



ESO's Innovations in Astronomical Instrumentation

*Optical & IR Wavelengths; VLT-oriented
In no way a full compendium (due apologies)*

Innovation: A key tool in a worldwide race

- ESO VLT Instrumentation & associated R&D
 - ⇒ *Taper the ESO Community, a vibrant innovation source*
 - ⇒ *Partner with Industry, adapting available technologies*
 - ⇒ *In a worldwide 'coopetition' field*
- And, yes, it occasionally failed!



ESO Instrument Innovations

- **A new instrumentation paradigm**
- Embracing the detector revolution
- The science-optimized modes zoo
- Beating atmospheric turbulence with AO
- Conclusions

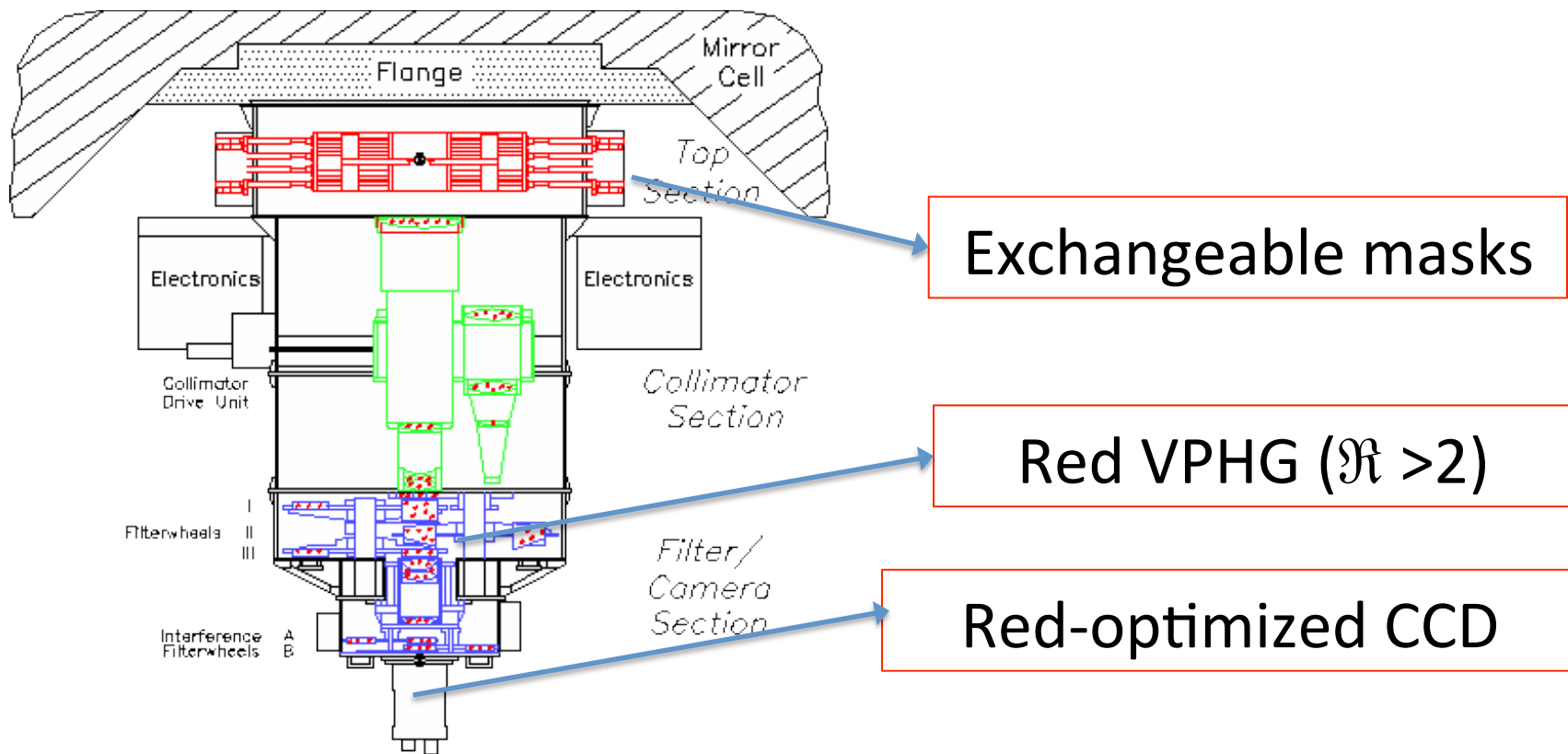
The VLT instrumentation paradigm

- An extensive observing package
(4 Telescopes/12 Instruments on standby)
- Keeping up with evolving science priorities
(through instrument upgrades & replacement)



Instrument upgrade rolling plan

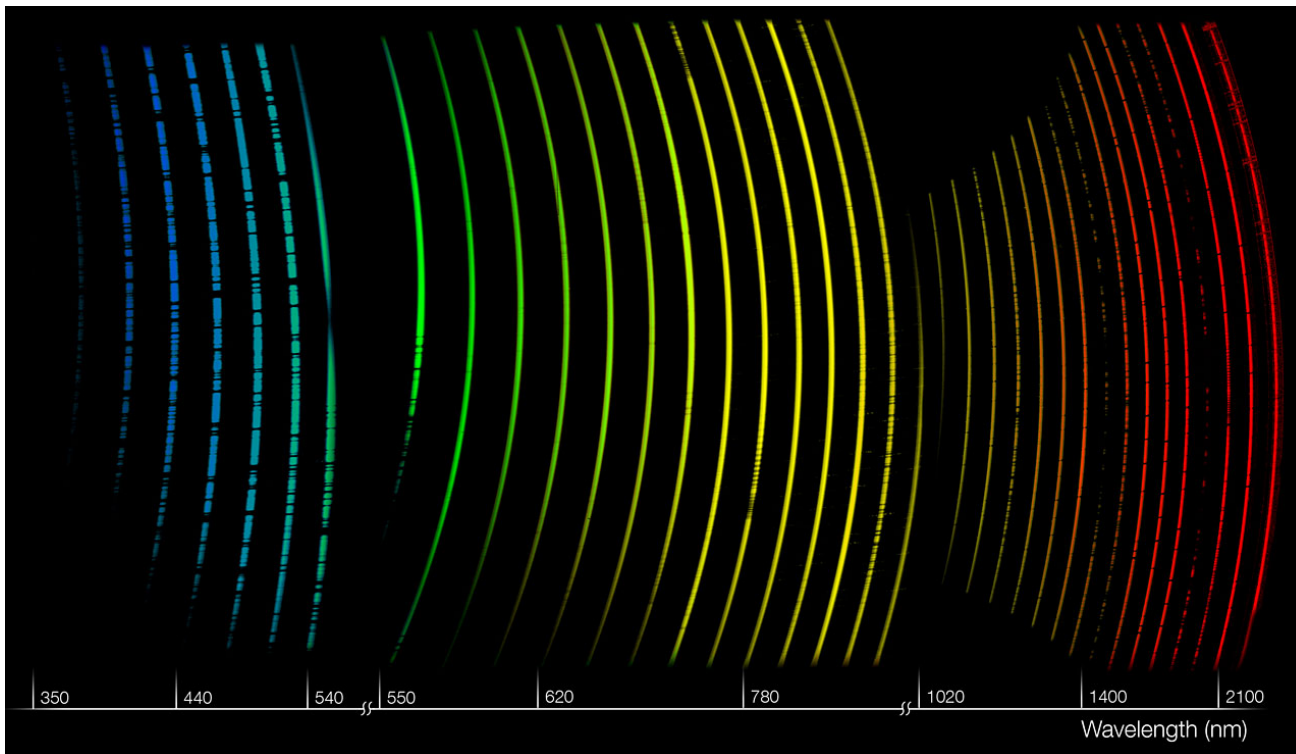
FORS 2 red-optimized ($z > 1$ galaxy surveys)



A concerted effort from the builder's Consortium & ESO

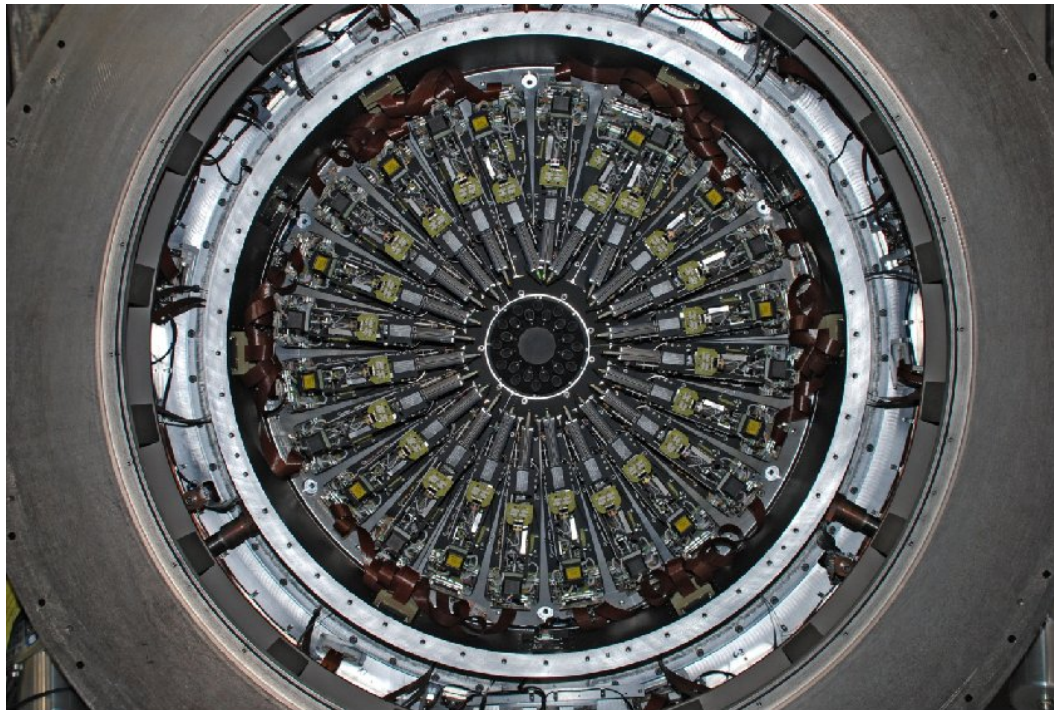
Evolving by Instrument replacement

- 2nd Generation: selected cutting-edge capabilities
 - ⇒ 0.3 μm -2.5 μm single exposure coverage (X-shooter)
(epitome of the multi-way spectrograph)



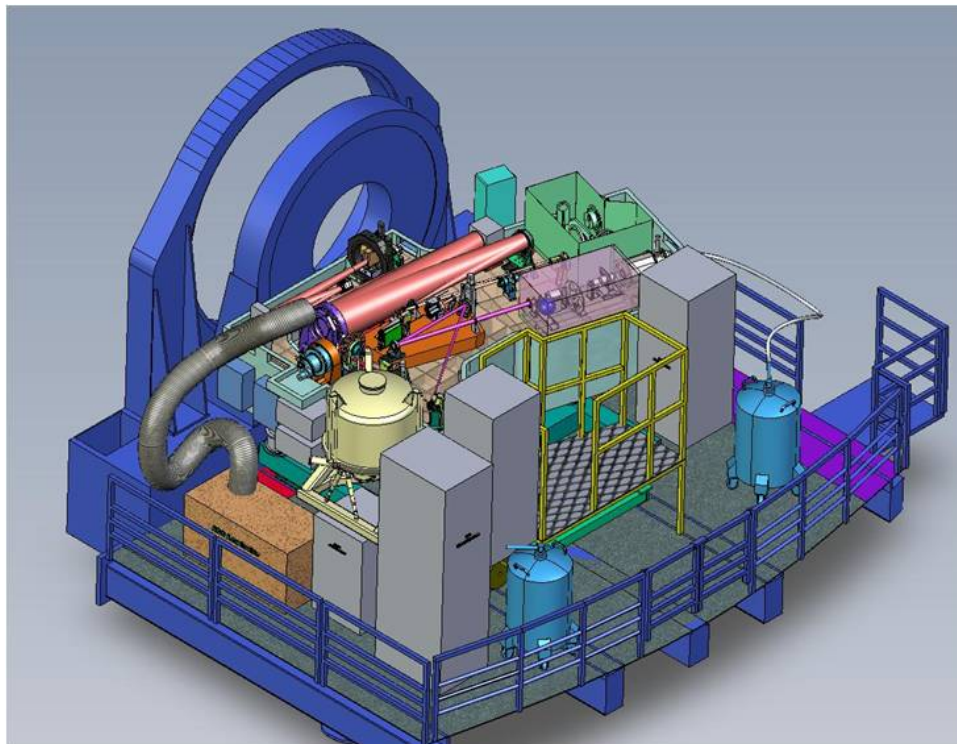
Evolving by Instrument replacement

- 2nd Generation: selected cutting-edge capabilities
 - ⇒ high-z galaxy s surveys (IR KMOS)
cryogenic positioning



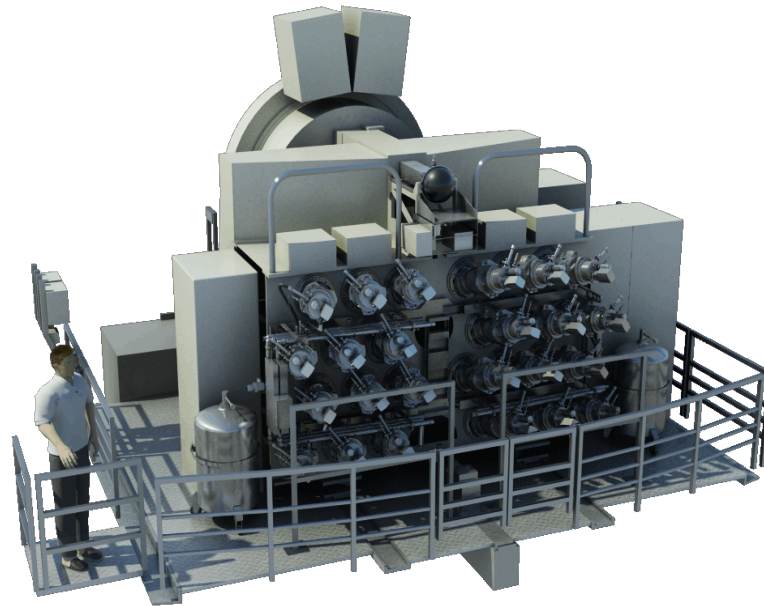
Evolving by Instrument replacement

- 2nd Generation: selected cutting-edge capabilities
 - ⇒ exoplanet direct detection (SPHERE)
high-contrast AO, coronagraph, Δ spectro-imaging



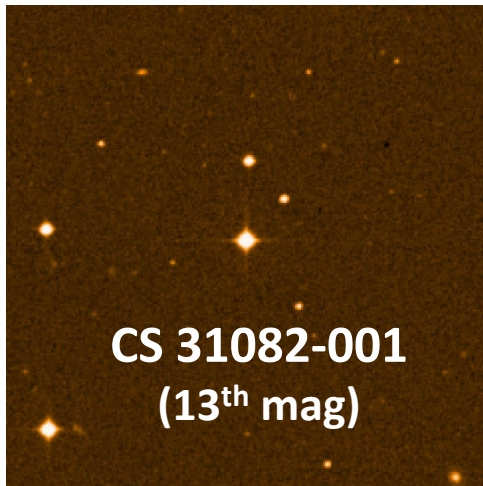
Evolving by Instrument replacement

- 2nd Generation: selected cutting-edge capabilities
 - ⇒ blank sky ultra-deep detection (Optical MUSE)
spectrograph serial production

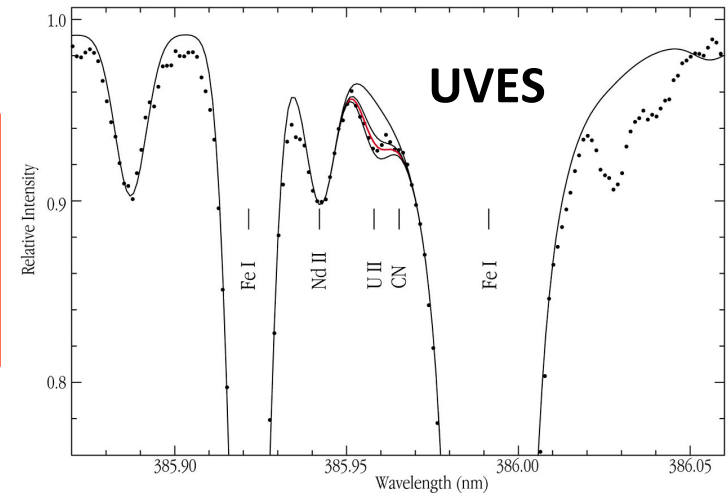


Within a global data/process flow

- ⇒ Old hat for space data; quite new for the ground
- ⇒ prepare-observe-calibrate-reduce-archive-extract
(a huge HW/SW effort for instrument control & data handling)
- ⇒ instrument-related (builders); e-infrastructure (ESO)



U-238 Abundance
⇒ $T_H > 1.25 \cdot 10^9 \text{ yr.}$
(Cayrel et al. 2001)



UVES: getting a working data reduction pipeline right from day one

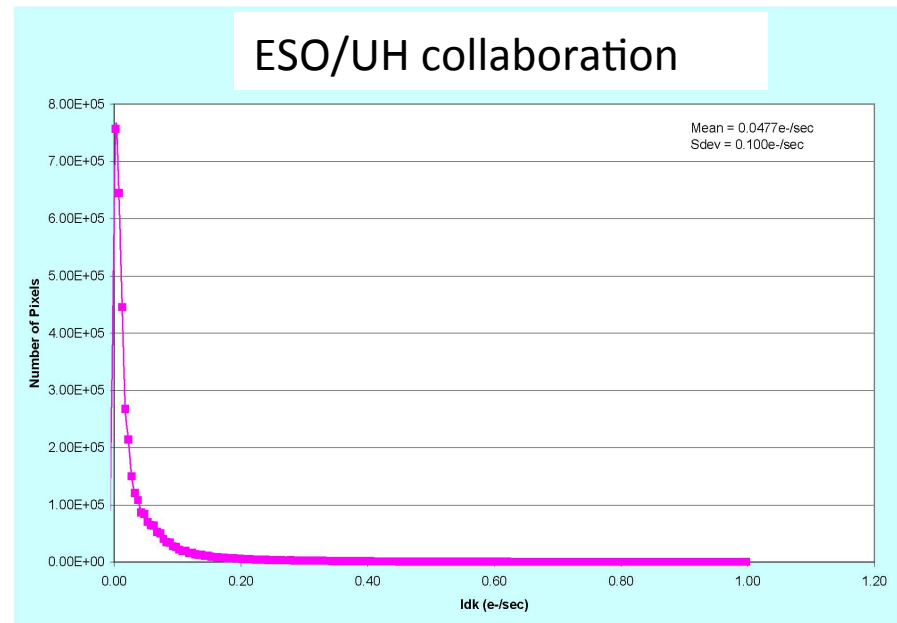
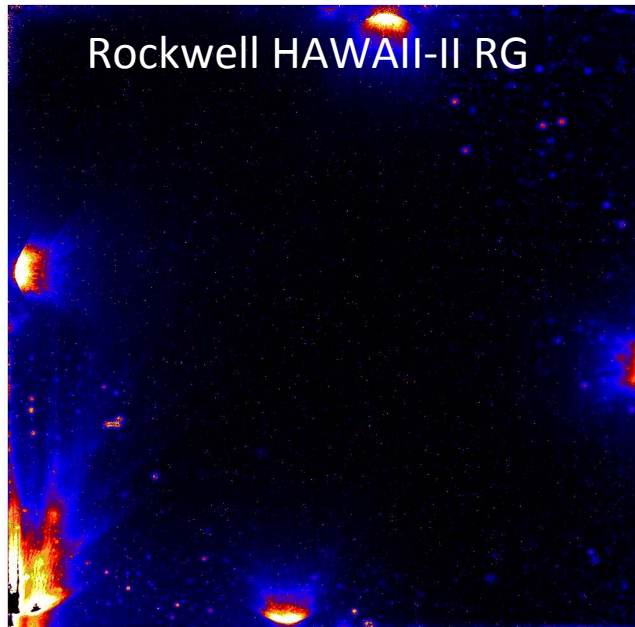
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Embracing the detector revolution

- Large 2-D Optical/IR digital detectors
(plus fast versions for AO WFS)
- Astronomy-tuned in collaboration with Industry
⇒ better QE; much better read-out/dark noise

Map of Entire Array Dark Current.

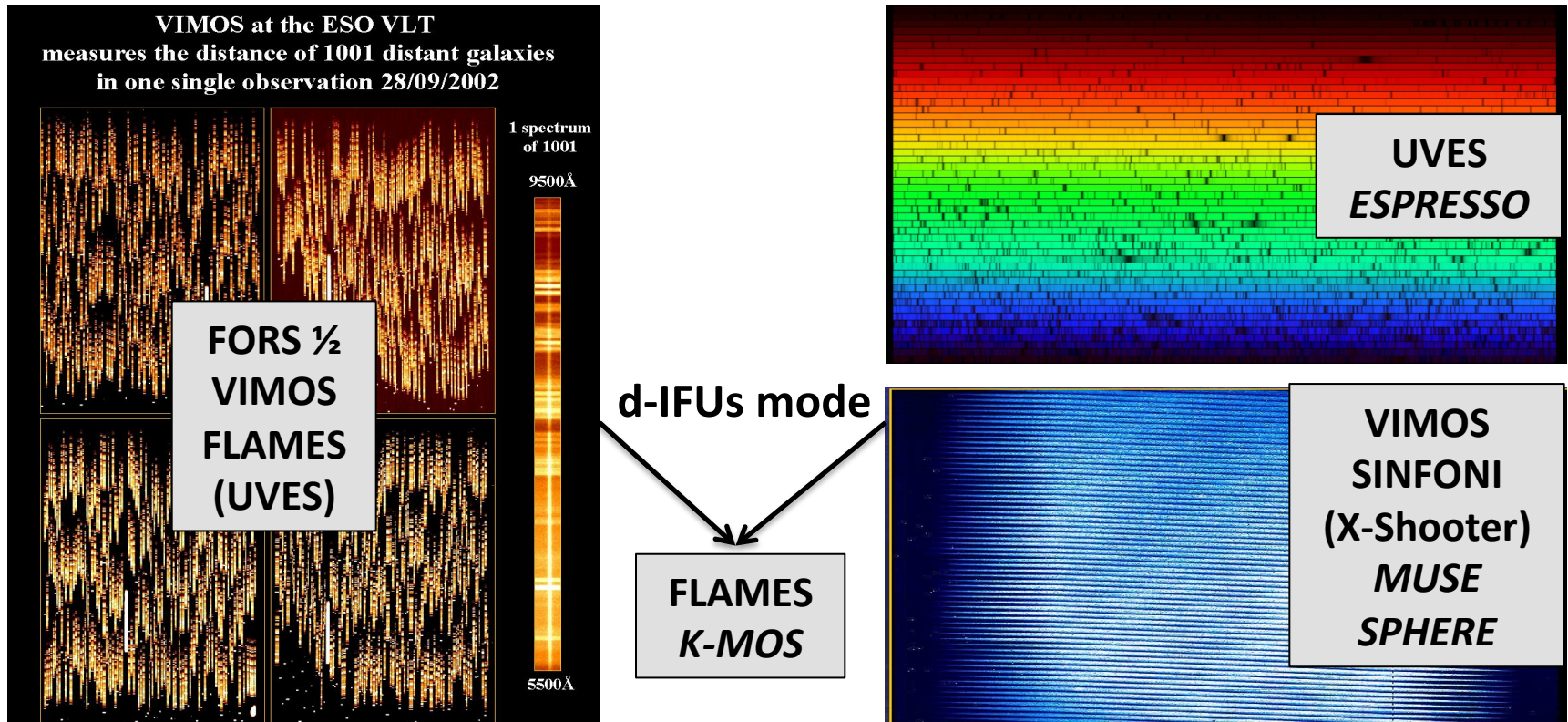


ESO Instrument Innovations

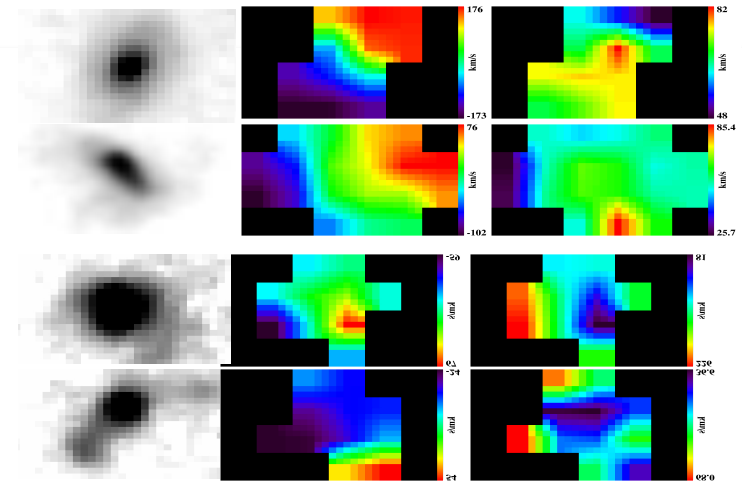
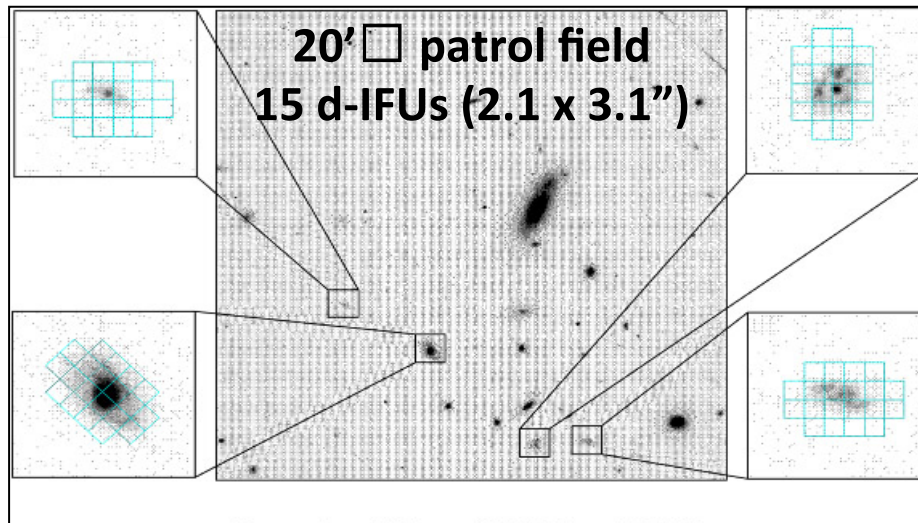
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Science-optimized modes Zoo

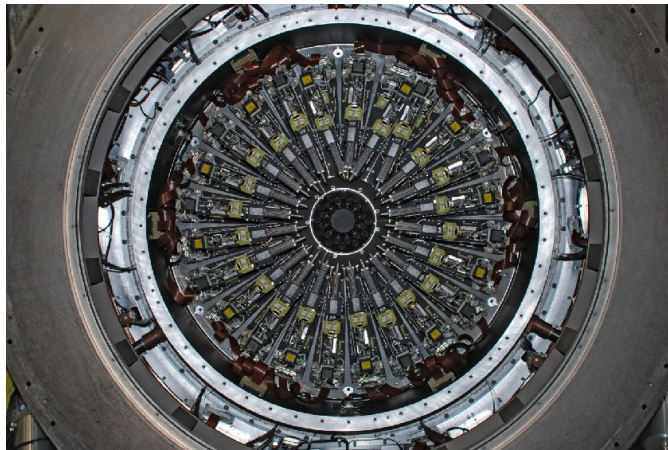
- ⇒ X-dispersed Echelle Spectrograph for stars & quasars
- ⇒ Multi-Object Spectrograph for galaxy surveys
- ⇒ Integral Field Spectrograph for single small objects



Flames: the 1st deployable IFUs Mode



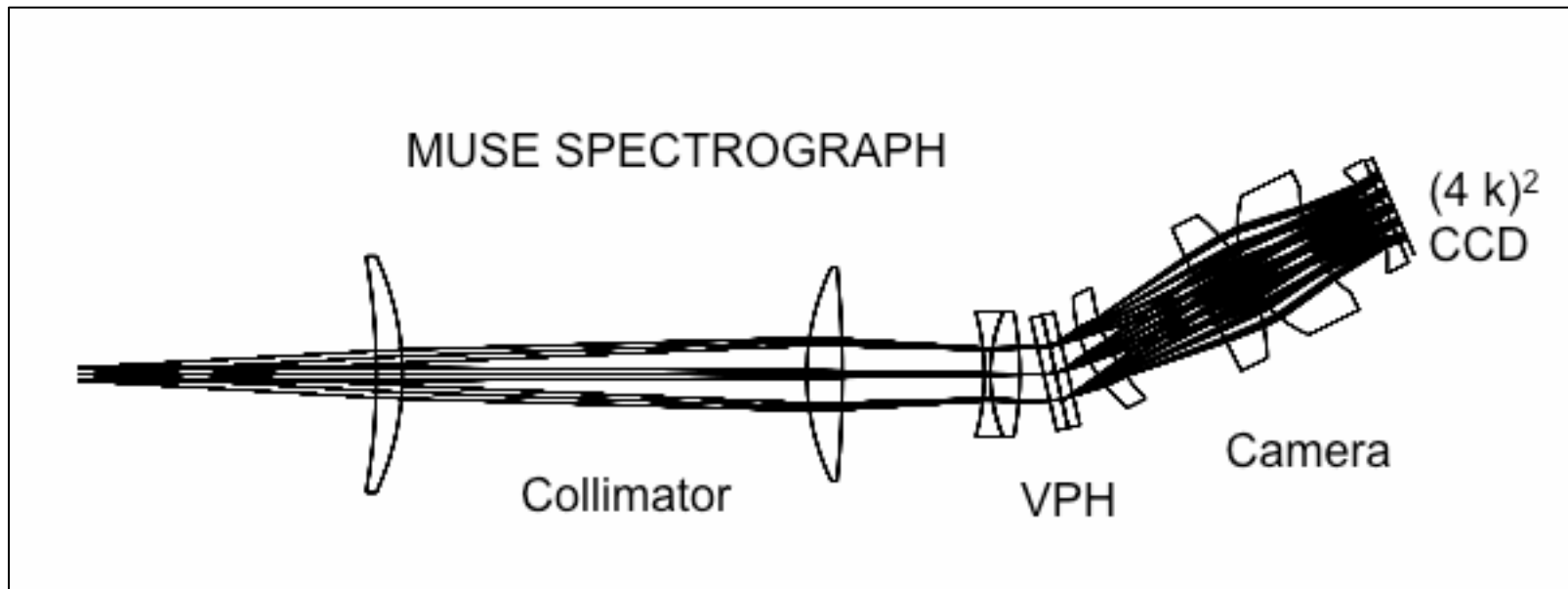
Optical (FLAMES) & NIR (KMOS) Galaxy Physics survey



**KMOS, 24 d-IFUs
7.2' patrol field
2.8" x 2.8" IFU**

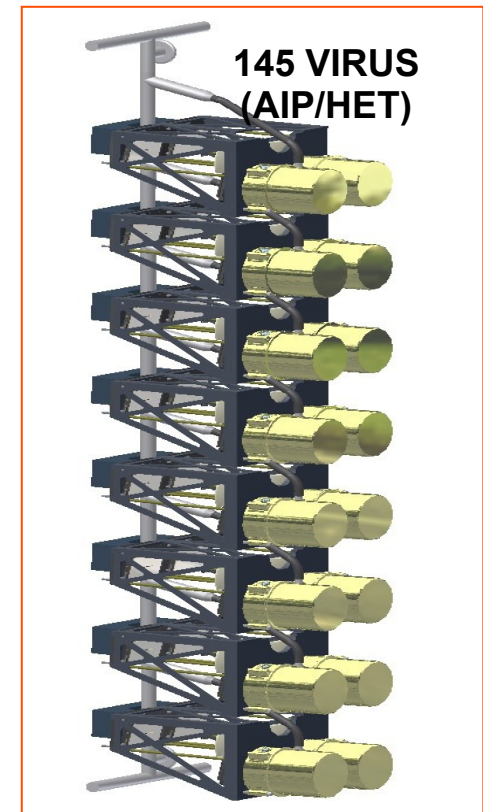
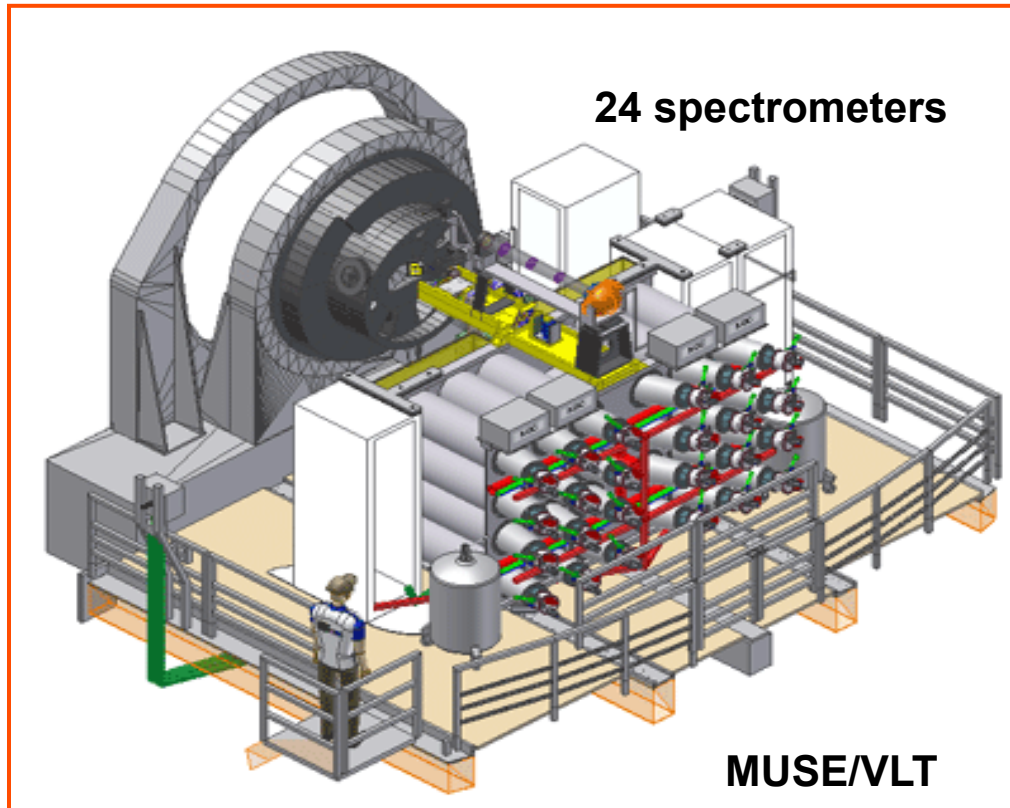
Towards smaller, cheaper, faster Instruments

- Rise of the 1-octave fixed format spectrograph
 - ⇒ starting with UVES (compact X-dispersed echelle)
 - ⇒ introducing cheap twisted optics (*MUSE*)
 - ⇒ now using (cheap) aspheric lenses (*Espresso*)
 - ⇒ plus compact cryogenics, high multiplex controller, ...



Towards smaller, cheaper, faster Instruments

- Going the multiple Instrument path (size gain)
⇒ VIMOS (x 4); MUSE (x 24)



ESO Instrument Innovations

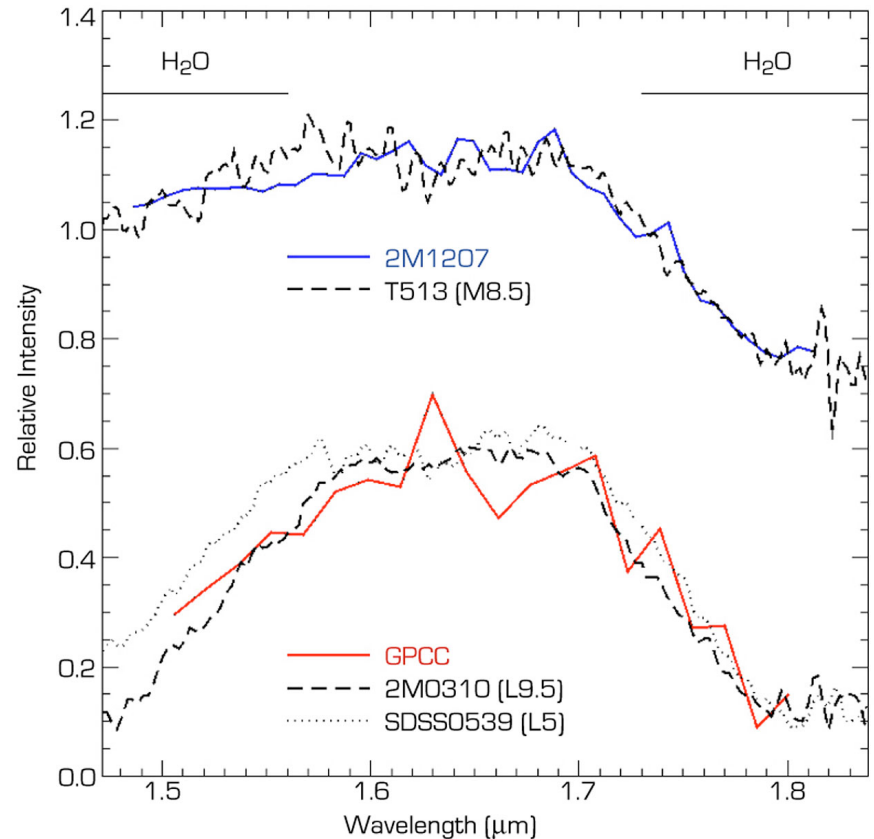
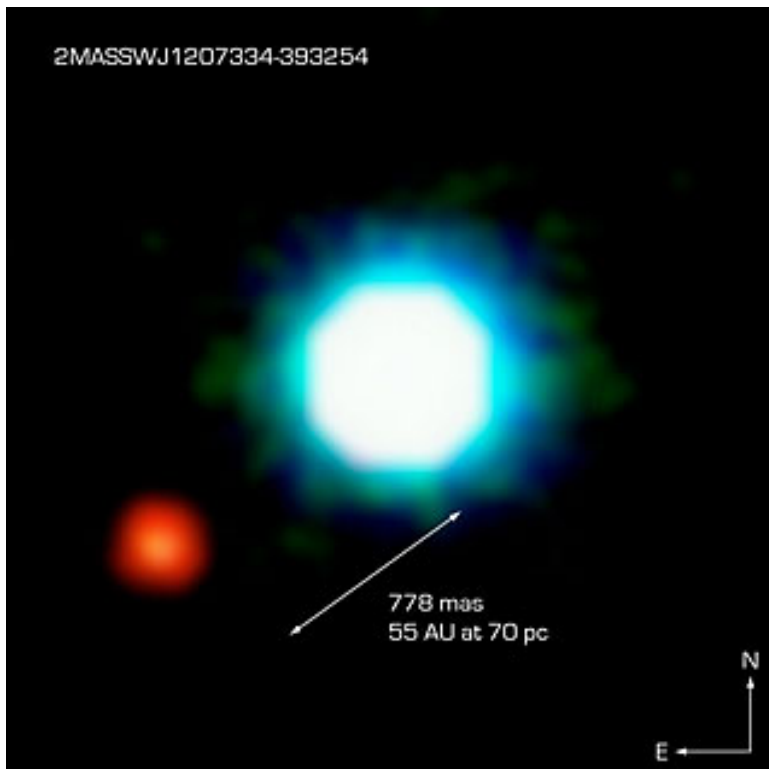
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Beating the Atmosphere: *The Adaptive Optics Saga*

- A source of (so far) endless R&D [VLTi too!]
- With many variants (SCAO, GLAO, MCAO, LTAO, MOAO), largely initiated in Europe
- With critical components (WFS, RTC, DM) scaling strongly with telescope size & wavelength
- Soon an 8-m Adaptive-Optics Telescope
 - ⇒ on its own scientific merit
 - ⇒ but also preparing for the E-ELT

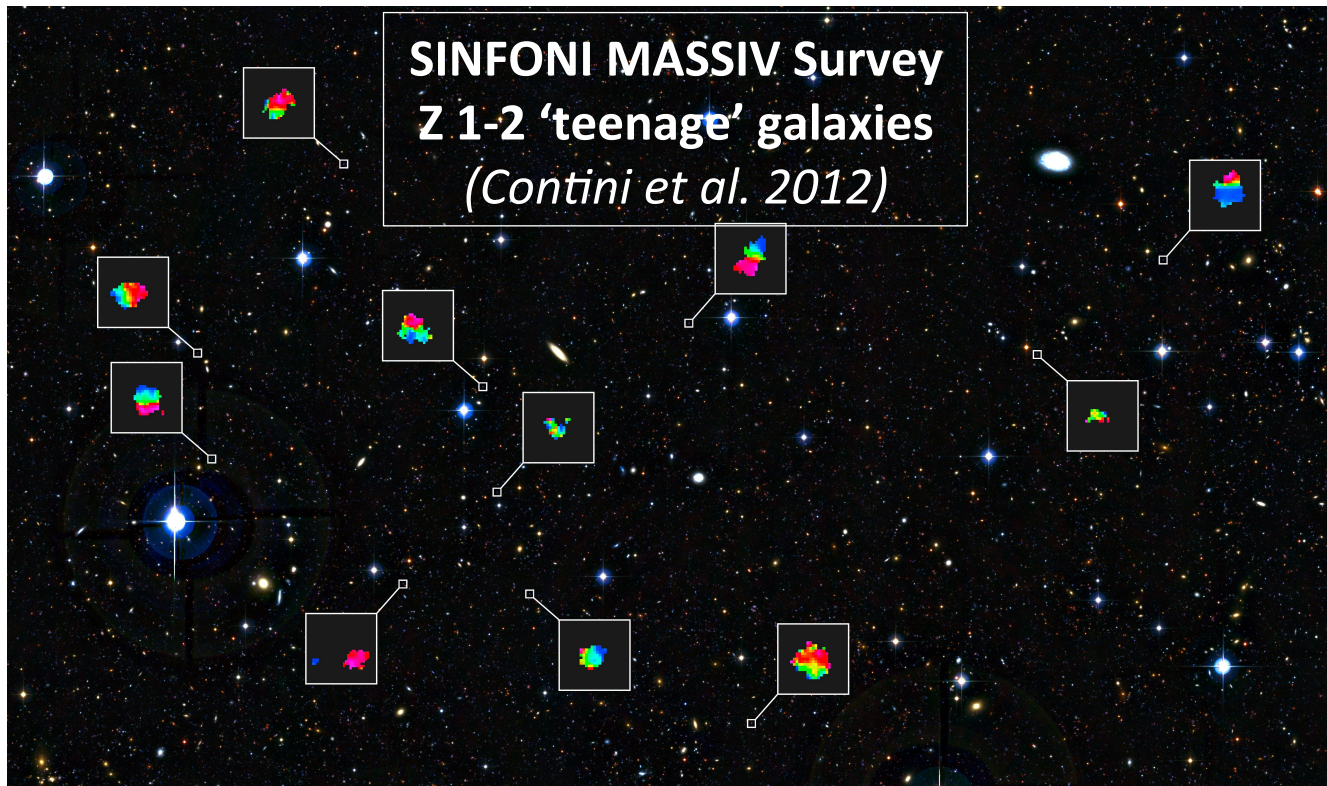
The Adaptive Optics Saga

- NAOS, a successful general-use AO ‘imager’
- Also R&D test-bed (*differential Imaging, coronagraph*)



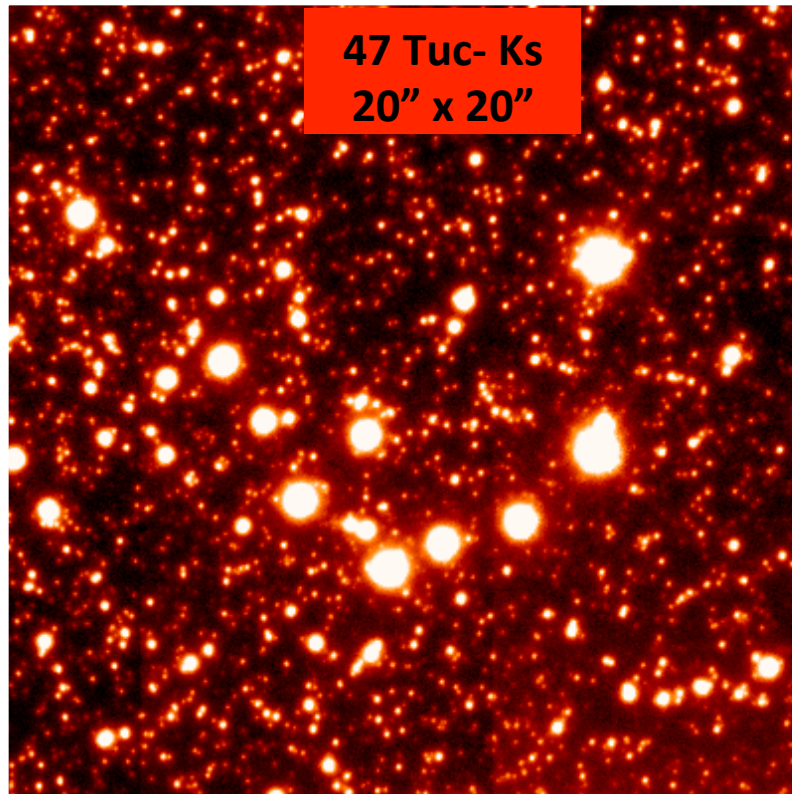
The Adaptive Optics Saga

- SINFONI, NIR Integral Field Spectrograph (with/without Adaptive Optics)



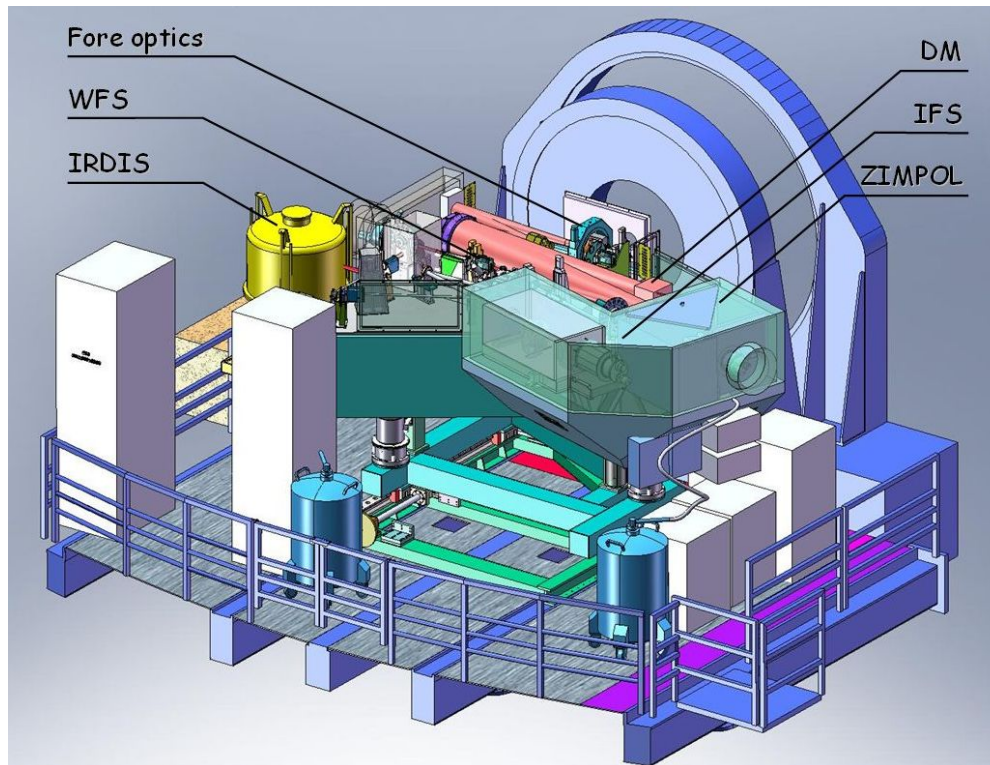
Beating the Atmosphere: *Adaptive Optics Advanced Modes*

- MCAO: wide-field AO Imaging
⇒ 1st Lab/on sky prototyping (MAD)



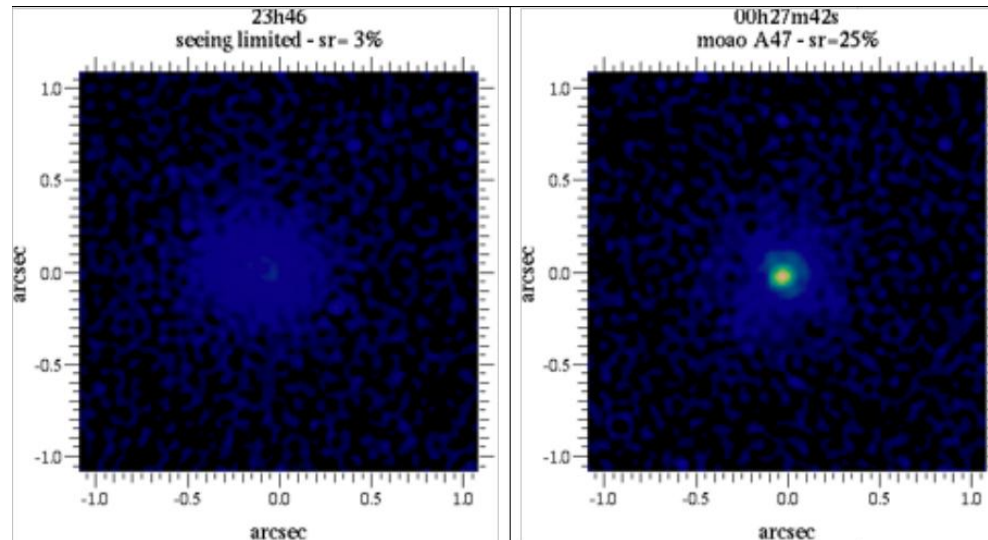
Beating the Atmosphere: *Adaptive Optics Advanced Modes*

- XAO: Planet imaging searcher (*SPHERE*)



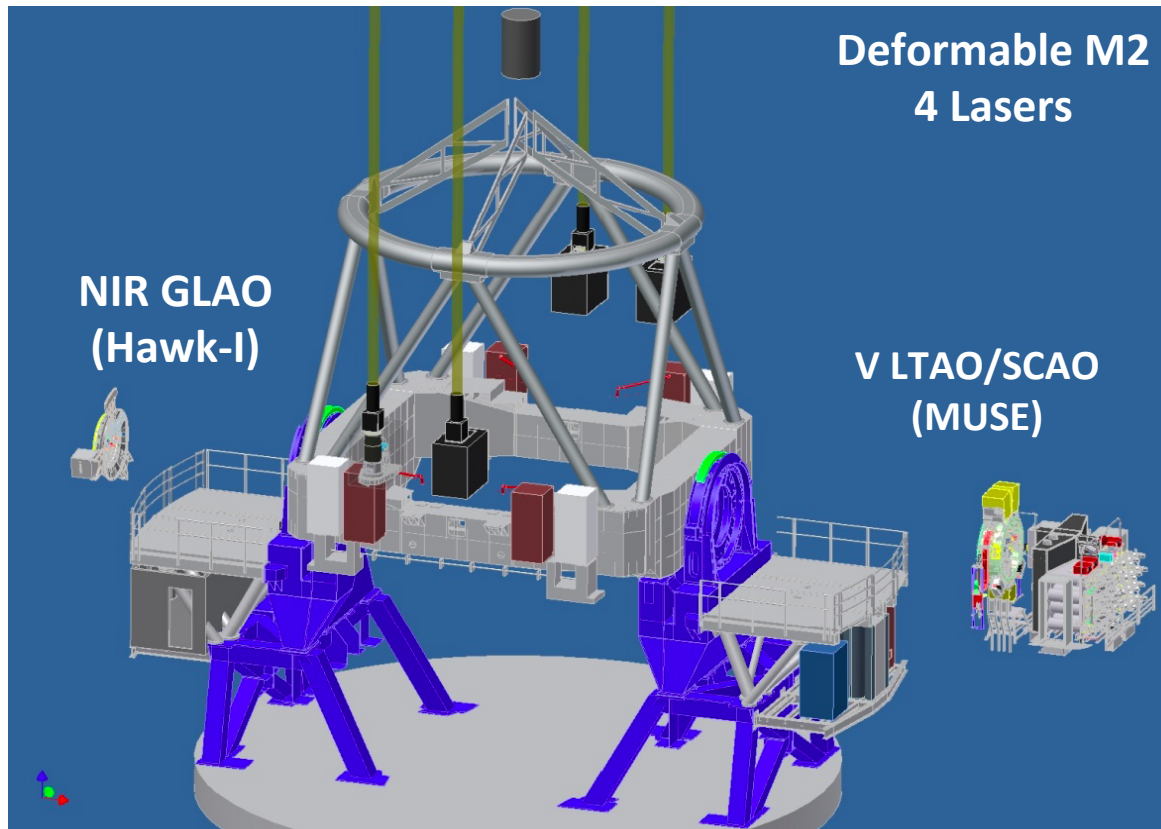
Beating the Atmosphere: *Adaptive Optics Advanced Modes*

- MOAO: AO surveys with an ‘unlimited’ patrol field
⇒ principle 1st demonstrated at La Palma (CANARY)



The Adaptive Optics Saga

- Soon one 8-m Adaptive-Optics Telescope
⇒ advanced AO modes – science efficiency boost



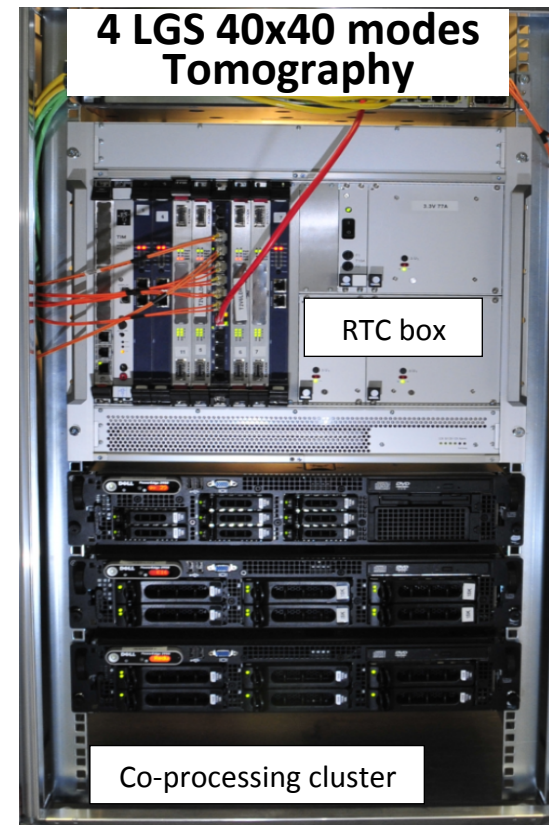
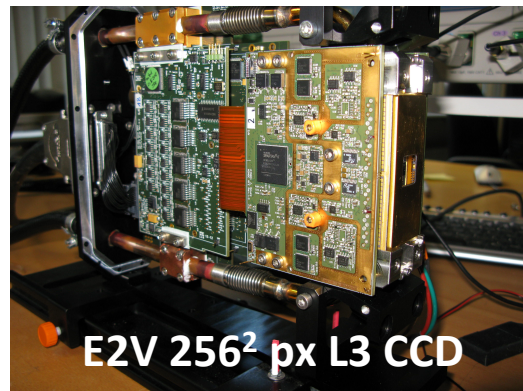
The Adaptive Optics Saga

- Soon an 8-m Adaptive-Optics Telescope
⇒ critical components developed



Beating the Atmosphere: *The Adaptive Optics Saga*

- Scaling up components: VLT → *E-ELT*



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A Few Conclusions

- Long-term R&D vital for ESO competitiveness
- Still much progress ahead- no more $\times 10^3$ though *AO saga, (3D?) detectors, photonic devices*
- In any case huge scaling up ahead *to meet E-ELT instrumentation challenge*
- Requires to organize, plan, man & fund

Deep thanks to the many people at ESO, in the ESO Community & worldwide that made it possible