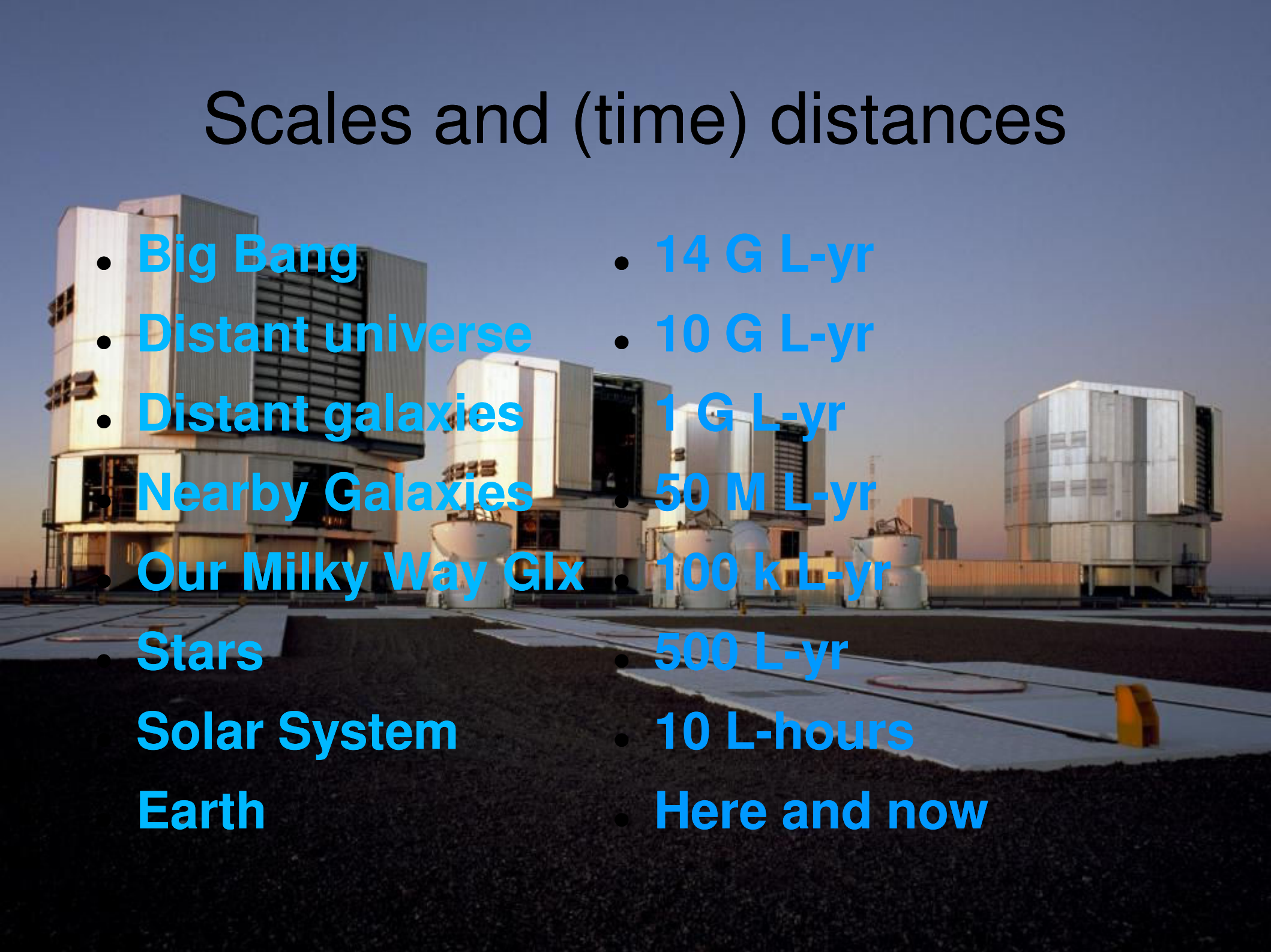
Large telescopes
...in a vast Universe

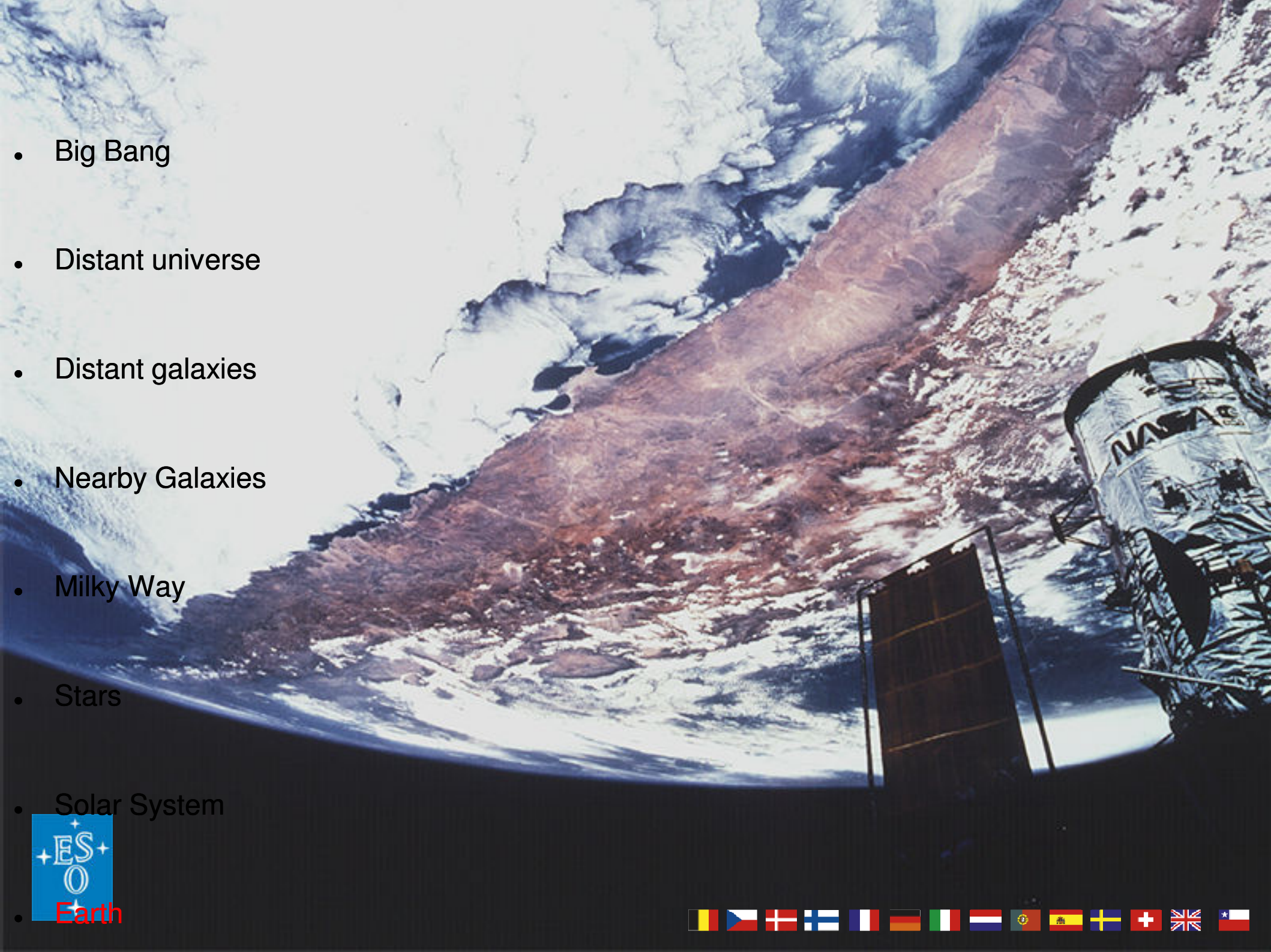
Olivier Hainaut
ESO

Scales and (time) distances



- Big Bang — 14 G L-yr
- Distant universe — 10 G L-yr
- Distant galaxies — 1 G L-yr
- Nearby Galaxies — 50 M L-yr
- Our Milky Way Glx — 100 k L-yr
- Stars — 500 L-yr
- Solar System — 10 L-hours
- Earth — Here and now

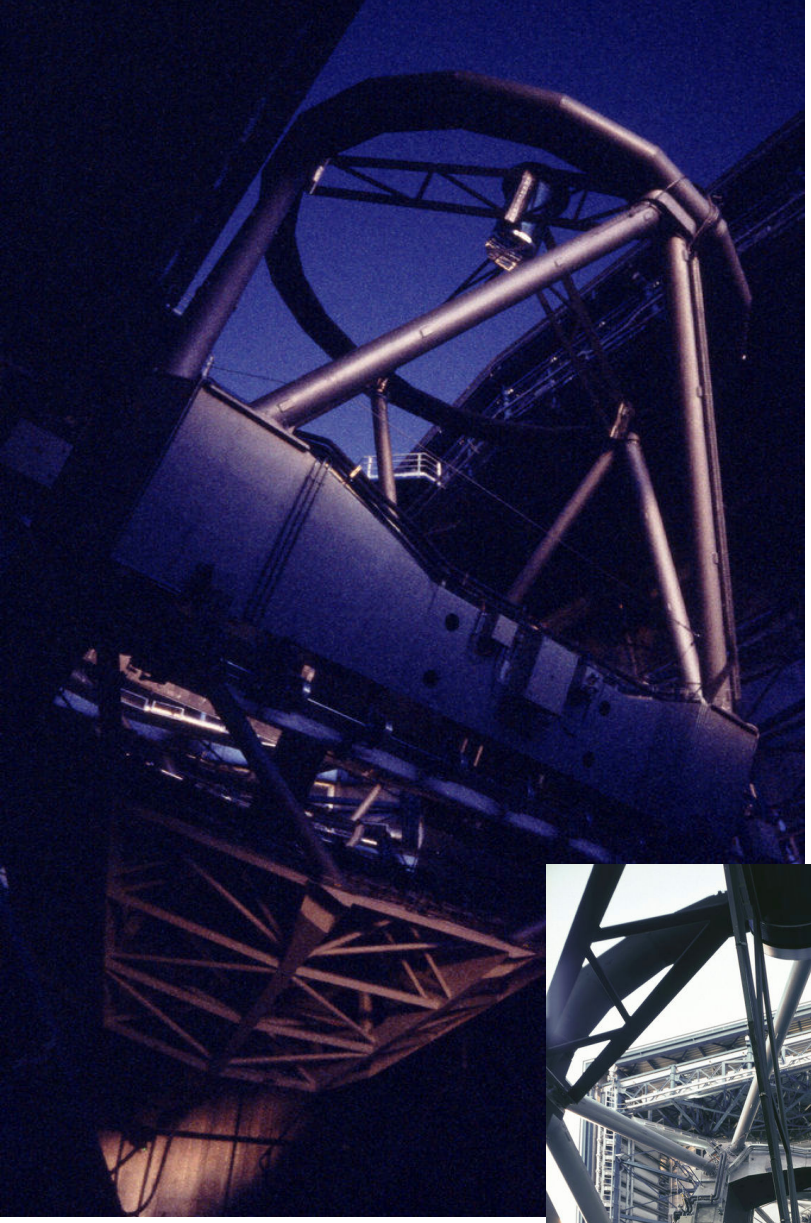

European Southern Observatory
Very Large Telescope
4*8.2m + 4*1.8m
Paranal, Chile
Big Bang
Distant universe
Distant galaxies
Nearby Galaxies
Milky Way
Earth

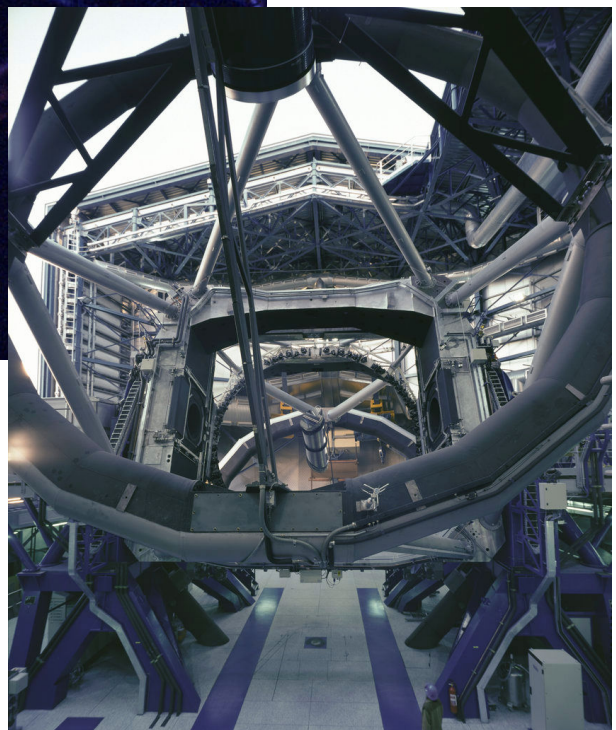


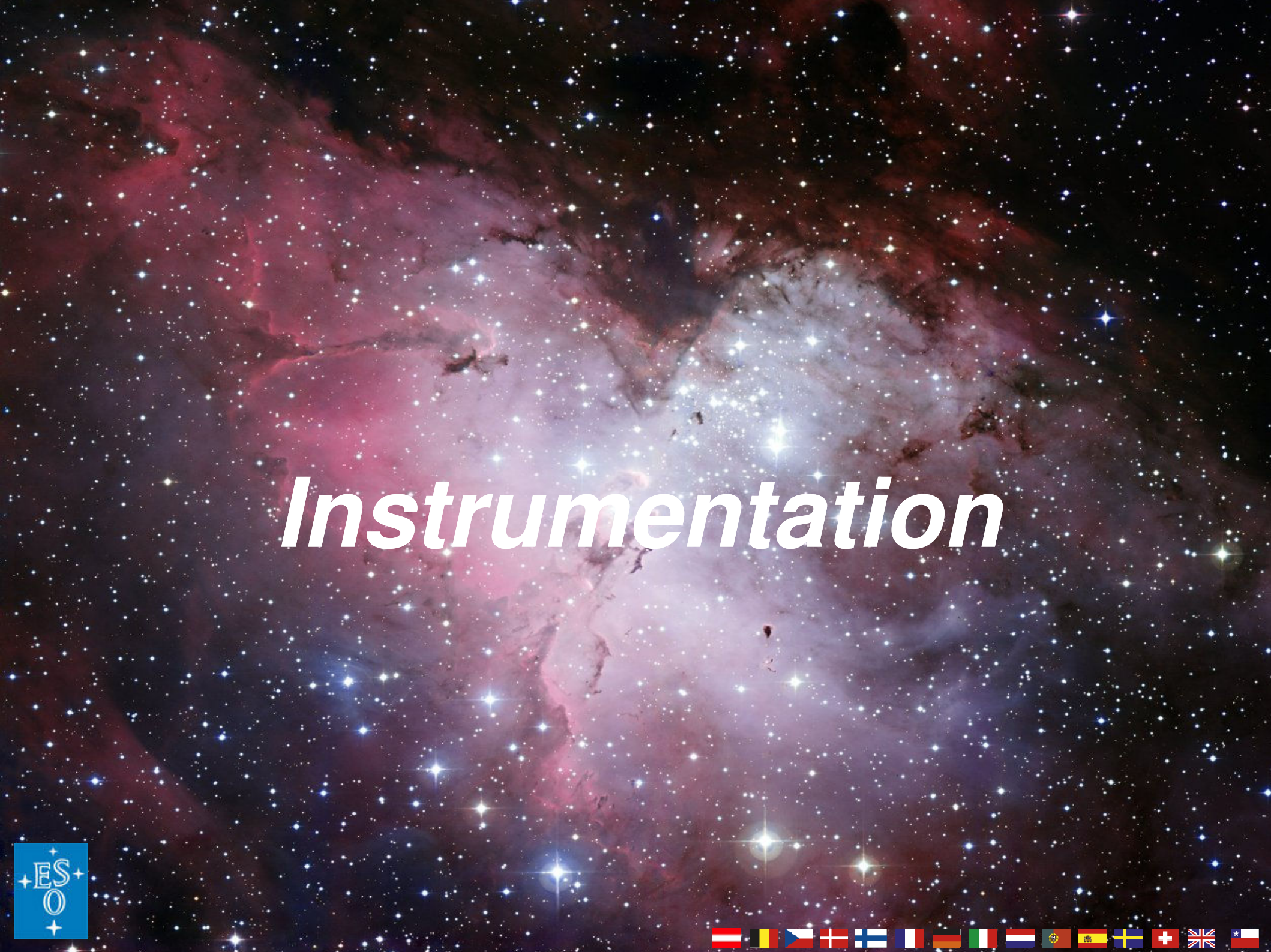
- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars
- Solar System
- Earth

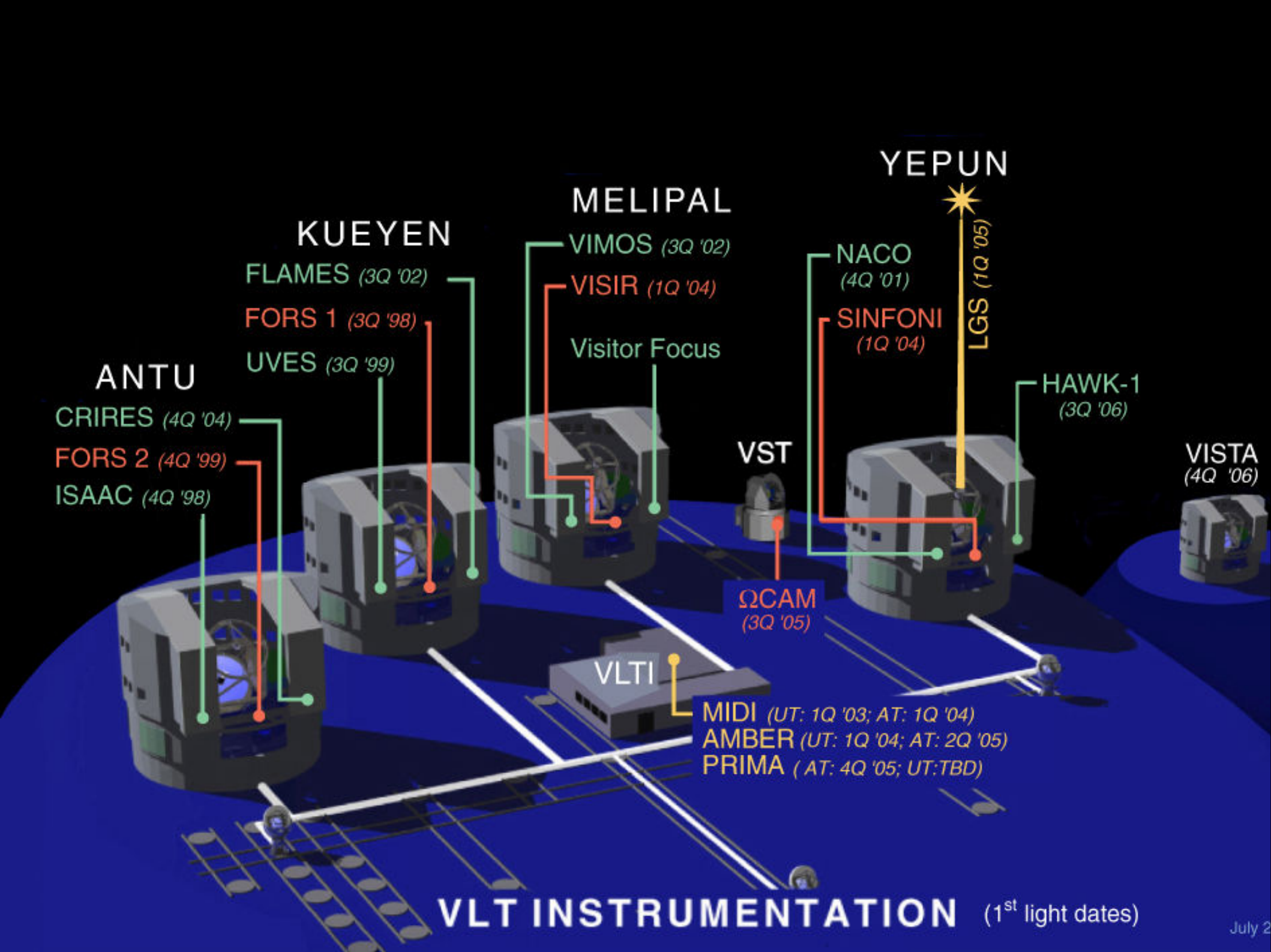

www.atacamaphoto.com

« Unit Telescope »

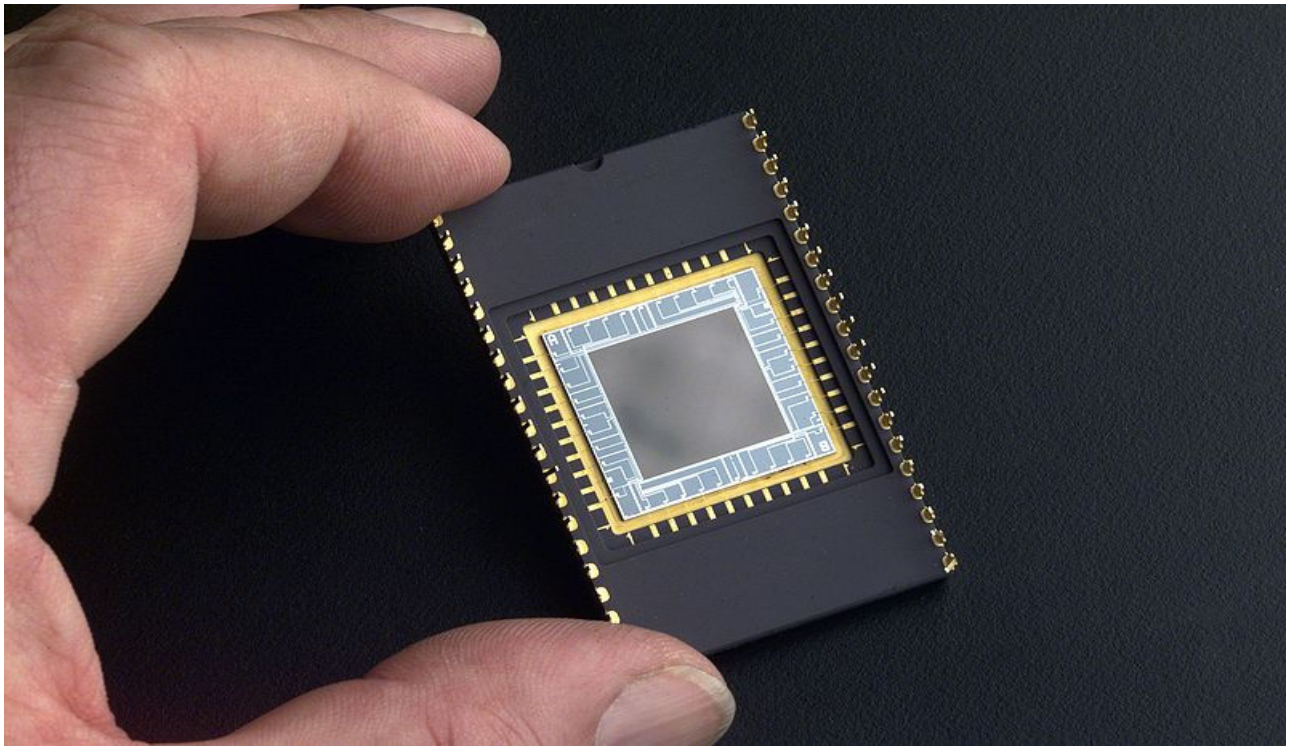





Instrumentation

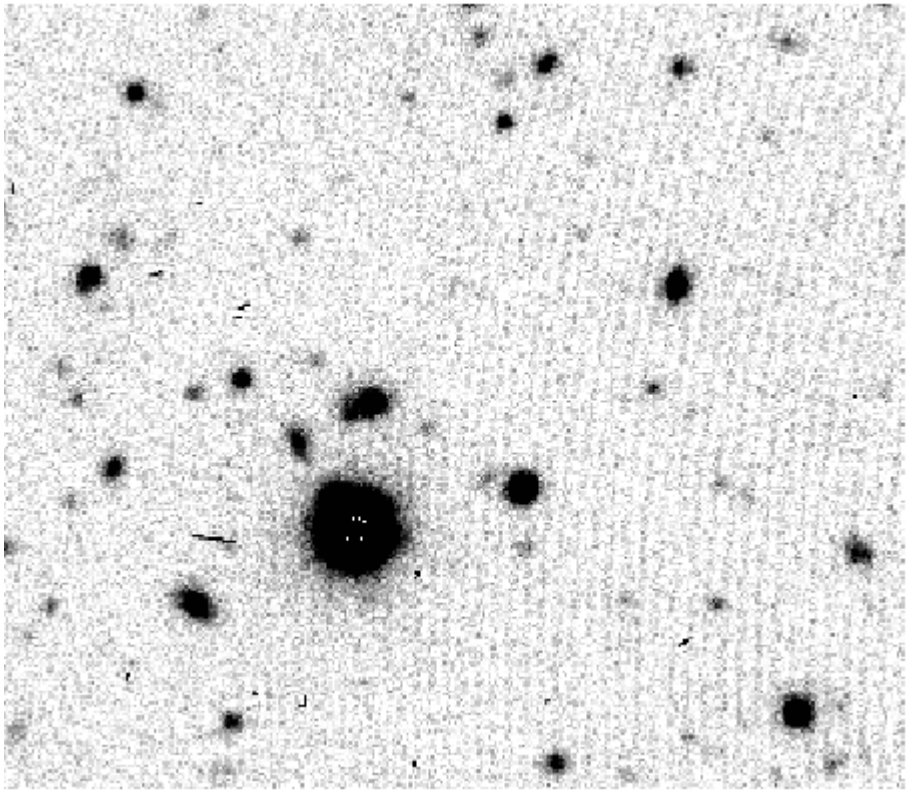

YEPUN
LGS (1Q '05)
MELIPAL
VIMOS (3Q '02)
VISIR (1Q '04)
Visitor Focus
KUEYEN
FLAMES (3Q '02)
FORS 1 (3Q '98)
UVES (3Q '99)
NACO
(4Q '01)
SINFONI
(1Q '04)
HAWK-1
(3Q '06)
ANTU
CRIRES (4Q '04)
FORS 2 (4Q '99)
ISAAC (4Q '98)
VST
VISTA
(4Q '06)
ΩCAM
(3Q '05)
VLTI
MIDI (UT: 1Q '03; AT: 1Q '04)
AMBER (UT: 1Q '04; AT: 2Q '05)
PRIMA (AT: 4Q '05; UT:TBD)
VLT INSTRUMENTATION (1st light dates)
July 2

Imaging



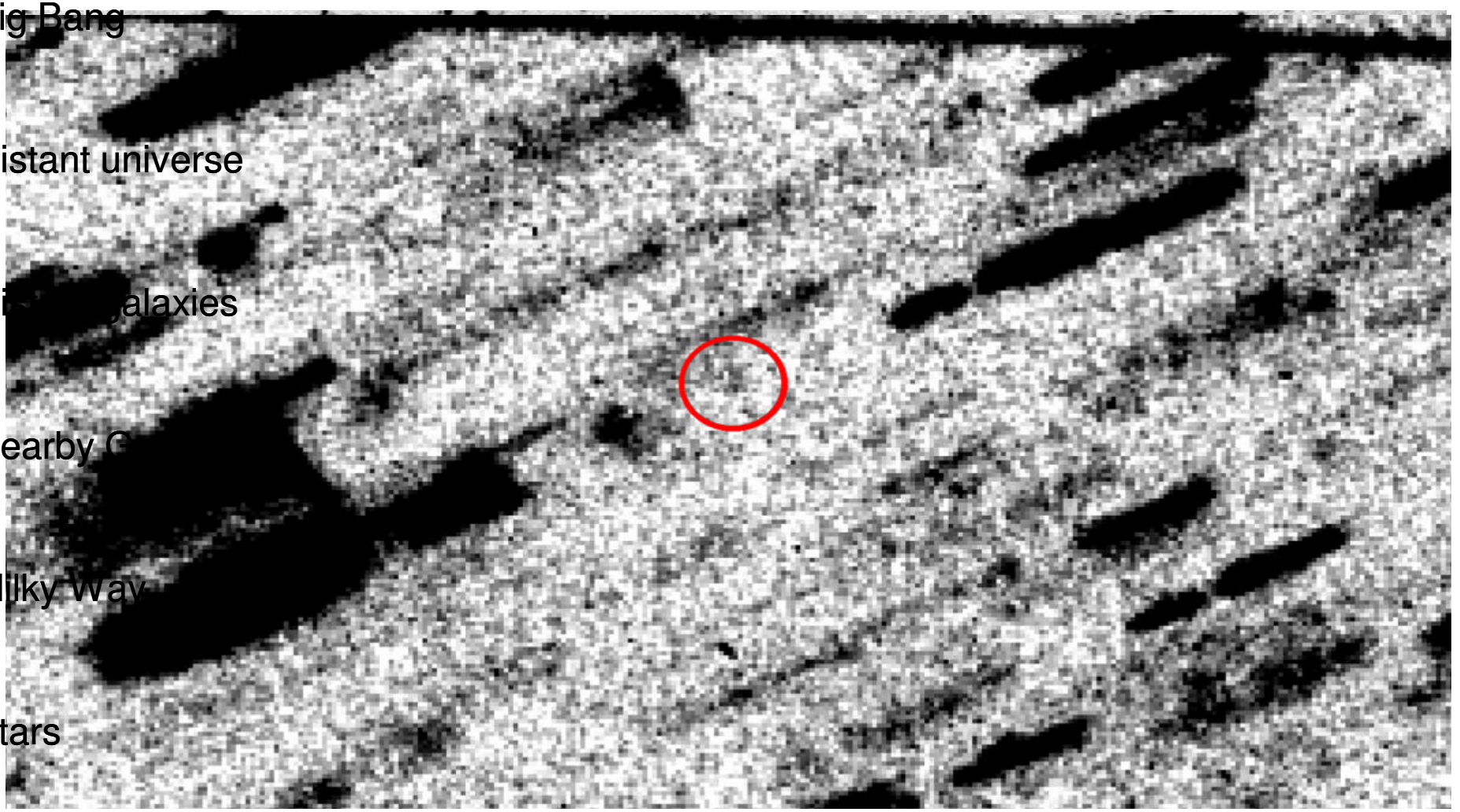
Deep Imaging: TransNeptunian Objects in our Solar System

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars
- Solar System
- Earth



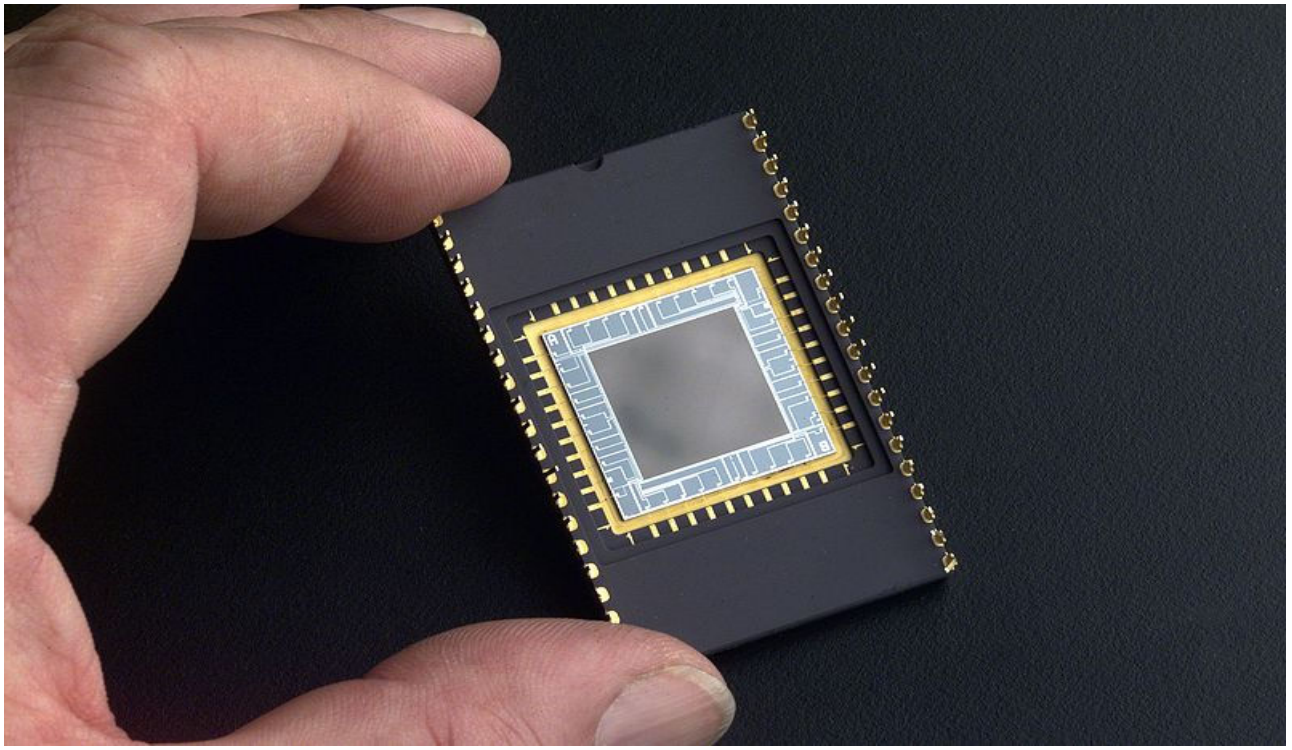
Halley's Comet

- Big Bang
- Distant universe
- Di[illegible]galaxies
- Nearby G[illegible]
- Milky Way
- Stars
- Solar System
- Earth

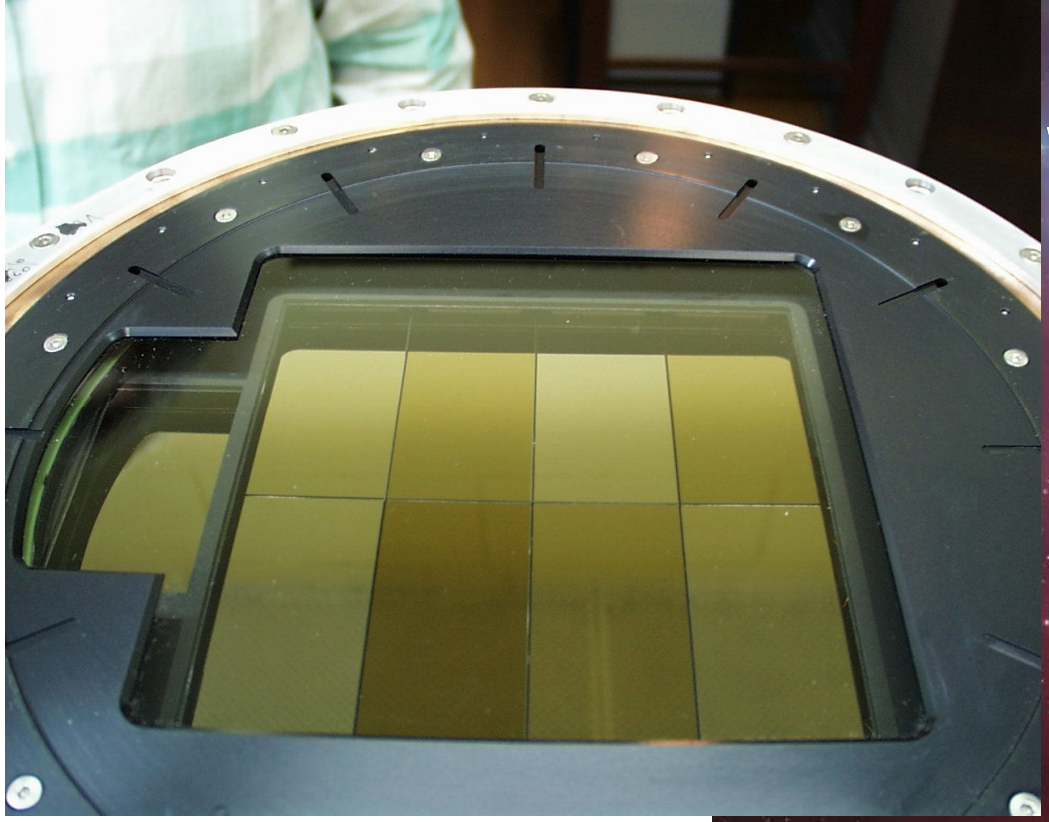


Comet 1P/Halley at 28AU
Mag=28.5
Exposure: 3 UT's for 3 nights

Imaging



Wide Field Imaging



Young stars in nebula

M8, the Lagoon Nebula

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars (4000Ly)
- Solar System
- Earth

Dying star, Planetary Nebula

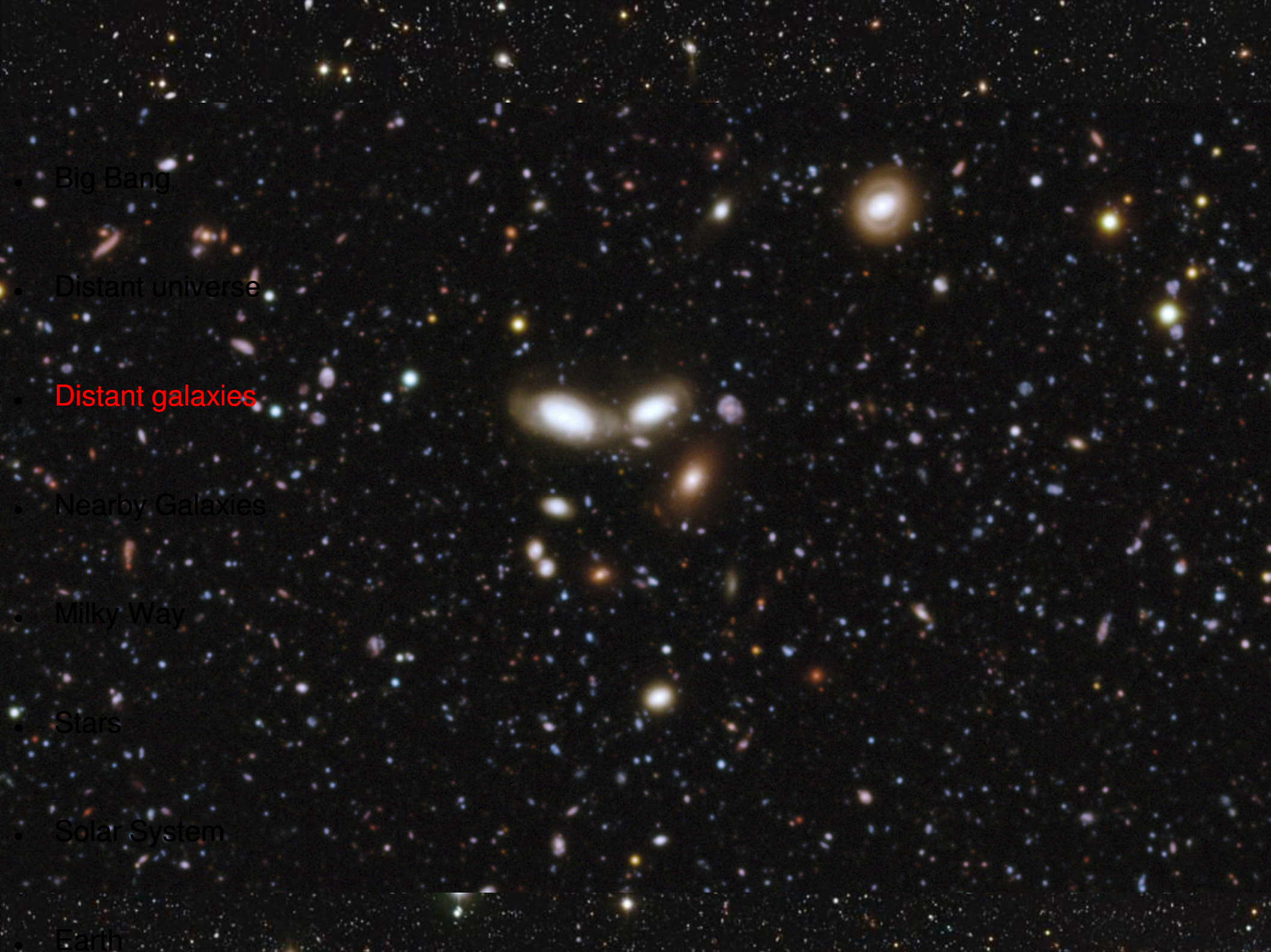
Helix Nebula

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars (700Ly)
- Solar System
- Earth

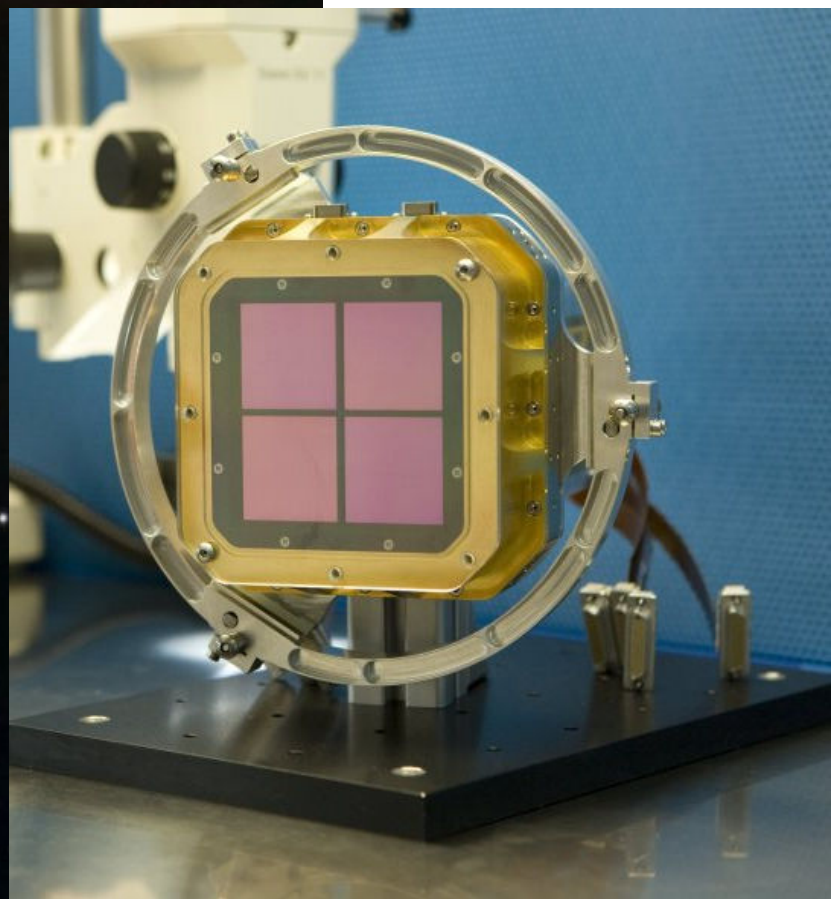
Nearby Galaxy

Southern Pinwheel Galaxy, M83 = NGC 5236

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies (15MLy)
- Milky Way
- Stars
- Solar System

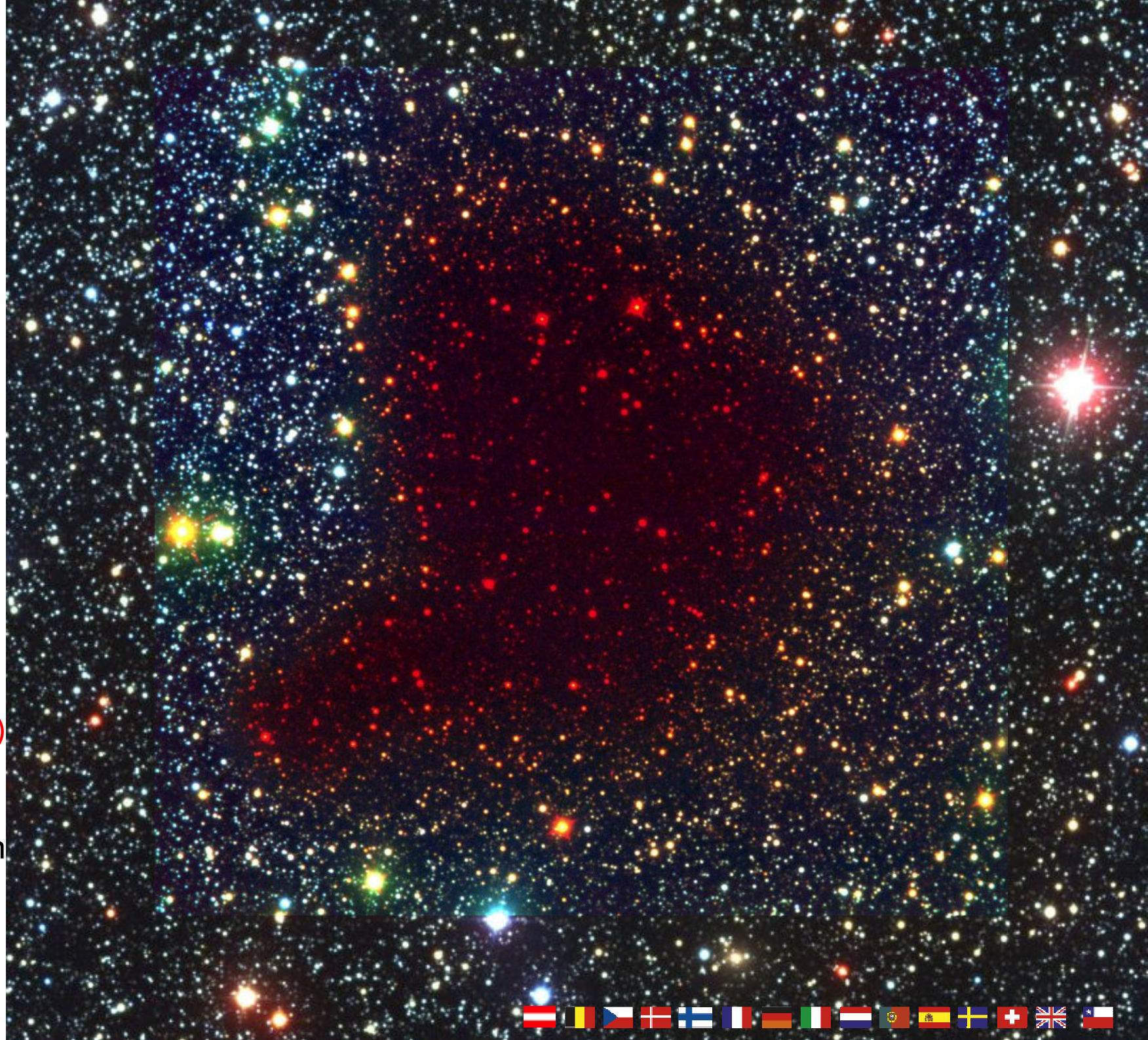

Big Bang
Distant universe
Distant galaxies
Nearby Galaxies
Milky Way
Stars
Solar System
Earth

Infrared:
peek through the dust



Blue +
Green +
INFRAred

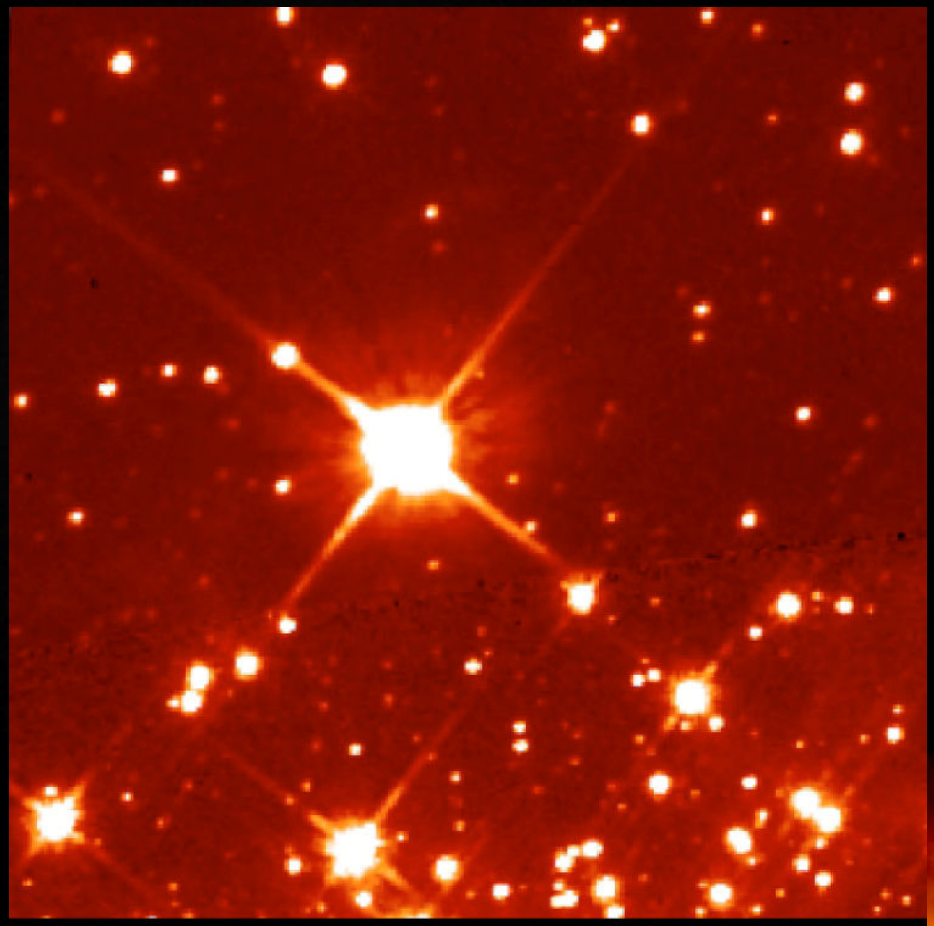
- Milky Way
- Stars (400Ly)
- Solar System
- Earth



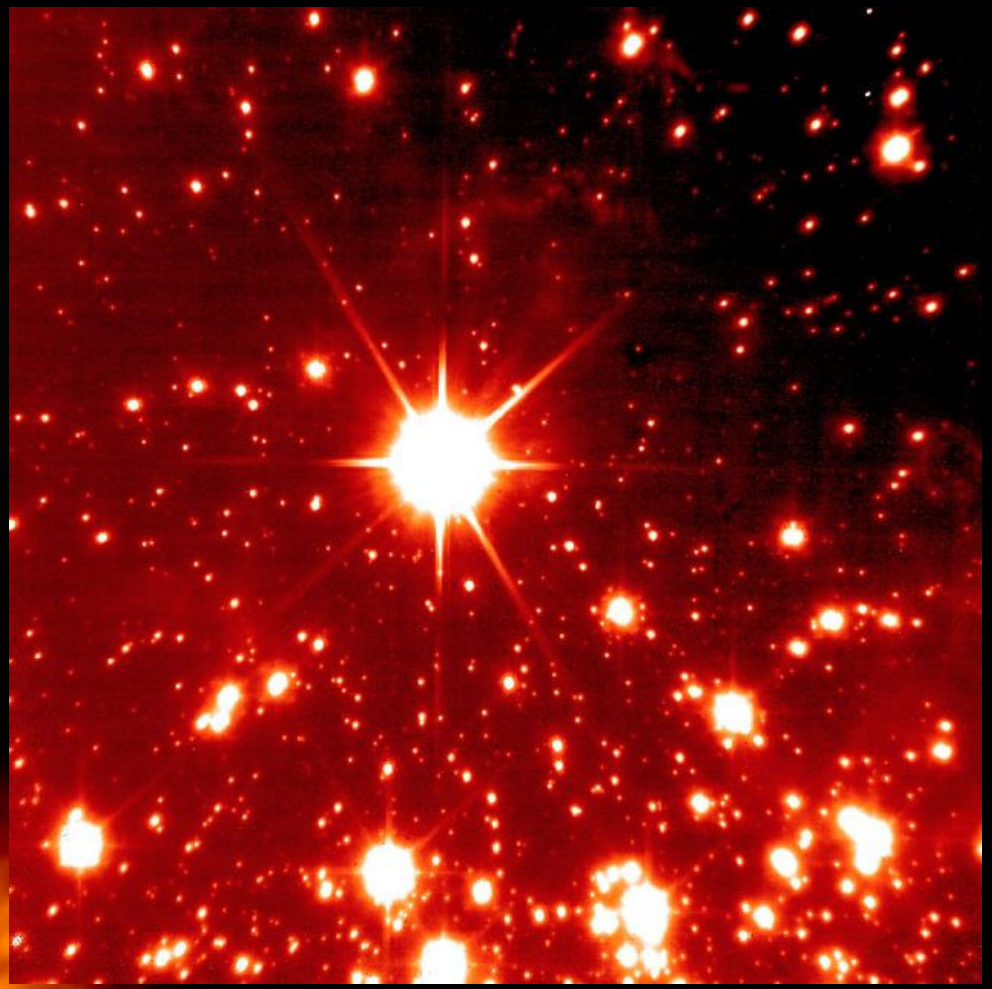

Adaptive Optics

Adaptive Optics

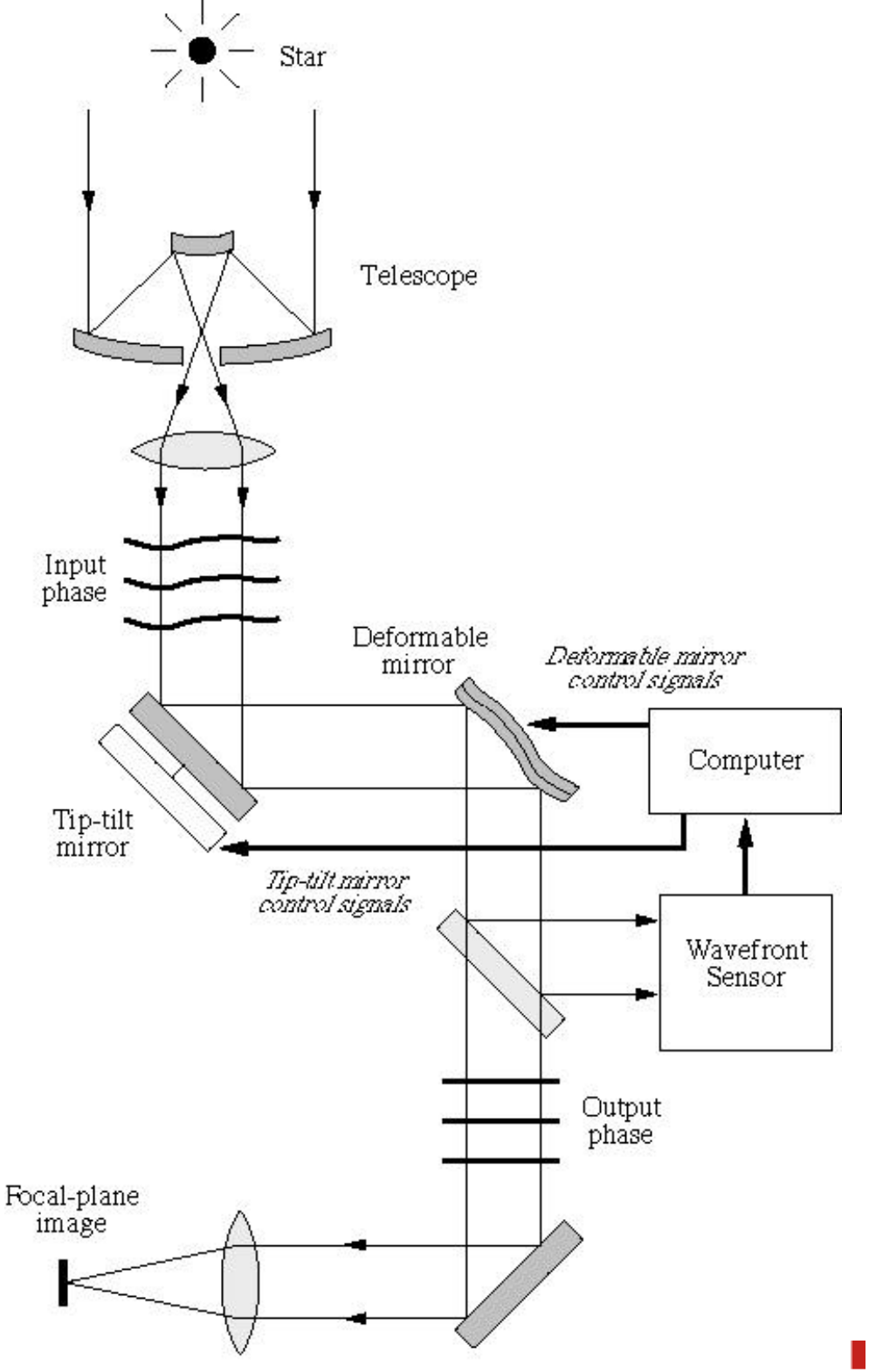
Beat the atmospheric turbullence



HST-WFPC2 (I-band)



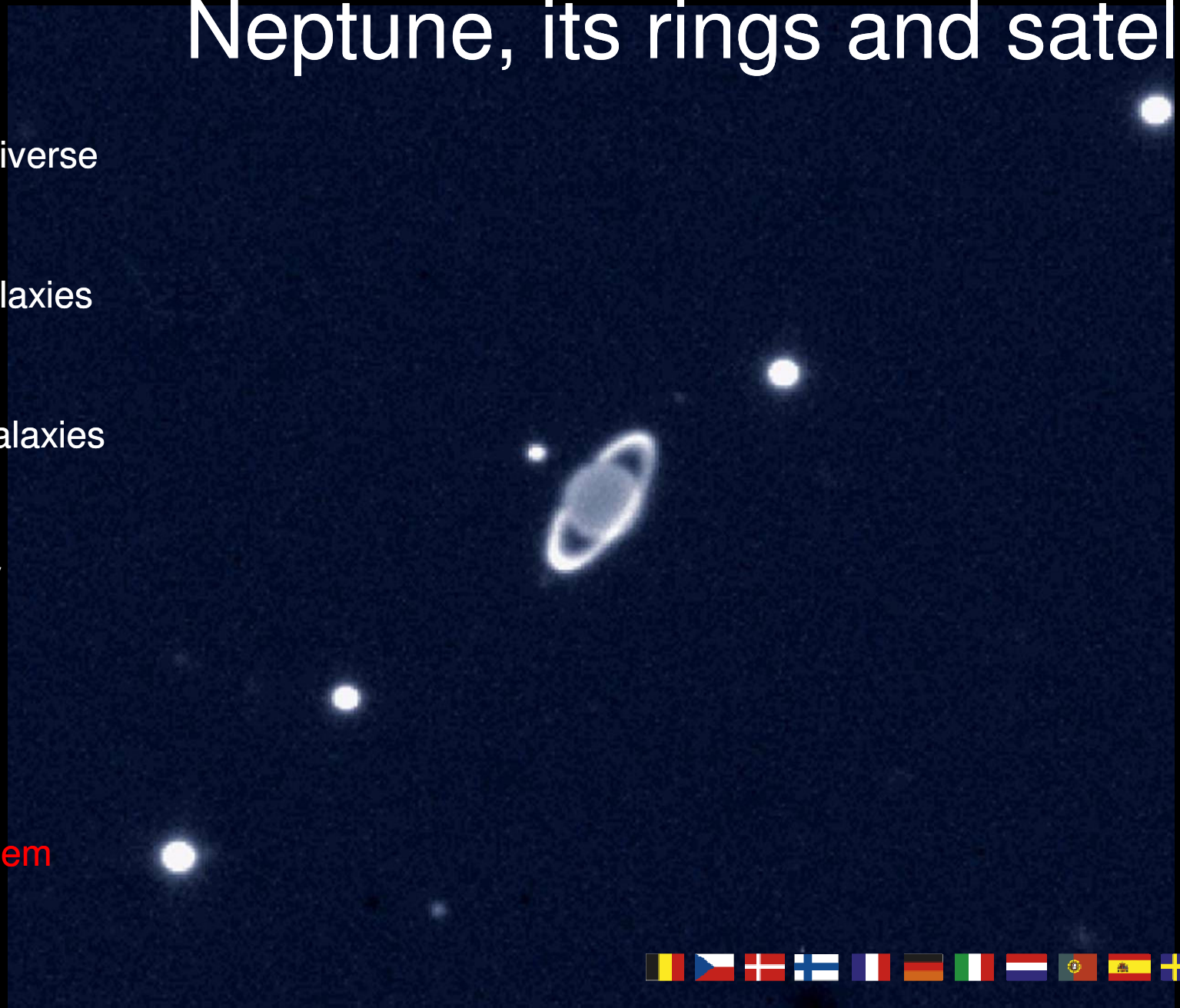
VLT


Star
Telescope
Input
phase
Deformable
mirror
Deformable mirror
control signals
Computer
Tip-tilt
mirror
Tip-tilt mirror
control signals
Wavefront
Sensor
Output
phase
Focal-plane
image

- video

Adaptive Optics: Neptune, its rings and satellites

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
-
- Solar System
-

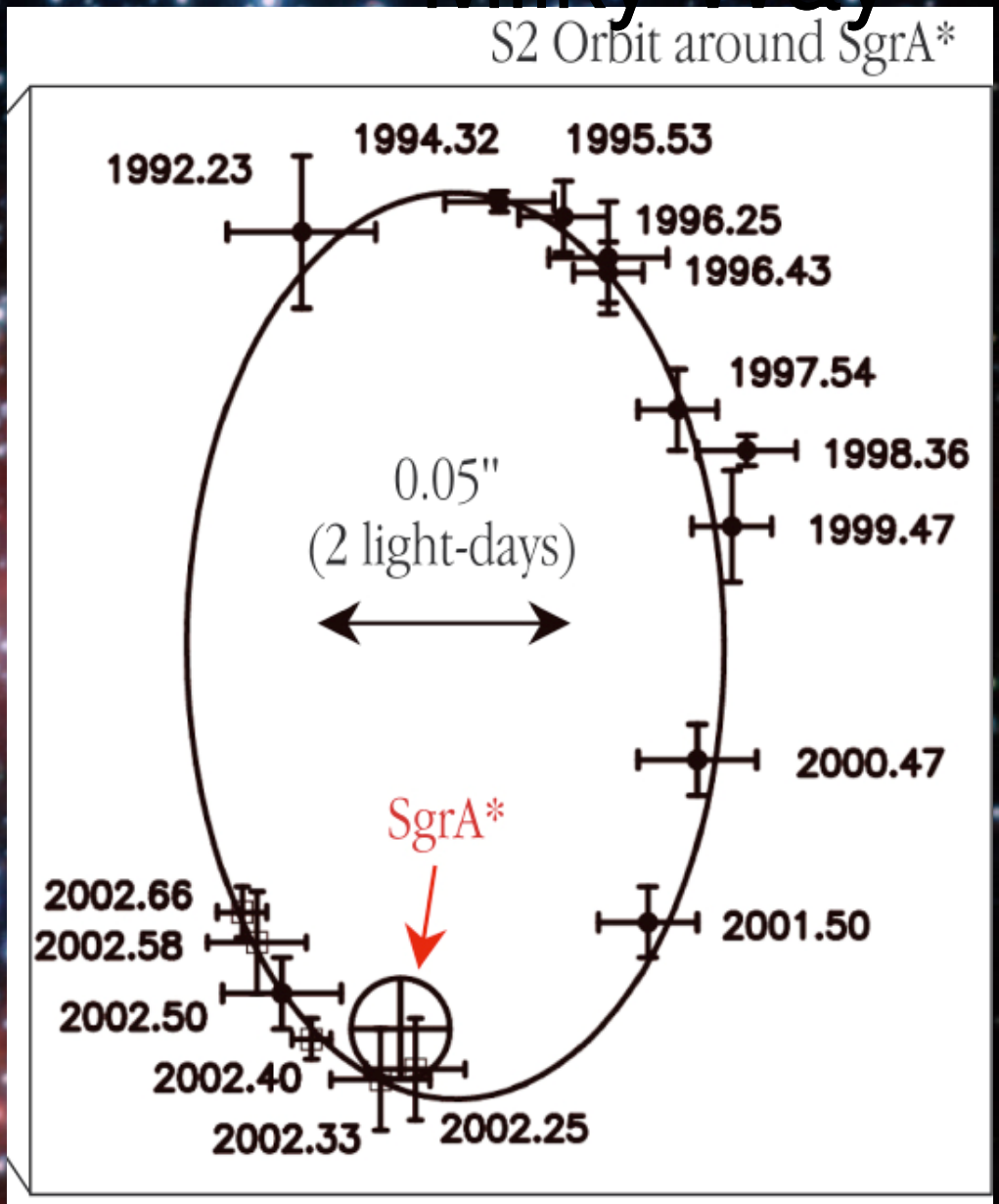


Adaptive Optics: the giant black hole at the centre of the Milky Way

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars
- Solar System

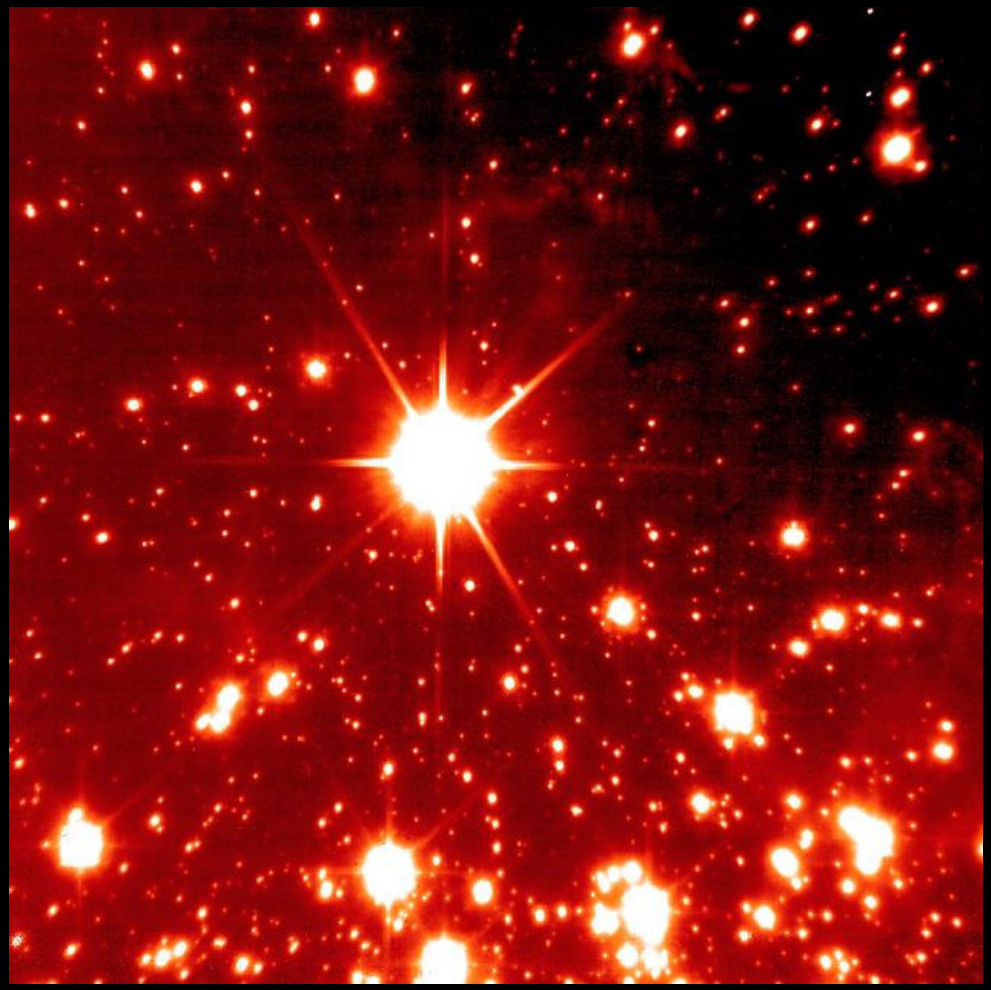
VIDEO

- Earth



Adaptive Optics: requires a reference star

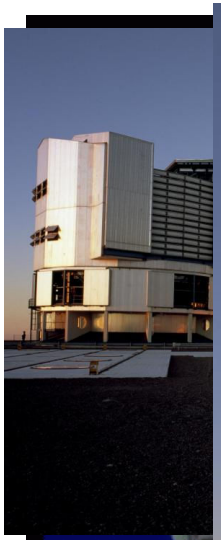
Only 10% of the sky is observable

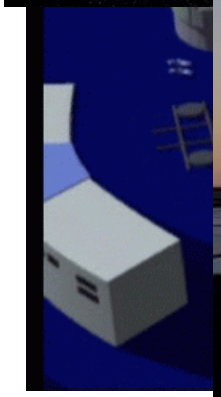


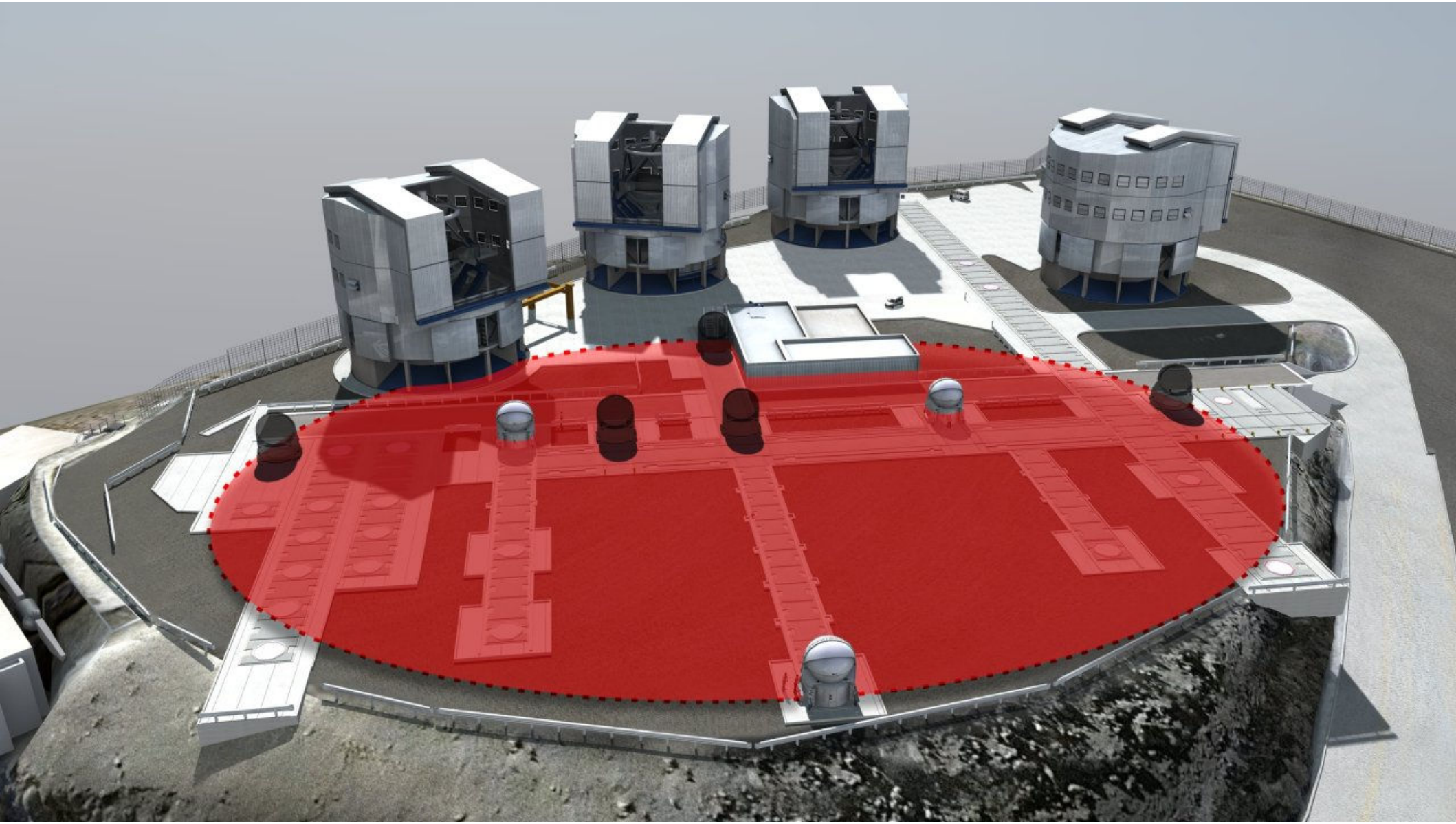
Étoile de référence artificielle:
Laser Guide Star


VLTI
Interferometry

VLTI:
Interferometric combination of the light from various telescopes

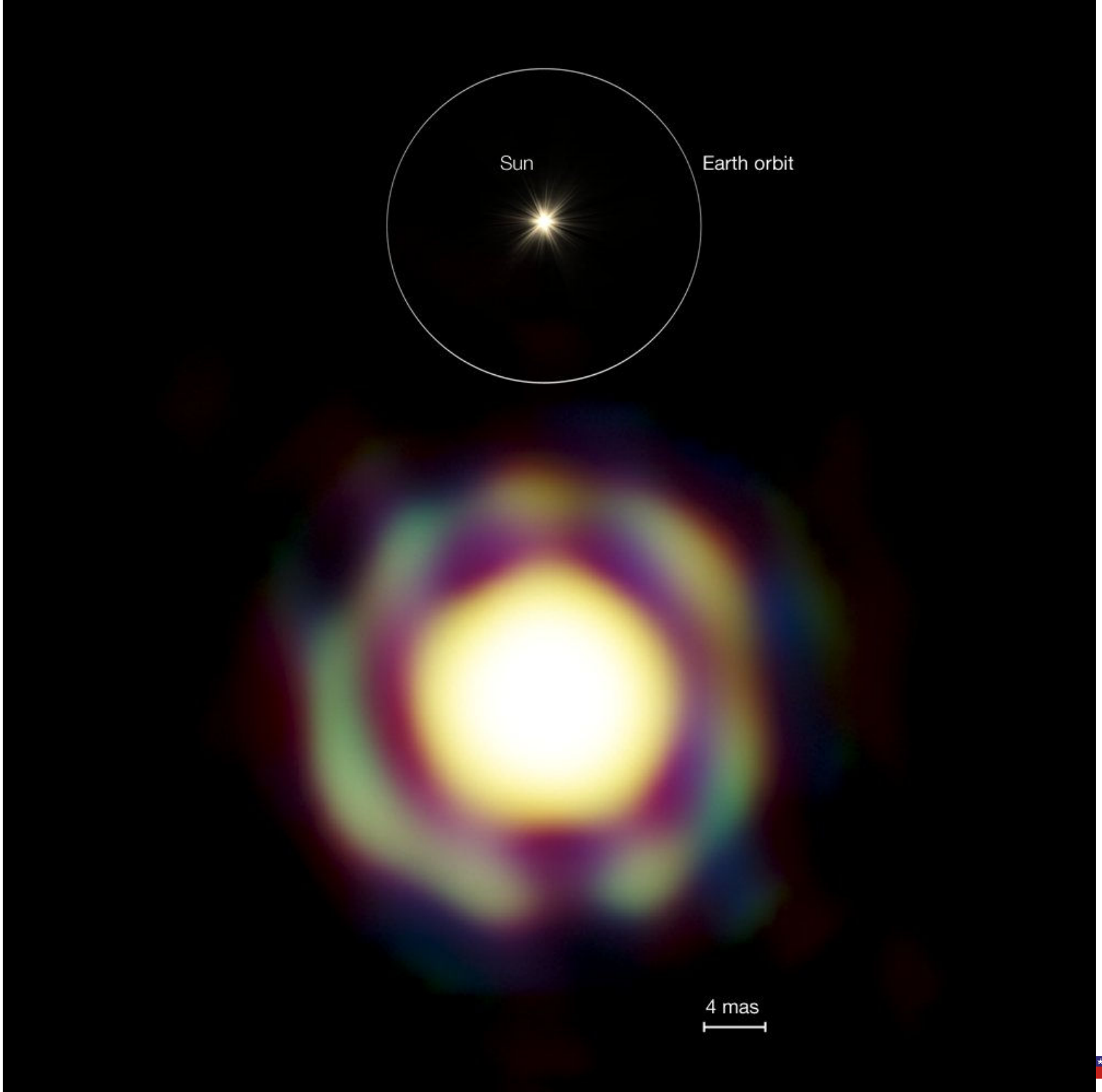




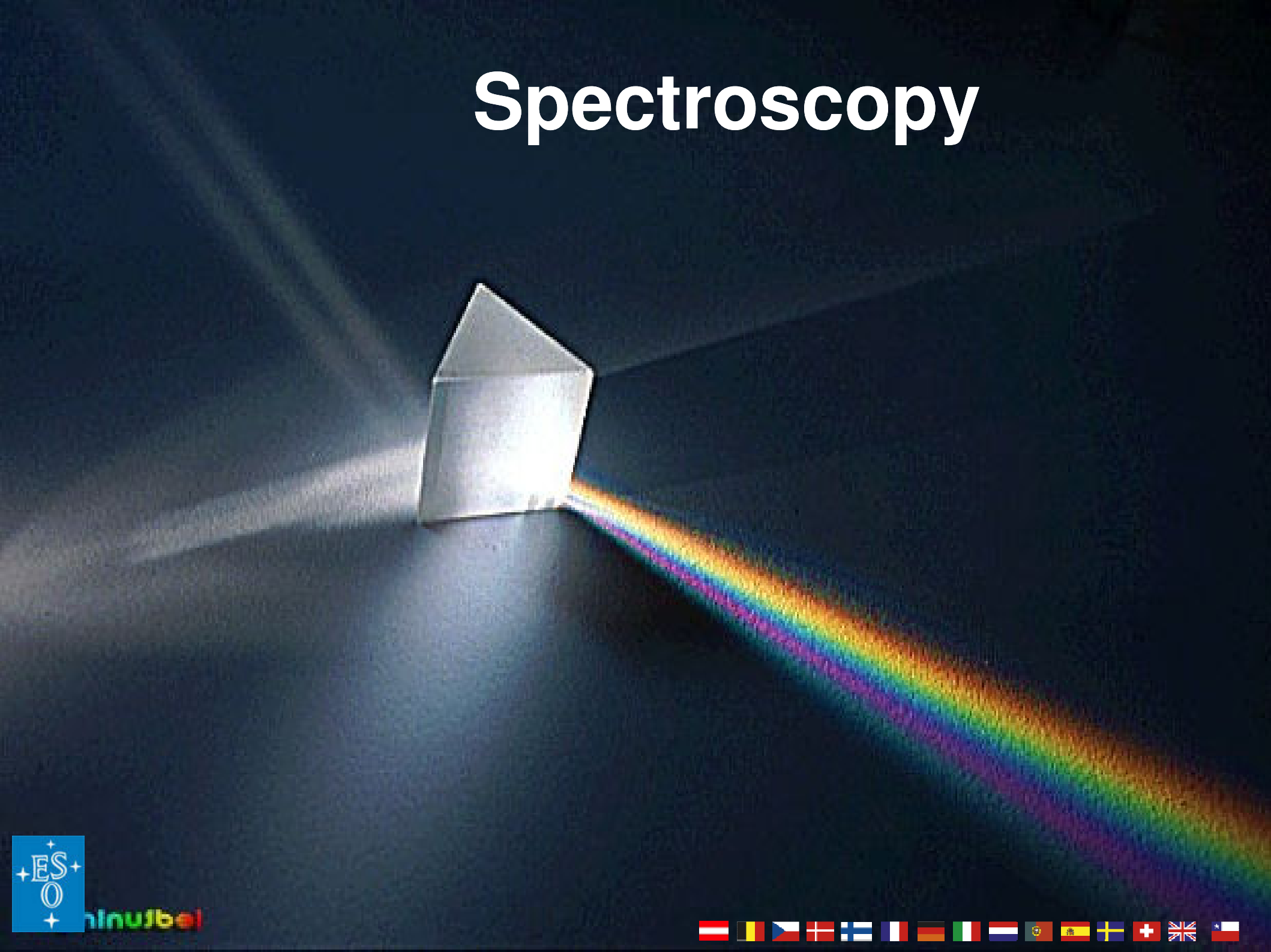


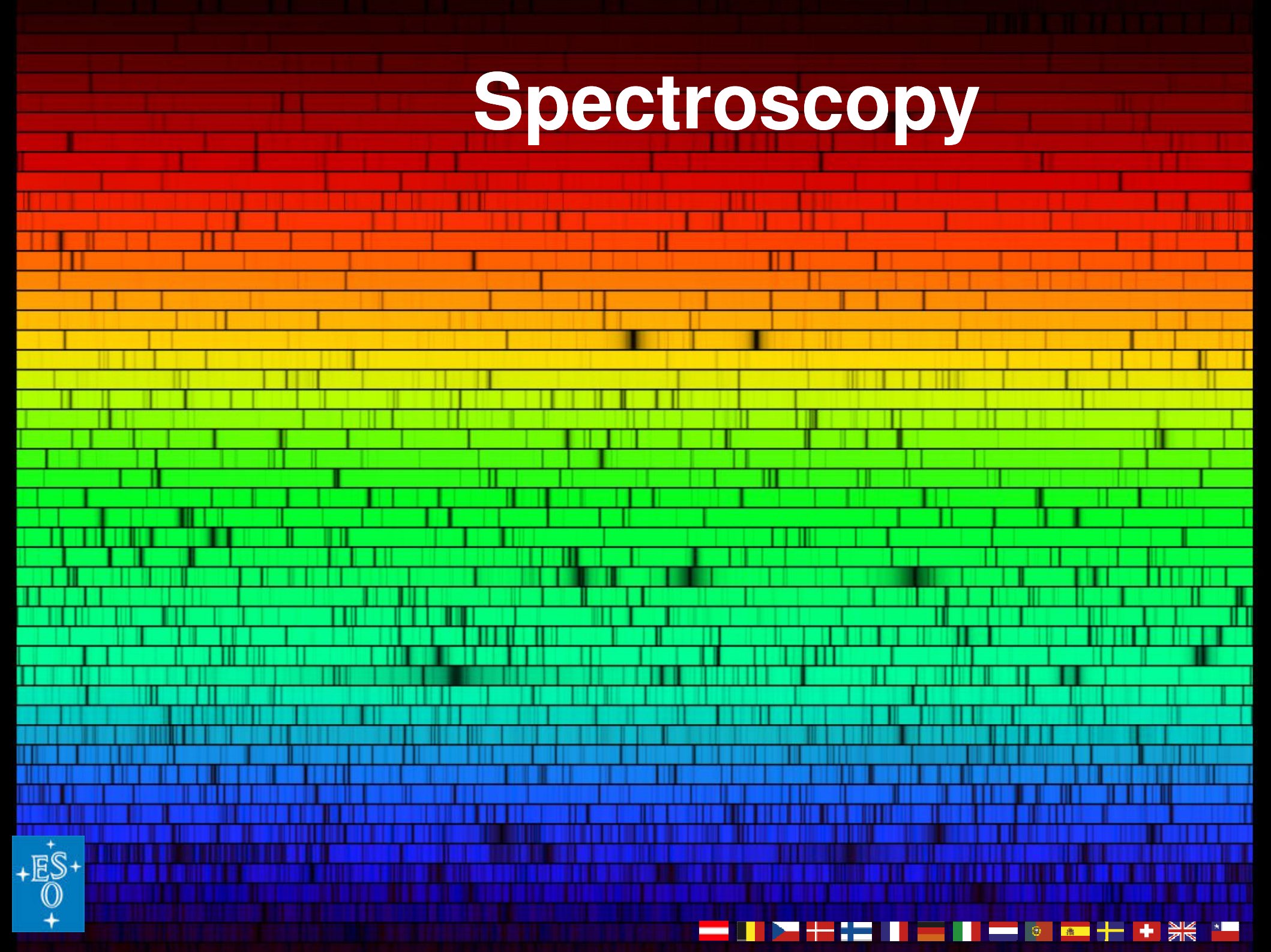
- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars
- Solar System
- Earth

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars (500Ly)
- Solar System
- Earth

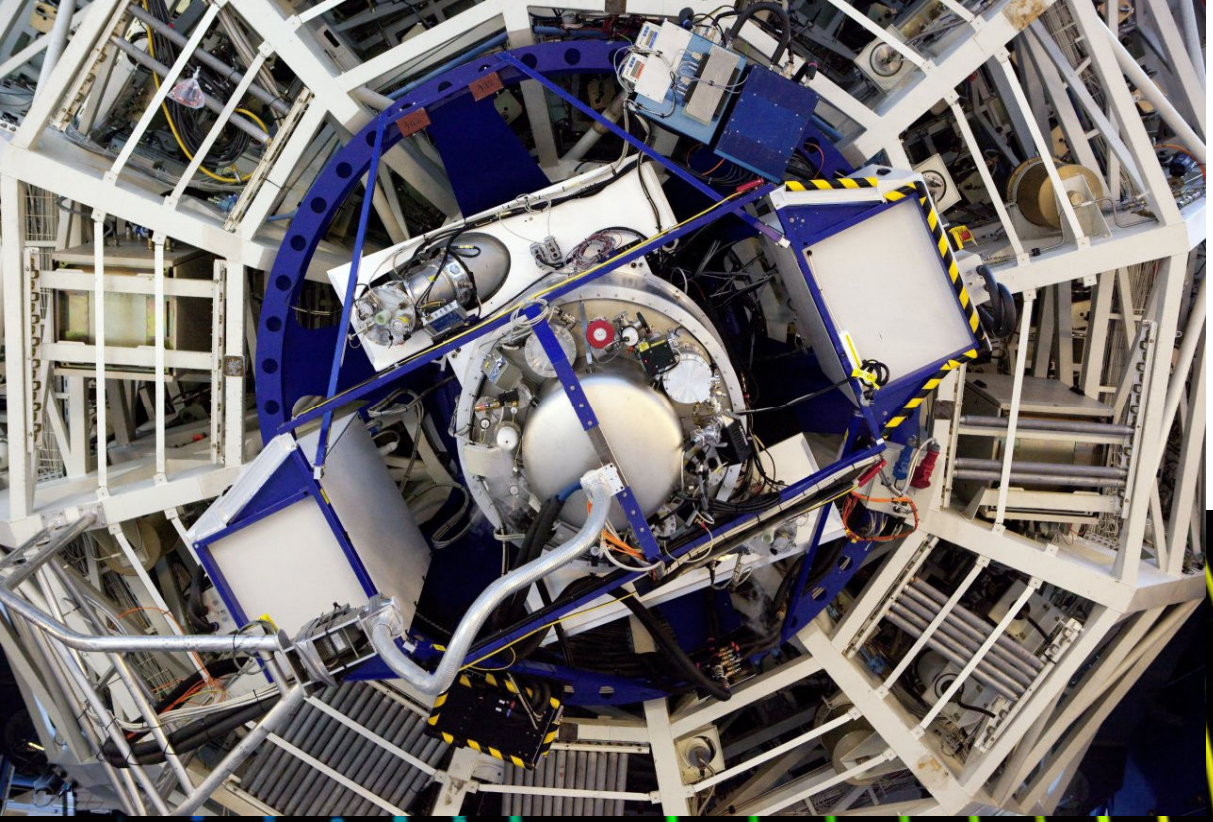


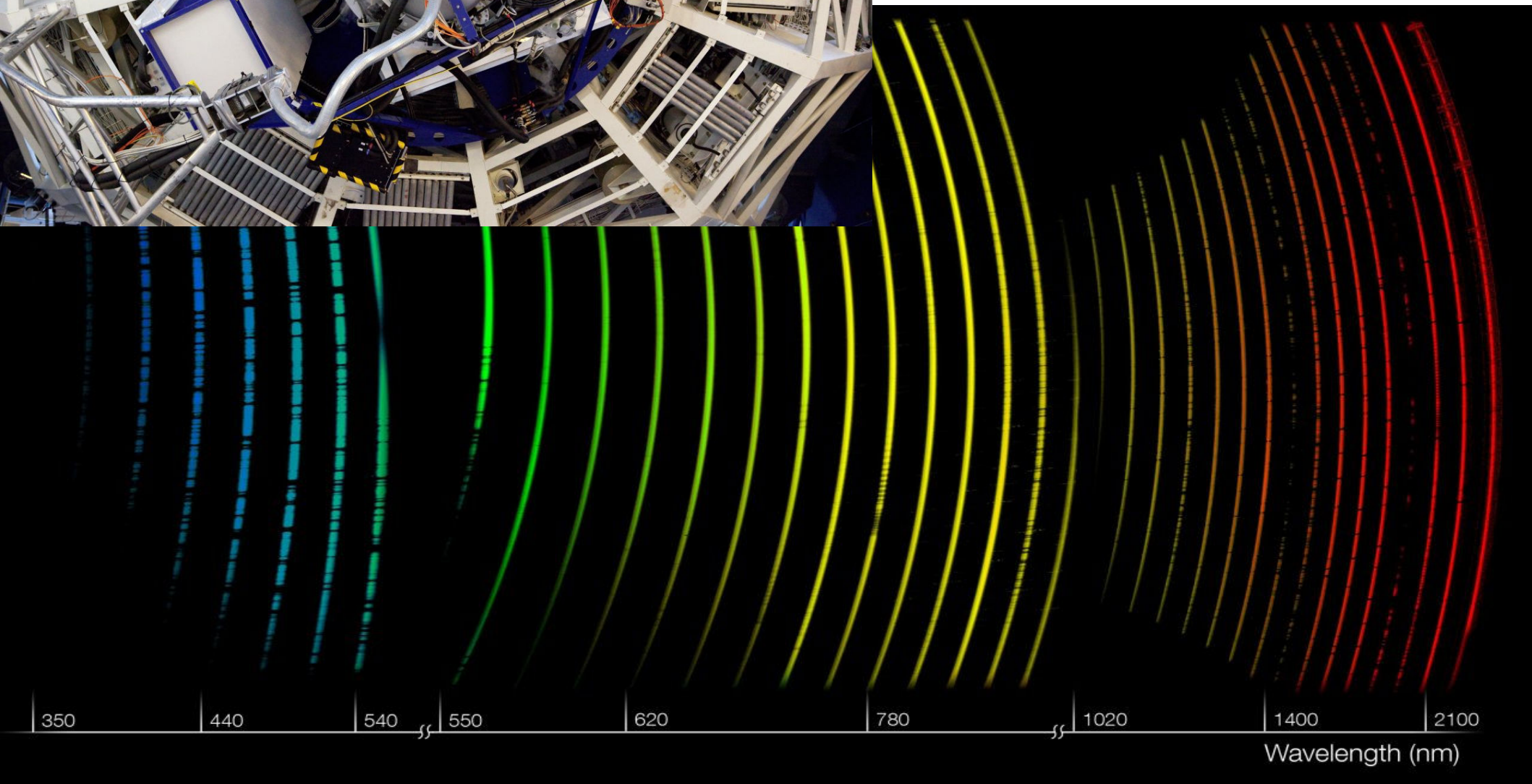
Spectroscopy



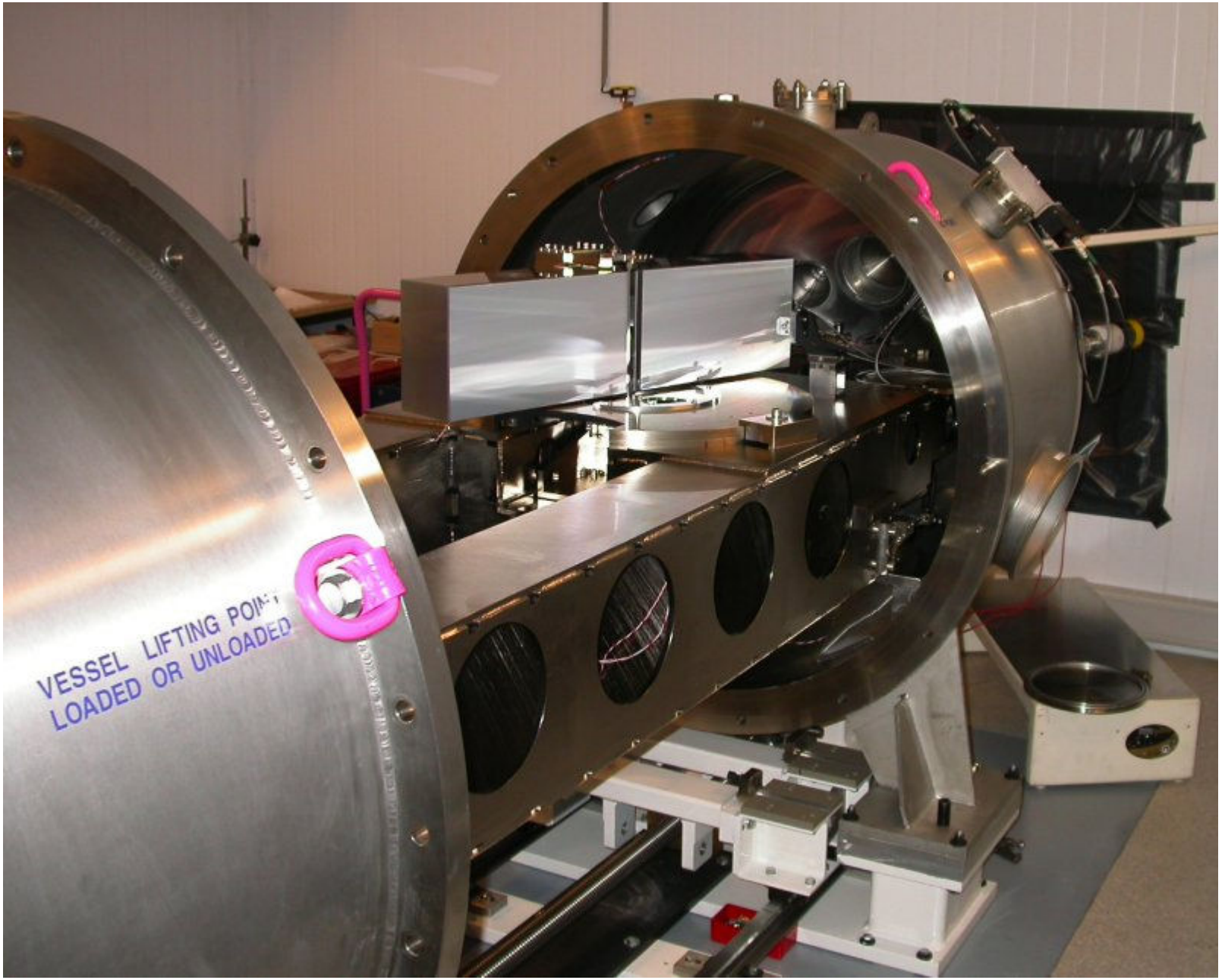

Spectroscopy

Spectrographers: X-Shooter, longest spectra





Spectrographer:
HARPS, the most stable



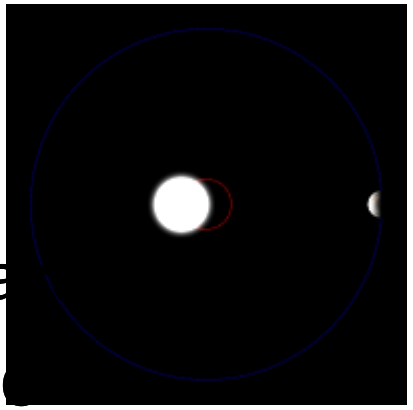
Spectrographer: HARPS
A star with 3 planets

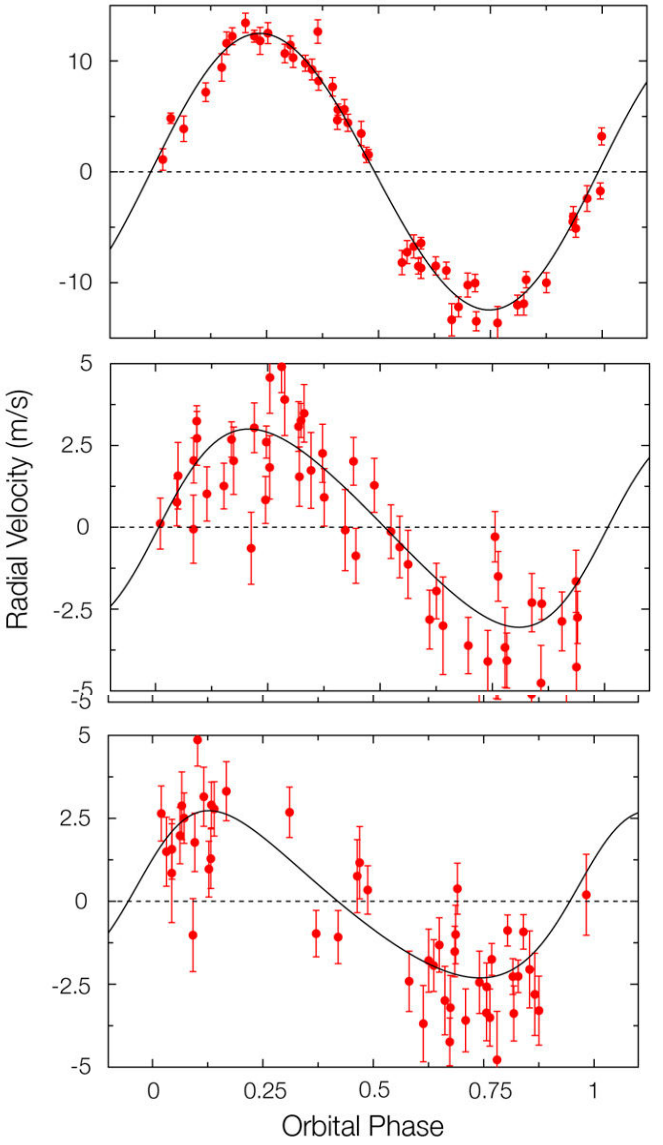
- Star Gliese 581

→**3 planets**:

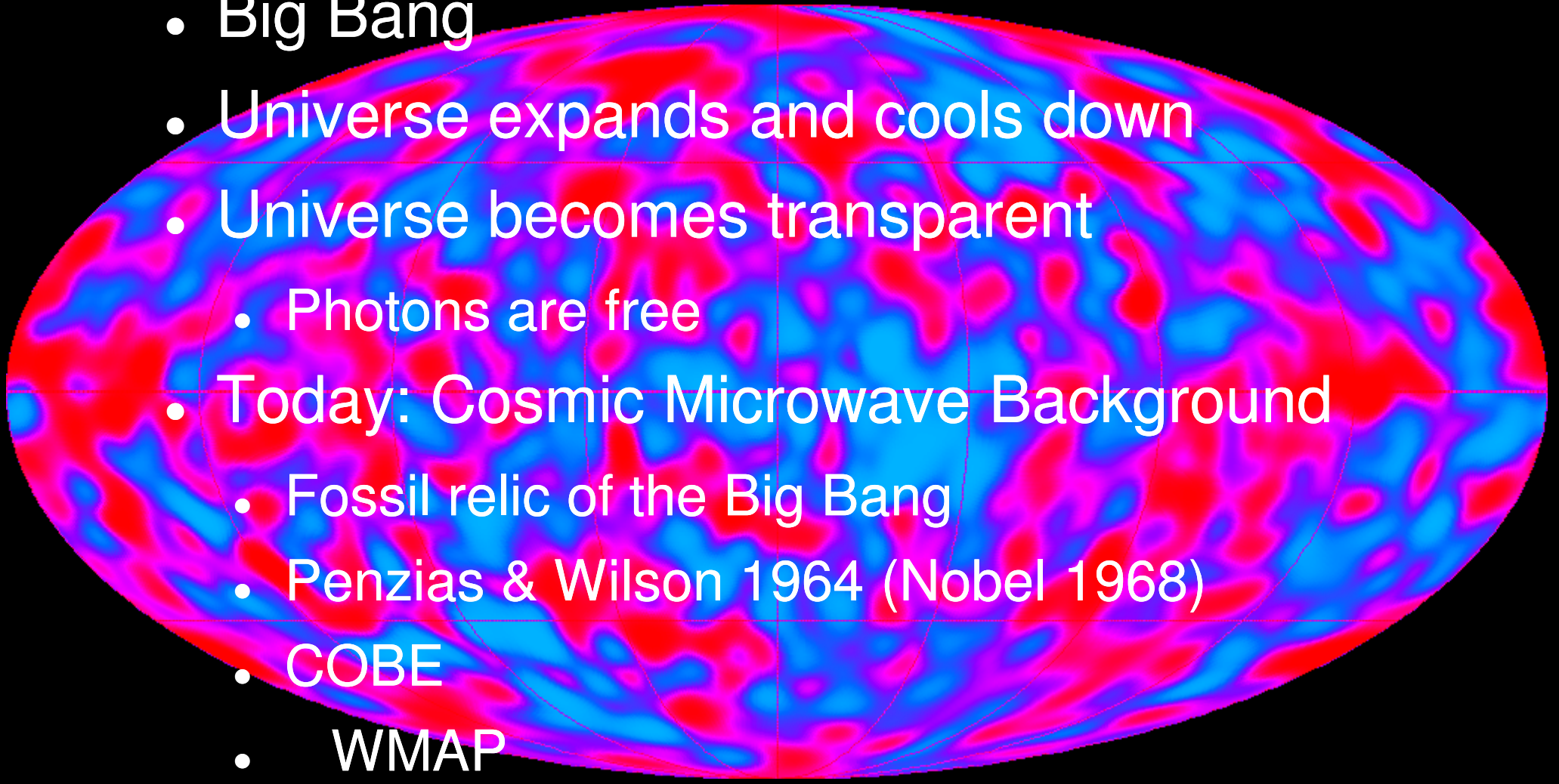
5x, 8x and 15x Earth's ma

- 5x in **Habitable Zon**





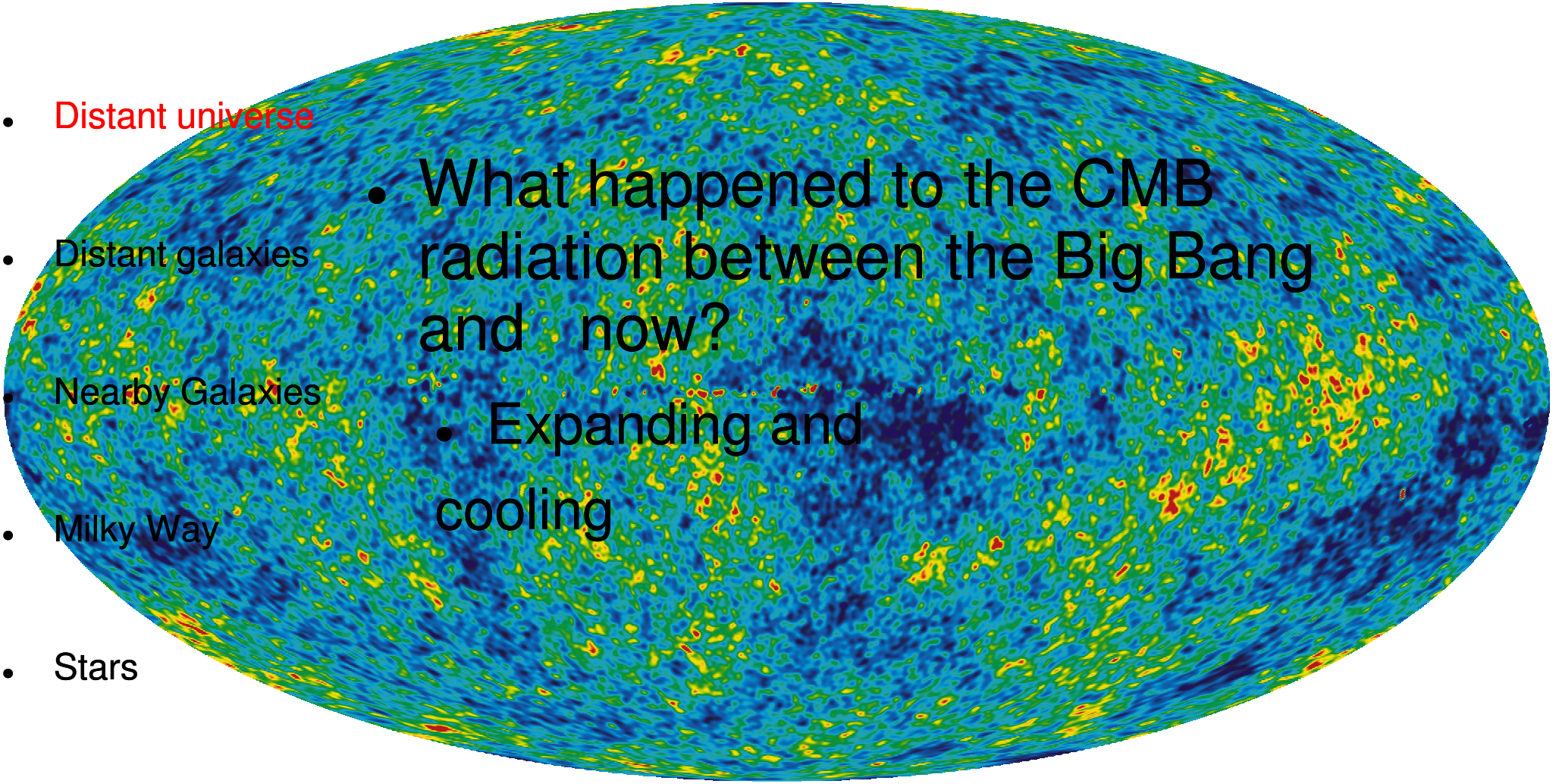
Cosmic Background



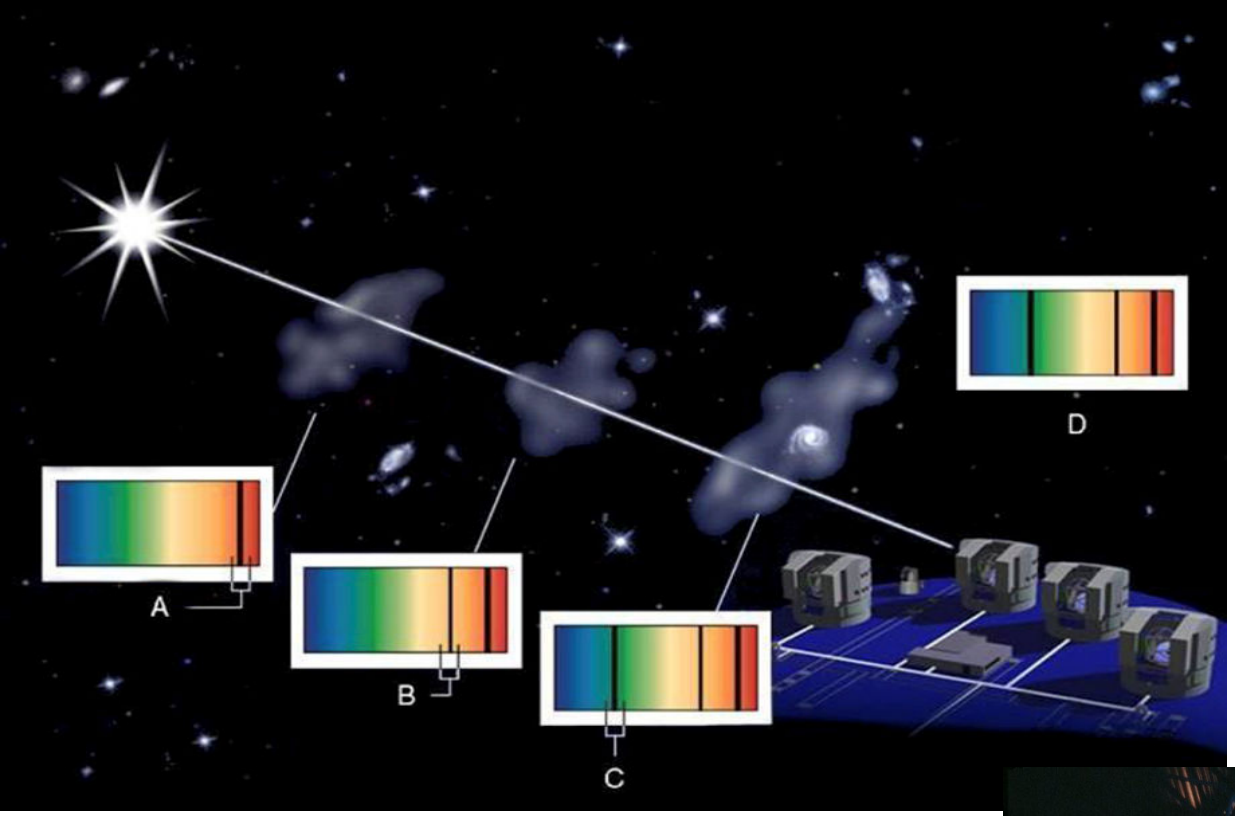
- Big Bang
- Universe expands and cools down
- Universe becomes transparent
  - Photons are free
- Today: Cosmic Microwave Background
  - Fossil relic of the Big Bang
  - Penzias & Wilson 1964 (Nobel 1968)
  - COBE
  - WMAP
  - Planck (launched May 2009)

Cosmic Background

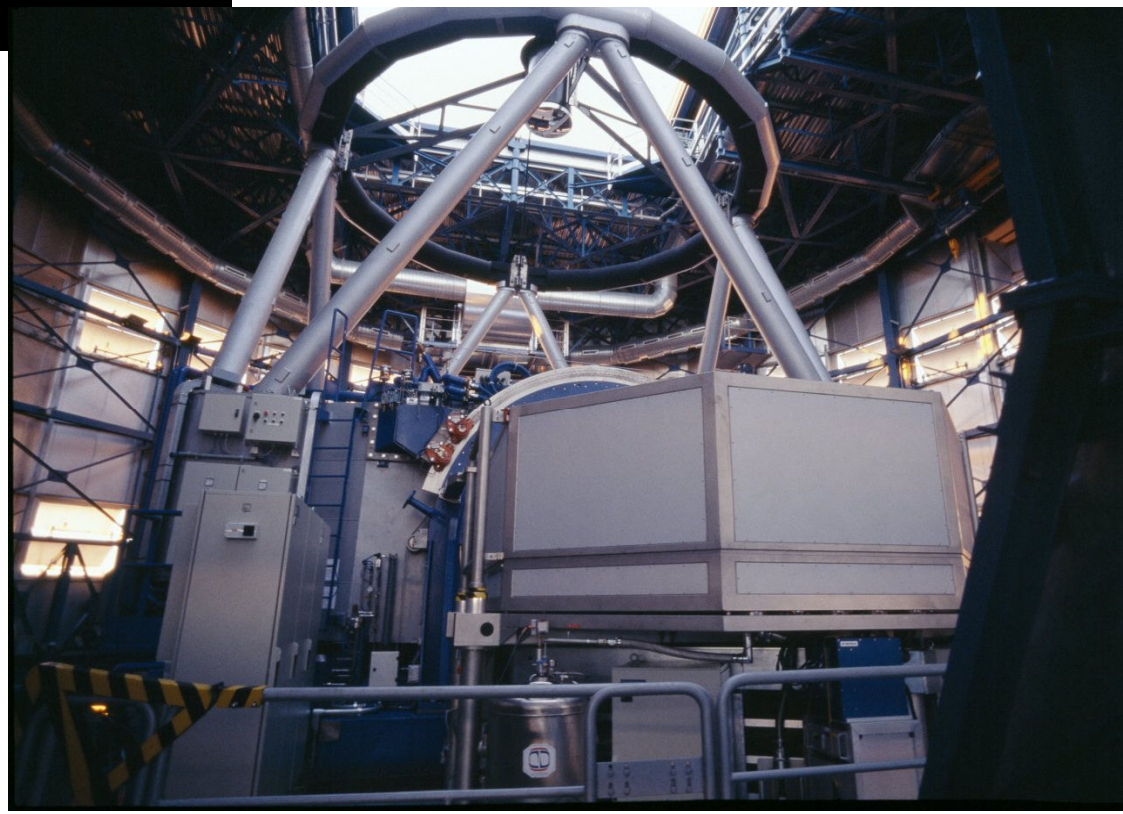
- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars
- Solar System
- Earth



- What happened to the CMB radiation between the Big Bang and now?
  - Expanding and cooling

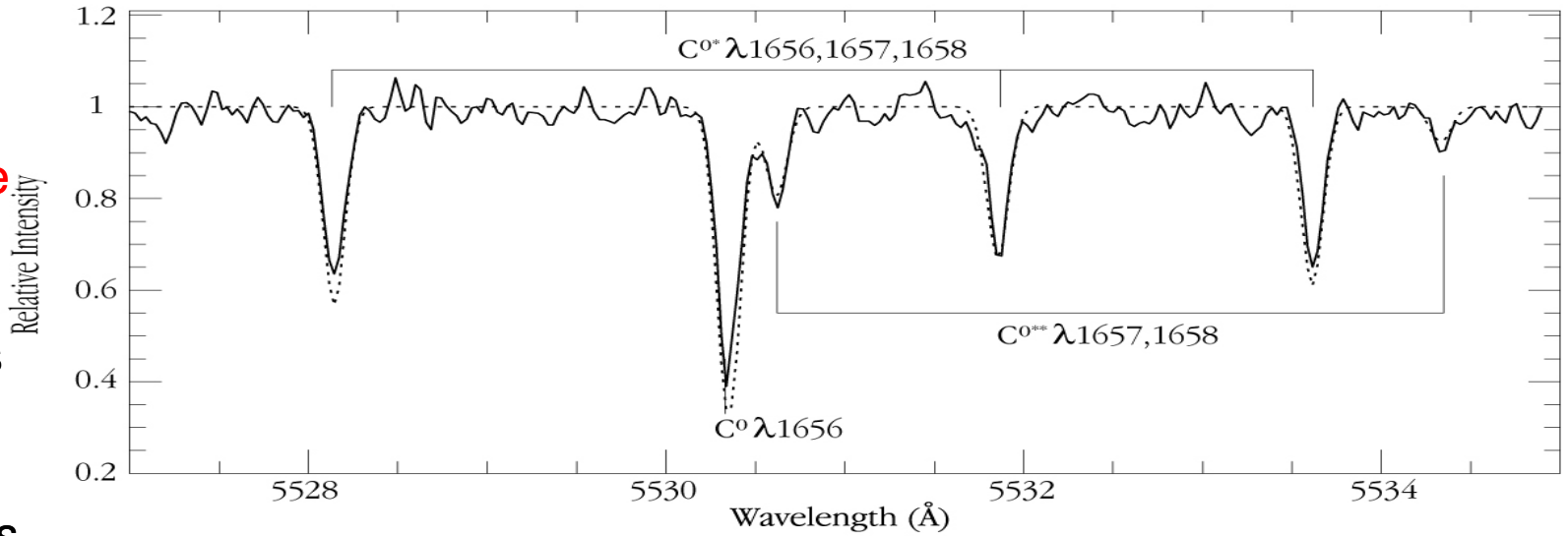


Quasar
PKS1232+0815
(z=2.57)
+ cloud at z=2.34



Cosmic Background

- Big Bang
- Distant universe
- Distant galaxies
- Nearby Galaxies
- Milky Way
- Stars
- Solar System
- Earth



- Quasar PKS1232+0815 (z=2.57)
  + cloud at z=2.34

Temperature:

Measured = 10 +/- 4 K

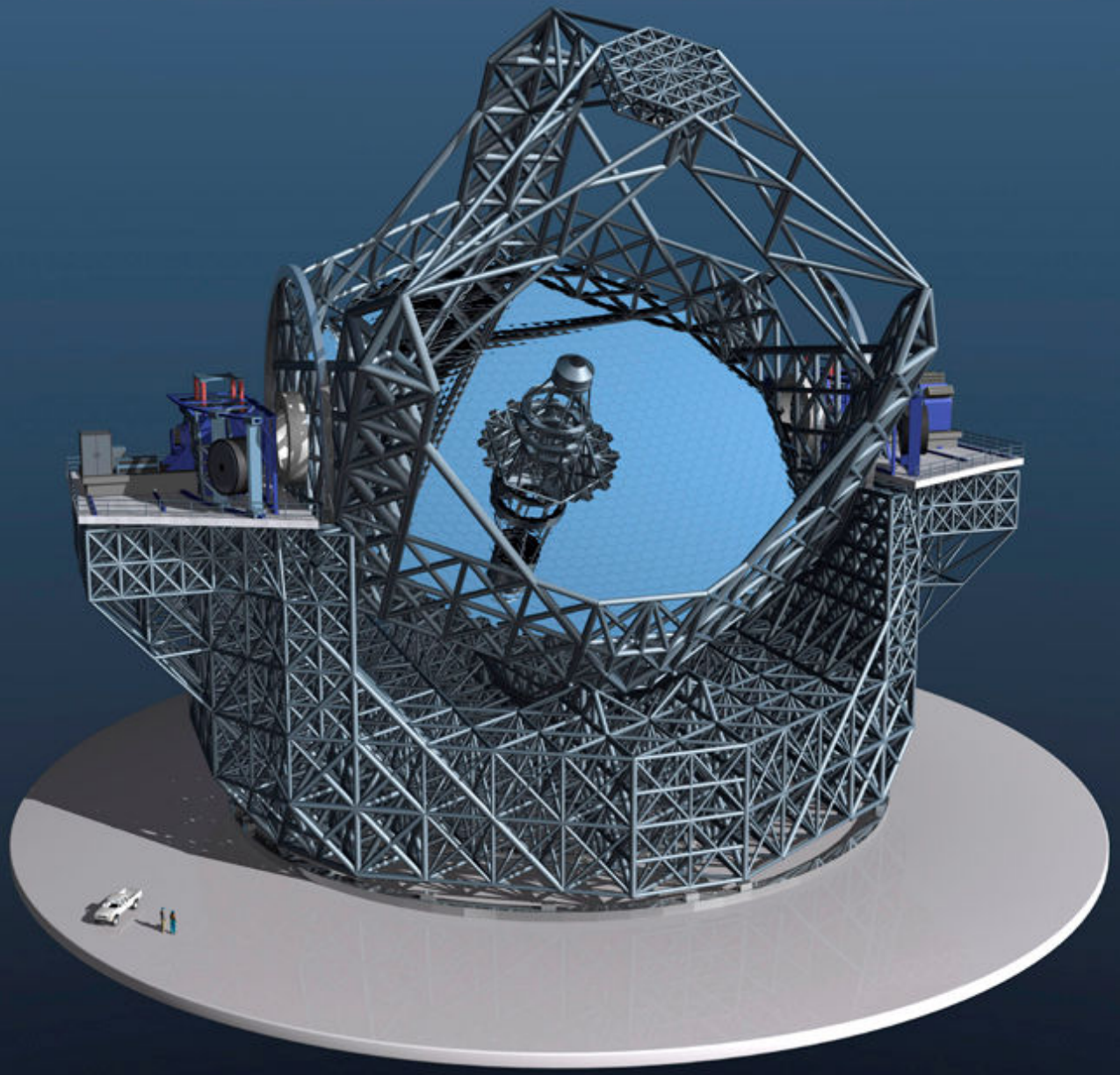
Theory : 9 K **OK**

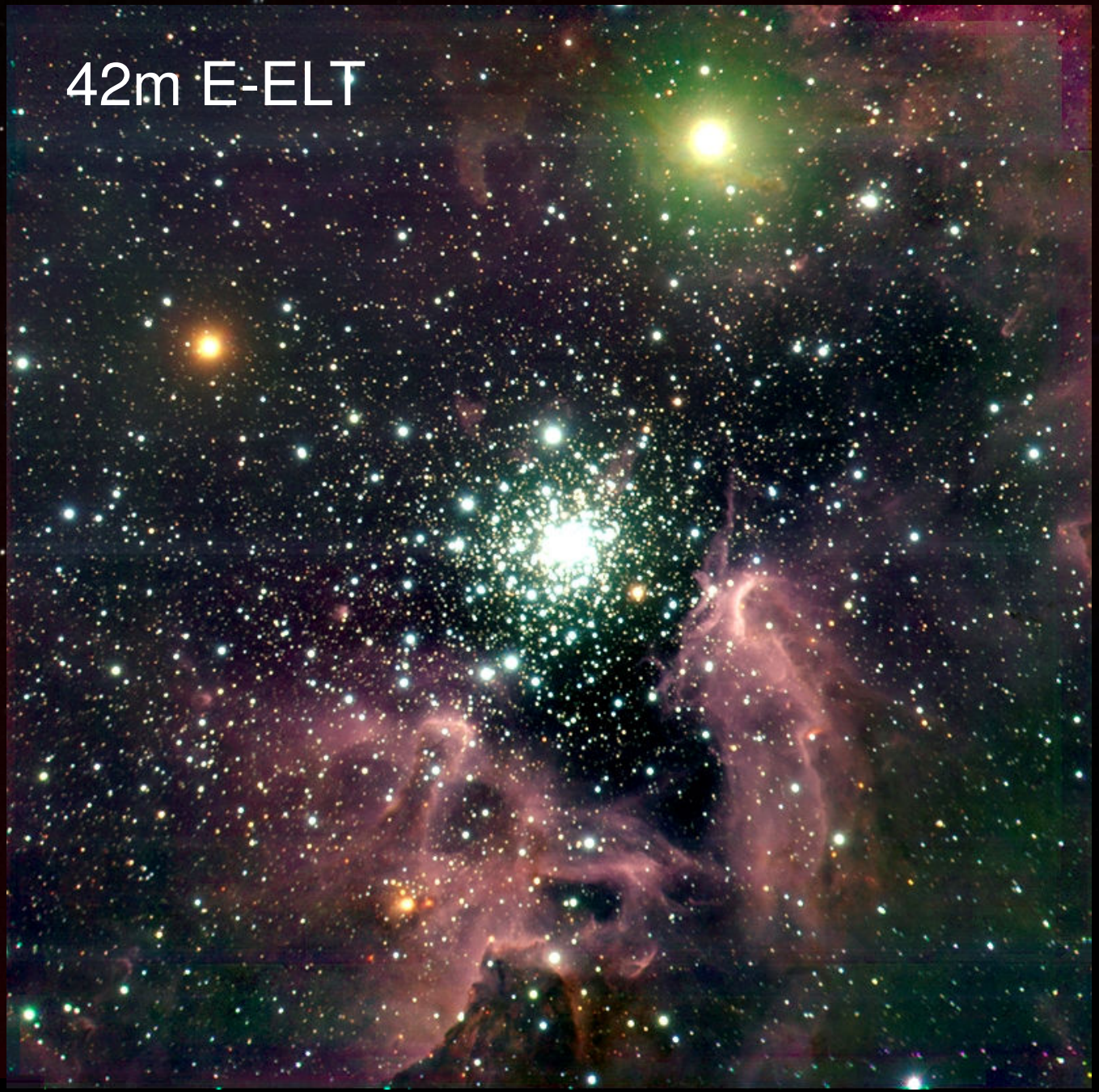
Future: tomorrow's telescopes

E-ELT

European Extremely Large Telescope

European Extremely Large Telescope
E-ELT





Ground Based traditional image

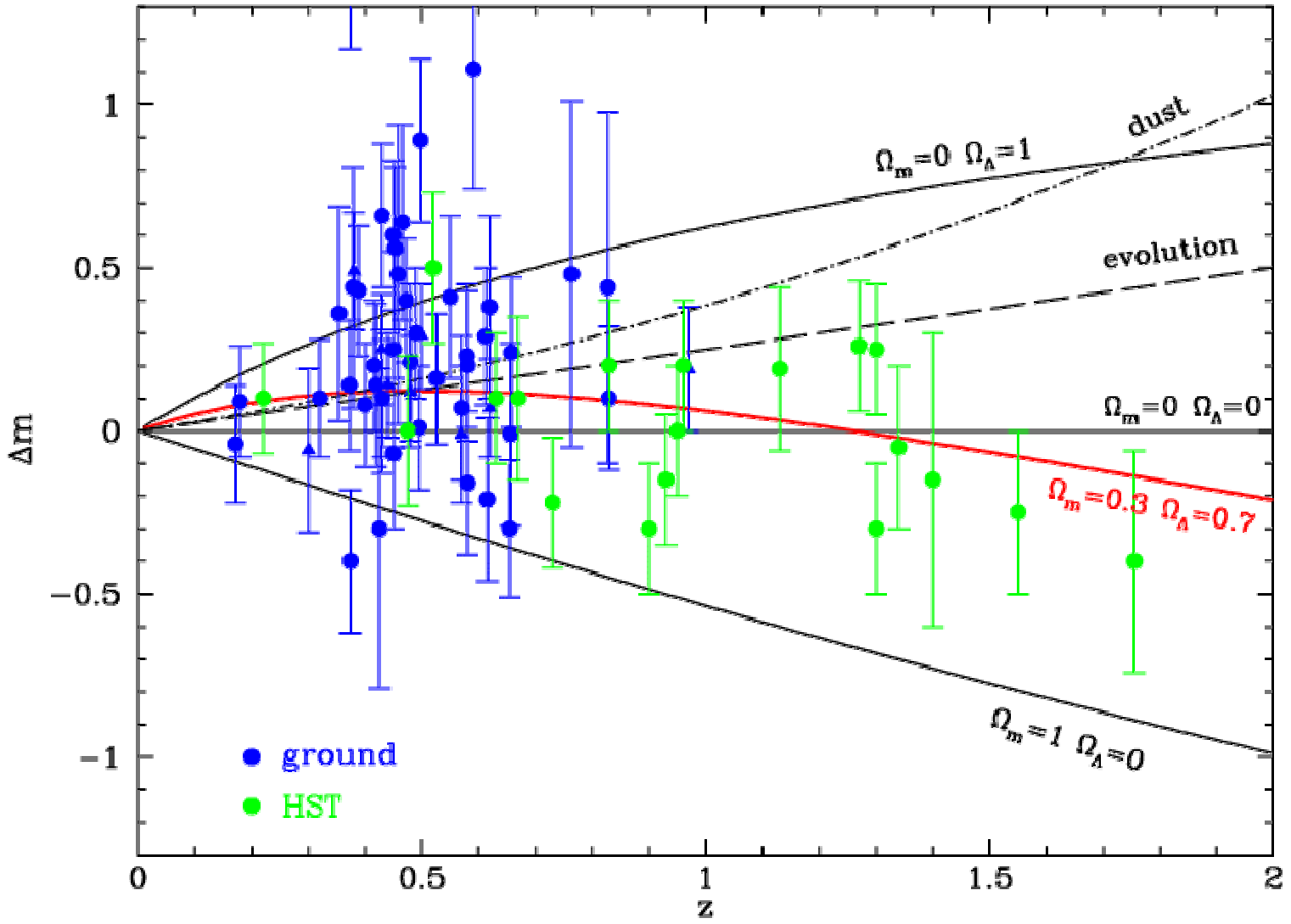
A sample science program

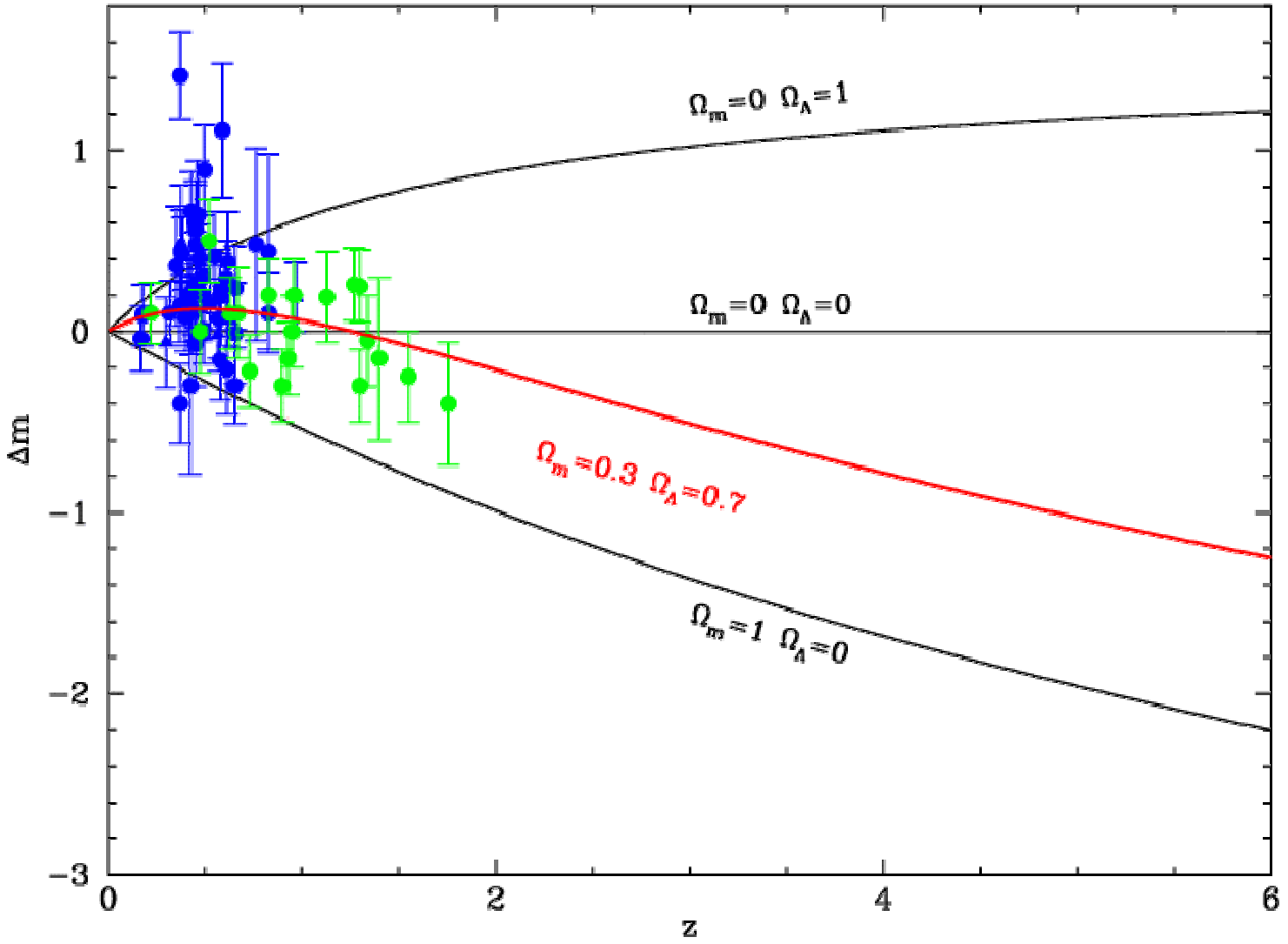
(Della Valle & Gilmozzi, 2007)

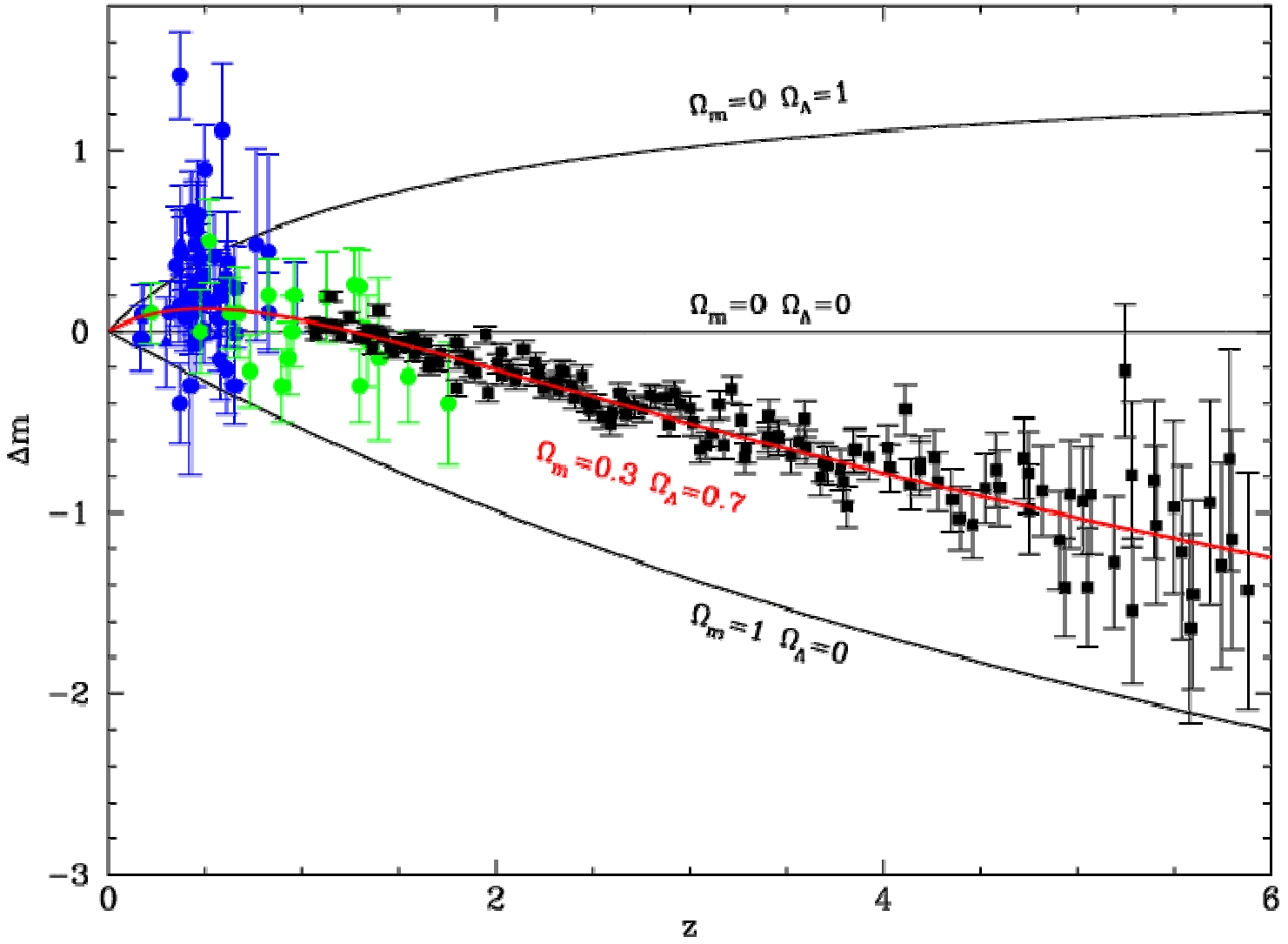
The cosmic star formation rate from SNe

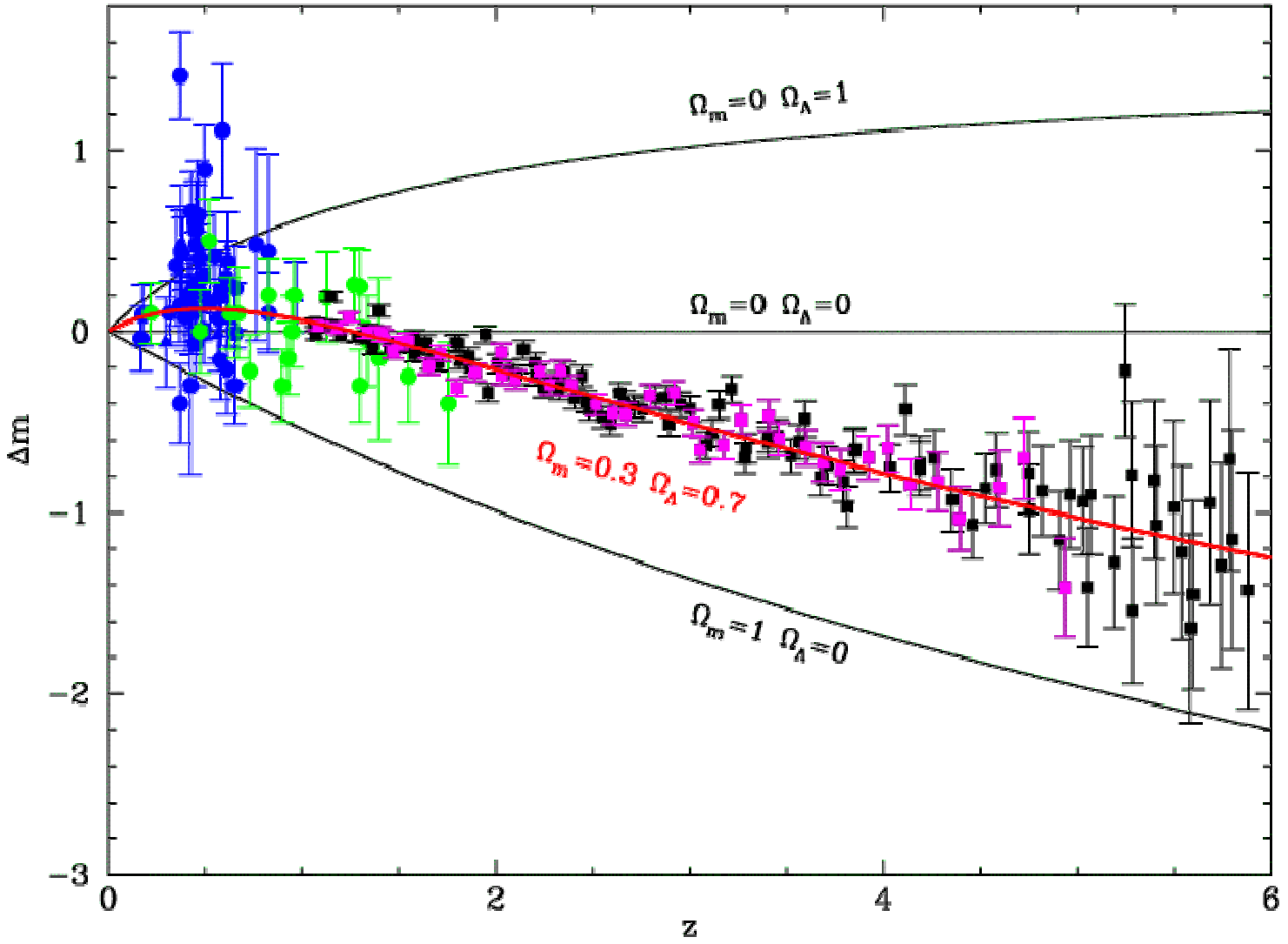
- Use supernovae (Ia ***and*** core-collapse) to determine the cosmic SFR up to z~6 as derived from stars with $3\ M_\odot < M < 40\ M_\odot$ This is much more accurate than using UV flux or Hα methods (which give information on stars with $M > 40\ M_\odot$)

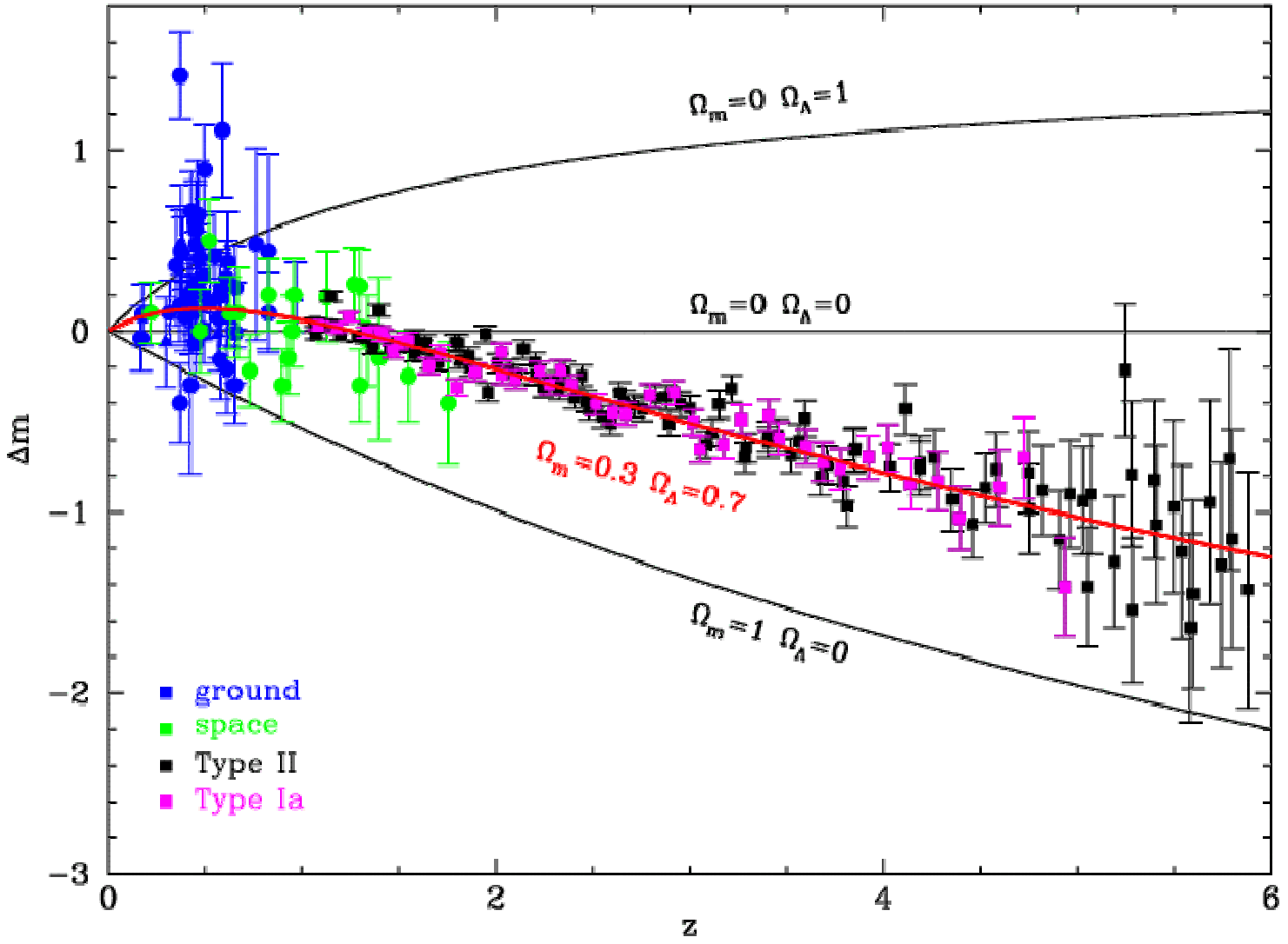
- As a "bonus" these observations will also allow to probe different cosmological models (e.g. alternatives to Λ)


Δm
z
1
0.5
0
−0.5
−1
0
0.5
1
1.5
2
dust
evolution
Ω_m=0 Ω_Λ=1
Ω_m=0 Ω_Λ=0
Ω_m=0.3 Ω_Λ=0.7
Ω_m=1 Ω_Λ=0
ground
HST


Ω_m=0 Ω_Λ=1
Ω_m=0 Ω_Λ=0
Ω_m=0.3 Ω_Λ=0.7
Ω_m=1 Ω_Λ=0
Δm
z
1
0
−1
−2
−3
0
2
4
6


Ω_m=0 Ω_Λ=1
Ω_m=0 Ω_Λ=0
Ω_m=0.3 Ω_Λ=0.7
Ω_m=1 Ω_Λ=0
Δm
z
1
0
−1
−2
−3
0
2
4
6


Ω_m=0 Ω_Λ=1
Ω_m=0 Ω_Λ=0
Ω_m=0.3 Ω_Λ=0.7
Ω_m=1 Ω_Λ=0
Δm
z
1
0
−1
−2
−3
0
2
4
6


Ω_m=0 Ω_Λ=1
Ω_m=0 Ω_Λ=0
Ω_m=0.3 Ω_Λ=0.7
Ω_m=1 Ω_Λ=0
ground
space
Type II
Type Ia
Δm
z
1
0
−1
−2
−3
0
2
4
6

video

First operation support astronomers recruited