Write Or Radiate

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UMBC CSEE Seminar
December 9, 2011

PHYSICIST

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$$E = h\nu$$

$$E = mc^2$$

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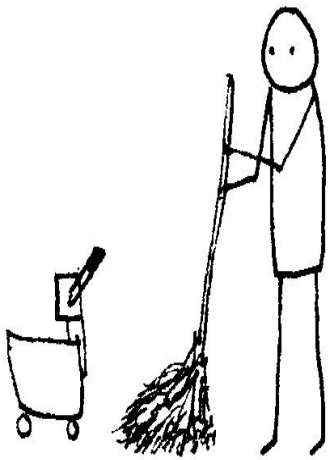
communication theorist



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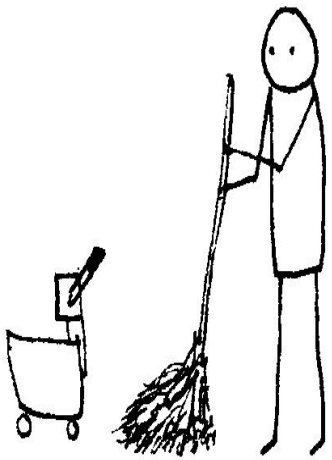

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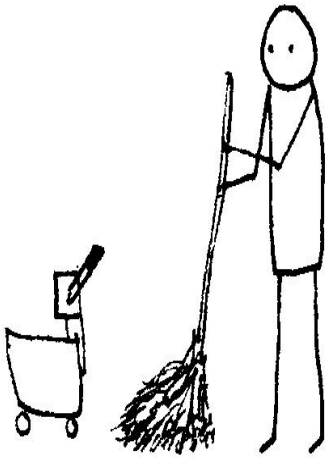

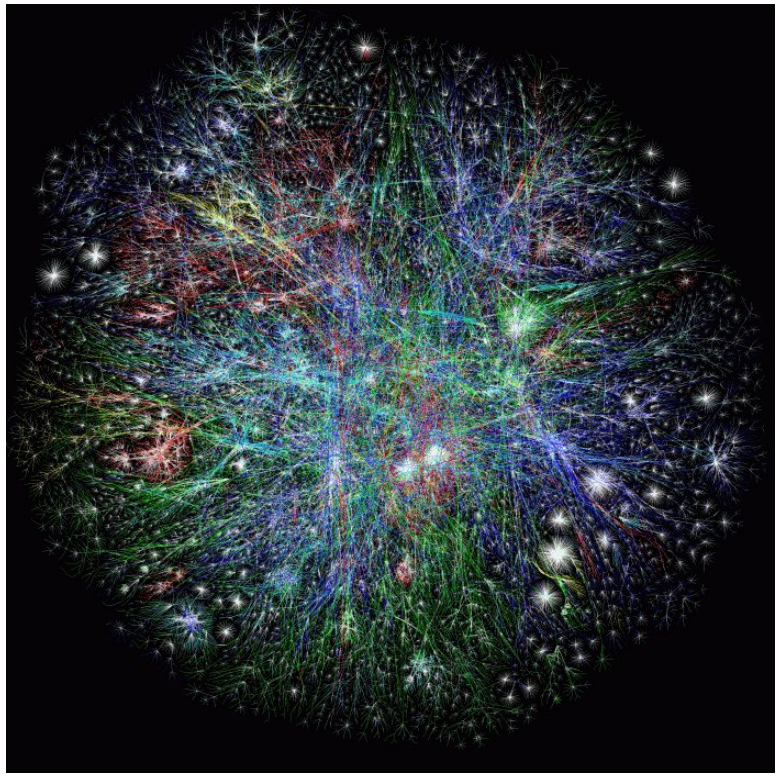

The Usual Cocktail Party Response

Wireless Research As Usual, then an EPIPHANY!

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

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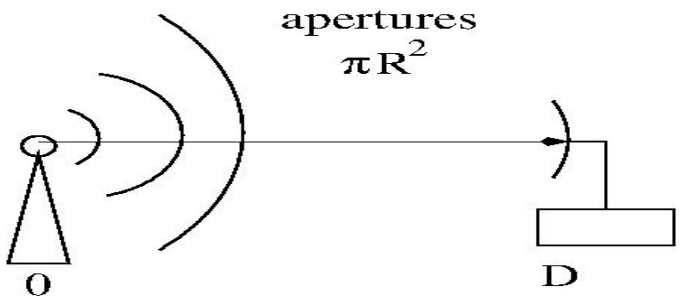
COMPLETELY RIDICULOUS, RIGHT??!!

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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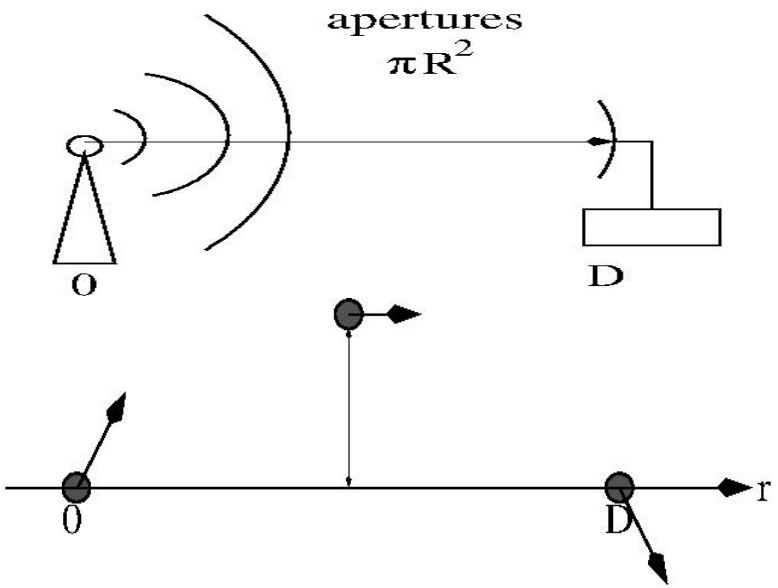

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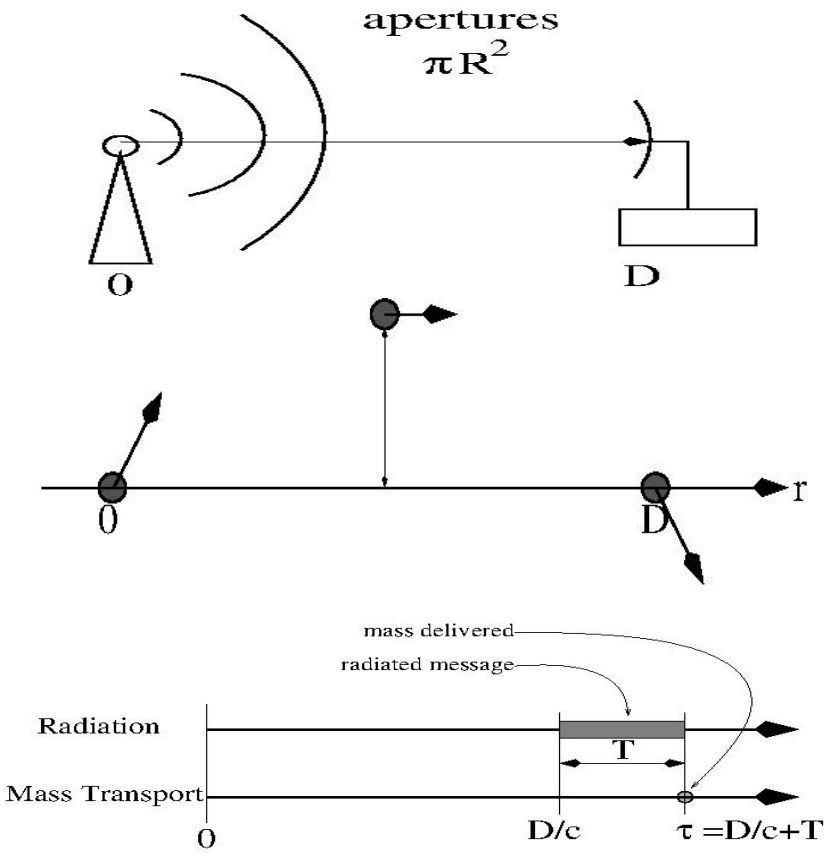

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- Large TW:

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

Writing Energy Requirements (ROCKET SCIENCE!)

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

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

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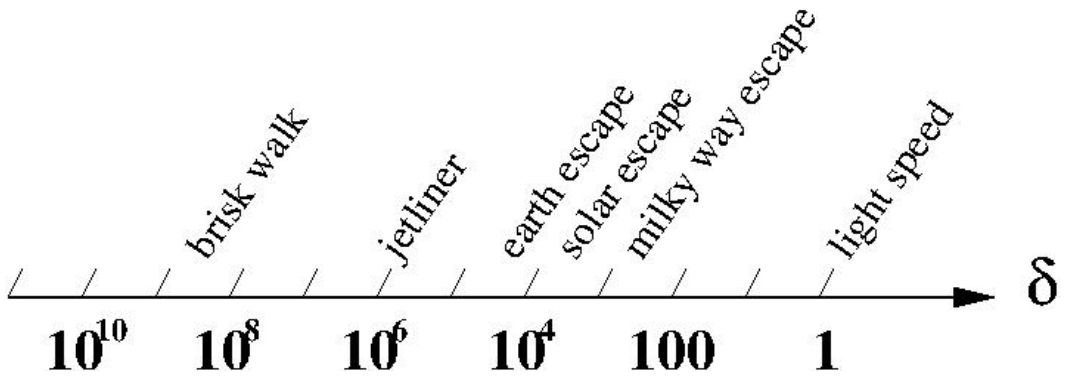

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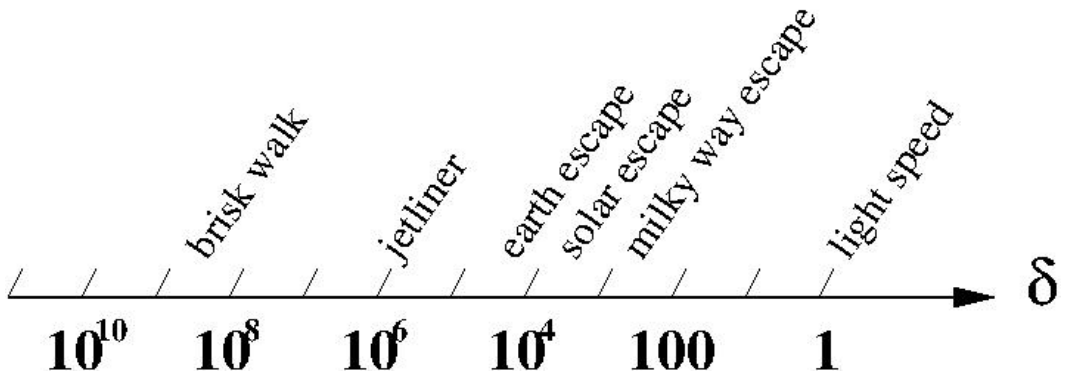

Artillery: adds a factor of 2 to energy
Escape: small penalty if $\bar{v} > 2 \times$ escape velocity

Radiation to Transport Energy Ratio

$$\Omega \equiv \frac{E_r}{E_w}$$

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

Equal Receiver/Transmitter Apertures

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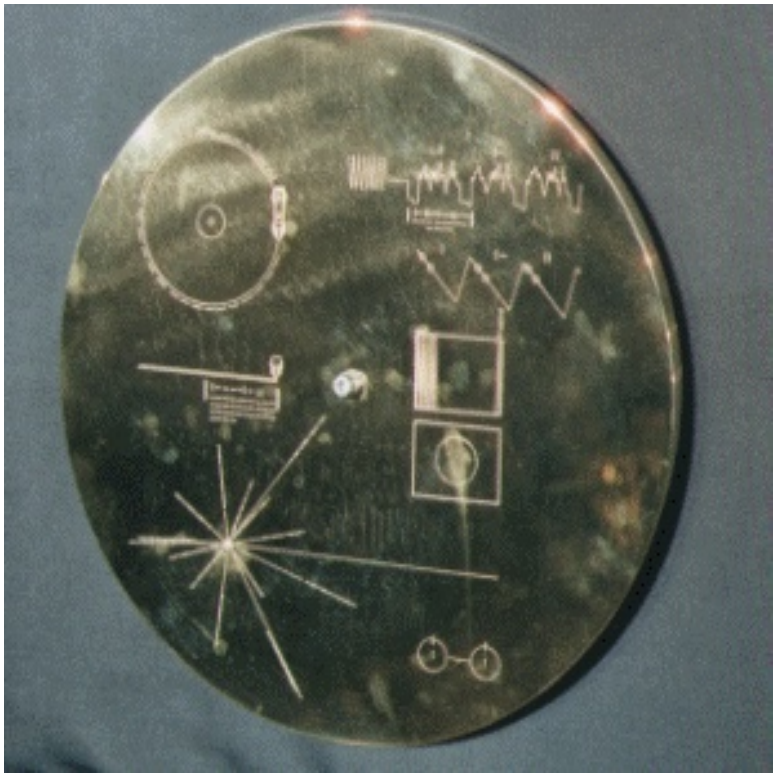
VERY antisocial!

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

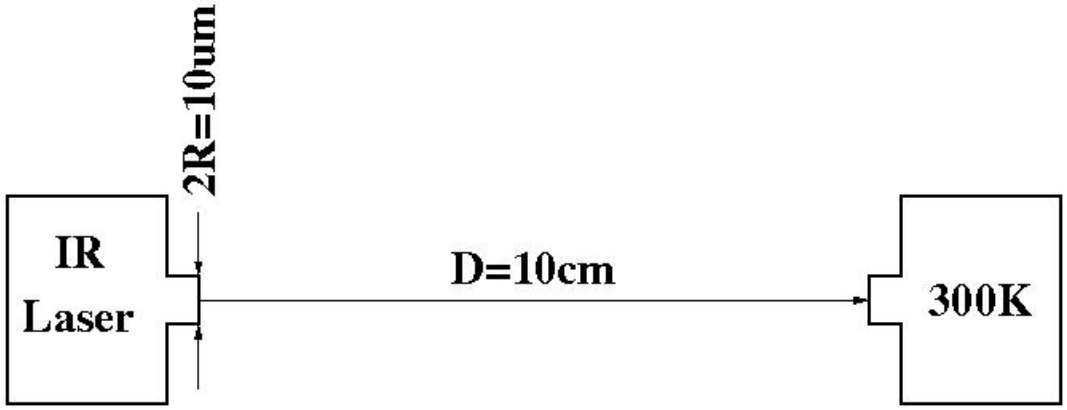
$\tilde{\rho} = 3 \times 10^{24}$
1 GHz Carrier
$R = 5$cm (handheld receiver)
Temperature $300K$

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

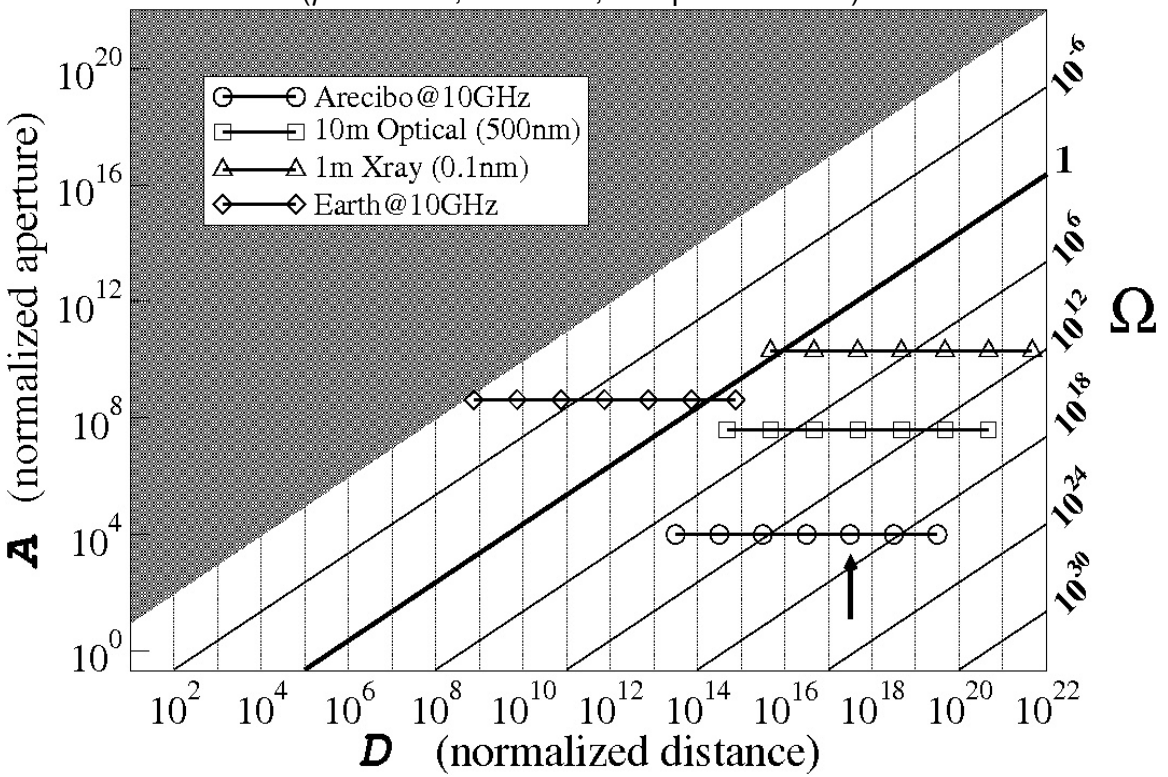
$\delta = 10^9$, $\lambda = 1\mu$m



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

Interstellar

($\tilde{\rho} = 10^{22}$, $\delta = 10^{3}$, Temperature $3K$)



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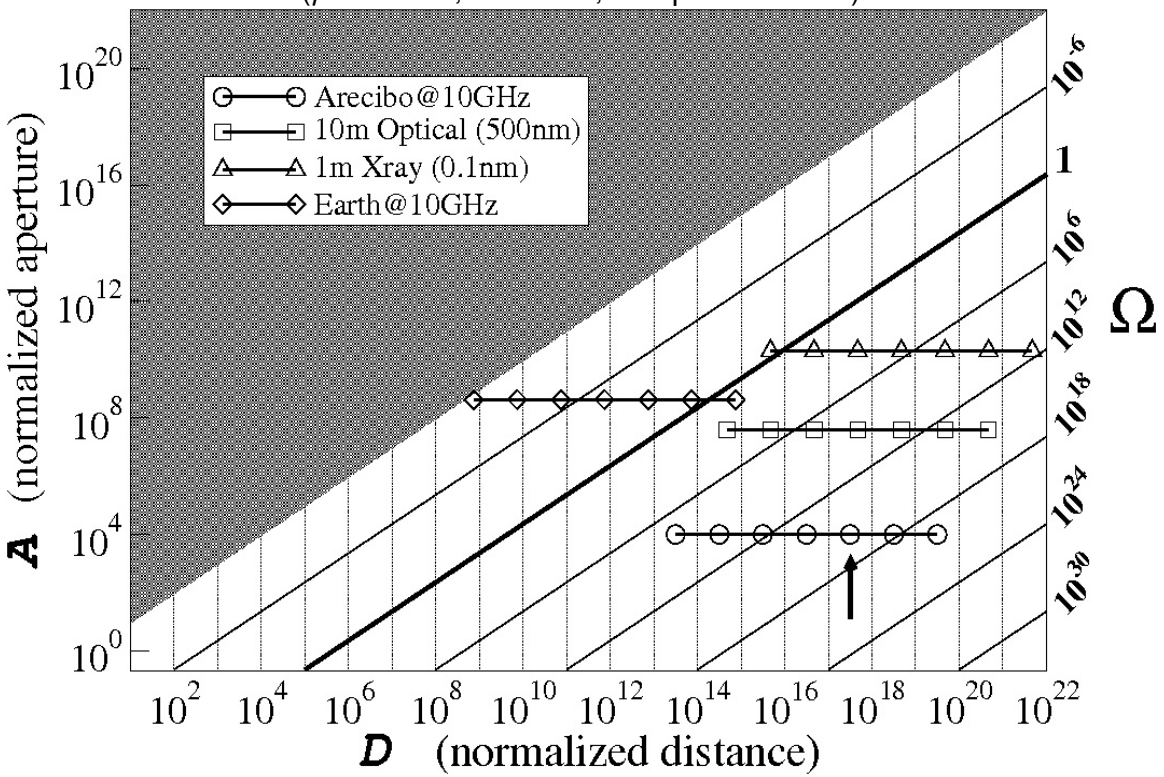

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Radiation/Matter: (24 megaton blast) / (Shelve 5 lb sugar bag)

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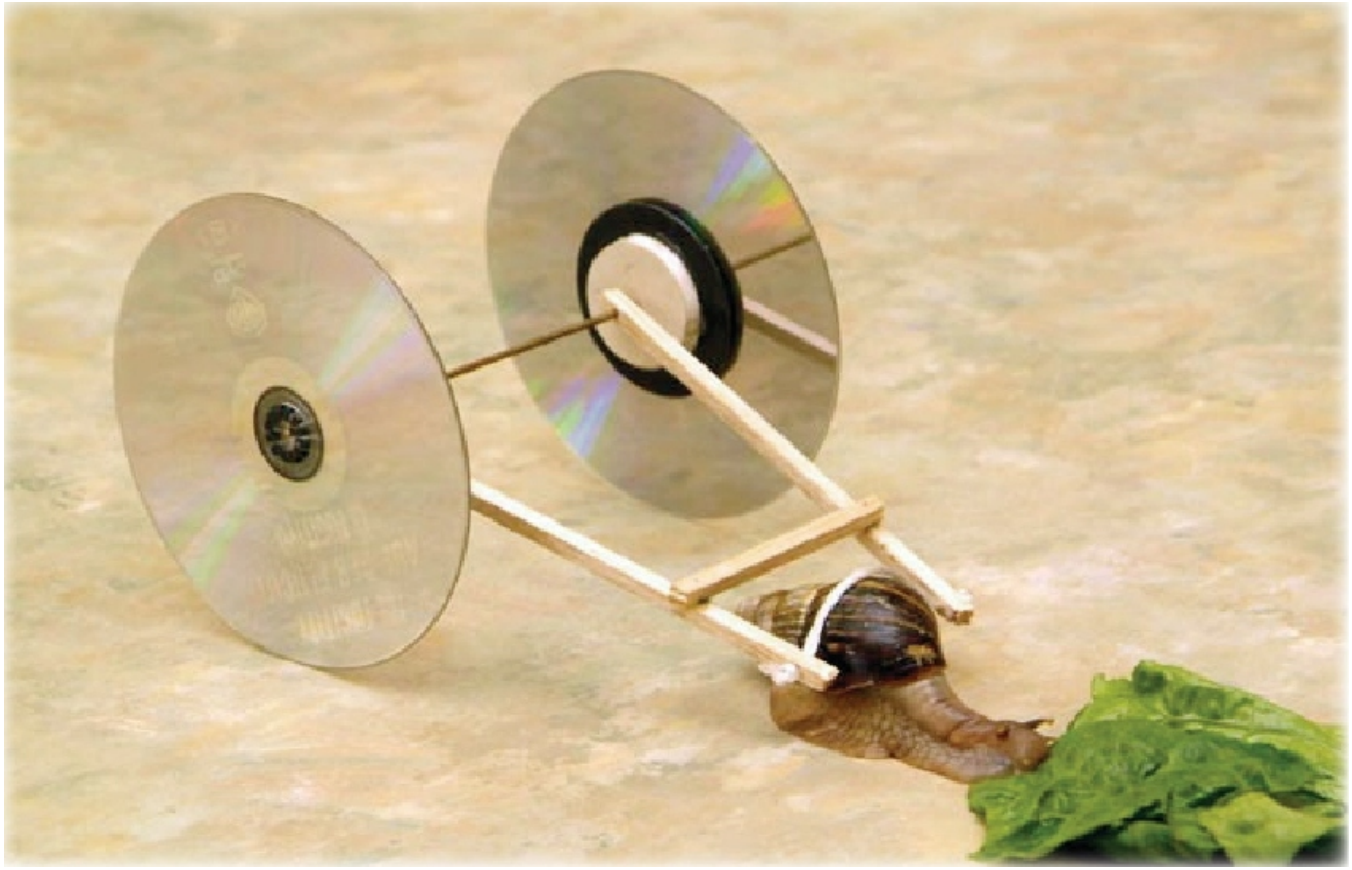
- Asides:
  - ETA nearest star: ≈ 100 kilo-years
  - Rocket Launch: distance up $\times 9$.
  - Use 3 DVDs (instead of gold disc): distance down $\times 10$
  - Use 1 gram of "RNA": distance down $\times 10^6$
    ($\approx 1/4000$ distance to nearest star)

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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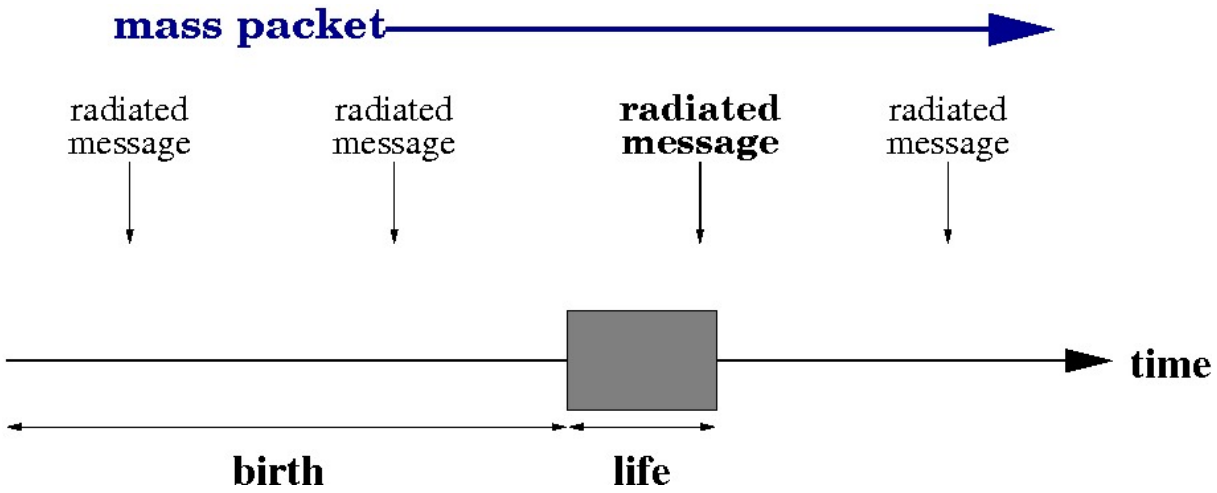
- **Radiation Penalty**
  - Impermanence and Repetition
  - Localizability
- **Matter Penalties**
  - Preservation
  - Broadcast
  - Inscription Energy
  - Deceleration @Target
  - Navigation
  - Advertisement

Matter Persists – Radiation Vanishes



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- **How many radiated repetitions?**

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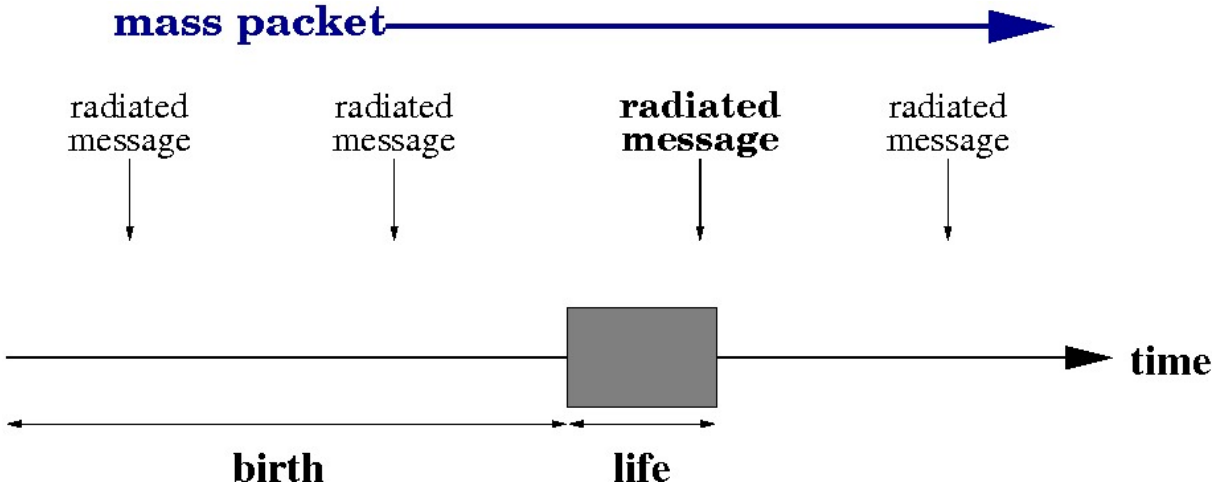

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  - $\Phi = 0.99 \rightarrow 2 \times 10^5$
  - $\Phi = 0.9999 \rightarrow 2 \times 10^7$

Come Eat Me!

Cosmic Insults

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- **Clever Composition, Coding and Correction?**
  - need better channel characterization

Is Radiation Better for Broadcast?

- Milky Way stellar density 2.8×10^{-2} stars (LY)$^{-3}$
- Spherical galaxy, Arecibo receiver, $\tilde{\rho} = 10^{22}$, $\delta = \frac{c}{v} = 10^3$

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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)

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

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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- Biological systems
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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