Wearable Accelerometer Devices to Assess Sleep Disorders

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National Jewish Health

National Jewish Health® for kids

Website with Slides and Articles

https://www.nationaljewish.org/sdu-assessment

Overview

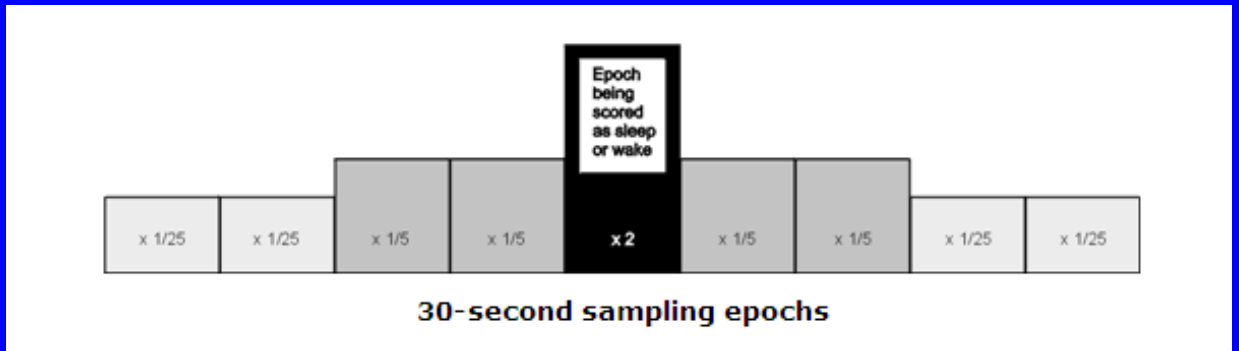
- What is actigraphy
- Understanding the actigram
- Research on actigraphy and commercial wearables in pediatrics
- ICSD-III indications for actigraphy
- Case studies / diagnose by diagram

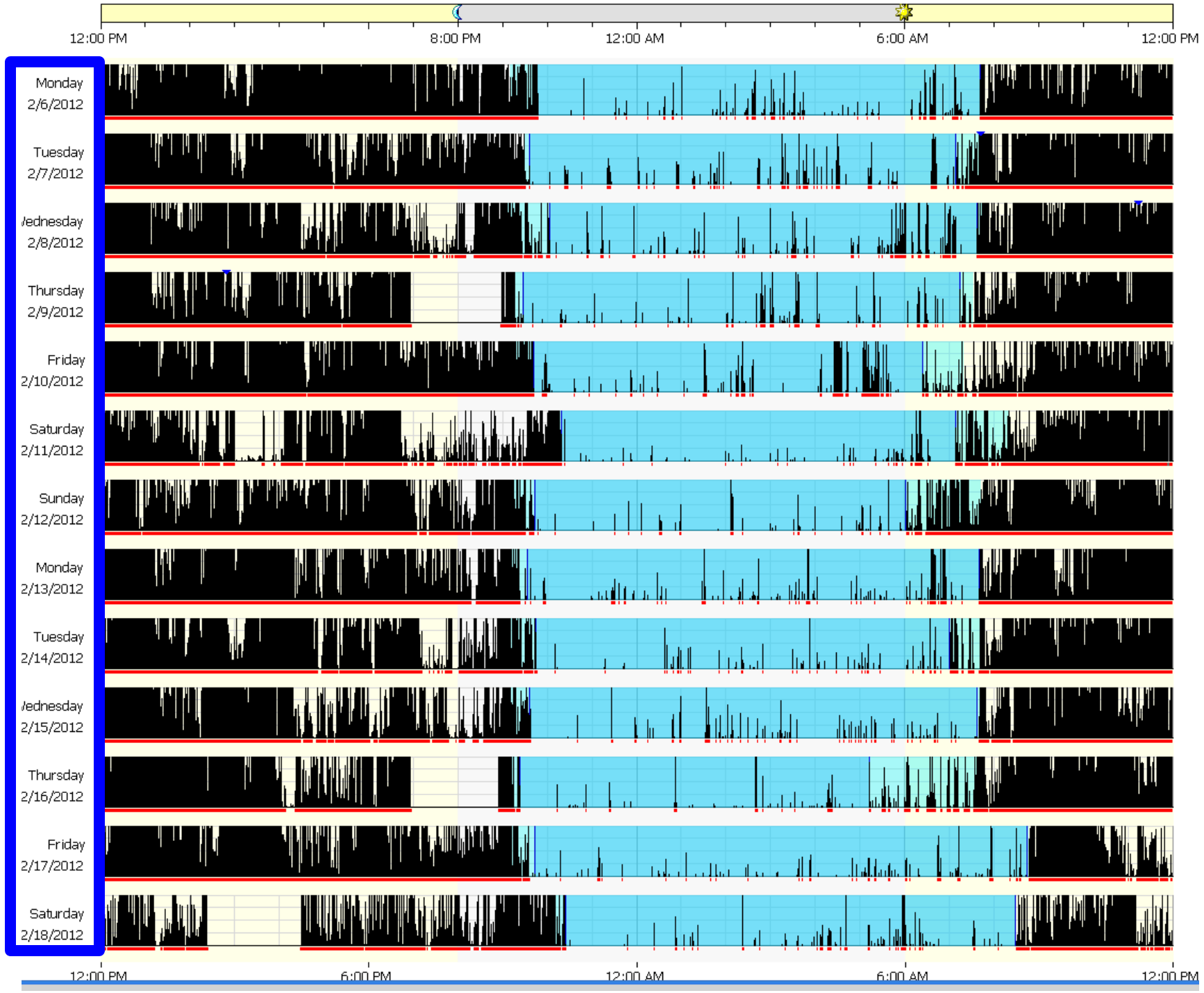
What is Actigraphy?

- Ambulatory device that measures movement with a piezoelectric accelerometer
  - *Movements are frequent and large during wakefulness, but absent or small during sleep*
- Worn on wrist for multiple 24-hour periods in the natural environment (i.e., 3-14 nights)
- Data stored for extended periods
- Reader/interface device used to transfer data from device to computer

Actigraphy *Estimates* Sleep

- Device-specific software used to score & analyze data
- Activity counts translated into epochs (e.g., 30 sec. or 1 minute)
- Algorithm used to determine if each epoch is “sleep” or “wake”
  - Based on activity count of that epoch, plus the epochs before and after

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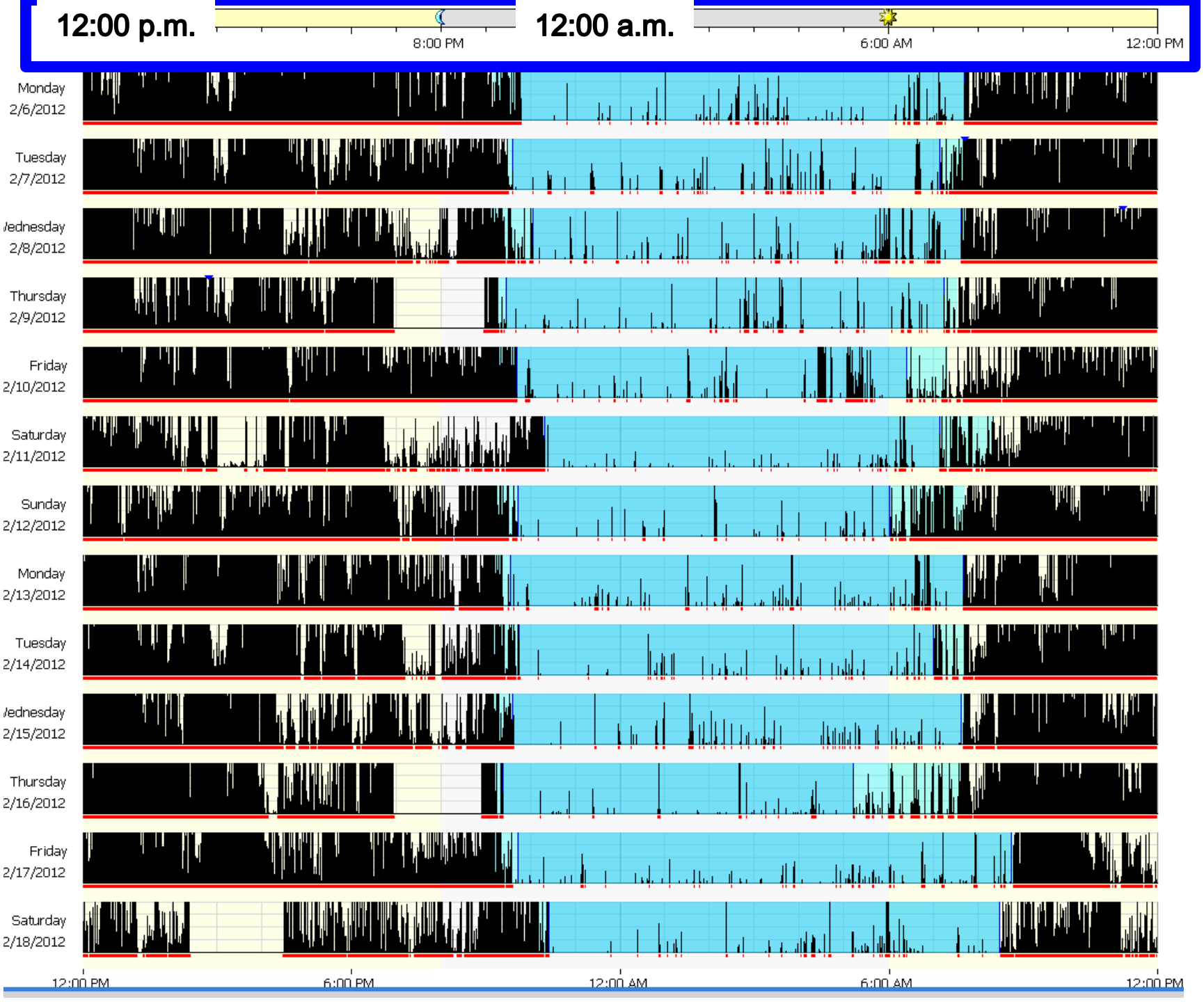
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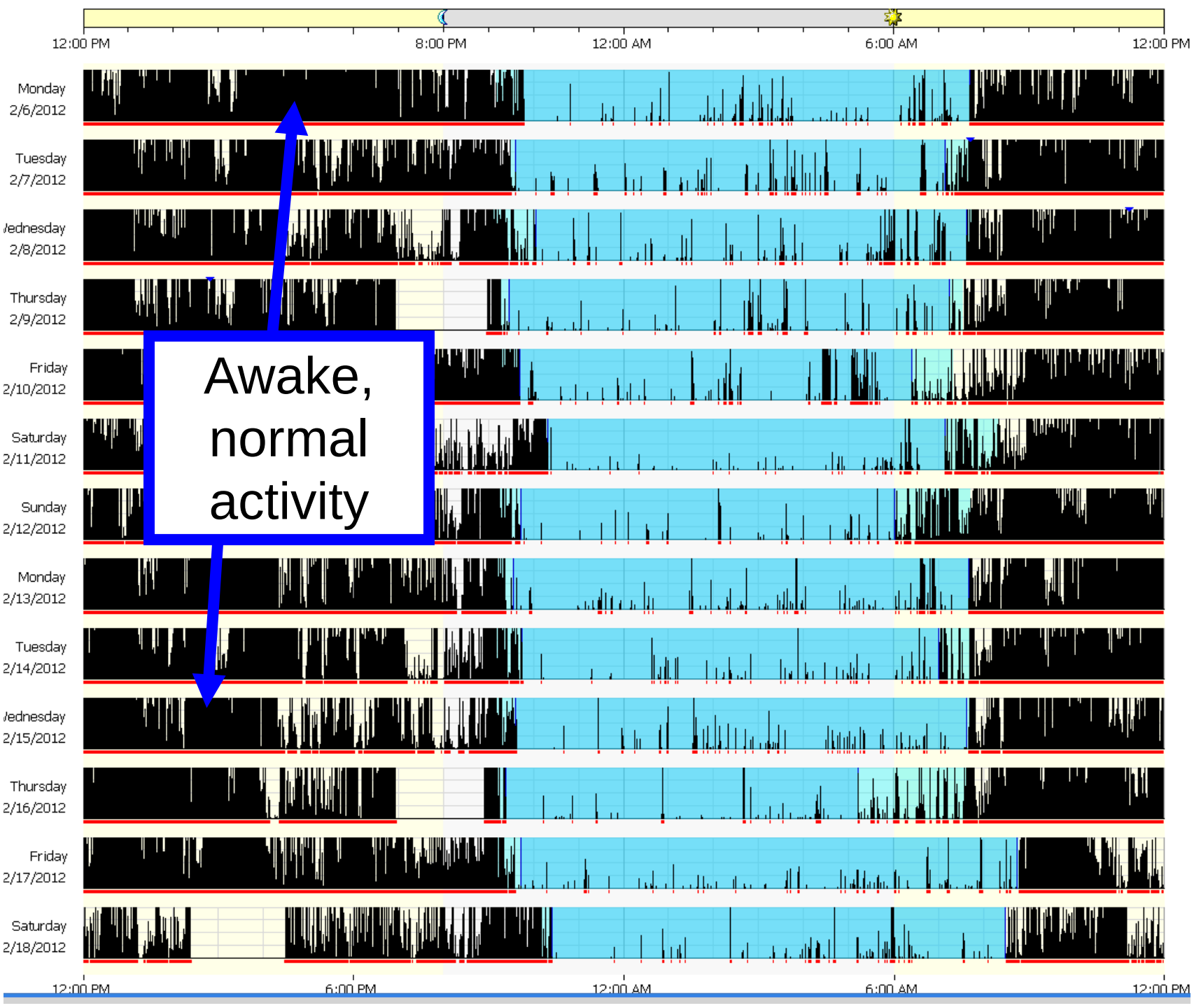
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Awake, normal activity
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6:00 PM
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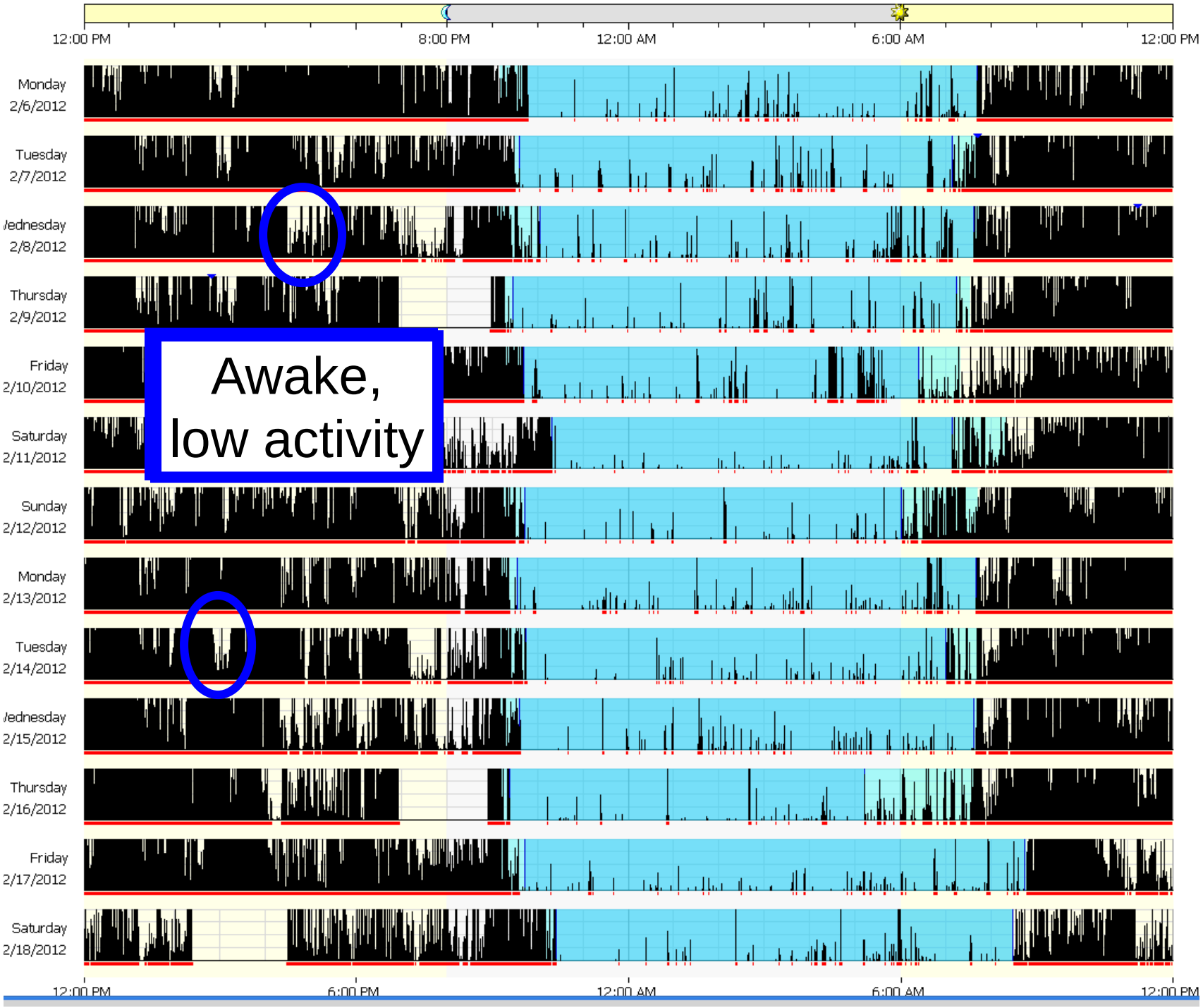
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Awake,
low activity
12:00 PM
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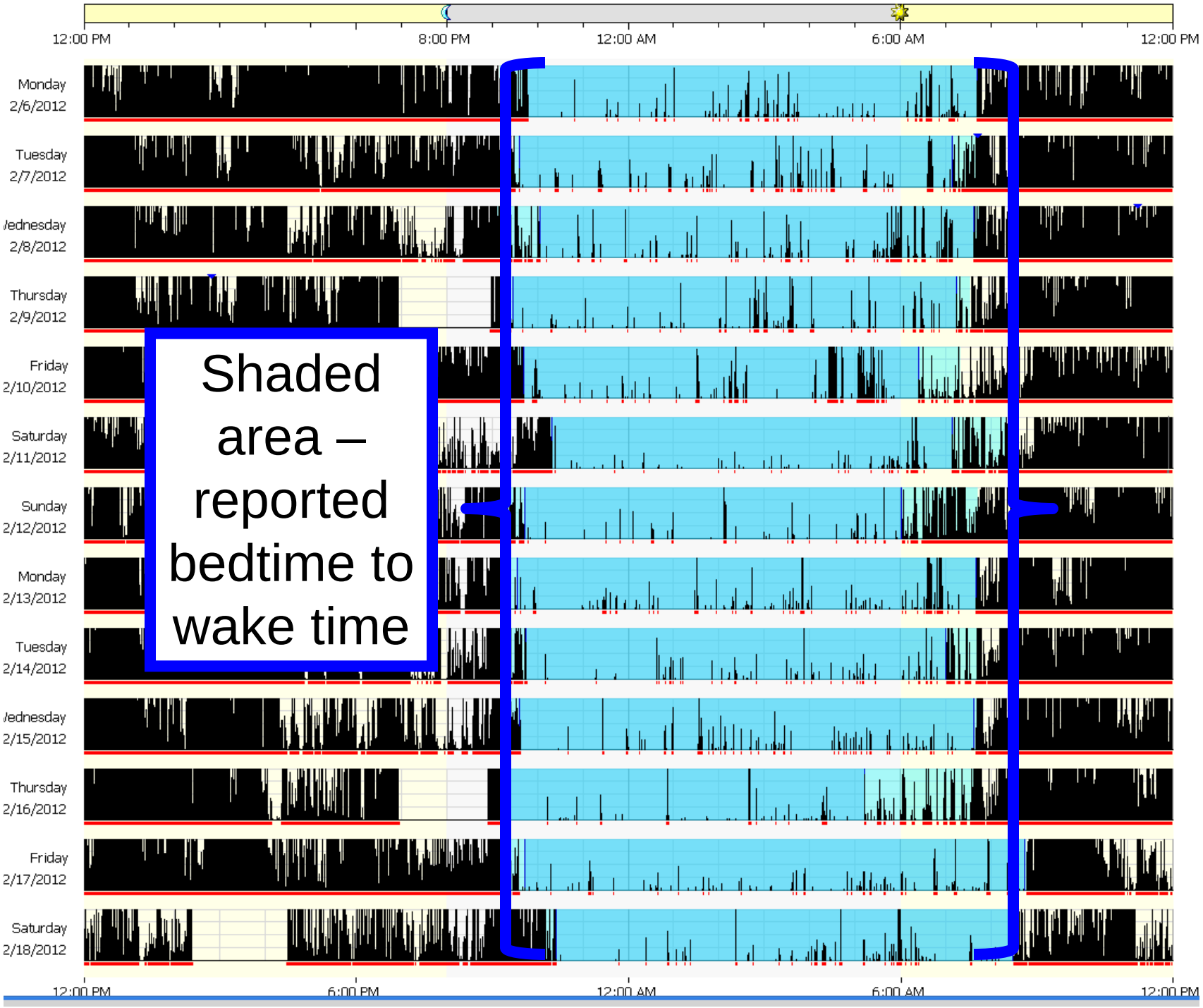
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Shaded area – reported bedtime to wake time
12:00 PM
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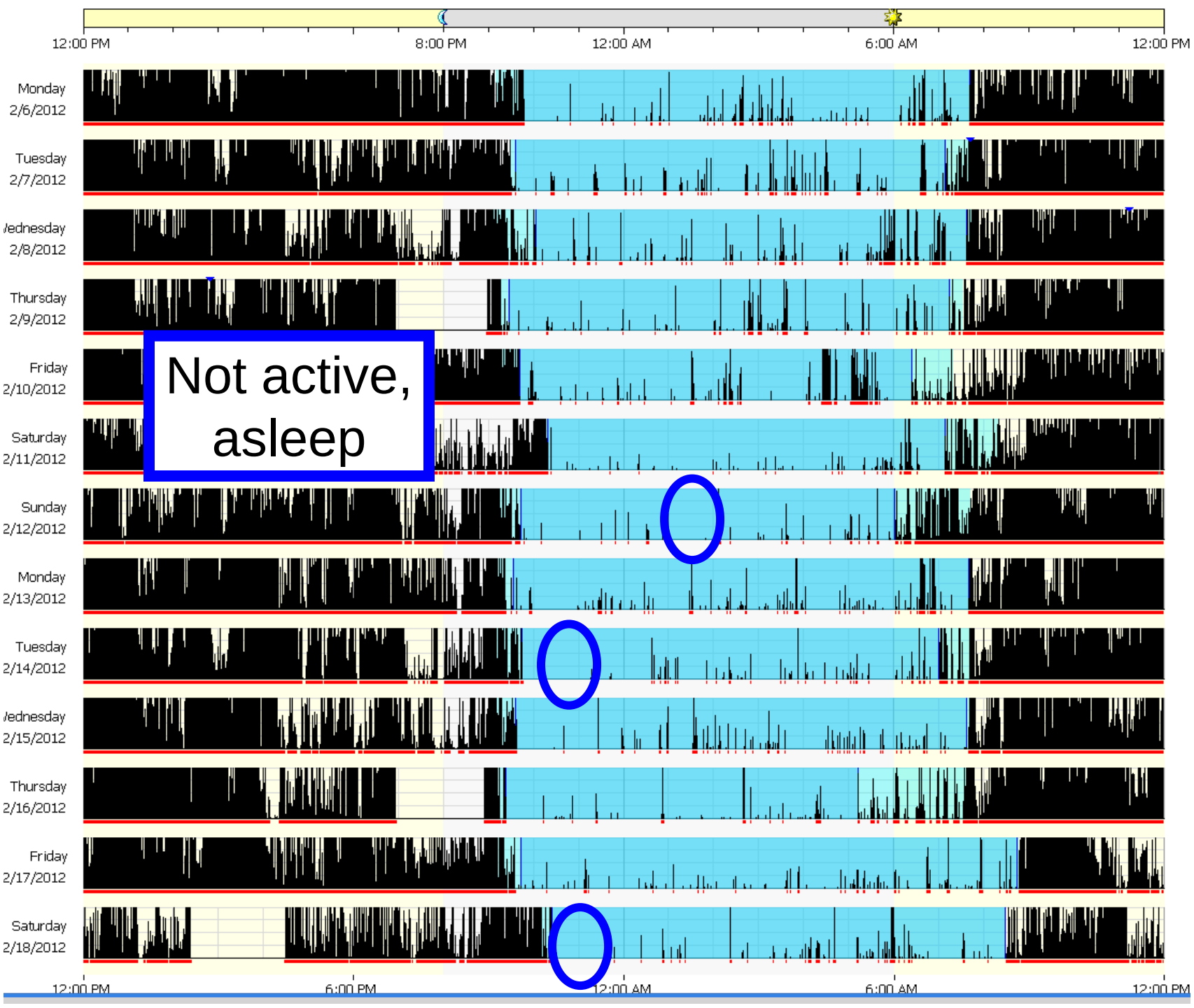
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Not active, asleep
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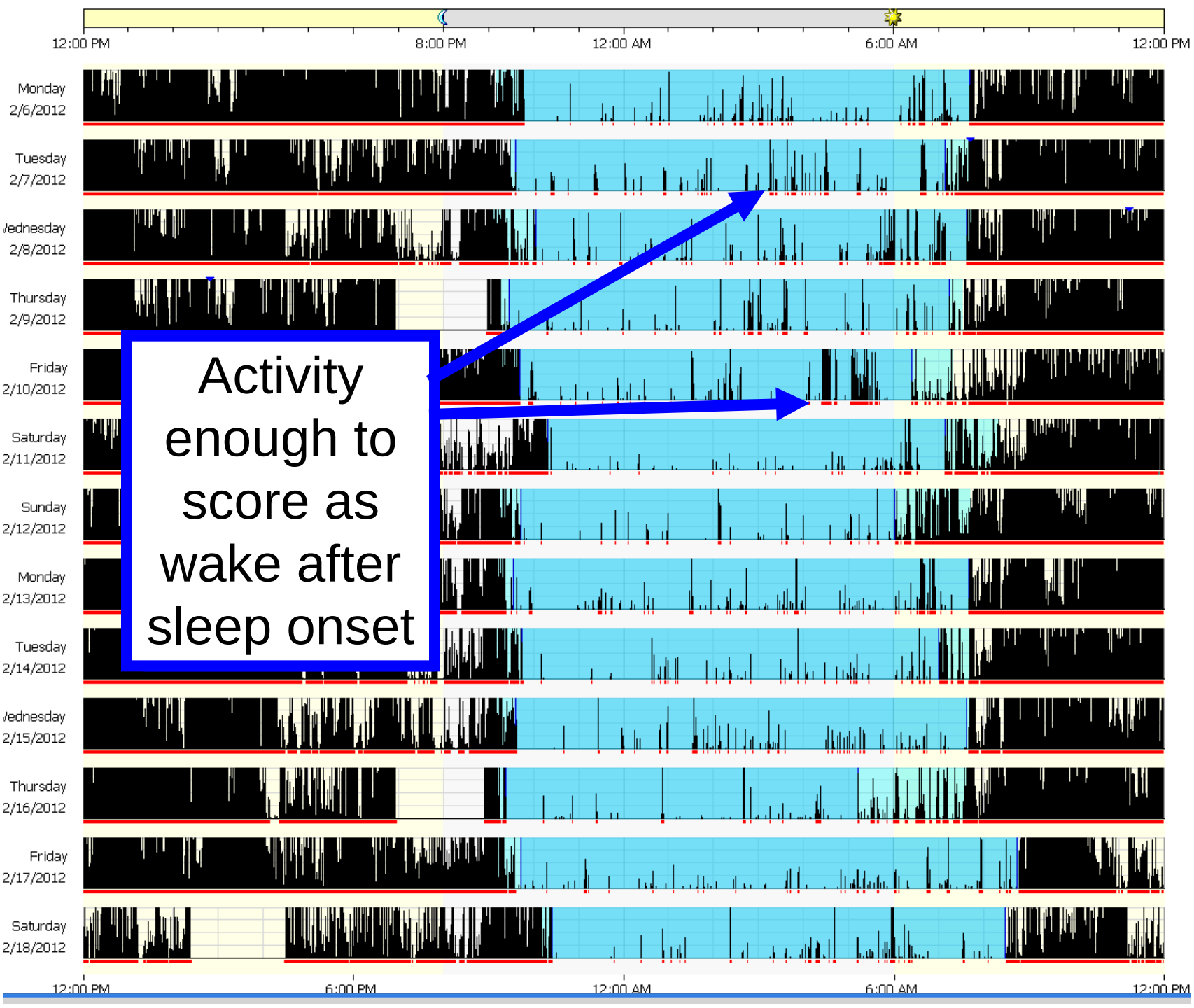
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Activity enough to score as wake after sleep onset
12:00 PM
6:00 PM
12:00 AM
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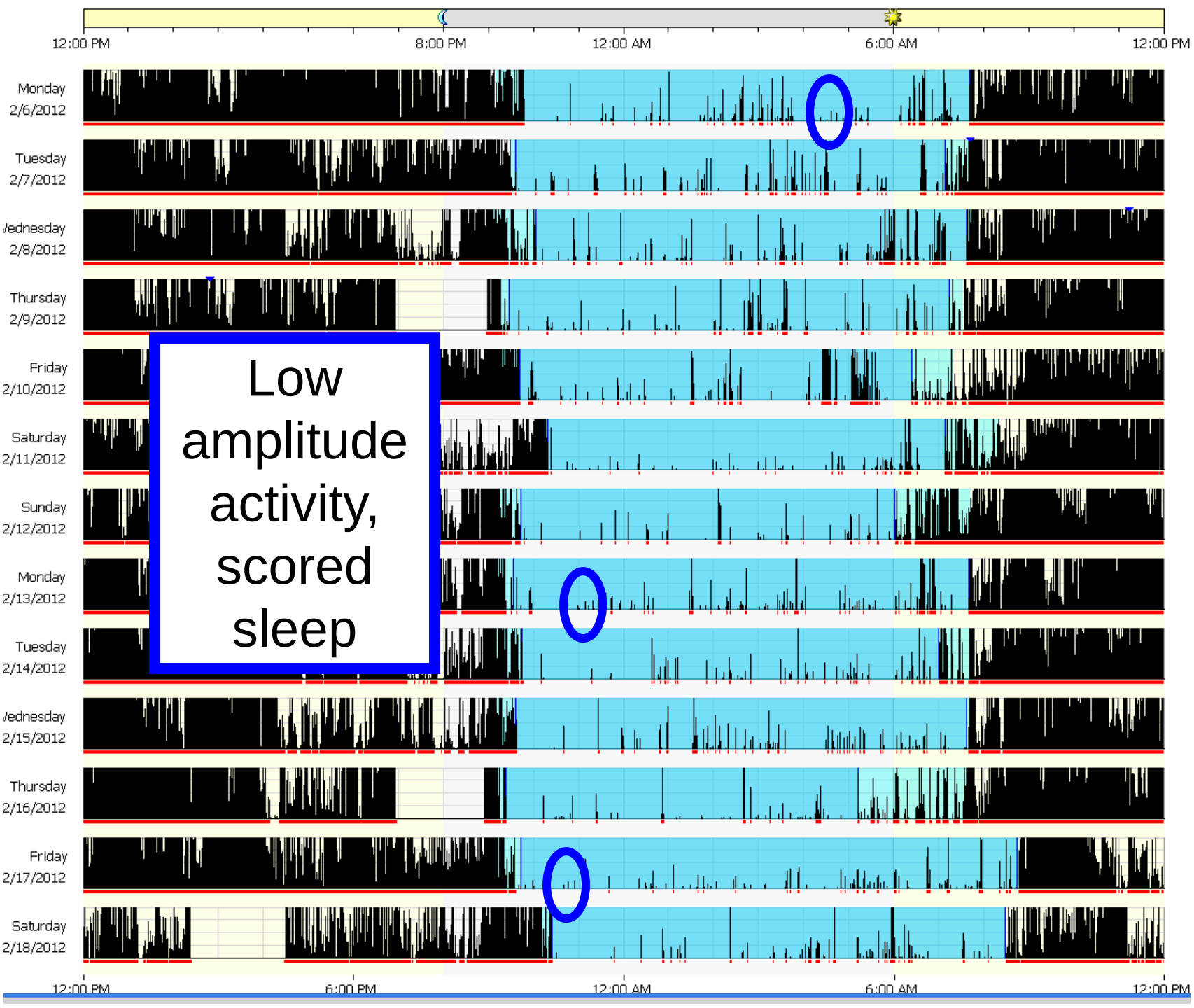
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2/16/2012
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12:00 PM
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12:00 AM
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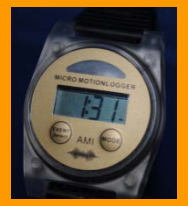
Low amplitude activity, scored sleep

Nuts and Bolts of Actigraphy

Choosing a Device

- Cost
  - Device
  - Interface
  - Software
  - Batteries
  - Warranty/Maintenance/Technical Support
- What is your patient population?
  - Size and weight of device
  - Durability and water resistance
  - Features (watch, light meter, event marker)
  - Has it been validated in your patient population?

	 AMI Motionlogger MicroWatch	 P/R Actiwatch 2	 P/R Actiwatch Spectrum Plus	 P/R Actiwatch Spectrum PRO
Startup costs	$2795 (device, cable, unlimited use software)	$800 (device, docking, license)	$1225 (device, cable, license)	$1375 (device, cable, license)
Additional Devices	$995	$750	$975	$1125
Interface	Cable/IR	Docking	MicroUSB cable	Micro USB cable
Battery	CR2450	Rechargeable (factory replaced)	Rechargeable (factory replaced)	Rechargeable (factory replaced)
Runtime	30 d	30 d	60 d	50 d
Additional Costs	Batteries	Additional license $250	Additional license $250	Additional license $250
Light Sensor	X	X	X	X
Event Marker	X	X	X	X
Off-Wrist	X		X	X
Subjective Report				X

More Information Needed

- Don’t rely on actigraphy alone!
- Daily sleep diary
  - Time got into bed
  - Time attempted to fall asleep
  - Time woke to start day
  - Removal of watch
  - Typical day?
- Light meter
- Compliance with tx recommendations

Reviewing and Scoring Data

- Review actigram with sleep diary for inconsistencies/artifact
  - Inaccurate documentation, device problem, or atypical night
- Set sleep interval manually with sleep diary (and/or event marker when present)
- Use scoring algorithm/sensitivity level that is appropriate for your population

Variables to Consider

Sleep Diary/Event Marker

- Bedtime (time attempted to fall asleep)
- Wake Time (time woke to start day)
- Sleep Opportunity (min from Bedtime to Wake Time)

Actigraphy

- Sleep Onset Time
- Sleep Onset Latency (reported BT to SOT)
- Sleep Offset Time
- Total Sleep Time
- Night Wakings (frequency/duration)
- Sleep Efficiency (TST/Sleep Opportunity)

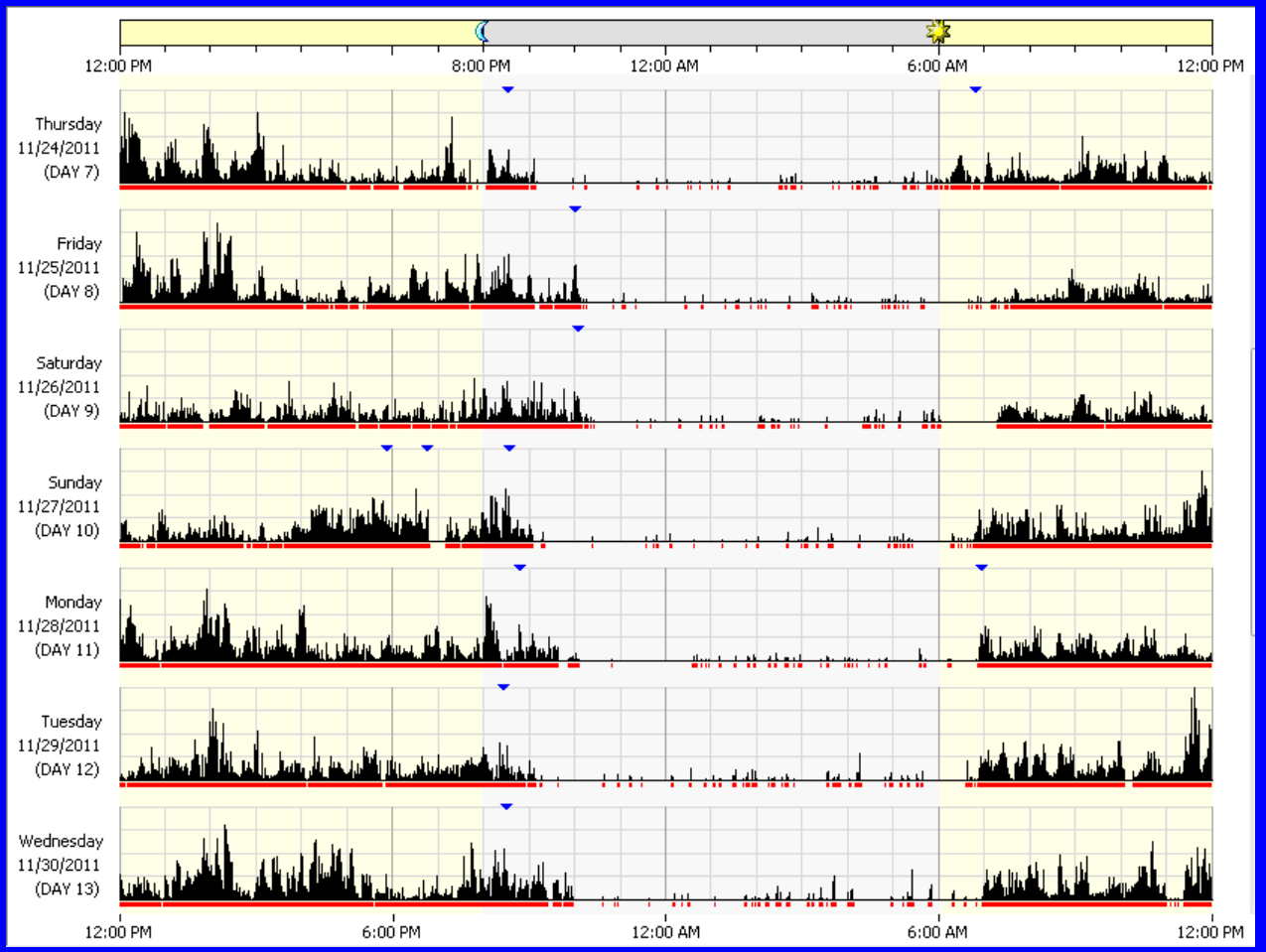
Daytime Variables

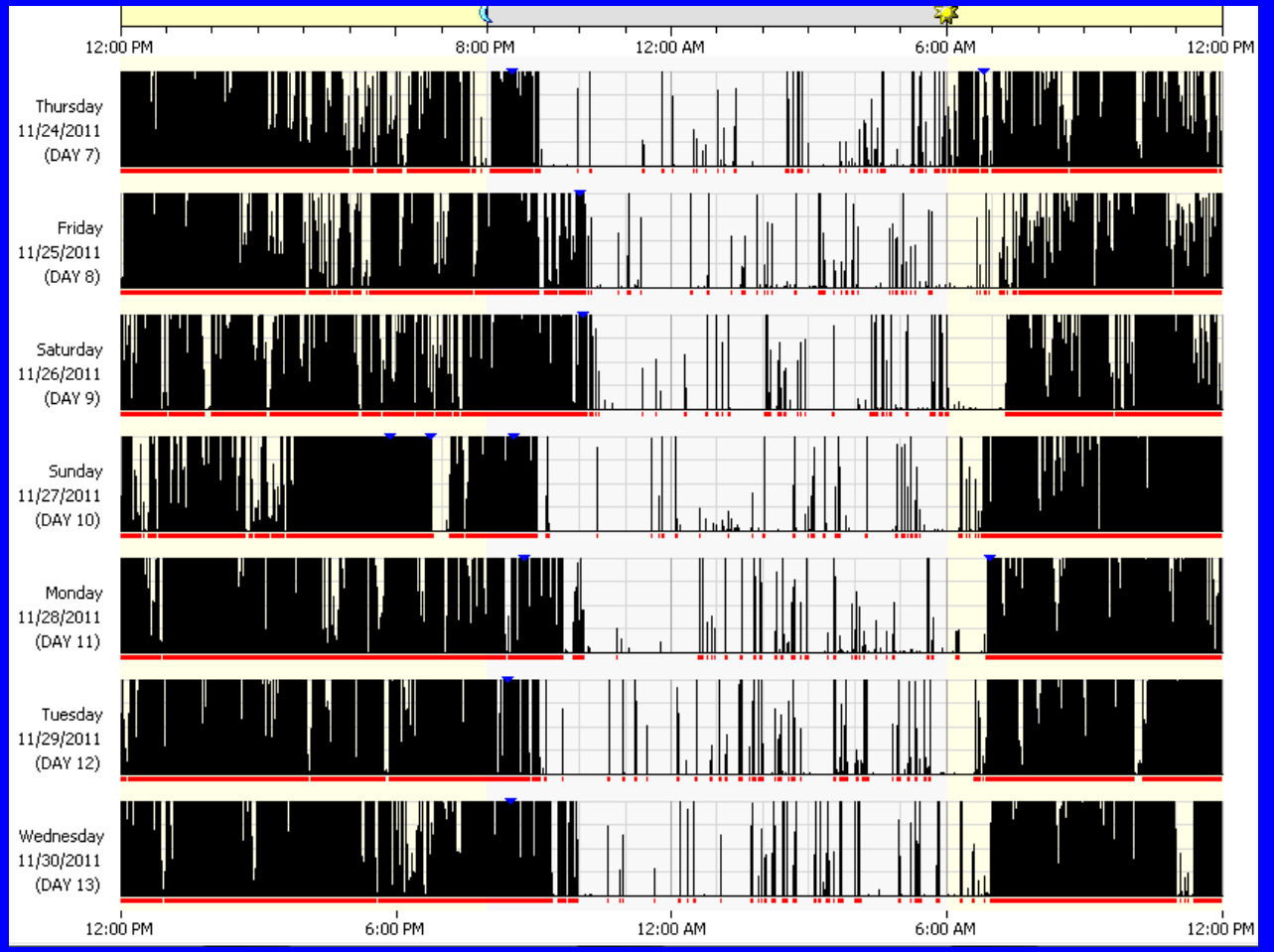
- Sleep episodes (naps and otherwise)
- Percent time asleep during day

Reviewing and Scoring Data

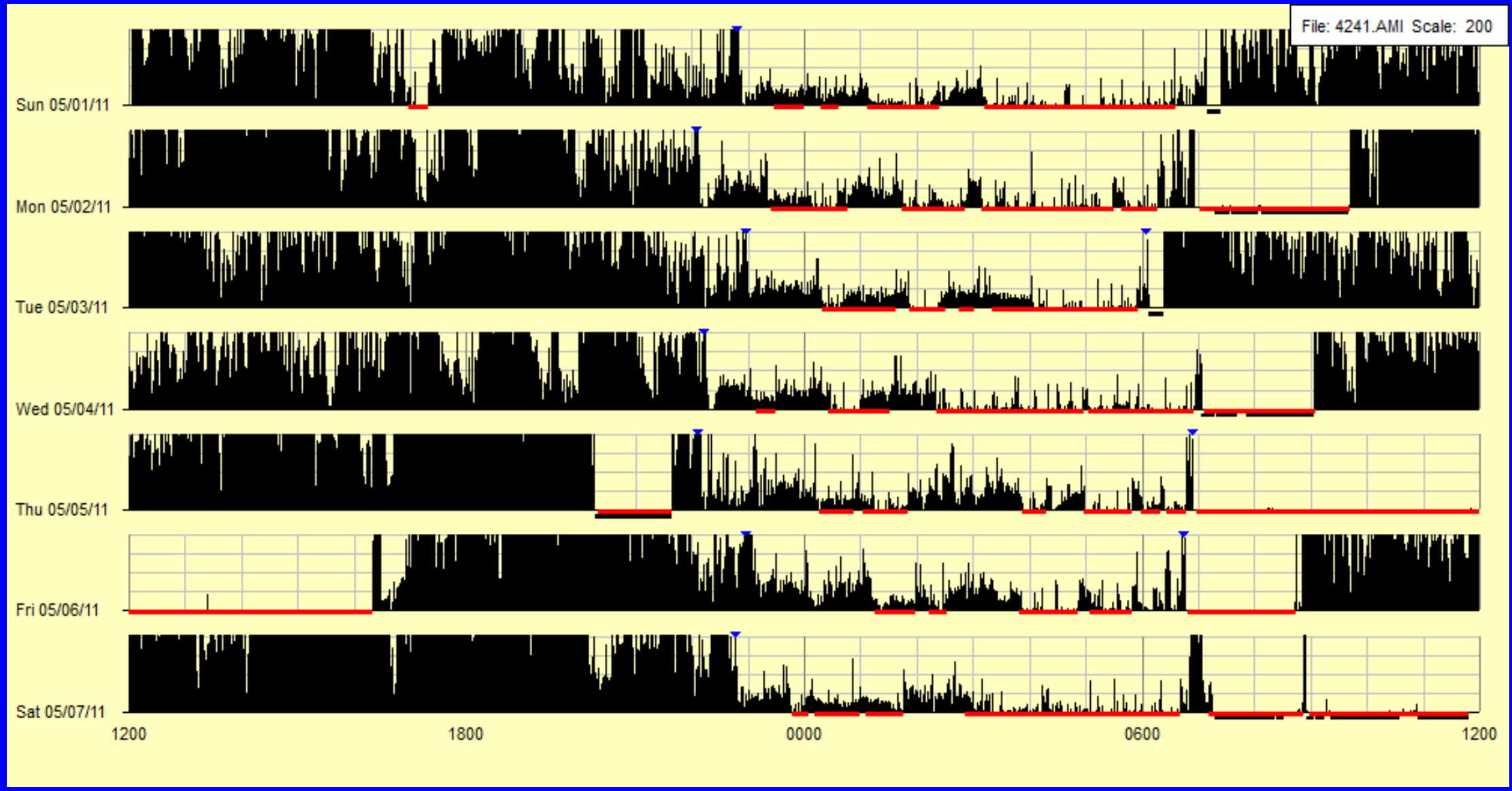
- Review actigram with sleep diary for artifact or inconsistencies
  - Inaccurate documentation, device problem, or atypical night
- Set sleep interval manually with sleep diary and/or event marker when present
- Use scoring algorithm/sensitivity level that is appropriate for your population

Manually Set Your Scale





Beware of Artifact



The SBSM Guide to Actigraphy Monitoring: Clinical and Research Applications

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Behavioral Sleep Medicine (2015), 13, S4-S38

Validity of Actigraphy

Evidence for Actigraphy

- Practice parameters published in 1995
  - Actigraphy accepted as a research tool
- Practice parameters Update for 2002
  - Actigraphy reliable to detect normal sleep
  - Not indicated for routine diagnosis, assessment or management of any sleep disorders, but useful adjunct in certain disorders
- Practice parameters update for 2007
  - Revised evidence-based indications for clinical care

REVIEW ARTICLES

Use of Actigraphy for the Evaluation of Sleep Disorders and Circadian Rhythm Sleep-Wake Disorders: An American Academy of Sleep Medicine Systematic Review, Meta-Analysis, and GRADE Assessment

Michael T. Smith, MA, PhD[1]; Christina S. McCrae, PhD[2]; Joseph Cheung, MD, MS[3]; Jennifer L. Martin, PhD[4,5]; Christopher G. Harrod, MS[6]; Jonathan L. Heald, MA[6]; Kelly A. Carden, MD[7]

SPECIAL ARTICLES

Use of Actigraphy for the Evaluation of Sleep Disorders and Circadian Rhythm Sleep-Wake Disorders: An American Academy of Sleep Medicine Clinical Practice Guideline

Michael T. Smith, MA, PhD[1]; Christina S. McCrae, PhD[2]; Joseph Cheung, MD, MS[3]; Jennifer L. Martin, PhD[4,5]; Christopher G. Harrod, MS[6]; Jonathan L. Heald, MA[6]; Kelly A. Carden, MD[7]

- 81 studies reviewed using the GRADE assessment
- "Suggest" the use of actigraphy (conditional recommendation)
  - Adult and pediatric insomnia disorder
  - Adult and pediatric CRSWD
  - Integrated with HST to estimate TST in adults
  - Monitor TST prior to MSLT in adult and pediatrics
  - Adult insufficient sleep syndrome
- "Recommend" ***NOT*** using in place of EMG for PLMD in adult or pediatric patients

Pediatric Specific Validation

Reference	Population (n)	Device	Compared	Placement
Sadeh et al. (1991)	12-48 months (11)	AMA-32	PSG	Left leg
Sadeh et al. (1994)	Adults (20), adolescents (16)	AMA-32	PSG	Both wrists
Sadeh et al. (1995)	Infants (41)	AMA-32	PSG	Left ankle
Gnidovec et al. (2002)	Infants (10)	Gaehwhiler	Direct observation	Left ankle
So et al. (2005)	Infants (22)	AW-64	PSG	Between ankle/knee
Hyde et al. (2007)	Children (1-12 yrs, 45)*	AW-64	PSG	Non-dominant wrist
Sitnick et al. (2008)	Preschoolers (58)*	AW-64	Video	Non-dominant ankle
Sung et al. (2009)	Preterm infants	AW-64	Video	Right leg between ankle/knee
Tilmanne et al. (2009)	Infants (354)	Healthdyne	PSG	Ankle
Insana et al. (2010)	Infants (22)	AW-64	PSG	Ankle
Weiss et al. (2010)	Adolescents (30)	Sleepwatch, Actiwatch, Actical	PSG	Non-dominant wrist (Actical on trunk)
Meltzer et al. (2012)	3-18 years (115)	Sleepwatch, Actiwatch	PSG	Non-dominant wrist

Meltzer et al., (2012), *Use of Actigraphy in Pediatric Sleep Research*, Sleep Med Rev.

Pediatric Specific Validation

Reference	Population (n)	Device	Compared	Placement
Sadeh et al. (1				eg
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Meltzer et al. (2012)	3-18 years (115)	Sleepwatch, Actiwatch	PSG	Non-dominant wrist

71% of comparisons show good sensitivity to detect sleep (>85%)

59% of comparisons show poor specificity to detect wake (<60%)

Meltzer et al., (2012), *Use of Actigraphy in Pediatric Sleep Research*, Sleep Med Rev.

Commercial Wearables

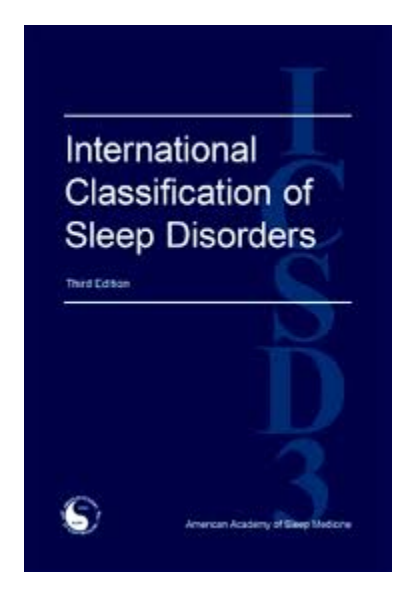
Pediatric Specific Validation

Reference	Age (n)	Device	Sensitivity/ Specificity	TST	SE	Notes
Meltzer et al. (2015)	3 to 17 y (63)	Fitbit Ultra	0.86 / 0.52 (N) 0.70 / 0.79 (S)	+41m (N) -105m (S)	+8% (N) -21% (S)	Similar findings across age groups
de Zambotti et al. (2015)	12 to 22 y (65)	Jawbone UP	Not provided	+10m	+2%	Underestimated TST in younger adol, overestimated in older adol.
Toon et al. (2015)	3 to 18 y (78)	Jawbone UP Motion X 24/7	0.93 / 0.63 (UP)	+9m (UP) +106m (MX)	+2% (UP) +17% (MX)	UP underestimate TST in preschool, overestimate in school-age/adolescents
de Zambotti et al. (2016)	*17.3 ± 2.5 y* (32)	FitbitCharge HR	0.97 / 0.42	+8m	+1.8%	Heart rate negligibly lower (0.9 bpm) than ECG
de Zambotti et al. (2017)	14 to 22 y (41)	ÖURA ring	0.96 / 0.48	+1m	Not provided	Discrepancies much greater for those with more WASO
Pesonen & Kuula (2018)	11y or 18 y (34)	Polar Fitness Tracker	0.93 / 0.77 (11y) 0.91 / 0.83 (18y)	-29m (11y) -21m (18y)	-4.5% (11y) -2.9% (18y)	A370 model

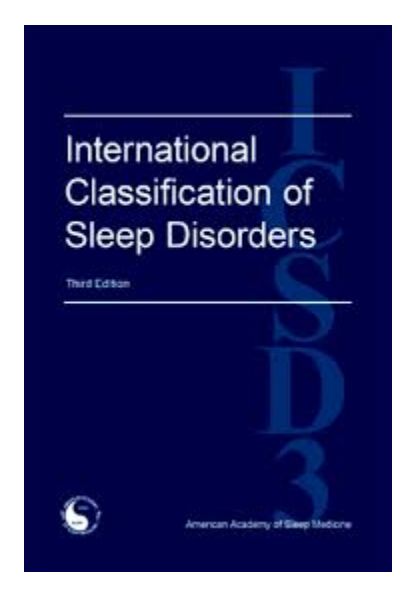
When Should Actigraphy Be Used?

ICSD-3 and Actigraphy

- Narcolepsy
- Idiopathic Hypersomnia
- Insufficient Sleep Syndrome
- Long Sleeper
- Circadian Rhythm Sleep Disorders
  - Delayed Sleep-Wake Phase Sleep Disorder
  - Irregular Sleep-Wake Rhythm Disorder
  - Non-24-Hour Sleep-Wake Rhythm Disorder
  - Shift Work Disorder
- Periodic Limb Movement Disorder



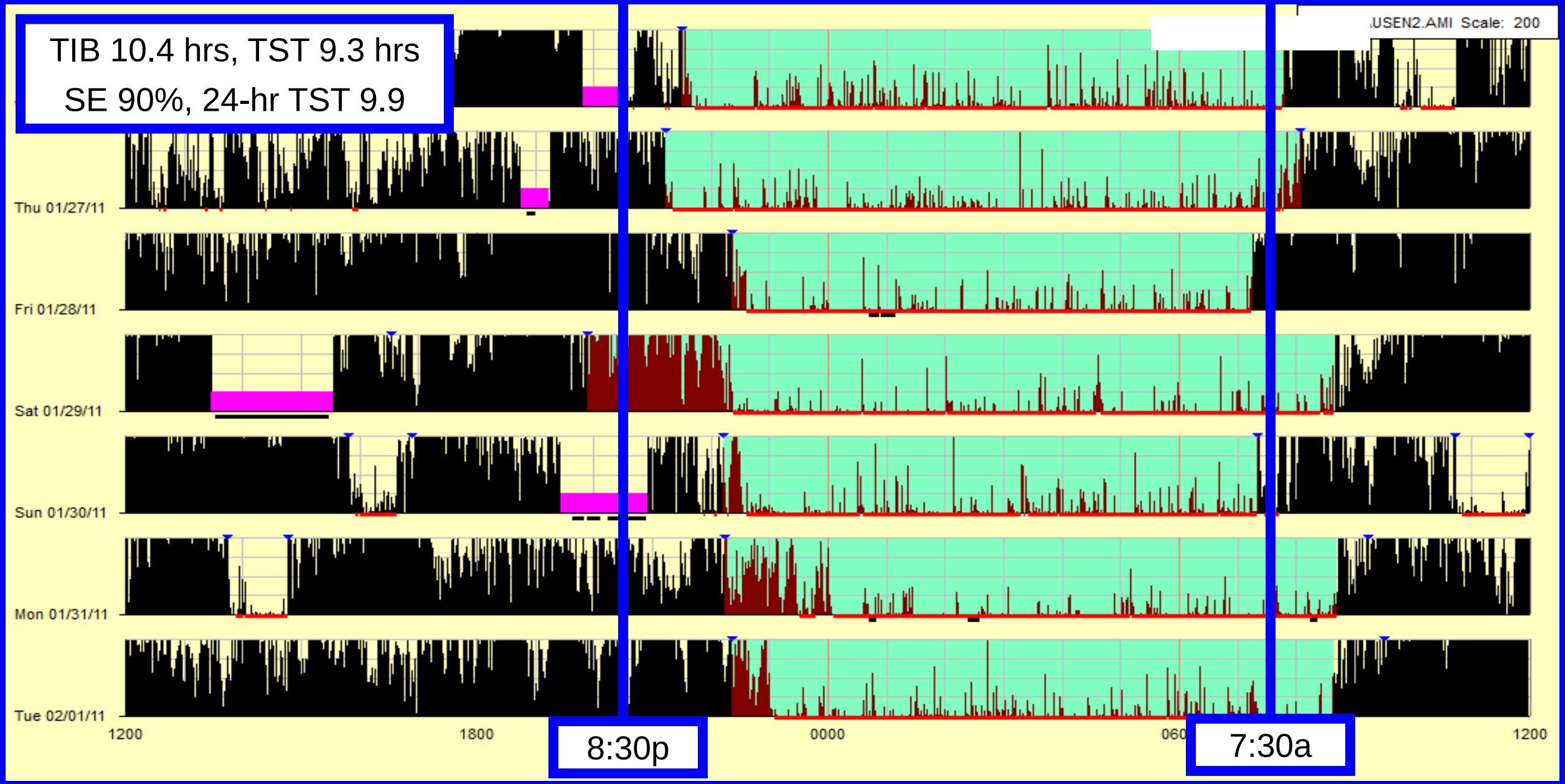
Narcolepsy



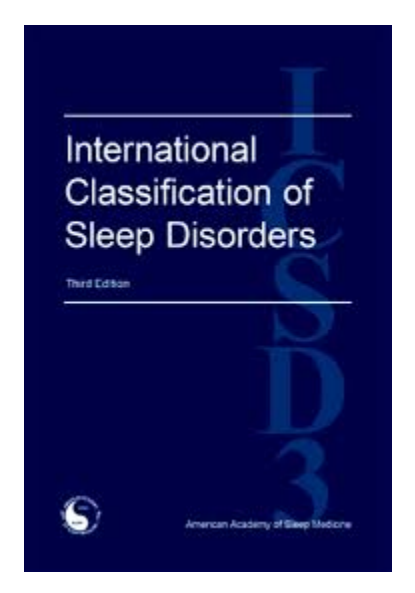
Strongly recommended:

- **MSLT preceded by ≥7 days of actigraphy with sleep log** to establish if results biased by insufficient sleep, shift work, or circadian rhythm sleep disorder

11 Year Old Male



Idiopathic Hypersomnia



Diagnostic Criteria D:

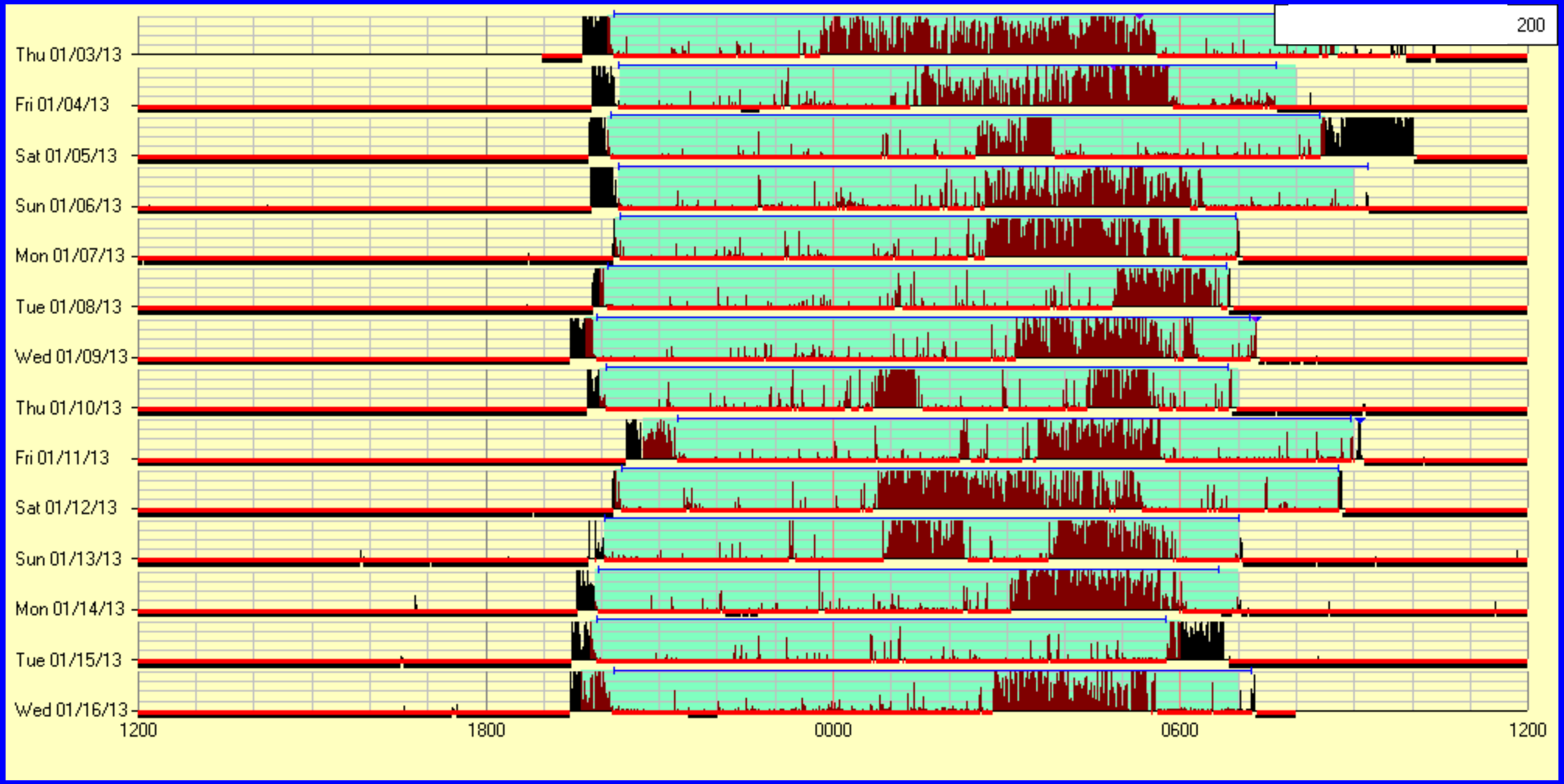
The presence of ≥ 1 of the following:

1. MSLT shows mean SOL ≤ 8 minutes
2. Total 24-hour sleep time is ≥ 660 minutes (11 hrs) by 24-hour PSG ***or by wrist actigraphy in association with a sleep log*** (averaged over at least seven days with unrestricted sleep)

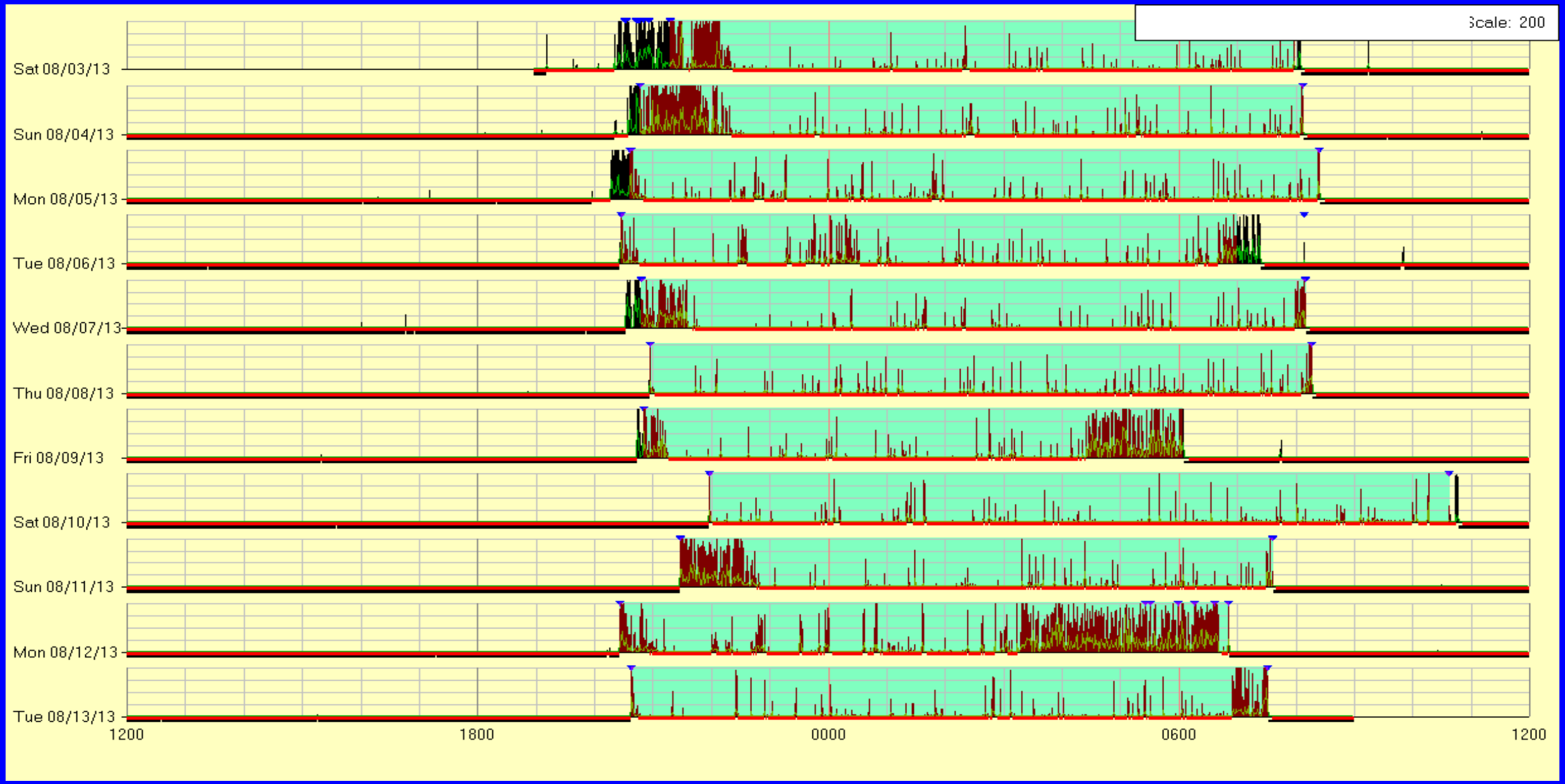
Idiopathic Hypersomnia

- 6.5 year old girl with SPD
- Difficulty self-soothing at bedtime, early sleep termination, daytime behavior issues, restless sleep
- Started melatonin with significant improvements in sleep onset and sleep maintenance (sleeping thru night)
- Ferritin 30 ng/mL
- Still sleepy during day

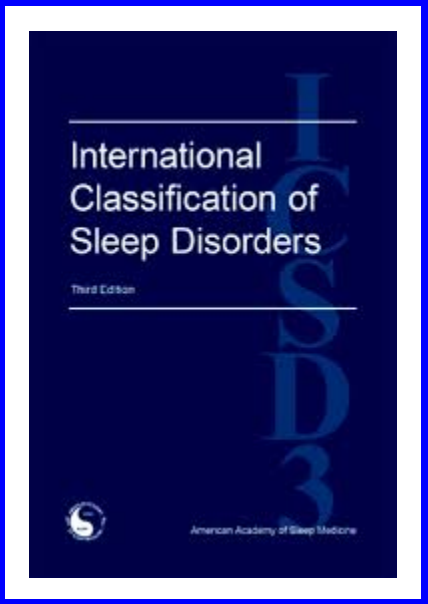
Refractory Insomnia



Post Treatment



Insufficient Sleep Syndrome

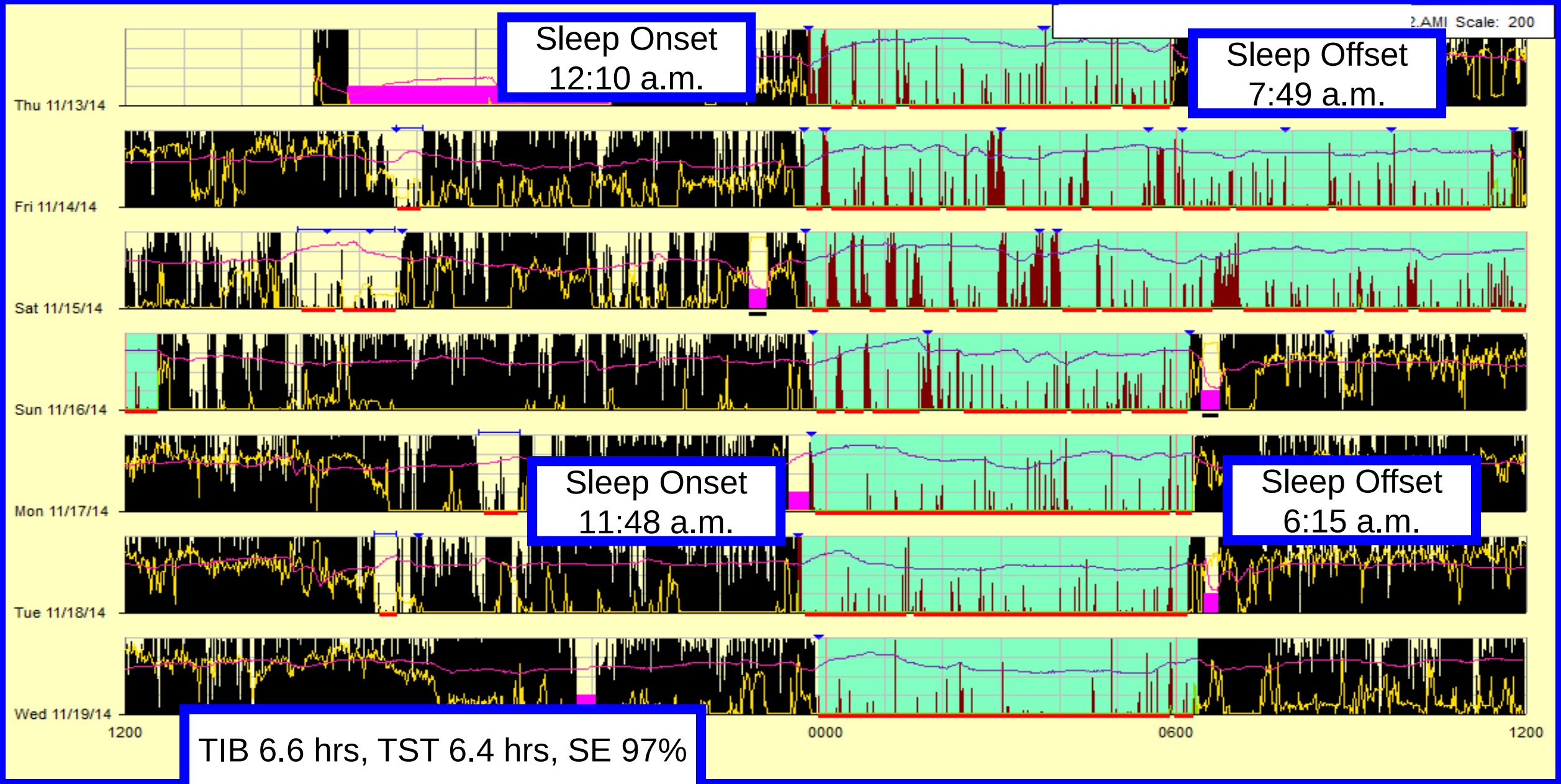


Diagnostic Criteria B:

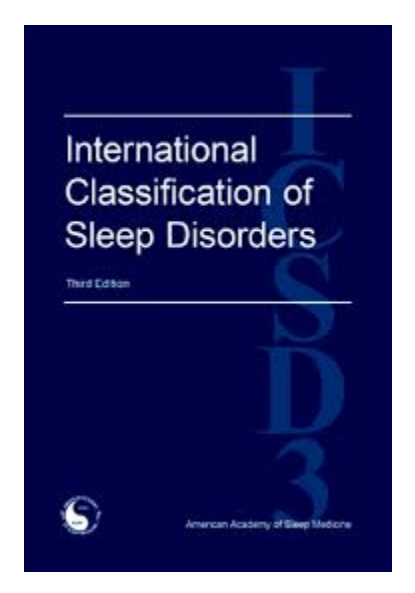
The patient's sleep time, established by personal or collateral history, sleep logs, ***or actigraphy*** is usually shorter than expected for age

Notes: If there is doubt about the accuracy of personal history or sleep logs, ***then actigraphy should be performed, preferably for ≥ 2 wks***

15 Year Old Female



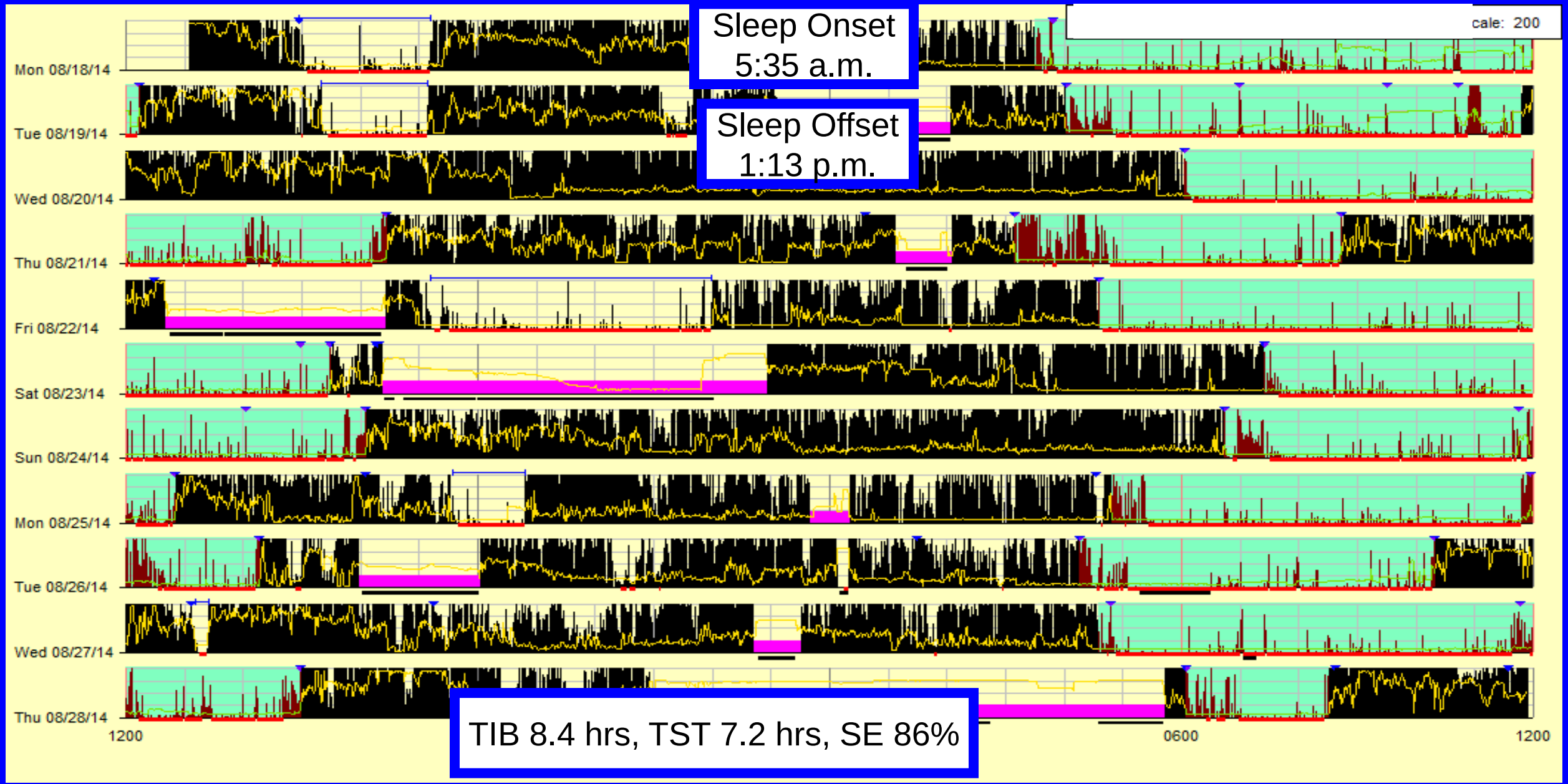
Circadian Rhythm Sleep Disorders



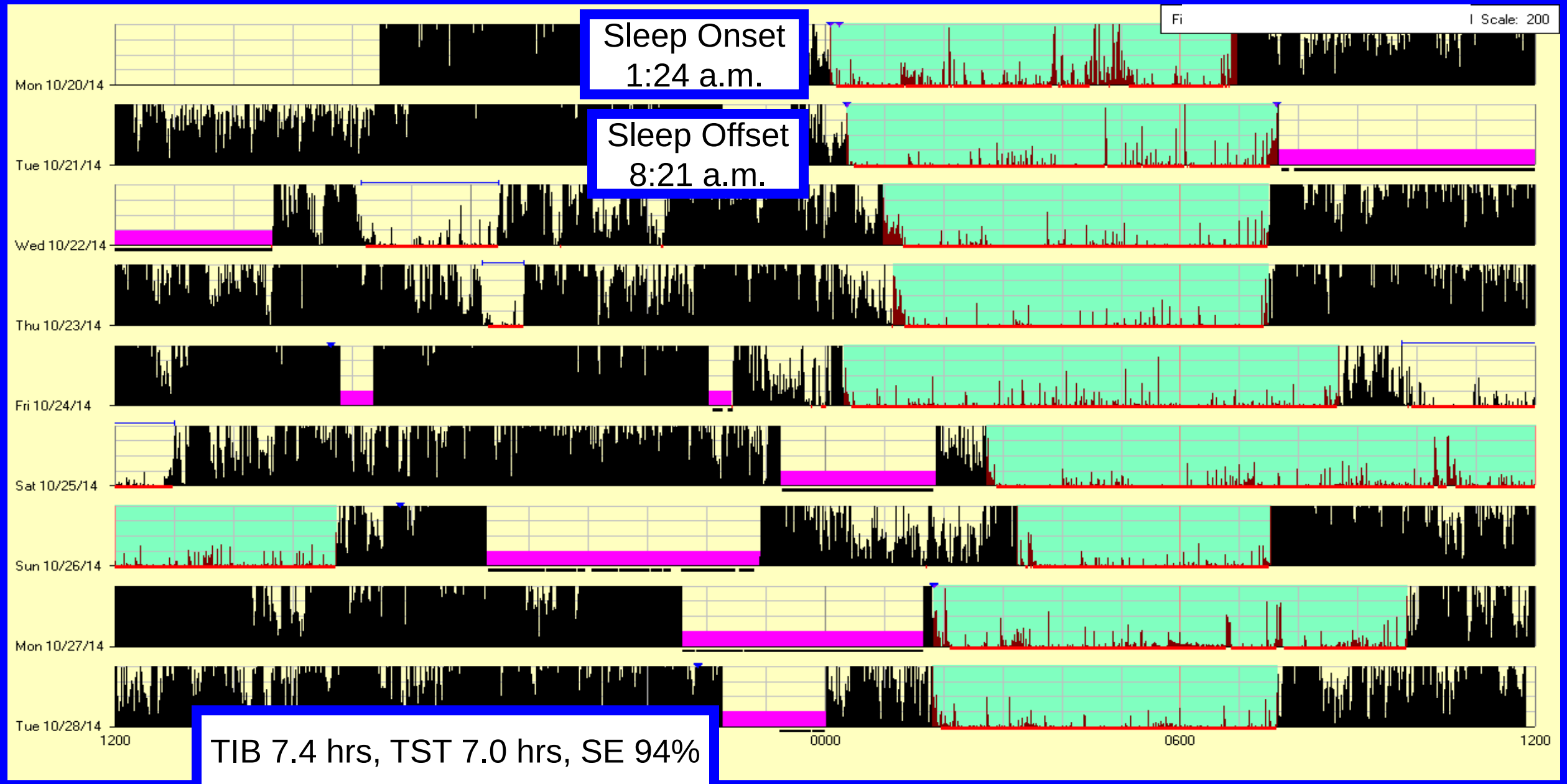
Diagnostic Criteria D:

Sleep log and, whenever possible, ***actigraphy monitoring for at least 7 days (preferably 14 days)*** demonstrate a delay in the timing of the habitual sleep period. Both work/school days and free days must be included within this monitoring

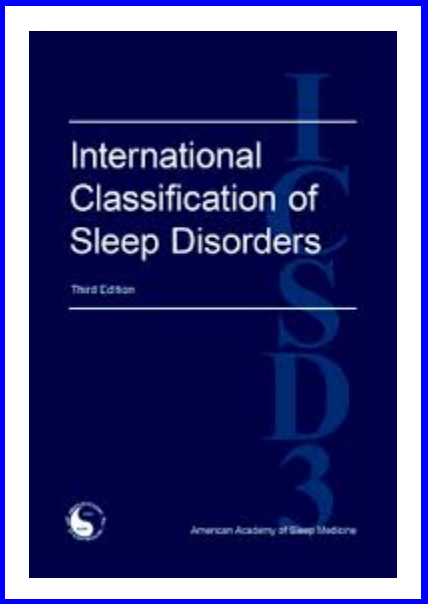
24 Year Old Female



24 Year Old Female



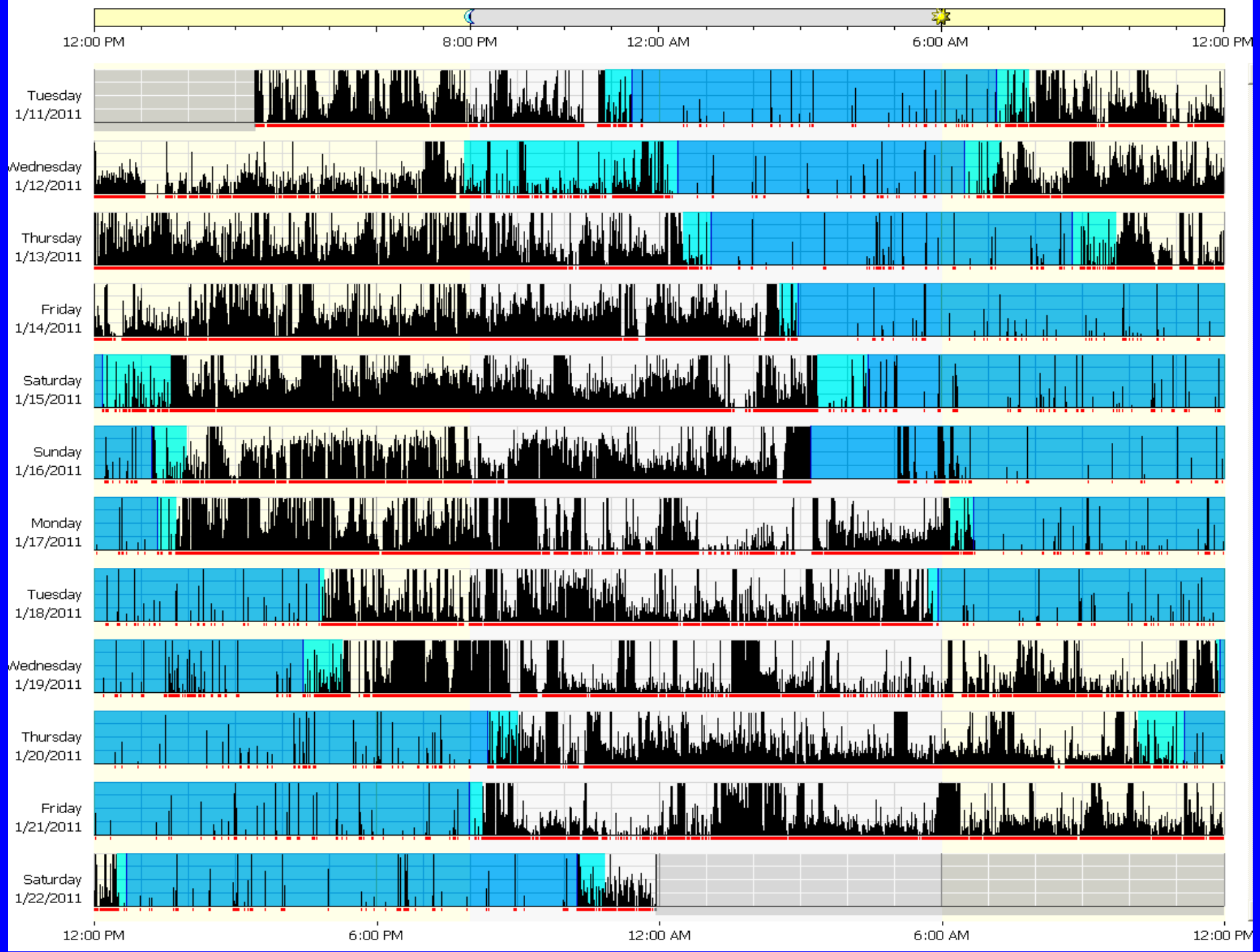
Non-24-Hour Sleep-Wake Rhythm Disorder



Daily sleep logs and actigraphy for at least 14 days, preferably longer for blind persons, demonstrate pattern of sleep and wake times that typically delay each day, with a circadian period that is usually longer than 24 hours

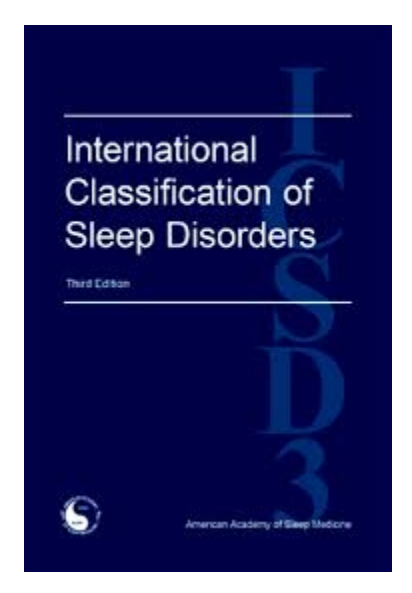
21 Year Old Female

- Inconsistent sleep pattern, began age 10 years, got worse age 14-15 years
- Doesn’t feel drowsy, but knows it is time to sleep when temples get tense
- Unable to finish high school (GED), got trade degree, only able to hold job 4 months due to sleep schedule
- Unemployed


12:00 PM
8:00 PM
12:00 AM
6:00 AM
12:00 PM
Tuesday
1/11/2011
Wednesday
1/12/2011
Thursday
1/13/2011
Friday
1/14/2011
Saturday
1/15/2011
Sunday
1/16/2011
Monday
1/17/2011
Tuesday
1/18/2011
Wednesday
1/19/2011
Thursday
1/20/2011
Friday
1/21/2011
Saturday
1/22/2011
12:00 PM
6:00 PM
12:00 AM
6:00 AM
12:00 PM

Periodic Limb Movement Disorder

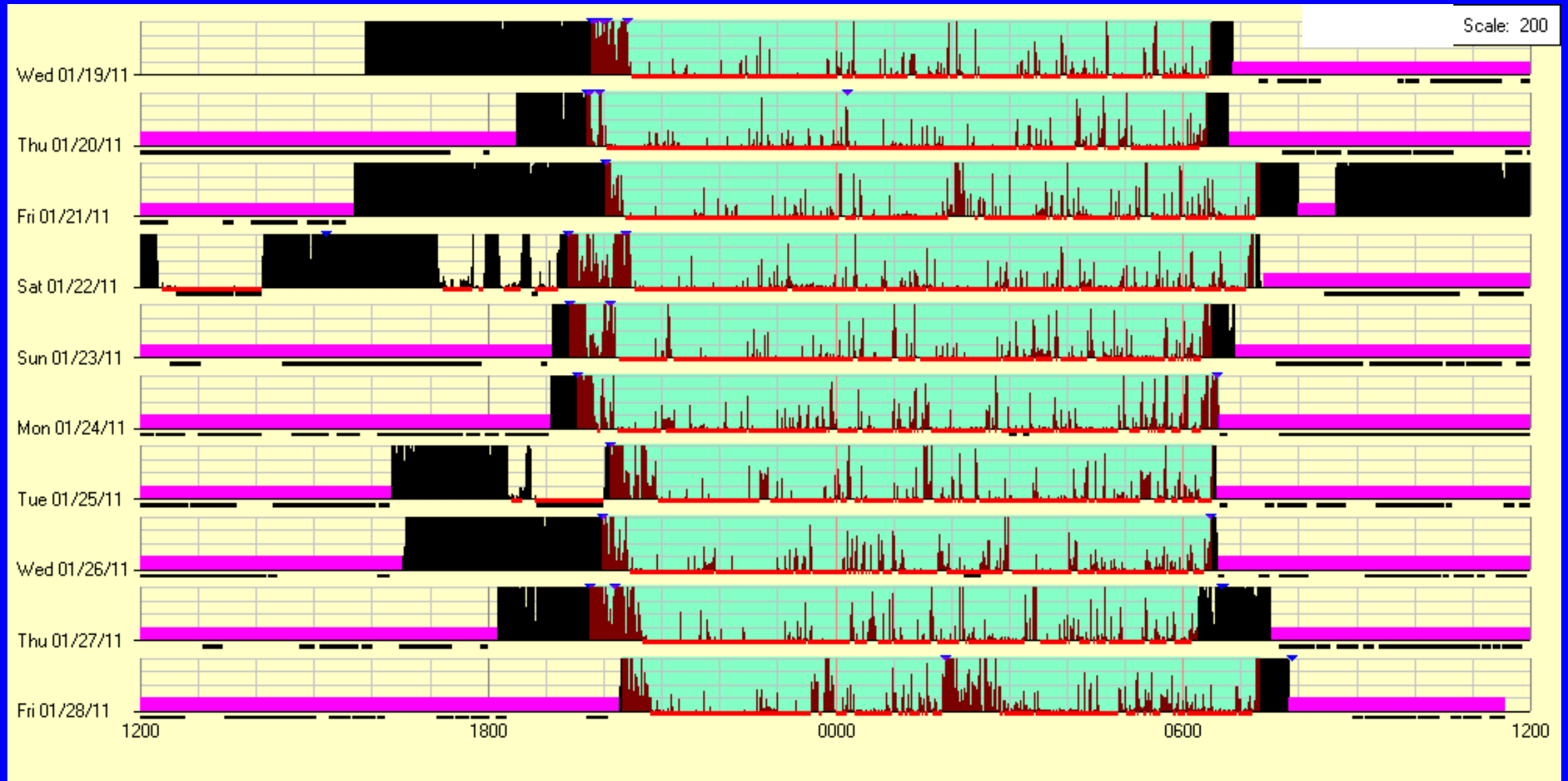
- Leg actigraphy has been validated against PSG for the measurement of PLMS and provides a methodology to assess PLMS in large populations, as well as night-to-night variability



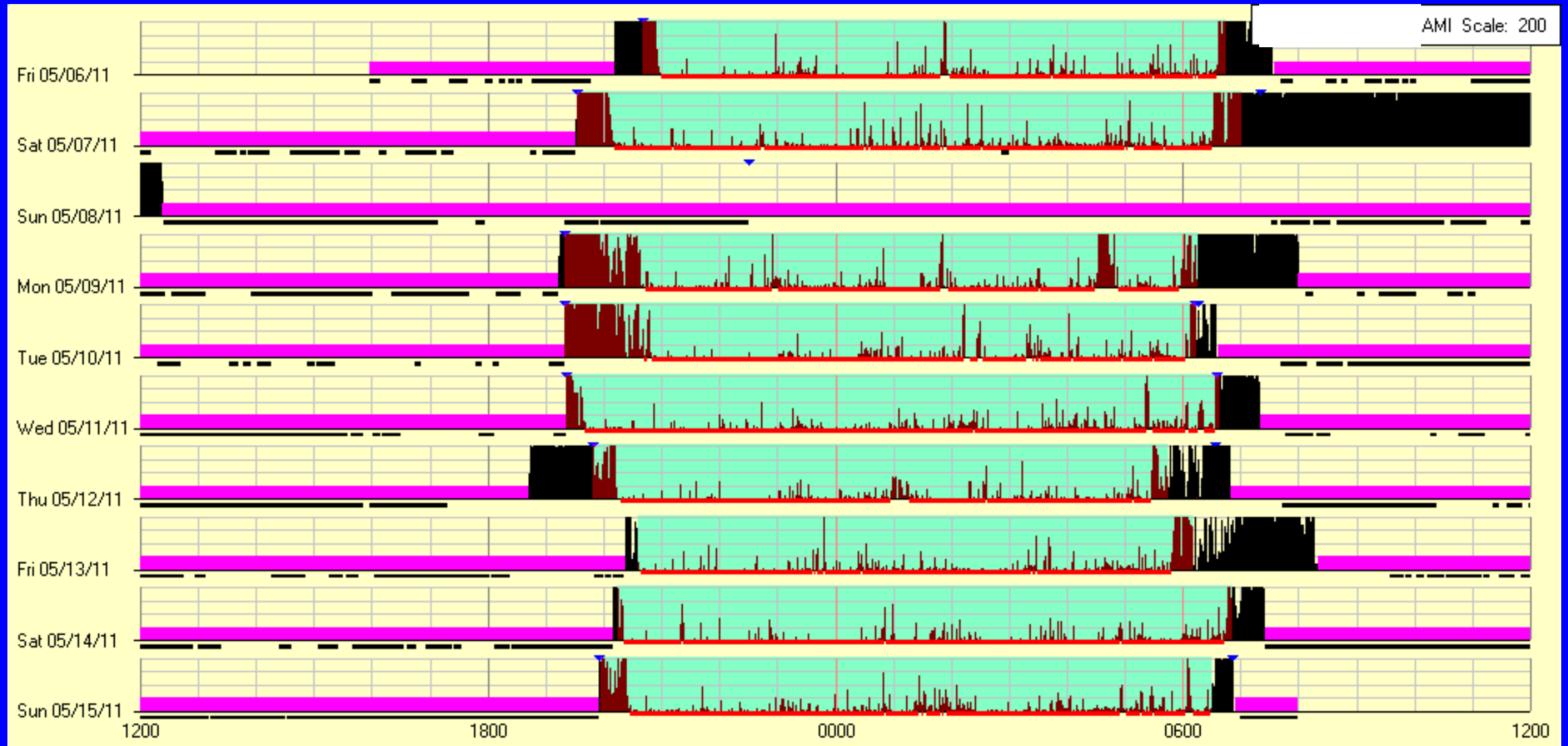
Restless Sleepers

- 7 year old boy
- Difficulties falling asleep and multiple night wakings
- Daytime fatigue and behavior problems
- Restless sleeper
- Low serum ferritin (20 ng/mL)

Pre Treatment



Post Treatment



VARIABLE	FIRST STUDY	CURRENT STUDY
Reported Bedtime	7:48 p.m.	7:51 p.m.
Actigraphy Sleep Onset	8:30 p.m.	8:22 p.m.
Reported Wake Time	6:43 a.m.	6:30 a.m.
Actigraphy Sleep Offset	6:35 a.m.	6:14 a.m.
Sleep Onset Latency	41.4 minutes	31.4 minutes
Sleep Opportunity	10.7 hours	10.7 hours
Actual Sleep Time	8.6 hours	9.3 hours
Sleep Efficiency	79%	87%
Night Wakings > 20 minutes	1.6 wakings	0.8 wakings
% No Activity	54.4%	63.5%
% Low Activity	23.8%	22.1%
% Moderate to High Activity	21.7%	14.3%

Summary and Review

- Actigraphy provides estimate of sleep-wake patterns in patient's natural sleep environment for up to 2 weeks
- Data can be used for differentials and treatment planning
- Important to have a sleep diary (and to get the actigraph back)
- Consumer wearables likely have a place in clinical/research settings to provide sleep pattern data, but further validation needed (which is difficult as devices change so rapidly)

Thank You!

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