



The 21st Century: The Century of Biology on Earth and Beyond

Coloquios Paco Yndurain

Universidad Autonoma De Madrid

September 26, 2018

Dr. Jill Tarter – Emeritus Chair for SETI Research, SETI Institute

Life Beyond Earth

- Discover it
 - In situ biomarkers
 - Remote biosignatures



Life Beyond Earth

- Discover it
 - In situ biomarkers
 - Remote biosignatures
- Communicate with it
 - Technosignatures
 - Serendipitous observations



Life Beyond Earth

- Discover it
 - In situ biomarkers
 - Remote biosignatures
- Communicate with it
 - Technosignatures
 - Serendipitous observations
- Export it
 - Moon, Mars, Asteroids
 - Breakthrough StarShot, 100 Year Starship Study, Icarus





“...strong indications of life beyond Earth in a decade and definitive evidence within 10 to 20 years.”

Ellen Stofan
former NASA Chief Scientist

The Saline Slopes
of
MARS

“...we are currently on a
journey to Mars”

John Grunsfeld
AA NASA's SMD (ret'd)

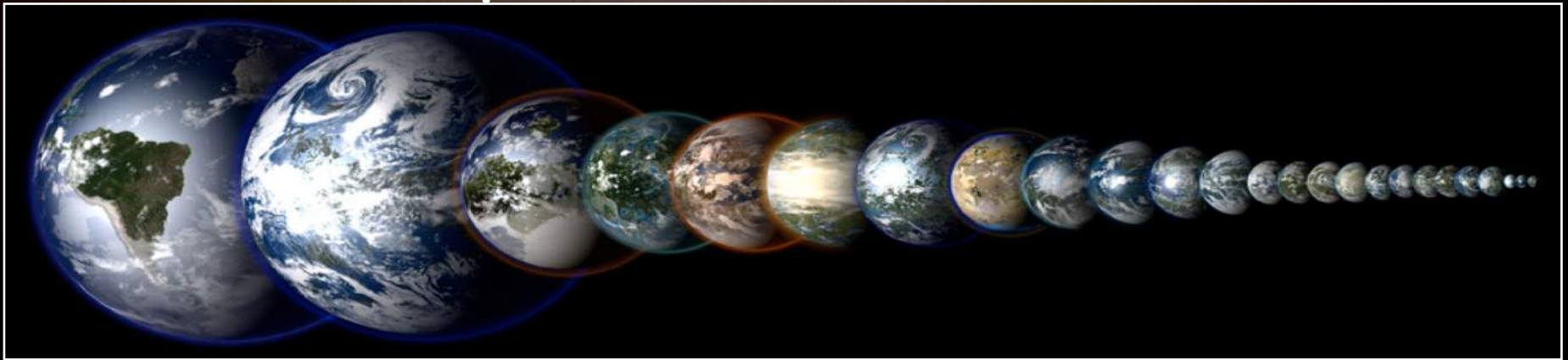
GAME CHANGERS

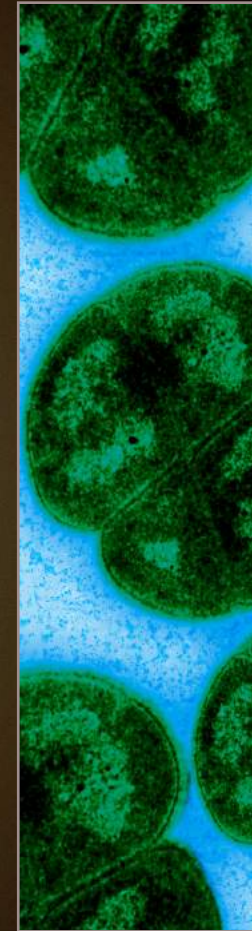
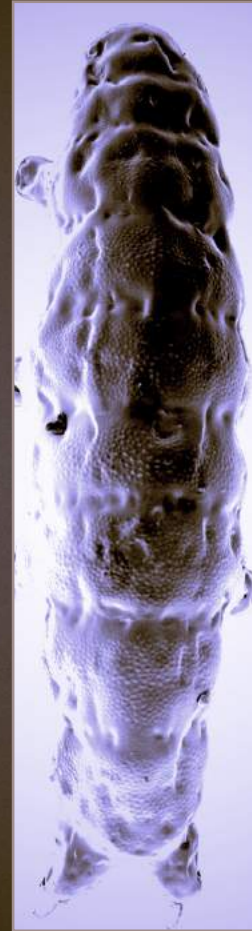
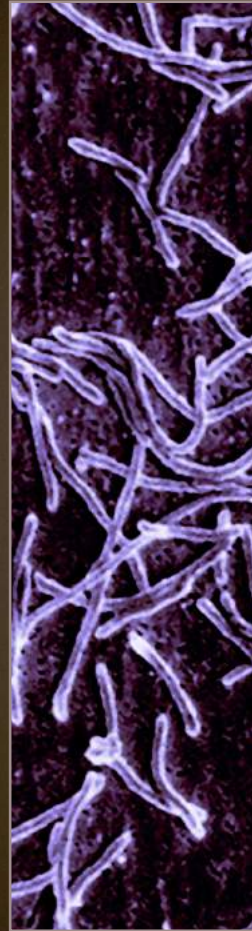
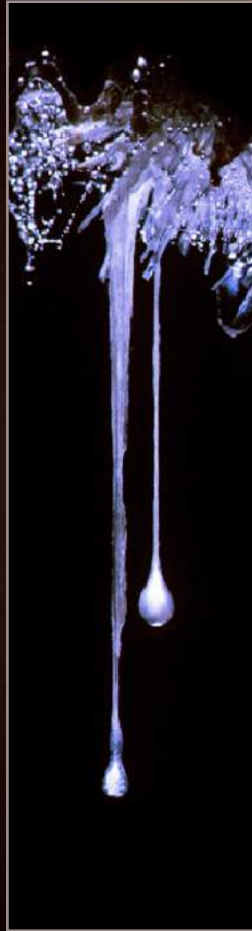
FROM THE 20TH CENTURY



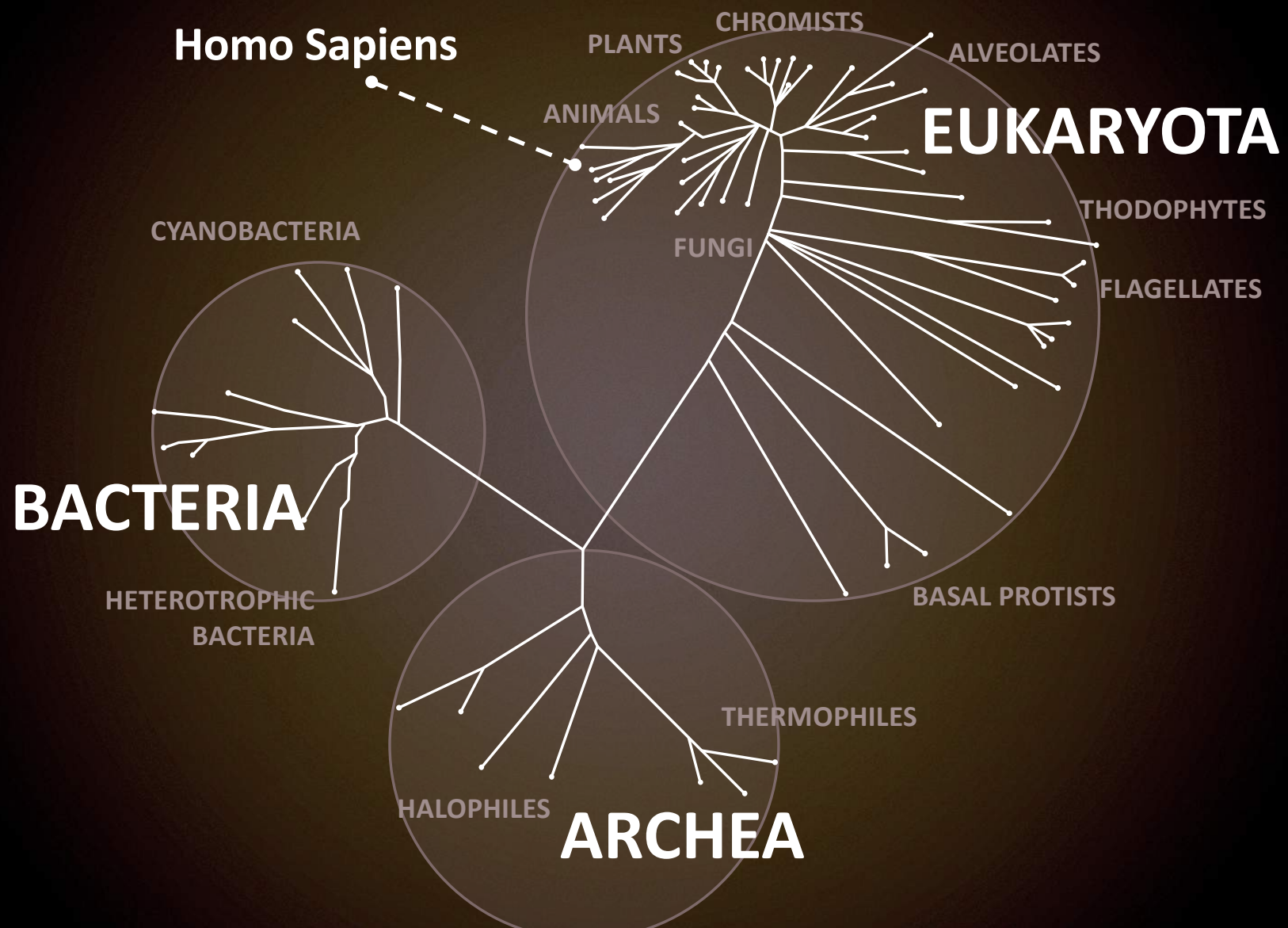
Extremophiles

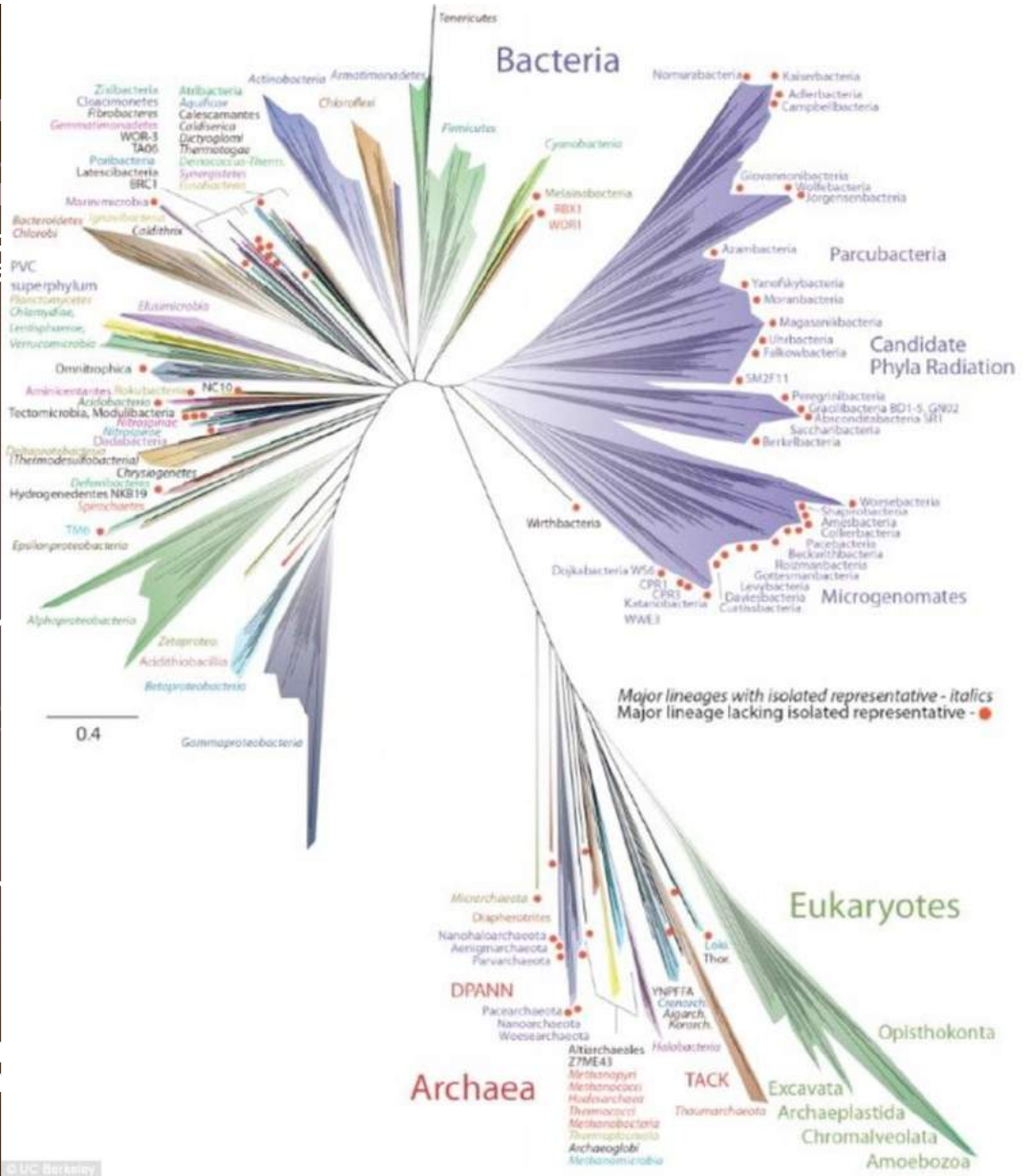
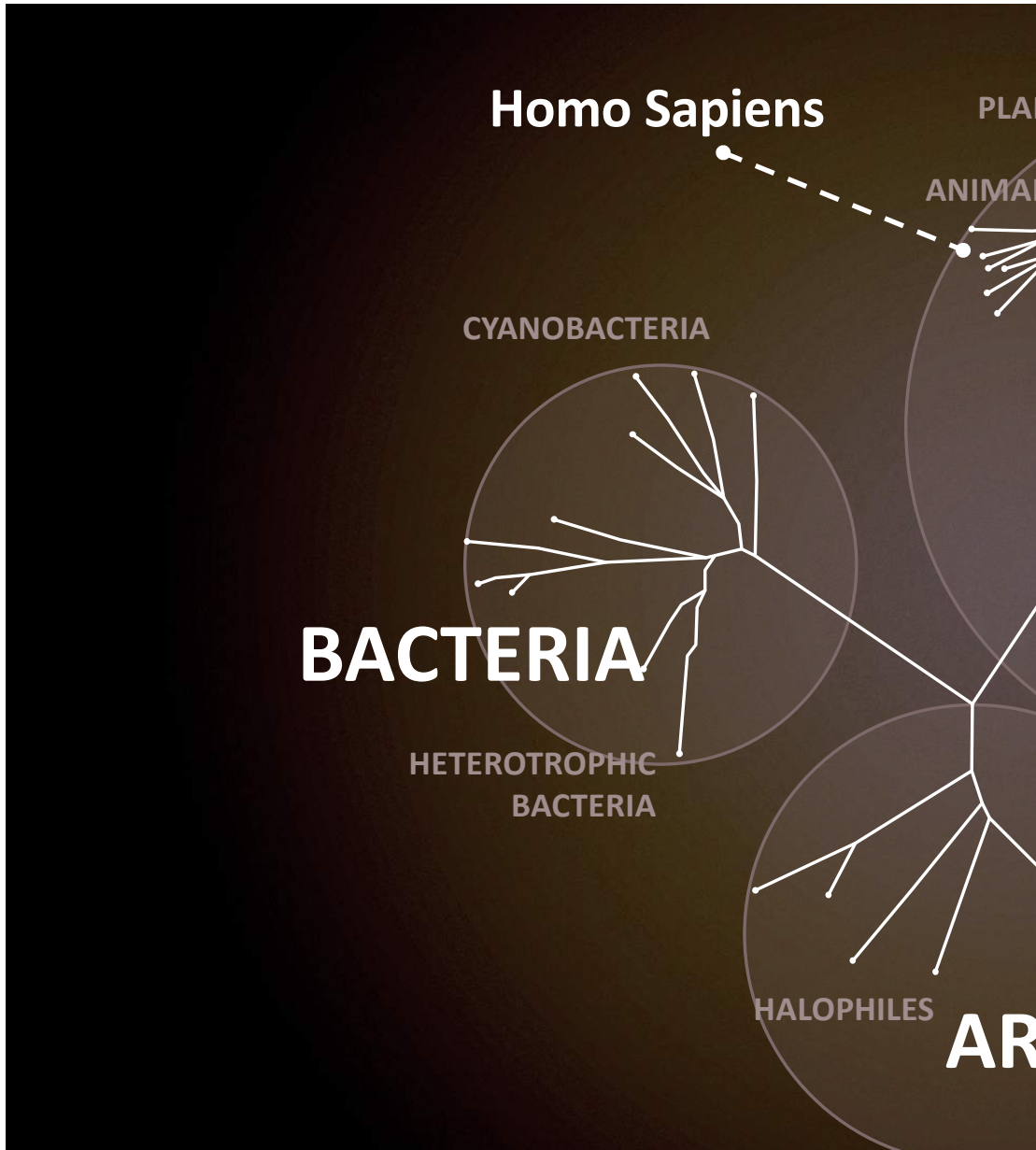
Exoplanets and Exomoons



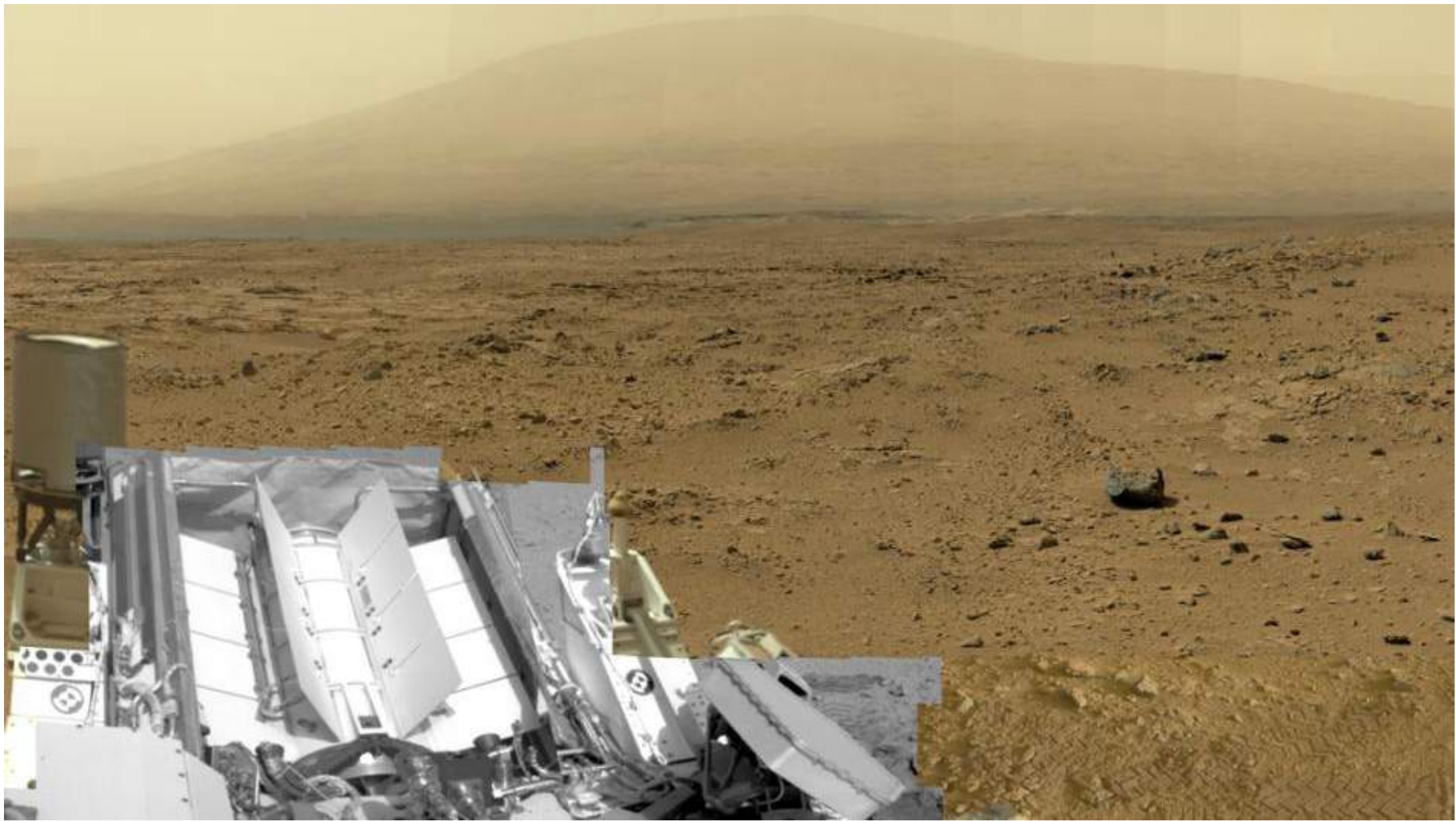


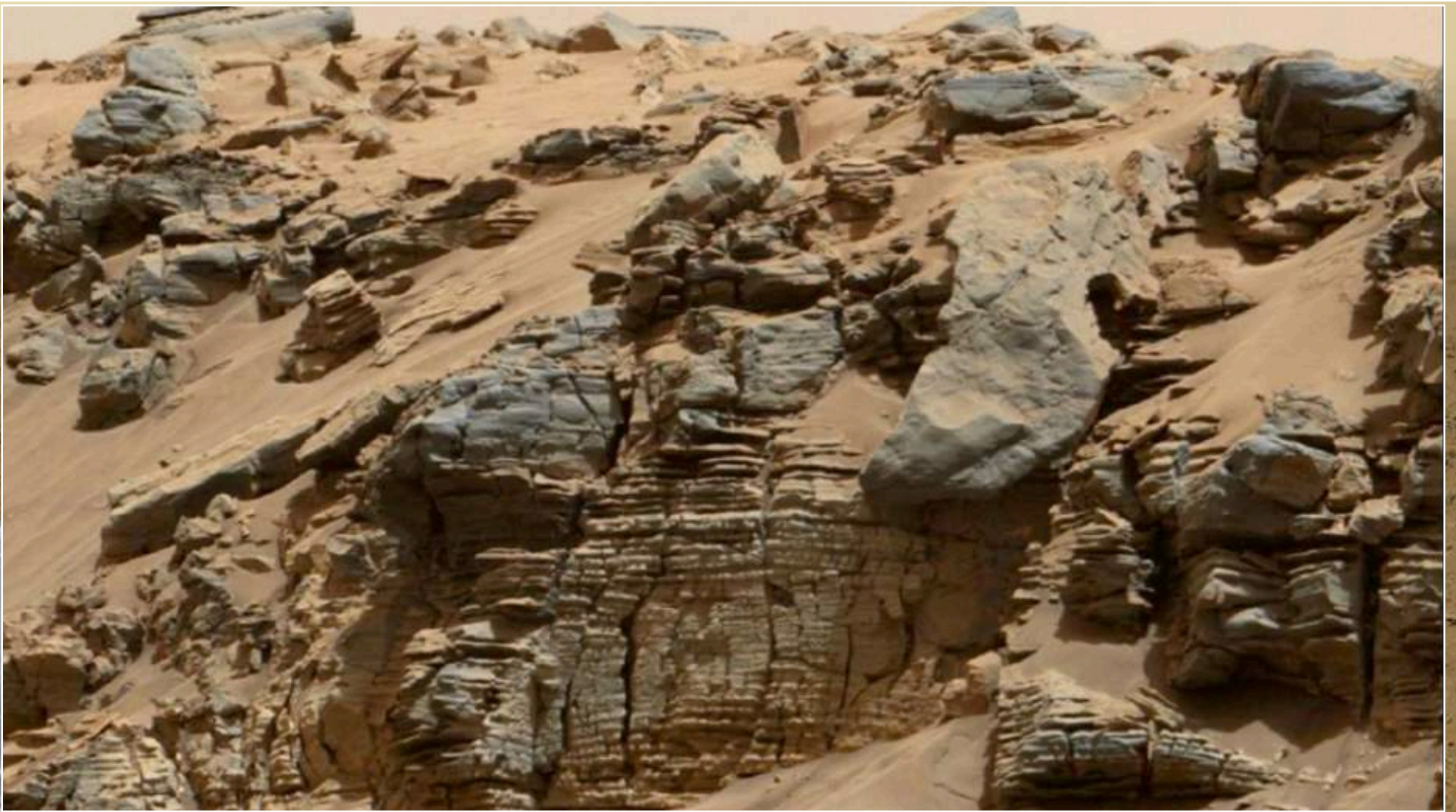
"SNOTTITE" IMAGE COURTESY OF DR. KENNETH INGHAM / TARDIGRADE IMAGE COURTESY OF DAIKI HORIKAWA, NASA AMES RESEARCH CENTER

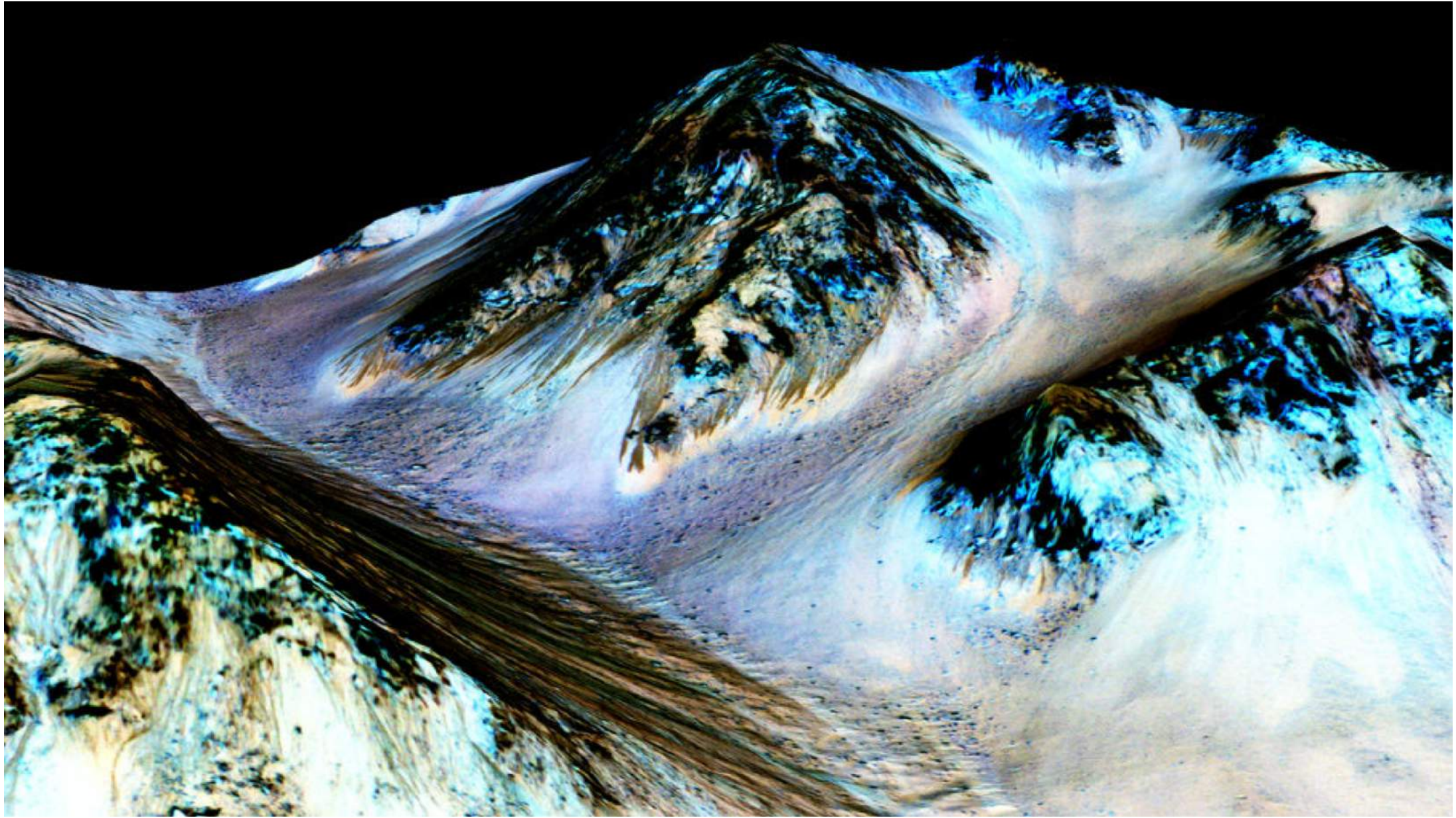


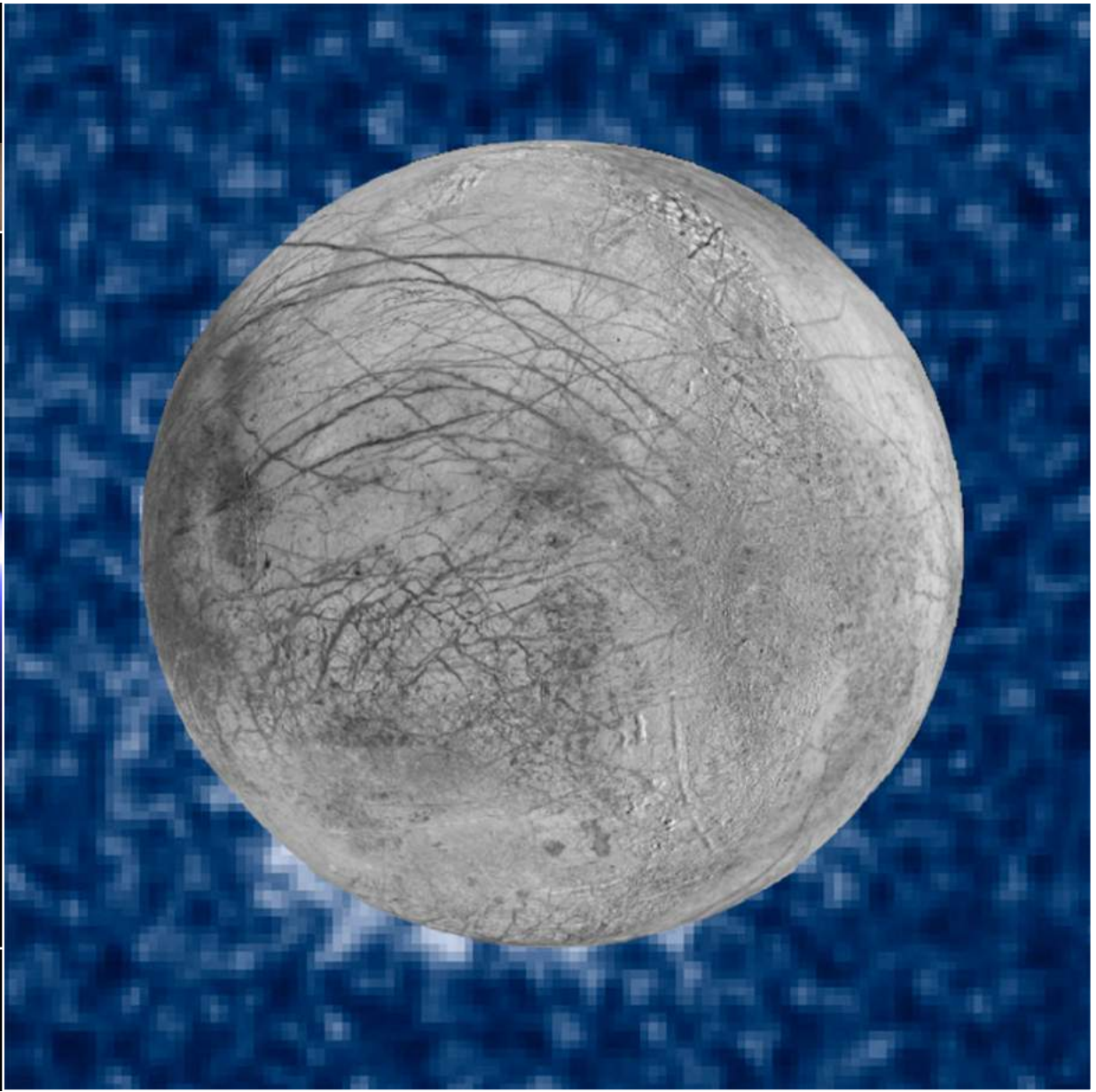
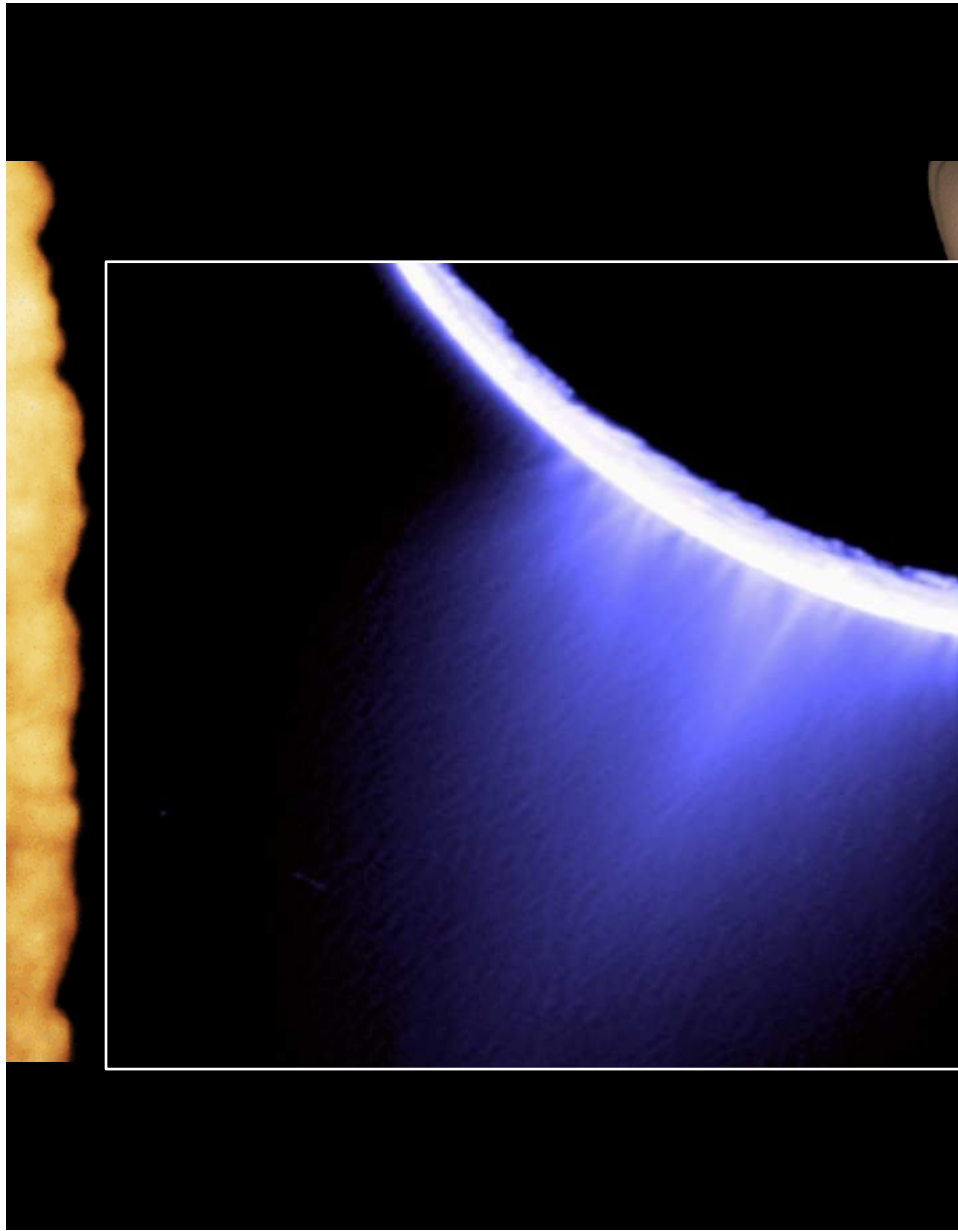


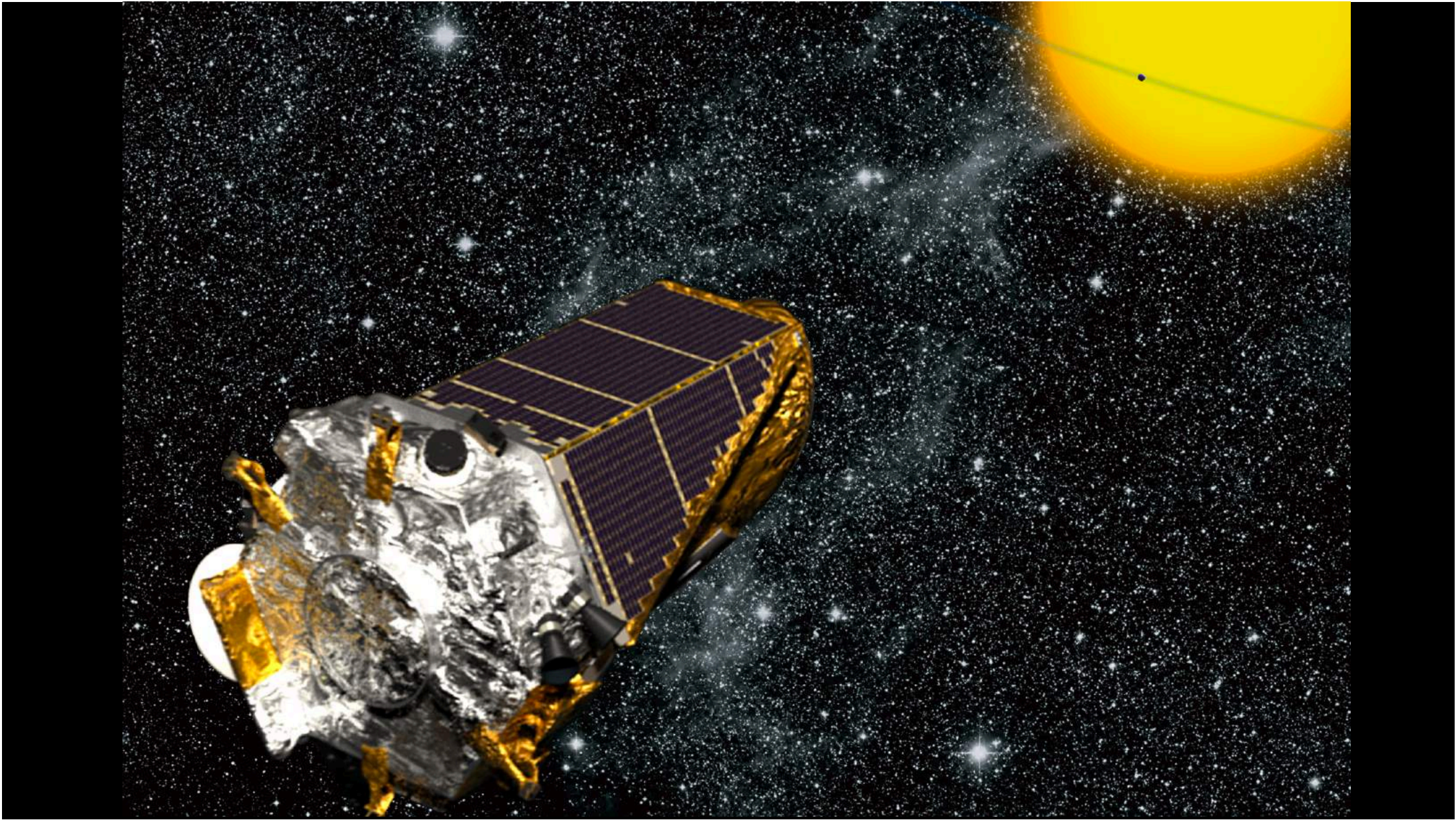
© UC Berkeley

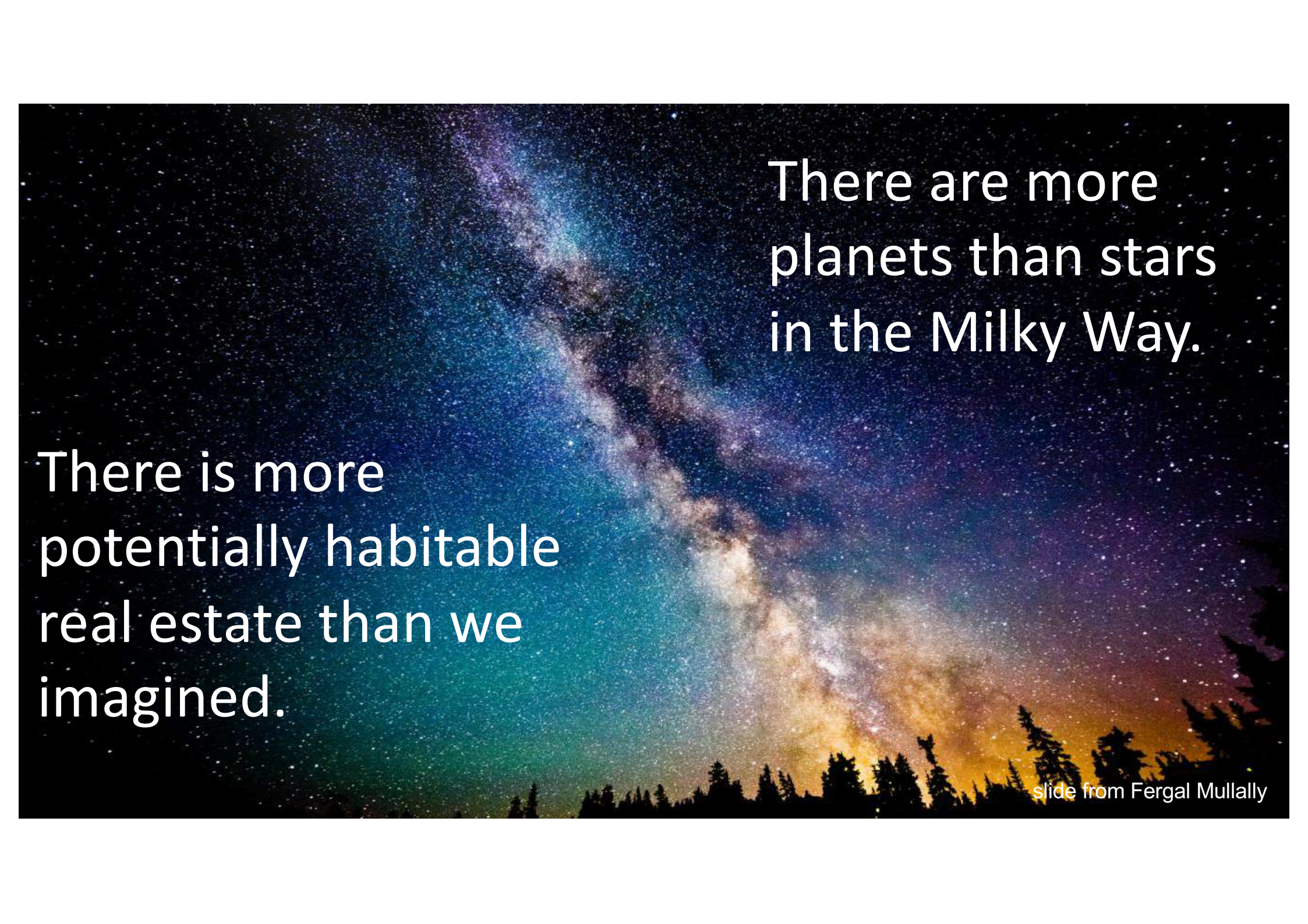










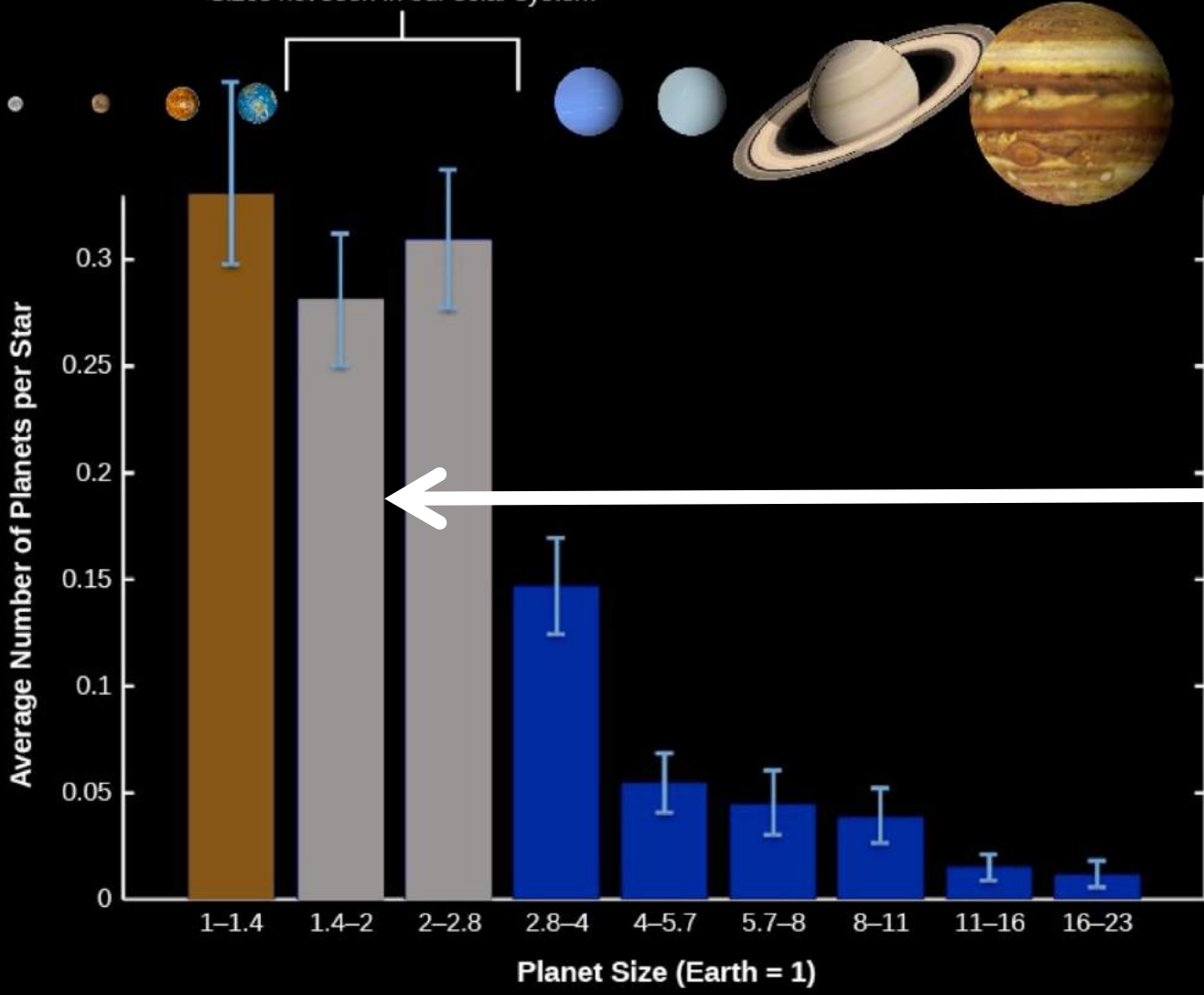


There are more
planets than stars
in the Milky Way.

There is more
potentially habitable
real estate than we
imagined.

slide from Fergal Mullally

Sizes not seen in our solar system

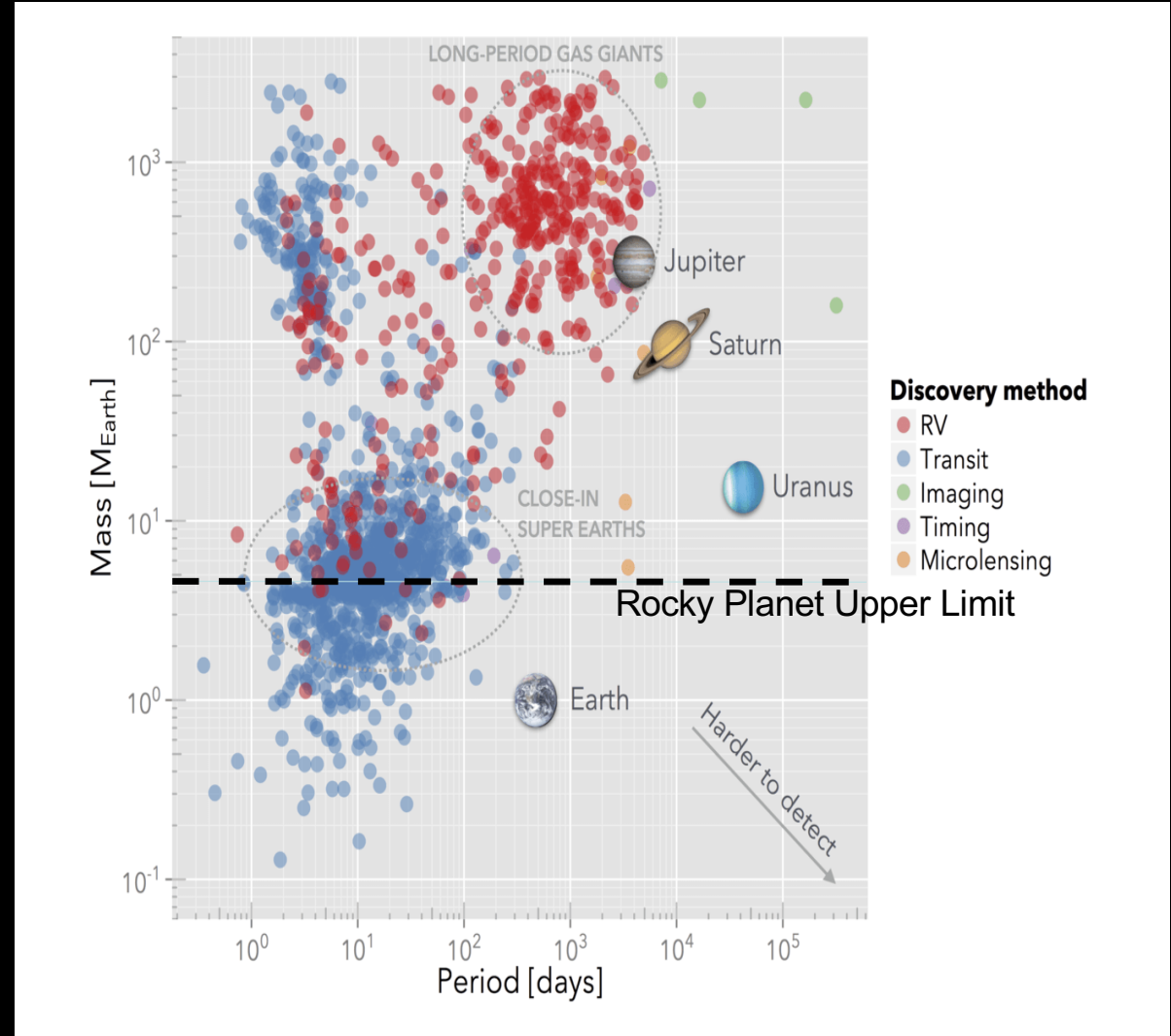


SUPER EARTH'S
and
MINI-NEPTUNES

Images by Stefano Meschiari



Period
Semi-major axis
Radius
or Mass or both \Rightarrow Density



SEVEN EXOPLANETS ABOVE THE FOLD

"All the News That's Fit to Print"

The New York Times

Late Edition
Today, patchy morning fog, partly sunny, warm, high 64. Tonight, mostly cloudy, mild, low 52. Tomorrow, clouds and sunshine, showers, high 66. Weather map is on Page B9.

VOL. CLXVI ... No. 57,517 © 2017 The New York Times Company NEW YORK, THURSDAY, FEBRUARY 23, 2017 \$2.50



JPL, GAZETHOUSE

A rendering of newly discovered Earth-size planets orbiting a dwarf star named Trappist-1 about 40 light-years from Earth. Some of them could have surface water.

TRUMP RESCINDS OBAMA DIRECTIVE ON BATHROOM USE

ENTERING CULTURE WARS

Question of Transgender Rights Splits DeVos and Sessions

This article is by Jeremy W. Peters, Jo Becker and Julie Hirschfeld Davis.

WASHINGTON — President Trump on Wednesday rescinded protections for transgender students that had allowed them to use bathrooms corresponding with their gender identity, overruling his own education secretary and placing his administration firmly in the middle of the culture wars that many Republicans have tried to leave behind.

In a joint letter, the top civil rights officials from the Justice Department and the Education Department rejected the Obama administration's position that nondiscrimination laws require schools to allow transgender students to use the bathrooms of their choice.

That directive, they said, was improperly and arbitrarily devised, "without due regard for the primary role of the states and local school districts in establishing

Circling a Star Not Far Away, 7 Shots at Life

By KENNETH CHANG

Uber's Culture Of Gutsiness Under Review

By MIKE ISAAC

Migrants Hide, Fearing Capture on 'Any Corner'

By VIVIAN YEE

IMMIGRATION A police department worries a crackdown will harm work to fight gangs. PAGE A11

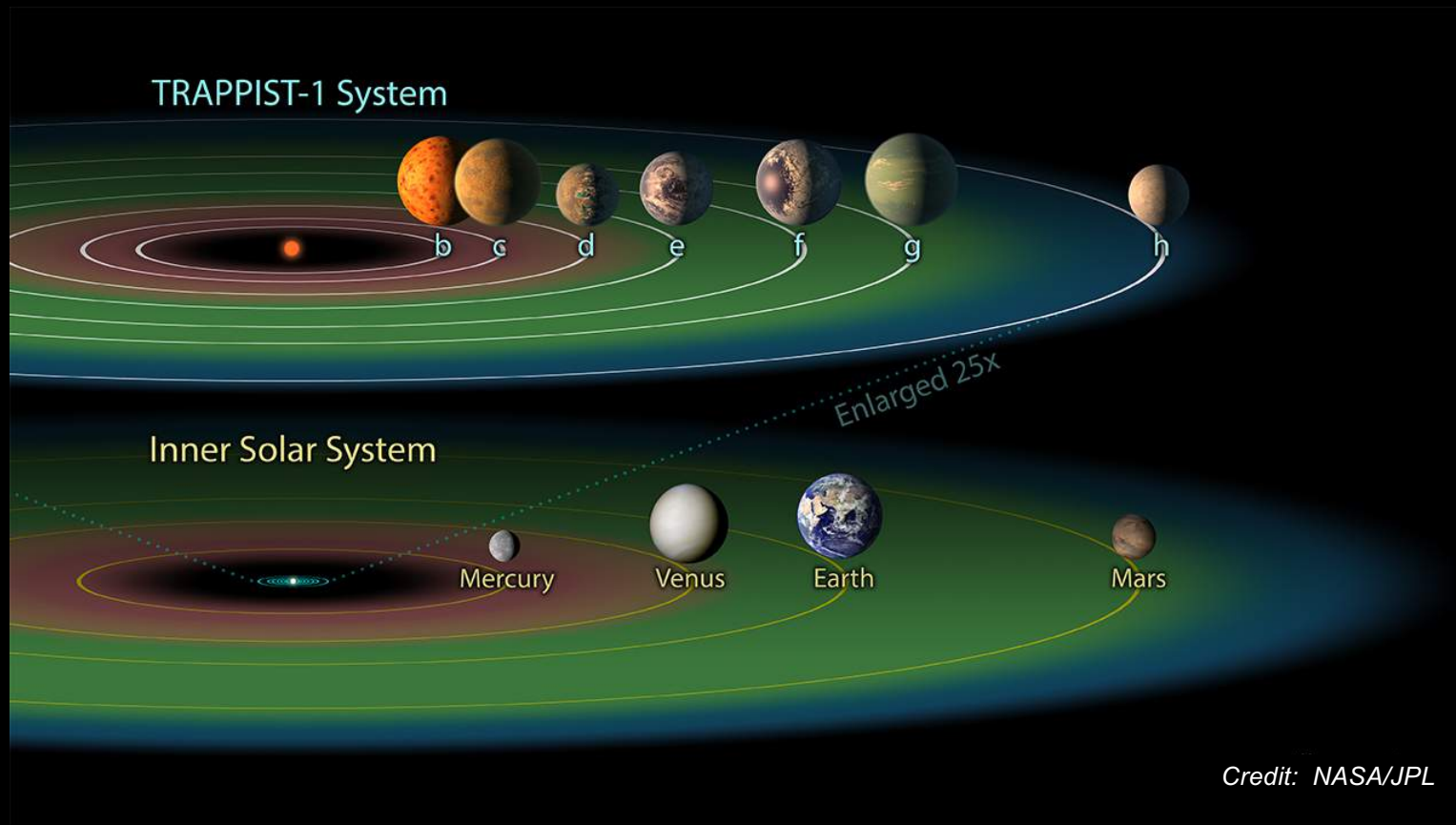
MEXICO The secretary of state pays a visit at a time of rising

duras.

If deportation has always been a threat on paper for the 11 million people living in the country illegally, it rarely imperiled those who did not commit serious crimes. But with the Trump ad-

TRAPPIST-1 DISCOVERY

The Richest Set of Earth-sized Planets Ever Found



HERE and NOW

HERE

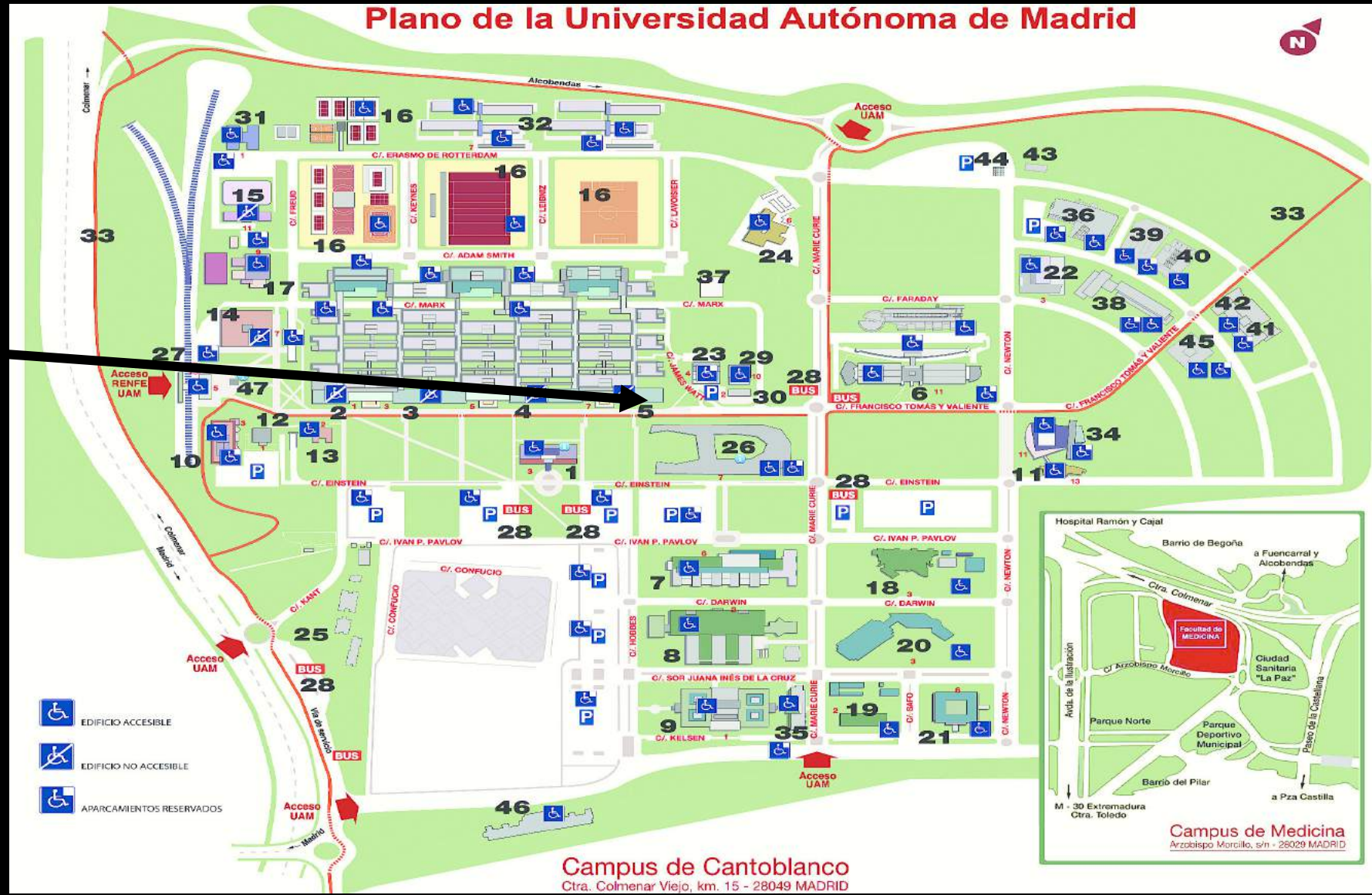


FACULTAD DE CIENCIAS



HERE

Plano de la Universidad Autónoma de Madrid



Campus de Cantoblanco
Ctra. Colmenar Viejo, km. 15 - 28049 MADRID

Campus de Medicina
Arzobispo Morcillo, s/n - 28029 MADRID

HERE



Madrid

Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus

Google Earth

HERE





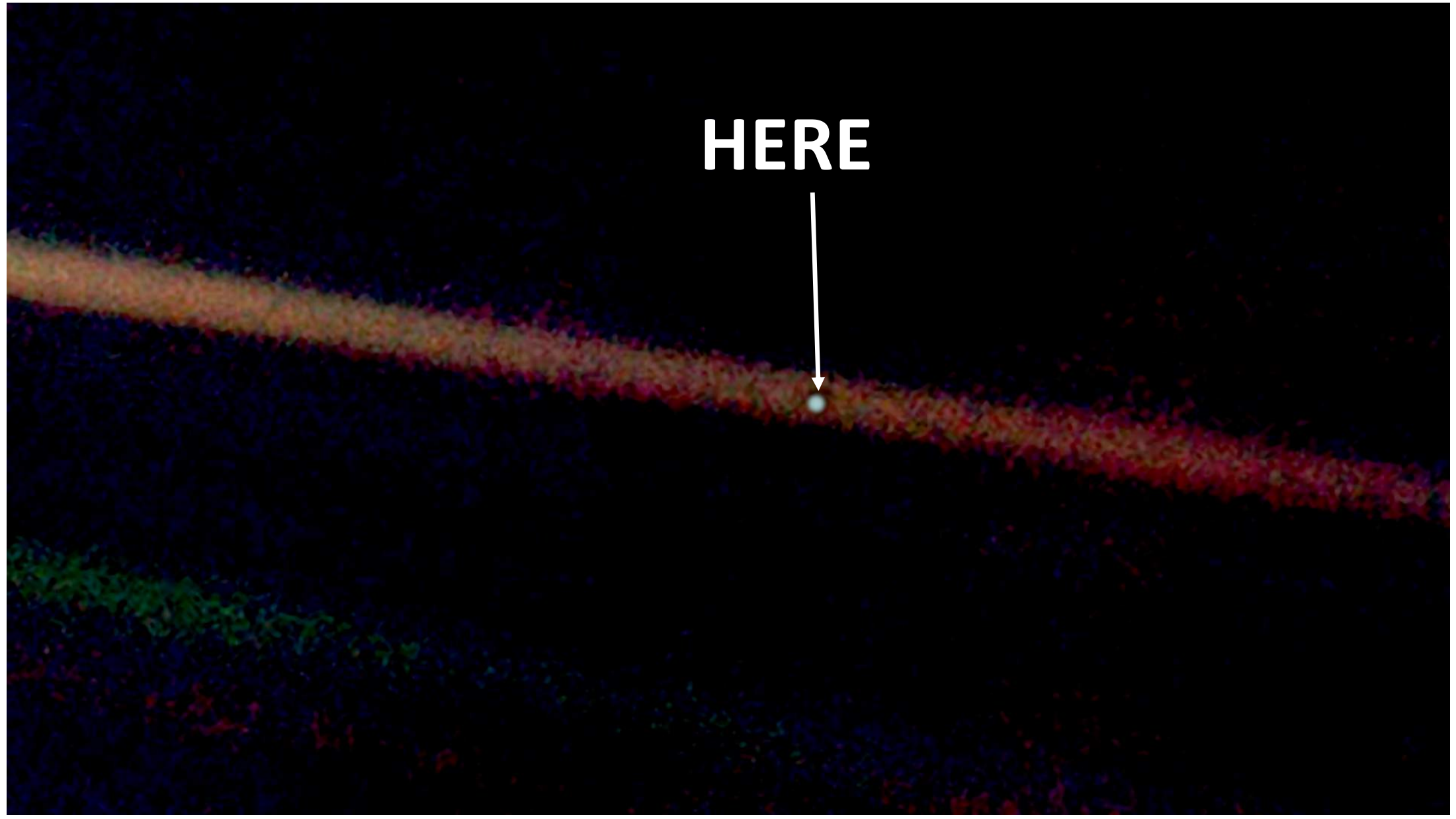
HERE

Earthrise/ William Anders/ Apollo 8

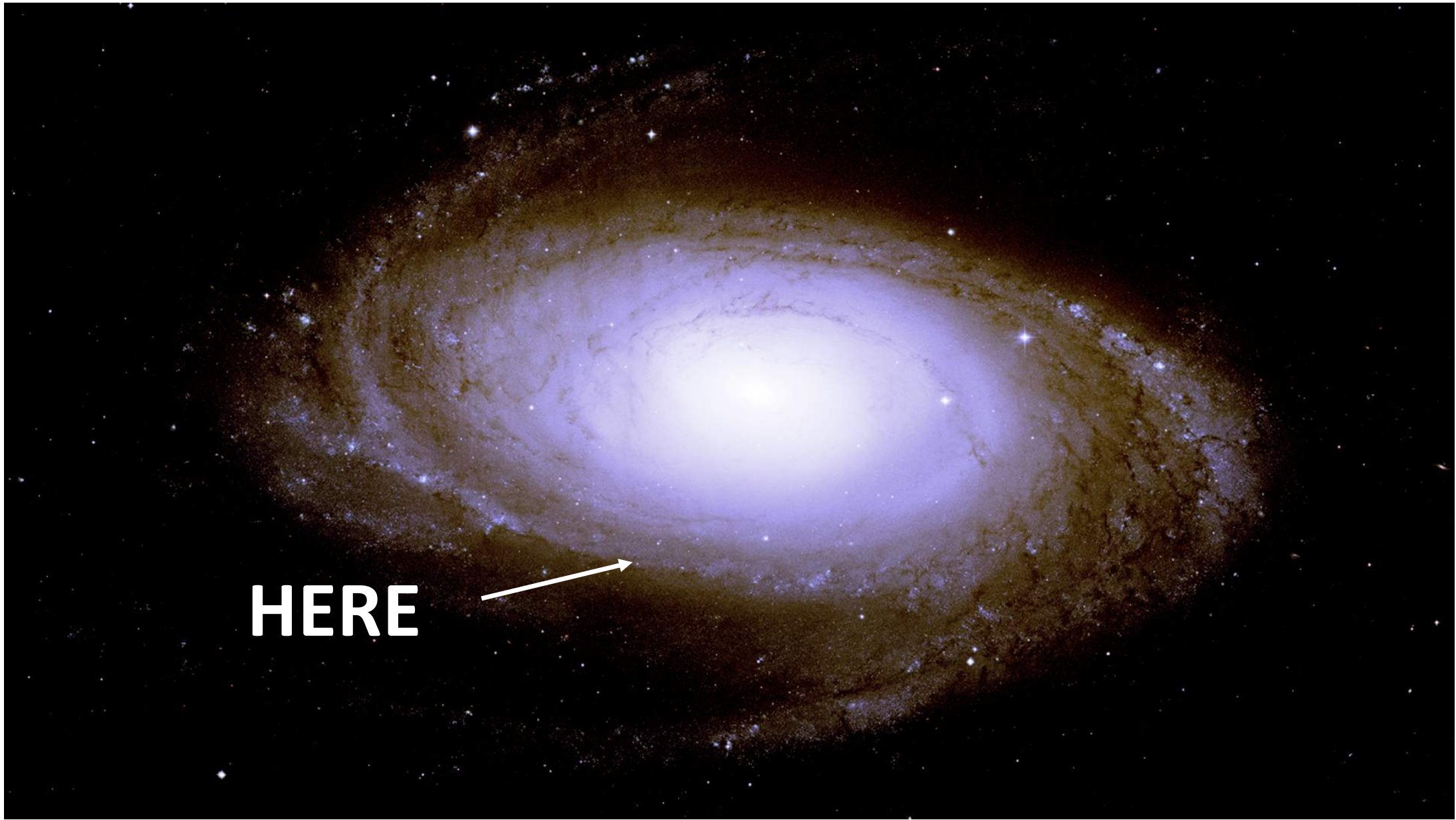
HERE



HERE

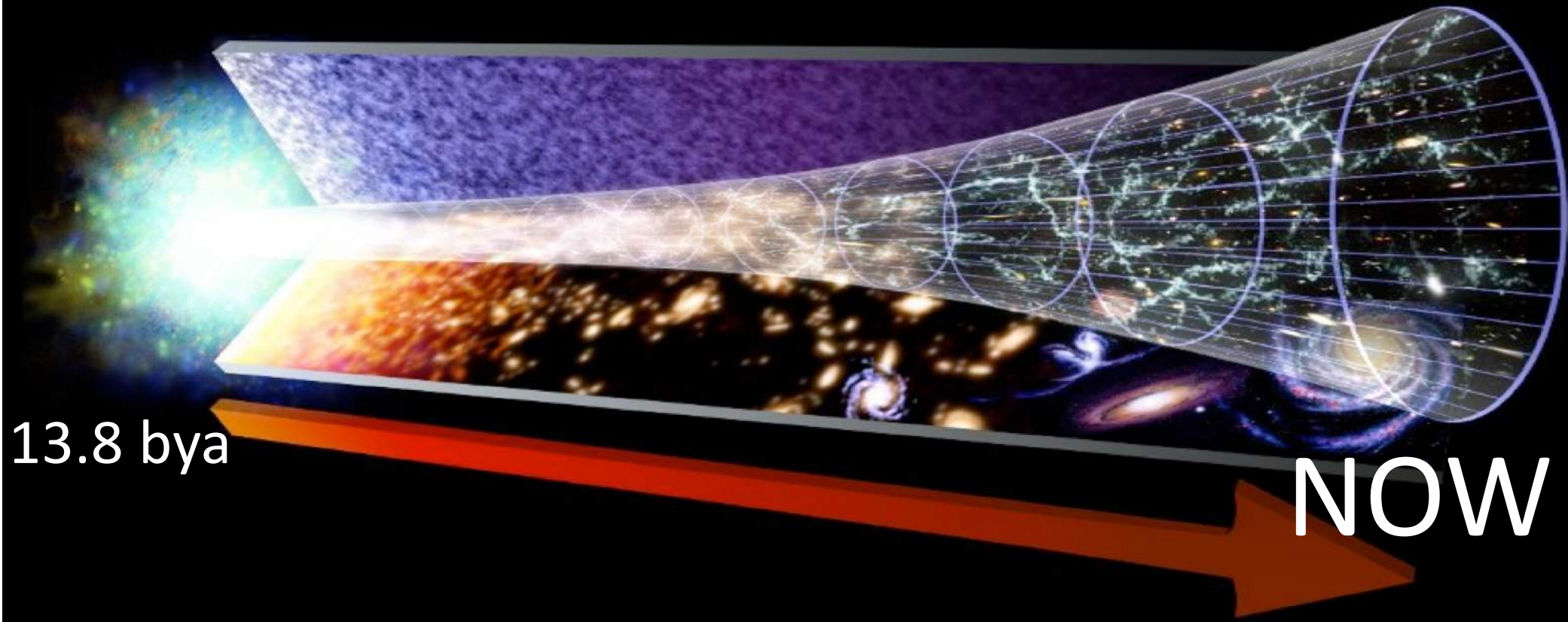


HERE





← **HERE**



13.8 bya

NOW

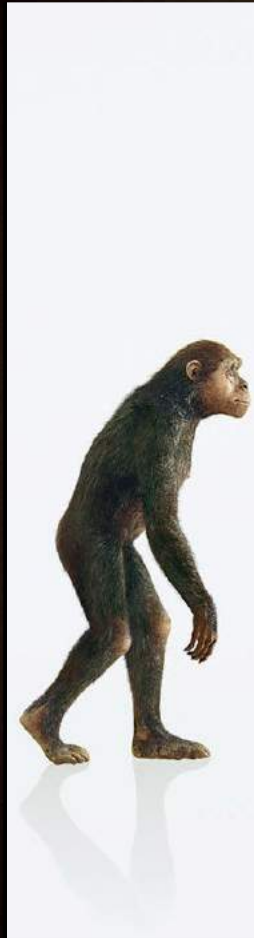
Credit: NASA/GSFC/Dana Berry

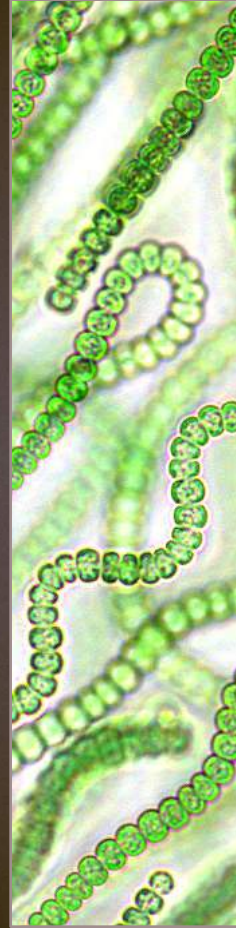
















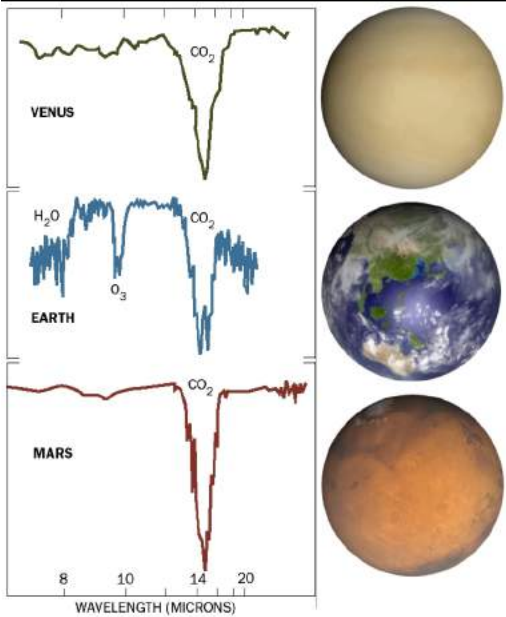
IT TAKES A COSMOS TO MAKE A HUMAN



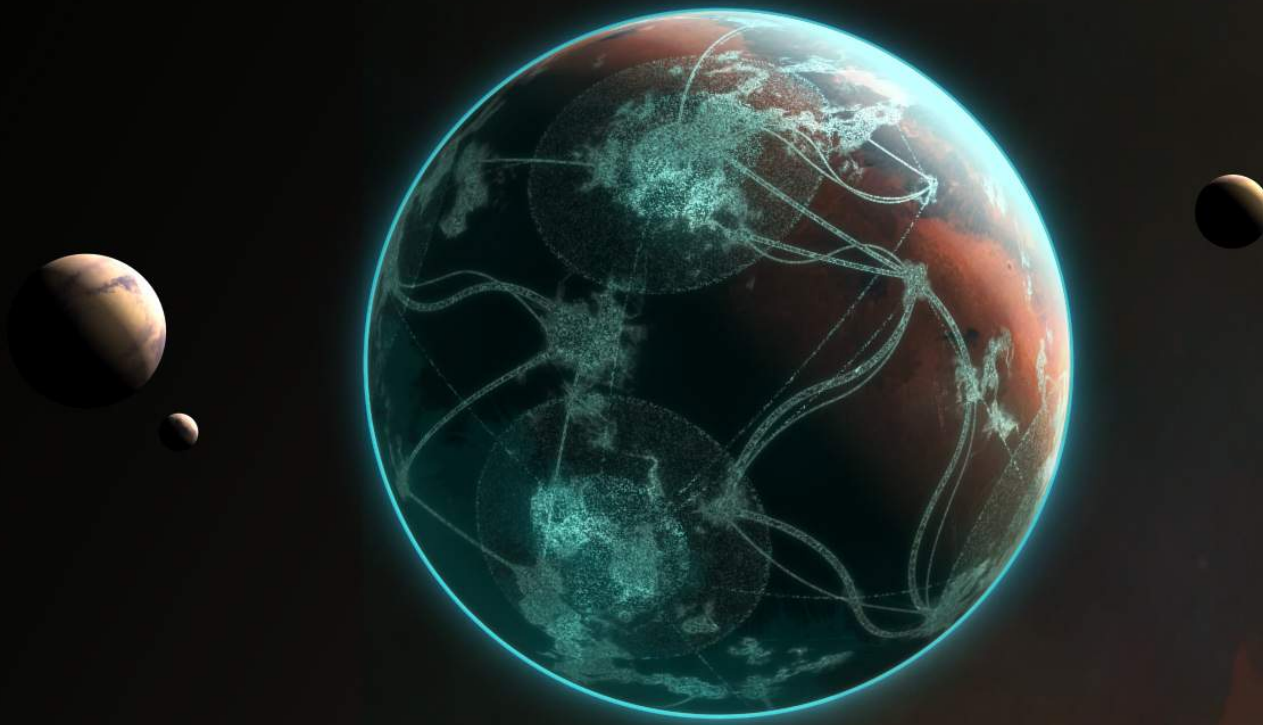


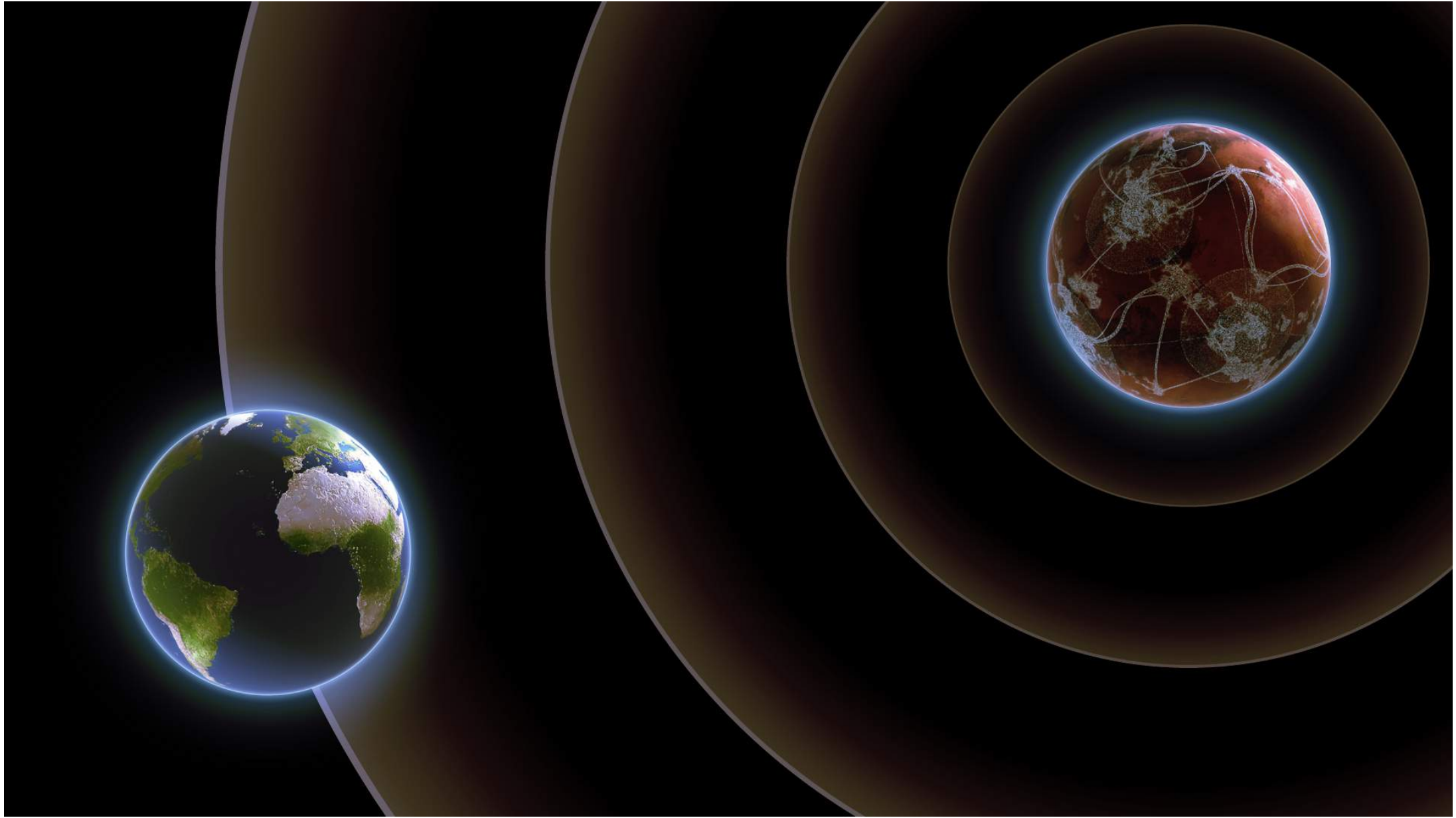


BIOSIGNATURES



TECHNOSIGNATURES









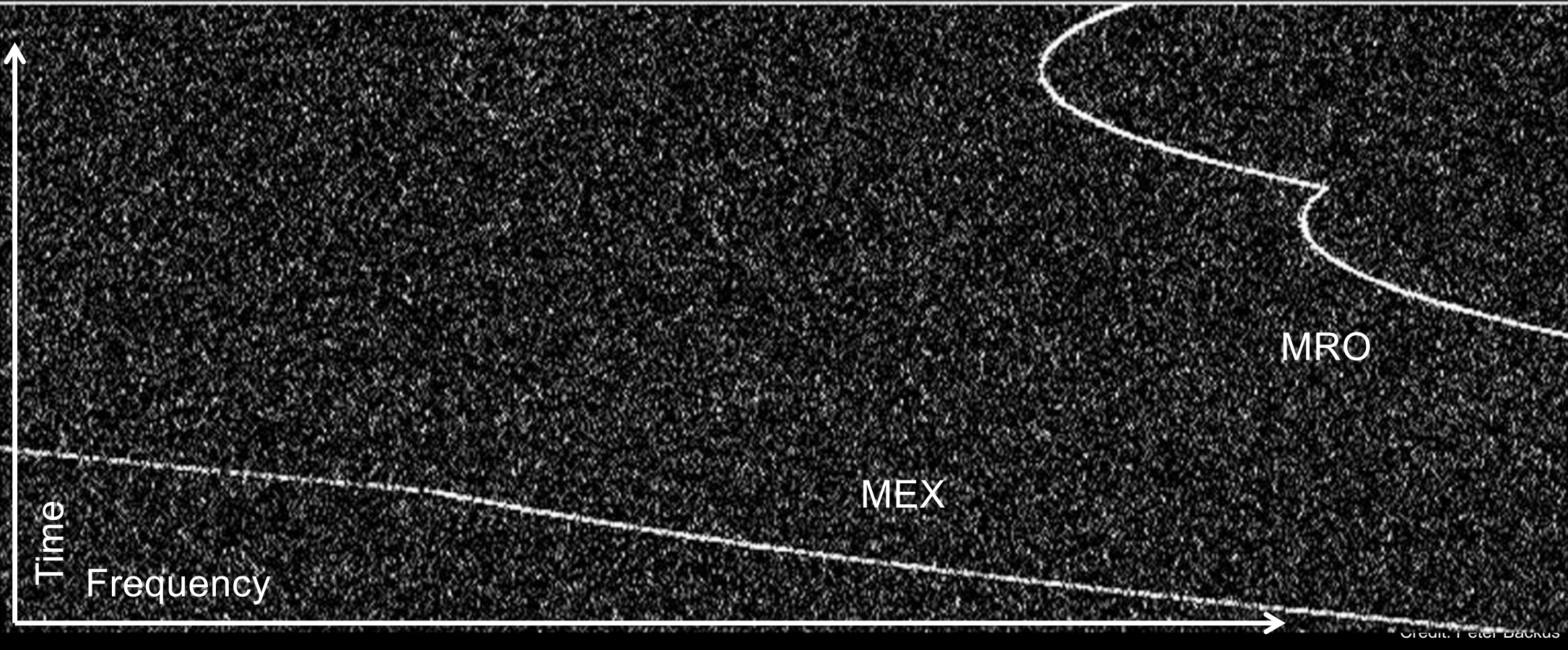


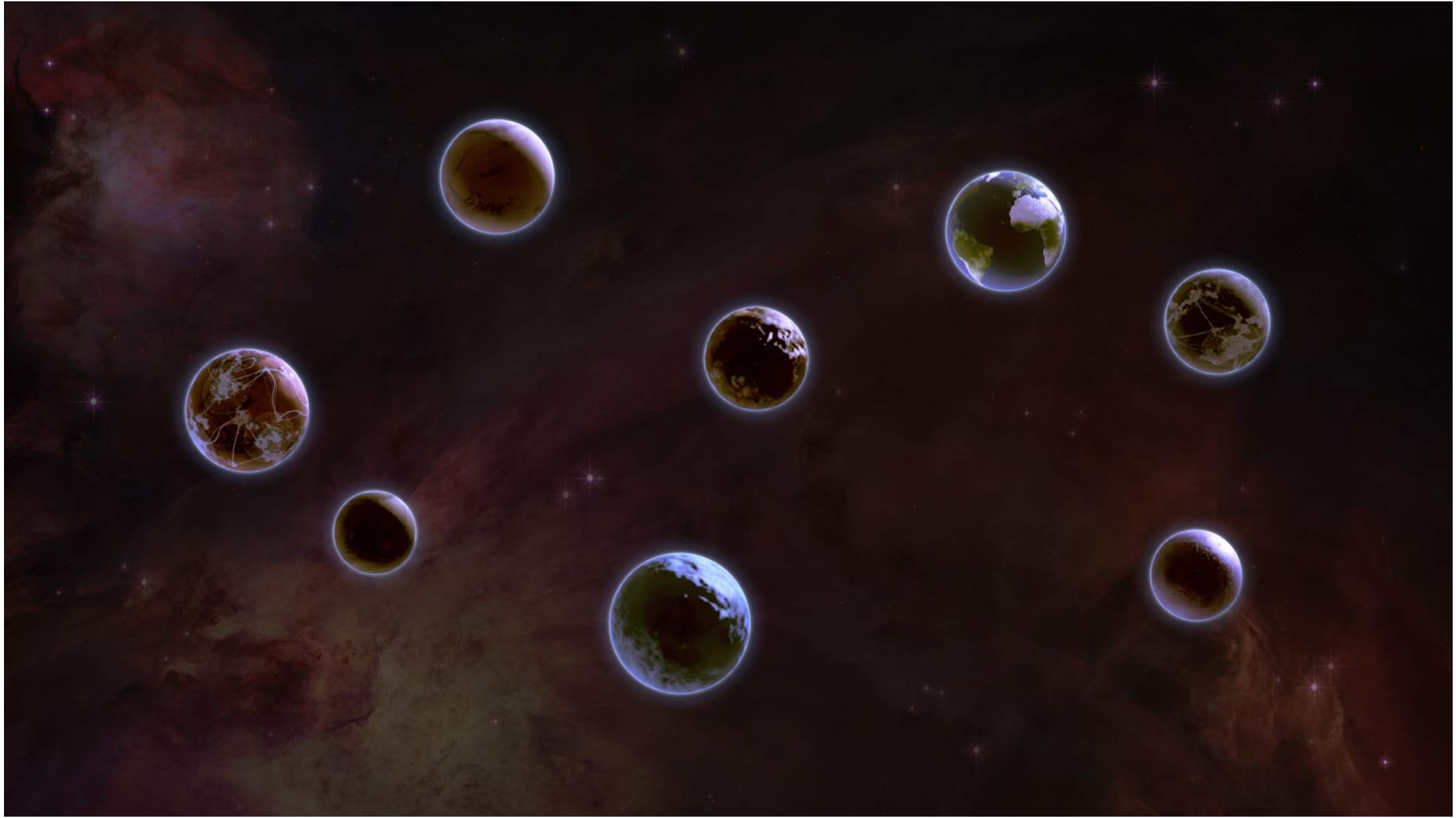
NIROSETI

RADIO: NATURAL VS. ENGINEERED

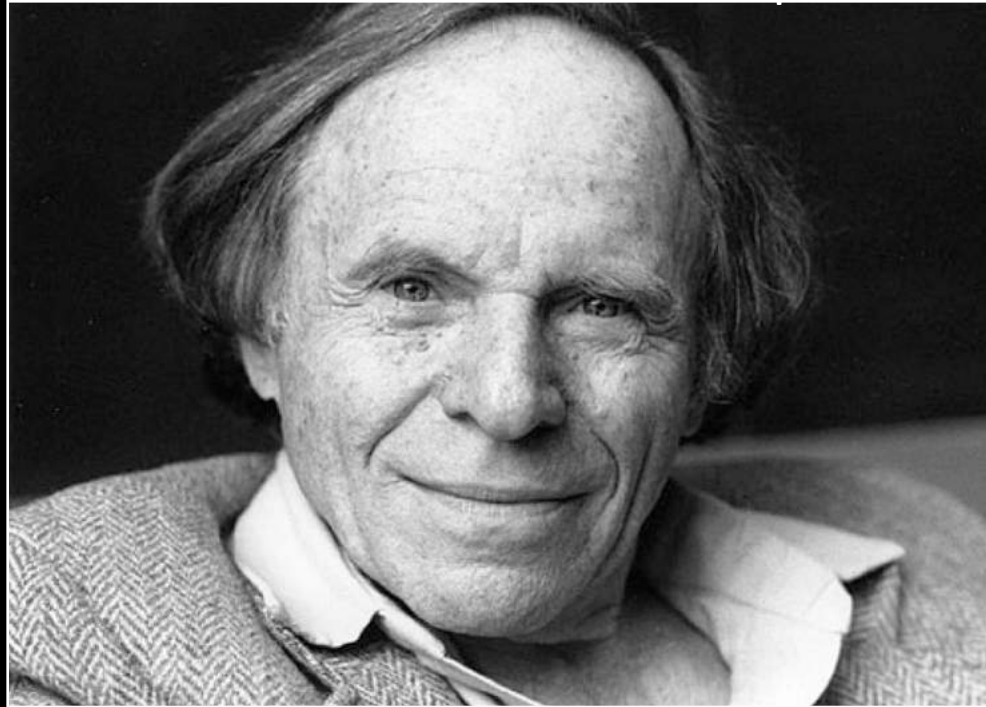
Waterfall: File: 2011-11-15_19-19-12.UTC.act3151.dx3017.id-2.R.archive-compamp

Center Freq: 8439.757867 MHz Subband: 0659 BW: 533.3 Hz #Half Frames: 0256 ActId: 3151





Prof. Philip Morrison



SETI IS THE ARCHEOLOGY OF THE FL OUR

THE **NUMBER** OF CIVILIZATIONS IN OUR GALAXY WITH WHICH COMMUNICATION IS POSSIBLE

$$N =$$

$$\int_{\Omega} D(t_1, x) \frac{\partial \varphi(t_1, x)}{\partial t_1} (-\Delta t, x) \lim_{\Delta t \rightarrow 0^+} \int_0^T \int_{\Omega} D(t_1, x) \frac{\partial \varphi(t_1, x)}{\partial t_1} \exp[-ik] D(t_1, x) \frac{\partial \varphi(t_1, x)}{\partial t_1} (-\Delta t, x)$$

THE AVERAGE **RATE** OF STAR FORMATION PER YEAR IN OUR GALAXY

$$R_*$$



THE FRACTION OF THOSE STARS WITH **PLANETS**

$$f_p$$



THE AVERAGE **NUMBER** OF THOSE PLANETS THAT MAY DEVELOP AN **ECOSYSTEM**

$$N_e$$



THE FRACTION OF THOSE PLANETS THAT SUCCEED IN **DEVELOPING LIFE**

$$f_l$$



THE FRACTION OF THOSE PLANETS WITH LIFE THAT DEVELOP **INTELLIGENT LIFE**

$$f_i$$



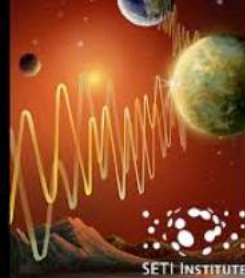
THE FRACTION OF THOSE PLANETS WITH INTELLIGENT LIFE THAT DEVELOP **INTERSTELLAR COMMUNICATION**

$$f_c$$



THE AVERAGE **LENGTH** OF TIME SUCH CIVILIZATIONS SURVIVE AND CONTINUE TO SEND COMMUNICATIONS

$$L$$

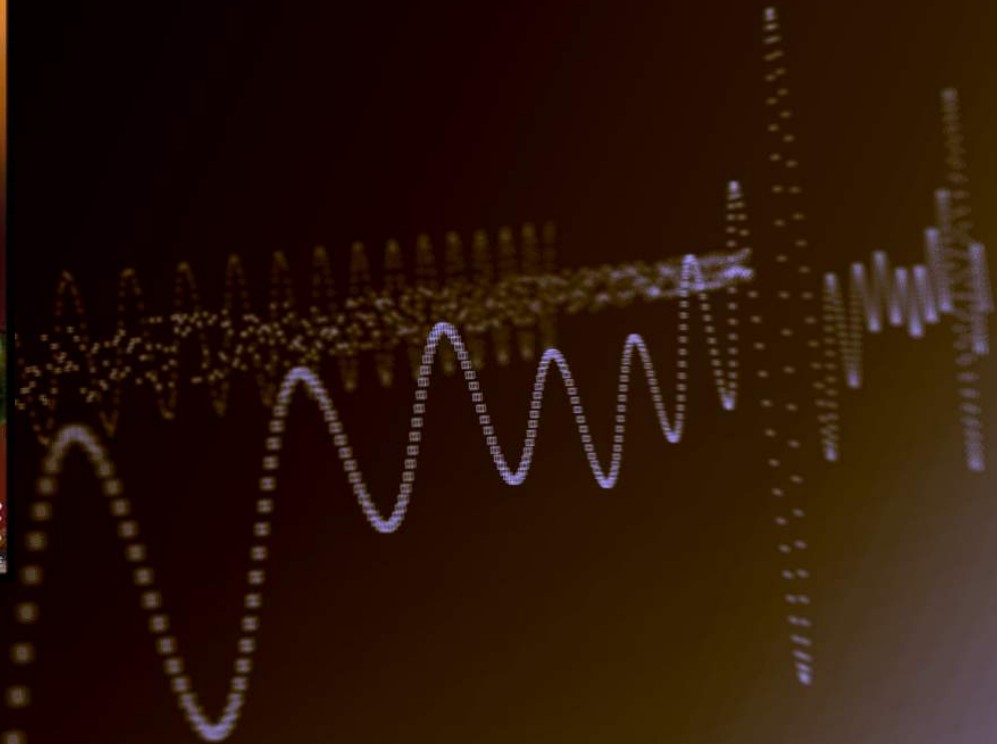
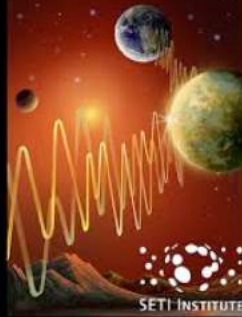


THE NUMBER OF CIVILIZATIONS IN OUR GALAXY WITH WHICH COMMUNICATION IS POSSIBLE

THE AVERAGE LENGTH OF TIME SUCH CIVILIZATIONS SURVIVE AND CONTINUE TO SEND COMMUNICATIONS

$$N \approx L$$

$$\int_{\Omega} l E d\Omega_1 d\Omega_2 k^2 \frac{d\sigma(\theta, E)}{d\Omega_1 d\Omega_2} \frac{\varphi(t_1, x)}{\varphi(t_1 - \Delta t, x)}$$
$$\lim_{T \rightarrow 0^+} \int_0^T \int_{\Omega} D(t_1, x) \frac{\varphi(t_1, x)}{\varphi(t_1 - \Delta t, x)}$$
$$\int_0^T \int_{\Omega} D(t_1, x) \frac{\partial \varphi}{\partial t_1} \exp[-ik(t_1, x)]$$





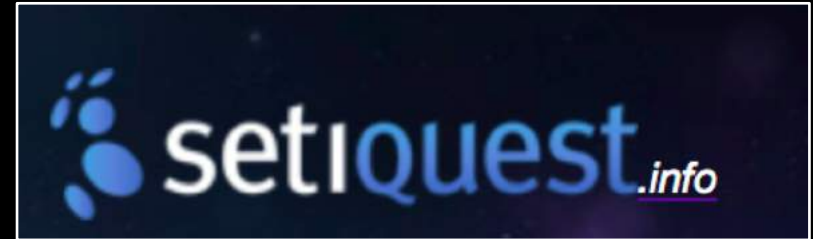
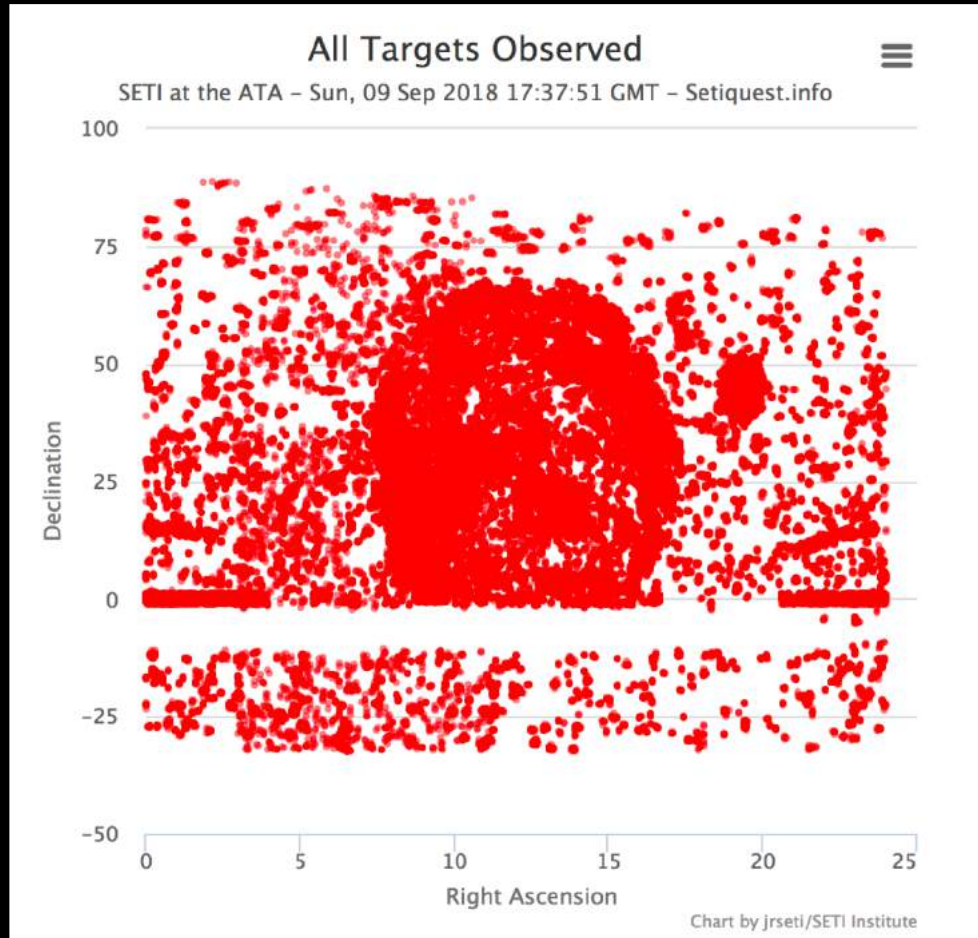
THE ATA- 42





THE ATA-42

20,000 RED DWARF SURVEY





BREAKTHROUGH LISTEN

\$100 M OVER 10 YEARS FROM YURI MILNER

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\$100 M C

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BREAKTHROUGH LISTEN



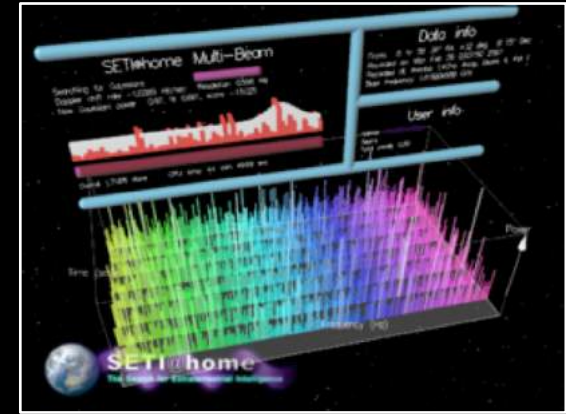


LOFAR
Low Frequency Transients

MORE SETI TODAY



MWA



SETI@home

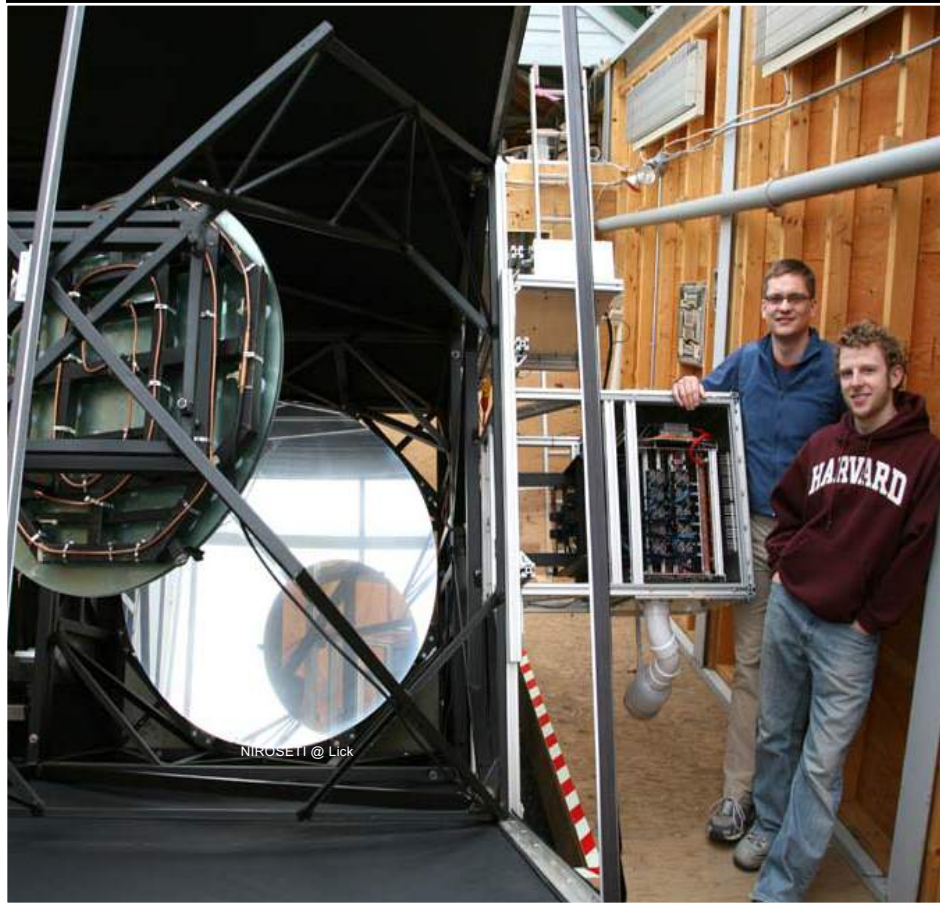
ALFA at Arecibo
Astropulse &
Other signals



SETI Italia

Center Frequency: 8450 MHz	Center Frequency: 8450 MHz	Center Frequency: 8450 MHz	Center Frequency: 8450 MHz					
Sky Frame	Data Source	Report	Data Analyzed	Date Submitted				
426	sp00426_20130521_090393	2013-0001	Monrovia High School	2013-05-21				
435	sp00435_20130521_132330	2013-0001	Monrovia High School	2013-05-21				
436	sp00436_20130214_120030	2013-0001	A&E Lewis Center Space Science Class	2013-02-14				
		2013-0002	Steve Levin	2013-02-14				
486	sp00486_20130501_100650	2013-0001	St. Mary's School	2013-05-01				
502	sp00502_20130214_105300	2013-0001	A&E Lewis Center Space Science Class	2013-02-14				
504	sp00504_20130214_102010	2013-0001	A&E Lewis Center Space Science Class	2013-02-14				
511	sp00511_20130526_111708	2013-0001	St. Mary's School	2013-05-26				
560	sp00560_20130608_122119	2013-0001	Galago Connecticut	2013-06-17				
565	sp00565_20130500_110038	2013-0001	St. Mary's School	2013-05-24				
566	sp00566_20130128_112036	2013-0001	St. Mary's School	2013-01-28				
		2013-0002	Steve Levin	2013-01-28				
576	sp00576_20130207_064925	2013-0001	Monrovia High School	2013-02-07				

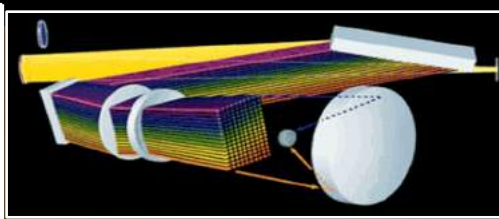




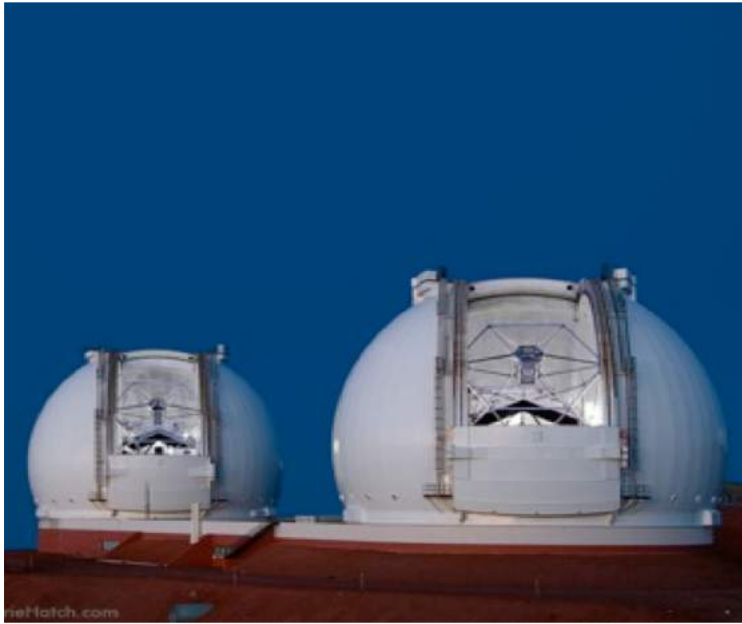
NIROSETI @ Lick

Harvard Sky Survey

NIROSETI Lick Obs.

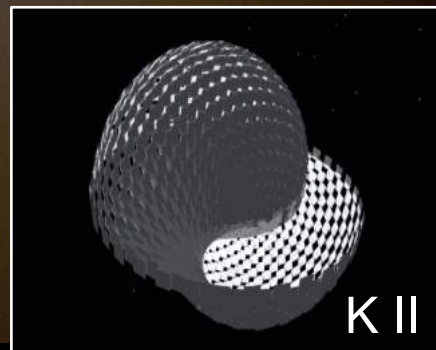


Keck
HIRES

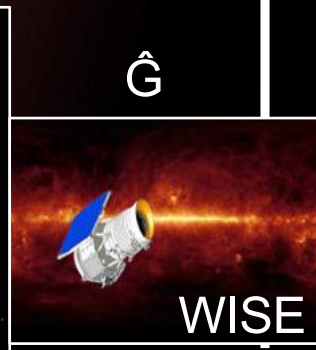


seeMatch.com

OSSETI



K II



G

WISE

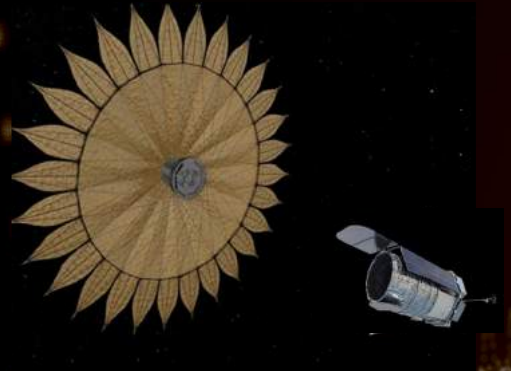


K III

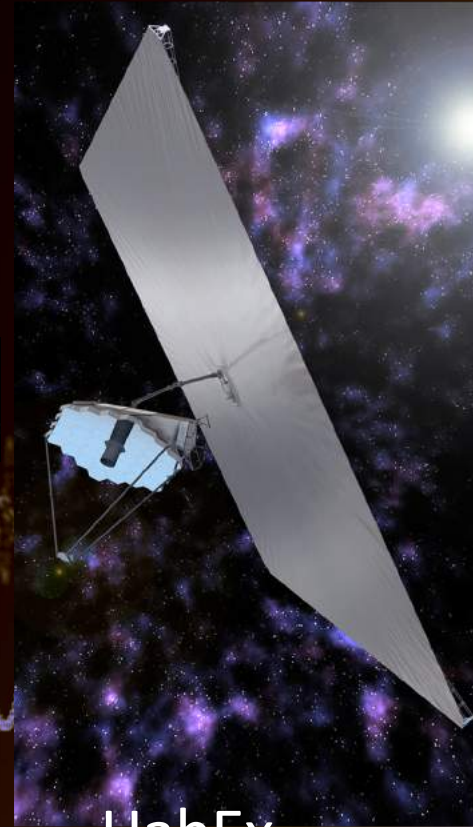
THE FUTURE



JWST and then ???

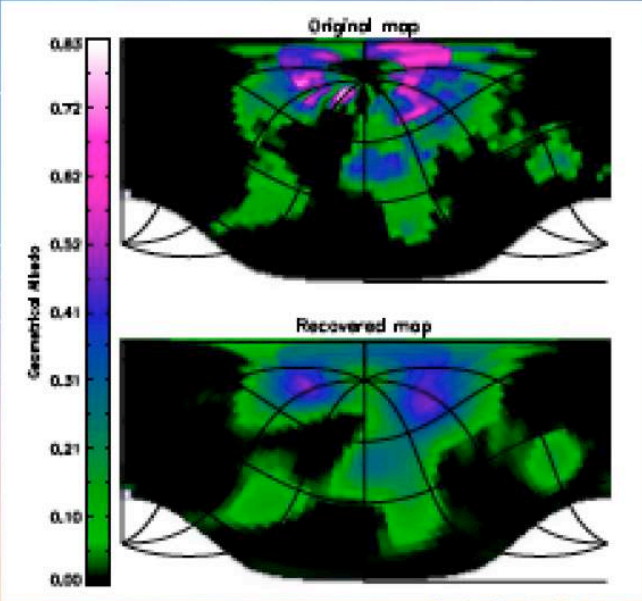
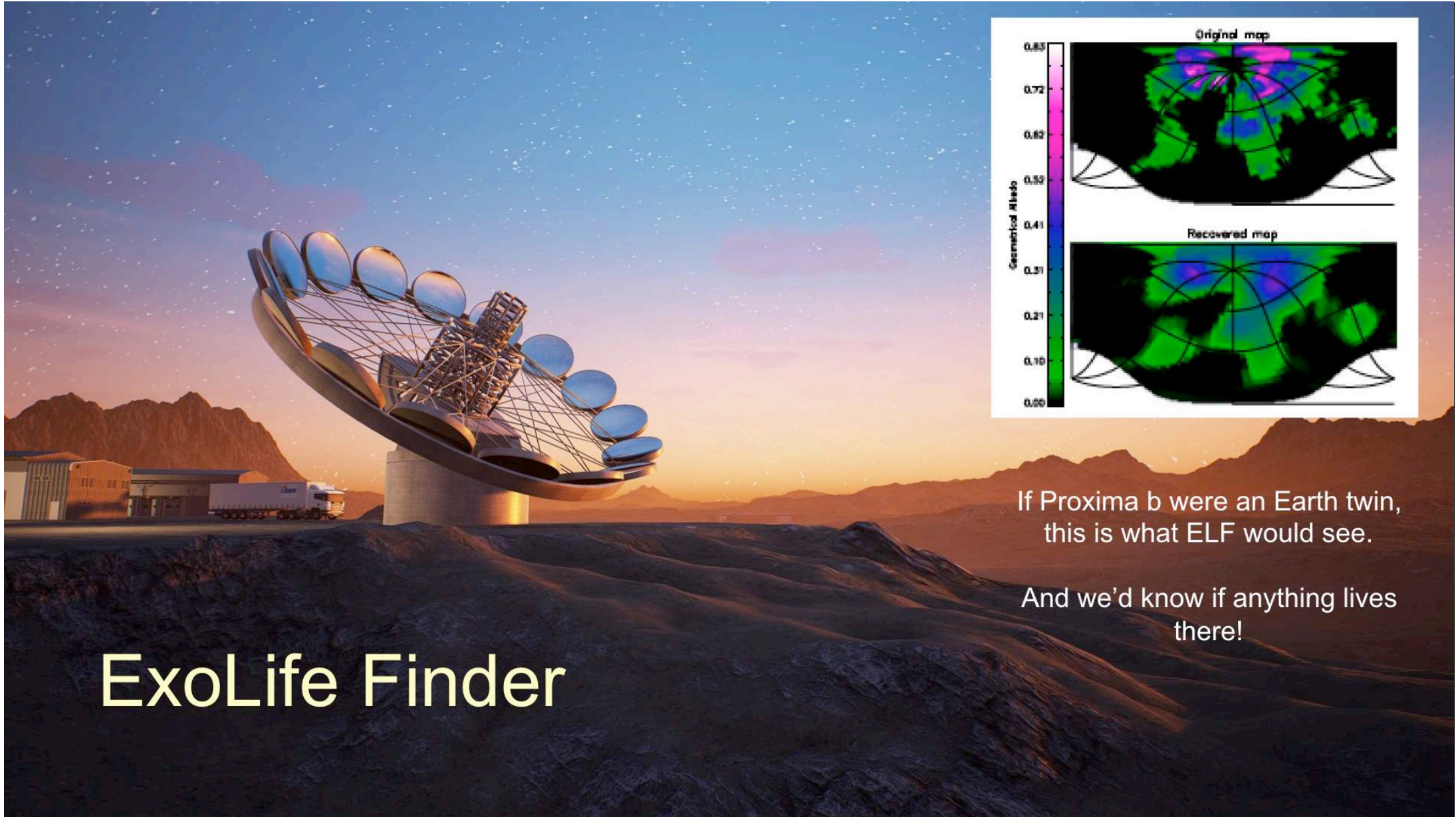


WFIRST



HabEx
or
LUVOIR

IMAGING / BIOSIGNATURES



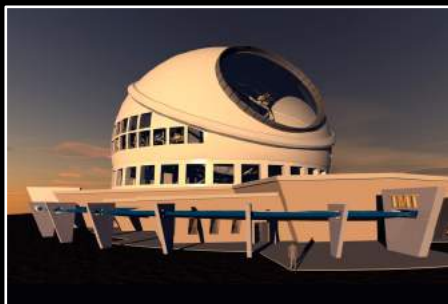
If Proxima b were an Earth twin,
this is what ELF would see.

And we'd know if anything lives
there!

ExoLife Finder

THE FUTURE

TMT

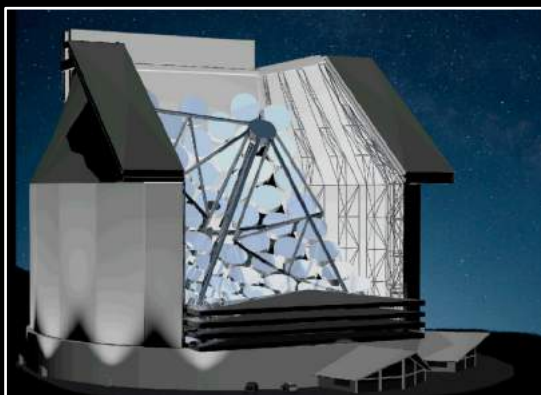


E-ELT

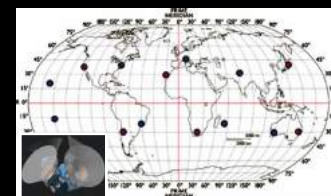


ngVLA

GMT

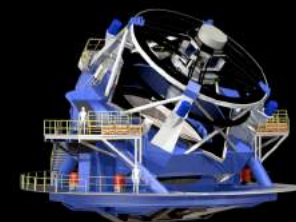


Colossus

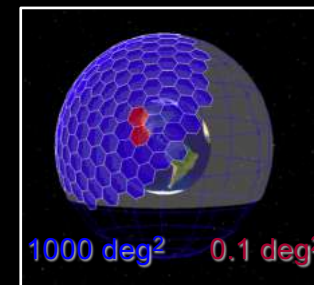


LASER²ETI

LSST



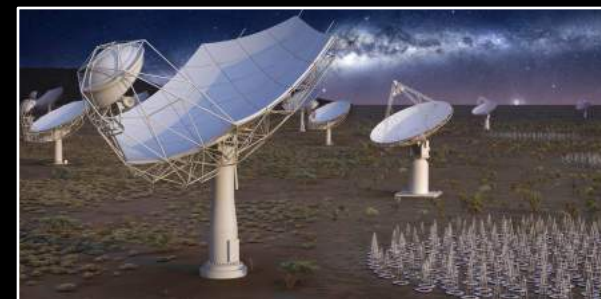
PANOSETI



1000 deg² 0.1 deg²



FAST



SKA

SETI/OSETI



A photograph showing the Earth rising over the horizon of the Moon. The Earth is a bright blue and white sphere in the center, set against the blackness of space. The foreground shows the dark, cratered surface of the Moon with a low horizon line.

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

Caleb Scharf (2014)