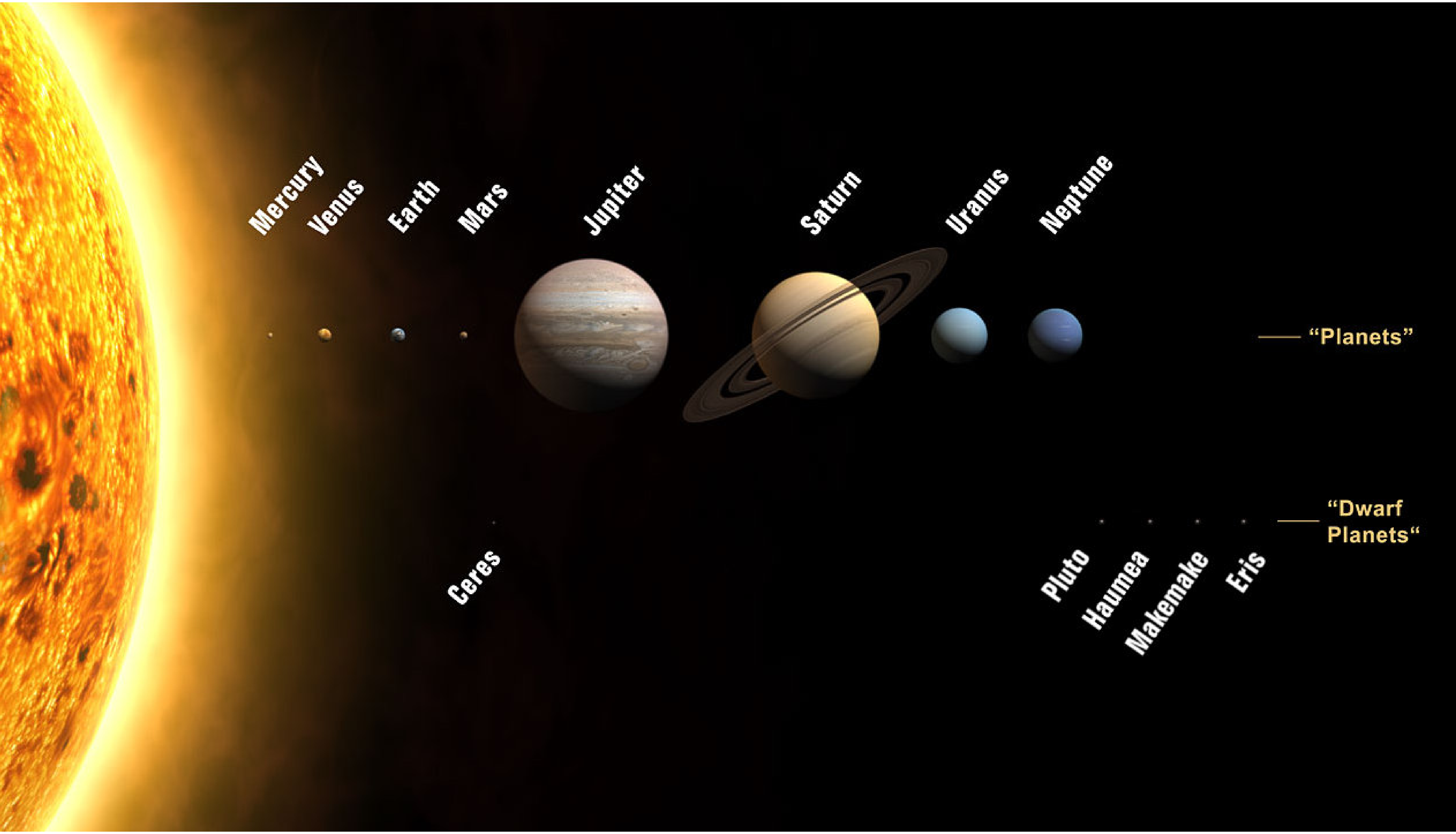
Astronomy in the New Millenium

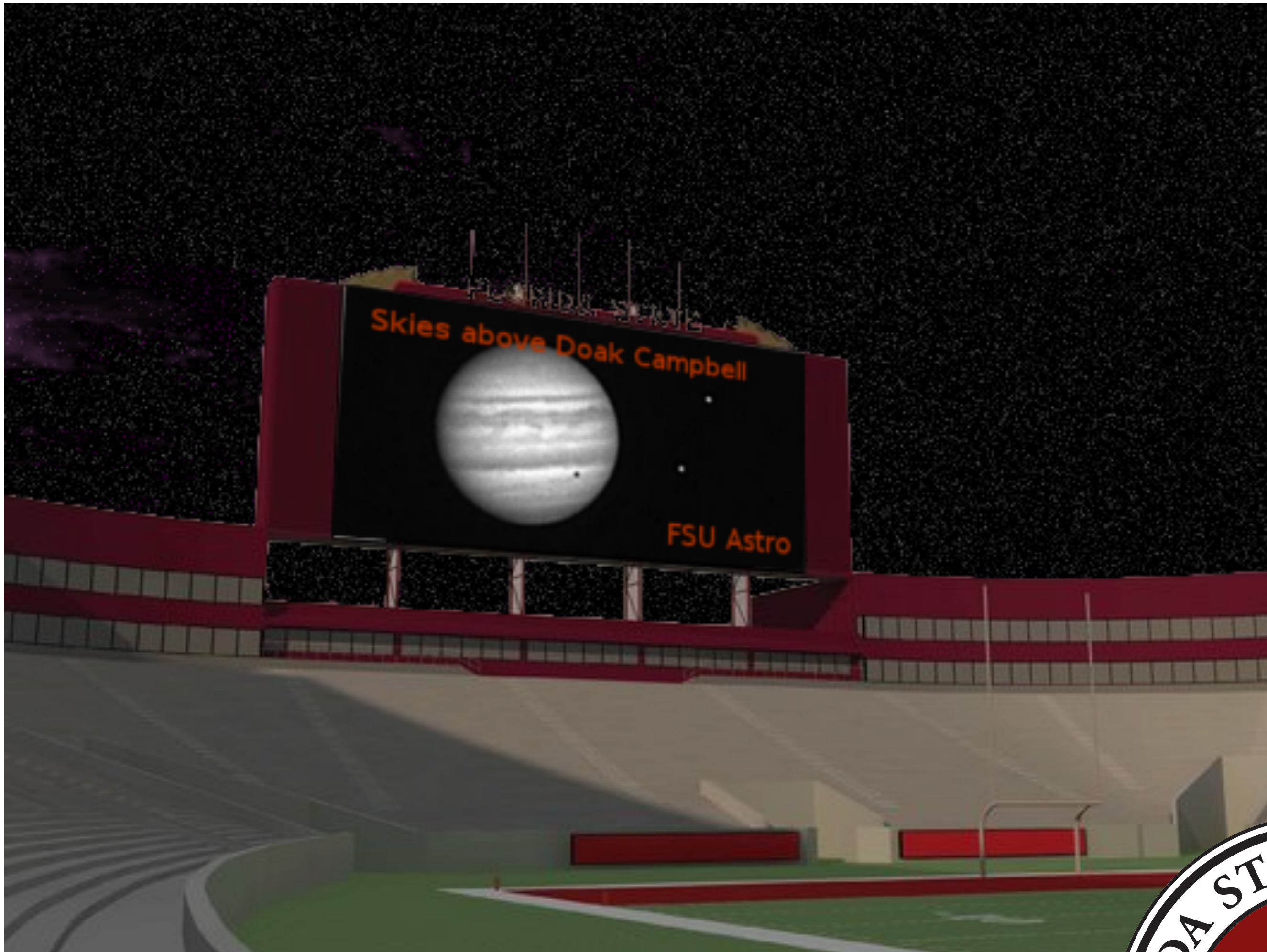
Simons Observatory site, Atacama, Chile

Kevin Huffenberger
Department of Physics

What's out there to look at?


Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
"Planets"
Ceres
Pluto
Haumea
Makemake
Eris
"Dwarf Planets"

What's up there to look at?

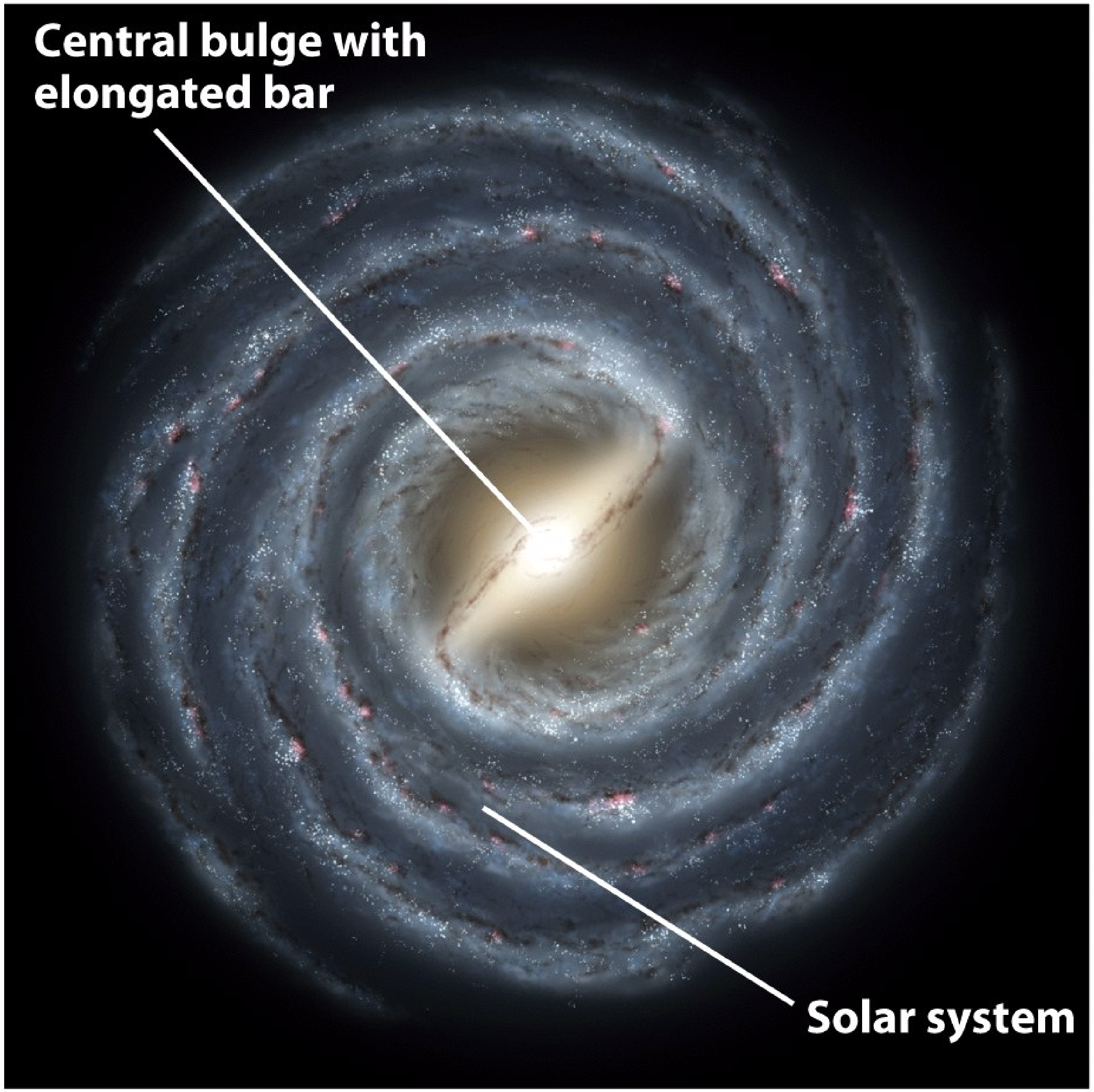


FLORIDA STATE UNIVERSITY
VIRES ARTES MORES
1851

Planning now for new FSU campus observatory

Stars

Disk's spiral structure



The structure of the Milky Way's disk

Figure 23-16a

Size and shape of Milky Way

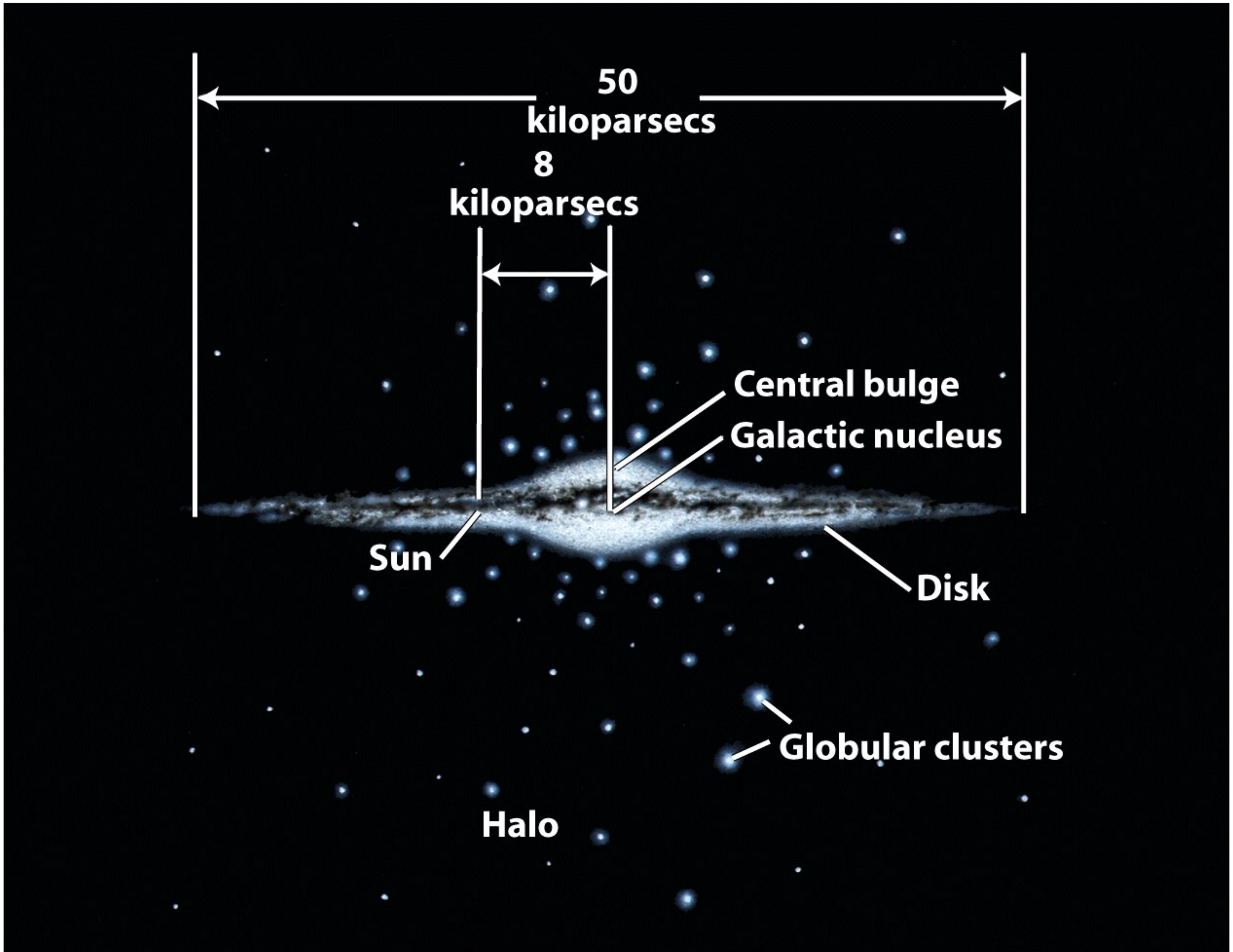


Figure 23-7
Universe, Eighth Edition

Andromeda galaxy

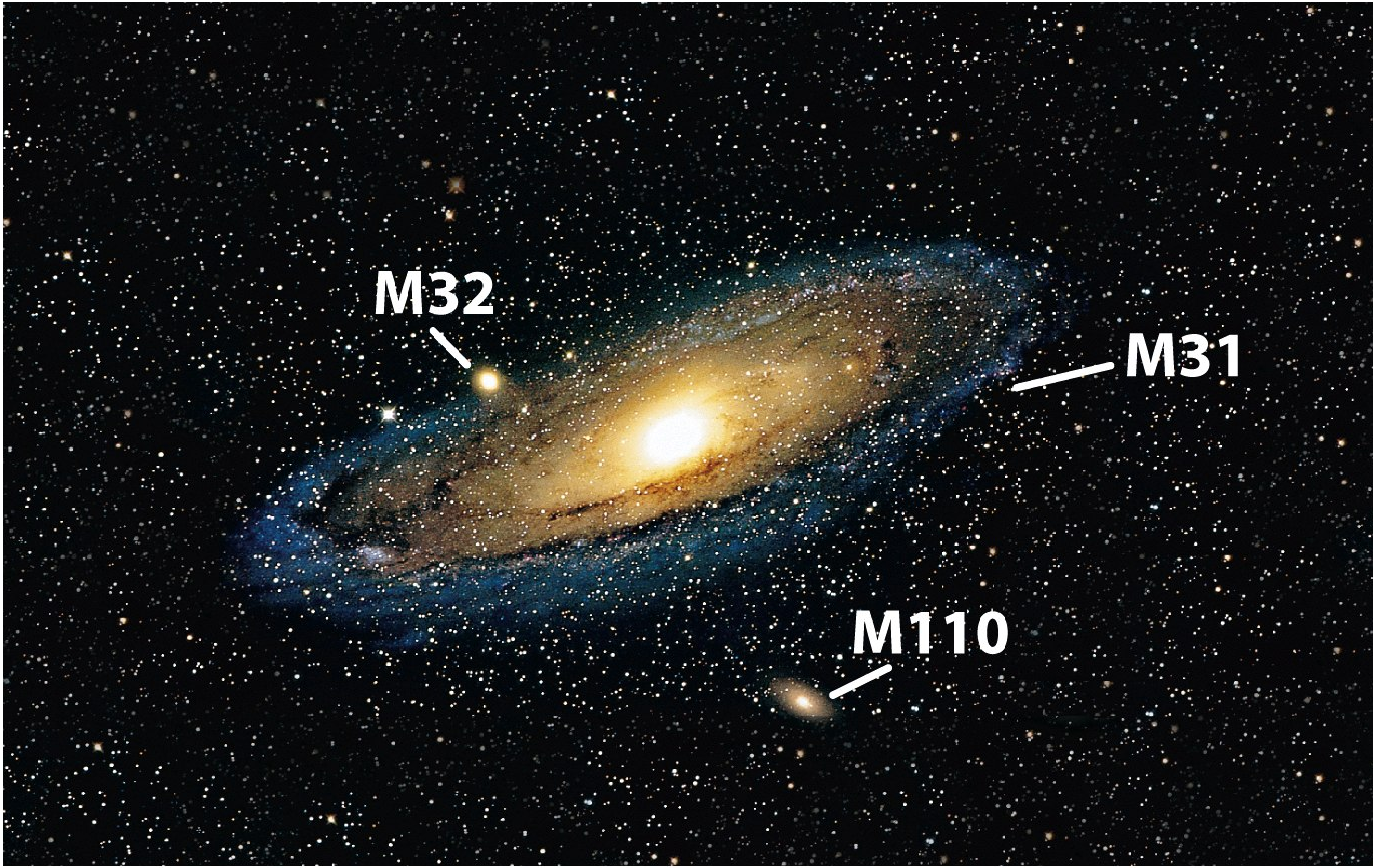
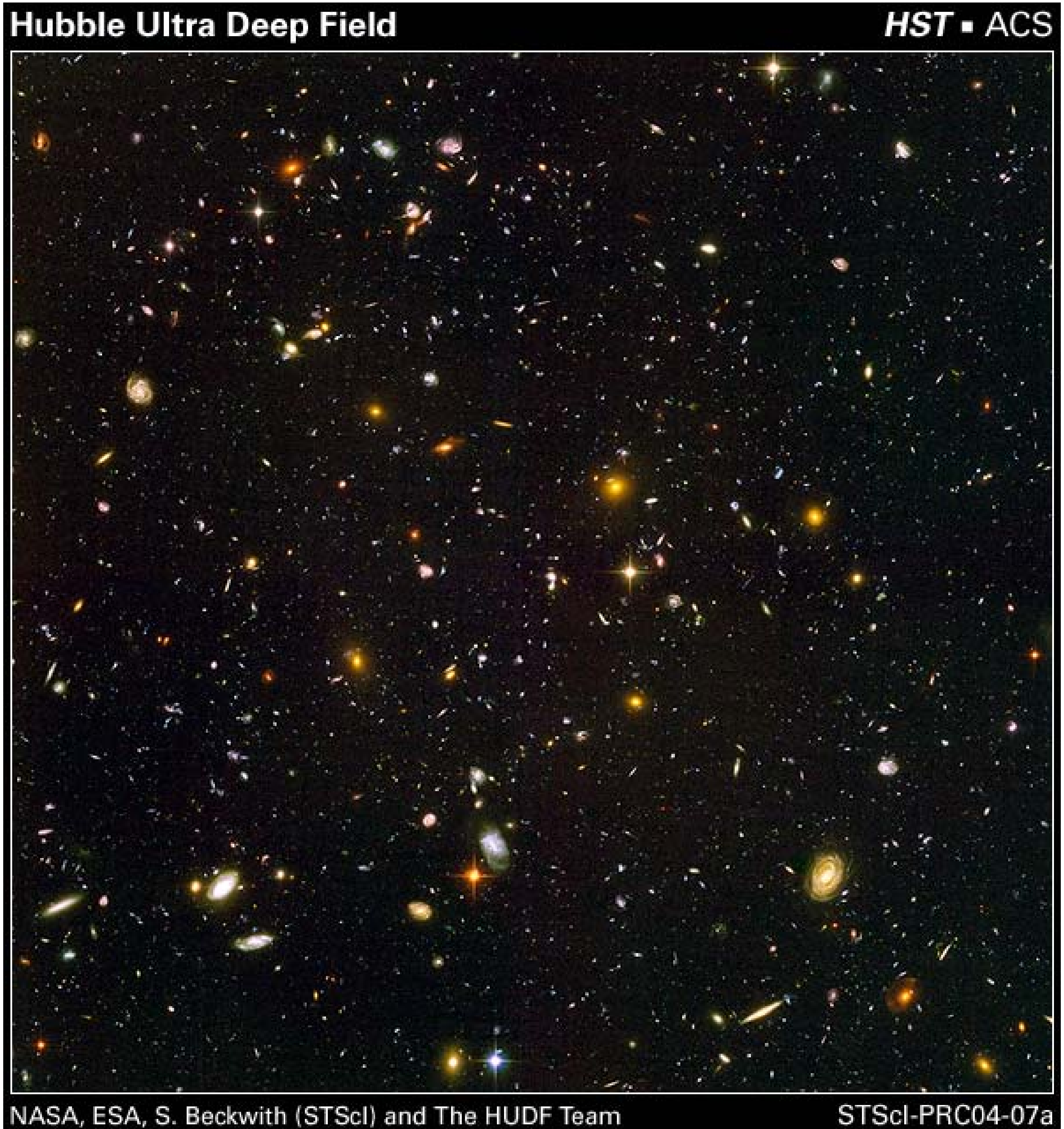
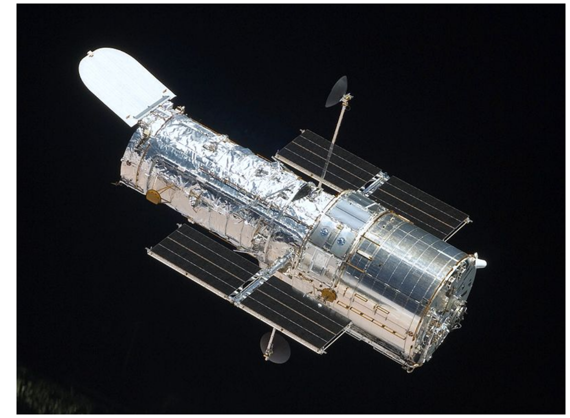


Figure 24-3
Universe, Eighth Edition

~ 700 kpc = 2 Mly away

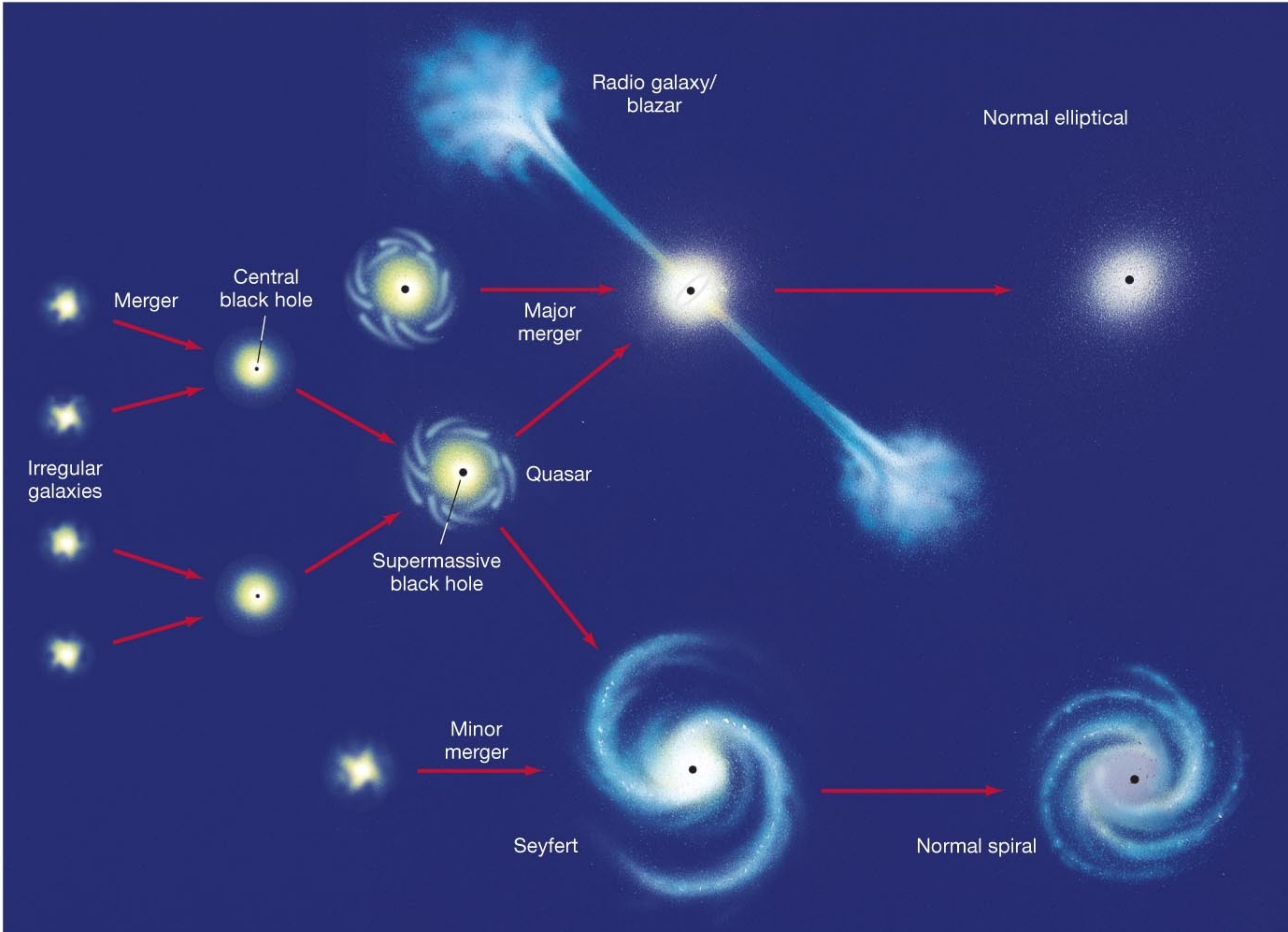


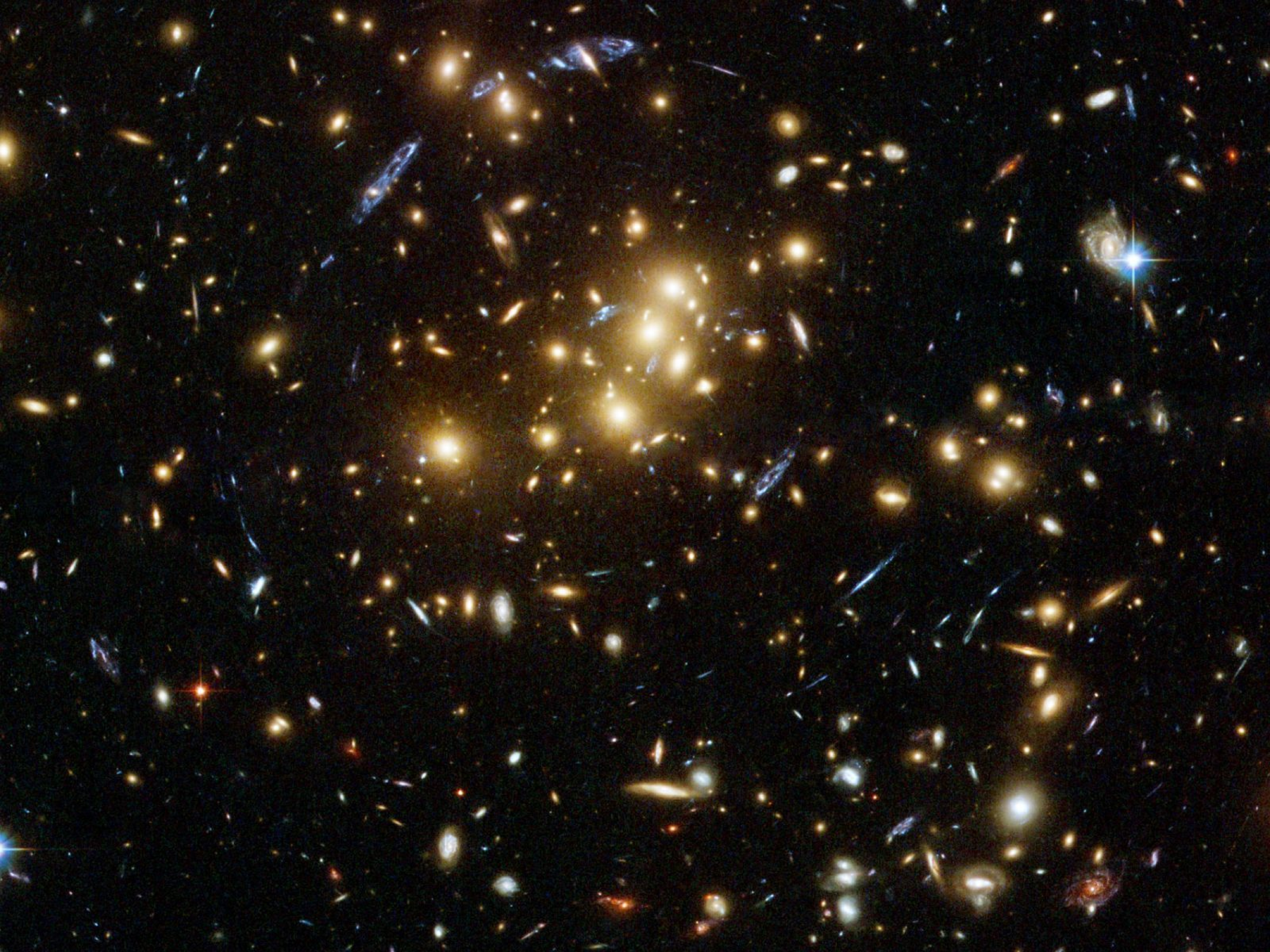


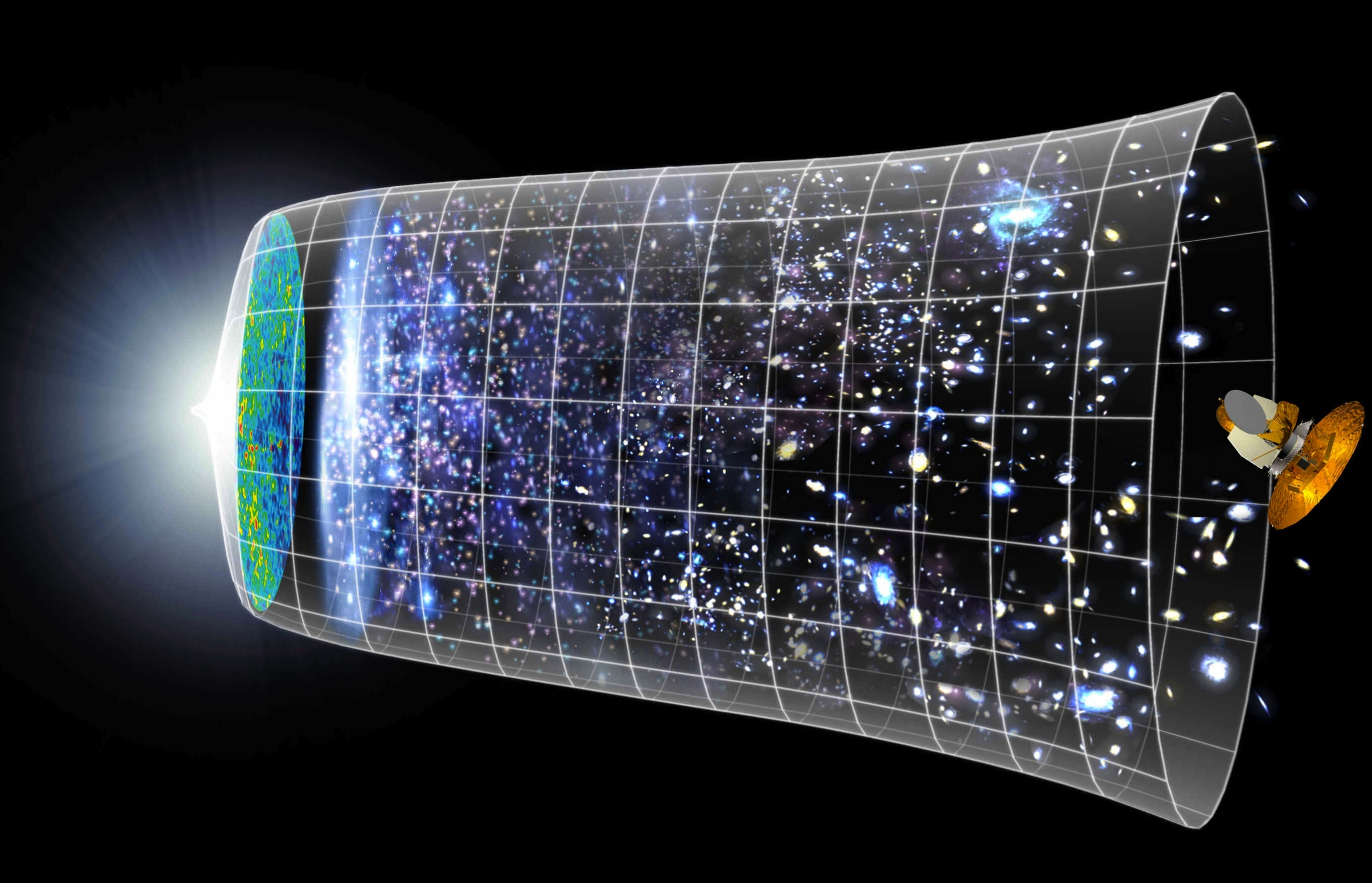
In Fornax,
11.0 arcmin^2

1 mm^2 @ 1 m

13 million such patches to cover sky.

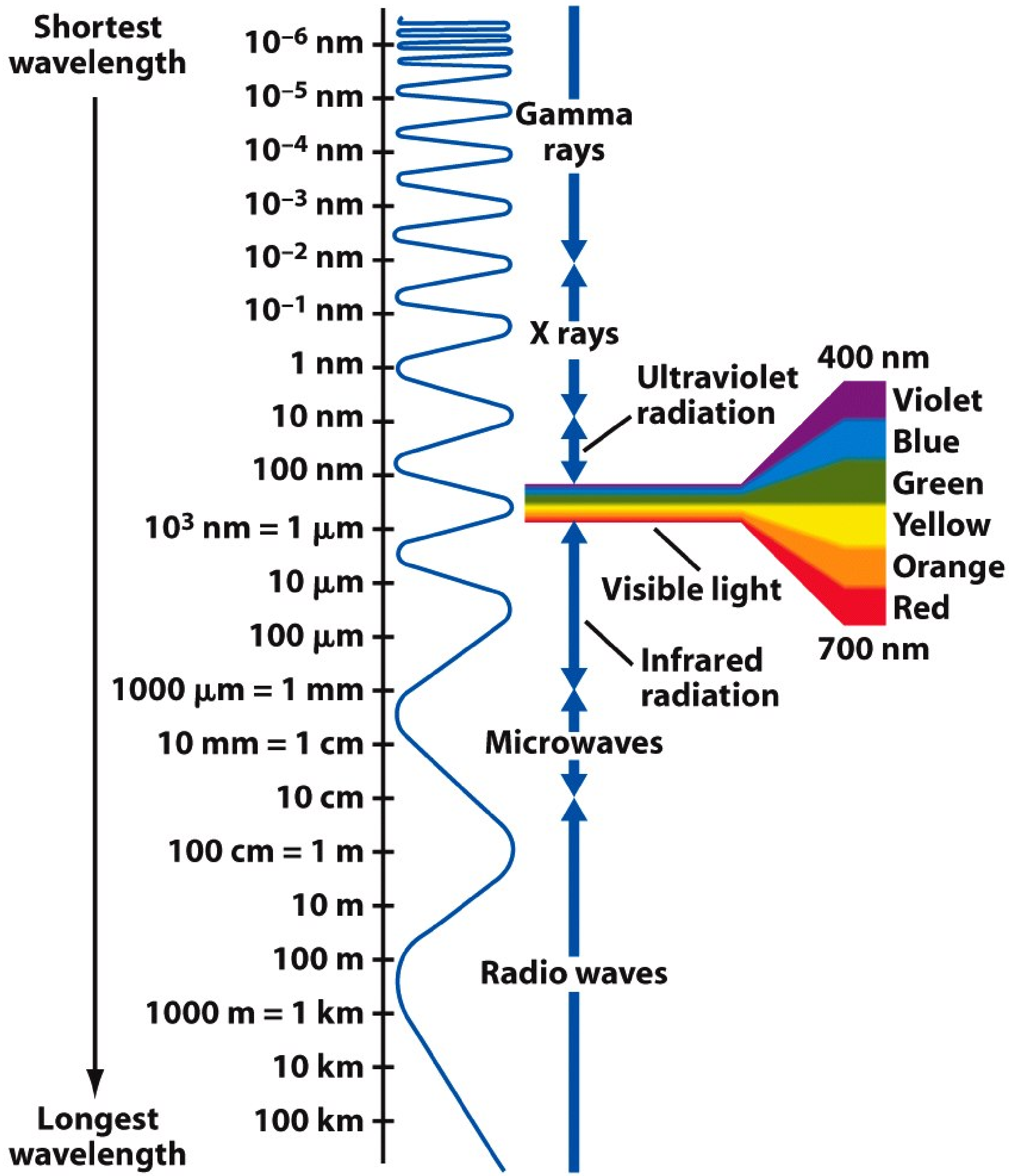

Radio galaxy/
blazar
Normal elliptical
Merger
Central
black hole
Major
merger
Irregular
galaxies
Quasar
Supermassive
black hole
Minor
merger
Seyfert
Normal spiral





How do we find it?

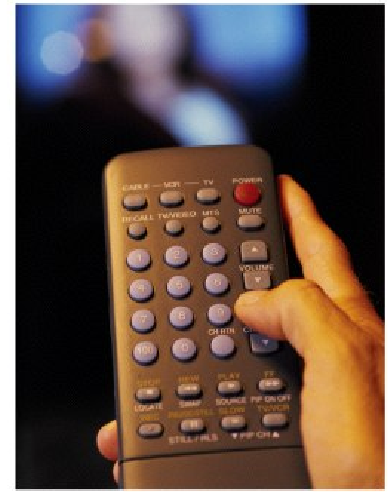
EM radiation characterized by wavelength



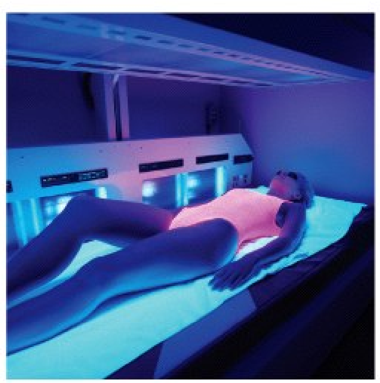
Practical uses of EM radiation

(a) Mobile phone: radio waves

(b) Microwave oven: microwaves



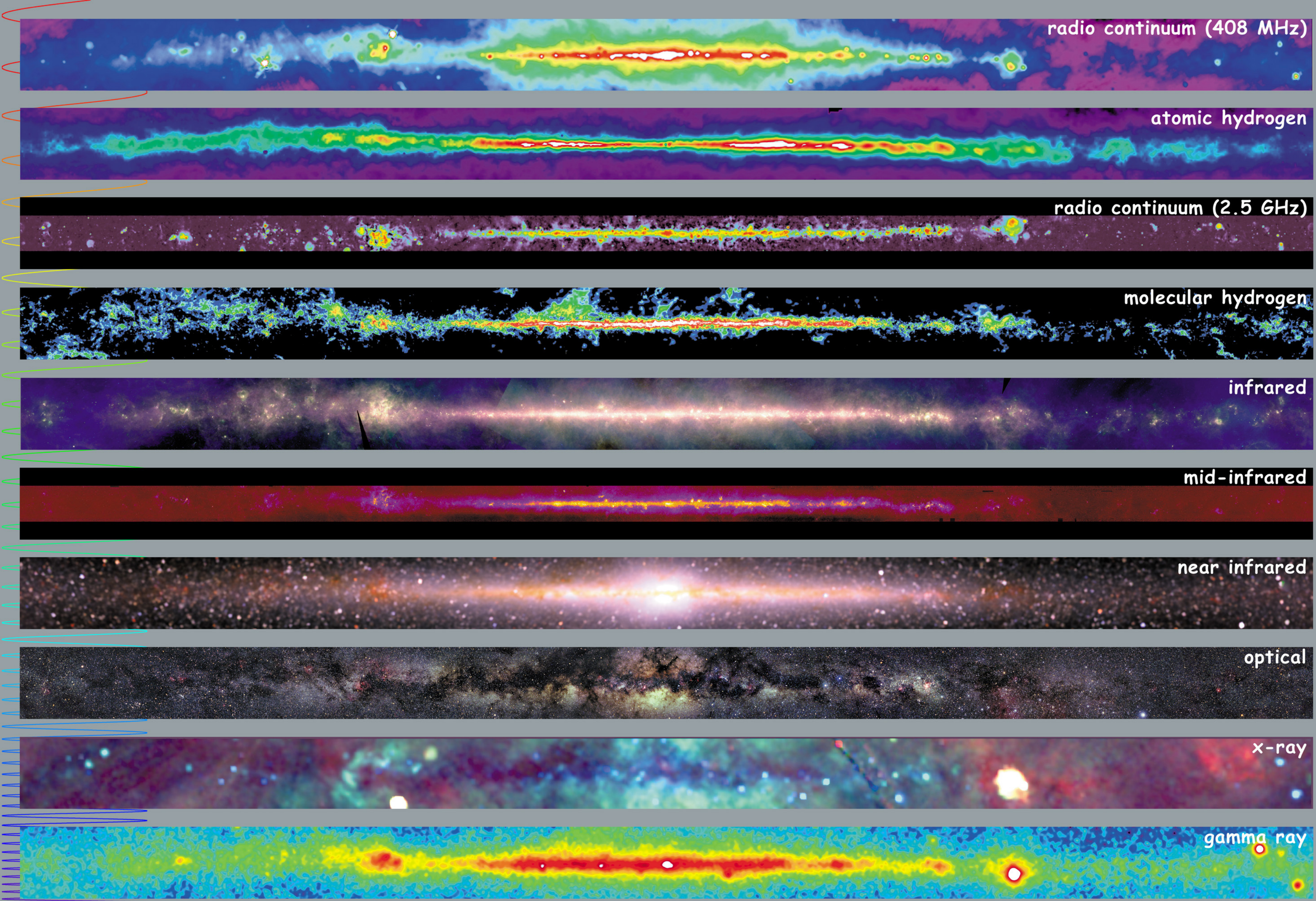
(c) TV remote: infrared light



(d) Tanning booth: ultraviolet light

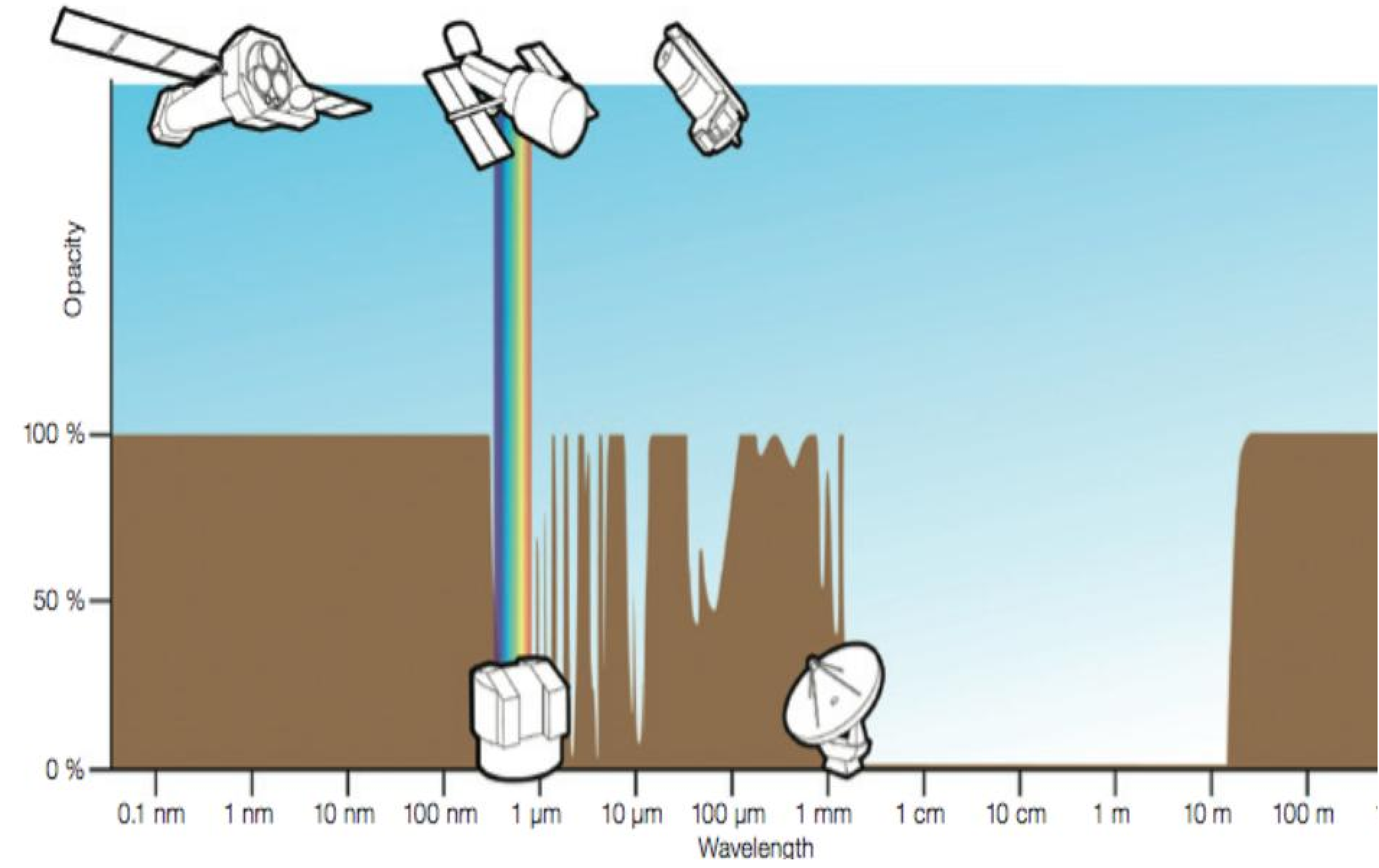
(e) Medical imaging: X rays.

(f) Cancer radiotherapy: gamma rays



http://adc.gsfc.nasa.gov/mw

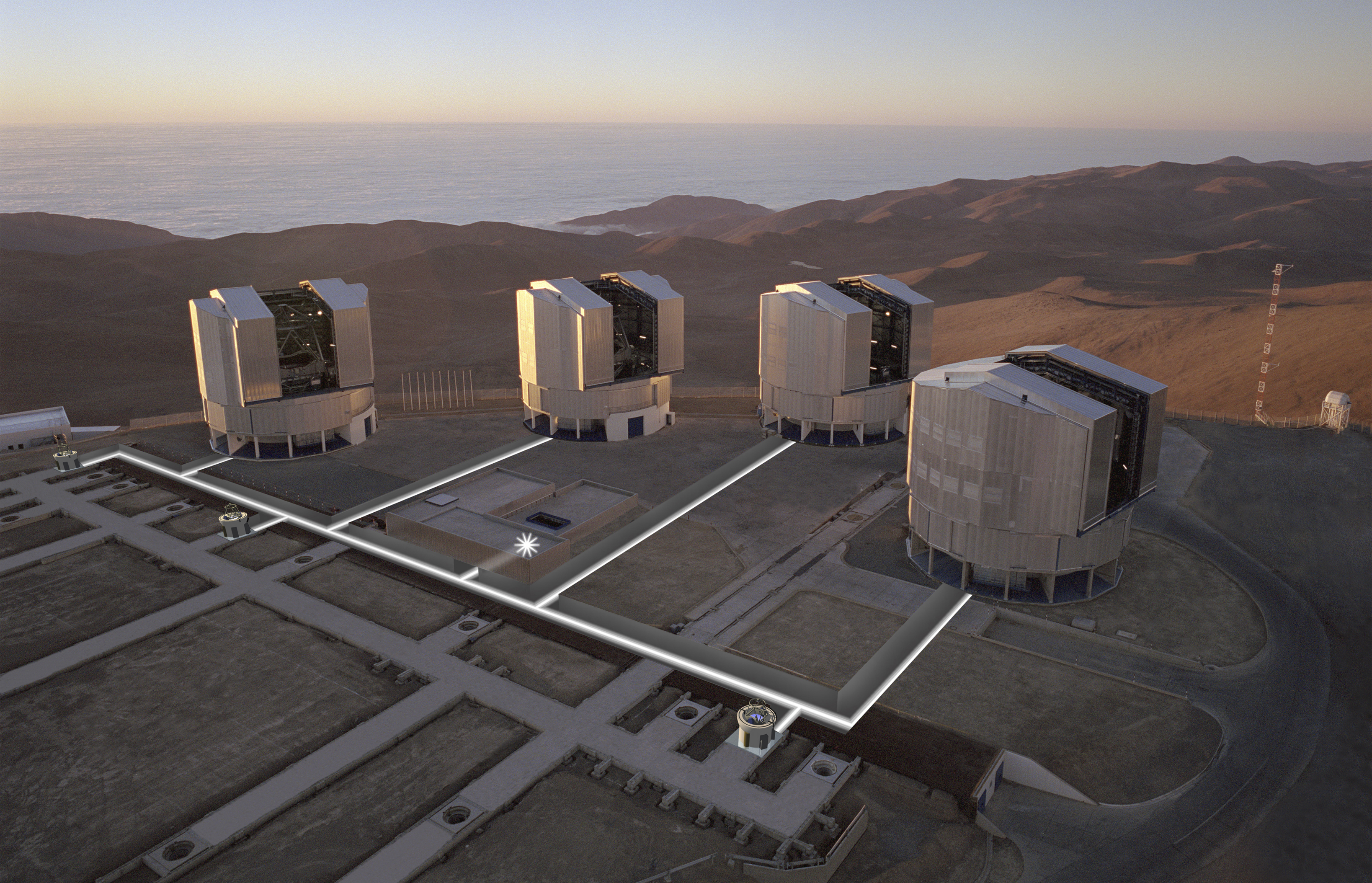
Multiwavelength Milky Way

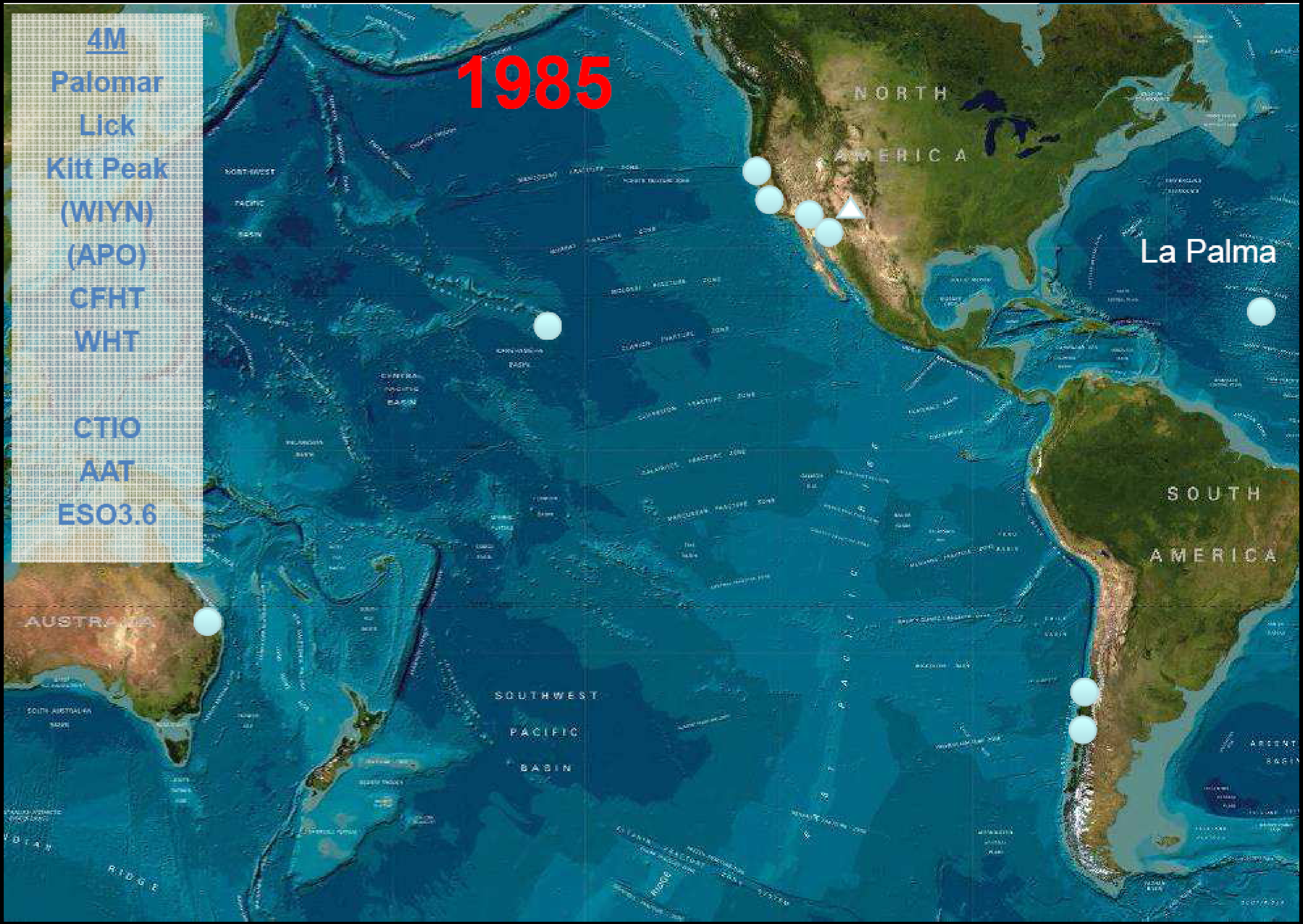

Opacity
100 %
50 %
0 %
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
Wavelength

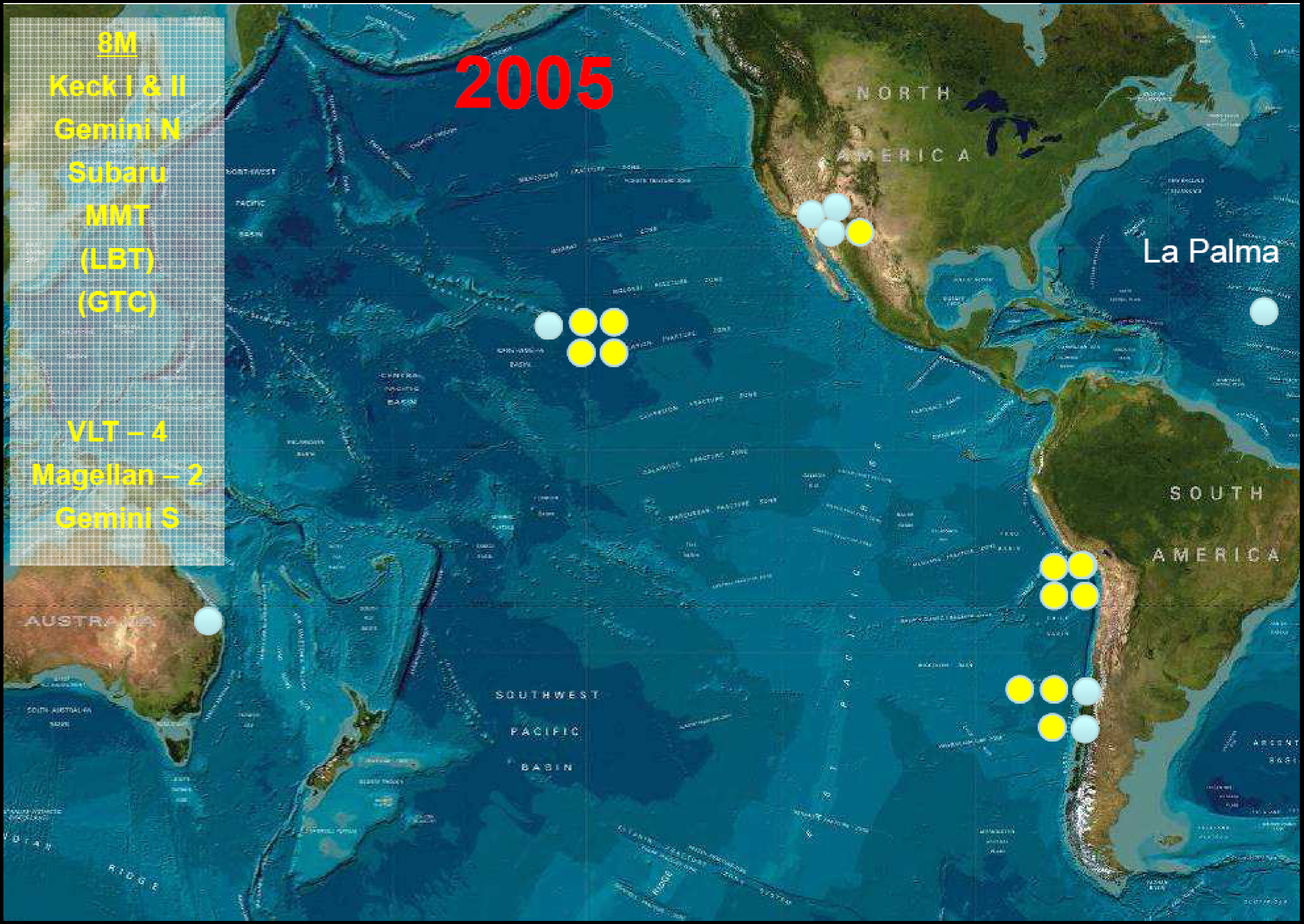
AIUC
CENTRO DE ASTRO-INGENIERIA UC

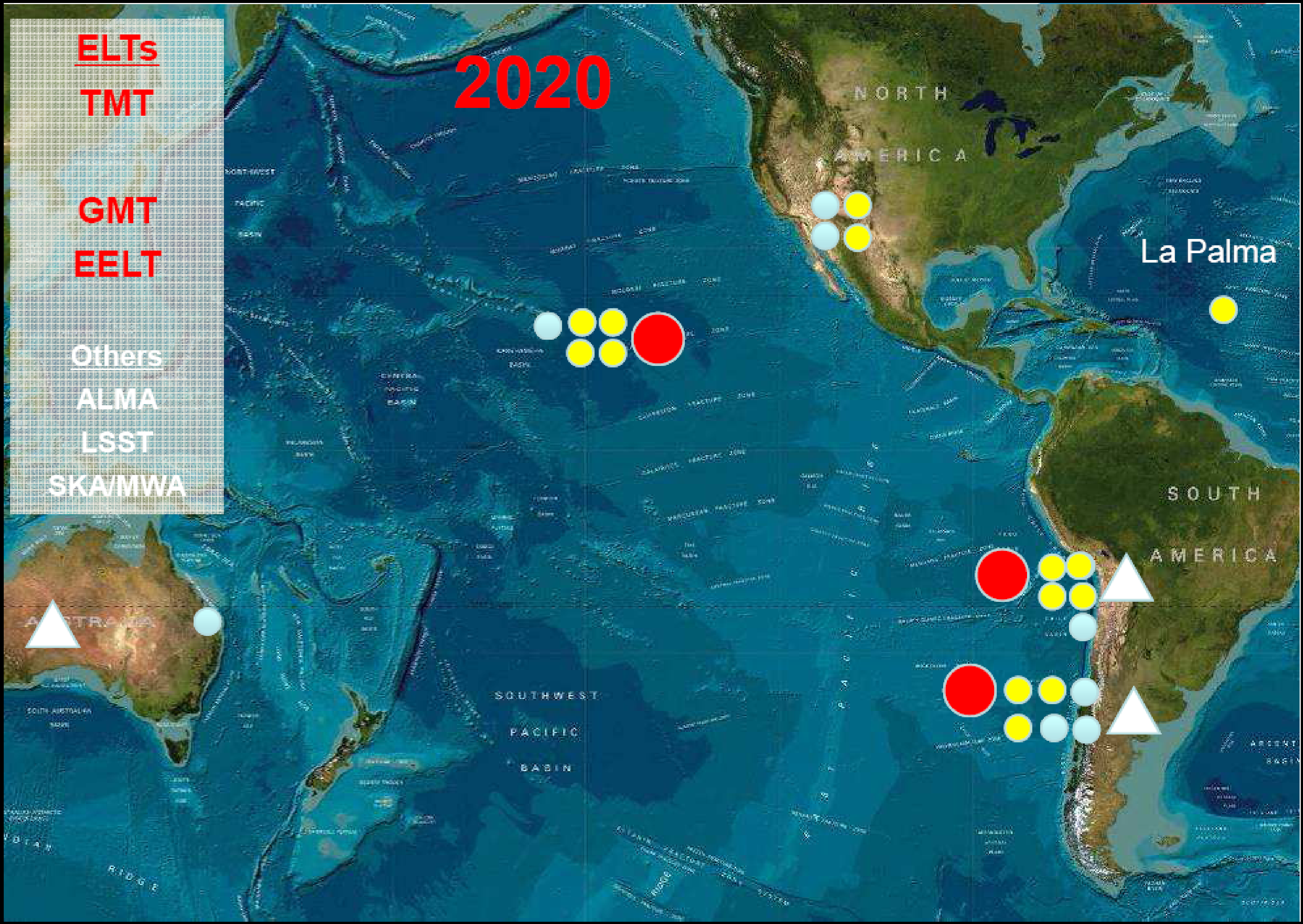
EL INCOMPARABLE CIELO CHILENO

L. Infante · Pontificia Universidad Católica de Chile

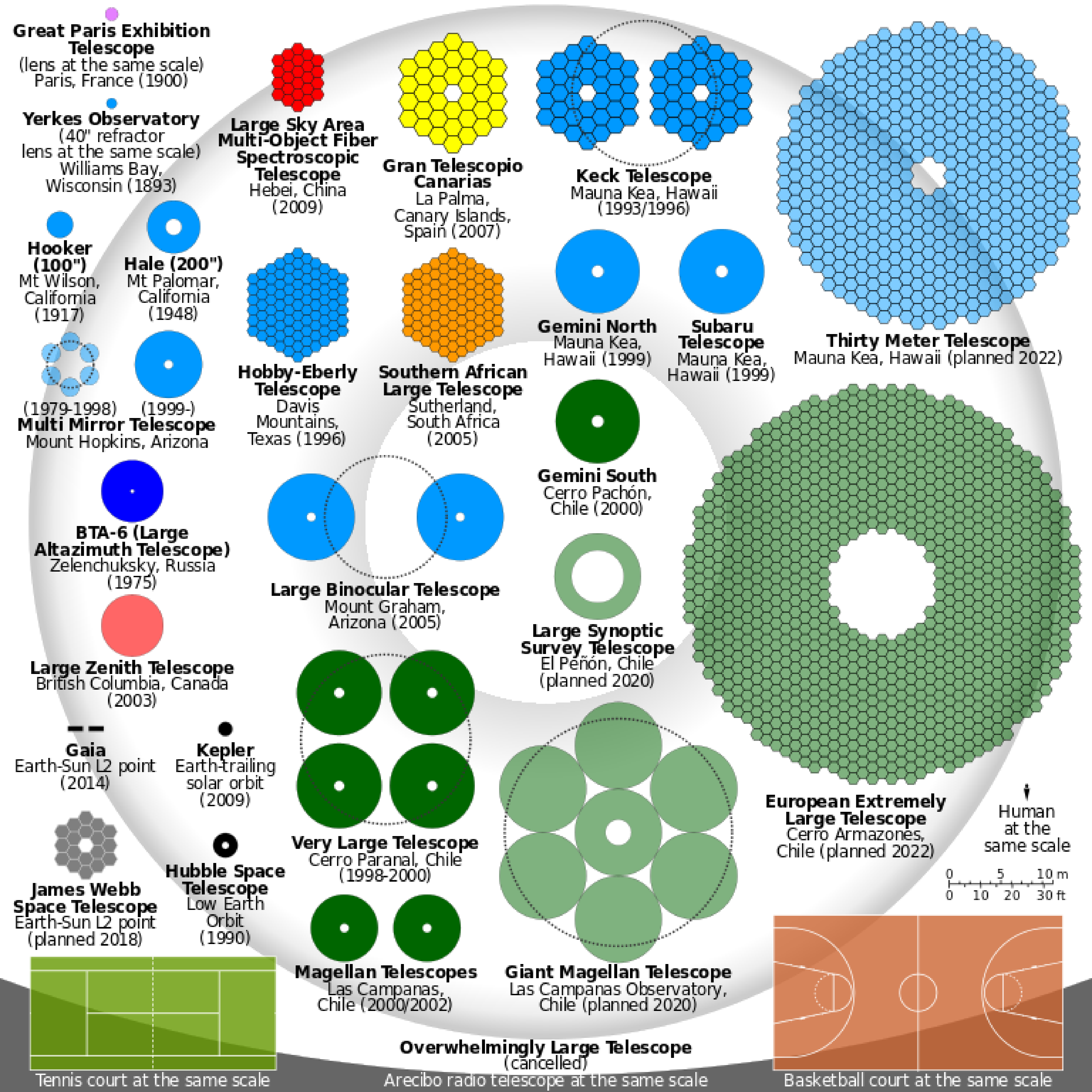


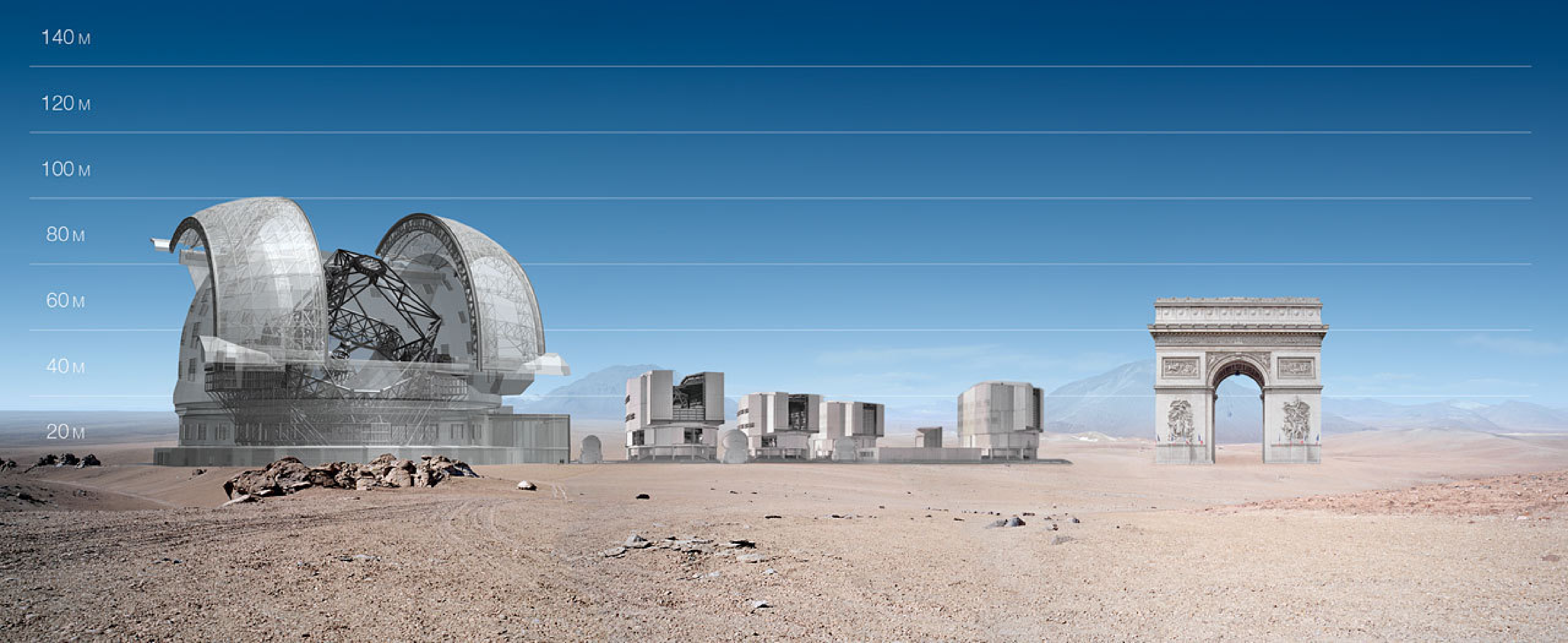

4M
Palomar
Lick
Kitt Peak
(WIYN)
(APO)
CFHT
WHT
CTIO
AAT
ESO3.6
1985
La Palma
NORTH
AMERICA
SOUTH
AMERICA
AUSTRALIA
SOUTHWEST
PACIFIC
BASIN

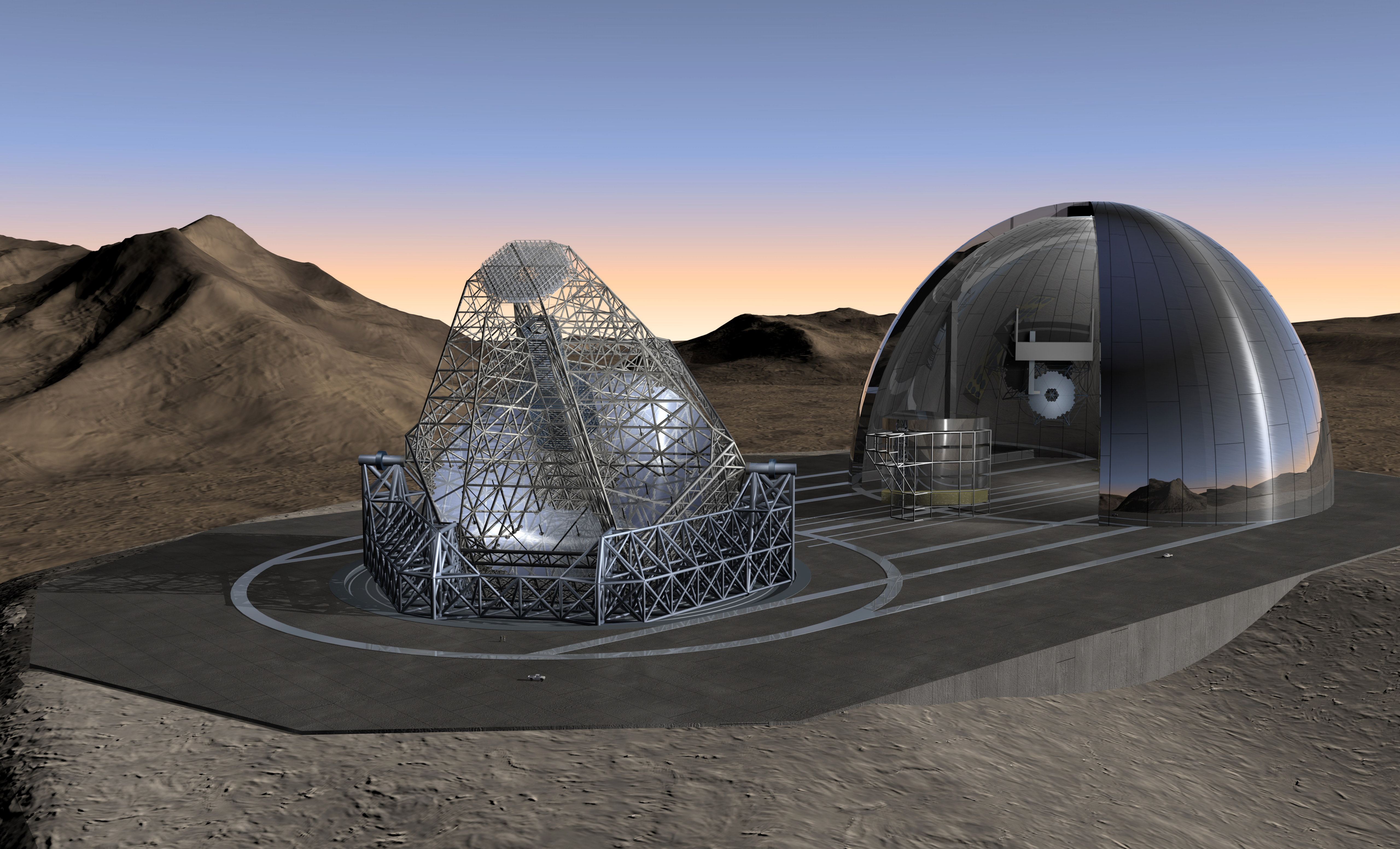

8M
Keck I & II
Gemini N
Subaru
MMT
(LBT)
(GTC)
VLT – 4
Magellan – 2
Gemini S
2005
NORTH
AMERICA
La Palma
SOUTH
AMERICA
AUSTRALIA
SOUTHWEST
PACIFIC
BASIN

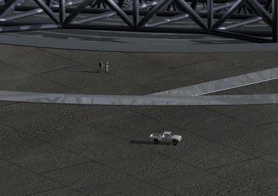


ELTs
TMT
GMT
EELT
Others
ALMA
LSST
SKA/MWA
2020
NORTH
AMERICA
La Palma
SOUTH
AMERICA
SOUTHWEST
PACIFIC
BASIN

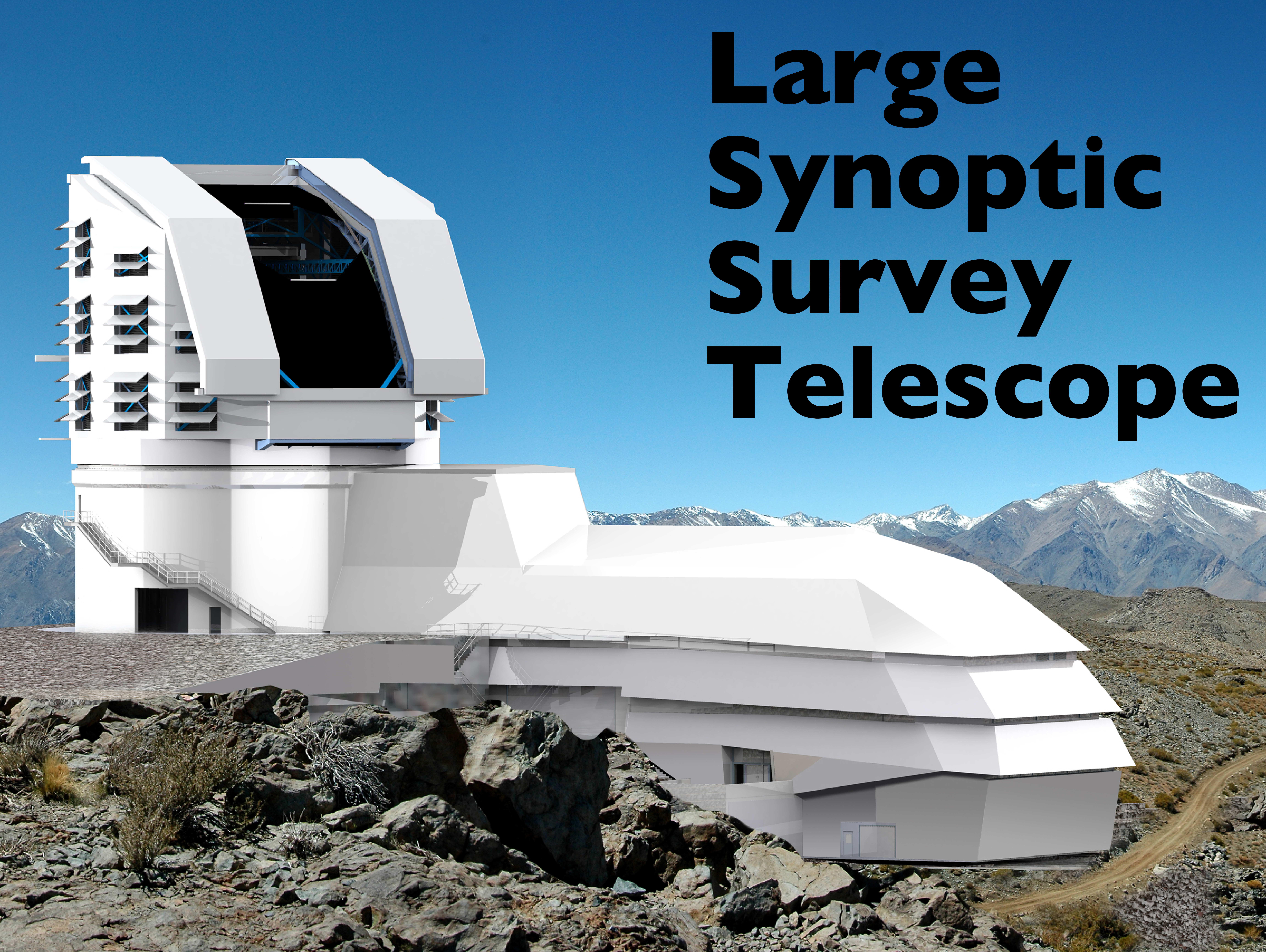

Great Paris Exhibition Telescope
(lens at the same scale)
Paris, France (1900)
Yerkes Observatory
(40" refractor lens at the same scale)
Williams Bay, Wisconsin (1893)
Large Sky Area Multi-Object Fiber Spectroscopic Telescope
Hebei, China (2009)
Gran Telescopio Canarias
La Palma, Canary Islands, Spain (2007)
Keck Telescope
Mauna Kea, Hawaii (1993/1996)
Hooker (100")
Mt Wilson, California (1917)
Hale (200")
Mt Palomar, California (1948)
Thirty Meter Telescope
Mauna Kea, Hawaii (planned 2022)
Gemini North
Mauna Kea, Hawaii (1999)
Subaru Telescope
Mauna Kea, Hawaii (1999)
(1979-1998)
(1999-)
Multi Mirror Telescope
Mount Hopkins, Arizona
Hobby-Eberly Telescope
Davis Mountains, Texas (1996)
Southern African Large Telescope
Sutherland, South Africa (2005)
Gemini South
Cerro Pachón, Chile (2000)
BTA-6 (Large Altazimuth Telescope)
Zelenchuksky, Russia (1975)
Large Binocular Telescope
Mount Graham, Arizona (2005)
Large Synoptic Survey Telescope
El Peñón, Chile (planned 2020)
Large Zenith Telescope
British Columbia, Canada (2003)
Gaia
Earth-Sun L2 point (2014)
Kepler
Earth-trailing solar orbit (2009)
European Extremely Large Telescope
Cerro Armazones, Chile (planned 2022)
Human at the same scale
Very Large Telescope
Cerro Paranal, Chile (1998-2000)
James Webb Space Telescope
Earth-Sun L2 point (planned 2018)
Hubble Space Telescope
Low Earth Orbit (1990)
0 5 10 m
0 10 20 30 ft
Magellan Telescopes
Las Campanas, Chile (2000/2002)
Giant Magellan Telescope
Las Campanas Observatory, Chile (planned 2020)
Overwhelmingly Large Telescope
(cancelled)
Tennis court at the same scale
Arecibo radio telescope at the same scale
Basketball court at the same scale


140 м
120 м
100 м
80 м
60 м
40 м
20 м



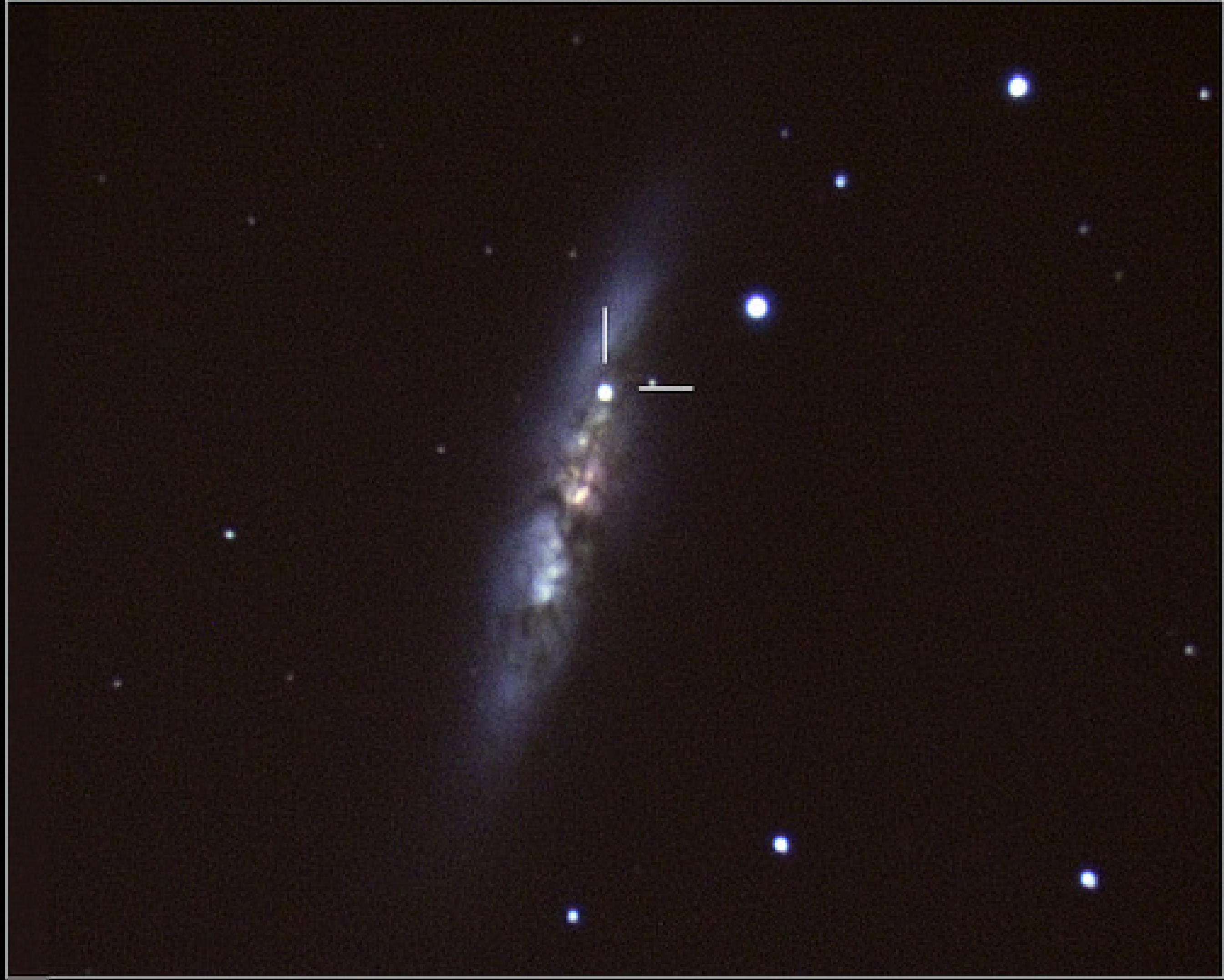


Large Synoptic Survey Telescope



M82 - January 4, 2014

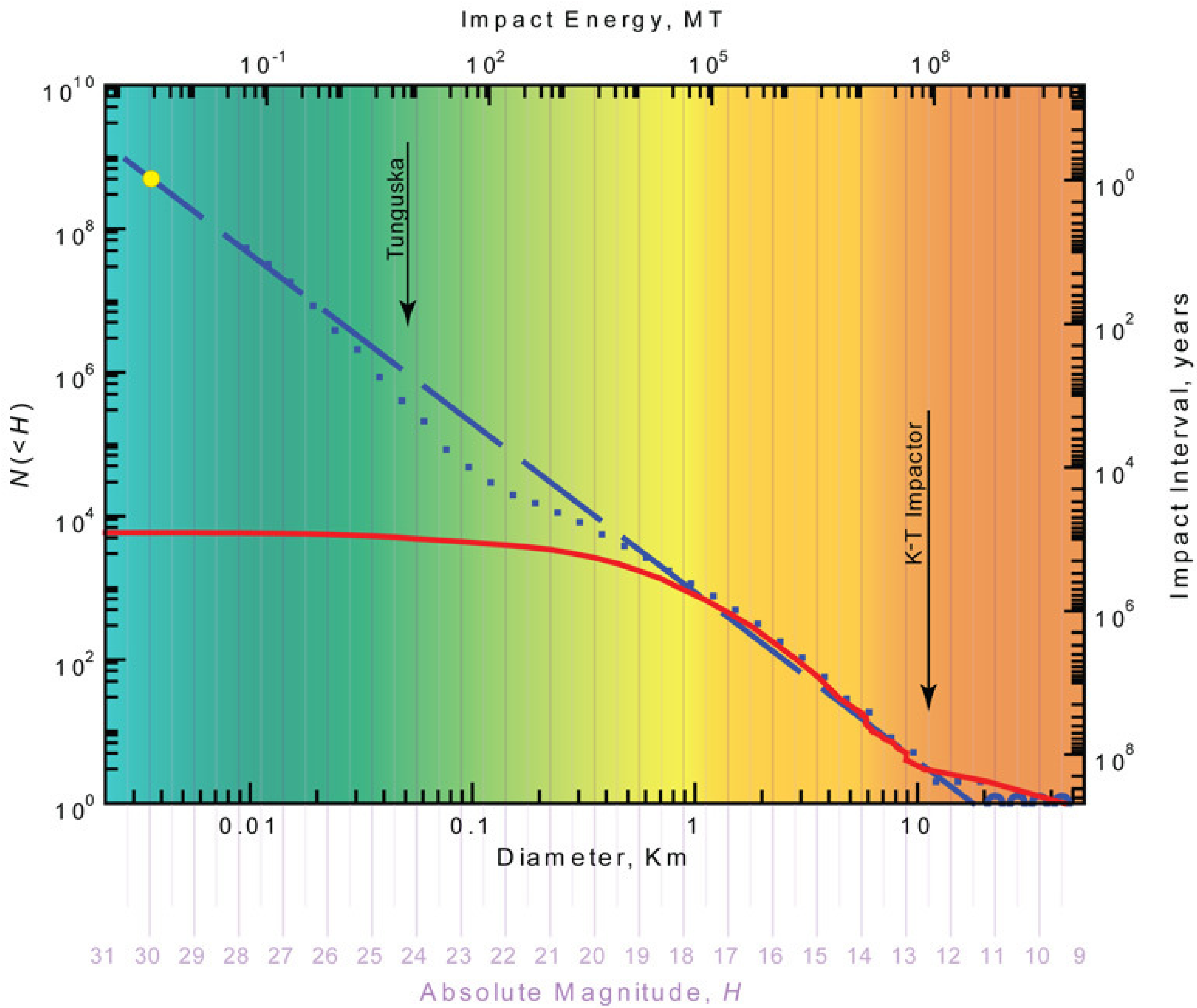
Scott MacNeill, Frosty Drew Observatory



M82 - January 22, 2014

Scott MacNeill, Frosty Drew Observatory

POTENTIAL DAMAGE TO EARTH FROM NEO IMPACT



- Estimated from discovered population
- Estimated from bolide observations
- Constant power law
- Discovered to 1.19.09

NO DAMAGE
D < 30 m (0.030 km)
Airburst in upper atmosphere, no significant ground damage.

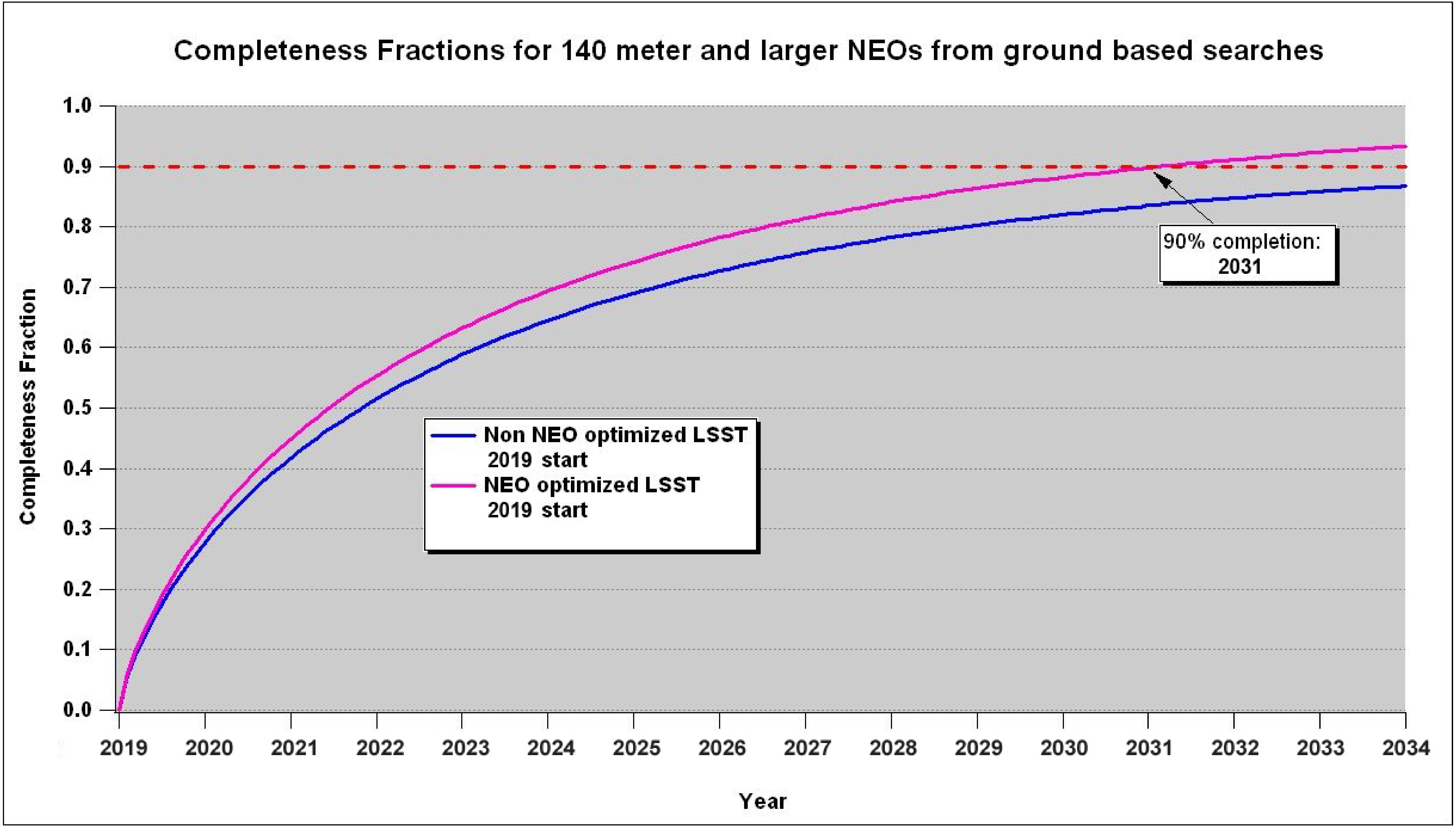
AIRBURST
30 m < D < 100 m
Airburst in lower atmosphere, causes damage similar to nuclear bomb blast above ground. Over ocean, no damage.

REGIONAL/TSUNAMI
100 m - 1 km
Surface impact, on land, makes crater a couple to a couple tens of km across. In the sea, raises a tsunami that can cause shoreline damage one to a few thousand km distant from the impact point.

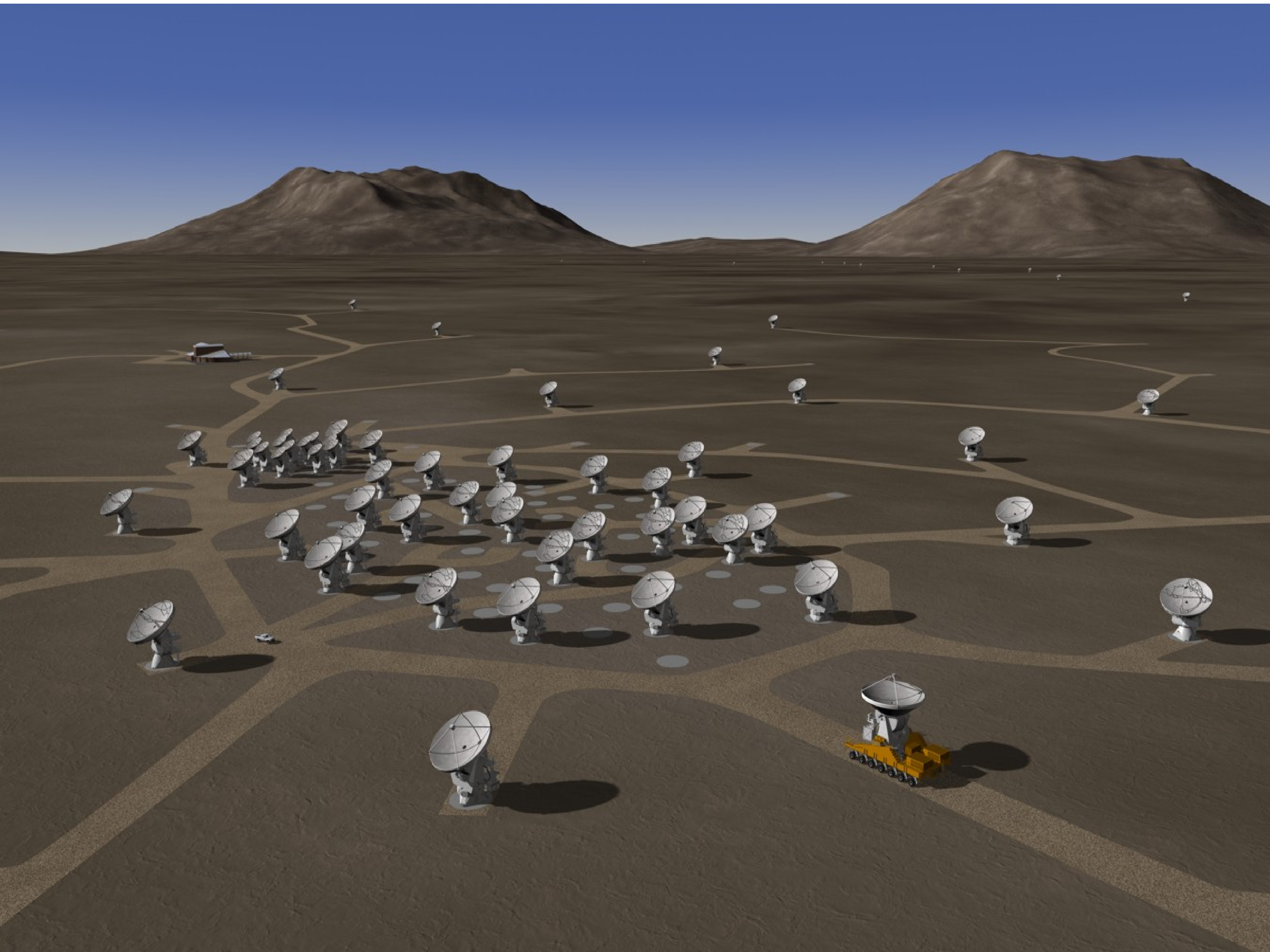
GLOBAL
1 km - 10 km
An impact into land or sea may raise enough dust into the stratosphere to cause a global climatic catastrophe, leading to mass starvation, disease, and general disruption of social order.

EXTINCTION
10 km and larger - possibility of mass extinction, certainly of some species and possibly humans.

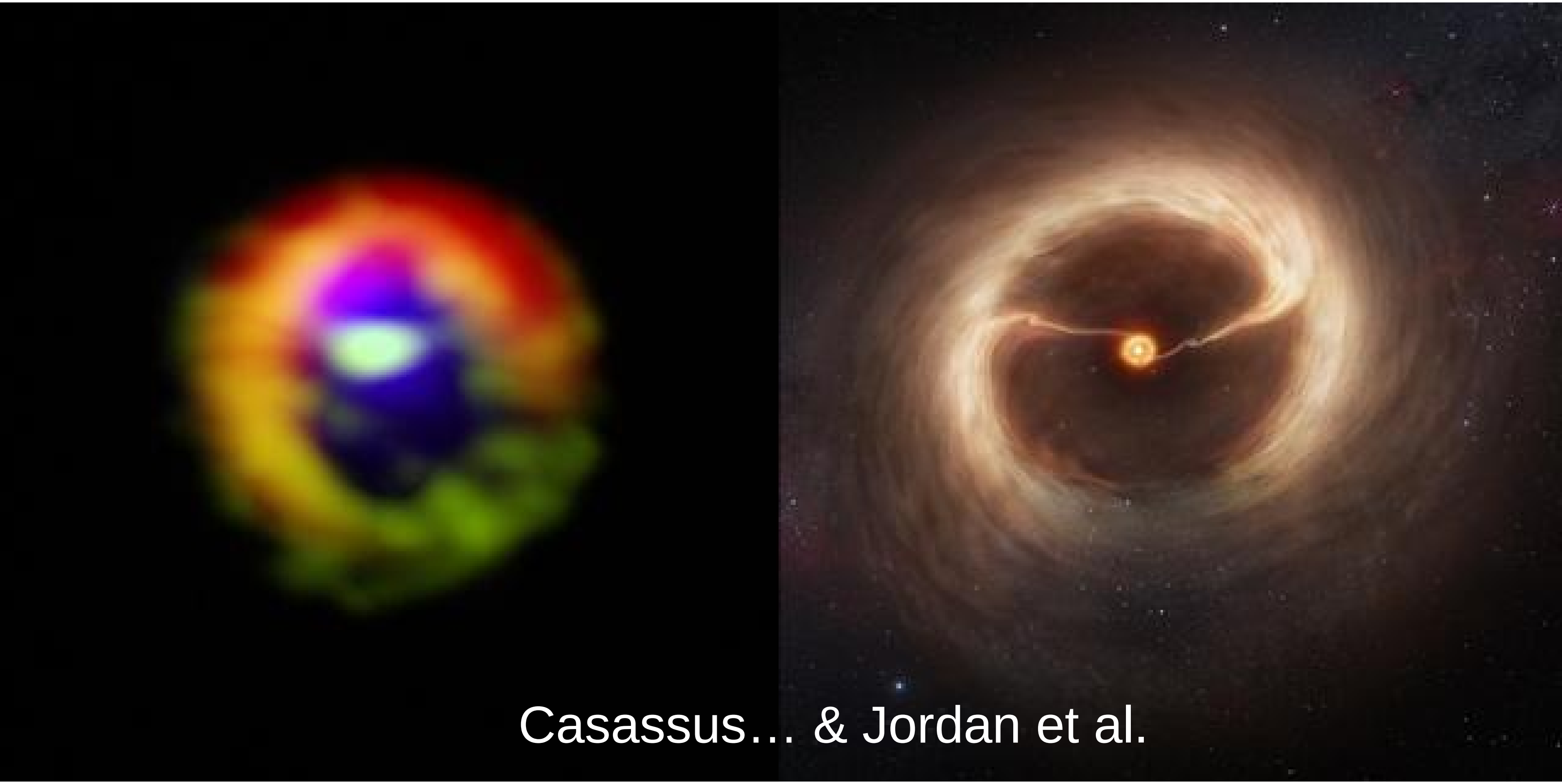
Image Credit: A. W. Harris, SSI/LSST


Completeness Fractions for 140 meter and larger NEOs from ground based searches
Completeness Fraction
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
Year
90% completion:
2031
Non NEO optimized LSST
2019 start
NEO optimized LSST
2019 start

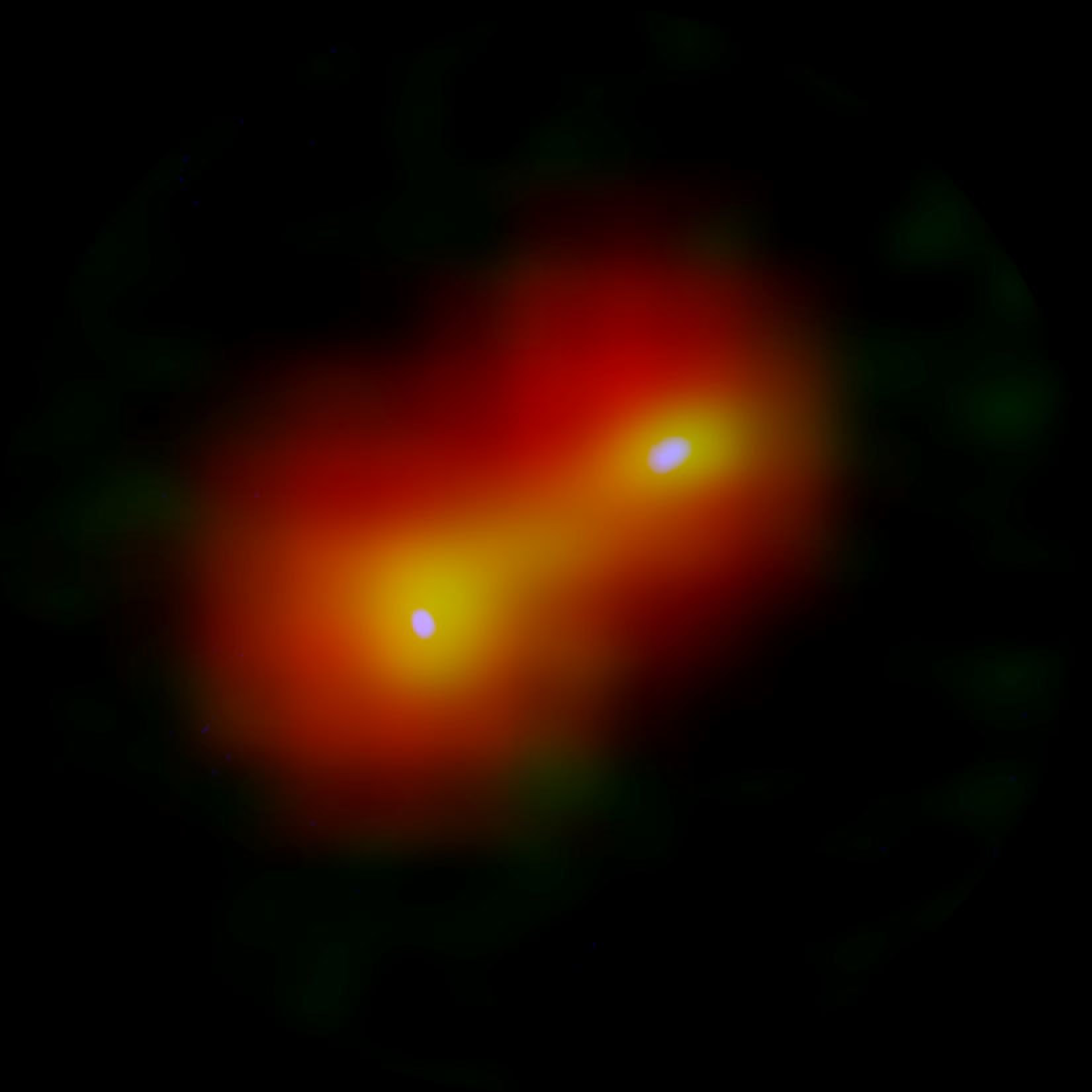

ALMA

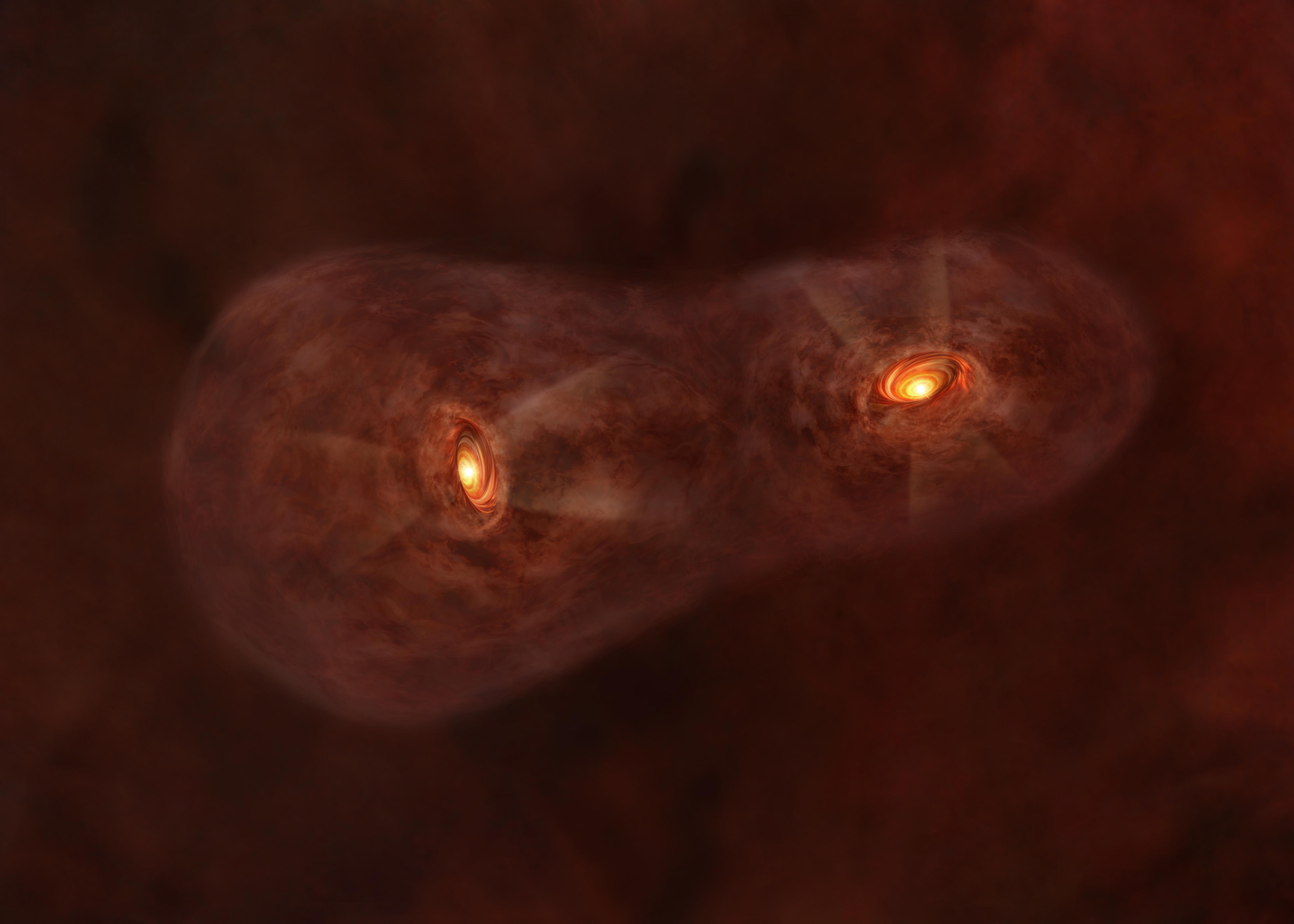


ALMA; giant planets

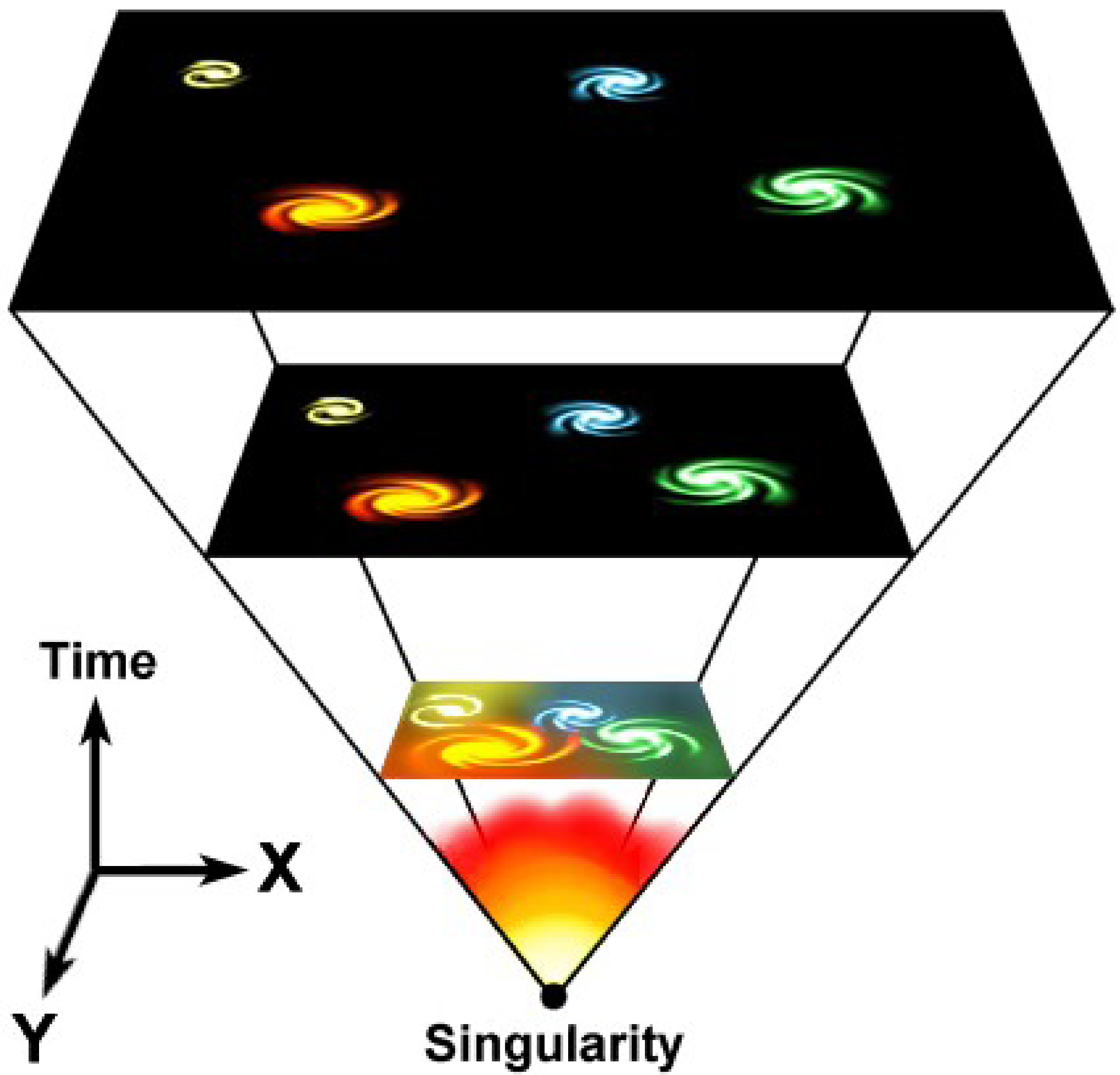


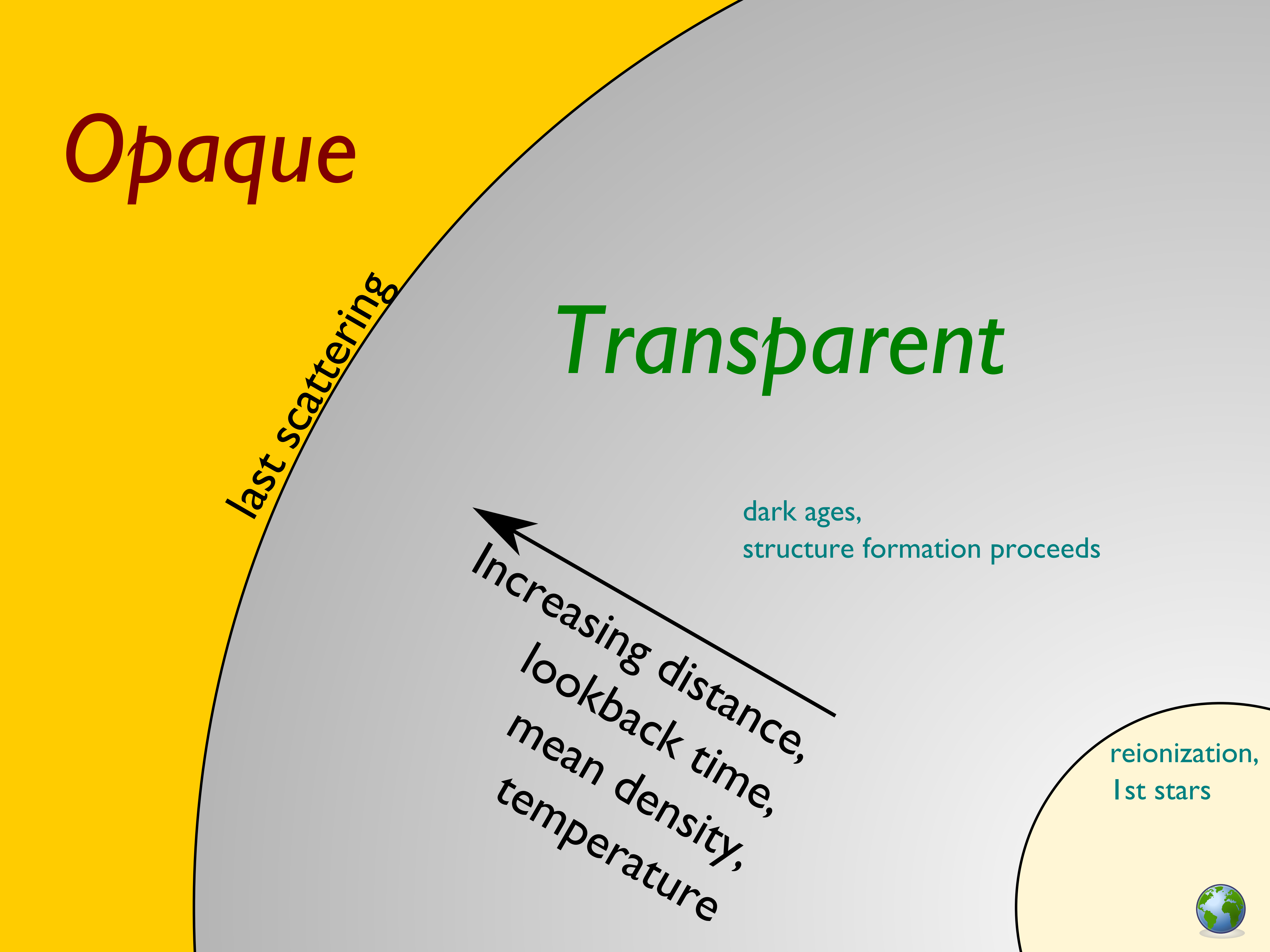
Casassus… & Jordan et al.



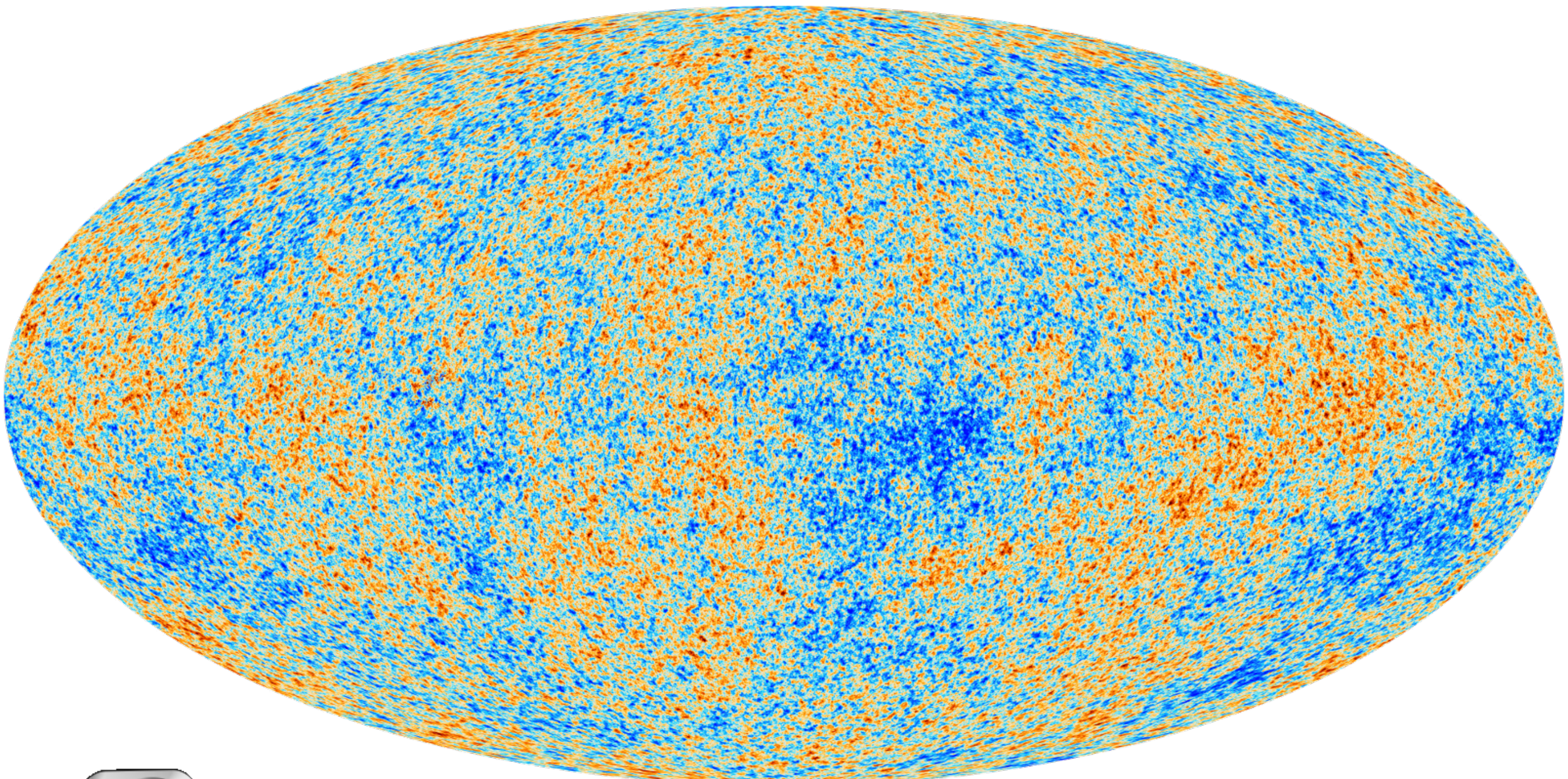


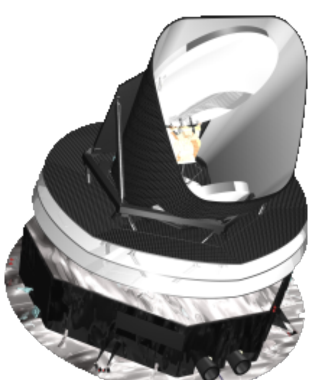
Expanding universe & the Big Bang




Opaque
last scattering
Transparent
dark ages,
structure formation proceeds
Increasing distance,
lookback time,
mean density,
temperature
reionization,
1st stars

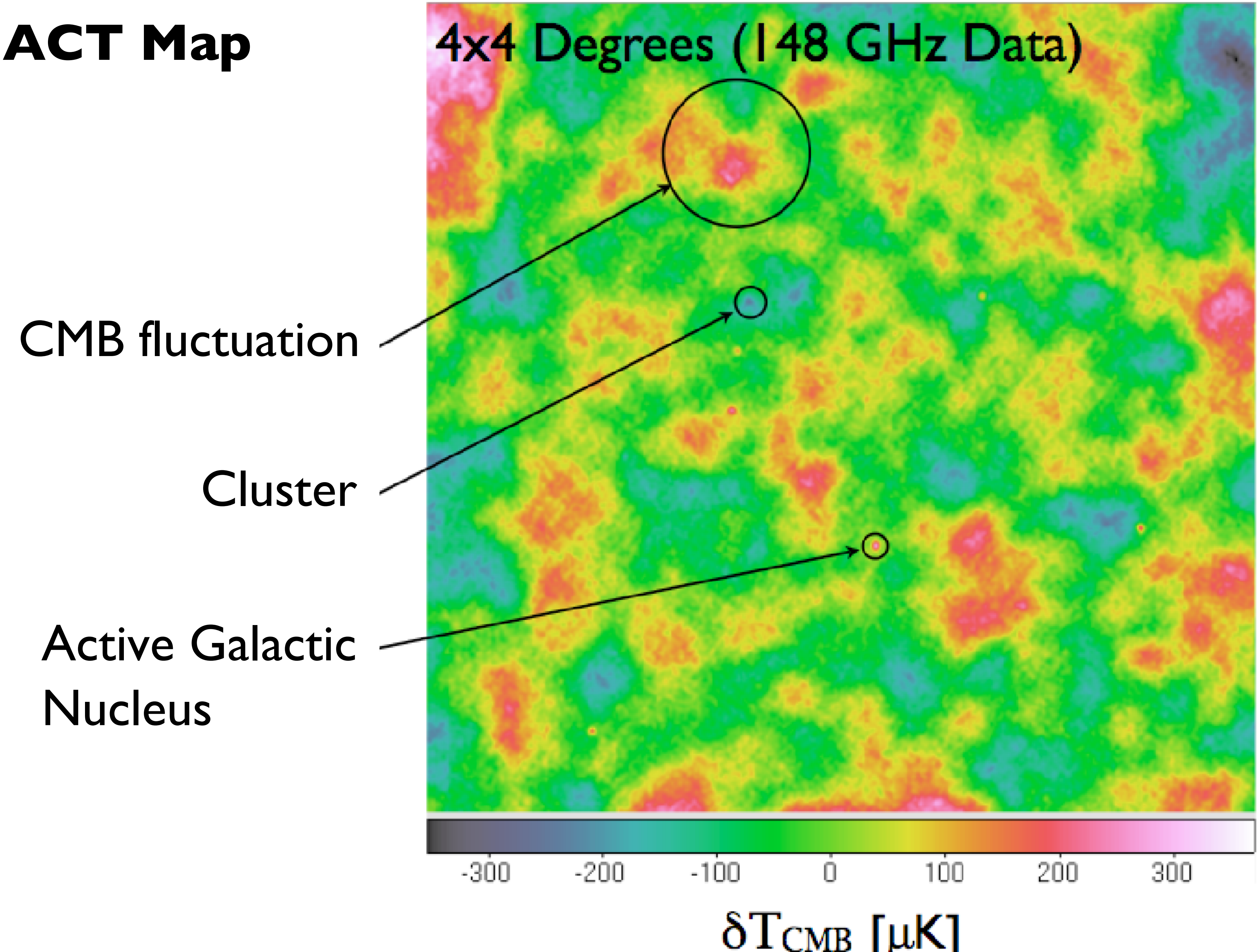
Cosmic Microwave Background

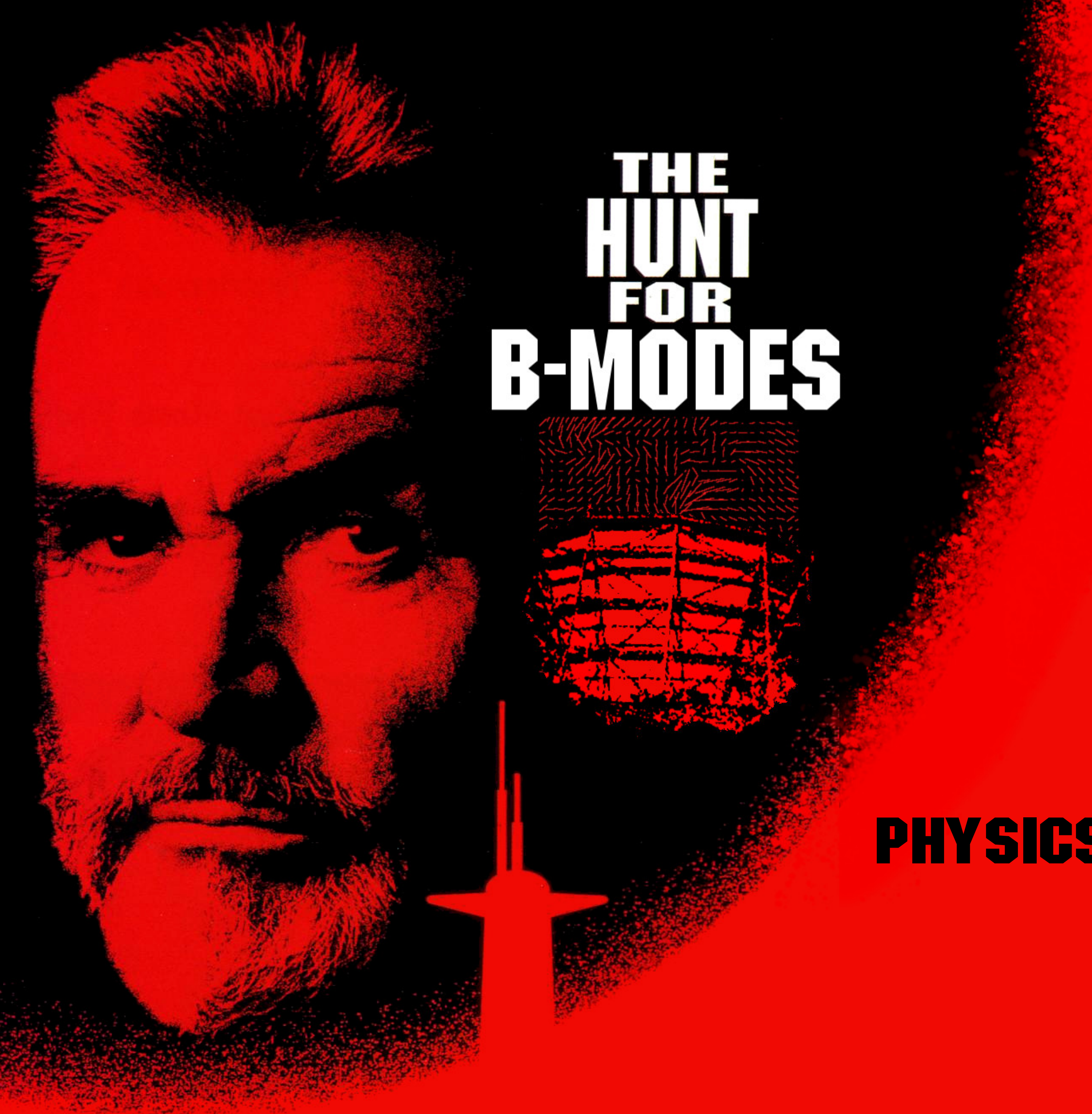




~ few hundred μK around mean *T*

ACT Map


4x4 Degrees (148 GHz Data)
CMB fluctuation
Cluster
Active Galactic Nucleus
-300
-200
-100
0
100
200
300
δTCMB [μK]



POLARIZATION SIGNATURE OF GRAVITY WAVES

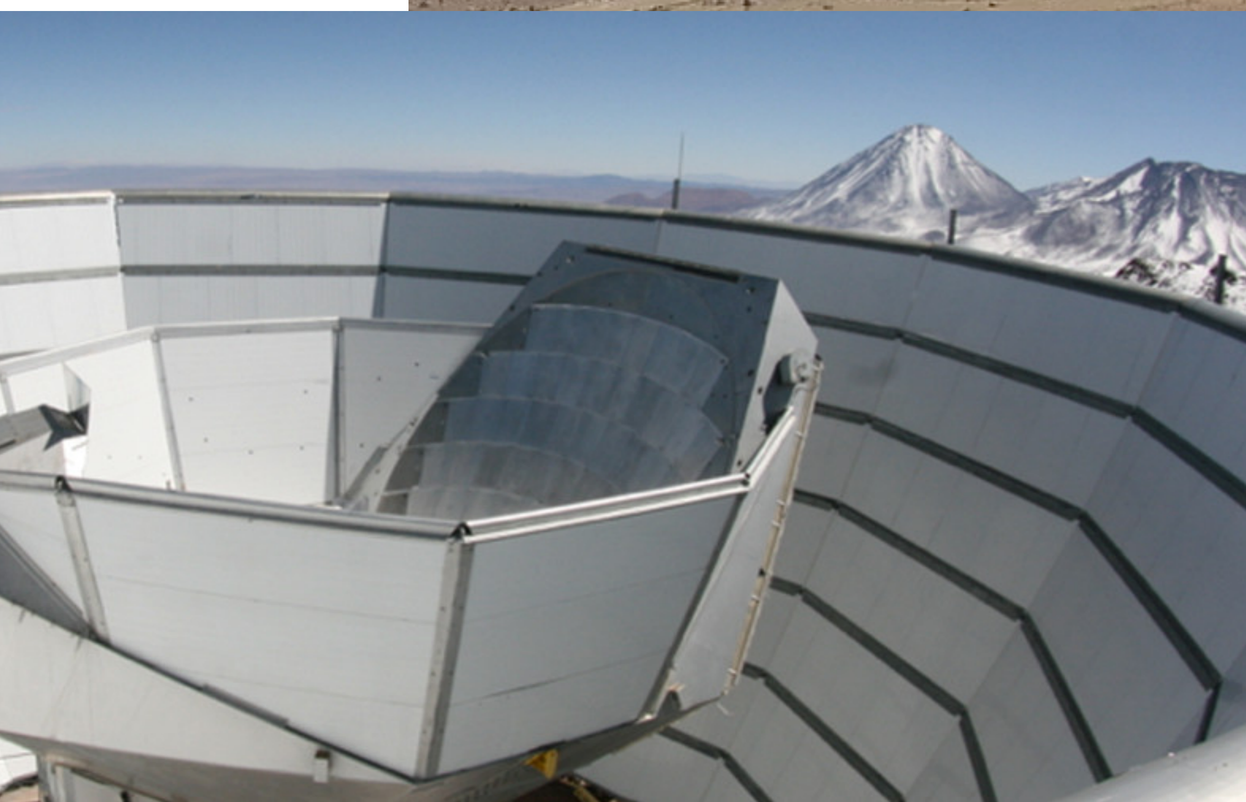
DISTINCTIVE OF INFLATION IN EARLY UNIVERSE

PHYSICS AT GRAND-UNIFIED-SCALE ENERGIES

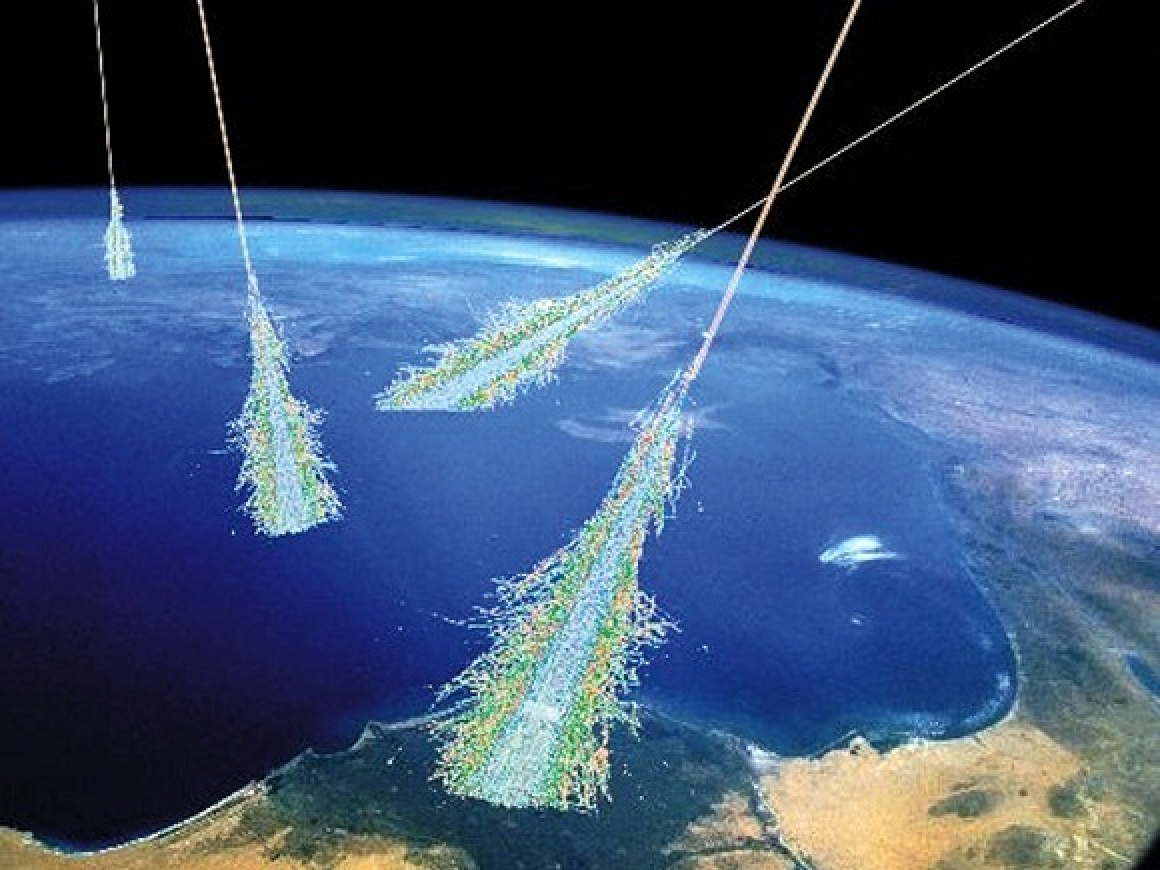
ACT, SIMONS OBSERVATORY, CMB-S4, MANY OTHERS

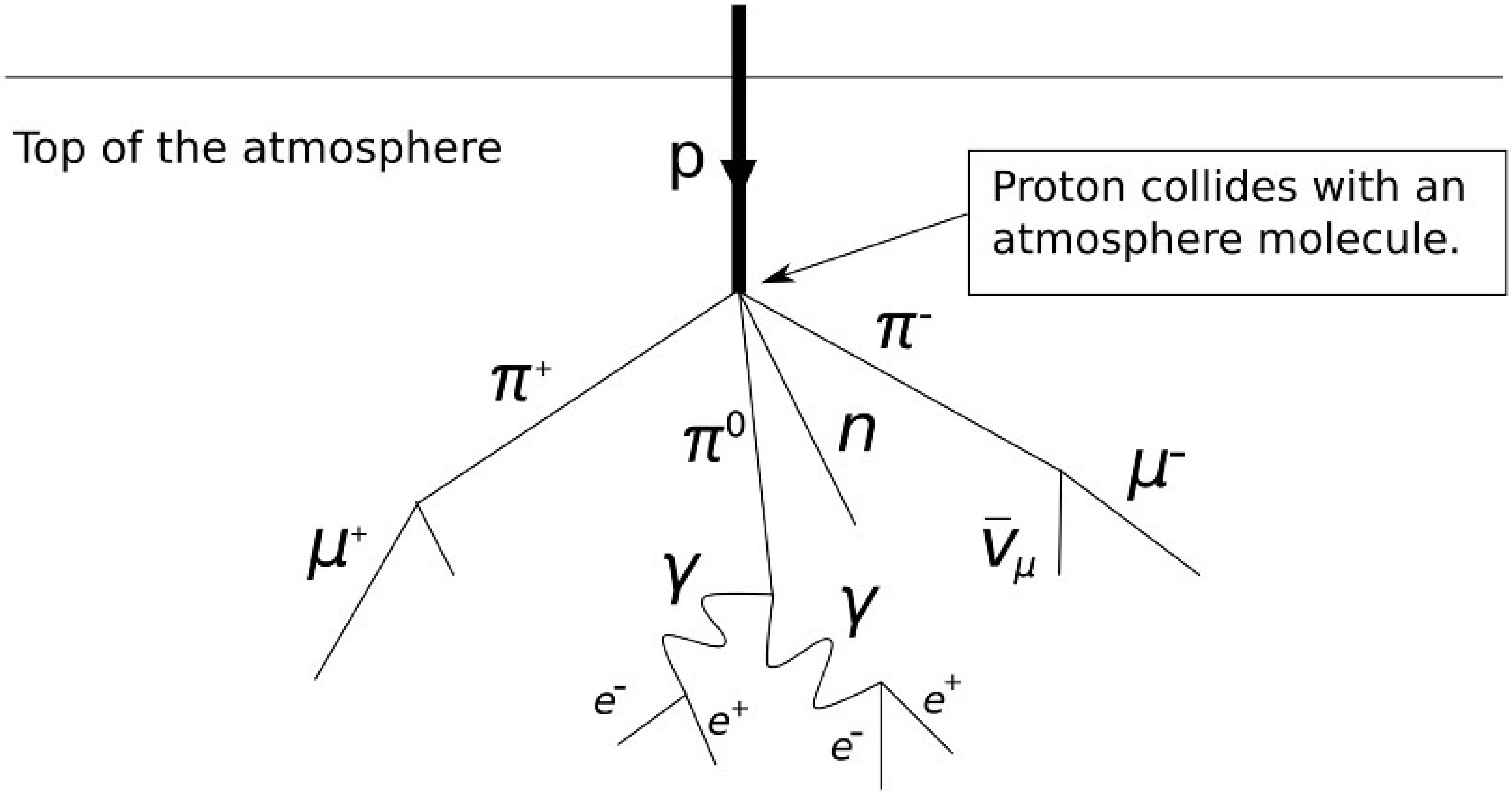
Atacama Cosmology Telescope and Simons Observatory

New observatory for CMB



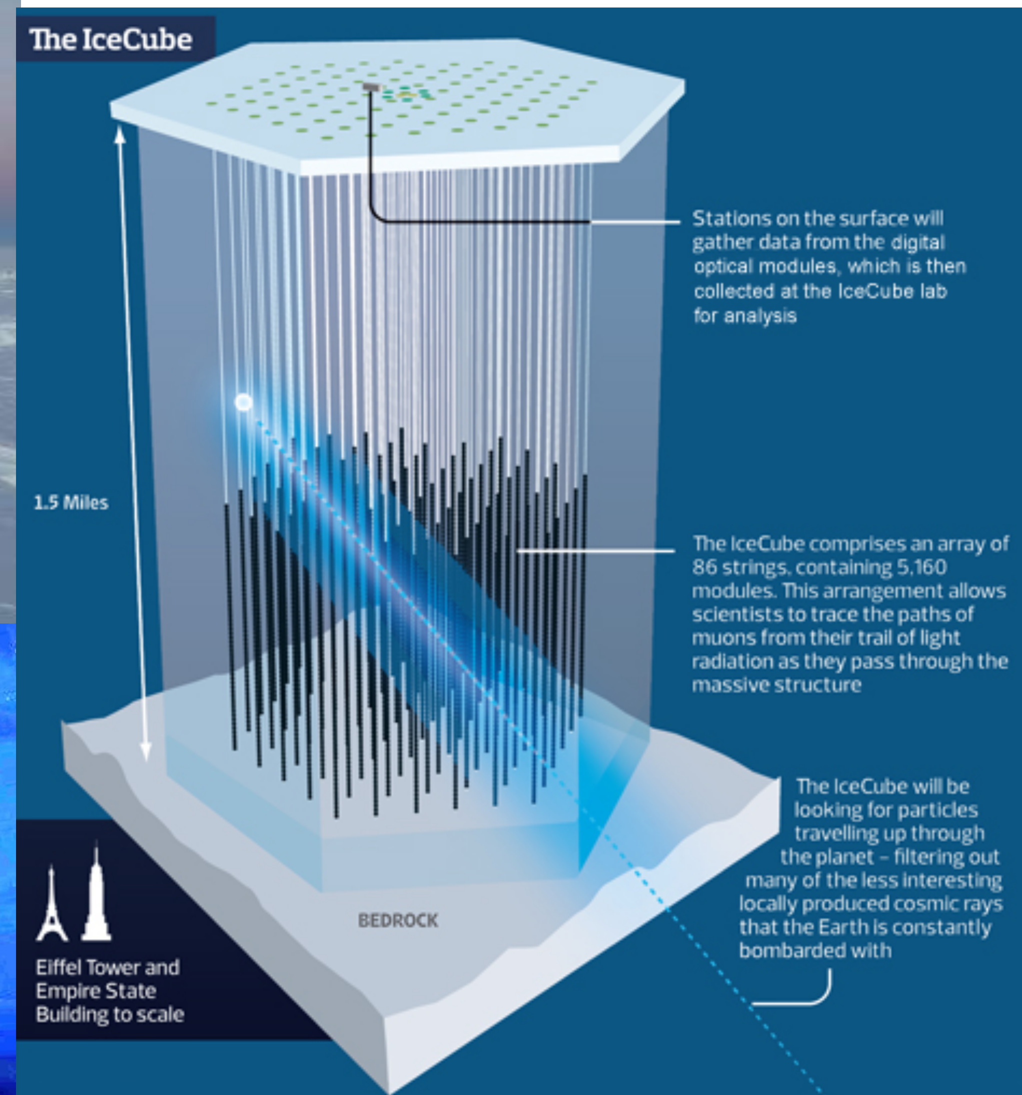

ALAIDE




Top of the atmosphere
p
Proton collides with an atmosphere molecule.
π^-
π^+
π^0
n
μ^-
μ^+
$\bar{\nu}_\mu$
γ
γ
e^-
e^+
e^-
e^+


LIMITE DE L'ATMOSPHÈRE

IceCube Neutrino Telescope




LIGO
Gravitational Waves