

# *Terrestrial life for habitable oxygen worlds*

– a perspective

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# *search for habitable planets* \_\_\_\_\_

## **why?**

- (a) detect (and study) new forms of life
- (b) open alternative evolutionary pathways for terrestrial life

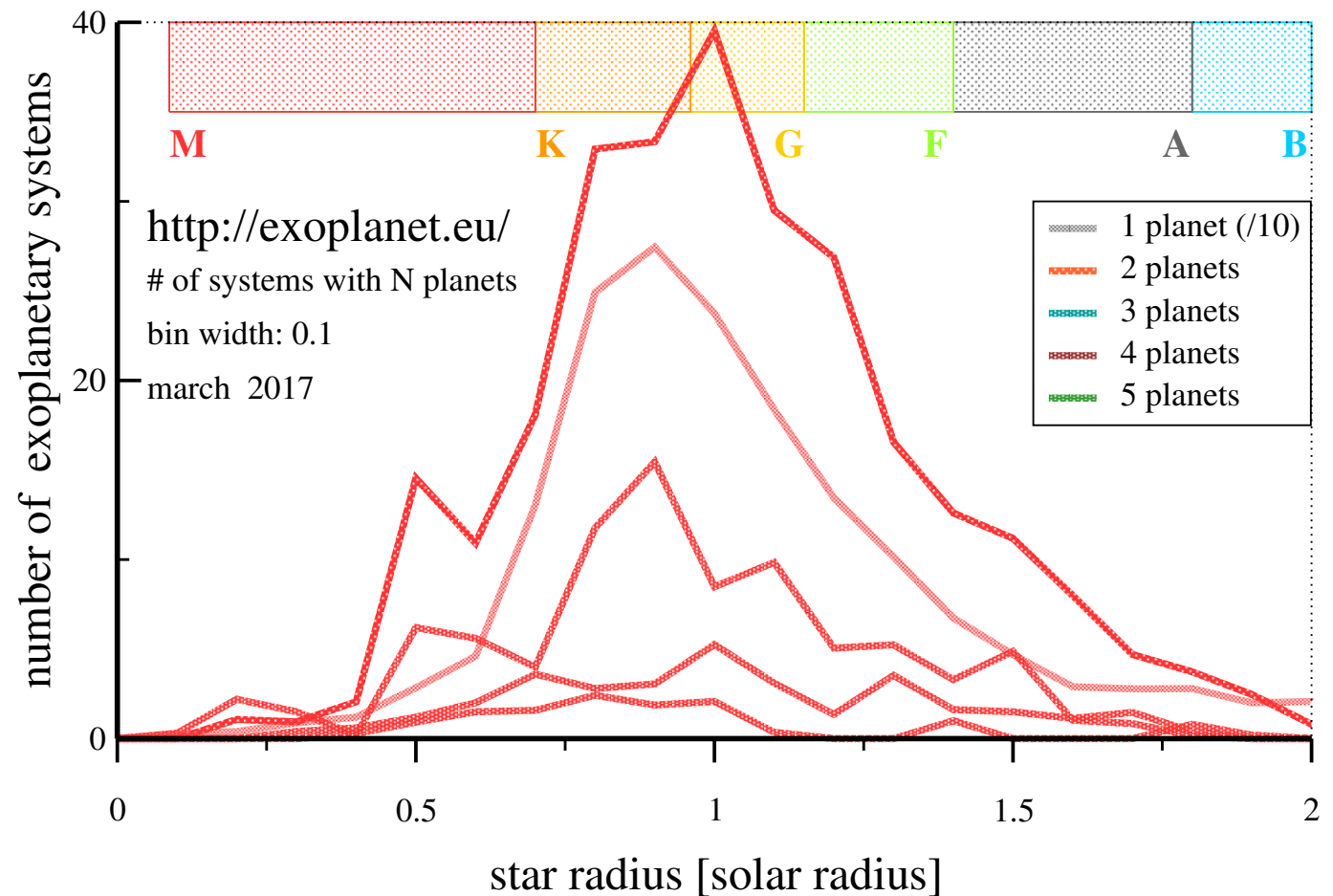
## **miniaturized interstellar missions technically feasible?**

- \* 50-100 years: passive acceleration/deceleration
- \* in situ synthesis of unicellular terrestrial organism
  - ⇒ **establish precambrian ecospheres on**
    - \* transiently habitable planets
    - \* oxygen planets

Developing Ecospheres on Transiently Habitable Planets: The Genesis Project

Gros; Astrophys. Space Sci. '16

# multi-planetary systems

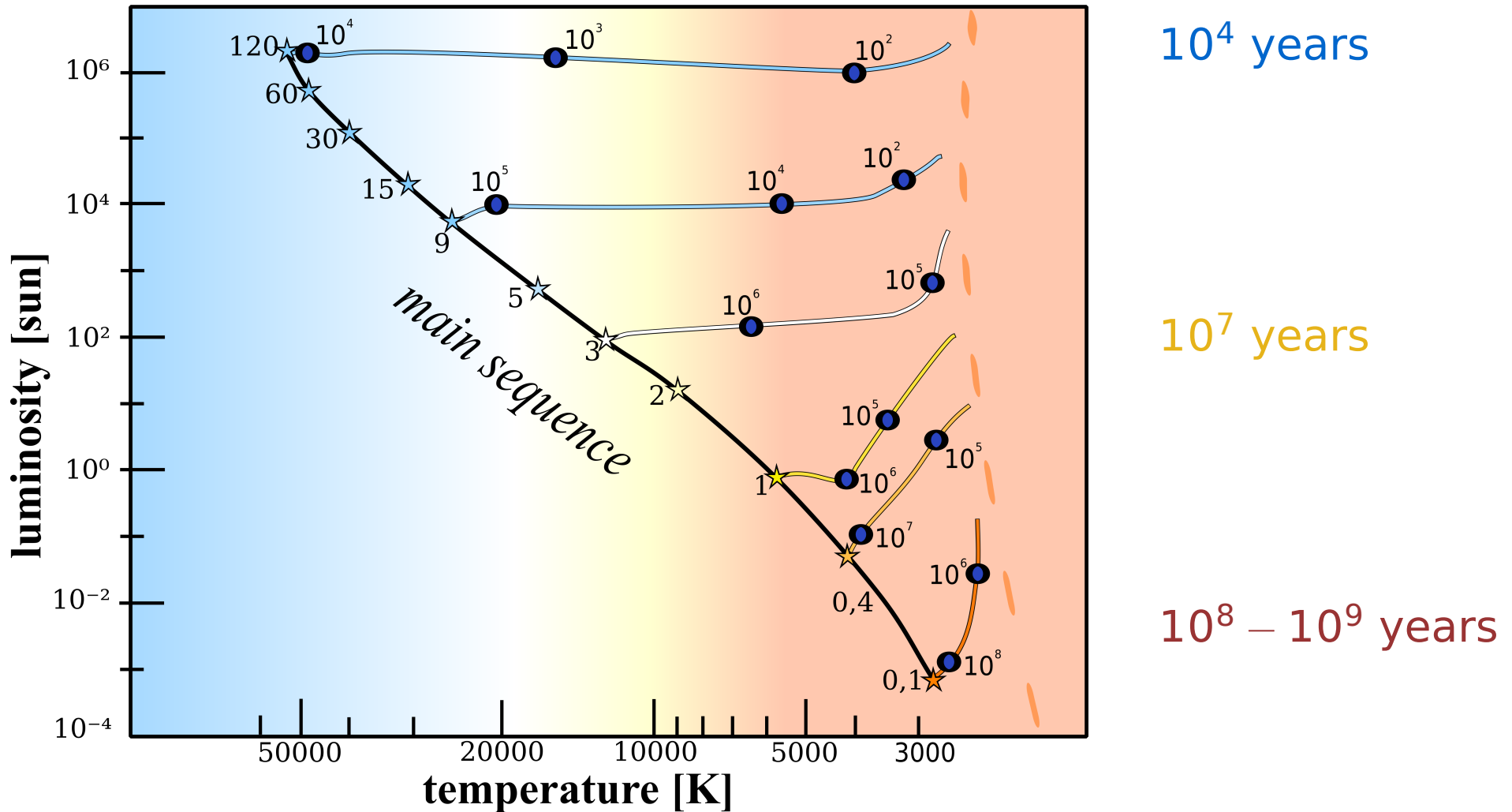


## billions of M-dwarf systems expected

- 3/4 of all star
- TRAPPIST-1 (radius: 0.12, 40 ljr, 7 planets)

[Shields, Ballard, Johnson '16]

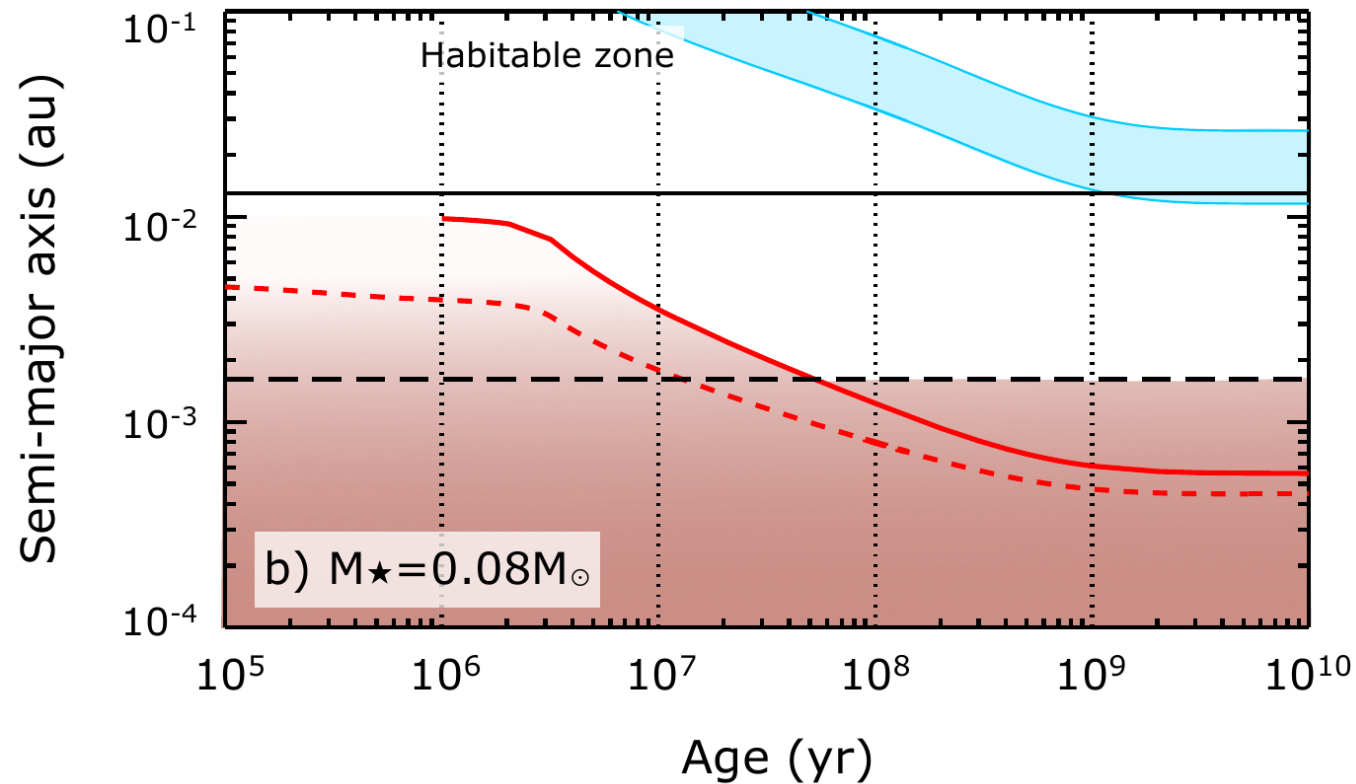
*pre main-sequence M dwarfs are hot \_\_\_\_\_*



slow protostar → main sequence Kelvin-Helmholtz contraction

# *habitable zone of M dwarfs moves inwards*

**TRAPPIST-1:**  $0.08M_{\odot}$ , age  $> 500$  Ma



solar flux  $\in [0.18, 1.5]_{\oplus}$   
position  $\approx$  T1-b / T1-c

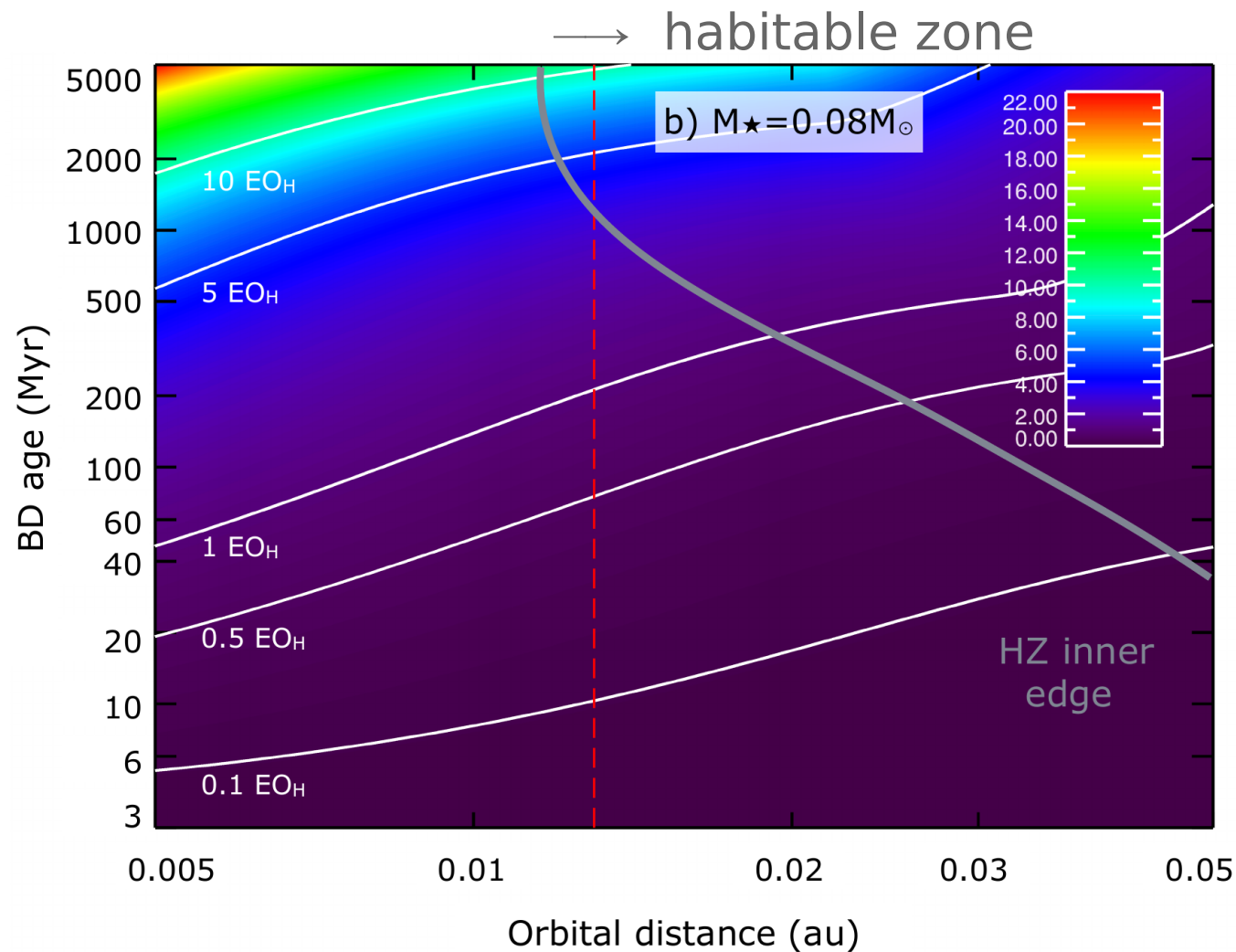
Roche limit

co-rotation / star  
radius

Water loss from terrestrial planets orbiting ultracool dwarfs:  
implications for the planets of TRAPPIST-1

Bolmont, Selsis, Owen, Ribas, Raymond, Leconte, Gillon; Mon. Notes R. Astron. Soc. '17

# massive water loss of ultracold dwarfs



[Bolmont et al. '17]

EO  $\equiv$  Ocean $_{\oplus}$

runaway greenhouse

wet stratosphere

$H_2O$  photodissociation

$H/O$  escape to space

depends on: FUV/XUV flux, planet mass/distance,  
pre-main-sequence phase, ...

# massive $O_2$ buildup on $M$ dwarfs \_\_\_\_\_

$O_2$ pressure (atm)			
T1-b	T1-c	T1-d	earth
420	350	30-490 (orbit)	0.2

[Bolmont et al. '17]

TRAPPIST-1:  $0.08M_{\odot}$

reduced for  $M \rightarrow M_{\odot}$

[Luger, Barnes; Astrobiology '15]

- $O_2$  removal: volcanic reduced gases, subduction, ...
- coldtrapping of  $H_2O$  with  $O_2$  buildup?
- initial 100 bar  $CO_2$ ?

## atmosphere may however be lost

- stellar wind/flares/CME → space
- tidal locking → freeze-out

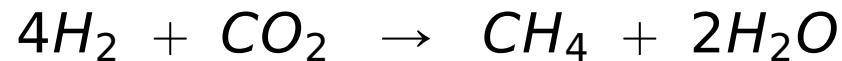
[Cohen et al. '14/15]

# *may life originate on oxygen planets? \_\_\_\_*

- \* abiogenesis in reducing environments

[Martin et al. '08]

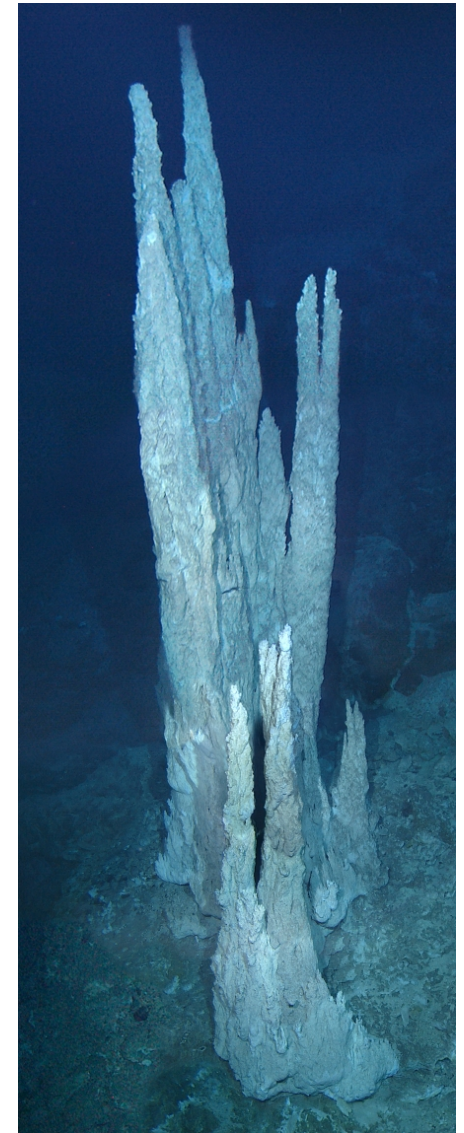
- \* white smokers / lost city scenario



- \* a local energy source ( $H_2$ ) powering prebiotic organic chemistry in restricted geometries

*are oxygen planets  
habitable but sterile?*

- \* lifetime of lost cities (Ma) enough for protocells to become  $O_2$  resistant?



[Nasa]



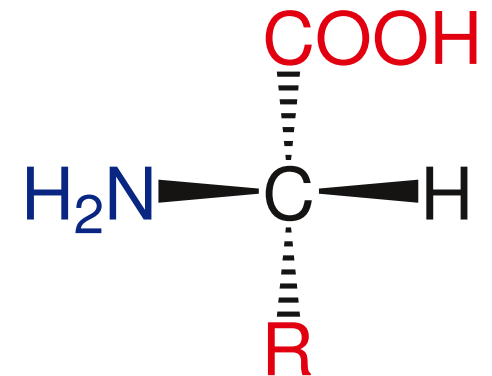
# *oxygen toxicity* \_\_\_\_\_

- humans: 0.4-0.6 bar (long-term)
- E. Coli, C-elegans  $\approx$  100% oxygen

[Baez, Shiloach '14; Van Voorhies, Ward '00]

## **cultivation**

terrestrial life tolerating 20-200 bars  $O_2$ ?



## **reprogramming the genetic code?**

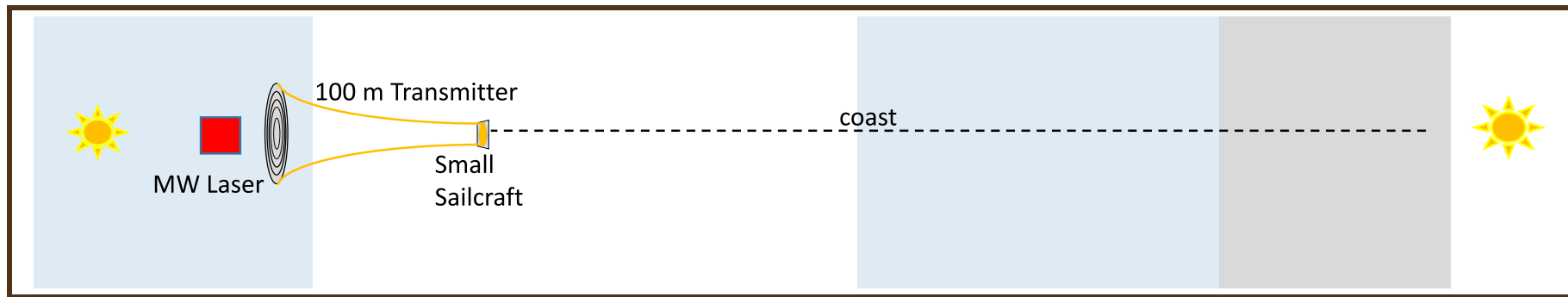
optimal orthogonal translation  $\rightarrow$  non-canonical amino acids

[O'Donoghue, Ling, Wang, Söll '13]

quadruplets (instead of triplets) nucleotide code?

[Chin '12; Lajoie, Söll, Church '16]

# *interstellar microprobes* \_\_\_\_\_



[Montgomery, Lubin]

## Nasa projects

### DEEP-IN

Directed Energy System  
for Interstellar Missions

### Wafercraft

Wafer Scale  
Spacecraft Development

## Starshot breakthrough initiative

Yuri Milner, Stephen Hawking, Mark Zuckerberg ...  
 $\alpha$  Centauri flyby

[Moon et al. '16]

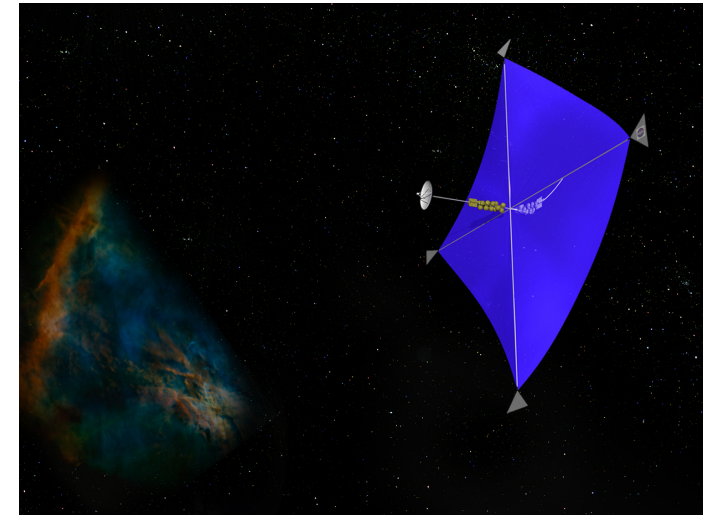
### surviving cosmic radiation damage

self-healing via thermal annealing of  
gate-all-around nanowire transistors

# *slowing down an interstellar craft \_\_\_\_\_*

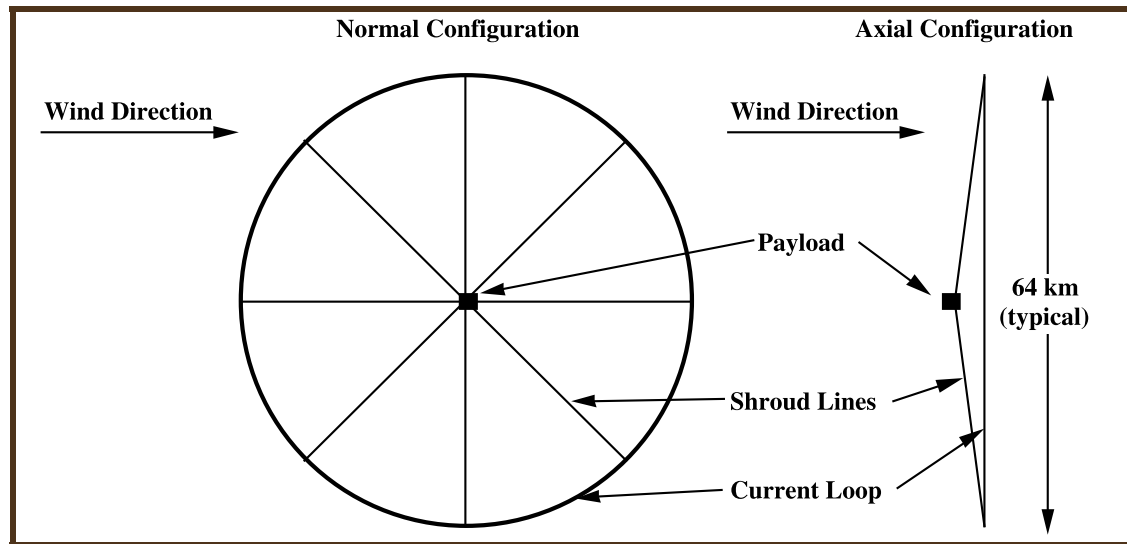
[Heller, Hippke; ApJ Lett. '17]

## **solar sail**



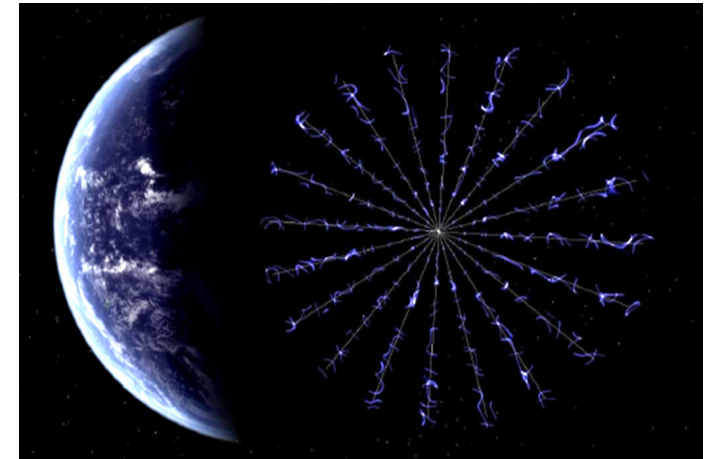
[Nasa]

## **magnetic sail**



[Zubrin '99]

## **electric sail**



# Genesis mission \_\_\_\_\_

## miniaturized spacecraft

launch	laser	minutes
cruising	–	centuries
deceleration	magnetic sail	centuries
seeding	from orbit	centuries
evolution	on planet	Ma-Ga

## on-board gen laboratory (in situ synthesis)

autotrophs → heterotrophs (uni-cellular)

## pre-cambrian biosphere

evolution → complex life



*not for human benefit* \_\_\_\_\_

## **millenia-long mission duration**

- ▷ launch-and-forget
- ▷ no inter-generational contract

## **precondition for exoplanet seeding**

<i>no benefit</i>	⇒	<i>time is irrelevant</i>
	⇒	<i>passive deceleration</i>

# Genesis project - cons \_\_\_\_\_

## moral imperative (?)

*humanity as a species has to be egoistic*

- money spent needs to have a benefit

## ‘playing’ with creation not allowed (?)

- synthetic life is an active research field

## planetary protection

- transiently habitable planets (brown dwarfs)
- sterile planets (oxygen planets)

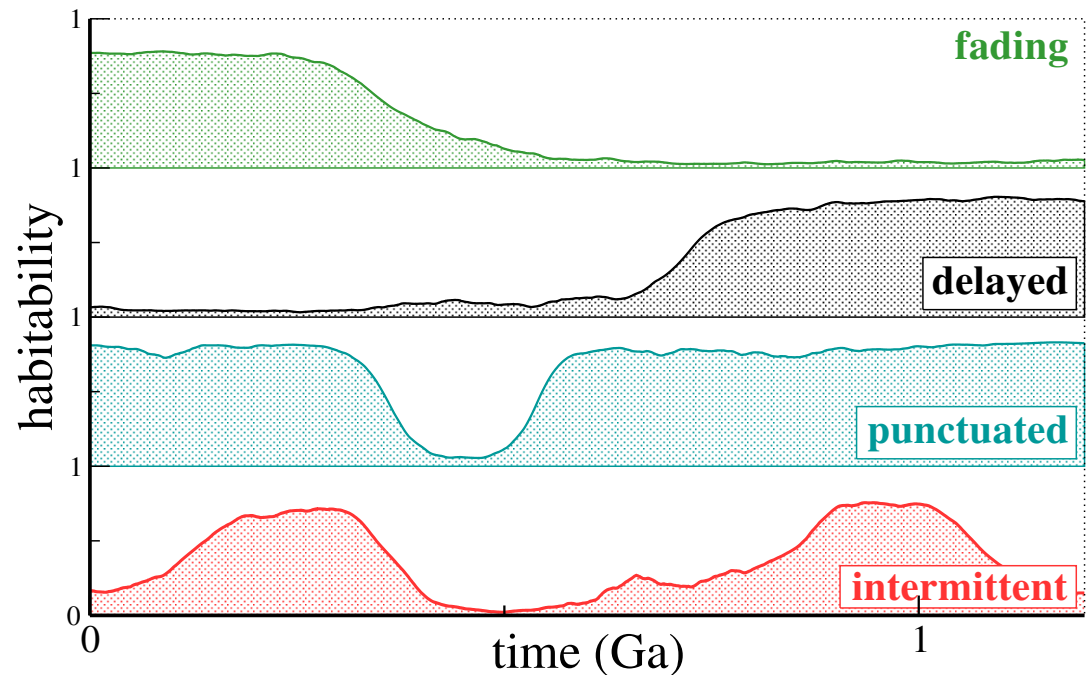
# outlook

## exoplanets come in large varieties

- ▷ habitability
- ▷ ...
- ▷  $200 \cdot 0.75 \cdot 0.2 = 30$  billion oxygen planets

[Tuomi, '14]

[Gros '16]



*transiently habitable / lifeless planets*  
» *opportunities for terrestrial life?*