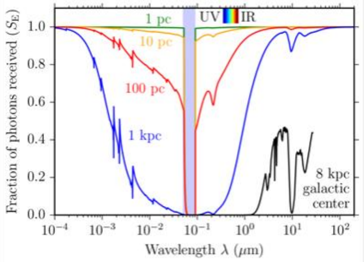
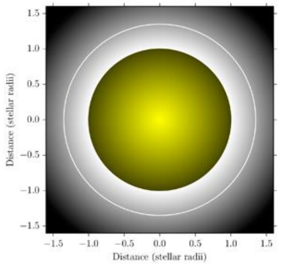
Interstellar communication

16 papers on Interstellar communication & Travel



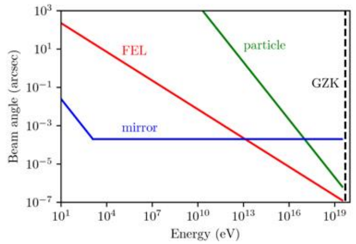
I. Maximized data rate for lightweight space-probes

Hippke, M. 2018, International Journal of Astrobiology (ADS, PDF)



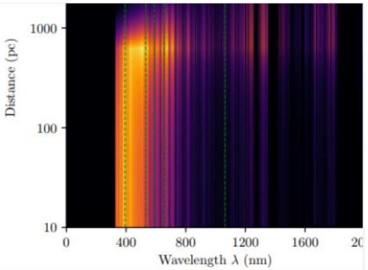
II. Application to the solar gravitational lens

Hippke, M. 2017, Acta Astronautica (ADS, PDF)



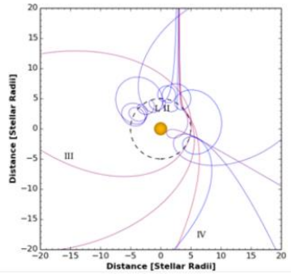
III. Optimal frequency to maximize data rate

Hippke, M., Forgan, D. H. 2017 (ADS, PDF)



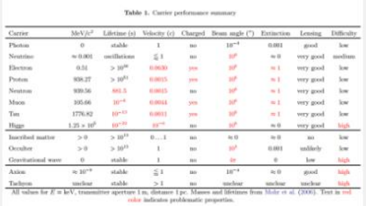
X. The colors of optical SETI

Hippke, M. 2018, Journal of Astrophysics and Astronomy (in press) (ADS, PDF)



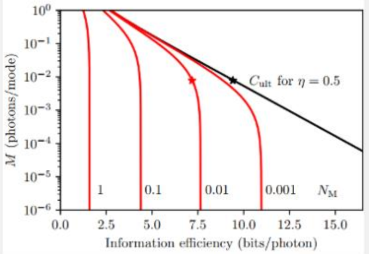
Photogravimagnetic assists of light sails

Forgan, D., Heller, R., Hippke, M. 2018, Monthly Notes of the Royal Astronomical Society (ADS, PDF)



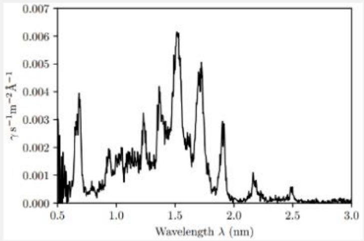
IV. Benchmarking information carriers

Hippke, M. 2017, Acta Astronautica (ADS, PDF)



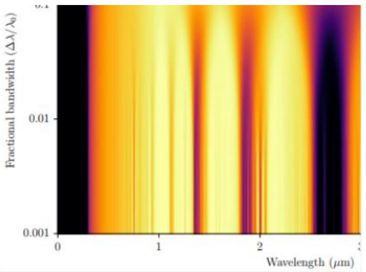
V. Introduction to photon information efficiency (in bits per photon)

Hippke, M. 2017 (ADS, PDF)



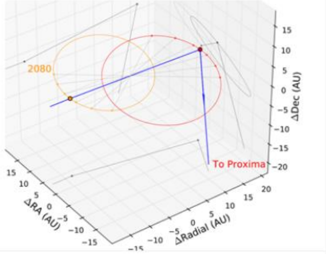
VI. Searching X-ray spectra for narrowband communication

Hippke, M., Forgan, D. H. 2017 (ADS, PDF)



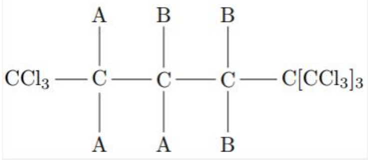
XI. Short pulse duration limits of optical SETI

Hippke, M., 2018, Journal of Astrophysics and Astronomy (in press) (ADS, PDF)



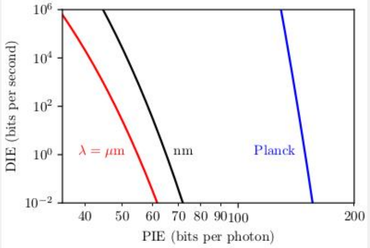
Optimized trajectories to the nearest stars using lightweight high-velocity photon sails

Heller, R., Hippke, M., Kervella, P. 2017, Astronomical Journal (ADS, PDF)



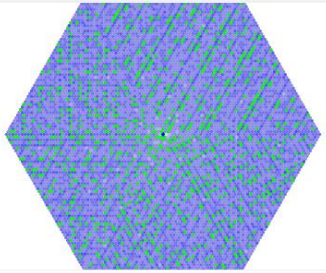
VII. Benchmarking inscribed matter probes

Hippke, M., Leyland, P., Learned J. G. 2017, Acta Astronautica (ADS, PDF)



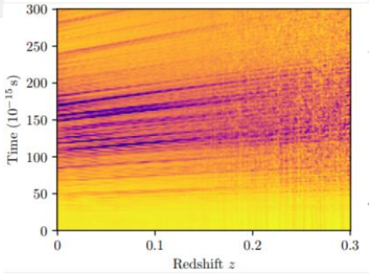
VIII. Hard limits on the number of bits per photon

Hippke, M., 2018 (ADS, PDF)



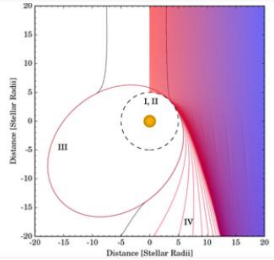
IX. Message decontamination is impossible

Hippke, M., Learned, J. G. 2018 (ADS, PDF)



Periodic Spectral Modulations Arise from Non-random Spacing of Spectral Absorption Lines

Hippke, M. 2018 PASP in press (ADS, PDF)



Deceleration of high-velocity interstellar photon sails into bound orbits at alpha Centauri

Heller, R., Hippke, M. 2017, Astrophysical Journal Letters (ADS, PDF)

Spaceflight from Super-Earths is difficult

Hippke, M. 2018, International Journal of Astrobiology (ADS, PDF)

Early ideas: Trees

Carl Friedrich Gauß (~1830):

- Cut a giant triangle in the Siberian forest
- Plant wheat inside

"a correspondence with the inhabitants of the moon could only be begun by means of such mathematical contemplations and ideas, which we and they have in common"

Early ideas: Trees

Early ideas: Kerosene

Joseph von Littrow (1830s):

- Dig trenches in the Sahara desert
- In precise geometric shapes
- Fill these with kerosene
- Light up at night to signal our presence

"The Door to Hell"

Derweze, Turkmenistan: Natural gas, burning for decades

Early ideas: Canals

Large transformations on the surface of the Earth

1869 Suez canal

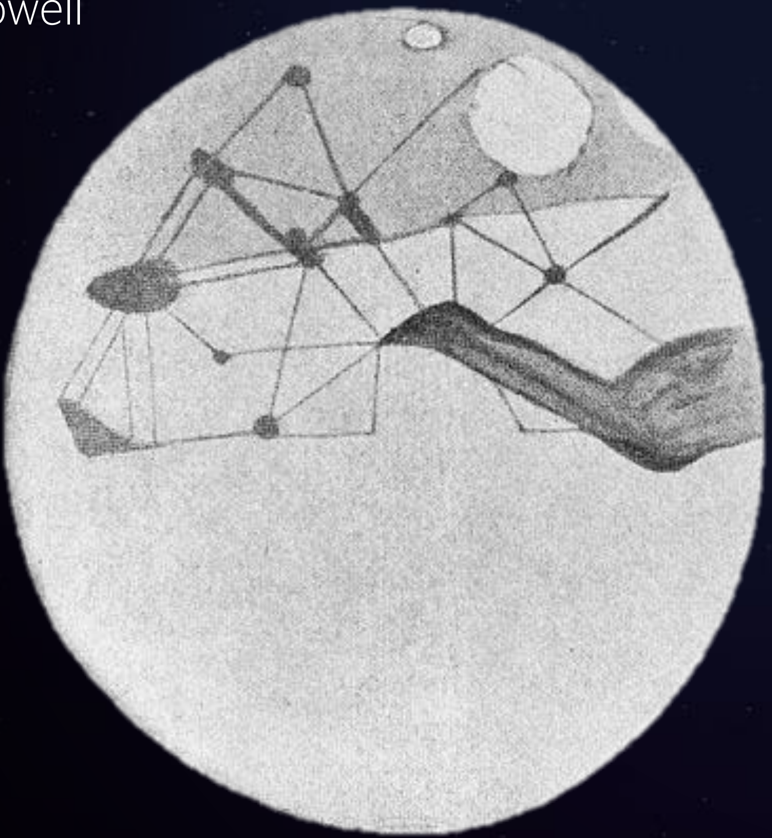
1880 Panama canal

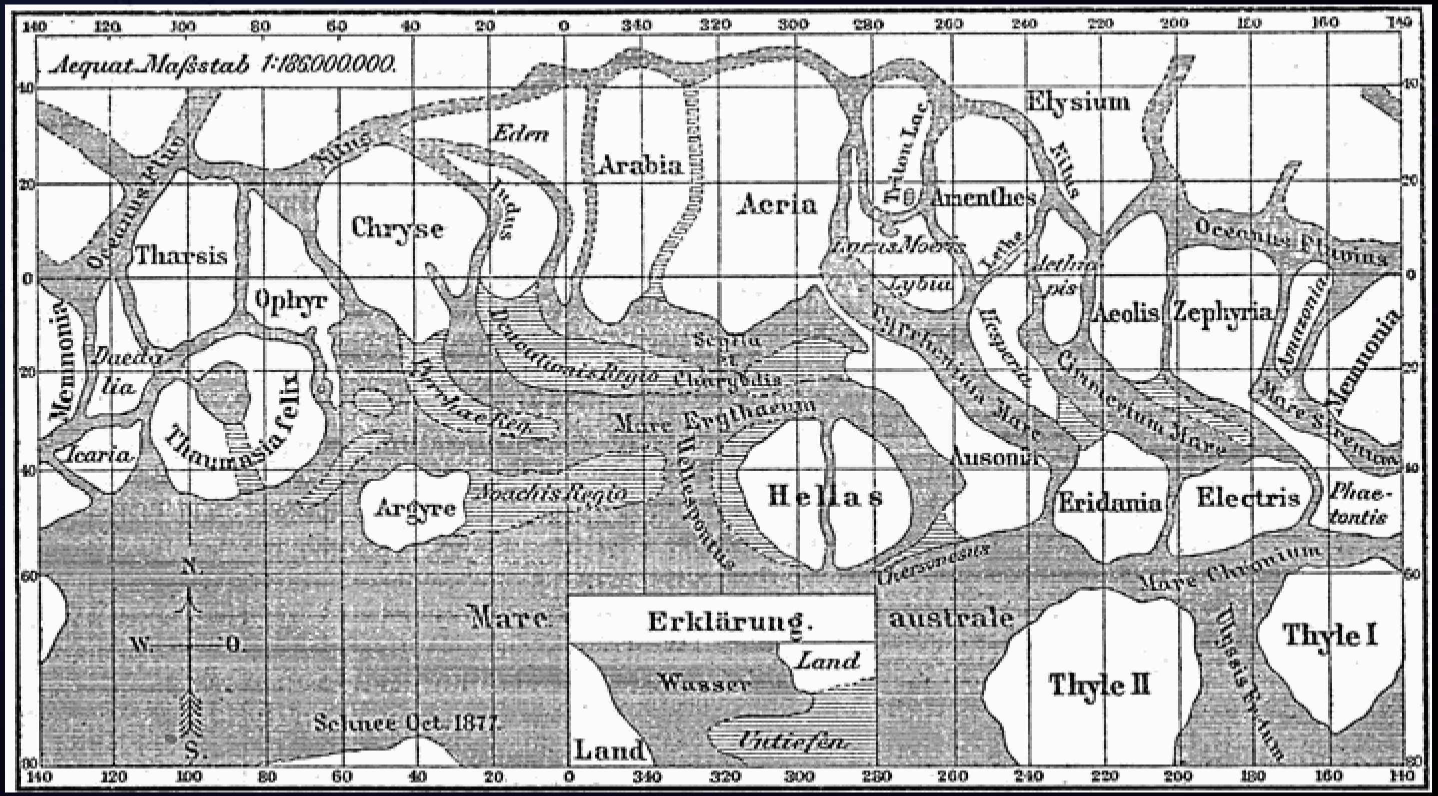
Canals on other planets?

Discovery by Giovanni Schiaparelli (1877)

Confirmations:

- 1889 Charles A. Young
- 1892 W. H. Pickering
- 1904 Lowell



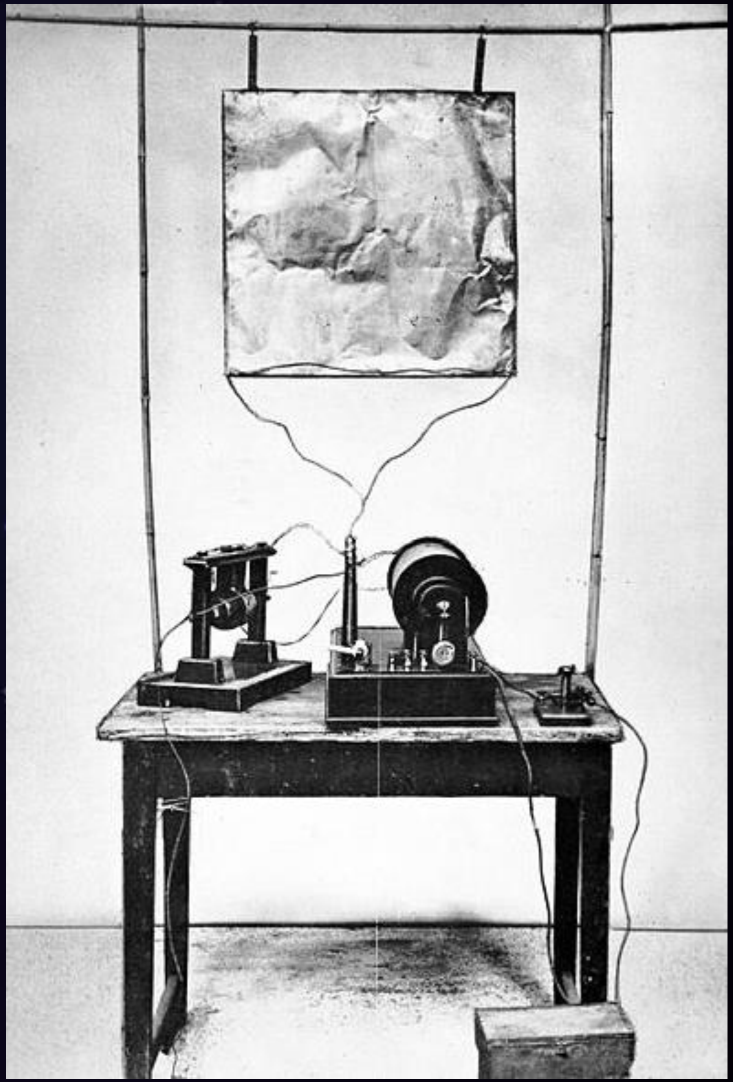


Early ideas: Radio!

First radio transmission by Guglielmo Marconi (December 1894)

Nikola Tesla (1901)

- Searched for radio signals
- Detected coherent signals which he believed to originate from intelligent beings on Mars



Start of the Search for Extraterrestrial Intelligence (SETI)

"And Cocconi came to me one day – I've often reported this – and said, 'You know what, Phil? If there are people out there, won't they communicate with gamma rays that'll cross the whole galaxy?' And I said, 'Gee, I know nothing about that (...) Why not use radio? It's much cheaper. You get many more photons per watt and that must be what counts.' And we began working on that and pretty soon we knew enough about radio astronomy to publish a paper called, *Searching for Interstellar Communications*. "

Cocconi, Guiseppe & Morrison, Phil (1959), "Searching for Interstellar Communications". *Nature*, 184, 844

Superiority of radio over all other methods?

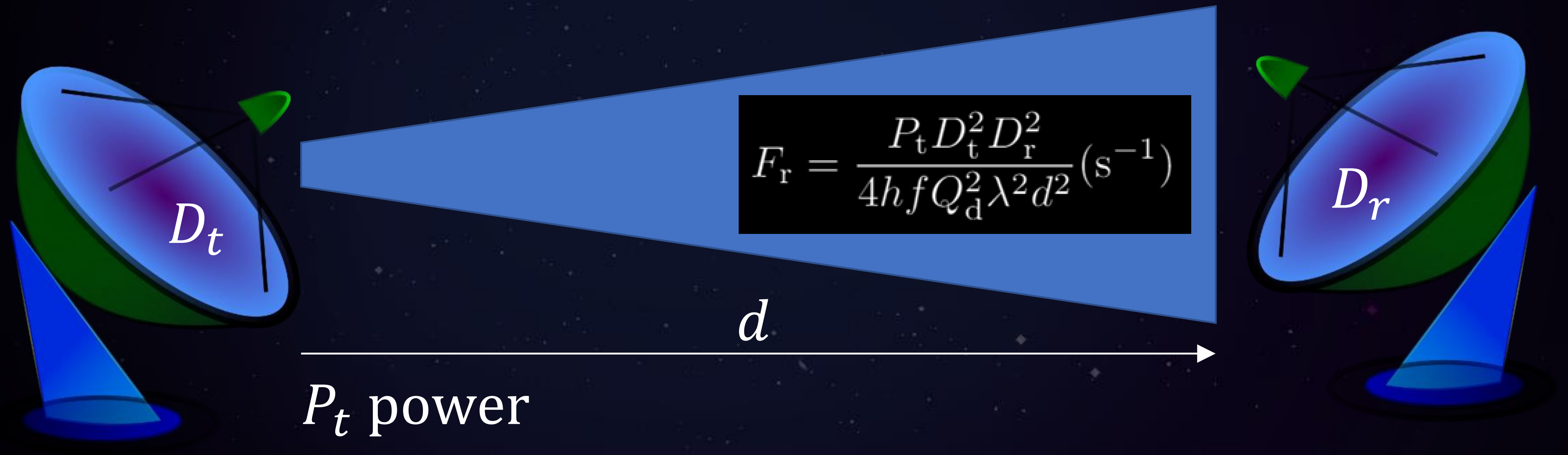
Radio is better because (1959 argument):

- „I know nothing about gamma rays“
- “You get many more photons per watt and that must be what counts”
- (The laser will only be invented 3 months later…)

"Interstellar and Interplanetary Communication by Optical Masers"

Maiman, T. H. 1960, *Nature*, 187, 493

It was quickly realized that the tighter beam of optical communication can increase the data rate compared to radio (Schwartz, R. N., & Townes, C. H. 1961, Nature, 190, 205)



P_t power

$Q \sim 1.22$

$\lambda = c/f$

h Planck's constant

The first interstellar communication

- Our first interstellar probes are small and uncrewed (e.g., Voyager 2)
- The first spaceship reaching a neighbouring star is likely a small, uncrewed probe (see Breakthrough Starshot) (open for debate about this…)
- Such a probe will not (because: **can not!**) use radio to transmit data back to Earth
- Most likely option (2019 perspective): Laser
- (Q: Why do we still focus on radio SETI?)

But: What about methods „better" than lasers?

- X-ray lasers?
- Gamma rays?
- Neutrinos?
- Gravitational waves?
- Axions?
- …?

A deep dive for the specialists in the room (one minute)

Given some restrictions on technology, transmitter and receiver sizes, energy levels, and distance, what is the optimal spectrum to maximize the amount of information transferred?

$$T'_C = \left(\frac{2A_T A_R}{3qc^2 D^2} \frac{k_B \nu_{\max}^3}{\dot{E}_{\text{tot}}} \right)^{-1}$$

What is the data rate (in bits per second)?

$$\dot{C} = \frac{\bar{\nu}\chi}{\ln 2} \left(1 + \ln \frac{\dot{E}}{h\nu_{\max}\bar{\nu}\chi} \right) = \frac{2}{\ln 2} \frac{A_T A_R \nu^2 \bar{\nu}}{qc^2 D^2} \left(1 + \ln \frac{q\dot{E}c^2 D^2}{h\nu_{\max}^3 \bar{\nu} A_T A_R} \right)$$

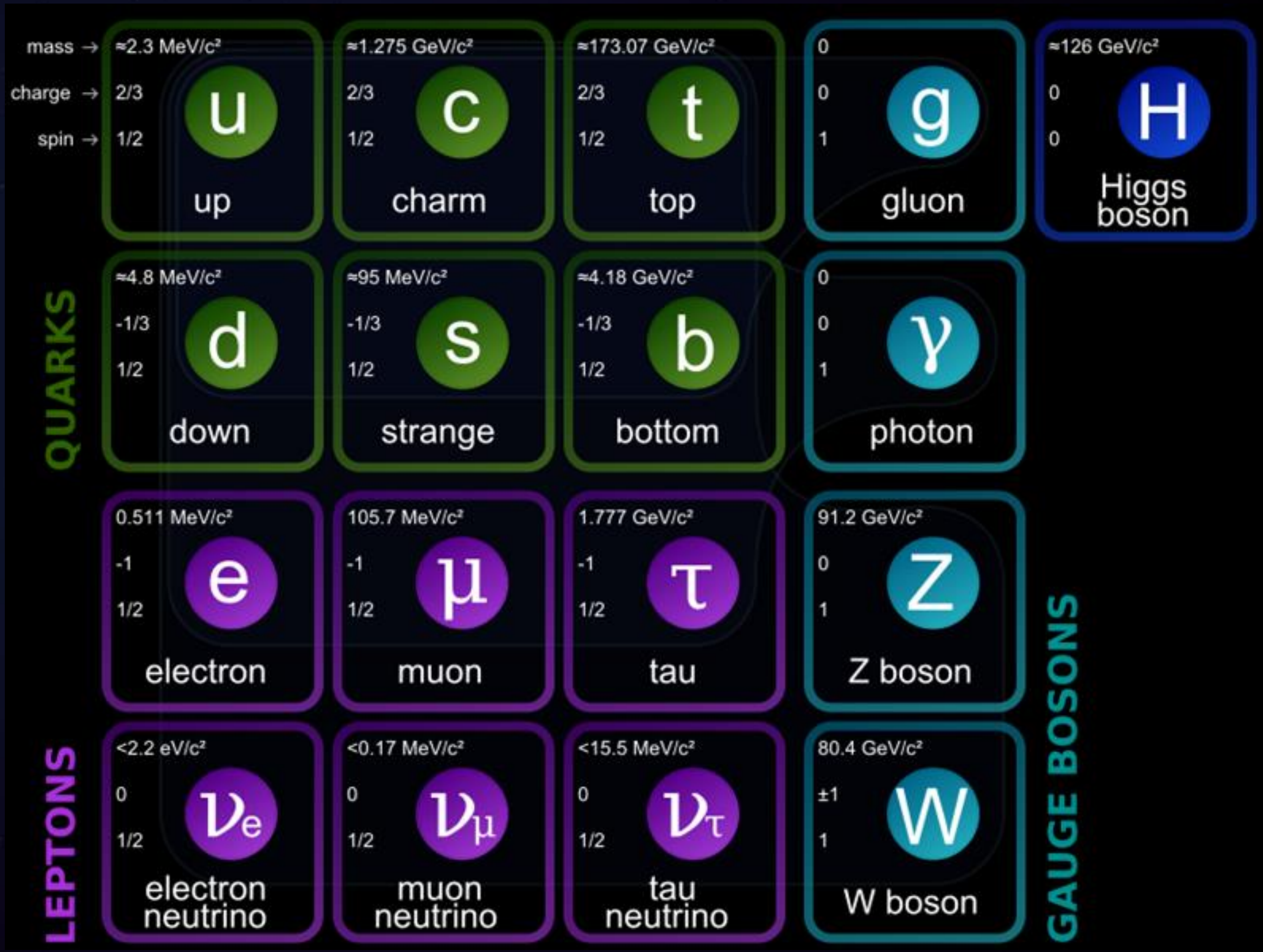
Source: Lacki & Hippke (2024) in prep ☺

The particle zoo: Neutrinos, gravitional waves, and the unknown Unknowns

[Neutrino communication is]

"so difficult that an advanced civilization may purposely choose such a system in order to find and communicate only with ETCs at their own level of development."

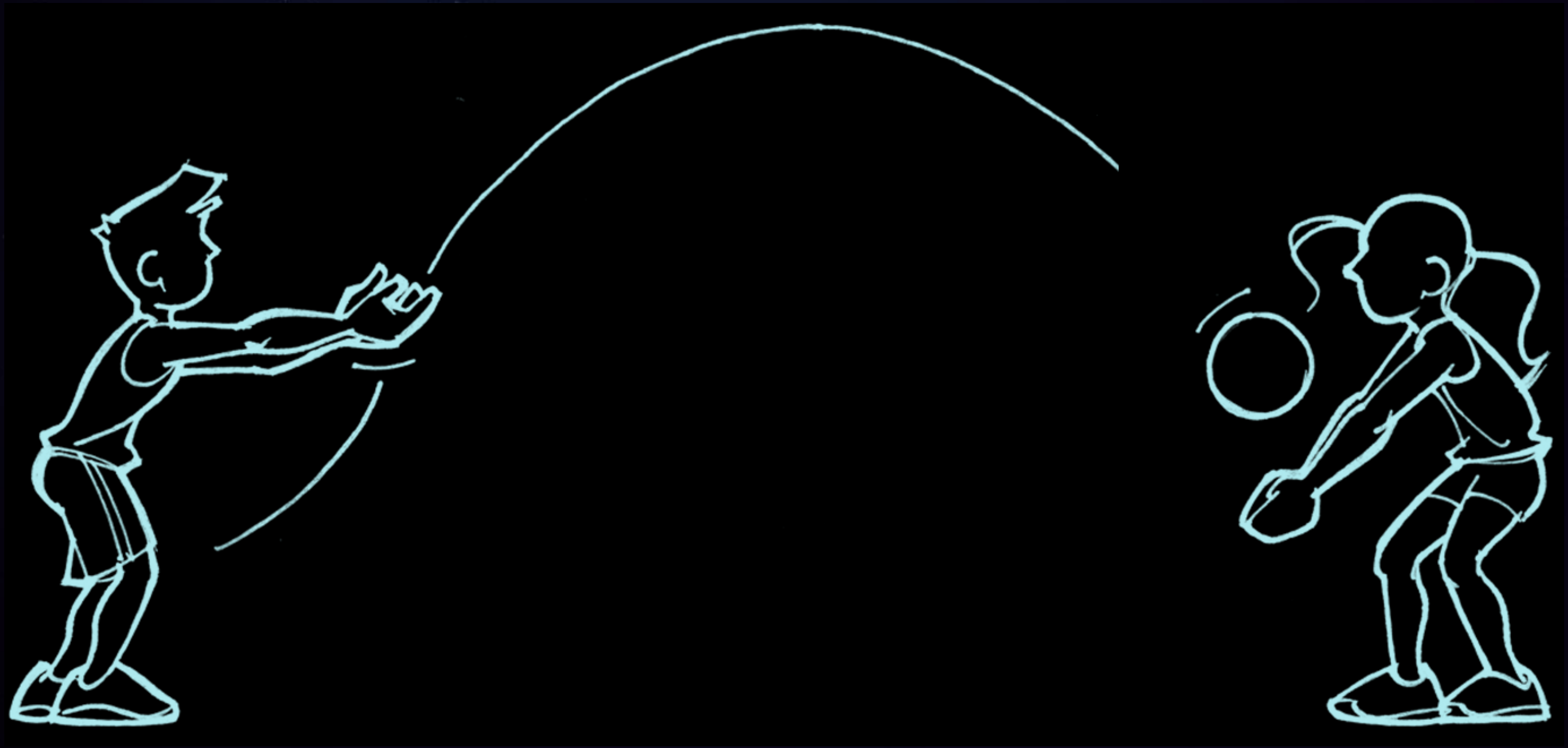
Subotowicz, 1979



Inscribed matter: Throw the data

What are the energy minima per bit of information, for photons versus matter?

In principle: Kinetic energy invested into accelerating a mass can (almost) be recovered during its deceleration



Energy per bit of information / photons versus matter

Let us assume you pay twice, acceleration + deceleration

Photons: $C_\gamma \sim\propto \eta d^{-2} D_t^2 D_r^2$ $(\mathrm{bits\ J^{-1}})$ with

η: efficiency (good),

d: distance (bad),

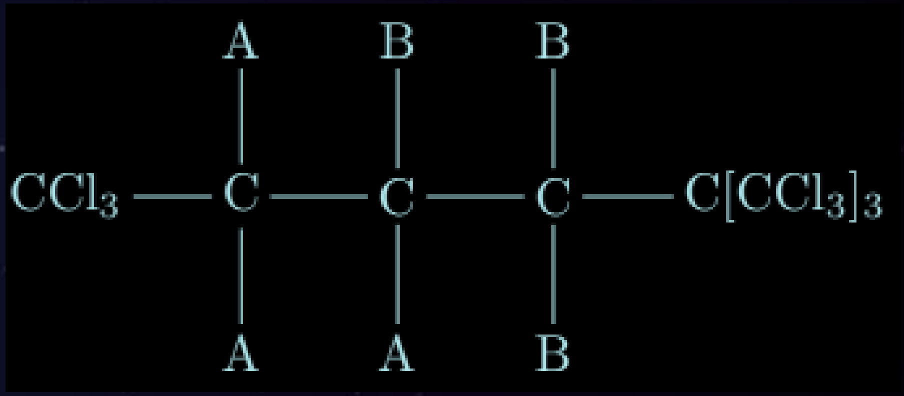
D: apertures (good)

Matter: $C_{\mathrm{rel}} \sim\propto S\eta L^{-1} v^{-2}$ $(\mathrm{bits\ J^{-1}})$ with

S: information density (bits per gram) (good),

L: relativistic Lorentz factor (irrelevant <0.2 c),

v: velocity (bad)



Denser storage is good. DNA is $\mathbf{5 \times 10^{21} bits\ g^{-1}}$ plus structural overhead

Slower velocity is good. Assume something realistic (cf. interstellar dust) → order 0.1 c

Energy per bit of information / photons versus matter

- Matter is more energy efficient in any configuration after some critical distance *d*
- Trade of between velocity and energy efficiency
- Energy equivalence for 100 pc, S~0.1 DNA, v=0.1 c

  → Requires (filled) photon apertures of 100 km (optical) to 1000 km (radio)

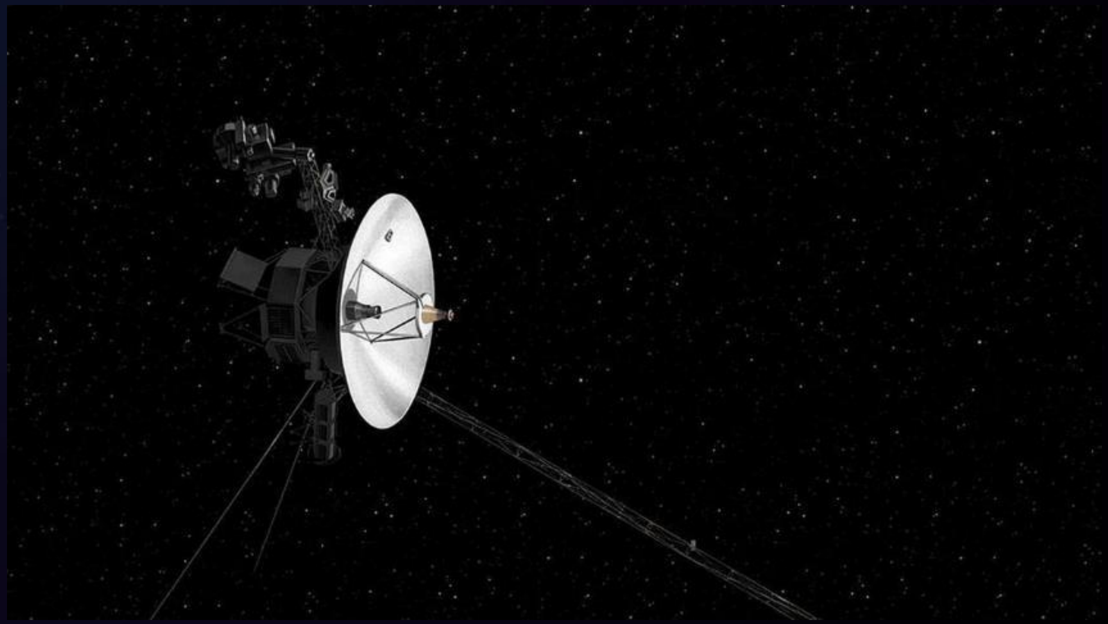
Conclusion

- A small spaceship (meter-sized probe) at Alpha Cen can transmit back data (images) with a laser (but not with radio)

- Transmitting LARGE amounts of data to FAR AWAY stars is expensive (and requires synchronicity)

Strong use case to send probes

- Decelerate at the target star and wait to be discovered (async) ☺
- No assumptions on technology required (Gamma rays? Lasers? Radio? Neutrinos?)
- Best „bang for buck" (data per money)



Strong use case to search for probes

- If we can send interstellar probes, and
- If other technological life exists,
- Then we should search our solar system for probes

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Backup

Interstellar communication

Interstellar communication matrix

How	Lighthouse/Beacon	Targeted laser	Targeted probe
What	"I'm here"	Information	More information
Where	Many places	2 locations	2 locations
Who	One transmitter, many receivers	A - B	A - B
When	Synchronous	Synchronous	Asynchronous
Why	Announce presence	Share information	Share information and legacy/heritage