



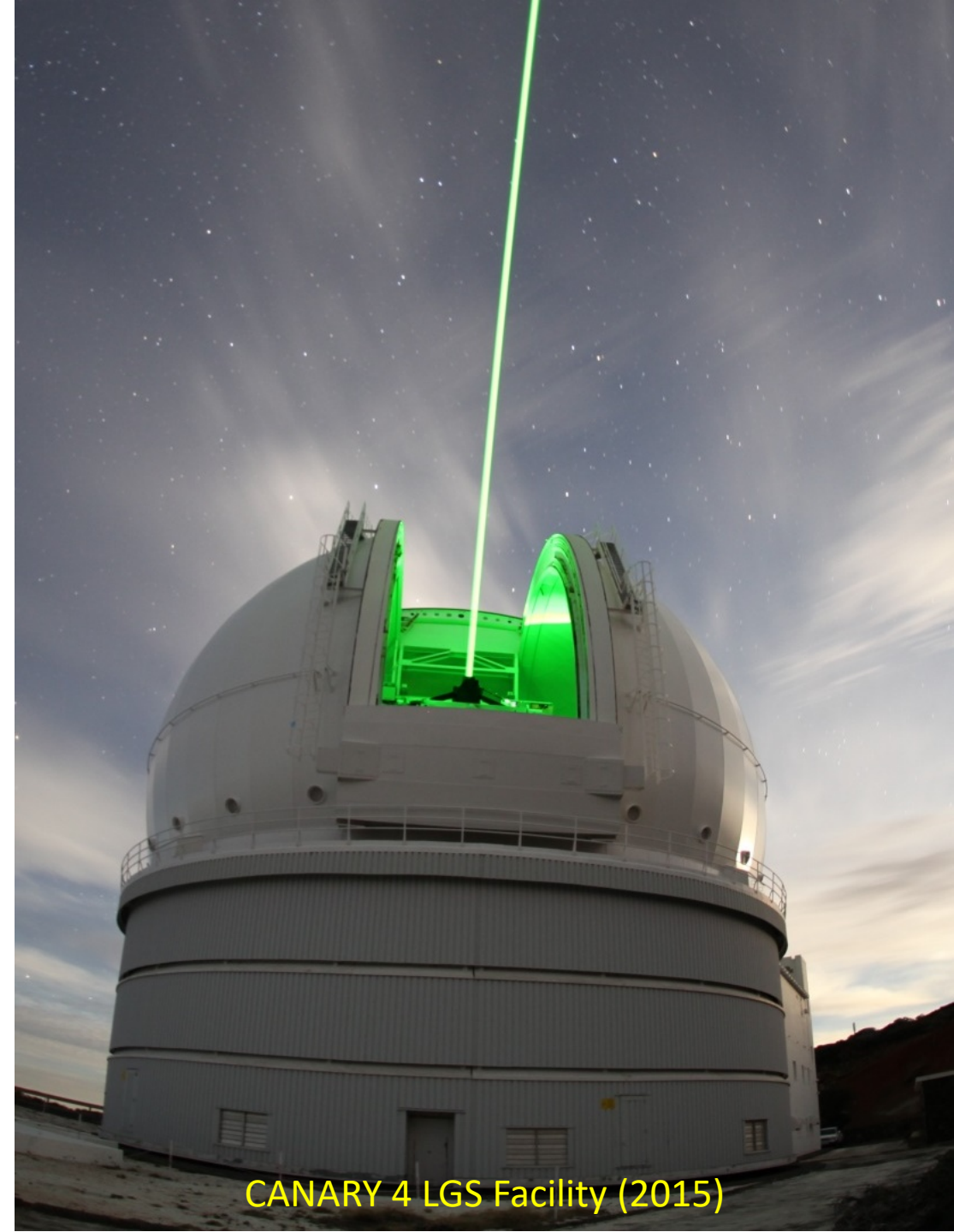
OPTICON community access program for instrument development

Tim Morris, Durham University



Overview

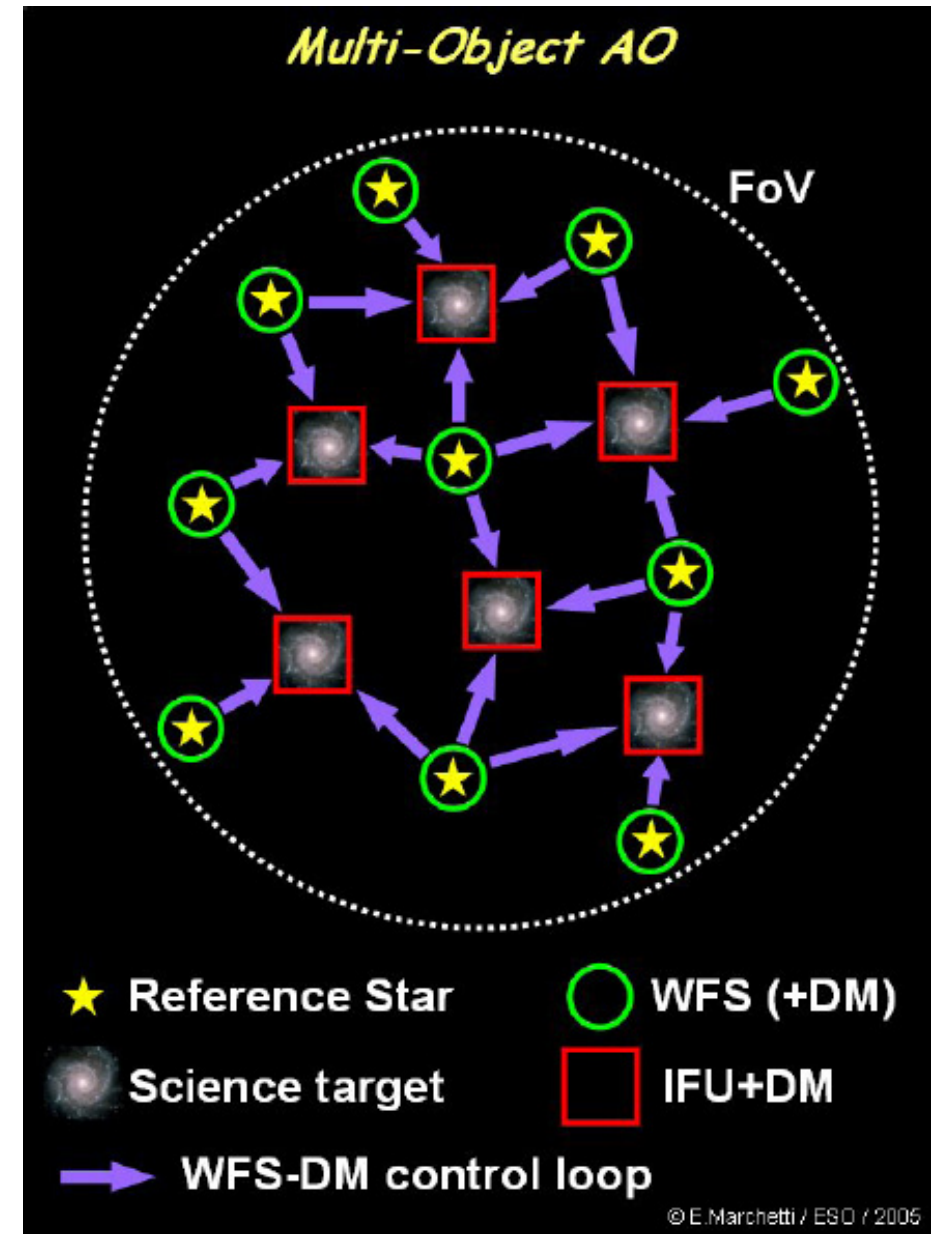
- Introduction to CANARY
- OPTICON access program
- Future instrument development



CANARY 4 LGS Facility (2015)

CANARY goal

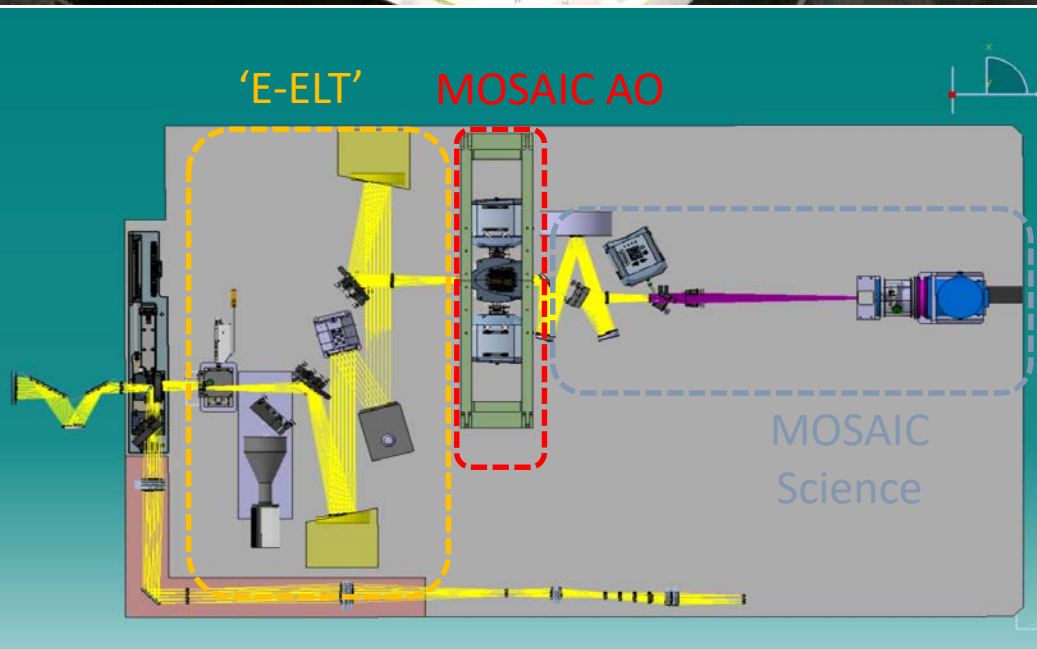
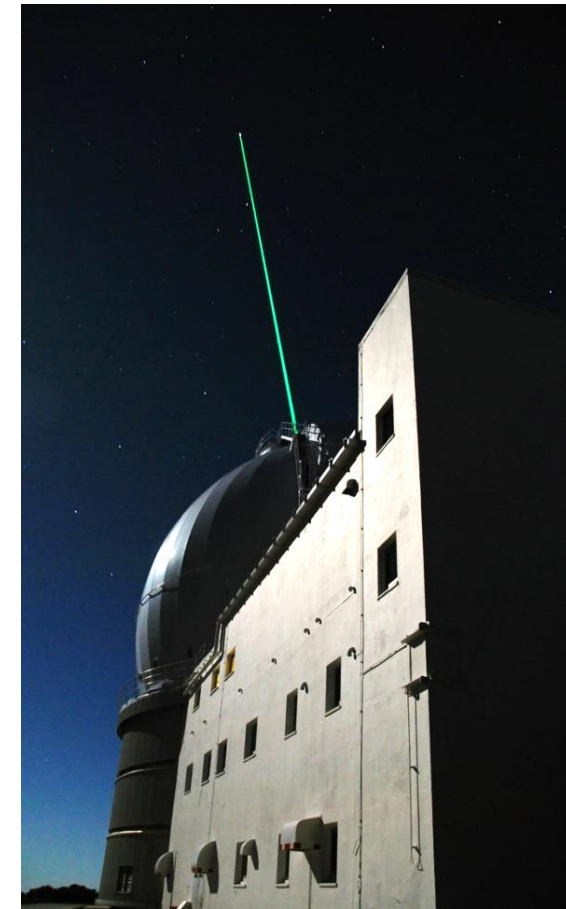
- CANARY project started in 2008 with the primary goal of proving that **Multiple-Object Adaptive Optics (MOAO)** works
 - Required operating mode for EAGLE/MOSAIC ELT instruments
- MOAO provides 'islands' of AO correction around widely spaced targets
- MOAO uses **multiple off-axis guide stars** to estimate **AO correction for any line of sight**



CANARY

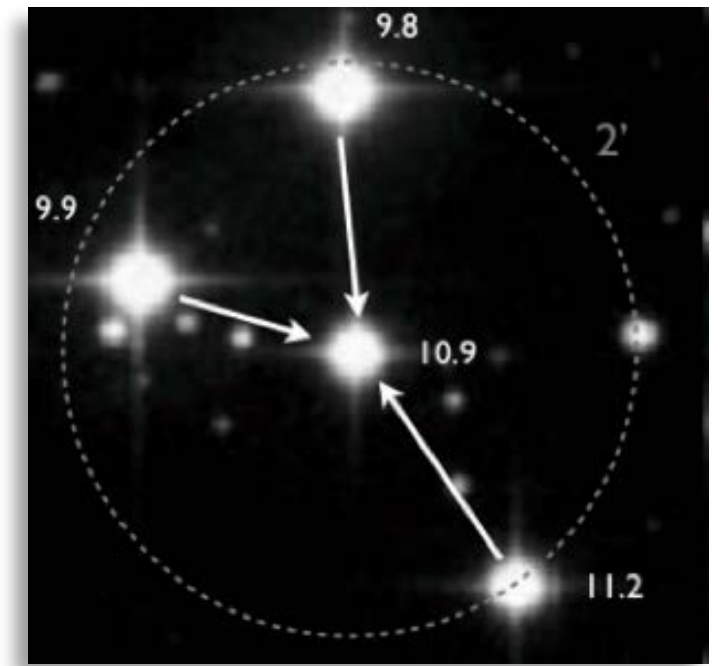


- Goal was to create a **single science channel** MOAO system
- Installed on the WHT in La Palma
- Built in **4 phases** of increasing complexity
 - Started with 3 x natural guide stars only in 2010
 - Built to ELT-like multi-LGS configuration in 2015

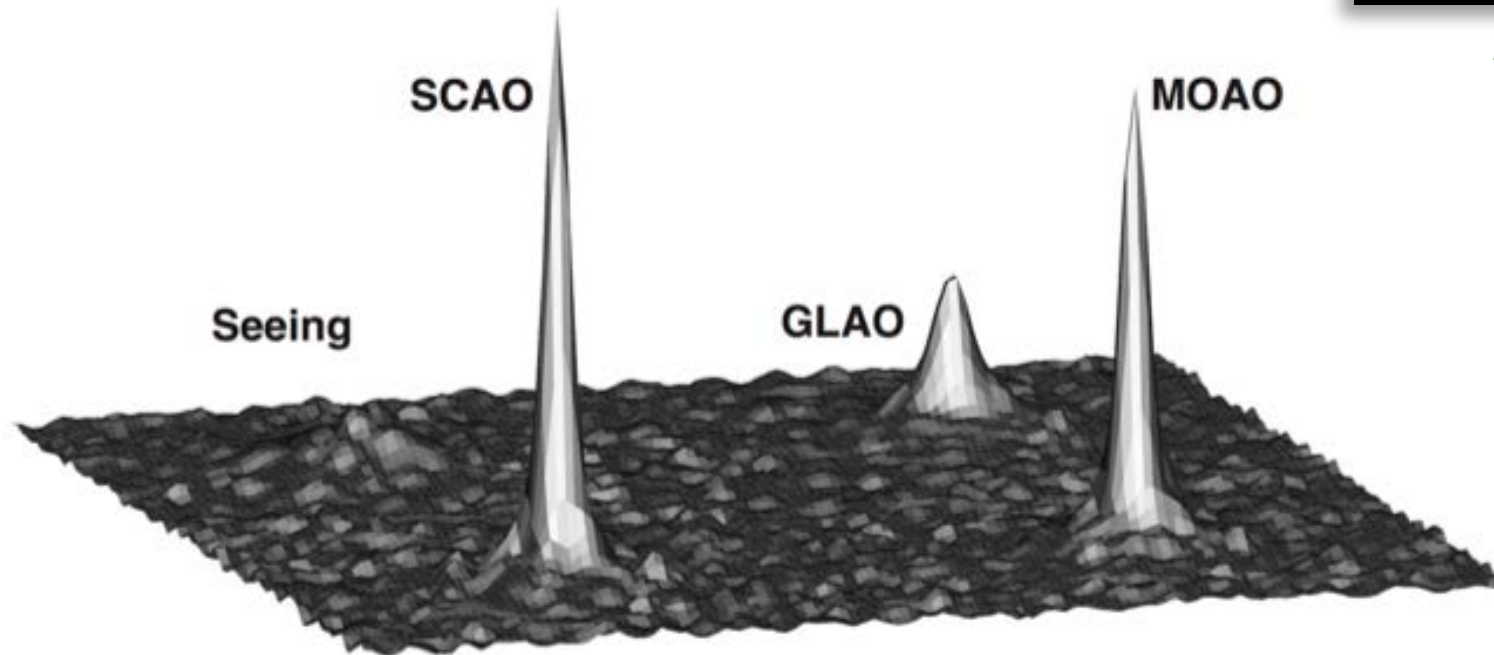


NGS GLAO/MOAO (2010)

- **CANARY Phase A** (NGS only) completed 2010
- Used 3 off-axis NGS to correct for an on-axis source
 - Compared to other types of AO correction
- First ever on-sky demonstration of fully tomographic AO working
- Similar configuration to first light E-ELT control system

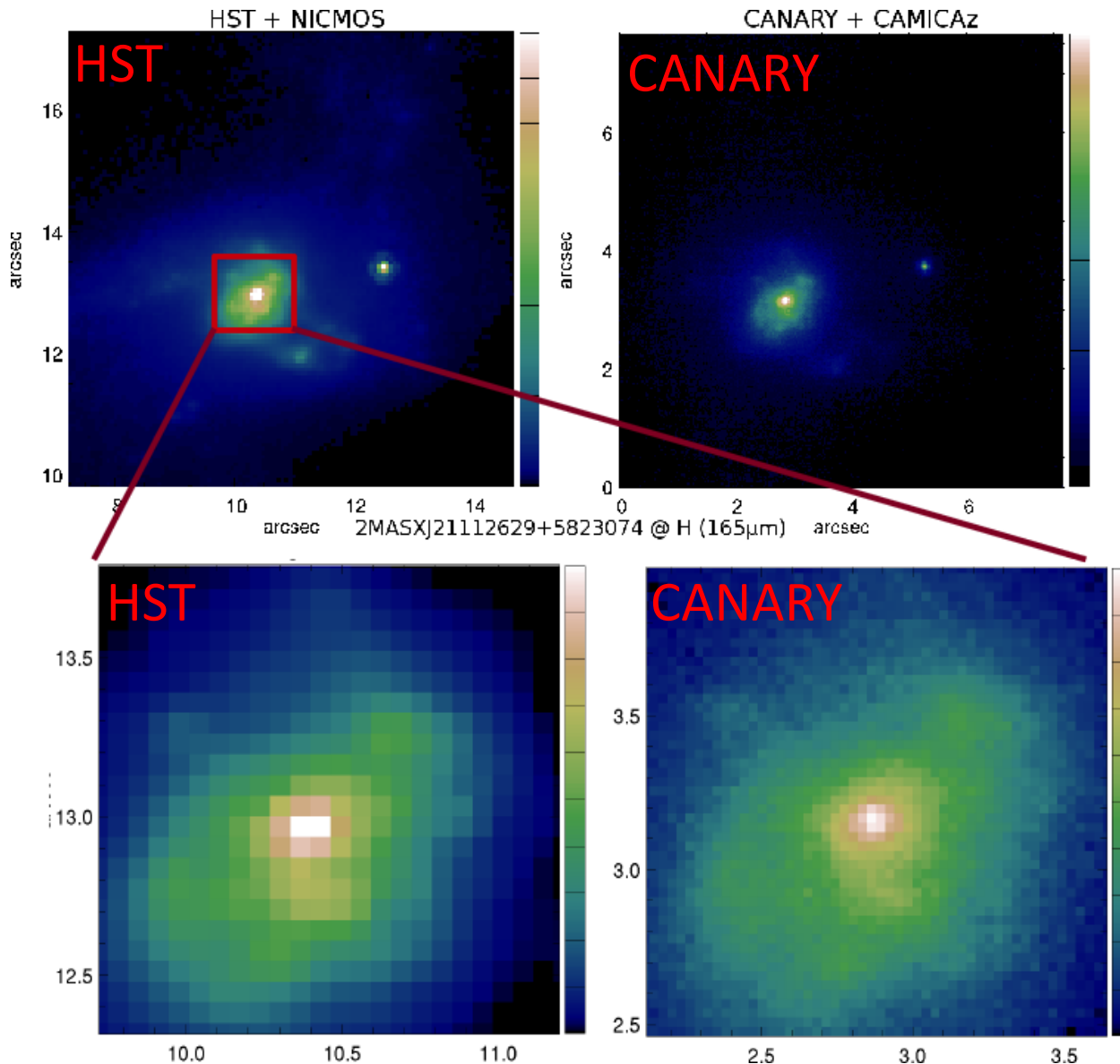


Asterism 47 and Phase A AO performance at 1.53 μ m



Gendron *et al* A&A, 529, L2 (2011) for the initial Phase A results

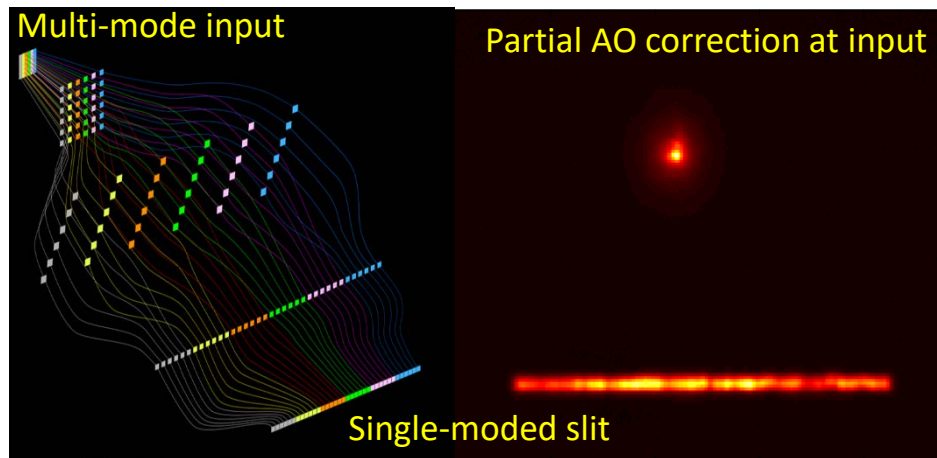
MOAO science demonstration (2013)



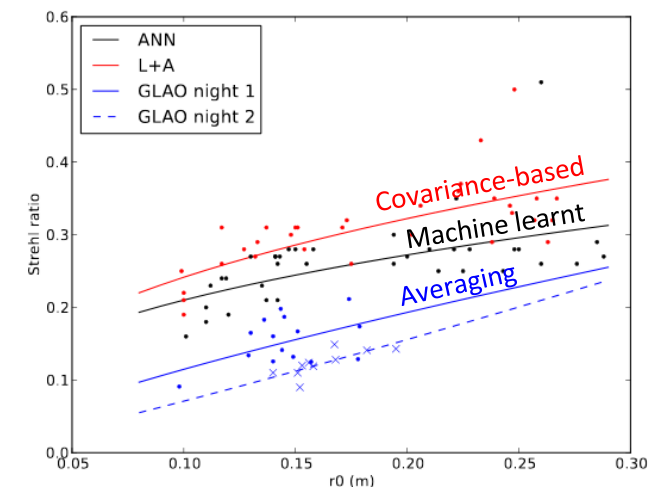
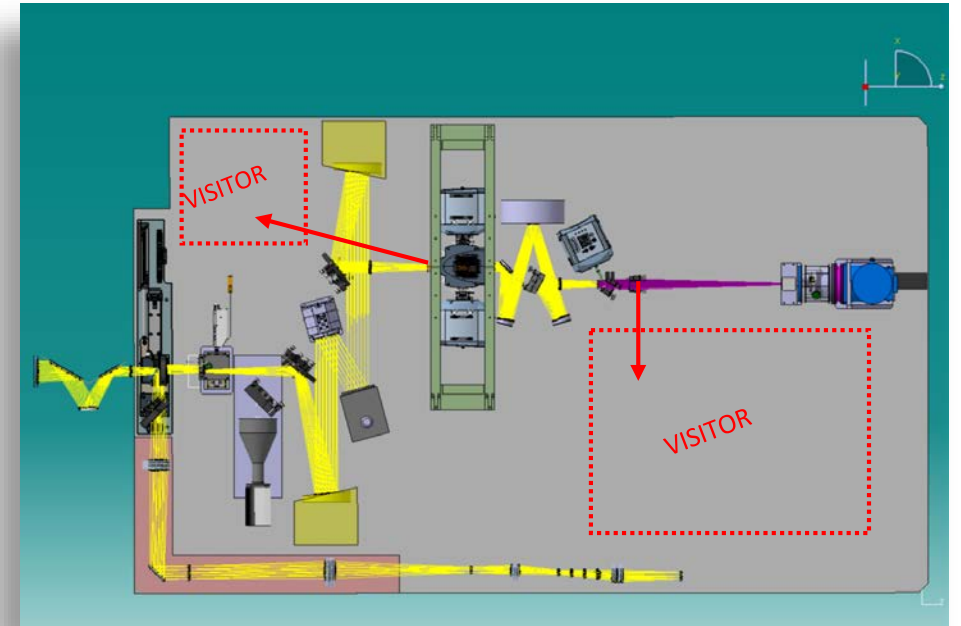
- Completely reconfigured system
- CANARY operating in open-loop laser guide star tomographic mode
 - 4 off-axis laser guide stars and 1 off-axis star for image stabilisation
- H-band Science observation demonstration
 - Total ~60 min exposure
- System stable throughout observation

CANARY: A flexible on-sky testbench

- During 2012-2015 CANARY has hosted several visitor hardware/software experiments:
 - LQG modal control for both NGS and LGS (Sivo+, Opt. Express 22, p23565, 2014)
 - Tomographic AO correction using artificial neural networks (Osborn+, MNRAS 441, p2508 2014)
 - First on-sky tests of the CuReD reconstructor (Bitenc+, MNRAS 448, p1199, 2015)
 - Astrophotonic reformatting for diffraction-limited spectroscopy (Harris+, MNRAS 450, p428, 2015)



Photonic reformatting of multi-mode input to single-mode slit



Artificial neural network AO control versus covariance-based tomographic reconstruction

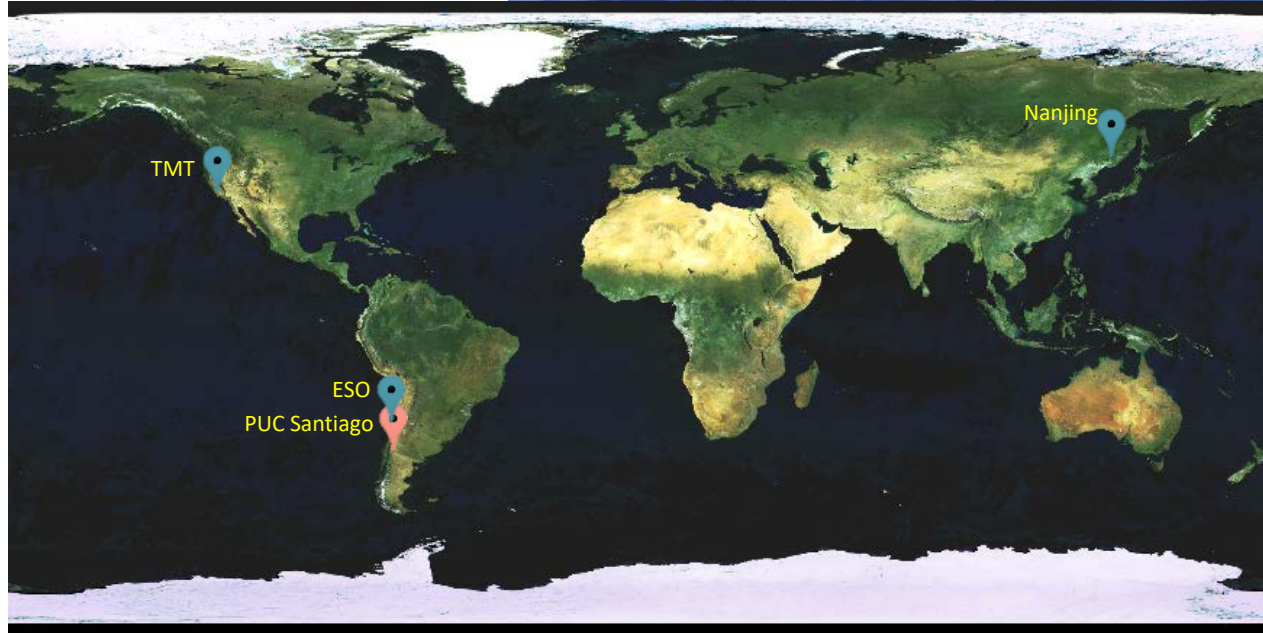
CANARY: Sodium LGS testbench (2016-)



- More recent CANARY configurations included an off-axis sodium LGS
- 40m off-axis to recreate ELT geometry
- Collaboration between CANARY, ESO, DLR and INAF-Roma
- Additional experiments using CANARY infrastructure investigating uplink correction for satellite communications
- Resulted in open data release of WFS data hosted by ESO:

https://www.eso.org/sso/login?service=https%3A%2F%2Fwww.eso.org%3A443%2FUserPortal%2Fsecurity_check

CANARY Users



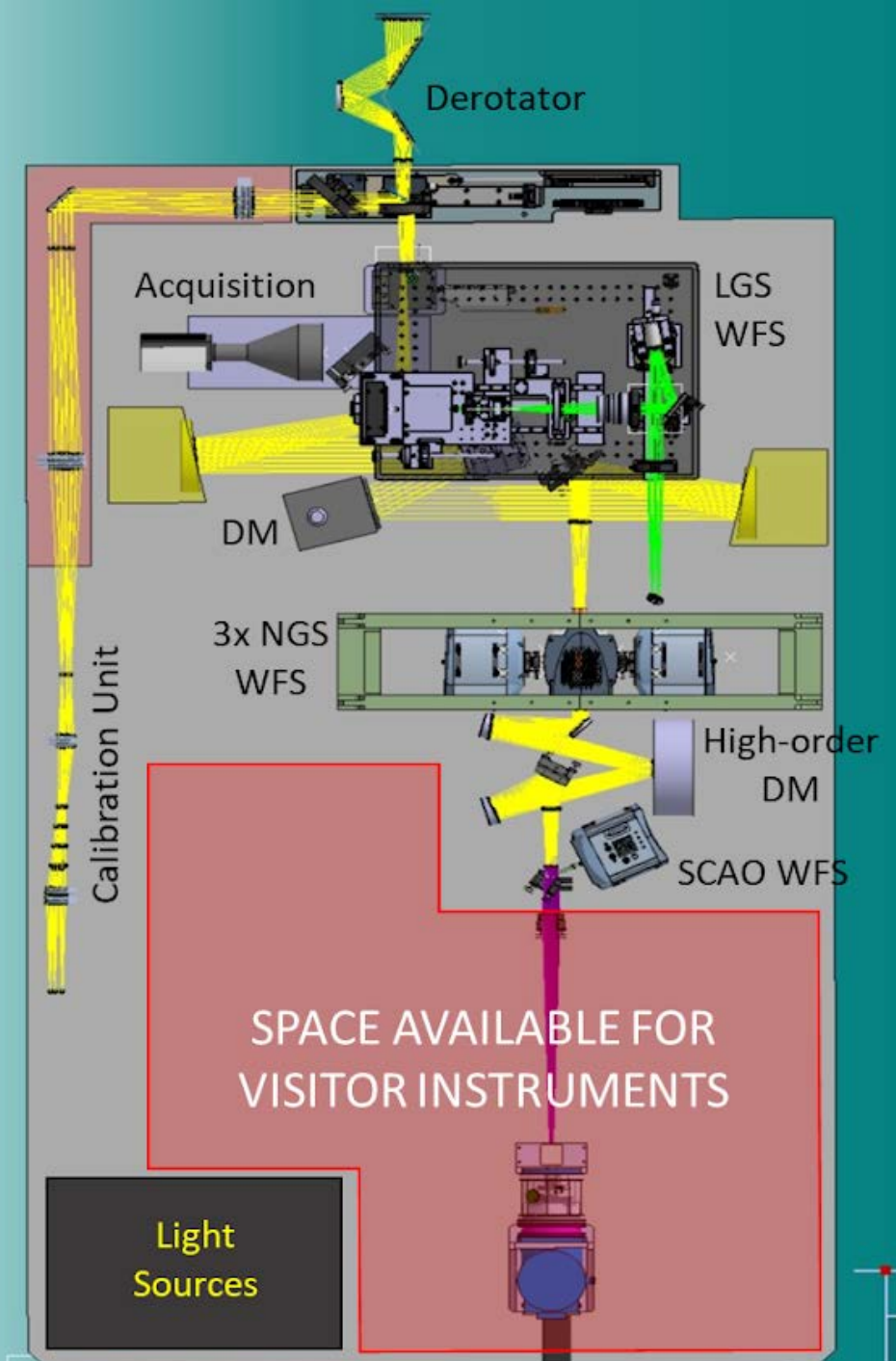
Mostly EU with some international involvement

Not spread much outside the OPTICON AO community

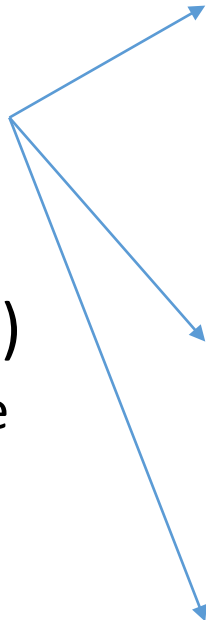


OPTICON access program

- New instrumentation concepts require on-sky validation before they are used in facility-class instruments
- On-sky facilities like CANARY are rare:
 - Large telescope
 - Visitor foci for small (1m x 1m) experiments
 - Large optical bench in a Nasmyth platform
 - AO corrected focus
- Needed funding to offer this to the wider community



OPTICON access program

- OPTICON programme has several work packages planning CANARY observations
 - WP1 contains €150K for ING telescope access until 2020 (4.2m WHT & 2.5m INT)
 - Pays for up to 20-30 nights of telescope time
 - In addition to the main TNA budget
 - Allocated by separate Instrumentation TAC
 - ING board agreed to support these observations with a reduced cost for telescope time for experiments involving their funding community members
 - ESO also providing resources to operate the sodium LGS
- 
- **WP1** Adaptive Optics
 - **WP2** Fast Cameras
 - **WP3** Fast Detectors
 - **WP4** Freeform Mirrors
 - **WP5** Additive Manufacturing
 - **WP6** Astrophotonics
 - **WP7** Light sensitive Materials
 - **WP8** Next generation instruments
 - **WP9** Management
 - **WP10** Adaptive Optics Network
 - **WP11** Interferometry Network
 - **WP12** Training Schools
 - **WP13** Time-Domain Astronomy
 - **WP14** Technology Foresight
 - **WP15** Community sustainability
 - **WP16** TNA access

First CANARY OPTICON call

- Call issued end December 2019
- 4 visitor experiments selected for 19A:
 - Testing temporal AO control algorithms (FR)
 - Diffraction-limited astrophotonic high resolution spectrograph (NL/DE)
 - Astrophotonic pupil interferometer (DE)
 - Two new high-sensitivity XAO WFSs (FR/UK)
- A 5th seeing-limited tapered fibre HR spectrograph test at the 2.5m INT (UK)
- Each will get 2-3 nights observing over a 7+ day period
 - Limited by overhead in operating CANARY

OPTICON WP10 AO networking

Home AO simulation **CANARY tests** Publications Workshops

CANARY AO TEST PLATFORM

A COMMUNITY ON-SKY AO TESTBENCH

CANARY is an on-sky tomographic adaptive optics demonstrator installed at the 4.2m William Herschel Telescope in the Canary Islands. Since initial commissioning in 2010, it has since provided the first on-sky demonstrations of NGS and LGS MOAO, LTAO and tomographic LQG control as well as hosting several visitor experiments. CANARY was developed by an EU-wide consortium, led by Durham University and Observatoire de Paris, LESIA. The WHT is operated by the Isaac Newton Group of Telescopes (ING).

OPTICON has provided funds to allow members of the instrumentation community to apply for observing time using CANARY to test novel instrumentation concepts that would benefit from on-sky demonstration. Up to 20 nights of observing time is available to be shared between several projects that will be allocated by a committee representing both the OPTICON and ING instrumentation communities. Observations will be supported by members of the CANARY team who will be able to assist with the design, installation and operation of your experiment with CANARY.

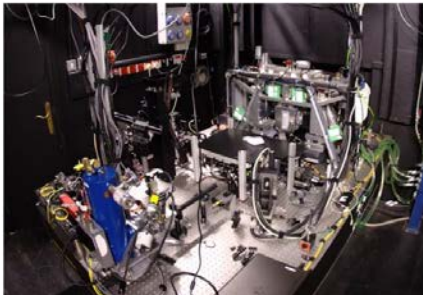
These pages detail the means with which you can apply for CANARY time, and provide descriptions of the facilities available for use. Applications are also welcome for collaborative experiments that may require only parts of the CANARY system. Further details of the CANARY testbench and the other facilities covered by this call, including the use of ESO's 'Wendelstein' laser guide star are detailed [here](#).

CALL FOR PROPOSALS

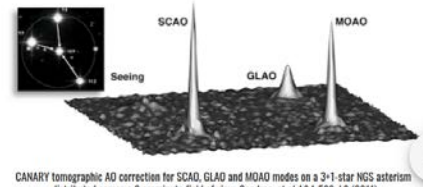
We currently have an initial call for proposals that will close at **23:59 UTC on 14th December 2018** for experiments covering the observing periods 19A (Feb-Jul) and 19B (Aug-Jan). We expect to issue a second call in April.



CANARY at the WHT using ESO's Wendelstein laser guide star launch system (Image: L. Bardou)



CANARY installed in the WHT Nasmyth platform with the blue NIR imaging camera installed at the primary AO corrected output focus (Image: CANARY team)



CANARY tomographic AO correction for SCAO, GLAO and MOAO modes on a 3-1 star NGS asterism distributed across a 2 arcminute field of view. Gendron et al. A&A 529, L2 (2011)

<https://sites.google.com/view/opticon-ao/canary-tests>

CANARY OPTICON call

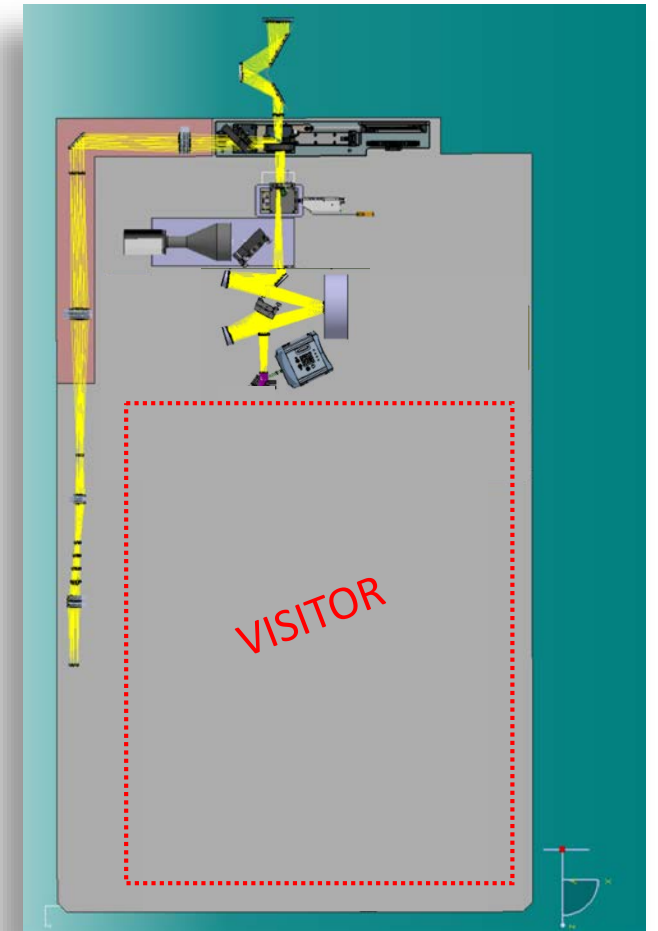
- OPTICON has not paid for the development of any of the visitor instruments
 - Funds (some) travel for selected proposals
 - Limited funding for the CANARY team to help with interfacing and operations
- CANARY was not designed for long-term operation or easy installation
 - Initial 4 year program still running 10 years later
 - 2-3 weeks to install and get running
- Effort + travel it's typically ~€50-80K per observing run
 - Losing a run to weather often means project can't be re-run
- Excellent support from the ING for the last decade
 - WHT access with not be as open in the future

Future instrumentation development

- The CANARY proposals were (obviously) AO-focused
 - Two AO development, two requiring AO correction
- 1/6 of proposal PIs had been involved with CANARY in the past
 - 66% of proposals contained an ex-CANARY team member/visitor
- From the first round of proposals, all requested the simplest AO system possible:
 - Single on-axis bright object
 - With better AO correction at shorter wavelengths than CANARY typically provides
- What would we want in the future?

Future instrumentation development

- Target concepts that haven't been tested on-sky
- AO community is targeting next-gen VLT/ELT instruments
- Wider instrumentation groups “just” want an AO corrected focus
- CANARY could be much simpler and support larger visitor instruments
 - Needs to be easier to install and operate
- Huge benefits to be gained just by enabling access to AO telemetry data from existing instruments
 - Data not even normally saved when running...
 - Data reduction pipelines all proprietary and documentation is non-existent



Reconfigured CANARY bench

Future instrumentation development

What we need

- Access to ~4m diameter (or larger) telescope for most AO
- Short on-sky runs (4-7 nights)
 - “Guaranteed” with sufficient advance notice to build the instrument (1-2 years in advance)
 - Require very good access to the telescope
- An optical bench on a Nasmyth platform
- An AO corrected focal plane
 - Re-engineer CANARY to lower installation overheads but only a few nights per year
 - Go elsewhere? GTC is very attractive for ELT development (10m, segmented pupil)
- Funding for effort to support visitor instruments
 - Typically costs 50-80K€ (effort + travel) to support an observing run with CANARY
- Open access to AO telemetry data
 - Get new instruments to have a mechanism to save this
 - The AO “Virtual Observatory”