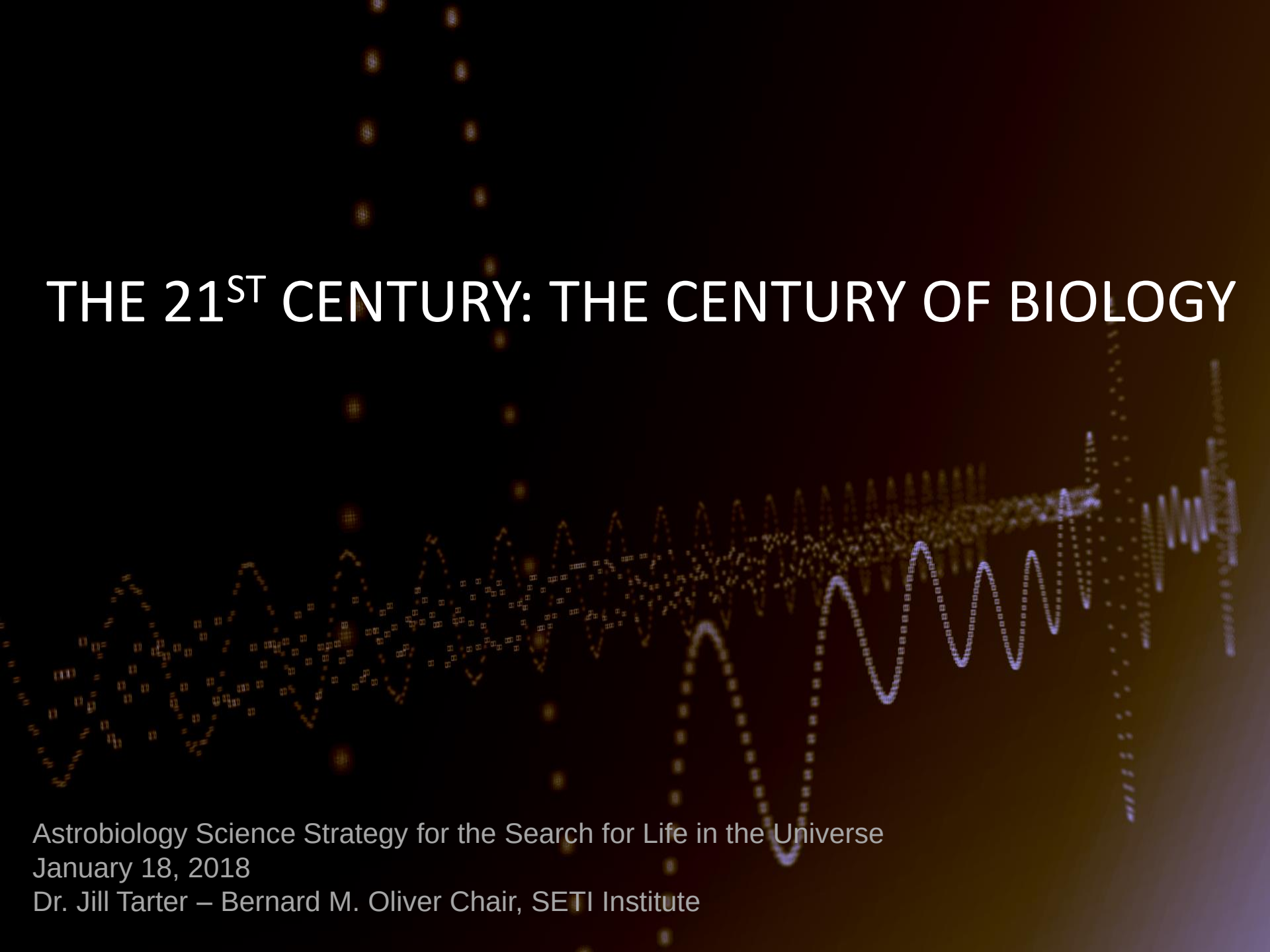
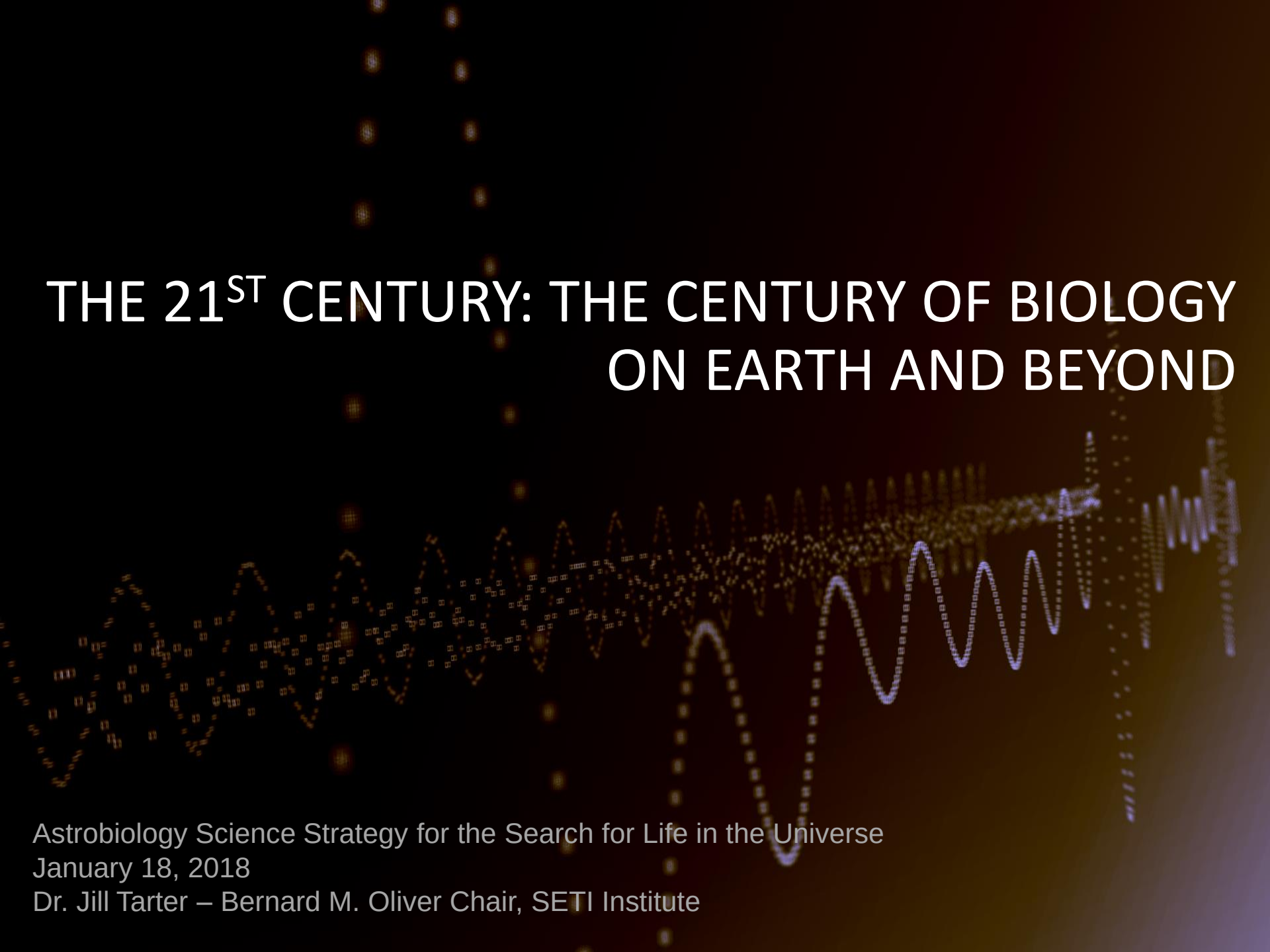
THE 21ST CENTURY: THE CENTURY OF BIOLOGY



Astrobiology Science Strategy for the Search for Life in the Universe
January 18, 2018
Dr. Jill Tarter – Bernard M. Oliver Chair, SETI Institute

THE 21ST CENTURY: THE CENTURY OF BIOLOGY ON EARTH AND BEYOND



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Life Beyond Earth

- Discover it
  - In situ biomarkers
  - Artifacts in the solar system
  - Remote biosignatures

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- Detect its work product
  - Technosignatures
  - Serendipitous observations

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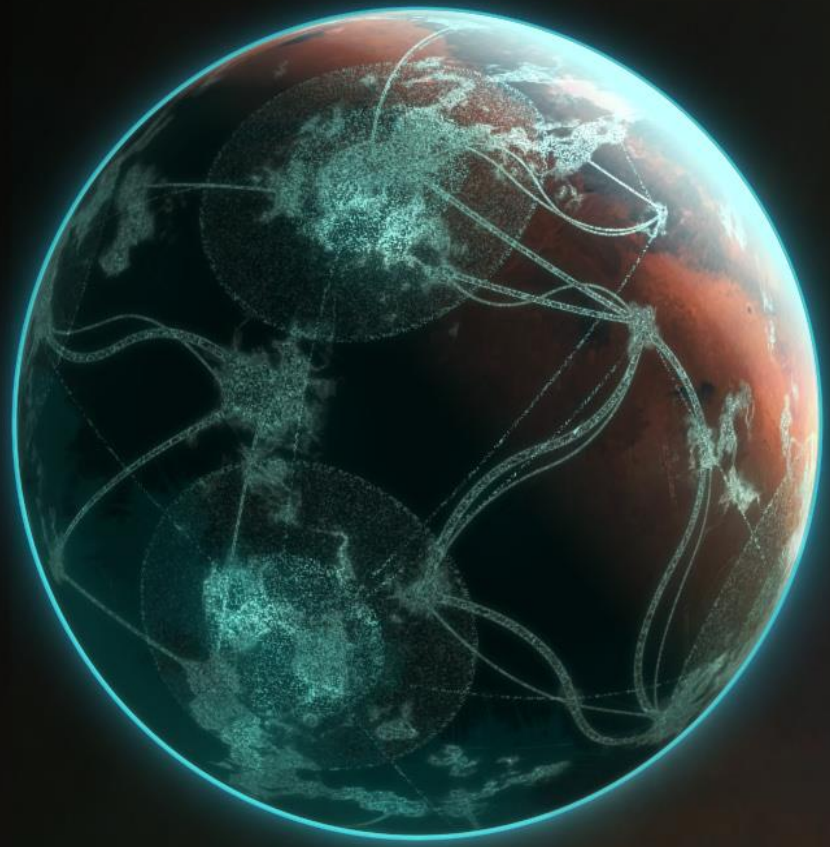
  - Technosignatures
  - Serendipitous observations
- Export it
  - Moon, Mars, Asteroids
  - Breakthrough StarShot, 100 Year Starship Study, Icarus

We Need To Watch Our Language

- SETI ≠ The Search for ExtraTerrestrial Intelligence
  can't define Intelligence
  uses technology as a proxy for intelligence
- SETI == searching for evidence of somebody else's technology
- pragmatic definition of technology == ability to **deliberately** modify an environment in ways that can be sensed over interstellar/interplanetary distances (including unintended consequences)
- SETI ≠ CETI --- the search precedes the decoding



A SEARCH FOR TECHNOSIGNATURES

Charge to This SSB Committ

- Identify the most promising key rese[illegible] in the field of the search for signs of life [illegible] progress is likely in the next 20 years;
- Discuss which of the key g[illegible]e addressed by U.S. and international s[illegible]ns and ground telescopes in operat[illegible]velopment;
- Discuss how to [illegible]nerships (interagency, international [illegible] private) in furthering the study of life's ori[illegible]on, distribution, and future in the universe;
- Make [illegible]endations for advancing the research, ob[illegible]he measurements, and realizing NASA's goal [illegible]h for signs of life in the universe

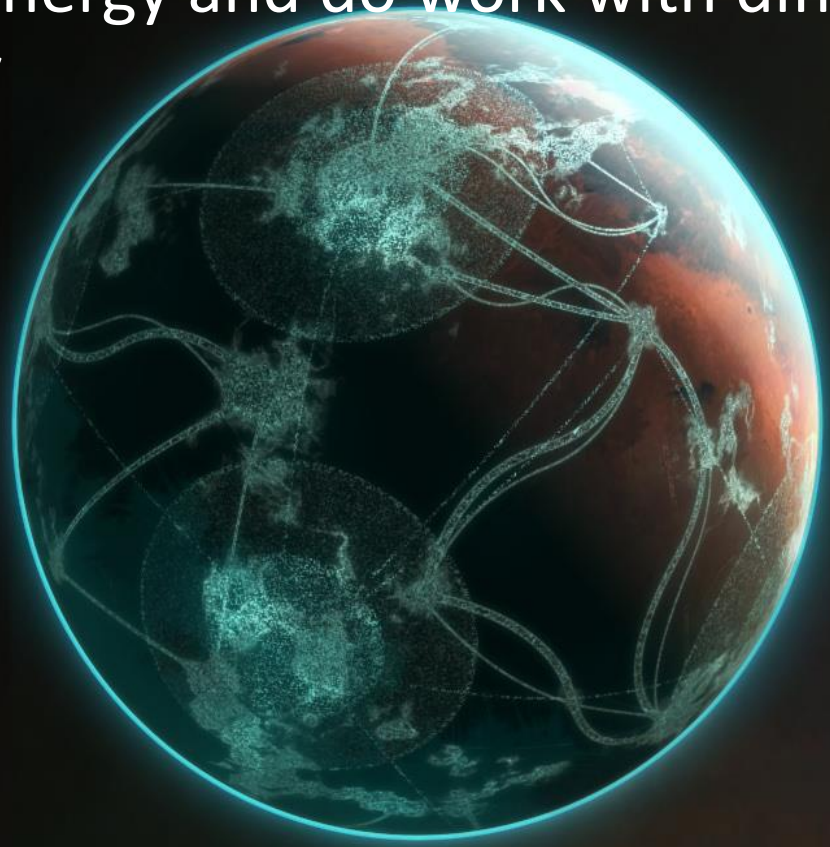
Technosignatures, Technosignatures, Technosignatures

What Do Technologies Do?

- Harvest energy and do work with different levels of efficiency
- What kind of energy?
  - Chemical combustion and fermentation
  - Wind, Solar, Wave
  - Geothermal
  - Nuclear
  - ???
- What kind of work?
  - Generate, transfer, store information
  - Construction (local, regional, global, solar system(s))
  - Transportation
  - Resource extraction
  - Manufacturing / replication
  - Maintain homeostasis

What Do Technologies Do?

- Harvest energy and do work with different levels of efficiency



1962 Clarke's three laws

1. When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong.

2. The only way of discovering the limits of the possible is to venture a little way past them into the impossible.

3. Any sufficiently advanced technology is indistinguishable from magic.

Karl Schroeder’s third law

1. …
2. …
3. Any sufficiently advanced technology is indistinguishable from nature.

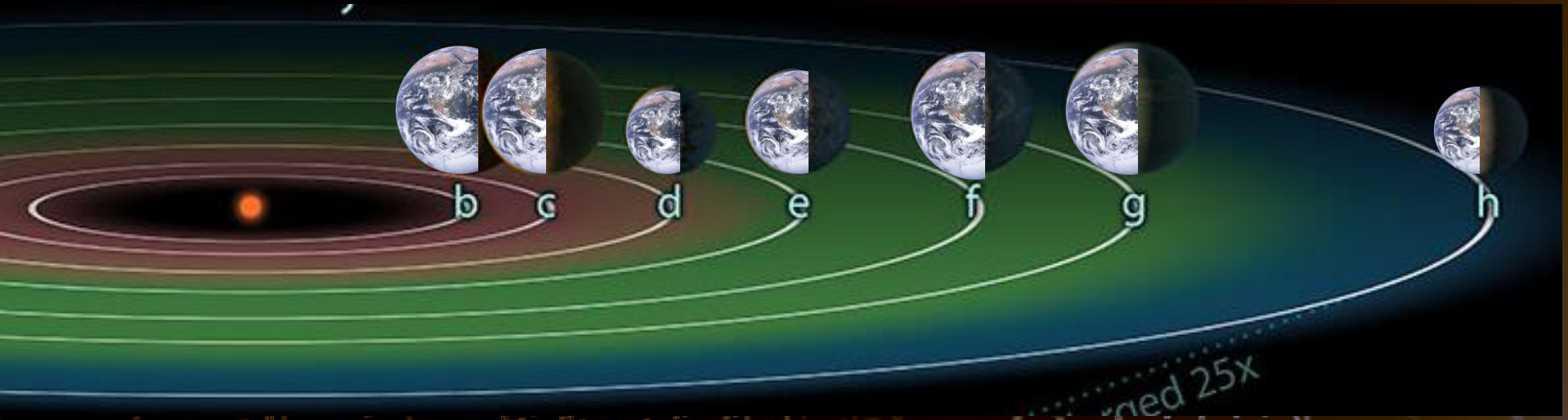
Natural vs. Engineered To Be Natural

- Unexpected albedo or ‘glint’
- Surface temperature is ‘wrong’
- Lack of extreme weather
- Latitudinal homogeneity

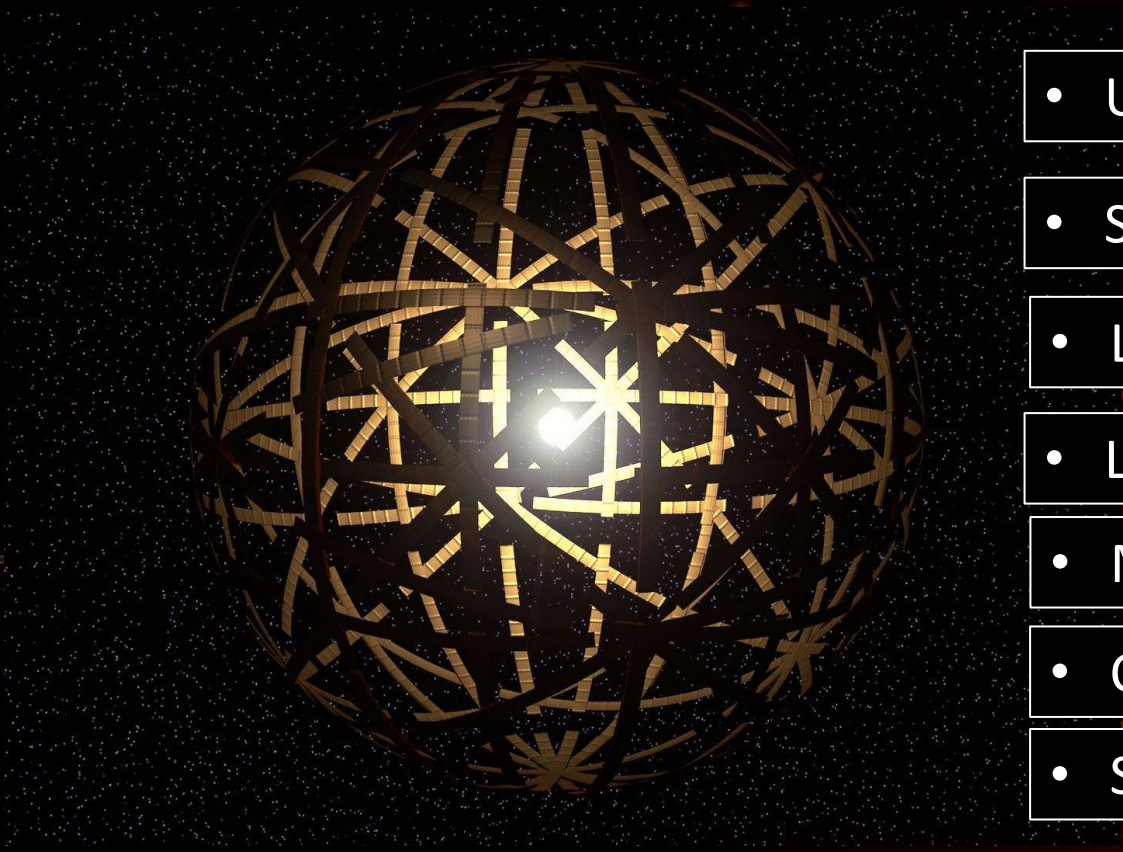
Natural vs. Engineered To Be Natural

- Unexpected albedo or ‘glint’
- Surface temperature is ‘wrong’
- Lack of extreme weather
- Latitudinal homogeneity
- Multiple identical planets

Terraformed TRAPPIST-1



Natural vs. Engineered To Be Natural



- Unexpected albedo or ‘glint’
- Surface temperature is ‘wrong’
- Lack of extreme weather
- Latitudinal homogeneity
- Multiple identical planets
- Clusters of habitable worlds
- Stellar modifications

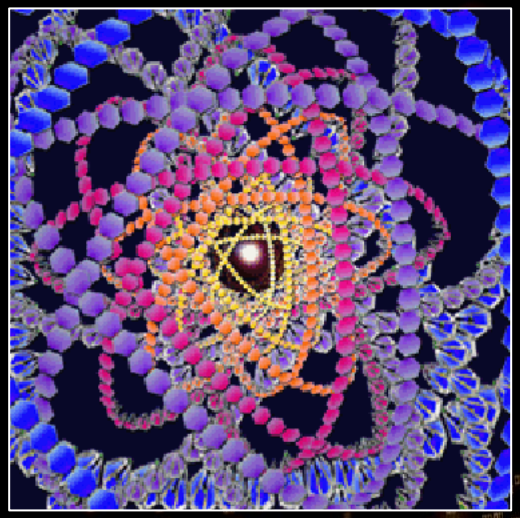
Nick Bostrom's third law*

1. …
2. …
3. Any sufficiently advanced technology is indistinguishable from the goal programmed into an insufficiently constrained and boxed superintelligent singleton.

* I'm putting words in his mouth. He is a philosopher writing about Generalized AI

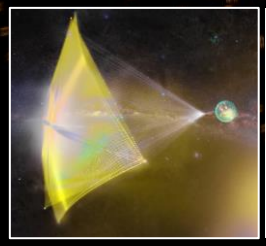
Natural vs. Engineered By Machines

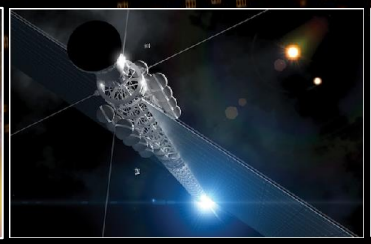
Where should we look for GAIs?



Matrioshka Brains around host star
(Thermal IR excess and signals between other brains)

Sources of great energy
BHs and Neutron Stars
(pulsar planets?)





StarShot, Dragonfly, Starwisp – in our own SS
(Lagrange points, asteroids?)

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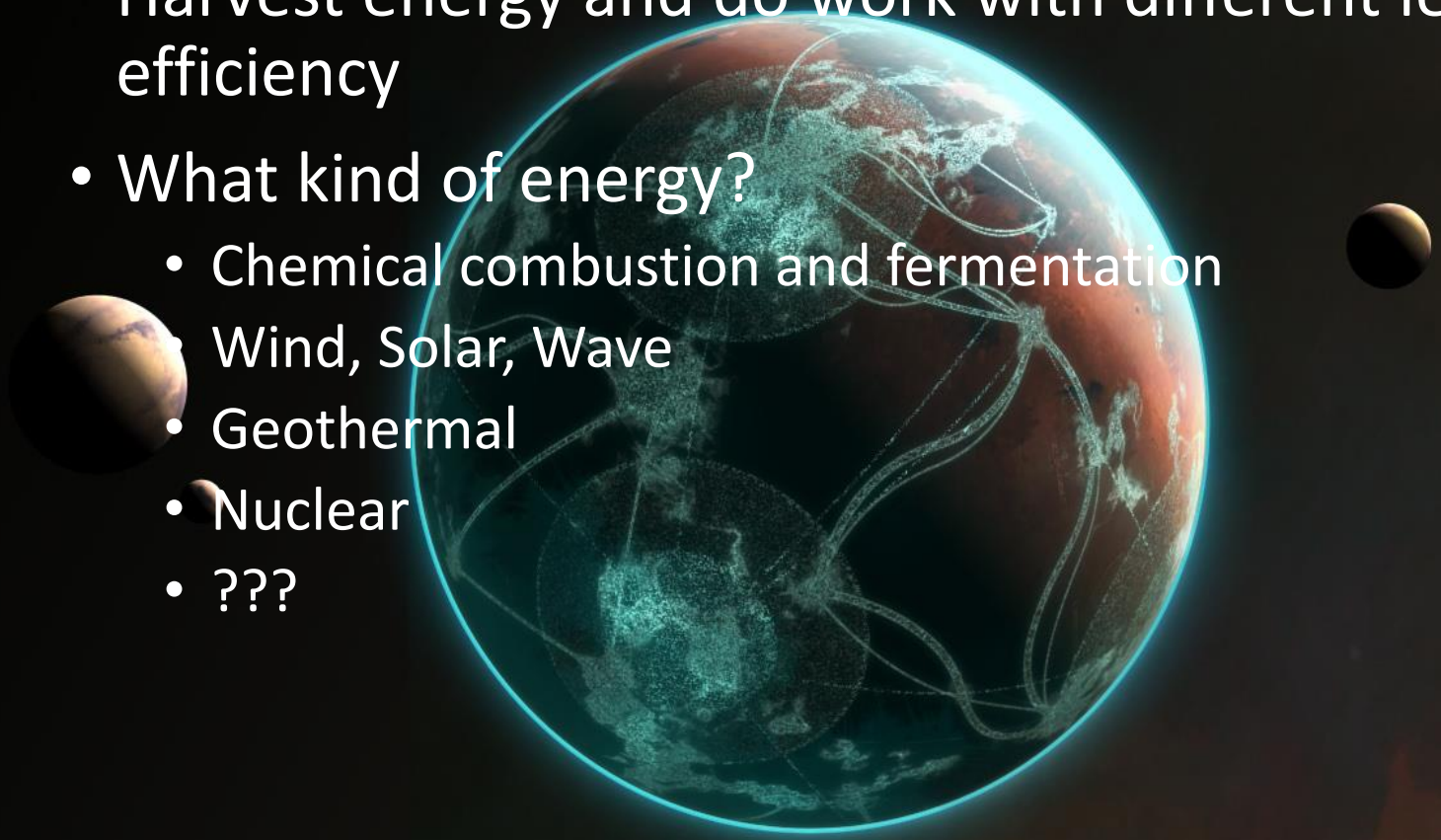
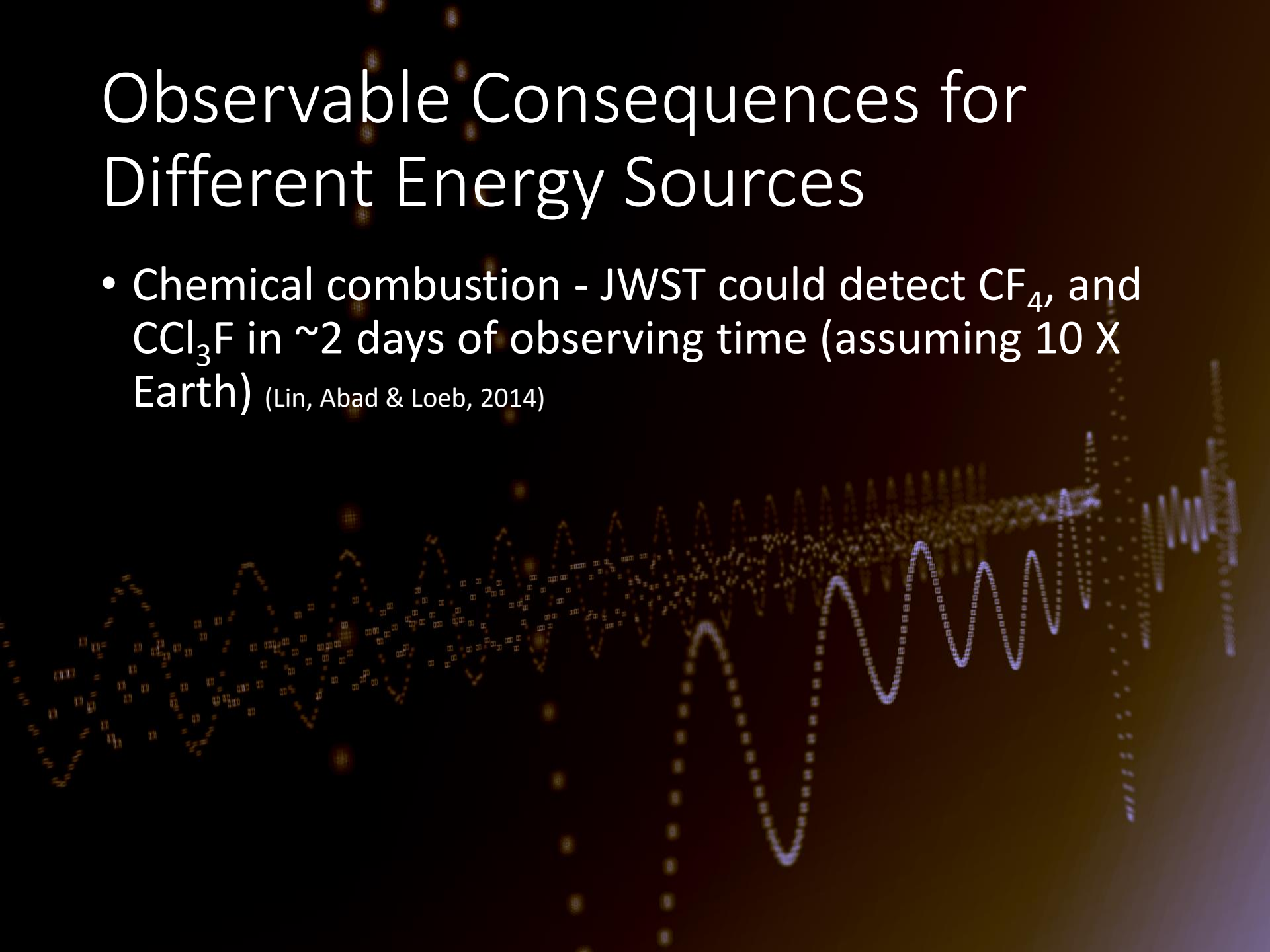


Observable Consequences for Different Energy Sources

- Chemical combustion - JWST could detect CF_4, and CCl_3F in ~2 days of observing time (assuming 10 X Earth) (Lin, Abad & Loeb, 2014)



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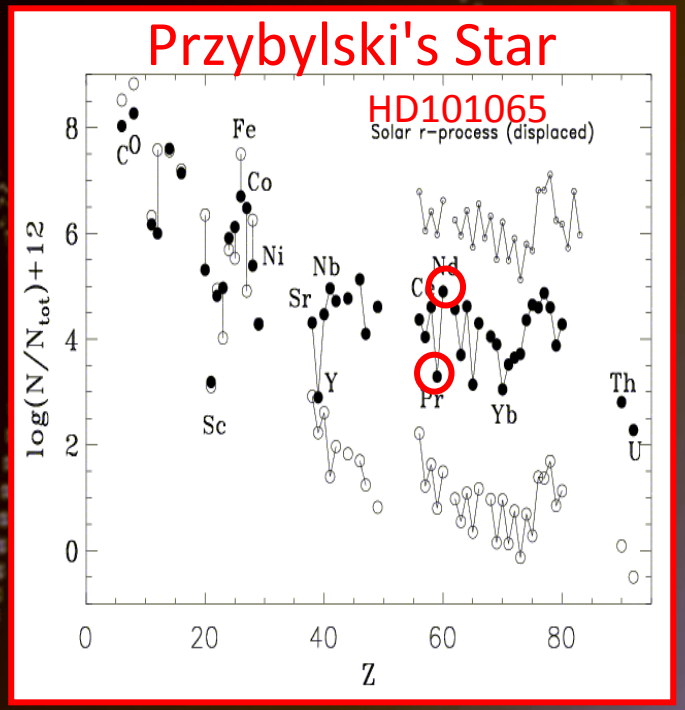

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- Nuclear
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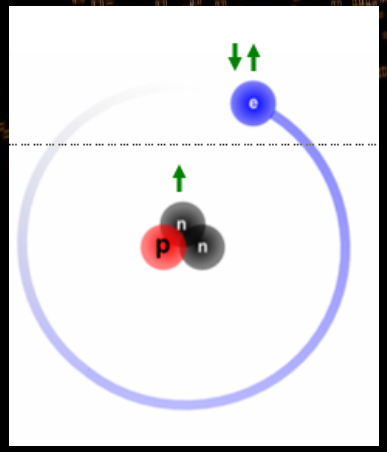
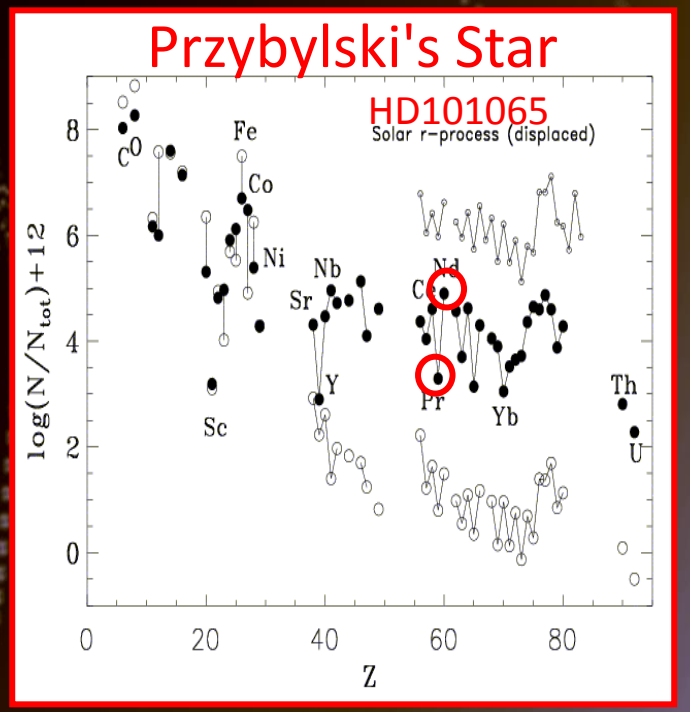
  - Fusion – Tritium leakage. 12.6 year half life. Analog to 21cm HI hyperfine transitions at 1516 MHz. Emission near a star would be intriguing. (Valdes and Freitas, 1986)





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Observable Consequences of Work

- Generate, Store Information: Computronium, Matrioshka Brains, paperclips or some other transformation of all material (Bostrom 2014, Musk 2016 …)
  HEAT
- Construction: Dyson Swarms/ Megastructures/ Disappearing Stars (Villarroel, Imaz, Berstet, 2016), Star-tickling and the Galactic Internet (Learned, Kudritzki, Pakvasa & Zee, 2008)
  MODS STAR SPECTRUM (FREQUENCY & TIME)
- Manufacturing/replication: grey goo (Drexler, 1986)
  LACK OF DIVERSITY

Observable Consequences of Work

- Generate, Store Information: Computronium, Matrioshka Brains, paperclips or some other transformation of all material (Bostrom 2014, Musk 2016 …) HEAT
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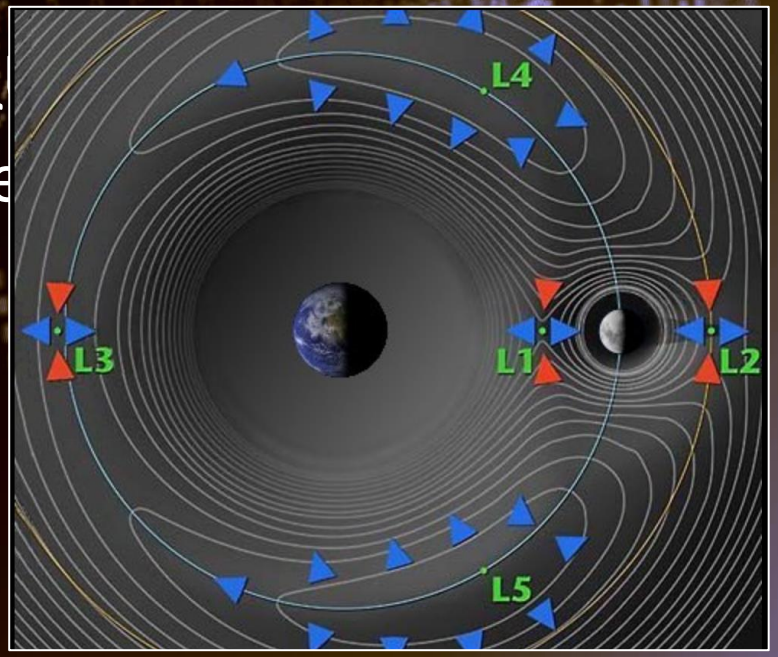
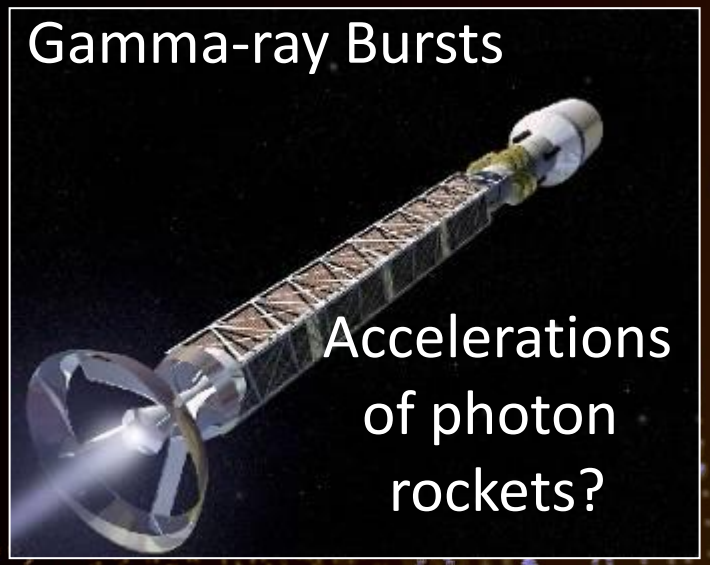
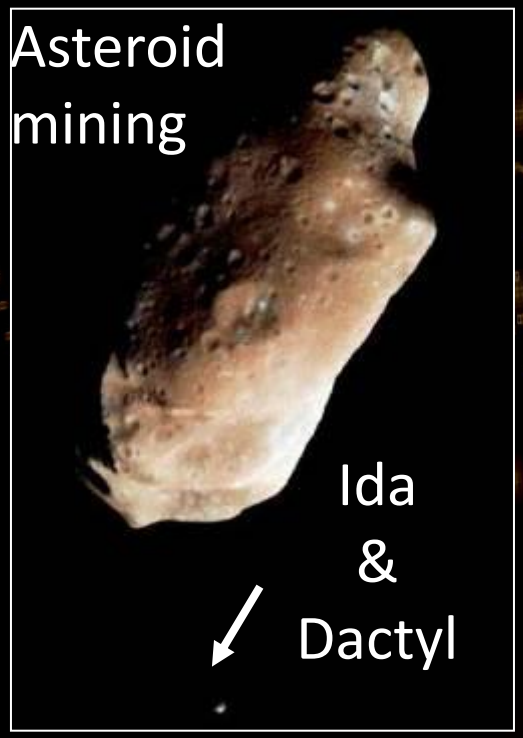
- Manufacturing/replication: gre LACK OF DIVERSITY
  - Probes made by molecular manufacturing could mean Kordylewski Clouds are real made of diamondoid nanobots (Freitas, 2017)



Observable Consequences of Work

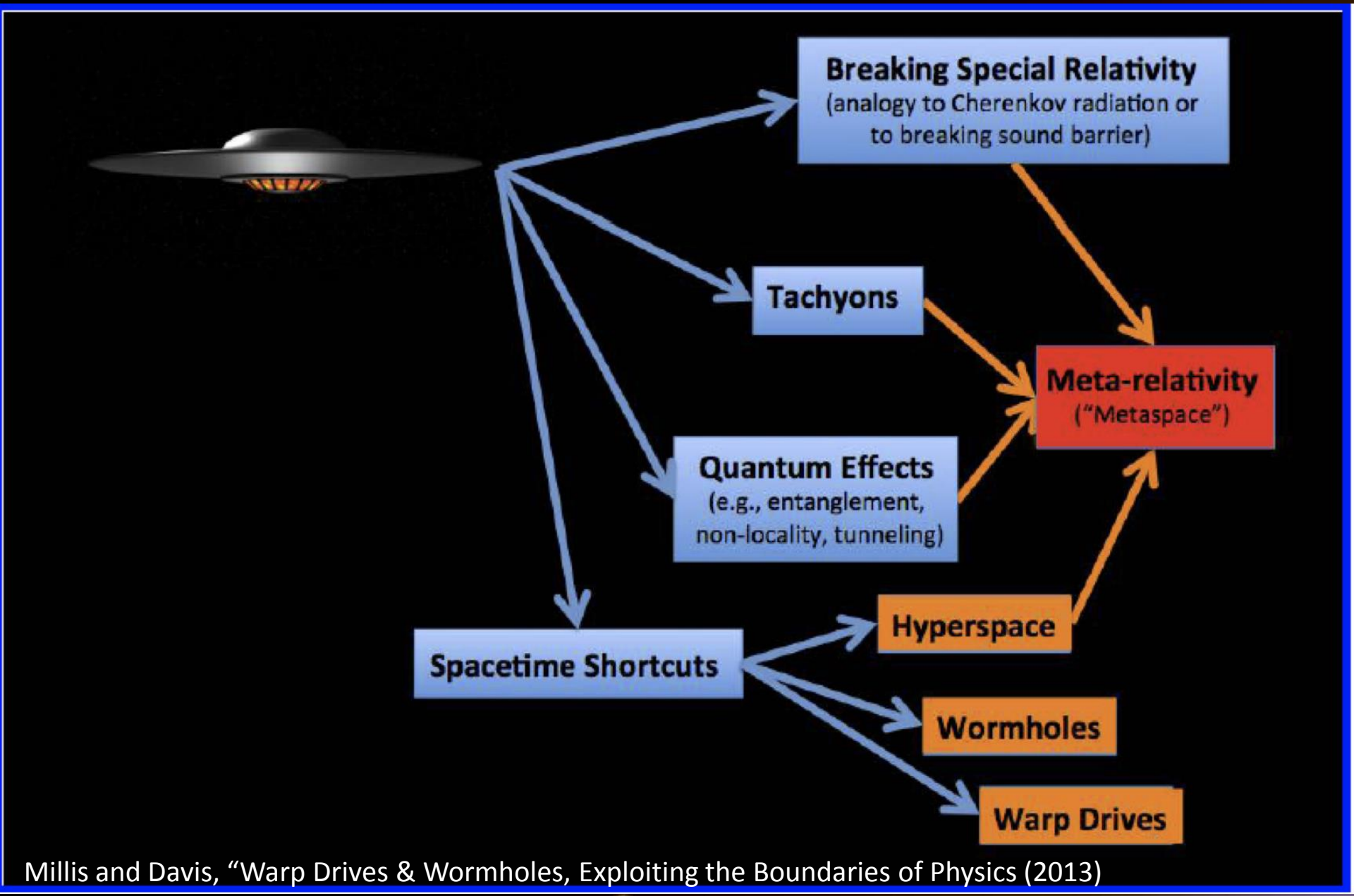
- Transportation:
  - Relativistic ‘Boldly Going’ (Corbet, 1999)





- Breakthrough Starshot @.2c
- Slow generational ships (Papagiannis, 1982)

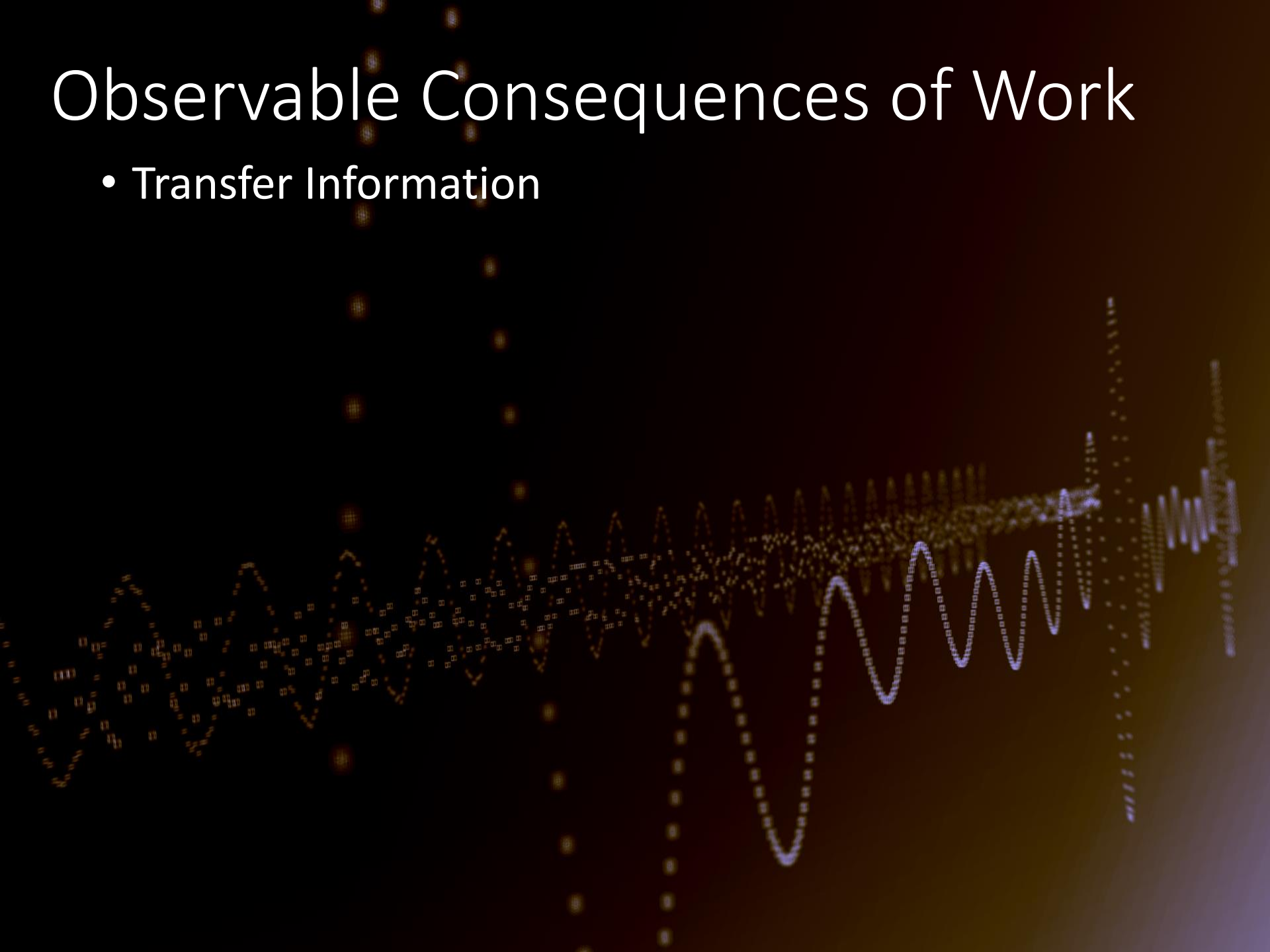
FTL Travel



Millis and Davis, "Warp Drives & Wormholes, Exploiting the Boundaries of Physics (2013)

Observable Consequences of Work

- Transfer Information



Multi-Messenger Universe

- Carriers of information over vast distances
  - photons – EM waves
  - particles of matter
    - neutral or charged
    - massless or massive
    - negative energy tachyons?
  - entangled pairs
  - gravitational waves
  - FTL travel via wormholes or warp drives

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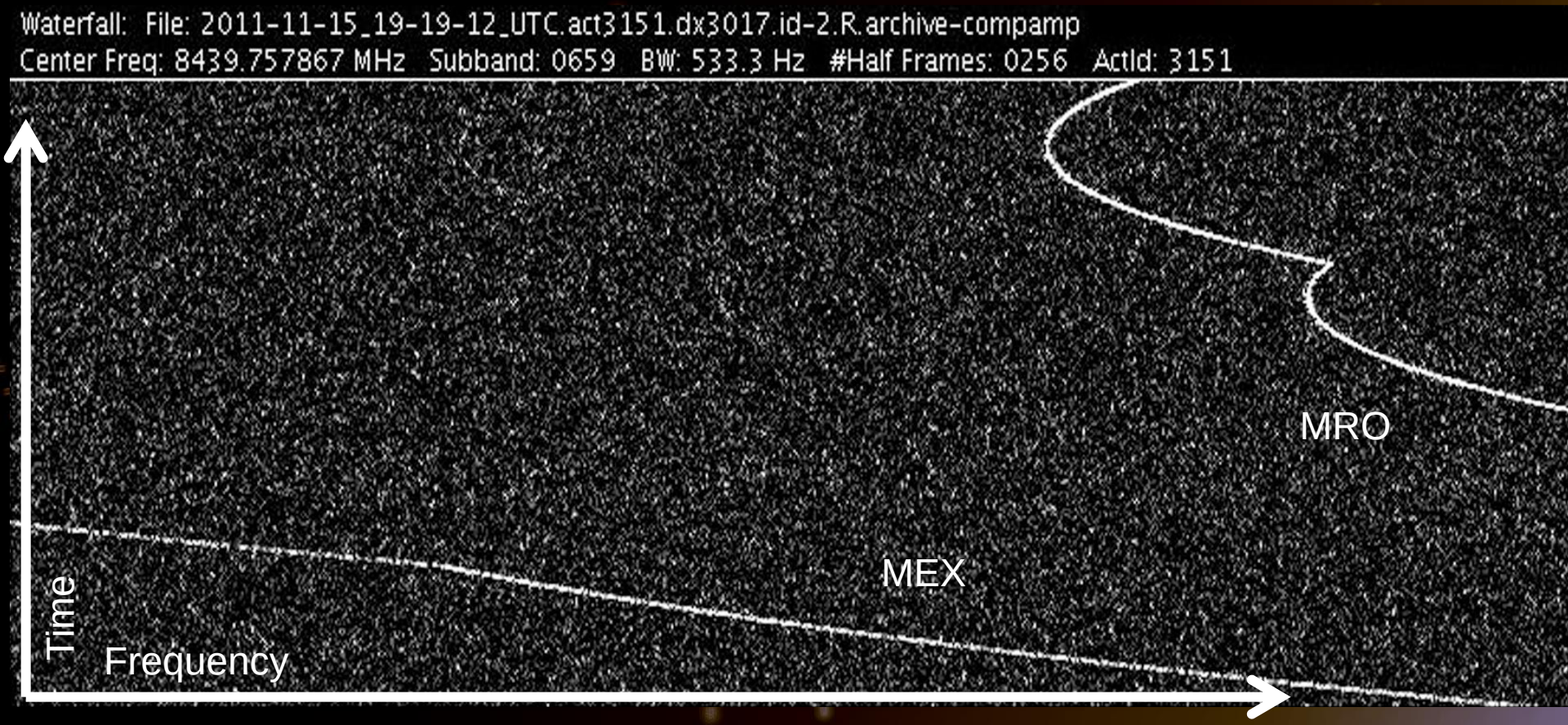
NIROSETI

Radio: Natural vs. Engineered



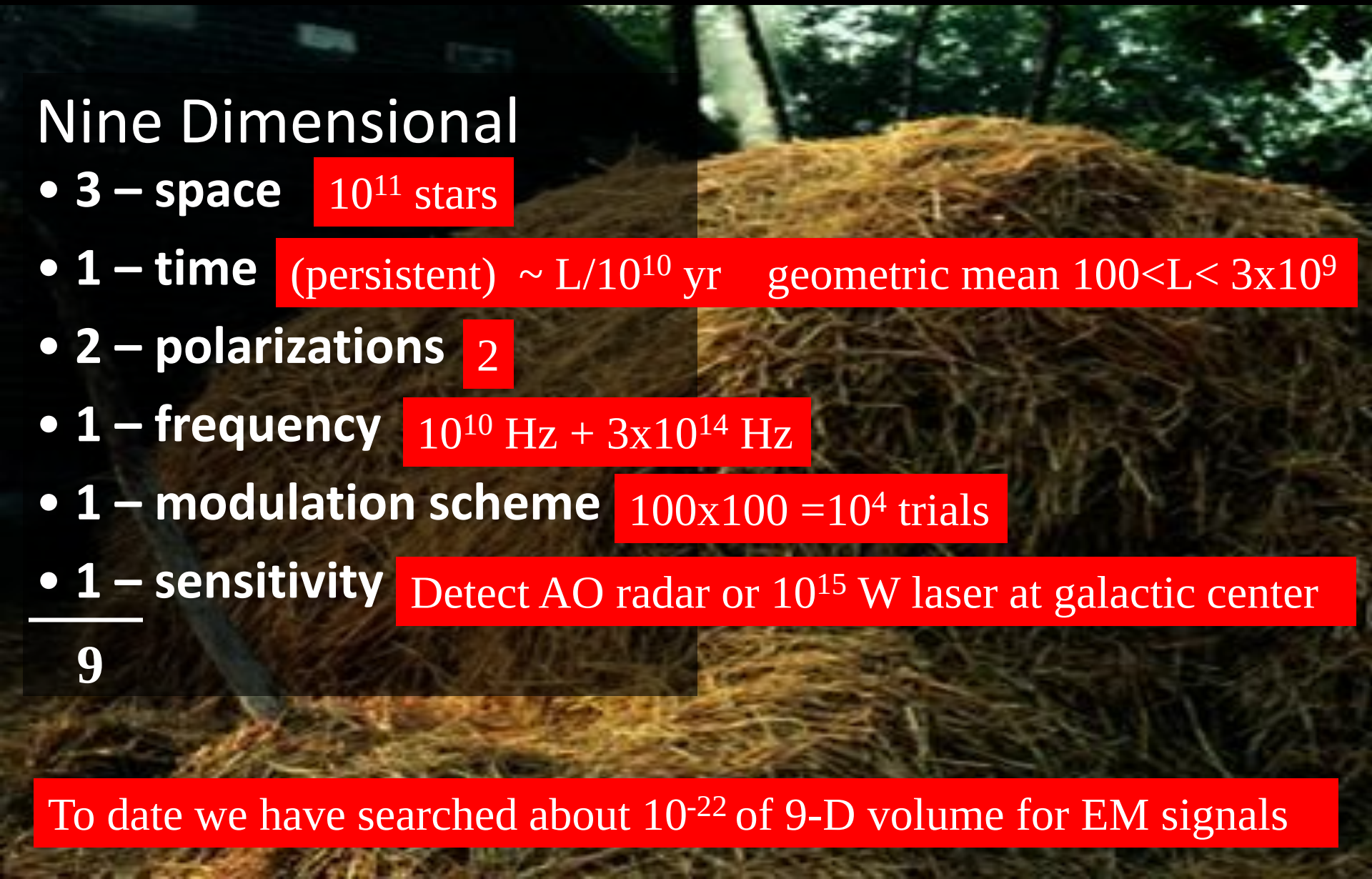
The EM Cosmic Haystack Is Huge

Nine Dimensional

- **3 – space**
- **1 – time**
- **2 – polarizations**
- **1 – frequency**
- **1 – modulation scheme**
- **1 – sensitivity**

9

The EM Cosmic Haystack Is Huge



Nine Dimensional

- **3 – space** 10^{11} stars
- **1 – time** (persistent) ~ $L/10^{10}$ yr geometric mean $100 < L < 3 \times 10^{9}$
- **2 – polarizations** 2
- **1 – frequency** 10^{10} Hz + 3×10^{14} Hz
- **1 – modulation scheme** $100 \times 100 = 10^{4}$ trials
- **1 – sensitivity** Detect AO radar or 10^{15} W laser at galactic center

9

To date we have searched about 10^{-22} of 9-D volume for EM signals

50+ YEARS OF SETI TO DATE

Opportunities Now For Large Improvement

- New and faster instrumentation
- Beginning to have access to the transient sky
- AI and neural networks are beginning to allow data to call attention to signals that are present, rather than just looking for pre-defined artifacts
- Opportunities for data mining and commensal observing are increasing.
- Graduate and undergraduate curricula now available

The ATA-42


THE ATA-42

20,000 RED DWARF SURVEY

setiquest.info

Kepler Field

Geosynchronous Belt

B EN

$100 M I MILNER

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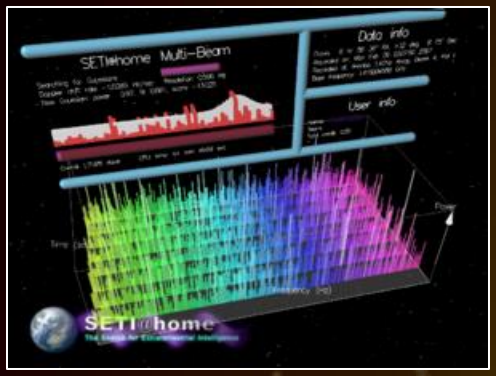
BREAKTHROUGH LISTEN

MORE SETI TODAY

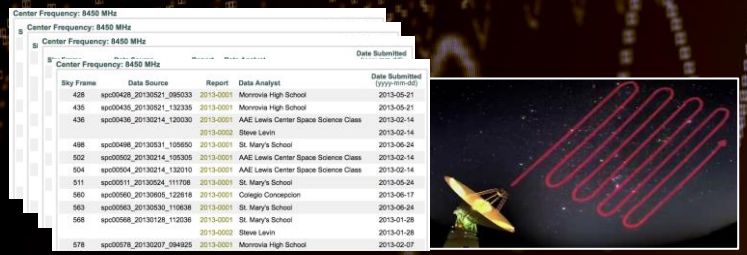
LOFAR
Low Frequency Transients



SETI@home

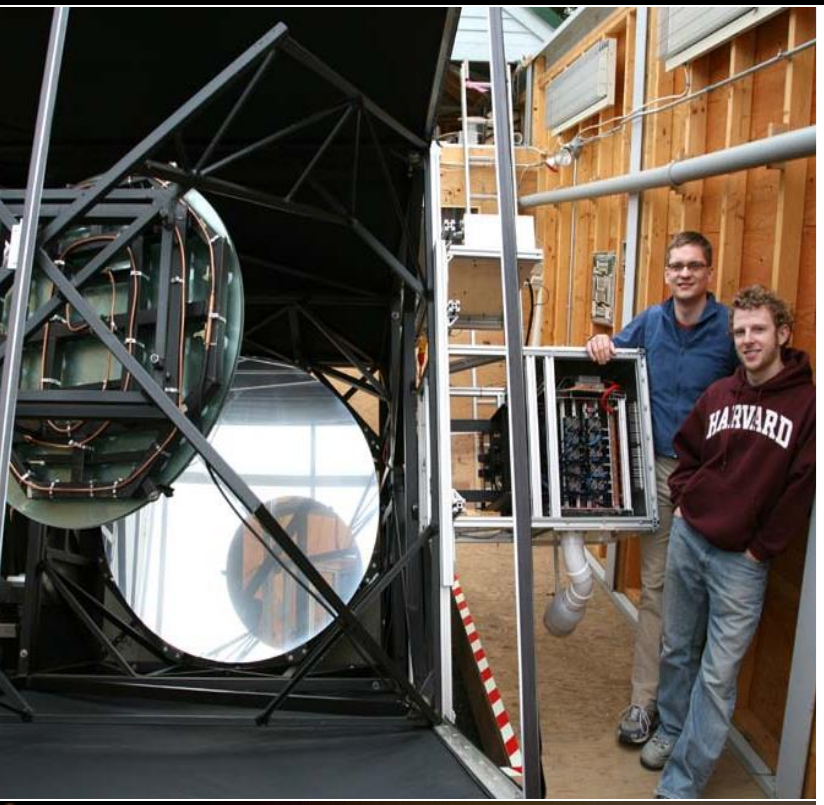
Project Dorothy
15 Countries

SETI Italia

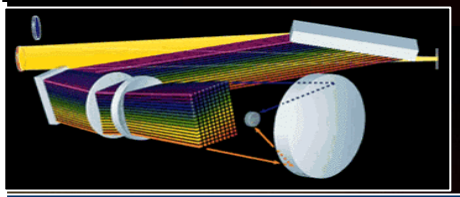


ALFA at Arecibo
Astropulse &
Other signals

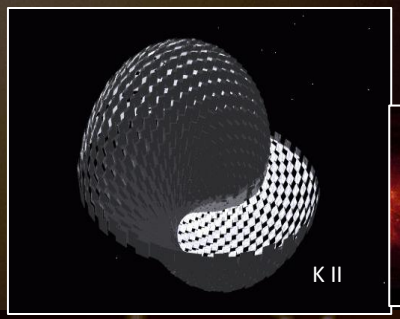
OSETI



Harvard – Sky Survey



Keck
HIRES



K II

Ĝ

WISE

K III

Potential OSETI ‘Telescopes’

Veritas (commensal or datamining)

Heliostat at night

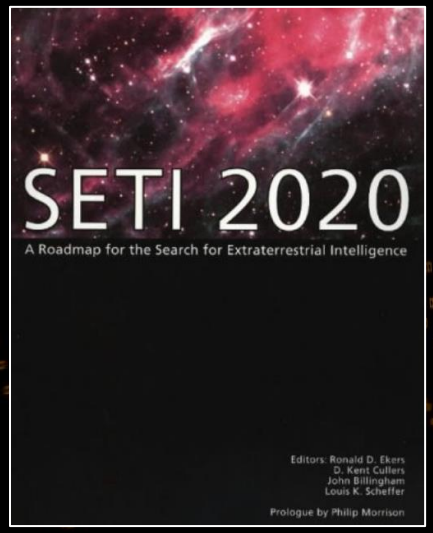
Breakthrough Watch

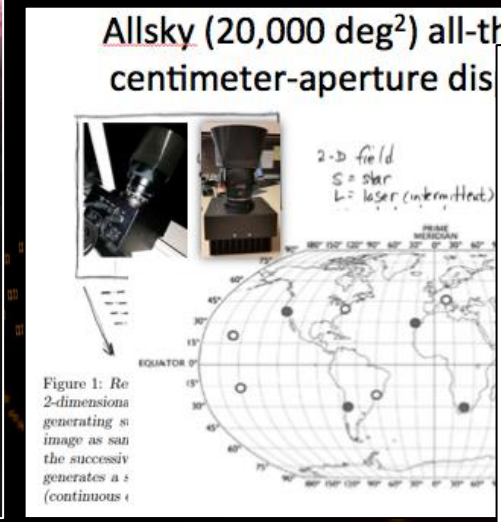
Instrument upgrades to VISIR on VLT
Alpha Centauri A & B
image planets w. R_p~$2R_\oplus$
Targets for Breakthrough
Listen & Starshot

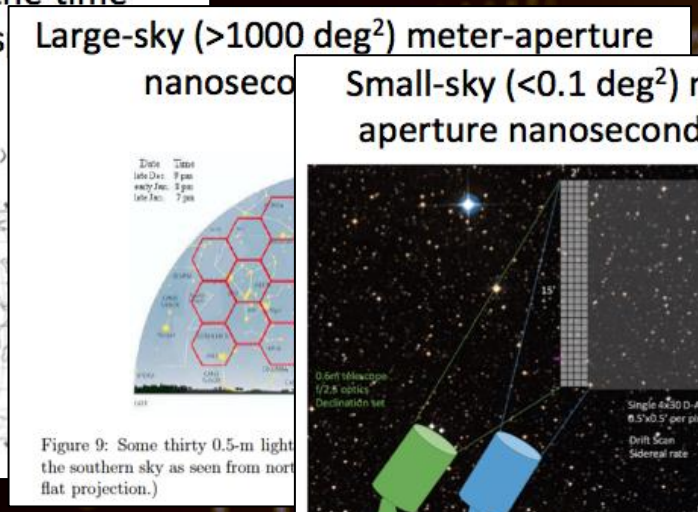
Olivier Guyon & Markus Kasper

MANY UNKNOWNS - BUT COMPELLING REASONS TO SEARCH
ALL-SKY, ALL-THE-TIME, AT ALL FREQUENCIES

OSS







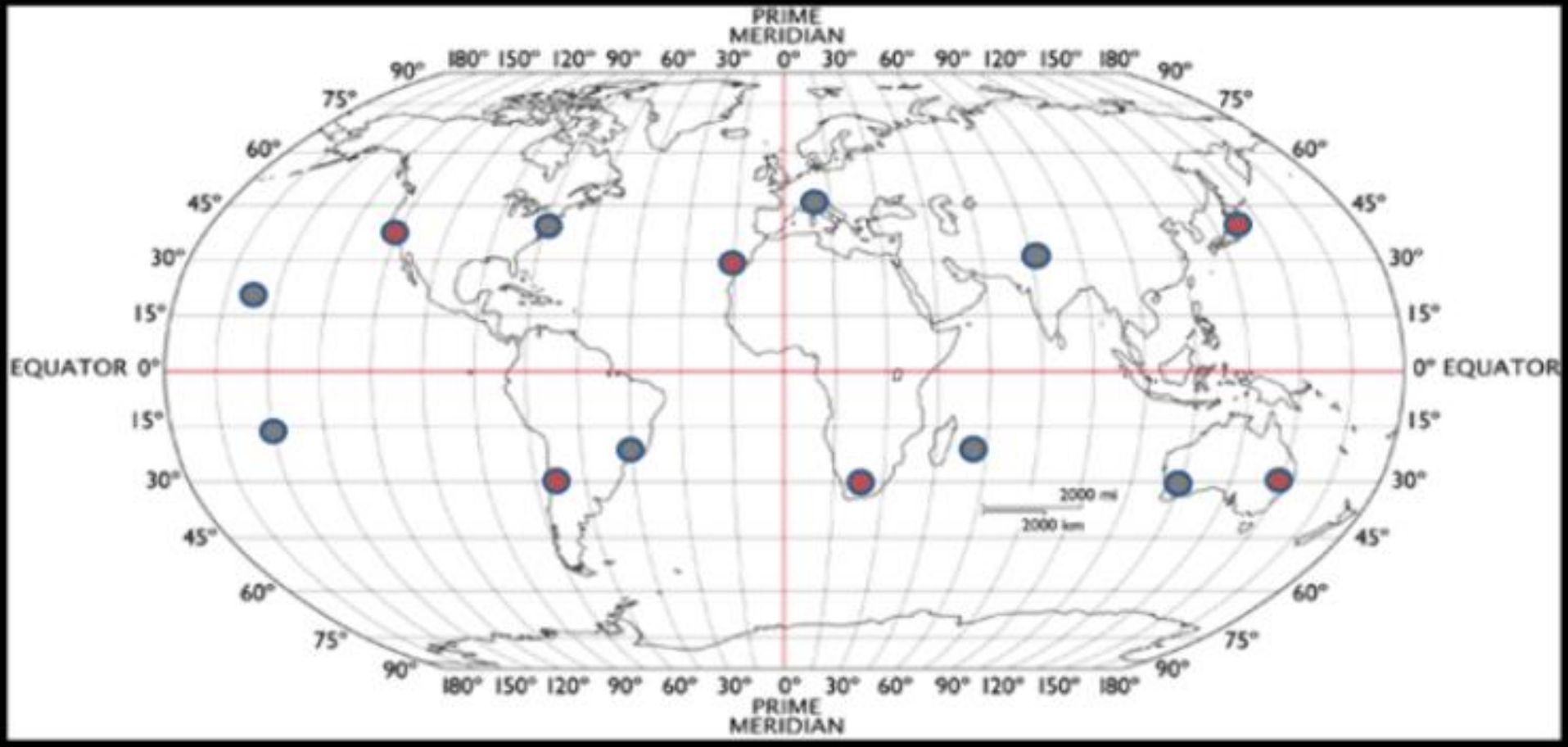
Shelley Wright & team

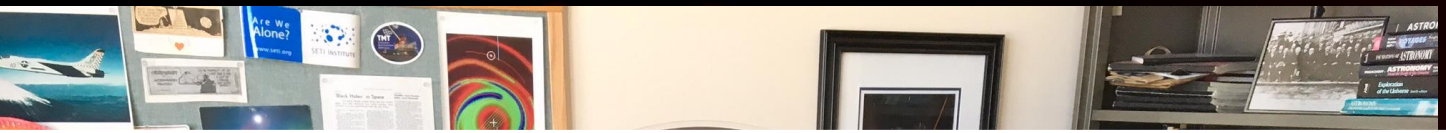
Join the first project ever to scan the *whole sky all the time* for laser flashes from an extraterrestrial civilization!

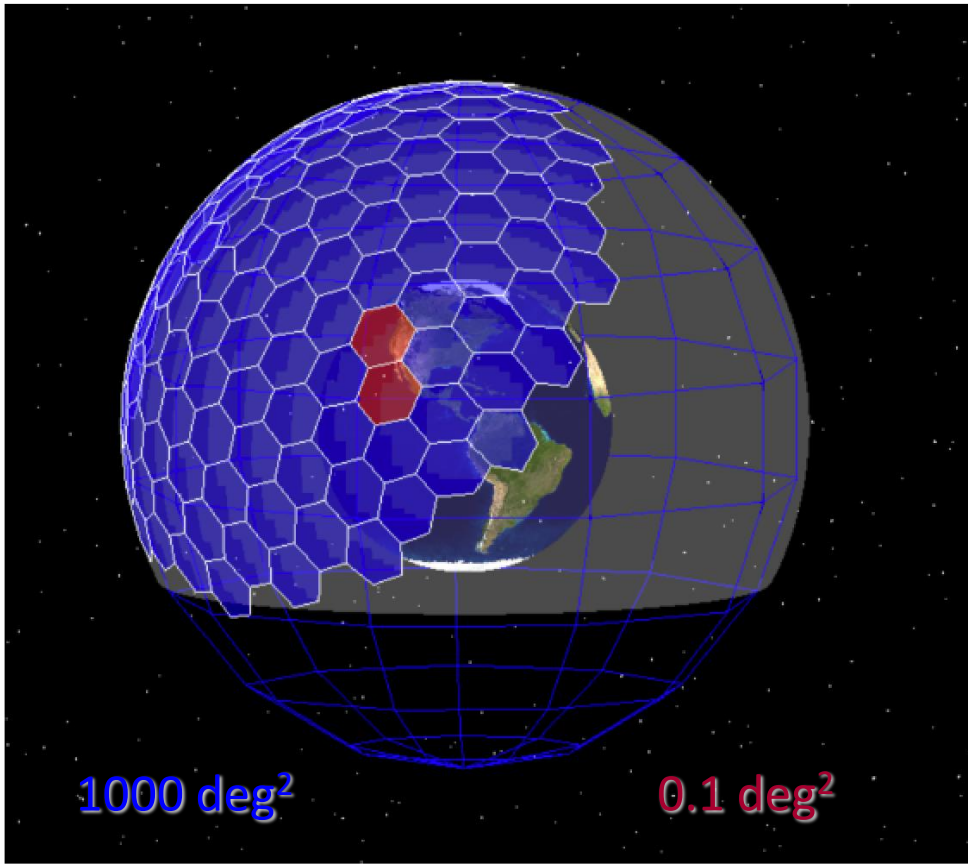
LASER SETI

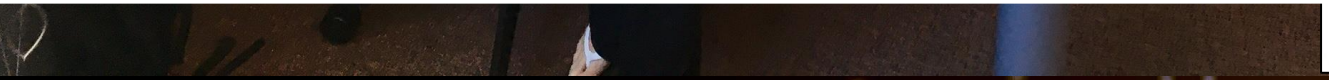
Learn more at laserseti.org

SETI INSTITUTE


PRIME
MERIDIAN
180° 150° 120° 90° 60° 30° 0° 30° 60° 90° 120° 150° 180°
90°
75°
60°
45°
30°
15°
EQUATOR 0°
0° EQUATOR
2000 mi
2000 km
PRIME
MERIDIAN

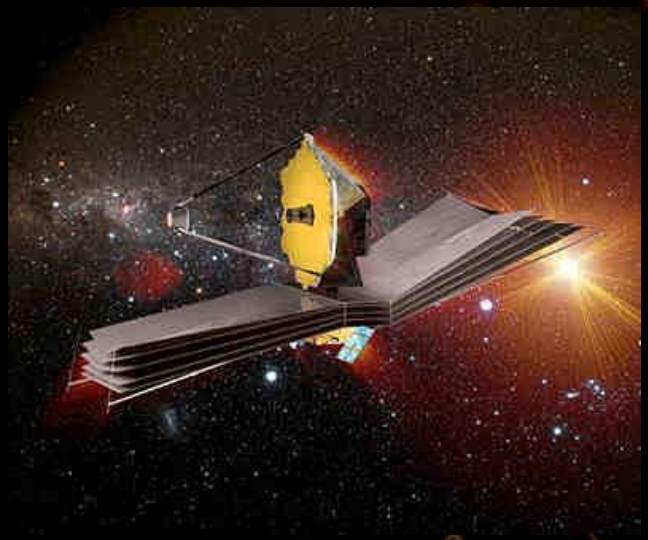

Are We Alone?
SETI INSTITUTE
TNT
ASTRONOMY


1000 deg²
0.1 deg²

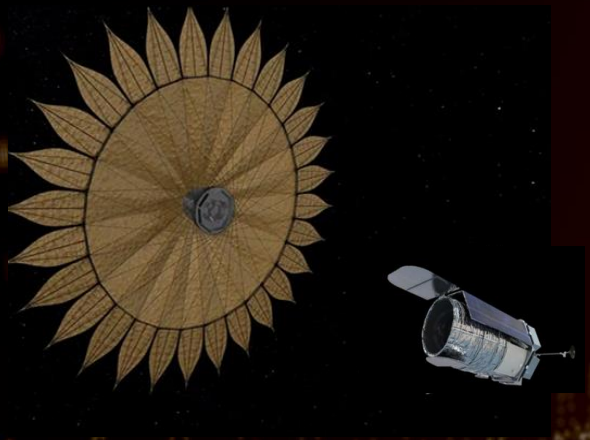



East
West

THE FUTURE



JWST and then ???

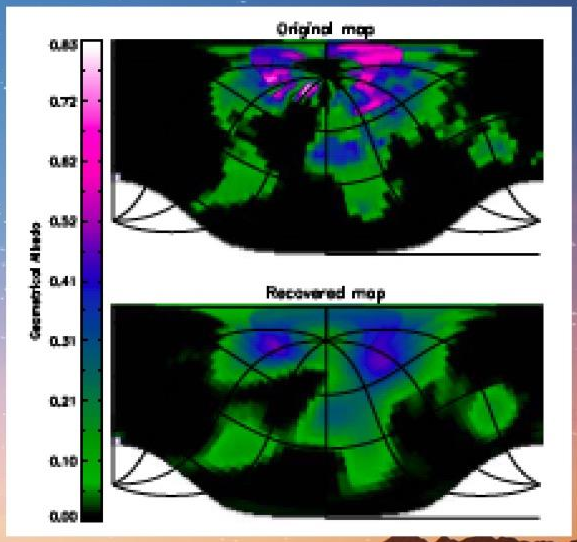


HabEx

LUVOIR

IMAGING / BIOSIGNATURES

ExoLife Finder

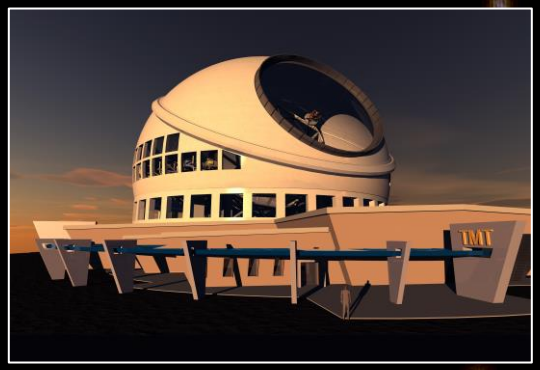


If Proxima b were an Earth twin, this is what ELF would see.

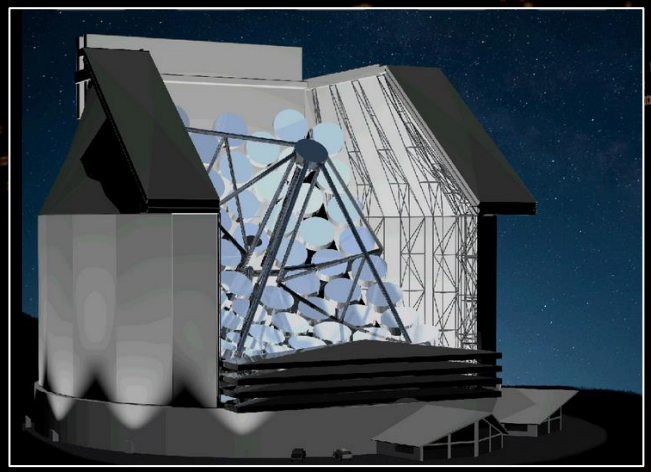
And we'd know if anything lives there!

THE FUTURE

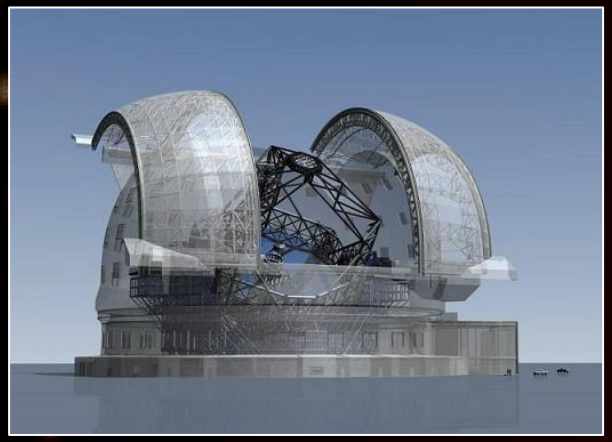
TMT



GMT

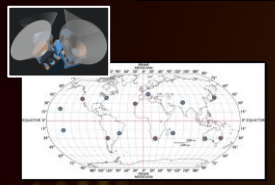


Colossus



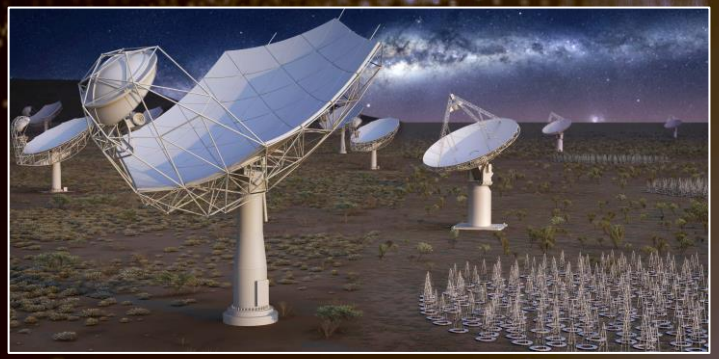
E-ELT

LSST



Laser SETI

FAST



SKA

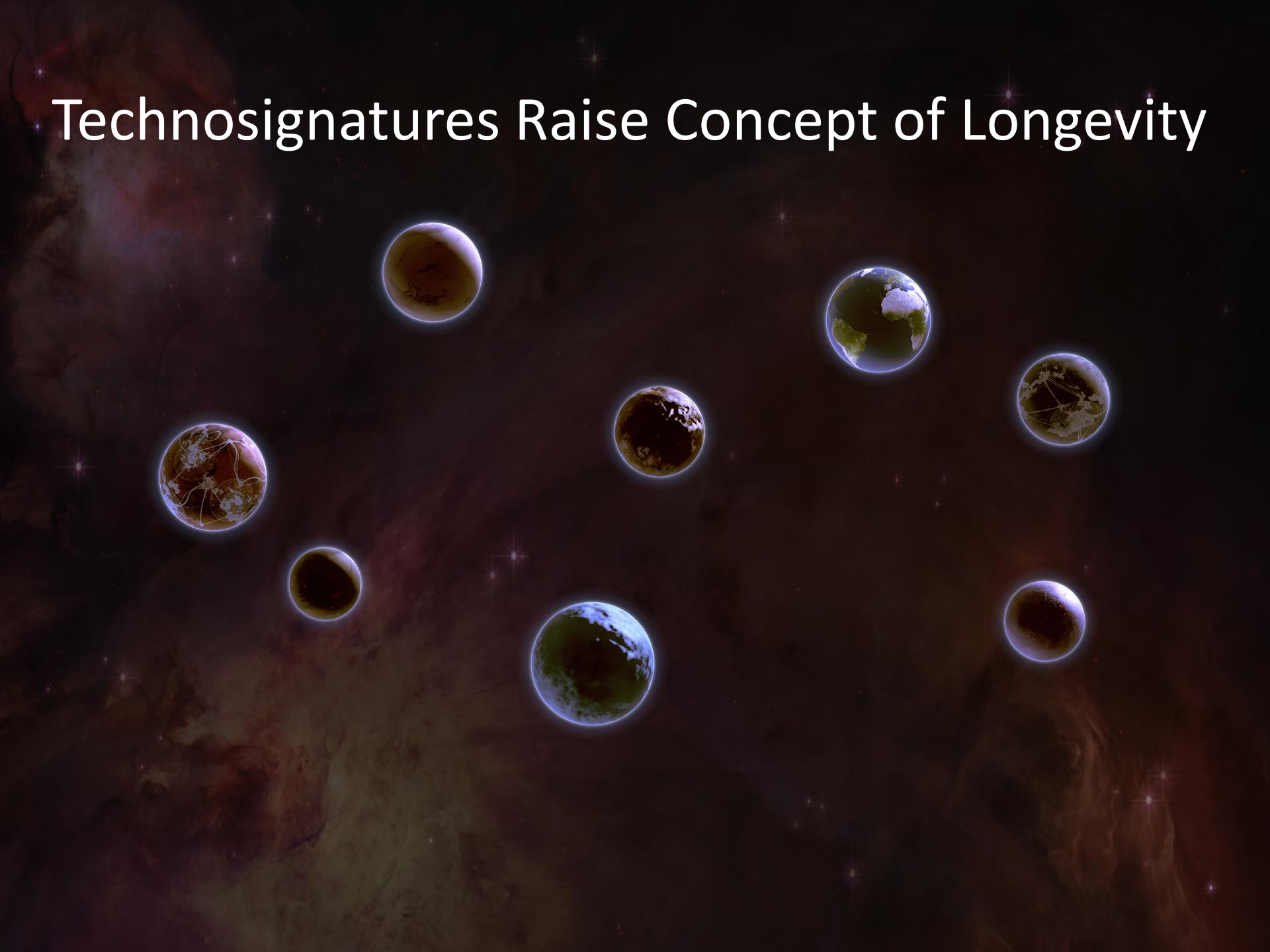
SETI/OSETI

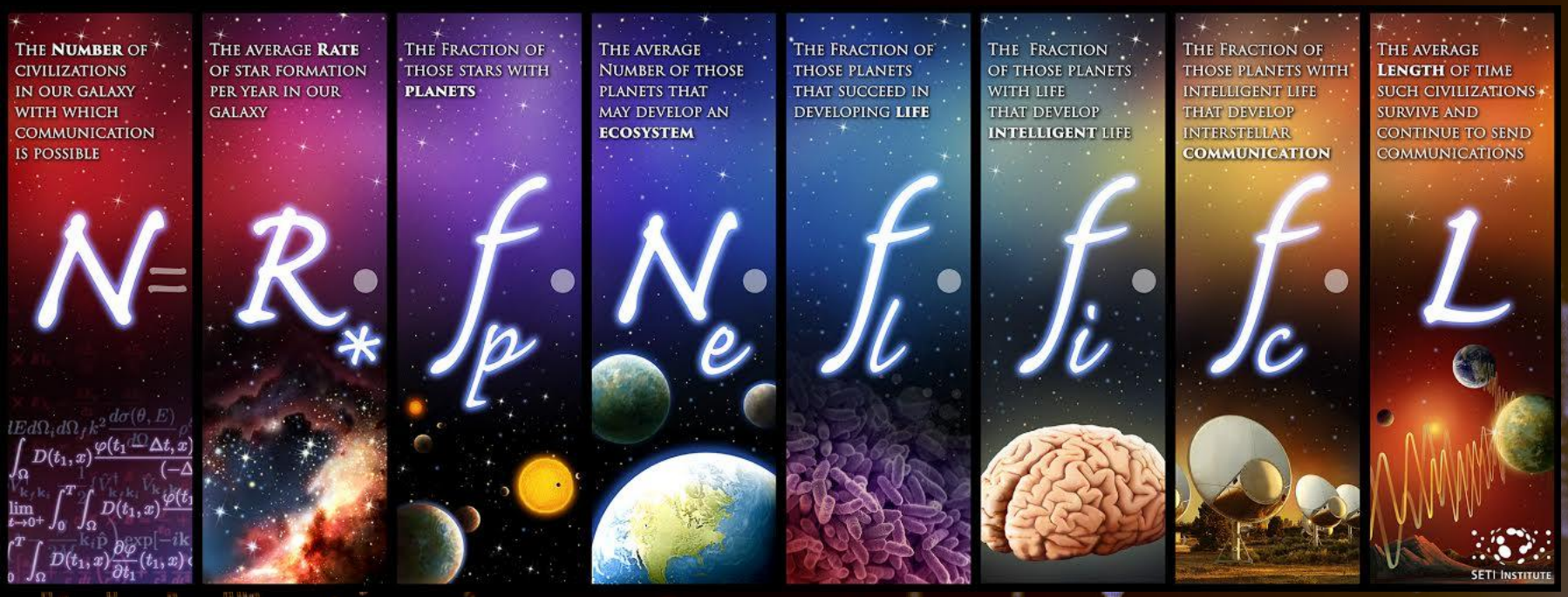
On Dealing With A Discovery

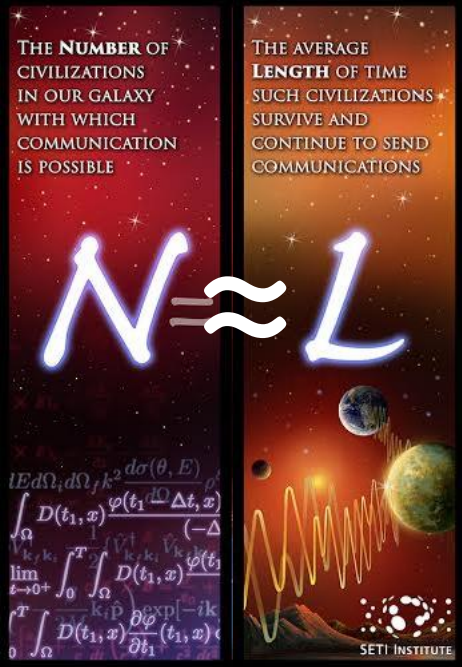
- Confirm at Discovery Site or with team
- Get Independent confirmation if possible (quietly)
- Submit template paper
- Calculate a Rio Scale 2.0* preliminary rating
- Send IAU Telegram
  - All observatories can then attempt other observations
  - Continuous time monitoring (if appropriate)
  - Have thus educated cadre of local experts for media
- Tell the world

*The Rio scale assigns a score to claimed detections of technosignatures to characterise their significance in a manner easily digestible by the general public. Depends on nature of evidence and credibility of detection

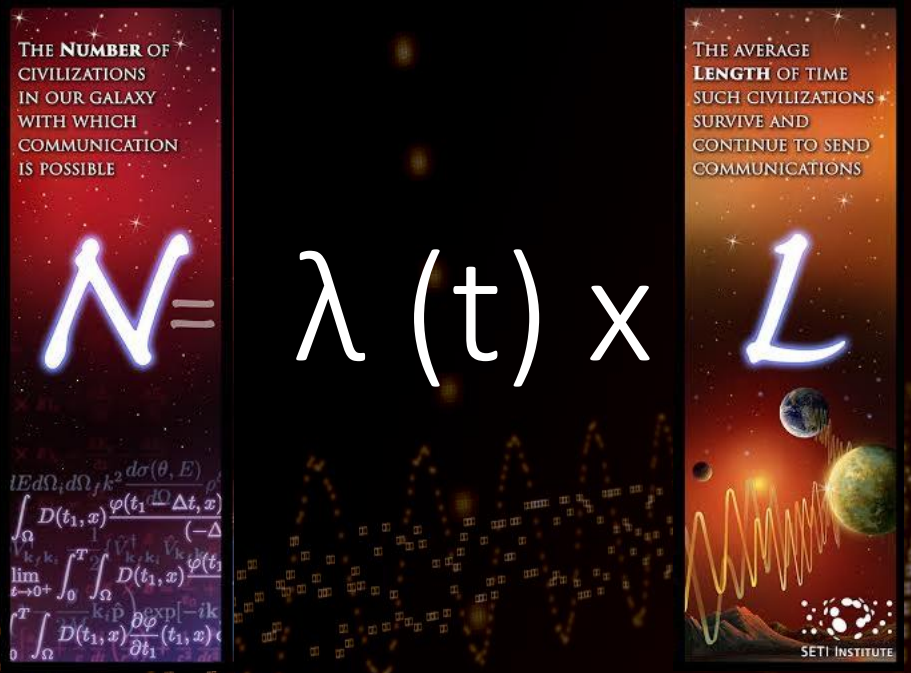
Technosignatures Raise Concept of Longevity




THE NUMBER OF CIVILIZATIONS IN OUR GALAXY WITH WHICH COMMUNICATION IS POSSIBLE
N =
THE AVERAGE RATE OF STAR FORMATION PER YEAR IN OUR GALAXY
R*
THE FRACTION OF THOSE STARS WITH PLANETS
fp
THE AVERAGE NUMBER OF THOSE PLANETS THAT MAY DEVELOP AN ECOSYSTEM
Ne
THE FRACTION OF THOSE PLANETS THAT SUCCEED IN DEVELOPING LIFE
fl
THE FRACTION OF THOSE PLANETS WITH LIFE THAT DEVELOP INTELLIGENT LIFE
fi
THE FRACTION OF THOSE PLANETS WITH INTELLIGENT LIFE THAT DEVELOP INTERSTELLAR COMMUNICATION
fc
THE AVERAGE LENGTH OF TIME SUCH CIVILIZATIONS SURVIVE AND CONTINUE TO SEND COMMUNICATIONS
L
SETI INSTITUTE


THE NUMBER OF CIVILIZATIONS IN OUR GALAXY WITH WHICH COMMUNICATION IS POSSIBLE
N≈L
THE AVERAGE LENGTH OF TIME SUCH CIVILIZATIONS SURVIVE AND CONTINUE TO SEND COMMUNICATIONS
SETI INSTITUTE

Nathalie Cabrol has suggested that λ (t) is an excellent opportunity for forming a Virtual, cross-disciplinary Institute to refine search strategy for technosignatures.



Balbi, A. (2017) The Impact of the Temporal Distribution of Communicating Civilizations on their Detectability. Submitted to Astrobiology.

On a finite world, a cosmic perspective isn't a luxury; it is a necessity.

Caleb Scharf (2014)

Earthrise/ William Anders/ Apollo 8