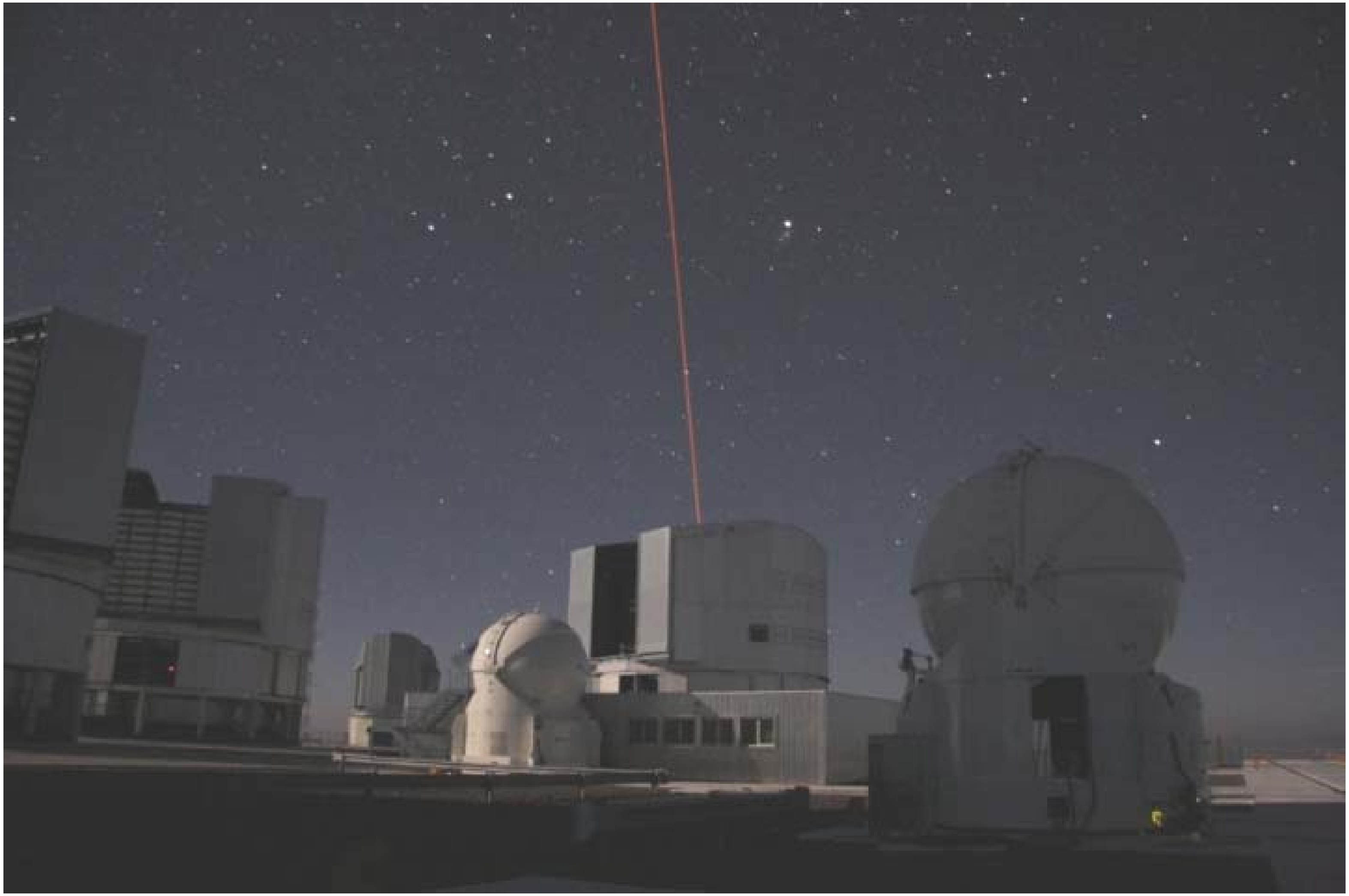
ESO - The European Southern Observatory

Bruno Leibundgut
Director for Science

European Southern Observatory

- Mission
  - Develop and operate world-class observing facilities for astronomical research
  - Organize collaborations in astronomy
- Intergovernmental treaty-level organization
  - Founded in 1962 by 5 countries (50 years in 2012!)
  - Today 14 member states, Brazil will become 15th
- Observatories in Chile
  - La Silla Paranal: VLT, VLTI, 3.6m, NTT, VISTA, VST
  - Chajnantor: APEX and ALMA partnerships
- HQ in Garching and Office in Santiago

Three major programmes

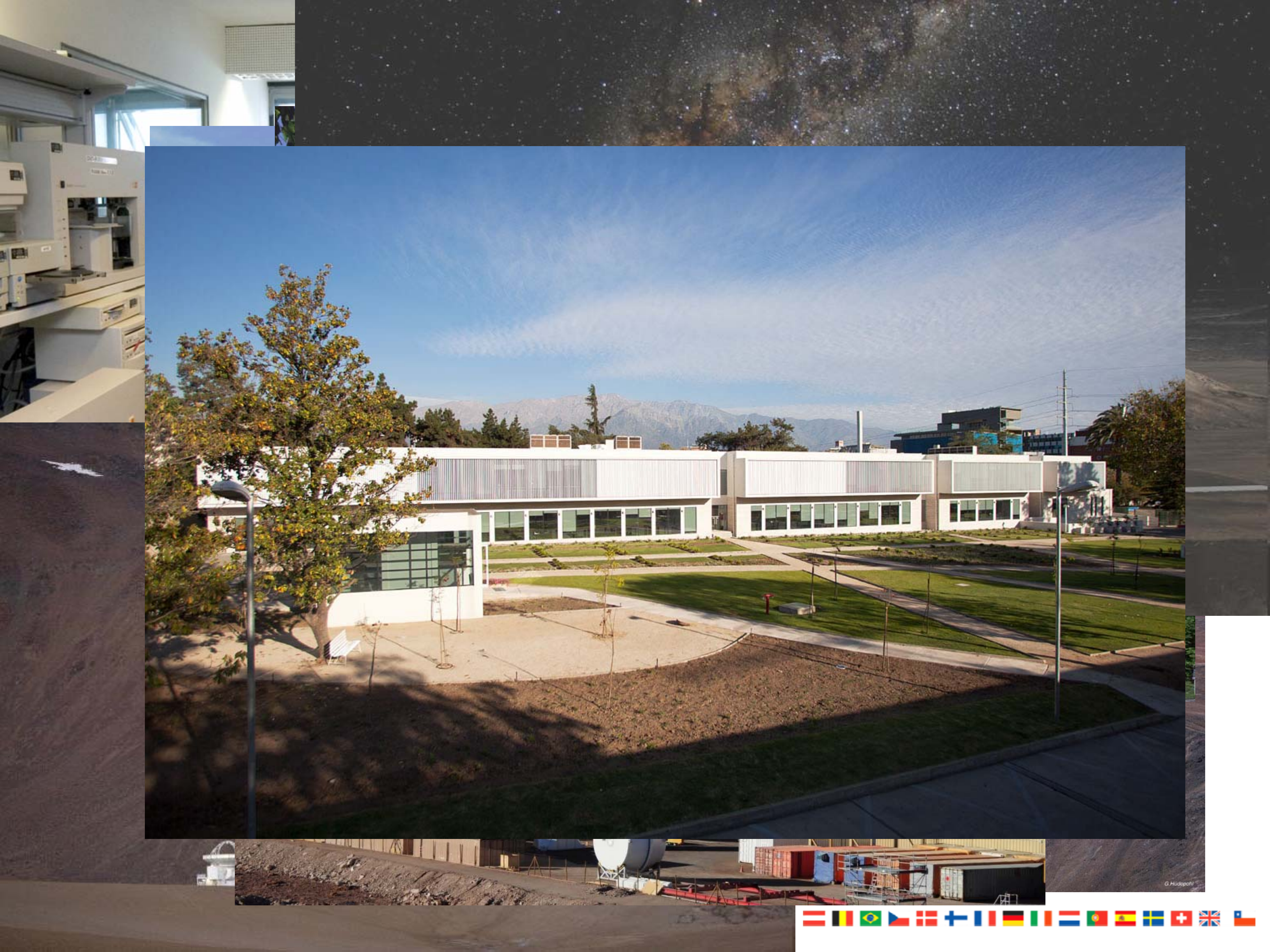


Three major programmes

Three major programmes

ESO's sites


Garching bei München
Chajnantor
Paranal
La Silla
Santiago
Earth at Night
More information available at:
http://antwrp.gsfc.nasa.gov/apod/ap001127.html
Astronomy Picture of the Day
2000 November 27
http://antwrp.gsfc.nasa.gov/apod/astropix.html


G.Hüdepohl

La Silla: ESO's first observatory

Two of the most productive 4-m class telescopes in the world

- ESO 3.6-m telescope, since 1976
- New Technology Telescope NTT (3.58 m), since 1989

300 refereed publications per year!

The VLT is the world´s most productive ground-based facility producing more than one scientific paper per day!

La Silla Paranal

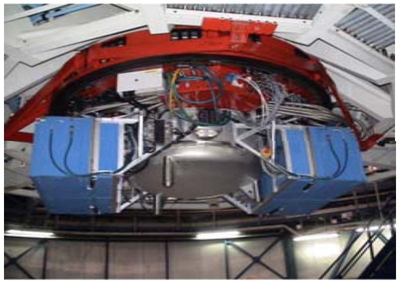
- VLT/I (Paranal)
  - Instrumentation operating, in assembly and planned
    - Covers the available optical infrared wavelengths 300nm to 20μm
    - Angular resolution from seeing limit to 50 μ-arcseconds
    - FORS2, ISAAC, UVES, FLAMES, NACO, SINFONI, CRIRES, VISIR, HAWK-I, VIMOS, X-Shooter, laser guide star facility KMOS, MUSE, SPHERE, Adaptive Optics Facility, ESPRESSO
    - MIDI, AMBER, PRIMA (astrometry), (PIONIER), GRAVITY, MATISSE
    - VISTA/VIRCAM
    - VST/ΩCam

Current VLT Instruments

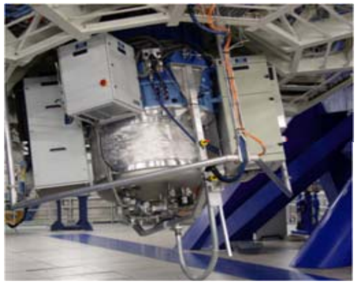
FORS2

FLAMES

VISIR



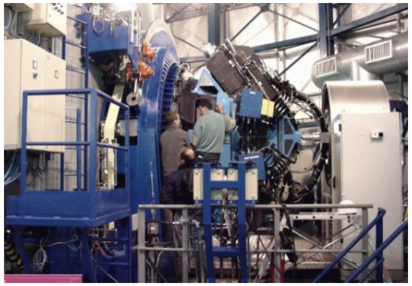
SINFONI



CRIRES

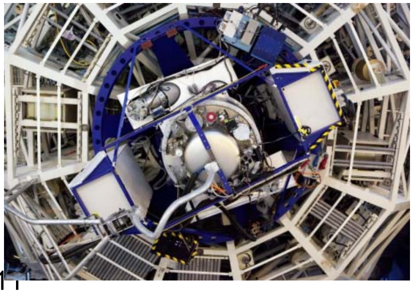
UVES

VIMOS

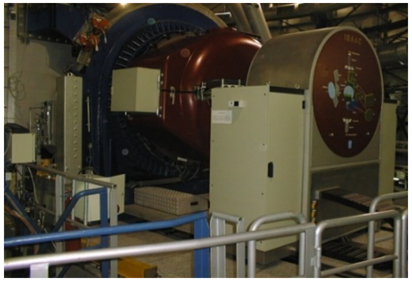


NACO

X-shooter



ISAAC



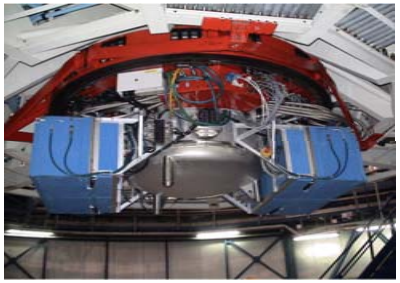
HAWK-I

VLT Instruments 2012

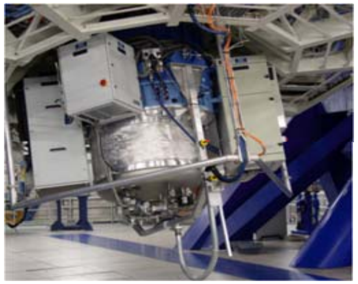
FORS2

FLAMES

VISIR



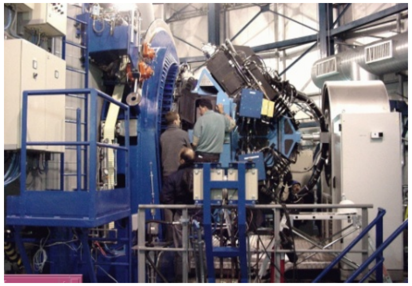
SINFONI



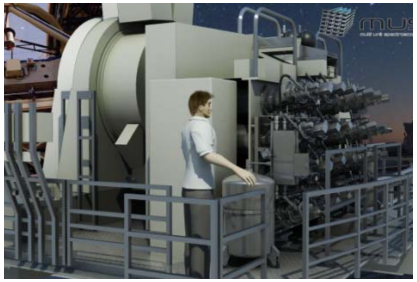
CRIRES

UVES

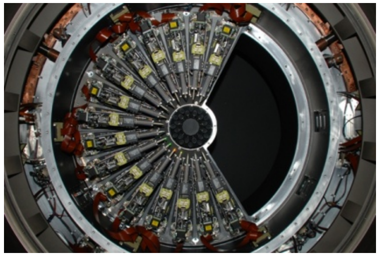
VIMOS



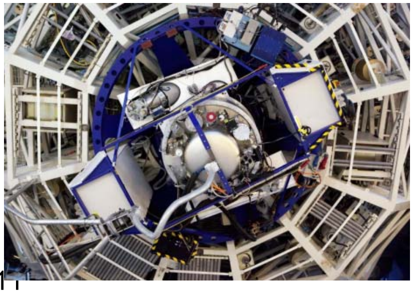
MUSE



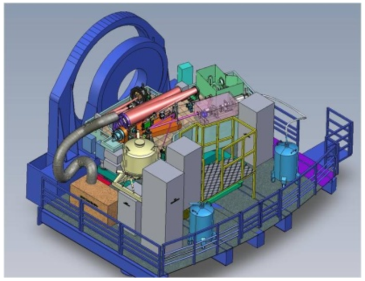
KMOS



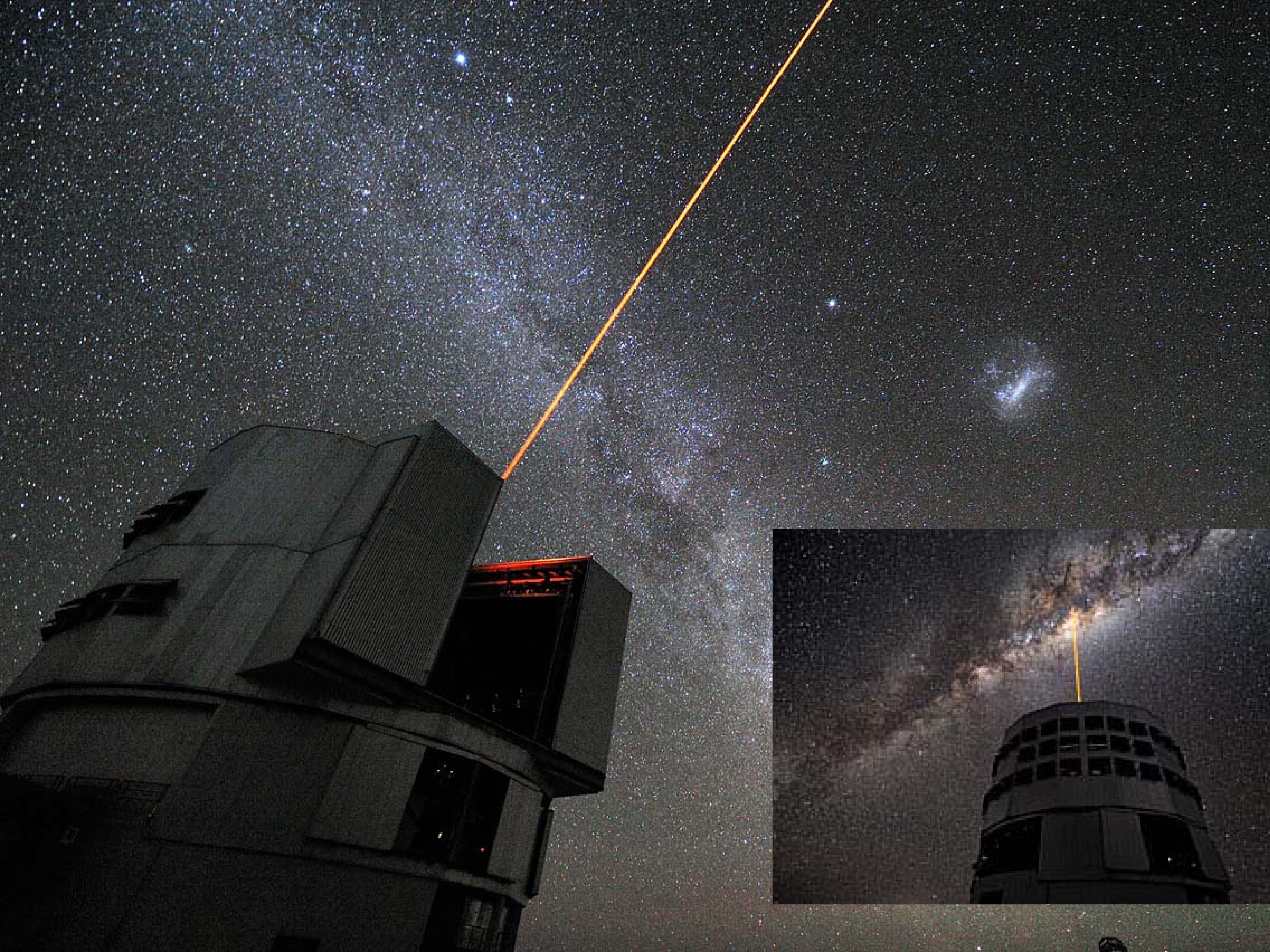
X-shooter



SPHERE



HAWK-I



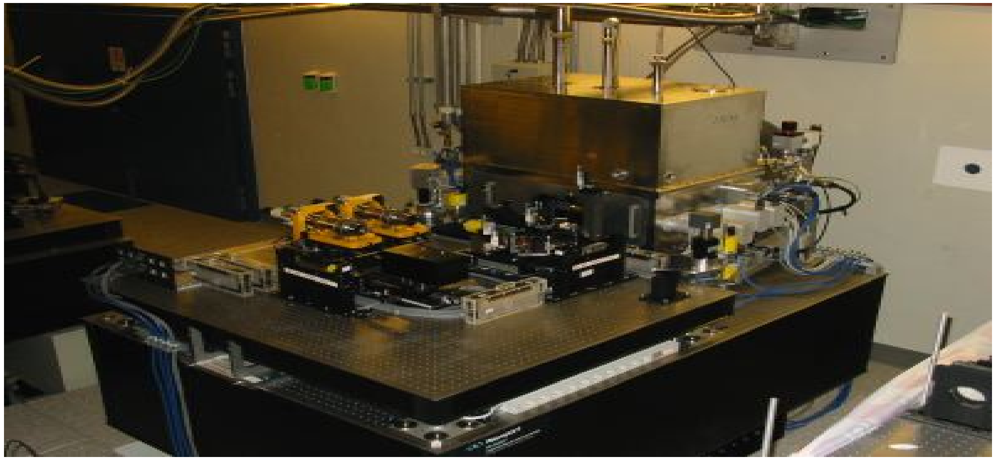
VLTI - Very Large Telescope Interferometry

VLTI acts like a virtual 100-meter telescope

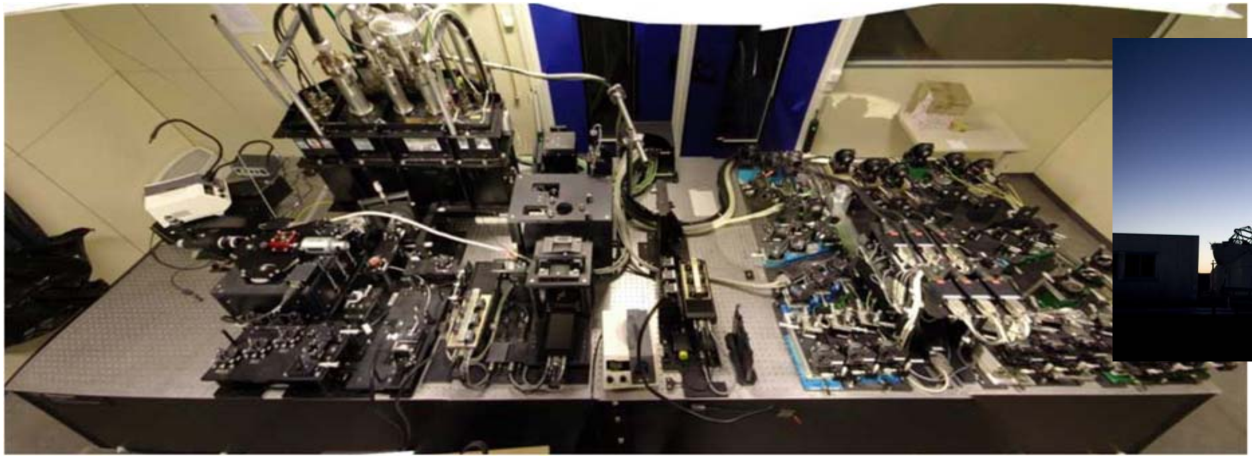
VLTI Instruments




MIDI



AMBER



La Silla Paranal

- La Silla
  - Medium-sized telescopes (3.6m, 3.5m NTT, 2.2m)
  - Small telescopes closed/funded externally
  - Continue operations with long-term programmes
    - HARPS, EFOSC2, SOFI, FEROS, WFI, visitor instruments
  - New initiatives and specific experiments
    - Euler, Tarot-II, REM, QUEST, TRAPPIST

- APEX
  - Covers sub-mm and mm wavelengths 0.3 to 3 mm
  - SHFI (Swedish Heterodyne Facility Instrument), LABOCA, SABOCA, CHAMP+, Z-Spec

La Silla: 5 Operational Instruments

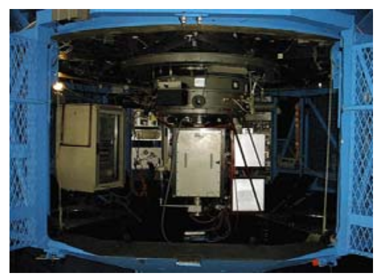
3.6m

HARPS

NTT

SOFI

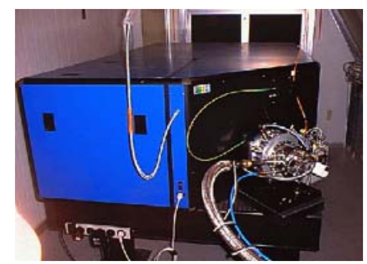
EFOSC2



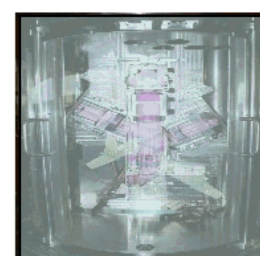
2.2m

WFI

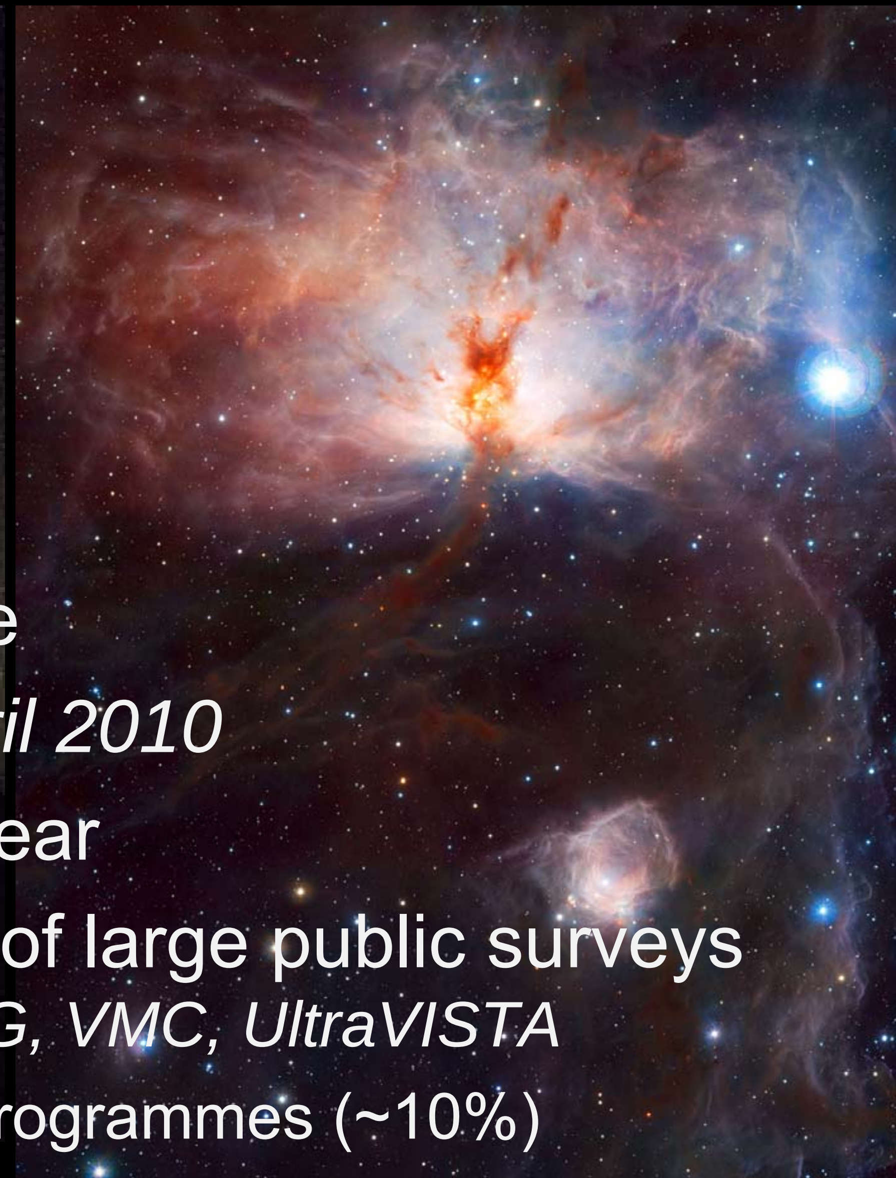
FEROS



GROND



VISTA: Visible and Infrared Survey Telescope for Astronomy



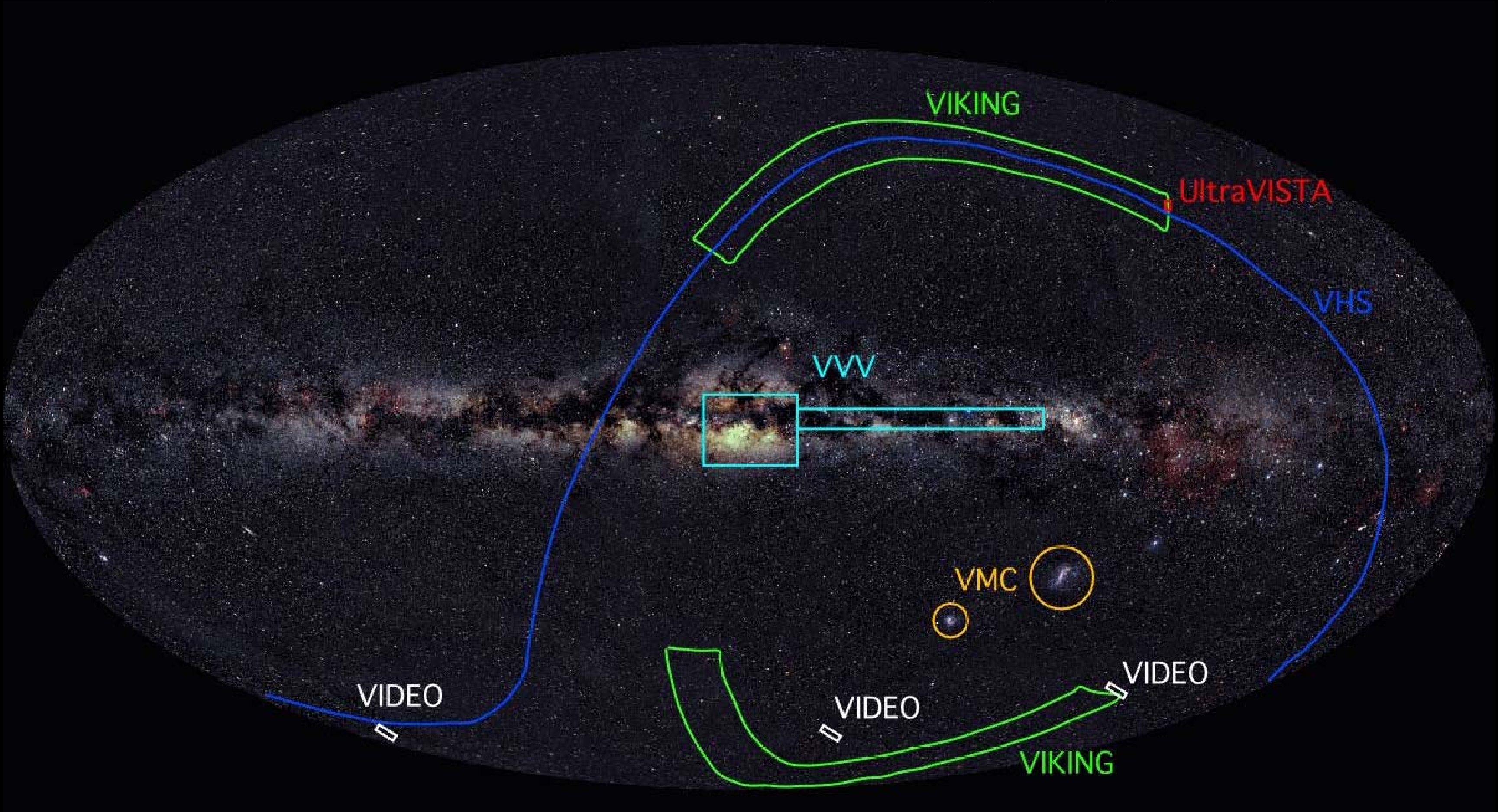
- 4.1-m survey telescope

  in operation since April 2010
- In operations for one year
- Multi-year programme of large public surveys

  VHS, VVV, VIDEO, VIKING, VMC, UltraVISTA
- limited access to regular programmes (~10%)

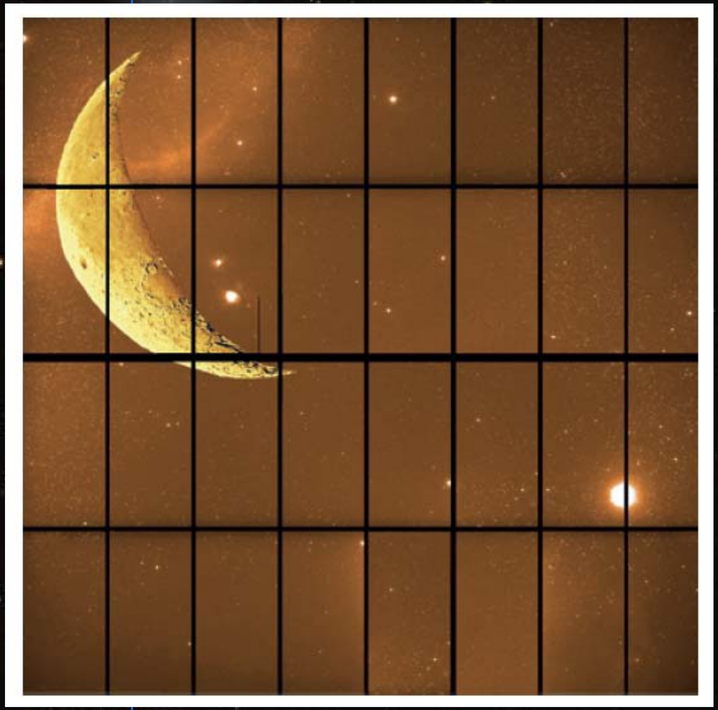
VISTA Public Surveys

Six public surveys ongoing



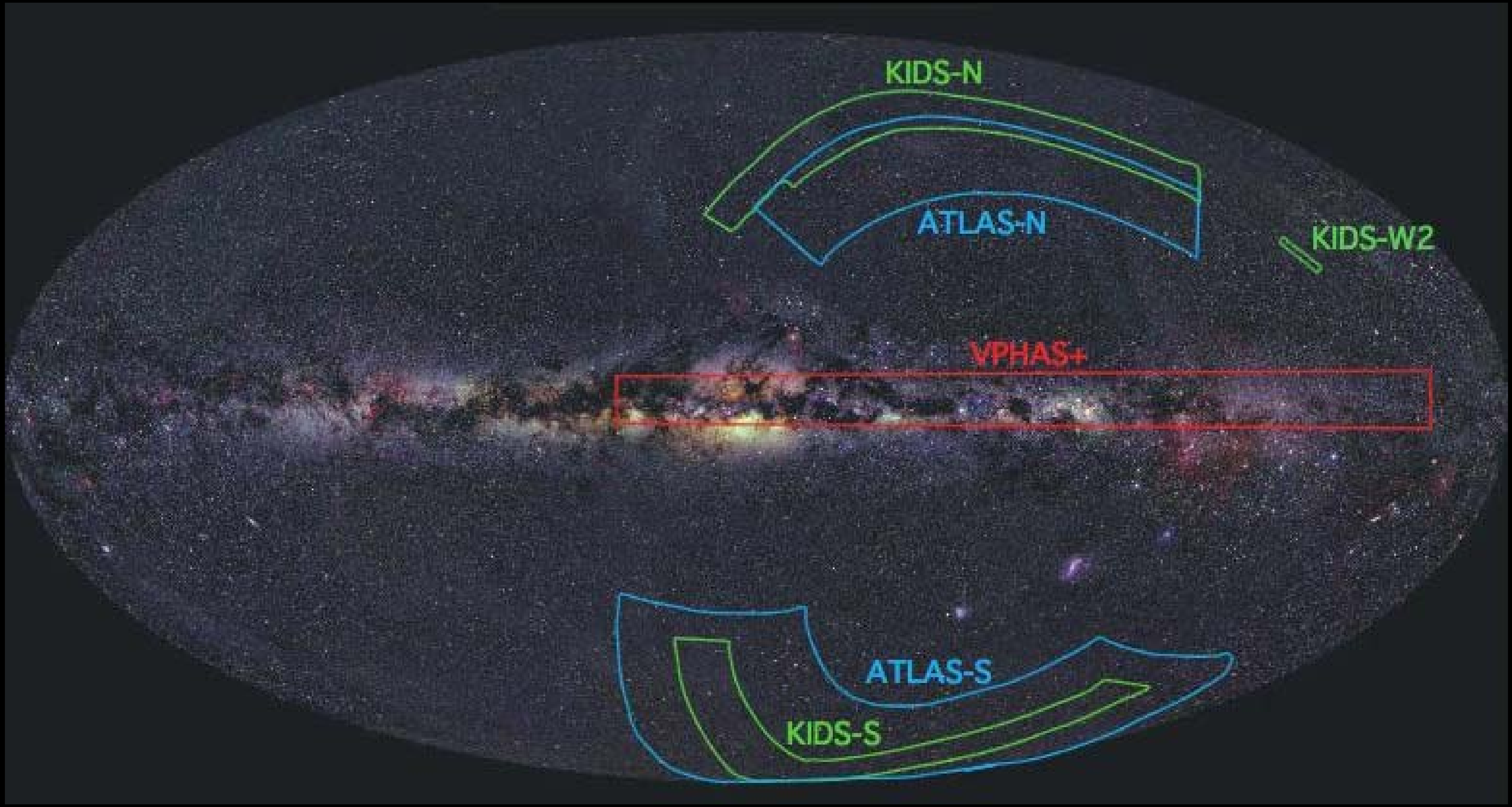
VST: VLT Survey Telescope

- 2.6-m optical telescope with 32 CCDs
- Science Verification ongoing
- Start of operations in October 2011
  - focus on three public surveys (KIDS, ATLAS, VPHAS+)



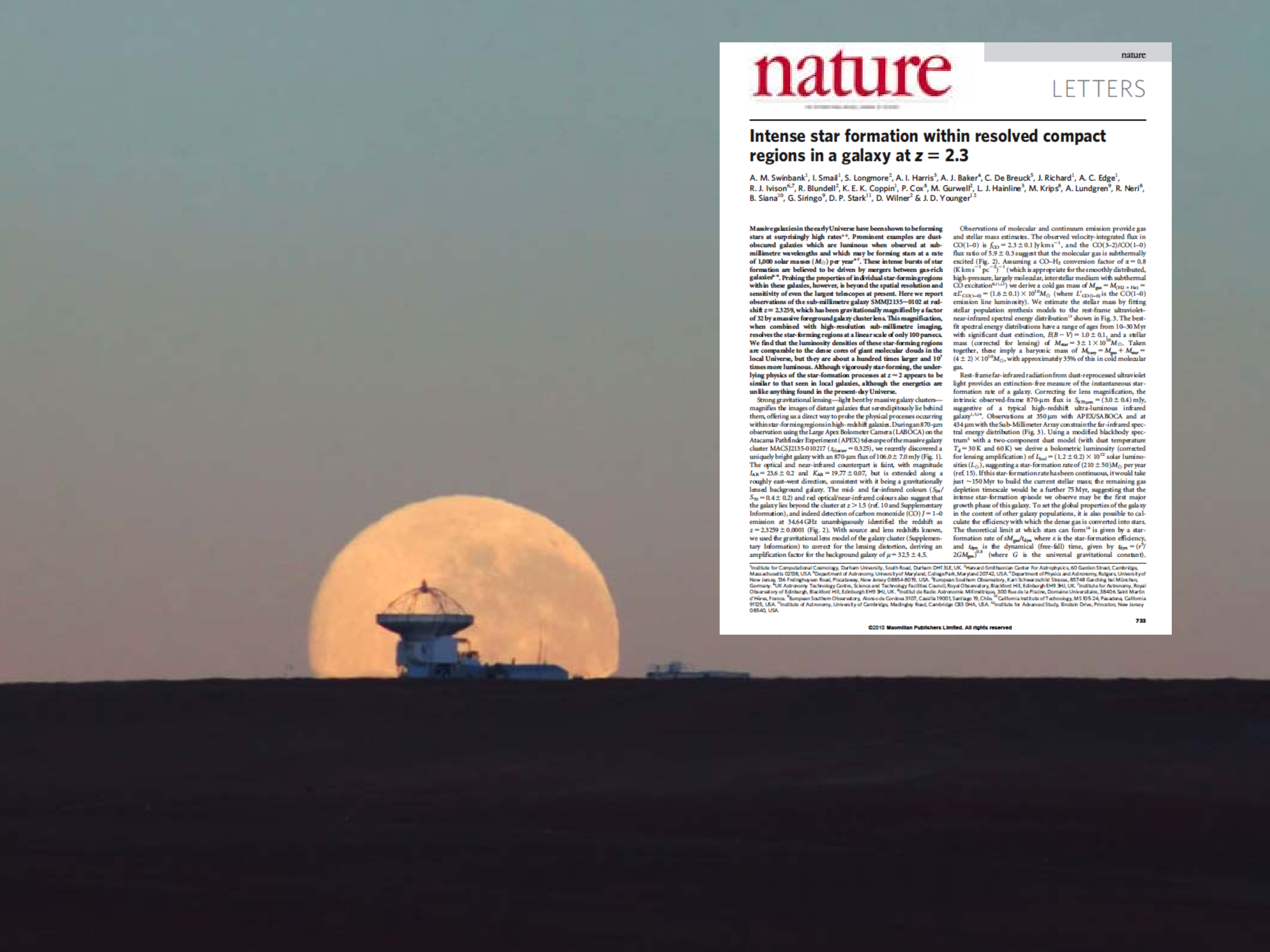
VST Public Surveys

Three public surveys
(and several GTO surveys)



APEX: an ALMA prototype

APEX in operation on Chajnantor



nature

Intense star formation within resolved compact regions in a galaxy at $z = 2.3$

A. M. Swinbank[1], I. Smail[1], S. Longmore[2], A. I. Harris[3], A. J. Baker[4], C. De Breuck[5], J. Richard[1], A. C. Edge[1], R. J. Ivison[6,7], R. Blundell[2], K. E. K. Coppin[1], P. Cox[8], M. Gurwell[2], L. J. Hainline[3], M. Krips[8], A. Lundgren[9], R. Neri[8], B. Siana[10], G. Siringo[9], D. P. Stark[11], D. Wilner[2] & J. D. Younger[12]

Massive galaxies in the early Universe have been shown to be forming stars at surprisingly high rates[1–3]. Prominent examples are dust-obscured galaxies which are luminous when observed at sub-millimetre wavelengths and which may be forming stars at a rate of 1,000 solar masses ($M_\odot$) per year[4–7]. These intense bursts of star formation are believed to be driven by mergers between gas-rich galaxies[8,9]. Probing the properties of individual star-forming regions within these galaxies, however, is beyond the spatial resolution and sensitivity of even the largest telescopes at present. Here we report observations of the sub-millimetre galaxy SMMJ2135−0102 at redshift $z = 2.3259$, which has been gravitationally magnified by a factor of 32 by a massive foreground galaxy cluster lens. This magnification, when combined with high-resolution sub-millimetre imaging, resolves the star-forming regions at a linear scale of only 100 parsecs. We find that the luminosity densities of these star-forming regions are comparable to the dense cores of giant molecular clouds in the local Universe, but they are about a hundred times larger and 10^7 times more luminous. Although vigorously star-forming, the underlying physics of the star-formation processes at $z \approx 2$ appears to be similar to that seen in local galaxies, although the energetics are unlike anything found in the present-day Universe.

Strong gravitational lensing—light bent by massive galaxy clusters—magnifies the images of distant galaxies that serendipitously lie behind them, offering us a direct way to probe the physical processes occurring within star-forming regions in high-redshift galaxies. During an 870-μm observation using the Large Apex Bolometer Camera (LABOCA) on the Atacama Pathfinder Experiment (APEX) telescope of the massive galaxy cluster MACSJ2135-010217 ($z_{cluster} = 0.325$), we recently discovered a uniquely bright galaxy with an 870-μm flux of 106.0 ± 7.0 mJy (Fig. 1). The optical and near-infrared counterpart is faint, with magnitude $I_{AB} = 23.6 \pm 0.2$ and $K_{AB} = 19.77 \pm 0.07$, but is extended along a roughly east–west direction, consistent with it being a gravitationally lensed background galaxy. The mid- and far-infrared colours ($S_{24}/S_{70} = 0.4 \pm 0.2$) and red optical/near-infrared colours also suggest that the galaxy lies beyond the cluster at $z > 1.5$ (ref. 10 and Supplementary Information), and indeed detection of carbon monoxide (CO) $J = 1$–0 emission at 34.64 GHz unambiguously identified the redshift as $z = 2.3259 \pm 0.0001$ (Fig. 2). With source and lens redshifts known, we used the gravitational lens model of the galaxy cluster (Supplementary Information) to correct for the lensing distortion, deriving an amplification factor for the background galaxy of $\mu = 32.5 \pm 4.5$.

Observations of molecular and continuum emission provide gas and stellar mass estimates. The observed velocity-integrated flux in CO(1–0) is $f_{CO} = 2.3 \pm 0.1$ Jy km s^{-1}, and the CO(3–2)/CO(1–0) flux ratio of 5.9 ± 0.3 suggest that the molecular gas is subthermally excited (Fig. 2). Assuming a CO–H_2 conversion factor of $\alpha = 0.8$ (K km s^{-1} pc^{-2})$^{-1}$ (which is appropriate for the smoothly distributed, high-pressure, largely molecular, interstellar medium with subthermal CO excitation[9,11,12]) we derive a cold gas mass of $M_{gas} = M_{(H2+He)} = \alpha L'_{CO(1-0)} = (1.6 \pm 0.1) \times 10^{10} M_\odot$ (where $L'_{CO(1-0)}$ is the CO(1–0) emission line luminosity). We estimate the stellar mass by fitting stellar population synthesis models to the rest-frame ultraviolet–near-infrared spectral energy distribution[13] shown in Fig. 3. The best-fit spectral energy distributions have a range of ages from 10–30 Myr with significant dust extinction, $E(B-V) = 1.0 \pm 0.1$, and a stellar mass (corrected for lensing) of $M_{star} = 3 \pm 1 \times 10^{10} M_\odot$. Taken together, these imply a baryonic mass of $M_{bary} = M_{gas} + M_{star} = (4 \pm 2) \times 10^{10} M_\odot$, with approximately 35% of this in cold molecular gas.

Rest-frame far-infrared radiation from dust-reprocessed ultraviolet light provides an extinction-free measure of the instantaneous star-formation rate of a galaxy. Correcting for lens magnification, the intrinsic observed-frame 870-μm flux is $S_{870\mu m} = (3.0 \pm 0.4)$ mJy, suggestive of a typical high-redshift ultra-luminous infrared galaxy[1,3,14]. Observations at 350 μm with APEX/SABOCA and at 434 μm with the Sub-Millimeter Array constrain the far-infrared spectral energy distribution (Fig. 3). Using a modified blackbody spectrum[3] with a two-component dust model (with dust temperature $T_d = 30$ K and 60 K) we derive a bolometric luminosity (corrected for lensing amplification) of $L_{bol} = (1.2 \pm 0.2) \times 10^{12}$ solar luminosities ($L_\odot$), suggesting a star-formation rate of $(210 \pm 50) M_\odot$ per year (ref. 15). If this star-formation rate has been continuous, it would take just ~150 Myr to build the current stellar mass; the remaining gas depletion timescale would be a further 75 Myr, suggesting that the intense star-formation episode we observe may be the first major growth phase of this galaxy. To set the global properties of the galaxy in the context of other galaxy populations, it is also possible to calculate the efficiency with which the dense gas is converted into stars. The theoretical limit at which stars can form[16] is given by a star-formation rate of $\epsilon M_{gas}/t_{dyn}$ where ϵ is the star-formation efficiency, and t_{dyn} is the dynamical (free-fall) time, given by $t_{dyn} = (r^3/2GM_{gas})^{0.5}$ (where G is the universal gravitational constant).

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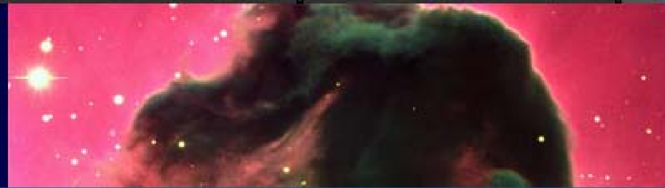
European Southern Observatory



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18 Feb 2011

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Intranet

ESO is the foremost intergovernmental astronomy organisation in Europe and the world's most productive astronomical observatory. It operates three sites in Chile — La Silla, Paranal and Chajnantor — on behalf of its fifteen member states. It builds ALMA together with international partners, and designs the European Extremely Large Telescope.

ESO, the European Southern Observatory, builds and operates a suite of the world's most advanced ground-based astronomical telescopes.

www.eso.org

Latest Press Releases

Reflected Glory

A Picture-perfect Barred Galaxy

The Orion Nebula: Still Full of Surprises

The Orion Nebula: Still Full of Surprises The ethereal-looking image of the Orion Nebula was captured using the Wide Field Imager on the MPG/ESO 2.2-metre telescope at the La Silla Observatory, Chile. This nebula is much more than just a pretty face, offering astronomers a close-up view of a massive star-forming region to help advance our understanding of stellar birth and evolution. The data used for this image were selected by Igor Chekalin (Russia), who participated in ESO's Hidden Treasures 2010 astrophotography competition. Igor's composition of the Orion Nebula was the seventh highest ranked entry in the competition, although another of Igor's

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Announcements

09 Feb 2011 — Hold the Universe in Your Hand
02 Feb 2011 — Café & Kosmos 7 February 2011
01 Feb 2011 — ESOcast 26: Life at the Paranal Observatory
26 Jan 2011 — First "3D View" from the VLT Interferometer
07 Jan 2011 — Hot Off the Press: Issue 10 of CAPjournal

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Picture of the Week

A Galactic Petri Dish

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Top 100 Images

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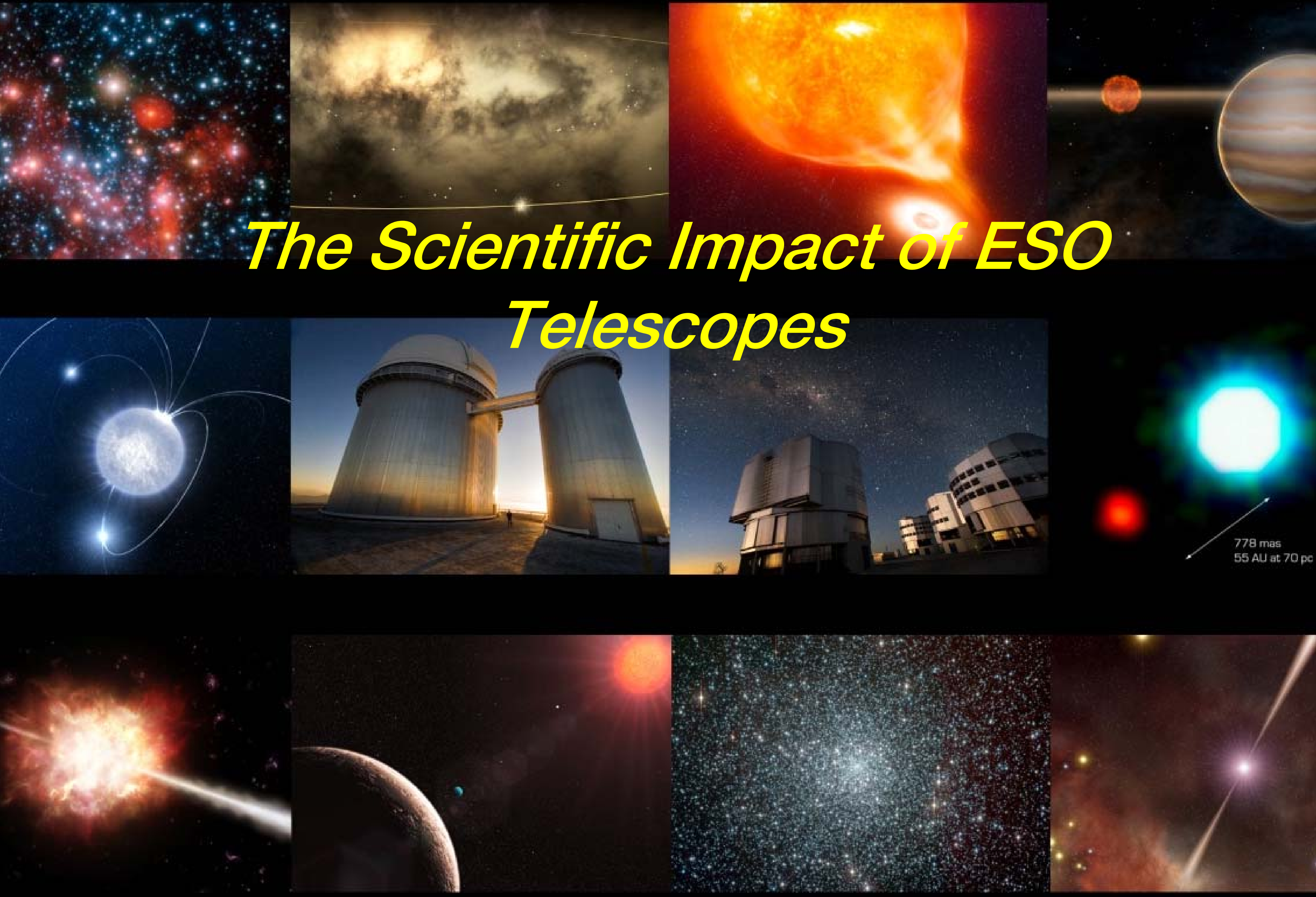
Portal to the Universe

The Scientific Impact of ESO Telescopes



naturenews

Published online 6 February 2009 | Nature | doi:10.1038/news.2009.81

News

The world's top ten telescopes revealed

The best observatories ranked by their scientific impact.

Eric Hand

It doesn't take a big mirror to have a big impact. The Sloan Digital Sky Survey, a project conducted with a modest 2.5-metre-wide telescope in New Mexico, performed the most highly cited science in 2006, according to a new analysis of the top ten 'high impact' astronomical observatories[1].

SDSS image of Messier 51, the Whirlpool Galaxy.

Sloan Digital Sky Survey

"It measures how hot the science of the telescope is," says Juan Madrid of McMaster University in Hamilton, Canada, of the top-ten table he has released for most years since 1998. "In a way it measures how good the time-allocation committee is and how good the telescope is. I will also say it measures how good the scientists are."

Also in the top five is another modest telescope — Swift, a satellite that looks for γ-ray bursts — followed by three technological giants of the astronomy world: the Hubble Space Telescope, the four 8-metre

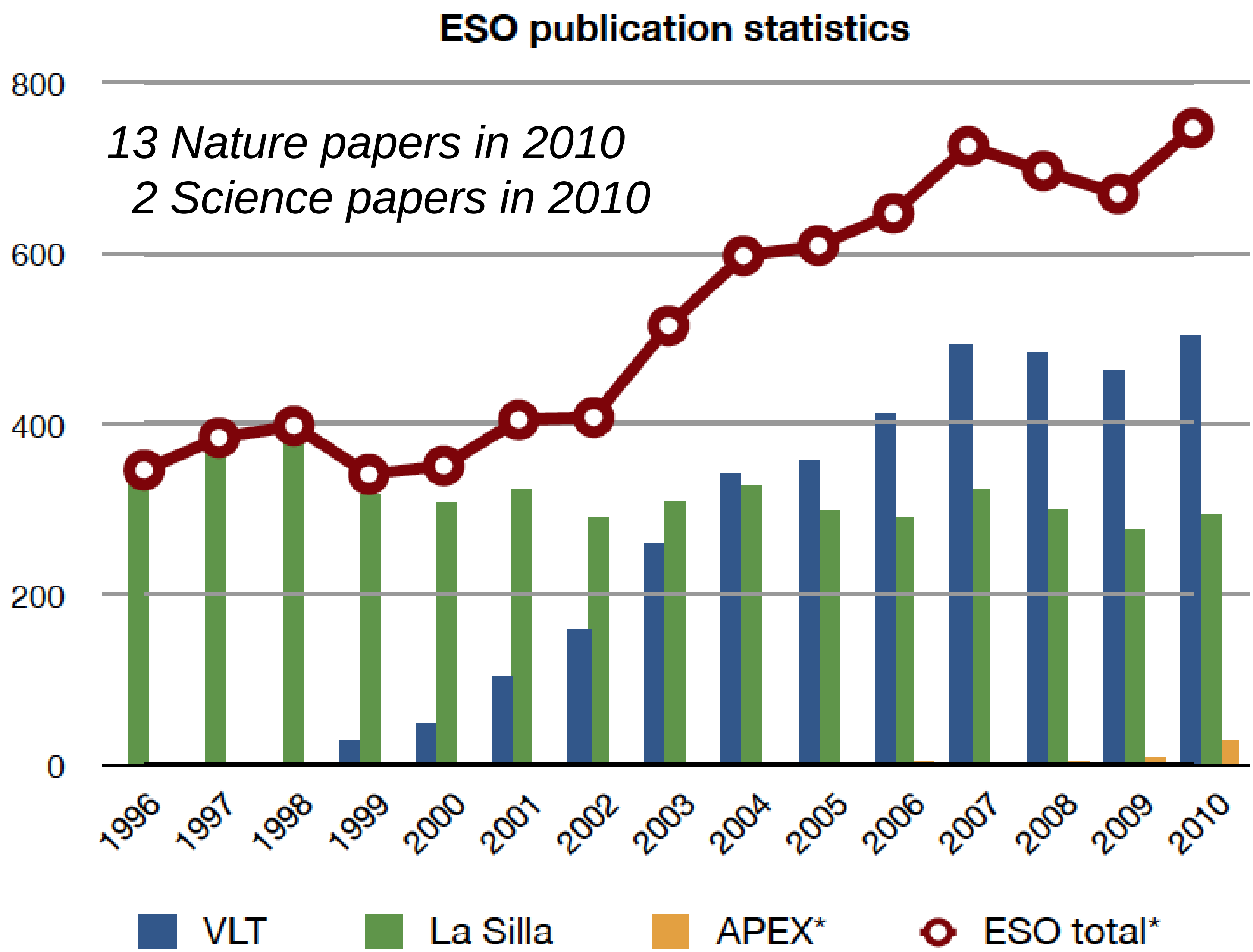
HIGH-IMPACT OBSERVATORIES

Rank	Facility	Citations	Participation
1	SDSS	1892	14.3%
2	Swift	1523	11.5%
3	HST	1078	8.2%
4	ESO	813	6.1%
5	Keck	572	4.3%
6	CFHT	521	3.9%
7	Spitzer	469	3.5%
8	Chandra	381	2.9%
9	Boomerang	376	2.8%
10	HESS	297	2.2%

Key
SDSS - Sloan Digital Sky Survey
HST – Hubble Space Telescope
ESO – European Southern Observatory
CFHT – Canada France Hawaii Telescope
HESS - High Energy Stereoscopic System

Madrid, J. P. & Macchetto, D.

ESO publication statistics



ALMA currently under construction

Partnership between ESO, NRAO, NAOJ

Early science in 2011

Full operations in 2013

ALMA will operate at wavelengths of 0.3 to 9.6 mm

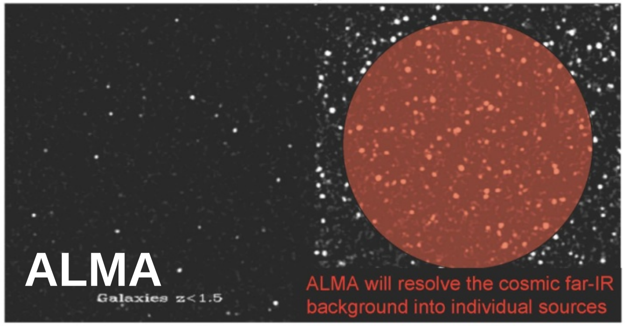
ALMA

- Science requirements
  - Detect CO and [CII] in Milky Way galaxy at z=3 in < 24 hr
  - Dust emission, gas kinematics in proto-planetary disks
  - Resolution to match Hubble, JWST and 8-10m with AO
  - Complement to Herschel
- Specifications
  - 66 antennas (54x12m, 12x7m)
  - 14 km max baseline (< 10mas)
  - 30-1000 GHz (10–0.3mm), up to 10 receiver bands

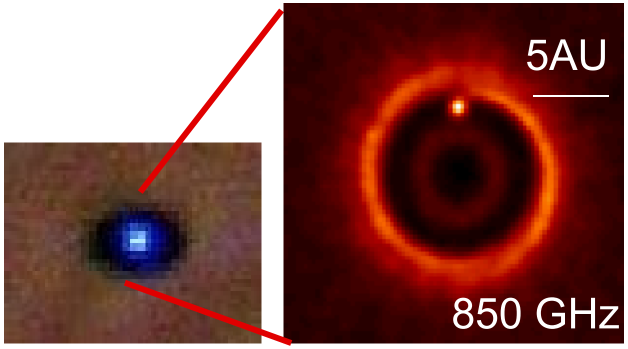
(12 days of integration)

z<1.5 z>1.5

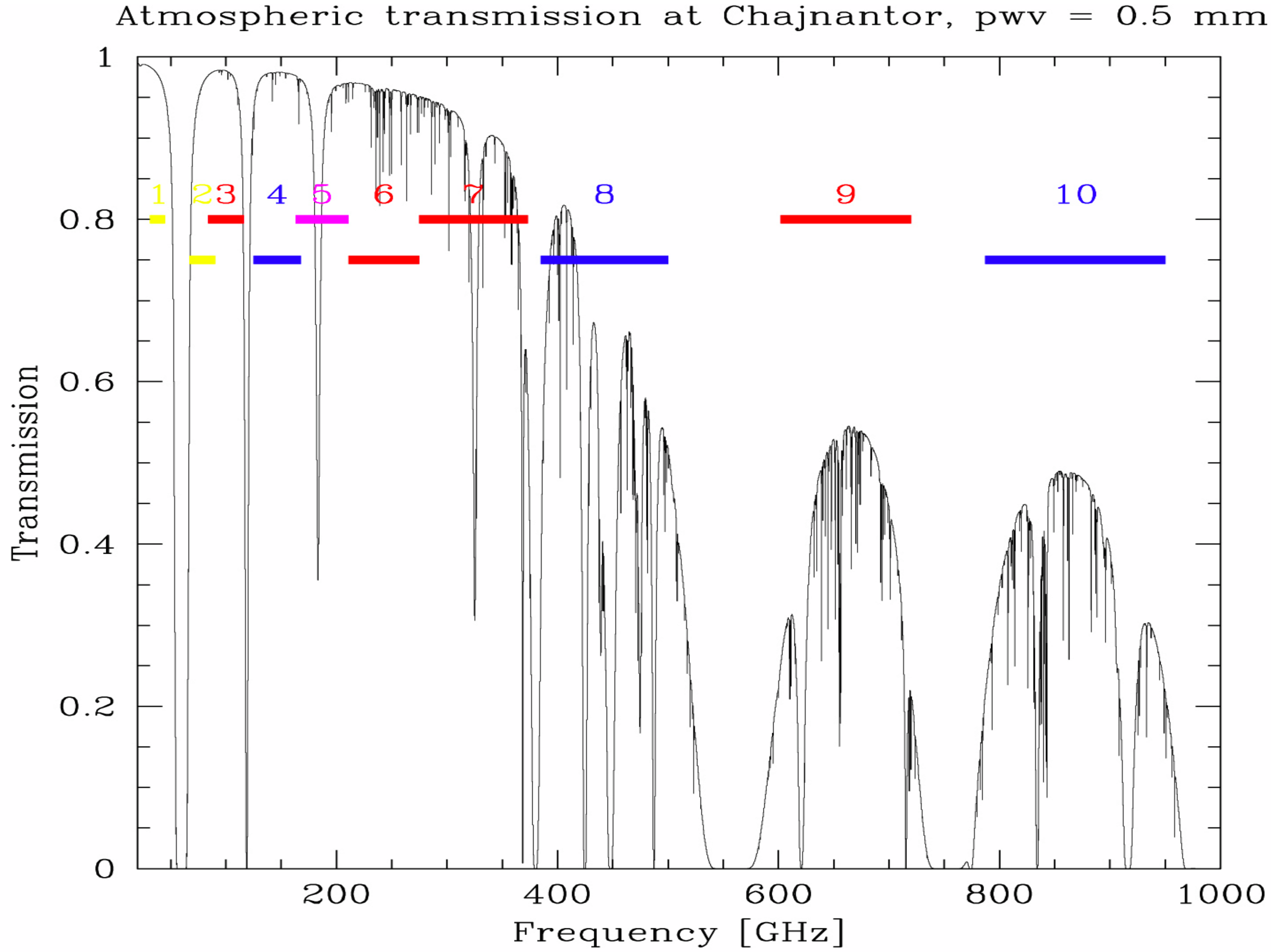
simulation 3 days of integration 4'x4' arcmin



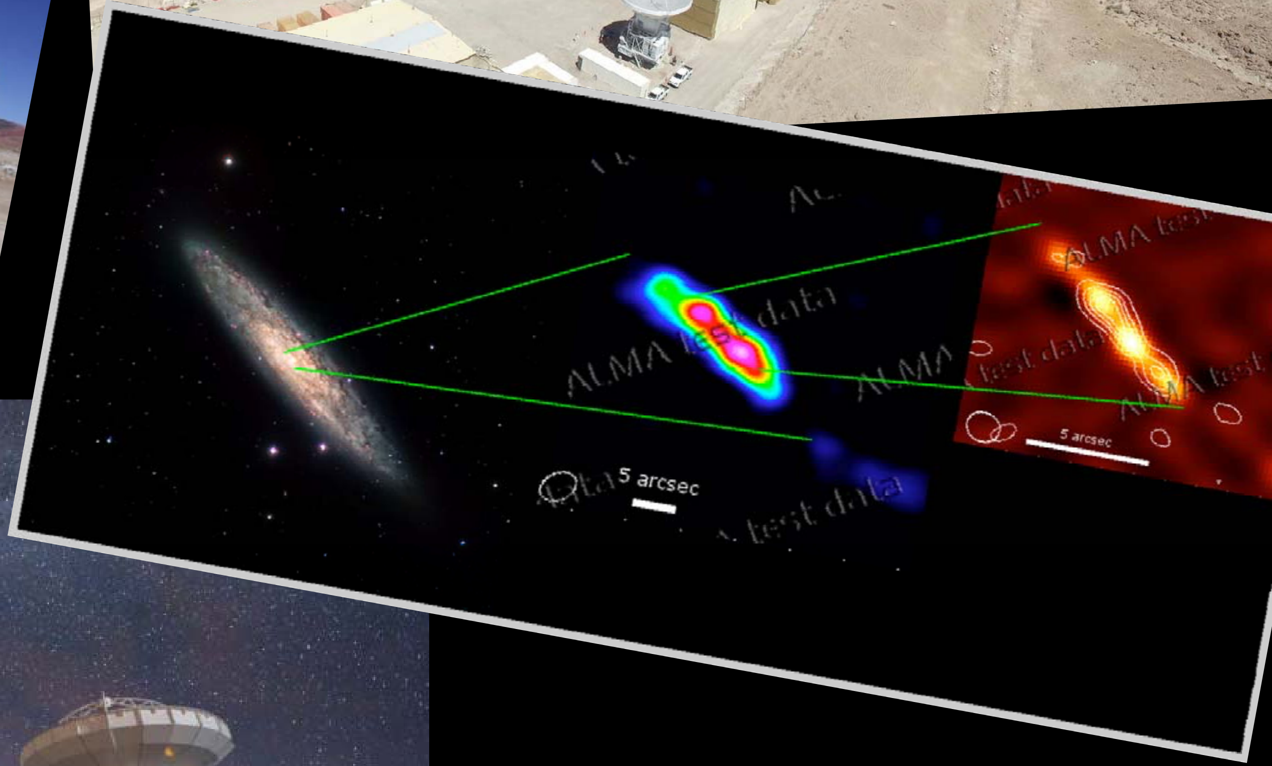
z<1.5 z>1.5

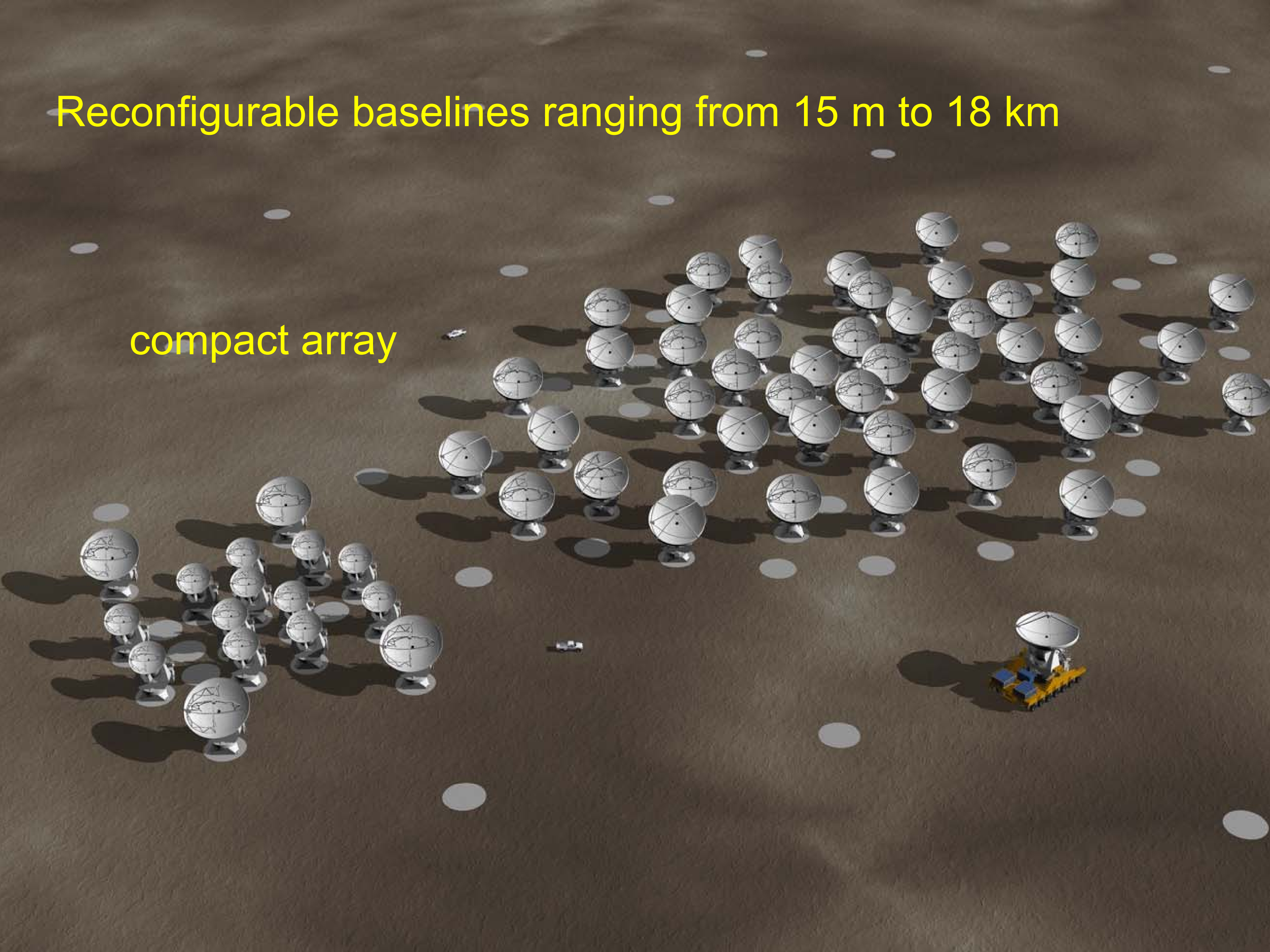


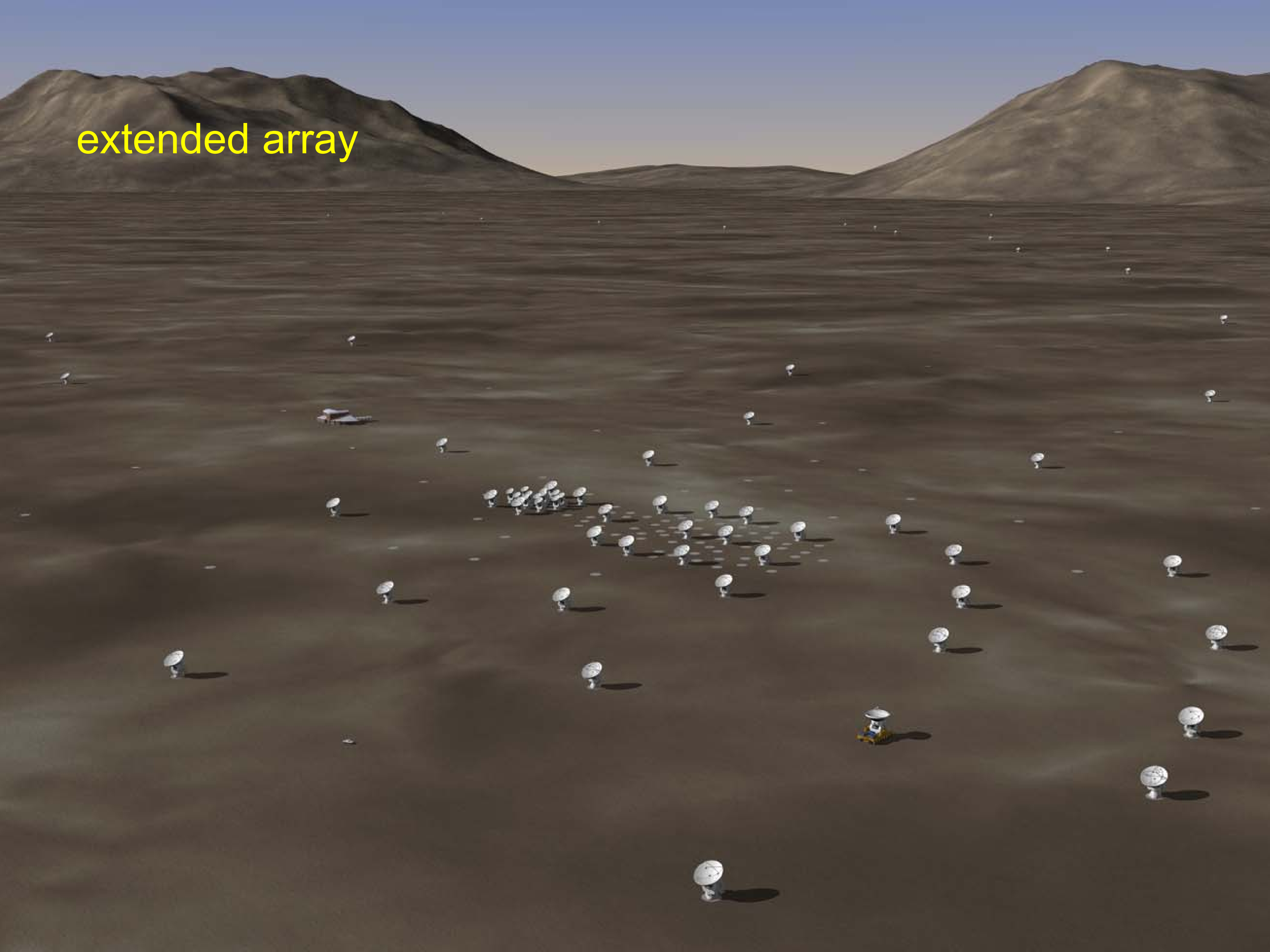
Atmosphere above Chajnantor



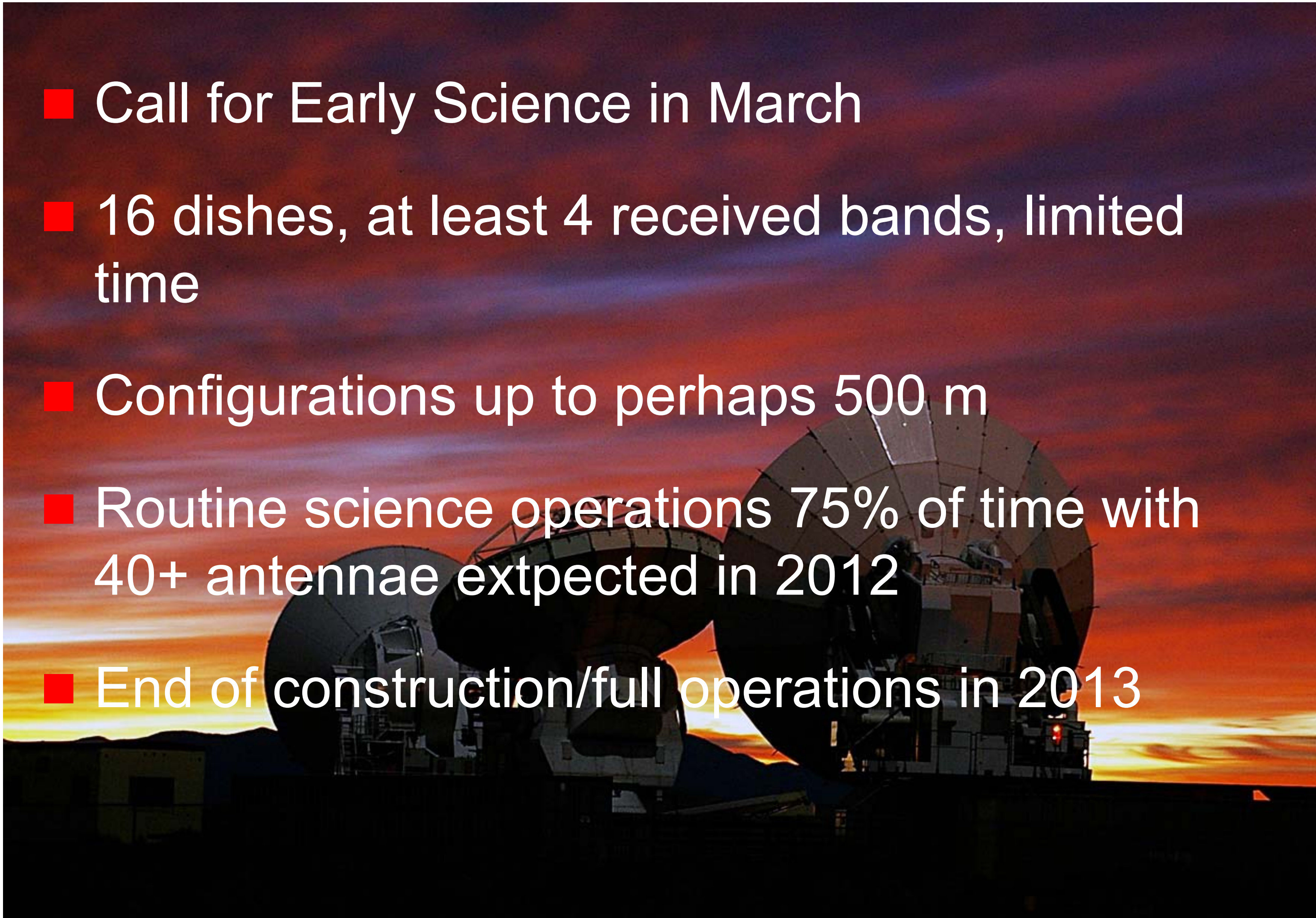
Adding the 7m antennas


ALMA test data
5 arcsec
5 arcsec


Reconfigurable baselines ranging from 15 m to 18 km
compact array


extended array

ALMA Early Science



- Call for Early Science in March
- 16 dishes, at least 4 received bands, limited time
- Configurations up to perhaps 500 m
- Routine science operations 75% of time with 40+ antennae extpected in 2012
- End of construction/full operations in 2013

An ELT in the making

- ALMA now has more collecting area than any of the future E-ELT
  - 17 antennas working as array (7 August 2011)
  - 136 baselines
  - >900 proposals for Early Science (Cycle 0)

English Español

Atacama Large Millimeter/submillimeter Array

In search of our Cosmic Origins

search... GO

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Plan for ALMA Early Science Cycle 0

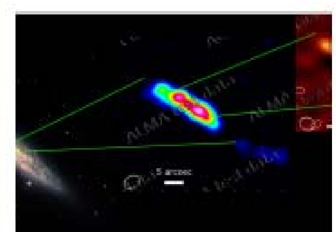
Friday, 07 January 2011

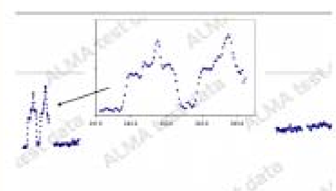
www.almaobservatory.org

The Joint ALMA Observatory (JAO) expects to start ***Early Science observations* (Cycle 0)** on a best effort basis late in 2011 and a call for proposals will be issued at the end of the first quarter of 2011. The purpose of *Early Science* will be to deliver scientifically useful results to the astronomy community and to facilitate the ongoing characterization of ALMA systems and instrumentation as the capability of the array continues to grow. *Early Science* will not be allowed to delay unduly the construction of the full 66-antenna array, but nonetheless provides an important opportunity for first science from this cutting edge facility. Early Science will continue through Cycle 1 and until construction of the ALMA array is complete.

The first release of ALMA test data to the astronomy community will be through the **Science Verification program**. Science Verification will involve observations of objects designed to test ALMA systems and confirm their performance. The first data from these tests will be available by the time of the ALMA *Early*

Test Images





E-ELT: The World's Biggest Eye on the Sky


Cerro Armazones
-24.58ºN -70.18ºW
3064 m
Cerro Paranal
-24.6ºN -70.4ºW
2600 m
©2009 Google


Cerro Armazones
Cerro Paranal

Five-mirror design

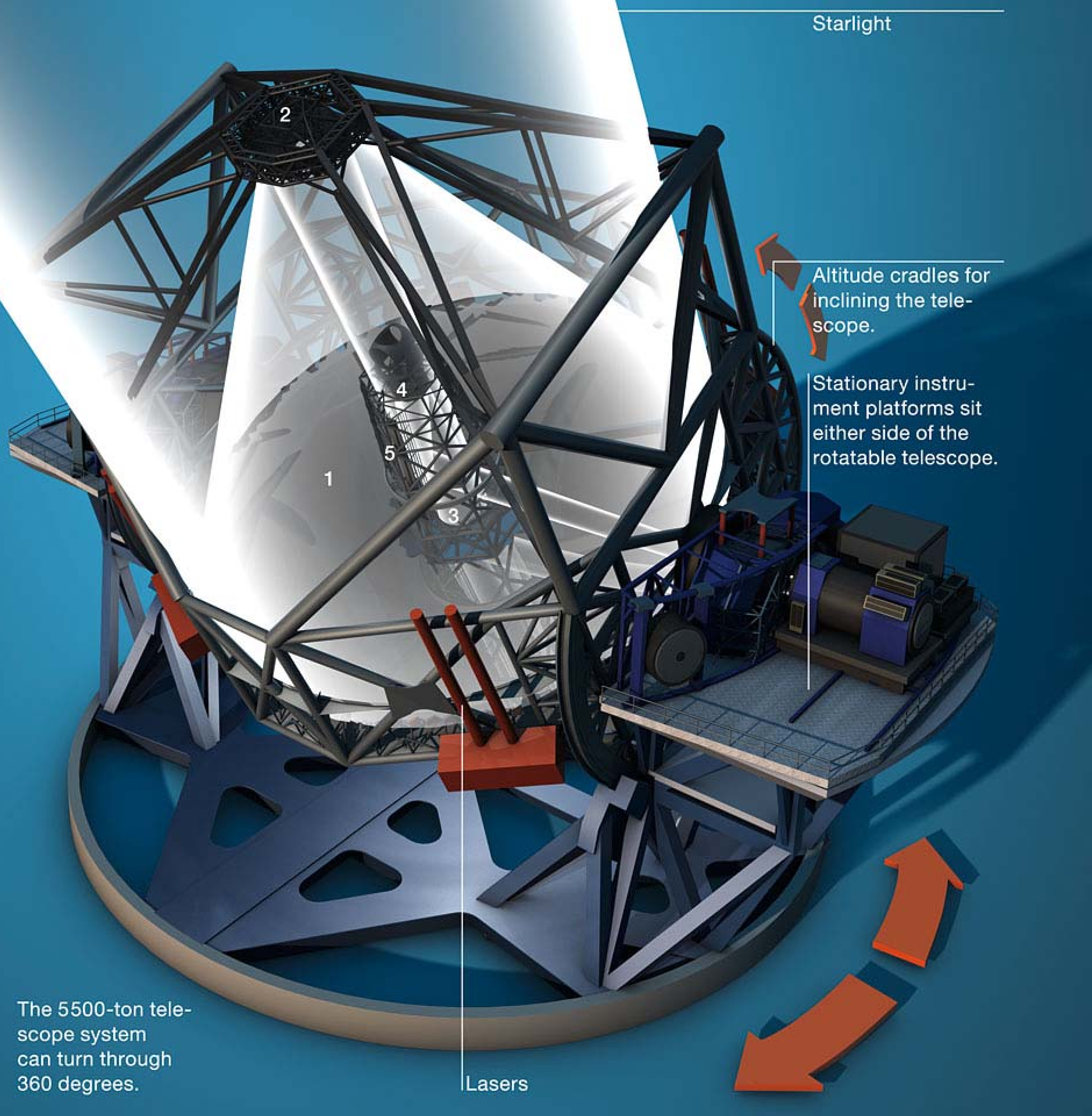
1 **The 42-metre primary mirror** collects light from the night sky and reflects it to a smaller mirror located above it.

2 **The 6-metre secondary mirror** reflects light back down to a still smaller mirror nestled in the primary mirror.

3 **The third mirror** relays light to an adaptive flat mirror directly above.

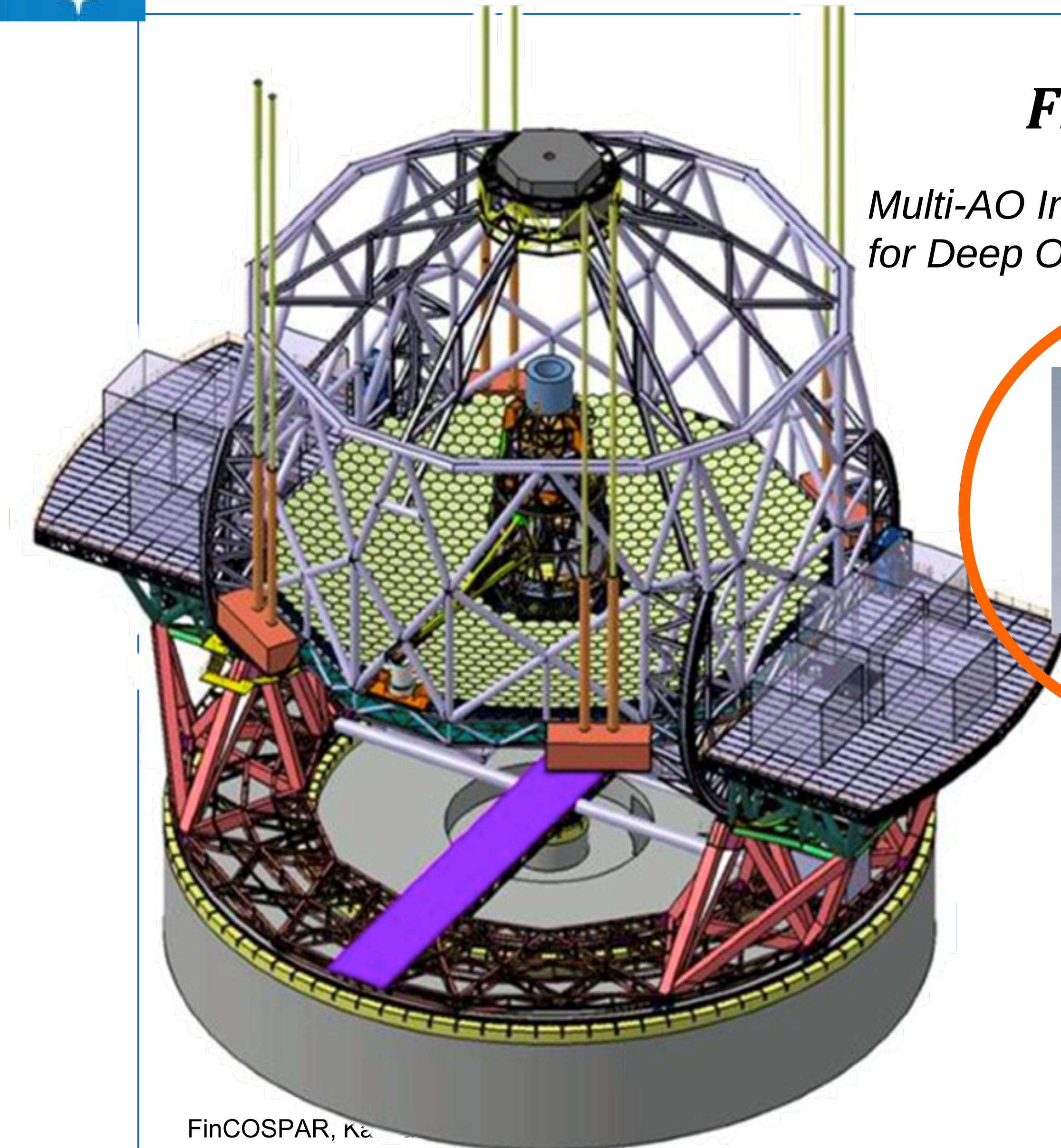
4 **The adaptive mirror** adjusts its shape a thousand times a second to correct for distortions caused by atmospheric turbulence.

5 **A fifth mirror,** mounted on a fast-moving stage, stabilises the image and sends the light to cameras and other instruments on the stationary platform.



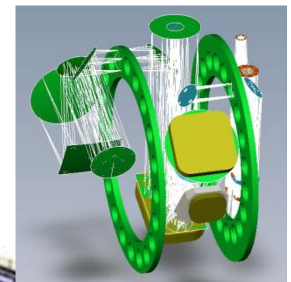
E-ELT's Vision

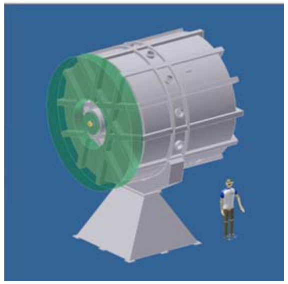
E-ELT: first light instruments



First Light Instruments

Multi-AO Imaging Camera for Deep Observations





Optical/NIR IFU

Extremely Exciting Science

Exoplanets

detection and characterisation down to Earth masses

Fundamental physics

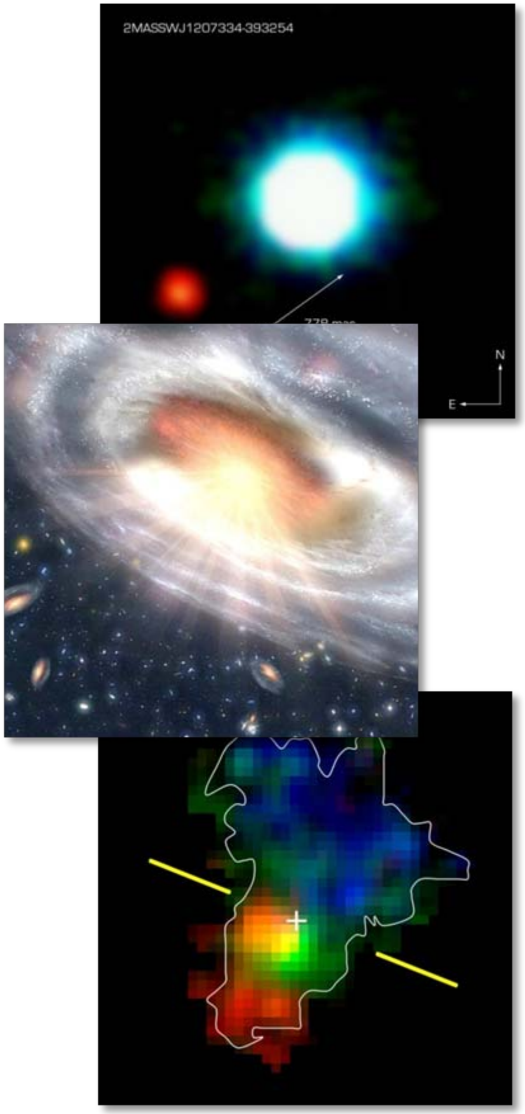
expansion history of the universe, physics laws variations with time

Black holes

physics at the edge of black holes, evolution of black holes with time

Structure formation

watching the first galaxies form, resolving distant galaxies into stars

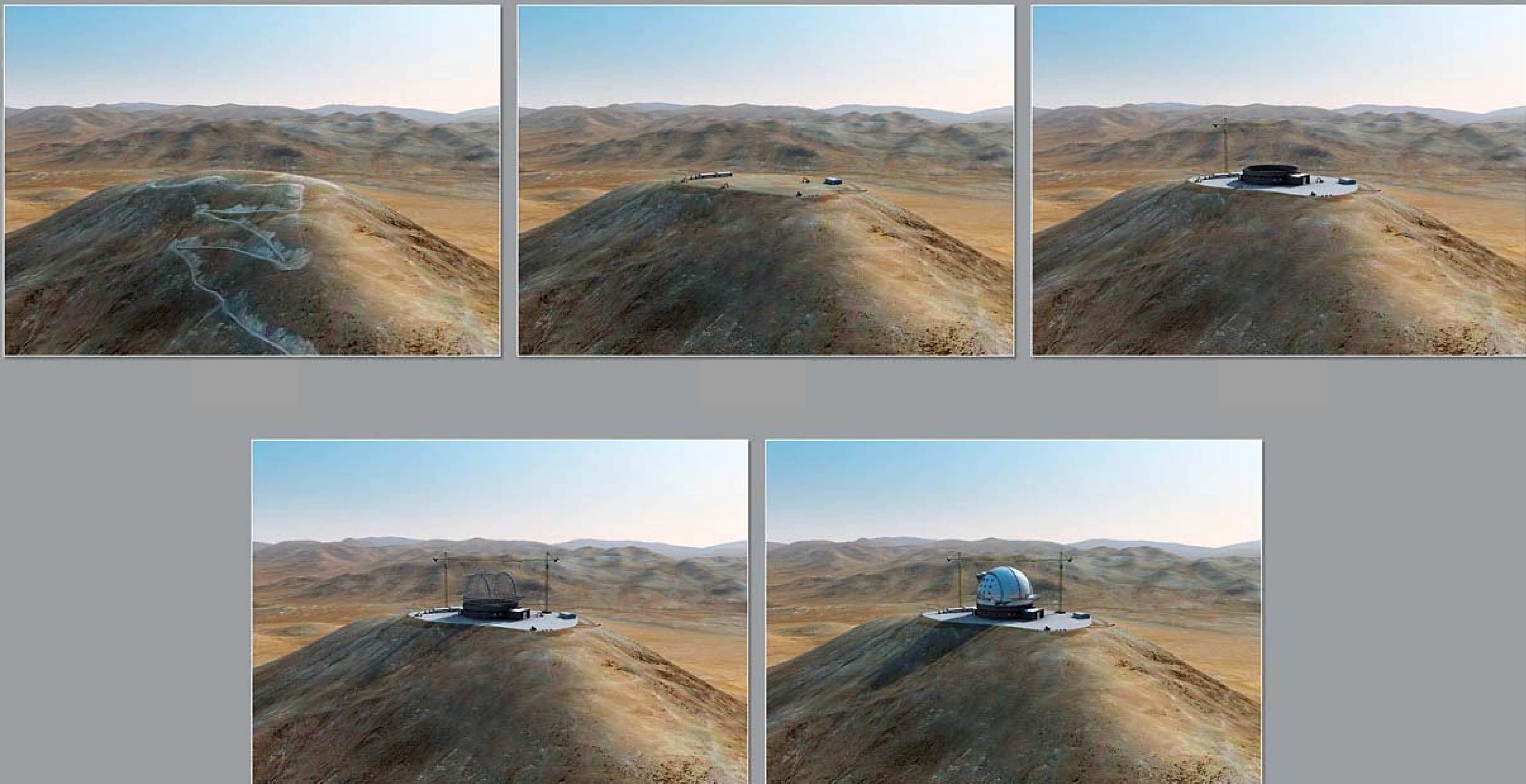


Extremely Exciting Science

Synergies with the VLT, JWST and ALMA

The Unknown

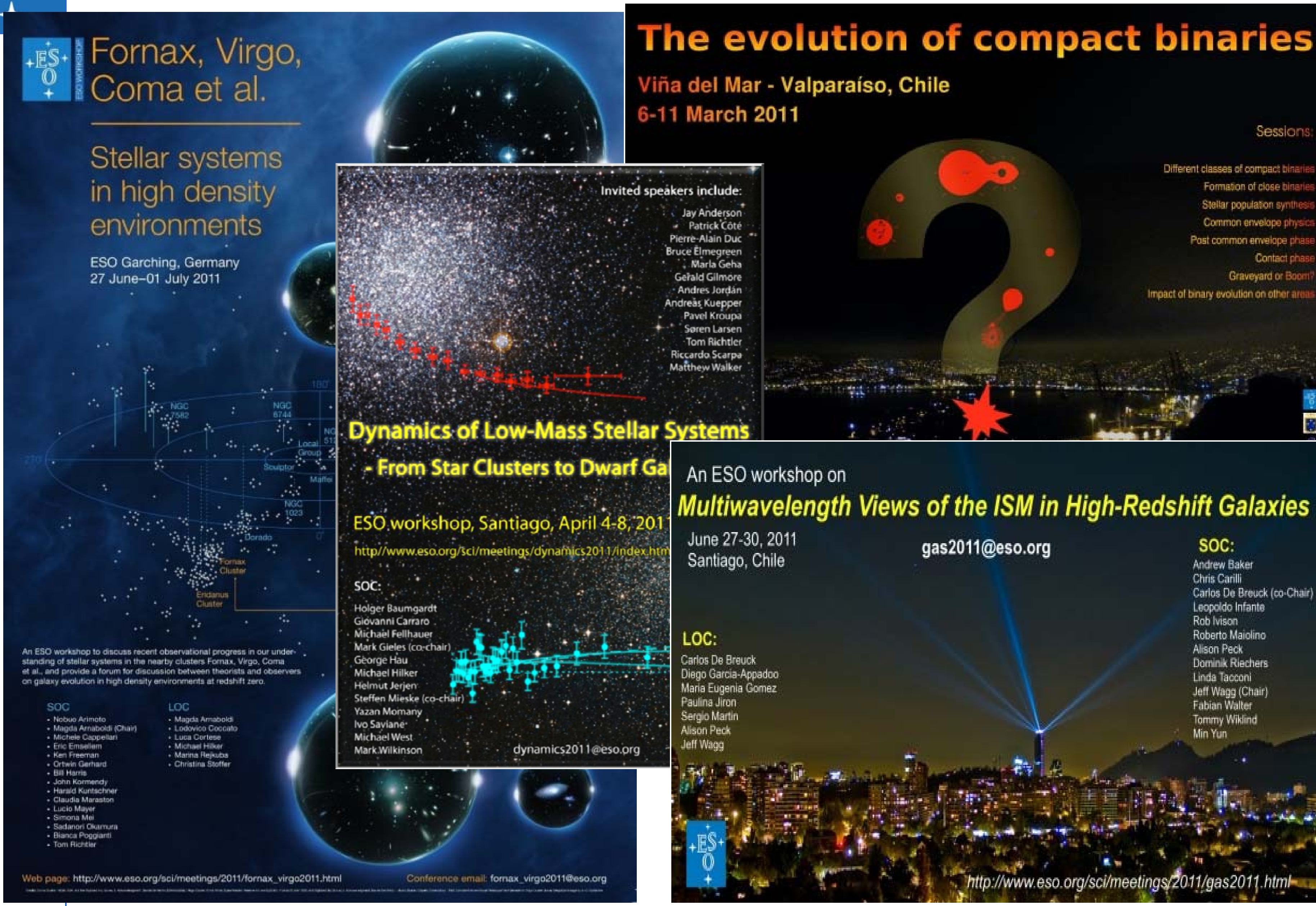
E-ELT first light possible in 2021



ESO Fellowship programme

- Open to all nationalities, but preference to ESO member countries
- 3 years in Garching or 4 in Chile
- Chile Fellows do research plus observatory work
- Garching Fellows do research plus support work
- Deadline for applications is 15 October

ESO Workshops



ESO's goals for the next five years

- Best science from La Silla Paranal Observatory
  - Second generation instruments (VLT/VLTI)
  - Key surveys with VST and VISTA
  - Long-term programs for unique science on La Silla
  - Prepare for ALMA science with APEX
- Deliver ALMA on time and budget
- Design world-leading E-ELT, and secure funding for construction and operations