**Record: 1**

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| **Title:** | ask Astro. |
| **Source:** | Astronomy; Feb2003, Vol. 31 Issue 2, p68, 2p, 2 color |
| **Document Type:** | Article |
| **Subject Terms:** | ASTRONOMY<br>MILKY Way<br>GALAXIES<br>ASTRONOMERS<br>SPACE sciences<br>STARS<br>AERONAUTICS in astronomy |
| **Abstract:** | Presents questions to the magazine concerning astronomy. How do astronomers estimate the number of stars in the Milky Way Galaxy; Discussion of the Earth's tilt on the rotation axis; How rockets propel themselves through space; Discussion of the expansion of the universe. |
| **Lexile:** | 1020 |
| **Full Text Word Count:** | 1310 |
| **ISSN:** | 00916358 |
| **Accession Number:** | 8767504 |
| **Database:** | Middle Search Plus |

# ask Astro

**Counting Stars, Earth's Tilt, Propulsion, Local Expansion**

**How do astronomers estimate the number of stars in the Milky Way Galaxy? I've seen numbers anywhere from 100 billion to 400 billion. That's quite a range! And do these estimates include the borderline almost-stars, the numerous brown dwarfs? - Al Martin, Naperville, Illinois**

One, two, three...

OK, that's not going to work. There are far too many to count.

The numbers you found for the stars in the galaxy span a range because no one really knows how many stars there are - it depends on many different variables. We cannot count or even make a good statistical sample because our vision can't penetrate very deeply into the interior of the Milky Way. There's too much absorption of starlight by interstellar dust.

So much for astronomy - but let's see where physics gets us.

The simplest approach starts with a determination of the galaxy's mass. The Sun has a more-or-less circular orbit around the center of the galaxy. To a reasonable approximation, it responds to the combined gravitational attraction of the stars that lie inside its orbit. Using Kepler's Laws as generalized by Isaac Newton, you can treat the galaxy and the Sun as a simple two-body problem, and derive the galaxy's mass. (This is just like finding the Sun's mass from Earth's orbit.)

Since the Sun orbits so far from the galactic center - about 28,000 light-years - most of the galaxy's stellar mass lies inside the Sun's orbit. But we need to make a small correction for the mass outside our orbit. When that's added in, the overall number comes out as a bit above 100 billion solar masses.

But that's mass, not stars. So it's back to astronomy.

Most stars are dim, cool M-type dwarfs. Figuring that the average star has about half a solar mass, we find between 200 and 300 billion stars. However, astronomers don't have a good handle yet on the number of the faintest M dwarfs, nor for brown dwarfs. These might double the number of stars derived above.

So in the end, between 200 and 400 billion stars seems reasonable. Clearly, however, we still have a lot to learn about our own stellar system. - Jim Kaler, professor of astronomy, University of Illinois

**How would life be different if there were no 23.5° tilt of Earth's rotation axis? - Sam Platts, Sylmar, California**

If Earth's axis stood vertical to the plane of its orbit, the Sun would rise and set in the same place every day as seen from any fixed location. Furthermore, the Sun would reach the same maximum height in the sky each day and shed the same warmth and light every day in the year. This unchanging cycle would eliminate the seasons.

If each part of Earth's surface received a more constant amount of heat from the Sun, this would also change weather patterns by creating a more steady east-west air flow than exists today. At present, seasonal heating and cooling of polar regions send large masses of air to different latitudes.

Another change is that Earth's axis would not precess, meaning that the location of the North Celestial Pole would remain fixed. Today there's a North Pole star called Polaris, which helped our ancestors navigate before compasses and other technology were available. Without the present tilt, the North Celestial Pole would lie in Draco, and there would be no bright North Pole star to navigate by. This might have delayed the spread of humans over the oceans in the Northern Hemisphere of such an Earth.

In the Southern Hemisphere there is no South Pole star today, nor would there be one on an Earth without a tilt. Such a world would have a few dim stars, such as Delta, Epsilon, and Eta1 and Eta2 Doradus clustered around what would be the South Celestial Pole. Perhaps, on a tiltless Earth, these would enable deep-water navigation in the Southern Hemisphere to develop before it would in the north. - Neil F. Comins, Department of Physics and Astronomy, University of Maine at Orono

**How do rockets propel themselves through space? - Cam Crower, Pleasant Prairie, Wisconsin**

People often wonder how a rocket works, especially out in space "where there's no air to push against." The easiest way to understand a rocket engine is to blow up a balloon with air and tie the nozzle closed. Why doesn't it fly away? The answer is that the air pressure inside is balanced in all directions. The force pushing the balloon up is exactly balanced by a force pushing down, and the same holds for every other direction.

Now blow up another balloon, but this time simply hold the nozzle shut. Notice that just like the tied-off balloon, this one doesn't want to fly around; again, all the forces are in balance. But when you let go of the nozzle, the situation changes. Abruptly, the internal forces are no longer exactly balanced. More specifically, the force pushing ahead isn't counterbalanced because the air to do it is rushing out the nozzle. As a result, the balloon flies off.

A rocket engine's combustion chamber works the same way - it's a metal and ceramic balloon filled with extremely hot gases that push hard on the walls. With one end open, the forces are unbalanced in a forward direction - and we're go for liftoff. - Robert Burnham, Contributing Editor

**If the expansion of the universe is due to space itself expanding and not galaxies flying apart through space, then shouldn't the space between the planets in our solar system also expand and thereby cause the planets to be moving farther apart? - Jere Yost, San Bruno, California**

It would do exactly as you say except that on distance scales as small as within a solar system - or within a galaxy - the gravitational field of all the local matter overwhelms the gravitational force produced by matter lying at great distances. This means a gravitationally-bound collection of objects like a solar system behaves as a single unit from a cosmological point of view.

To back up a moment, it's not correct to say "space is expanding." What's expanding is space-time - that is, the gravitational field produced by all the matter in the universe is progressively weakening due to the expansion. (This is not the same thing as the notion that gravity is becoming weaker over time - those theories have not panned out. Instead, what's happening is that the universe is becoming less dense and as a result, the strength of its gravitational field at any given local point is decreasing.)

So where's the changeover point? Where do local effects give way to the universal? The scale on which things become "locally bound" is at about the size of clusters of galaxies. Within these structures, the formation of galaxies, as well as stars (and planets) within galaxies, is governed by the strength of the local gravitational field relative to the universe's rate of expansion. Another way to say this is that wherever the local material has enough mass that its gravitational field dominates the universal field, matter will form into small-scale structures such as galaxies and stars.

In fact, this is how structure forms in any cosmological model. When astronomers look at the first structures to emerge in the early universe, this principle helps them estimate how much matter, dark and light, the early universe contained. - Steven Shore, professor of astrophysics, Indiana University at South Bend

PHOTO (COLOR): The Milky Way truly does contain "billions and billions" of stars.

PHOTO (COLOR): This deep visible light and infrared view reveals distant protogalaxies in the infancy of the expanding universe.

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Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P.O. Box 1612, Waukesha, WI 53187. Please tell us your full name and where you live.

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