NJC Team 1 DRQ

Linxi, Jun Wei, Joel, Chenxi

2024-05-16

2.3

This is NJC team 1's R Markdown document for our DRQ section.

The data was taken from NASA exoplanet website click here where we filter using R to take the CONFIRMED STATUS and ignore the FLASE POSITIVES. We then took the masses of planets and attach them to each koi_name. The rest of the rows that did not have mass given, has a value of NA.

```
library(openxlsx)
library(ggplot2)
library(readr)
library(tidyr)
library(dplyr)
unfiltered_kepler_data <- read.csv2('unfiltered_kepler_data.csv', header = TRUE, sep=",")
koi_planet_masses_updated <- read.csv2('koi_planet_masses_updated.csv', header = TRUE, sep=",")
mydata <- unfiltered_kepler_data
mydata <- mydata[order(mydata$kepoi_name), ]

mass_data <- koi_planet_masses_updated$`koi_mass(log10 earth masses)`
length_diff <- nrow(mydata) - length(mass_data)

# Add NA values to the shorter vector to match the data frame's row count
mass_data <- c(mass_data, rep(NA, length_diff))

# Add the short vector as a new column in the data frame
mydata$koi_mass <- mass_data

mydata <- mydata[mydata$koi_pdisposition=="CANDIDATE",]
mydata <- mydata[(mydata$koi_disposition=="CONFIRMED"|mydata$koi_disposition=="CANDIDATE"),]
tibble(mydata)
```

```
## # A tibble: 4,716 x 142
##    rowid  kepid kepoi_name kepler_name koi_disposition koi_vet_stat koi_vet_date
##    <int>  <int> <chr>      <chr>       <chr>           <chr>        <chr>
##  1    11 1.14e7 K00001.01  "Kepler-1 ~ CONFIRMED       Done         2018-08-16
##  2    12 1.07e7 K00002.01  "Kepler-2 ~ CONFIRMED       Done         2018-08-16
##  3  1275 1.07e7 K00003.01  "Kepler-3 ~ CONFIRMED       Done         2018-08-16
##  4  2136 3.86e6 K00004.01  "Kepler-16~ CONFIRMED       Done         2018-08-16
##  5  2761 8.55e6 K00005.01  ""          CANDIDATE       Done         2018-08-16
```

```
##  6  3115 1.19e7 K00007.01  "Kepler-4 ~ CONFIRMED       Done         2018-08-16
##  7    13 6.92e6 K00010.01  "Kepler-8 ~ CONFIRMED       Done         2018-08-16
##  8   230 5.81e6 K00012.01  "Kepler-44~ CONFIRMED       Done         2018-08-16
##  9   610 9.94e6 K00013.01  "Kepler-13~ CONFIRMED       Done         2018-08-16
## 10   965 1.09e7 K00017.01  "Kepler-6 ~ CONFIRMED       Done         2018-08-16
## # i 4,706 more rows
## # i 135 more variables: koi_pdisposition <chr>, koi_score <chr>,
## #   koi_fpflag_nt <int>, koi_fpflag_ss <int>, koi_fpflag_co <int>,
## #   koi_fpflag_ec <int>, koi_disp_prov <chr>, koi_comment <chr>,
## #   koi_period <chr>, koi_period_err1 <chr>, koi_period_err2 <chr>,
## #   koi_time0bk <chr>, koi_time0bk_err1 <chr>, koi_time0bk_err2 <chr>,
## #   koi_time0 <chr>, koi_time0_err1 <chr>, koi_time0_err2 <chr>, ...
```

Over here, we import the data we created

```
library(openxlsx)
library(ggplot2)
library(readr)
library(tidyr)
library(dplyr)


unfiltered_kepler_df <- read.csv("kepler_data_new1.csv", header = TRUE, sep=",")
filtered_kepler_df = filter(unfiltered_kepler_df, `koi_disposition`=="CONFIRMED"|`koi_disposition`=="CA
tibble(filtered_kepler_df)
```

```
## # A tibble: 4,090 x 40
##    loc_rowid kepid    kepoi_name kepler_name     koi_disposition koi_fpflag_nt
##    <chr>     <chr>    <chr>      <chr>           <chr>                   <int>
##  1 11        11446443 K00001.01  "Kepler-1 b"    CONFIRMED                   0
##  2 12        10666592 K00002.01  "Kepler-2 b"    CONFIRMED                   0
##  3 1275      10748390 K00003.01  "Kepler-3 b"    CONFIRMED                   0
##  4 2136      3861595  K00004.01  "Kepler-1658 b" CONFIRMED                   0
##  5 2761      8554498  K00005.01  ""              CANDIDATE                   0
##  6 3115      11853905 K00007.01  "Kepler-4 b"    CONFIRMED                   0
##  7 13        6922244  K00010.01  "Kepler-8 b"    CONFIRMED                   0
##  8 230       5812701  K00012.01  "Kepler-448 b"  CONFIRMED                   0
##  9 610       9941662  K00013.01  "Kepler-13 b"   CONFIRMED                   0
## 10 965       10874614 K00017.01  "Kepler-6 b"    CONFIRMED                   0
## # i 4,080 more rows
## # i 34 more variables: koi_fpflag_ss <int>, koi_fpflag_co <int>,
## #   koi_fpflag_ec <int>, koi_period <dbl>, koi_period_err1 <dbl>,
## #   koi_period_err2 <dbl>, koi_time0bk <dbl>, koi_time0bk_err1 <dbl>,
## #   koi_time0bk_err2 <dbl>, koi_depth <dbl>, koi_depth_err1 <dbl>,
## #   koi_depth_err2 <dbl>, koi_prad <dbl>, koi_prad_err1 <dbl>,
## #   koi_prad_err2 <dbl>, koi_teq <int>, koi_teq_err1 <lgl>, ...
```

2.4 Data

2.4.1 Habitable Zone Calculations

(a) Compile the list of masses of the parent stars, with columns containing the KOI, stellar surface gravity, stellar radius, and the mass of the parent stars

```
library(readr)
library(tidyr)
library(tidyverse)
new_kepler_df2 <- select(filtered_kepler_df, kepoi_name, koi_slogg, koi_srad ) %>%
mutate("Mass of Star/kg" = (((10**koi_slogg)/100) * (koi_srad * 696000000)**2) / (6.67 * (10 ** -11) ))
rename("Stellar surface gravity / log10(cm/s**2)" = koi_slogg, "Stellar radius / Solar radii"= koi_srad
tibble(new_kepler_df2)
```

```
## # A tibble: 4,090 x 4
##    `KOI NAME` Stellar surface gravity~1 Stellar radius / Sol~2 `Mass of Star/kg`
##    <chr>                          <dbl>                  <dbl>             <dbl>
##  1 K00001.01                       4.46                  0.964           1.93e30
##  2 K00002.01                       4.02                  1.95            2.89e30
##  3 K00003.01                       4.59                  0.763           1.65e30
##  4 K00004.01                       3.66                  2.99            2.95e30
##  5 K00005.01                       4.01                  1.79            2.38e30
##  6 K00007.01                       4.10                  1.54            2.19e30
##  7 K00010.01                       4.17                  1.45            2.26e30
##  8 K00012.01                       4.31                  1.37            2.76e30
##  9 K00013.01                       3.87                  3.03            4.91e30
## 10 K00017.01                       4.24                  1.29            2.08e30
## # i 4,080 more rows
## # i abbreviated names: 1: `Stellar surface gravity / log10(cm/s**2)`,
## #   2: `Stellar radius / Solar radii`
```

(b) Find the habitable zone of the parent stars, with columns containing the KOI, stellar mass, the luminosity, and the inner and outer radii of the habitable zone.

```
library(readr)
library(tidyr)
library(tidyverse)
new_kepler_df1 <- select(filtered_kepler_df, kepoi_name, koi_slogg, koi_srad, koi_steff ) %>%
mutate("Mass of star/kg" = (((10**koi_slogg)/100) * (koi_srad * 696000000)**2) / (6.67 * (10 ** -11) ))
mutate("Luminosity ratio" = (((koi_srad* 696000000)/(6.957*10**8))**2)*((koi_steff/6000)**4)) %>%
mutate("Inner radii/AU" = ((1/1.1)*(`Luminosity ratio`))**0.5)%>%
mutate("outer solar radiii/AU" = ((1/0.53)*(`Luminosity ratio`))**0.5)%>%
rename("Stellar surface gravity / log10(cm/s**2)" = koi_slogg, "Stellar radius / Solar radii"= koi_srad
tibble(new_kepler_df1)
```

```
## # A tibble: 4,090 x 8
##    `KOI NAME` `Stellar surface gravity / log10(cm/s**2)` Stellar radius / Sola~1
##    <chr>                                          <dbl>                  <dbl>
##  1 K00001.01                                       4.46                  0.964
```

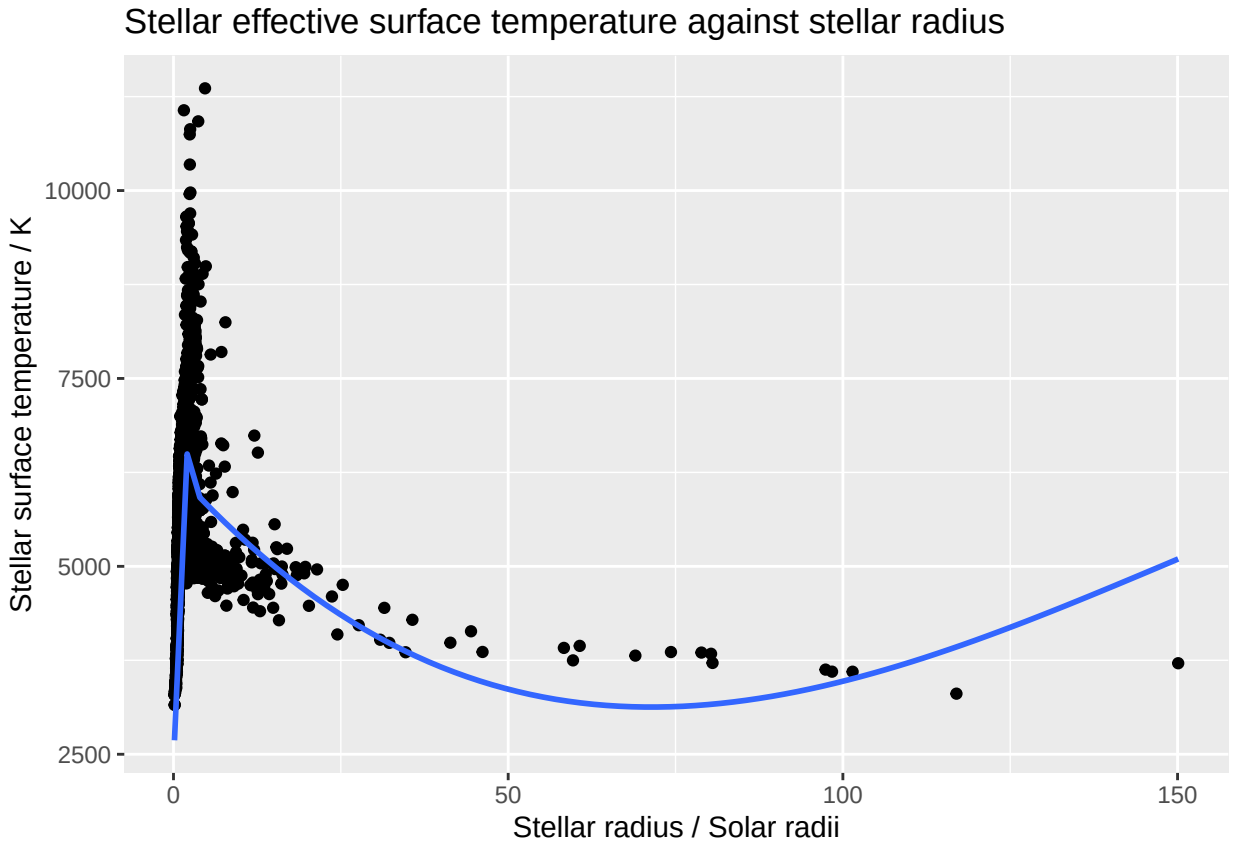
```
##  2 K00002.01                                    4.02                  1.95
##  3 K00003.01                                    4.59                  0.763
##  4 K00004.01                                    3.66                  2.99
##  5 K00005.01                                    4.01                  1.79
##  6 K00007.01                                    4.10                  1.54
##  7 K00010.01                                    4.17                  1.45
##  8 K00012.01                                    4.31                  1.37
##  9 K00013.01                                    3.87                  3.03
## 10 K00017.01                                    4.24                  1.29
## # i 4,080 more rows
## # i abbreviated name: 1: `Stellar radius / Solar radii`
## # i 5 more variables: `Stellar effective surface temperature/K` <int>,
## #   `Mass of star/kg` <dbl>, `Luminosity ratio` <dbl>, `Inner radii/AU` <dbl>,
## #   `outer solar radiii/AU` <dbl>
```

2.4.2 Stellar Correlation Plotting

(c) Stellar surface temperature against stellar radius

```
library(ggplot2)
library(readr)
kepler_df <- read.csv("kepler_data_new1.csv", header = TRUE, sep = ",")
ggplot(data = kepler_df, aes(x=koi_srad, y=koi_steff)) +
  geom_point() + geom_smooth(method="gam", se = FALSE)+
  labs(title="Stellar effective surface temperature against stellar radius", y = "Stellar surface tempe
```

The graph below shows that the Stellar surface temperature is approximately linearly related to the stellar radii with a positive gradient untill around 1 solar radii, then it decreases expo-

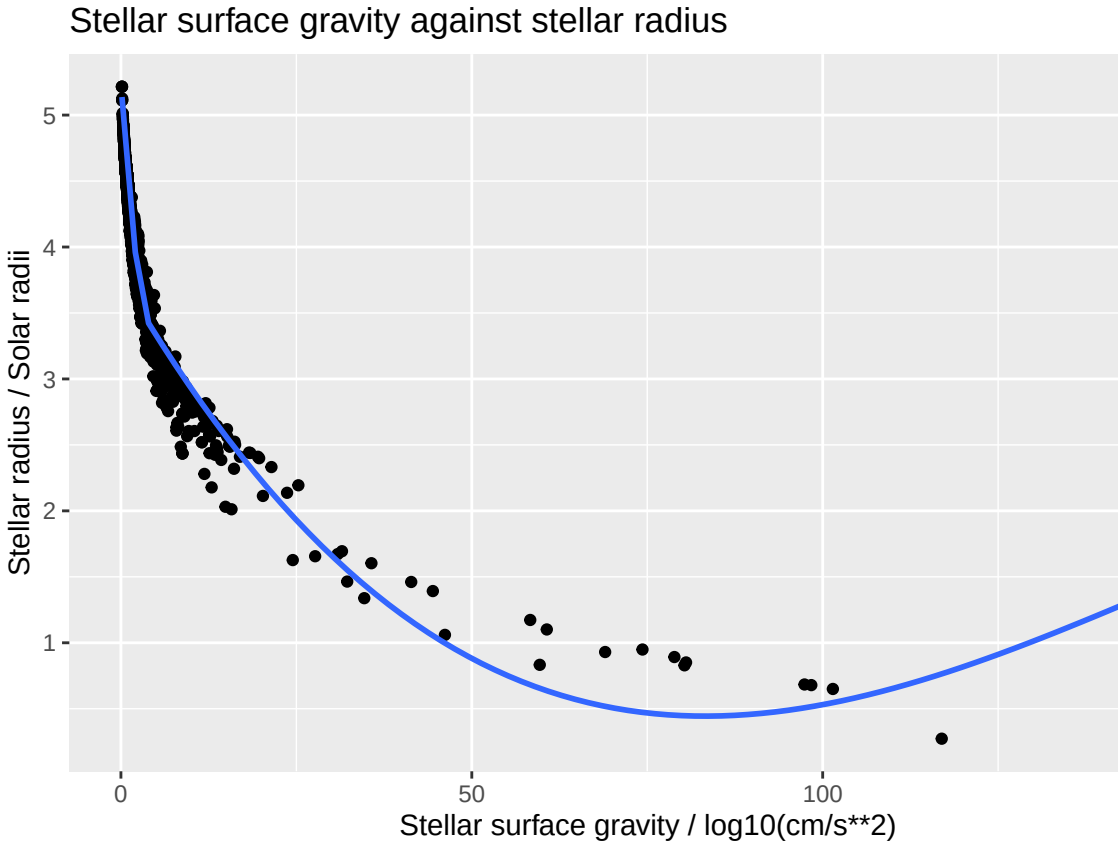


nentially

(d) Stellar surface gravity against stellar radius

```
ggplot(data = kepler_df, aes(x=koi_srad, y=koi_slogg)) +
  geom_point() + geom_smooth(method="gam", se = FALSE)+
  labs(title="Stellar surface gravity against stellar radius", x = "Stellar surface gravity / log10(cm/
```

The graph below shows that the Stellar radius is approximately inversely proportionate to the stellar surface gravity.



2.4.3 Identify Habitable Exoplanet

(e) Use Kepler's Third Law to find the orbital radii of the exoplanets in astronomical units (AU), with columns containing the KOI and the orbital radius.

```
library(readr)
library(tidyr)
library(tidyverse)



new_kepler_df <- select(filtered_kepler_df, kepoi_name, koi_slogg, koi_srad, koi_period, koi_steff, koi
mutate("Mass of planet/kg" = (10 ** koi_mass) * 5.972 *(10**24)) %>%
mutate("Mass of star/kg" = ((((10**koi_slogg)/100) * (koi_srad * 696000000)**2) / (6.67 * (10 ** -11) ))
mutate("Orbital radii of planet/AU" = (((`Mass of star/kg` + `Mass of planet/kg`) * 6.67 * (10 ** -11) *
mutate("Inner radii/AU" = ((1/1.1)*(((koi_srad* 696000000)/(6.957*10**8))**2)*((koi_steff/6000)**4))**0
mutate("Outer solar radii/AU" = ((1/0.53)* (((koi_srad* 696000000)/(6.957*10**8))**2)*((koi_steff/6000)*
rename("Orbital Period of planet/Days"= koi_period, "Stellar surface gravity / log10(cm/s**2)" = koi_slo
tibble(new_kepler_df)
```

```
## # A tibble: 4,090 x 12
##    `KOI NAME` `Stellar surface gravity / log10(cm/s**2)` Stellar radius / Sola~1
```

```
##    <chr>                                          <dbl>                  <dbl>
##  1 K00001.01                                       4.46                  0.964
##  2 K00002.01                                       4.02                  1.95
##  3 K00003.01                                       4.59                  0.763
##  4 K00004.01                                       3.66                  2.99
##  5 K00005.01                                       4.01                  1.79
##  6 K00007.01                                       4.10                  1.54
##  7 K00010.01                                       4.17                  1.45
##  8 K00012.01                                       4.31                  1.37
##  9 K00013.01                                       3.87                  3.03
## 10 K00017.01                                       4.24                  1.29
## # i 4,080 more rows
## # i abbreviated name: 1: `Stellar radius / Solar radii/AU`
## # i 9 more variables: `Orbital Period of planet/Days` <dbl>,
## #   `Stellar effective surface temperature/K` <int>, koi_mass <dbl>,
## #   kepler_name <chr>, `Mass of planet/kg` <dbl>, `Mass of star/kg` <dbl>,
## #   `Orbital radii of planet/AU` <dbl>, `Inner radii/AU` <dbl>,
## #   `Outer solar radii/AU` <dbl>
```

(f) Write down the list of exoplanets in the habitable zone.

```
library(readr)
library(tidyr)
library(dplyr)
library(tidyverse)
new_kepler_df <- select(filtered_kepler_df, kepoi_name, koi_slogg, koi_srad, kepler_name, koi_period, k
mutate("Mass of planet/kg" = (10 ** koi_mass) * 5.972 *(10**24)) %>%
mutate("Mass of star/kg" = ((((10**koi_slogg)/100) * (koi_srad * 696000000)**2) / (6.67 * (10 ** -11) ))
mutate("Orbital radii of planet/AU" = (((`Mass of star/kg` + `Mass of planet/kg` ) * 6.67 * (10 ** -11)
mutate("Inner radii/AU" = ((1/1.1)*(((koi_srad* 696000000)/(6.957*10**8))**2)*((koi_steff/6000)**4))**0
mutate("Outer solar radii/AU" = ((1/0.53)* (((koi_srad* 696000000)/(6.957*10**8))**2)*((koi_steff/6000)
rename("Orbital Period of planet/Days"= koi_period, "Stellar surface gravity / log10(cm/s**2)" = koi_sl
Potentially_Habitable_Planets <- new_kepler_df %>%
  mutate(lower_bound = pmin(`Inner radii/AU`, `Outer solar radii/AU`),
         upper_bound = pmax(`Inner radii/AU`, `Outer solar radii/AU`)) %>%
  filter(`Orbital radii of planet/AU` >= lower_bound & `Orbital radii of planet/AU` <= upper_bound) %>%
  select(-lower_bound, -upper_bound)

tibble(Potentially_Habitable_Planets)
```

```
## # A tibble: 90 x 13
##    `KOI NAME` Stellar surface gravity / l~1 Stellar radius / Sol~2 `Kepler Name`
##    <chr>                                <dbl>                  <dbl> <chr>
##  1 K00087.01                             4.45                  0.886 "Kepler-22 b"
##  2 K00179.02                             4.26                  1.30  "Kepler-458 ~
##  3 K00463.01                             4.97                  0.283 "Kepler-560 ~
##  4 K00682.01                             4.23                  1.29  ""
##  5 K00701.03                             4.65                  0.662 "Kepler-62 e"
##  6 K00841.04                             4.58                  0.817 ""
##  7 K00854.01                             4.76                  0.491 "Kepler-705 ~
##  8 K00881.02                             4.58                  0.75  "Kepler-712 ~
##  9 K00902.01                             4.75                  0.509 ""
```

```
## 10 K01168.01                          4.23                  1.31  ""
## # i 80 more rows
## # i abbreviated names: 1: ‘Stellar surface gravity / log10(cm/s**2)‘,
## #   2: ‘Stellar radius / Solar radii/AU‘
## # i 9 more variables: ‘Orbital Period of planet/Days‘ <dbl>,
## #   ‘Stellar effective surface temperature/K‘ <int>, koi_mass <dbl>,
## #   ‘Planet Radius/ earth radii‘ <dbl>, ‘Mass of planet/kg‘ <dbl>,
## #   ‘Mass of star/kg‘ <dbl>, ‘Orbital radii of planet/AU‘ <dbl>, ...
```

2.4.4 Size Categorisation

(g) Assume the exoplanet orbits are circular.Refer to Table 1 in DRQ. Classify each of the planets into the following types: Asteroids, Mercurians, Sub-earth, Earth, Super Earth, Neptunians, Jovians.

```
Asteroids <- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 0 & `Mass of planet/kg`<= 0.00001 * 5.972 *(10**24) & `Planet Radius/ ea
Mercurians<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` <= 0.1 * 5.972 *(10**24)& `Mass of planet/kg`>= 0.00001 * 5.972 *(10**24) &
Subearth<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 0.1 * 5.972 *(10**24)& `Mass of planet/kg`<= 0.5 * 5.972 *(10**24) & `Pl
Earth<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 0.5 * 5.972 *(10**24)& `Mass of planet/kg`<= 2 * 5.972 *(10**24) & `Plan
SuperEarth<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 2 * 5.972 *(10**24)& `Mass of planet/kg`<= 10 * 5.972 *(10**24) & `Plane
Neptunians<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 10 * 5.972 *(10**24)& `Mass of planet/kg`<= 50 * 5.972 *(10**24) & `Plan
Jovians<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 50 * 5.972 *(10**24)& `Mass of planet/kg`<= 5000 * 5.972 *(10**24) & `Pl
SubStar<- Potentially_Habitable_Planets %>%
  filter(`Mass of planet/kg` >= 5000 * 5.972 *(10**24))
# View the filtered data
print(Asteroids)
```

```
##  [1] KOI NAME
##  [2] Stellar surface gravity / log10(cm/s**2)
##  [3] Stellar radius / Solar radii/AU
##  [4] Kepler Name
##  [5] Orbital Period of planet/Days
##  [6] Stellar effective surface temperature/K
##  [7] koi_mass
##  [8] Planet Radius/ earth radii
##  [9] Mass of planet/kg
## [10] Mass of star/kg
## [11] Orbital radii of planet/AU
## [12] Inner radii/AU
## [13] Outer solar radii/AU
## <0 rows> (or 0-length row.names)
```

```
print(Mercurians)
```

```
##  [1] KOI NAME
##  [2] Stellar surface gravity / log10(cm/s**2)
##  [3] Stellar radius / Solar radii/AU
##  [4] Kepler Name
##  [5] Orbital Period of planet/Days
##  [6] Stellar effective surface temperature/K
##  [7] koi_mass
##  [8] Planet Radius/ earth radii
##  [9] Mass of planet/kg
## [10] Mass of star/kg
## [11] Orbital radii of planet/AU
## [12] Inner radii/AU
## [13] Outer solar radii/AU
## <0 rows> (or 0-length row.names)
```

```
print(Subearth)
```

```
##  [1] KOI NAME
##  [2] Stellar surface gravity / log10(cm/s**2)
##  [3] Stellar radius / Solar radii/AU
##  [4] Kepler Name
##  [5] Orbital Period of planet/Days
##  [6] Stellar effective surface temperature/K
##  [7] koi_mass
##  [8] Planet Radius/ earth radii
##  [9] Mass of planet/kg
## [10] Mass of star/kg
## [11] Orbital radii of planet/AU
## [12] Inner radii/AU
## [13] Outer solar radii/AU
## <0 rows> (or 0-length row.names)
```

```
print(Earth)
```

```
##    KOI NAME Stellar surface gravity / log10(cm/s**2)
## 1 K01422.05                                    4.866
## 2 K02626.01                                    4.867
## 3 K03456.02                                    4.373
## 4 K04878.01                                    4.368
##   Stellar radius / Solar radii/AU   Kepler Name Orbital Period of planet/Days
## 1                           0.383  Kepler-296 e                      34.14205
## 2                           0.398 Kepler-1652 b                      38.09707
## 3                           1.062                                   486.12702
## 4                           1.068                                   449.01499
##   Stellar effective surface temperature/K koi_mass Planet Radius/ earth radii
## 1                                   3526     0.13                       1.06
## 2                                   3554     0.26                       1.58
## 3                                   6008    -0.03                       1.18
## 4                                   6031    -0.01                       1.04
##   Mass of planet/kg Mass of star/kg Orbital radii of planet/AU Inner radii/AU
## 1      8.056006e+24    7.825105e+29                  0.1509027      0.1261687
## 2      1.086725e+25    8.469520e+29                  0.1666818      0.1332006
## 3      5.573395e+24    1.933489e+30                  1.1984500      1.0157171
```

```
## 4      5.836061e+24    1.933015e+30                  1.1365586      1.0292913
##   Outer solar radii/AU
## 1            0.1817650
## 2            0.1918955
## 3            1.4632926
## 4            1.4828483
```

```
print(SuperEarth)
```

```
##     KOI NAME Stellar surface gravity / log10(cm/s**2)
## 1  K00087.01                                     4.446
## 2  K00463.01                                     4.970
## 3  K00701.03                                     4.653
## 4  K00854.01                                     4.757
## 5  K01876.01                                     4.678
## 6  K02020.01                                     4.695
## 7  K02102.01                                     4.550
## 8  K02194.03                                     4.387
## 9  K02757.01                                     4.481
## 10 K02762.01                                     4.636
## 11 K02834.01                                     4.631
## 12 K02992.01                                     4.716
## 13 K03010.01                                     4.734
## 14 K04016.01                                     4.557
## 15 K04036.01                                     4.620
## 16 K04087.01                                     4.705
## 17 K04103.01                                     4.566
## 18 K04247.01                                     4.512
## 19 K04742.01                                     4.677
## 20 K04745.01                                     4.615
## 21 K04978.01                                     4.402
## 22 K05087.01                                     4.218
## 23 K05202.01                                     4.494
## 24 K05216.01                                     4.531
## 25 K05227.01                                     4.351
## 26 K05236.01                                     4.367
## 27 K05269.01                                     4.491
## 28 K05276.01                                     4.634
## 29 K05423.01                                     4.403
## 30 K05455.01                                     4.534
## 31 K05506.01                                     4.449
## 32 K05536.01                                     4.558
## 33 K05541.01                                     4.522
## 34 K05552.01                                     4.386
## 35 K05592.01                                     4.488
## 36 K05602.01                                     4.504
## 37 K05609.01                                     4.085
## 38 K05613.01                                     4.490
## 39 K05653.01                                     4.599
## 40 K05702.01                                     4.454
## 41 K05715.01                                     4.613
## 42 K05737.01                                     4.463
## 43 K05796.01                                     4.378
## 44 K05835.01                                     4.473
```

```
## 45 K05874.01                                    4.378
## 46 K05878.01                                    4.629
## 47 K05903.01                                    4.535
## 48 K05938.01                                    4.345
## 49 K06239.01                                    4.525
##    Stellar radius / Solar radii/AU   Kepler Name Orbital Period of planet/Days
## 1                            0.886   Kepler-22 b                      289.86407
## 2                            0.283  Kepler-560 b                       18.47763
## 3                            0.662   Kepler-62 e                      122.38587
## 4                            0.491  Kepler-705 b                       56.05608
## 5                            0.580  Kepler-991 b                       82.53412
## 6                            0.546 Kepler-1058 b                      110.96437
## 7                            0.753 Kepler-1097 b                      187.74661
## 8                            0.950                                    445.21685
## 9                            0.885 Kepler-1690 b                      234.63565
## 10                           0.659 Kepler-1341 b                      132.99555
## 11                           0.675 Kepler-1362 b                      136.20511
## 12                           0.553                                     82.65952
## 13                           0.522 Kepler-1410 b                       60.86610
## 14                           0.747 Kepler-1540 b                      125.41323
## 15                           0.707 Kepler-1544 b                      168.81133
## 16                           0.561  Kepler-440 b                      101.11070
## 17                           0.801 Kepler-1552 b                      184.77271
## 18                           0.945                                    349.41047
## 19                           0.595  Kepler-442 b                      112.30314
## 20                           0.701  Kepler-443 b                      177.66866
## 21                           0.966                                    339.18998
## 22                           1.261                                    651.07431
## 23                           0.958                                    535.93723
## 24                           0.891                                    377.31115
## 25                           0.972                                    371.56492
## 26                           1.115                                    550.86514
## 27                           0.924                                    371.50631
## 28                           0.696                                    220.72014
## 29                           1.100                                    366.55705
## 30                           0.883                                    292.09809
## 31                           1.031                                    641.60204
## 32                           0.815                                    392.72811
## 33                           0.901                                    339.63383
## 34                           0.992                                    295.95891
## 35                           0.960                                    482.51701
## 36                           0.963                                    403.16315
## 37                           1.423                                    535.15150
## 38                           0.946                                    346.41740
## 39                           0.672                                    188.66410
## 40                           1.007                                    511.88200
## 41                           0.742                                    189.96173
## 42                           0.960                                    376.24253
## 43                           1.044                                    495.85419
## 44                           0.962                                    474.96952
## 45                           1.007                                    287.33114
## 46                           0.689                                    211.54114
## 47                           0.850                                    253.79043
## 48                           1.155                                    545.20560
```

```
## 49                            0.884                                406.49622
##    Stellar effective surface temperature/K koi_mass Planet Radius/ earth radii
## 1                                    5516     0.68                       2.34
## 2                                    3395     0.49                       1.55
## 3                                    4926     0.64                       1.72
## 4                                    3593     0.70                       1.94
## 5                                    4316     0.82                       2.45
## 6                                    4441     0.68                       2.11
## 7                                    5303     1.00                       2.95
## 8                                    5670     0.42                       1.37
## 9                                    5422     0.90                       2.56
## 10                                   4523     0.83                       2.51
## 11                                   4648     0.82                       2.35
## 12                                   3952     0.73                       2.03
## 13                                   3808     0.52                       1.39
## 14                                   4641     0.90                       3.14
## 15                                   4798     0.62                       1.69
## 16                                   4133     0.62                       1.61
## 17                                   5273     0.89                       2.41
## 18                                   5878     0.91                       2.41
## 19                                   4401     0.47                       1.30
## 20                                   4721     0.74                       2.32
## 21                                   5544     0.91                       2.75
## 22                                   5696     0.32                       1.55
## 23                                   6014     0.74                       1.83
## 24                                   5897     0.98                       2.56
## 25                                   5735     0.59                       1.89
## 26                                   5912     0.77                       2.06
## 27                                   5696     0.91                       2.88
## 28                                   5150     0.80                       2.00
## 29                                   5857     0.95                       2.63
## 30                                   5955     0.78                       2.09
## 31                                   6277     0.60                       1.61
## 32                                   5701     0.70                       1.85
## 33                                   5823     0.84                       2.04
## 34                                   5505     0.73                       2.10
## 35                                   6168     0.86                       2.30
## 36                                   5812     0.96                       2.49
## 37                                   5468     0.62                       2.70
## 38                                   5754     0.90                       2.41
## 39                                   4788     0.79                       2.02
## 40                                   6141     0.99                       2.56
## 41                                   5335     0.73                       1.93
## 42                                   5916     0.46                       1.32
## 43                                   5613     0.80                       2.41
## 44                                   6287     0.97                       2.44
## 45                                   5426     0.67                       2.07
## 46                                   5433     0.68                       1.88
## 47                                   5426     0.77                       2.06
## 48                                   6273     0.60                       1.66
## 49                                   5847     0.84                       1.77
##    Mass of planet/kg Mass of star/kg Orbital radii of planet/AU Inner radii/AU
## 1       2.858379e+25    1.592062e+30                0.79577691     0.71428352
## 2       1.845524e+25    5.428321e+29                0.08871492     0.08642798
```

```
## 3       2.606873e+25    1.431557e+30                0.43228033     0.42563291
## 4       2.993090e+25    1.000589e+30                0.22795220     0.16795167
## 5       3.945661e+25    1.163988e+30                0.31027676     0.28627225
## 6       2.858379e+25    1.072699e+30                0.36781095     0.28532681
## 7       5.972000e+25    1.461109e+30                0.57892277     0.56108237
## 8       1.570796e+25    1.597864e+30                1.06064053     0.80924144
## 9       4.743728e+25    1.721786e+30                0.70946695     0.68936732
## 10      4.037568e+25    1.364154e+30                0.44963071     0.35721278
## 11      3.945661e+25    1.414817e+30                0.46242236     0.38638869
## 12      3.207154e+25    1.154896e+30                0.30977951     0.22884814
## 13      1.977515e+25    1.072590e+30                0.24645444     0.20056390
## 14      4.743728e+25    1.461281e+30                0.44240226     0.42631649
## 15      2.489544e+25    1.513322e+30                0.54565698     0.43124919
## 16      2.489544e+25    1.158826e+30                0.35471517     0.25391132
## 17      4.635748e+25    1.715369e+30                0.60425577     0.59011473
## 18      4.854224e+25    2.108416e+30                0.98980994     0.86512600
## 19      1.762462e+25    1.222156e+30                0.38723801     0.30535715
## 20      3.281858e+25    1.470716e+30                0.55923258     0.41397528
## 21      4.854224e+25    1.710200e+30                0.90501171     0.78670509
## 22      1.247728e+25    1.907756e+30                1.44966629     1.08403534
## 23      3.281858e+25    2.078852e+30                1.31026329     0.91808047
## 24      5.703216e+25    1.958159e+30                1.01646503     0.82097201
## 25      2.323378e+25    1.539661e+30                0.92862313     0.84707429
## 26      3.516574e+25    2.102047e+30                1.33942744     1.03259998
## 27      4.854224e+25    1.920599e+30                0.99953752     0.79432883
## 28      3.768077e+25    1.514646e+30                0.65264107     0.48911625
## 29      5.322551e+25    2.222685e+30                1.04007096     0.99984235
## 30      3.598486e+25    1.936485e+30                0.85381865     0.82968383
## 31      2.377496e+25    2.170751e+30                1.49872235     1.07634455
## 32      2.993090e+25    1.743443e+30                1.00432024     0.70185611
## 33      4.131615e+25    1.961292e+30                0.94812050     0.80948119
## 34      3.207154e+25    1.738265e+30                0.83087317     0.79655306
## 35      4.326332e+25    2.058899e+30                1.21776161     0.96771697
## 36      5.446529e+25    2.149538e+30                1.09591888     0.86191788
## 37      2.489544e+25    1.788556e+30                1.24497255     1.12732803
## 38      4.743728e+25    2.008514e+30                0.96835360     0.82988754
## 39      3.682305e+25    1.302660e+30                0.55900168     0.40819337
## 40      5.836061e+25    2.094844e+30                1.27401219     1.00622721
## 41      3.207154e+25    1.640214e+30                0.60639113     0.55957866
## 42      1.722344e+25    1.943726e+30                1.01203926     0.89025815
## 43      3.768077e+25    1.890139e+30                1.20524648     0.87152325
## 44      5.573395e+25    1.997298e+30                1.19289233     1.00751237
## 45      2.793314e+25    1.758537e+30                0.81779994     0.78555653
## 46      2.858379e+25    1.467341e+30                0.62774345     0.53887375
## 47      3.516574e+25    1.798583e+30                0.75852333     0.66308148
## 48      2.377496e+25    2.144157e+30                1.33905926     1.20426192
## 49      4.131615e+25    1.901066e+30                1.05774015     0.80076825
##    Outer solar radii/AU
## 1             1.0290324
## 2             0.1245125
## 3             0.6131879
## 4             0.2419595
## 5             0.4124181
## 6             0.4110560
```

```
## 7             0.8083232
## 8             1.1658335
## 9             0.9931369
## 10            0.5146185
## 11            0.5566508
## 12            0.3296900
## 13            0.2889423
## 14            0.6141727
## 15            0.6212790
## 16            0.3657973
## 17            0.8501486
## 18            1.2463436
## 19            0.4399127
## 20            0.5963934
## 21            1.1333665
## 22            1.5617152
## 23            1.3226324
## 24            1.1827331
## 25            1.2203374
## 26            1.4876149
## 27            1.1443496
## 28            0.7046452
## 29            1.4404226
## 30            1.1952838
## 31            1.5506355
## 32            1.0111288
## 33            1.1661789
## 34            1.1475540
## 35            1.3941412
## 36            1.2417218
## 37            1.6240848
## 38            1.1955773
## 39            0.5880637
## 40            1.4496210
## 41            0.8061569
## 42            1.2825502
## 43            1.2555597
## 44            1.4514724
## 45            1.1317118
## 46            0.7763283
## 47            0.9552682
## 48            1.7349196
## 49            1.1536266
```

```
print(Neptunians)
```

```
##     KOI NAME Stellar surface gravity / log10(cm/s**2)
## 1  K00881.02                                    4.585
## 2  K00902.01                                    4.746
## 3  K01168.01                                    4.232
## 4  K01830.02                                    4.548
## 5  K02102.01                                    4.550
## 6  K02210.02                                    4.589
## 7  K04105.01                                    4.472
```

```
## 8  K04418.01                                  4.534
## 9  K04898.01                                  4.444
## 10 K05021.01                                  4.504
## 11 K05085.01                                  4.538
## 12 K05142.01                                  4.502
## 13 K05222.01                                  4.455
## 14 K05337.01                                  4.493
## 15 K05380.01                                  4.453
## 16 K05546.01                                  4.411
## 17 K05706.01                                  4.473
## 18 K05790.01                                  4.624
## 19 K05932.01                                  4.576
##    Stellar radius / Solar radii/AU   Kepler Name Orbital Period of planet/Days
## 1                            0.750  Kepler-712 c                     226.89048
## 2                            0.509                                   83.92494
## 3                            1.309                                  856.67211
## 4                            0.800  Kepler-967 c                     198.71063
## 5                            0.753 Kepler-1097 b                     187.74661
## 6                            0.759 Kepler-1143 c                     210.63149
## 7                            0.999                                  363.41165
## 8                            0.903                                  333.03842
## 9                            1.064                                  409.87844
## 10                           0.965                                  288.07937
## 11                           0.882                                  327.06300
## 12                           0.808                                  198.89586
## 13                           1.048                                  367.67580
## 14                           0.951                                  470.65357
## 15                           1.024                                  369.93355
## 16                           1.137                                  514.27150
## 17                           1.022 Kepler-1636 b                     425.48354
## 18                           0.713                                  178.26698
## 19                           0.801                                  355.86134
##    Stellar effective surface temperature/K koi_mass Planet Radius/ earth radii
## 1                                     5067     1.26                       4.53
## 2                                     3960     1.33                       4.78
## 3                                     6449     1.13                       3.87
## 4                                     5180     1.13                       3.56
## 5                                     5303     1.00                       2.95
## 6                                     4895     1.06                       3.23
## 7                                     6025     1.12                       3.14
## 8                                     5743     1.09                       3.19
## 9                                     6167     1.10                       2.72
## 10                                    5825     1.18                       3.01
## 11                                    5750     1.01                       2.82
## 12                                    5184     1.04                       3.33
## 13                                    6140     1.02                       2.77
## 14                                    6039     1.06                       2.99
## 15                                    6158     1.04                       3.24
## 16                                    6343     1.05                       3.01
## 17                                    5977     1.14                       3.20
## 18                                    4899     1.04                       3.71
## 19                                    5736     1.22                       2.79
##    Mass of planet/kg Mass of star/kg Orbital radii of planet/AU Inner radii/AU
## 1       1.086725e+26    1.571141e+30                  0.6729225      0.5102129
```

```
## 2       1.276791e+26    1.048403e+30                0.3030122      0.2114933
## 3       8.056006e+25    2.123107e+30                1.8038967      1.4424899
## 4       8.056006e+25    1.641620e+30                0.6250544      0.5687716
## 5       5.972000e+25    1.461109e+30                0.5789228      0.5610824
## 6       6.856773e+25    1.623963e+30                0.6474698      0.4818763
## 7       7.872629e+25    2.148937e+30                1.0225507      0.9608774
## 8       7.347165e+25    2.025201e+30                0.9458668      0.7891395
## 9       7.518303e+25    2.285472e+30                1.1309391      1.0722052
## 10      9.038988e+25    2.158476e+30                0.8771403      0.8675761
## 11      6.111106e+25    1.949978e+30                0.9228006      0.7726675
## 12      6.548168e+25    1.506313e+30                0.6077632      0.5753468
## 13      6.253452e+25    2.274130e+30                1.0501666      1.0468547
## 14      6.856773e+25    2.043872e+30                1.1948024      0.9189650
## 15      6.548168e+25    2.161188e+30                1.0367089      1.0288871
## 16      6.700694e+25    2.418876e+30                1.3407340      1.2120995
## 17      8.243655e+25    2.254210e+30                1.1541557      0.9673994
## 18      6.548168e+25    1.553359e+30                0.5707988      0.4534118
## 19      9.911053e+25    1.755326e+30                0.9425847      0.6982954
##    Outer solar radii/AU
## 1             0.7350381
## 2             0.3046877
## 3             2.0781228
## 4             0.8194007
## 5             0.8083232
## 6             0.6942150
## 7             1.3842878
## 8             1.1368736
## 9             1.5446722
## 10            1.2498733
## 11            1.1131433
## 12            0.8288733
## 13            1.5081510
## 14            1.3239067
## 15            1.4822659
## 16            1.7462109
## 17            1.3936837
## 18            0.6532076
## 19            1.0059991
```

```
print(Jovians)
```

```
##    KOI NAME Stellar surface gravity / log10(cm/s**2)
## 1 K00682.01                                    4.229
## 2 K01208.01                                    4.397
## 3 K01209.01                                    4.548
## 4 K01431.01                                    4.515
## 5 K03663.01                                    4.506
## 6 K05124.01                                    4.396
##   Stellar radius / Solar radii/AU Kepler Name Orbital Period of planet/Days
## 1                           1.289                                   562.1726
## 2                           1.118                                   700.0030
## 3                           0.791                                   272.0868
## 4                           0.931                                   345.1589
## 5                           0.913 Kepler-86 b                       282.5254
```

```
## 6                           0.966                                  276.8795
##   Stellar effective surface temperature/K koi_mass Planet Radius/ earth radii
## 1                                   5589     3.07                      10.90
## 2                                   6487     1.75                       6.43
## 3                                   5587     1.77                       5.95
## 4                                   5597     1.87                       7.79
## 5                                   5725     3.20                       8.98
## 6                                   5324     2.12                      11.67
##   Mass of planet/kg Mass of star/kg Orbital radii of planet/AU Inner radii/AU
## 1      7.016488e+27    2.044554e+30                  1.3467315      1.0668652
## 2      3.358302e+26    2.264520e+30                  1.6109643      1.2465738
## 3      3.516574e+26    1.604891e+30                  0.7649935      0.6542176
## 4      4.427105e+26    2.060592e+30                  0.9743470      0.7727672
## 5      9.464982e+27    1.941039e+30                  0.8370659      0.7928849
## 6      7.872629e+26    1.686735e+30                  0.7869543      0.7255070
##   Outer solar radii/AU
## 1            1.5369790
## 2            1.7958762
## 3            0.9424984
## 4            1.1132869
## 5            1.1422694
## 6            1.0452015
```

```
print(SubStar)
```

```
##    KOI NAME Stellar surface gravity / log10(cm/s**2)
## 1 K01298.02                                    4.684
## 2 K03761.01                                    4.603
## 3 K04460.01                                    4.332
## 4 K04940.01                                    4.629
## 5 K05869.01                                    4.589
##   Stellar radius / Solar radii/AU  Kepler Name Orbital Period of planet/Days
## 1                           0.582 Kepler-283 c                      92.74958
## 2                           0.664                                  164.95040
## 3                           1.080                                  284.72721
## 4                           0.630                                   84.64059
## 5                           0.691                                  114.40619
##   Stellar effective surface temperature/K koi_mass Planet Radius/ earth radii
## 1                                   4141     4.91                       1.87
## 2                                   5001     5.07                      11.23
## 3                                   5497     5.04                       2.02
## 4                                   4386     4.68                       1.72
## 5                                   4641     5.06                       2.42
##   Mass of planet/kg Mass of star/kg Orbital radii of planet/AU Inner radii/AU
## 1      4.854224e+29    1.188334e+30                  0.3785395      0.2644368
## 2      7.016488e+29    1.283597e+30                  0.5881835      0.4400177
## 3      6.548168e+29    1.819450e+30                  0.9108369      0.8646963
## 4      2.858379e+29    1.226800e+30                  0.3443260      0.3211191
## 5      6.856773e+29    1.346011e+30                  0.4644345      0.3943570
##   Outer solar radii/AU
## 1            0.3809608
## 2            0.6339114
## 3            1.2457246
## 4            0.4626202
```

```
## 5           0.5681303
```

```
output_path <- "Data taken from website and filtered with R.xlsx"
write.xlsx(mydata, file = output_path, row.names = TRUE)
output_path1 <- "Question part (a).xlsx"
write.xlsx(new_kepler_df2, file = output_path1, row.names = TRUE)
output_path2 <- "Question part (b).xlsx"
write.xlsx(new_kepler_df1, file = output_path2, row.names = TRUE)
output_path3 <- "Question part (e).xlsx"
write.xlsx(new_kepler_df, file = output_path3, row.names = TRUE)
output_path4 <- "Question part (f).xlsx"
write.xlsx(Potentially_Habitable_Planets, file = output_path4, row.names = TRUE)
output_path5 <- "Question part (g) Asteroids.xlsx"
write.xlsx(Asteroids, file = output_path5, row.names = TRUE)
output_path6 <- "Question part (g) Mercurians.xlsx"
write.xlsx(Mercurians, file = output_path6, row.names = TRUE)
output_path7 <- "Question part (g) Subearth.xlsx"
write.xlsx(Subearth, file = output_path7, row.names = TRUE)
output_path8 <- "Question part (g) Earth.xlsx"
write.xlsx(Earth, file = output_path8, row.names = TRUE)
output_path9 <- "Question part (g) SuperEarth.xlsx"
write.xlsx(SuperEarth, file = output_path9, row.names = TRUE)
output_path10 <- "Question part (g) Neptunians.xlsx"
write.xlsx(Neptunians, file = output_path10, row.names = TRUE)
output_path11 <- "Question part (g) Jovians.xlsx"
write.xlsx(Jovians, file = output_path11, row.names = TRUE)
output_path12 <- "Question part (g) SubStar.xlsx"
write.xlsx(SubStar, file = output_path12, row.names = TRUE)
```