ESPRESSO e gli strumenti di nuova generazione per VLT

Stefano Cristiani

INAF-Trieste Observatory

I N A F

I am indebted to S. D'Odorico, P.Molaro, M.Murphy, L. Pasquini, F. Pepe, T. de Zeeuw. Many thanks!

VLT papers use data generated by VLT instruments, including visitor instruments for which observing time is recommended by the ESO OPC (Observing Programmes Committee), e.g, VLT Ultracam. Instrument-level data for the VLT are available since the beginning of operations, i.e., from publication year 1999 onwards.

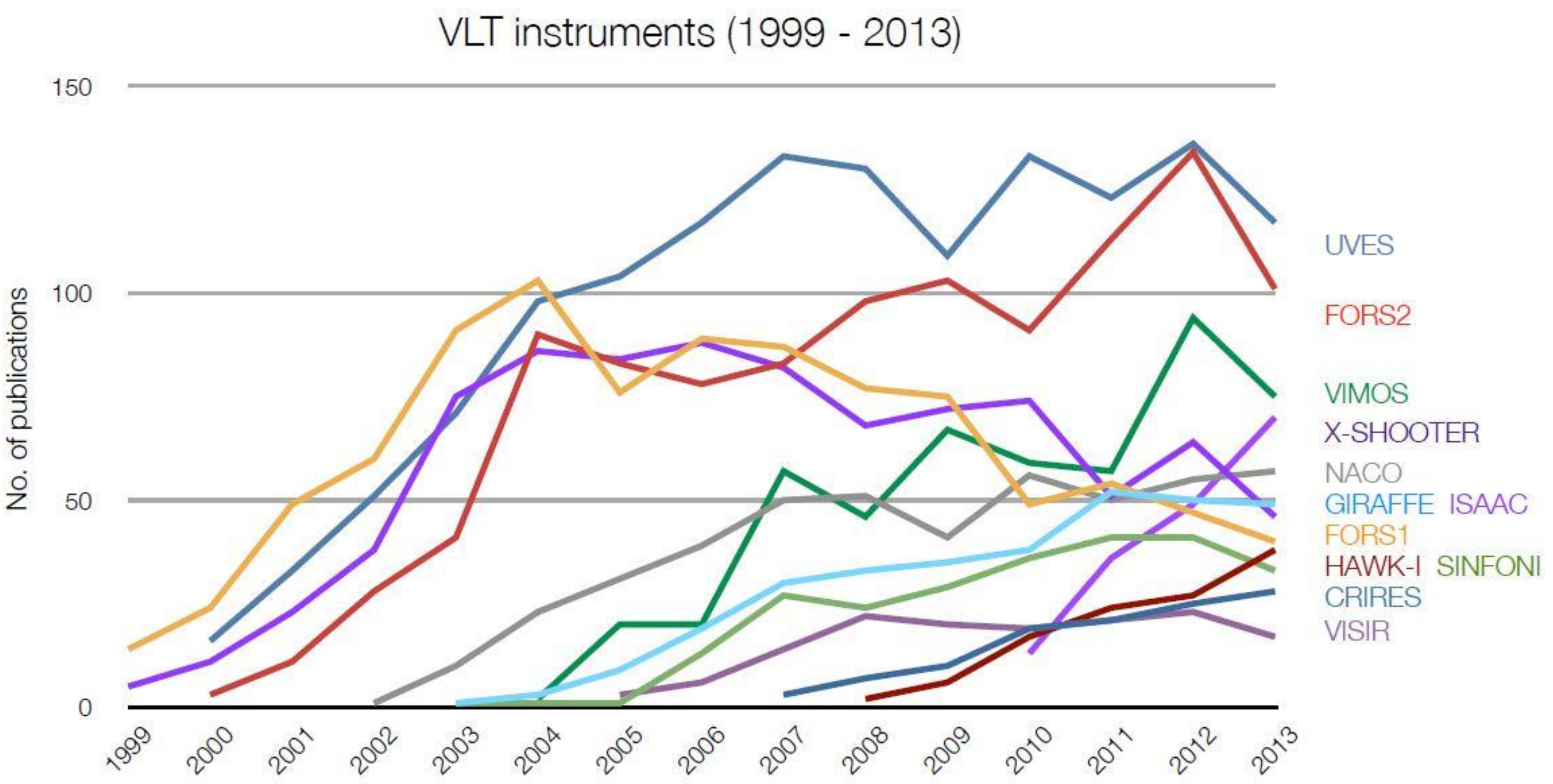


Fig. 4: Refereed publications using data from VLT instruments

NACO = NAOS + CONICA
SINFONI = SPIFFI + MACAO

Grothkopf & Meakins 2014

The VLT Instrumentation Program

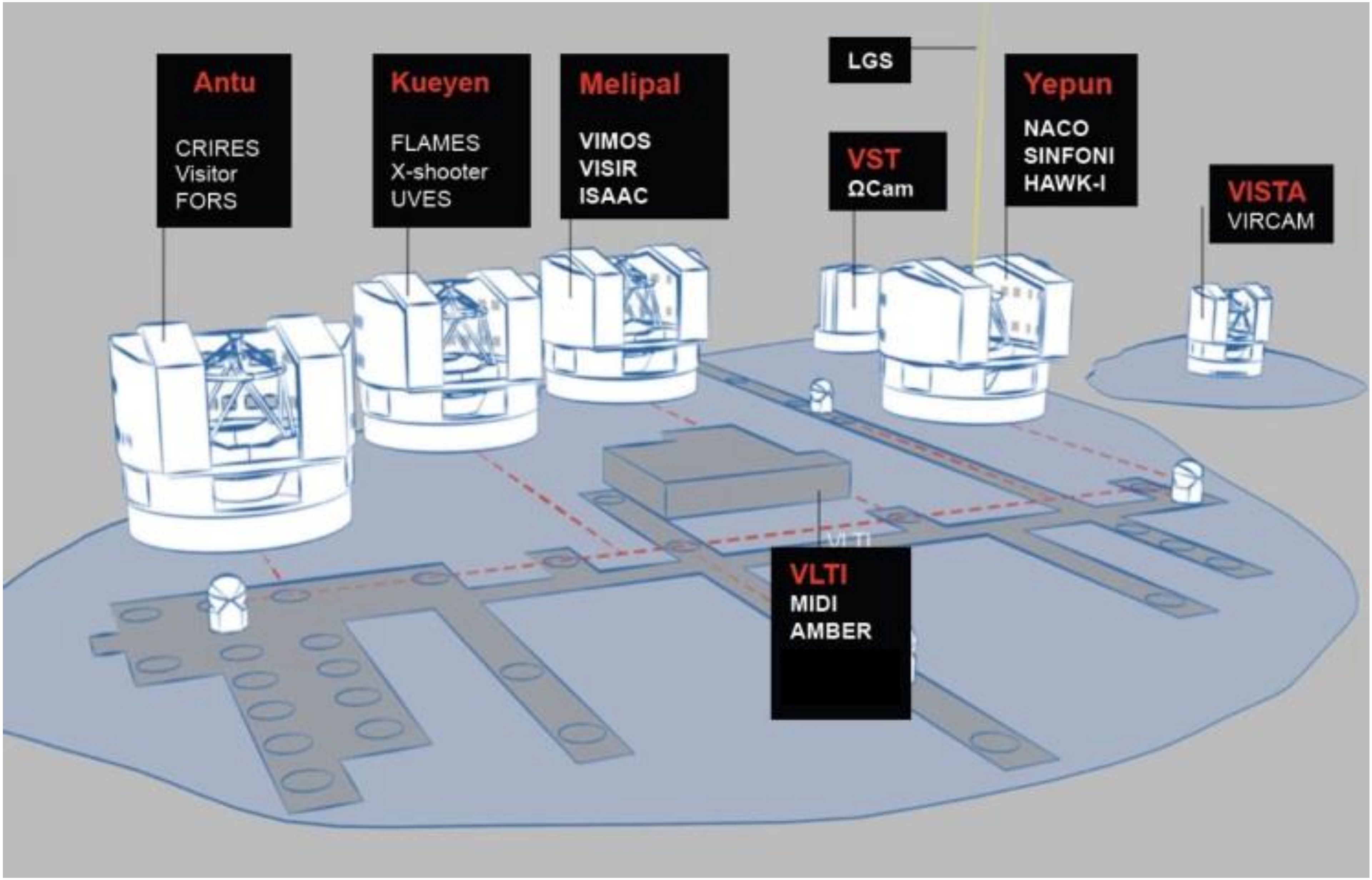
An Instrumentation Plan defined with the community at the early stage of the program (1989); adjusted along the way taking into account the scientific and technical developments

- Of the 11 1st Generation Instruments, 4 built by ESO, 7 by consortia led by external PI, with significant ESO contributions, project support and control.
- Instruments built according to set of agreed specifications and subject to regular review process. For externally-built instruments hardware cost paid by ESO, **FTE** (Full Time Equivalent) in exchange of **GTO** (Guaranteed Observing Time). 1 VLT night = 50kEURO, 1 qualified FTE=75kEURO
- 1st Generation with budget of 30 Ml EURO,~ 400 GTO nights. In budget, largely in time, world-wide competitive , with many excellence peaks

Advantages of the ESO Approach to Instrumentation Procurement

- *For ESO:*
  - *It made it possible to realize within budget the ambitious VLT Instrumentation program*
  - *It favored the active participation/ownership of a large fraction of the community in the VLT project*
- *For the external institutes:*
  - *A competent instrumentation team can be built around the project and acquires unique expertise at the forefront of advanced instrumentation.*
  - *It makes easier to get support for the infrastructure from the national agencies.*
  - *GTO time is a great opportunity to carry out major investigations which have an impact in the field*

Paranal Instrumentation (in 2013)



Focus Occupancy

With the arrival of KMOS all VLT/I foci will be used, including the incoherent combined focus (ESPRESSO in 2016).

Three instruments (ISAAC, NACO and MIDI) are de-commissioned (2013-2014) and replaced by 2nd generation instruments (SPHERE, MUSE, and GRAVITY, respectively). In the future, each time a new instrument is proposed and accepted, the instrument to be de-commissioned should be identified upfront, at the time of the selection on the basis of e.g. scientific potential, complementary with the new instrument (and therefore coverage of the parameter space), instrument status and future perspectives.

FLAMES, VIMOS (GIRAFFE) >> MOONS

HAWK-I >> ERIS

UVES

AMBER

VISIR

Pre E-ELT (instruments starting before 2018)

1) maintaining a balance between general purpose (workhorse) and dedicated (specialized) instruments.
2) dictated by the strategies in the E-ELT era (white paper). Focused experiments? Large collaborations? (4UTs? 4 clones?)

After HST, during the JWST years

Missing UV Spectroscopy and high-resolution UBVR imaging

Focus on High-resolution spectroscopy, bright sources, diffraction limit at short wavelengths (B-R), Flexible operations, wide field, wide wavelength.

New generation instruments

KMOS
MUSE
SPHERE
AOF
ESPRESSO
MATISSE
VISIR up.

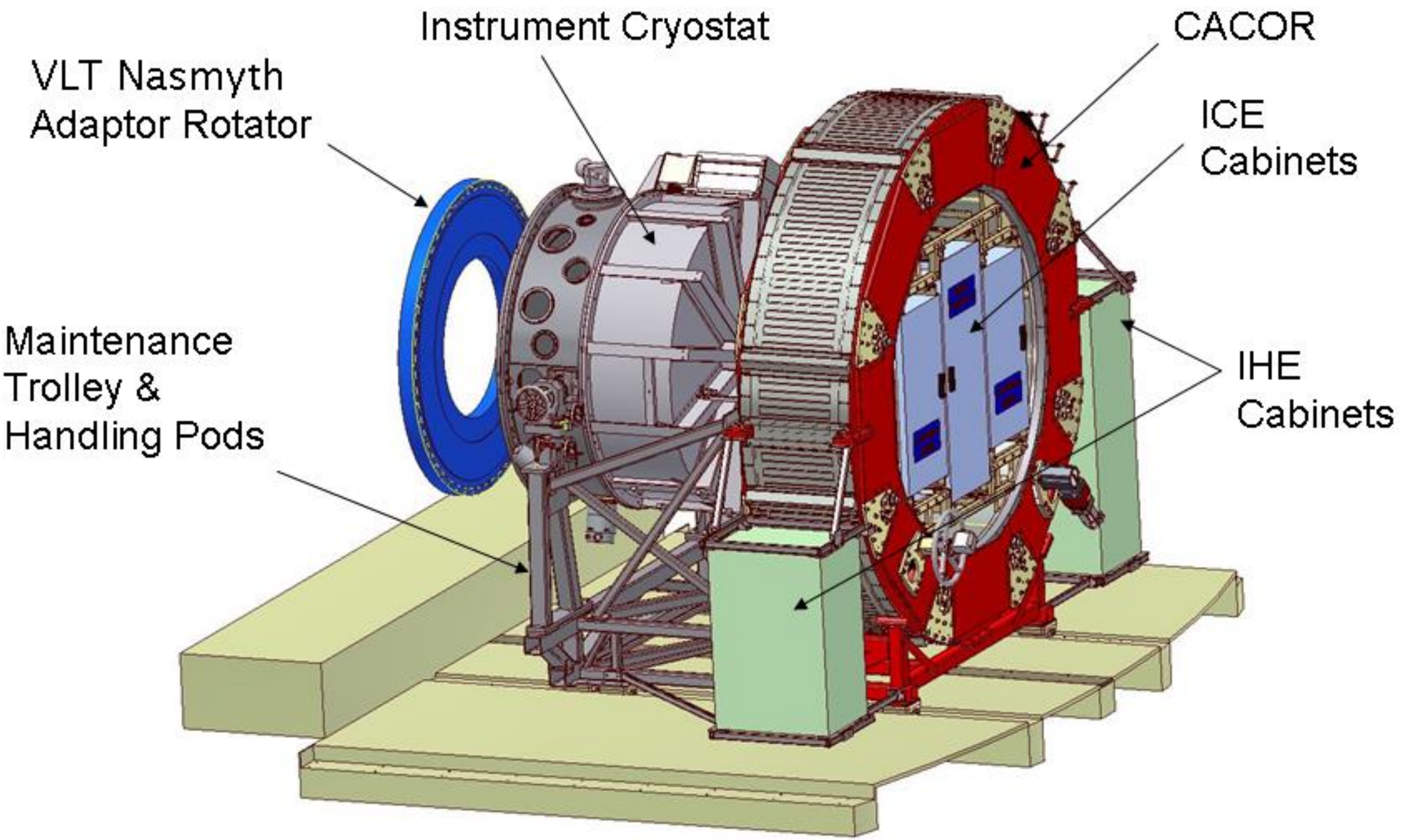
GRAVITY
Las.Freq.Comb
ERIS

(CUBES)
CRIRES up.
MOS

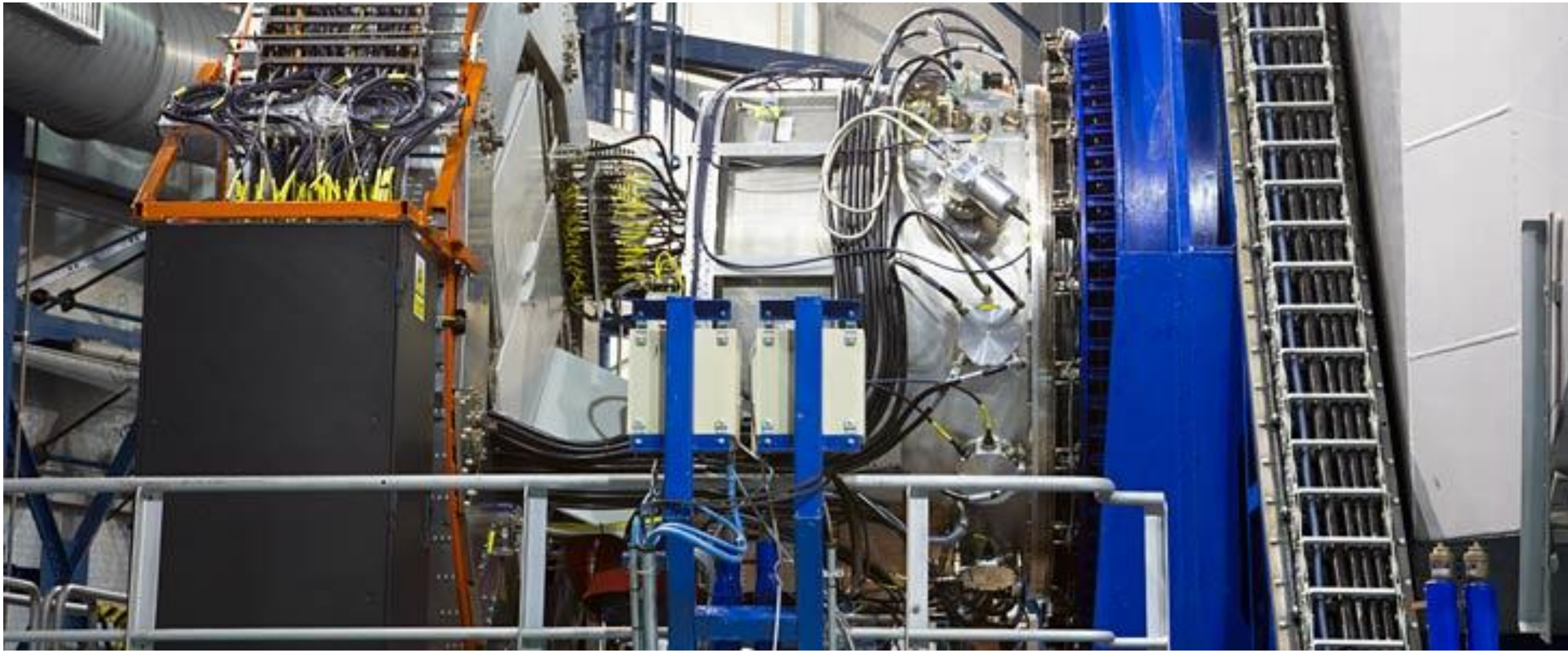
~ 1 instrument / year

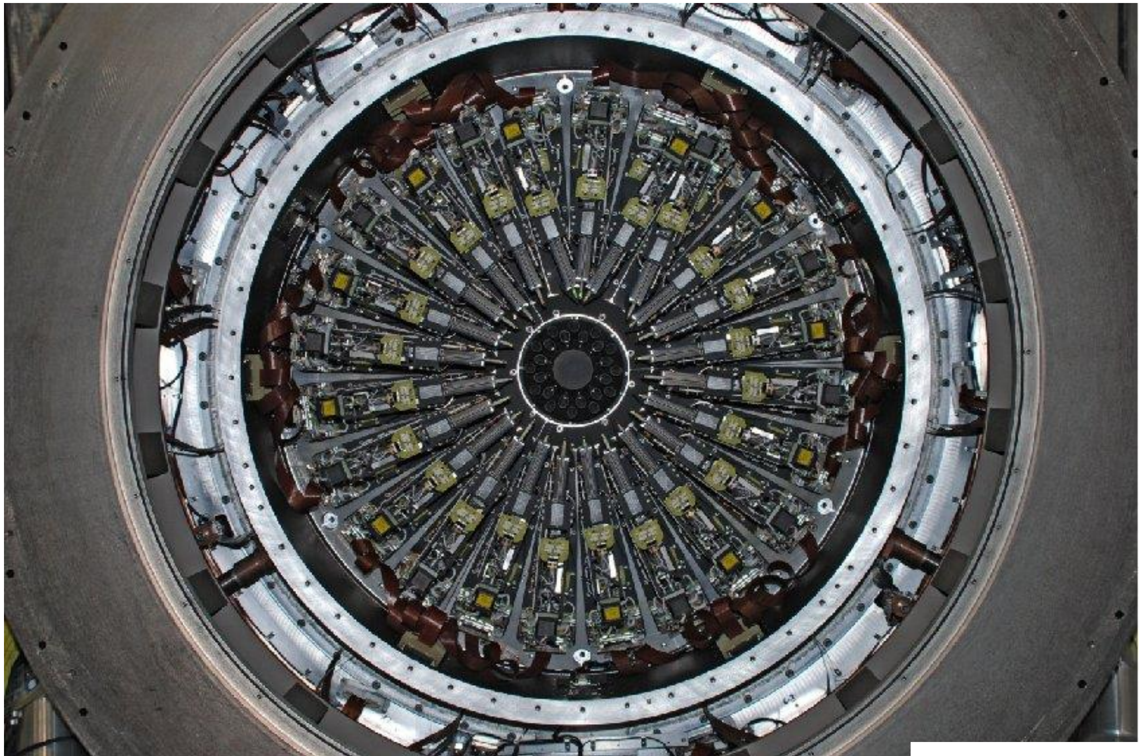
KMOS

integrated-field-unit (24 sub-fields, 2.8”x2.8”), medium-resolution (R~3000–4000) .   spectrograph covering the 0.8–2.5 micron region



KMOS – operational since end 2013 (first light Nov 21, 2012)





KMOS

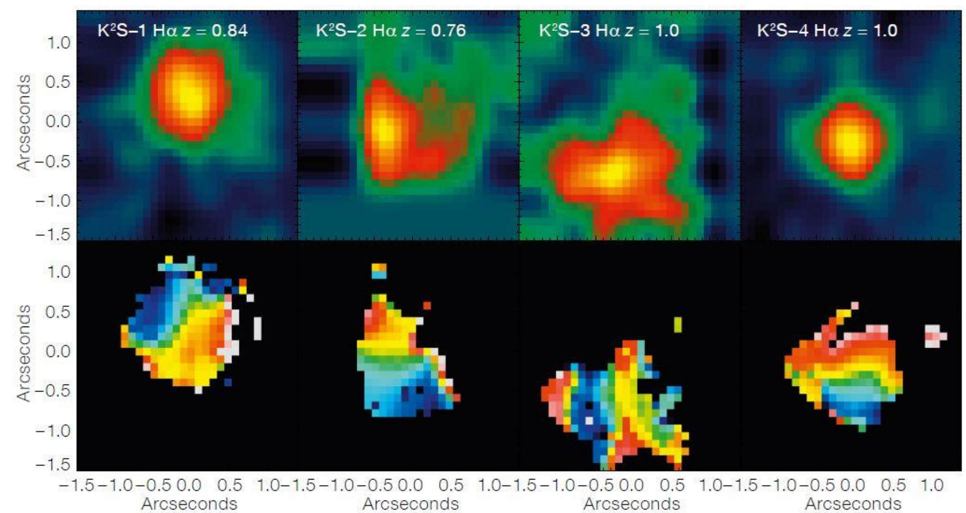
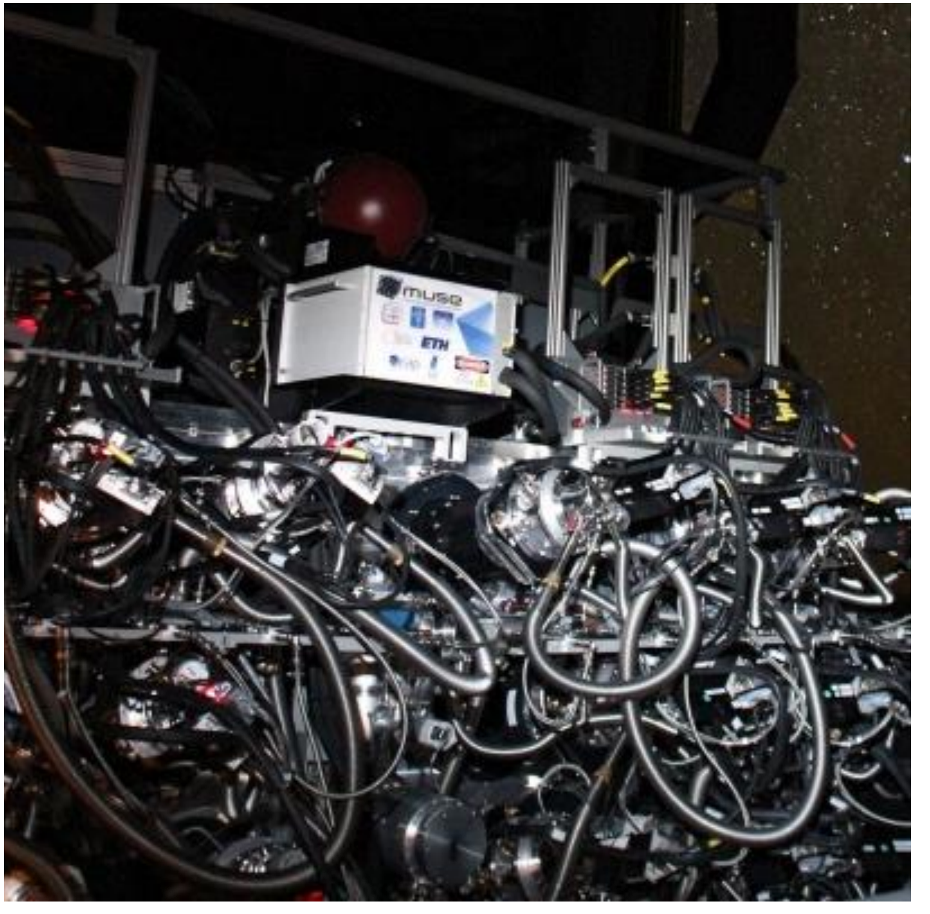


Figure 4. (Top) Hα emission line maps (top) and derived velocity fields (bottom) for a sample of faint $z \sim 1$ emission-line galaxies in the GOOD-South field. The brightest targets have an observed integrated Hα flux of 1.0×10^{-16} ergs cm^{-2} s^{-1}. These data were obtained with only 30 minutes of on-source exposure using KMOS and demonstrate the power of this facility instrument for such surveys. Reductions courtesy of Mark Swinbank.

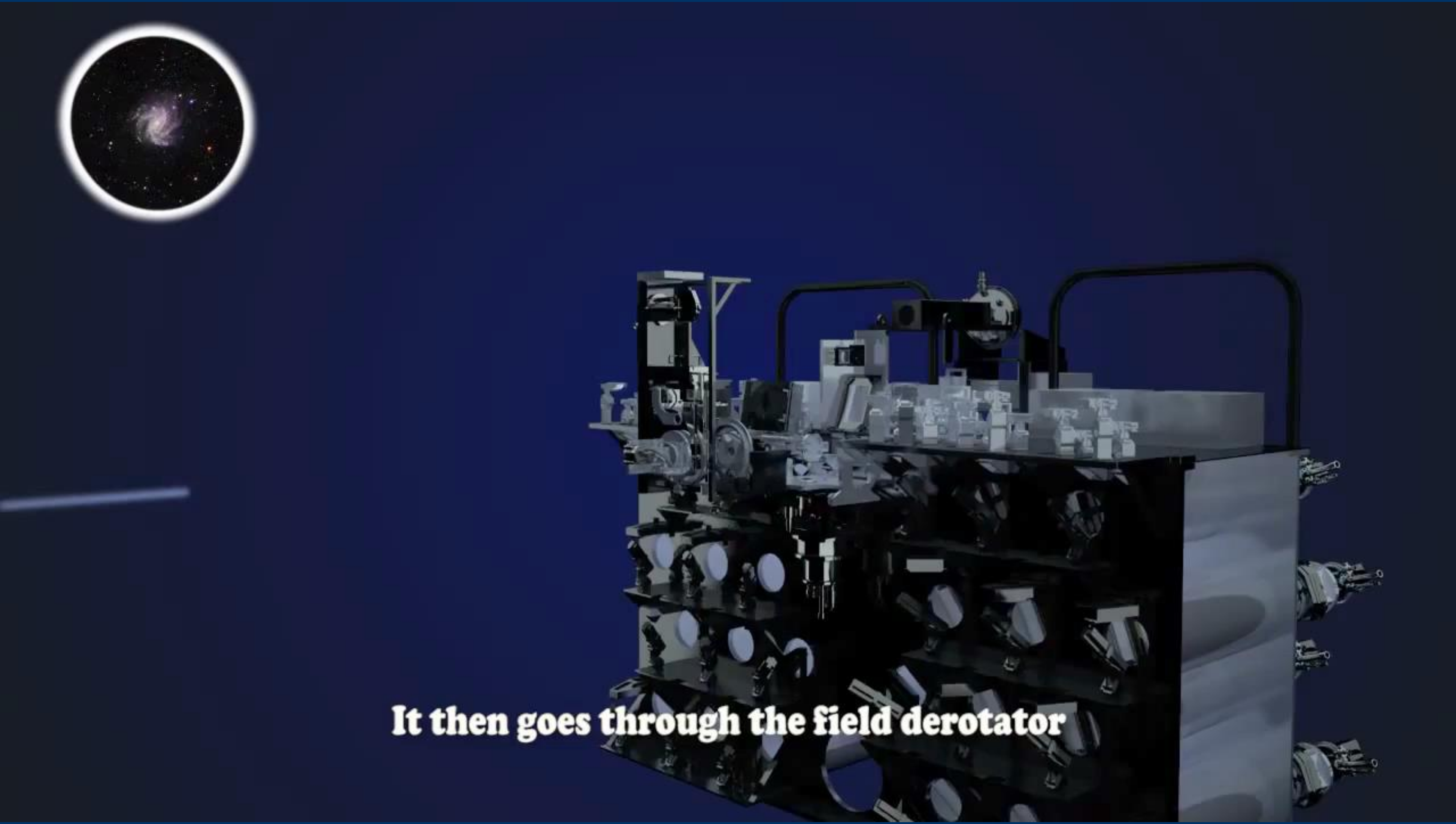
MUSE – commissioned 2014 – offered P94

integral field spectrograph

Observational Parameters	
Spectral range (simultaneous)	0.465-0.93 µm
Resolving power	2000@0.46 µm
	4000@0.93 µm
Wide Field Mode (WFM)	
Field of view	1x1 arcmin ^{2}
Spatial sampling	0.2x0.2 arcsec ^{2}
Spatial resolution (FWHM)	0.3-0.4 arcsec
Gain in ensquared energy within one pixel with respect to seeing	2
Condition of operation with AO	70%-ile
Sky coverage with AO	70% at Galactic Pole
Limiting magnitude in 80h	I_{AB} = 25.0 (R=3500)
	I_{AB} = 26.7 (R=180)
Limiting Flux in 80h	3.9 10^{-19}erg.s^{-1}.cm^{-2}
Narrow Field Mode (NFM)	
Field of view	7.5x7.5 arcsec ^{2}
Spatial sampling	0.025x0.025 arcsec ^{2}
Spatial resolution (FWHM)	0.030-0.050 arcsec
Strehl ratio	10-30%
Limiting Flux in 1h	2.3 10^{-18}erg.s^{-1}.cm^{-2}
Limiting magnitude in 1h	R_{AB} = 22.3
Limiting surface brightness in 1h	R_{AB} = 17.3 $arcsec^{-2}$

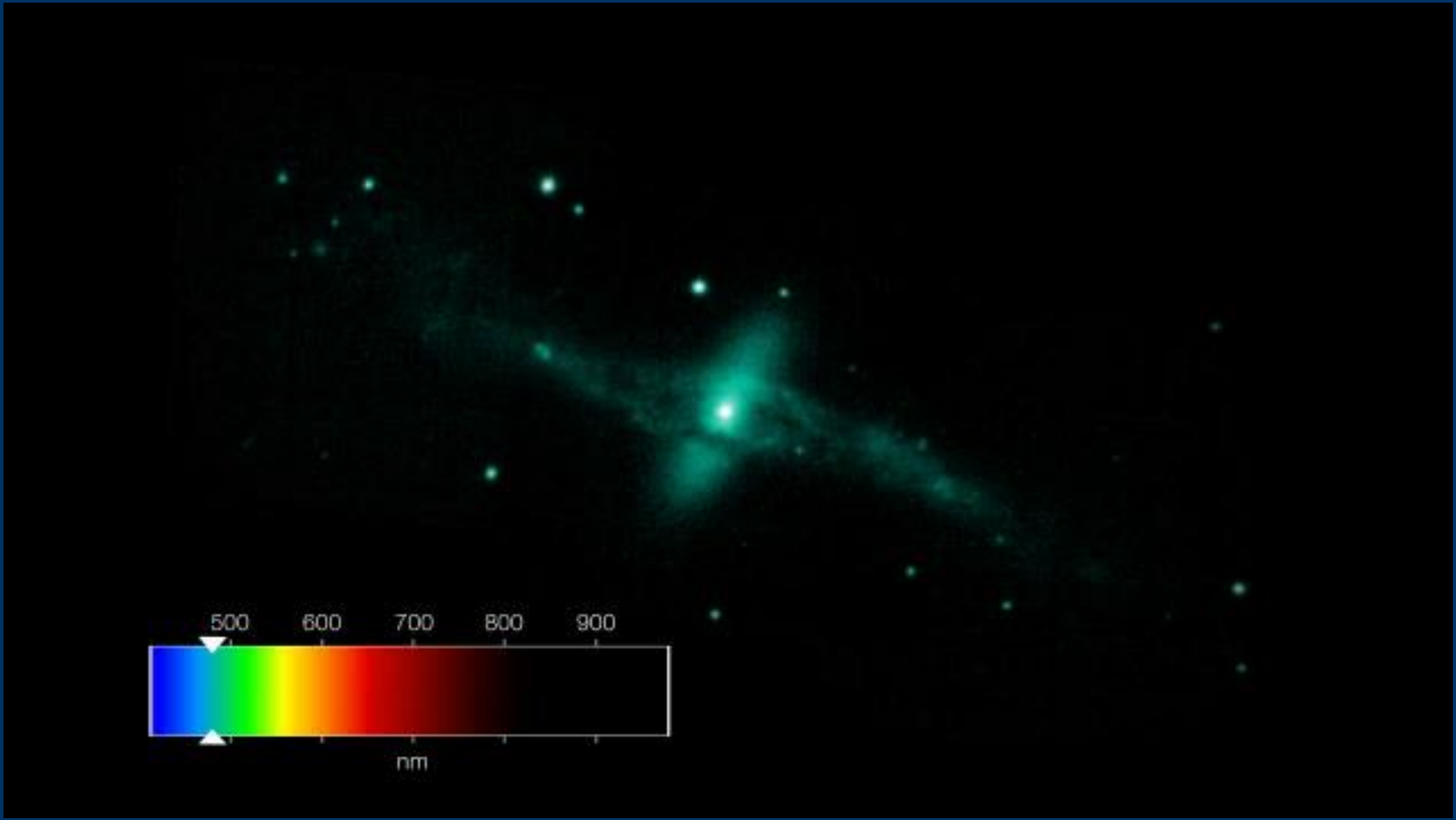


MUSE light path



(http://www.youtube.com/watch?v=e5TopF7DGMg)

MUSE observations: 3D of NGC 4650A

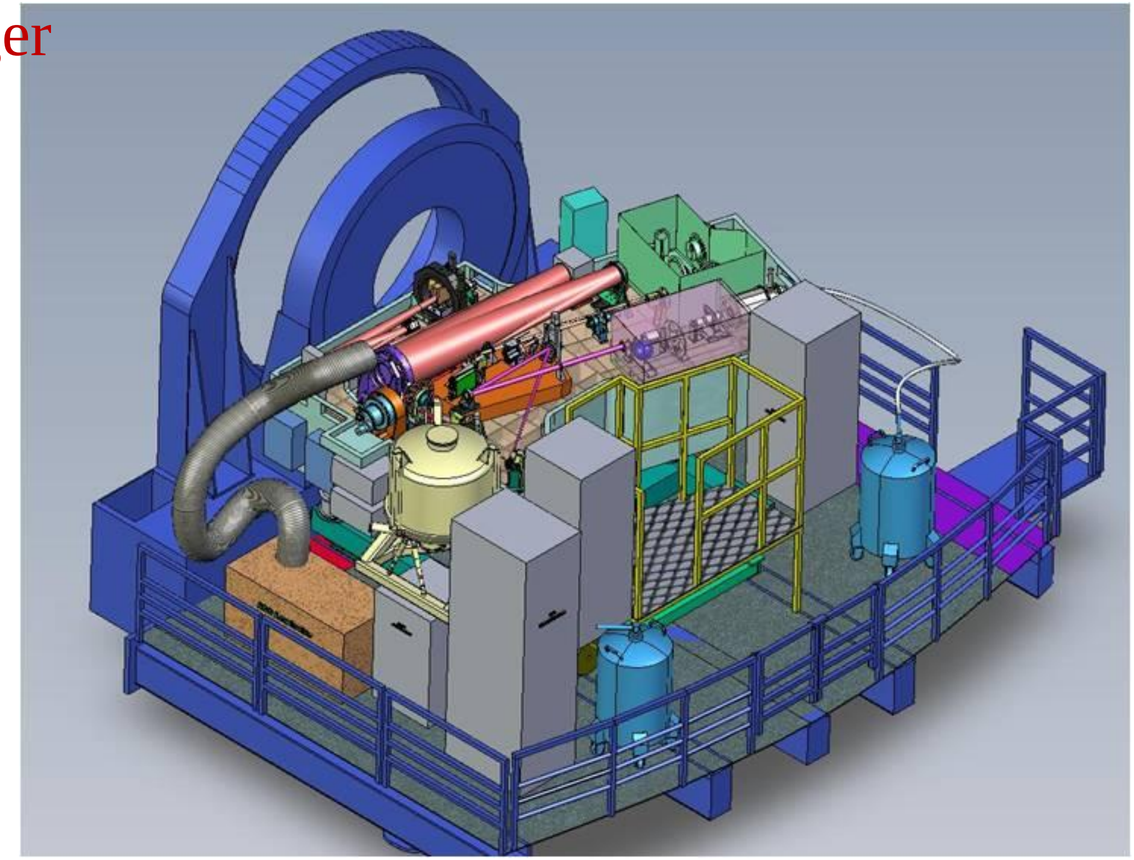


http://www.eso.org/public/archives/videos/hd_1080p25_screen/eso1407d.mp4

Spectro-Polarimetric High-contrast Exoplanet REsearch - SPHERE

Status: First light on telescope: 2014,   Preliminary Acceptance Europe, Dec 2013

- Common path with eXtreme Adaptive Optics (SAXO)
- Infra-Red Dual-beam Imager and Spectrograph (IRDIS)
- Infra-red Integral Field Spectrograph (IFS)
- Visible Differential Imager (ZIMPOL)



Spectro-Polarimetric High-contrast Exoplanet REsearch - SPHERE

French PI, German CoPI, Italian Project Scientist;

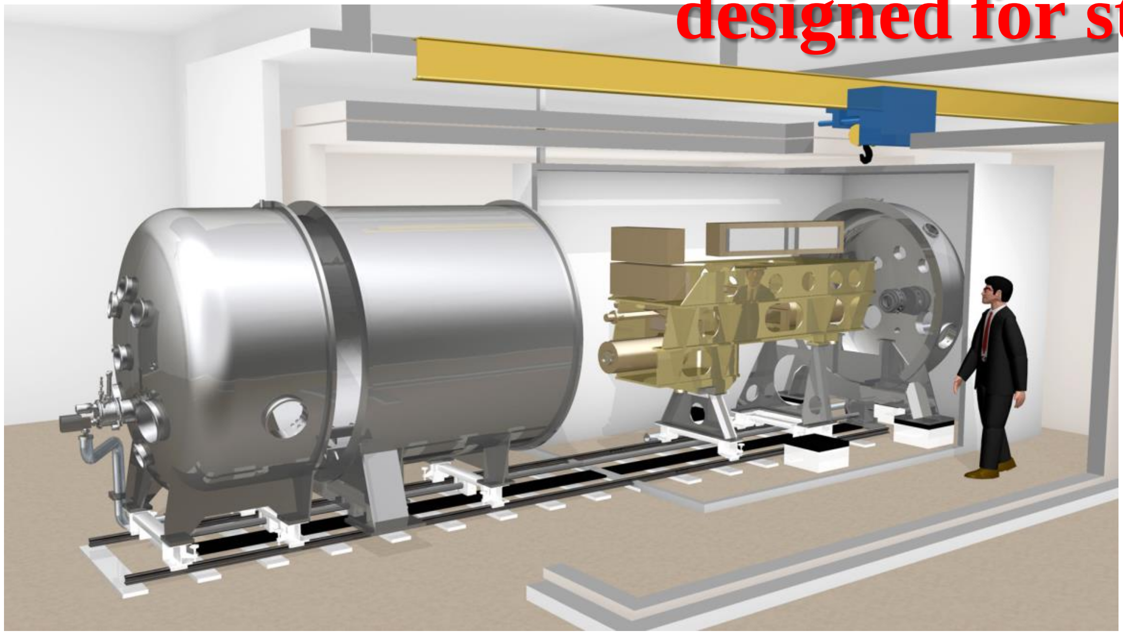
INAF OA Padova (Catania, Capodimonte, IASF Milano*)*

28.3 FTES+ 500kE (~20% of the total external effort)

- *Tasks: IFS unit, instrument control software, scientific program*
- *250 GTO nights, to be used in a coordinated way by the Consortium*

ESPRESSO: **E**chelle **SP**ectrograph for **R**ocky **E**xoplanets and **S**table **S**pectroscopic **O**bservations

designed for stability and sensitivity



ΔRV =1 m/s

ΔT =0.01 K

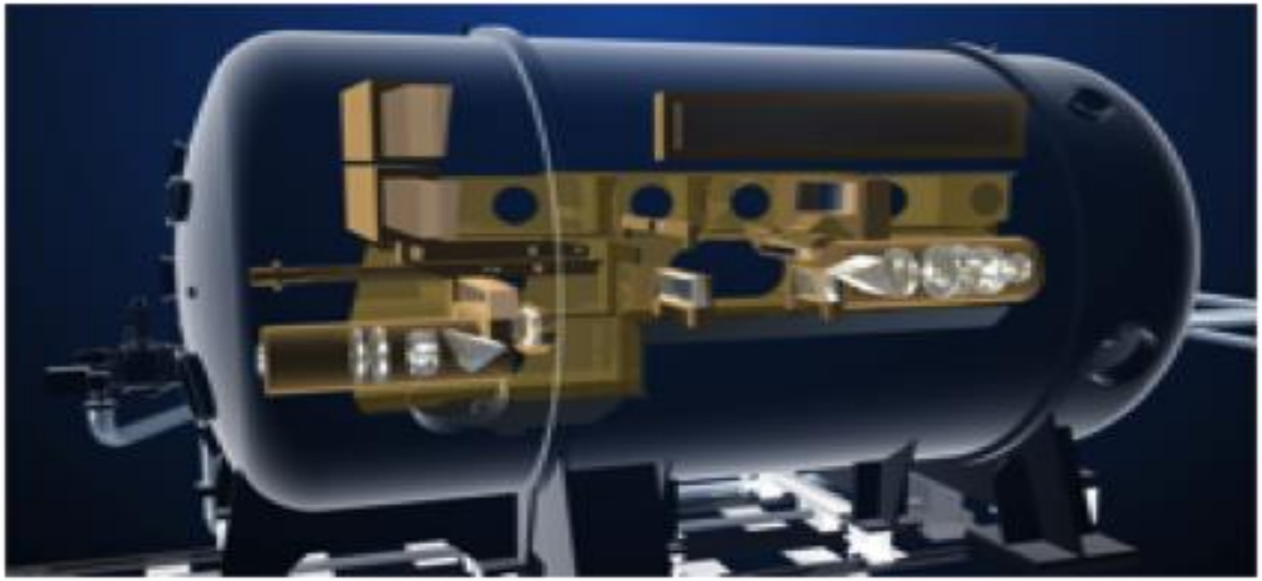
Δp=0.01 mBar

ΔRV =1 m/s

Δλ=0.00001 A

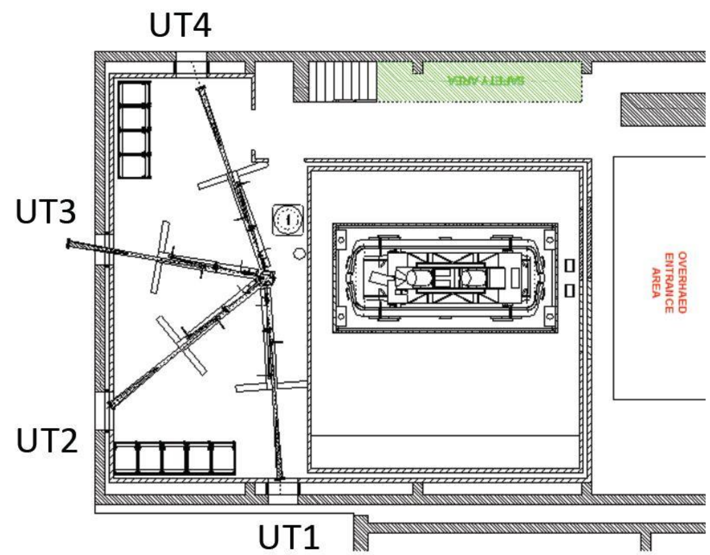
15 nm

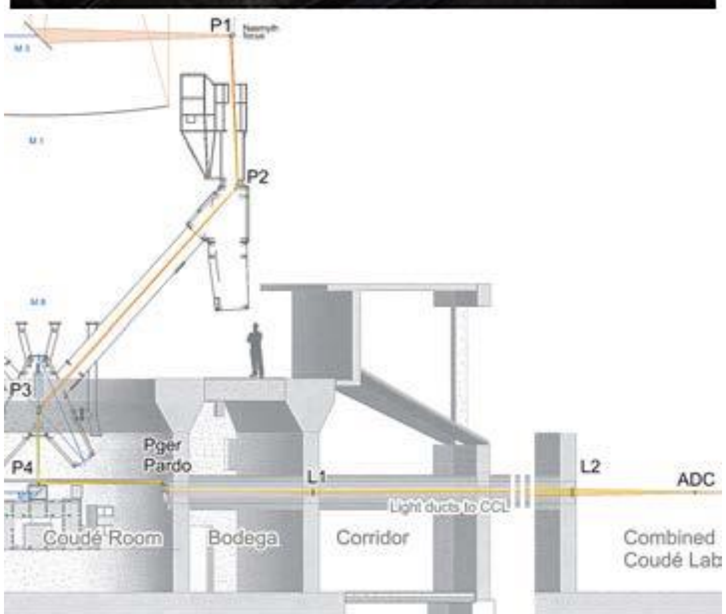
1/1000 pixel

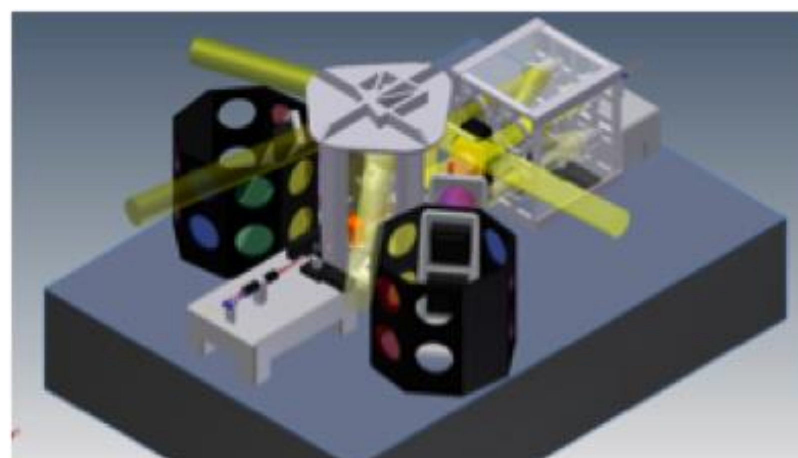


ESPRESSO @ the CCL of VLT

Distances to Combined Lab
UT 1 – 69 m
UT 2 – 48 m
UT 3 – 63 m
UT 4 – 63 m



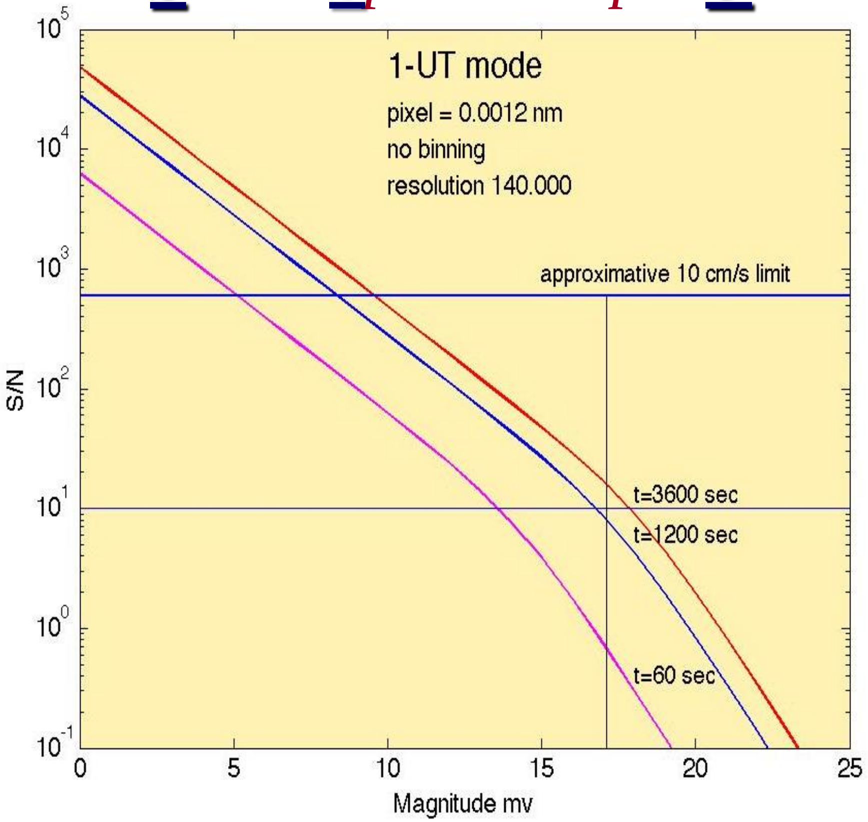


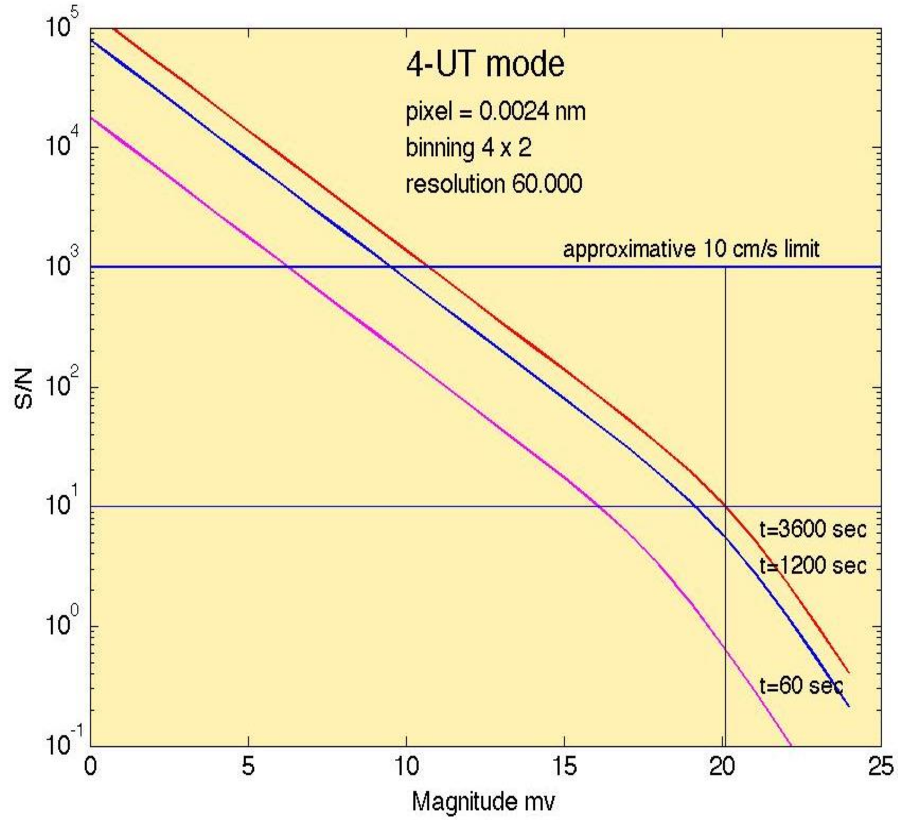


Sensitivity + Stability:

***E**chelle **SP**ectrograph for **R**ocky **E**xoplanets*

*and **S**table **S**pectroscopic **O**bservations*





The ESPRESSO Team

ESO:

H. Dekker, G. Avila, B. Delabre, O.Iwert, F.Kerber, G.LoCurto, J.L.Lizon, A.Manescau, L. Pasquini

IAC/Spain

R. Rebolo, M.Amate, R. García López, J.M.Herreros, J.L.Rasilla, S.Santana, F.Tenegi, M.R.Zapatero Osorio,

INAF-Trieste/Brera:

S.Cristiani, V.Baldini, R. Cirami, I.Coretti, G.Cupani,V. D'Odorico, V. De Caprio, P. Di Marcantonio, P. Molaro, E.Poretti, M. Riva, P.Santin, P. Spano`, E.Vanzella, M. Viel, F.M. Zerbi

Observatoire Geneve/Phinst Bern:

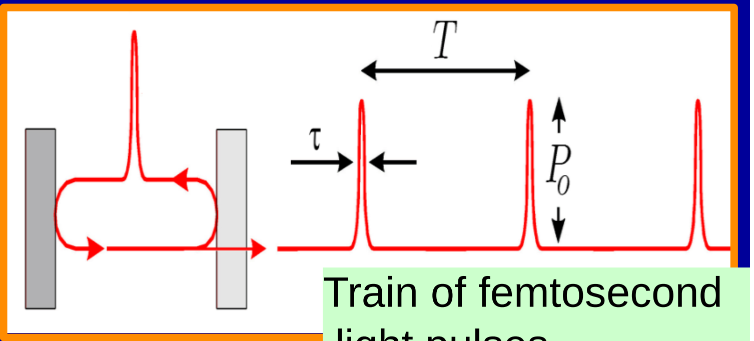
F.Pepe, W.Benz, M. Fleury, I.Hughes, Ch. Lovis, M. Mayor, D.Megevand, M.Pichard, D. Queloz, D.Sosnowska, S. Udry

Portugal (CAUP/FCUL Porto-Lisboa) :

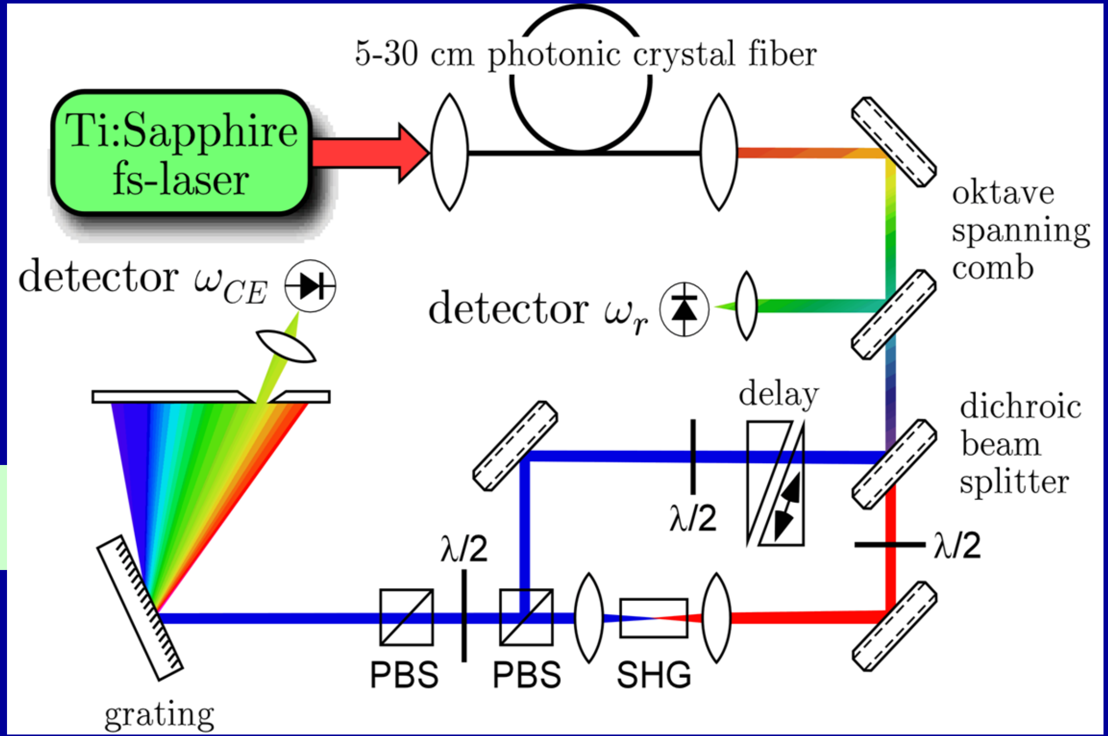
N.Santos, M.Abreu, A.Armorim, A.Cabral, P.Figueira, J.Lima, A.Moitinho, M.Monteiro, J.Pinto Coelho

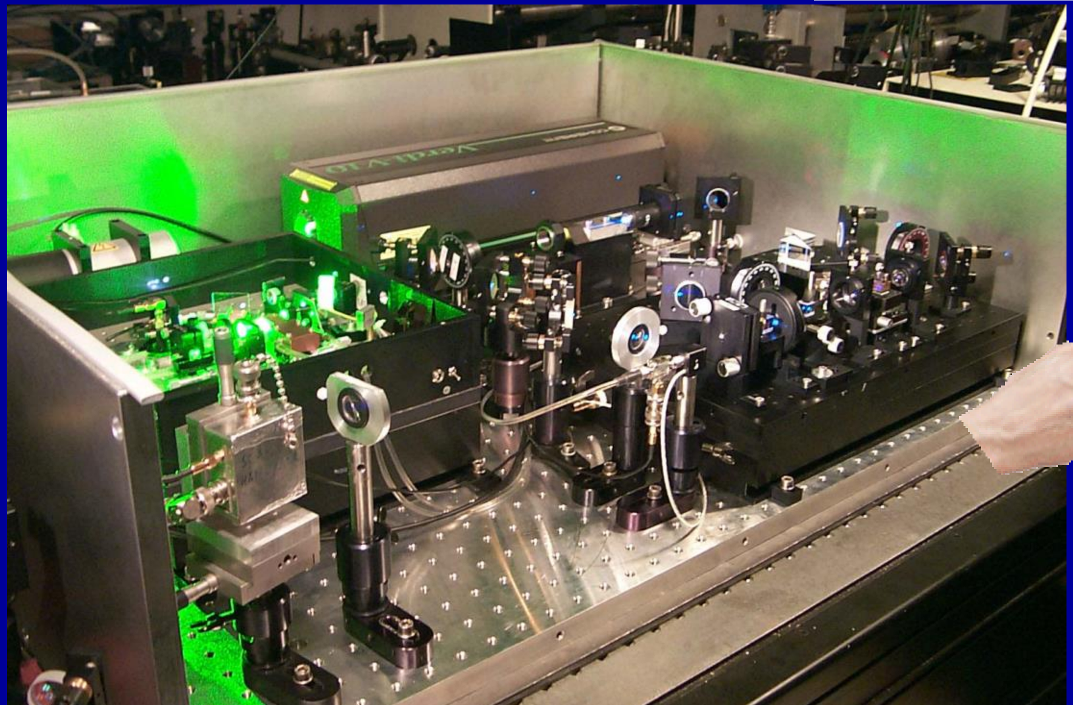
Laser Comb

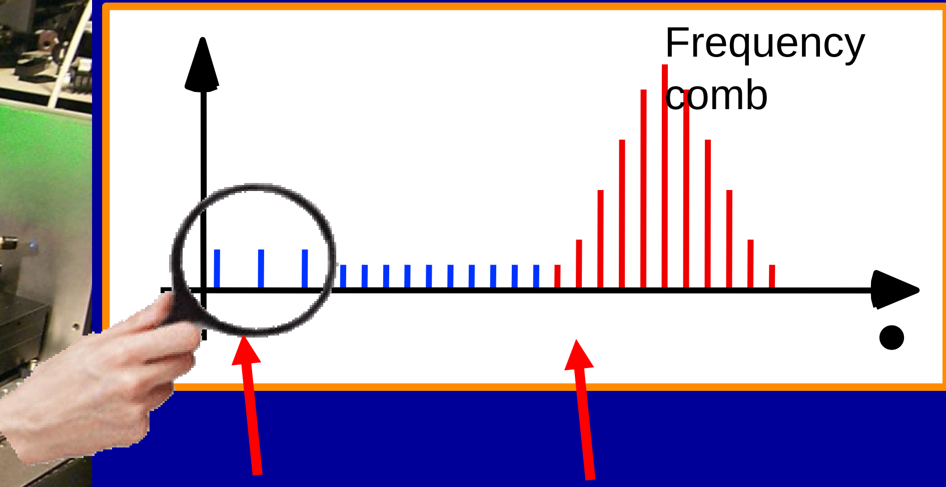
Thomas Udem (MPQ)



Train of femtosecond light pulses







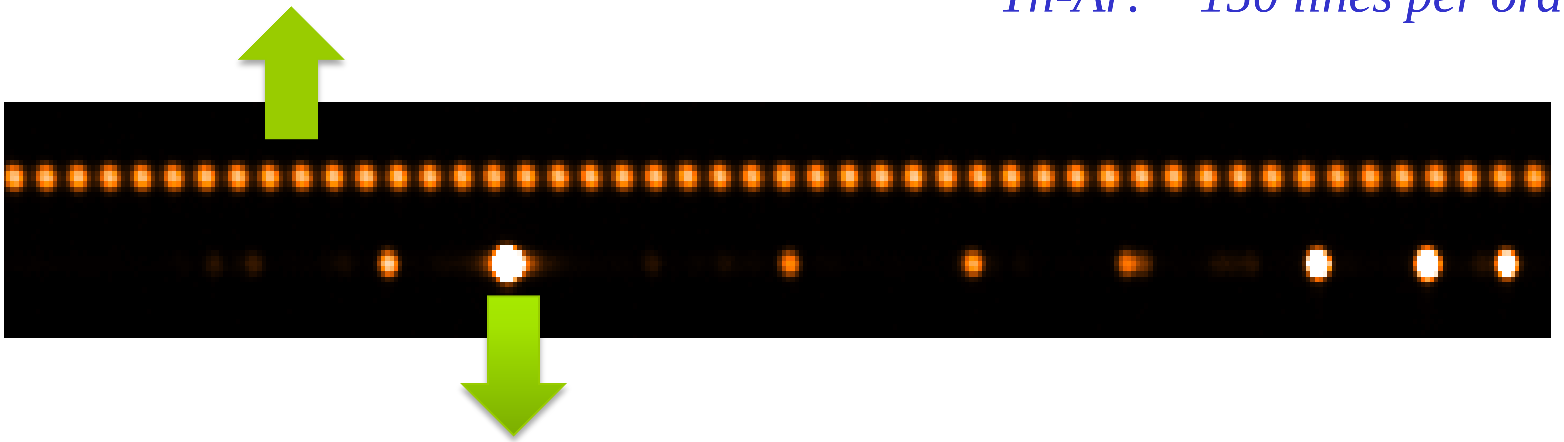
Zero offset and line spacing known with absolute precision (limit = atomic clock.)

Laser Frequency Comb

Astro-comb: ~ 450 lines per order

Th-Ar: ~ 150 lines per order

Astro-comb



Th-Ar

*Measure RV of 61 Vir using 30 wavelength calibration files on **one** stellar spectrum*

	Comb RV mean	Th RV mean	Comb RV RMS	Th RV RMS
1 order	-7.73132km/s	-7.66583km/s	7.7cm/s	220cm/s
72 orders	-	-7.69770km/s	0.9/0.8cm/s *	24cm/s

* Extrapolation to 72 orders

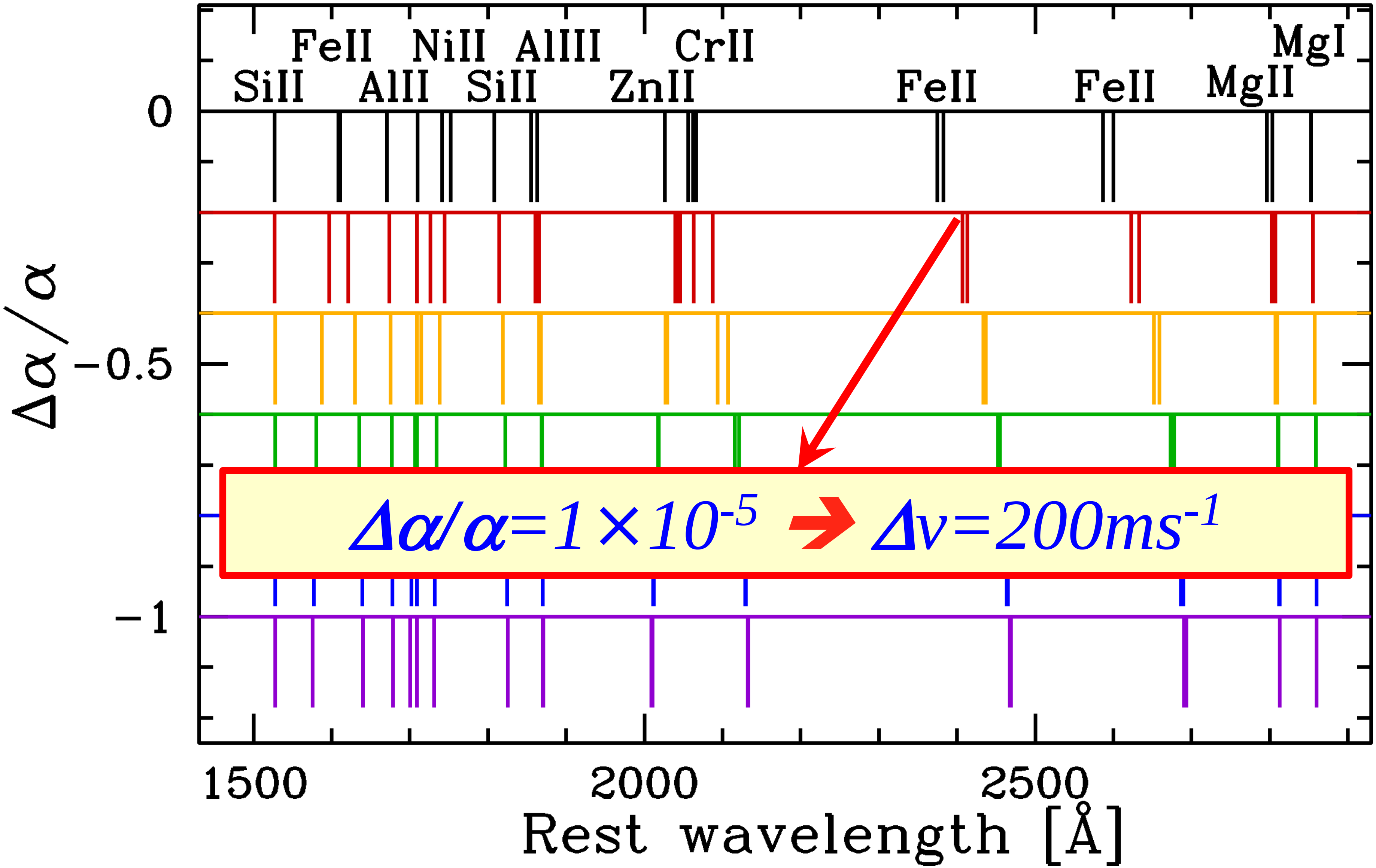
Fundamental? Constants?:

See Murphy ESO 50yrs

- *[Note: Only low-energy limits of constants discussed here]*
- *Why "fundamental"?*
  - *Cannot be calculated within Standard Model*
- *Why "constant"?*
  - *Because we don't see them changing*
  - *No theoretical reason – see above*
- *Best of physics: Relative stability of* $\alpha \sim 10^{-17}\,yr^{-1}$ *(Rosenband et al. 2008)*
- *Worst of physics: Sign of incomplete theory?*

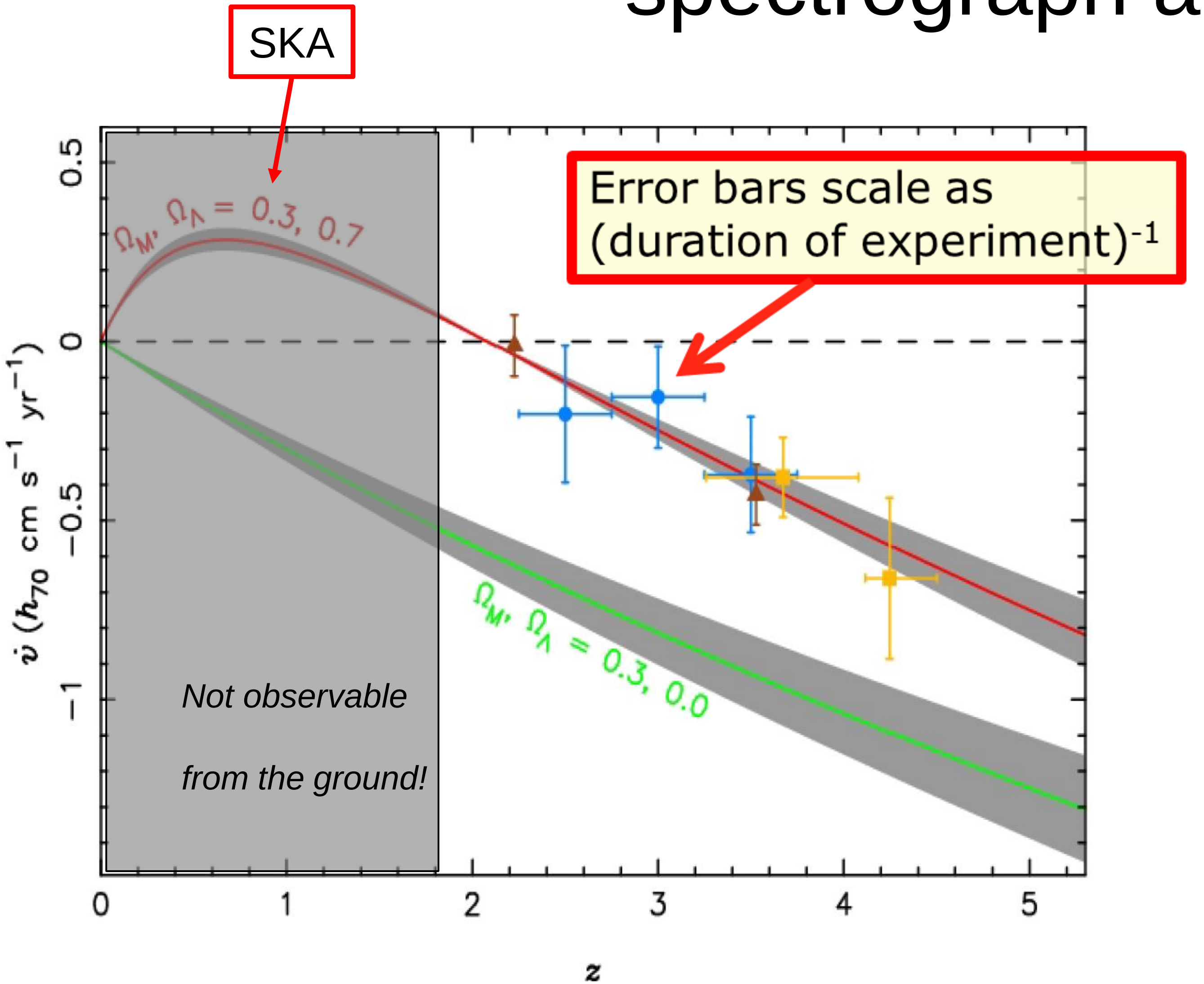
- *Constancy based on Earth-bound, human time-scale experiments*
- *Extension to Universe seems a big assumption*

The Many Multiplet (MM) method:



Sandage Test
Cosmic Expansion

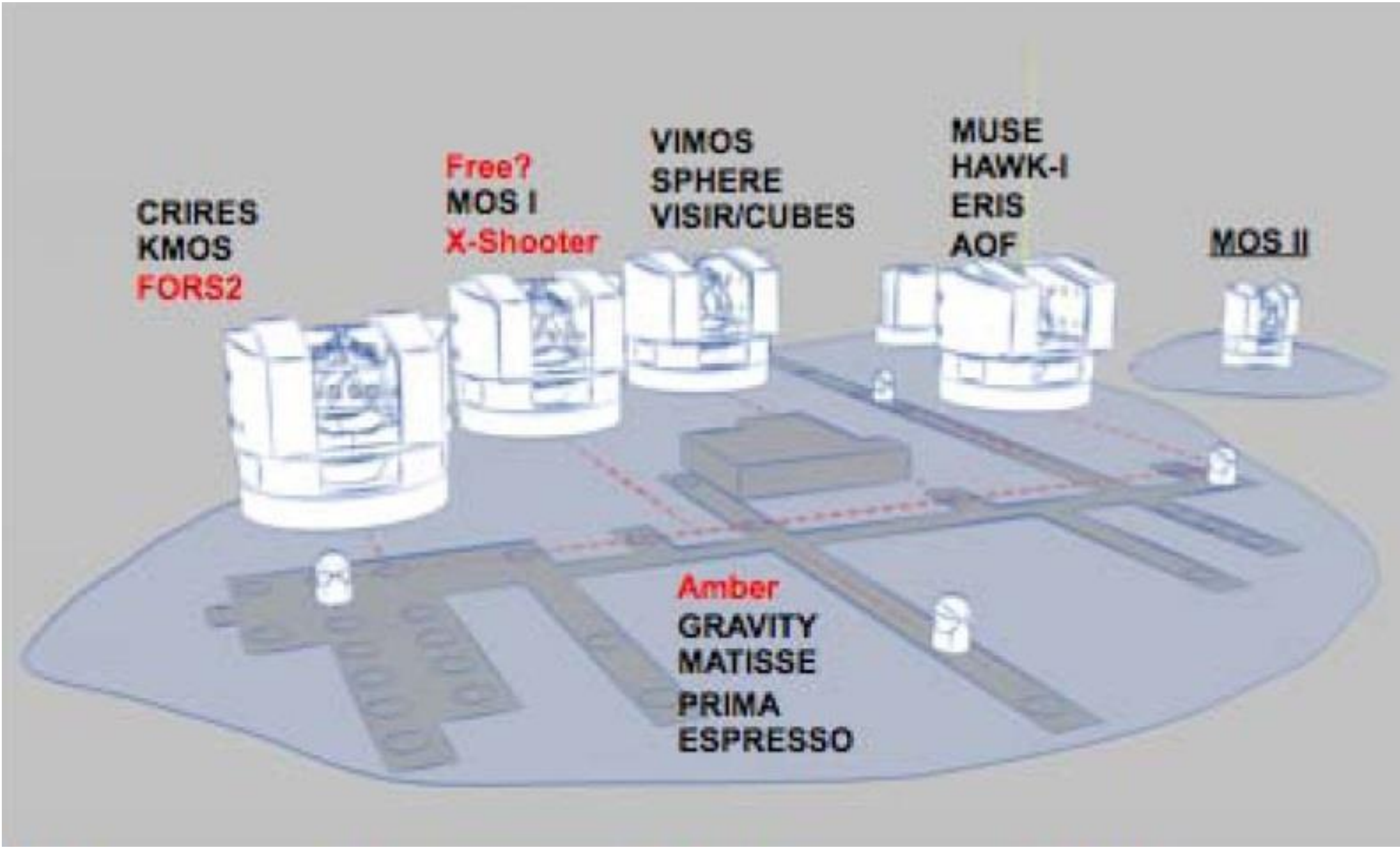
Feasibility Test with a Rs~10^5 spectrograph at the E-ELT



- Different coloured points reflect different targeting strategies
- 4000 hrs on 39-m E-ELT over 21.5 years, *or*
- 1200 hrs on 39-m E-ELT over 40 years

Pasquini et al. 2005, Cristiani et al. 2007, Liske et al. 2008

Paranal Instrumentation (in 2018)



Decomm. ISAAC, NACO, MIDI, UVES?

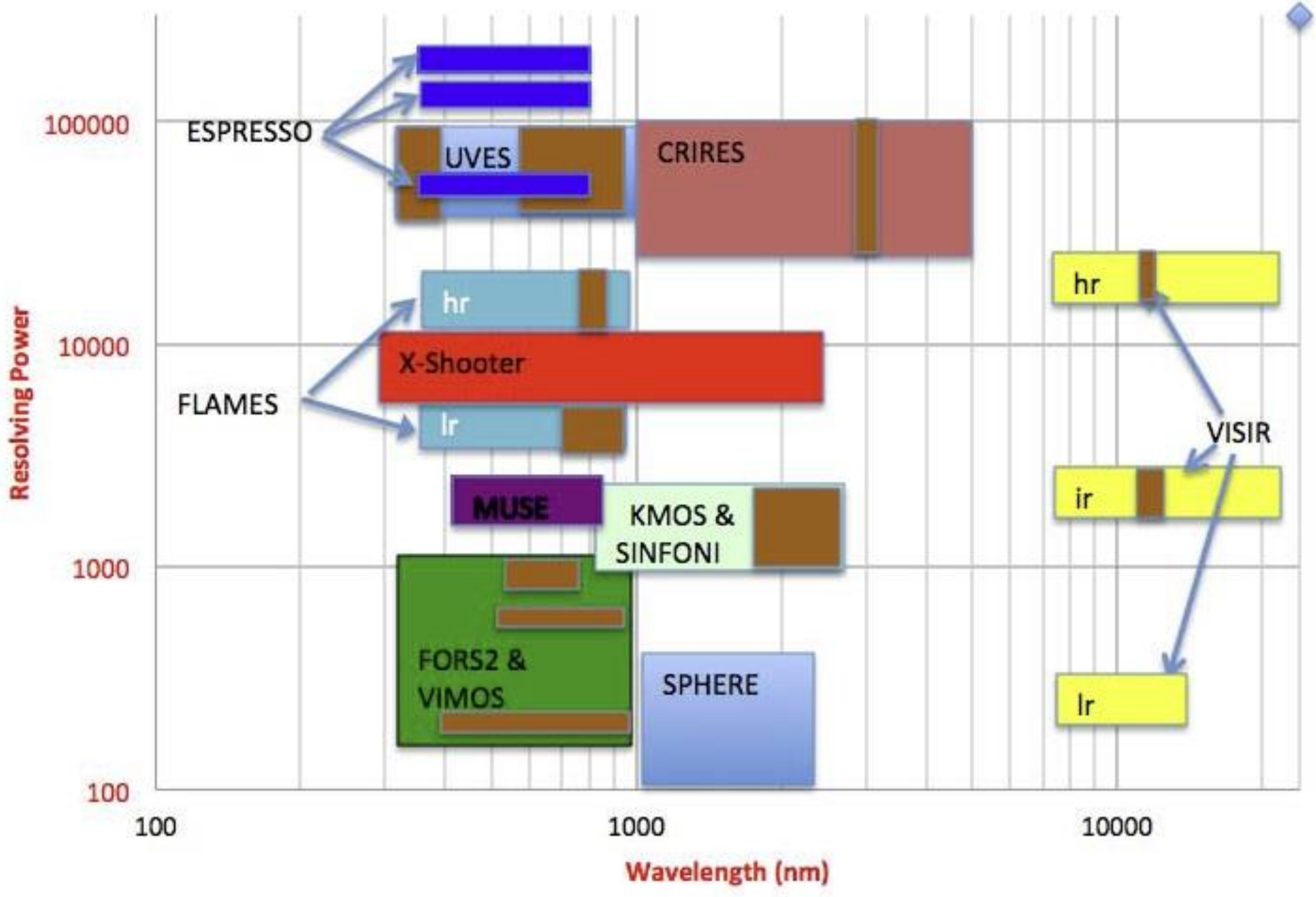
Characteristics of Paranal imagers in 2018

FORS2	(0.3 -1µm 6.8x6.8 arcmin)
VIMOS	(0.35-1µm 4x7x8 arcmin)
VST+ΩCAM	(0.3 -1µm 1x1 degree)
VISTA(?)	(0.8-2.5µm eq.46x46 arcmin)
AO assisted	
HAWK-I + AOF (GLAO)	(0.8-2.4µm 7x7 arcmin)
Diffraction Limit (1UT)	
SPHERE	(0.6-2.3µm 11x11 arcsec)
ERIS	(1-5µm 2x2 arcmin)
VISIR	(8-24µm 32x32 arcsec)
Diffraction Limit (VLTI)	
MATISSE	(3.5-12µm ~1 arcsec)
GRAVITY	(2-2.4µm 2 arcsec)

Characteristics of Paranal spectrographs in 2018

AMBER	(1.46-2.5μm R=35-12000)
GRAVITY	(2-2.4μm R=22-500-4000)
VISIR	(8-13μm R~500)
FORS2	(0.3-1μm R=300-3000)
MUSE	(0.46-0.93μm R=3000)
SINFONI	(1.1-2.45μm R=2-4000)
VIMOS	(0.36-0.9μm R=200-2500)
KMOS	(0.8-2.5μm R=3600)
SPHERE	(1-2.3μm R=100-700)
MOONS	(0.8-1.6μm R=6000-20000)
XSHOOTER	(0.3-2.4μm R=6-10000)
FLAMES(?)	(0.37-0.9μm R=6-20000)
VISIR	(10μm R=3200, 25000)
CRIRES	(0.95-5μm R=40-100000)
UVES	(0.3-1μm R=40-120000)
ESPRESSO	(0.38-0.8μm R=120-220000/4UT 60000)

Resolving power vs. wavelength



Characteristics of some Paranal modes in 2018

Polarimetry: FORS2 (Circ. and Lin.), SPHERE, CRIRES?, VISIR?

High/Contrast/Coronography: SPHERE, VISIR?

RV Precision:

ESPRESSO (<0.1 m/s), CRIRES (<3 m/s)

Fast Photometry: VISIR (5ms?), HAWK-I Bust mod(2ms), FORS2 (2ms)

Astrometry: GRAVITY (30 µarcsec, goal 10), ERIS (300 µarcsec)

Considerations and prospects

- *ITALY - Limited participation to the 1st generation VLT instruments.*
- *Good match with the scientific and technical strength of the community and the Italian share of the ESO budget for the 2nd generation.*
- *Need of careful planning and proper resources to take full advantage of the Italian GTO nights*
- *On the managerial side, need to quantify return of the investment (both for ESO and INAF)*
- *Strong participation to the E-ELT instrument studies. Need to consolidate the projects and proper follow-up/ lobby by INAF in the coming crucial phase of the project*

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