

A night sky view of a galaxy cluster, likely the Abell 1689 cluster, featuring a central bright yellowish-white galaxy surrounded by numerous smaller galaxies in various colors (red, blue, green). The foreground shows the silhouette of a telescope dome with a thin orange laser beam pointing upwards.

# ULTIMATE-SUBARU

with Wide-Field Ground-Layer Adaptive Optics



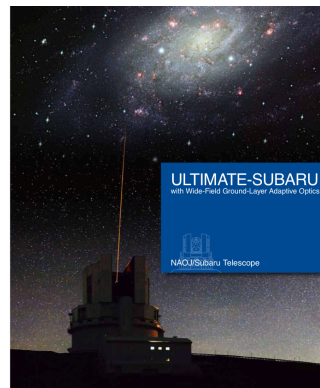
NAOJ/Subaru Telescope

## Adaptive Optics

Christophe Clergeon

# ULTIMATE SUBARU – A New AO For Subaru Telescope

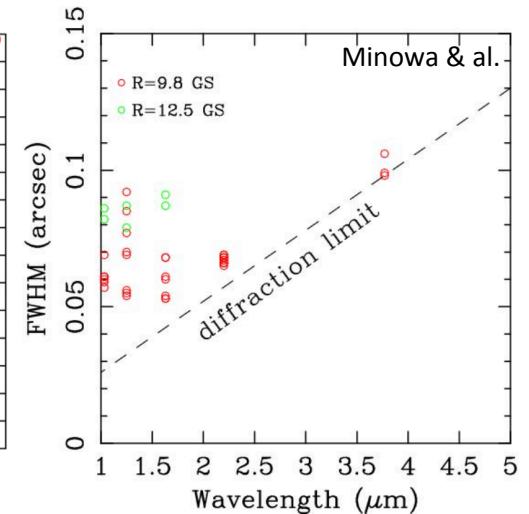
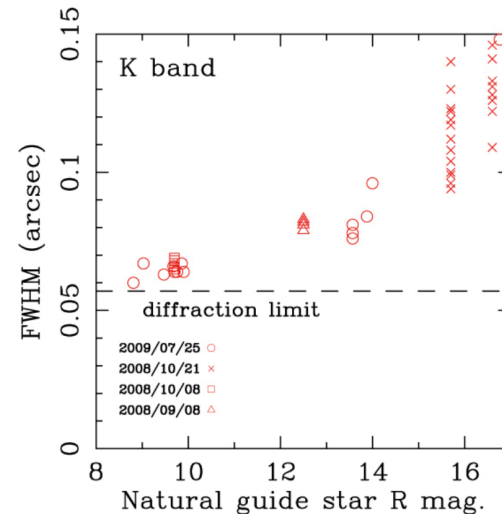
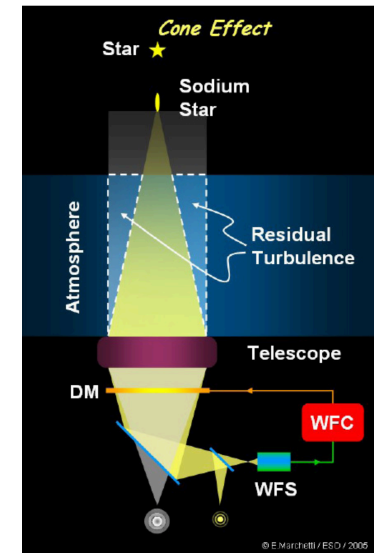
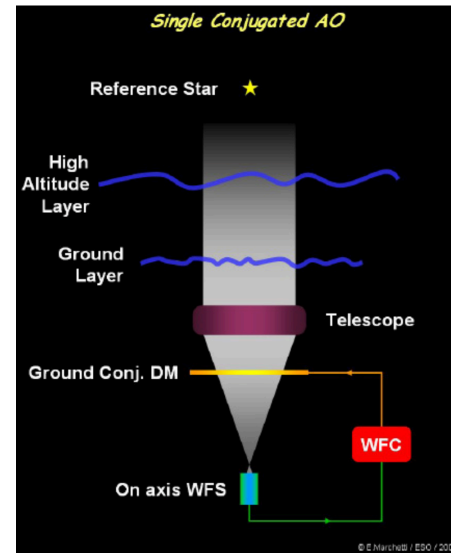
- Introduction : which AO for next generation instruments
- ULTIMATE Subaru, New AO system overview
- GLAO Expected Performances
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# Introduction – Actual Subaru Adaptive Optics

## AO188 Specifications

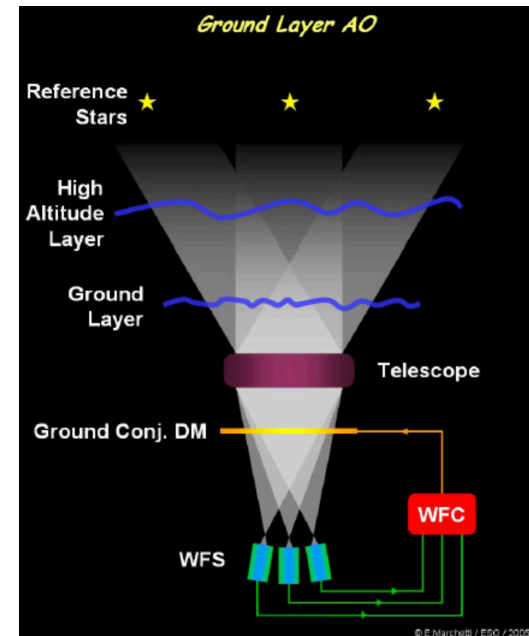
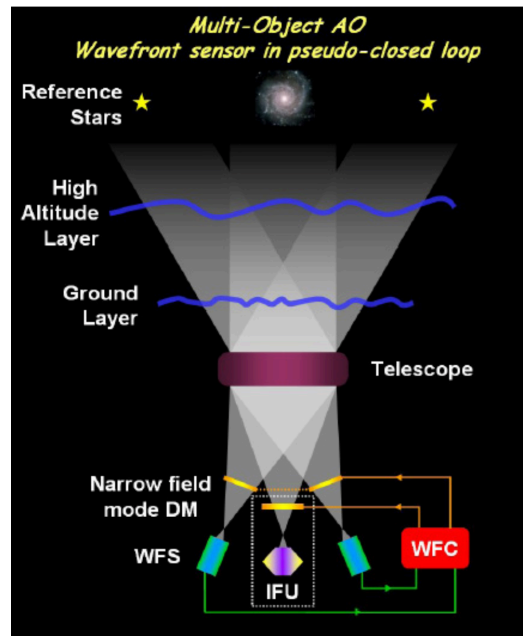
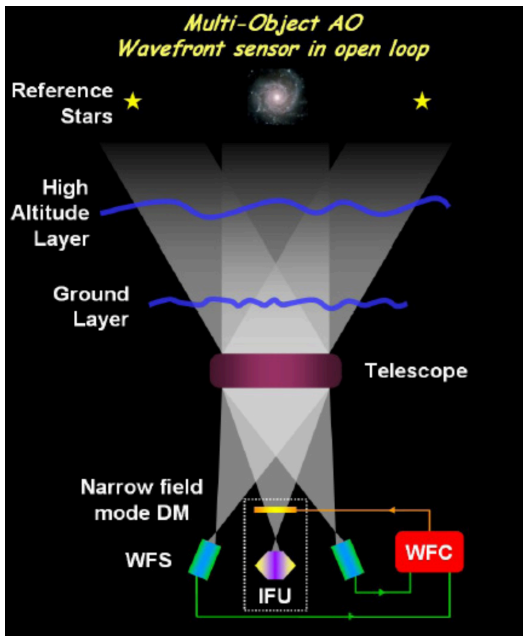
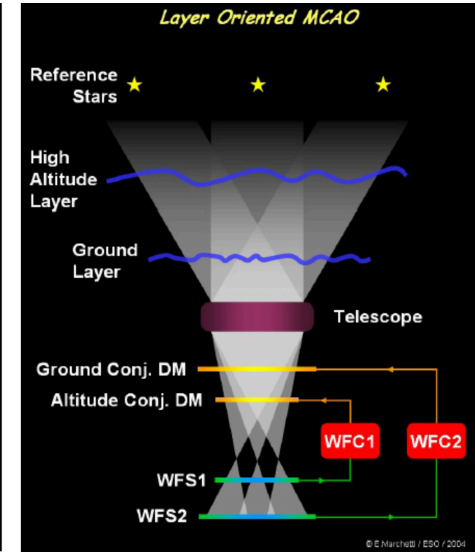
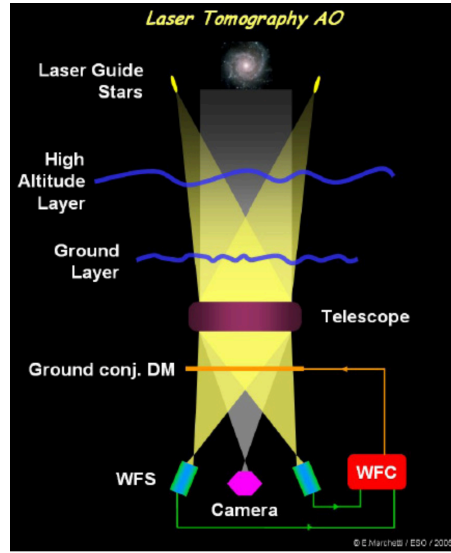
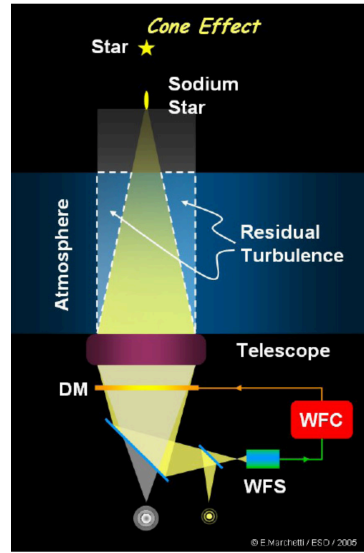
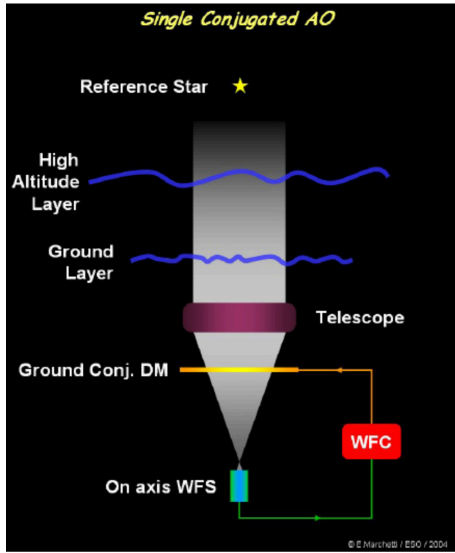
<b>HO</b>	Curvature (Roddier)	
	188 sub-pupils	
	1 KHz	
<b>LO (LGS)</b>	Shack-Hartmann	
	4 cells	
<b>DM</b>	Bimorph - 188 actuators	
<b>Corrected FoV</b>	2' NGS	IRCS 50''
	3' LGS	
<b>NGS</b>	Since 2006	
<b>LGS</b>	Since 2011	



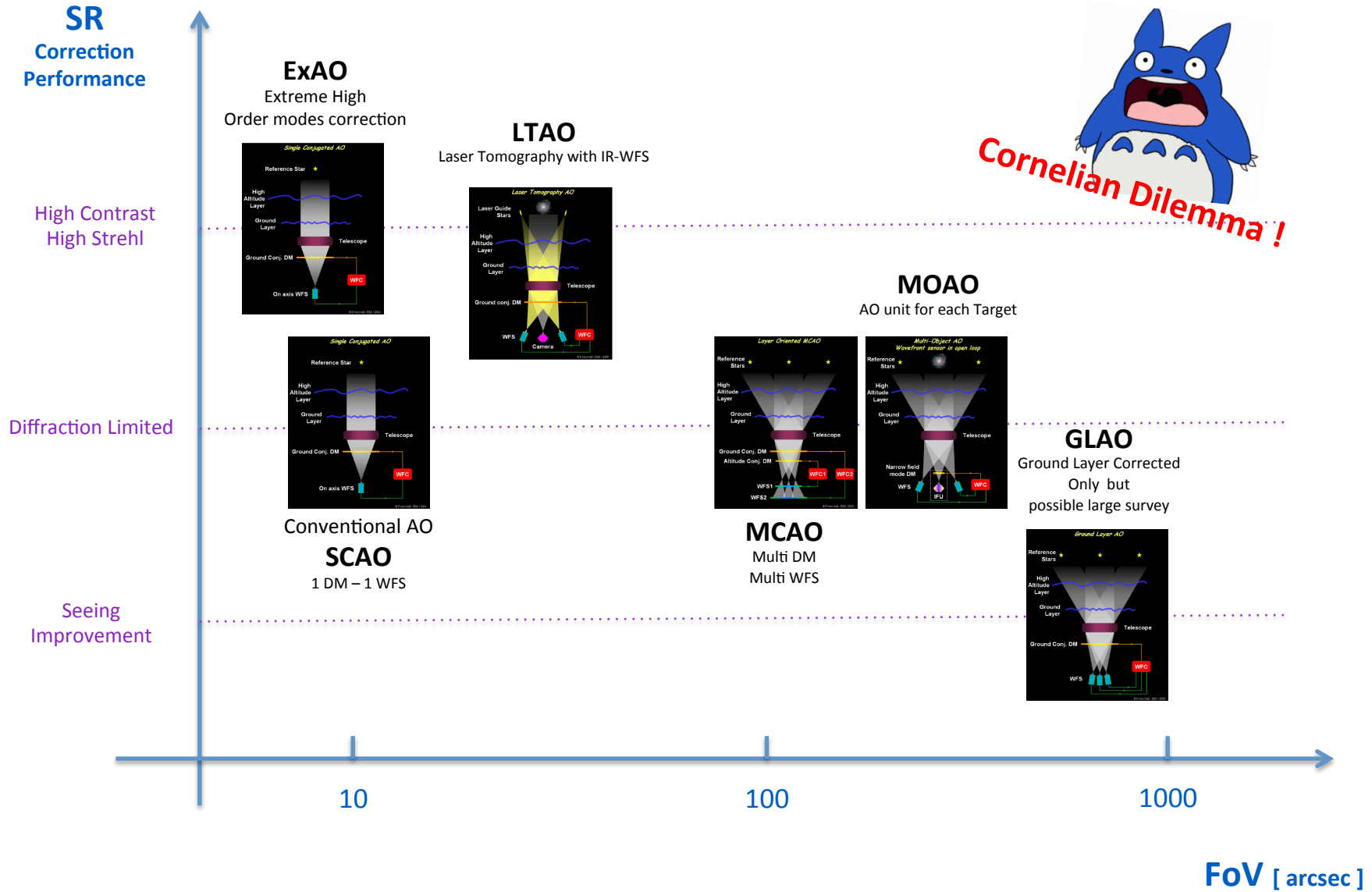
FWHM as a function of R-magnitude of the NGS and the observed wavelength under good seeing condition of 0.4 arcsec.

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# Introduction – New AO perspectives for SUBARU -- Multiple Choices !!!



# Introduction – New AO perspectives for SUBARU -- SR or FoV



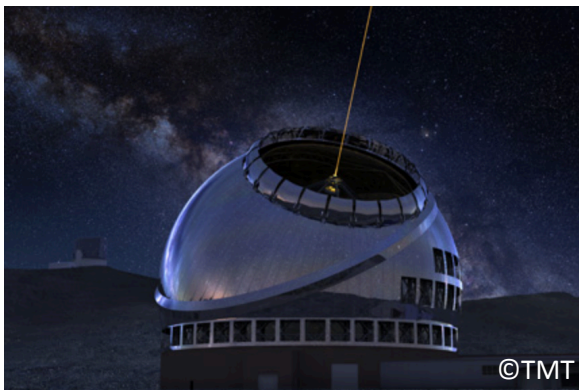
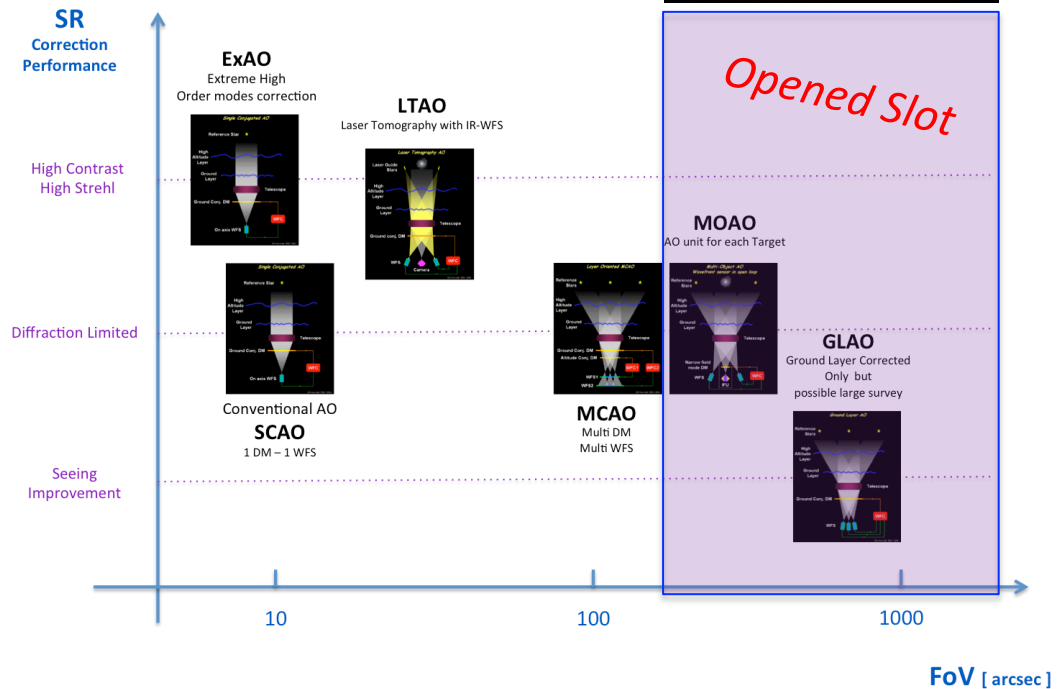
# Introduction – New AO perspectives for SUBARU

## Mauna Kea AO Strategy

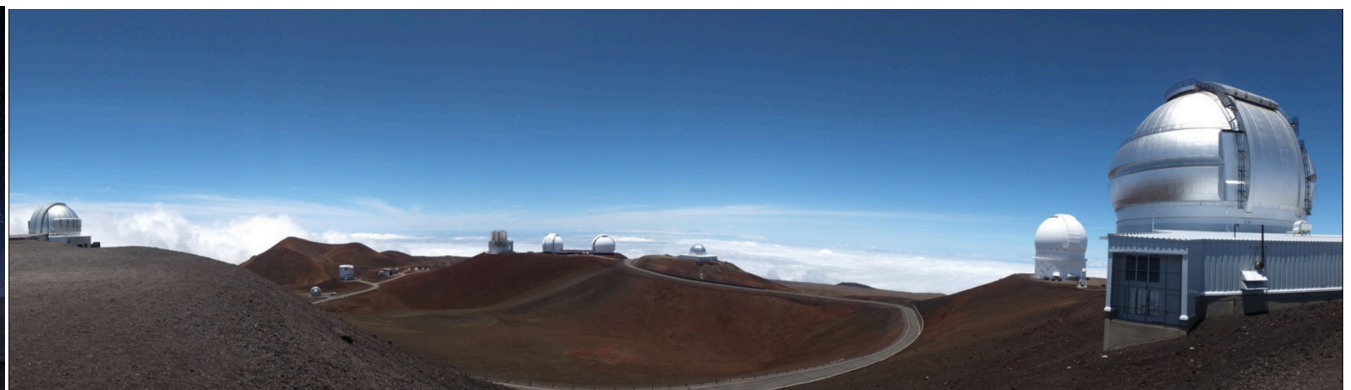
Keck	LTAO
Gemini	MCAO ( id. GEMS Gemini South)
TMT	Narrow Field IR AO (NFIRAOS) MCAO
CFHT	GLAO - IMAKA -> cf. M. Chun talk

## ULTIMATE-Subaru Instruments (cf. Minowa-san presentation)

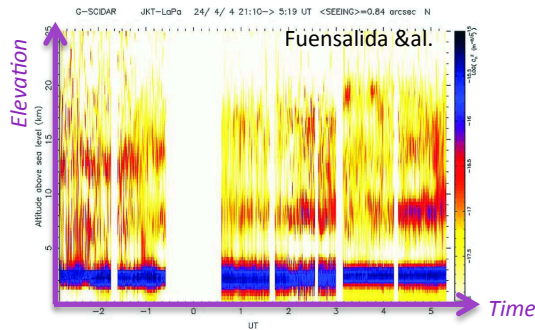
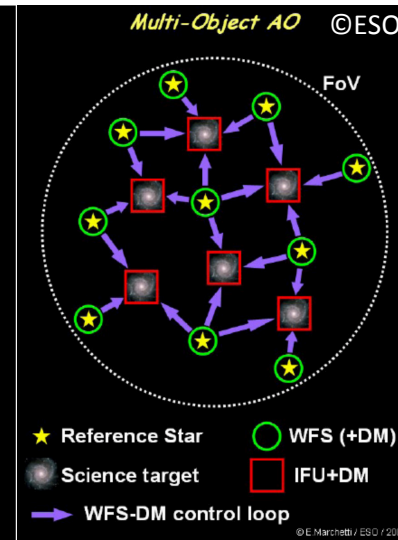
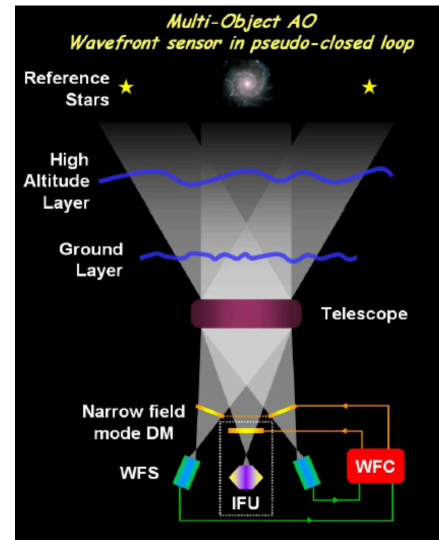
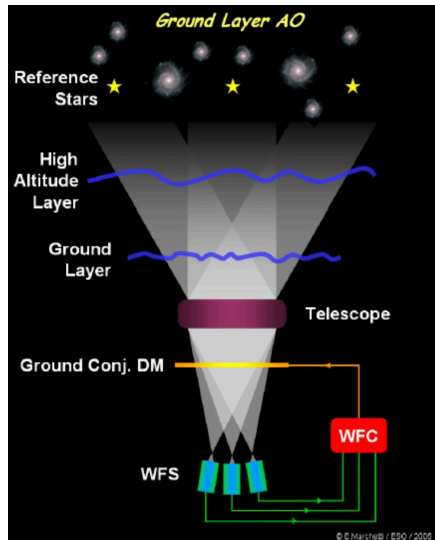
Wide FoV Imager  
Multi-Object IFU Spectroscopy  
Multi-Object spectrograph



©TMT



# Introduction – New AO perspectives for SUBARU



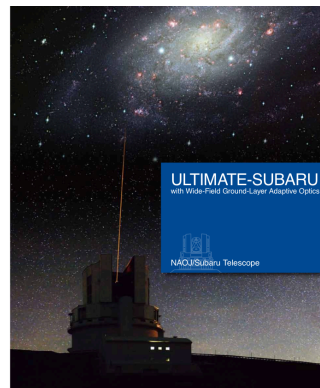
FOR/FOV  
Image Quality  
Targets

GLAO	MOAO
15 arcmin	3 arc min
FWHM/2	Diffracted limited
Full	Known

**GLAO for ULTIMATE Subaru :**  
 With the largest FoV correction provided by a MaunaKea observatory,  
 Optimal Seeing Conditions  
**A perfect asset beside ELTs**

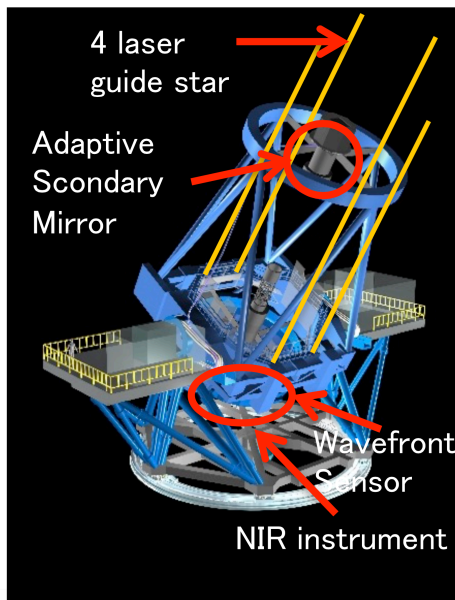
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- GLAO Expected Performances
- The TOPTICA Laser system
- The Adaptive Secondary Mirror
- Status and Conclusion

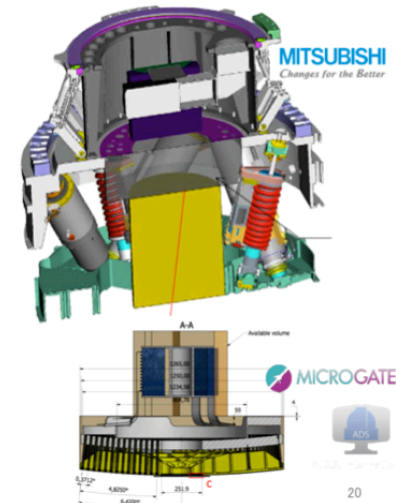
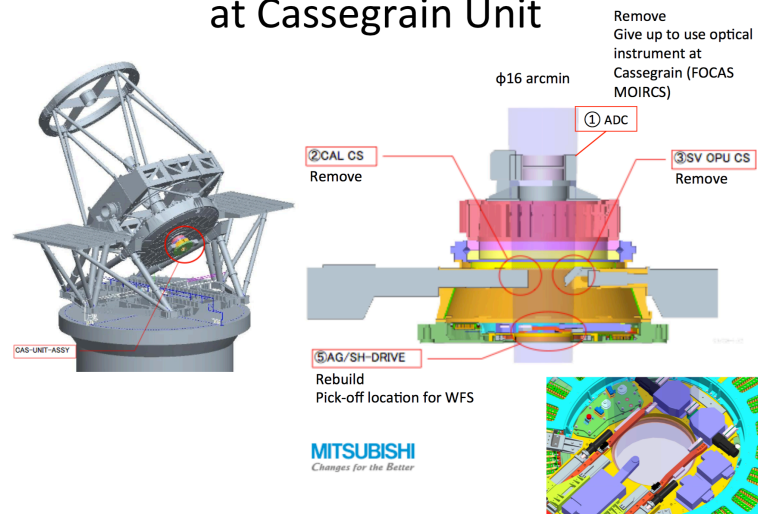


# ULTIMATE SUBARU – New AO system overview

Item	Specification
Guide stars	4 LGS, NGS(2~4)
Location of guide stars	The edge of FoV > 15' (LGS), Within the FoV (NGS)
Wavefront sensors	Each guide stars (Guide star oriented)
Wavefront sensor type	Shack-Hartmann
Tip-tilt wavefront sensor type	2 × 2 Shack-Hartmann wavefront sensor or pyramid. (visible or NIR)
Sub apertures	> 100
Frame rate of wavefront sensor	> 500Hz
Deformable mirror	Adaptive secondary mirror
Actuators	~1000
AO control type	GLAO (LTAO, ExAO modes)

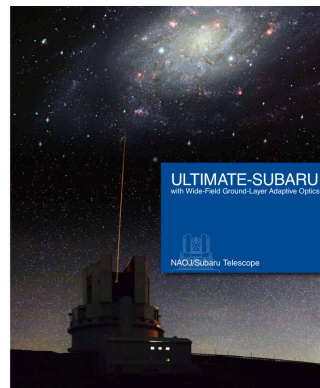


## Wavefront sensor (WFS) at Cassegrain Unit



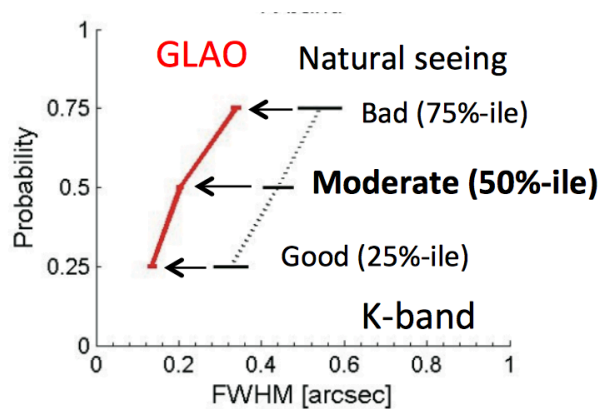
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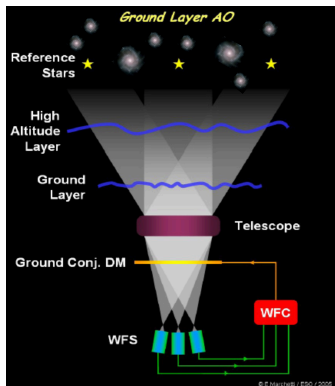
# ULTIMATE SUBARU – GLAO Expected Performances

- Sky coverage: **Almost entire sky!**
- Seeing improvement ↓ ↓



Band	Natural Seeing (")			GLAO (")		
	Good	Moderate	Bad	Good	Moderate	Bad
J	0.38	<b>0.50</b>	0.71	0.17	<b>0.26</b>	0.44
H	0.38	<b>0.46</b>	0.60	0.15	<b>0.23</b>	0.39
K	0.33	<b>0.44</b>	0.54	0.14	<b>0.20</b>	0.34

VLT (Le Louarn and al.) : Seeing 0.8" -> GLAO 0.4" K – 7.5' FoV



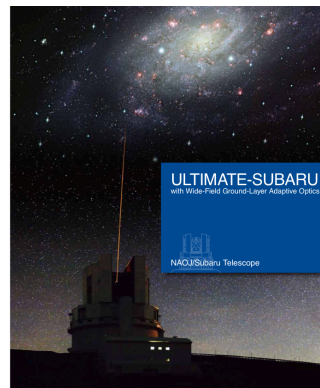
Zenith angle dependency

	0°	15°	30°	45°	60°
Seeing	0.44"	0.49"	0.52"	0.60"	0.76"
GLAO	0.20"	0.28"	0.31"	0.38"	0.55"

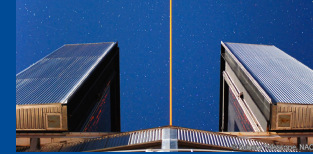
S. Oya

# ULTIMATE SUBARU – A New AO For Subaru Telescope

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# ULTIMATE SUBARU – TOPTICA LASER and Launching Location



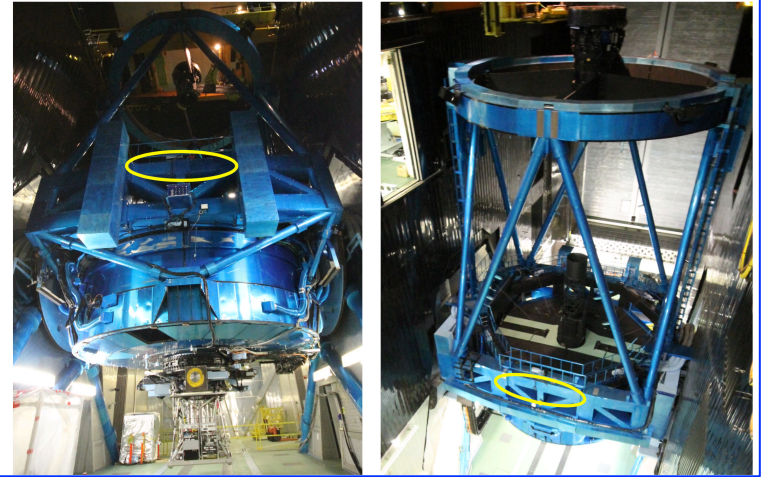
## The TOPTICA fiber laser system :

- Continuous wave (CW)
- **20W** with optical repumping of D2b.
- Diode pump fiber laser with second harmonic generation
- Electronics rack (1m x 1m x 2m – 700 Kg) and one laser head.

## Advantages:

- 20W and wavelength **extremely stable**
- Ability to detune off wavelength
- **Fast startup** (<40 minutes with calibration)
- Continuous and manual health checks to monitor performance
- Efficiency; **low power usage** compared to existing laser systems

## Candidate location for laser head and laser launching telescope (LLT)

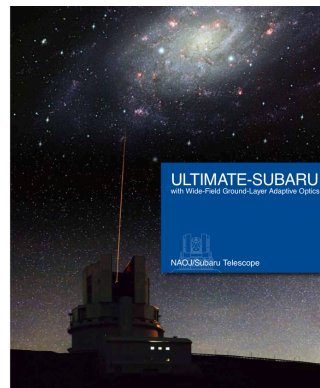


Preliminary experiment at Keck II using TOPTICA fiber laser reported that the generated LGS is **brighter than 9th magnitude** equivalent (actual Subaru laser : 4.5W ~ 13<sup>th</sup> magnitude)



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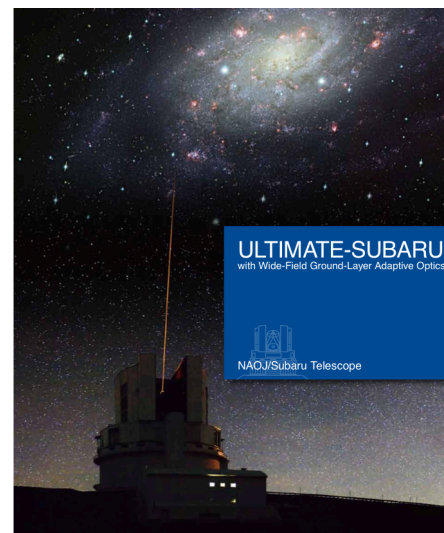
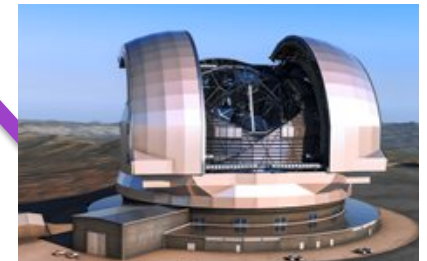
# ULTIMATE SUBARU – Adaptive Secondary Mirror

## Ultimate Subaru ASM Goals

- First ASM on Mauna Kea
- Main GLAO system and Subaru Upgrade
- Large corrected FOV
- Higher actuator stroke

## ASMs projects overview

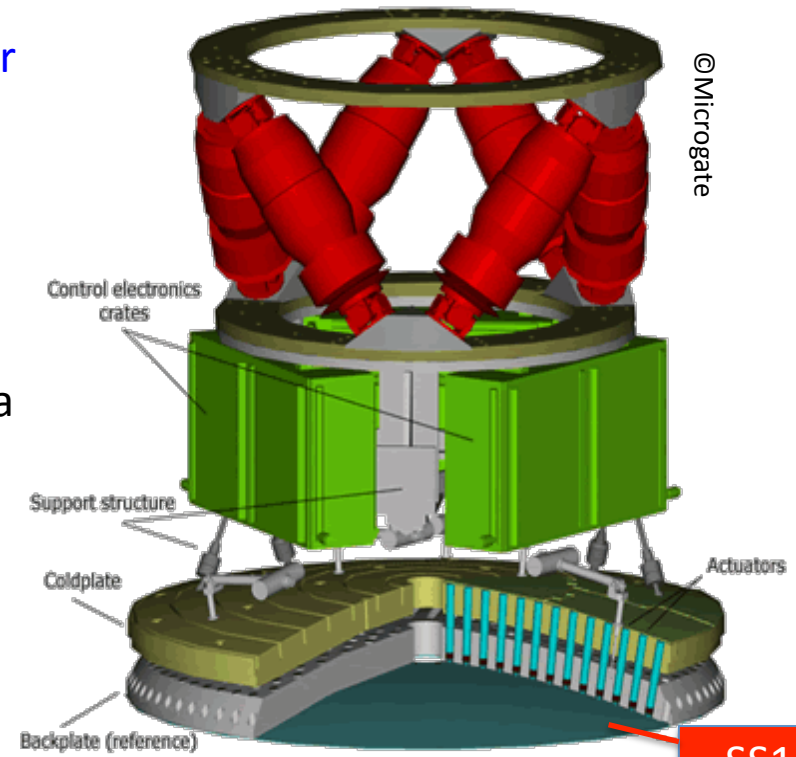
- MMT: 1 ASM (2002) – 336 actuators
  - LBT: 2 ASMs (2010) – 672 actuators
  - Magellan (2012) – 585 actuators
  - VLT : 1ASM (early 2016) – 1170 actuators
  - E-ELT M4
  - GMT ( 7 x 672 actuators ASM)
- 
- ULTIMATE SUBARU – 924 actuators



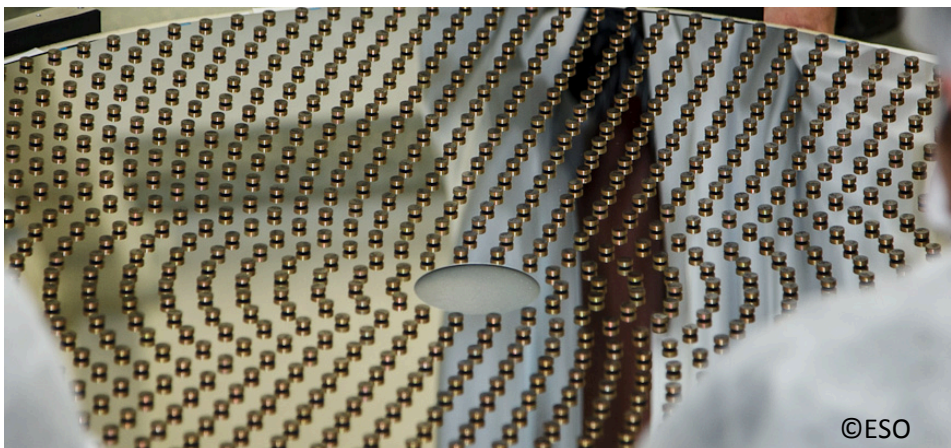
## Adaptive Secondary Mirror : Overview (1/4)

### SS1: The deformable Zerodur concave shell – mirror

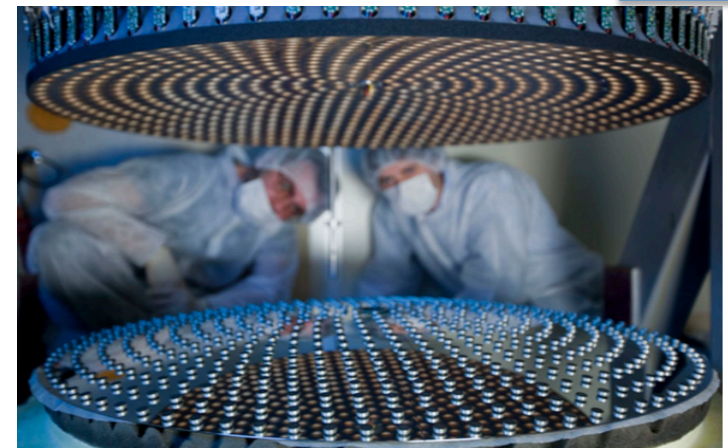
- The main and most critical part of the system.
- Magnets are glued at its surface for activation.
- Back surface of the shell is spherical and match a reference plate (see next slide).
- The Shell also has a central hole where connected membrane is attached to provide lateral and rotational constraints (position adjustments).



©Microgate



©ESO

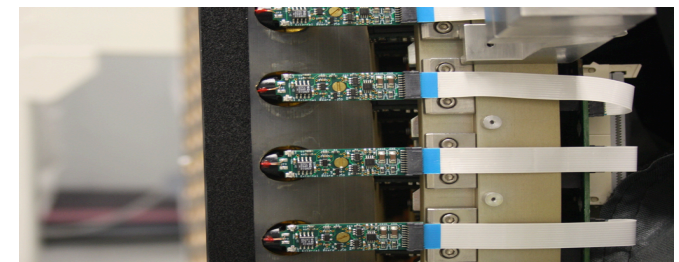
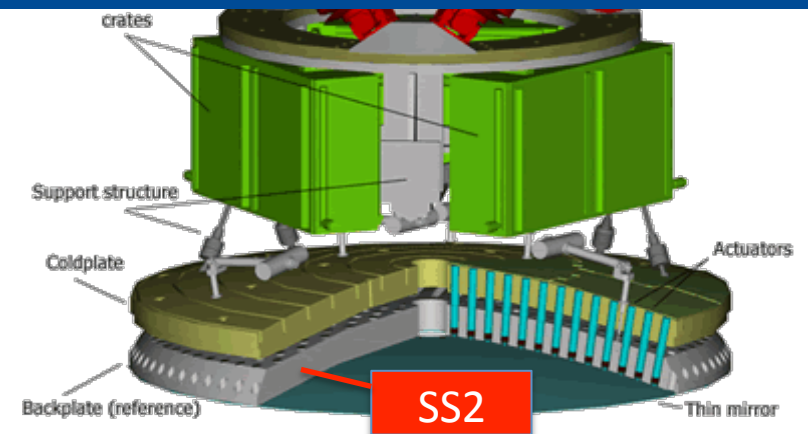


## Adaptive Secondary Mirror : Overview (2/4)

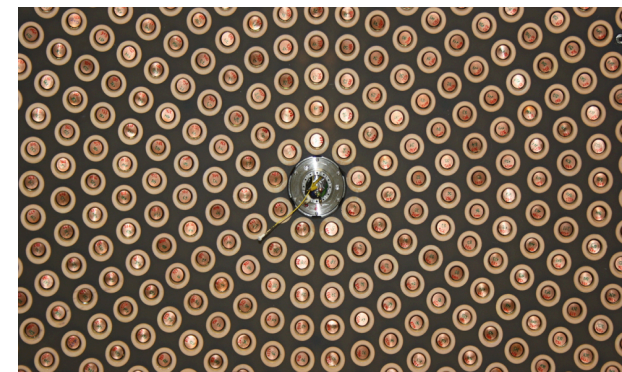
### SS2:

The backplate or reference body .

- Composed of bored holes and attached to the cold plate.
- Position reference for the mirror shell.
- The actuators (coil cold-fingers, see next slide) supported by the cold plate pass through the bored holes to reach the deformable mirror.



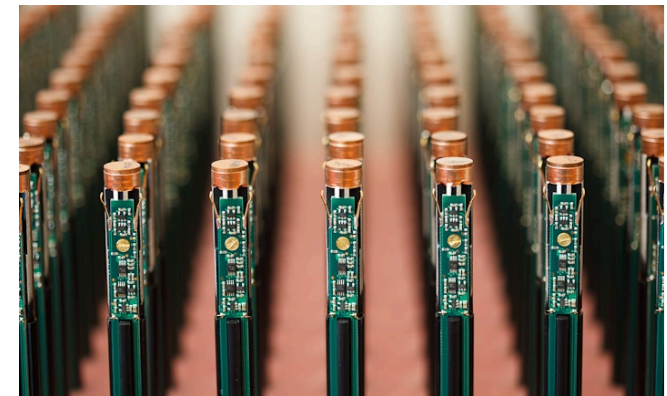
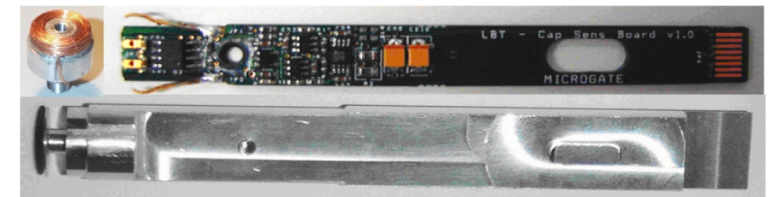
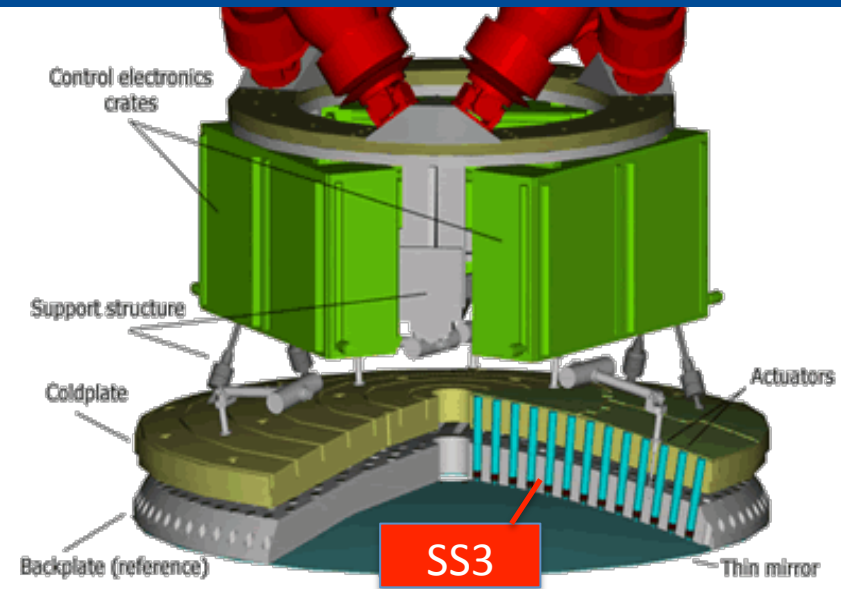
A ring of conductive is deposited around each magnet glued on the shell (SS5) and is mirrored on the reference body. These two opposite coatings constitute a capacitance used as space sensor (RT mirror position meas.)



## Adaptive Secondary Mirror : Overview (3/4)

### SS3: The actuators ( voice-coiled – 12mm diam.).

- Voice-coiled Placed on aluminum cold finger tips (structure and heat dissipator) in front of a magnet glued on the thin mirror shell.
- Force applied by each coil on each magnet deforms locally the thin mirror shell.
- Connected to an electronic small board providing the contacts to pick the capacitive sensor signal and related pre-amplification and demodulation electronics.
- All analog signals are converted to digital on the DSP boards (SS1) at 72 KHz.
- Provide a passive bias force pulling the magnet to hold the shell against the reference plate even when the system is switched off





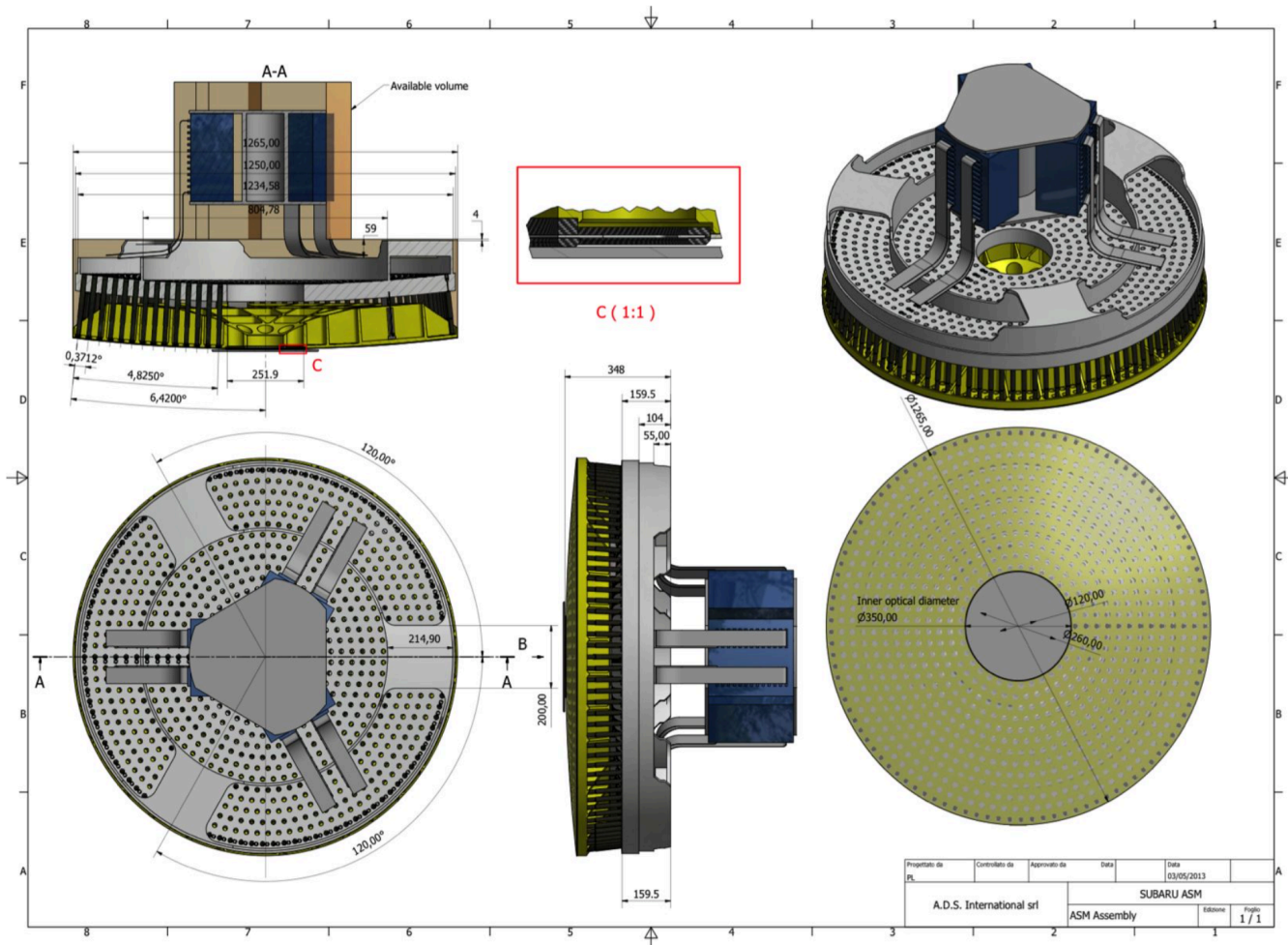
# Ultimate Subaru Adaptive Secondary Mirror

## Contractor (TBC)

- Microgate – ADS  
ADOTPICA  
(Italy)

## Specifications (Preliminary Design)

- VLT Design
- 1.265 meters  
(actual Subaru 2<sup>nd</sup>  
mirror)
- Shell: 1.6mm thick
- 924 actuators  
(35mm spaced)
- Stroke : 60  $\mu\text{m}$  (TBC)

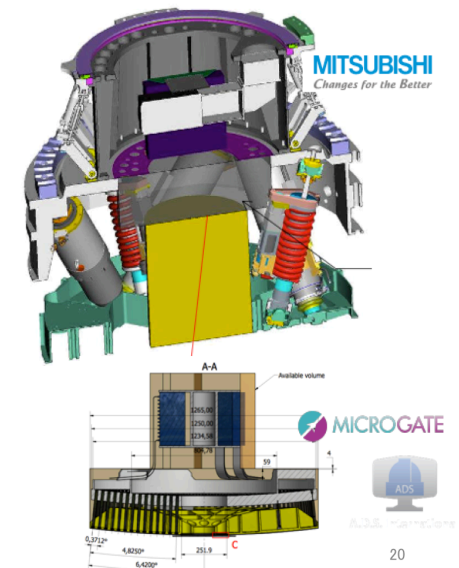
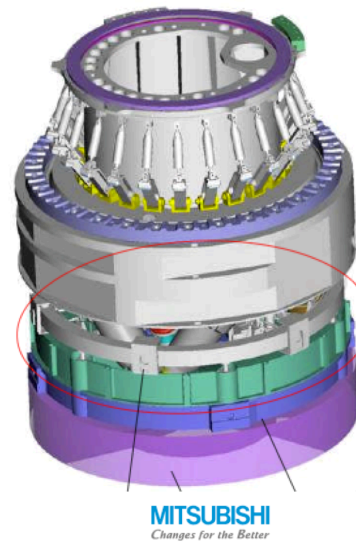


# Ultimate Subaru Adaptive Secondary Mirror integration

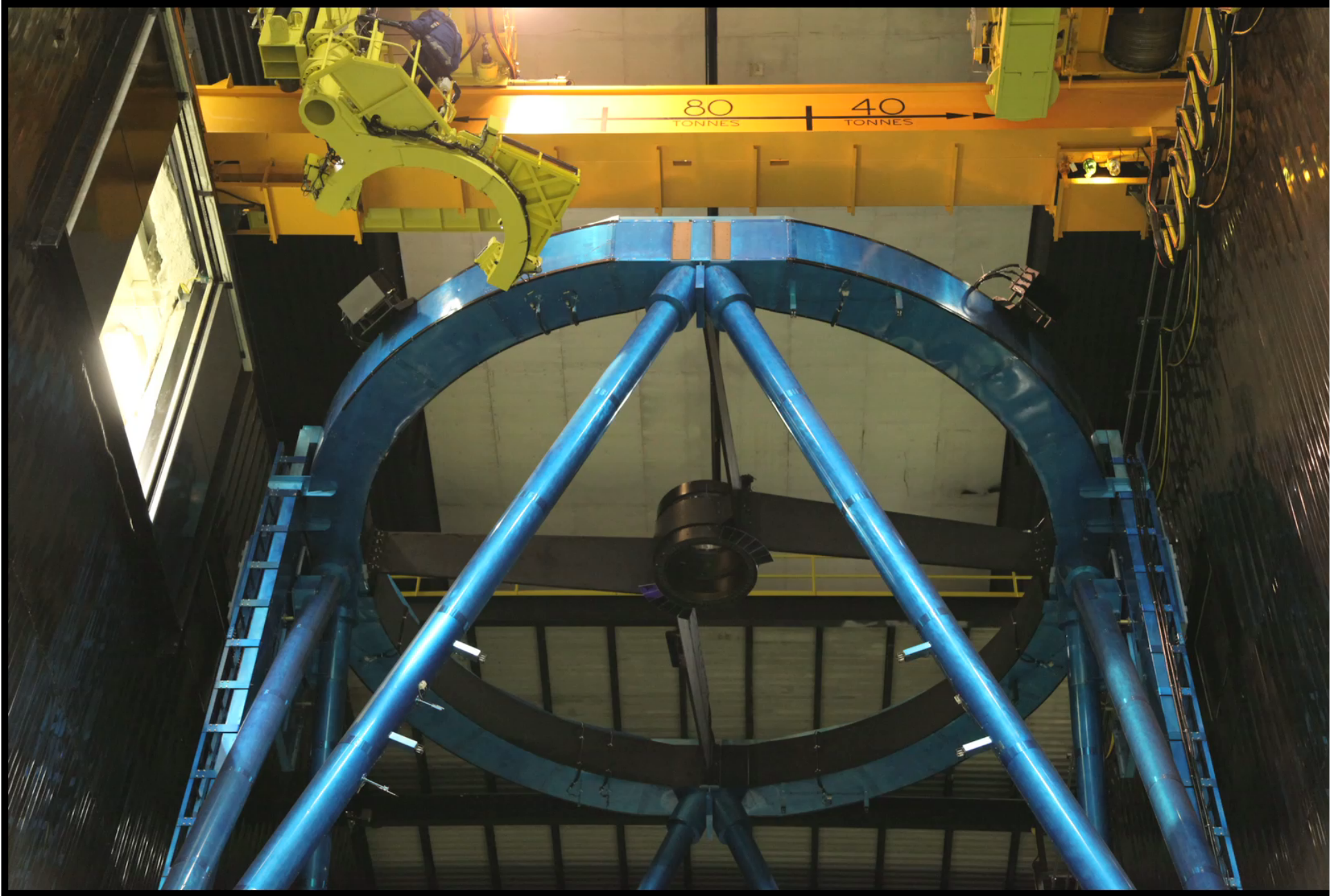
**Challenge :** must be removable from prime focus (HSC-PFS observations) – **More than once month every month !**

## Solutions

- Modification of the existing IR secondary mirror holder (ASM fit actual size and weight spec 3 tons).
- Use of actual Top Unit exchanger / high competent Day Crew
- Estimated total mass, weight, center of gravity, are also within the required specification of top unit of Subaru Telescope.
- Additional internal battery to maintain gap btw ref plate and shell

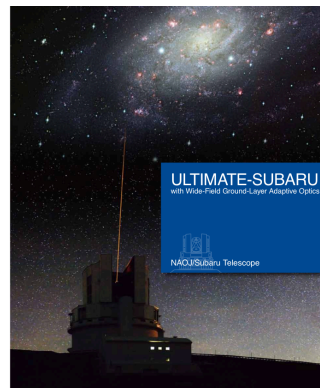




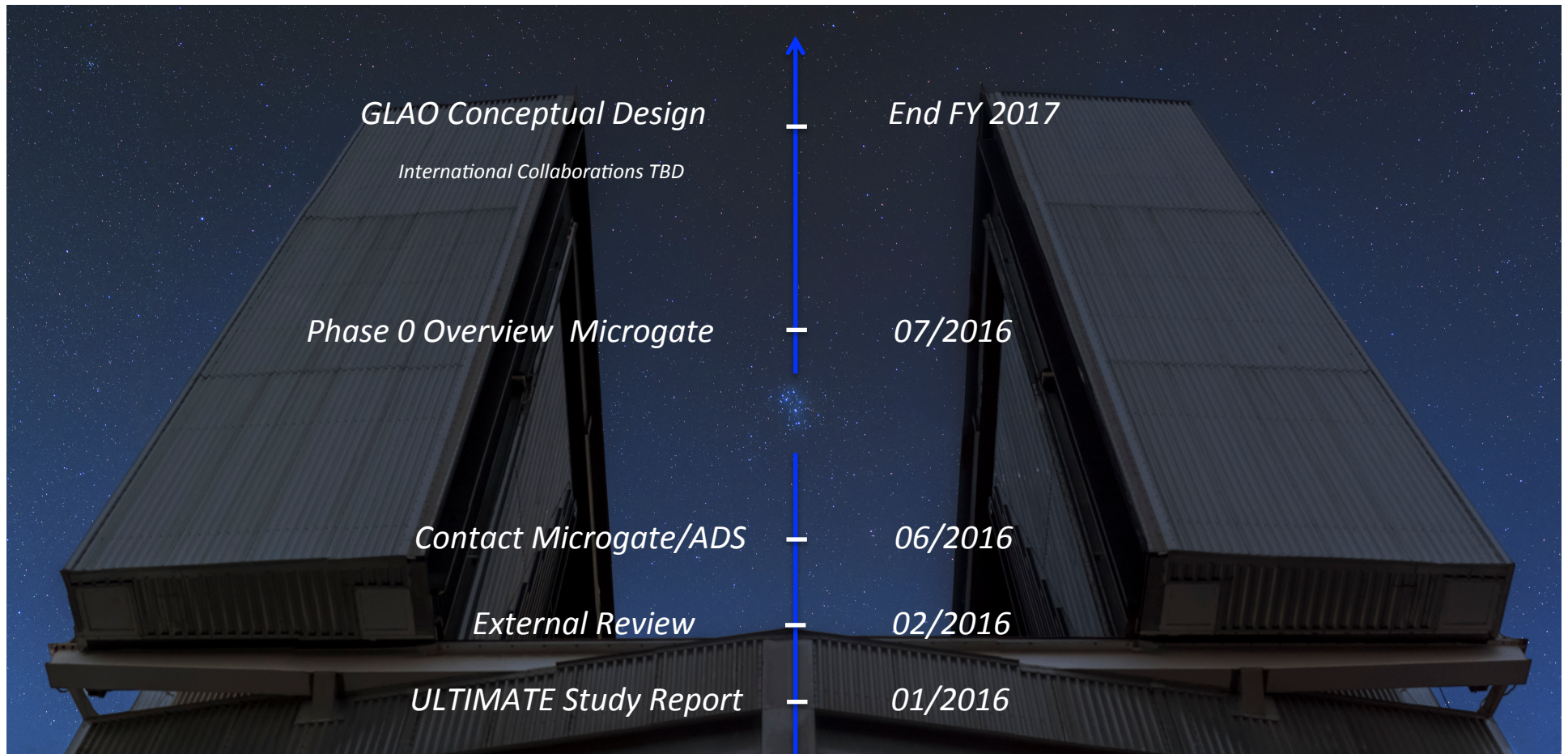
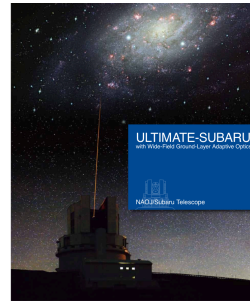


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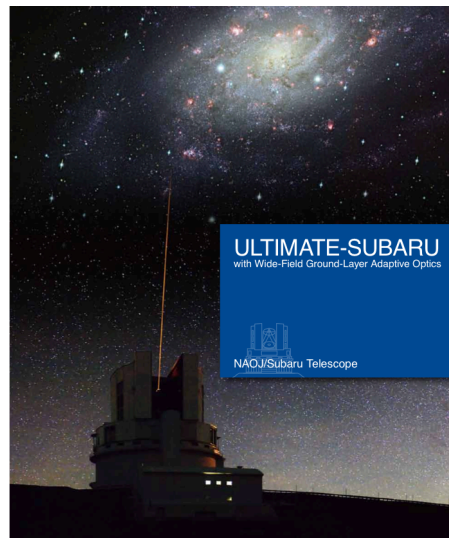


# ULTIMATE SUBARU - GLAO -- Status



## ULTIMATE SUBARU – GLAO -- Conclusion

- Mauna Kea is one of the Best site for GLAO
- ULTIMATE-Subaru unique and perfect asset for ELTs
- ASM will increase dramatically the Subaru telescope performances  
Sciences cases will be developed during this workshop
- Keep Subaru in the list of competitive telescopes
- Upcoming Conceptual Design expected at the end of 2017 FY  
with possible International collaborations



MAHALO

ありがとうございます