ING press release
12 December, 2022

WEAVE First Light

The Isaac Newton Group of Telescopes (ING) and the WEAVE instrument team present first-light observations with the WEAVE spectrograph. WEAVE is a powerful, next-generation multi-fibre spectrograph on the William Herschel Telescope (WHT) at the Observatorio del Roque de los Muchachos (La Palma, Canary Islands), now being commissioned on-sky and already generating high-quality data.

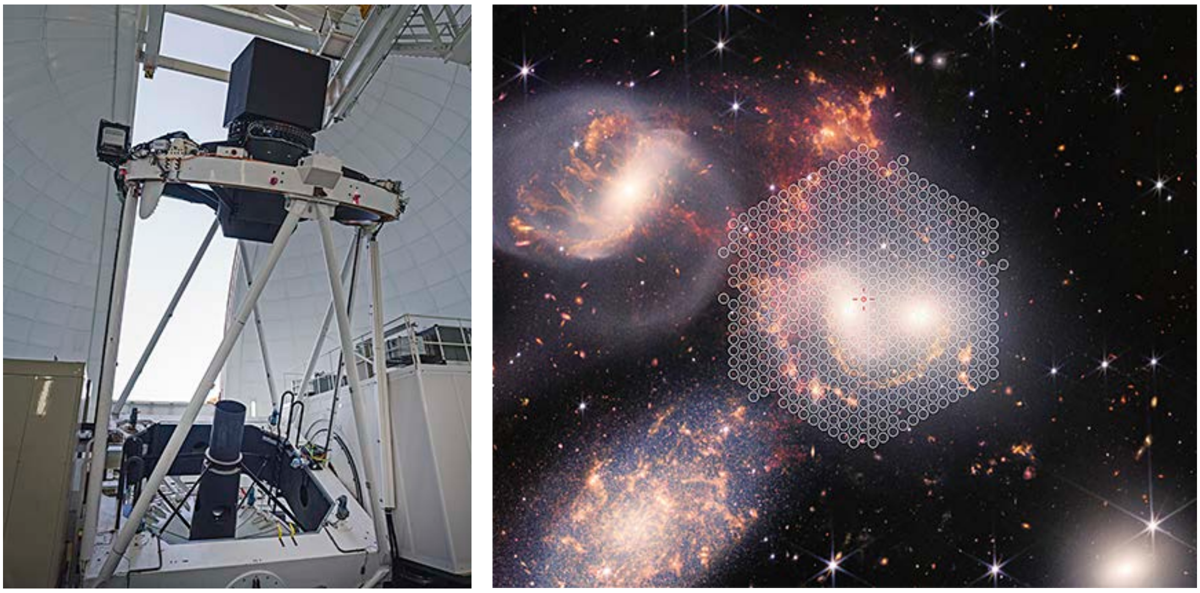
First-light observations were carried out with its large integral-field unit (LIFU) fibre bundle, one of WEAVE's three fibre systems. When using the LIFU, 547 closely packed optical fibres transmit the light in a hexagonal area of the sky to the spectrograph, where it is analysed and recorded.

The LIFU was aimed at NGC 7318a and NGC 7318b, two galaxies at the heart of Stephan's Quintet, a group of interacting galaxies. It's been observed with Hubble, Spitzer, Chandra and many other telescopes, and recently by JWST. It's also famous for its cinematic role in the 1946 Christmas film *It's a Wonderful Life*. The group, 280 million light-years from Earth in the constellation Pegasus, is undergoing a major galaxy collision and provides a natural laboratory for the consequences of galaxy collisions on the evolution of galaxies.

Marc Balcells, ING Director, explains: "Our goal was to host a unique instrument that would allow astronomers to carry out cutting-edge astronomical research. It's been fantastic to receive generous financial support from the national research agencies in the three partner countries, as well as contributions from non-ING countries. We are now happy to show that the LIFU part of WEAVE not only works, but produces high-quality data. The ING telescopes will continue to provide results of high scientific impact for years to come. We expect soon to announce subsequent first-light events for the other observing modes, now undergoing their own final tuning and calibration."

Gavin Dalton, WEAVE's Principal Investigator said, "The wealth of complexity revealed in this way by a single detailed observation of this pair of nearby galaxies provides insights into the interpretation of the many millions of spectra that WEAVE will obtain from galaxies in the distant Universe, and provides an excellent illustration of the power and flexibility of the WEAVE facility."

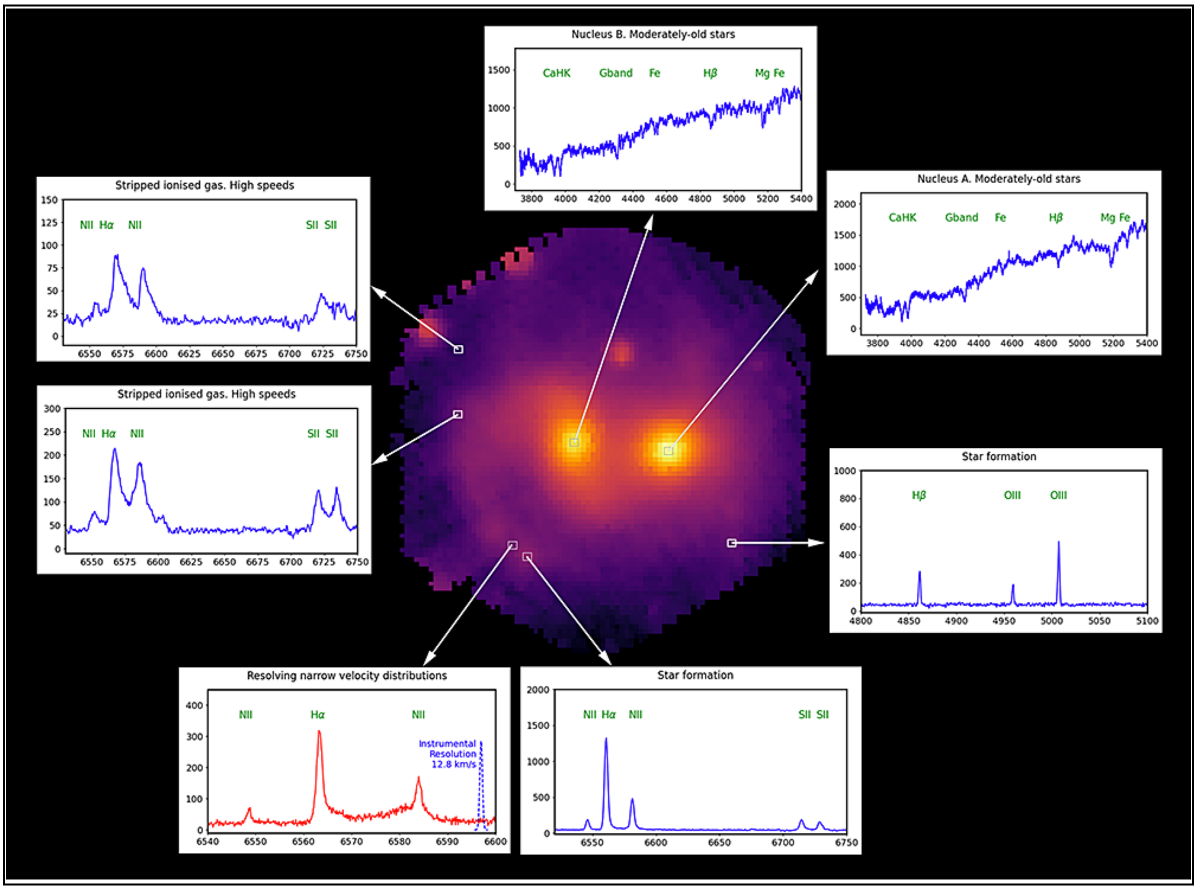
Scott Trager, WEAVE's Project Scientist: "These observations show the power of WEAVE to unravel the complex phenomena involved in the evolution of galaxies throughout the history of the Universe. The more than 500 members of the WEAVE Science Team and the members of the wider ING community will certainly make great discoveries with WEAVE's exciting new capabilities."



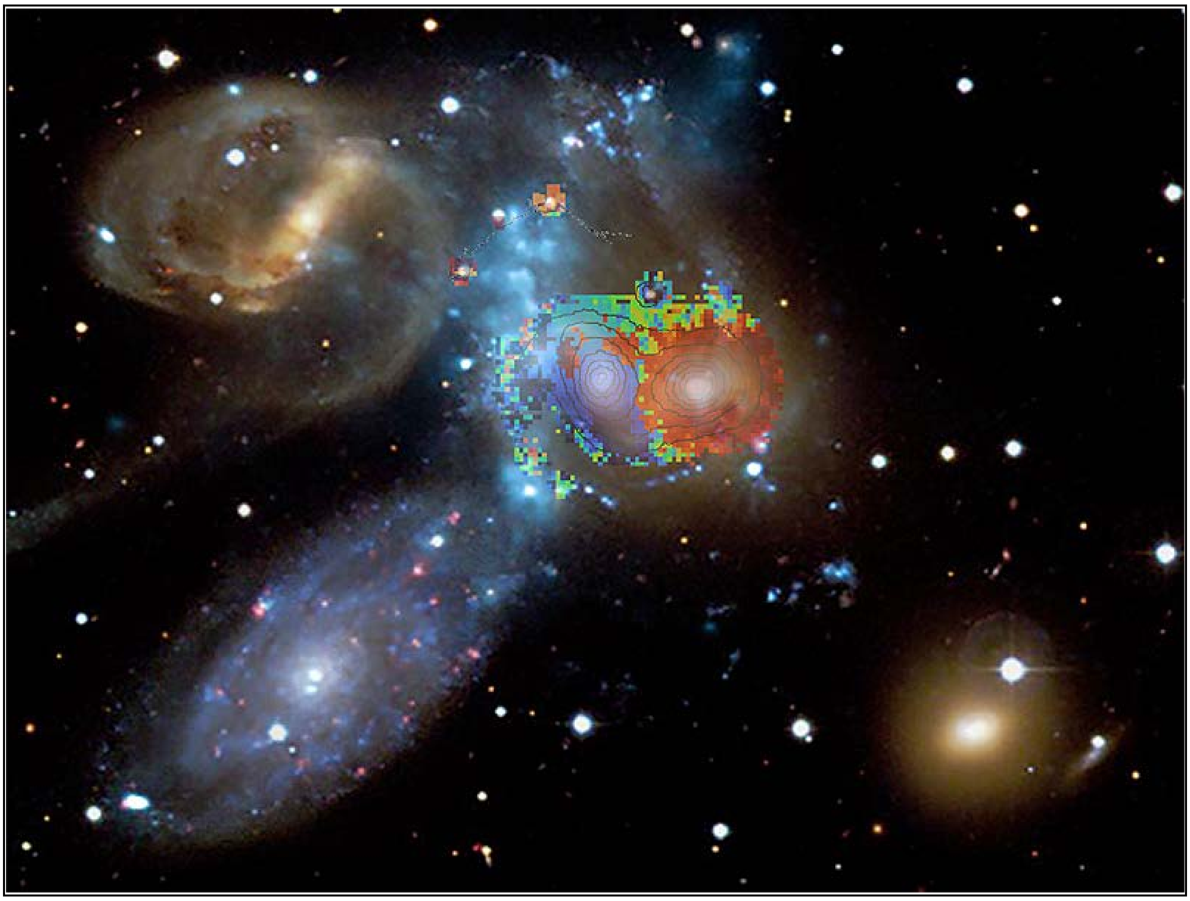
Left: The William Herschel Telescope with WEAVE. The WEAVE positioner is housed in the 1.8-metre black box above the top-end ring. Optical fibres run along the telescope structure to the enclosure on the left, which houses the WEAVE spectrograph. Credit: Sebastian Kramer. Large format: PNG. Right: The JWST image with the WEAVE LIFU pointing at Stephan's Quintet for the first-light observation. The LIFU gathers light from 547 points on the sky for analysis by the WEAVE spectrograph (each circle indicates an optical fibre 2.6 arcseconds in diameter). The observation provides physical information from each separate region of each galaxy as well as their immediate environment, covering 120,000 light years from top to bottom. Credits: NASA, ESA, CSA, STScI (background image); This composite has made use of "Aladin sky atlas" developed at CDS, Strasbourg Observatory, France. Large format: PNG.

About the First-Light Observations

The WEAVE LIFU measures separate spectra for 547 different regions of the two galaxies and their vicinity, recording the colours of their light from the ultraviolet to the near-infrared. These spectra reveal the motions of stars and gas, the chemical composition of the stars, the temperatures and densities of the gas clouds, and more. From these data, astronomers can learn how galaxy collisions transform the galaxies in the group.



The advantage of the LIFU comes from the sheer amount of information contained in each observation. With small shifts of telescope pointing, WEAVE/LIFU produced spectra at a total of 31500 locations in and around the galaxies, in just 2 hours. The intensity of light from the fibres builds the image of the galaxies shown in the centre. The individual spectra (intensity at each wavelength; seven examples shown) provide a wealth of information about the physical conditions at each location. At the two galaxy nuclei (top-right) the spectra indicate moderately-old stars (one billion years) and no on-going star formation. The narrow, peaked spectra in the lower-right are typical of gas (hydrogen, oxygen, nitrogen, sulfur) heated to over 10,000 degrees by very young stars, whereas the broad, asymmetric peaks in the spectra shown on the left indicate turbulent shocks between gas clouds. WEAVE is particularly accurate at measuring wavelengths, or velocities. In the bottom-left panel (in red) obtained in the high spectral resolving power mode, velocity distributions as narrow as 12.8 km/s can be measured. Credit: WEAVE Team. Large format: PNG.



Blue, green and red colours, according to velocities derived from the WEAVE spectra, are overlaid on a composite image of Stephan's Quintet, which features galaxy star light (CFHT telescope), and X-ray emission of hot gas (blue vertical band, Chandra X-ray observatory). The velocities indicate that the centre-left galaxy (NGC 7318b, blue), is a late intruder, entering the group from behind at 800 km/s (nearly 3,000,000 km/h) through the centre of Stephan's Quintet. This high-speed collision creates havoc in NGC 7318b. Hydrogen gas clouds, the fuel for the formation of new stars, are being stripped off the galaxy. This will likely cause formation of new stars in the galaxy to severely slow down. The WEAVE spectra will help to figure out the fate of the stripped gas as it evolves in the space between the group galaxies. Credits: X-ray (blue): NASA/CXC/CfA/E. O'Sullivan, optical (brown): Canada-France-Hawaii-Telescope/Coelum, WEAVE's LIFU: WEAVE Team. Large format: PNG.

WEAVE, A Next Generation Spectrograph

WEAVE is a multi-mode, multi-fibre spectrograph installed on the WHT at the Observatorio Roque de los Muchachos (ORM), La Palma in the Canary Islands. WEAVE was built by a consortium of European astronomical institutions, led by the UK Science and Technology Facilities Council to become the next-generation spectroscopic facility for the WHT.

WEAVE uses optical fibres to gather light from celestial sources and transmits it to a two-arm spectrograph. The spectrograph separates the light into its different wavelengths, or colours, and records them on large-format CCD light detectors. The raw data are transferred over the internet to computers in Cambridge and Tenerife, and the science-ready products are stored in an archive on La Palma for scientific use. The resulting spectra contain the fingerprint of physical and chemical properties of stars, galaxies, and interstellar and intergalactic gas, which astronomers use to test their theories about the Universe.

WEAVE's versatility is one of its biggest strengths. While the LIFU mode hosts 547 fibres closely-packed to image extended areas of the sky, in the MOS mode up to 960 individual fibres can be separately positioned using two robots to gather light from many hundreds of stars, galaxies or quasars. In the mIFU mode, the fibres are organised into 20 units, each consisting of 37 fibres, that are used to study small extended targets such as nebulae and distant galaxies.

WEAVE provides velocities along the line of sight, through the Doppler effect. Depending on the scientific objective, astronomers choose among two spectral resolving powers: at low resolution the spectra distinguish velocity differences of approximately 5 km/s and, at high resolution, 1.2 km/s. Even at its low resolving power, WEAVE records the line-of-sight velocities of stars with accuracies similar to those of the transverse velocities measured by ESA's Gaia satellite.

Who Will Use WEAVE?

In the coming five years the ING will assign 70% of the time available on the WHT to eight major surveys with WEAVE, selected out of those proposed by the astronomical communities of the partner countries. Together, these surveys will require spectra of several milion stars and galaxies, a goal now obtainable thanks to WEAVE's ability to observe almost 1000 objects at a time.

The ING will also make 30% of the time available for projects selected competitively from those proposed by astronomers in the ING partner countries. These projects will leverage WEAVE's versatility to provide fast responses to immediate questions. There are also channels for programmes that jointly exploit WEAVE and the diverse capabilities of the telescopes in the Canarian Observatories such as the 10.4-metre Gran Telescopio Canarias.

Eight Surveys with WEAVE

Over 500 astronomers from across Europe have organized eight major surveys using WEAVE, covering studies of stellar evolution, Milky Way science, galaxy evolution and cosmology. In synergy with the European Space Agency's Gaia satellite, the MOS mode of WEAVE will be used to obtain spectra of several million stars in the disk and the halo of our host galaxy, enabling Milky Way archaeology. Galaxies near and far, some detected by the LOFAR radio telescope will be studied to learn the history of their growth. And quasars will be used as beacons to map the spatial distribution and interaction of gas and galaxies when the Universe was only around 20% of its current age.

WEAVE Funding and Construction

ING initiated plans to build WEAVE after extensive consultation with the ING user community about what was needed for the future. There was a broad consensus that a world-class wide-field multi-object spectrograph was required, to exploit from the ground the huge surveys being undertaken by powerful telescopes such as as ESA's Gaia, thereby helping to address the main astrophysical challenges foreseen for the next decade or so.

In 2016, the countries of the ING partnership (the UK, Spain and the Netherlands), joined by France and Italy, signed an agreement to design and build WEAVE, with each country contributing major components as listed below, and with the ING providing auxiliary systems and overall project management.

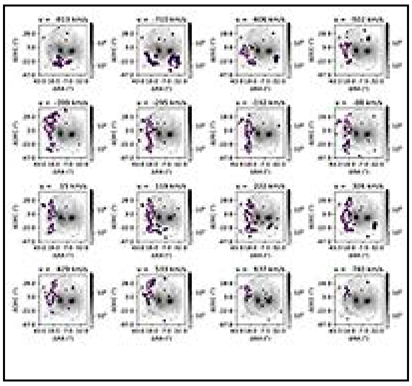
The instrument construction team is led by Gavin Dalton from Oxford University as Principal Investigator, Scott Trager from Groningen University as Project Scientist, Don Abrams from ING as Project Manager, and Chris Benn from ING as Instrument Scientist. The main components of WEAVE are:

- Fibre–positioner, developed by the University of Oxford and RAL Space in the UK, with support from the IAC.
- Prime-focus corrector, designed by ING and SENER, provided by the Instituto de Astrofísica de Canarias (IAC) in Spain and manufactured by SENER. Support from Konkoly Observatory (HU). Lenses were polished by KiwiStar in New Zealand, funded from STFC, NOVA, INAF and ING, and mounted at SENER Aeroespacial (Spain) by SENER and ING.
- Spectrograph, built by NOVA in the Netherlands with optical design by RAL Space in the UK, optics manufactured at INAOE (MX) and support from INAF (IT) and the IAC (ES).
- Field Rotator, provided by the Instituto de Astrofísica de Canarias (IAC) in Spain and manufactured by IDOM (Spain).
- Optical fibres, provided by the Observatoire de Paris in France, manufactured in France, Canada and USA.
- LIFU, built by NOVA (NL).
- CCD detectors system, provided by Liverpool John Moores University in the UK.
- Data processing, analysis and archiving, led by the University of Cambridge (UK) with support from the IAC (ES) and INAF (IT).
- Observation control system, built by the ING.

WEAVE's construction has been funded by the Science and Technology Facilities Council (STFC, UK), the Netherlands Research School for Astronomy (NOVA, NL), the Dutch Science Foundation (NWO, NL), the Isaac Newton Group of Telescope (ING, UK/NL/ES), the Astrophysical Institute of the Canaries (IAC, ES), the Ministry of Economy and Competitiveness (MINECO, ES), the Ministry of Science and Innovation (MCI), the European Regional Development Fund (ERDF), the National Institute for Astrophysics (INAF, IT), the French National Centre for Scientific Research (CNRS, FR), Paris Observatory – University of Paris Science and Letters (FR), Besançon Observatory (FR), Region île de France (FR), Region Franche-Comté (FR), Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE, MX), National Council for Science and Technology (CONACYT, MX), Lund Observatory (SE), Uppsala University (SE), the Leibniz Institute for Astrophysics (AIP,DE), Max-Planck Institute for Astronomy (MPIA, DE), University of Pennsylvania (US), and Konkoly Observatory (HU).

Additional Material

WEAVE spectrograph in the laboratory. Credit: NOVA. Large format: JPG.



Channel velocity maps. Credit: Scott Trager. Large format: PNG.

Scanning movie reveals chaotic motions in the hydrogen gas caused by the galaxy collision in Stephan's Quintet. Credits: Scott Trager. NASA, ESA, CSA, STScI (background image). Available formats: MP4 | WEBM.

More Information

Related publications

Shoko Jin et al., 2022, "The wide-field, multiplexed, spectroscopic facility WEAVE: Survey design, overview, and simulated implementation", *MNRAS*, accepted for publication. Paper.

Related links

- WEAVE instrumental overview.
- WEAVE science surveys.
- WEAVE web site.
- WEAVE news.

About the Isaac Newton Group of Telescopes

The Isaac Newton Group of Telescopes is a unit of the Science and Technology Facilities Council (STFC) established on La Palma. It operates the 4.2-metre William Herschel Telescope and the 2.5-metre Isaac Newton Telescope with financial assistance from the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO) of the Netherlands, and the Instituto de Astrofísica de Canarias (IAC) in Spain.