

WAKE REGISTER

*Recoiling supermassive black holes, wake kinematics,
and the biological limits of an organic observer at $1.341 \times 10^3 \text{ km s}^{-1}$.*

*A working paper on gravitational-wave recoil, Bondi–Hoyle capture,
strong-shock cooling in the circumgalactic medium, and whether a
living body can occupy the same speed corridor as a runaway hole.*

MATTHEW RAYNOR · WAKE REGISTER · WORKING PAPER

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Observer likeness of Matthew Raynor used by authority of the sitter.

An observer is in Plates III and IV. The physics that follows is the reason the hole stays small.

Plates

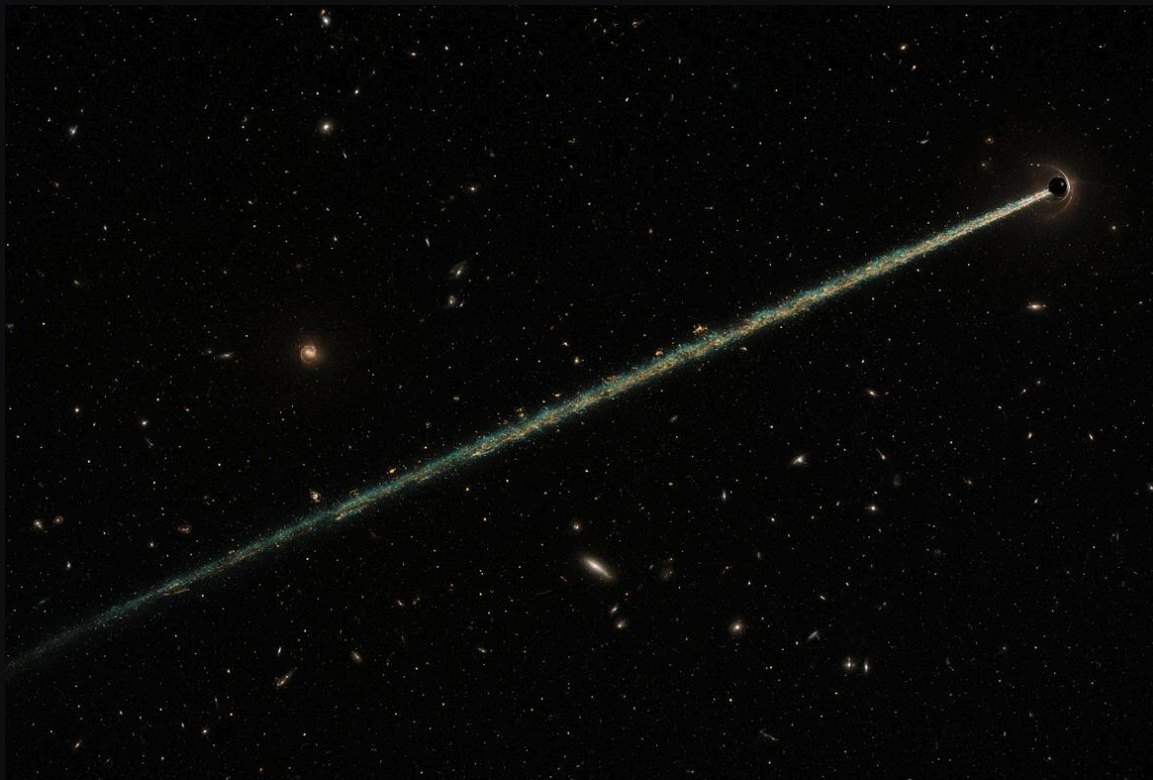


Plate I. The wake. Recoil first. Ornament later.

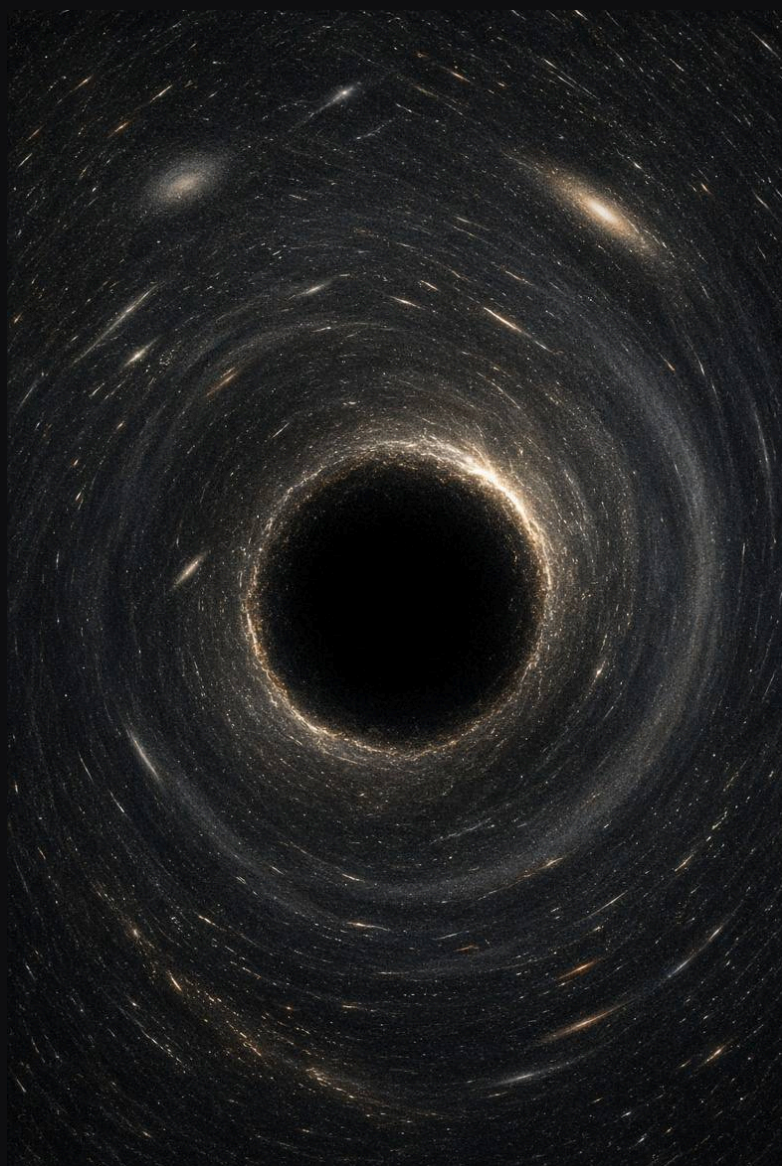


Plate II. Too close. The sky combed into arcs.



Plate III. Human scale. The same object, a quay, an observer.

The filament in the sky of Plate III is not a meteor and not a satellite trail. It is a diagram of proper motion drawn at the wrong distance on purpose. What follows is the machinery that makes that diagram legal.



Plate IV. Looking up. Face and scratch.

Plate IV is the same observer reduced to a sightline. The four-velocity of that sightline is written after the hydro.

1 The reference speed

This paper takes as its working speed

$$v_M = 3 \times 10^6 \text{ mph}, \quad (1)$$

the corridor occupied by recoiling supermassive remnants and certain hypervelocity stars. Convert first, argue second.

$$1 \text{ mph} = 0.44704 \text{ m s}^{-1}, \quad v_M = 1.341 \times 10^6 \text{ m s}^{-1} = 1.341 \times 10^3 \text{ km s}^{-1}. \quad (2)$$

In units the field actually uses:

$$v_M = 1341 \text{ km s}^{-1} = 4.47 \times 10^{-3} c. \quad (3)$$

That is not a relativistic jet and not an ordinary galactic orbital speed. It sits in a thin corridor occupied by three families of object:

1. natal kicks of stellar-mass black holes from asymmetric core-collapse ($v \sim 10^2\text{--}10^3 \text{ km s}^{-1}$);
2. gravitational-wave recoil of merged supermassive remnants (nonspinning ceiling $\sim 175 \text{ km s}^{-1}$; spinning superkicks up to $\sim 10^3\text{--}5 \times 10^3 \text{ km s}^{-1}$);
3. three-body slingshots in a hierarchical SMBH system, of the same order.

The van Dokkum et al. (2023) candidate wake at $z = 0.964$ has projected length 62 kpc and a stellar-age gradient that implies

$$t_{\text{eject}} \simeq 39 \text{ Myr}, \quad v_{\text{BH}} \simeq 1600 \text{ km s}^{-1} \simeq 3.58 \times 10^6 \text{ mph}. \quad (4)$$

So v_M is not an invented scale. It is the rounded form of a real recoil corridor. This register keeps the scale and treats the hole as a bead, not a poster.

Time of flight for a 200,000 ly filament at 1600 km s^{-1} :

$$1 \text{ ly} = 9.461 \times 10^{15} \text{ m}, \quad (5)$$

$$L = 2 \times 10^5 \text{ ly} = 1.892 \times 10^{21} \text{ m}, \quad (6)$$

$$t = \frac{L}{v} = \frac{1.892 \times 10^{21}}{1.6 \times 10^6} \text{ s} = 1.18 \times 10^{15} \text{ s} \simeq 37 \text{ Myr}. \quad (7)$$

The hole at the tip is already 37 million years late for the plate. That is the geometry of the problem.

2 Geometry of the hole

Schwarzschild radius, photon sphere, innermost stable circular orbit:

$$r_s = \frac{2GM}{c^2}, \quad (8)$$

$$r_{\text{ph}} = \frac{3GM}{c^2} = \frac{3}{2}r_s, \quad (9)$$

$$r_{\text{ISCO}} = \frac{6GM}{c^2} = 3r_s. \quad (10)$$

For a Kerr hole of dimensionless spin $a_* = Jc/GM^2$ with $|a_*| \leq 1$,

$$r_+ = \frac{GM}{c^2} \left(1 + \sqrt{1 - a_*^2} \right), \quad (11)$$

$$r_{\text{ph}}^{\pm} = \frac{2GM}{c^2} \left\{ 1 + \cos \left[\frac{2}{3} \arccos(\mp a_*) \right] \right\}. \quad (12)$$

A $10^8 M_{\odot}$ hole has

$$r_s = 2.95 \times 10^{11} \left(\frac{M}{10^8 M_{\odot}} \right) \text{ m} \simeq 2.0 \text{ au}. \quad (13)$$

On Plate I that object is a bead. Correctly.

Gravitational redshift for a static observer at radius r :

$$1 + z = \left(1 - \frac{r_s}{r} \right)^{-1/2}. \quad (14)$$

Escape speed at r :

$$v_{\text{esc}}(r) = c \sqrt{\frac{r_s}{r}}. \quad (15)$$

The Einstein field equation:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \quad (16)$$

In vacuum outside the hole, $T_{\mu\nu} = 0$ and Λ is irrelevant at these scales, so $G_{\mu\nu} = 0$. The wake is not vacuum. The wake is $T_{\mu\nu}$.

3 Where the kick comes from

Asymmetric gravitational waves carry net linear momentum. The remnant recoils the other way.

$$\frac{dP^i}{dt} = -\frac{c^3}{32\pi G} n^i r^2 \left\langle \dot{h}_{jk}^{\text{TT}} \dot{h}_{\Gamma\Gamma}^{jk} \right\rangle_{S^2}. \quad (17)$$

For a binary of masses m_1, m_2 ,

$$q = \frac{m_2}{m_1} \leq 1, \quad \eta = \frac{q}{(1+q)^2} = \frac{m_1 m_2}{(m_1 + m_2)^2}, \quad \delta m = \frac{m_1 - m_2}{m_1 + m_2}. \quad (18)$$

Unequal-mass, nonspinning fit (González / Baker / Campanelli family):

$$V_m = A\eta^2 \sqrt{1 - 4\eta} (1 + B\eta), \quad (19)$$

with $A \sim 1.2 \times 10^4 \text{ km s}^{-1}$, $B \sim -0.93$. The maximum of that branch is

$$V_m^{\max} \simeq 175 \text{ km s}^{-1} \quad \text{near } q \simeq 0.36. \quad (20)$$

Not enough to leave a massive host. Spin supplies the rest:

$$V_{\perp} = H \eta^2 \frac{q\alpha_1^{\parallel} - \alpha_2^{\parallel}}{1 + q}, \quad (21)$$

$$V_{\parallel} = K \eta^2 \frac{|q\alpha_1^{\perp} - \alpha_2^{\perp}|}{1 + q} \cos(\phi_{\Delta} - \Phi). \quad (22)$$

Aligned opposite in-plane spins at $q \sim 1$ drive $V_{\parallel}$ into the thousands of kilometres per second. That is how a hole ends up on Plate I with a 62 kpc piece of string behind it.

Three-body ejection is the other legal channel. In a hierarchical triple the lightest hole can be slung at

$$v \sim v_{\text{bin}} \sqrt{\frac{m_{\text{bin}}}{m_{\text{ej}}}}, \quad (23)$$

where v_{bin} is the inner binary's orbital speed at the moment of scattering. Same corridor of velocities, different ancestry.

4 Motion through gas

A hole of mass M moving at speed v through circumgalactic gas of density ρ and sound speed c_s accretes at the Bondi–Hoyle–Lyttleton rate

$$\dot{M}_{\text{BHL}} = \frac{4\pi G^2 M^2 \rho}{(v^2 + c_s^2)^{3/2}}. \quad (24)$$

For $v \gg c_s$ this collapses to

$$\dot{M}_{\text{BHL}} \simeq 4\pi G^2 M^2 \rho v^{-3}. \quad (25)$$

Ram pressure:

$$P_{\text{ram}} = \rho v^2. \quad (26)$$

Mach number:

$$\mathcal{M} = \frac{v}{c_s}. \quad (27)$$

For $T \sim 10^5 \text{ K}$ ionised CGM, $c_s \sim 30\text{--}50 \text{ km s}^{-1}$, so a 1600 km s^{-1} hole is running at $\mathcal{M} \sim 30\text{--}50$. Strong-shock territory.

Rankine–Hugoniot jump conditions for an ideal gas with $\gamma = 5/3$:

$$\frac{\rho_2}{\rho_1} = \frac{(\gamma + 1)\mathcal{M}^2}{(\gamma - 1)\mathcal{M}^2 + 2} \xrightarrow{\mathcal{M} \rightarrow \infty} \frac{\gamma + 1}{\gamma - 1} = 4, \quad (28)$$

$$\frac{P_2}{P_1} = \frac{2\gamma\mathcal{M}^2 - (\gamma - 1)}{\gamma + 1}, \quad (29)$$

$$\frac{T_2}{T_1} = \frac{[2\gamma\mathcal{M}^2 - (\gamma - 1)][(\gamma - 1)\mathcal{M}^2 + 2]}{(\gamma + 1)^2\mathcal{M}^2}. \quad (30)$$

Post-shock temperature for a strong shock:

$$T_2 \simeq 1.4 \times 10^7 \left(\frac{v}{10^3 \text{ km s}^{-1}} \right)^2 \text{ K}. \quad (31)$$

At 1600 km s^{-1} that is $T_2 \sim 3.6 \times 10^7 \text{ K}$. X-ray gas. It cools. Cooling is why there are stars in the filament instead of only a scar of heat.

The Euler equation with gravity:

$$\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} = -\frac{\nabla P}{\rho} - \nabla \Phi + \mathbf{a}_{\text{visc}}, \quad (32)$$

closed by continuity and Poisson:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) = 0, \quad (33)$$

$$\nabla^2 \Phi = 4\pi G \rho. \quad (34)$$

Energy:

$$\frac{\partial e}{\partial t} + \nabla \cdot [(e + P)\mathbf{v}] = \rho \mathbf{v} \cdot \nabla \Phi - n^2 \Lambda(T) + \mathcal{H}. \quad (35)$$

$\Lambda(T)$ is the cooling function. $\mathcal{H}$ is any heating the hole still contributes. A starved, fast-moving remnant does not contribute much. The wake is a cooling problem with a moving boundary condition.

5 Why the stars get older down the string

If the hole triggers star formation at the instant it passes a parcel of gas, stellar age along the wake is a clock:

$$\tau(s) = \frac{s}{v_{\text{BH}}}, \quad (36)$$

where s is distance from the tip. That is the van Dokkum fit: colours going red as one walks back toward the former host, τ rising from $\sim 1 \text{ Myr}$ at the head to $\sim 39 \text{ Myr}$ at the galaxy. The hole does not drag the stars with it. They are born nearly at rest with respect to the CGM and stay. The observed line-of-sight speeds along the wake ($\sim 100\text{--}330 \text{ km s}^{-1}$) are therefore not v_{BH} . They are the shocked and mixed gas, not the bullet.

Downstream turbulent entrainment:

$$\frac{d}{ds}(\rho_w A_w v_w) = \xi \rho_{\text{CGM}} 2\pi R_w v_{\text{rel}}, \quad (37)$$

with ξ an entrainment efficiency of order 10^{-1} or less. This is why a JWST velocity jump at the tip can be $\sim 600 \text{ km s}^{-1}$ across a kiloparsec and then decay toward the host. The bullet keeps 1600. The gas forgets.

6 Lensing, the photon ring, Plate II

Deflection of a light ray with impact parameter b in Schwarzschild:

$$\hat{\alpha}(b) = \frac{4GM}{c^2 b} + \frac{15\pi}{4} \left(\frac{GM}{c^2 b} \right)^2 + \mathcal{O}(b^{-3}). \quad (38)$$

The Einstein angle for a thin lens:

$$\theta_E = \sqrt{\frac{4GM}{c^2} \frac{D_{LS}}{D_L D_S}}. \quad (39)$$

Critical impact parameter for photon capture:

$$b_c = \sqrt{27} \frac{GM}{c^2} = 3\sqrt{3} \frac{GM}{c^2}. \quad (40)$$

Rays with $b \downarrow b_c$ wind many times and form the photon ring — the thin unstable wire of light on Plate II. That plate is not an accretion disk. It is the sky as a congruence of null geodesics,

$$\frac{d^2 x^\mu}{d\lambda^2} + \Gamma_{\alpha\beta}^\mu \frac{dx^\alpha}{d\lambda} \frac{dx^\beta}{d\lambda} = 0, \quad (41)$$

combed by $\Gamma_{\alpha\beta}^\mu$ until the background galaxies become hair.

7 What v_M is not

	v	v/c
this work, v_M	$1.34 \times 10^3 \text{ km s}^{-1}$	4.5×10^{-3}
van Dokkum et al. candidate (projected)	$\sim 1.6 \times 10^3 \text{ km s}^{-1}$	5.3×10^{-3}
nonspinning GW recoil, max	$\sim 175 \text{ km s}^{-1}$	5.8×10^{-4}
spinning superkick, upper simulations	$\sim (1\text{--}5) \times 10^3 \text{ km s}^{-1}$	~ 0.01
Sgr A* hypervelocity star	$\sim 1.7 \times 10^3 \text{ km s}^{-1}$	5.6×10^{-3}
solar coronal mass ejection	$\sim 1.3 \times 10^3 \text{ km s}^{-1}$	4.5×10^{-3}
relativistic jet spine	$\gtrsim 0.9c$	$\gtrsim 0.9$

A solar coronal-mass ejection happens to live at the same order of speed. That coincidence is not a physical identification.

A jet is a beamed MHD wind with

$$\Gamma = \frac{1}{\sqrt{1 - \beta^2}} \gg 1. \quad (42)$$

A recoiling hole is a compact mass with $\Gamma - 1 \sim 10^{-5}$. Plate I is the second thing.

8 Partial inventory — the equations that actually run

Gravity:

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}. \quad (43)$$

Null rays:

$$k^\alpha \nabla_\alpha k^\mu = 0, \quad k^\mu k_\mu = 0. \quad (44)$$

Ideal MHD in the shocked CGM:

$$\partial_t \rho + \nabla \cdot (\rho \mathbf{v}) = 0, \quad (45)$$

$$\partial_t (\rho \mathbf{v}) + \nabla \cdot (\rho \mathbf{v} \mathbf{v} + \mathbb{I}(P + B^2/2\mu_0) - \mathbf{B} \mathbf{B}/\mu_0) = -\rho \nabla \Phi, \quad (46)$$

$$\partial_t \mathbf{B} = \nabla \times (\mathbf{v} \times \mathbf{B}), \quad (47)$$

$$\nabla \cdot \mathbf{B} = 0. \quad (48)$$

Cooling that makes the stars:

$$n^2 \Lambda(T) \text{ with } \Lambda(T) \text{ peaking near } 10^5 \text{ K}. \quad (49)$$

A clock:

$$\tau(s) = s/v_{\text{BH}}. \quad (50)$$

A confession:

$$\text{Plate I} \neq \text{an observation}. \quad (51)$$

9 The observer on the quay

Plate IV is a four-velocity with glasses.

Take the observer as instantaneously at rest in a local Earth frame S on the quay. Then

$$u_{\text{obs}}^\mu = (c, 0, 0, 0) \quad \text{in } S, \quad u_\mu u^\mu = -c^2. \quad (52)$$

A photon from the wake arrives on a null geodesic k^μ with

$$k^\mu k_\mu = 0, \quad \omega_{\text{obs}} = -u_\mu k^\mu. \quad (53)$$

If the source is the van Dokkum candidate at redshift $z = 0.964$, the observed frequency is

already crushed by expansion before any peculiar motion of the hole matters:

$$1 + z_{\text{cos}} = \frac{a(t_{\text{obs}})}{a(t_{\text{em}})} = 1.964, \quad \omega_{\text{obs}} = \frac{\omega_{\text{em}}}{1 + z_{\text{cos}}}. \quad (54)$$

The hole's peculiar speed $v_{\text{BH}} \simeq 1600 \text{ km s}^{-1}$ adds only a Doppler sliver. For an angle θ between $\mathbf{v}_{\text{BH}}$ and the line of sight,

$$1 + z_{\text{pec}} = \frac{\sqrt{1 - \beta^2}}{1 - \beta \cos \theta}, \quad \beta = \frac{v_{\text{BH}}}{c} \simeq 5.3 \times 10^{-3}. \quad (55)$$

Even head-on, $z_{\text{pec}} \simeq \beta \simeq 0.005$. Cosmology owns the colour. Recoil owns the length of the string.

Aberration of the filament's apparent direction is of the same order:

$$\cos \theta_{\text{obs}} = \frac{\cos \theta + \beta}{1 + \beta \cos \theta} \implies \Delta \theta \sim \beta \sim 0.3^\circ \quad (56)$$

at most. Plate IV does not see a warped sky because the observer is slow. Plate II is what you get if you stop being slow.

Light-travel time from a source at $z = 0.964$ in a flat Λ CDM sketch ($H_0 = 70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_m = 0.3$):

$$t_{\text{look}} = \int_0^z \frac{dz'}{(1 + z')H(z')}, \quad H(z) = H_0 \sqrt{\Omega_m(1 + z)^3 + \Omega_\Lambda}. \quad (57)$$

That integral is $\sim 7.6 \text{ Gyr}$. The 39 Myr clock in the wake is a local proper-time stub at the far end of a 7.6 Gyr glance. Plate IV is looking at something that finished moving before there were quays.

The measured specific intensity along a ray, ignoring scattering:

$$I_\nu / \nu^3 = \text{const} \quad (58)$$

in the absence of emission and absorption. The wake's [O III] and H α are the places that sentence fails — bound electrons doing work in the cooling gas.

If the observer blinks, the four-velocity does not. That is the whole difference between a person and a geodesic.

10 Matthew Raynor at v_M

Write the observer into the working speed and refuse to lie about γ .

Let the observer's rest mass be a laboratory figure, not a medical claim:

$$m = 70 \text{ kg}, \quad v_M = 3 \times 10^6 \text{ mph} = 1.34112 \times 10^6 \text{ m s}^{-1}. \quad (59)$$

Then

$$\beta_M = \frac{v_M}{c} = 4.473 \times 10^{-3}, \quad (60)$$

$$\gamma_M = (1 - \beta_M^2)^{-1/2} = 1.000010006. \quad (61)$$

Time dilation and length contraction at this speed are ten parts per million. A year of ship time differs from a year of quay time by

$$\Delta t \simeq (\gamma_M - 1)t \simeq 5.3 \text{ minutes per year}. \quad (62)$$

Relativity is not the story. Energy is the story. The exact relativistic kinetic energy

$$K = (\gamma_M - 1)mc^2 \quad (63)$$

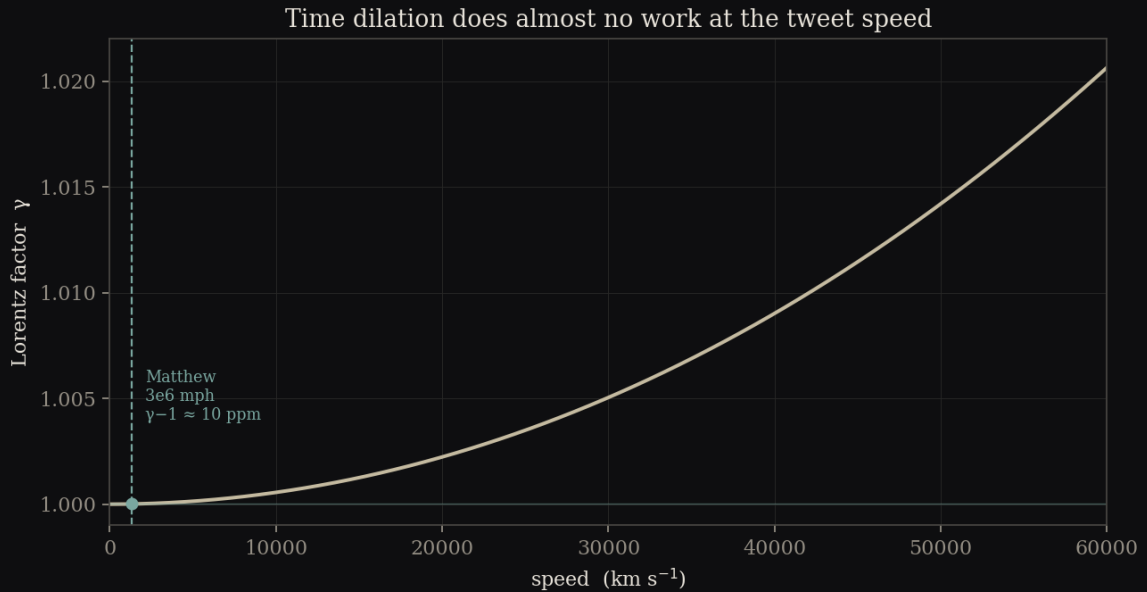
and the Newtonian twin

$$K_N = \frac{1}{2}mv_M^2 \quad (64)$$

agree to one part in 10^5 :

$$K \simeq K_N = 6.295 \times 10^{13} \text{ J} = 15.05 \text{ kilotons of TNT}. \quad (65)$$

A 70 kg body at v_M carries the yield of a small fission weapon *if that energy is dumped*. Flying past a star at constant v_M dumps nothing. Hitting air dumps everything.



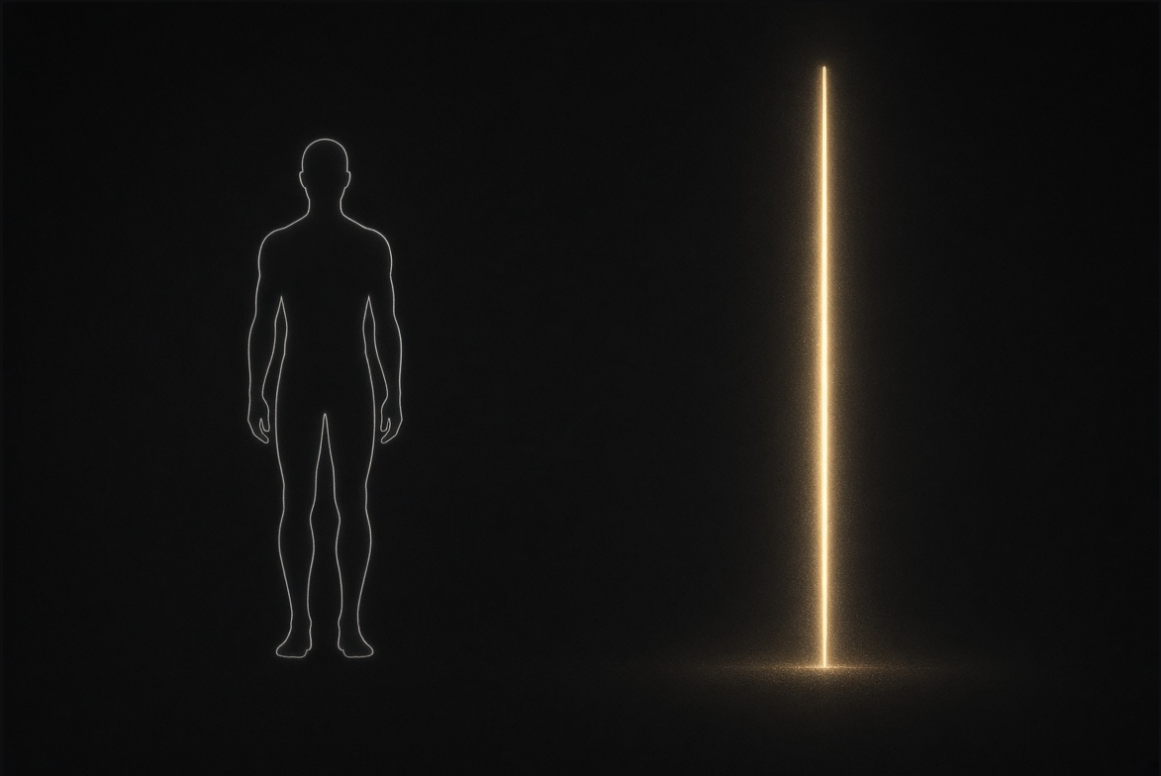
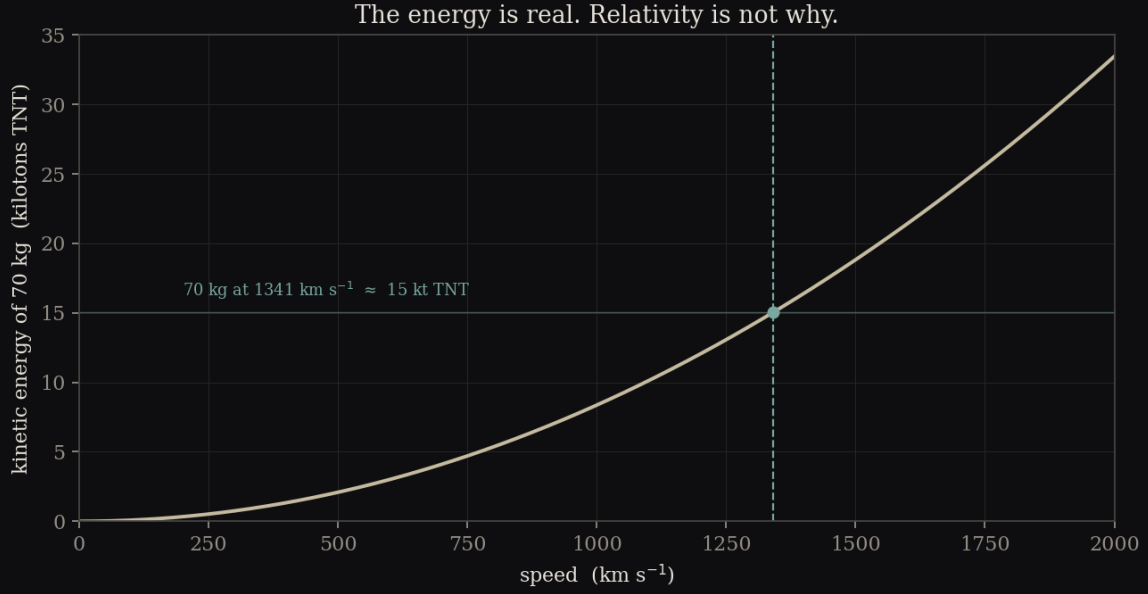


Plate E. Seventy kilograms, and the quiet column of what that motion is worth.

11 How v_M could be occupied

Not by walking. Not by being thrown from a black hole. A human body at $r \sim 10 r_s$ of a $10^8 M_\odot$ hole is a tidal problem, not a transport problem. The legal channels are engineering.

Reach v_M at one g .

$$t = \frac{v_M}{g_\oplus} = 1.368 \times 10^5 \text{ s} = 1.58 \text{ days.} \quad (66)$$

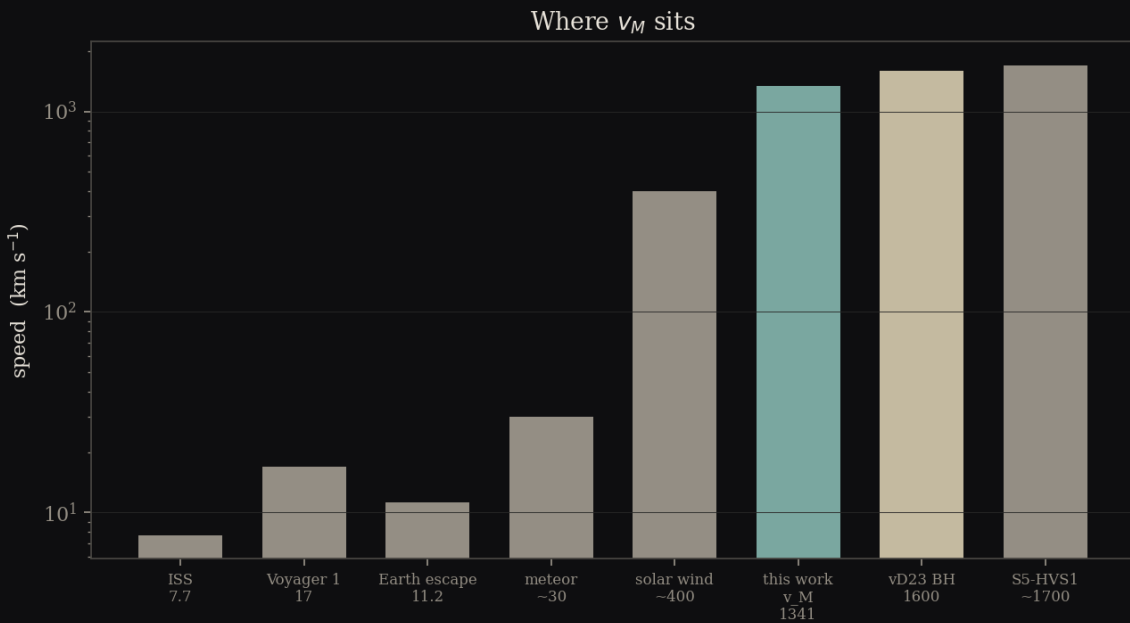
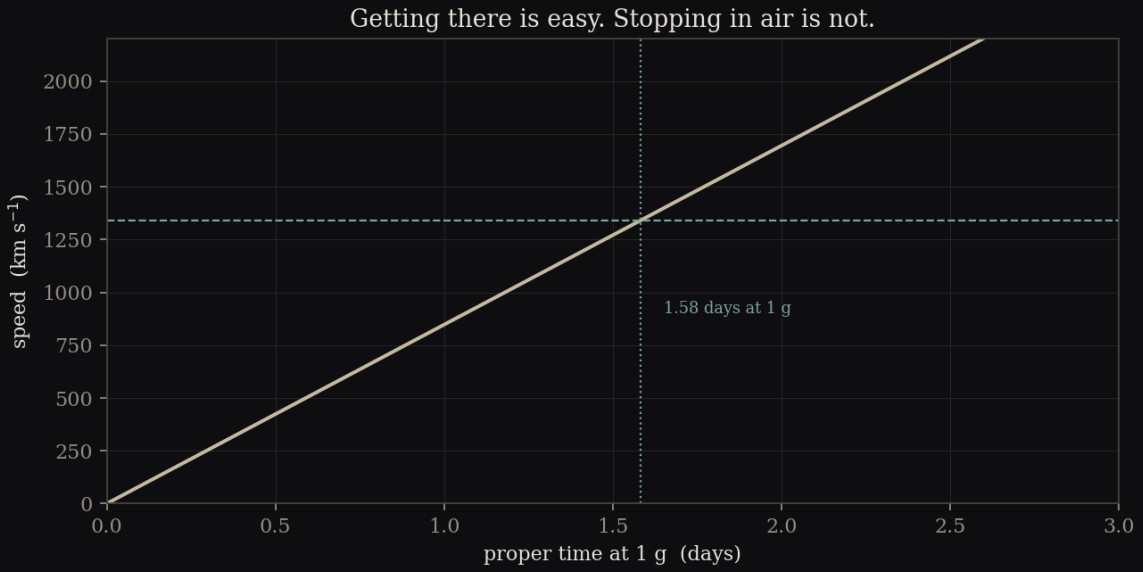
Distance during a constant $1 g$ burn from rest:

$$s = \frac{1}{2} g_{\oplus} t^2 = 9.18 \times 10^{10} \text{ m} \simeq 0.61 \text{ au.} \quad (67)$$

Getting to the number is easy if you have a drive that can hold 9.8 m s^{-2} for thirty-eight hours. Chemical rockets cannot. A high- I_{sp} electric or fusion stage can, in principle. Photon rocket mass ratio for exhaust at c :

$$\frac{m_0}{m_1} = e^{\Delta v/c} = e^{\beta_M} \simeq 1.00448. \quad (68)$$

Four-tenths of a percent of the ship as radiated energy. The physics of the rocket equation is gentle. The physics of the atmosphere is not.



What will not work. Earth orbital speed 7.7 km s^{-1} . Voyager 17 km s^{-1} . Solar escape from 1 au about 42 km s^{-1} . Gravity assists rearrange momentum already in the Solar System; they do not mint 1341 km s^{-1} from a standing start on a quay. A Hills-mechanism ejection from Sgr A* can throw a *star* at this speed. It cannot throw an unprotected vertebrate and have the vertebrate remain a vertebrate.

The only honest vehicle. A shielded capsule in vacuum, accelerated slowly, never asked to share air with v_M . Plate V is what happens if you ignore that sentence. Plate VI is the interior of the sentence obeyed.



Plate V. Thermosphere at v_M . The shock is the physics. The craft is a hypothesis.



Plate VI. Interior. The only version of this speed in which organic tissue has a chance.

12 What happens to organic life

Three regimes. Only one of them is survivable.

Regime A — tissue in air

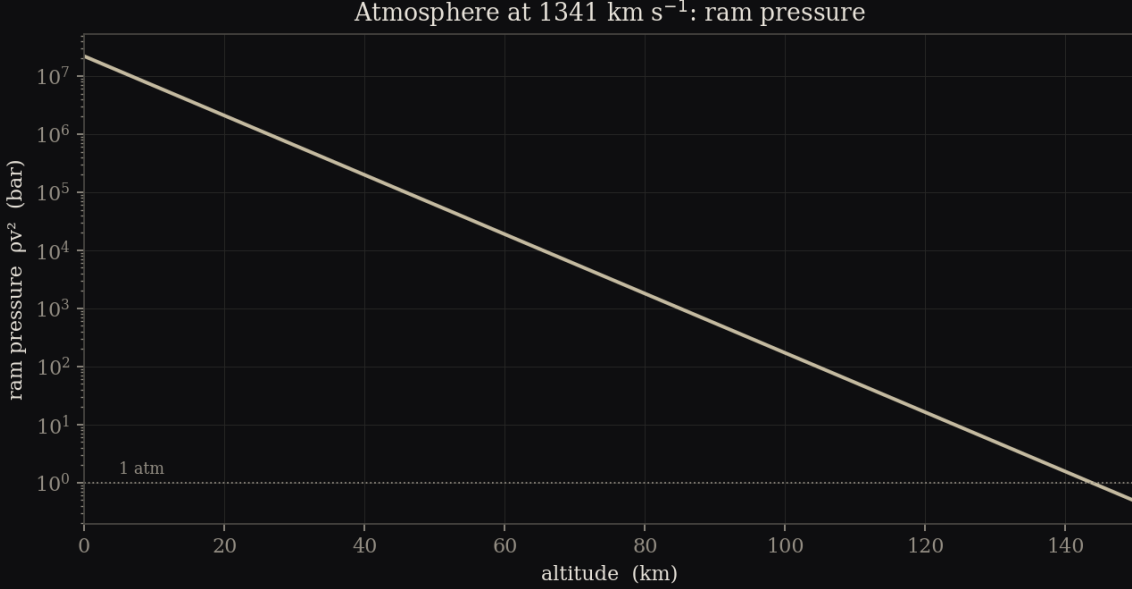
Ram pressure and stagnation enthalpy at sea-level density $\rho_0 = 1.225 \text{ kg m}^{-3}$:

$$P_{\text{ram}} = \rho_0 v_M^2 = 2.20 \times 10^{12} \text{ Pa} \simeq 2.2 \times 10^7 \text{ bar}, \quad (69)$$

$$h_{\text{stag}} \simeq \frac{1}{2} v_M^2 = 9.0 \times 10^{11} \text{ J kg}^{-1}. \quad (70)$$

A characteristic temperature from $h \sim c_p T$ with $c_p \sim 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$ is of order 10^9 K . The number is not a skin temperature. It is the statement that the oncoming air has nowhere to put its

kinetic energy except ionisation. A meteoroid at 30 km s^{-1} already becomes a fireball. v_M is forty times that. There is no ablation shield for a coat and a pair of glasses. Regime A is not a medical case. It is a plasma case.



Even at 80 km, ρ has fallen by four orders of magnitude and P_{ram} is still tens of bars. The first honest altitude for v_M is the exosphere and above.

Regime B — tissue in vacuum, unshielded

No ram pressure from air. Instead, a flux of interstellar particles.

Take a quiet local ISM, $n_H \sim 0.1 \text{ cm}^{-3} = 10^5 \text{ m}^{-3}$. Each proton in the ship's frame carries

$$E_p \simeq \frac{1}{2} m_p v_M^2 \simeq 9.4 \text{ keV}. \quad (71)$$

That is a soft X-ray photon's energy, delivered as a nucleus. Column in one year of flight:

$$N = n_H v_M t_{\text{yr}} \simeq 4.2 \times 10^{18} \text{ m}^{-2}. \quad (72)$$

Energy fluence on an unshielded square metre:

$$F \simeq N E_p \simeq 6.4 \text{ kJ m}^{-2} \text{ yr}^{-1}. \quad (73)$$

As heat, that is modest — a few watts per square metre. As radiation biology it is a surface problem: 9 keV protons stop in the first tens of microns of tissue or fabric. The skin dose is not a whole-body gray count from this channel alone. Dust is the violent term. A $1 \mu\text{g}$ grain at v_M carries

$$K_{\text{grain}} = \frac{1}{2} (10^{-9} \text{ kg}) v_M^2 \simeq 900 \text{ J}. \quad (74)$$

That is a rifle cartridge, delivered by a particle you cannot see. Unshielded organic life in the ISM at v_M does not cook. It is perforated, over months, by grit.

Galactic cosmic rays are a separate, slower poison and are not unique to this speed.

Regime C — tissue inside a hull

This is the only regime in which the word *life* remains operational.

Required of the hull:

1. never enter Regime A;
2. present a bumper or Whipple shield to grains — here forty times faster than typical meteoroid design speeds, so the bumper must be thicker or sacrificial and stand-off;
3. hold $1 g$ for 1.58 days if that is how v_M is reached, which human cardiovascular and vestibular systems already know how to do;
4. reject waste heat from the drive, which is a ship problem, not a relativity problem.

What does *not* happen in Regime C at v_M :

- no twin paradox worth writing home about (5 minutes per year);
- no Lorentz-contracted observer (the contraction of a 1.8 m body is $18 \mu\text{m}$);
- no mass increase that a scale would report to the cook (the inertial mass shift is 0.7 g);
- no Cerenkov glow from the body in air, because the body is not in air.

What *does* happen: the ordinary brutalities of closed-loop life support, radiation already present in deep space, and the engineering fact that slowing down is the same 1.58 days in reverse — and must not be attempted in an atmosphere.

Tissues, in one paragraph

Organic tissue is a low-density, high-water, enzyme-run machine. It tolerates a few g for days, a few sievert accumulated over years if repair keeps up, and almost no ram-pressure heating at all. v_M does not uniquely ionise biochemistry through γ . It uniquely ionises the *medium* the biochemistry is flying through. Keep the medium off the skin and the biochemistry does not notice v_M . Put the medium on the skin and the biochemistry is no longer the right unit of description.

13 The Matthew Raynor equations, collected

$$v_M = 1.34112 \times 10^6 \text{ m s}^{-1}, \quad (75)$$

$$\beta_M = 4.473 \times 10^{-3}, \quad (76)$$

$$\gamma_M = 1.000010006, \quad (77)$$

$$K_M = (\gamma_M - 1)mc^2 \simeq \frac{1}{2}mv_M^2 = 6.295 \times 10^{13} \text{ J}, \quad (78)$$

$$t_{1g} = v_M/g_{\oplus} = 1.58 \text{ d}, \quad (79)$$

$$s_{1g} = \frac{1}{2}g_{\oplus}t_{1g}^2 = 0.61 \text{ au}, \quad (80)$$

$$E_p = \frac{1}{2}m_pv_M^2 = 9.4 \text{ keV}, \quad (81)$$

$$P_{\text{ram}}(\rho_0) = \rho_0 v_M^2 = 2.2 \times 10^{12} \text{ Pa}. \quad (82)$$

The black hole on Plate I can carry this speed because it is not organic. The observer on Plates III–IV and VI can carry this speed only inside a sentence that begins with *hull* and ends with *never air*.

Closing note

This register is Matthew Raynor research on recoiling supermassive black holes and the biological constraint at v_M . The plates are illustrations, not telescope data. The physics is real recoil, a real class of wake, real jump conditions, a real clock in the stellar colours, and a real four-velocity on a quay.

Plate I is the wake. Plate II is the tax for standing in the wrong place. Plate III is the same object at human height. Plate IV is the sightline. Plates V and VI are the two answers to whether organic life can share the corridor: no, if air; only, if hull.

The interesting number was never the miles per hour. It was $\gamma_M - 1 = 10^{-5}$, and the twenty million atmospheres waiting in the first metre of weather.

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Observer likeness of Matthew Raynor used by authority of the sitter.

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No telescope catalogue. No silent reuse of the face.