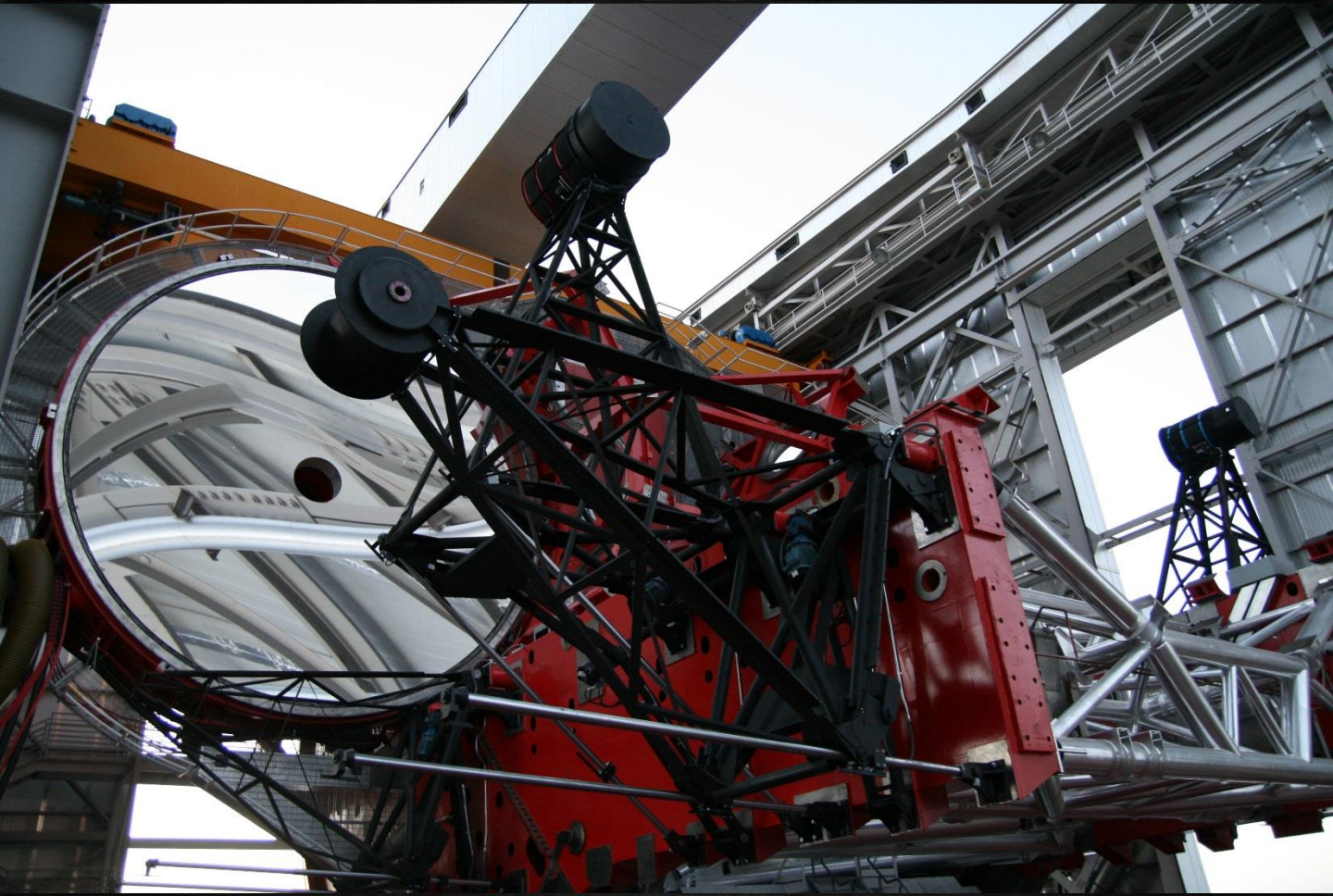
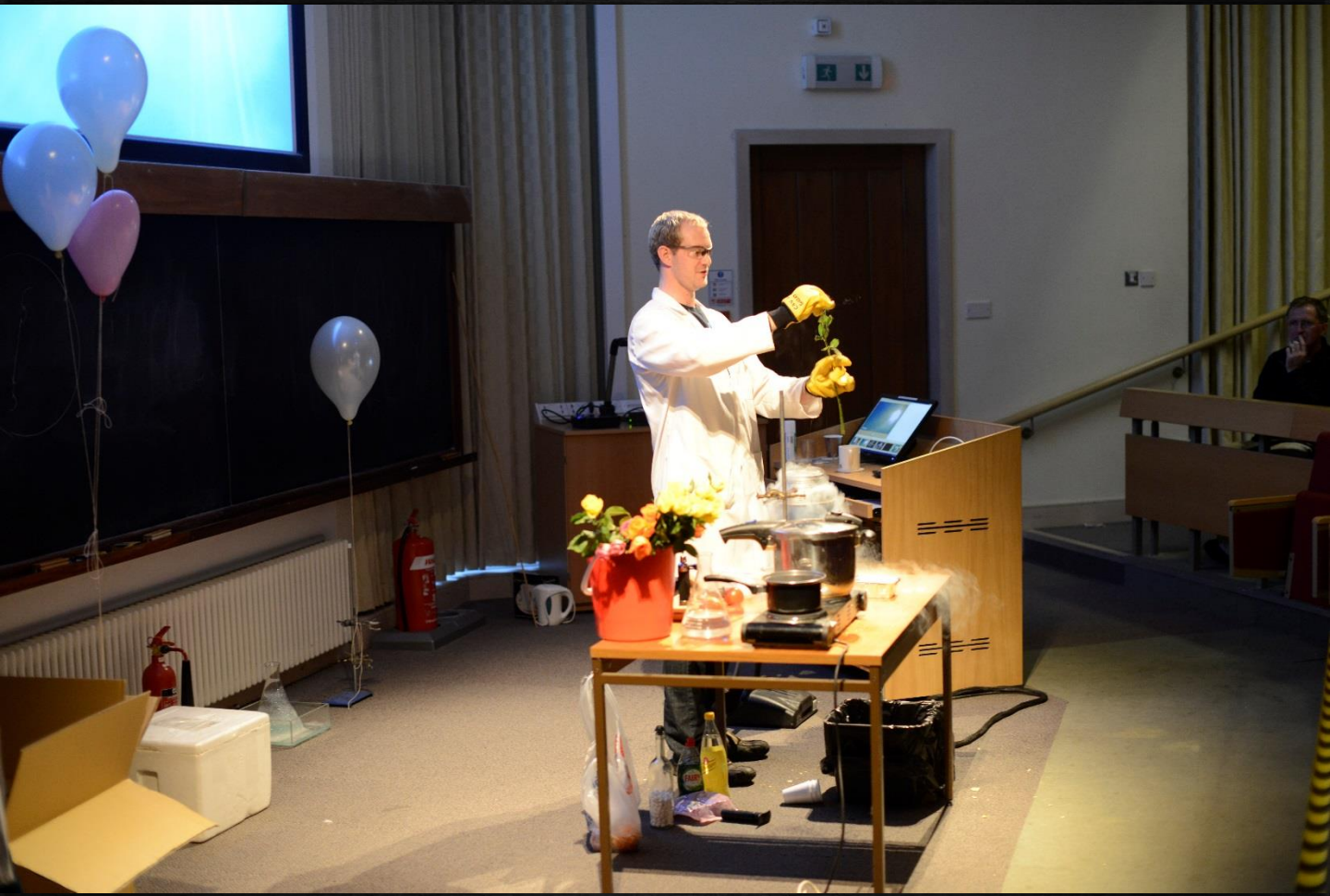
Our Place in the Universe

From Earth to the Stars

Jonathan Crass

UNIVERSITY OF NOTRE DAME





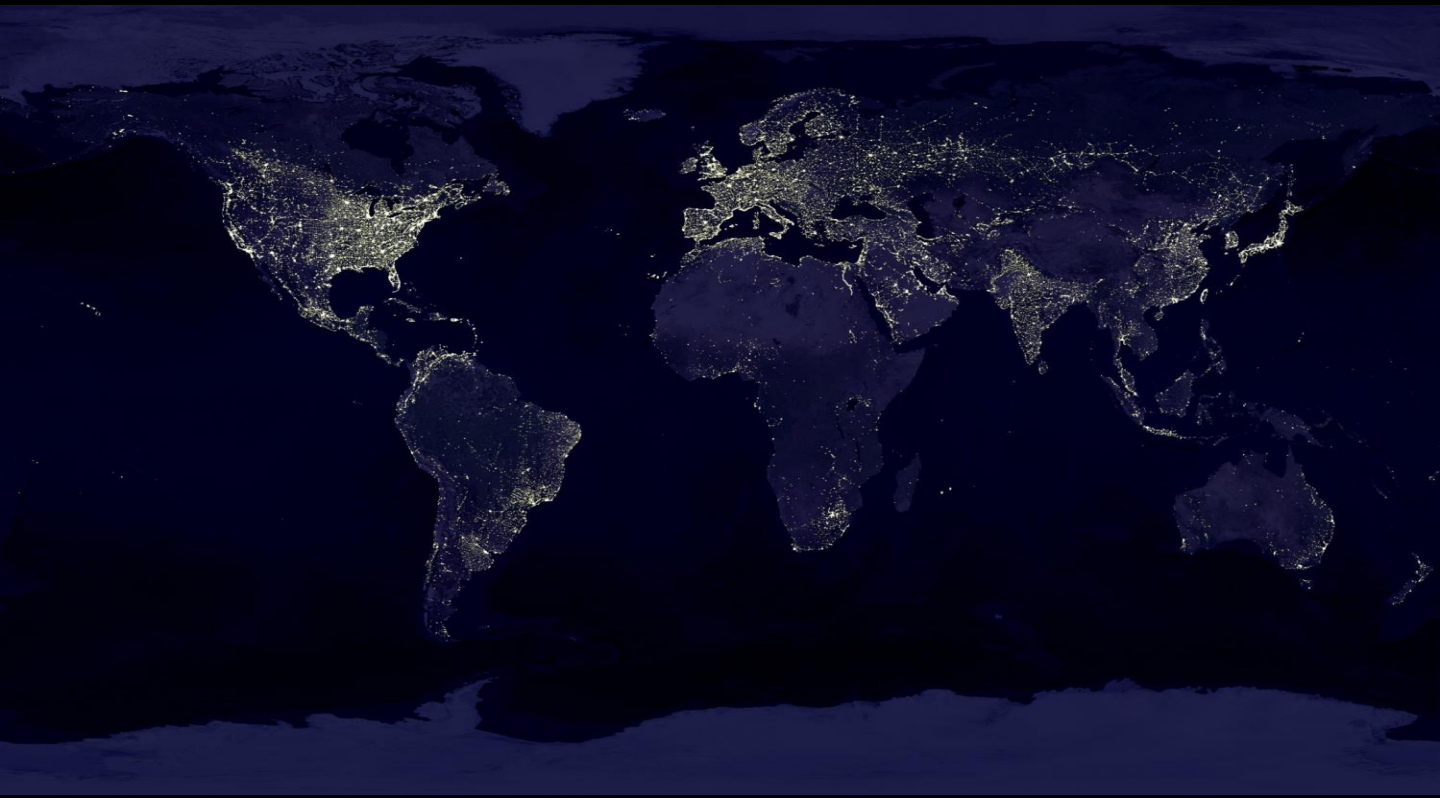
Our Place in the Universe

- So just where are we in the Universe?
  - What makes up the Universe?
  - The distance scale
- The changing and evolving Universe
  - The Big Bang
  - The birth, life and death of stars
  - Making the galaxies we see


London

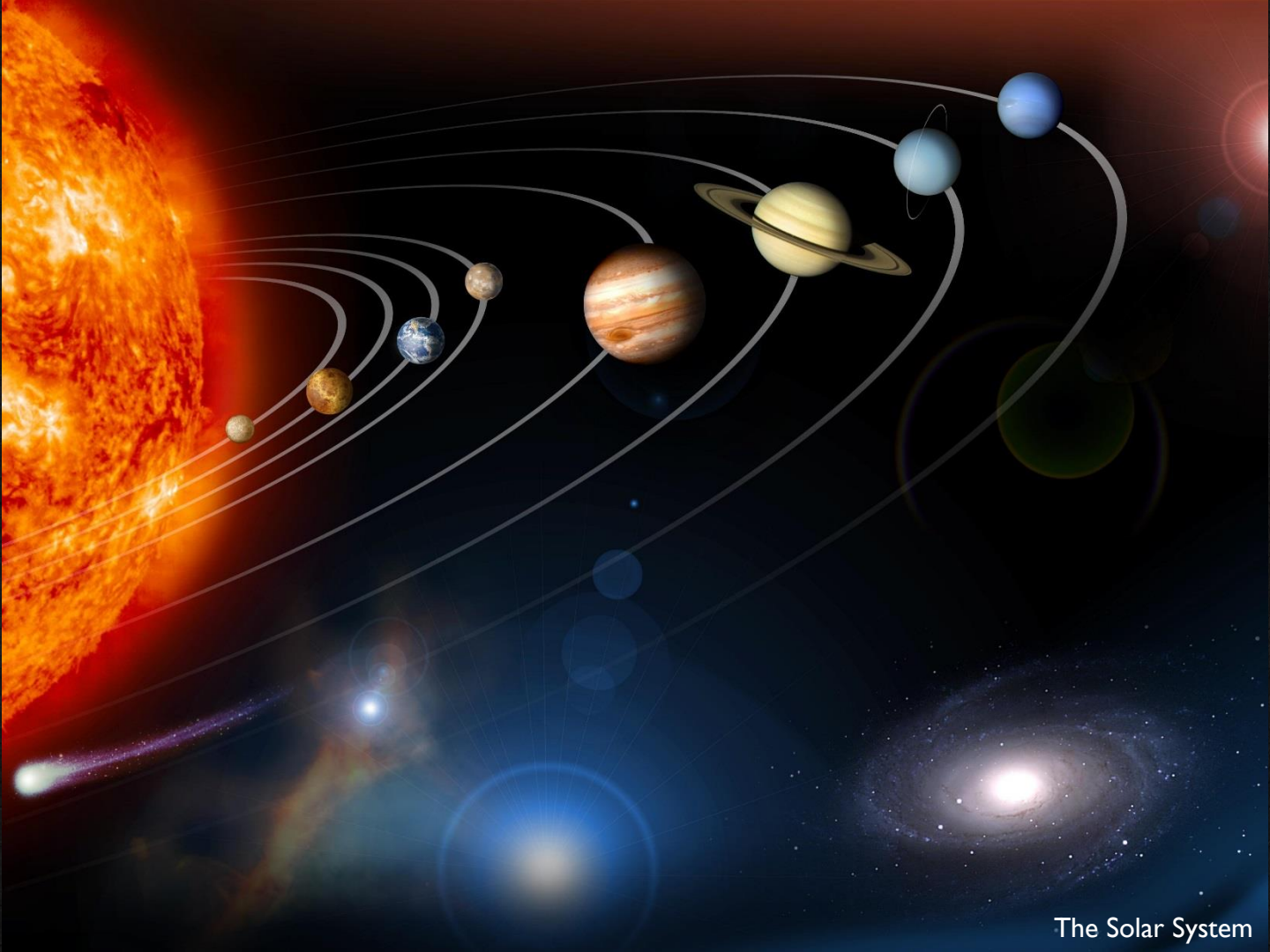
The United Kingdom

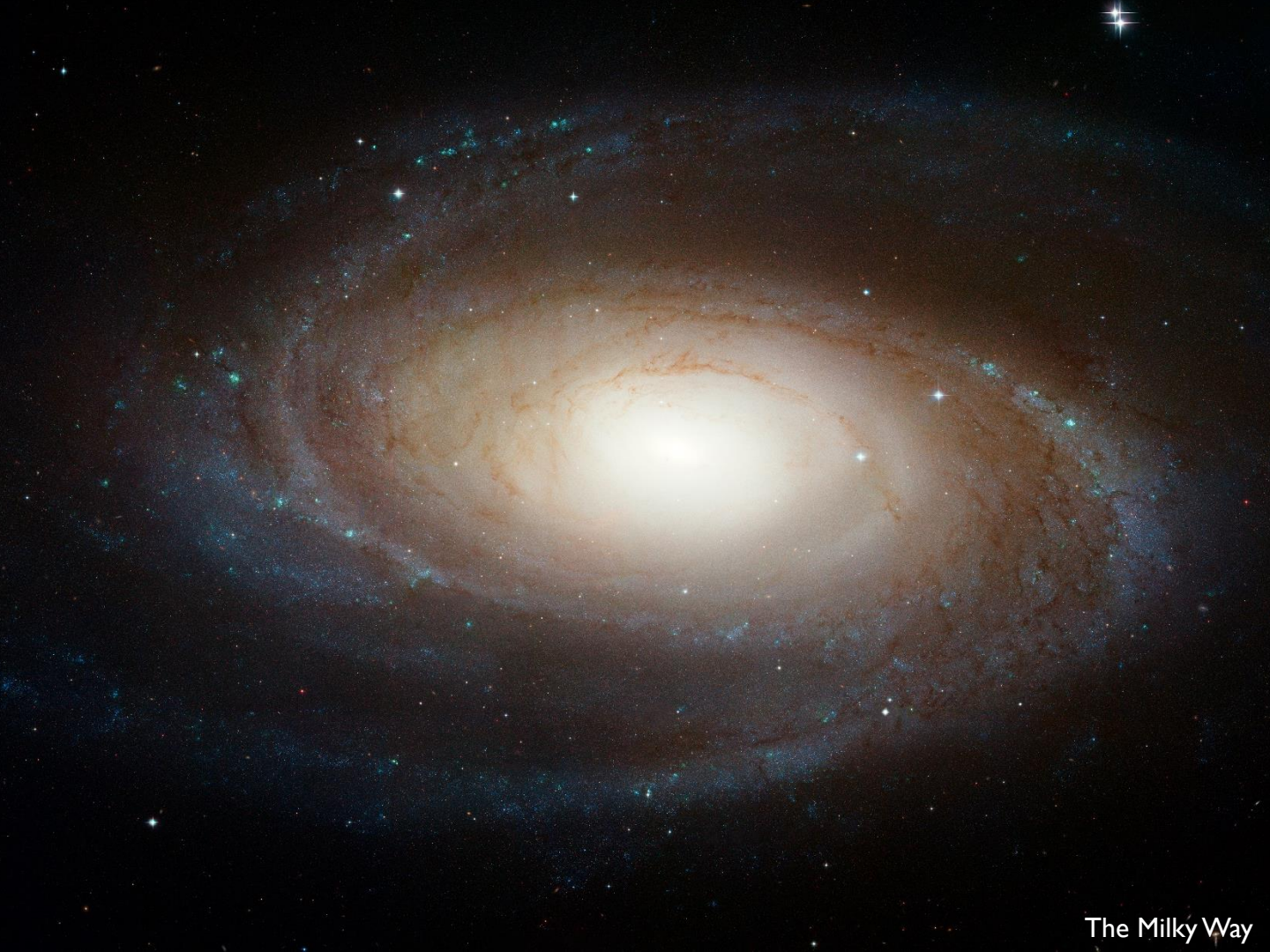
Europe



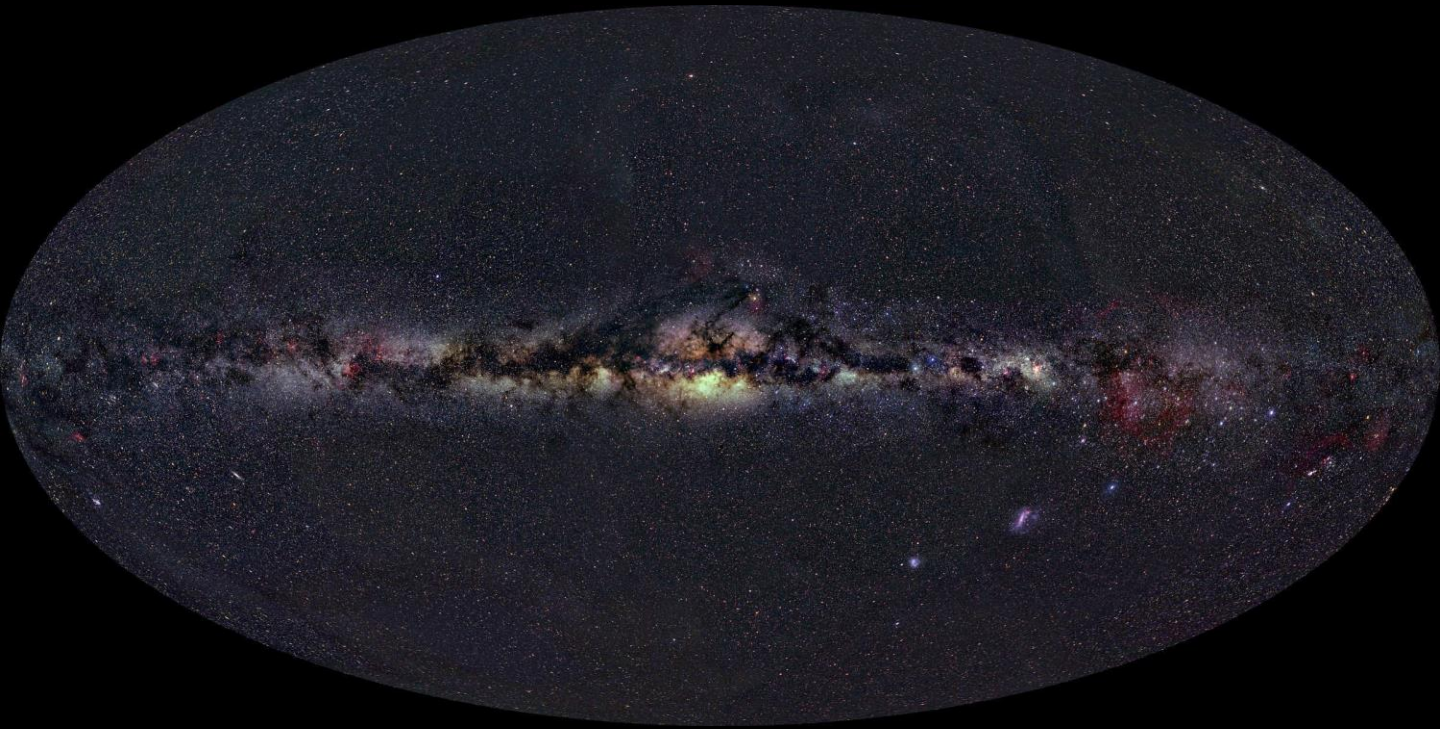
The Earth

The Earth

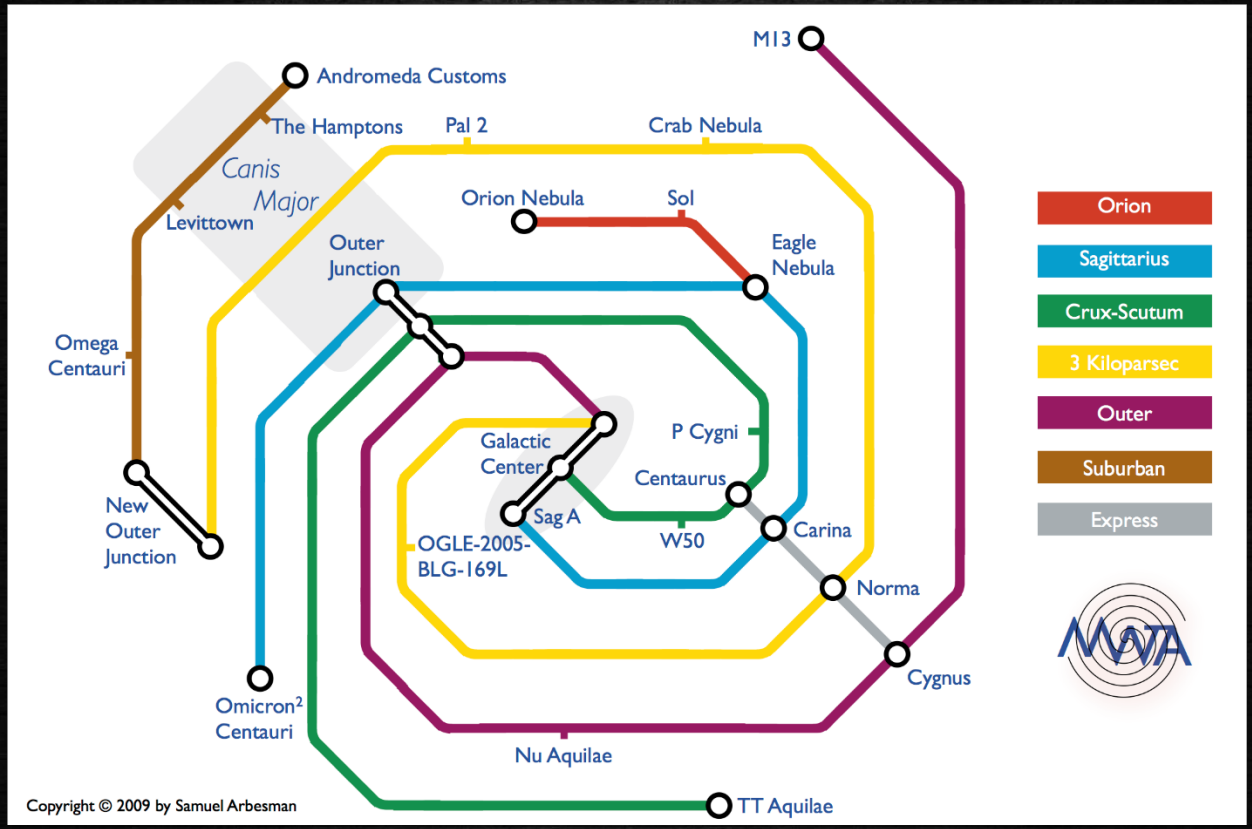

The Solar System

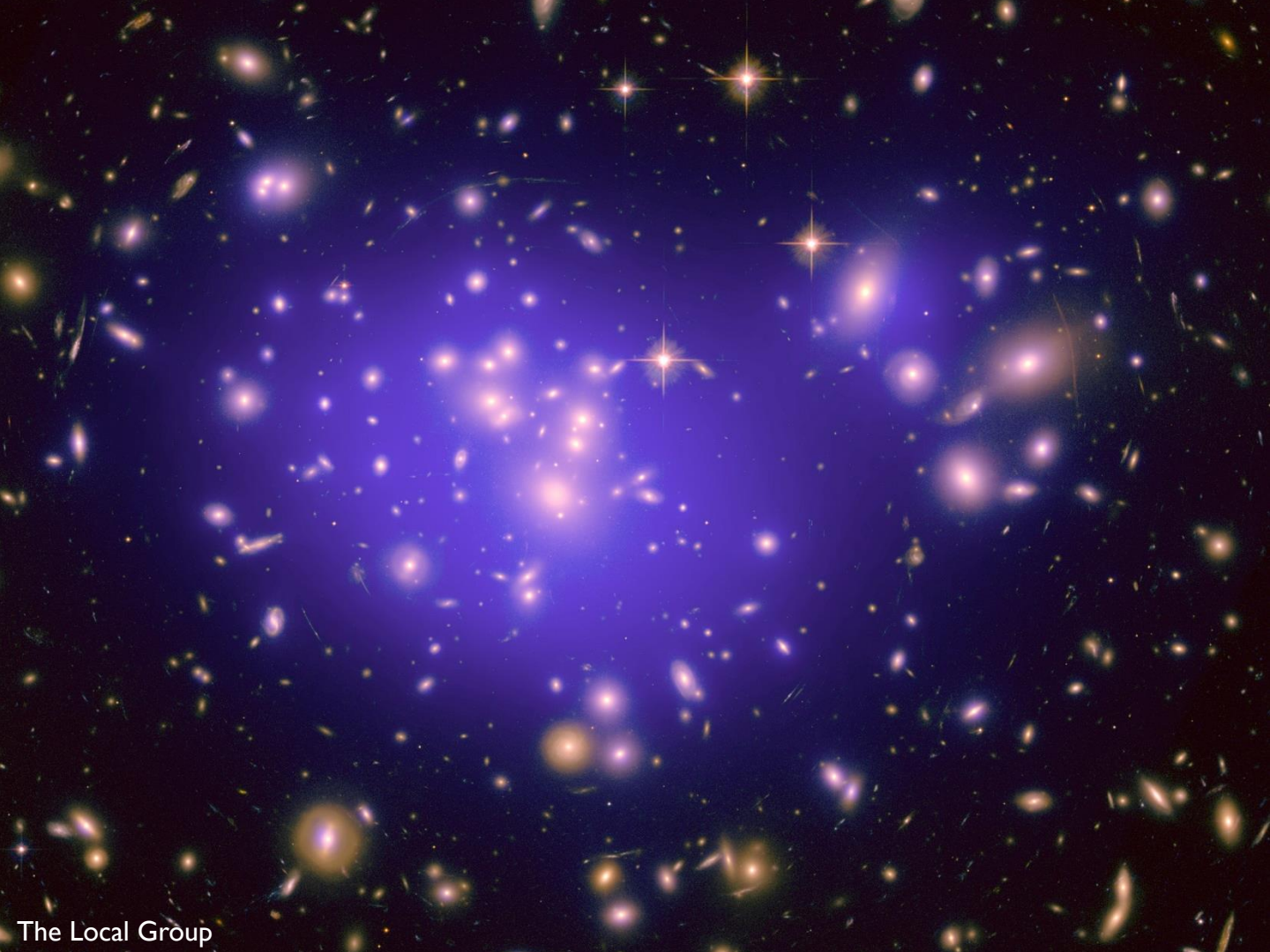


The Milky Way

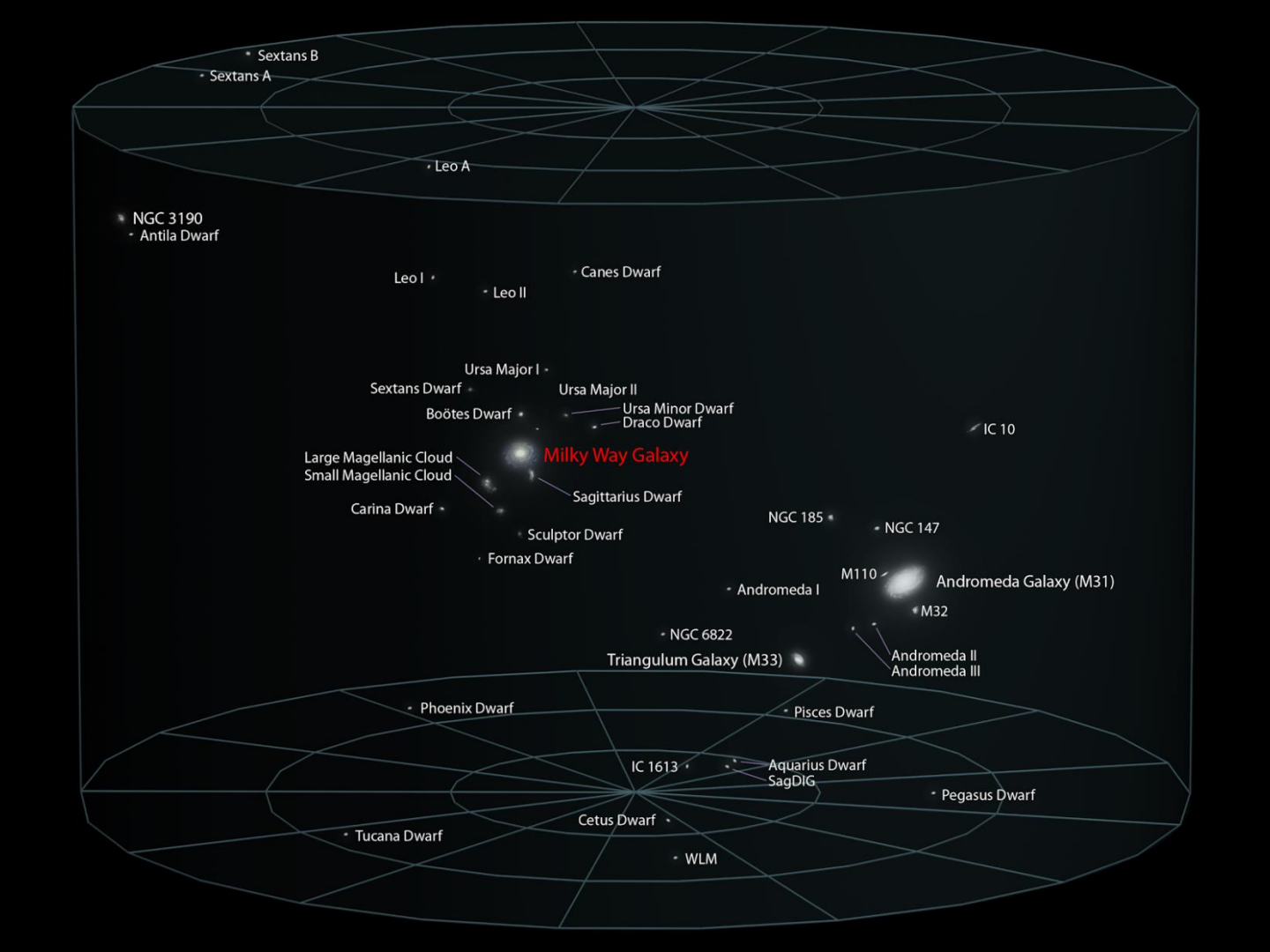


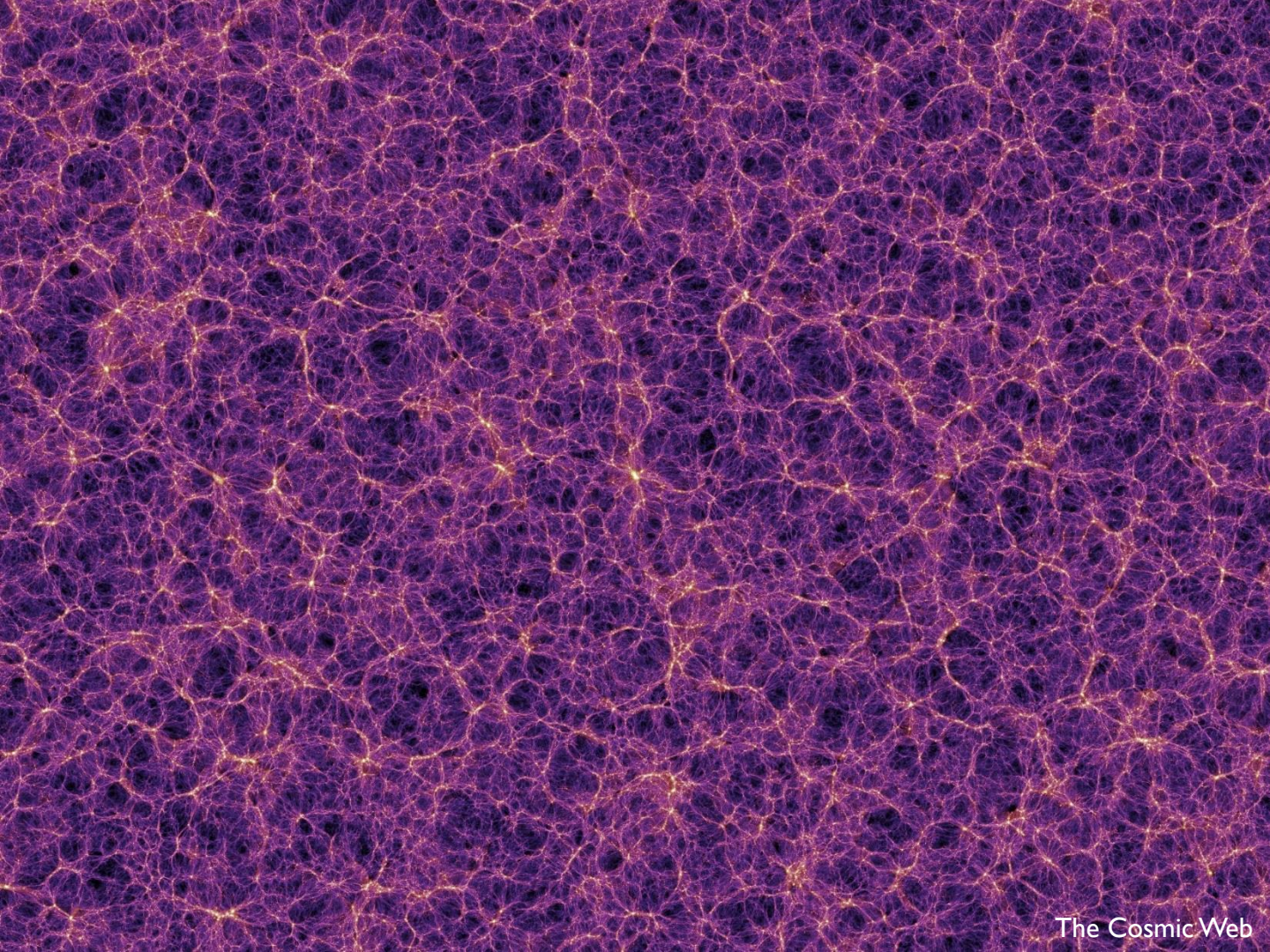
The Milky Way Transit Map

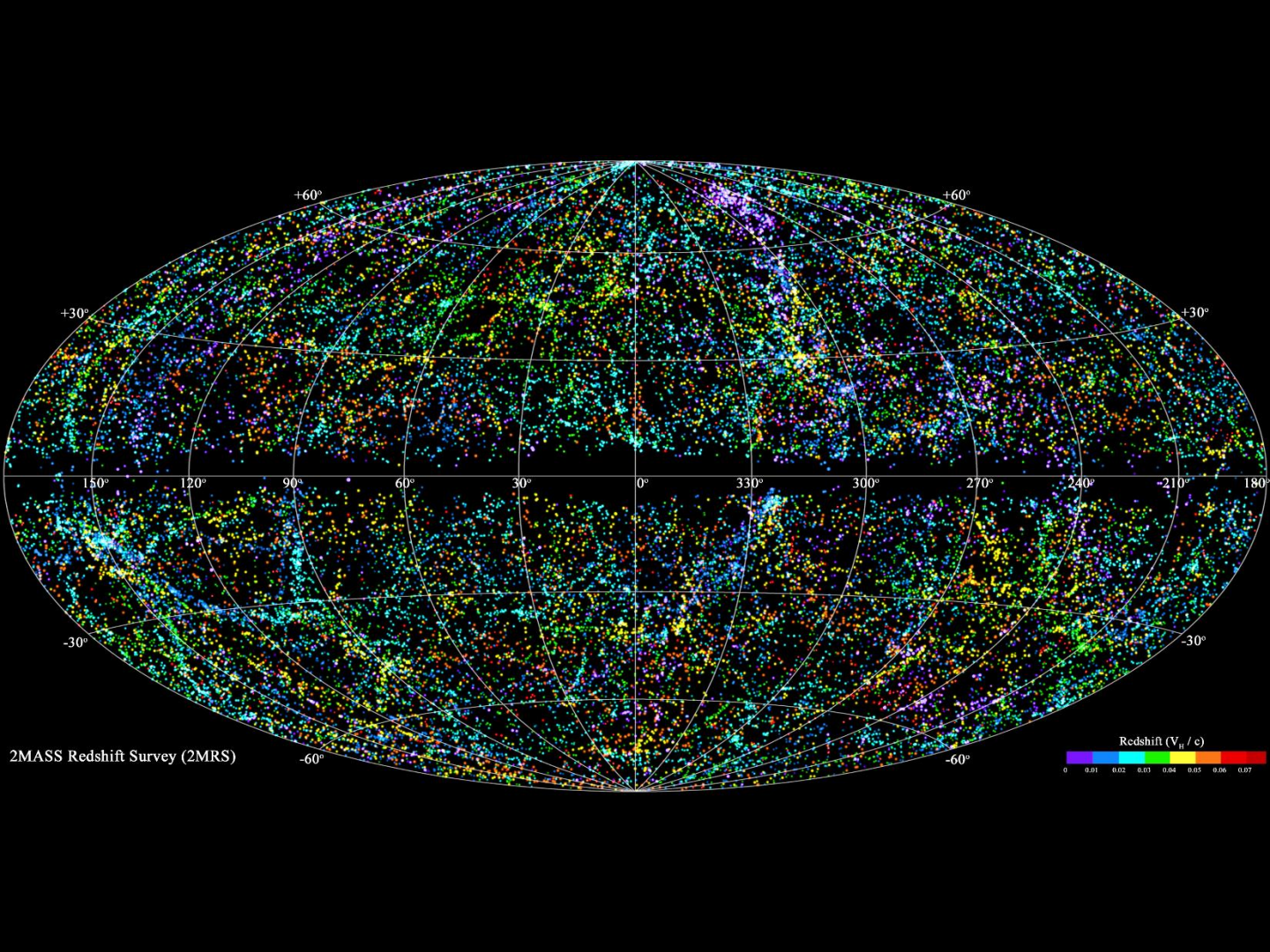


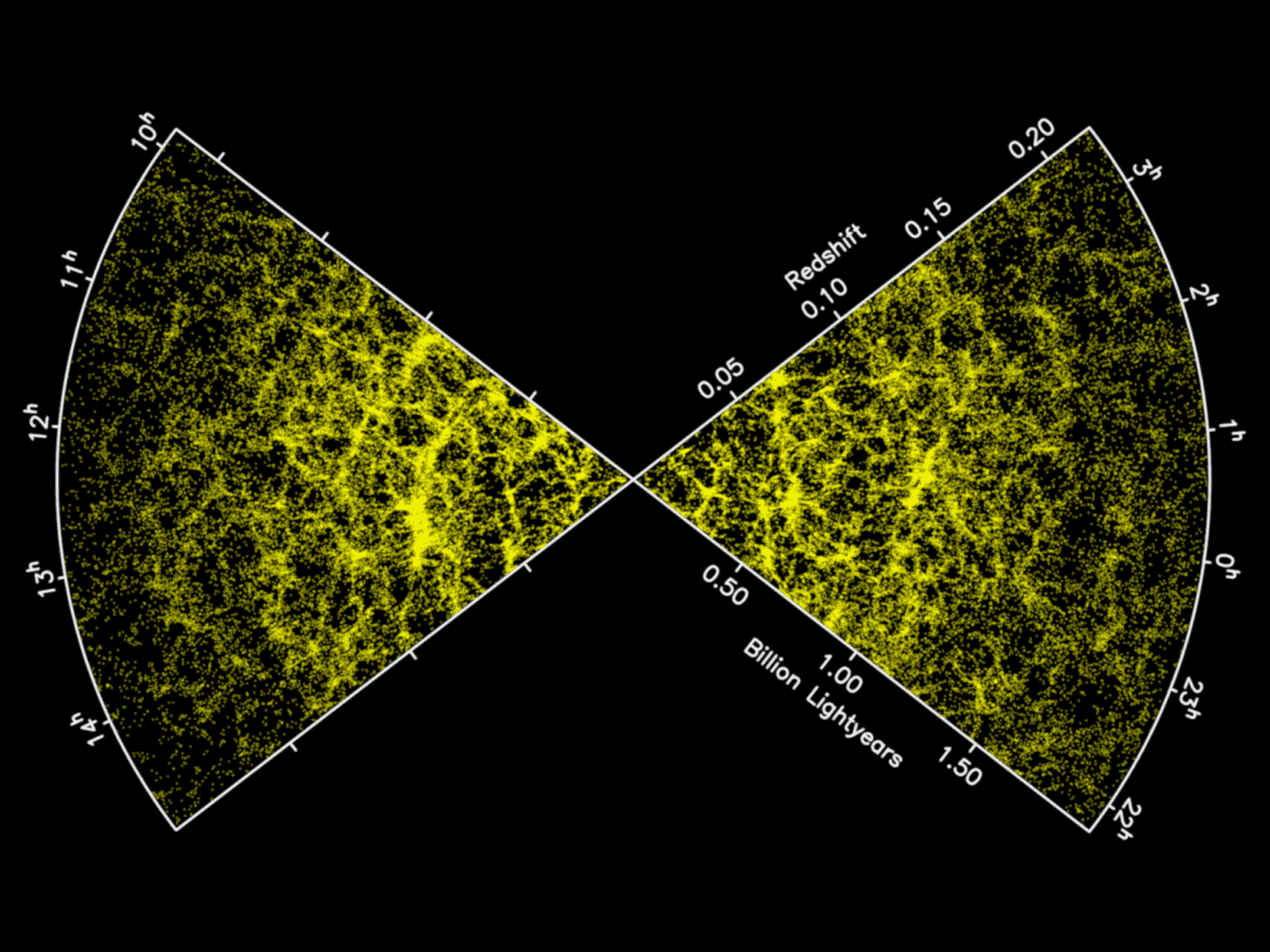


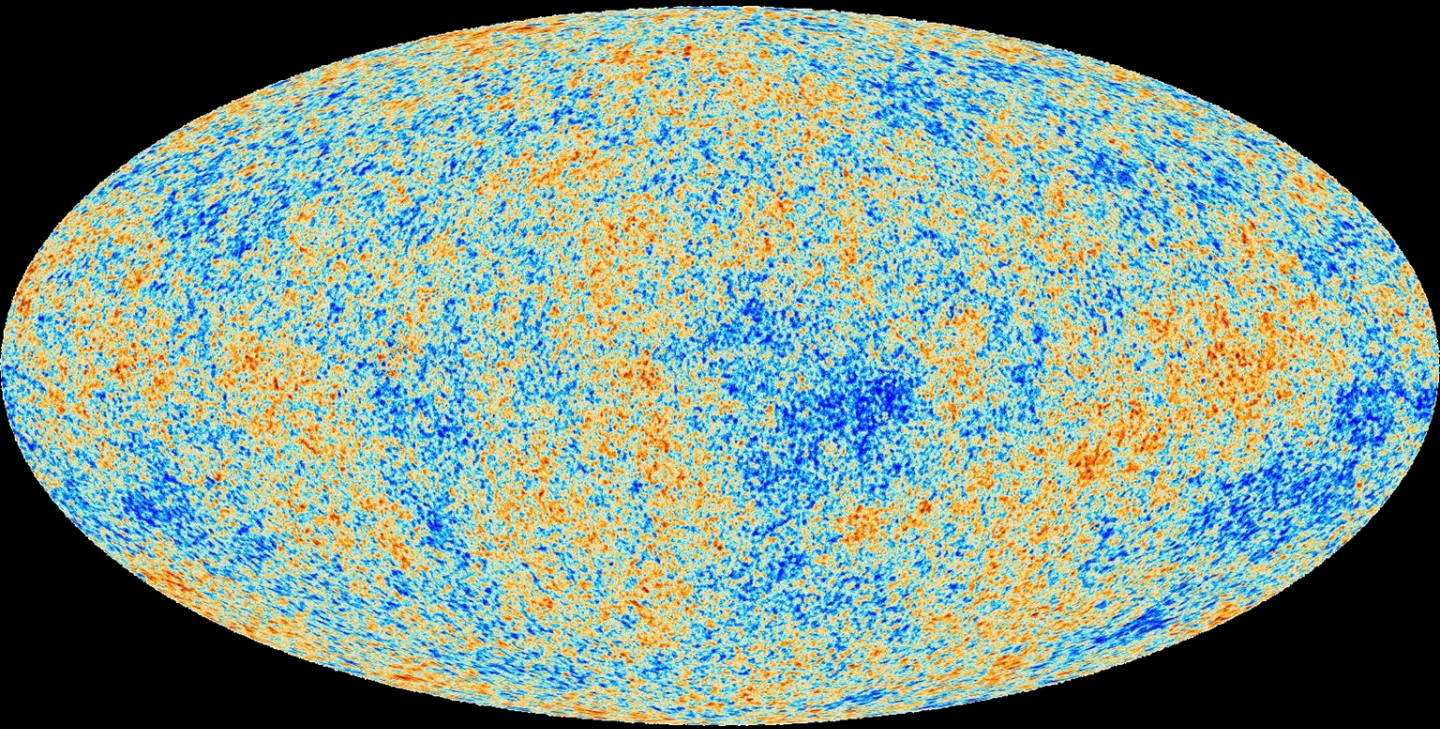
The Local Group


Sextans B
Sextans A
Leo A
NGC 3190
Antila Dwarf
Leo I
Canes Dwarf
Leo II
Ursa Major I
Sextans Dwarf
Ursa Major II
Boötes Dwarf
Ursa Minor Dwarf
Draco Dwarf
IC 10
Large Magellanic Cloud
Small Magellanic Cloud
Milky Way Galaxy
Sagittarius Dwarf
Carina Dwarf
NGC 185
NGC 147
Sculptor Dwarf
Fornax Dwarf
M110
Andromeda Galaxy (M31)
Andromeda I
M32
NGC 6822
Triangulum Galaxy (M33)
Andromeda II
Andromeda III
Phoenix Dwarf
Pisces Dwarf
IC 1613
Aquarius Dwarf
SagDIG
Pegasus Dwarf
Cetus Dwarf
Tucana Dwarf
WLM


The Cosmic Web


+60°
+60°
+30°
+30°
150°
120°
90°
60°
30°
0°
330°
300°
270°
240°
210°
180°
-30°
-30°
-60°
-60°
2MASS Redshift Survey (2MRS)
Redshift (V_H / c)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07


10h
11h
12h
13h
14h
1h
2h
3h
0h
23h
22h
Redshift
0.05
0.10
0.15
0.20
0.50
1.00
1.50
Billion Lightyears



The Cosmic Microwave Background

So where are we?

Our Earth Address

Cunard Line,
Southampton,
Hampshire,
United Kingdom,
Europe,
The Earth

Our Universal Address

Cunard Line,
The Earth,
The Solar System,
The Milky Way,
The Local Group,
The Universe

Cosmic Distances

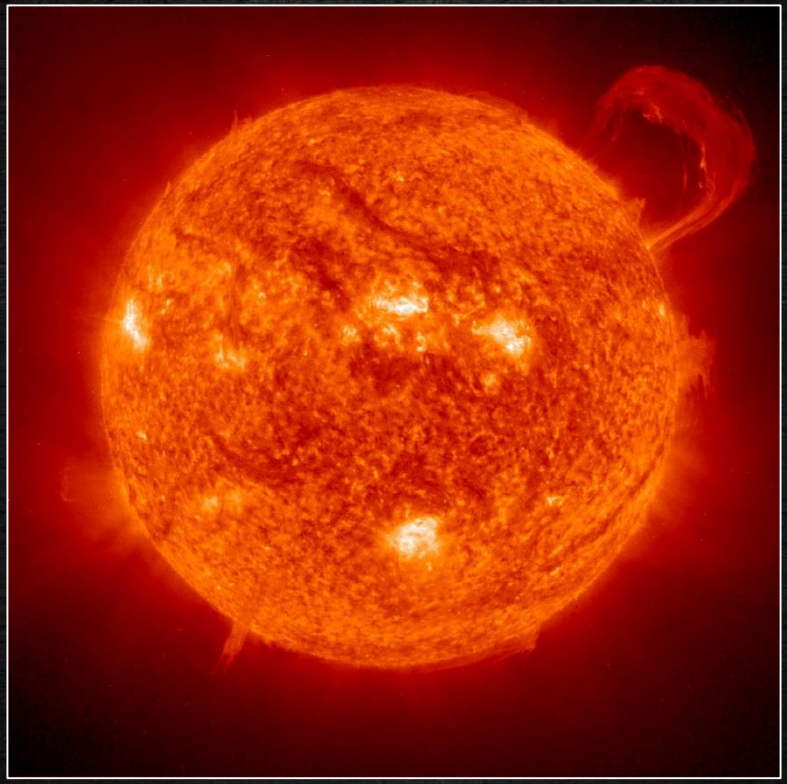
Distances in Astronomy

Southampton to New York: 3,420 miles / 5,500km

Distances in Astronomy

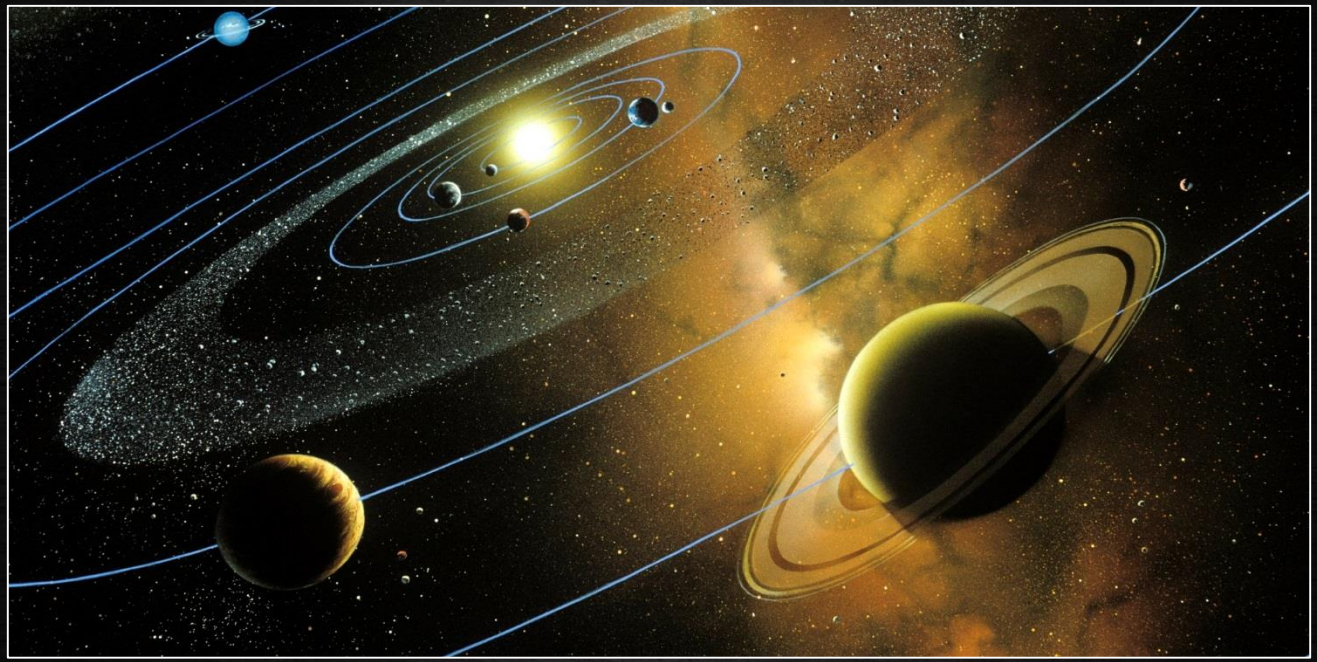
Earth to the Moon: 238,900 miles / 384,400 km

Distances in Astronomy

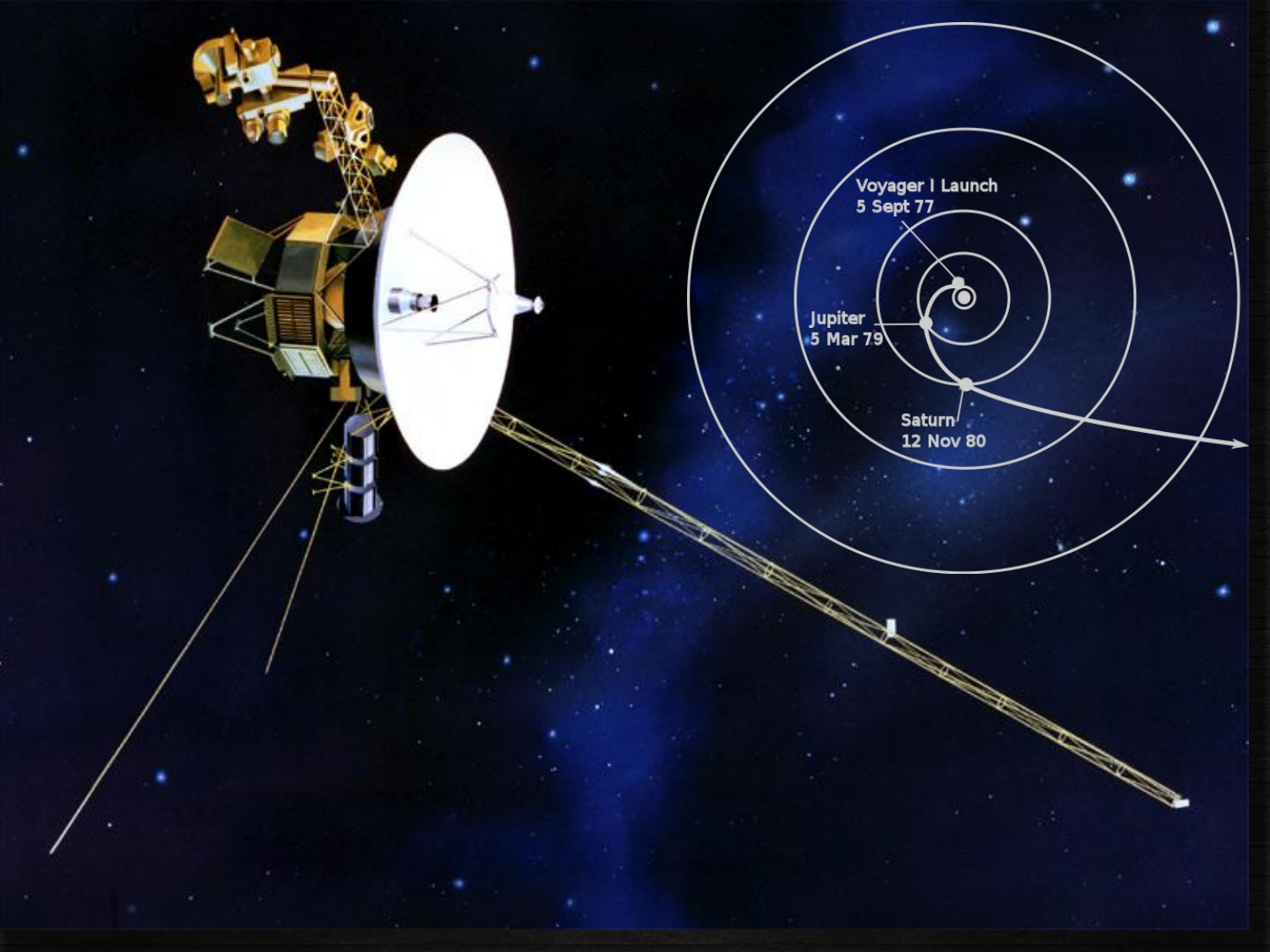


Earth to the Sun: 92,960,000 miles / 149,600,000 km

Distances in Astronomy



The edge of the Solar System: 9,000,000,000 miles / 14,484,096,000 km


Voyager I Launch
5 Sept 77
Jupiter
5 Mar 79
Saturn
12 Nov 80


Queen Mary 2

Distances in Astronomy

- At the maximum speed of Queen Mary 2 (35mph)
  - Southampton to New York:

    4 days
  - Earth to the Moon:

    284 days
  - Earth to the Sun:

    302 years
  - To the edge of the Solar System:

    29,334 years

Distances in Astronomy

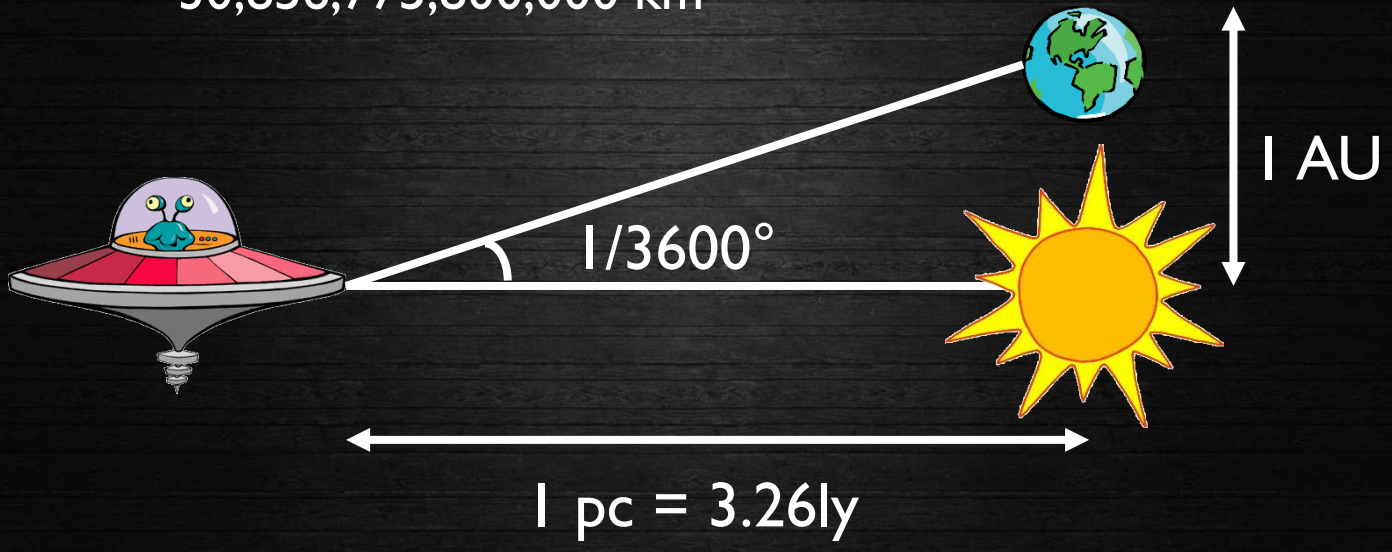
- At the speed of light
  - Southampton to New York:
    0.0183 seconds
  - Earth to the Moon:
    1.28 seconds
  - Earth to the Sun:
    8.3 minutes
  - To the edge of the Solar System:
    13.4 hours

Units of Distance

- 1 Astronomical Unit (AU)
  - The average distance between the Sun and the Earth
  - 149,597,871 km
- 1 Light Year (ly)
  - The distance light would travel in 1 year
  - 9,460,528,410,000 km

Units of Distance

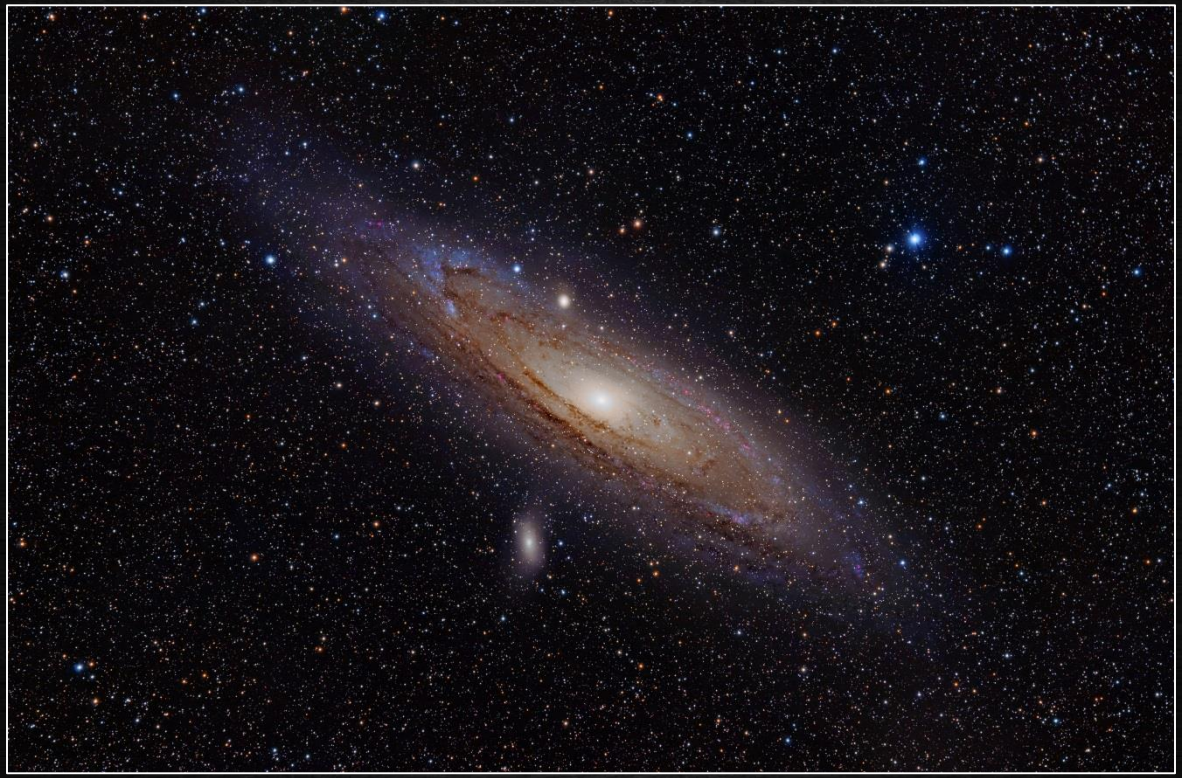
- 1 Parsec (pc)
  - Based upon the Earth's rotation around the Sun
  - 30,856,775,800,000 km



Distances in Astronomy

To the centre of the Galaxy: 25,900 light years

Distances in Astronomy



To the Andromeda Galaxy: 2,538,000 light years

Distances in Astronomy

To the most distant Galaxy known: 13,000,000,000 light years

Our Location – a Summary

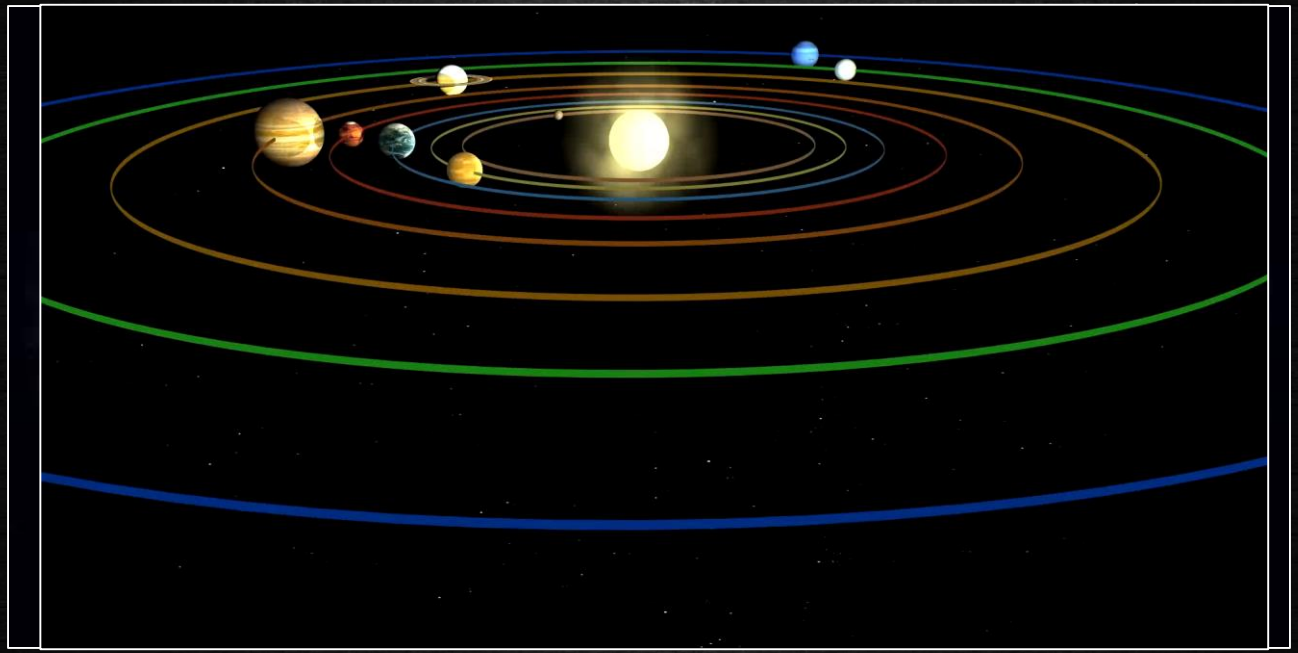
- We are:

On Earth	km/miles
Which is in the Solar System	50-100 AU
Which is in the Milky Way	50 thousand ly/pc
Which is in the Local Group	10 million ly/pc
Which is in the Cosmic Web	Billion ly/pc
Which is in the Universe	13.7 Billion ly/pc

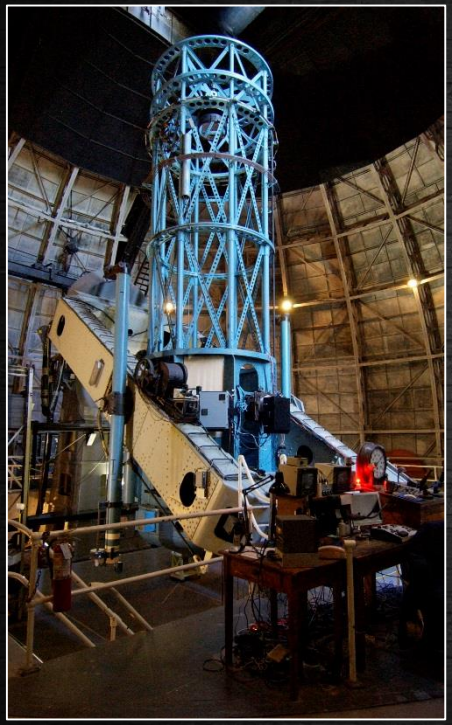
The changing and evolving Universe

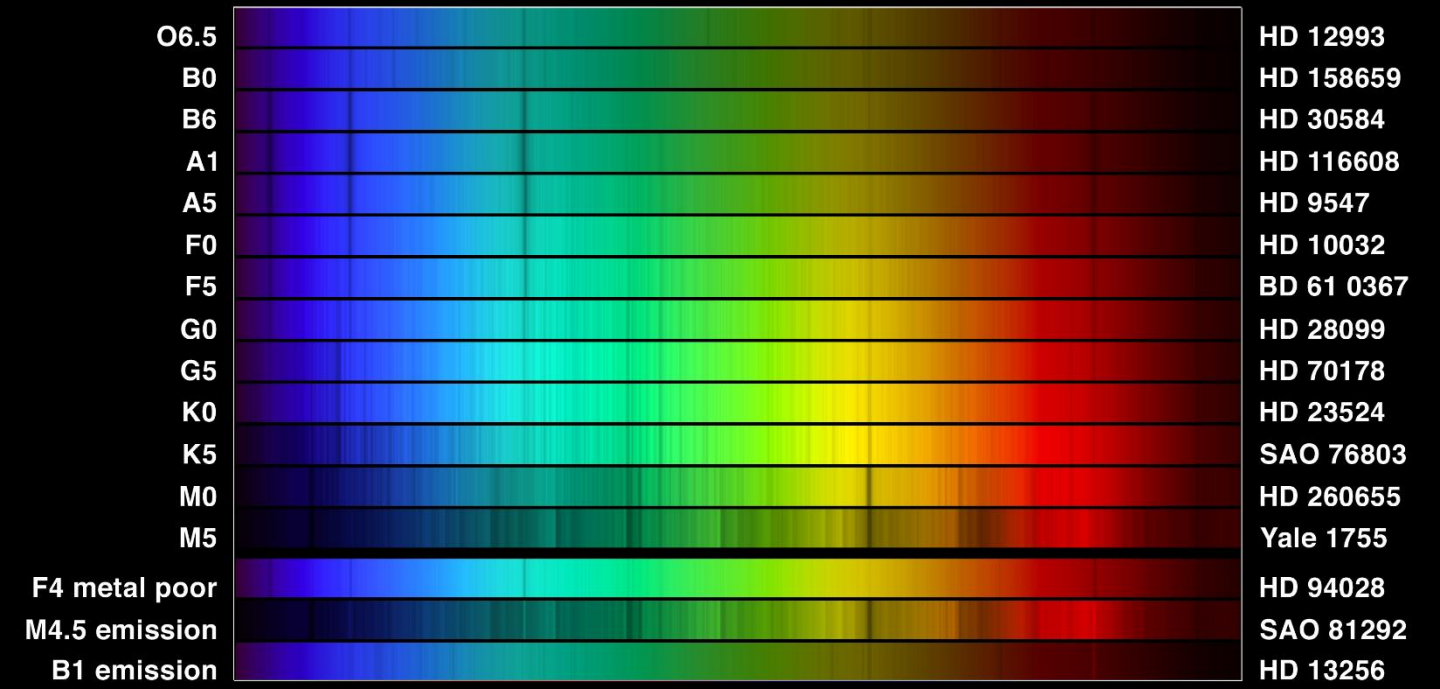
The Universe Today

- The Universe isn't static – it evolves



Starting at the beginning

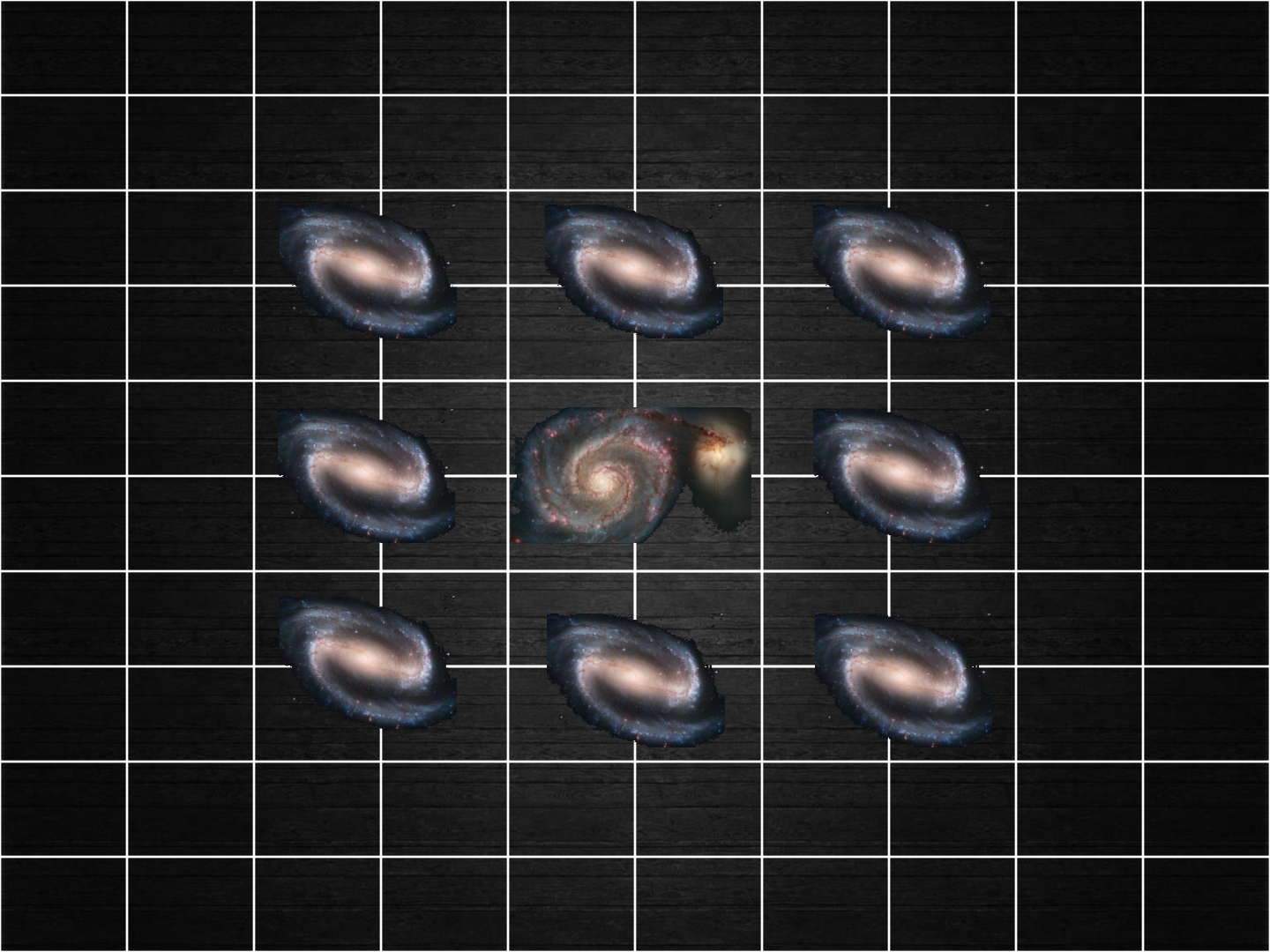



O6.5
B0
B6
A1
A5
F0
F5
G0
G5
K0
K5
M0
M5
F4 metal poor
M4.5 emission
B1 emission
HD 12993
HD 158659
HD 30584
HD 116608
HD 9547
HD 10032
BD 61 0367
HD 28099
HD 70178
HD 23524
SAO 76803
HD 260655
Yale 1755
HD 94028
SAO 81292
HD 13256

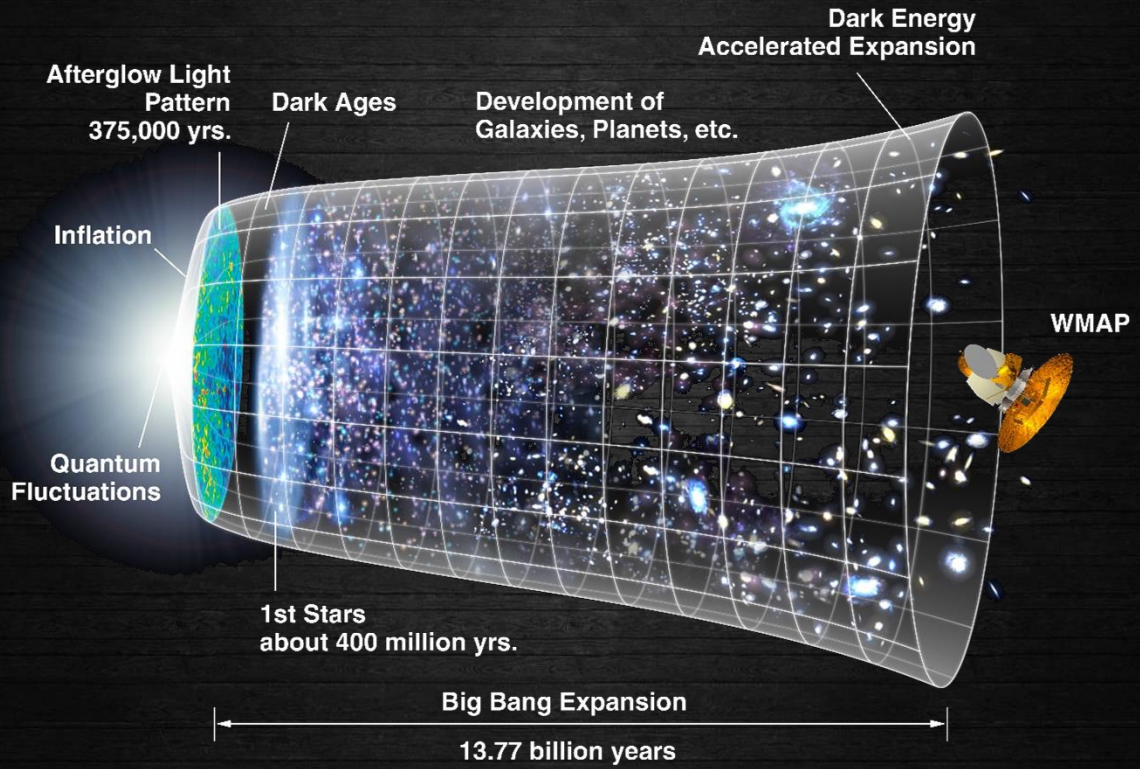
The Expansion of the Universe

- The objects further away are moving away fastest
- Everything appears to be moving away from Earth

- So are we in a "special" place?

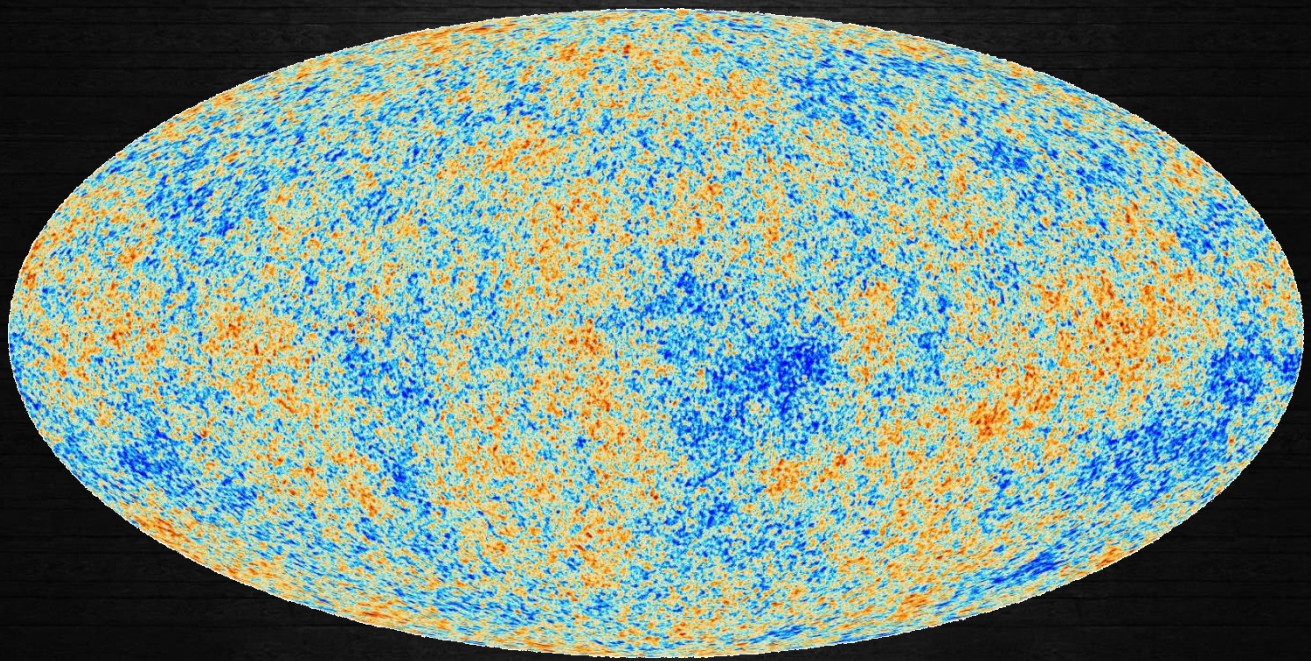


The Big Bang

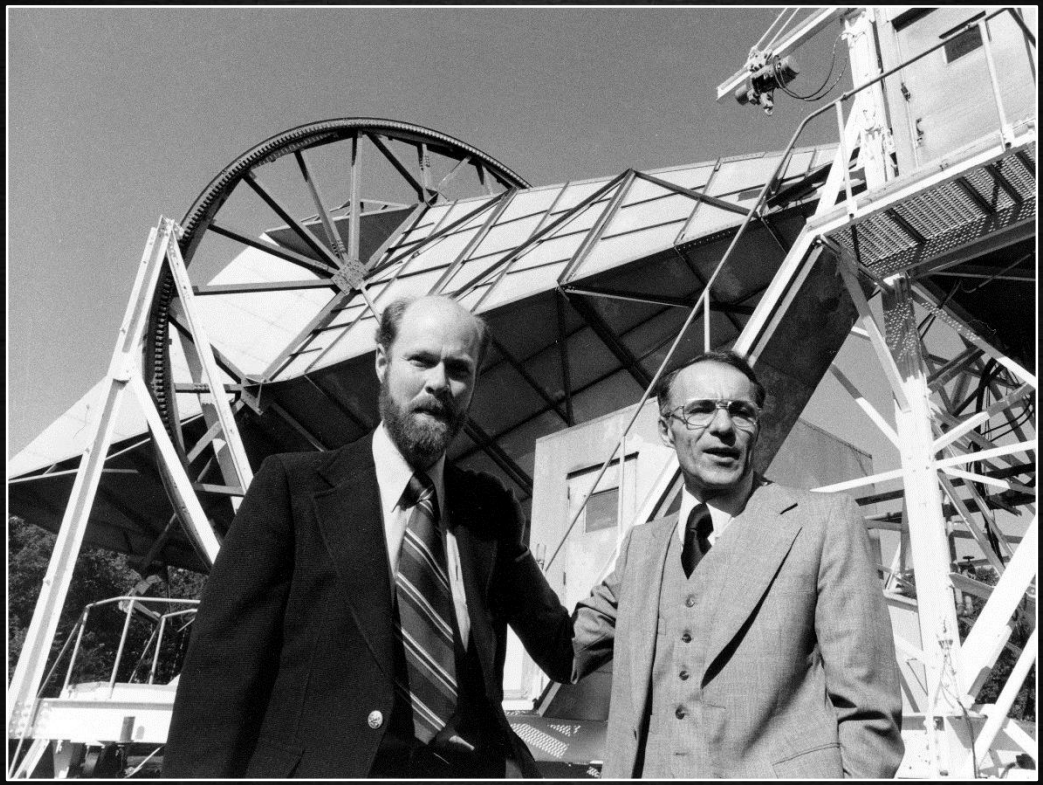


1,000,000,000,000,000,000,000,000,000,000,000°C

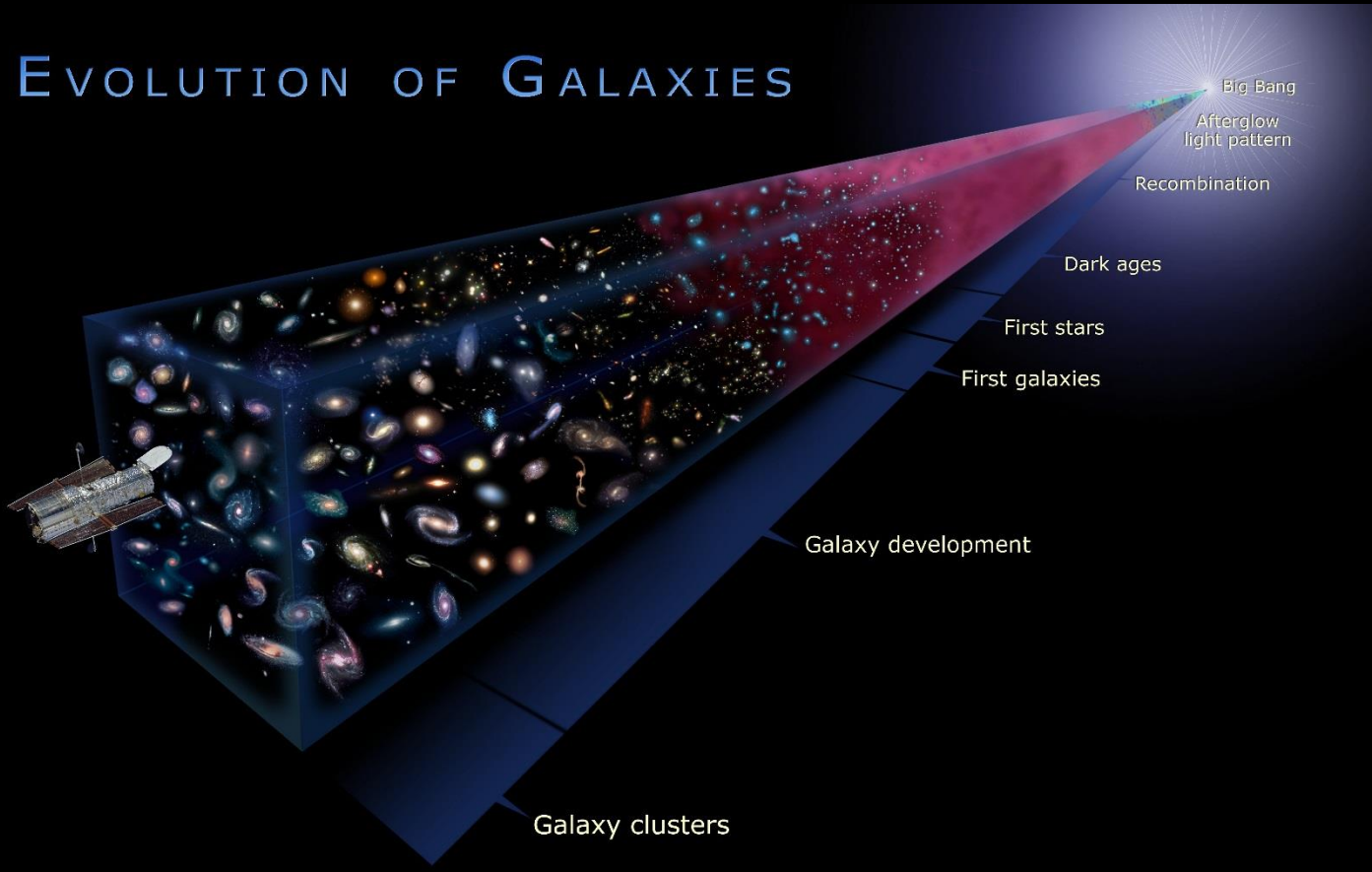
The Cosmic Microwave Background



The Cosmic Microwave Background



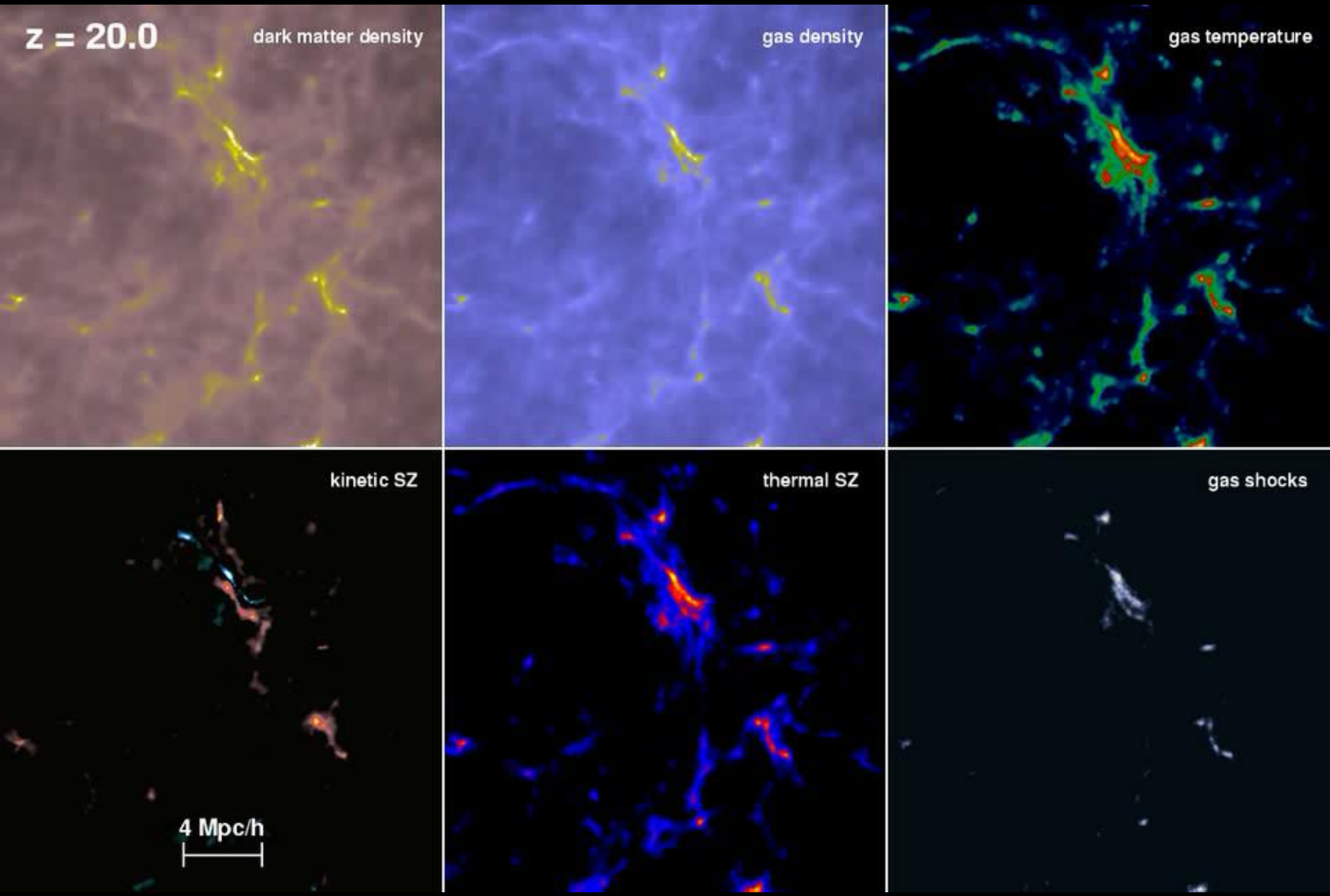
Evolution of Galaxies



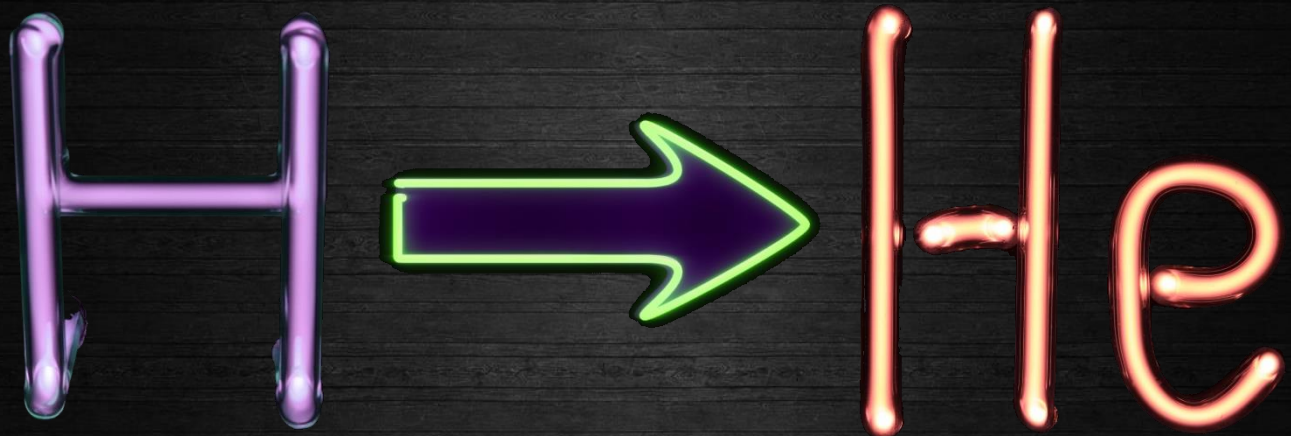
Forming Structure

- The Universe is clumpy

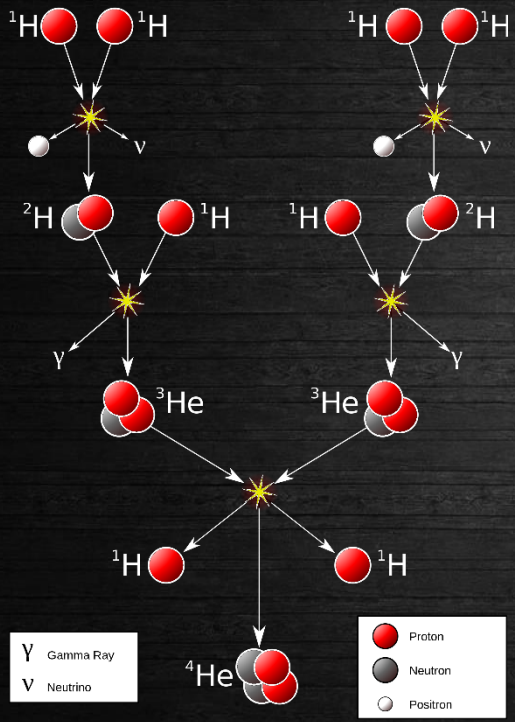
It's all the fault of Gravity!


z = 20.0
dark matter density
gas density
gas temperature
kinetic SZ
thermal SZ
gas shocks
4 Mpc/h

How do stars work?



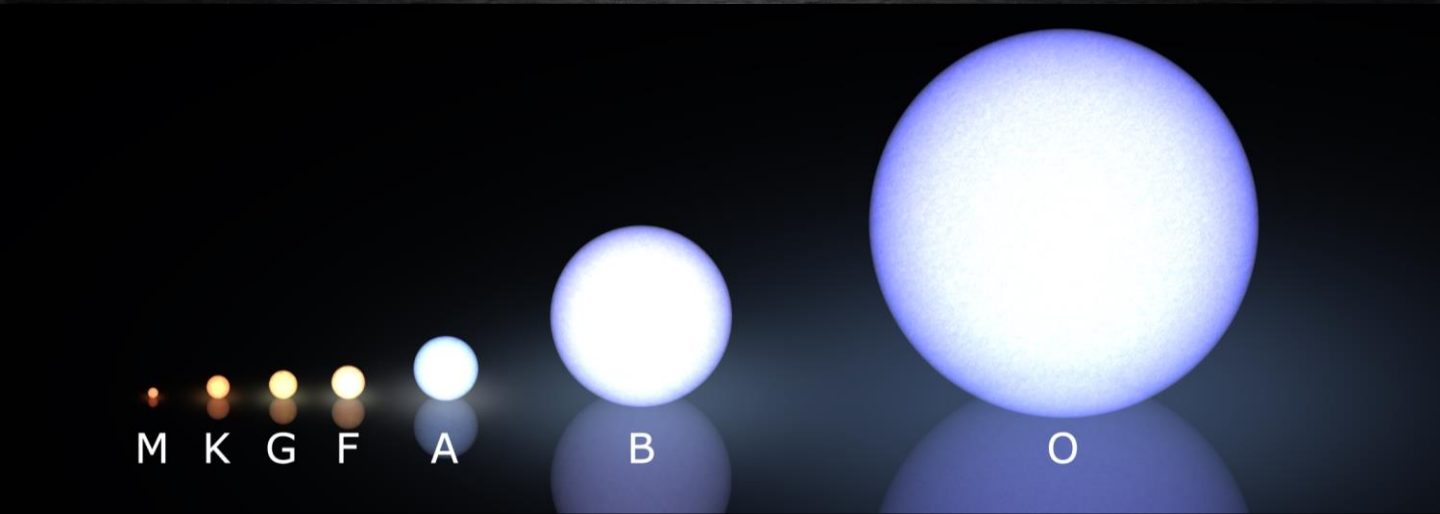
Stellar Nucleosynthesis

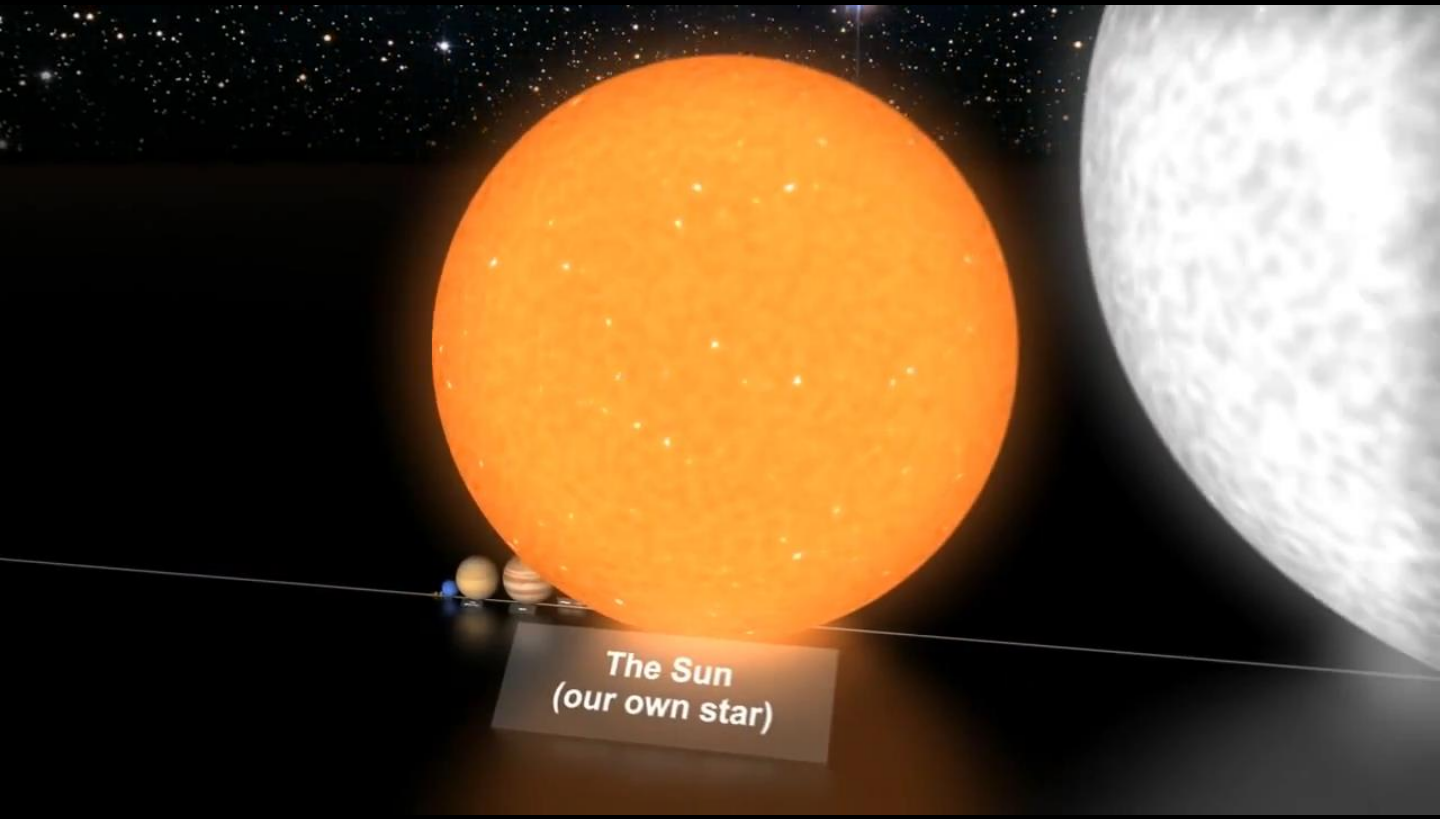


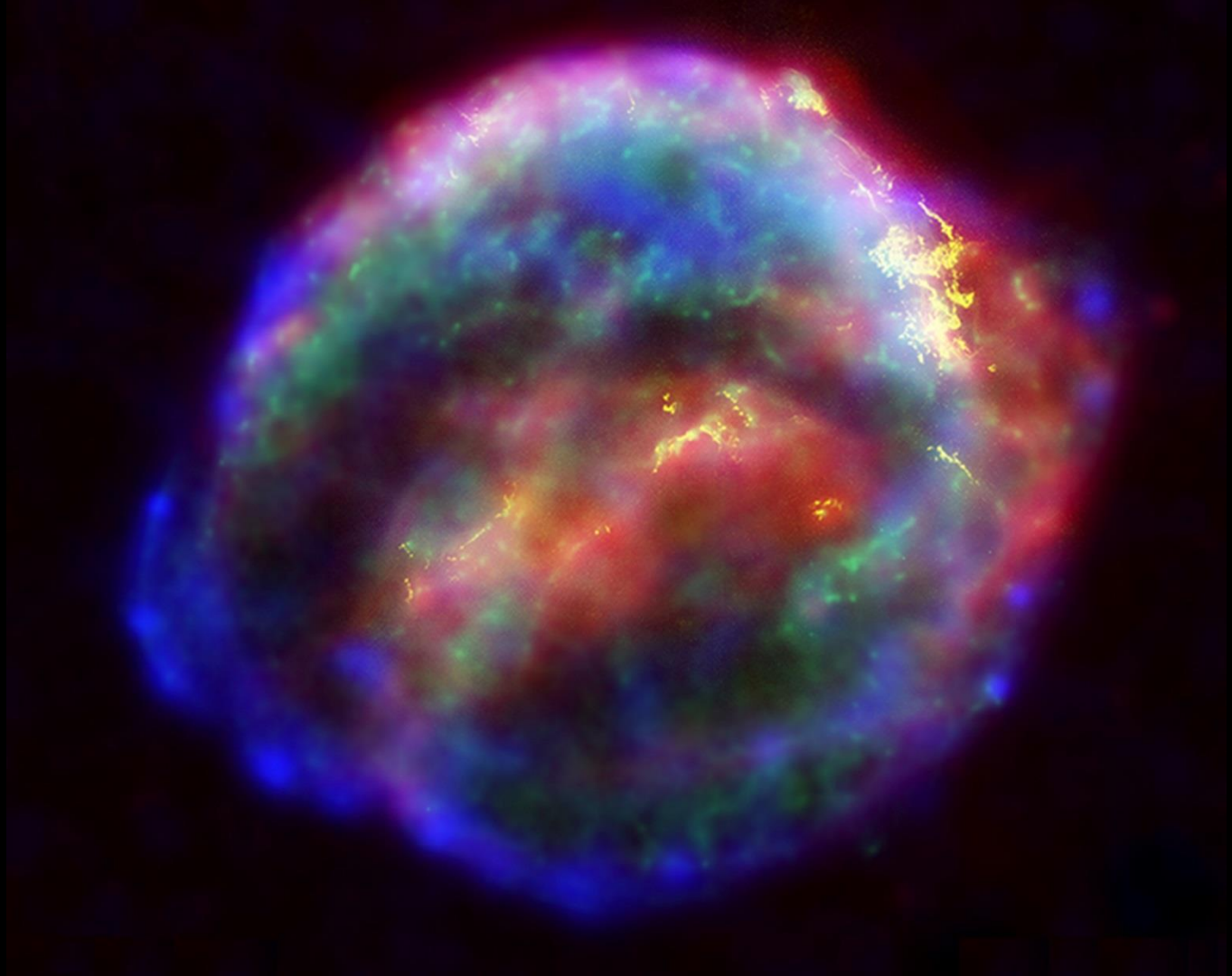
- Releases energy through a chain of reactions
- Powers all stars
- Doesn't just work with Hydrogen to Helium!

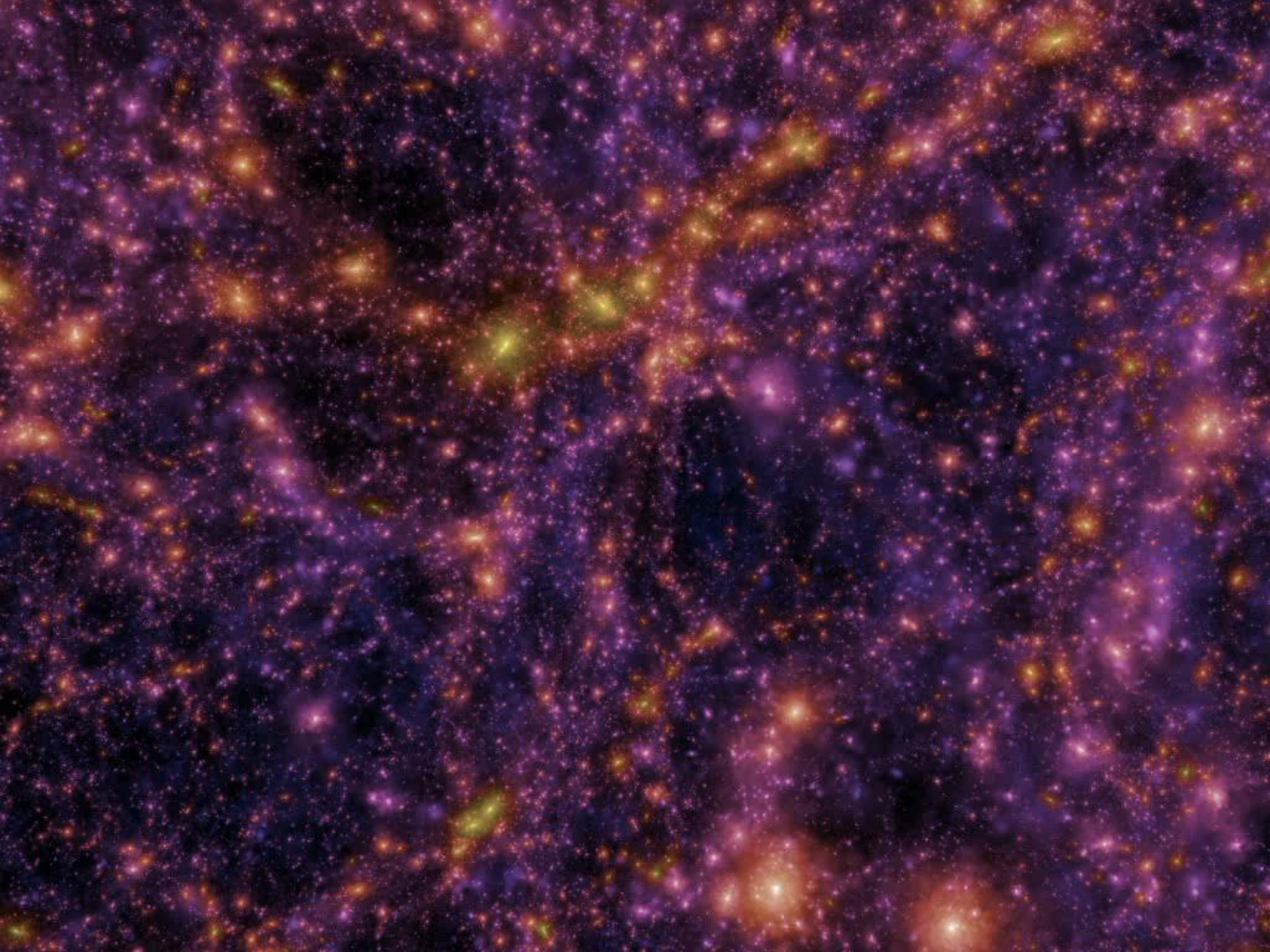
So is the Sun special?

	Minimum	Maximum	The Sun
Size	0.4 × Radius of Sun	15 × Radius of Sun	1
Mass	0.3 × Mass of Sun	60 × Mass of Sun	1
Temperature	3500 K	25,000+ K	5,500K




The Sun
(our own star)





The Spitzer Infrared Nearby Galaxies Survey (SINGS) Hubble Tuning-Fork

The Spitzer Space Telescope observed 75 galaxies as part of its SINGS (Spitzer Infrared Nearby Galaxies Survey) Legacy Program. The galaxies are presented here in a Hubble Tuning-Fork diagram, which groups galaxies according to the morphology of their nuclei and spiral arms. The designation of these galaxies and their placement in the diagram is based on their visible-light appearance. The main goal of the SINGS program is to characterize the infrared properties of a wide range of galaxy types. The images of the galaxies are composites created from data taken by IRAC (the Infrared Array Camera) at 3.6 and 8.0 μm, and MIPS (the Multiband Imaging Photometer for Spitzer) at 24 μm.

The infrared range probed by these and other observations taken for the SINGS project allows for the detailed study of star formation, dust emission, and the distribution of stars in each galaxy. Light from old stars appears as blue in the images, while the lumpy knots of green and red light are produced by dust clouds surrounding newly born stars. The elliptical galaxies on the left are almost entirely made of old stars, while spiral galaxies like our own Milky Way are rich in young stars and the raw materials for future star formation.

More information can be found at:
http://sings.stsci.edu/

Ellipticals

Irregulars

Strong Bulge

Strong Bulge

Weak Bulge

Weak Bulge

Unbarred Spirals

Intermediate Spirals

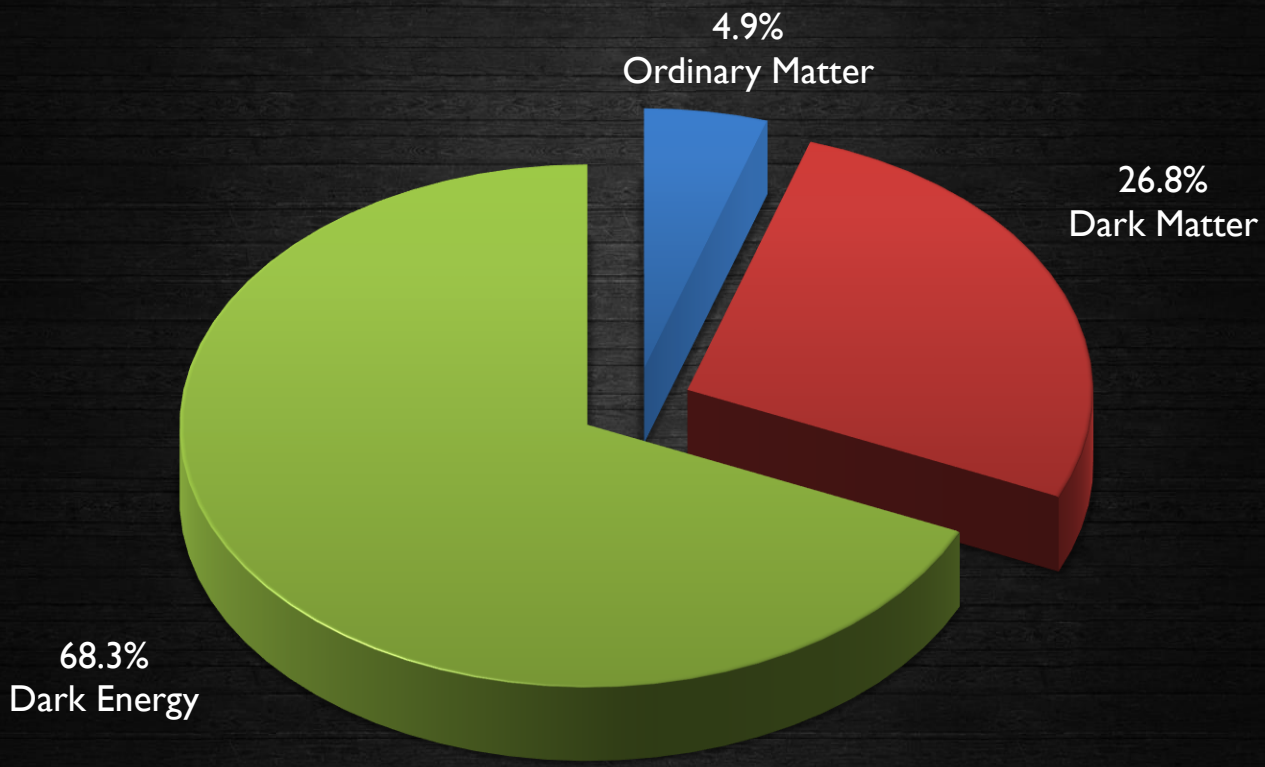
Barred Spirals

Poster and composite images created from SINGS observations by Karl D. Gordon (Oct 2007)
Blue=IRAC 3.6μm (stars)
Green=IRAC 8μm
(aromatic features from dust grains/molecules)
Red=MIPS 24μm (warm dust)

SINGS Team

Robert Kennicutt, Jr. (Principle Investigator), Daniela Calzetti (Deputy Principle Investigator), Charles Engelbracht (Technical Contact), Lee Armus, George Bendo, Caroline Bot, Brent Buckalew, John Cannon, Daniel Dale, Bruce Draine, Karl Gordon, Albert Grauer, David Hollenbach, Tom Jarrett, Lisa Kewley, Claus Leitherer, Aigen Li, Sangeeta Malhotra, Martin Meyer, John Moustakas, Eric Murphy, Michael Regan, George Rieke, Marcia Rieke, Helene Roussel, Kartik Sheth, J.D. Smith, Michels Thornley, Fabian Walter & George Helou

The Universe of Today




Thank you