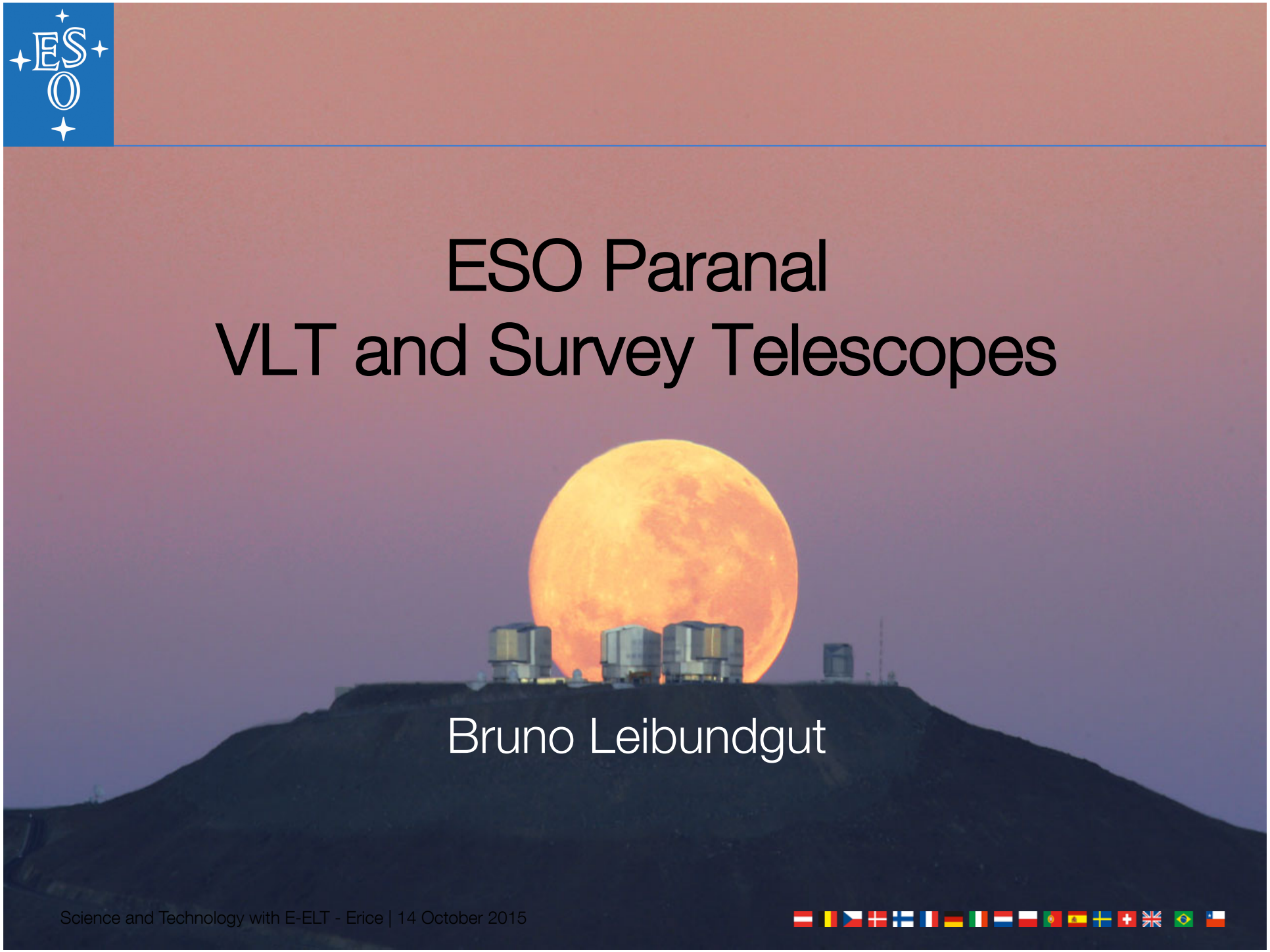
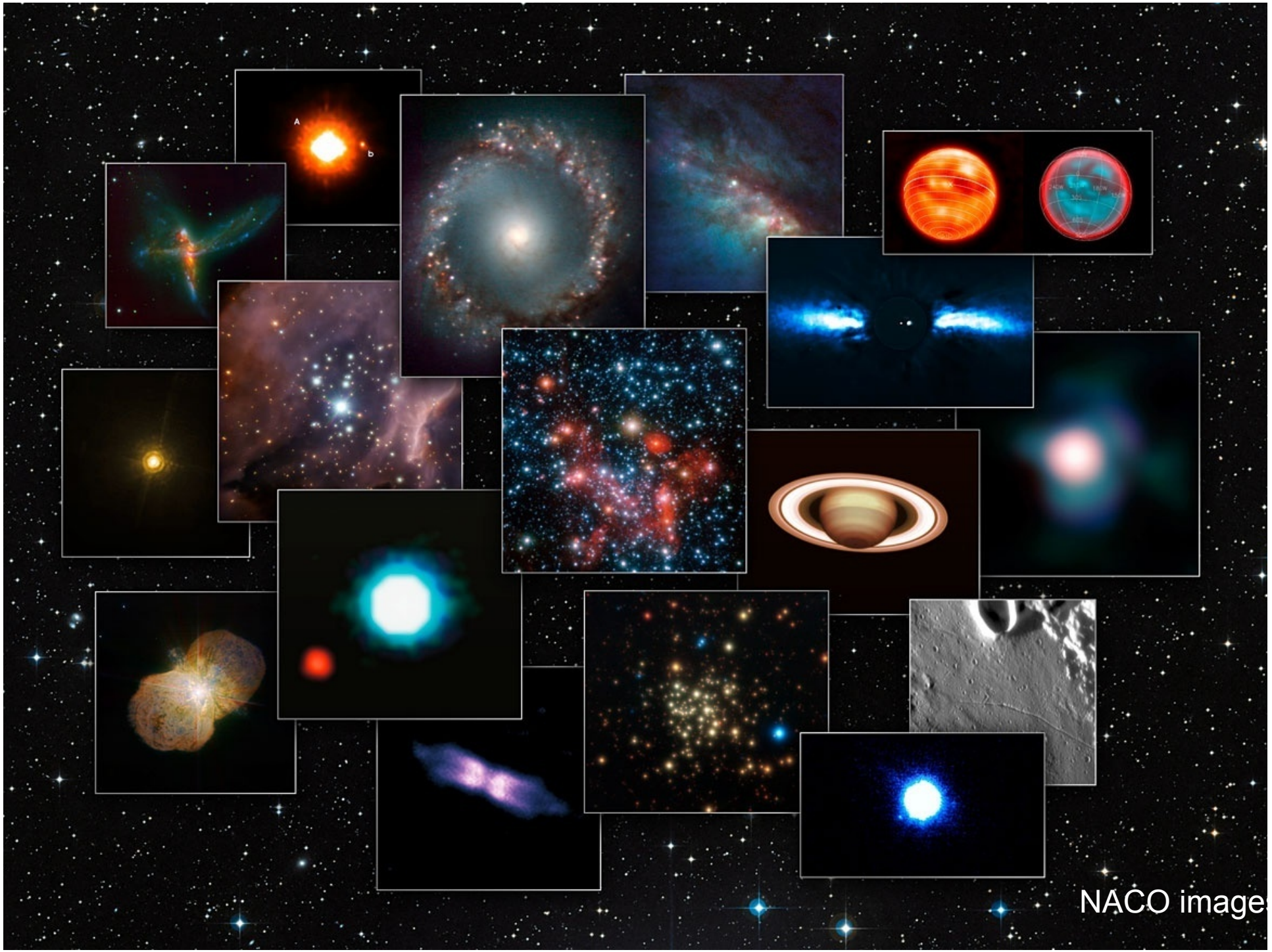
ESO Paranal
VLT and Survey Telescopes



Bruno Leibundgut

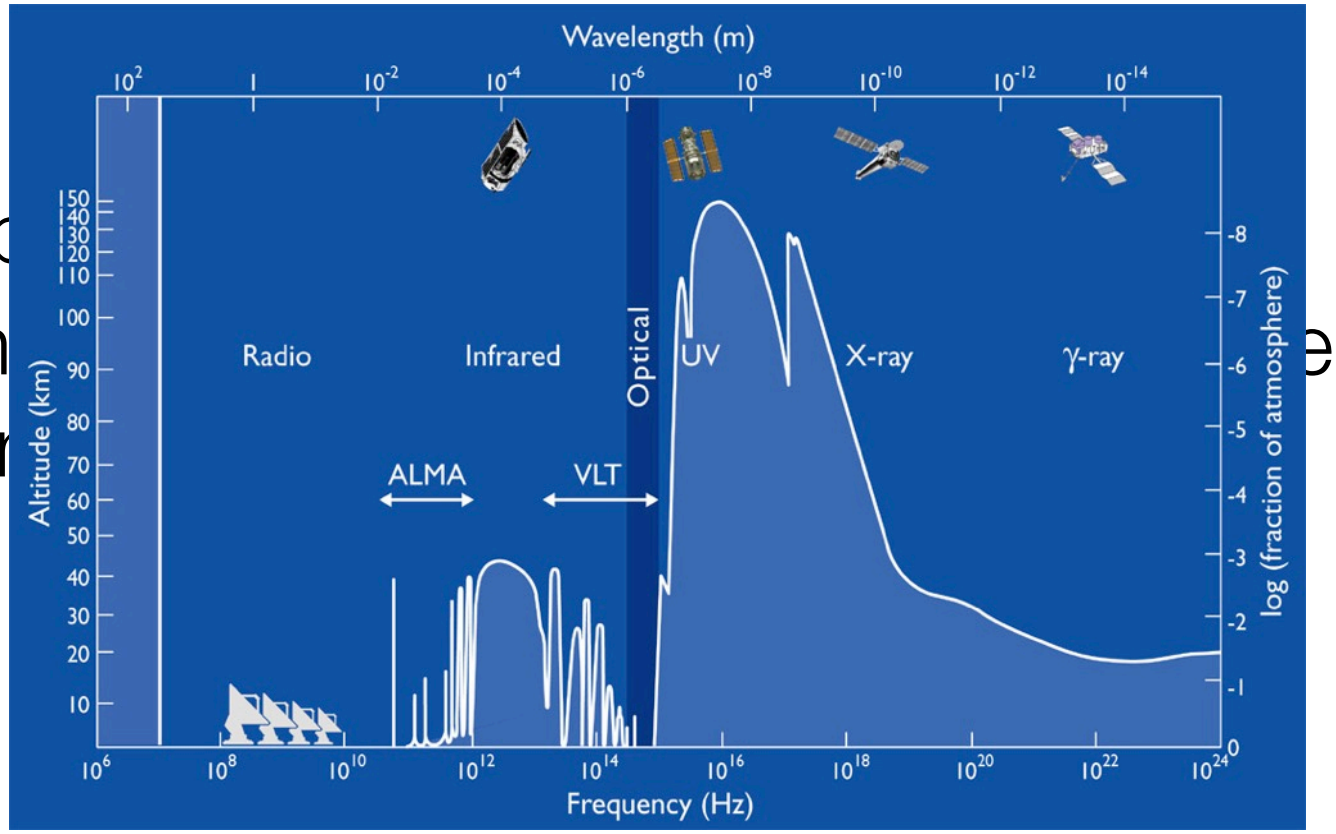

A
b
NACO image

Astrophysics in a Golden Age

- Full coverage of electro-magnetic spectrum

  MAGIC/HESS/VERITAS →Fermi/INTEGRAL → XMM/Chandra/Swift/Rossi XTE → Galex → HST/Gaia → ground-based optical/IR → ISO/Spitzer → Herschel → Planck→ IRAM/JCMT/APEX/ALMA/NOEMA → radio telescopes

- Astro-p
  - cosm es,
    dark m



Current ground-based facilities

- Large telescopes for a wide variety of investigations

OIR Astronomy

- Part of the multi-wavelength universe
  - central region for many processes

> Almost every new astronomical source, whether discovered by radio telescopes on the ground or by infrared, ultraviolet, X-ray, or gamma-ray telescopes in space, must be observed by ground-based OIR telescopes to understand its physical nature and significance.

McCray et al. 1995
A Strategy for Ground-Based Optical and Infrared Astronomy

Consider the future

- Within the decade the following scientific progress can be expected:
  - Detailed knowledge of a comet's core (Rosetta)
  - Detailed dynamical structure of a fair fraction of the Milky Way (Gaia)
  - Cosmological parameters determined to high accuracy (Planck), but nature of Dark Matter and Dark Energy unclear
  - Detailed checks on strong gravity performed (GC)
  - Thousands of exo-planets
  - Many exo-planet atmospheres characterised
  - Fundamental physics questions to be addressed through astrophysics, e.g. fundamental constants or quantum theories of space time

Consider the future (cont.)

- Within the decade the following scientific progress can be expected:
  - Combination of objects with very different environmental parameters in close neighbourhood (cold gas, shocks, hot plasmas).
    - mass transfer and mass loss in close binaries
    - neutron stars in supernova remnants
    - dust formation around stars and in shocks
    - the environment of active galactic nuclei
    - cooling in galaxy clusters
    - detailed structures in transition disks
    - planetary nebulae
  - High-redshift galaxies near the time of recombination characterised in deep extragalactic fields
  - The first sources of gravitational waves may have been detected

ESO Science Newsletter

- Regular electronic newsletter with latest information
  - Topics in September
    - Report on ALMA Cycle 3 Proposal Review
    - ESO Period 97 Proposal Submission Statistics
    - Application for ESO Studentships
    - VLTI Resumes Observations
    - ALMA Cycle User Survey Results
    - ALMA Status Report
    - Release of stacked Images and Source Lists of VST ATLAS Survey
    - IMPRS Astrophysics Studentships 2016


European Southern Observatory

ESO Science Newsletter October 2015

08 Oct 2015

SPHERE NIR images of asteroid Ceres

This newsletter is a summary of recent ESO Science Announcement items. Follow the links or visit ESO Science Announcements to read more.

Science Announcements

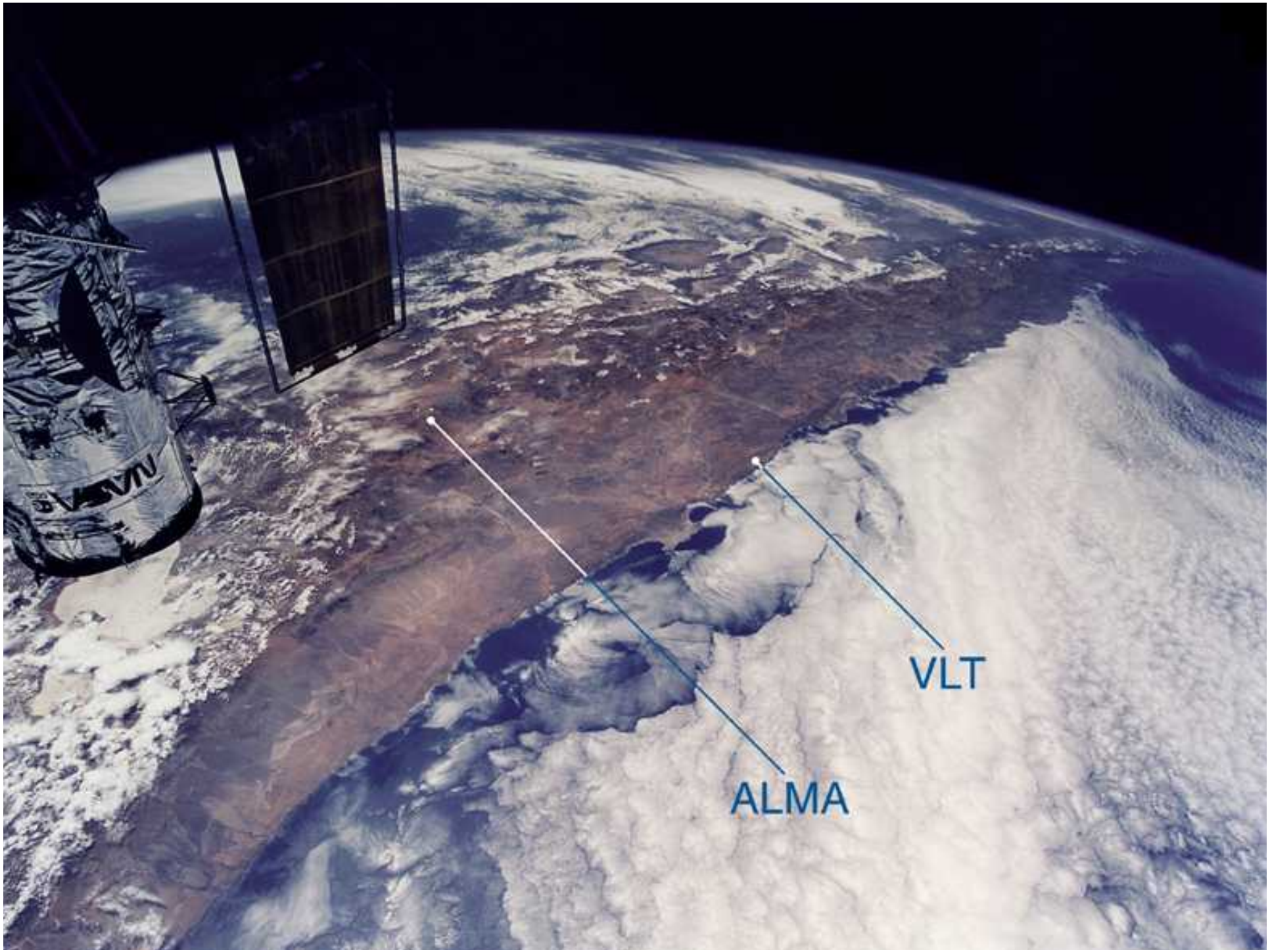
Report on ALMA Cycle 3 Proposal Review

07 Oct 2015:

Humble beginnings

Paranal and Armazonas

M. Tarenghi

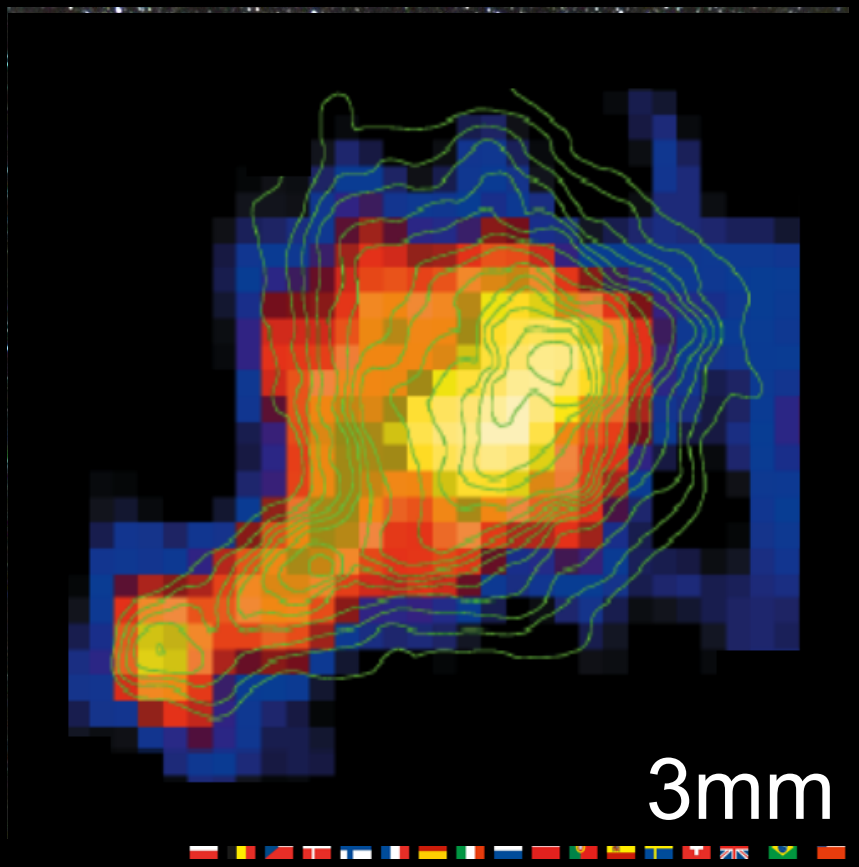

VLT
ALMA

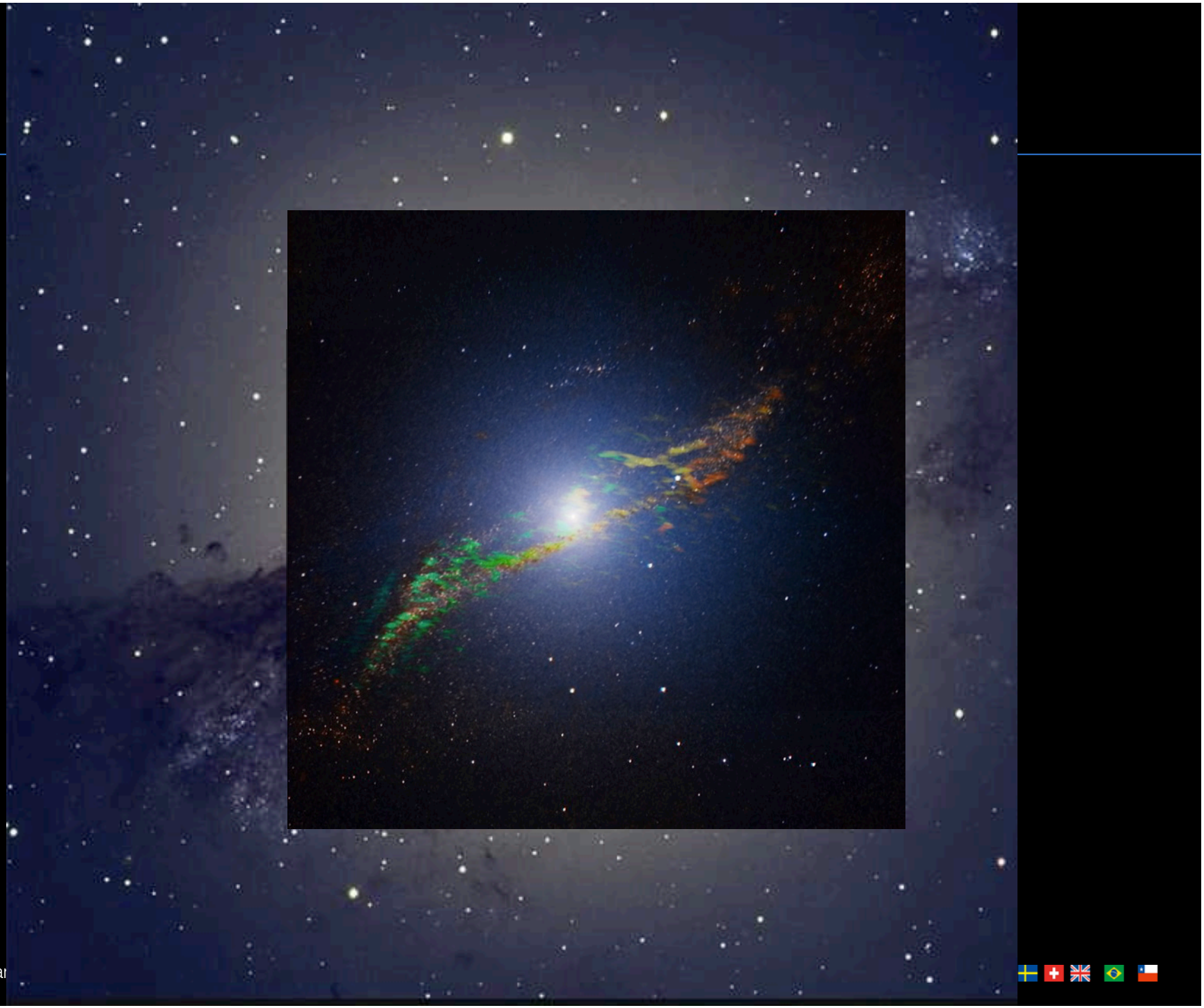
ALMA transporter

ALMA observing

Why telescopes and antennas?

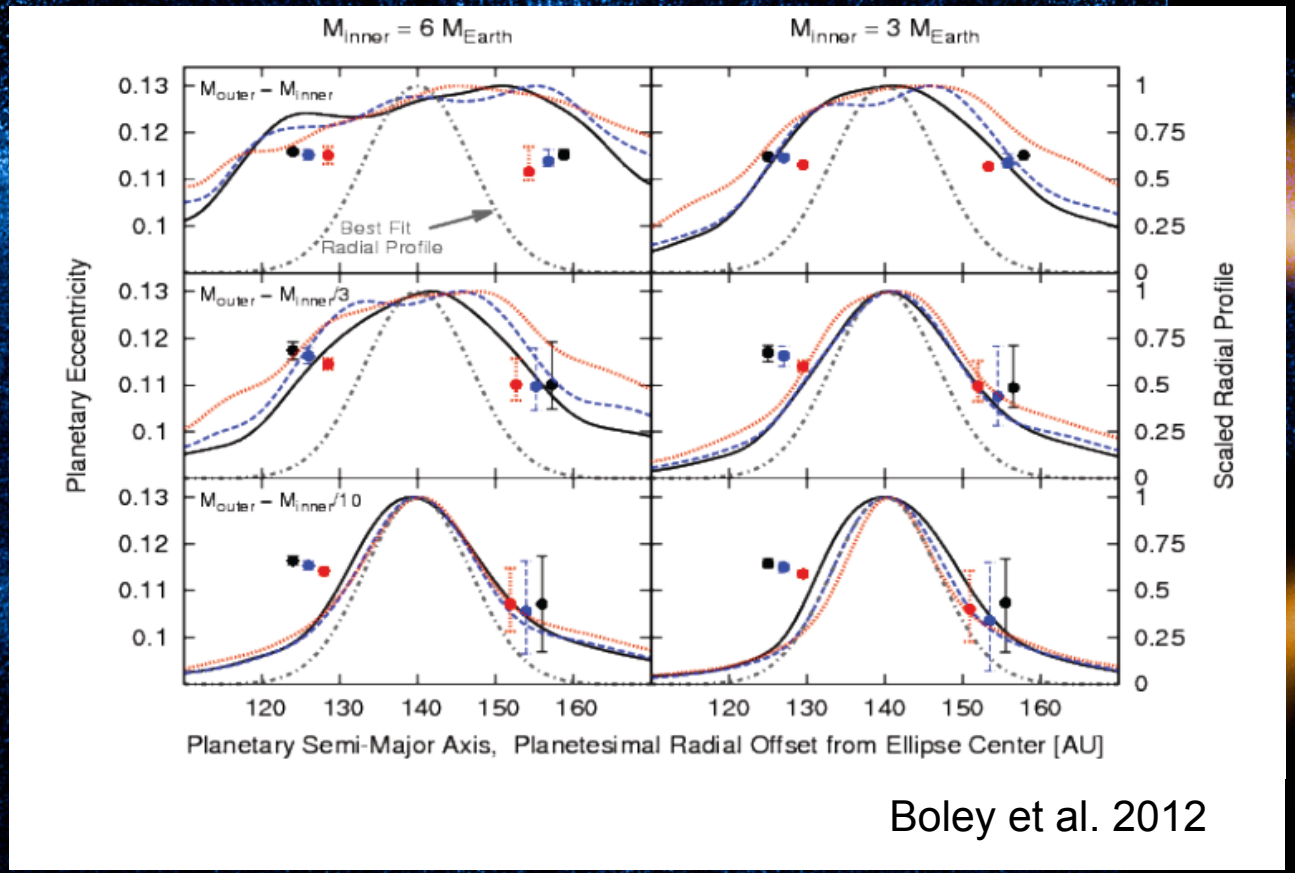
- The strength of black bodies
- Example: heat images





Planet dust rings

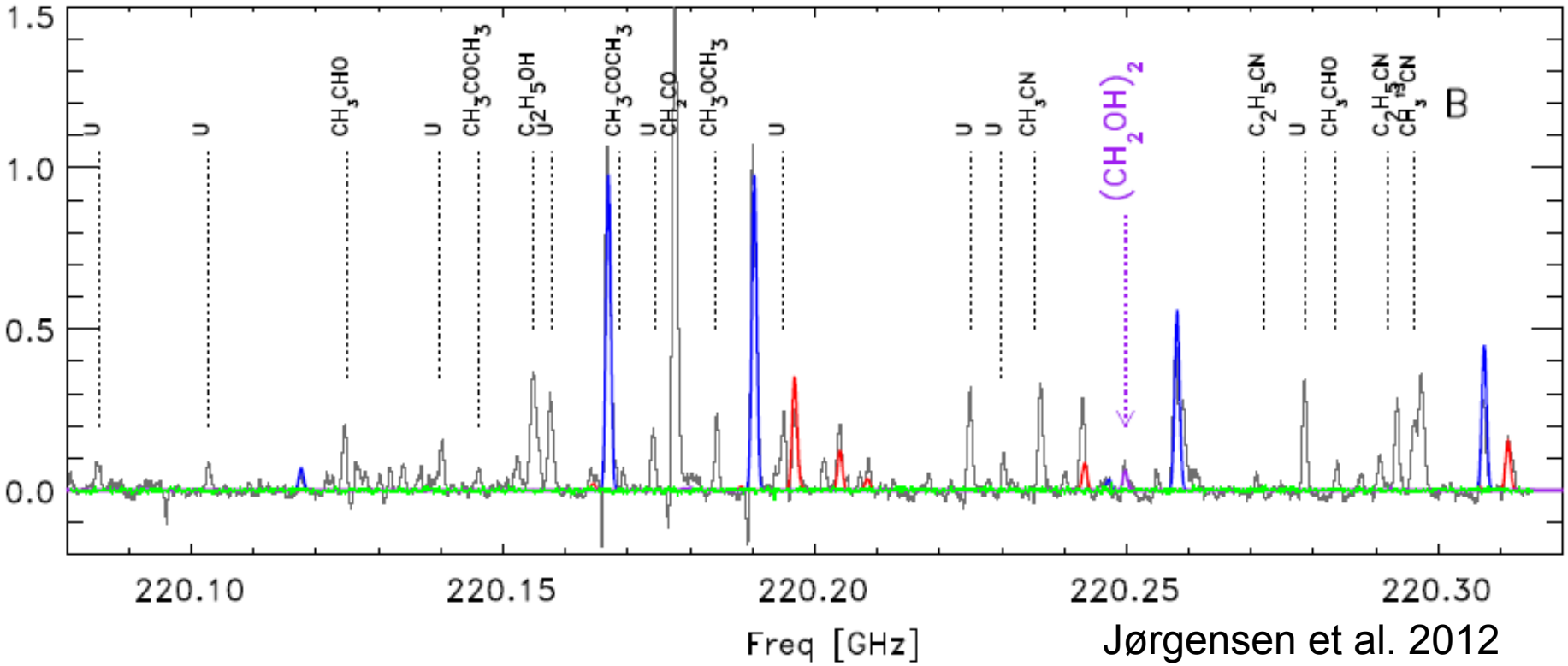
- Dust ring around Fomalhaut
- Hints for two planets → a few Earth masses



Boley et al. 2012

Complex molecules in space

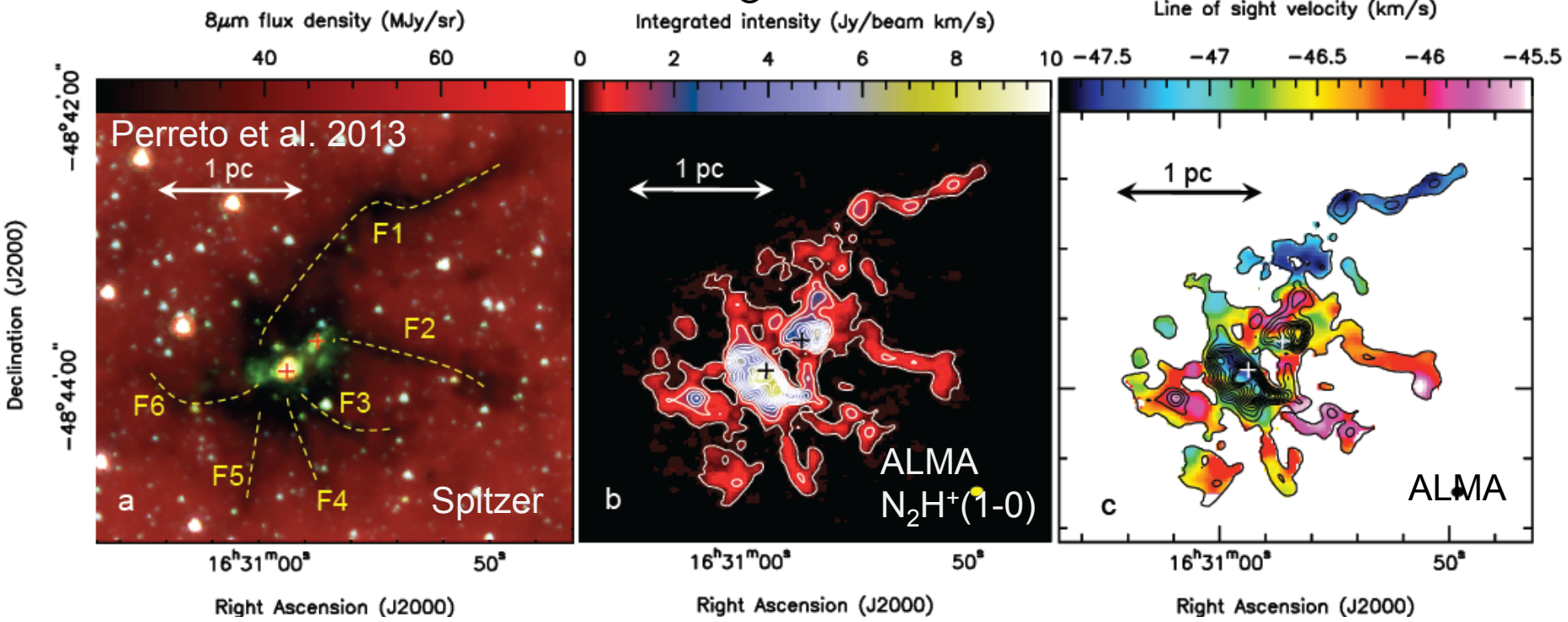
- Detection of sugar molecule
  - glycolaldehyde $HCOCH_2OH$ and several alcohols
    - e.g. methyl formate, ketene (CH_2CO), trans-ethanol (t-C_2H_5OH)
  - Class 0 binary proto-star with about solar mass



Jørgensen et al. 2012

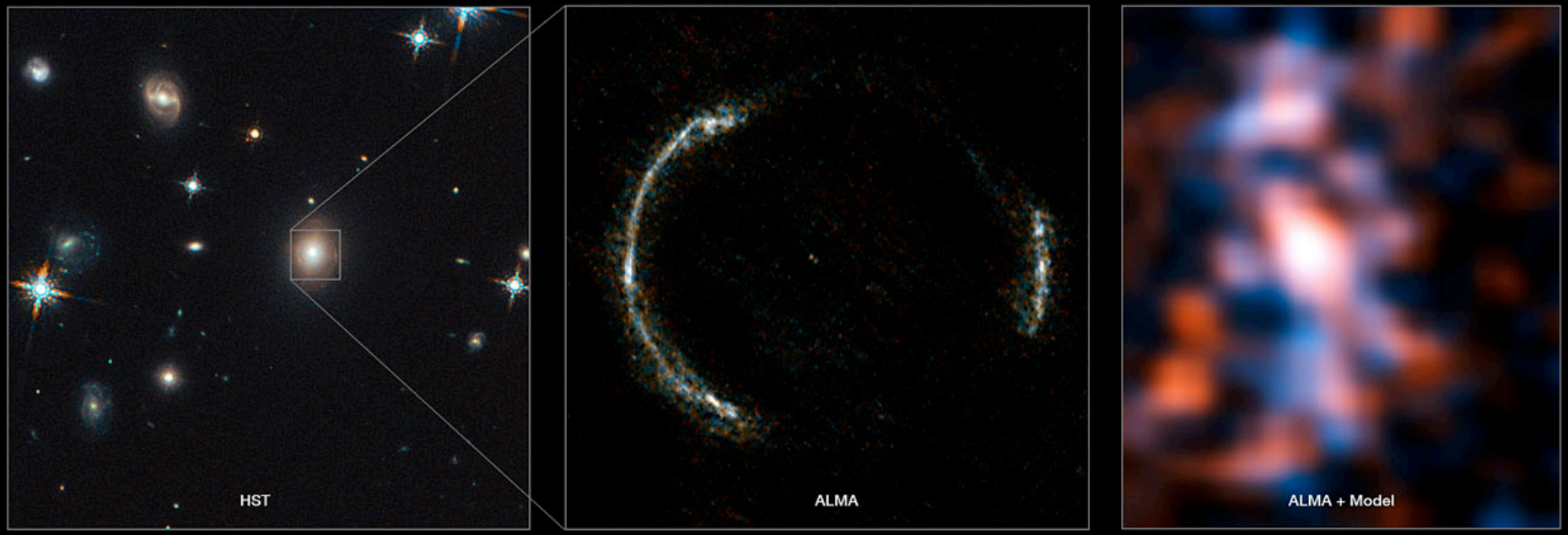
Formation of supermassive stars

- Infrared Dark Cloud SDC335.579-0.272
  - 5500±800 $M_\odot$ complex
  - Two massive star forming cores
- M1: $545^{+700}_{-385} M_\odot$ core
  - mass infall rate: $\dot{M}_{inf} = (2.5 \pm 1.0) 10^{-3}$ $M_\odot$/yr
  - will yield 750±300 $M_\odot$ in a freefall time ($3\ 10^4$ years)



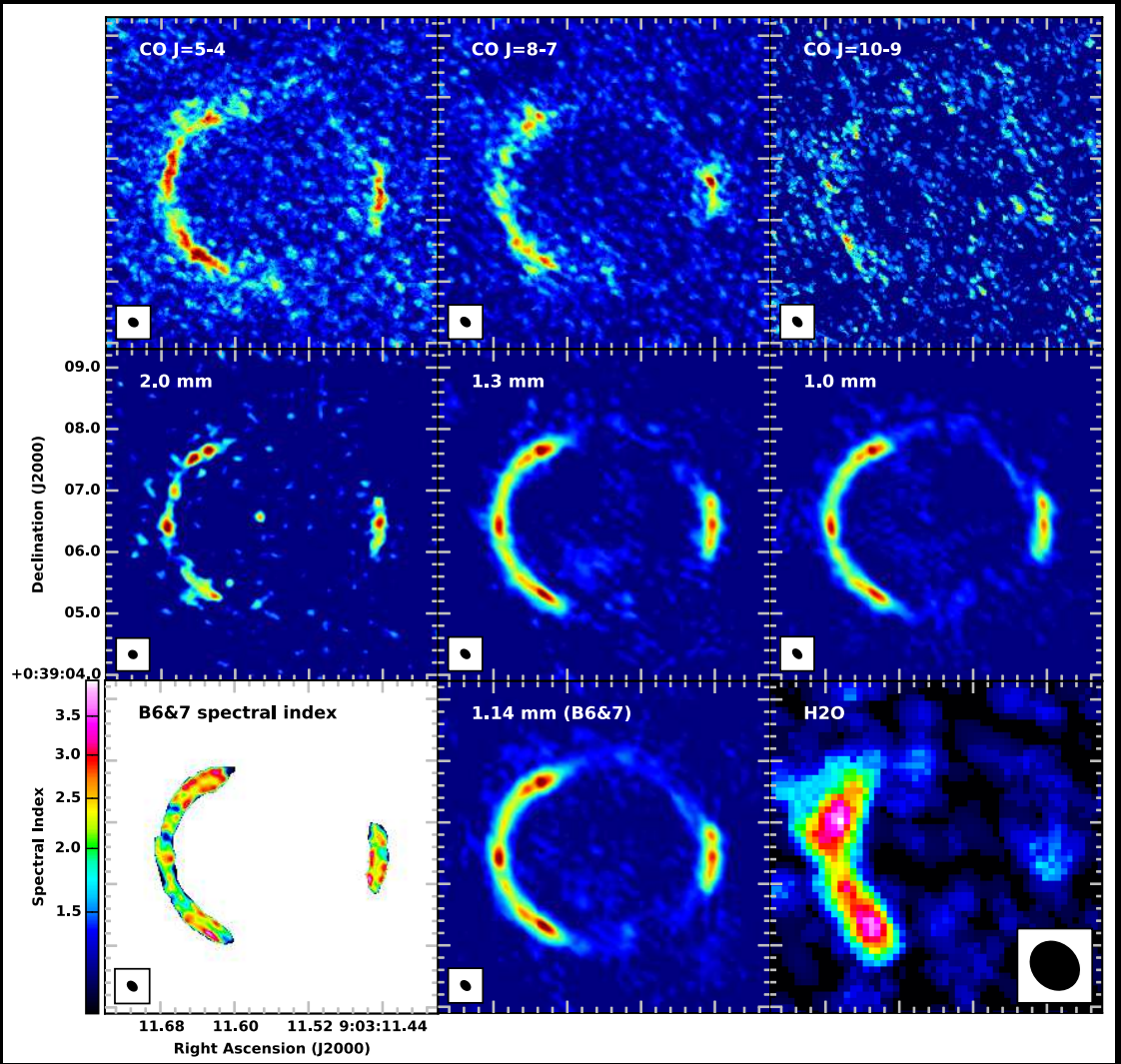
Lensed galaxy image

- Cold gas in a lensed galaxy observed with ALMA
  - source redshift: z_S=3.042
  - lens redshift: z_L=0.299



Lensed galaxy

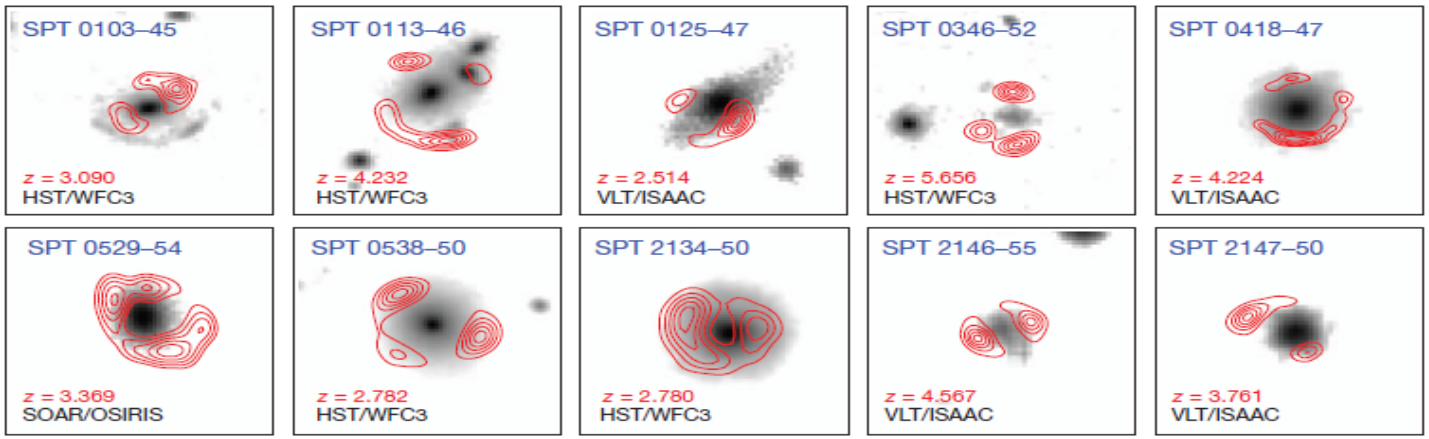
- Detection of carbon monoxide



Vlahakis et al. 2015

Distant galaxies with ALMA

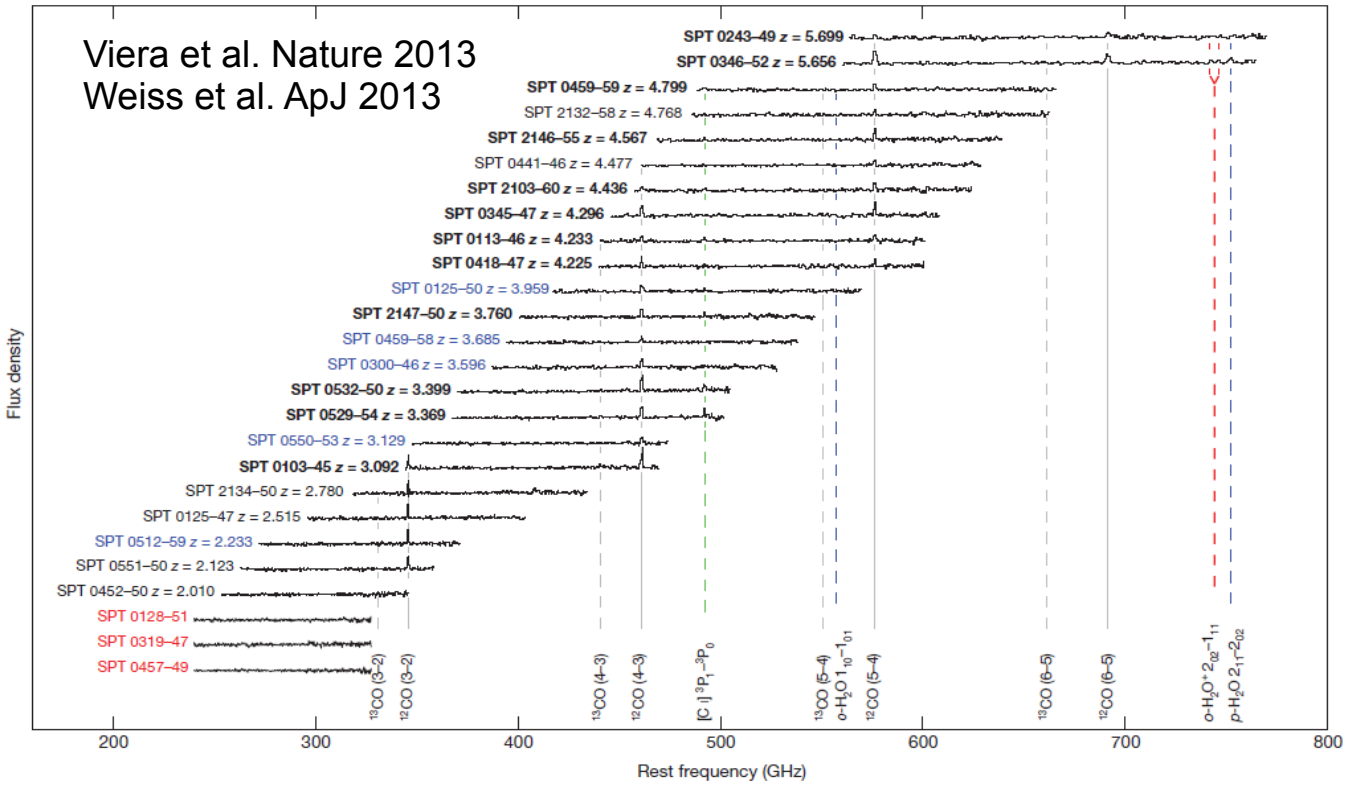
- Follow-up of mm sources discovered with the South Pole Telescope (SPT)
  - Detected many high-redshift galaxies (<z>=3.5)
  - 860μm ALMA imaging (Cycle 0 – 16 antennas)
    - 47 candidates → several clearly lensed sources
    - Integration times 1 minute
    - 2 objects at z=5.7 with high star formation rate > 500 $M_\odot$ yr^{-1}



Viera et al. Nature 2013; Hezaveh et al. ApJ 2013

Distant galaxies with ALMA

- Secure redshifts for many sources
  - ALMA 3mm spectroscopy
  - Integration times about 10 minutes
    - Lines detected of ^{12}CO, ^{13}CO, CI, H_2O



The three modes of the VLT

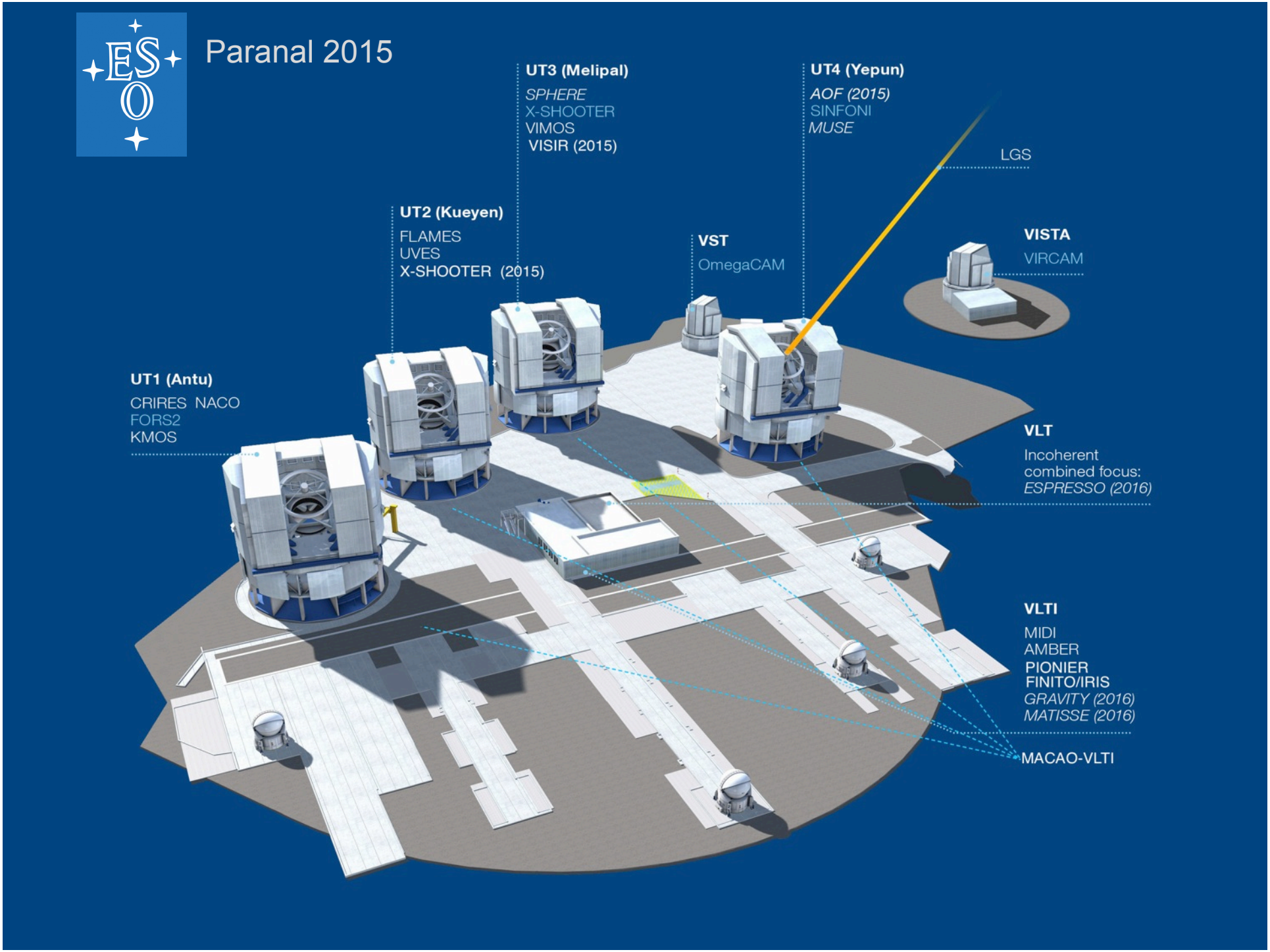
Incoherent combined focus (ESPRESSO)

Coherent combined focus Interferometry (PIONIER, GRAVITY, MATISSE)

Individual use of the unit telescopes (Cassegrain and Nasmyth foci)

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, NACO, SINFONI, VISIR, HAWK-I, VIMOS, X-Shooter, laser guide star facility, KMOS, MUSE, SPHERE, Adaptive Optics Facility, CRIRES+, ESPRESSO, MOONS, ERIS
- VLTI
  - PIONIER, GRAVITY, MATISSE
- VISTA
  - VIRCAM, 4MOST
- VST
  - ΩCam


Paranal 2015
UT3 (Melipal)
SPHERE
X-SHOOTER
VIMOS
VISIR (2015)
UT4 (Yepun)
AOF (2015)
SINFONI
MUSE
LGS
UT2 (Kueyen)
FLAMES
UVES
X-SHOOTER (2015)
VST
OmegaCAM
VISTA
VIRCAM
UT1 (Antu)
CRIRES NACO
FORS2
KMOS
VLT
Incoherent
combined focus:
ESPRESSO (2016)
VLTI
MIDI
AMBER
PIONIER
FINITO/IRIS
GRAVITY (2016)
MATISSE (2016)
MACAO-VLTI

VLT Opportunities

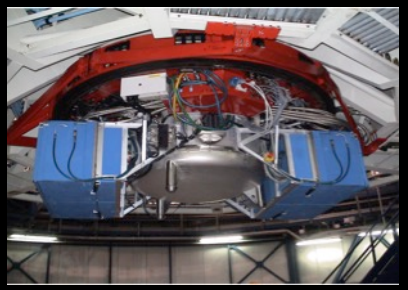
- Four 8m telescopes
  - flexibility
  - scientific throughput
    - 1200 observing nights/year
- Successful operational model
  - expand existing model to allow new modes
    - high time resolution photometry and spectroscopy
    - faster turnaround (currently DDT)
    - closer interaction with user, 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

VLT Instruments 2015

FORS2

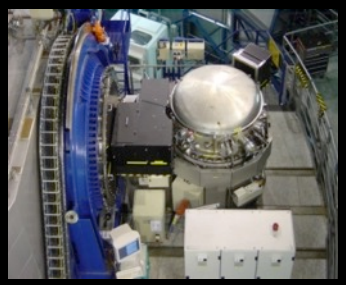
FLAMES

VISIR



SINFONI

CRIRES

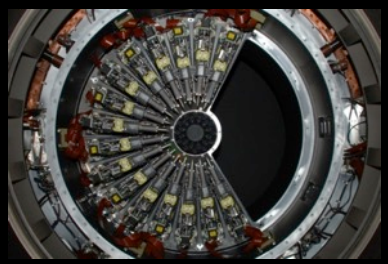


UVES

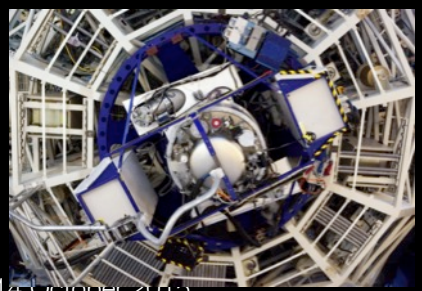
VIMOS

MUSE

KMOS



X-shooter

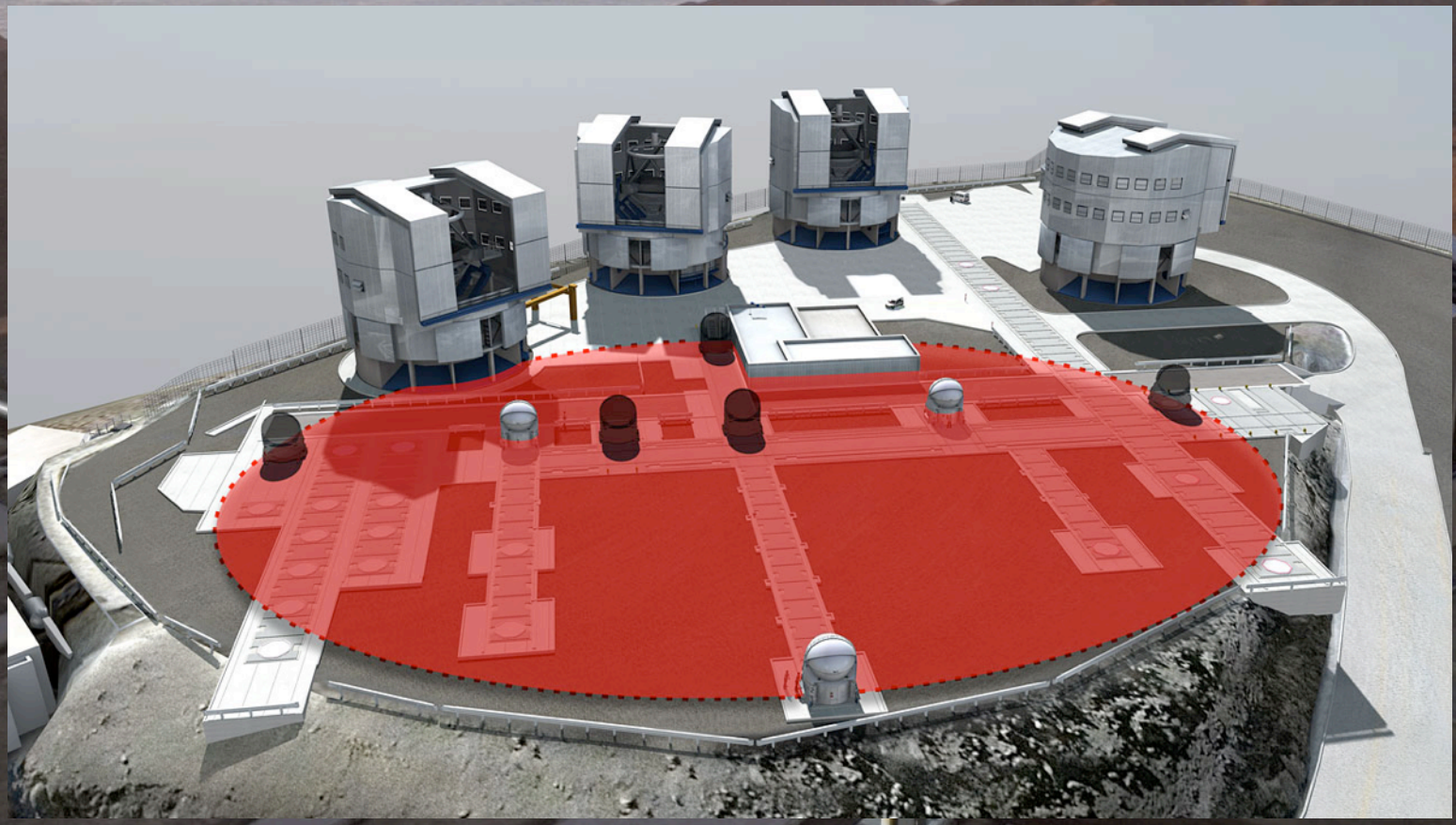


SPHERE

HAWK-I

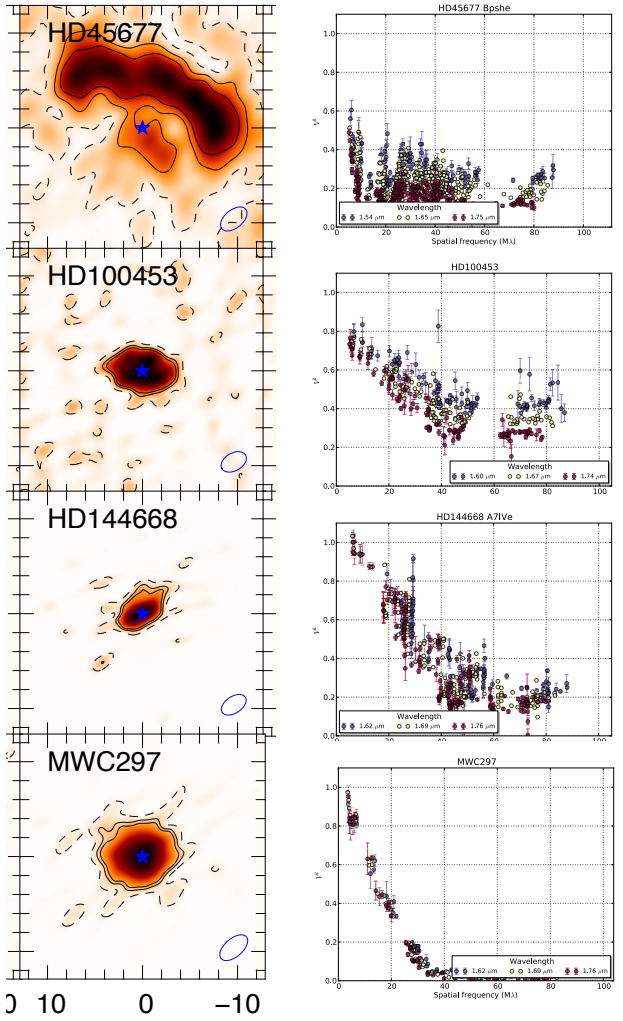
VLTI - Very Large Telescope Interferometry

The VLTI is a virtual 100-Meter Telescope



VLTI results

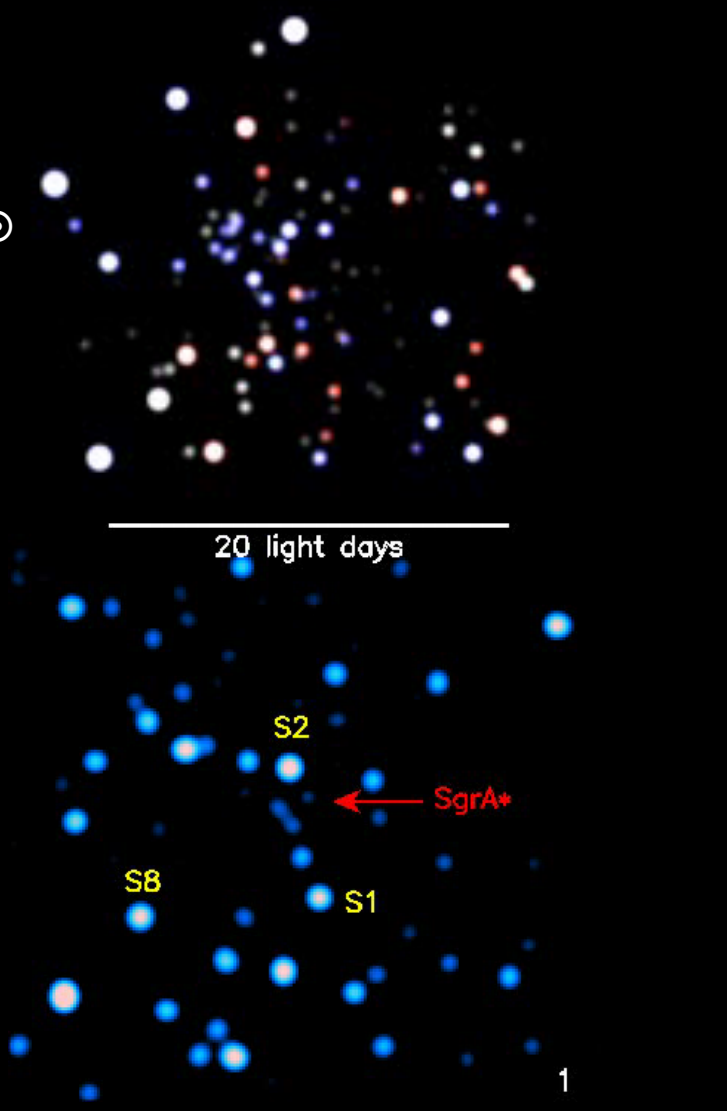
- Disks around stars
  - observe the inner boundary of accretion disks
  - strong vertical and radial dust composition segregation
    - silicates → graphite → refractory
  - evidence for clumps and temporal variability



Berger et al. VLTI PIONIER

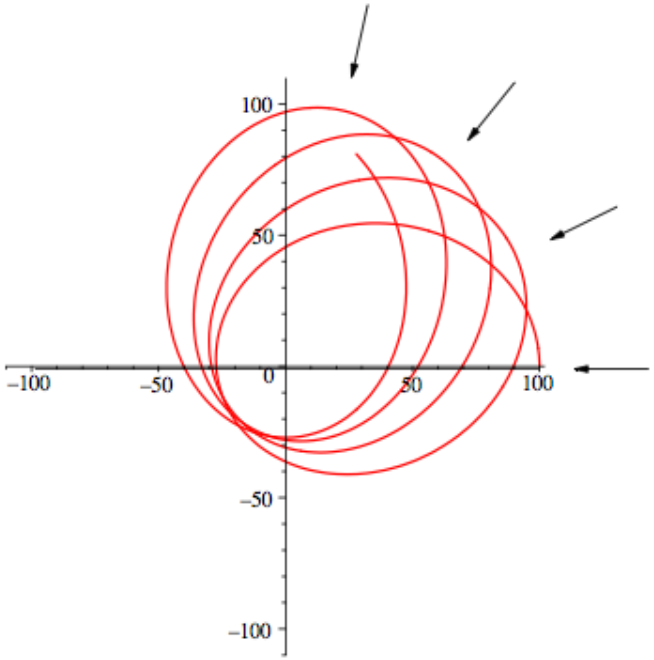
Our own black hole

- Mass determination through stellar orbits
  - $M_\bullet=(4.26\pm0.14_{stat}\pm0.2_{sys})\cdot10^6\ M_\odot$
  - $D=8.36\pm0.1_{stat}\pm0.15_{sys}$ kpc
- $M_\bullet$ and Sgr A* within <0.3mas
- Structure around the black hole revealed through flashes
- Testing General Relativity in the strong gravitational field



Galactic Center

- Pericenter shift probes the nature of the black hole
  - measure post-Newtonian effects

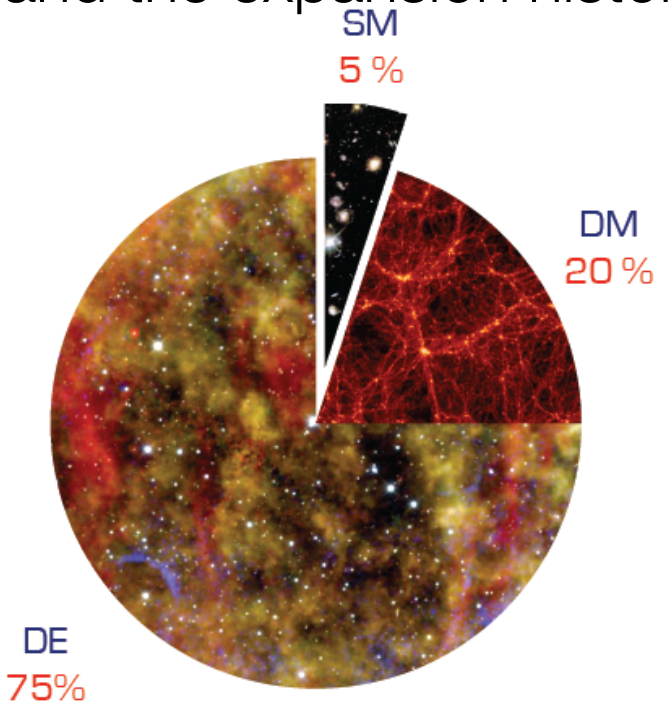


$$\Phi = -\frac{G\,M}{r} + f\,\frac{G\,M\,l^2}{c^2\,r^3}$$

Higher order terms necessary to take into account GR in the strong gravity regime
GRAVITY aims at constraining them

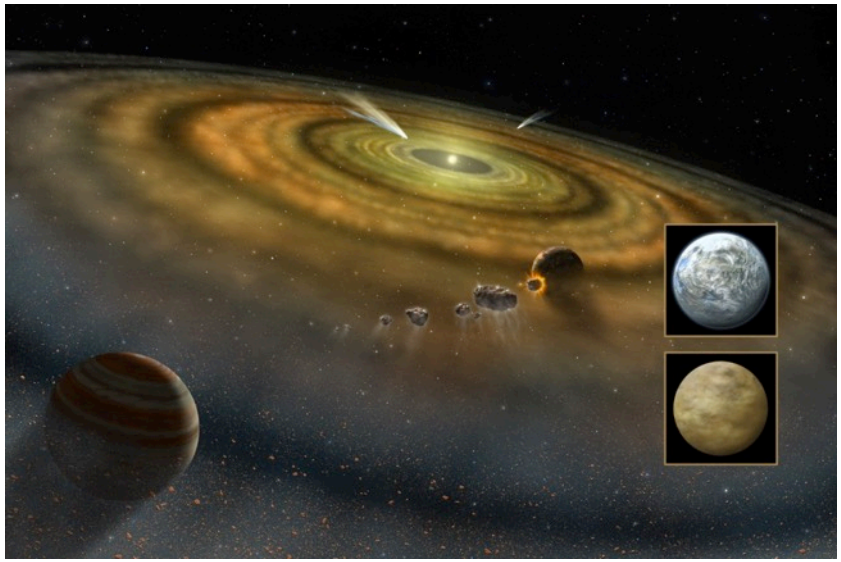
What matters in the Universe?

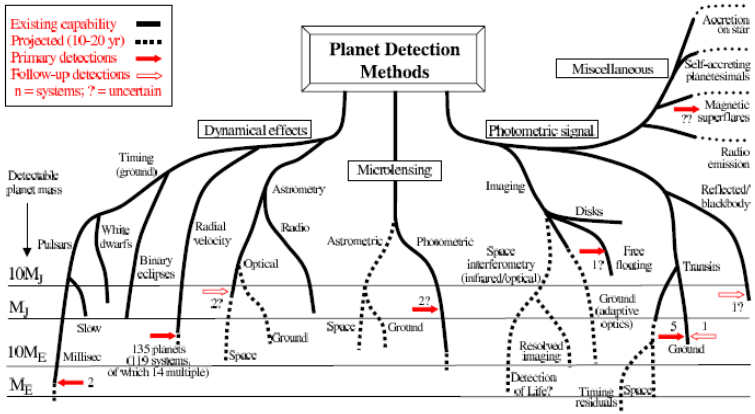
- Characterisation of dark matter and dark energy
  - Requires large samples
    - sample a large fraction of the universe
  - Multi-year and (often) multi-telescope projects
  - Measure the distribution of matter and the expansion history of the universe
    - Baryonic acoustic oscillations
    - Weak lensing
    - Supernovae
    - Galaxy clusters
    - Redshift distortions



Planets, planets, planets

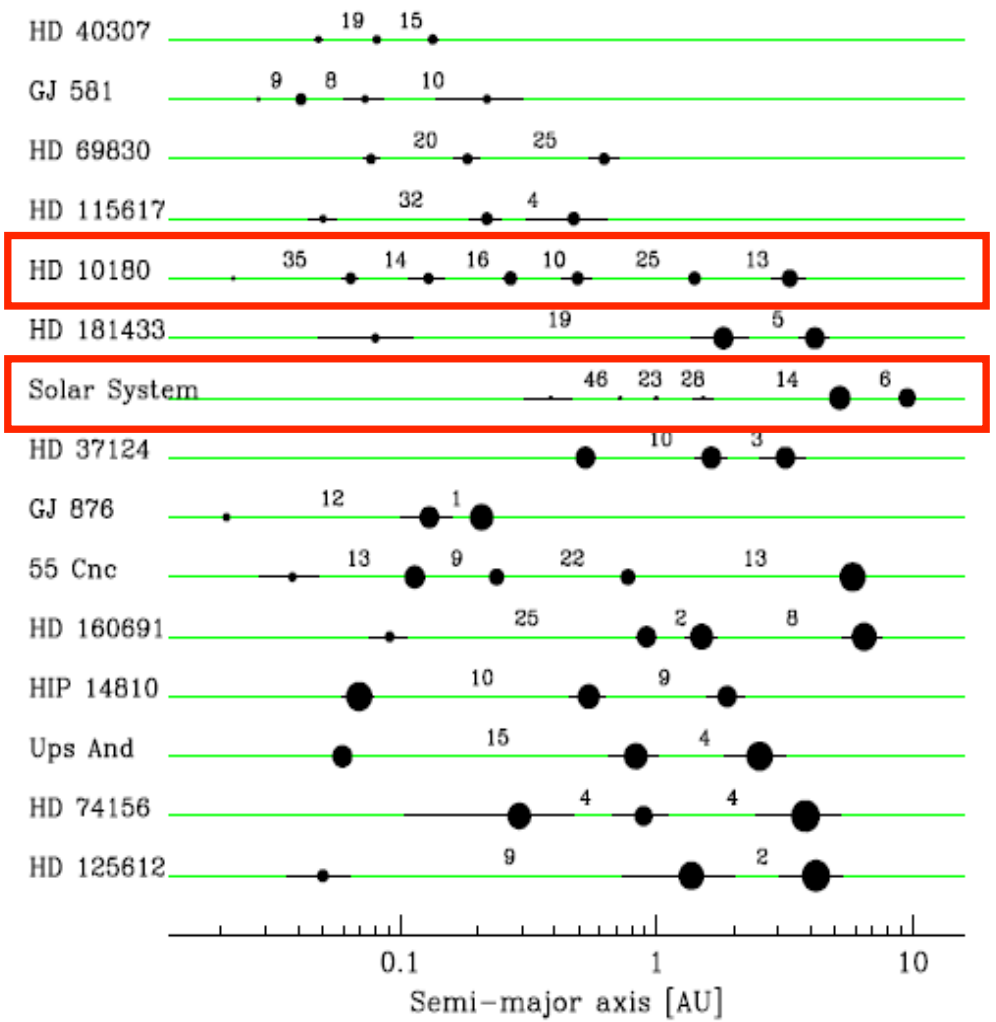
- Planets everywhere
  - Radial velocities
  - Direct imaging
  - Transits
- Characterisation
  - Planetary systems, masses, chemical composition, temperatures





Richest planetary system known

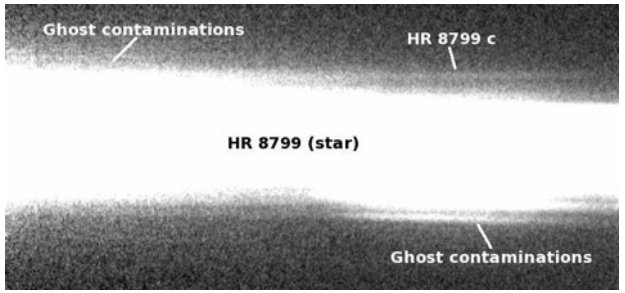
- Five planets with $12M_\oplus < M < 25M_\oplus$ at distances $0.06AU < D < 1.4AU$
- One candidate with $M=1.4M_\oplus$ at $D=0.02AU$ and another with $M=65M_\oplus$ at $3.4AU$

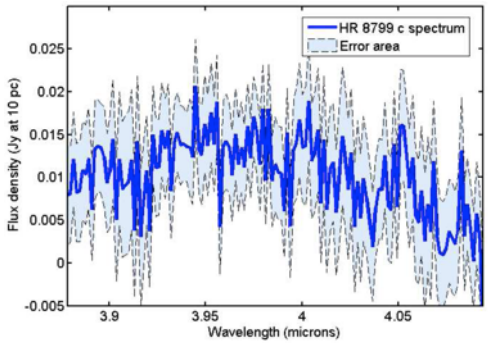


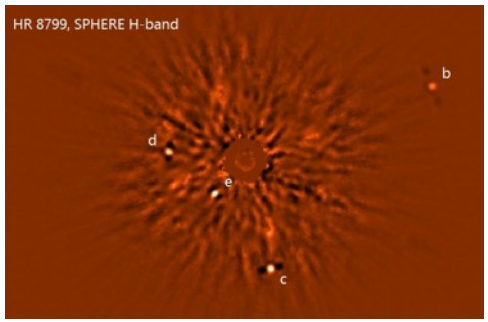
Lovis et al. 2010

The ESO exo-planet machinery

- HARPS at 3.6m telescope (NIRPS)
  - best radial velocity machine at a 4m telescope extremely stable spectrograph
  - ESPRESSO at VLT in the future
- NACO/SPHERE/ERIS
  - adaptive optics supported imaging and spectroscopy
- VLTI
  - highest spatial resolution for follow-up observations of known systems
- NACO/ERIS/SINFONI/FORS2
  - transit measurements, atmospheres of exo-planets
- CRIRES+
  - spectroscopy of atmospheres

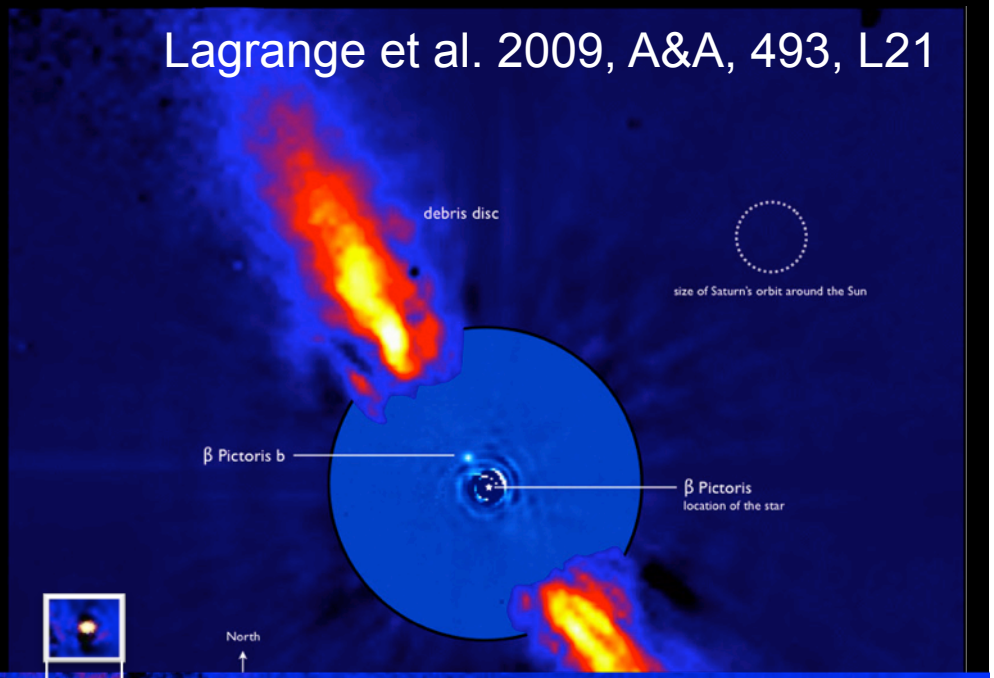


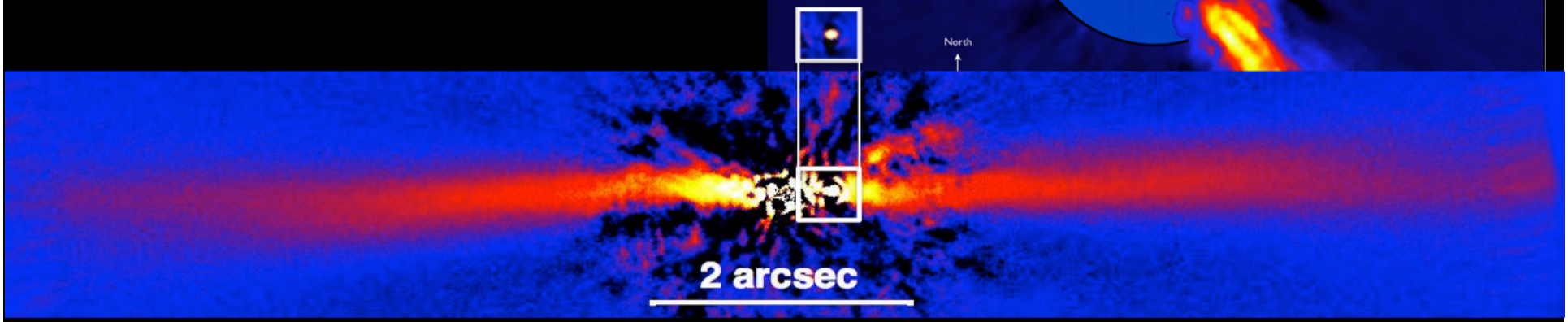




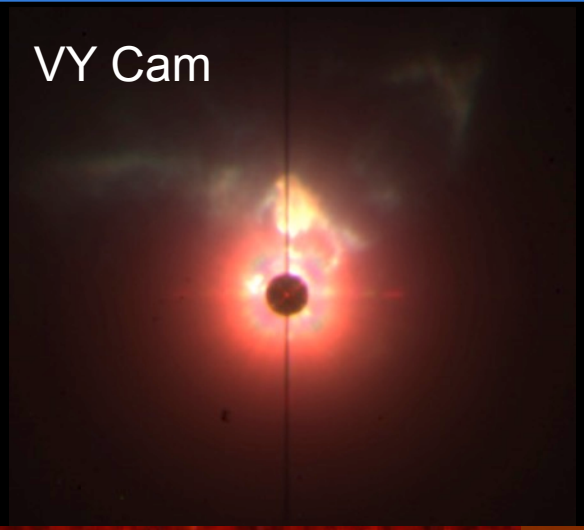
β Pic planet

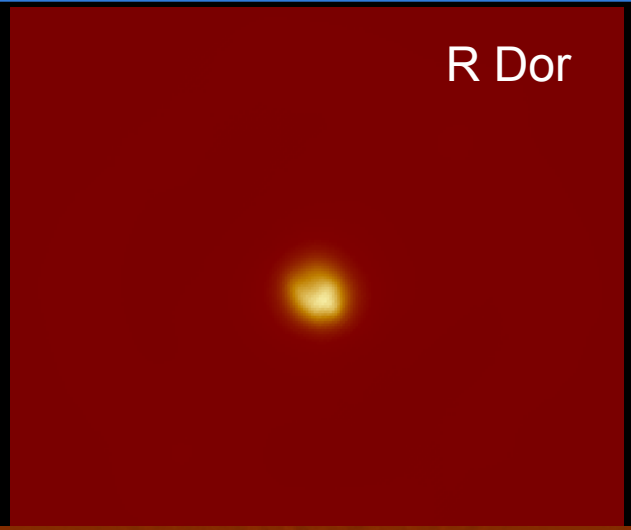
- Planet (~10 M_{jup}) within the massive dust disk
- Orbit only a few AU
- NACO imaging
- SPHERE imaging
  - planet – star separation
    - ~350 mas

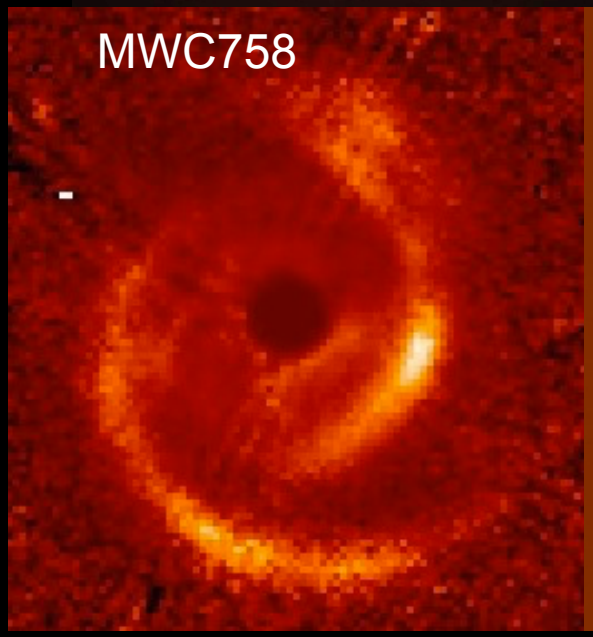


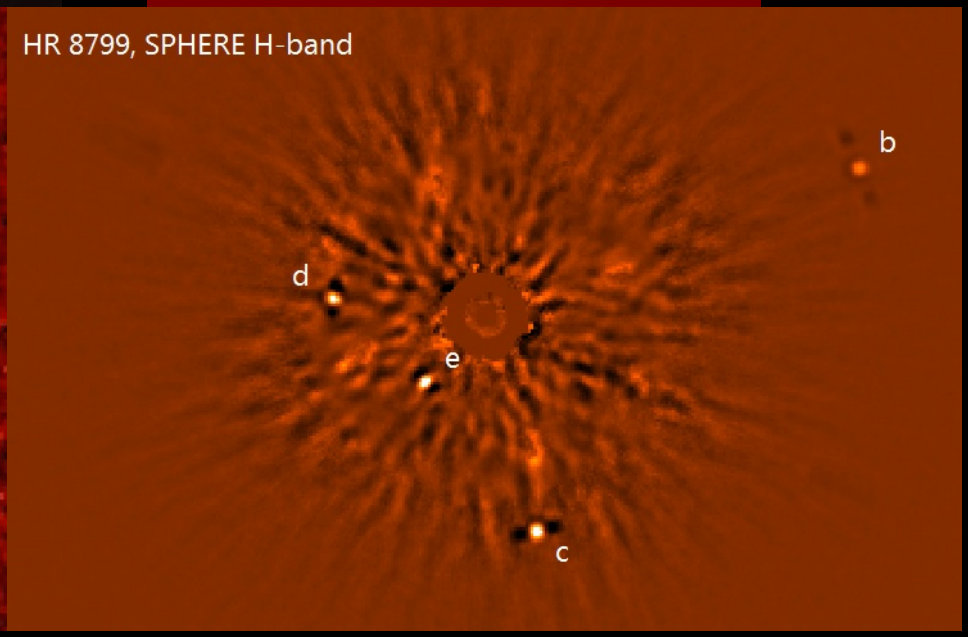


Exciting SPHERE Results







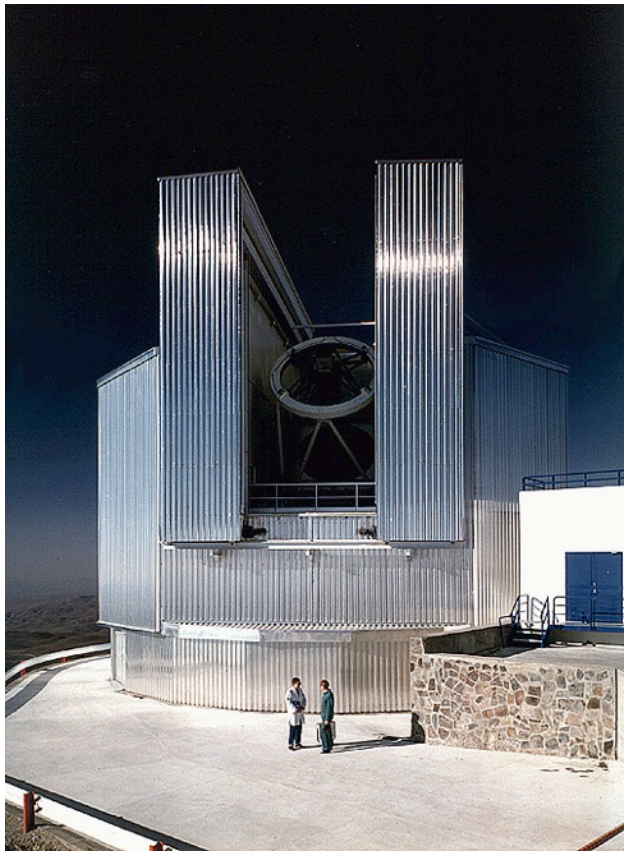


Transient Sky

- Changing sky – next frontier
  - Solar system objects
    - near-Earth objects
  - Exo-planets
  - Variable stars
    - window into stellar physics
    - distance indicators
    - VVV, VMC, VIDEO, VST/SUDARE, (La Silla/QUEST), PESSTO
  - Gravitation
    - time scale depends on the strength of the gravitational field
      - X-ray binaries
      - black holes
    - electro-magnetic counterparts of sources of gravitational waves
      - merging white dwarfs, neutron stars, black holes
      - core-collapse supernovae

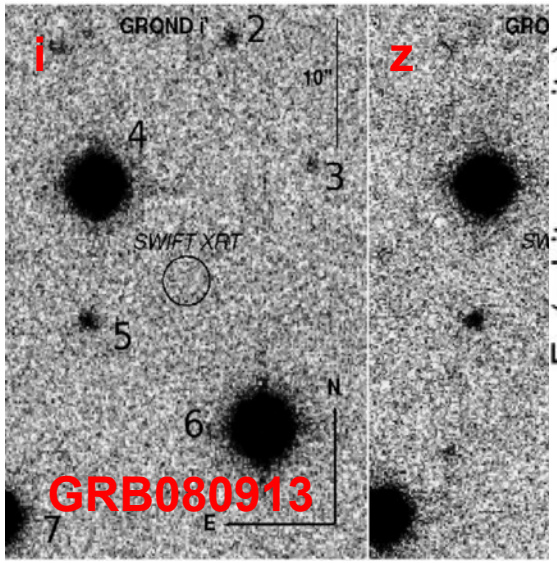
Transient Sky

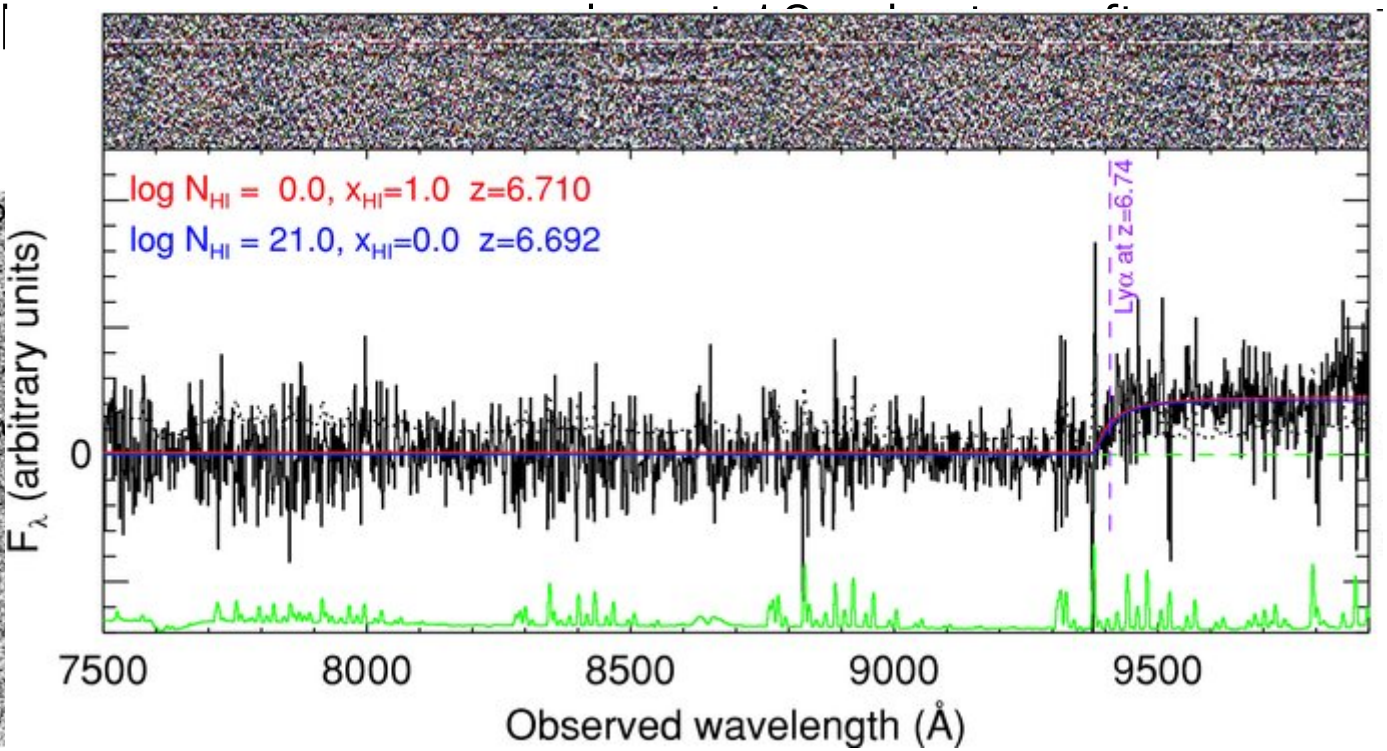
- Dedicated telescopes
- Dedicated operational modes
  - large Target of Opportunity fraction
  - flexible scheduling
  - variable timescales
- Database requirements
  - systematic archiving
  - time series
  - correlation analyses



Gamma-Ray Bursts

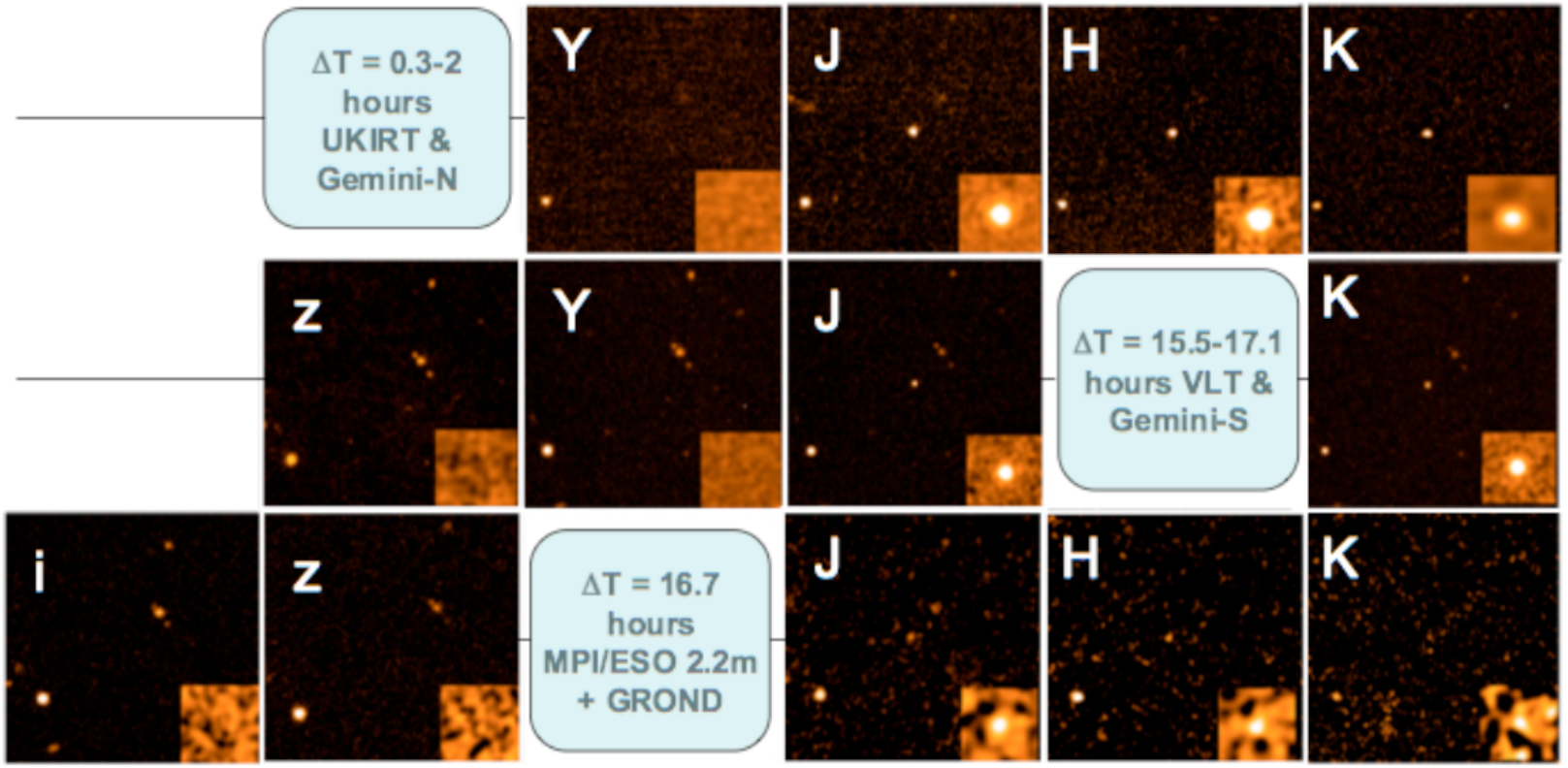
- Most distant stellar objects ever observed
  - redshifts 6.7 and 8.2 (tentative)
  - lookback time of nearly 12.5 billion years (or 95% of the age of the universe)
- VLT equipped with rapid response mode
  - allows to ol
    detection





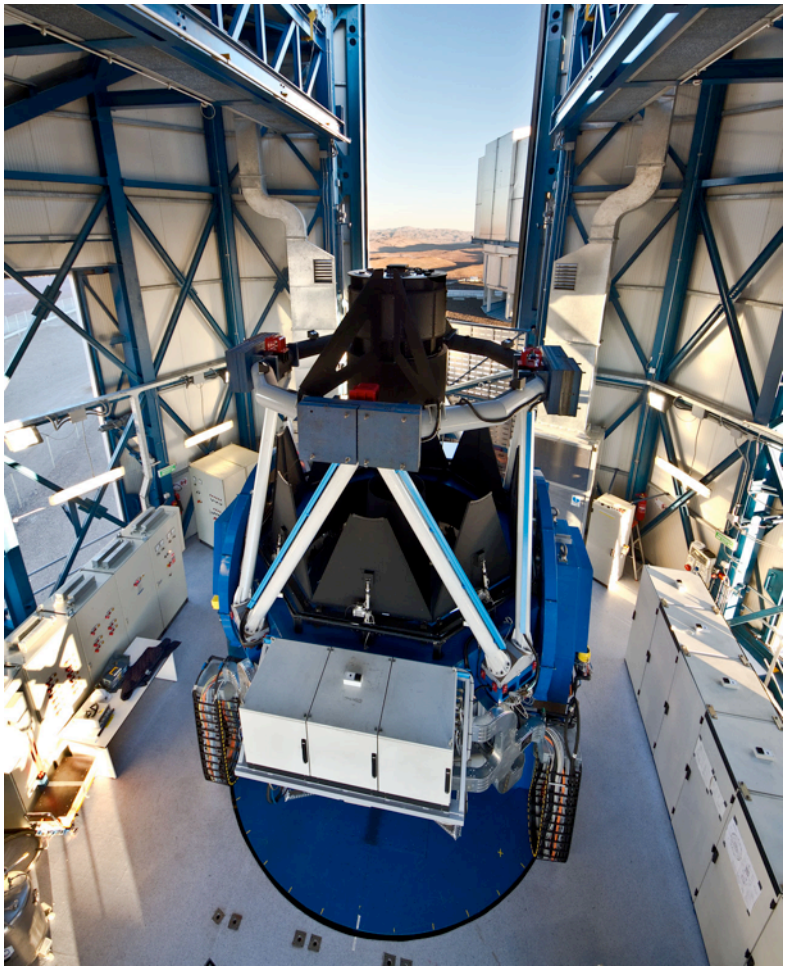
Most distant stellar object yet observed – GRB 090423

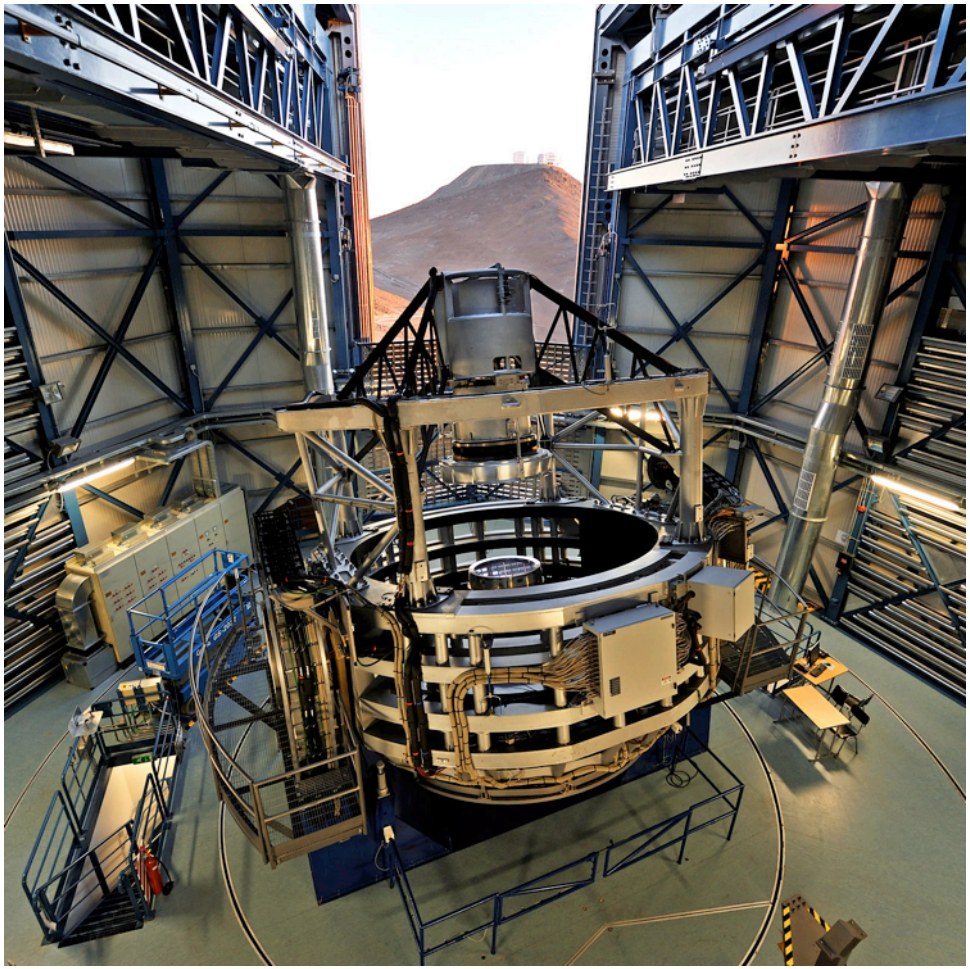
- Optical drop-out, bright in the near-infrared
- Rapid decline



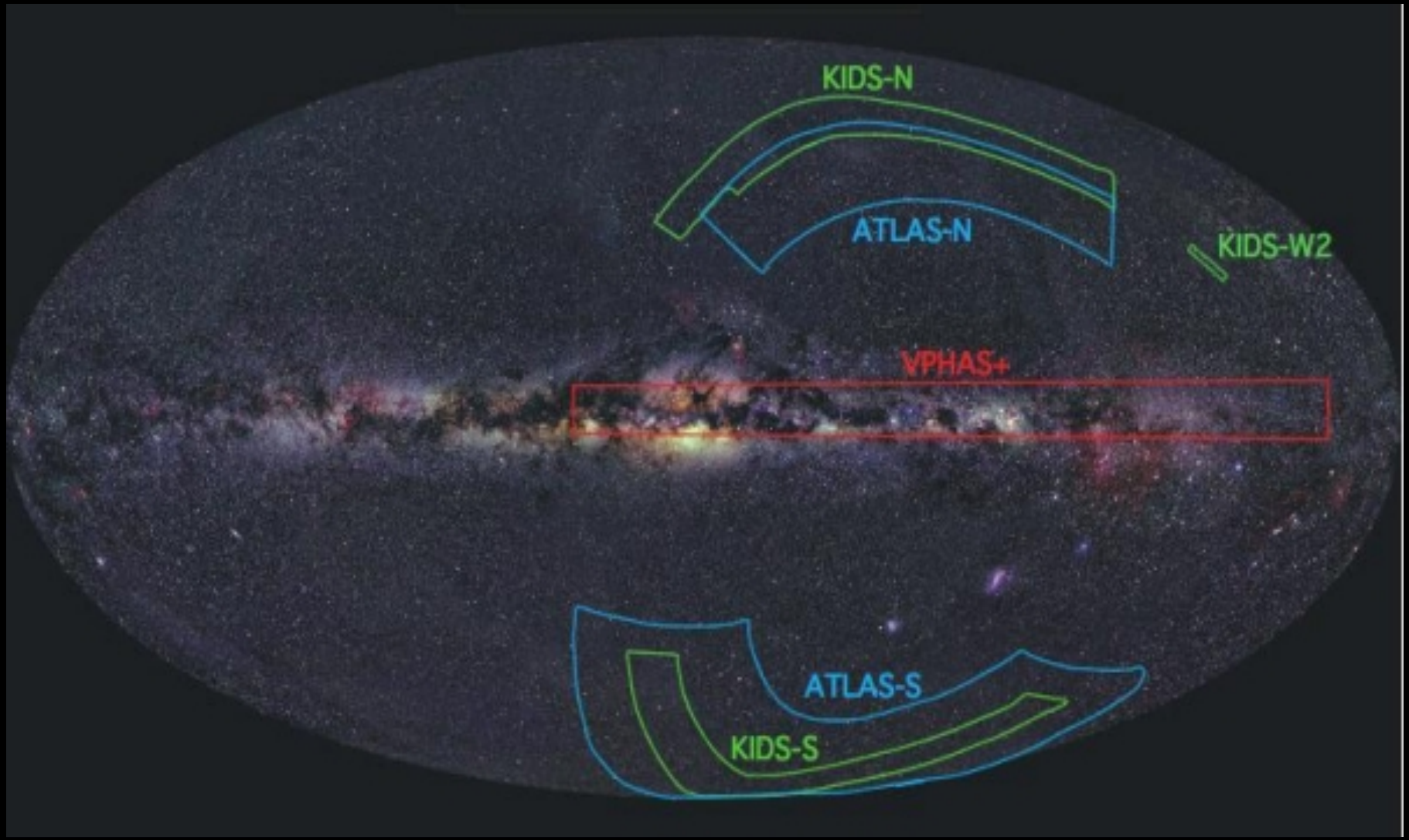
The Survey Telescopes

- VST 2.6m for optical and VISTA 4.1m für infrared observations
- Coordinated sky surveys in 5-year projects



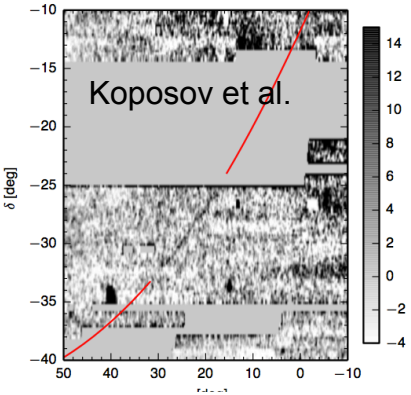


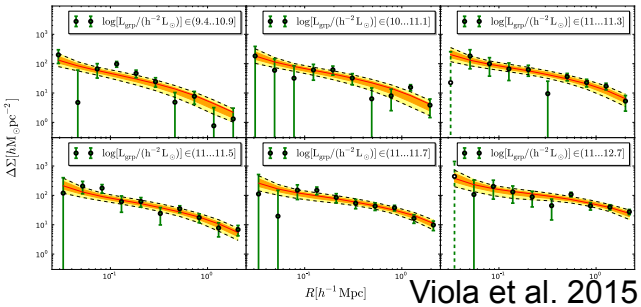
Public Surveys

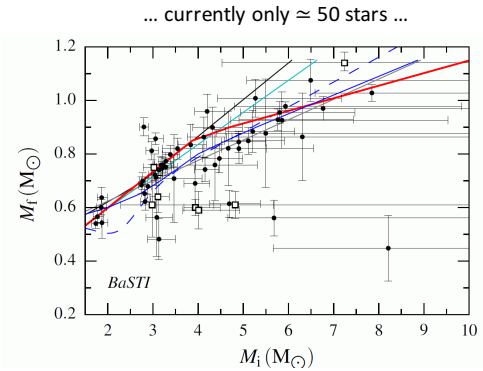


Some early results

- ATLAS
  - discovery of Crater dwarf galaxy
  - cold stellar stream
- KIDS
  - lensing by galaxy groups
    - statistical
    - velocity dispersions from GAMA
- VPHAS+
  - combined with IPHAS
    - northern survey with INT

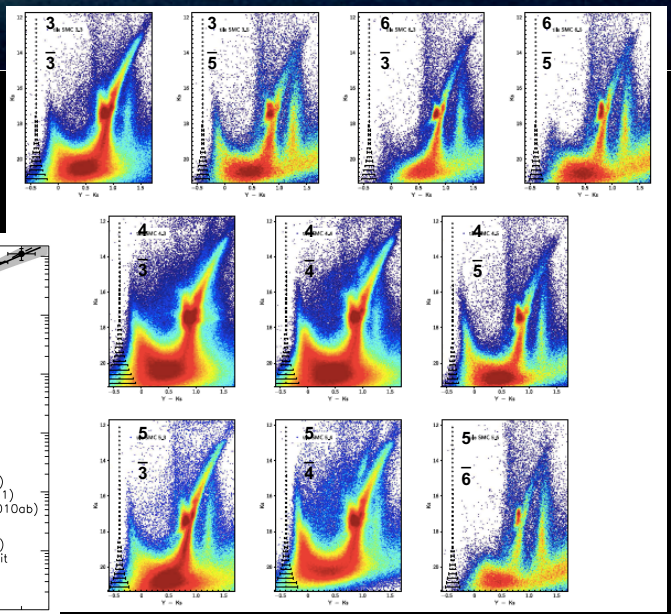


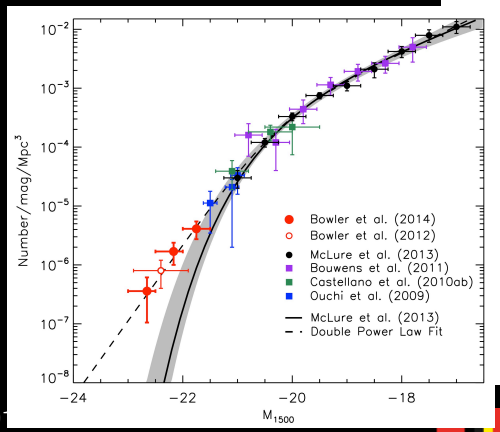




Some early results

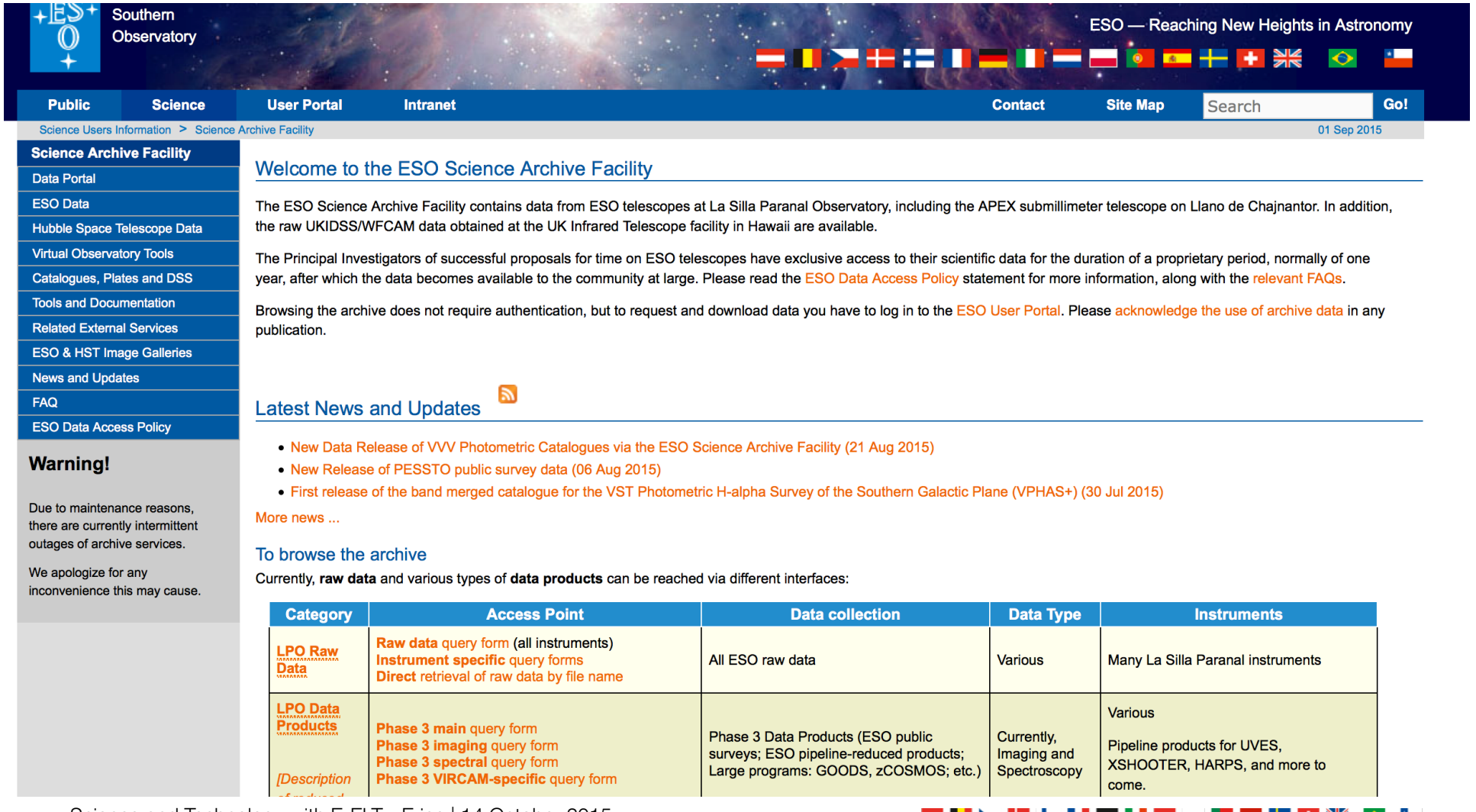
- VVV
  - detailed structure of the inner galaxy/bulge/bar
  - stellar density and mass profile of the bulge mass
  - map galactic structure
- VMC
  - star formation history in the SMC
    - not uniform across the galaxy
- UltraVISTA
  - z~7 luminosity function deviates from lower z ones





ESO Science Archive

- Rich resource



Southern Observatory

ESO — Reaching New Heights in Astronomy

Public | Science | User Portal | Intranet | Contact | Site Map | Search | Go!

Science Users Information > Science Archive Facility

01 Sep 2015

Science Archive Facility

- Data Portal
- ESO Data
- Hubble Space Telescope Data
- Virtual Observatory Tools
- Catalogues, Plates and DSS
- Tools and Documentation
- Related External Services
- ESO & HST Image Galleries
- News and Updates
- FAQ
- ESO Data Access Policy

Warning!

Due to maintenance reasons, there are currently intermittent outages of archive services.

We apologize for any inconvenience this may cause.

Welcome to the ESO Science Archive Facility

The ESO Science Archive Facility contains data from ESO telescopes at La Silla Paranal Observatory, including the APEX submillimeter telescope on Llano de Chajnantor. In addition, the raw UKIDSS/WFCAM data obtained at the UK Infrared Telescope facility in Hawaii are available.

The Principal Investigators of successful proposals for time on ESO telescopes have exclusive access to their scientific data for the duration of a proprietary period, normally of one year, after which the data becomes available to the community at large. Please read the ESO Data Access Policy statement for more information, along with the relevant FAQs.

Browsing the archive does not require authentication, but to request and download data you have to log in to the ESO User Portal. Please acknowledge the use of archive data in any publication.

Latest News and Updates

- New Data Release of VVV Photometric Catalogues via the ESO Science Archive Facility (21 Aug 2015)
- New Release of PESSTO public survey data (06 Aug 2015)
- First release of the band merged catalogue for the VST Photometric H-alpha Survey of the Southern Galactic Plane (VPHAS+) (30 Jul 2015)

More news ...

To browse the archive

Currently, **raw data** and various types of **data products** can be reached via different interfaces:

Category	Access Point	Data collection	Data Type	Instruments
LPO Raw Data	**Raw data** query form (all instruments) **Instrument specific** query forms **Direct** retrieval of raw data by file name	All ESO raw data	Various	Many La Silla Paranal instruments
LPO Data Products *[Description*	**Phase 3 main** query form **Phase 3 imaging** query form **Phase 3 spectral** query form **Phase 3 VIRCAM-specific** query form	Phase 3 Data Products (ESO public surveys; ESO pipeline-reduced products; Large programs: GOODS, zCOSMOS; etc.)	Currently, Imaging and Spectroscopy	Various Pipeline products for UVES, XSHOOTER, HARPS, and more to come.

Recent new VLT instruments

- SPHERE – extreme adaptive optics system in the NIR and optical
- MUSE – largest integral field unit available
  - see Dimitri's results yesterday
- KMOS – multi-IFU system in the NIR
  - examples in Dimitri's talk yesterday
- X-shooter – new workhorse instrument for individual objects
  - covers 400nm to 1.8μm simultaneously

Planned new VLT instruments

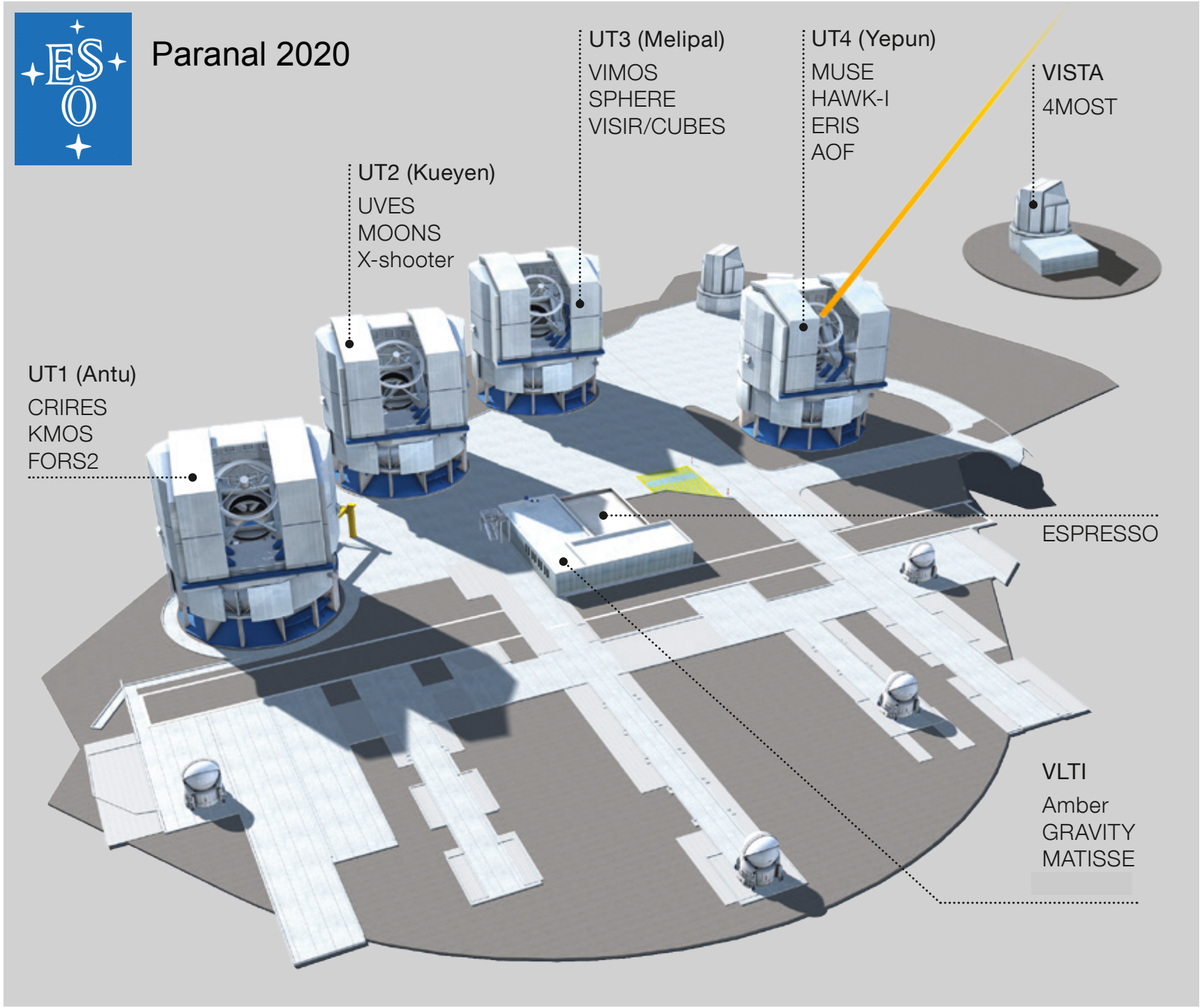
- ESPRESSO – extremely stable high-resolution spectrograph
  - can use all four unit telescopes together
- Adaptive Optics Facility (AOF)
  - "seeing improver" for HAWK-I (ground-layer AO)
  - optical AO for MUSE
  - 4 laser guide stars
- ERIS – new NIR AO imager (NACO replacement)
  - includes SINFONI upgrade
- 4MOST (VISTA) – high multiplex optical spectroscopy
- MOONS – high multiplex NIR spectroscopy
- CUBES – UV high-resolution spectroscopy

New VLTI instruments

- (Existing) PIONIER – closure-phase NIR imager
- GRAVITY – highest angular resolution system in K-band
- MATISSE – highest angular resolution system in infrared

Planned new instruments for La Silla

- SOXS (Son of X-shooter)
  - copy of X-shooter
  - use for transient spectroscopy
  - only instrument on NTT
- NIRPS (Near-Infrared Planet Searcher)
  - IR spectrograph with R~100000
  - complement HARPS
  - search for low-mass planets around low-mass stars
  - planet characterisation
  - together with HARPS on the 3.6m telescope
- Start in early 2020


Paranal 2020
UT3 (Melipal)
VIMOS
SPHERE
VISIR/CUBES
UT4 (Yepun)
MUSE
HAWK-I
ERIS
AOF
VISTA
4MOST
UT2 (Kueyen)
UVES
MOONS
X-shooter
UT1 (Antu)
CRIRES
KMOS
FORS2
ESPRESSO
VLTI
Amber
GRAVITY
MATISSE

ESO – an integrated system

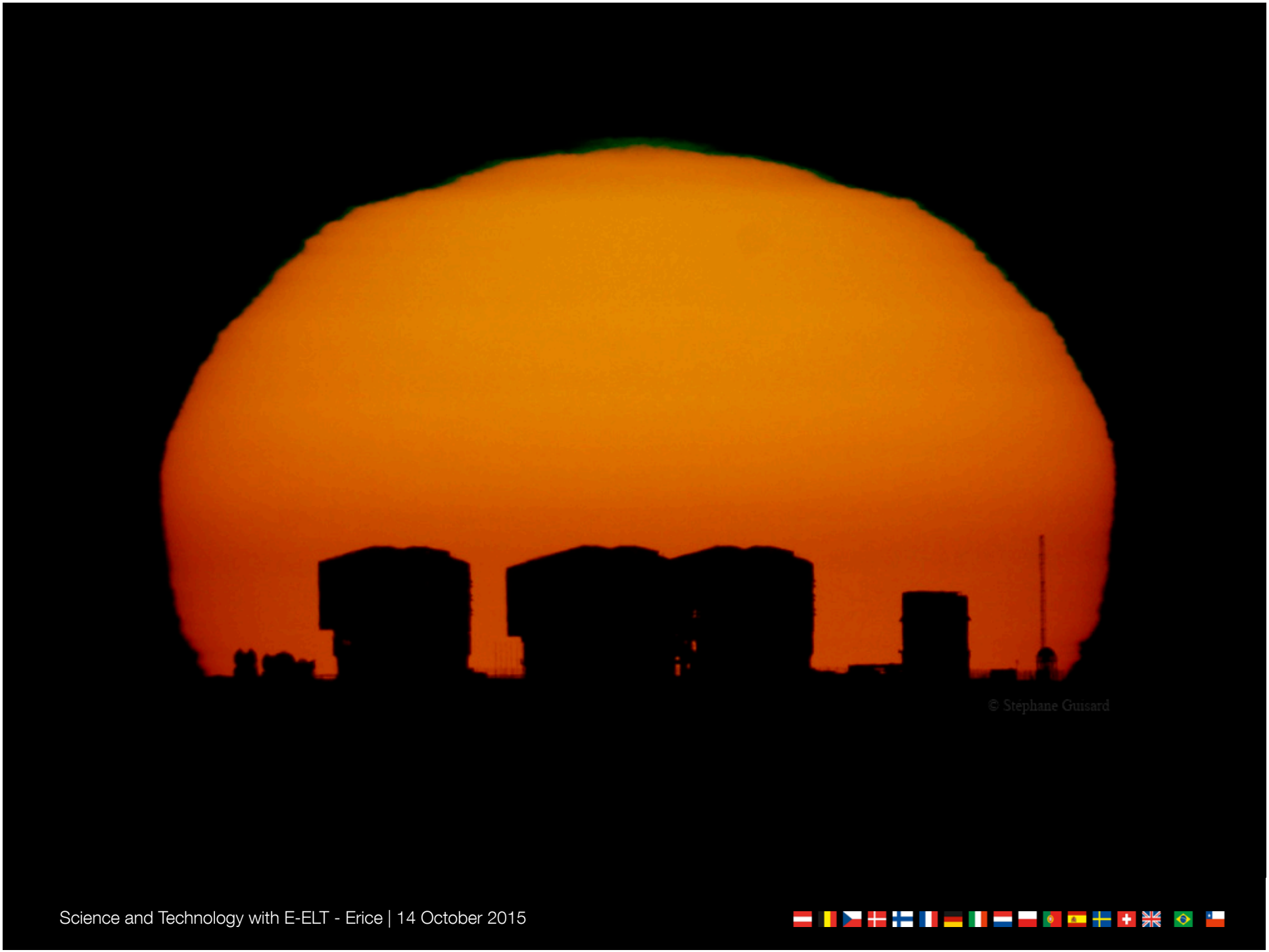
- ALMA and E-ELT
  - Flagship facilities
- VLT
  - Unique capabilities
    - interferometry
    - large instrument complement, flexibility, modern operations model
- La Silla/4m telescopes
  - Transients: NTT; exo-planets: 3.6m;
    multi-object spectroscopy: VISTA;
    platform for smaller experiments: La Silla
- ESO Archive
  - Rich resource of optical and near-infrared data
    - large coherent data sets from surveys
    - advanced data products

Astronomy in the 2020s

- OIR sky measured to ~25 mag
- Thousands of transient alerts per day
- Matching capabilities at (almost) all other wavelengths
  - angular resolution
  - sensitivity
  - sky coverage
- Astroparticle detections
- Diverse astronomical community with considerable overlap with other sciences (chemistry, biology)

OIR Future Strategies

- Flexibility
  - Astrophysics covers many topics and techniques
  - Completeness of instrumentation
  - Reaction to interesting new events, object and topics
- Coordination
  - Instrumentations programmes at different facilities
    - either through a large pool or through collaboration between observatories
  - Planning between ground and space
  - Time allocation between observatories
- Operations
  - inbuilt flexibility
  - archive → open distribution of data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