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Gravity Takes a Starring Role — But It May Not Be What You Think

by Jeffrey Bennett (Big Kid Science)

G*ravity* plays a starring role in the new movie of the same title, but it's not the role that most people think. Before I explain, let me emphasize that, overall, the movie does an outstanding job with its scientific accuracy. While the movie takes some dramatic license, it stays quite accurate in illustrating the role of gravity, and in showing how people and objects move in space. The misconception arises when we ask about the role gravity plays.

If you read the reviews — or for that matter, even many statements from NASA — you will be led to think that gravity is absent in space. After all, people often refer to space as a "zero gravity" environment (the movie *2001: A Space Odyssey* famously showed a complex set of instructions for its "zero gravity toilet"), and NASA usually refers to the conditions in orbit as "microgravity."

To see why these descriptions are so misleading, consider this experiment that I've done with thousands of high school and college students. First, ask "Why are astronauts weightless in space?" Almost all the students will answer "because there's

Astronaut Bruce McCandless II, mission specialist, participates in a extra-vehicular activity (EVA) during the STS 41-B mission of the Space Shuttle Challenger in February 1984. He is performing this EVA without being tethered to the shuttle. Image: NASA

no gravity in space." Then immediately follow with "Why does the Moon orbit the Earth?" The students will begin to say "because of gravi…" — at which point you'll literally see jaws drop as they realize that they are about to give you an answer that directly contradicts the one they gave you a few seconds before. In other words, most people know that gravity keeps Earth orbiting the Sun and the Moon orbiting Earth, which clearly means that there *is* gravity in space. In fact, simple calculations show that the strength of Earth's gravity in low-Earth orbit (where the movie *Gravity* takes place) is only about 10% less than the strength

Sunset over the Indian Ocean from the International Space Station (ISS). Taken by a member of Expedition 23 in May 2010. Image: NASA of gravity right here on the ground, and it is this relatively strong gravity that holds spacecraft and astronauts in orbit rather than allowing them to fly off into deep space.

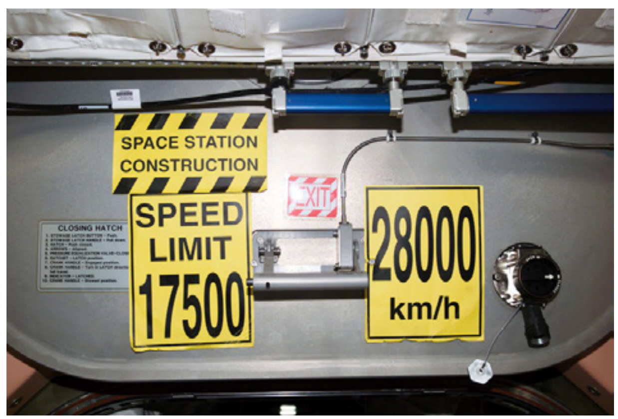
So why, then, do the astronauts float around as if there's no gravity? To understand the answer, first imagine that you are standing on a scale on the edge of a diving platform. The scale reads your weight because gravity is pushing you against it, while the platform makes sure the scale stays in place. Now suppose that someone pushes you and the scale off the platform, so you both start falling toward the water. Because you and the scale are both falling — you are in *freefall* — you'll no longer be pushing against the scale and it will therefore read zero. In other words, while you are falling, you will have become weightless. More generally, you are in freefall and therefore weightless whenever there is no ground or anything else pushing back against you. That's why gymnasts and divers can tumble and twist like astronauts while they are in the air. The only difference is that astronauts remain weightless for much longer, which brings us to the true role of gravity in the movie.

The International Space Station in November 2009 seen from the Space Shuttle Atlantis. Image: NASA/Crew of STS-129

Astronaut Karen Nyberg floating freely in the Unity node of the International Space Station in September 2013. Image: NASA

Gravity is always present in space and always pulling everything in Earth orbit toward the ground, including the Shuttle, the Hubble Space Telescope, the International Space Station, and the astronauts. The only reason these objects don't quickly crash to Earth is that they are also moving forward at the same time, and at a very high speed — about 17,000 miles per hour at the Space Station's altitude. This speed essentially ensures that they move forward just as rapidly as they fall, and as a result they remain at the same altitude as they circle around Earth. (It reminds me of Douglas Adams' statement in *The Hitchhiker's Guide to the Galaxy* that the trick to flying is to "throw yourself at the ground and miss.") Indeed, the movie also shows what happens if a bit of air resistance begins to slow you down: You then start to lose altitude, which causes a fiery reentry as you plough through the atmosphere at high speed.

To summarize the lessons: There is gravity in space, and in low-Earth orbit its strength is only a little different than its strength on the ground. Therefore, "zero gravity" and "microgravity" are both misnomers, and the correct explanation for what we see in the movie Gravity — and for what really happens in space — is that astronauts are weightless because they are in a continual state of freefall as they orbit Earth. Gravity is indeed the star, but because of its presence, not its absence.



A close-up view of "speed limit" parody signs on a space station hatchway photographed in 2006 by an Expedition 12 crewmember. The speeds cited — in both English and metric measurements — are equivalent to the station's velocity, keeping it in orbit. Image: NASA

For those wondering about the overall scientific accuracy of the movie, here is a brief list of the major ways in which the movie takes dramatic license:

- The movie begins with the Space Shuttle visiting the Hubble Space Telescope to make repairs and upgrades. The Shuttle really did this (three times), but since the Shuttles have been retired, it will not happen again.
- The Hubble Space Telescope and the International Space Station do not actually share the same orbital path, so in reality an astronaut jet pack could not get you from the Hubble's orbit to the Station's orbit.

- China does not currently have a space station, though they have plans to build one in the future.
- While space junk poses a real threat, the movie has debris taking out both the Shuttle and communications satellites— but the latter are in much higher orbits and therefore would be unaffected by debris in low-Earth orbit.

If you want to be very picky, there are a number of other details that the movie doesn't get exactly right, but in my opinion these are pretty insignificant, and even the major points above represent an appropriate use of dramatic license in an excellent movie.

Astronaut and mission specialist Kathryn Thornton performing an extra-vehicular activity (EVA) during the STS-61 mission in December 1993. This mission of the Space Shuttle Endeavor dedicated to servicing the Hubble Space Telescope. Image: NASA

Post script: Given that there's nothing actually "micro" about gravity in space, you may wonder why NASA talks about "microgravity." Personally, I think it is a very poor word choice, but here's the rationale behind it: In flight training, it's standard to describe the forces that pilots (or astronauts) feel when they accelerate in "gees," a term that comes from the physics abbreviation g for the acceleration of gravity. For example, a force of one gee means you feel your normal weight, two gees means you feel twice your normal weight, and so on. When you are in freefall and hence weightless, you don't feel any force on you at all, which means we can say the force on you is "zero gees." In other words, we can say that you feel a force of zero gees in orbit, even though there's still plenty of gravity. In their drive for precision, NASA recognized that the forces on orbiting spacecraft and astronauts are not *exactly* zero, because they are always subject to at least some tiny accelerations from forces that include Earth's tidal influence; NASA therefore decided that it would be more accurate to say "micro gees" rather than "zero gees," which they then translated into the term "microgravity." So the term arose with good intentions, but it's still misleading and therefore far better to describe the conditions of freefall and orbit as *weightlessness* (or near-weightlessness if you want to be as precise as NASA).

Jeffrey Bennett holds a PhD in Astrophysics from the University of Colorado at Boulder, and has taught at all levels from elementary through graduate level astronomy. He has written several best-selling textbooks, as well as books for the general public. He is also the creator and author of the children's series "Science Adventures with Max the Dog" for which he won the 2013 American Institute of Physics Science Communication Award. You can learn more about weightlessness in the newest installment in the series *Max Goes to the Space Station*, which also discusses many other topics that appear in the movie *Gravity*. He is the founder of Big Kid Science, a company dedicated to educating and inspiring children with the wonders of science. His five children's books are all scheduled for launch on the Orbital 1 resupply mission (currently scheduled for December 17, 2013) to the International Space Station for the new Story Time From Space program, in which videos of astronauts reading the books from orbit will be posted freely along with classroom curriculum materials.

Featured Activities

From the NASA Educator Guide *The Case of the Phenomenal Weather*

- **Going Down Anyone?** The force of gravity is the focus of this demonstration using a ruler, string and a paper clip. Students observe that the Earth's gravity is always downward toward the center of the Earth. See more at: http://nasawavelength.org/resource/nw-000-000-002-628/#sthash.tAMQArSL.dpuf
- **3, 2, 1 … Blast Off!!!** Students understand how satellites are placed in orbit by launching marbles into space, using two plastic rulers and clay. They describe the forces that determine the trajectory of flight. See more at: http://nasawavelength.org/resource/nw-000-000-002-621/#sthash.jXQiFWLz.dpuf

From the book *Max Goes to the Space Station*

- **Elevator Science.** Students investigate the force of gravity through riding on an elevator.

Resources for Further Exploration

Astronomer Phil Plait reviews the movie Gravity
http://www.slate.com/blogs/bad_astronomy/2013/10/04/ba_movie_review_gravity.html

Big Kid Science. A source for children's books on space science and exploration, as well as related activities supporting the reading component of learning.
http://www.bigkidscience.com/

Story Time From Space. A program sending children's books and demonstrations to the International Space Station where astronauts will videotape themselves reading books to the children of Earth. The astronauts on the ISS will also conduct and videotape educational demonstrations to complement the science concepts in the Story Time From Space books.

To make Story Time from Space even more useful to educators, cross-content curriculum is under development to support the Next Generation Science Standards. All of these materials, along with the videos from orbit, are found on the Story Time From Space website, providing easy access for educators, families, libraries, science centers, scouts and others.
http://storytimefromspace.com/

Spaceflight and Gravity

NASA's International Space Station Webpage
http://www.nasa.gov/mission_pages/station/main/index.html#.Up0C_yi9zHM

NASA's Microgravity Education Webpage
http://www.nasa.gov/audience/foreducators/microgravity/home/

NASA's Microgravity Educator Guide
http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Microgravity_Teachers_Guide.html

You Tube Videos

Inside the ISS — Splitting Hairs About Gravity, with Sandra Bullock
https://www.youtube.com/watch?v=fJujRJMiKVs

Why Are Astronauts Weightless?
https://www.youtube.com/watch?v=iQOHRKKNNLQ

Free Falling in Outer Space
https://www.youtube.com/watch?v=tAUXIEr-VzM

Angry Birds and Pigs Go Weightless!!!
https://www.youtube.com/watch?v=deAcVKv5_2I

Wringing out Water on the ISS - for Science!
https://www.youtube.com/watch?v=o8TssbmY-GM

Shuttle's Toilet Requires Special Training
https://www.youtube.com/watch?v=m1wwzwvfsC0

Minute Physics: What is Gravity?
https://www.youtube.com/watch?v=p_o4aY7xkXg

Simulations for Gravity and Orbital Motion

NASA's Space Place Shoot a Cannonball Into Orbit
http://spaceplace.nasa.gov/how-orbits-work/en/

PhET project at the University of Colorado: Move the sun, earth, moon and space station to see how it affects their gravitational forces and orbital paths. Visualize the sizes and distances between different heavenly bodies, and turn off gravity to see what would happen without it!
http://phet.colorado.edu/en/simulation/gravity-and-orbits

Newtonian Mountain lets you shoot a ball from a mountain on the Earth.
http://Galileo.phys.Virginia.EDU/classes/109N/more_stuff/Applets/newt/applet.html

Projectile Orbits and Satellite Orbits
http://physci.kennesaw.edu/javamirror/ntnujava/projectileOrbit/projectileOrbit.html