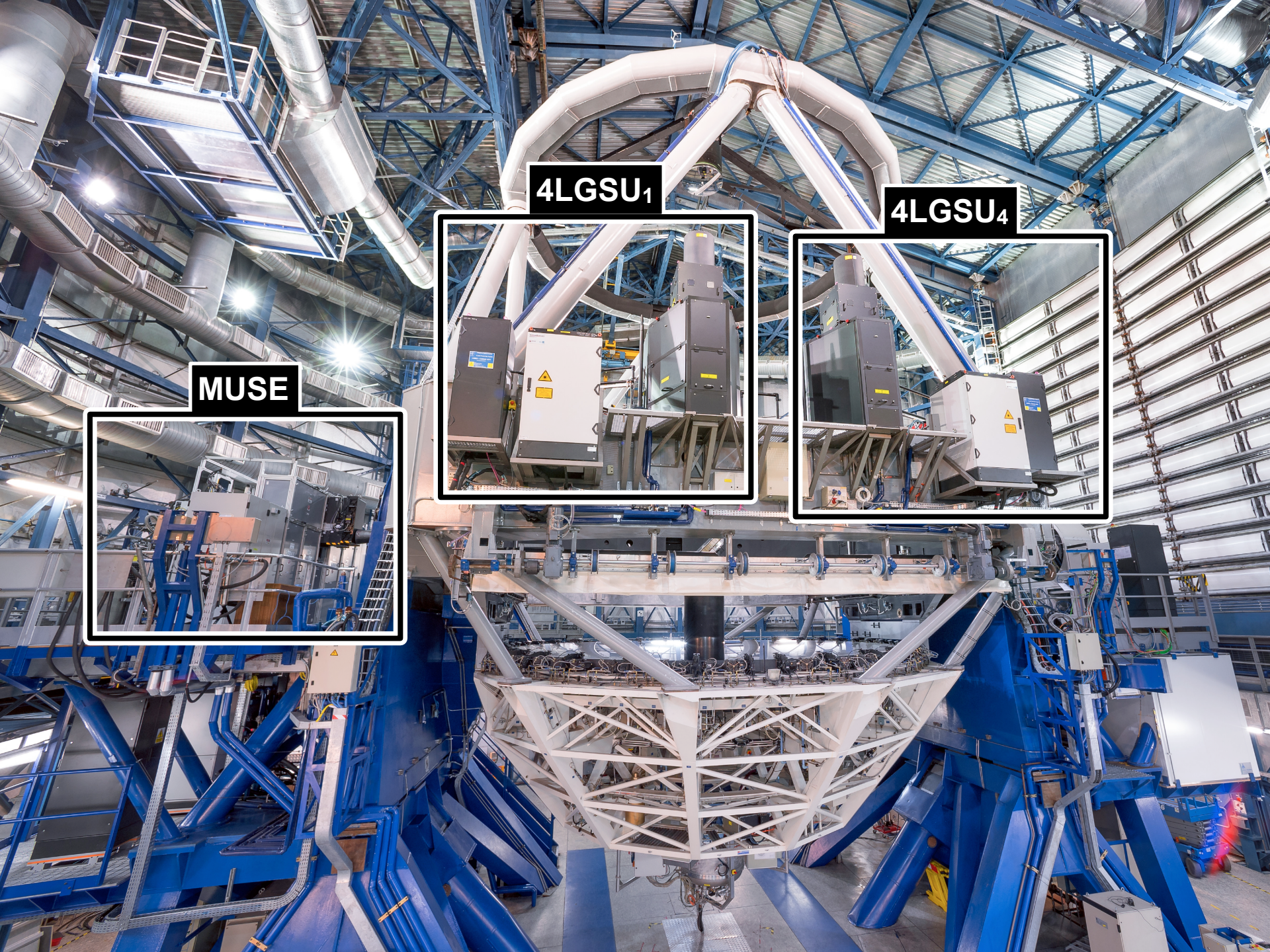
“LGS are for free.”

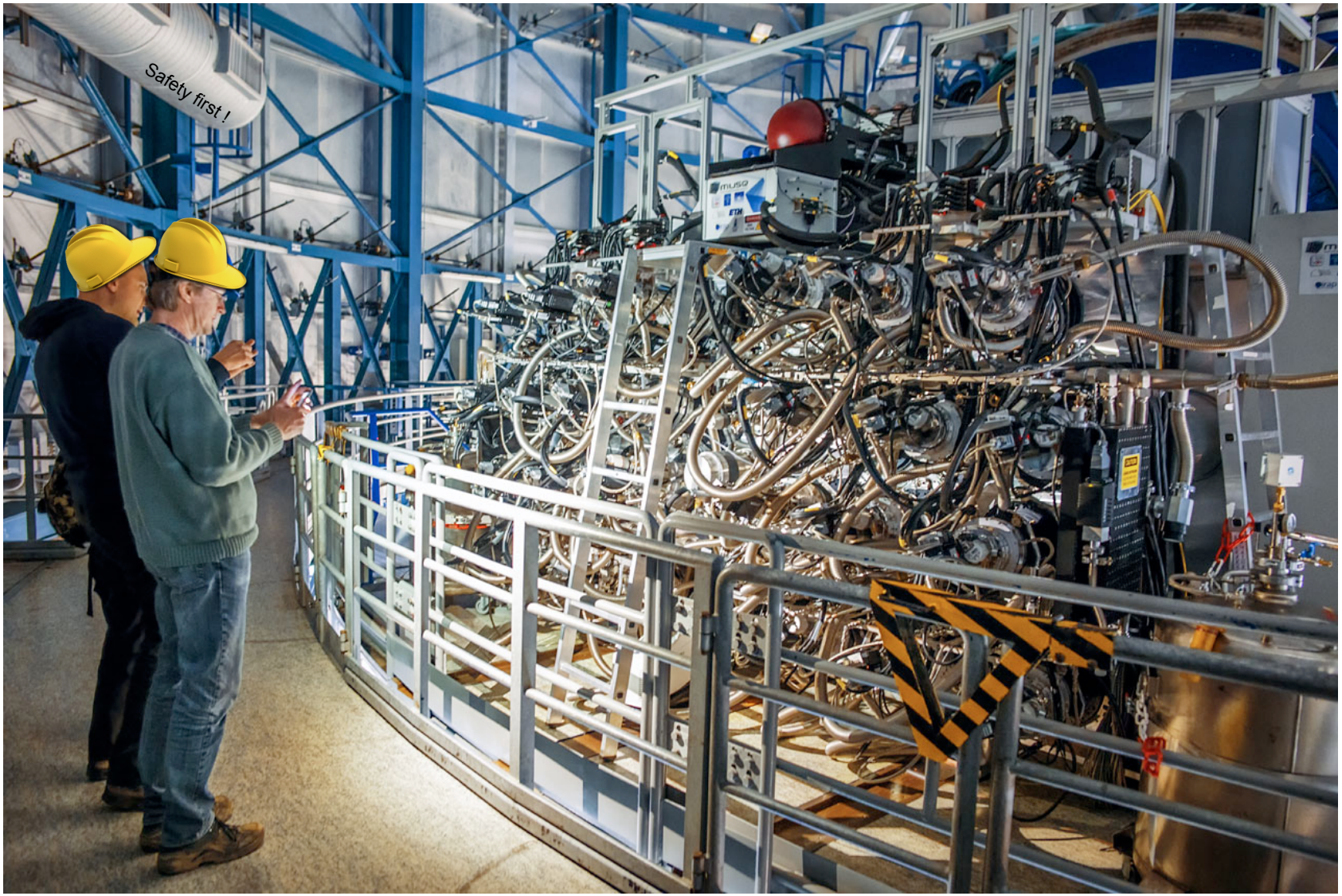
Someone in the first row, this Tuesday.

“LGS are for free. Almost.”

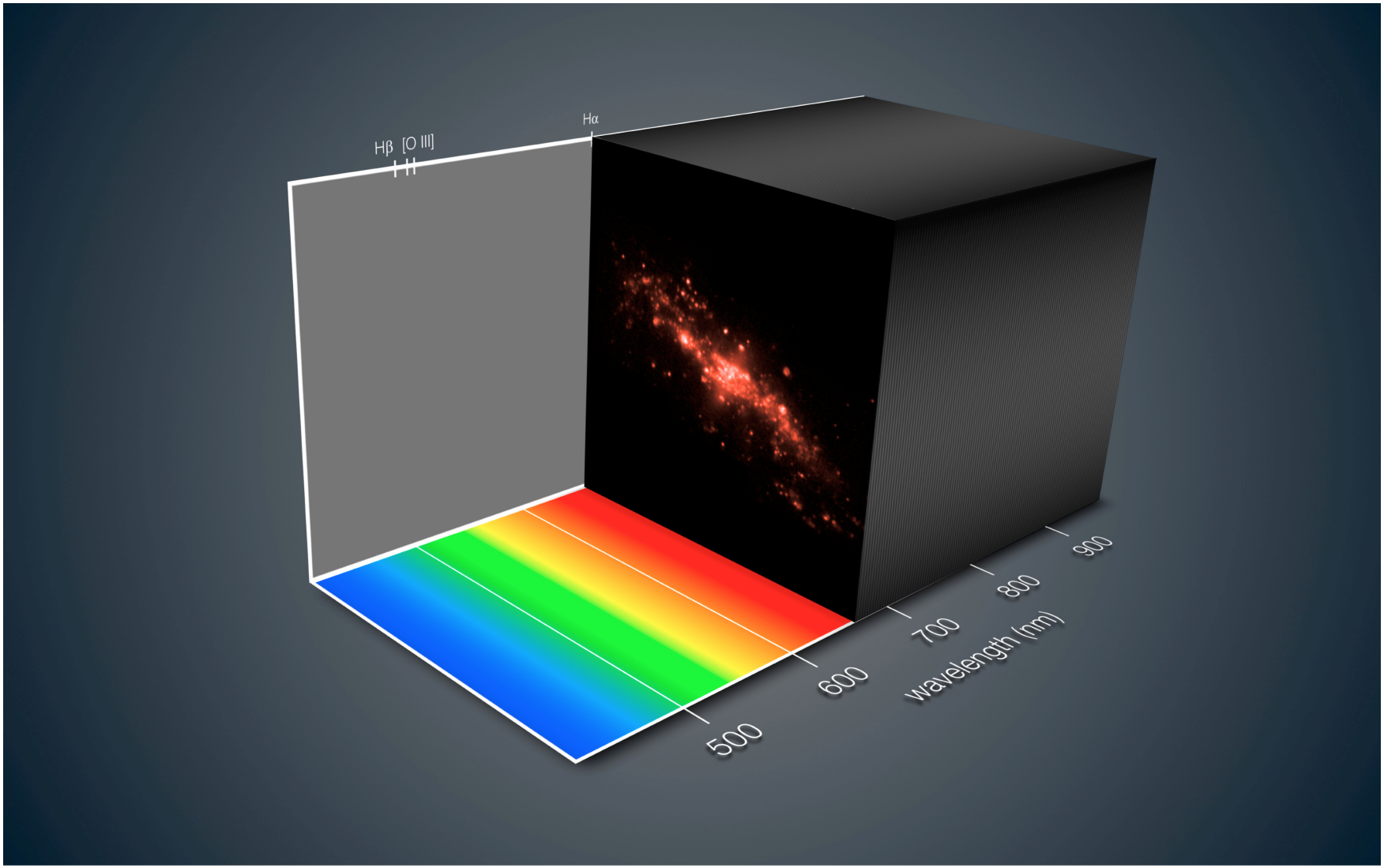
Me, now.


MUSE
4LGSU1
4LGSU4

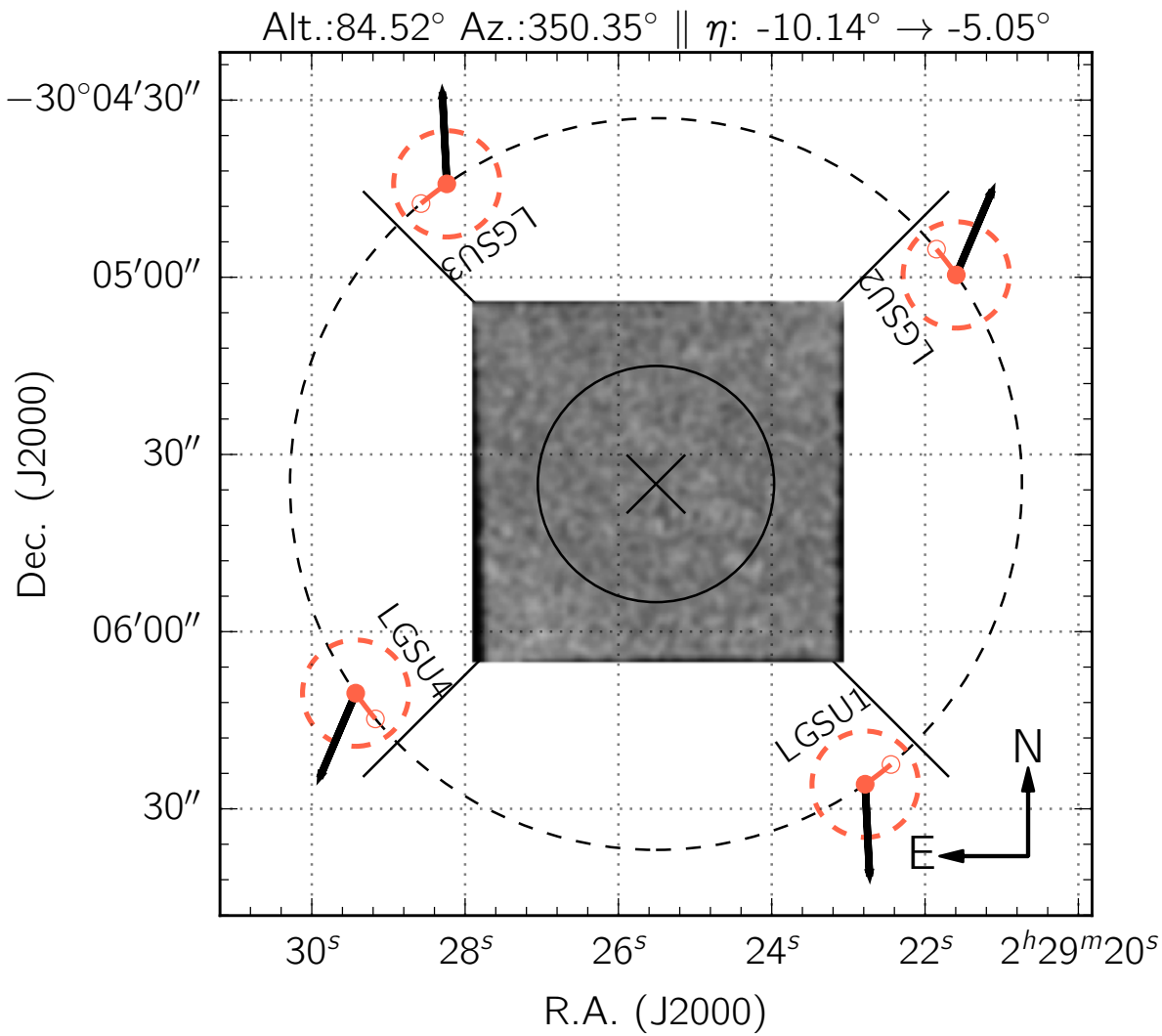
MUSE



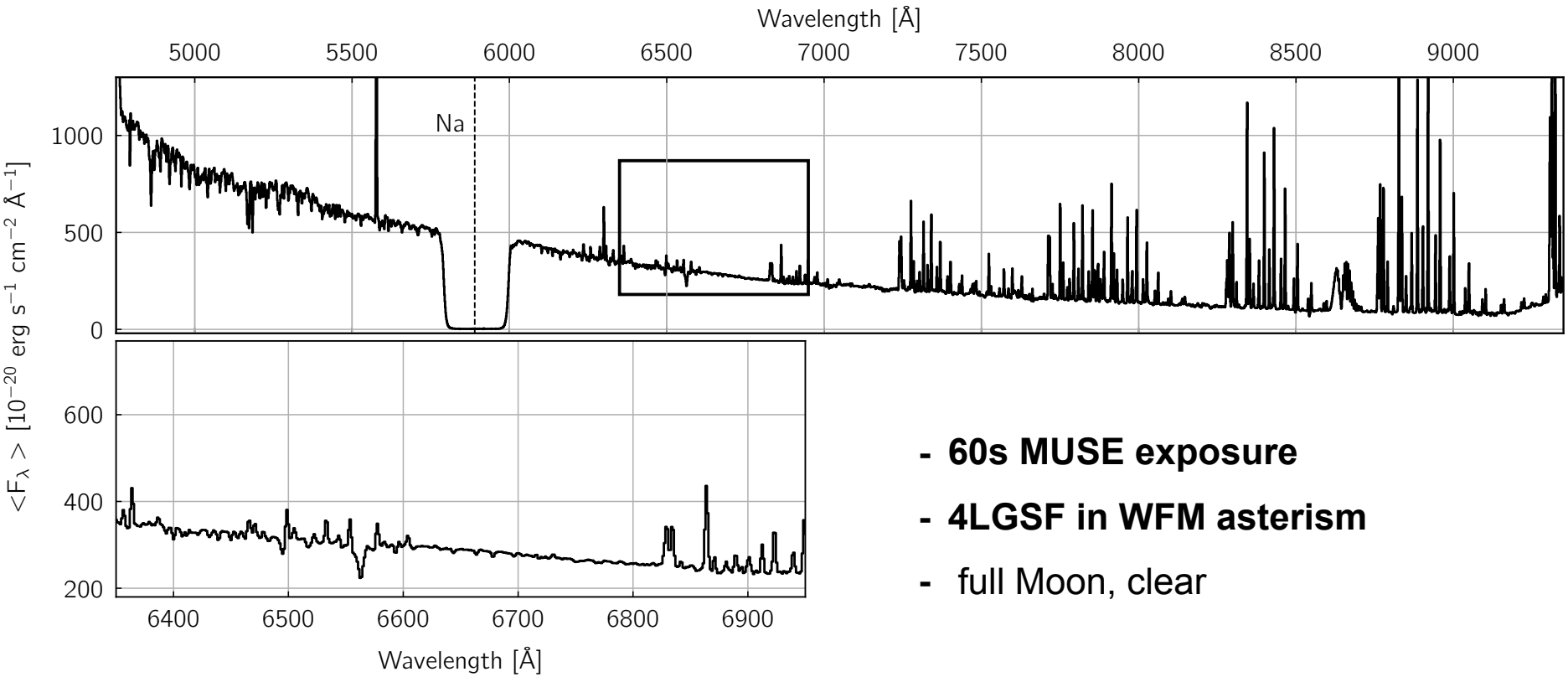
MUSE data



The MUSE-WFM asterism

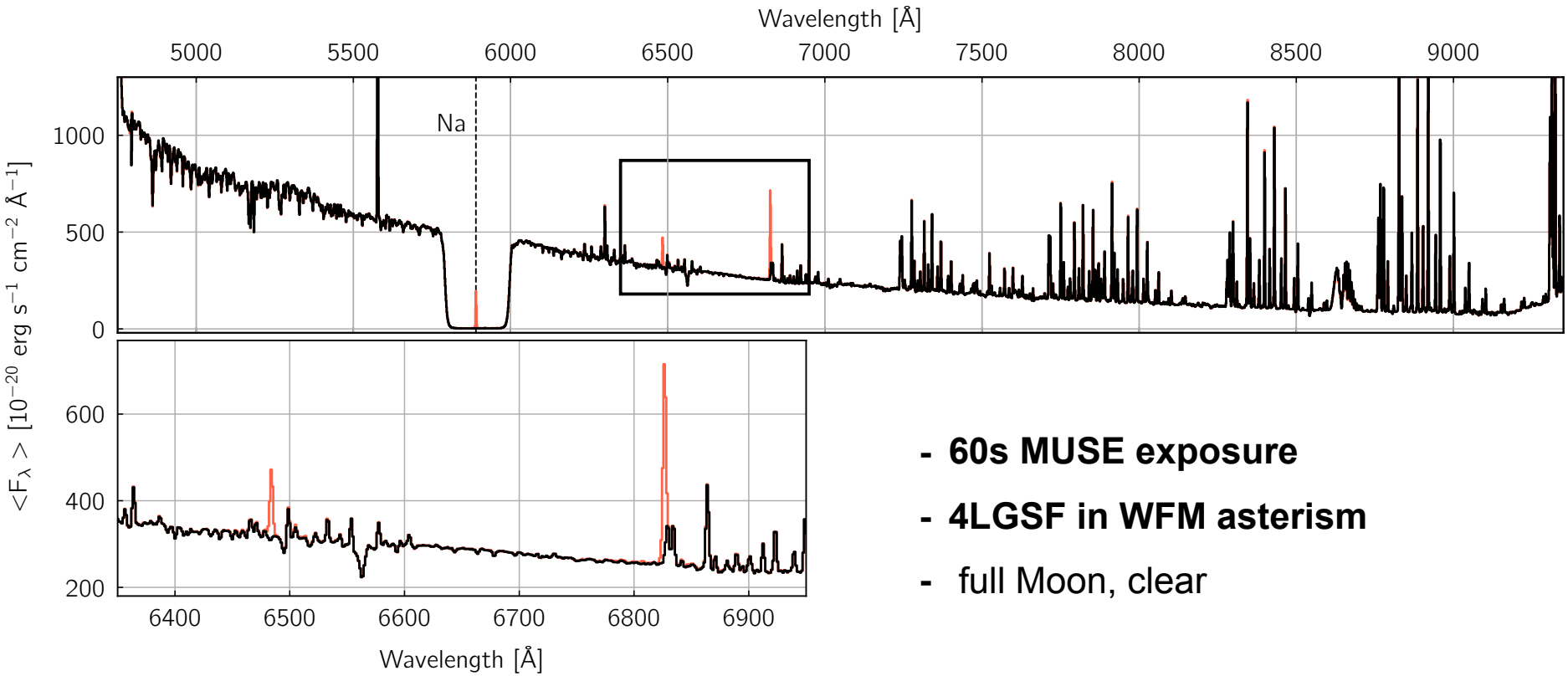


MUSE spectra with 4LGSF



- **60s MUSE exposure**
- **4LGSF in WFM asterism**
- full Moon, clear

MUSE spectra with 4LGSF



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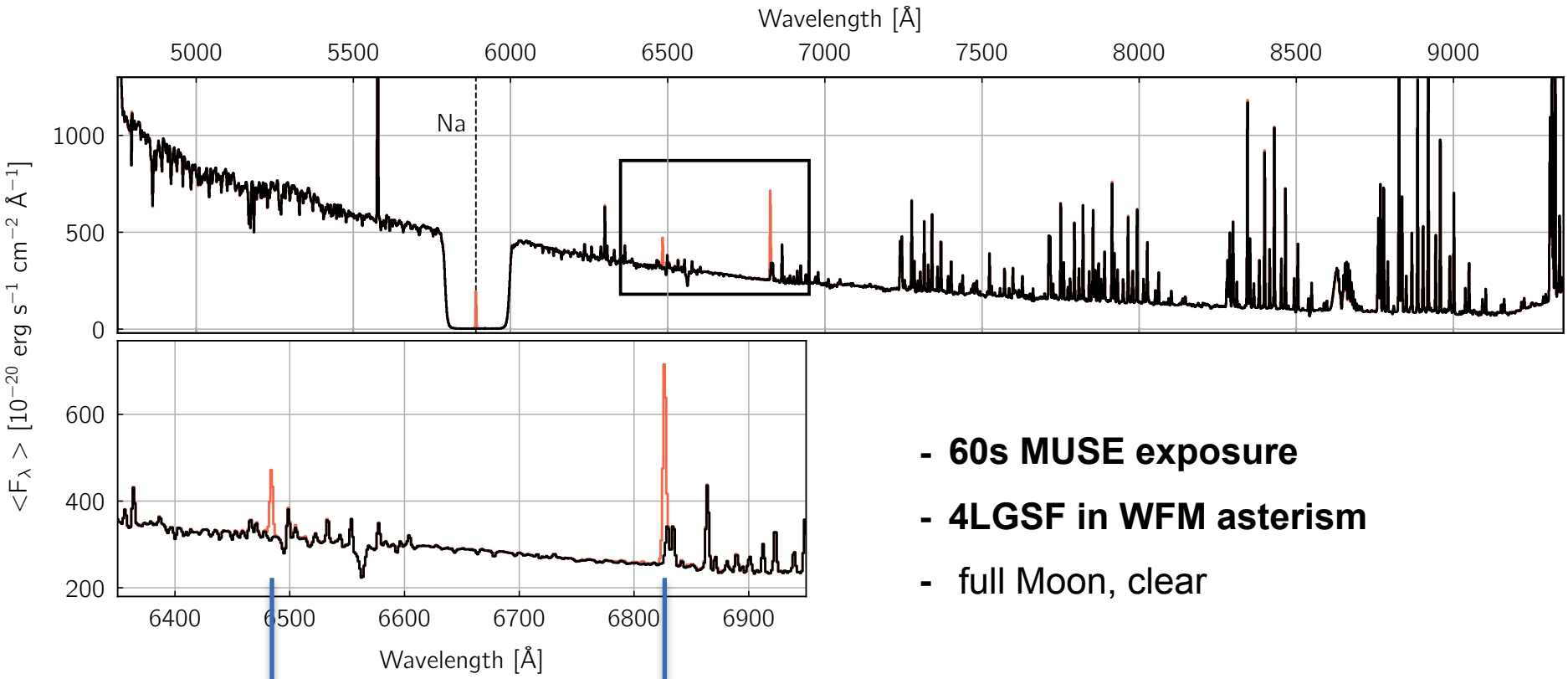
MUSE spectra with 4LGSF



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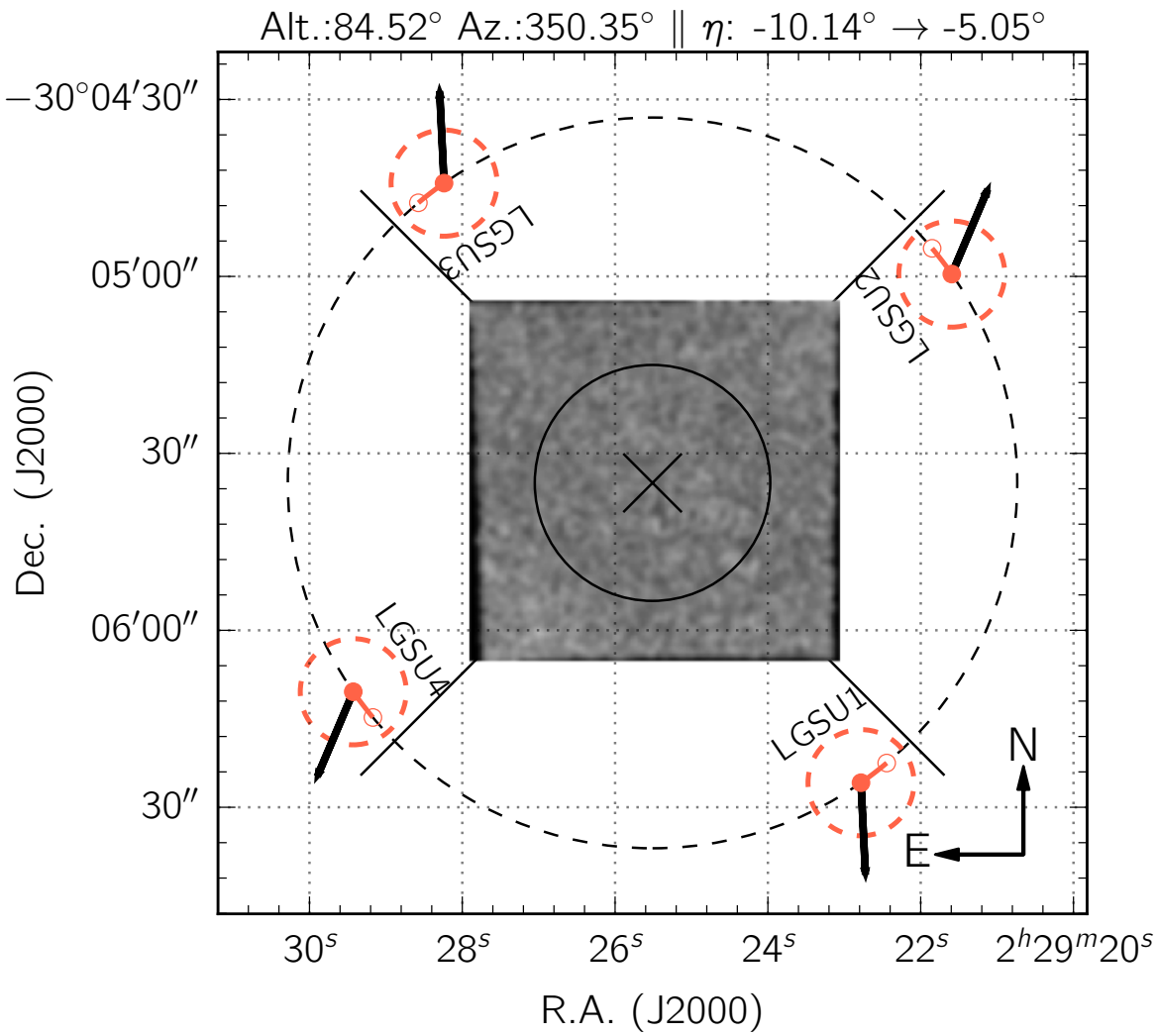
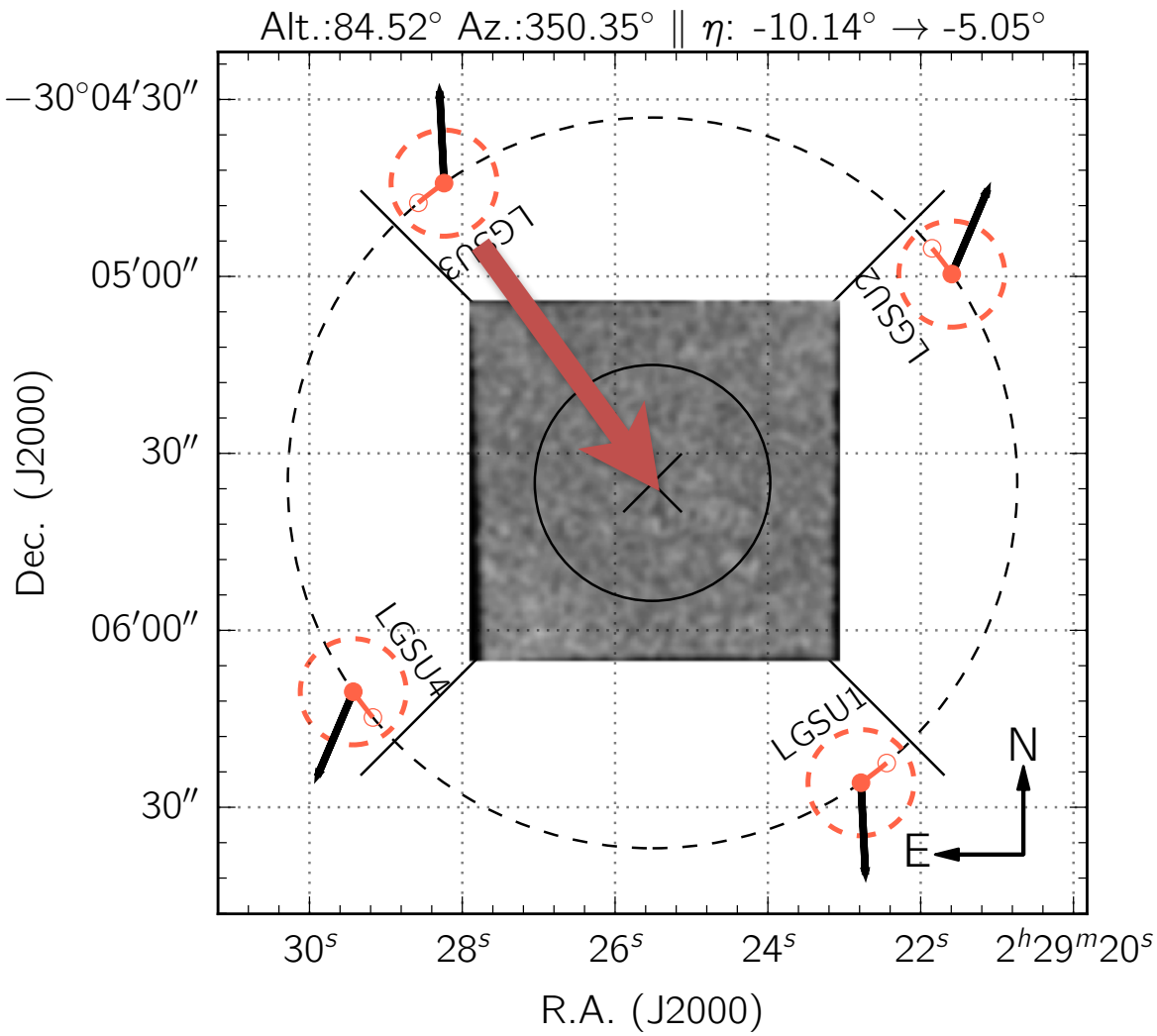
648 nm **683 nm**

The MUSE-WFM asterism

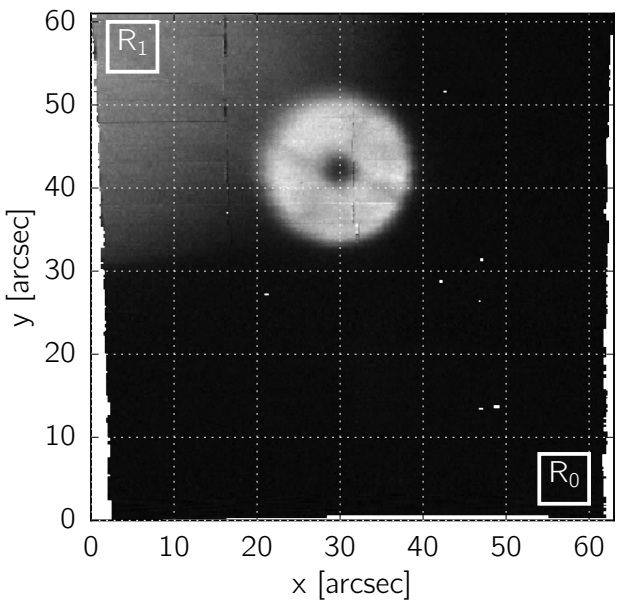


The MUSE-WFM asterism



UT4-MUSE view of UT4-4LGSUx

589 nm **648 nm** **683 nm**



?

UT4-MUSE view of UT4-4LGSUx

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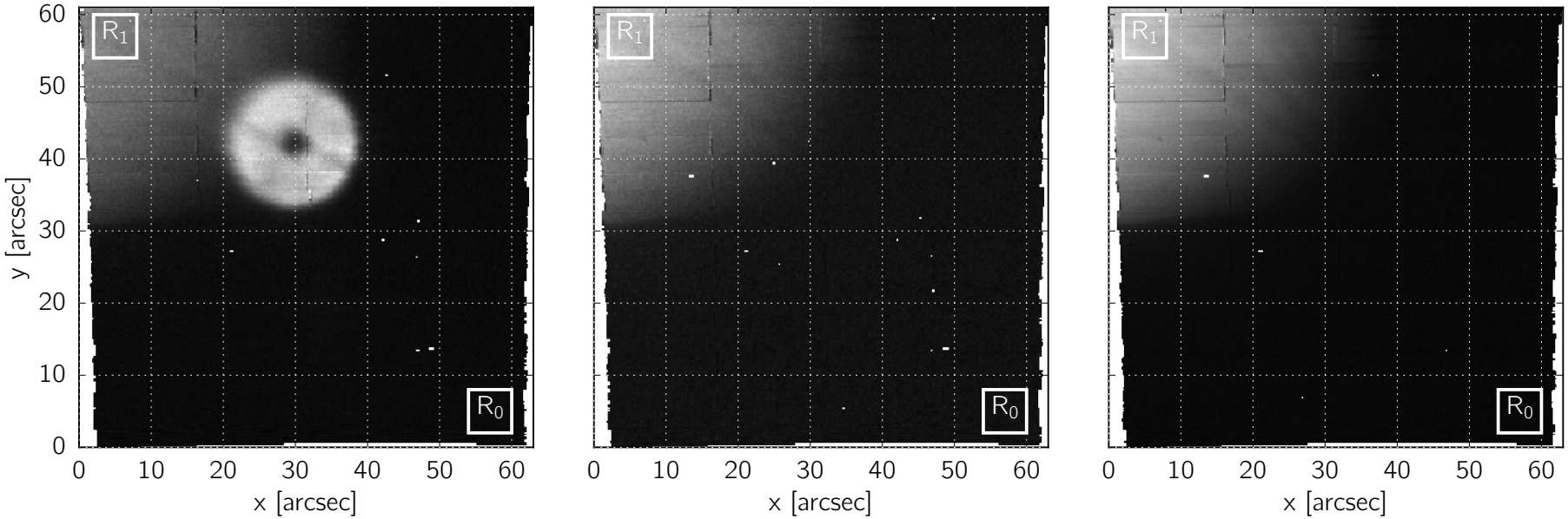
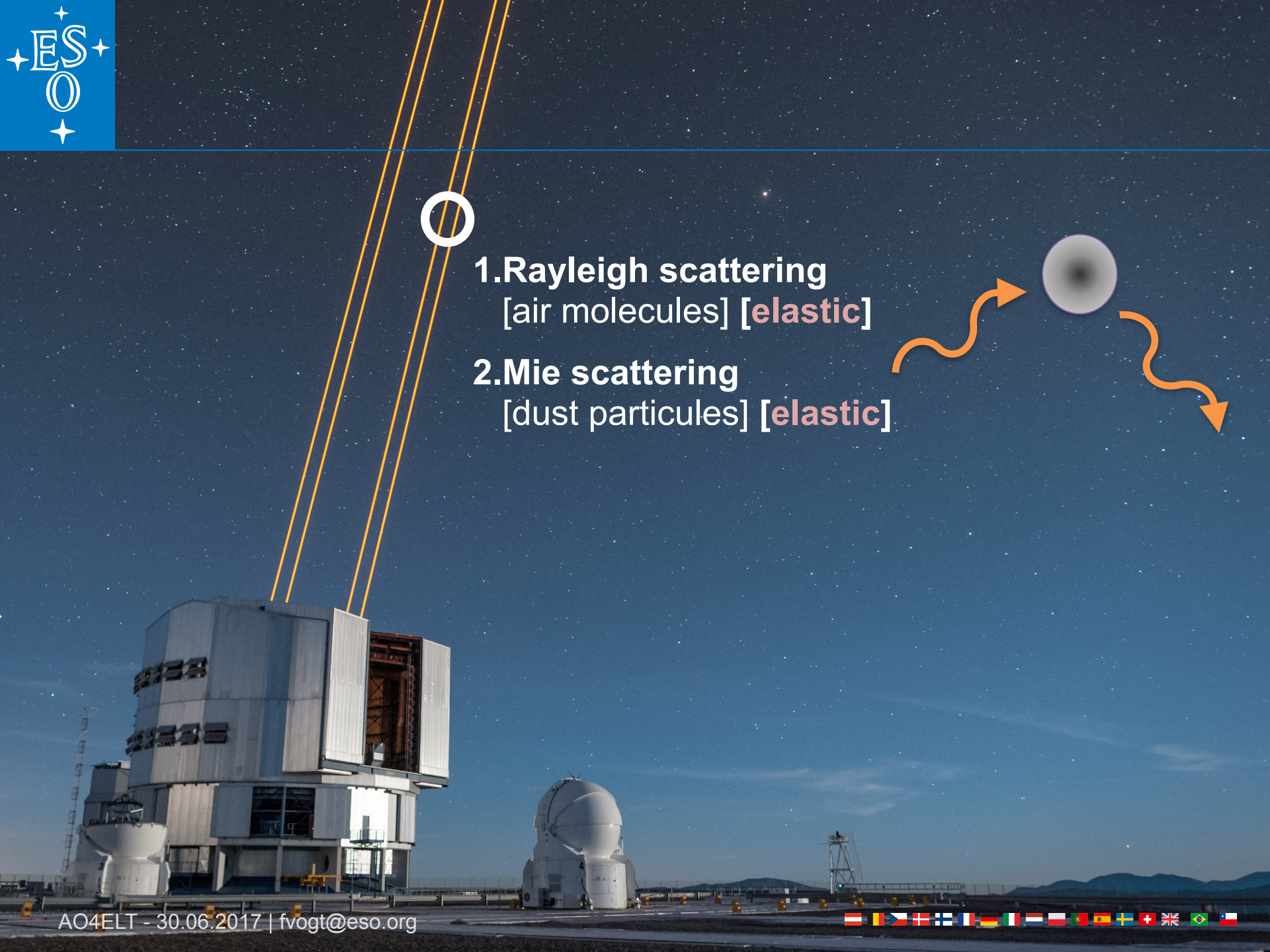
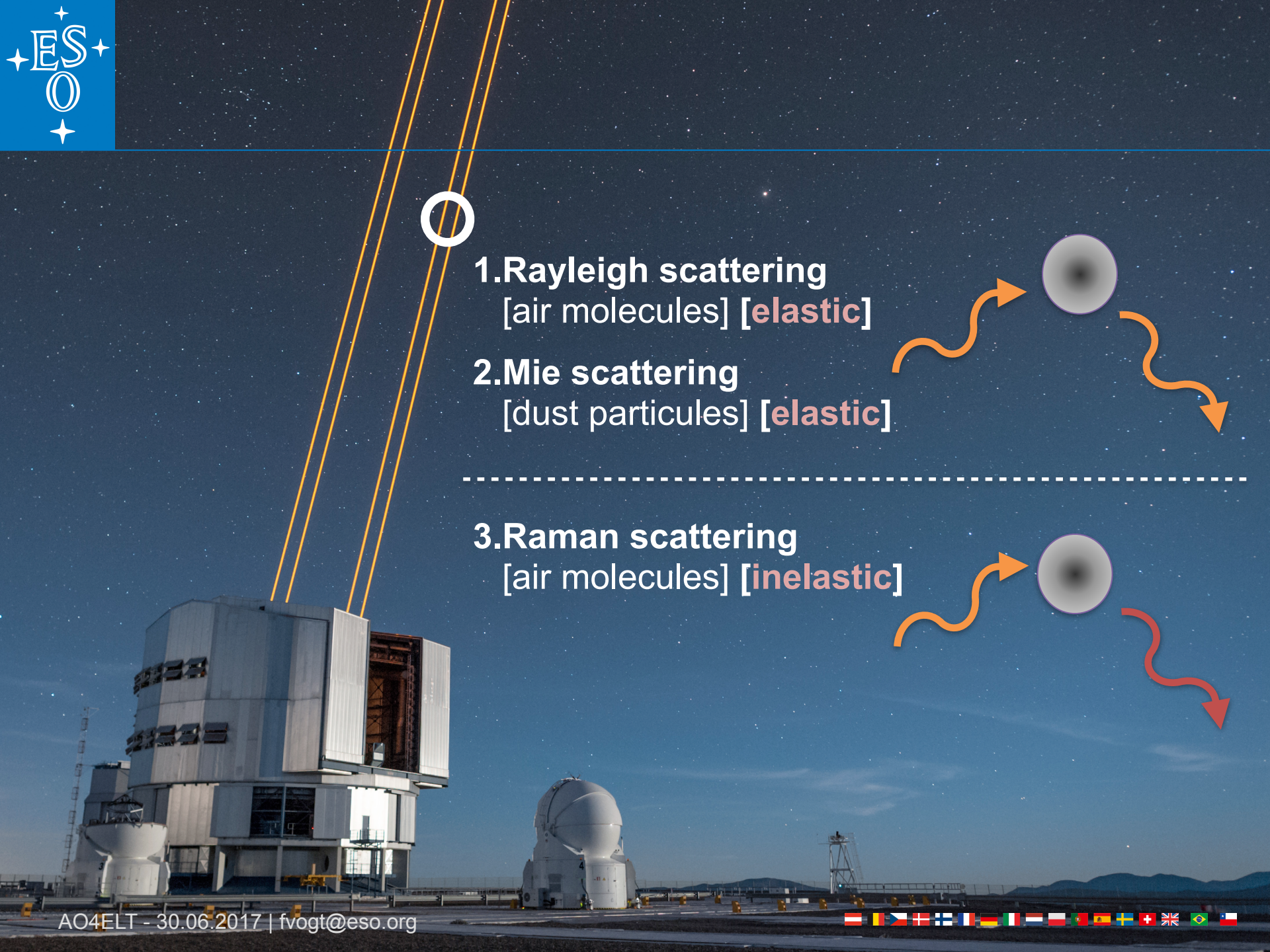



1.Rayleigh scattering
[air molecules] [elastic]
2.Mie scattering
[dust particules] [elastic]


1.Rayleigh scattering
[air molecules] [elastic]
2.Mie scattering
[dust particules] [elastic]
3.Raman scattering
[air molecules] [inelastic]

What theory predicts

Main components of "Atacama fresh desert air"

N_2: 78% | O_2: 21% | CO_2: 0.04% | H_2O: <1% ? | CH_4: 0.0002%

What theory predicts

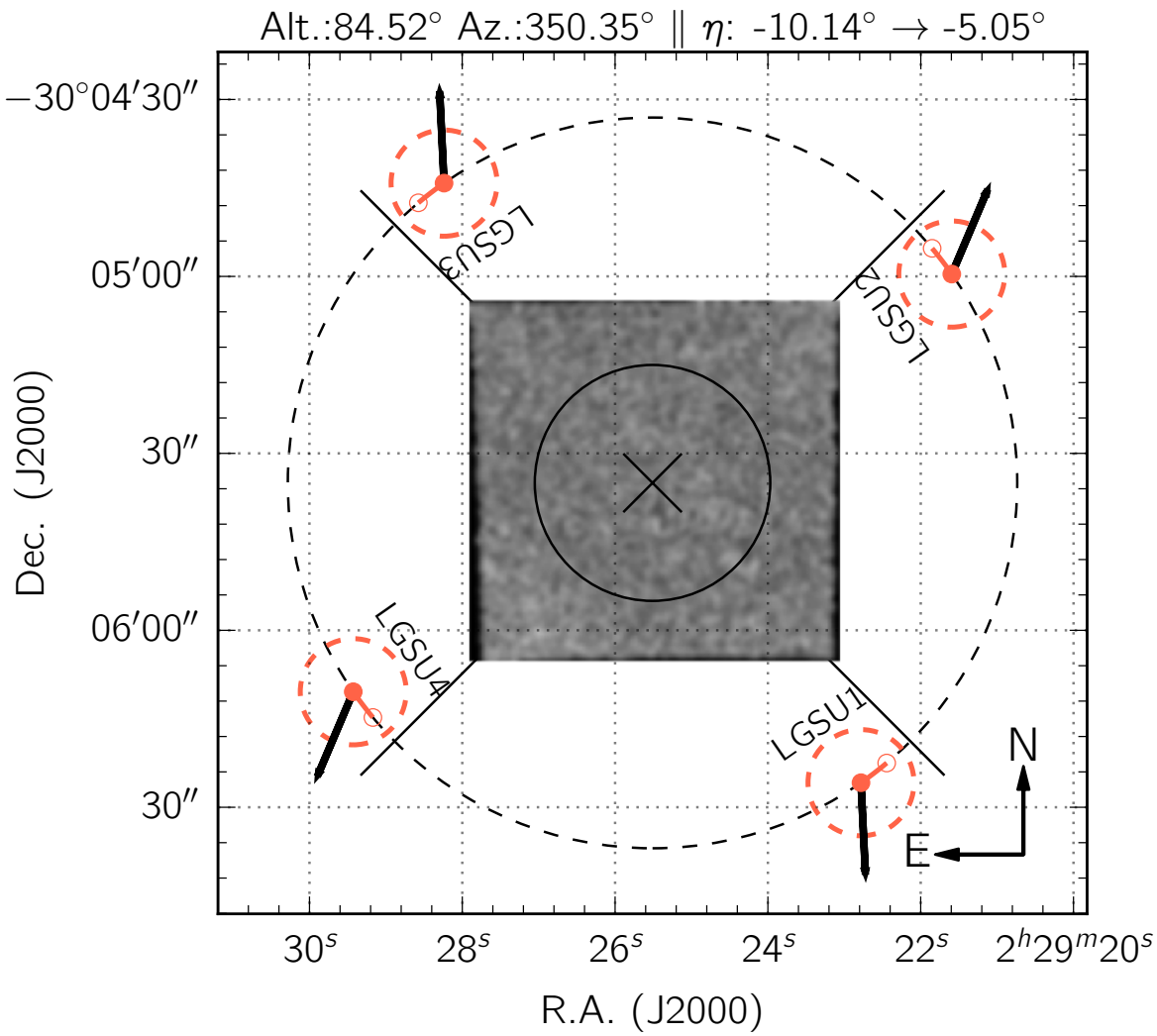
Main components of "Atacama fresh desert air"

N_2: 78% | O_2: 21% **CO_2: 0.04% | H_2O: <1% ? | CH_4: 0.0002%**

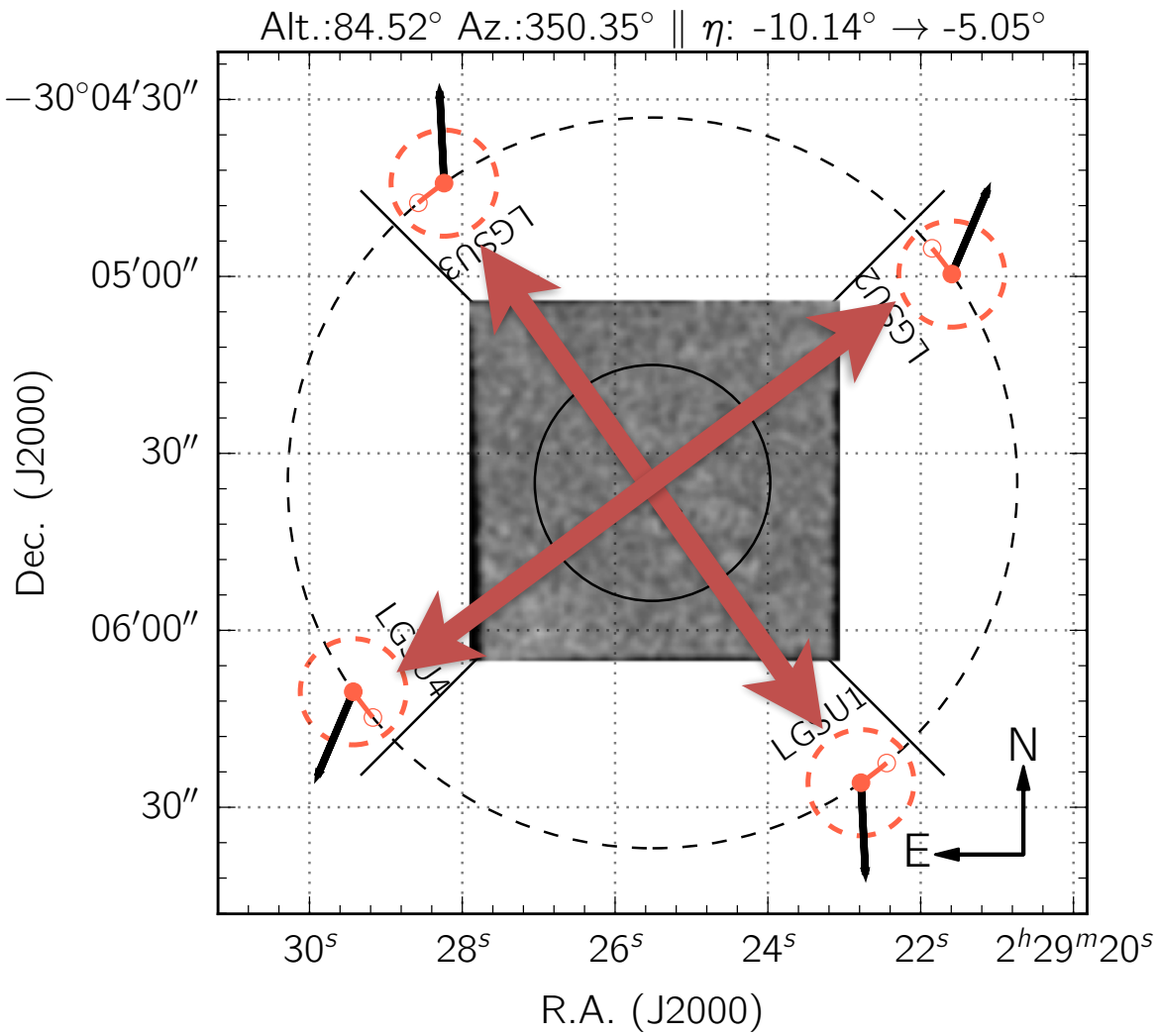
Raman line	λ_{4LGSF}	CO_2	CO_2	$O_2(\nu_{1\leftarrow 0})$	$N_2(\nu_{1\leftarrow 0})$	CH_4	$O_2(\nu_{2\leftarrow 0})$	H_2O	$N_2(\nu_{2\leftarrow 0})$
Raman shift $[cm^{-1}]$	–	1285.8	1388.1	1556.4	2330.7	2914.2	3089.2	3651.7	4631.2
λ_{obs} [Å]	5889.959	6372.57	6414.39	6484.39	6827.17	7110.43	7200.02	7503.93	8099.23
Flux $[10^{-20}\,erg\,s^{-1}\,cm^{-2}\,W^{-1}]$									

What about the other lines ?

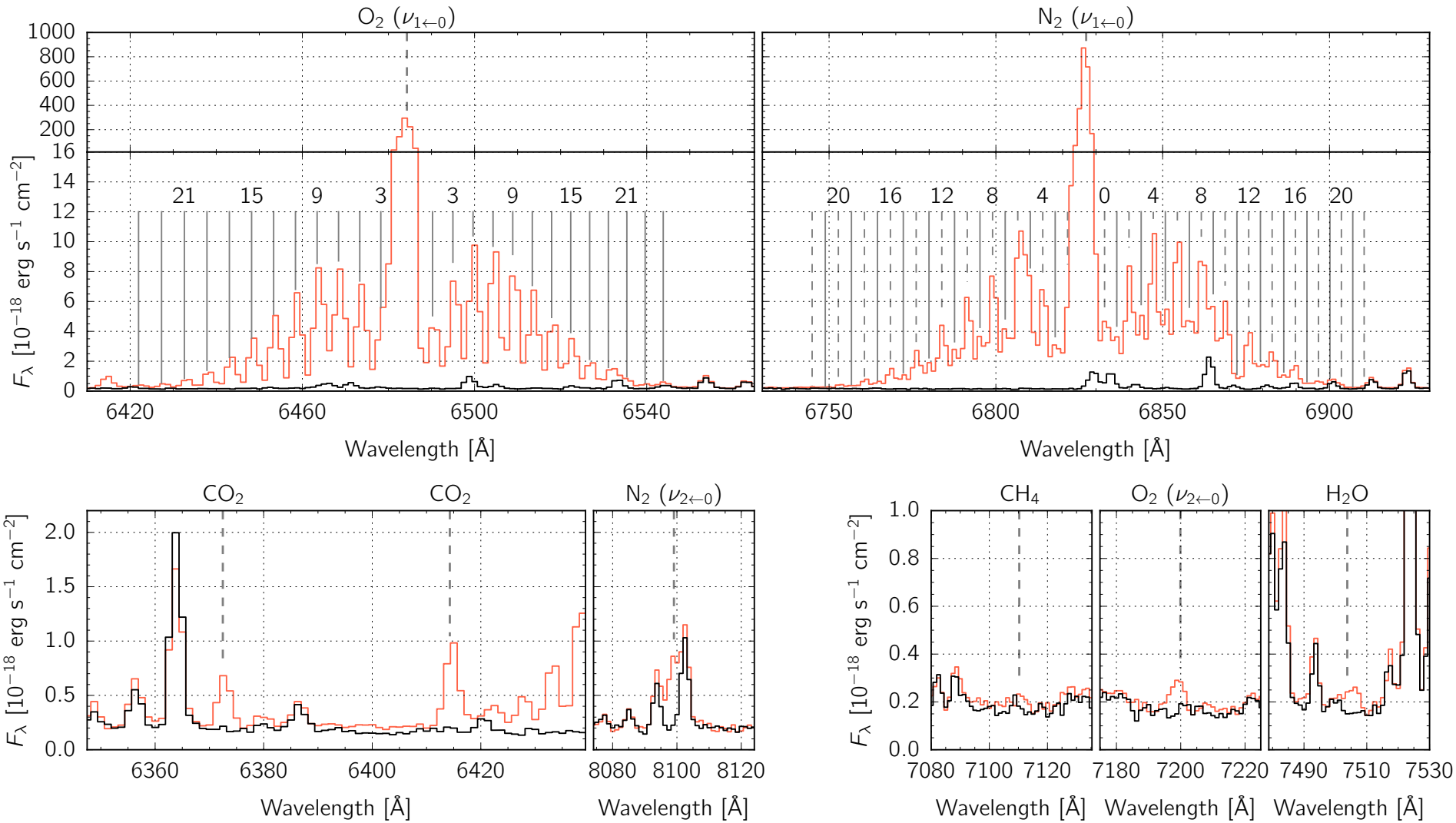
The MUSE-WFM asterism



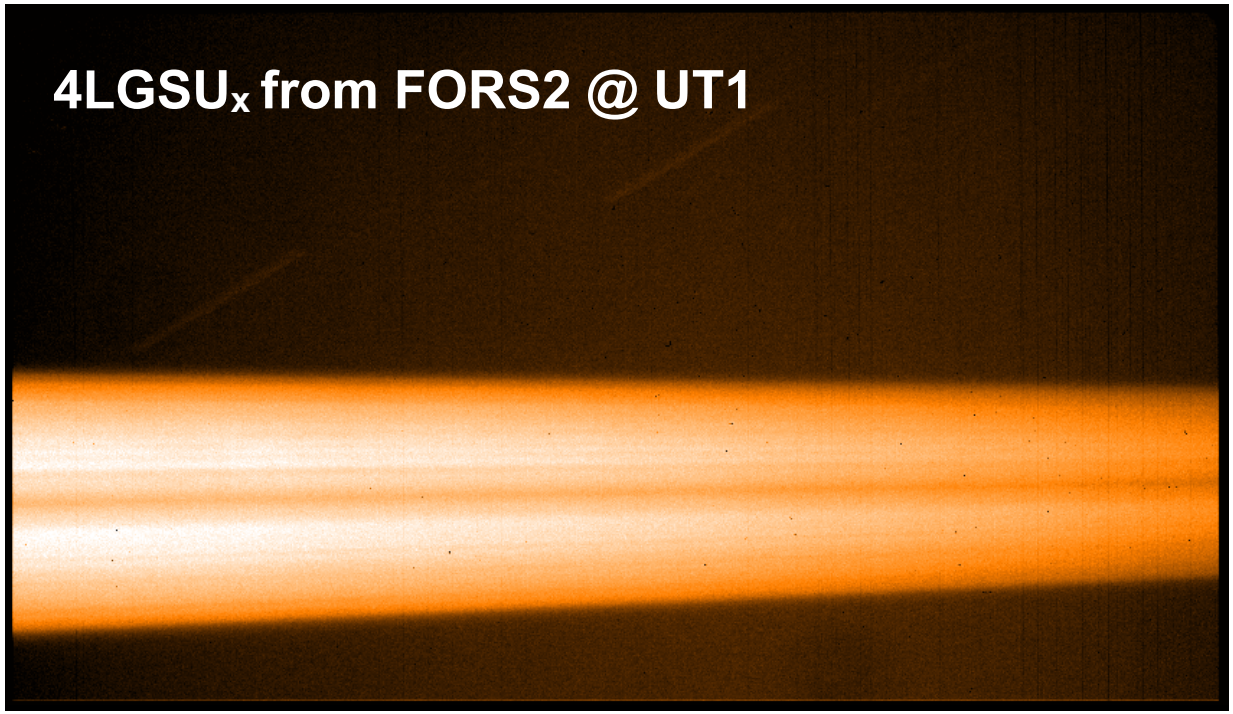
The MUSE-WFM asterism



UT4-MUSE view of UT4-4LGSU$_{1+2+3+4}$



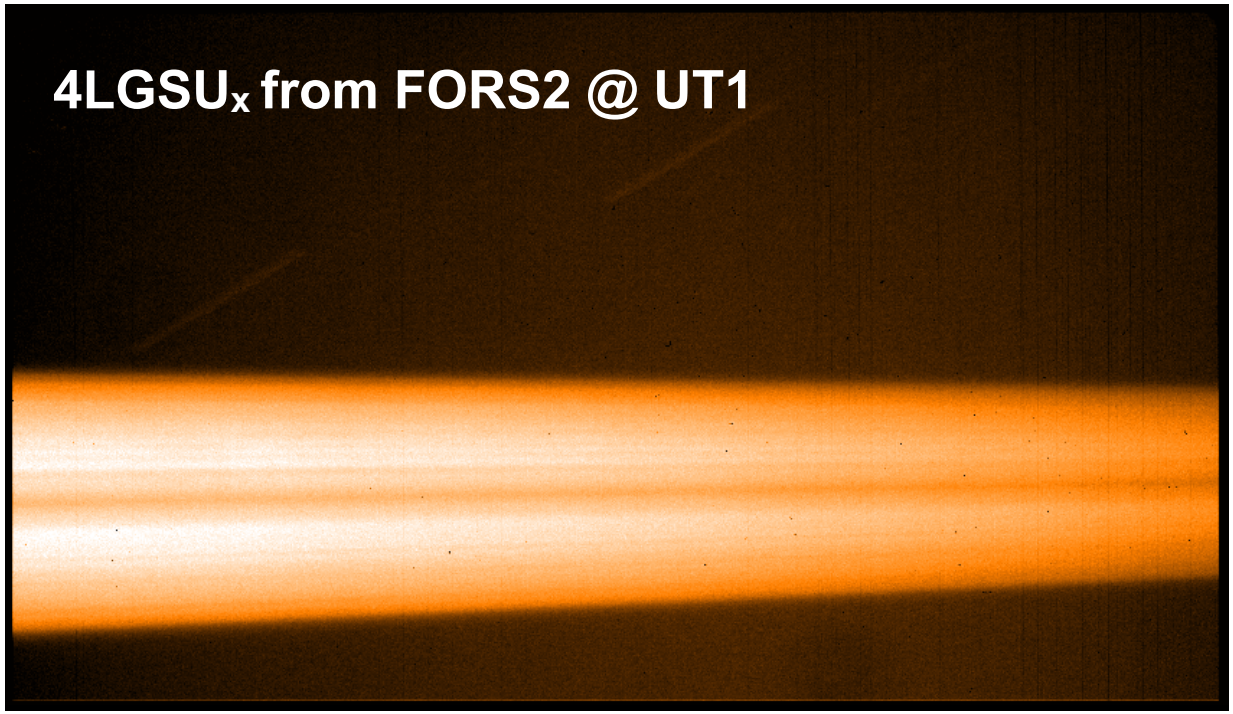
How bad is it ?



How bad is it ?

Raman lines:

- **Complex :-(**
- **Faint :-)**



Raman line	λ_{4LGSF}	CO_2	CO_2	$O_2(\nu_{1\leftarrow 0})$	$N_2(\nu_{1\leftarrow 0})$	CH_4	$O_2(\nu_{2\leftarrow 0})$	H_2O	$N_2(\nu_{2\leftarrow 0})$
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λ_{obs} [Å]	5889.959	6372.57	6414.39	6484.39	6827.17	7110.43	7200.02	7503.93	8099.23
Flux $[10^{-20}\,erg\,s^{-1}\,cm^{-2}\,W^{-1}]$	$1.9 \cdot 10^7$	11.3	18.9	$6.8 \cdot 10^3$	$2.0 \cdot 10^4$	$\lesssim 1.1$	3.2	2.7	16.1

Impact of Raman scattering

- additional emission lines →
- complex & extended structures →
- redshifted by 48nm - 220 nm →

Impact of Raman scattering

- additional emission lines → impacts spectrographs more
- complex & extended structures → tough to clean a posteriori
- redshifted by 48nm - 220 nm → can’t be fixed with a notch filter

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"Raman" laser collisions !

LGS + optical instrument !

“Raman” laser collisions

Summary for UT1

The Laser Traffic Control System (LTCS) helps to avoid your observations from being affected by laser emission. This may happen when your telescope crosses the laser beam. The LTCS provides a warning when your observations may be affected.

Last updated: 3 Apr 2015 04:41:59

LTCS System Health	HEALTHY	Shows LTCS system health. If System is DOWN, no lasing should be occurring (i.e. observe normally). If system is HEALTHY, observe other fields for status as noted in descriptions.
URL State	OK	Shows the state of the UT1 URL that provides information to the LTCS. If it is not OK with green background the observations on this telescope are not protected from the laser.
Override State	NO	Shows if the laser impacted flag, FOV and data logging flag are overridden or not.
Laser Sensitive	YES	Shows if the UT1 observation is laser sensitive. This flag will be NO when the telescope is moving to a new target. If it is NO during the exposure time, the observation will not be protected from the laser.

CURRENT LASER IMPACT STATUS

Messages (Alarms) (Warnings) :

Collision with the UT4 laser is predicted. Collision starts at 7:36:17 and finishes at 9:09:07. UT4 has PRIORITY.

Use the query tool below to check a new target for possible laser impact.

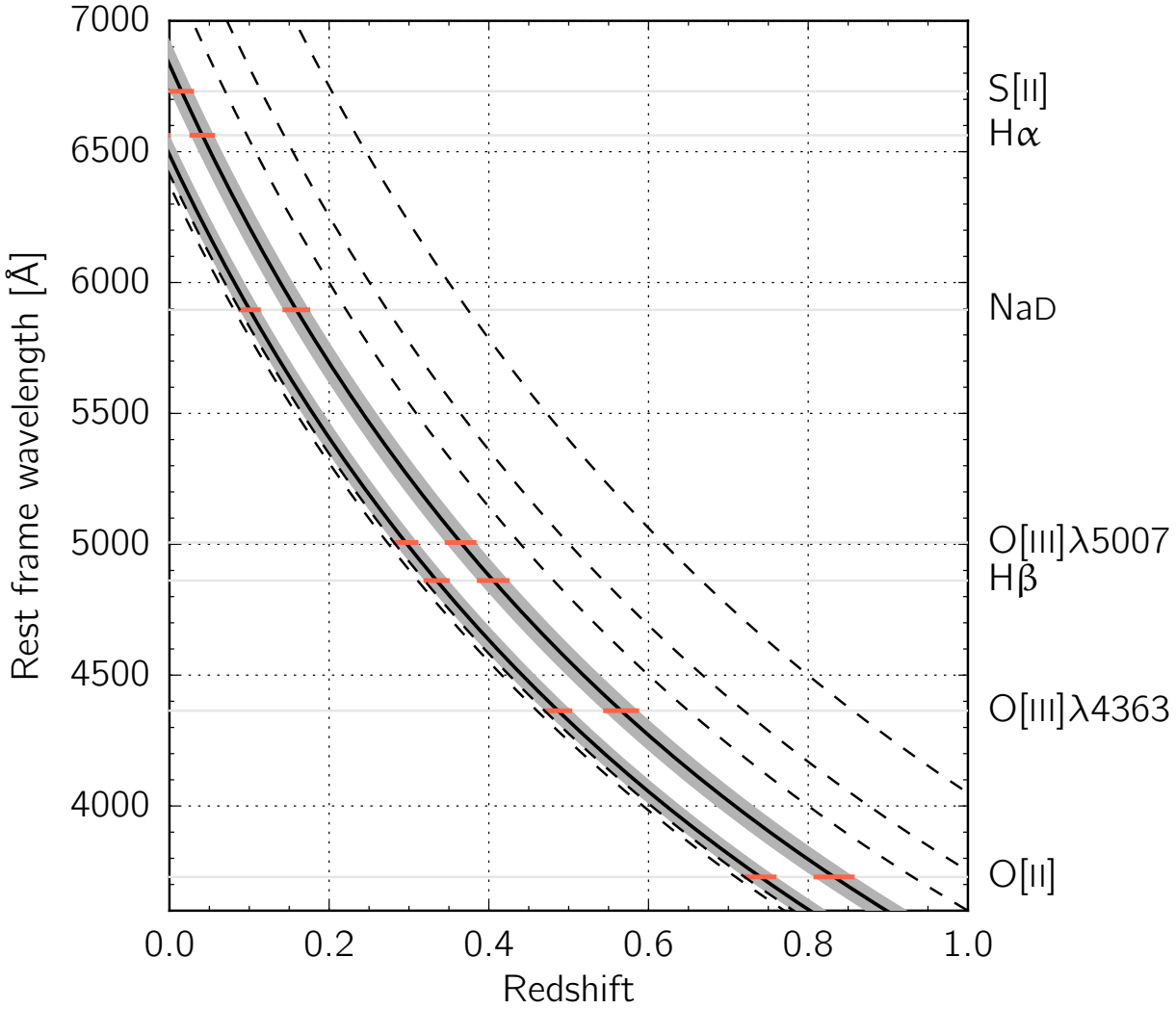
Query for new target | Override values

LTCS Main Page
Status & Alarms Summary
Configuration
Query Tool
Telescope Status

Original version from: CARA, W.M. Keck Observatory.

Amico et al. (2015)

Impact for targets at higher z



Take-home messages:

Rayleigh scattering $\Leftrightarrow$ Raman scattering

Notch filter $\neq$ Solution

Raman scattering $\propto P_{\mathrm{LGS}}$

$$\lambda_{\mathrm{Raman}} = f(\lambda_{\mathrm{LGS}})$$

"Raman" **laser collisions**

LGS + optical instrument

Detection and Implications of

Laser-Induced Raman Scattering at Astronomical Observatories

Frédéric Vogt[1] - ESO Fellow - **fvogt@eso.org**

Physical Review X: 7.021044 | arXiv:1706.07050

with
D. Bonaccini Calia[2], W. Hackenberg[2], C. Opitom[1], M. Comin[2], L. Schmidtobreik[1], J. Smoker[1], I. Blanchard[1], M. Espinoza Contreras[1], I. Aranda[1], J. Milli[1], Y. L. Jaffe[1], F. Selman[1], J. Kolb[1], P. Hibon[1], H. Kuntschner[2], and P.-Y. Madec[2]

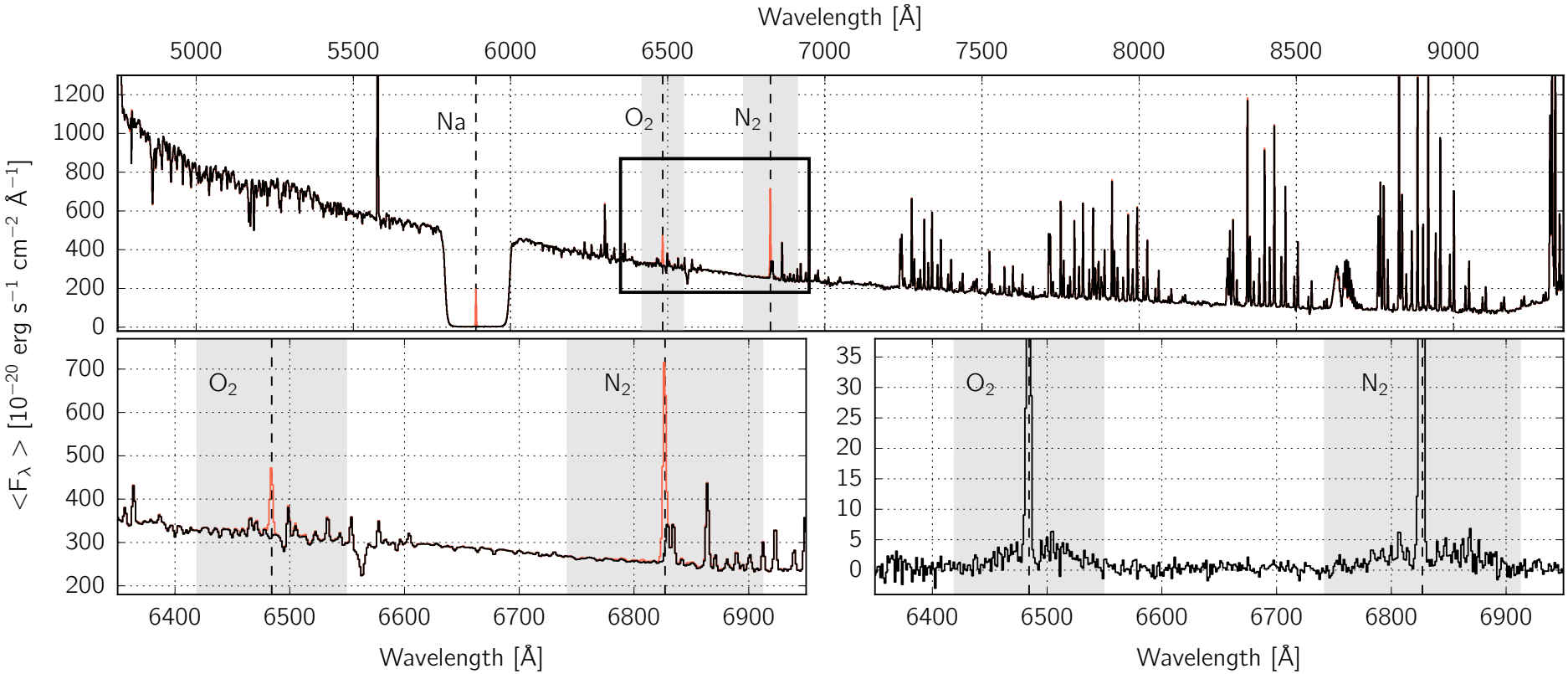
1. ESO, Chile. 2. ESO, Germany.

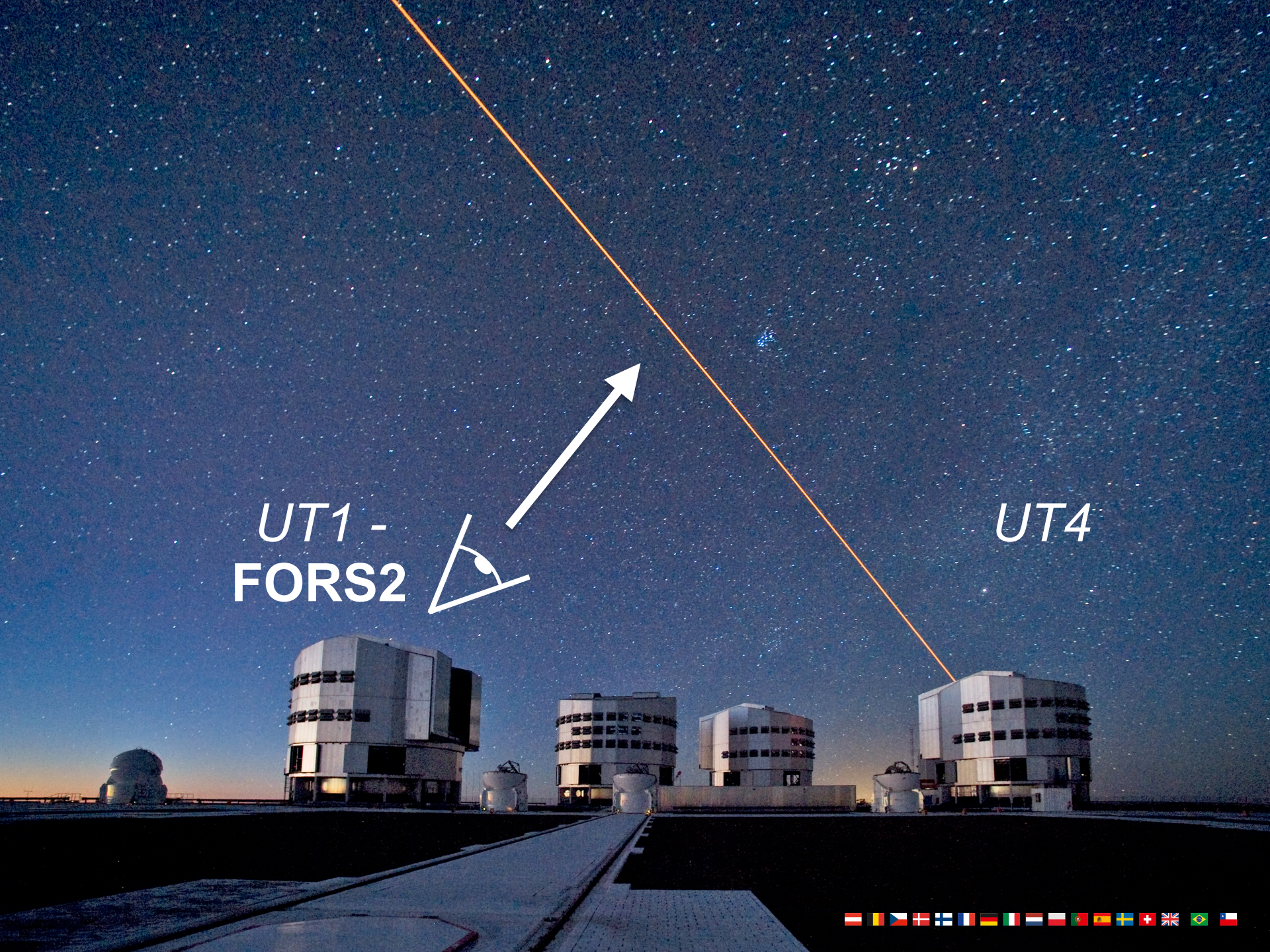
Laser wavelength dependant !

Table II. Wavelength of the main atmospheric, laser-induced Raman scattering lines as a function of the LGS exciting wavelength at different astronomical telescopes.

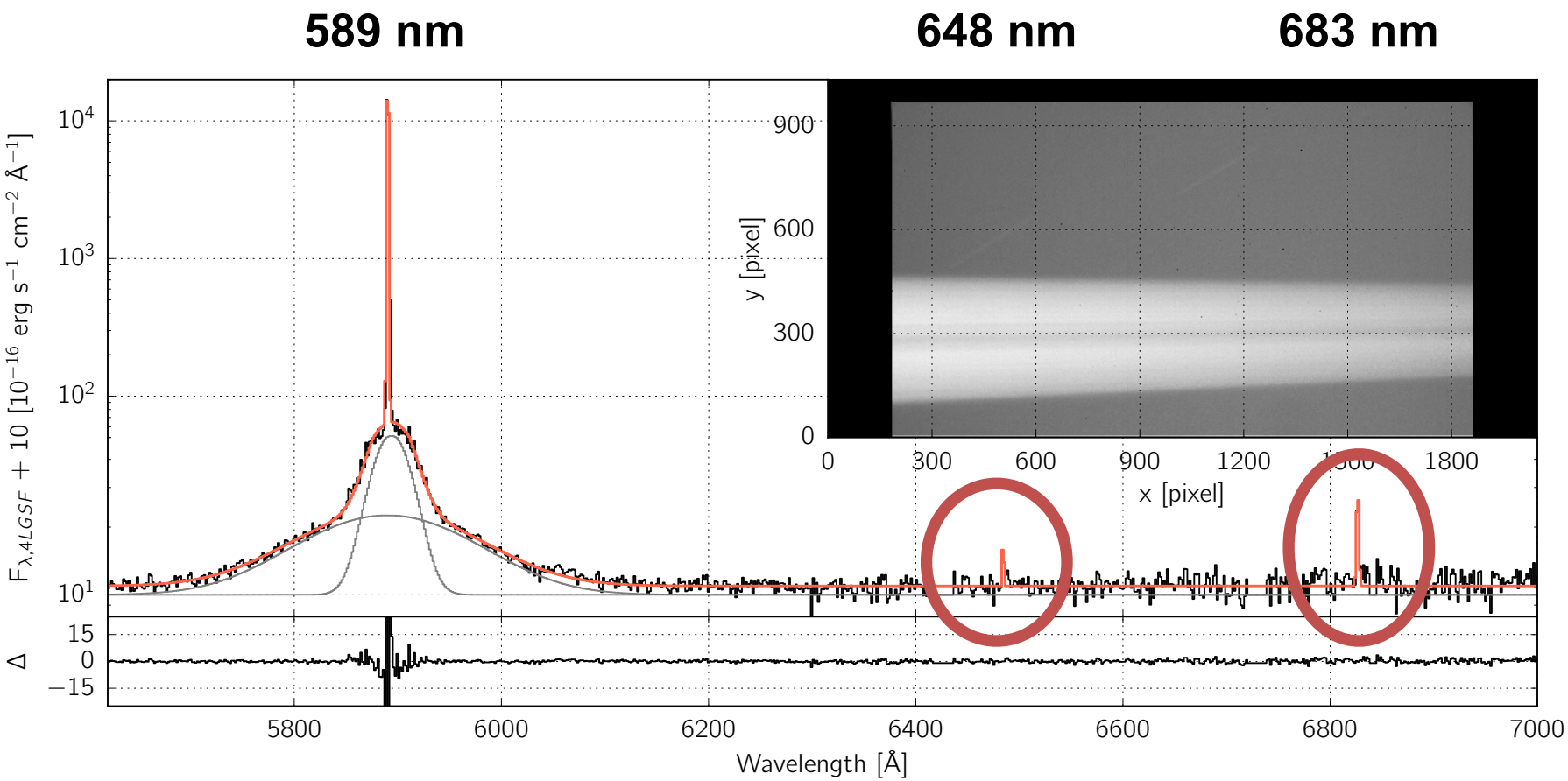
Telescope	LGS system	λ_{LGS} [nm]	CO_2 [nm]	CO_2 [nm]	$O_2(\nu_{1\leftarrow 0})$ [nm]	$N_2(\nu_{1\leftarrow 0})$ [nm]	CH_4 [nm]	$O_2(\nu_{2\leftarrow 0})$ [nm]	H_2O [nm]	$N_2(\nu_{2\leftarrow 0})$ [nm]
Gemini North	ALTAIR [8, 9]									
Gemini South	GeMS [10–12]									
W. M. Keck	LGSAO [6, 7]									
Lijang 1.8-m Telescope	LGS-AOS [65]									
Shane 3-m Telescope	ShaneAO [66, 67]									
Subaru	AO188 [13, 14]	589	637	641	648	683	711	720	750	810
VLT (UT4)	4LGSF [16, 20]									
VLT (UT4)	PARLA [15]									
Thirty Meter Telescope	LGSF [68, 69]									
Giant Magellan Telescope	GMT AO [70]									
Extremely Large Telescope	ATLAS & MAORY [71–74]									
Large Binocular Telescope	ARGOS [75, 76]	532	571	574	580	607	630	637	660	706
William Hershel Telescope	GLAS [77]	515	552	555	560	585	606	612	634	676
Hale 5-m Telescope	PULSE [78]	355	372	373	376	387	396	399	408	425
Southern Astrophysical Research Telescope	SAM [79]									

MUSE spectra with 4LGSF in WFM

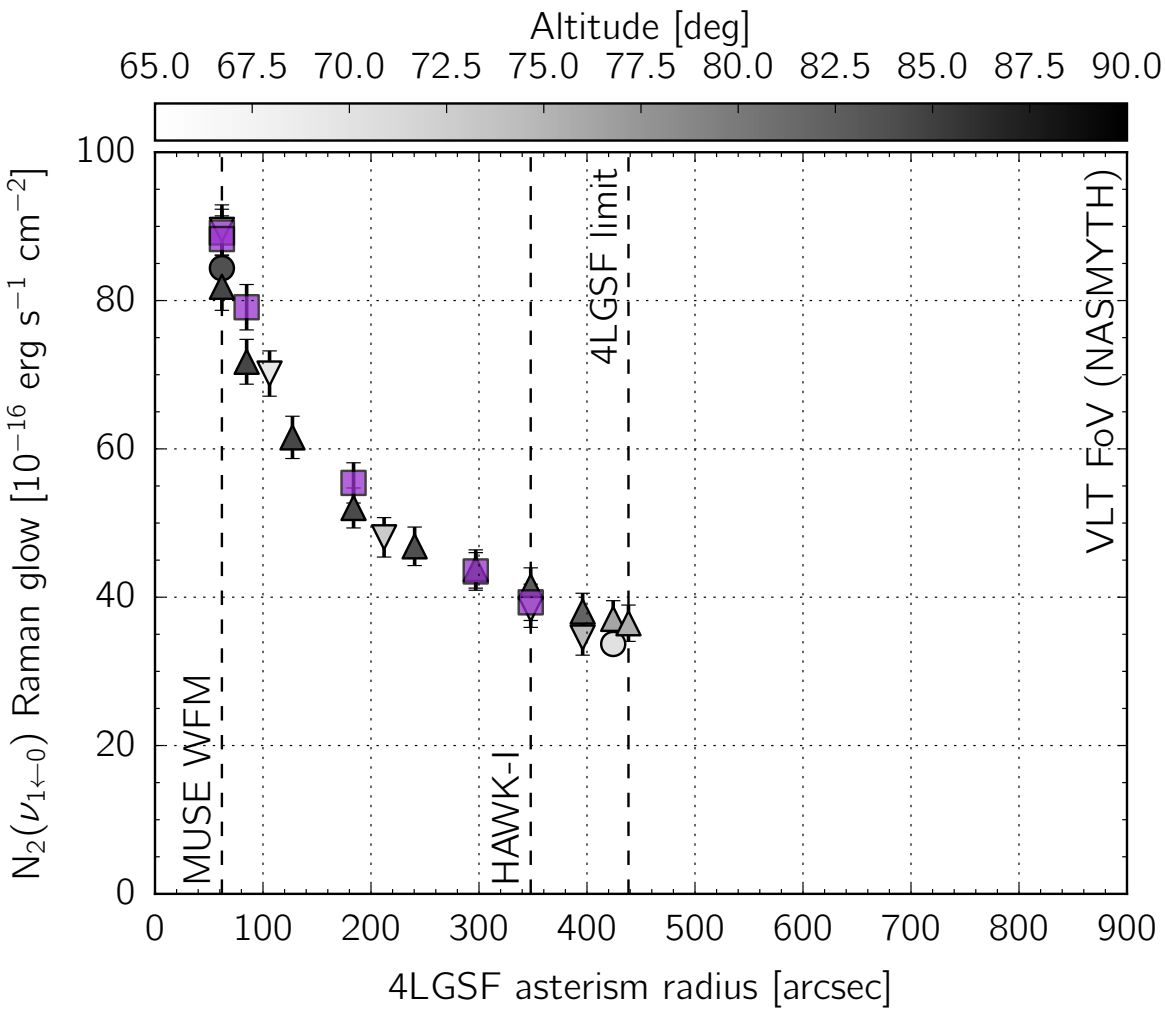



UT1 -
FORS2
UT4

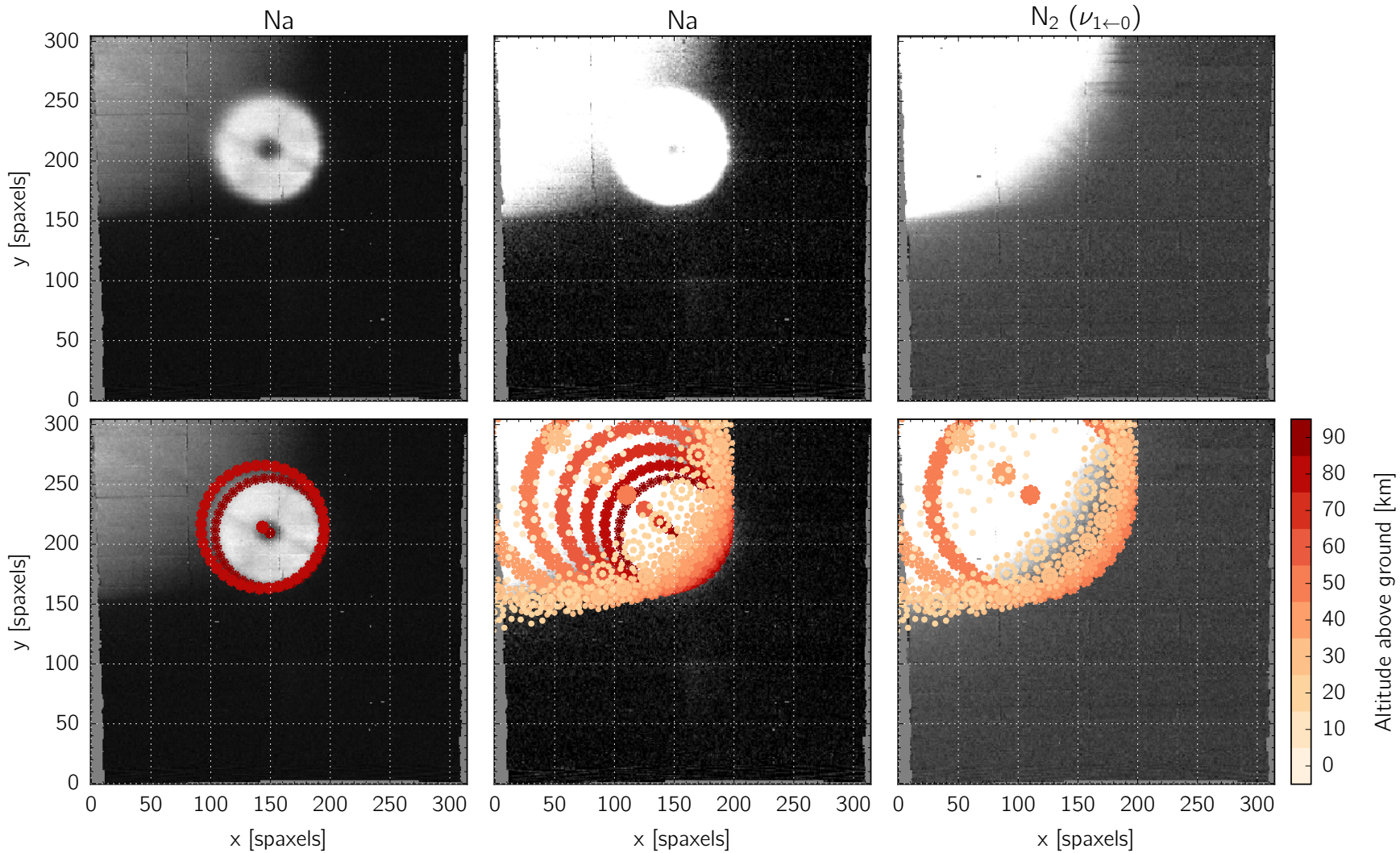
UT1-FORS2 view of UT4-4LGSUx



The MUSE case



Height of Raman emission



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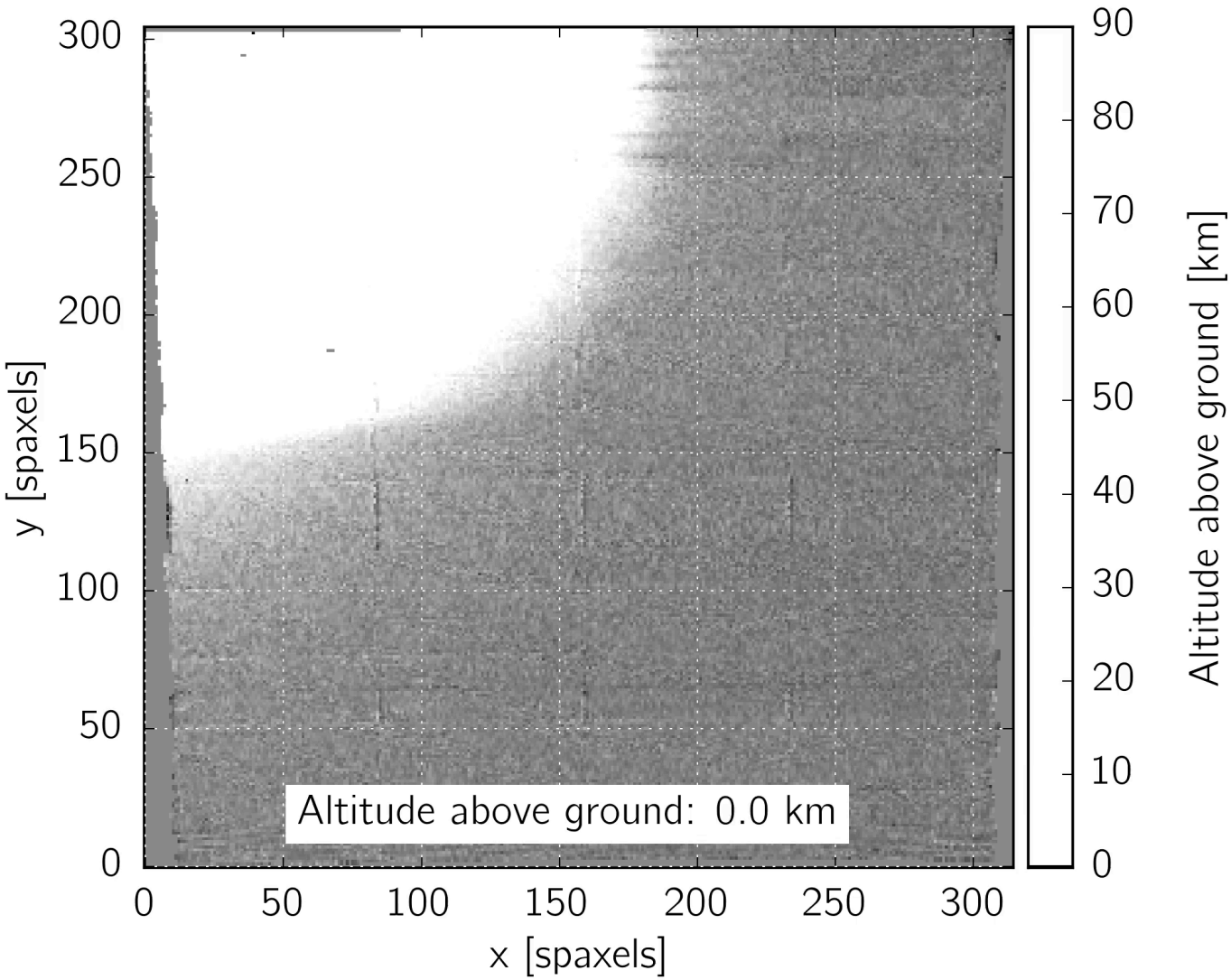
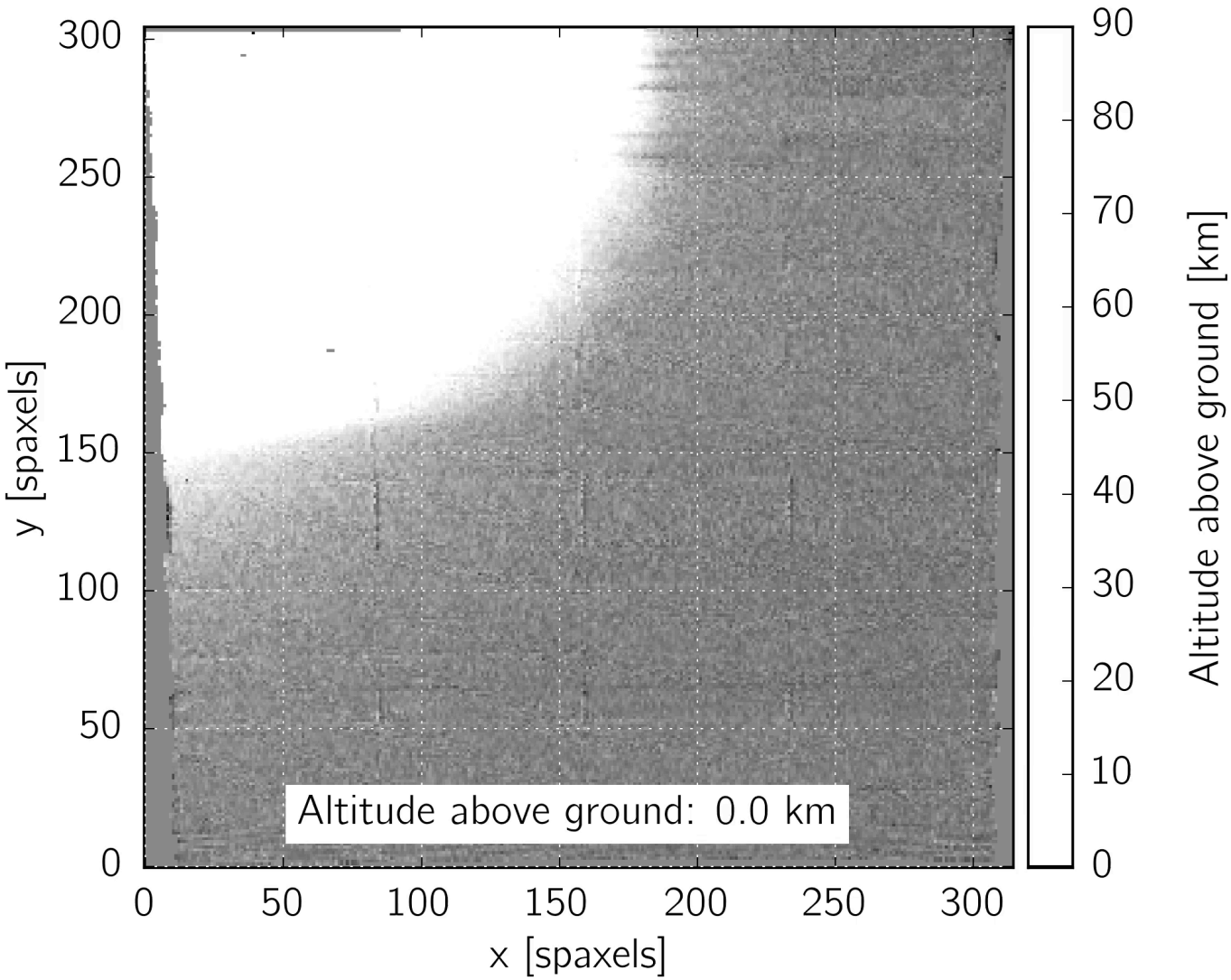
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