

HENRI DESLANDRES: FROM MOLECULAR TO SOLAR PHYSICS

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Abstract: Henri Deslandres was one of the first French astrophysicists. Aged 28, he left a promising military career for research on molecular spectra and later on the atmosphere of the Sun. He developed a considerable instrumentation in both domains. In particular, he conceived and built several generations of spectroheliographs at Paris, then Meudon Observatories, and initiated a systematic patrol of solar activity and solar–terrestrial relations that has survived to this day. He directed Meudon Observatory from 1908 to its merging with Paris Observatory in 1926, and was also Director of the merged institutions until his retirement in 1928. In this paper, I concentrate on his work on the Sun, in which he showed considerable qualities as an instrument builder, an organizer and an observer, although he was not so successful in interpreting observations. I leave to others a study of his considerable, life-long work on molecular spectra.

Keywords: Deslandres, Janssen, Cornu, Paris Observatory, Meudon Observatory, Sun, solar and stellar chromosphere, solar corona, solar activity, solar–terrestrial relations, spectroheliograph, molecular spectra

1 INTRODUCTION

Amongst the first French astrophysicists, the most remarkable are undoubtedly François Arago (1786–1853), Jules Janssen (1824–1907), Henri Deslandres (1853–1948) and Charles Nordmann (1881–1940). Scientific biographies have been devoted to Arago (Lequeux, 2008), Janssen (Launay, 2012) and Nordmann (Lequeux, 2010), but nothing exists about Deslandres, except for an excellent, but short biography (Tenn, 1993), a few obituaries (d’Azambuja, 1948; Stratton, 1954, with an almost complete list of publications), and three papers by Dollfus (2003a; 2003b; 2005). The present paper aims to fill this gap.

Henri Deslandres (Figure 1) was born in Paris on 24 July 1853 into a military family. He entered the École Polytechnique in 1872 and graduated in 1874. He started a military career as an engineering officer and rose to the rank of *Capitaine*. But he was increasingly interested in science, and resigned in 1881 to work in the laboratory of his former teacher Alfred Cornu (1841–1902) at the École Polytechnique. However, he retained from his military days some behavioral rigidity that caused occasional problems. He was very devoted to his work and also extremely absent-minded, as we will see from the following anecdote:

Deslandres was engaged to the daughter of Alfred Cornu. An engagement lunch had been prepared as usual, but Deslandres, who was working for his doctorate, went that morning to the laboratory to check some results. He was so absorbed that he stayed there all day without eating, forgetting the lunch. The next morning, he found Cornu in the laboratory who

asked him: “Where were you yesterday?” “But I was here, I worked all day.” “We have been waiting for you, sir!” Needless to say, the engagement was broken off. (Lequeux, 2022: 176).

But this might have been what psychologists call a ‘missed opportunity’. In any case, many years would pass before Deslandres married.

2 THE SPECTROCOPIST

Deslandres’ first scientific activity was spectroscopy. This was at a time when physicists tried to put some order into the incredible diversity of atomic and molecular spectra, with no help from theories (that did not yet exist). Deslandres concentrated on molecular spectra, a particularly complex topic.



Figure 1: Henri Deslandres (1853–1948), in 1910 (courtesy: Paris Observatory).

In his first publication [Deslandres \(1885a\)](#) showed that the telluric near-ultraviolet bands observed in the spectrum of the Sun were due to water vapor and not to oxygen as was generally believed at the time, and he reported the laboratory discovery of a new water band. He then studied the ultraviolet spectrum, recorded by photography, of some nitrogen compounds obtained in the laboratory but still unidentified. Reading the corresponding paper ([Deslandres, 1885b](#)) shows that Deslandres was already a confirmed spectroscopist, struggling successfully with many difficulties in a new field of research. He then remarked that there was a general law in the distribution of frequencies of the lines forming bands of various molecules: they are in arithmetic progression. We know now that this is a consequence of the fact that for many simple molecules the energies of the rotational levels for a given electronic and vibrational energy are proportional to $J(J+1)$, J being the rotational quantum number. But Deslandres could not know this.

Deslandres also discovered that a similar property exists for the band heads of various molecules (due as we know at present to the quantification of vibration). He summarized these properties by a simple formula giving the approximate frequencies of the lines of a diatomic molecule, which is still in use under the name of Deslandres' Formula ([Deslandres, 1887](#)):

$$f_{mn} - f_0 = Am^2 + Bn^2, \quad (1)$$

where f_0 is the frequency of the fundamental line, and m and n are integers. For diatomic molecules, the constants A and B in this formula were to yield respectively the masses and separation distances of the atoms forming the molecules and the force between them, when quantum mechanics was developed many years later. Such was the subject of Deslandres' PhD, obtained in 1888. He kept an interest in molecular spectra throughout his long life, making experiments in the physics laboratory at Meudon, in particular on the action of magnetic fields on molecules for which he developed with Alfred Perot (1863–1925) an electromagnet reaching 63,000 gauss (6.3 tesla), a record at that time. In this machine, the electric current circulated in thin ribbons, first of copper then of silver, cooled by a circulation of oil and later of water ([Deslandres and Perot, 1914a; 1914b](#)).

Later, [Deslandres \(1924\)](#) announced another property: for 34 spectra of various molecules: the frequency of the head of the most intense band is approximately a multiple of the same far-infrared frequency (1062.5 cm^{-1}),

and similarly for some atoms and ions. No convincing explanation was given.

Deslandres worked throughout his life on the spectra of molecules, and published many papers on this topic, especially in *Comptes Rendus Hebdomadaires des Séances de l'Académie des Sciences* (all digitized in gallica.bnf.fr). For a list of publications of Deslandres in this journal see [Stratton, 1954](#), and *Comptes Rendus*: 1866, Tables, p. 178; 1896, Tables, p. 187; 1911, Tables, p. 195; 1926, Tables, p. 261. His last paper on molecular spectra ([Deslandres, 1940](#)) was presented at the Academy of Sciences when he was 93. I will not describe his activities in this area due to lack of competence, and also because they do not belong in an astronomy journal, but a short summary is given in the obituary by [Stratton \(1954\)](#); Stratton was the Director of the American Bureau of Standards). They certainly would merit the attention of historians who specialize in the history of atomic and molecular physics.

In 1888 Deslandres had moved to the physics laboratory at Sorbonne, but he was not there for long as he was hired the following year by Paris Observatory. The Director, Admiral Ernest Mouchez (1821–1892), wanted to introduce astrophysics, an area that had been neglected by his predecessor, Urbain Le Verrier (1811–1877). One of the programs was to check with radial velocities the motion of the Sun in the Milky Way, discovered by William Herschel using proper motions, and to study spectroscopic variable stars (see [Espitalier, 1893: 278](#)). At the Observatory there was a 1.2-m diameter reflecting telescope, the largest in the world at that time, but the mirror was rather bad. It was, however, considered sufficient for spectroscopy. Deslandres attached a prism spectrograph to it ([Figure 2](#)). As it was difficult to make observations at the Newtonian focus of the telescope, he installed an optical system that allowed him to observe at the level of the primary mirror. Circulation of water in the double wall of the spectrograph kept the temperature constant ([Figure 3](#)). The spectrum of the target star was photographed beside the various comparison spark spectra.

Deslandres also made some observations of stellar radial velocities using Foucault's siderostat (for an image, see [Lequeux and Georgelin, 2022: 21](#)), but with little success: only a few were obtained. Clearly it was problematic for him to enter a rather new field plagued with many technical difficulties and, in his case, inconvenient instruments. The great German specialist Hermann Carl Vogel

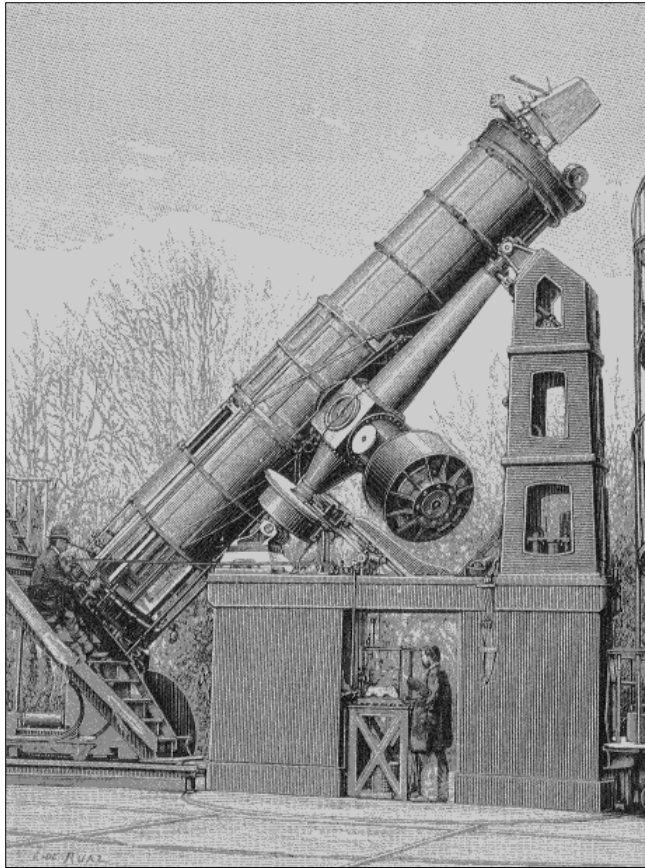


Figure 3 (right): Schematic diagram of Deslandres' spectrograph installed on the 120-cm telescope. The collimator A feeds the spectrograph, equipped with three flint prisms. The spectrum is recorded on a photographic plate, C. The small movable total-reflection prism H allows to register a reference spectrum of iron or other atoms next to that of the star. KK is the vehicle for visual observation at the Newtonian focus, here displaced from the telescope axis. Note the double wall EEEE and GGGG to keep the temperature of the spectrograph constant thanks to circulation of water (after Deslandres, 1898: 56).

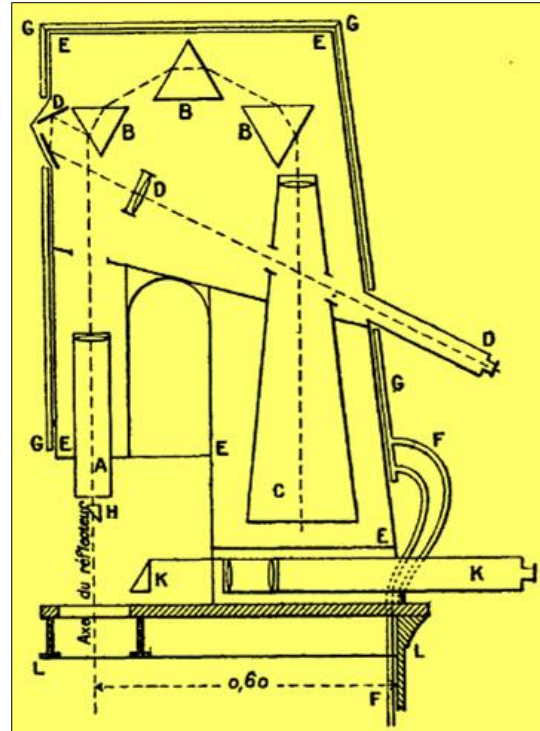


Figure 2 (left): The prism spectrograph attached by Deslandres to the prime focus of the 120-cm diameter reflecting telescope of Paris Observatory. The observer was sitting on stairs next to the primary mirror (after Espitalier: 1893: 276).

(1841–1907), who observed many stellar radial velocities with the 30-cm diameter refractor in Potsdam (47 velocities before 1891), explains in an excellent review paper (Vogel, 1900: 232):

In publishing his observations of ζ Herculis, Deslandres [Deslandres, 1894a] made a remark concerning the Paris telescope of 1.2 meters aperture, to which his spectrograph was attached, from which it appears that the stability of the telescope is hardly what it should be for such delicate investigations; and, possibly because the mirror did not unite perfectly all the rays on the slit, the exposure had to be made 50 per cent longer than with the [75-cm diameter] Pulkova refractor. In these unsuitable conditions may also be found the reason why so few observations of stellar motion by Deslandres have been made known.

Indeed, Deslandres had given up provisionally with such observations when he joined Meudon Observatory in 1898, invited by Janssen; the radial velocity program was continued at slow pace in Paris by Maurice Hamy (1861–1936), Pierre Salet (1875–1936) and

occasionally Gaston Millochau (1866–1922, also at Meudon Observatory) with a temperature-regulated spectrograph built in 1906 by Gautier and mounted on the Grand Coudé Equatorial (Hamy, 1925); results have been published for only 22 stars.

However, Vogel (1900: 233) mentions something more interesting:

At the suggestion of Poincaré of Paris, Deslandres has, on the other hand, made spectrographic researches on the motion of the planets, and on the rotation of Jupiter, which are of importance. The investigations showed, in accordance with Poincaré's assumptions, that in the case of a body which shines by diffuse reflected light, the displacement of lines in its spectrum depends not only on the motion of the body with reference to the observer, but also on the motion of the body with reference to the source of light by which it is illuminated.

Indeed there were controversies about the Doppler–Fizeau Effect for light, and Henri Poincaré (1854–1912) had encouraged astronomers to make verifications (see Lequeux,

2020: 38–44). One was to measure the effect on the two edges of the Sun observed spectroscopically with a long slit and to compare this with its known rotation velocity. Deslandres (1895a) made a similar measurement of Jupiter that rotates rapidly, with full agreement with theory, and also with Poincaré's theory on the Doppler–Fizeau Effect for a moving object illuminated by another source of light (Poincaré, 1895). Deslandres (1895b) also confirmed the observation of James Keeler (1857–1900), who had measured in the same way the rotation of Saturn's rings, showing that they did not rotate like a solid body.

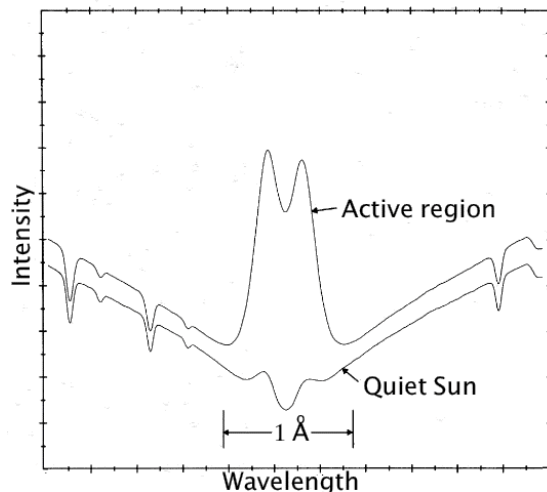


Figure 4: Profiles of the central part of the K line of ionized calcium. Bottom: in a quiet region of the solar disk; top: in an active region of the chromosphere like a prominence, hotter than the photosphere, the center of the line appears in emission, with a small absorption at the middle. By selecting the emission with the exit slit of the spectroheliograph one can map the chromosphere. Measuring its Doppler–Fizeau wavelength shift allows the motions of the emitting gas to be obtained (adapted from White and Livingston, 1981: Figure 1).

3 THE FIRST SOLAR STUDIES

In 1891 Deslandres started making spectroscopic studies of the Sun, in parallel with the studies cited above. I don't know if this was in the plans of the Observatory's Director Admiral Mouchez, but, in any case, he was proud to present Deslandres' achievements to the Academy (Mouchez, 1892).

The independent detection by Janssen and Joseph Norman Lockyer (1836–1920) of solar prominences outside total solar eclipses through spectroscopic detection of their emission lines, which occurred immediately after the 1868 total eclipse, raised considerable interest amongst astronomers. Many of them repeated this observation, for which it suffices to place the entrance slit of the spectrograph tangentially at a small distance off the edge of the disk of the Sun. Also, Janssen (1869a)

mapped the prominences around a part or the disk by using a spectrograph with long entrance and exit slits, fixing the telescope and thus letting the image of the Sun move through the entrance slit due to its diurnal motion.

In 1869, Janssen presented at the 39th Meeting of the British Association for the Advancement of Science in Exeter a short communication proposing to map entirely an object in an emission line in the following way: an image of the object would be projected on the entrance slit of a (probably direct-vision) spectroscope rotating rapidly around an axis perpendicular to the slit; when looking at the exit slit adjusted on an emission line, one would see a monochromatic image of the object thanks to the persistence of light impressions (Janssen, 1869b). Janssen (1893: 456) claimed priority for the idea, reproducing the text of the preceding reference and noting that “Mr. Hale substituted rectilinear motion for rotary motion.” (my English translation).

All this was visual. In April 1891, George Ellery Hale (1868–1938), who had his own private Astro-Physical Observatory at Kenwood, near Chicago, attached to his brand new 12-inch Brashear equatorial a photographic spectroheliograph (Hale, 1893). After a first, rather unsuccessful, design the instrument was reconstructed by Brashear as a grating spectrograph with long entrance and exit slits. A mechanical system driven by a clepsydra ensured the simultaneous automatic motion of the slits to produce on a photographic plate a monochromatic image of the Sun. This image was in the bright central reversal of the very broad K line of ionized calcium, which originates in the chromosphere and active regions of the disk (Figure 4).

This is the context within which Deslandres began solar spectroscopy. He acknowledged that:

Every day in many observatories, the chromosphere and the prominences are observed by the method of M. Janssen, but with the eye only, and in the brightest part of the visible spectrum, the red, the yellow and the green. (Deslandres, 1891; 1892; my English translation)

Deslandres (1894d: 211) remarked that Italian observatories were particularly active in such observations.

He used Foucault's siderostat feeding a 32-cm diameter objective and a prism spectrograph to photograph the Sun in the H, K and other ultraviolet lines. He noted that Hale

had proposed "... several very ingenious systems, with a narrow slit ..." but that his device could not apply to the whole edge of the Sun and did not give the velocities; thus, he was not yet aware of the latest version of Hale's spectroheliograph described above. Deslandres' own spectroheliograph rotated around an axis centered on the center of the solar disk, in steps so that the radial velocity could be measured at each step. As we have seen, the idea of a rotating spectrograph was proposed in 1869 by Janssen, but Deslandres does not allude to this. This may be the reason why Janssen (1893) claimed priority for this and more generally for using a spectrograph with entrance and exit slits. Deslandres was not cited by Janssen, which may reveal that there was competition between Paris and Meudon Observatories.

With his assistant Joseph Mittau (b. 1874), Deslandres (1892) modified his apparatus to reach shorter ultraviolet wavelengths: he used now a mirror as objective, quartz lenses and a Rowland grating. His successive spectrographs and his observations are described in detail in a paper (Deslandres, 1894b) in which he acknowledges Janssen's idea of the two-slits spectroheliograph but notes that, due to the poor sensitivity of photographic plates in the red it could only be implemented after the discovery of the structure of the H and K solar lines. In this paper, Deslandres (1894b: 70n) also wrote that

... the first publication of Mr. Hale (American Journal of Science, June 1891) preceded my own publication, but I only learnt about this later ... My results ... had been shown to several people from the Observatory, well before Mr. Hale's publication. (my English translation).

Deslandres (1894c), also described an instrument in which the fixed image of the Sun was scanned by the entrance slit in 100 successive steps by a translation of the whole spectrograph, hence also of the exit slit. The latter slit was wide enough to cover a dark part of the line on each side of the emission part (see Figure 4), so that the radial velocity could be measured by the displacement of this emission. The total duration of the observation was 10 minutes. This is what Deslandres called the 'Appareil enregistreur des vitesses radiales'; in English he called this Spectro-register of the velocities (Deslandres, 1909: 283). Another type of spectroheliograph used a continuous displacement of the two slits and a much narrower exit slit so that the central K line emission or only a part of it was used, yielding a monochromatic image of the chromosphere; he called this instrument an

'Appareil enregistreur des formes' (shapes), or in English simply a Spectroheliograph. The various possibilities of the different types of spectroheliographs, and their advantages and disadvantages, are described in Deslandres (1894d). One of the first images of the solar chromosphere in the K line has been preserved, and is shown in Figure 5.

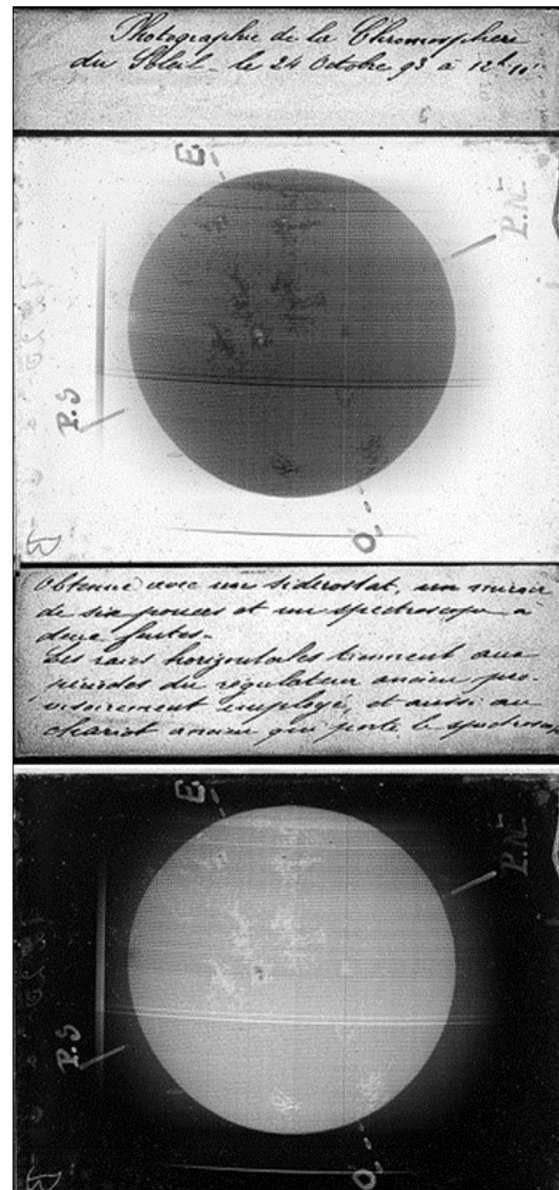


Figure 5: The first preserved photograph of the chromosphere. Top: the original negative. The caption reads: "Photograph of the solar chromosphere, 24 October 1893 at 12h 10. Obtained with a siderostat, a six-inch mirror and a two-slit spectroscope. The horizontal lines are due to the periods of the old regulator used provisionally, and also to the old chariot that supports the spectroscope." (my English translation). Bottom: a positive obtained from this negative, for better view (from the bass2000 data base).

The American, French and Russian astronomers who were active in observing the solar chromosphere were perfectly aware of what their competitors were doing. Their

papers were often translated and published in other languages. Hale visited France in 1891 and was received by Deslandres, who showed him his instruments and took him to dinner and the opera. When he saw that Deslandres was on the verge of surpassing him, he "... at once decided that unless I wanted to lose the whole field of work I had better come home, and sail in again." (cited by [Tenn, 1993; 19](#)). While awaiting the first ship back home, he made a quick tour of European observatories, and visited Deslandres again to find that the latter had observed 7 hydrogen lines, 3 more than he had, "... so he is a little ahead. But I am inclined to think he will have to hustle to keep ahead, if I know myself." (*ibid.*).

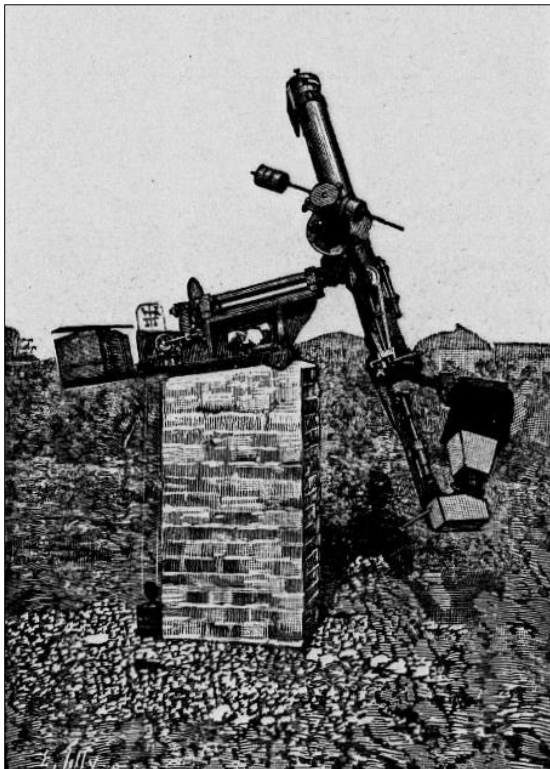


Figure 6: Deslandres' solar corona spectrograph, for the total eclipse of 1893 in Senegal (after [Deslandres, 1893b: 250](#)).

We can find traces of this competition and claims for priority in [Deslandres \(1893a\)](#), and of scientific disagreements in [Deslandres \(1894e\)](#). For his part, Hale rarely cited or criticized Deslandres in his papers. The competition was not fierce, however, and the two men held each other in high esteem: Hale was elected in 1909 as Foreign Member of the French Academy of Sciences with the support of Deslandres, and a few years later Hale chaired the Committee of the US National Academy of Science which awarded a medal to Deslandres. Hale was also certainly active in the attribution of the 1921 Bruce medal to Deslandres.

In 1893, Deslandres was sent to Senegal by the Bureau des Longitudes to observe the 16 April total solar eclipse. Together with the usual equipment to photograph the corona, he installed a spectrograph for the ultraviolet, discovered several coronal emission lines and, using their Doppler–Fizeau Effect, showed that the corona rotated roughly like the Sun. [Figure 6](#) shows his instrument. A detailed account, in English, of Deslandres' observations is given by [Hale \(1896\)](#).

Deslandres also directed an eclipse expedition to Japan in 1896, which did not produce results due to bad weather. He wrote ([Deslandres, 1901: 129](#); my English translation):

These very brief observations always require large expenses of time and money. Their preparation must be long and meticulous; one has to organize special equipment differing from the ordinary ones, and construct a special observatory in a country that is often remote and has difficult access.

The Japan expedition was only decided six weeks before the date of departure, and I must say, for reasons more political than astronomical ... 50 days being necessary to travel from Paris to Yesso, 50 days of stay and as many for returning to France, plus a month of rest in Japan and another month to unpack the crates, this expedition has taken at least nine months. The loss of time and the expenses had been enormous – for a simple observation of two minutes that has been impeded by clouds. The disproportion between the effort and the result is striking.

4 AT MEUDON OBSERVATORY

Janssen certainly was impressed by Deslandres' spectroheliographs and jealous of the Paris Observatory, so he managed to hire Deslandres at Meudon from the beginning of 1898. Deslandres was certainly happy to benefit from more money, and perhaps more freedom. Moreover, Hale was now Director of the Yerkes Observatory and could not continue his full-time spectroheliograph observations, although he occasionally observed the Sun with a spectrograph attached to the great refractor, noticing that the $H\alpha$ line had a profile similar to the H and K lines. Thus, Deslandres had less serious competition.

As could be expected, the first thing Deslandres installed upon his arrival at Meudon was a spectroheliograph, or rather two interchangeable spectroheliographs, one with low-wavelength resolution using a single prism, and the other with a higher resolution, thanks

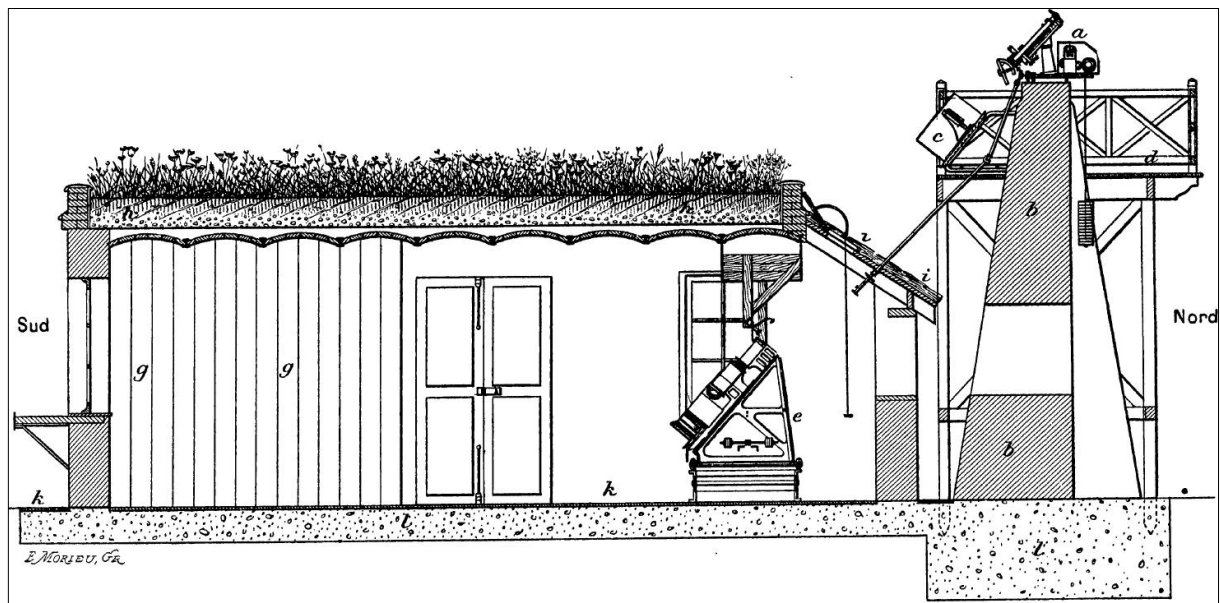


Figure 7: The first spectroheliographs installed at Meudon Observatory in 1898–1899. *a* is a polar siderostat with its clockwork, installed on top of pillar *b*. The light from the Sun enters the building covered with earth and vegetation for thermal isolation. *c* is the 20-cm diameter objective. The two interchangeable spectroheliographs are supported by a carriage allowing lateral translation. These spectroheliographs were adapted from instruments taken from Paris Observatory. *gg* is a photographic laboratory (after Deslandres, 1905: 343).

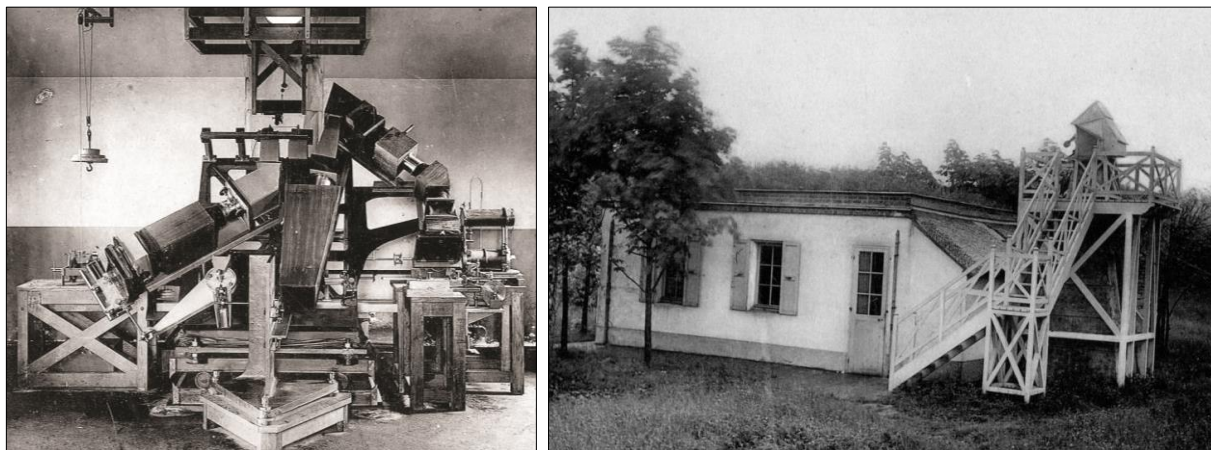


Figure 8 (left): Photograph of the first Meudon spectroheliographs, ca. 1900. A rolling carriage supports two spectrographs and can be moved laterally either continuously thanks to a clepsydra visible at the right or by steps by a mechanism partly visible on the left. To the right, the grating spectrograph (for a schematic, see Figure 11). To the left, the lower-resolution prism spectrograph. A system of levers insured the displacement of the photographic plate in parallel to that of the entrance slit. The total weight of the mobile equipment was about 500 kg. Courtesy Paris Observatory. An announcement was made by Deslandres (1899b), in an article to which Janssen added a long note, indicating that this spectroheliograph will ensure "... the beginning of the observations which must be continued regularly and constitute a true service of the Observatory." (my English translation).

Figure 9 (right): External view of the spectroheliograph building. The polar siderostat and the entrance hole were covered by protecting panels (courtesy: Paris Observatory).

to a Rowland grating. Each of them could be used either for shapes or for radial velocities, the first use requiring a continuous motion ensured by a clepsydra like in Hale's instrument, and the second use a motion by steps. To feed them, Deslandres used the only available siderostat, a polar one that had been used by Janssen to observe the 1874 transit of Venus (for a photograph, see Lequeux, 2022: Figure 5). Figure 7 shows this equipment, which Deslandres (1905) described in

great detail. Figure 8 is a photograph of the set-up, Figure 9 is an external view of the building, and Figure 10 shows the polar siderostat in its shelter.

Deslandres (1899b) also took many photographs of celestial objects with the Great Meudon Equatorial (and all have been preserved at Meudon). It was apparently the first time that the photographic part of the double refractor was used regularly. Deslandres com-

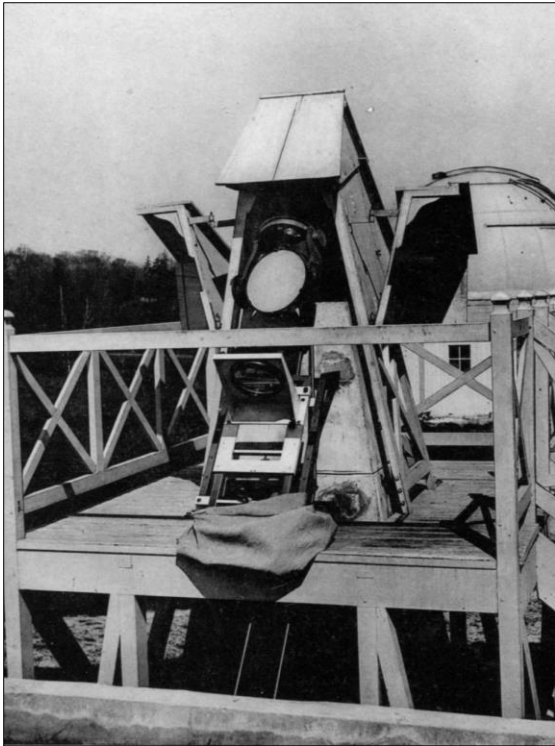


Figure 10: The polar siderostat, with its shelter open. Note the objective in its inclined square support below the siderostat flat mirror (courtesy: Paris Observatory).

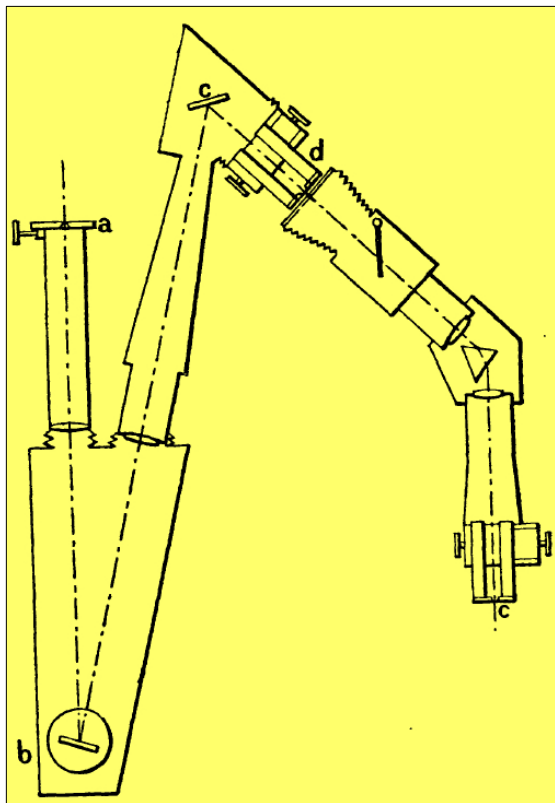


Figure 11: Deslandres' first high-resolution spectroheliograph (c.f. Figure 8). a is the entrance slit, b the grating, c a flat mirror, c the exit slit (bottom right). A third slit in d cuts the light diffused by the grating, hence the need for another prism spectrograph. This instrument was replaced later by a two-slit one, a new grating producing much less diffused light (after Deslandres, 1905: 369).

plained about the lack of stability of this instrument, which was less troublesome for visual observations. Some of these photographs have been published (Deslandres, 1900c). As expected, given the very large f/d of the telescope, the photograph of the Orion Nebula (Figure 12) shows only a little extended emission, next to the Trapezium.

Deslandres also continued his measurements of stellar radial velocities with a spectrograph attached to the photographic part of the great equatorial. Most of the year 1902 was devoted to such observations, in which several spectroscopic binaries were discovered (Deslandres, 1903). He also showed by spectroscopy that Uranus rotated in the retrograde direction, like the revolution of its satellites (Deslandres, 1902a).

In spite of his reservations mentioned above, Deslandres directed a solar eclipse expedition in 1900 to Argamasilla in Spain (Deslandres, 1900a; 1901), and still another one in 1905 to Burgos, also in Spain. The first one was productive: he detected infrared radiation from the corona, which was found again, but weaker, in the second eclipse. He even succeeded in detecting this radiation outside of a total eclipse (Deslandres, 1900b). In Deslandres' papers, there was no interpretation of this radiation, which is actually emitted by the dust present in the corona.

In his review of Deslandres' work, Hale (1896) makes the following remark:

M. Deslandres himself believes in the electrical origin of the chromosphere, prominences and corona, an idea which since the very beginning of prominence observations has been held by many solar physicists. The electrical hypothesis is founded upon the apparent fact that the characteristic spectrum of hydrogen can be produced only by means of an electric discharge ... The supposition on which it rests is rather insecure ... but it has the merit of indicating new points of view from which future investigations of solar phenomena may profitably be examined.

Indeed, it led Deslandres to imagine that the Sun could be an emitter of radio waves (Deslandres and Décombe, 1902).¹ Already, in 1893, he had the idea that the active regions of the Sun could emit 'rayons cathodiques' (jets of electrons), an idea supported by his own laboratory experiments (see Deslandres, 1898). But he did not explain how electron jets would emit radio waves. In his 1902 paper, he tried to explain why Scheiner, Wilsing and Nordmann did not succeed in detecting radio waves from the Sun.² He suggested a set-up that, according to him, would

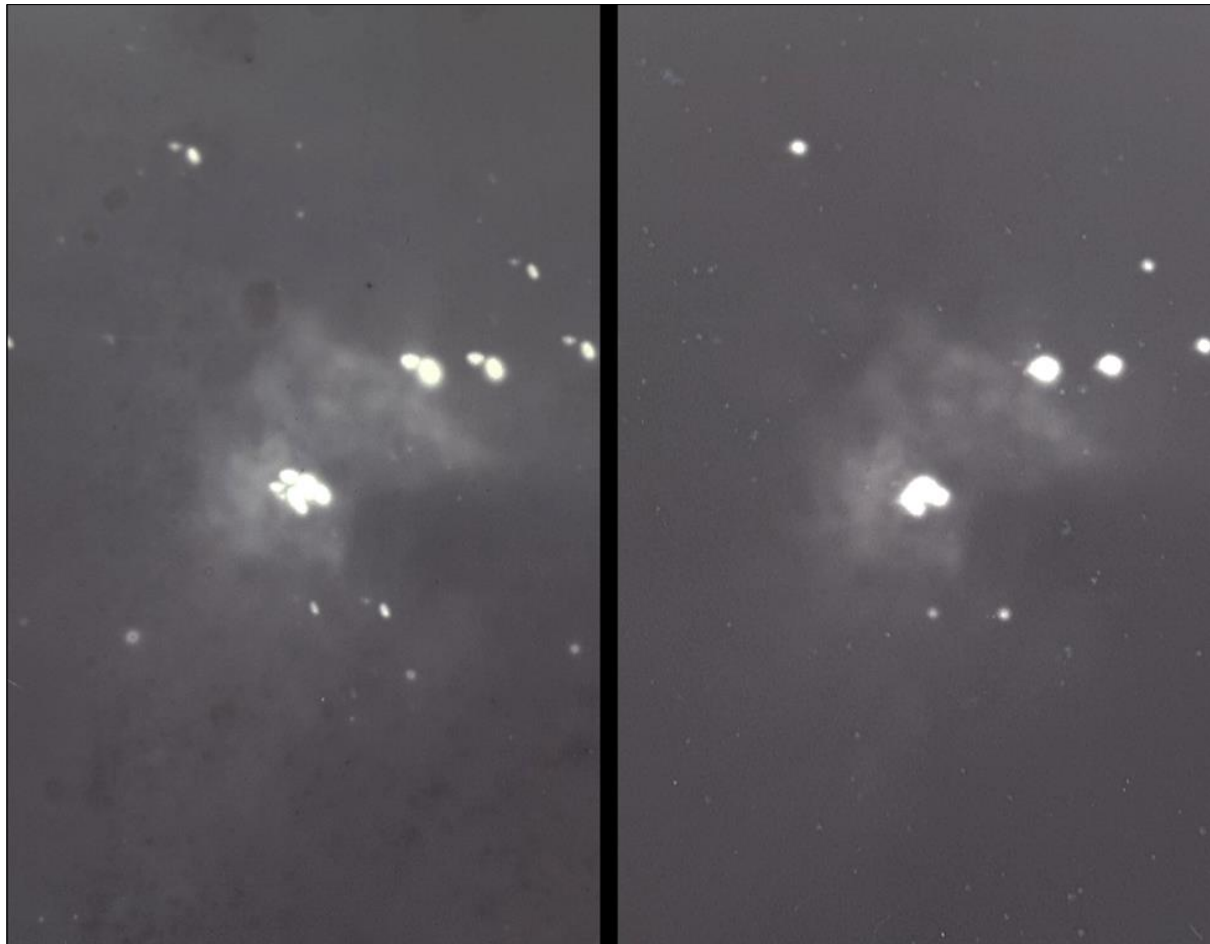


Figure 12. The Orion nebula photographed by Deslandres with the Meudon large refractor. Left, a 'double' image illustrating the mechanical instability of the telescope, 24 February 1899. Right, a good image the following night. South to the top (courtesy: Paris Observatory).

make this detection possible. But, wisely, he concluded that

A long series of observations will be required in order to decide if the surface of the Earth receives from the Sun waves similar to hertzian waves. (Deslandres and Decombe, 1902: 530; our English translation).

Indeed, we had to wait until 1942 for such a detection! Deslandres (1902b) also tried to apply his ideas about 'rayons cathodiques' to spiral nebulae, noting that similar ideas had been proposed by Svante Arrhenius (1859–1927) and Nordmann.

Deslandres' considerable activity, which I have not even fully described, found its reward in his election to the Academy of Sciences on 1 December 1902, in replacement of Hervé Faye (1814–1902). Now, he would not be obliged anymore to have his communications to the Academy presented by Janssen. He was almost completely independent, and was helped from 1899 by a very young man, Lucien d'Azambuja (1884–1970), aged 15, whom he paid from his own pocket.

Relations between Deslandres and Janssen progressively deteriorated. He hoped to succeed Janssen as the Director of the Observatory, but the latter stuck to his position until his death in December 1907. As Deslandres had relations in the political world, he succeeded in being promoted in July 1906 to the role of 'Deputy Director in Charge of Administrative Problems,' a function that was created for him. On his installation on 28 July there was a clash between him and Janssen in front of the staff (for details see Launay, 2008: 254). 'War' was declared, and after Janssen's death it continued for some time between Deslandres and Mrs Janssen and her daughter (Lequeux, 2022: 176).

5 DESLANDRES AND DEVELOPMENT OF THE SPECTROHELIOGRAPH

Deslandres was not fully satisfied with the first spectroheliographs he had installed in Meudon: the polar siderostat was not of good quality, and its use forced the spectrographs to be inclined by about 45°, which caused mechanical difficulties. In 1906 he obtained



Figure 13: A part of Meudon Observatory in 1910. **B** ('bâtiment du petit sidérostât') is the shelter of the first spectroheliographs fed by the polar siderostat **A** (see [Figures 7 and 8](#)), with the addition of a cœlostât **C** lent by the Bureau des Longitudes. **D** ('bâtiment du grand sidérostât') is a large building, 24 m long and 6 m wide, housing the new spectroheliographs, fed either by an old, provisional cœlostât **E** or by a new Foucault siderostat **F** with a 1-m mirror (after [Deslandres, 1910: 14](#)).

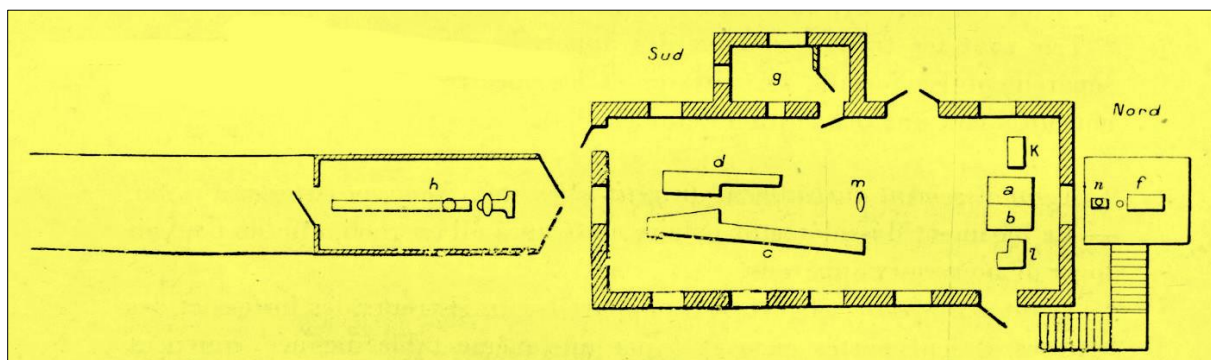


Figure 14: The modified 'bâtiment du petit sidérostât'. *a* and *b* are the first spectroheliographs, fed by the polar siderostat *f*. *c* is a spectroheliograph for radial velocities and *d* a large grating spectroheliograph. They are fed by the 2-mirror cœlostât *h* through a concave mirror *m*. *g* is a new photographic laboratory (after [Deslandres, 1910: 18](#)).

funds from the Government to renew the solar equipment at the Observatory. Things moved quickly: in 1908, most of the changes were made, including the construction of a large building to house a new generation of spectroheliographs ([Figure 13](#)). They are described in detail by [Deslandres \(1910\)](#).

He made important changes to the first spectroheliograph building represented in [Figures 7 and 9](#), adding new instruments ([Figures 13 and 14](#)). This building was called the 'bâtiment du petit sidérostât' (building of the small siderostat). It does not exist any more.

The most important change was the construction and equipment of a new building, called the *bâtiment du grand sidérostât* (the building of the large siderostat). This large 24m × 6m stone building ([Figure 15](#)), which still exists, contained a complex set of instruments fed on the south side by a two-mirror

cœlostât ([Figure 16](#)) and on the north side by a Foucault-type siderostat with a single 1-m diameter mirror ([Figure 17](#)). In fact, this siderostat has never been used for solar observations, but only to observe bright stars spectroscopically and compare them with the Sun. After several changes, the definitive set-up of 1909 featured no less than four interconnected instruments ([Figures 18 and 19](#)), which could be used for all possible purposes on different solar lines, but in particular K and H α . The resolution was such that the various parts of the K and other lines could be observed separately, giving access to different layers of the chromosphere ([Figure 20](#)).

This combination was very versatile and used modern techniques; in particular the simultaneous motions of the image of the Sun on the entrance slit and on the photographic plates were ensured by synchronous motors,

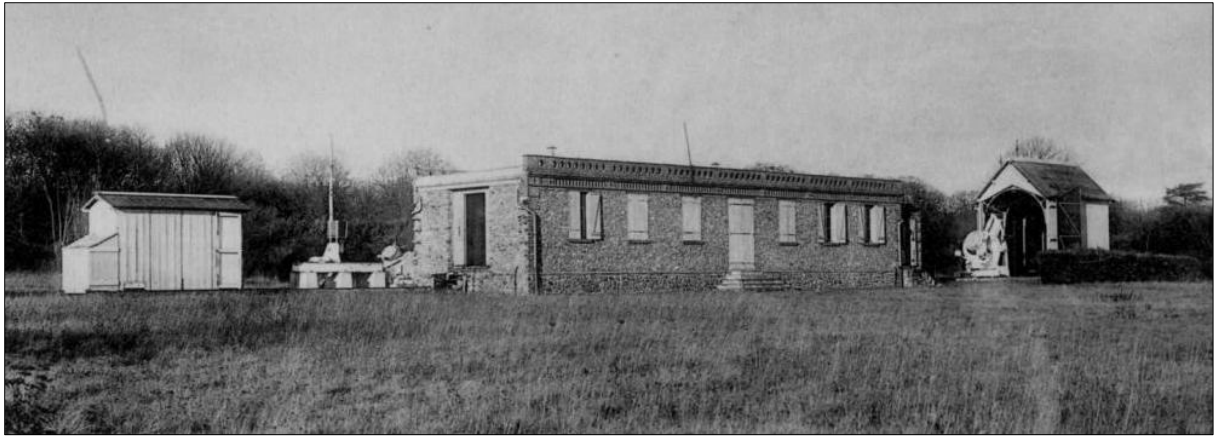


Figure 15: The grand sidérostât building. To the left (south side), the cœlostât with its rolling shelter. To the right (north side), the Foucault siderostat with its shelter (courtesy: Paris Observatory).

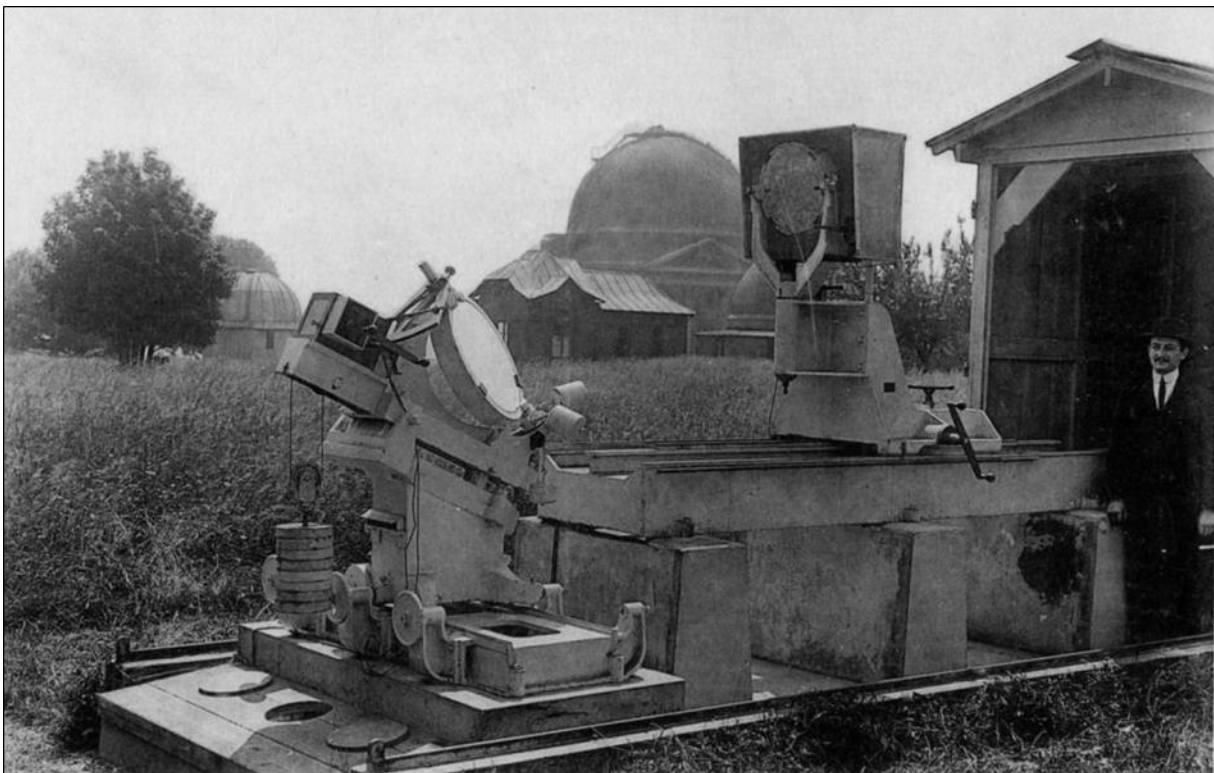


Figure 16: The cœlostât of the grand sidérostât building. It is located to the south of the building. Deslandres is standing to the right, in front of the rolling shelter. The first flat mirror, inclined, reflects the light from the Sun to the second mirror. Both are covered here. In the background just right of center is the large dome of the great refractor; the dome of the equatorial table is on the right (partly obscured); the dome of a small equatorial is on the left (partly hidden by the large tree); and between them is the provisional meridian room (now destroyed) with its strange roof. This undated photograph has probably been taken in the late 1920s (courtesy: Paris Observatory).

which had been developed for telegraphic communications by Émile Baudot (1845–1903) and built by Jules Carpentier. All this was achieved by just four people: Deslandres, d'Azambuja, Vital Burson (Assistant Astronomer, 1881–1932) and the mechanic Dubourg (d. 1921).

We will now discuss briefly the results obtained by the new versions of the spectro-heliographs.

Figure 21 presents, as an example, three images of the Sun. The top one, in the center of the K line but outside the emission part, shows the deeper layers of the chromosphere. A small sunspot is visible as a dark dot. The middle image was taken in the reversal at the center of the K line emission, and corresponds to higher layers. Note the extended dark filaments on the right of the image. The bottom image was taken step-by-step in the K line with the 'spectro-register of



the velocities', hence the strips visible on the disk. In each strip, the velocities of the emission can be measured as seen in [Figure 22](#).

Many other spectroheliographic images have been digitized in the bass2000 data base, and can be accessed via <https://bass2000.obspm.fr/piwig/o/>.

What could Deslandres derive from all this material? This

Figure 17: The Foucault siderostat, to the north of the grand sidérostat building, present state. Its rolling shelter is on the right, and the light from the Sun or stars is reflected to the left in the building (courtesy: Paris Observatory, photograph by Council).

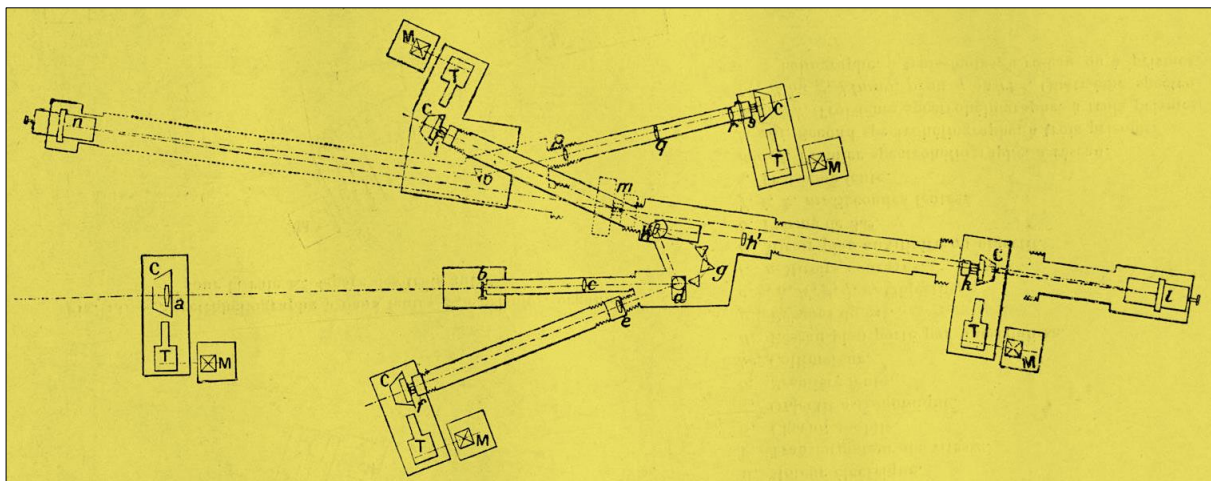


Figure 18: The complex instrument of the grand sidéostat building in 1910. The cœlostat (not represented) to the left sends the light from the Sun to the objective *a*, which forms the image of the Sun on the entrance slit *b*. This image can be swept uniformly or by steps by moving the carriage *C* holding the objective, thanks to the motor *M* and the gearbox *T*. Four identical motors *M* and gearboxes *T* move the photographic plates in synchronism. *c* is the collimator, and *d* a retractable plane grating. When in place, it feeds a first 3-m long spectrograph *ef*, for the H α line. When retracted, the light is dispersed by the three prisms *g* and feeds the second, 3-m spectrograph *hi*, for the K line. A retractable and directional flat mirror in *h* can send the light to the third spectrograph *h'k* to the right, which can isolate any line, the prisms being set at their minimum deviation for this line. The fourth spectrograph, 14-m long, consists of the concave mirror *l* (extreme right), a second slit in *m*, another concave mirror *n* (extreme left), a 30° prism in *o*, three lenses *p*, *q*, *r* and a third slit in *s*. Its principle is similar to that of the spectrograph represented as [Figure 11](#). Its dispersive elements are either the grating or the three prisms, and it can be used for any line. It gives the best results but needs longer exposure times than the three other spectrographs (after [Deslandres, 1910: 37.](#)).

can be appreciated through an address given by Deslandres before the Royal Astronomical Society on 11 June 1909 (Deslandres, 1909).

He first noticed that the double emission at the center of the K line (K_{2V} and K_{2R} in [Figure 20](#)) extended outside the limb of the Sun, so that it was due to the ionized calcium of a gas located above the photosphere. This layer must have been rather thick, because the K_2 emission extended to some height above the limb.

The broad, darker K_1 part of the K line cor-

responds to a lower layer, that he called the reversing layer, "... which is so revealed for the first time other than a solar eclipse". (Deslandres, 1909: 357). Note that the ideas of the time on radiation transfer were simplistic: the reversing layer simply does not exist, but this was only demonstrated in the years 1920–1923 by Meghnad Saha (1893–1956) in India, Karl Schwarzschild (1873–1916) in Germany and Edward A. Milne (1896–1950) and Sir Arthur Eddington (1882–1944) in England.³ This has obviously been difficult to understand and to accept, and

we still find mention of the reversing layer in treatises of the 1930's. But Deslandres was right in claiming that the K_1 part of the K line comes from deeper than the chromospheric emission (in fact it comes from the photosphere).

The K_3 absorption on the K_2 emission was supposed by Deslandres to come from some upper layer, but he did not say much about its origin.

Then he compared images in visible light (hence in fact in the continuum) with images in the K_1 , K_2 and K_3 filters, to conclude:

The spots which are the principal character of the surface progressively diminish from the surface; they disappear in the layer K_3 , or are notably large and black.

The facular regions, on the other hand, remain bright and progressively increase in width.

Besides this, on the new layer K_3 , new details appear; it shows black lines, called by us filaments, often very long, more or less large or curved, generally with sharp edges, and also large regions less bright than the ground and with uncertain limits.

The filaments, like the spots, remain at the same place during several rotations, and are the seat of special disturbances; they seem to have in the superior chromosphere the same importance as spots in the surface and low atmosphere. Generally the filaments are prolonged on every side by similar lines called alignments, less black, neat and continuous, which extend from an edge of the Sun to the opposite edge; and as the alignments can be followed often several days, it may be thought that they form a closed ring in the atmosphere. Some other alignments, not connected with a filament, are also visible on the same image. Upon the whole the filaments and alignments form a special net, which is the principal character of the upper layer of calcium.

Then Deslandres continues in describing what Hale and he observed with the $H\alpha$ line, which is not very different except that alignments are not visible.

Some examples of the so-called alignments are drawn on Figures 18 and 19 in Deslandres (1910: 58) and Figure 5 in Deslandres and d'Azambuja (1913: 419). I am suspicious about their existence, as the eye has a tendency to find alignments in any complex image (remember the Mars canals!). Inspection of the original photographs shows

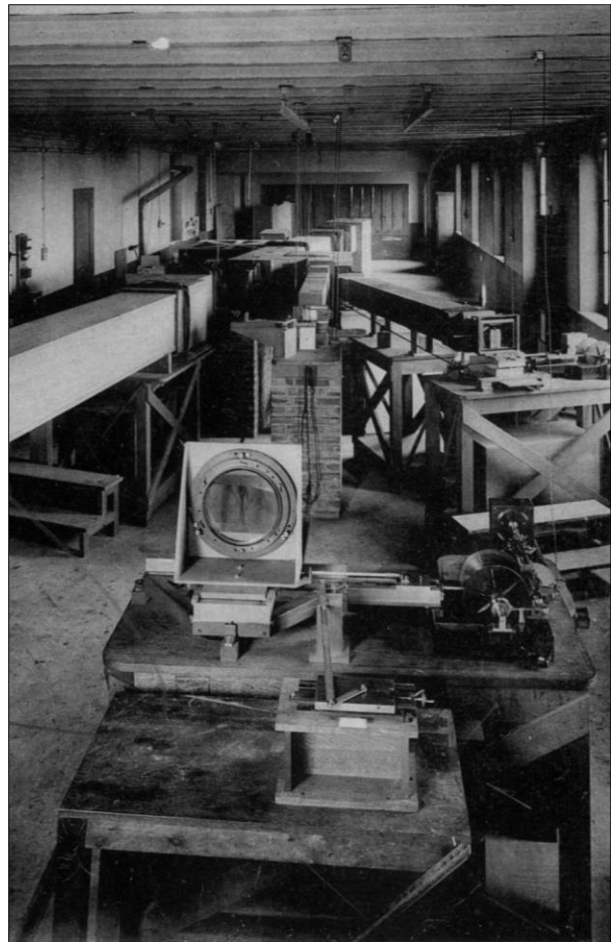


Figure 19: Contemporary photograph of the interior of the building of the grand siderostat; compare with Figure 18 (courtesy: Paris Observatory).

nothing conspicuous.

Deslandres and d'Azambuja (1913) introduced synoptic views of the solar phenomena (sunspots, faculae, filaments, etc.) during a full rotation of 28 days (Figure 23); this representation was continued until 2003 in Meudon.

There was no convincing physical interpretation of these observations, in spite of promises by Deslandres. This was not his

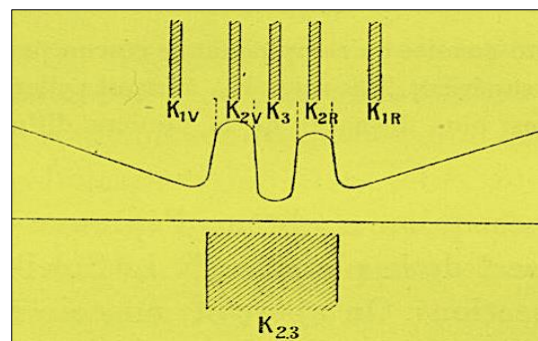


Figure 20: Positions of the exit slit of the spectroheliographs in the profile of the K line. Compare to the line profiles of Figure 4 (after Deslandres, 1910: Figure 1).

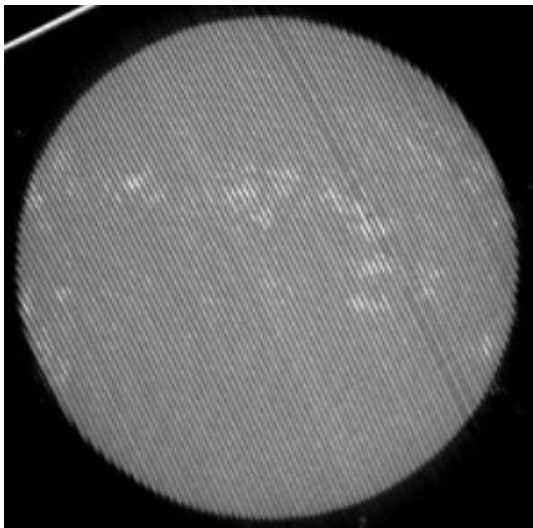
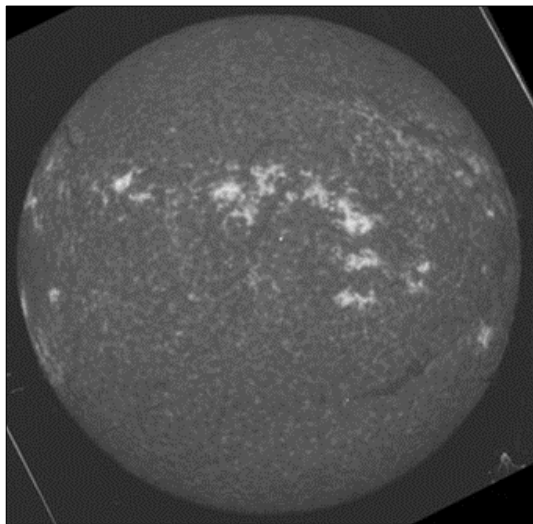
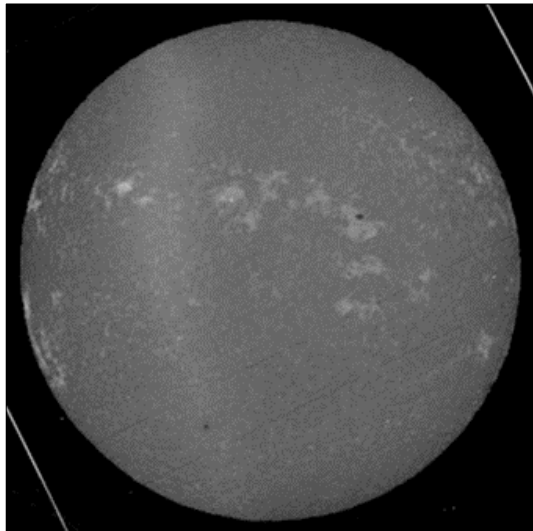


Figure 21: Three images of the chromosphere on 7 April 1919. From top to bottom: image in filter K_{1V} ; image in filter K_3 (see Figure 20 for positions of the filters); image in the center of the K line, with successive positions of the entrance slit, for radial velocities (from the bass2000 data base).

fault, as any interpretation would rest on plasma physics and magnetohydrodynamics that simply would not appear for many years, essentially after WWII. But he missed the discovery of the solar magnetic field (Hale, 1908), even though he was familiar with the Zeeman effect used in this discovery. On his side, he proposed that a weak magnetic field would curve the ‘cathodic rays’ of the corona near the solar poles, or could be the cause of the spiral arms in nebulae! He also proposed that a weak magnetic field would curve the motions of protuberances or filaments observed with the ‘spectro-register of the velocities’ (Deslandres, 1911). He was very disturbed by Hale’s announcement of strong magnetic fields in the solar photosphere, and insisted on his prediction of a very weak value in the chromosphere, searching for various arguments in favor of his ideas in the literature (Deslandres, 1929), but in vain.

He was happier with his studies of stellar chromospheres. These had been discovered in 1913 by Gustav Eberhard (1867–1940) and Karl Schwarzschild in three giant K stars (Arcturus, Aldebaran and σ Geminorum), which showed, like the Sun, a reversal of the H and K lines. Deslandres and Burson (1922) found this in other stars and showed that several displayed a K_3 -type absorption at the center of the emission, hence have a chromosphere similar to that of the active regions of the Sun. This was done with simple spectrographs attached to different instruments, and later to the 1-m diameter Foucault siderostat. Deslandres attributed these important chromospheres to X-rays emitted by the very hot interiors of the stars!

6 THE REIGN OF DESLANDRES (1908–1927)

After the death of Janssen in 1907, Deslandres became officially the Director of the Observatory. At that time there were only five astronomers in Meudon: Deslandres, d’Azambuja, Burson, Jean Bosler (1878–1973) and Perot. The latter, who was previously a Professor at the Marseilles University, had joined the Observatory in 1908 as the ‘Physicien de l’Observatoire’. He used the Perot–Fabry Interferometer that he had invented with Charles Fabry (1867–1945) in 1895, placed in the ‘bâtiment du petit sidérostat’ (in c of Figure 14), to detect the gravitational redshift of solar lines (Georgelin and Lequeux, 2021: 254) and to study the motion of prominences. Later, he worked with

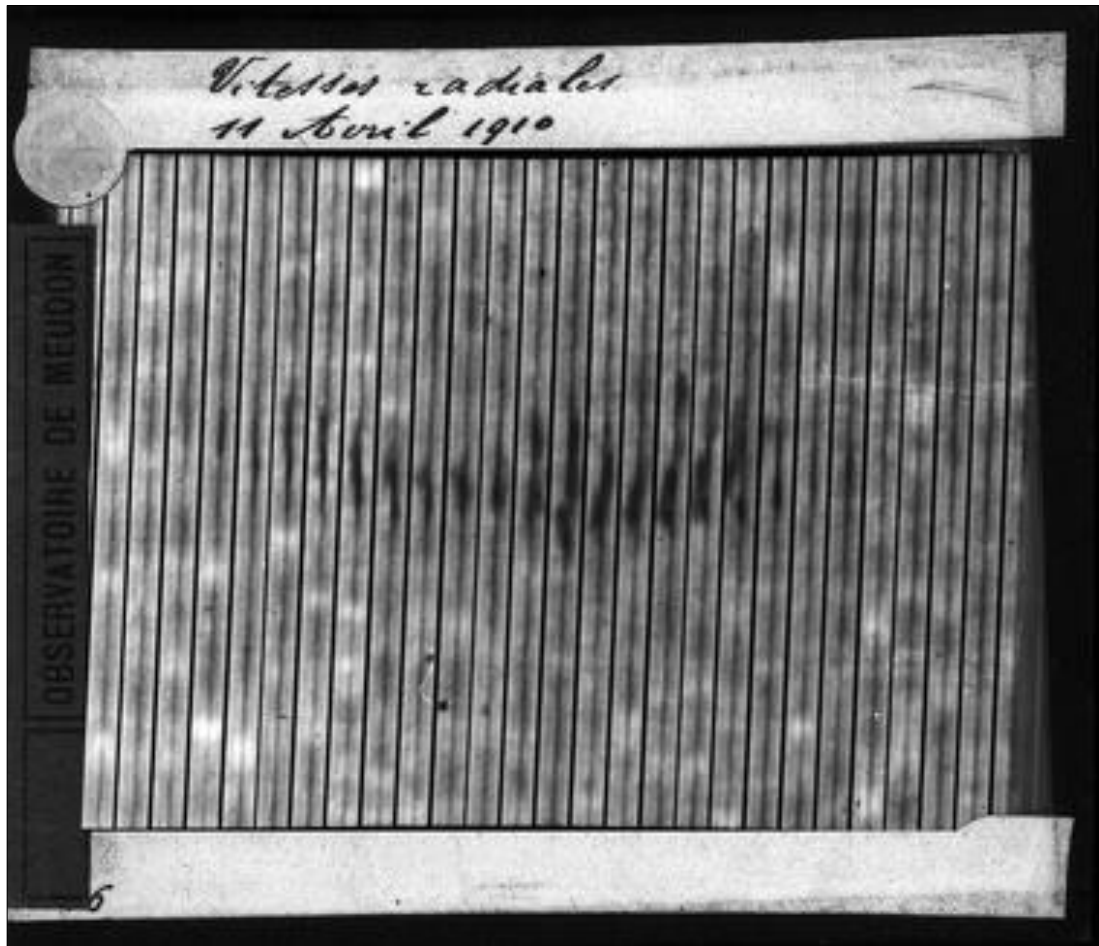


Figure 22: Portions of the dispersed images of filaments produced by the 'spectro-register of velocities'. The spectral image of a filament, which is dark, is displaced by the Doppler-Fizeau Effect (from the bass2000 data base).

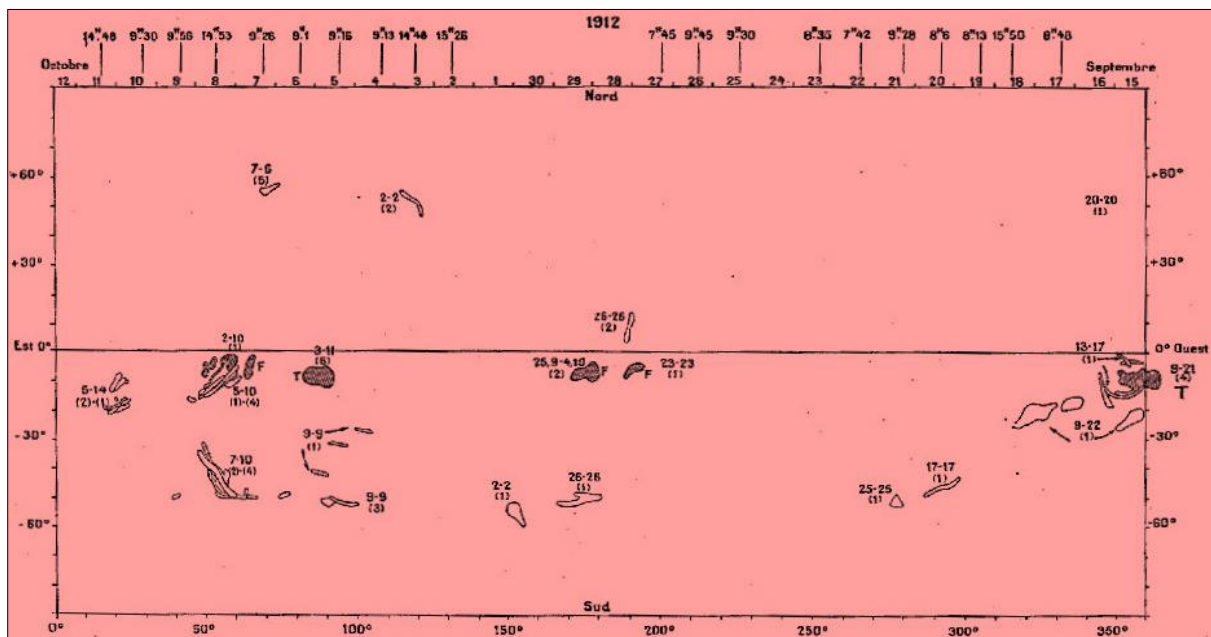


Figure 23: Synoptic view of solar atmospheric phenomena during rotation #789 of the Sun (minimum of activity). The latitude is in ordinates and the longitude in abscissae, and the days of meridian crossing are marked at the top, with the time of observation. Faculae are labeled T if they contain a spot, F otherwise. The two numbers above each feature indicate the extreme dates of the appearance of this feature, and the number in parentheses its intensity (after [Deslandres and d'Azambuja, 1913](#)).

Deslandres to produce extremely large magnetic fields (see above). While the solar observations were reserved for professional astronomers, all the others were made by amateurs like Eugène Antoniadi (1870–1944).

There were also in the Observatory two technicians, a secretary, a guard, a concierge and a gardener. Everyone was housed in what remained of the château or in the out-buildings.

At the same time there were about 16 permanent astronomers at Paris Observatory, and Deslandres complained that physical astronomy (today we would say astrophysics) was neglected in favor of classical astronomy. But, in any case, WWI was to change the situation completely.

Deslandres, d’Azambuja, Burson and three other members of the personnel were mobilized in 1914, and Bosler in 1915. Perot remained in Meudon, where he acted as the interim Director and worked on telecommunications by radio. The solar patrol with the spectroheliograph was continued by a technician named Coroyer (for details, see [Lequeux, 2022](#)).

Deslandres was not sent to the front because of his age (he was 61 at the beginning of WWI), but nevertheless he returned to active service, as a major and later, lieutenant-colonel in the Génie, the Army Engineers. Together with Colonel Jouhandeau he invented a new type of cannon (mortier J. D.), 1000 copies of which were constructed and used in the last part of the war (d’Azambuja, 1948: 183). Of course, his scientific activities were very limited until the end of the war, although he remained rather active at the Academy of Sciences: his only scientific paper was concerned with the effects of intense cannon shots on the production of rain (Deslandres, 1917).

Deslandres was slightly injured during the war. He was only demobilized at the beginning of 1919, and resumed his Observatory activities on 1 May that year. He found the Observatory personnel rather unchanged with respect to the pre-war years, and this was to last until 1926, except for the departure of Bosler to Marseilles, who was replaced in 1920 by Bernard Lyot (1897–1952), and the arrival in 1922 of an astronomer from Algiers Observatory named Fernand Baldet (1885–1964), then in 1924 another one, Henri Grenat (1900–1968), and in 1925 Henri Mineur (1899–1954) and Miss Stefania Mărcineanu (1882–1944). In 1923, Perot had brought to

the Observatory a young female Assistant, Miss Marguerite Roumens (1898–1985). After Perot’s death in 1925, she worked with Deslandres and d’Azambuja. She married d’Azambuja in 1935. The d’Azambujas became faithful collaborators and successors of Deslandres in solar studies.

The solar observations were of high quality under Deslandres and d’Azambuja, and without strong competition as Hale had partly abandoned solar research, while the Mount Wilson astronomers focused on galactic and extragalactic work. The solar patrol was however interrupted during WWI, except for ordinary photographs of the photosphere on large plates, which was abandoned after some time through lack of such plates.

The year 1920 was the first in which the functioning of the observatory was normal. Clearly Deslandres was busy with its reorganization and had little time left for personal research. His only publication that year was about the chromospheres of stars.

In 1921, a recording magnetometer was installed in a wooden annex of the Grand Sidéostat building. It was devoted to the perturbations of the terrestrial magnetic field due to solar activity, a topic that was beginning to be considered of importance. There was even a bell that rang when the magnetic field was disturbed! That year, just as in preceding one, Deslandres’ research focused on stellar chromospheres, in collaboration with Burson (who probably made most of the observations). But he had others interests, as we will see now.

In the [Annual Report for 1921](#), there is a long discussion on pages 28–33 about a possible reorganization of French observatories. Deslandres noted that amongst the 11 public observatories in France, only Meudon was fully devoted to astrophysics,⁴ while most large observatories elsewhere in the world specialized in this area of astronomy, with numerous personnel, large instruments and often in good mountain sites. Paris Observatory, which contained one third of all French astronomers, had the worst location of all French observatories.

The Annual Report for 1922 contains the same complaints. Deslandres noted that the Minister, conscious of the situation, has ordered an inspection of French observatories before deciding what to do. Deslandres was put in charge of this review, which necessitated travels to all the French observatories and possible mountain sites for new observatories in the Alps and Pyrenees; the latter seemed

to possess better sites, near Font-Romeu (Deslandres, 1923). These travels took a large part of 1922 and of the beginning of 1923. Deslandres' two publications in 1922 were concerned with a stellar chromosphere and 'the emission of X-rays, ultra-X-rays and particles by celestial bodies' (Deslandres, 1922); very little remains of these ideas.

Deslandres' report was presented in October 1922. He summarizes its conclusions as follows (Annual Report for 1922: 18, our English translation):

[The report] proposes a better distribution of the personnel, the increase of the resources devoted to physical astronomy, and the creation of mountain observatories. It also asks for the reduction of the meridian apparatuses and visual equatorials in service, the suppression, or the reduction, or the conservation in their current state of the French observatories not favored by a beautiful sky, or suffocated in the cities. The resources in personnel and material thus made available would be reserved for other observatories better located, or for the mountain observatories that are to be created.

This plan was inspired only by scientific reasons; but it alarmed the habits taken, the acquired situations, and met a certain opposition. However, in the idea of its author, it should be applied only gradually, taking largely into account, as far as the personnel were concerned, the previous services and the most respectable acquired rights.

Not surprisingly, nothing came of these recommendations. Deslandres complained about this on several occasions, in particular in the Annual Report for 1926, where he wrote:

We are obviously witnessing an evolution of Astronomy and it is important that we do not remain behind. A reorganization of our observatories is necessary; it is indicated briefly in the report on the general inspection of the French observatories which was entrusted to me in 1922. The old branch of Astronomy, dealing with the precise measurement of the position of the stars, and called the position branch, still has the same importance; the large recent operation of world longitudes, so well prepared and conducted by the Bureau des Longitudes and the Observatories of Paris and Algiers, shows clearly that its domain is still very important, but one can, without inconvenience, especially in France, reduce the number of its instruments, and transfer to the new branch the personnel made available.

This text looks like a last-ditch effort. Deslandres does not speak anymore of clos-

ing several observatories and building new mountain ones, but only of transferring part of the personnel from some observatories to others. He congratulates the 'position branch' astronomers for a recent development with modern means (radio transmission was used for determining longitudes), but did not mention (voluntarily) the enormous enterprise of the Carte du Ciel that took most of their efforts for many years. In spite of his kind words, nothing happened except for the merging of Paris and Meudon Observatories, an idea that had already been in the air for several years.

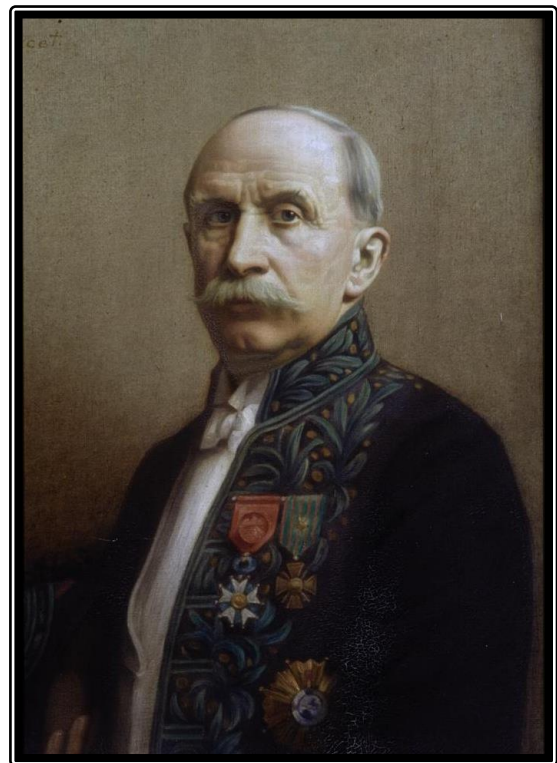


Figure 24: Deslandres in Academician suit, by Antony Troncet, date unknown. In the portrait gallery of Paris Observatory (courtesy: Paris Observatory, photograph J.-M. Kollar).

7 DIRECTOR OF THE PARIS-MEUDON OBSERVATORY

The merging of the two observatories, was decided by decree of 5 October 1926, and became official on 1 January 1927. The first result was the suppression of four positions at Meudon: the Director, the Secretary and two Astronomers! However, the Meudon Secretary was soon re-installed as it proved impossible to run everything from Paris. Deslandres, at the height of his glory (Figure 24), became the Director of the merged institutions, but only for three years: he had to retire by law on 1 November 1929.

Deslandres saw some advantages in this merging (Annual Report for 1926: 3):

It will be easier to orient the young astronomers towards the new branch; and it will be possible to transport to the terrace of Meudon, in a purer air, not charged of dust, the portable instruments for position astronomy that are at present in Paris.

In the first report of the merged observatories, [Deslandres \(1928\)](#) even proposed to move progressively all instruments of positional astronomy from Paris to Meudon, and to install instead in Paris physics laboratories

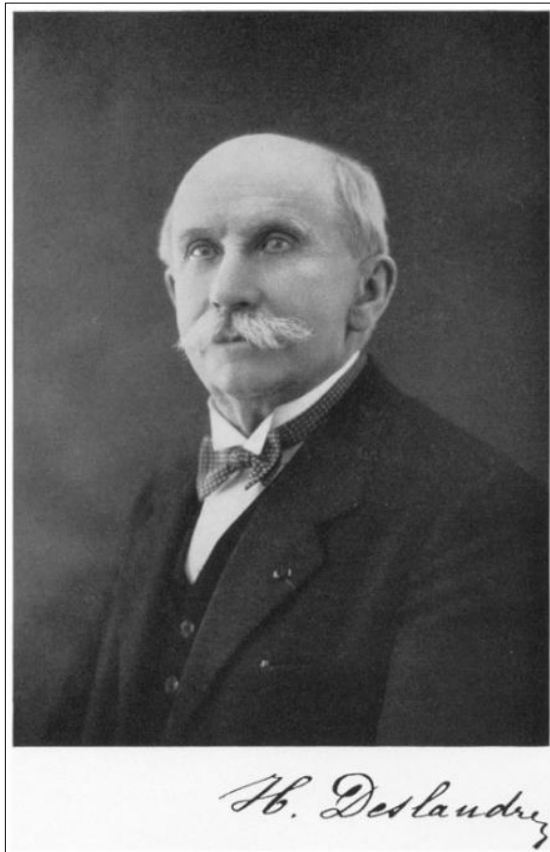


Figure 25: Photograph of Deslandres, age unknown (after [d'Azambuja, 1948](#) and [Stratton, 1954](#)).

and workshops. This was again wishful thinking: the only result was the construction in 1928–1929 of a meridian room to house some of the Paris instruments. It was never finished and was destroyed a few years later.

We should not be surprised that Deslandres had very little time for research while he was reorganizing the merged observatories. In a few communications to the Academy of Sciences, he presented his ideas about the emission of particles by the Sun, which produces terrestrial magnetic storms. He wrote:

Magnetic storms are due, as we know, to a corpuscular radiation emanating from the Sun, of mainly negative electric charge. Everything happens as if the Sun

had under its surface a deep layer rotating like a solid body; and this quasi-solid layer bears 24 volcanoes, variable like the terrestrial volcanoes, and uniformly distributed around the axis of rotation, which reject outside the electrified matter of the inner masses. ([Deslandres, 1927](#)).

Needless to say, nothing survives of these strange elucidations, based on poor statistics.

8 CONCLUDING REMARKS

Deslandres retired on 1 November 1929 and was replaced by Ernest Esclanon (1876–1954), coming from Strasbourg Observatory. He was unanimously regarded by his colleagues. Indeed, he had always paid much attention to their promotions and working conditions, even if he was sometimes a little brusque, and he always acknowledged their contributions without taking credit for them. He was well-known to astronomers worldwide, and received numerous honors: for a list, see [d'Azambuja \(1948\)](#).

Deslandres ([Figure 25](#)) did not work on astronomy after retirement, only on molecular spectra. The end of his long life was saddened by the death of his only child, Philippe, in an airplane accident on 31 March 1939.

Deslandres was certainly at his best in conceiving, constructing and using instrumentation, sometimes very sophisticated and using the most modern techniques available. He was a first-class observer and experimentalist, and a remarkable organizer with considerable insight. He had ideas on many subjects, some of them premonitory, for example on the radio emission by the Sun. But his theoretical ideas about the Sun and its atmosphere were not so successful, not entirely his fault because the relevant physics was simply not available during his life. His scientific heritage is mainly on the observation of solar atmosphere and activity, which is still very vivid today.

9 NOTES

1. Louis-Philibert Décombe (1873–1957) was a French physicist who had a practical knowledge of the emerging radio detection techniques, hence his association with Deslandres: his 1898 doctoral thesis is entitled “*Multiple resonance of electrical oscillations*”. There is not much information on him.
2. In a note following that of Deslandres and Décombe, [Nordmann \(1902\)](#) writes with considerable insight (my English translation):

The negative character of the result I obtained in my experiments made on Mont Blanc ... could be explained by the fact that the electromagnetic radiations from the Sun must have been absorbed by the rarefied upper layers of the Earth's atmosphere.

Indeed, his set-up was sensitive to long wavelengths reflected (not absorbed) by the ionosphere. The idea of a reflecting layer was suggested also in 1902 by Heaviside and Kennelly, but this layer, the ionosphere, was only discovered in 1925 by Appleton. For the early attempts by Nordmann and others to detect radio waves from the Sun, see Débarbat et al., (2007).

3. Transfer of line radiation through a solar or stellar atmosphere is not a question of crossing layers with different temperatures. Resonant scattering in the lines plays the major role. The atoms or ions in a certain layer absorb in one of their resonance transitions the radiation coming mainly from deeper layers where it is more intense than in the more superficial layers, and re-emit it isotropically in this same transition, as much towards the outside as towards the inside. The radiation towards the outside, the one we observe, is therefore weaker than the one towards the inner layers; the result is a net weakening of the radiation at the transition wavelength outside of the atmosphere, so that the line appears in absorption. The absorption lines of the Sun and stars do not correspond to a decrease in temperature or a decrease in density, but appear simply because the atmosphere is open to the outside with respect to radiation.
4. Note that what Deslandres considered as 'Astronomie physique' (we would now call astrophysics) was limited to the Solar System and stars: studies of the Galaxy and other galaxies were completely neglected. In spite of the work of a few pioneers in the 1930s, galactic and extragalactic astronomy had to wait for after WWII to develop in France.

10 ACKNOWLEDGEMENTS

I am grateful to the creators of DeepL translator for their decisive help in translating some difficult French texts into English.

I wish to thank Wayne Orchiston for improving the language of this paper. I am also grateful to Jean-Marie Malherbe for providing me with a summary of solar observations made with spectroheliographs at Meudon

after Deslandres, as reproduced below in Appendix 1.

11 APPENDIX 1: THE MEUDON SPECTROHELIOGRAPHS AFTER DESLANDRES

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The potential of Meudon spectroheliographs and their instrumental and scientific heritage has been summarized by Malherbe et al. (2022).

The Meudon spectroheliographs were modified several times after the retirement of Deslandres, while his 'spectro-register of the velocities' was abandoned definitively in 1939: observations with this instrument were beautiful, but there was a lack of manpower for their interpretation which was a long and delicate task.

In 1950, d'Azambuja modified some parts of the long focus (7 m) spectroheliograph, which was used for research but not for systematic observations, in order to record simultaneously two lines. After the retirement of the d'Azambujas (1954 and 1959 respectively for Mr and Mrs d'Azambuja), this spectrograph was again modified by Raymond Michard (1925–2015) and Jean Rayrole (1932–2008) to produce the first PCM (*Plaques de Champs Magnétiques*, or magnetic field plates) (Michard and Rayrole, 1965). They used a Hale–Nicholson grid located at the entrance slit of the spectrograph fed by the 75-cm Foucault siderostat and a new 40-cm, long focus Gregorian telescope. It worked like the spectro-register of the velocities, forming spectra of an iron line sensitive to the Zeeman Effect, and scanning active regions, the telescope and the plate moving simultaneously by steps. The Hale grid was composed of circular polarizing strips providing alternatively $\sigma+$ and $\sigma-$ polarizations along the slit. This set-up is the ancestor of the Meudon magnetograph built by Rayrole in the 1980s, then of the THEMIS solar telescope at Tenerife, developed by Rayrole and INSU/CNRS. In 2002, the Meudon spectroheliograph, now equipped with CCD detectors, was transformed into a classical spectrograph scanning the Sun, the selecting slit in the spectrum and the moving plate having been suppressed.

The scientist responsible for the spectroheliograph since 1996 is Jean-Marie Malherbe, who will retire in 2023. Malherbe also

created the BASS2000 data base in 1995, for which Jean Aboudarham became responsible in 2001, and will remain so until his retirement in 2024.

Synoptic maps have been drawn continuously from 1919 to 2003 (most are on-line on BASS2000) together with associated tables, but they were stopped at the retirement of the last drawer (Germaine Zlicaric), who was not replaced. Note that long collections of solar observations such as those of Meudon, Coïmbra, Kodaikanal and Mount Wilson are of considerable interest, because they allow us, for example, to recover past magnetic fields before the advent of magnetographs of the

1970s, or the solar irradiance before the direct measurements by satellites in the 1980s, using the Call K proxy. They also record rare events, constraining the MHD models of solar structures.

The alignments mentioned by Deslandres in 1910 have not been confirmed. However, one knows today that filaments delineate large regions of weak magnetic fields of opposite polarities, so that long structures, such as polar crown filaments forming at the beginning of a new cycle, can look like a discontinuous ring around the Sun, at high latitudes; but, of course, Deslandres did not know this.

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