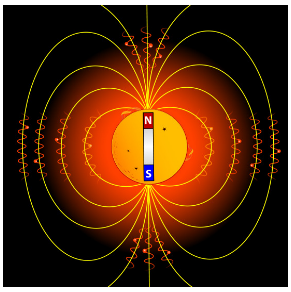
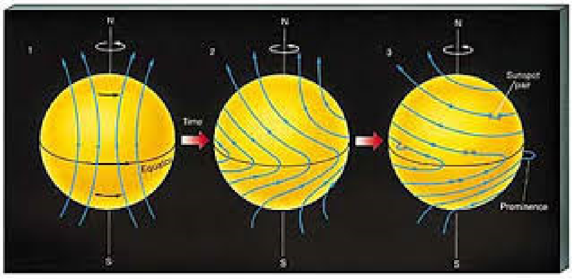
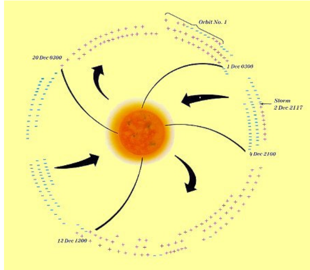
Sun – Part 19 - Magnetic field 1







Solar magnetic field   Field line distortion causes sunspots   Solar magnetosphere

Like all stellar magnetic fields, that of the Sun is generated by the motion of the conductive plasma within it. This motion is created through convection, a form of energy transport involving physical movements of material. Field generation is believed to take place in the Sun's convective zone where the convective circulation of the conducting plasma functions like a dynamo, generating a dipolar stellar magnetic field.

In the solar dynamo, the kinetic energy of the hot, highly ionised gas inside the Sun develops self-amplifying electric currents which are converted into the solar magnetic field which gives rise to solar activity. This conversion is due to a combination of differential rotation (different angular velocity of rotation at different latitudes of a gaseous body), Coriolis forces and electrical induction. These rotational effects, and the fact that electrical current distribution can be quite complicated, influence the shape of the Sun's magnetic field, both on large and local scales.

In 1952, the American father and son solar astronomers Harold and Horace Babcock developed the solar magnetograph with which they made the first ever measurements of magnetic fields on the Sun's surface. Their work enabled them to develop a model which explains their extensive observations and spectrographic analysis of solar magnetic field behaviour. In this, from large distances, the Sun's magnetic field is a simple dipole, with field lines running between the poles. However, inside the Sun, the rotational effects which help create the field also distort the field lines. The result is that the poloidal (pole to pole) magnetic field lines under the photosphere become increasingly twisted until they are parallel at the equator (the toroidal field).

The local active regions of the Sun, including sunspots, are thought to be generated as these distorted magnetic field lines rise through the photosphere. In these areas of high distortion, particularly in the equatorial regions, the magnetic field can become highly concentrated, producing activity when they emerge on the surface. The localised field lines exert a force on the plasma, effectively increasing pressure without a comparable gain in density. As a result, the magnetised region rises relative to remainder of plasma until it reaches the photosphere. Where it breaks through the surface, the magnetic field lines create coronal loops on the surface, and the related phenomenon of sunspots. Coronal loops are magnetic flux tubes which are formed within the convection zone. Filled with hot plasma, they form arches extending upwards from the photosphere into the corona. It is theorised that these loops contribute to the very high temperatures found in the corona. The two ends of the loop, the footprints, are located in regions of the photosphere of opposite magnetic polarity to each other.

Sunspots are regions of intense magnetic activity on the Sun's surface. They form a visible component of magnetic flux tubes. Due to the differential rotation of the star, these tubes become curled up and stretched, inhibiting convection. This creates zones of lower than normal temperature, explaining why sunspots are visibly darker than the surrounding photosphere. Solar magnetic activity is also associated with short term, but explosively energetic surface events including solar flares and coronal mass ejections.

Another feature of the solar dynamo model is that the electric currents are alternating, not direct. This means that their direction, and thus the direction of the magnetic field they generate, alternates more or less periodically, changing amplitude and direction, although still aligned closely with the axis of rotation of the Sun. This explains the existence of the 11-year solar cycle.

Surface activity appears to be related to age and rotation rate of main sequence stars like the Sun. Young stars with rapid rotation rates exhibit strong activity, while middle aged, stars, lie the Sun, with slower rotations rates show low levels of activity that vary in cycles. Some older stars display almost no magnetic filed related activity,

Magnetosphere Stars with a magnetic field generate a magnetosphere that extends outwards into surrounding space. The field lines originate at one magnetic pole and end at the other pole, forming a closed loop. The magnetosphere contains charged particles trapped form the solar wind which then move along the field lines. As the star rotates, the magnetosphere rotates with it, dragging along the charged particles, creating a torque on the ejected matter.

This results in transfer of angular momentum from the Sun to surrounding space, causing slowing of its rotation rate. However, like other stars, rotation will never cease. Rapidly rotating stars have a higher mass loss rate, resulting in faster loss of momentum. However, as the rotation rate slows, so does angular deceleration. By this means, the Sun, like other stars will gradually approach, but never quite reach, a state of zero rotation.

Sources: Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, www.en.wikipedia.org