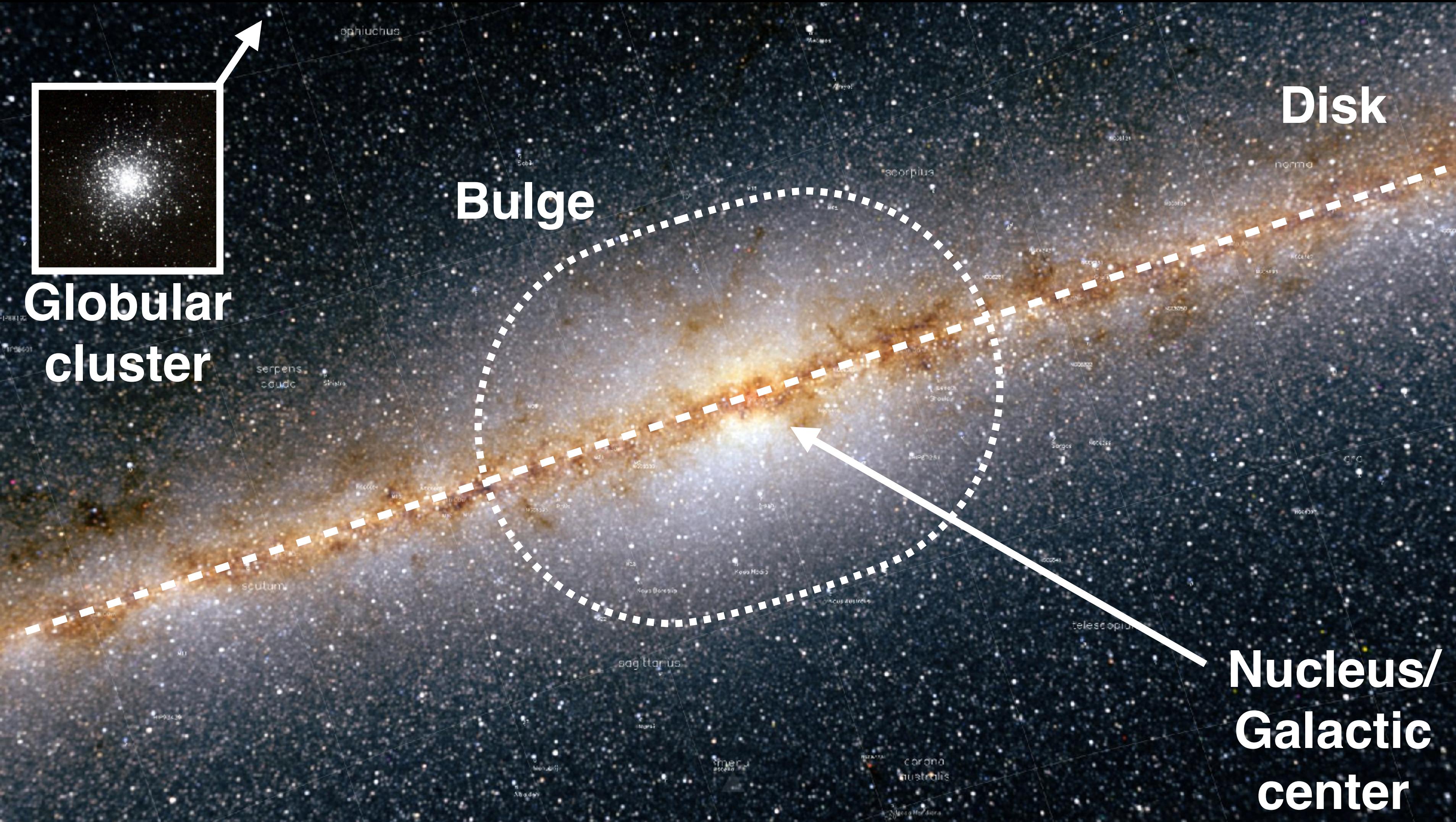


ISM: The Interstellar Medium

The gas and dust between and around the stars in a galaxy

The Milky Way (infrared view):



The Disk



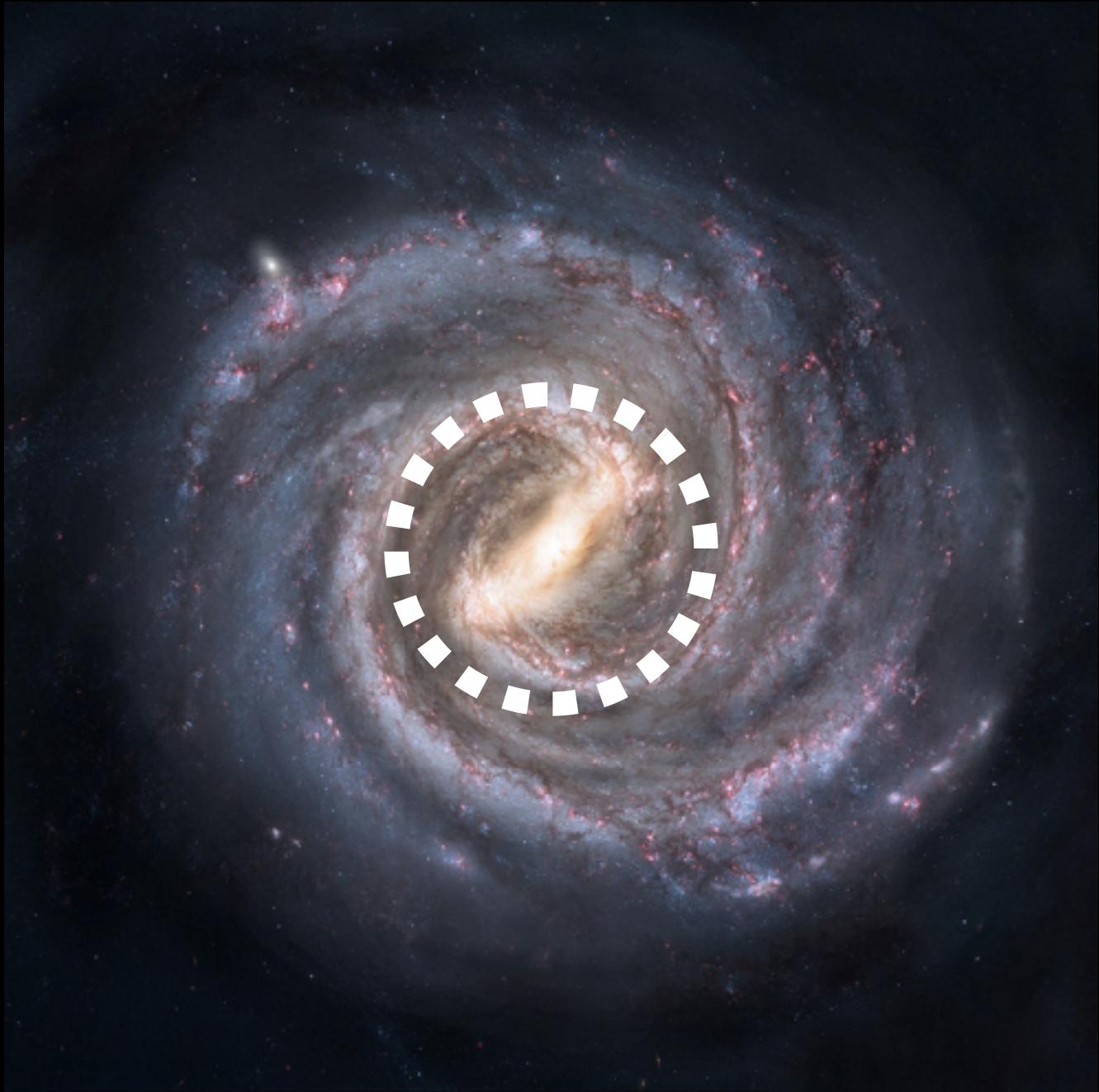
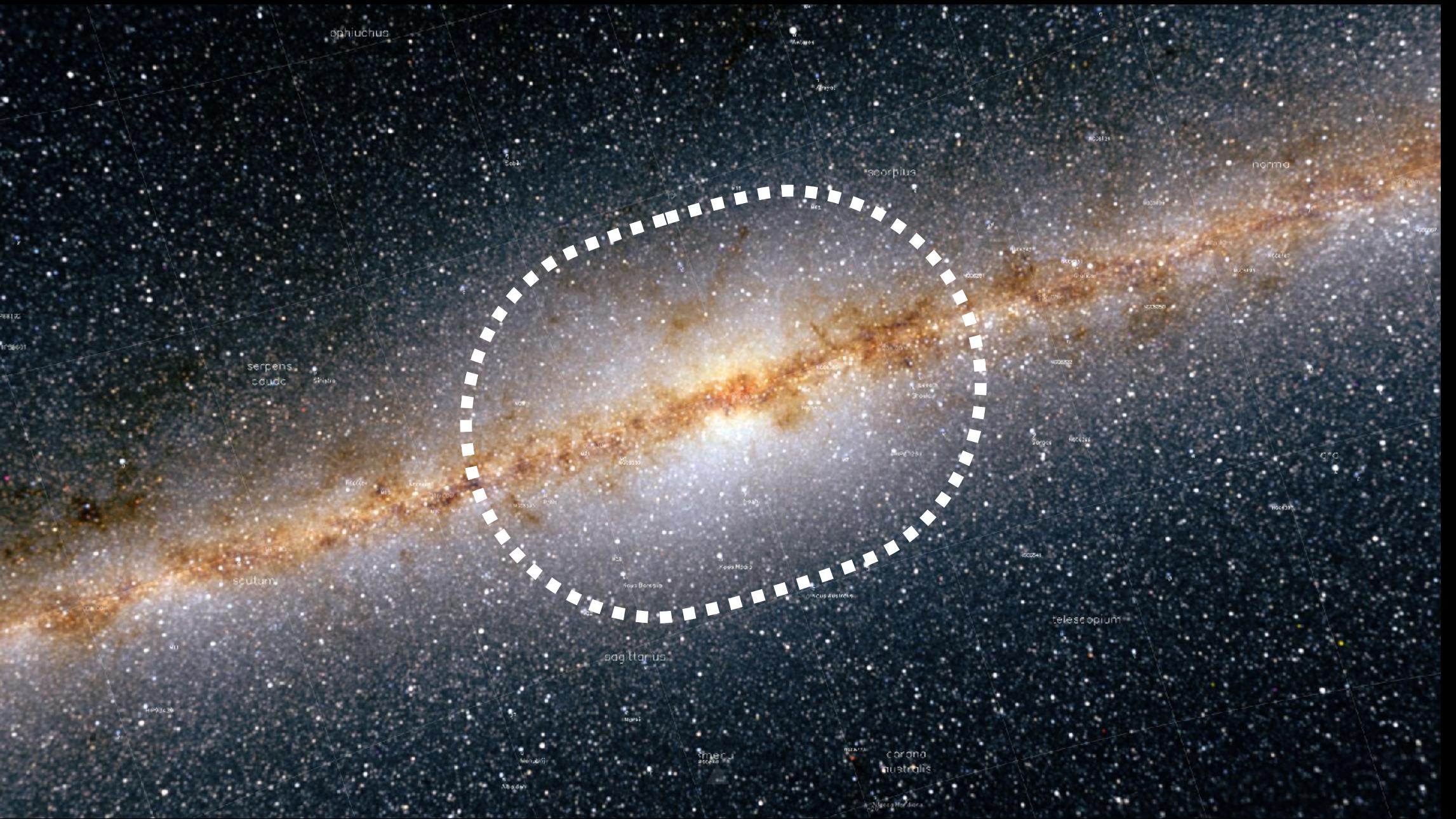
Flat, circular shape (like a DVD)

Contains younger (bluer stars)

Contains gas and dust

Contains the spiral arms of the Galaxy

The Bulge



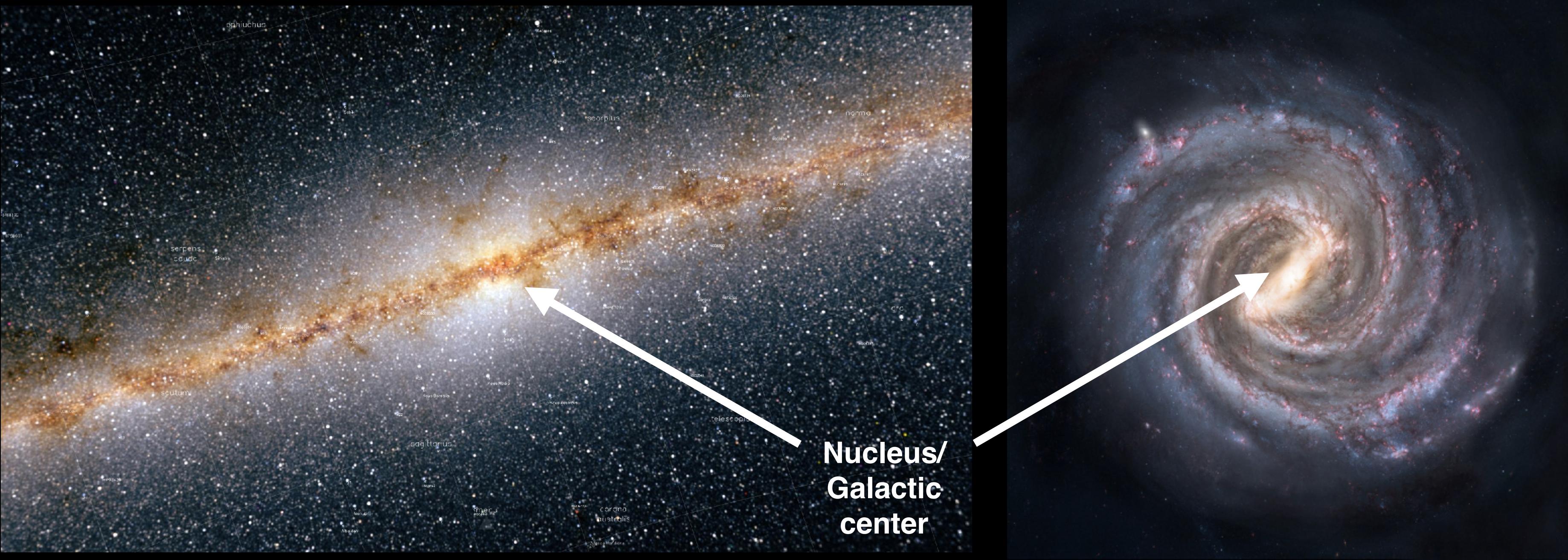
Centrally located

Spheroidal (squashed) shape

Contains older (redder stars)

Contains the central bar of our galaxy

The Galactic center



The very central light years of the Galaxy

Contains a supermassive black hole

The Halo

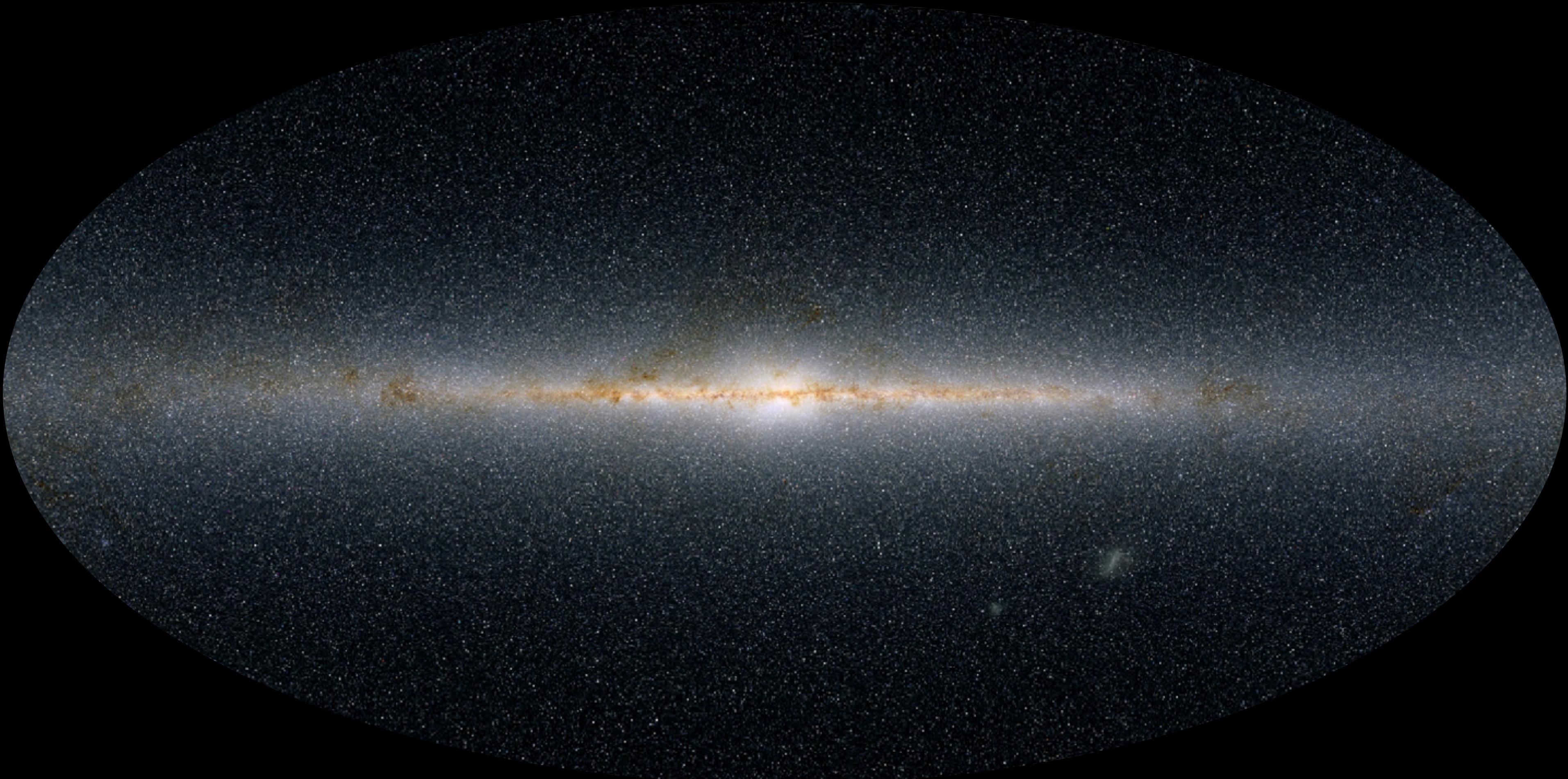


Giant, spheroidal shape surrounding the Galaxy
Contains the oldest stars
The location of most of the globular clusters in the Galaxy
Contains hot, X-ray gas
Dominated by dark matter

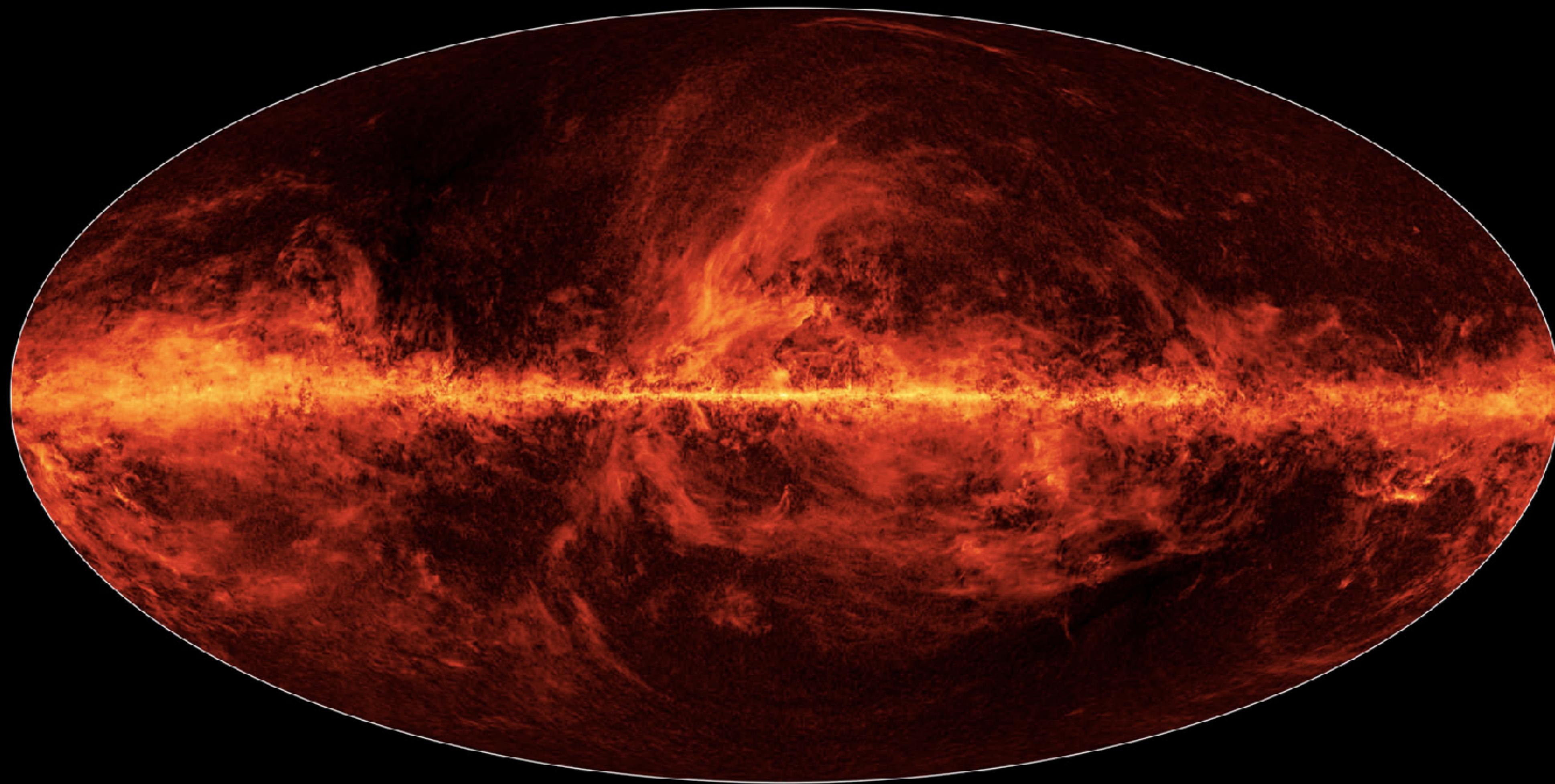
Optical



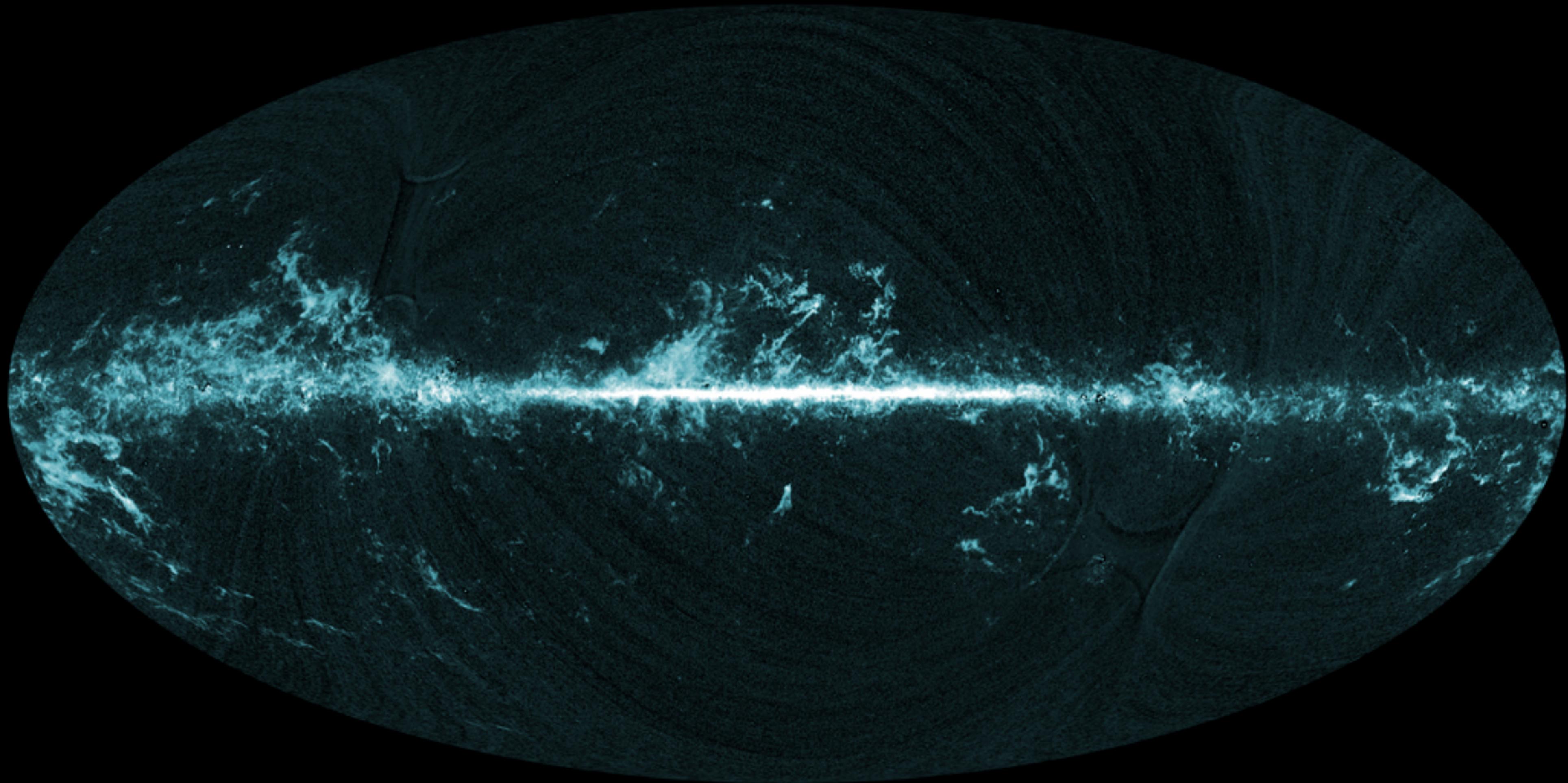
Infrared



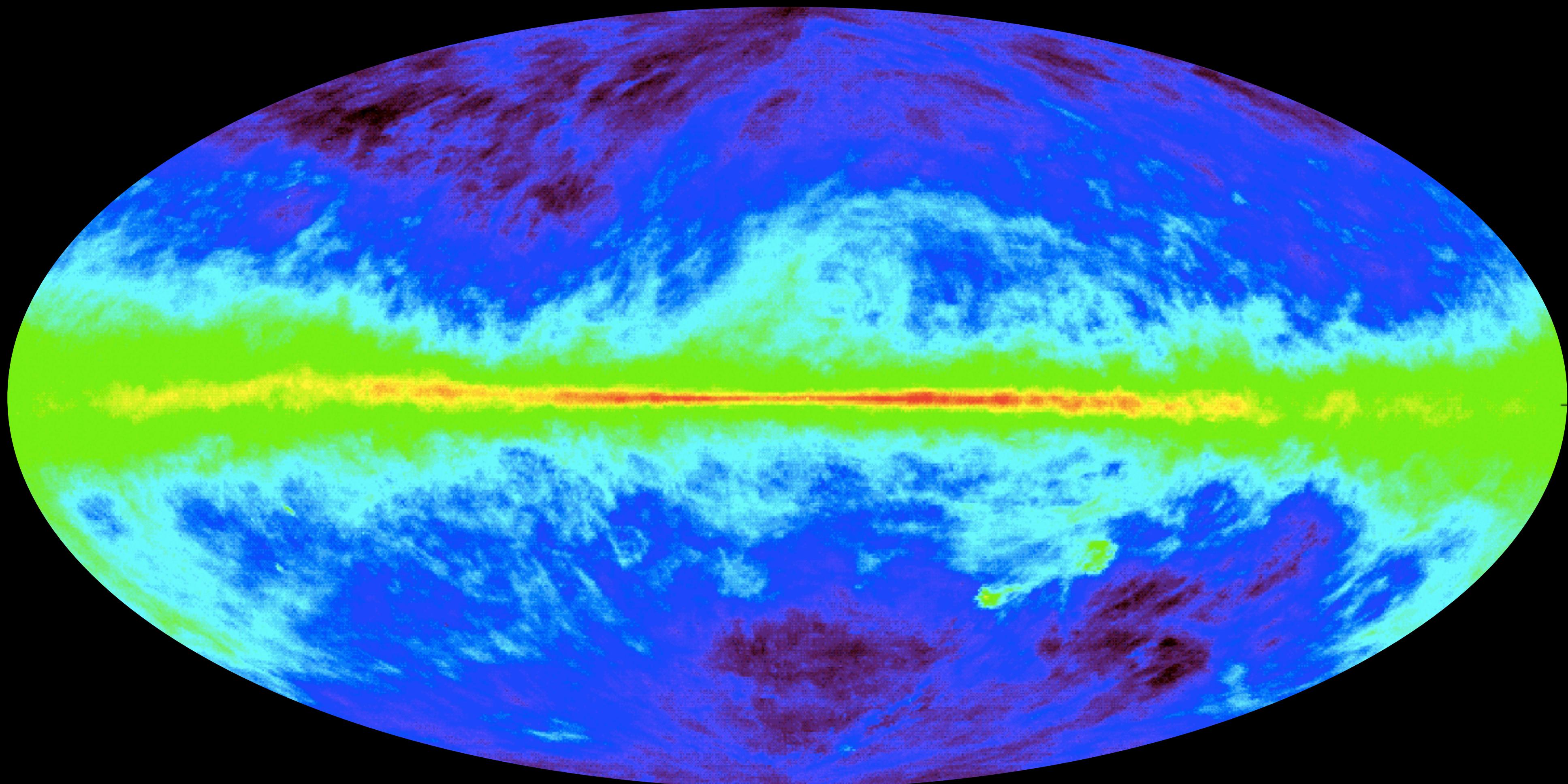
Dust



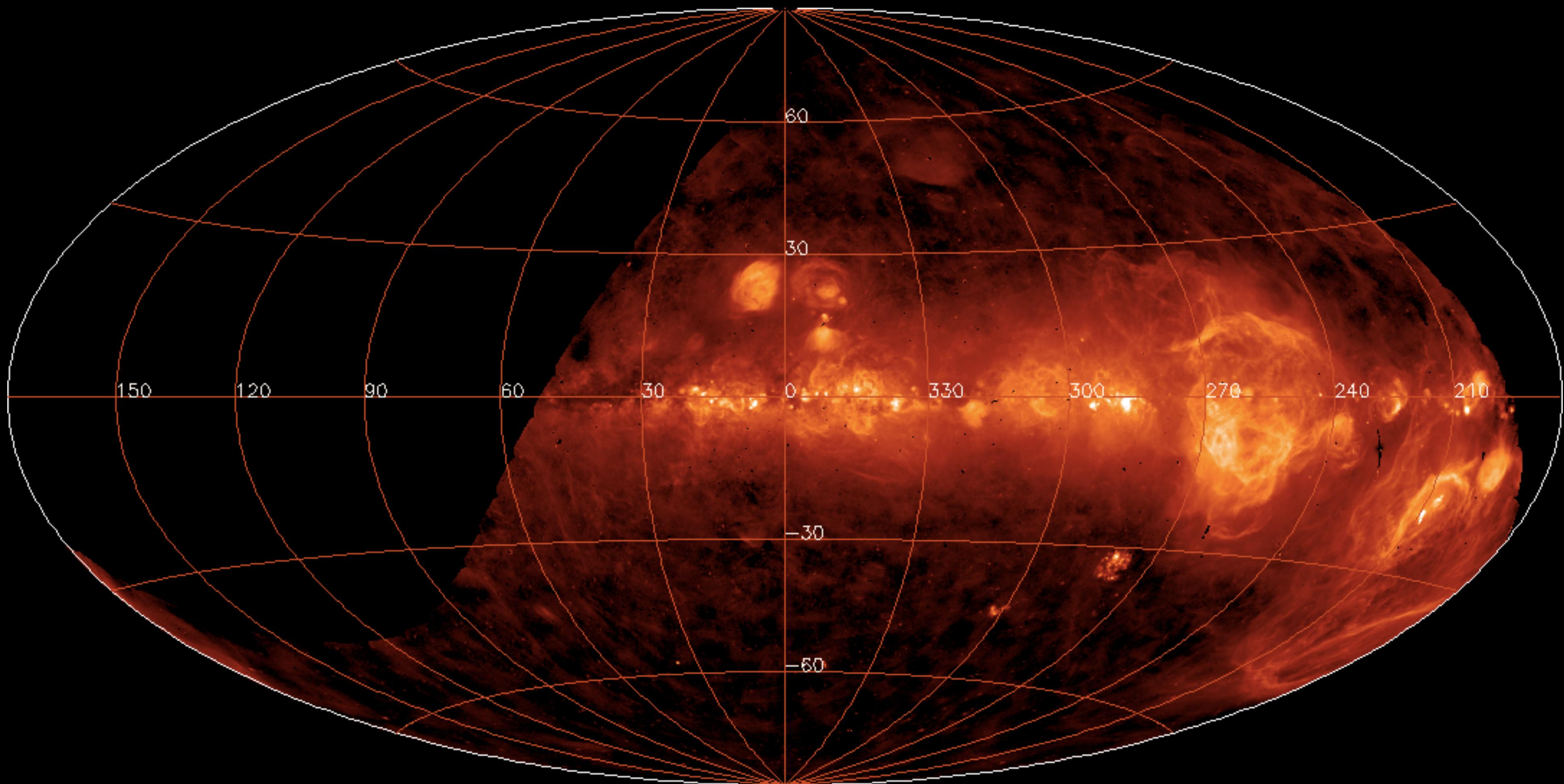
Molecular Hydrogen



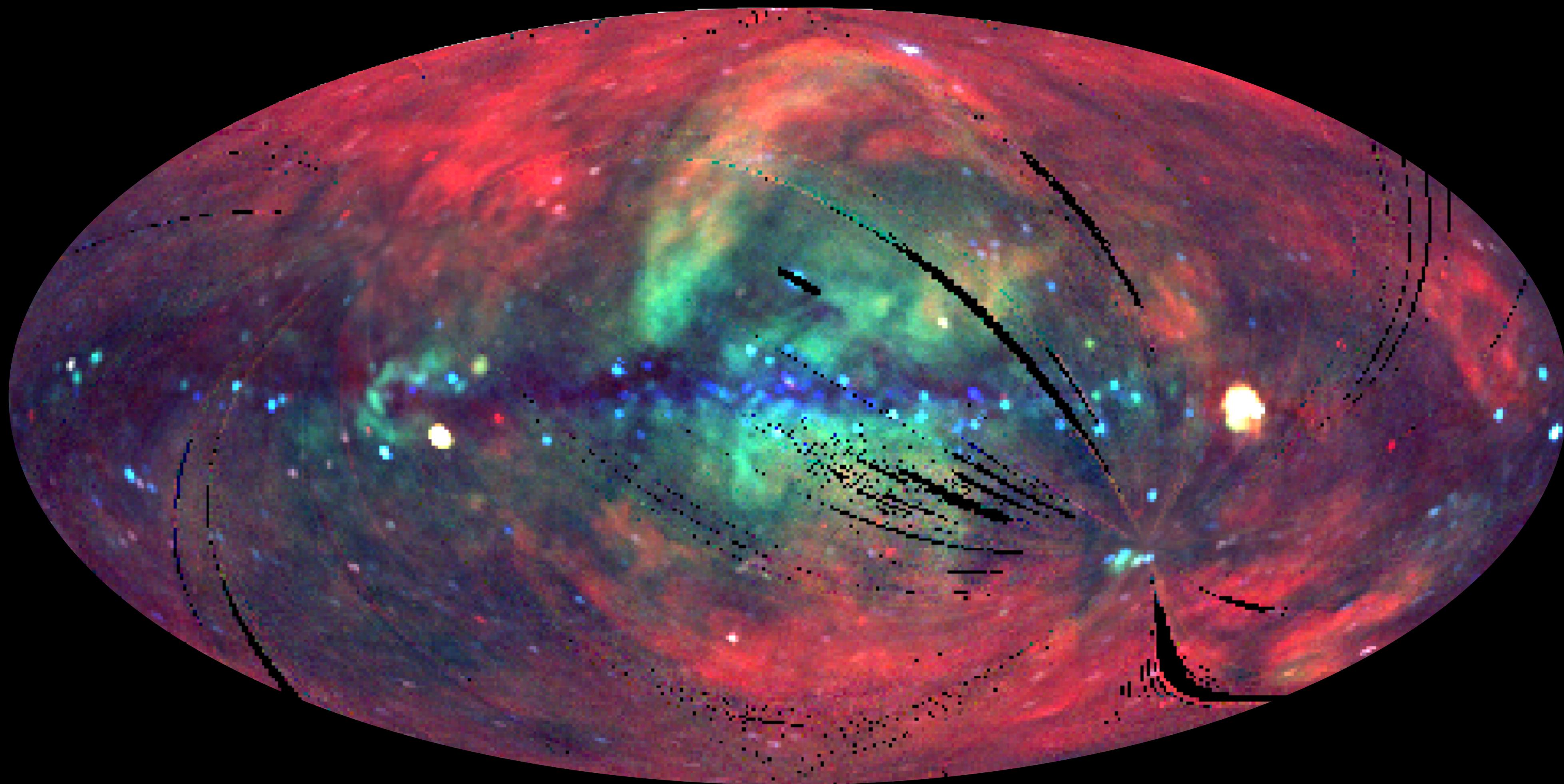
Neutral Hydrogen

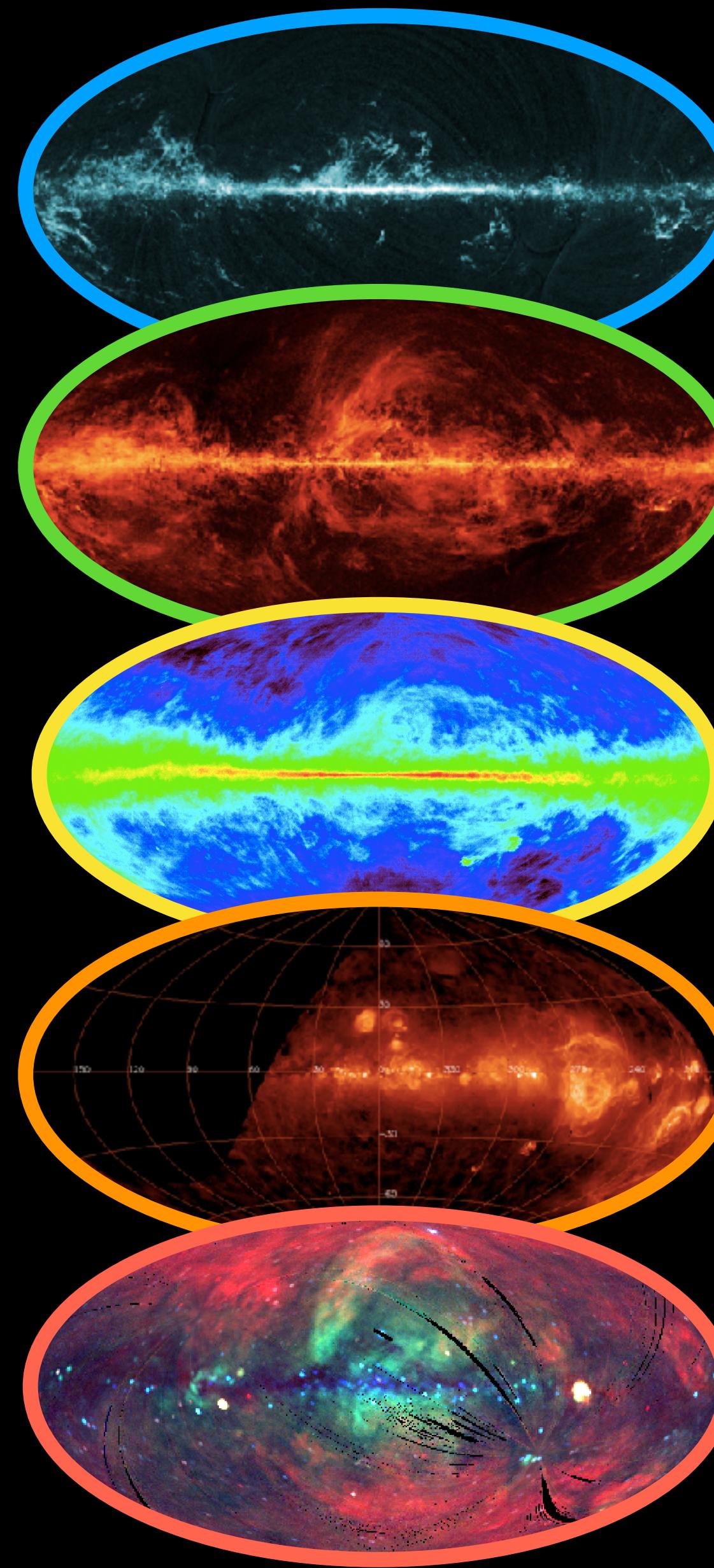


Ionized Hydrogen



X-Ray gas





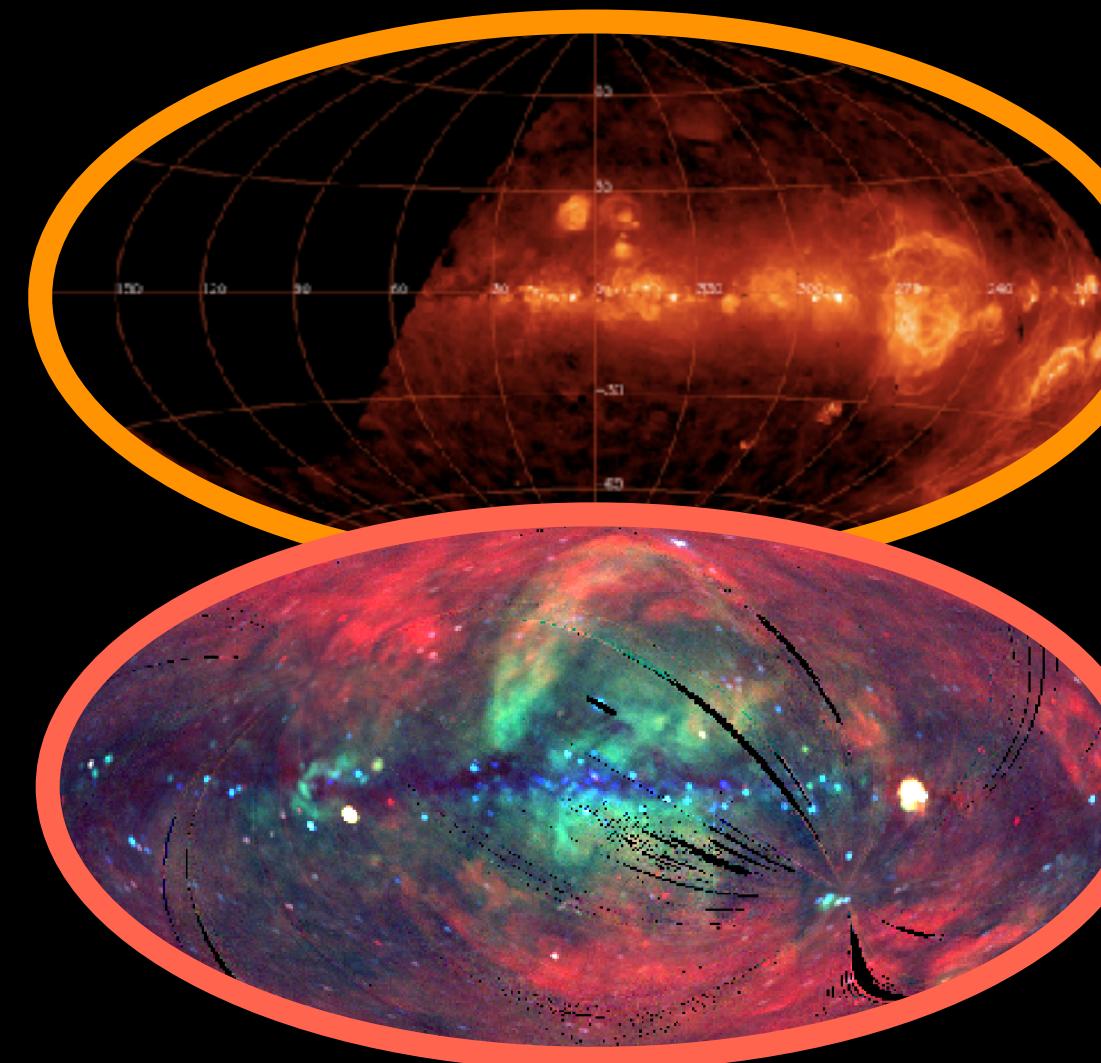
Component	Fractional volume	Scale height (pc)	Temperature (K)	Density (particles/cm ³)	State of hydrogen
Molecular clouds	< 1%	80	10–20	10^2 – 10^6	molecular
Cold neutral medium (CNM)	1–5%	100–300	50–100	20–50	neutral atomic
Warm neutral medium (WNM)	10–20%	300–400	6000–10000	0.2–0.5	neutral atomic
Warm ionized medium (WIM)	20–50%	1000	8000	0.2–0.5	ionized
H II regions	< 1%	70	8000	10^2 – 10^4	ionized
Coronal gas Hot ionized medium (HIM)	30–70%	1000–3000	10^6 – 10^7	10^{-4} – 10^{-2}	ionized (metals also highly ionized)

WIM/HIM

Component	Fractional volume	Scale height (pc)	Temperature (K)	Density (particles/cm ³)	State of hydrogen
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Takes up the majority of the volume

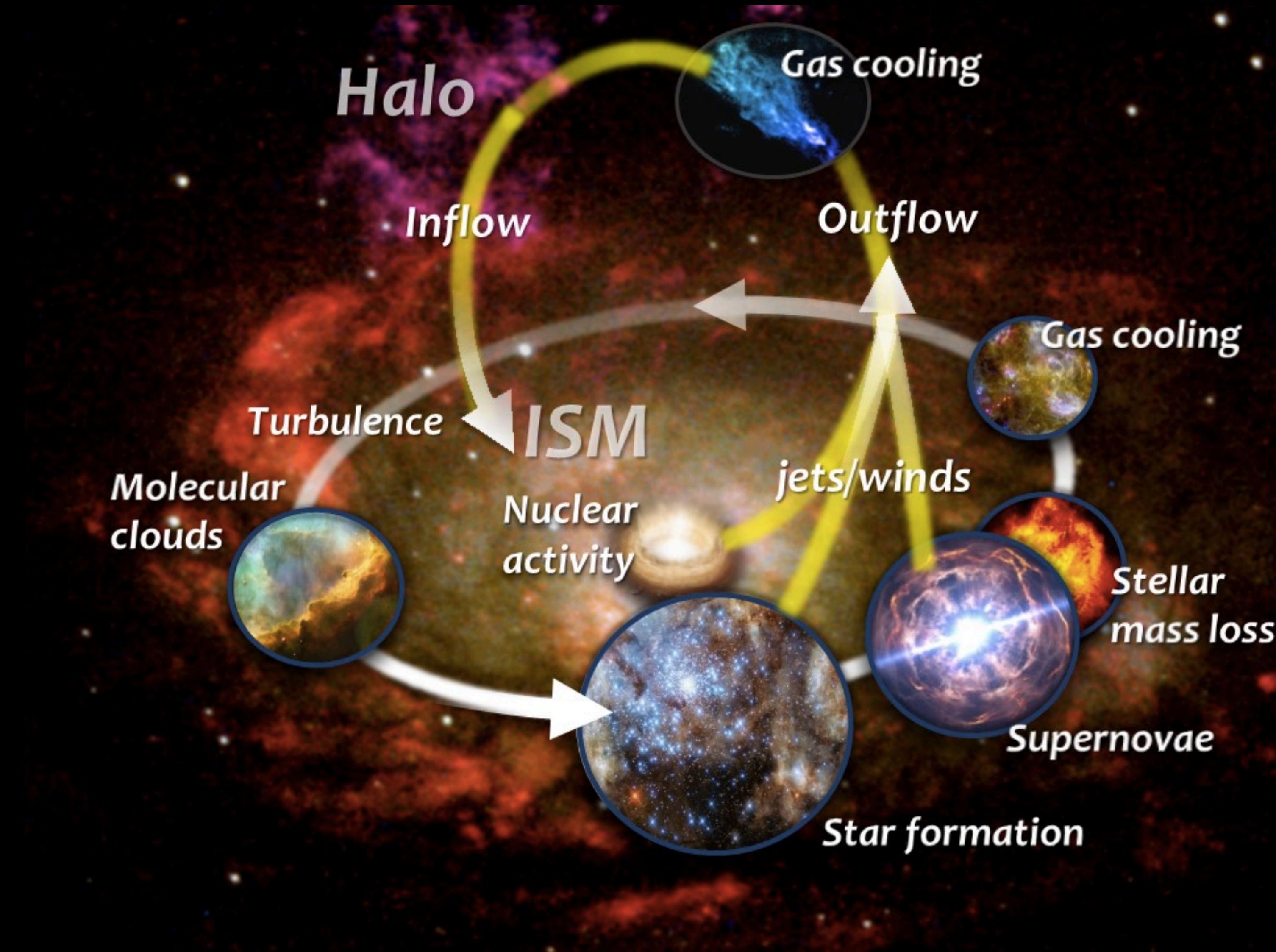
Associated with outflows and the halo of a galaxy



Warm ionized medium (WIM)	20–50%	1000	8000	0.2–0.5	ionized
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Coronal gas Hot ionized medium (HIM)	30–70%	1000–3000	10^6 – 10^7	10^{-4} – 10^{-2}	ionized (metals also highly ionized)
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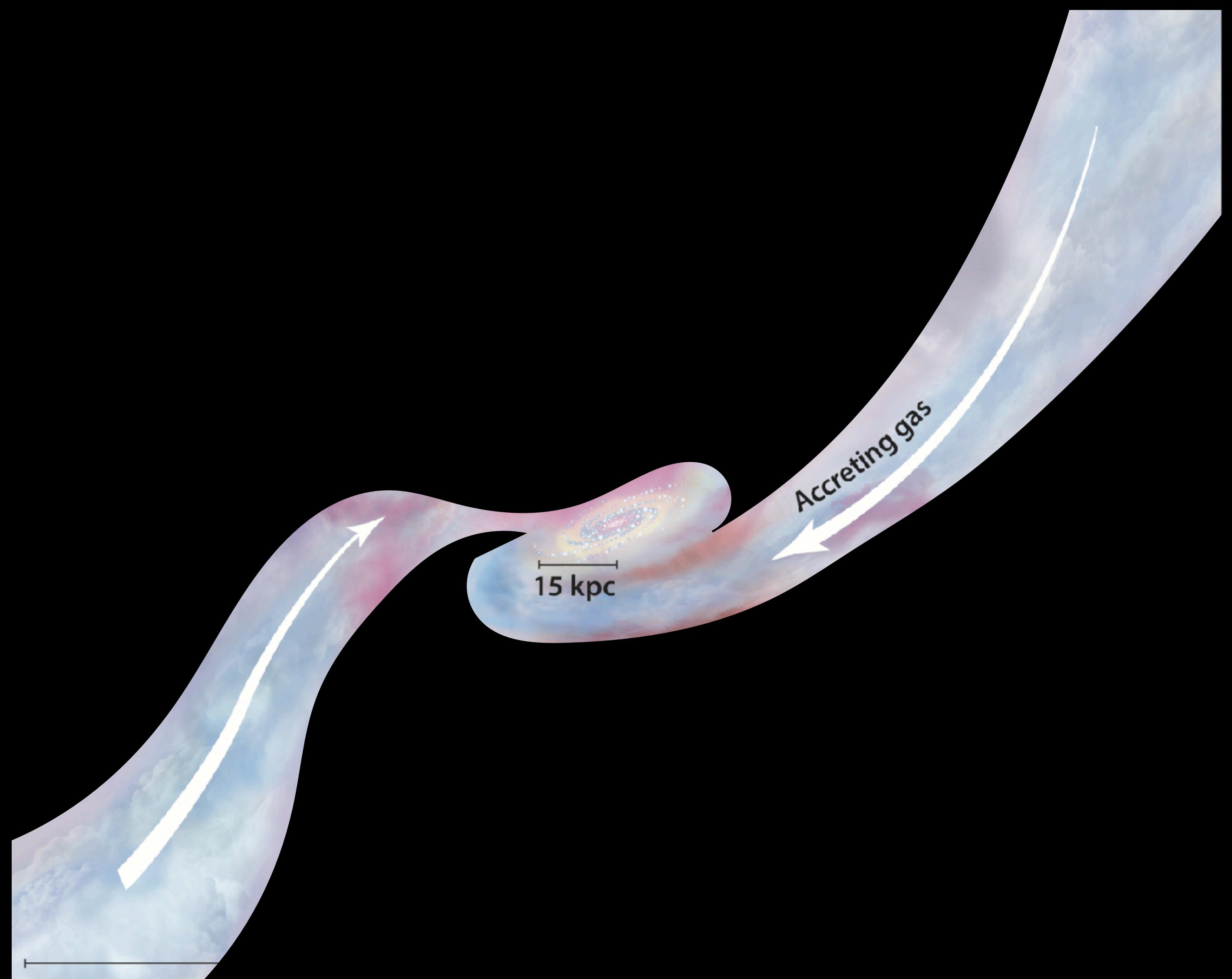
The ISM and the baryon cycle

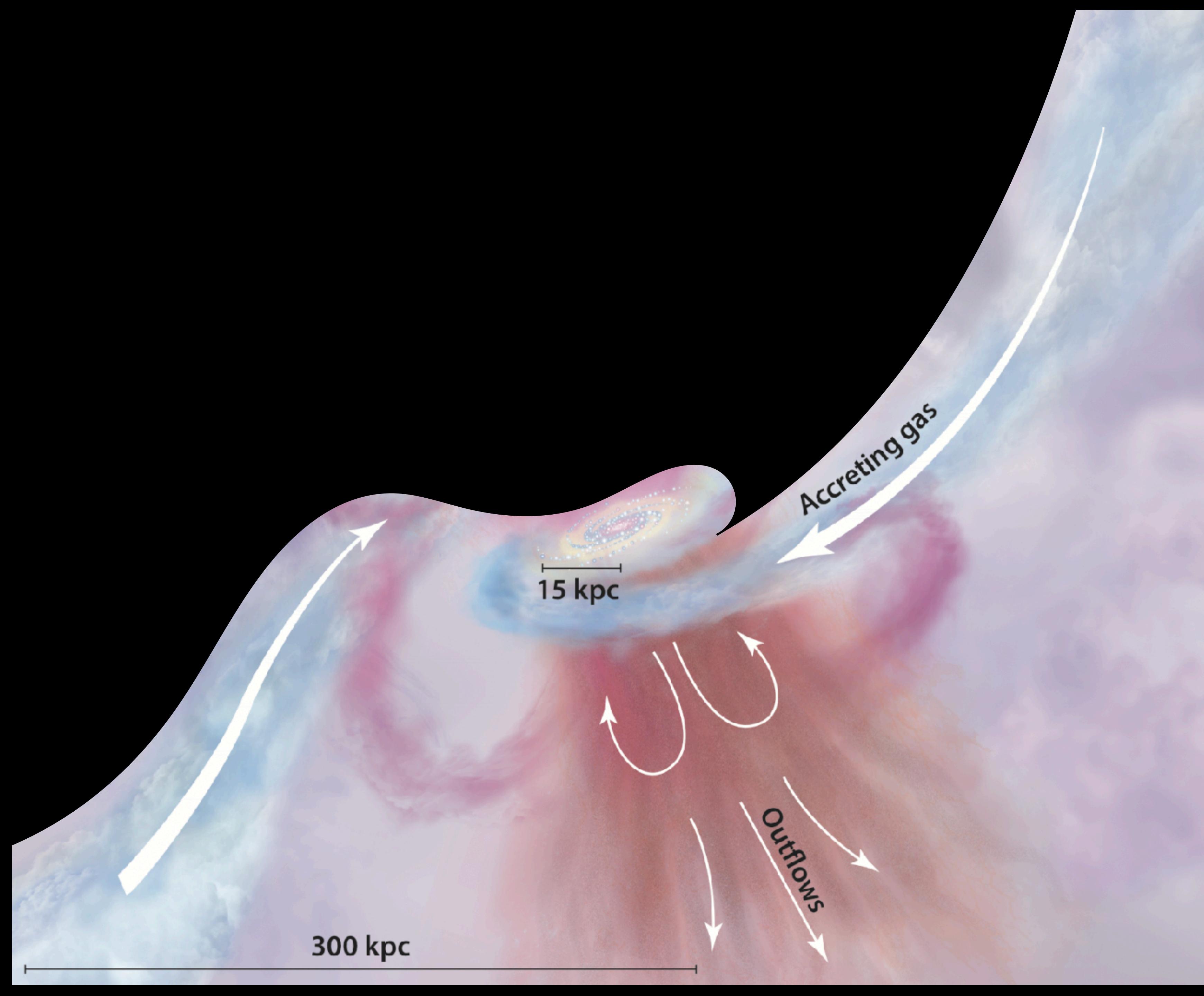


Galaxies are made of
gas and stars

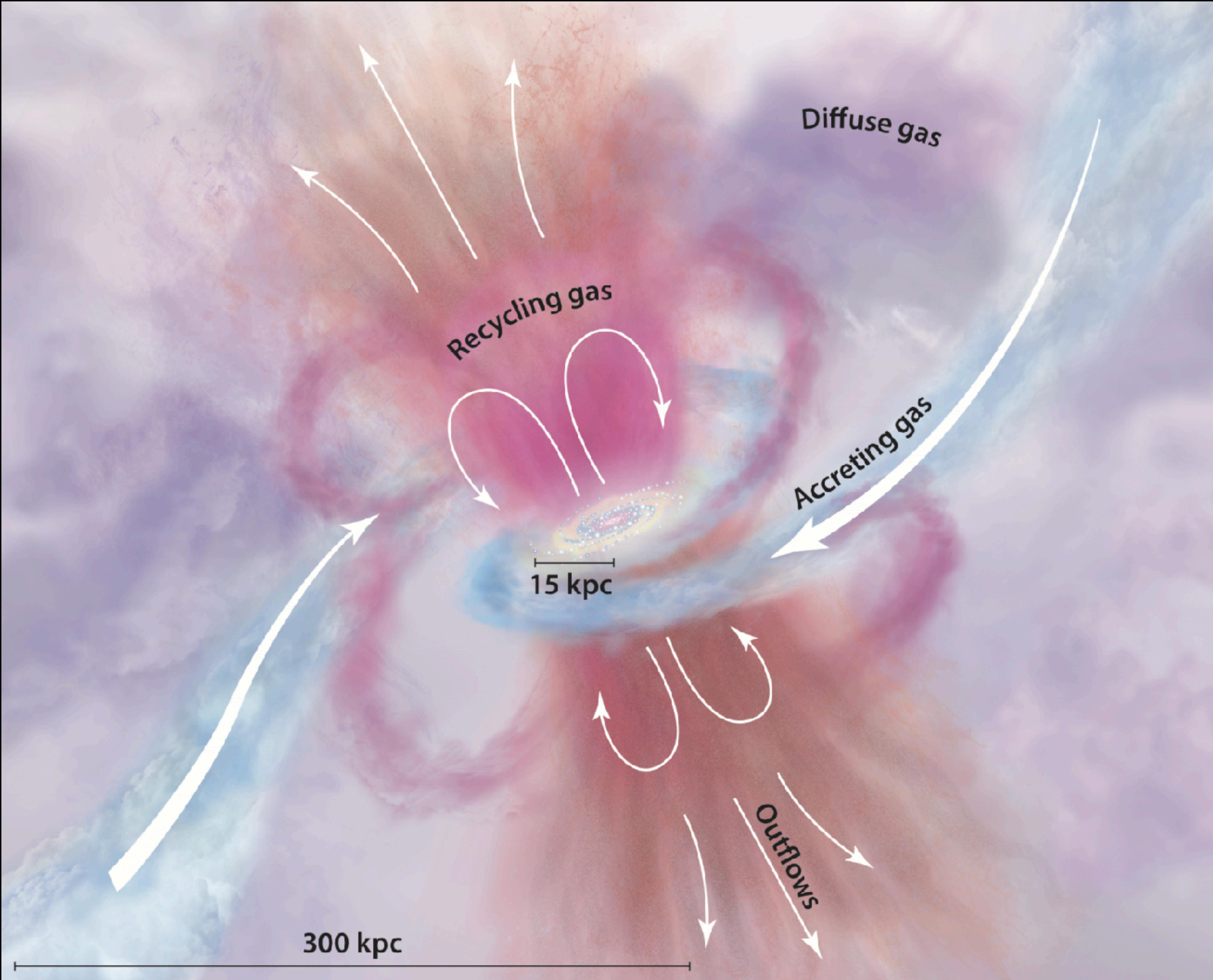


Galaxies grow by collecting gas and forming it into new stars





Dying stars (and active black holes) spew gas back out of the galaxy



Some of that gas returns to the galaxy, starting the cycle all over again

BUT when a galaxy runs out of gas, it will stop forming stars and 'die'

A composite image of the starburst galaxy M82. The central region is dominated by intense red and orange light, indicating regions of massive star formation. This central star-forming region is surrounded by a translucent blue glow, likely representing ionized gas. The galaxy's spiral structure is visible as a faint, curved band of light extending towards the bottom left. Numerous small white stars are scattered across the dark, black background of space.

A starburst galaxy
with a powerful wind

M82



M82

Infrared Optical Xray

Dust & Molecular Gas

Ionized Gas

X-Ray Plasma

A composite infrared image of the M82 galaxy. The central region is dominated by a bright, white and yellow core, representing young stars. This is surrounded by a large, diffuse red and orange glow, which is primarily dust heated by starlight. Interspersed throughout the red glow are numerous small, blue and cyan spots, which are regions of active star formation where molecular gas is being converted into stars.

M82

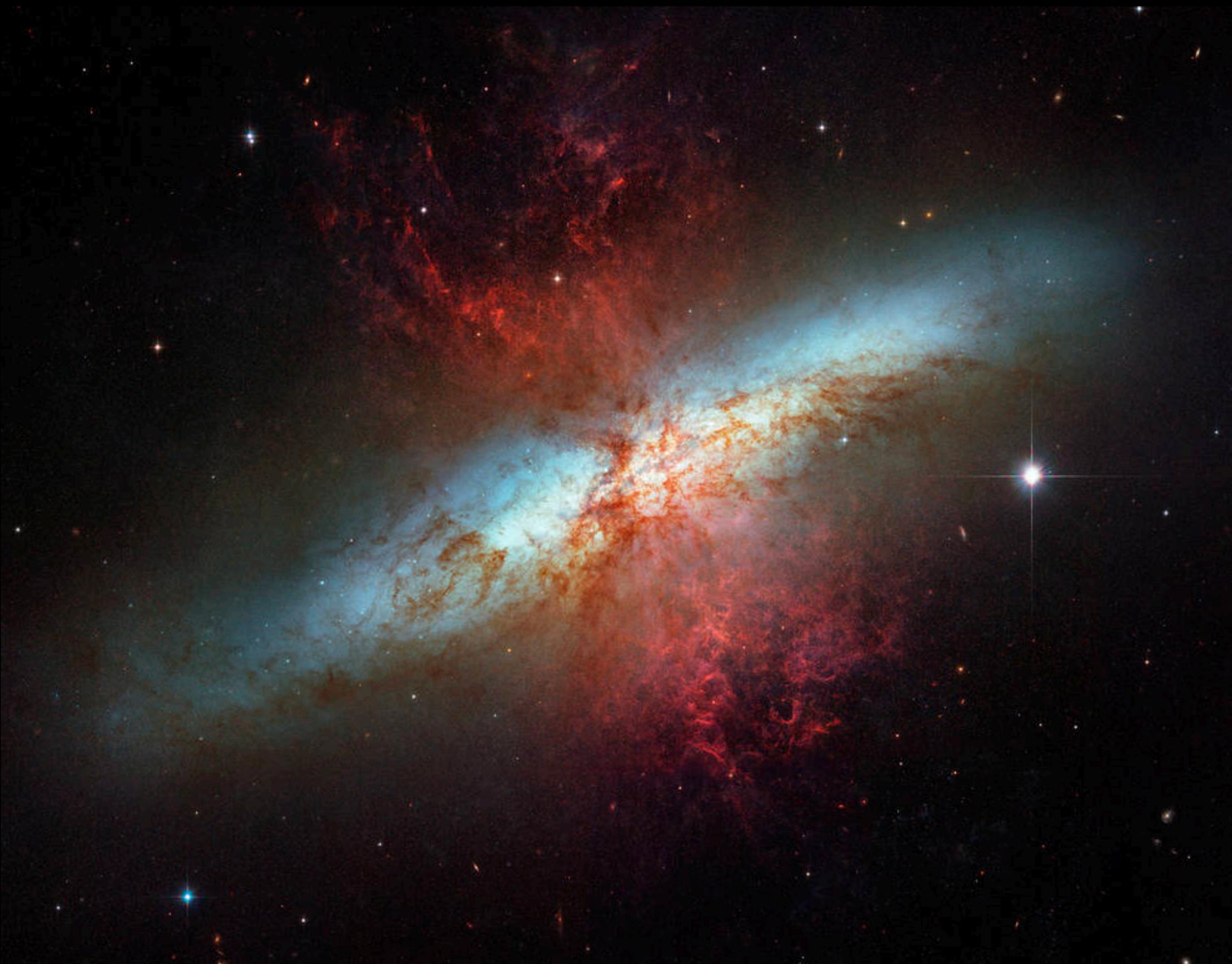
Infrared

Dust & Molecular Gas



M82

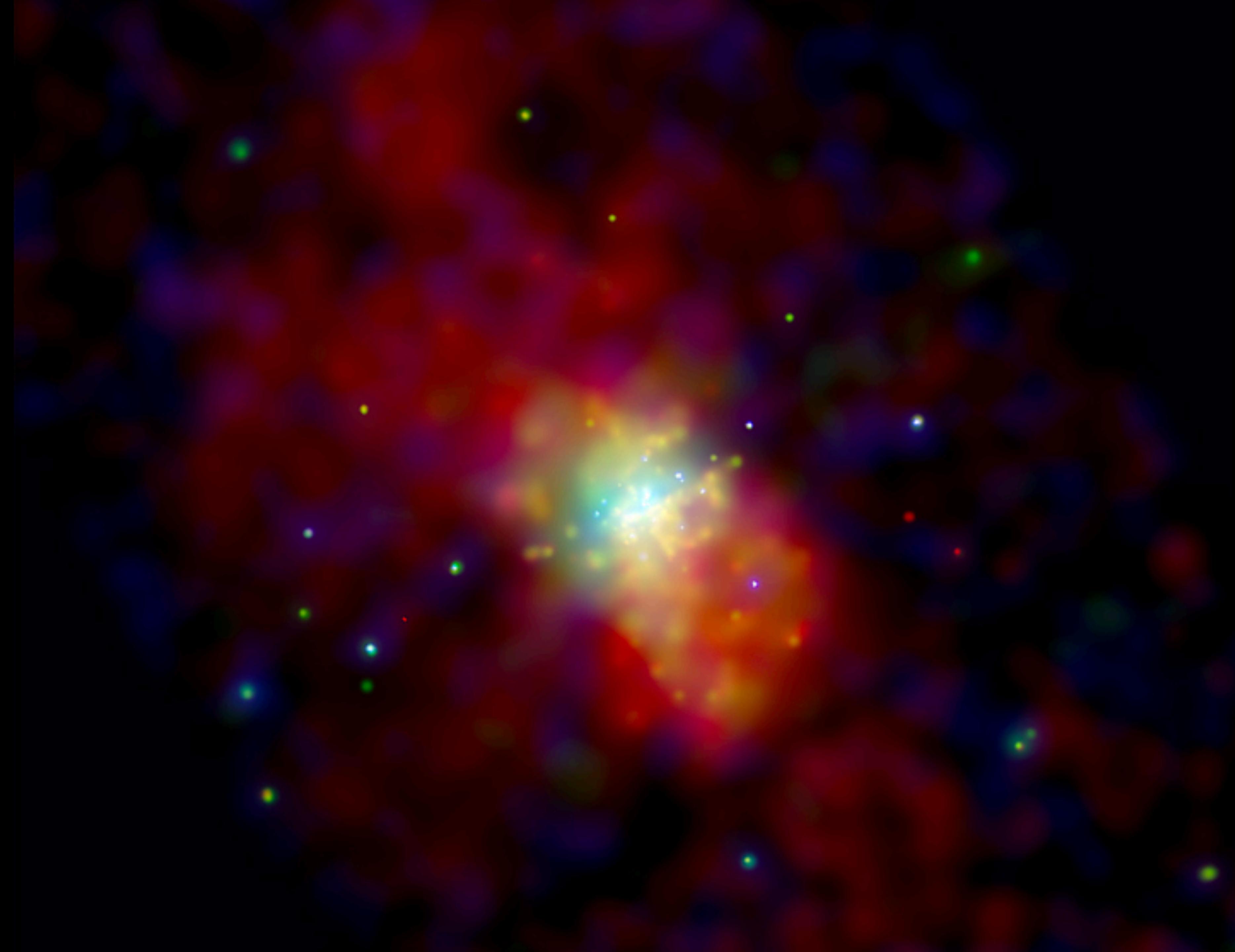
Optical



Ionized Gas



Hubble



M82

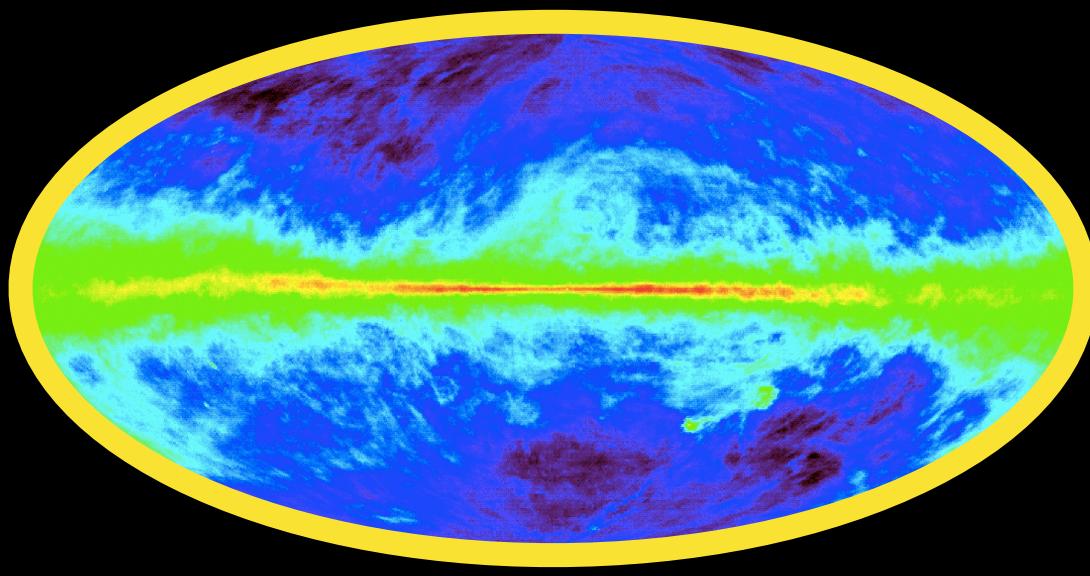
Xray

X-Ray Plasma



Chandra

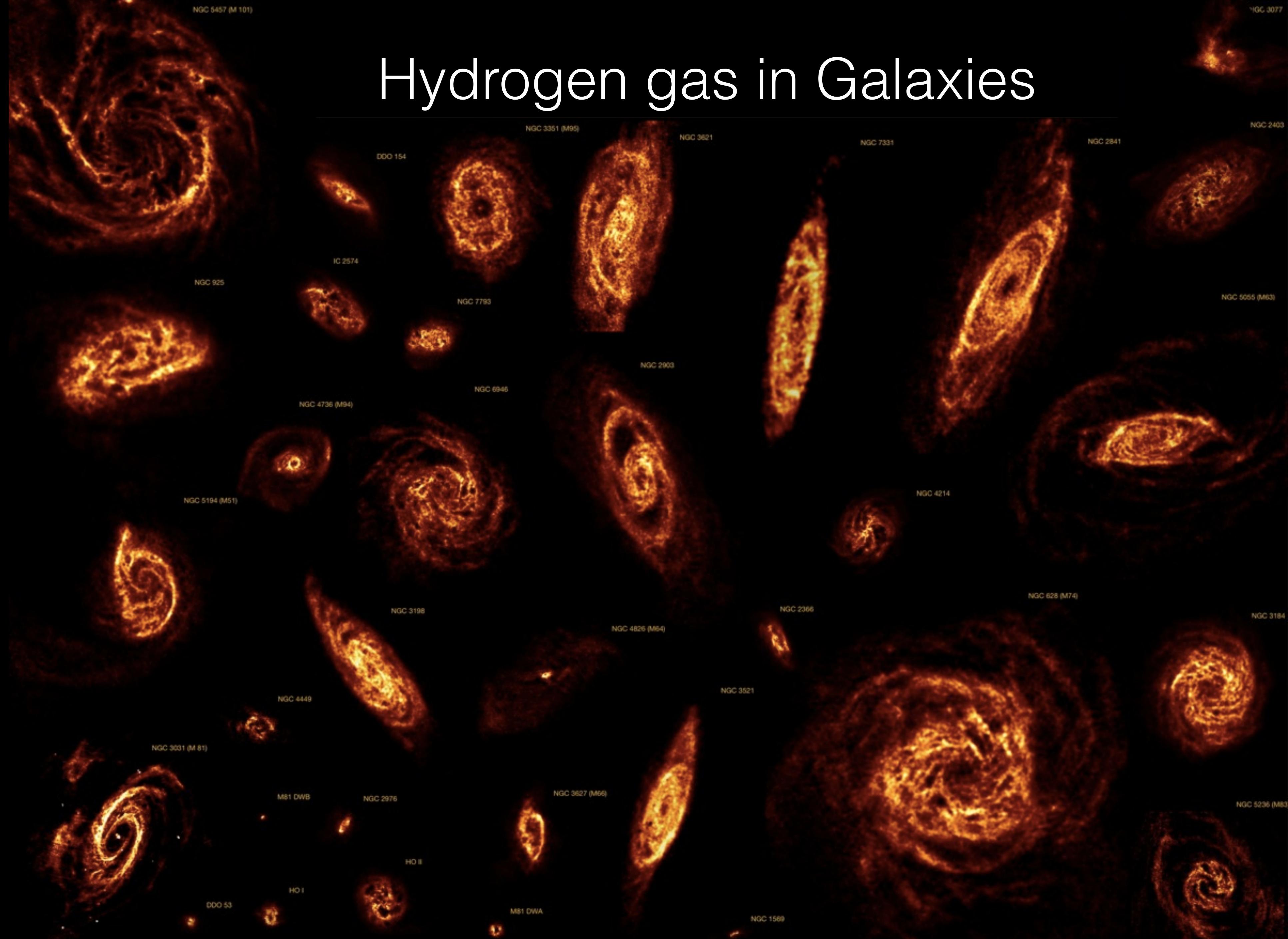
WNM



Component	Fractional volume	Scale height (pc)	Temperature (K)	Density (particles/cm ³)	State of hydrogen
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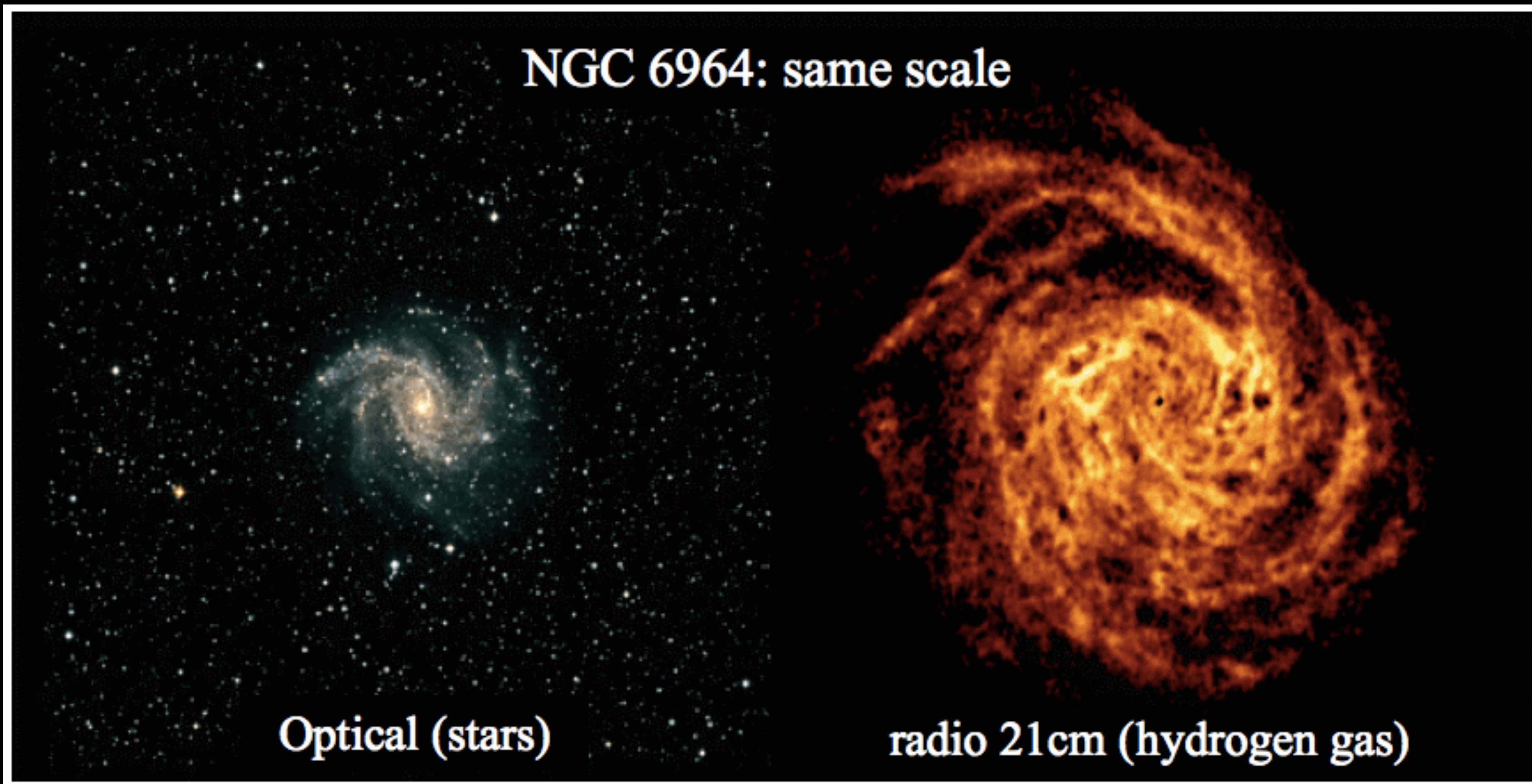
Warm neutral medium (WNM)	10–20%	300–400	6000–10000	0.2–0.5	neutral atomic
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One of the dominant components of gas in a galaxy's disk— but NOT directly associated with star formation



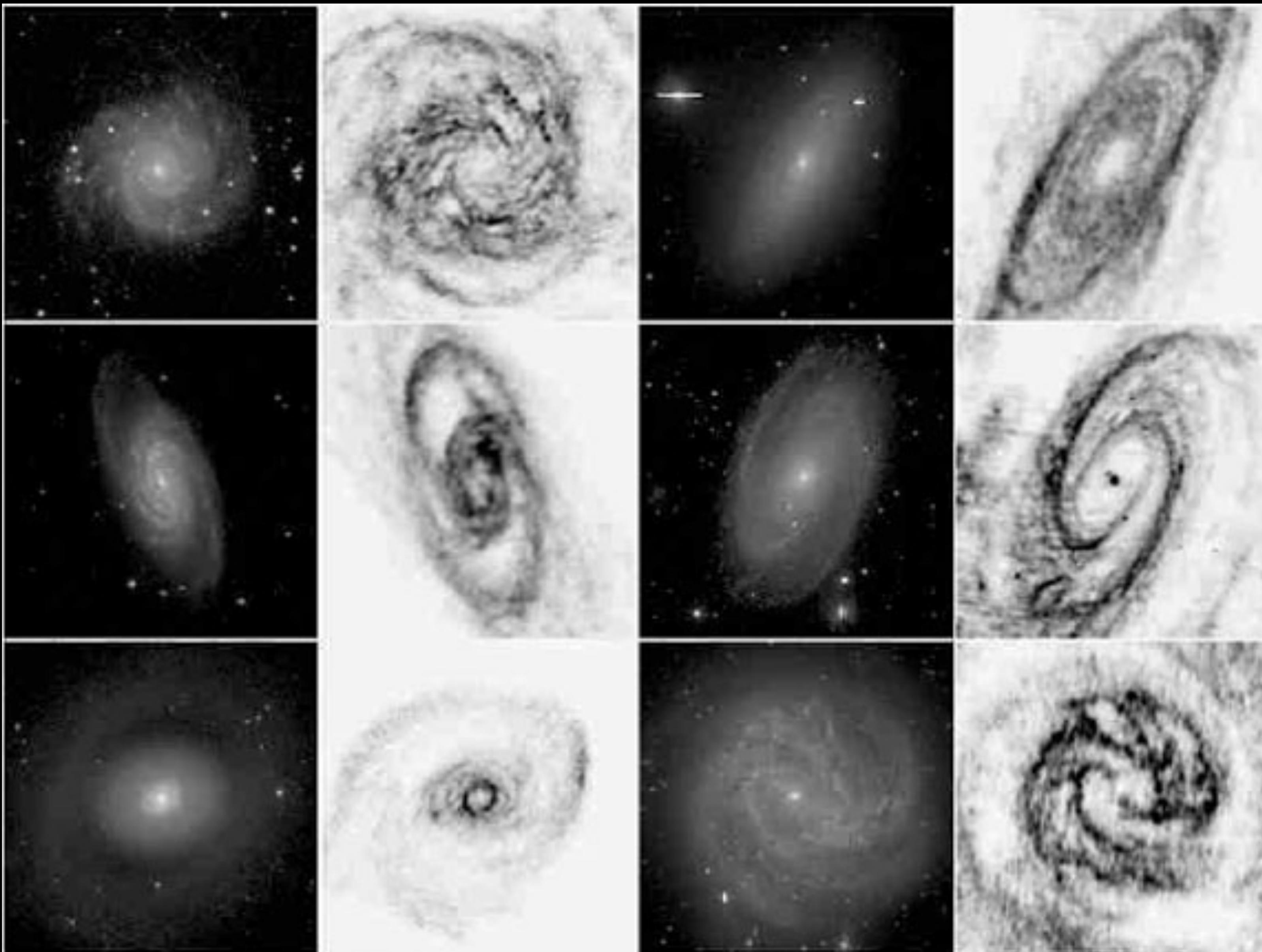
Hydrogen gas in Galaxies

Spiral galaxies like ours have an enormous reservoir of Hydrogen gas



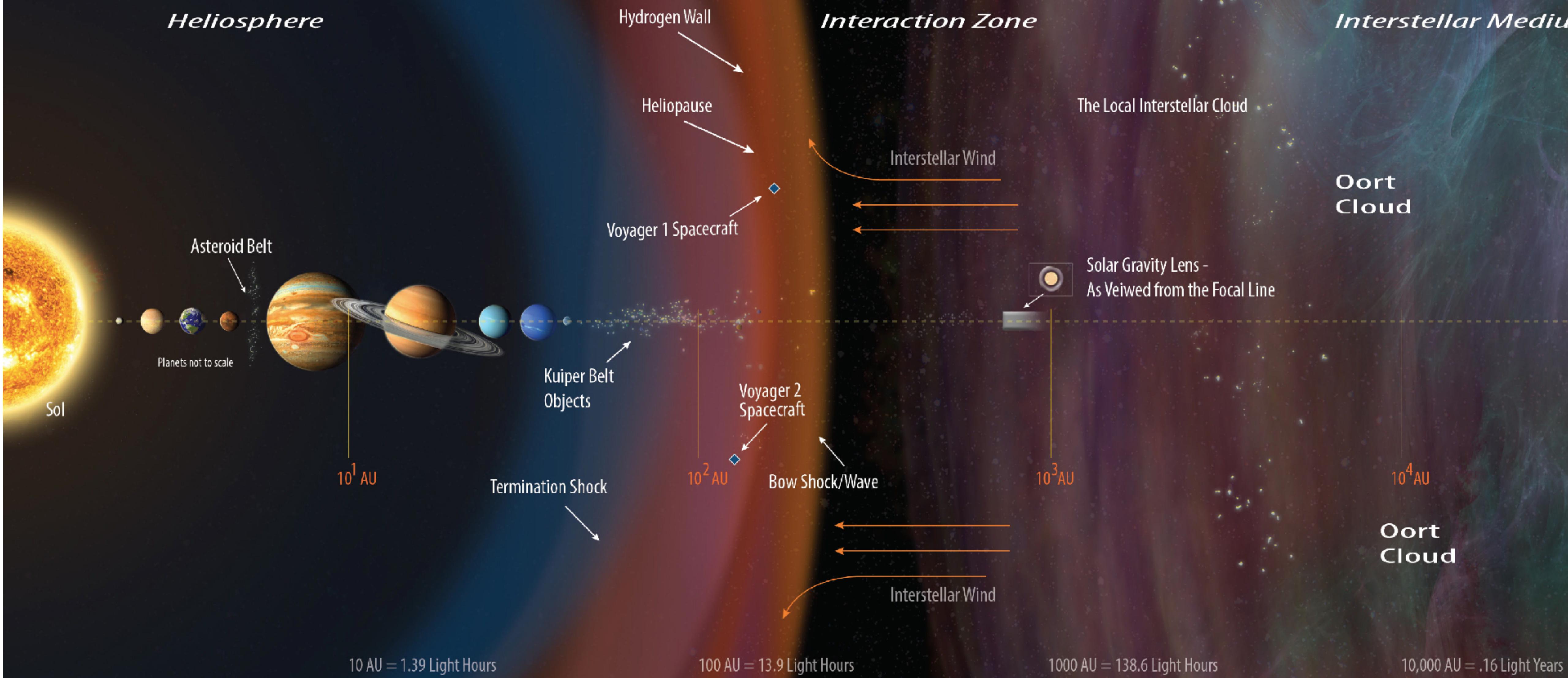
Stars

Hydrogen



In general, this hydrogen gas extends far beyond where you see stars in galaxies.

The Interstellar Medium



Action Zone

Interstellar Medium

The Local Interstellar Cloud

Interstellar Wind

Oort Cloud

Solar Gravity Lens -
As Viewed from the Focal Line



10^3 AU

10^4 AU

10^5 AU

Oort Cloud

The G Cloud

Rogue
Planets

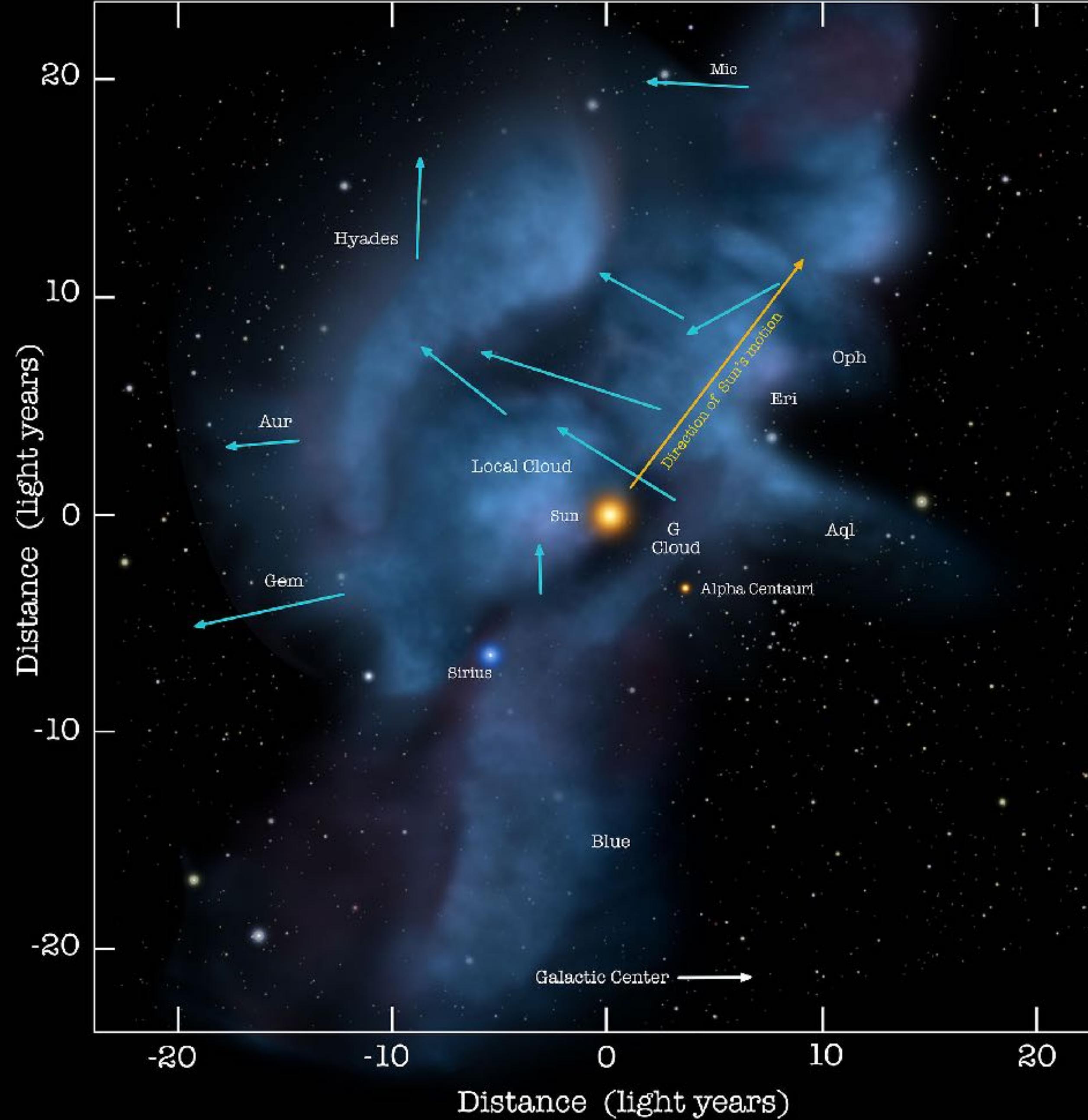
Alpha Centauri

Interstellar Wind

1000 AU = 138.6 Light Hours

10,000 AU = .16 Light Years

100,000 AU = 1.58 Light Years

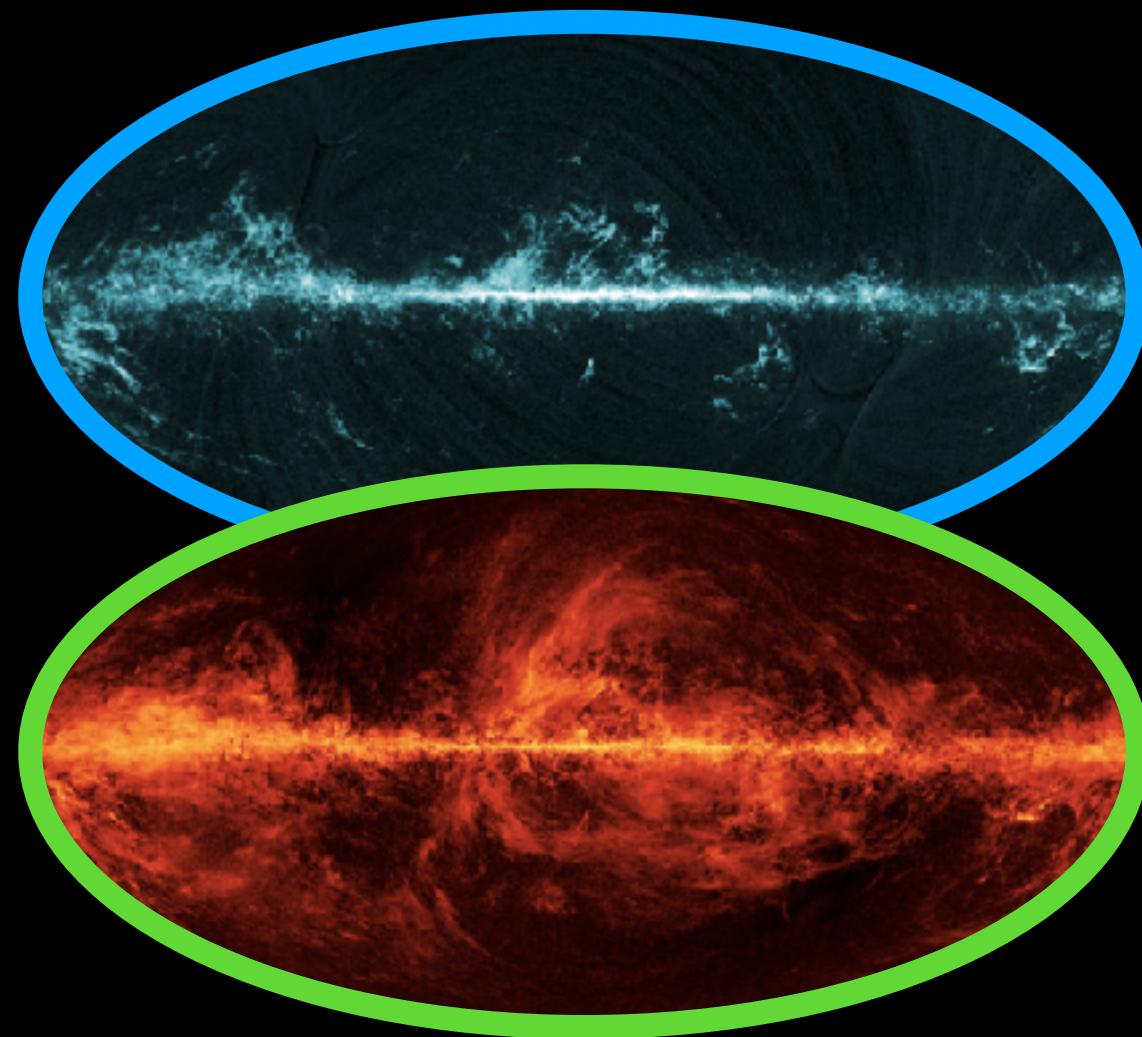


The local cloud:
A wisp of interstellar gas that the sun
(and other nearby stars) are currently
moving through

Why?

Gas and stars have different dynamics
in a galaxy, because the gas is a
collisional system (individual atoms and
molecules are constantly hitting each
other), but the stars are collisionless
(they only interact with the overall
gravitational potential of the galaxy)

CNM/GMCs



Component	Fractional volume	Scale height (pc)	Temperature (K)	Density (particles/cm ³)	State of hydrogen
Molecular clouds	< 1%	80	10–20	10^2 – 10^6	molecular
Cold neutral medium (CNM)	1–5%	100–300	50–100	20–50	neutral atomic

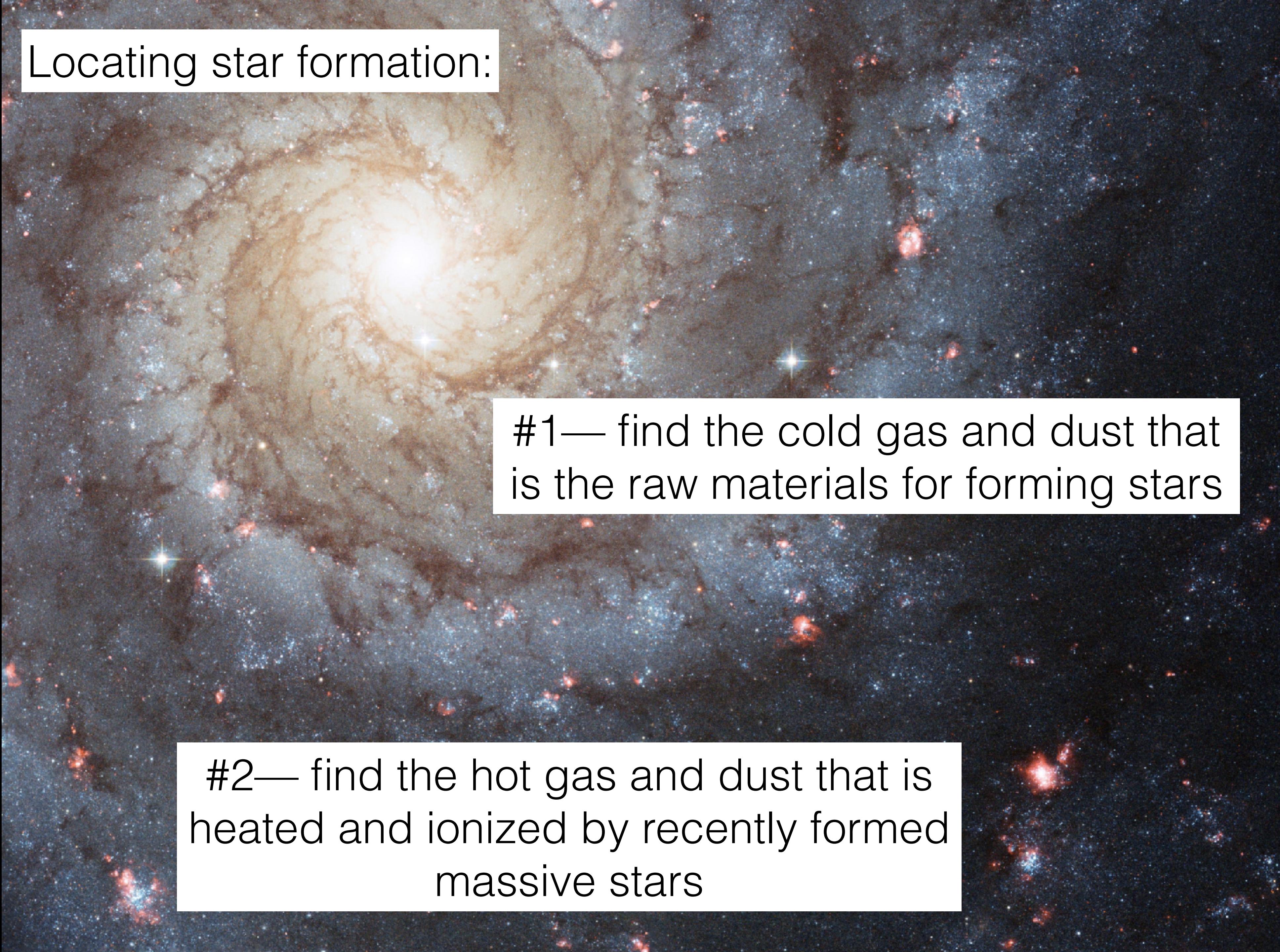
This is the gas in the disk that IS directly associated with star formation

Locating star formation:



Where would you look for the
youngest stars in this picture?

Locating star formation:



#1— find the cold gas and dust that is the raw materials for forming stars

#2— find the hot gas and dust that is heated and ionized by recently formed massive stars

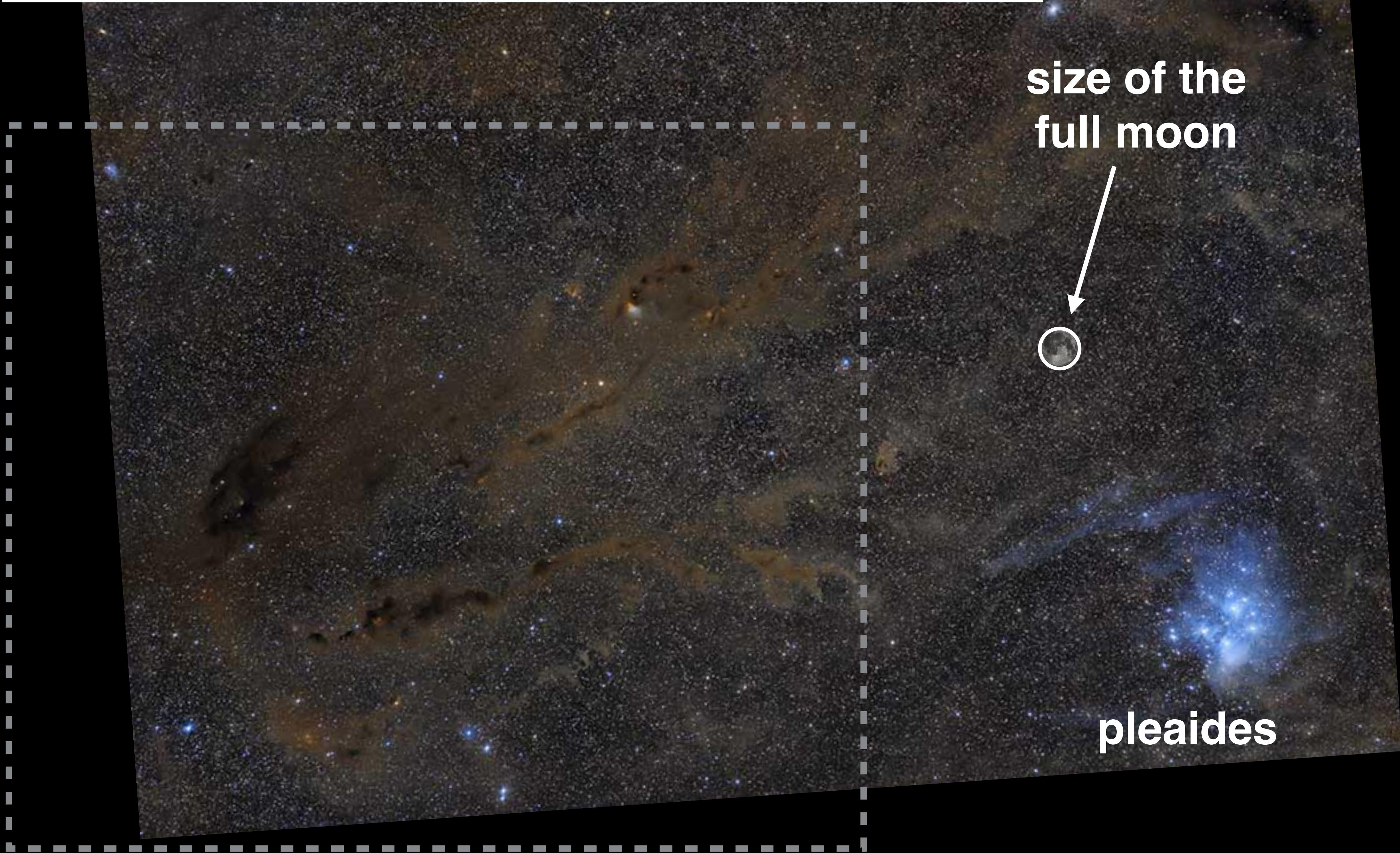
Optical Wavelengths

Taurus

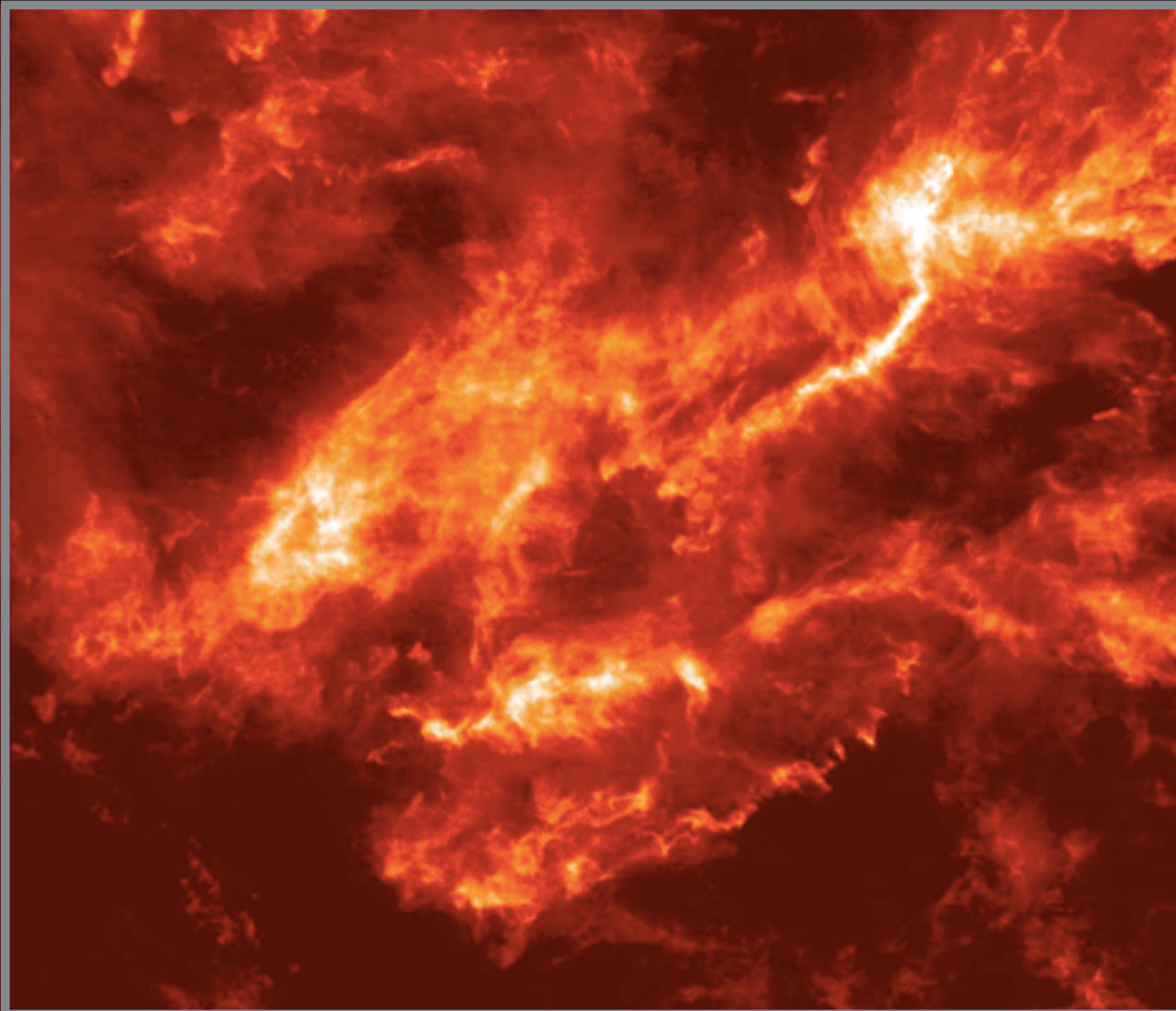
Pleiades



The Taurus Molecular cloud

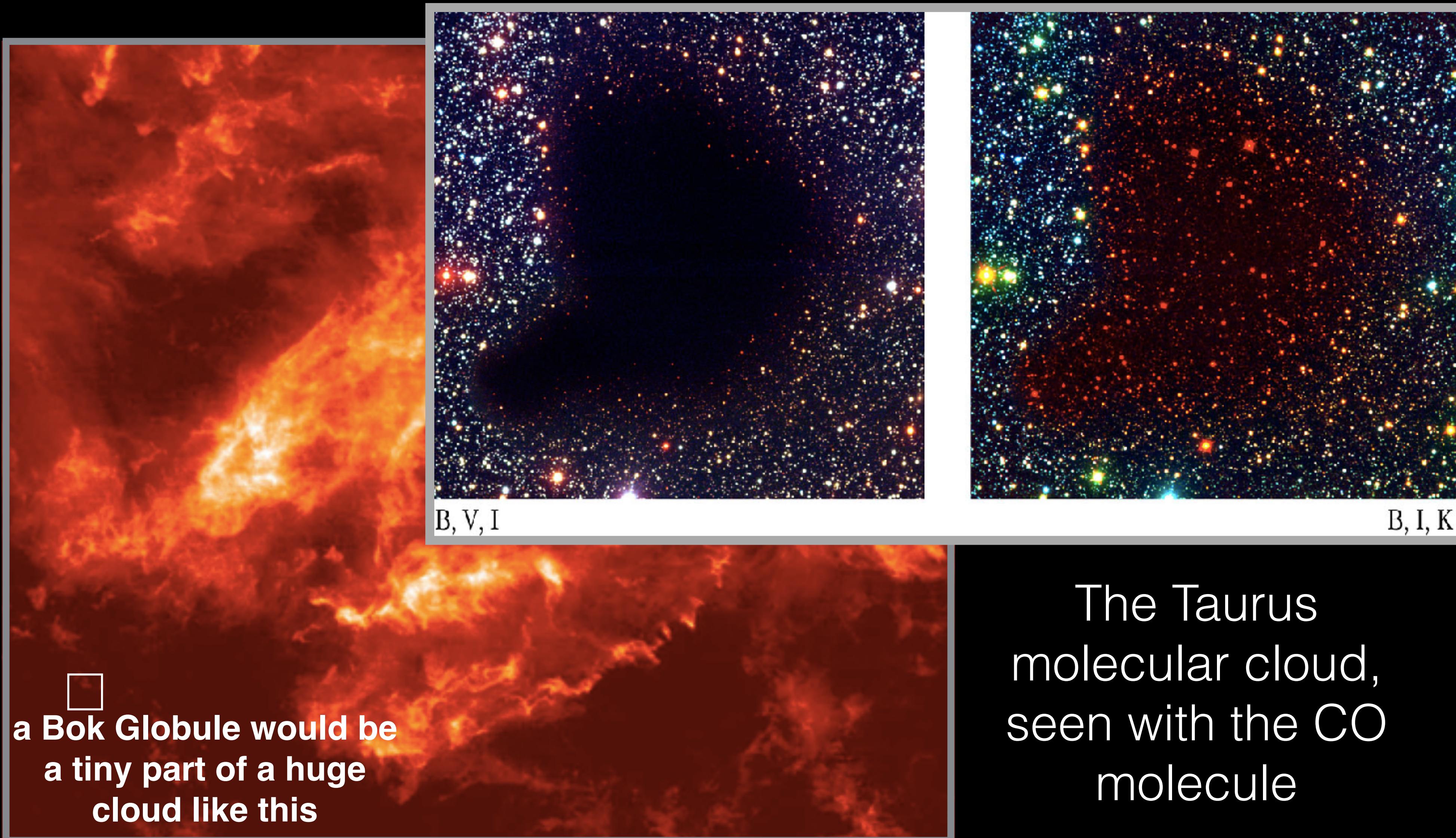


At millimeter wavelengths, instead of blocking light, the gas and dust itself gives off light.

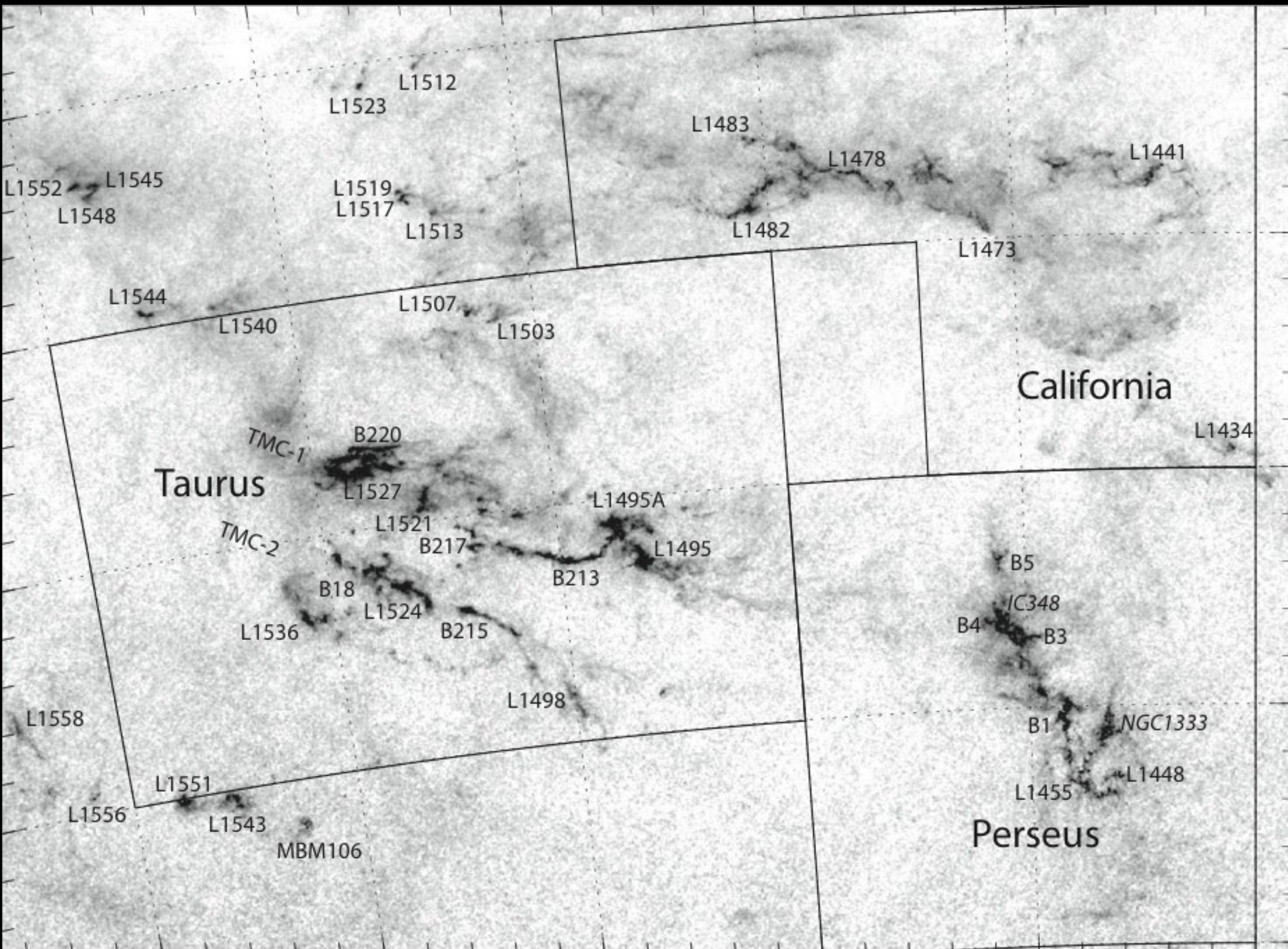


At home, your microwave emit millimeter-wavelength light to make molecules in your food vibrate and heat up. This is the reverse.

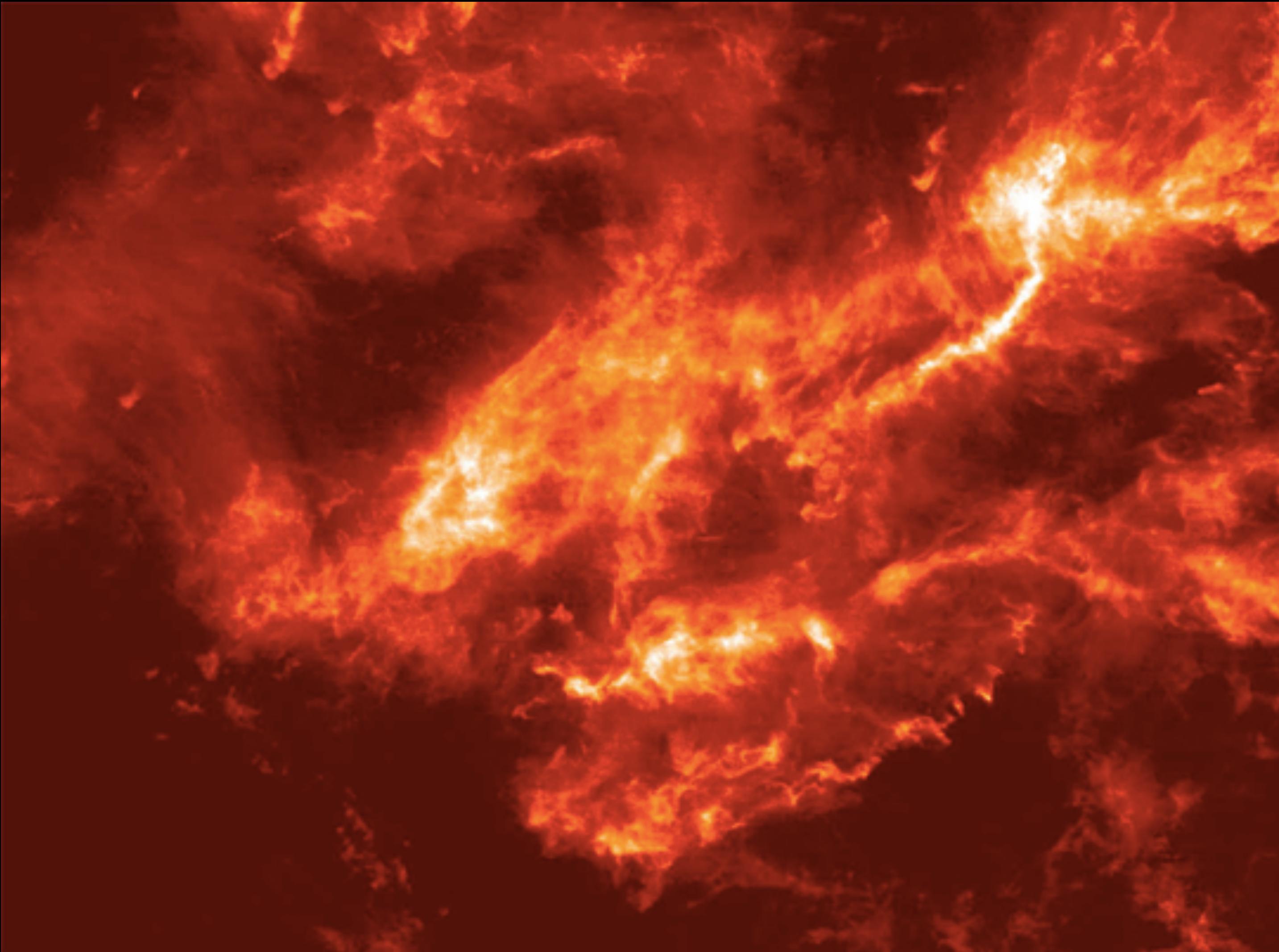
Molecular clouds: the birthplace of star clusters



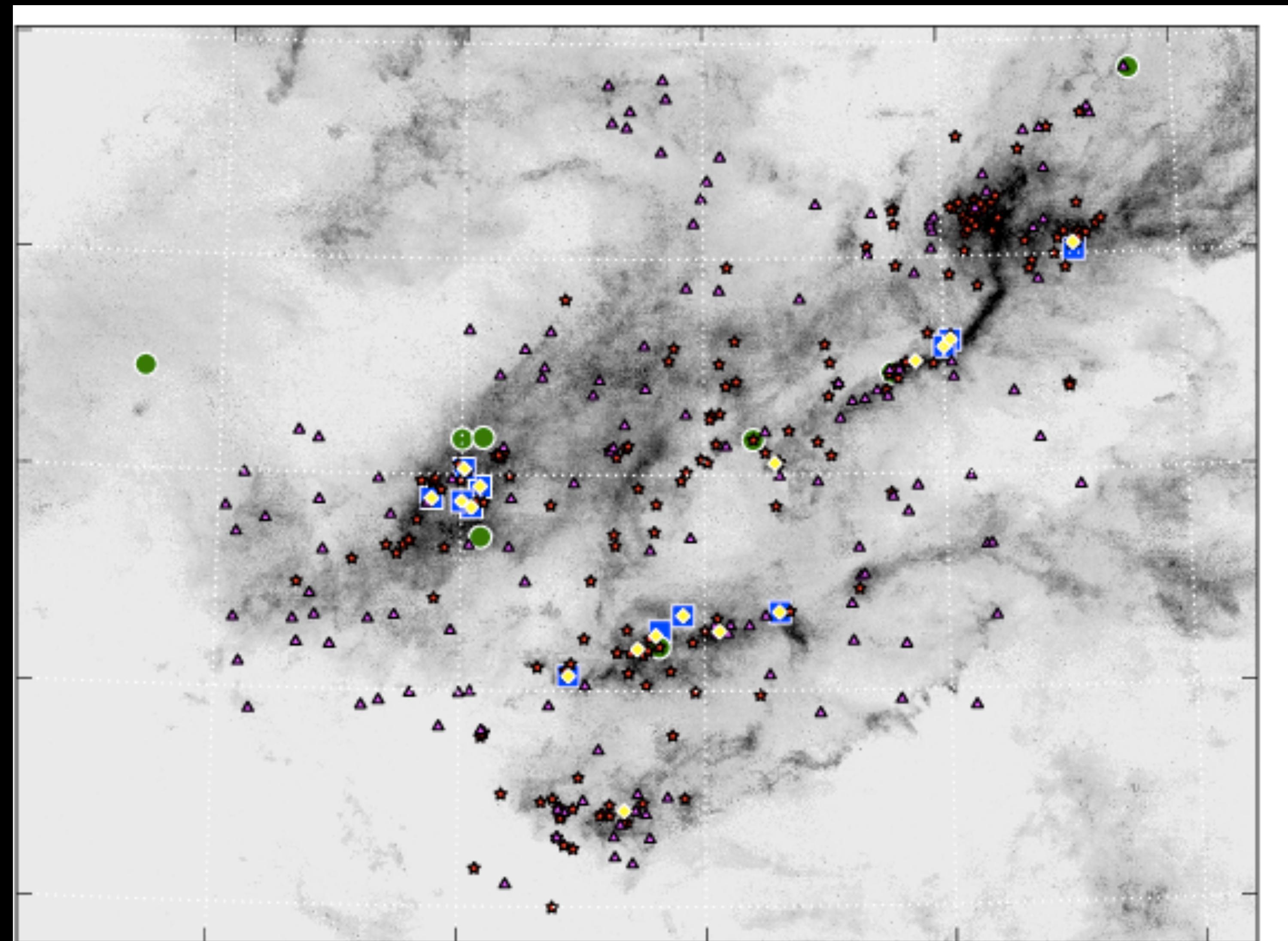
Taurus is one of many molecular clouds in the sky



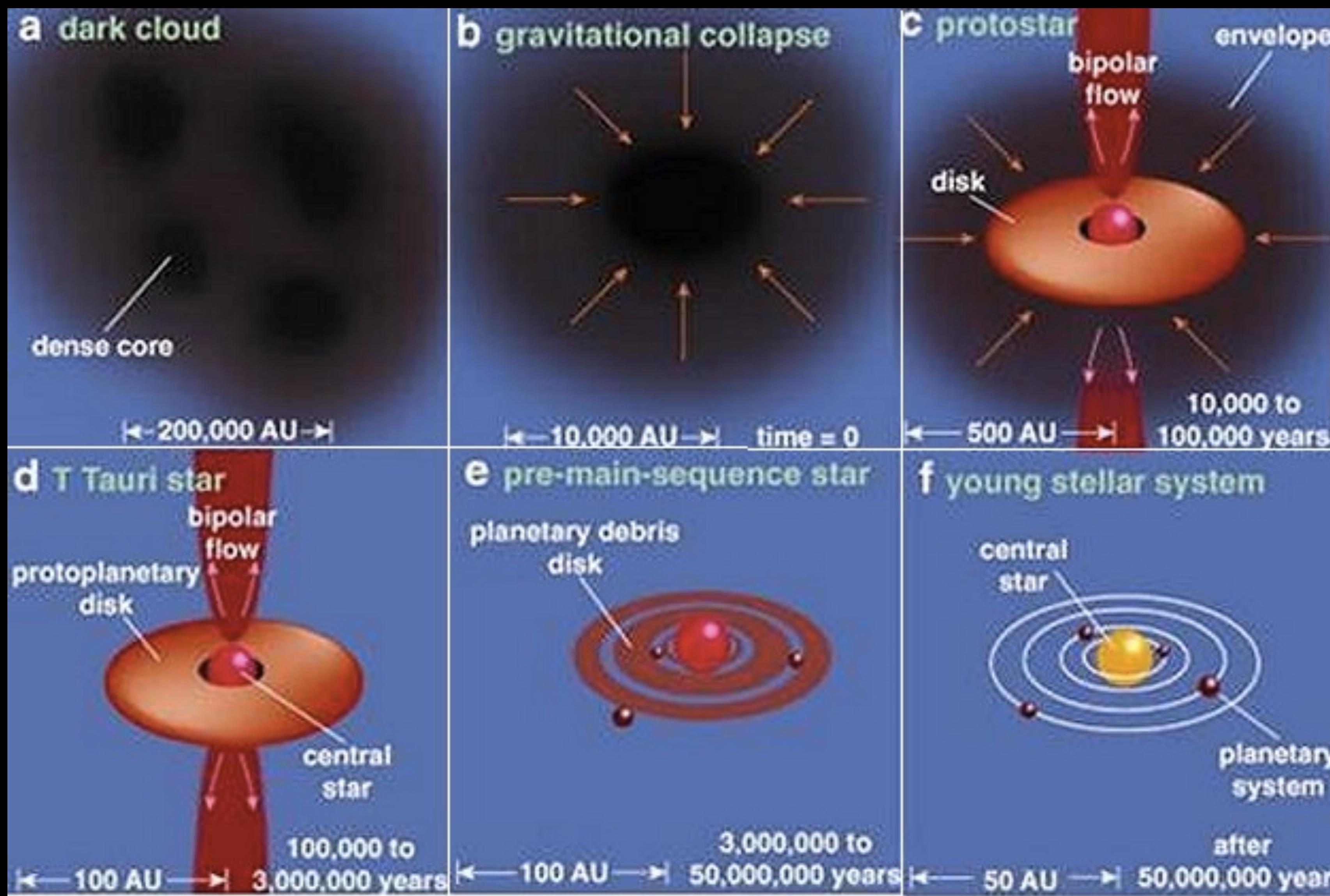
Only 430 light years away, it is one of the nearest places where stars are currently forming.



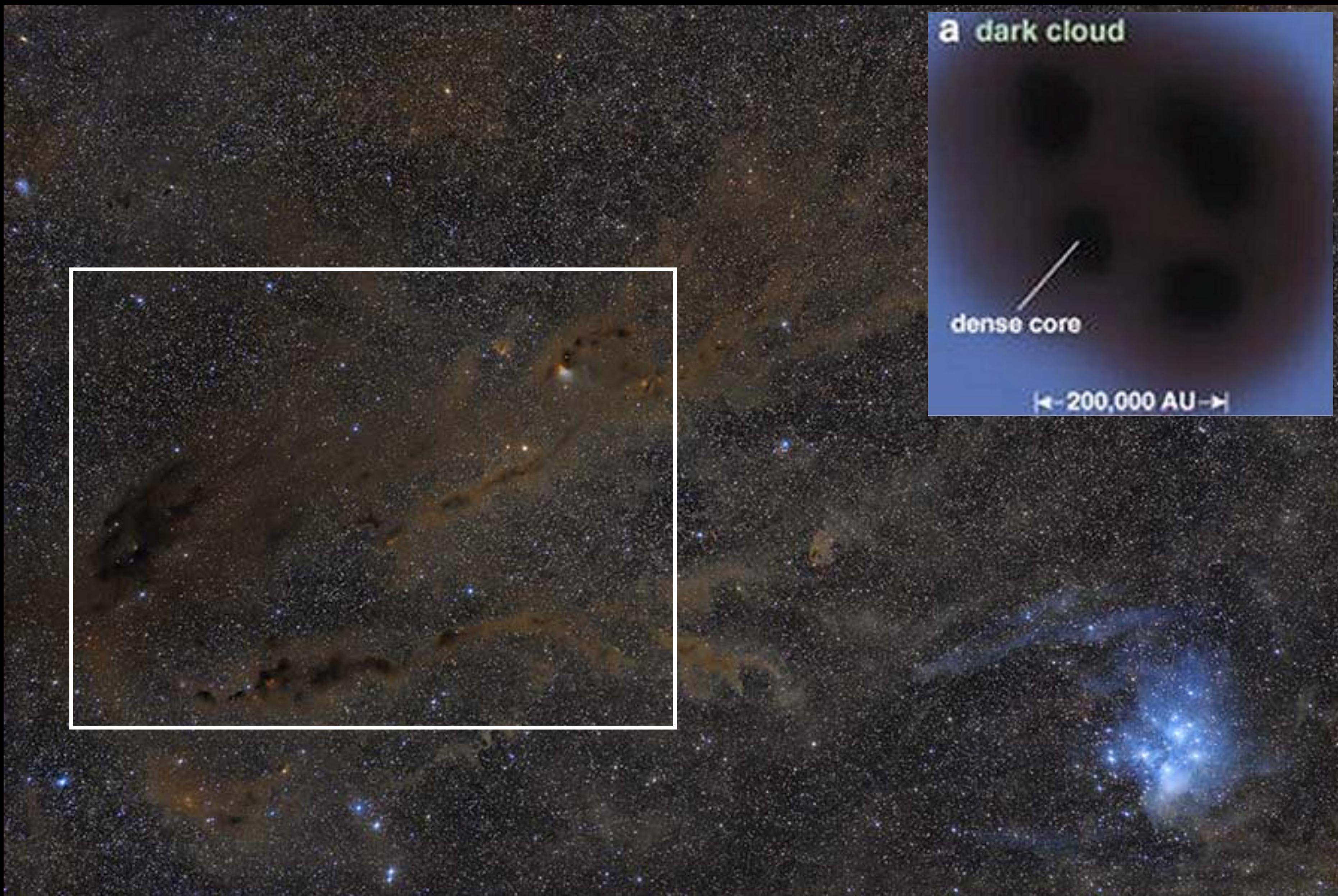
Location of baby stars in Taurus



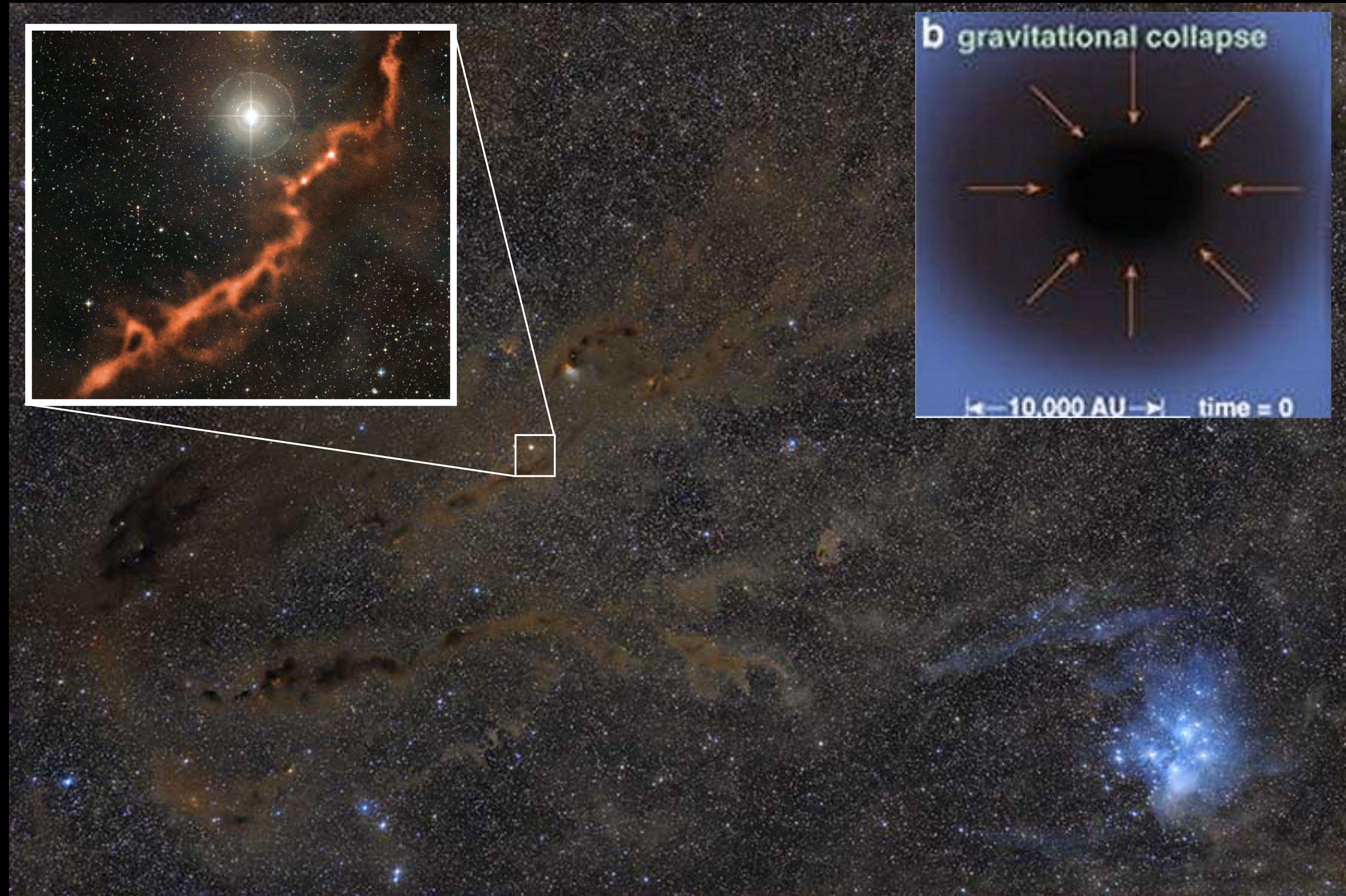
Stages of star formation

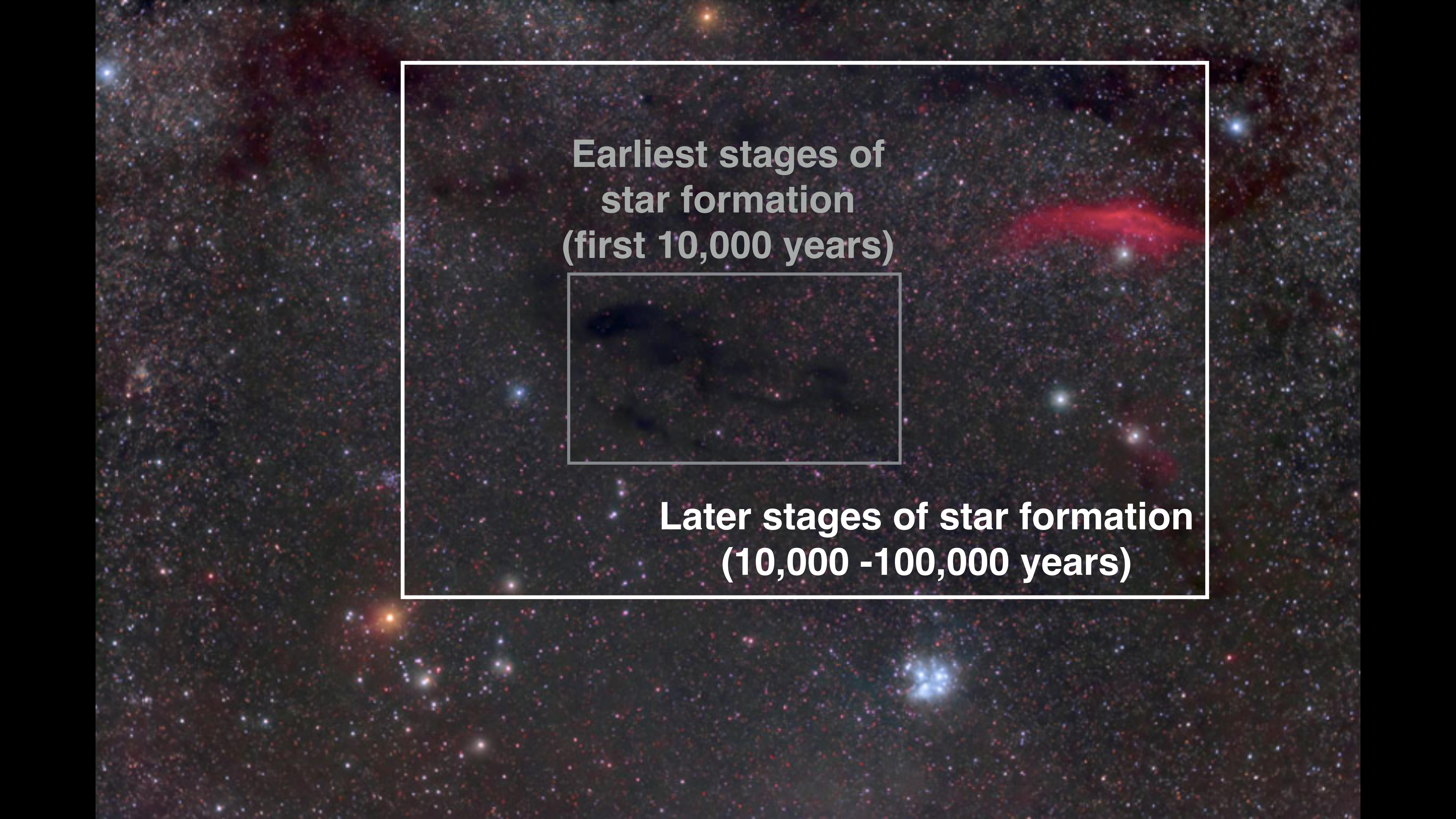


Stage 1: Dark (molecular) Cloud



Stage 2: Gravitational collapsing clumps





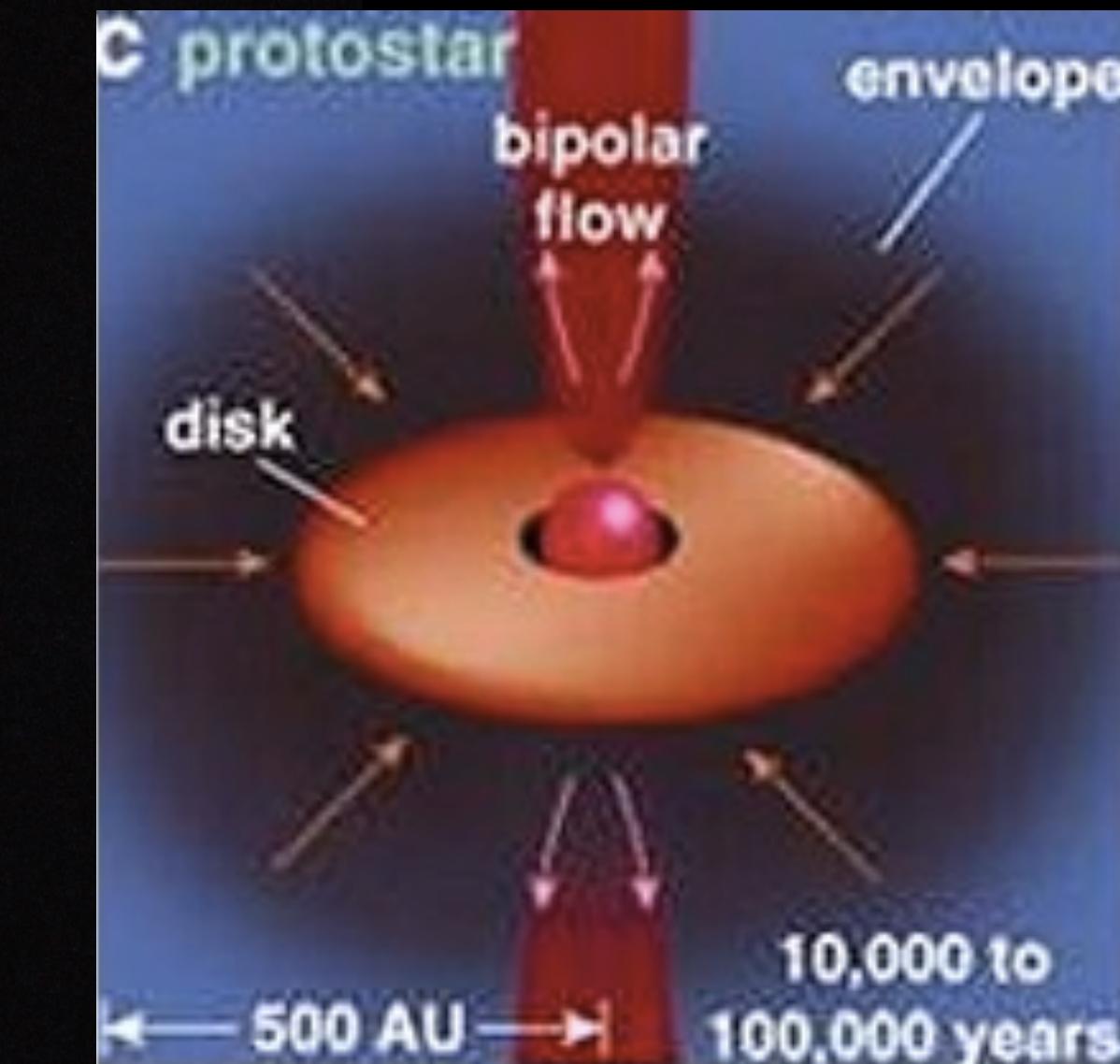
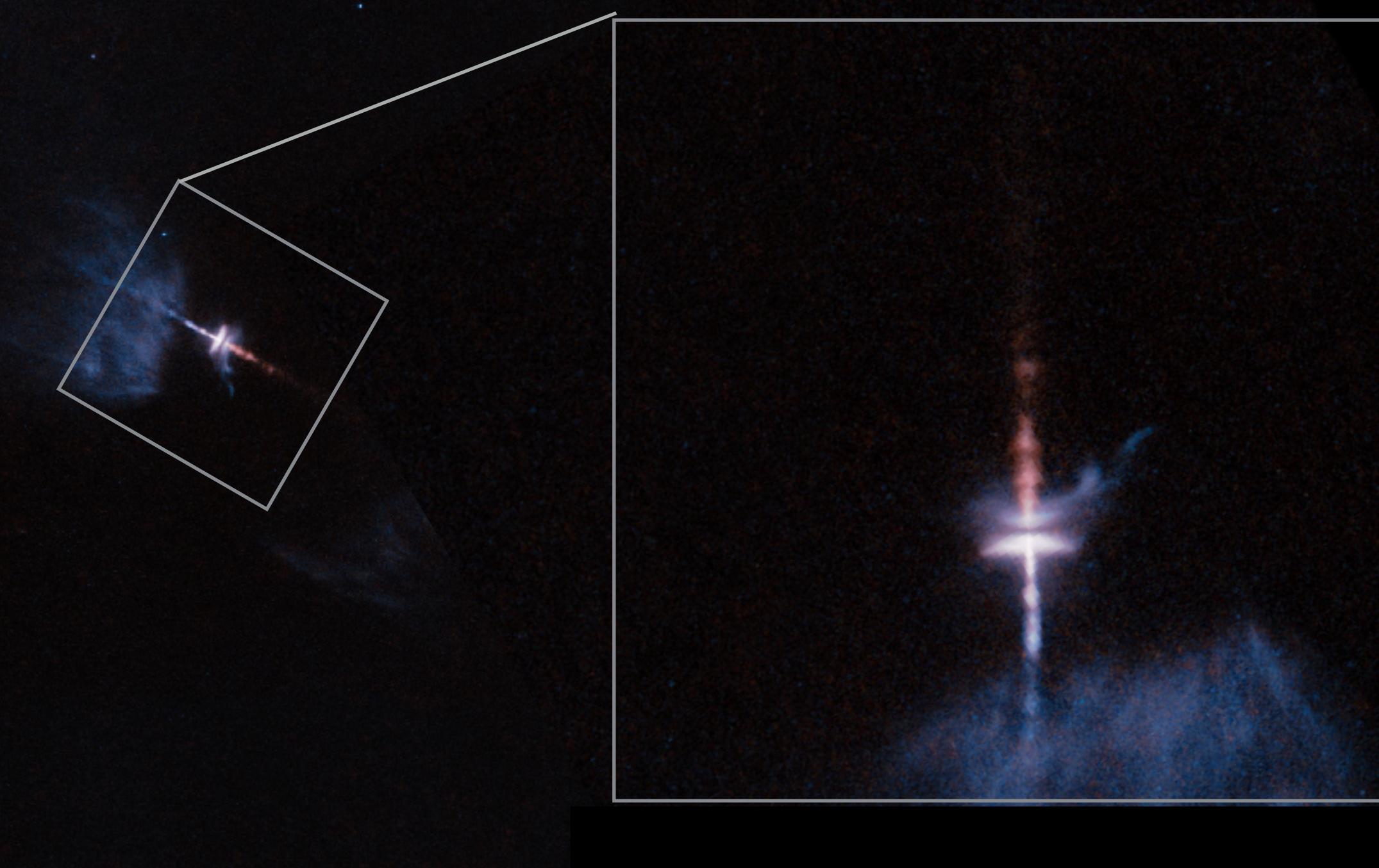
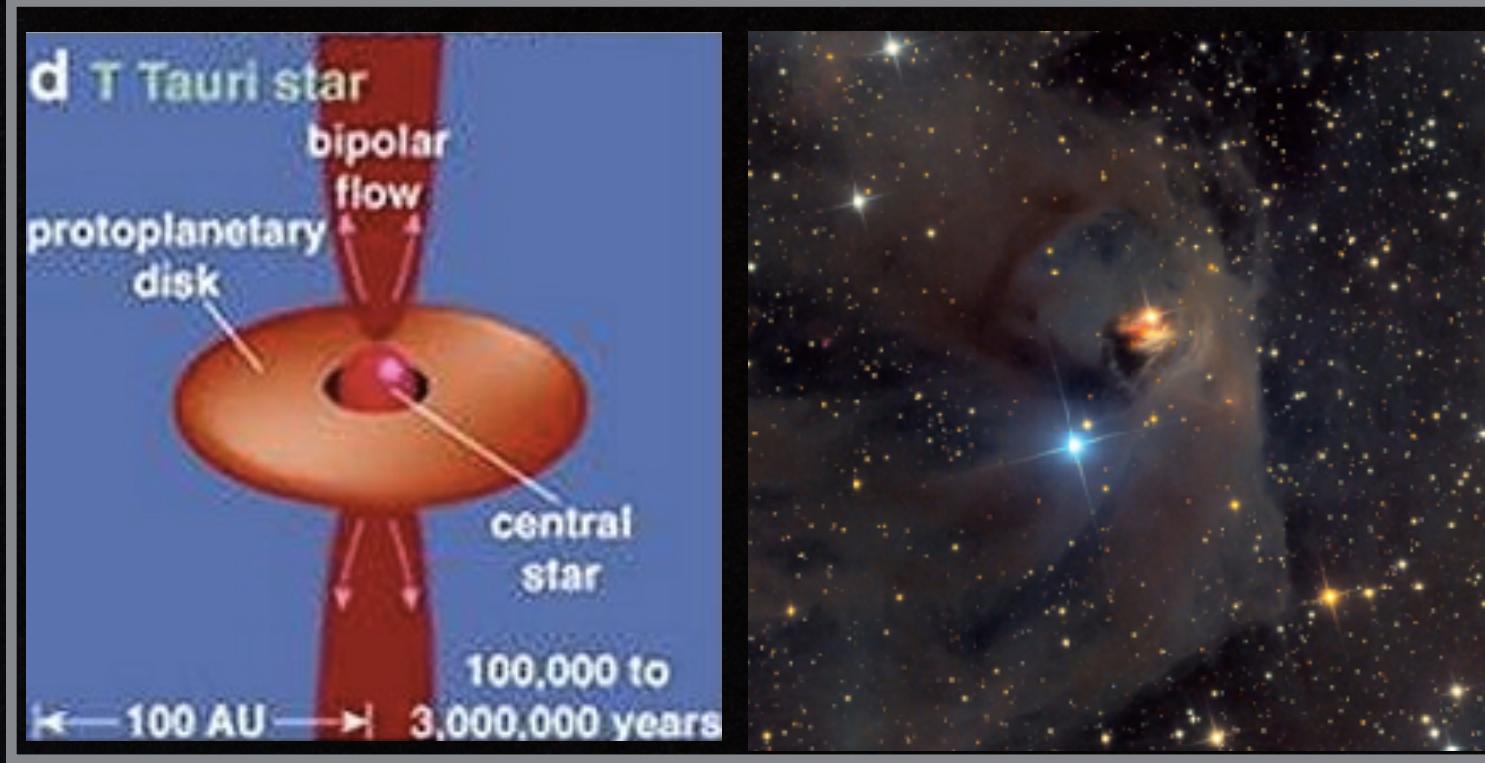
**Earliest stages of
star formation
(first 10,000 years)**

**Later stages of star formation
(10,000 -100,000 years)**

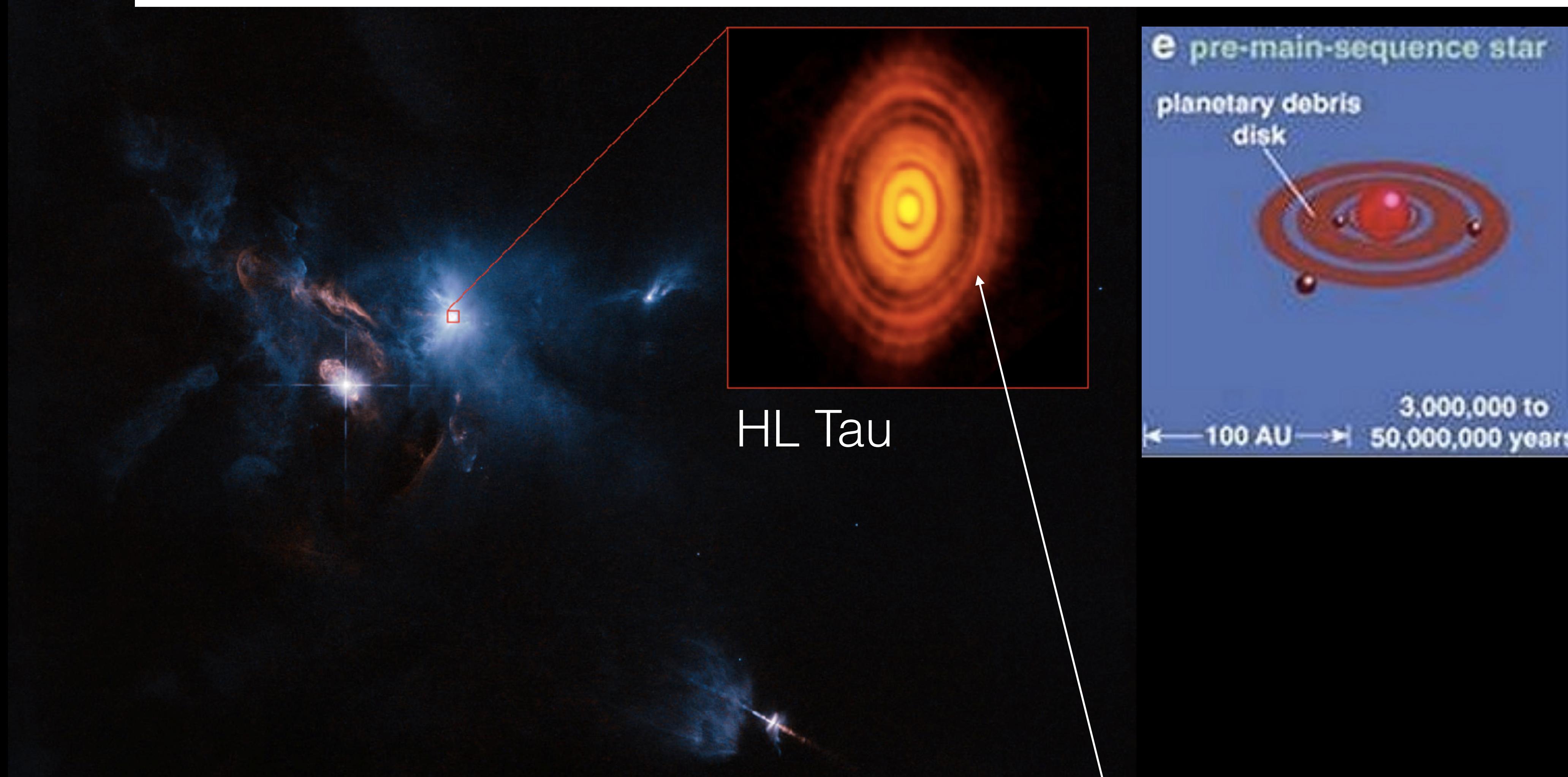


Protostars: HL and XZ Tau

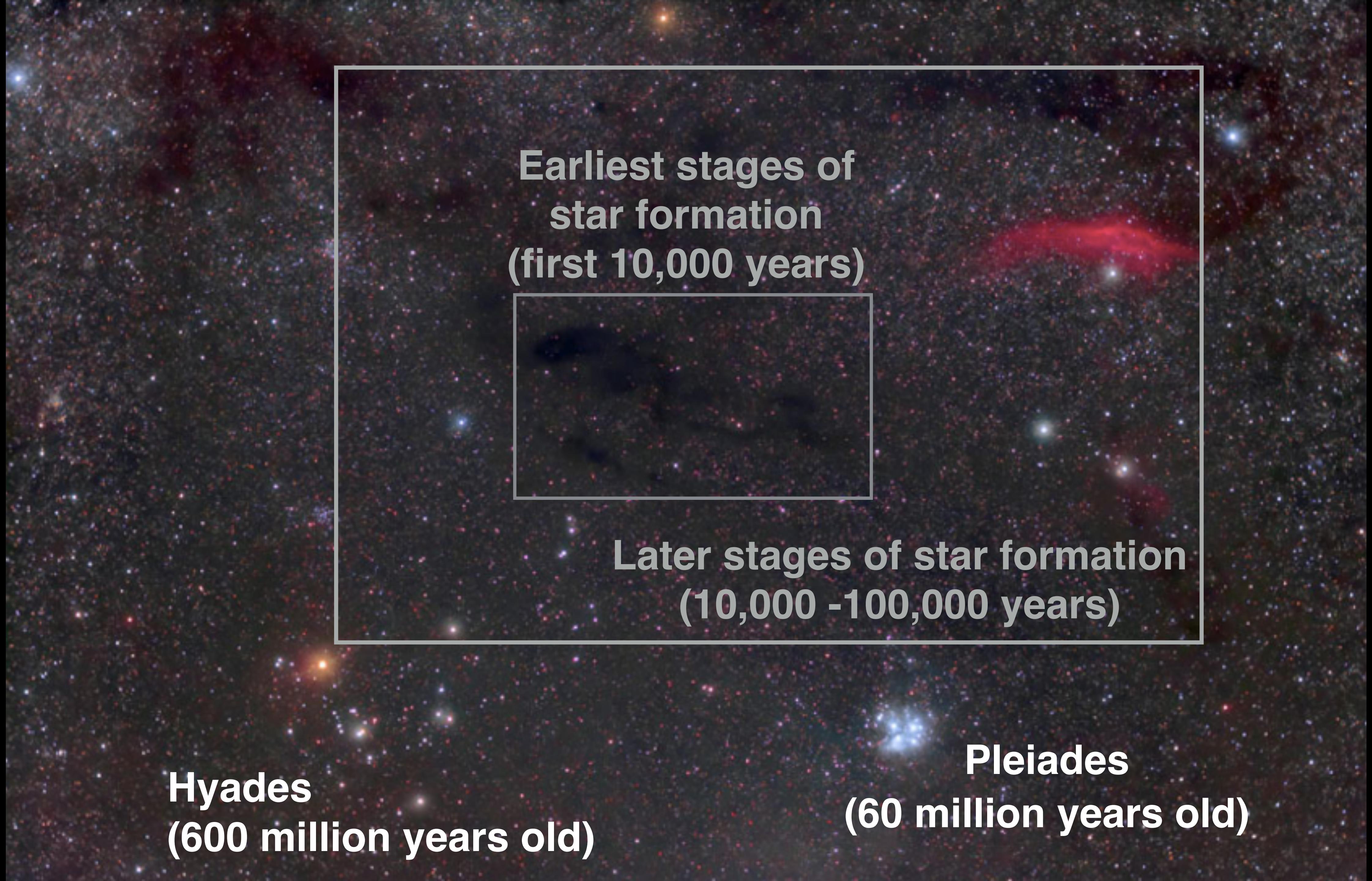
Stage 3/4: Outflowing and accreting Protostars



Stage 5: Planet formation



Astronomers think these gaps
between rings in the star's disk may
be caused by forming planets!



Hyades
(600 million years old)

Pleiades
(60 million years old)

**Earliest stages of
star formation
(first 10,000 years)**

**Later stages of star formation
(10,000 -100,000 years)**

Orion: The hunter

A photograph of a dark night sky filled with stars. In the upper right quadrant, the bright stars of Orion's Belt are visible. Below them, the stars of Canis Major are also prominent. The foreground shows the silhouette of mountain ranges against the dark sky.

also his dog
buddy, **Canis Major**

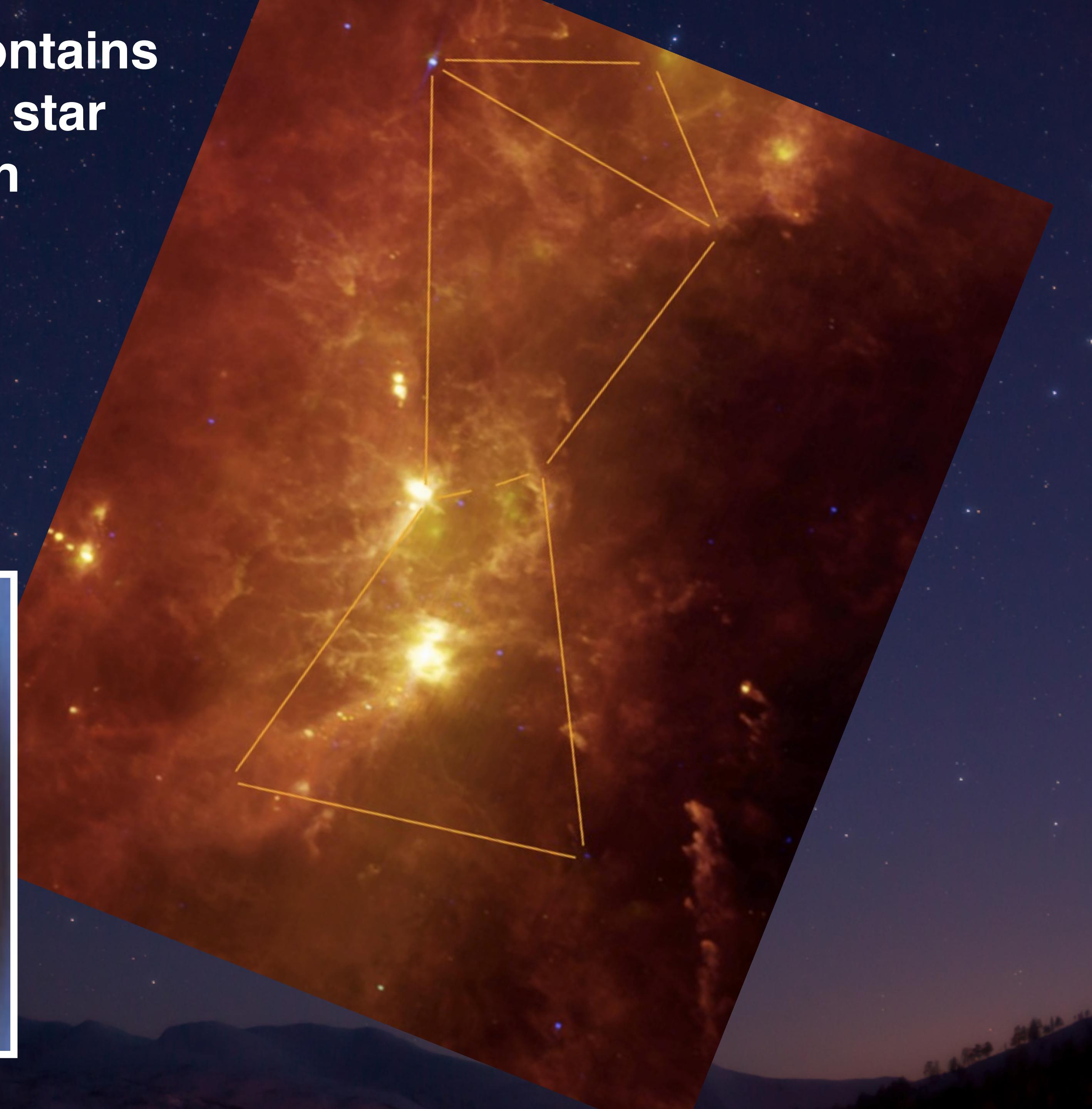
This is what it looks like in
infrared light



The molecular cloud contains
the earliest stages of star
formation in Orion

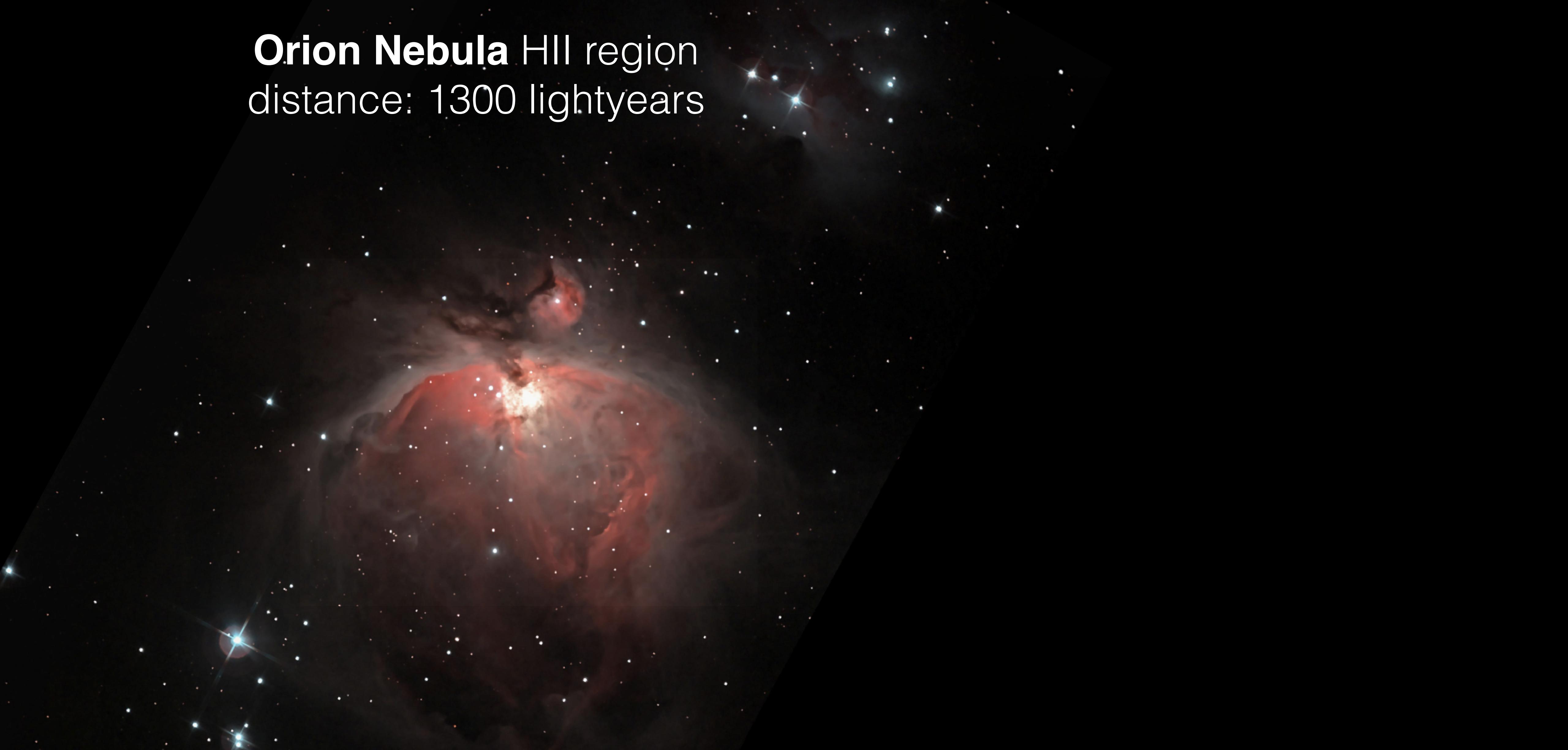
a dark cloud

dense core





Orion Nebula HII region distance: 1300 lightyears

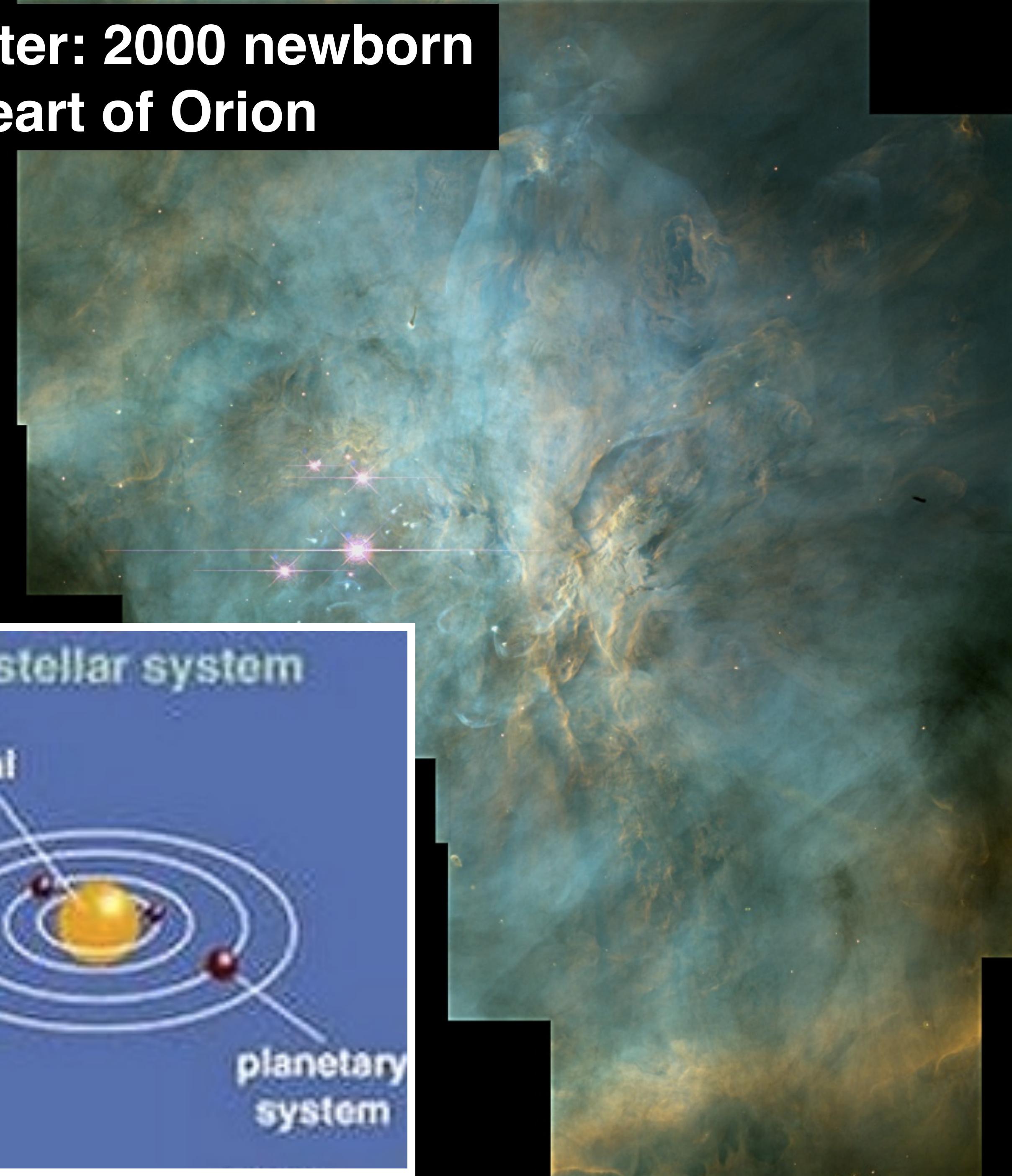


The nearest place massive blue-white stars 10-50 times as big as the sun are currently being born.



The Trapezium cluster: 2000 newborn stars in the heart of Orion

Here, massive stars are ionizing and sculpting the cloud they were born from



Protoplanetary disks (Proplyds): Massive, baby stars

For massive stars, these stages happen so fast that you see many of them occurring simultaneously in the same cloud.

