Lab_10R

36-290 – Statistical Research Methodology

Week 10 Thursday – Fall 2021

Data

Below we read in the `EMLINE_MASS` dataset, in which the strengths of 10 emission lines are recorded for each of 21,046 galaxies, along with the galaxy masses.

```
rm(list=ls())
file.path = "https://raw.githubusercontent.com/pefreeman/36-290/master/EXAMPLE_DATASETS/EMLINE_MASS/emission_line_mass.Rdata"
load(url(file.path))
rm(file.path)
x = predictors$H_ALPHA
x.tmp = log10(x[x>0])
y     = responses[x>0,1]
x     = x.tmp
df    = data.frame(x,y)
```

Today we are simply playing around with kernel density estimation and kernel regression, so all we are going to keep is the values for the strongest emission line, the so-called "Hα" line at 656 nanometers (which we will call x), and the masses (which we will call y). We also filter the data so as to keep only positive emission line strengths, so that we can implement a logarithmic transformation for x.

Questions

Question 1

Do some EDA. First, use `ggplot2` to create histograms of both x and y, and then use it to make a scatter plot of x and y. Don't worry about downsampling the amount of data; rather, change the transparency of the points by setting the alpha parameter to, e.g., 0.1.

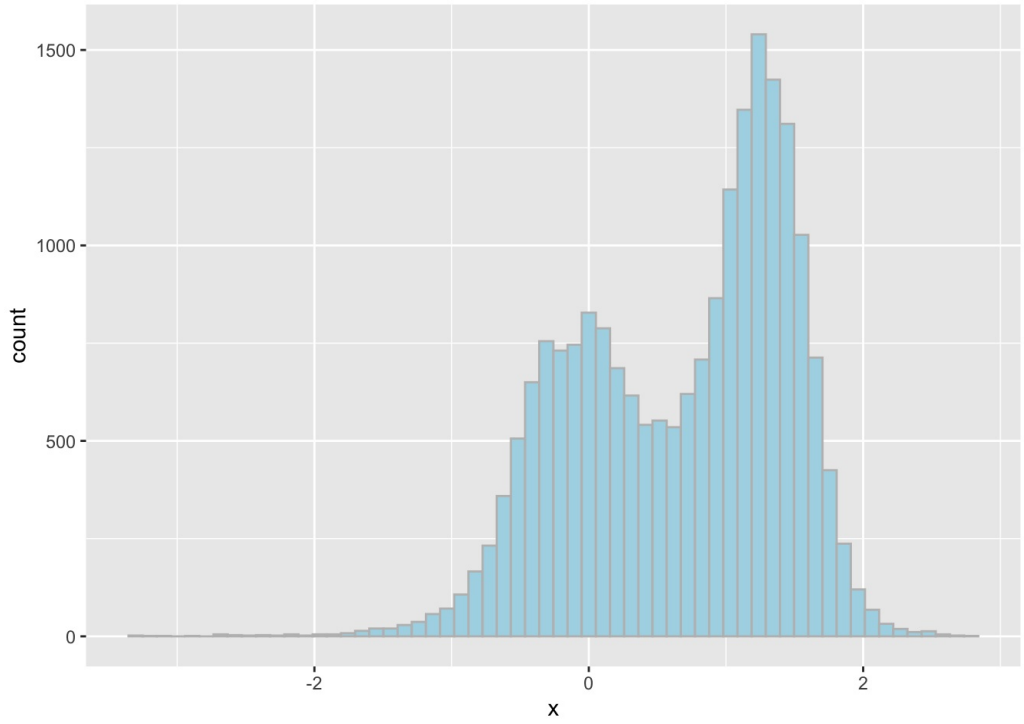
```
library(ggplot2)
library(tidyverse)
```

```
## ── Attaching packages ─────────────────────────────────────── tidyverse 1.3.1 ──
```

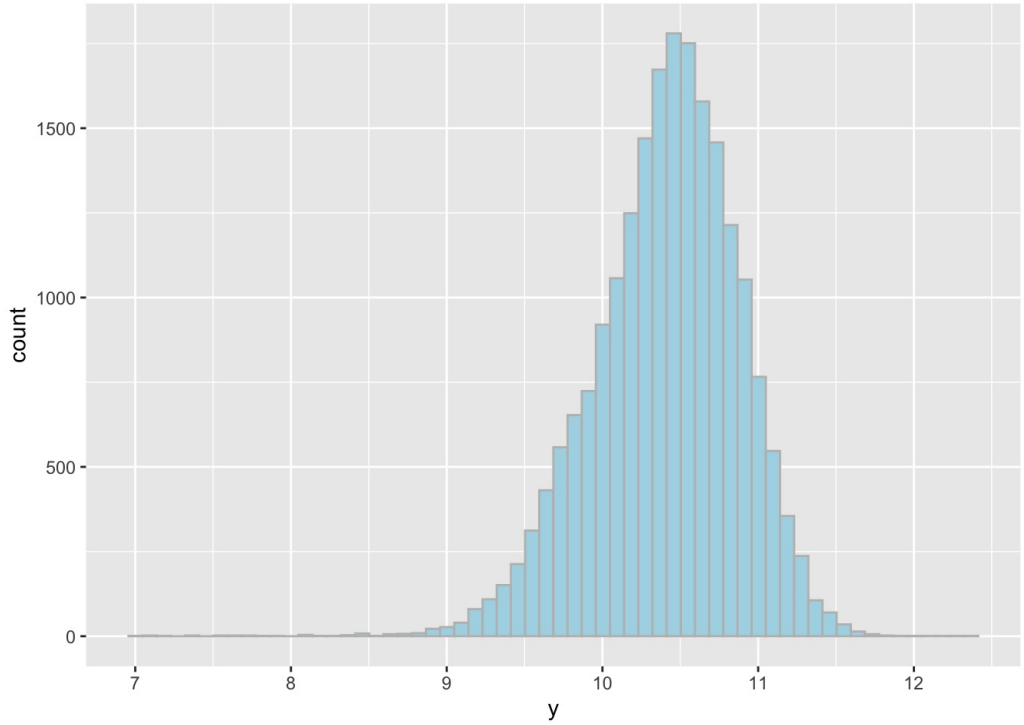
```
## ✓ tibble  3.1.4     ✓ dplyr   1.0.7
## ✓ tidyr   1.1.3     ✓ stringr 1.4.0
## ✓ readr   2.0.1     ✓ forcats 0.5.1
## ✓ purrr   0.3.4
```

```
## ── Conflicts ────────────────────────────────────────── tidyverse_conflicts() ──
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

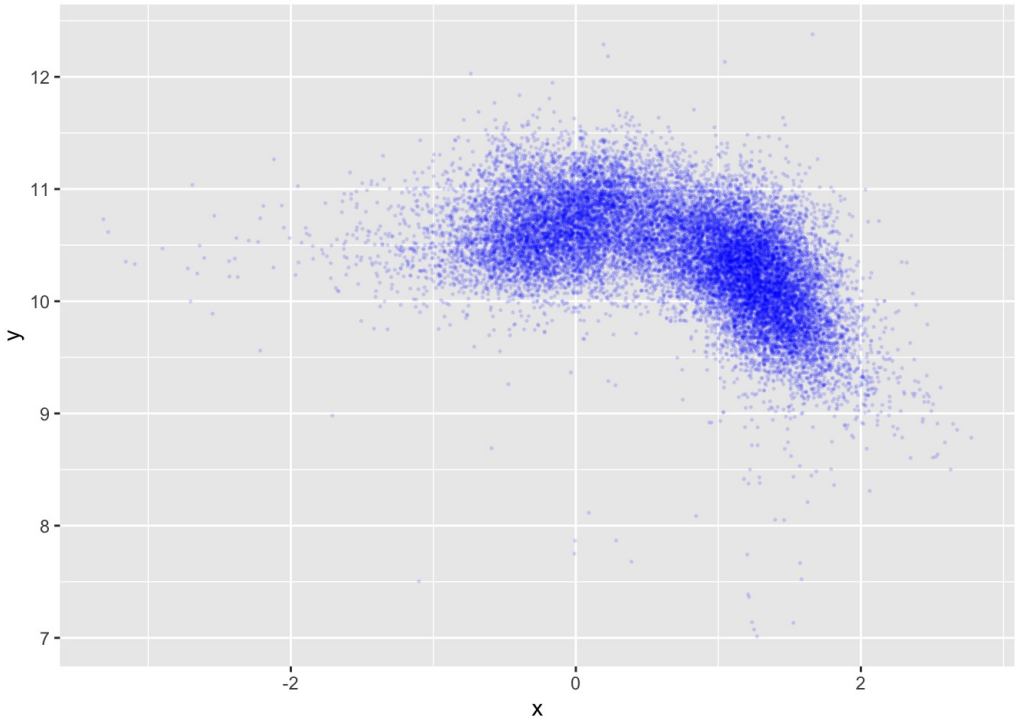
```
ggplot(data=df,mapping=aes(x)) + geom_histogram(color="grey",fill="lightblue",bins=60)
```




```
ggplot(data=df,mapping=aes(y)) + geom_histogram(color="grey",fill="lightblue",bins=60)
```




```
ggplot(data=df,mapping=aes(x,y)) + geom_point(color="blue",size=.3, alpha=.1)
```



Question 2

Create a density estimate for x using the `density()` function and the default bandwidth. Print the default bandwidth. Then overlay the density estimate on top of a density histogram. One creates a density histogram by adding an extra argument to `geom_histogram()`: `aes(y=..density..)`. One can then overlay the density estimate using an additional call to `geom_line()`, to which you pass a data frame with the x output of `density()` in one column and the y output of `density()` in the other.

```
d.estimate1=density(x, bw="nrd0", adjust =1)
d.estimate1
```

```
##
## Call:
##  density.default(x = x, bw = "nrd0", adjust = 1)
##
## Data: x (20722 obs.);    Bandwidth 'bw' = 0.09539
##
##        x                 y
##  Min.   :-3.6016   Min.   :0.0000024
##  1st Qu.:-1.9358   1st Qu.:0.0014043
##  Median :-0.2701   Median :0.0221424
##  Mean   :-0.2701   Mean   :0.1499336
##  3rd Qu.: 1.3957   3rd Qu.:0.2919921
##  Max.   : 3.0615   Max.   :0.6761376
```

```
"Default bandwith `bw`=0.09539"
```

```
## [1] "Default bandwith `bw`=0.09539"
```

```
df.estimate1 = data.frame(d.estimate1$x,d.estimate1$y)
df.estimate1
```

```
##     d.estimate1.x d.estimate1.y
## 1    -3.601622381  3.083997e-06
## 2    -3.588583037  4.620915e-06
## 3    -3.575543693  6.793147e-06
## 4    -3.562504349  9.879722e-06
## 5    -3.549465005  1.419070e-05
## 6    -3.536425661  1.997696e-05
## 7    -3.523386317  2.757447e-05
## 8    -3.510346973  3.733631e-05
## 9    -3.497307629  4.961376e-05
## 10   -3.484268285  6.473235e-05
## 11   -3.471228941  8.296379e-05
## 12   -3.458189597  1.044952e-04
## 13   -3.445150253  1.293976e-04
## 14   -3.432110909  1.578895e-04
```

```
## 15   -3.419071565  1.893794e-04
## 16   -3.406032221  2.232530e-04
## 17   -3.392992877  2.588226e-04
## 18   -3.379953533  2.952656e-04
## 19   -3.366914189  3.316683e-04
## 20   -3.353874845  3.670812e-04
## 21   -3.340835501  4.005798e-04
## 22   -3.327796157  4.313274e-04
## 23   -3.314756813  4.586081e-04
## 24   -3.301717469  4.814267e-04
## 25   -3.288678125  5.000455e-04
## 26   -3.275638781  5.145124e-04
## 27   -3.262599437  5.250493e-04
## 28   -3.249560093  5.320004e-04
## 29   -3.236520749  5.357734e-04
## 30   -3.223481405  5.367814e-04
## 31   -3.210442061  5.353891e-04
## 32   -3.197402717  5.318723e-04
## 33   -3.184363373  5.263152e-04
## 34   -3.171324029  5.186625e-04
## 35   -3.158284685  5.090215e-04
## 36   -3.145245341  4.973119e-04
## 37   -3.132205997  4.834928e-04
## 38   -3.119166653  4.676096e-04
## 39   -3.106127309  4.498315e-04
## 40   -3.093087965  4.304730e-04
## 41   -3.080048621  4.099972e-04
## 42   -3.067009277  3.890008e-04
## 43   -3.053969933  3.682626e-04
## 44   -3.040930589  3.486713e-04
## 45   -3.027891245  3.309100e-04
## 46   -3.014851901  3.155768e-04
## 47   -3.001812557  3.031404e-04
## 48   -2.988773213  2.939272e-04
## 49   -2.975733869  2.881285e-04
## 50   -2.962694525  2.858258e-04
## 51   -2.949655181  2.870330e-04
## 52   -2.936615837  2.917496e-04
## 53   -2.923576493  3.004397e-04
## 54   -2.910537149  3.130008e-04
## 55   -2.897497805  3.297324e-04
## 56   -2.884458461  3.511439e-04
## 57   -2.871419117  3.778501e-04
## 58   -2.858379773  4.105090e-04
## 59   -2.845340429  4.497399e-04
## 60   -2.832301085  4.960293e-04
## 61   -2.819261741  5.496318e-04
## 62   -2.806222397  6.105810e-04
## 63   -2.793183053  6.788637e-04
## 64   -2.780143709  7.525018e-04
## 65   -2.767104365  8.299119e-04
## 66   -2.754065021  9.091573e-04
## 67   -2.741025677  9.880541e-04
## 68   -2.727986333  1.064300e-03
## 69   -2.714946989  1.135620e-03
## 70   -2.701907645  1.199909e-03
## 71   -2.688868301  1.255380e-03
## 72   -2.675828957  1.300123e-03
## 73   -2.662789613  1.333012e-03
## 74   -2.649750269  1.354924e-03
## 75   -2.636710925  1.366505e-03
## 76   -2.623671581  1.368907e-03
## 77   -2.610632237  1.363704e-03
## 78   -2.597592893  1.352774e-03
## 79   -2.584553549  1.338173e-03
## 80   -2.571514205  1.322006e-03
## 81   -2.558474861  1.306286e-03
## 82   -2.545435517  1.293143e-03
## 83   -2.532396173  1.284078e-03
## 84   -2.519356829  1.279770e-03
## 85   -2.506317485  1.280514e-03
## 86   -2.493278141  1.286126e-03
## 87   -2.480238797  1.295999e-03
## 88   -2.467199453  1.309175e-03
## 89   -2.454160109  1.324458e-03
## 90   -2.441120765  1.340542e-03
## 91   -2.428081421  1.356145e-03
## 92   -2.415042077  1.369844e-03
## 93   -2.402002733  1.381008e-03
```

```
## 94   -2.388963389  1.389399e-03
## 95   -2.375924045  1.395158e-03
## 96   -2.362884701  1.398769e-03
## 97   -2.349845357  1.400981e-03
## 98   -2.336806013  1.402697e-03
## 99   -2.323766669  1.404854e-03
## 100  -2.310727325  1.408301e-03
## 101  -2.297687981  1.413751e-03
## 102  -2.284648637  1.421750e-03
## 103  -2.271609293  1.432001e-03
## 104  -2.258569949  1.444140e-03
## 105  -2.245530605  1.457614e-03
## 106  -2.232491261  1.471774e-03
## 107  -2.219451917  1.485981e-03
## 108  -2.206412573  1.499699e-03
## 109  -2.193373229  1.512582e-03
## 110  -2.180333885  1.524535e-03
## 111  -2.167294541  1.535734e-03
## 112  -2.154255197  1.546813e-03
## 113  -2.141215853  1.558615e-03
## 114  -2.128176509  1.572063e-03
## 115  -2.115137165  1.588124e-03
## 116  -2.102097821  1.607727e-03
## 117  -2.089058477  1.631690e-03
## 118  -2.076019133  1.660650e-03
## 119  -2.062979789  1.695010e-03
## 120  -2.049940445  1.734903e-03
## 121  -2.036901101  1.780623e-03
## 122  -2.023861757  1.831240e-03
## 123  -2.010822413  1.885790e-03
## 124  -1.997783069  1.943347e-03
## 125  -1.984743725  2.002936e-03
## 126  -1.971704381  2.063626e-03
## 127  -1.958665037  2.124645e-03
## 128  -1.945625693  2.185481e-03
## 129  -1.932586349  2.245983e-03
## 130  -1.919547005  2.306441e-03
## 131  -1.906507661  2.367990e-03
## 132  -1.893468317  2.432201e-03
## 133  -1.880428973  2.501091e-03
## 134  -1.867389629  2.577026e-03
## 135  -1.854350285  2.662603e-03
## 136  -1.841310941  2.760497e-03
## 137  -1.828271597  2.873311e-03
## 138  -1.815232253  3.003416e-03
## 139  -1.802192909  3.152812e-03
## 140  -1.789153565  3.323761e-03
## 141  -1.776114221  3.518422e-03
## 142  -1.763074877  3.734715e-03
## 143  -1.750035533  3.971851e-03
## 144  -1.736996189  4.228413e-03
## 145  -1.723956845  4.502434e-03
## 146  -1.710917501  4.791486e-03
## 147  -1.697878157  5.092794e-03
## 148  -1.684838813  5.403353e-03
## 149  -1.671799469  5.720063e-03
## 150  -1.658760125  6.039840e-03
## 151  -1.645720781  6.359256e-03
## 152  -1.632681437  6.675803e-03
## 153  -1.619642093  6.987638e-03
## 154  -1.606602749  7.293483e-03
## 155  -1.593563405  7.592674e-03
## 156  -1.580524061  7.885164e-03
## 157  -1.567484717  8.171503e-03
## 158  -1.554445373  8.452780e-03
## 159  -1.541406029  8.730527e-03
## 160  -1.528366685  9.006701e-03
## 161  -1.515327341  9.283820e-03
## 162  -1.502287997  9.563937e-03
## 163  -1.489248653  9.848928e-03
## 164  -1.476209309  1.014048e-02
## 165  -1.463169965  1.044007e-02
## 166  -1.450130621  1.074906e-02
## 167  -1.437091277  1.106873e-02
## 168  -1.424051933  1.140045e-02
## 169  -1.411012589  1.174599e-02
## 170  -1.397973245  1.210949e-02
## 171  -1.384933901  1.249208e-02
## 172  -1.371894557  1.289709e-02
```

```
## 173  -1.358855213  1.332831e-02
## 174  -1.345815869  1.378988e-02
## 175  -1.332776525  1.428604e-02
## 176  -1.319737181  1.482087e-02
## 177  -1.306697837  1.539803e-02
## 178  -1.293658493  1.602048e-02
## 179  -1.280619149  1.669237e-02
## 180  -1.267579805  1.741623e-02
## 181  -1.254540461  1.818704e-02
## 182  -1.241501117  1.900263e-02
## 183  -1.228461773  1.985992e-02
## 184  -1.215422429  2.075523e-02
## 185  -1.202383085  2.168461e-02
## 186  -1.189343741  2.264425e-02
## 187  -1.176304397  2.363095e-02
## 188  -1.163265053  2.464246e-02
## 189  -1.150225709  2.568000e-02
## 190  -1.137186365  2.674457e-02
## 191  -1.124147021  2.783887e-02
## 192  -1.111107677  2.896890e-02
## 193  -1.098068333  3.014257e-02
## 194  -1.085028989  3.136952e-02
## 195  -1.071989645  3.266074e-02
## 196  -1.058950301  3.402819e-02
## 197  -1.045910957  3.548424e-02
## 198  -1.032871613  3.704115e-02
## 199  -1.019832269  3.872481e-02
## 200  -1.006792925  4.053519e-02
## 201  -0.993753581  4.247813e-02
## 202  -0.980714237  4.455902e-02
## 203  -0.967674893  4.678108e-02
## 204  -0.954635549  4.914555e-02
## 205  -0.941596205  5.165197e-02
## 206  -0.928556861  5.429867e-02
## 207  -0.915517517  5.708331e-02
## 208  -0.902478173  6.000631e-02
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## 210  -0.876399485  6.628542e-02
## 211  -0.863360141  6.963149e-02
## 212  -0.850320797  7.312294e-02
## 213  -0.837281453  7.676929e-02
## 214  -0.824242109  8.058299e-02
## 215  -0.811202765  8.457918e-02
## 216  -0.798163421  8.877522e-02
## 217  -0.785124077  9.318996e-02
## 218  -0.772084733  9.785727e-02
## 219  -0.759045389  1.028049e-01
## 220  -0.746006045  1.080311e-01
## 221  -0.732966701  1.135484e-01
## 222  -0.719927357  1.193646e-01
## 223  -0.706888013  1.254822e-01
## 224  -0.693848669  1.318976e-01
## 225  -0.680809325  1.386006e-01
## 226  -0.667769981  1.455746e-01
## 227  -0.654730637  1.527971e-01
## 228  -0.641691293  1.602560e-01
## 229  -0.628651949  1.679015e-01
## 230  -0.615612605  1.756896e-01
## 231  -0.602573261  1.835852e-01
## 232  -0.589533917  1.915548e-01
## 233  -0.576494573  1.995675e-01
## 234  -0.563455229  2.075958e-01
## 235  -0.550415885  2.156160e-01
## 236  -0.537376541  2.236081e-01
## 237  -0.524337197  2.315549e-01
## 238  -0.511297853  2.394313e-01
## 239  -0.498258509  2.472265e-01
## 240  -0.485219165  2.549225e-01
## 241  -0.472179821  2.624974e-01
## 242  -0.459140477  2.699245e-01
## 243  -0.446101133  2.771722e-01
## 244  -0.433061789  2.842044e-01
## 245  -0.420022445  2.909813e-01
## 246  -0.406983101  2.974605e-01
## 247  -0.393943757  3.035880e-01
## 248  -0.380904413  3.092898e-01
## 249  -0.367865069  3.145668e-01
## 250  -0.354825725  3.193939e-01
## 251  -0.341786381  3.237556e-01
```

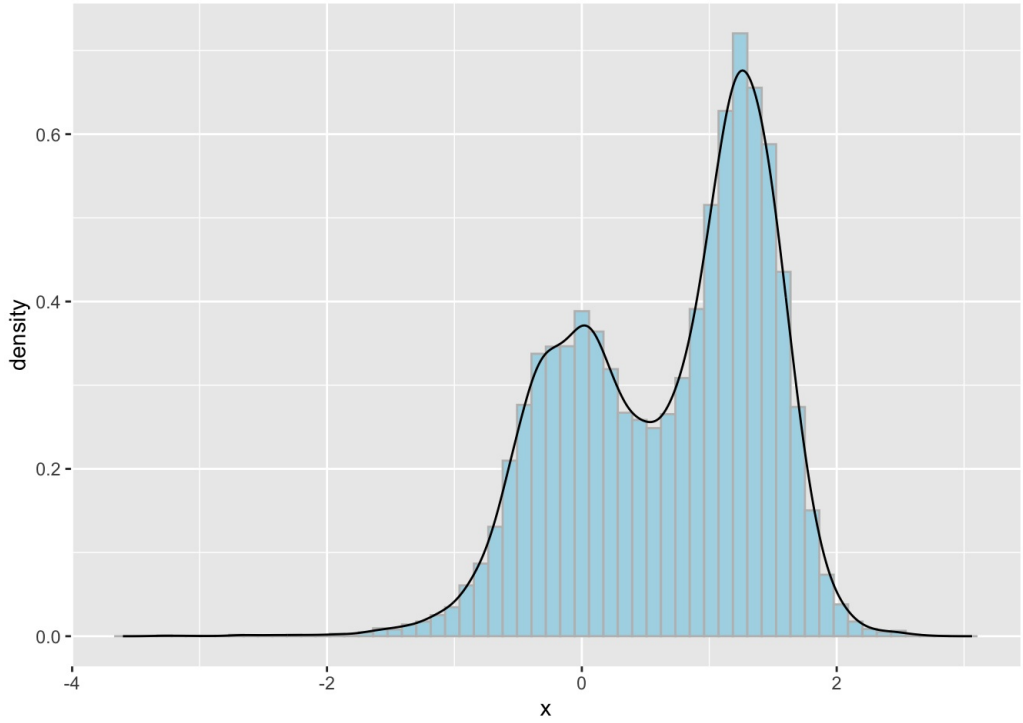
```
## 252  -0.328747037  3.276469e-01
## 253  -0.315707693  3.310743e-01
## 254  -0.302668349  3.340554e-01
## 255  -0.289629005  3.366185e-01
## 256  -0.276589661  3.388019e-01
## 257  -0.263550317  3.406353e-01
## 258  -0.250510973  3.421853e-01
## 259  -0.237471629  3.435327e-01
## 260  -0.224432285  3.447381e-01
## 261  -0.211392941  3.458609e-01
## 262  -0.198353597  3.469573e-01
## 263  -0.185314253  3.480786e-01
## 264  -0.172274909  3.492690e-01
## 265  -0.159235565  3.505642e-01
## 266  -0.146196221  3.519895e-01
## 267  -0.133156877  3.535731e-01
## 268  -0.120117533  3.553024e-01
## 269  -0.107078189  3.571554e-01
## 270  -0.094038845  3.591018e-01
## 271  -0.080999501  3.611000e-01
## 272  -0.067960157  3.630978e-01
## 273  -0.054920813  3.650350e-01
## 274  -0.041881469  3.668448e-01
## 275  -0.028842125  3.684569e-01
## 276  -0.015802781  3.697987e-01
## 277  -0.002763437  3.707506e-01
## 278   0.010275907  3.712871e-01
## 279   0.023315251  3.713592e-01
## 280   0.036354595  3.709300e-01
## 281   0.049393939  3.699759e-01
## 282   0.062433283  3.684874e-01
## 283   0.075472627  3.664687e-01
## 284   0.088511971  3.639372e-01
## 285   0.101551315  3.609224e-01
## 286   0.114590659  3.574485e-01
## 287   0.127630003  3.535538e-01
## 288   0.140669347  3.493321e-01
## 289   0.153708691  3.448390e-01
## 290   0.166748035  3.401299e-01
## 291   0.179787379  3.352583e-01
## 292   0.192826723  3.302754e-01
## 293   0.205866067  3.252290e-01
## 294   0.218905411  3.201636e-01
## 295   0.231944755  3.151207e-01
## 296   0.244984099  3.101463e-01
## 297   0.258023443  3.052823e-01
## 298   0.271062787  3.005580e-01
## 299   0.284102131  2.960046e-01
## 300   0.297141475  2.916507e-01
## 301   0.310180819  2.875224e-01
## 302   0.323220163  2.836423e-01
## 303   0.336259507  2.800287e-01
## 304   0.349298851  2.766949e-01
## 305   0.362338195  2.736484e-01
## 306   0.375377539  2.709212e-01
## 307   0.388416883  2.684796e-01
## 308   0.401456227  2.663048e-01
## 309   0.414495571  2.643796e-01
## 310   0.427534915  2.626848e-01
## 311   0.440574259  2.612011e-01
## 312   0.453613603  2.599105e-01
## 313   0.466652947  2.587989e-01
## 314   0.479692291  2.578572e-01
## 315   0.492731635  2.570855e-01
## 316   0.505770979  2.565083e-01
## 317   0.518810323  2.561219e-01
## 318   0.531849667  2.559475e-01
## 319   0.544889011  2.560108e-01
## 320   0.557928355  2.563394e-01
## 321   0.570967699  2.569617e-01
## 322   0.584007043  2.579043e-01
## 323   0.597046387  2.591907e-01
## 324   0.610085731  2.608398e-01
## 325   0.623125075  2.628839e-01
## 326   0.636164419  2.653422e-01
## 327   0.649203763  2.681844e-01
## 328   0.662243107  2.714066e-01
## 329   0.675282451  2.750028e-01
## 330   0.688321795  2.789662e-01
```

```
## 331   0.701361139  2.832913e-01
## 332   0.714400483  2.879746e-01
## 333   0.727439827  2.930161e-01
## 334   0.740479171  2.984200e-01
## 335   0.753518515  3.042274e-01
## 336   0.766557859  3.104399e-01
## 337   0.779597203  3.170579e-01
## 338   0.792636547  3.240999e-01
## 339   0.805675891  3.315846e-01
## 340   0.818715235  3.395293e-01
## 341   0.831754579  3.479487e-01
## 342   0.844793923  3.568534e-01
## 343   0.857833267  3.662492e-01
## 344   0.870872611  3.761359e-01
## 345   0.883911955  3.865617e-01
## 346   0.896951299  3.974554e-01
## 347   0.909990643  4.087877e-01
## 348   0.923029987  4.205273e-01
## 349   0.936069331  4.326374e-01
## 350   0.949108675  4.450758e-01
## 351   0.962148019  4.577962e-01
## 352   0.975187363  4.707486e-01
## 353   0.988226707  4.838807e-01
## 354   1.001266051  4.971394e-01
## 355   1.014305395  5.104629e-01
## 356   1.027344739  5.237794e-01
## 357   1.040384083  5.370277e-01
## 358   1.053423427  5.501434e-01
## 359   1.066462771  5.630580e-01
## 360   1.079502115  5.756983e-01
## 361   1.092541459  5.879861e-01
## 362   1.105580803  5.998381e-01
## 363   1.118620147  6.111665e-01
## 364   1.131659491  6.218368e-01
## 365   1.144698835  6.317285e-01
## 366   1.157738179  6.407959e-01
## 367   1.170777523  6.489557e-01
## 368   1.183816867  6.561343e-01
## 369   1.196856211  6.622702e-01
## 370   1.209895555  6.673164e-01
## 371   1.222934899  6.712423e-01
## 372   1.235974243  6.740337e-01
## 373   1.249013587  6.756930e-01
## 374   1.262052931  6.761376e-01
## 375   1.275092275  6.754722e-01
## 376   1.288131619  6.737798e-01
## 377   1.301170963  6.711077e-01
## 378   1.314210307  6.675035e-01
## 379   1.327249651  6.630123e-01
## 380   1.340288995  6.576741e-01
## 381   1.353328339  6.515225e-01
## 382   1.366367683  6.445835e-01
## 383   1.379407027  6.368760e-01
## 384   1.392446371  6.283166e-01
## 385   1.405485715  6.190106e-01
## 386   1.418525059  6.089650e-01
## 387   1.431564403  5.981877e-01
## 388   1.444603747  5.866902e-01
## 389   1.457643091  5.744895e-01
## 390   1.470682435  5.616085e-01
## 391   1.483721779  5.480772e-01
## 392   1.496761123  5.339324e-01
## 393   1.509800467  5.192000e-01
## 394   1.522839811  5.039088e-01
## 395   1.535879155  4.881691e-01
## 396   1.548918499  4.720405e-01
## 397   1.561957843  4.555849e-01
## 398   1.574997187  4.388661e-01
## 399   1.588036531  4.219488e-01
## 400   1.601075875  4.048984e-01
## 401   1.614115219  3.877804e-01
## 402   1.627154563  3.706601e-01
## 403   1.640193907  3.536115e-01
## 404   1.653233251  3.367104e-01
## 405   1.666272595  3.200129e-01
## 406   1.679311939  3.035759e-01
## 407   1.692351283  2.874526e-01
## 408   1.705390627  2.716921e-01
## 409   1.718429971  2.563382e-01
```

```
## 410   1.731469315  2.414293e-01
## 411   1.744508659  2.269984e-01
## 412   1.757548003  2.130721e-01
## 413   1.770587347  1.997283e-01
## 414   1.783626691  1.869425e-01
## 415   1.796666035  1.747101e-01
## 416   1.809705379  1.630360e-01
## 417   1.822744723  1.519225e-01
## 418   1.835784067  1.413689e-01
## 419   1.848823411  1.313728e-01
## 420   1.861862755  1.219297e-01
## 421   1.874902099  1.130335e-01
## 422   1.887941443  1.046811e-01
## 423   1.900980787  9.691887e-02
## 424   1.914020131  8.966836e-02
## 425   1.927059475  8.291293e-02
## 426   1.940098819  7.663306e-02
## 427   1.953138163  7.080642e-02
## 428   1.966177507  6.540814e-02
## 429   1.979216851  6.041137e-02
## 430   1.992256195  5.578788e-02
## 431   2.005295539  5.150888e-02
## 432   2.018334883  4.755835e-02
## 433   2.031374227  4.391587e-02
## 434   2.044413571  4.053049e-02
## 435   2.057452915  3.738095e-02
## 436   2.070492259  3.444894e-02
## 437   2.083531603  3.171906e-02
## 438   2.096570947  2.917866e-02
## 439   2.109610291  2.681742e-02
## 440   2.122649635  2.462696e-02
## 441   2.135688979  2.260027e-02
## 442   2.148728323  2.074308e-02
## 443   2.161767667  1.904404e-02
## 444   2.174807011  1.748928e-02
## 445   2.187846355  1.607254e-02
## 446   2.200885699  1.478710e-02
## 447   2.213925043  1.362586e-02
## 448   2.226964387  1.258134e-02
## 449   2.240003731  1.164585e-02
## 450   2.253043075  1.081157e-02
## 451   2.266082419  1.007069e-02
## 452   2.279121763  9.424141e-03
## 453   2.292161107  8.854886e-03
## 454   2.305200451  8.354247e-03
## 455   2.318239795  7.915003e-03
## 456   2.331279139  7.530003e-03
## 457   2.344318483  7.192134e-03
## 458   2.357357827  6.894313e-03
## 459   2.370397171  6.629500e-03
## 460   2.383436515  6.390751e-03
## 461   2.396475859  6.171525e-03
## 462   2.409515203  5.965464e-03
## 463   2.422554547  5.764778e-03
## 464   2.435593891  5.564527e-03
## 465   2.448633235  5.360644e-03
## 466   2.461672579  5.150038e-03
## 467   2.474711923  4.930656e-03
## 468   2.487751267  4.701499e-03
## 469   2.500790611  4.462589e-03
## 470   2.513829955  4.214883e-03
## 471   2.526869299  3.959926e-03
## 472   2.539908643  3.700634e-03
## 473   2.552947987  3.440434e-03
## 474   2.565987331  3.182305e-03
## 475   2.579026675  2.929114e-03
## 476   2.592066019  2.683473e-03
## 477   2.605105363  2.447626e-03
## 478   2.618144707  2.223381e-03
## 479   2.631184051  2.012070e-03
## 480   2.644223395  1.814554e-03
## 481   2.657262739  1.632497e-03
## 482   2.670302083  1.465156e-03
## 483   2.683341427  1.311539e-03
## 484   2.696380771  1.171040e-03
## 485   2.709420115  1.042914e-03
## 486   2.722459459  9.263361e-04
## 487   2.735498803  8.204385e-04
## 488   2.748538147  7.243530e-04
```

```
## 489   2.761577491  6.372378e-04
## 490   2.774616835  5.583004e-04
## 491   2.787656179  4.876338e-04
## 492   2.800695523  4.236583e-04
## 493   2.813734867  3.658047e-04
## 494   2.826774211  3.136267e-04
## 495   2.839813555  2.667459e-04
## 496   2.852852899  2.248394e-04
## 497   2.865892243  1.876246e-04
## 498   2.878931587  1.548435e-04
## 499   2.891970931  1.262473e-04
## 500   2.905010275  1.016864e-04
## 501   2.918049619  8.109971e-05
## 502   2.931088963  6.379438e-05
## 503   2.944128307  4.945468e-05
## 504   2.957167651  3.775319e-05
## 505   2.970206995  2.835873e-05
## 506   2.983246339  2.094505e-05
## 507   2.996285683  1.519932e-05
## 508   3.009325027  1.082972e-05
## 509   3.022364371  7.571476e-06
## 510   3.035403715  5.231855e-06
## 511   3.048443059  3.578129e-06
## 512   3.061482403  2.402234e-06
```

```
ggplot(data=df,mapping=aes(x)) + geom_histogram(aes(y=..density..),color="grey",fill="lightblue",bins=60)+ geom_lin
e(data=df.estimate1,aes(x = d.estimate1.x, y =d.estimate1.y))
```



Question 3

Using the formula for the Silverman rule that is given in the notes, compute the default bandwidth by hand. Do you get the same value as returned by `density()`? (If you don't…you coded the formula incorrectly.)

```
#s is the sample standard deviation and is the inter-quartile range


#s = sd(x)=0.7736771

#d.estimate$n=20722

#IQR/1.34=0.9526457

h = 0.9*(0.7736771)*(20722^(-1/5))
h
```

```
## [1] 0.09539287
```

Question 4

Repeat Q2, but use the unbiased cross-validation estimator, whose use is specified in the notes. Again, print the bandwidth and make the same density estimate overlaid onto histogram plot as in Q2. Stare hard at the two plots, the one here and the one in Q2: can you see any differences in the density estimates?

```
d.estimate=density(x, bw="ucv", adjust =1)
d.estimate
```

```
##
## Call:
##  density.default(x = x, bw = "ucv", adjust = 1)
##
## Data: x (20722 obs.);    Bandwidth 'bw' = 0.05836
##
##        x                 y
##  Min.   :-3.4905   Min.   :0.000004
##  1st Qu.:-1.8803   1st Qu.:0.001583
##  Median :-0.2701   Median :0.027016
##  Mean   :-0.2701   Mean   :0.155106
##  3rd Qu.: 1.3402   3rd Qu.:0.299222
##  Max.   : 2.9504   Max.   :0.697426
```

```
#Default Bandwidth 'bw' = 0.05836

df.estimate = data.frame(d.estimate$x,d.estimate$y)
df.estimate
```

```
##      d.estimate.x d.estimate.y
## 1   -3.4905317238 4.612954e-06
## 2   -3.4779271769 8.592507e-06
## 3   -3.4653226300 1.532062e-05
## 4   -3.4527180831 2.617532e-05
## 5   -3.4401135362 4.289964e-05
## 6   -3.4275089893 6.824707e-05
## 7   -3.4149044424 1.036580e-04
## 8   -3.4022998955 1.504487e-04
## 9   -3.3896953485 2.088459e-04
## 10  -3.3770908016 2.775239e-04
## 11  -3.3644862547 3.533404e-04
## 12  -3.3518817078 4.314065e-04
## 13  -3.3392771609 5.055637e-04
## 14  -3.3266726140 5.692485e-04
## 15  -3.3140680671 6.166125e-04
## 16  -3.3014635202 6.436739e-04
## 17  -3.2888589733 6.492317e-04
## 18  -3.2762544264 6.352924e-04
## 19  -3.2636498795 6.068563e-04
## 20  -3.2510453326 5.710763e-04
## 21  -3.2384407856 5.366062e-04
## 22  -3.2258362387 5.104734e-04
## 23  -3.2132316918 4.968286e-04
## 24  -3.2006271449 4.968363e-04
## 25  -3.1880225980 5.087505e-04
## 26  -3.1754180511 5.285152e-04
## 27  -3.1628135042 5.506921e-04
## 28  -3.1502089573 5.694946e-04
## 29  -3.1376044104 5.797326e-04
## 30  -3.1249998635 5.775384e-04
## 31  -3.1123953166 5.608152e-04
## 32  -3.0997907697 5.294087e-04
## 33  -3.0871862228 4.850355e-04
## 34  -3.0745816758 4.310152e-04
## 35  -3.0619771289 3.718689e-04
## 36  -3.0493725820 3.133705e-04
## 37  -3.0367680351 2.608108e-04
## 38  -3.0241634882 2.185571e-04
## 39  -3.0115589413 1.898244e-04
## 40  -2.9989543944 1.763438e-04
## 41  -2.9863498475 1.781622e-04
## 42  -2.9737453006 1.935958e-04
## 43  -2.9611407537 2.193591e-04
## 44  -2.9485362068 2.509015e-04
## 45  -2.9359316599 2.829609e-04
## 46  -2.9233271129 3.103093e-04
```

```
## 47  -2.9107225660 3.286072e-04
## 48  -2.8981180191 3.352314e-04
## 49  -2.8855134722 3.299137e-04
## 50  -2.8729089253 3.148619e-04
## 51  -2.8603043784 2.960550e-04
## 52  -2.8476998315 2.809269e-04
## 53  -2.8350952846 2.773704e-04
## 54  -2.8224907377 2.929729e-04
## 55  -2.8098861908 3.340056e-04
## 56  -2.7972816439 4.045236e-04
## 57  -2.7846770970 5.056601e-04
## 58  -2.7720725500 6.352034e-04
## 59  -2.7594680031 7.875498e-04
## 60  -2.7468634562 9.541009e-04
## 61  -2.7342589093 1.124117e-03
## 62  -2.7216543624 1.285953e-03
## 63  -2.7090498155 1.428505e-03
## 64  -2.6964452686 1.542631e-03
## 65  -2.6838407217 1.619904e-03
## 66  -2.6712361748 1.660267e-03
## 67  -2.6586316279 1.666417e-03
## 68  -2.6460270810 1.643390e-03
## 69  -2.6334225341 1.597919e-03
## 70  -2.6208179872 1.537238e-03
## 71  -2.6082134402 1.468019e-03
## 72  -2.5956088933 1.395647e-03
## 73  -2.5830043464 1.323983e-03
## 74  -2.5703997995 1.255639e-03
## 75  -2.5577952526 1.192678e-03
## 76  -2.5451907057 1.137478e-03
## 77  -2.5325861588 1.093425e-03
## 78  -2.5199816119 1.065101e-03
## 79  -2.5073770650 1.057840e-03
## 80  -2.4947725181 1.078332e-03
## 81  -2.4821679712 1.126490e-03
## 82  -2.4695634243 1.199706e-03
## 83  -2.4569588773 1.290885e-03
## 84  -2.4443543304 1.389112e-03
## 85  -2.4317497835 1.481303e-03
## 86  -2.4191452366 1.554465e-03
## 87  -2.4065406897 1.598098e-03
## 88  -2.3939361428 1.606204e-03
## 89  -2.3813315959 1.578492e-03
## 90  -2.3687270490 1.520534e-03
## 91  -2.3561225021 1.442852e-03
## 92  -2.3435179552 1.359127e-03
## 93  -2.3309134083 1.283880e-03
## 94  -2.3183088614 1.230653e-03
## 95  -2.3057043145 1.210270e-03
## 96  -2.2930997675 1.224062e-03
## 97  -2.2804952206 1.269051e-03
## 98  -2.2678906737 1.337397e-03
## 99  -2.2552861268 1.417914e-03
## 100 -2.2426815799 1.498109e-03
## 101 -2.2300770330 1.566447e-03
## 102 -2.2174724861 1.614369e-03
## 103 -2.2048679392 1.637671e-03
## 104 -2.1922633923 1.636933e-03
## 105 -2.1796588454 1.616907e-03
## 106 -2.1670542985 1.585048e-03
## 107 -2.1544497516 1.549616e-03
## 108 -2.1418452046 1.517848e-03
## 109 -2.1292406577 1.495100e-03
## 110 -2.1166361108 1.483720e-03
## 111 -2.1040315639 1.483051e-03
## 112 -2.0914270170 1.491959e-03
## 113 -2.0788224701 1.509475e-03
## 114 -2.0662179232 1.535484e-03
## 115 -2.0536133763 1.570939e-03
## 116 -2.0410088294 1.617584e-03
## 117 -2.0284042825 1.677318e-03
## 118 -2.0157997356 1.751358e-03
## 119 -2.0031951887 1.839446e-03
## 120 -1.9905906417 1.939321e-03
## 121 -1.9779860948 2.046608e-03
## 122 -1.9653815479 2.155182e-03
## 123 -1.9527770010 2.257933e-03
## 124 -1.9401724541 2.346779e-03
## 125 -1.9275679072 2.415679e-03
```

```
## 126 -1.9149633603 2.461641e-03
## 127 -1.9023588134 2.484080e-03
## 128 -1.8897542665 2.485497e-03
## 129 -1.8771497196 2.471556e-03
## 130 -1.8645451727 2.450847e-03
## 131 -1.8519406258 2.434228e-03
## 132 -1.8393360789 2.433731e-03
## 133 -1.8267315319 2.461096e-03
## 134 -1.8141269850 2.526183e-03
## 135 -1.8015224381 2.635581e-03
## 136 -1.7889178912 2.791769e-03
## 137 -1.7763133443 2.993105e-03
## 138 -1.7637087974 3.234668e-03
## 139 -1.7511042505 3.511508e-03
## 140 -1.7384997036 3.814626e-03
## 141 -1.7258951567 4.138719e-03
## 142 -1.7132906098 4.480549e-03
## 143 -1.7006860629 4.837910e-03
## 144 -1.6880815160 5.208515e-03
## 145 -1.6754769690 5.588909e-03
## 146 -1.6628724221 5.973877e-03
## 147 -1.6502678752 6.356602e-03
## 148 -1.6376633283 6.729497e-03
## 149 -1.6250587814 7.085403e-03
## 150 -1.6124542345 7.418687e-03
## 151 -1.5998496876 7.725830e-03
## 152 -1.5872451407 8.005370e-03
## 153 -1.5746405938 8.257272e-03
## 154 -1.5620360469 8.481199e-03
## 155 -1.5494315000 8.682030e-03
## 156 -1.5368269531 8.864937e-03
## 157 -1.5242224061 9.038295e-03
## 158 -1.5116178592 9.213808e-03
## 159 -1.4990133123 9.405384e-03
## 160 -1.4864087654 9.626777e-03
## 161 -1.4738042185 9.888537e-03
## 162 -1.4611996716 1.019515e-02
## 163 -1.4485951247 1.054330e-02
## 164 -1.4359905778 1.092188e-02
## 165 -1.4233860309 1.131395e-02
## 166 -1.4107814840 1.170023e-02
## 167 -1.3981769371 1.206336e-02
## 168 -1.3855723902 1.239114e-02
## 169 -1.3729678433 1.268067e-02
## 170 -1.3603632963 1.294399e-02
## 171 -1.3477587494 1.319989e-02
## 172 -1.3351542025 1.347342e-02
## 173 -1.3225496556 1.379247e-02
## 174 -1.3099451087 1.418388e-02
## 175 -1.2973405618 1.466965e-02
## 176 -1.2847360149 1.526376e-02
## 177 -1.2721314680 1.597019e-02
## 178 -1.2595269211 1.678279e-02
## 179 -1.2469223742 1.768691e-02
## 180 -1.2343178273 1.866260e-02
## 181 -1.2217132804 1.968843e-02
## 182 -1.2091087334 2.074475e-02
## 183 -1.1965041865 2.181568e-02
## 184 -1.1838996396 2.288780e-02
## 185 -1.1712950927 2.395112e-02
## 186 -1.1586905458 2.499696e-02
## 187 -1.1460859989 2.601742e-02
## 188 -1.1334814520 2.700648e-02
## 189 -1.1208769051 2.796183e-02
## 190 -1.1082723582 2.888665e-02
## 191 -1.0956678113 2.979076e-02
## 192 -1.0830632644 3.069100e-02
## 193 -1.0704587175 3.161073e-02
## 194 -1.0578541706 3.257885e-02
## 195 -1.0452496236 3.362824e-02
## 196 -1.0326450767 3.479378e-02
## 197 -1.0200405298 3.610985e-02
## 198 -1.0074359829 3.761839e-02
## 199 -0.9948314360 3.933973e-02
## 200 -0.9822268891 4.128200e-02
## 201 -0.9696223422 4.344797e-02
## 202 -0.9570177953 4.583104e-02
## 203 -0.9444132484 4.841640e-02
## 204 -0.9318087015 5.118198e-02
```

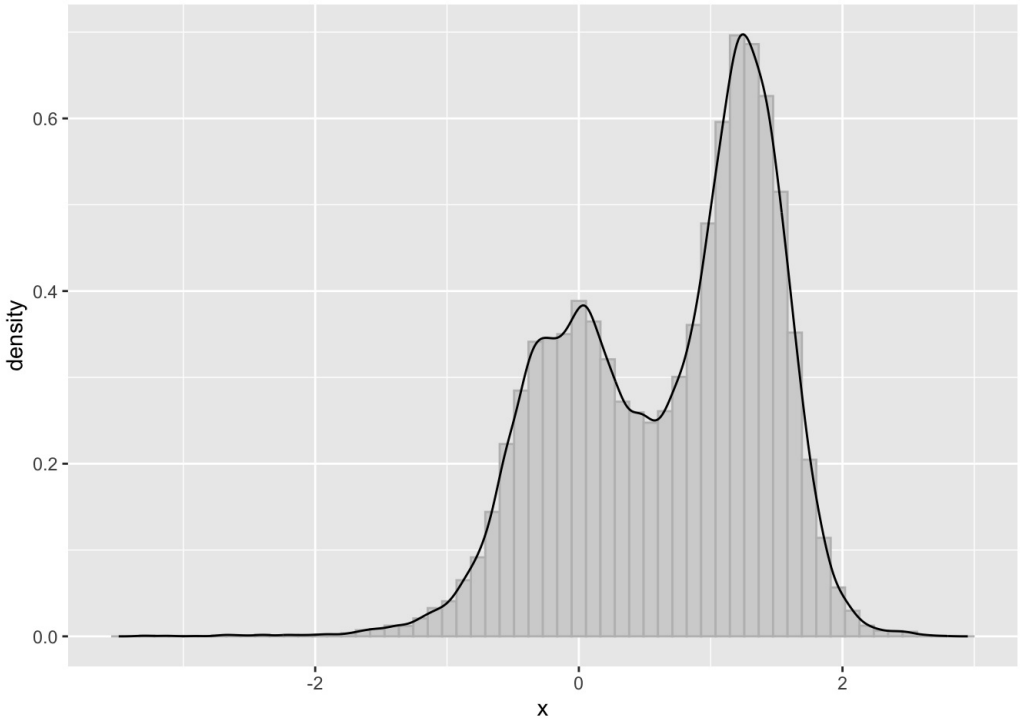
```
## 205 -0.9192041546 5.409951e-02
## 206 -0.9065996077 5.713582e-02
## 207 -0.8939950607 6.025537e-02
## 208 -0.8813905138 6.342431e-02
## 209 -0.8687859669 6.661594e-02
## 210 -0.8561814200 6.981647e-02
## 211 -0.8435768731 7.302932e-02
## 212 -0.8309723262 7.627619e-02
## 213 -0.8183677793 7.960269e-02
## 214 -0.8057632324 8.305461e-02
## 215 -0.7931586855 8.667700e-02
## 216 -0.7805541386 9.051031e-02
## 217 -0.7679495917 9.458916e-02
## 218 -0.7553450448 9.894511e-02
## 219 -0.7427404978 1.036106e-01
## 220 -0.7301359509 1.086223e-01
## 221 -0.7175314040 1.140215e-01
## 222 -0.7049268571 1.198513e-01
## 223 -0.6923223102 1.261504e-01
## 224 -0.6797177633 1.329451e-01
## 225 -0.6671132164 1.402412e-01
## 226 -0.6545086695 1.480166e-01
## 227 -0.6419041226 1.562193e-01
## 228 -0.6292995757 1.647718e-01
## 229 -0.6166950288 1.735206e-01
## 230 -0.6040904819 1.823255e-01
## 231 -0.5914859350 1.910440e-01
## 232 -0.5788813880 1.995498e-01
## 233 -0.5662768411 2.077516e-01
## 234 -0.5536722942 2.156078e-01
## 235 -0.5410677473 2.231350e-01
## 236 -0.5284632004 2.304052e-01
## 237 -0.5158586535 2.375323e-01
## 238 -0.5032541066 2.446496e-01
## 239 -0.4906495597 2.518825e-01
## 240 -0.4780450128 2.593231e-01
## 241 -0.4654404659 2.670109e-01
## 242 -0.4528359190 2.749278e-01
## 243 -0.4402313721 2.829856e-01
## 244 -0.4276268251 2.910406e-01
## 245 -0.4150222782 2.989403e-01
## 246 -0.4024177313 3.065263e-01
## 247 -0.3898131844 3.136474e-01
## 248 -0.3772086375 3.201696e-01
## 249 -0.3646040906 3.259840e-01
## 250 -0.3519995437 3.310147e-01
## 251 -0.3393949968 3.352240e-01
## 252 -0.3267904499 3.386150e-01
## 253 -0.3141859030 3.412309e-01
## 254 -0.3015813561 3.431484e-01
## 255 -0.2889768092 3.444669e-01
## 256 -0.2763722623 3.452961e-01
## 257 -0.2637677153 3.457325e-01
## 258 -0.2511631684 3.458828e-01
## 259 -0.2385586215 3.458429e-01
## 260 -0.2259540746 3.456865e-01
## 261 -0.2133495277 3.454872e-01
## 262 -0.2007449808 3.453240e-01
## 263 -0.1881404339 3.452828e-01
## 264 -0.1755358870 3.454539e-01
## 265 -0.1629313401 3.459246e-01
## 266 -0.1503267932 3.467696e-01
## 267 -0.1377222463 3.480429e-01
## 268 -0.1251176994 3.497707e-01
## 269 -0.1125131524 3.519497e-01
## 270 -0.0999086055 3.545490e-01
## 271 -0.0873040586 3.575150e-01
## 272 -0.0746995117 3.607879e-01
## 273 -0.0620949648 3.642626e-01
## 274 -0.0494904179 3.678305e-01
## 275 -0.0368858710 3.713728e-01
## 276 -0.0242813241 3.747504e-01
## 277 -0.0116767772 3.778041e-01
## 278  0.0009277697 3.803603e-01
## 279  0.0135323166 3.822436e-01
## 280  0.0261368635 3.832934e-01
## 281  0.0387414105 3.833850e-01
## 282  0.0513459574 3.824472e-01
## 283  0.0639505043 3.804754e-01
```

```
## 284  0.0765550512 3.775340e-01
## 285  0.0891595981 3.737486e-01
## 286  0.1017641450 3.692867e-01
## 287  0.1143686919 3.643113e-01
## 288  0.1269732388 3.590372e-01
## 289  0.1395777857 3.535996e-01
## 290  0.1521823326 3.480911e-01
## 291  0.1647868795 3.425689e-01
## 292  0.1773914264 3.370665e-01
## 293  0.1899959733 3.316045e-01
## 294  0.2026005203 3.261989e-01
## 295  0.2152050672 3.208626e-01
## 296  0.2278096141 3.156036e-01
## 297  0.2404141610 3.104211e-01
## 298  0.2530187079 3.053042e-01
## 299  0.2656232548 3.002372e-01
## 300  0.2782278017 2.952100e-01
## 301  0.2908323486 2.902328e-01
## 302  0.3034368955 2.853599e-01
## 303  0.3160414424 2.806728e-01
## 304  0.3286459893 2.762803e-01
## 305  0.3412505362 2.722974e-01
## 306  0.3538550832 2.688241e-01
## 307  0.3664596301 2.659283e-01
## 308  0.3790641770 2.636332e-01
## 309  0.3916687239 2.619142e-01
## 310  0.4042732708 2.607021e-01
## 311  0.4168778177 2.598924e-01
## 312  0.4294823646 2.593576e-01
## 313  0.4420869115 2.589613e-01
## 314  0.4546914584 2.585722e-01
## 315  0.4672960053 2.580776e-01
## 316  0.4799005522 2.573905e-01
## 317  0.4925050991 2.564665e-01
## 318  0.5051096460 2.553373e-01
## 319  0.5177141930 2.540724e-01
## 320  0.5303187399 2.527815e-01
## 321  0.5429232868 2.516012e-01
## 322  0.5555278337 2.506790e-01
## 323  0.5681323806 2.501550e-01
## 324  0.5807369275 2.501477e-01
## 325  0.5933414744 2.507419e-01
## 326  0.6059460213 2.519839e-01
## 327  0.6185505682 2.538806e-01
## 328  0.6311551151 2.564048e-01
## 329  0.6437596620 2.595014e-01
## 330  0.6563642089 2.630955e-01
## 331  0.6689687559 2.671117e-01
## 332  0.6815733028 2.714421e-01
## 333  0.6941778497 2.759792e-01
## 334  0.7067823966 2.806429e-01
## 335  0.7193869435 2.853782e-01
## 336  0.7319914904 2.901677e-01
## 337  0.7445960373 2.950396e-01
## 338  0.7572005842 3.000679e-01
## 339  0.7698051311 3.053610e-01
## 340  0.7824096780 3.110418e-01
## 341  0.7950142249 3.172221e-01
## 342  0.8076187718 3.239804e-01
## 343  0.8202233188 3.313498e-01
## 344  0.8328278657 3.393202e-01
## 345  0.8454324126 3.478555e-01
## 346  0.8580369595 3.569484e-01
## 347  0.8706415064 3.665697e-01
## 348  0.8832460533 3.767342e-01
## 349  0.8958506002 3.874876e-01
## 350  0.9084551471 3.988713e-01
## 351  0.9210596940 4.108970e-01
## 352  0.9336642409 4.235294e-01
## 353  0.9462687878 4.366813e-01
## 354  0.9588733347 4.502232e-01
## 355  0.9714778816 4.640048e-01
## 356  0.9840824286 4.778789e-01
## 357  0.9966869755 4.917251e-01
## 358  1.0092915224 5.054639e-01
## 359  1.0218960693 5.190611e-01
## 360  1.0345006162 5.325210e-01
## 361  1.0471051631 5.458685e-01
## 362  1.0597097100 5.591503e-01
```

```
## 363  1.0723142569 5.723923e-01
## 364  1.0849188038 5.855982e-01
## 365  1.0975233507 5.987434e-01
## 366  1.1101278976 6.117688e-01
## 367  1.1227324445 6.245753e-01
## 368  1.1353369915 6.370190e-01
## 369  1.1479415384 6.489092e-01
## 370  1.1605460853 6.600139e-01
## 371  1.1731506322 6.700746e-01
## 372  1.1857551791 6.788308e-01
## 373  1.1983597260 6.860531e-01
## 374  1.2109642729 6.915758e-01
## 375  1.2235688198 6.953033e-01
## 376  1.2361733667 6.971708e-01
## 377  1.2487779136 6.974258e-01
## 378  1.2613824605 6.962487e-01
## 379  1.2739870074 6.938443e-01
## 380  1.2865915544 6.904190e-01
## 381  1.2991961013 6.861689e-01
## 382  1.3118006482 6.812731e-01
## 383  1.3244051951 6.758882e-01
## 384  1.3370097420 6.701382e-01
## 385  1.3496142889 6.641000e-01
## 386  1.3622188358 6.577874e-01
## 387  1.3748233827 6.511410e-01
## 388  1.3874279296 6.440314e-01
## 389  1.4000324765 6.362797e-01
## 390  1.4126370234 6.276663e-01
## 391  1.4252415703 6.179935e-01
## 392  1.4378461172 6.072271e-01
## 393  1.4504506642 5.953722e-01
## 394  1.4630552111 5.825050e-01
## 395  1.4756597580 5.687490e-01
## 396  1.4882643049 5.542473e-01
## 397  1.5008688518 5.391373e-01
## 398  1.5134733987 5.235345e-01
## 399  1.5260779456 5.075247e-01
## 400  1.5386824925 4.911654e-01
## 401  1.5512870394 4.744927e-01
## 402  1.5638915863 4.575316e-01
## 403  1.5764961332 4.403072e-01
## 404  1.5891006801 4.228545e-01
## 405  1.6017052271 4.052200e-01
## 406  1.6143097740 3.874839e-01
## 407  1.6269143209 3.697350e-01
## 408  1.6395188678 3.520582e-01
## 409  1.6521234147 3.345330e-01
## 410  1.6647279616 3.172302e-01
## 411  1.6773325085 3.002133e-01
## 412  1.6899370554 2.835435e-01
## 413  1.7025416023 2.672848e-01
## 414  1.7151461492 2.515072e-01
## 415  1.7277506961 2.362836e-01
## 416  1.7403552430 2.216818e-01
## 417  1.7529597899 2.077536e-01
## 418  1.7655643369 1.945241e-01
## 419  1.7781688838 1.819851e-01
## 420  1.7907734307 1.701310e-01
## 421  1.8033779776 1.588669e-01
## 422  1.8159825245 1.481138e-01
## 423  1.8285870714 1.378188e-01
## 424  1.8411916183 1.279524e-01
## 425  1.8537961652 1.185121e-01
## 426  1.8664007121 1.095201e-01
## 427  1.8790052590 1.010158e-01
## 428  1.8916098059 9.304549e-02
## 429  1.9042143528 8.565219e-02
## 430  1.9168188998 7.886689e-02
## 431  1.9294234467 7.270203e-02
## 432  1.9420279936 6.714796e-02
## 433  1.9546325405 6.217204e-02
## 434  1.9672370874 5.772029e-02
## 435  1.9798416343 5.374813e-02
## 436  1.9924461812 5.013366e-02
## 437  2.0050507281 4.679214e-02
## 438  2.0176552750 4.364890e-02
## 439  2.0302598219 4.064488e-02
## 440  2.0428643688 3.774108e-02
## 441  2.0554689157 3.491967e-02
```

```
## 442  2.0680734627 3.218172e-02
## 443  2.0806780096 2.954247e-02
## 444  2.0932825565 2.702515e-02
## 445  2.1058871034 2.465476e-02
## 446  2.1184916503 2.245304e-02
## 447  2.1310961972 2.043516e-02
## 448  2.1437007441 1.860833e-02
## 449  2.1563052910 1.697435e-02
## 450  2.1689098379 1.553432e-02
## 451  2.1815143848 1.426244e-02
## 452  2.1941189317 1.314212e-02
## 453  2.2067234786 1.215475e-02
## 454  2.2193280255 1.128101e-02
## 455  2.2319325725 1.050230e-02
## 456  2.2445371194 9.802342e-03
## 457  2.2571416663 9.168677e-03
## 458  2.2697462132 8.593689e-03
## 459  2.2823507601 8.074810e-03
## 460  2.2949553070 7.613667e-03
## 461  2.3075598539 7.214230e-03
## 462  2.3201644008 6.880365e-03
## 463  2.3327689477 6.613415e-03
## 464  2.3453734946 6.412125e-03
## 465  2.3579780415 6.268777e-03
## 466  2.3705825884 6.168353e-03
## 467  2.3831871354 6.097441e-03
## 468  2.3957916823 6.042558e-03
## 469  2.4083962292 5.991007e-03
## 470  2.4210007761 5.931132e-03
## 471  2.4336053230 5.852267e-03
## 472  2.4462098699 5.744754e-03
## 473  2.4588144168 5.600301e-03
## 474  2.4714189637 5.412742e-03
## 475  2.4840235106 5.179005e-03
## 476  2.4966280575 4.899998e-03
## 477  2.5092326044 4.581060e-03
## 478  2.5218371513 4.231759e-03
## 479  2.5344416982 3.864942e-03
## 480  2.5470462452 3.497177e-03
## 481  2.5596507921 3.142997e-03
## 482  2.5722553390 2.813770e-03
## 483  2.5848598859 2.516934e-03
## 484  2.5974644328 2.255380e-03
## 485  2.6100689797 2.027652e-03
## 486  2.6226735266 1.828928e-03
## 487  2.6352780735 1.652563e-03
## 488  2.6478826204 1.491842e-03
## 489  2.6604871673 1.341536e-03
## 490  2.6730917142 1.198877e-03
## 491  2.6856962611 1.063754e-03
## 492  2.6983008081 9.380936e-04
## 493  2.7109053550 8.246810e-04
## 494  2.7235099019 7.266902e-04
## 495  2.7361144488 6.438356e-04
## 496  2.7487189957 5.739708e-04
## 497  2.7613235426 5.137239e-04
## 498  2.7739280895 4.591959e-04
## 499  2.7865326364 4.069672e-04
## 500  2.7991371833 3.548535e-04
## 501  2.8117417302 3.022296e-04
## 502  2.8243462771 2.498976e-04
## 503  2.8369508240 1.996086e-04
## 504  2.8495553710 1.534278e-04
## 505  2.8621599179 1.131418e-04
## 506  2.8747644648 7.985585e-05
## 507  2.8873690117 5.384399e-05
## 508  2.8999735586 3.463031e-05
## 509  2.9125781055 2.155503e-05
## 510  2.9251826524 1.285228e-05
## 511  2.9377871993 7.332985e-06
## 512  2.9503917462 3.999644e-06
```

```
ggplot(data=df,mapping=aes(x)) + geom_histogram(aes(y=..density..),color="grey",fill="lightgrey",bins=60)+ geom_lin
e(data=df.estimate,aes(x = d.estimate.x, y =d.estimate.y))
```



I do see slight differences in the density estimates. This one (compared to the previous one in question 2) is less smoothed and closer to the shape of the histogram.

Question 5

Density estimates tend to work fine with unbounded data, but can exhibit boundary bias if the data values are bounded on either or both sides. Repeat Q4, except run the code for only x values between 0 and 1, and set the bandwidth manually to 0.1. What do you observe?

```
df.new = filter(df, x<=1 & x>=0)

d.estimate2=density(df.new$x, bw=0.1, adjust =1)
d.estimate2
```

```
##
## Call:
##  density.default(x = df.new$x, bw = 0.1, adjust = 1)
##
## Data: df.new$x (6524 obs.);  Bandwidth 'bw' = 0.1
##
##        x                 y
##  Min.   :-0.30000   Min.   :0.001655
##  1st Qu.: 0.09997   1st Qu.:0.203632
##  Median : 0.49994   Median :0.821325
##  Mean   : 0.49994   Mean   :0.624380
##  3rd Qu.: 0.89991   3rd Qu.:0.931110
##  Max.   : 1.29987   Max.   :1.031557
```

```
df.estimate2 = data.frame(d.estimate2$x,d.estimate2$y)
df.estimate2
```

```
##     d.estimate2.x d.estimate2.y
## 1   -0.2999950817   0.001654691
## 2   -0.2968642260   0.001832877
## 3   -0.2937333704   0.002031211
## 4   -0.2906025147   0.002243739
## 5   -0.2874716590   0.002478610
## 6   -0.2843408033   0.002739134
## 7   -0.2812099477   0.003017683
## 8   -0.2780790920   0.003324545
## 9   -0.2749482363   0.003663745
## 10  -0.2718173806   0.004025609
## 11  -0.2686865250   0.004422995
## 12  -0.2655556693   0.004860741
## 13  -0.2624248136   0.005326697
## 14  -0.2592939580   0.005836773
## 15  -0.2561631023   0.006396714
## 16  -0.2530322466   0.006991417
```

```
## 17  -0.2499013909   0.007640364
## 18  -0.2467705353   0.008350292
## 19  -0.2436396796   0.009102618
## 20  -0.2405088239   0.009920954
## 21  -0.2373779683   0.010813100
## 22  -0.2342471126   0.011756424
## 23  -0.2311162569   0.012779245
## 24  -0.2279854012   0.013890474
## 25  -0.2248545456   0.015062834
## 26  -0.2217236899   0.016329933
## 27  -0.2185928342   0.017701805
## 28  -0.2154619786   0.019145926
## 29  -0.2123311229   0.020701748
## 30  -0.2092002672   0.022380408
## 31  -0.2060694115   0.024143537
## 32  -0.2029385559   0.026036943
## 33  -0.1998077002   0.028072798
## 34  -0.1966768445   0.030206327
## 35  -0.1935459889   0.032490126
## 36  -0.1904151332   0.034937278
## 37  -0.1872842775   0.037496113
## 38  -0.1841534218   0.040226330
## 39  -0.1810225662   0.043141742
## 40  -0.1778917105   0.046183394
## 41  -0.1747608548   0.049418260
## 42  -0.1716299991   0.052860635
## 43  -0.1684991435   0.056444032
## 44  -0.1653682878   0.060242677
## 45  -0.1622374321   0.064271045
## 46  -0.1591065765   0.068455042
## 47  -0.1559757208   0.072875912
## 48  -0.1528448651   0.077547943
## 49  -0.1497140094   0.082389572
## 50  -0.1465831538   0.087488579
## 51  -0.1434522981   0.092858644
## 52  -0.1403214424   0.098411125
## 53  -0.1371905868   0.104239579
## 54  -0.1340597311   0.110356624
## 55  -0.1309288754   0.116667193
## 56  -0.1277980197   0.123269585
## 57  -0.1246671641   0.130174868
## 58  -0.1215363084   0.137282503
## 59  -0.1184054527   0.144694207
## 60  -0.1152745971   0.152419010
## 61  -0.1121437414   0.160352144
## 62  -0.1090128857   0.168597150
## 63  -0.1058820300   0.177160544
## 64  -0.1027511744   0.185934868
## 65  -0.0996203187   0.195023644
## 66  -0.0964894630   0.204430443
## 67  -0.0933586074   0.214046916
## 68  -0.0902277517   0.223974527
## 69  -0.0870968960   0.234213528
## 70  -0.0839660403   0.244656718
## 71  -0.0808351847   0.255401308
## 72  -0.0777043290   0.266443950
## 73  -0.0745734733   0.277680804
## 74  -0.0714426176   0.289202558
## 75  -0.0683117620   0.301002087
## 76  -0.0651809063   0.312981246
## 77  -0.0620500506   0.325221922
## 78  -0.0589191950   0.337713161
## 79  -0.0557883393   0.350364887
## 80  -0.0526574836   0.363247988
## 81  -0.0495266279   0.376347765
## 82  -0.0463957723   0.389584538
## 83  -0.0432649166   0.403016167
## 84  -0.0401340609   0.416624431
## 85  -0.0370032053   0.430342240
## 86  -0.0338723496   0.444212644
## 87  -0.0307414939   0.458214262
## 88  -0.0276106382   0.472294564
## 89  -0.0244797826   0.486480336
## 90  -0.0213489269   0.500747526
## 91  -0.0182180712   0.515059828
## 92  -0.0150872156   0.529426705
## 93  -0.0119563599   0.543822026
## 94  -0.0088255042   0.558227000
## 95  -0.0056946485   0.572633143
```

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## 96  -0.0025637929   0.587012930
## 97   0.0005670628   0.601365930
## 98   0.0036979185   0.615665569
## 99   0.0068287741   0.629883664
## 100  0.0099596298   0.644038517
## 101  0.0130904855   0.658085796
## 102  0.0162213412   0.671997425
## 103  0.0193521968   0.685810309
## 104  0.0224830525   0.699463170
## 105  0.0256139082   0.712928791
## 106  0.0287447639   0.726262054
## 107  0.0318756195   0.739385987
## 108  0.0350064752   0.752274940
## 109  0.0381373309   0.765000675
## 110  0.0412681865   0.777472167
## 111  0.0443990422   0.789665971
## 112  0.0475298979   0.801669202
## 113  0.0506607536   0.813378747
## 114  0.0537916092   0.824773909
## 115  0.0569224649   0.835955256
## 116  0.0600533206   0.846809803
## 117  0.0631841762   0.857320022
## 118  0.0663150319   0.867597748
## 119  0.0694458876   0.877522495
## 120  0.0725767433   0.887080198
## 121  0.0757075989   0.896391565
## 122  0.0788384546   0.905331058
## 123  0.0819693103   0.913888226
## 124  0.0851001659   0.922190147
## 125  0.0882310216   0.930108659
## 126  0.0913618773   0.937636950
## 127  0.0944927330   0.944905937
## 128  0.0976235886   0.951787168
## 129  0.1007544443   0.958277367
## 130  0.1038853000   0.964508827
## 131  0.1070161556   0.970354973
## 132  0.1101470113   0.975815851
## 133  0.1132778670   0.981022808
## 134  0.1164087227   0.985853089
## 135  0.1195395783   0.990309756
## 136  0.1226704340   0.994521098
## 137  0.1258012897   0.998369854
## 138  0.1289321454   1.001861728
## 139  0.1320630010   1.005120094
## 140  0.1351938567   1.008034569
## 141  0.1383247124   1.010613075
## 142  0.1414555680   1.012972515
## 143  0.1445864237   1.015010453
## 144  0.1477172794   1.016736586
## 145  0.1508481351   1.018260100
## 146  0.1539789907   1.019487275
## 147  0.1571098464   1.020429139
## 148  0.1602407021   1.021186229
## 149  0.1633715577   1.021674021
## 150  0.1665024134   1.021904448
## 151  0.1696332691   1.021968774
## 152  0.1727641248   1.021791886
## 153  0.1758949804   1.021386226
## 154  0.1790258361   1.020833451
## 155  0.1821566918   1.020067840
## 156  0.1852875474   1.019101994
## 157  0.1884184031   1.018007883
## 158  0.1915492588   1.016728960
## 159  0.1946801145   1.015277693
## 160  0.1978109701   1.013716500
## 161  0.2009418258   1.011997640
## 162  0.2040726815   1.010133202
## 163  0.2072035371   1.008176371
## 164  0.2103343928   1.006087724
## 165  0.2134652485   1.003878788
## 166  0.2165961042   1.001593964
## 167  0.2197269598   0.999201582
## 168  0.2228578155   0.996712471
## 169  0.2259886712   0.994162807
## 170  0.2291195269   0.991528050
## 171  0.2322503825   0.988818245
## 172  0.2353812382   0.986061964
## 173  0.2385120939   0.983241154
## 174  0.2416429495   0.980365034
```

```
## 175  0.2447738052   0.977455219
## 176  0.2479046609   0.974499507
## 177  0.2510355166   0.971506274
## 178  0.2541663722   0.968490843
## 179  0.2572972279   0.965446237
## 180  0.2604280836   0.962379997
## 181  0.2635589392   0.959301806
## 182  0.2666897949   0.956209315
## 183  0.2698206506   0.953109255
## 184  0.2729515063   0.950006300
## 185  0.2760823619   0.946902162
## 186  0.2792132176   0.943802796
## 187  0.2823440733   0.940708465
## 188  0.2854749289   0.937624411
## 189  0.2886057846   0.934555855
## 190  0.2917366403   0.931499209
## 191  0.2948674960   0.928462750
## 192  0.2979983516   0.925451002
## 193  0.3011292073   0.922457052
## 194  0.3042600630   0.919491750
## 195  0.3073909186   0.916558961
## 196  0.3105217743   0.913648935
## 197  0.3136526300   0.910774662
## 198  0.3167834857   0.907939382
## 199  0.3199143413   0.905130967
## 200  0.3230451970   0.902364139
## 201  0.3261760527   0.899641545
## 202  0.3293069084   0.896949108
## 203  0.3324377640   0.894302898
## 204  0.3355686197   0.891705000
## 205  0.3386994754   0.889139789
## 206  0.3418303310   0.886624325
## 207  0.3449611867   0.884160161
## 208  0.3480920424   0.881730502
## 209  0.3512228981   0.879353062
## 210  0.3543537537   0.877028894
## 211  0.3574846094   0.874740388
## 212  0.3606154651   0.872505602
## 213  0.3637463207   0.870325125
## 214  0.3668771764   0.868180860
## 215  0.3700080321   0.866090929
## 216  0.3731388878   0.864055504
## 217  0.3762697434   0.862056296
## 218  0.3794005991   0.860111247
## 219  0.3825314548   0.858220161
## 220  0.3856623104   0.856364825
## 221  0.3887931661   0.854562795
## 222  0.3919240218   0.852813565
## 223  0.3950548775   0.851099229
## 224  0.3981857331   0.849436791
## 225  0.4013165888   0.847825505
## 226  0.4044474445   0.846247957
## 227  0.4075783001   0.844720486
## 228  0.4107091558   0.843242178
## 229  0.4138400115   0.841796251
## 230  0.4169708672   0.840398315
## 231  0.4201017228   0.839047371
## 232  0.4232325785   0.837727352
## 233  0.4263634342   0.836453135
## 234  0.4294942899   0.835223709
## 235  0.4326251455   0.834023762
## 236  0.4357560012   0.832867477
## 237  0.4388868569   0.831753915
## 238  0.4420177125   0.830668499
## 239  0.4451485682   0.829624808
## 240  0.4482794239   0.828622050
## 241  0.4514102796   0.827646311
## 242  0.4545411352   0.826710708
## 243  0.4576719909   0.825814657
## 244  0.4608028466   0.824944791
## 245  0.4639337022   0.824113938
## 246  0.4670645579   0.823321777
## 247  0.4701954136   0.822555328
## 248  0.4733262693   0.821827334
## 249  0.4764571249   0.821137772
## 250  0.4795879806   0.820473861
## 251  0.4827188363   0.819848476
## 252  0.4858496919   0.819261919
## 253  0.4889805476   0.818701389
```

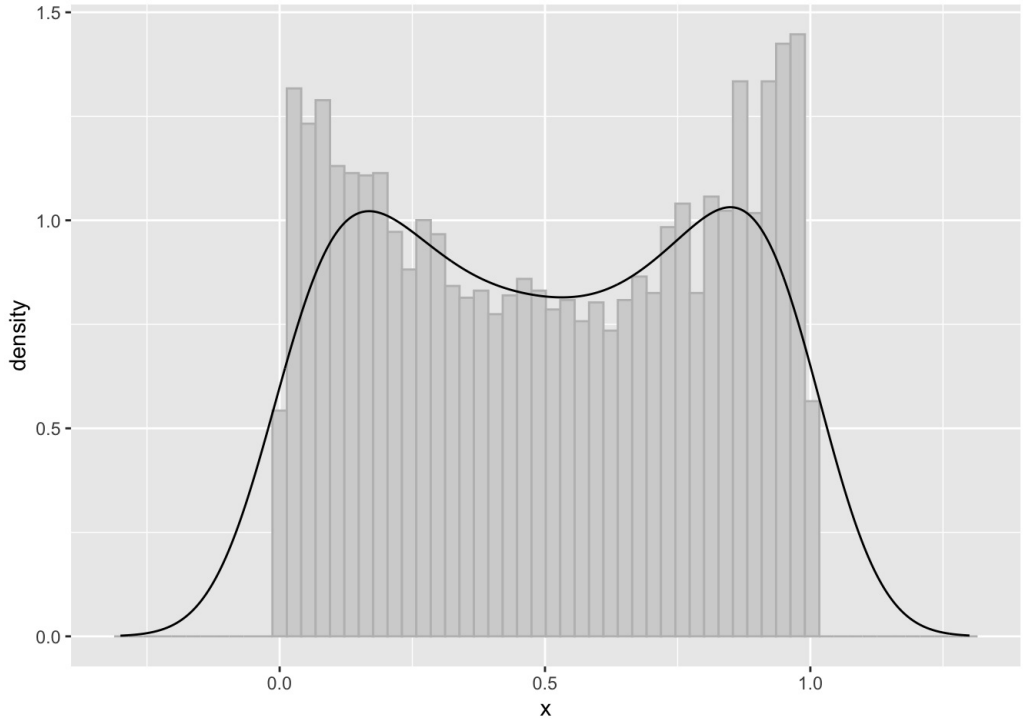
```
## 254  0.4921114033   0.818180123
## 255  0.4952422590   0.817698746
## 256  0.4983731146   0.817244218
## 257  0.5015039703   0.816830353
## 258  0.5046348260   0.816458089
## 259  0.5077656816   0.816113920
## 260  0.5108965373   0.815812442
## 261  0.5140273930   0.815554871
## 262  0.5171582487   0.815327026
## 263  0.5202891043   0.815144457
## 264  0.5234199600   0.815008616
## 265  0.5265508157   0.814904453
## 266  0.5296816714   0.814848615
## 267  0.5328125270   0.814842723
## 268  0.5359433827   0.814870713
## 269  0.5390742384   0.814950414
## 270  0.5422050940   0.815083555
## 271  0.5453359497   0.815252937
## 272  0.5484668054   0.815477621
## 273  0.5515976611   0.815759367
## 274  0.5547285167   0.816079777
## 275  0.5578593724   0.816459138
## 276  0.5609902281   0.816899164
## 277  0.5641210837   0.817380243
## 278  0.5672519394   0.817923831
## 279  0.5703827951   0.818531527
## 280  0.5735136508   0.819182532
## 281  0.5766445064   0.819899374
## 282  0.5797753621   0.820683469
## 283  0.5829062178   0.821512910
## 284  0.5860370734   0.822411158
## 285  0.5891679291   0.823379385
## 286  0.5922987848   0.824394701
## 287  0.5954296405   0.825481323
## 288  0.5985604961   0.826640132
## 289  0.6016913518   0.827847412
## 290  0.6048222075   0.829127939
## 291  0.6079530631   0.830482265
## 292  0.6110839188   0.831886038
## 293  0.6142147745   0.833364369
## 294  0.6173456302   0.834917461
## 295  0.6204764858   0.836520533
## 296  0.6236073415   0.838198803
## 297  0.6267381972   0.839952110
## 298  0.6298690529   0.841755469
## 299  0.6329999085   0.843633968
## 300  0.6361307642   0.845587074
## 301  0.6392616199   0.847589835
## 302  0.6423924755   0.849666966
## 303  0.6455233312   0.851817567
## 304  0.6486541869   0.854016951
## 305  0.6517850426   0.856289224
## 306  0.6549158982   0.858633118
## 307  0.6580467539   0.861024448
## 308  0.6611776096   0.863486468
## 309  0.6643084652   0.866017547
## 310  0.6674393209   0.868594233
## 311  0.6705701766   0.871238688
## 312  0.6737010323   0.873948904
## 313  0.6768318879   0.876702405
## 314  0.6799627436   0.879520000
## 315  0.6830935993   0.882399291
## 316  0.6862244549   0.885319021
## 317  0.6893553106   0.888298368
## 318  0.6924861663   0.891334514
## 319  0.6956170220   0.894407682
## 320  0.6987478776   0.897535107
## 321  0.7018787333   0.900713505
## 322  0.7050095890   0.903924867
## 323  0.7081404446   0.907184130
## 324  0.7112713003   0.910487480
## 325  0.7144021560   0.913819002
## 326  0.7175330117   0.917190923
## 327  0.7206638673   0.920598820
## 328  0.7237947230   0.924029246
## 329  0.7269255787   0.927491239
## 330  0.7300564344   0.930979677
## 331  0.7331872900   0.934484013
## 332  0.7363181457   0.938009544
```

```
## 333  0.7394490014   0.941550348
## 334  0.7425798570   0.945099284
## 335  0.7457107127   0.948657271
## 336  0.7488415684   0.952217489
## 337  0.7519724241   0.955776781
## 338  0.7551032797   0.959330978
## 339  0.7582341354   0.962872264
## 340  0.7613649911   0.966402127
## 341  0.7644958467   0.969910524
## 342  0.7676267024   0.973388565
## 343  0.7707575581   0.976843114
## 344  0.7738884138   0.980257414
## 345  0.7770192694   0.983621451
## 346  0.7801501251   0.986948259
## 347  0.7832809808   0.990213490
## 348  0.7864118364   0.993405992
## 349  0.7895426921   0.996545811
## 350  0.7926735478   0.999600125
## 351  0.7958044035   1.002556685
## 352  0.7989352591   1.005443403
## 353  0.8020661148   1.008218138
## 354  0.8051969705   1.010867639
## 355  0.8083278261   1.013428528
## 356  0.8114586818   1.015848575
## 357  0.8145895375   1.018113690
## 358  0.8177203932   1.020269992
## 359  0.8208512488   1.022254519
## 360  0.8239821045   1.024052582
## 361  0.8271129602   1.025720481
## 362  0.8302438159   1.027184057
## 363  0.8333746715   1.028428332
## 364  0.8365055272   1.029520322
## 365  0.8396363829   1.030374438
## 366  0.8427672385   1.030975799
## 367  0.8458980942   1.031402464
## 368  0.8490289499   1.031557466
## 369  0.8521598056   1.031426464
## 370  0.8552906612   1.031098640
## 371  0.8584215169   1.030466023
## 372  0.8615523726   1.029515307
## 373  0.8646832282   1.028346585
## 374  0.8678140839   1.026841604
## 375  0.8709449396   1.024988634
## 376  0.8740757953   1.022898118
## 377  0.8772066509   1.020442639
## 378  0.8803375066   1.017612579
## 379  0.8834683623   1.014527827
## 380  0.8865992179   1.011053288
## 381  0.8897300736   1.007181993
## 382  0.8928609293   1.003041994
## 383  0.8959917850   0.998492380
## 384  0.8991226406   0.993529325
## 385  0.9022534963   0.988287393
## 386  0.9053843520   0.982622062
## 387  0.9085152076   0.976533076
## 388  0.9116460633   0.970159514
## 389  0.9147769190   0.963355739
## 390  0.9179077747   0.956125395
## 391  0.9210386303   0.948609781
## 392  0.9241694860   0.940664856
## 393  0.9273003417   0.932298382
## 394  0.9304311974   0.923651330
## 395  0.9335620530   0.914584112
## 396  0.9366929087   0.905108684
## 397  0.9398237644   0.895362974
## 398  0.9429546200   0.885214744
## 399  0.9460854757   0.874680066
## 400  0.9492163314   0.863891031
## 401  0.9523471871   0.852725585
## 402  0.9554780427   0.841203685
## 403  0.9586088984   0.829448801
## 404  0.9617397541   0.817351731
## 405  0.9648706097   0.804935929
## 406  0.9680014654   0.792313582
## 407  0.9711323211   0.779390733
## 408  0.9742631768   0.766193805
## 409  0.9773940324   0.752821252
## 410  0.9805248881   0.739196399
## 411  0.9836557438   0.725347973
```

```
## 412  0.9867865994   0.711358569
## 413  0.9899174551   0.697170378
## 414  0.9930483108   0.682813673
## 415  0.9961791665   0.668353460
## 416  0.9993100221   0.653751873
## 417  1.0024408778   0.639039904
## 418  1.0055717335   0.624263706
## 419  1.0087025891   0.609405886
## 420  1.0118334448   0.594497298
## 421  1.0149643005   0.579564492
## 422  1.0180951562   0.564610516
## 423  1.0212260118   0.549665234
## 424  1.0243568675   0.534735386
## 425  1.0274877232   0.519843872
## 426  1.0306185789   0.505018756
## 427  1.0337494345   0.490247305
## 428  1.0368802902   0.475571162
## 429  1.0400111459   0.461015866
## 430  1.0431420015   0.446550059
## 431  1.0462728572   0.432232557
## 432  1.0494037129   0.418085750
## 433  1.0525345686   0.404060987
## 434  1.0556654242   0.390232291
## 435  1.0587962799   0.376618419
## 436  1.0619271356   0.363155158
## 437  1.0650579912   0.349929477
## 438  1.0681888469   0.336956158
## 439  1.0713197026   0.324157494
## 440  1.0744505583   0.311630927
## 441  1.0775814139   0.299387080
## 442  1.0807122696   0.287337059
## 443  1.0838431253   0.275586200
## 444  1.0869739809   0.264140941
## 445  1.0901048366   0.252903649
## 446  1.0932356923   0.241984966
## 447  1.0963665480   0.231387263
## 448  1.0994974036   0.221006665
## 449  1.1026282593   0.210956620
## 450  1.1057591150   0.201235674
## 451  1.1088899706   0.191736172
## 452  1.1120208263   0.182572016
## 453  1.1151516820   0.173738292
## 454  1.1182825377   0.165125892
## 455  1.1214133933   0.156847061
## 456  1.1245442490   0.148893859
## 457  1.1276751047   0.141157873
## 458  1.1308059604   0.133747840
## 459  1.1339368160   0.126653301
## 460  1.1370676717   0.119768427
## 461  1.1401985274   0.113196916
## 462  1.1433293830   0.106926318
## 463  1.1464602387   0.100854999
## 464  1.1495910944   0.095080405
## 465  1.1527219501   0.089588630
## 466  1.1558528057   0.084283540
## 467  1.1589836614   0.079255440
## 468  1.1621145171   0.074489484
## 469  1.1652453727   0.069896034
## 470  1.1683762284   0.065557668
## 471  1.1715070841   0.061459087
## 472  1.1746379398   0.057517835
## 473  1.1777687954   0.053808467
## 474  1.1808996511   0.050315659
## 475  1.1840305068   0.046964541
## 476  1.1871613624   0.043821603
## 477  1.1902922181   0.040871863
## 478  1.1934230738   0.038048185
## 479  1.1965539295   0.035409160
## 480  1.1996847851   0.032940452
## 481  1.2028156408   0.030582584
## 482  1.2059464965   0.028386589
## 483  1.2090773521   0.026339010
## 484  1.2122082078   0.024387770
## 485  1.2153390635   0.022576818
## 486  1.2184699192   0.020893739
## 487  1.2216007748   0.019293461
## 488  1.2247316305   0.017813407
## 489  1.2278624862   0.016442313
## 490  1.2309933418   0.015141601
```

```
## 491  1.2341241975   0.013942796
## 492  1.2372550532   0.012835827
## 493  1.2403859089   0.011788040
## 494  1.2435167645   0.010825704
## 495  1.2466476202   0.009939949
## 496  1.2497784759   0.009103428
## 497  1.2529093316   0.008337802
## 498  1.2560401872   0.007635364
## 499  1.2591710429   0.006973458
## 500  1.2623018986   0.006369755
## 501  1.2654327542   0.005817650
## 502  1.2685636099   0.005298566
## 503  1.2716944656   0.004826774
## 504  1.2748253213   0.004396683
## 505  1.2779561769   0.003993220
## 506  1.2810870326   0.003627792
## 507  1.2842178883   0.003295723
## 508  1.2873487439   0.002984911
## 509  1.2904795996   0.002704379
## 510  1.2936104553   0.002450267
## 511  1.2967413110   0.002212952
## 512  1.2998721666   0.001999504
```

```
ggplot(data=df.new,mapping=aes(x)) + geom_histogram(aes(y=..density..),color="grey",fill="lightgrey",bins=60)+ geom
_line(data=df.estimate2,aes(x = d.estimate2.x, y =d.estimate2.y))
```




```
The estimate line does not match the histogram at all, and it is very removed from the actual shape of the histogra
m. It also extends past the range of values that x takes.
```

Question 6

Pick 20 points at random from the initial, unbounded x sample. Perform density estimates with “gaussian”, “triangular”, and “epanechnikov” kernels. Use `ggplot()` to draw the three density estimates (without the histogram). Do you see any significant differences in the estimates? Change the number of randomly sampled points to 500 and redo the plot…are there still any discernible differences?

```
set.seed(100)
s=sample(x, 20)

k.gaussian =density(s, bw="nrd0", adjust =1, kernel="gaussian")

k.triangular=density(s, bw="nrd0", adjust =1, kernel="triangular")

epanechnikov= density(s, bw="nrd0", adjust =1, kernel="epanechnikov")



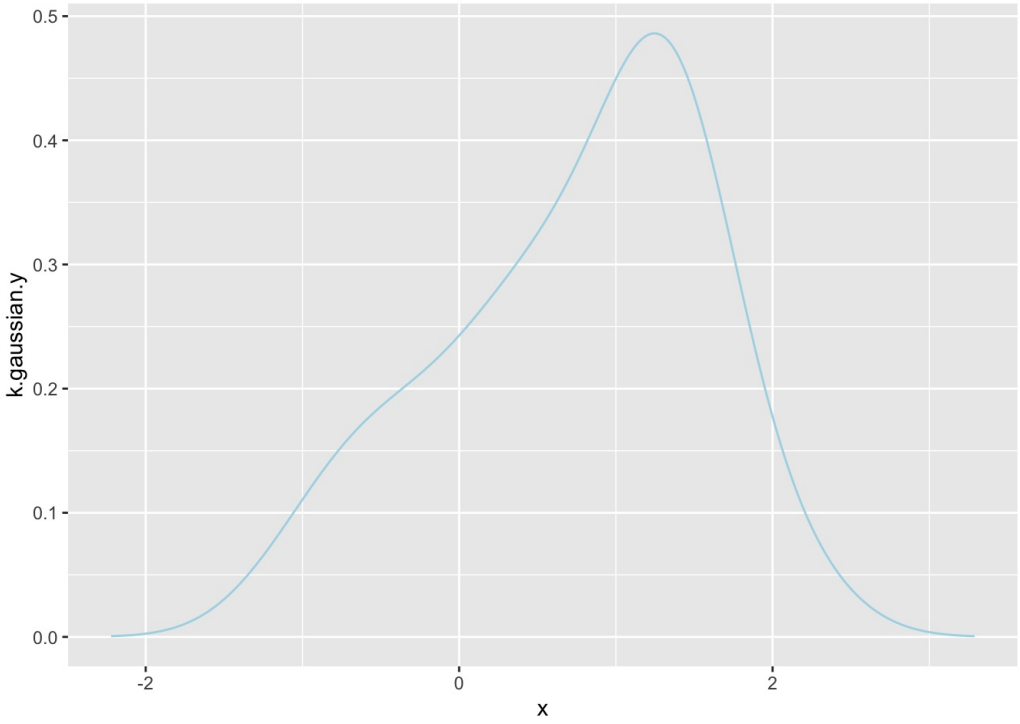
k.gaussian = data.frame(k.gaussian$x,k.gaussian$y)
k.triangular=data.frame(k.triangular$x,k.triangular$y)
epanechnikov=data.frame(epanechnikov$x,epanechnikov$y)


k.gaussian_plot =ggplot(data=df,mapping=aes(x)) + geom_line(data=k.gaussian,aes(x = k.gaussian.x, y =k.gaussian.y),
color="lightblue")

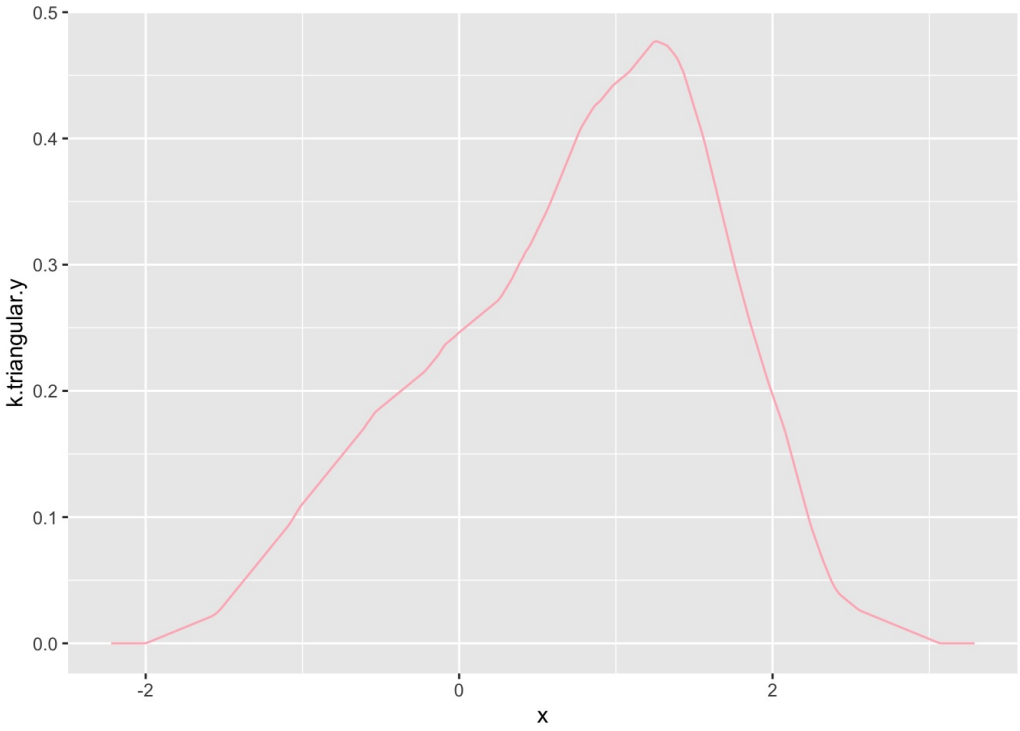
k.triangular_plot =ggplot(data=df,mapping=aes(x)) + geom_line(data=k.triangular,aes(x = k.triangular.x, y =k.triang
ular.y),color="lightpink")

epanechnikov_plot =ggplot(data=df,mapping=aes(x)) + geom_line(data=epanechnikov,aes(x = epanechnikov.x, y =epanechn
ikov.y),color="lightgreen")

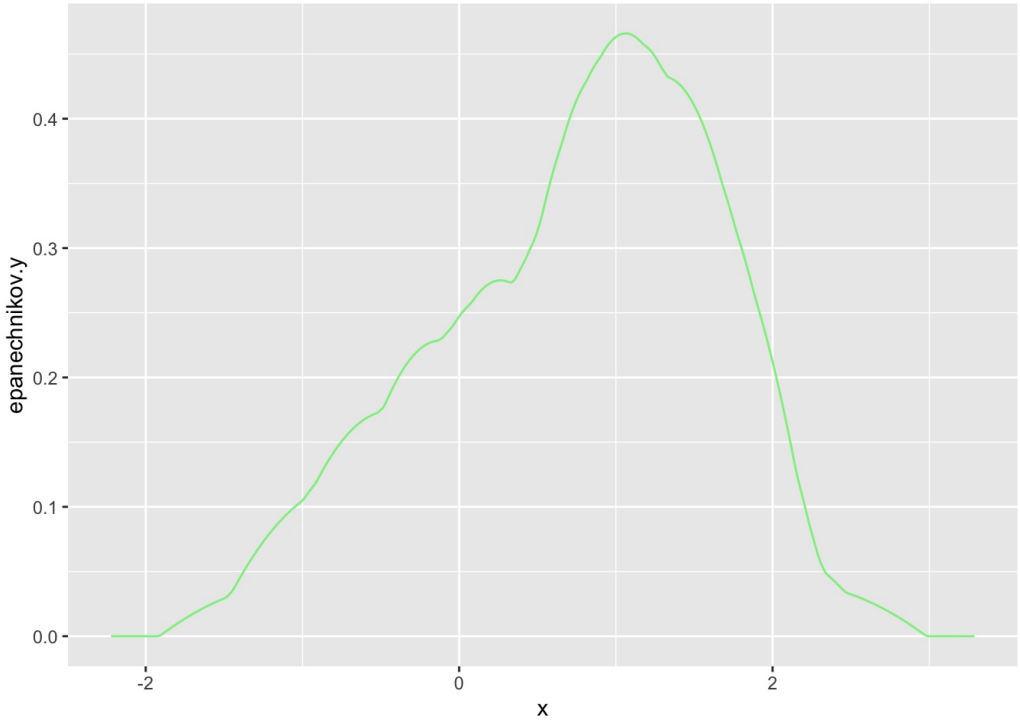

k.gaussian_plot
```




```
k.triangular_plot
```




```
epanechnikov_plot
```




```
set.seed(100)
s.500=sample(x, 500)


k5.gaussian =density(s.500, bw="nrd0", adjust =1, kernel="gaussian")

k5.triangular=density(s.500, bw="nrd0", adjust =1, kernel="triangular")

epanechnikov.5= density(s.500, bw="nrd0", adjust =1, kernel="epanechnikov")



k5.gaussian = data.frame(k5.gaussian$x,k5.gaussian$y)
k5.triangular=data.frame(k5.triangular$x,k5.triangular$y)
epanechnikov.5=data.frame(epanechnikov.5$x,epanechnikov.5$y)
epanechnikov.5
```

```
##     epanechnikov.5.x epanechnikov.5.y
## 1       -3.215811722     3.733932e-17
## 2       -3.203853202     3.704854e-17
```

```
## 3       -3.191894681     4.120951e-18
## 4       -3.179936160     2.365626e-17
## 5       -3.167977639     2.439574e-17
## 6       -3.156019118     3.337741e-17
## 7       -3.144060598     3.366554e-17
## 8       -3.132102077     1.882897e-17
## 9       -3.120143556     2.294166e-17
## 10      -3.108185035     1.432978e-17
## 11      -3.096226514     4.984219e-17
## 12      -3.084267993     7.848339e-17
## 13      -3.072309473     3.326943e-06
## 14      -3.060350952     4.121114e-05
## 15      -3.048392431     1.863174e-04
## 16      -3.036433910     3.524732e-04
## 17      -3.024475389     5.152617e-04
## 18      -3.012516869     6.737768e-04
## 19      -3.000558348     8.266275e-04
## 20      -2.988599827     9.750521e-04
## 21      -2.976641306     1.119203e-03
## 22      -2.964682785     1.259081e-03
## 23      -2.952724265     1.394480e-03
## 24      -2.940765744     1.524268e-03
## 25      -2.928807223     1.649782e-03
## 26      -2.916848702     1.771023e-03
## 27      -2.904890181     1.887990e-03
## 28      -2.892931661     2.000121e-03
## 29      -2.880973140     2.106997e-03
## 30      -2.869014619     2.209601e-03
## 31      -2.857056098     2.307931e-03
## 32      -2.845097577     2.401988e-03
## 33      -2.833139057     2.490850e-03
## 34      -2.821180536     2.574816e-03
## 35      -2.809222015     2.654509e-03
## 36      -2.797263494     2.729929e-03
## 37      -2.785304973     2.801075e-03
## 38      -2.773346452     2.866668e-03
## 39      -2.761387932     2.927724e-03
## 40      -2.749429411     2.984507e-03
## 41      -2.737470890     3.037016e-03
## 42      -2.725512369     3.085158e-03
## 43      -2.713553848     3.127576e-03
## 44      -2.701595328     3.165721e-03
## 45      -2.689636807     3.199593e-03
## 46      -2.677678286     3.238250e-03
## 47      -2.665719765     3.311394e-03
## 48      -2.653761244     3.489650e-03
## 49      -2.641802724     3.670362e-03
## 50      -2.629844203     3.843174e-03
## 51      -2.617885682     4.007439e-03
## 52      -2.605927161     4.161536e-03
## 53      -2.593968640     4.305620e-03
## 54      -2.582010120     4.441157e-03
## 55      -2.570051599     4.568148e-03
## 56      -2.558093078     4.686591e-03
## 57      -2.546134557     4.794152e-03
## 58      -2.534176036     4.892414e-03
## 59      -2.522217516     4.982130e-03
## 60      -2.510258995     5.063300e-03
## 61      -2.498300474     5.135923e-03
## 62      -2.486341953     5.196945e-03
## 63      -2.474383432     5.249387e-03
## 64      -2.462424911     5.293282e-03
## 65      -2.450466391     5.328631e-03
## 66      -2.438507870     5.354750e-03
## 67      -2.426549349     5.369918e-03
## 68      -2.414590828     5.376538e-03
## 69      -2.402632307     5.374612e-03
## 70      -2.390673787     5.364140e-03
## 71      -2.378715266     5.343722e-03
## 72      -2.366756745     5.313068e-03
## 73      -2.354798224     5.273868e-03
## 74      -2.342839703     5.226121e-03
## 75      -2.330881183     5.169827e-03
## 76      -2.318922662     5.102872e-03
## 77      -2.306964141     5.026397e-03
## 78      -2.295005620     4.941376e-03
## 79      -2.283047099     4.847808e-03
## 80      -2.271088579     4.745693e-03
## 81      -2.259130058     4.632201e-03
```

```
## 82      -2.247171537     4.509905e-03
## 83      -2.235213016     4.379062e-03
## 84      -2.223254495     4.239673e-03
## 85      -2.211295975     4.091278e-03
## 86      -2.199337454     3.931708e-03
## 87      -2.187378933     3.763591e-03
## 88      -2.175420412     3.587181e-03
## 89      -2.163461891     3.409339e-03
## 90      -2.151503370     3.256231e-03
## 91      -2.139544850     3.215734e-03
## 92      -2.127586329     3.184209e-03
## 93      -2.115627808     3.148411e-03
## 94      -2.103669287     3.108340e-03
## 95      -2.091710766     3.063049e-03
## 96      -2.079752246     3.012887e-03
## 97      -2.067793725     2.958452e-03
## 98      -2.055835204     2.899744e-03
## 99      -2.043876683     2.836762e-03
## 100     -2.031918162     2.768203e-03
## 101     -2.019959642     2.695130e-03
## 102     -2.008001121     2.617785e-03
## 103     -1.996042600     2.559914e-03
## 104     -1.984084079     2.570819e-03
## 105     -1.972125558     2.644826e-03
## 106     -1.960167038     2.712637e-03
## 107     -1.948208517     2.772222e-03
## 108     -1.936249996     2.823261e-03
## 109     -1.924291475     2.864800e-03
## 110     -1.912332954     2.895658e-03
## 111     -1.900374434     2.917969e-03
## 112     -1.888415913     2.931733e-03
## 113     -1.876457392     2.947678e-03
## 114     -1.864498871     3.030673e-03
## 115     -1.852540350     3.171643e-03
## 116     -1.840581829     3.312754e-03
## 117     -1.828623309     3.441562e-03
## 118     -1.816664788     3.564570e-03
## 119     -1.804706267     3.780486e-03
## 120     -1.792747746     4.022638e-03
## 121     -1.780789225     4.260068e-03
## 122     -1.768830705     4.494834e-03
## 123     -1.756872184     4.750605e-03
## 124     -1.744913663     5.109499e-03
## 125     -1.732955142     5.455719e-03
## 126     -1.720996621     5.789120e-03
## 127     -1.709038101     6.109701e-03
## 128     -1.697079580     6.416365e-03
## 129     -1.685121059     6.727423e-03
## 130     -1.673162538     7.125416e-03
## 131     -1.661204017     7.557205e-03
## 132     -1.649245497     7.973260e-03
## 133     -1.637286976     8.369329e-03
## 134     -1.625328455     8.872053e-03
## 135     -1.613369934     9.388641e-03
## 136     -1.601411413     9.894510e-03
## 137     -1.589452893     1.037926e-02
## 138     -1.577494372     1.083723e-02
## 139     -1.565535851     1.127152e-02
## 140     -1.553577330     1.168445e-02
## 141     -1.541618809     1.207601e-02
## 142     -1.529660288     1.244620e-02
## 143     -1.517701768     1.278783e-02
## 144     -1.505743247     1.310757e-02
## 145     -1.493784726     1.340595e-02
## 146     -1.481826205     1.368295e-02
## 147     -1.469867684     1.393732e-02
## 148     -1.457909164     1.423923e-02
## 149     -1.445950643     1.461090e-02
## 150     -1.433992122     1.505388e-02
## 151     -1.422033601     1.556888e-02
## 152     -1.410075080     1.617065e-02
## 153     -1.398116560     1.675772e-02
## 154     -1.386158039     1.731403e-02
## 155     -1.374199518     1.783631e-02
## 156     -1.362240997     1.832441e-02
## 157     -1.350282476     1.877055e-02
## 158     -1.338323956     1.926223e-02
## 159     -1.326365435     1.986995e-02
## 160     -1.314406914     2.057830e-02
```

```
## 161     -1.302448393     2.133458e-02
## 162     -1.290489872     2.218358e-02
## 163     -1.278531352     2.316141e-02
## 164     -1.266572831     2.418478e-02
## 165     -1.254614310     2.521659e-02
## 166     -1.242655789     2.625226e-02
## 167     -1.230697268     2.720974e-02
## 168     -1.218738747     2.820917e-02
## 169     -1.206780227     2.920054e-02
## 170     -1.194821706     3.015414e-02
## 171     -1.182863185     3.108343e-02
## 172     -1.170904664     3.214512e-02
## 173     -1.158946143     3.341154e-02
## 174     -1.146987623     3.491336e-02
## 175     -1.135029102     3.662752e-02
## 176     -1.123070581     3.834988e-02
## 177     -1.111112060     4.028202e-02
## 178     -1.099153539     4.223256e-02
## 179     -1.087195019     4.427754e-02
## 180     -1.075236498     4.656658e-02
## 181     -1.063277977     4.916048e-02
## 182     -1.051319456     5.191482e-02
## 183     -1.039360935     5.474730e-02
## 184     -1.027402415     5.766259e-02
## 185     -1.015443894     6.072178e-02
## 186     -1.003485373     6.397036e-02
## 187     -0.991526852     6.713710e-02
## 188     -0.979568331     7.024493e-02
## 189     -0.967609811     7.333112e-02
## 190     -0.955651290     7.646132e-02
## 191     -0.943692769     7.967223e-02
## 192     -0.931734248     8.277805e-02
## 193     -0.919775727     8.578444e-02
## 194     -0.907817206     8.870929e-02
## 195     -0.895858686     9.153448e-02
## 196     -0.883900165     9.427065e-02
## 197     -0.871941644     9.691965e-02
## 198     -0.859983123     9.952706e-02
## 199     -0.848024602     1.021460e-01
## 200     -0.836066082     1.047513e-01
## 201     -0.824107561     1.073303e-01
## 202     -0.812149040     1.099178e-01
## 203     -0.800190519     1.124996e-01
## 204     -0.788231998     1.150390e-01
## 205     -0.776273478     1.178647e-01
## 206     -0.764314957     1.211373e-01
## 207     -0.752356436     1.246796e-01
## 208     -0.740397915     1.283137e-01
## 209     -0.728439394     1.318175e-01
## 210     -0.716480874     1.352734e-01
## 211     -0.704522353     1.386056e-01
## 212     -0.692563832     1.419219e-01
## 213     -0.680605311     1.452956e-01
## 214     -0.668646790     1.486862e-01
## 215     -0.656688270     1.520557e-01
## 216     -0.644729749     1.553100e-01
## 217     -0.632771228     1.584884e-01
## 218     -0.620812707     1.616642e-01
## 219     -0.608854186     1.649563e-01
## 220     -0.596895665     1.684429e-01
## 221     -0.584937145     1.721667e-01
## 222     -0.572978624     1.762853e-01
## 223     -0.561020103     1.809882e-01
## 224     -0.549061582     1.861234e-01
## 225     -0.537103061     1.916225e-01
## 226     -0.525144541     1.973504e-01
## 227     -0.513186020     2.032063e-01
## 228     -0.501227499     2.090958e-01
## 229     -0.489268978     2.147336e-01
## 230     -0.477310457     2.201953e-01
## 231     -0.465351937     2.255972e-01
## 232     -0.453393416     2.310782e-01
## 233     -0.441434895     2.368694e-01
## 234     -0.429476374     2.425369e-01
## 235     -0.417517853     2.483488e-01
## 236     -0.405559333     2.542278e-01
## 237     -0.393600812     2.600680e-01
## 238     -0.381642291     2.658520e-01
## 239     -0.369683770     2.718935e-01
```

```
## 240     -0.357725249     2.777501e-01
## 241     -0.345766729     2.833757e-01
## 242     -0.333808208     2.888306e-01
## 243     -0.321849687     2.937519e-01
## 244     -0.309891166     2.988024e-01
## 245     -0.297932645     3.036360e-01
## 246     -0.285974124     3.082382e-01
## 247     -0.274015604     3.128412e-01
## 248     -0.262057083     3.170789e-01
## 249     -0.250098562     3.212768e-01
## 250     -0.238140041     3.256974e-01
## 251     -0.226181520     3.303265e-01
## 252     -0.214223000     3.346672e-01
## 253     -0.202264479     3.387811e-01
## 254     -0.190305958     3.424921e-01
## 255     -0.178347437     3.459129e-01
## 256     -0.166388916     3.492117e-01
## 257     -0.154430396     3.526494e-01
## 258     -0.142471875     3.563054e-01
## 259     -0.130513354     3.599279e-01
## 260     -0.118554833     3.634858e-01
## 261     -0.106596312     3.670036e-01
## 262     -0.094637792     3.705186e-01
## 263     -0.082679271     3.737481e-01
## 264     -0.070720750     3.767002e-01
## 265     -0.058762229     3.793858e-01
## 266     -0.046803708     3.818349e-01
## 267     -0.034845188     3.841337e-01
## 268     -0.022886667     3.862485e-01
## 269     -0.010928146     3.881013e-01
## 270      0.001030375     3.895936e-01
## 271      0.012988896     3.905540e-01
## 272      0.024947417     3.912963e-01
## 273      0.036905937     3.917616e-01
## 274      0.048864458     3.919619e-01
## 275      0.060822979     3.919016e-01
## 276      0.072781500     3.914893e-01
## 277      0.084740021     3.907452e-01
## 278      0.096698541     3.896475e-01
## 279      0.108657062     3.883830e-01
## 280      0.120615583     3.871725e-01
## 281      0.132574104     3.860848e-01
## 282      0.144532625     3.848751e-01
## 283      0.156491145     3.834955e-01
## 284      0.168449666     3.818020e-01
## 285      0.180408187     3.796139e-01
## 286      0.192366708     3.769729e-01
## 287      0.204325229     3.741455e-01
## 288      0.216283749     3.712344e-01
## 289      0.228242270     3.682092e-01
## 290      0.240200791     3.648942e-01
## 291      0.252159312     3.610824e-01
## 292      0.264117833     3.568439e-01
## 293      0.276076353     3.523914e-01
## 294      0.288034874     3.478781e-01
## 295      0.299993395     3.433190e-01
## 296      0.311951916     3.386909e-01
## 297      0.323910437     3.345463e-01
## 298      0.335868958     3.310726e-01
## 299      0.347827478     3.282877e-01
## 300      0.359785999     3.257442e-01
## 301      0.371744520     3.236543e-01
## 302      0.383703041     3.219946e-01
## 303      0.395661562     3.206167e-01
## 304      0.407620082     3.193111e-01
## 305      0.419578603     3.181442e-01
## 306      0.431537124     3.170685e-01
## 307      0.443495645     3.163303e-01
## 308      0.455454166     3.159575e-01
## 309      0.467412686     3.158047e-01
## 310      0.479371207     3.154318e-01
## 311      0.491329728     3.150492e-01
## 312      0.503288249     3.146055e-01
## 313      0.515246770     3.140560e-01
## 314      0.527205290     3.133547e-01
## 315      0.539163811     3.132712e-01
## 316      0.551122332     3.132096e-01
## 317      0.563080853     3.132609e-01
## 318      0.575039374     3.134831e-01
```

```
## 319      0.586997894     3.135332e-01
## 320      0.598956415     3.139375e-01
## 321      0.610914936     3.143251e-01
## 322      0.622873457     3.148473e-01
## 323      0.634831978     3.157084e-01
## 324      0.646790499     3.161496e-01
## 325      0.658749019     3.168970e-01
## 326      0.670707540     3.183335e-01
## 327      0.682666061     3.205195e-01
## 328      0.694624582     3.232968e-01
## 329      0.706583103     3.265599e-01
## 330      0.718541623     3.298692e-01
## 331      0.730500144     3.332819e-01
## 332      0.742458665     3.369598e-01
## 333      0.754417186     3.412759e-01
## 334      0.766375707     3.457919e-01
## 335      0.778334227     3.503135e-01
## 336      0.790292748     3.549541e-01
## 337      0.802251269     3.598034e-01
## 338      0.814209790     3.648571e-01
## 339      0.826168311     3.700069e-01
## 340      0.838126831     3.750420e-01
## 341      0.850085352     3.799213e-01
## 342      0.862043873     3.847125e-01
## 343      0.874002394     3.900699e-01
## 344      0.885960915     3.959361e-01
## 345      0.897919435     4.021379e-01
## 346      0.909877956     4.085818e-01
## 347      0.921836477     4.151896e-01
## 348      0.933794998     4.222372e-01
## 349      0.945753519     4.296133e-01
## 350      0.957712040     4.372735e-01
## 351      0.969670560     4.451893e-01
## 352      0.981629081     4.533454e-01
## 353      0.993587602     4.616287e-01
## 354      1.005546123     4.694988e-01
## 355      1.017504644     4.773083e-01
## 356      1.029463164     4.852790e-01
## 357      1.041421685     4.932631e-01
## 358      1.053380206     5.008986e-01
## 359      1.065338727     5.080991e-01
## 360      1.077297248     5.149121e-01
## 361      1.089255768     5.214192e-01
## 362      1.101214289     5.276412e-01
## 363      1.113172810     5.337735e-01
## 364      1.125131331     5.395219e-01
## 365      1.137089852     5.448445e-01
## 366      1.149048372     5.497883e-01
## 367      1.161006893     5.539850e-01
## 368      1.172965414     5.575315e-01
## 369      1.184923935     5.606144e-01
## 370      1.196882456     5.632533e-01
## 371      1.208840976     5.653462e-01
## 372      1.220799497     5.665524e-01
## 373      1.232758018     5.674296e-01
## 374      1.244716539     5.679510e-01
## 375      1.256675060     5.680256e-01
## 376      1.268633581     5.673790e-01
## 377      1.280592101     5.662082e-01
## 378      1.292550622     5.646789e-01
## 379      1.304509143     5.626828e-01
## 380      1.316467664     5.601873e-01
## 381      1.328426185     5.575066e-01
## 382      1.340384705     5.544889e-01
## 383      1.352343226     5.511953e-01
## 384      1.364301747     5.474378e-01
## 385      1.376260268     5.430127e-01
## 386      1.388218789     5.381804e-01
## 387      1.400177309     5.325548e-01
## 388      1.412135830     5.262413e-01
## 389      1.424094351     5.192697e-01
## 390      1.436052872     5.116643e-01
## 391      1.448011393     5.038005e-01
## 392      1.459969913     4.954740e-01
## 393      1.471928434     4.867926e-01
## 394      1.483886955     4.777788e-01
## 395      1.495845476     4.683003e-01
## 396      1.507803997     4.581931e-01
## 397      1.519762517     4.476528e-01
```

```
## 398      1.531721038     4.367699e-01
## 399      1.543679559     4.255375e-01
## 400      1.555638080     4.135390e-01
## 401      1.567596601     4.013642e-01
## 402      1.579555122     3.892217e-01
## 403      1.591513642     3.772411e-01
## 404      1.603472163     3.655168e-01
## 405      1.615430684     3.540092e-01
## 406      1.627389205     3.425539e-01
## 407      1.639347726     3.311668e-01
## 408      1.651306246     3.199240e-01
## 409      1.663264767     3.089231e-01
## 410      1.675223288     2.977422e-01
## 411      1.687181809     2.864221e-01
## 412      1.699140330     2.752116e-01
## 413      1.711098850     2.641664e-01
## 414      1.723057371     2.531339e-01
## 415      1.735015892     2.420714e-01
## 416      1.746974413     2.308445e-01
## 417      1.758932934     2.194375e-01
## 418      1.770891454     2.079648e-01
## 419      1.782849975     1.968978e-01
## 420      1.794808496     1.862379e-01
## 421      1.806767017     1.759483e-01
## 422      1.818725538     1.660328e-01
## 423      1.830684058     1.564938e-01
## 424      1.842642579     1.474500e-01
## 425      1.854601100     1.389748e-01
## 426      1.866559621     1.310229e-01
## 427      1.878518142     1.236180e-01
## 428      1.890476663     1.167768e-01
## 429      1.902435183     1.105129e-01
## 430      1.914393704     1.043273e-01
## 431      1.926352225     9.834715e-02
## 432      1.938310746     9.264118e-02
## 433      1.950269267     8.723973e-02
## 434      1.962227787     8.234615e-02
## 435      1.974186308     7.764763e-02
## 436      1.986144829     7.325599e-02
## 437      1.998103350     6.923016e-02
## 438      2.010061871     6.555527e-02
## 439      2.022020391     6.228574e-02
## 440      2.033978912     5.907968e-02
## 441      2.045937433     5.606769e-02
## 442      2.057895954     5.338021e-02
## 443      2.069854475     5.096969e-02
## 444      2.081812995     4.874018e-02
## 445      2.093771516     4.665883e-02
## 446      2.105730037     4.471187e-02
## 447      2.117688558     4.288272e-02
## 448      2.129647079     4.118285e-02
## 449      2.141605599     3.940994e-02
## 450      2.153564120     3.763881e-02
## 451      2.165522641     3.589668e-02
## 452      2.177481162     3.418373e-02
## 453      2.189439683     3.256740e-02
## 454      2.201398204     3.087900e-02
## 455      2.213356724     2.912021e-02
## 456      2.225315245     2.735643e-02
## 457      2.237273766     2.577250e-02
## 458      2.249232287     2.429640e-02
## 459      2.261190808     2.277415e-02
## 460      2.273149328     2.123533e-02
## 461      2.285107849     1.977759e-02
## 462      2.297066370     1.873171e-02
## 463      2.309024891     1.767504e-02
## 464      2.320983412     1.664478e-02
## 465      2.332941932     1.567662e-02
## 466      2.344900453     1.480707e-02
## 467      2.356858974     1.410537e-02
## 468      2.368817495     1.338109e-02
## 469      2.380776016     1.266229e-02
## 470      2.392734536     1.197418e-02
## 471      2.404693057     1.134118e-02
## 472      2.416651578     1.067522e-02
## 473      2.428610099     1.005404e-02
## 474      2.440568620     9.471840e-03
## 475      2.452527140     8.908803e-03
## 476      2.464485661     8.323079e-03
```

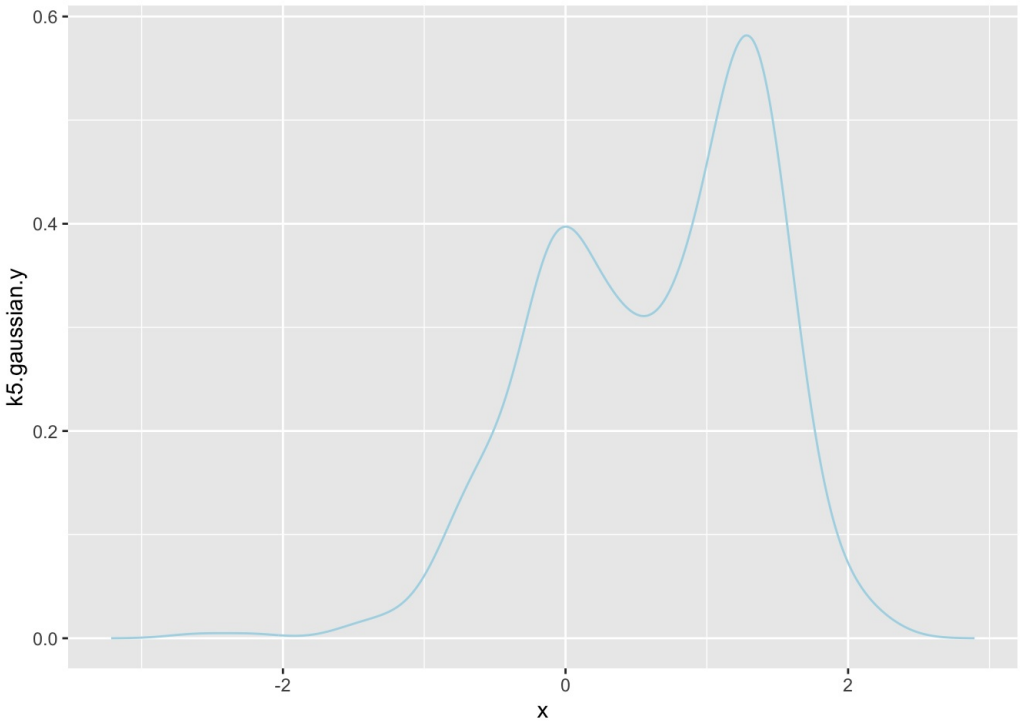
```
## 477      2.476444182     7.709590e-03
## 478      2.488402703     7.074734e-03
## 479      2.500361224     6.418511e-03
## 480      2.512319745     5.741220e-03
## 481      2.524278265     5.041040e-03
## 482      2.536236786     4.427292e-03
## 483      2.548195307     3.839428e-03
## 484      2.560153828     3.253282e-03
## 485      2.572112349     2.668456e-03
## 486      2.584070869     2.218919e-03
## 487      2.596029390     1.865002e-03
## 488      2.607987911     1.649782e-03
## 489      2.619946432     1.524268e-03
## 490      2.631904953     1.394480e-03
## 491      2.643863473     1.259081e-03
## 492      2.655821994     1.119203e-03
## 493      2.667780515     9.750521e-04
## 494      2.679739036     8.266275e-04
## 495      2.691697557     6.737768e-04
## 496      2.703656077     5.152617e-04
## 497      2.715614598     3.524732e-04
## 498      2.727573119     1.863174e-04
## 499      2.739531640     4.121114e-05
## 500      2.751490161     3.326943e-06
## 501      2.763448681     0.000000e+00
## 502      2.775407202     0.000000e+00
## 503      2.787365723     0.000000e+00
## 504      2.799324244     0.000000e+00
## 505      2.811282765     0.000000e+00
## 506      2.823241286     0.000000e+00
## 507      2.835199806     0.000000e+00
## 508      2.847158327     0.000000e+00
## 509      2.859116848     0.000000e+00
## 510      2.871075369     0.000000e+00
## 511      2.883033890     0.000000e+00
## 512      2.894992410     0.000000e+00
```

```
k5.gaussian_plot =ggplot(data=df,mapping=aes(x)) + geom_line(data=k5.gaussian,aes(x = k5.gaussian.x, y =k5.gaussian
.y), color="lightblue")

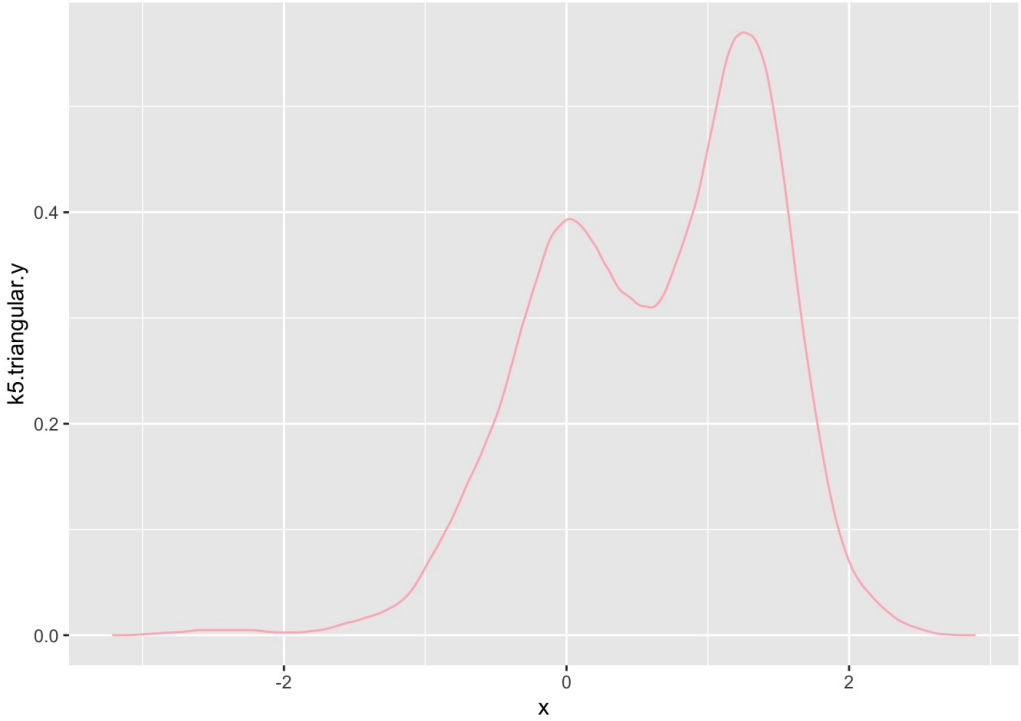
k5.triangular_plot =ggplot(data=df,mapping=aes(x)) + geom_line(data=k5.triangular,aes(x = k5.triangular.x, y =k5.tr
iangular.y),color="lightpink")

epanechnikov.5_plot =ggplot(data=df,mapping=aes(x)) + geom_line(data=epanechnikov.5,aes(x = epanechnikov.5.x, y =ep
anechnikov.5.y),color="lightgreen")

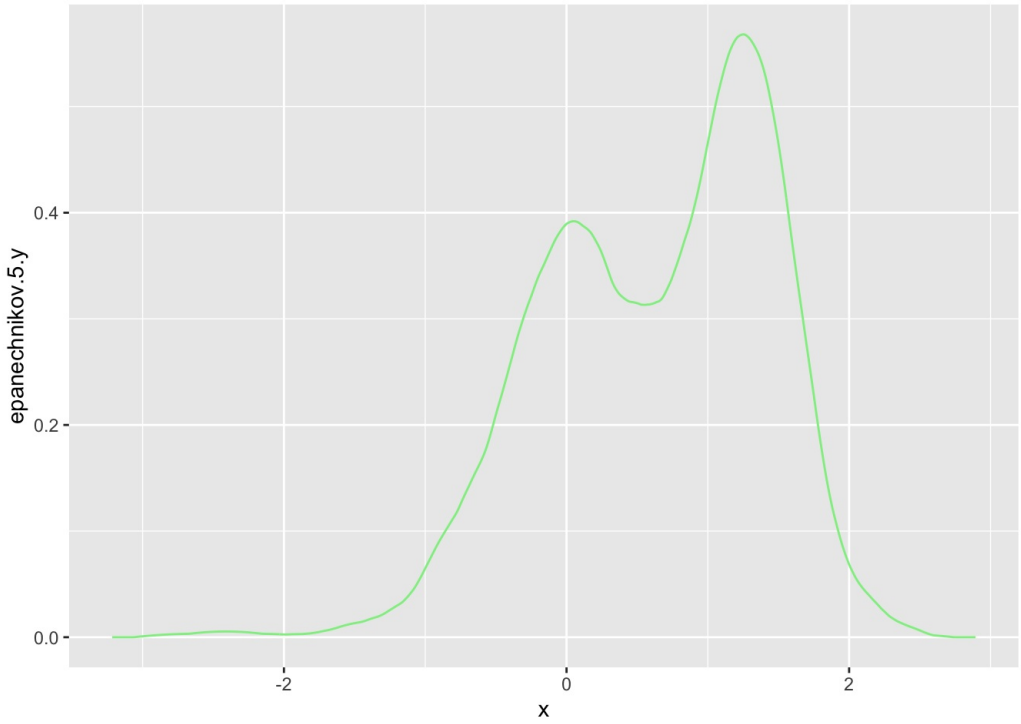

k5.gaussian_plot
```



```
k5.triangular_plot
```




```
epanechnikov.5_plot
```




```
There are fairly similar, gaussian tends to be smoother where the curved peaks are but generally all three seem to
take on similar shapes. When we resample to 500 points, the graph seems to have two peaks instead of one.
```

Question 7

Estimate galaxy mass from emission-line strength using the Nadaraya-Watson kernel estimator.

In the normal model learning paradigm, you split the data and learn the model using the training data, then apply the model to predict response values for the test data. You then compute the MSE.

For Nadaraya-Watson, the way this would play out is that we would split the data, then perform, e.g., cross-validation on the *training* set to determine the optimal value of h. We would then apply this value of h when working with the test data, and when computing the MSE.

Here, we are going to keep things simple: do not split the data, and compute a plug-in value of h using one of the `bandwidth` functions in the base `stats` package. (Type, e.g., `?bw.nrd0` at the prompt in the Console pane.) Estimate $\hat{y}$ for all the data using a Gaussian kernel, then plot the predicted response vs. the observed response. (Note that this is a little tricky! First, you have to specify `x.points=x` in the call to `ksmooth()`, so that the model is actually evaluated at the input points x rather than along a default grid. Then you have to compare `out$y`

versus `y[order(x)]` in the diagnostic plot, because `ksmooth()` sorts the x values in ascending order. This is all a bit painful to figure out. Your final diagnostic plot won't look great…but that's OK, because we've really simplified the regression here [only one predictor variable, not 10].)

```
bw.nrd0(x)
```

```
## [1] 0.09539287
```

```
#0.09539287

gaussian.kernel = density(x, bw=0.09539287, adjust =1, kernel="gaussian")


k= ksmooth(x, y, bandwidth = 0.09539287,
        range.x = range(x),
        n.points = max(100L, length(x)), x.points=x)
observed=gaussian.kernel$y
```