P08-002: Can the Mammalian Circadian System Adapt to the Martian Photoperiod?

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***Background*:** Aberrant light:dark cycles (T-cycles) that deviate considerably from our naturally evolved intrinsic period (τ) of ~24 h pose severe environmental challenges for the mammalian circadian system. But adaptability to T-cycles that deviate only slightly (<1 h) from T24, notably the Martian 12.33-h light:12.33-h dark cycle (T24.66) remains largely unexplored. ***Objectives*:** Here we examined the effects of T24.66 on circadian entrainment, ultradian rhythm, sleep and alertness, as well as hippocampus-mediated object memory in wildtype mice (C57BL/6). ***Results*:** T24.66 lengthened τ, allowing rest–activity rhythm to realign with the slightly longer Martian photoperiod without free running (**Fig. 1A–C**). Circadian rhythmic power was not dampened under T24.66 but ultradian noise was amplified, as revealed by fast Fourier transform (FFT) and wavelet analysis (**Fig. 1D–F**). Despite circadian realignment, sleep pattern was altered with increased sleep at midnight due to an advance in the siesta peak (**Fig. 2B,2E**). EEG spectral analysis revealed that waking EEG theta activity (8–12 Hz) was attenuated at night (**Fig. 2C,2D,2F,2G**). These time-of-day dependent changes in sleep pattern and alertness were accompanied by attenuated short-term object memory at night, due to dysregulated response to familiar objects without affecting response to novelty (**Fig. 2H–J**). ***Conclusion*:** Our results highlight certain inevitable neurophysiological and functional changes among personnel participating in space exploration missions.

Fig. 1: *Circadian entrainment*

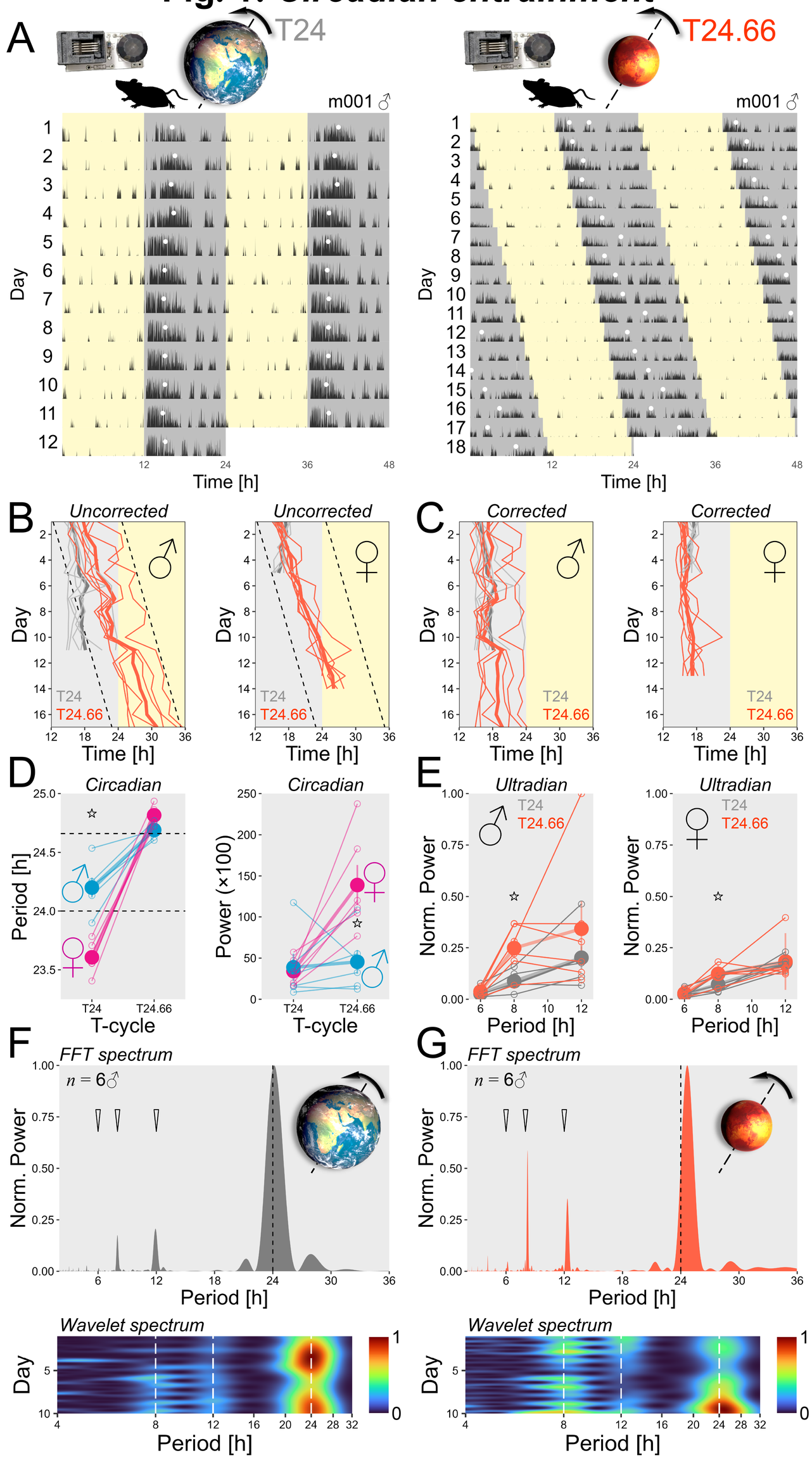

Fig. 1. Circadian rhythm is entrained to T24.66 but ultradian noise is amplified at the 8-h harmonic. ***A*:** Double-plotted actograms of home cage PIR activity from a male mouse; daily activity midpoints are indicated by white dots. ***B*** and ***C*:** Activity midpoints (6♀ and 6♂) under T24.66 plotted on the T24 clock (*Uncorrected*; panel **B**) *versus* local Mars clock (*Corrected*; panel **C**); dashed diagonal lines in panel **B** demarcate onset and termination of the dark phase under T24.66. ***D*:** Circadian period length and FFT power within 23.5–24.5 h; dashed horizontal lines indicate reference lines of 24 h and 24.66 h. ***E*:** Normalized FFT power at 12-h, 8-h, and 6-h harmonics. Star symbols in panels **D** and **E** indicate significant effects of Sex and T-cycle from ANOVAs (ps < 0.05). ***F*** and ***G*:** FFT (***top***) and wavelet spectra (***bottom***) of group-average PIR activity record in male mice; power values in FFT and wavelet spectra are normalized to the peak power value in the corresponding spectrum. In ***top*** panels, the dashed vertical line indicates the reference line of 24 h and inverted triangles indicate ultradian harmonics at 12 h, 8 h, and 6 h in the FFT spectrum. In ***bottom*** panels, dashed vertical lines indicate periods at 24 h, 12 h, and 8 h in the wavelet spectrum. Ultradian 8-h harmonic power was elevated in both FFT and wavelet spectra under T24.66 (panel **G**, ***top*** and ***bottom***).

Fig. 2: *Sleep, alertness, & short-term memory*

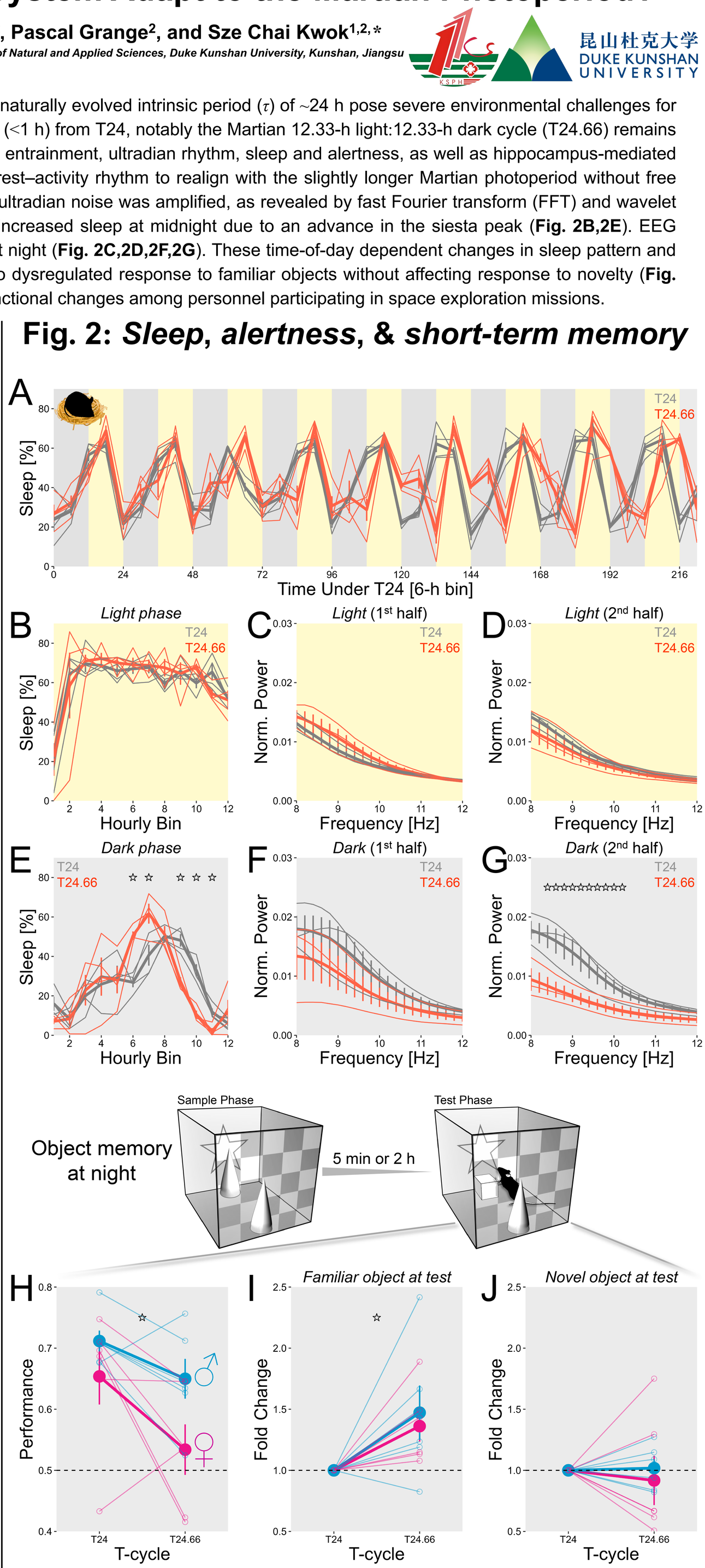

Fig. 2. Increased nocturnal sleep due to an earlier siesta is accompanied by attenuated waking EEG fast theta activity and a decline in hippocampus-mediated short-term object memory performance. ***A*:** Non-invasive assessment of sleep–wake cycles using piezoelectric sensors (4♂); data from T24.66 are plotted on the uncorrected timescale to visualize the change in sleep–wake cycles relative to T24. ***B*:** Piezoelectric sensor-defined sleep amount in hourly bins in the light phase; T24.66 data are plotted on the local Mars clock (i.e., each hourly bin lasts for 61.66 min). ***C*** and ***D*:** Normalized waking frontal EEG fast theta activity (8–12 Hz) in the first and second halves of the light phase (3♂); EEG power is normalized to total power in the waking EEG spectrum. ***E*:** Piezoelectric sensor-defined sleep in the dark phase (same mice in panel **B**). ***F*** and ***G*:** Normalized waking EEG fast theta activity in the first and second halves of the dark phase (same mice in panels **C** and **D**). ***H*:** Object discrimination performance at night (6♀ and 6♂); the effect of Sex did not interact with the effect of T-cycle on object memory. ***I*:** Fold changes in familiar object exploration under T24.66 relative to T24. ***J*:** Fold changes in novel object exploration under T24.66 relative to T24. Star symbols indicate significant effects of T-cycle from within-subjects ANOVAs (ps < 0.05).