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Winds from the stars

Ken Tapping, 20th November, 2018

Whether we have been lucky enough to see a total eclipse of the Sun for ourselves, or have just seen pictures, the most striking thing is the pearly streamers and loops of the solar corona. It is always there, but swamped by the glare of light from the solar disc. However, when that is blocked by the Moon, we see the corona extending off far into space. In fact, our world lies inside the outer reaches of the solar corona. This part of the Sun is hot, over a million degrees Celsius. The “body” of the Sun, which provides us with heat and light, is cooler, a mere 6000 °C. The corona is hard for us to see because it is very rarefied, and also so hot that it does not produce visible light; it glows with x-rays. This raises a fascinating issue. If the bottom of the corona is touching the 6000 °C Sun, and the top of the corona merges with the cold of interplanetary space, how can it be so hot? The laws of thermodynamics say that heat flows from hot objects to cool ones, not the other way round.

Physicist Eugene Parker pointed out something even more intriguing. The solar corona cannot be stable. It has to be flowing out into space at hundreds or even thousands of kilometres a second. We now know that Parker was right, and call this continuous outward flow of hot, ionized gas and magnetic fields the solar wind. Usually it is a “brisk breeze”, but sometimes an instability in the solar magnetic fields catapults a huge mass of material off into space at high speed. These masses, called “coronal mass ejections” can cause us serious problems on Earth.

Almost all stars have their equivalents of the solar wind. Some are merely light breezes, while others emit blasts that extend far into space, blowing bubbles in the gas and dust clouds between the stars, which we can see with our telescopes. In some cases, a pair of stars that are close together, orbiting one another, have a sort of wind competition. A shock wave forms where the two winds collide, causing all sorts of interesting high-energy physical processes to happen.

As stars age, most of them swell up into red giants. Since they have the same masses as they had beforehand, they become less dense, and the outer parts of the star, being now much further out, have less gravitational attraction holding them down, so they start to flow out into space as a particularly dense wind. This rate of mass loss can be quite high. A typical isolated star, like the Sun, will swell up, eject a lot of its mass, leaving its core as a white dwarf star, about the size of the Earth, but so dense a teaspoonful would weigh tonnes. If the star is, say, several times the mass of the Sun, it goes unstable, eventually blowing up. Things get more interesting if that star has a companion star orbiting it, forming a double-star system.

Typically, when a double-star system forms, one sibling grabs more material than the other. In a sort of cosmic justice, greedier stars burn brighter and age faster, swelling up into red giants while their less massive siblings are still enjoying their longer maturity. In this case, the companion star captures material blowing off the red giant. Eventually the red giant loses enough material to end up as a white dwarf. In the meantime, the star that collected the material is now massive enough to brighten and age faster, so that it eventually swells into a red giant and starts losing material at a faster rate. Some of this falls onto the surface of the white dwarf that was originally the greedier star. If this happens fast enough and enough mass is collected, instabilities develop which result in a nuclear fusion explosion, blowing the originally more massive star apart. What's left is either a neutron star, a few kilometres in diameter, or a black hole, with the originally less massive star orbiting it. The companion star might survive.

Venus lies low in southeast before dawn. After dark Mars is low in the south-southwest. The Moon will be Full on the 22nd.

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