This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

Work Package 7

Multi-Conjugate Adaptive Optics for EST

O. von der Lühe, KIS

with the project partners

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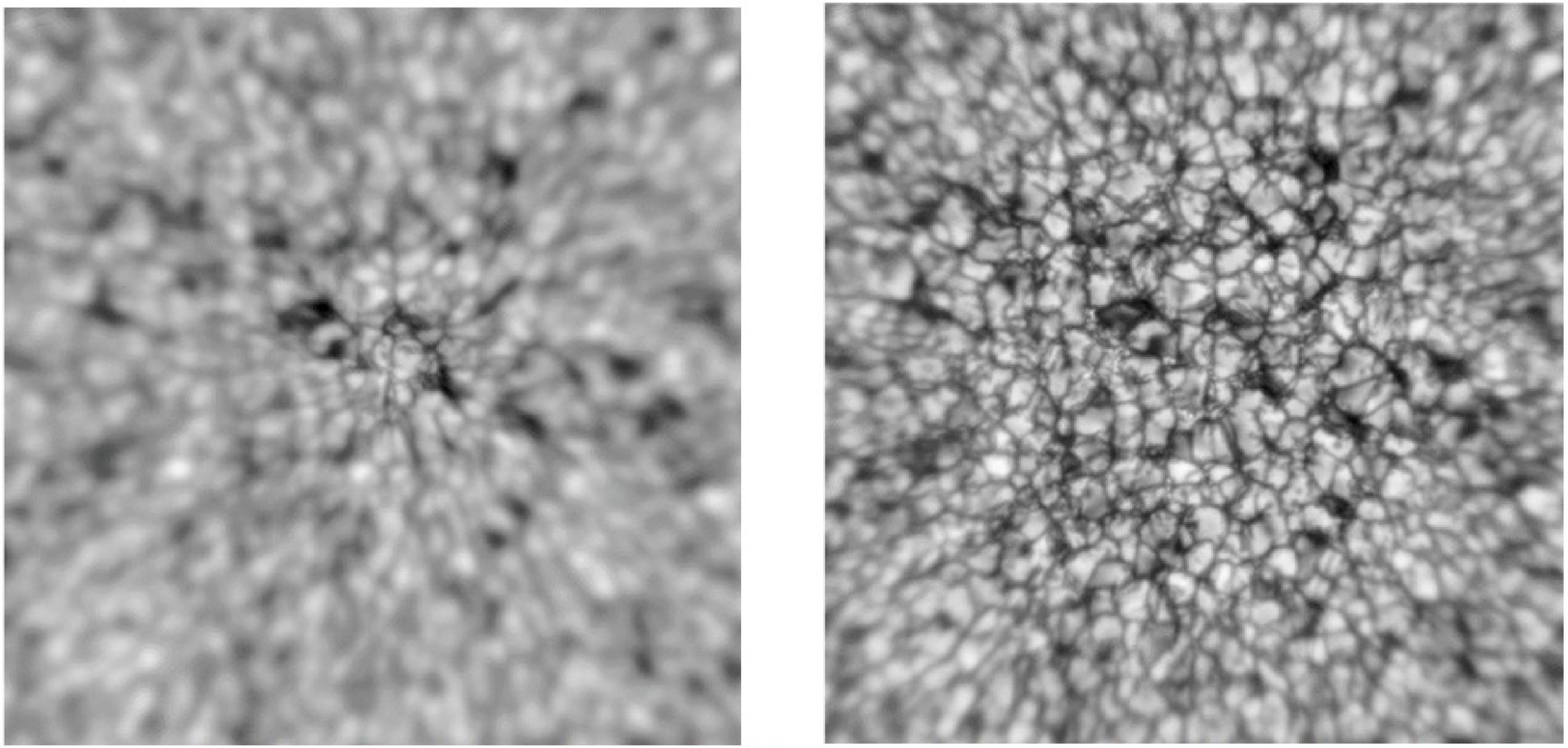

Conventional (left) and multi-conjugate (right) solar adaptive optics (Schmidt et al., Astron. Astrophys. 597, L8, 2017). Conventional AO produces a sharp image only at the center of the field, limited to a single isoplanatic patch of 5 arcsec. MCAO extends the compensated field to 30 arcsec with three deformable mirrors in this case.

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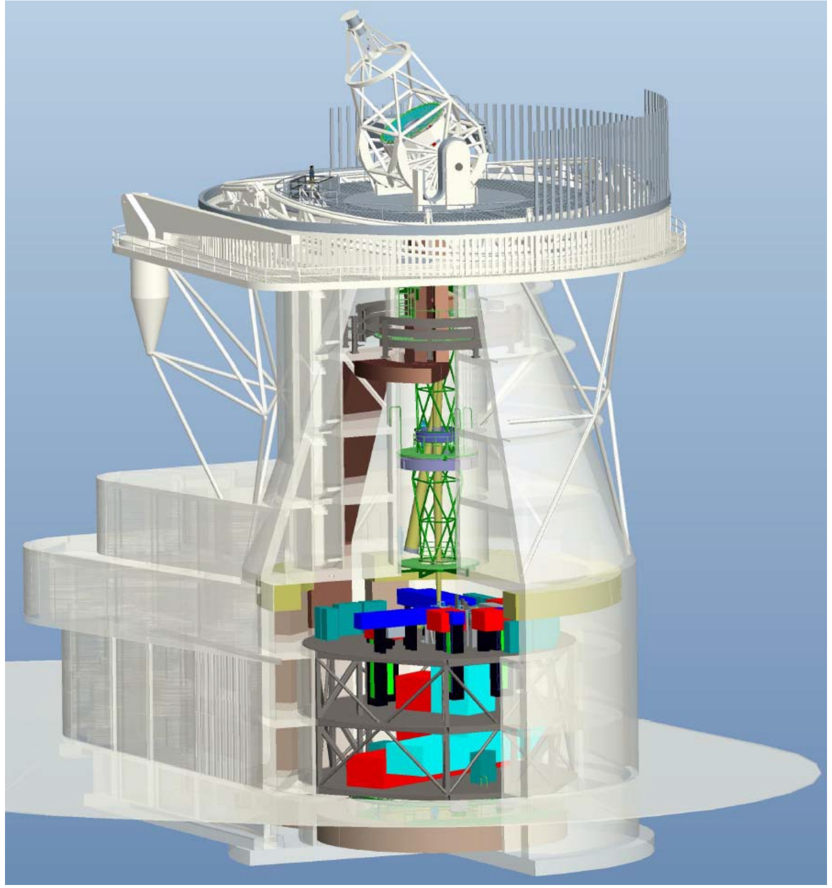
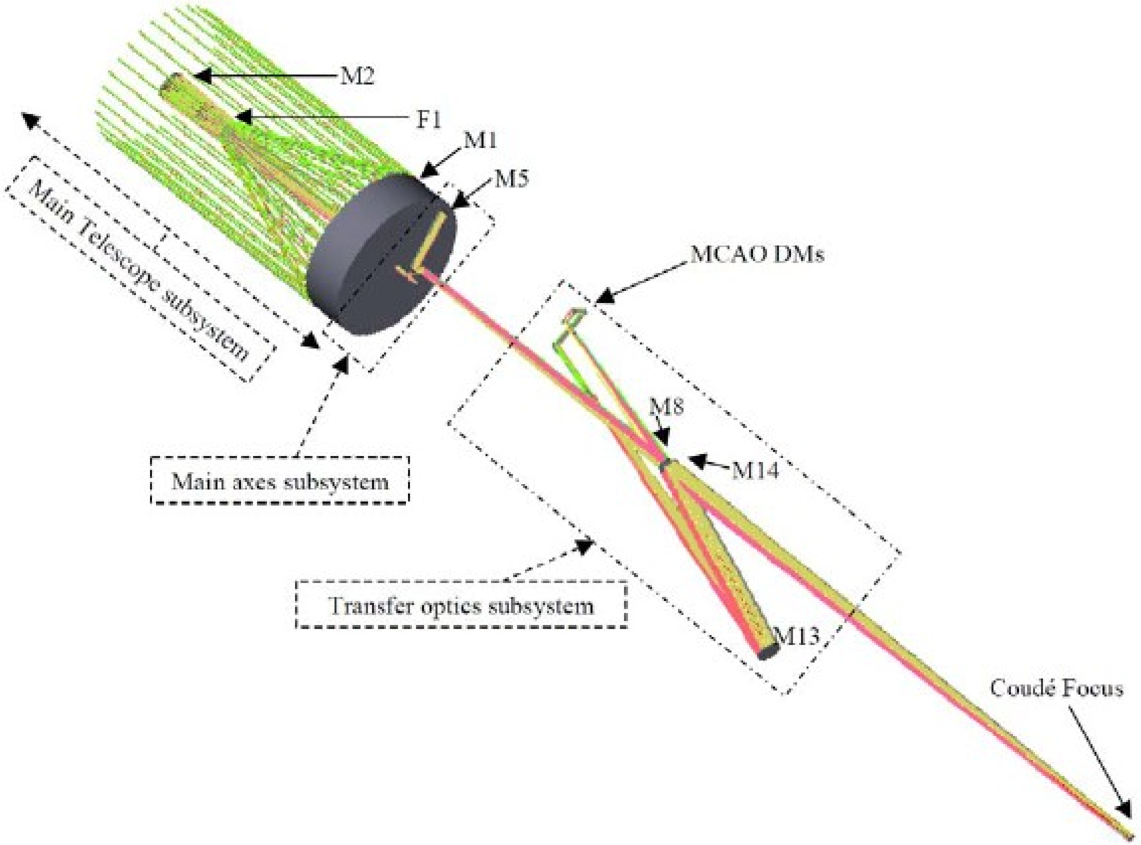
EST MCAO System (Design Study)





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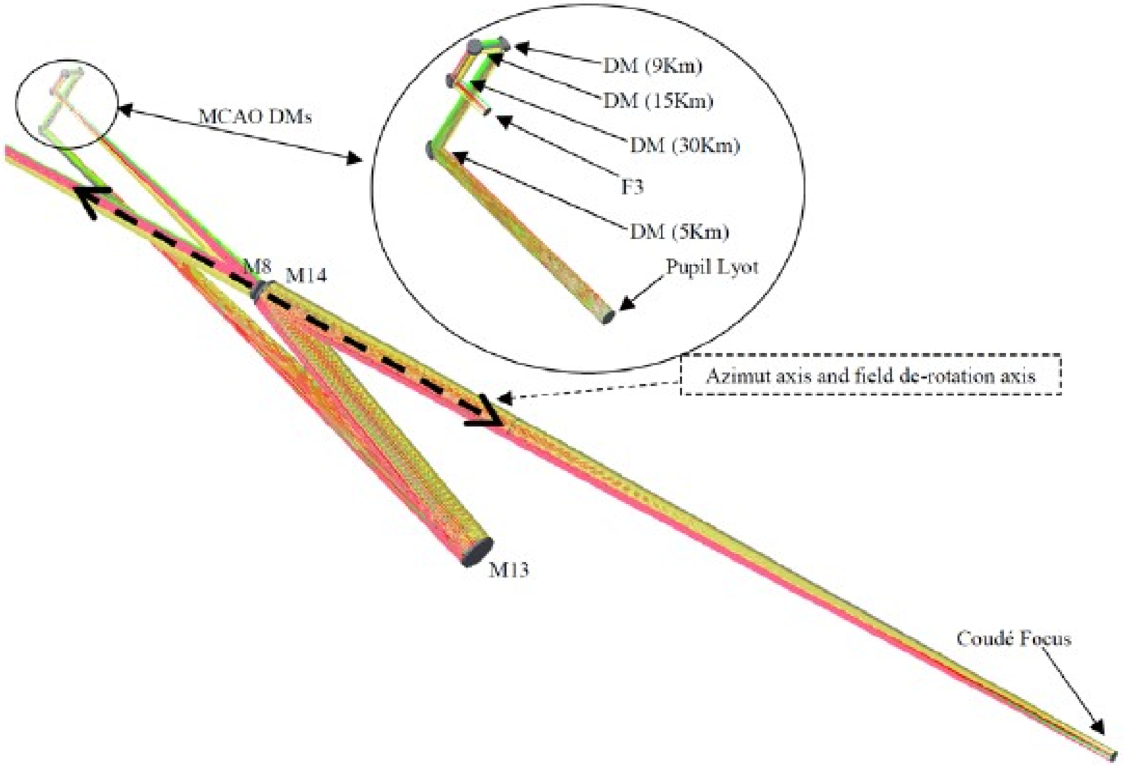
EST MCAO System

- The EST multi-conjugate AO system consists of four deformable mirrors for distant layers in the atmosphere which complement the deformable mirror in the pupil plane
- So far, solar MCAO systems used at most two DMs with conjugates in the higher atmosphere
- Present studies are limited to simulations of atmospheric propagation



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Previous Activities

- EST Design Study
  - Conceptual Design
- SOLARNET I (WP70)
  - MCAO simulation, DM organization
  - Turbulence Characterization at RdLM & OT
  - Influence of EST building on local turbulence
- GREST (WP6)
  - Deformable mirrors (45 degree inclination)

SOLARNET

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Goals of SOLARNET II MCAO JRA

- Carry out all necessary remaining research work needed to complete a full **Preliminary Design** for the EST MCAO system
  - a **PD** is a design where all major technical choices are solved
  - Systems engineering, choice of WFS concept, choice of DM technology
- Do the research and develop the methods needed to understand MCAO performance and its limitations
- **Demonstrate the viability** of the design and methods **on the sky**
  - Build a prototype which implements pupil DM and four HA DMs and the WFS to demonstrate a closed-loop system on the sky
  - Use prototype to verify performance, control concepts, simulations etc.

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Work package No	Workpackage Title	Lead Participant No	Lead participant short name	Person Month	Start Month	End Month
1	Project Coordination and Management	1	KIS	221/61	1	48
2	NA1: Coordination for improved exploitation of solar physics infrastructures	4	SU	54/25	1	48
3	NA2: Network activities to foster synergistic collaborations	8	UNICT	67/67	1	48
4	NA3: Engagement, Dissemination and Communication	12	NU	53/26	1	48
5	JRA1: Towards a European Solar Data Centre	1	KIS	228/214	1	48
6	JRA2: Advanced instrumentation development		IAC	269/218	1	48
7	JRA3: Multi-Conjugate Adaptive Optics for EST	1	KIS	301/143	1	48
8	JRA4: Solar Physics Research Integrated Network Group - SPRING	1	KIS	248/150	1	48
9	TA1: Trans-National Access Programme	4	SU	39/39	1	48
10	VA1: Virtual Access Programme	3	UiO	79/79	1	48

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Objectives

- Develop and a prototype MCAO system which is representative for the EST MCAO,
- Test the prototype in the laboratory and at the GREGOR solar telescope in Tenerife,
- Develop and test alternative concepts based on neural networks for controlling the MCAO,
- Develop tools to characterize the performance of solar MCAO as an input to WP 5,
- Characterize the high altitude turbulence at the EST sites and investigate turbulence prediction,
- Develop EST-specific wave front sensor and deformable mirror technology.

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Participants and Personnel

Work package number	7	Lead beneficiary				KIS		
Work package title	JRA3 Multi-Conjugate Adaptive Optics for EST							
Participant number	1	2	6	34	33	4	35	
Short name of participant	KIS	IAC	INAF	Durham	Oviedo	SU	HES-SO	IOSB
PMs per participant:	25	28	29	12	26	12	10	2
Start month	1		End month		48			

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Description of Work - Subworkpackages

- **Prototype development** **KIS**, IAC, Durham, Oviedo, ALPAO
- **Neural Network Control** **Oviedo**, IAC, KIS
- **Performance characterization** **SU**, HESS-SO KIS, IOSB)
- **Technology development** **INAF**, ALPAO

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7.1 Prototype Development

- Build, test and verify a version of the EST MCAO system which is scaled down to a 1.5 m pupil (instead of 4 m)
  - Error budgets through dynamic simulations
- Perform on-sky testing and verification at GREGOR
  - Goal is to demonstrate compensation of a 1 arcmin field
- Acquire four volume control DMs
  - Two will be purchased by KIS for further use with a GREGOR MCAO
  - Two will be provided by ALPAO
  - Use existing pupil conjugate DM at GREGOR
- Use prototype to test/verify new wavefront sensing and control concepts

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7.2 Neural Network Control System

- Evaluate the feasibility of a tomographic reconstructor based on Convolutional Neural Networks (CNN)
- Take advantage of the high potential of deep-learning techniques which are especially adapted to the problem
  - Oviedo has already successfully implemented such a technique for night time AO applications
- Integrate CNN control system into prototype for on-sky evaluation/verification

SOLARNET

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7.3 Performance Characterization and Prediction

- Develop tools to characterize the performance of the EST MCAO system and to generate the information needed to remove the residual disturbances from observed data (LE-PSF; interface to WP 5)
- Differential Characterization of RdlM and OT sites
- Evaluate forecast techniques for relevant atmospheric parameters

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7.4 Technology Research

- Strategies to parallelize wave front sensing for a 4m aperture telescope
  - Distributed wave front sensing with several cameras
- Deformable mirror technologies
  - Heat management for large format DMs for solar applications
  - Migration of CHARA anisotropic actuator patterns for 45° illumination for solar applications

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Deliverables

Deliverables (brief description and month of delivery)
D7.1 Report on Prototype Opto-Mecanical Design (T0+8)
D7.2 Laboratory Integration and DM Test Report (T0+18)
D7.3 Prototype Lab Test Report (T0+30)
D7.4 Prototype On-Sky Test Report (T0+48)
D7.5 Prototype Final Report (including data evaluation report) (T0+48)
D7.6 Simulation Results (T0+15)
D7.7 Neural Network Lab Integration and Test Report (T0+27)
D7.8 Neural Network On-Sky Integration and Test Report (T0+39)
D7.9 Report on PSF Estimation (T0+30)
D7.10 Report on Data Analysis and Transfer to WP 5 (T0+42)
D7.11 Results of Turbulence Profile Comparison (T0+30)
D7.12 Turbulence Prediction Report on available measurements (T0+12)
D7.13 Turbulence Prediction Report model geometry (T0+24)
D7.14 Turbulence Prediction Report on preliminary analysis of model performances (T0+36)
D7.15 Turbulence Prediction Final report on strategy for model calibration and validation (T0+48)
D7.16 Modular WFS Report on the preliminary opto-mechanical design of the demonstrator (T0+12)
D7.17 Modular WFS Report on hardware implementation and integration of the WFS prototype (T0+30)
D7.18 Modular WFS Report on laboratory tests (T0+36)
D7.19 Modular WFS Final report on system performances (T0+48)

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