

# *Some Dates in the Exploration of the Magnetosphere*

- ~1000
  - Magnetic compass discovered in China
- 1600
  - William Gilbert publishes in London "De Magnete" ("on the magnet"). His explanation of the compass: the Earth is a giant magnet.
- 1741
  - Hiorter and Celsius note that the polar aurora is accompanied by a disturbance of the magnetic needle.
- 1777
  - Charles Augustin de Coulomb in Paris builds a sensitive magnetometer, using a magnet suspended by a long flexible string. Using this, he proves that the magnetic attraction (and also the electric one) decrease like the inverse square of the distance.
- 1820
  - Hans Christian Oersted discovers electromagnetism. André-Marie Ampère deduces that magnetism is basically the force between electric currents.
- 1851
  - Samuel Schwabe, a German amateur astronomer, announces the discovery of the 11-year sunspot cycle.
- 1859
  - Richard Carrington in England observes a violent and rapid eruption near a sunspot; 17 hours later a large magnetic storm begins.
- 1892
  - George Elery Hale introduces the spectroheliograph, observing the Sun in the light of a single spectral line such as H- $\alpha$ . Using it he observes a solar flare and confirms the connection between flares and magnetic storms.
- 1900-3
  - Kristian Birkeland experiments with beams of electrons aimed at a magnetized sphere ("terrella") in a vacuum chamber. The electrons hit near the magnetic poles, leading him to propose that the polar aurora is created by electron beams from the Sun.
  - Birkeland also observes magnetic disturbances associated with the aurora,

suggesting to him that localized "polar magnetic storms" exist in the auroral zone.

- 1902
  - Marconi successfully sends radio signals across the Atlantic Ocean. Oliver Heaviside suggests that the radio waves found their way around the curving Earth because they were reflected from electrically conducting layer at the top of the atmosphere.
- 1926
  - Gregory Breit and Merle Tuve measure the distance to the conducting layer by measuring the time needed for a radio signal to bounce back.
  - R. Watson-Watt proposes naming the layer "ionosphere."
- 1930-1
  - After Birkeland's "electron beam" theory is disproved, Sydney Chapman and Vincent Ferraro in England propose that magnetic storms are caused when plasma clouds ejected from the Sun envelop the Earth.
- 1949
  - A sudden increase in cosmic rays is traced to an eruption on the Sun. A much larger event occurs in February 1956.
- 1953
  - Owen Storey proves that "whistler" radio waves are produced by lightning and are often guided through distant space along field lines of the Earth's magnetic field.
- 1954
  - Meredith, Gottlieb and Van Allen use a rocket in the auroral zone to detect radiation from the aurora.
- 1955
  - Radio emissions from Jupiter are detected, mystify observers.
- 1957
  - Sputnik 1 launched by the Soviet Union, the first artificial satellite.
- 1958
  - Explorer 1, launched by the US January 31, observes the radiation belt; Explorer 3, launched in March, comes up with the first clear evidence for its existence.
  - Eugene Parker (Chicago) proposes the theory of the solar wind.
  - Pioneer 3 observes the outer radiation belt.
  - "Project Argus", 3 small nuclear bombs above the south Atlantic Ocean, creates (3 times) artificial radiation belts, lasting about 2 weeks. The project also creates artificial aurora.

- 1959
  - Thomas Gold proposes the name "Magnetosphere".
- 1961
  - James Dungey in Britain proposes a mechanism for transmitting solar wind energy to the magnetosphere by direct magnetic linkage between the two.
  - Ian Axford and Colin Hines (Canada) raise an alternative possibility, of energization by fluid friction at the boundary between the two.
- 1962
  - The magnetopause, boundary between magnetosphere and the solar wind, is observed by Explorer 12.
  - In July, an H-bomb test ("Project Starfish") by the US above the central Pacific Ocean creates a radiation belt of high-energy electrons, parts of which remain until 1967. The new belt creates aurora at Samoa and unexpectedly knocks out 3 artificial satellites.
- 1964
  - IMP-1 (Interplanetary Monitoring Platform 1) reports a large bow shock formed in the solar wind ahead of the magnetosphere, and a long magnetic tail on the night side of the Earth.
  - Syun-Ichi Akasofu (Japan-US) and Sydney Chapman revive and expand Birkeland's notion of a "polar magnetic storm", now named "magnetospheric substorm."
- 1971
  - Ionospheric oxygen ions found among energetic particles trapped in the Earth's magnetic field, evidence that O<sup>+</sup> ions are pulled out of the ionosphere and accelerated (Ed Shelley et al., Lockheed).
- 1974
  - A large-scale pattern of extensive electric currents flowing from space into the polar cap and out again is traced by Alfred Zmuda and Jim Armstrong of the Johns Hopkins U. Applied Physics Lab, using the Navy's "Triad" satellite.
- 1977
  - The S3-3 satellite of the U.S. Air Force observes the upward acceleration of O<sup>+</sup> ions, related to the downward acceleration of electrons in the polar aurora.
- 1981
  - High resolution images are obtained by Lou Frank's group in Iowa of the entire auroral zone, using the Dynamics Explorer satellite.
- 1983
  - ISEE-3 (International Sun-Earth Explorer 3) explores the distant magnetotail, observes that the distant tail plasma flows (past about 70 RE) away from Earth.

This is later confirmed by the Geotail spacecraft.

- 1985
    - An "artificial comet" is produced by a cloud of barium ions, released by the German IRM (Ion Release Module) satellite. Meanwhile another AMPTE spacecraft, CCE (Charge Composition Explorer) observes mass and energy distribution in the ring current, including its peak energies around 65 keV.
  - 1991
    - Severe solar-produced shock wave hits the magnetosphere, produces an additional (temporary) radiation belt.
  - 2004
    - the [HESS telescope array](#) in Namibia maps a circular source of high-energy gamma rays, evidence for the origin of cosmic rays in supernovas.
    - 16 December 2004---Voyager 1 apparently crosses the [termination shock](#) of the solar wind, at which it slows down below the Alfvén speed (magnetic equivalent to sound velocity). That shock is the first sign of resistance to the solar wind by the interstellar plasma.
    - 27 December--- [powerful gamma ray burst](#) arrives, apparently from a "magnetar" in our own galaxy.
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