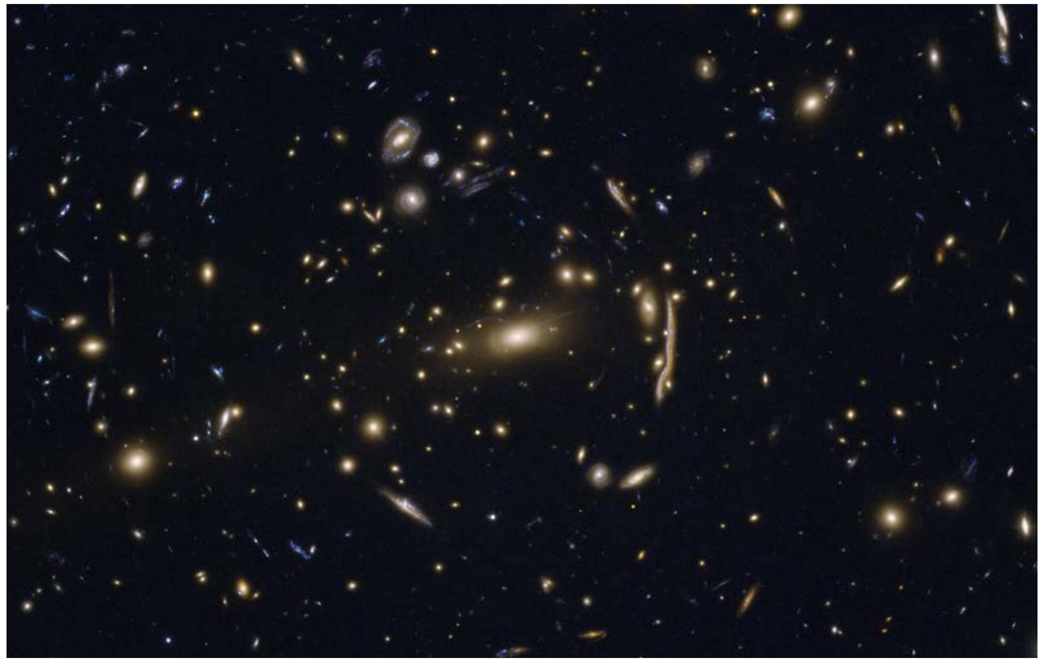


Galaxy clusters like MACS J1206.2-0847 stay together because the force of gravity among neighboring galaxies overpowers the force of dark energy — and the expansion of the universe — on the scale of the cluster. ESA/HUBBLE & NASA

Expanding space

Q | IF THE UNIVERSE IS EXPANDING, DOES THE SPACE INSIDE AN ATOM EXPAND, TOO? SINCE THE SPACE INSIDE AN ATOM IS MOST OF ITS VOLUME, THAT MEANS THAT MATTER WOULD BE EXPANDING AT THE SAME RATE.

Hugh Cedric
Beijing, China

A | We've known since the early 20th century that the universe is expanding — after observations by Edwin Hubble and others showed that other galaxies are almost all moving away from us — and the greater their distance, the faster they're doing so. Astronomers long expected that this cosmic expansion should be slowing down due to the combined gravitational pull of the universe's seen and unseen matter. However, in the late 1990s, two teams of astronomers — one led by Brian Schmidt and Adam Riess and the other by Saul Perlmutter — discovered evidence, using exploding stars in other galaxies, that cosmic expansion was not, in fact, slowing down, but actually accelerating. The three team leaders later shared the 2011 Nobel Prize in Physics for this accomplishment. The mysterious culprit, originally conceived of by Albert Einstein and which modern cosmologists call "dark energy," produces repulsive gravitational effects that cause the average distance between galaxies to increase faster and faster over time. Determining dark energy's true nature remains one of the greatest mysteries in theoretical physics today.

So, does the existence of dark energy in our accelerating universe mean that space is expanding everywhere, even on small scales such as those inside of an atom, where most of the volume is effectively "empty" space? The short answer is no! And we should all count ourselves lucky that we live in such a universe. Thankfully, the local electromagnetic forces that hold the atom's positively charged nucleus and negatively charged electrons together, as well as the strong nuclear forces confining the nucleus, are significantly stronger than the potentially disruptive forces of dark energy.

On larger scales, electromagnetic and gravitational forces prevent planets and moons from expanding as the universe expands. On still larger scales, the force of gravity that binds together systems like stars, solar systems, galaxies, and galaxy clusters is similarly stronger than the local effects of dark energy, which needs vast swaths of space to cause cosmic-scale accelerated expansion. Still, cosmologists can easily imagine "big rip" universes where dark energy was stronger than these local forces, either early on or at late times in cosmic history. In such universes, dark energy could have prevented stars or galaxies from forming or even eventually ripped apart atoms themselves as the expanding universe accelerated itself into oblivion. Needless to say, if this was such a universe, we wouldn't be here to discuss it!

Andrew Friedman
Assistant Research Scientist, University of California, San Diego

Q | WHEN WILL THE SUN BECOME A BLACK DWARF?

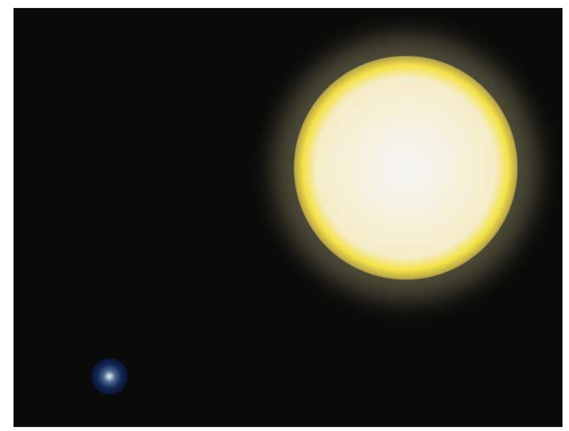
Isaiah Charnow
Irvington, New York

A | Black dwarfs are the very last stage of Sun-like stars. Currently in its main sequence hydrogen-burning phase, our Sun has about 4.5 billion years left before it enters the next stage of its life, puffing up to become a red giant. As a red giant, the Sun will eventually burn not only hydrogen, but also helium. But after about 1 to 2 billion years, it will exhaust its supply of nuclear fuel entirely and its core will contract into a white dwarf made of carbon and oxygen, while the outer layers of its atmosphere drift away as a planetary nebula.

White dwarfs are roughly the size of Earth, but the Sun as a white dwarf will be about 200,000 times denser than our planet. These objects no longer burn fuel to generate light or heat, but because they start out hot — 10,000 kelvins or more — and have immensely high density, they continue shining with residual heat and cool slowly. It takes a white dwarf roughly 10 trillion years (nearly 730 times the current age of the universe, which is 13.7 billion years) to cool off enough that it no longer gives off visible light and becomes what astronomers term a black dwarf.

So, the Sun won't become a black dwarf for trillions of years — and, in fact, no black dwarfs exist yet, simply because the universe has not been around long enough to allow even the earliest stars to reach this stage.

Alison Klesman
Associate Editor



A white dwarf such as IK Pegasi B (lower left) is much smaller than the Sun (also shown, for reference), but hundreds of thousands times denser than Earth. When a white dwarf cools enough that it no longer gives off visible light, it becomes a black dwarf. The Sun won't become a black dwarf for trillions of years, and even the oldest white dwarfs have not had time to cool enough to become black dwarfs yet. RJHALL, CHRKL (WIKIMEDIA COMMONS)

Q | IS IT POSSIBLE TO SEE METEORS ON MARS, OR IS THE ATMOSPHERE TOO THIN?

Allan Burger
Passaic, New Jersey

A | We use the term "meteor" to refer to the light produced when material from space enters a planet's atmosphere. Friction between the air and the fast-moving object creates light. If any part of the object survives to impact the ground, it is called a meteorite.

On March 7, 2004, NASA's Mars rover Spirit captured a streak in the martian sky (enhanced in the inset at upper right). It is likely the first image of a meteor seen on another world. NASA/JPL/CORNELL/TEXAS A&M

We do know that meteorites exist on the surface of Mars. As of July 2018, at least six meteorites had been confirmed and formally named, all found by robotic rovers. But could they have produced light on the way down? The answer is yes — despite the atmosphere's low density, meteors should be visible on Mars.

In 2008, researchers announced they'd seen, in data taken by the Mars Global Surveyor satellite, signatures of a meteor shower in the martian atmosphere. The shower had taken place in April 2003, as material from Comet 79P/du Toit-Hartley streaked through the air, leaving a fleeting layer of plasma in the atmosphere about 50 to 59 miles (80 to 95 kilometers) above Mars' surface. The satellite hadn't seen the meteors themselves, but it did detect signs of the resulting plasma.

From the ground, Mars rovers have also looked to the skies in search of meteors. A June 2, 2005, paper in *Nature* reported that a streak in the martian sky, imaged March 7, 2004, by the Mars Exploration Rover Spirit, was likely a meteor associated with debris from Comet 114P/Wiseman-Skiff. If so, it is the first image of a meteor seen on another world. However, based on its location and motion, researchers could not rule out the possibility that the streak may have been the defunct Viking 2 orbiter, which still orbits the Red Planet.

Additionally, the panoramic cameras on Spirit and its sister Mars rover, Opportunity, were periodically pointed upward to observe the martian sky at night, looking for telltale streaks left by meteors. In composite images taken by Spirit on November 18, 2005 — a time when Mars was passing through the debris trail left by Comet 1P/Halley — three streaks that may be meteor trails through the martian atmosphere appear. However, streaks can also be caused by cosmic rays hitting the camera's detector — so, again, it's hard to tell for sure whether the images captured meteors.

Alison Klesman
Associate Editor

SEND US YOUR QUESTIONS

Send your astronomy questions via email to askastro@astronomy.com, or write to Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.