This short history of Jean-Louis Steinberg's legacy is based upon texts borrowed, without citation, from the works of many scientists probably more deserving than me of the honour to pay tribute to him. I hope they will not criticize me; my intention is only to spread knowledge of our scientific community's debt and gratitude towards Jean-Louis.

I focus on his life outside science. The strength of his convictions during the 70 years of his life snatched from Nazi barbarity comes from his feeling of being uniquely privileged to have survived. At the back of his mind he knew that thousands of similar victims of past, present and future genocides have been deprived of the ability to conceive, realize or even know of the formidable projects of which man is capable. Towards the end of his life he wished, above all, to diminish the bestiality deeply hidden within all of us. I want to repeat the story he told in schools, and which is of great interest, and an importance lesson for all of us.

1. Jean-Louis Steinberg

1.1. His Youth

Jean-Louis Steinberg was born in Paris on June 7, 1922. His brother Claude was born three years later, his sister Annie died of meningitis shortly after birth, and his second brother Michel was thirteen years younger than him.

His father, Germain Steinberg, joined the army in the First World War, was wounded on the front at Verdun, and was awarded the *Croix de Guerre* (a French military decoration). After four years of fighting during which three of his brothers were killed, he became an absolute pacifist.

His mother, Germaine Steinberg, had a good secondary education, something very rare at that time for a French woman of modest background. She brought up her children, teaching them gender equality and the importance of education and culture. Jean-Louis loved his mother and kept repeating how much he missed her, even when he was older than 80.

From the age of 4 to 14 he attended the *École Alsacienne*, a French school in Paris. He was influenced by the innovative teaching methods and mixed classes (unusual at that time), and he acquired an openness towards the world. In his early years he did not know what a Jew was, his parents were atheist and did not talk about God or religion at home. He did not know or feel any anti-Semitism at that time.

In 1936 financial problems obliged his parents to take him out of this school. He had a crisis of adolescence, becoming turbulent and undisciplined, and he was expelled from two Parisian high schools in one year. In 1937 at the Lycée Saint-Louis in Paris, he became aware of political and social issues which would influence his future: among his classmates there were right-wing activists who made him aware of his condition of "Jew", and hence of anti-Semitism. He became friendly with Bernard Ridoux, who lived in the same neighbourhood as him. The father of this friend, who was blinded during the war, had been a Communist candidate for all elections. For two different reasons, Bernard and Jean-Louis were the victims of extreme right-wing students and a racist, anti-Communist literature teacher.

In 1938, his mother offered him a book entitled *Madame Curie: A Biography*. After reading it, he told his mother that he wished to become a research scientist.

In 1939, he took an A-level examination in elementary mathematics. In September of that year, the war was declared.

1.2. The Occupation and the Vichy Regime

From 1940 to 1944, the German Occupation and the armistice signed by Pétain were accompanied by anti-Jewish legislation (165 Vichy legal documents and 20 German ordinances) that governed the fate of "Jewish" families. The book by Jean-Louis and Daniel Périer entitled *Des quatre, un seul est rentré* (*Of the four, only one returned*) is a precise testimony of what his family experienced during these four years of persecution which ended with deportation.

His father, who was awarded the French *Croix de Guerre*, obeyed the law and registered his family under the Vichy administration. Jean-Louis could enrol at university because his father's decoration in Verdun exempted him from the higher education restrictions imposed on Jews. The family members remained solidly united. They were obliged to wear the Star of David during administrative procedures, and whenever they did not wear it they lived in fear of controls.

To support the family, despite the continual danger, his father undertook work forbidden to Jews. In addition to the hardships endured by all, the family experienced the anguish and insecurity of victims targeted by the racist laws. His mother deprived herself of basic necessities to feed her husband and children.

While still studying at the Paris-Sorbonne University he decided, without informing his family, to join the *Jeunesses communistes* and the Resistance. In 1941, the brother of his high school friend Bernard Ridoux introduced him to clandestine activities. Under the cover of the Youth Hostels, an organisation recognised by the Vichy authorities, the French Communist Party built a clandestine network linking young people with propaganda and intelligence activities. He thus learned the rules of clandestinity and triangular organisation. He produced tracts for distribution in cinemas, painted inscriptions on walls at night, and trained a troop which, under the umbrella of cultural activities in the neighbourhoods, enabled him to identify new recruits. He experienced moments of intense solidarity and acquired great rigour in self-control and risk assessment.

In the summer of 1943, the organisation considered three of its members were a little too agitated. Jean-Louis was sent to get some rest in the Normandy countryside. During this week of camping in Flers, a commune in the Orne region of Normandy, he met a farmers' wife from whom he bought, at normal prices, butter, milk and cheese – scarce products in Paris outside the exorbitant black market tariffs. This woman agreed to his request to take his very young brother in as a lodger. Michel owes his life to her.

During these years, he studied science at the Paris-Sorbonne University and was admitted to the physics laboratory to prepare a doctorate in engineering. Yves Rocard, a discreet and deaf senior lecturer who suddenly disappeared in September 1943, was working in this laboratory. Jean-Louis later learned the role played by Yves Rocard in the secret war of radar research services.

In 1944, Jean-Louis obtained a PhD in engineering.

1.3. Deportation: *Des quatre, un seul est rentré*

From July 16, 1942, the night of the Vel d'Hiv roundup, the thousands of arrests and deportations of Jewish families became a daily threat. Initially, his parents thought that their French origin and the price in blood paid by the family during the First World War would preserve them. But at the end of 1942, the roundup concerned all Jews, including those "of French origin". When they heard rumours of imminent roundups, they were forced to separate and seek refuge individually among non-Jewish friends who risked to host them temporarily for the night. On June 6, 1944, the announcement of the Normandy landing brought the hope that this precarious life would end, but on June 18, 1944, Jean-Louis's parents and his brother Claude were arrested at 2 a.m. and taken to Drancy. His young brother, Michel, who was boarded out in Normandy, escaped this roundup thanks to Jean-Louis's self-control that prevented his parents from answering the police officers' pressing questions.

Des quatre, un seul est rentré describes the "great voyage" of convoy No. 76 which left Drancy on June 30, 1944 and arrived in Auschwitz-Birkenau on July 4. On the arrival platform, Jean-Louis, Claude and their father were chosen to work at the Buna-Monowitz camp located near the IG Farben chemical plant. Their mother, weakened by the deprivations of the war years and unable to work, was immediately sent to be killed.

In the evening of July 4, Jean-Louis became a number, the A 16878, which was to remain forever engraved on his left arm.

In the camp, he was separated from his brother and his father, whom he rarely saw thereafter. Jean-Louis was assigned to forced labour which he would not have survived if he had not met Alfred Besserman, a member of the Communist resistance network inside the camp. After questioning him about what he had done before being deported, he allowed Jean-Louis to join the organisation. This network succeeded in partially penetrating some centres of strategic importance for survival in the camp (the administrative centre which organises the assignments to the various tasks, the kitchens, the *revier* – a sick-bay for concentration camp inmates). The network also had contacts with the Polish resistance outside the camp, and also fought against the kapos, Polish common law detainees used by the Nazis to control and supervise the activities of the deportees.

Jean-Louis considered that he owed his life to this network of Communist activists. Via this network he discovered the fate of his mother upon arrival in Birkenau. It enabled him to be assigned to the less exhausting work of a commando in which he was a locksmith; and from time to time he received additional rations diverted by the network when they succeeded in hiding a death.

One day he met his father who announced happily that he had been selected to go to a sanatorium because he was too weak to work. He knew what that meant: he would never see his father again.

On January 18, 1945, fleeing from the Red Army advance, the SS pushed the deportees along snow-covered roads at –15°C, a 34-mile walk to Gleiwitz; those who staggered were shot, and the survivors were crammed onto open train trucks exposed to the snow and icy wind. After a five-day trip from Gleiwitz to the Dora camp in Buchenwald, of the 135 people crowded onto Jean-Louis' truck, only 30 survivors remained on arrival.

A few days later, he learned that his brother had not survived this death march. Jean-Louis was the only survivor of the four members of his family who had been deported seven months earlier.

Dora was a "political" camp to which many resistance fighters were deported. Jean-Louis was found to be fit for work and assigned to the tunnel where the V2 rockets were assembled. Suffering from purulent otitis, he was admitted to the sick-bay where a French doctor, who had been deported for resistance activities, spared him an immediate return to forced labour by operating on him for mastoiditis. Jean-Louis was still in this sick-bay when the Americans liberated the camp on April 11, 1945; he weighed 35 kg.

Many heard him saying that he was lucky enough to have been given a reprieve, and this "luck" he attributed to the camp resistance network and to the fact that towards the end of the war the Nazi regime was desperate to replace the workforce which it has decimated in the earlier years of the "final solution". In the convoy No. 1 which left Drancy in March 1942, there were 1112 deportees at the beginning, and five months later only 4 survivors. The 76th and penultimate convoy, with 1156 deportees including Jean-Louis, left on June 30, 1944, and ten months later, there were 182 survivors. Survival possibilities were "higher" for the deportees in the last convoys.

A few days after the liberation of the Dora camp, the Americans evacuated the French survivors by DC-3 from Nordhausen to Le Bourget. After a meal at the *Place des Ternes*, they were taken to a gymnasium on the *Boulevard Brune* where they were subjected to a security interrogation. The *Direction de la Surveillance du Territoire* (French Directorate of Territorial Surveillance) sent the CIA the files compiled during these interrogations. Identified as a Communist member of the internal resistance network at the Monowitz camp, Jean-Louis was never able to obtain a permanent visa for the USA and always had to wait until the day before departure to receive a temporary visa. He had to be accompanied by a duly mandated colleague whenever he moved within American laboratories, whether at NASA, Los Alamos or Berkeley. It made him smile, but it very often astonished his colleagues and scientific friends.

1.4. The Return to Life, Madeleine and Jean-Louis's Couple

Jean-Louis moved to his parents' house, breaking with his fiancée of before the deportation. In his book, he explains that the ten months living in a camp hardened him and made him intransigent: there are the good people and the bad people, those who held and fought and all the others, or almost all the others... During his lifetime, he doubted the ability of men to maintain their dignity when placed in extreme conditions. He kept his distance from any person who lacked an ethical sense, or showed outrageous individualism.

As soon as he returned was became active within the Communist Party and one day he found himself with American soldiers who wished to discuss the political situation with the French Communists. Jean-Louis realised that it would be useful to improve his English and remembered a French-English friend he had met in 1942, Madeleine White, whom he contacted. She was also active in the French Communist Party. A little later they decided to live together, and married in 1946. They took in Michel, Jean-Louis's young brother who had escaped deportation. In 1948, they had a child, Alain. Their 62 years of living together were woven with friendships and encounters, personal accomplishments and collective adventures of an uncommon richness. For many of their friends, their very different personalities were inseparable.

In view of the official opposition of the French Communist Party to the future family planning movement (May 1956), then the intervention of Russian tanks in Budapest (November 1956), they left the Communist Party in 1956. They always maintained their friendship and respect for the activists they had known. They always fought against social inequalities. They personally helped many young people who, thanks to them, could overcome social barriers created by our education system. The testimonies collected in the guest book show the impact of these personal actions.

They shared with many friends their appreciation of theatre, cinema, trips and holidays in their house in Chapias (Ardèche), and professionally both were intensely active in science and services for French astronomy.

A difficulty in family relations is reflected in the testimonies collected in the guest book published in memory of Jean-Louis. With Michel and Alain, who were raised at the end of the war, relational difficulties created a discord over a long period of time which extended into the 1980s. This may be due to Jean-Louis's very heavy professional work load and his consequent unavailability, but another aspect seems to me to be just as important: for years, Jean-Louis, like Madeleine, refrained from mentioning his deportation in front of Michel and Alain. Too often he had encountered misunderstanding of the narrative that he told, even the close relatives whom he met just after the liberation remained incredulous about the horrors he described.

Many other deportees also remained silent for several years after their return from the camps. Although Jean-Louis did not hide the tattoo on his left arm, it created a sort of taboo in the family. This was coupled with his apparent insensitivity and strong intransigence on personal issues.

For example, I have twice noted that, because of his terrible memories, Jean-Louis could not bear to witness the pain of colleagues who had lost close relatives in dramatic conditions. He withdrew into an incomprehensible silence, as if he was insensitive. Much later, in our last long conversations, he explained to me that he could not face this type of situation without recalling the arrival of his mother in Birkenau, and that he felt an intense need to be alone to chase away the memories which haunted him. Those who may have sometimes thought Jean-Louis to be insensitive should understand that he was, in fact, the exact opposite.

By 1946 he was determined to use the period of grace offered by his survival to undertake new projects, thus temporarily burying the past.

2. Radioastronomy from the ground

2.1. Radioastronomy in France: Earliest Beginnings 1946-1952

Keen to return to research, Jean-Louis was drawn to the physics laboratory at the École Normale Supérieure (ENS) in Paris. Yves Rocard was appointed director of this laboratory in 1946. One by one, he approached the few engineers and researchers then wandering the corridors of the facility. and suggested forming a new radio astronomy program to Jean-François Denisse and Jean-Louis Steinberg. They were joined in 1949 by Emile Jacques Blum, who was quickly followed in the early 1950s by

Jacques Arsac, André Boischot, Émile Le Roux, Paul Simon, Jean Delannoy, Bernard Morlet and James Lequeux.

Working flat out, this small group would soon narrow the huge lead gained by England, Australia, Canada, and the USA, countries that had poured massive human and financial resources into radio receivers as part of the war effort.

Yyes Rocard was a high-ranking navy officer and provided assistance from the Marine Nationale. A DCA projector mirror and a 3 m Wurzburg radar antenna were installed on the laboratory roof. Jean-Louis Steinberg installed two giant Wurzburg radars , fitted with 7.5 m dishes, in the French Navy's laboratory at Marcoussis, 30 kilometers south of Paris. A third Wurzburg was sited at the Meudon observatory by Marius Laffineur of the Institut d'Astrophysique de Paris (IAP).

Receivers on centimetric, decimetric and decametric wavelengths were developed with lamp electronics by Jean-Louis, E. Le Roux and E. Blum.

J.F. Denisse studied the theory of plasma emissions from the corona surrounding the sun. He spent two years in the United States to narrow down the fields in which the group could make rapid advances.

At the Institut d'Astrophysique de Paris (IAP), M. Laffineur was behind an ingenious automatic guidance system that used an electro-mechanical computer, which greatly enhanced the pointing accuracy of the Wurzburg radar antenna.

J. Arsac tested his theory of non-redundant arrays of antennas on a prototype interferometer capable of increasing spatial resolution. He was looking for efficient electronic systems to compute the Fourier transforms and process the signals given by the antennas.

From 1949 to 1955, Marcoussis and the roof of the École Normale Supérieure (ENS) were the sites of the bulk of radio astronomy observations in France. E. Le Roux's giant Wurzburg radar antenna and 33 cm receiver gave researchers the means to map the emission of ionized hydrogen in the galactic plane, marking the group's first publication in this field.

The angular resolution of the radio antennas available at that time was not sufficient to map the sun, but observations of eclipses provided two-dimensional radio images of the Sun's corona.

The partial solar eclipse on April 28, 1949 was observed in Paris as part of a test. The French Navy provided assistance for a fairly large-scale expedition to observe the annular eclipse on September 1, 1951 from a position close to the Markala dam on the Niger river. Then J.F. Denisse observed the February 25, 1952 eclipse from Dakar, with the same radar antenna equipment that had been used in Markala. On this occasion, the Sun was observed in Paris and many other sites simultaneously. A summary of their results was published by J.F. Denisse, J.L. Steinberg and E.J. Blum in Nature in 1953 and showed that the coronal emission was asymmetrical at 169 MHz: the radial extension was greater in equatorial regions than in polar regions.

Armed with these results, Steinberg set off for the URSI (International Union of Radio Science) congress in Sydney, Australia, in August 1952 Visiting the Australian facilities, he was particularly impressed by the advances made by Chris Christiansen, who developed a 32-antenna E-W interferometer at Potts Hill. From 1951 onwards, the spatial resolution of this instrument was used to determine the dimension and altitude of the emission regions of the lower solar corona at 21 cm (1420 MHz).

2.2. Nançay Station 1952 to 1959

The trip to Australia convinced Jean-Louis Steinberg that if they were to keep up with their Australian counterparts, France needed to install an interferometric array with an East-West arm and a North-South arm on a large, flat plot, far removed from electromagnetic pollution. On his return, he pitched his ideas to his director, Y. Rocard. He was given the task of costing the project, which he promptly did, despite his lack of experience in major construction and infrastructure works. The cost estimates, delivered within a few weeks, came out at FF 25 million (1952 francs, equivalent to around €500,000). Y. Rocard immediately submitted his request for finance to the French Department of Education which was duly granted. All the funding was then allocated to Jean-Louis to complete the project, with the sole proviso that he report on the development of the array. The whole flurry of costing, application and receipt of funding took less than six months. For this group of very young radio astronomers – J.F. Denisse was the oldest at 37, all the others were under 30 – approval of funding for the project was a sign of confidence in them. Fired with enthusiasm, they set to with renewed determination.

The ENS purchased the Nançay site the following year in 1953. Since Y. Rocard did not have enough space to house transistor development by Pierre Aigrain, and since Danjon, the head of the Paris Observatory, was eager to develop radio astronomy, the team migrated to the Meudon Observatory and gradually moved their observation equipment to Nançay. J.F. Denisse was appointed to head up radio astronomy at Meudon. Jean-Louis Steinberg, E. J. Blum and the entire team would now spend most of their time in Nançay building the station, before transferring their instrumentation from Paris and Marcoussis and starting their first major project.

A picture speaks a thousand words, and these photographs of this "pioneer camp" do just that.

a) First (small-scale) Instruments in Nançay

Small instruments were built to test receivers, conduct interferometric observations and provide the data for the publication of scientific findings prior to completing the large-scale instruments.

Steinberg and Ilya Kazes studied fluctuations in the solar radio signal and calculated the size (around 100 m) of the ionospheric inhomogeneities that cause the scintillations. For thse observations they built two global flux reveivers with 1,5 m dishes, one being mobile on a rail track. Jean-Louis built a centimetric interferometer with two 2-m antennas at a distance of 60 m . He worked with M. Kundu to draw up a one-dimensional map of the active centers on the Sun's surface with a spatial resolution of one arc minute (1957).

With Monique Pick, he designed and built an interferometer with 16 mirrors distributed along the arm of a 23 m US Air Force radar antenna. The receivers functioned at 9320 MHz, 3.2 cm with a resolution of 4.5 arc minutes on the solar corona. This instrument is still in use today for monitoring solar activity.

b) Large-scale Instruments in Nançay

The variable baseline interferometer comprises two mobile 7.5 m mirrors on two axes: 1500 m EW and 380 m NS. They operate at the hydrogen line frequency (1420 MHz, 21 cm).

Jean-Louis called on the army to help with leveling the platform, the SNCF to install the rails at a 6 m gauge, and a firm of mechanics for the base and support of equatorially-mounted mirrors. E. Le Roux developed the signal acquisition and transfer electronics to capture the interferometer fringes. Scientific observations started in April 1959. J. Lequeux's thesis established the map of galactic radio sources and marked the initial results of the very laborious efforts to stabilize the fringes.

E. J. Blum was responsible for the interferometric array over very high (metric) frequencies (169 MHz): 32 5-m dishes were arrayed east to west over a distance of 1,500 m giving an angular resolution of 4 arc minutes. Blum equipped this network with very sensitive and stable receivers. Full-configuration observations commenced in April 1957 and André Boischot published the first observations of Type IV solar radio emissions. This interferometer would be supplemented by a north-south array and receivers operating at other frequencies.

These two large-scale instruments marked French radio astronomy's first steps in the use of heavy equipment.

2.3. Large Radio Telescope 1959-1965

It's the mid-1950s and large-diameter radio telescopes appeared in Australia, Germany, Holland, Great Britain and the USA. Starting in 1955, the radio astronomy group examined two concepts to prepare for future developments:

- a 21 cm variable-baseline interferometer with two 25-30 m mirrors to obtain images of the brightest galactic and extra-galactic sources with good angular resolution;

- a large hectometric collector to observe weak sources with high spectral resolution of the 21 cm line.

The group had to abandon the interferometer Jean-Louis was looking into, since the electronic computers of the day were not sufficiently powerful to process the Fourier transforms of the signals fast enough.

However the large collector faced also a problem, French industry did not have the capability to build a very large orientable parabolic mirror to the specifications required for observations at 21 cm. A 1958 article by John Kraus describing the radio telescope under construction at the University of Ohio in the United States caught J.F. Denisse's attention and he discussed with Jean-Louis and E. Blum the possibiity of adopting this concept at Nançay. J. Arsac studied the optics. French manufacturers could meet the specifications as the movable parts are separated into flat panels of "only" 40 tonnes, mounted on a single horizontal axis. This meant the secondary spherical mirror was fixed and rigid, and therefore easier to produce.

It was 1962, after 3 years of hard work, everything seemed to be in place. Efficiency tests showed 5 mm accuracy in terms of surface quality – twice as accurate as the specifications required – but the Compagnie Française d'Entreprises was unable to measure the tilt and to control the servo-coupling of the mobile panels or to monitor the sources at the focal point. Pointing accuracy was only 10 arc minutes, instead of 1 arc minute.

Jean-Louis resolved these problems, with the help of Michel Ginat, François Biraud, and James Lequeux, while heading up the Service d'astronomie spatiale, which he founded in 1963. It took three more years of work before the large radio telescope was inaugurated by Charles de Gaulle on May 15, 1965.

Steinberg and J. Lequeux published a monograph in 1963, entitled "Radioastronomie " reviewing the state of knowledge in the field at the time. Its success soon led to its translation into English and Russian.

3. Birth of Astronomy & Astrophysics

Jean-Louis often said "the only thing that counts is what's written and read". No doubt this conviction was why he accepted the post of chief editor of the Annales d'Astrophysique, one of three French astronomy journals, with the Bulletin Astronomique and the Journal des Observateurs. Assisted by his wife Madeleine, they worked evenings and weekends on their editorial duties, as there were only so many hours in a working day.

In the whirlwind that was May 1968 in France, the couple was not immune to questioning the usefulness of their work. They studied citations of French articles and realized that their journal, and therefore the work of many of the country's astronomers, was unknown outside France. Something had to be done!

They found the same for other European journals, but to a lesser degree for those published in English.

Assisted by Denisse, Pecker, Jan Oort and Andres Reiz, Stuart Pottasch and Jean-Louis pulled off the merger of the three French journals with Dutch, Scandinavian, German and Czech journals. Other journals would follow.

The first issue appeared in January 1969. Jean-Louis, backed by Madeleine, who spoke fluent English and Russian, and Stuart Pottasch, were chief editors for five years – a period of spectacular success for the journal.

4. Development of Space Research at the Paris Observatory: 1963-

"After the completion of the pointing system of the "Grand Radiotélescope", I was somewhat at a loss: I had studied more instrumentation than scientific problems over the last few years. J.F. Denisse felt it and he suggested that I should study the galactic radio emission at frequencies too low for the waves to reach the ground. I was immediately tempted by that new challenge which meant using space techniques of which I knew nothing. So, I had to learn a lot of new science, a lot of technology and to hire people to create a team"

Result: he created a spatial radio astronomy department at the Observatory.

Four years after the first Sputnik flight, France created its own space center in 1961. The Centre National d'Etudes Spatiales (CNES) was allocated a large budget to resource its research laboratories to design and develop the complex and technically demanding instruments for space flight. Under an agreement with this new space agency, Jean-Louis put together a team of 15 engineers and technicians and seven researchers in the space of two years.

“I wanted to build a team bringing together technicians, engineers and physicists interested in instrument design and data processing plus some others with a strong interest in theory. This team conception was later found very efficient.”

4.1. Low-frequency Galactic Radio Emission

In their early experiments, the team launched dipole antennas above the ionosphere to capture the radio signals from the galactic plane.

The resonance frequency of the ionospheric plasma blocks all emissions from the universe coming to us at frequencies below 10 MHz. Dipole antenna, dozens of meter in length, are needed to study very low frequencies in the hectometric frequency range.

Canada marked its entry into space exploration with the launch of its first satellite on September 29, 1962, Alouette 1, to carry out detailed ionospheric exploration. Alouette 1's probe was fitted with a very large dipole antenna that extended from its shell. Jean-Louis sent three engineers to Ottawa for training, R. Knoll, M. Auger and G. Dumas.

Rubis rockets were designed to test the third stage of the Diamant launcher. They were able to mount the antennas above the ionosphere going up to 2,000 km. Rubis 2 was launched in 1965 and Rubis 4 in 1967. The receivers and antennas proved resistant to the vibrations and behaved to perfection. 1972 saw Sang Hoang present the lab's first thesis on measuring galactic noise in hectometric waves and on the performance of the antennas.

4.2. Dipole Antenna Performance in Plasma

The antenna radiation resistance measured on Rubis turned out to be quite different from what had been expected near the plasma frequency. In 1967 Jean-Louis asked Nicole Meyer Vernet – a new member of the team – to conduct a series of ionospheric experiments to shed light on the behavior of dipole antennas in plasma. In the period 1970 to 1973 she had three Dragon launches from the Biscarosse Center in the Landes region for her experiments. The EIDI 1, 2, and 3 on-board antennas and receivers were designed to analyze the parameters likely to impact the antenna's coupling with the ambient plasma.

She developed a theory to predict impedance measurements at least for frequencies higher than plasma frequency. She demonstrated that the antenna resonates with the longitudinal electrostatic waves of the local plasma that cause the electron sheath surrounding the antenna to oscillate. The closer the antenna length to the Debye length, the higher the radiation resistance near the plasma frequency.

4.3. Franco-Soviet Cooperation, ROSEAU, Stereoscopic Observations, Ray Tracing

The CNES signed the first Franco-Soviet agreement on cooperation in space in 1966, heralding the launch of the first scientific payload with a Soviet launcher, about which nothing was known - except for the fact that it went further and carried heavier payloads than the Diamant rockets. Steinberg lost no time in coordinating matters with his friend, François Ducastel, who was head of ionospheric research at the French center for telecommunications research, CNET (Centre National d'Etudes des Télécommunications). The CNES appointed Ducastel as lead scientist with responsibility for the

Roseau (Radio Observation par Satellite Excentrique à Automatisme Unique) payload. ROSEAU was the lab's first satellite mission and the receiver and antennas used were the precursors to the payload flown later on ISEE 3.

Unfortunately, work on ROSEAU was suspended in November 1969, a victim of the budget cuts imposed on the CNES as part of the post-1968 austerity program. Although it was a hard blow for all those who had given three years of work on the project, it did not deter cooperation with the Soviet space program.

Armed with the information from solar observations at Nançay, Jean-Louis was convinced that to understand the physics of coronal radiation, they would have to measure its directivity and monitor source displacement. He proposed simultaneous observations coordinated between radio receivers on an interplanetary space mission and similar receivers sited at Nançay. The data would allow comparisons of the intensity of the signals received and the spectro-temporal evolution of the bursts observed simultaneously.

May 28, 1971: the Mars 3 Russian space probe carried the STEREO I experiment which conducted observations on 169 MHz, at metric wavelength, simultaneously with the Nançay interferometer.

On August 10, 1973, Mars 7 was launched carrying the French STEREO-5 experiment operating on 30 and 60 MHz in the decametric wave range, again coordinated for simultaneous observations with a decametric receiver at Nançay.

In 1974, Jean-Louis and Costa Caroubalos published the first stereoscopic observations made on Earth and in interplanetary space, up to two observation directions separated by 80°.Many other papers would follow. Analyzing the directivity of Type III and Type 1 sources, and the temporal profiles yielded valuable information on the properties of the radiation and the propagation of waves in the corona.

Jean-Louis now returned to a 1971 work done with Yolande Leblanc to explain the size of the coronal radio sources observed at Nançay. He applied and developed a ray tracing technique, proposed by Fokker in 1965, for the propagation through the solar corona in the presence of inhomogeneities. Working with Costa Caroubalos, he applied the technique to explain the observations on STEREO I.

Sang Hoang, Michel Poquerusse, and Jean-Louis Bougeret added still more published papers, based on the STEREO observations and experiments.

4.4. ISEE 3 (International Sun Earth Explorer) Mission

In 1973, NASA and the European Space Agency (ESA) launched a joint call for proposals for a mission designed to explore the relations between the Sun, the Earth, and the interplanetary medium. ISEE 1 and 2 turn in eccentric orbit around the Earth in the terrestrial magnetosphere. ISEE 3 oscillates around the Lagrange L1 point between the Sun and the Earth analyzing the solar wind upstream from Earth.

Jean-Louis proposed two experiments and was surprised when both were accepted. Christopher Harvey was given the PI (principal Investigator) responsibility for measuring the integrated plasma density and its fluctuations between ISEE 1 and 2, while Jean Louis took on the PI responsibility for the 3D radio mapping experiment on ISEE 3. This experiment drew on and updated the concepts and techniques used for ROSEAU.

The main objective was to provide a map of the spiral structure of the magnetic field in the solar wind, including outside the ecliptic. A long dipole antenna (rotating in a plane perpendicular to the spin axis of the probe), plus a short antenna (aligned on the spin axis) angularly tracked the displacement of the energy particles that excite the interplanetary plasma and are guided by the magnetic field.

The quality of the receivers developed by G. Epstein, G. Huntzinger and R.Knoll and the ongoing dialog between engineers and researchers during the mission bore fruit with a far higher volume of results than initially envisaged. As the themes of papers published in journals were covered in the talk, I will just give a very brief summary.

a) characterization of Type II bursts

associated with solar flares, interplanetary shocks and geomagnetic disturbances which are attributed to electrons accelerated in the shock fronts (with H. Cane, R. Stone, and J. Fainberg);

b) the effect of propagation on the apparent position of Type III sources

, measuring the speed of electrons that excite Type IIIs (with G.Dulk, S. Hoang, A.Lecacheux, .J.L. Bougeret. and M. Poquerusse);

c) radiation from the foreshock

observed from Lagrange L1, comparison with the observations made by ISEE 1, the observations demonstrate that the source region is in the solar wind just before the impact on the foreshock. The emission mechanism is the same as for Type III sources, the electrons are accelerated in the shock front and escape upstream in the solar wind where they excite plasma frequency and harmonic emissions (with S. Hoang, C. Lacombe, and D. Burgess);

d) observation of the auroral terrestrial noise:

in 1982**,** ISEE3 was sent in the magneto tail and in the solar wind downward from Earth, it was possible to observe the source of auroral kilometric radiation, and to explain the size and position of the source. The ray tracing technique was used with a density model, taking into account the densities observed by other satellites in the magnetosheath and the shock wave, and adding in inhomogeneities that are 10 times denser in the magnetosheath than in the solar wind (with C. Lacombe and S. Hoang);

e) highlighting a new terrestrial emission (low-frequency bursts)

separate from the auroral kilometric radiation. The propagation model used for the auroral emission could not explain the large size of this low-frequency source, which remains an unresolved problem (with C. Lacombe and S. Hoang);

f) highlighting Isotropic Terrestrial Kilometric Radiation (ITKR)

associated with changes in the auroral kilometric radiation spectrum, but reception at the Lagrange point is not modulated by the rotation of the antennas; therefore the radiation appears practically isotropic. Here again, it is difficult to pinpoint which solar wind inhomogeneities could extend a terrestrial source to this point (with C. Lacombe and S. Hoang);

g) quasi-thermal noise:

in 1978, Nicole Meyer Vernet developed the theory of thermal noise in anisotropic hot plasma; her paper was rejected for publication on the grounds that it was "of no practical interest". This was 10 days before the launch of ISEE3; early in 1979, Jean-Louis Steinberg presented her with a spectrum measured on ISEE 3 in the absence of any solar activity, and asked if she could explain it. She simply had to compare these observations against the theory to find that antennas with a very-low-noise receiver very accurately measure both the density and temperature of solar wind electrons. Theoretical development to take into account protons distribution function moving at solar wind velocity and dust yields a spectrum that fully coincides with the observations. ISEE 3's antennas and receivers prove to be a highly sensitive and fast instrument for measuring the local parameters in the interplanetary plasma (with N. Meyer, S. Hoang, C. Perche, and P. Couturier);

Meyer's paper that had been rejected in August 1978 was accepted the following March 1979, with the addition of a comparison between the observed spectrum and the theoretical spectrum.

h) Plasma in the Tail of the Giacobini Zinner Comet

When ISEE 3 encountered the tail of Giacobini Zinner on September 1, 1986, the radio experiment was the only one to be able to quickly measure the parameters of the ambient plasma. The density and temperature variations in the ionized tail and the flanks of the comet interacting with the solar wind were measured for the first time (with N. Meyer, S. Hoang, C. Perche, and P. Couturier).

4.5. Other Interplanetary Missions

Between the launch of ISEE 3 on August 10, 1978 and his last paper on space data in 2004, Jean-Louis Steinberg authored or co-authored some 60 papers (an average of three per year), based on the data collected by ISEE 3. The LESIA plasma team were selected for many other space missions on the strength of this wealth of results and the close collaboration between researchers, engineers, and technicians throughout the mission: Ulysses, Wind, Cassini, and Stereo continue to deliver excellent results. BepiColombo is due to be launched in 2017, while Solar Orbiter will leave the launch pad in 2018… equipped with the increasingly sophisticated radio receivers built at the laboratory.

5. His life as a “Research scientist” (1986-2016)

In 1986 Michel Combes succeeded Jean-Louis as director of DESPA, which became the CNRS entity encompassing all the diverse space research groups of the Paris Observatory in a single laboratory with a single local administration.

It is impossible to mention here all the space missions in which contributions from DESPA (now renamed LESIA) were included, either by solicitation or competitive selection. Jean-Louis’ heritage has been successfully exploited by his successors. The interests of the laboratory expanded to encompass ground-based instrumentation: for the VLT the ESO introduced technical specifications comparables with those of space research. Adaptive optics and later interferometry were added to the competences of the laboratory.

Once free from his administrative responsibilities for the laboratory, Jean-Louis regularly published scientific papers until 2004, when he published his last article based upon results of analysis of the data from ISEE ; it is presented at this meeting by Catherine Lacombe. From 2006 to 2011 he contributed to six articles in the Journal of Astronomical History and Heritage, concerning the history of French radio astronomy.

During all the years after shedding his managerial responsibilities his door remained open to all who needed help or advice. He often talked with younger members of the laboratory, who consulted him for comment and criticism of papers they had prepared for publication or presentation, and he continued to visit the engineers and technicians to keep abreast of their latest developments.

From 1993 he started visiting schools to present his experience of the war and what he had survived after being deported. "Pour quoi si tard ?" ("Why so late ? ") is the title of the penultimate chapter the book "Des quatre, un seul est rentré » ("Of the four, only one returned") in which he explains how he began to feel the necessity of this action. The comments of teachers who welcomed him into their class-rooms show the impact of his interventions.

He stopped coming regularly to Meudon when Madeleine's health deteriorated. When she died in 2008, he was overwhelmed. For the first time ever there were tears in his eyes when I met him after her death.

Jean-Louis himself wrote on page 89 of his book published in 2004, four years before her death, "The first time I found myself in bed with Madeleine, I sobbed my heart out "…"I think that I have never cried since" (it was in 1946). Jean-Louis probably passed 58 years without shedding a single tear. But his separation from Madeleine turned the last page of a part of his life which, until then, he seemed to have observed from the outside.

With the help of friends, he created a dossier on Madeleine's selfless work of resistance when she was incarcerated in the camp in Vittel. In 2013, the Yad Vashem World Holocaust Remembrance Centre in Jerusalem posthumously honoured Madeleine White Steinberg as one of"The Righteous Among the Nations".

Jean-Louis continued visiting school classes, and his former colleagues and collaborators continued to visit him. He still went to the cinema and theatre, he visited museums, he was still attentive and lively, but his stamina was decreasing. He passed away on 21 January 2016 in his apartment in the rue Vasco de Gama, in Paris.

Not wishing to end on this sad note, I reiterate the qualities which made him the man he was, as confirmed by the Livre d'Or dedicated to him.

He was enthusiastic, engaging, and intransigent on ethical matters, respected the liberty of action of his colleagues, was visionary in his projects, and open to the world. Jean-Louis was a natural leader, because he inspired in everyone the same energy as had permitted him to survive.

Thank you Jean-Louis for the legacy which you have left us.

Pierre Couturier le 3 November 2017