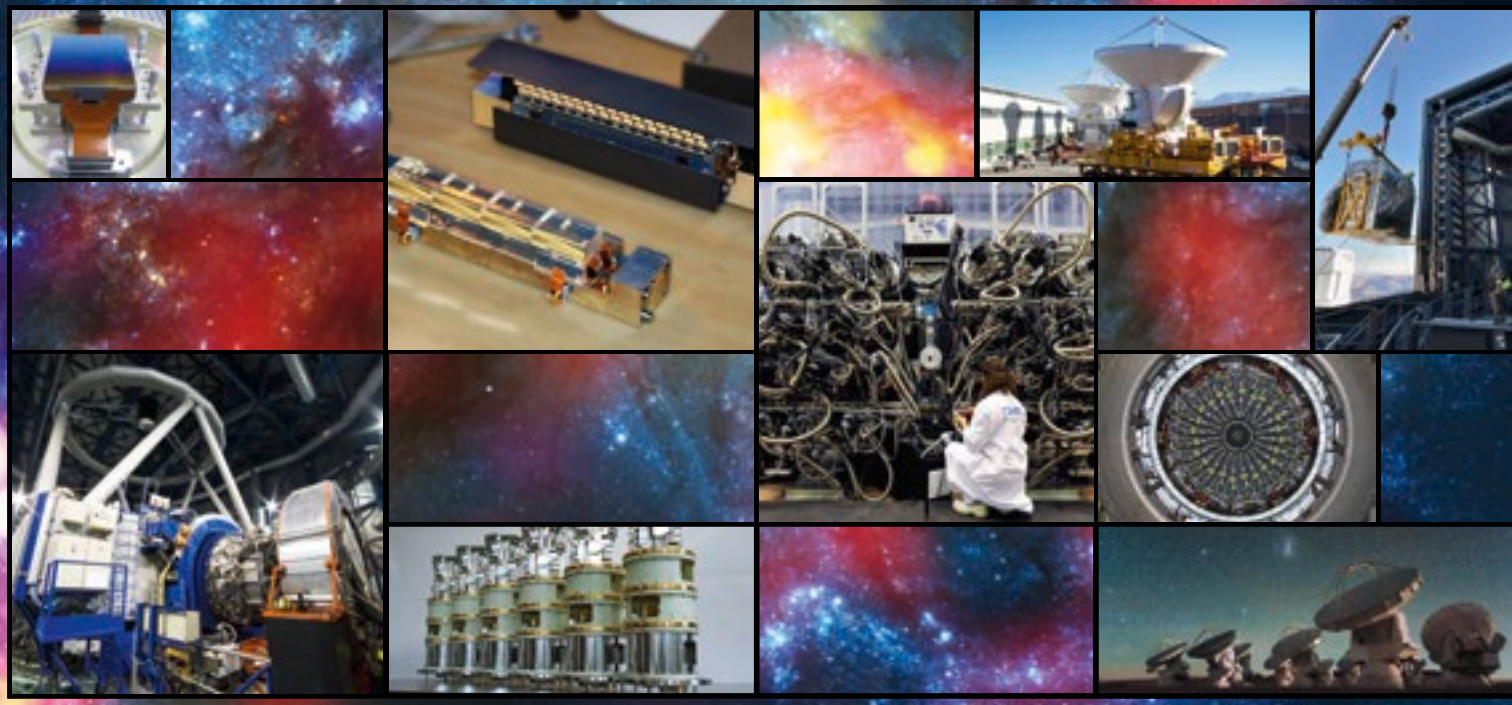
MUSE Consortium
Lead institute: CRAL – Centre de Recherche Astronomique de Lyon (France)
ESO – European Southern Observatory
AIP – Astrophysikalisches Institut Potsdam (Germany)
ETH – Eidgenössische Technische Hochschule (Zurich – Switzerland)
IAG – Institut für Astrophysik Göttingen (Germany)
IRAP – Institut de Recherche en Astrophysique et Planétologie (Toulouse – France)
Leiden Observatory (NOVA – the Netherlands)

KMOS Consortium
CfAI – Centre for Advanced Instrumentation, Durham University (UK)
UK ATC – UK Astronomy Technology Centre (Edinburgh – UK)
MPE – Max Planck Institut für extraterrestrische Physik (Garching – Germany)
USM – Universitäts-Sternwarte München (Germany)
ESO – European Southern Observatory
University of Oxford (UK)

ALMA
ALMA is a partnership of ESO (representing its Member States), NSF (USA) and NINS (Japan), together with NRC (Canada) and NSC and ASIAA (Taiwan), in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ.

www.eso.org



Back-cover images (from top left to bottom right): The large format MUSE detector. Credit: ESO | MUSE image slicer. Credit: ESO/CRAL | KMOS on the VLT at the time of first light. Credit: ESO/G. Lombardi (glphoto.it) | Band 9 receiver cartridges for ALMA. Credit: ESO/NOVA

Front-cover images (from top left to bottom right): First European ALMA Antenna Handed Over to Joint ALMA Observatory. Credit: ESO/S. Rossi | Installation of VLT Instrument MUSE. Credit: G. Hüdepohl (atacamaphoto.com)/ESO | The MUSE instrument. Credit: Eric Le Roux/Service Communication/UCBL/MUSE | The KMOS spectrograph. Credit: STFC/UKATC/ESO | ALMA by night. Credit: ESO/C. Malin

Background image: Antennae Galaxies composite of ALMA and Hubble observations.
Credit: ALMA (ESO/NAOJ/NRAO). Visible light image: the NASA/ESA Hubble Space Telescope

Exploring the Universe in 3D with MUSE, KMOS and ALMA

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MUSE

MUSE, the Multi Unit Spectroscopic Explorer, is a second generation VLT instrument located on the Nasmyth platform of the VLT Unit Telescope 4 (UT4). It is a large-format integral field spectrograph, based on image-slicing technology, and has a modular structure composed of 24 identical integral field unit modules that together sample a contiguous 1 arcminute^2 field of view in Wide Field Mode (WFM) sampled at 0.2 arcseconds/pixel. MUSE will initially be used in seeing limited WFM only.

MUSE will later exploit the VLT Adaptive Optics Facility in combination with the GALACSI adaptive optics (AO) module. The Adaptive Optics Facility will include a new deformable secondary mirror for UT4 and four laser guide stars that will be observed in conjunction with a single, real "tip-tilt" star to measure and correct for aberrations introduced by atmospheric seeing. When offered, it will provide ground layer AO correction for the WFM. In the future, a Narrow Field Mode with laser tomography AO correction will be made available. This mode will cover a smaller field of view with finer spatial resolution.

Key parameters			
	Wide Field Mode	WFM plus ground layer AO	WFM plus laser tomography AO
Simultaneous wavelength range	Extended: 465–930 nm Nominal: 480–930 nm	Nominal and extended ranges excluded range 584–594 nm (Na notch)	Only nominal range: 480–930 nm excluded range 584–594 nm (Na notch)
Spectral resolving power ($\lambda/\Delta\lambda$)	1770 at 480 nm 3590 at 930 nm	1770 at 480 nm 3590 at 930 nm	1740 at 480 nm 3450 at 930 nm
Field of view	59.9″ × 60.0″	59.9″ × 60.0″	7.42″ × 7.43″
Spatial sampling	0.20″ × 0.21″	0.20″ × 0.21″	0.025″/pix
Tip-tilt star location		3.4′ maximum diameter, outside the MUSE field of view	Within the MUSE field of view (on-axis)
Tip-tilt star limiting magnitude		17.5 (*V*-band)	15 (*J*–*H*-band)

KMOS

The *K*-band Multi-object Spectrograph, KMOS, is a multi-integral field unit spectrograph observing in the near-infrared *IZJHK* bands. This unique instrument can simultaneously observe 24 individual fields of 2.8 arcseconds × 2.8 arcseconds on the sky. The fields are selected by pick-off mirrors mounted on robotic arms and fed to image slicing integral field units that reformat the light into a pseudo long slit which is the input to the KMOS spectrograph. In practice there are three spectrographs of identical design, each fed by the light from eight IFUs. The instrument is fully cryogenic with an operating temperature in the range 115–120 K; the detectors are operated at 40 K. The main parameters of the instrument are summarised in the table on the right. KMOS has two principal observing modes: either the 24 arms can be placed on objects distributed over a 7.2 arcminute patrol field or the arms are set in a fixed configuration to map a contiguous field ("mosaic" mode). KMOS observes with the natural seeing delivered by the telescope.

Key parameters	
Total wavelength coverage	780–2460 nm
Simultaneous wavelength range in all fields of view	*IZ* band: 779–1079 nm *YJ* band: 1025–1344 nm *H* band: 1456–1846 nm *K* band: 1934–2460 nm *H*+*K*: 1484–2422 nm
Spectral resolving power ($\lambda/\Delta\lambda$)	*IZ* band: 3400 *YJ* band: 3600 *H* band: 4000 *K* band: 4200 *H*+*K*: 2000
Field of View of each IFU	2.8″ × 2.8″
Spatial sampling	0.2″ × 0.2″
Patrol field	7.2′ diameter circle
Number of IFUs	24

An indication of the limiting magnitudes achievable with KMOS in a one-hour exposure with signal/noise of five is given in the table on the right. The exposure time calculator (http://www.eso.org/observing/etc/) should be used to estimate the sensitivity limits reachable under different observing conditions and for extended sources.

Band	Magnitude (Vega)
IZ	19.9
YJ	20.1
H	19.8
HK	19.8
K	17.9

ALMA

The Atacama Large Millimeter/submillimeter Array (ALMA) is composed of 66 high-precision antennas located on the Chajnantor Plateau of the Chilean Andes at an elevation of about 5000 metres. ALMA consists of 66 antennas: fifty 12-metre diameter antennas for the 12-metre array, twelve 7-metre antennas for the 7-metre array, and four 12-metre array for the total power array. The 12-metre array antennas can be repositioned over a region of 16 kilometres in extent, allowing observations to be made with different spatial resolutions. ALMA is designed to cover all atmospheric transparency windows from 35 GHz through 950 GHz. ALMA is located at latitude = −23.029°, longitude = −67.755°. Targets as far north as declination +40°, corresponding to a maximum source elevation at Chajnantor of ~25°, can be observed from the ALMA site.

Key parameters		
	Early Science (Cycle 2)	Full array
Total frequency coverage	84 to 720 GHz	35 to 950 GHz
Total wavelength coverage	0.4 to 3.6 mm	0.3 to 8.6 mm
Simultaneous bandwidth	16 GHz (2 polarisations × 4 basebands × 2 GHz/baseband	
Spectral resolution	> 0.008 × (f/300 GHz) km/s	
Number of spectral channels	15360 (in dual polarisation mode)	
Field of view (primary beam)	~20.6″ × (300/f GHz)	
Angular resolution	~0.2″ × (300/f GHz) × (1 km/max. baseline)	
Number of antennas	50 × 12-metre (12-metre array), plus 12 × 7-metre & 4 × 12-metre (ACA)	
Number of baselines	Up to 1225	
Maximum baseline lengths	0.15–16 km	

The following table provides the typical sensitivities that can be achieved with the full ALMA (50 antennas in the main array) in 60 seconds on source, using a bandwidth of 7.5 GHz and dual polarisation.

Band	Frequency	Wavelength	Sensitivity	Angular resolution
	GHz	mm	mJy/beam	arcseconds
1	35–50	6.0–8.6	0.04	13–0.08
2	67–90	3.3–4.5	0.06	6–0.04
3	84–116	2.6–3.6	0.07	4.8–0.032
4	125–163	1.8–2.4	0.06	3.2–0.023
5	163–211	1.4–1.8	0.11	2.5–0.021
6	211–275	1.1–1.4	0.09	1.9–0.014
7	275–373	0.8–1.1	0.15	1.5–0.01
8	385–500	0.6–0.8	0.28	1.04–0.008
9	602–720	0.4–0.5	1.1	0.66–0.005
10	787–950	0.3–0.4	1.2	0.51–0.004