

Write Or Radiate

Christopher Rose
Rutgers University, [WINLAB](#)

Cal Tech Lunch Bunch
October 25, 2011

PHYSICIST



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$$E = h\nu$$

$$E = mc^2$$

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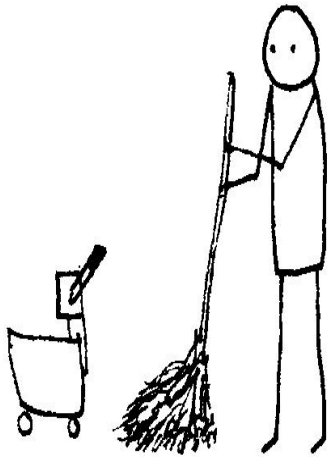


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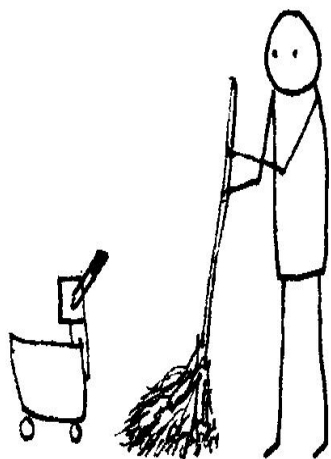


communication theorist



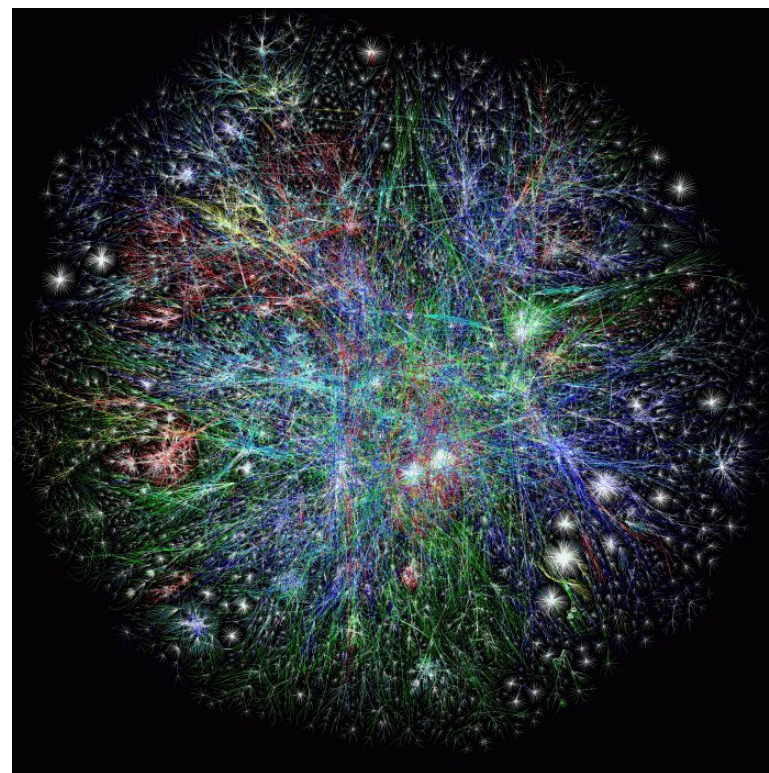
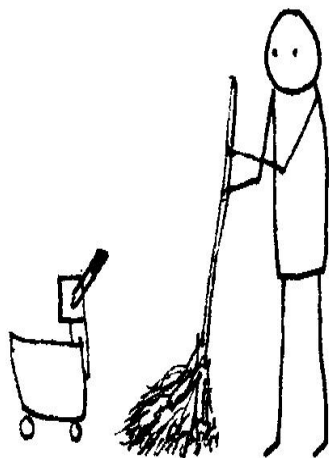
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The Usual Cocktail Party Response



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Forget Radio! **Write** message down! **Toss** it to recipient!

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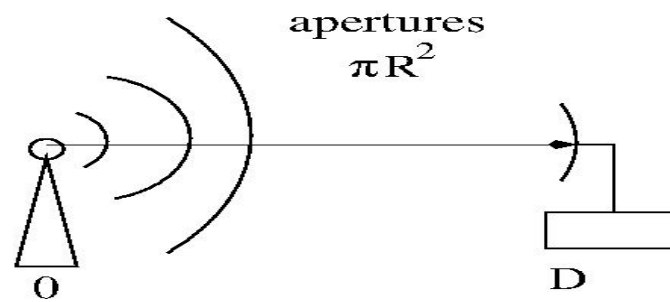
COMPLETELY RIDICULOUS, RIGHT??!!

Look More Closely At What We Think We Know

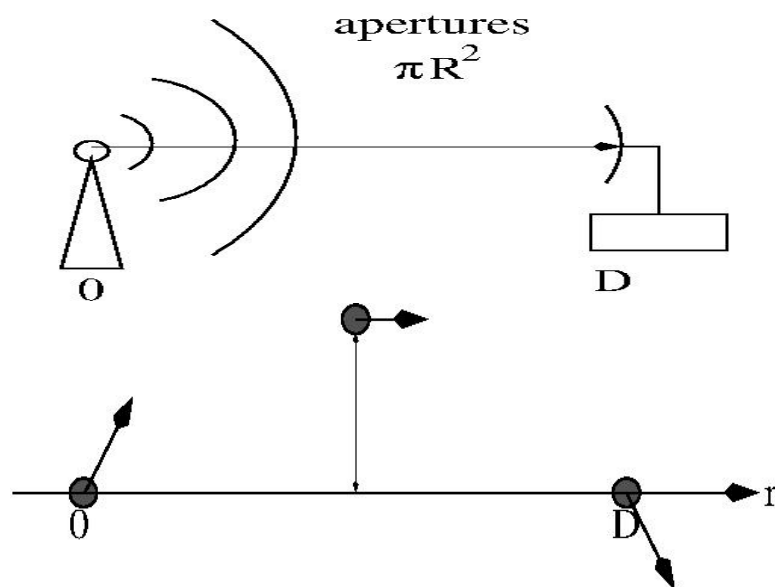
A truck filled with storage media, driven across town, is a very reliable high bit rate channel.

—Comm. Theory Collective Subconscious

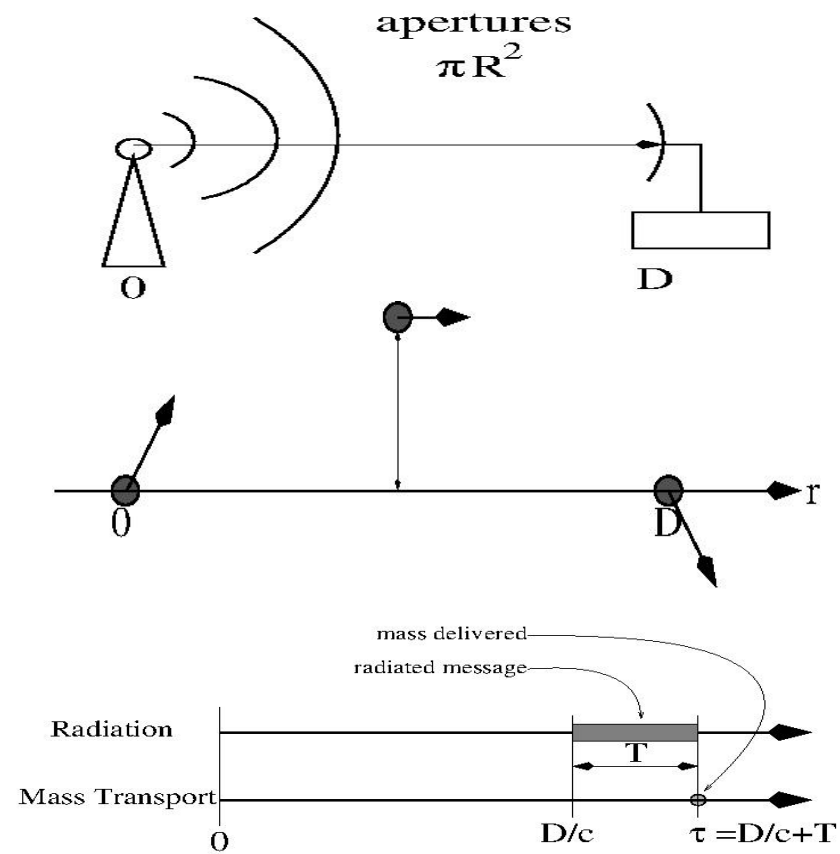
A Little Analytic Rigor



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Radiation Energy Requirements

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- Large TW :

$$\mathcal{E}_r \geq BN_0 \left(\frac{4\pi D^2}{AG} \right) \ln 2$$

Writing Energy Requirements (ROCKET SCIENCE!)

$$\mathcal{E}^* = \min_{x(t)} \max_t \mathcal{E}(t)$$

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Inscribed Matter Energy Requirements

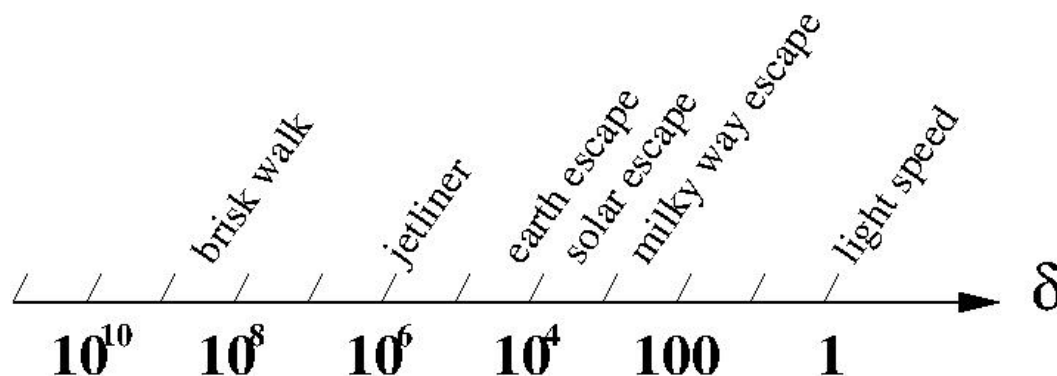
Message size B bits, mass information density $\tilde{\rho}$ bits/kg

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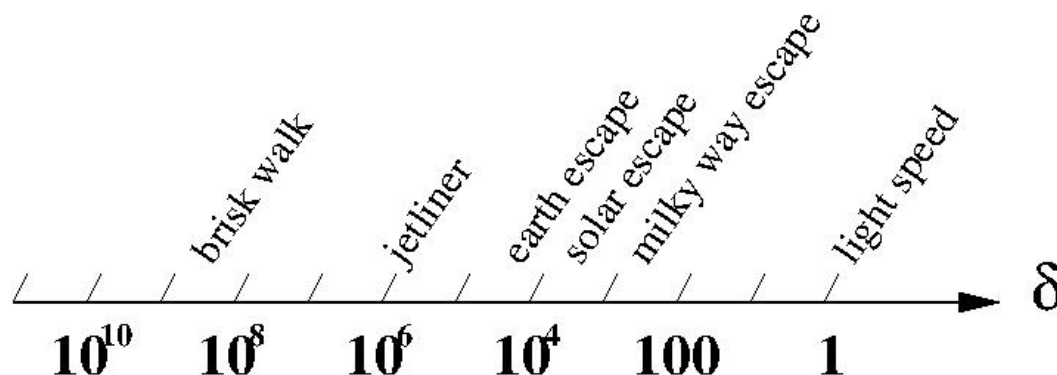
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Artillery: adds a factor of 2 to energy

Escape: small penalty if $\bar{v} > 2 \times$ escape velocity

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$$\Rightarrow \Omega \geq \left[\frac{\tilde{\rho} N_0}{c^2} \right] \left[\frac{8}{\pi^2} \left(\frac{\mathcal{D}}{\mathcal{A}} \right)^2 \right] (2 \ln 2) \delta^2 \Leftarrow$$

Equal Receiver/Transmitter Apertures

Mass Information Density, $\tilde{\rho}$

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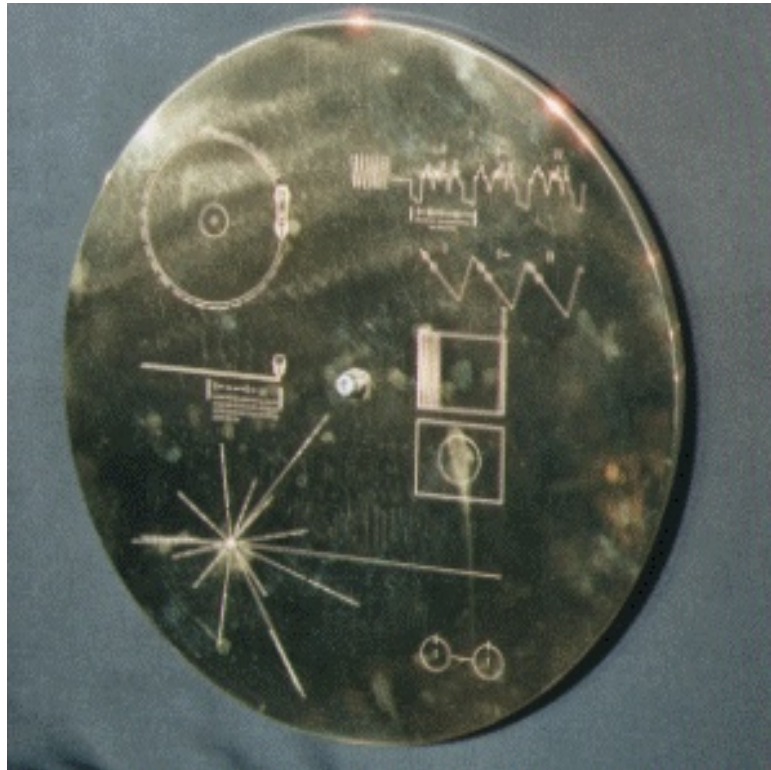
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VERY antisocial!

Empirical Mass Information Densities I

Voyager Spacecraft: 10^6 bits/kg



Empirical Mass Information Densities II

- **20 lb paper @ 1000dpi:** 2×10^{10} bits/kg
- **DVD:** 3×10^{12} bits/kg
- **Magnetic Storage** with FeO_2 : 2×10^{17} bits/kg
- **Optical Lithography** with SiO_2 : 3.85×10^{18} bits/kg
- **E-beam Lithography** with SiO_2 : 1.54×10^{21} bits/kg
- **STM** with Xe on Ni: 1.74×10^{22} bits/kg
- **RNA:** 3.6×10^{24} bits/kg
- **Li + Be:** 7.5×10^{25} bits/kg

Radiation vs. Inscribed Matter

Terrestrial Artillery vs. Radiation

$$\tilde{\rho} = 3 \times 10^{24}$$

1 GHz Carrier

$R = 5\text{cm}$ (handheld receiver)

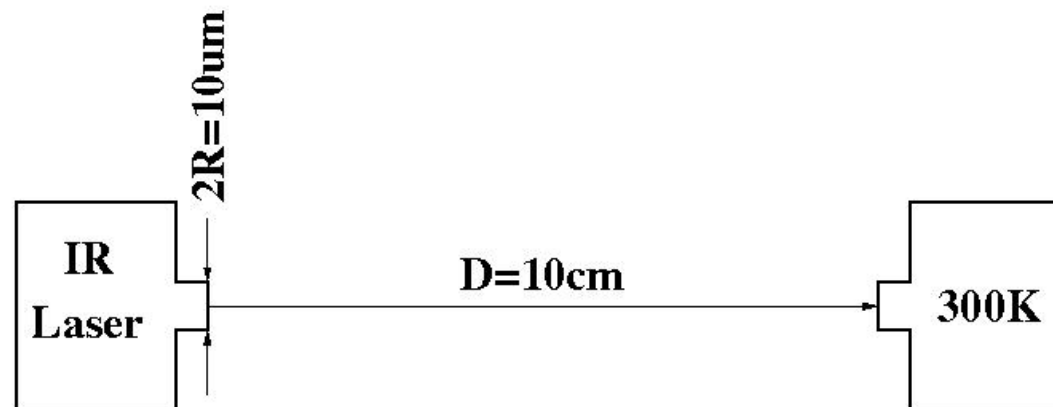
Temperature $300K$

Range (meters)	Transit Time	Ω
10	1.43 sec	1.3×10^7
100	4.5 sec	1.3×10^8
10^3	14.3 sec	1.3×10^9
10^4	45 sec	1.3×10^{10}

Aside: ≈ 4 minutes between NYC and Boston ballistically (320km).

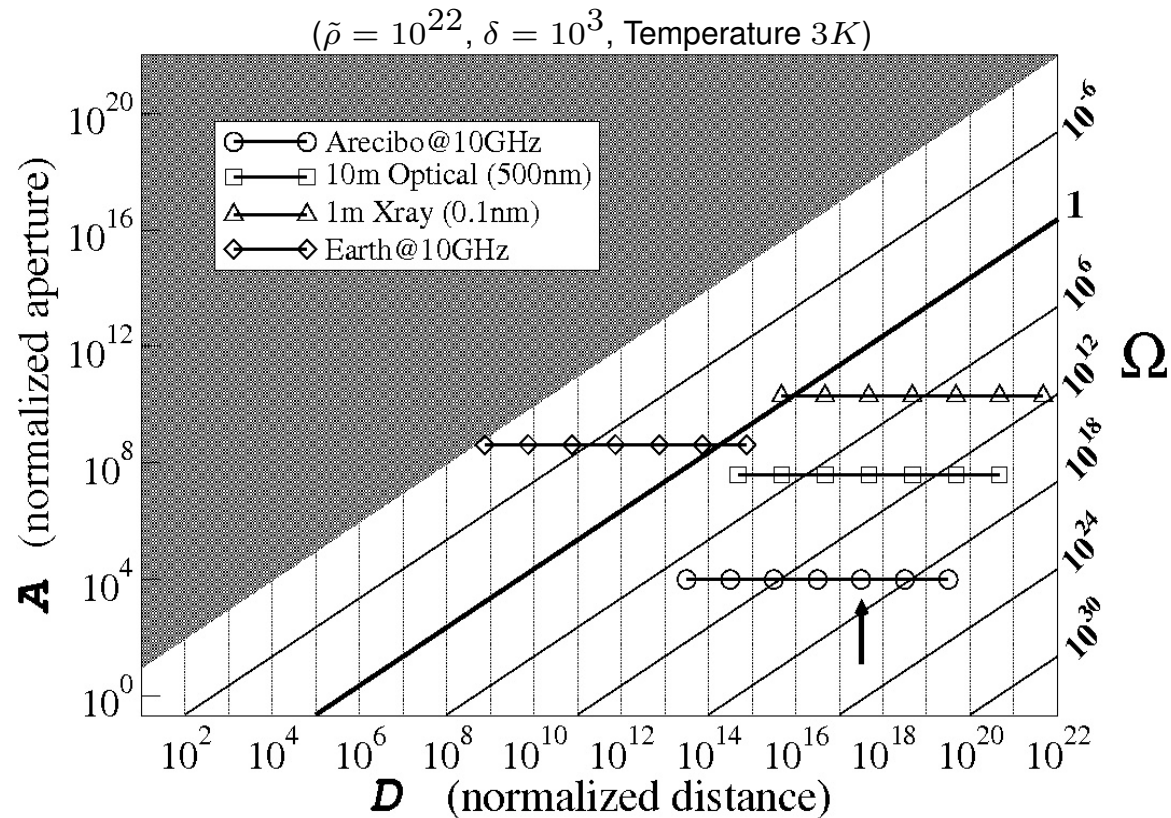
Wafer to Wafer Laser Links

$$\delta = 10^9, \lambda = 1\mu\text{m}$$



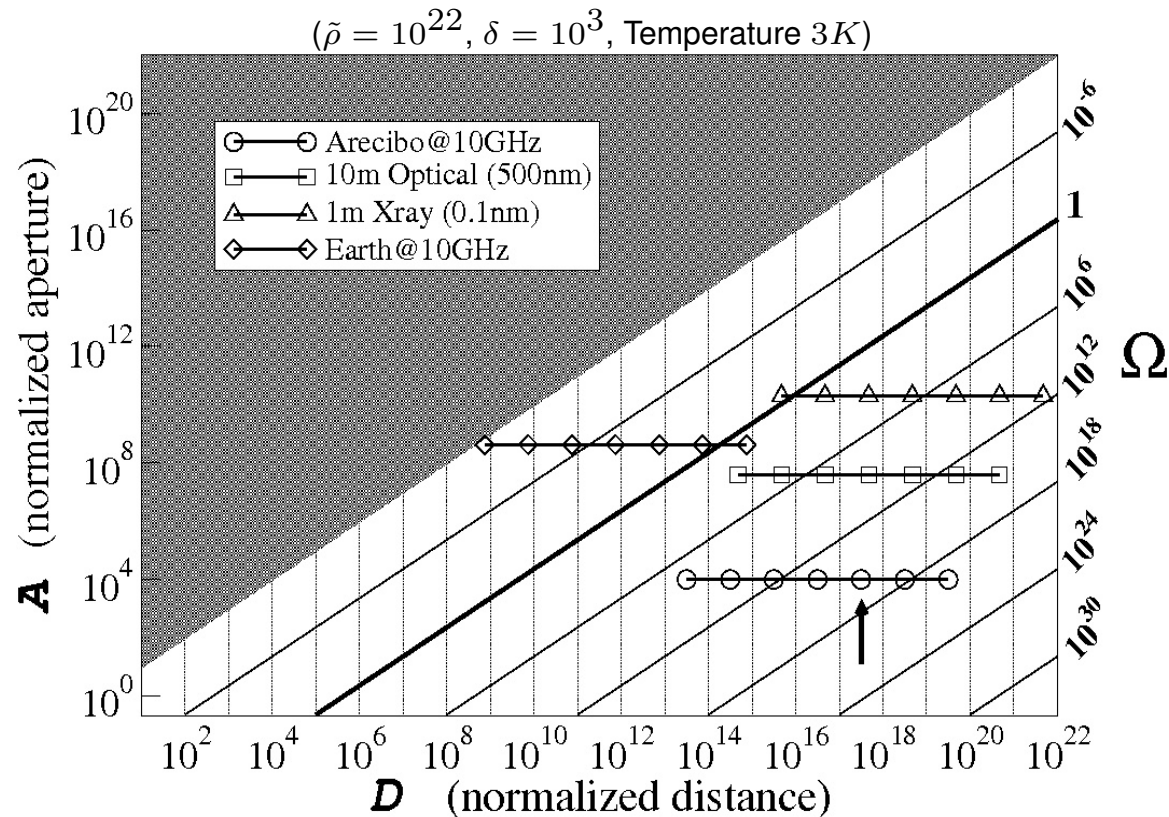
Magnetic chits: $\Omega \geq 10^4$
STM-inscribed chits: $\Omega \geq 5 \times 10^8$

Interstellar



→ 10k LY, Arecibo-Arecibo: $\Omega \geq 5 \times 10^{15}$

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Radiation/Matter: (24 megaton blast) / (Shelve 5 lb sugar bag)

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- 10^9 bit payload
- 900 kg mass
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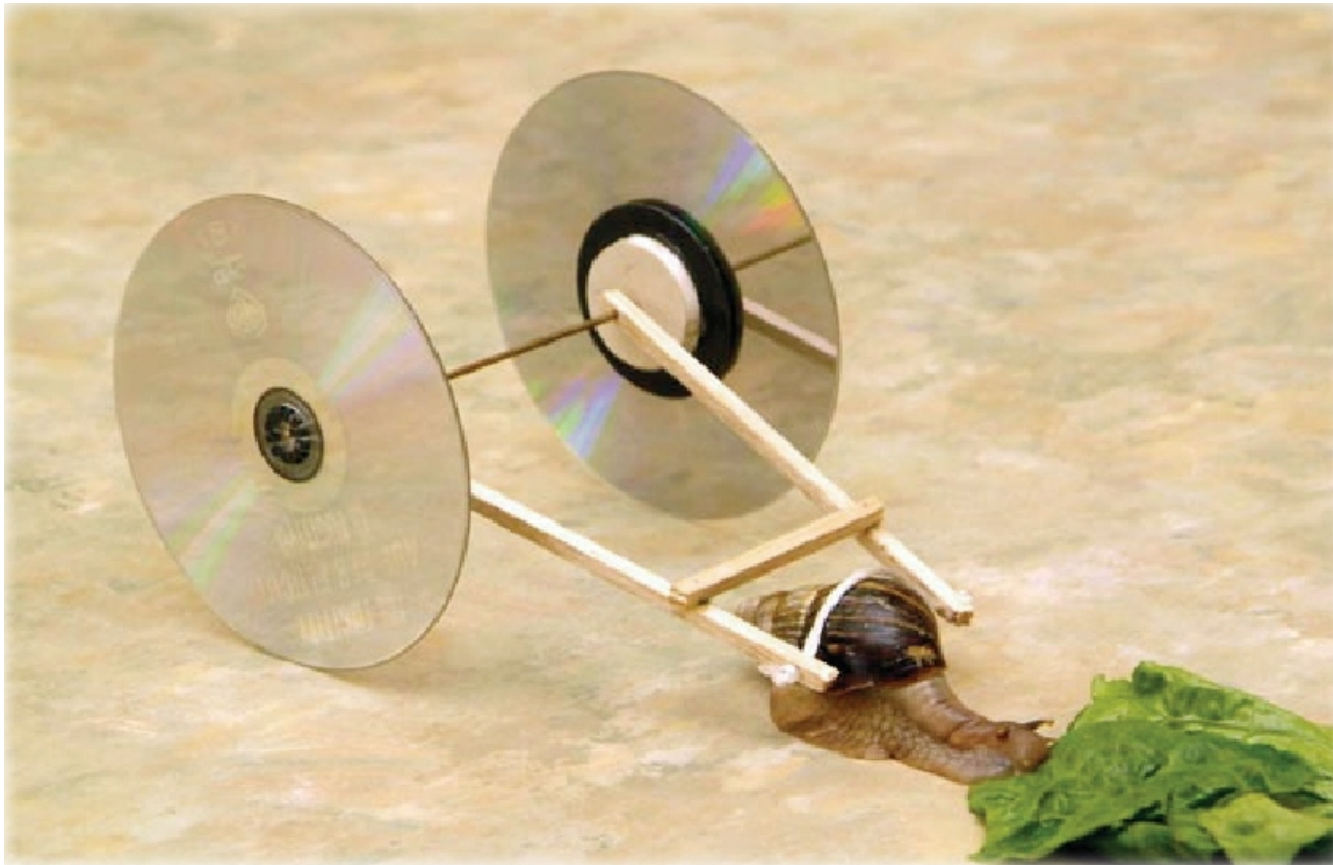
Breakeven Distance: ≈ 2000 light years

- Asides:
 - ETA nearest star: ≈ 100 kilo-years
 - Rocket Launch: distance up $\times 9$.
 - Use 3 DVDs (instead of gold disc): distance down $\times 10$
 - Use 1 gram of “RNA”: distance down $\times 10^6$
($\approx 1/4000$ distance to nearest star)

Communications Theory Has Spoken

**If delay can be tolerated, inscribed
matter is *stunningly* more
energy-efficient than radiation**

Sluggish Data vs. ADSL



Annals of Improbable Research 11(4), 2005

hey, Hey HEY!!!! What About ... ?

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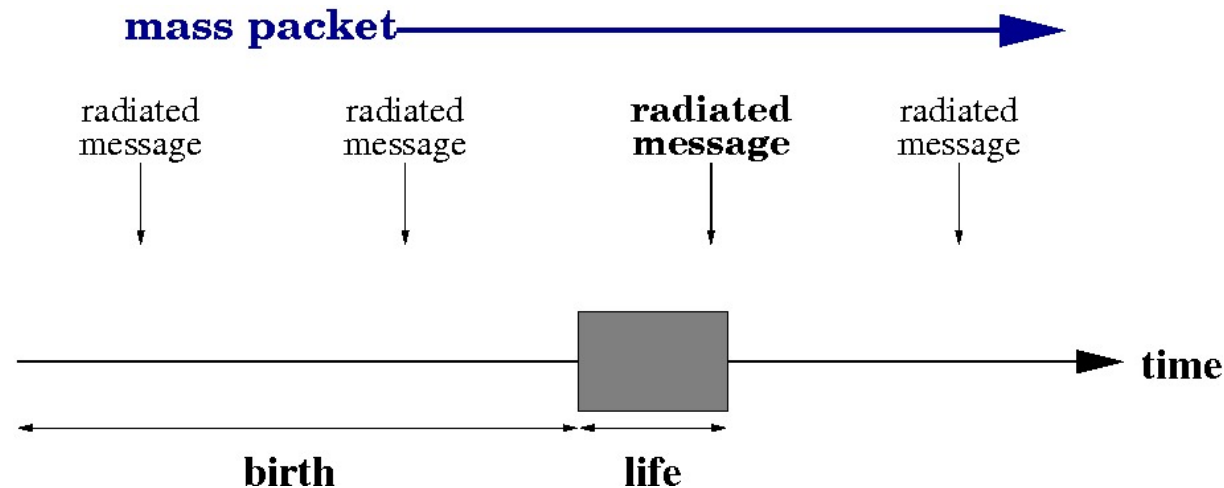
- **Radiation Penalty**

- Impermanence and Repetition
- Localizability

- **Matter Penalties**

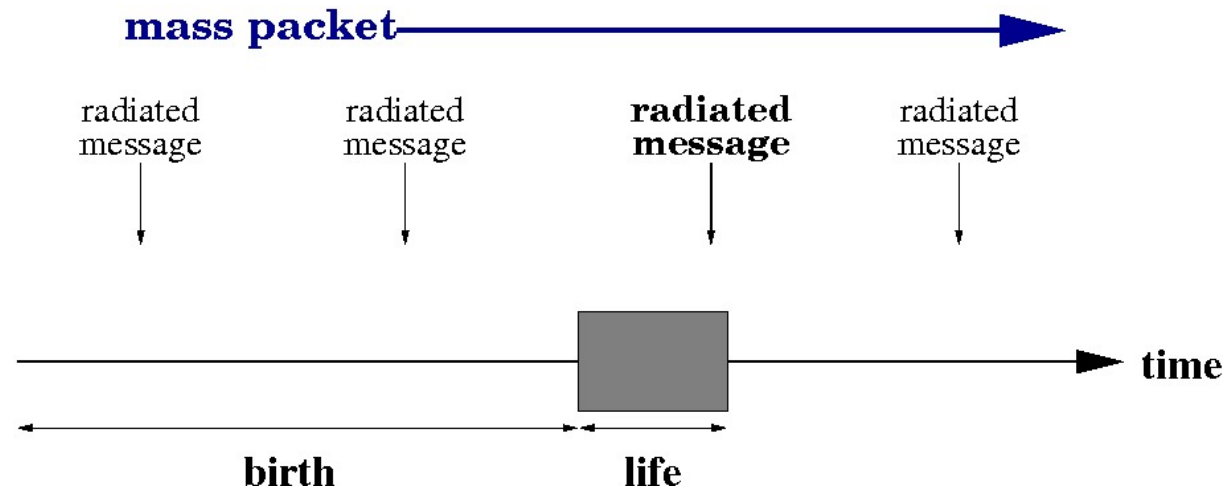
- Preservation
- Broadcast
- Inscription Energy
- Deceleration @Target
- Navigation
- Advertisement

Matter Persists – Radiation Vanishes



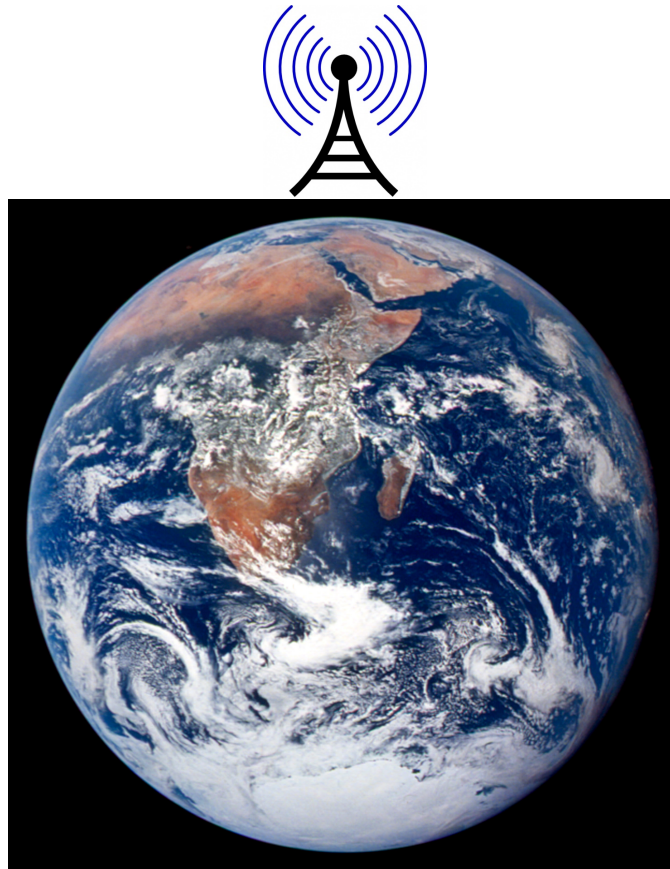
- Civilization Birth Rate: $\alpha = 1/10^9$ per year
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- **How many radiated repetitions?**

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 - $\Phi = 0.99 \rightarrow 2 \times 10^5$
 - $\Phi = 0.9999 \rightarrow 2 \times 10^7$

Come Eat Me!



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- **Clever Composition, Coding and Correction?**

- need better channel characterization

Is Radiation Better for Broadcast?

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Visible Universe: $D = 1.37 \times 10^{10}$ LY

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Construction energy probably not a problem

Parking the Package (traditional rocketry)

- Exhaust braking
- Energy penalty (excess mass): $e^{\frac{c}{\delta g I_{sp}}}$
- $I_{sp} \equiv$ Specific Impulse
 - Chemical: 10^2
 - Nuclear Electric: 10^4
 - Fusion: 10^6
- $I_{sp} = 20,000, \delta = 1000 \rightarrow$ **penalty** 4.6
- $\delta = 100$ or $I_{sp} = 2000 \rightarrow$ **penalty** 4.4×10^6

Gravitational Perturbations

Angular Deflection: $\theta \approx \frac{2MG}{v_0^2 y_0}$ (radians)

- $M = 2 \times 10^{30} \text{kg}$ (solar)
- $v_0 = c/1000$
- Stellar Density: $2.8 \times 10^{-2} \text{ stars (LY)}^{-3}$
- 10kLY trip mean miss distance: $\approx 0.14 \text{LY}$

Aim not a big problem

Message Advertisement?

Solar Space is BIG

Big Rock?



Big Rock?



Somewhat antisocial

Odd Rock?



Seeded Comet?



Active Probe?



Micro Ark?



Are we there yet!?!?

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- Chip-to-chip or mote-to-mote
 - smart dust tossing inscribed dust
- Biological systems
 - construction/dispersal cost for messenger molecules

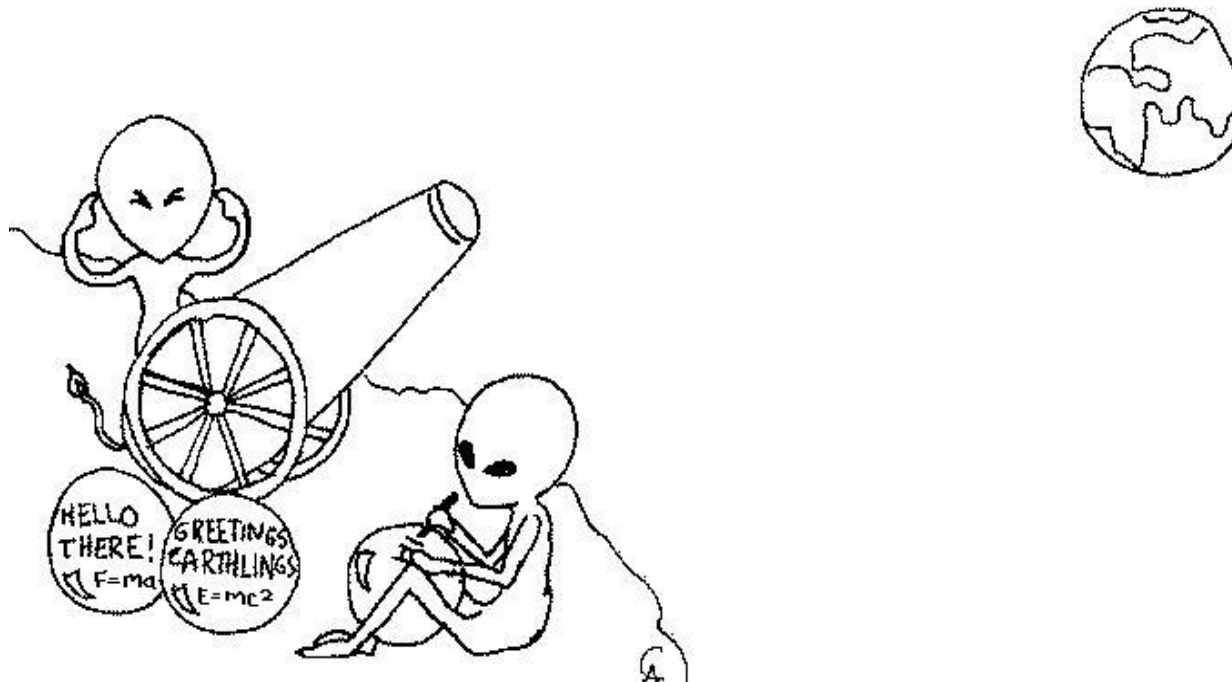
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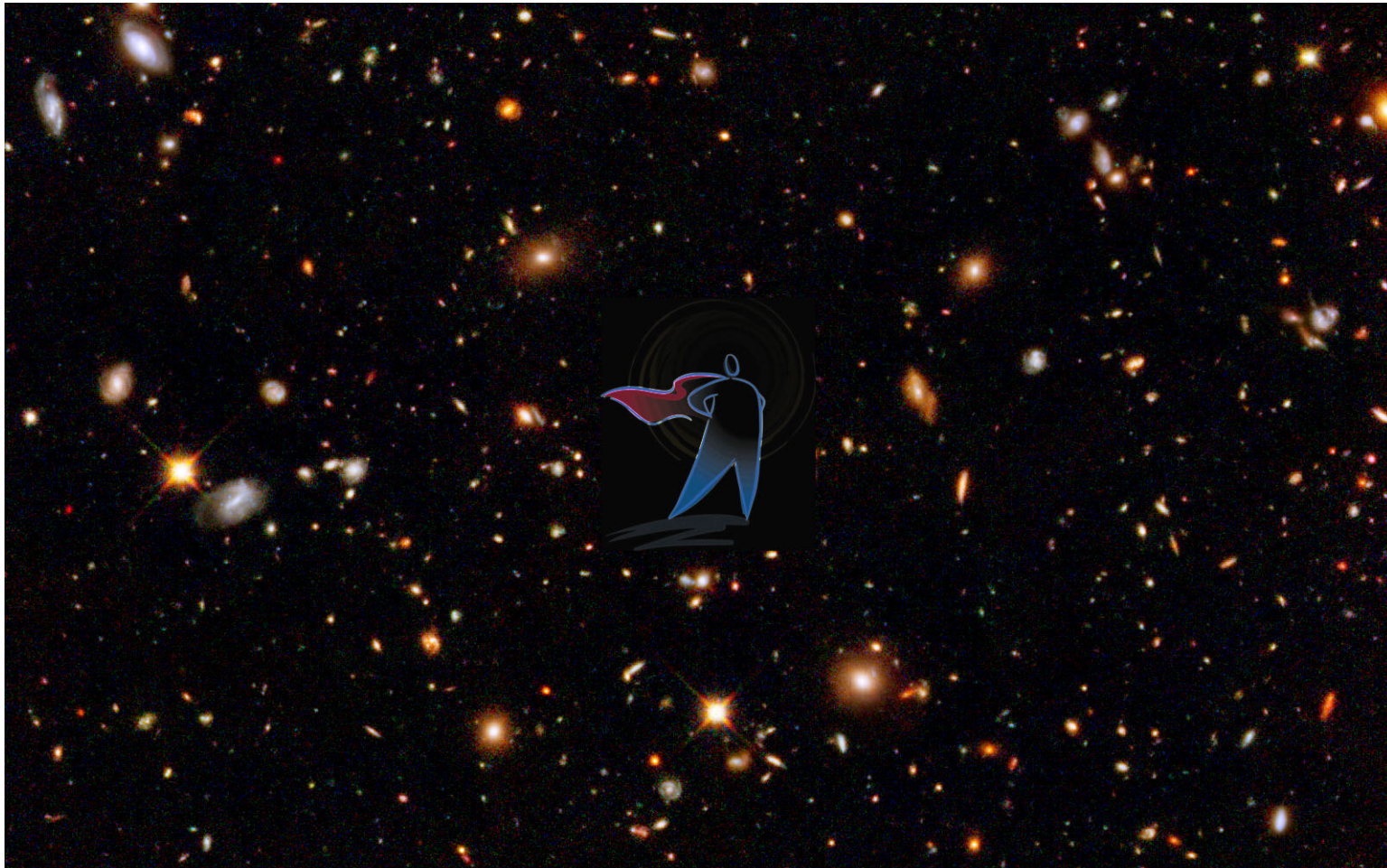
But perhaps most important ...

Great Comm. Theory Party Banter



AND...

COMMUNICATION THEORIST



Learn More



Nature 431, pp.47–49, September 2, 2004

Web Site: <http://www.winlab.rutgers.edu/~crose/cgi-bin/cosmicP.html>