 2 2 2 2 2 2 3 1 2 2 2 2 2 3 2 2 2 2 2 2 2
##  [667] 2 3 3 3 3 2 2 2 2 2 3 2 2 3 3 1 1 1 3 2 2 2 2 3 2 2 2 3 2 2 3 2 3 2 2 2 2
##  [704] 2 2 2 2 3 2 2 3 2 2 2 2 2 2 3 3 2 2 3 3 2 2 2 2 2 2 3 2 2 2 2 2 1 2 2 2 2
##  [741] 2 2 2 3 2 2 2 2 2 2 2 3 3 1 1 1 2 3 2 3 2 3 2 2 3 3 2 3 3 2 3 2 3 2 2 2 2
##  [778] 2 3 3 1 3 3 3 2 2 2 2 2 2 2 3 3 3 3 3 3 2 2 3 3 2 2 2 3 1 1 3 2 1 2 1 2
##  [815] 1 2 2 2 2 2 2 2 2 2 2 1 2 2 1 1 1 3 2 2 2 2 3 3 1 2 2 2 3 3 3 2 2 3 3 2 3
##  [852] 3 2 2 2 2 3 3 3 2 1 1 1 3 3 3 2 2 2 1 3 3 3 3 3 3 3 3 2 1 1 3 2 3 1 1 3 2
##  [889] 3 1 2 2 1 2 2 2 2 2 1 1 3 1 3 3 3 2 3 3 1 1 2 1 3 3 2 2 3 3 3 3 3 1 3 1 2 3
##  [926] 3 1 1 1 1 2 3 1 1 1 3 2 2 3 2 1 1 1 1 1 1 3 2 2 2 2 2 1 2 3 2 3 2 1 3 2
##  [963] 1 1 1 1 1 1 3 2 2 2 2 3 2 2 3 1 1 1 1 2 3 3 2 3 3 2 3 2 2 2 3 2 3 2 1 1 3
## [1000] 3 2 3 2 3 3 3 3 2 3 3 3 2 3 2 3 3 3 3 3 3 1 3 3 2 2 2 3 3 2 3 3 3 3 2 3 2
## [1037] 3 3 2 3 2 2 1 1 2 1 2 2 3 3 3 3 1 3 3 3 3 3 3 2 3 2 2 2 3 3 3 2 3 3 3 2 2
## [1074] 2 3 1 1 3 3 1 3 3 3 3 2 2 3 3 2 3 2 1 2 2 3 2 2 2 3 1 3 3 3 3 1 3 1 3 3 1
## [1111] 1 2 3 3 2 3 2 2 3 1 2 3 2 2 2 2 2 2 2 3 3 3 1 3 3 1 1 1 1 3 1 1 3 3 1 1 3
## [1148] 2 3 2 3 3 3 3 3 3 3 3 3 1 1 1 3 3 3 1 1 1 1 1 1 1 3 3 3 2 2 3 2 2 2 3 3
## [1185] 3 3 1 3 3 3 3 3 3 2 2 2 1 3 1 3 3 1 1 1 3 3 1 3 1 1 3 3 1 3 2 1 1 1
##
## Within cluster sum of squares by cluster:
## [1] 184.6077 209.8415 191.9699
##  (between_SS / total_SS =  69.3 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
The number of groups and the number of data in each group?  3 clusters of sizes 162, 687, 369
Ratio of the between-cluster sum-of-squares to the total sum-of-squares: .693 or 69.3%
```

Question 4

Use the `hclust()` function to build a hierarchical clustering tree for your data frame, and use the basic `plot()` function to display the dendrogram. Examine different forms of linkage: which one makes for the best-looking output? (This should not be confused with: which one gives the best clustering result? Note: there is no “right” answer here; best-looking is in the eye of the statistical consultant.) Despite talking up the dendrogram in class, is this actually useful output here? Why or why not? If your client asked for a dendrogram, what step might you want to consider taking before providing one?

```
hc.out <- hclust(dist(df.new),method="complete")
plot(hc.out)
```



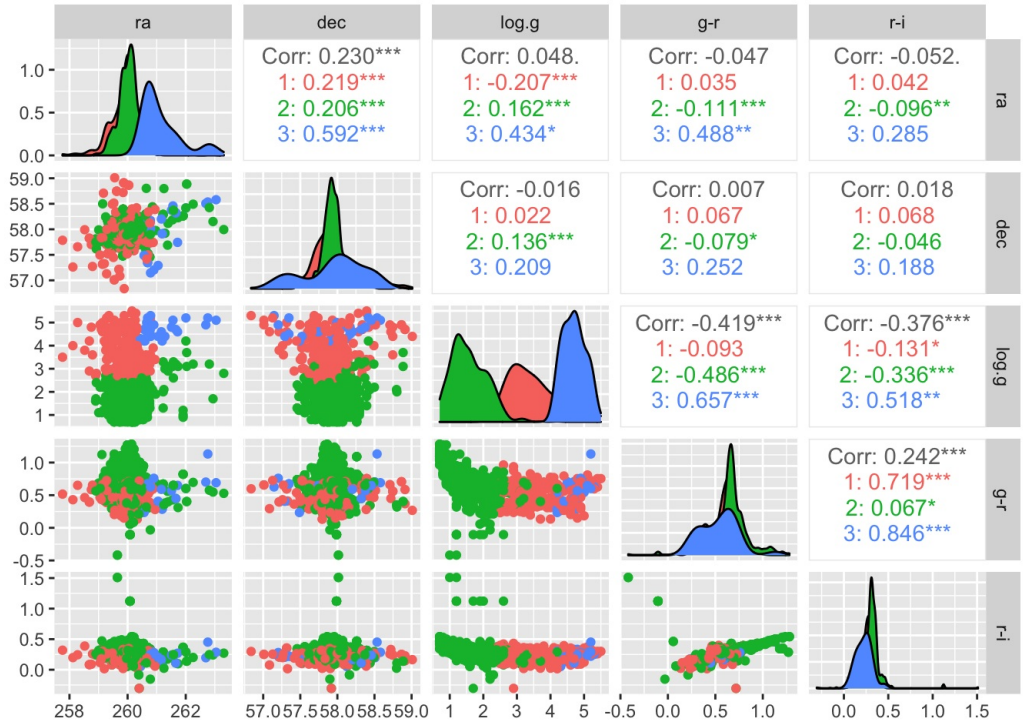

```
Dendrograms are a little hard to read with larger sample sizes so I am not sure if this is as useful in this case.
If a client asked for a dendrogram, a step that I might want to consider taking before providing one is considering
the different linkage
```

Question 5

Use the `cutree()` function to map each observation to a cluster, then use `ggpairs()` to display the clusters in a similar manner as above for K-means. Assume the same number of clusters as you did for K-means. Does the output look the same or different from K-means? Is this what you expected? Why or why not? (Hint: if `cluster` is the output from `cutree()`, then `color=factor(cluster)` will properly color each of the points.) Visualizing the output of hierarchical clustering in this manner (rather than using a dendrogram) is better when the sample size is large.

```
cut.tree <- cutree(hc.out, k= 3)

ggpairs(df.new,mapping=aes(color=factor(cut.tree)), progress=FALSE)
```




```
The output looks different from K-means. It is what I expected in the sense that I thought the results would differ
from the K-means. However I suppose I didn't expect it to be as drastically different.
```

Question 6

In your future life as a statistical consultant, you may be faced with a situation where you need to implement new methodologies for which you have no prior knowledge. In short, you have to learn on the fly. And so it will be here. In the notes, I mention Gaussian Mixture Models… so below, I want you to implement a GMM-based analysis using the `ClusterR` package. Assume *two* clusters. Your final goal is to figure out the proportions of the observations that can be confidently placed in either Cluster 1 or Cluster 2 (cluster probabilities <0.05 or >0.95). The placement of the rest of the observations can be considered ambiguous. Issues thinking this through or issues with implementation? Office hours! (Note: you will have to install `ClusterR` .)

```
library(ClusterR)
```

```
## Loading required package: gtools
```

```
gmm <- GMM(df.new, 2, dist_mode= "maha_dist",seed_mode = "random_subset", km_iter=10, em_iter=10)

gmm
```

```
## $centroids
##          [,1]     [,2]     [,3]      [,4]      [,5]
## [1,] 260.0350 57.93306 1.496076 0.6982978 0.3328339
## [2,] 260.0871 57.94392 3.110588 0.5753608 0.2543947
##
## $covariance_matrices
##           [,1]       [,2]      [,3]       [,4]        [,5]
## [1,] 0.0861551 0.01236742 0.2212275 0.03940175 0.016592889
## [2,] 0.5011535 0.09806214 1.2876865 0.02214659 0.006136507
##
## $weights
## [1] 0.6261437 0.3738563
##
## $Log_likelihood
##                   [,1]          [,2]
##    [1,]  -8.522442980  9.536301e-01
##    [2,] -18.288221249  3.239933e-01
##    [3,]   1.281754652  6.770201e-01
##    [4,]   2.581910576 -5.164855e-01
##    [5,]  -9.247785368  8.491561e-01
##    [6,]   1.532111224 -4.333541e-01
##    [7,]  -4.831689585  9.809473e-01
##    [8,]  -3.085531141 -3.524495e+00
##    [9,]  -3.085531141 -3.524495e+00
##   [10,]  -3.099721025 -2.523886e+00
##   [11,]  -2.817864636 -3.227747e+00
##   [12,]  -2.755382349 -2.840870e+00
##   [13,]  -1.133022931 -4.618487e+00
##   [14,]   0.188944427 -6.773606e+00
##   [15,]   1.882615428  5.722317e-01
##   [16,]  -4.105376863  1.048051e+00
##   [17,]   1.472393698  3.423018e-01
##   [18,]   1.848202216 -5.961803e-01
##   [19,]  -7.984287130  3.430137e-01
##   [20,]  -5.626671066  2.465342e-01
##   [21,]   2.222476743 -2.513988e+00
##   [22,]  -0.500376033 -1.082819e+00
##   [23,]   1.490445914 -3.632355e-01
##   [24,]  -0.401521404  7.094280e-01
##   [25,]   2.154641332 -6.067493e-01
##   [26,]  -7.439690555  4.976487e-01
##   [27,]  -0.658883766  3.265591e-02
##   [28,]  -5.196854049  5.068306e-01
##   [29,]  -0.909270313  1.150198e-01
##   [30,]  -0.909270313  1.150198e-01
##   [31,]  -3.927641358  4.741226e-01
##   [32,]  -0.293717661 -1.553694e-01
##   [33,]   1.951052708 -6.371425e-01
##   [34,]   1.954600179 -8.872947e-01
##   [35,]   2.433475156 -2.957705e-01
##   [36,]   2.165808651 -5.925179e-01
##   [37,]   2.433475156 -2.957705e-01
##   [38,]   2.520332344 -3.008647e-02
##   [39,]  -4.742492955 -2.813074e-02
##   [40,]   0.694781259 -3.786755e+00
##   [41,]   0.472080604 -1.202076e+00
##   [42,]   0.284176345 -7.328345e-01
##   [43,]   0.406050846 -1.338801e+00
```

```
##   [44,]   0.294818758 -1.483291e+00
##   [45,]   0.294818758 -1.483291e+00
##   [46,]  -0.063252405 -1.795570e+00
##   [47,]  -5.425038807  7.329179e-01
##   [48,]   2.743307702 -1.205966e-01
##   [49,]   2.413158910 -8.042213e-01
##   [50,]   2.743307702 -1.205966e-01
##   [51,]   2.398969026  1.963877e-01
##   [52,]   2.680825415 -5.074738e-01
##   [53,]   2.398969026  1.963877e-01
##   [54,]   2.680825415 -5.074738e-01
##   [55,]   2.569593327 -6.519646e-01
##   [56,]   2.746855173 -3.707489e-01
##   [57,]  -6.634137820  4.203288e-01
##   [58,]  -3.267514923 -4.439009e+00
##   [59,]   1.100288456 -5.694704e+00
##   [60,]   0.141511784 -6.575901e+00
##   [61,]  -0.953529135 -7.641697e+00
##   [62,]  -0.661487731 -7.466143e+00
##   [63,]  -0.953529135 -7.641697e+00
##   [64,]   2.516710850 -1.279785e+00
##   [65,]   1.819477063 -1.306050e+00
##   [66,]   2.351262602 -4.624025e-01
##   [67,]   1.801739708 -5.528835e-02
##   [68,]   1.517902358 -1.068806e+00
##   [69,]   1.583932116 -9.320810e-01
##   [70,]   1.030861752 -2.748146e-01
##   [71,]   1.580384645 -6.819287e-01
##   [72,]   1.583932116 -9.320810e-01
##   [73,]   1.995325717 -1.115043e+00
##   [74,]   2.151760134 -9.627865e-01
##   [75,] -31.581422981 -1.932978e+00
##   [76,] -22.620719371 -1.145794e+00
##   [77,] -26.897660694 -1.504440e+00
##   [78,] -33.233081736 -2.091356e+00
##   [79,] -25.426811257 -1.377125e+00
##   [80,]   2.120691907 -5.044069e-01
##   [81,]   1.786995644 -9.378792e-01
##   [82,]  -4.420370748  6.286788e-01
##   [83,]   2.117144436 -2.542546e-01
##   [84,]   2.117144436 -2.542546e-01
##   [85,]   1.943430061 -7.856226e-01
##   [86,]   1.943430061 -7.856226e-01
##   [87,]   2.047567207 -1.408273e-01
##   [88,]   2.054662149 -6.411318e-01
##   [89,]  -8.836466531  4.968875e-01
##   [90,]   2.141519336 -3.754478e-01
##   [91,]   2.534569498 -1.475384e+00
##   [92,]   3.090729937 -7.529302e-01
##   [93,]   1.198239268  2.617153e-01
##   [94,]   1.083459709  3.673767e-01
##   [95,]   1.696178015 -4.914040e-01
##   [96,]   1.696178015 -4.914040e-01
##   [97,]   2.875449315 -1.215415e+00
##   [98,]   2.497087261 -8.121172e-01
##   [99,]   2.319825415 -1.093333e+00
##  [100,] -12.142211074  6.741779e-01
##  [101,]   2.007032784 -1.548514e-01
##  [102,]  -1.814795172  9.438817e-01
##  [103,]   3.052507276  9.288047e-02
##  [104,]  -1.538940701  1.025397e+00
##  [105,]   2.642471893 -1.469951e+00
##  [106,]   2.905154895 -4.077976e-01
##  [107,]   2.696423206 -6.751566e-02
##  [108,]   2.696423206 -6.751566e-02
##  [109,]  -2.430392736  6.479552e-01
##  [110,]   2.483386065 -7.647016e-01
##  [111,]   1.922982086 -3.070826e+00
##  [112,]   2.190648591 -2.774078e+00
##  [113,]   1.721345340 -3.230848e+00
##  [114,]   2.253130878 -2.387201e+00
##  [115,]   1.182464859 -3.574191e+00
##  [116,]   1.474506264 -3.398637e+00
##  [117,]   0.414248615  5.939533e-01
##  [118,]   2.337578742 -8.309461e-01
##  [119,]   2.494013159 -6.786895e-01
##  [120,]  -0.390231098 -2.394050e+00
##  [121,]  -0.859991745 -1.220948e+00
##  [122,]  -0.035707405 -1.831619e+00
```

```
##  [123,]  -0.838706919 -2.721861e+00
##  [124,]  -0.591867844 -2.554073e+00
##  [125,]   1.764097312 -2.080284e+00
##  [126,]   0.981925227 -2.841568e+00
##  [127,]   1.698067553 -2.217009e+00
##  [128,]   1.576193053 -1.611043e+00
##  [129,]   1.416211165 -1.513148e+00
##  [130,]  -0.587161994 -3.877097e+00
##  [131,]   2.601053718 -9.301689e-01
##  [132,]  -4.399127172  6.255626e-01
##  [133,]   1.108919455  4.434302e-01
##  [134,]   2.746845722 -2.745545e-02
##  [135,]   1.144575086  6.505861e-01
##  [136,]   2.805604777 -1.999648e+00
##  [137,]   2.649170360 -2.151905e+00
##  [138,]  -0.841044497  2.930812e-01
##  [139,]  -1.272240361  3.443816e-01
##  [140,]   0.984786029 -6.470454e-01
##  [141,]   0.636899882 -7.990880e-02
##  [142,]   2.551223457 -2.064173e-01
##  [143,]   2.759955146 -5.466993e-01
##  [144,]  -0.515897388  3.950719e-01
##  [145,]   0.028260613 -2.731672e+00
##  [146,]   0.028260613 -2.731672e+00
##  [147,]   0.017618200 -1.981215e+00
##  [148,]  -0.128173804 -2.883928e+00
##  [149,]   0.205522459 -2.450456e+00
##  [150,]  -0.128173804 -2.883928e+00
##  [151,]   2.548542954 -2.186694e+00
##  [152,] -56.009929419 -1.514474e+02
##  [153,] -55.651858256 -1.511351e+02
##  [154,]  -1.907657571 -7.273388e+00
##  [155,]   2.743251640 -9.676042e-01
##  [156,]   2.607167203 -2.415154e-01
##  [157,]   1.549933202  1.866695e-01
##  [158,]   0.023436526 -7.782769e+00
##  [159,]   0.360680260 -7.599449e+00
##  [160,]  -3.570936744 -2.119841e+00
##  [161,]   2.319916324 -1.405956e+00
##  [162,]   2.587582828 -1.109208e+00
##  [163,]   2.587582828 -1.109208e+00
##  [164,]   2.305726440 -4.053468e-01
##  [165,]  -0.205178974 -5.857005e+00
##  [166,]   0.086862431 -5.681451e+00
##  [167,]  -1.779688171  4.966374e-02
##  [168,]   2.256093333 -3.998840e-01
##  [169,]  -0.057913175 -6.779730e+00
##  [170,]  -0.395156909 -6.963050e+00
##  [171,] -17.556826118 -6.595497e-01
##  [172,] -26.270690653 -1.278946e+00
##  [173,]  -7.163324843 -1.733304e-01
##  [174,]   0.831307291 -1.558213e+00
##  [175,]  -4.195186070  4.799720e-01
##  [176,]  -0.109239080 -7.186139e-02
##  [177,]  -3.016378038  4.317322e-01
##  [178,]   0.172617309 -7.757229e-01
##  [179,]  -1.587183459  3.011286e-01
##  [180,]   0.172617309 -7.757229e-01
##  [181,]   0.165522367 -2.754184e-01
##  [182,]  -0.860398719  1.752302e-01
##  [183,]   1.947874466 -3.009736e-01
##  [184,]   0.988967823 -6.544688e-01
##  [185,]  -5.631784026 -1.157815e+00
##  [186,]   2.004776945 -2.854977e+00
##  [187,]  -2.490004422 -1.201701e+00
##  [188,]   1.306149603  8.262440e-01
##  [189,]   0.920156068  8.853103e-01
##  [190,]   1.203322159  1.472496e-01
##  [191,]   0.320892137 -1.264105e+00
##  [192,]   0.247767437 -9.005256e-01
##  [193,]  -2.412532446 -2.291436e-01
##  [194,]   0.317344666 -1.013953e+00
##  [195,]   0.341719566 -1.135146e+00
##  [196,]   0.143630291 -1.545321e+00
##  [197,]   0.341719566 -1.135146e+00
##  [198,]   0.247767437 -9.005256e-01
##  [199,]   0.341719566 -1.135146e+00
##  [200,]  -9.069482192  7.119488e-01
##  [201,]   1.884128775 -3.919336e-02
```

```
##  [202,]  -0.886475310 -4.065740e-01
##  [203,]  -0.907302739 -5.355330e-01
##  [204,]  -0.910850210 -2.853808e-01
##  [205,]  -0.886475310 -4.065740e-01
##  [206,]  -1.095206998 -6.629201e-02
##  [207,] -10.422101736 -1.891595e+00
##  [208,]  -9.048294503 -2.909380e+00
##  [209,]  -9.048294503 -2.909380e+00
##  [210,]  -2.732277217 -5.776448e-01
##  [211,] -14.248145342 -1.294119e+00
##  [212,]  -4.330640477 -2.474029e+00
##  [213,]  -4.598306982 -2.770776e+00
##  [214,]  -4.799943728 -2.930798e+00
##  [215,]  -5.068067630 -1.597673e+00
##  [216,]  -4.268158190 -2.087151e+00
##  [217,]  -4.441872565 -2.618519e+00
##  [218,]  -5.068067630 -1.597673e+00
##  [219,]  -4.441872565 -2.618519e+00
##  [220,] -11.591886885 -8.211374e-01
##  [221,]  -1.785614108 -2.145538e+00
##  [222,]  -2.143685272 -2.457817e+00
##  [223,]  -1.674382021 -2.001047e+00
##  [224,]  -1.608352262 -1.864322e+00
##  [225,]  -0.043462755  3.594325e-02
##  [226,]   0.165268934 -3.043387e-01
##  [227,]  -0.659015406  3.063324e-01
##  [228,]  -4.946599143  6.981433e-01
##  [229,]  -0.156406901 -3.048054e-01
##  [230,]  -0.308571868 -5.912880e-01
##  [231,]  -8.414436090  6.491037e-01
##  [232,]  -1.341587896  3.596651e-01
##  [233,] -10.342014388  2.032673e-01
##  [234,]   1.375545792 -6.862591e-01
##  [235,]   1.375545792 -6.862591e-01
##  [236,]   0.342529764  2.646940e-01
##  [237,]  -5.892301602  5.727249e-01
##  [238,]   0.645163385 -1.084414e+00
##  [239,]  -0.063883999 -2.209277e+00
##  [240,]   0.739115515 -1.319034e+00
##  [241,]   0.714740615 -1.197841e+00
##  [242,]   0.384591823 -1.881466e+00
##  [243,]  -1.198570562  3.491611e-01
##  [244,]   0.175236671 -6.686242e-01
##  [245,]  -1.584564096  4.082273e-01
##  [246,]  -0.092429833 -9.653717e-01
##  [247,]  -2.015759960  4.595277e-01
##  [248,]  -1.198570562  3.491611e-01
##  [249,]   1.724289556  4.180382e-01
##  [250,]  -3.127535706 -3.018666e+00
##  [251,]   0.524125346 -4.898919e+00
##  [252,]   0.770964422 -4.731131e+00
##  [253,]   1.402444106 -1.627302e+00
##  [254,]   1.517223665 -1.732964e+00
##  [255,]   2.036250716 -9.836935e-01
##  [256,]   2.036250716 -9.836935e-01
##  [257,]   2.036250716 -9.836935e-01
##  [258,]   2.102280474 -8.469686e-01
##  [259,]   1.566947465 -1.440464e+00
##  [260,]   0.537922859 -8.316861e+00
##  [261,] -26.612808701 -2.695447e+00
##  [262,]   2.185994713 -2.888361e+00
##  [263,]   2.717780251 -2.044714e+00
##  [264,]   1.264600612 -7.144033e+00
##  [265,]   0.708440173 -7.866486e+00
##  [266,] -16.180401069 -2.080510e+00
##  [267,] -12.295646212 -9.231474e-01
##  [268,]   0.618196222 -5.635533e+00
##  [269,]   0.062035783 -6.357987e+00
##  [270,]   0.062035783 -6.357987e+00
##  [271,]  -0.476844697 -6.701330e+00
##  [272,]  -3.589726852 -2.258679e-01
##  [273,]   1.806451377 -5.709005e+00
##  [274,]  -3.624463009  6.035328e-01
##  [275,]   1.821101330  3.452312e-02
##  [276,]  -2.690240771  4.872789e-01
##  [277,]   1.670467665 -2.681115e-01
##  [278,]   1.540986605 -9.940307e-02
##  [279,]   1.540986605 -9.940307e-02
##  [280,]   1.266225159  1.041540e-01
```

```
##  [281,]   2.778559303 -1.413381e+00
##  [282,]  -2.533132784 -5.061902e+00
##  [283,]  -1.524949052 -4.261790e+00
##  [284,]   1.147046868 -4.831873e+00
##  [285,]   1.147046868 -4.831873e+00
##  [286,]   0.820853644  2.132124e-02
##  [287,]   0.003664246  1.316879e-01
##  [288,]   2.257143165 -6.095869e-01
##  [289,]   2.403419342 -1.227962e+00
##  [290,]   2.330294642 -8.643821e-01
##  [291,]   2.279854718 -4.023944e-02
##  [292,]   1.814684403 -2.473128e+00
##  [293,]   1.445970827 -2.034950e+00
##  [294,]   1.616595128 -2.883302e+00
##  [295,]   1.727827215 -2.738812e+00
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##  [301,]   2.800451639 -5.099958e-01
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##  [320,]   2.257232656  2.646335e-01
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##  [971,]   1.827527205 -1.753097e+00
##  [972,]   1.938759292 -1.608606e+00
##  [973,]  -0.902133015 -1.498480e+00
##  [974,]  -3.632010127 -7.136708e-01
##  [975,]   0.948387077 -1.532293e+00
##  [976,]   1.146476353 -1.122118e+00
##  [977,]  -0.060639293 -2.483460e-01
##  [978,] -15.518836334  2.999478e-01
##  [979,] -24.236731617 -2.503005e-01
##  [980,] -27.314037479 -5.282271e-01
##  [981,] -22.765882180 -1.229860e-01
##  [982,]   2.516684894  3.907824e-01
##  [983,]   0.894473945  4.336516e-01
##  [984,]   2.498700299 -1.435320e-01
##  [985,]   2.718074400 -1.234271e+00
##  [986,]  -0.843424660  8.982102e-01
##  [987,]  -1.472963661 -3.850179e-01
##  [988,]   1.136517132  5.118357e-01
##  [989,] -24.416525497 -7.106200e+01
##  [990,] -24.040716979 -7.200048e+01
##  [991,] -24.040716979 -7.200048e+01
```

```
##  [992,] -23.936579833 -7.135568e+01
##  [993,] -24.211341280 -7.115213e+01
##  [994,] -24.040716979 -7.200048e+01
##  [995,] -26.596879716 -7.068430e+01
##  [996,] -24.040716979 -7.200048e+01
##  [997,] -14.812870052  5.016137e-01
##  [998,]  -6.910139708  9.385836e-01
##  [999,]   1.154449257  3.833521e-01
## [1000,]  -0.344491693  8.830515e-01
## [1001,]   2.576837149 -6.211511e-01
## [1002,]  -2.054269819 -2.243676e+00
## [1003,]   2.131472495 -2.388367e-01
## [1004,]   0.045142500 -1.254785e+00
## [1005,]  -3.930989598 -6.529230e-01
## [1006,]  -2.230581044 -7.369314e-01
## [1007,]   2.412382807 -1.222051e-01
## [1008,]   2.777548912 -3.102305e-01
## [1009,]   2.161996260 -3.984126e-02
## [1010,]   1.118420024 -8.539547e-03
## [1011,]   1.368806571 -9.090341e-02
## [1012,]   1.918329464 -4.980175e-01
## [1013,]   2.335916217  7.523603e-01
## [1014,]   2.822956823 -4.163102e-02
## [1015,]   0.728096192 -2.298018e-01
## [1016,]  -0.725473287  2.199503e-02
## [1017,]   0.207940529 -1.135429e+00
## [1018,]  -3.339730982 -7.392147e-01
## [1019,]  -2.371355484 -3.569672e+00
## [1020,]  -2.352453778 -1.778587e+00
## [1021,] -10.698265692 -3.199227e-02
## [1022,]  -7.790504831 -2.380175e+00
## [1023,]  -7.042892662 -2.377115e+00
## [1024,]   2.353682825  1.990810e-01
## [1025,]   2.426807525 -1.644986e-01
## [1026,]   1.424104149 -6.853163e-01
## [1027,]  -6.908947810 -7.968827e-01
## [1028,]  -8.358969818 -7.952381e-01
## [1029,]   2.692296223 -8.835482e-03
## [1030,]   1.266100871  2.360584e-01
## [1031,]  -1.185467323  5.671585e-01
## [1032,]   0.243727256  4.365548e-01
## [1033,]  -0.559418698  9.407943e-01
## [1034,]   2.823319334  1.764702e-01
## [1035,]  -3.576589403 -3.480608e+00
## [1036,]  -0.491866911 -3.010980e+00
## [1037,]  -0.860580487 -2.572802e+00
## [1038,]  -3.767719445 -2.069209e+00
## [1039,]   1.504582667 -8.151375e-01
## [1040,]   1.647221038  8.445827e-01
## [1041,]   2.657203325  2.279190e-01
## [1042,]  -0.023667531 -1.715168e+00
## [1043,] -12.020479542 -8.924884e-01
## [1044,] -17.792645203 -1.257256e+00
## [1045,]   1.931104261  4.251433e-01
## [1046,] -15.815683702  3.491244e-01
## [1047,]   0.342548807 -2.146978e+00
## [1048,]   2.606241085 -2.880054e-01
## [1049,]   1.499531325  7.265131e-01
## [1050,]   0.664338697  1.758712e-01
## [1051,]   2.466591124  5.185196e-01
## [1052,]  -4.593782621  7.635784e-01
## [1053,]  -9.127395840  1.933414e-01
## [1054,]   0.052681871 -1.102128e-01
## [1055,]   0.997495998  8.045157e-01
## [1056,]  -0.133494380  1.558544e-01
## [1057,]   1.901520368  8.241201e-01
## [1058,]  -3.525043398 -9.250797e-01
## [1059,]  -2.366072319  1.153949e+00
## [1060,]   2.658938570 -1.142175e-01
## [1061,]   2.171897965  6.797738e-01
## [1062,]   2.721420858  2.726597e-01
## [1063,]  -0.218969483 -3.378536e+00
## [1064,]   2.523117078 -3.429733e-02
## [1065,]   1.427618762  5.297787e-01
## [1066,]  -0.710198430  9.431104e-01
## [1067,]   1.675091315  7.689746e-01
## [1068,]   2.473493581 -1.400240e-01
## [1069,]   1.722333941  1.070676e-01
## [1070,]  -4.512497425  4.150985e-01
```

```
## [1071,]  -1.911738209 -1.905803e+00
## [1072,]   2.427230102  2.656817e-01
## [1073,]   3.001859818  8.304124e-02
## [1074,]   1.721096912 -7.427988e-01
## [1075,]  -4.060019077 -3.468719e+00
## [1076,] -28.204765775 -2.182991e+00
## [1077,] -13.537926262 -1.167764e+00
## [1078,] -10.095454294 -1.077863e+00
## [1079,]   0.450470323  9.836062e-01
## [1080,] -13.079732555 -4.446806e-01
## [1081,]  -0.259652888  4.009348e-01
## [1082,]   1.708344076  8.283503e-01
## [1083,]   2.154744260  7.660429e-01
## [1084,]   0.391095410 -9.570032e-01
## [1085,]   1.393204836 -8.473148e-02
## [1086,]   1.045776085 -1.147467e+00
## [1087,]   0.766984921  5.719998e-01
## [1088,]   1.759757409 -1.512092e+00
## [1089,]   3.031567133 -2.623358e-01
## [1090,]  -0.684208773  1.118925e+00
## [1091,]   2.818353342 -9.216370e-01
## [1092,] -14.542430439 -1.809400e+00
## [1093,]   2.845670019  2.257523e-01
## [1094,]   2.433684185 -3.520885e+00
## [1095,]  -4.363433541 -3.192160e+00
## [1096,]   1.566055119 -3.109132e+00
## [1097,]   2.348227204 -2.347848e+00
## [1098,]   2.390491956 -1.588079e-01
## [1099,]  -5.681263180 -2.723616e+00
## [1100,] -27.935508438 -1.334065e+00
## [1101,]  -7.840299936 -2.241530e+00
## [1102,]   0.132220258  5.529737e-01
## [1103,]   0.776534997  9.055876e-02
## [1104,]   1.310942660  5.998400e-01
## [1105,] -12.277299279 -5.756382e-01
## [1106,] -16.408675879 -1.286235e+00
## [1107,] -29.804763322 -1.759382e+00
## [1108,] -22.601279294 -5.642678e+00
## [1109,] -12.344612965 -3.107987e-01
## [1110,] -32.823363709 -1.769275e+00
## [1111,] -27.017618426 -1.731821e+00
## [1112,]   2.692730708  4.442343e-01
## [1113,]   0.838255621  3.818890e-01
## [1114,]  -8.835036051 -7.607062e-01
## [1115,]   3.070513767  1.438322e-01
## [1116,]   2.296821866  6.308630e-01
## [1117,]   2.900233727 -2.700560e-01
## [1118,]   2.900233727 -2.700560e-01
## [1119,]  -0.631937892 -1.904126e+00
## [1120,] -22.263845706 -2.990396e+00
## [1121,]   2.416961041 -1.414568e+00
## [1122,]   0.694024606 -1.183712e-01
## [1123,]  -0.052789419 -8.040019e+00
## [1124,]  -0.052789419 -8.040019e+00
## [1125,]   0.194049657 -7.872230e+00
## [1126,]  -1.136465637 -1.716306e+00
## [1127,]   1.003314200 -2.598331e+00
## [1128,]   0.801677454 -2.758353e+00
## [1129,]   1.159748617 -2.446074e+00
## [1130,]  -0.964823684  2.148435e-01
## [1131,]  -8.120904788 -9.137833e-01
## [1132,] -15.321331894 -3.942447e+00
## [1133,] -27.390811209 -4.386061e+00
## [1134,] -12.005624571 -7.189286e-01
## [1135,] -10.009627140 -8.775350e-01
## [1136,] -38.377822256 -3.925362e+00
## [1137,] -58.063565989 -4.421957e+00
## [1138,] -48.979675756 -4.286660e+00
## [1139,] -40.003436374 -3.343785e+00
## [1140,] -16.281725012 -1.890184e+00
## [1141,] -78.318527908 -7.086485e+00
## [1142,] -11.444001195 -6.537271e-01
## [1143,]  -4.308670714 -5.562884e-01
## [1144,]  -1.131014686 -2.084307e-01
## [1145,] -15.889672619 -7.758445e+00
## [1146,] -19.081758040 -7.930710e+00
## [1147,]   0.375559592 -6.018064e-01
## [1148,]   0.751368110 -1.540289e+00
## [1149,] -15.064530777 -2.150961e+01
```

```
## [1150,]  -9.889030733 -2.559287e+01
## [1151,] -14.249739169 -2.483748e+01
## [1152,]  -4.759597555 -7.698501e+00
## [1153,]  -4.509211008 -7.780864e+00
## [1154,]  -9.280048916 -1.163699e+01
## [1155,]  -8.939257711 -1.170382e+01
## [1156,]   0.635946765 -3.801906e-01
## [1157,]  -3.697651160 -8.704778e+00
## [1158,]  -2.946491521 -8.951870e+00
## [1159,]  -2.143637261 -4.353385e+00
## [1160,] -26.911279964 -5.629439e+00
## [1161,] -30.226450749 -5.186340e+00
## [1162,] -24.601366518 -4.248577e+00
## [1163,]  -0.907845818 -6.373587e-01
## [1164,]  -9.221929519 -5.919412e+00
## [1165,] -33.303437486 -6.470754e+00
## [1166,] -58.177587920 -4.714583e+00
## [1167,] -58.177587920 -4.714583e+00
## [1168,] -61.232652857 -6.483442e+00
## [1169,] -59.321124203 -4.626399e+00
## [1170,] -44.611983667 -3.600526e+00
## [1171,] -67.229984778 -8.278335e+00
## [1172,] -51.756065622 -3.998616e+00
## [1173,] -26.158076993 -1.273339e+00
## [1174,]   0.056983344 -1.731001e+00
## [1175,]   1.433085654  9.554926e-01
## [1176,]   0.139498063  1.109394e+00
## [1177,]   3.217313566 -5.044842e-01
## [1178,]   3.043599191 -1.035852e+00
## [1179,]   0.680707513  8.351401e-01
## [1180,]   2.047419804  3.176593e-01
## [1181,]   2.695270832  1.795108e-01
## [1182,]   2.021179597  4.369662e-01
## [1183,]   0.929228752  7.508899e-01
## [1184,]  -5.406546631  7.779301e-01
## [1185,]  -4.393622501  6.755578e-01
## [1186,]  -3.729906107  7.778234e-01
## [1187,]  -7.260372413  3.343305e-01
## [1188,]  -2.853228744  7.603134e-01
## [1189,]   1.033412744  9.336155e-01
## [1190,]   1.419406278  8.745492e-01
## [1191,]   1.799499932  6.633754e-01
## [1192,]   1.072715193  7.892738e-01
## [1193,]  -1.007653874  1.056426e+00
## [1194,]   2.979102408  1.831891e-01
## [1195,]   2.276476929  1.025528e-02
## [1196,]   2.800801364 -7.120682e-01
## [1197,] -22.303519183 -2.869996e-01
## [1198,]  -0.271799024 -3.043351e-01
## [1199,] -57.461961650 -5.014751e+00
## [1200,]  -1.315178800  6.594007e-01
## [1201,] -27.027920380 -4.020800e+00
## [1202,] -43.666382423 -4.998614e+00
## [1203,] -59.980691477 -5.402079e+00
## [1204,] -45.498208752 -4.167763e+00
## [1205,] -45.040362355 -5.545370e+00
## [1206,] -64.658036413 -8.809203e+00
## [1207,] -69.821744364 -8.944055e+00
## [1208,] -40.745859980 -9.669085e+00
## [1209,] -51.059835120 -3.957989e+00
## [1210,] -42.443977543 -2.858913e+00
## [1211,] -25.882851048 -2.052902e+00
## [1212,] -21.282398478 -2.140200e+00
## [1213,] -33.572693036 -2.968190e+00
## [1214,]  -4.927923759 -3.969554e-01
## [1215,]  -5.941670936 -1.116402e+00
## [1216,] -27.036269014 -1.683128e+00
## [1217,] -37.128601749 -4.765710e+00
## [1218,] -51.955910320 -6.045605e+00
##
## attr(,"class")
## [1] "Gaussian Mixture Models"
```

```
#The GMM function in the ClusterR package is an R implementation of the Armadillo library class for modeling data a
s a Gaussian Mixture Model (GMM), under the assumption of diagonal covariance matrices. A number of function parame
ters can be tuned, among others the gaussian_comps, the dist_mode (eucl_dist, maha_dist), the seed_mode (static_sub
set, random_subset, static_spread, random_spread), the km_iter and the em_iter (more information about the paramete
rs can be found in the package documentation). I'll illustrate the GMM function using the synthetic data dietary_su
rvey_IBS,

#gmm = GMM(dat, 2, dist_mode = "maha_dist", seed_mode = "random_subset", km_iter = 10,

         # em_iter = 10, verbose = F)
```