OPTICON RadioNet Pilot

JA3.3 – Adaptive Optics in Action

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On behalf of the ORP AO teams at

IOTA, Porto, Durham, INAF-Arcetri, CNRS-LAM, CNRS-LESIA, ESO

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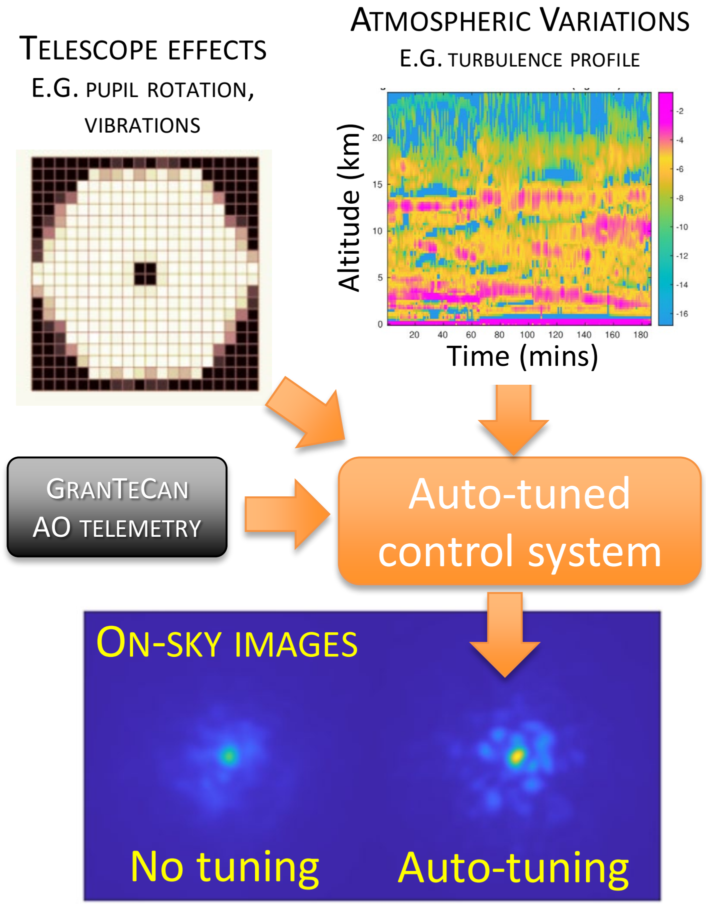
ORP Adaptive Optics activities

- AO activities split across two related WPs
  - TA12: On-sky access for instrument development
  - JA3.3: Enhancing TA12 facilities , virtual observatory, training
- Access to the primary facility offered in TA12 wasn't possible during ORP
- Rescoped JA3.3 work to target alternative facilities

JA3.3.1: Auto-tuned AO control for all

Goal
Develop improved real-time predictive AO control based on automated learning systems that operate to improve AO system performance autonomously without the need for expert intervention.
Rescoped plan
Demonstrate automatic optimisation on the new AO system for the 10.4m GranTeCan telescope rather than TA12 facility
Status
Goal met! Successful on-sky demonstration @ GTC ***Reported in Deliverable 4.8***



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JA3.3.2: AO Telemetry Format

Goals

1. Develop a common AO data telemetry format
2. Release telemetry datasets to AO community
3. Provide tools for data display and analysis

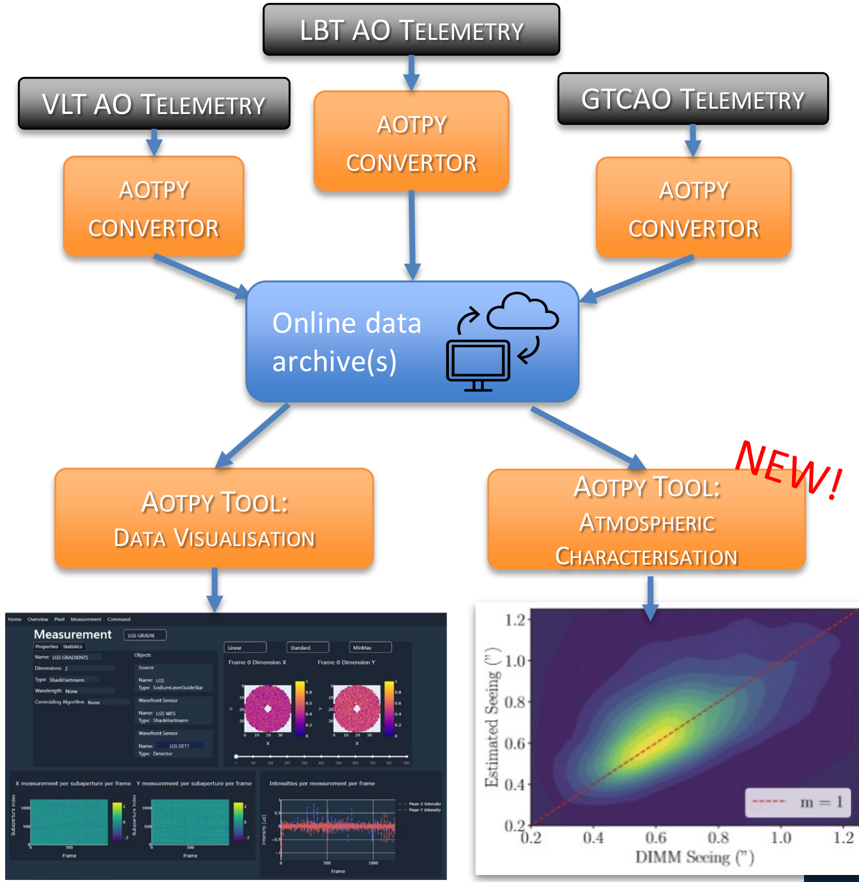
Rescoped plan

Focus on major AO facilities not offered under ORP

Status

Goals exceeded! Community release of AOTPy data format

- First public data releases from ESO's AO systems
- Works with many existing facility systems
  - 8 instruments on 5 telescopes (including ESO's VLT) and 1 simulation
- Display tools extended to provide complex image reconstruction algorithms – tested on-sky @ the LBT



JA3.3.3/3.3.4: Workshops and Schools

Title	Year	Purpose	Attendees
WFS in the VLT/ELT Era	2022,2024	Workshop bringing together results and techniques covering all aspects of wavefront sensing.	~180
Laser4AO	2023	Use of Laser Guide Stars within astronomy. ORP funding paid for travel bursaries.	46
COAT	2023	Turbulence workshop covering both astronomy and free-space optical communications. ORP funding used to pay for conference organisation.	~140
AO4ELT7	2023	Largest dedicated AO conference covering all aspects of astronomical AO.	>300
European AO Summer School	2021 - 2025	Cross-disciplinary AO school providing broad introduction to the principles, operation and development of AO systems	269 (online) 28 (in person)
AO Observer's School	2025	Focuses on providing hands-on and on-sky observation training for astronomical AO instrument users	~35
		TOTAL	**998**

JA3.3.4: EUROPEAN AO SUMMER SCHOOL

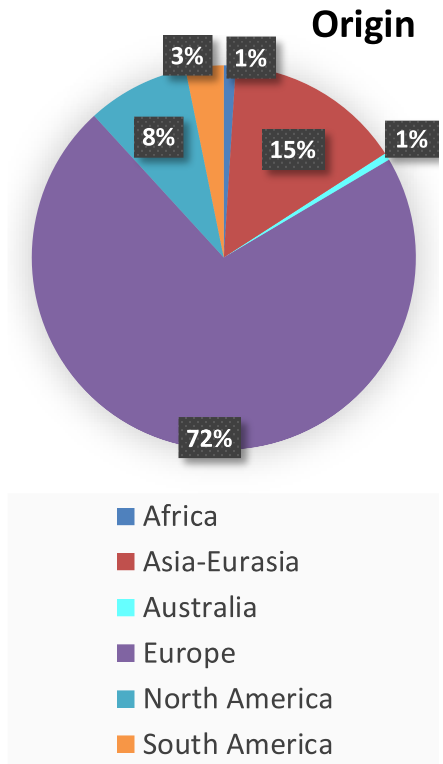
School goal: Introduce and train attendees to all aspects of astronomical and *non-astronomical* AO instrumentation

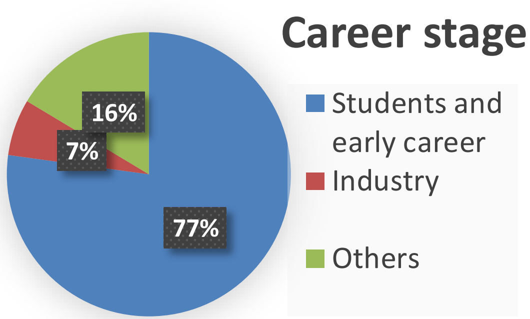
Fit to JA3.3.4: Train participants to understand, simulate and analyse AO system data through online worksheets and tutorials – focused on astronomical AO

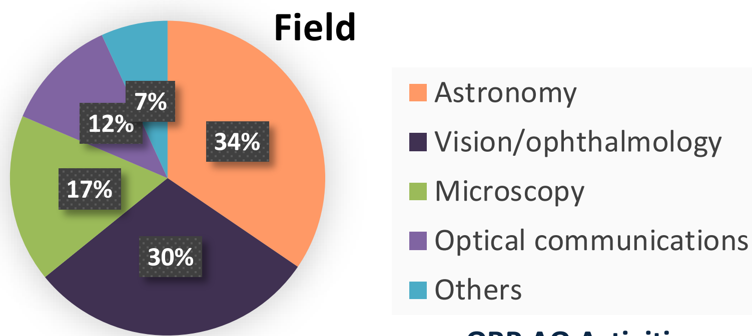
2021-2023: **Live demonstration of the VLT laser guide star AOF facility** showing AO observational overheads and acquisition sequences

Overview 2021-2024

- **85 attendees on average** across **3 online** schools 2021-2023
- **28 in person** + **9 online** in 2024
- Mostly MSc/PhD students and Early Career Researchers
- **Academic and industrial** attendees, **1/3 from astronomy**
- Attendees from **33 countries** (all continents except Antarctica ☺)







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Summary

- JA3.3 was targeted towards supporting and training the community of AO instrument users
  - Make facilities simpler to use, make data easier to access and process, provide training to use them
- Almost 1000 researchers have benefitted from ORP-funded AO training activities
  - Starting to see increased participation from outside astronomy – additional funding opportunities
- Every JA3.3 WP has achieved or exceeded their goals
  - Successfully deployed on 8-10m class major infrastructures

WP19/TA12 – Instrumentation TA

Tim Morris (Durham University)

On behalf of the TA12 teams at

CNRS-LESIA, ESO, INAF-ROMA

Funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004719.

On-sky instrumentation testing

- Development and testing of new instrumentation often requires access to an AO-corrected focal plane to prove concept works on-sky
- Access to these AO systems is very limited and expensive.
- It's increasingly difficult to bridge the gap between lab demonstration and concept's inclusion inside a facility instrument

WP19 GOAL(S)

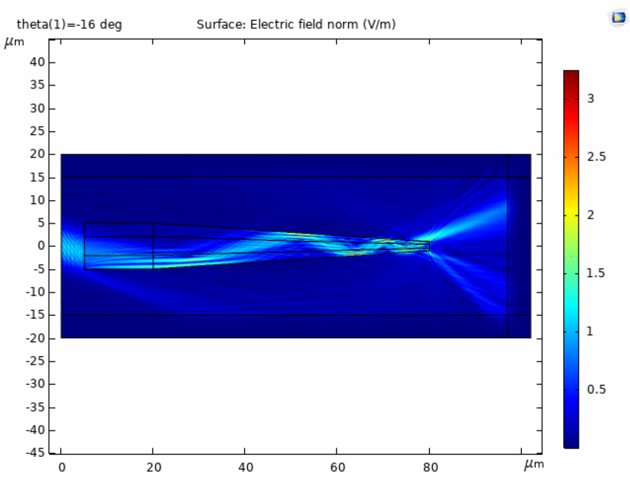
1. Provide an on-sky instrument development platform for instrumentation groups, researchers and astronomers
2. Make recommendations as to how this type of access could be funded in the future

Progress

- Final on-sky runs occurred in March/April 2024
  - INT/WLGSU: LATTE tip-tilt sensing experiments (12 nights)
  - INT: Adiabatic tapered fibre spectrograph (ExoHSpec) awarded 5 nights on INT
- Was not be able to access CANARY on the WHT throughout the ORP
  - WHT access costs were 80% of initial TA budget
  - Able to support additional Laser experiments
- TA12 staff funding helped support and extend JA3.3 activities

Basing TA around a single facility introduces risk and reduces potential impact of TA funds

WLGSU in operation outside the WHT



Tapered fibre coupling simulations with changing beam input angle (taken from https://star.herts.ac.uk/exohspec/)

On-sky experiments

Experiment	Institutes involved	Used
Laser frequency chirping and side-band repumping	Toptica Photonics AG (DE), Starfire Optical Range (US), ESO, INAF	WLGSU
LATTE: Measuring and controlling uplink LGS tip-tilt using off-axis telescopes	ESA, ESO, INAF	WLGSU, INT
Diffractive multi-LGS tests for MAVIS VLT instrument	IAC, ESO	WLGSU
Measurement of uplink scattering and Raman emissions	IAC, ESO, INAF	WLGSU, *GTC*
Daytime LGS observations through a MOF	SST, KIS, ESO, INAF, ESA	WLGSU, *SST*
Uplink scattering measurements for monostatic launch	Toptica Photonics AG, SOR, INAF, ESO	WLGSU
Measurement of geomagnetic field variations	Uni. Mainz, Uni. Berkeley, ESO, INAF	WLGSU
Polarisation, pumping and geomagnetic field coupling tests	INAF, ESO	WLGSU
ExoHSpec – spectroscopy with adiabatic tapered fibres	Uni. Hertfordshire, NARIT (Thailand)	INT

Publications

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2. Hellemeier, J.; Enderlein, M.; Hager, M.; Bonaccini Calia, D.; Johnson, R.L.; Lison, F.; Byrd, M.O.; Kann, L.A.; Centrone, M.; Hickson, P., Laser guide star return-flux gain from frequency chirping, Monthly Notices of the Royal Astronomical Society, Volume 511, Issue 3, April 2022, Pages 4660–4668, https://doi.org/10.1093/mnras/stac343 — Laser Physics
3. Lombardi, G.; Bonaccini Calia, D.; Centrone, M.; De Ugarte Postigo, A.; Geier, S., Laser Guide Stars uplink beam: Scattering and Raman emission measurements with the 10.4m Gran Telescopio Canarias, Monthly Notices of the Royal Astronomical Society, DOI: 10.1093/mnras/stac2209 — Atmospheric Physics
4. Bardou, L.; Gendron, É.; Rousset, G.; Gratadour, D.; Basden, A.; Bonaccini Calia, D.; Buey, T.; Centrone, M.; Chemla, F.; Gach, J.-L. et al., ELT-scale elongated LGS wavefront sensing: On-sky results, Astronomy and Astrophysics, DOI: 10.1051/0004-6361/202038330 — Astronomy
5. Ghosh, S., Boonsri, C., Martin, W., Jones, H. R. A., Choochalerm, P., Usher, S., Yerolatsitis, S., Wocial, T. & Wright, T., Mitigating Modal Noise in Multimode Circular Fibres by Optical Agitation using a Galvanometer 2 Jan 2024, In: RAS Techniques and Instruments. 3, 1, p. 8-18 11 p. https://doi.org/10.1093/rasti/rzad059 — Astronomy
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8. Choochalerm, P., Martin, B., Jones, H., Errmann, R., Yerolatsitis, S., Wright, T. & Buisset, C., Transmission properties of tapered optical fibres: Simulations and experimental measurements 1 Oct 2021, In: Optical Fiber Technology. 66, 8 p., 102632. https://doi.org/10.1016/j.yofte.2021.102632 — Fibre Optics
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10. Errmann, R., Cook, N., Jones, H., Anglada Escude, G., Sithajan, S., Semenko, E., Mkrtichian, D., Martin, B., Tanvir, T., Feng, F. & Collett, J., HiFLEx – a highly flexible package to reduce cross-dispersed Echelle spectra Jun 2020, In: Publications of the Astronomical Society of the Pacific. 132, 1012, 10 p., 064504. https://doi.org/10.1088/1538-3873/ab8783 — Astronomy

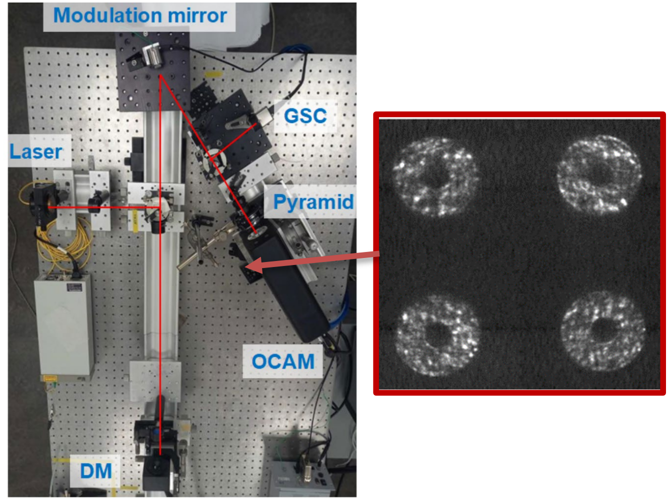
Some numbers…

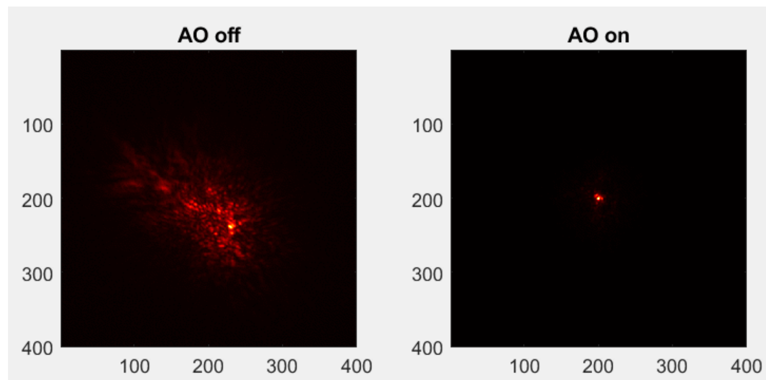
- ~70 users who have contributed to experiments or directly used facilities
- Participants from 7 countries
  - Non-EC: USA and Thailand
- Participants from 17 institutions
  - 5 industrial partners
  - Other: US Air Force, ESA
- 2 multi-facility observations (GranTeCan and Swedish Solar Telescope)
- 40% Early Career researchers/engineers

Collaborations with industry and fields outside astronomy may provide opportunities for co-funding/co-financing

Instrumentation TA beyond ORP

- At the start of ORP, the facilities offered under TA12 were unique in Europe
- Majority of past TA users had requested best possible AO correction
  - Diffraction limited, visible operation
- Alternative 1-2m class facilities have been/are being developed that can provide this
  - PAPYRUS @ Observatoire d'Haute Provence (FR)
  - EKARUS @ Asiago Observatory (IT)
- However, these are not operated as common user facilities
- Would be reliant on the AO teams that built them to want to provide TA





Future TA instrumentation funding should prioritise access to systems that can provide the highest levels of AO performance

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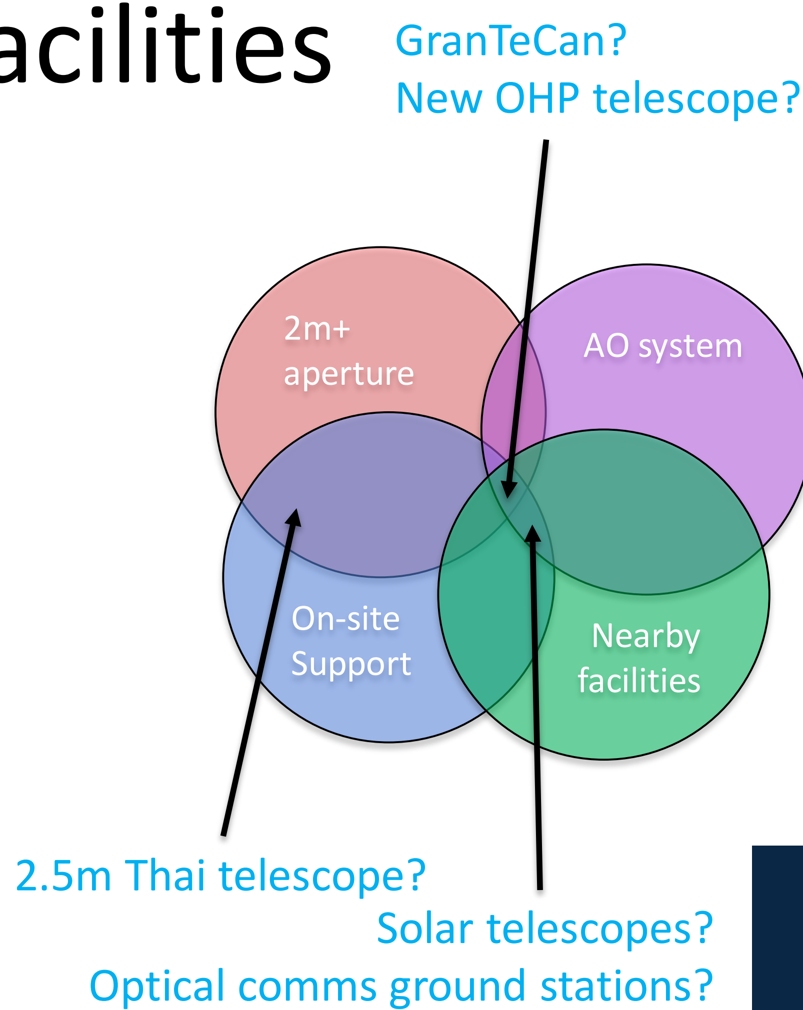
Alternative Facilities

- Only large telescope providing regular international access for low TRL AO instrument testing is Subaru with SCExAO
- Significant specialist AO effort funded by facility in supporting visitor instruments (~0.5-1 FTE)
- Since 2016, at least 2 new prototype systems have secured national funding for visitor-class instrumentation and are now open access instruments for the entire Subaru community
  - High-speed (>5kHz) spectro-imager (MEC – UCSB, USA)
  - Polarimetric Interferometer (VAMPIRES – U.Sydney, Australia)

Strategic observatory investment in instrument development activities can pay back short-term astronomical science impact



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Conclusions/Recommendations

- Basing TA around a single facility introduces risk and reduces potential impact of TA funds
  - *The number of facilities offered should be increased to avoid access risks and offer a broader range of instrument capabilities.*
- Collaborations with industry and fields outside astronomy may provide opportunities for co-funding/co-financing
  - *Extending access to both facilities and user applications from outside astronomy should be incorporated into any future TA program*
- Strategic observatory investment in instrument development activities can pay back short-term astronomical science impact
  - *Prepare study investigating benefits and long-term science return of direct observatory support of instrumentation development to attract new TA facilities*

- *Future TA instrumentation funding should prioritise access to systems that can provide the highest levels of AO performance*

These are covered in more detail in Deliverable 19.3