Edward J. Smith, Pioneer in Space Plasma Research (1927-2019)

Dr. Edward J. Smith, a pioneer of space plasma research, passed away on August 11, 2019, at age 91. Ed received a PhD in physics (his thesis advisor was Robert E. Holzer, also a space plasma physicist) from UCLA in 1959. Ed spent 1959 to 1961 at the Space Technologies Laboratory (now TRW) in El Segundo, California. Then he came to the Jet Propulsion Laboratory (JPL), California Institute of Technology, Pasadena, California, where he spent the remainder of his scientific life. In his early years at JPL, Ed took a sabbatical at the Royal Institute of Technology in Stockholm Sweden with Hannes Alfvén. They became lifelong friends from that visit.

Ed was typical of scientists of his age, building both the instruments and making major scientific discoveries. Ed was unique among his peers in that he was the first to not only fly a fluxgate magnetometer and vector helium magnetometers in space (VHMs have lower intrinsic noise than fluxgate magnetometers) but Scalar Helium magnetometers and dual vector/scalar mode magnetometers. Ed was also the first to build and fly triaxial search coil magnetometers in space for electromagnetic plasma wave studies. Ed gave his design of search-coil magnetometers to Europe and Japan where the basic designs were copied and flown in space by other scientists. Ed was the "father" for all of these space instruments.

Ed was an "experimenter" on the (fluxgate) magnetic field investigation on Mariner 2, the first successful mission to a planet (Venus, 1962). The other magnetometer experimenters were Chuck Sonett (NASA), Paul Coleman (NASA) and Leveritt Davis (Caltech). The plasma instrument experimenters were Marcia Neugebauer and Conway Snyder of JPL. Marcia and Conway used the plasma data to confirm Eugene Parker's prediction of the existence of the solar wind. Then for the Mariner 4, the first mission to Mars (1965) and Mariner 5, a second mission to Venus (1967), Ed was the Principal Investigator (P.I.) of the Vector Helium Magnetometer investigation. From the Mariner 5 interplanetary data, working with Leverett Davis (Caltech) and John Belcher (Davis' PhD student at the time), they identified Alfvén waves in the solar wind. Although much more is now known about these waves, the origins and eventual evolution still remain a mystery.

Also in the 1960s (launched 1964-1969 and missions extending into the 1970s), Ed was Principal Investigator of the search-coil magnetometers onboard the Orbiting Geophysical Observatory (OGO) satellites -1, -3 and -5. From these data, Ed and his colleagues were the first to identify the major electromagnetic plasma waves in the Earth's magnetosphere: plasmaspheric hiss, outer zone chorus, and magnetosheath lion roars. Ed first worked with Holzer and his students (Chris Russell was one) and then later with Richard Thorne (UCLA) and Bruce Tsurutani (JPL). These are the primary magnetospheric electromagnetic wave modes still studied today. An analysis technique by Ed's friend Bengt Sonnerup (Dartmouth College) called "minimum variance analysis" was found to be extremely useful for analyzing electromagnetic waves. Ed was the first to apply this technique, a method which is the main means of studying plasma wave details today.

The outer heliosphere was next for Ed. He was Principal Investigator of the magnetometer experiments on the twin spacecraft Pioneers 10 and 11. Pioneer 10 was launched in 1972 and Pioneer 11 ~ one year later in 1973. The spacecraft were built by TRW and the mission managed by NASA Ames. These were the first missions to go to the outer heliosphere, through the (then thought) potentially dangerous asteroid belts and to distant planets. The radio isotope thermoelectric generators (RTGs) gave power to these spacecraft going far from the Sun (a first). Pioneer 10 encountered the giant planet Jupiter in 1973 going in to a distance of 2.8 Jovian radii (132,000 km). The intense radiation belt fluxes were even higher than predicted, but Pioneer 10 survived. Ed was the first to characterize the planetary magnetic fields and the dynamic ever-changing magnetosphere (due to solar wind fluctuations). The bow shock was crossed 17 times during the encounter.

After the successful Pioneer 10 encounter, NASA and the scientists started planning for the Pioneer 11 encounter with Jupiter. If Pioneer 11 were sent even closer to the planet than Pioneer 10, Pioneer 11could be directed to an encounter with Saturn! NASA made the decision to send Pioneer 11 in to a distance 1/3 that of Pioneer 10. The trajectory was planned so that the spacecraft would miss the magnetic equator where the particle radiation was most intense. The mission was successful and Ed and his colleagues made even better (closer) measurements of the planetary magnetic fields.

The mission to Saturn was not without controversy. NASA asked the Pioneer 11 scientists to decide the trajectory of the Pioneer 11 Saturnian flyby: either go outside the Saturnian rings where the satellite would be safe, or go inside the rings where there was the danger of collisions with unseen ring particles. The vote of the P.I.s was not unamimous, but Ed's (and others) arguments and votes to go inside held the day. Pioneer 11 was sent into a distance of only 21,000 km from Saturn's cloud tops. Ed and colleagues were the first to characterize the planetary magnetic fields and the Saturnian magnetosphere.

During the transit to these distant planets, Ed and his colleagues made other discoveries. With John Wolfe, they were the first to identify an interaction between high speed solar wind streams and slow streams, a region they named "Corotating Interaction Regions" or CIRs. CIRs have been shown to be important for causing geomagnetic activity on Earth. With Pioneers 10 and 11 energetic particle experimenters (John Simpson of the University of Chicago, James Van Allen of the University of Iowa and Frank McDonald of the Goddard Space Flight Center), they discovered that fast forward and fast reverse collisionless shocks bounding the CIRs were accelerating energetic particles in deep interplanetary space between 3 and 10 AU. With Marcia Neugebauer and Bruce Tsurutani, Ed studied and characterized different types of interplanetary discontinuities.

Because of Pioneer 11's close encounter with Saturn, the satellite received a gravitational boost to become the first spacecraft to get out of the ecliptic plane. Although it only attained an angular distance of 17°, it was enough for Ed and colleagues to determine the shape of the heliospheric current sheet (HCS). Ed remembered a somewhat obscure prediction by his old friend Hannes Alfvén. The HCS became known as the “Alfvén ballerina skirt”. As the ballerina spins, her skirt will fluctuate up and down with warps in it.

The International Sun-Earth-Explorers were the first joint NASA-ESA mission to be flown. There were 3 spacecraft. ISEE-3 was a solar wind monitor placed in orbit around the L1 libration point (first to have achieved this orbit) and ISEE-1 and -2 were magnetospheric orbiting spacecraft. Ed Smith was the magnetometer P.I. on the ISEE-3 spacecraft and a Co-I on the plasma wave experiments on ISEE-1, -2 and -3.

With combined ISEE-3 magnetometer and plasma data Ed and colleagues identified and characterized what are now called Coronal Mass Ejections (CMEs), one of the causes of magnetic storms on Earth. Ed and Bruce Tsurutani of the ISEE-3 magnetometer team and members of the Los Alamos, New Mexico plasma team (Jack Gosling and Ron Zwickl; the P.I. was Sam Bame) were the first to identify and characterize interplanetary fast shocks using observational data.

The ISEE -1, -2, and -3 team were the first to collectively study the Earth’s foreshock regions where back-streaming energetic electrons and ions propagated into the solar wind generating plasma waves through in situ instabilities. Ed was also strongly involved in identifying a fundamental magnetosheath wave mode at Earth, Jupiter and Saturn called the mirror mode. With Charlie Kennel (UCLA), Ferd Coroniti (UCLA) and Fred Scarf (TRW) (and many other colleagues), Ed studied quasiparallel shock particle acceleration for the first time.

The ISEE-3 space mission had a very clever design engineer named Bob Farquhar. Bob found that by storing extra hydrazine gas onboard (this gas was used to keep ISEE-3 in orbit about the libration point), after the prime mission was accomplished, the spacecraft could be moved to other regions in space. This was an extremely novel concept at the time! The ISEE-3 team voted (the vote was again not unanimous) to move the spacecraft from the L1 orbit to a series of deep magnetotail passes reaching ~240 Earth radii (R_e). To accomplish this a series of lunar gravitational assists had to be planned and executed. From this new mission, Ed and colleagues determined that the magnetotail was not “fragmented” but still maintained a two-lobe structure all the way to 240 R_e. They also discovered slow shocks bounding the lobe-plasmasheet boundary and “plasmoids” flowing down the tail. With Fred Scarf, Charlie Kennel and Ferd Coroniti, Ed and colleagues identified electrostatic plasma wave modes in the tail and magnetosphere.

After the deep tail passes, there was still hydrazine gas available for further spacecraft maneuvers. Farquhar identified an opportunity to go through a comet’s tail. The ISEE-3 mission was renamed the International Cometary Explorer (ICE) which encountered comet Giacobini-Zinner in 1985. Ed showed that the cometary magnetic tail had a structure of draped magnetic fields as predicted (again) by Hannes Alfvén.

One of the biggest surprises with the cometary encounter was the detection of highly nonlinear plasma waves associated with neutral gas sublimated from the comet nucleus. As the neutral H_2O molecules become ionized by either photoionization or charge exchange from the solar wind, the newly formed ions are instantaneously affected by the solar wind electric fields and are accelerated so that they collectively are unstable and generate the waves. Ed and Bruce were the first to make this discovery. A theory by Ching Wu and Ron Davidson of the University of Maryland had clearly predicted this but was missed by the experimenters.

After the encounter of ICE with comet Grigg-Skjellerup, a spacecraft “armada” was sent to comet Halley (1986 encounter), the most famous of all comets. ICE was a distant participant ~1 million km away, but still managed to detect pickup ion waves. Hiroshi Oya (Tohoku University, Japan) invited Ed and Bruce to become Co-Is on the Japanese Sakigake plasma wave investigation going to Halley.

For the joint NASA-ESA Ulysses mission Ed not only supplied the Vector Helium Magnetometer as Co-I (Peter Hedgecock of Imperial College was the first P.I. and then later André Balogh), but he was also the NASA Project Scientist for the mission. Ed worked in conjunction with Peter Wenzel, the ESA Project Scientist to make the mission scientifically successful. By using the magnetometer data, Ed was able to determine that the Sun’s magnetic field does not simply disappear and then reverse polarity or simply rotate its dipole every 11 years but a more complex field dominates during the field reversal interval.

Ed supplied the (Dual Sensor Scalar) magnetometer for the Argentine Science Application Satellite (SAC-C) in 2000 and a vector/scalar helium magnetometer on the NASA/ESA Cassini mission which orbited Saturn. Ed also was a Co-I of the JUNO mission to Jupiter (arrival date 2016).

Ed was a member and Fellow of the American Geophysical Union, and a member of the American Association for the Advancement of Science and the American Astronomical Union. He was a recipient of two NASA medals for Exceptional Scientific Achievement and a NASA Distinguished Service medal. He was elected a Fellow of the American Geophysical Union. In 2005, he received the Arctowski medal from the U.S Academy of Sciences in recognition of contributions to solar-terrestrial research. Ed was the author or co-author of over 500 scientific articles. His research interests included Planetary Magnetism and Magnetospheric and Solar-Heliospheric physics. The achievements of Dr. Edward J. Smith as a pioneer of space science are truly remarkable.

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