Models for Marine Integrative Chronobiology

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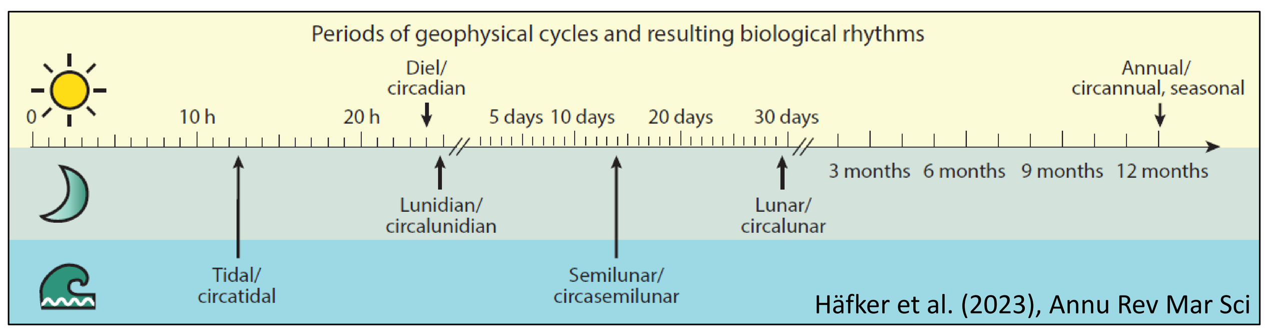
Research Focus & Approach

Environmental cycles and biological rhythms in the oceans are just as common as on land, and even more complex, due to the interacting forces of sun & moon, and because of the habitats vertical structure. The Marine Chronobiology group aims to decipher the environmental drivers and functioning of marine rhythms and clock systems, to provide a mechanistic understanding of how marine timing systems determine individual fitness, species interactions, and ecosystem functioning.

We therefore combine field observations & samplings with laboratory experiments on behavior & physiology, as well as cutting-edge molecular & genetic techniques, to generate an integrative picture of marine timekeeping.



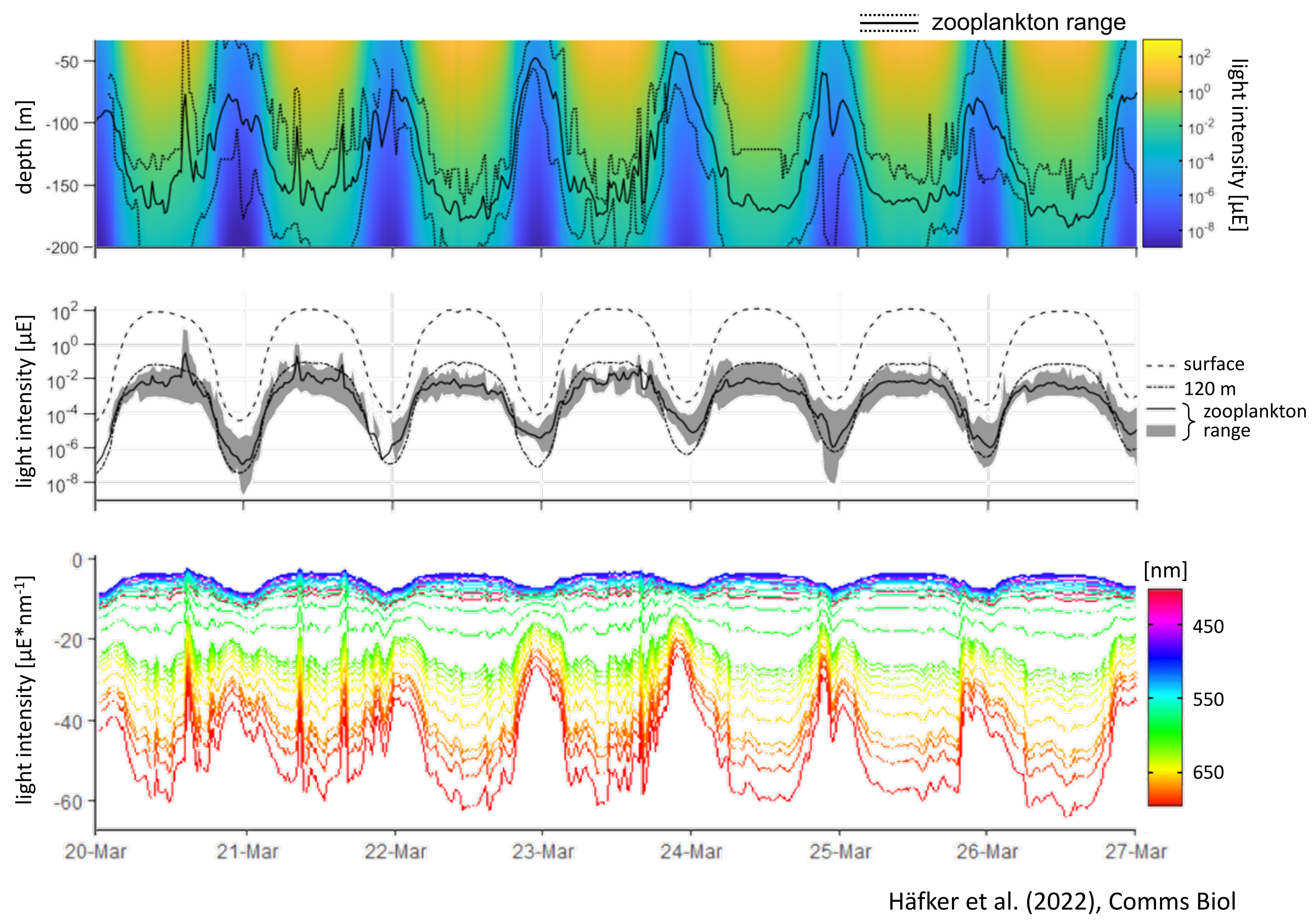
Overview of environmental cycles & period lengths in marine habitats.

Calanus finmarchicus – A zooplankton key species performing diel & seasonal vertical migrations

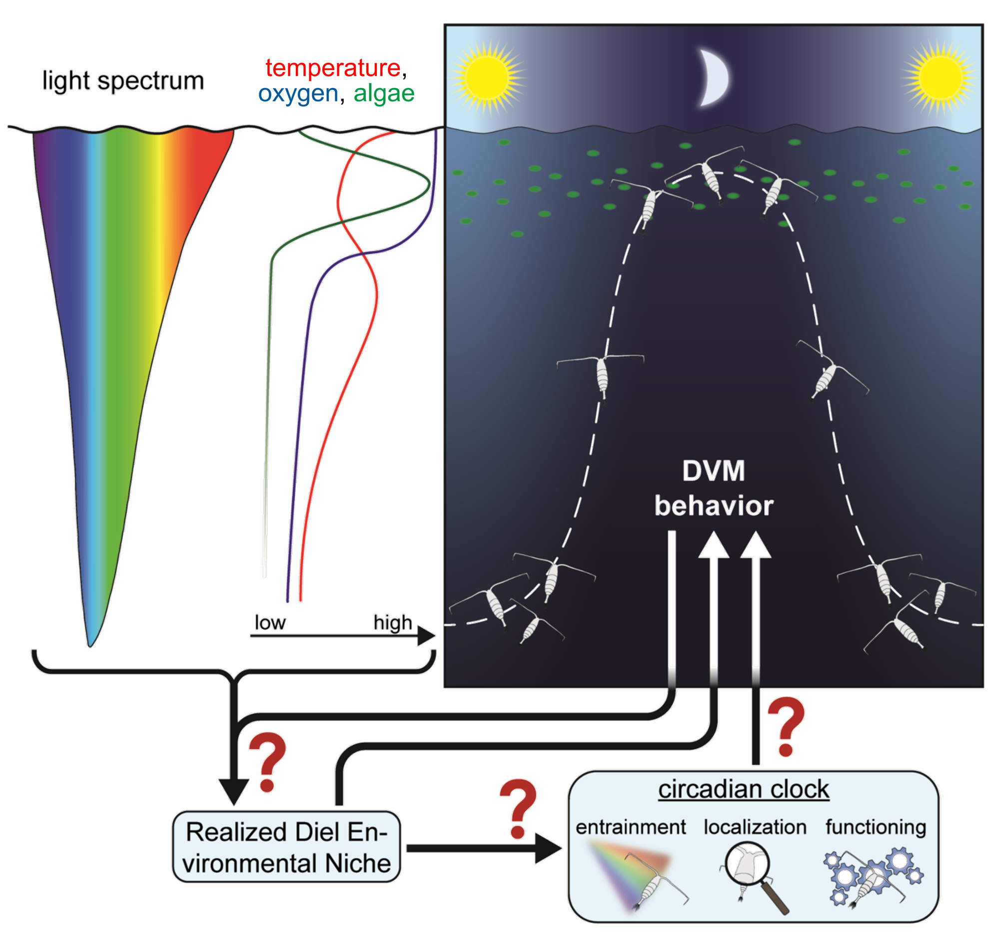
The copepod *C. finmarchicus* has a key position in the northern Atlantic pelagic food web as it feeds on phytoplankton and is a crucial food source for fish & whales.

Like countless other pelagic species, the copepod performs diel vertical migration (DVM), thereby shaping its own environmental cycles. We investigate functional adaptations of the copepod's circadian clock to the unique pelagic environmental cycles.

C. finmarchicus overwinters in deep waters relying on large lipid reserves. We explore the triggers of this seasonal migration and the role of clock mechanisms in day length measurement & seasonal entrainment.



DVM strongly affects the diel light cycle experience by zooplankton. While intensity change are minimized, the spectral composition changes drastically over the diel cycle. Light is often the main cue for clock entrainment, and the circadian clock regulates DVM behavior. How can the timing systems of pelagic species function under these unique "self-made" environmental cycles?



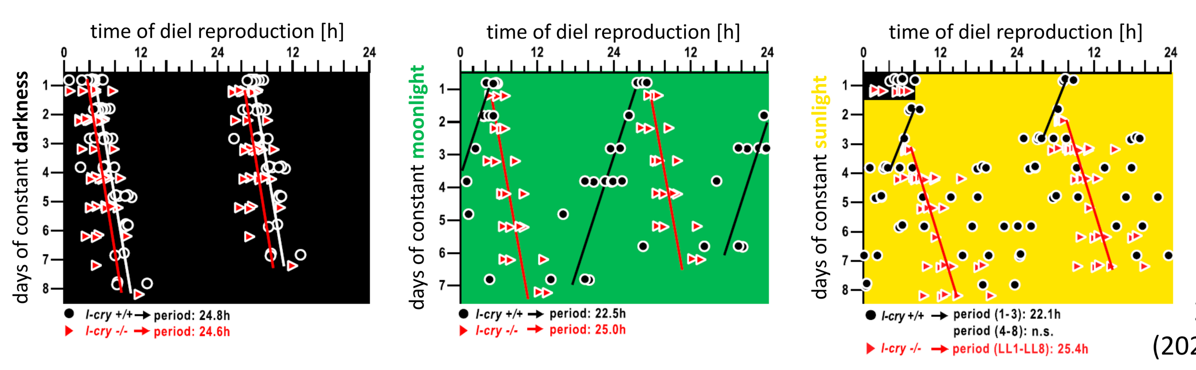
Interplay of copepod DVM behavior, environmental conditions and circadian clock. We investigate which environmental cues are central for clock functioning in the pelagic habitat, where in the copepod body the clock is localized, and how the clock functionally regulates diel rhythmic outputs like DVM, metabolic activity, and gene expression.

Platynereis dumerilii – A molecularly accessible worm model with a circalunar clock

The polychaete *P. dumerilii* lives on the seafloor in shallow coastal habitats. For reproduction, males and females go through a metamorphosis and swim into the open water where they simultaneously release their gametes in a "mating dance". Metamorphosis & mating are precisely timed to the lunar cycle and are controlled by a circalunar clock. The worm's circadian behavior and its reproductive rhythm provide excellent chronobiological outreads.

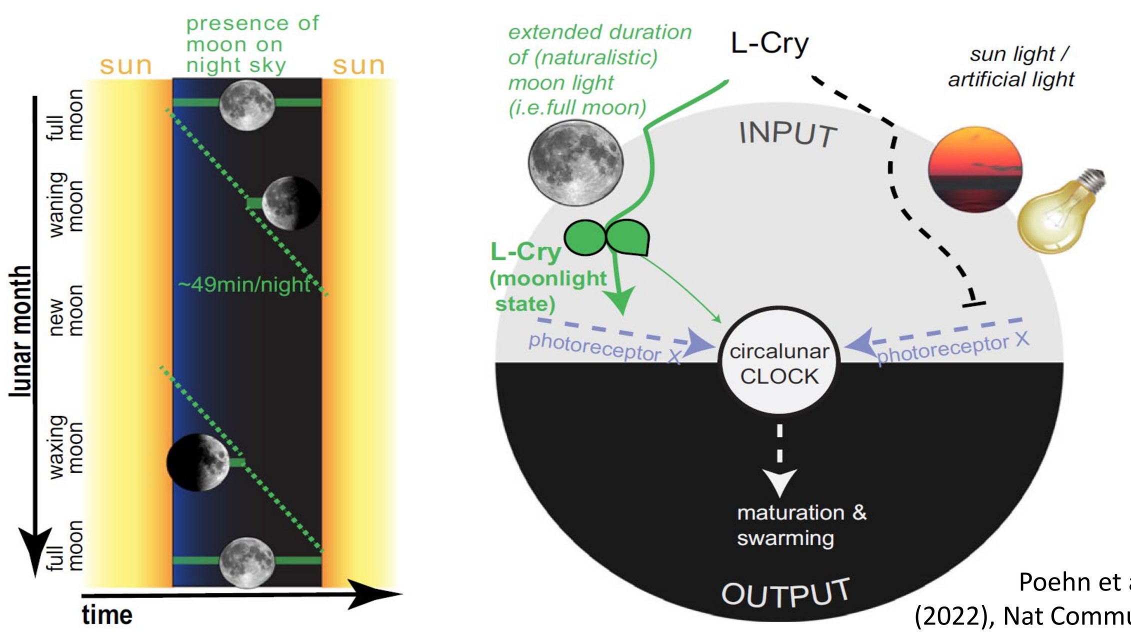
Various molecular techniques are established for *P. dumerilii*, including staining protocols (*in situ* hybridization, antibodies, HCR), transcriptomics/proteomics, cell culture assays, and targeted mutagenesis (TALENs, CRISPR). To date, >10 mutant worm strains have been established and are kept in culture.

Combining molecular work with behavioral monitoring and natural light measurements, we investigate how the worms perceive and distinguish sun- & moonlight, what molecular mechanisms translate environmental information into circadian & circalunar rhythms, and the basis of individual rhythmic variability among worms ("personalities") as well as its ecological relevance.



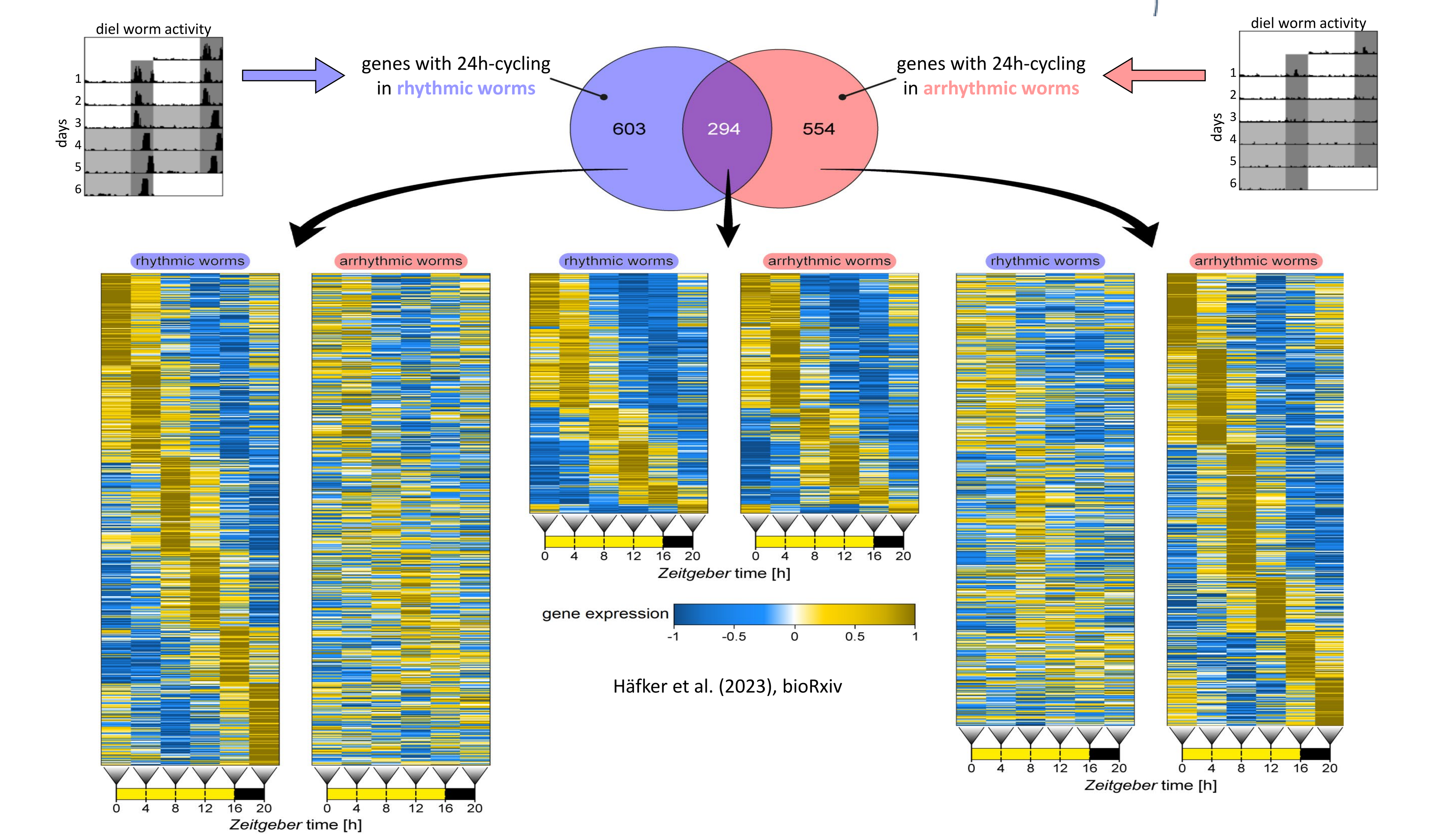
Zurl et al. (2022), PNAS

Reproductive timing requires L-cryptochrome. Mutants that lack this light receptor & clock component do not respond to moonlight, but stay rhythmic under sunlight.



Poehn et al. (2022), Nat Commun

L-cry is needed to entrain worms to the lunar moonlight cycle. The light receptor measures intensity, duration, and phase of a light source.



Individual worms strongly differ in their diel activity rhythms. Gene expression profiles reveal complex and multi-layered patterns of organismic rhythmicity, with behaviorally arrhythmic worms showing stronger metabolic rhythms. This highlights the importance of integrative chronobiological approaches that address different levels of biological organization simultaneously.

References

Häfker NS, Connan-McGinty S, Hobbs L, McKee D, Cohen JH, Last KS. (2022) Animal Behavior Is Central in Shaping the Realized Diel Light Niche. *Communications Biology* 5: 562. doi: 10.1038/s42003-022-03472-z

Häfker NS, Andreatta G, Manzotti A, Falciatore A, Raible F, Tessmar-Raible K (2023) Rhythms and Clocks in Marine Organisms" *Annual Review of Marine Science* 15: 509–38. doi: 10.1146/annurev-marine-030422-113038

Häfker NS, Holcik L, Vadiwala K, Beets I, Mat AM, Stockinger AW, Hammer S, Schoofs L, Raible F, Tessmar-Raible K (2023) Behavioral Rhythms Are Bad Predictors of General Organismal Rhythmicity. *bioRxiv.* doi: 10.1101/2022.07.16.500291

Poehn B, Krishnan S, Zurl M, Ćorić A, Rokvic D, Häfker NS, Jaenicke E, Arboleda E, Orel L, Raible F, Wolf E, Tessmar-Raible K (2022) A Cryptochrome Adopts Distinct Moon- and Sunlight States and Functions as Sun- versus Moonlight Interpreter in Monthly Oscillator Entrainment. *Nature Communications* 13: 5220. doi: 10.1038/s41467-022-32562-z

Zurl M, Poehn B, Rieger D, Krishnan S, Rokvic D, Veedin-Rajan VB, Gerrard E, Schlichting M, Orel L, Ćorić A, Lucas RJ, Wolf E, Helfrich-Förster C, Raible F, Tessmar-Raible K (2022) Two light sensors decode moonlight versus sunlight to adjust a plastic circadian/circalunidian clock to moon phase. *Proceedings of the National Academy of Sciences* 119: e2115725119. doi: 10.1073/pnas.2115725119

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