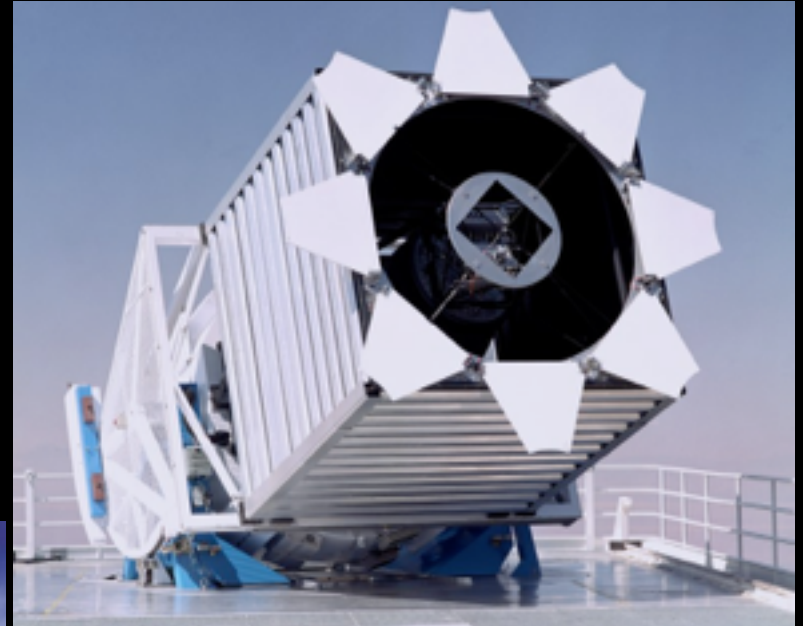
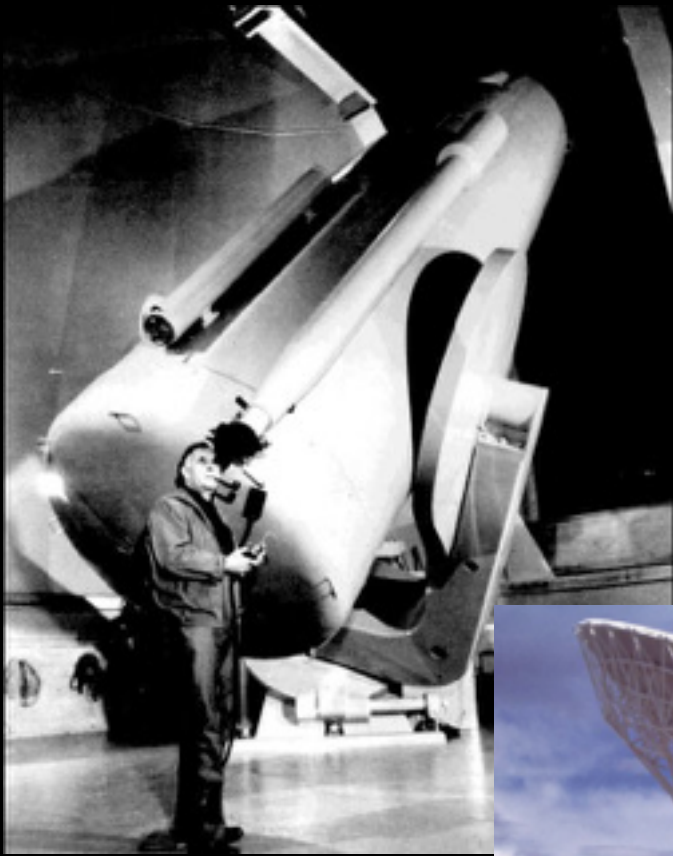


Galaxies Through Many Different Eyes



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But first, open up your
computers!

(activity time!)

<https://goo.gl/vbNShL>

How is this galaxy...

The Giant Elliptical Galaxy Messier 87 by



M87, 10x the
mass of the
Milky Way



...related to this galaxy?



Small Magellenic
Cloud, 1/100 the size
of the Milky Way



And how do you
use telescopes to
figure it out?



A menagerie of galaxies

Disc and Spiral Galaxies



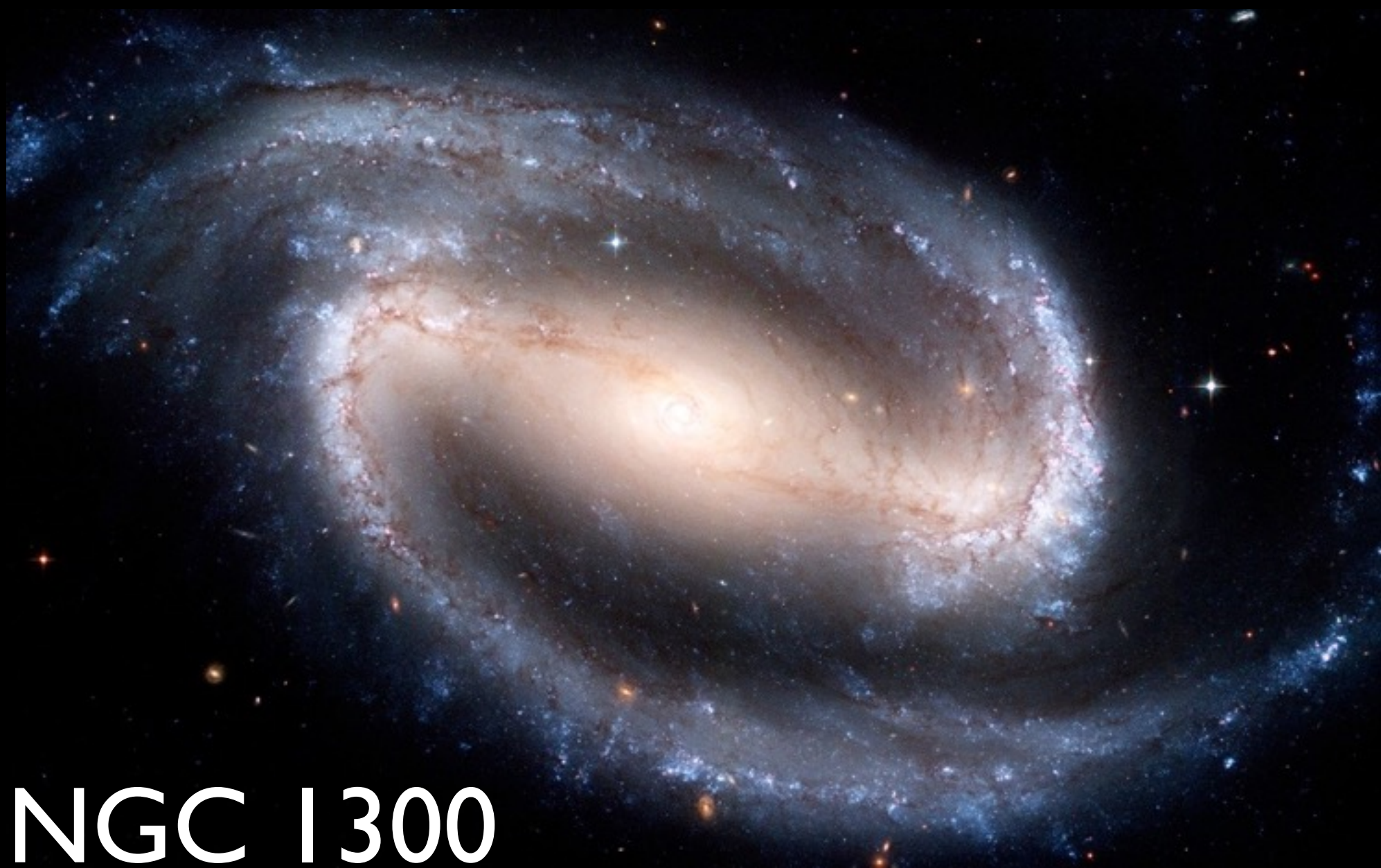
Andromeda galaxy

© Philip Perkins 1999



The Whirlpool Galaxy
(M51) and companion

Barred spirals



NGC 1300

Elliptical galaxies

M87 (NGC 4486)



Dwarf galaxies



Small Magellanic
Cloud (SMC)

Large Magellanic
Cloud (LMC)





NGC 147

Merging galaxies

“The Mice” (NGC 4676)



Galaxy evolution over cosmic time



Hubble Ultra Deep Field

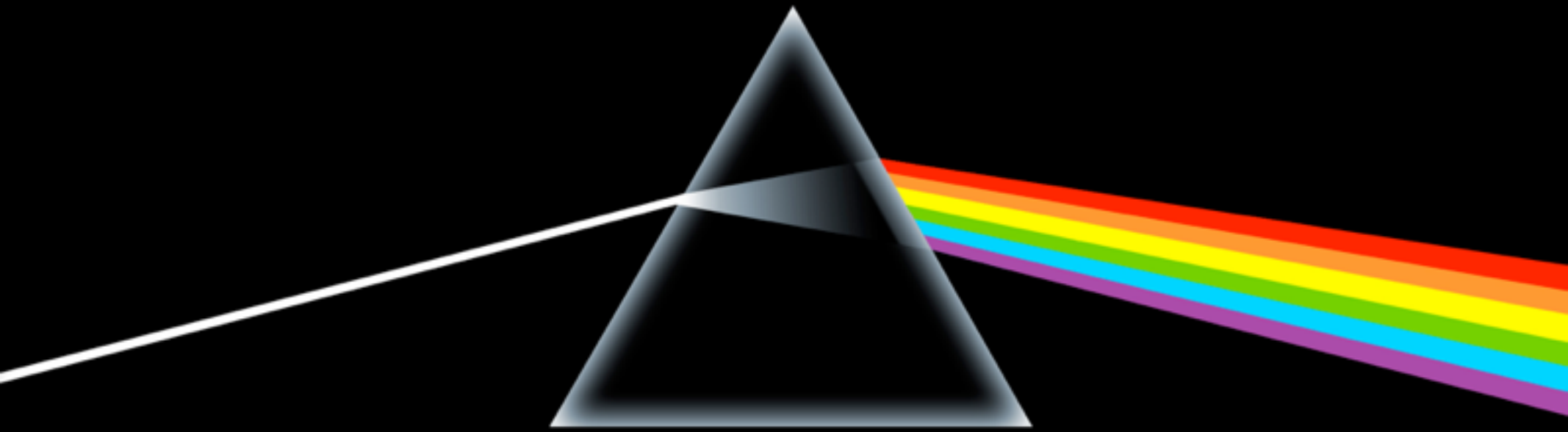
Questions (the big list)

- Why are there so many types of galaxies?
- Why do they have such different properties and sizes?
- Why do the populations change over time?
- Can galaxies change from one type to another?
- How do we figure this out?

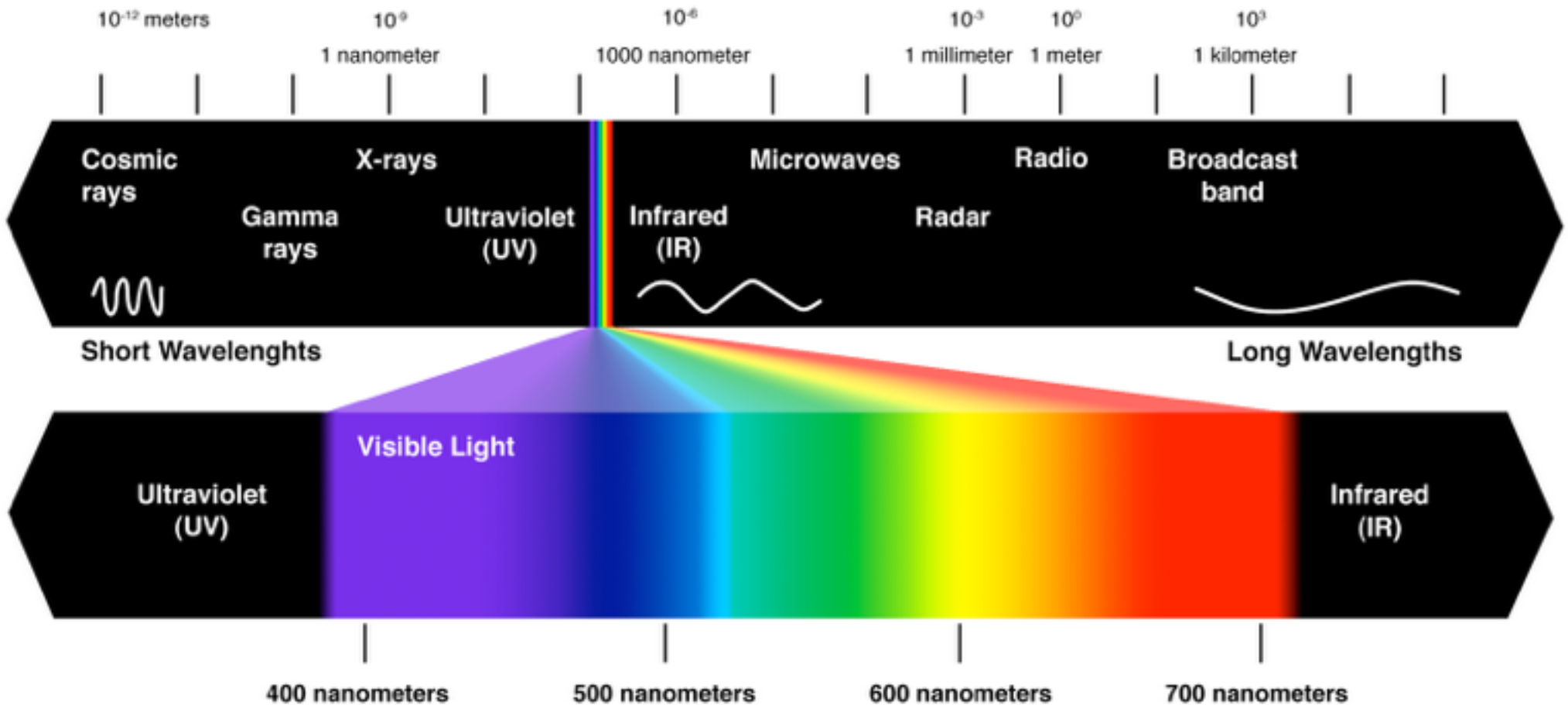
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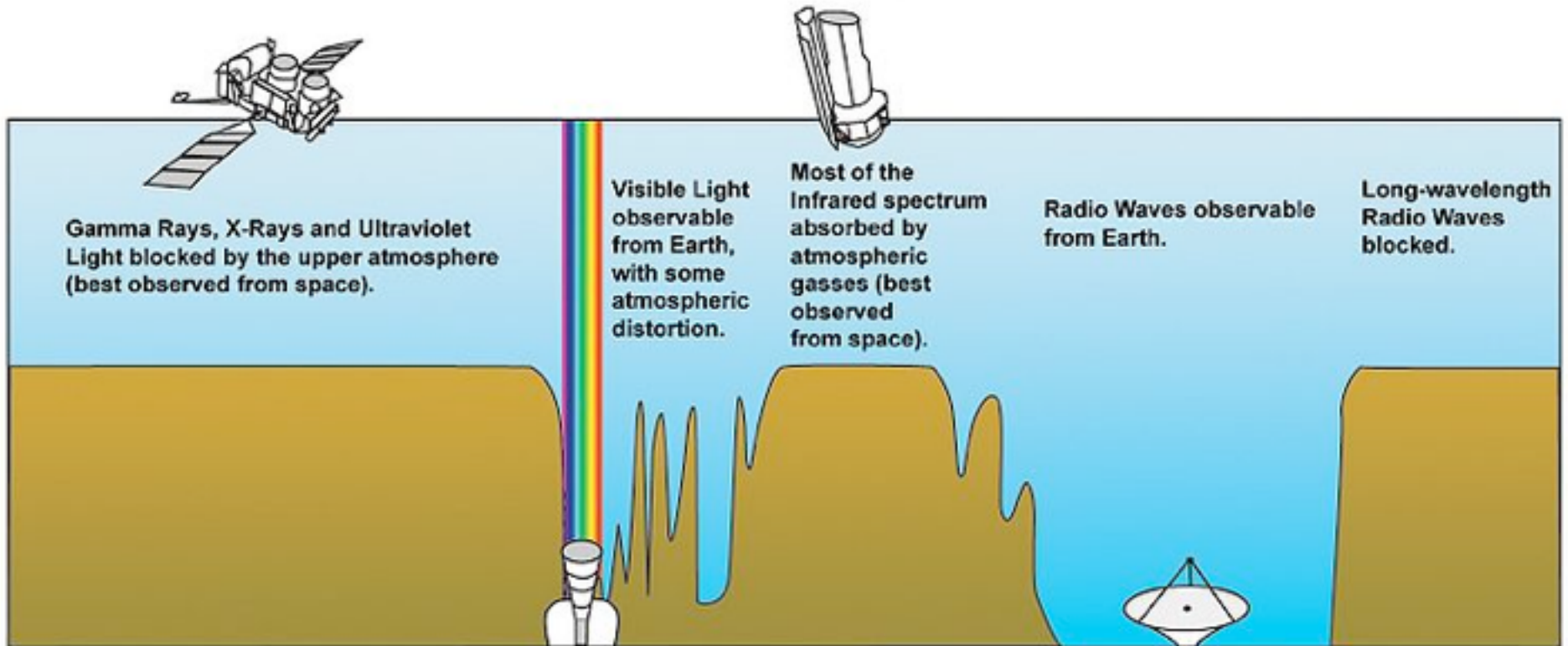
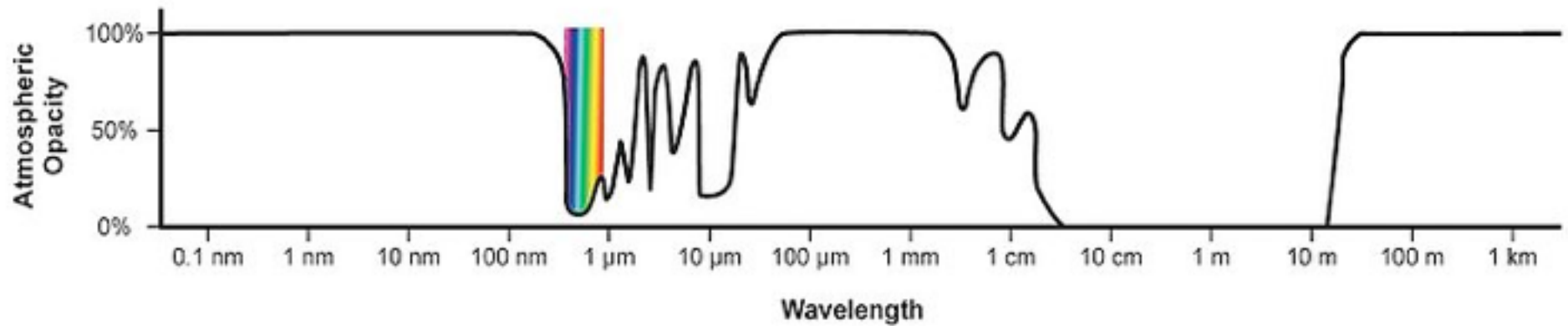
Electromagnetic Spectrum



Electromagnetic spectrum



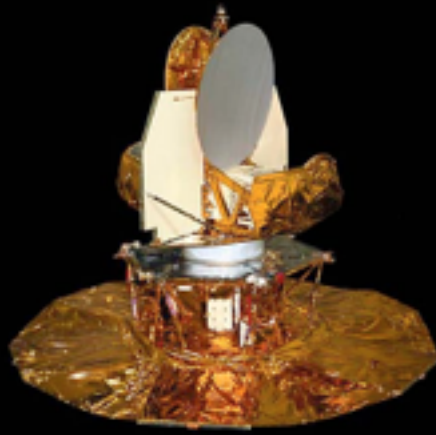
The “atmospheric window”



A multitude of
telescopes

Radio: $> \text{mm}$
wavelengths
(roughly)





MAPS2009

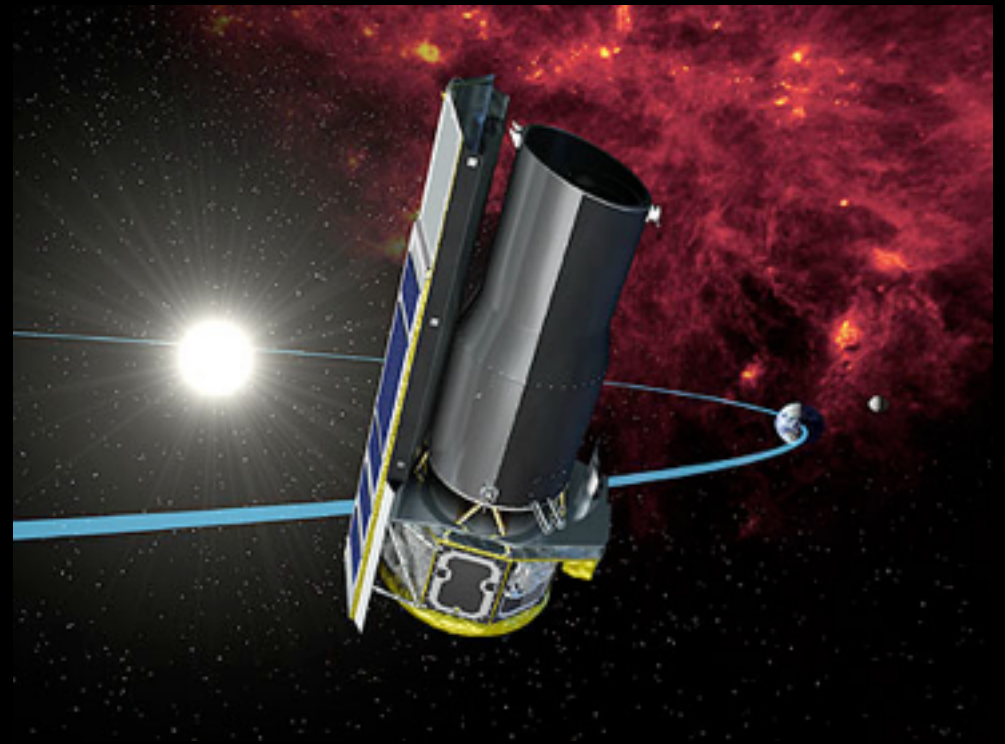
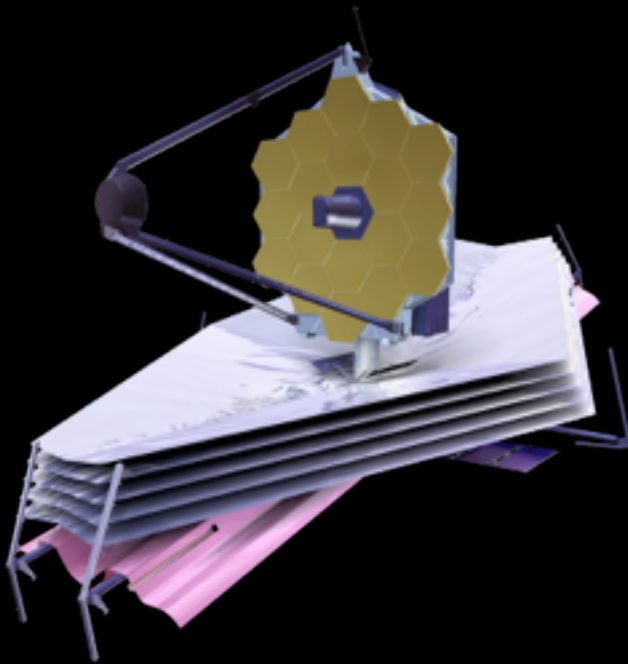


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Microwave
1 mm - 1 m

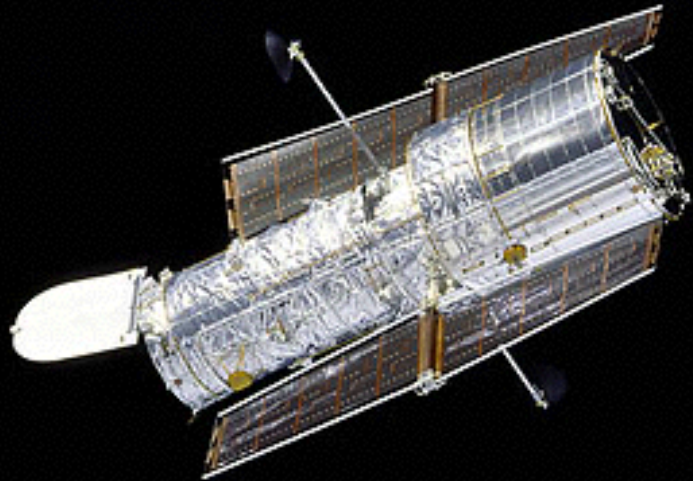


Infrared light
800 nm - 300 μm
(1-400 THz)

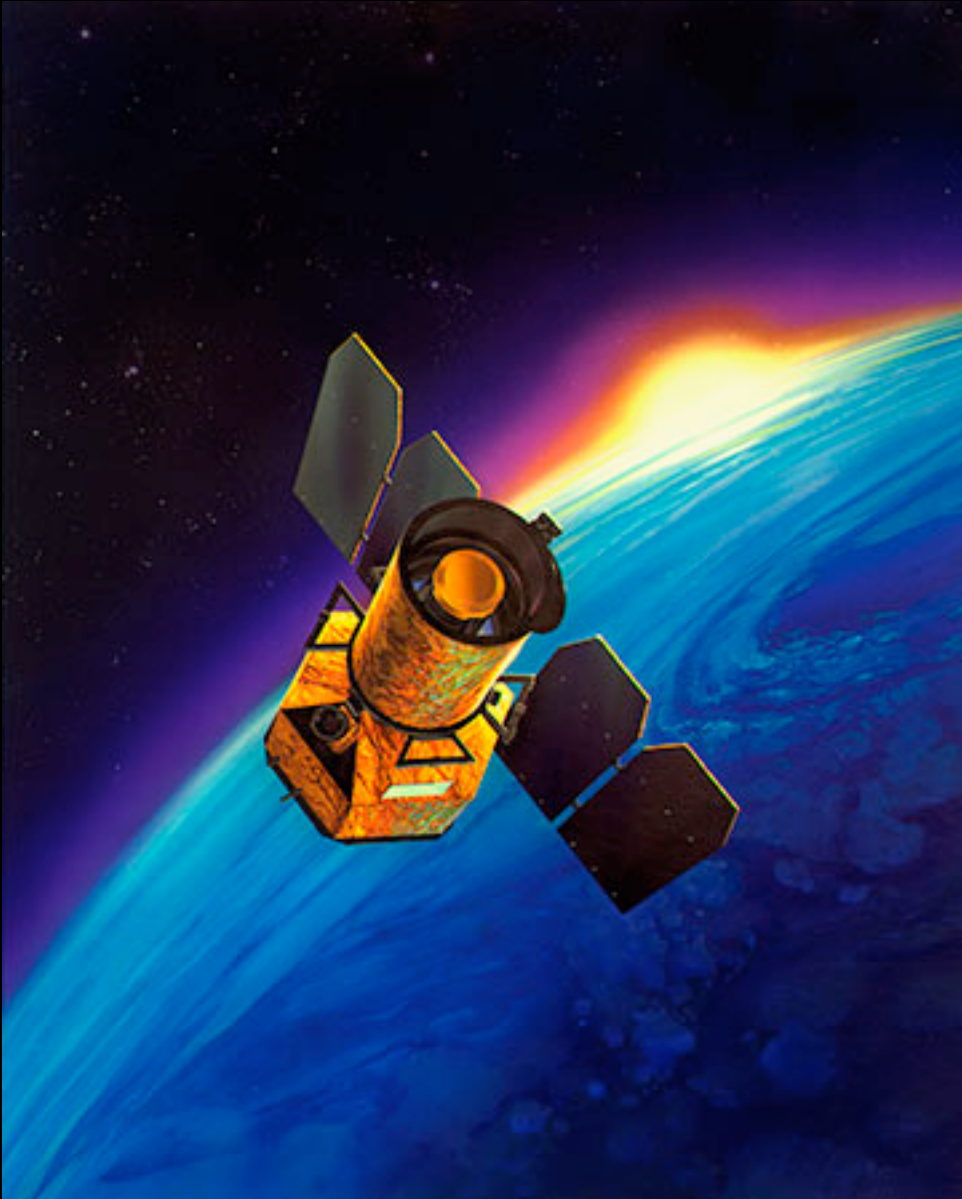




Optical light
~400-800 nm
(800-400 THz)

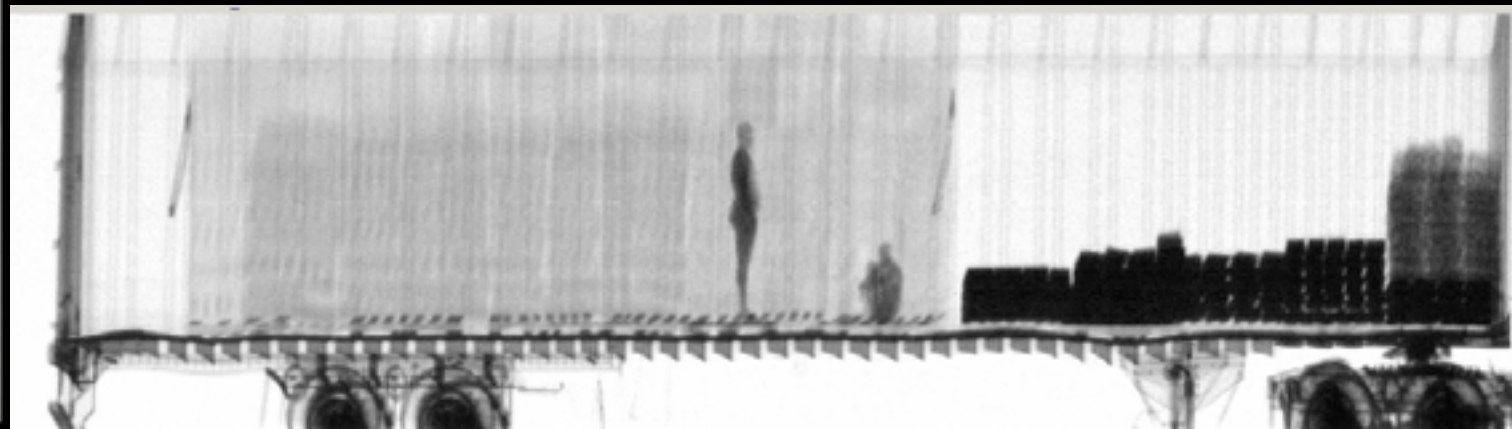


Ultraviolet 10 nm - 400 nm





X-ray: 0.1-10 nm
Gamma ray: < 0.1 nm



And now for some
examples!

The Andromeda Galaxy



Optical (400-800 nm)

Sees starlight!

The Andromeda Galaxy



Infrared: 24 micron (24,000 nm)

Looking at dust!

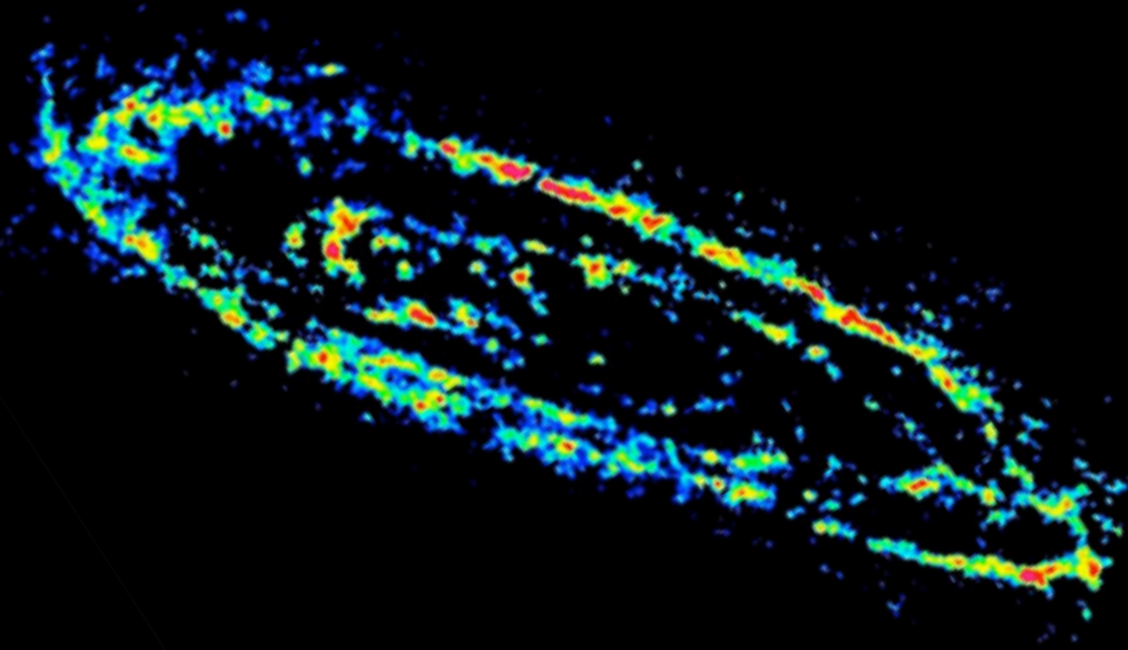
The Andromeda Galaxy



Radio: 21 cm
(210,000,000 nm)

See neutral
hydrogen!

The Andromeda Galaxy

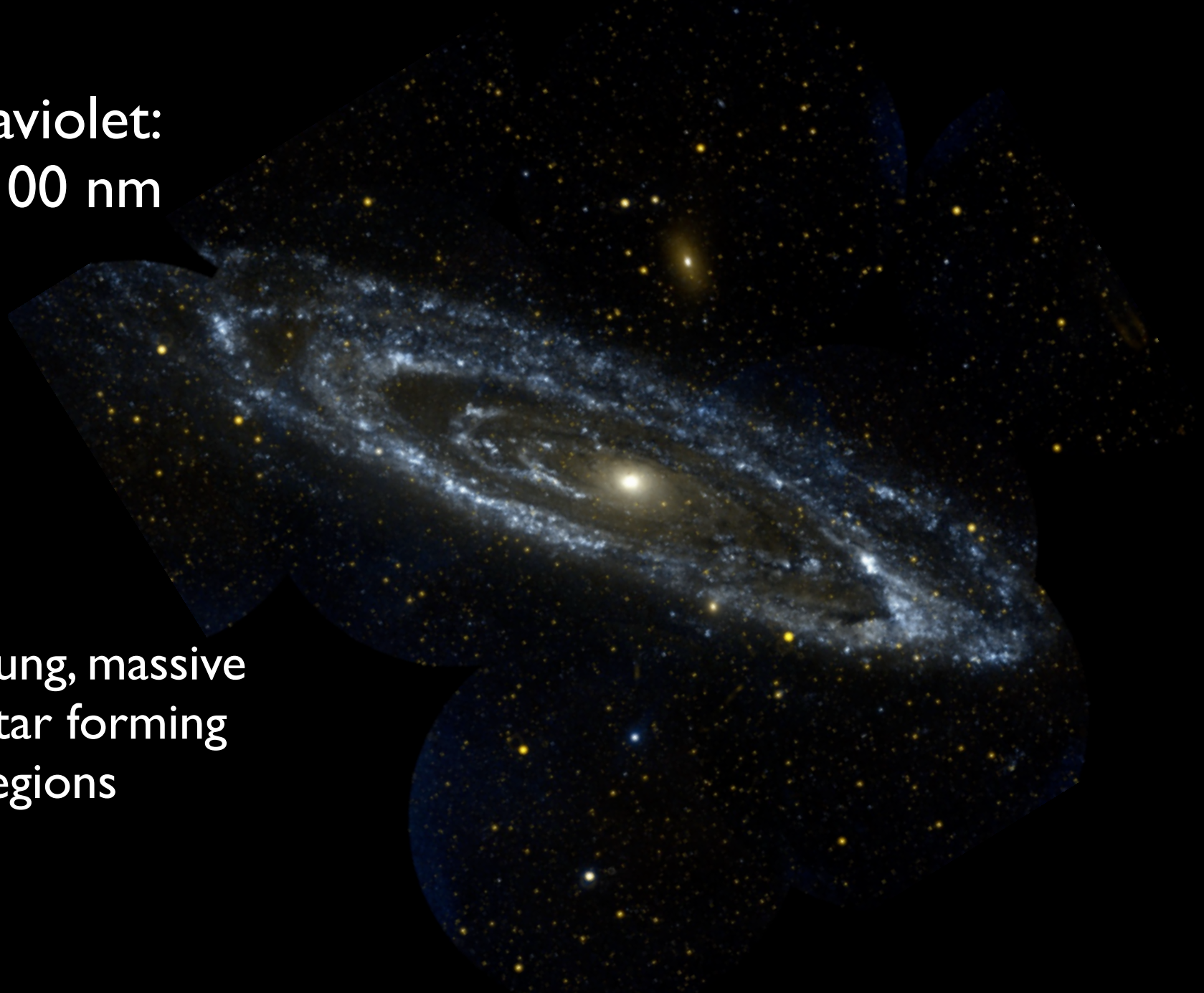


Radio: 2.6 mm
(2,600,000 nm)

Sees CO/cold gas

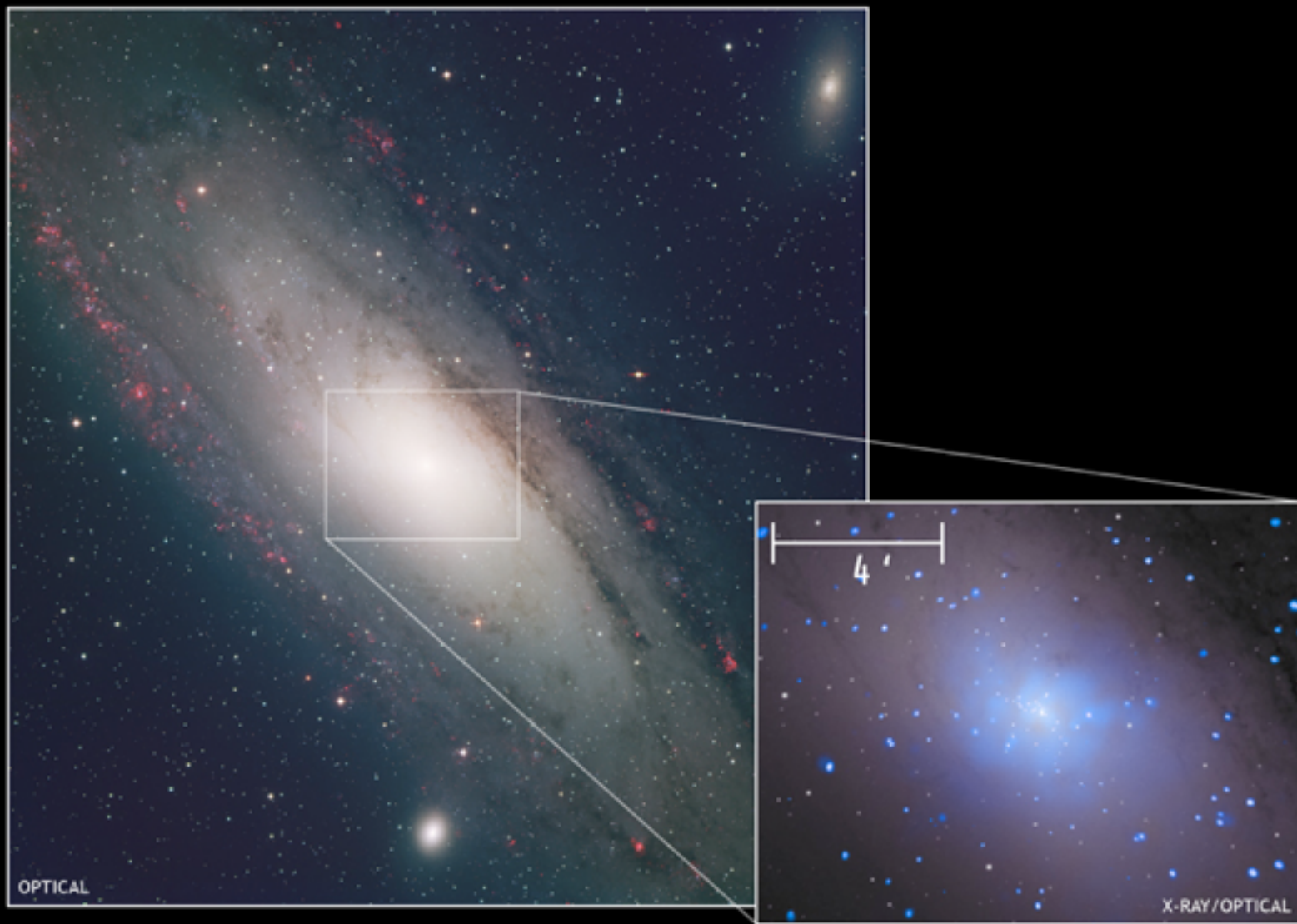
The Andromeda Galaxy

Ultraviolet:
~ 100 nm



Sees young, massive
stars, star forming
regions

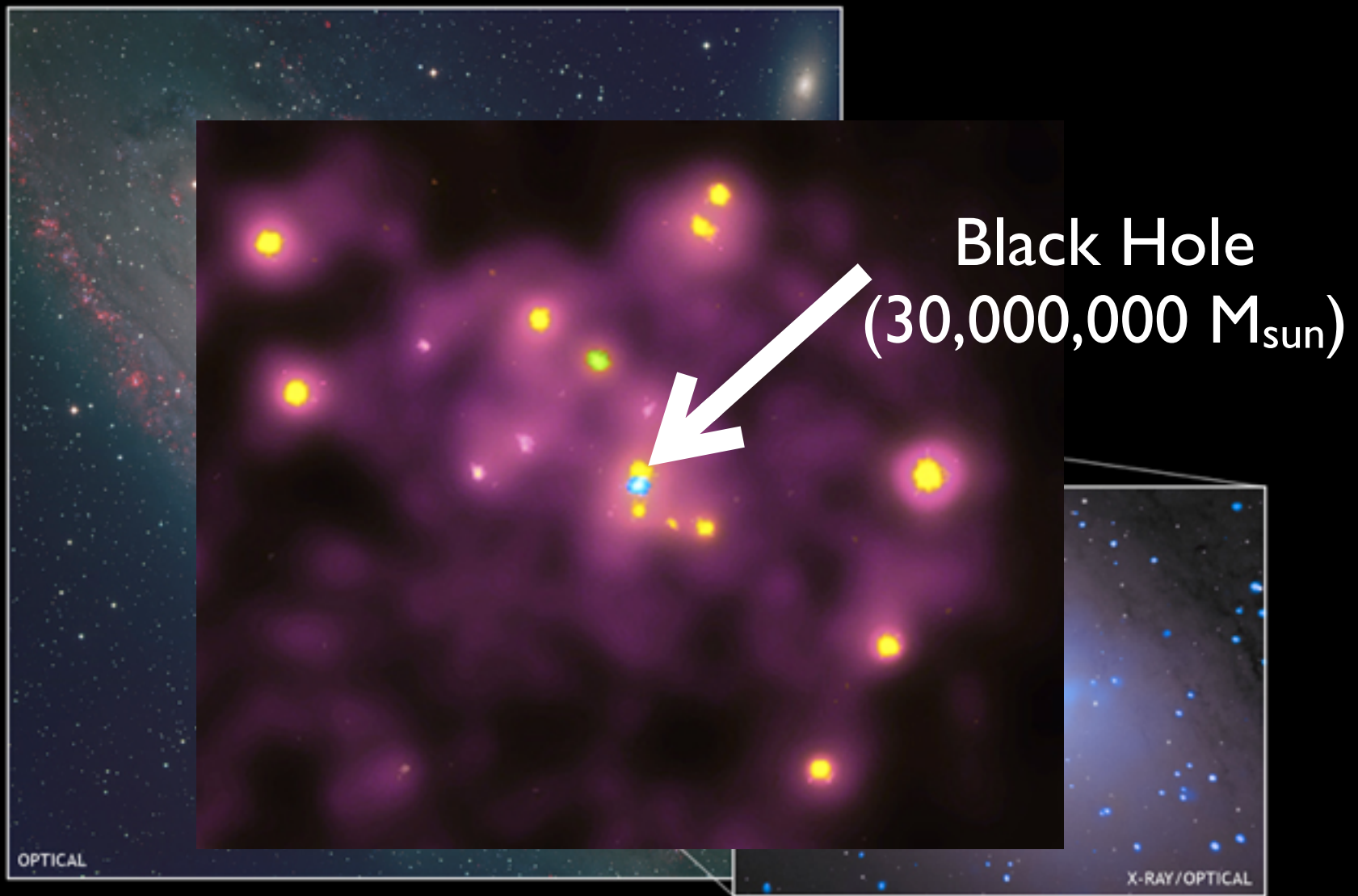
The Andromeda Galaxy



X-ray: approx. 1 nm

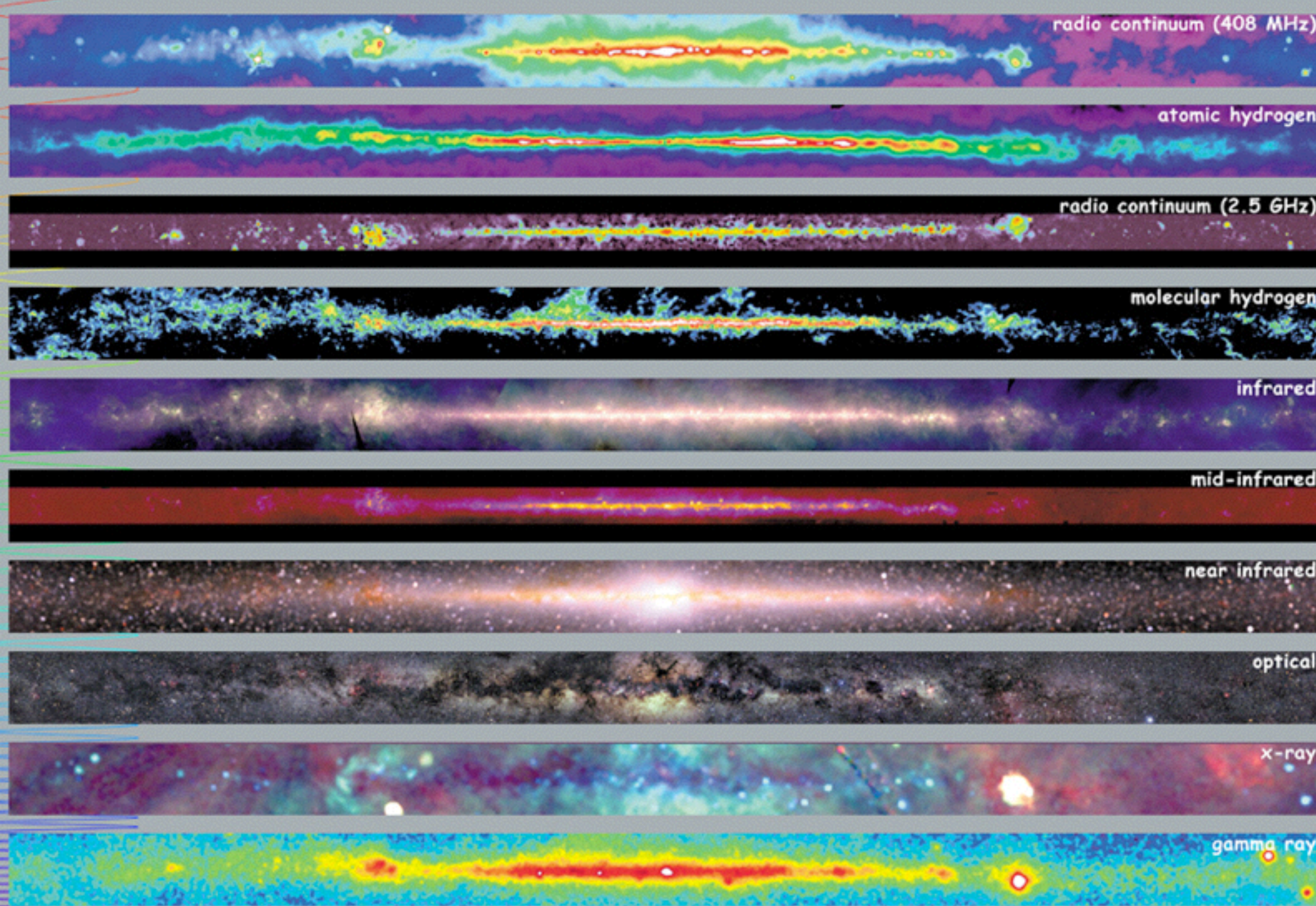
Sees: very hot gas ($> 10^6$ K)

The Andromeda Galaxy



X-ray: approx. 1 nm

Sees: very hot gas ($> 10^6$ K)



Multiwavelength Milky Way

Milky Way



Optical

Milky Way



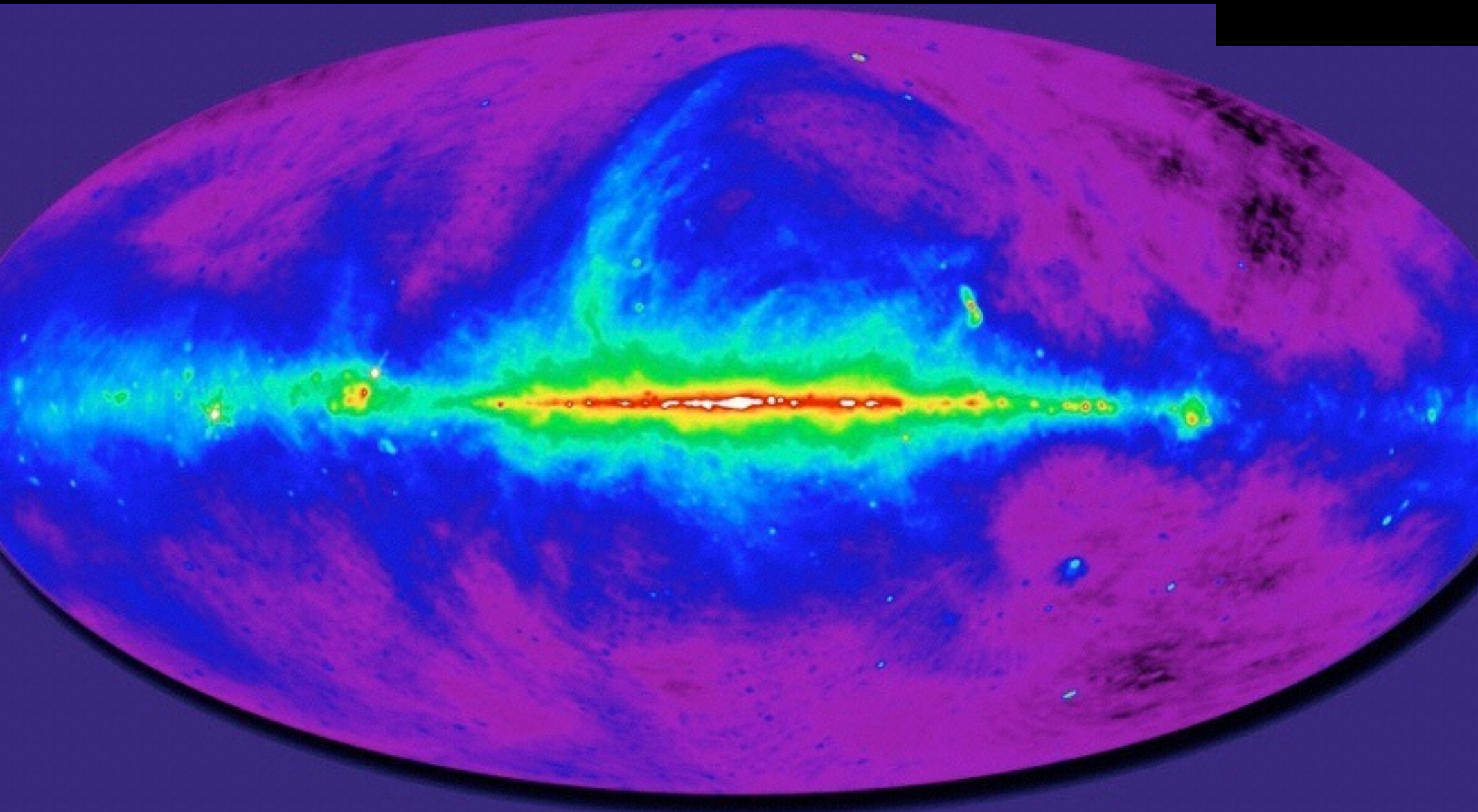
Near Infrared

Milky Way



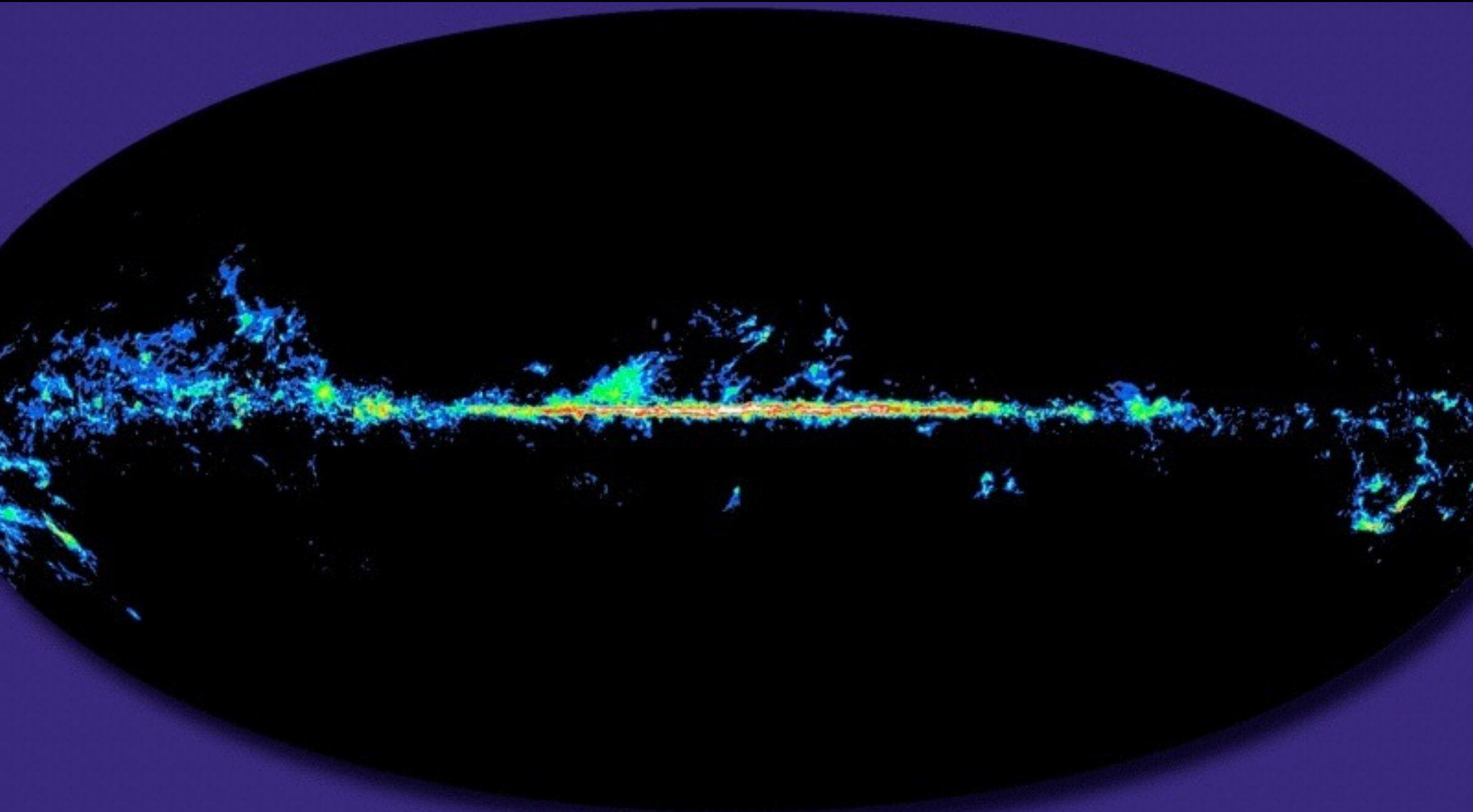
Infrared

Milky Way



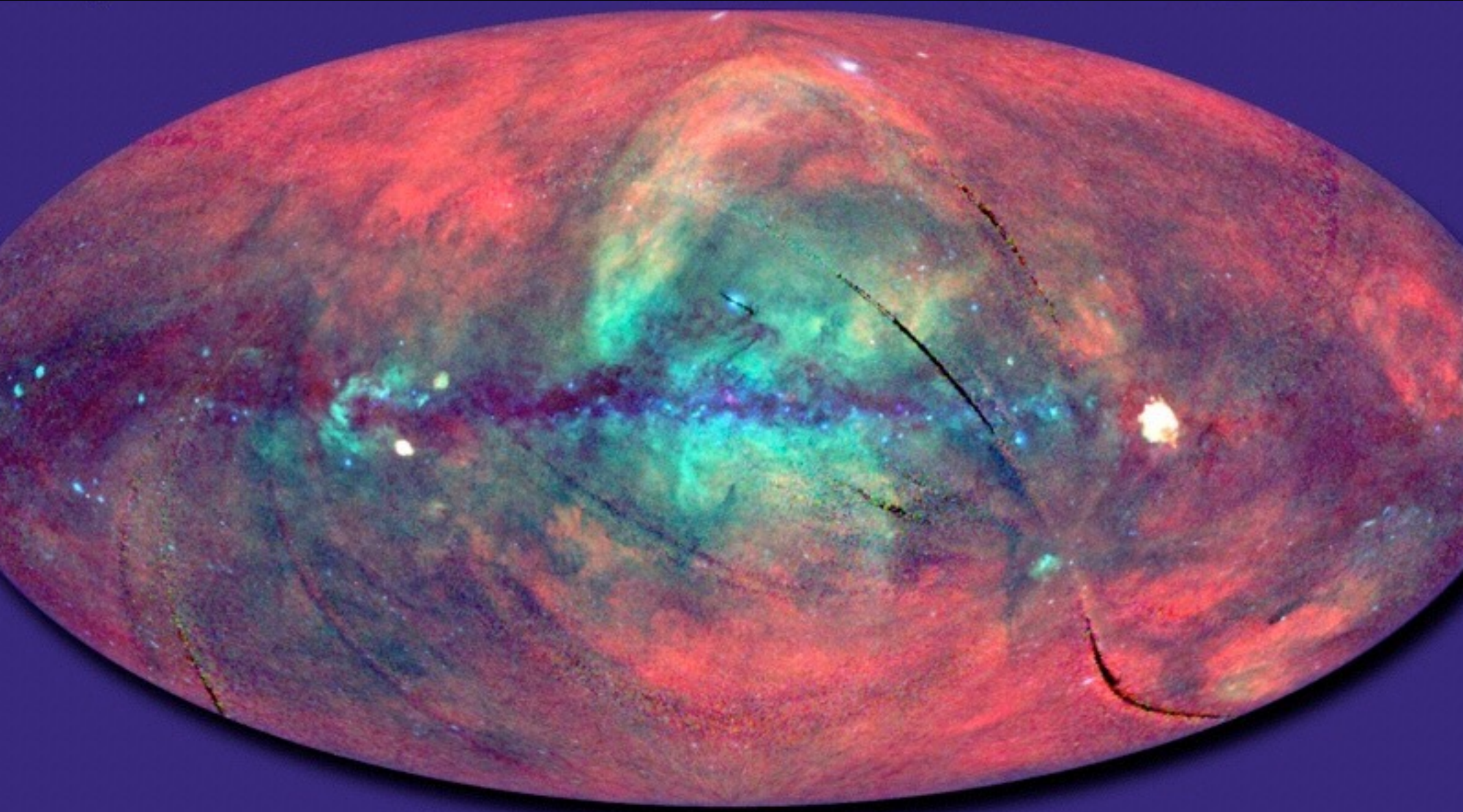
Radio - 408 Mhz

Milky Way



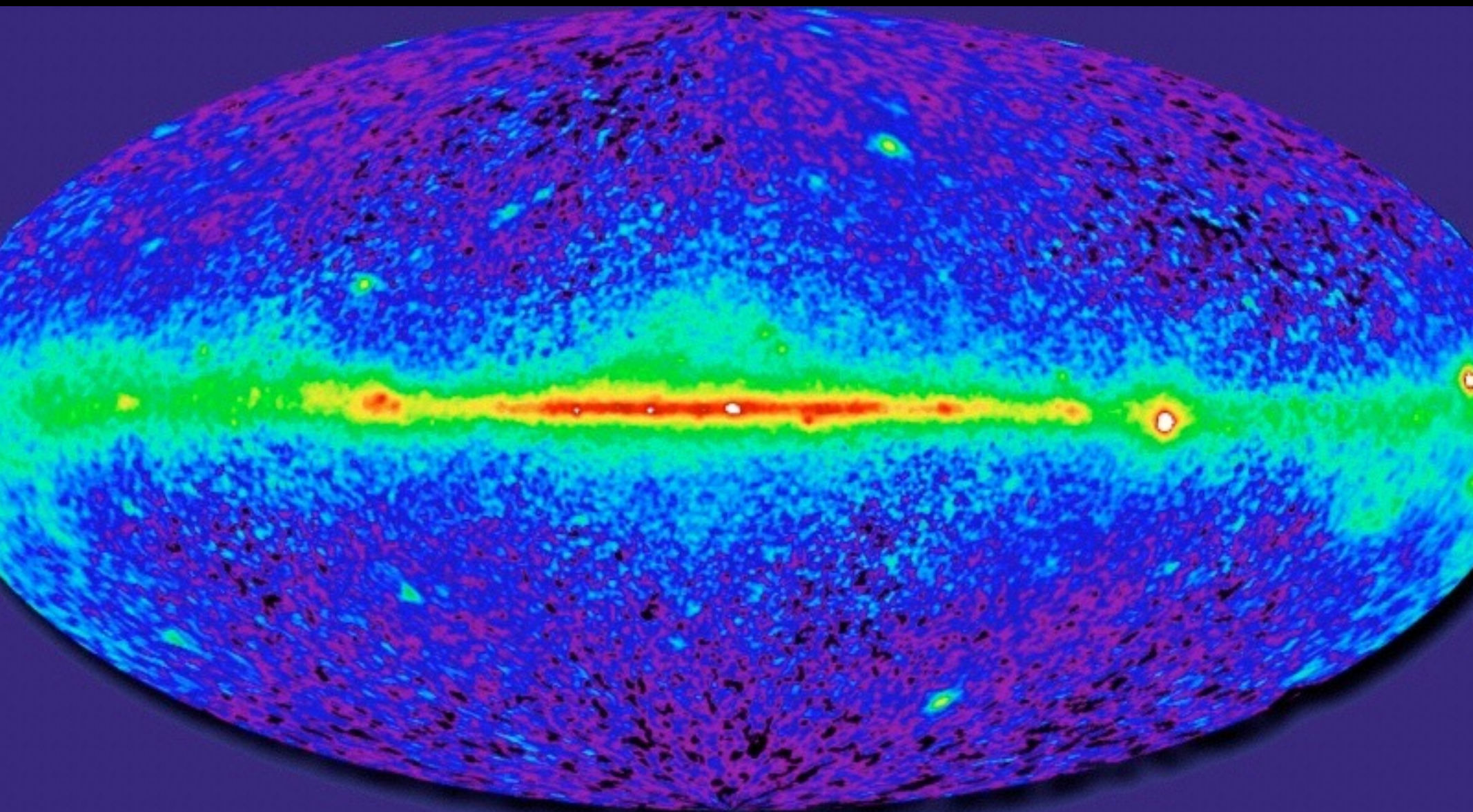
Radio - 118 Ghz

Milky Way



X-ray

Milky Way



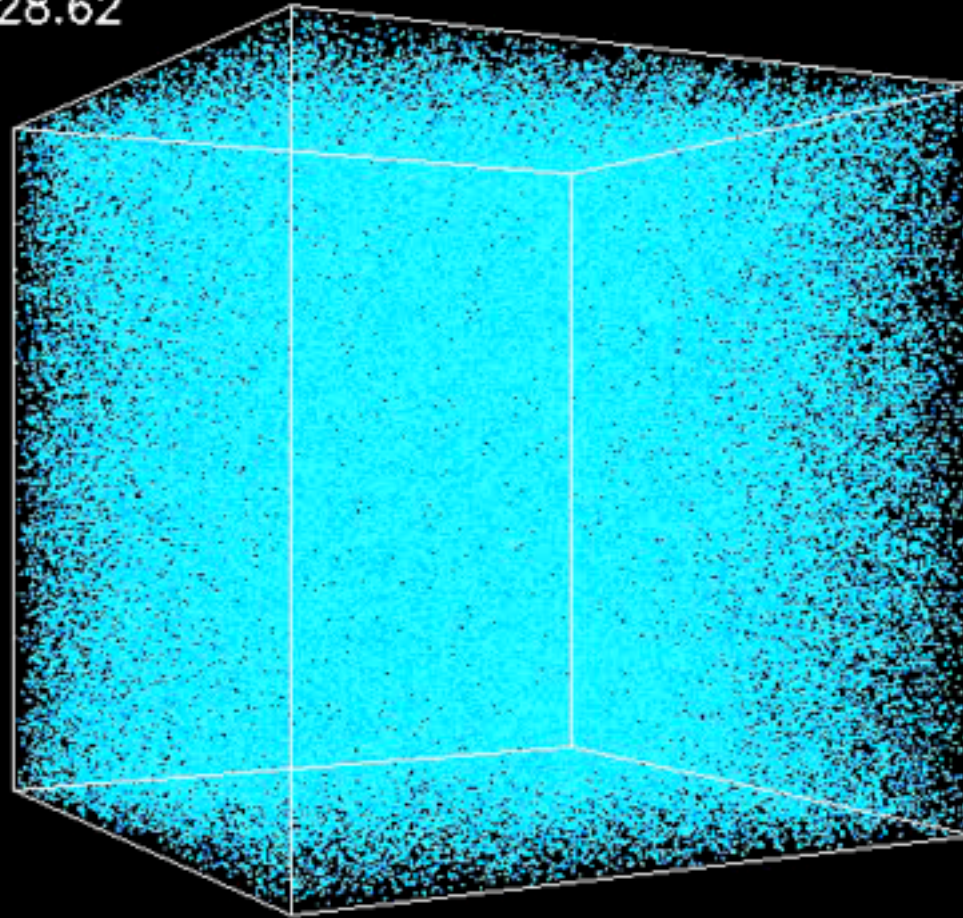
Gamma ray

Supercomputers: telescopes for theoretical astrophysicists



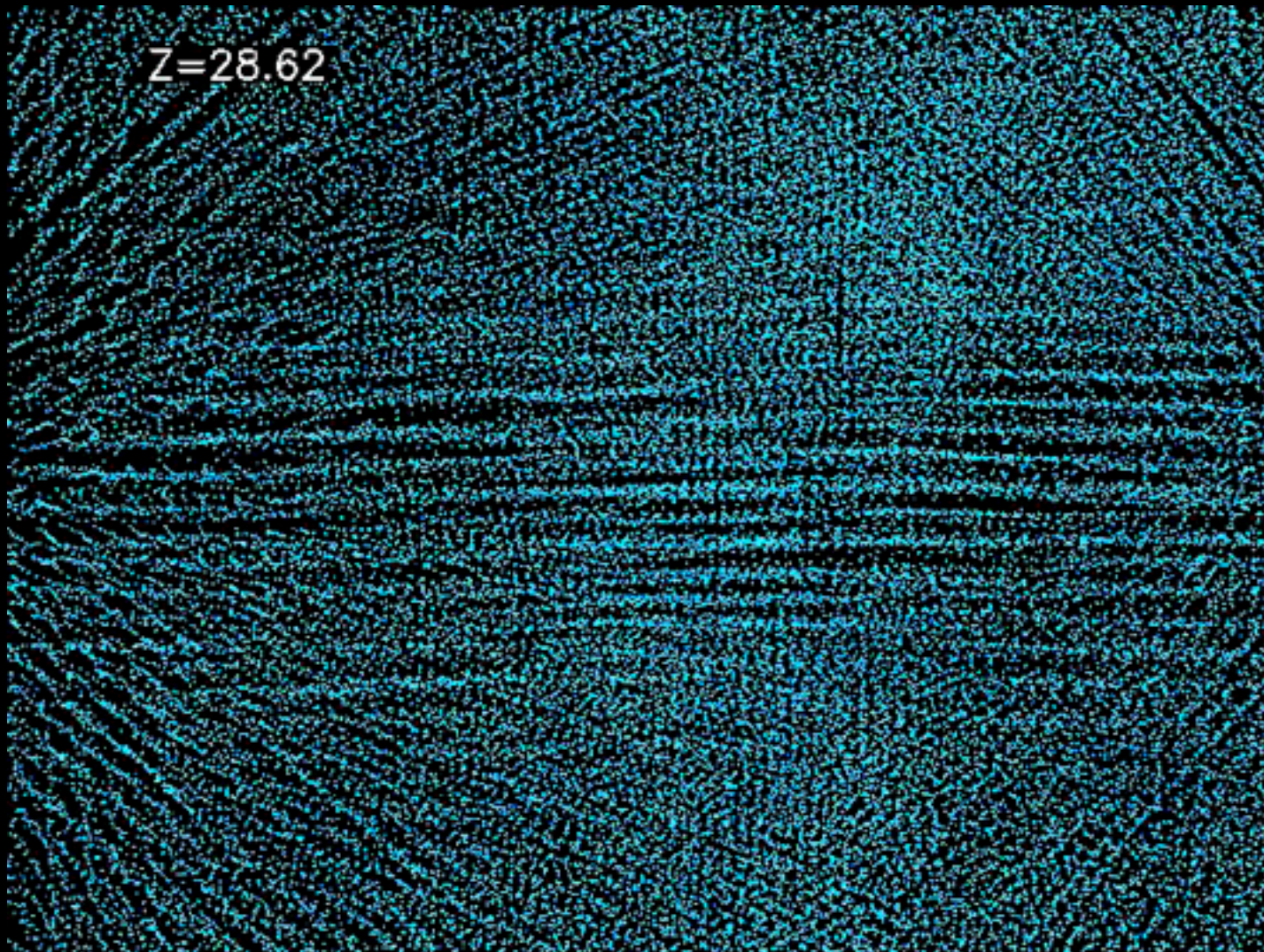
Formation of cosmological structure

$Z=28.62$



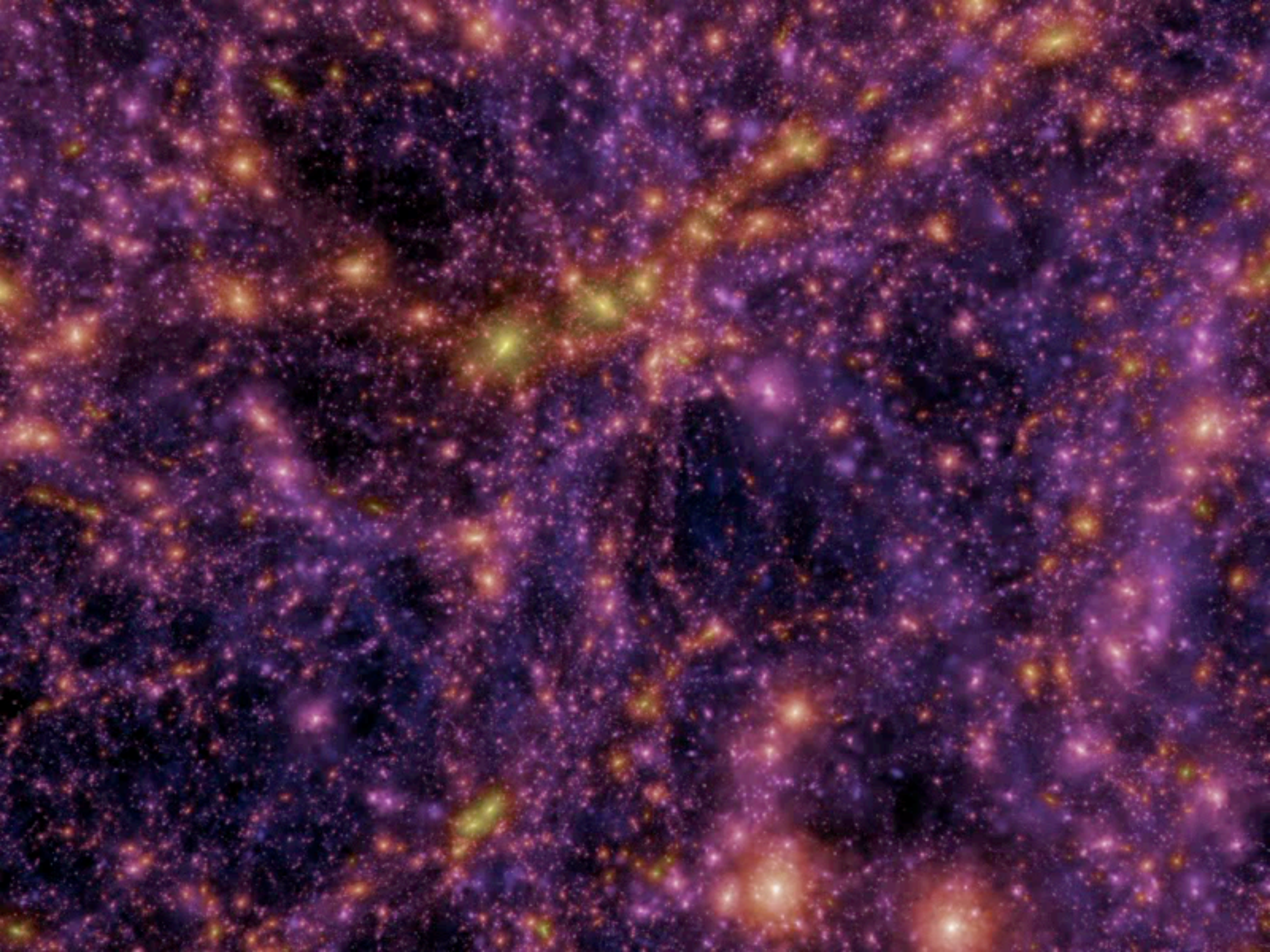
box size = 140 million light years across
start at $t \sim 1$ million years ABB, end at present day

Formation of a group of galaxies



Field of view = 14 million LY across

Final object = the Local Group (roughly)



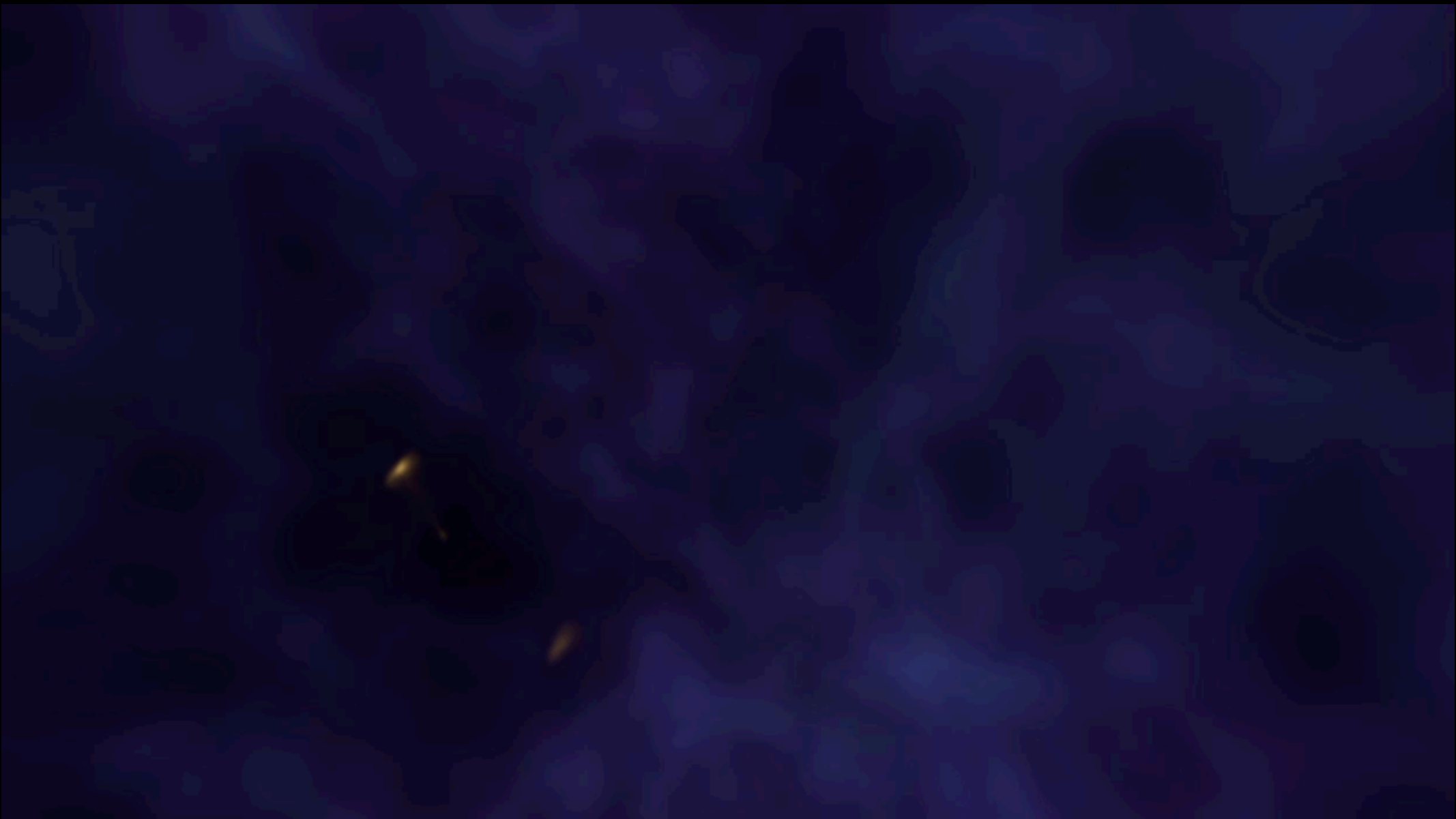
0.0 Gyr

Stars

10 kpc

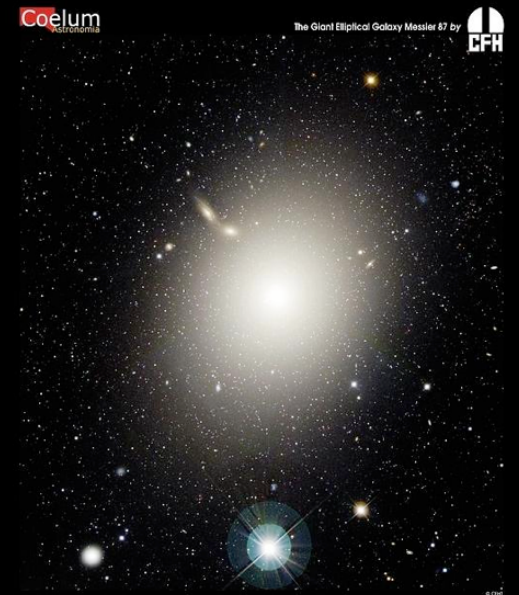

Movie c/o
Phil Hopkins,
CalTech

Galaxy formation - closeup

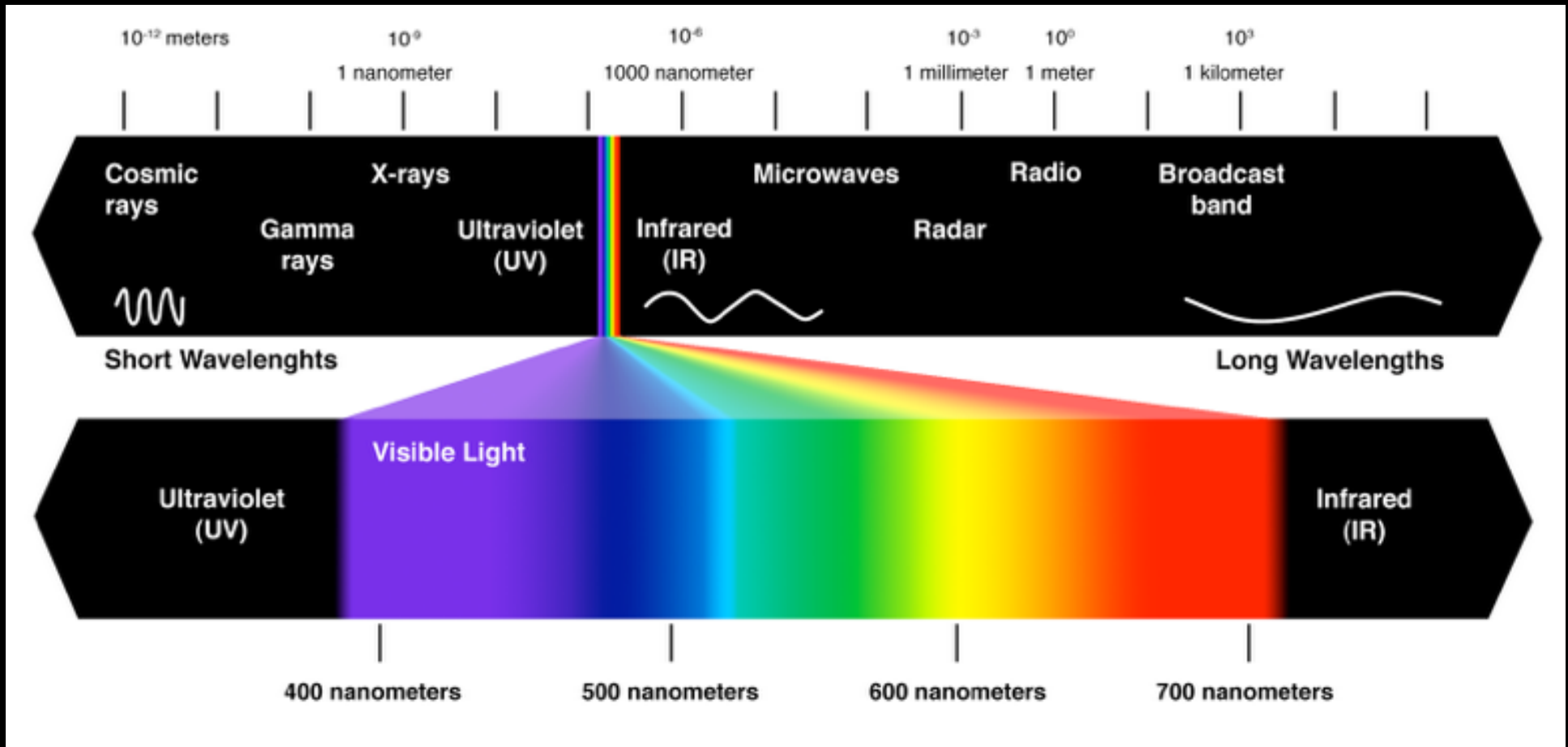


So, what did we learn?

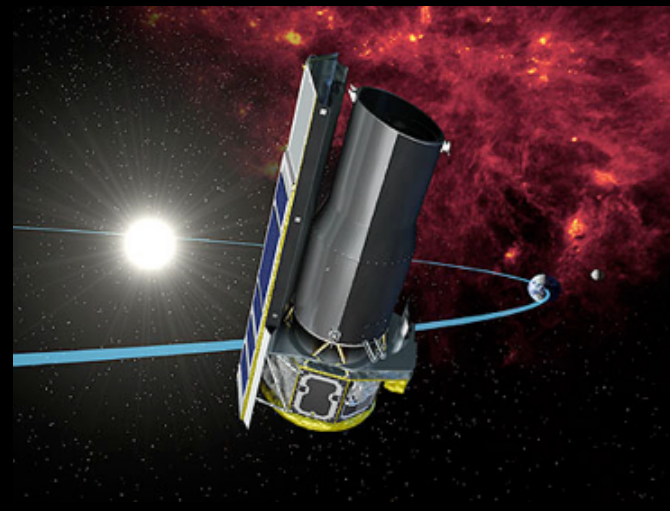
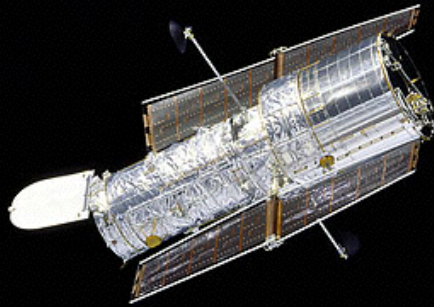
- Galaxies come in many shapes and sizes, and have wildly different properties



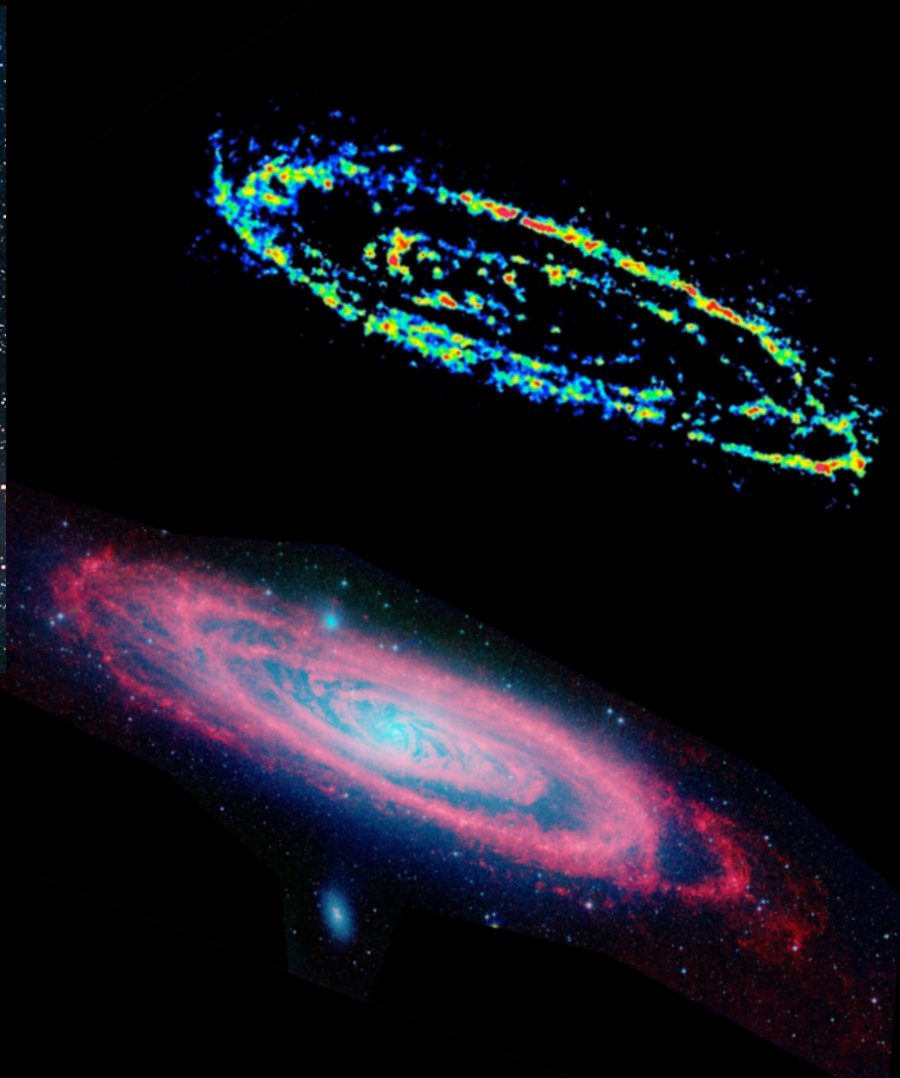
- The light that we can see with our eyes is only a small part of the electromagnetic spectrum...



- Astronomers have constructed telescopes that can see at many different wavelengths, from radio through gamma ray



- and looking at a galaxy over the whole spectrum of light teaches us important things about how galaxies form and what they're made out of!



- We can also use supercomputers as ‘theoretical telescopes’ to probe how galaxies form!



- Using these tools, we have discovered that the different types of galaxies - disc, spiral, dwarf, elliptical - are phases in the evolution of a galaxy!



Questions?

