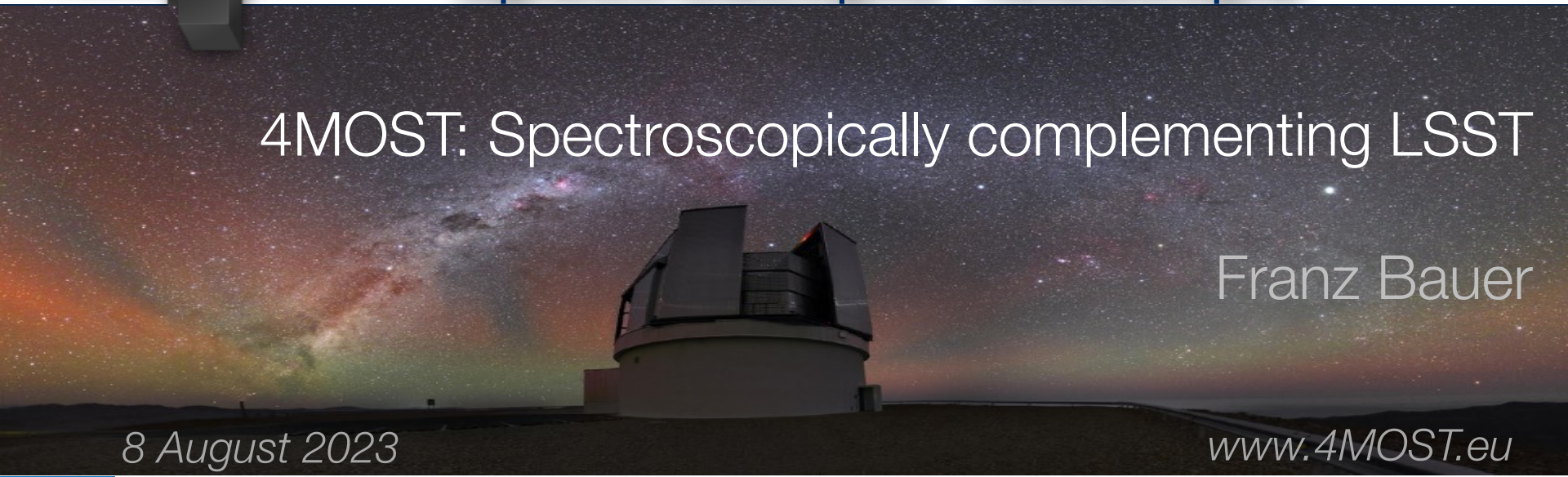
# 4MOST – 4m Multi-Object Spectroscopic Telescope



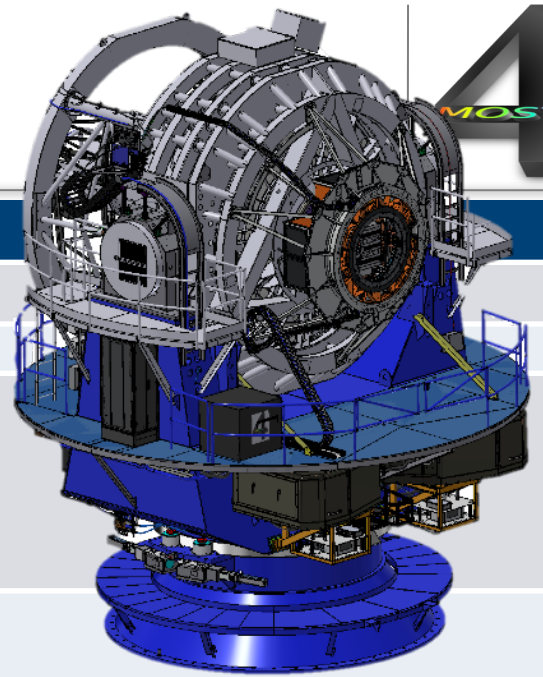
## 4MOST: Spectroscopically complementing LSST

Franz Bauer

*8 August 2023*

*www.4MOST.eu*

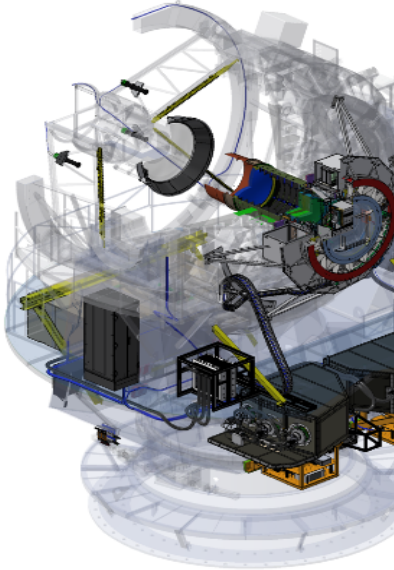
# Instrument Characteristics



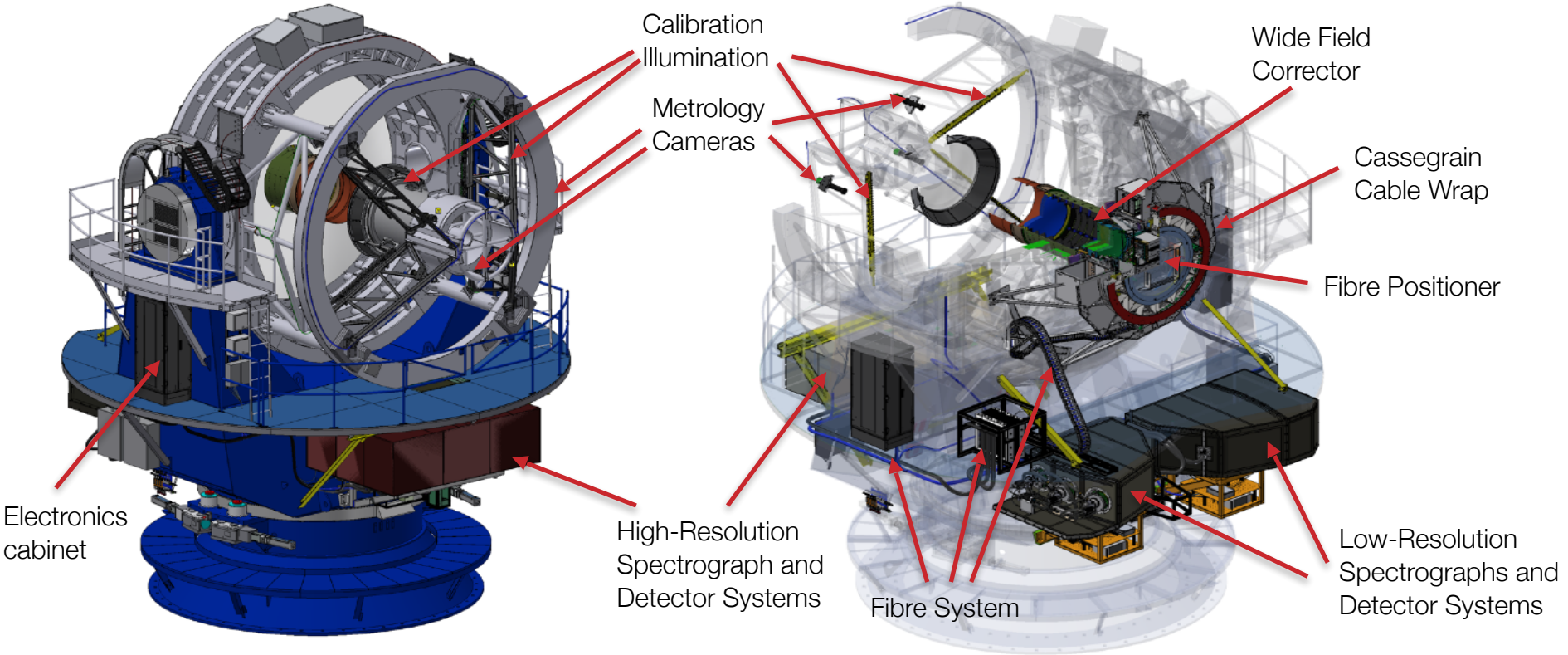
| | Specification | Design value |
|---|---|---|
| | Field-of-View (hexagon) | ~4.2 degree$^2$ (⌀>2.6°) |
| | Multiplex fiber positioner | 2436 |
| LRS | Medium Resolution Spectrographs (2x)<br># Fibres<br>Passband<br>Velocity accuracy<br>Spectral sampling (pixels/FWHM) | R~4000–7500<br>812 fibres (2x)<br>370–950 nm<br>< 1 km/s<br>> 2.8 pixels |
| HRS | High Resolution Spectrograph (1x)<br># Fibres<br>Passband<br>Velocity accuracy<br>Spectral sampling (pixels/FWHM) | R~20,000<br>812 fibres<br>392.6–435.5 nm, 516–573 nm, 610–679 nm<br>< 1 km/s<br>> 2.56 pixels |
| | # of fibers in Ø=2’ circle | >3 |
| | Fibre diameter | Ø=1.42 arcsec |

# 4MOST: Wide-field, high-multiplex optical spectroscopic survey facility for ESO

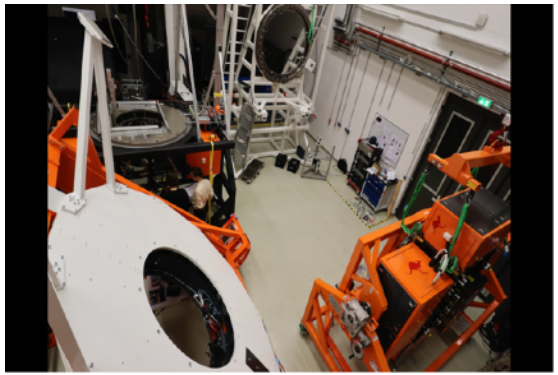
- **Status:**
  - 4MOST is in final assembly & test phase in Europe before shipment
  - First light on **VISTA** telescope **Q2-2024**
  - Operations start **Q4-2024** (at least 2x 5-year Surveys)
- **Science:**
  - Cosmology, galaxy evolution, high-energy, transients and Galactic science
  - Complement large-area space missions: Gaia, eROSITA, Euclid, PLATO
  - Complement ground-based surveys: SKA, Rubin, VST, VISTA, DES, etc.
- **Survey facility:**
  - Consortium delivers instrument, science operations, data products, science
  - Run all-sky 5 year public surveys in parallel, with ~yearly data releases
  - Key surveys organized by consortium in coordination with community
  - Add-on surveys from community and Chile through ESO peer-reviewed applications

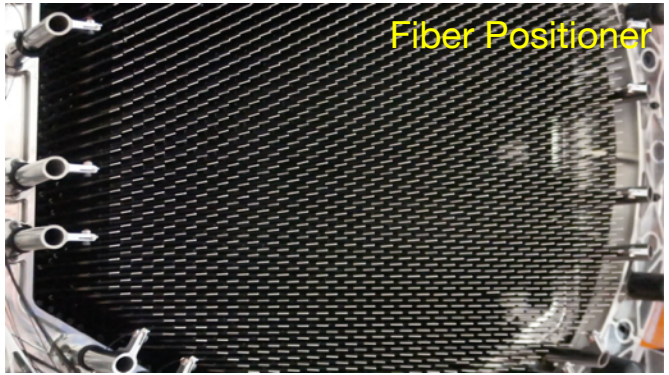


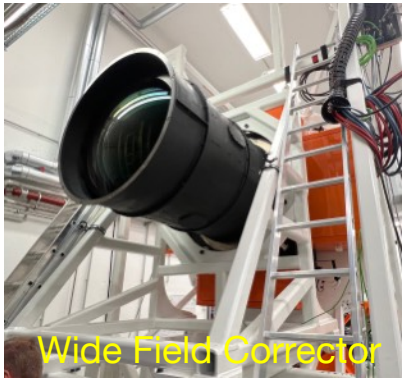
# 4MOST on VISTA



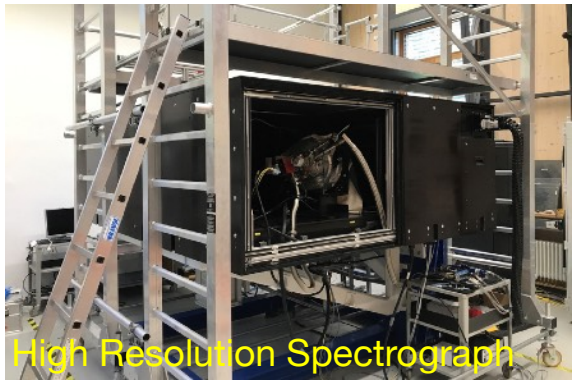
# Facility under final test in Potsdam, Germany







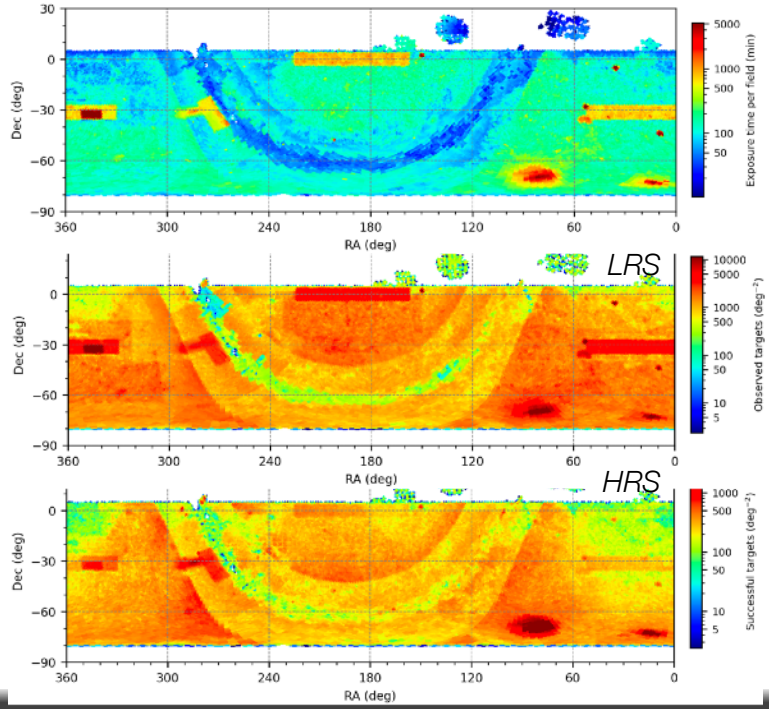


# 4MOST Observing Strategy

www.4MOST.eu

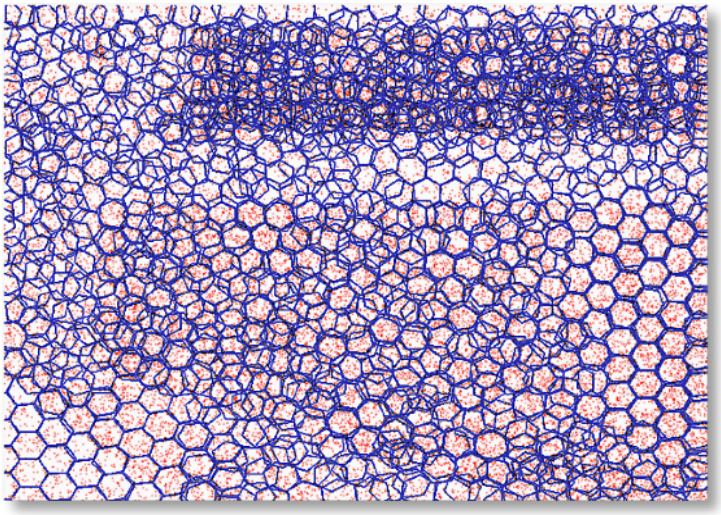
*ESO Messenger 175 & 190*

- Unique operations model for MOS instruments => suitable ***for most*** science cases
- 4MOST program defined by ***Consortium*** (70%) and ***Community*** (30%) ***Public Surveys*** of 5 years
- All Surveys will run ***in parallel,*** sharing fibres per exposure for increased efficiency
- ***Key Surveys*** set observing strategy
  - Millions of targets all sky
  - Fill all fibres
- ***Add-on Surveys*** for smaller surveys
  - Small fraction fibres all sky or
  - dedicated areas
  - $10^3$ to $10^6$ targets
- Several passes of sky with exposures 2–30 mins
- Wedding-cake distribution for total time 30min to 60h
- Will observe 13M galaxies+AGN & ~13M stars with LRS, ~4M stars with HRS in first 5-year survey



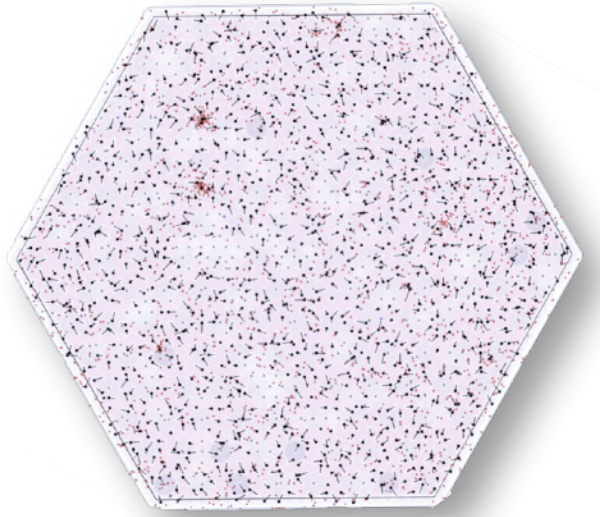
# 4MOST observing strategy

- Target and fibre hour pressure and completeness requirements drive the tiling; individual source exposure times and varying observing conditions (dark/grey/bright) included in scheduler.



Tempel et al. (2020b)

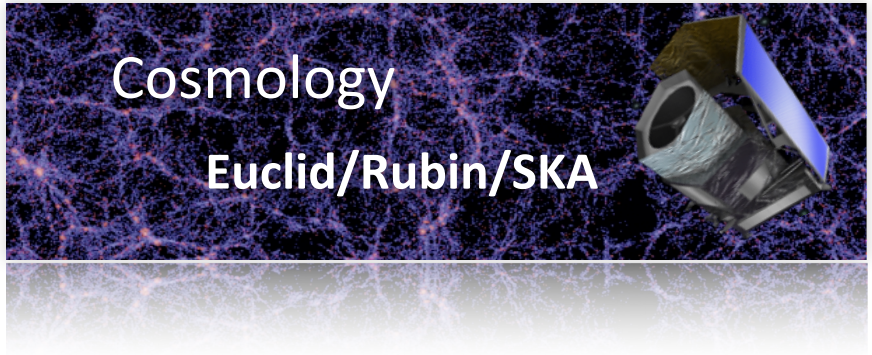
- Fibre-to-target assignment done probabilistically, using weights to homogenise requested completeness, using e.g. local target density and future exposure time available



Tempel et al. (2020a)

# Science Themes



# Ten Consortium Surveys

| No | Survey Name | Type | Survey (Co-)PI |
|---|---|---|---|
| S1 | Milky Way Halo LR Survey | **Gal** | Worley (IoA), Starkenburg (RuG) |
| S2 | Milky Way Halo HR Survey | **Gal** | Christlieb (ZAH) |
| S3 | Milky Way Disk and Bulge LR Survey | **Gal** | Chiappini (AIP), Minchev (AIP) |
| S4 | Milky Way Disk and Bulge HR Survey | **Gal** | Bensby (LU), Bergemann (MPIA) |
| S5 | Galaxy Clusters Survey | **exgal** | Comparat (MPE) |
| S6 | AGN Survey | **exgal** | Merloni (MPE) |
| S7 | Galaxy Evolution Survey (**WAVES**) | **exgal** | Driver (UWA), Liske (UHH) |
| S8 | Cosmology Redshift Survey | **exgal** | Richard (CRAL), Kneib (EPFL) |
| S9 | Magellanic Clouds Survey | (**ex**)**Gal** | Cioni (AIP) |
| S10 | Time-Domain Extragalactic Survey (**TiDES**) | **T-exgal** | Hook (Lancaster) |

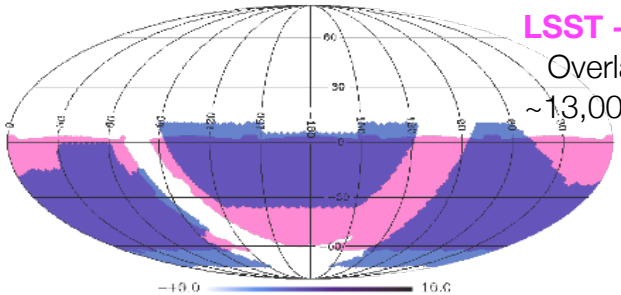
# Fifteen new Community Surveys

| Survey Name | Type | Survey (Co-)PI |
|---|---|---|
| 4MOST survey of dwarf galaxies and their stellar streams (**4DWARFS**) | Gal | Asa Skuladottir |
| 4MOST Gaia RRLyrae Survey (**4GRoundS**) | Gal | Rodrigo Ibata |
| The 4MOST Hemisphere Survey of the Nearby Universe (**4HS**) | exgal | Edward Taylor, Michelle Cluver |
| CHileAN Cluster galaxy Evolution Survey (**CHANCES**) | exgal | Christopher Haines, Yara Jaffé |
| The White Dwarf Binary survey (**WDB**) | T-Gal | Odette Toloza, Alberto Rebassa-Mansergas |
| The 4MOST Strong Lens Spectroscopic Legacy Survey (**4SLSLS**) | exgal | Thomas Collett |
| The 4MOST Survey of Young Stars (**4SYS**) | Gal | Giuseppe Germano Sacco |
| The 4MOST–Gaia Purely Astrometric Quasar Survey (**4G-PAQS**) | exgal | Jens-Kristian Krogager |
| Optical, Radio Continuum and HI Deep Spectroscopic Survey (**ORCHIDSS**) | exgal | Kenneth Duncan |
| A Stellar Population Survey using 4MOST (**4MOST-StePS**) | exgal | Angela Iovino |
| 4MOST Complete Calibration of the Color-Redshift Relation (**4C3R2**) | exgal | Daniel Gruen, Jamie McCullough |
| Spectroscopic Discovery of Binaries with Dormant Black Holes | T-Gal | Michał Pawlak, Tsevi Mazeh |
| Understanding of the Baryon Cycle with High-Resolution Quasar Spectroscopy | exgal | Celine Peroux |
| Stellar Clusters in 4MOST | Gal | Lucatello, Vallenari, Bragaglia |
| 4MOST Chilean AGN/Galaxy Evolution Survey (**ChANGES**) | (T)-exgal | Franz Erik Bauer, Paulina Lira |

# TiDES

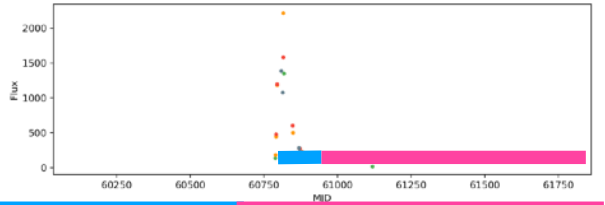
## The Time-Domain Extragalactic Survey

- Industrialisation of spectroscopic follow-up for transients + hosts.
- UK-led collaboration: Lancaster, Southampton, Dublin, Belfast, Surrey, UCL, Cambridge + other 4MOST surveys + 4SLSLS
- Enough fibre-hours to target all live-SN in any 4MOST pointing.
- ~10 live and bright SNe in any given 4MOST pointing



**LSST - 4MOST**
Overlap area
~13,000 sq deg

**~250,000 fibre-hr for time-domain science**
(~35k live transient spectra + 200k hosts)


Time window to get SN spectrum

Time window to get host-galaxy spectrum

TiDES Team - Dublin, 2022

# **Ch**ilean **AGN**/**G**alaxy **E**volution **S**urvey ( **ChAN·GES** )

## Key specifications

- ~4M parent AGN targets, variability + SED selection, LRS only, 1.4M-fibre hrs
- Goal sky area: >~10k deg$^2$ (maximize overlap with LSST) with ~30-60% completeness to r~21-22
- ~2x10$^5$ variable-selected AGN to be revisited (2-4x, ~6-month gap)
- Spectral campaign of multi-wavelength AGN in central LSST DDFs to r~23.5 to assess completeness and obscuration corrections.
- **~10$^5$ (fibre-hr) ToOs (~3-100 days window) from LSST to explore novel SMBH-related variability events (EVAGN, CSAGN, TDEs, …)**
- **~2000 lensed AGN + up to ~20,000 TDE hosts.**
- SNR/AA ~10 for $r_{fib}$ < 20.0/21.0 to ~3 for $r_{fib}$ > 21.5/22.5

# Schedule and Milestones

- Jun 2023:
  - All subsystems manufactured, assembled, integrated and verified
  - Start of final full system tests in Europe
- Nov 2023:
  - Full system integrated and verified at AIP, ***Preliminary Acceptance*** *Europe*
  - Start shipping to Paranal
- Jul 2024:
  - System delivered, installed and commissioned on telescope
- Oct 2024:
  - Data flow commissioned and survey program validation performed, ***Provisional Acceptance Chile***

- Nov 2024 – Oct 2029:
  - First science survey of 4MOST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MPE
THE UNIVERSITY OF WESTERN AUSTRALIA
UNIVERSITY OF CAMBRIDGE
Lancaster University
Durham University
UNIVERSITY OF Southampton
ESO
rijksuniversiteit groningen

# 4MOST Observing Strategy

- Undecided as yet the extent to which 4MOST will follow LSST footprints. Feasible, but may add unwanted additional complexity to scheduler