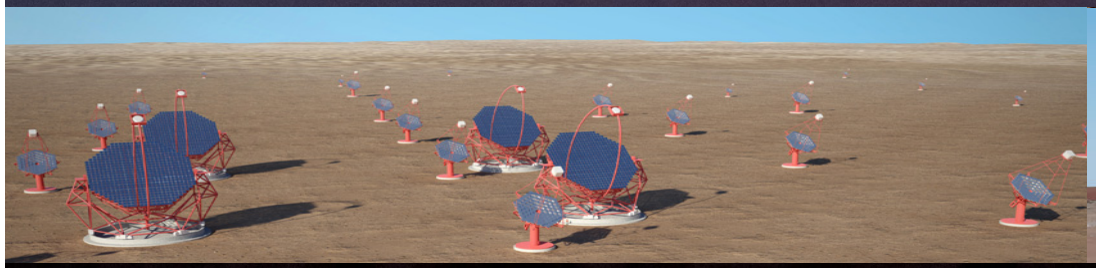


# ESO Facilities and Gaia

Bruno Leibundgut



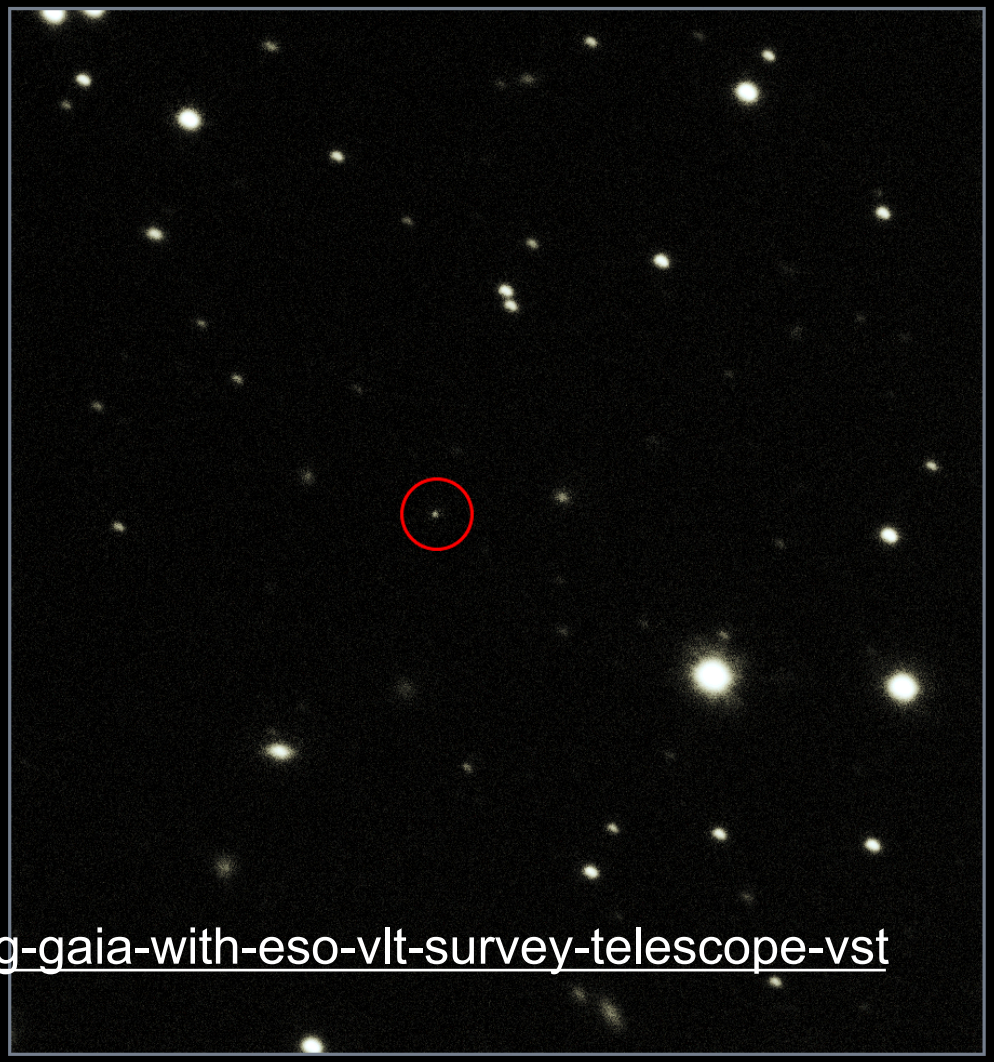

# Gaia Preparations

- Input catalogue and calibrations
  - ~46 nights in 2006 until 2011 (Gaia launch 2013)

| Mode | Telescope | Prog ID | Nights | | Instrument | Title |
|---|---|---|---|---|---|---|
| Service | NTT | 078.D-0114(A) | 16 | hrs | EMMI | *Exploring the red/near-IR spectra of hot stars in preparation of GAIA* |
| Service | 2.2 | 080.A-9001(A) | 0 | hrs | WFI | *Creating astrometric and photometric calibration fields for GAIA* |
| Service | 2.2 | 082.A-9018(A) | 0 | hrs | WFI | *Creating astronomic and photometric calibration fields for GAIA* |
| Service | VLT-Kueyen | 082.D-0339(A) | 32 | hrs | FLAMES | *Ground-based observations for Gaia's calibrations: Creating initial calibration fields at the Southern Ecliptic Pole* |
| Visitor | VLTI | 083.D-0029(A) | 1.5 | | AMBER | *Surface brightness asymmetries in Mira variables and supergiants: A threat to accurate Gaia parallaxes?* |
| Visitor | VLTI | 083.D-0029(B) | 1.5 | | AMBER | *Surface brightness asymmetries in Mira variables and supergiants: A threat to accurate Gaia parallaxes?* |
| Visitor | NTT | 083.D-0472(A) | 4 | | EFOSC2 | *Ground-based observations for Gaia's calibrations: spectral energy distributions of peculiar stars across the HR diagram* |
| Visitor | VLTI | 084.D-0131(A) | 3 | | AMBER | *Surface brightness asymmetries in Mira variables and supergiants: A threat to accurate Gaia parallaxes?* |
| Visitor | VLTI | 084.D-0131(B) | 3 | | AMBER | *Surface brightness asymmetries in Mira variables and supergiants: A threat to accurate Gaia parallaxes?* |
| Service | VLT-Kueyen | 084.D-0427(A) | 20 | hrs | FLAMES | *Ground-based observations for Gaia's calibrations: the Southern Ecliptic Pole initial calibration field* |
| Service | 2.2 | 085.A-9205(A) | 0 | hrs | WFI | *Photometry and astrometry for the GAIA mission* |
| Service | 2.2 | 086.A-9005(A) | 0 | hrs | WFI | *Creating astrometric and photometric calibration fields for Gaia* |
| Visitor | NTT | 086.D-0176(A) | 4 | | EFOSC2 | *Ground-based observations for Gaia's calibrations : Establishing the Grid of Spectro-Photometric Standard Stars.* |
| Service | VLT-Kueyen | 086.D-0295(A) | 30 | hrs | FLAMES | *Ground-based observations for Gaia's calibrations: the Southern Ecliptic Pole initial calibration field* |
| Visitor | NTT | 182.D-0287(A) | 5 | | EFOSC2 | *Ground-based observations for Gaia's calibrations : Establishing the Grid of Spectro-Photometric Standard Stars.* |
| Visitor | NTT | 182.D-0287(B) | 5 | | EFOSC2 | *Ground-based observations for Gaia's calibrations : Establishing the Grid of Spectro-Photometric Standard Stars.* |
| Visitor | NTT | 182.D-0287(C) | 7 | | EFOSC2 | *Ground-based observations for Gaia's calibrations : Establishing the Grid of Spectro-Photometric Standard Stars.* |
| Visitor | VLT-Kueyen | 380.C-0773(A) | 1 | | UVES | *Ground-based observations for GAIA: Building a homogeneous library of high-quality solar-analogue spectra for Solar-System research* |

# Gaia Observations

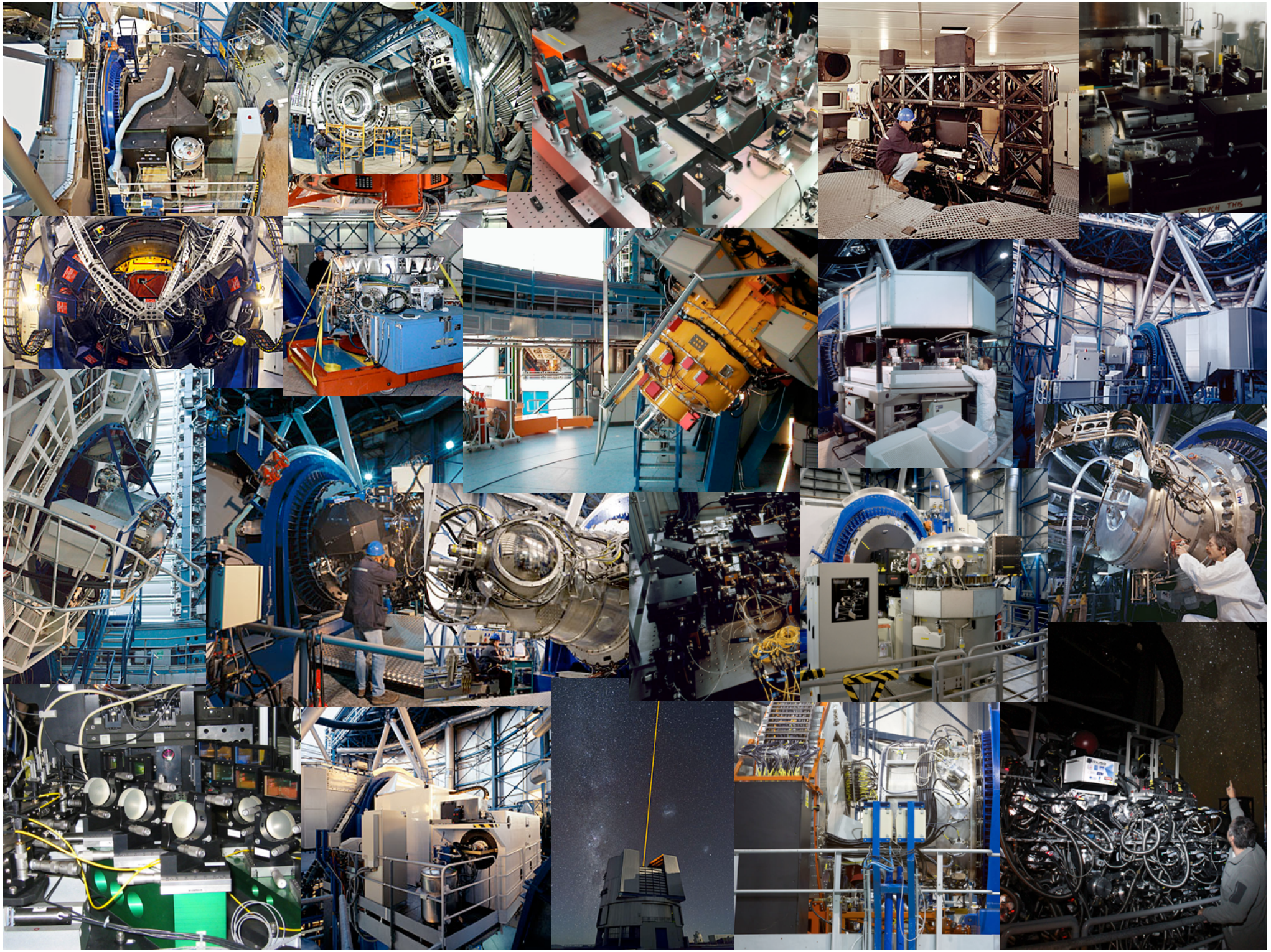
- Observe the Gaia satellite every night with the VST



https://sci.esa.int/web/gaia/-/61328-tracking-gaia-with-eso-vlt-survey-telescope-vst
https://www.eso.org/public/news/eso1908/

# La Silla Paranal Facilities

- VLT
  - Instrumentation operating, in assembly and planned
    - Covers the available optical infrared wavelengths 300nm to 20μm
    - Angular resolution from seeing limit to 50 μ-arcseconds
    - FORS2, UVES, FLAMES, VISIR, HAWK-I, X-Shooter, AOF, KMOS, MUSE, SPHERE, ESPRESSO, CRIRES, ERIS, MOONS
- VLTI
  - PIONIER, GRAVITY, MATISSE
- VISTA
  - VIRCAM, 4MOST
- VST
  - ΩCam
- NTT
  - EFOSC2, SOFI, SOXS
- 3.6m
  - HARPS, NIRPS



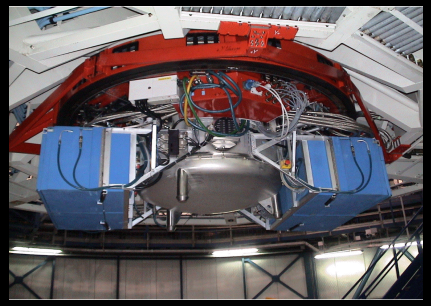
# VLT Instruments 2020

UT1 

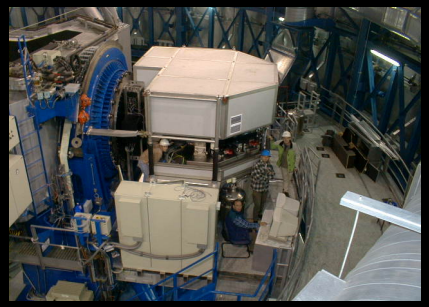
FORS2

UT2 

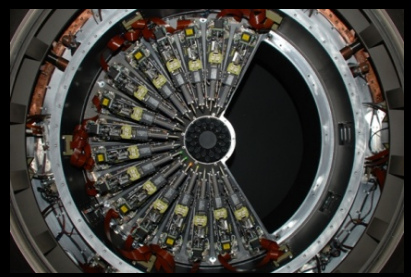
VISIR



UVES



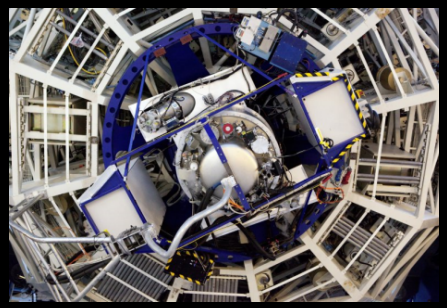
KMOS



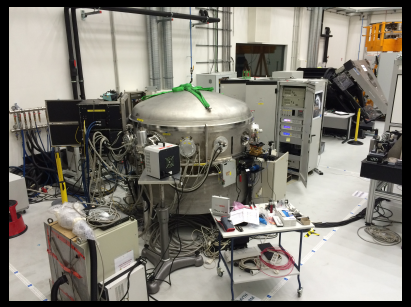
FLAMES

UT3 

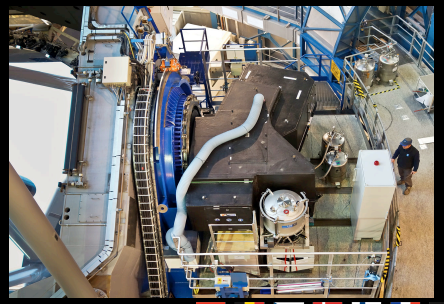
X-SHOOTER



CRIRES

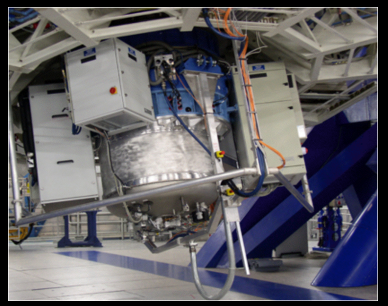


SPHERE

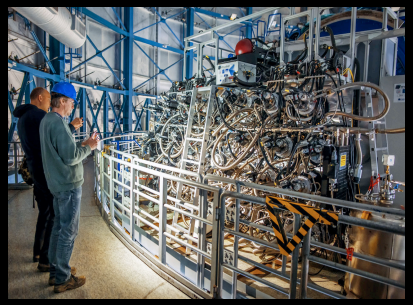


UT4 

ERIS

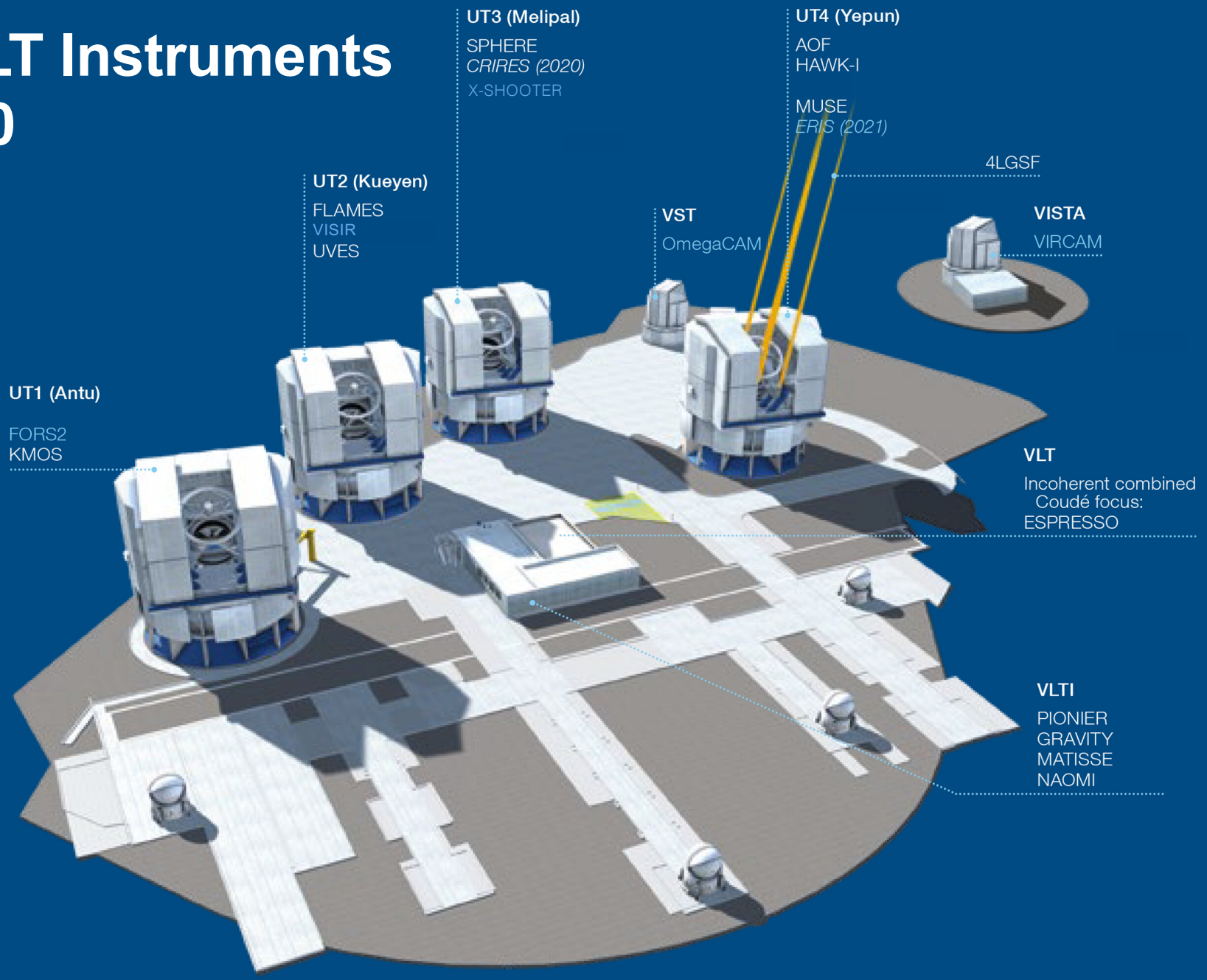


MUSE



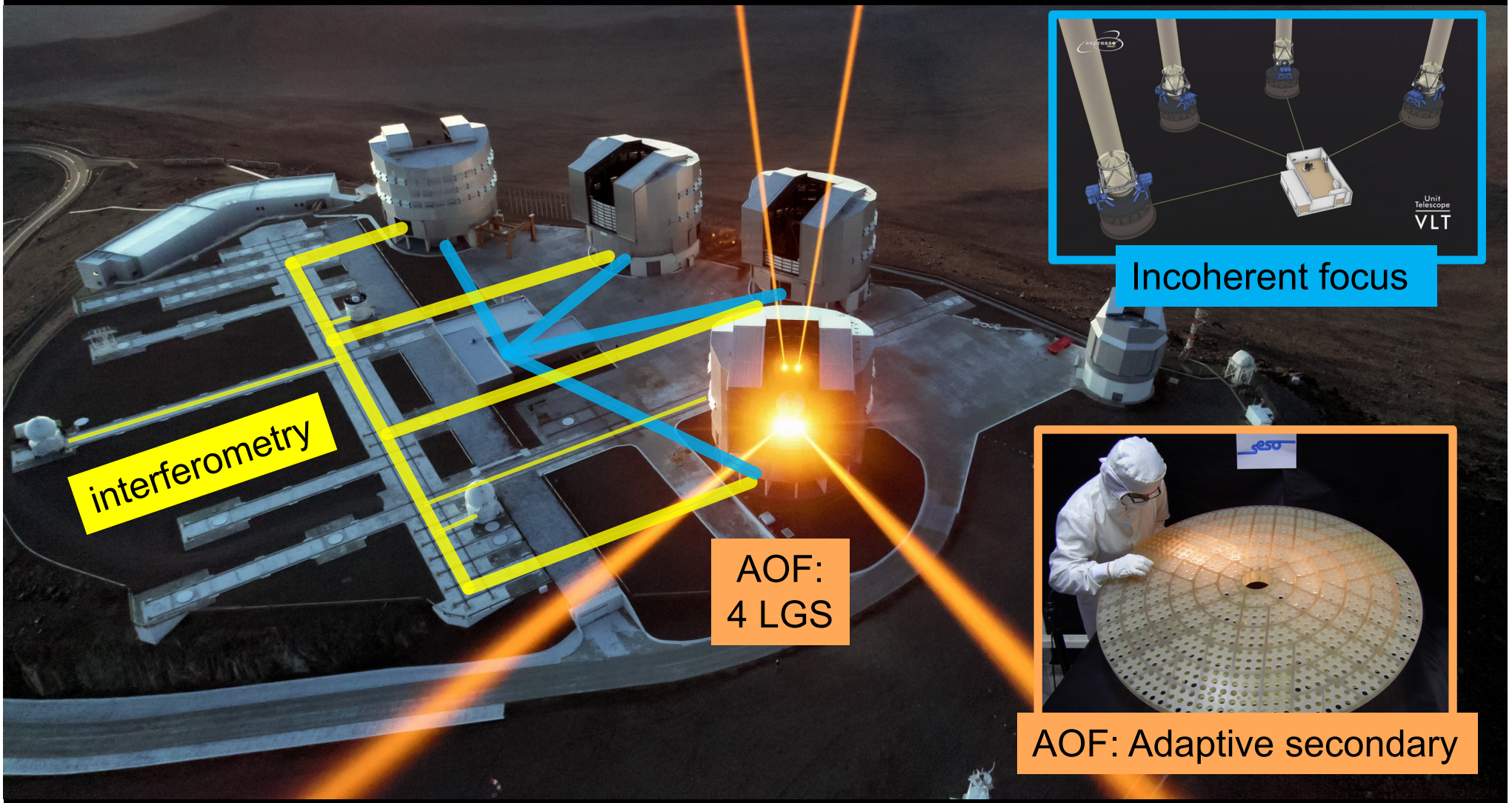
HAWK-I

# The VLT Instruments in 2020




Gaia Legacy, Barcelona - 18 February 2020

# VLT unique capabilities







Incoherent focus



AOF: Adaptive secondary

# Multi-Wavelength Astrophysics

- ESO offers access to optical, infrared and sub-mm wavelength ranges
- VLT/I provide many resolution scales
- Operational model adapted to fast reactions/transient targets

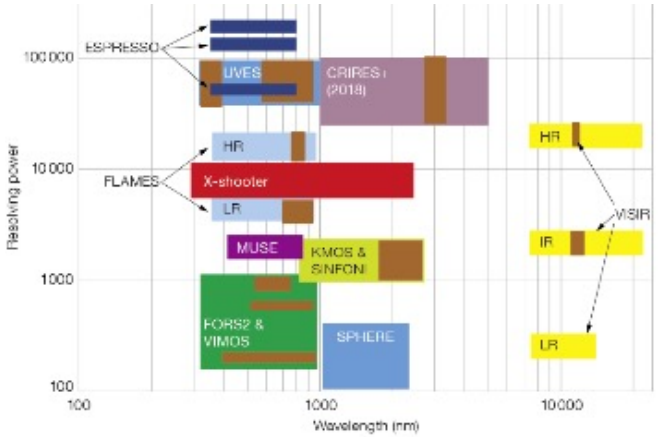



**Figure 1:** **Wavelength-Spectral Resolving power diagram for the VLT instruments of 1st and 2nd generation.**

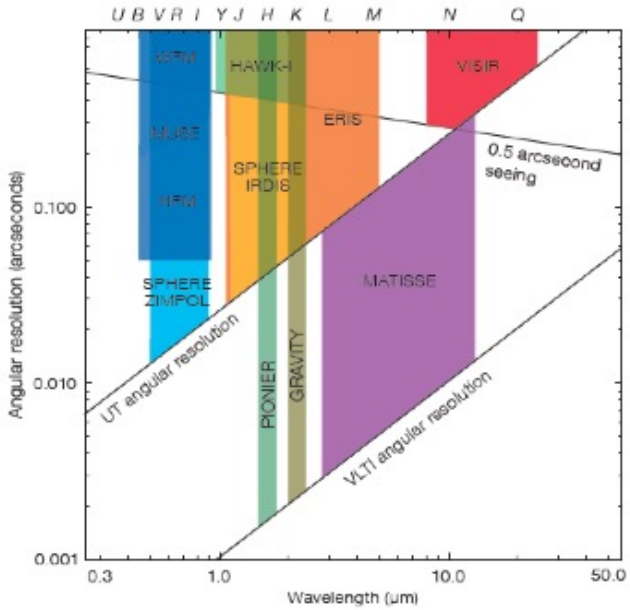



**Figure 2:** **Wavelength-angular resolution diagram for the VLT/I instruments of 1st and 2nd generation.**

# Science with Paranal/La Silla telescopes

- Contributions to nearly all of astrophysics
  - Solar system
    - Trans-Neptunian Objects, asteroids, comets
  - Exo-planets
    - direct imaging, temperate planets, planetary systems
  - Stellar physics
    - metal-poor stars, supernovae, neutron star mergers
  - Milky Way structure
    - galactic centre, distances
  - Galaxy evolution
    - redshift surveys, rotation curves, absorption studies
  - Cosmology
    - accelerating universe, background temperature, chemical evolution

# Upcoming instruments

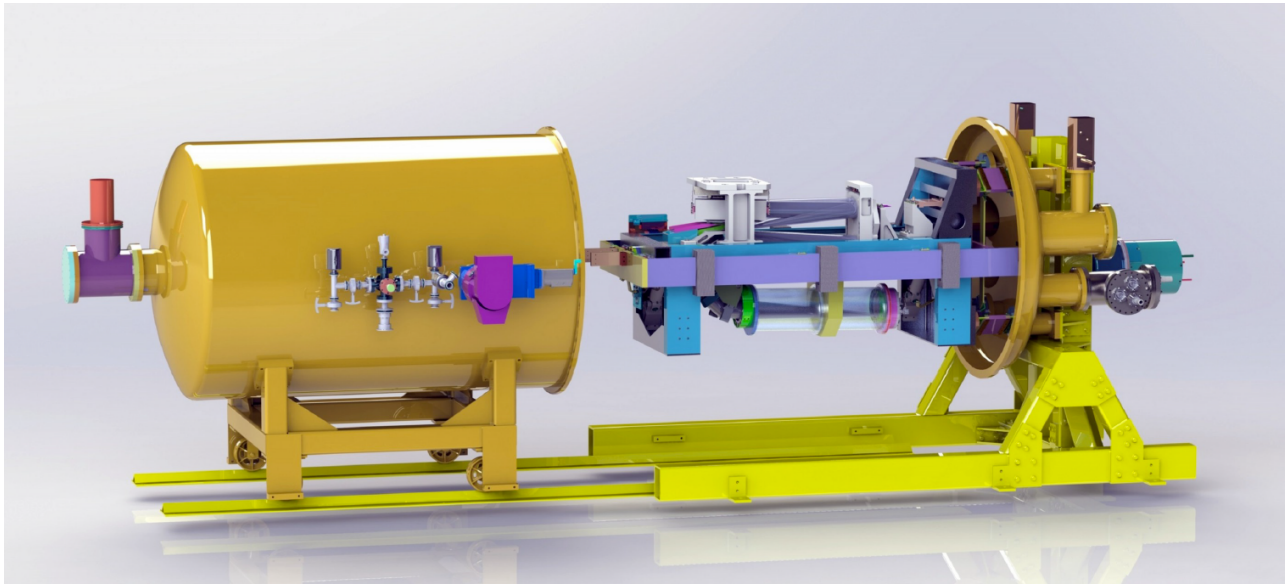
- CRIRES+ (2020): near-IR high-R spectrograph
  - Upgrade wavelength coverage; polarimetry
- ERIS (2021): near-IR AO imager / spectrograph
  - Imager, coronagraph, low-resolution spectrograph 1-5μm (replaces NACO)
  - IFU 1-2.5μm (SINFONI upgrade)
- MOONS (2022): near-IR medium-resolution MOS
  - 1001 fibres over 500 arcmin$^2$ (full VLT field-of-view)

# Instruments for the 4m telescopes

- NIRPS for the 3.6m (La Silla) **2020**
  - Complement HARPS in the near-IR for accurate radial velocities
- SoXS for the NTT (La Silla) **2021**
  - Vis-NIR medium-resolution spectrograph for transient follow up
- 4MOST for VISTA (Paranal) **2022**
  - Visible MOS
  - Operated by consortium

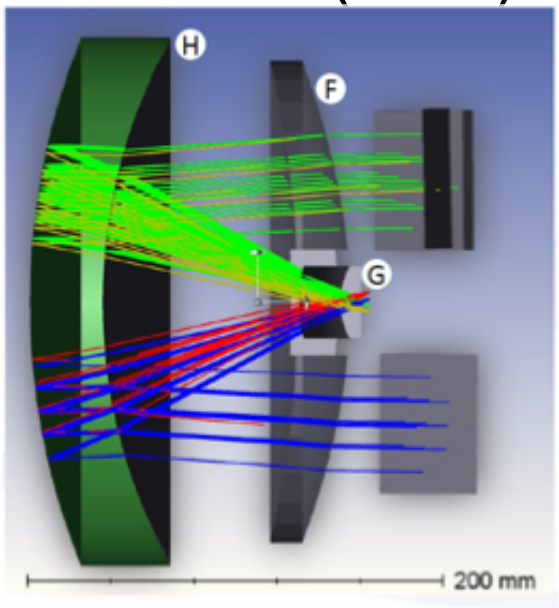
# NIRPS

- NIRPS @ 3.6m : High Accuracy NIR Spectrograph
  - NIR (970-1800 nm)
  - High Resolution: R>80000
  - AO-Assisted
  - Simultaneous observations with HARPS
  - $v_{rad} < 1\ m/\mathrm{sec}$

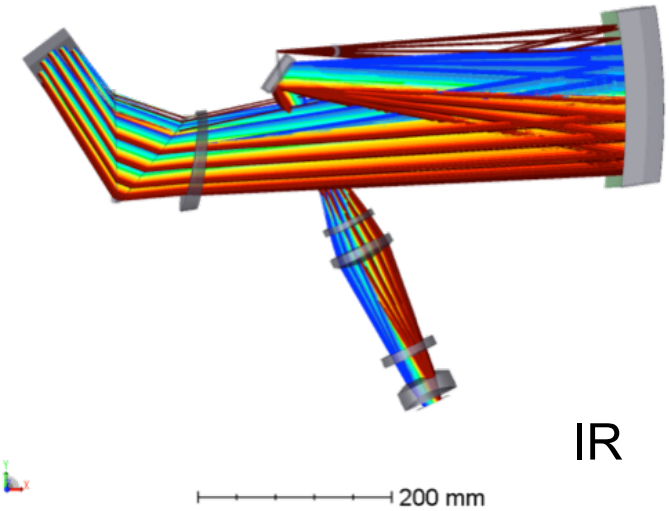


# SOXS

- SOXS @ NTT
  - Broad-band spectrograph, 350nm through 2.0μm
  - *R* ~ 4,500 (3,500–6,000)
  - Two arms (UV-VIS + NIR)
  - S/N ~ 10 spectrum, 1-hr exposure at *R* ~ 20
  - Acquisition camera (3'x3') to perform photometry in *ugrizY*




Vis




IR

# 4MOST

- 4MOST will conduct only surveys
  - 70% GTO to consortium for first 5 years of operations
    - builds instrument and operates it
    - handles all survey data
- 10 consortium GTO surveys
  - see talk by Christina Chiappini
- Call for Letters of Intent for community surveys
  - Deadline: 28 February 2020

# 4MOST Overview

- Main science drivers
  - Cosmology, galaxy evolution, high-energy, transients, Milky Way structure
  - Optical spectroscopy complement to
    - Euclid/LSST/SKA
    - eROSITA
    - Gaia
- Surveys only
  - runtime: 5 years
- Build and operated by consortium
  - PI: Roelof de Jong (AIP)
- Expected start of operations: 2022

# 4MOST Consortium Surveys

- Description in Messenger 175
  - https://www.eso.org/sci/publications/messenger/toc.html?v=175&m=Mar&y=19
- Presented at 4MOST workshop in May

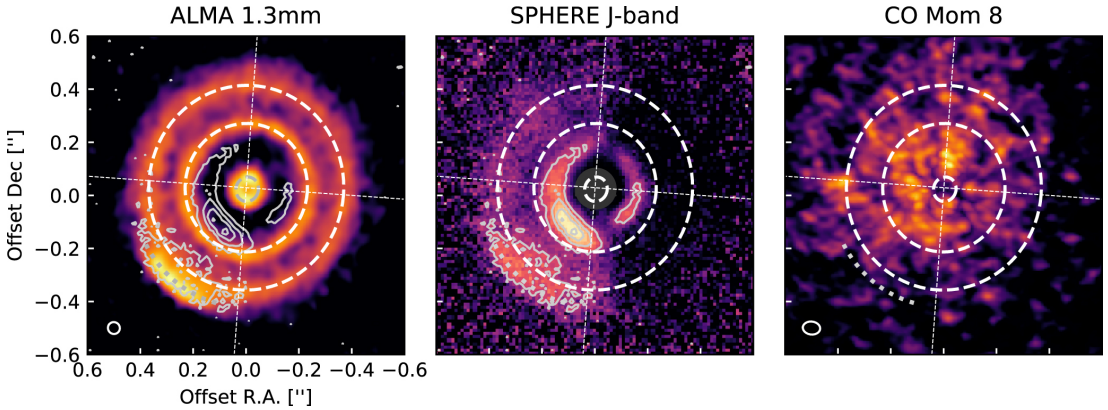
Table 2. 4MOST Consortium Surveys and their Principal Investigators. de Jong et al. 2019

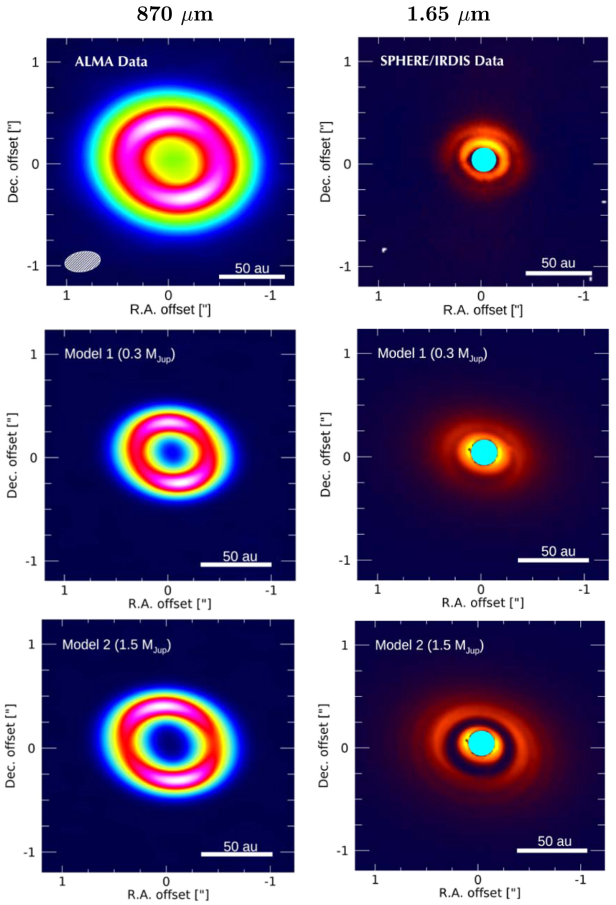
| No | Survey Name | Survey (Co-)PI |
|---|---|---|
| S1 | Milky Way Halo LR Survey | Irwin (IoA), Helmi (RuG) |
| S2 | Milky Way Halo HR Survey | Christlieb (ZAH) |
| S3 | Milky Way Disc and Bulge LR Survey (4MIDABLE LR) | Chiappini, Minchev, Starkenburg (AIP) |
| S4 | Milky Way Disc and Bulge HR Survey (4MIDABLE HR) | Bensby (Lund), Bergemann (MPIA) |
| S5 | Galaxy Clusters Survey | Finoguenov (MPE) |
| S6 | AGN Survey | Merloni (MPE) |
| S7 | Galaxy Evolution Survey (WAVES) | Driver (UWA), Liske (UHH) |
| S8 | Cosmology Redshift Survey | Richard (CRAL), Kneib (EPFL) |
| S9 | Magellanic Clouds Survey (1001MC) | Cioni (AIP) |
| S10 | Time-Domain Extragalactic Survey (TiDES) | Sullivan (Southampton) |

# ALMA

# Planet forming disks

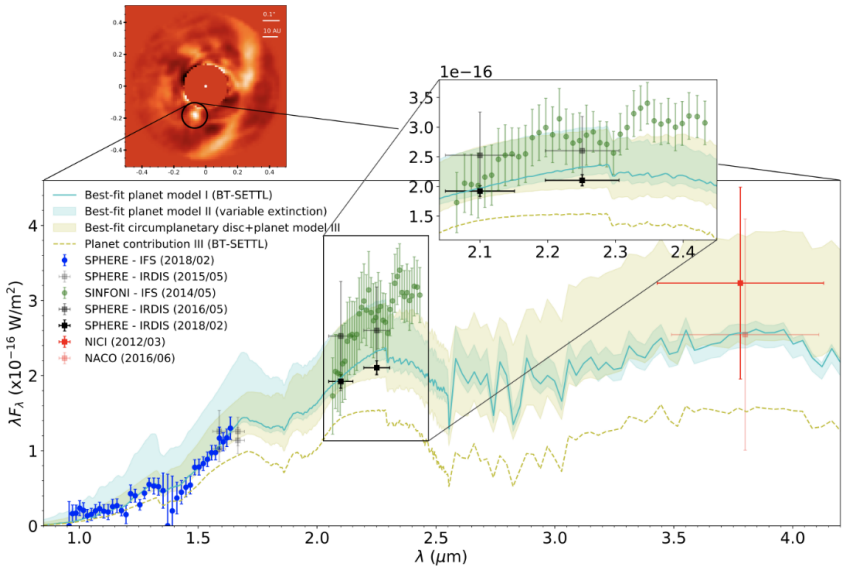
- Results from ALMA and VLT/SPHERE and VLT/MUSE
- DSHARP: presence of companion *(below; Perez et al. 2018)*
- Substructure due to Jovian planet *(right; Ruiz-Rodriguez et al. 2019)*



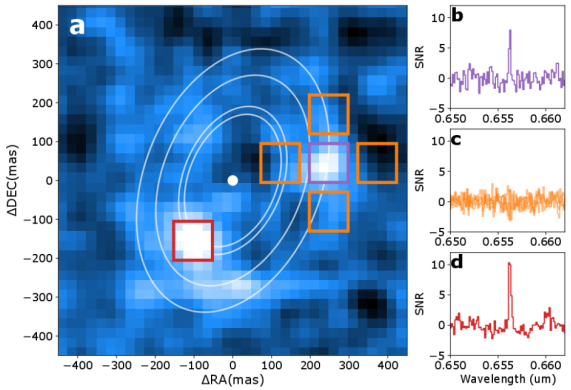



# Circumplanetary disks detected with ALMA and VLT

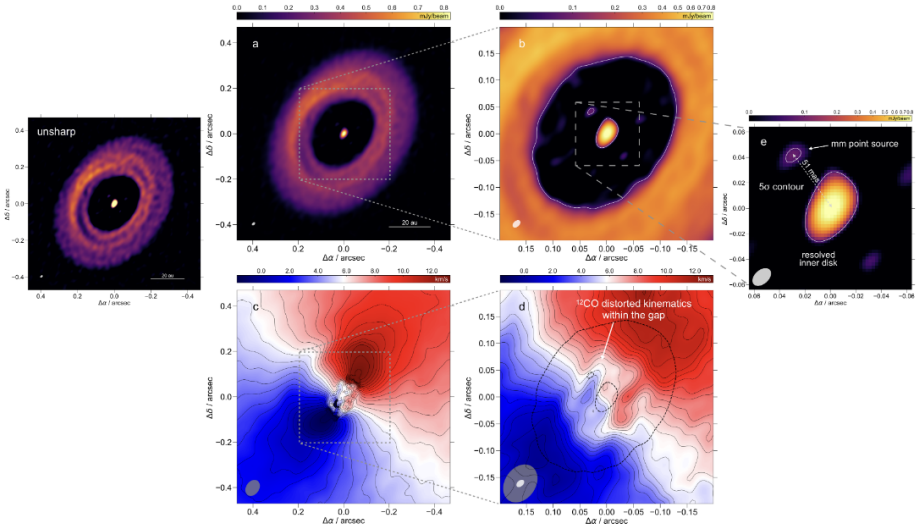
## PDS 70 b

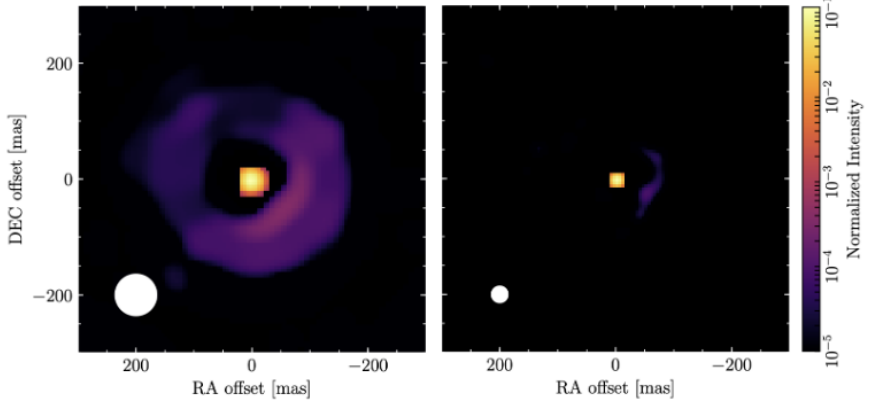



*Christiaens et al. (2019); Haffert et al. (2019)*




## HD 100456

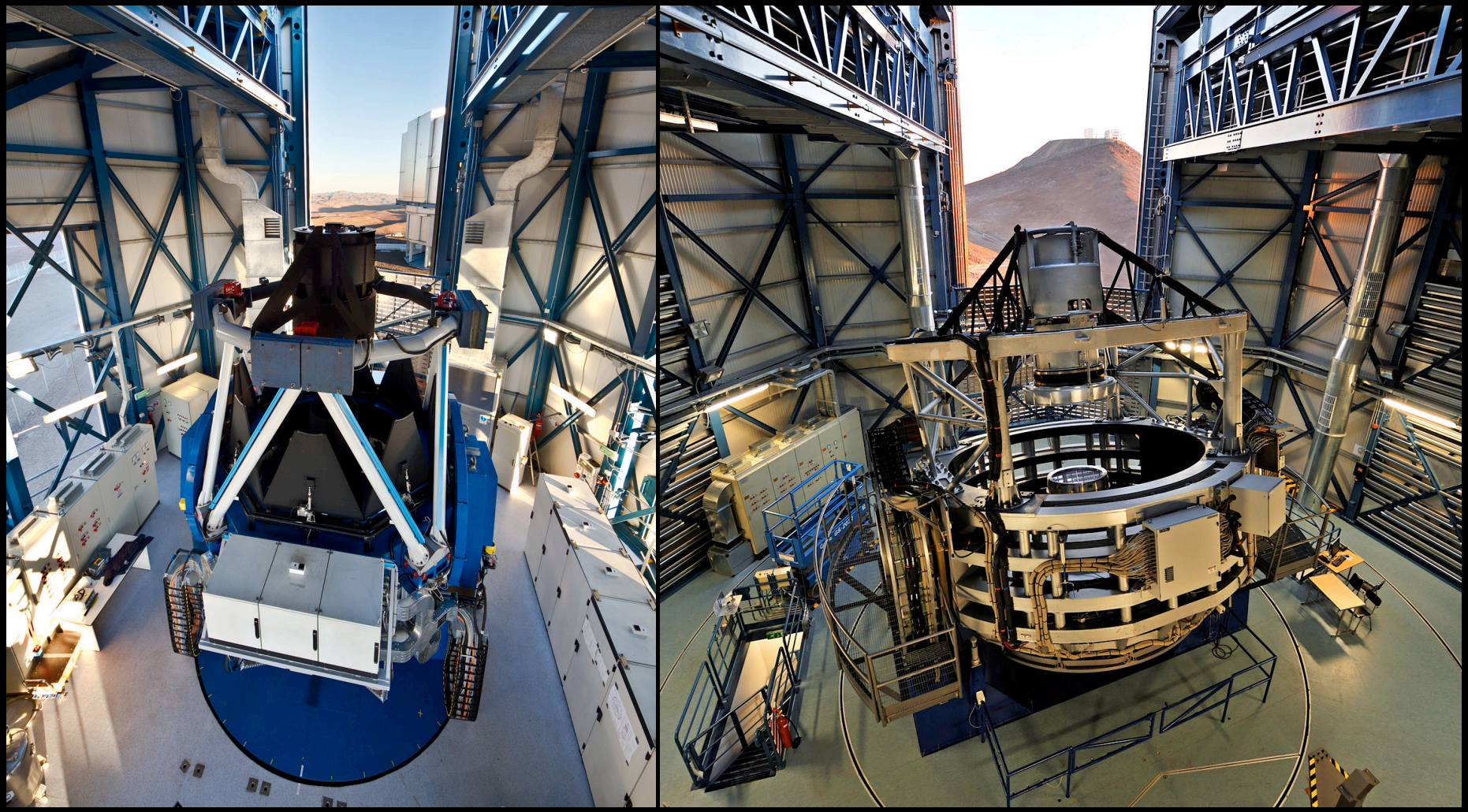


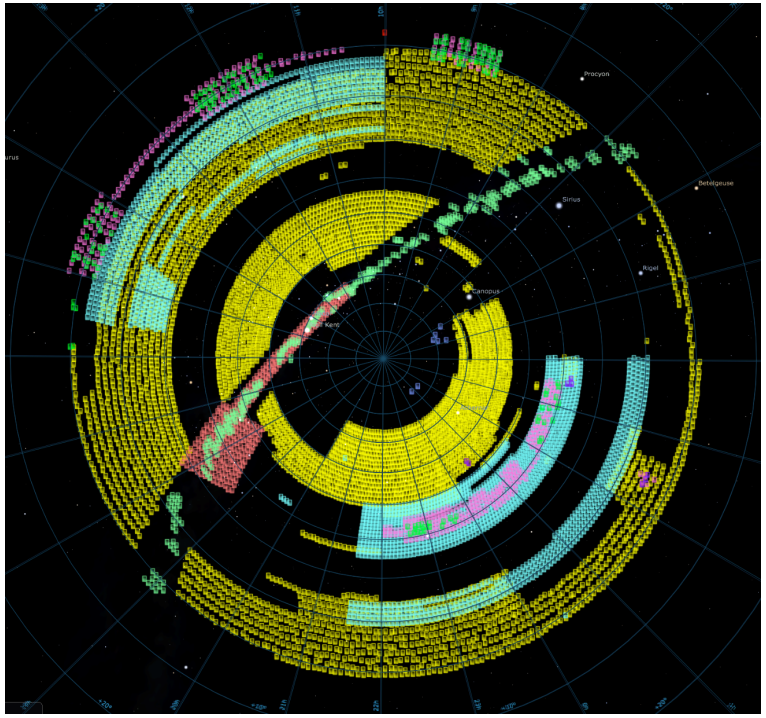

*Perez et al. (2019)*

# The Survey Telescopes

- VST 2.6m for optical and VISTA 4.1m for infrared observations



# ESO Public Surveys



- VST
  - VPHAS+, ATLAS (extensions), KiDS
- VISTA round 1 surveys
  - VVV, VIKING, UltraVISTA, VMC, VIDEO, VHS
- VISTA round 2 started
  - VINROUGE, UltraVISTA extension, VVVX, VEILS, GCAV, VISIONS, SHARKS
  - completion expected end 2020
- Spectroscopic Surveys
  - Gaia-ESO, PESSTO, VANDELS, LEGA-C

# VLT2030 workshop

https://www.eso.org/sci/meetings/2019/VLT2030.html

- Review the scientific and facilities' landscape
- Invite community to discuss their ideas and instrumental projects
- Probe what the community can do in addition to ELT instruments

ESO Messenger 177, 67 (2019)

# VLT Opportunities

- Four 8m telescopes
  - flexibility
  - scientific throughput
    - 1200 observing nights/year
- Successful operational model
  - expand existing model to allow new modes
    - high time resolution photometry and spectroscopy
    - faster turnaround (currently DDT)
    - closer interaction with user, e.g. remote observing
- Telescope system
  - spatial resolution from 1 degree to 2 mas
  - wavelength coverage from 320nm to 20μm
  - spectral resolutions from a few to 100000

# Strategic planning

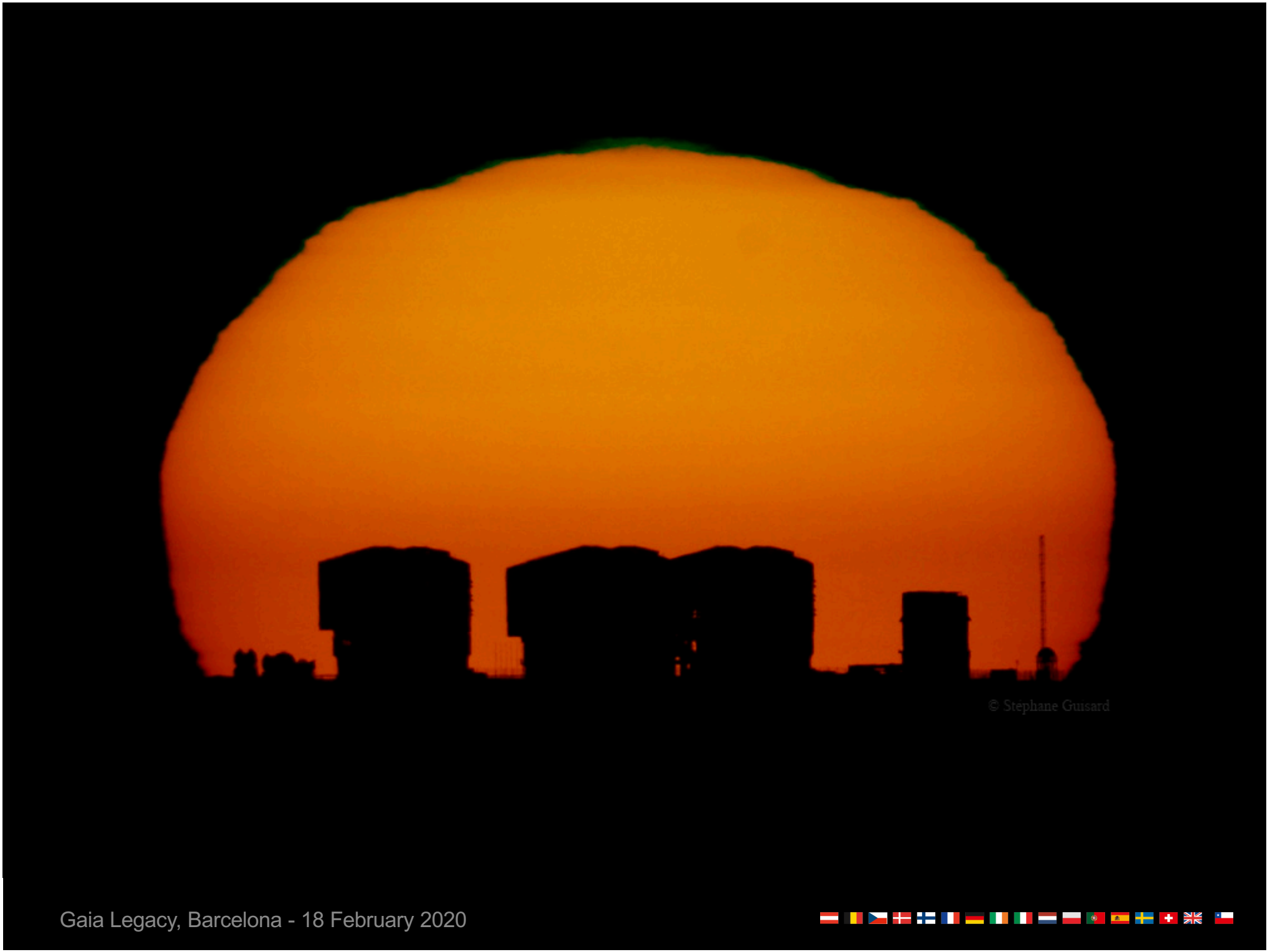
- Identify strengths
  - Very flexible Operation model
  - Variety of  instruments: workhorses and specialized
  - Uniqueness of the VLT facility
  - Complement ELT/JWST in the blue
  - Existing expertise in ESO and community
- Identify missing capabilites
  - Highly multiplexed wide field spectrograph for galaxies surveys → *deemed too expensive in our context*
  - High-resolution MOS for Galactic science

# VLT 2030

- Identify a set of new capabilities
  - high-angular resolution
    - interferometry
      - increase sensitivity
    - adaptive optics
      - increase field (multi-conjugate AO)
      - improve correction (Strehl, XAO)
  - new parameter space
    - blue IFU
  - high spectral resolution multiplex
    - “HR-MOS”
- Maintain competitive existing instrumentation

# HR-MOS

- Most planned MOS have R~4-20k, often on 4m telescopes (4MOST, WEAVE)
- Science cases requiring R~50k on 8m:
  - Velocities for Gaia stars R>16
  - r-process origin
  - detailed abundances of 100's thousands of halo stars
  - …
- Most requested facility in 2015 ESO users poll
- ESO willing to probe the idea in the community




Gaia Legacy, Barcelona - 18 February 2020