

## The Life Cycle of Spiral Arm Galaxies

James A. Marusek

Our solar system resides in a spiral arm galaxy called the Milky Way. A galaxy is a system of millions or billions of stars and the remnants of dead stars (black holes, white dwarfs, neutron stars), small bodies (planets, asteroids, comets), and disassociated atoms, ions and elementary particles, held together by gravitational and electromagnetic attraction. There are at least 2 trillion galaxies in our observable universe and many of these are spiral galaxies.

Spiral galaxies consist of a flat, rotating disk containing stars, gas and dust, and a central concentration of stars known as the bulge. Spiral galaxies resemble spiraling pinwheels. The spiral arms shine brightly in the night's sky because they are composed of the brightest stars in the universe. These are massive stars of spectral type "O" and slightly smaller type "B" stars using the Yerkes classification system. O-type stars are very hot and luminous, and appear in the visible spectrum as bluish-white. These stars are commonly called giants, and supergiants. These stars have between 15 and 90 times the mass of our Sun and surface temperatures between 30,000 and 52,000° K. They are between 30,000 times and several million times as luminous as our Sun.



Figure 1. NASA Spitzer Space Telescope image of Messier 81 Spiral Galaxy

Since the 1960s, there have been two leading hypotheses or models for the spiral structures of galaxies. These are star formation caused by density waves and star formation caused by shock waves in the interstellar medium.

Bertil Lindblad proposed the hypothesis that the arms represent regions of enhanced density (density waves) that rotate more slowly than the galaxy's stars and gas. As gas enters a density wave, it gets squeezed and makes new stars, some of which are short-lived blue stars that light the arms.

The other proposed hypothesis is referred to as the stochastic self-propagating star formation (SSPSF) model, in which star formation is continued through the energy dumped back into the interstellar medium by evolving massive stars, stellar winds, and supernovae. In other words, star formation is caused by shock waves in the interstellar medium.

The massive O- and B-type stars that occupy the spiral arms have relatively short life spans in the order of 3-30 million years depending on their size. Thus, due to the low probability of kinematic interaction during their lifetime, they are unable to stray far from the area in which they were formed. As these stars exhaust their nuclear fuel, they self-destruct in a massive explosion called a supernova leaving behind a remnant black hole or other stellar remnants. The spiral arms are constantly being refreshed and reinvigorated with newly formed stars. The spiral arms are the birthing factories for new stars within the galaxy.

After a supernova, the newly formed black hole does not just disappear. It remains in place and accumulates over time with other newly formed black holes producing a dense region of space that exerts significant gravitational and magnetic fields.

I find it confusing to state that the formation of new stars are due to something called gravitation waves or interstellar shock waves, when they can be simply explained by the gravitational fields exerted by this accumulated band of massive black holes.

The spiral arms are a region filled with the carcasses of dead stars (black holes). It is the strong gravitational fields exerted by those black holes that coalesce the clouds of gas to form the next wave of new brilliant stars.

---

At the center of a spiral arm galaxy is a central concentration of stars known as the bulge. Within the bulge of many galaxies an addition component is visible, a bar-like structure that extends from the inside edge of a spiral arm to the inside edge of a symmetrically opposing spiral arm. The midpoint of the central bar is the galactic center. Currently around two thirds of all aged spiral arm galaxies contain this central bar structure. But in the past the number of younger spiral arm galaxies that contained a central bar was believed to be far less. It is estimated that only 10% of the spiral arm galaxies had a bar structure about 8 billion years ago. So what is this central bar structure?

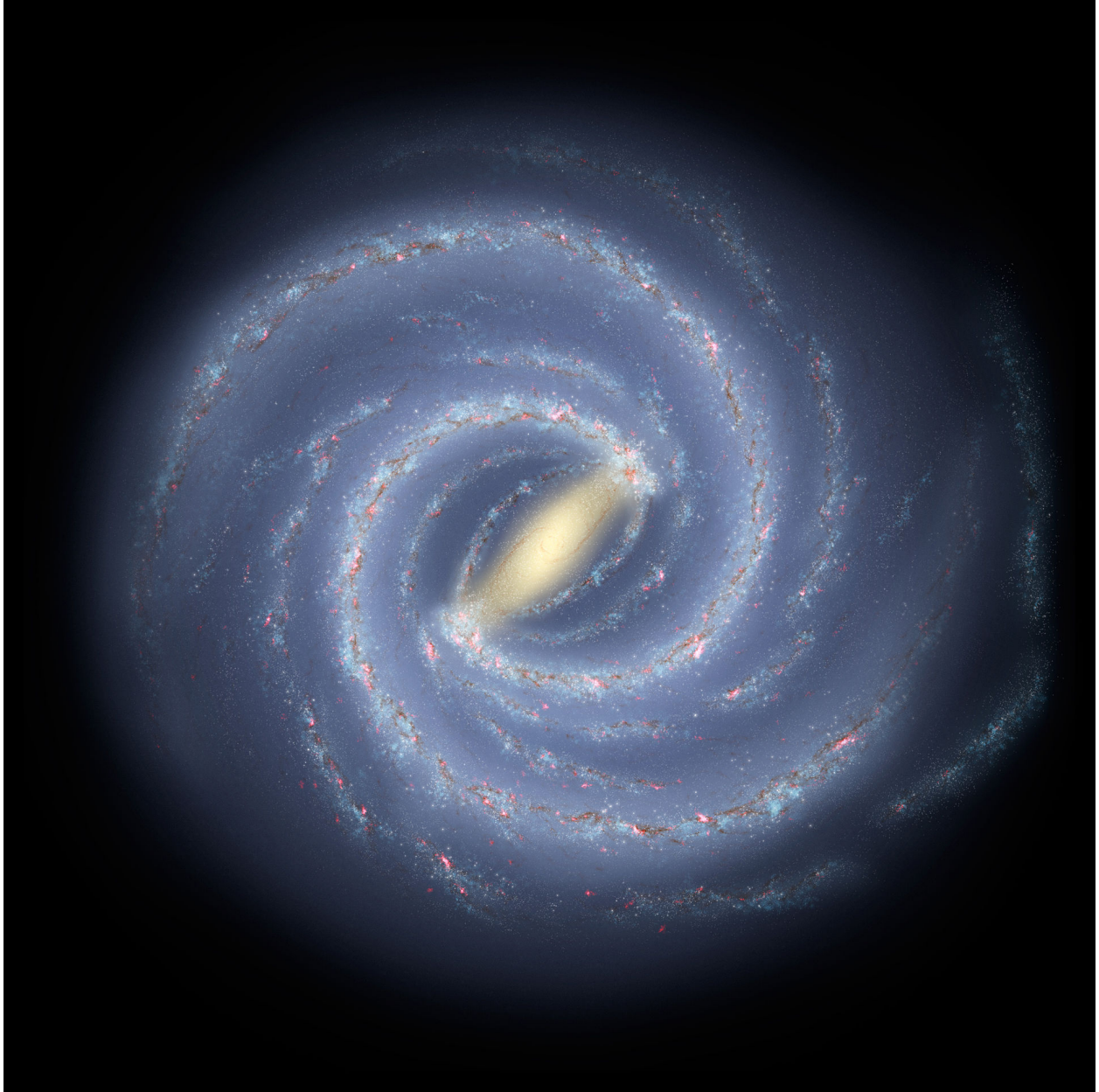


Figure 2. Detailed artist's impression of the structure of the Milky Way galaxy including the central bar. NASA/JPL-Caltech/ESO/R Hurt - <http://www.eso.org/public/images/eso1339g/>

The bar-like structure is extremely bright (even brighter than the spiral arms) and just like the spiral arms is composed of a tremendous amount of O- and B-type stars which are continually being refreshed and repopulated. As these stars reach the end of their life and explode into supernovas, they leave behind the carcasses of black holes. This means that the central bar contains an extremely dense region of black holes. Fast spinning black holes produce strong magnetic fields emanating primarily along their spin axis. The high concentration of black holes will cause these black holes to align together like a very large bar magnet. The sheer number of these aligned black holes intensifies their cumulative magnetic field strength, essential creating a magnetic corridor along the central bar.

---

Surrounding a galaxy is a halo of gases called the galactic corona. Referring to these as clouds of very hot gases is probably a misnomer. They are charged particles, primarily protons, traveling at very high velocities. One such cloud observed in our Milky Way galaxy is referred to as the Smith Cloud.

The Smith Cloud was discovered in 1963, but its origins and chemical makeup were a mystery for a long time. Some scientists thought that the cloud could be a starless galaxy or just a giant body of gas, falling in to the Milky Way from intergalactic space. Astronomers managed to figure out the chemical composition of the Smith Cloud matched the chemical thumbprint of our galaxy. This huge cloud of gas is approaching the edges of the Milky Way at a speed of around 193 miles per second (approximately 0.001c).

As a star goes supernova, it releases a great amount of energy (light) and also ejects a massive amount of matter (galactic cosmic rays), which are charged particles such as protons and pieces of atoms (ions). The charge particles released have near relativistic speeds. It is commonly thought that these particles dissipate in space in random spherical directions like a massive explosion. But that is not quite the case because these charge particles are being acted upon by very strong magnetic fields. These particles will follow the magnetic field lines in the central bar structure and in the spiral arms to the edge of our galaxy. They travel along a magnetic corridor. [Some scientists refer to these pathways as galactic chimneys. This coronal gas may be sustained by the galactic fountain, in which superbubbles of ionized gas from supernova remnants expand vertically through galactic chimneys into the halo.] All I have to say is this is a very strange way of articulating a very natural process.

The observed speed of the Smith Cloud (0.001c) may not just be a random number but might have significance. It might correspond to the speed that protons are traveling in the outer shell of the end-stage star just before it goes supernova. In which case this outer layer of the star (proton stream) is unwrapped and unbound and simply set free into space during a supernova explosion.

The Smith Cloud is around 9,800 light years long (or around 58 quadrillion miles). It is estimated to contain enough matter to generate over two million new stars in the galaxy. When the cloud of charged particles make its way back into the Milky Way following the magnetic field lines, astronomers believe it will trigger a huge star formation event.

As large brilliant O- and B-type stars deplete their supply of nuclear fuel, they erupt in a violent explosion called a supernova. They leave behind the carcasses called black holes. Black holes have great mass and produce strong magnetic fields. Black holes are not randomized but form the structure that drives the evolution of galaxies. In summary, as spiral arm galaxies age, the carcasses of the massive stars (black holes) accumulate. The black holes produce strong magnetic fields and align within the central bar to form a structure similar to a bar magnet. This strong magnetic field in the central bar and to a lesser extent in the spiral arms produce a magnetic pathway that focuses the charged

particles (galactic cosmic rays) generated from violent supernova explosions. These magnetic fields propel the charged particles to the outer edge of the galaxy, the galactic corona, and then these particles follow the magnetic field lines back towards the center of the galaxy, where they provide matter (fuel) to create the next generation of bright massive stars. Thus there is a continual process of star creation/star destruction within the spiral arm galaxies.