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BALLS OF HOT GAS

Ken Tapping, 16th February, 2016

Stars are often described as "Balls of Hot Gas". This is sort-of-true, but falls far short of the whole story. A good look at a dark, clear night sky will show that. We see stars of many colours and brightnesses, and they are up to all sorts of fascinating things, such as varying in brightness, some in cycles and others irregularly. Some explode and some don't. Some end up as neutron stars or black holes, and some don't.

The recipe for making a star is simple. We need a cloud of hydrogen. Since this is by far the most common material in the universe, we see the formation of new stars taking place almost everywhere. The story starts with a cloud of hydrogen becoming unstable and collapsing under its own gravity. As it collapses its core gets hotter, until nuclear fusion starts, with hydrogen being converted to helium and releasing a lot of energy. The radiation from the newborn star then blows away the rest of its birth cloud.

When we look at a star - the Sun is a typical example - we see a big ball of gas, with a nuclear fusion reactor in the middle. The weight of the overlying material compresses the core so that the nuclear fusion reaction continues. The heat from the nuclear fusion flows towards the surface of the star, providing a counter pressure to the inward pull of the star's gravity. Without this counter pressure the star would collapse, and probably explode. If the fusion reactor heats up and increases its energy production, the outward pressure increases, the star expands a bit, the core cools, the reactor slows, and things settle down again. If the reactor slows too much, the star collapses a bit, heating the core and speeding up the reactor. In stars like the Sun, the outward and inward pressures are nicely balanced. There are some stars where the balance is a bit unstable, and the stars oscillate, cycling in brightness.

With only one key ingredient in the recipe to make stars, the big thing that dictates how the life of a star will turn out is decided simply by how much hydrogen it collects before lighting up. The more it collects, the more pressure there is in the core, and the more fiercely the reactor runs. Doubling the mass of a star can make it something like 10-20 times brighter. So more massive stars don't live as long as less massive stars. They run out of fuel, collapse and usually blow themselves up. Some dwarf stars will shine for tens of billions of years. The Sun should be OK for around 10 billion years. There are giant stars that won't last 1 million.

Since the surface of a star is the part that is furthest from the core, gravity holding down the surface material is comparatively weak. This leads to the outward pressure of the radiation coming up from the core evaporating the surface material and pushing it out into space. We call this a "stellar wind". This happens on the Sun. In our case we call it the "solar wind". Massive stars are much bigger, and their surface gravity is weaker. They are also much brighter, so the outward radiation pressure is stronger. This leads to their surface material evaporating even more rapidly, forming a stronger stellar wind. Ageing stars tend to swell up into red giants, so that the gravity holding down the outer parts of the star gets even weaker, allowing the wind to get even stronger.

The need for a star to hang onto its surface material limits the range of masses stars can have. Too small a mass will mean that nuclear fusion won't start, or can't be sustained, so we will get either a giant planet or a "brown dwarf". Really giant stars can't happen because their furious radiation pressure would blow away their outer envelopes, reducing their masses while still very young. However, what the other stars get up to is still interesting and complicated enough to keep researchers very busy for the foreseeable future.

Jupiter rises about 8pm, Mars at 2am and Saturn at 4am. Venus lies low in the dawn glow. The Moon will be Full on the 22nd.

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