H-Units: A Hydrogen-Anchored, Earth-Independent Framework for Universal Time and Length

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Abstract

We propose a universal unit system grounded in cosmic invariants: the H-second and the H-meter. The H-second is defined as exactly 1.5×10^9 cycles of the hydrogen hyperfine transition (21-cm line), yielding $t_H \approx 1.056036$ s in SI units. The H-meter is the distance light travels in one H-second divided by 3×10^8, giving $d_H \approx 1.055306$ m. This proposal does *not* replace current or future physical clocks; it simply reframes the unit of time by anchoring its value to a universal atomic constant, while practical realizations continue using cesium fountains, optical lattice clocks, frequency combs, or future standards. The numerical choice 1.5×10^9 preserves near-continuity with the SI second and yields the elegant identity that the 21-cm hydrogen line equals exactly 20.000 H-cm. H-units restore Einstein's logical ordering—time defined first, distance derived from light-travel—while avoiding all Earth-based legacies and maintaining full compatibility with modern metrological practice.

1 Introduction

Modern timekeeping remains operationally grounded in Earth's historical legacy. Although the current SI second is defined through the caesium-133 hyperfine transition, its numerical value (9,192,631,770 cycles) was chosen to match the ephemeris second derived from Earth's orbital motion in 1900. The meter, likewise, is defined via the fixed numerical value of the speed of light, selected to preserve continuity with the historical meter derived from a 1790s Earth-meridian survey.

For terrestrial applications this legacy is harmless. But for interstellar science, navigation, and communication, an Earth-dependent calibration is conceptually and practically limiting. A framework that uses universal atomic constants as the anchor—without altering the technologies that realize the second—is desirable.

H-units adopt hydrogen's hyperfine frequency as the definitional anchor for time and derive length from light propagation over that interval. Hydrogen is abundant, eternal, and emits a sharp, universal spectral line. Crucially, in this framework hydrogen is *not* a required clock: realization is performed entirely by modern atomic and optical clocks through frequency-ratio measurements. Only the *value* of the unit is redefined.

2 History of Time and Length Standards

The evolution of the second and meter reflects increasing abstraction away from Earth-based artifacts toward universal constants.

2.1 History of the Second

Ancient divisions of the day into hours, minutes, and seconds emerged from Egyptian (duodecimal) and Babylonian (sexagesimal) systems. The terms *minute* and *second* trace to Ptolemy's *Almagest*. Mechanical clocks of the 16th century enabled practical measurement of seconds, and for centuries the second was defined astronomically as 1/86 400 of a mean solar day.

Irregularities in Earth's rotation made this inadequate. From 1956 to 1967 the second was tied to the ephemeris year 1900. In 1967 it was redefined as 9,192,631,770 periods of the caesium-133 hyperfine transition, with the numerical value calibrated to match the ephemeris second. Thus, although the physical definition is atomic, the numerical value still encodes an Earth-orbital legacy.

2.2 History of the Meter

The meter originated in 1791 as one ten-millionth of the distance from the equator to the North Pole along a meridian. In 1799 a platinum bar was constructed; in 1889 it was replaced by a platinum–iridium bar. In 1960 the krypton-86 wavelength replaced artifacts, and in 1983 the meter was defined as the distance light travels in 1/299 792 458 s—fixing c at exactly 299 792 458 m/s to maintain continuity with historical prototypes.

Table 1 summarizes the small but real changes made to the meter during each redefinition.

Year	Definition	Length Changed?	Approx. Change
1799	Platinum bar	—	—
1889	New Pt-Ir bar	Yes	$\sim$0.2 mm
1960	Kr-86 wavelength	Yes	Microns
1983	Light-travel time	Yes	Parts in 10^{-8}–10^{-9}

Table 1: Historical adjustments to the meter.

3 Motivation: The Need for Redefinition

Both the SI second and SI meter are operationally precise but numerically rooted in Earth. Their continuity choices—ephemeris time for the second, the meridian arc for the meter—make them planetary in origin. For interstellar metrology, units anchored solely in universal constants are preferable.

Hydrogen's hyperfine frequency is:

$$\nu_{\mathrm{H}} = 1.420\,405\,751\,768 \times 10^{9}\ \mathrm{Hz},$$

constant in the CMB rest frame and observable anywhere with a modest radio receiver and spectrometer. Hydrogen is the simplest, most abundant element in the universe, and its hyperfine transition provides a reproducible, cosmically accessible reference suitable for definitions.

4 Definition Versus Realization

A central principle of modern metrology is the distinction between:

- **Definition:** a statement fixing the exact value of a unit.
- **Realization:** the experimental method used to measure that unit.

The SI defines the second using caesium, but realizations increasingly rely on optical clocks. Likewise, the meter is defined using c but realized using interferometry.

H-units follow the same principle:

- Hydrogen defines the *value* of the H-second.
- Practical clocks—caesium fountains, hydrogen masers, optical lattice clocks, nuclear clocks, frequency combs—realize it through frequency-ratio measurements.

No change in clock hardware is required.

5 Definition of the H-Second and H-Meter

5.1 The H-Second

We define:

$$1 \text{ H-s} \equiv \frac{1.5 \times 10^9}{\nu_{\text{H}}},$$

where ν_{H} is the exact hydrogen hyperfine frequency. This yields:

$$t_H \approx 1.056036 \text{ s (SI)}.$$

The number 1.5×10^9 is chosen for two reasons:

1. **Continuity:** t_H is close to the SI second, enabling painless conversion.
2. **Numerical elegance:** with this choice, the 21-cm line becomes exactly 20.000 H-cm (see Appendix).

5.2 The H-Meter

Distance is defined through light-travel during one H-second:

$$1 \text{ H-m} \equiv \frac{c\,t_H}{3 \times 10^8}.$$

This ensures:

$$c = 3 \times 10^8 \text{ H-m/H-s},$$

yielding:

$$d_H \approx 1.055306 \text{ m (SI)}.$$

Thus, H-units implement Einstein's ordering:

$$t \quad \Rightarrow \quad d = c\,t.$$

6 Einstein's Logic Restored

Einstein's relativity is founded on the primacy of time and the universal invariance of the speed of light. Distance is operationally defined as the interval light traverses in a given time:

$$d = c\,t.$$

The SI, however, reverses this logic to preserve the historical meter: it fixes the numerical value of c and adjusts the definition of the meter accordingly. This is practical, but conceptually inverted.

H-units restore the natural hierarchy:

1. Define time from a universal atomic constant.
2. Derive distance from light-travel.

Space follows time, not vice versa.

7 Comparison to Alternative Approaches

Pulsars provide precise astrophysical clocks but exhibit spin-down evolution. The CMB is universal but lacks a sharp spectral feature. Planck units are universal but impractically small. Other proposed frequencies (11.8 MHz, 10 GHz, 1 kHz) are theoretically interesting but lack direct cosmic observability.

Hydrogen's hyperfine transition uniquely combines universality, sharpness, abundance, and detectability.

8 Appendix: The 21-cm Line and the Exact 20.000 H-cm

The hydrogen hyperfine wavelength in SI is:

$$\lambda_{\mathrm{H}} = 21.1061140542 \text{ cm}.$$

Since 1 H-cm = 1.055306 cm, we have:

$$\lambda_{\mathrm{H}} = 20.000 \text{ H-cm},$$

exactly by construction of the 1.5×10^9 cycle definition.

9 Conclusion

H-units provide Earth-independent, cosmically accessible definitions of time and length grounded in fundamental physical constants. They preserve compatibility with all modern clock technologies while restoring Einstein's logical sequence for constructing spacetime units. Earth may keep SI; interstellar science can adopt H-units.

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References

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