Polarity B

The Long of It

The Sun's magnetic field; sunspots

The Sun has a magnetic field, just like the Earth does, but the magnetic field of ~~the~~ Sun is much more complex and variable than that of the Earth. The Earth has one magnetic North (N) pole and one magnetic South (S) pole. Whether magnetic field is of the N or S kind is called the *polarity* of the magnetic field. The effects that the magnetic field of the Sun has on the Earth do not depend on the polarity: only the strength and orientation of the field are important, just like for crossing a road you care how many cars zip by (the "strength" of the flow of cars), what direction the road has (crossing at right angles is best) but not whether the cars move from left to right or from right to left (the "polarity" of the flow).

The Sun's magnetic field has more than one component. It has a rather weak global magnetic field which shows up best near the geographical poles of the Sun (and is referred to as the polar-cap field in the rest of this text), more or less like the magnetic field of the Earth, with N and S poles near the geographical poles, but this magnetic field is not very important for the Earth. On top of that, the magnetic field in certain places of the Sun is much stronger (about 5000 times stronger than that of the Earth). Such places appear on the surface as sunspots. On the Sun, each sunspot is a magnetic pole, either N or S. The Sun does not rotate around magnetic poles, just like the Earth does not rotate around its magnetic poles.

Sunspot groups; magnetic polarity order

Sunspots generally occur on the sun in groups which are usually oriented rougly in the East-West direction. You can see some sunspot groups on the full-disk continuum image map. The sunspots at the Westerly end of a sunspot group usually have the opposite magnetic polarity from the sunspots at the Easterly end. For instance, if the Westerly end has N polarity, then the Easterly end has S polarity. The order of polarities in the group, going from West to East, is then N-S. It turns out that almost all sunspot groups in the Northern half of the Sun have the same order of polarities, for instance N-S, and that almost all sunspot groups in the Southern half of the Sun have the opposite order, in this case S-N.

During the current solar cycle (about 1997 - 2008) the preceding sunspots in both hemispheres have their magnetic polarity equal to their geographic polarity (i.e., N in the northern hemisphere, S in the southern hemisphere).

The solar cycle; polarity change; poles exchanging place

The number of sunspots on the Sun varies in a cycle, called the solar cycle, which lasts on average 11 years. Near the minimum of the cycle, you hardly ever see a sunspot, and the sunspots that do appear are usually very small (about 1,000 miles across). Near the maximum of the cycle, you see many sunspots all the time, and some of them get to be very big (up to some 30,000 miles across). For a plot of the number of sunspots seen from this observatory during the last forty years, see the solar cycle page of Mr Sunspot's Answer Book. At the moment (in 1996) we are close to the minimum of the solar cycle.

The orientation of the weak polar-cap magnetic field of the Sun changes with the solar cycle, too. This change occurs roughly when the number of sunspots is at a maximum: then the magnetic field near the magnetic poles of the Sun decreases to zero and then increases with the opposite polarity from what it was before. This effect is sometimes referred to as the (magnetic) "pole reversal", but it does not mean that the *geographical* poles of the Sun change places or that the Sun turns upside down. You can compare this magnetic polarity change with the temperature changes on the Earth's poles: For one half year, the Earth's North Pole is relatively warm, and the South Pole is then relatively cold. During the next half year the situation is reversed (you might say that the "thermal polarity" of the Earth has reversed, or even that the "thermal poles have changes places"), but that does not mean that the geographical poles have traded places or that the Earth has turned upside down. And anyway, the global magnetic field of the Sun is much less important than the magnetic field associated with sunspots.

The polarity order of the sunspot groups turns around after each minimum of the solar cycle. If before the minimum (in the old cycle) the order in the Northern half of the Sun was N-S, then after the minimum (in the new cycle) it is S-N, and likewise in the Southern half of the Sun. This change in the order of the magnetic polarities or poles in sunspot groups in each half of the Sun is sometimes called a "polarity change", and you might also say that the "magnetic poles trade places" in sunspot groups from one solar cycle to the next one, though that is not a common expression. Again, the geographic poles of the Sun do not change places, nor does the whole Sun turn upside down.

Until the next sunspot maximum (expected around 2001) the magnetic polarity of the polar-cap fields is the same as the geographical polarity (i.e., N near the north pole, S near the south pole). After that (until about the following sunspot maximum) the magnetic polarity is the opposite of the geographical polarity.

Solar flares

If strong magnetic field gets twisted up too much, it may suddenly relax into a less twisted state. Because more twist means more energy, the magnetic field has to release energy to relax. This energy heats up the material and makes it shine brightly for about an hour. Such an event is called a solar flare. Most of the energy of a solar flare is released in the form of ultraviolet (UV) radiation. A small part is released as visible light or as X-rays, and another small part goes into cosmic rays (which are

Solar flare. Particals release into space actually made of particles) and other particles, which may be released into outer space.

Since the strongest magnetic field occurs in sunspots, solar flares are usually associated with sunspots. The number and average size of solar flares varies with the solar cycle. Near the minimum of the solar cycle there are almost no flares and if a flare should happen anyway then it is usually a very small one.

Radio communications

Some of the UV and X-rays and visible light from a solar flare may reach the surroundings of the Earth at the speed of light, in about 8 minutes. The UV and X-rays are mostly absorbed by the atmosphere, where they may interfere with the layers that reflect short-wave radio signals, causing disruption in the reception of such signals.

Communication satellites use different frequencies which are not reflected by those layers, and have a thick metal hull which stops most UV, cosmic, and X-rays, so these communications are not usually affected by solar flares, except if the satellite is hit by a cosmic or X-ray that has more energy than the satellite was designed to withstand. The X-rays and cosmic rays that are emitted during a solar flare come in many different amounts of energy, with numbers of cosmic ray particles and X-ray photons that decrease with increasing energy, so there is a small but non-zero chance of a satellite being hit by a particle or photon with more energy than the satellite was designed to withstand. The bigger the solar flare, the larger the chance of a satellite being hit by such an energetic particle or photon. It is estimated that a typical transistor in a satellite has a chance of one in a thousand years of being broken by a cosmic ray or X-ray.

FM radio signals are short-range and do not rely on the reflecting layers, so they are not affected by solar flares. AM radio signals are somewhere in between FM and short-wave signals.

Since solar flares follow the solar cycle, the disruptions in short-wave radio signals also follows the solar cycle: the most disruption occurs when the solar cycle is at its maximum.

Northern and Southern lights (aurorae)

(*) Some of the cosmic rays and other particles that are ejected during a solar flare may reach the Earth, if the magnetic field between the Sun and the Earth happens to be pointing in the right direction. Because these particles carry electrical charge, they are forced to move along the magnetic field of the Earth and tend to get closer to the surface only near the magnetic North and South poles of our planet, where they cause Northern and Southern light (aurora borealis and aurora australis), which are harmless and sometimes offer spectacular shows. The effects of these particles increase for about two days after a solar flare, and they they decrease again.

The occurrence of aurorae follows the solar cycle.

Electrical wires

A magnetic field is associated with travelling particles that carry electrical charge, such as those ejected during a solar flare. If an electrical wire is moved in a magnetic field, then an electric current is induced in the wire. This principle is used in electrical generators such as may be found on bicycles or in cars. If a magnetic field moves past an electric wire, or if the magnetic field at the wire changes, then you get the same effect.

If the magnetic effects associated with the particles from a solar flare manage to reach the surface of the Earth (mostly near the magnetic poles), then they may induce electrical currents in electrical wires. The induced currents are small and usually have no consequences. However, with the induced electrical currents is associated a voltage difference which is proportional to the size of the electrical circuit, so long wires experience larger induced voltage differences than short wires. If the electronics at either end of the wire are not sufficiently protected, then the magnetic effects from a solar flare might short out the circuit. However, the wires have to be very long indeed (say, many miles) before the induced voltage difference becomes appreciable, and such wires are usually only found in power grids which carry high voltage anyway, so they are usually sufficiently protected against this effect. It is rare for a solar flare to cause a short circuit, and if it does it most likely happens in a place and at a time when the Northern or Southern light is very strong, i.e., close to the magnetic poles and during a solar flare near the maximum of the solar cycle.

A related effect is that electrical currents are also induced in long metal pipe lines (such as those carrying oil), and these cause the pipes to corrode more quickly than they otherwise would.

Since these electrical effects are rare during the minimum of the solar cycle or far away from the Earth's magnetic poles, it is very likely that the power failures that occurred in some Western parts of the United States in 1995 and 1996 were not caused by solar flares.

Protection

Our electrical equipment must be shielded against the influence of outside magnetic and electrical effects, whether these come from the Sun or from Earth-based sources. The amount of shielding that is applied depends on how much it costs, how much protection it gives, how much outside influence is expected, and how expensive or important the equipment is. There is always a chance that bigger disturbances will occur than the protection can handle, no matter how good the protection is. Of course, the better the protection, the smaller the chance that it will be penetrated, and the higher the cost of maintaining it. (This holds for many kinds of disturbances, including solar flare effects, earthquakes, accidents, wars, and diseases.)

So, we have to expect that the protection of electrical equipment against disturbances will occasionally fail. Since this equipment is usually very important to the people who bought it, it is given a large amount of protection and fails only rarely. If the amount of magnetic disturbances coming from the Sun or from any other source were to increase more than expected, and were to cost us more than adding protection does, then we'll just have to apply more shielding.

Outer atmosphere

The outermost layers of the atmosphere of the Earth (at more than 100 miles above the surface) expand a little bit when the Sun is more active. Artificial satellites in low orbits around the Earth then experience more atmospheric drag. This extra drag slows down the satellite and changes its orbit, which may cause the operators of the satellite to lose track of it. In some cases the extra drag may cause a satellite to fall back to the Earth sooner than expected. This happened, for instance, to the Skylab satellite in 1979. However, most active satellites have propulsion systems that allow them to move back to the desired orbit.

Astronauts and airplane travellers

The increased amounts of radiation (UV and X-ray) that accompany a solar flare pose a health hazard for spacewalking astronauts, though not a dramatic one. The hazardous cosmic rays and other high-energy particles are deflected by the Earth's magnetic field in the direction of the magnetic poles, so astronauts in orbits that do not pass close by the Earth's magnetic poles are mostly safe from them. In very high orbits around the Earth (higher than the Space Shuttle can go) or close to the magnetic poles, or outside of the Earth's magnetic field (on your way to the Moon, for instance), there is no protection against these high-energy particles except what you bring along yourself.

High-flying aircraft receive much less protection from the atmosphere against X-rays (though the metal hull of airplanes blocks some of them), so frequent flyers have a slightly higher risk of radiation-induced diseases. The levels of such radiation are a bit higher still while a solar flare occurs. However, the total effect is very small and all in all it is still safer to fly than to drive a car. Even flight attendants and pilots, who spend much more time on airplanes than the average traveller does, do not have dramatically higher incidences of such diseases than ground-based travellers do.