A matter of gravity

Tapping, Ken

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/23000237
Skygazing: Astronomy through the seasons, 2016-04-26

A MATTER OF GRAVITY

Ken Tapping, 26th April, 2016

We've all seen images of astronauts floating in space as they work outside their spacecraft, or perform weightless gymnastics in the International Space Station; now imagine this. The new 1000km high observation tower and resort has opened, and you are standing on the observation platform, admiring the incredible view. You could watch for the International Space Station as it passes hundreds of kilometres below you. So, out of curiosity, you step off the platform. What would happen? Would you float in space, just like the astronauts? Actually it would be exactly the same as stepping off the top of an extra tall skyscraper. As you plummet straight down you will have quite a lot of time to wonder what you got wrong.

As we get further from the Earth, its gravitational attraction weakens, but at the top of that tower, the pull of gravity is only some 25% less than it is at the surface of the Earth. Why is it that the astronauts float and you fall? The answer is that nobody is floating. Everyone is falling.

If you make a running jump from the edge of that tower platform you would hit the ground some distance from the base of the tower. If you run faster, you will hit further away. If you were athletic enough to be running at about 30,000 km/h at the time you jumped, as expected, your path will gradually curve downwards, but the spherical Earth is curving away beneath you. The result is that you keep falling but you never hit the ground. You are in orbit. Anything in orbit is moving fast enough for the curve of their falling trajectory to follow the curvature of the Earth's surface. That is why we describe spacecraft, astronauts, the Moon orbiting the Earth, and the Earth orbiting the Sun all as being in a state of "Free Fall".

So if objects in space can orbit each other indefinitely, why would dust and gas clouds collapse, or black holes spiral into each other? Actually we get a clue from the International Space Station. Even at its height of hundreds of kilometres there is still a tiny bit of the Earth's atmosphere. When the station is moving through it at around 30,000 km/h it experiences a tiny but significant bit of drag. This eats away at its orbit, and if left would make the space station spiral lower and lower, into denser and denser atmosphere until it finally burns up. To stop this happening, a small boost has to be applied periodically, to replace the lost energy.

Imagine a collapsing cosmic gas cloud in the process of forming a new star. The collisions between the particles cause them to lose energy as heat, causing them to spiral inwards. As the collapse proceeds, the collisions get more frequent, accelerating the collapse and producing more heat. This can be detected using telescopes such as the Atacama Large Millimetre Array (ALMA). We have found many examples of collapsing clouds in the process of forming new stars or planets. An event like this took place about 4.5 billion years ago, giving birth to the Sun and the other objects making up the Solar System.

The two black hole example is more intriguing. A black hole is a huge mass of material, up to millions of times the mass of the Sun in many cases, so compressed under its own gravity that the intensity of its gravitational field strongly distorts the fabric of space. As black holes move through space they make bow waves in the fabric of space similar to the ones preceding ships as they move through the water. In both cases making a bow wave takes energy. So two black holes orbiting one another lose energy by creating these bow waves. This causes them to spiral into one another. The Earth makes such a bow wave too, but it is too weak to easily detect.

Jupiter is in the southern sky after sunset; look for a whitish, bright, starlike object, shining steadily, like a lamp. Mars and Saturn rise around midnight. The Moon will reach Last Quarter on the 29th.

Ken Tapping is an astronomer with the National Research Council's Dominion Radio Astrophysical Observatory, Penticton, BC, V2A 6J9.
Tel (250) 497-2300, Fax (250) 497-2355
E-mail: ken.tapping@nrc-cnrc.gc.ca