



Cosmic Magnetic Fields

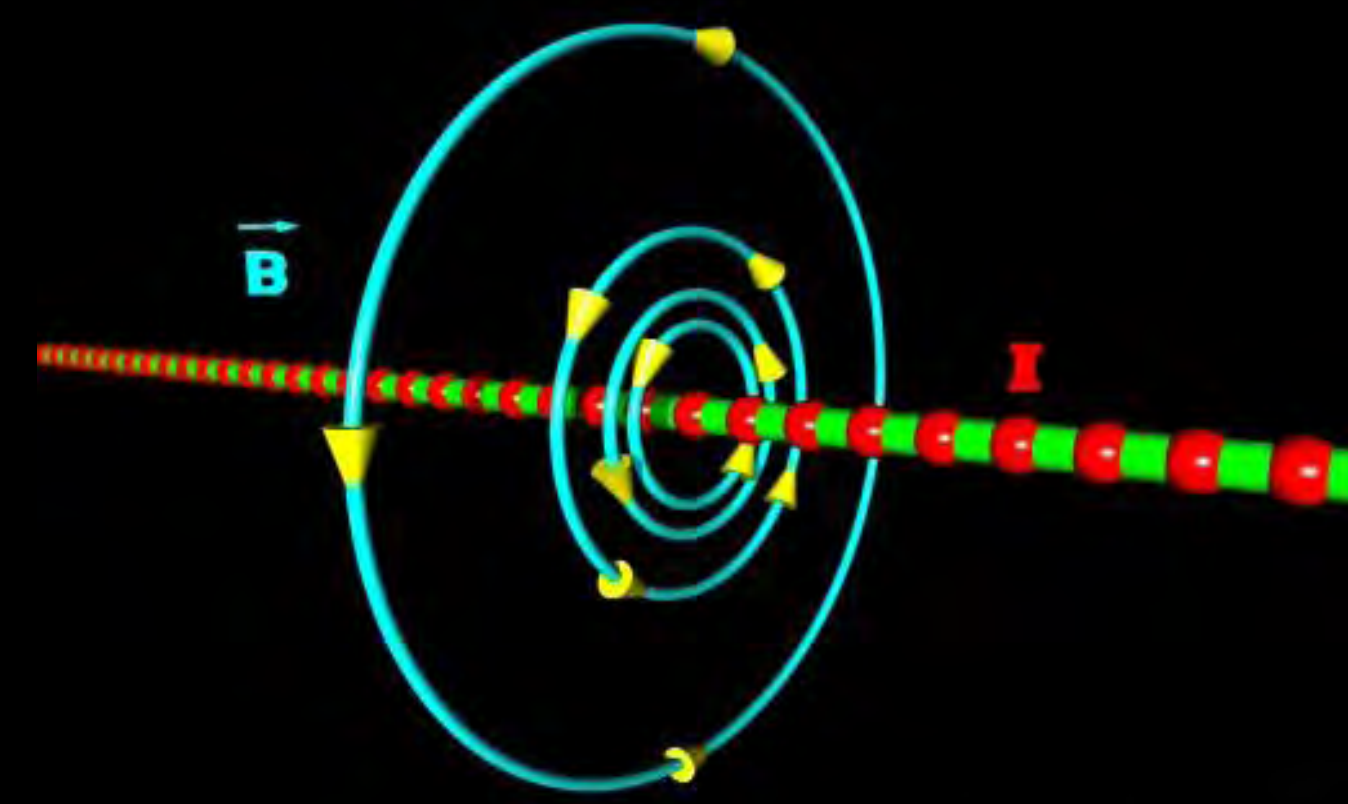
ELECTROMAGNETISM BASICS

Electric and magnetic **FIELDS** are regions of space in which **ELECTROMAGNETIC FORCES** act. In Astronomy, magnetic fields are more important than electric.

LIGHT (electromagnetic radiation) is an **ELECTROMAGNETIC WAVE** of vibrating electric and magnetic fields.

Electric and magnetic fields are made up of lines of force called **FIELD LINES**; the more **BUNCHED UP** the field lines, the stronger the field.

Magnetic fields are **ALWAYS** associated with **ELECTRIC CURRENTS**. A current-carrying wire produces a circular magnetic field. Moving a permanent magnet back and forth inside a wire coil **INDUCES** an electric current in the coil.

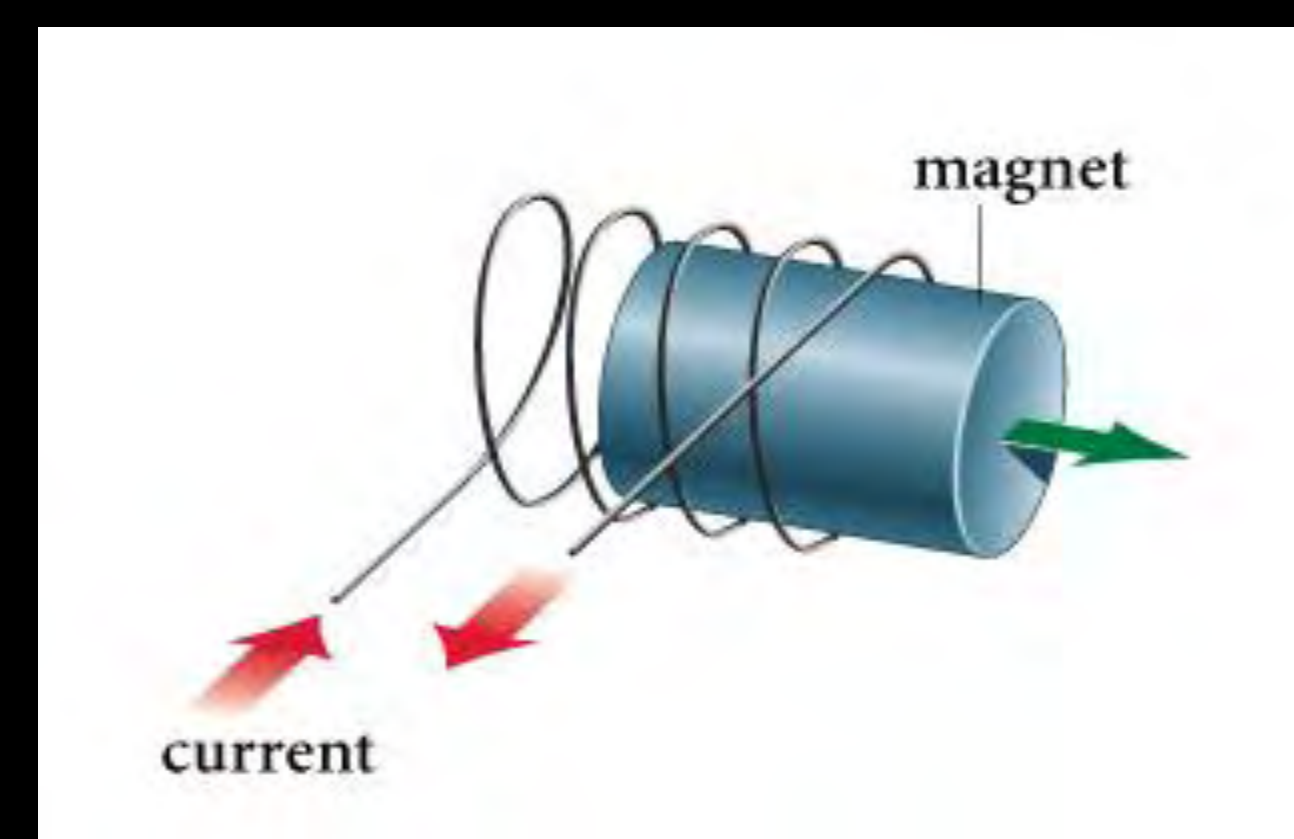
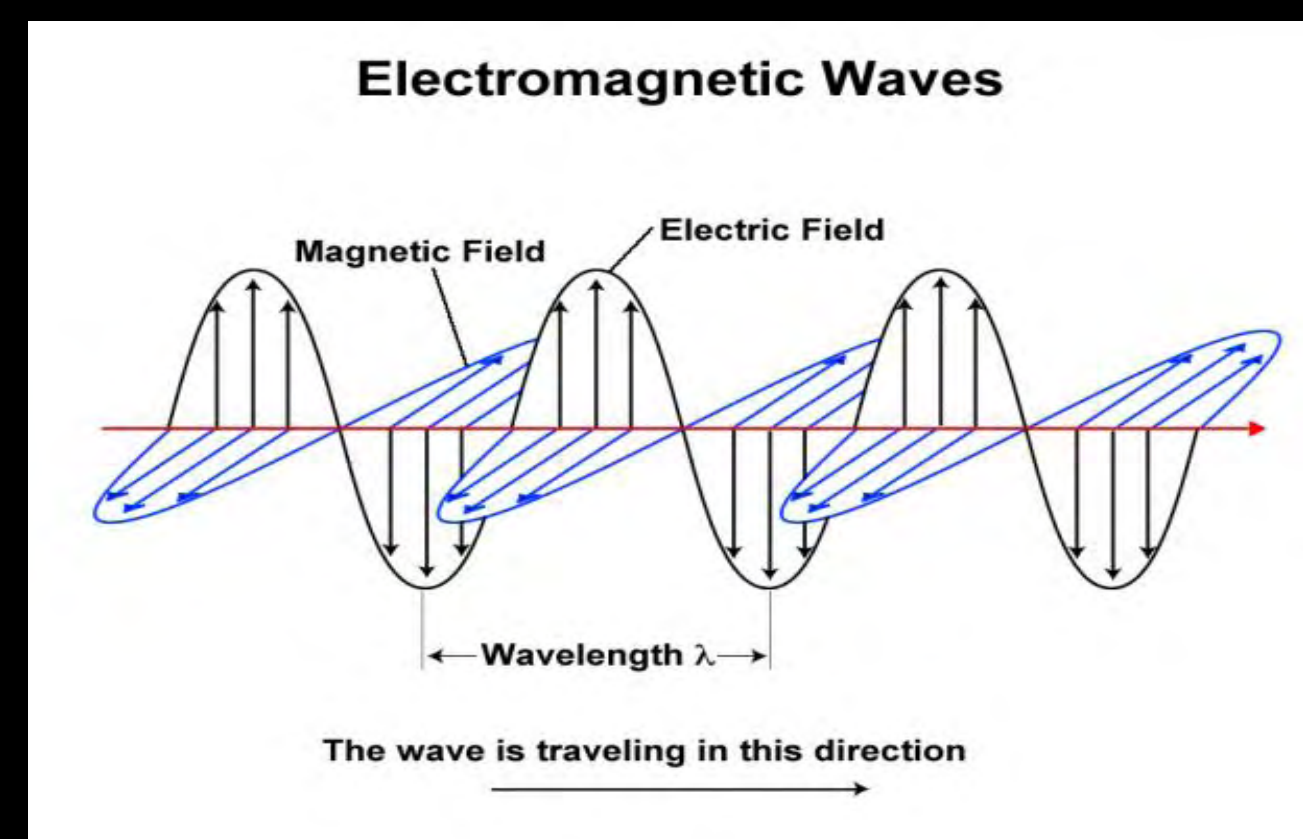


WHY SHOULD WE CARE?

Most of the regular matter in the universe is in the **PLASMA STATE**, which means it is a gas of freely moving **POSITIVE** and **NEGATIVE CHARGES**...which means there must be electric currents therein...and hence magnetic fields as well.

Because of the **GREAT SIZE** of astrophysical objects, it takes a **VERY LONG TIME** for a magnetic field to **DIFFUSE** out of them...field lines are **FROZEN IN** the gas like billion strands of hair in chapati dough.

When clouds of plasma get **COMPRESSED, STRETCHED, SHEARED, TWISTED** or **MIXED**, so do the magnetic fields inside them. When gravity collapses a plasma cloud, the field lines bunch together, then the **MAGNETIC PRESSURE** helps to support the gas cloud against gravitational collapse. Field lines also resist being stretched, just like **GUITAR STRINGS**. This **MAGNETIC TENSION** can help to transfer momentum and energy between gas particles joined by a field line.



HOW DO WE MEASURE THEM?

THE ZEEMAN EFFECT

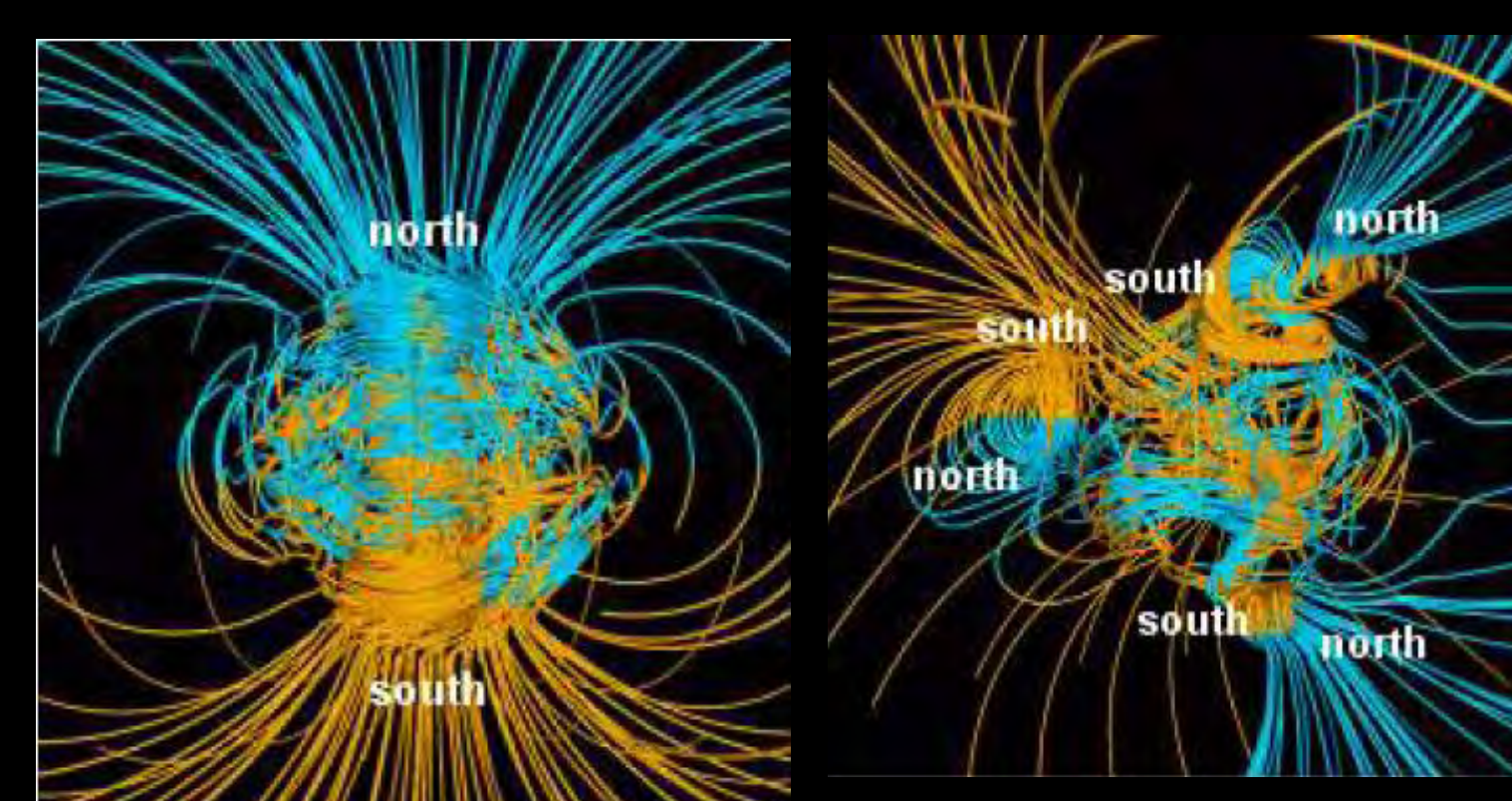
The energies of the different **ELECTRONIC CONFIGURATIONS** of an atom do not normally depend on its orientation. However, the presence of a magnetic field introduces a preferred direction, with one result being that certain **ENERGY LEVELS** of the atom are split into sublevels. The difference in energy between these sublevels is proportional to the strength of the magnetic field—if this energy separation can be measured, then the field strength can be deduced. In practice, this is done by measuring the **SPLITTING OR BROADENING** of an emission line in the spectrum of a source.

SYNCHROTRON RADIATION

This is the radio emission that is beamed by **ELECTRONS** spiraling around magnetic field lines at close to the speed of light. If the density of relativistic electrons can be estimated, then measuring the intensity of synchrotron radiation can give us the **STRENGTH** of the component of the magnetic field in the **PLANE** of the sky. This emission can also be **POLARIZED**, which means that it can be oriented along an axis. With this extra information, it is possible to determine the **DIRECTION** of the magnetic field lines (but with 180 degree ambiguity).

FARADAY ROTATION

This can be used to get the component of the magnetic field along the line of sight from the Earth to the source. The polarization angle of the radio emission slowly rotates as the radiation makes its way through a magnetized medium. The amount of rotation is proportional to the **LINE-OF-SIGHT COMPONENT** of the magnetic field and to the square of the wavelength of the radiation, so by measuring the polarization angle at different wavelengths we can determine the **STRENGTH** and **DIRECTION** of this component of the magnetic field.



EARTH AS A MAGNET

Not only is Earth's magnetic field useful for navigation (a compass needle points along the field lines) but it **PROTECTS** us from the **SOLAR WIND** of charged particles streaming from the sun as well as from energetic charged particles known as **COSMIC RAYS**.

Some particles from the sun manage to follow the magnetic field lines down to the **POLAR REGIONS**. There they can collide with atoms of nitrogen and oxygen in the upper atmosphere, leading to beautiful displays of light known as **AURORA**.

Earth's field is known to **REVERSE** itself—the magnetic poles more or less trade places—every 3,00,000 years on average, though the timing is actually quite erratic (the last reversal occurred some 7,80,000 years ago).

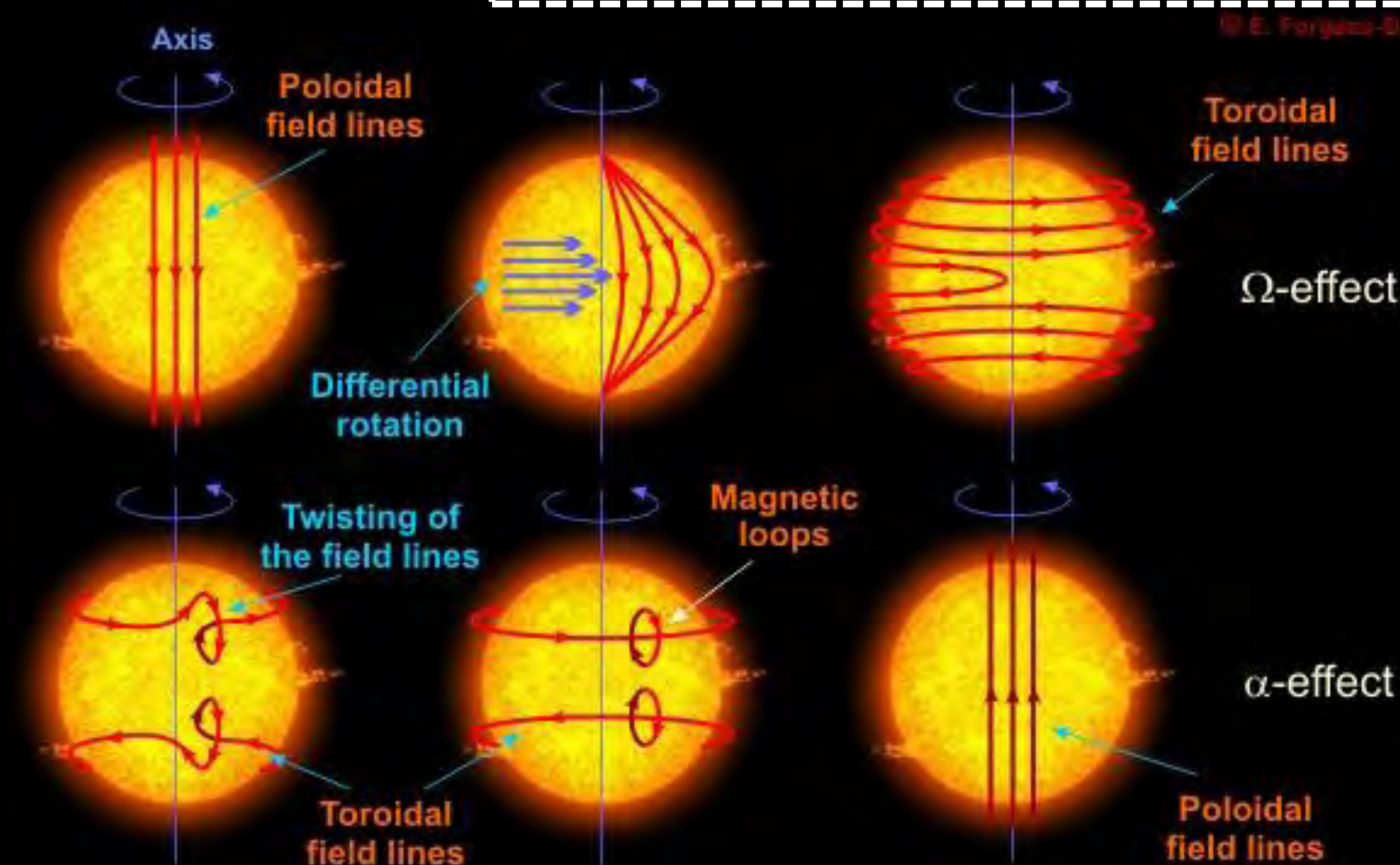
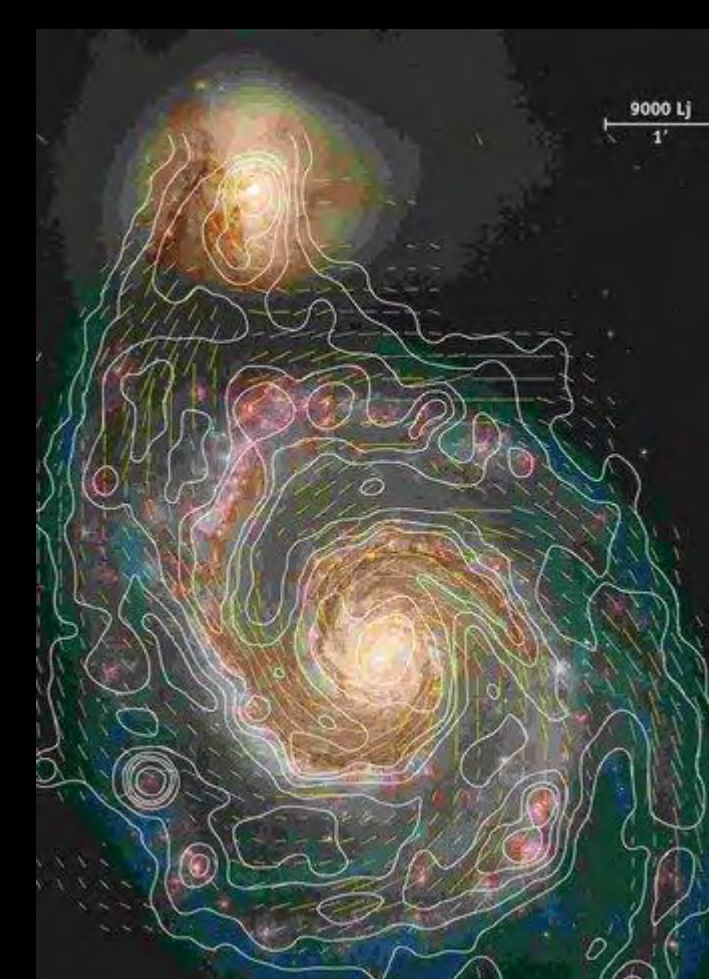
DYNAMO

A plasma is in constant movement, both in terms of its average motion (e.g. **ROTATION** inside a disk) as well as its **TURBULENT RANDOM MOTION**.

Due to the field lines being stretched and twisted by these motions, the field can become **ENHANCED** with time.

This process, whereby **KINETIC ENERGY** of the plasma is converted to **MAGNETIC ENERGY**, is known as **DYNAMO**.

Dynamos can grow the magnetic field **EXPONENTIALLY** with time, but initially they require a small **SEED FIELD** on which to operate.



© E. Ferragamo-Dagka

