Analysis of Vettius Valens

Definitions

```
library(ggplot2)
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(cowplot)
```

```
##
## ************************************************************
```

```
## Note: As of version 1.0.0, cowplot does not change the
```

```
##   default ggplot2 theme anymore. To recover the previous
```

```
##   behavior, execute:
##   theme_set(theme_cowplot())
```

```
## ************************************************************
```

```
library(tidyr)
library(broman)
```

```
# Order of bodies
ORDER_OF_BODIES = c('Saturn',
                    'Jupiter',
                    'Mars',
                    'Sun',
                    'Venus',
                    'Mercury',
                    'Moon')
names(ORDER_OF_BODIES) <- c("Sa", "J", "Mar", "Su", "V", "Mer", "Moo")
# For plots
theme_basic <- function () {
  theme_bw(base_size=12) %+replace%
    theme(
      axis.text=element_text(colour="black")
    ) %+replace%
    theme(
      panel.grid=element_blank()
```

```
    )
}
```

Singles

We read in the sentiments of the singles.

```
singles.sentiments <- read.csv('../../data/singles-qualities.csv',
                               header=T,
                               stringsAsFactors = F)
# Get in useful format
singles.sentiments.df <- singles.sentiments %>% group_by(PLANET, SENTIMENT) %>%
  summarise(count=n()) %>%
  mutate(total=sum(count),
         prop=count/total)
# remove 'total' variable
singles.sentiments.df$total <- NULL
# Make sure list is complete (some sentiments are missing where none listed in input data)
full_data <- expand.grid(PLANET=singles.sentiments.df$PLANET, SENTIMENT=singles.sentiments.df$SENTIMENT
singles.sentiments.df <- unique(left_join(tbl_df(full_data),singles.sentiments.df))
```

```
## Joining, by = c("PLANET", "SENTIMENT")
```

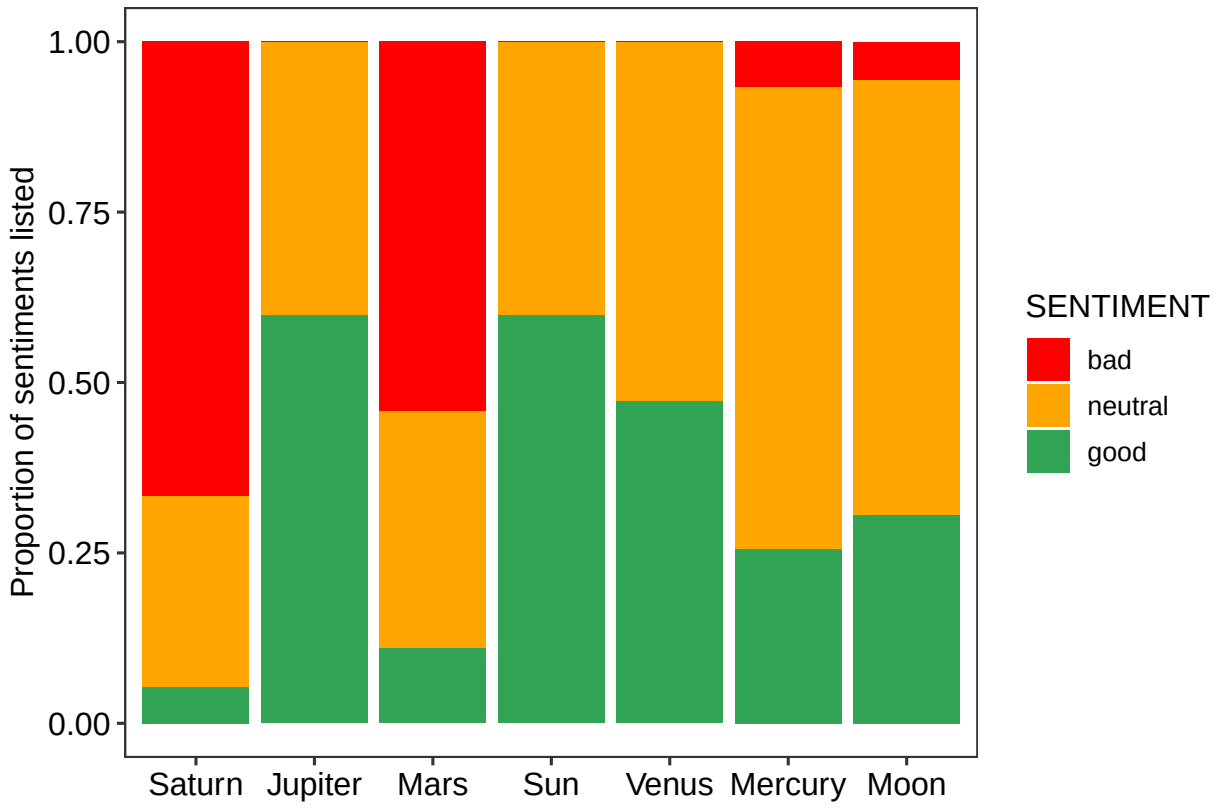
```
## Warning: Column `PLANET` joining factor and character vector, coercing into
## character vector
```

```
## Warning: Column `SENTIMENT` joining factor and character vector, coercing into
## character vector
```

```
singles.sentiments.df$count[is.na(singles.sentiments.df$count)] <- 0
singles.sentiments.df$prop[is.na(singles.sentiments.df$prop)] <- 0
# Order planets and sentiments
singles.sentiments.df$PLANET <- ordered(singles.sentiments.df$PLANET,
                                        levels=ORDER_OF_BODIES)
singles.sentiments.df$SENTIMENT <- ordered(singles.sentiments.df$SENTIMENT,
                                         levels=c("bad", "neutral", "good"))
# Overall sentiment index
singles.overall.sentiments <- singles.sentiments.df %>% group_by(PLANET) %>%
  summarise(sentiment=prop[which(SENTIMENT=="good")]-prop[which(SENTIMENT=="bad")])
```

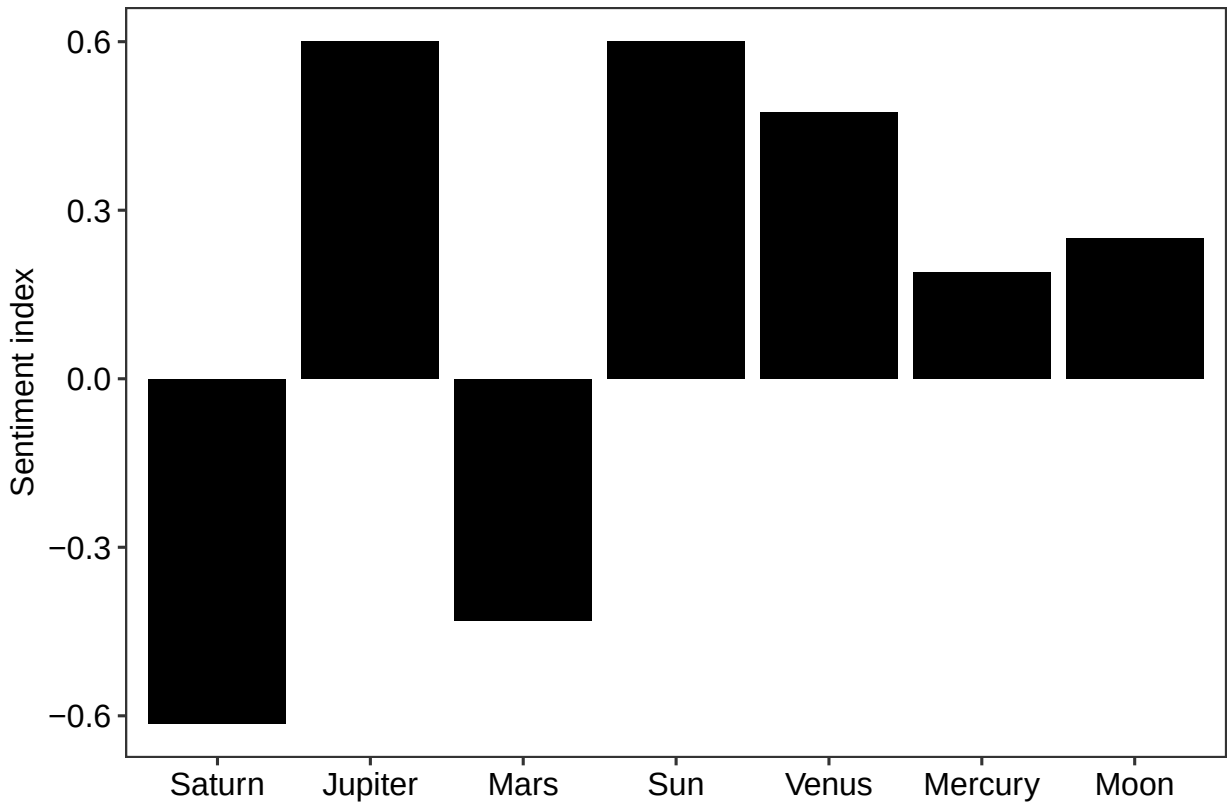
We then plot the sentiments of the singles.

```
# Plot them
ggplot(singles.sentiments.df, aes(PLANET, prop, fill=SENTIMENT))+
  geom_bar(stat="identity")+
  theme_basic()+
  xlab("")+
  scale_fill_manual(values=c("red", "orange", "#31a354"))+
  ylab("Proportion of sentiments listed")
```



Also plot overall sentiment index (good - bad).

```
ggplot(singles.overall.sentiments, aes(PLANET, sentiment))+
  geom_bar(stat="identity", fill="black")+
  theme_basic()+
  xlab("")+
  ylab("Sentiment index")
```



Doubles

We read in the sentiments of the double conjunctions (e.g. Saturn and Jupiter).

```
doubles.sentiments <- read.csv('../../data/doubles-qualities.csv',
                               header=T,
                               stringsAsFactors = F)
# Get in useful format
doubles.sentiments.df <- doubles.sentiments %>% group_by(DOUBLE, SENTIMENT) %>%
  summarise(count=n()) %>%
  mutate(total=sum(count),
         prop=count/total)
# remove 'total' variable
doubles.sentiments.df$total <- NULL
# Make sure list is complete (some sentiments are missing where none listed in input data)
full_data <- expand.grid(DOUBLE=doubles.sentiments.df$DOUBLE, SENTIMENT=doubles.sentiments.df$SENTIMENT
doubles.sentiments.df <- unique(left_join(tbl_df(full_data),doubles.sentiments.df))
```

```
## Joining, by = c("DOUBLE", "SENTIMENT")
```

```
## Warning: Column `DOUBLE` joining factor and character vector, coercing into
## character vector
```

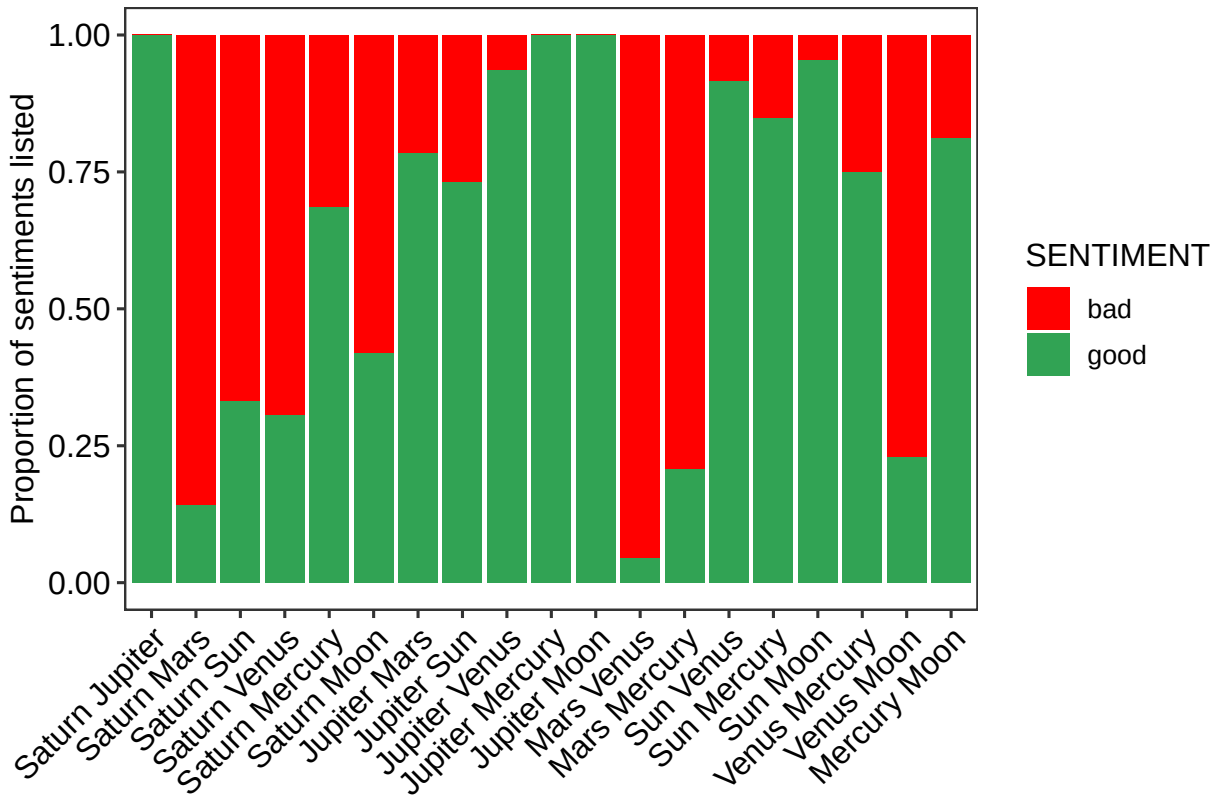
```
## Warning: Column `SENTIMENT` joining factor and character vector, coercing into
## character vector
```

```
doubles.sentiments.df$count[is.na(doubles.sentiments.df$count)] <- 0
doubles.sentiments.df$prop[is.na(doubles.sentiments.df$prop)] <- 0


# Order planets and sentiments
```

```
doubles.sentiments.df$body.1 <- sapply(stringr::str_split(doubles.sentiments.df$DOUBLE, pattern=" "),
                                       function(x) x[1])
doubles.sentiments.df$body.1 <- ordered(ORDER_OF_BODIES[doubles.sentiments.df$body.1],
                                        levels=ORDER_OF_BODIES)
doubles.sentiments.df$body.2 <- sapply(stringr::str_split(doubles.sentiments.df$DOUBLE, pattern=" "),
                                       function(x) x[2])
doubles.sentiments.df$body.2 <- ordered(ORDER_OF_BODIES[doubles.sentiments.df$body.2],
                                        levels=ORDER_OF_BODIES)
doubles.sentiments.df$bodies.sorted <- sapply(1:nrow(doubles.sentiments.df),
                                              function(x)
                                                paste(as.character(sort(unlist(c(doubles.sentiments.df[x,"body.1"
                                                                                 doubles.sentiments.df[x,"body.2"
                                                      collapse=" "))
# Make body 1 and 2 be in order of bodies as expected
doubles.sentiments.df$body.1 <- gsub(" .*", "", doubles.sentiments.df$bodies.sorted)
doubles.sentiments.df$body.2 <- gsub(".* ", "", doubles.sentiments.df$bodies.sorted)
doubles.sentiments.df$body.1 <- ordered(doubles.sentiments.df$body.1,
                                        levels=ORDER_OF_BODIES)
doubles.sentiments.df$body.2 <- ordered(doubles.sentiments.df$body.2,
                                        levels=ORDER_OF_BODIES)
doubles.sentiments.df$order.body.string <- paste0(as.numeric(doubles.sentiments.df$body.1),
                                                  as.numeric(doubles.sentiments.df$body.2))
# Order bodies again (this is hacky but it works)
doubles.sentiments.df$bodies.sorted <- ordered(doubles.sentiments.df$bodies.sorted,
                                               levels=unique(doubles.sentiments.df$bodies.sorted[order(do

doubles.sentiments.df$SENTIMENT <- ordered(doubles.sentiments.df$SENTIMENT,
                                           levels=c("bad", "good"))

# Also make a dataframe with an overall sentiment index
doubles.overall.sentiments <- doubles.sentiments.df %>% group_by(body.1, body.2, bodies.sorted, order.bo
  summarise(sentiment=prop[which(SENTIMENT=="good")]-prop[which(SENTIMENT=="bad")])
```

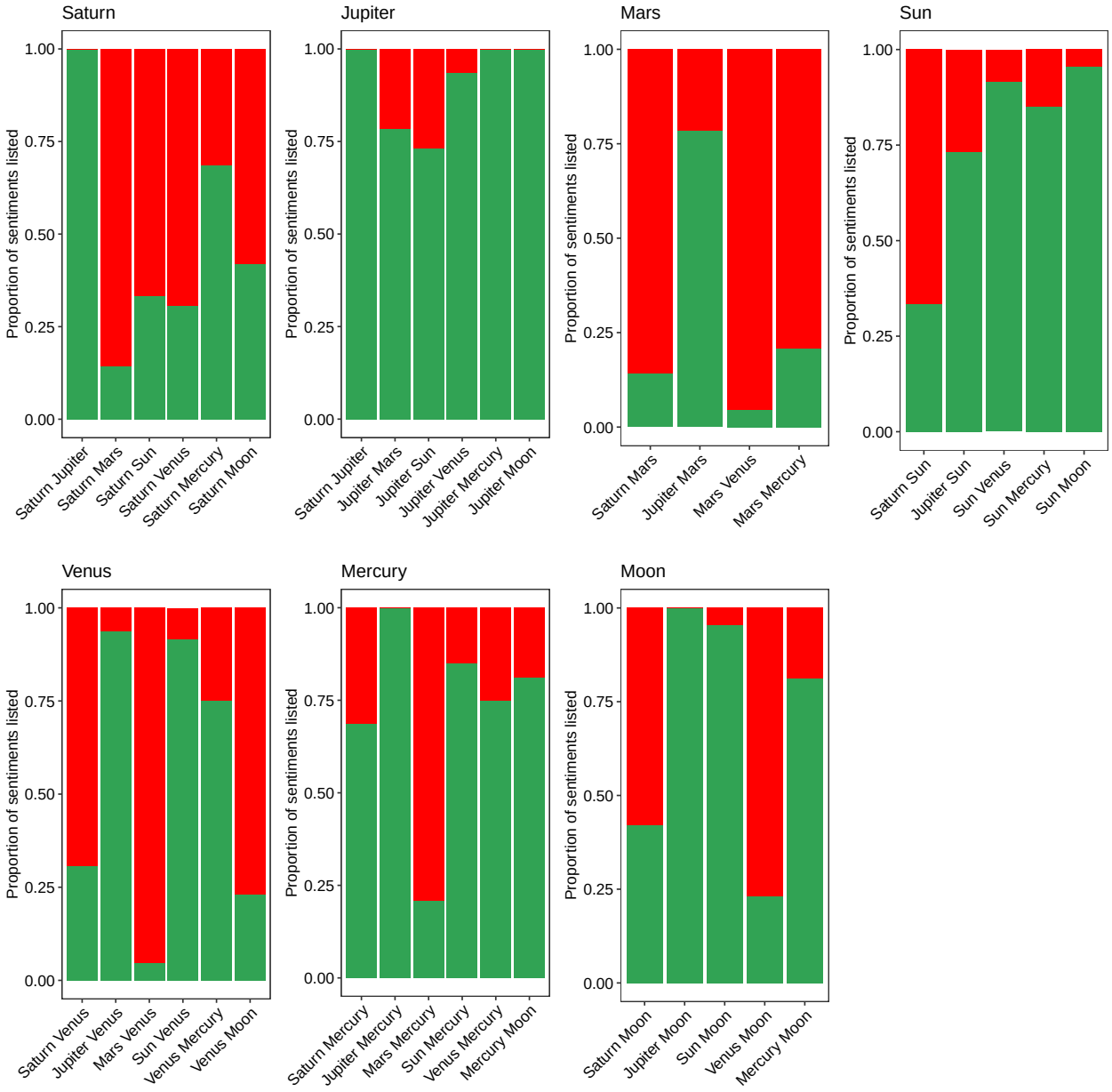
We then plot the sentiments of the doubles.

```
# Plot them
ggplot(doubles.sentiments.df, aes(bodies.sorted, prop, fill=SENTIMENT))+
  geom_bar(stat="identity")+
  theme_basic()+
  xlab("")+
  scale_fill_manual(values=c("red",  "#31a354"))+
  ylab("Proportion of sentiments listed")+
  theme(axis.text.x=element_text(angle=45, hjust=1))
```



A function to plot all the doubles involving a particular planet.

```
plotDoublesWithPlanet <- function(planet){
  # Subset to only doubles involving planet
  local.planet.df <- doubles.sentiments.df[grep(planet, doubles.sentiments.df$bodies.sorted),]
  ggplot(local.planet.df, aes(bodies.sorted, prop, fill=SENTIMENT))+
  geom_bar(stat="identity")+
  theme_basic()+
  xlab("")+
  scale_fill_manual(values=c("red", "#31a354"))+
  ylab("Proportion of sentiments listed")+
  theme(axis.text.x=element_text(angle=45, hjust=1))+
    ggtitle(planet)+
    theme(legend.position = "none")
}
# Make all these plots and combine them
p.doubles.saturn <- plotDoublesWithPlanet("Saturn")
p.doubles.jupiter <- plotDoublesWithPlanet("Jupiter")
p.doubles.mars <- plotDoublesWithPlanet("Mars")
p.doubles.sun <- plotDoublesWithPlanet("Sun")
p.doubles.venus <- plotDoublesWithPlanet("Venus")
p.doubles.mercury <- plotDoublesWithPlanet("Mercury")
p.doubles.moon <- plotDoublesWithPlanet("Moon")
cowplot::plot_grid(p.doubles.saturn, p.doubles.jupiter,
                   p.doubles.mars, p.doubles.sun,
                   p.doubles.venus, p.doubles.mercury,
                   p.doubles.moon, nrow=2)
```



Note that Valens misses out two doubles which involve Mars: Mars + Sun, and Mars + Moon.

Predicting doubles from singles

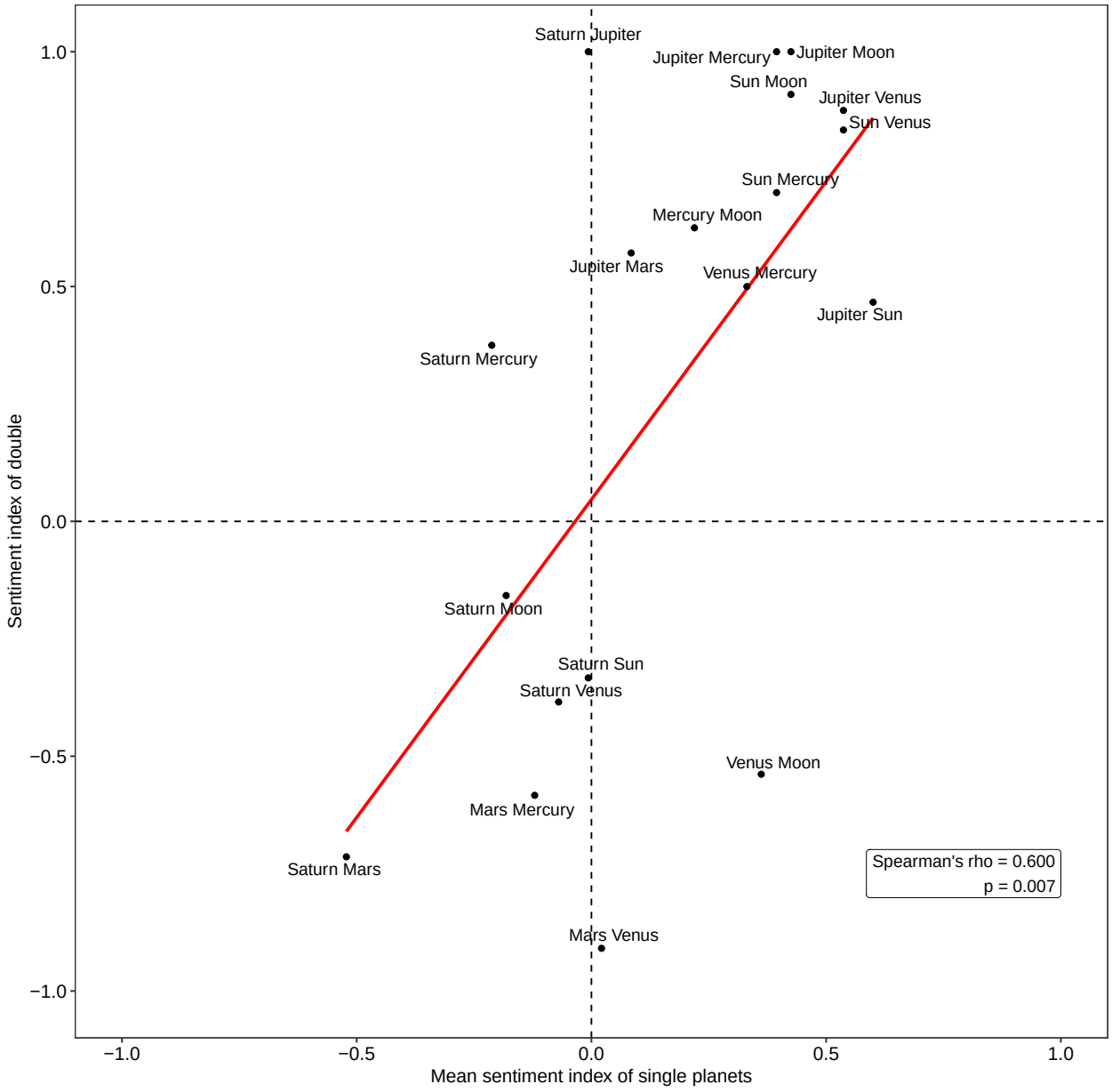
If we know the sentiment proportions associated with single planets, can we predict the sentiment of the doubles?

```
# getSingleScores <- function(double, sentiment="good", mean=TRUE, singles=singles.sentiments.df){
#     double.bodies <- ordered(unlist(stringr::str_split(double, pattern=" ")),
#                              levels=ORDER_OF_BODIES)
#     prop <- 0
#     for (body in double.bodies){
#       new.prop <- as.numeric(singles[which(singles$PLANET==body &
#                                      singles$SENTIMENT==sentiment), "prop"]  )
#       prop <- prop +  new.prop
```

```
#     }
#     if (mean==FALSE){
#       return(prop)
#     }
#     else{
#       return(prop/2)
#     }
# }
getSingleScores <- function(conjunction, mean=TRUE, singles=singles.overall.sentiments){
    conjunction.bodies <- ordered(unlist(stringr::str_split(conjunction, pattern=" ")),
                            levels=ORDER_OF_BODIES)
    prop <- 0
    for (body in conjunction.bodies){
      new.prop <- as.numeric(singles[which(singles$PLANET==body), "sentiment"])
      prop <- prop +  new.prop
    }
    if (mean==FALSE){
      return(prop)
    }
    else{
      return(prop/length(conjunction.bodies))
    }
}

doubles.overall.sentiments$mean.single.sentiments <- sapply(doubles.overall.sentiments$bodies.sorted,
                                                            function(x) getSingleScores(x, mean=TRUE))
# Add correlation score
spearman.cor <- cor.test(doubles.overall.sentiments$mean.single.sentiments, doubles.overall.sentiments$
```

```
## Warning in cor.test.default(doubles.overall.sentiments$mean.single.sentiments, :
## Cannot compute exact p-value with ties
```

```
p.sentiments.doubles.singles <- ggplot(doubles.overall.sentiments, aes(mean.single.sentiments, sentimen
    stat_smooth(method="lm", se=FALSE, colour="red")+
  geom_point(colour="black")+
  theme_basic()+
  ggrepel::geom_text_repel(aes(label=bodies.sorted))+
    coord_fixed()+
  xlim(c(-1, 1))+
  ylim(c(-1,1))+
  geom_hline(yintercept = 0, linetype='dashed')+
    geom_vline(xintercept = 0, linetype='dashed')+
  xlab("Mean sentiment index of single planets")+
  ylab("Sentiment index of double")+
  annotate(geom="label", label=paste0("Spearman's rho = ", myround(spearman.cor$estimate, 3), "\n",
                                      "p = ", myround(spearman.cor$p.value, 3)), x=1, y=-0.75, hjust=1)
p.sentiments.doubles.singles
```



We see that there is a strong correlation between the mean sentiment index for the component singles and the sentiment index of the double conjunction.

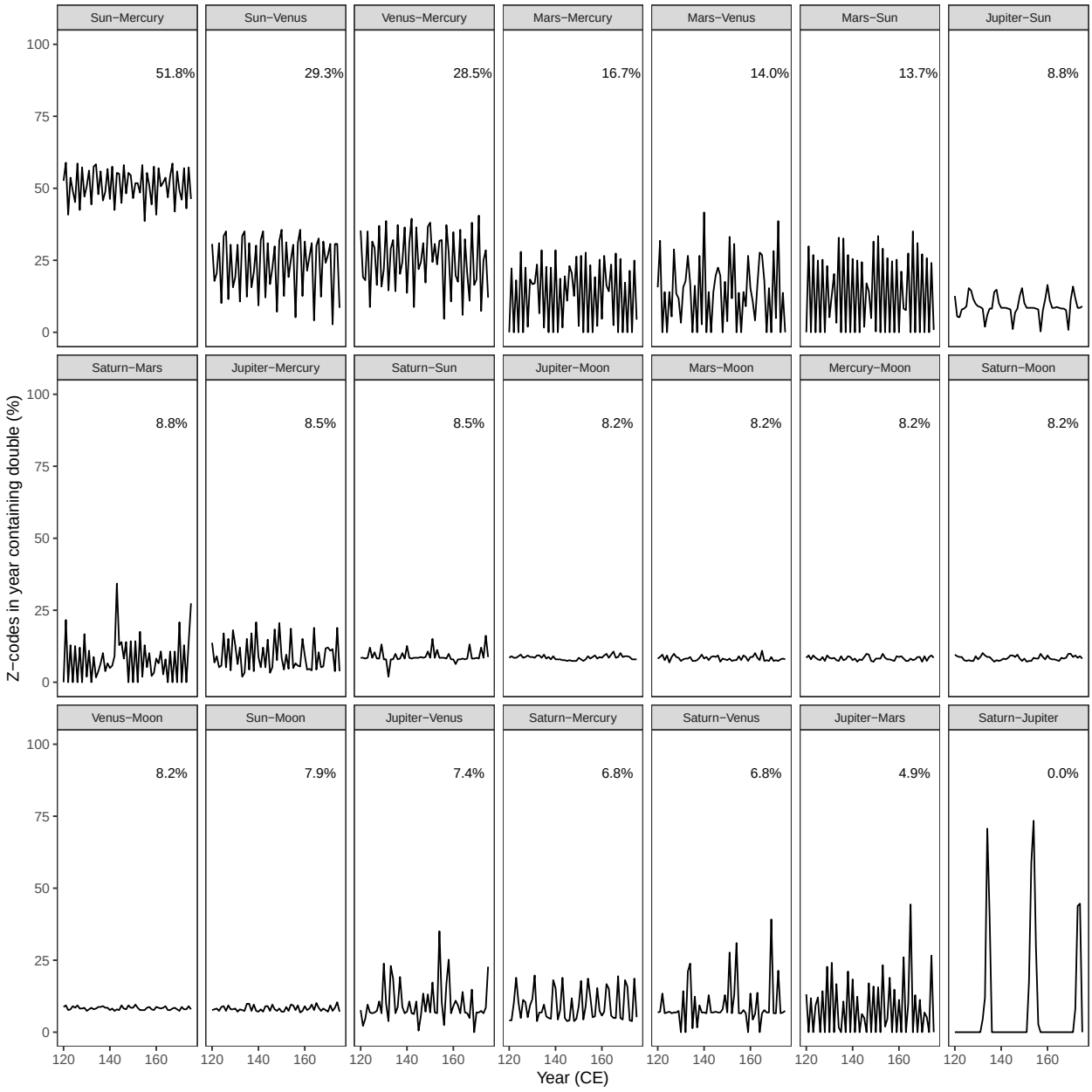
Double conjuction occurrences

Read in the frequencies of the double conjunctions.

```
double.occurrences <- read.csv('../../data/0-CE-200-CE-double-occurrence-per-year.csv', header=F,strings
colnames(double.occurrences) <- c("year", "double", "occurrence")
double.occurrences.median <- double.occurrences %>% group_by(double) %>%
  summarise(median=median(occurrence))
order.of.doubles <- double.occurrences.median$double[order(double.occurrences.median$median, decreasing
double.occurrences.median$year <- 160
double.occurrences.median$y <- 11
double.occurrences.median$double <- ordered(double.occurrences.median$double,
```

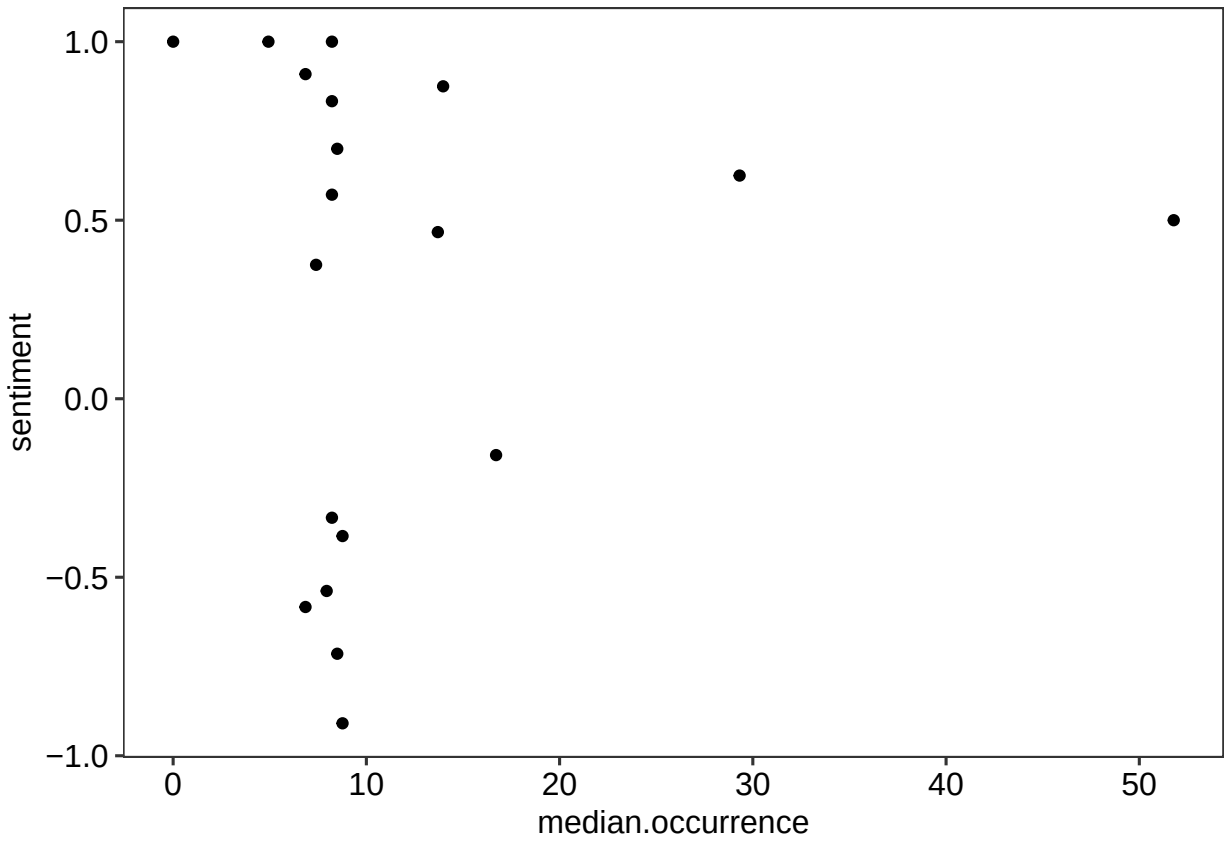
```
                                    levels=order.of.doubles)
double.occurrences.median$median.plot <- myround(double.occurrences.median$median, 1)
double.occurrences$double <- ordered(double.occurrences$double,
                                     levels=order.of.doubles)

# Make plot
occurrences.plot <- ggplot(double.occurrences, aes(year, occurrence, group=double))+
  geom_line()+
  theme_bw()+
  xlab("Year (CE)")+
  ylab("Z-codes in year containing double (%)")+
  facet_wrap(~double, ncol=7)+
  theme(panel.grid = element_blank())+
  ylim(c(0,100))+
  xlim(c(120, 175))+
  theme(strip.text = element_text(size=8))+
  geom_text(data=double.occurrences.median,
            aes(year, 90, label=paste0(median.plot, "%"), group=double),
            hjust=0, size=3)
occurrences.plot
```

```
## Warning: Removed 3003 rows containing missing values (geom_path).
```



Does median occurrence relate to mean sentiment index?

```
double.occurrences.median$bodies.sorted <- ordered(gsub("-", " ",double.occurrences.median$double),
                                                   levels=levels(doubles.overall.sentiments$bodies.sorte
median.occurrences.doubles <- double.occurrences.median$median
names(median.occurrences.doubles) <- double.occurrences.median$bodies.sorted
# Add to sentiment
doubles.overall.sentiments$median.occurrence <- median.occurrences.doubles[doubles.overall.sentiments$bo
ggplot(doubles.overall.sentiments, aes(median.occurrence, sentiment))+
  geom_point()+
  theme_basic()
```



Not obviously. But perhaps there is a linear model term we can use.

```
summary(lm(sentiment ~ mean.single.sentiments + median.occurrence, data=doubles.overall.sentiments))
```

```
##
## Call:
## lm(formula = sentiment ~ mean.single.sentiments + median.occurrence,
##     data = doubles.overall.sentiments)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -1.07939 -0.35603  0.05497  0.33136  0.95689
##
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)
## (Intercept)              0.0565613  0.1916160   0.295  0.77165
## mean.single.sentiments   1.3581772  0.4166253   3.260  0.00492 **
## median.occurrence       -0.0008909  0.0114380  -0.078  0.93888
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.5439 on 16 degrees of freedom
## Multiple R-squared:  0.4017, Adjusted R-squared:  0.327
## F-statistic: 5.372 on 2 and 16 DF,  p-value: 0.01641
```

Again, it appears not.

Triples

```
triples.sentiments <- read.csv('../../data/triples-qualities.csv',
                               header=T,
                               stringsAsFactors = F)
# Get in useful format
triples.sentiments.df <- triples.sentiments %>% group_by(TRIPLE, SENTIMENT) %>%
  summarise(count=n()) %>%
  mutate(total=sum(count),
         prop=count/total)
# remove 'total' variable
triples.sentiments.df$total <- NULL
# Make sure list is complete (some sentiments are missing where none listed in input data)
full_data <- expand.grid(TRIPLE=triples.sentiments.df$TRIPLE, SENTIMENT=triples.sentiments.df$SENTIMENT)
triples.sentiments.df <- unique(left_join(tbl_df(full_data),triples.sentiments.df))
```

```
## Joining, by = c("TRIPLE", "SENTIMENT")
```

```
## Warning: Column `TRIPLE` joining factor and character vector, coercing into
## character vector
```

```
## Warning: Column `SENTIMENT` joining factor and character vector, coercing into
## character vector
```

```
triples.sentiments.df$count[is.na(triples.sentiments.df$count)] <- 0
triples.sentiments.df$prop[is.na(triples.sentiments.df$prop)] <- 0


# Order planets and sentiments
triples.sentiments.df$body.1 <- sapply(stringr::str_split(triples.sentiments.df$TRIPLE, pattern=" "),
                               function(x) x[1])
triples.sentiments.df$body.1 <- ordered(ORDER_OF_BODIES[triples.sentiments.df$body.1],
                                levels=ORDER_OF_BODIES)
triples.sentiments.df$body.2 <- sapply(stringr::str_split(triples.sentiments.df$TRIPLE, pattern=" "),
                               function(x) x[2])
triples.sentiments.df$body.2 <- ordered(ORDER_OF_BODIES[triples.sentiments.df$body.2],
                                levels=ORDER_OF_BODIES)
triples.sentiments.df$body.3 <- sapply(stringr::str_split(triples.sentiments.df$TRIPLE, pattern=" "),
                               function(x) x[3])
triples.sentiments.df$body.3 <- ordered(ORDER_OF_BODIES[triples.sentiments.df$body.3],
                                levels=ORDER_OF_BODIES)
triples.sentiments.df$bodies.sorted <- sapply(1:nrow(triples.sentiments.df),
                                      function(x)
                                        paste(as.character(sort(unlist(c(triples.sentiments.df[x,"body.1
                                                                         triples.sentiments.df[x,"body.2
                                              collapse=" "))
# Make body 1 and 2 be in order of bodies as expected
triples.sentiments.df$body.1 <- sapply(stringr::str_split(triples.sentiments.df$bodies.sorted, pattern=
                               function(x) x[1])
triples.sentiments.df$body.2 <- sapply(stringr::str_split(triples.sentiments.df$bodies.sorted, pattern=
                               function(x) x[2])
triples.sentiments.df$body.3 <- sapply(stringr::str_split(triples.sentiments.df$bodies.sorted, pattern=
                               function(x) x[3])
triples.sentiments.df$body.1 <- ordered(triples.sentiments.df$body.1,
                                      levels=ORDER_OF_BODIES)
```

```
triples.sentiments.df$body.2 <- ordered(triples.sentiments.df$body.2,
                                        levels=ORDER_OF_BODIES)
triples.sentiments.df$body.3 <- ordered(triples.sentiments.df$body.3,
                                        levels=ORDER_OF_BODIES)

triples.sentiments.df$order.body.string <- paste0(as.numeric(triples.sentiments.df$body.1),
                                                  as.numeric(triples.sentiments.df$body.2),
                                                  as.numeric(triples.sentiments.df$body.3))
# Order bodies again (this is hacky but it works)
triples.sentiments.df$bodies.sorted <- ordered(triples.sentiments.df$bodies.sorted,
                                               levels=unique(triples.sentiments.df$bodies.sorted[order(t

triples.sentiments.df$SENTIMENT <- ordered(triples.sentiments.df$SENTIMENT,
                                           levels=c("bad", "neutral", "good"))

# Also make a dataframe with an overall sentiment index
triples.overall.sentiments <- triples.sentiments.df %>% group_by(body.1, body.2,body.3, bodies.sorted, 
  summarise(sentiment=prop[which(SENTIMENT=="good")]-prop[which(SENTIMENT=="bad")])
```

Now we see how this correlates with component singles or doubles.

```
getDoubleScoresForTriple <- function(triple, double.data=doubles.overall.sentiments, mean=TRUE){
  triple.bodies <- ordered(unlist(stringr::str_split(triple, pattern=" ")),
                           levels=ORDER_OF_BODIES)

  # combinations
  doubles <- ordered(combn(triple.bodies, 2), levels=ORDER_OF_BODIES)
  doubles <- sapply(c(1, 3, 5), function(x) paste(c(doubles[x], doubles[x+1]), collapse= ' '))

  doubles.ordered <- sapply( doubles,
                  function(x) paste(as.character(sort(unlist(strsplit(fixed = TRUE, split=" ", x))), c
  doubles.ordered <- as.data.frame(doubles.ordered)
  set.of.doubles <- sapply(c(1,2, 3),
         function(x) paste(ORDER_OF_BODIES[as.numeric(as.character(doubles.ordered[1,x]))],
                           ORDER_OF_BODIES[as.numeric(as.character(doubles.ordered[2,x]))]))

  prop <- 0
  i <- 0
  props <- c()
  for (double in set.of.doubles){
    if (!double  %in% c("Mars Sun", "Mars Moon")){
      new.prop <- double.data[which(double.data$bodies.sorted==double),"sentiment"]
      prop <- prop +  new.prop
      props <- c(props, as.numeric(new.prop))
      i <- i+1
    }

  }
  mean.prop <- prop/i
  if (mean==TRUE){
    return(as.numeric(mean.prop))
  }
  else{
    return(sum(props))
```

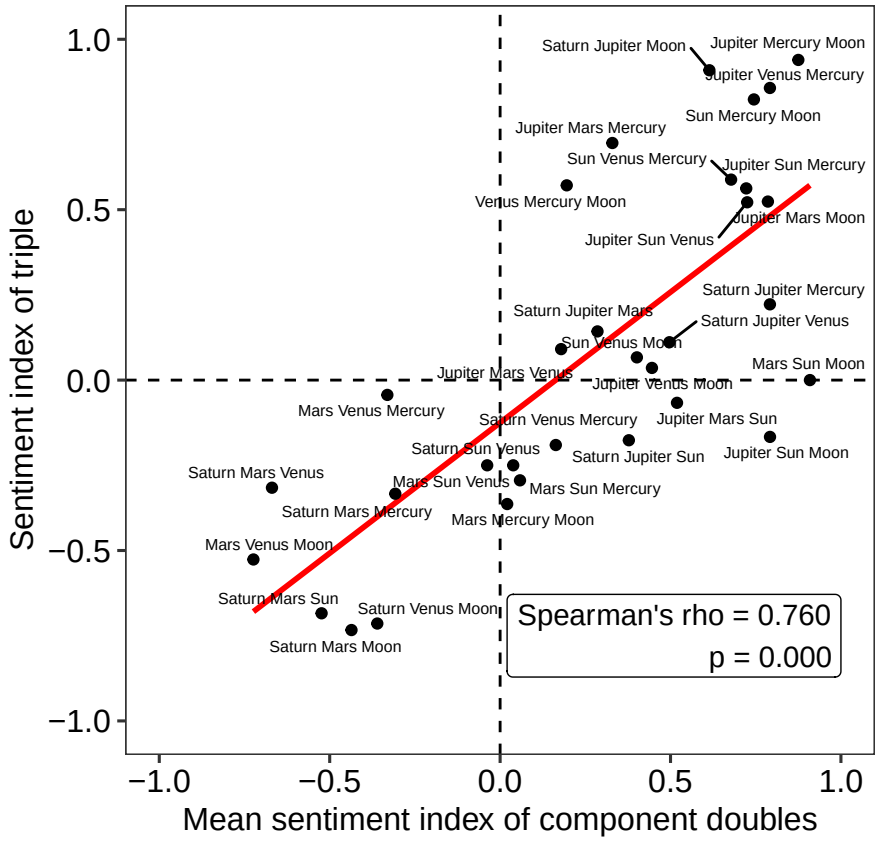
```
  }
}
triples.overall.sentiments$mean.double.sentiment <- sapply(triples.overall.sentiments$bodies.sorted, fu
```

Now we plot this relationship.

```
spearman.cor.triple.double <- cor.test(triples.overall.sentiments$mean.double.sentiment, triples.overall
```

```
## Warning in cor.test.default(triples.overall.sentiments$mean.double.sentiment, :
## Cannot compute exact p-value with ties
```

```
p.sentiments.triples.doubles <- ggplot(triples.overall.sentiments, aes(mean.double.sentiment, sentiment
    stat_smooth(method="lm", se=FALSE, colour="red")+
  geom_point(colour="black")+
  theme_basic()+
  ggrepel::geom_text_repel(aes(label=bodies.sorted), size=2)+
    coord_fixed()+
  xlim(c(-1, 1))+
  ylim(c(-1,1))+
  geom_hline(yintercept = 0, linetype='dashed')+
    geom_vline(xintercept = 0, linetype='dashed')+
  xlab("Mean sentiment index of component doubles")+
  ylab("Sentiment index of triple")+
  annotate(geom="label", label=paste0("Spearman's rho = ", myround(spearman.cor.triple.double$estimate,
                                      "p = ", myround(spearman.cor.triple.double$p.value, 3)), x=1, y=-0
p.sentiments.triples.doubles
```

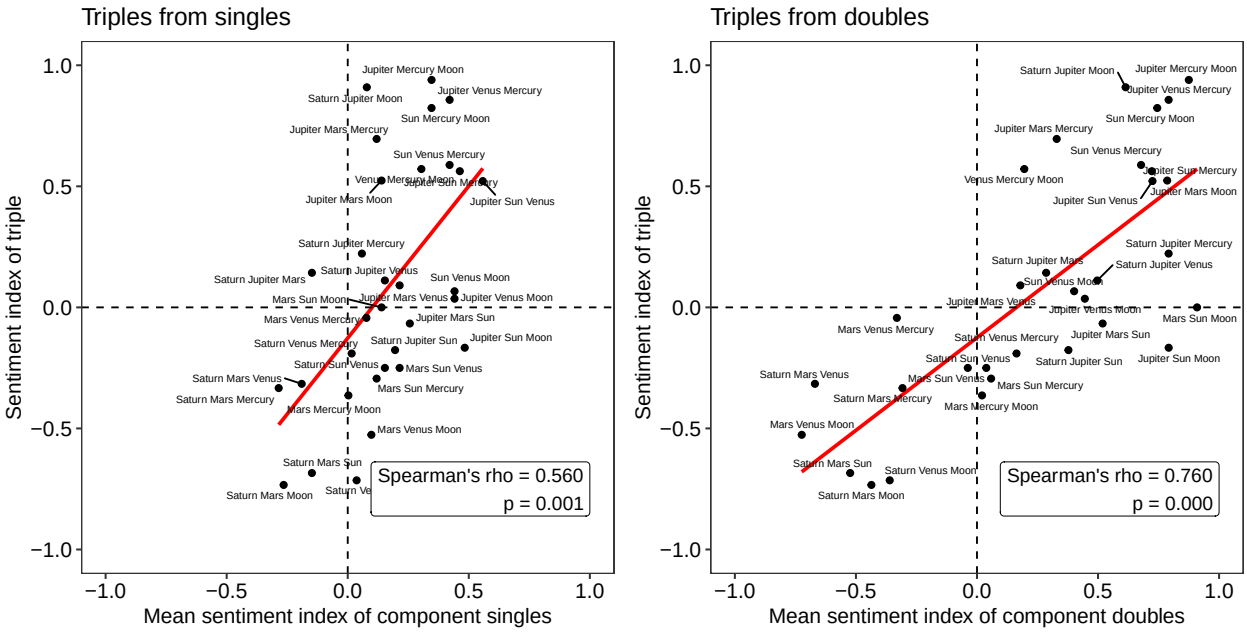


Is this stronger or weaker if we just consider component singles?

```
triples.overall.sentiments$mean.single.sentiment <- sapply(triples.overall.sentiments$bodies.sorted, fu
spearman.cor.triple.single <- cor.test(triples.overall.sentiments$mean.single.sentiment, triples.overall
```

```
## Warning in cor.test.default(triples.overall.sentiments$mean.single.sentiment, :
## Cannot compute exact p-value with ties
```

```
p.sentiments.triples.singles <- ggplot(triples.overall.sentiments, aes(mean.single.sentiment, sentiment
    stat_smooth(method="lm", se=FALSE, colour="red")+
  geom_point(colour="black")+
  theme_basic()+
  ggrepel::geom_text_repel(aes(label=bodies.sorted), size=2)+
    coord_fixed()+
  xlim(c(-1, 1))+
  ylim(c(-1,1))+
  geom_hline(yintercept = 0, linetype='dashed')+
    geom_vline(xintercept = 0, linetype='dashed')+
  xlab("Mean sentiment index of component singles")+
  ylab("Sentiment index of triple")+
  annotate(geom="label", label=paste0("Spearman's rho = ", myround(spearman.cor.triple.single$estimate,
                                      "p = ", myround(spearman.cor.triple.single$p.value, 3)), x=1, y=-0
# Plot both of them
cowplot::plot_grid(p.sentiments.triples.singles+ggtitle("Triples from singles"), p.sentiments.triples.d
```



Could we model the single sentiments by the occurrence of the double conjunctions in some way? Can we use just rank of median occurrence?

```
doubles.overall.sentiments$rank <- rank(doubles.overall.sentiments$median.occurrence)
summary(lm(sentiment ~ mean.single.sentiments + rank, data=doubles.overall.sentiments))
```

```
##
## Call:
## lm(formula = sentiment ~ mean.single.sentiments + rank, data = doubles.overall.sentiments)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
```

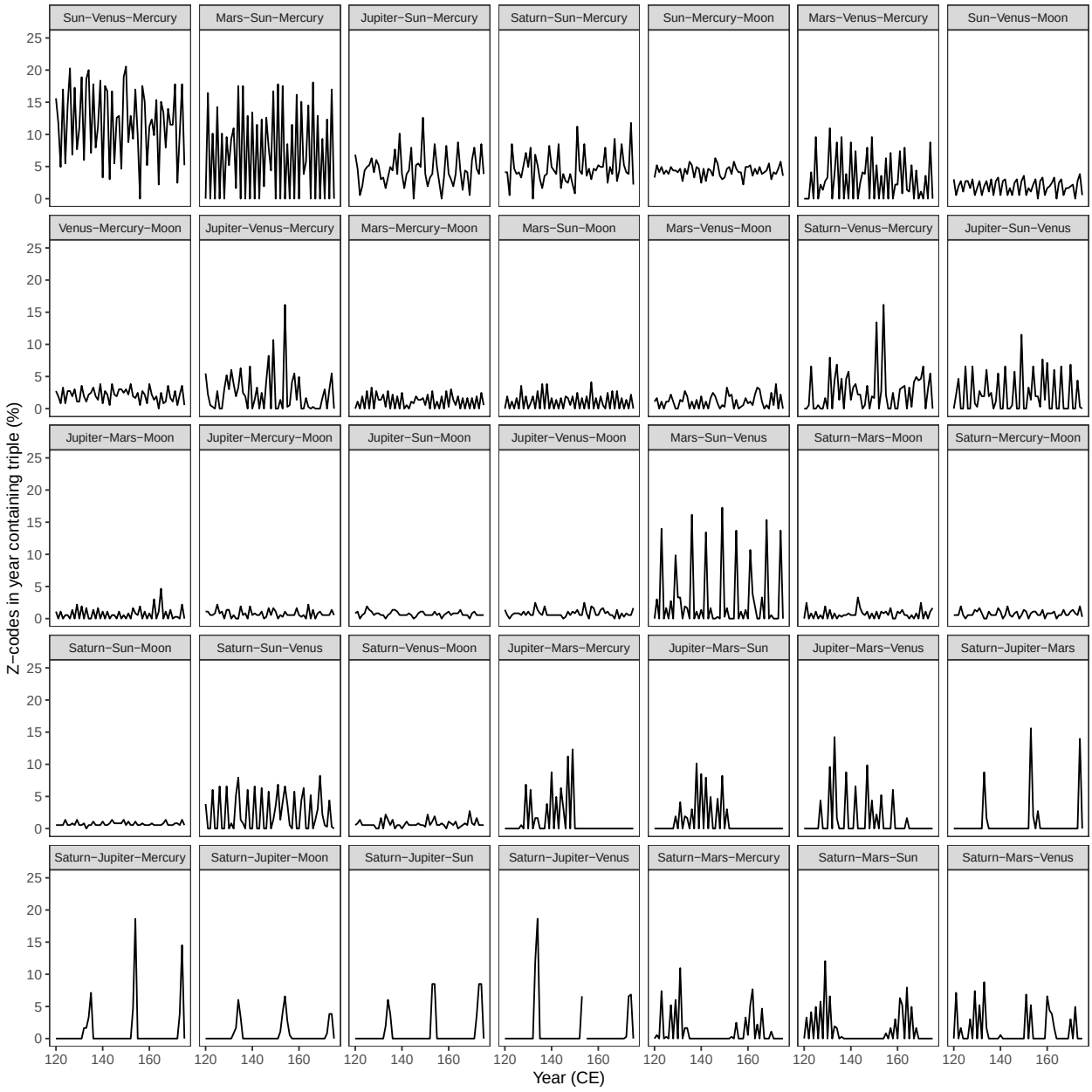
```
## -1.1703 -0.2699  0.1485  0.3039  0.7842
##
## Coefficients:
##                         Estimate Std. Error t value Pr(>|t|)
## (Intercept)              0.27050    0.25888   1.045  0.31161
## mean.single.sentiments   1.37606    0.40095   3.432  0.00342 **
## rank                    -0.02276    0.02223  -1.024  0.32119
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.527 on 16 degrees of freedom
## Multiple R-squared:  0.4383, Adjusted R-squared:  0.3681
## F-statistic: 6.243 on 2 and 16 DF,  p-value: 0.009908
```

Look at triples occurrences.

```
triple.occurrences <- read.csv('../../data/0-CE-200-CE-triple-occurrence-per-year.csv', header=F,strings
colnames(triple.occurrences) <- c("year", "triple", "occurrence")
triple.occurrences.median <- triple.occurrences %>% group_by(triple) %>%
  summarise(median=median(occurrence))
order.of.triples <- triple.occurrences.median$triple[order(triple.occurrences.median$median, decreasing
triple.occurrences.median$year <- 160
triple.occurrences.median$y <- 11
triple.occurrences.median$triple <- ordered(triple.occurrences.median$triple,
                                    levels=order.of.triples)
triple.occurrences.median$median.plot <- myround(triple.occurrences.median$median, 1)
triple.occurrences.median$triple <- ordered(triple.occurrences.median$triple,
                              levels=order.of.triples)
triple.occurrences$triple <- ordered(triple.occurrences$triple,
                                          levels=order.of.triples)
# Make plot
occurrences.plot.triples <- ggplot(triple.occurrences, aes(year, occurrence, group=triple))+
  geom_line()+
  theme_bw()+
  xlab("Year (CE)")+
  ylab("Z-codes in year containing triple (%)")+
  facet_wrap(~triple, ncol=7)+
  theme(panel.grid = element_blank())+
  ylim(c(0,25))+
  xlim(c(120, 175))+
  theme(strip.text = element_text(size=8))+
  geom_text(data=triple.occurrences.median,
            aes(year, 90, label=paste0(median.plot, "%"), group=triple),
            hjust=0, size=3)
occurrences.plot.triples
```

```
## Warning: Removed 5005 rows containing missing values (geom_path).
```

```
## Warning: Removed 35 rows containing missing values (geom_text).
```



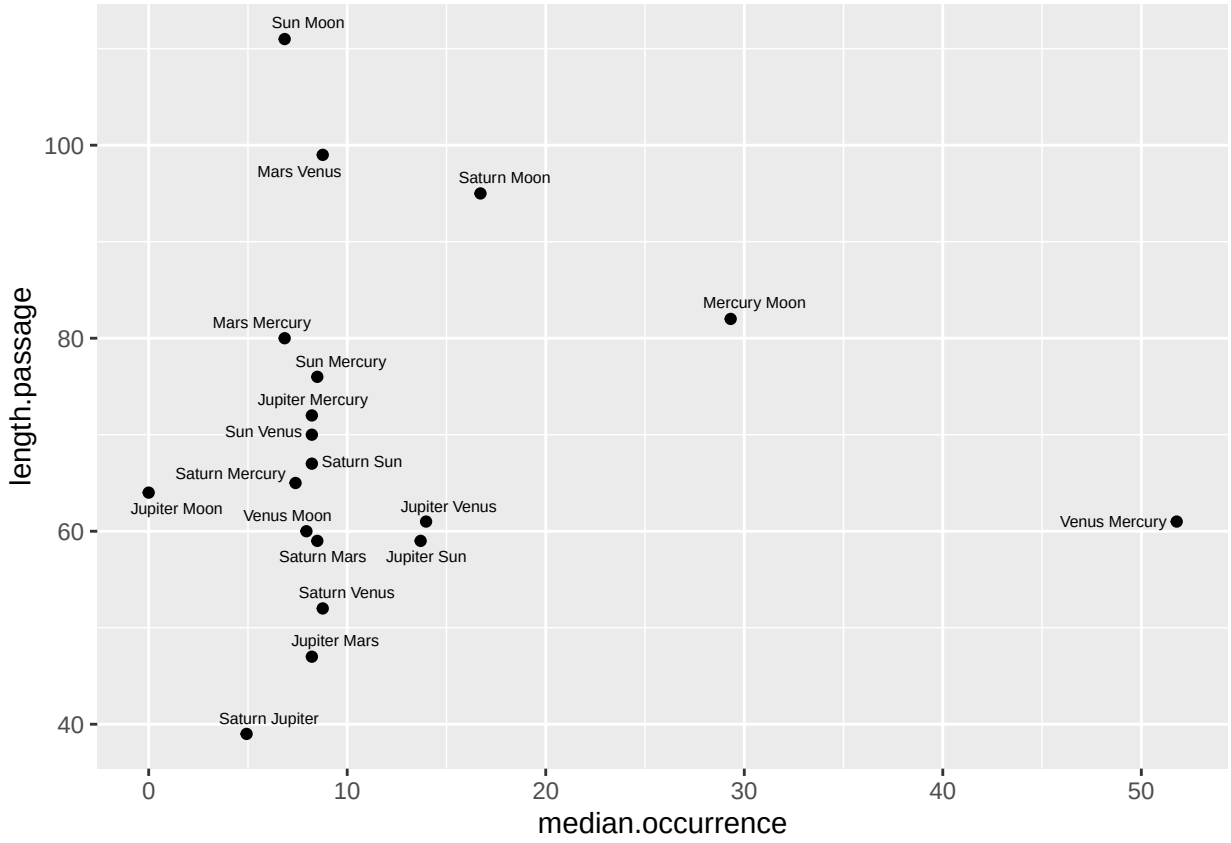
Textual analysis

Using tidytext to look computationally at similarity of descriptions.

First, consider just the length of the descriptions.

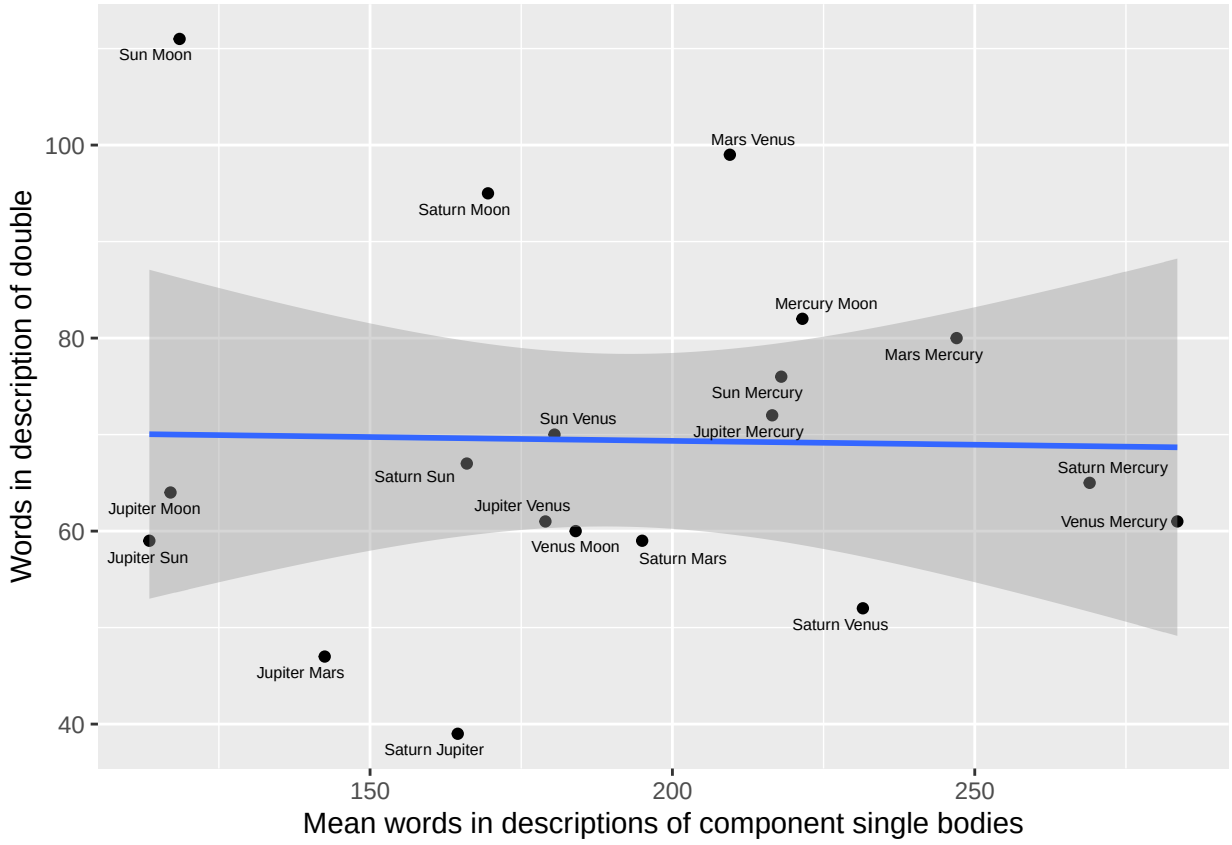
```
# Length of descriptions play a role?
getLengthPassage <- function(conjunction){
  df <- tibble(word=scan(paste0('../../../Texts for analysis/names-removed-Riley English Translation (2
  mutate(line=row_number())
  return(as.numeric(nrow(df)))
}
# Add to doubles
doubles.overall.sentiments$length.passage <- as.numeric(sapply(gsub(" ", "-", doubles.overall.sentiments
```

```
      function(x) getLengthPassage(x)))
# Plot
ggplot(doubles.overall.sentiments, aes(median.occurrence, length.passage)) +
  geom_point()+
  ggrepel::geom_text_repel(aes(label=bodies.sorted), size=2)
```

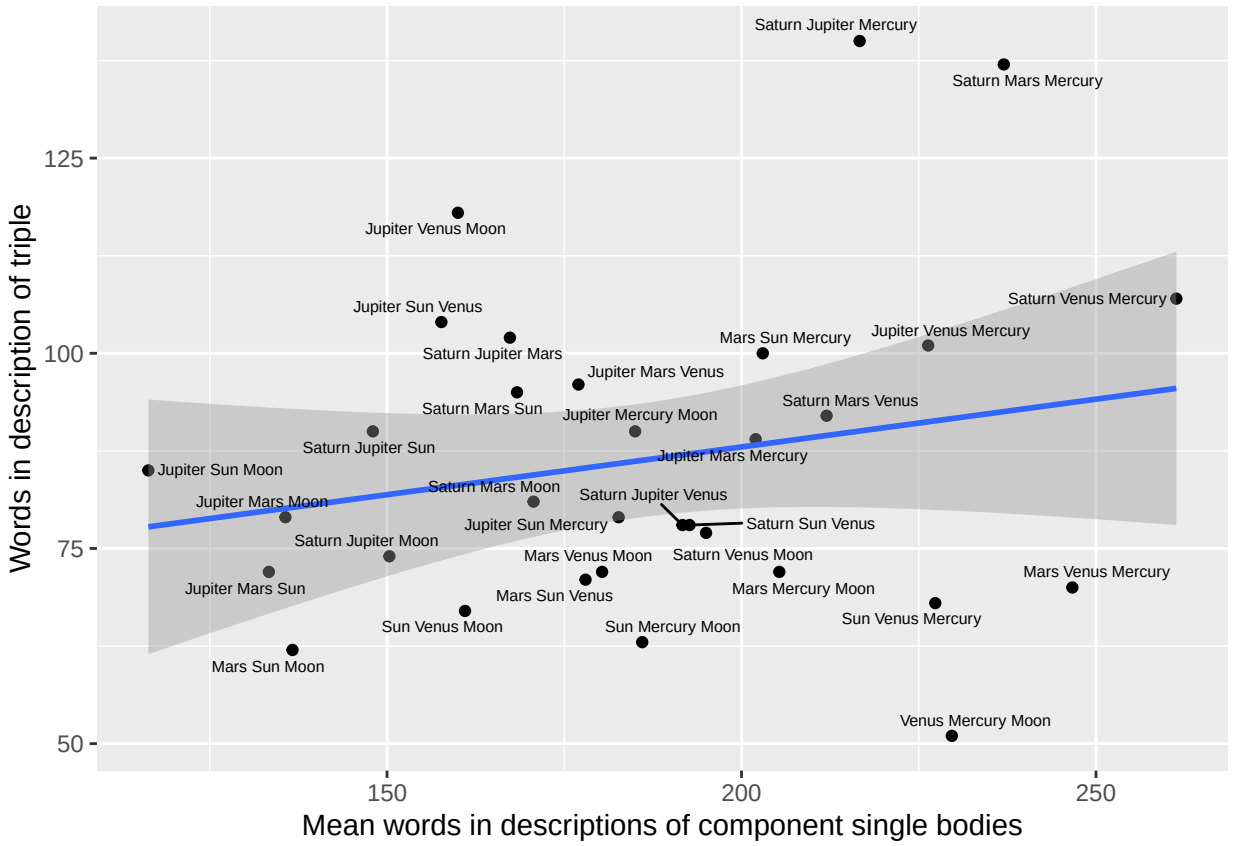



```
# Note that the Sun and the Moon have the longest description

# Are they explained by length of the singles?
singles.overall.sentiments$length.passage <- as.numeric(sapply(gsub(" ", "-", singles.overall.sentiments
       function(x) getLengthPassage(x)))
getSingleLengths <- function(conjunction, mean=TRUE, singles=singles.overall.sentiments){
    conjunction.bodies <- ordered(unlist(stringr::str_split(conjunction, pattern=" ")),
                          levels=ORDER_OF_BODIES)
    prop <- 0
    for (body in conjunction.bodies){
      new.prop <- as.numeric(singles[which(singles$PLANET==body), "length.passage"])
      prop <- prop +  new.prop
    }
    if (mean==FALSE){
      return(prop)
    }
    else{
      return(prop/length(conjunction.bodies))
    }
}
doubles.overall.sentiments$mean.length.single <- sapply(doubles.overall.sentiments$bodies.sorted,
```

```
                                                    function(x) getSingleLengths(x))
ggplot(doubles.overall.sentiments, aes(mean.length.single, length.passage))+
  geom_point()+stat_smooth(method="lm")+
  xlab("Mean words in descriptions of component single bodies")+
  ylab("Words in description of double")+
  ggrepel::geom_text_repel(aes(label=bodies.sorted), size=2)
```




```
# Triples lengths
triples.overall.sentiments$length.passage <- as.numeric(sapply(gsub(" ", "-", triples.overall.sentiments
      function(x) getLengthPassage(x)))
triples.overall.sentiments$mean.length.single <- sapply(triples.overall.sentiments$bodies.sorted,
      function(x) getSingleLengths(x))
# Are these explained by the lengths of the singles?
ggplot(triples.overall.sentiments, aes(mean.length.single, length.passage))+
  geom_point()+stat_smooth(method="lm")+
  xlab("Mean words in descriptions of component single bodies")+
  ylab("Words in description of triple")+
  ggrepel::geom_text_repel(aes(label=bodies.sorted), size=2)
```




```
# Weak positive relationship, heavily driven by the outliers: Saturn Jupiter Mercury and Saturn Mars Me
```

```
library(tidytext)
conjunction <- "Jupiter Mars Mercury"
df1 <- tibble(word=scan(paste0('../../../Texts for analysis/names-removed-Riley English Translation (20
  mutate(line=row_number(), name=conjunction)
conjunction <- "Jupiter Mars Venus"
df2 <- tibble(word=scan(paste0('../../../Texts for analysis/names-removed-Riley English Translation (20
  mutate(line=row_number(), name=conjunction)
for (conjunction in as.character(triples.overall.sentiments$bodies.sorted)){
  df <- tibble(word=scan(paste0('../../../Texts for analysis/names-removed-Riley English Translation (2
  mutate(line=row_number(), conjunction=conjunction)
  if (exists("full.df")){
      full.df <- rbind(full.df, df)
  }
  else{
    full.df <- df
  }
}

# Co-occurring words
library(widyr)
library(stopwords)
full.df.stop <- full.df %>%
    anti_join(get_stopwords())
```

```
## Joining, by = "word"
```

```
full.df.stop <- full.df.stop %>%
  filter(!word %in% c("They", "men", "make", "bring", "cause", "These", "stars", "become", "men,"))
words_by_conjunction <- full.df.stop %>%
  pairwise_count(item=word, feature=conjunction, sort=TRUE)
# Words that appear in the same overall description
full.df.stop.sorted <- full.df.stop %>%
  count(word, sort=TRUE)

# Similarity
for (conjunction in as.character(doubles.overall.sentiments$bodies.sorted)){
  df <- tibble(word=scan(paste0('../../../Texts for analysis/names-removed-Riley English Translation (2
  mutate(line=row_number(), conjunction=conjunction)
  if (exists("doubles.descriptions")){
      doubles.descriptions <- rbind(doubles.descriptions, df)
  }
  else{
    doubles.descriptions <- df
  }
}
for (planet in as.character(ORDER_OF_BODIES)){
  df <- tibble(word=scan(paste0('../../../Texts for analysis/names-removed-Riley English Translation (2
  mutate(line=row_number(), conjunction=planet)
  if (exists("single.descriptions")){
      single.descriptions <- rbind(single.descriptions, df)
  }
  else{
    single.descriptions <- df
  }
}
# Look at Saturn to start with
doubles.descriptions.saturn <- doubles.descriptions %>% mutate(Saturn=grepl("Saturn", conjunction))
# are those with saturn more similar to saturn to those without saturn
saturn.words <- (doubles.descriptions.saturn %>% filter(Saturn==TRUE))$word
nonsaturn.words <- (doubles.descriptions.saturn %>% filter(Saturn==FALSE))$word
table(saturn.words %in% (single.descriptions %>% filter(conjunction=="Saturn"))$word)
```

```
##
## FALSE  TRUE
##   238   139
```

```
table(saturn.words %in% (single.descriptions %>% filter(conjunction!="Saturn"))$word)
```

```
##
## FALSE  TRUE
##   217   160
```

```
table(sample(nonsaturn.words, size=length(saturn.words)) %in% (single.descriptions %>% filter(conjunctio
```

```
##
## FALSE  TRUE
##   232   145
```

```
table(sample(nonsaturn.words, size=length(saturn.words)) %in% (single.descriptions %>% filter(conjunctio
```

```
##
## FALSE  TRUE
```

```
##   192   185
```

```
table(sample(saturn.words, size=100) %in% sample((single.descriptions %>% filter(conjunction=="Mercury"]
```

```
##
## FALSE  TRUE
##    76    24
```

```
# Get positive sentiments from Bing 2004 corpus
positive <- get_sentiments("bing") %>% filter(sentiment == "positive")
# Look at positive words
df %>%
semi_join(positive) %>%
count(word, sort = TRUE)
```

```
## Joining, by = "word"
```

```
## # A tibble: 0 x 2
## # ... with 2 variables: word <chr>, n <int>
```