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Science and technology in the 20th century as seen through the journal *Ibérica* (1914–2003)

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The desire to found the magazine *Ibérica* with the slogan "science accessible to everyone" was sparked by the solar eclipse in August 1905, which was a total eclipse in Tortosa. This is the story told by the founder of the Ebro Observatory and the magazine *Ibérica*, Ricardo Cirera, in October 1913. Today we might call this new enterprise *scientific magazineism*. The *Institut d'Estudis Catalans* (Institute of Catalan Studies, IEC), which had been founded a few years earlier, on 18 June 1907, also sought to cultivate the professional sciences in Catalonia.

Below are two photographs of the solar corona (Fig. 1). The first was taken in white light in the midst of a full solar eclipse. The disc of the Moon conceals the photosphere and the solar chromosphere. The rays of gas of the corona are curved by the sun's magnetic field, the dipole. The second photograph also shows the rays of gas from the Sun's corona, also curved by solar magnetism, but this time taken in ultraviolet light. A comparison of the two images shows that the appearance of the solar corona depends on the wavelengths that we use to explore it. One of the aims of the geophysicists at the Ebro Observatory was to share scientific progress with an enlightened public.

The subtitle of *Ibérica* was 'The Progress of the Sciences and its Applications,' and the publisher was the Ebro Observatory. From the publishing standpoint, it was quite bold to offer a new weekly from the countryside, several kilometers from Tortosa, where communications other than a telephone and a wireless telegraph were lacking. The name *Ibérica* came from the Ebro River, which runs near the Observatory, located in Roquetes, downstream from Tortosa. On 7 November 1914, the efforts of Ricardo Cirera were recognized, as he was awarded the Alfonso XII Grand Cross of Civil Merit by the Infanta Isabel de Borbón.

Without science we cannot understand society

It has been over 400 years since Galileo gazed up at the sky, in 1609. He designed his telescope with two lenses, one convex, converging lens, the finder, and another concave, diverging lens, the eyepiece. With it, he managed to amplify images 30-fold, which, for the first time, revealed sunspots, the phases of Venus, the craters on the Moon and the four moons of Jupiter. Galileo accepted the heliocentric system devised by Copernicus, a Polish astronomer, and changed our vision of the world, although in his time he was condemned, first in 1616 by Cardinal Inquisitor Saint Roberto Bellarmine and again in 1633 by Pope Urban VIII.

In 1908, Ortega y Gasset said, "If Europe somehow transcends the Asians, Africans, it is owing to science. Europe = Sci-

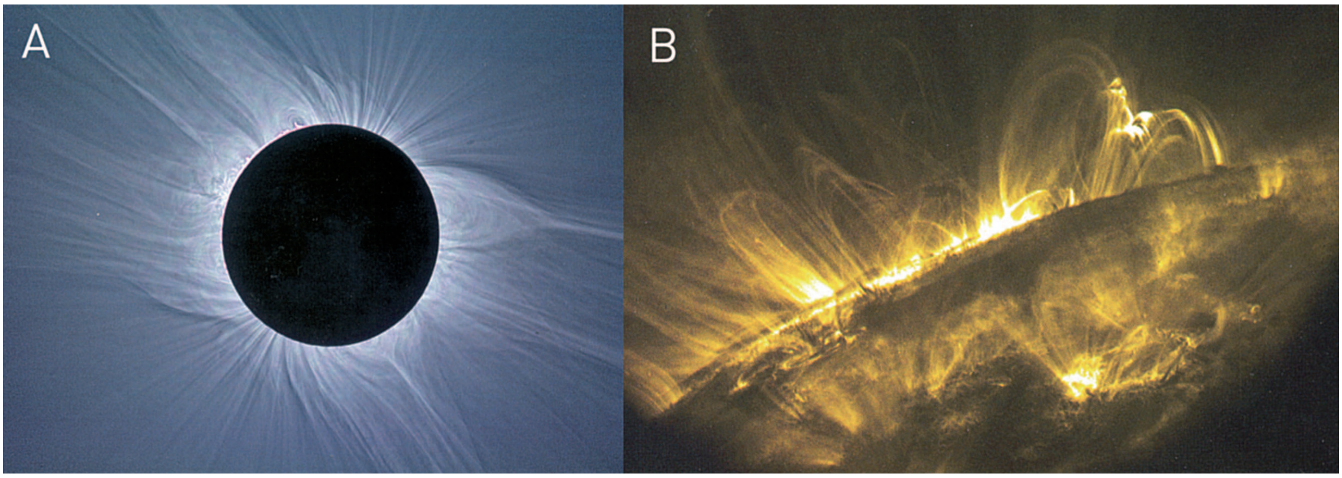

Fig. 1. (**A**) Photo from the TRACE satellite, 2010, Lockheed Martin/NASA. (**B**) Photo showing the rays of gas from the Sun's corona, taken in ultraviolet light.

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ence. It is necessary above all for Spain to produce science, and in the meantime let us take pains to conceal the native vulgarity." It is clear that science affects every aspect of our lives; it is essential. We can realize our place in the universe just by gazing up at the firmament. Astronomy and the fundamental sciences contribute to our everyday lives, even helping us to achieve a more peaceful, egalitarian society. Many cities in Spain have an observatory within the city limits—proof of the important role of science in modern society. In 1914, there was a similar appreciation of science. Ricardo Cirera reminds us that he was often asked for "a publication aimed at an enlightened audience;" but the main problem, in his eyes, was how to achieve the right tone.

The Ebro Observatory was a geophysical observatory with several departments: Heliophysics, Meteorology, Electricity, Magnetics and Seismology. Its staff was on the writing team for *Ibérica*, which contained articles on biology, medicine, the natural sciences and geophysics. Furthermore, next to the Observatory, Eduardo Vitoria had founded the Ebro Chemical Laboratory, which would later move to Barcelona, where it was renamed the *Institut Químic de Sarrià* (Sarrià Chemical Institute). Another foundation, located in Roquetes, also near the observatory, was the Ebro Biology Laboratory, established by Jaime Pujiula. In 1940, after the Spanish Civil War ended, it also moved to Sarriá, Barcelona. All three foundations were supported by the Company of Jesus.

Topics covered in *Ibérica*

The refracting telescope. Copies of the weekly *Ibérica* until December 1936 show us that the Observatory staff strongly supported the magazine. The Observatory's equipment and instruments were commonly used at the time. The most important instrument at the Observatory was the refracting telescope. This was what 19th century tastes required, even though continuing to reproduce Galileo's telescope no longer yielded satisfactory results.

In order to avoid chromatism on the lens (irisation), a long focal distance is needed through an extremely long telescope tube. Lenses had to be created based on two kinds of glass, crown and flint, in order to limit both the effects of chromatism and spherical aberration, thus ensuring that red and blue had the same focal point. The latest refracting telescope of that time, from the 1900 Paris World Exhibition, measured 83 cm in diameter but the next generation of telescopes, with mirrors instead of refracting lenses, Cassegrain-style, would change everything. However, for over a year, the Observatory's 1904 refracting telescope had produced a daily photo of the Sun (as it still does today, in 2011) for submission to the Meudon Observatory in Paris. The photo showed the spots on the photosphere (solar zones with temperatures lower than that of the photosphere are referred to as *sunspots*) and was accompanied by calculations of the Wolf number on solar activity. *Ibérica* published a monthly extensive summary of the activity of the solar photosphere during the previous month. Today, the observatory no longer has a Heliophysics Department; rather, it is a part of the Meteorology, Climate and Solar Activity Department, but the day-to-day work has remained the same.

Seismology. *Ibérica* has a long history of contributions on this topic because of the earthquake registry at the Ebro Observatory, which is the oldest in Spain. The traditional stations were the Central Station in Toledo, the Seismic Observatory of Cartuja (Granada), the San Fernando Observatory, the Fabra Observatory (Barcelona) and the Ebro Observatory (Fig. 2).

Seismology had always been a subject of interest among *Ibérica* readers. It offers a better understanding of the processes that take place inside our planet or it can reveal where oil fields might lie. For example, a company that prospects for oil might install a network of seismographs on the ground and then, at a calculated distance, explode a dynamite charge, simulating an earthquake. The seismic wave would then be refracted in an oil-bearing sediment. Today, we can use seismographic measurements to ascertain whether a country has test-exploded an atomic bomb, even in a remote desert. When the United States conducted its first atomic tests of U-235 in Alamogordo, New Mexico, on 16 July 1945, in the midst of World War II, although these tests were an absolute war secret, they were detected by all the seismic observatories. An artificial earthquake cannot be concealed. One month later, in August, the U-235 bomb exploded over Hiroshima, killing many thousands of people, most of them civilians.

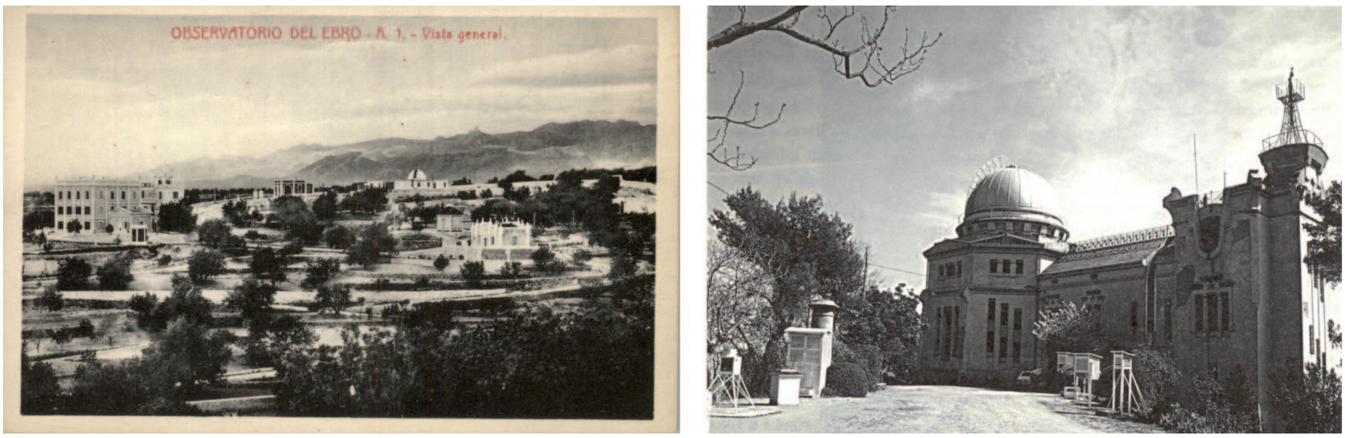

Fig. 2. Left, the Ebro Observatory (Roquetes). Right, the Fabra Observatory (Barcelona).

A seismograph is a suspended mass, a pendulum that remains immobile due to inertia even when everything around it is moving. If this pendulum has a stylus that drags along the ground, during an earthquake it will scratch lines upon the surface below it, in the direction of the epicenter. In the 1950s, I was shown the Ebro Observatory's Mainka-Ebro seismograph, weighing 1500 kg, and a register, which consisted of a moistened-paper drum (some machines used smoked paper) where a stylus attached to the seismic pendulum drew sinuous lines. The stylus was a lever made of a very slim reed weighing just a few grams. The difference between the two sides of the lever indicated the amplifying power of the seismograph. The reed, activated by a timing device with a small electromagnet, marked the time signals in seconds. Today this seismograph is, of course, completely outdated.

In modern versions, the seismograph is an electronic device similar to an accelerometer. When the Earth moves, the goal is to keep the mass of the pendulum electronically immobile through feedback from the circuit. The force needed to immobilize the pendulum is then recorded. The underlying principle is Newton's formula $F = ma$ (force = mass × acceleration). However, achieving a 'broadband' seismograph is not a trivial endeavor, as the device must be equally capable of recording an insignificant tremor, perhaps very distant, and a violent earthquake—without the stylus leaving the recording band.

A group of seismographs can be used to precisely locate the epicenter (the point where a geographic fault ruptures) in three dimensions. This is accomplished with P and S waves, which trace curved lines due to the variations in the density and composition of the Earth's interior. P waves are compression waves in the direction of the epicenter which cross both water (1450 m/s) and granite (5000 m/s). In S waves, the Earth's movement is perpendicular to the propagation direction. S waves move more slowly than P, or primary, waves. *Ibérica* readers were interested in the nature of seismic, elastic waves, which provide information on the mantel and core of the Earth, where we cannot venture and which can only be explored with P and S waves.

Ibérica's articles about seismology also introduced its readers to Andrija Mohorovičić, at the time the Chairman of the University of Zagreb (he retired in 1921). Mohorovičić demonstrated that inside the Earth there is discontinuity between the upper and lower mantel, as shown by the P and S waves of the seismograph. At that time these ideas received little credence, but the network of seismographs ended up proving him right: there is an upper level, the crust, which spreads over the continents and varies between 35 to 54 km in thickness, and sometimes much more, over which are the oceans, ranging in depth from 5 to 9 km. Deeper down is the mantel. The Mohorovičić or Moho Discontinuity lies between the crust and the mantel.

On 18 April 1906, a year after the Ebro Observatory was founded, the San Francisco earthquake struck, leaving 3000 people dead and 300,000 residents homeless. Studies on this violent earthquake were published in *Ibérica* for the next 10 years. The cause of the earthquake was the rupture of the San Andreas fault along a distance of 477 km, shifting the ground from right to left for 6–8 m. The quake lasted between 25 and 46 s. It was the first to be documented by photographs and on film, and it posed a host of questions: Is the interior of the Earth solid or liquid? What temperature is it? The iron-based core of the Earth creates the magnetic dipole with the poles to which compasses are oriented. Why does the magnetic pole move with respect to the geographic pole (magnetic declination)? *Ibérica* answered these questions.

Electrotechnics. In its Specimen Issue, published in September 1913, *Ibérica* boldly attempted to industrialize an essentially agricultural Spain, where half the population worked on farms. It was an initiative spearheaded at the magazine by Dr. José A. Pérez del Pulgar, the founder of the Higher Technical Engineering School (ICAI, Madrid), which joyously celebrated its centennial in 2008. Pérez del Pulgar also founded the ICAI journal *Anales* in 1922, and in 1929 was awarded the Gold Medal by Spain's Minister of Labor.

It is worth recalling the definition of 'electrotechnics' at that time. In 1882, Thomas Edison built the first continuous-current electrical grid, 110 volts, in New York for 59 clients. In 1887, Nikola Tesla registered his patent to distribute electrical energy using alternating current. In this rivalry between Edison (continuous current) and Tesla (alternating current), Tesla prevailed. The first School of Electromechanical Engineering was created in Darmstadt, Germany, in 1882. In *Ibérica*, Dr. J. A. Pérez del Pulgar wrote the following texts throughout several issues.

"What is Electrotechnics in our day? It is an applied science that is thoroughly practical and not at all theoretical, which does not mean that it is not eminently mathematical in its study procedures. Furthermore, it often requires new means of calculation from mathematical analysis, as the ones existing are not sufficient. [...] Today the sciences are called theoretical not because they make greater or lesser use of calculation but because they are based on hypothetical considerations which are more or less inaccessible to experimentation. Electrotechnics is an experimental though eminently mathematical science, and among the experimental sciences it belongs to what are called the industrial sciences. Its purpose is to transform one product into another that is more useful for daily life. [...] The purpose of the transformations studied by electrotechnics is also energy, but in its electrical form, the most manageable of all, the most easily transportable and the one used in the most varied and useful of applications. [...] In its strict sense, electrotechnics encompasses the calculation and construction of electrical generators powered by thermal and hydraulic machines, the transformation of one current into another, the transport of energy and its use through traction, heat, light, etc.[...] The construction of generators has reached such colossal proportions in recent years that we in Spain can hardly imagine it. [...] Just a single Chicago Edison Company factory produces 160,000 kW (almost 220,000 horsepower), more energy than what is supplied by all the factories currently operating in Madrid and Barcelona. [...] The first Edison Company power station was founded ten years ago with 84,000 kW, more than the total produced in all the factories in Madrid. The total amount of energy supplied by Edison is around 645,000 horsepower. We in Spain would not know what to do with all that energy. [...] The size of modern alternators is such that the old working procedures have been inverted. Instead of bringing the pieces that need to be worked to the tooling machines with a crane, today in the large construction companies, such as AEG in Berlin, the enormous cranes come with huge drills, riveting machines and the like and takes them to the piece to be worked. Just calculate the winch needed to repair a 50 mT generator. [...] There are factories meant for custom-building devices, such as Siemens-Halske in Berlin, founded in 1895, which has more than 5000 workers today. Worldwide copper production has quintupled since 1880, most of it used in the electrical industry to electrify railways, etc. The problems of the railways have been resolved through alternating-current motors, which may soon transform traction procedures. And we now have electrical lighting instead of gaslight. [...] There is not a single industry that does not use a wide variety of electric motors. [...] Let us close this introduction in *Ibérica* by expressing the desire to witness this peerless industry flourish in our homeland."

The Spanish Civil War (1936-1939) and the second period (1945–1961)

The weekly *Ibérica* continued to be published until December 1936, in the midst of the Spanish Civil War. The Ebro Observatory remained in operation until April 1938. On 1 April 1939 the Observatory resumed its activities with the help of the National Ravaged Regions and Rebuilding Service, although this did not benefit *Ibérica*. Publication of the magazine remained suspended until 1945, due to the post-war economy. The second period of *Ibérica* began in 1945; this time it was issued every two weeks and in a smaller format than during the first period. The editorial office was located at number 3, Palau Street (Barcelona). Its director and editor-in-chief was Ignacio Puig, who had previously worked at the San Miguel Geophysical Observatory, located on the outskirts of Buenos Aires (Argentina). He died in 1961, and with his death the second period in *Ibérica*'s history came to an end.

The magazine's contributors comprised a variety of professionals from Spain and several observatories abroad, including the Montserrat Observatory in Cienfuegos, Cuba, and the Belén Observatory in Havana, Cuba. It examined topics in the natural sciences, such as the observations of Ramón Margalef; however, similar to the first period, articles on biology, zoology, medicine and the natural science did not even account for 50% of those published. Moreover, the economic problems in the long post-war period were reflected in the magazine. At that time, the most important subjects covered were related to semiconductors, transistors and televisions. The vacuum tube was losing ground.

The transistor

The bipolar transistor was invented in 1947 by John Bardeen, Walter Brattain and William Shockley (Bell Laboratories). The group's achievement was recognized in 1960 with the Nobel Prize for Physics. The bipolar transistor replaced the thermionic valve with three electrodes, the triode. The device is a type of semiconductor that operates as an amplifier, oscillator, switch or rectifier. The bipolar junction transistor is manufactured on a monocrystal of germanium, silicon or gallium arsenide. These materials have semiconductor properties, i.e., intermediate between those of conductors, such as metals; and insulators, such as diamond.

At room temperature, some of the electrons of a silicon or germanium crystal can leap from the conduction band, absorbing the energy needed and leaving the corresponding gap in the valence band. The energy required is between 1.12 and 0.67 eV for silicon and germanium, respectively. If a small percentage of impurities is added to the silicon or germanium, that is, trivalent or pentavalent chemical elements, we say that the semiconductor is doped. These impurities become part of the crystalline structure, replacing a silicon or germanium atom. In order to form the NP joint of the transistor, donor elements from electrons (N) are used, such as arsenic or phosphorous, together with acceptor elements (P) such as indium, aluminum and gallium. NP joints result in PNP and NPN transistors.

The behavior of transistors resembles that of two diodes: one between the base and the emitter (direct polarity) and the second between the base and the collector (reverse polarity). In English, the word 'transistor' is an abbreviation of transfer resistor. Nowadays, transistors can be found in any device. The Nobel Prize recognition came at almost the same time as a rival invention: the field-effect transistor (FET), in which the source-collector current is controlled with an electrical field. FETs have a high entry impedance. The thermionic valve, today virtually fallen out of use, has the same characteristics as the FET: the current that crosses it depends on the tension of the grid.

We should recall that the ENIAC (Electronic Numeric Integrator and Computer), introduced in 1946 and the first computer used widely, had 17,468 thermionic valves and 7200 crystal diodes; it weighed around 30 tonnes and consumed 200 kW. The 1947 transistor was revolutionary, paving the way for modern electronics. Finally, we must mention MOSFET, a metal-oxide-semiconductor FET transistor. MOSFET allowed the design of extremely compact circuits, which were necessary for ICs (integrated circuits). Today we have CMOS technology, which uses two kinds of MOSFET with low current, uncharged N and P channels.

Transistors have a silicon base and three artificially doped parts: emitter, collector and base. Unlike the valve, the transistor is controlled by current and yields an amplified current. Its functioning can only be explained by quantum mechanics. A phototransistor is sensitive to electromagnetic radiation at frequencies close to visible light. Its current is regulated by incident light.

The third period: July 1962–2005

In 1961, *Ibérica* was in need of a new director, and the Ebro Observatory, which had very close ties to the magazine, was charged with providing one. I, Pascual Bolufer, then Director of the Timetable and Atmospherics Service and Deputy Director of Geomagnetism and Telluric Currents, was chosen. I was

Fig. 3. Left, cover of the first issue of *Ibérica* (1914). Right, cover of one of the last issues of the journal (2005).

later replaced at the Observatory by Edmundo Benedetti Kalikowski, an electrical engineer.

Ibérica once again expanded, with a format resembling that of the first period. Issued on a monthly basis, *Ibérica* remained in circulation until 2005, when its publication became unfeasible (Fig. 3). Times had changed, and the huge, multinational publishing houses reigned. Compared with the scope of the Spanish edition of *National Geographic*, a small publishing house had no chance of producing a comparable magazine. In 2005, the modest-sized observatories in Madrid and Barcelona, which had been in operation for many decades, were in similar straits. A giant multinational telescope, the ELT, which would probably be installed in the Andes Mountains in Chile, was being planned to which Spain would make an annual monetary contribution. This kind of partnership is what common sense advised.

The editions of *Ibérica* during its third period covered the topics that were the most interesting at that time: lasers, the expansion of the universe, dark energy, computer science, digital signal processing, and HD and 3-D television. Articles on biology and medicine were scarce and took up fewer pages. The observatories provided *Ibérica* with information on seismographic networks, atmospheric data, the Lyot solar filter and more. The most newsworthy scientific topic during this period was the ionosphere. The ionospheric probe, purchased in France by Eduardo Galdón and the Ebro Observatory in 1955, contributed to this interest.

The ionosphere

Covering the atmosphere that envelopes Earth is another, invisible layer: the ionosphere. It was discovered by Scottish physicist R. Watson-Watt in 1926. In the following year, Edward V. Appleton, the 1947 Nobel Prize winner, confirmed the existence of the ionosphere. Beginning with the Earth's surface, the troposphere, stratosphere, mesosphere, and ionosphere (between 50 and 600 km in altitude) could be distinguished. The ionosphere is a sphere of electrons, atoms and electrically charged molecules. It exists because of the ultraviolet and X-ray radiation from the Sun. In the stratosphere (12–45 km in altitude), solar radiation creates an ozone layer. At an altitude higher than 80 km, the atmosphere is so rarefied that there are free electrons for short periods of time, before they are captured by a nearby positive ion. The free electrons participate in propagating radio waves. This ionized plasma-containing layer is called the ionosphere. In the plasma, negative free electrons and positive ions attract each other through the electromagnetic force, but their kinetic temperature is too high to allow them to remain joined in a stable, neutral molecule.

Ultraviolet rays, X-rays and other short rays from the Sun are ionizing radiation because at these frequencies the photons have enough energy to expel an electron from a neutral atom. In this process, the electrons travel at such a high speed that the temperature of the electronic gas created is much higher (thousands of kelvin) than that of the ion or neutral atom. The opposite of ionization is recombination, in which the free electron is captured by a positive ion. This takes place spontaneously and causes a photon to be released, which incorporates the energy produced during recombination. At a lower altitude in the ionosphere, the gas density rises and recombination is more prevalent because the gas molecules and ions are closer together.

The balance between ionization and recombination determines the ionization level. This, in turn, depends on the Sun's activity, that is, the radiation received from the Sun. There is a diurnal and seasonal ionization cycle, with less solar radiation received in the wintertime. The Sun's activity depends on the sunspot cycle (around 11 years long): the greater the number of sunspots, the higher the radiation. Since there is an inversion in the polarity of the Sun's magnetic field in every cycle, a solar cycle lasts 22 years. The 11-year cycle directly affects the ionosphere, and it seems to influence the Earth's climate as well. Apparently, rings indicating tree growth are smaller when there are fewer sunspots and the temperatures are cooler, although these observations remain in dispute. Rudolf Wolf started studying sunspots in 1848 and later developed the Wolf number, with 11-year cycles, to indicate the Sun's activity, which is important in the ionosphere.

Radio waves are reflected and refracted in the ionosphere almost identically to the way a ray of light hits a transparent solid. A critical frequency is produced in this layer which depends on the angle at which the radio wave hits. For this reason, we often use the MUF (maximum usable frequency) in telecommunications, a higher radio frequency that no longer is reflected but is instead absorbed in the layer.

The diurnal and nocturnal ionospheres are quite different, and their effect on different layers varies substantially: the D layer extends from 60 to 90 km in altitude. It is ionized by solar radiation in the range of 121 nm to X-rays with a wavelength of 1 nm. Since the degree of recombination is high, total ionization is low due to frequent electron collisions. As a result, high-frequency (HF) radio waves are not reflected in the D layer but partially absorbed, starting at 10 MHz and lower frequencies. Higher frequencies are absorbed less. In addition, absorption is higher during the day than at night. Very-low-frequency waves (3–30 kHz) are well reflected in the D layer, but not in the E Layer (see below), which is higher in altitude. At night, the D layer retains some ionization due to the galactic cosmic rays. During chromospheric flares, the D layer undergoes a sudden rise in ionization, which heavily attenuates medium- and high-frequency radio waves. The E layer was discovered by Edward E. Appleton in 1924. It is located at an altitude of 90–120 km. Its ionization is due to 1- to 10-nm X-rays and distant ultraviolet. The E layer readily reflects frequencies of 10 MHz and below, and it partially absorbs higher frequencies. The sporadic E Layer reflects frequencies of 50 MHz and higher, sometimes up to 200 MHz. The E layer disappears at night, since there is no solar light.

At an altitude of 150–600 km is the F layer, which is the most important layer. Atomic oxygen is ionized by ultraviolet rays from 10 to 100 nm. The F layer forms a single layer at night, while during the day it splits into F_1 and F_2. Due to its electronic density, the F layer makes shortwave radio communication possible over large distances. Amateur radio operators and the military owe a great deal to the F layer. In September 2005, the first centennial of the invention of the radio was celebrated. The event is a reminder that even before 1900 amateur radio operators communicated with each other without telegraph wires, thanks to the ionosphere.

Chromospheric flares

Chromospheric flares, a glow visible in a cluster of sunspots, were first observed by R. Hodgson in 1859. They pose a serious threat to radio communications and astronauts since they alter the Earth's magnetic field. Flares are caused by a large explosion in the sunspot zone that is propagated from the photosphere to the chromosphere and the corona, sometimes with large emissions of coronal gas. The plasma heats up to tens of thousands and even millions of kelvin and accelerates electrons, protons and heavy ions almost to the speed of light. On 20 January 2005, protons took only 15 min to reach the planet Earth at half the speed of light.

Chromospheric flares produce radiation throughout the entire electromagnetic spectrum, from radio to gamma waves. They can last anywhere from a few to dozens of minutes and account for phenomena such as the aurora borealis and the aurora australis. Astronauts traveling to the Moon during a chromospheric flare would be in grave danger and the equipment in the Space Station would suffer a breakdown. Predicting chromospheric flares is difficult because we do not know which active region will produce them. There can be several per day if many clusters of sunspots on the Sun are active.

The Atmospherics Department at the Ebro Observatory

A geophysical observatory urgently needs to know when a chromospheric flare has happened. In the 1960s, a receiver in the Observatory's Ionosphere Office showed an event, and a telescope fitted out with a Lyot filter was immediately pointed at the Sun. The geomagnetism registers also showed the flare, but they were located underground, in the darkness. Very-low-frequency radio waves (10–30 kHz) triggered by storms are propagated at vast distances by the waveguide formed by the Earth's surface, which is semi-conductive, and the D layer of the ionosphere, at an altitude of around 80 km. Radio waves follow the curve of the Earth with very little attenuation, with the geographic origin of the storm being hardly relevant. The least-attenuated frequency is 27 kHz.

I designed a non-heterodyne radio receiver without an intermediate frequency at 27 kHz with wavelengths of 11 km. The outgoing signal activated a pen on a paper register with 1-min time signals. Under normal conditions, the graph is a curve with a few waves, but when a flare takes place the rise in the ionization of the D layer activates the stylus to the right. The alarm works.

The IEC in the 21st century

The motto that Ricardo Cirera chose for *Ibérica* back in 1913, "science accessible to everyone." is still valid today. Spreading scientific information is a difficult art. It falls within the gap between publications written for experts and professionals and those targeted at the average citizen. This is the field of scientific journalism, which includes television, and it aims to spark questions in its readers. Science is part of our everyday life, and it inspires no end of questions. Perhaps when you see someone using his or her tiny mobile phones in the underground with no apparent antenna and perfect reception, it will inspire you to find out how digital signals are processed.

But where is science heading? We are now celebrating the 50th anniversary of the laser. Not even the boldest imagination could have predicted its numerous successes: the four-level He-Ne laser, the microwave laser, the laser clock that enables us to do without information on the Earth's rotation to define seconds and international atomic time, the laser that destroys a missile 140 km away, CDs, DVDs, Blu Ray discs, Lasik in medicine, nuclear inertial fusion (NIF), laser impulses at femto- and attoseconds and more.

It is impossible to predict the future of science.