Spectral Typing

Here we will take a look at the spectral typing of stars toward Cep OB3b.

```
#devtools::install_github("rstudio/reticulate")
library(reticulate)
use_python("/anaconda3/bin/python")
library(readr)
library(dplyr)
```

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

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

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

```
library(ggplot2)
source("/Users/thomasallen/cep_ob3b/cepr/lib/helpers.R")

#library('ProjectTemplate')
#project_directory<-"/Users/thomasallen/cep_ob3b/cepr"
#setwd(project_directory)
#load.project()
```

```
import sys as sys
sys.path.append("/Users/thomasallen/Code/python_scripts/Functions")
```

```
import sys as sys
sys.path.append("/Users/thomasallen/Code/python_scripts/Functions")
from hecto_funcs import hectospec_fits_open_index
from astropy.io import ascii
import numpy as np
import matplotlib.pyplot as plt
dir_in='/Users/thomasallen/cep_ob3b/data/Spectroscopy/'
standards_fn=dir_in+'spec_standards.dat'
#print(standards_fn)
stand=ascii.read(standards_fn)
spt=stand['col1']
fn=stand['col2']
num=stand['col3']
off = np.arange(len(fn))
#print(fn)
#print('Off')
#print(off)
#psize=16
#fsize=22
#fsize2=24
#fig = plt.figure(figsize=(10,15))
#plt.gcf().subplots_adjust(bottom=0.15,left=0.15)
#plt.subplot(1,1,1)
```

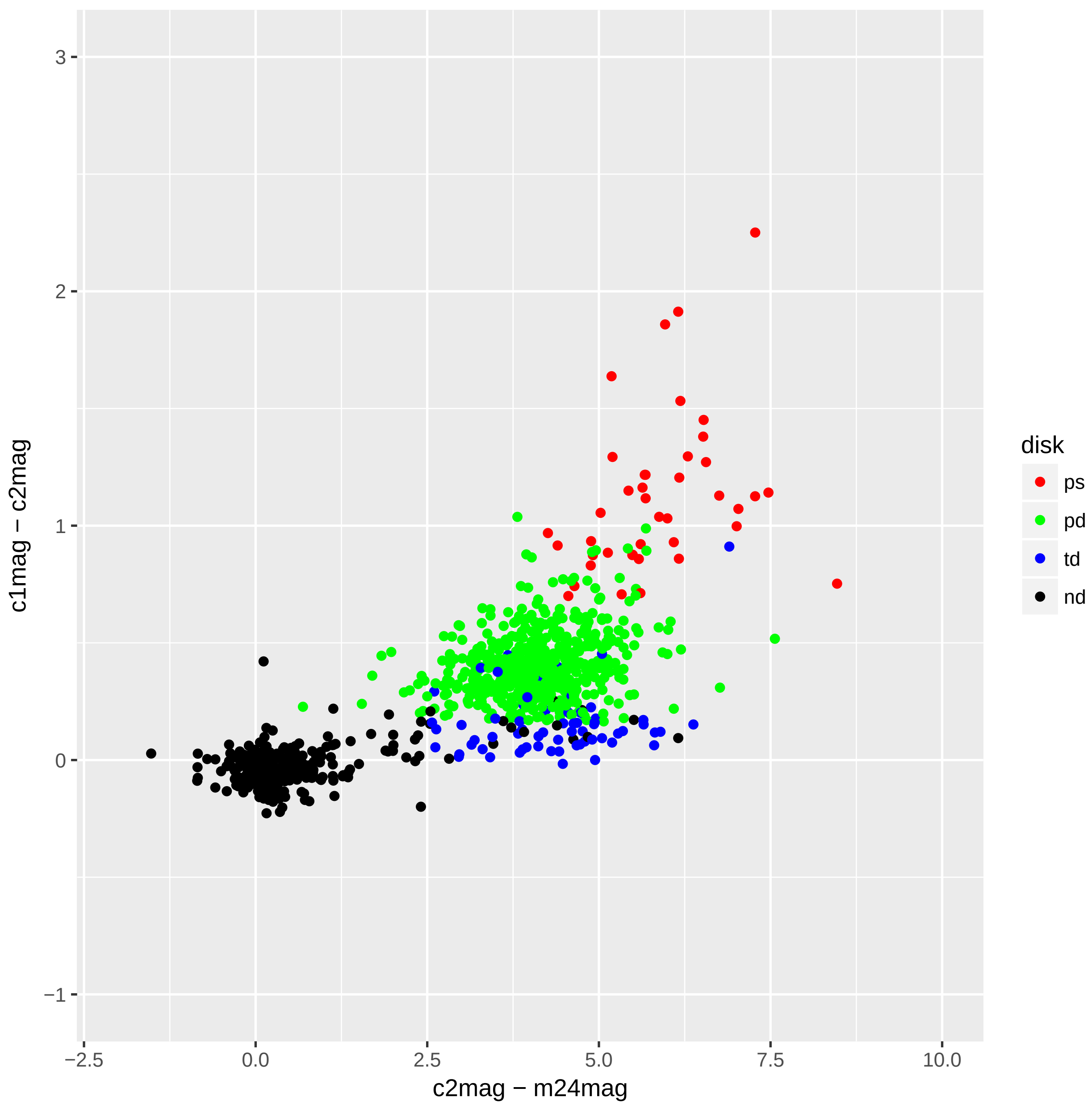


Figure 1: image

```
#plt.ylim=[0,100]
#plt.xlabel(r"Wavelength ($\mu \mathrm{m}$)",fontsize=fsize2)
#
#plt.show()
```

We read in the data set. Here we will start with the `full.df.csv` dataset. For details about this data set see the data documentation. We are interested in the spectral typing of the stars with *Hectospec* spectra.

```
data_path <- "/Users/thomasallen/cep_ob3b/cepr/data/"
data_path2 <- "/Users/thomasallen/cep_ob3b/data/"

#full.df.csv

full.df <- read_csv(paste(data_path2,"full.df.csv",sep=""))
```

```
## Warning: Missing column names filled in: 'X1' [1]
```

```
## Parsed with column specification:
## cols(
##   .default = col_double(),
##   X1 = col_integer(),
##   bmag = col_character(),
##   berr = col_character(),
##   vmag = col_character(),
##   verr = col_character(),
##   imag = col_character(),
##   ierr = col_character(),
##   cluster = col_character(),
##   cloud = col_character(),
##   disk = col_character(),
##   xray = col_character(),
##   acis = col_character(),
##   spec = col_character(),
##   chelle = col_character(),
##   spt = col_character(),
##   spterr = col_character(),
##   tio = col_character(),
##   tior = col_character(),
##   cah = col_character(),
##   cahr = col_character()
##   # ... with 28 more columns
## )
```

```
## See spec(...) for full column specifications.
```

```
#head(full.df)
gsdss.df <- read_csv(paste(data_path,"gsdss.csv",sep=""))
```

```
## Parsed with column specification:
## cols(
##   mag = col_double(),
##   err = col_double()
## )
```

```
rsdss.df <- read_csv(paste(data_path,"rsdss.csv",sep=""))
```

```
## Parsed with column specification:
```

```
## cols(
##   mag = col_double(),
##   err = col_double()
## )
```

```r
full.df <- full.df %>%
    mutate(gmag=gsdss.df$mag,gerr=gsdss.df$err) %>%
    mutate(rmag=rsdss.df$mag,rerr=rsdss.df$err)

full.df <- full.df %>%
    mutate(bmag=as.numeric(bmag)) %>%
    mutate(berr=as.numeric(berr)) %>%
    mutate(vmag=as.numeric(vmag)) %>%
    mutate(verr=as.numeric(verr)) %>%
    mutate(imag=as.numeric(imag)) %>%
    mutate(ierr=as.numeric(ierr))
```

We want the objects that have spectral types. These will be rows where the columns `spt`, the spectral type as classified by eye, and `spt_old`, the spectral type as classified by regression.

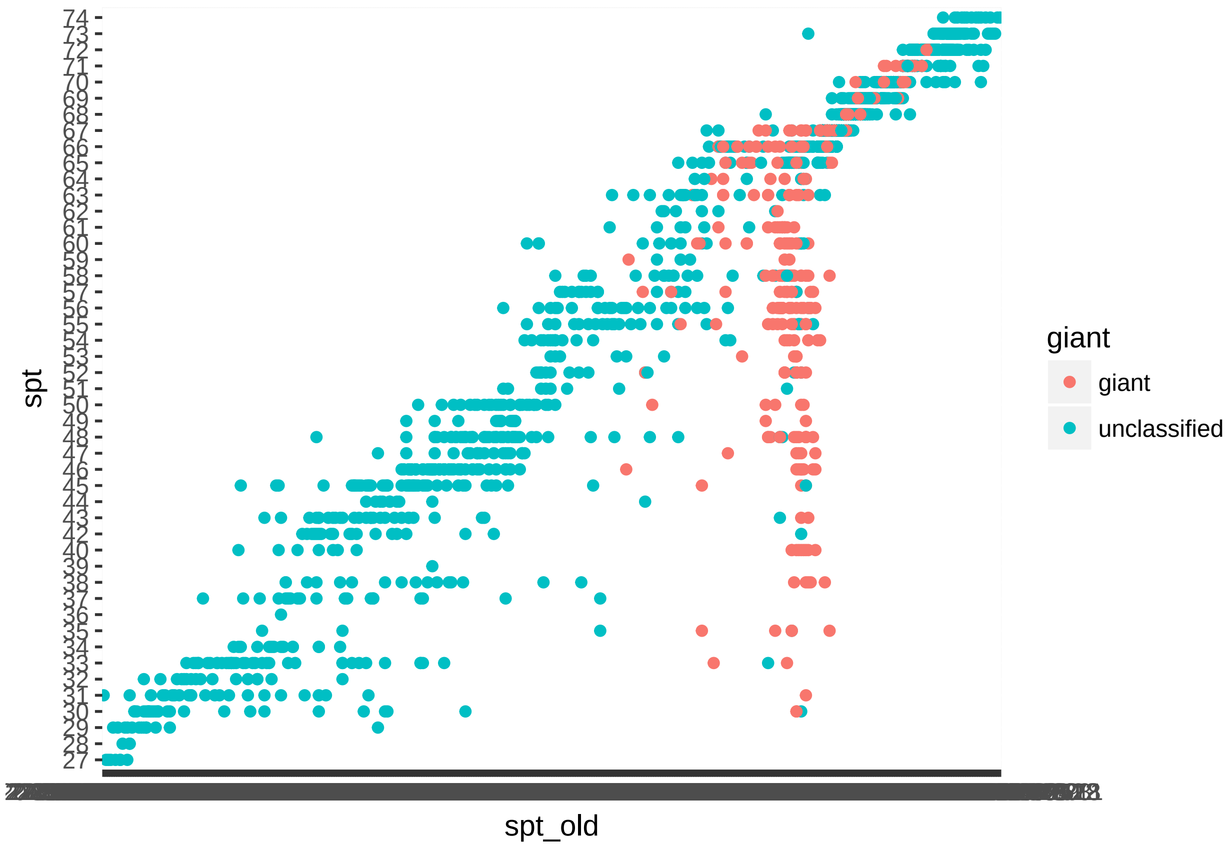
Lets make a column that tells us which stars we classified as probable background giants.

```r
full.df <- full.df %>%
    mutate(giant = ifelse(cagiant == "giant" | nagiant == "giant", "giant", "unclassified"))


spt.df <- full.df %>%
    filter(is.na(spt)==FALSE & is.na(spt_old)==FALSE)


head(spt.df)
```

```
## # A tibble: 6 x 93
##      X1    ra   dec  bmag  berr  vmag  verr  imag  ierr  jmag   jerr  hmag
##   <int> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  <dbl> <dbl>
## 1  4666  343.  62.4    NA    NA    NA    NA    NA    NA  13.8 0.025   12.4
## 2  4760  344.  62.3    NA    NA    NA    NA    NA    NA  13.8 0.025   13.1
## 3  4925  343.  62.4    NA    NA    NA    NA    NA    NA  14.8 0.046   13.7
## 4  5949  343.  62.4    NA    NA    NA    NA    NA    NA  15.3 0.0580  14.2
## 5  6017  344.  62.4    NA    NA    NA    NA    NA    NA  13.6 0.035   13.0
## 6  7049  344.  62.4    NA    NA    NA    NA    NA    NA  13.0 0.023   12.6
## # ... with 81 more variables: herr <dbl>, kmag <dbl>, kerr <dbl>,
## #   c1mag <dbl>, c1err <dbl>, c2mag <dbl>, c2err <dbl>, c3mag <dbl>,
## #   c3err <dbl>, c4mag <dbl>, c4err <dbl>, m24mag <dbl>, m24err <dbl>,
## #   cluster <chr>, cloud <chr>, disk <chr>, xray <chr>, acis <chr>,
## #   spec <chr>, chelle <chr>, spt <chr>, spterr <chr>, tio <chr>,
## #   tior <chr>, cah <chr>, cahr <chr>, spt_old <chr>, spterr_old <chr>,
## #   nagiant <chr>, cagiant <chr>, minxray.ra <int>, minxray.dec <int>,
## #   minxray.id <chr>, minxray.rcnts <int>, minxray.ncnts <int>,
## #   minxray.npflux <int>, minxray.npfluxerr <int>, minxray.nh <int>,
## #   minxray.nherr <int>, minxray.kt1 <int>, minxray.kt1err <int>,
## #   minxray.aflux <int>, minxray.uflux <int>, minxray.rchi <int>,
## #   medxray.ra <dbl>, medxray.dec <dbl>, medxray.id <chr>,
## #   medxray.rcnts <int>, medxray.ncnts <dbl>, medxray.npflux <dbl>,
## #   medxray.npfluxerr <dbl>, medxray.nh <dbl>, medxray.nherr <dbl>,
## #   medxray.kt1 <int>, medxray.kt1err <int>, medxray.aflux <dbl>,
```

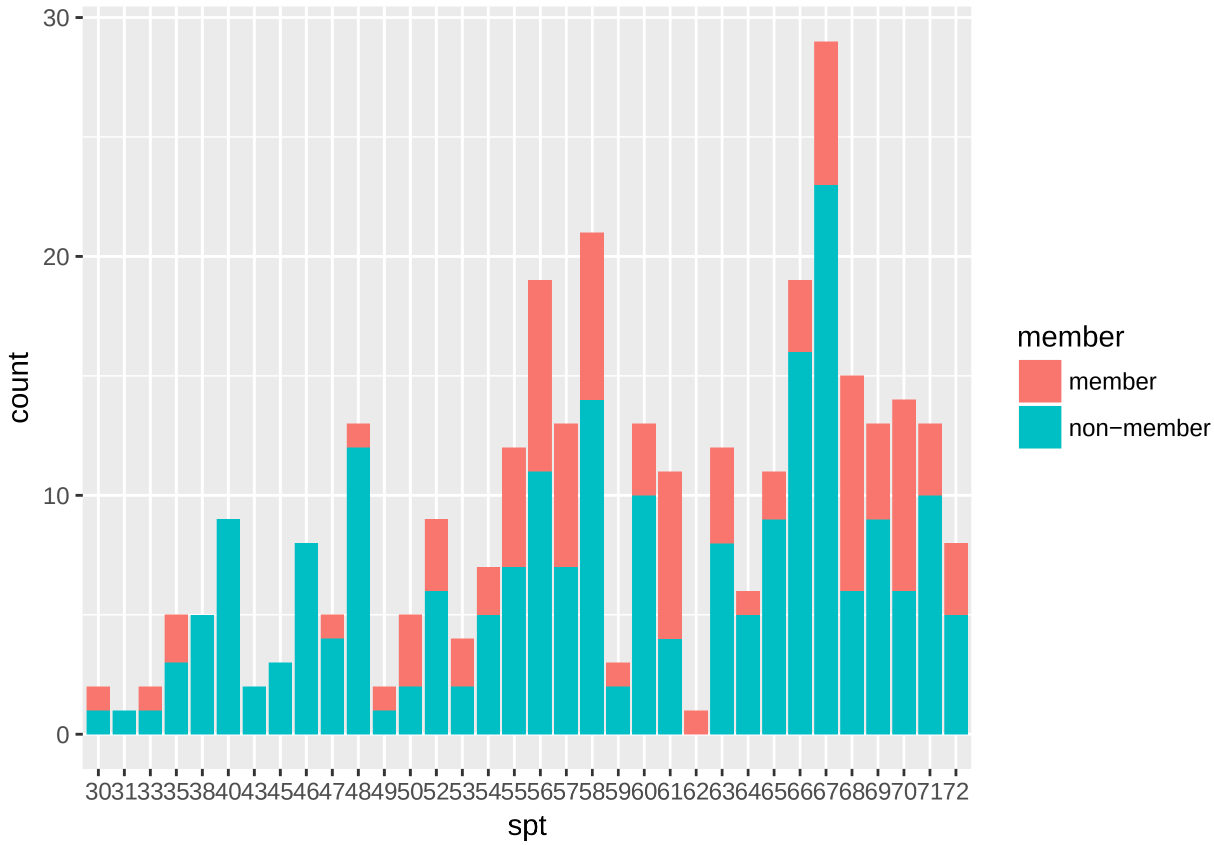
```
## #   medxray.uflux <dbl>, medxray.rchi <dbl>, maxxray.ra <dbl>,
## #   maxxray.dec <dbl>, maxxray.id <chr>, maxxray.rcnts <int>,
## #   maxxray.ncnts <dbl>, maxxray.npflux <dbl>, maxxray.npfluxerr <dbl>,
## #   maxxray.nh <dbl>, maxxray.nherr <dbl>, maxxray.kt1 <dbl>,
## #   maxxray.kt1err <dbl>, maxxray.aflux <dbl>, maxxray.uflux <dbl>,
## #   maxxray.rchi <dbl>, lbol.teff.sa.lbol <chr>, lbol.teff.sa.teff <chr>,
## #   lbol.teff.sa.sa <chr>, member <chr>, gmag <dbl>, gerr <dbl>,
## #   rmag <dbl>, rerr <dbl>, giant <chr>
```

```r
plot1 <- spt.df %>% ggplot(aes(x=spt_old,y=spt,color=giant)) +
    geom_point()


plot1
```



It looks like many of the stars classified as K5/K6 background giants have the wrong spectral classification. Lets look at the distibution of visually determined spectral types of these "background giants".

```r
spt.df %>%
    filter(giant=="giant") %>%
    ggplot(aes(x=spt,fill=member)) + geom_bar()
```



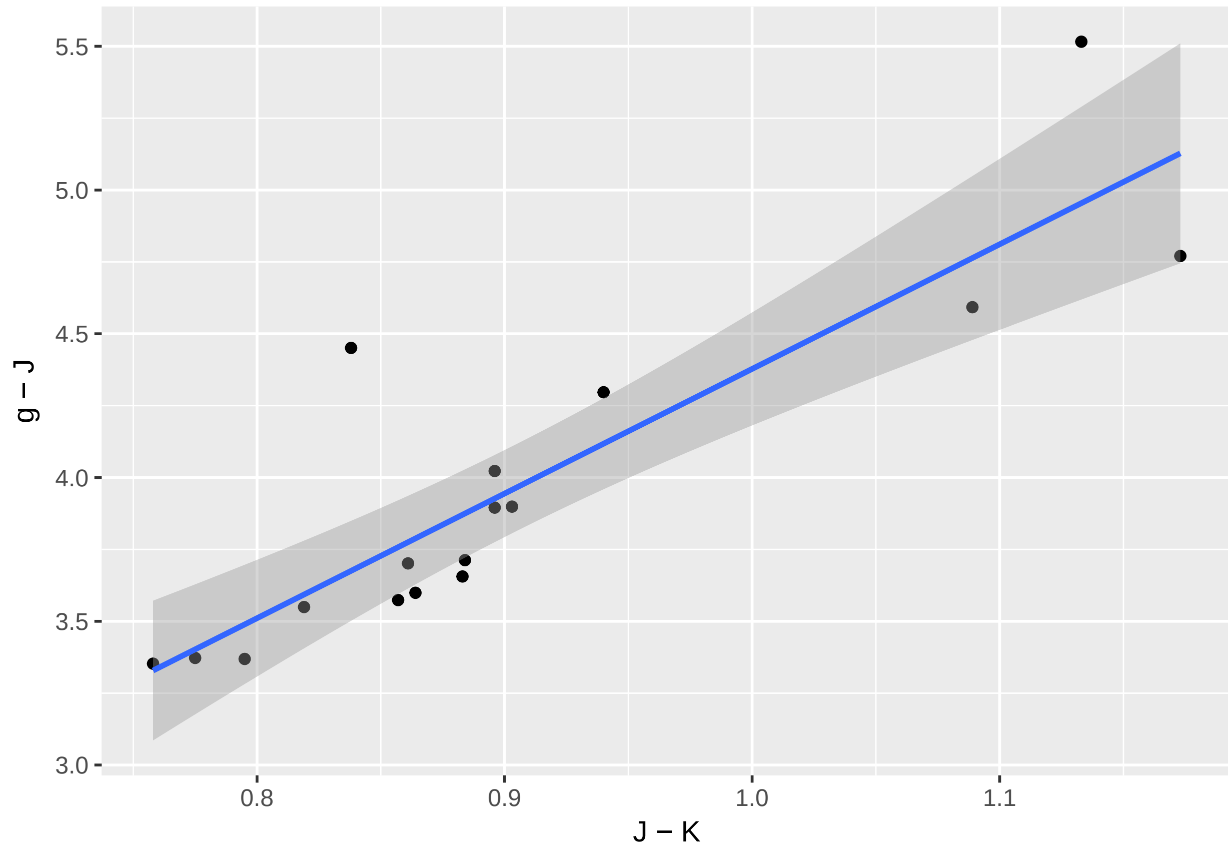
Ok, so after removing potential members, there are about 25 K5/K6 stars that still remain, and over 20 K7s.

```
ext_cc_plot_fit <- function(df,c1=vmag,c2=jmag,c3=kmag,xtitle="J - K",ytitle="V - J")  {

    # Plots X - J vs. J - K and fits a linear model
    # Slope of linear model is used to derive Ax/Aj extinction coefficient

    c1<-enquo(c1)
    c2<-enquo(c2)
    c3<-enquo(c3)

    df.plot <- df %>%
        filter(giant=="giant") %>%
        filter(member=="non-member") %>%
        filter(is.na(!!c2)==FALSE & is.na(!!c3)==FALSE & is.na(!!c1)==FALSE) %>%
        filter(spt==65 | spt==66) %>% # | spt==67)


        #mutate(c1=as.numeric(c1)) %>%
        mutate(x=!!c2 - !!c3,y= !!c1 - !!c2) %>%
        select(x,y)
    #filter(jmk < 1.75)


    plot <- df.plot %>%
        ggplot(aes(x=x,y=y)) +
        geom_point() +
```

```r
        geom_smooth(method='lm') +
        labs(x=xtitle,y=ytitle)

    fit <- lm(y ~ x, data = df.plot)
    print(summary(fit))
    #print(plot)

    return(plot)
  #
}
```

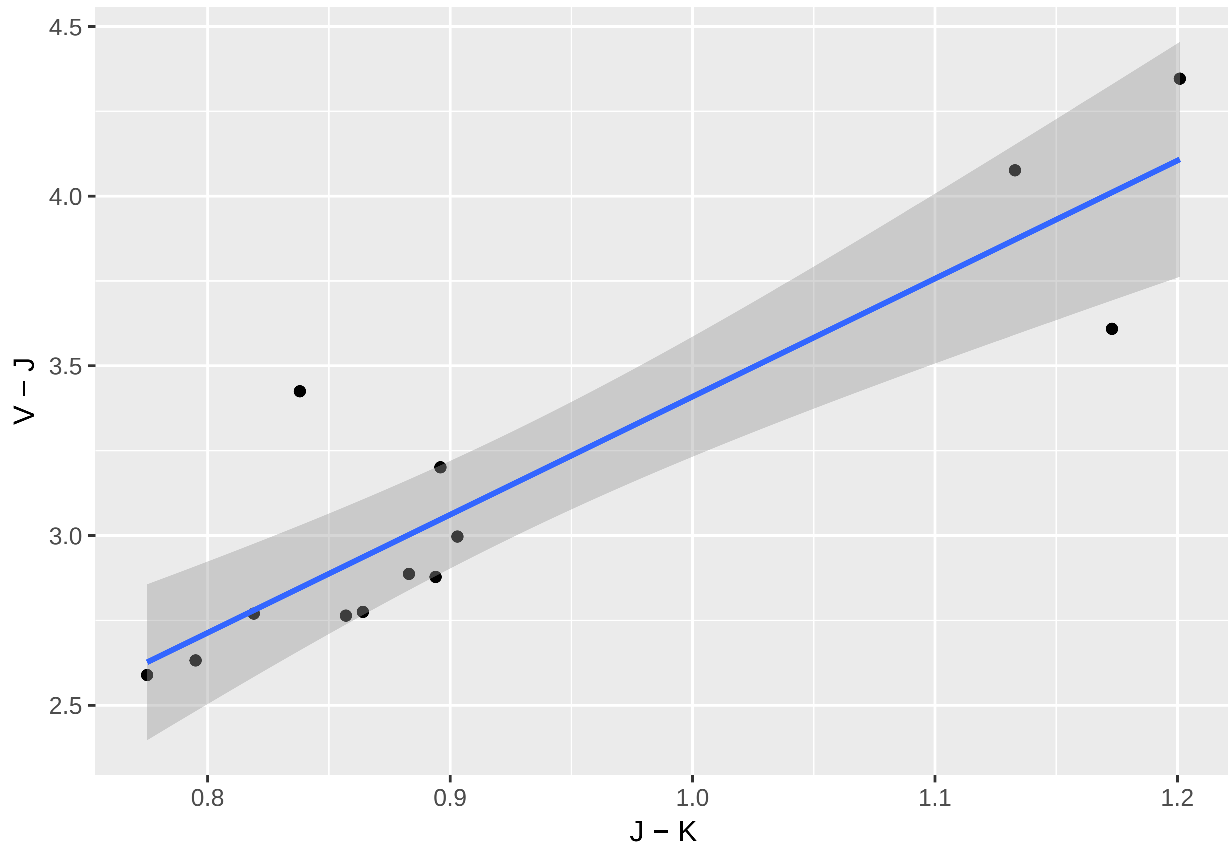
```r
# g - J

spt.df %>% ext_cc_plot_fit(c1=gmag,ytitle="g - J")
```

```
##
## Call:
## lm(formula = y ~ x, data = df.plot)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.35719 -0.17104 -0.05845  0.02387  0.77533
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.04265    0.55792   0.076     0.94
## x            4.33510    0.61231   7.080 3.75e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2926 on 15 degrees of freedom
## Multiple R-squared:  0.7697, Adjusted R-squared:  0.7543
## F-statistic: 50.12 on 1 and 15 DF,  p-value: 3.747e-06
```



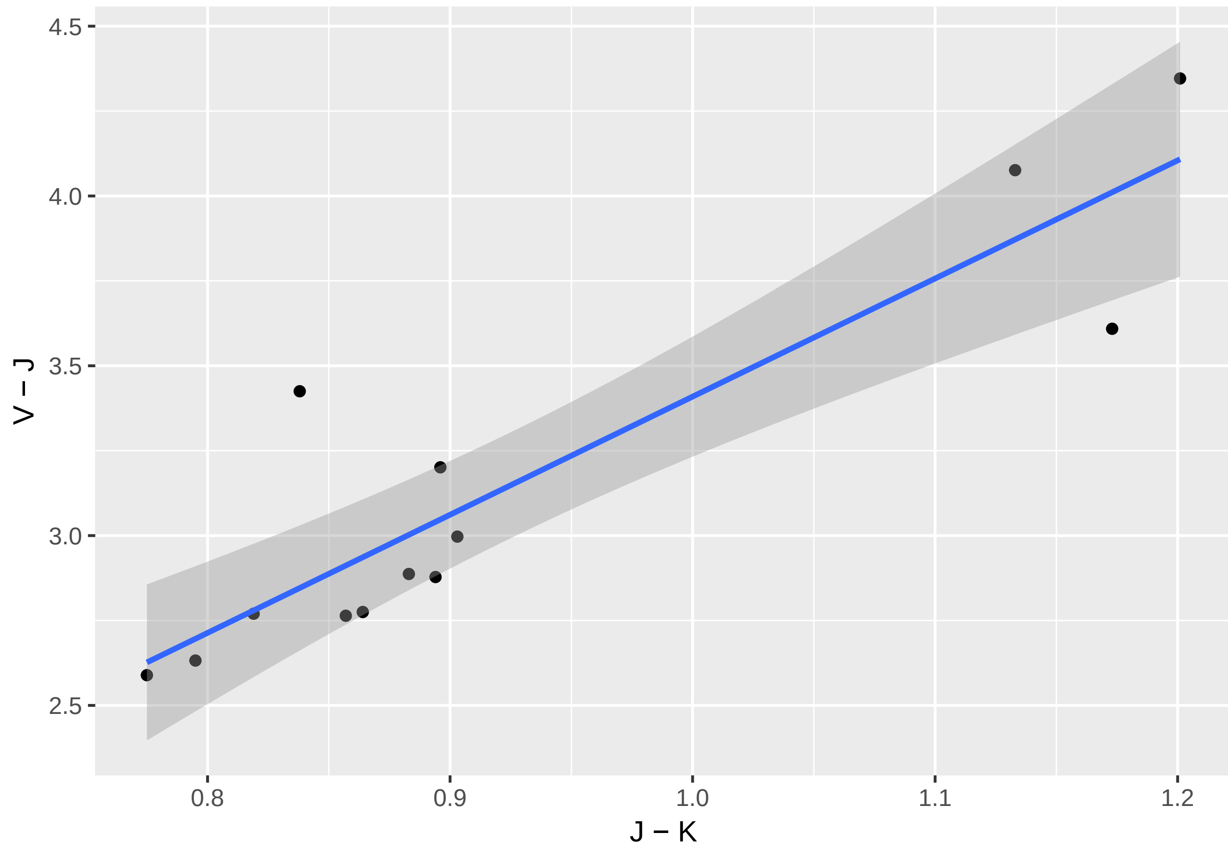

```r
# V - J

spt.df %>% ext_cc_plot_fit(c1=vmag,ytitle="V - J")
```

```
##
## Call:
## lm(formula = y ~ x, data = df.plot)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.40187 -0.14781 -0.06417  0.15355  0.57927
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.06887    0.47660  -0.144    0.888
## x            3.47804    0.50926   6.830 2.84e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2554 on 11 degrees of freedom
## Multiple R-squared:  0.8092, Adjusted R-squared:  0.7918
## F-statistic: 46.64 on 1 and 11 DF,  p-value: 2.84e-05
```



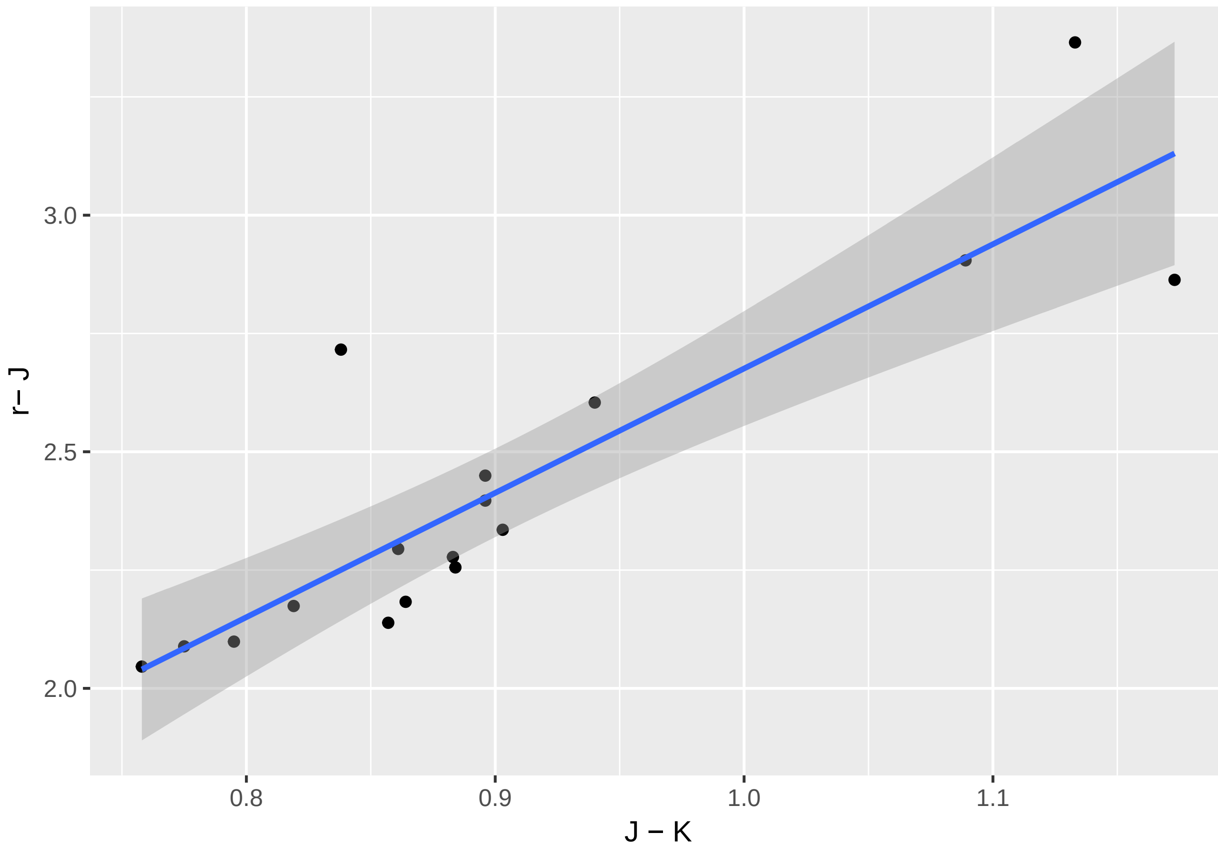

```r
# V - J
# Filter outlier

spt.df %>%
    filter(jmag - kmag < 1.75) %>%
    ext_cc_plot_fit(c1=vmag,ytitle="V - J")
```

```
##
## Call:
## lm(formula = y ~ x, data = df.plot)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.40187 -0.14781 -0.06417  0.15355  0.57927
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) -0.06887    0.47660  -0.144    0.888
## x            3.47804    0.50926   6.830 2.84e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.2554 on 11 degrees of freedom
## Multiple R-squared:  0.8092, Adjusted R-squared:  0.7918
## F-statistic: 46.64 on 1 and 11 DF,  p-value: 2.84e-05
```




```r
# r - J

spt.df %>% ext_cc_plot_fit(c1=rmag,ytitle="r- J")
```

```
##
## Call:
## lm(formula = y ~ x, data = df.plot)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -0.26718 -0.09085 -0.01599  0.00600  0.46569
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)  0.04814    0.34434   0.140    0.891
## x            2.62776    0.37791   6.953 4.63e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.1806 on 15 degrees of freedom
## Multiple R-squared:  0.7632, Adjusted R-squared:  0.7474
## F-statistic: 48.35 on 1 and 15 DF,  p-value: 4.627e-06
```




```r
alam <- function(slope) {

    alam <- slope * (1 - 0.397) + 1

    return(alam)

}

alam(4.3)
```

```
## [1] 3.5929
```

```r
alam(3.5)
```

```
## [1] 3.1105
```

```r
alam(2.6)
```

```
## [1] 2.5678
```