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FROM THE BIG BANG TO FOSSIL BUTTE: THE COSMIC BIOGRAPHY OF AN ATOM

Shane L. Larson
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Fossil Butte National Monument
22 August 2009

STORYLINE

- Atoms
- In the Sky Tonight
- The Beginning
- Getting Older
- Cosmic Recycling

What are we talking about?

- Look at the natural world around you. Not everything is the same.
- If I pick up two different rocks here at Fossil Butte, they invariably look different.
- Not just size and shape, but their color and their composition.
- What are they made of?



CONSIDER A CHERRY PIE...

- Suppose I cut a piece out of a cherry pie. And eat it.
- I get **bigger**, and the cherry pie gets **smaller**.
- How many times do I have to cut the cherry pie in half before I get to the smallest piece of “stuff”?

Only about 90 times.

- These small bits of stuff are **atoms**, and everything is made from them.



WHAT KINDS OF ATOMS?

- What are these atoms?
- A rock and a piece of cherry pie are quite different, but they are made up of the same building blocks, in different proportions and combinations
- There are **92 known naturally occurring** kinds of atoms. These are called the **ELEMENTS**.



ORDINARY EARTHLY ORGANISMS

For every 10,000 atoms in an average organism, there are:

- 6500 oxygen atoms
- 1800 carbon atoms
- 1000 hydrogen atoms
- 300 nitrogen atoms
- 150 calcium atoms
- 100 phosphorus atoms
- 25 potassium atoms
- 25 sulfur atoms
- 15 chlorine atoms
- 15 sodium atoms
- 5 magnesium atoms
- 65: traces of other stuff...



THE EARTH'S CRUST

For every 10,000 atoms in Earth's crust, there are:

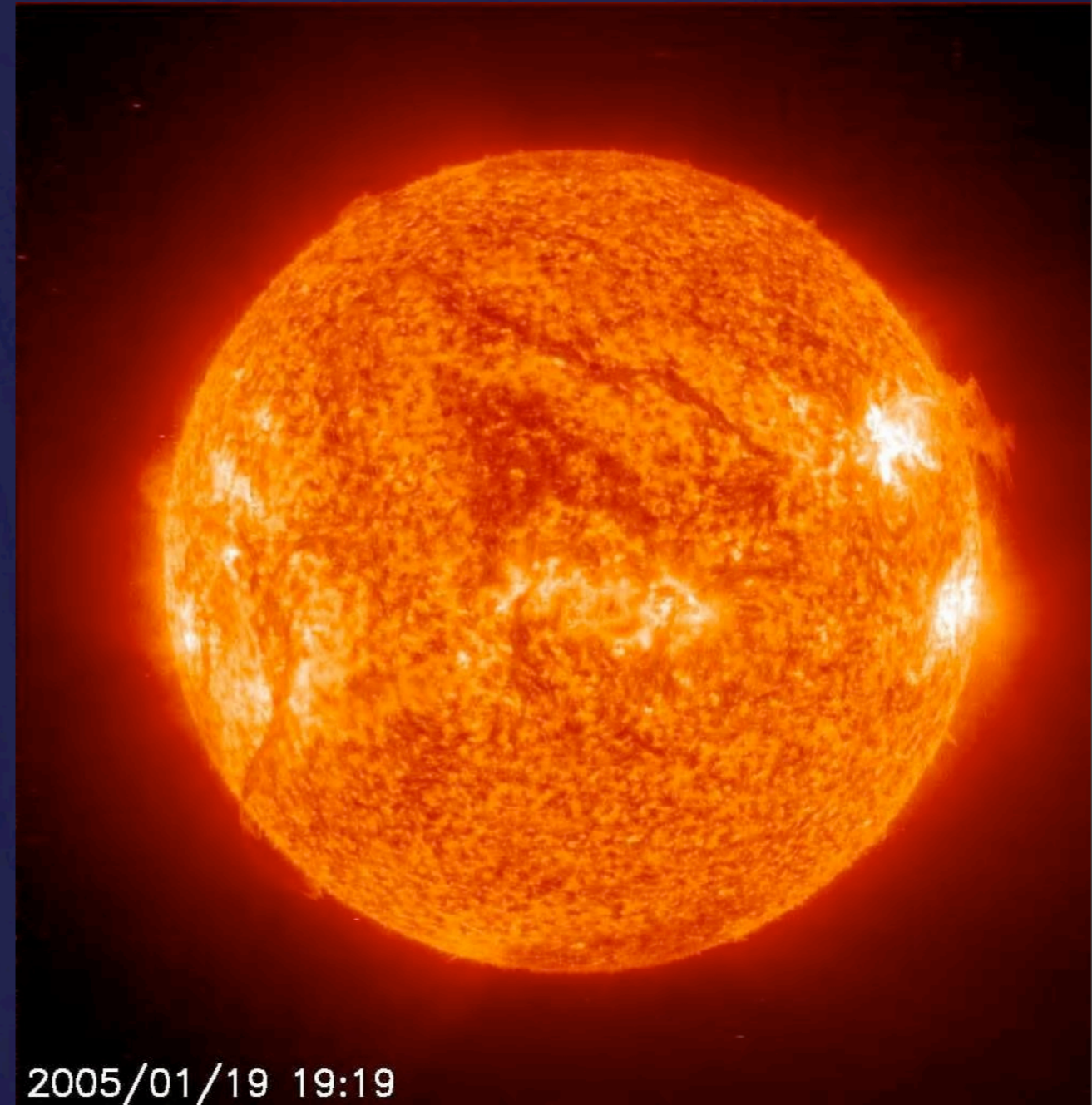
- 4640 oxygen atoms
- 2820 silicon atoms
- 830 aluminum atoms
- 560 iron atoms
- 410 calcium atoms
- 230 sodium atoms
- 230 magnesium atoms
- 210 potassium atoms
- 60 titanium atoms
- 10 hydrogen atoms



WHAT IS THE SUN MADE OF?

For every 10,000 atoms in the Sun, there are:

- 9149 atoms of hydrogen
 - 779 atoms of helium
 - 62 atoms of oxygen
 - 6 atoms of carbon
 - 3 atoms of neon
 - 1 atom of nitrogen
- and even less of everything else.



Hydrogen is the most common element in the universe!

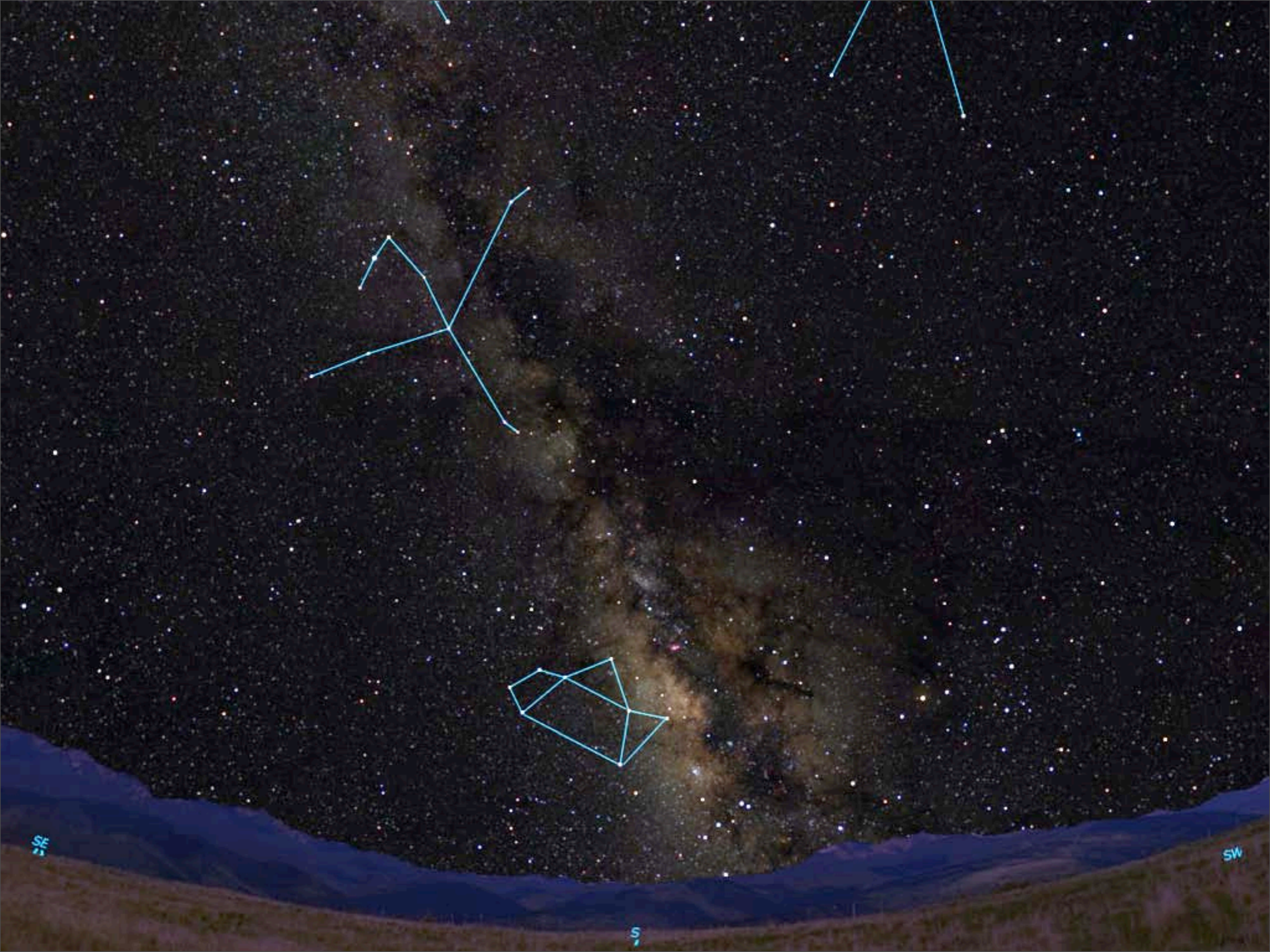
OUR STORY IN THE SKY TONIGHT



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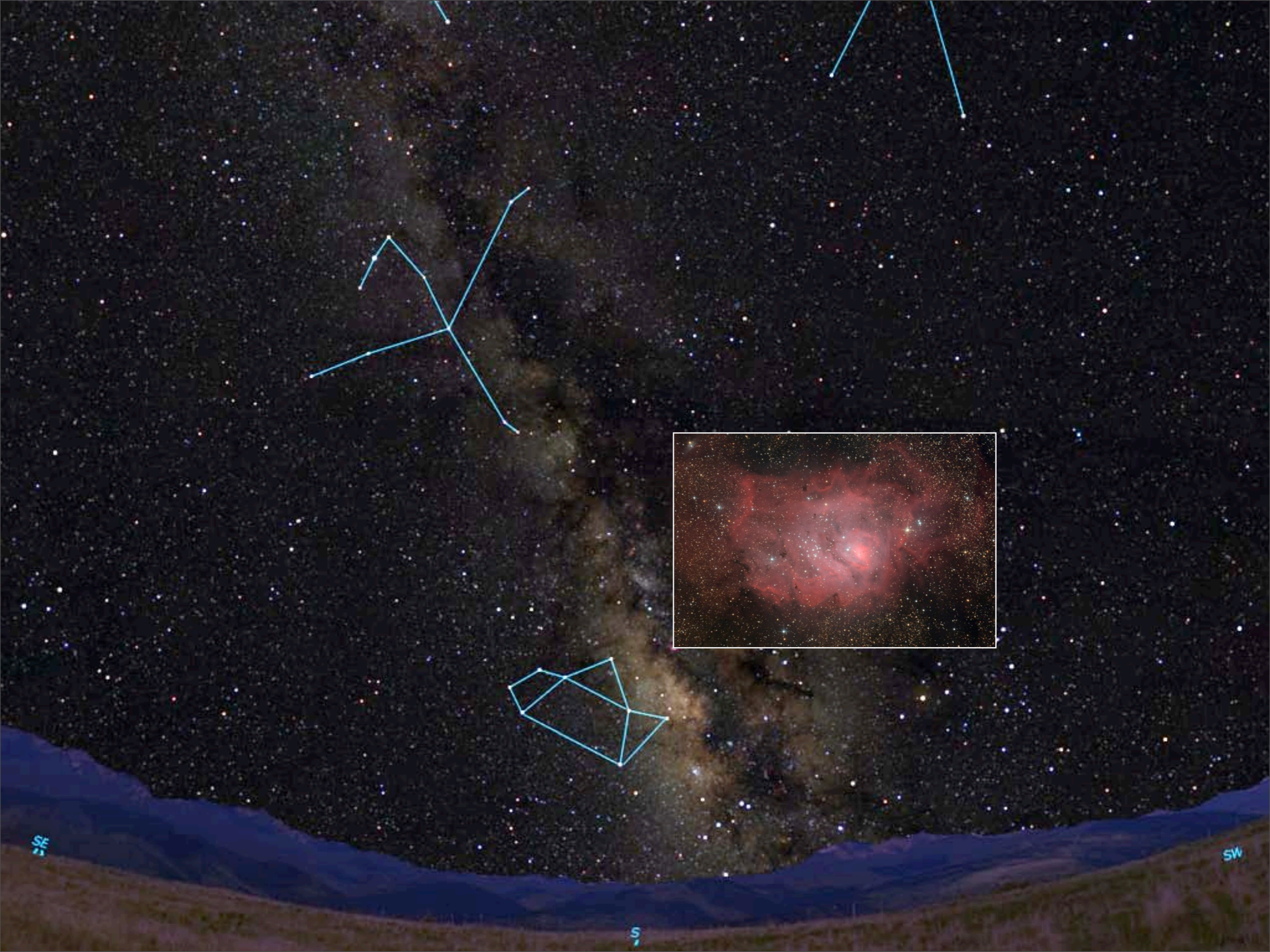
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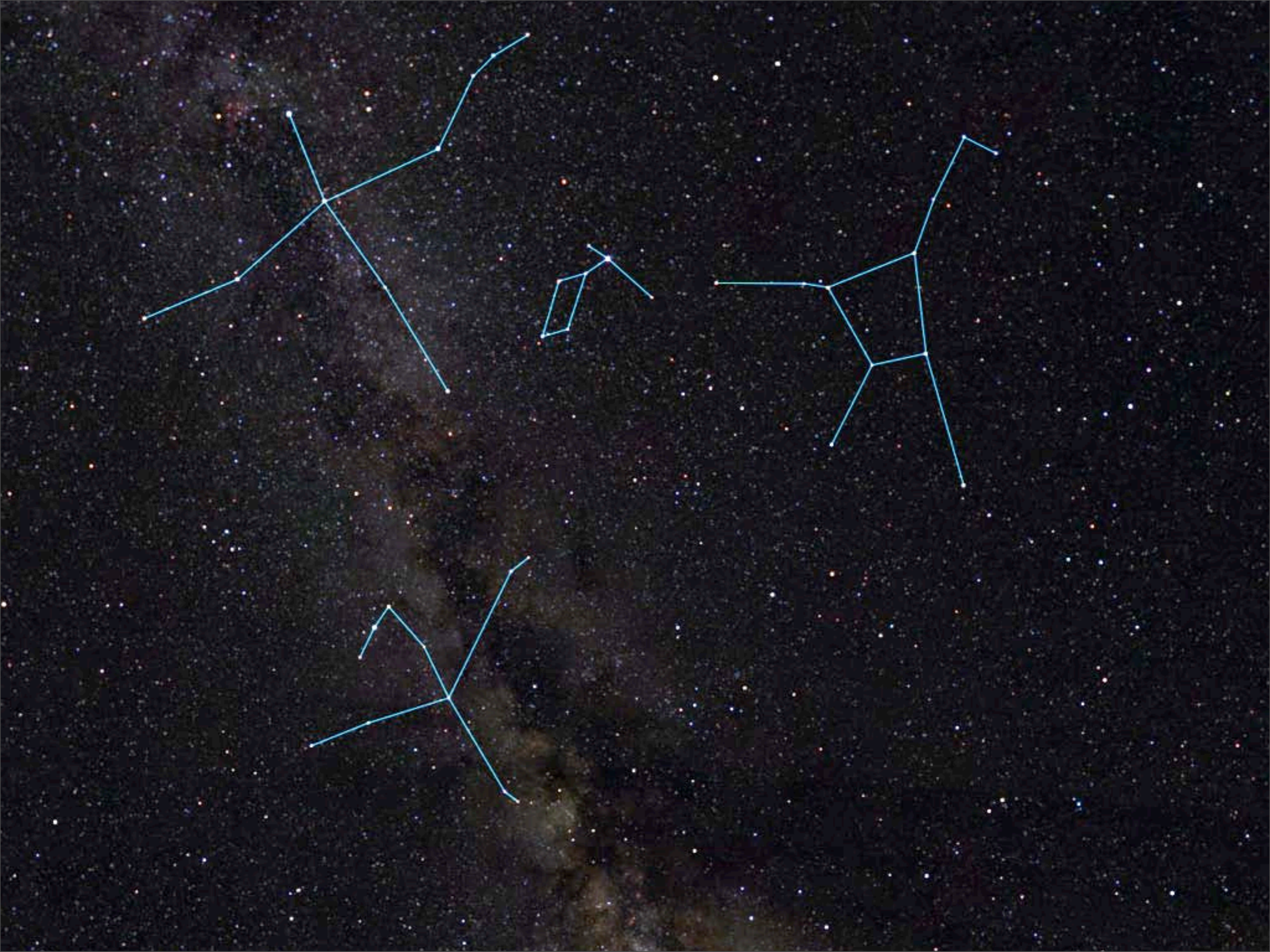
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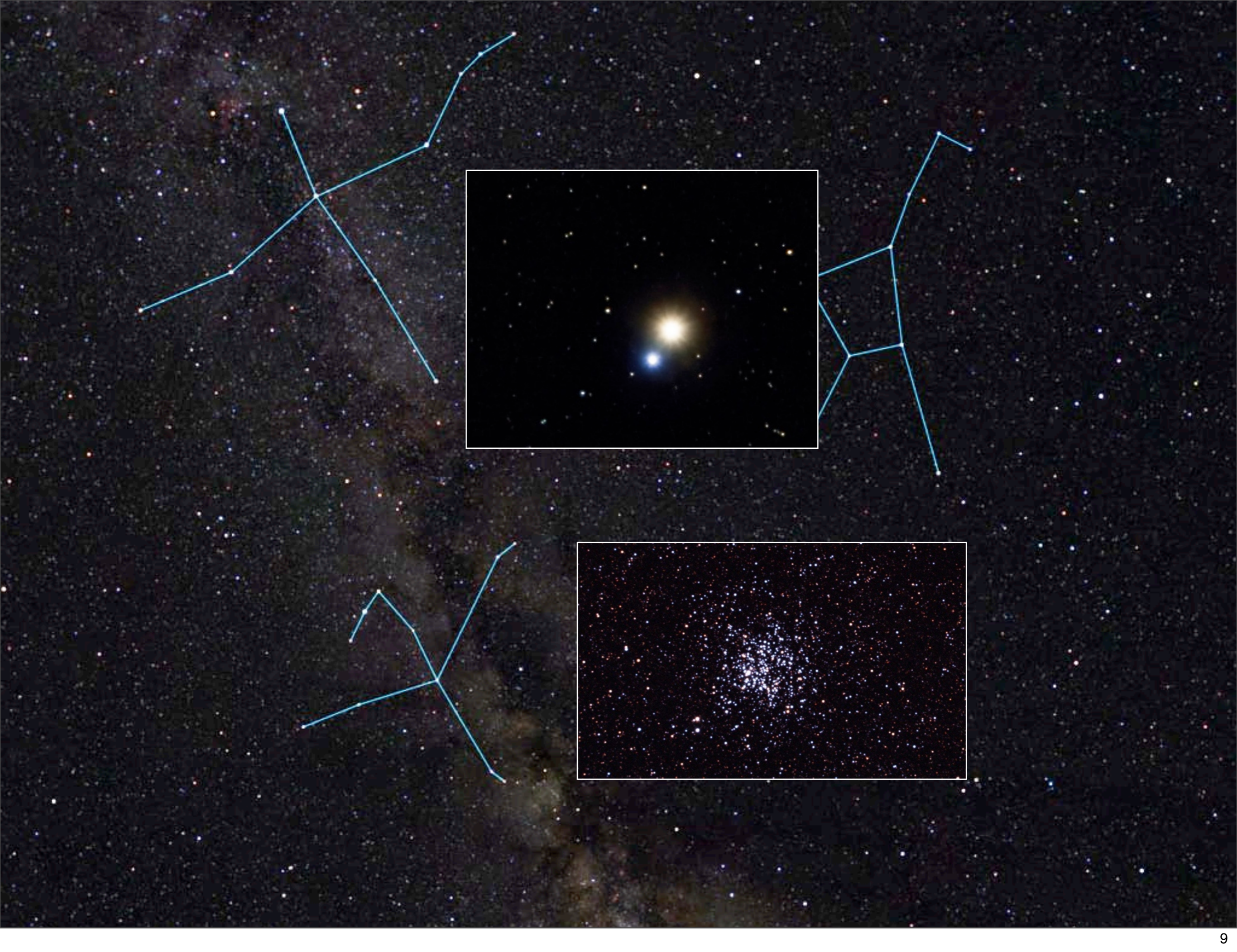


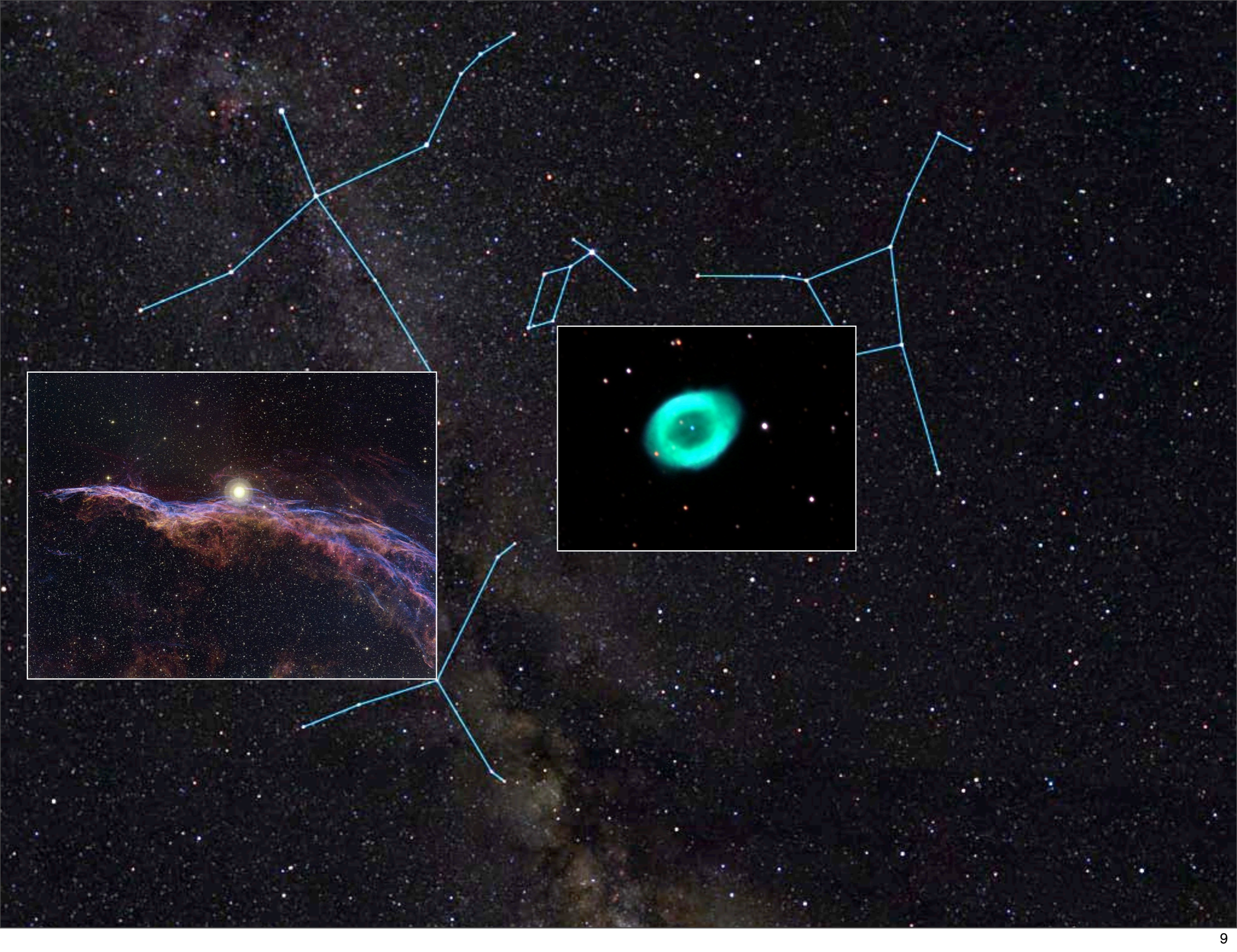
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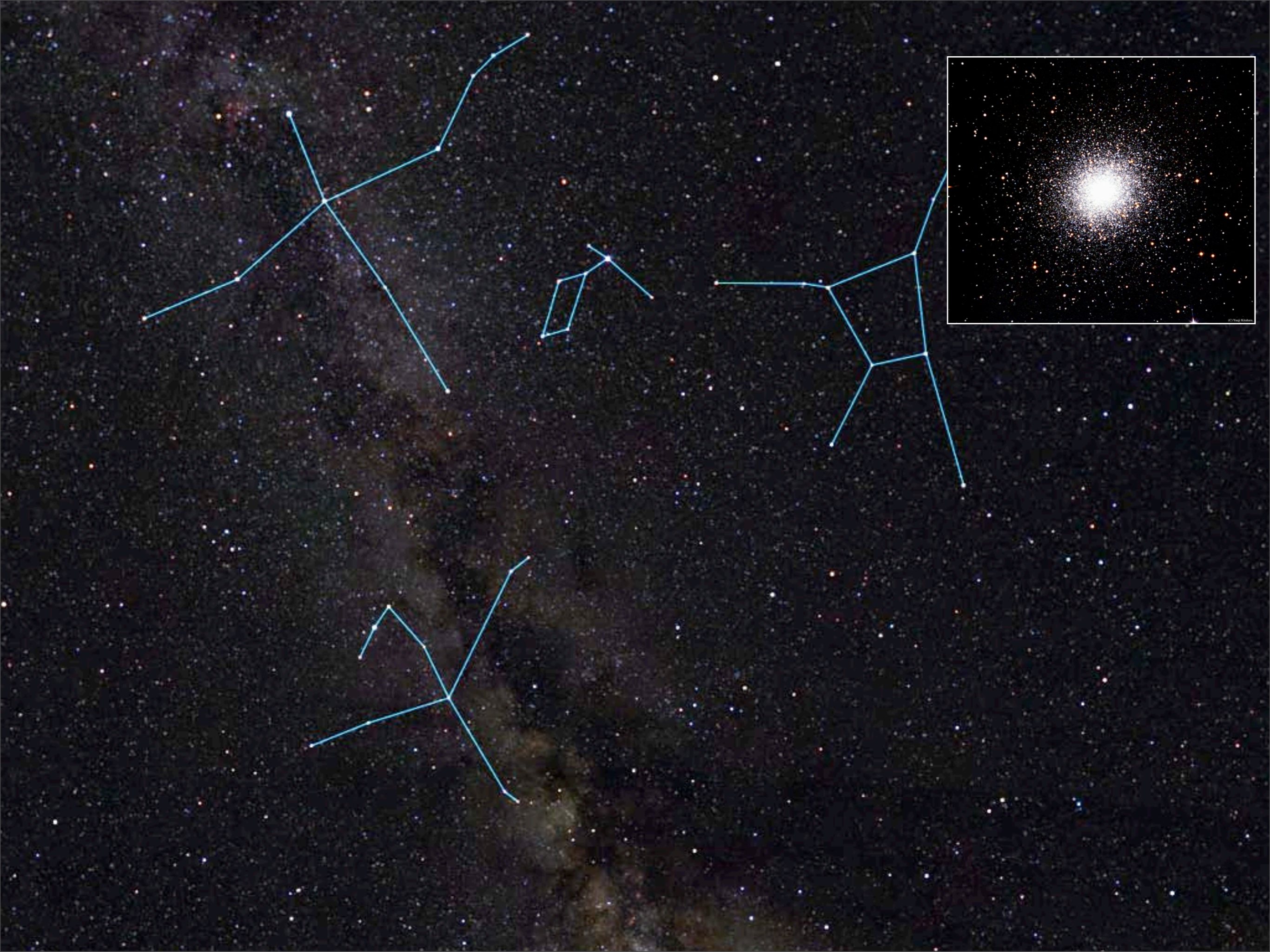
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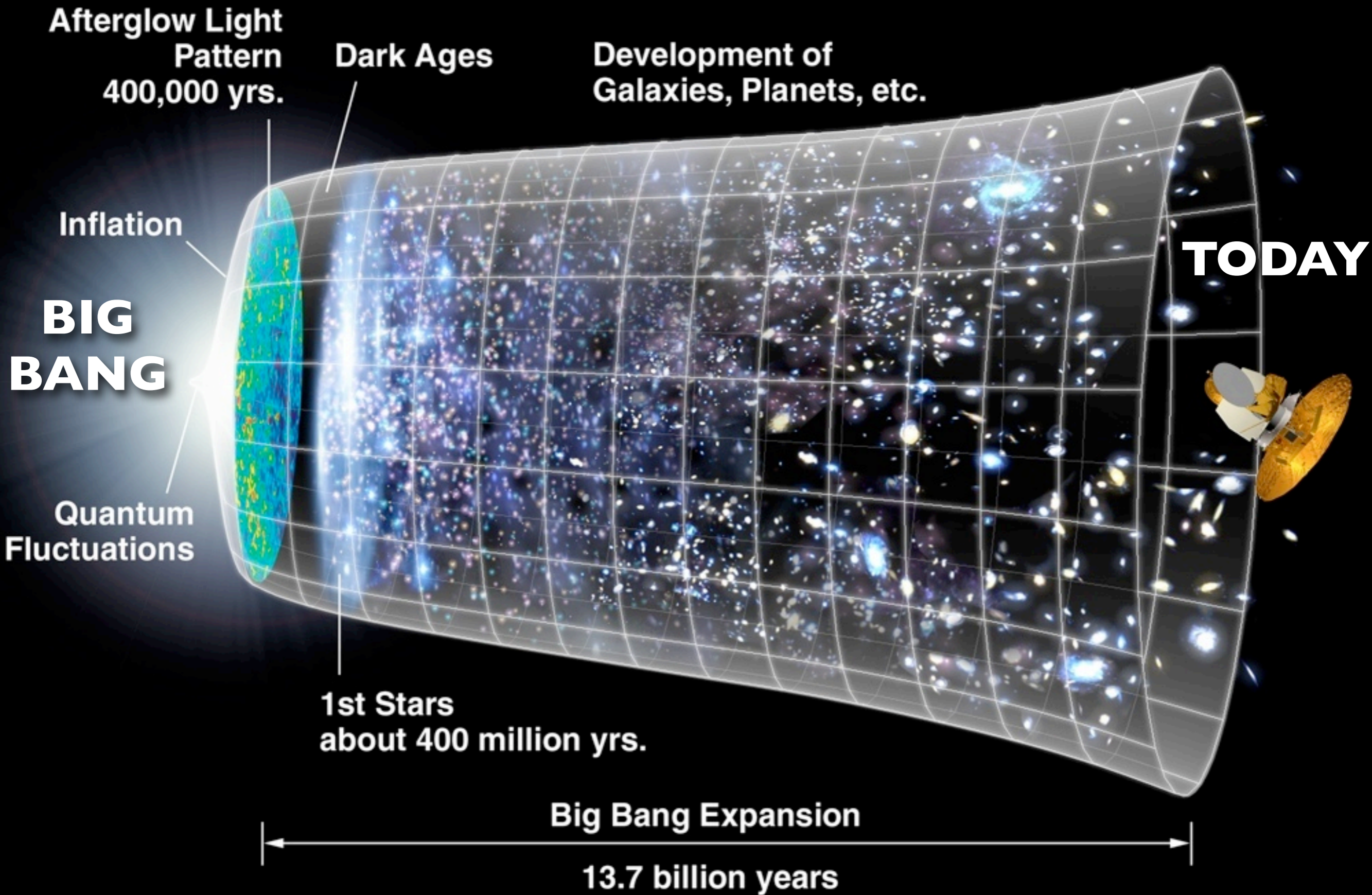
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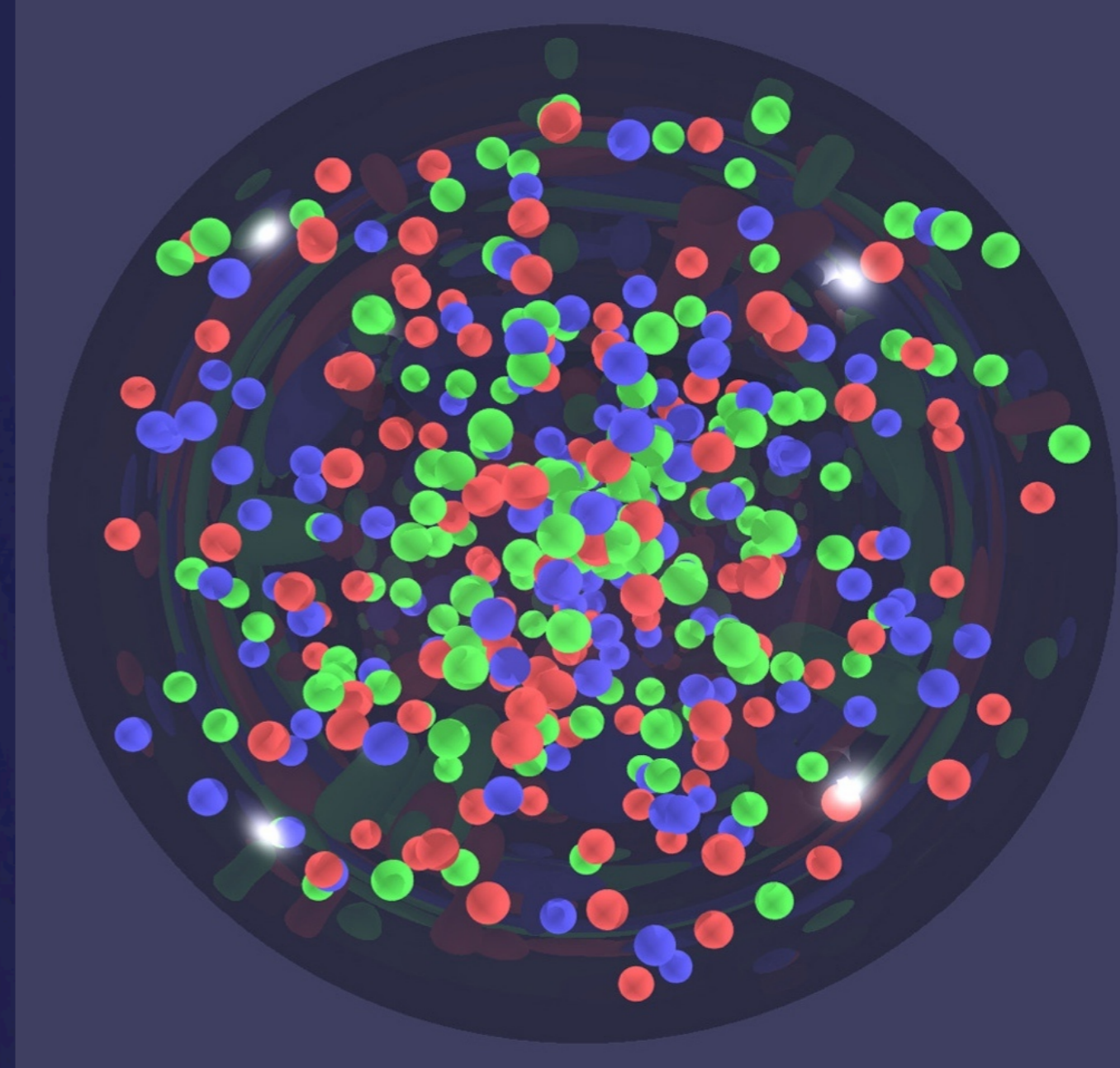






IN THE BEGINNING...

- There was a **Primordial Soup** of electrons, protons, neutrons, and photons.
- It was so hot, electrons couldn't stick to protons
- By ~400,000 years, Cosmos cooled off to ~3000° C and **atoms** formed
- For every 1,000,000,000 atoms:
 - | **Lithium**
 - 100,000 **Helium**
 - 1,000,000 **Deuterium**
 - 998,899,999 **Hydrogen**



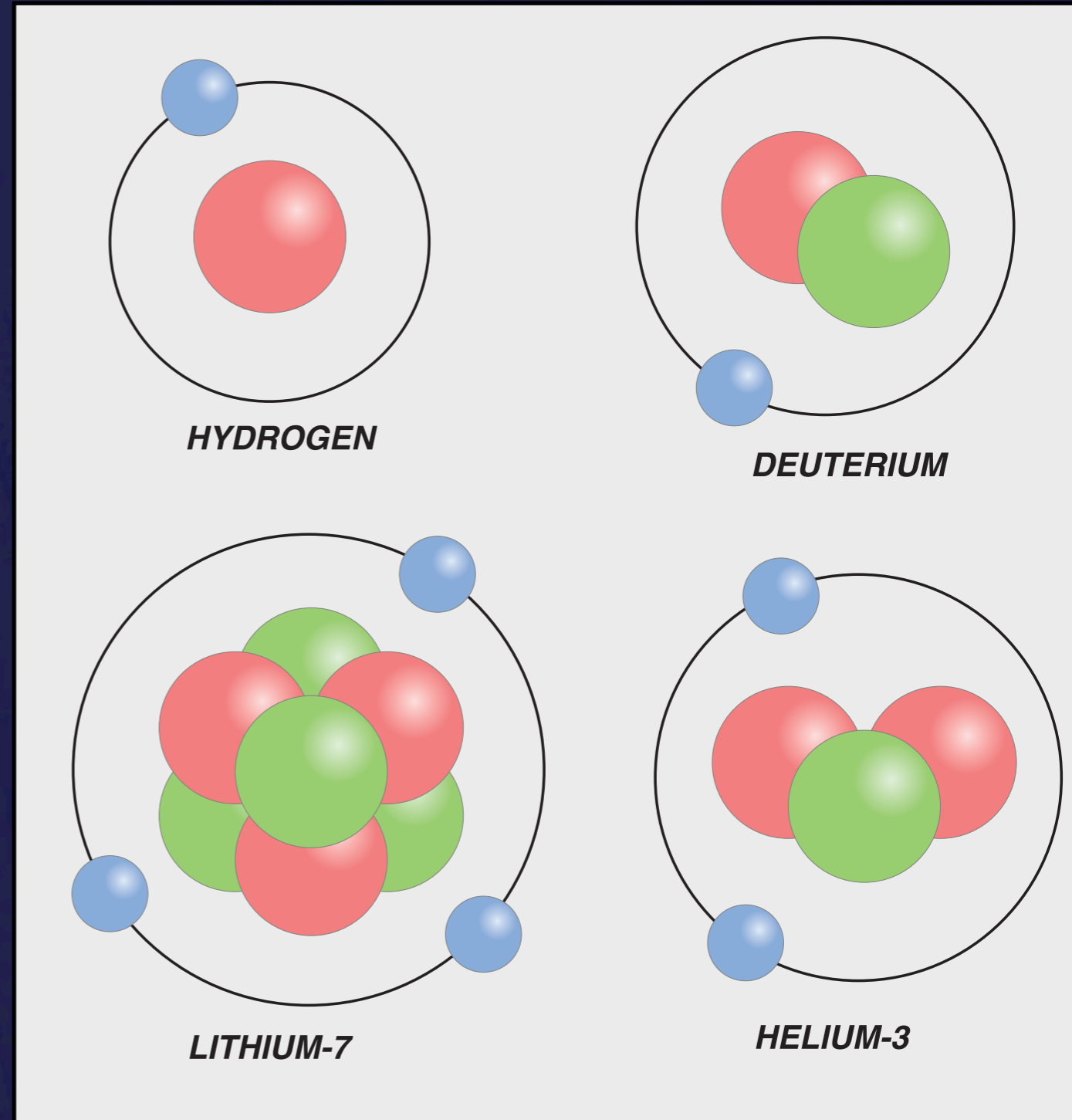
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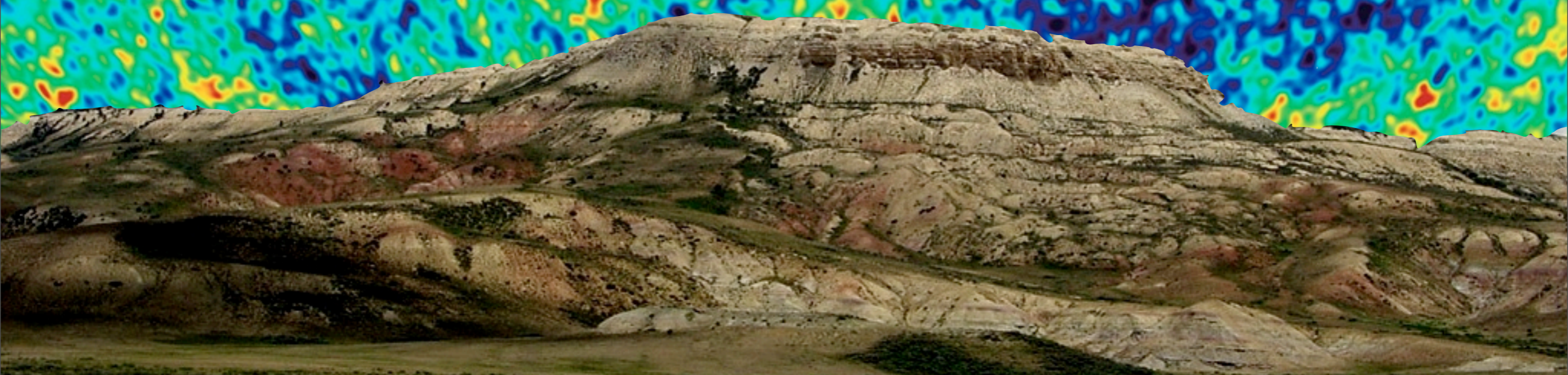
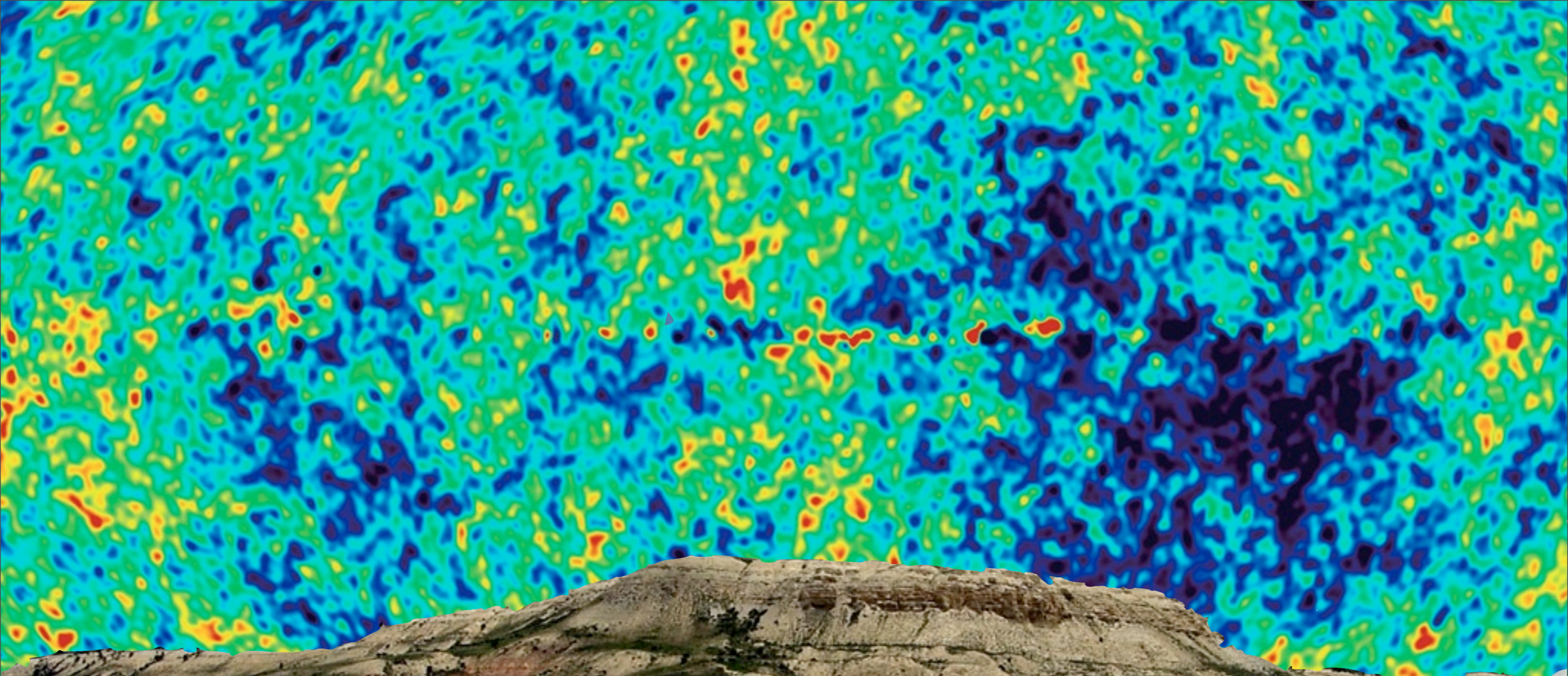
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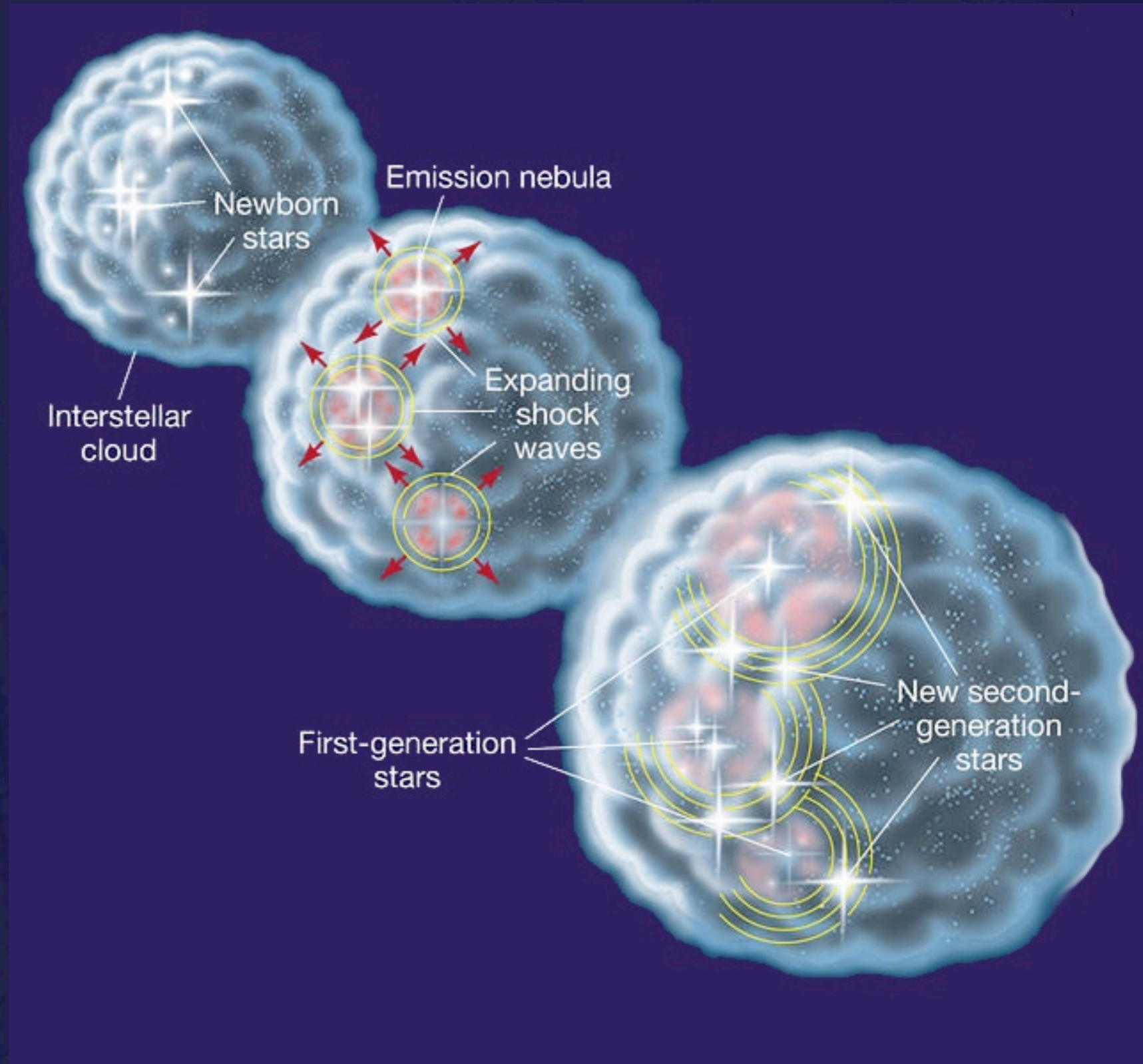


THE WHOLE SKY

- The Cosmic Microwave background arrives from every point on the sky. It is the signature of formation of the first atoms (**nucleosynthesis**).

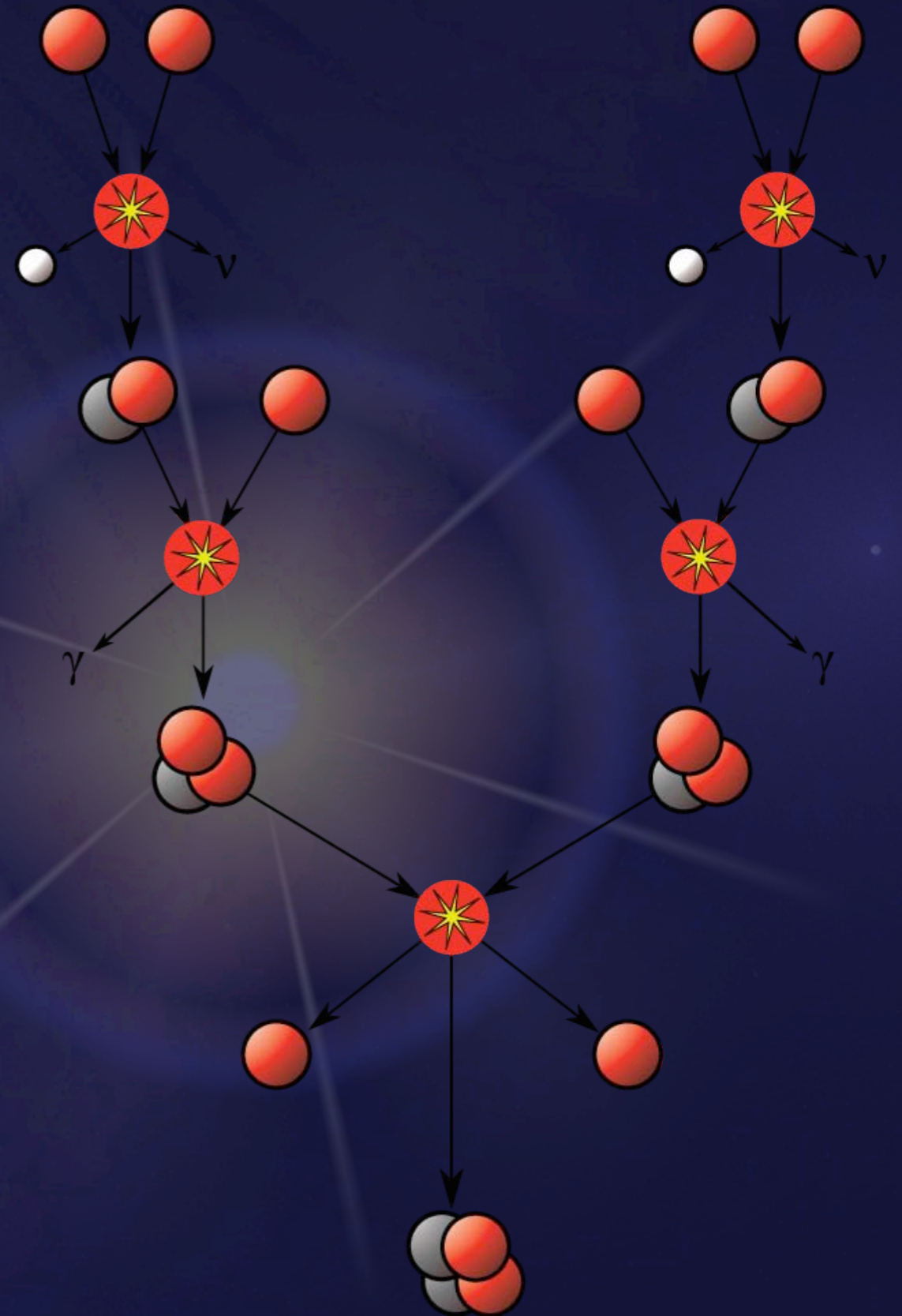
GETTING TOGETHER WITH FRIENDS...

- 400 million years after the birth of atoms, gas gathers together and stars begin to form.
- Gravity pulls the gas together into balls that collapse to become stars
- When the stars “turn on”, stellar winds blow and cause new stars to form



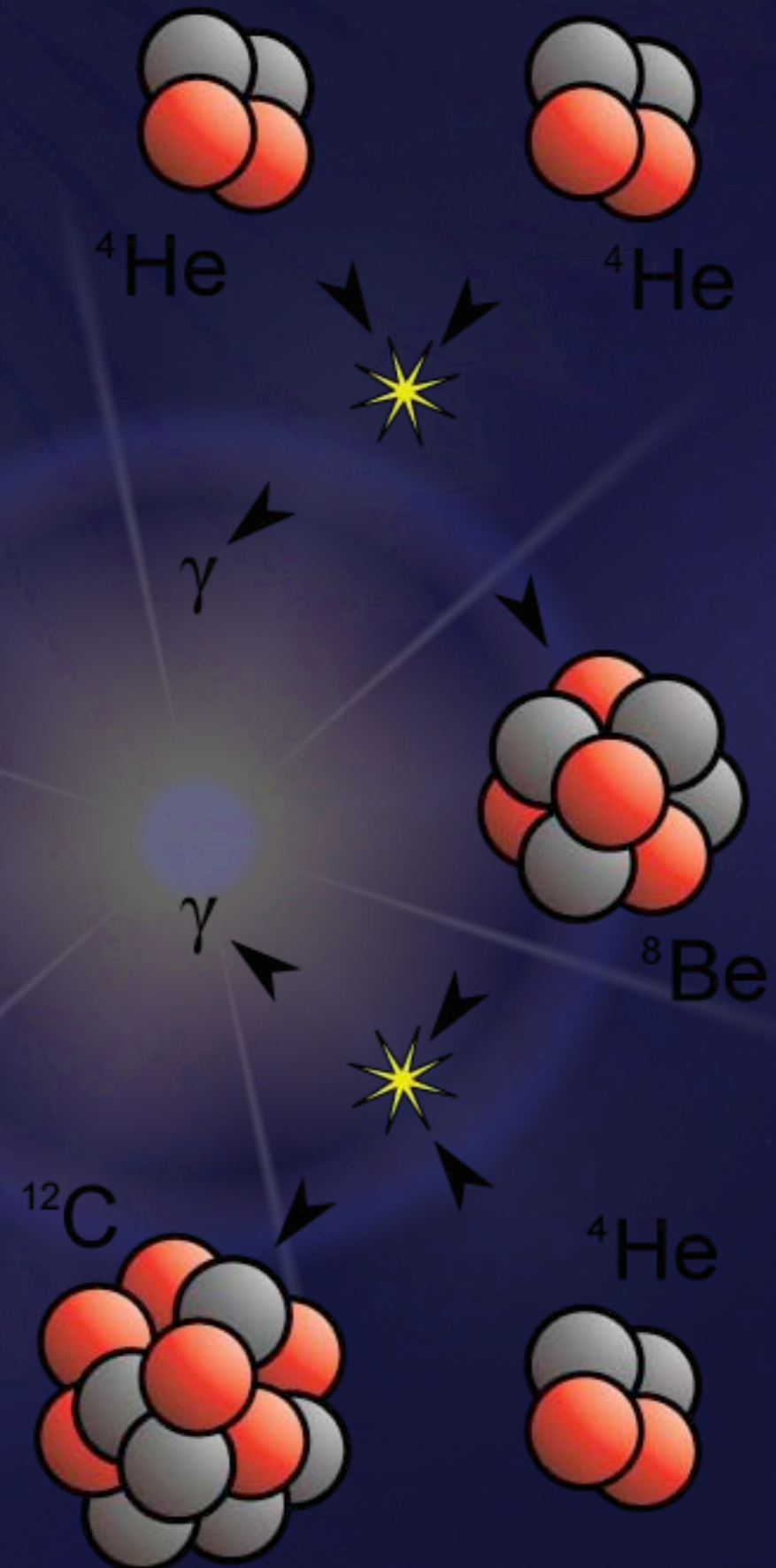
HYDROGEN TRANSFORMED...

- In the cores of the stars, temperatures are so high **nuclear fusion** begins
- Bang hydrogen atoms together and they make new elements, like **helium!**
- Bang helium together, and make new elements like **carbon!**
- Process continues all the way up to **IRON.**
- In the process, you get energy (**LIGHT**) out of the star



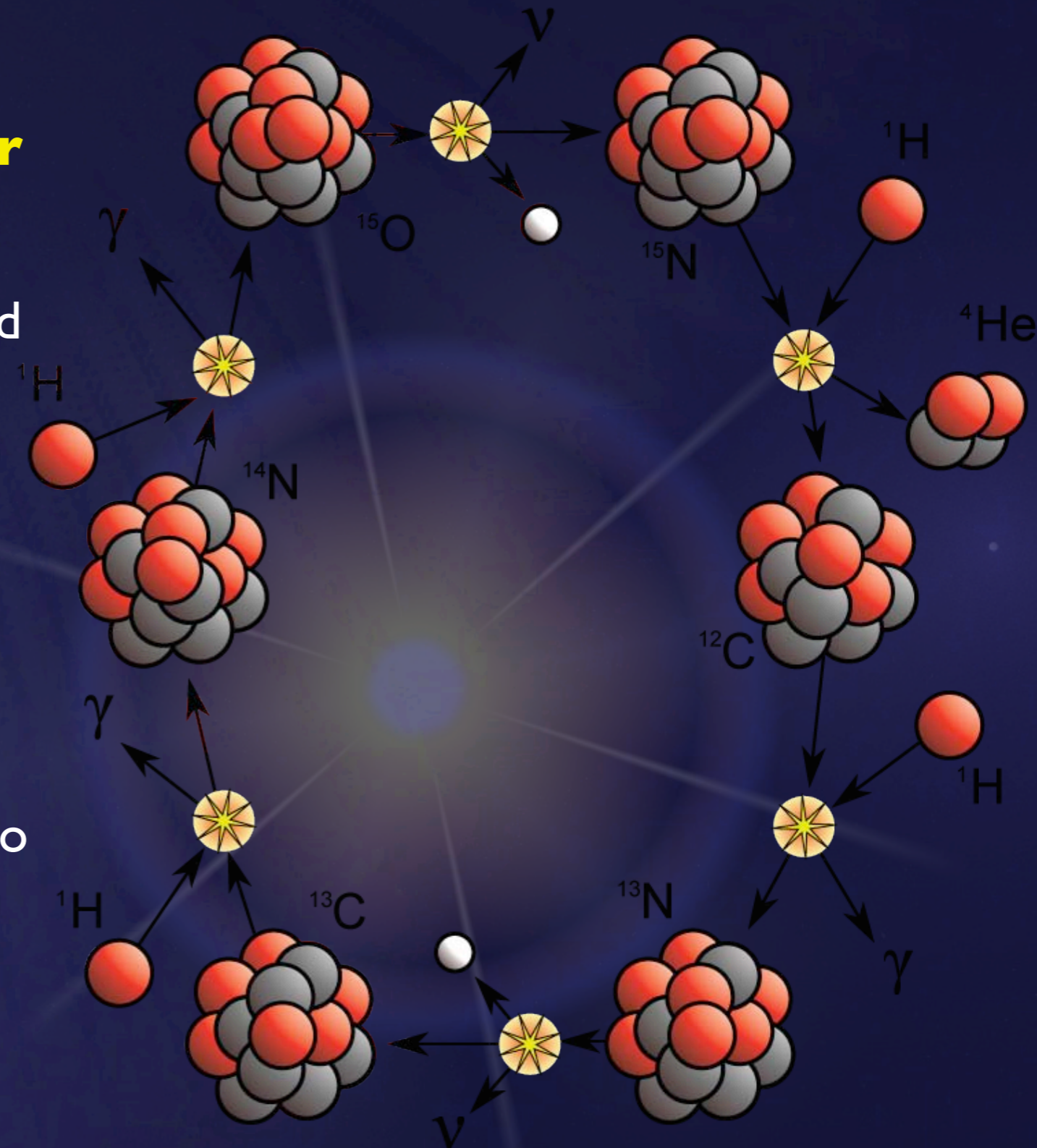
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THE COSMOS IS ALIVE...

- The births of the stars makes wondrous sights in the Cosmos that you and I can see with small telescopes and binoculars!
- The nebulae are **stellar nurseries**
- There stars eventually blow away the remnants of their parent nebula, leaving an **open cluster**
- Some stars are born together as **binaries**, destined to always have a companion over their long lives



M8 : The Lagoon Nebula

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M11 : The Wild Duck Cluster

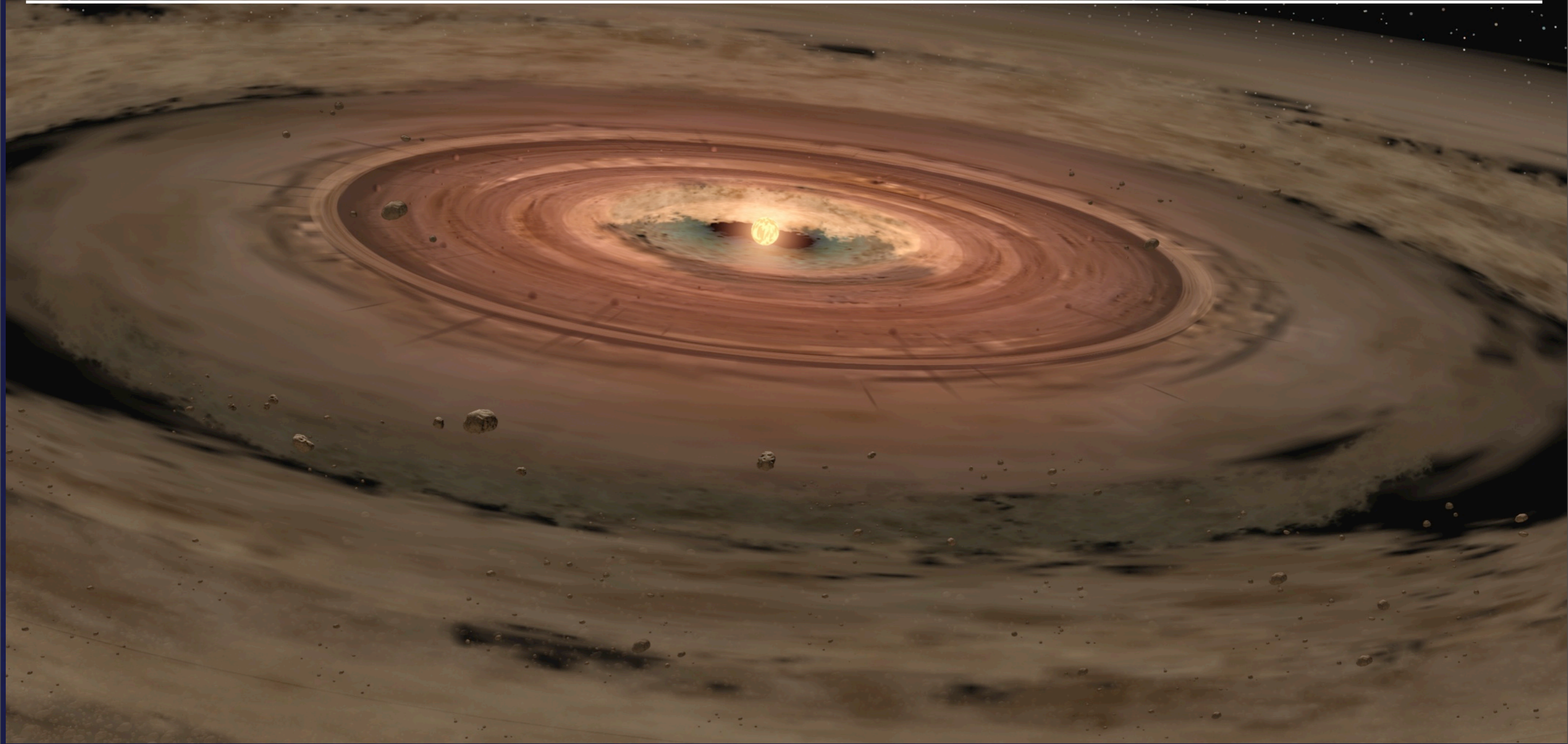
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Albireo (Beta Cygni)

FORMATION OF PLANETS...

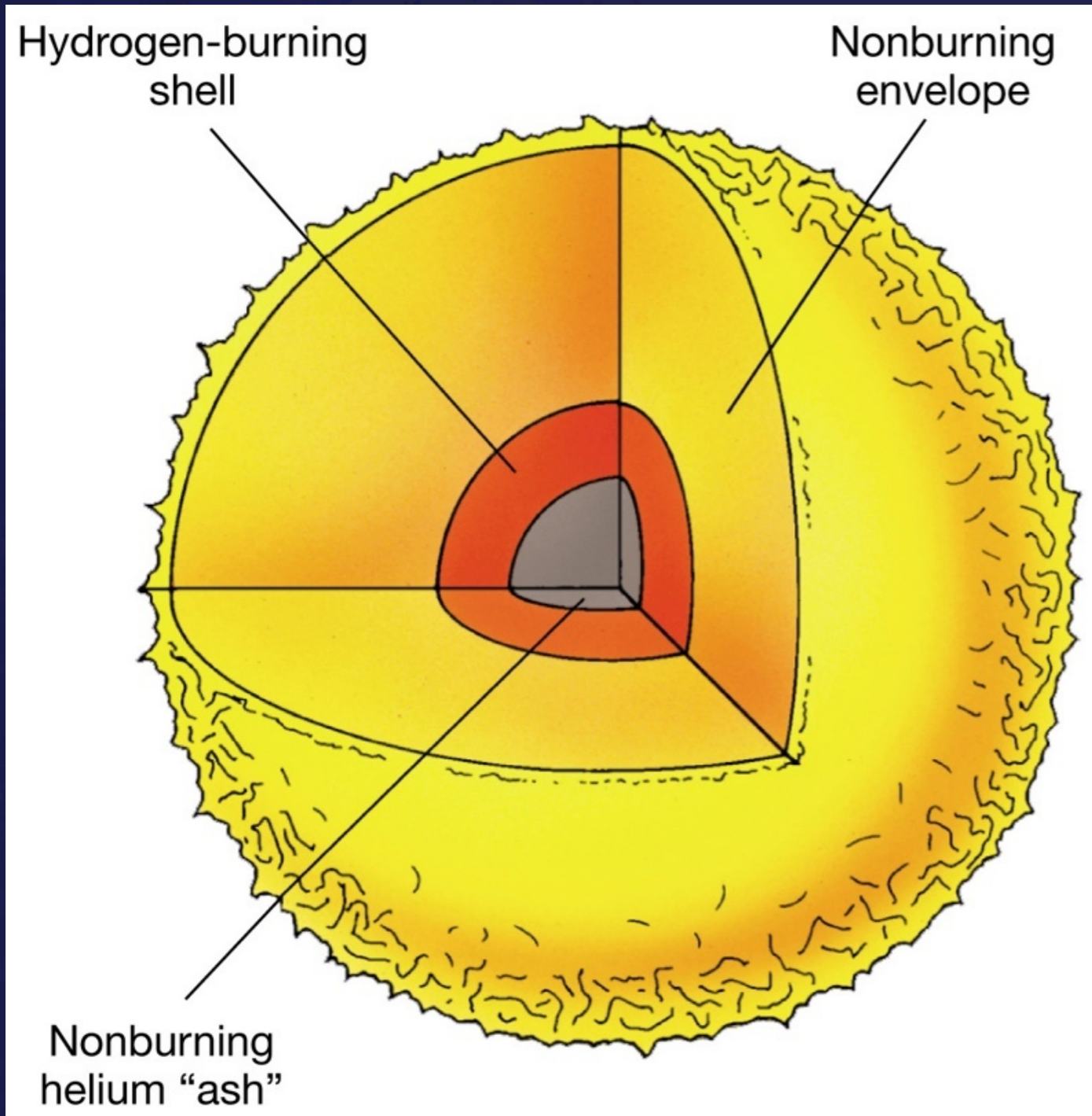


- During the early stages of star formation, gas that doesn't become the star forms the planets.
- All the atoms on the planet today came from the atoms of the nebula that formed our parent star. As of yesterday, there are **373 known planets...**

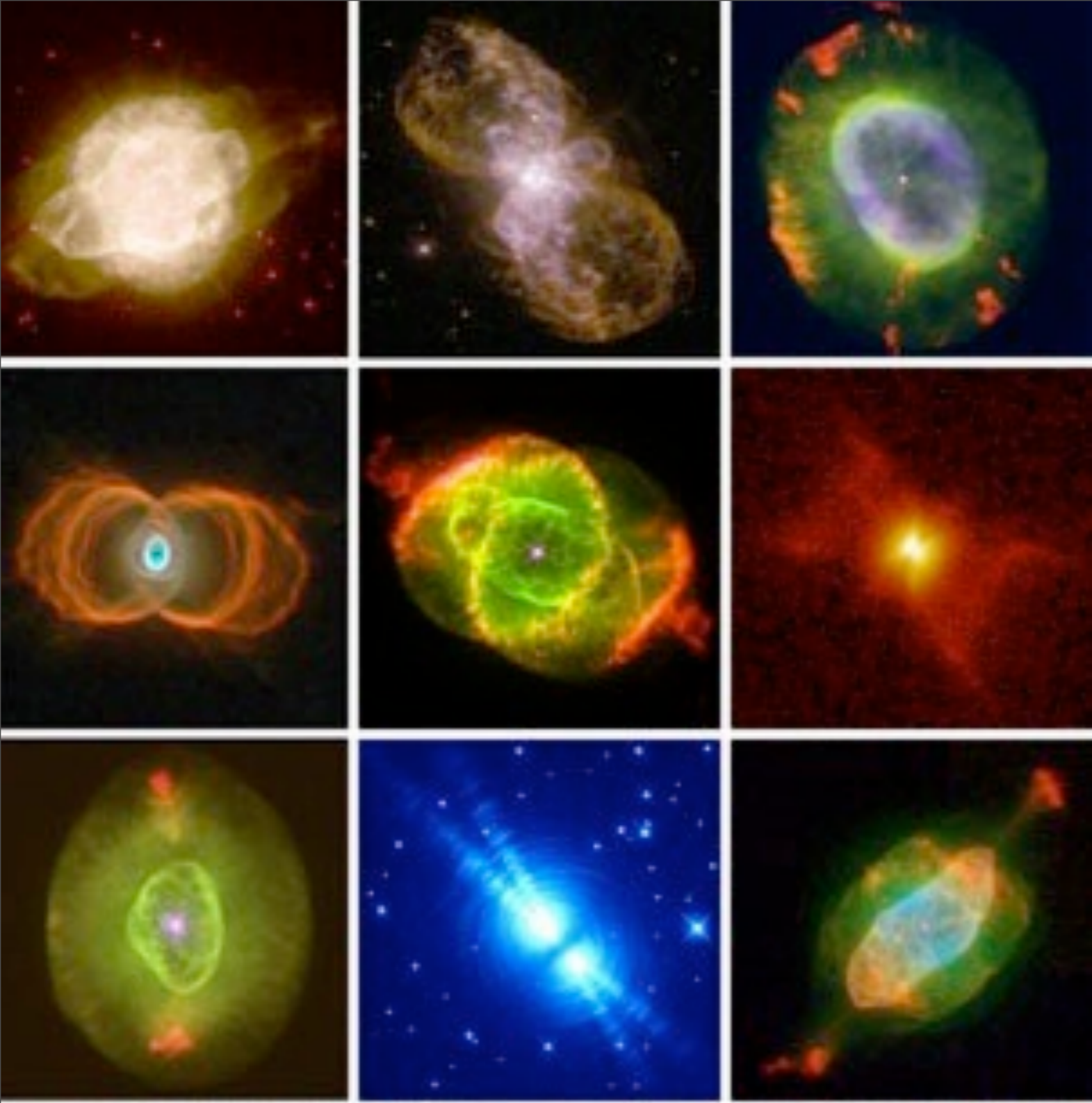
STELLAR MIDLIFE...

- Stars spend most of their lives “on the **main sequence**”
 - They get up in the morning, they burn hydrogen into helium...
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OLD LOW MASS STARS...



- The stars burn as long as there is hydrogen in the core to burn
- For stars like the Sun, when too much helium builds up the burning starts to **sputter**
- The star throws off its atmosphere, and the core shrinks to form a **white dwarf**
- These nebulae are called **planetary nebulae** (they are round)



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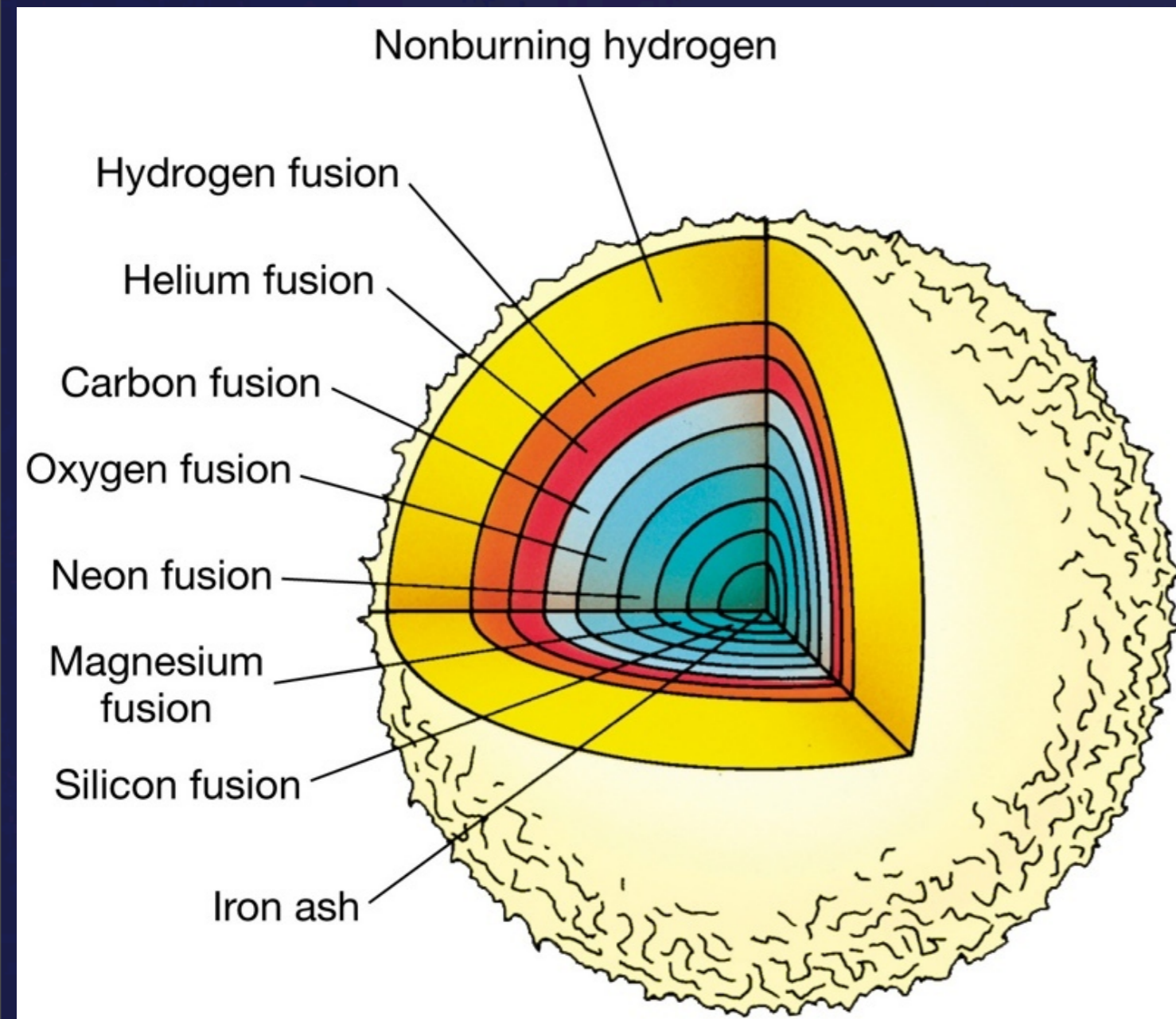
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M57 (The Ring Nebula in Lyra)

OLD HIGH MASS STARS...



- High mass stars have an astonishing fate...
- They can use nuclear fusion to make atoms as complicated as iron...
- Once they start making iron, nuclear fusion **shuts down**
- The star collapses, and explodes in a **supernova explosion**

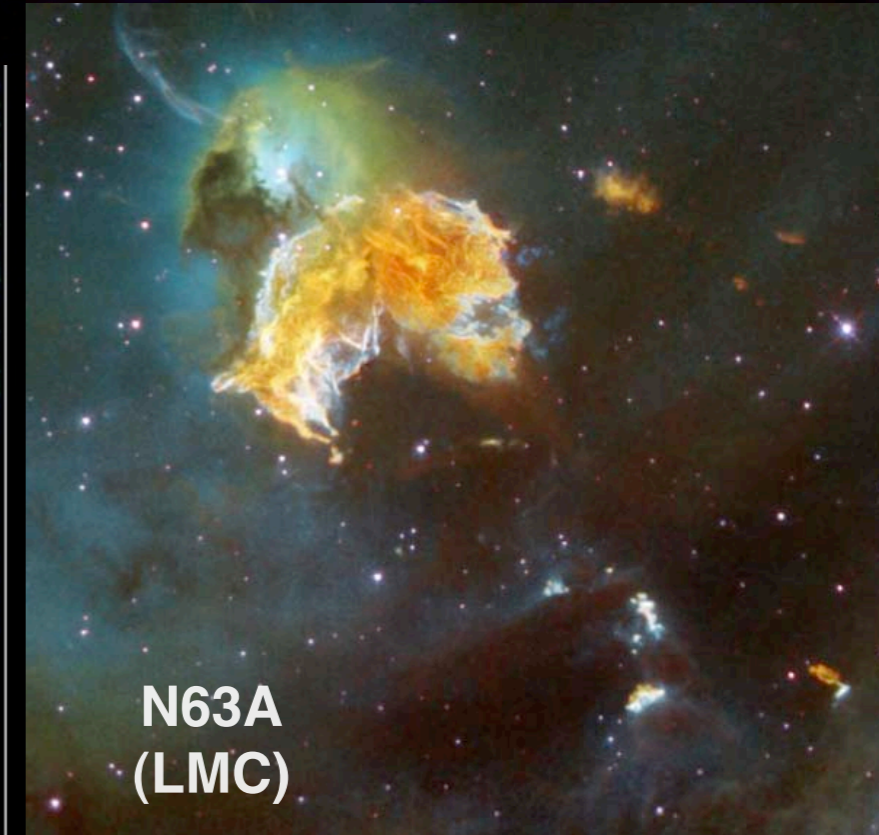
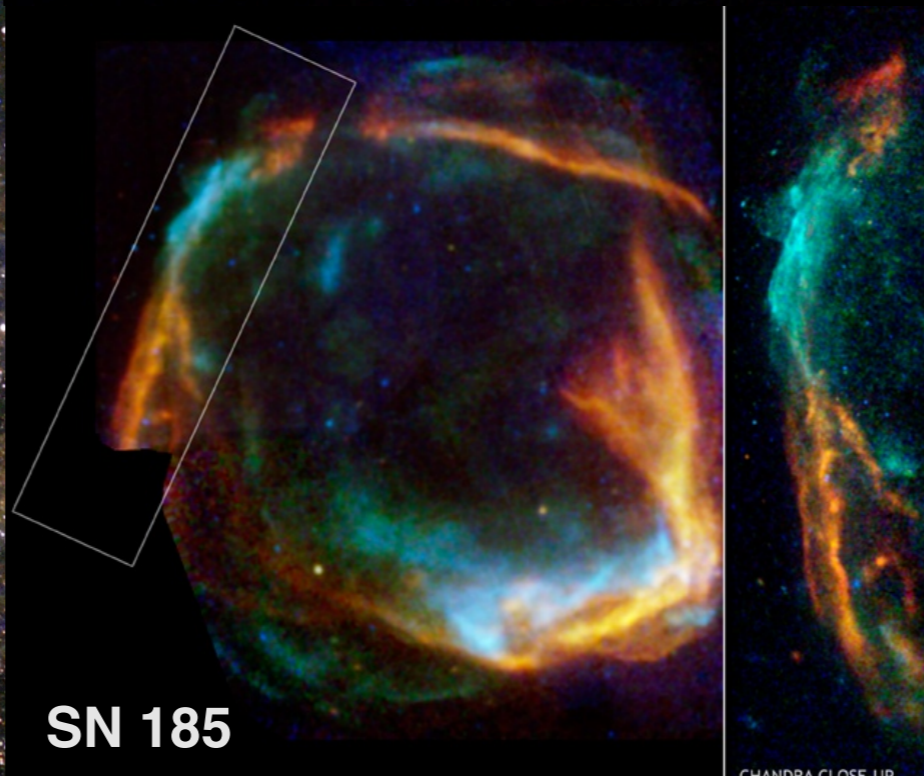
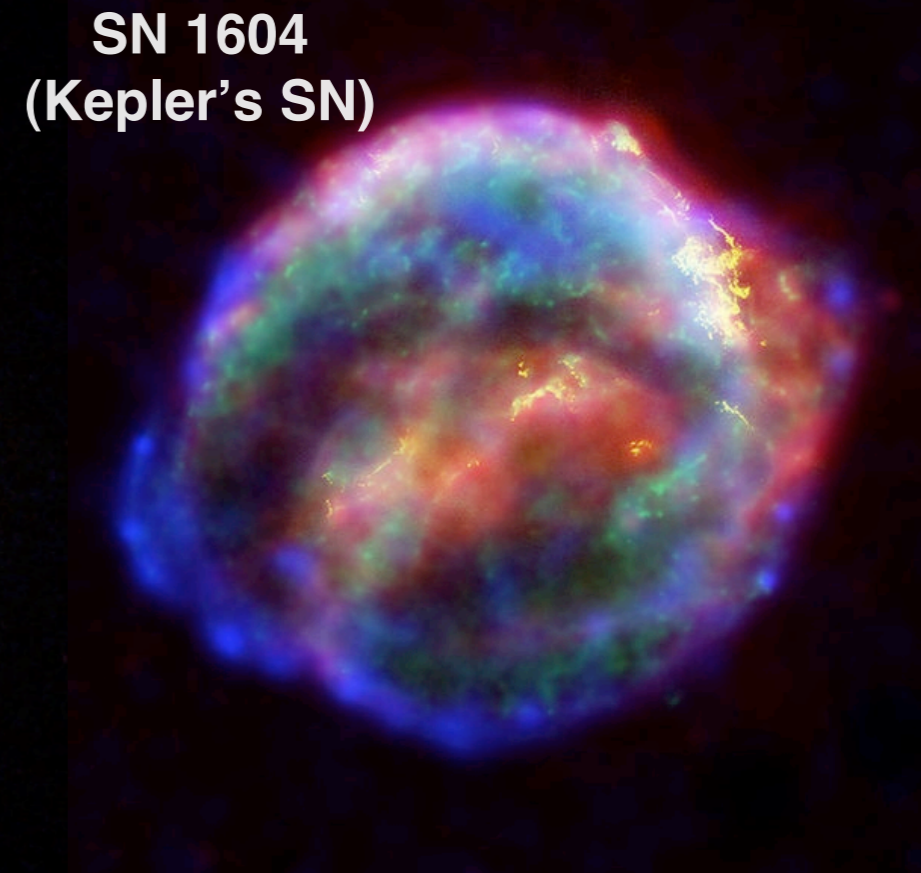
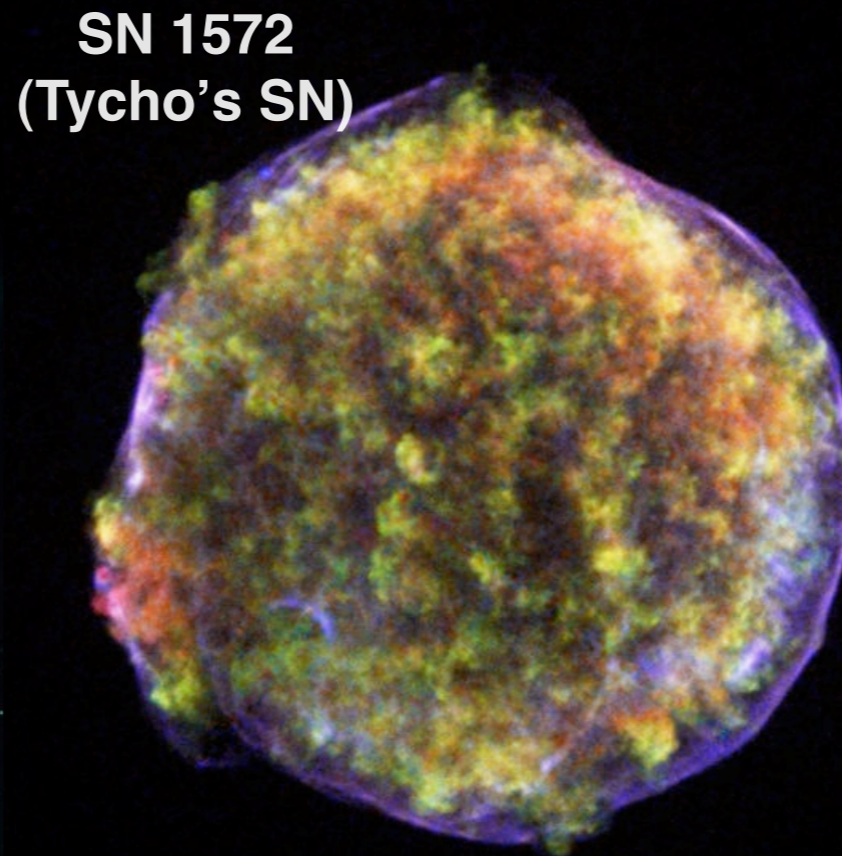
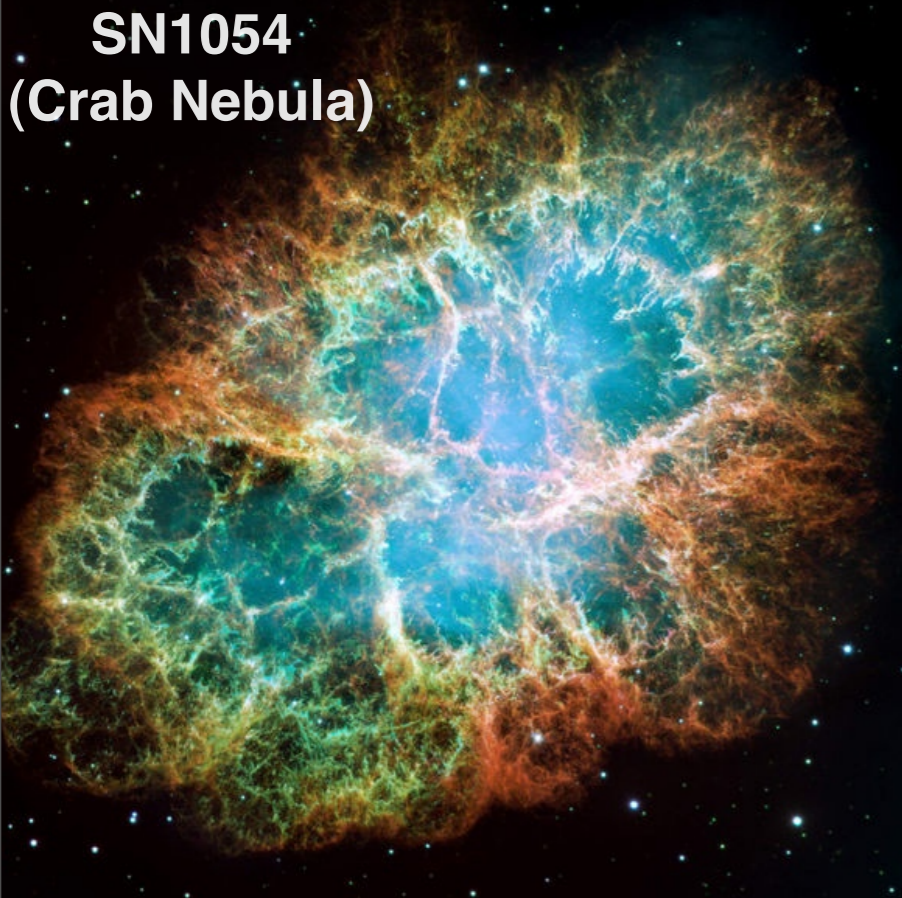
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SUPERNOVA REMNANTS

- The explosion blows all the atoms outside the core back into the Cosmos



SUPERNOVA REMNANTS

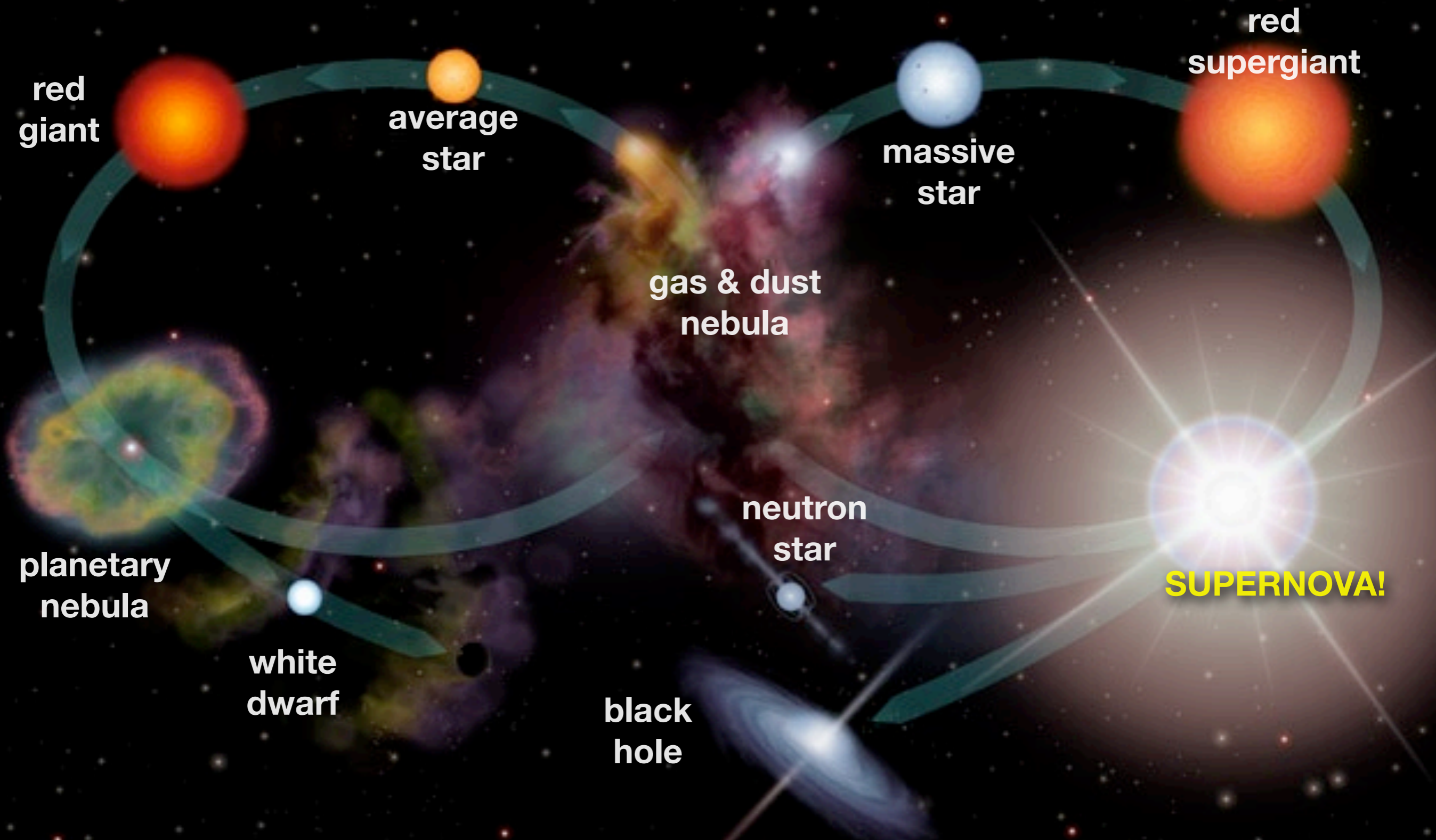
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Western Veil Nebula (NGC 6960)

COSMIC RECYCLING...

- The gas goes back into the Cosmos, where it becomes the next generation of stars, the next planets, the next rocks under your feet here at Fossil Butte...



Is that all there is?

- Suppose I count how much light I can see in the Cosmos (created by atoms)
- Suppose I count how much gravity I can see in the Cosmos
- Now suppose I compare these two numbers
- If atoms were all there was, these **should be the same!**

**Atoms are only
4% of all there
is in the Cosmos.**



LAST THOUGHTS...

- Carl Sagan once wrote (**Cosmos**): “The desire to be connected with the Cosmos reflects a profound reality: we are connected. Not in trivial ways... but in the deepest ways.”
- In the lives of stars we see reflections of our own lives on Earth — stars are born, live long and lustrous lives, and eventually die, returning once again to the Cosmos from whence they came.

THANKS! ENJOY OBSERVING!