



4MOST: the 4-metre Multi-Object Spectroscopic Telescope

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IA NCU



<https://www.4most.eu>

Overview



1. science
2. technology
3. astropolitics

- image credits: click on image; logos link to institutes



1. science



- wide-field multi-object spectroscopy

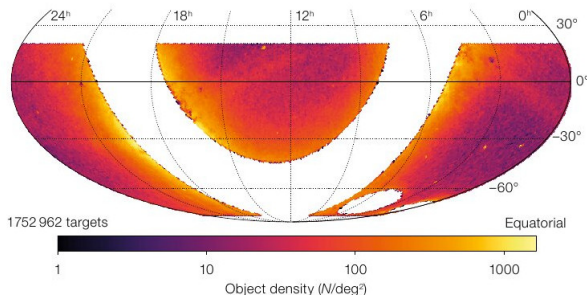
Consortium Surveys:

- ▶ Milky Way/MCs – galactic archaeology (S1–S4 / S9)
 - ▶ MW stellar/DM halo
 - ▶ MW bulge/disc
 - ▶ metallicity/dynamical history of DM/stellar sub-halos forming MW + MCs
- ▶ cosmology: (S5–S8 + S10)
 - ▶ galaxy evolution – nature vs nurture
 - ▶ AGNs
 - ▶ large-scale structure
 - ▶ FLRW dark-energy phenomenology
 - $d_A(z)$, $d_L(z)$, $d_\perp(z)$

Milky Way: halo



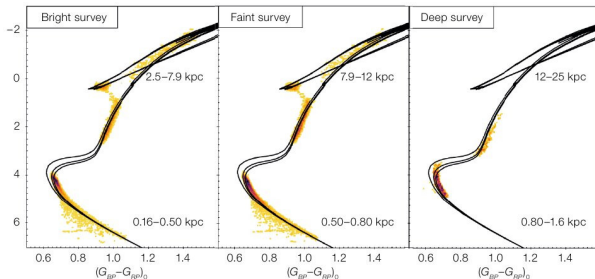
- ▶ stellar halo + (via kinematics) DM halo – low-res (S1)
 - 10000 sq.deg. high gal.lat. $|b|$, $\lesssim 2M$ targets
 - halo giants – Mg b triplet, Ca II triplet $\rightarrow$
 $\sigma(v_{\parallel}) \sim 1\text{--}2$ km/s
 - $\sigma([Fe/H]) \sim 0.15$ dex, $\sigma([\alpha/Fe]) \sim 0.1$ dex



Milky Way: halo



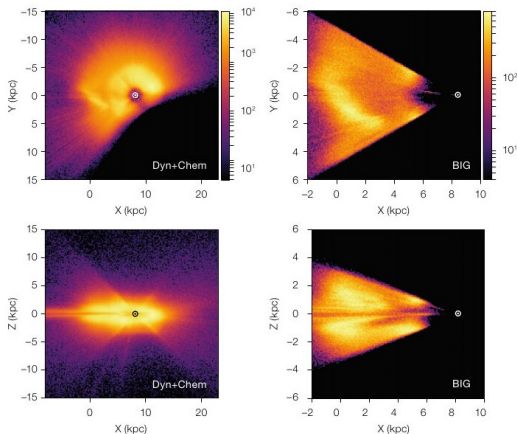
- ▶ stellar halo + (via kinematics) DM halo – high-res (S2)
 - 2M targets, abundances of $\lesssim 20$ elements,
 $\sigma([X/Fe]) \sim 0.2$ dex
 - abundance + kinematics $\Rightarrow$ locally formed stars vs accreted dwarf gals
 - stars: globular clusters $\rightarrow$ stellar halo?
 - Pop III? metal-poor $[Fe/H] < -2.0$ halo stars



Milky Way: disc/bulge



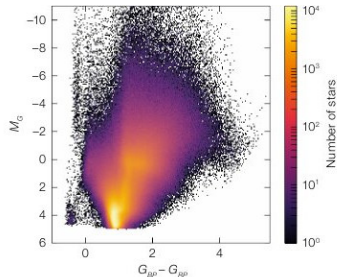
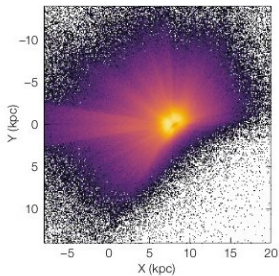
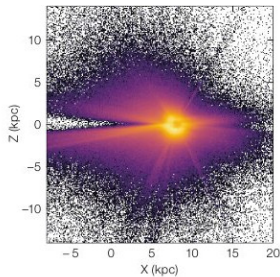
- ▶ bulge + disc – low-res (S3) 4MIDABLE-LR
 - bar, spiral arms, vertical distributions
 - stellar radial migration
 - chrono-chemo-dynamics
 - disc–bulge–halo relations



Milky Way: disc/bulge



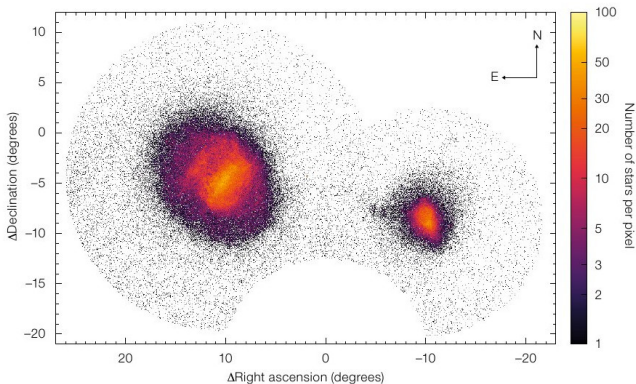
- ▶ bulge + thin/thick disc – high-res (S4) 4MIDABLE-HR, $\sim 4\text{M}$ targets
 - $R \sim 20000$
 - $v_{\parallel}$, rotation, M , age, multiplicity
 - $\sigma([X/H]) \sim 0.05$ dex, $S/N > 100/\text{\AA}$



Local Group: Magellanic Clouds



- ▶ LMC + SMC + M Bridge + Stream – 1001MC (S9)
 - 0.5 M targets $G < 19.5$ @1000 sq.deg.
 - $\sigma(v_{\parallel}) \sim 2$ km/s + GAIA $\sigma(v_{\perp}) \sim 2.5$ km/s
 - kinematics + chemistry $\Rightarrow$ formation + history
 - MC massive stars, metallicity ($\sigma \sim \pm 0.2$ dex)



Extragalactic: galaxy clusters



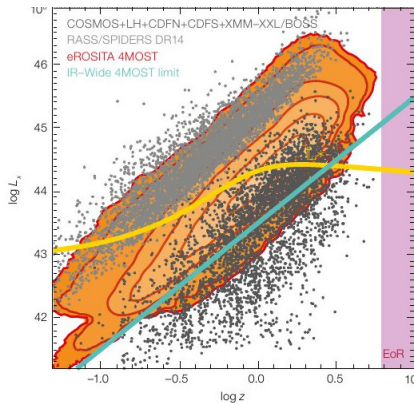
- ▶ clusters (S5) – eROSITA (X-ray) complement
 - 1M targets, 40k groups/clusters, $z \lesssim 1.4$
 - $z > 0.7$ brightest cluster galaxy
 - $z < 0.7$ – 10–100 cluster members
 - cluster mass + correlation functions
 - $z < 0.2$ WHIM: warm hot intergalactic medium



Extragalactic: AGNs



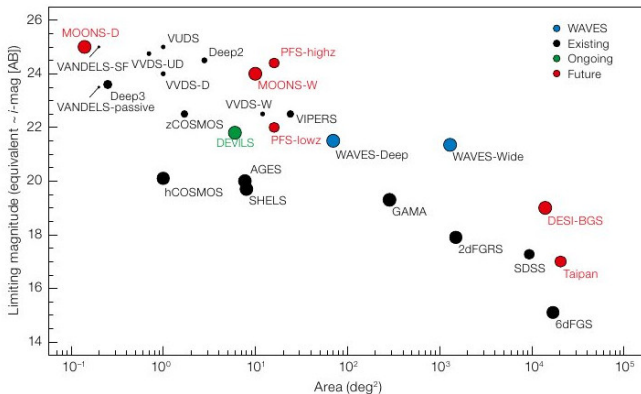
- ▶ AGNs (S6): $\lesssim 1\text{M}$ SMBHs; $0 \lesssim z \lesssim 6$; 10k sq.deg.
 - eROSITA point-like + WISE mid-IR obscured
 - $f_{0.5-2\text{keV}} > 10^{-14} \text{ erg/s/cm}^2$ 80–90% complete
 - SMBH–galaxy relations; correlation function
 - unobscured AGNs X:UV stand. candle: $3 < z$



Extragalactic: gal evolution



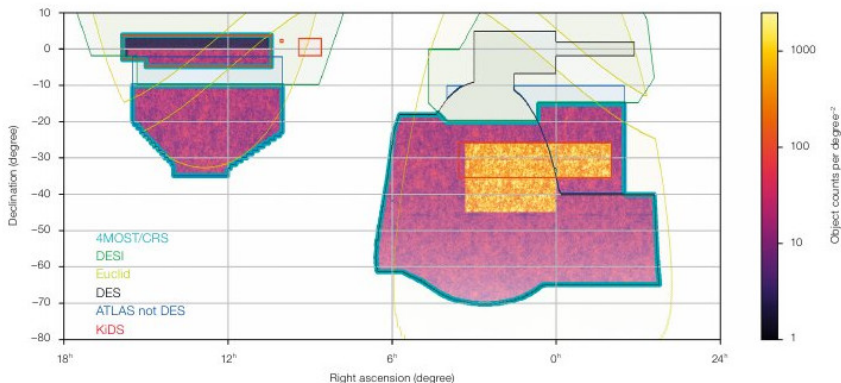
- ▶ galaxy evolution (WAVES, S7) – sky: KiDS + VIKING
 - $\sim 1.6\text{M}$ targets; 1 kpc–10 Mpc; $z < 0.1 \dots z \sim 0.8$
 - gal bulg/disc/bar evolution; gal merger rates
 - 1200 sq.deg. $z \lesssim 0.2$; 50 sq.deg. $z \sim 0.5$
 - groups, filaments, voids
 - 4×4 sq.deg. $z \sim 0.8$



Extragalactic: cosmo



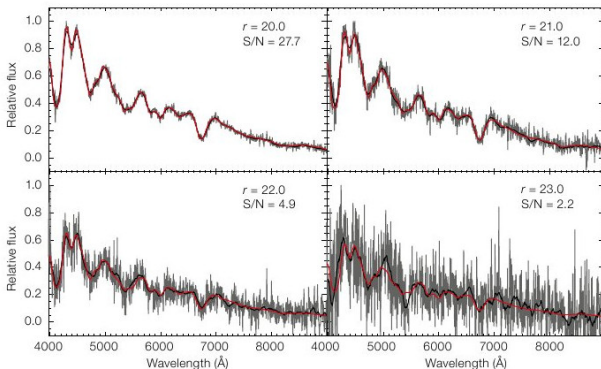
- ▶ cosmological redshift survey (S8, CRS)
 - 8M targets; $0.15 < z < 3.5$; ~ 7500 sq.deg.
 - complement to photom/radio: Rubin–LSST, SKA, Euclid
 - weak gal–gal lensing
 - redshift space distortion (z_{pec})
 - better fits to rigidly expanding cosmological model



Extragalactic: $d/dt \neq 0$



- ▶ time-variable objects (S10, TiDES)
 - 250k fibre-hours
 - (i) SNe; (ii) SNe hosts; (iii) AGN reverberation mapping
 - LSST 10^5 photom $\rightarrow$ 4MOST z
 - ~ 30 LRS targets $\forall$ 4MOST exposure (piggyback)
 - (i) 30k live transients; (ii) 50k z ; (iii) 25k fibre-hours



Community surveys



- ▶ 6 galactic:
 - stellar clusters; WD binaries; young stars; Gaia RR Lyrae; binaries with dormant BHs; stellar streams in dwarf galaxies
- ▶ 9 extragalactic:
 - cluster galaxy evolution; AGN/gal survey; baryon cycle in QSOs; hemisphere nearby survey; strong grav. lens survey; colour-redshift calibration; stellar populations; optical/radio continuum/HI deep; 4MOST–Gaia astrometric QSO survey

2. technology

Technology: VISTA



VISTA (Visible and Infrared Survey Telescope for Astronomy)

– 4.1m ESO telescope @Paranal

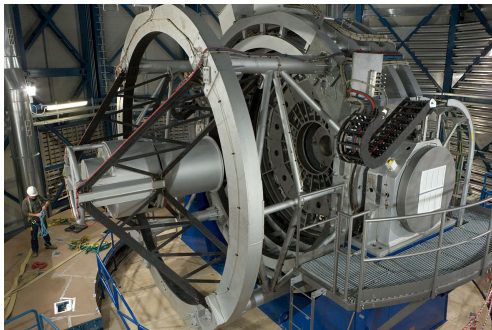
- ▶ wide field – originally 1.65° diameter FOV
- ▶ built 1999–2009 by UK consortium
- ▶ in-kind UK contribution to ESO
- ▶ IR survey starting 2010 – VISTA Kilo-Degree Infrared Galaxy Survey (VIKING)



Technology: VISTA



- ▶ alt-azimuth
- ▶ quasi-Ritchey-Chretien optics
- ▶ $f/1$ primary, $f/3.25$ focus at Cassegrain
- ▶ instrument @rotator on back of primary mirror
- ▶ instrument needs wide-field corrector



Tech: 4MOST



4MOST instrument (replaces VISTA camera)

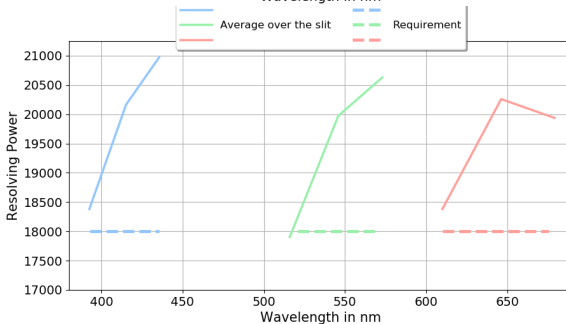
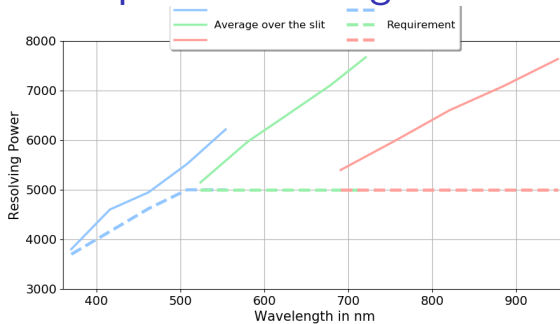
- ▶ FOV 4.2 sq.deg.
- ▶ 2436 simultaneous spectra
- ▶ 1 high-res spectrograph; 2 low-res spectrographs

Tech: more 4MOST parameters

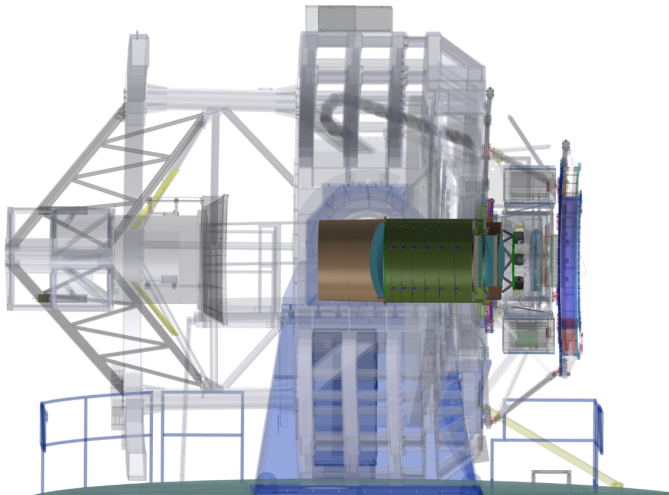


- ▶ sky access: 30k sq.deg.– zenith $< 55^\circ$
- ▶ on-sky fibre aperture: diam 1.45 arcsec
- ▶ min fibre distance: 15 arcsec
- ▶ fibre-hours/year: LRS – 3.2 Mh/yr; HRS: 1.6 Mh/yr
- ▶ slew to field: 3.5 minutes
- ▶ prepare for science exposure: 4.4 minutes
- ▶ spectral resolution: LRS – 4000–7700; HRS – 18,000–21,000
- ▶ spectral sampling: $\gtrsim 2.5$ pixel/FWHM
- ▶ $\sigma(v_{\parallel}) < 1$ km/s (stars)

Tech: 4MOST spectral coverage



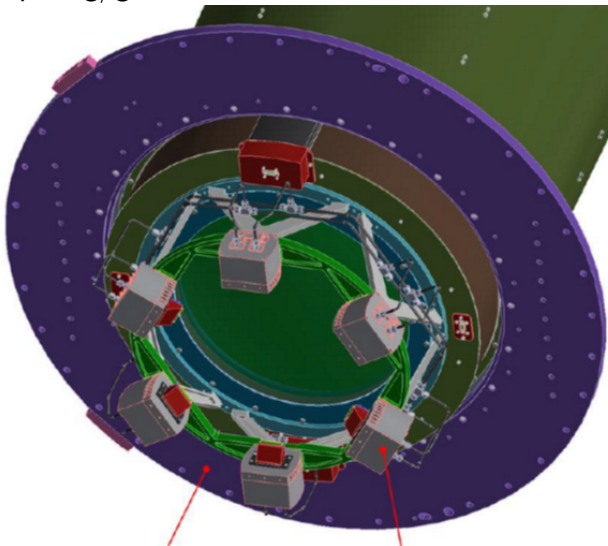
Tech: wide-field corrector



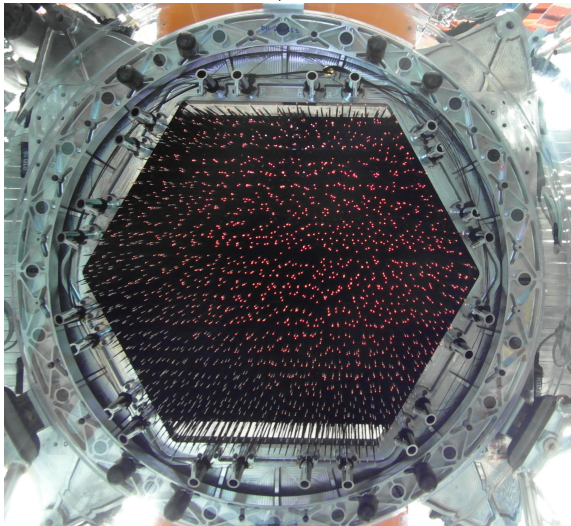
Tech: AG + WFS



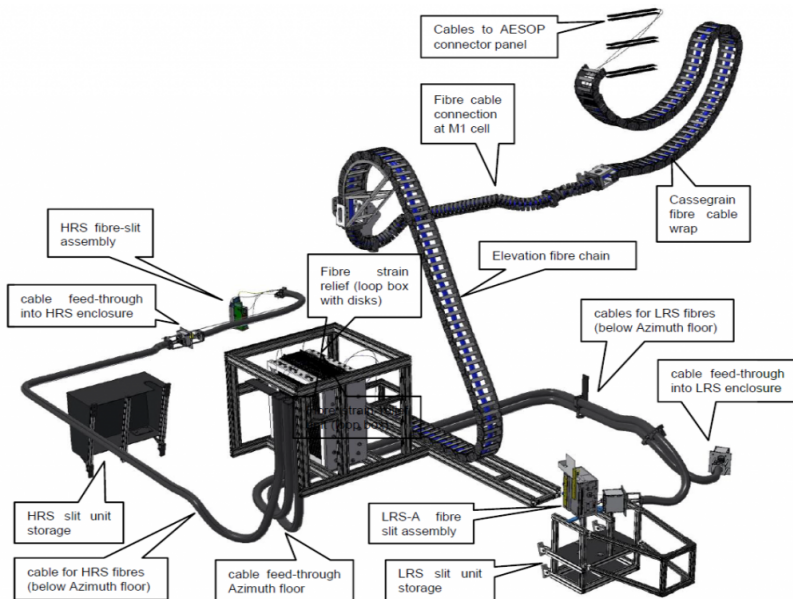
acquiring/guidance and wave front sensor cameras



AESOP: spine/fibre positioner



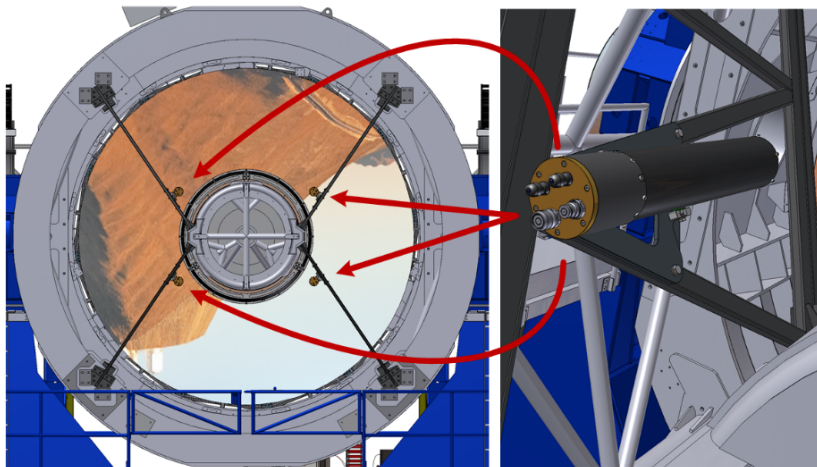
Tech: fibrefeed



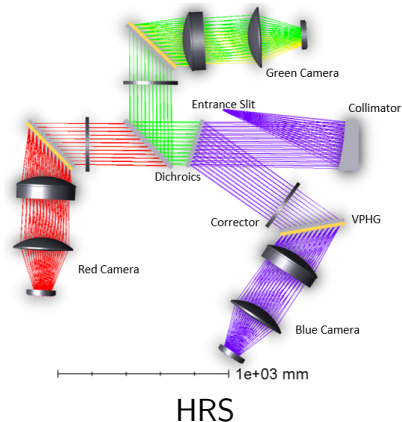
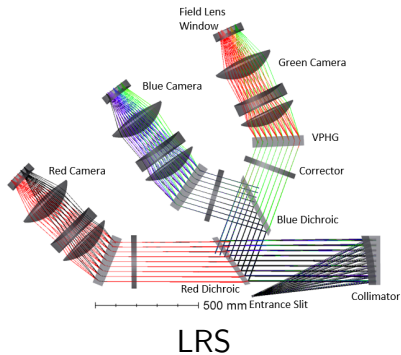
Tech: metrology



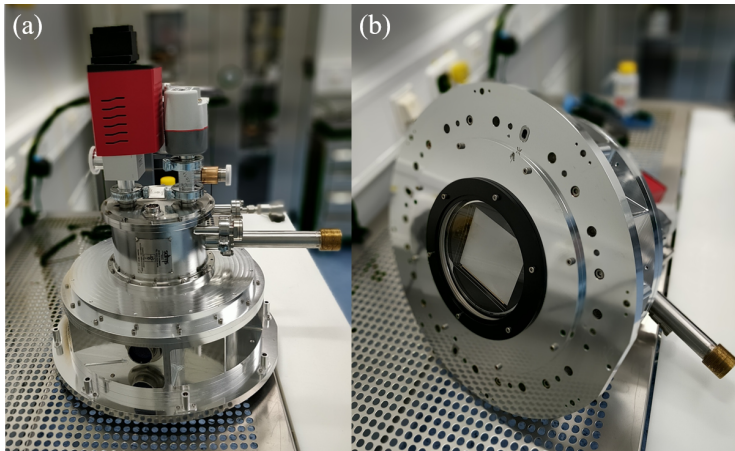
measure fibre positions, convert to celestial positions



Tech: spectrographs – low/high resolution

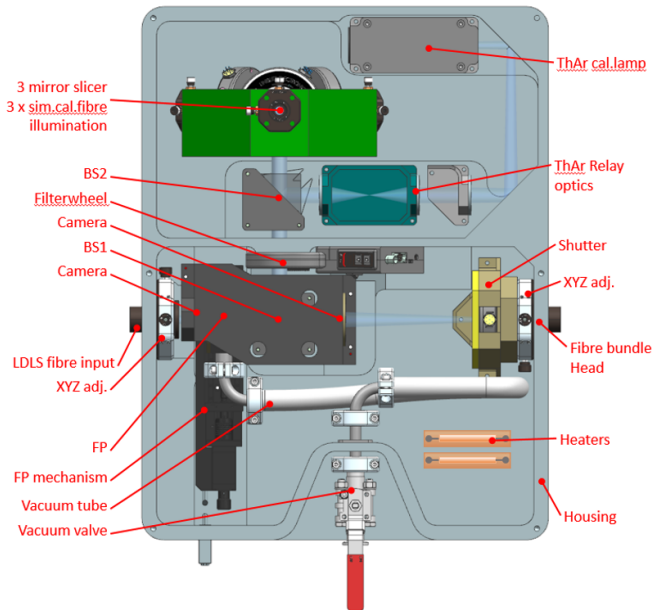


Tech: CCDs

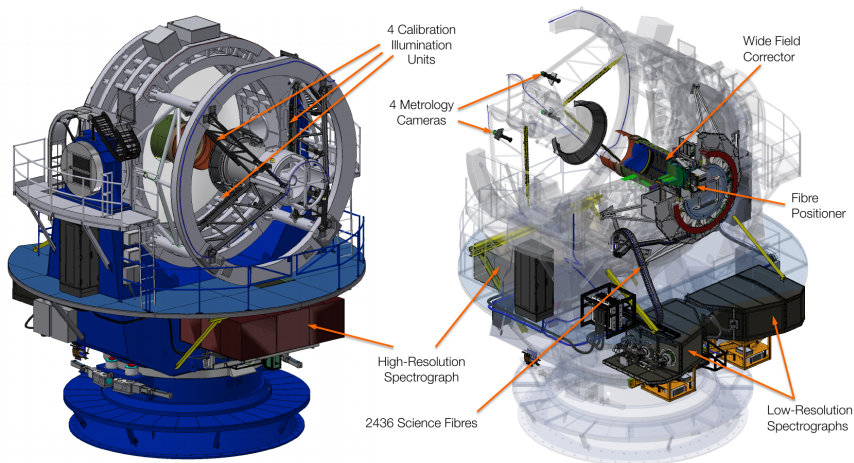


6144×6160 pix; 15 μm ; readout noise $< 2.3 \text{ e}^-$ @100 kHz

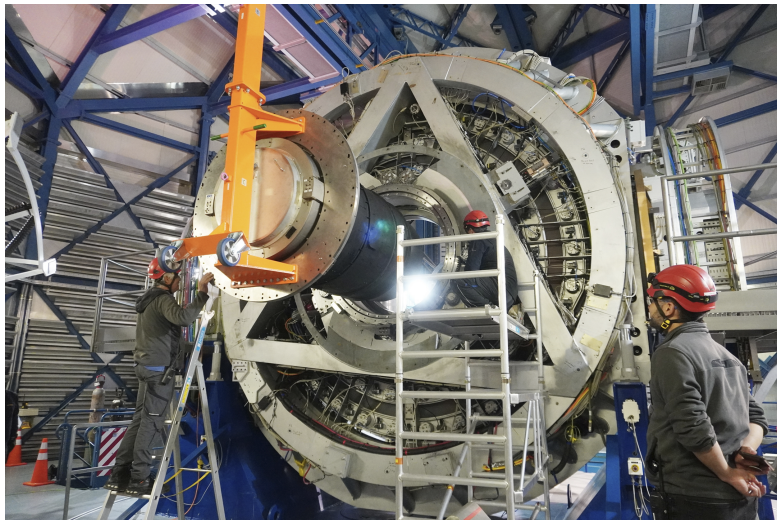
Tech: calibration



Tech: full assembly (model)

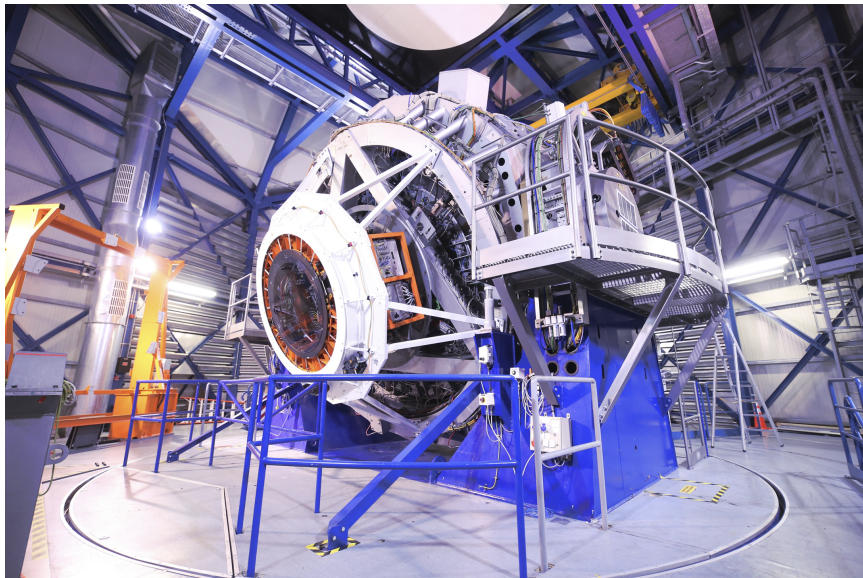


Tech: WFC being installed

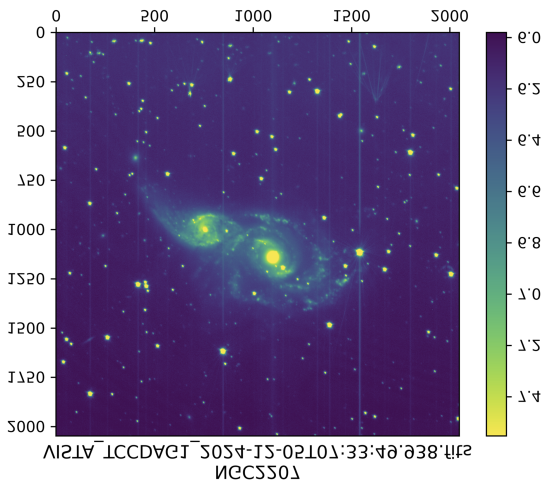


4MOST installed @VISTA @Paranal late 2024

Tech: full assembly



First technical light 2024-12-05



IC2163 (left ~ East) + NGC2207 (right ~ West); N is up

3. astropolitics

Politics: 4MOST Consortium



- ▶ HQ@AIP Potsdam: PI – Roelof de Jong
- ▶ EU/CH + ex-EU (UK) + Australia, since < 2011





- ▶ public pdf file: [Science-Team-Policies](#)
- ▶ PhD students: see especially: §6.3, §6.4
- ▶ data access: §15
- ▶ scientific exploitation §16
- ▶ data sharing: §17
- ▶ publication policies: §18; co-authorship: §18.1.1
- ▶ code of conduct: §19
- ▶ conflict resolution: §20



- ▶ institutes/Co-Investigators:
 - **UMK** (Roukema) + CFT (Bilicki) + NCBJ (Pollo) + CAMK (Smiljanic)
- ▶ Consortium formally created 2021-12-31
- ▶ MoU: UMK/Pol4MOST + AIP/4MOSTCons – signed Nov/Dec 2024
- ▶ Pol4MOST Polish Research Infrastructure Map – application in **urgent** preparation
- ▶ Pol4MOST rolling grant application – in preparation – commit 2a9941fb/2024-12-11: 83 pp including annexes
- ▶ each Co-I + 1 postdoc + unlimited PhD students have data rights

Conclusion



- ▶ big fraction of southern sky
- ▶ ~ 30 million spectra over first 5 years
- ▶ galactic archaeology + galaxy/AGN evolution + cosmology
- ▶ observations should start late 2025