AOF: first on-sky performance of the GALACSI GLAO mode

or how to close 10 loops in less than 5 minutes

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AOF timeline

**2005-2013:** Concept, design, manufacturing, assembly

**2014:** System tests of GRAAL in the lab

**2015:** System tests of GALACSI in the lab
- Installation of GRAAL at the VLT UT4
- Installation of 1 LGS
- Combined test of GRAAL + 1 LGS

**2016:** Installation and test of the 4LGSF
- Installation of the DSM
- UT4 telescope re-commissioning with the DSM

**2017:**
- 01-02: Installation of GALACSI at the VLT UT4
- 02: Validation of the DSM performance using the GRAAL on-axis NGS mode
- 03-09: Commissioning of the GALACSI GLAO, including MUSE in Wide-Field Mode
- 10-12: Comm. of the GRAAL GLAO mode, including HAWK-I

**2018:**
- 01-05: Commissioning of GALACSI in Narrow-Field Mode
GALACSI

GLAO to feed the MUSE Wide-Field Mode:

- Seeing enhancer in $1 \times 1 \text{arcmin}^2$ FoV @ 750 nm
- 4 LGSs located $\approx 1 \text{arcmin}$ from the optical axis
- No optics inserted in the MUSE scientific FoV

Four 40x40 Shack-Hartmann 1 kHz LGS WFS + 1 Tip-Tilt 200 Hz NGS sensor (50-110”), all using $<1e \text{RON CCD220 from e2v}$

4LGSF return flux often 3-4 times the initial spec

Uses the 1156 actuators of the DSM (600 modes). Actuator low death rate ($<1 \text{per year}$) which anyway don’t affect performance
AOF control - GALACSI

- Science light
- LGS light
- TT NGS light
- VLT GS light

Commands

Offloads

WFS

- M1
  - Focus, Coma, 90 s
  - VLT axes
    - Tip, Tilt, 200 Hz
  - Z>3, 1 kHz
- Tip-Tilt, 1 s
- Z=5, 6, >8
- 45 s, 6, >8

- Hexapod
  - M3
  - Tip-Tilt

- Sensor

Laser

Launch

Telescope

LGS Field Selector

Jitter, 10 s

Focus, Compensator

LGS SH

Jitter, 1 kHz

Commissioning Camera

Weighting map update

Na layer tracking

Mis-reg. > CM LUT

TT CM derotation

Background Follower

Low flux freezing

Low flux freezing

Na layer tracking

LGS focalization

Focus bootstrap

Dark Follower

M1 passive support

Pointing model
**GALACSI Acquisition sequence**

**Preset of telescope, 4LGSF, motors, RTC, MUSE**
- MUSE AOF Acquisition
  - MUSE AOF acquisition
    - Preset Phase
      - 4LGSF FS Preset
      - Telescope Preset
      - Set DSM in TF mode
      - Deploy GALACSI mode
      - Disable DSM simulation on RTC
    - 4LGSF LPC Preset (set asterism)
    - AOF Preset
    - LGS WFS initial setup
    - Tip/Tilt Sensor Bootstrap
      - Tip/Tilt Sensor Camera Bootstrap
    - Sky map measurements
    - NGS Detection and Centering

**NGS acquisition**
- High Order Loop Closure
  - Close jitter loop
  - Close focus offload loop
  - Bootstrap High Order Control Matrix

**LGS acquisition**
- LGS WFS Camera Bootstrap
  - Set AODRIVEN
  - LGS Set Search Mode
  - LGS JM Search
  - LGS Apply Corrections
  - LGS Unset Search Mode
  - LGS Check Flux
  - LGS Focus bootstrap
  - LGS Skymap Measurements

**Wait for 1 Act. Opt. correction**

**2 Act. Opt. correction**

**Close LGS WFS loops. Take control of telescope**

**Close NGS TT loop**

**Close auxiliary loops**

50 sec
Control of the 4LGSF

4LGSF Laser Pointing Camera
4 sec exposure

GALACSI Commissioning Camera
1 sec exposure
The AOF: an Adaptive Telescope

- Pointing model
- Instrumental offsets
- Laser Pointing Camera in parallel to NGS Acquisition
- Spiral search

 Acquisition of the Lasers

- In non-Adaptive Mode, the telescope Active Optics set the position of the Scientific focus
- Focus Compensator tracks Sodium Layer
- Focus bootstrap minimizes Focus on LGS WFS
- When in Adaptive Mode, the Active Optics WFS used as Truth Sensor sends focus offsets to the Focus Compensator
- This Focus is immediately corrected by the High-Order loop and the DSM, and seen corrected by the Science instrument
- It is then slowly offloaded to the DSM Hexapod

 Focus Loop

- Average DSM commands
- Measure Truth Sensor Focus

Adaptive Telescope Loop

- Focus offload
- Offset Focus Compensator
- M1 support

- Coma offload
- High-order offload

90 sec
Displays
GLAO performance on sky #1

91% of the stars are in spec, 67% in goal

EE gain variation w.r.t. mean (%) vs.
- Star #
- Star SNR
- Star distance to center (arcsec)

EE in 0.2" spaxel

EE gain: 2.14 ± 0.09
GLAO performance on sky #2
GLAO performance on sky #3

EE gain at 747 nm

Turbulence ratio in the first km (%)
Various results:

- NGS faint-end results confirm the ones obtained in Garching: V magnitude 18.5 can be offered comfortably.
- Beyond that GALACSI can still be used in “TT-free” mode (TT from Field Stabilization at 65 Hz far away in the FoV).
- Bright LGSs → no WFSing optimization required.
- Jitter Loop keeps the LGS spots close to the WFS center.
- Insignificant Non Common Path Aberrations.
- Low sensitivity to loop gain and number of controlled modes.
- Aircraft detection (< twice a night) freezes the LGS and Jitter loops for ~10 seconds.
- When conditions are favorable (strong Ground layer), excellent performance improvement down to 500 nm.
- Atmospheric and Performance parameters estimation from RTC data available every minute.
MUSE results

http://muse-vlt.eu/blog/
To be Continued...