With NOMAD on board ExoMars

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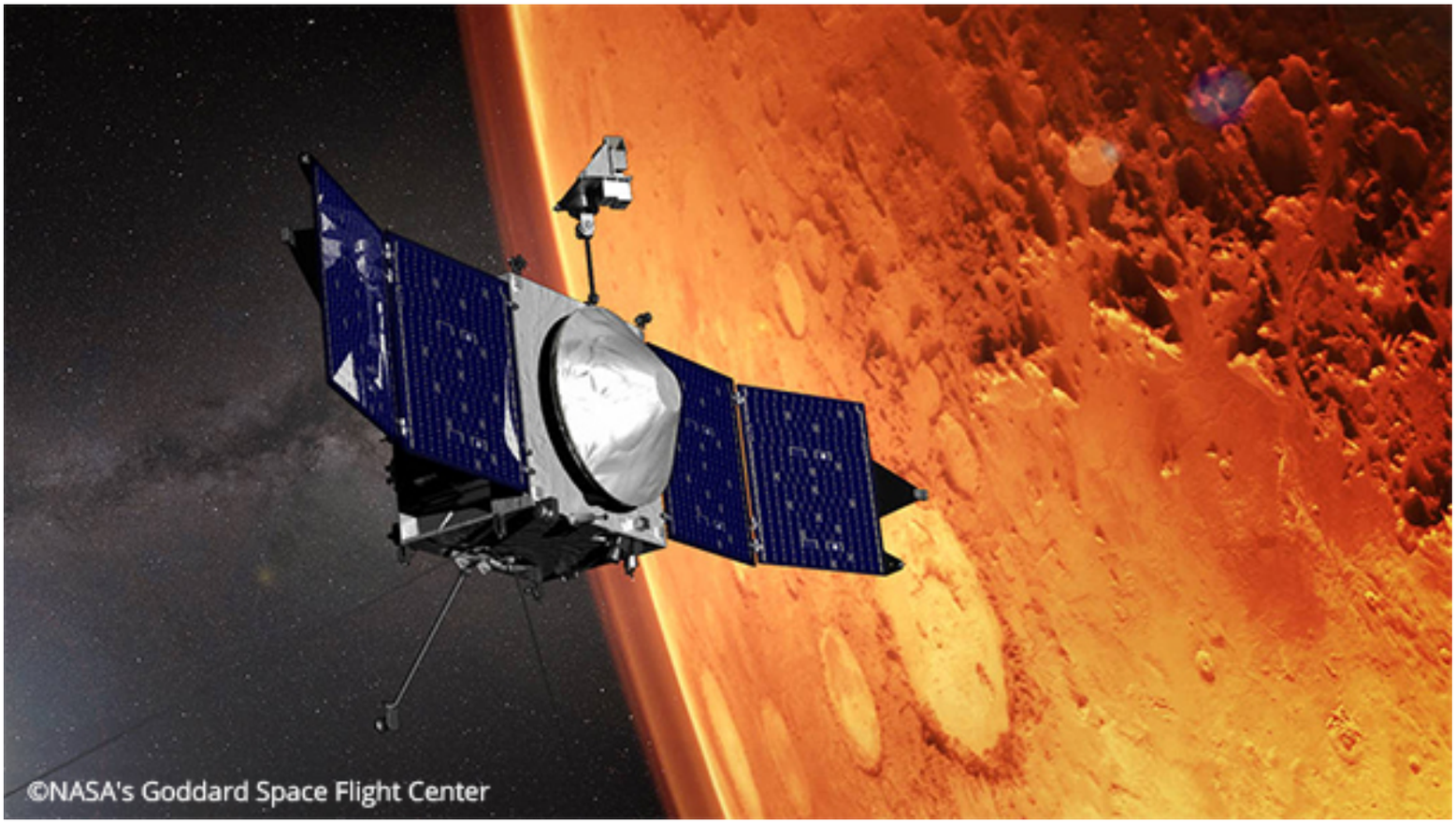
Arnaud Stiepen has adjusted his watch to Martian time. In fact, he has become a specialist in the analysis of atmospheric phenomena on Mars. When the European probe ExoMars lands on the red planet, new data will become available and will need to be analysed. He developed his expertise at the University of Colorado where he had the opportunity to work on data provided by the American probe MAVEN. One of his key interests will be in diffuse aurora and the evolution of the Martian atmosphere which would be key to any hope of finding life on the planet.

On October 19th, Europe will land on Mars. **Arnaud Stiepen**, a postdoctoral researcher at the **LPAP** (Laboratory of Planetary and Atmospheric Physics) in the STAR Institute (Space sciences, Technologies and Astrophysics Research) of the University of Liege, has been looking forward to this moment with a great deal of interest. Indeed, on that date, the Schiaparelli robot, alias EDM (Entry descent & landing Demonstrator Module) is expected to land on the Red Planet. It will be released by the Russo-European probe ExoMars (Exobiology on Mars), three days before it is placed in orbit around Mars. If it arrives intact, this technological lander, which was developed in Italy by Thales Alenia Space, will become the third probe to land on the Red Planet thanks to a scientific partnership with Roscosmos. Russia was the first country to achieve this feat with Mars-3 (December 2nd 1971). The United States had a scientific laboratory on Mars with the Viking robot (July 1st 1976).



On the same day - and this event will be closely followed by Arnaud Stiepen - the orbital platform TGO (Trace Gas Orbiter) which weighs 3.73 tonnes, will become a satellite of Mars in an extremely elliptical orbit between 300 and 95.850 km around the Red Planet. It will relay the signals from Schiaparelli during its descent and later on from the surface of Mars. It will then place itself in a circular orbit at around 400 km in order to fulfil a scientific mission which has been planned for 2022. On board, a Belgian instrument will represent the ESA (European Space Agency): it is the triple spectrometer **NOMAD** (Nadir & Occultation for Mars Discovery) created by **BIRA-IASB** (Belgian Institute for Space Aeronomy) with OIP Sensor Systems (Oudenaerde) and **Amos** (Liege), and tested at the **CSL** (Liege Space Centre/ University of Liege). This instrument will show what the Martian atmosphere is composed of, even at low concentrations.

The researchers at the LPAP are interested in studying the data from NOMAD in order to get a better understanding of the Martian atmosphere.

The data lessons of MAVEN

In the LPAP, Arnaud Stiepen is a specialist in the atmospheres of Mars and Venus and the auroral phenomena they produce. Recently, he participated in the use of observations made by an instrument on board **MAVEN** (Mars Atmosphere & Volatile Evolution), a NASA probe which has been travelling around the Red Planet since September 21st 2014. For his post-doctorate, this researcher from Liege spent a year - from September 2014 to September 2015 - at the University of Colorado in Boulder. In the context of a long collaboration which

developed thanks to the friendly relationship between the LASP (Laboratory for Atmospheric & Space Physics) in Boulder and the LPAP of the University of Liege.

"I spent a very productive year at Boulder from a research point of view. The University of Colorado is very well funded, which contributes to the responsiveness of its researchers. At no time did I feel scientifically inferior to them. Our training is of a very high standard. Why else would our American colleagues call upon our expertise? The quality of our research enables us to reach the same high standards with less funding than laboratories in America are used to". Thanks to the fact that he had access to observations made by the spectrometer from the University of Colorado on board NASA's MAVEN probe, he was able to confirm the baffling presence of "diffuse" auroras in the atmosphere of the Red Planet (see article: "**Martian auroras uncovered**").

Arnaud Stiepen wants to know more about the phenomena he revealed about the atmospheric environment of Mars. He is currently interested in the abundance of data captured by sensors in the UV (**ultraviolet**). Observations in this spectral waveband are a speciality of the Institute for Astrophysics and Geophysics of Liege. *"What interests me is a new type of aurora, different to those discovered on Mars by the ESA's Mars Express probe in 2005. These are diffuse auroras which have been detected on a section of the Red Planet in its Northern hemisphere. What is surprising is that these auroras appear very low in the atmosphere, under the effect of higher energy electrons than is the case during the appearance of discreet auroras".*

While working on the observations made by the MAVEN probe, the astrophysicist from Liege did not expect to have confirmation of so-called "diffuse" auroras. This was one of the first results provided by MAVEN in December 2014 thanks to its IUVS (Imaging UV Spectrograph) instrument. For one year, Arnaud Stiepen was part of the team that examined the data from the ultraviolet imaging spectrograph. He took part in a press conference organised by NASA to speak about the surprises he had uncovered in these "diffuse" auroras which are difficult to detect due to the very faint light coming from them. *"This type of aurora is caused by high-energy particles which for this reason are unpredictable. There is no possibility of studying the phenomenon in a routine way: you have to be in the right place at the right time in order to detect and study them".* By means of MAVEN, it is possible to use several instruments to conduct combined observations of this auroral phenomenon. *"You need to understand where the electrons that cause the aurora are coming from, how they are accelerated by following the lines of the magnetic field…"*

At the heart of the Martian tragedy

The auroras are not the only focus of Arnaud Stiepen's interest. Mars has the particularity of having a very thin atmosphere, composed of 95 % carbon dioxide (carbonic gas).

The observations made by the American probes on Mars show that the atmospheric pressure on Mars 3.5 million years ago was 150 times greater than its current level, a level similar to our own planet… What is the explanation for the slow and inevitable metamorphosis that was produced resulting in the near disappearance of the Martian atmosphere? The MAVEN probe provided new evidence about the dramatic evolution of Mars thanks to the **IUVS** (Imaging Ultraviolet Spectrograph) developed by the **LASP** (Laboratory for Atmospheric and Space Physics) of the University of Colorado. This renowned laboratory became interested in the work of Arnaud Stiepen, who studied the atmospheres of Earth's neighbouring planets Venus and Mars for his doctoral thesis. He drew on his expertise on processing the data transmitted by the IUVS.

The IUVS instrument observes the atmosphere at different altitudes by sweeping across it following vertical zones in search of markers due to the luminescence and auroras. From the position, intensity and shape of these emissions, it is possible to get an understanding of the dynamic and chemical processes which produced them. The IUVS provides a new view of the impact of solar activity on the atmospheric behaviour of Mars. *"What particularly interests me, is to know whether the Martian atmosphere is capable of changing rapidly and how it changes under the effects of the Sun and gravitational waves that are spread across the surface of Mars".* The participation of Arnaud Stiepen in research by the LASP could only be beneficial to the LPAP. So this expert on the atmospheres of Mars and Venus who hails from Liege distinguished himself by contributing to a major discovery on the evolution of the Martian atmosphere: the progressive erosion of this atmosphere over a period of 3 to 4 billion years due to the impact of **ions** and **electrons** emitted by the sun.

"This erosion continues as long as there is an atmosphere", explains Arnaud Stiepen*, "Most of all, we want to understand this slow process by taking a trip back in time*. *We would like to determine the mass that the Martian atmosphere lost over a period of three to four billion years*. *In this way, we will be able to extrapolate what the Martian atmosphere will be like in the future".* He also refers to a shift in paradigm in the context of his investigation: *"Before we had the information from the MAVEN probe, we thought that the erosion of the Martian atmosphere by the* ***solar wind*** *was somewhat calm. We now know that this was absolutely not the case. We were able to understand the fact that the solar wind wore away the atmosphere over the ages due to its violent eruptions. These energetic solar events are a very important element which must be taken into account in terms of the overall erosion".*

This phenomenon of erosion cannot be underestimated. As the co-author of a report on the data from MAVEN with regard to this process, Arnaud Stiepen points out: *"What we know, is that the atmosphere some three to four billion years ago was denser, warmer and capable of retaining liquid water on its surface. And then, over time - in the order of hundreds of millions of years - this layer became eroded. In this study, I used the airglow value, that is to say the light produced by the excited atmosphere. This gives us information about the composition, dynamics and the atmospheric winds".* If the Sun is shown to be more active and is reheating the atmosphere, we can understand that more of the atmosphere was released into space. The evolution of

the Martian atmosphere reveals the action of the solar wind. *"It's a little bit like wind erosion on a mountain".* The major discovery concerns the role of CMEs (Coronal Mass Ejections) or ejections of the coronal mass as accelerators of erosion. The Red Planet sometimes finds itself in the path of this high-energy plasma ejected from the Sun. Because the planet does not have a magnetic field to deflect these ejections, it directly excites the Martian atmosphere and accelerate its erosion.

Using NOMAD for better results

This behaviour of CMEs is enough to stimulate the curiosity of Arnaud Stiepen. Especially as the LPAP is counting on his productive collaboration with the IASB to make the most of the observations made by NOMAD. *"If the objective of the first instrument developed in Belgium is the study of methane in the atmosphere, we can use this for the measurement of other constituents and dynamics processes. I am counting on having access to the data to learn more about my subjects of interest concerning Mars which are the "diffuse" auroras and atmospheric erosion".*