Issue 2 - October 2025

# THE WST CHRONICLE

Pushing the Boundaries of Spectroscopic Surveys

The discovery power of the WST

Interview with L. Fréour, S. Bisero, and G. Gausachs

Unveiling the cosmic web

# Table of contents

The WST Chronicle is the magazine of the Wide-field Spectroscopic Telescope (WST) project, which is funded by the European Union under the HorizonEU research and innovation programme. It is published by the WST WP 6.3. The articles presented here reflect only the views of the project.

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**Cover image:** Euclid's view of the Perseus cluster of galaxies (Credit: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi). **Back cover image:** Euclid image of a bright Einstein ring around galaxy NGC 6505 (Credit: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre, G. Anselmi, T. Li). As mentioned in the cosmology article, the WST will have much synergy with Euclid.

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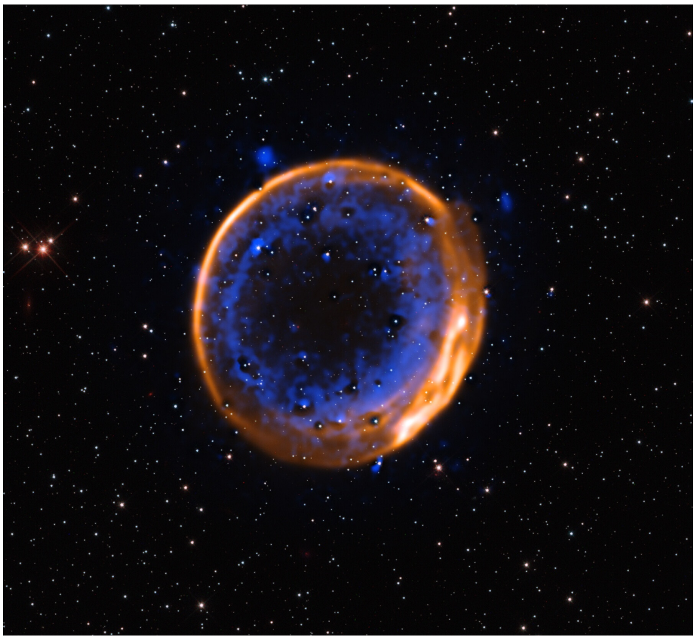

Credit: ESO/P. Das et al. Background stars (Hubble): K. Noll et al.

# COORDINATOR MESSAGE

With the launch of the WST *Chronicle*, the coordinator Roland Bacon outlined the journey that has brought the WST project to its present stage, culminating in the start of the EU-funded concept study earlier this year. In this second issue, I would like to highlight the growing momentum and remarkable progress within our consortium, as well as the strategic opportunities that lie ahead.

In July 2024, ESO launched the Expanding Horizons initiative to identify the next facility after the ELT completion and that we plan to propose the WST to ESO within that framework. A central element of this programme is the recently announced ESO call for White Papers, which opened on 25 June and will accept submissions until 15 December 2025. These are intended to help framing the scientific questions and challenges that  we expect to emerge in the 2040s and beyond. The White Paper  process indeed offers a unique opportunity for everyone interested in the future of astronomy—including members of the WST Science Team—to contribute their science ideas and perspectives.

Turning to the WST progress, the project was presented to the broader community during a highly successful and very well attended Special Session at the EAS 2025 meeting in Cork last July. On the technical front, the first face-to-face consortium progress meeting on telescope and instrument development took place in mid-June 2025. Reports from both events are included in this issue of the *Chronicle*.

Also, thanks to the effort of many people, several documents were delivered to the EU Granting Authority, including the Telescope Level 1 Requirements; the WST Top Level Requirements; Data Management plan; Communication, Exploitation, and Dissemination Plan; and, recently, the Telescope Optical Design Report. Equally important, during its July 2025 meeting, the Steering Committee adopted the WST Code of Conduct (also submitted to the EU) and the Consortium Publication Policy, both documents being crucial to ensure a healthy, respectful, and inclusive collaboration and to reward everyone who is contributing to the Consortium activities.

Looking ahead, the next stages of the project are rapidly taking shape. A very recent meeting of the Science Working Group leaders at EPFL in Lausanne highlighted the excellent progress made in developing the WST science cases in all the different areas. The first version of the WST ETC will be ready in November allowing a detailed quantitative assessment of the science cases. Also, over the coming months, these efforts will be consolidated into a unified scientific framework and progressively integrated into the WST Survey Plan, also making use of the facility simulator that is being developed.

Meanwhile, the telescope's opto-mechanical and structural designs, along with the instrument concepts, are advancing toward key trade-off decisions scheduled for February 2026. In parallel, the operations, sustainability, and site selection work packages continue to progress at full speed, maintaining close coordination and synergy with the other components of the project.

Finally, to further engage the community, a WST workshop will be held at Universidad Andrés Bello in Santiago on December 15–16, 2025, aimed at informing the broader Chilean scientific community about the WST objectives and unique capabilities, and encouraging local researchers to join the collaboration.

Let me conclude by highlighting that the *Chronicle* provides  both a platform to communicate progress within our large Consortium and a bridge to the wider community. In these pages we will publish updates on the project, in-depth articles on scientific and technical topics,  interviews to team members.  In this issue you will indeed meet three enthusiastic WST collaborators: Sofia Bisero, who is exploring the key synergies between the WST and the Einstein Telescope; Laurane Fréour, who is leading the crucial sustainability analysis; and Gaston Gausachs, who is coordinating the team of engineers who are tackling the challenges of the WST telescope structure and dome design.

I would like to close by expressing my sincere thanks to all members of the Consortium. The scale and ambition of WST are formidable, but what makes it possible is the collective effort, enthusiasm, and commitment that each of you brings to the project.

Sofia Randich
Deputy Coordinator

# THE DISCOVERY POWER OF THE WST

As presented in the science case white paper (Mainieri et al., 2024), we have shown that the WST will enable transformative science across many areas of astrophysics beyond 2040. However, predicting the key scientific topics more than 15 years into the future is inherently difficult and uncertain. Past experience reminds us to remain modest—there is a non-negligible risk of overlooking major future scientific developments. For example, when the Very Large Telescope (VLT) science case was published in 1997 (Renzini & Leibundgut), it did not mention the field of exoplanets, despite the first discovery by Mayor & Queloz occurring just two years earlier.

It is therefore essential, beyond the proposed science case, to consider the discovery potential of the facility and its ability to adapt to new scientific questions. Here, we focus on the discovery power of the WST; its adaptability to new emerging scientific fields will be covered in another issue.

The discovery power of a new facility is typically linked to its ability to explore new regions of parameter space—for instance, accessing new wavelength domains or achieving an order-of-magnitude improvement in spatial resolution. While we have demonstrated that the WST will enable novel science through synergies with future facilities (such as SKAO and next-generation gravitational wave detectors), some readers may still perceive WST's intrinsic discovery power as limited. One might argue that WST is simply a larger version of 4MOST or a more powerful MUSE—incremental rather than revolutionary.

On the contrary, we assert that the WST possesses significant intrinsic discovery power. This power arises not solely from new parameter spaces, but primarily from its unprecedented statistical power (sheer numbers of observations) and the unique capability of simultaneous parallel observations provided by its instrumentation. We expand upon these crucial points in the following sections.

### The discovery space of the MOS

With the exception of a few magnitude-limited samples that may be targeted by the multiple-object spectrograph (MOS), most sources will be preselected based on additional criteria. For instance, broad-band colours (e.g., Lyman-break selection) or spectro-photometric redshifts from other facilities such as *Euclid* or *LSST/Rubin* will guide the target selection. Each of its input catalogs have their own bias: for example the Lyman-break selection is biased towards continuum selected sample and the photometric redshifts have also some intrinsic bias, especially at faint magnitude (Brinchmann et al. 2017). As a result, the discovery space of the WST MOS is inherently more limited compared to an imager or an integral field spectrograph (IFS), due to this reliance on prior selection.

However, the true discovery potential of the WST MOS lies in the sheer scale of its dataset. With samples at least an order of magnitude larger than those from upcoming facilities—e.g., 300 million galaxies compared to 13 million with 4MOST—the WST will be uniquely positioned to uncover rare or unexpected outliers, simply through the power of numbers.

Previous facilities have demonstrated that the power of large numbers is a key driver of discovery. A prime example is the *Sloan Digital Sky Survey* (SDSS), which, despite being conducted on a relatively modest telescope for its time, revolutionised astronomy through its ability to collect spectroscopy for millions of sources.

As illustrated in Figure 1, one of the major discoveries enabled by SDSS was the mass-dependent age bimodality of galaxies and the identification of the “green valley” between the two main populations. These features emerged clearly only because of the statistical power of the large sample; they would not have been detectable in significantly smaller datasets. This example highlights how statistical scale, even

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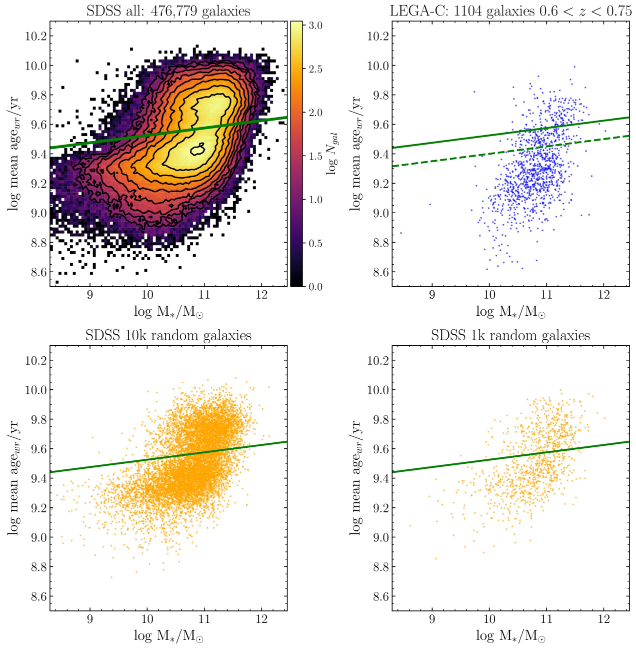

**Figure 1.** Galaxy distributions in mean stellar age vs stellar mass. (Top left) Full SDSS sample for z < 0.22, revealing a mass-dependent age bimodality and a green valley (solid line). (Top right) The smaller LEGA-C sample (van der Wel et al. 2016) cannot reveal such distinctions robustly as indicated by a tentative location of the green valley (dashed line) with respect to SDSS. (Bottom panels) Subsets of the SDSS sample comprising $10^4$ (left) and $10^3$ (right) galaxies indicating the required sample size to locate key features. The WST has the capability to generate samples as large as $10^6$ galaxies that can be studied in subsets according to various physical properties. Credit: S. Zibetti.

■■■ without fundamentally new observational capabilities, can lead to transformative insights—a principle that strongly supports the case for the WST.

Over 24 years of operation, SDSS has collected and released spectroscopic data for more than 6 million galaxies (as of Data Release 17, published in December 2021). In contrast, the WST is expected to observe 300 million galaxies in just five years, representing a quantum leap in statistical power and marking a transformative step forward for large-scale galaxy spectroscopic surveys.

### The discovery space of the IFS

Unlike a MOS, which requires preselection of individual sources, the Integral Field Spectrograph (IFS) collects data from all sources within its field of view—whether compact or diffuse—without prior selection. This key property means that the IFS discovery space is proportional to the number of resolved spaxels (spatial pixels) in the instrument. It is also proportional to the number of resolved spectral elements measured simultaneously in each exposure.

The product of these two dimensions—spatial and spectral—is referred to as the number of resolved voxels, and serves as a useful proxy for the IFS's discovery potential. Naturally, the achieved depth for a given telescope time must also be considered, as well as the fraction of open-shutter telescope time during which the IFS is actively observing.

Assuming:

- A spatial resolution of 0.5 arcseconds;
- A spectral resolution of $R = 3\,500$ over the 0.37–0.97 µm range;
- 100% IFS usage during telescope time;
- 85% efficiency (open-shutter time vs total telescope time); and
- 1-hour exposures,

the total number of resolved voxels can be estimated as the product of the number of resolved spatial elements, the number of resolved spectral elements, and the total number of exposures collected over a 5-year survey. **We estimate that, over a 5-year survey, WST's IFS would collect an extraordinary 6.7 × $10^{12}$ resolved voxels.**

To provide context, we normalise this value using a similar calculation for MUSE over a 5-year survey, based on its instrumental parameters. Assuming 70% operational usage, 80% efficiency, and 2-hour exposures (to reach a similar signal-to-noise ratio as the WST), MUSE would collect approximately 1.5 × $10^{11}$ resolved voxels over the same period. **This** ■■■

**means that, relative to MUSE, WST would have a discovery power 45 times greater.**

Applying the same methodology to other instruments, we estimate that the relative discovery power of the WST is 1 500 that of KCWI at Keck and 90 times that of HARMONI on the ELT. These comparisons highlight the exceptional discovery potential of WST as a spectroscopic IFS survey machine.

The comparison with MUSE is particularly meaningful, as MUSE has proven to be by far the most scientifically productive instrument on the VLT over its 10 years of operation. But most importantly, among the 1 270 published papers, a significant fraction stem from unexpected discoveries—phenomena not anticipated in the original telescope time proposals. Moreover, this remarkable scientific output likely underrepresents MUSE's full discovery potential, due to the absence of advanced data analysis tools capable of automated source detection and cataloging.

In contrast, for the WST, the development and deployment of such tools will be an integral part of the facility's operational model, ensuring that its discovery space is fully exploited from the outset. One of the other key advantages of the WST IFS parallel observation mode is that it is always observing. When the telescope pointing is driven by the MOS, the IFS will simply observe random fields located at the center of the MOS field. Except when the telescope is pointed toward the plane of the Milky Way, most of these random fields will resemble the blank deep fields previously observed with MUSE. These fields have already proven to be scientifically rich, contributing to about one third of all MUSE publications (Roth M., 2024), with a significant portion of those results involving unexpected discoveries. This highlights the powerful potential of serendipitous science enabled by continuous parallel observations—a strength that is uniquely enabled by the WST.

## WST as a discovery spectroscopic time-domain machine

Thanks to the start of operations of Rubin/LSST, we can anticipate major breakthroughs in time-domain science over the coming decade. With up to 10 million events expected each night, the demand for spectroscopic follow-up will be immense. The WST is well positioned to play a critical role in addressing this challenge, significantly enhancing the scientific return of Rubin/LSST.

From the outset, WST's operational model will be designed to support time-domain science, a field expected to grow increasingly important in the coming decades. In addition to following up alerts from other facilities, the WST will be capable of generating its own alerts based on transient events identified through its spectroscopic observations. Survey strategies will include split exposures to enable revisits at defined cadences. For instance, deep-field observations will allow for numerous repeated measurements, while the wide-area survey—covering 300 million galaxies and 20 million stars in the Milky Way—will include at least three repeated observations across its full footprint.

Spectroscopic time-domain events represent a largely unexplored frontier. Certain phenomena, such as subtle changes in emission-line equivalent widths or slight wavelength shifts, may remain undetectable with the LSST alone. However, WST's vast spectroscopic sample offers a unique opportunity to uncover a fraction of these elusive events. We are therefore convinced that the WST offers a powerful and complementary discovery capability to Rubin/LSST, opening new windows into time-domain astrophysics. ■

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# “SUSTAINABILITY SHOULD BE TAKEN INTO ACCOUNT AS EARLY AS POSSIBLE”

## An interview with Laurane Fréour

One of the future challenges in astronomy is not only to look beyond our planet, but to look after it. Greenhouse gas emissions are a serious concern, and we know that astronomical research is responsible for non-negligible contributions. Over the past few years, ESO, ESA, and many other institutions have introduced initiatives to minimise their own impact. Since the start, the WST has incorportaed sustanaibility as an integral part of the project. We talk with Laurane Fréour, who is working for the work package on sustainability.

**Could you give us an overview of what is the environmental impact of astronomy and what is sustainability?**
As astronomers, we have a unique perspective on the Earth, its fragility, and the absence of a “planet B”. Yet, our carbon footprint remains substantial[1]. Research infrastructures alone account for 36 tonnes of $CO_2$ per astronomer per year[2], nearly 18 times the Paris Agreement’s 2050 target of two tonnes of $CO_2$ per person per year. This number is roughly equivalent to eating 1 kg of beef every day or 14 round-trip flights from Vienna to New York. Research infrastructures are therefore the main contributors to our carbon footprint. We thus not only have the opportunity but the responsibility to lead by example in the greening of our research practices, to “*meet the needs of the present without compromising the ability of future generations to meet their own needs.*” This is the definition of sustainability provided by the United Nations Brundtland Commission in 1987.

There are three pillars to sustainability: economy, society, and ecology. They are interconnected: the economy should be a tool for society to prosper, which is only possible if society evolves together with the environment on which it relies. When talking about environmental sustainability, we often focus on the carbon footprint. However, the environmental aspect of sustainability is much broader, encompassing, for instance, water consumption, resource use, and more. And that’s what we try to evaluate within the WST consortium.

**How does the WST plan to minimise its environmental impact during its construction and operation?**
Given the early stage of the project, we are currently focusing on a few areas noted as potential environmental “hotspots”, such as the systems to cool the detectors, the data centres, and other hardware, which will be needed to process the data generated by the instruments, or the site selection for the construction. By identifying these hotspots early, we can already start influencing design decisions and choices to ensure that sustainability is taken into consideration.

Laurane is a postdoctoral researcher at the University of Vienna, working on the sustainability of the Wide-field Spectroscopic Telescope.

**How can we ensure that a project is sustainable? Are there specific criteria that the WST aims to meet?**
A first step in ensuring that a project is sustainable is to evaluate its (potential) impact. Regarding environmental sustainability, this can be done by carrying out *Life Cycle Assessments* (LCAs), which evaluate the environmental impact of a project throughout its lifecycle (raw material extraction, construction, operation, etc.). This has already been done in constructed telescopes[3]. To maximise the sustainability of a project, such an analysis should be taken into account as early as possible, for

instance, during the concept study, as we will try to do with the WST. In that way, environmental sustainability can be used as a trade-off parameter, together with technical requirements and cost.

**What are the biggest obstacles, and what do you find most stimulating?**
Interestingly, the biggest obstacle is also what I find most stimulating. We are at a very early stage in the project and are missing a lot of data to carry out a proper LCA analysis on the full telescope. This is both challenging and exciting, as this means that design choices remain open and that sustainability can be used as a trade-off parameter. Another thing that I find really stimulating is the multitude of experts involved in the consortium, and with whom I am regularly interacting. My position requires understanding the technology behind the telescope and the instruments through regular exchanges with the engineers, as well as good communication skills and a solution-oriented mindset.

**How do you decide what to compromise on and what not to?**
That is definitely a hard question! There are some aspects on which we can’t compromise because of the highly innovative and technical nature of the WST, which requires cutting-edge technology, such as optical systems. There are other aspects where sustainable considerations can lead to more economic solutions in the long term, like minimising the energy and water consumption of cooling systems and data centres, and that’s one of our current focuses.

**What inspired you to embark on this area of research?**
During my PhD Thesis, I studied globular clusters, among the oldest star clusters in the universe. I am passionate about astronomy, but I am also well-grounded. In a world that is increasingly more divided, where the 1.5% of the richest grab 47.5% of the total wealth[4], where about 2.33 billion people were facing moderate or severe food insecurity in 2023[5], I kept wondering what our role is as astronomers and as teachers in this context of social and climate crisis. That’s something that I decided to tackle in my PhD Thesis, which has an interdisciplinary dimension. I believe in the unifying power of astronomy and the beauty of the Earth shared from our perspective as mobilising narratives. But I think that this message can only be taken seriously if we reassess our own practices. I have an engineering degree too, so it seemed like a logical step for me to continue in this area of research, on the environmental impact of research infrastructure.

**From a community perspective, how important is sustainability perceived to be within the astronomical community?**
There are growing concerns regarding the climate crisis within the astronomical community. That’s good, but still insufficient to trigger a change in our practices. Gokus et al.[6] found that the total distance travelled by astronomers in 2019 was roughly 1.5 times the distance between the Earth and the Sun. To this astronomical number, we must also add the carbon footprint of our research infrastructures and the environmental cost of data centres and supercomputing. Sustainability considerations are not a top priority on the agenda of astronomers right now. In this context, institutions like ESA or ESO have a role to play as a change catalyst. Sustainability has, for the first time, been made an explicit criterion by ESO in the planning of next-generation facilities (the *Expanding Horizons* call). That’s very encouraging! International societies like the EAS should also be at the forefront of the sustainable transition, by, for instance, pushing for a fully online annual meeting. These online formats for big conferences are not only more sustainable but also more affordable, inclusive, and accessible. They can be as engaging as in-person conferences if they make use of innovative platforms that enable lively interactions rather than relying solely on traditional video calls.

**Can you recommend any online resources on the topic of sustainability in astronomy to an interested reader?**
I can recommend joining Astronomers for Planet Earth (A4E, a4e.org) and/or checking their website. A lot of resources are publicly available there, whether it is to learn about climate science, to communicate and teach about climate, or to understand the environmental impact of our profession. Personally, I joined A4E three years ago and got increasingly active within the community. Regularly connecting with colleagues sharing similar concerns, resources, and proactively discussing actions and solutions is incredibly rewarding both personally and professionally.

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# UNVEILING THE COSMIC WEB WITH THE WST

The large-scale distribution of matter in the Universe forms a complex network of structures, often referred to as the cosmic web. This web spans an enormous range of densities, from the most massive clusters of galaxies, where matter is tightly bound by gravity, to the most underdense regions known as cosmic voids, characterized mostly by empty space. Mapping these structures and understanding how they evolve will provide crucial information to address pressing open questions in cosmology and astrophysics. It will allow us to test theories of structure formation, study how galaxies' evolution is affected by different environments, and also place stringent constraints on dark matter, dark energy, and elusive particles such as massive neutrinos. Achieving this requires a facility capable of measuring distances and physical properties for an unprecedented number of galaxies across cosmic time. The Wide-Field Spectroscopic Telescope (WST) is conceived precisely to meet this challenge.

The unique strength of the WST lies in its ability to probe the full density spectrum of the cosmic web. Its spectral coverage (0.37–0.97 microns) allows it to probe the local Universe as well as galaxies at redshifts beyond four, thus following the growth of structure over more than 12 billion years of cosmic history. Furthermore, the dual approach of a multi-object (MOS) and an integral-field spectrograph (IFS) ensures both statistical power and detailed studies of dense regions and serendipitous sources. Two redshift surveys will allow us to span a wide range of cosmic times: the legacy low-z survey targeting multiple tracers at $z<2$, and the high-z survey, pushing the limit up to $z\sim7$ with Lyman-alpha emitters (LAE) from the Lyman-alpha Parallel Survey, as shown in Figure 1.

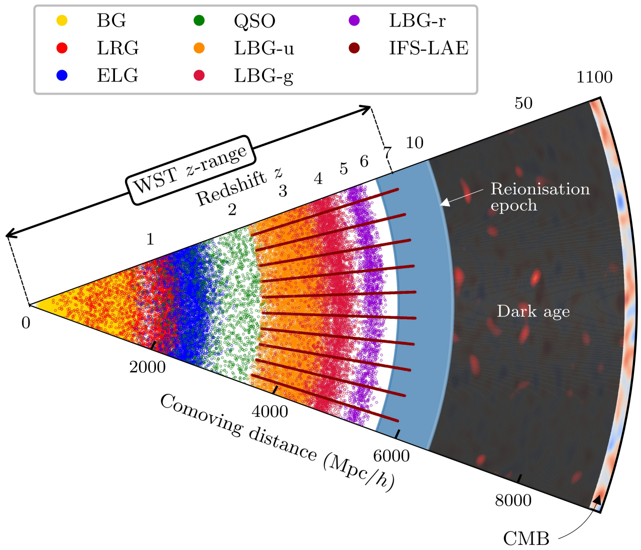

**Figure 1:** Schematic light-cone representation of the WST Cosmology Surveys. The WST's unique feature is its capacity to probe large-scale structures with galaxies in the redshift range $2 < z < 7$. The MOS-LR targets will probe the range $0 < z < 5.5$, while the IFS will probe thousands of pencil beams with LAEs up to $z \sim 7$. Figure from Mainieri et al. 2024.

In galaxy clusters, it will measure the dynamics of thousands of galaxies per system, providing precise estimates of cluster masses and insights into the processes that quench star formation in dense environments. Thanks to its dual-instrument design, which combines MOS and IFS, the WST will simultaneously probe both the cores of clusters and their extended outskirts. The IFS will provide detailed, contiguous coverage of central regions, capturing the complex dynamical interactions, mergers, and feedback processes that occur in the densest environments. The IFS will also measure the redshifts of numerous strongly lensed galaxies behind the cluster providing a precise mapping of the Dark Matter. The MOS, with its ability to target tens of thousands of galaxies over larger areas, will map the external parts of clusters and the infall regions where galaxies are being accreted. This combination will allow, for the first time, a comprehensive dynamical picture of clusters, from the virialized inner cores to the outskirts where the

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environment begins to influence galaxy properties. Such observations are essential for calibrating clusters as cosmological probes, measuring their total masses, and constraining the growth of structure as predicted by different models of dark matter and dark energy.

In filaments and sheets, the WST will trace the flow of galaxies and matter across vast regions of the cosmic web. Filaments are the channels through which galaxies and gas feed clusters. By mapping galaxies along these filaments in three dimensions, the WST will reveal how matter accretes onto clusters and how galaxy evolution is shaped by anisotropic large-scale environments. Moreover, filaments are particularly sensitive to the nature of Universe's components: their thickness, internal structure, and connectivity patterns depend on how dark matter clusters on small scales, and on the total sum of neutrino masses, as shown in Figure 2. The WST's precision mapping of filaments will therefore offer new constraints on whether dark matter is cold, warm, or exhibits self-interactions.

The vast void catalogues built by the WST will complement these studies by probing the underdense end of the cosmic density spectrum. Given that cosmic voids typically span tens of megaparsecs, obtaining a statistically significant catalogue requires surveying vast regions of the Universe while preserving high spatial resolution, to accurately trace even the most underdense environments, which are naturally poor in cosmic tracers (e.g., galaxies or galaxy clusters). The WST survey satisfies both of these conditions by covering a wide area of the sky with unprecedented depth, thereby sampling unprecedented large cosmological volumes, and maintaining a high tracer density across a broad redshift range. Thanks to these characteristics, we can obtain precise information on void shapes, dynamics, and abundance, as well as direct access to

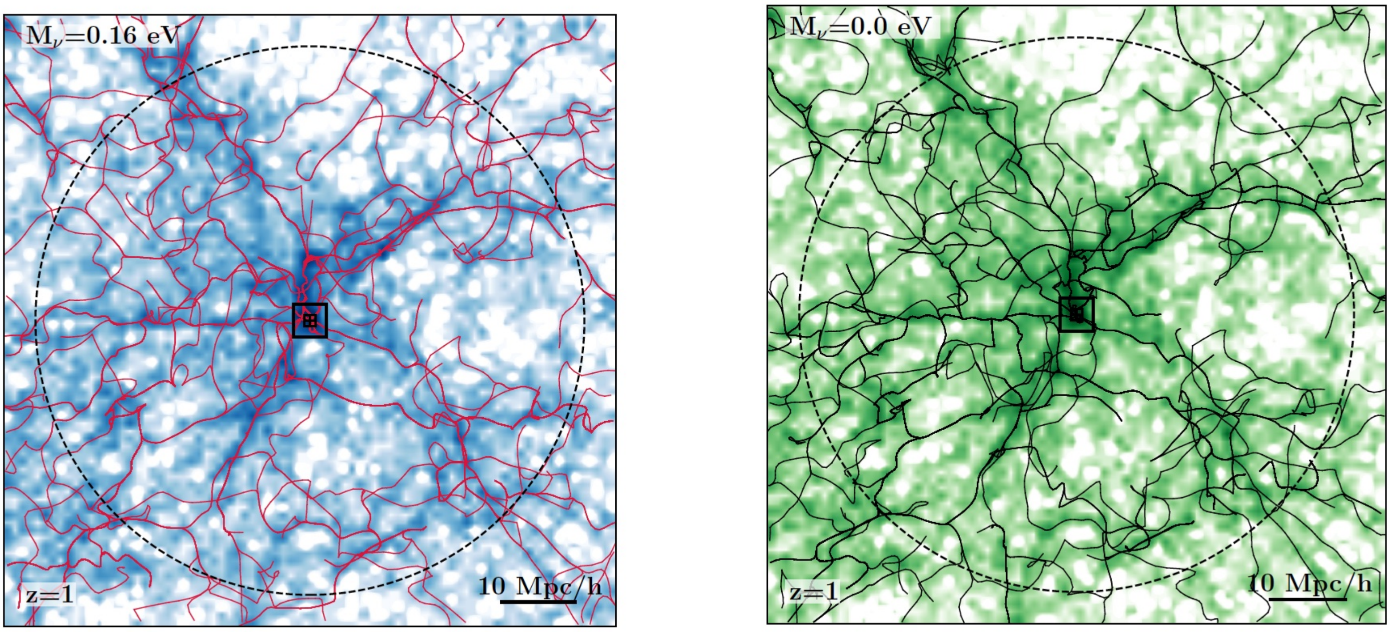


**Figure 2:** Simulated massive clusters from the DEMNUni simulations. The two clusters are generated with the same properties (massive cluster at $z$=1 in a 40 $h^{-1}$ Mpc thick slice), but different total neutrino masses (0.16 and 0 eV in the blue and green distributions, respectively), showing the different filamentary structure generated in the two cosmologies. The circle and square in the middle represent the MOS and IFS footprints, respectively. Figure from Mainieri et al. (2024).

the properties of the isolated galaxies residing in their interiors. For example, we expect that the cosmological constraints derived from the modelling of the void size distribution will be significantly tighter than those previously obtained with the last data release of the Baryon Oscillation Spectroscopic Survey (BOSS) and those forecast for *Euclid*, even when considering only the WST's void population at $z < 1.5$ (see Figure 3).

Owing to their different sensitivities to dark matter, dark energy, neutrinos, and the growth of structure, the simultaneous study of galaxy clusters, filaments, and voids can fully exploit the complementarity of these cosmic structures. This joint analysis provides exceptionally tight combined constraints, capable of breaking intrinsic parameter degeneracies within the standard cosmological model, while also opening a new window to the exploration of alternative cosmologies such as modified gravity, evolving dark energy, and primordial non-Gaussianities.

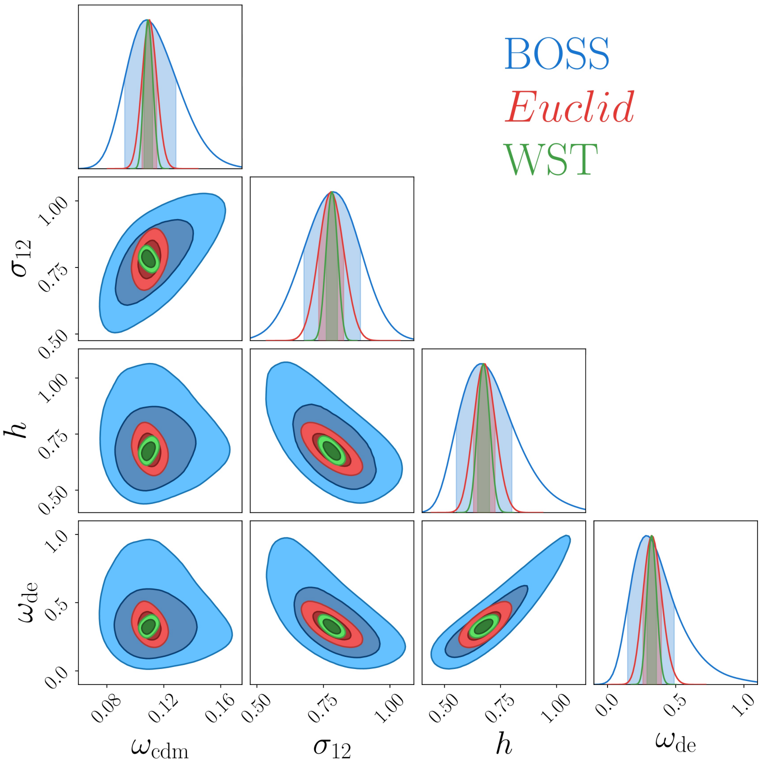


**Figure 3:** Confidence contours for the main ΛCDM parameters obtained with BOSS data (blue), compared with cosmological forecasts for a Euclid-like survey (red) and for WST (green). The relative improvement in constraining power is about 65% when moving from BOSS to Euclid, and about 45% from *Euclid* to the WST. We highlight, however, that the WST forecasts are derived considering only cosmic voids expected at $z<1.5$, thus not fully capturing the potential of the survey.

With the WST, we will produce the most comprehensive map of the cosmic web ever constructed, extending from the richest galaxy clusters to the emptiest voids. This map will contained 480 million of galaxy redshift at $z<2$, and more than 130 million galaxies in the redshift range $2<z<7$. It will not only describe the spatial distribution of matter but also capture its evolution, providing direct measurements of how structures grow under the influence of dark matter, dark energy, and massive neutrinos. At the same time, the enormous spectroscopic database will revolutionise our understanding of galaxy evolution across environments and cosmic time. The WST thus represents a transformative step for observational cosmology: a facility capable of turning the cosmic web into a laboratory for fundamental physics, where the densest and most rarefied regions of the Universe can be studied within a single, coherent framework.

# THE WST AT THE EAS 2025

A Special Session (SS7) dedicated to the WST was held on June 23rd at the annual European Astronomical Society meeting in Cork (Ireland). The aim of this special session was to inform the astronomical community on the development of the WST project and further involve them in shaping what will be a key facility in the 2040s. The meeting was very well attended and included 17 talks, between invited and contributed, covering the broad range of science that such a facility will be addressing.

The opening talk was given by Roland Bacon, the coordinator of the recently approved Horizon concept study, who summarised the scientific motivation of this new facility and gave a general update on the significant progress made on the design of the WST. It was followed by two presentations: by Annagrazia Puglisi, describing the effort made to embed equity, diversity and inclusion principles in the WST collaboration, and by Bodo Ziegler on the special attention devoted by the project on environmental impact and long-term sustainability.

The remaining of the meeting was then dedicated to cover the very wide range of science in the WST domain with multiple invited and contributed talks: time domain astrophysics (review by Richard A. Anderson), galactic science (review by Vanessa Hill), extragalactic astrophysics (review by Jorryt Matthee), and cosmology (review by Jean-Paul Kneib).

The meeting was concluded by a discussion with a panel of experts (Anja Anderson, Sarah Bosman, Cristina Chiappini, Laurent Eyer, Kyle Dawson, Silvia Piranomonte) moderated by Vincenzo Mainieri. The presentations and the discussion at this special session strongly supported the need for the WST to achieve transformational progresses in multiple scientific areas.

# SCIENCE FACE-TO-FACE MEETING

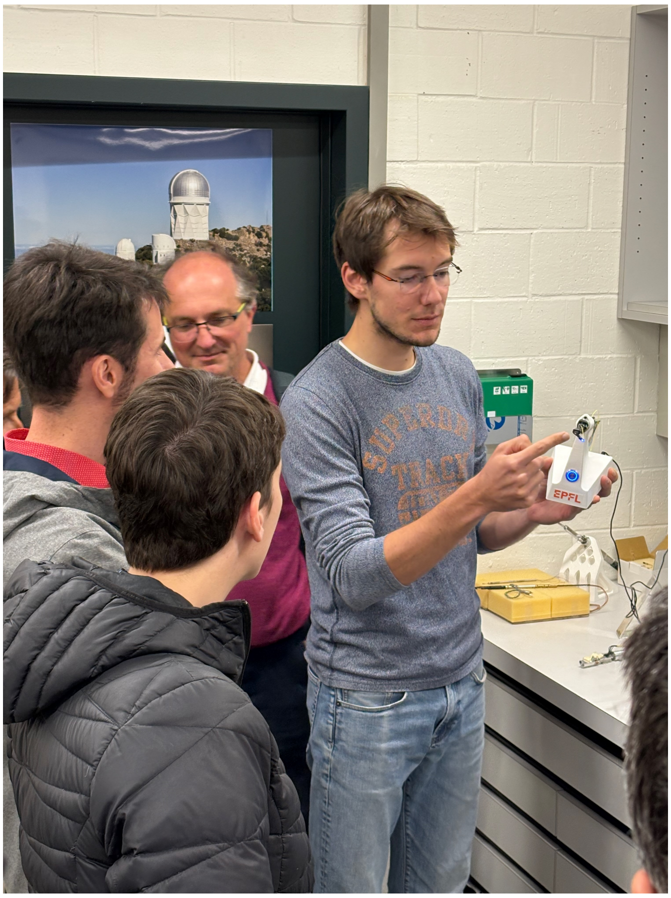
On October 1 and 2, the leaders of the five science working groups (cosmology, extragalactic, galactic, resolved stellar populations and time-domain) and the survey plan work-package met at EPFL in Lausanne for a face-to-face meeting. This follows the previous face-to-face meeting hold at ESO in March of this year. The science working groups have been very active in the past months to further develop the science drivers for WST, with a particular focus on science questions that cannot be addressed with current (or planned facility) and will remain key in the 2040s. This started from a critical revision of what was presented in the WST White Paper, and expanded to consider new exciting science areas on which the WST will have a transformational impact. The rich set of science cases discussed at the meeting clearly showed emerging overarching broad questions that the WST will be uniquely positioned to address.

Another important topic discussed at the meeting are the strong synergies that the WST will have with other major facilities, for example with SKA to understand the sources of cosmic reionisation, or with the third generation of gravitational wave detectors (such as the Einstein Telescope) to understand the physics of kilonovae and use gravitational waves as a new cosmological probe.

It is essential that the science ideas developed by the working groups are submitted to the call for white papers issued by ESO in the framework of the Expanding Horizons initiative (submission deadline on December 15th).

Finally, the meeting also included a visit to the laboratories of the Astrobots Group, devoted to the development of optical fibre positioner robots for future astrophysics instrumentation.

We thank Jean-Paul Kneib, Mark Sargent, Sebastien Pernecker and colleagues at EPFL for the organisation and hospitality.



# “THE WST IS AN AMBITIOUS FACILITY WITH A BIG POTENTIAL”

## An interview with PhD student Sofia Bisero

**When did you first join the WST, and what motivated you to get involved?**
I joined the WST project during the first year of my PhD, at the beginning of 2023. It was an interesting opportunity, since Integral Field Spectroscopy (IFS) and Multi-Object Spectroscopy (MOS) have not been highly explored in time domain astronomy before, and they could be pivotal, particularly in the era of the third generation gravitational wave interferometers, for multi-messenger astronomy, that is the focus of my PhD research. In this context, I carried out simulations of WST observations.

**Could you briefly describe your research interests and how they connect to your role in WST?**
My research is focused on the electromagnetic (EM) counterparts of gravitational wave events. Multi-messenger astronomy with gravitational waves (GW) is an emerging field, with the main bottleneck currently lying on the GW detection side, since today the detection rate of binary neutron stars (BNS) mergers is low. With the next-generation gravitational wave interferometers, the number of BNS detections will dramatically increase, and the bottleneck will shift to the search for the electromagnetic counterparts. Facilities like the WST could be pivotal in realising the immense potential of BNS multi-messenger observations, thanks to its large field of view, high sensitivity, and high multiplexing. Therefore I am studying the impact of the WST IFS and MOS on this research.

**In your view, what are the most exciting ways in which the WST could transform time-domain astronomy?**
My answer is somehow shaped by my research interests, but one exciting opportunity is WST enabling the systematic discovery and follow-up of kilonovae — rare, faint, and fast-evolving transients linked to neutron star mergers, whose spectra carry signatures of heavy element nucleosynthesis via the r-process, thought to be responsible for forming elements heavier than iron, such as gold and platinum.

**How does the WST compare to other facilities used for time-domain science?**
I think telescope-level Target of Opportunities (ToOs), combined with such a high degree of multiplexing, represent a real innovation in time-domain astronomy.

**How has working within the WST contributed to your growth as a researcher so far?**
Contributing to the White Paper and in co-writing the binary neutron star merger multi-messenger science case made me realise the level of coordination effort and attention to details required at every step of developing such a large and ambitious project.

**In your experience, is there space for young scientists to play an active role in WST?**
Absolutely! I could actively contribute through my simulation work to the White Paper, and I now co-coordinate the multi-messenger subgroup. I feel that responsibilities and opportunities are also given to junior researchers, and that my voice is heard.

**Time-domain astronomy often relies on synergies between different facilities. How has it been for you to work at the intersection of two different communities?**
It is challenging because the organisation of the communities, as well as approaches to data and source modeling, differ. At the same time, it is very inspiring to see how differences are enriching, and talking with people working in different areas and collaborating toward common goals is highly motivating.

**Finally, what excites you most about being part of the WST?**
I find the WST to be an ambitious facility with a big potential, and I feel the enthusiasm in this growing collaboration, of which I am very happy to be part. The fact that time-domain science has been included from these very early stages is particularly exciting. ■

# THE WST OPERATIONS

The Operations work-package is responsible for developing the science-driven operational concept and the data flow architecture required to deliver the WST ambitious scientific program. It defines how the WST will function, from survey design and scheduling, through data reduction and analysis, to long-term archiving and community access. Its central goal is to ensure that the WST can operate sustainably, with the flexibility to execute multiple surveys simultaneously and provide science-ready data products of the highest quality.

The first priority is the development of the **Science Operational Concept.** This framework must enable efficient simultaneous use of multi-object spectroscopy (MOS) and integral-field spectroscopy (IFS), despite their differing exposure cycles and calibration frames. The operational concept will be natively conceived with a time-dependent mindset, explicitly accommodating the requirements of time-domain variability, thereby making the system truly transformational.

A critical product is the **Facility Simulator**, a prototype survey planner and target allocation tool to be used by the Survey Plan work package. This code will be developed to balance efficiency across multiple simultaneous surveys, some MOS-driven and some IFS-driven, also retaining flexibility to implement “last minute” adjustments for Targets of Opportunity and time-variability programs. This balance between efficiency and flexibility is central to WST' scientific mission.

**The Science Data Flow** is another Operations cornerstone. A high level of efficiency must be maintained to deal with the daily cycle of observations: raw data must be transferred, processed, and quality-checked in parallel with the acquisition of new observations. This becomes particularly demanding for time-domain science, which ■■■

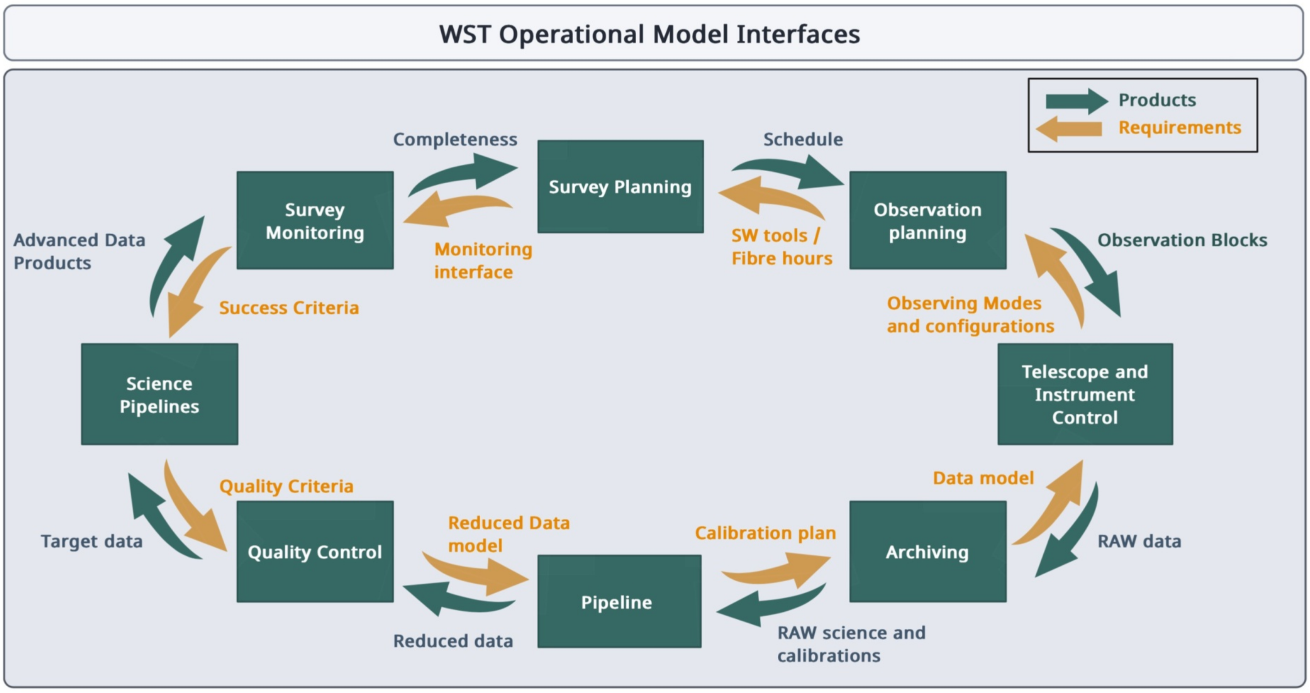


Image courtesy of Oscar Gonzalez.

■ ■ ■ requires rapid data turnaround and automated alerting.

**MOS and IFS data reduction and analysis pipelines** are therefore a major focus. Existing frameworks from existing facilities will be critically reviewed, but new developments will be essential at the WST scale. Beyond pipeline design, we will explore new approaches to data analysis, including data mining and machine-learning techniques, to maximize the scientific return from the unprecedented data volumes.

The **archive and data management system** will be designed to store millions of spectra and datacubes in a sensible, accessible way. Metadata tracking and quality control must be embedded throughout the data flow, ensuring compliance with FAIR principles and Virtual Observatory standards. The expected scale of WST data products makes this a non-trivial challenge: telescope telemetry, monitoring data, and potential alert systems could substantially increase the already huge data volumes.

Underlying all of these tasks are the constraints of **computing and sustainability**. The common assumption that “computing is cheap” is no longer valid; power consumption, data movement, and hardware costs must be carefully managed. Trade-offs between on-site processing, remote data centres, and near-archive reduction will need to be evaluated, striking a balance between efficiency and energy footprint, as brute-force solutions may no longer be viable in the 2040+ era. At the same time, advances in artificial intelligence are likely to transform operations, from data reduction and analysis to adaptive survey scheduling, offering both new capabilities and opportunities to mitigate computational costs.

The WST will generate a data volume far exceeding that of any existing ESO instruments, ushering ESO into the era of big data; the challenges dealing with such an amount of data are substantial. Nevertheless, by leveraging the lessons of current survey facilities, critically reviewing existing methods, and pioneering innovative approaches, we will define a robust operational model that will allow the WST to transform raw photons into high-quality, science-ready products to deliver an unprecedented spectroscopic legacy for the astronomical community. ■

The Operations face-to-face meeting will be held in Milan on November 18th and 19th. Anyone interested in participating (both in person or online) can register using this online form.

# WST TELESCOPE AND INSTRUMENTS PROGRESS MEETING

The first in person WST telescope and instruments progress meeting took place on 16th to 20th June 2025, kindly hosted by ESO in Garching. The purpose of the meeting was to bring the team together to report on progress, develop design ideas and to enable networking and collaboration.

The meeting began with an introduction from Roland Bacon followed by news updates from the Science and Operations Teams. Laurane Fréour presented an overview of WST's sustainability activity and explained what factors should be considered during the lifetime of WST. Most of the meeting was allocated to presentations by the telescope and instrument teams, with plenty of time for questions, general discussions, and more focussed splinter meetings. Of course, the WST dinner was another great opportunity for further enthusiastic discussions!

During the final day of the meeting all participants were given the opportunity to provide feedback on what went well and areas for improvement. Further work is needed to define requirements and interfaces and to facilitate communication. Overall, the meeting was considered very successful, generating new design ideas, raising awareness of outstanding design tasks, and facilitating planning.

Members of the LRMOS, HRMOS and Advanced Technology teams discussing spectrograph design possibilities. Several new designs were presented, including an innovative folded Schmidt camera made with solid glass.

Members of the fibre positioners design teams discussing the list of trade study parameters, such as multiplex and patrol field, that will be used to select the positioner design for the WST. The trade study meeting will take place in February 2026.

Philippe, Roland, and Vincenzo watching Corentin's presentation on the IFS spectrograph.

# “ To WORK ON A BLANK SLATE IS A PRIVILEGE ”

## An interview with Gaston Gausachs, mechanical engineer

**Tell us a little about you.**
I was born and grew up in a small city in north-east Quebec called Sept-Iles. On top of experiencing the cold harsh winters in this corner of the world, I was also lucky to witness the aurora borealis that would occasionally colour the night sky. My university years were spent in Chile where my family is originally from and this is also where I got my first job working at the Gemini Observatory.

**What did you do at Gemini?**
At the 8m Gemini South Telescope, I was performing mechanical engineering work in support of day time operations and instrumentation design. For over 10 years, I honed my engineering skills both on site and at the design board, working on various instruments such as *GSAOI, CANOPUS,* and *GPI*.

**But you have now moved, haven't you? Where do you now work?**
Wanting to explore the world a bit further, I decided to move to Australia while continuing to work in the same field. I work at the Research School of Astronomy and Astrophysics, ANU, in Canberra, Australia, where I lead the mechanical engineering group. The group has increased in size in recent years to support a large portfolio of ground-based astronomy and space related engineering projects.

**Anything particular you worked on?**
Soon after joining the ANU in early 2016, I was tasked to deliver the mechanical engineering design for *Veloce*, a high-precision radial velocity spectrograph, installed at the 4m Anglo Australian Telescope, located at Siding Spring Observatory. Furthermore, the insight gained at Gemini has been key to my work designing large portions of MAVIS, an instrument currently undergoing Final Design Review with ESO and designed for Yepun at the Very Large Telescope.

**What is your role in the WST project?**
ANU is responsible for two sub-work packages—WP3.4 - Telescope Structure and WP3.5 - Enclosure—and my role has been to prepare the early mechanical engineering designs for both. This work is done in close collaboration with the optical designer to ensure an optimum transfer of the light through the telescope and all the way to the instruments.

**What is your particular interest in working on the WST project?**
The chance to work on a blank slate of the optical beam is always a privilege from an engineering point of view. While the major requirements are already dictated from the type of science and choices made for the larger optics, the vast majority are yet to be defined and this creates and interesting challenge in itself.

**Can you say something more about the mechanical engineering of the telescope and enclosure?**
While the telescope is definitely not competing in size with the current giants being built, the challenges are real when considering the large amount of spectrographs in the IFS and MOS stations. There is a considerable amount of work required to adequately determine the energy consumption and dissipation inside the enclosure. The telescope borrows many design elements and cues from the E-ELT, for example the M1 segments and cell geometry. A particular design complexity lies in the layout of the IFS relay path as it folds the optical beam under the azimuth platform before directing it down inside the telescope pier.

**What are the greatest challenges you are facing in this project?**
Every opportunity where the team has met in person has been a highlight during this project. In contrast, the main difficulty, coming from being down under (in Australia), is the distance and time zone difference with Europe.

**What do you think makes the WST unique?**
The enthusiasm everyone displays to collaborate and progress the design definitely makes this project a rewarding engineering experience. ■

# EVOLUTION OF THE ESO FLAGSHIP TELESCOPES AND THE WST

It is insightful to place the WST within the broader context of the evolution of ESO's flagship optical telescopes. By "flagship," we refer to the major programs into which the organisation has invested the majority of its resources, excluding smaller telescopes that, while contributing to ESO's success, operate on a different scale. These flagship telescopes—namely the 3.6m, the four Unit Telescopes of the Very Large Telescope (VLT), and the Extremely Large Telescope (ELT)—have played a central role in shaping ESO.

As illustrated in the attached figure, from the founding of ESO and the first light of the 3.6m in La Silla in 1977 to the expected first light of the ELT in 2029, the past 50 years have witnessed a remarkable two-orders-of-magnitude increase in both telescope aperture (a factor of 5 and 120 for the VLT and ELT, respectively) and spatial resolution (from 1 arcsecond with EFOSC on the 3.6m to 50 milliarcseconds with MUSE-NFM on the VLT, and an anticipated 5 milliarcseconds with MICADO on the ELT).

In contrast, other key observational parameters—field of view and multiplex—have not followed the same growth trend. While the field of view expanded from 5 arcminutes with EFOSC2 on the 3.6m to 22 arcminutes with MOONS on the VLT, it will shrink again for the ELT, with a maximum of 7 arcminutes available for MOSAIC. This limitation arises naturally from the conservation of étendue, which makes achieving wide fields increasingly difficult as telescope aperture increases. It is worth noting that the increase in field of view between the 3.6m and the VLT was enabled by the development of large-format detectors and the ability to host large instruments on the VLT's Nasmyth platforms—factors that effectively compensated for the VLT's fivefold larger étendue compared to the 3.6m. A similar pattern appears in the multiplexing capability—the number of objects that can be observed simultaneously. From 10 with EFOSC2 to 1,000 with MOONS on the VLT, this number is expected to drop to just 300 with MOSAIC on the ELT.

**The WST proposes a shift in paradigm.** Rather than pushing further in aperture and spatial resolution, it targets dramatic improvements in field of view (2 degrees) and multiplexing (30,000), while still offering twice the aperture of the VLT and maintaining solid spatial resolution (0.5 arcseconds). This exploration of a new region of parameter space promises transformative science and offers strong complementarity to the ELT's massive aperture and ultra-high resolution. With its broad scientific scope and strong synergies with other large facilities (e.g., Rubin, Euclid, Einstein Telescope, SKAO), the WST fills a crucial gap in the global portfolio of large-scale research infrastructures. Its unparalleled survey capabilities position ESO to fully embrace the Big Data era. ■