Title: Life, the Universe, and the Search for Extraterrestrial Intelligence (SETI)

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Abstract: Hollywood movies about aliens abound, but do they really exist? The real scientific search for evidence of life, and particularly intelligent life, elsewhere in the cosmos is just as exciting as the Â“reelÂ” version, and a lot more logical. So far, there is Â‘life-as-we-know-itÂ’ to guide our speculations and observations. But a new appreciation for the tenacity of life, a growing respect for the world of microbes, and new search technologies involving observatories and spacecraft are rapidly expanding our viewpoint. Many expect surprises. SETI is at the forefront of this research and has plans to extend its range out even further into the galaxy, looking for evidence of someone elseÂ’s technology. In the next few decades, scientists will take a much closer look at places within our solar system where liquid water (even vast oceans) may exist and harbor life. They will also probe the closest stars to see if other Â‘EarthsÂ’ and biospheres exist. Dr. Jill Tarter will describe research in a discipline some call Â“the archaeology of the futureÂ”. <kw>Jill Tarter, extraterrestrial intelligence, SETI, \'archaeology of the future\', stardust, microbes, extreme life conditions, astrobiology, Kepler probe, Corot probe </kw>

Life, The Universe, And SETI In A Nutshell

Perimeter Institute

March 7, 2007

Jill Tarter

Director, Center for SETI Research --- SETI Institute

Bernard M. Oliver Chair for SETI

Who Cares About SETI?

Who Cares About SETI?

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"Either we are alone in the universe, or we are not. Either way, it's a mighty sobering thought." – Bill Watterson

Who Cares About SETI?

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Who Cares About SETI?

And what we are looking for is technology

s a mighty sobering
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Today's Take Home Message

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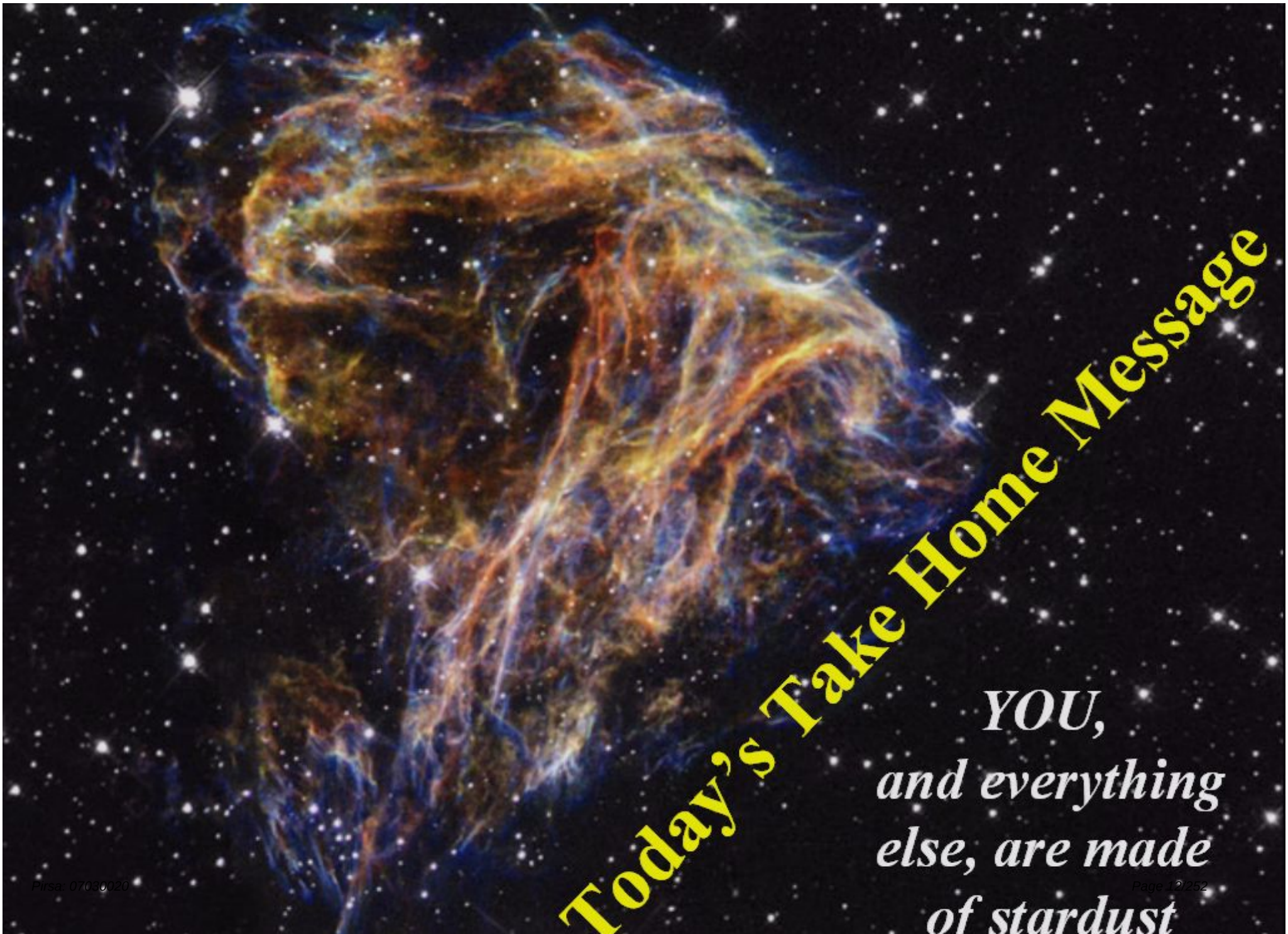
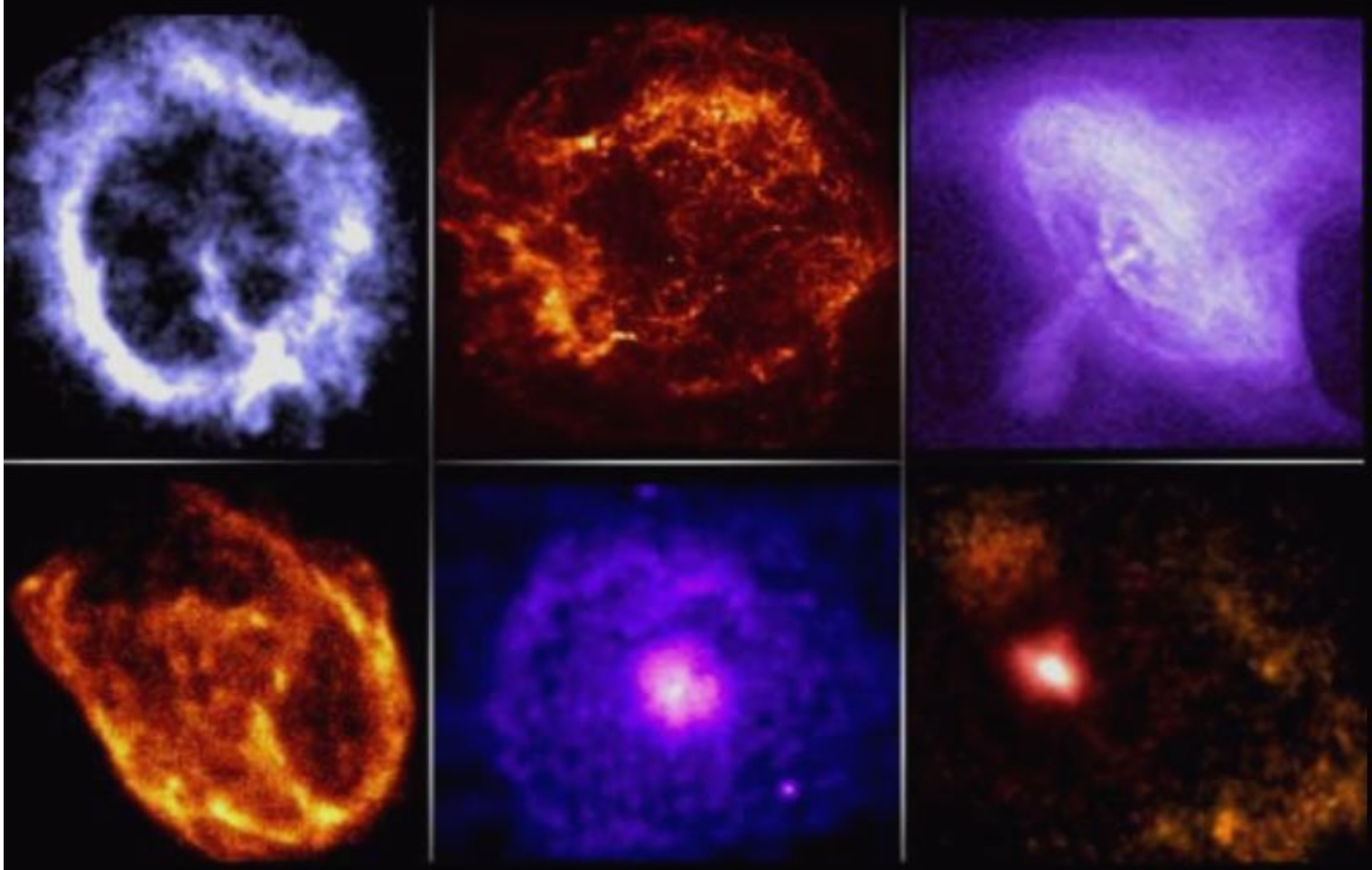
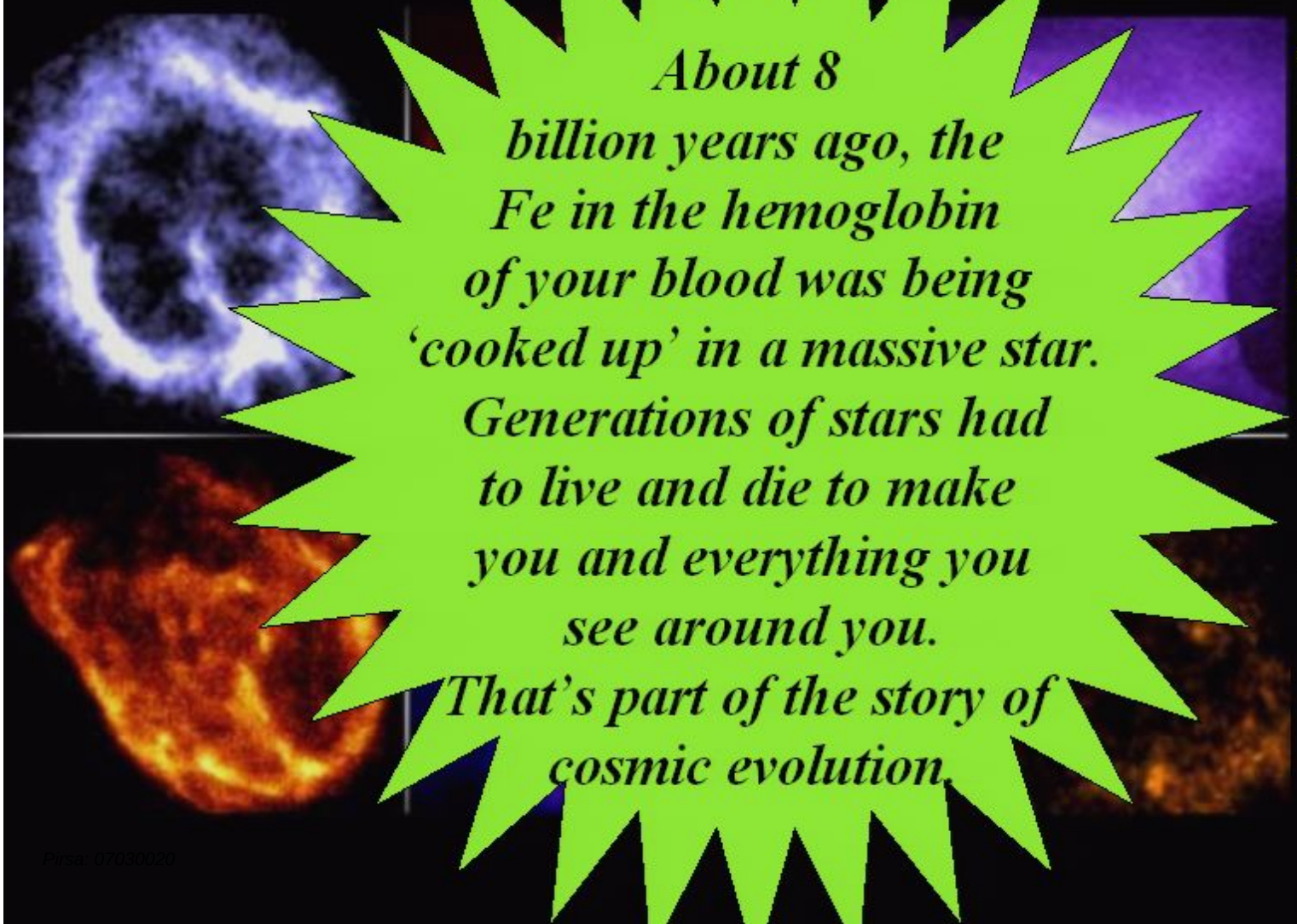

Today's Take Home Message
YOU,
and everything
else, are made
of stardust

Where Did We Come From?



The astronomers' answer

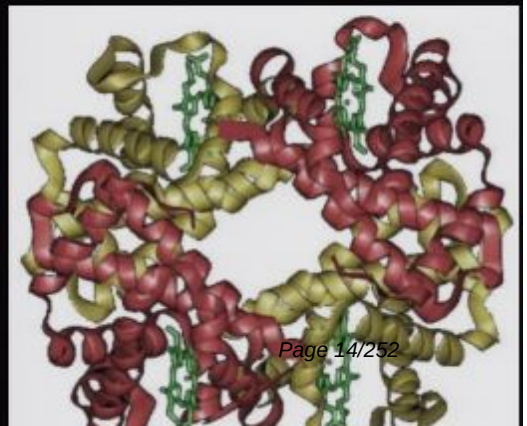
Where Did We Come From?



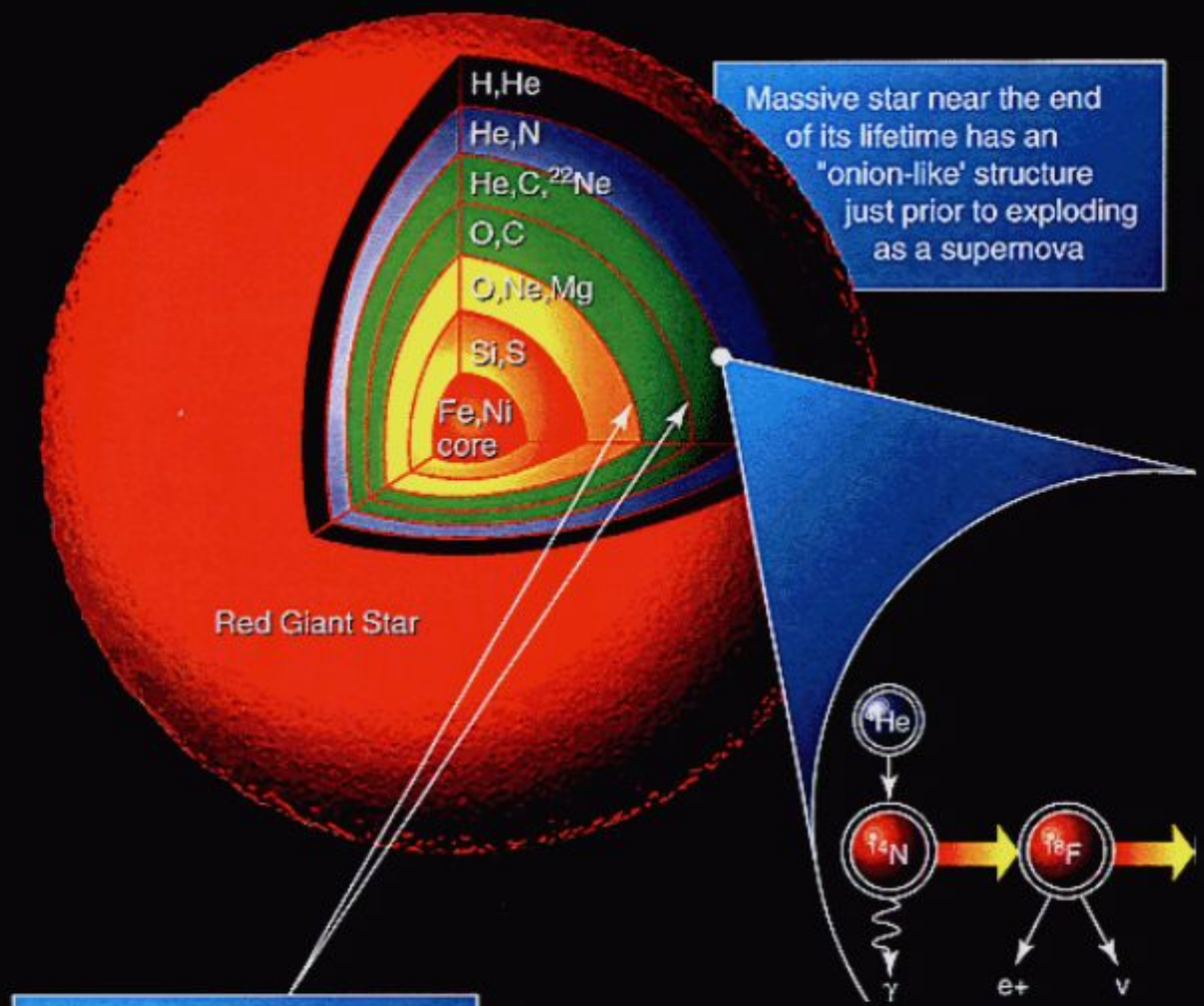
About 8 billion years ago, the Fe in the hemoglobin of your blood was being 'cooked up' in a massive star. Generations of stars had to live and die to make you and everything you see around you. That's part of the story of cosmic evolution.

The astronomers' answer

Hemoglobin



Old, Massive Star: Onion Model



Nuclear burning occurs at the boundaries between zones

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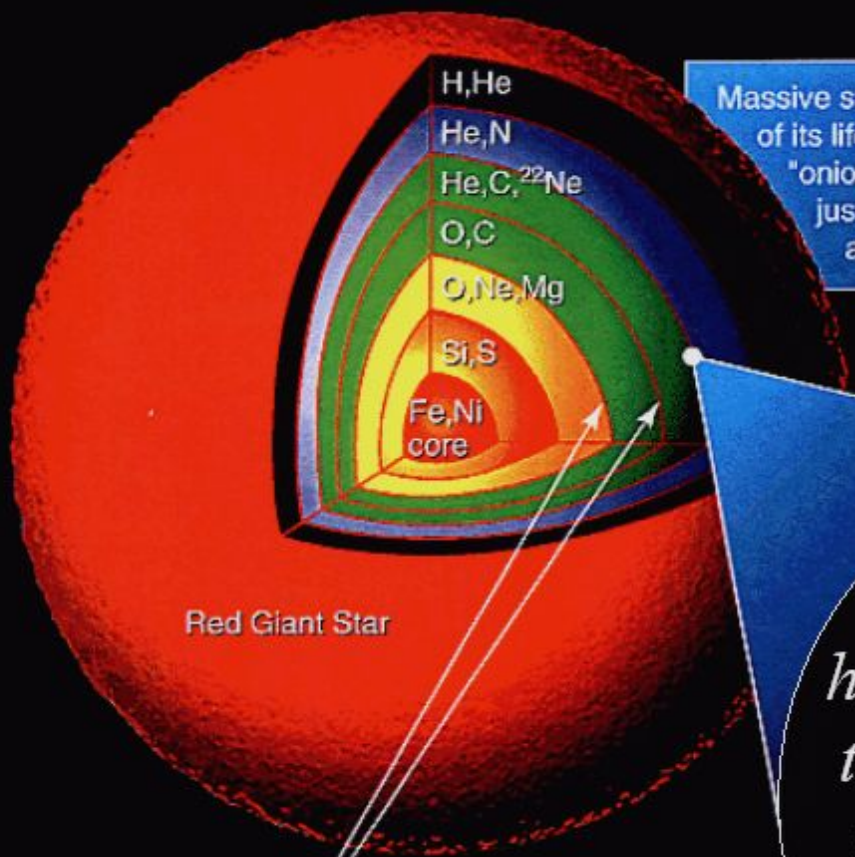

Massive star near the end of its lifetime has an "onion-like' structure just prior to exploding as a supernova

To make elements heavier than Fe, and to get the good stuff out, the star has to explode!
A supernova

Nuclear burning occurs at the boundaries between zones

A Supernova Remnant

A Star Dies, A Pulsar Is Born…
In A Supernova

A Star Dies, A Pulsar Is Born…
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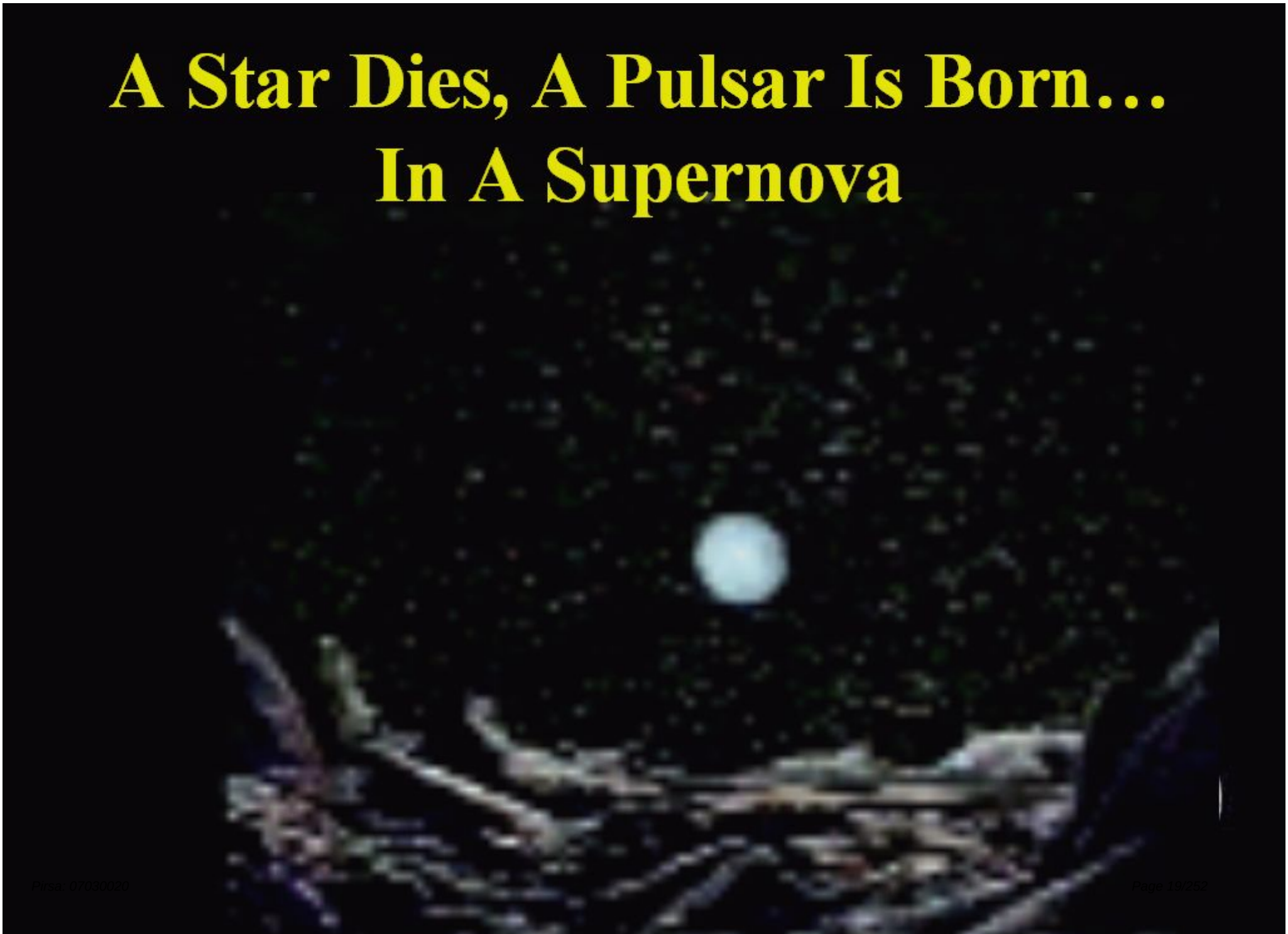

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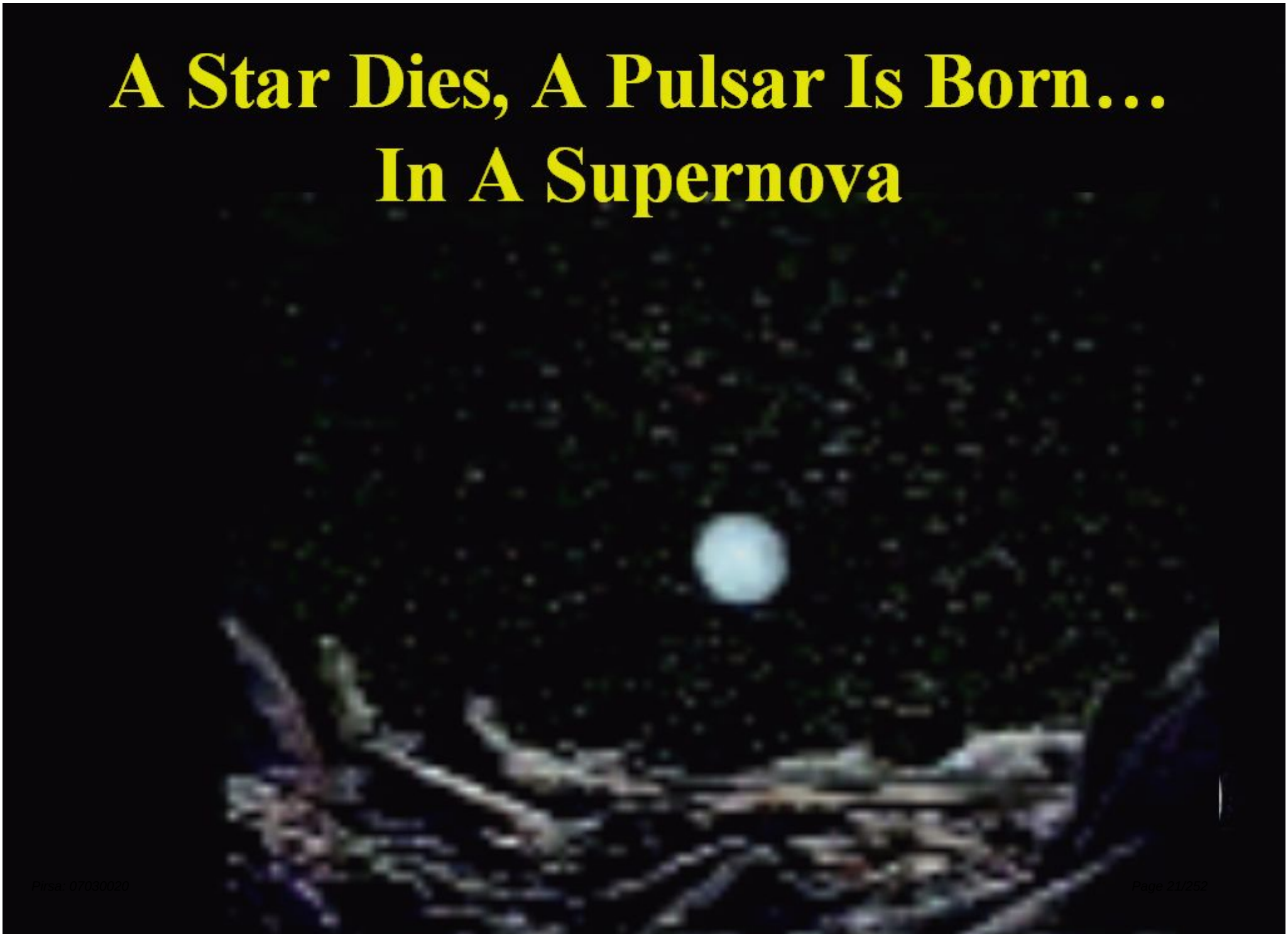

A Supernova Remnant

A Supernova Remnant

We are made of stardust!

ET: The Numbers Are Compelling

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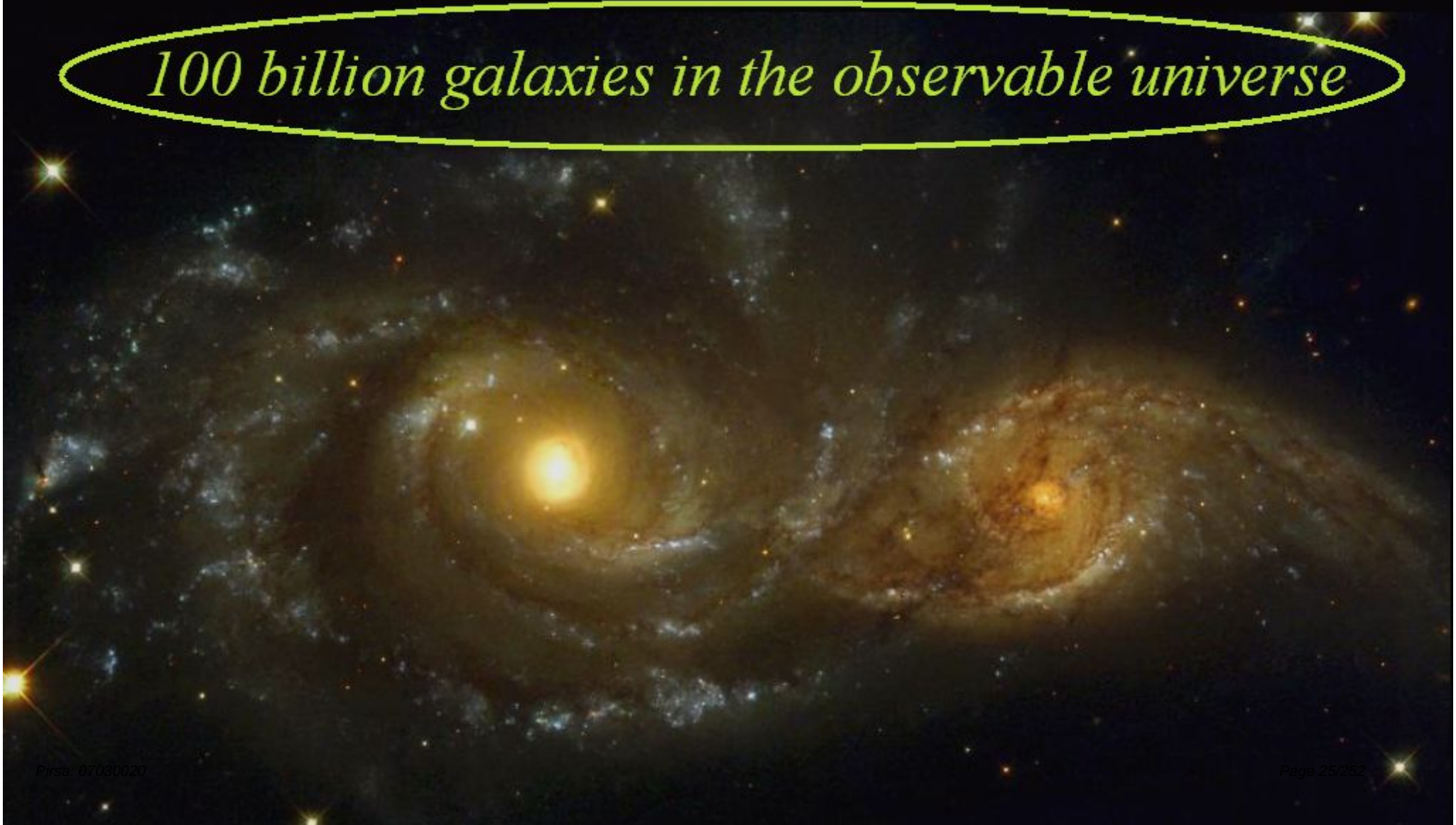
100 billion galaxies in the observable universe



ET: The Numbers Are Compelling

100 billion galaxies in the observable universe

> 100 billion stars in each galaxy

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> 10^{22} stars out there!

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Exoplanets & Extremophiles

> 10^{22} stars out there!

Extremophiles: Microbes Are Finally Getting Respect

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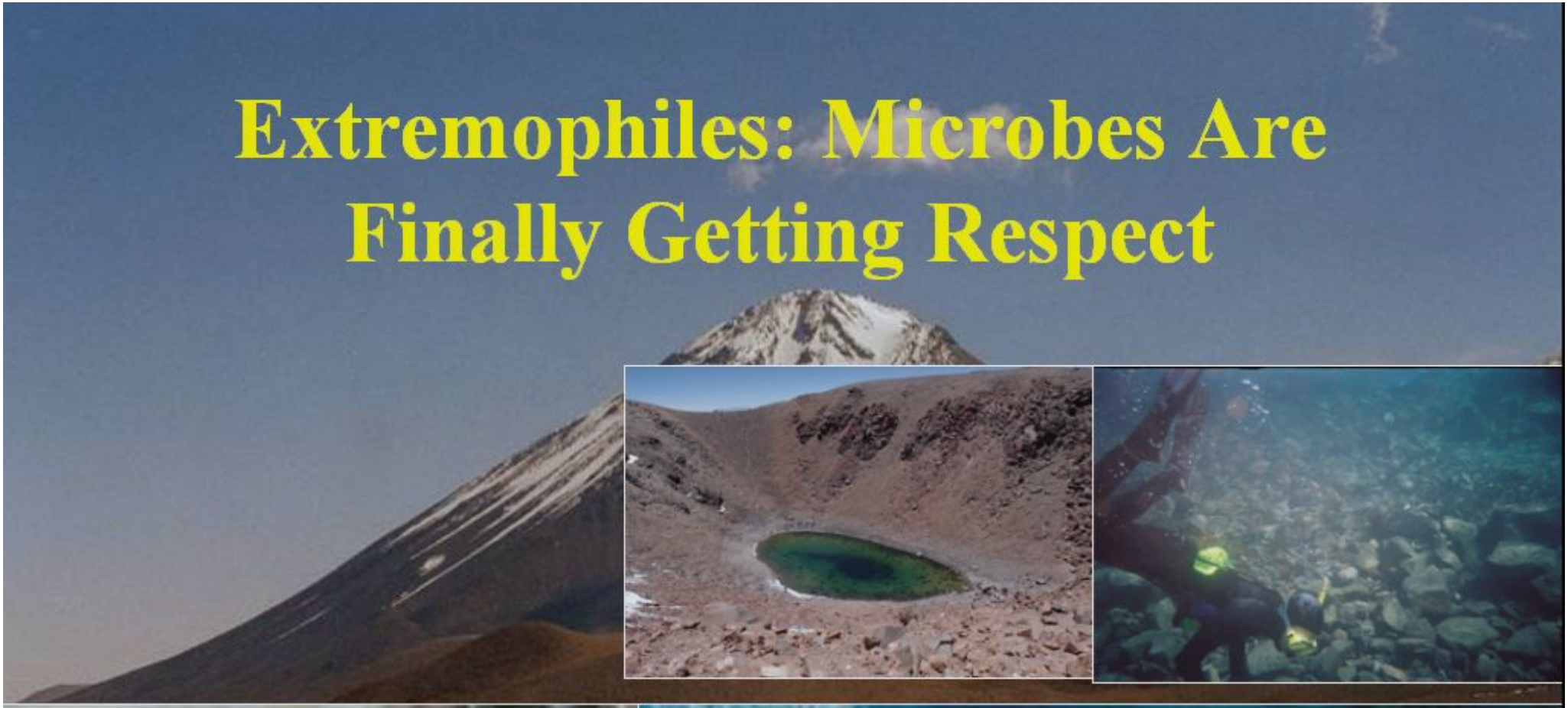

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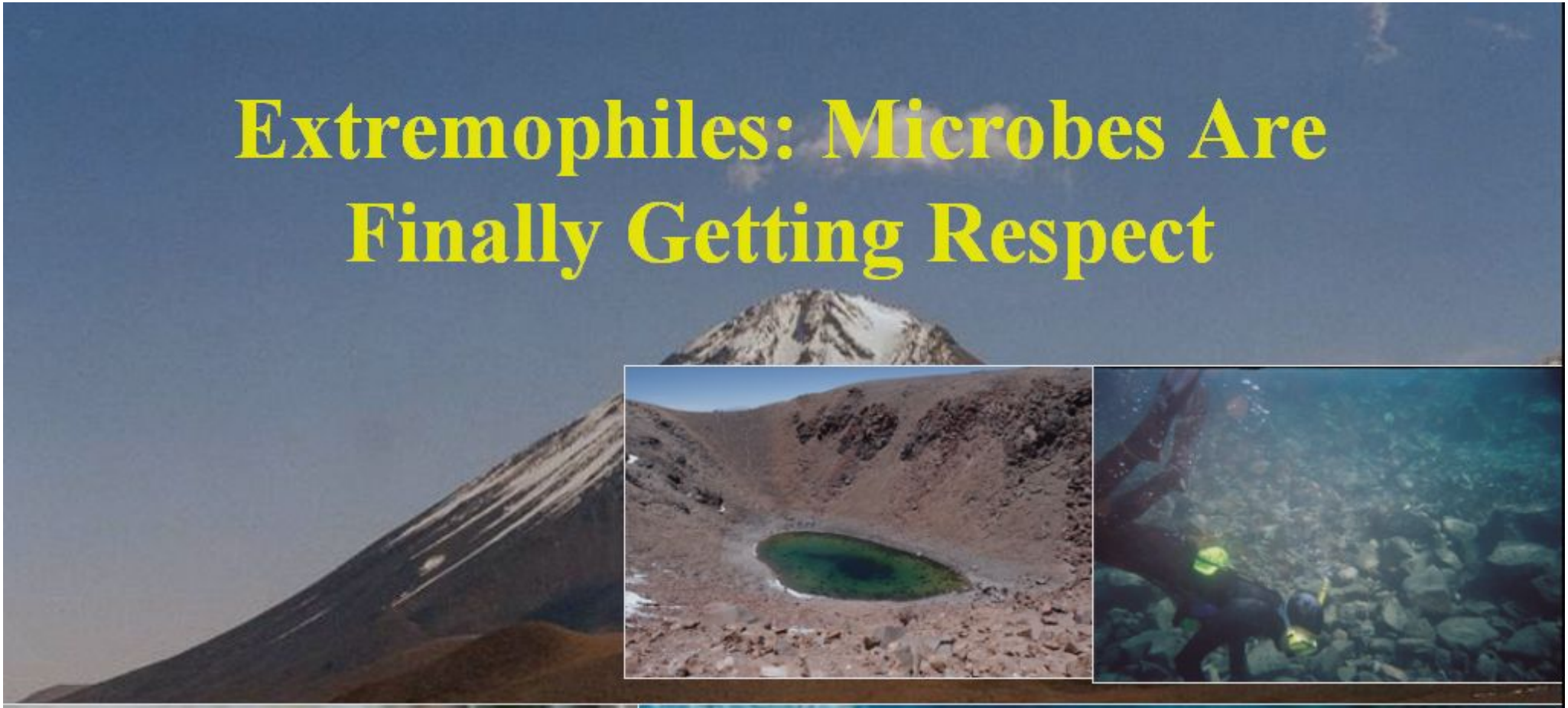

Extremophiles: Microbes Are Finally Getting Respect

← 0 – 100 degrees C →

← ph ~ 7 →

UV ↑

Radioactivity ↑

Salinity ↑

Moisture ↓

← Pressure ~ 1bar →

Sunlight ↓

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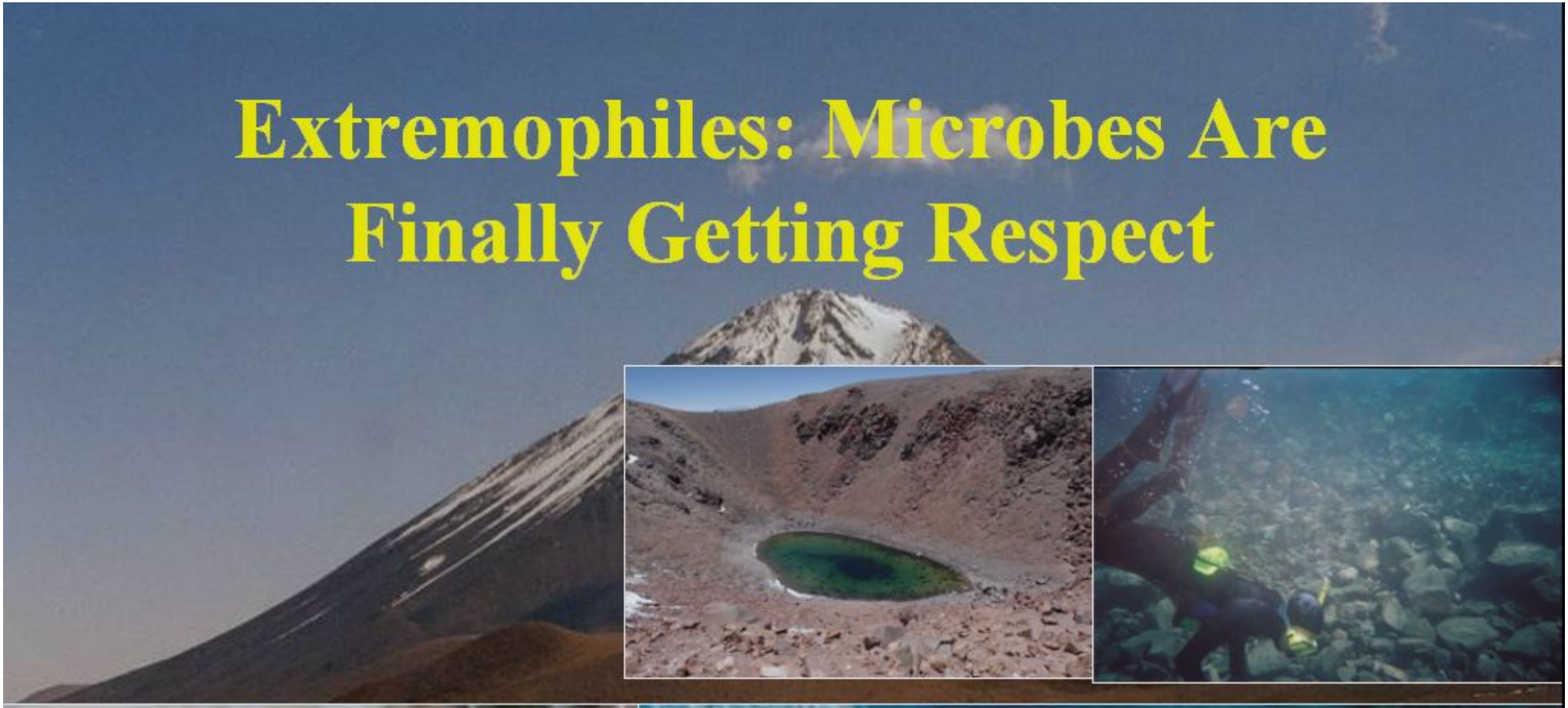

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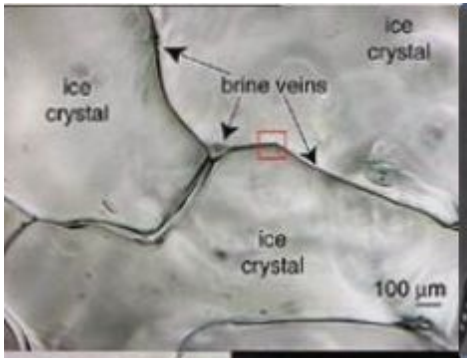

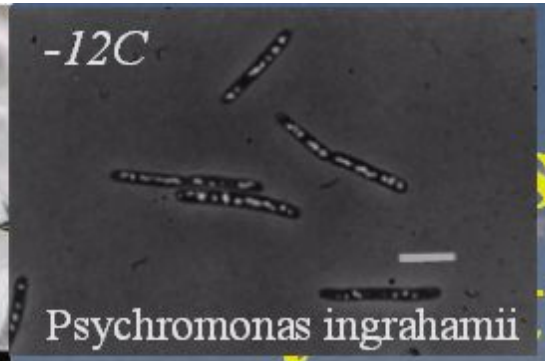

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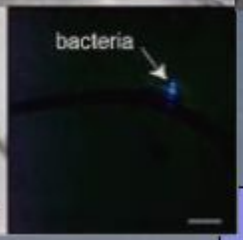

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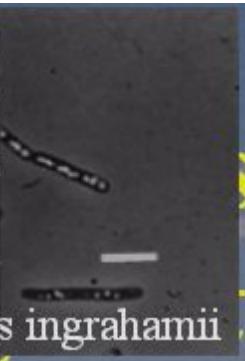

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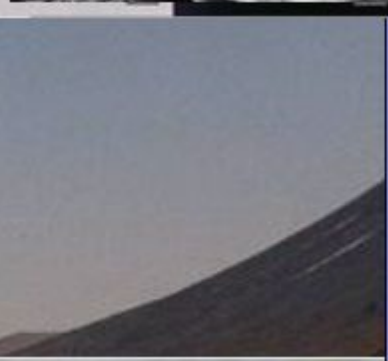

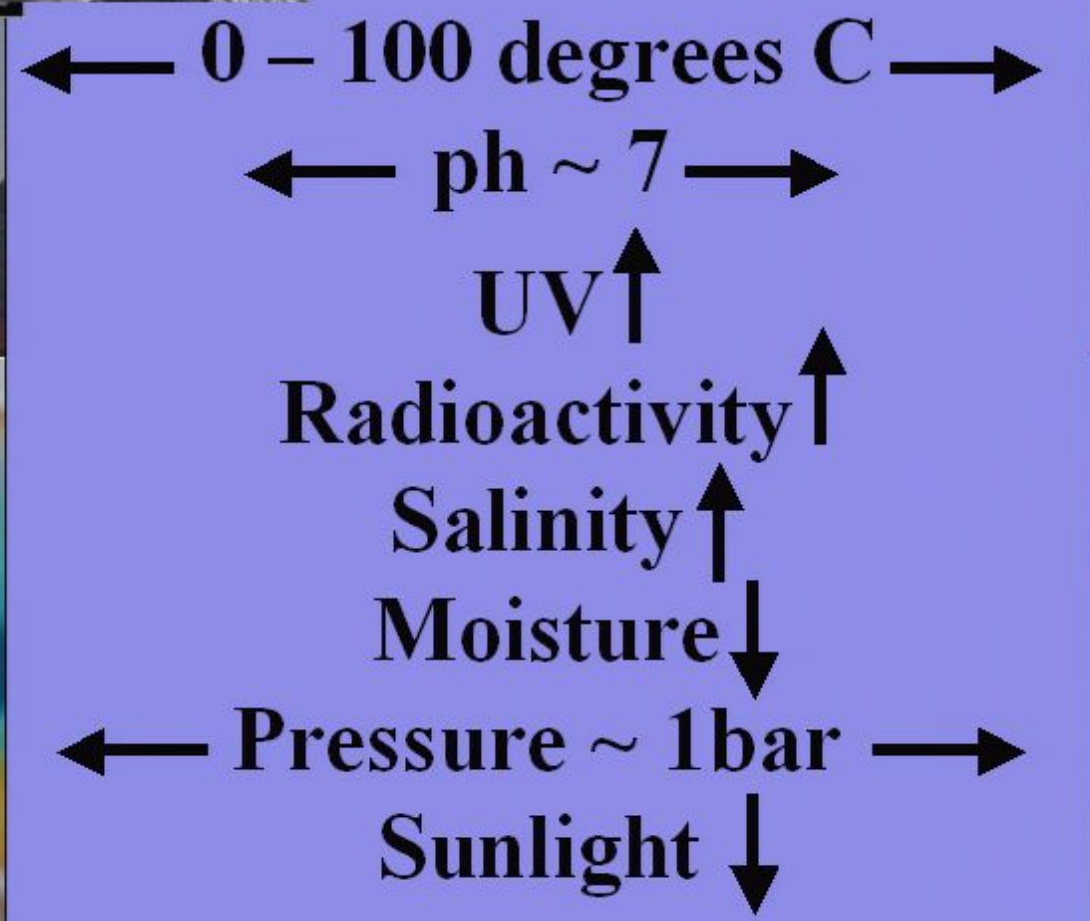

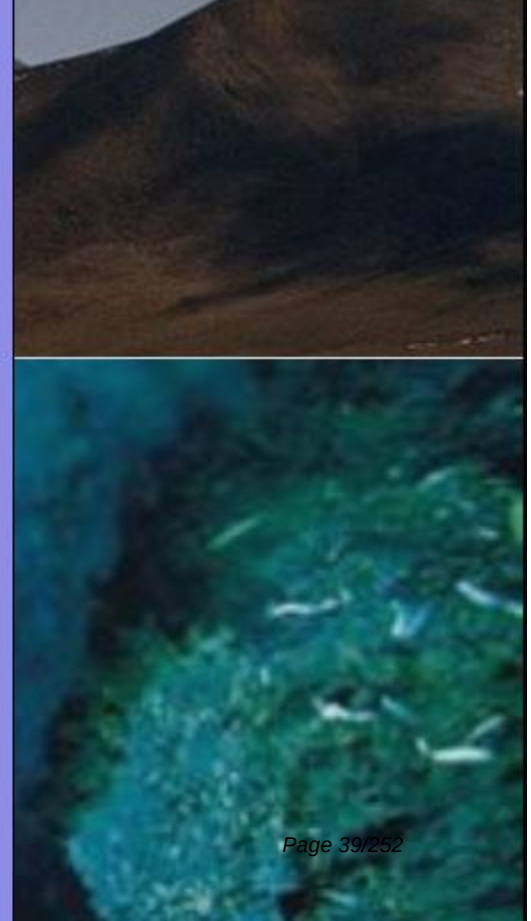

ingrahamii

1 mm

← 0 – 100 degrees C →

← ph ~ 7 →

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Radioactivity ↑

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Sunlight ↓

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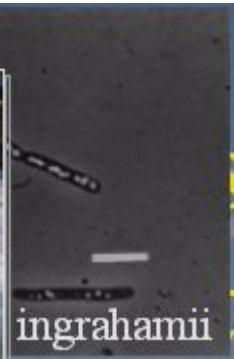

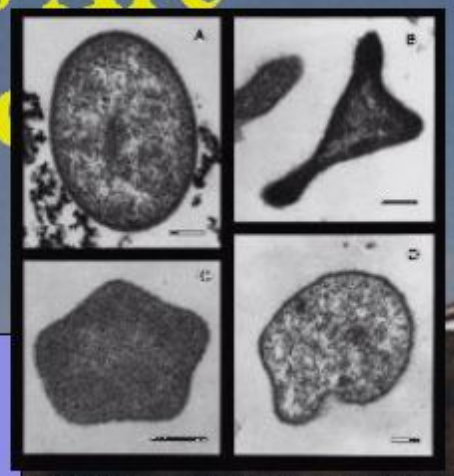

Strain 121 to 130ºC

← 0 – 100 degrees C →

← ph ~ 7 →

UV ↑

Radioactivity ↑

Salinity ↑

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← Pressure ~ 1bar →

Sunlight ↓

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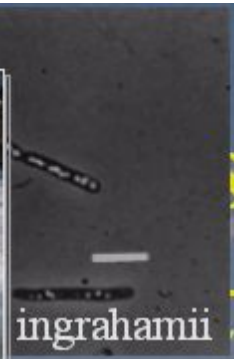

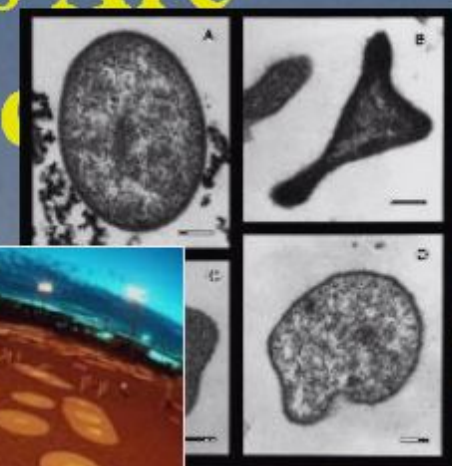

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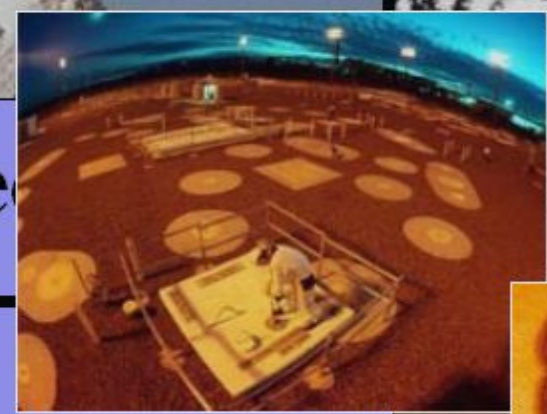


D. Radiodurans

← 0 – 100 degre

← ph ~ 7 –

UV ↑

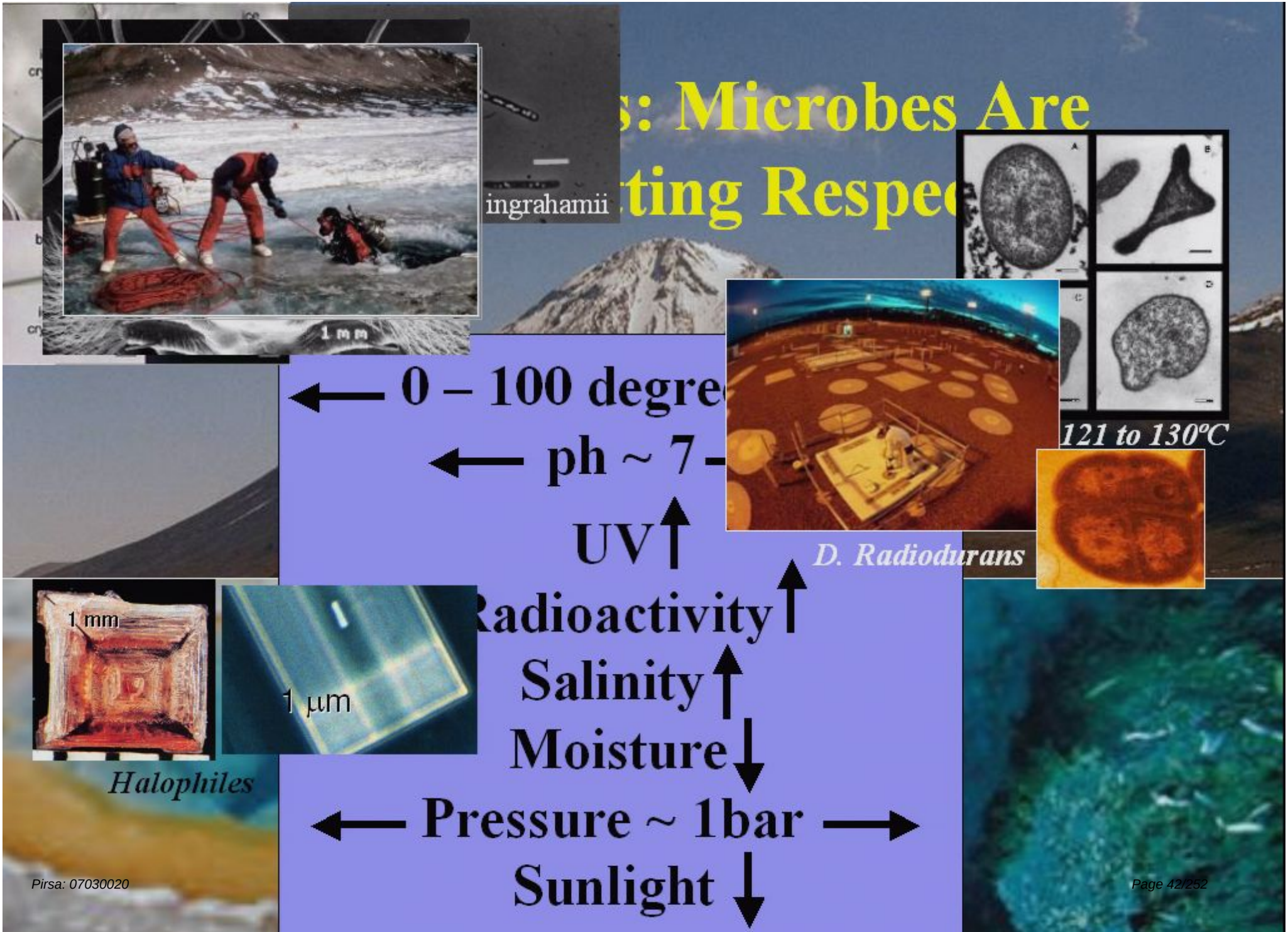
Radioactivity ↑

Salinity ↑

Moisture ↓

← Pressure ~ 1bar →

Sunlight ↓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1 mm
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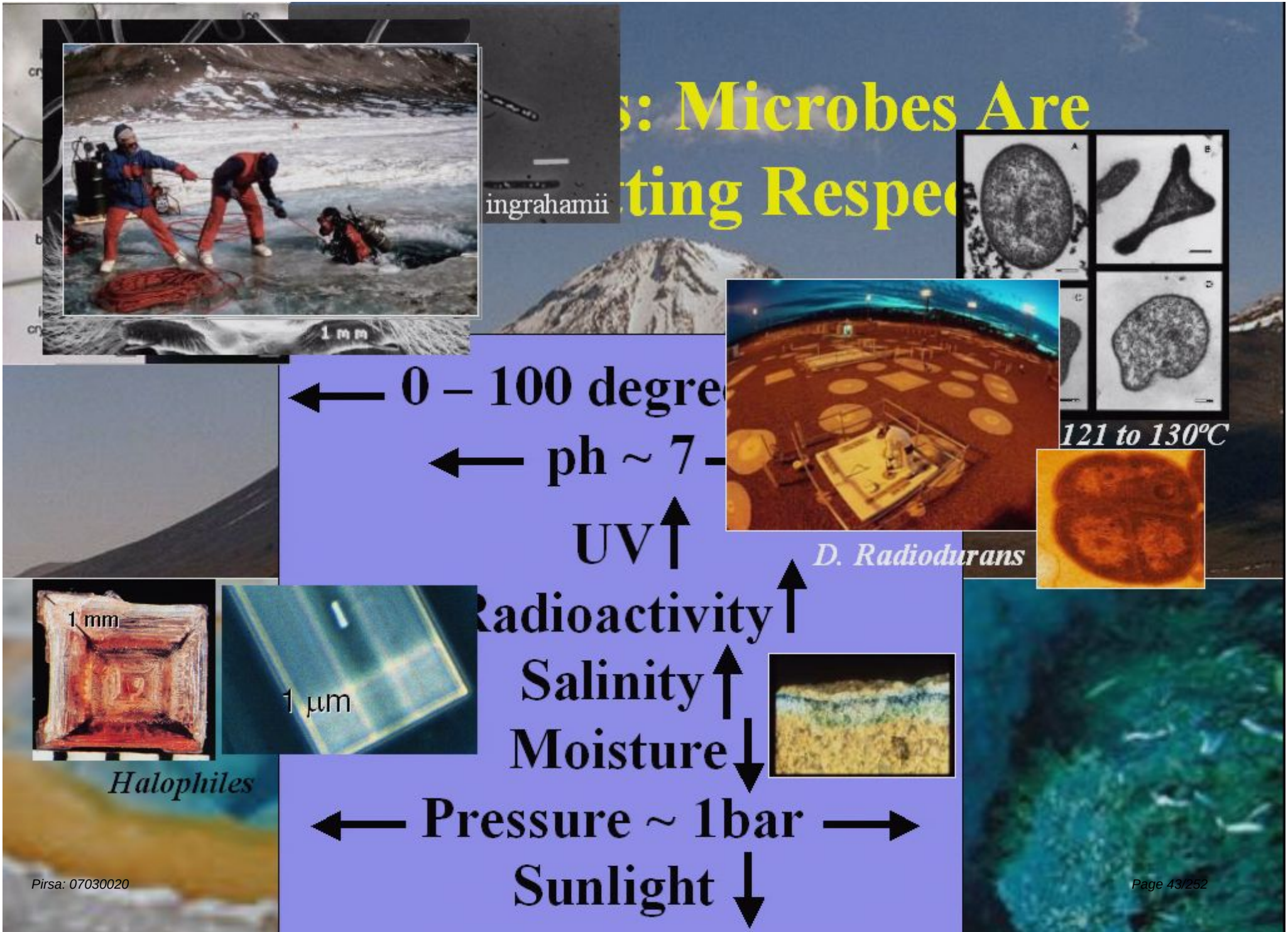
Sunlight
1 mm
1 µm
Halophiles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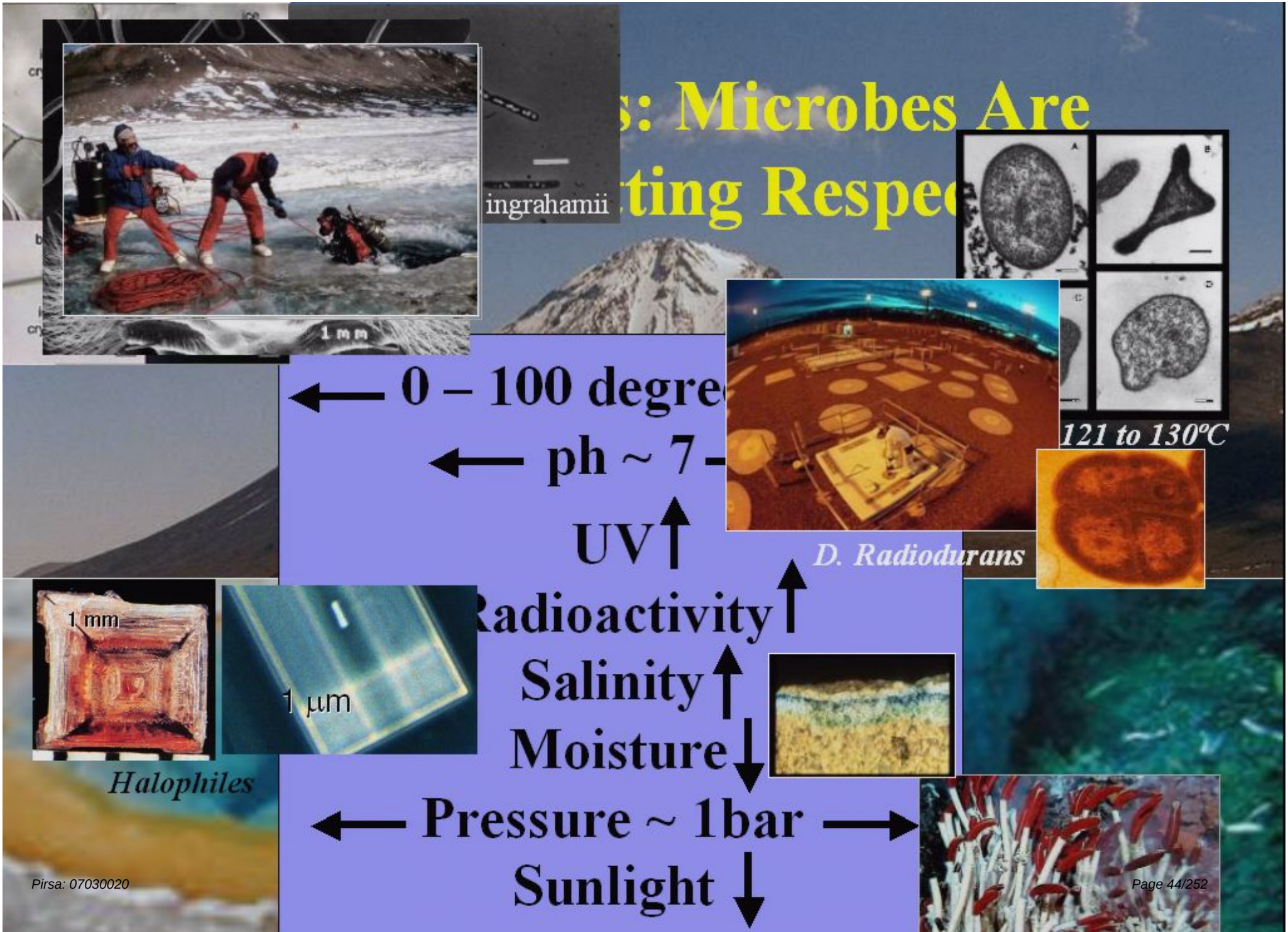
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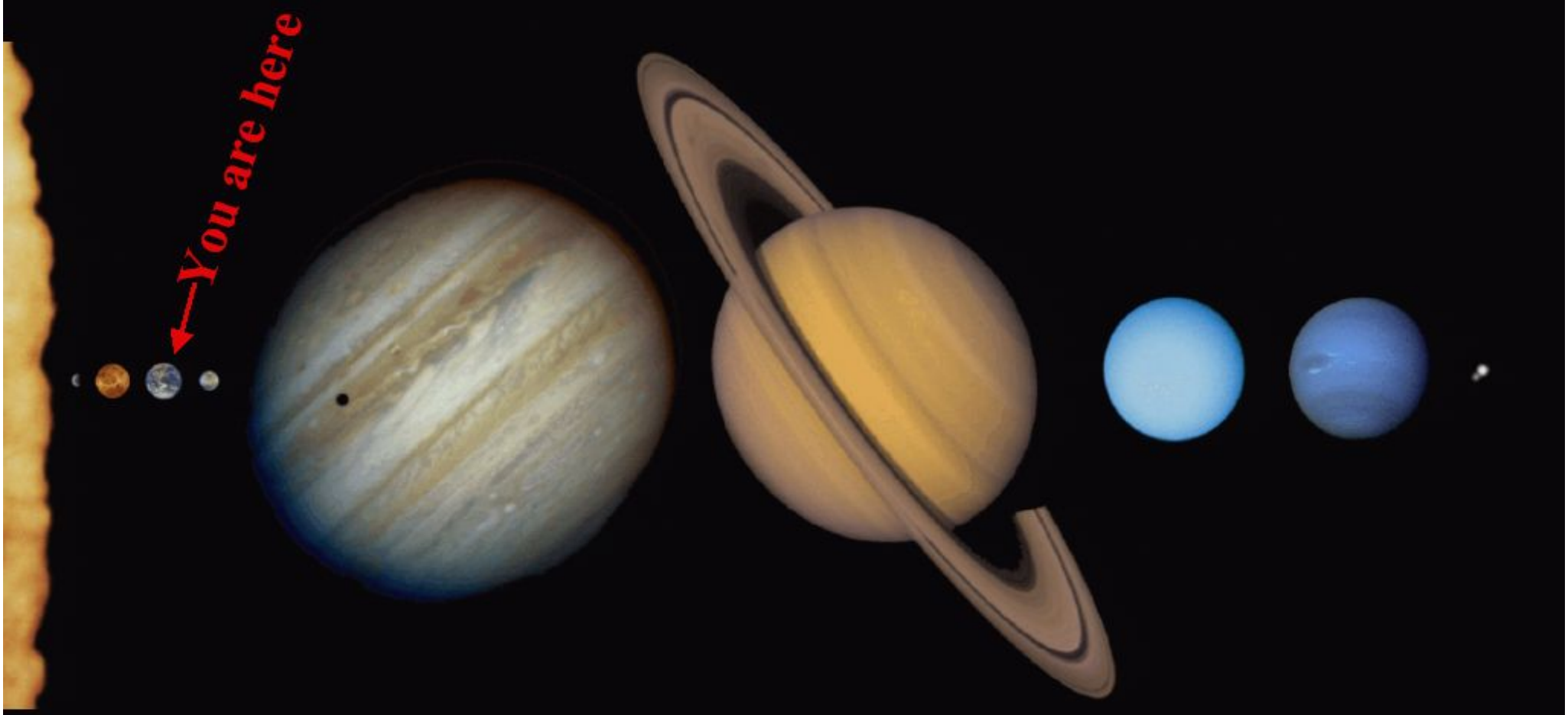
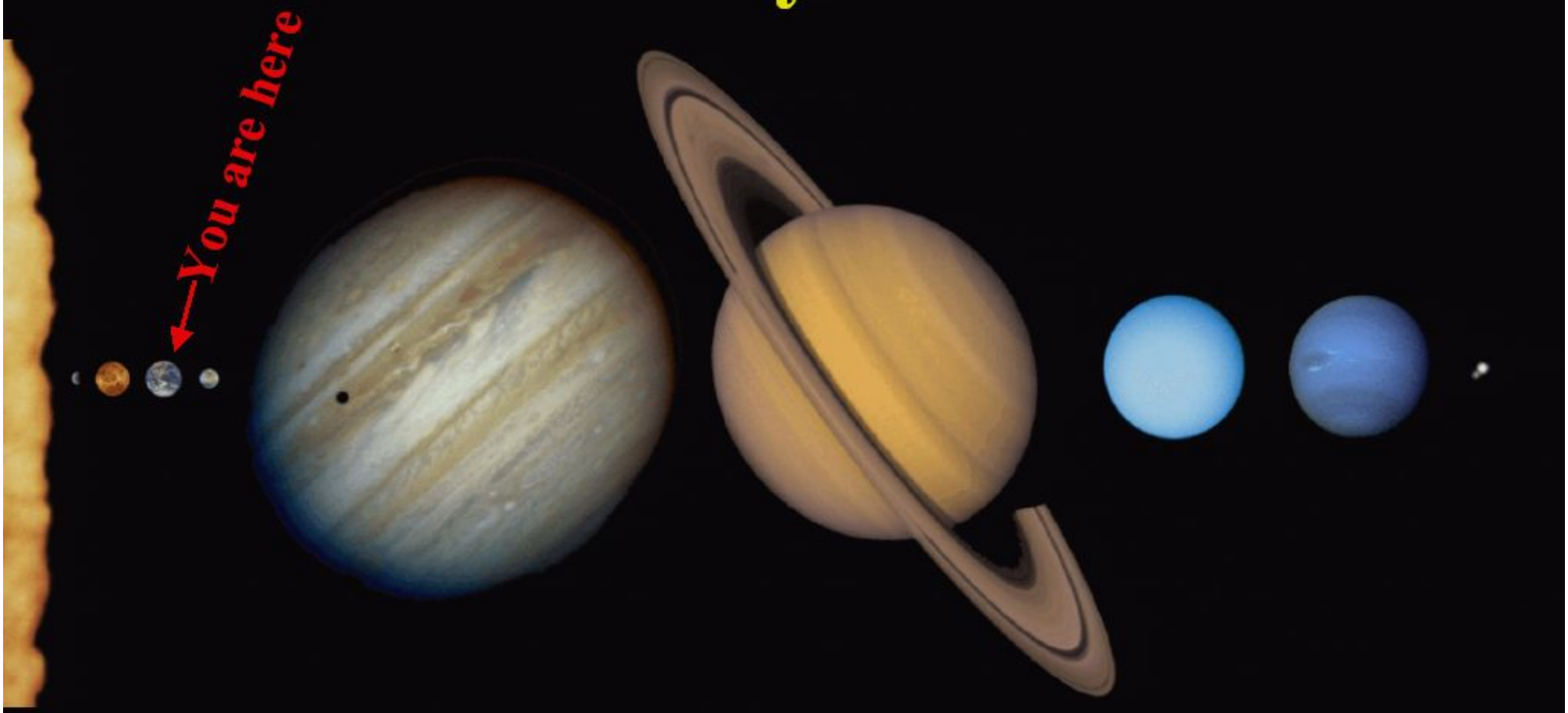
Life As We Know It Is A Planetary Phenomenon



Life As We Know It Is A Planetary Phenomenon

How Many Planets?



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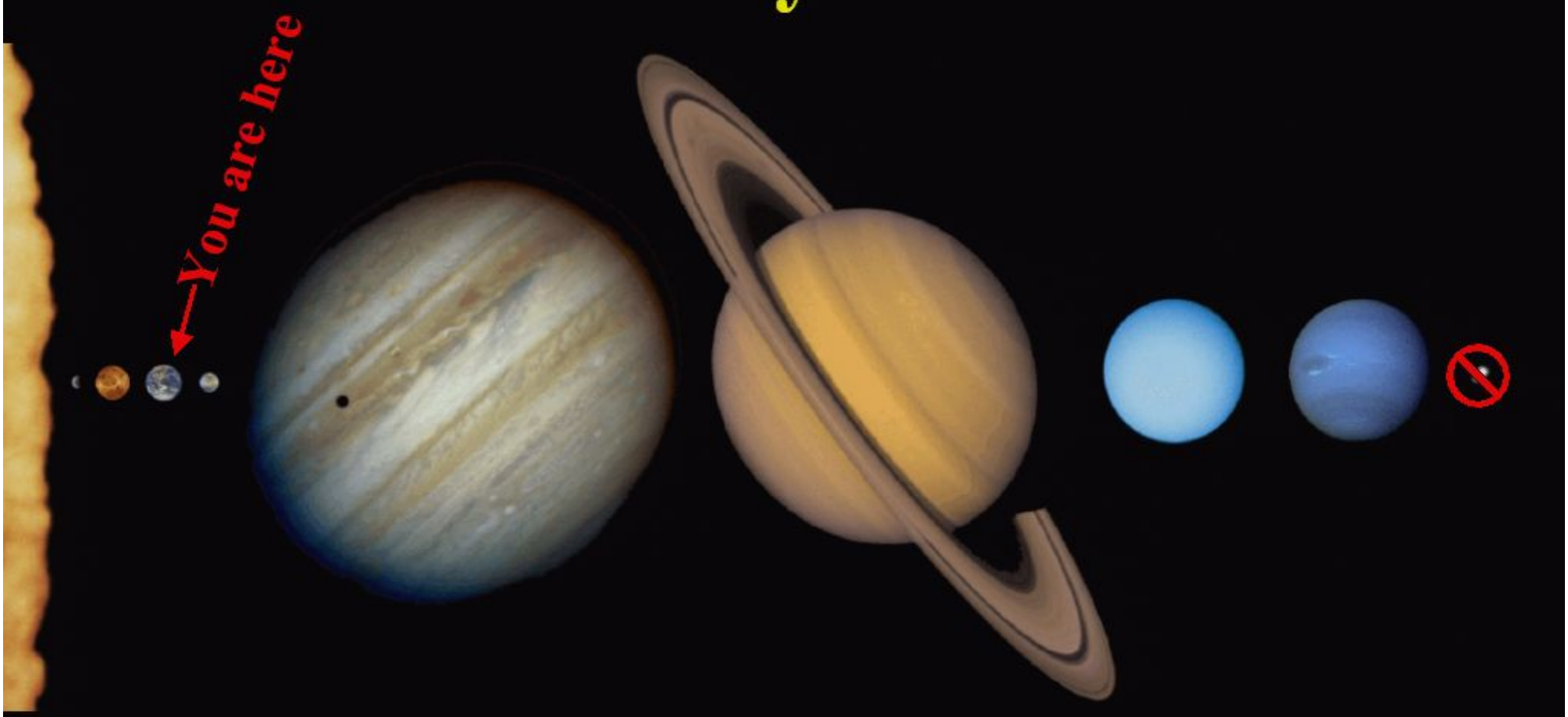
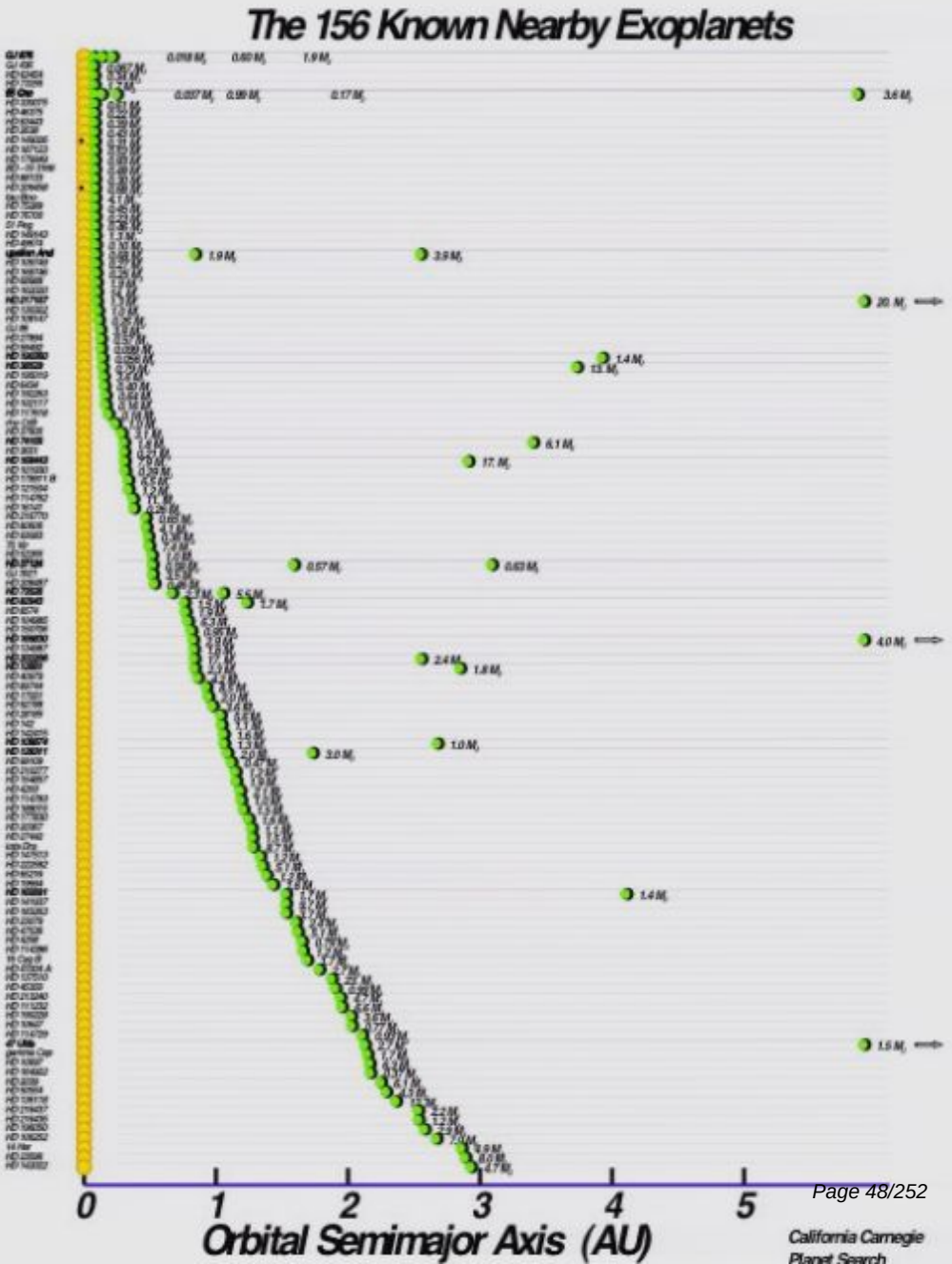
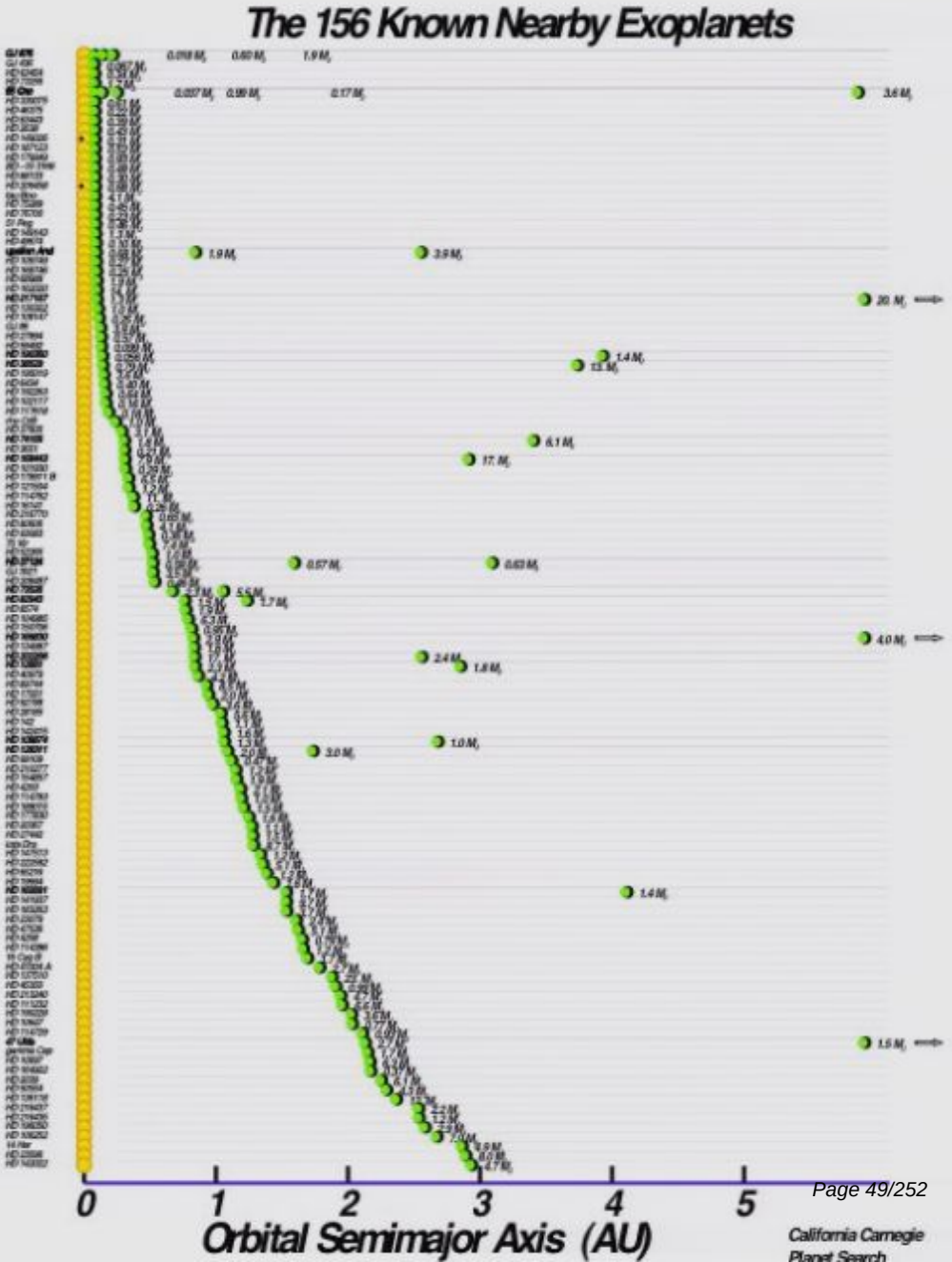


We Know That Other Stars Have Planets



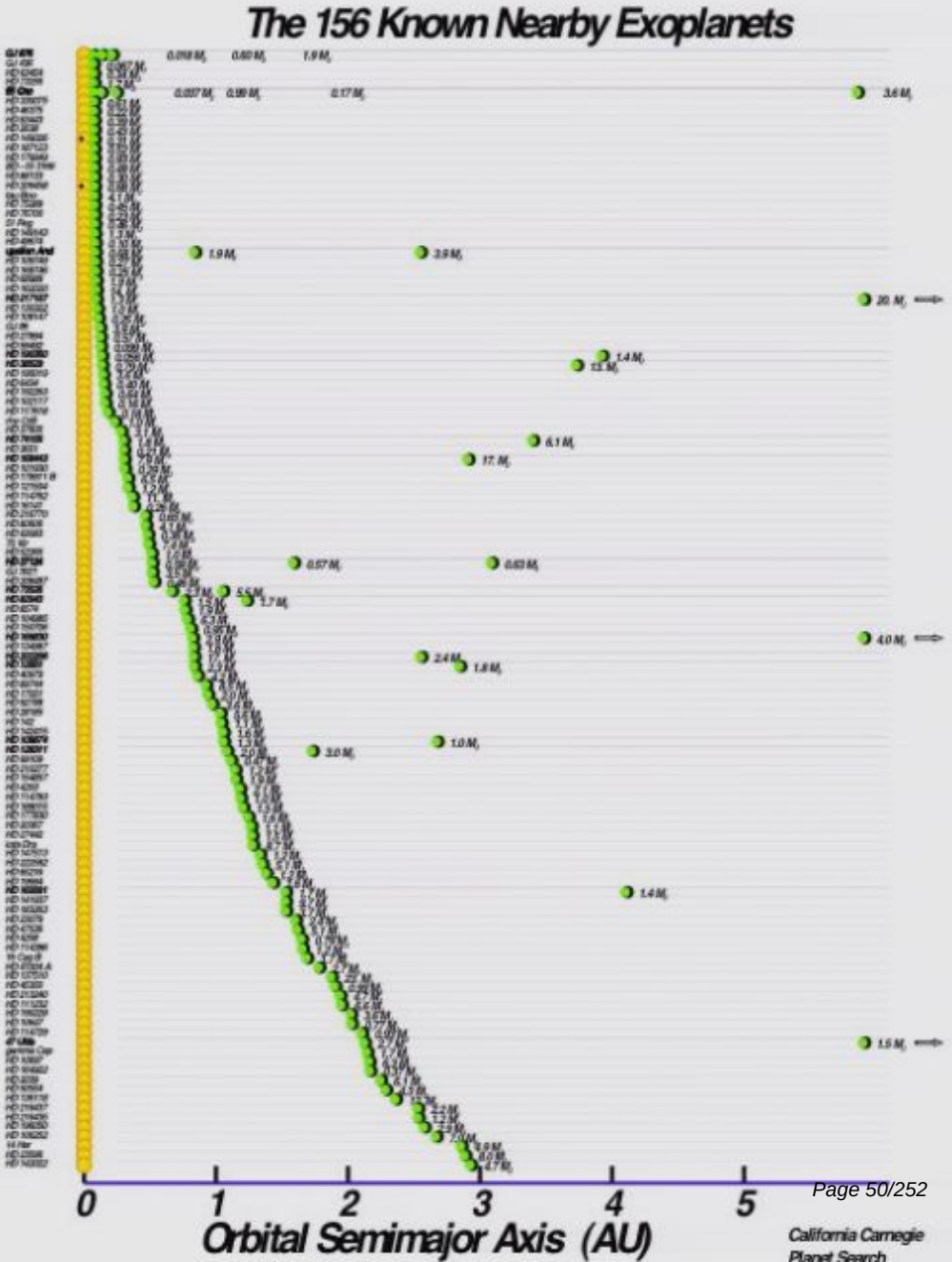
We Know That Other Stars Have Planets

✓ 211(+4) planets



We Know That Other Stars Have Planets

- ✓ 211(+4) planets
- ✓ 183 stars (+2 pulsars)



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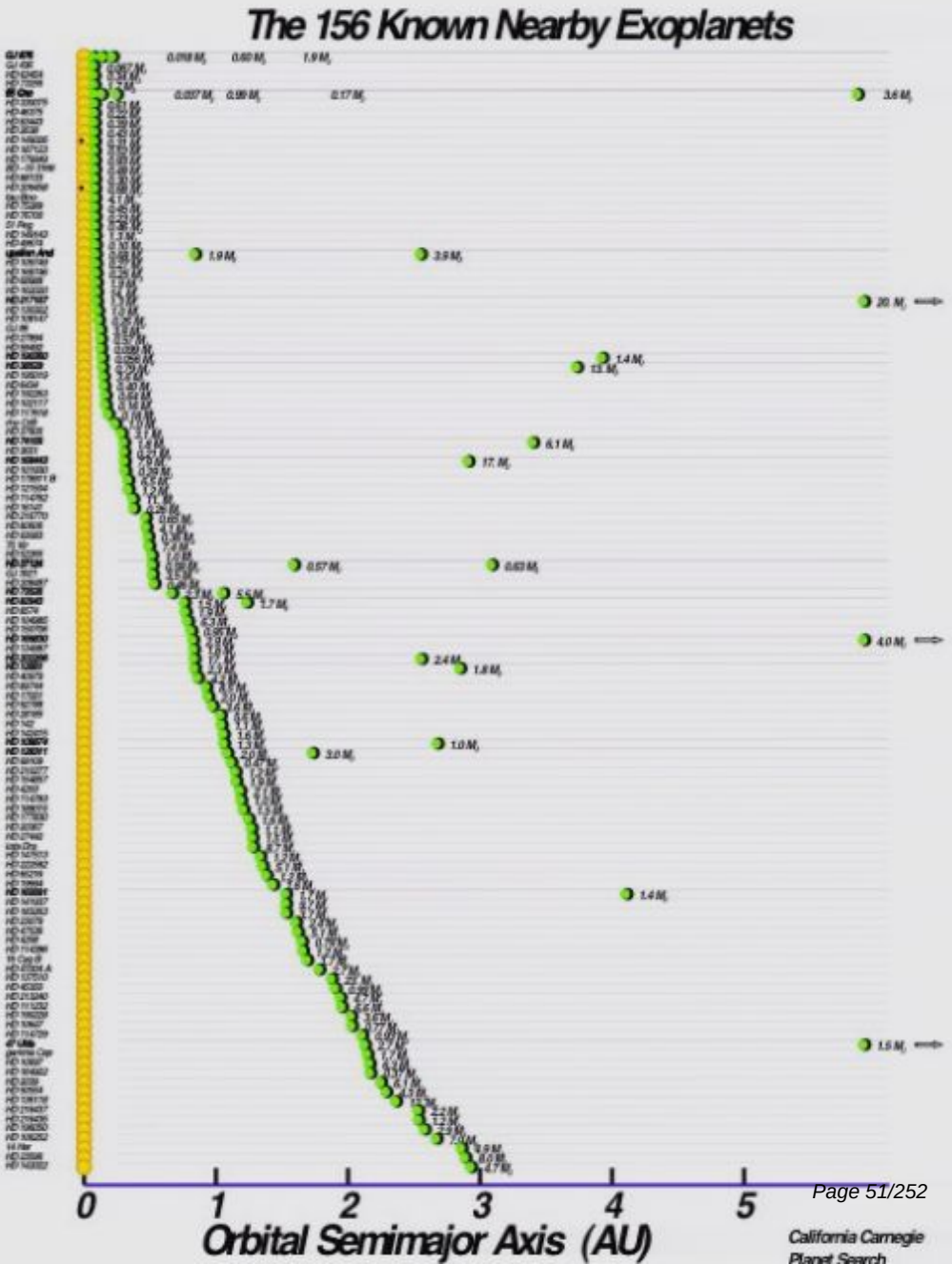

We Know That Other Stars Have Planets

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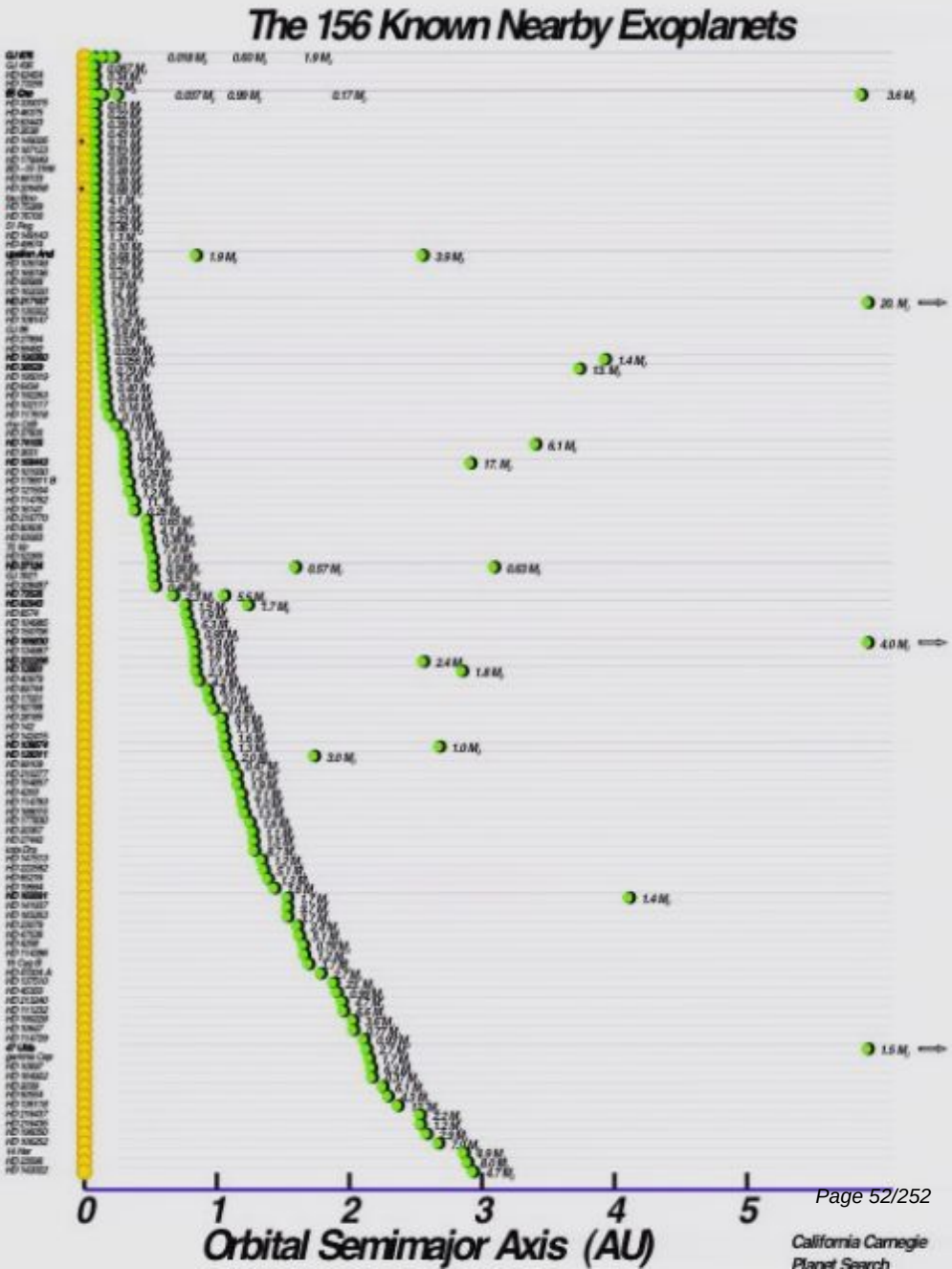
- ✓ Maybe the first image



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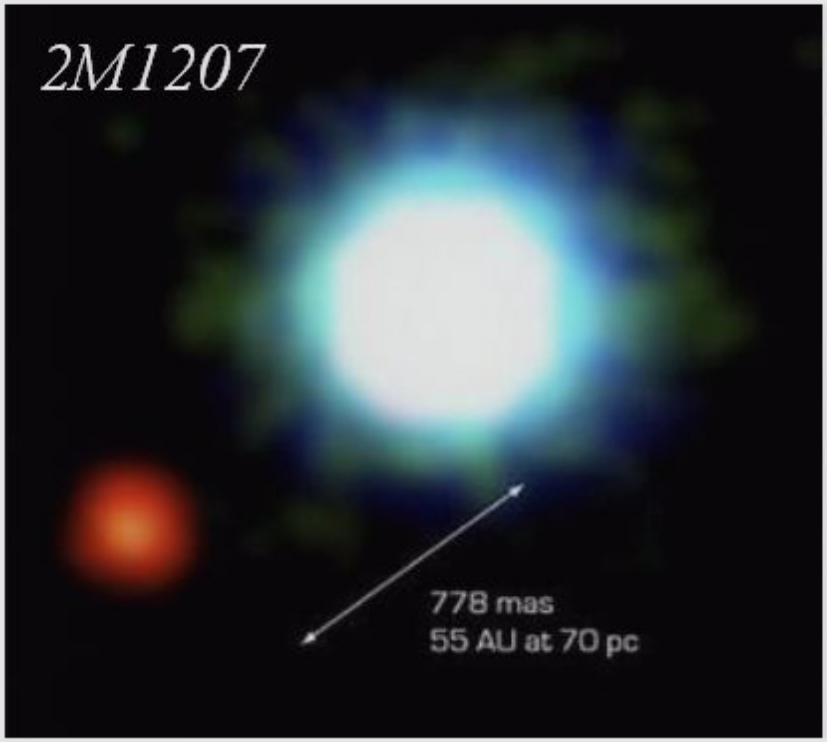

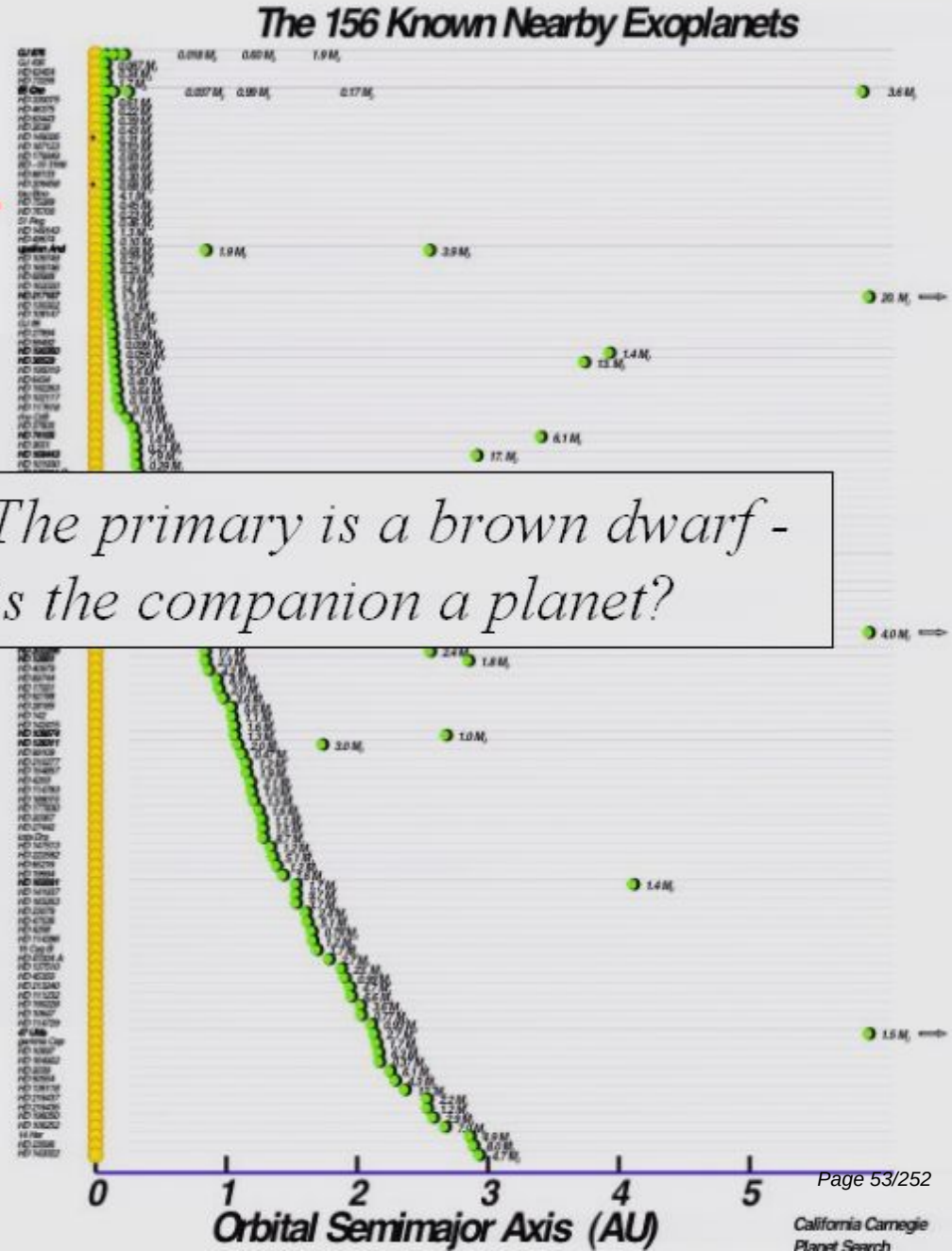

The primary is a brown dwarf - is the companion a planet?

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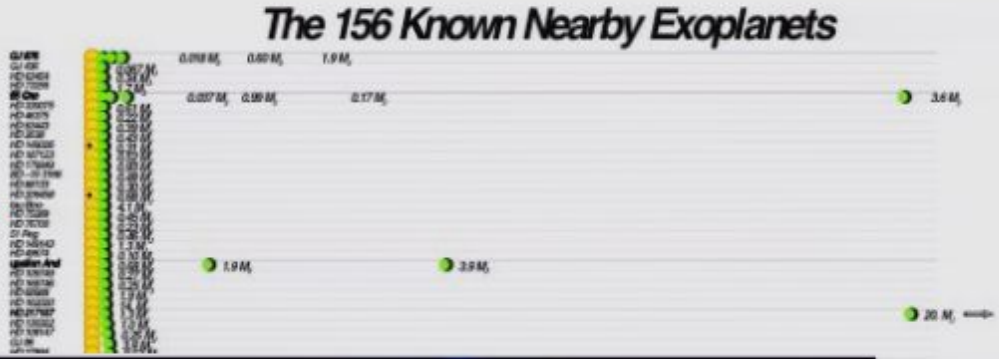
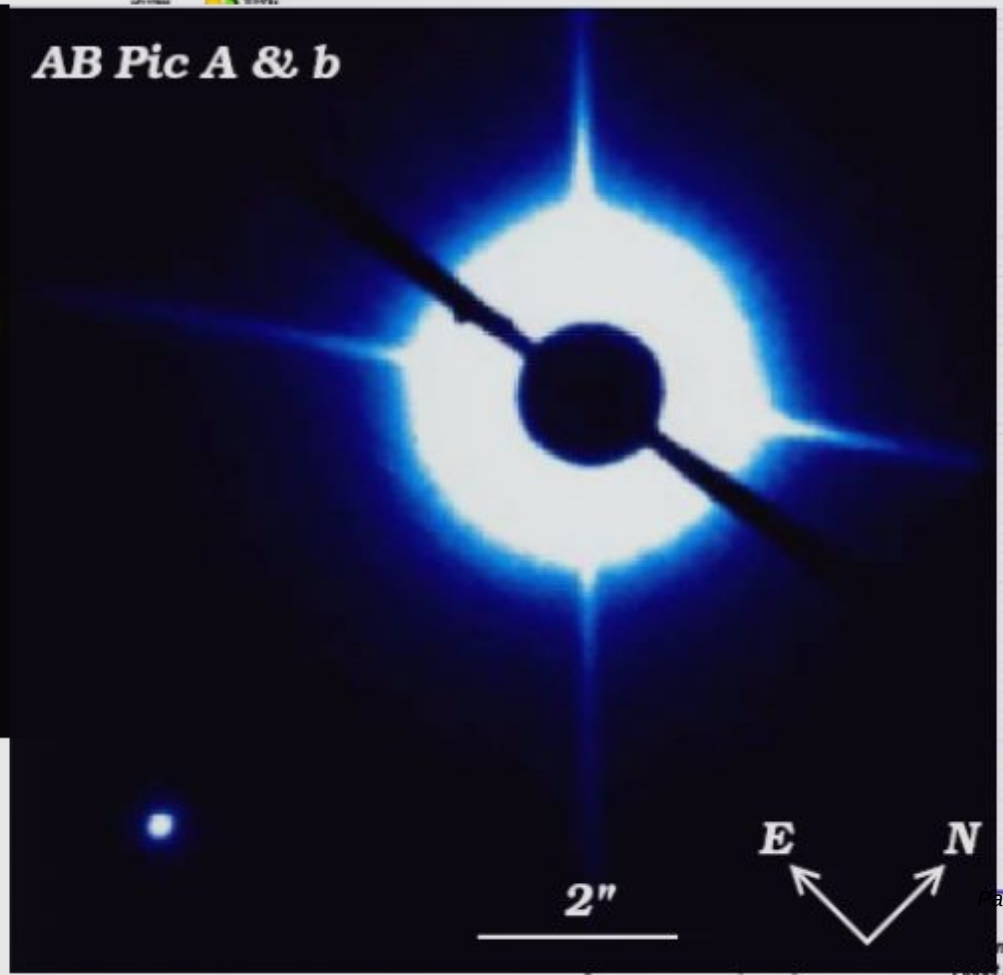
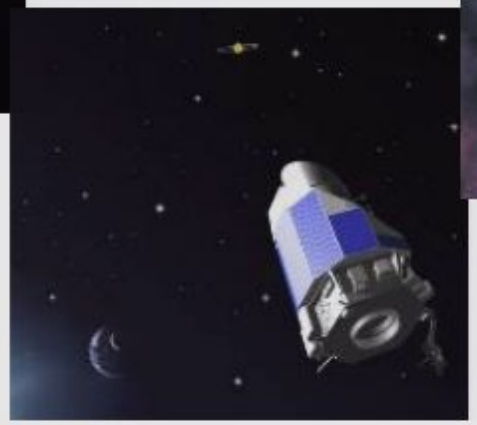




We Know That Other Stars Have Planets

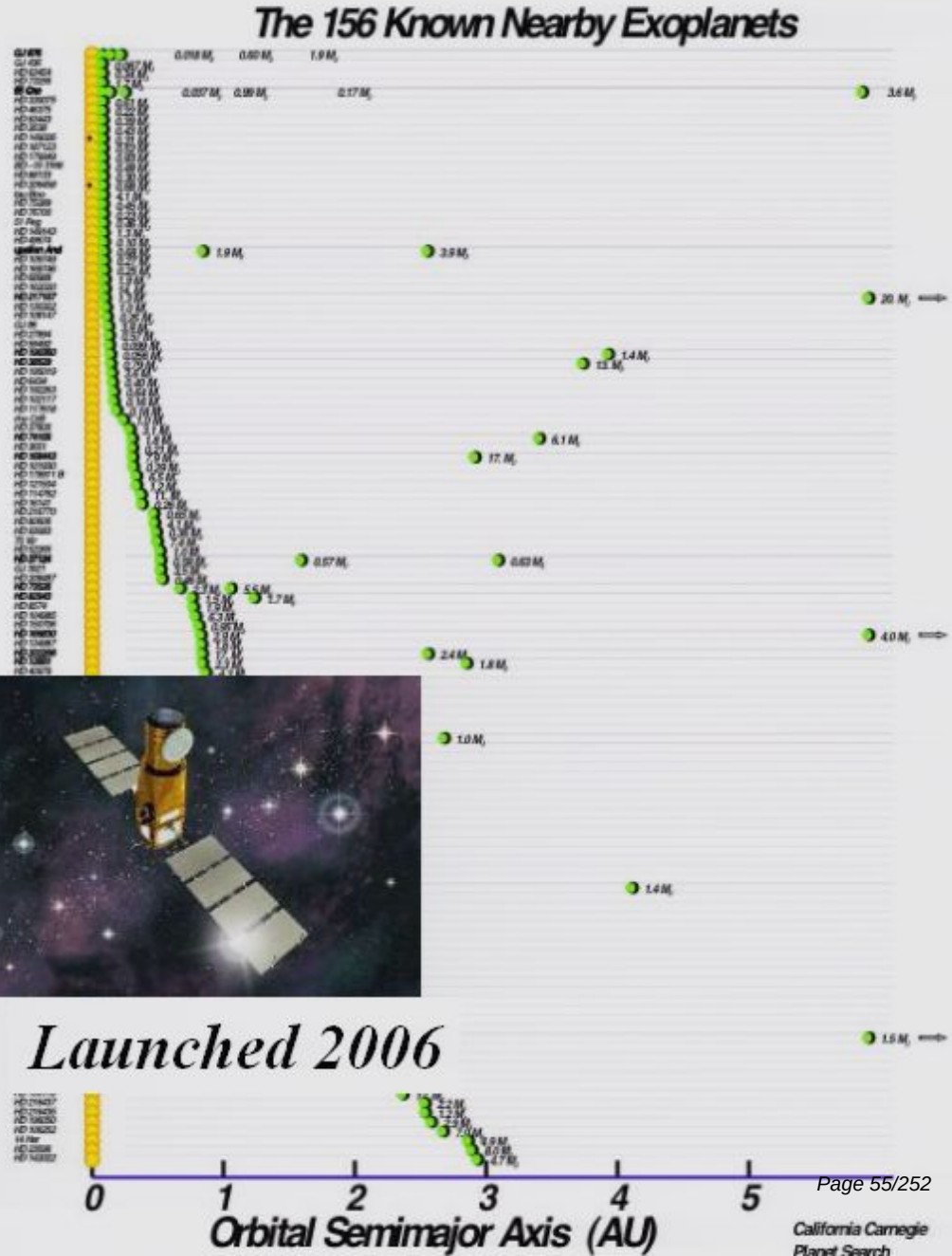
- ✓211 (+4) planets
- ✓183 stars (+ 2 pulsars)
- ✓Indirect detection (no image)
- ✓ No solar system analogs, yet

Detecting Earth size planets is a job for Kepler and Corot



Launch 2008

Launched 2006



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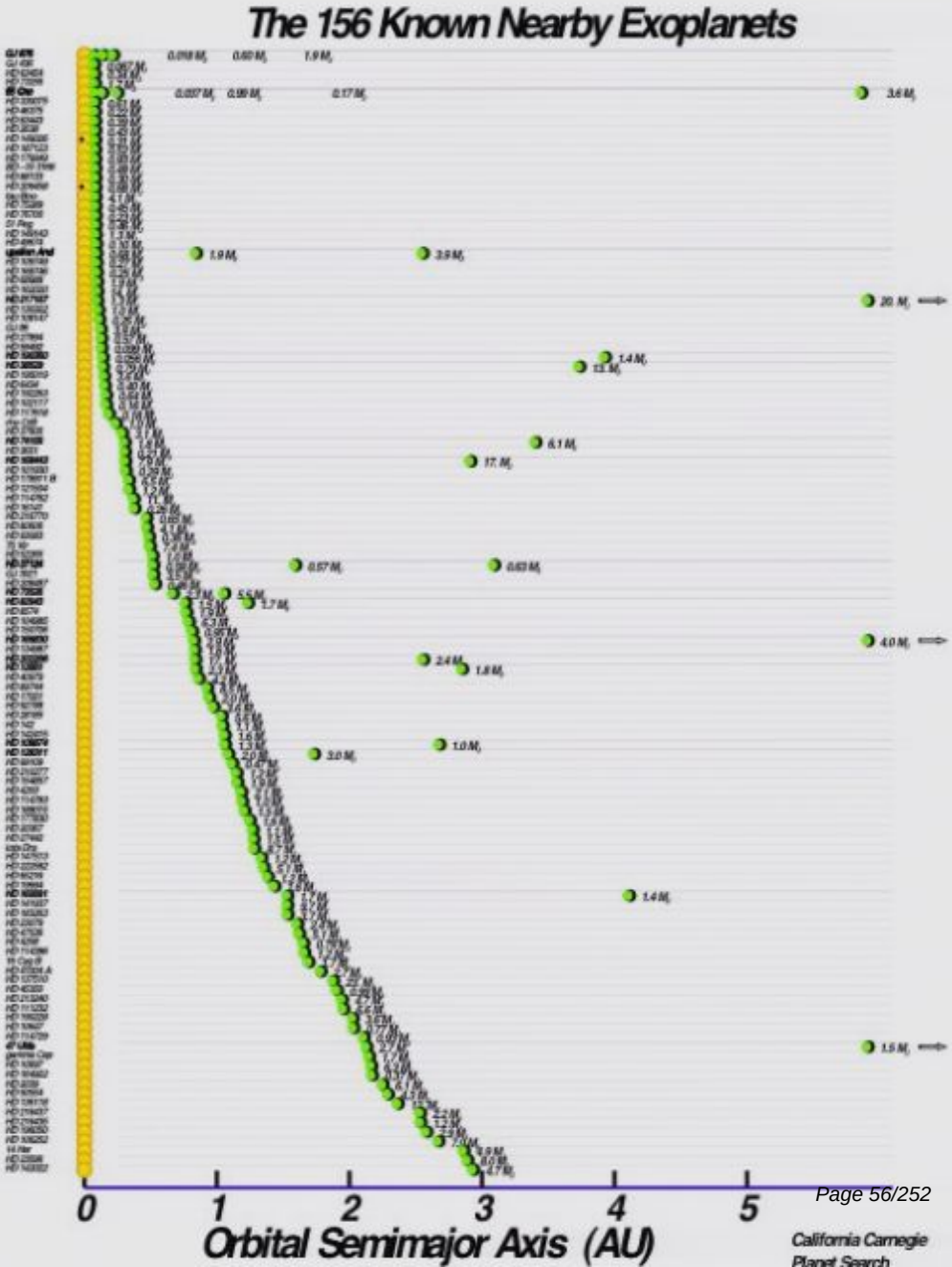

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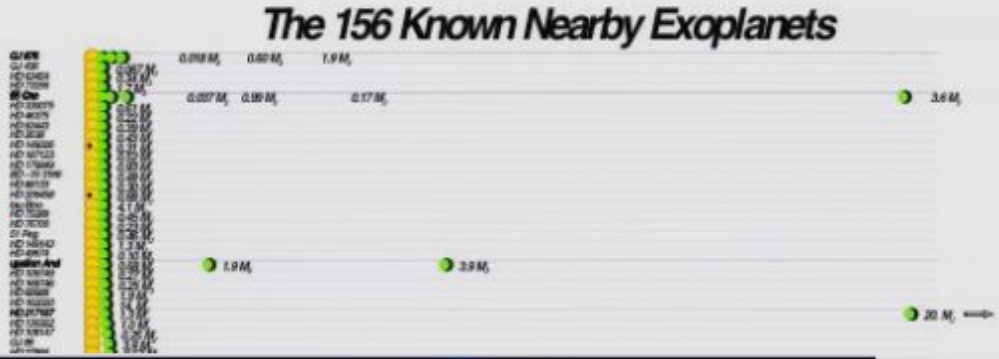

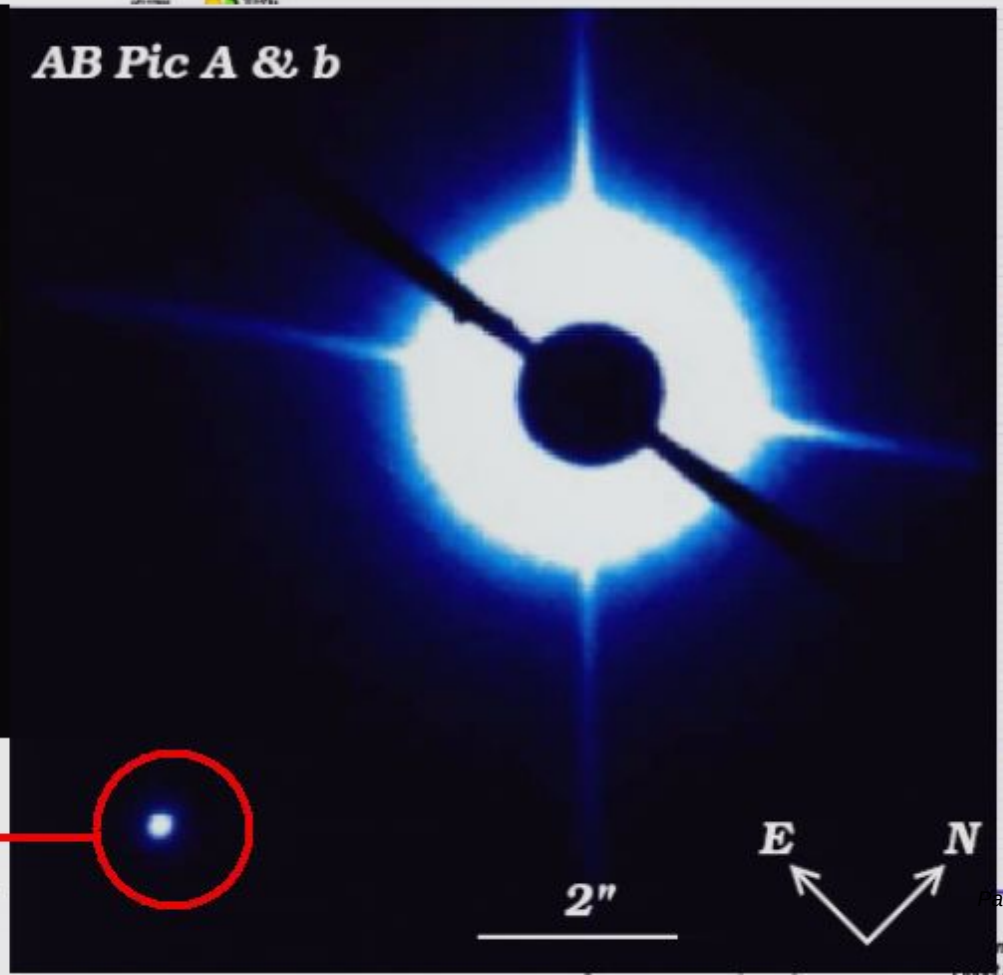

Mass = 13-14 M_{Jup}

may be a Brown Dwarf

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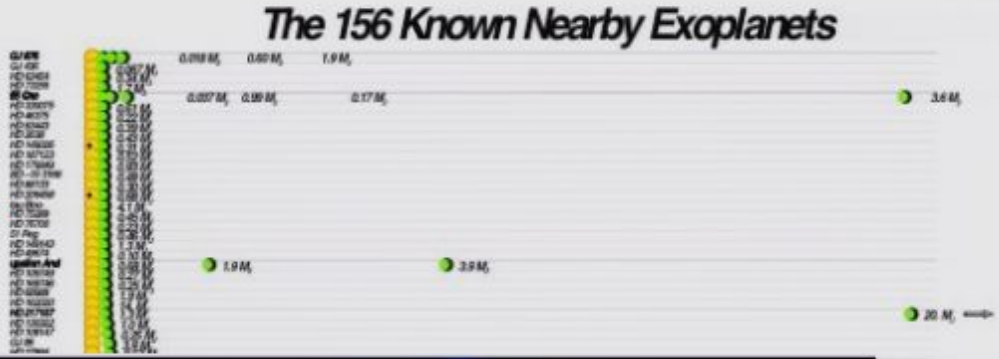

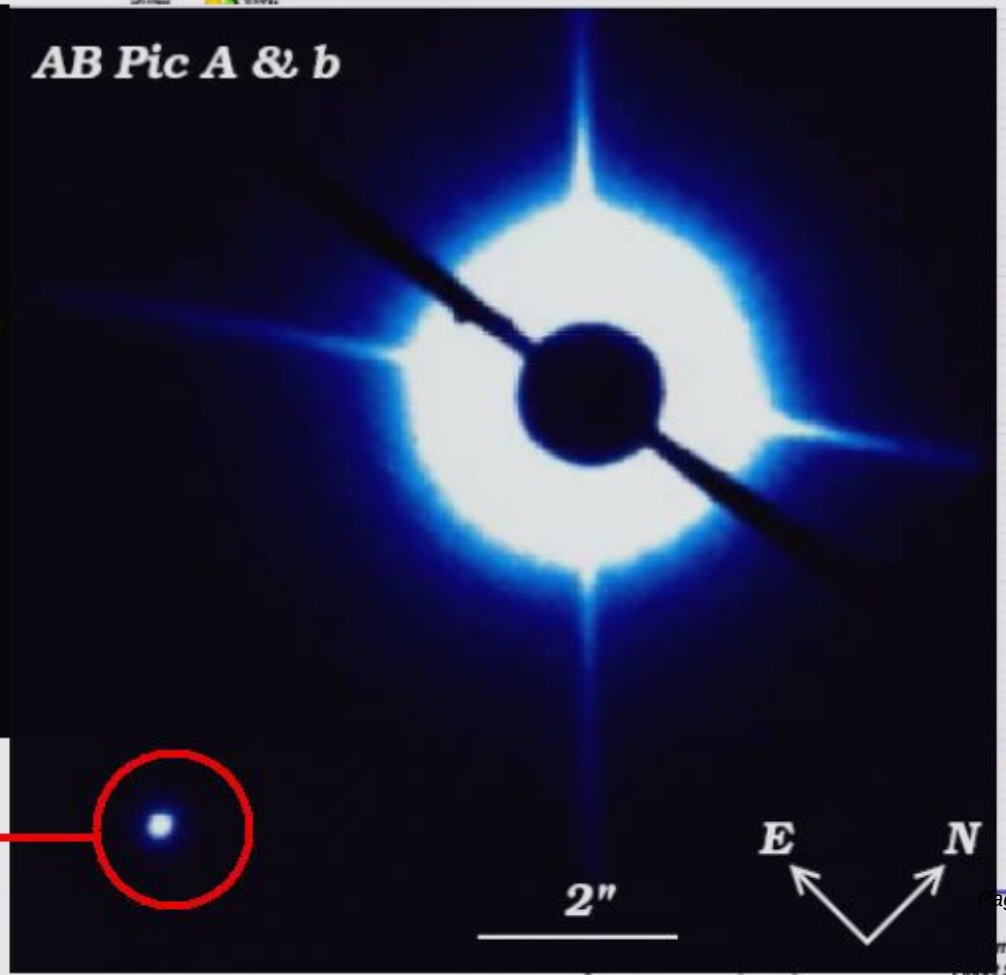

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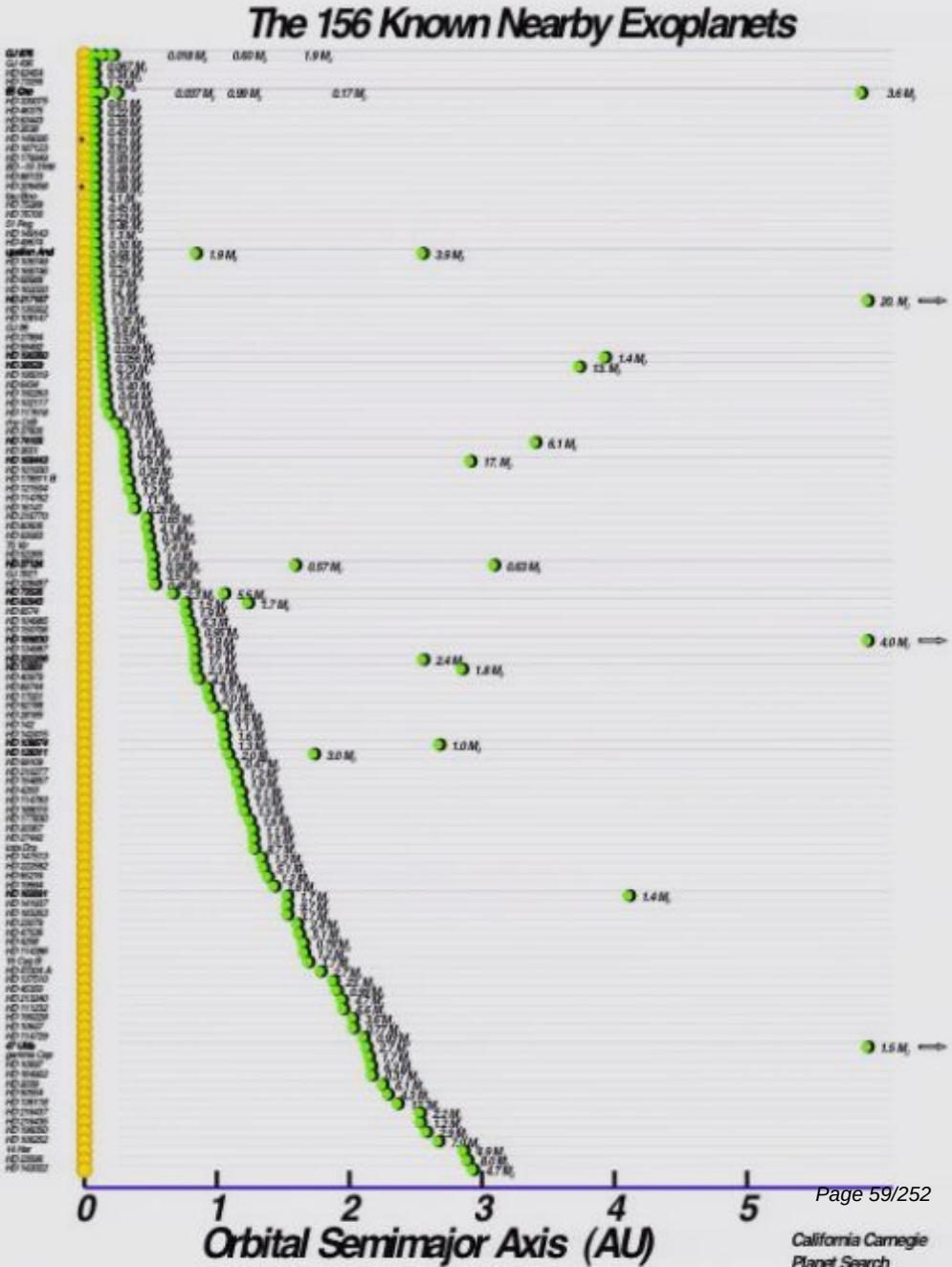

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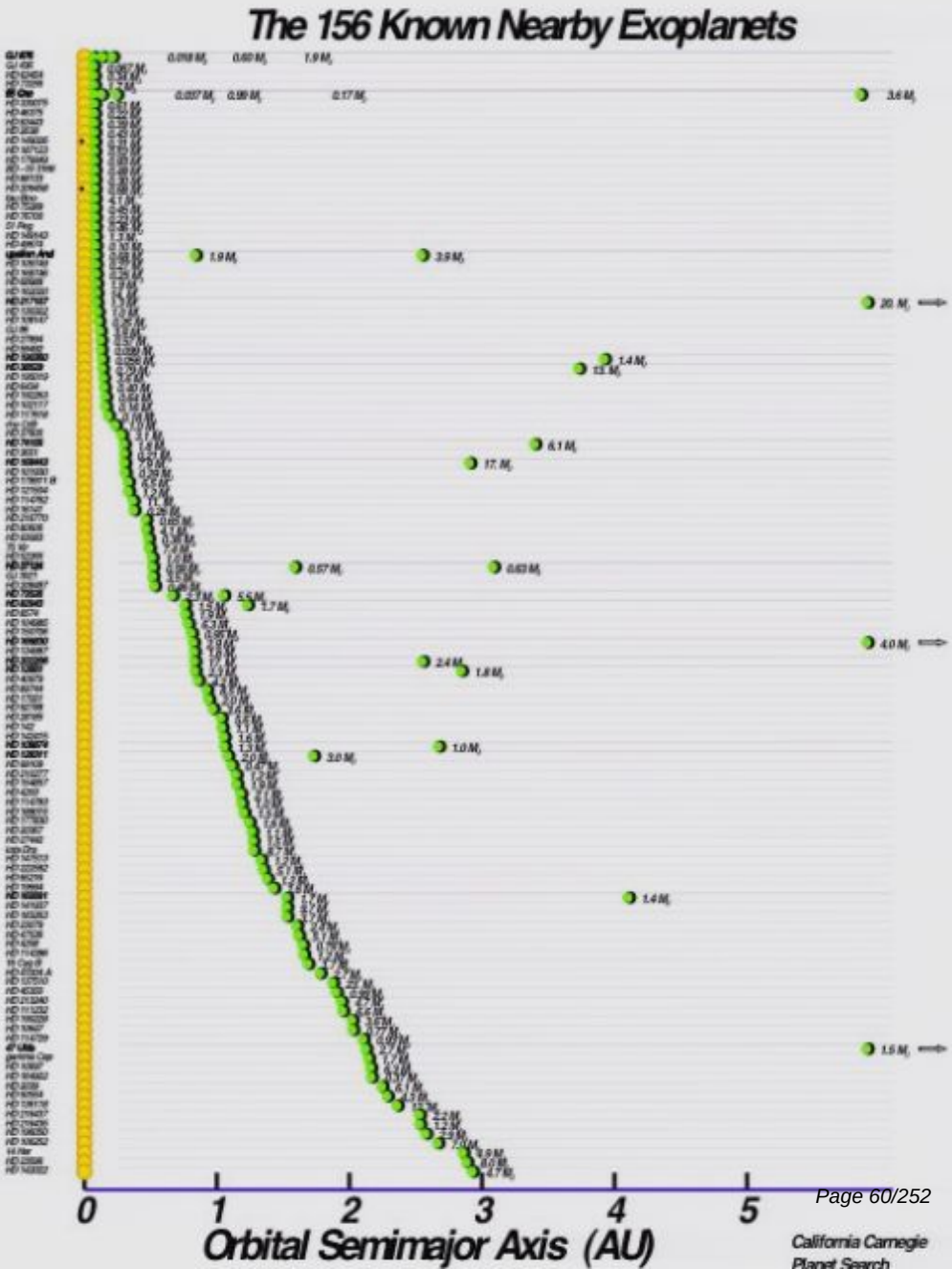

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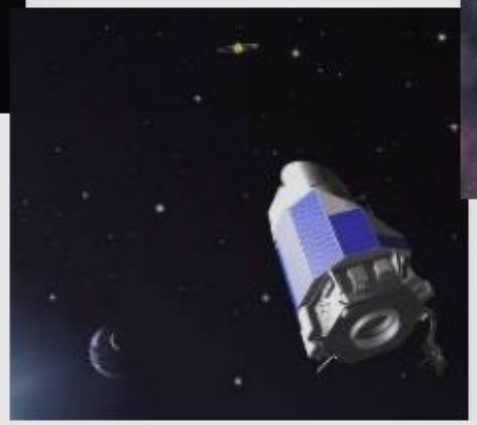
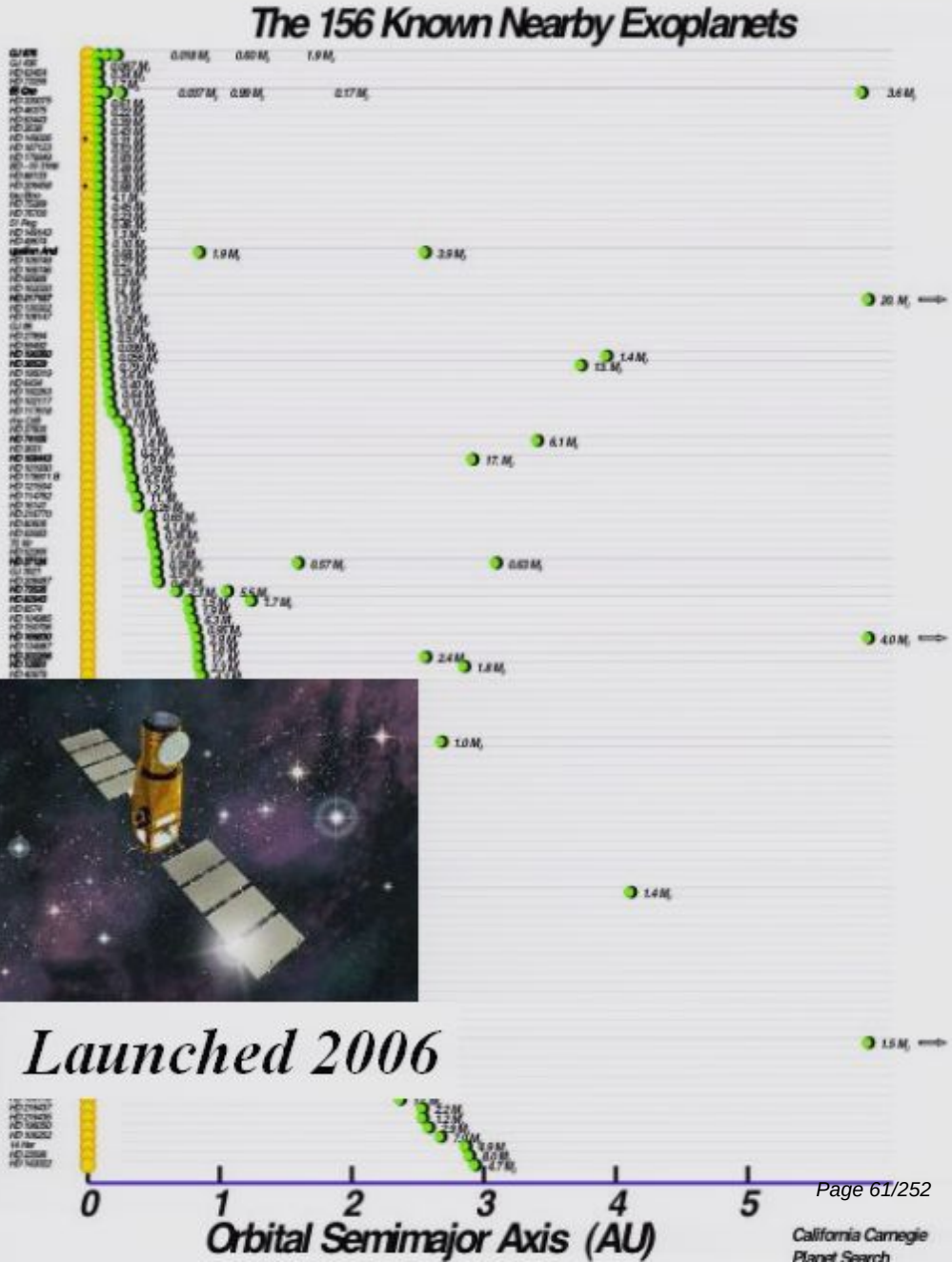


Launch 2008

Launched 2006



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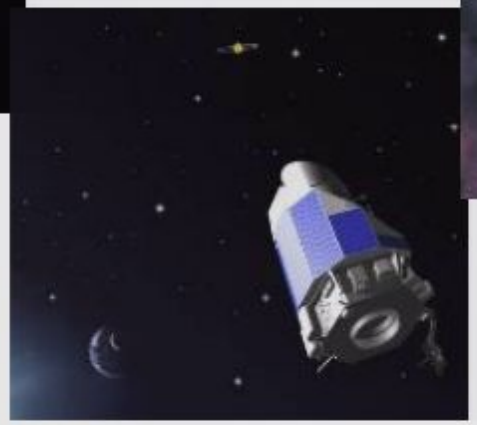

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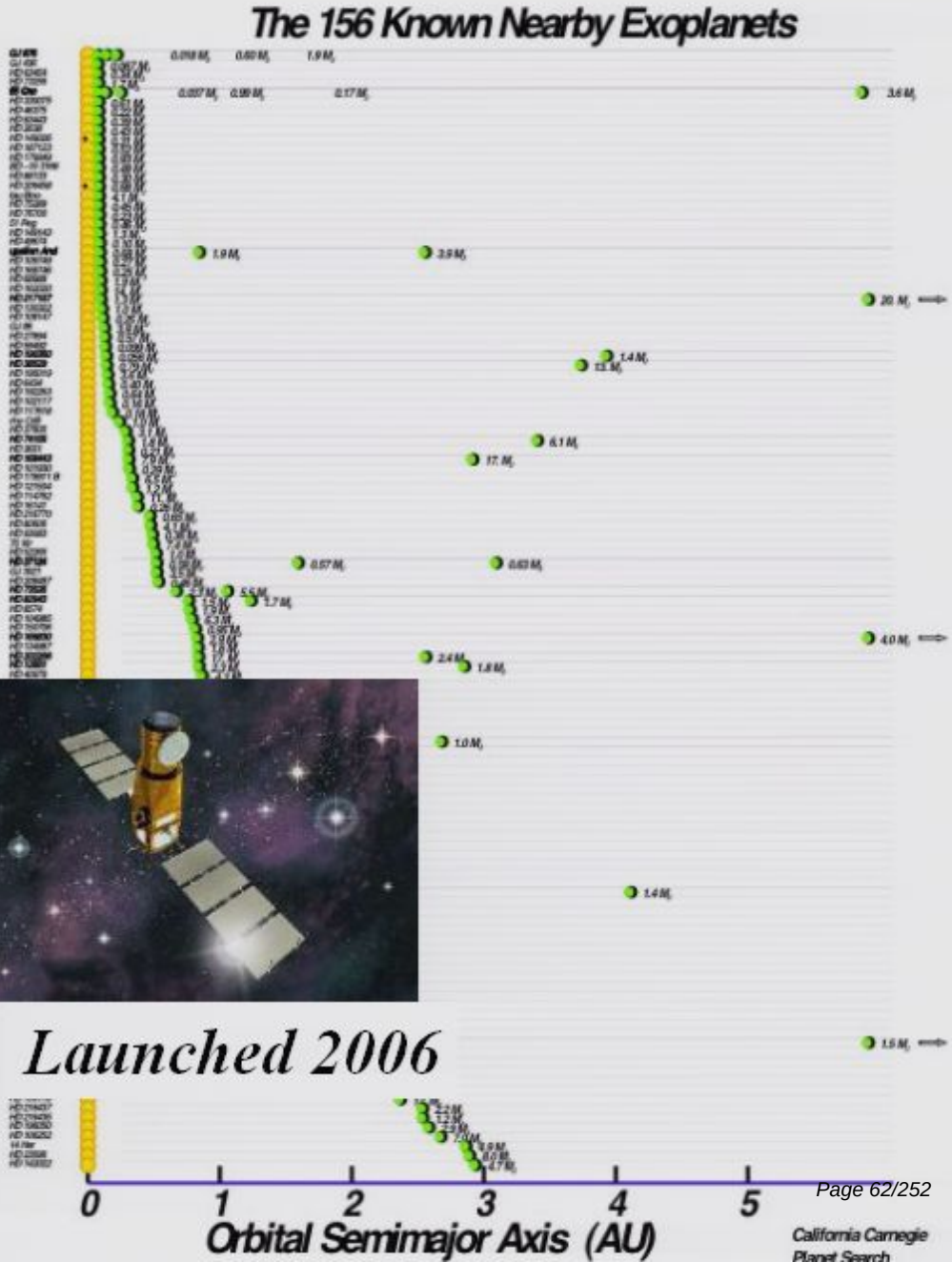

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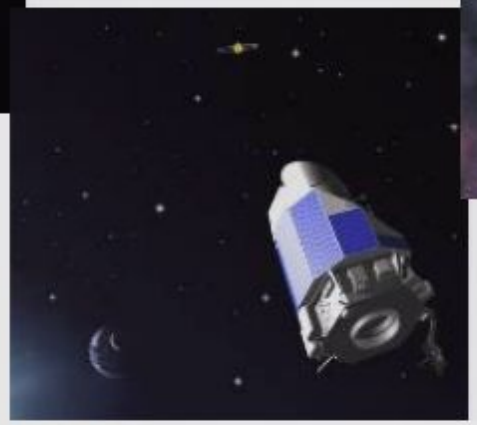

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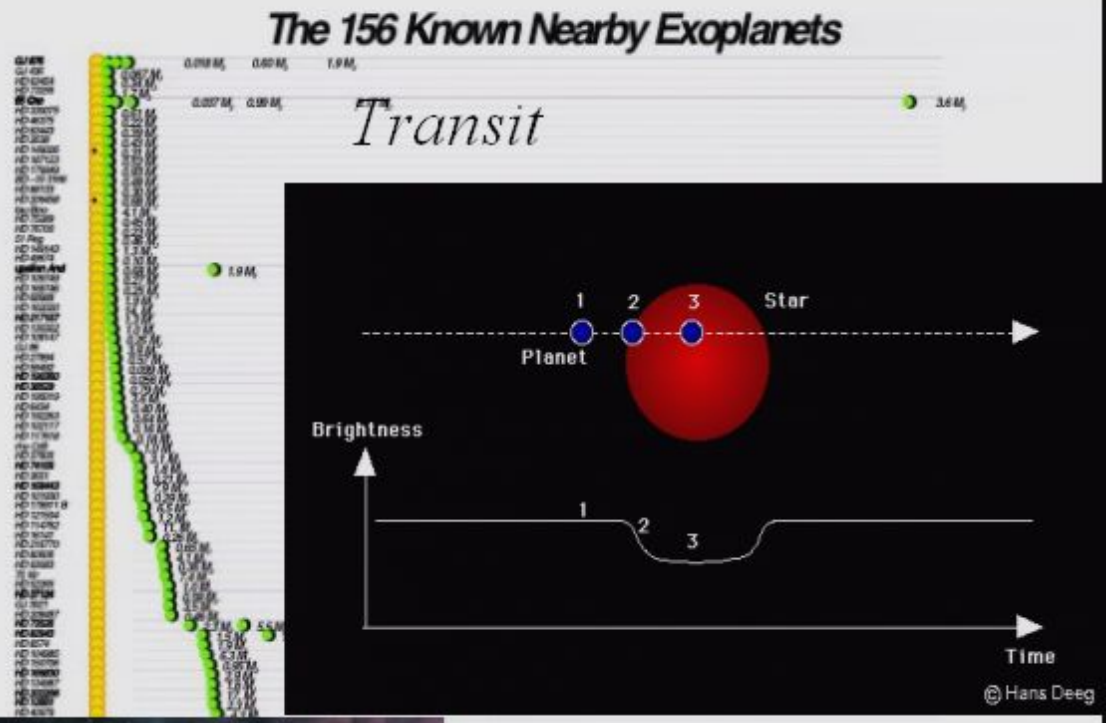

Good Planets Are Hard To Find

One

Good Planets Are Hard To Find

One

Among billions?

Looking For Life

- Solar System Exploration
  - NASA & ESA
  - Mars Spirit & Opportunity

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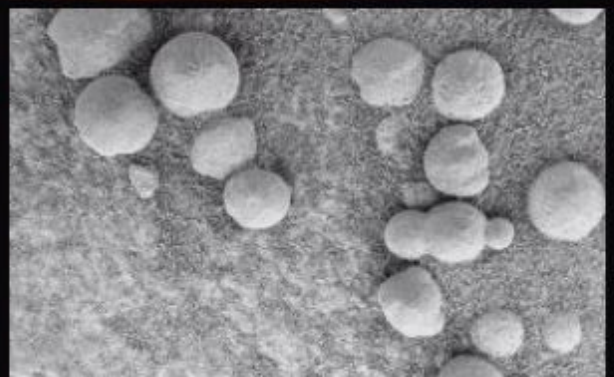

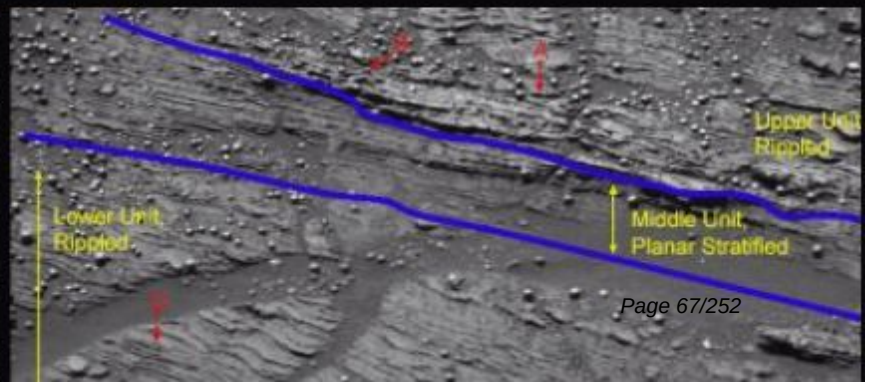

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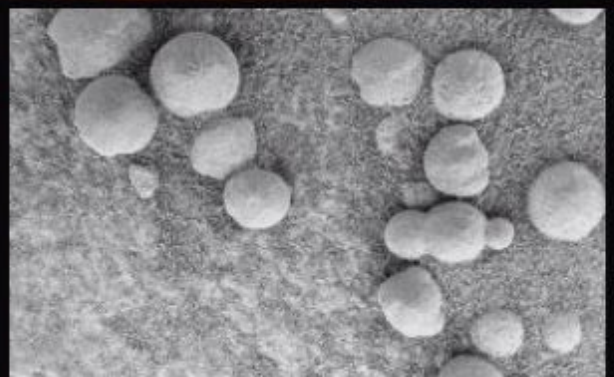
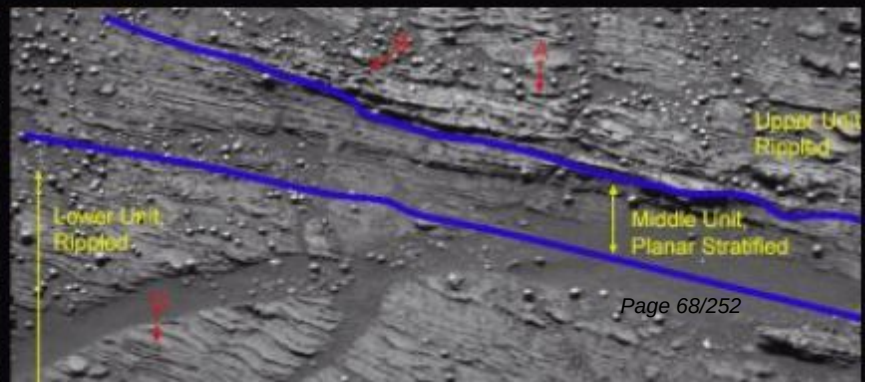
Follow the water





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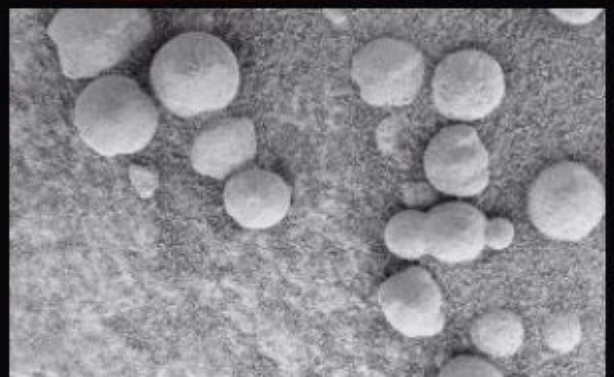

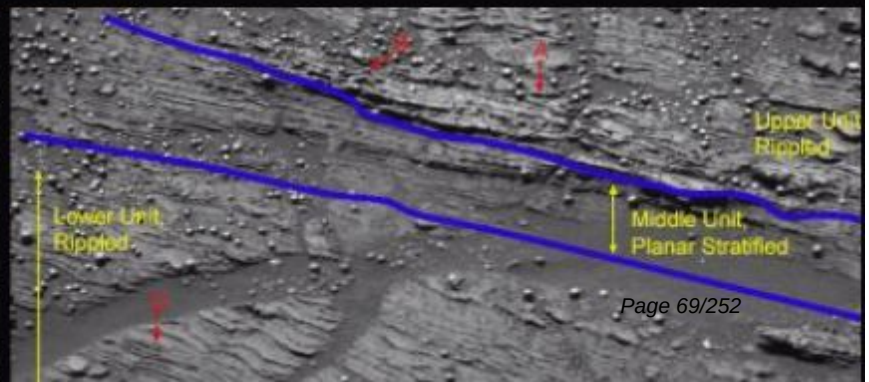

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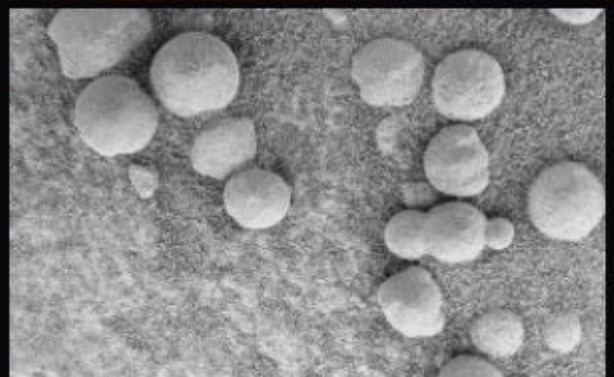

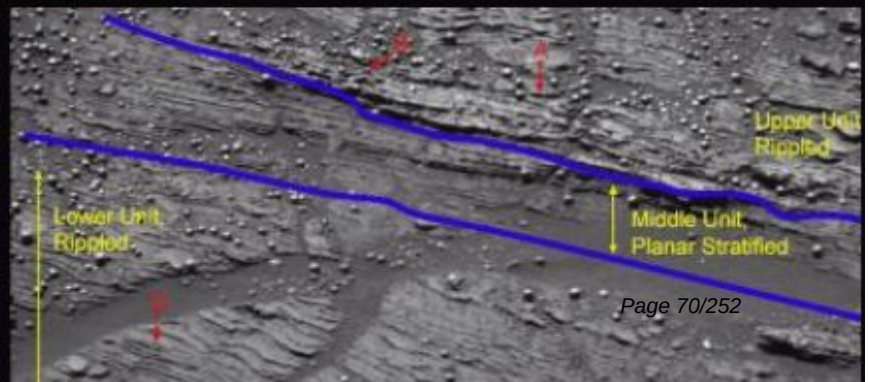

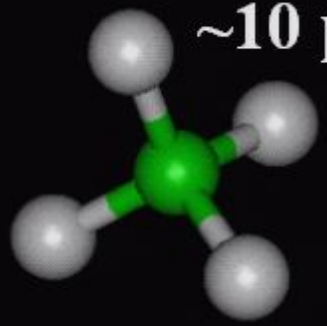

~10 ppb methane in Martian atmosphere?????

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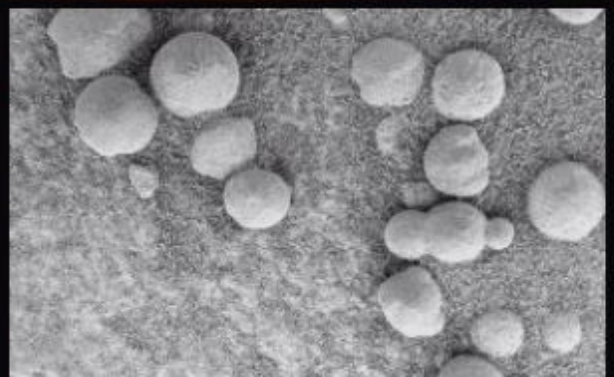

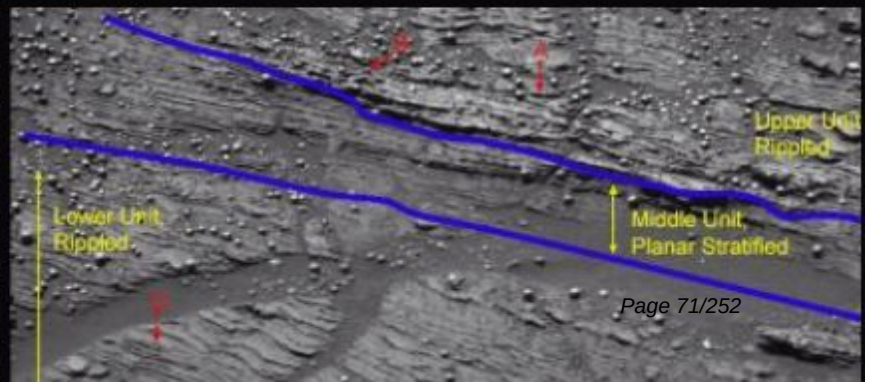

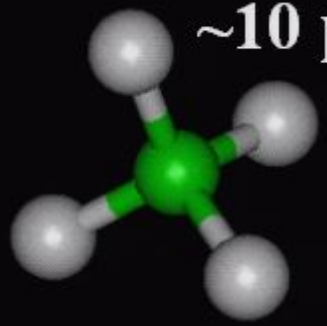

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Looking For Life

MRO

Mars Science Lab

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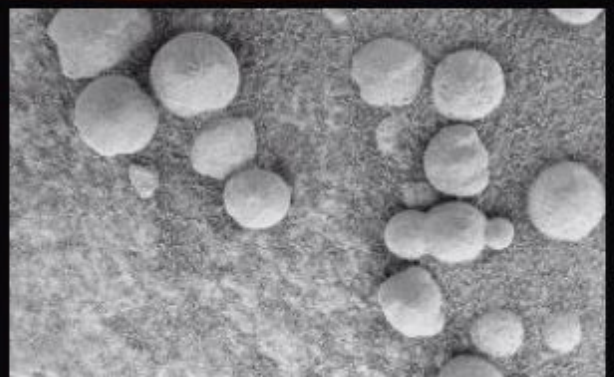
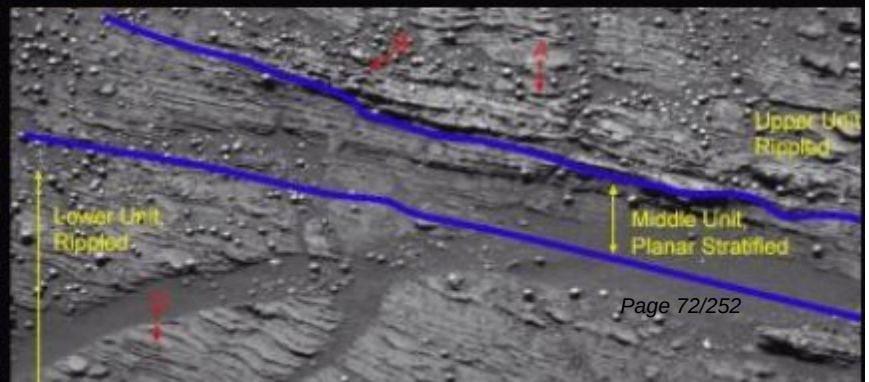
  - Mars Spi

Follow the water





MRO
Middle Unit
Planar Stratified

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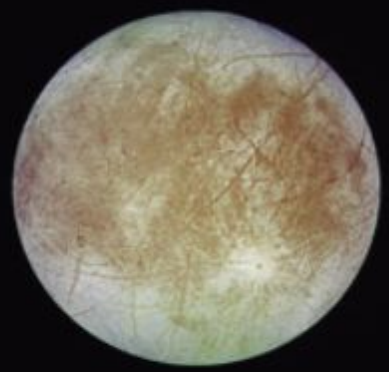
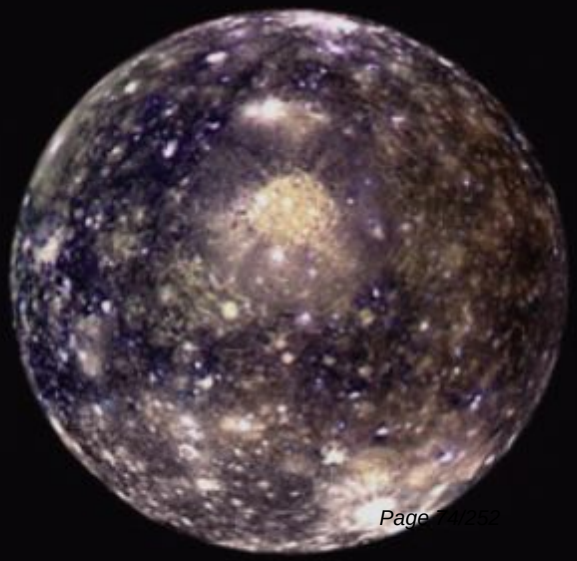


Europa

Ganymede



Callisto

Looking For Life

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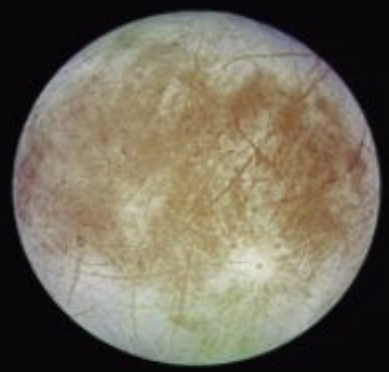
Enceladus



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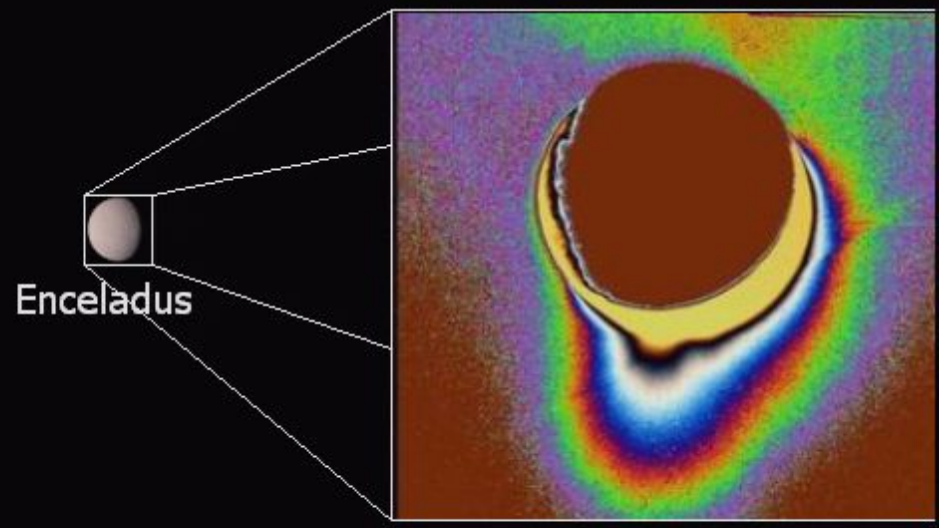

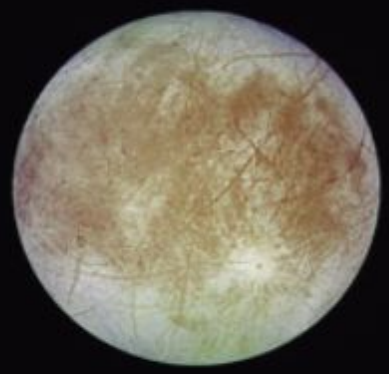

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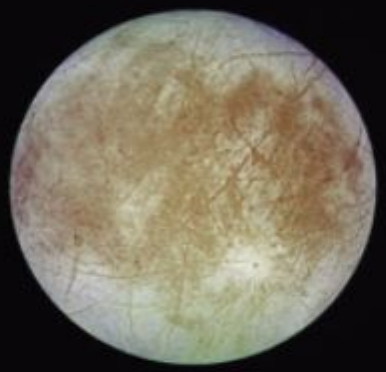
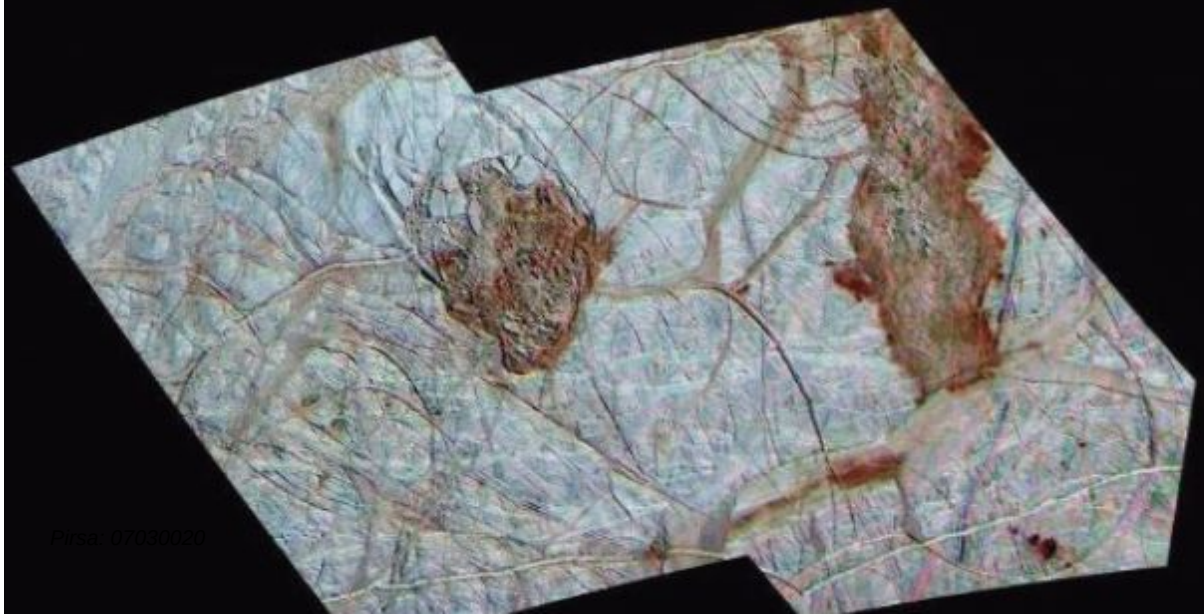


Europa

Earth's Moon



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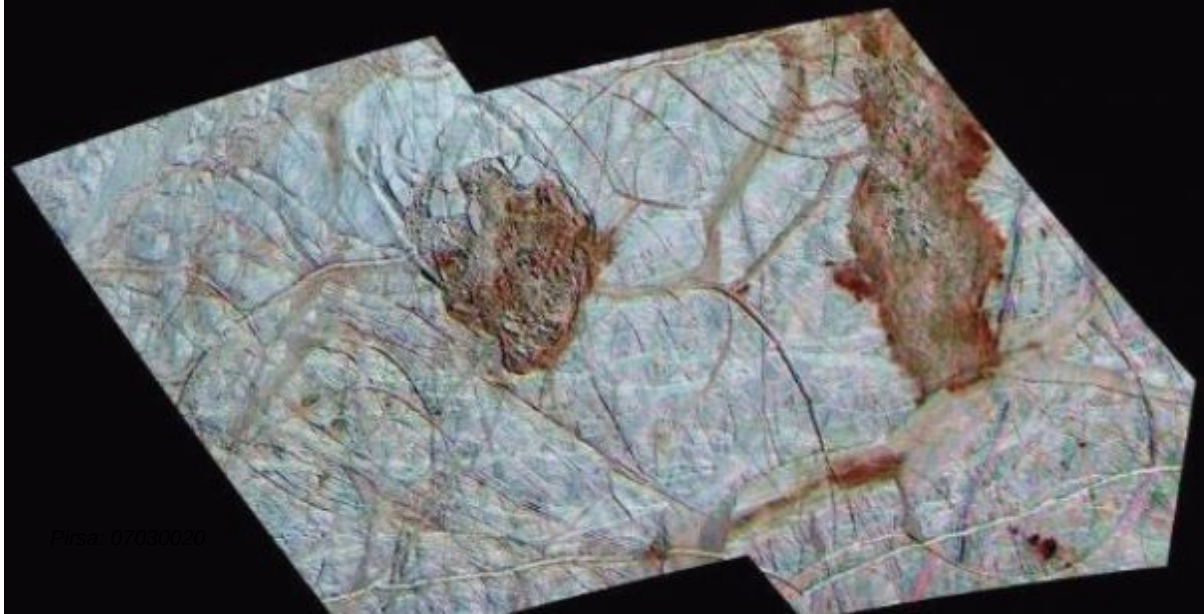

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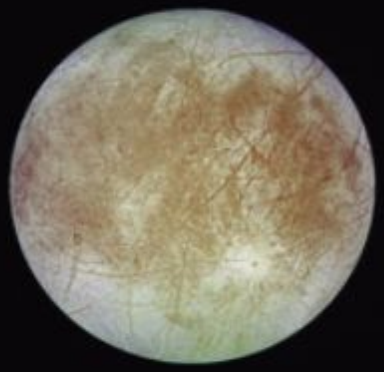

Enceladus

Europa

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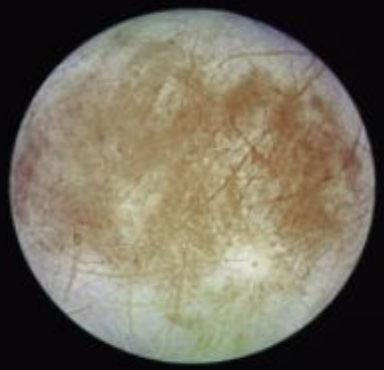
Finding a second genesis in our solar system would greatly strengthen the arguments for the ubiquity of life in the universe!



Enceladus

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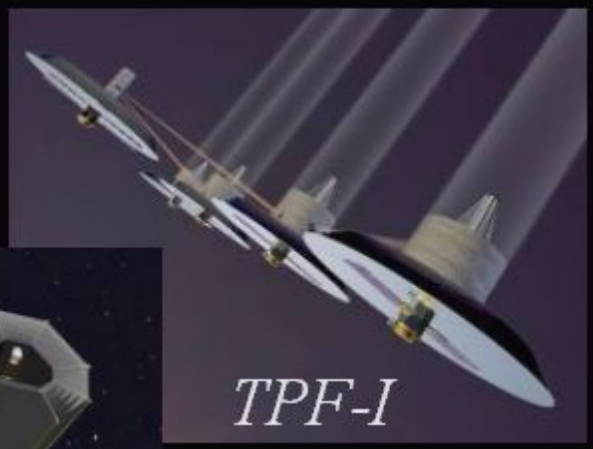
Looking For Life Near Other Stars

- Single-pixel images of terrestrial exoplanets
- Chemical assay of their atmospheres



NASA
Terrestrial Planet Finder

ESA
Darwin

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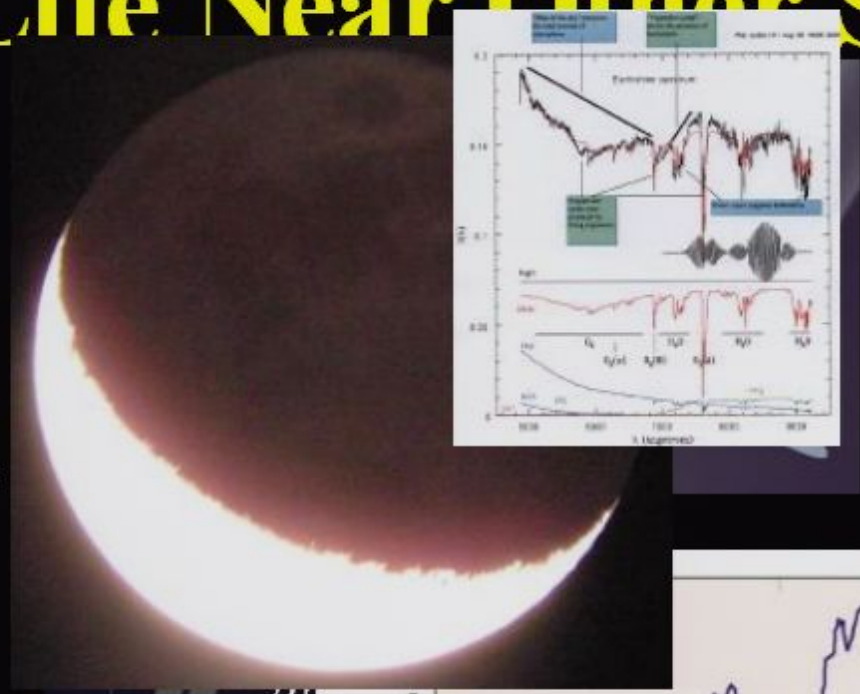
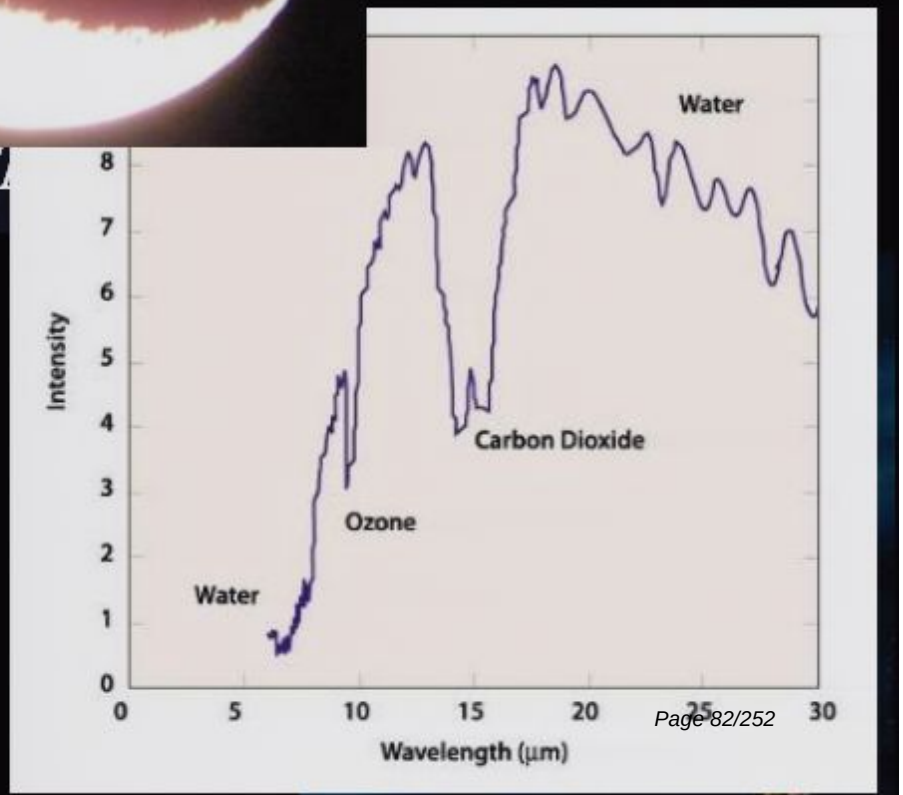


NASA Terrestrial Planet

Biosignatures



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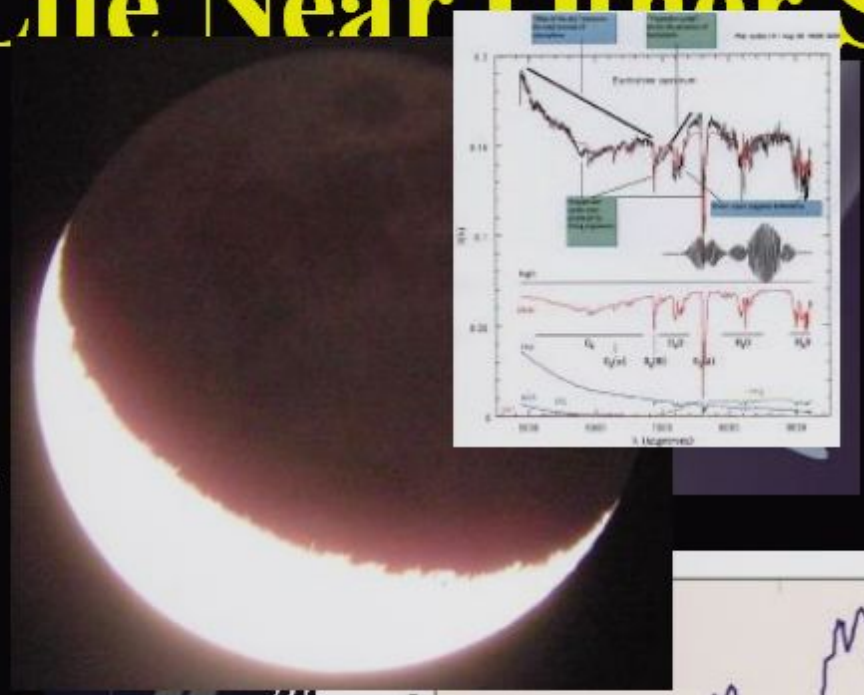

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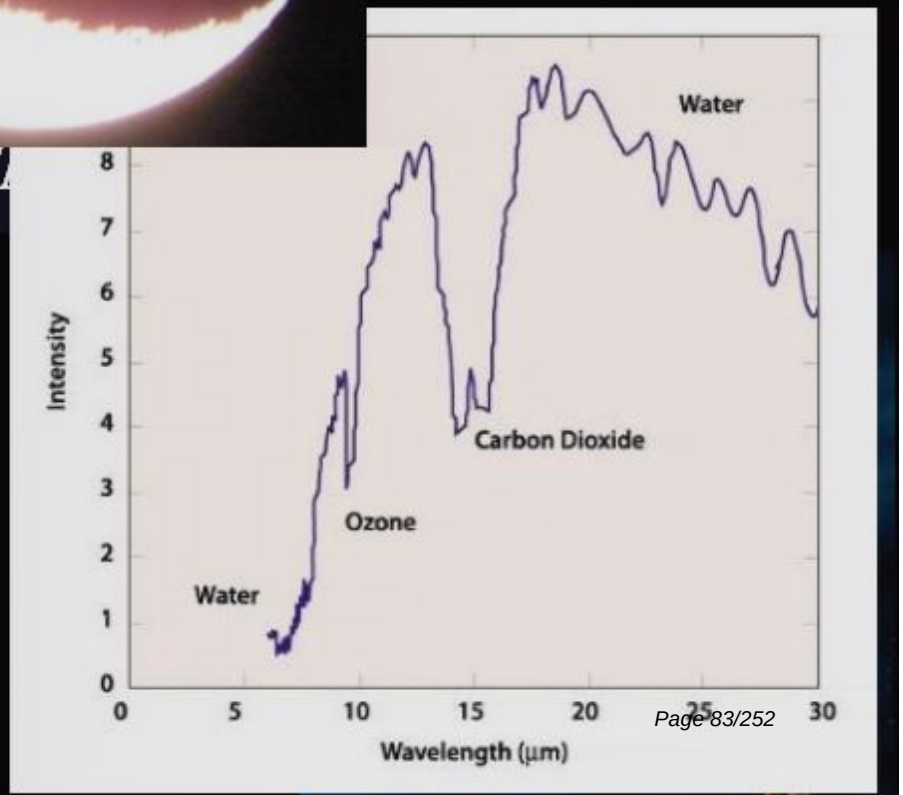

Ozone ⇒ Life!!!!

Looking For Intelligent Life

Hollywood is probably the biggest fan!

Looking For Intelligent Life

Contact was the closest thing to reality!

As Good As *Contact* Was, It Wasn't Perfect

As Good As *Contact* Was, It Wasn't Perfect

No headpones

As Good As *Contact* Was, It Wasn't Perfect

Kent's last name is Cullers

No headpones

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Kent's last name is Cullers

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$10^{11} \times 10^{-18} \neq 10^{6}$

Script writer couldn't do math

As Good As *Contact* Was, It Wasn't Perfect

No walkie-talkies at radio observatories

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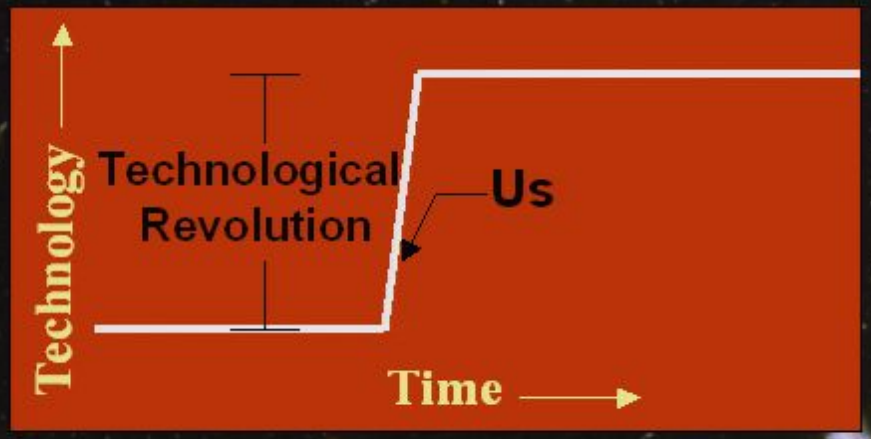
They forgot the champagne

Any Detectable Technology
Will Be Older Than We Are

Any Detectable Technology Will Be Older Than We Are



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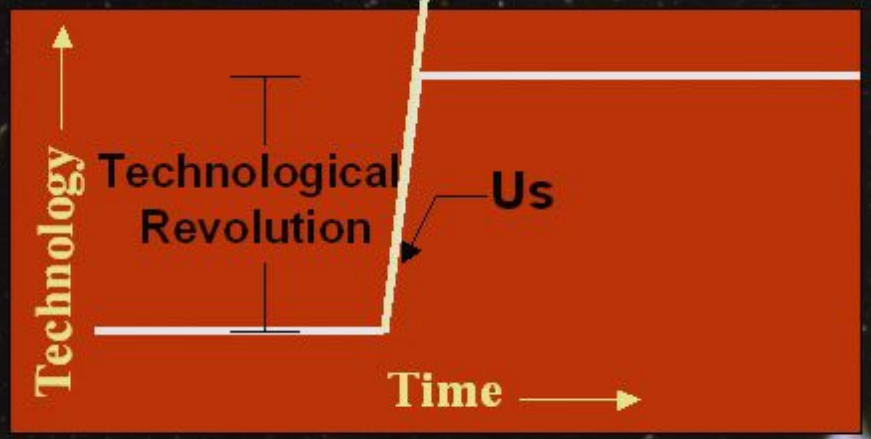
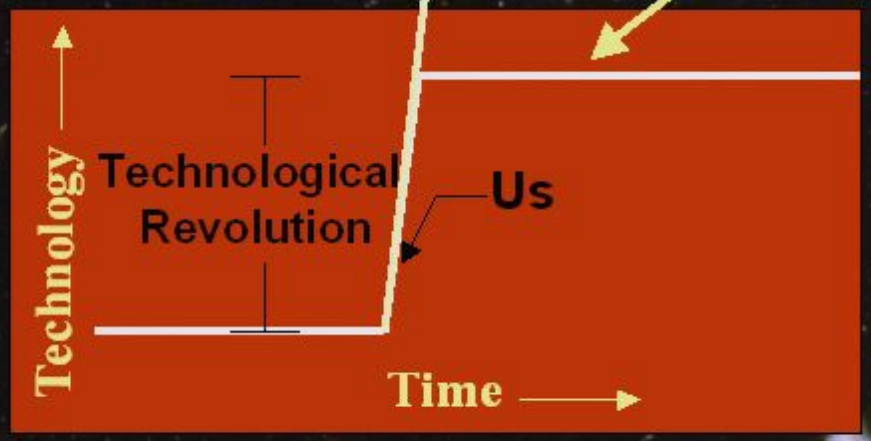


Any Detectable Technology Will Be Older Than We Are

If technology is long-lived,then we will find them here



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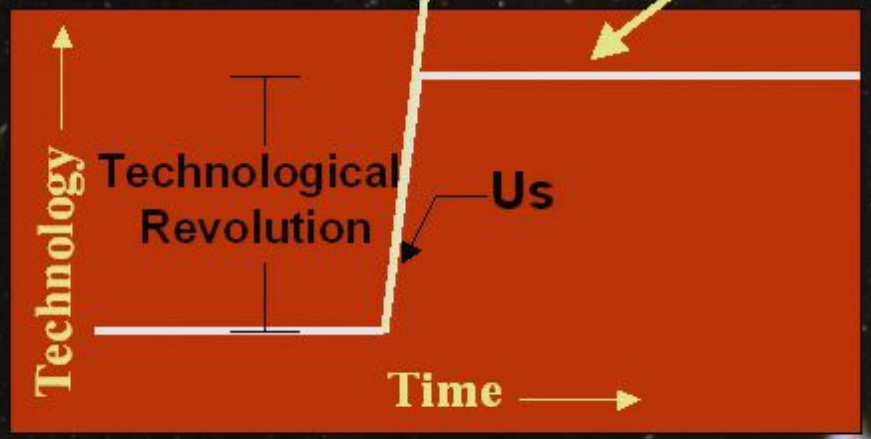
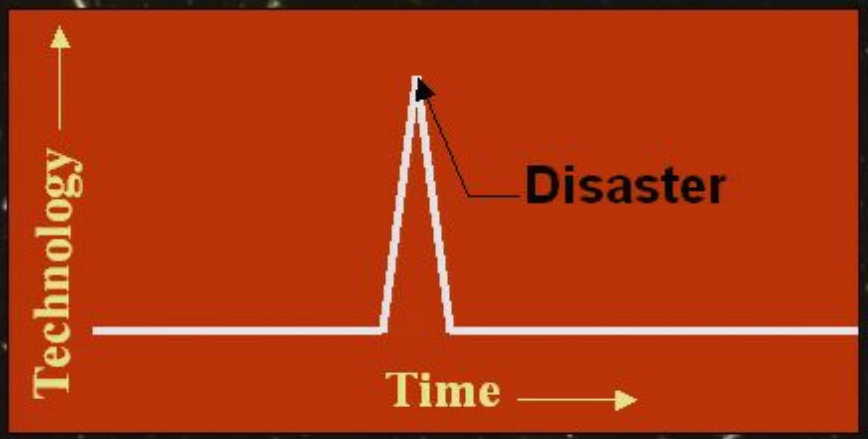
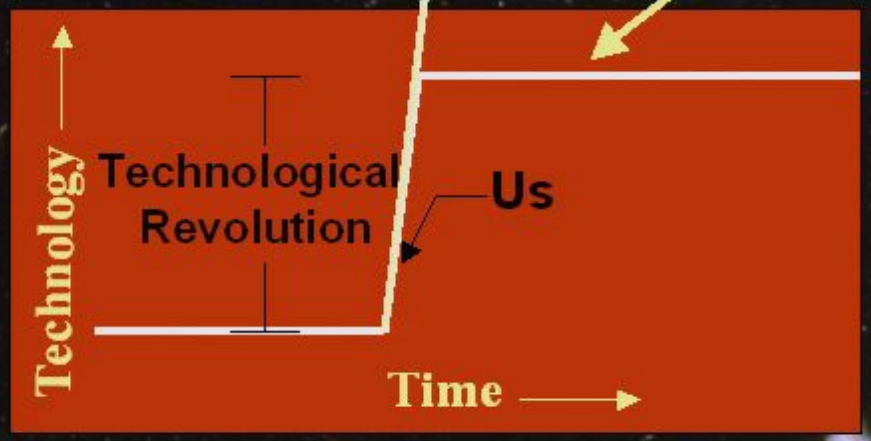


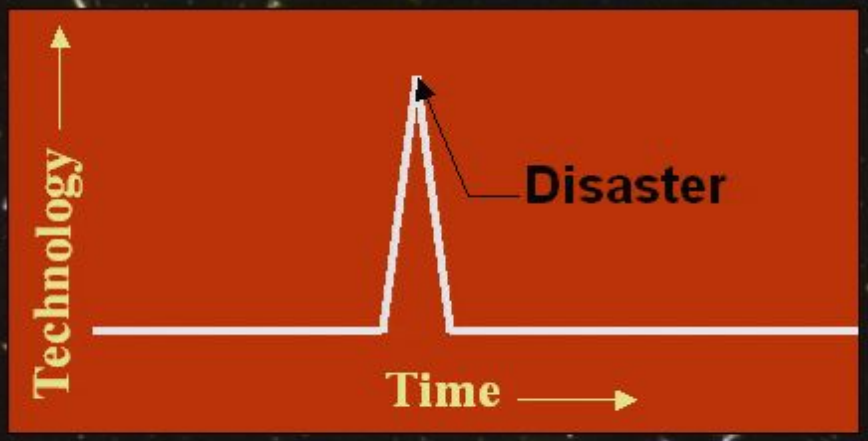


Any Detectable Technology Will Be Older Than We Are

If technology is long-lived, then we will find them here

If technology is short-lived, then we will not find them





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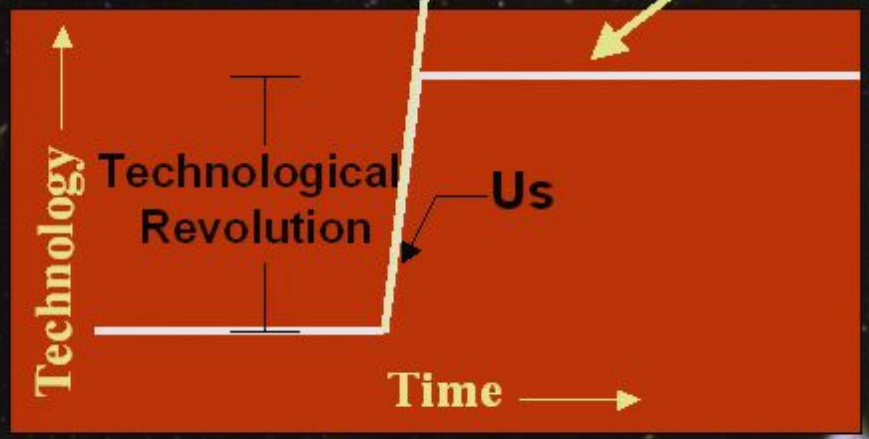
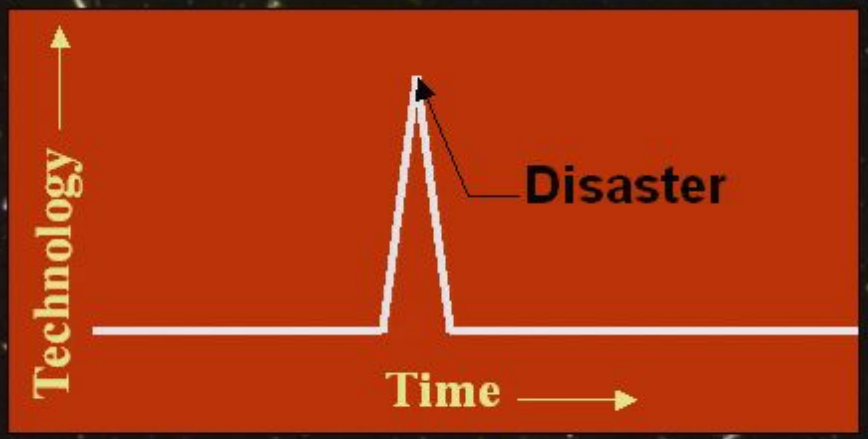
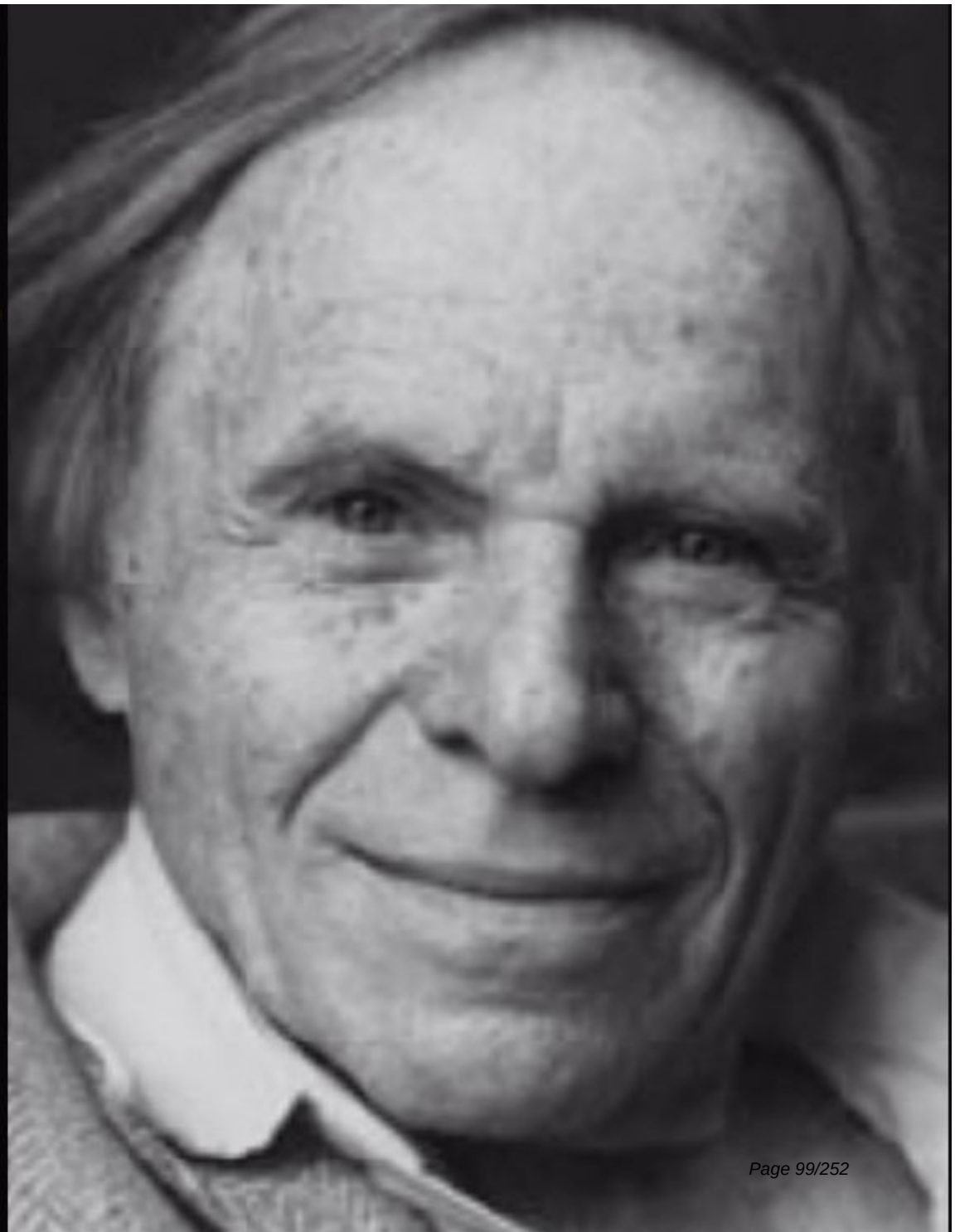




Unless technology is long-lived, SETI will not succeed

SETI Is The Archeology Of The Future *

* Phil Morrison



SETI Is The Archeology Of The Future *

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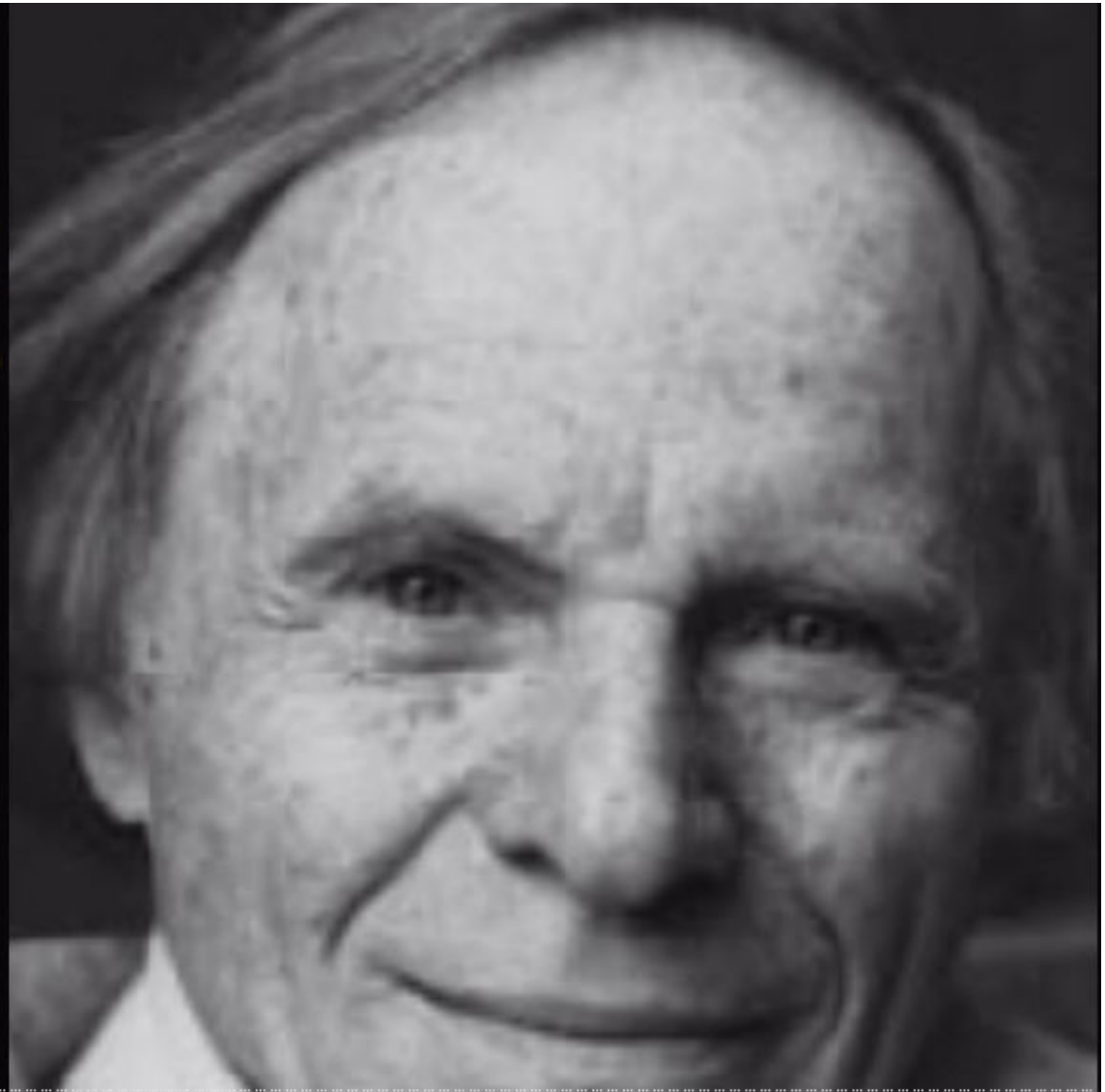


A detected signal tells us about their PAST, and our FUTURE

The Cosmic Haystack Is Huge

The Cosmic Haystack Is Huge

Nine Dimensional

The Cosmic Haystack Is Huge

Nine Dimensional

- **3 – space**

The Cosmic Haystack Is Huge

Nine Dimensional

- **3 – space**
- **1 – time**

The Cosmic Haystack Is Huge

Nine Dimensional

- 3 – space
- 1 – time
- 2 – polarizations

The Cosmic Haystack Is Huge

Nine Dimensional

- 3 – space
- 1 – time
- 2 – polarizations
- 1 – frequency

The Cosmic Haystack Is Huge

Nine Dimensional

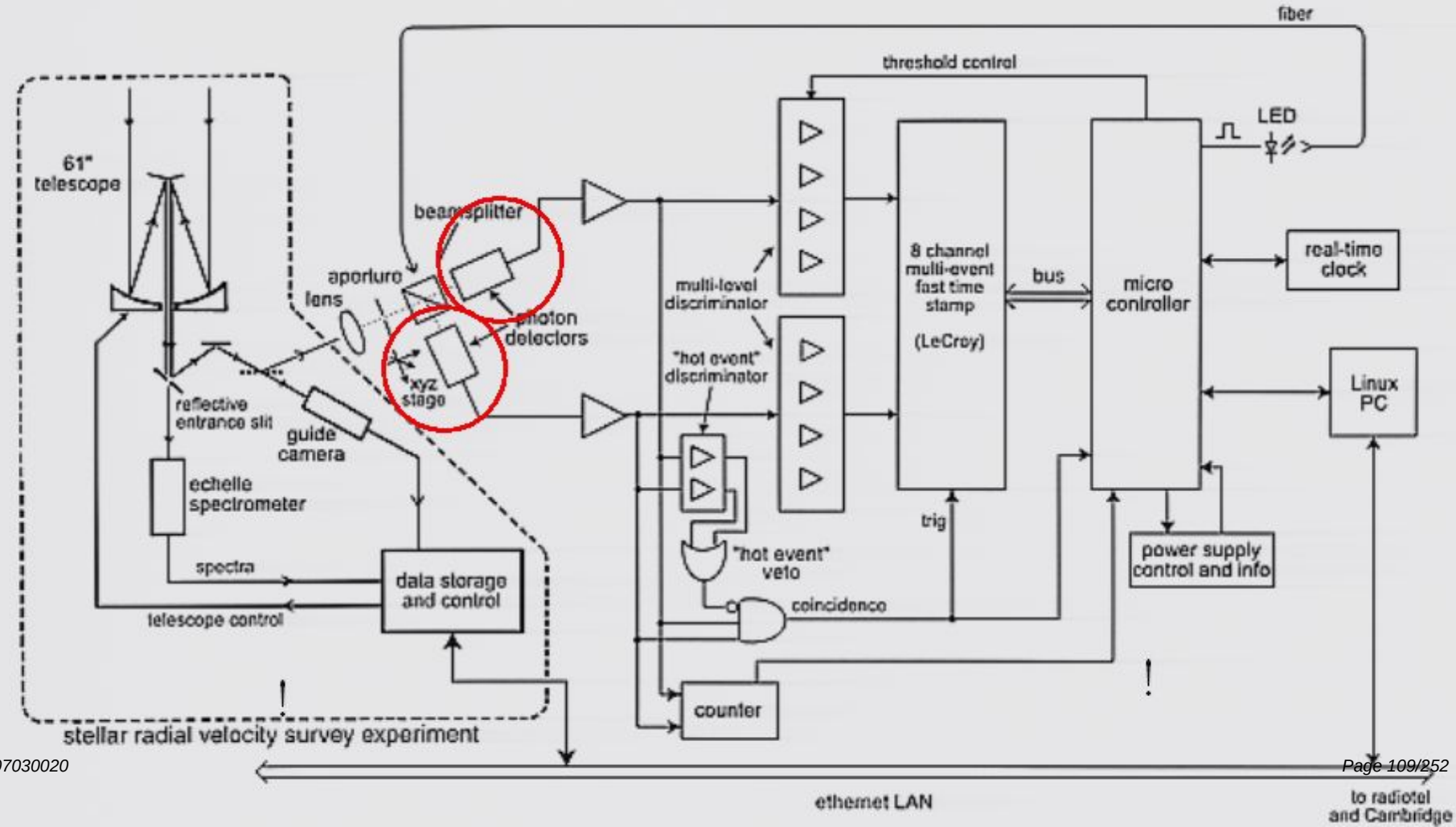
- 3 – space
- 1 – time
- 2 – polarizations
- 1 – frequency
- 1 – modulation scheme

The Cosmic Haystack Is Huge

Nine Dimensional

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

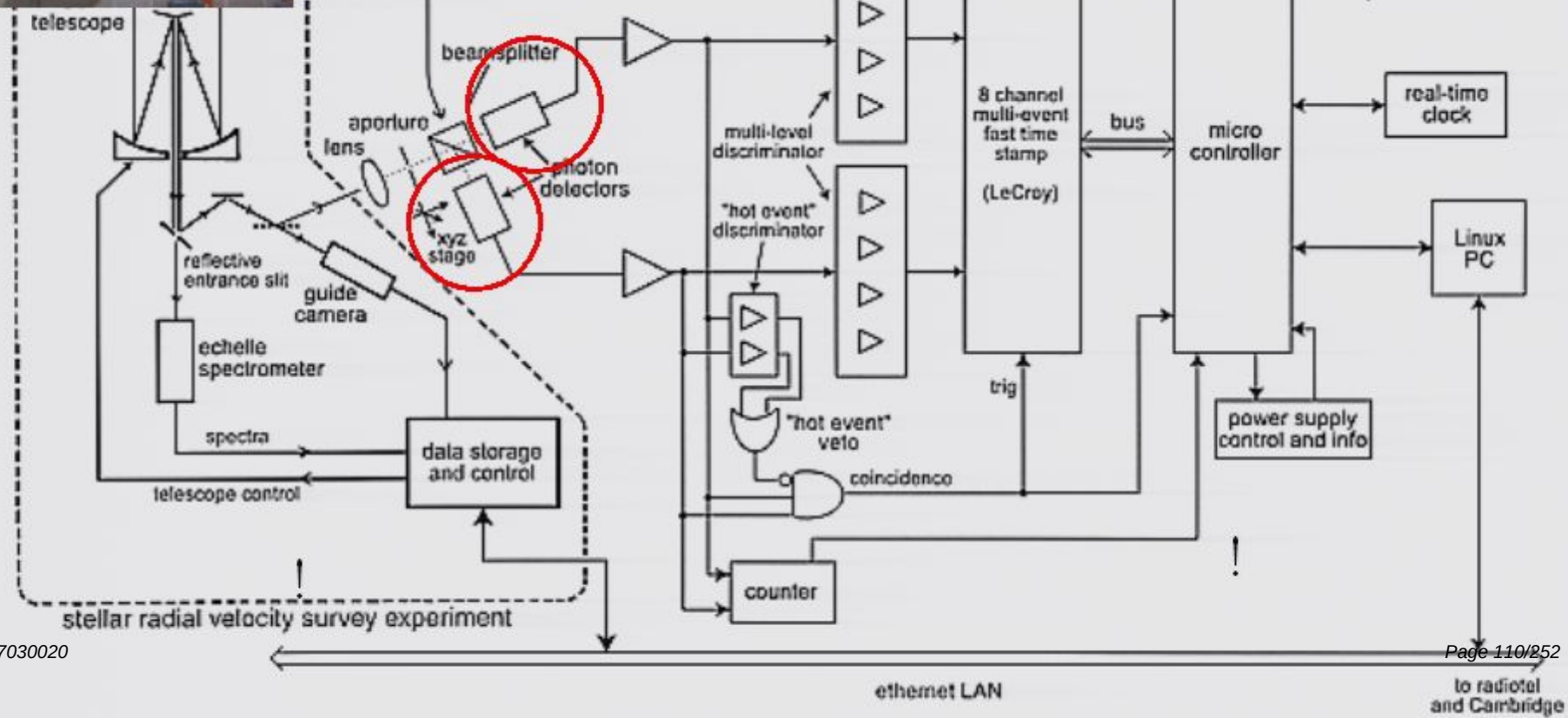
Optical SETI
(Broadband Nanosecsond Pulses)



Berkeley

Optical SETI

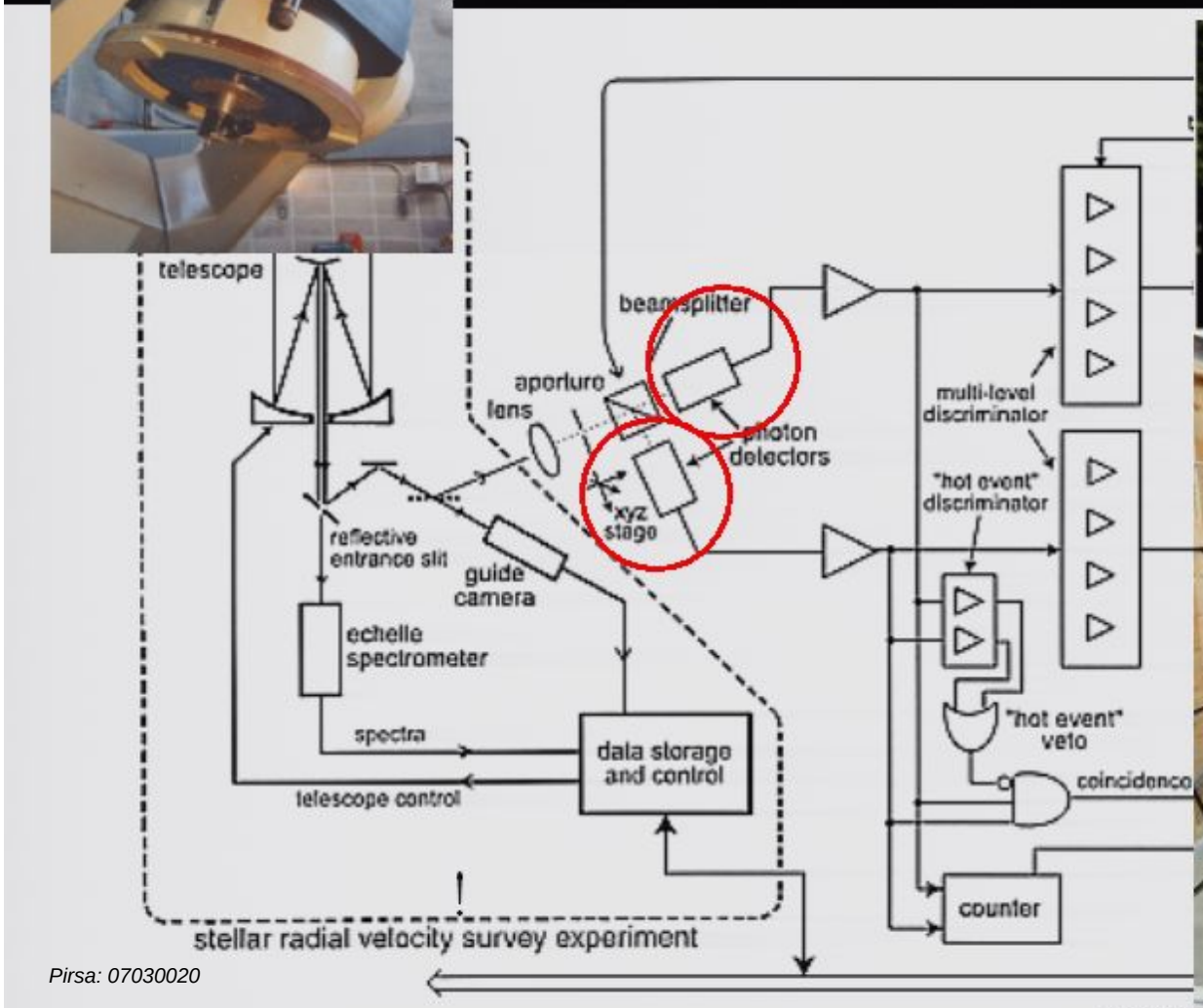
roadband Nanosecsond Pulses)



Berkeley

Optical SETI

roadband Nanosecsond Pulses)

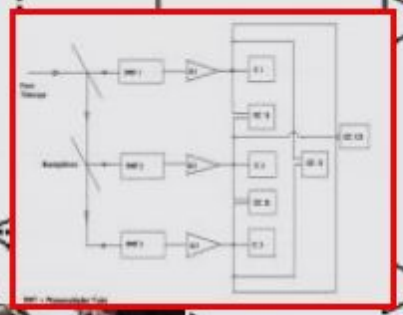


Harvard

Berkeley

Optical SETI

roadband Nanosecsond Pulses)



telescope

reflective entrance slit

multi-level discriminator

"hot event" discriminator

"hot event" veto

coincidence

counter

a storage
d control

ment

ethernet

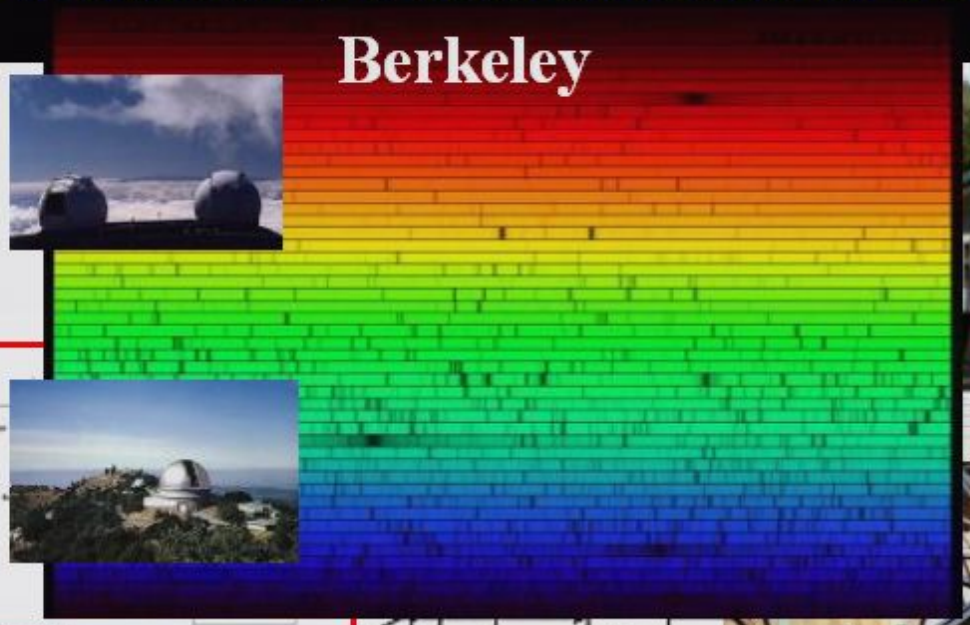
Lick

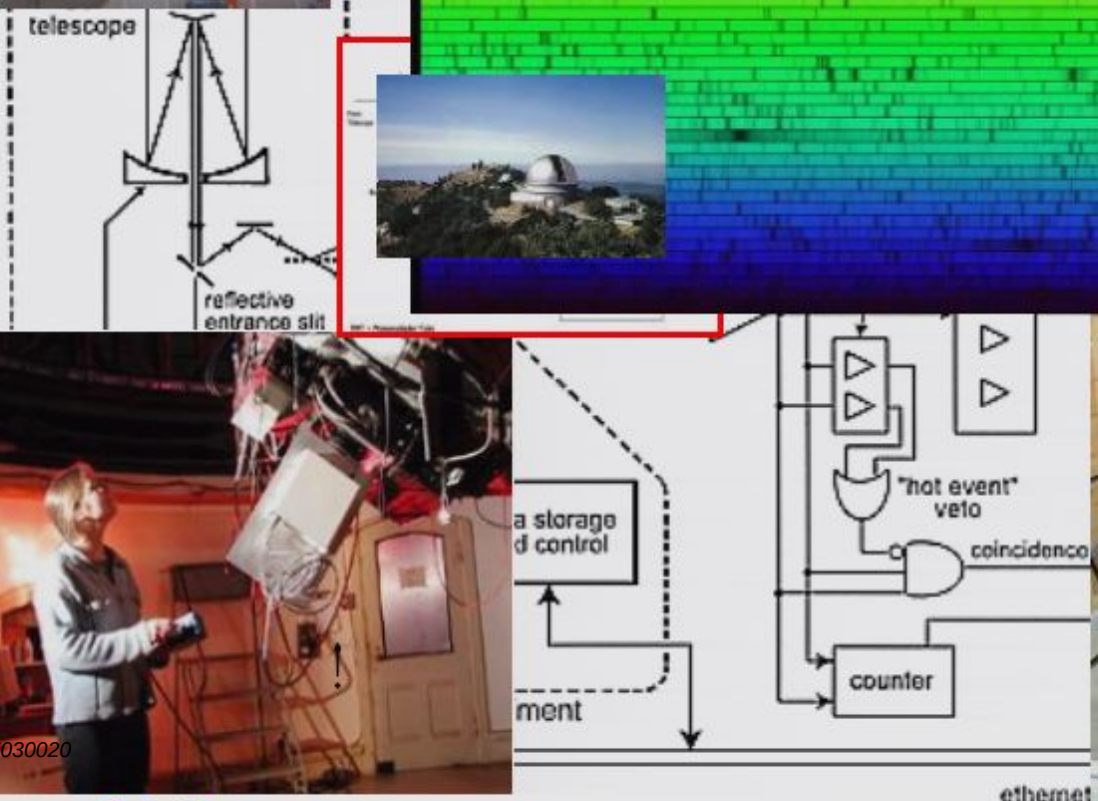
Harvard

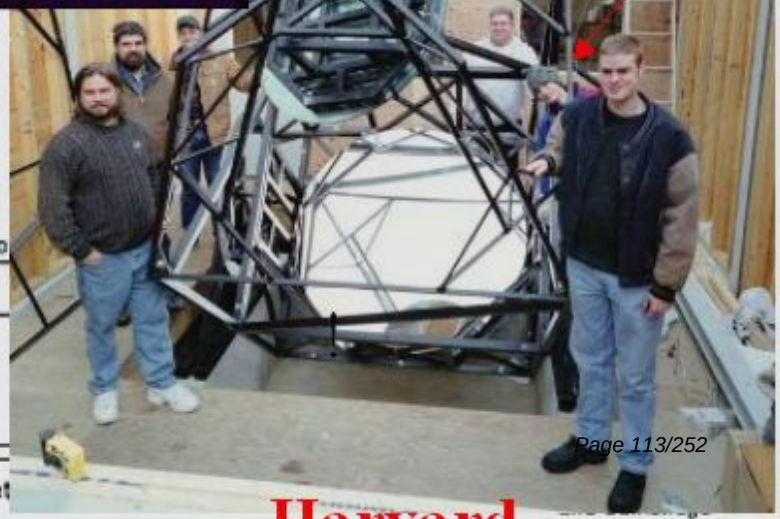
Optical SETI

roadband Nanosecsond Pulses)

Berkeley



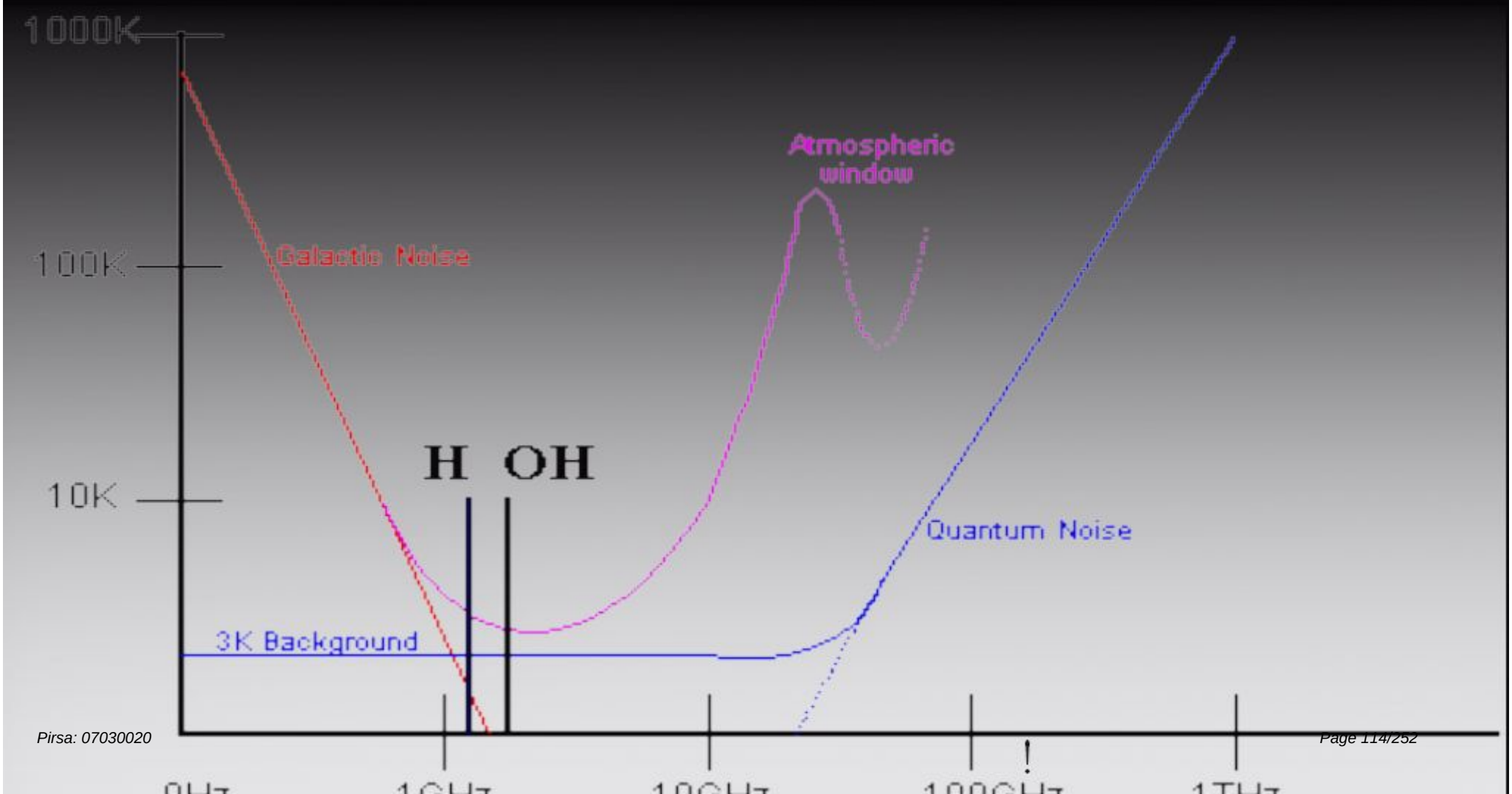




Lick

Harvard

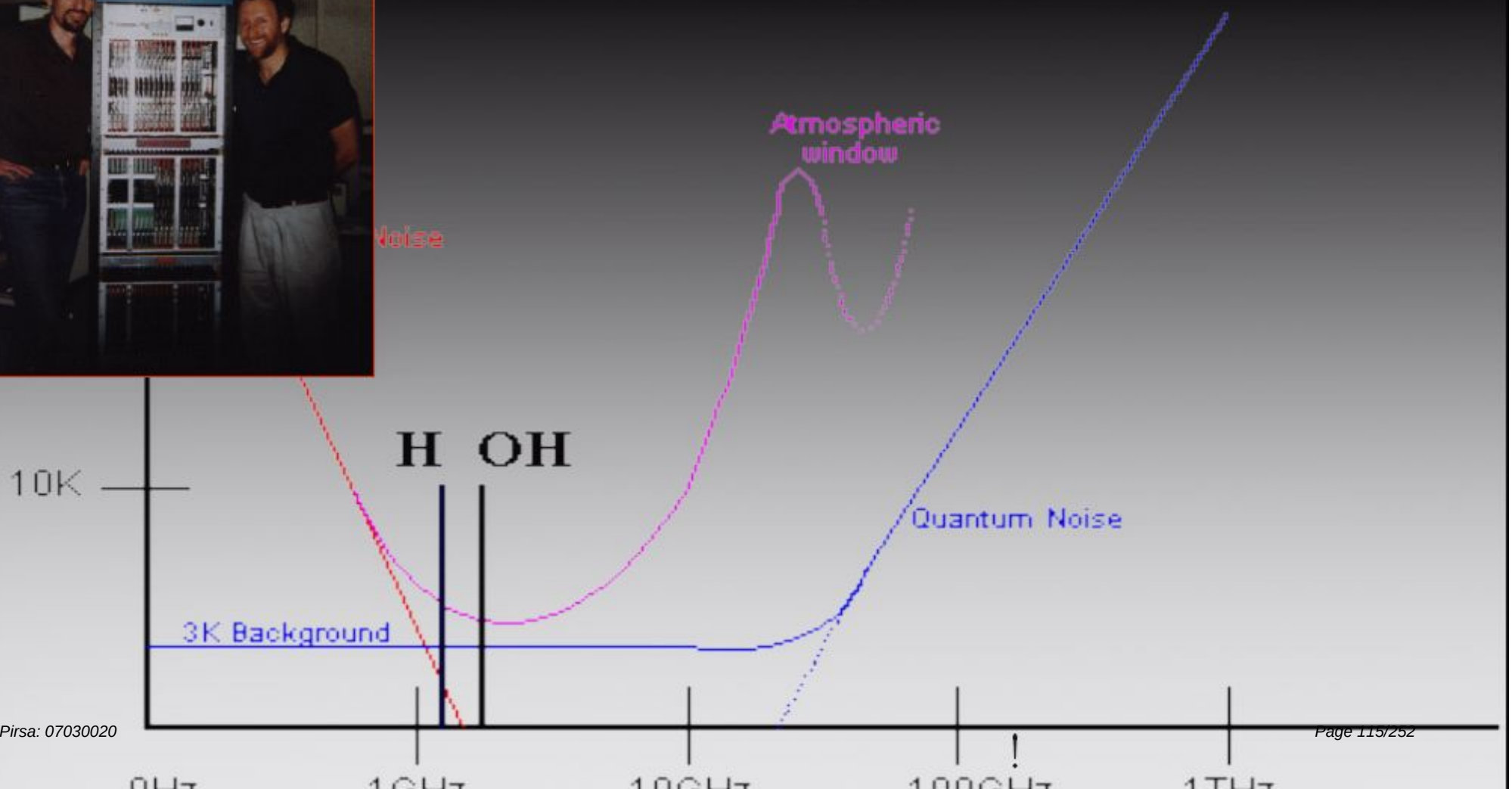
Recent SETI Observations
Microwave SETI



Recent SETI Observations

Microwave SETI

SERENDIP IV



Recent SETI Observations

Microwave SETI

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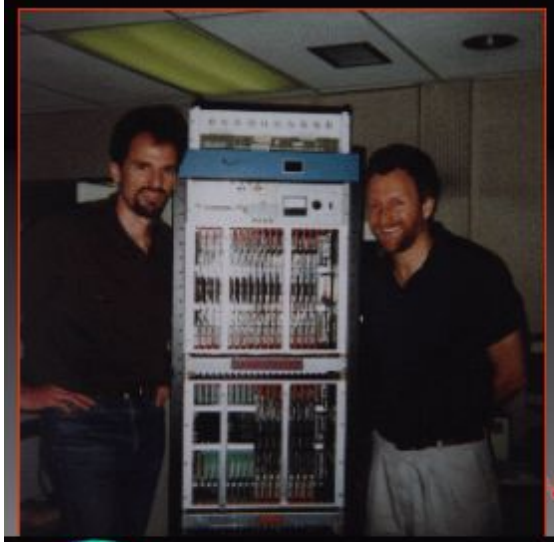
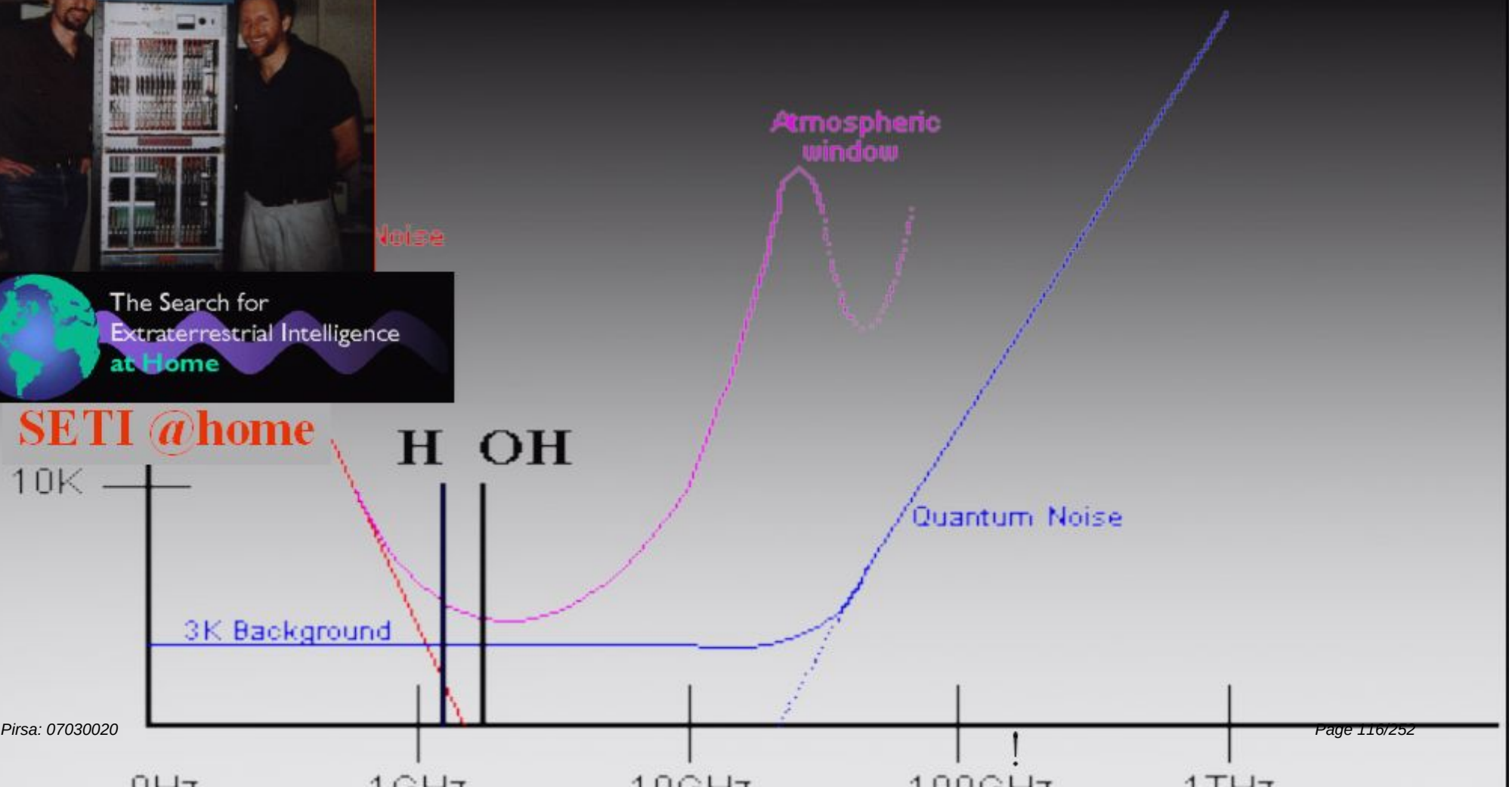


The Search for Extraterrestrial Intelligence at Home

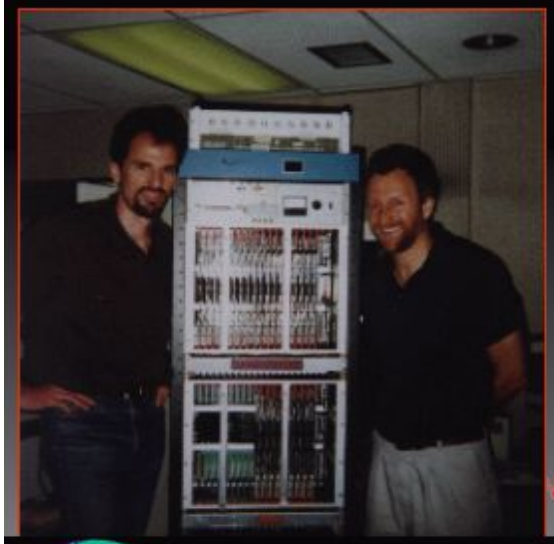
SETI @home



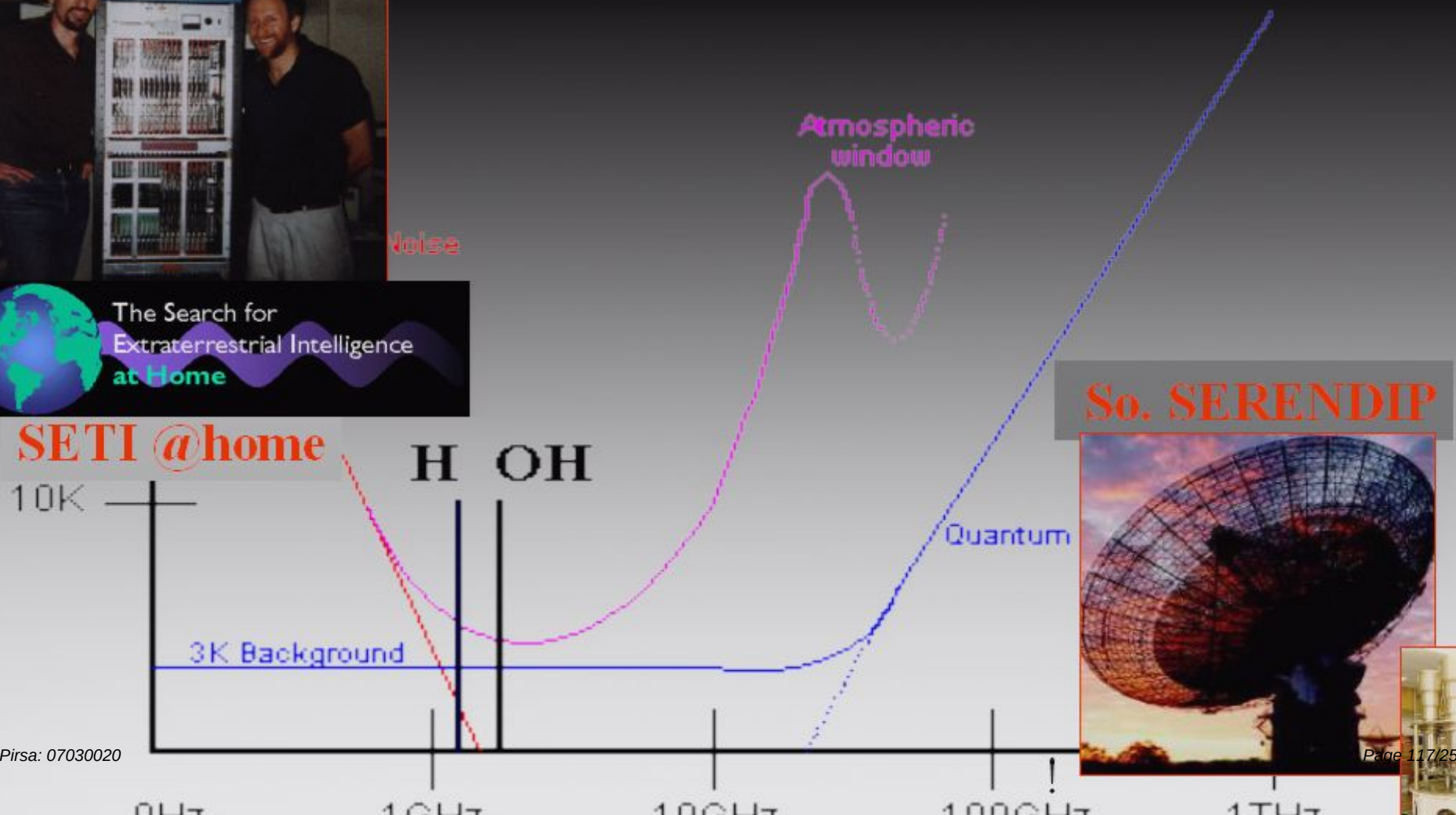
Recent SETI Observations

Microwave SETI

SERENDIP IV



SETI @home

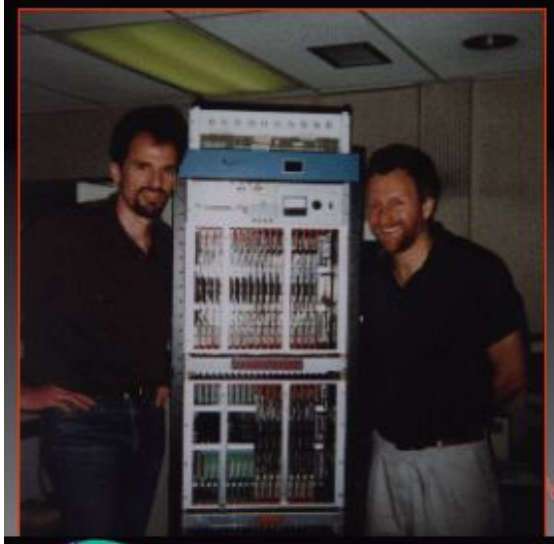


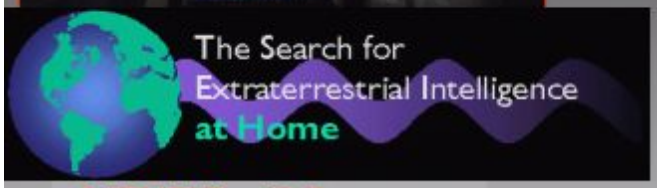
So. SERENDIP

Recent SETI Observations

Microwave SETI

SERENDIP IV





SETI @home

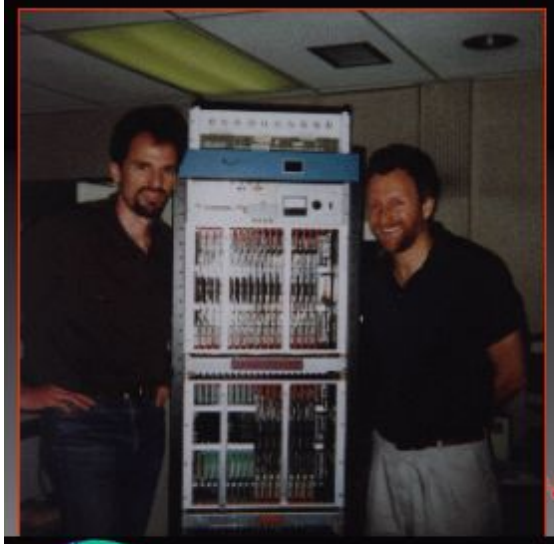
Project Argus

So. SERENDIP

Recent SETI Observations

Microwave SETI

SERENDIP IV



Phoenix

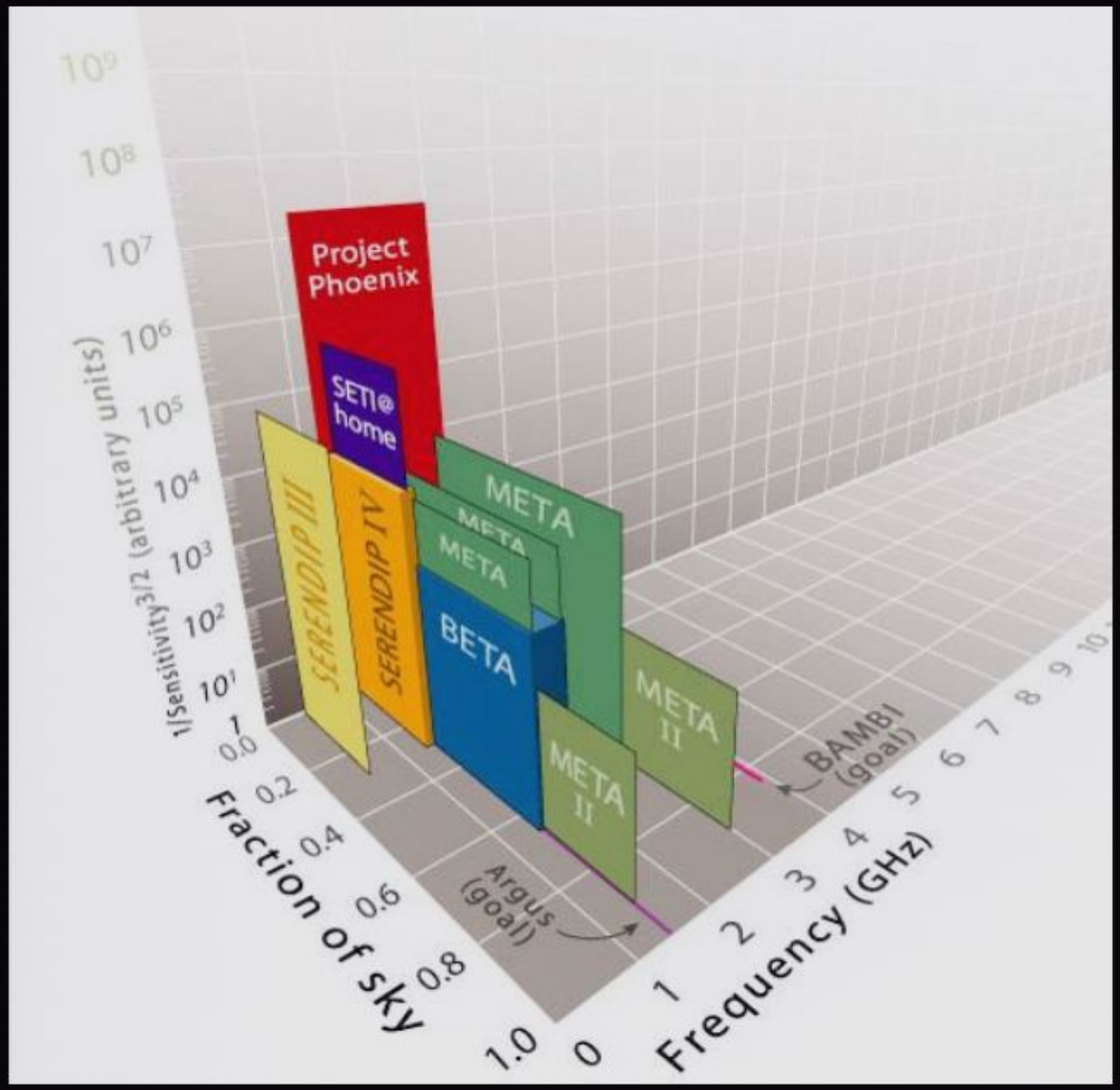
The Search for Extraterrestrial Intelligence at Home

SETI @home

So. SERENDIP

Project Argus

Results to Date



OSETI

Results to Date

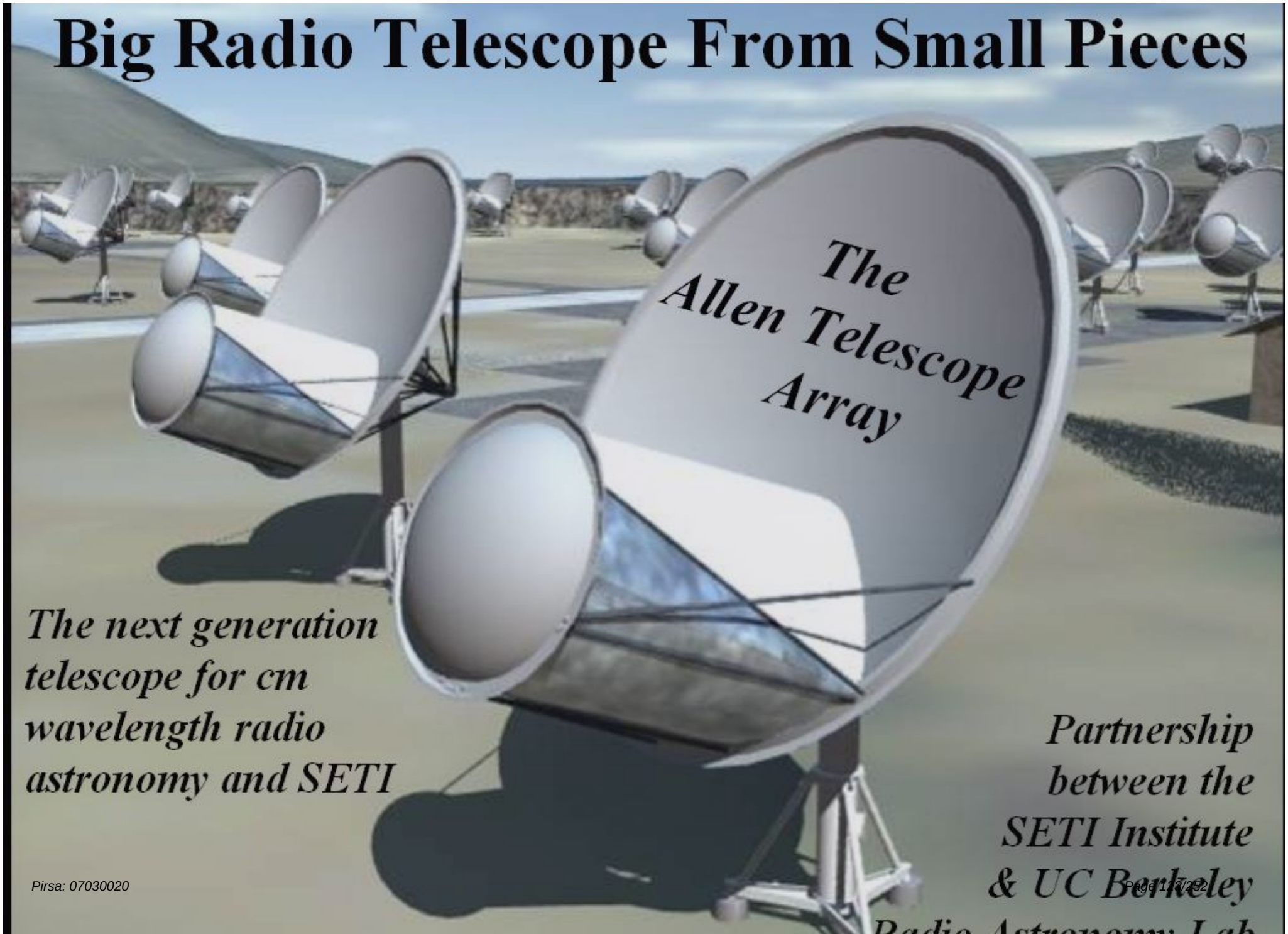
OSETI

We've hardly begun to search!

Big Radio Telescope From Small Pieces

The next generation telescope for cm wavelength radio astronomy and SETI

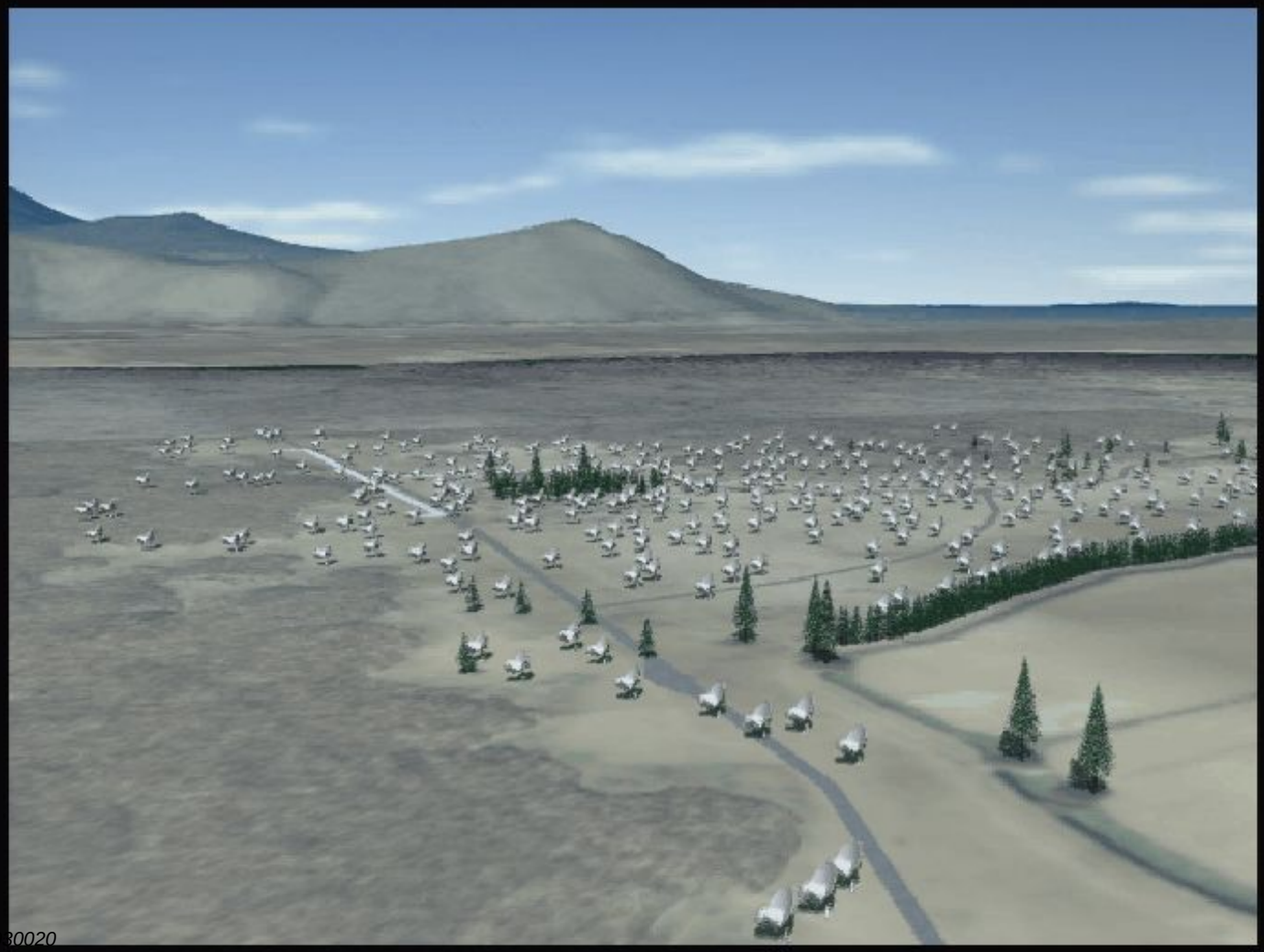
Big Radio Telescope From Small Pieces



The next generation telescope for cm wavelength radio astronomy and SETI

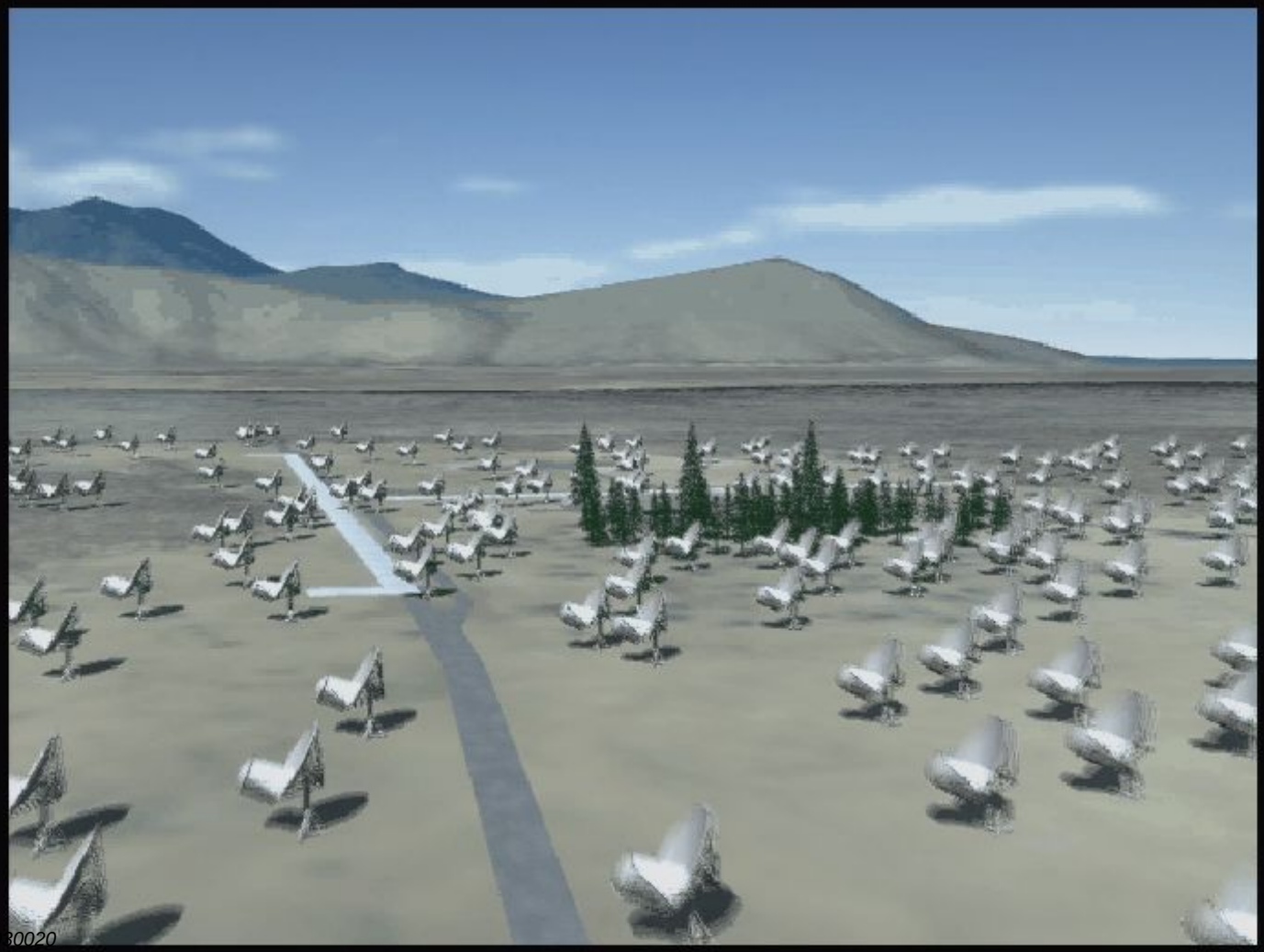
Partnership between the SETI Institute & UC Berkeley Radio Astronomy Lab

The Allen Telescope Array



Hat Creek in northern CA ~ 2008 - 9 depending on rate of funding

The Allen Telescope Array



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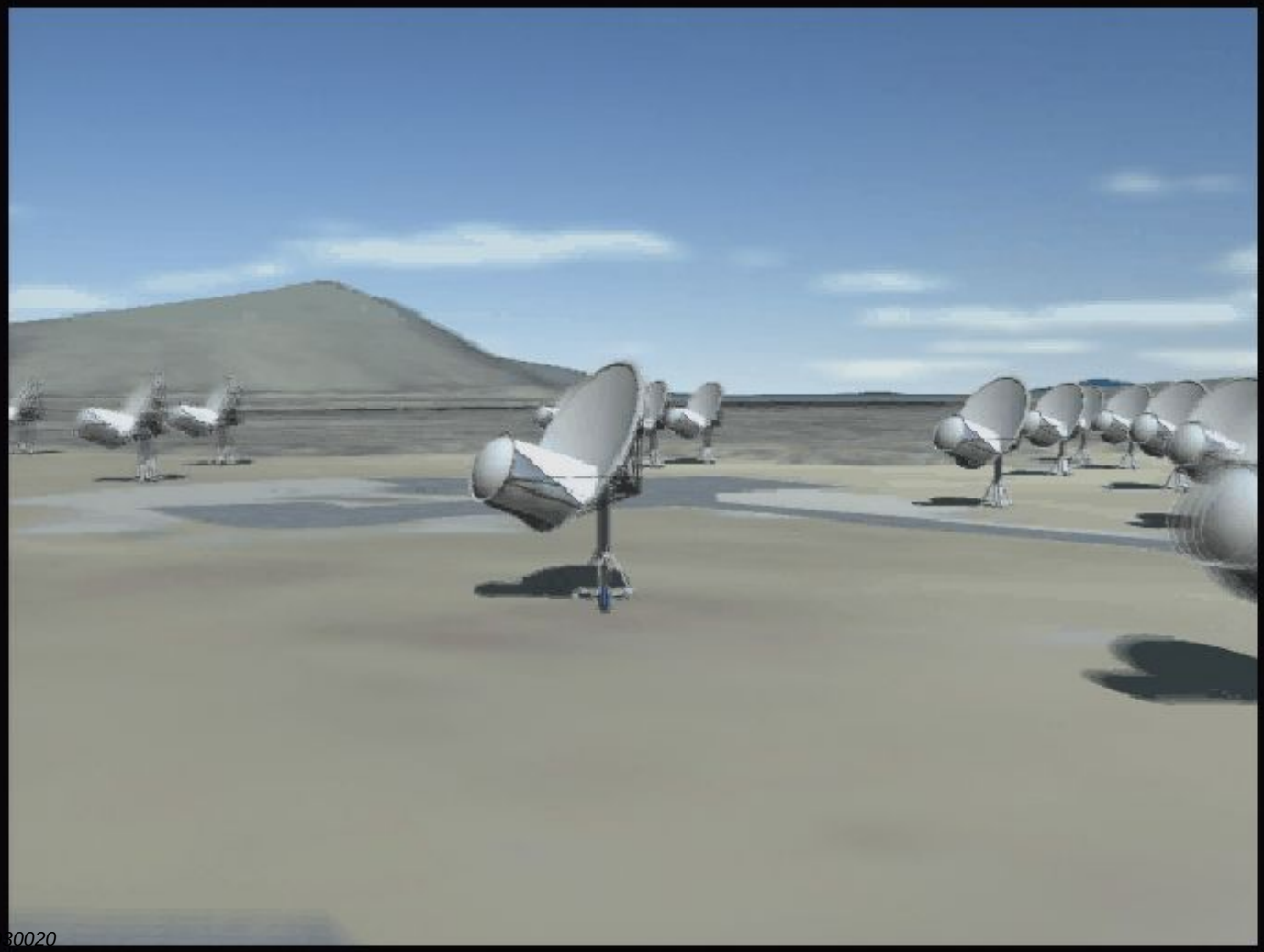

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The Allen Telescope Array

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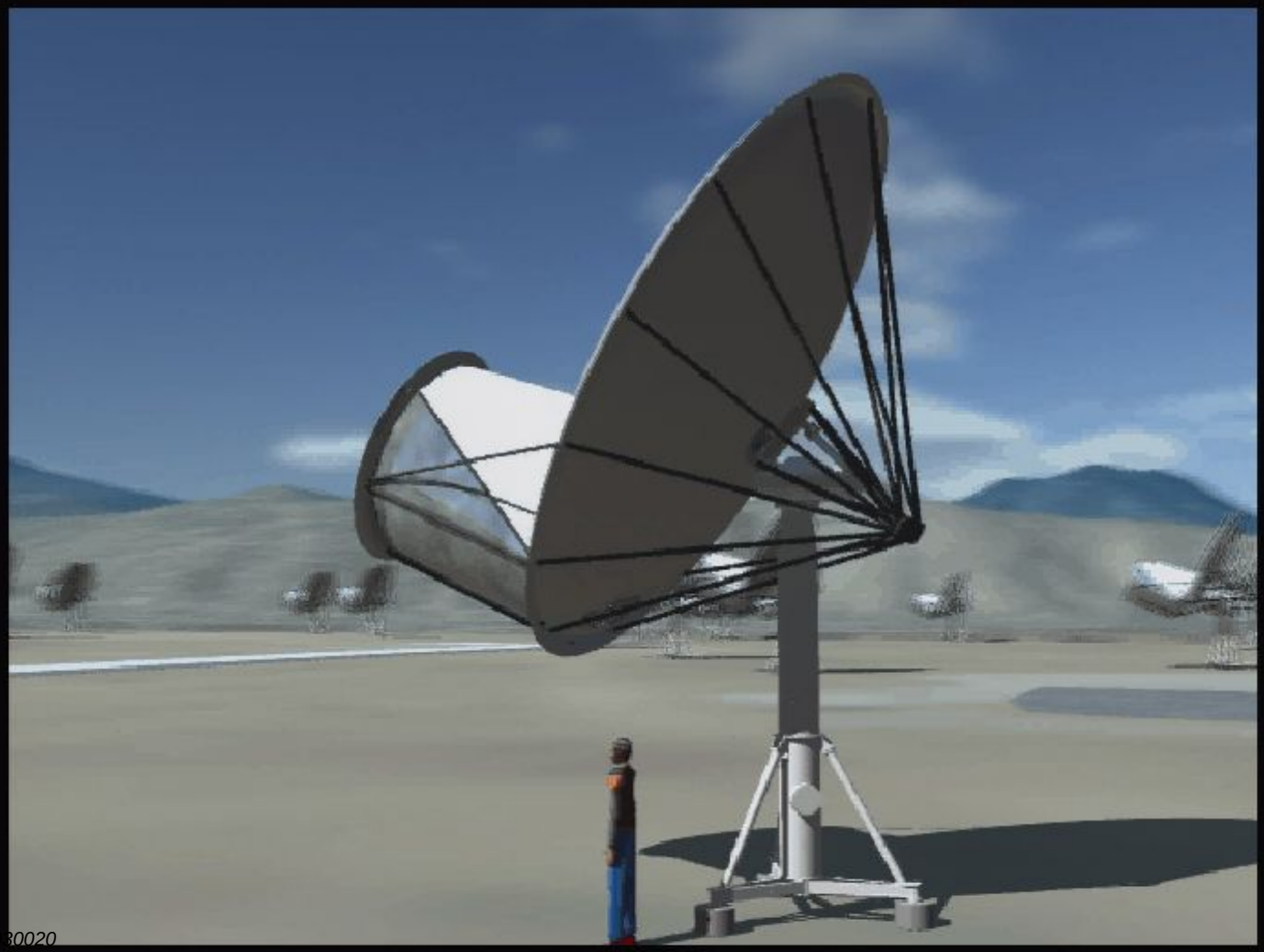

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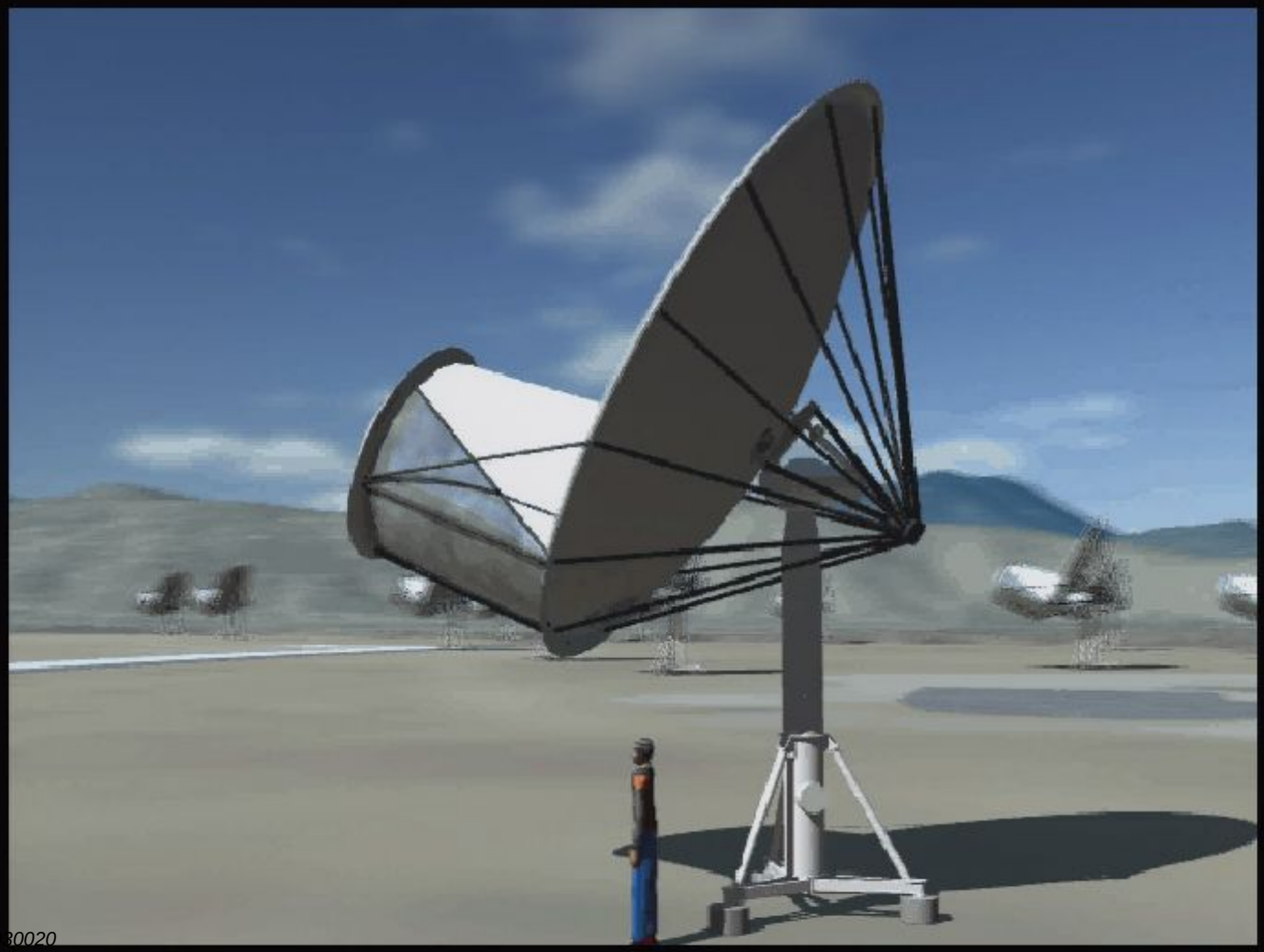

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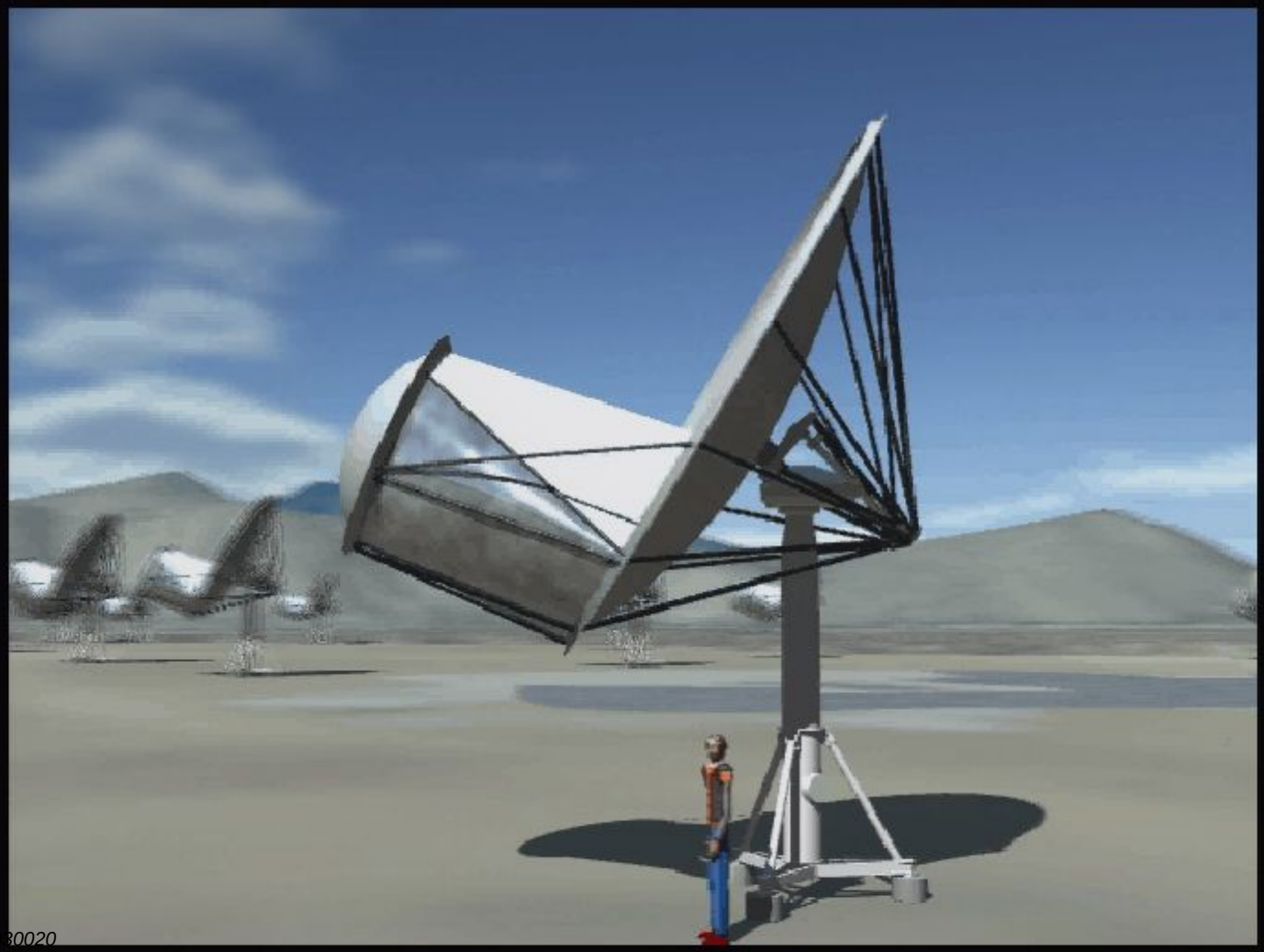

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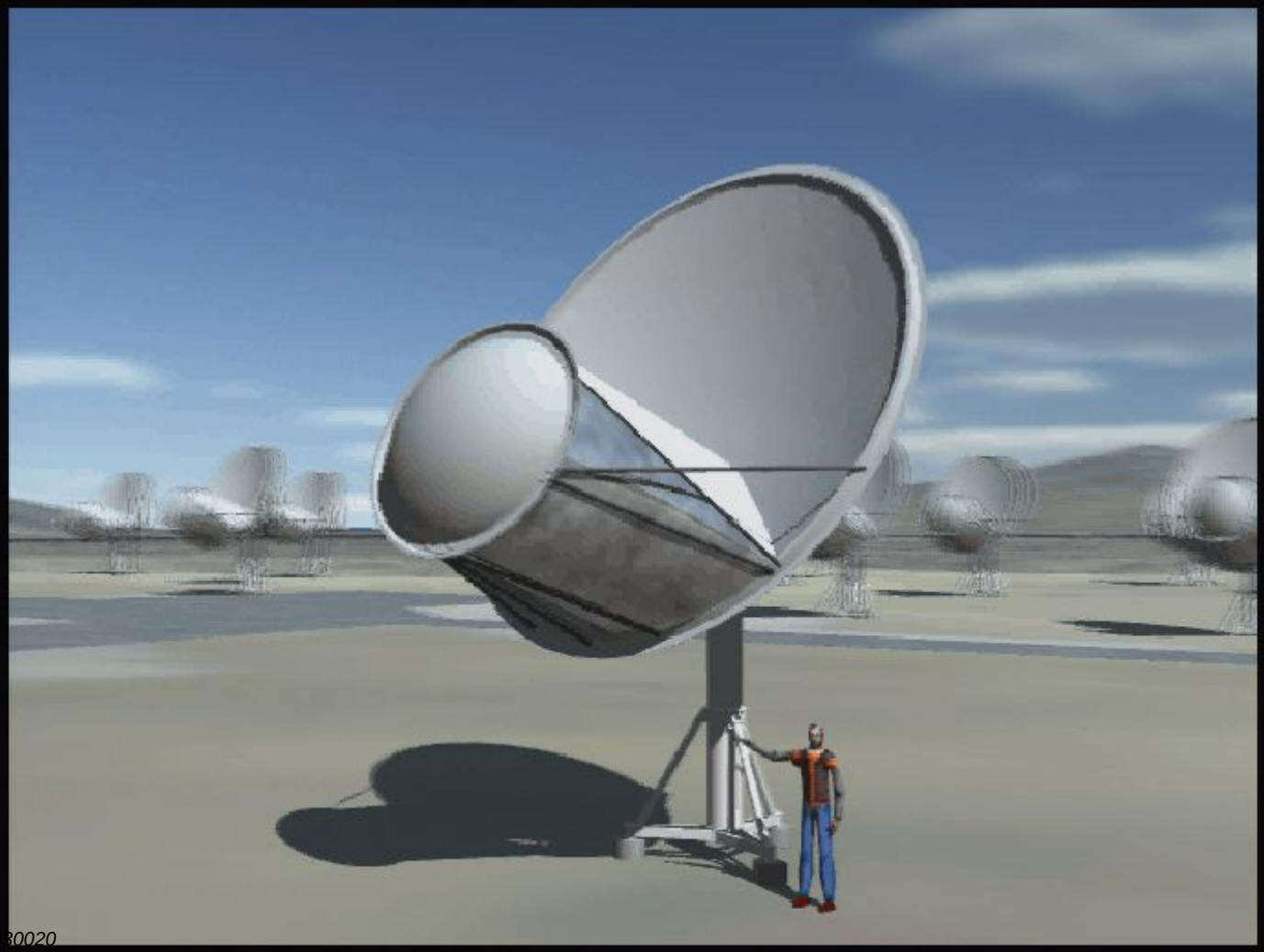

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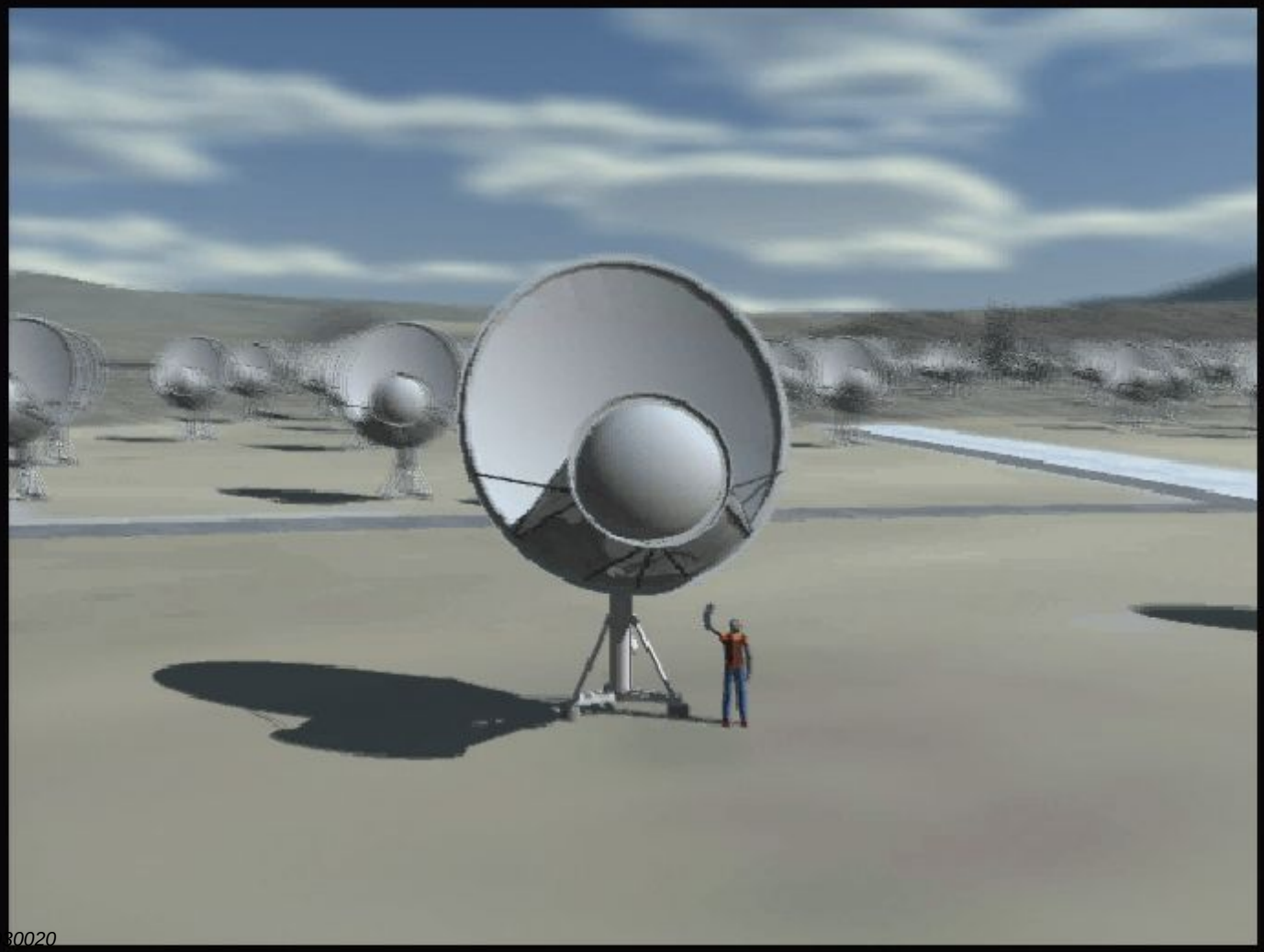

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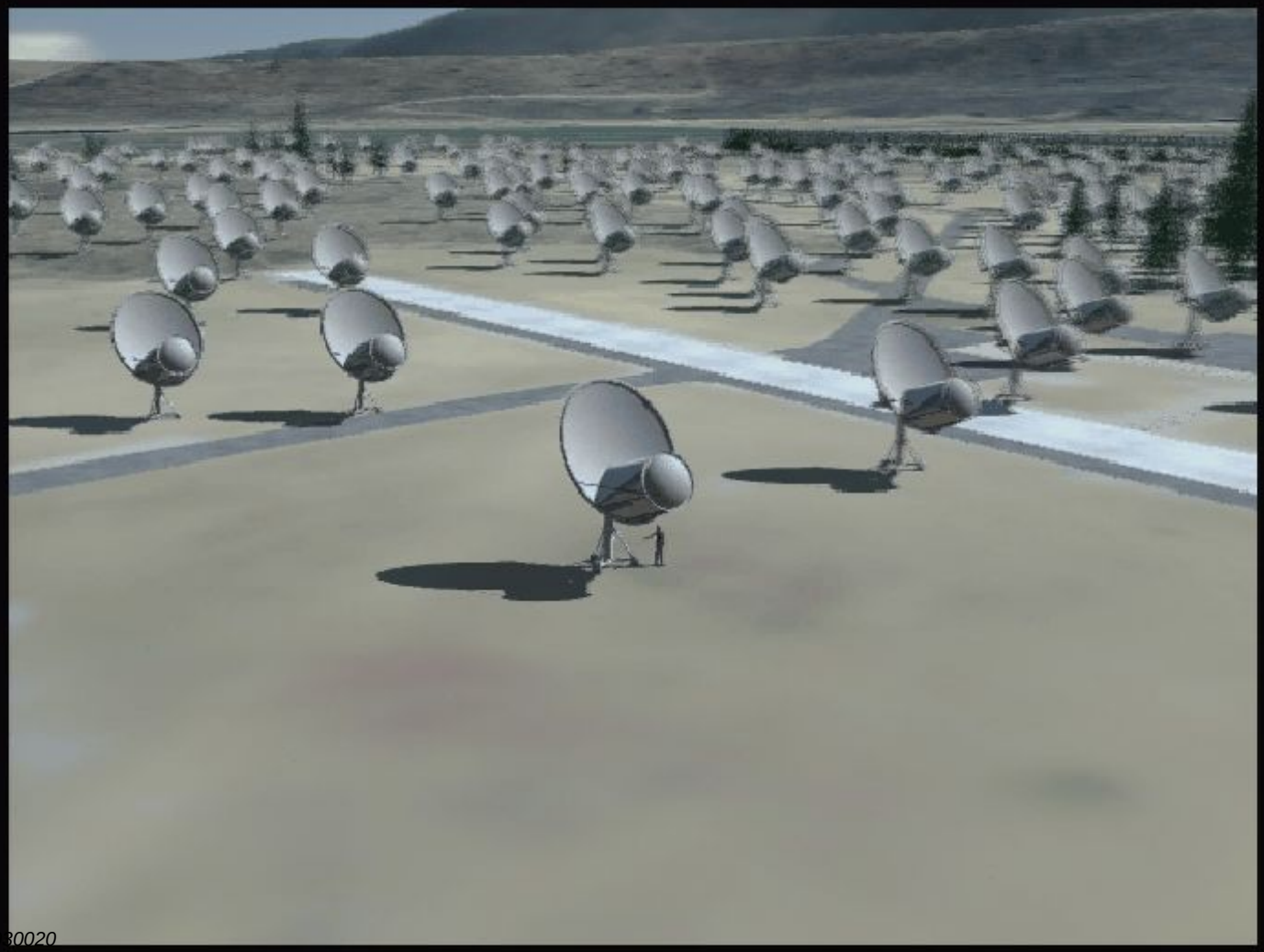

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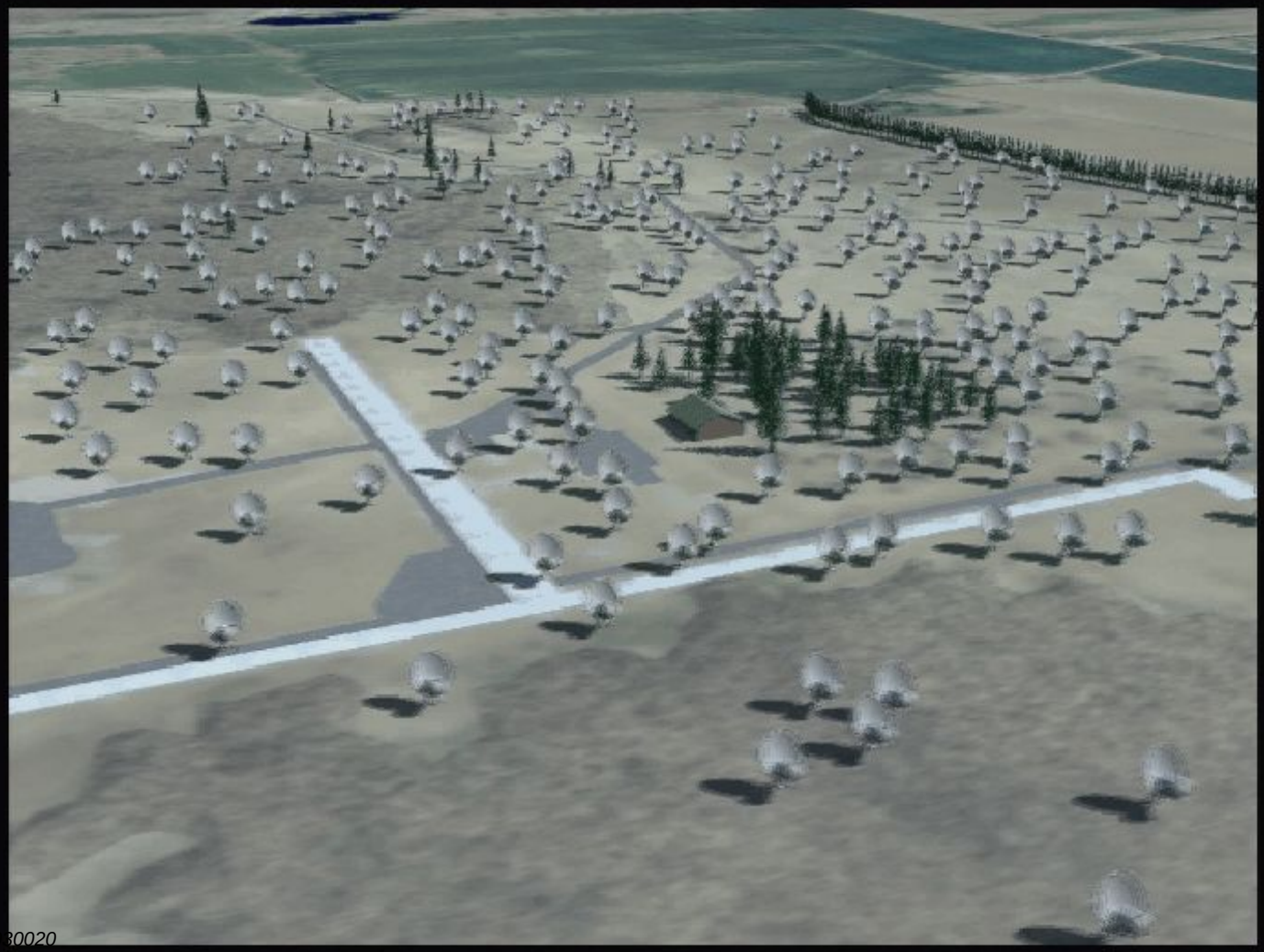

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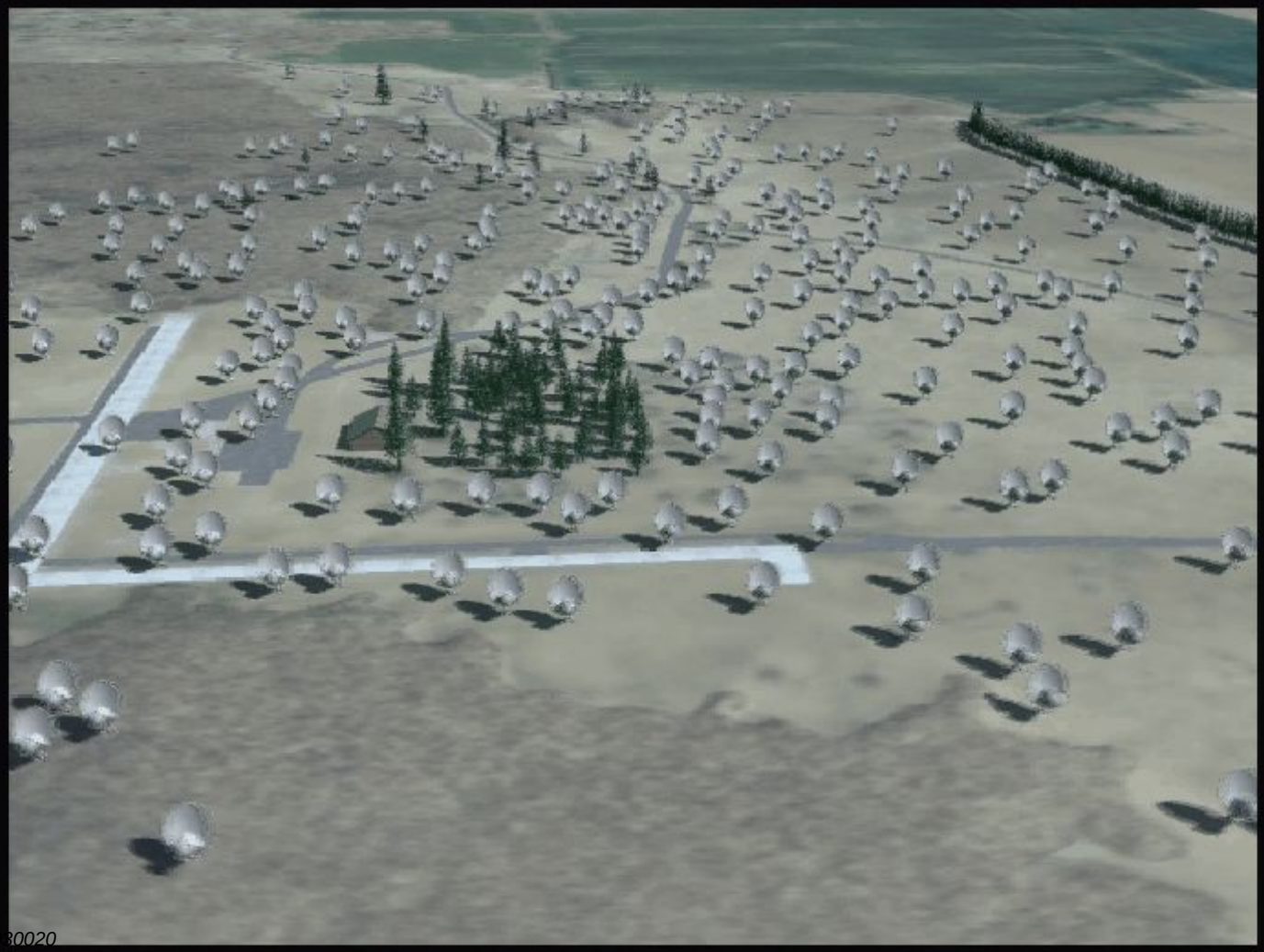

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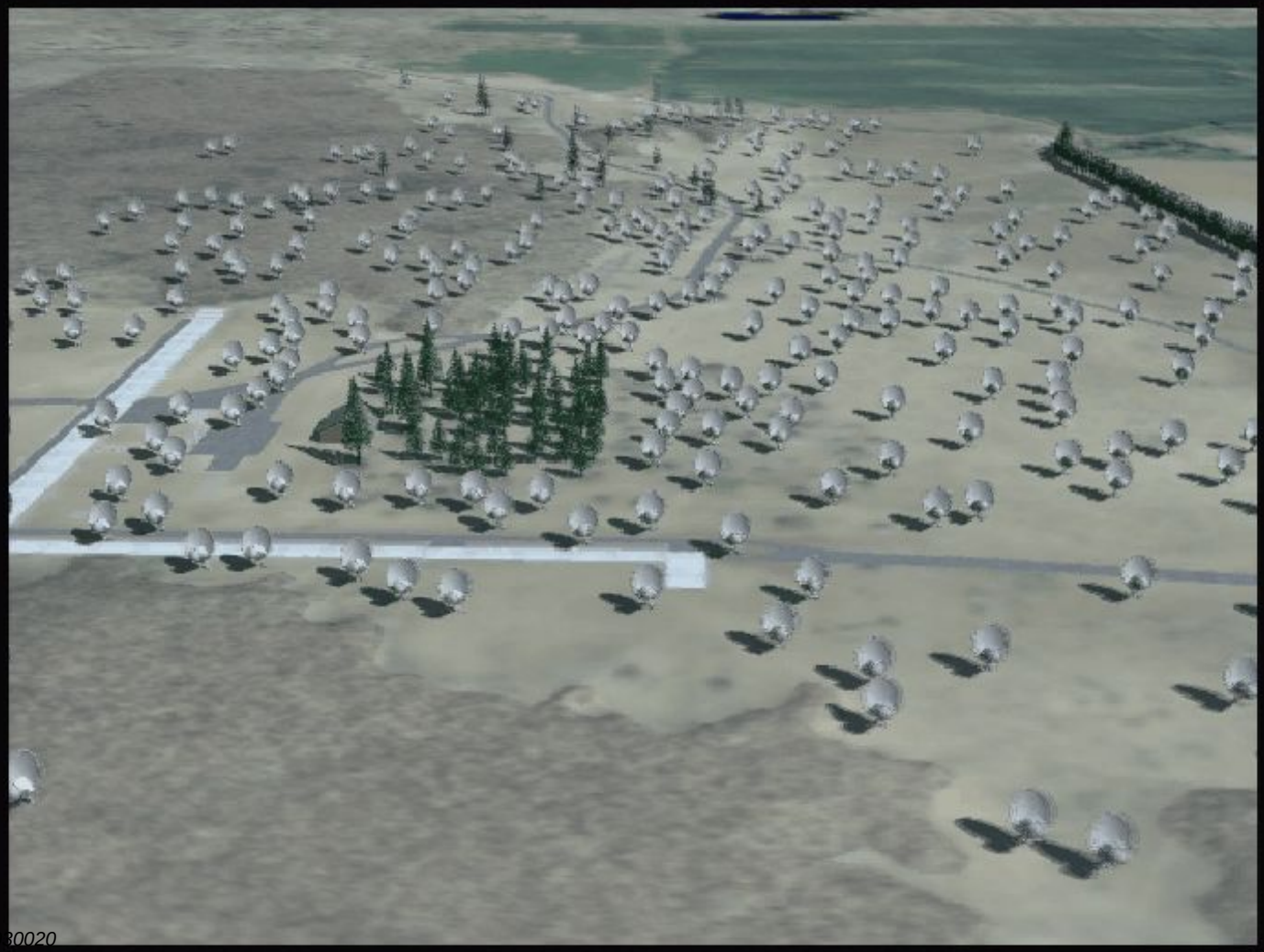

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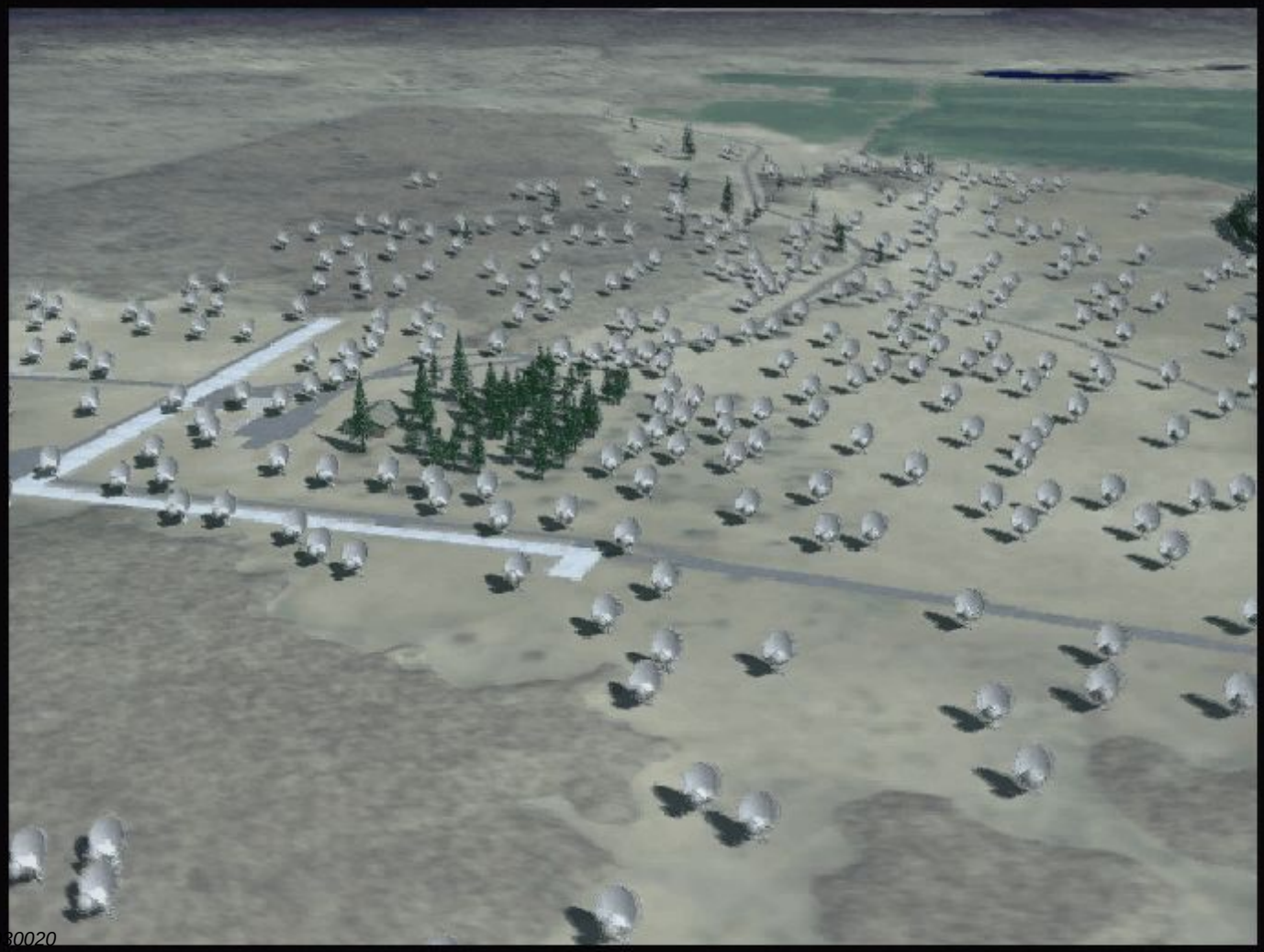

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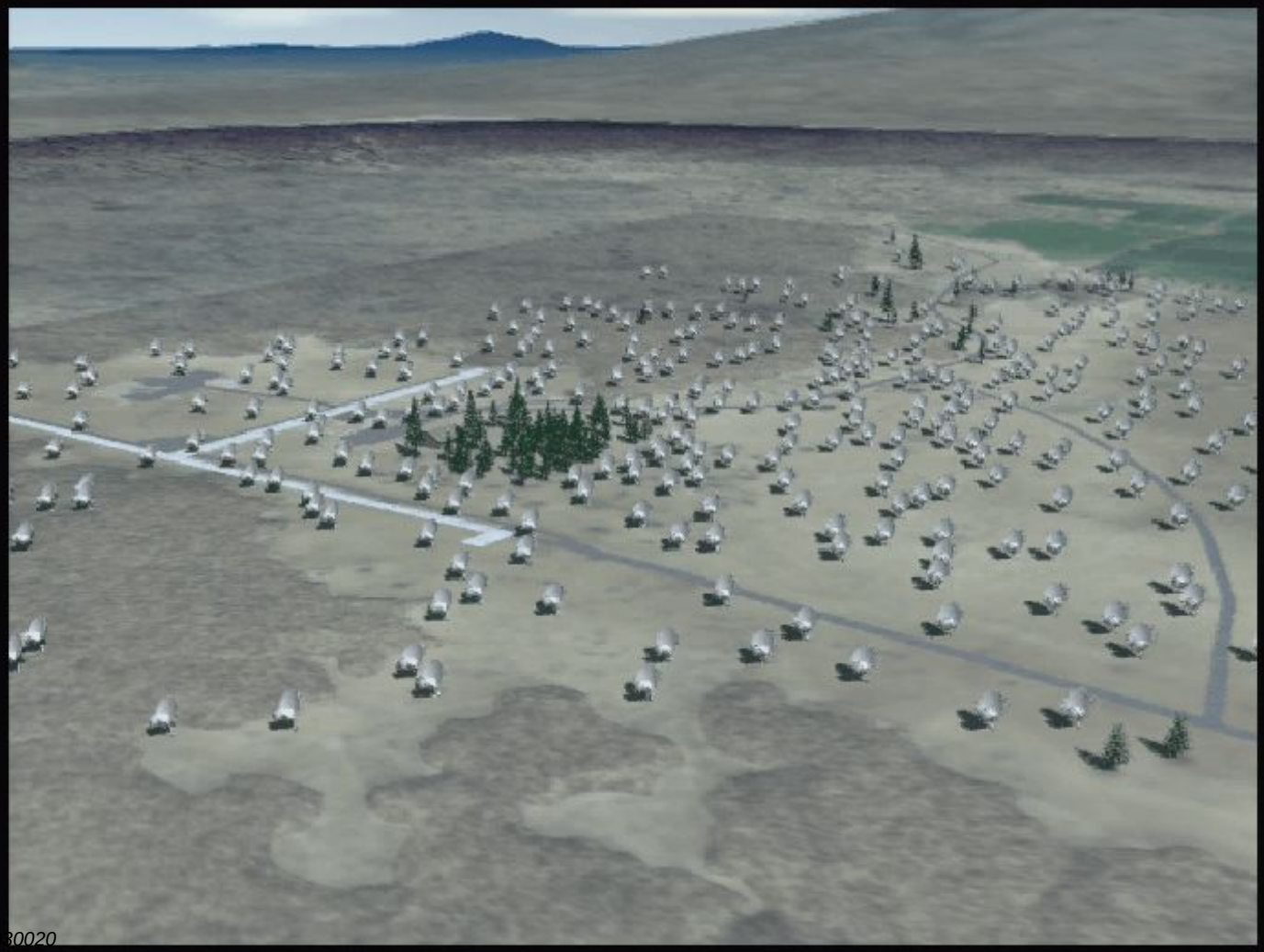

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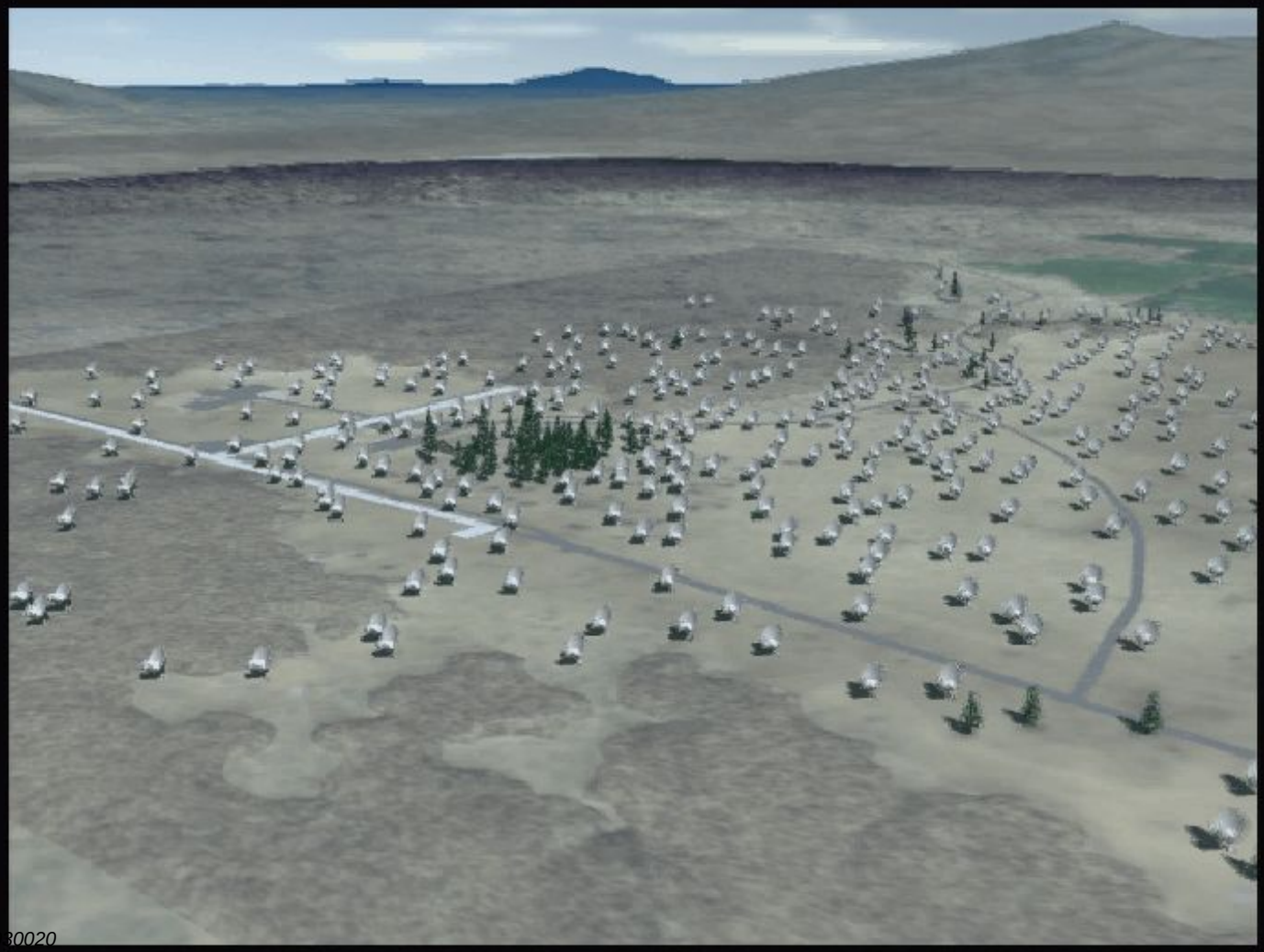

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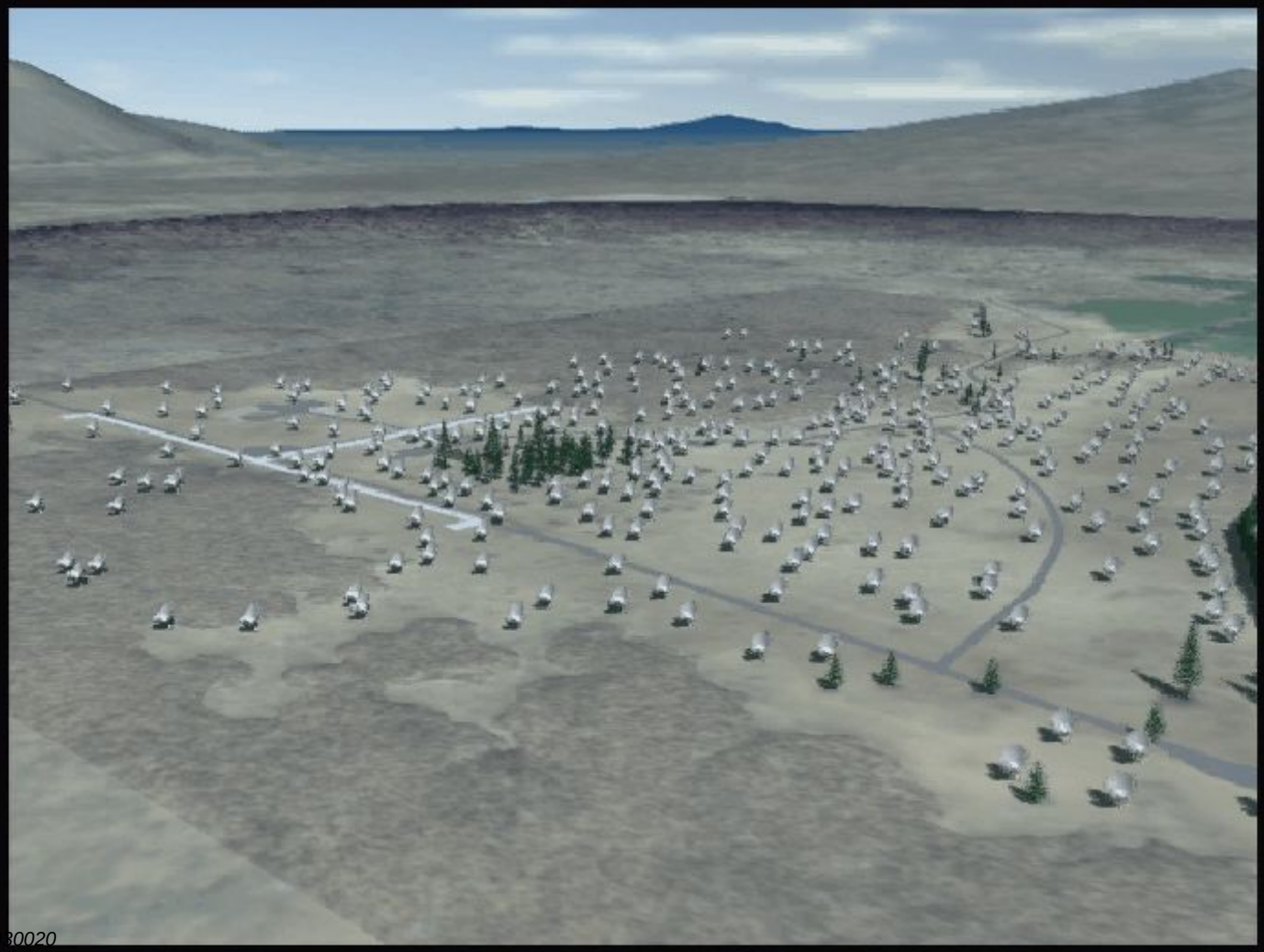

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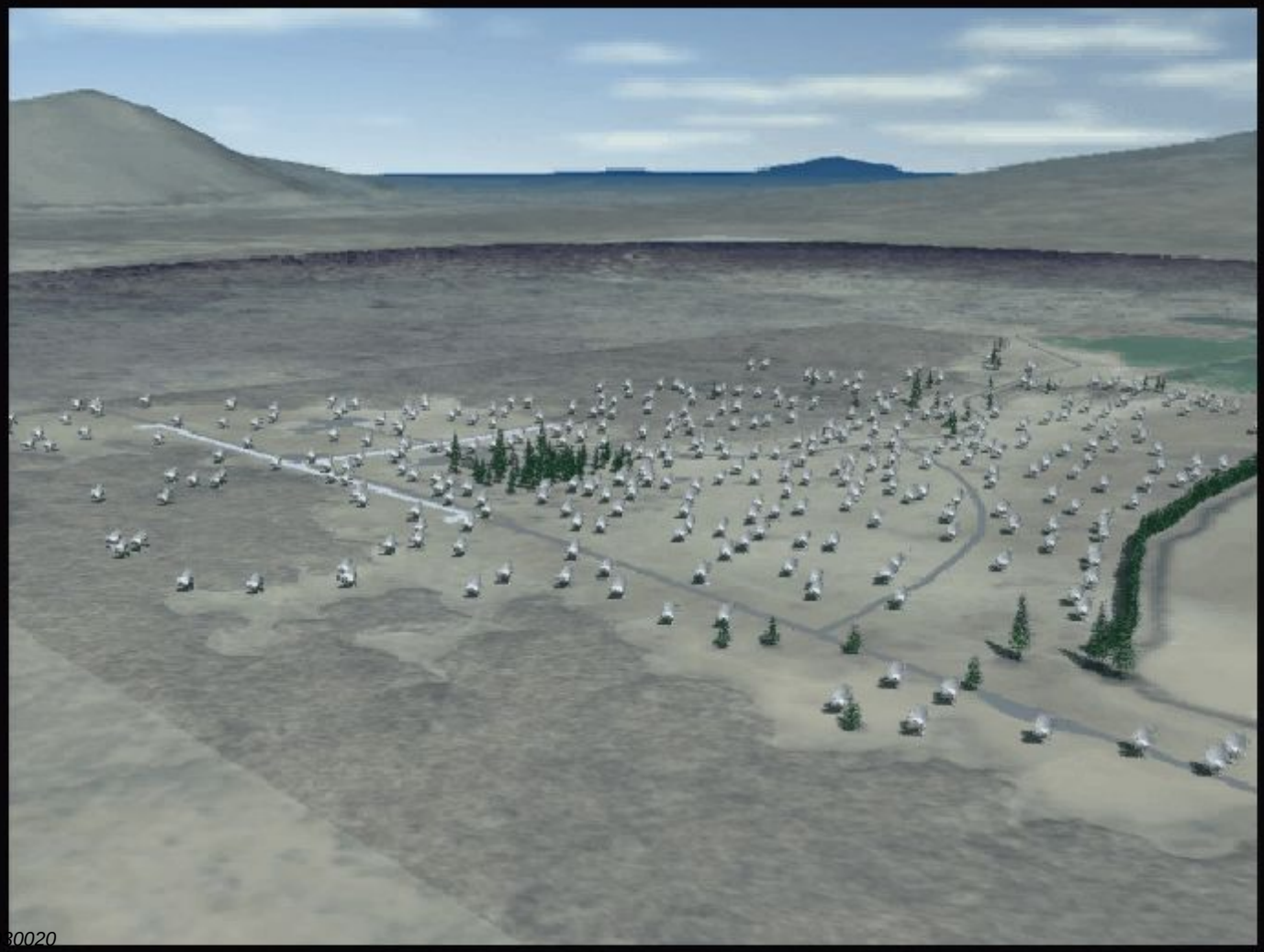

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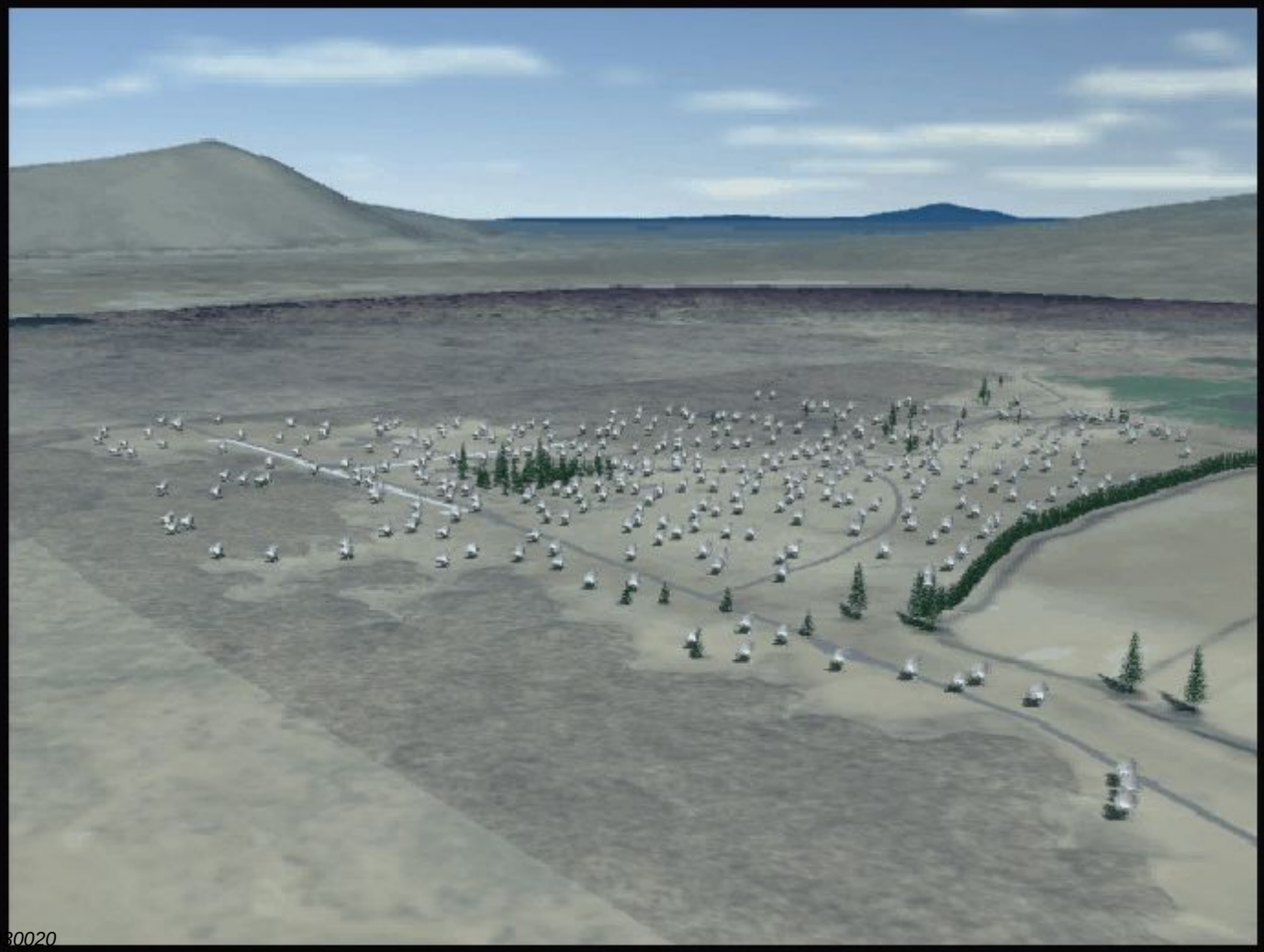

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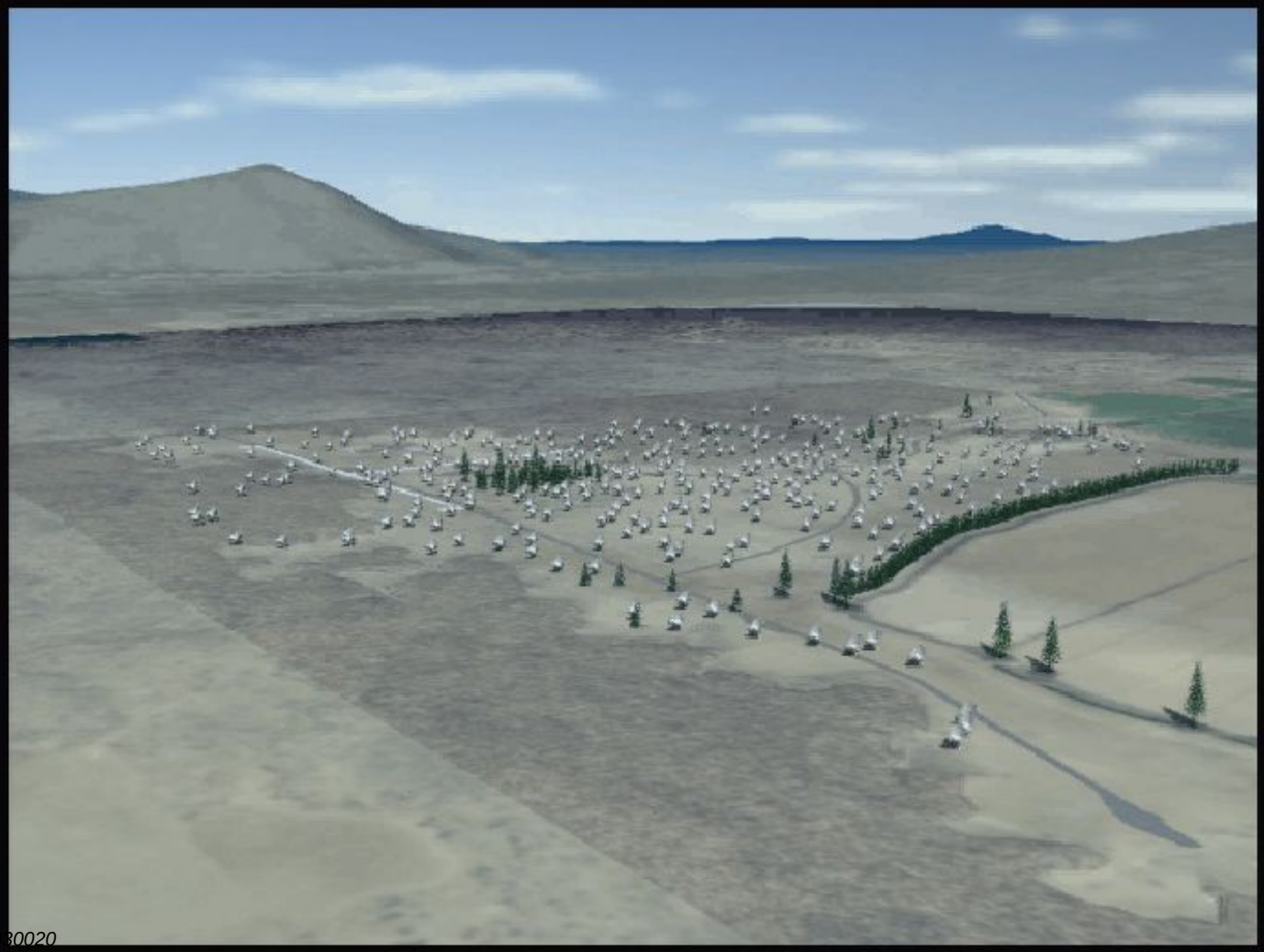
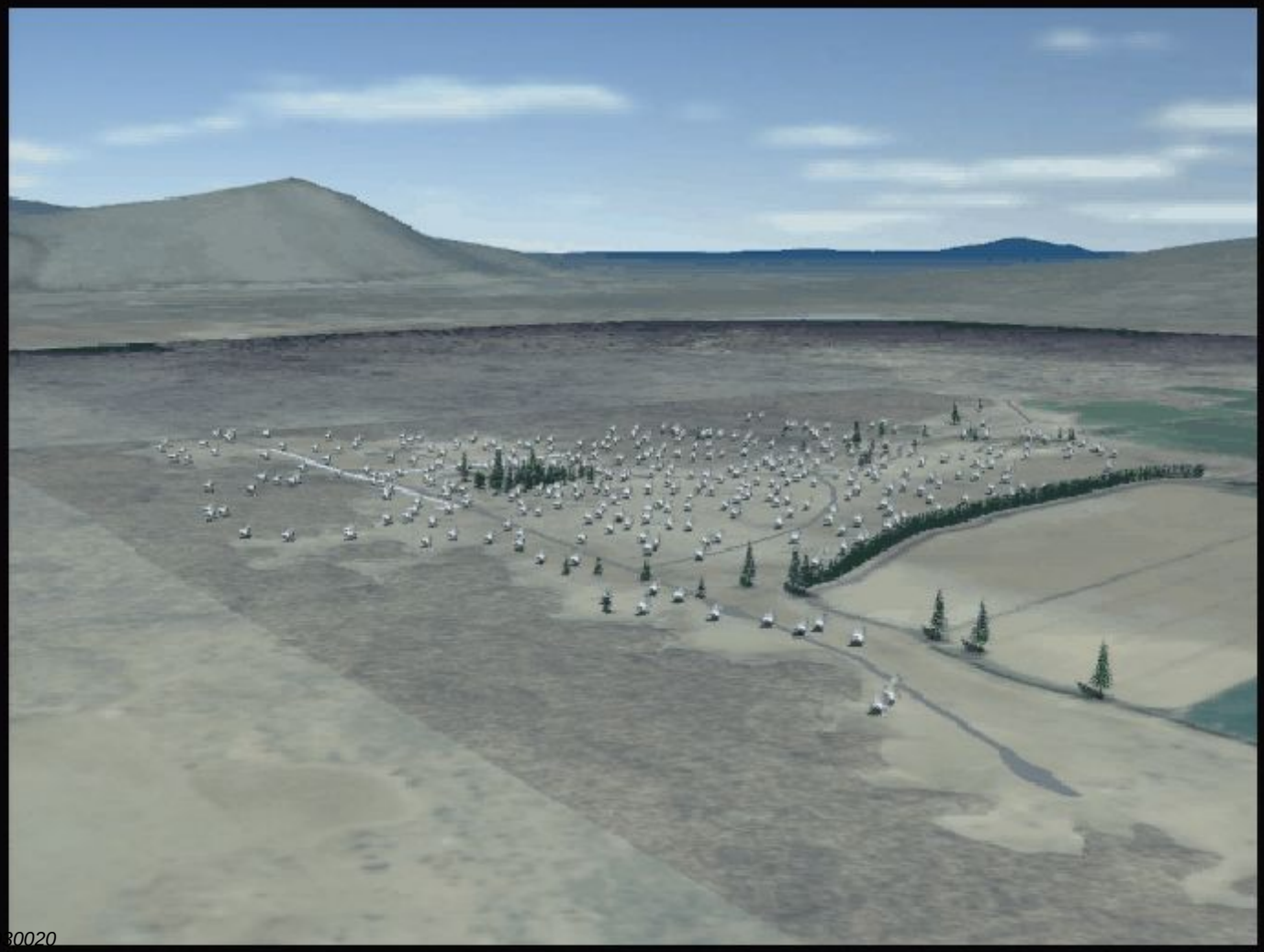


Hat Creek in northern CA ~ 2008 - 9 depending on rate of funding

The Allen Telescope Array



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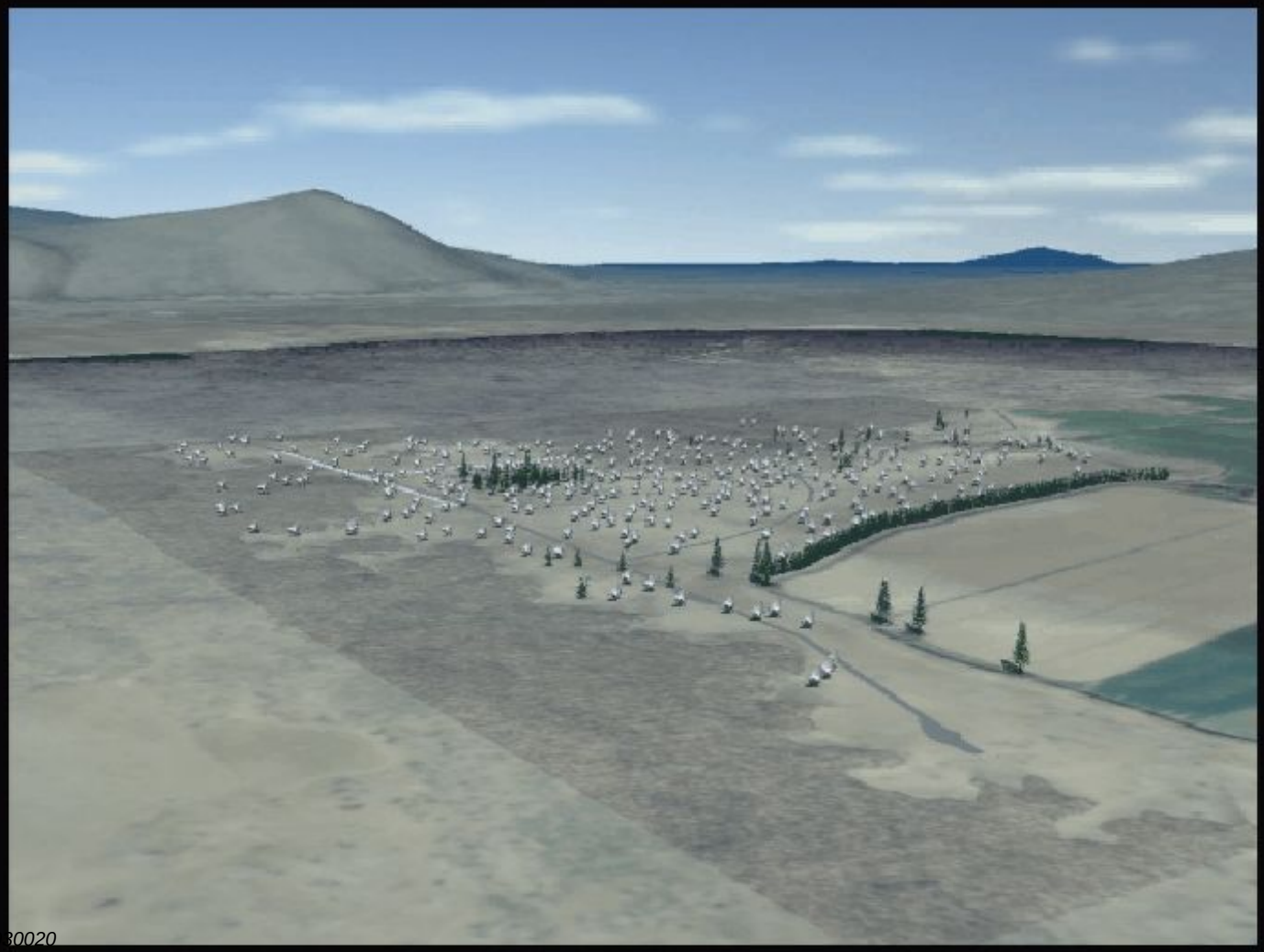

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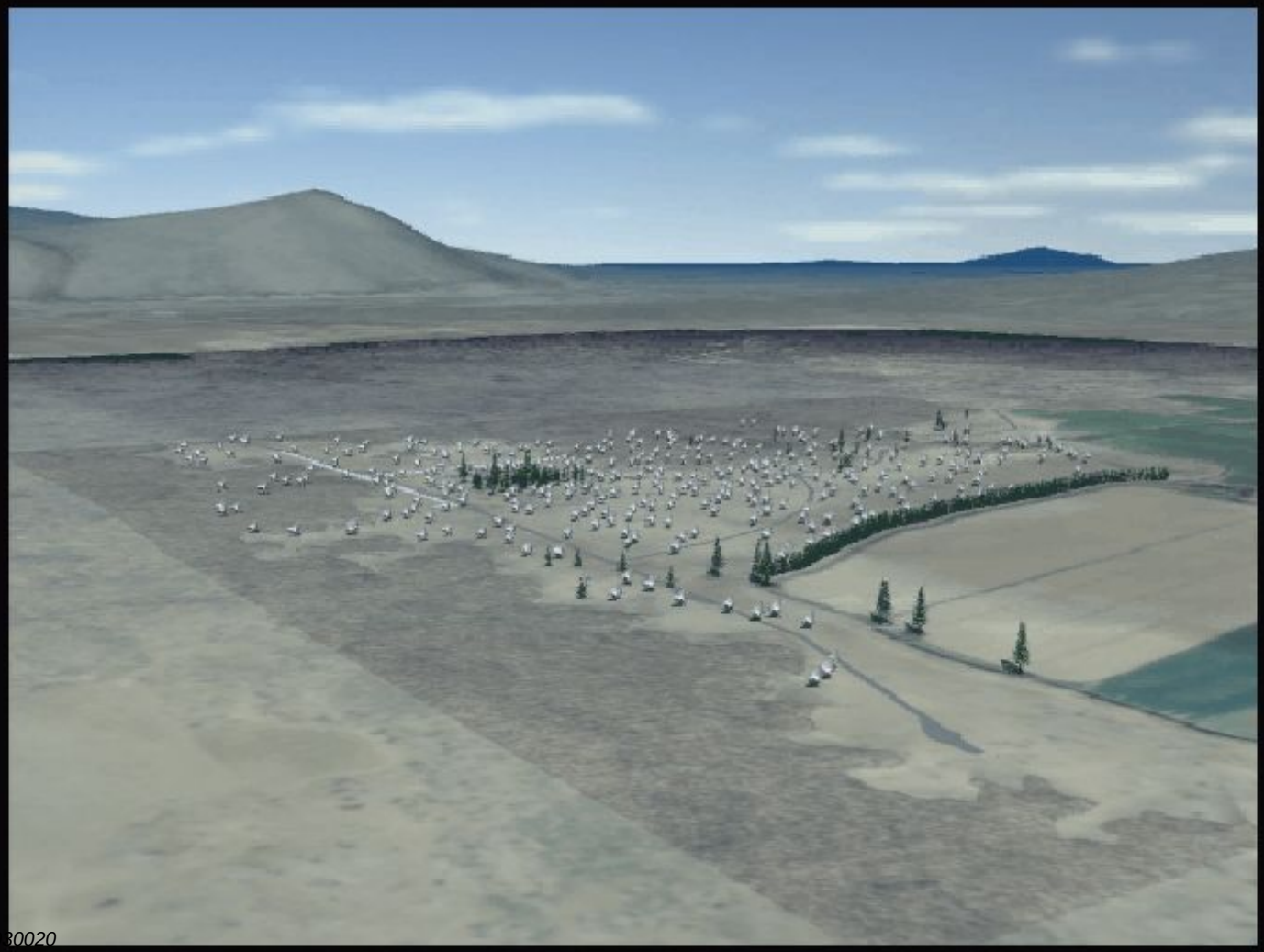

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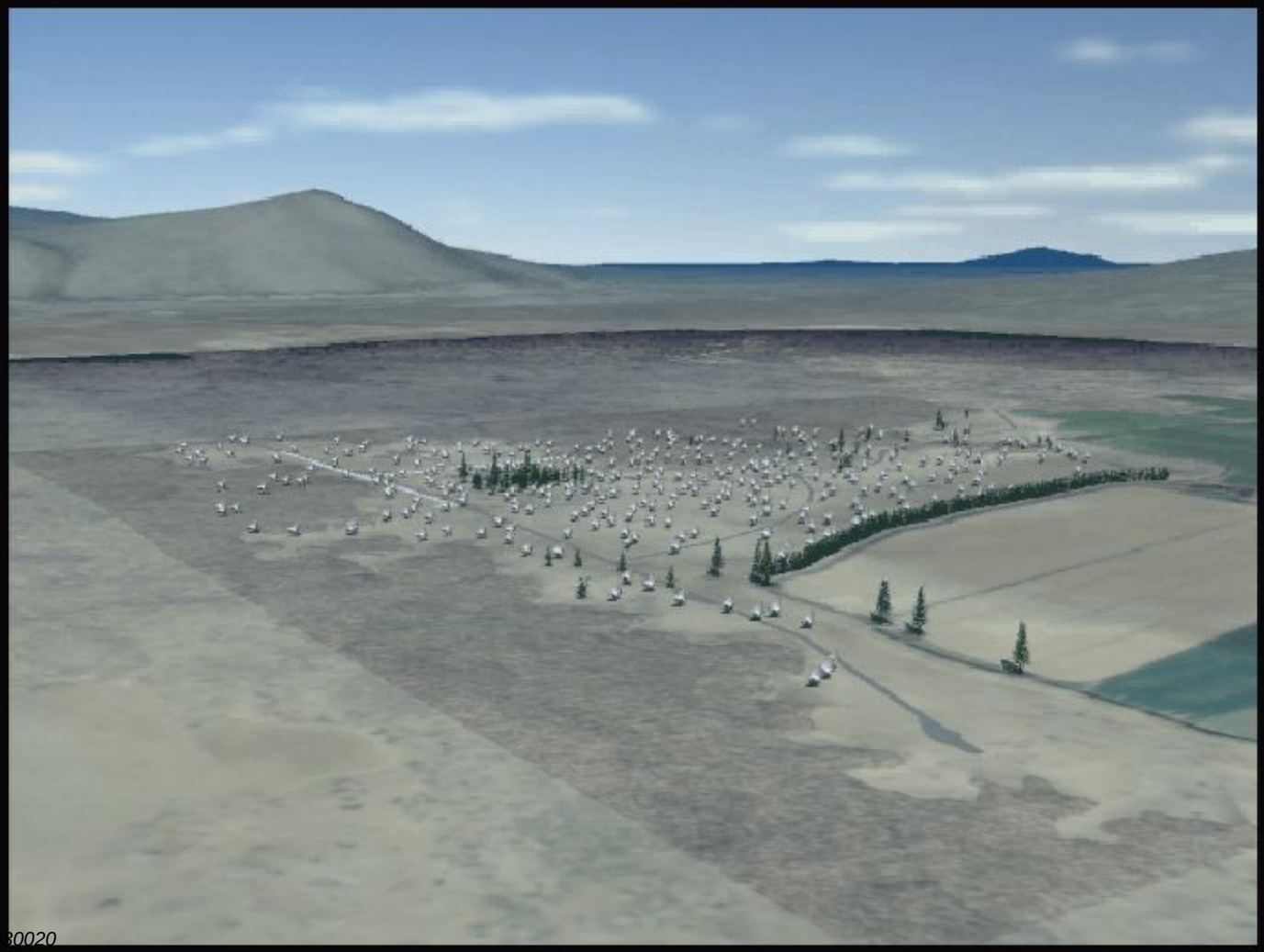

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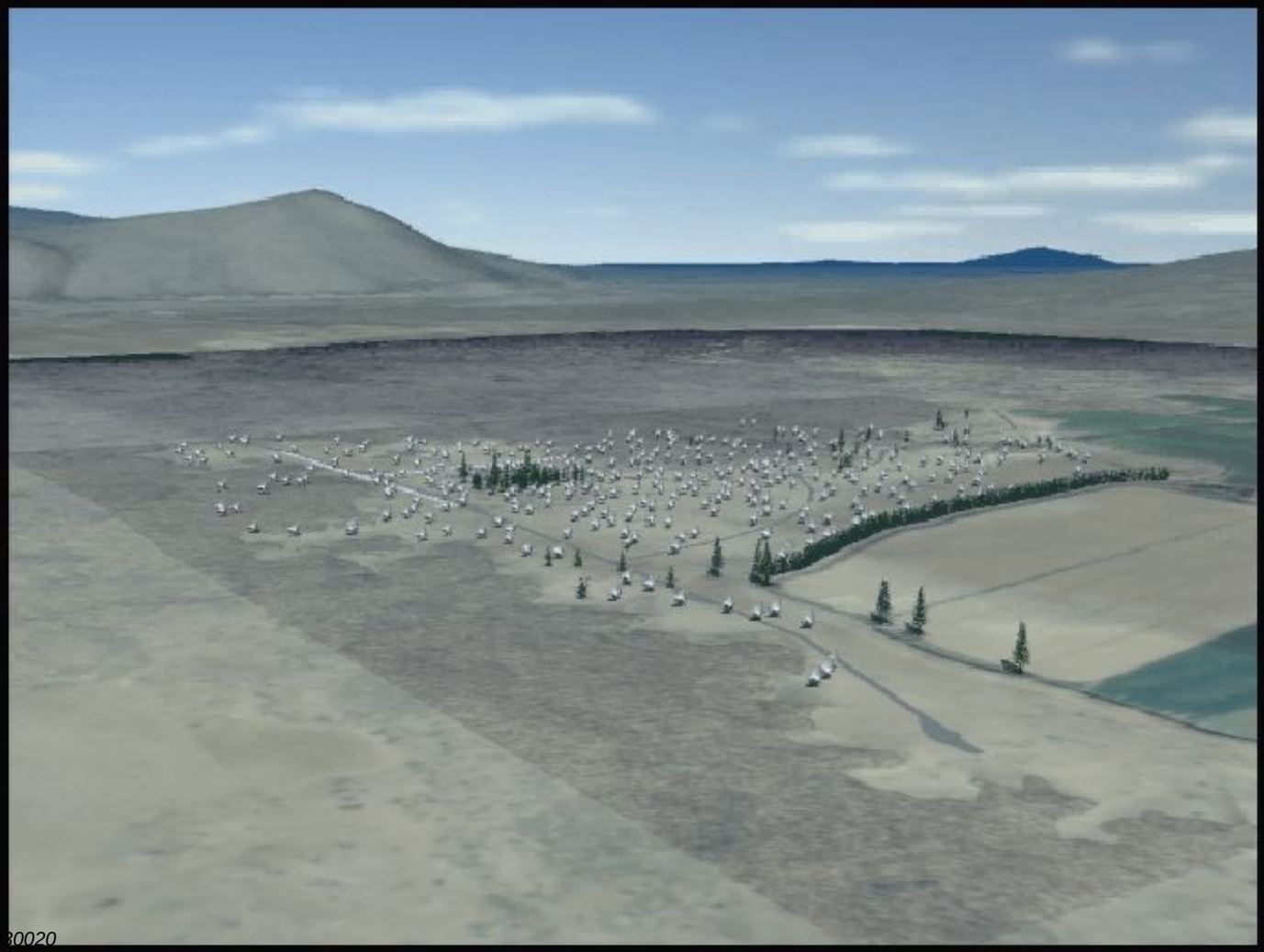

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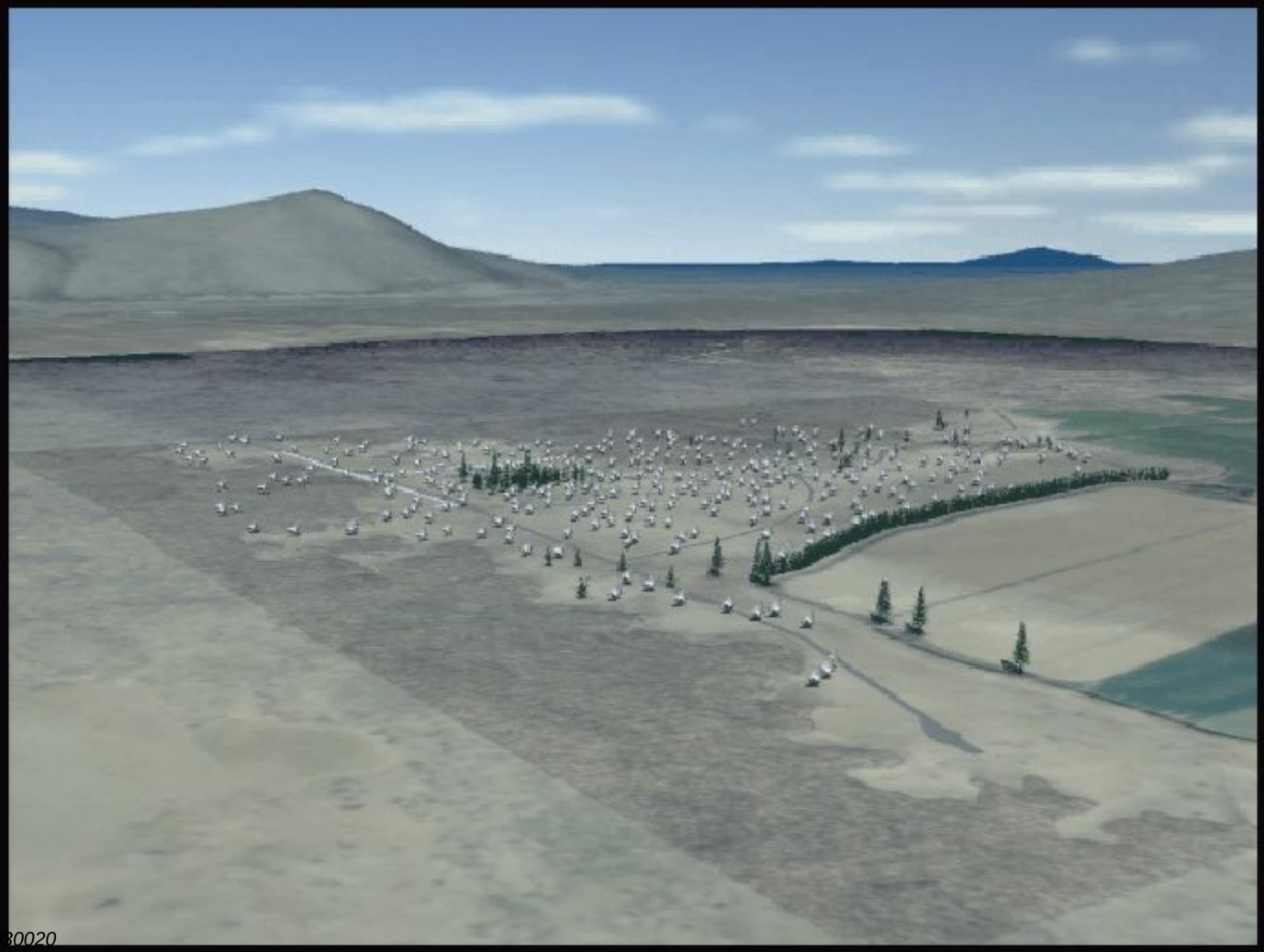

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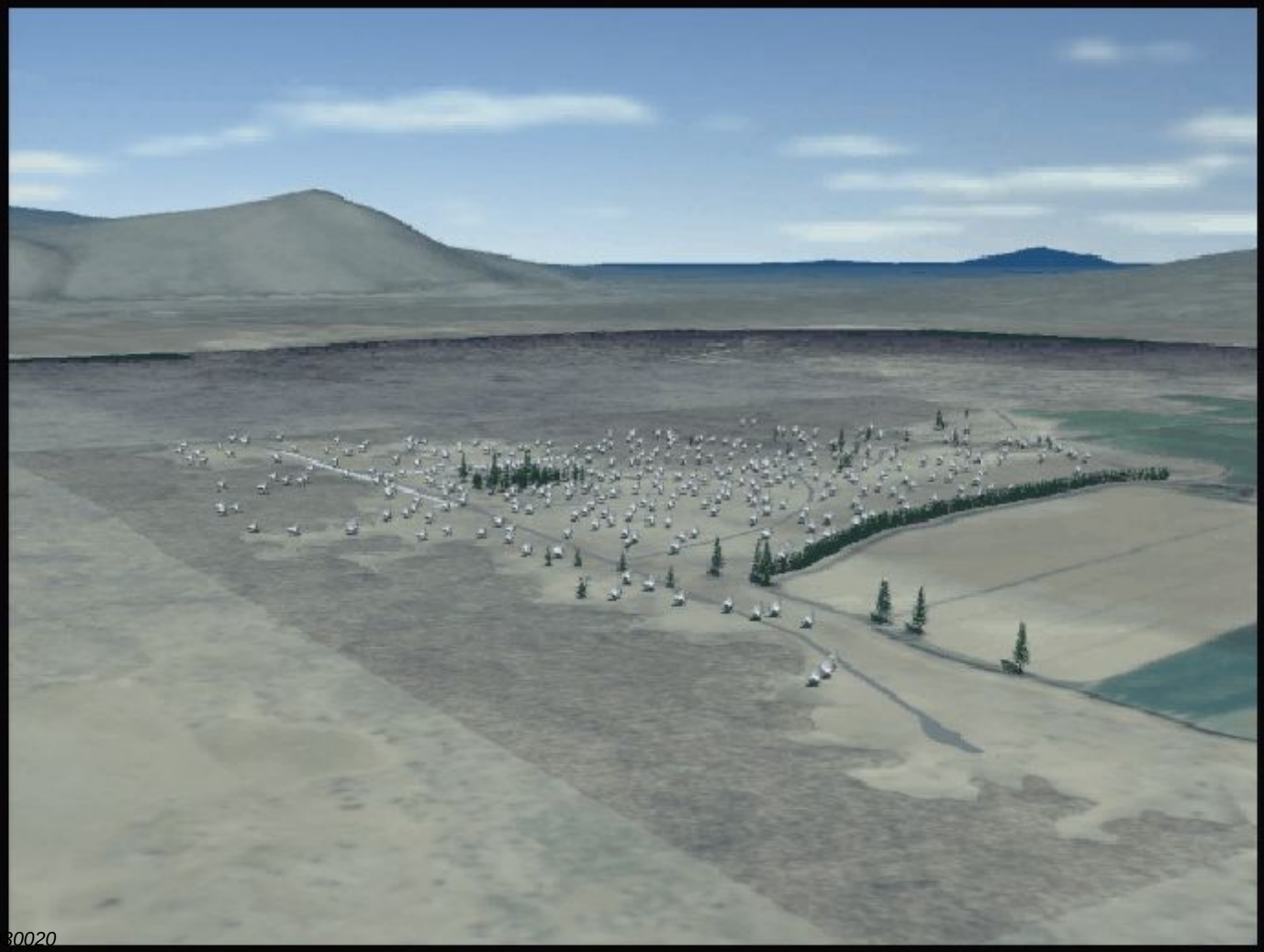

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Radio Telescope – Reinvented

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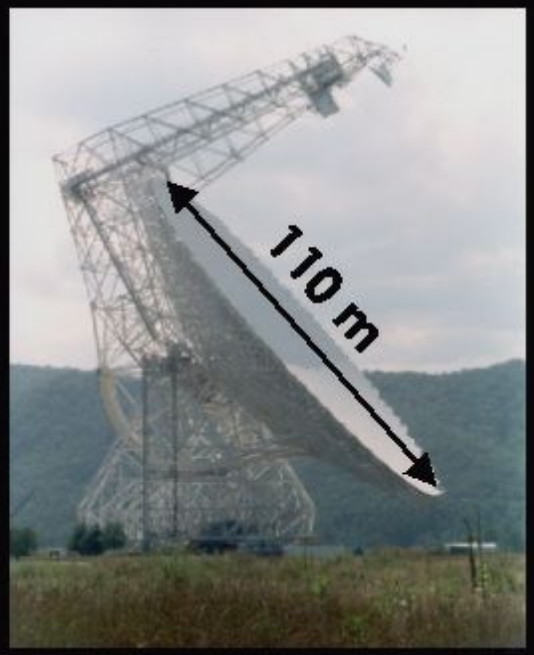
- A "Traditional" Telescope
- Large single dish
  → Expensive
    - Construction – "big iron"
    - Electronics – custom



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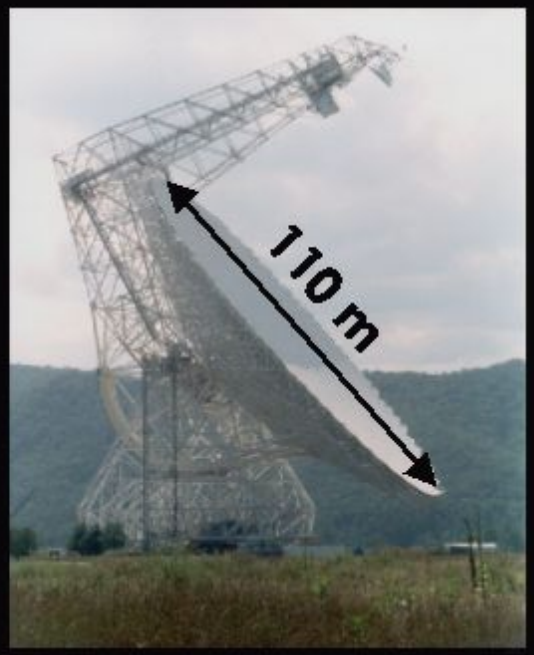

- A "New" Telescope
- Many small dishes
  → Cheaper construction
- Commercial electronics, computers & FPGAs

The Allen Telescope Array

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- 350 dishes (6.1 m) spread over ~ 700 m (0.44 mi)

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View of the Sky from a 6 m Dish

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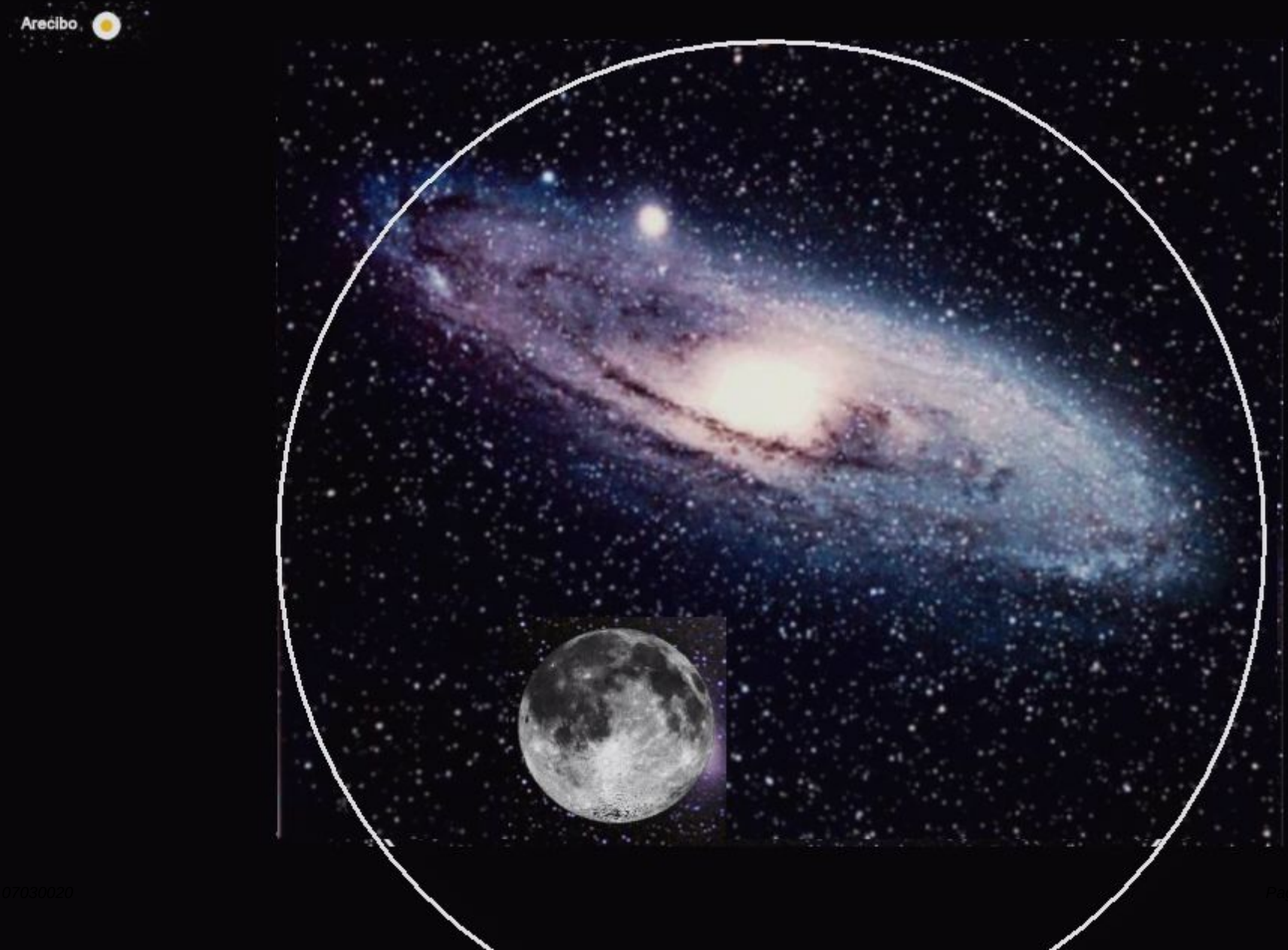

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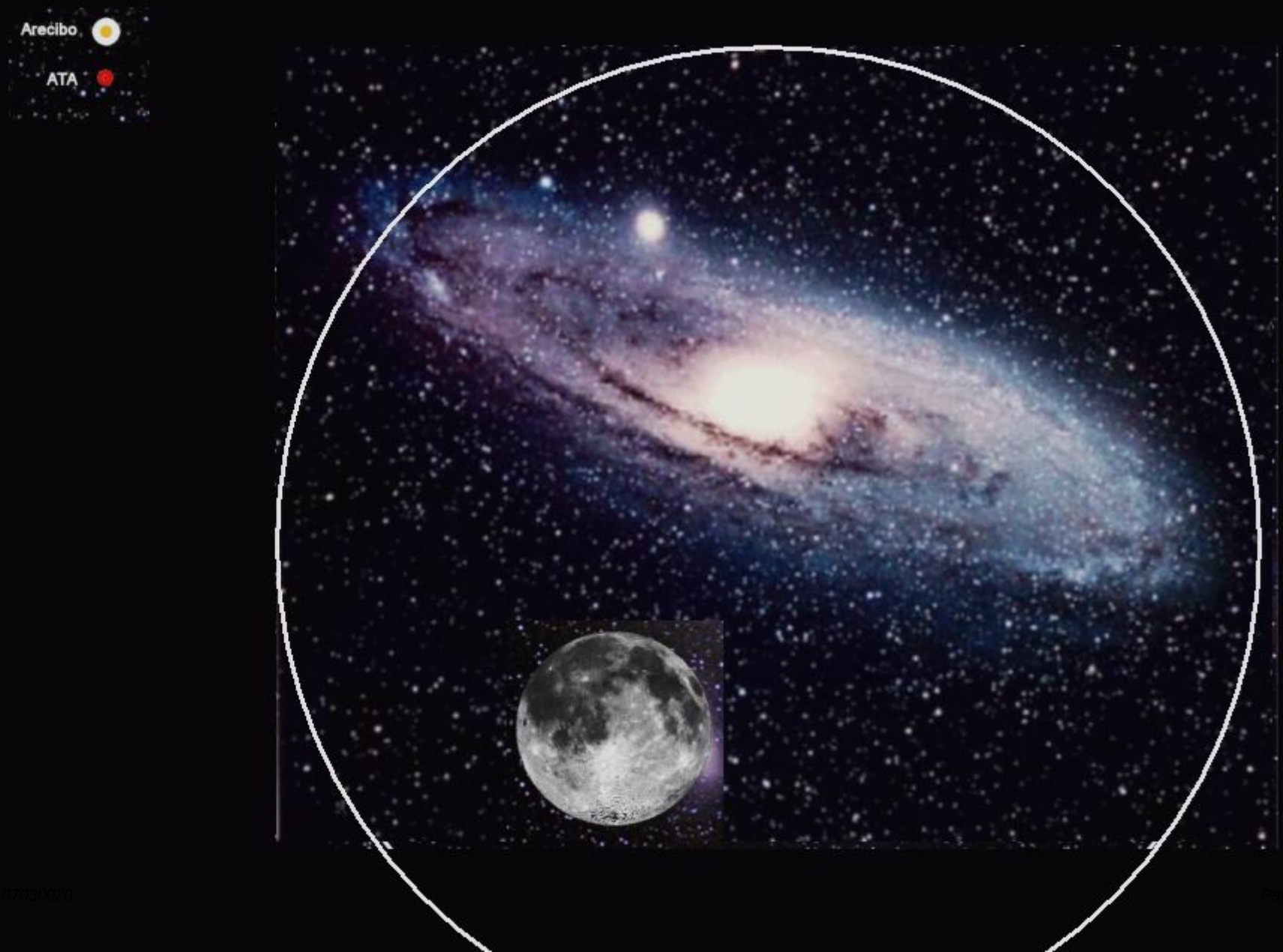
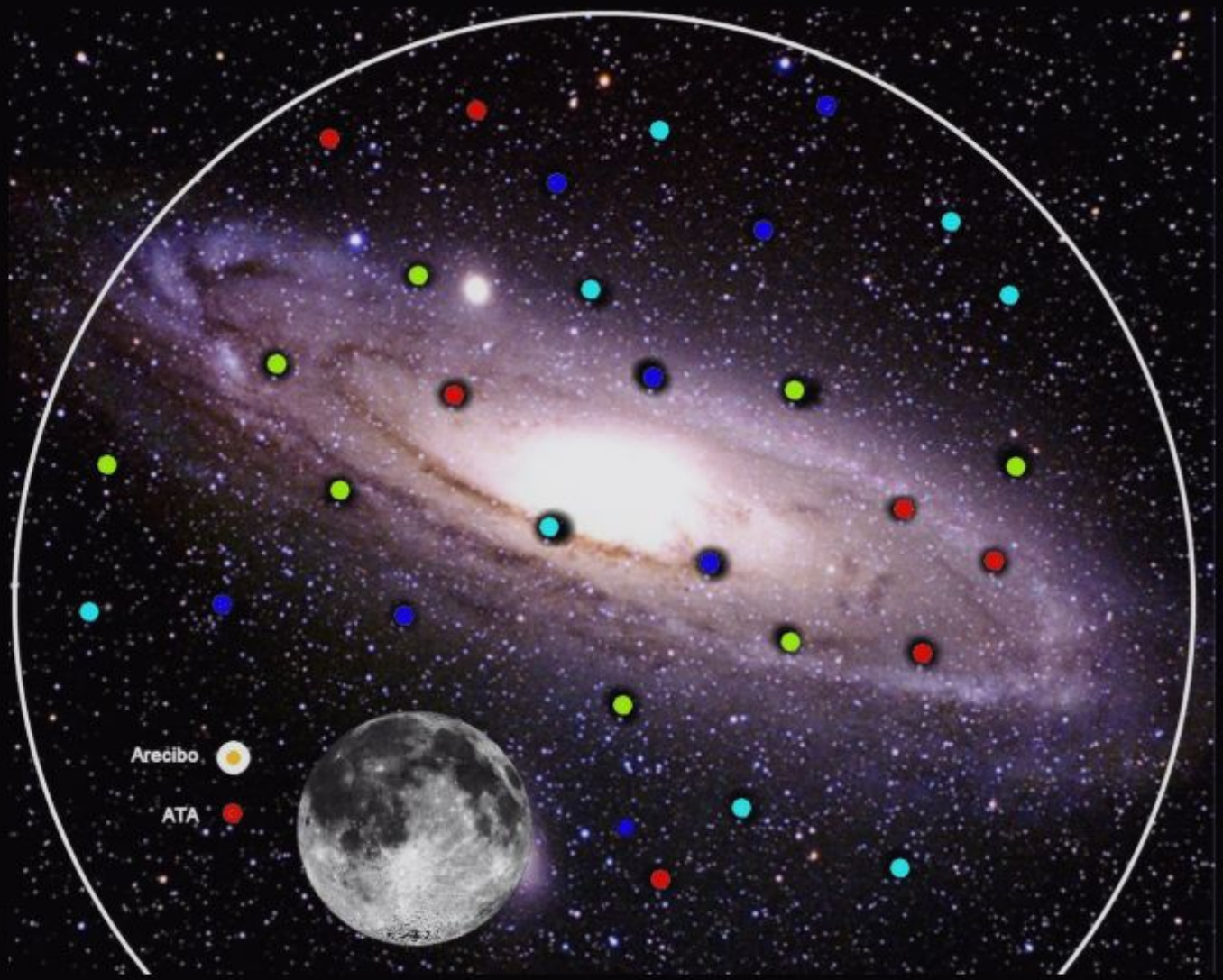


Adding Up (Phasing) All the Dishes

Beam former generates 16 dual-pol pencil beams anywhere in the sky (100 MHz) 4 beams at each of 4 frequencies



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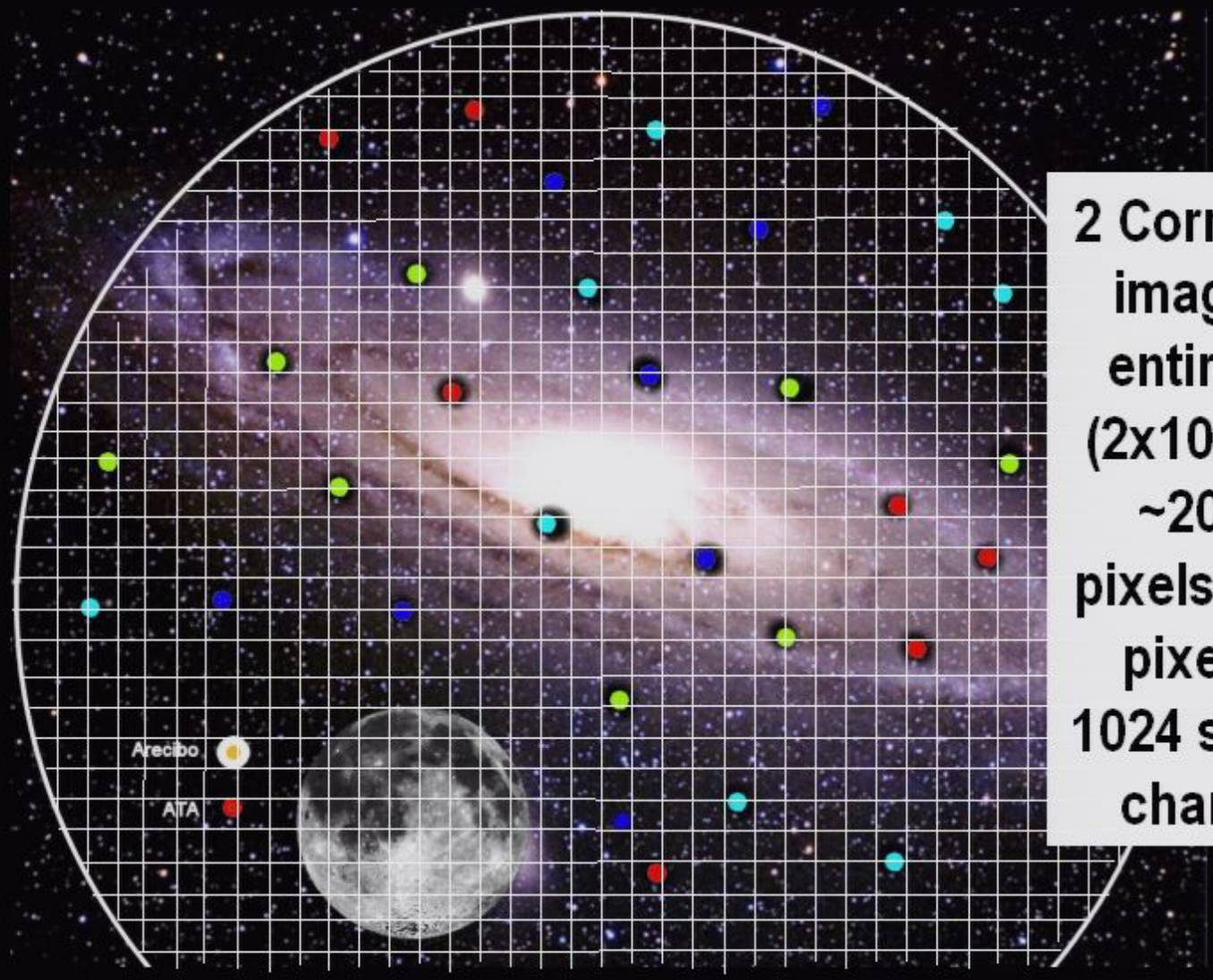

2 Correlators image the entire FoV (2x100 MHz) ~20,000 pixels – each pixel has 1024 spectral channels

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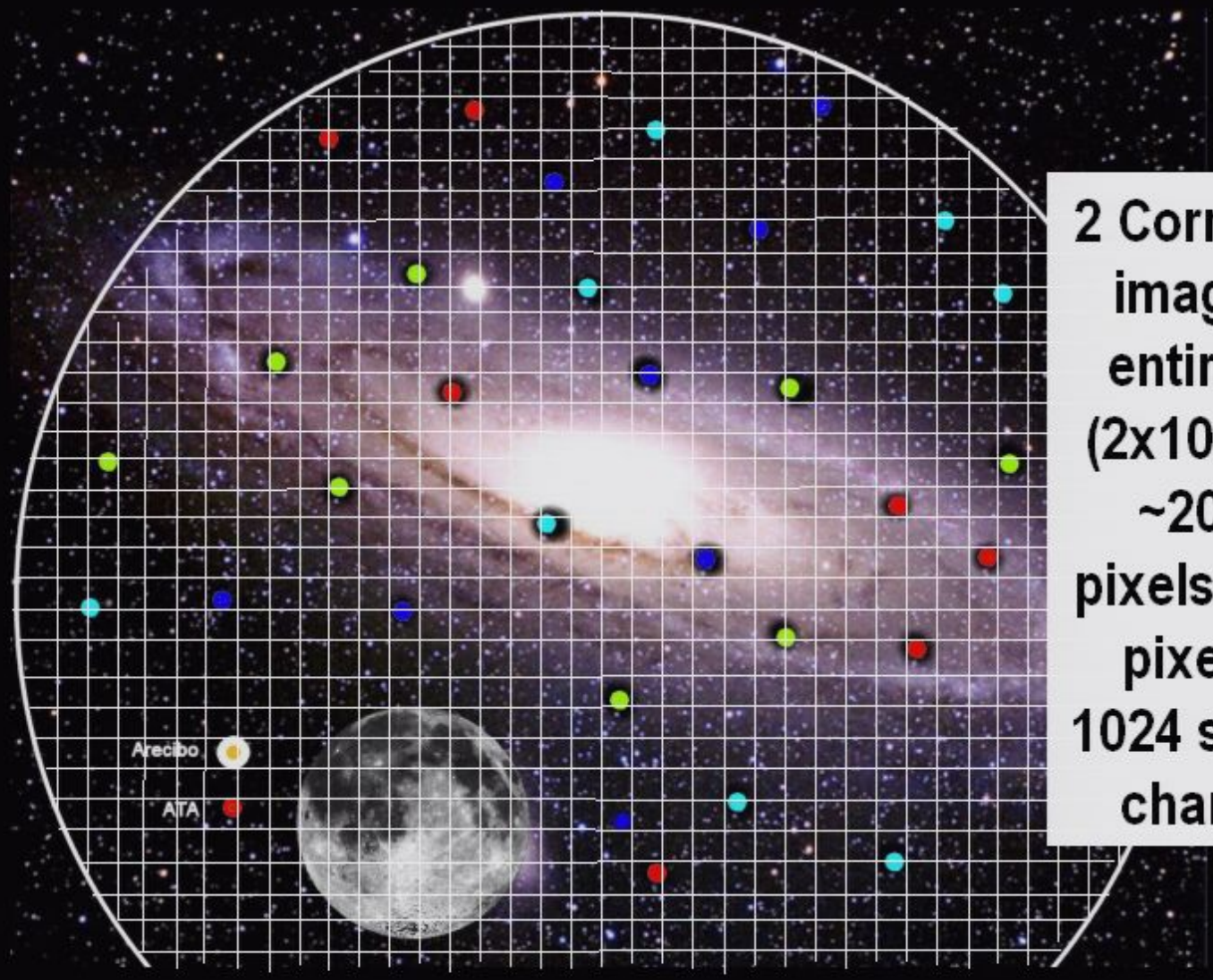

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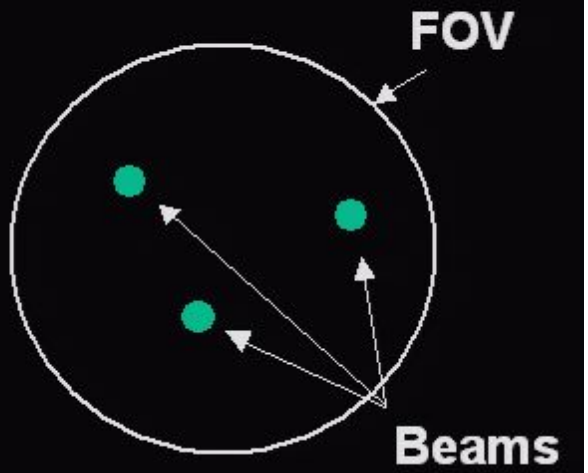
SETI on the ATA

SonATA



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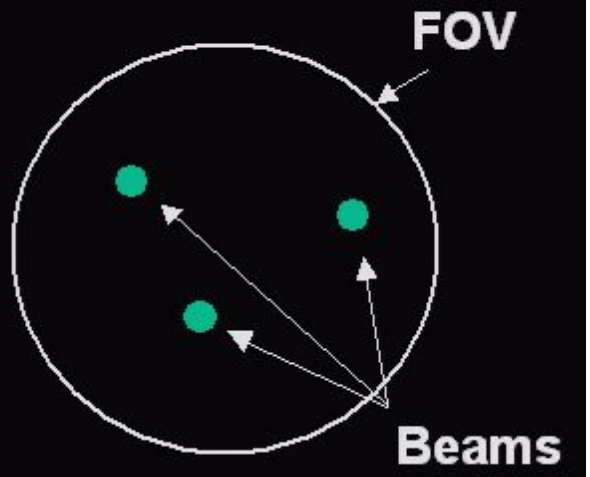
- Use three beams (virtual telescopes) within the Field of View (FOV)



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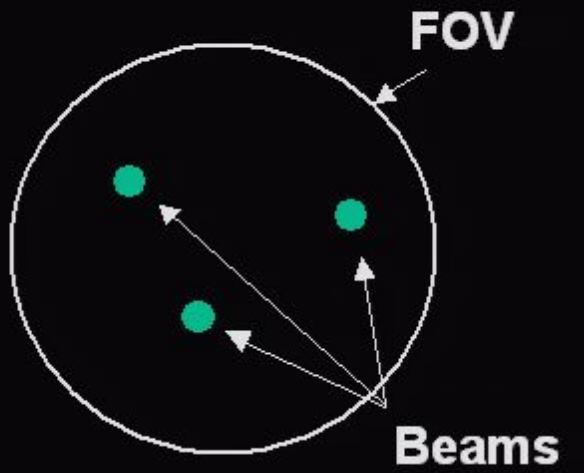

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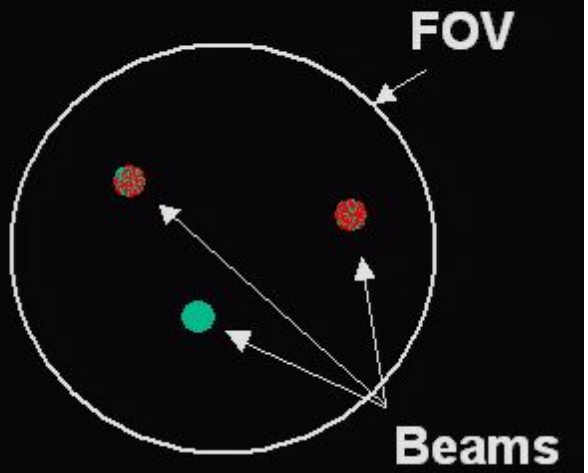

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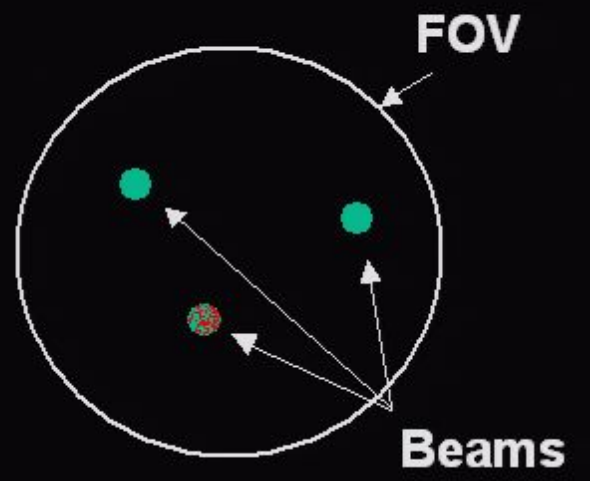
- A signal that appears to come from only one star is ***interesting***



SETI before the ATA

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  - Only about 800 stars to ~250 light years

Ultra-wideband Feed/Receiver
0.5 – 11.2 GHz

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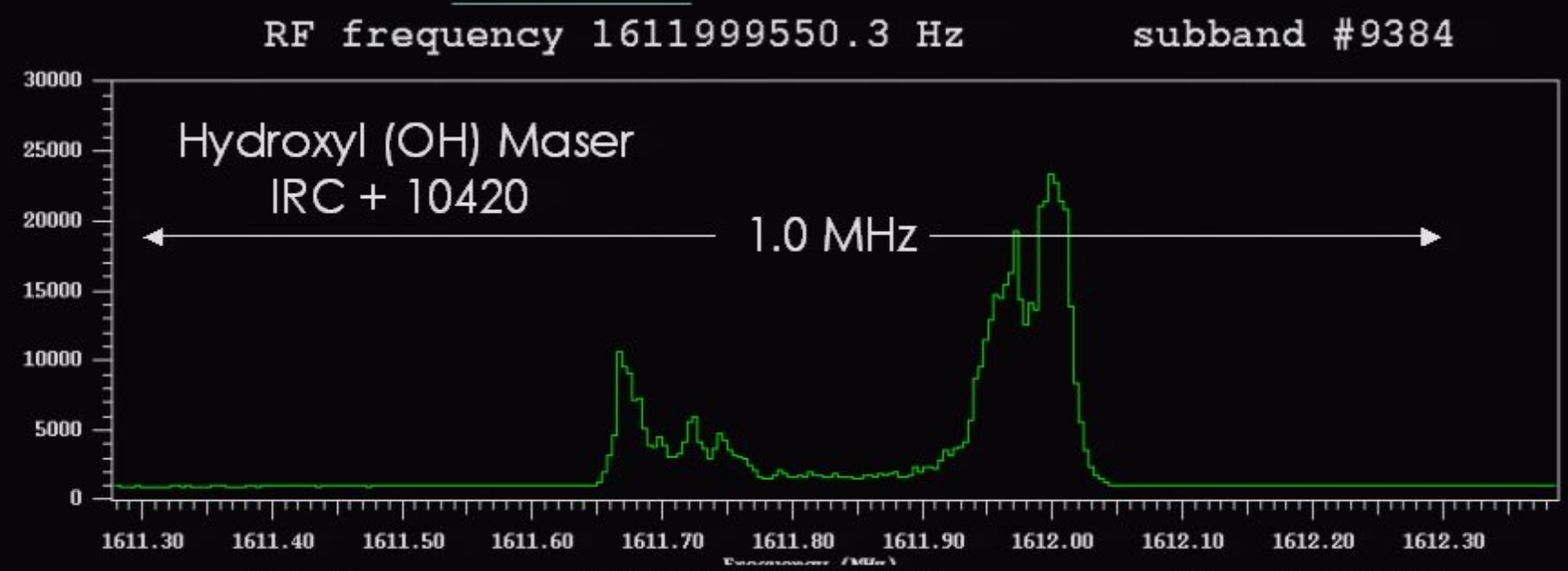
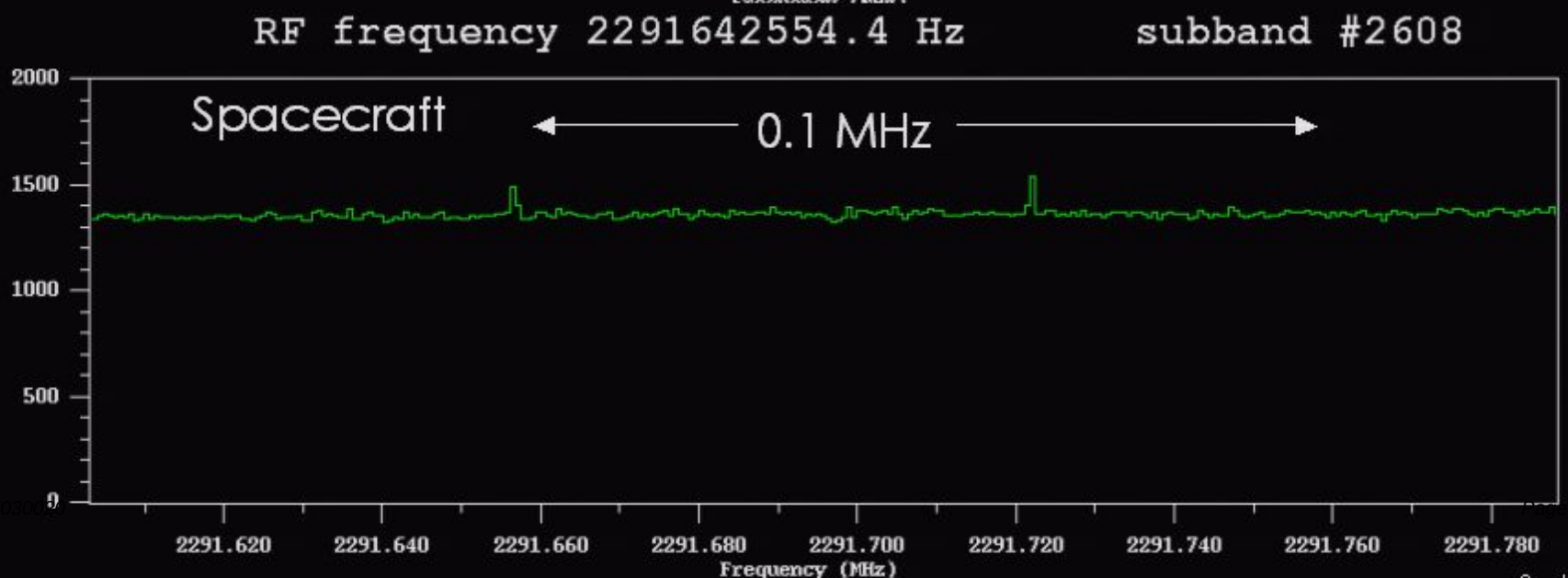
Astrophysics vs. Technology





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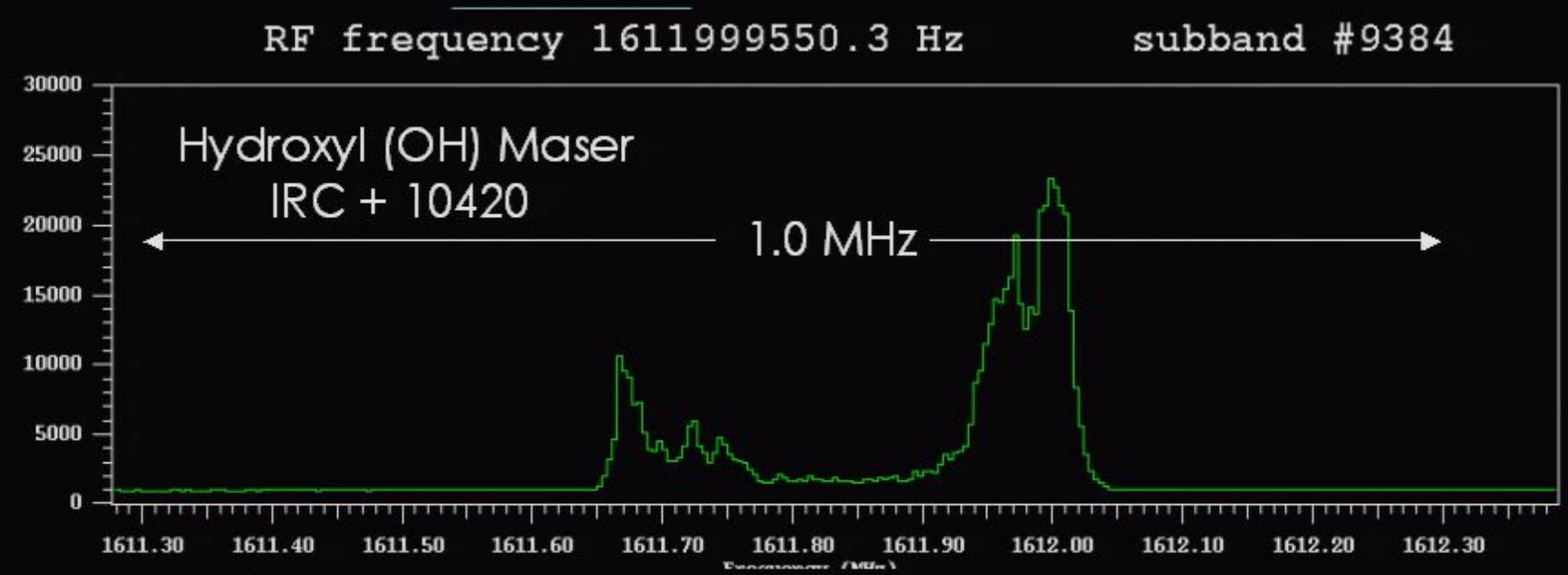
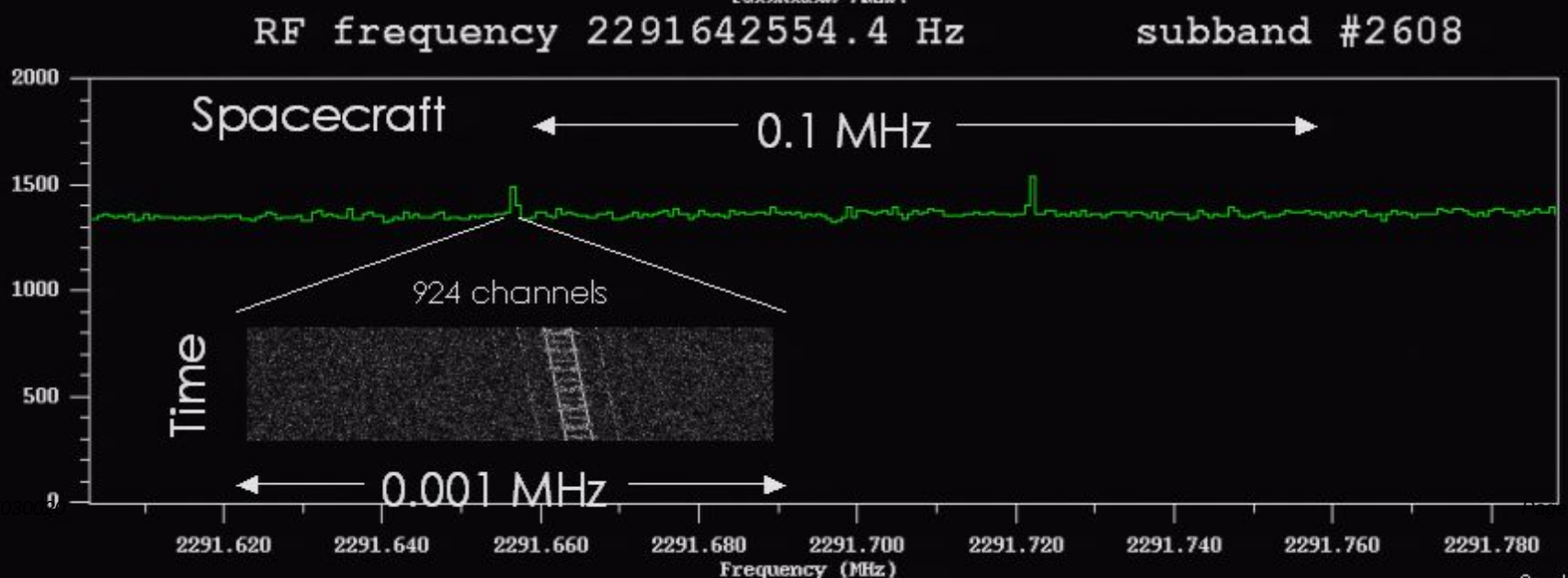
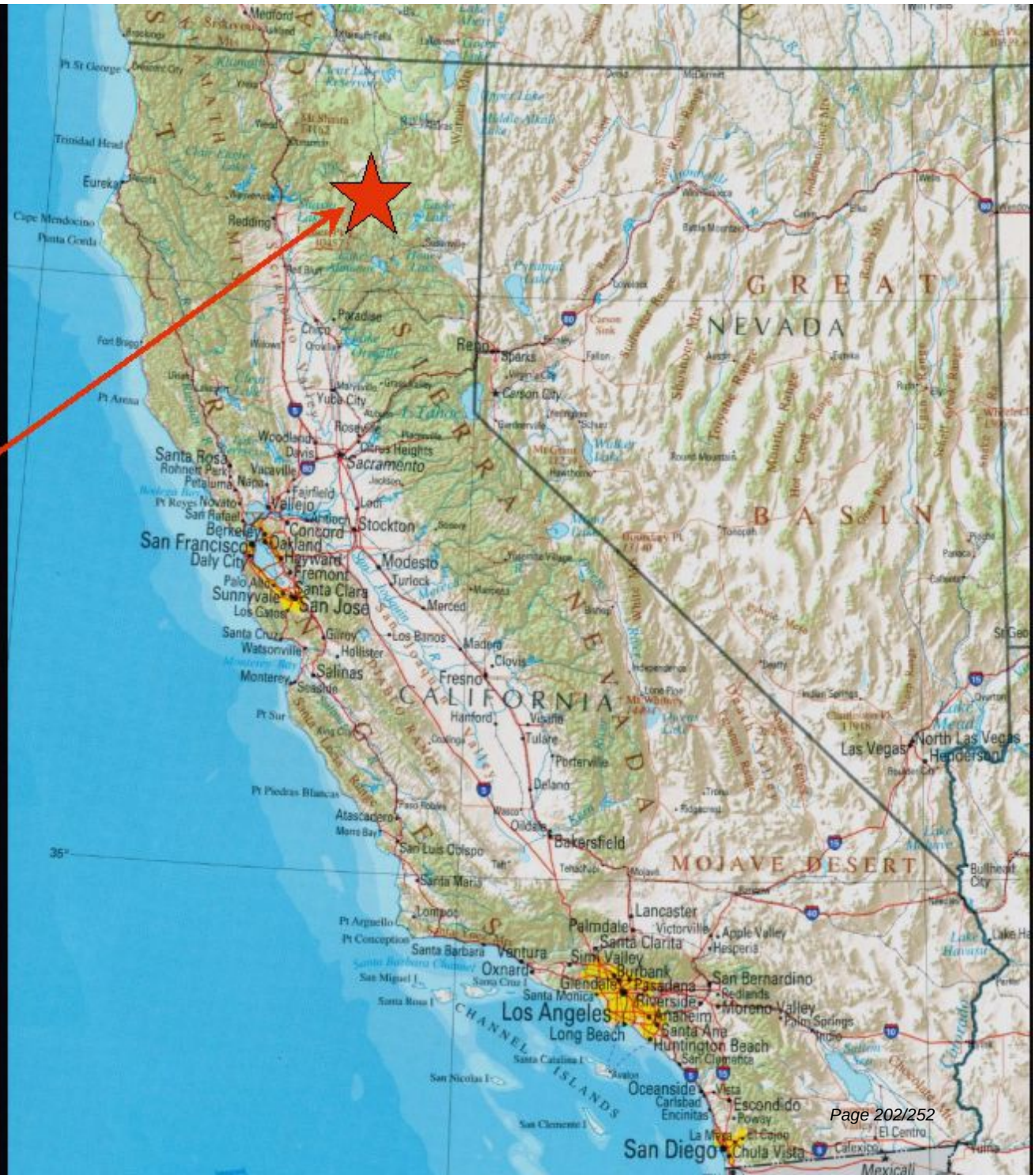




Hat Creek
Radio Observatory
is here.



Hat Creek Radio Observatory

Construction Tent

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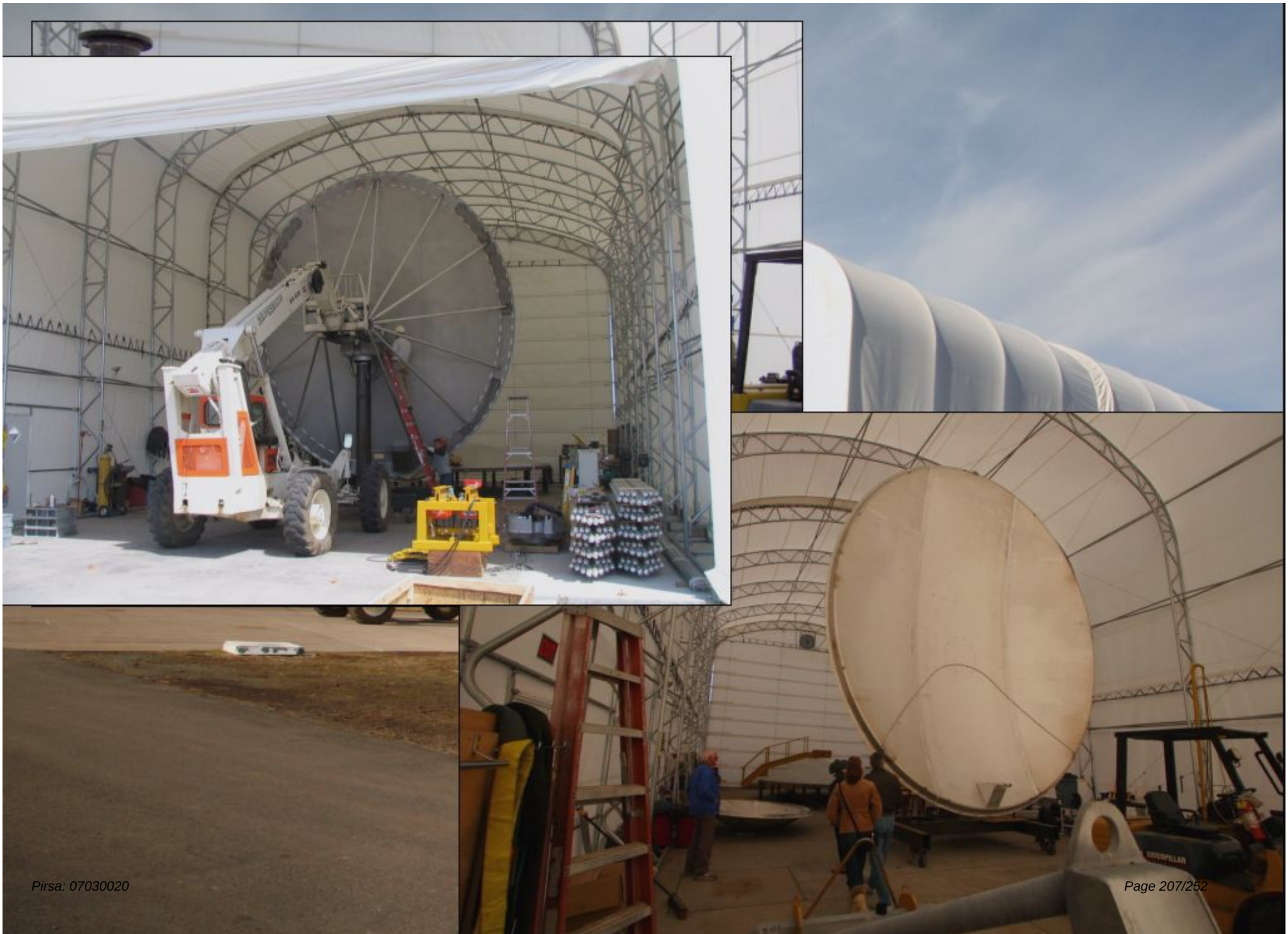

BBC RADIO COLLECTION

DON'T PANIC!

THE HITCH HIKER'S GUIDE TO THE GALAXY SERIES TWO

BBC RADIO COLLECTION

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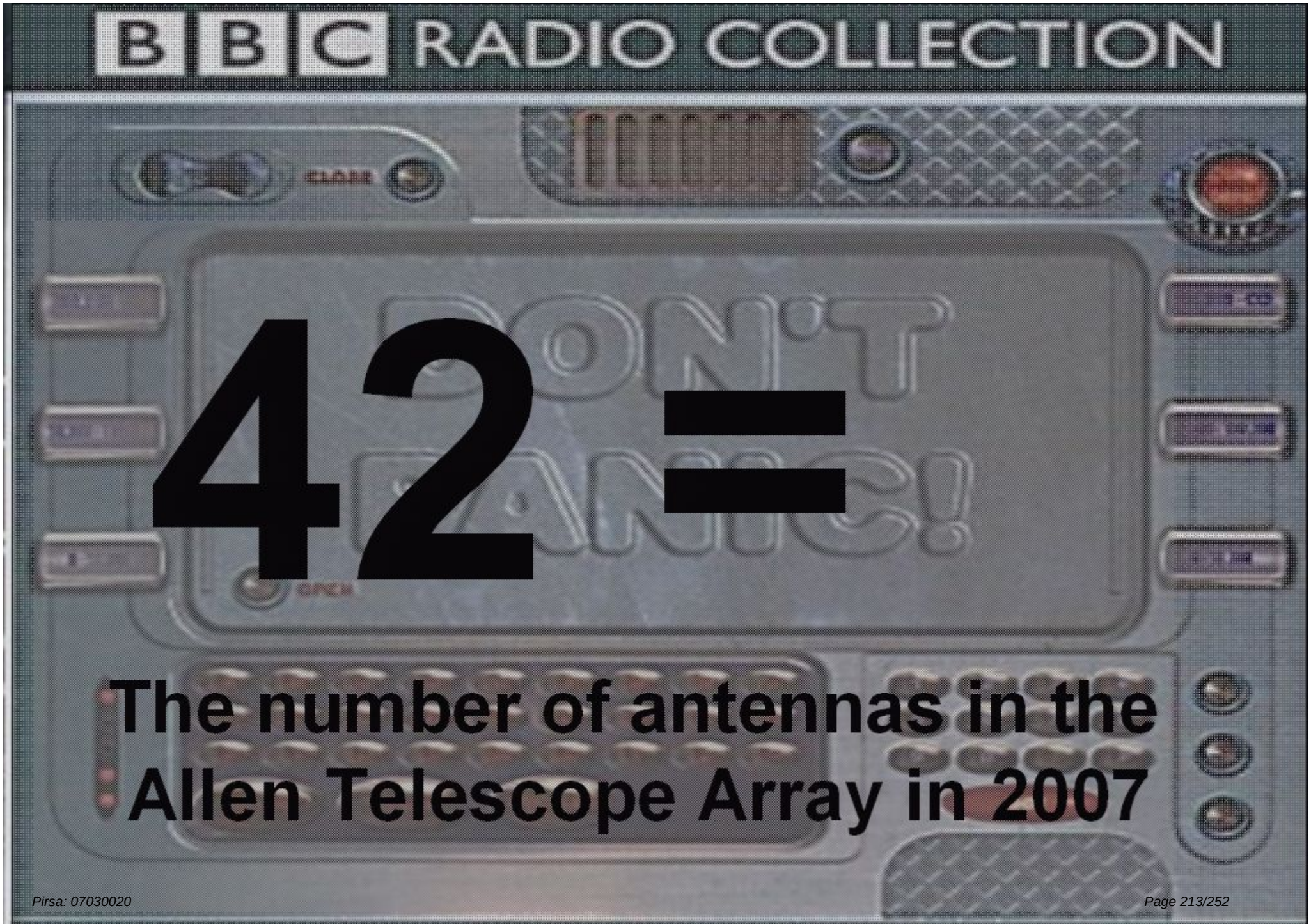
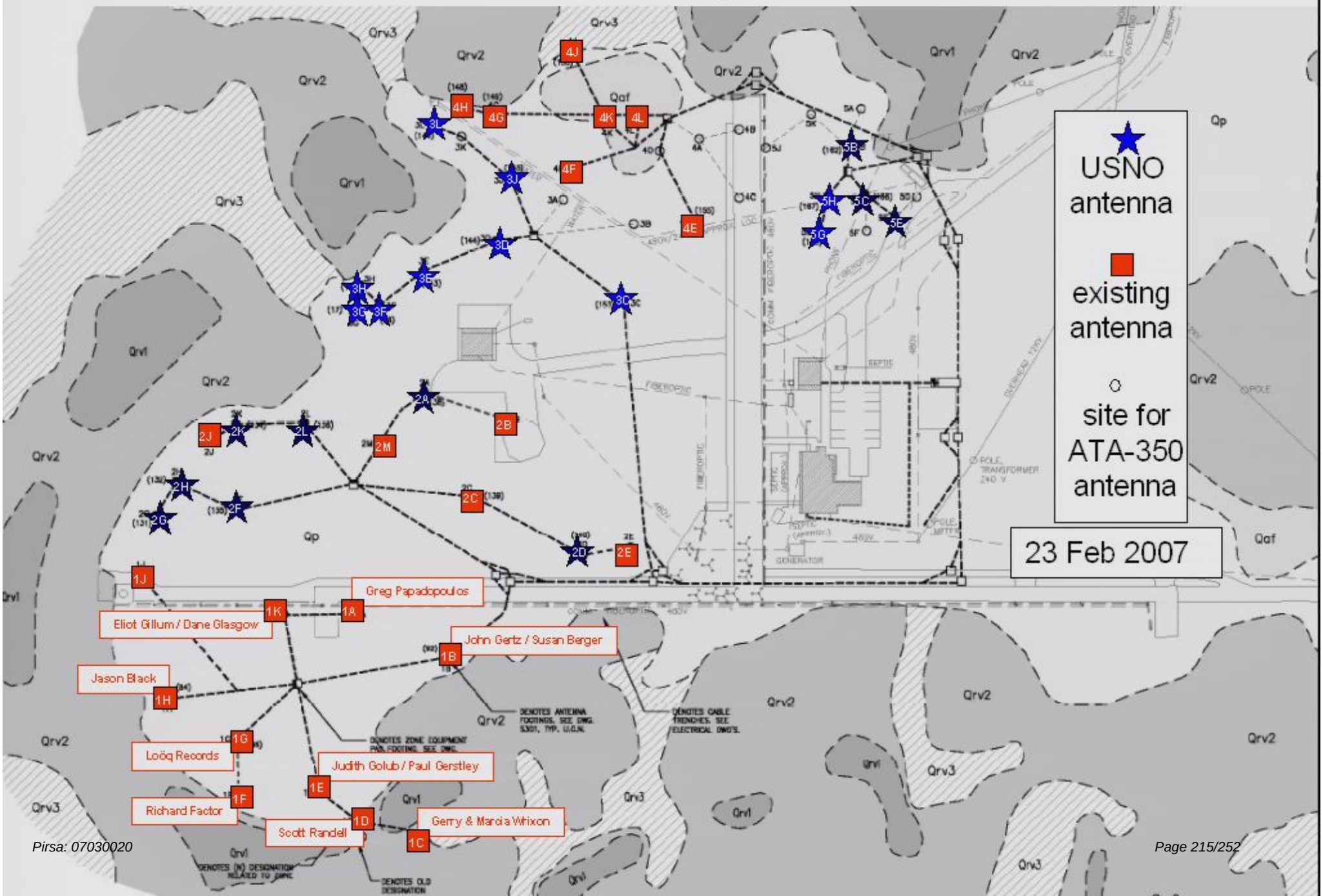

BBC RADIO COLLECTION
42 =
The number of antennas in the Allen Telescope Array in 2007

Antenna #42 !!!! 2/23/07

ATA-42 Siteplan



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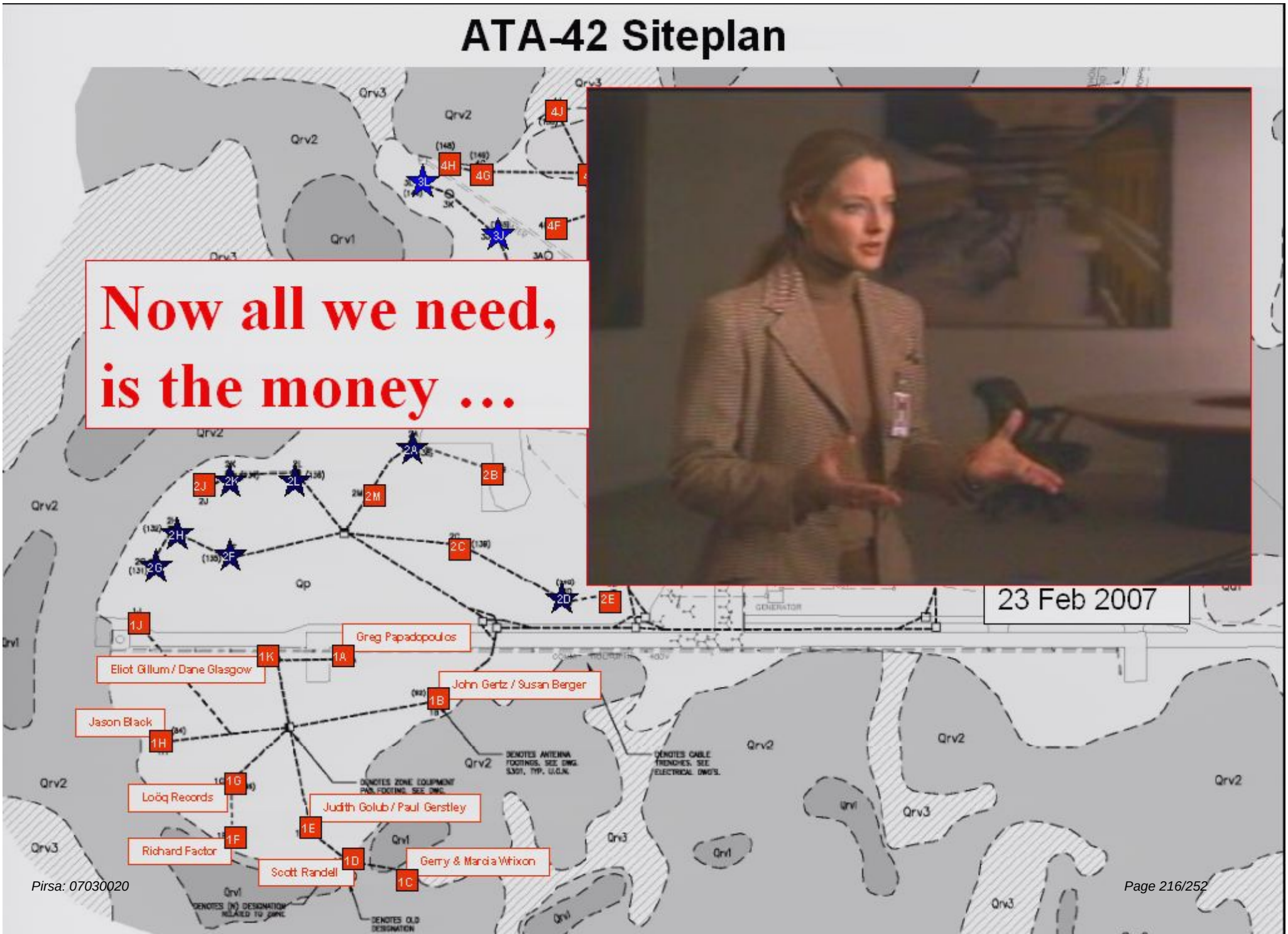

M31 - Andromeda

Familiar optical image

ATA-42 Siteplan

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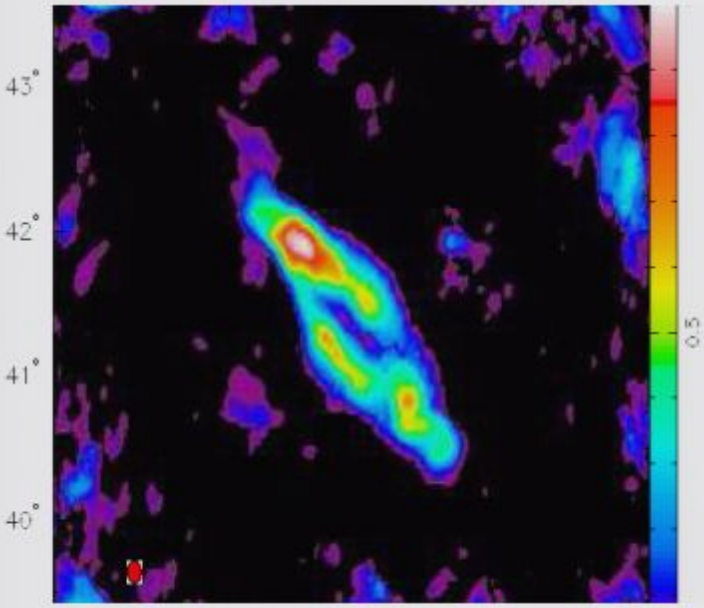

ATA-4

Map made in June 2005 using 4 antennas and FX4 correlator prototype.
Includes continuum data

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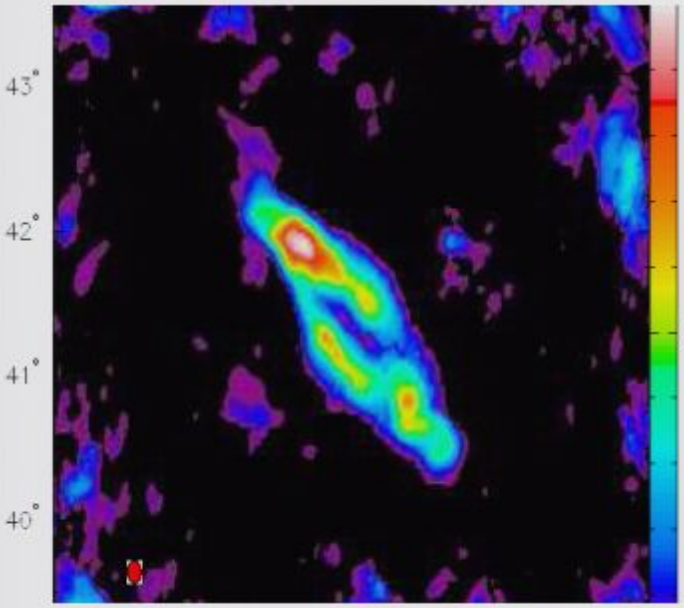

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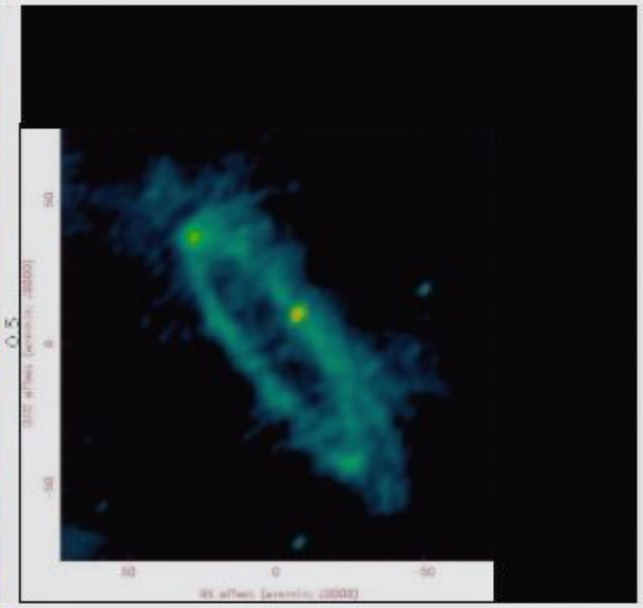

ATA-7

Map made in Sept. 2006 using 7 antennas and two FX4 correlator prototypes. Includes continuum data

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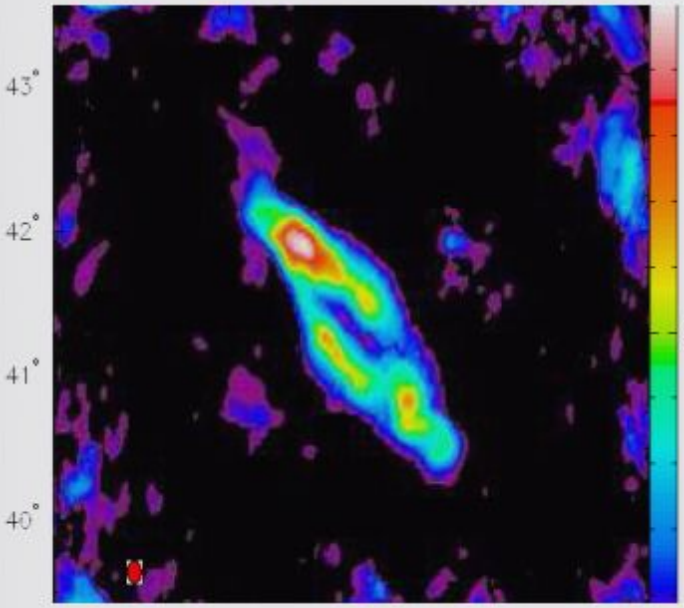

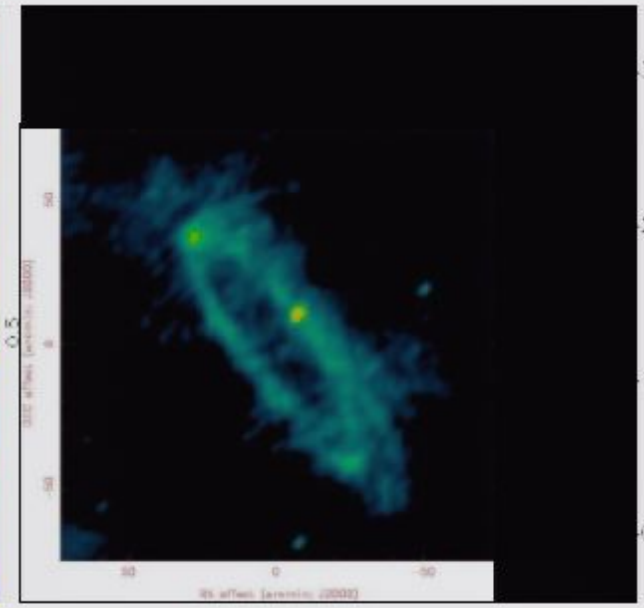

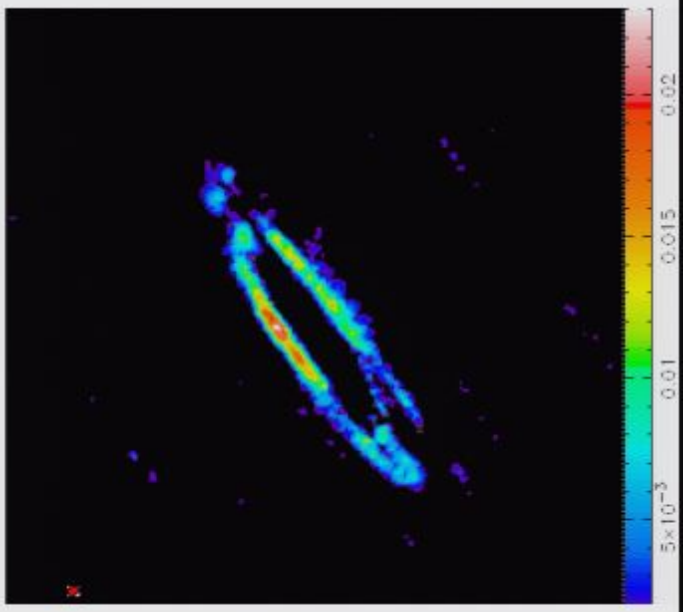

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Map made in June 2005 using 4 antennas and FX4 correlator prototype. Includes continuum data

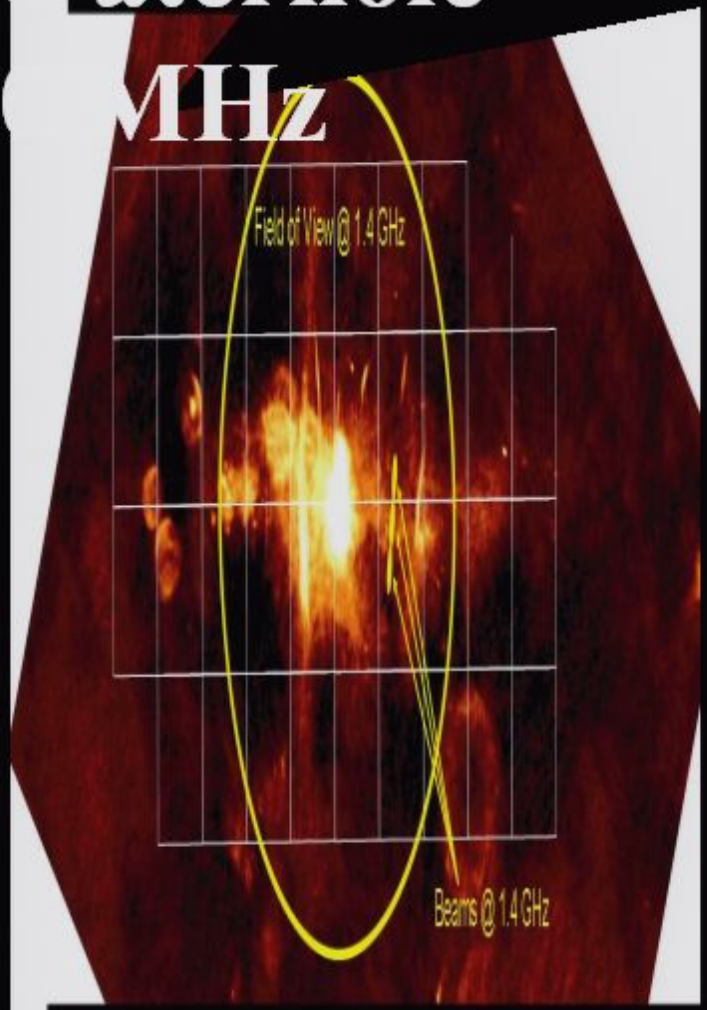
ATA-7

Map made in Sept. 2006 using 7 antennas and two FX4 correlator prototypes. Includes continuum data

ATA-20

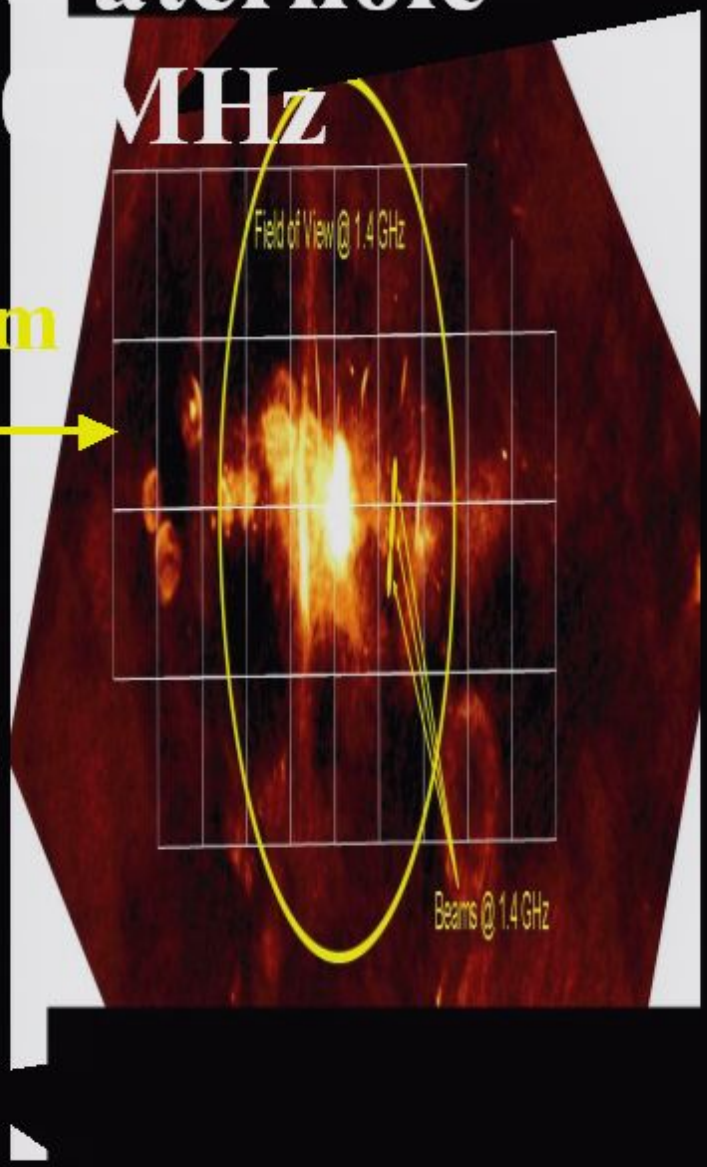
Map made in Jan. 2007 using 7 antennas at a time, two FX4 correlator prototypes. Includes only HI channels

SETI Survey of Inner Galactic Plane Over the 'Waterhole' 1420 – 1720 MHz



SETI Survey of Inner Galactic Plane Over the 'Waterhole' 1420 – 1720 MHz

FOV of 6.1 m antenna at 1.4 GHz



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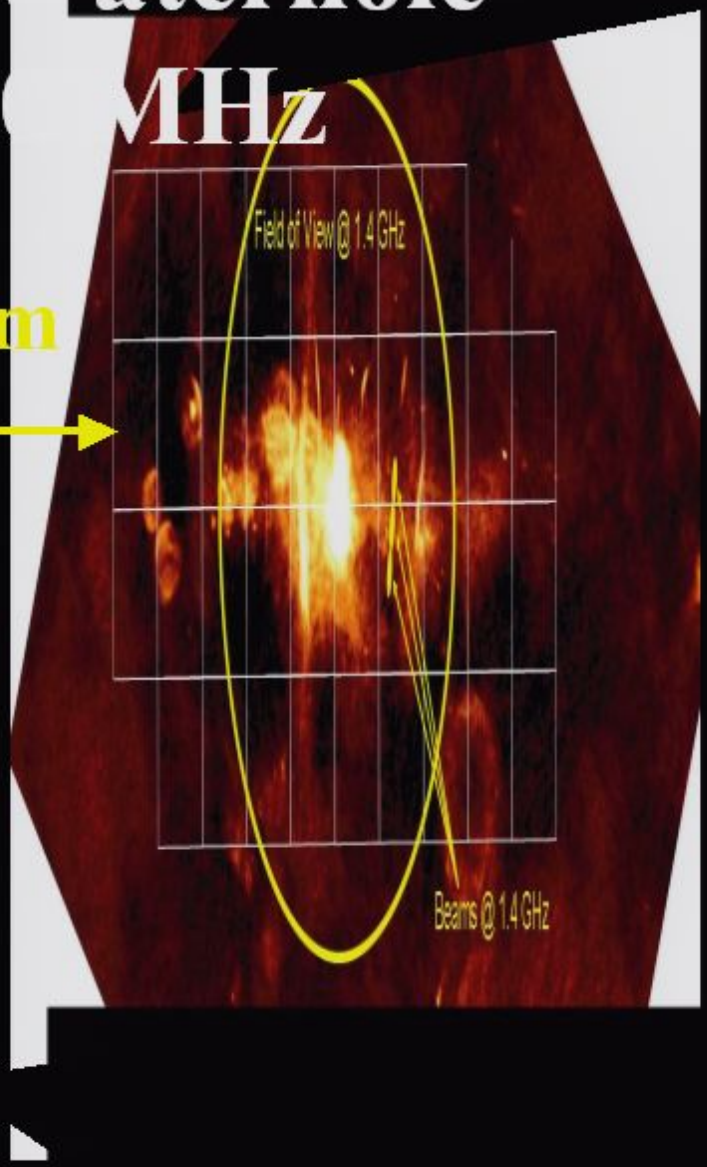

Phased array beam at 1.4 GHz

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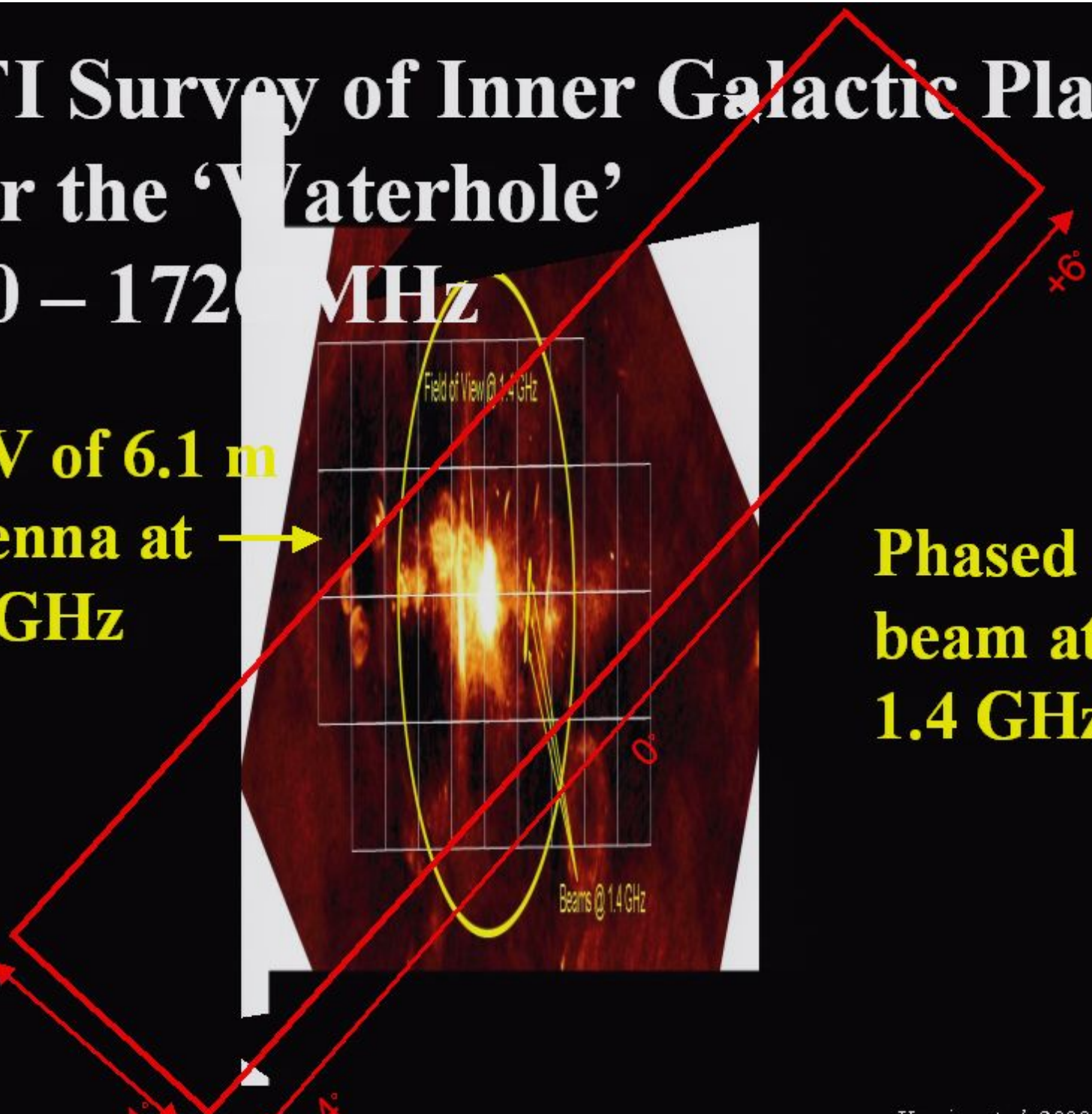

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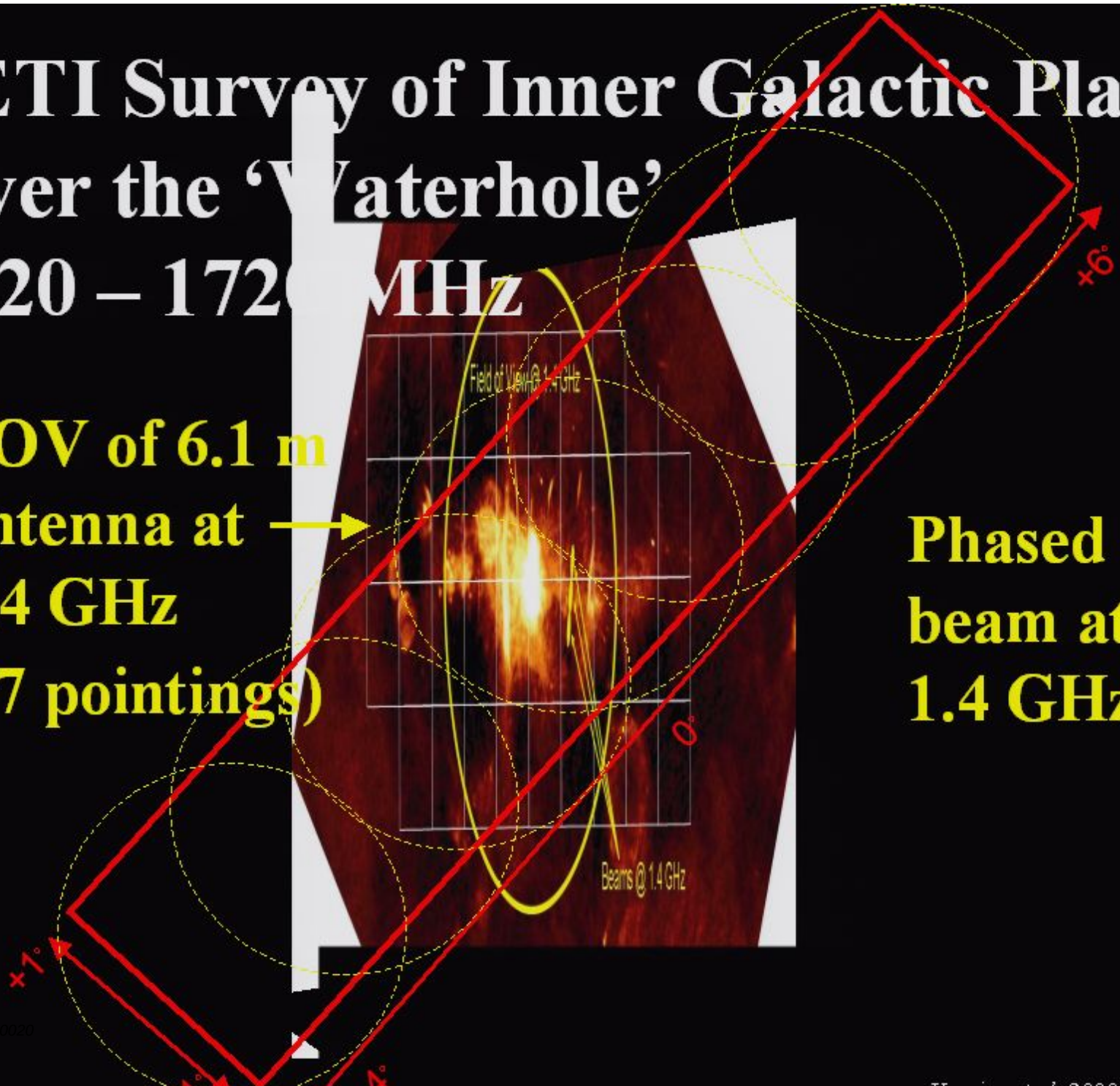

FOV of 6.1 m antenna at 1.4 GHz (~7 pointings)

Phased array beam at 1.4 GHz

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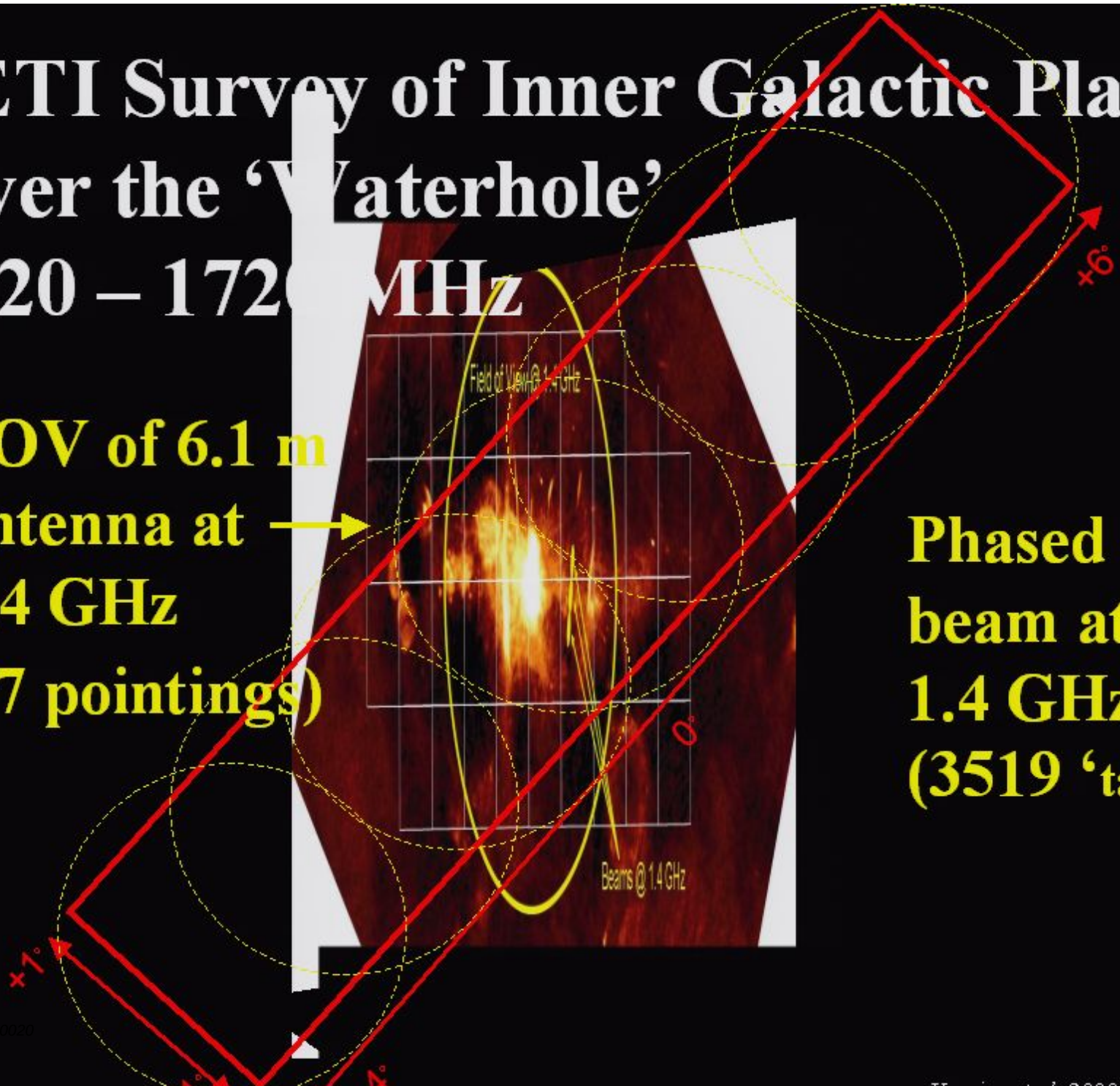


FOV of 6.1 m antenna at 1.4 GHz (~7 pointings)

Phased array beam at 1.4 GHz (3519 'targets')

Begin Targeted Search

Begin Targeted Search

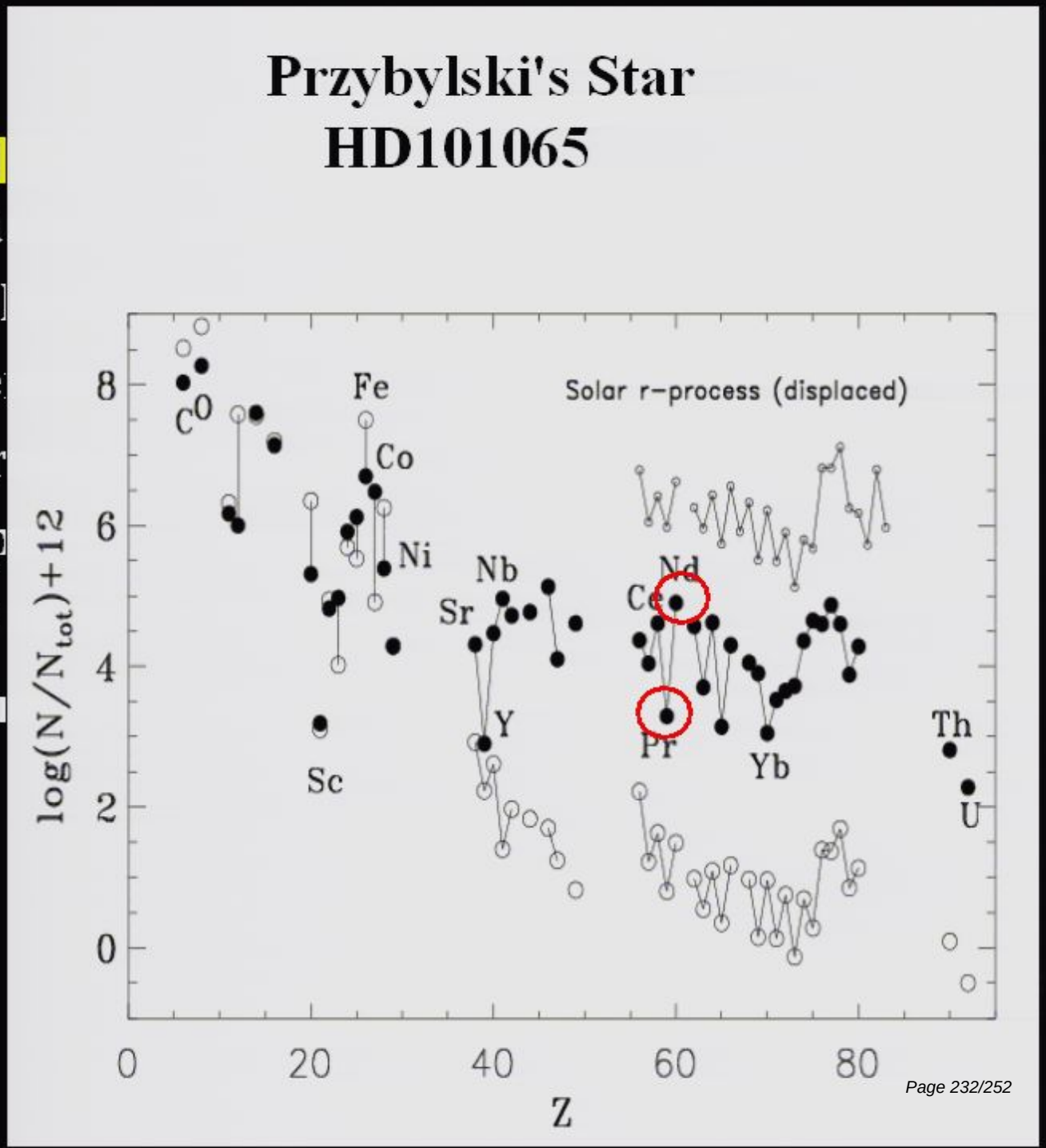
- Start with nearest 100 stars
  - Sensitivity limitation mitigated by closeness
  - Never observed above 3 GHz
  - Long observations to probe slow rep pulses

Begin Targeted Search

- Start with nearest 100 stars
  - Sensitivity limitation mitigated by closeness
  - Never observed above 3 GHz
  - Long observations to probe slow rep pulses
- Targets of opportunity
  - Extrasolar planetary systems
  - ‘weird’ stars

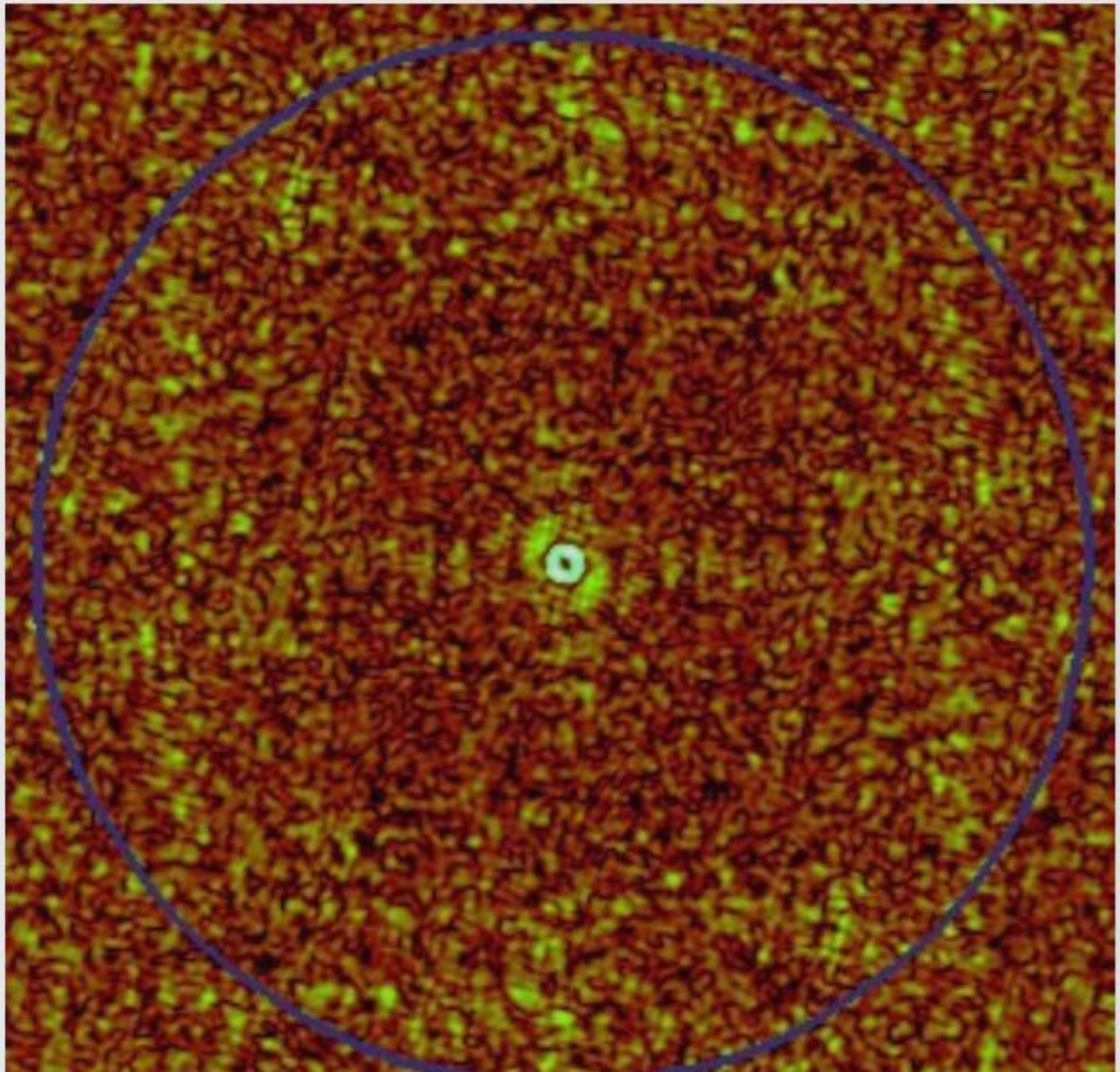
Begi

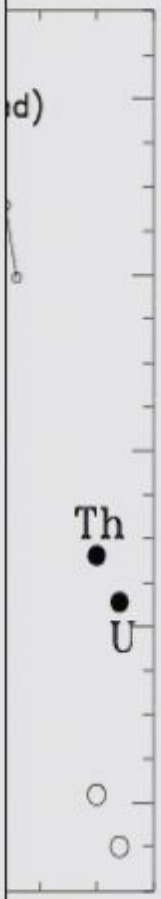
- Start with nea
  - Sensitivity
  - Never obse
  - Long obser
- Targets of opp
  - Extrasolar
  - 'weird' star



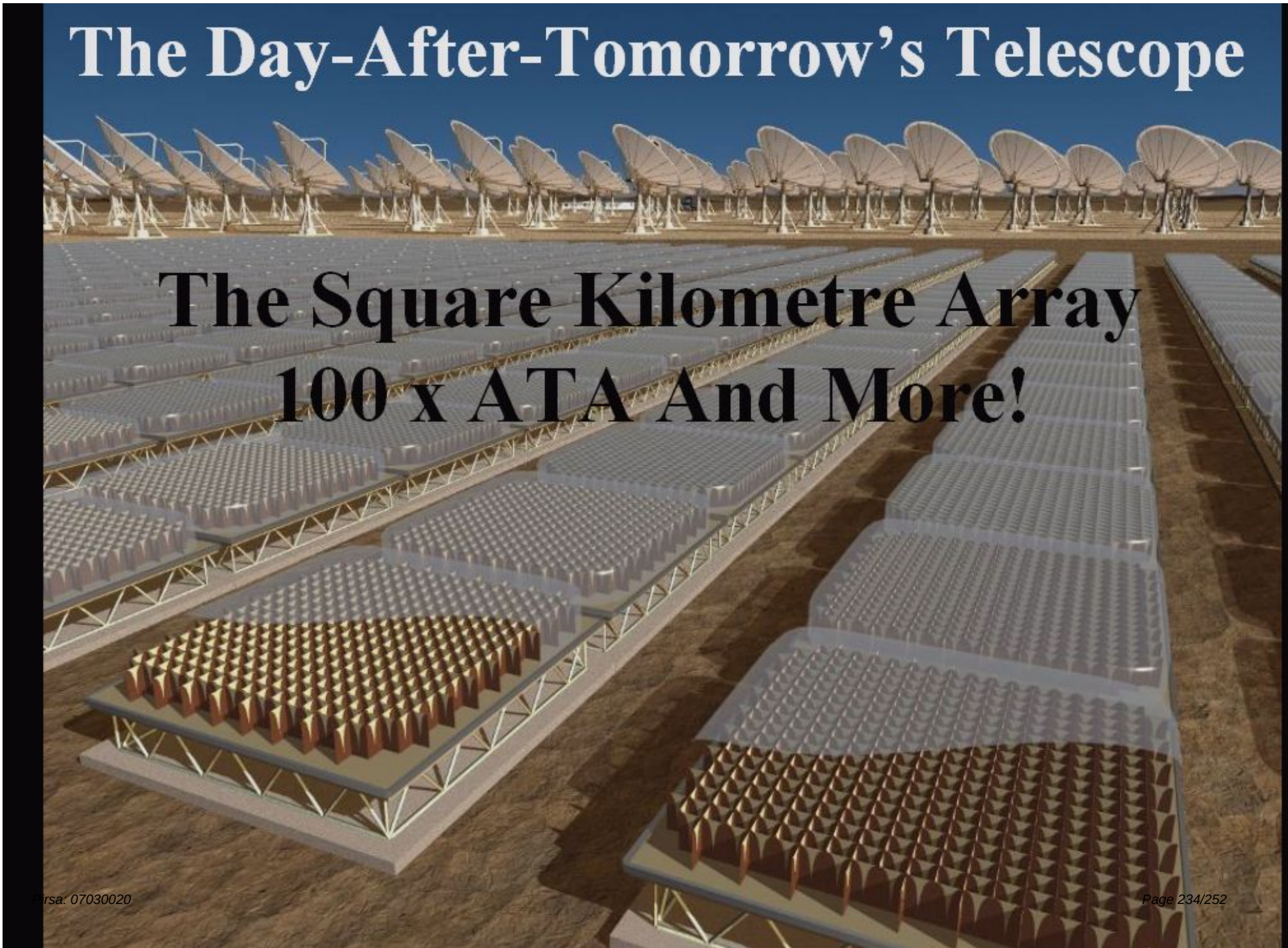
Ring Beam

Measures radiation around a star while excluding the star itself.





The Day-After-Tomorrow's Telescope



The Day-After-Tomorrow's Telescope

100 times the sensitivity ⇨
10 times the distance for given Tx

Transmitter	P_{EIRP}	Detection Limit $10^{-28} - 10^{-29}$ W/m^2
Cell phones	1 W	.003 - .01 ly
TV	300 kW	2 - 6 ly
Airport radars	10^8 W	30 - 100 ly
Arecibo radar	2×10^{13} W	15,000 - 50,000 ly

The Day After Tomorrow: OSETI

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Commensal OSETI
?? Cherenkov VERITAS Array

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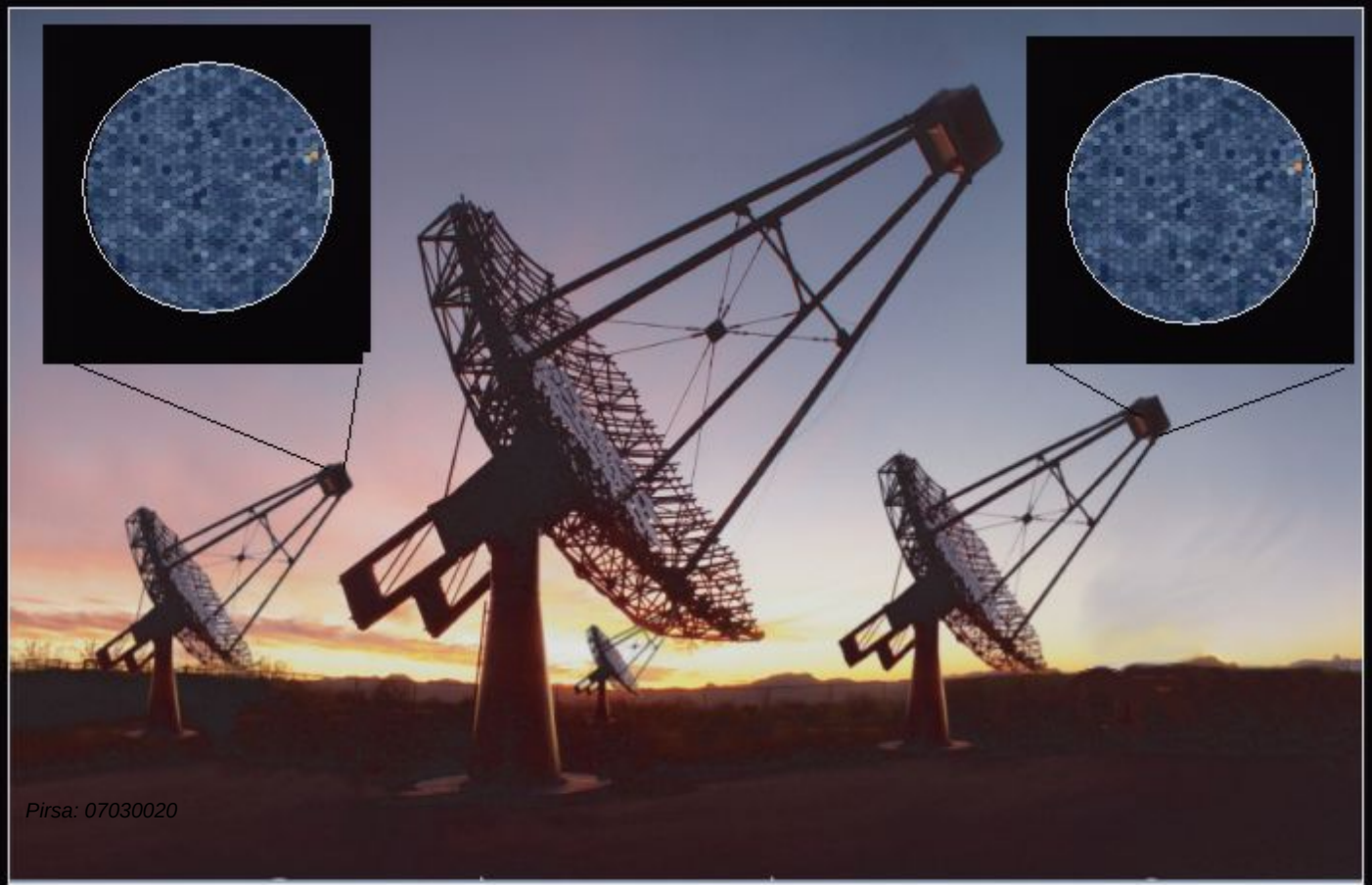
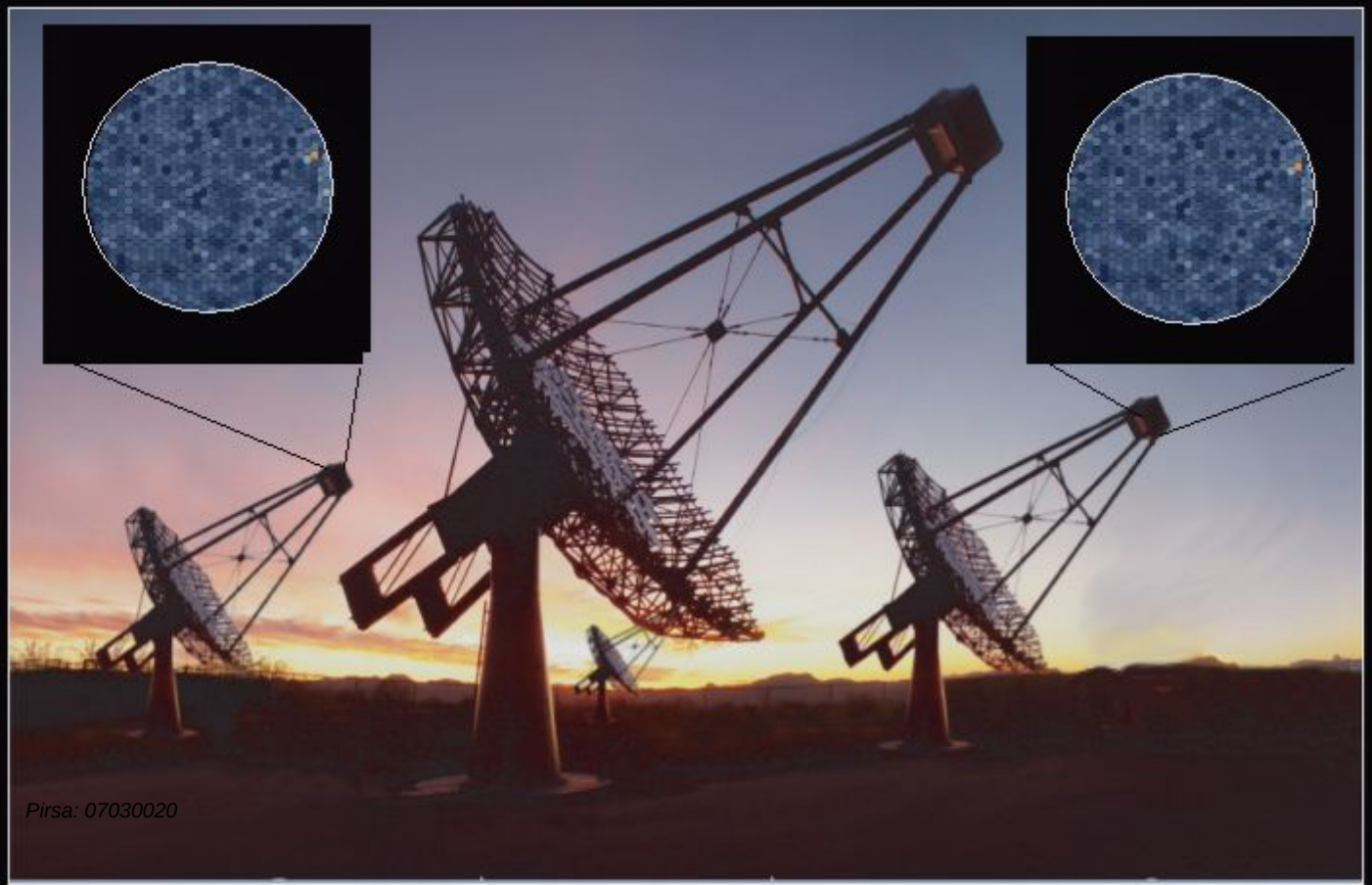


The Day After Tomorrow: OSETI

Commensal OSETI
?? Cherenkov VERITAS Array

Piggybacking on large projects



The Day After Tomorrow: OSETI

Commens
?? Chem

ELT, OWL ...
commensal?
user?
Overesolution?

Piggybacking on large projects

Other ideas

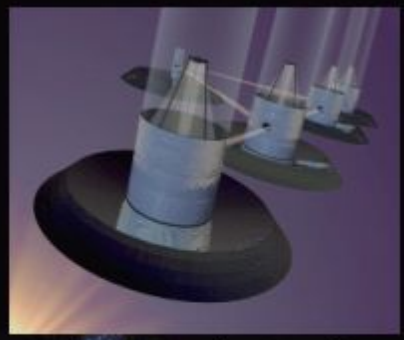
The Day After Tomorrow: OSETI

Commens
?? Cher

ELT, OWL ...
commensal?
user?
Overesolution?

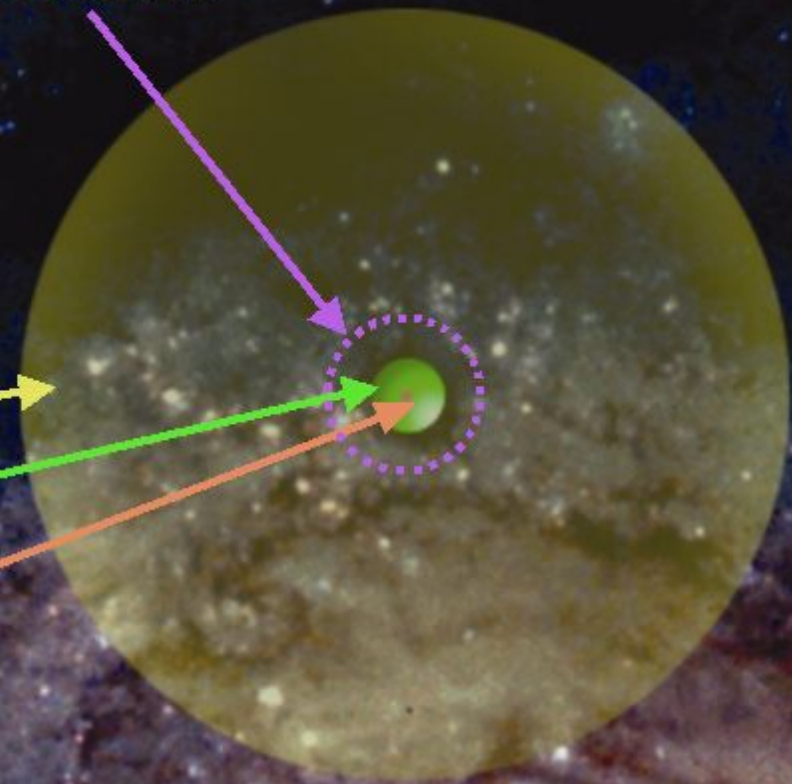
Piggybacking on large projects

Darwin/TPF
OSETI



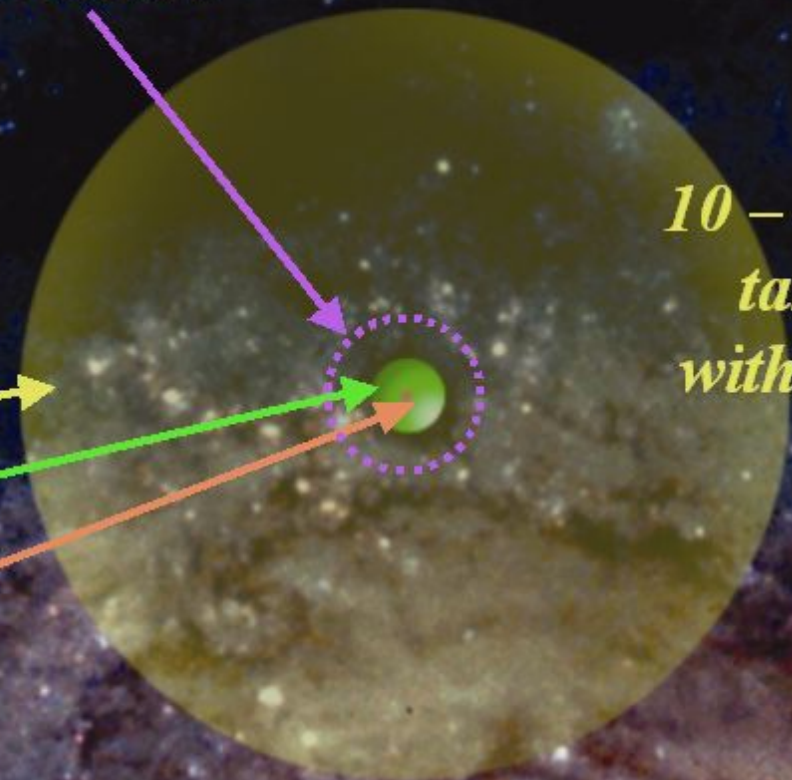
Other ideas

Expand The Galactic Exploration



Over the next few decades our tools will become Commensurate with the size of the SETI task

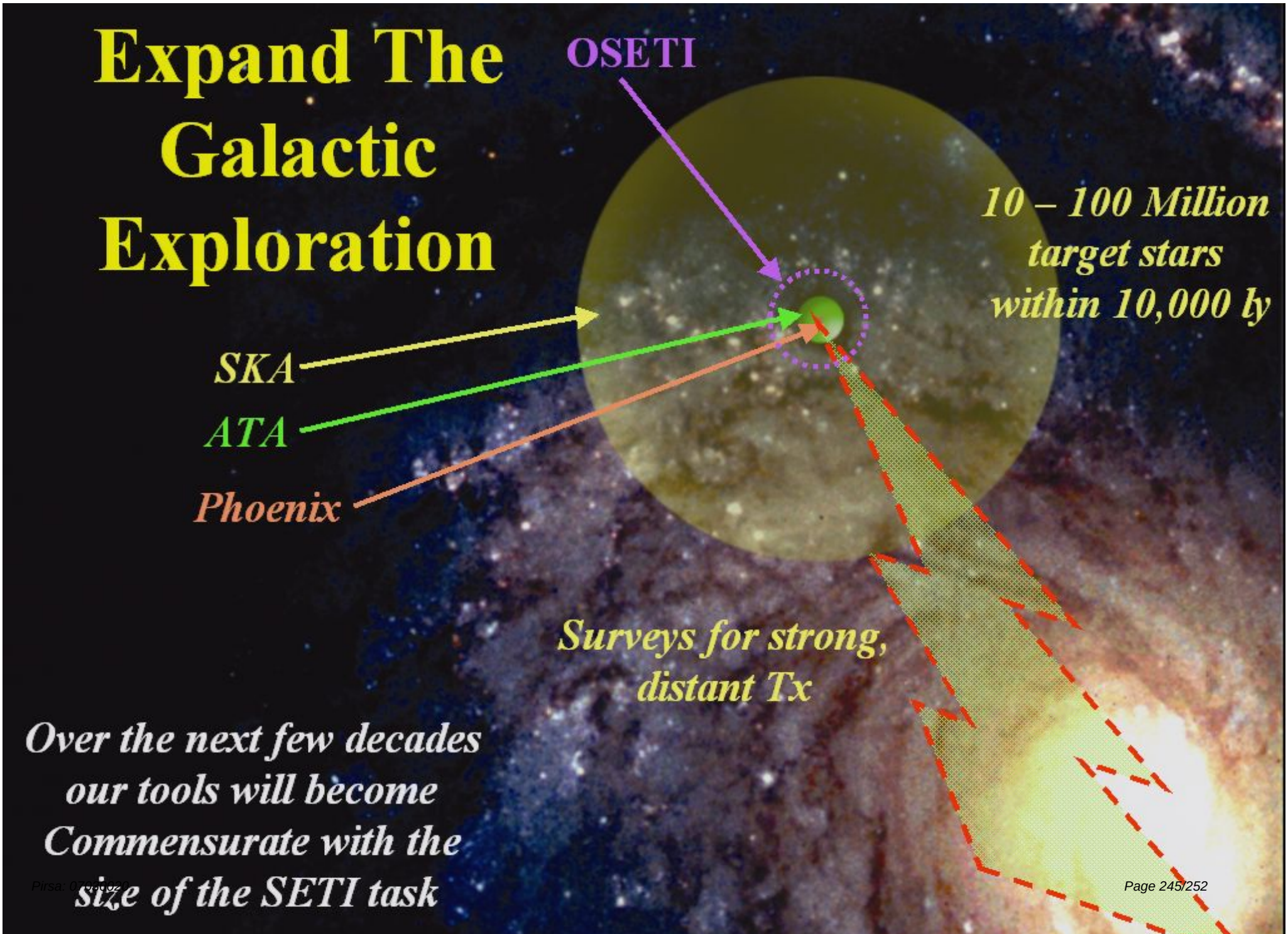
Expand The Galactic Exploration



10 – 100 Million target stars within 10,000 ly

Over the next few decades our tools will become Commensurate with the size of the SETI task

Expand The Galactic Exploration



Over the next few decades our tools will become Commensurate with the size of the SETI task

Should We Broadcast?

Should We Broadcast?

Who Should Speak For Earth?

What Should They Say?

Should We Broadcast?

Who Should Speak For Earth?

What Should They Say?

Transmission requires:

Long term commitment

Global cooperation and coordination

Should We Broadcast?

Who Should Speak For Earth?

What Should They Say?

Not yet ---

When we grow up,
we can start.

Transmis
Lon
Glo
lination

I Do Not Know When, Or If SETI Will Succeed

But I am convinced that Cocconi and Morrison Were Right …

"The probability of success
is difficult to estimate;
but if we never search
the chance of success is zero."

Cocconi and Morrison, Nature (1959)

“The

Stay tuned!

n

the is zero.”

Cocconi and Morrison, Nature (1959)