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Advancing movement & sleep research

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GGIR training: Day 2

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BEFORE WE START

- Focus of this course
- Questions
- Video recording
- Slides + Documentation + Example data:
<https://www.accelting.com/ggir-training-materials/>

Day 1: questions?



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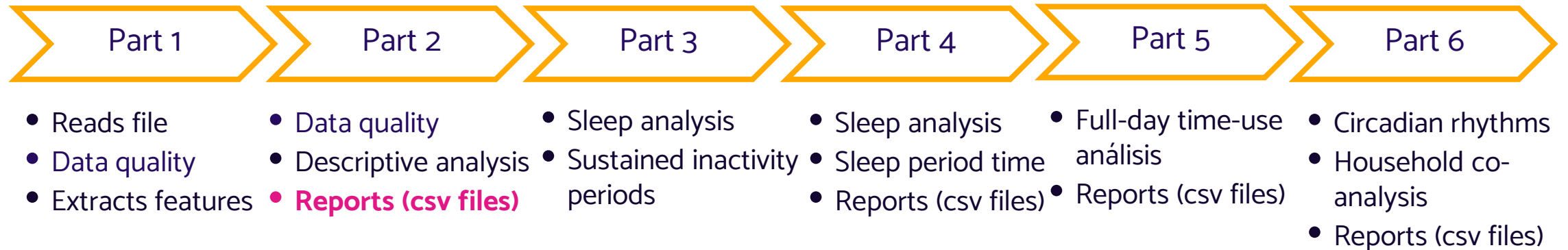
Learning goals for this session

- Understand what is in the Part 2 Output.
- Learn about sleep detection with GGIR:
 - Understand how it works
 - Know how to use it yourself

Part 2 Output



The GGIR pipeline



For documentation of all variable names see:

<https://wadpac.github.io/GGIR/articles/GGIRoutput.html#ggir-part-2>

Part 2

Output

- meta
 - csv
 - ID01.csv
 - ...
- results
 - QC
 - data_quality_report.csv
 - plot_to_check_data_quality.pdf
 - part2_daysummary.csv
 - part2_daysummary_longformat.csv
 - part2_summary.csv

Part 2

Output

- meta
 - csv
 - ID01.csv
 - ...
- results
 - QC
 - data_quality_report.csv
 - plot_to_check_data_quality.pdf
 - **part2_dayssummary.csv**
 - **part2_dayssummary_longformat.csv**
 - part2_summary.csv

Output from Part 2

Note: Are all values in the first Excel column? Check out GGIR parameters `sep_reports` and `dec_reports`

Day-level features (wide)

`do.report = 2`

part2_daysummary.csv

ID	filename	calendar_date	N valid hours	N hours	weekday	measurementday	qwindow_timestamps	qwindow_names
11	011_45400.cwa	2019-03-28T00:00:00+0100	24	24	Wednesday	2	0_8_24	0_8_24
11	011_45400.cwa	2019-03-29T00:00:00+0100	24	24	Thursday	3	0_8_24	0_8_24
11	011_45400.cwa	2019-03-30T00:00:00+0100	24	24	Friday	4	0_8_24	0_8_24
11	011_45400.cwa	2019-03-31T00:00:00+0100	23	24	Saturday	5	0_8_24	0_8_24
11	011_45400.cwa	2019-03-31T00:00:00+0100	10	24	Sunday	6	0_8_24	0_8_24

Output from Part 2

Day-level features (wide)

`do.report = 2`

```
GGIR(  
  [...]  
  # Data cleaning  
  includedaycrit = 16,  
  [...])
```

part2_daysummary.csv

ID	filename	calendar_date	N valid hours	N hours	weekday	Measurement day
11	011_45400.cwa	2019-03-28T00:00:00+0100	24	24	Wednesday	2
11	011_45400.cwa	2019-03-29T00:00:00+0100	24	24	Thursday	3
11	011_45400.cwa	2019-03-30T00:00:00+0100	24	24	Friday	4
11	011_45400.cwa	2019-03-31T00:00:00+0100	23	24	Saturday	5
11	011_45400.cwa	2019-03-31T00:00:00+0100	10	24	Sunday	6


Output from Part 2

Day-level features (wide)

`do.report = 2`

Only if qwindow is defined, e.g.
`qwindow = c(0, 8, 24)`

`part2_daysummary.csv`



ID	Measurement day	qwindow_ timestamps	mean_ENMO_ mg_0-24hr	MVPA_E5S_T100_ ENMO_0-24hr	mean_ENMO_ mg_0-8hr	MVPA_E5S_T100_ ENMO_0-8hr	mean_ENMO_ mg_8-24hr	MVPA_E5S_T100_ ENMO_8-24hr
11	2	0_8_24	50.297	146.833	5.368	2.167	72.762	144.667
11	3	0_8_24	16.099	51.833	4.024	3.417	22.136	48.417
11	4	0_8_24	38.232	170.417	7.903	8.5	53.396	161.917
11	5	0_8_24	15.085	41.25	7.393	4.167	18.932	37.083
11	6	0_8_24						

Output from Part 2

Day-level features (long)

Only if qwindow is defined, e.g.
qwindow = c(0, 8, 24)

do.report = 2

part2_daysummary_longformat.csv

ID	filename	calendar_date	N_valid_hours	N_hours	N_valid_hours_in_window	N_hours_in_window	weekday	measurement_day	qwindow_timestamps	qwindow_name
11	011_45400.cwa	2019-03-28T00:00:00+0100	24	24	8	8	Wednesday	2	00:00-8:00	0-8hr
11	011_45400.cwa	2019-03-29T00:00:00+0100	24	24	8	8	Thursday	3	00:00-8:00	0-8hr
11	011_45400.cwa	2019-03-30T00:00:00+0100	24	24	8	8	Friday	4	00:00-8:00	0-8hr
11	011_45400.cwa	2019-03-31T00:00:00+0100	23	23	8	8	Saturday	5	00:00-8:00	0-8hr
11	011_45400.cwa	2019-03-28T00:00:00+0100	24	24	16	16	Wednesday	2	08:00-24:00	8-24hr
11	011_45400.cwa	2019-03-29T00:00:00+0100	24	24	16	16	Thursday	3	08:00-24:00	8-24hr
11	011_45400.cwa	2019-03-30T00:00:00+0100	24	24	16	16	Friday	4	08:00-24:00	8-24hr
11	011_45400.cwa	2019-03-31T00:00:00+0100	23	23	15	15	Saturday	5	08:00-24:00	8-24hr
11	011_45400.cwa	2019-03-28T00:00:00+0100	24	24			Wednesday	2	00:00-24:00	0-24hr
11	011_45400.cwa	2019-03-29T00:00:00+0100	24	24			Thursday	3	00:00-24:00	0-24hr
11	011_45400.cwa	2019-03-30T00:00:00+0100	24	24			Friday	4	00:00-24:00	0-24hr
11	011_45400.cwa	2019-03-31T00:00:00+0100	23	23			Saturday	5	00:00-24:00	0-24hr

Output from Part 2

Note: There is no `part2_summary_longformat.csv` regardless of whether `qwindow` is used.

Person-level features

`do.report = 2`

`part2_summary.csv`

ID	device_sn	bodylocation	filename	start_time	startday	samplefreq	device	meas_dur_dys
11	45400	not extracted	011_45400.cwa	2019-03-27T00:00:00+0100	Tuesday	50	axivity	6.99

All days

ID	N valid WEdays	N valid WKdays	AD_mean_ENMO_mg_0-24hr	AD_mean_ENMO_mg_0-8hr	AD_mean_ENMO_mg_8-24hr
11	2	5	28.809	6.222	40.102

Only if `qwindow` is defined, e.g. `qwindow = c(0, 8, 24)`

Weekdays

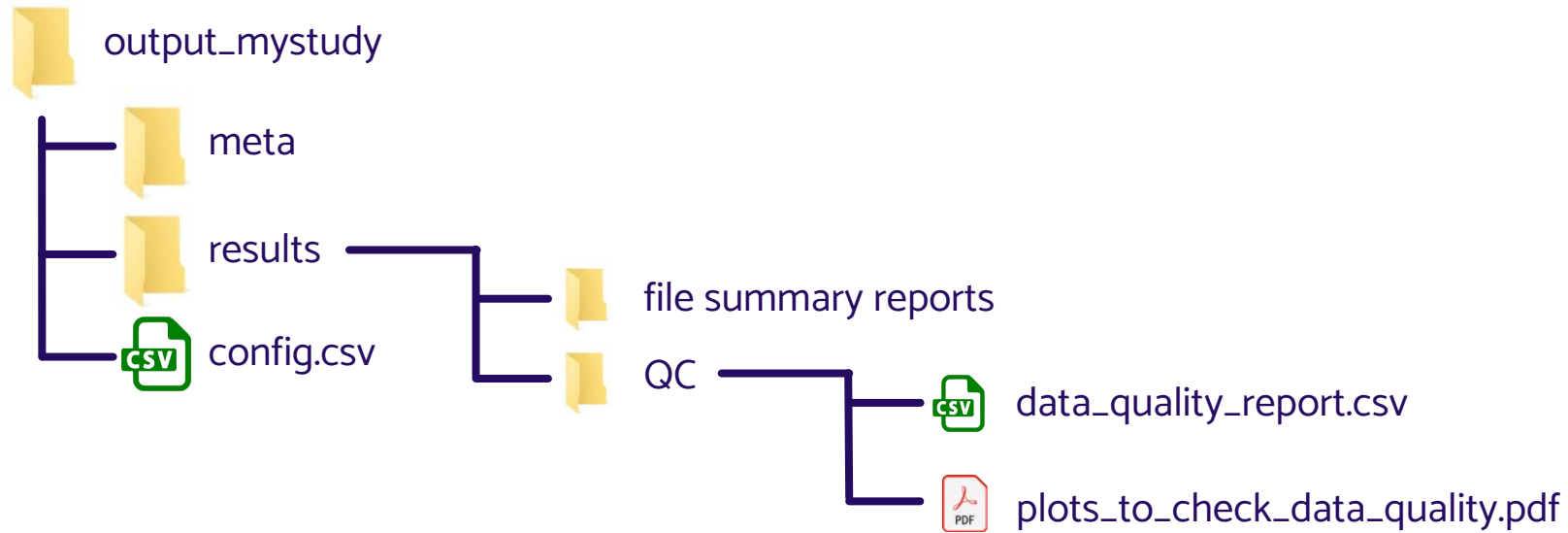
ID	N valid WEdays	N valid WKdays	WD_mean_ENMO_mg_0-24hr	WD_mean_ENMO_mg_0-8hr	WD_mean_ENMO_mg_8-24hr
11	2	5	33.197	5.471	47.06

Weekend days

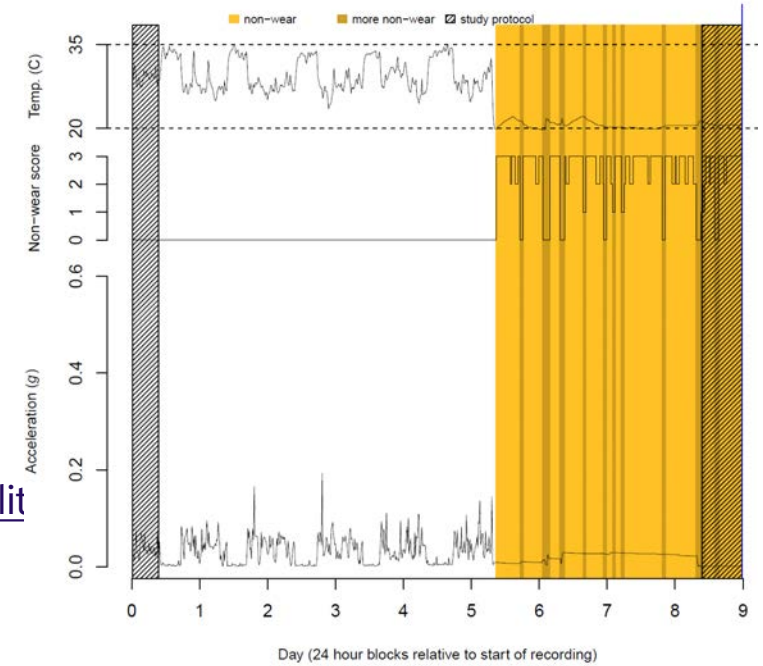
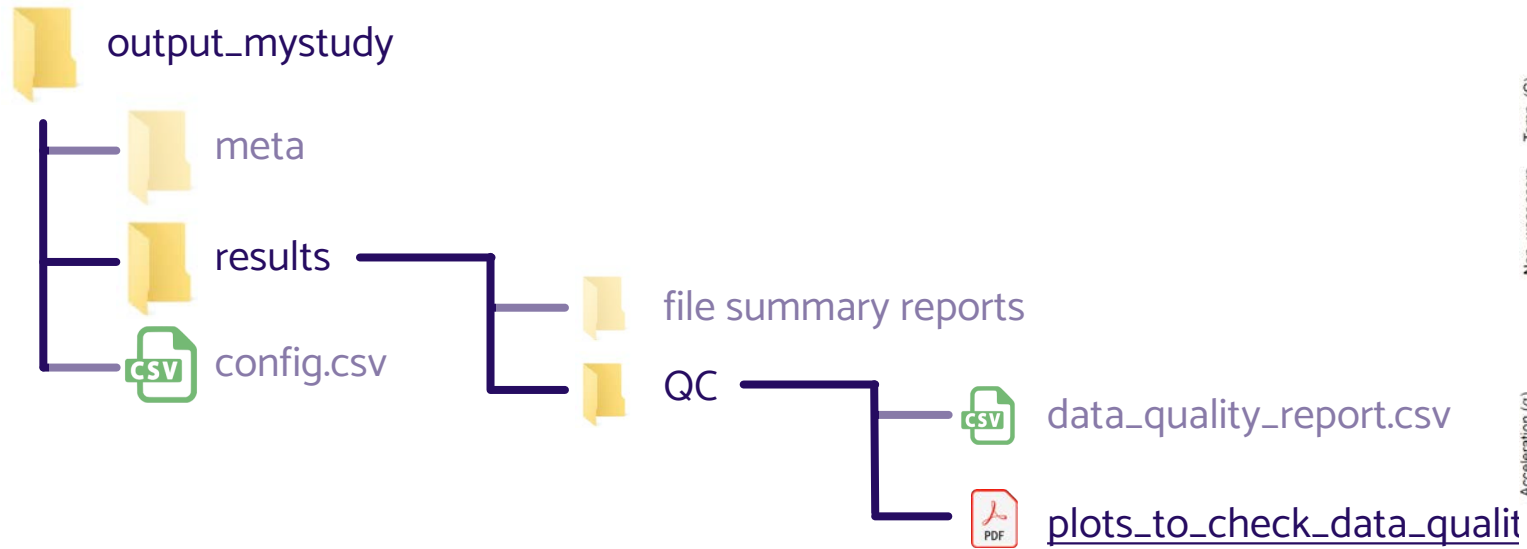
ID	N valid WEdays	N valid WKdays	WE_mean_ENMO_mg_0-24hr	WE_mean_ENMO_mg_0-8hr	WE_mean_ENMO_mg_8-24hr
11	2	5	17.838	8.099	22.707

AD_ = all days
WD_ = weekdays
WE_ = weekend days
WWD_ = weighted weekdays
WWE_ = weighted weekend days

The GGIR pipeline (output folder)



The GGIR pipeline (output folder)



Output from Part 2

Epoch-level features

`epochvalues2csv = TRUE` *# default = FALSE!!*

output_axivity > meta > csv		
<input type="checkbox"/> Name	Status	Date modified
<input checked="" type="checkbox"/> 011_45400_cwa.cwa.RData.csv	🔄	6/2/2022 9:46 AM
<input checked="" type="checkbox"/> 013_42151_cwa.cwa.RData.csv	✅	6/2/2022 9:46 AM
<input checked="" type="checkbox"/> 015_44944_cwa.cwa.RData.csv	✅	6/2/2022 9:46 AM
<input checked="" type="checkbox"/> 017_42151_cwa.cwa.RData.csv	✅	6/2/2022 9:46 AM

Signal metrics only!

For time series of sleep and bout classification, see GGIR part 5 (as discussed on day 3)

	A	B	C
1	timestamp	anglez	ENMO
2	2019-03-27T00:00:00+0100	-25.347	0.0022
3	2019-03-27T00:00:05+0100	-25.3816	0.0017
4	2019-03-27T00:00:10+0100	-25.342	0.0025
5	2019-03-27T00:00:15+0100	-24.8968	0.0027
6	2019-03-27T00:00:20+0100	-25.3328	0.0027
7	2019-03-27T00:00:25+0100	-25.4124	0.0024
8	2019-03-27T00:00:30+0100	-25.2169	0.002
9	2019-03-27T00:00:35+0100	-25.7494	0.0023
10	2019-03-27T00:00:40+0100	-25.5495	0.0024
11	2019-03-27T00:00:45+0100	-26.3225	0.0021
12	2019-03-27T00:00:50+0100	-25.4574	0.0022
13	2019-03-27T00:00:55+0100	-25.2172	0.0028
14	2019-03-27T00:01:00+0100	-24.6724	0.0025
15	2019-03-27T00:01:05+0100	-25.0957	0.0023
16	2019-03-27T00:01:10+0100	-24.5152	0.0026
17	2019-03-27T00:01:15+0100	-24.996	0.0033
18	2019-03-27T00:01:20+0100	-26.0688	0.0019
19	2019-03-27T00:01:25+0100	-25.278	0.0028
20	2019-03-27T00:01:30+0100	-25.5993	0.0023
21	2019-03-27T00:01:35+0100	-25.8586	0.0024

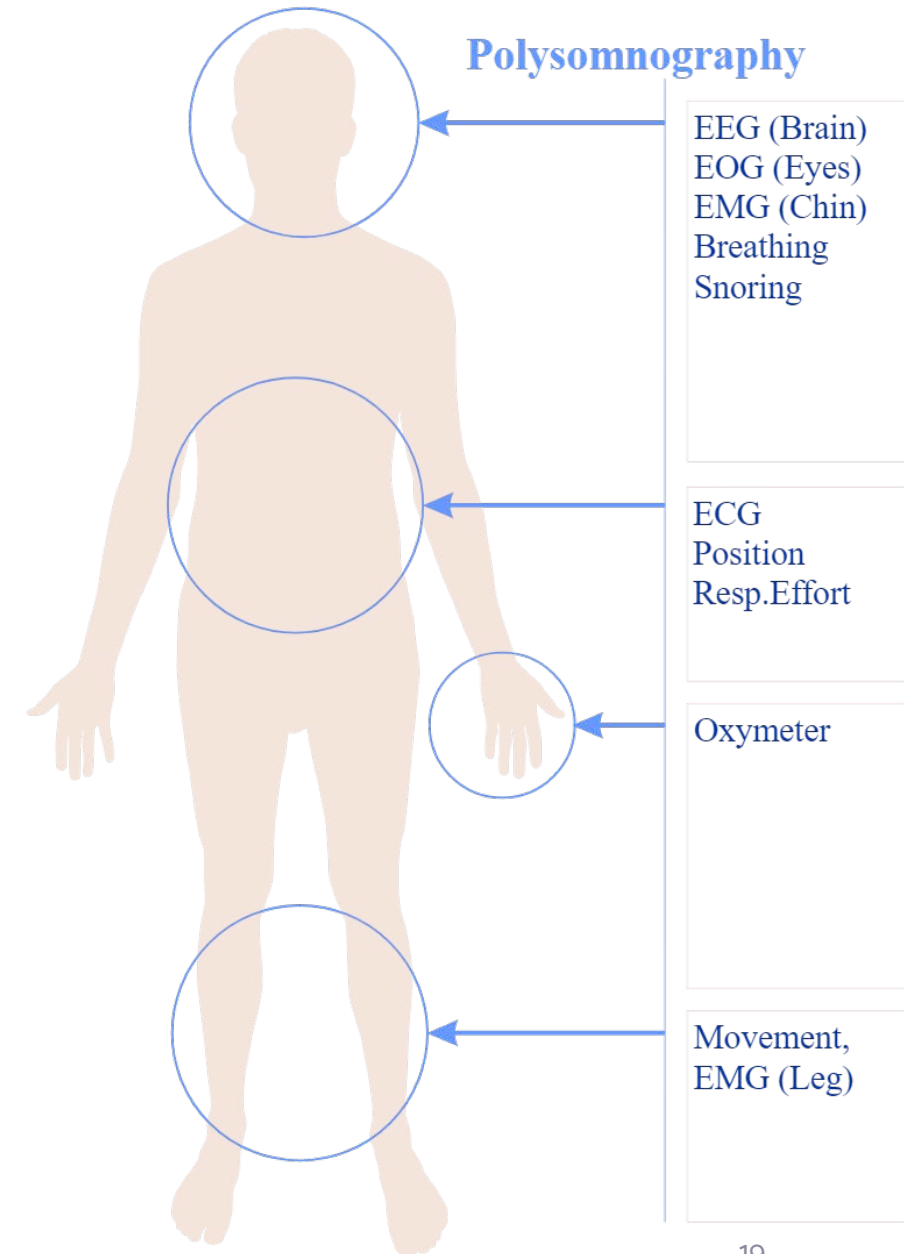
Sleep & accelerometers



Polysomnography

Lab-based

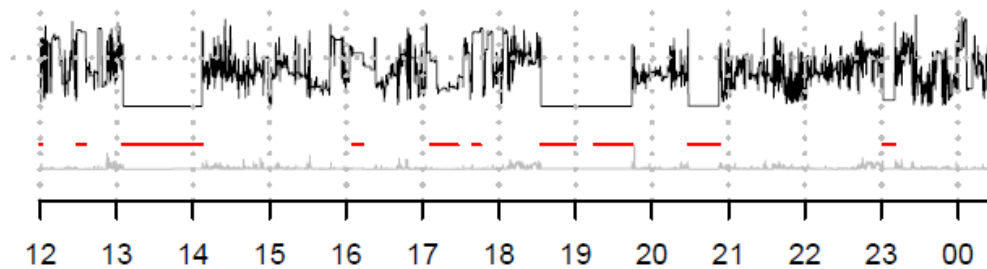
- Reference method for sleep assessment
- Combination of monitors:
 - EEG
 - Heart rate
 - Gases exchange
 - Blood oxygen levels
 - Others
- Specialist go over the signal and classify 30-sec epochs into **sleep stages**



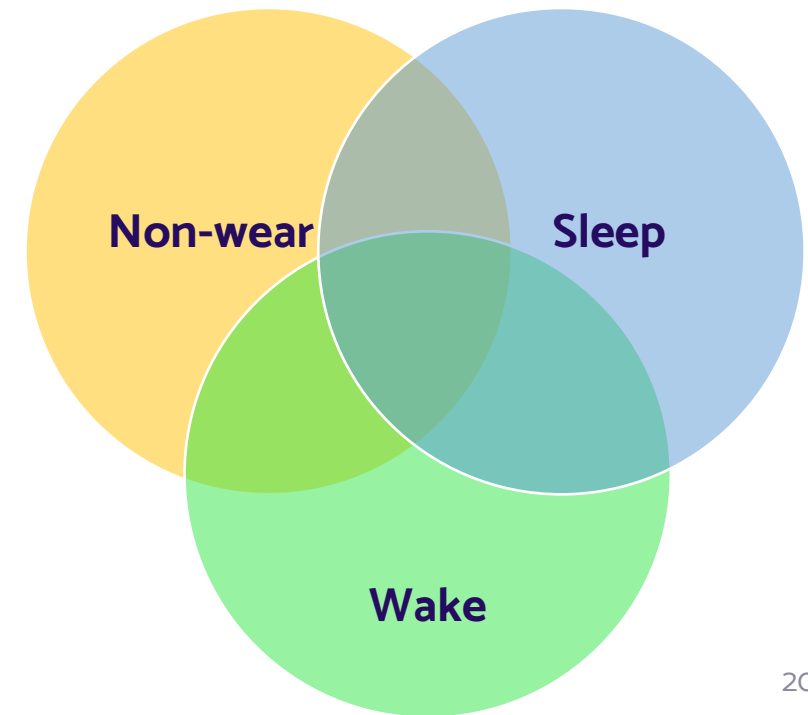
Accelerometer-based sleep assessment

Free living

- **Challenge 1:** distinguish sleep, wake, and non-wear
 - Lack of movement
 - Lack of postural change



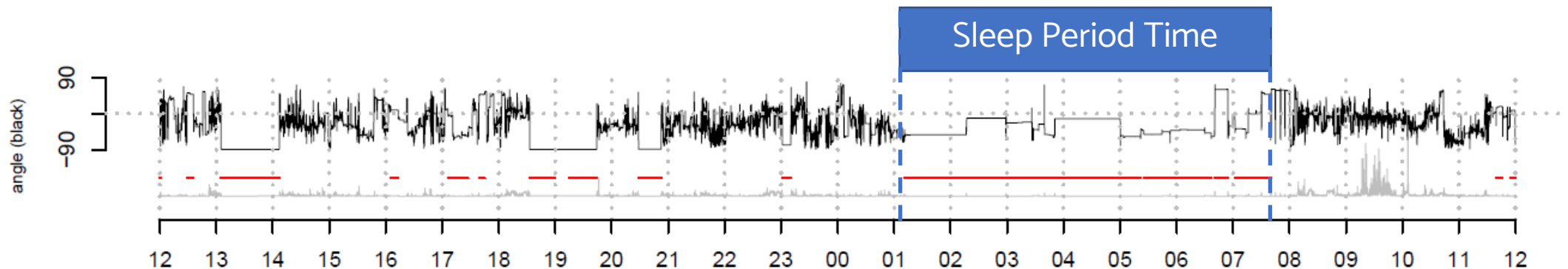
- Term: Sustained Inactivity Bout, abbreviated as SIB



Accelerometer-based sleep assessment

Free living

- **Challenge 2:** separate daytime and nighttime (**Sleep Period Time**)
 - Algorithms
 - Sleep diaries



Sleep/rest detection



The GGIR pipeline



The GGIR()

Sleep analysis

```
GGIR(  
  [...]  
  # Sleep analysis  
  HASIB.algo = "vanHees2015",  
  [...])
```

```
GGIR(  
  [...]  
  # Sleep analysis  
  HASIB.algo = "Sadeh1994",  
  [...])
```

```
GGIR(  
  [...]  
  # Sleep analysis  
  HASIB.algo = "ColeKripke1992",  
  [...])
```

```
GGIR(  
  [...]  
  # Sleep analysis  
  HASIB.algo = "Galland2012",  
  [...])
```


Rest/Wake detection

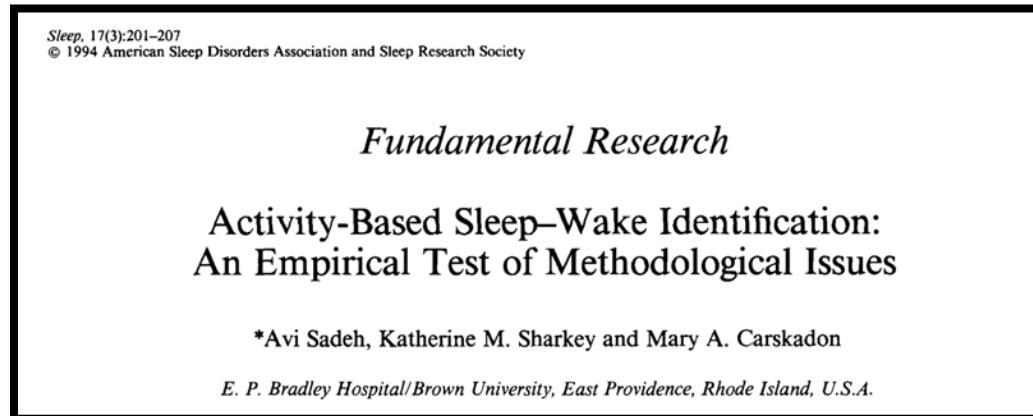
Algorithms



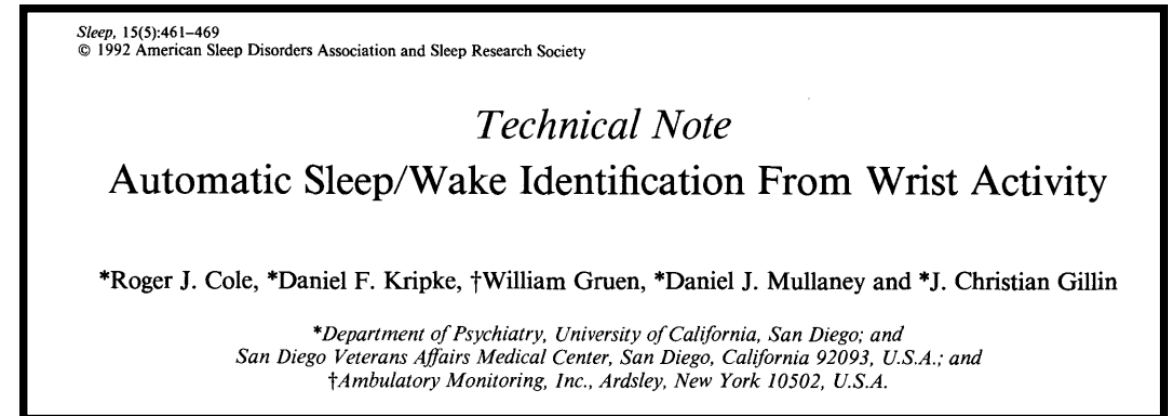
doi: 10.1371/journal.pone.0142533



doi: 10.1016/j.sleep.2012.01.018

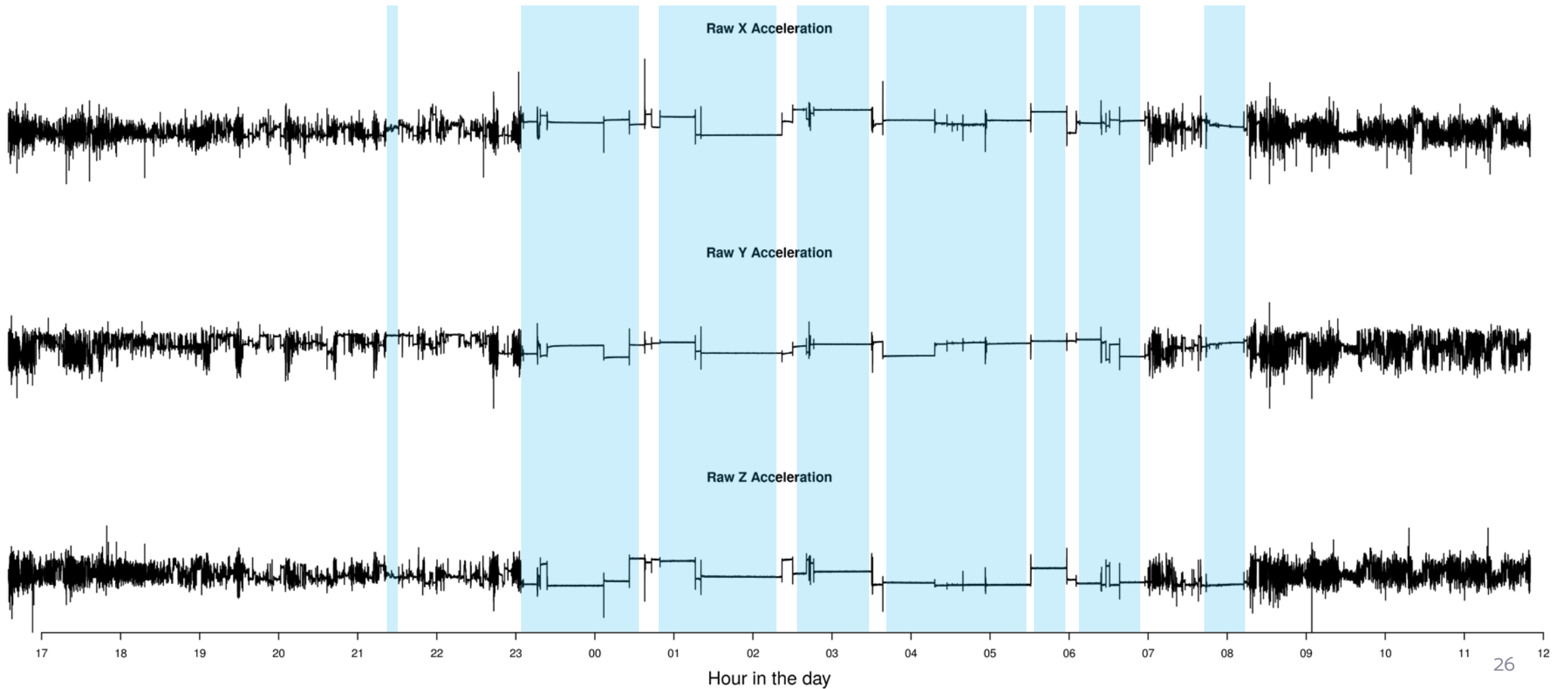


doi: 10.1093/sleep/17.3.201



doi: 10.1093/sleep/15.5.461

Rest/Wake detection



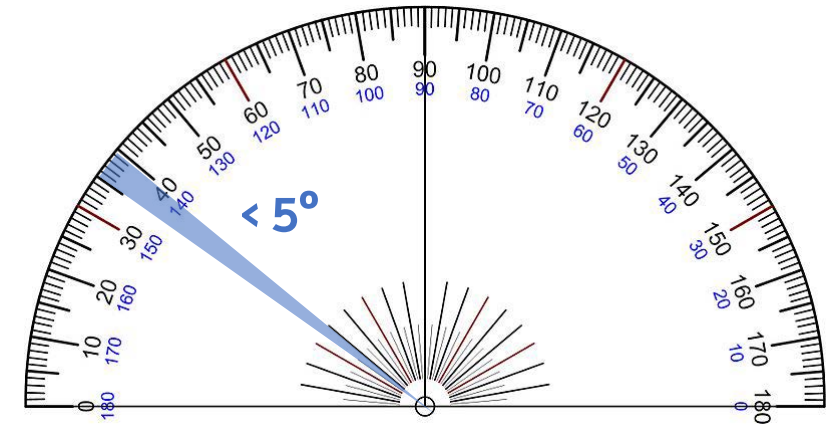
vanHees2015

- Interpretable as lack of posture change and lack of movement, regardless of agreement with neurological sleep
- Angle is a more visual concept than magnitude of acceleration

Angle of z-axis (independent of attachment orientation across brands)

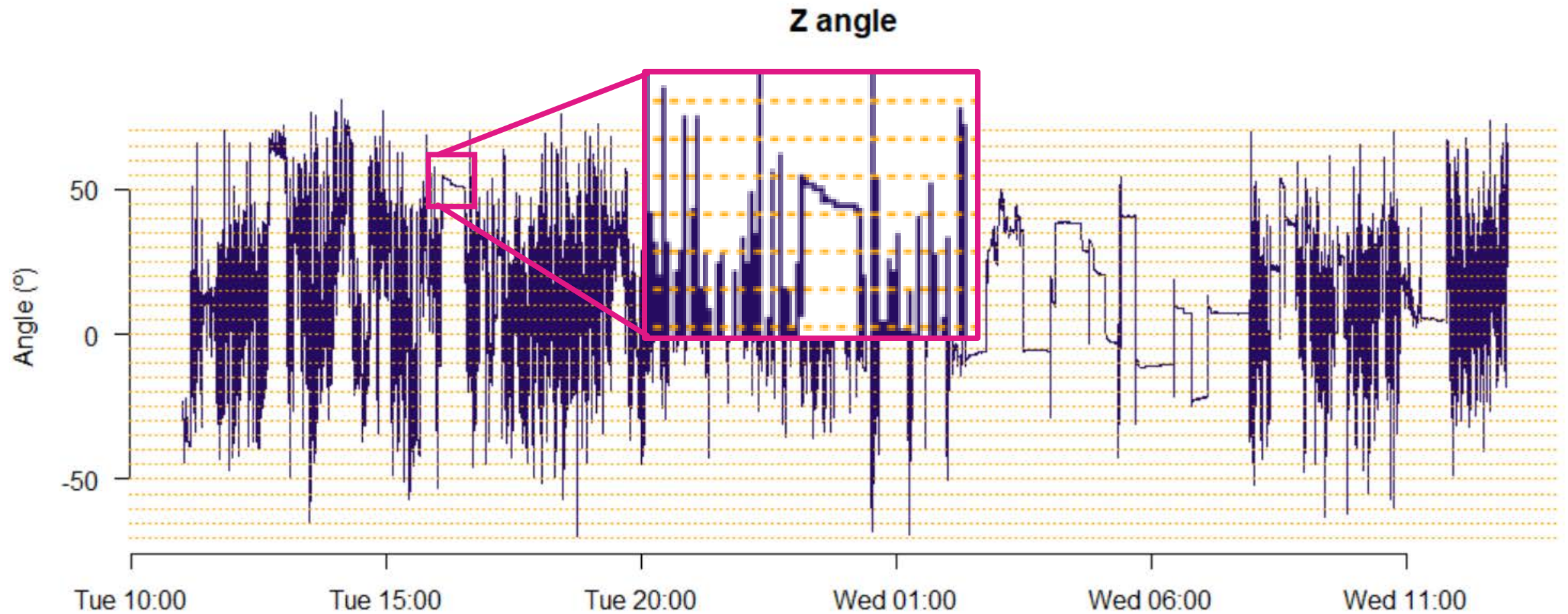


> 5 minutes



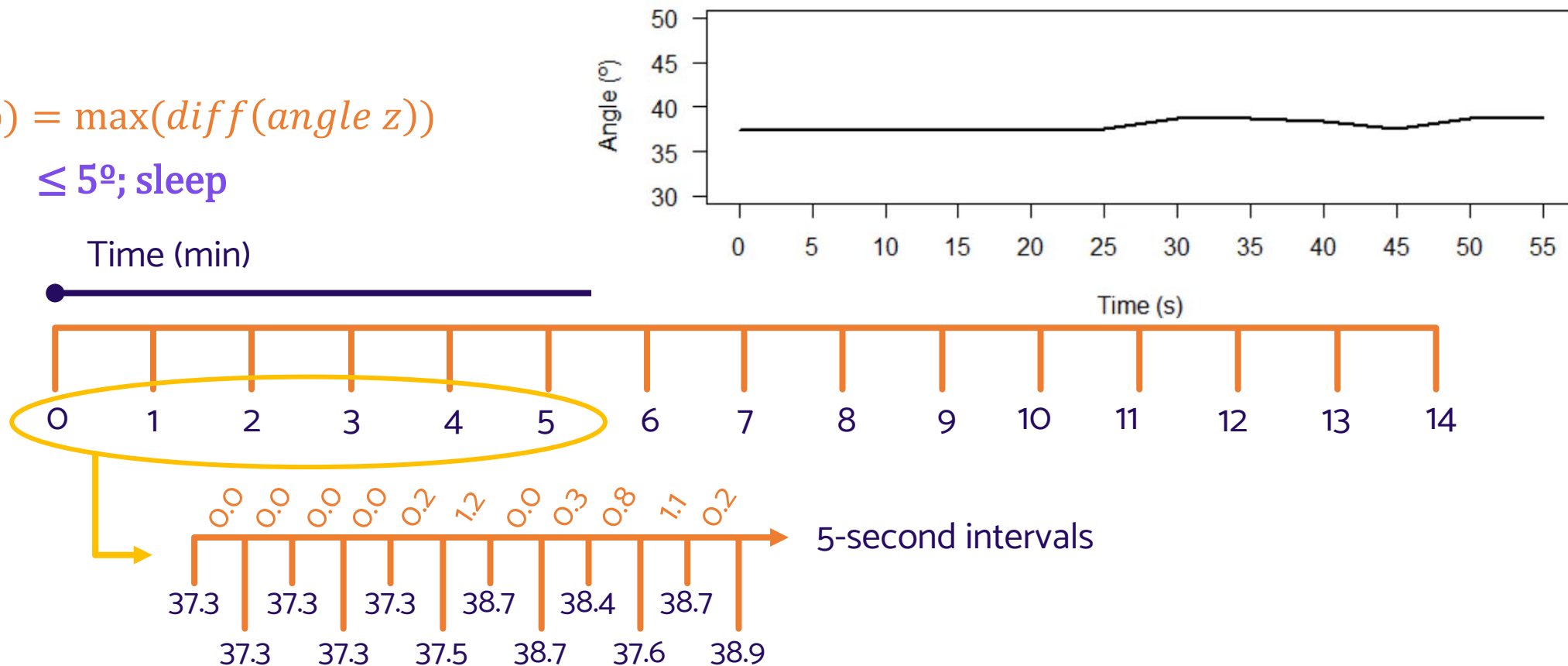
[This Photo](#) by Unknown Author is licensed under [CC BY-SA](#)

vanHees2015



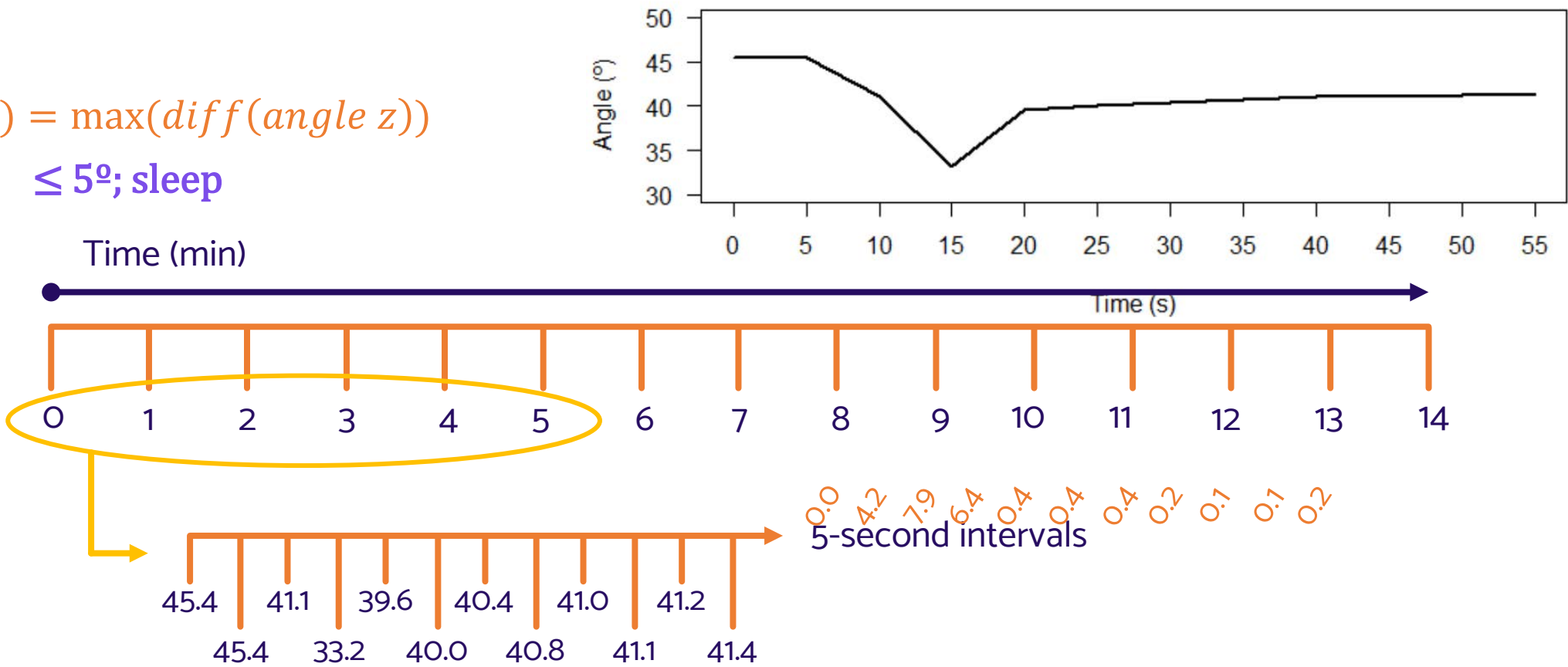
vanHees2015

$$p(\text{Sleep}) = \max(\text{diff}(\text{angle } z)) \leq 5^\circ; \text{sleep}$$

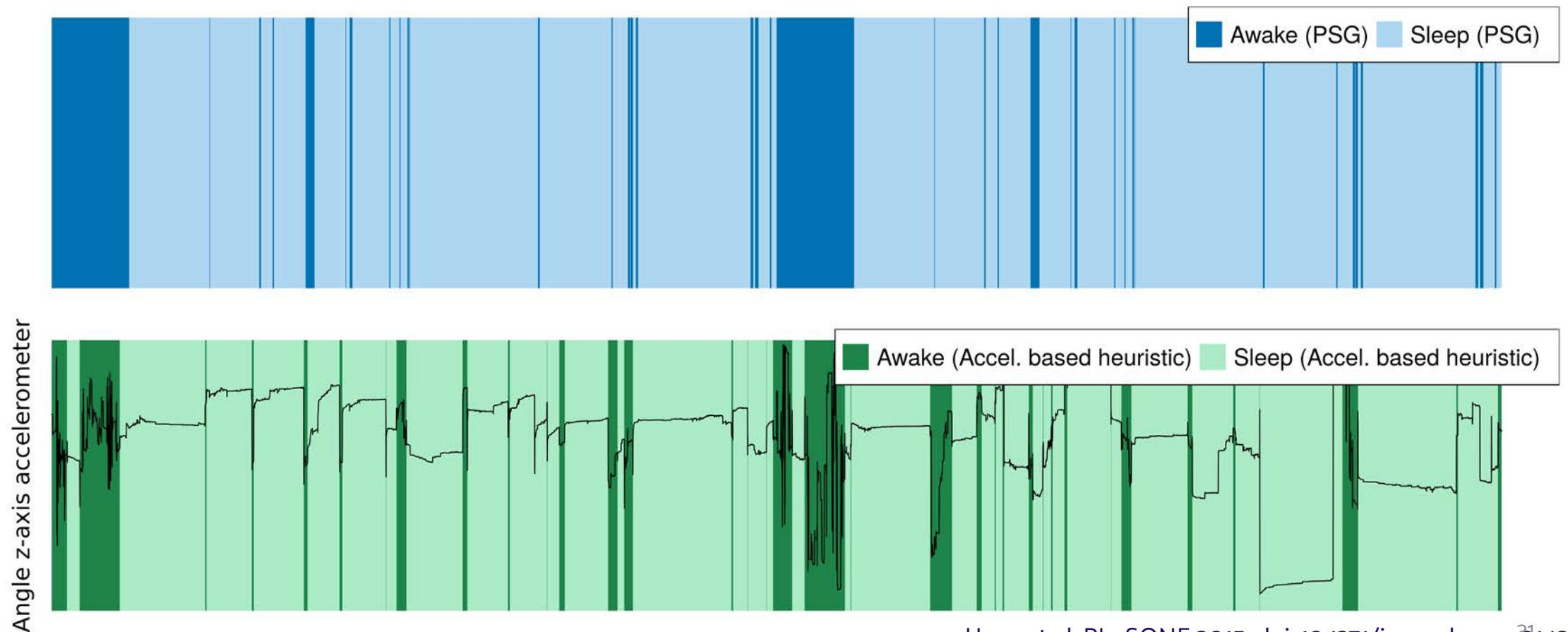


vanHees2015

$p(\text{Sleep}) = \max(\text{diff}(\text{angle } z))$
 $\leq 5^\circ; \text{sleep}$



vanHees2015



The GGIR()

Sleep analysis

```
GGIR(  
  [...]  
  # Acceleration metrics  
  do.anglez = TRUE,  
  # Sleep analysis  
  HASIB.algo = "vanHees2015",  
  anglethreshold = 5,  
  timethreshold = 5,  
  [...])
```

Count-based algorithms

- Sadeh1994
- ColeKripke1992
- Galland2012



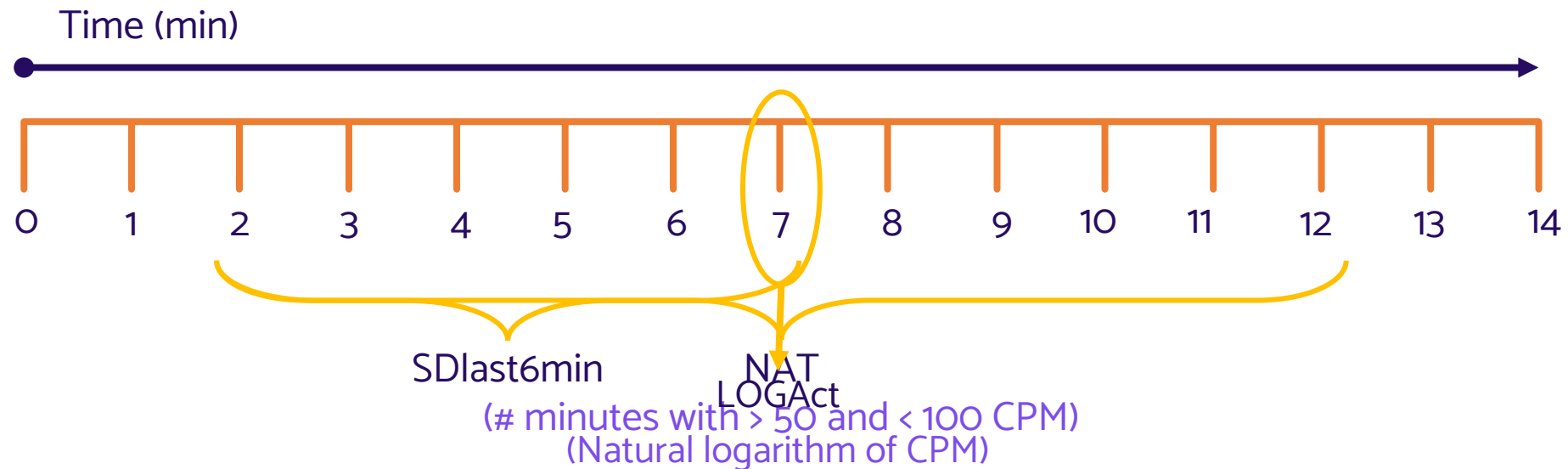
For reflection on:

- Count-based algorithms see: https://wadpac.github.io/GGIR/articles/chapter8_SleepFundamentalsSibs.html#sib-count-based-algorithms-experimental
- Replicating the original zero-crossing count see: https://wadpac.github.io/GGIR/articles/chapter4_AccMetrics.html#notes-on-implementation-of-zero-crossing-counts

Count-based algorithms

“Sadeh1994”

$$p(\text{Sleep}) = 7.601 - 0.065 \cdot \text{MeanCPM5 min} - 1.08 \cdot \text{NAT} - 0.056 \cdot \text{SDlast6min} - 0.703 \cdot \text{LOGAct} \\ \geq 0; \text{ sleep}$$

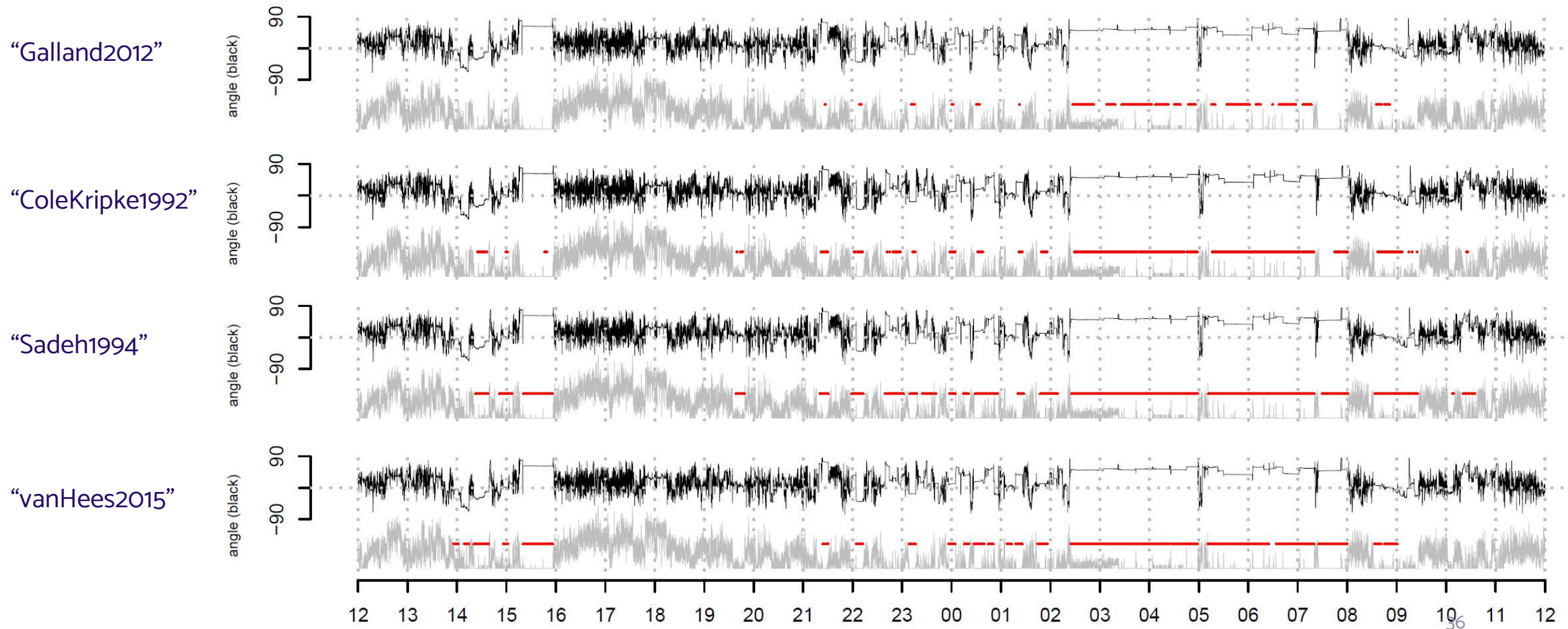


The GGIR()

Sleep analysis

```
GGIR(  
  [...]  
  # Acceleration metrics  
  do.zcx = TRUE, do.zcy = TRUE, do.zcz = TRUE,  
  do.neishabouricounts= TRUE,  
  # Sleep analysis  
  HASIB.algo = "Sadeh1994",  
  Sadeh_axis = "Y",  
  [...])
```

Rest/Wake detection



Rest/Wake detection

Summary of algorithms to detect SIBs in GGIR

Algorithm	Population	Device	Attachment site
vanHees2015	Adults n = 28 (11 female), 21-72 yr	GENEActiv	Wrist
Sadeh1994	Adults n = 20 (11 female), 21-25 yr Children n = 16 (11 female), 10-16 yr	AMI Motionlogger actigraph	Wrist
ColeKripke1992	Adults n = 41 (9 female), 50 ± 15 yr	AMI Motionlogger actigraph	Wrist
Galland2012	Infants n = 33 (9 female), 10-22 weeks	Actical	Shin

Sleep Period Time



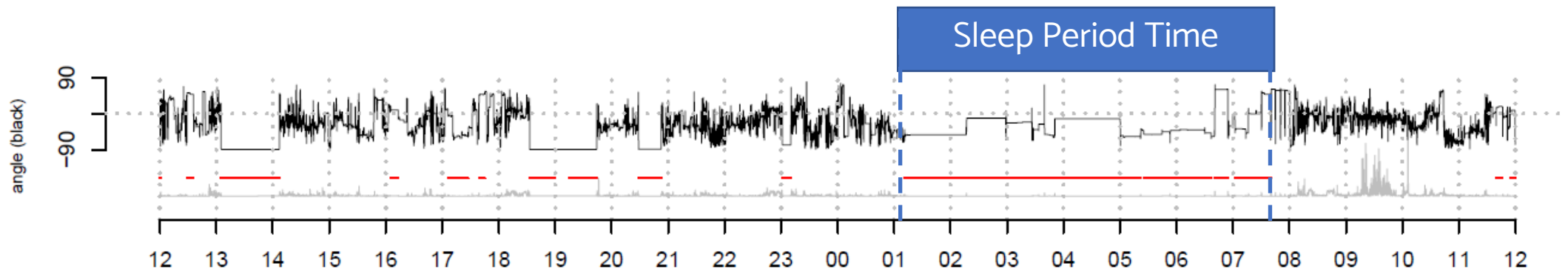
The GGIR pipeline



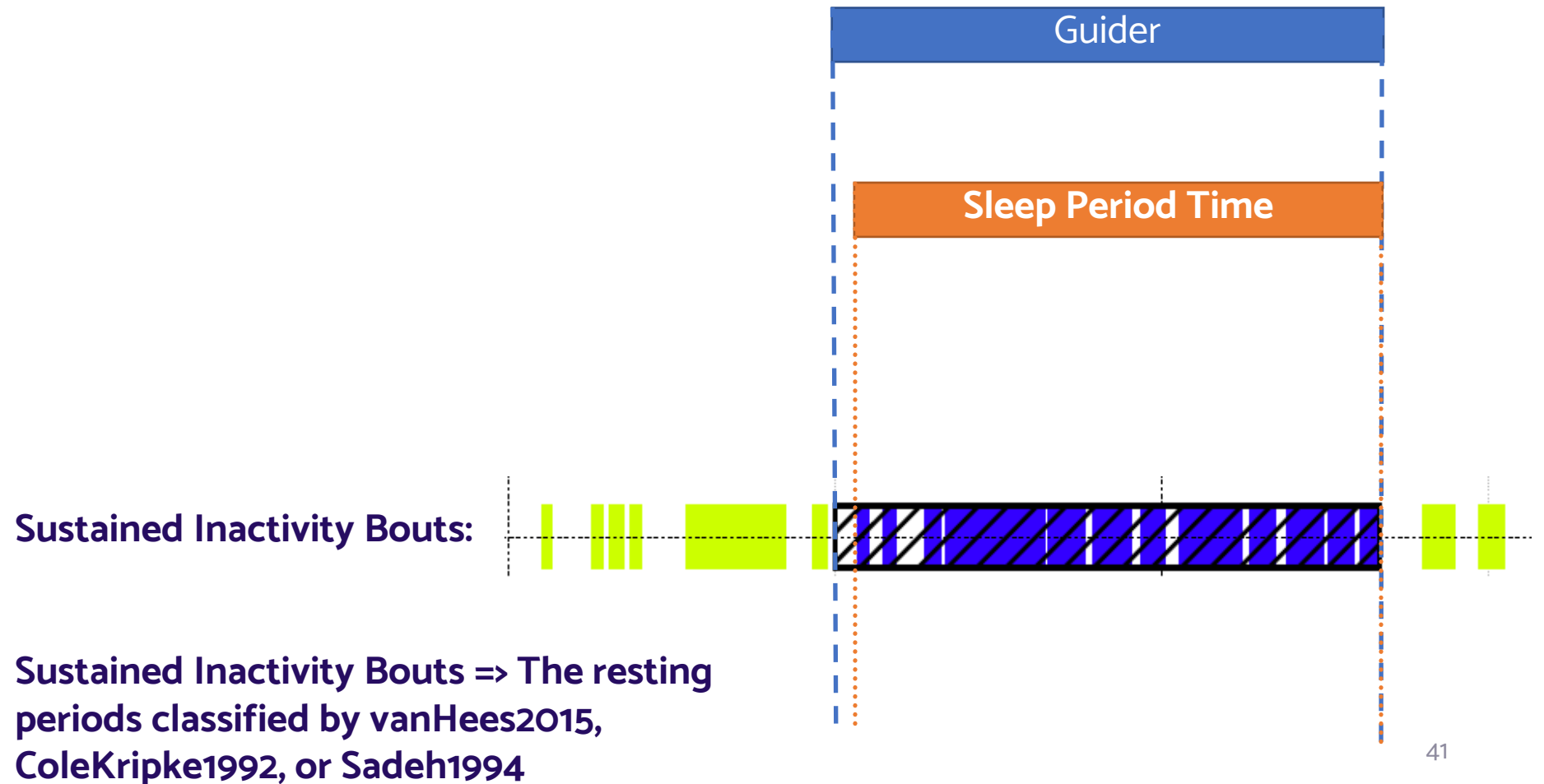
Accelerometer-based sleep assessment

Free living

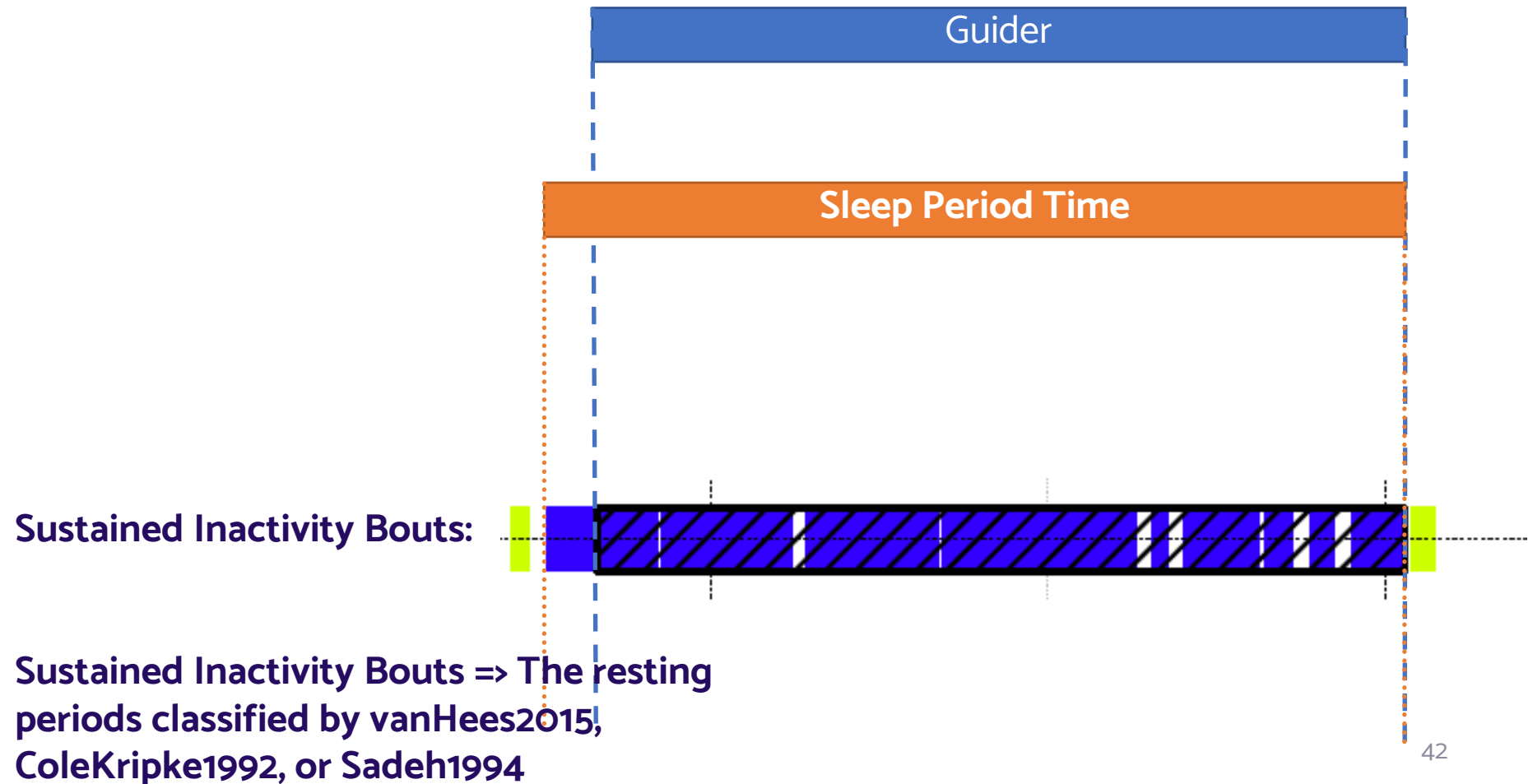
- **Challenge 2:** separate daytime and nighttime (**Sleep Period Time**)
 - Algorithms
 - Sleep diaries



“Guiders” to guide SPT window detection



“Guiders” to guide SPT window detection



Guiders

Guider	Definition	Relevant arguments to use it
HDCZA		
HorAngle		
sleep log		
NotWorn		

HDCZA algorithm

- No convincing gold standard exists for free-living conditions
- Heuristic method, 'trained' with unlabeled data from 20 random individuals.

Change in wrist angle over time invariant to sensor orientation

5 second rolling medians of raw signals x, y, z

$$\text{angle}_z = \left(\tan^{-1} \frac{a_z}{\sqrt{a_x^2 + a_y^2}} \right) \cdot 180/\pi$$

Consecutive 5 second averages

Absolute difference between successive values

Rolling median using 5 minute window

Detect when values < (10th percentile of values in day* · 15)

Keep blocks > 30 minutes

Include time gaps < 60 minutes

Longest block in day*

Guider-window

Threshold per individual

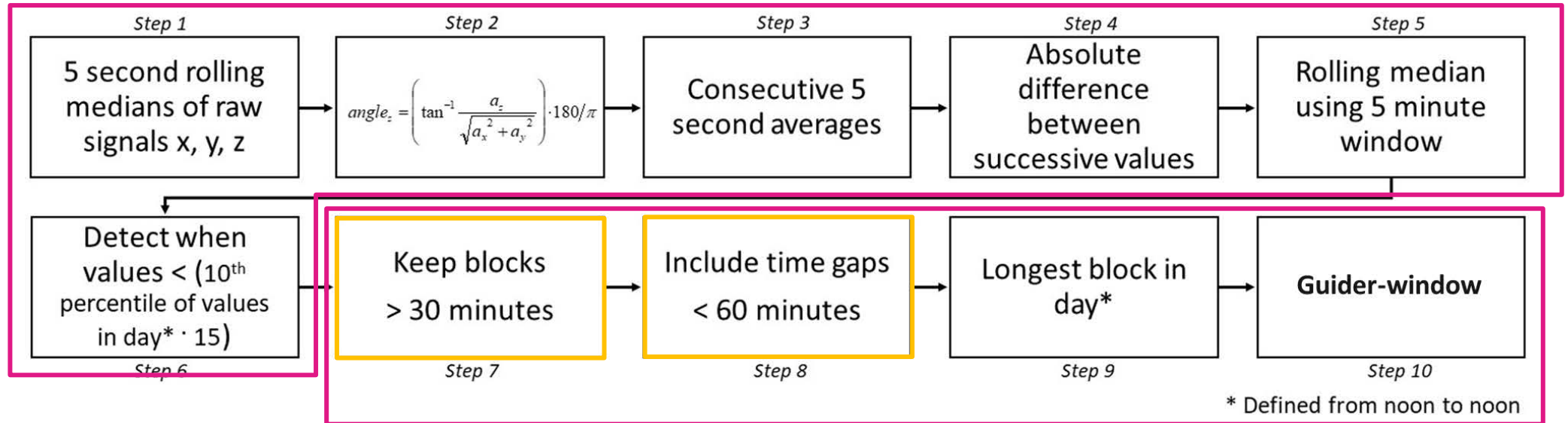
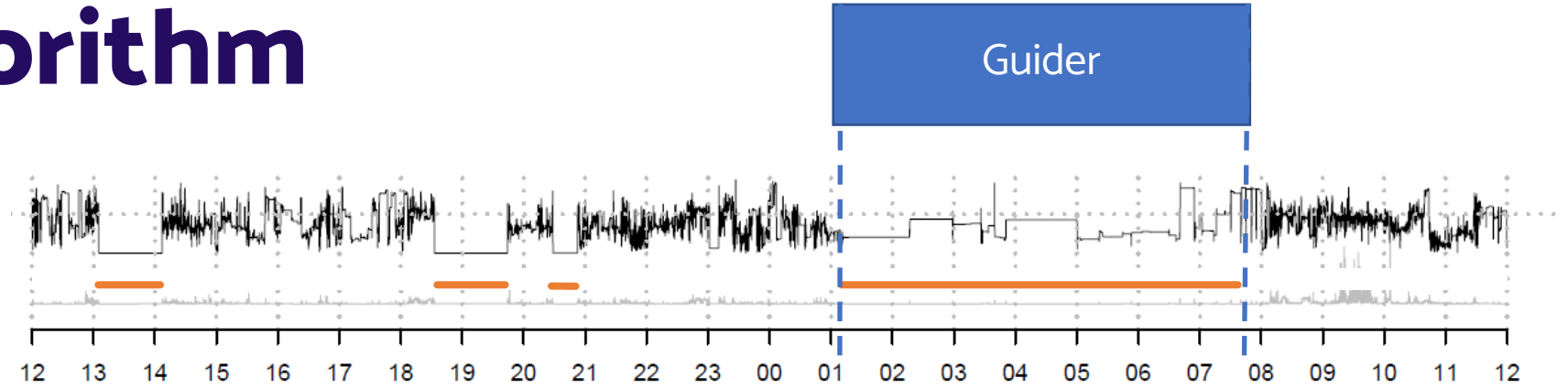
My assumptions about what a sleep period is

Step 10

* Defined from noon to noon

HDCZA algorithm

HDCZA algorithm



How Guiders deal with Non-wear

- Parameter **HASPT.ignore.invalid** allows to indicate whether invalid time segments should be ignored in the guider detection.

- **FALSE** (default), invalid but imputed time segment are used.

Assumption that imputation takes care of missing data

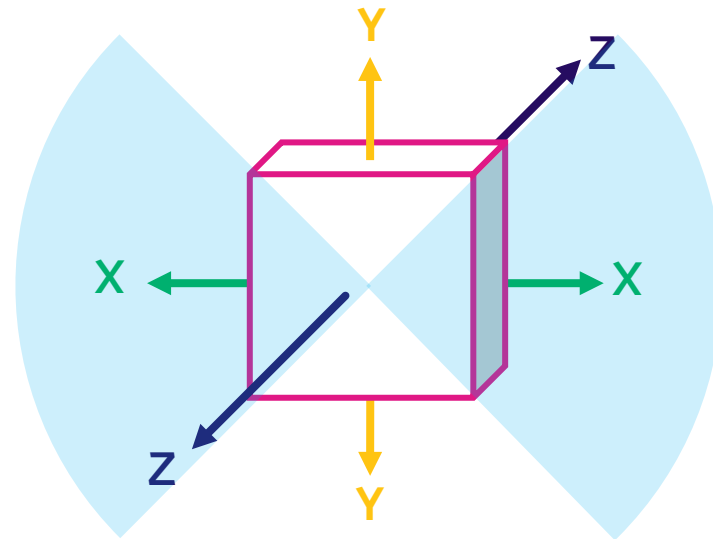
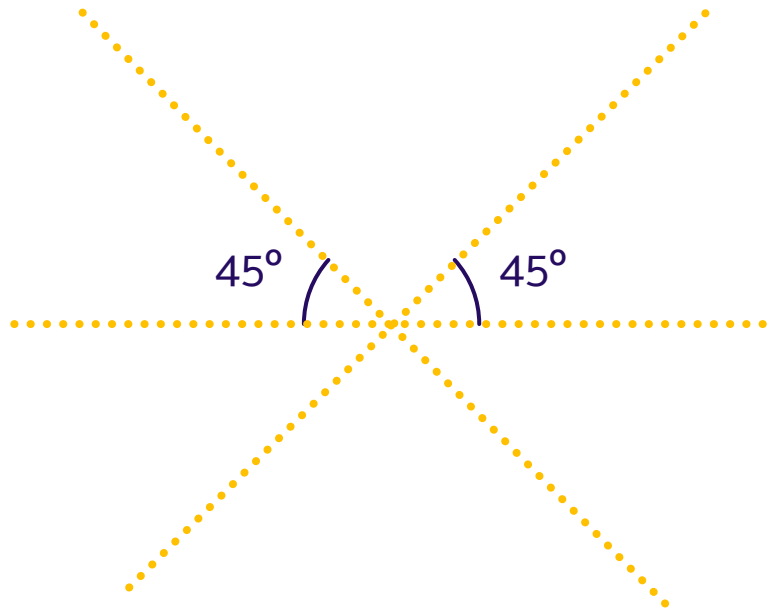
- **TRUE**, invalid time segments are ignored.

Sensor not worn during day

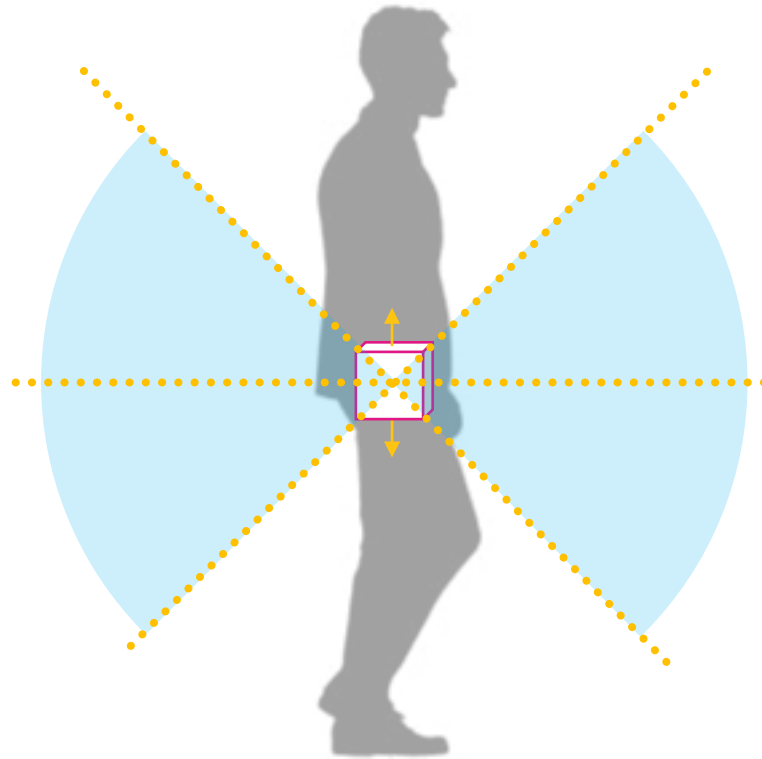
- **NA**, then invalid time segments are considered to be no movement segments in the guider detection.

Sensor possibly not worn during night or concern about accidentally detecting sleep as non-wear

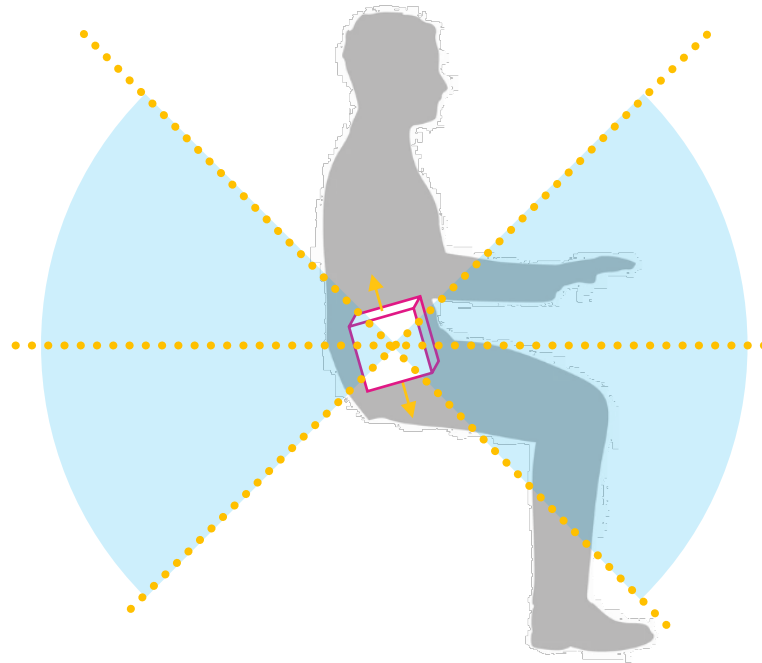
HorAngle algorithm



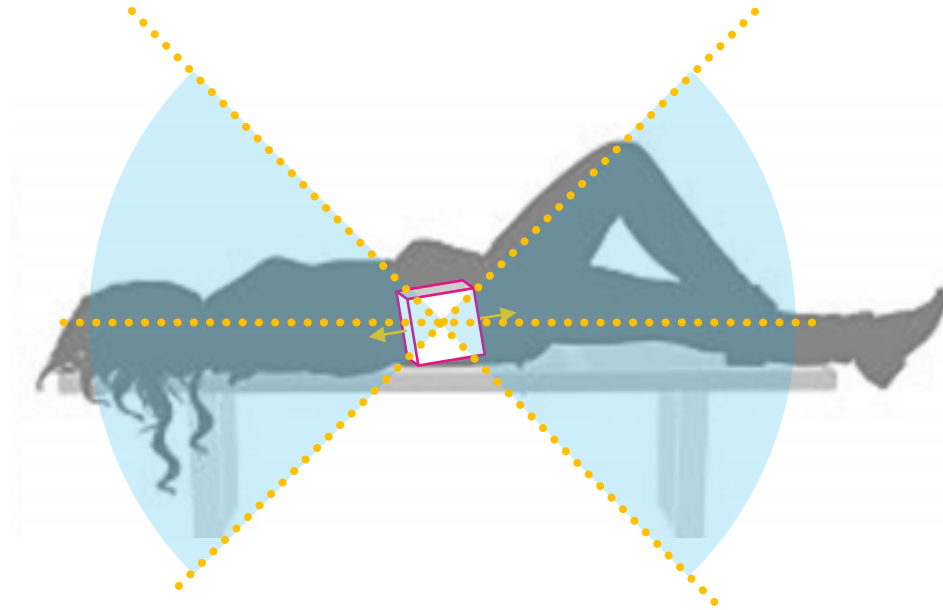
HorAngle algorithm (experimental)



HorAngle algorithm (experimental)



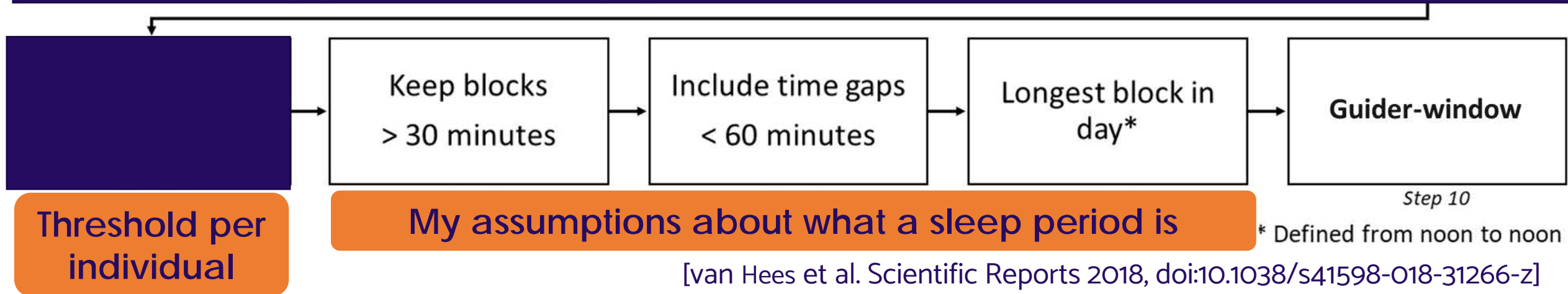
HorAngle algorithm (experimental)



HorAngle algorithm

Change in wrist angle over time invariant to sensor orientation

DETECTION OF PERIODS OF THE DAY LYING DOWN

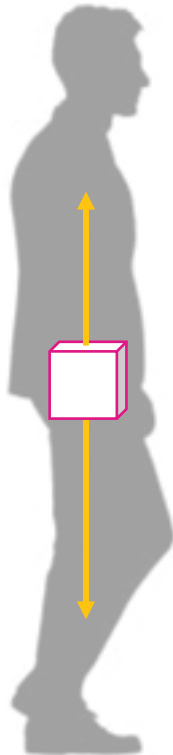


[van Hees et al. Scientific Reports 2018, doi:10.1038/s41598-018-31266-z]

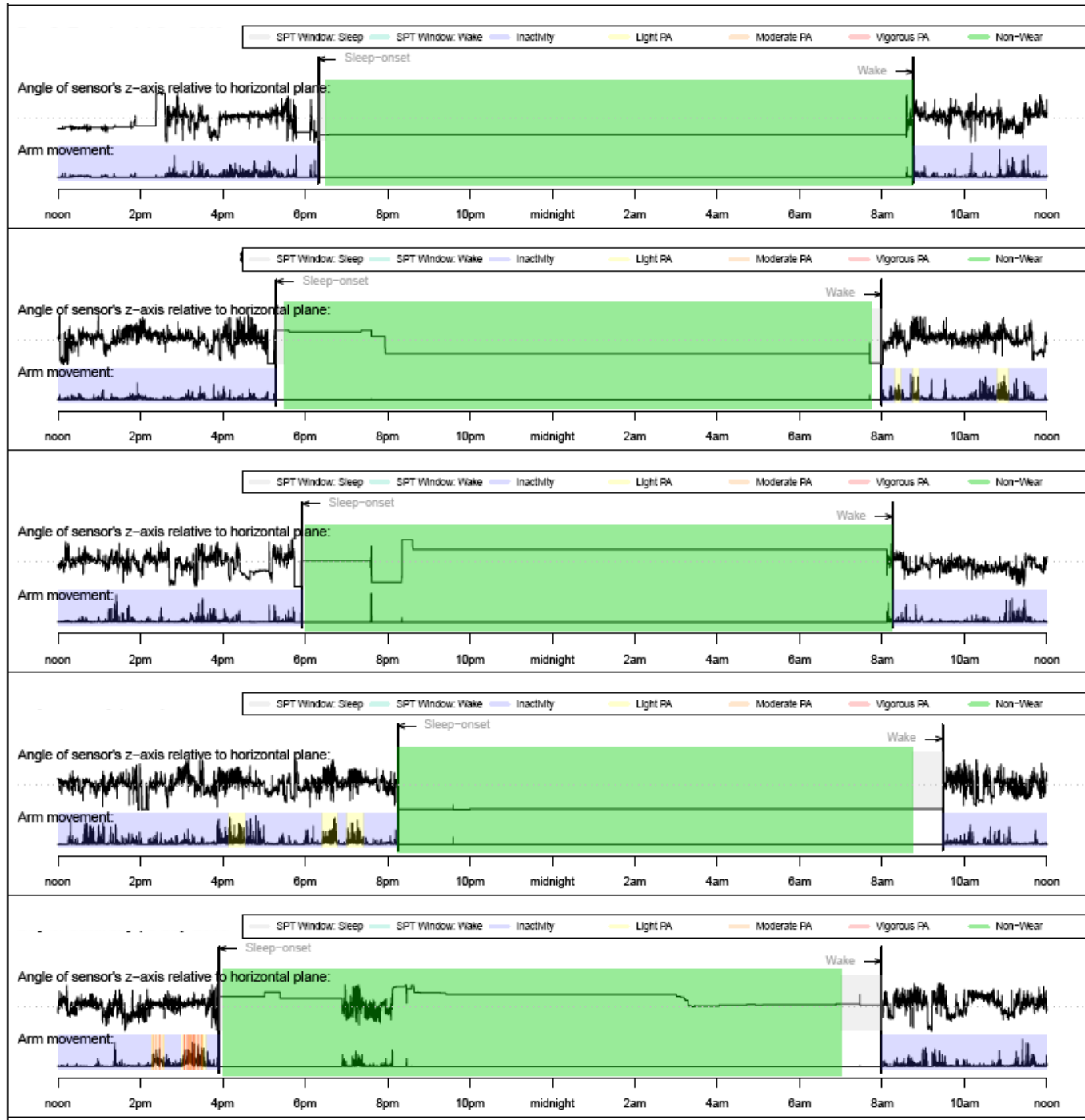
The GGIR()

Sleep analysis

```
GGIR(  
  [...]  
  # Sleep analysis  
  HASPT.algo = "HorAngle",  
  HASPT.ignore.invalid = NA,  
  sensor.location = "hip",  
  longitudinal_axis = 2, # if not provided it will be estimated  
  [...])
```



NotWorn



The GGIR()

Sleep analysis

```
GGIR(  
  [...]  
  # Sleep analysis  
  HASPT.algo = "NotWorn",  
  do.imp = FALSE,  
  HASPT.ignore.invalid = FALSE,  
  ignorenonwear = FALSE,  
  includenightcrit = 8,  
  includedaycrit = 8,  
  [...])
```

```
GGIR(  
  [...]  
  HASPT.algo = c("NotWorn", "HDCZA"),  
  [...])
```

```
GGIR(  
  [...]  
  HASPT.algo = c("NotWorn", "HorAngle"),  
  [...])
```

When worn for at
least 75% of the
time (in that night)

The GGIR()

Sleep analysis guided by heuristic algorithm

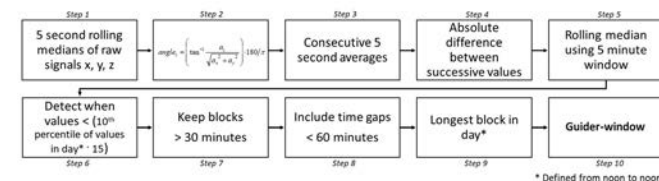
GGIR(

[...]

Sleep analysis

HASPT.algo = "HDCZA",

[...])



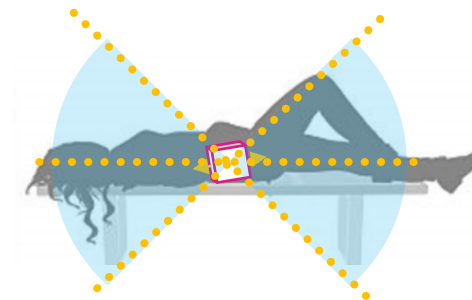
GGIR(

[...]

Sleep analysis

HASPT.algo = "HorAngle",

[...])



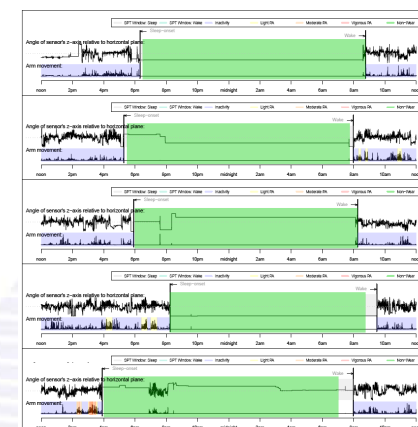
GGIR(

[...]

Sleep analysis

HASPT.algo = "NotWorn",

[...])



Sleeplog

```
GGIR(  
  [...]   
  # Sleep analysis  
  loglocation = "C:/mystudy/mysleeplog_basic.csv",  
  [...])
```

NOTE: If night is not available, in-built algorithms will be used

Basic sleeplog

colid = 1



coln1 = 2



ID	Onset_n1	Wakeup_n1	Onset_n2	Wakeup_n2	Onset_n3	Wakeup_n3	Onset_n4	Wakeup_n4
01	23:00:00	07:00:00	23:45:00	08:20:00	23:15:00	08:00:00	00:30:00	
02	22:30:00	07:30:00	22:35:00	07:00:00	23:45:00	09:05:00	23:44:00	09:00:00
03	23:45:00	07:10:00	00:02:00	08:30:00	22:50:00	07:25:00	23:00:00	07:38:00
04	00:10:00	09:00:00				07:30:00	00:25:00	09:10:00

Advanced sleeplog

colid = 1



Note: parameter coln1 is not needed and ignored

ID	D1_date	D1_wakeup	D1_inbed	D1_nap_start	D1_nap_end	D1_nonwear1_off	D1_nonwear1_on	D2_date
01	2022-06-24	07:00:00	23:15:00	15:00:00	15:45:00	13:35:00	14:10:00	2022-06-25
02	2022-06-26	07:30:00	23:45:00			09:05:00	10:30:00	2022-06-27
03	2022-07-24	07:10:00	22:50:00	13:02:00	13:30:00	18:00:00	19:10:00	2022-07-25
04	2022-06-14	09:00:00	00:50:00			20:30:00	21:00:00	2022-06-15

Advanced sleeplog

- Date columns → “date”
- Wakeup columns → “wakeup”
- Sleep onset columns → “onset”, “inbed”, “tobed”, “lightsout”
- Napping columns → “nap”
- Nonwear columns → “nonwear”

ID	D1_date	D1_wakeup	D1_inbed	D1_nap_start	D1_nap_end	D1_nonwear1_off	D1_nonwear1_on	D2_date
01	2022-06-24	07:00:00	23:15:00	15:00:00	15:45:00	13:35:00	14:10:00	2022-06-25

Guider & SIB => SPT

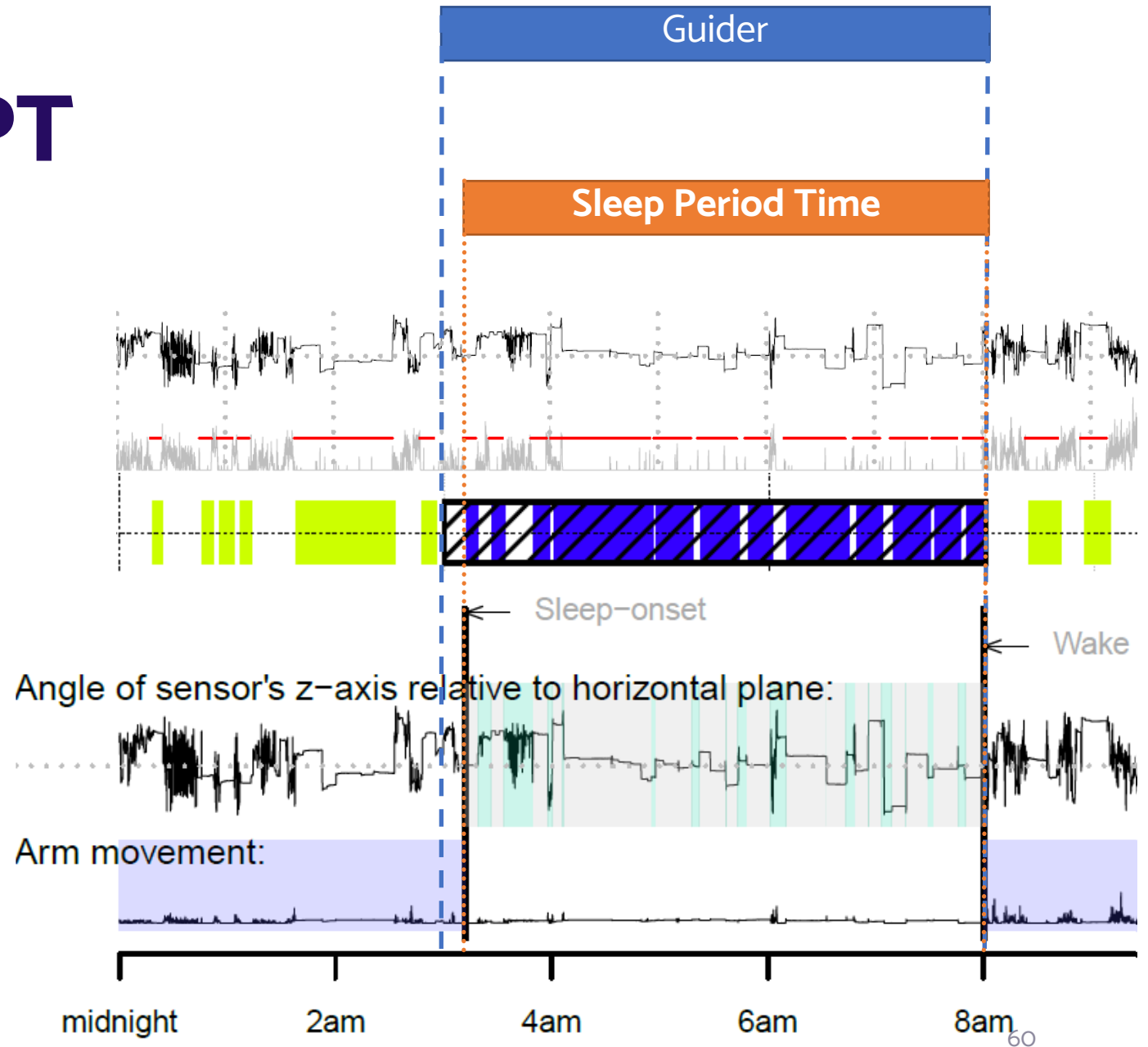
Default behaviour

Guider →

Sleep Onset	Wake
3:00:00	8:00:00

SPT →

Sleep Onset	Wake
3:12:05	8:00:00



Guider & SIB => SPT

Sleeplog: time in bed or lights out

GGIR(

[...]

Sleep analysis

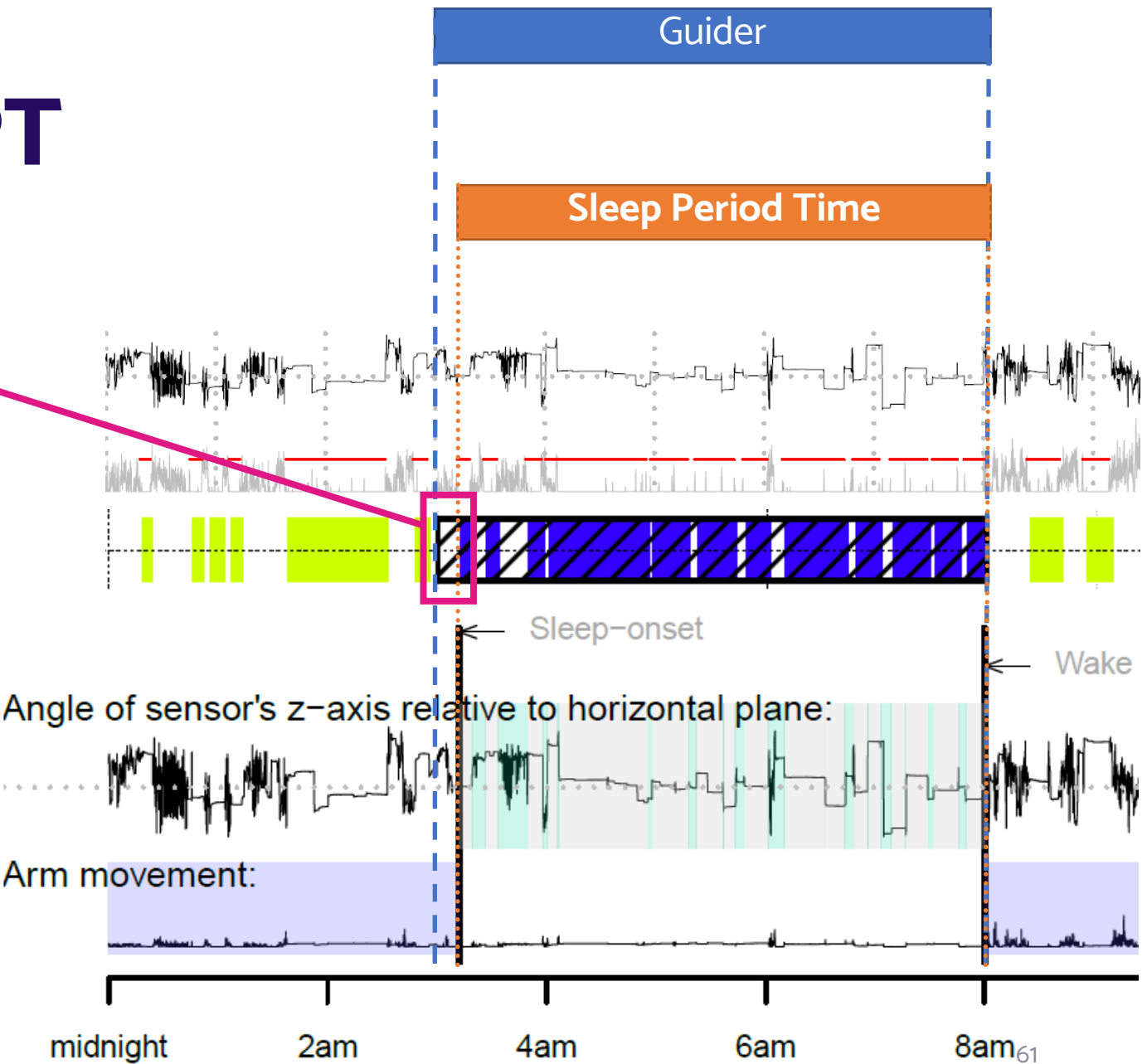
sleepwindowType = "TimeInBed",

[...])

Only relevant for
sleeplog as guider

Sleep Onset	Wake
3:12:05	8:00:00

Sleep latency
Sleep efficiency



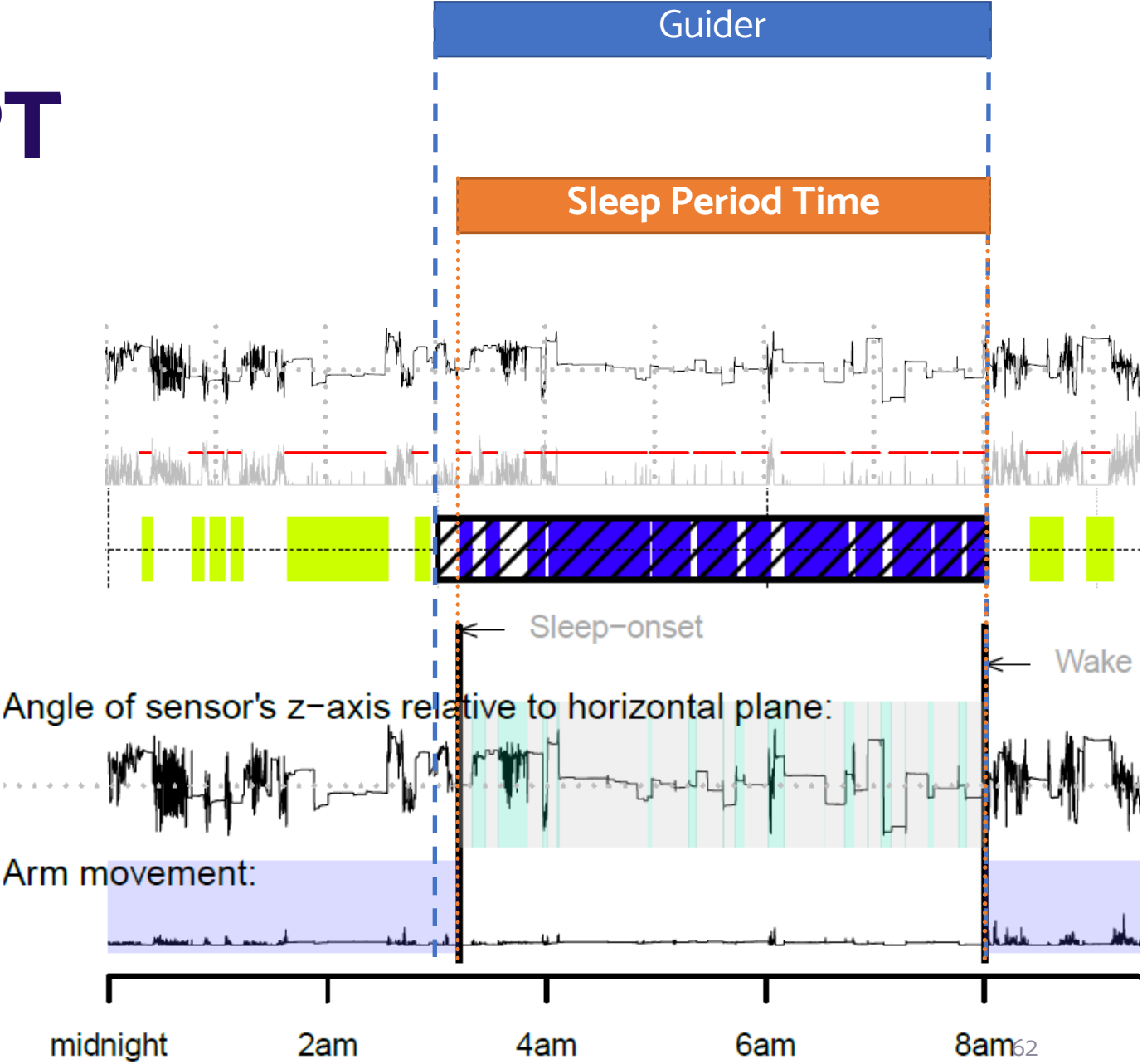
Guider & SIB => SPT

Sleeplog: time sleep onset

```
GGIR(  
  [...]  
  # Sleep analysis  
  sleepwindowType = "SPT",  
  [...])
```

Only relevant for
sleeplog as guider

Sleep Onset	Wake
3:12:05	8:00:00



The GGIR()

Sleep analysis guided by sleeplog

GGIR(

[...]

Sleep analysis with basic sleeplog

`loglocation` = "C:/mystudy/mysleeplog_basic.csv",

`colid` = 1, `coln1` = 2,

`sleepwindowType` = "SPT", **OR** `sleepwindowType` = "TimeInBed",

[...])

GGIR(

[...]

Sleep analysis with advanced sleeplog

`loglocation` = "C:/mystudy/mysleeplog_advanced.csv",

`colid` = 1,

`sleepwindowType` = "SPT", **OR** `sleepwindowType` = "TimeInBed",

[...])

Guiders

Summary of guiders

Guider	Definition	Relevant arguments to use it
HDCZA	HDCZA algorithm (van Hees 2018)	HASPT.algo = "HDCZA"
HorAngle	HorAngle algorithm intended to detect lying posture	HASPT.algo = "HorAngle" longitudinal_axis = 2 sensor.location = "hip"
sleep log	Reported sleep diaries (basic or advanced)	loglocation = "C:/mystudy/sleeplog.csv" sleepwindowType = "TimeInBed" or sleepwindowType = "SPT" colid = 1 If basic sleeplog: coln1 = 2
NotWorn	NotWorn algorithm aimed to use the longest non-wear period	HASPT.algo = "NotWorn" do.imp = FALSE, HASPT.ignore.invalid = NA, ignorenonwear = FALSE, includenightcrit = 8, includedaycrit = 8

“Unusual” sleepers

- More than one sleep period time per day?
- Daysleeper?
 - If sleeplog wake-up > 12pm → re-do sleep analysis from 6pm-to-6pm
 - If other guider wake-up > 11am → re-do sleep analysis from 6pm-to-6pm
 - Classified as daysleeper in reports
 - Intended to adapt the algorithm to night workers

Other input parameters

GGIR(
[...]

[...]

Data cleaning

do.report = 4,

includenightcrit = 16,

[...])



16 hours available from noon-to-noon or from 6pm-to-6pm

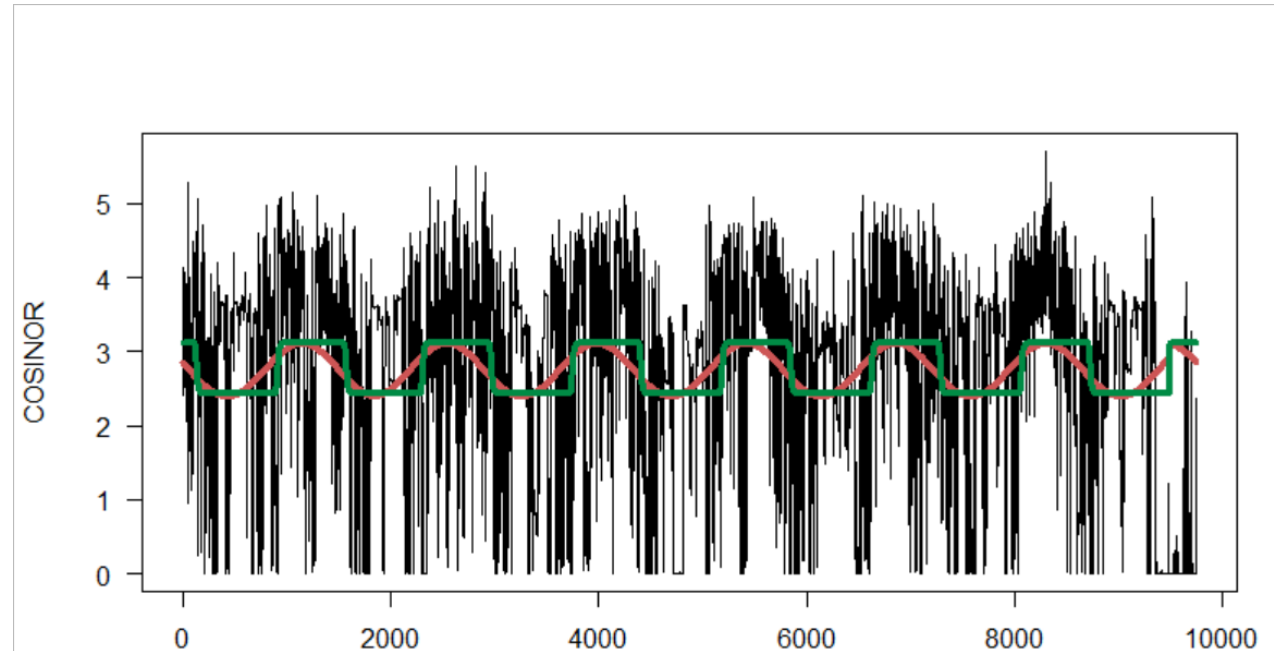
Other variables

Circadian rhythms

Part 2 & 6

- **MXLX** – (consecutive) Most and Least active X hours
 - Timing (start time)
 - Average acceleration
 - Intensity gradient
- Cosinor & Extended Cosinor (Marler et al. 2006)

```
GGIR(  
  [...]  
  winhr = c(5, 10),  
  cosinor = TRUE,  
  part6CR = TRUE, mode = 6,  
  part6Window = c("start", "end")  
  [...])
```



Other variables

Circadian rhythms

```
GGIR(  
  [...]  
  IVIS.activity.metric = 2  
  IVIS_acc_threshold = 20  
  [...])
```

Part 2

- IV & IS – Intradaily Variability & Interdaily Stability (after van Witting 1990 and Someren 1996, both in Bio Psychiatry)
- Not perfect as original method description lacked detail on count calculation
- Currently being revised and optimized, and available in GGIR soon

Assignment 2 (build on assignment 1)

Preparation:

- Use the same script as in assignment 1.
- Copy this assignment to your R script and turn it into a comment by adding a # at the start of each line **Hint: A quicker way is to select the lines and press Ctrl+Shift+C**

Task:

1. Update your R script to analyse the data for sleep with GGIR part 3 and 4 with the sleeplog as provided.
2. Note that ID 4 does not have a sleeplog. Can you spot this in the output and can you see how GGIR handles this?
3. Look at the part4_nightsummary.csv column names, can you figure out what they mean?

Hint: The following page provides some guidance

<https://wadpac.github.io/GGIR/articles/GGIRoutput.html#ggir-part-4>

Day Evaluation

Thank you!

