R Notebook

TODO:

a) split series into shorter bits and see if the spectrum changes

```
rm(list=ls())
setwd("~/WORKSHOP/QAANAAQ/")
library(sp)
library(nleqslv)
library(lubridate)
```

```
##
## Attaching package: 'lubridate'
```

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

```
library(oce)
```

```
## Loading required package: gsw
```

```
library(nloptr)
library(maps)
library(ggplot2)
library(ggmap)
```

```
## i Google's Terms of Service: <https://mapsplatform.google.com>
##   Stadia Maps' Terms of Service: <https://stadiamaps.com/terms-of-service/>
##   OpenStreetMap's Tile Usage Policy: <https://operations.osmfoundation.org/policies/tiles/>
## i Please cite ggmap if you use it! Use `citation("ggmap")` for details.
```

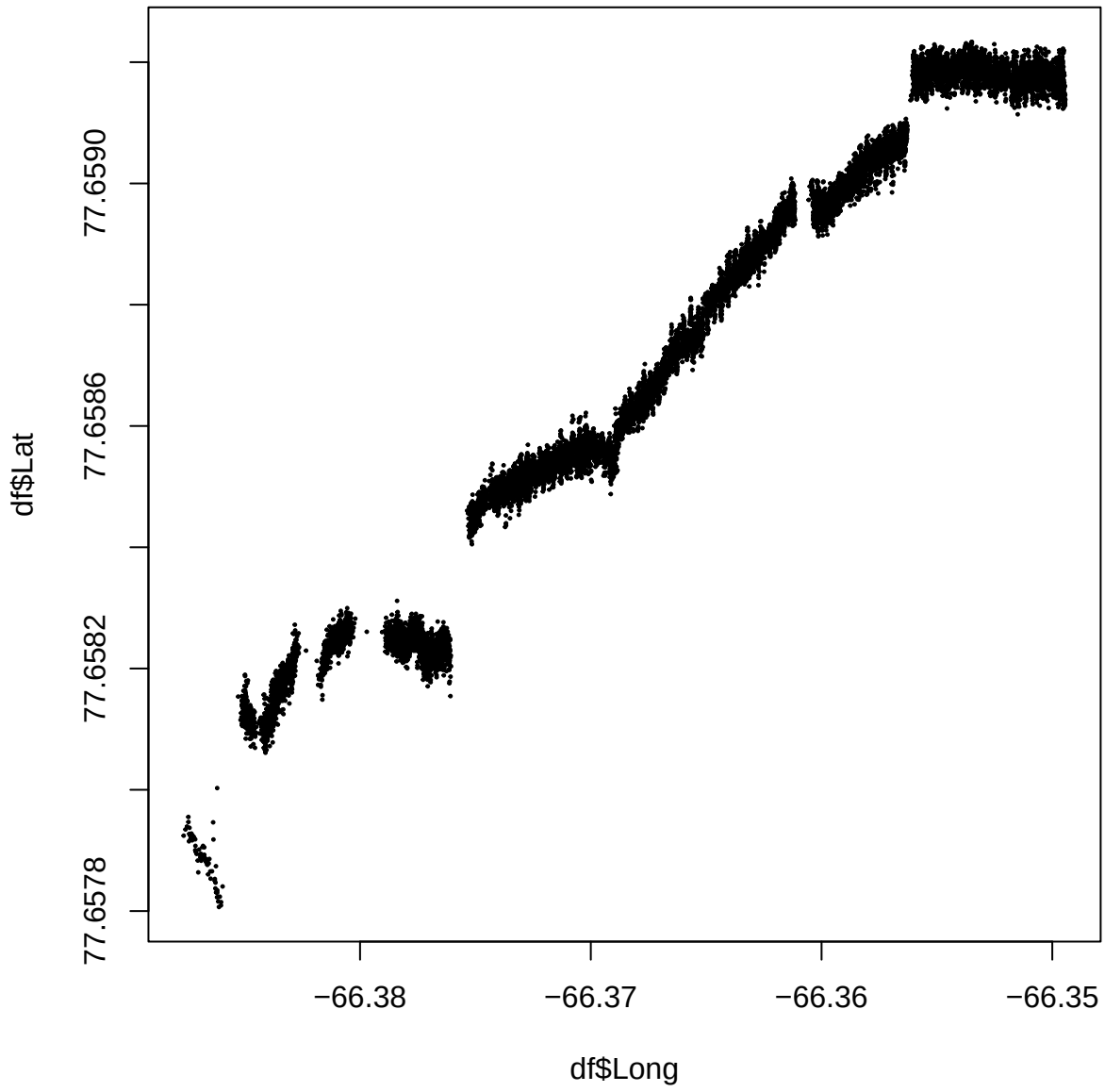
```
library(parallel)
library(sf)
```

```
## Linking to GEOS 3.8.0, GDAL 3.0.4, PROJ 6.3.1; sf_use_s2() is TRUE
```

```
library(e1071)
if (!requireNamespace("astrochron", quietly = TRUE)) {
  install.packages("astrochron")
}
library(astrochron)
```

```
## Welcome to astrochron v1.2 (2023-08-25)

##
## Attaching package: 'astrochron'

## The following object is masked from 'package:e1071':
##
##     tune

## The following objects are masked from 'package:oce':
##
##     detrend, lowpass
```

```
#
df <- read.csv("DATA/EXB_csv.csv",sep=",",header=T)
parsed_date <- strptime(df$DateTime.UTC..YYMMDDHHmmss., format="%Y-%m-%dT%H:%M:%S")
# Convert to POSIXct
df$POSIX <- as.POSIXct(parsed_date) #,tz="UTC")
df <- df[,-3]
#
plot(df$Long,df$Lat,pch=19,cex=0.2)
```

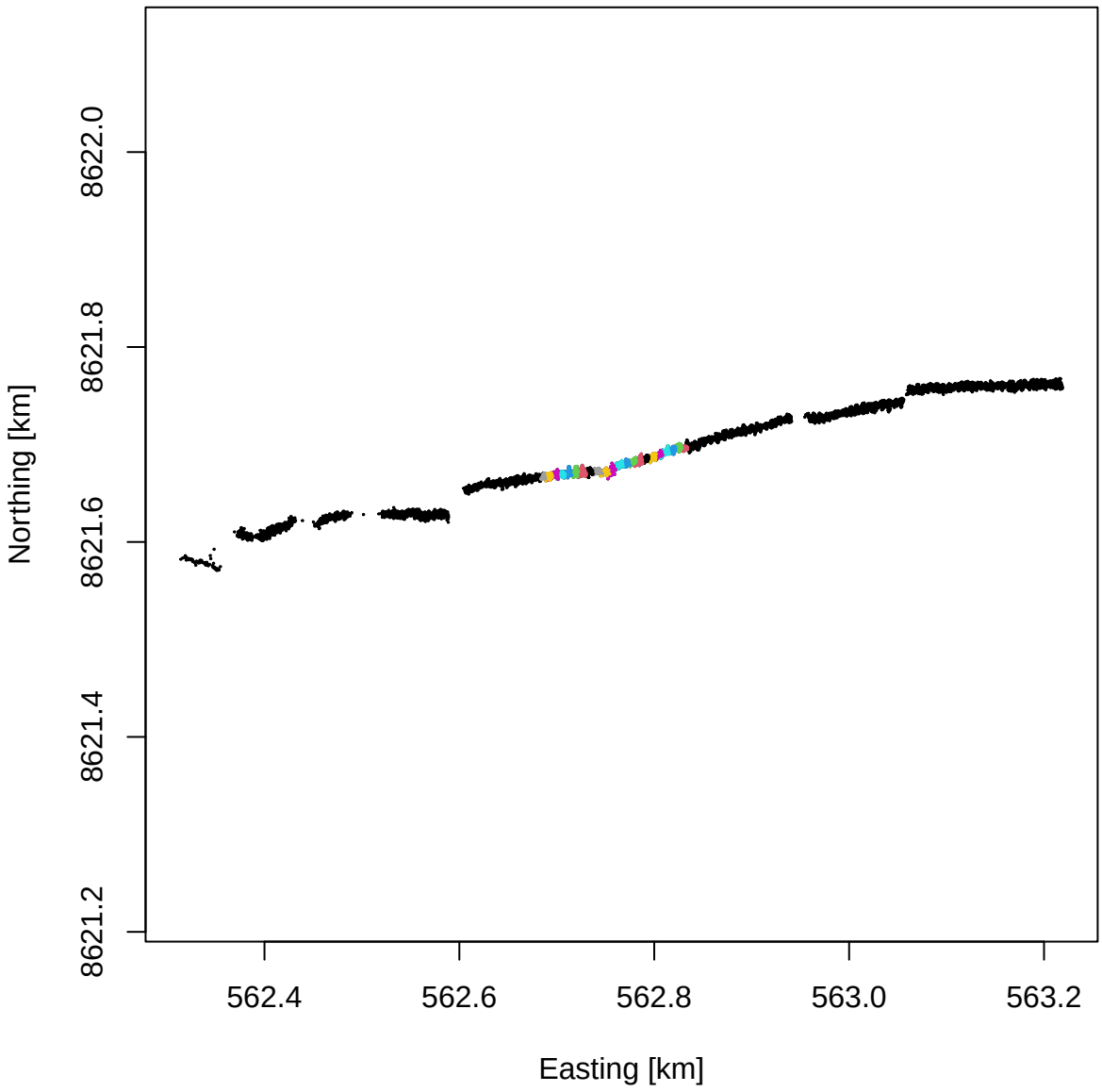



```
# length of series in hours
len_h <- difftime(max(df$POSIX),min(df$POSIX),units = "hour")
# expected resolution
HWFM <- (1/as.numeric(len_h)) # in freq units
# width
half_width_24 <- (1/(1/24+HWFM) - 24)/2 # in period units (hours, here)
half_width_5p6 <- (1/(1/5.63+HWFM) - 5.63)/2 # in period units (hours, here)
```

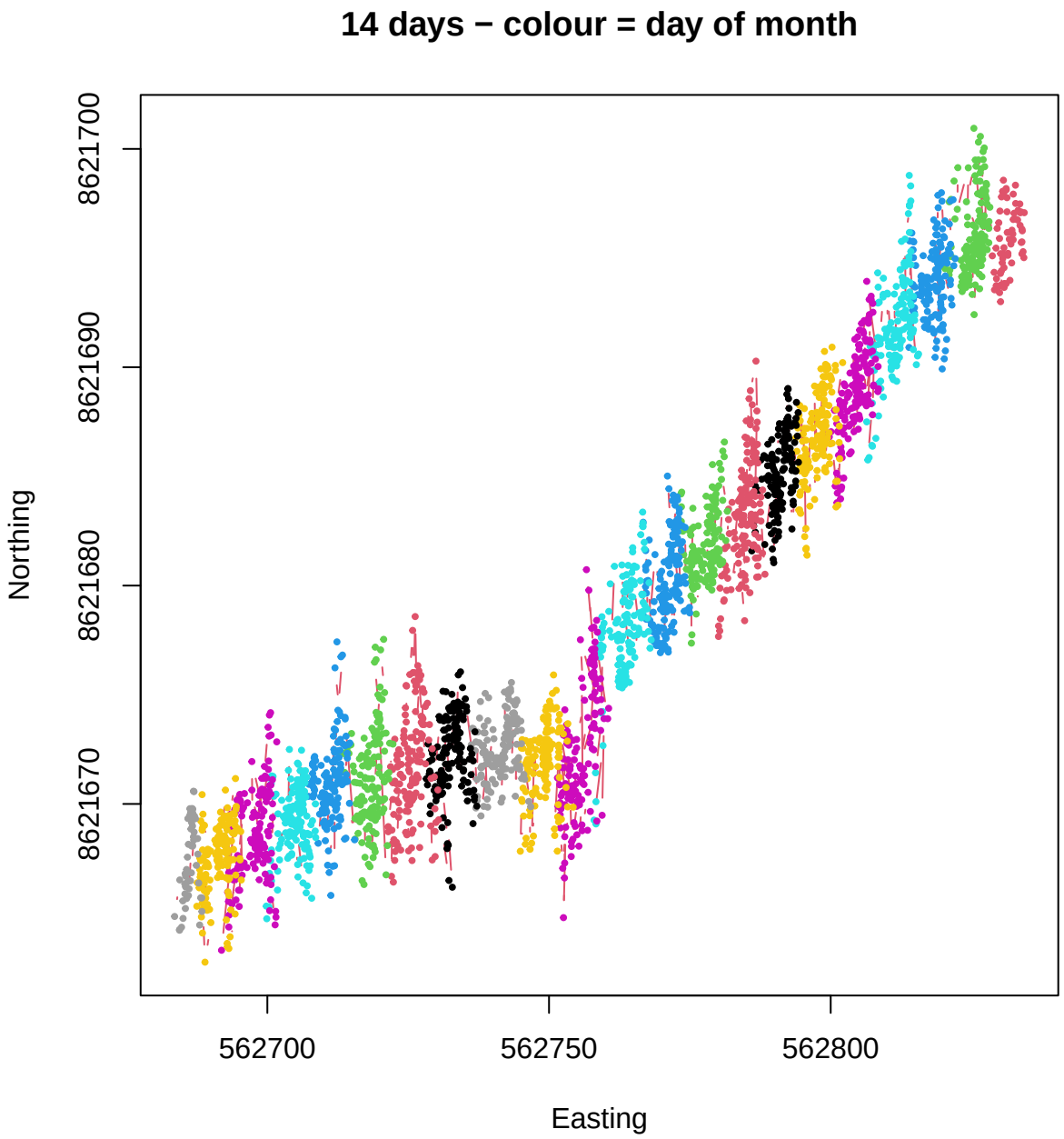
lat/lon to northings/eastings

```
# Create a SpatialPoints object
points <- SpatialPoints(cbind(df$Long, df$Lat), proj4string = CRS("+proj=longlat +ellps=WGS84"))

# Define the target projection
```

```r
#target_projection <- "+proj=tmerc +lat_0=49 +lon_0=-2 +k=0.9996012717 +x_0=400000 +y_0=-100000 +ellps=
#target_projection <- "+proj=utm +zone=19X +ellps=WGS84 +datum=WGS84 +units=m +no_defs"
target_projection <- "+proj=utm +zone=19 +ellps=WGS84 +datum=WGS84 +units=m +no_defs"

# Transform the coordinates to the target projection
transformed_points <- spTransform(points, CRS(target_projection))

# Extract the eastings and northings
eastings <- transformed_points@coords[,1]
northings <- transformed_points@coords[,2]



# Create a data frame with the eastings and northings
df$easting <- eastings
df$northings <- northings
plot(df$easting/1000,df$northings/1000,asp=1,xlab="Easting [km]",ylab="Northing [km]",pch=19,cex=0.1)
idx <- 8000:11000
points(df$easting[idx]/1000,df$northings[idx]/1000,pch=19,cex=0.1,col=day(df$POSIX))
```




```
plot(df$easting[idx],df$northings[idx],type="b",col=day(df$POSIX),pch=19,main="14 days - colour = day o
```



##

Why the positive Easting?? Because UTM zone 19X has 'its meridian' at 108 degrees west ....

Note: There is a tendency for the points each day to start in the Northa nd then as time passes (right to left) the points drift South.

calculate speeds between points observed

```
speed <- NULL
u <- NULL
v <- NULL
for (i in 1:(nrow(df)-1))
{
  d_easting <- df$easting[i+1]-df$easting[i]
```

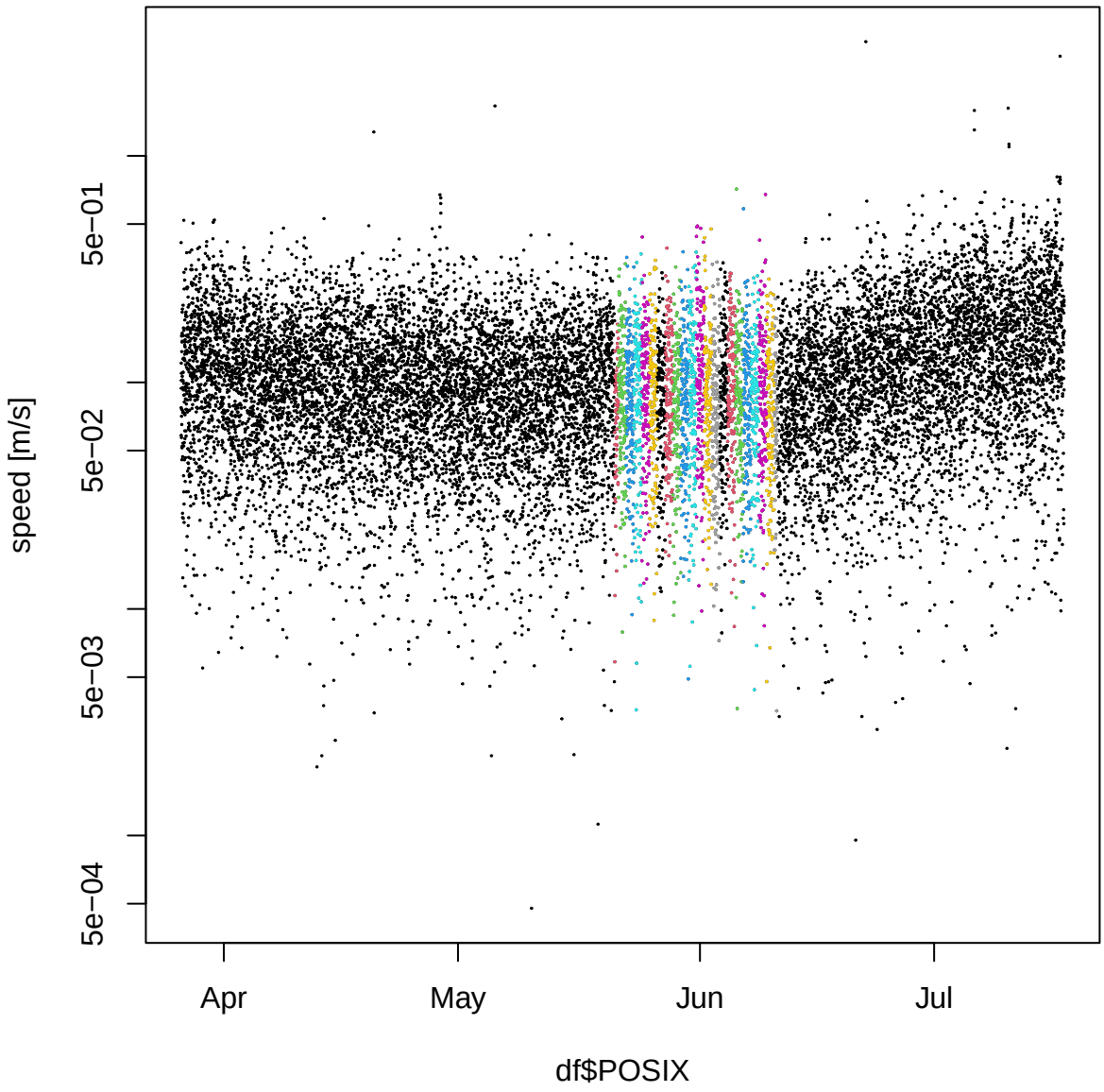
```
  d_northing <- df$northings[i+1]-df$northings[i]
  d_easting <- (d_easting)
  d_northing <- (d_northing)
  dr <- sqrt((d_easting)^2+(d_northing)^2)
  dt <- as.numeric(df$POSIX[i+1]-df$POSIX[i])
  speed <- c(speed,dr/dt)
  u <- c(u,d_easting/dt)
  v <- c(v,d_northing/dt)
}
speed <- c(speed,NA)
u <- c(u,NA)
v <- c(v,NA)
df$speed <- speed
df$u <- u
df$v <- v
```

plots

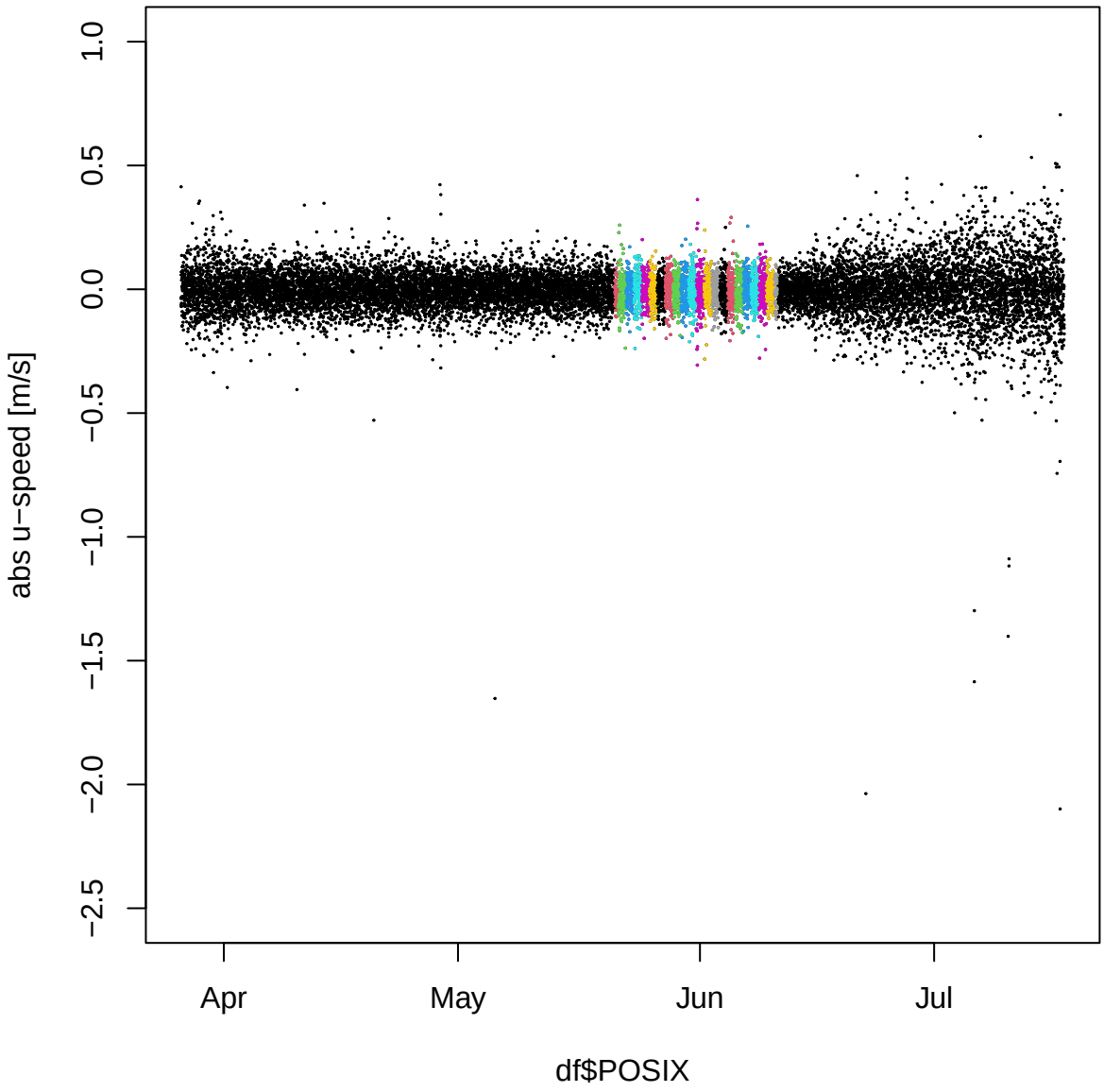
```
plot(df$POSIX,df$speed,pch=19,cex=0.1,main="EXB bouy at Qaanaaq 2024",ylab="speed [m/s]",log="y")
```

```
## Warning in xy.coords(x, y, xlabel, ylabel, log): 1 y value <= 0 omitted from
## logarithmic plot
```

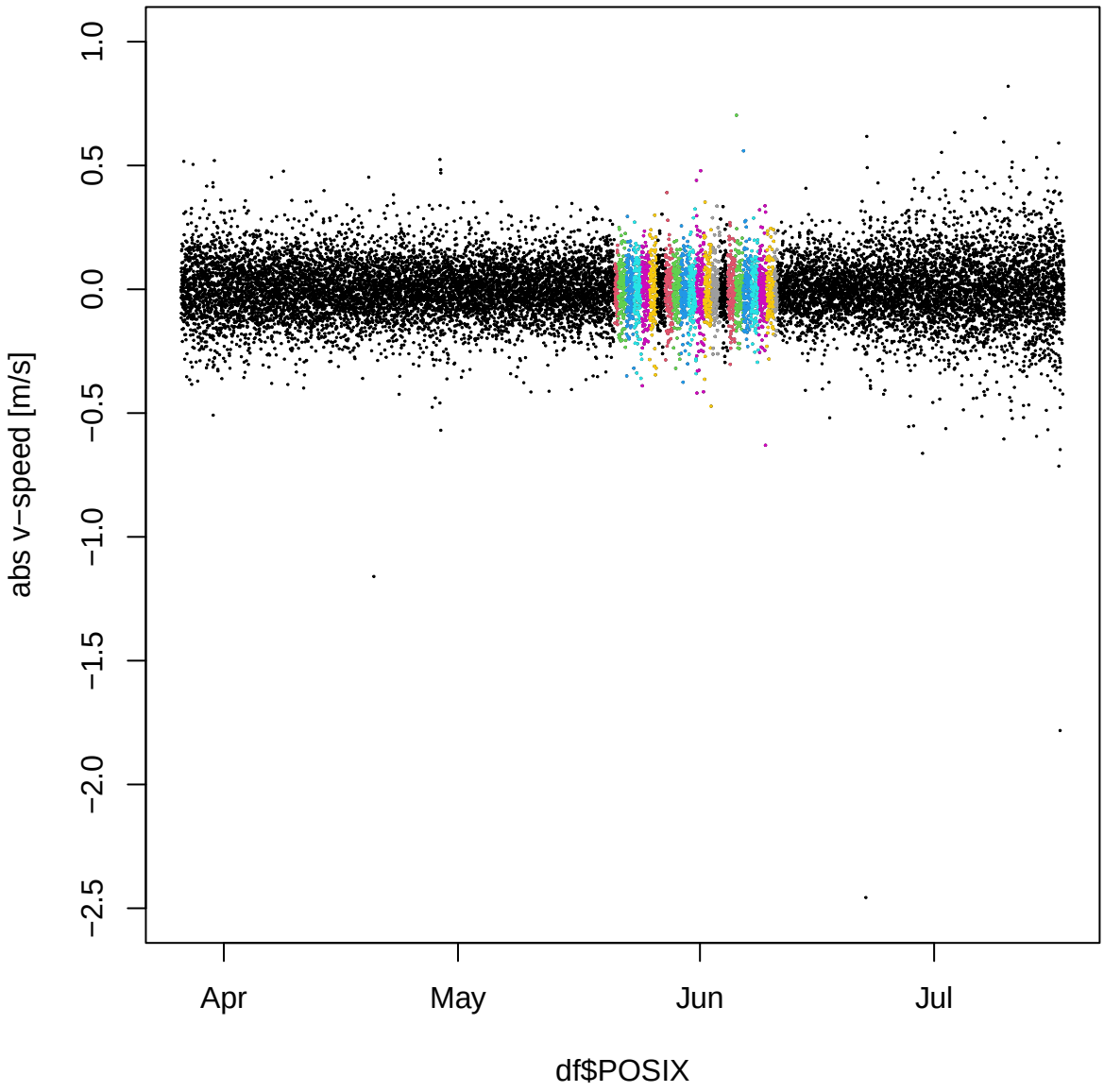
```
points(df$POSIX[idx],df$speed[idx],pch=19,cex=0.1,col=day(df$POSIX))
```



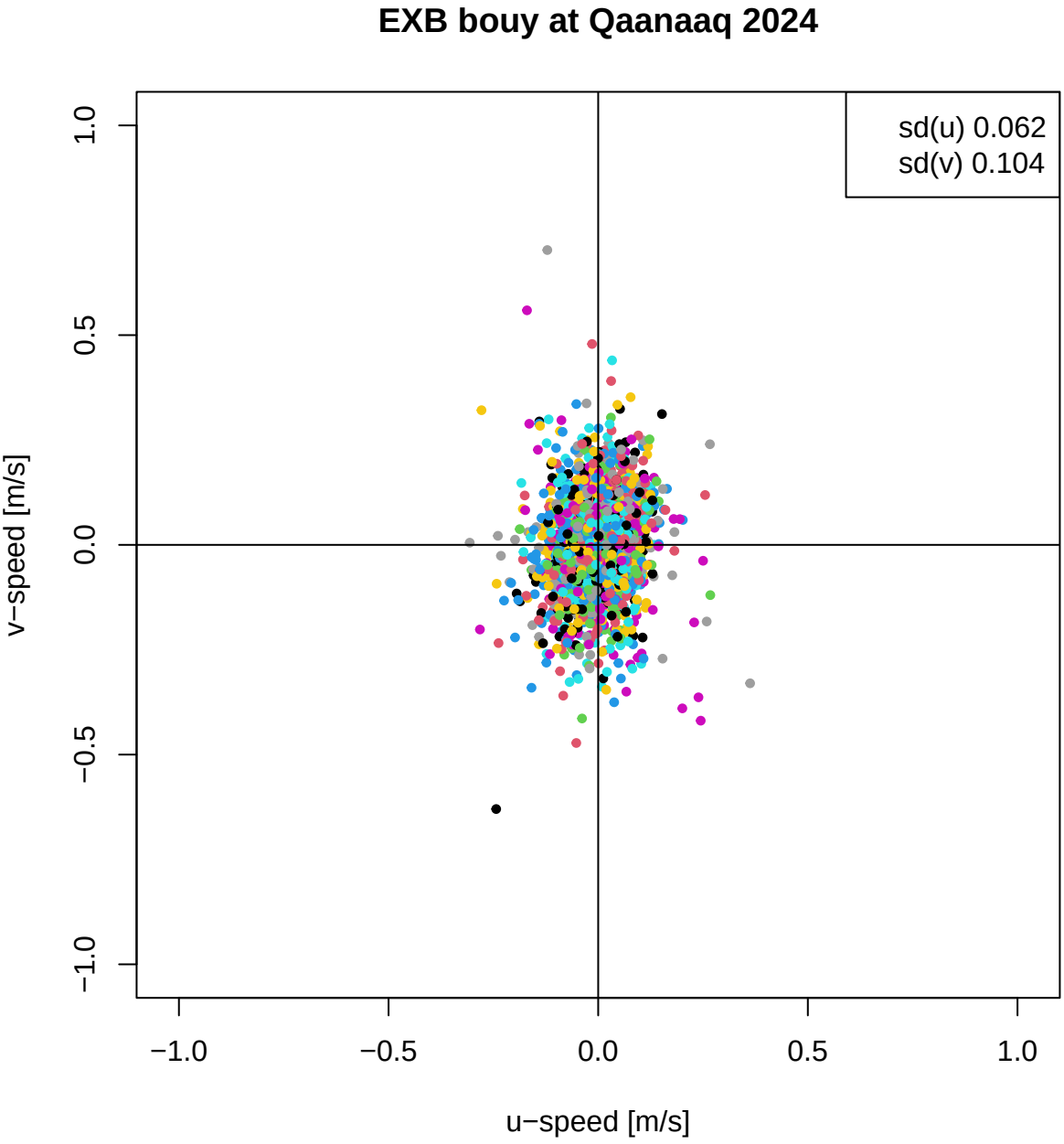

```
uv_ran <- c(-2.5,1)
plot(df$POSIX,df$u,pch=19,cex=0.1,main="EXB bouy at Qaanaaq 2024",ylab="abs u-speed [m/s]",ylim=uv_ran)
points(df$POSIX[idx],df$u[idx],pch=19,cex=0.1,col=day(df$POSIX))
```




```
plot(df$POSIX,df$v,pch=19,cex=0.1,main="EXB bouy at Qaanaaq 2024",ylab="abs v-speed [m/s]",ylim=uv_ran)
points(df$POSIX[idx],df$v[idx],pch=19,cex=0.1,col=day(df$POSIX))
```




```
#
plot(df$u[idx],df$v[idx],pch=19,cex=0.6,main="EXB bouy at Qaanaaq 2024",ylab="v-speed [m/s]",col=hour(d
abline(h=0)
abline(v=0)
disp_u <- round(sd(df$u[idx]),3)
disp_v <- round(sd(df$v[idx]),3)
legend("topright",legend=c(paste("sd(u)",disp_u),paste("sd(v)",disp_v)))
```



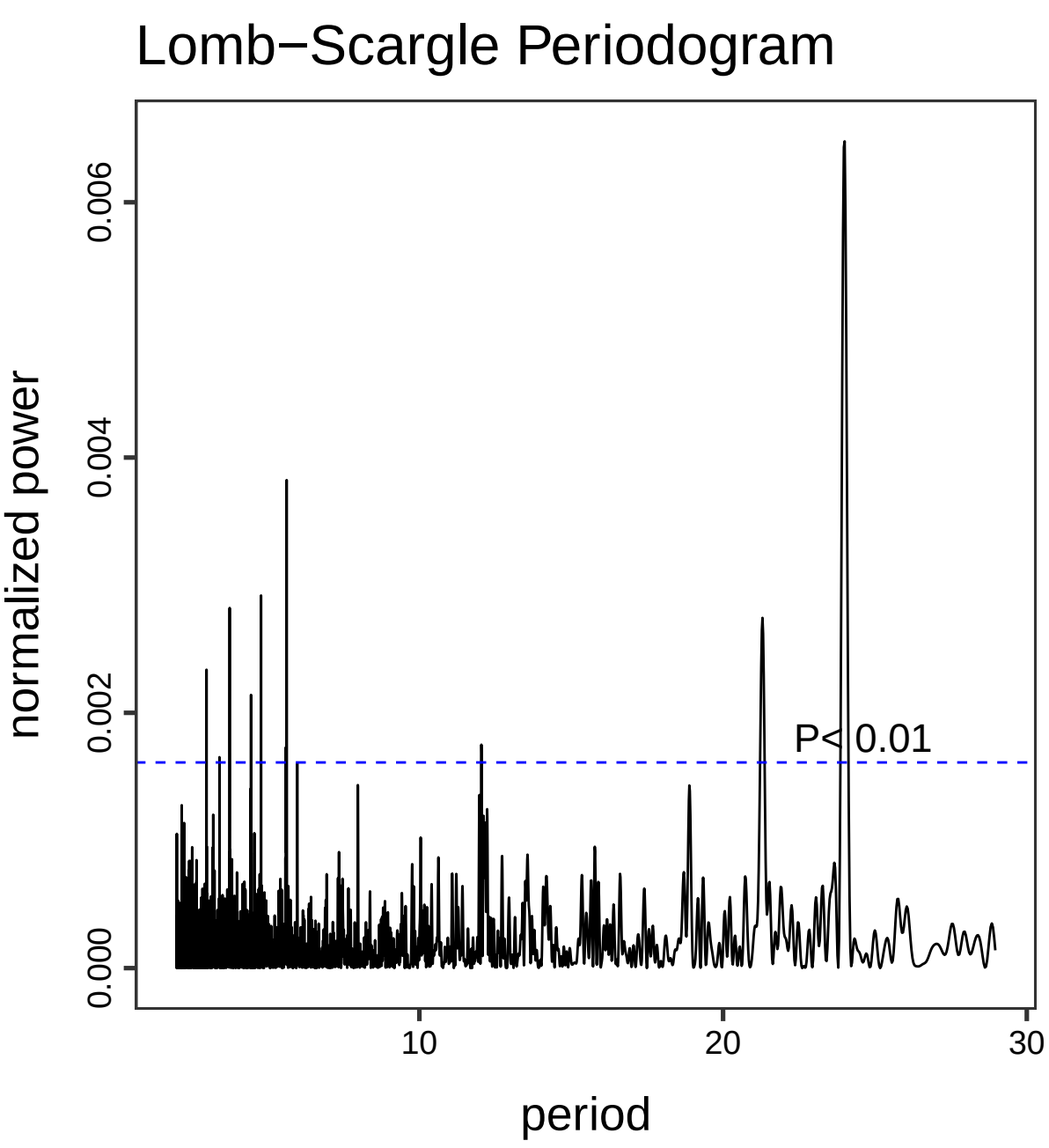
Comment

The northing speed dispersion is greater than the easting dispersion - more

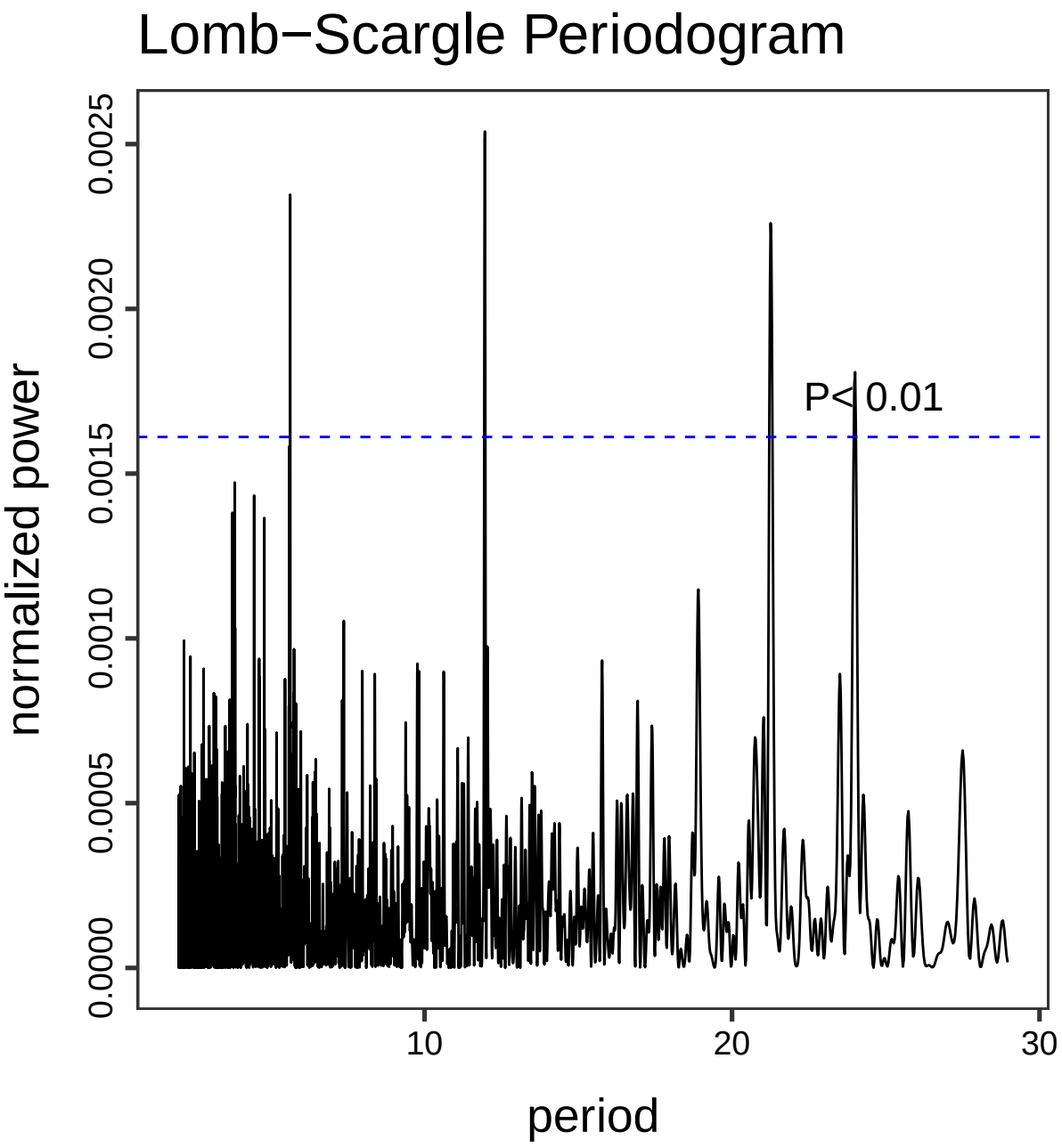
Scargle periodogram

```
library(lomb)
df <- na.omit(df)
df$hours <- as.numeric(difftime(df$POSIX, min(df$POSIX), units = "hours"))
# speed
```

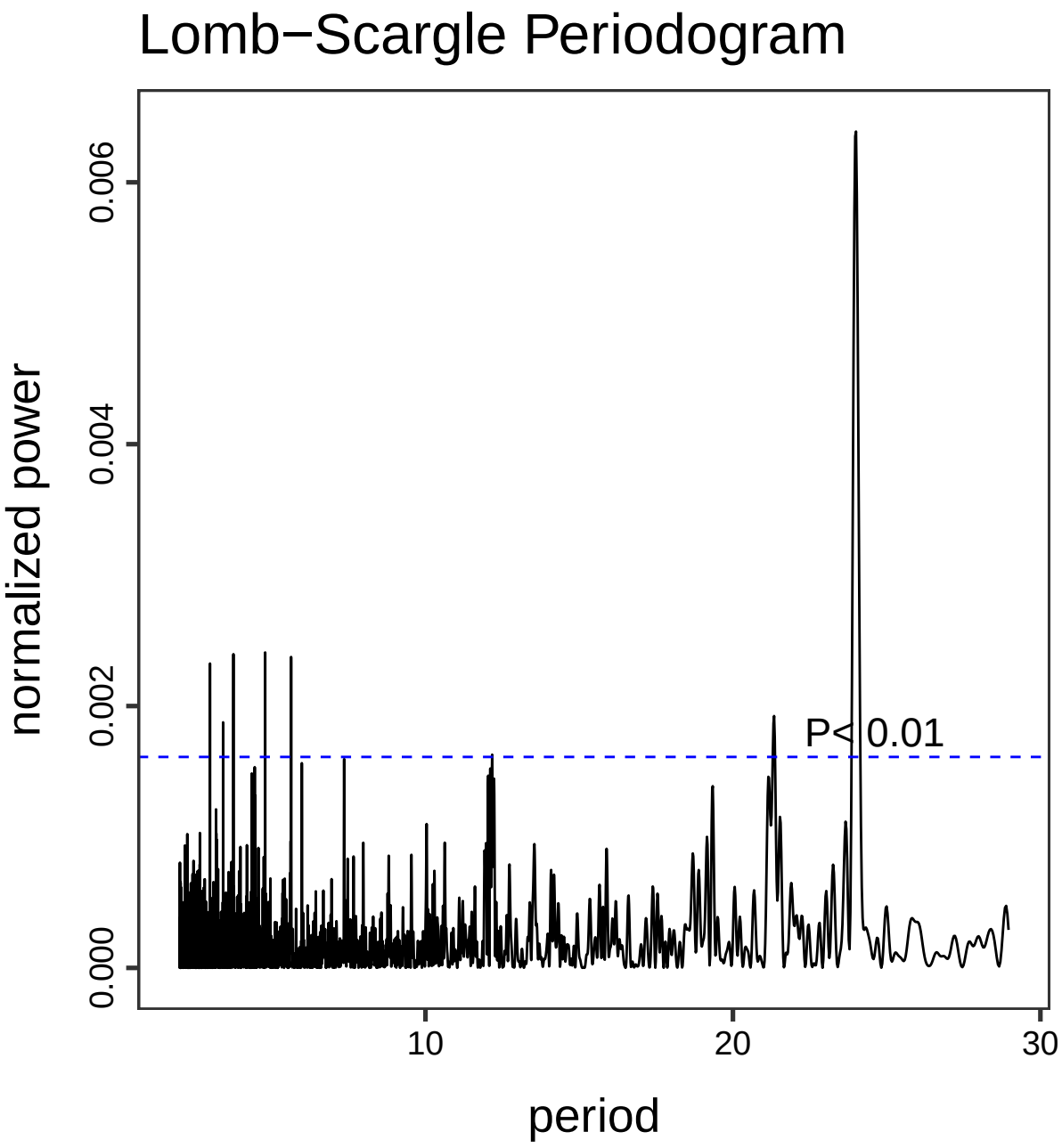
```r
test_period_in_hours <- 15
test_signal <- sin(2*pi/test_period_in_hours*df$hours)*0.0 #0.005
# Compute Lomb-Scargle periodogram
ls_periodogram <- lsp(cbind(df$hours, df$speed-mean(df$speed)+test_signal), fit.sin = TRUE, type="perio
```



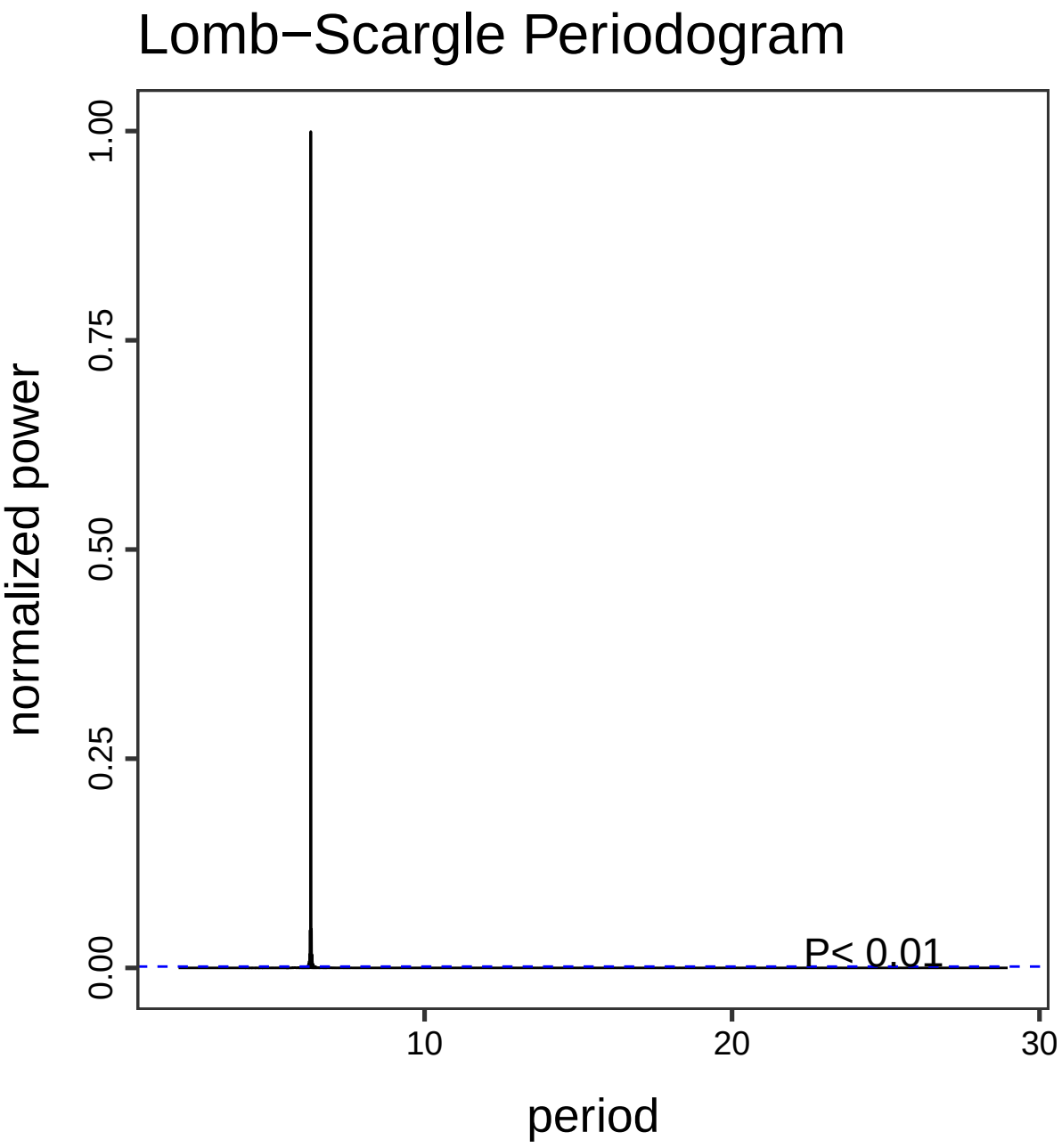

```r
# u
# Compute Lomb-Scargle periodogram
ls_periodogram_u <- lsp(cbind(df$hours, abs(df$u-mean(df$u))), fit.sin = TRUE, type="period",   from=2,
```




```
# v
# Compute Lomb-Scargle periodogram
ls_periodogram_v <- lsp(cbind(df$hours, abs(df$v-mean(df$v))), fit.sin = TRUE, type="period",   from=2,
```




```
# test signal
test_period_in_hours <- 6.3
test_signal <- sin(2*pi/test_period_in_hours*df$hours)*0.001
ls_periodogram_test <- lsp(cbind(df$hours, test_signal), fit.sin = TRUE, type="period",   from=2, to = 1
```



plots

```
pdf("FIGURES/spectra.pdf")
par(mfrow=c(3,1))
plot(ls_periodogram$scanned, ls_periodogram$power, type = 'l', xlab = 'Period [hours]', ylab = 'Power i
#abline(v=test_period_in_hours,col=2,lwd=1)
#abline(v=24,col=2,lwd=1)
#abline(v=12,col=2,lwd=1)
#abline(v=12.41666,col=4,lty=3,lwd=3)
#abline(v=24/3,col=2,lwd=1)
```

```r
#abline(v=24/4,col=2,lwd=1)
#abline(v=24/5,col=2,lwd=1)
lines(ls_periodogram_u$scanned, ls_periodogram_u$power,col=2,lwd=2)
lines(ls_periodogram_v$scanned, ls_periodogram_v$power,col=4,lwd=2)
abline(h=ls_periodogram$sig.level,col="green",lty=3,lwd=2)
legend("top",legend="black : speed, red : u, blue : v")


plot(ls_periodogram$scanned, ls_periodogram$power, type = 'l', xlab = 'Period [hours]', ylab = 'Power i
abline(v=test_period_in_hours,col=2,lwd=1)
abline(v=24,col=2,lwd=1)
abline(v=12,col=2,lwd=1)
abline(v=12.41666,col=4,lty=3,lwd=3)
abline(h=ls_periodogram$sig.level,col="green",lty=3,lwd=2)
legend("topleft",legend="M2 marked with blue stippled")
lines(ls_periodogram_u$scanned, ls_periodogram_u$power,col=2,lwd=2)
lines(ls_periodogram_v$scanned, ls_periodogram_v$power,col=4,lwd=2)

plot(ls_periodogram$scanned, ls_periodogram$power, type = 'l', xlab = 'Period [hours]', ylab = 'Power i
abline(v=24+half_width_24,lty=3)
abline(v=24-half_width_24,lty=3)
abline(v=test_period_in_hours,col=2,lwd=1)
abline(v=24,col=2,lwd=1)
abline(v=12,col=2,lwd=1)
abline(v=12.41666,col=4,lty=3,lwd=3)
abline(v=21.2895,col=4,lty=3,lwd=3)
abline(h=ls_periodogram$sig.level,col="green",lty=3,lwd=2)
legend("top",legend="24 and 21.2895 hours")
lines(ls_periodogram_u$scanned, ls_periodogram_u$power,col=2,lwd=2)
lines(ls_periodogram_v$scanned, ls_periodogram_v$power,col=4,lwd=2)

plot(ls_periodogram$scanned, ls_periodogram$power, type = 'l', xlab = 'Period [hours]', ylab = 'Power i
abline(v=5.6299+half_width_5p6,lty=3)
abline(v=5.6299-half_width_5p6,lty=3)

abline(v=test_period_in_hours,col=2,lwd=1)
abline(v=5.6299,col=2,lwd=1)
abline(h=ls_periodogram$sig.level,col="green",lty=3,lwd=2)
lines(ls_periodogram_u$scanned, ls_periodogram_u$power,col=2,lwd=2)
lines(ls_periodogram_v$scanned, ls_periodogram_v$power,col=4,lwd=2)
legend("topleft",legend=c("vertical : 5.6299 hours","u red, v blue, speed black"))

# spectrum of test signal
plot(ls_periodogram_test$scanned, ls_periodogram_test$power, type = 'l', xlab = 'Period [hours]', ylab =
dev.off()
```

```
## pdf
##   2
```

Comments

There is a strong speed signal at 24 hours - mainly due to a strong northing speed. This implies a north-south oscillating motion.

consider the phase

```
# Example data (replace this with your actual time series)
#set.seed(123)

time_points <- difftime(df$POSIX,min(df$POSIX),units = "hour")
regular_time_grid <- seq(min(time_points), max(time_points), length.out = (max(time_points)-min(time_po

interpolated_values <- approx(x = time_points, y = df$speed, xout = regular_time_grid)$y


# Compute Lomb-Scargle periodogram with phase using astrochron
lsp_result <- periodogram(
  cbind(regular_time_grid,interpolated_values),
  demean=T,
  detrend=T,
  background=1,
  bc=1,
  pl=2,
  verbose=T,
  genplot=T,
  output=1
)
```

```
##
## ----- CALCULATING PERIODOGRAM FOR STRATIGRAPHIC SERIES -----
##  * Number of data points in stratigraphic series: 16292
##  * Stratigraphic series length (space or time): 2715.333
##  * Sampling interval (space or time): 0.1666769
##  * Mean value removed= 0.1184243
##  * Linear trend removed. m= 1.880493e-05 b= -0.02553083
##  * Nyquist frequency: 2.999816
##  * Rayleigh frequency: 0.0003682563
##  * Padded to 32584 points
##  * Estimated AR1 coefficient = 0.4829095
```

```
# Extract frequency, amplitude, and phase
frequency <- lsp_result$Frequency
amplitude <- lsp_result$Amplitude
power <- lsp_result$Power
phase <- lsp_result$Phase

# Plot the Lomb-Scargle periodogram
plot(1/frequency, power, type = "b", xlab = "1/Frequency", ylab = "Power", col = "blue", lty = 1, xlim=
```

```r
# Optionally, plot the phase information
plot(1/frequency, phase, type = "b", xlab = "1/Frequency", ylab = "Phase", col = "red", lty = 1, xlim=c
```

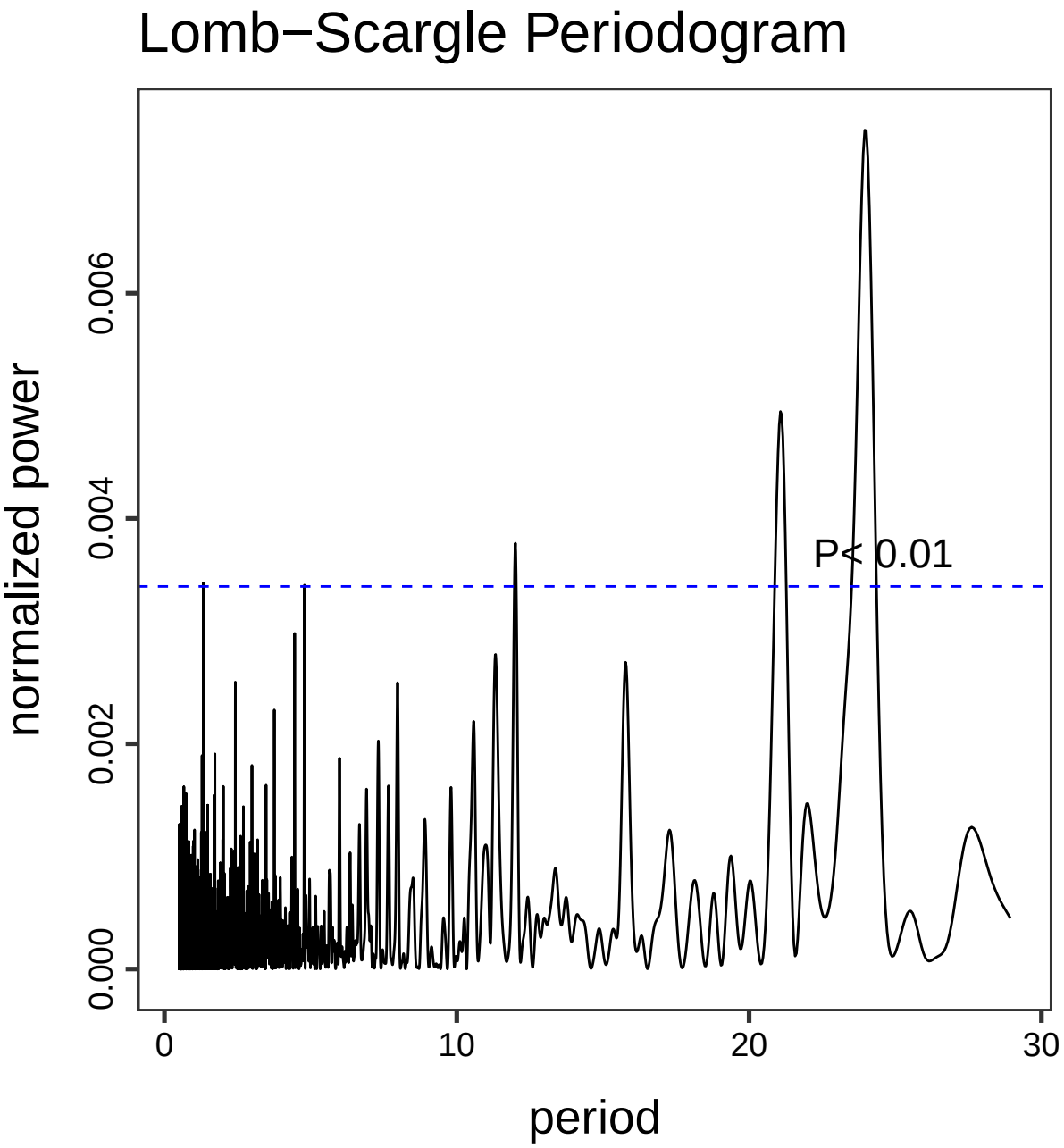
Define function to perform Lomb-Scargle with user options

```r
lsp_pth <-
  function(x_orig,
           y_orig,
           type_str = 'period',
           ofac = 1,
           ifwindow = 'none',
           from = .5,
           to = 29,
           if_test = FALSE,
           test_signal_period=5.5)
  {
    # echo inputs
    print(paste("length of x and y :",length(x_orig),length(y_orig)))
    # type_str    :  'period' or 'frequency'
    x <- x_orig
    y <- y_orig - mean(y_orig, na.omit = T)
    # apply window
    if (ifwindow == 'Hanning') {
      win <- hanning.window(length(y_orig))
      y <- y * win
    }
    # add test_signal if required
    if (if_test){
      testsignal <- 0.01*sin(2*pi/test_signal_period*x)
      y <- y + testsignal
      print(paste("Added a test signal at period ",test_signal_period))
    }
    lsp_out <-
      lsp(
        cbind(x, y),
        fit.sin = TRUE,
        type = type_str,
        from = from,
        to = to,
        ofac = ofac
      )
    return(list(
      'freq_or_period' = lsp_out$scanned,
      'power' = lsp_out$power
    ))
  }
```

calculation

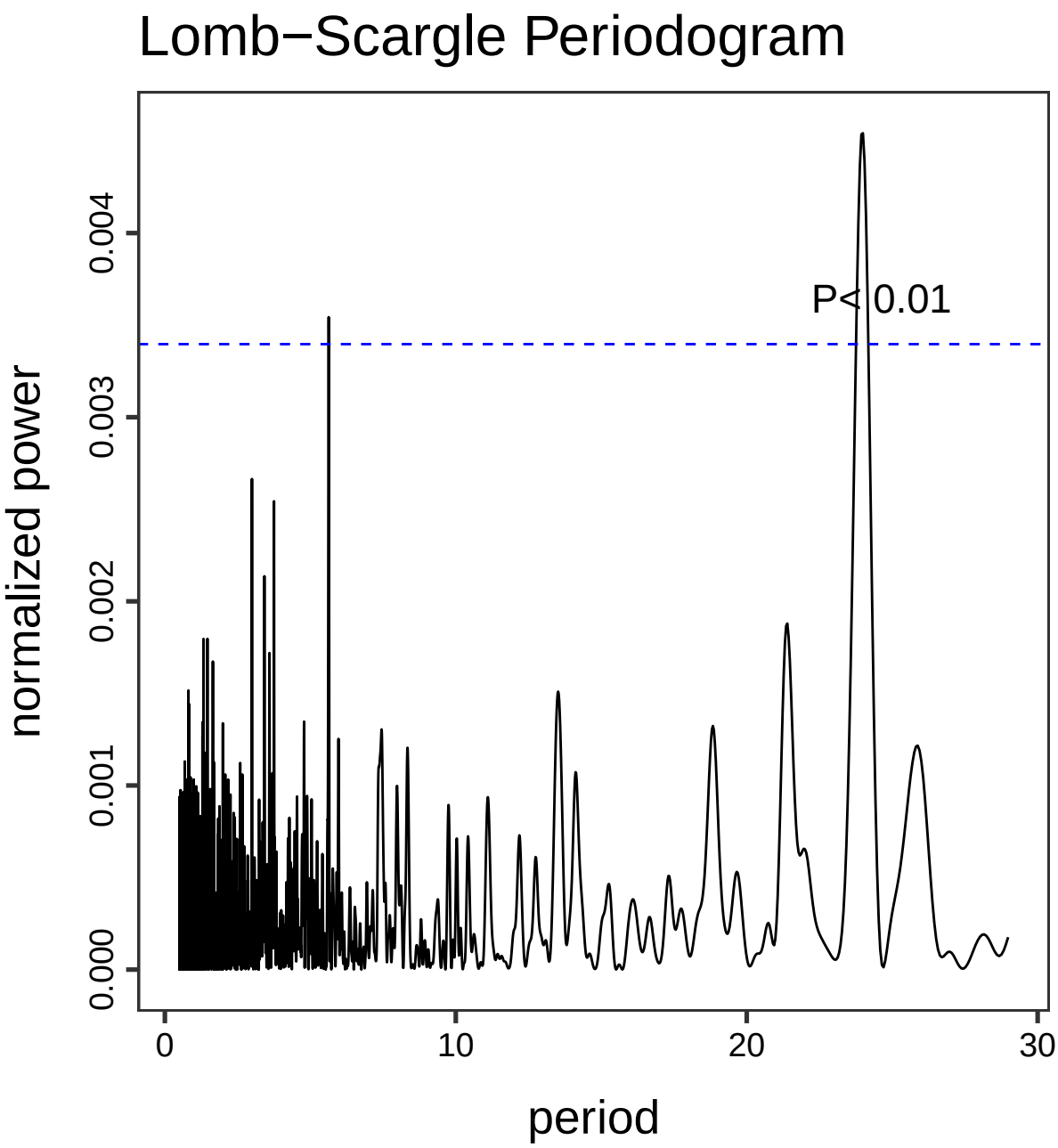
```
idx <- 1:(nrow(df)/2)
type_str <- 'period'
out1 <- lsp_pth(df$hours[idx], df$speed[idx],type_str,ofac=8,if_test=F,test_signal_period=20,ifwindow="
```

```
## [1] "length of x and y : 8140 8140"
```




```
#
idx <- (nrow(df)/2):nrow(df)
out2 <- lsp_pth(df$hours[idx], df$speed[idx],type_str,ofac=8,if_test=F,test_signal_period=20,ifwindow="
```

```
## [1] "length of x and y : 8141 8141"
```




```
#
```

Plots

```
xlab_str <- "f [1/hours]"
if (type_str == 'period'){xlab_str='Period [hours]'}
#
pdf("FIGURES/spectra_2.pdf")
```

```r
par(mfrow=c(2,1))
plot(out1$freq_or_period,out1$power,col='red',type="l",xlab=xlab_str,ylab="Power",main="First and secon
lines(out2$freq_or_period,out2$power,col='blue',type="l",lwd=3,xlim=c(10,25))
abline(v=12.41666,col=4,lty=3,lwd=3)
abline(v=24,col=4,lty=3,lwd=3)
#
plot(out1$freq_or_period,out1$power,col='red',type="l",xlab=xlab_str,ylab="Power",main="First and secon
lines(out2$freq_or_period,out2$power,col='blue',type="l",lwd=3,xlim=c(5,11))
#
plot(out1$freq_or_period,out1$power,col='red',type="l",xlab=xlab_str,ylab="Power",main="First and secon
lines(out2$freq_or_period,out2$power,col='blue',type="l",lwd=1.7,xlim=c(2,6))
#
plot(out1$freq_or_period,out1$power,col='red',type="l",xlab=xlab_str,ylab="Power",main="First and secon
lines(out2$freq_or_period,out2$power,col='blue',type="l",lwd=1.7,xlim=c(.5,2.1))
dev.off()
```

```
## pdf
##   2
```