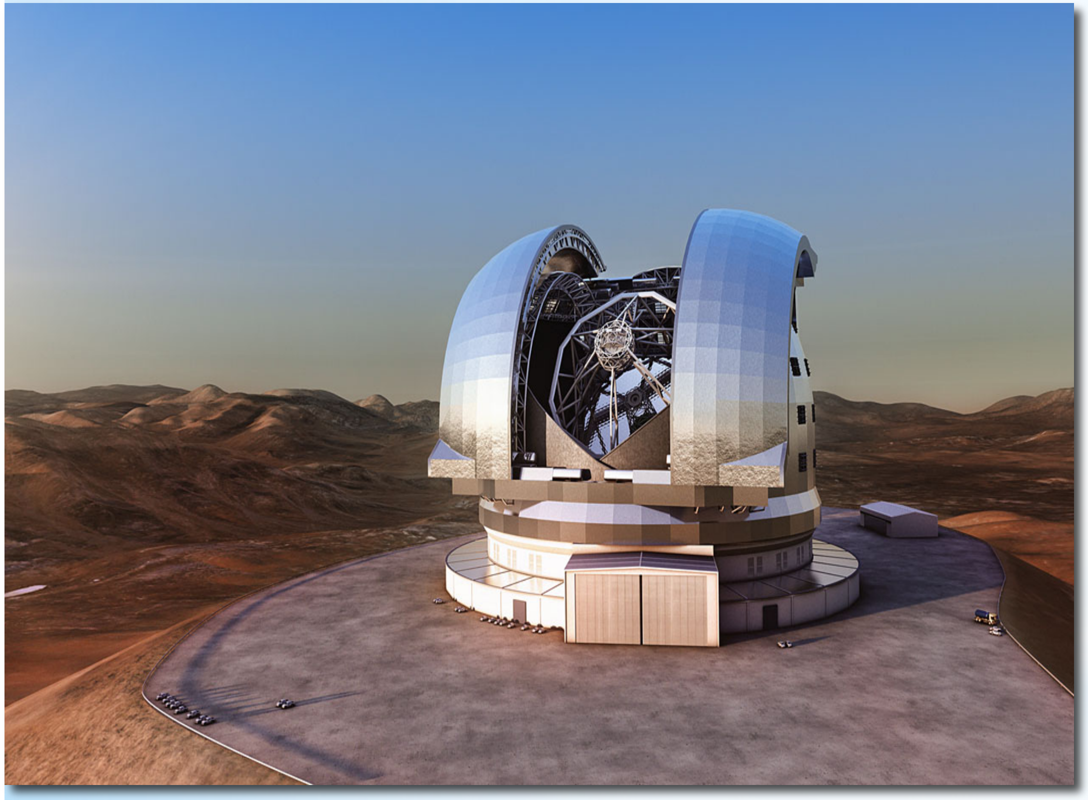
Science with E-ELT: current status

G. Bono

UNIVERSITA' DEGLI STUDI DI ROMA Tor Vergata



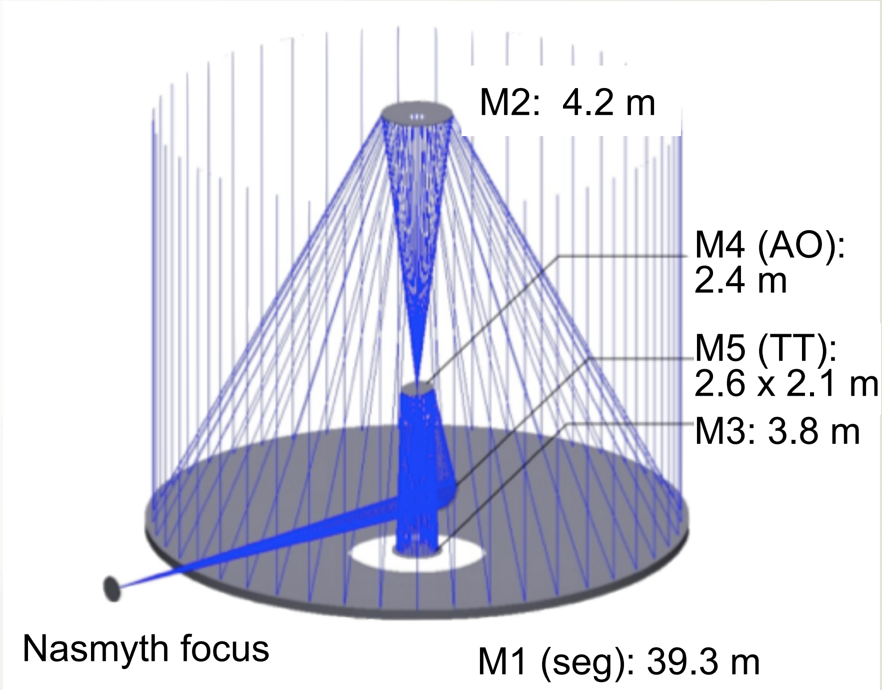
Outline of the talk

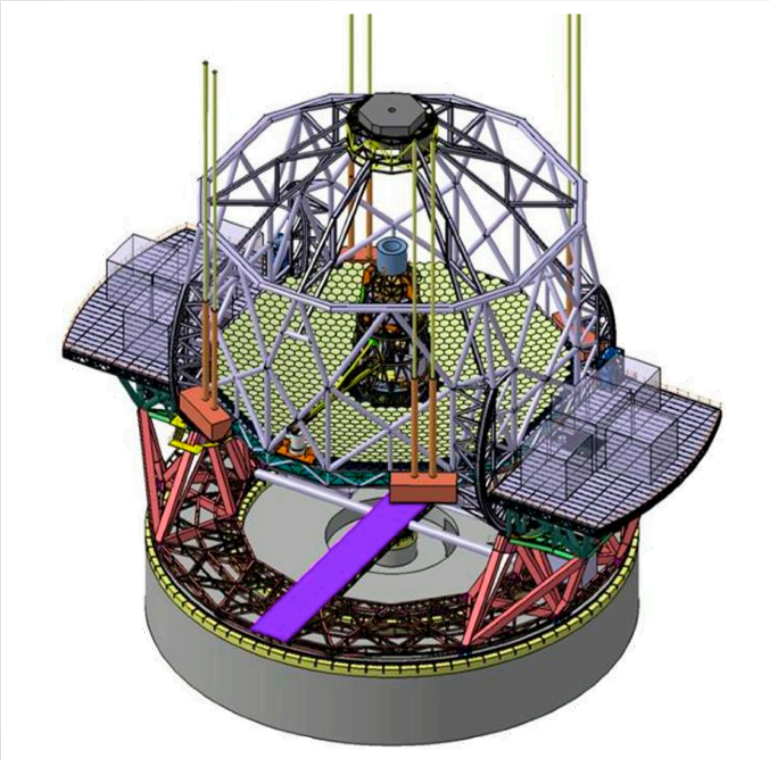
- E-ELT in a nutshell
- First light + 3,4,5
- Deep along the MS
- *Conclusions*

Sait, Milano, 16th May 2014

The Telescope

- Nasmyth telescope with a segmented primary mirror.
- Novel 5 mirror design to include adaptive optics in the telescope.
- Classical 3-mirror anastigmat + 2 flat fold mirrors (M4, M5).





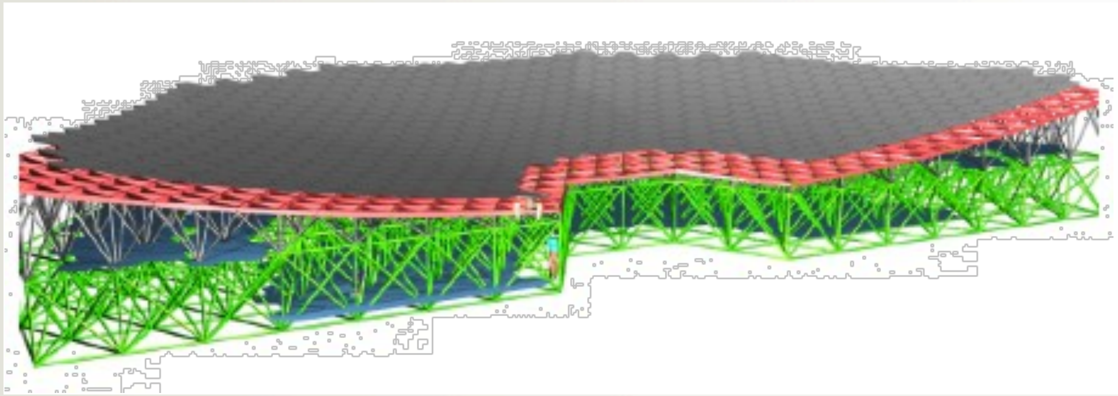
Multiple laser guide stars, launched from the side.

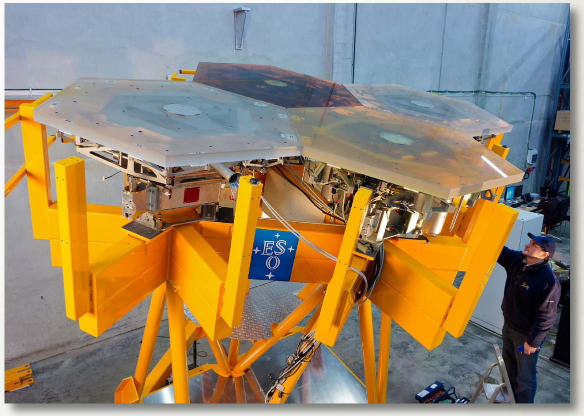
Two instrument platforms nearly the size of tennis courts can host 3 instruments each + Coudé lab.

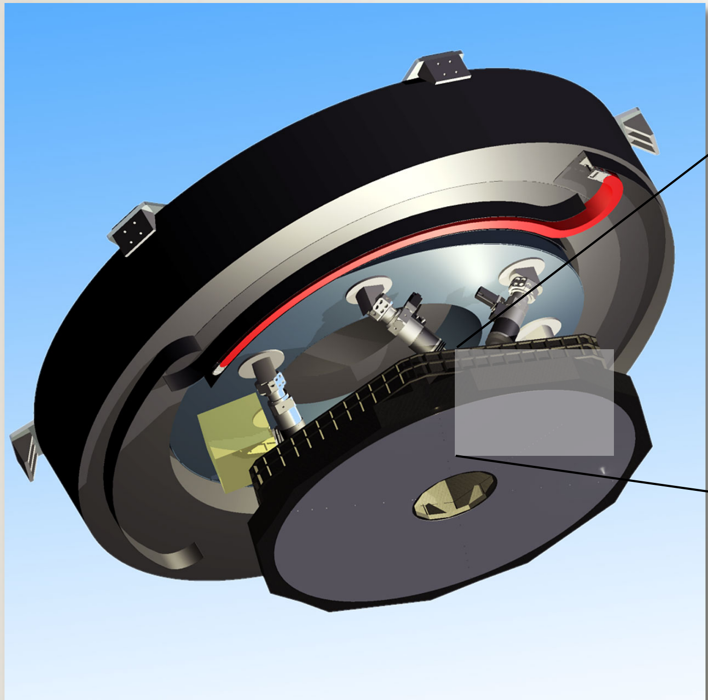
Nearly 3000 tonens of moving structure.

The Mirrors

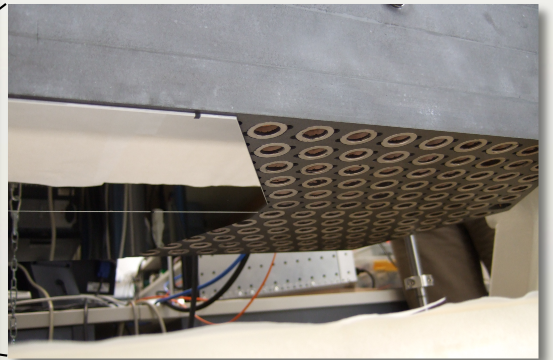
M1: 39.3 m, 798 hexagonal segments of 1.45 m tip-to-tip: 978 m^2 collecting area







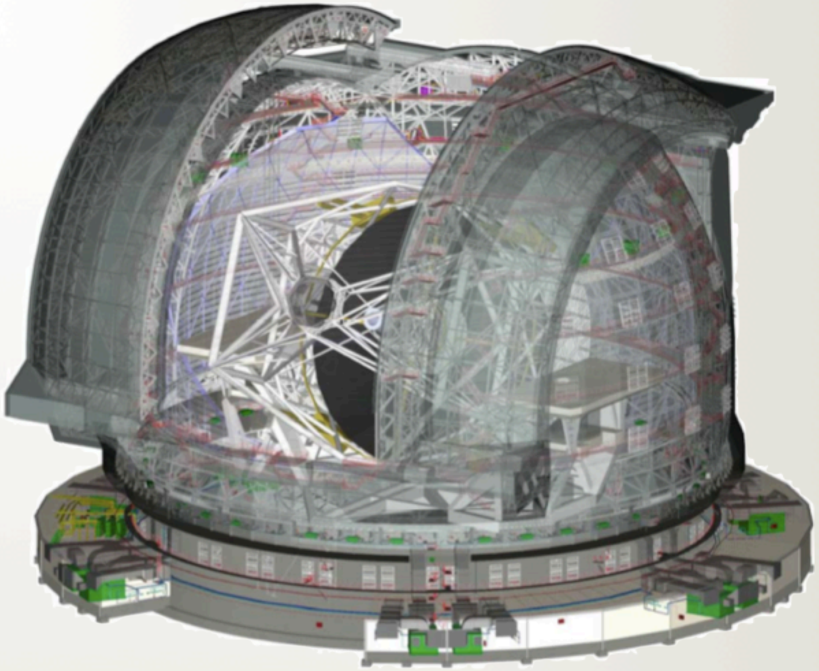
M4: 2.4 m, flat, adaptive
6000 to 8000 actuators

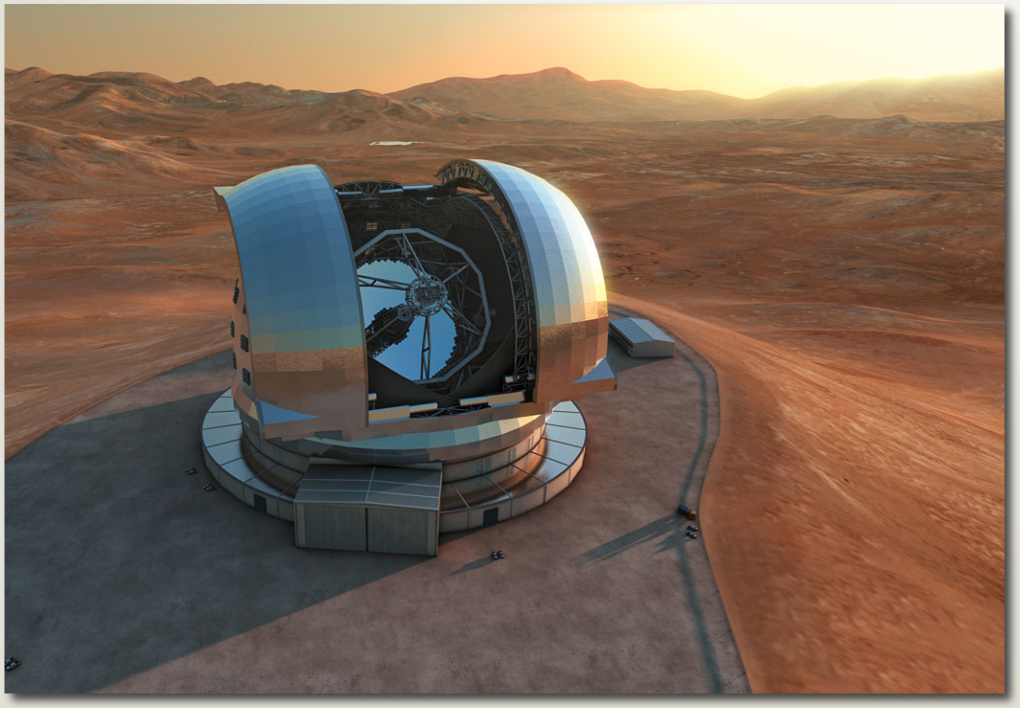


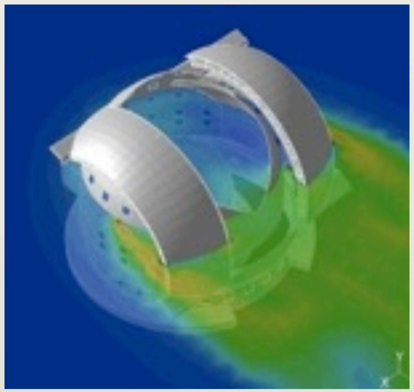
M5: 2.6 x 2.1 m, flat,
provides tip-tilt correction

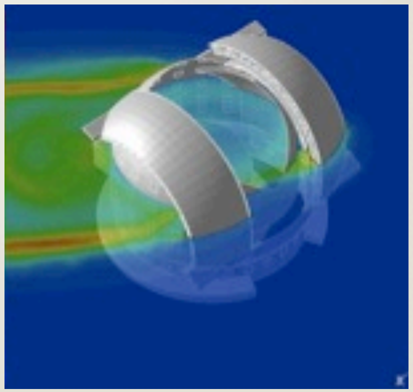
The Dome

- Classical design.
- Diameter = 86 m, height = 74 m.
- ~3000 tonnes of steel.
- Fully air-conditioned and wind shielded.



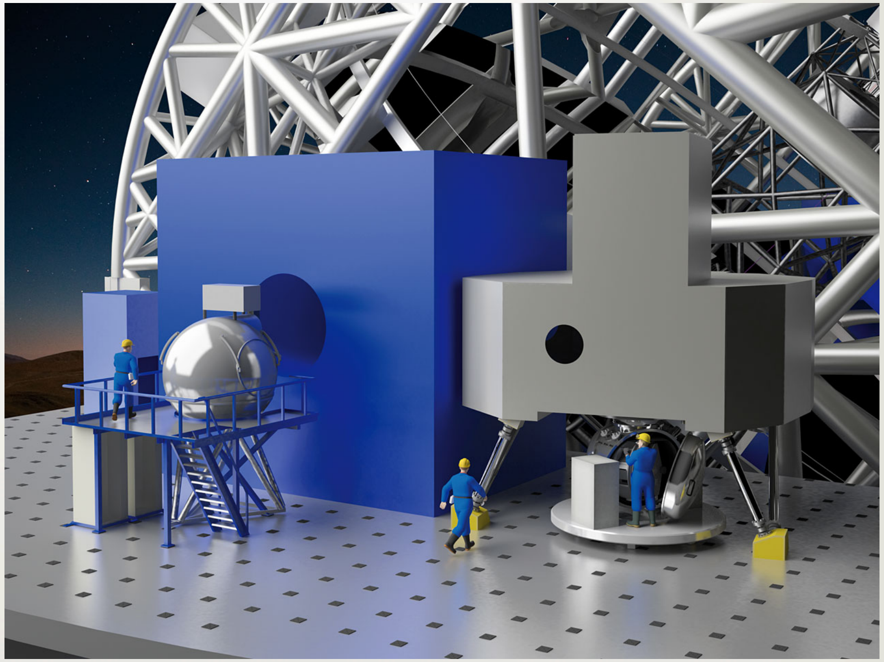






Instrument Roadmap

- Following recommendations by the SWG and STC, 2 first-light instruments have been identified, kick-off: 2012.
- Next group (ELT-3, 4 and 5) broadly identified. Scientifically equal and so sequence is determined by technical readiness. Kick-off: every two years.
- Planet camera and spectrograph on separate track.
- Flexibility is maintained by including an as yet unspecified instrument (ELT-6).
- All phase A studies remain in the pool of possible instruments.



E-ELT Science Working Group

Mark McCaughrean
Eline Tolstoy
Andrea Cimatti
Isobel Hook (Chair)
Hans-Uli Kaeufl
Rafael Rebolo
Sofia Feltzing
Piero Madau
Mike Merrifield
Christophe Lovis
Fernando Comeron
Jacqueline Bergeron
Wolfram Freudling
Hans Zinnecker
Piero Rosati
Martin Haehnelt
Raffaele Gratton
Matt Lehnert
Jose Miguel Rodriguez Espinosa

Previous members:
Peter Shaver, Bob Fosbury, Willy Benz, Marijn Franx (former Chair), Vanessa Hill, Stephane Udry, Markus Kissler-Patig, Bruno Leibundgut, Arne Ardeberg, Didier Queloz

First Generation E-ELT Instruments

First Light:

E-ELT -- CAM (MICADO): R. Davies

E-ELT -- IFS (HARMONI): N. Thatte

3) E-ELT – MIR: L, M, N

4) E-ELT – HIRES (Optical – NIR)

5) E-ELT – MOS: Fibers + IFUs (optical, NIR)

6) E-ELT – Not defined yet

E-ELT Project Science Team (May 2012)

PST + ESO representative + Scientific PIs of approved instruments

J. Liske

P. Padovani

Solar & Extra-solar planets	Stellar populations	Galaxies & cosmology	Technology
G. Chauvin	G. Bono (chair)	I. Hook	J. Cepa
T. Encrenaz	R. Gredel	R. Kotak	T. Herbst
D. Queloz	O. Kochukhov	C. Martins	R. Ragazzoni
C. Keller			

Reports: E-ELT Project Scientist
Advices: E-ELT Project Manager

Top Level Requirements

E-ELT Project Science Team

TLRs for the first light instruments released in 2013:

1-- E-ELT CAM

2-- E-ELT IFU

TLRs for 3,4 & 5 instruments released early this year

3 – E-ELT MIR

4 – E-ELT HIRES

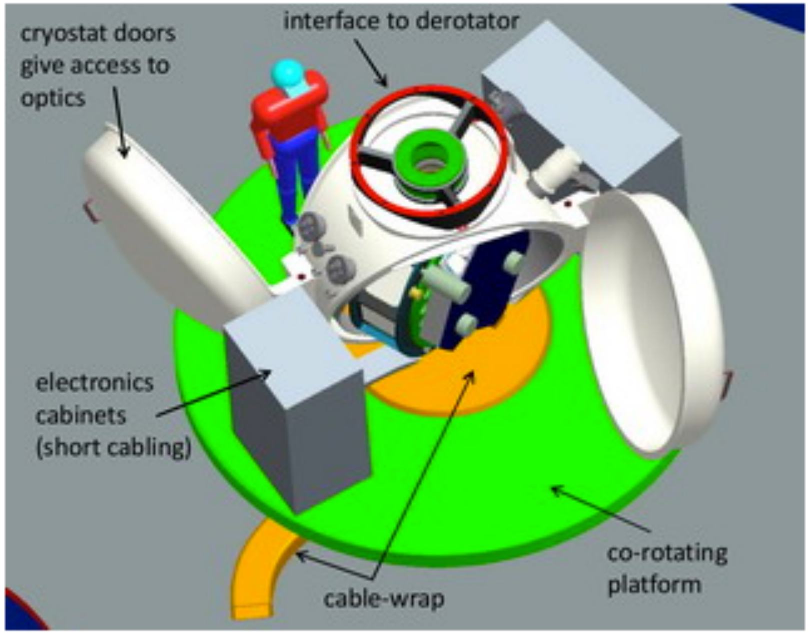
5 – E-ELT MOS

Formal approval of the TLRs by STC

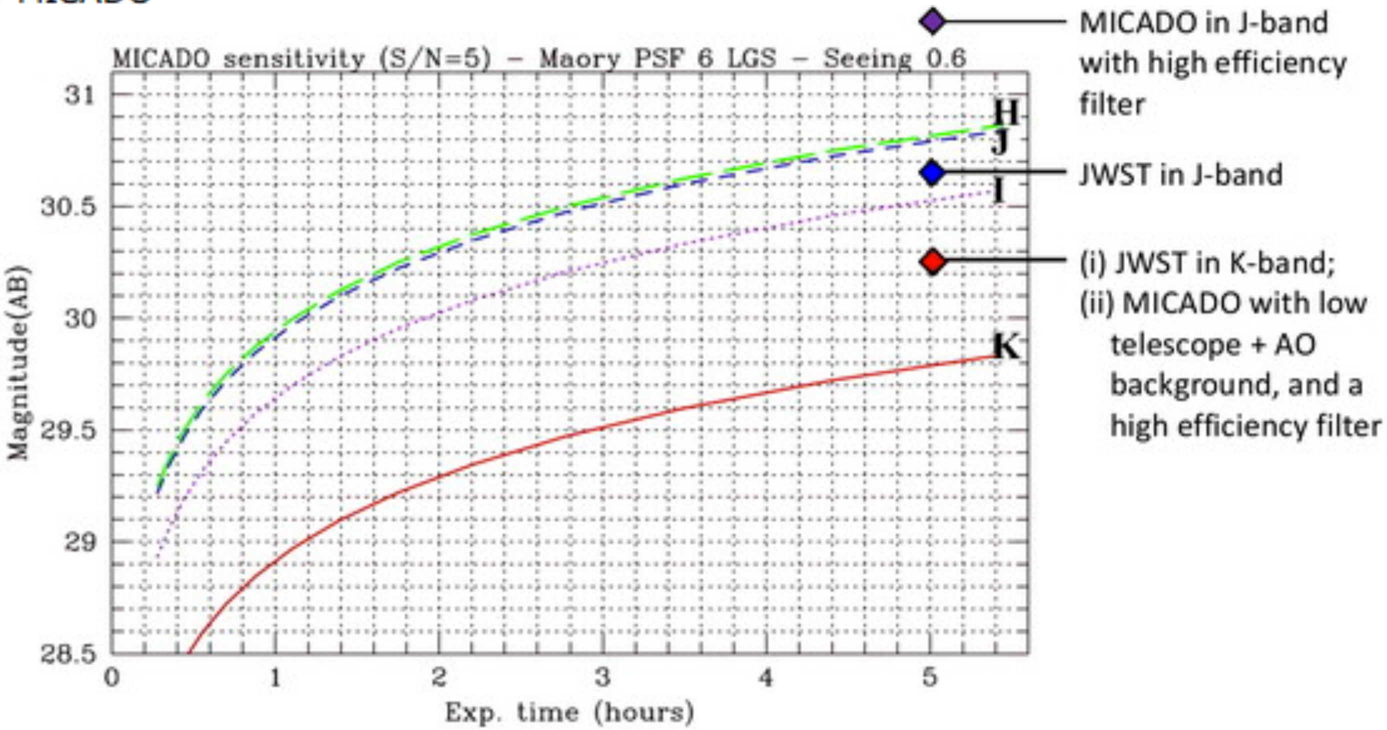
+STC sub-com for E-ELT (Chair: A.M. Lagrange)

E-ELT CAM: MICADO

Plus SCAO + MAO

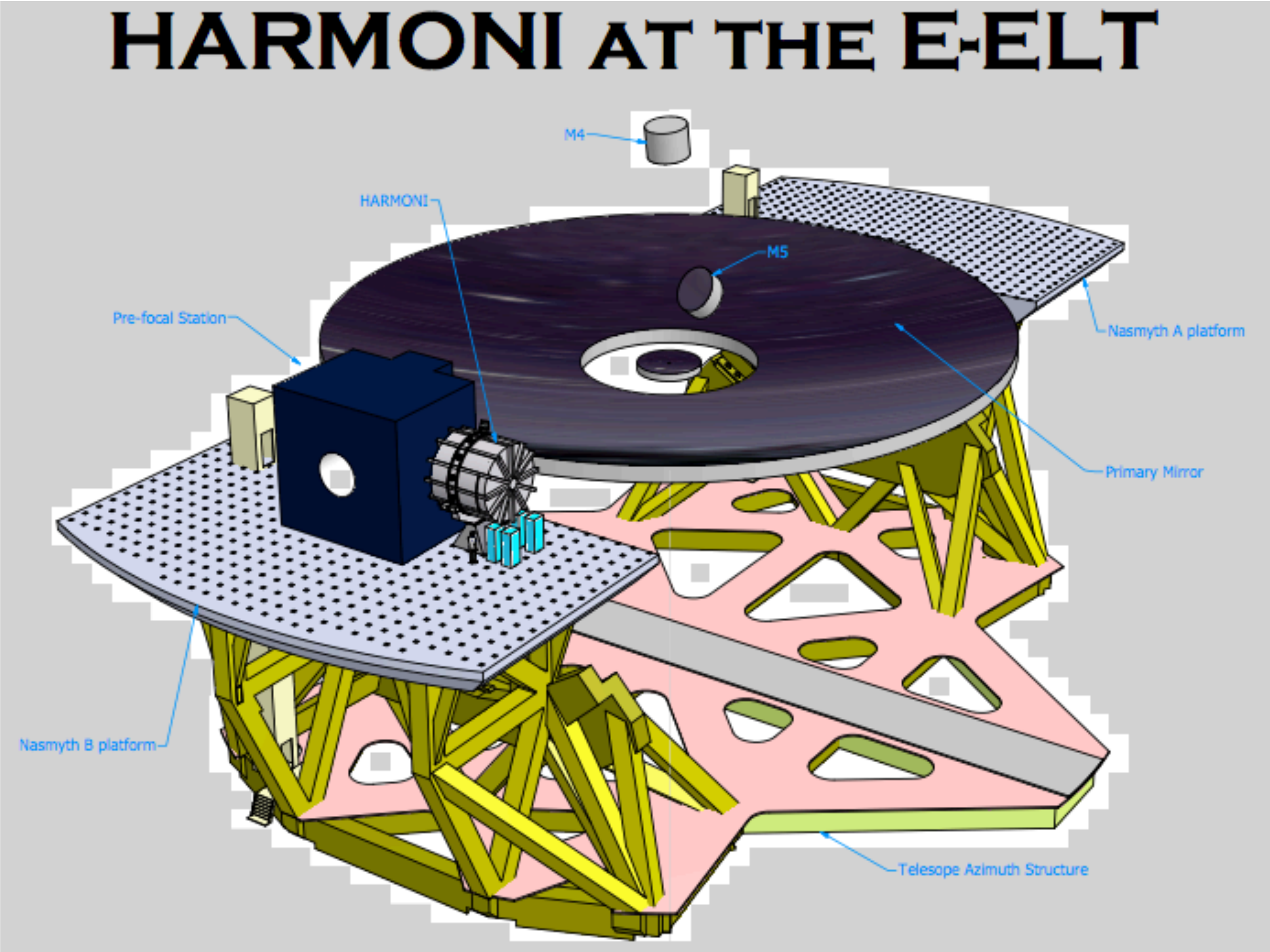


Overview of MICADO

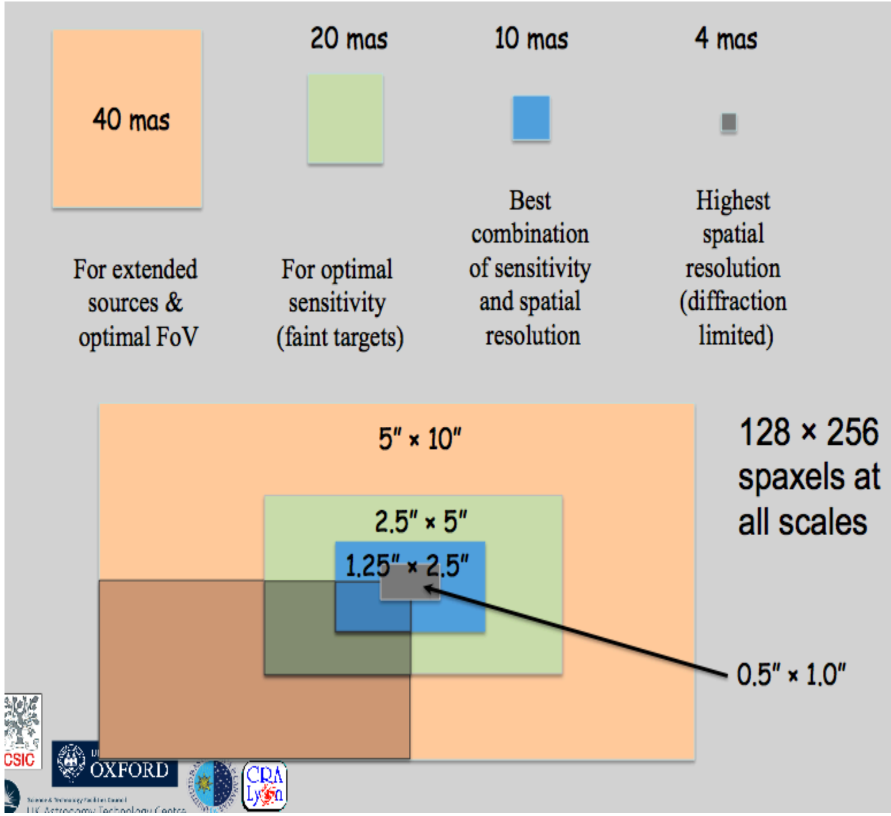


Broadband imaging sensitivity of MICADO as a function of integration time

E-ELT Integral Field Spectrograph: HARMONI



E-ELT Integral Field Spectrograph: HARMONI



Plus SCAO

Wavelength Ranges & Resolving Powers

Bands	R
V+R, I+z+J, H+K	~4000
V, R, I+z, J, H, K	~10000
Z, J_high, H_high, K_high	~20000

- Exploring adding simultaneous V-K coverage at R~500-1000
- Re-assessing the need for high spectral resolving power at visible wavelengths (< 0.8 micron)

Requirements for IFS@E-ELT in J,H,K-band

Large FoV	> a few arcsec
High multiplex	> intrinsic
Spatial res.	< 0.004—0.005 arcsec

Abundances (Iron, α-, s-, r-elements)

High-res R~20,000

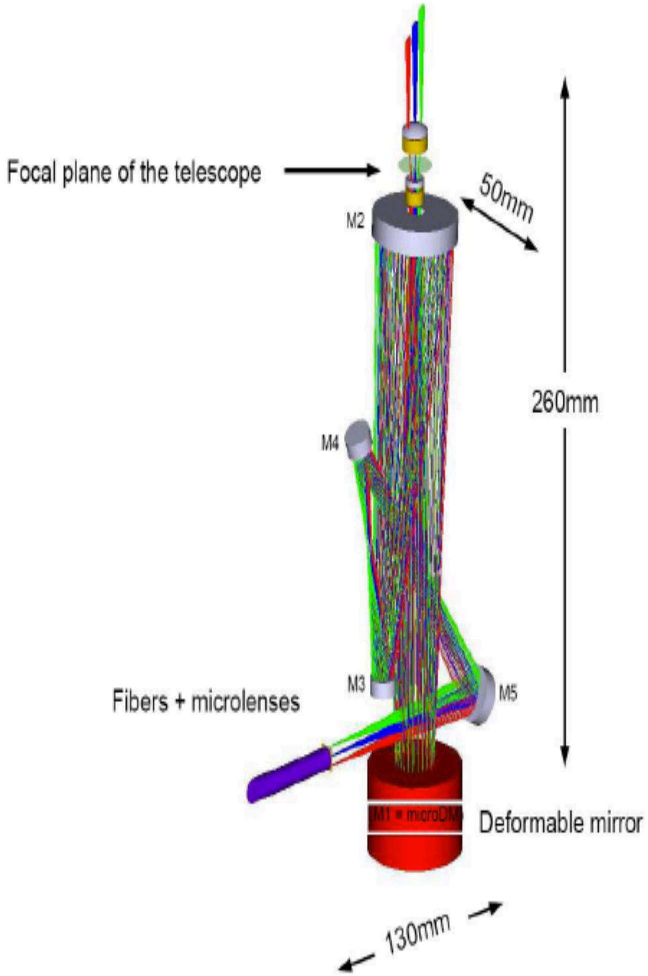
Limiting mag. K~23 mag

CRIRES (+GIANO) update crucial step,

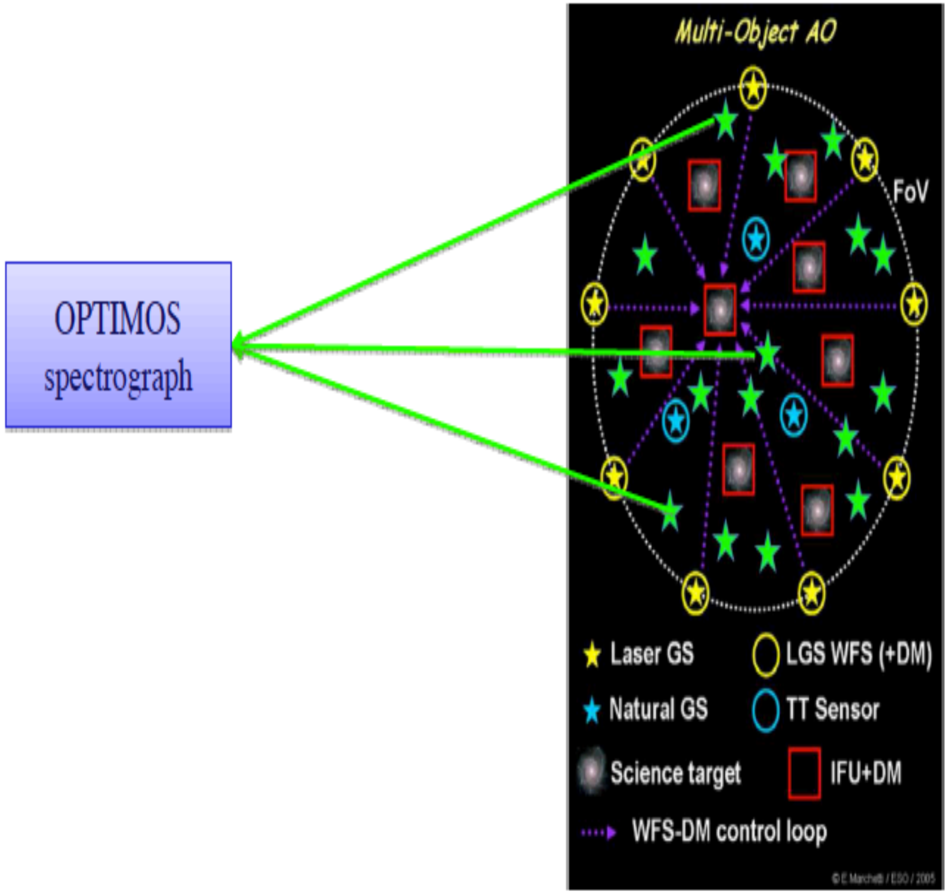
atmosphere model, line identification

E-ELT: MOS (Fiber Only Option)

AO Fibre Feed – “Bottle”



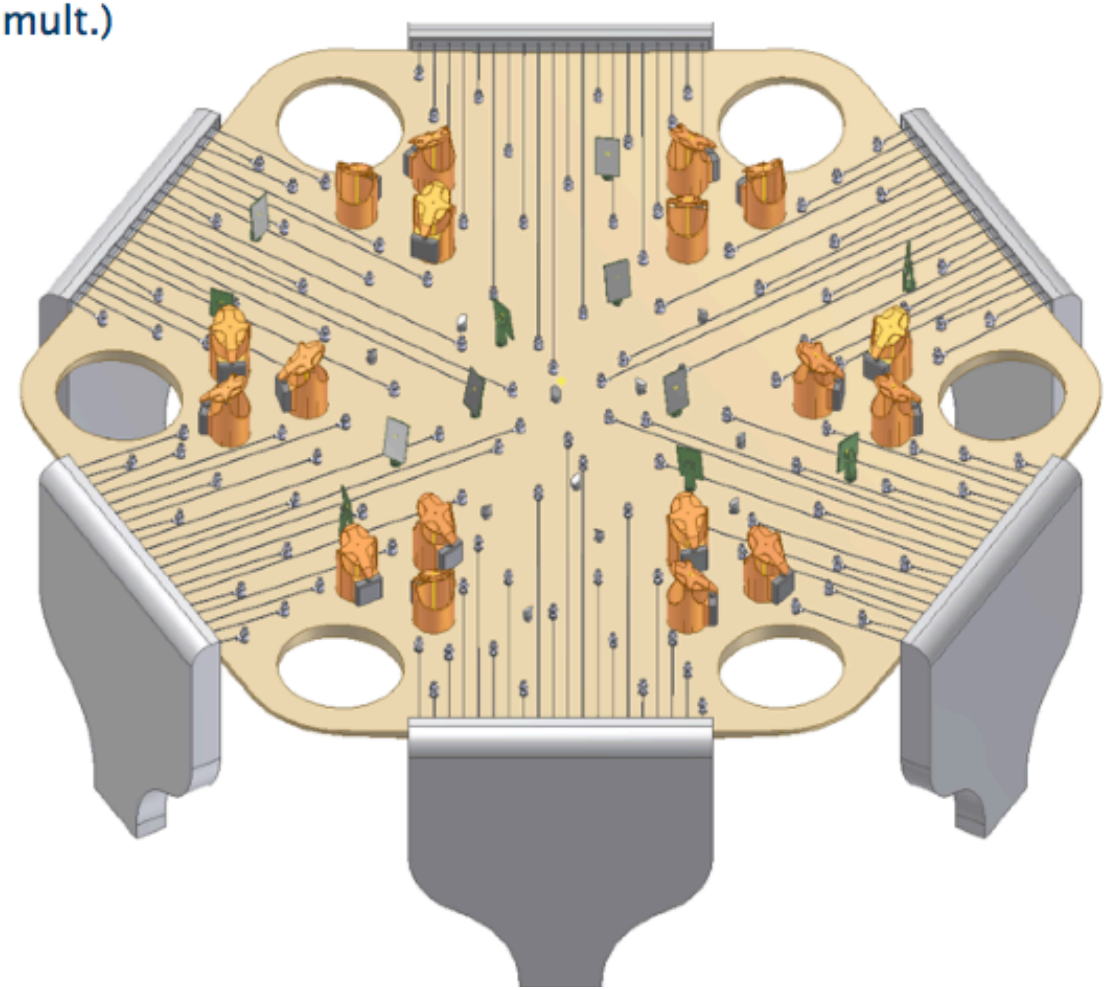
A shared focal plane



E-ELT: MOS

MOSAIC: Fiber Only Option

6x LGS
5x NGS
10x science (high def.)
120x science (high mult.)



E-ELT: MOS (Mixed Architecture design)

MOSAIC

Mixed Architecture Design

Pick and place robot arms

Assumptions

Multiple robot arms will speed up reconfiguration times.

Robots can fit within back focal distance.

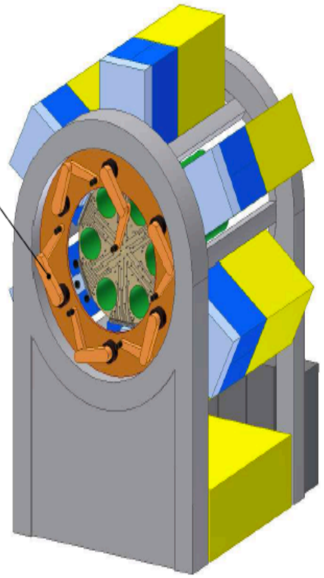
Known issues

Complex arrangement.

Reconfiguration performance TBD.

Placement on curved focal surface.

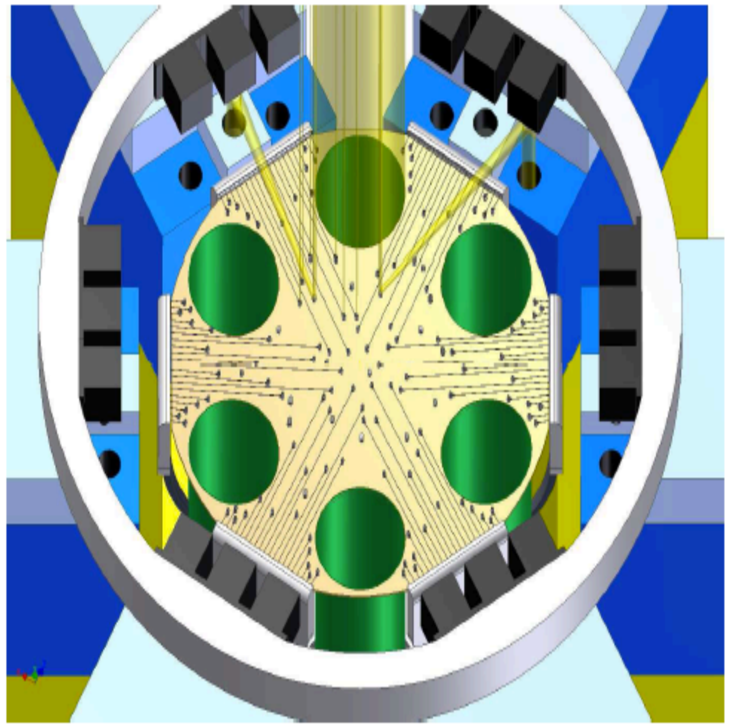
Intermediate fold mirror may require mirror angle to be set using robot arm.

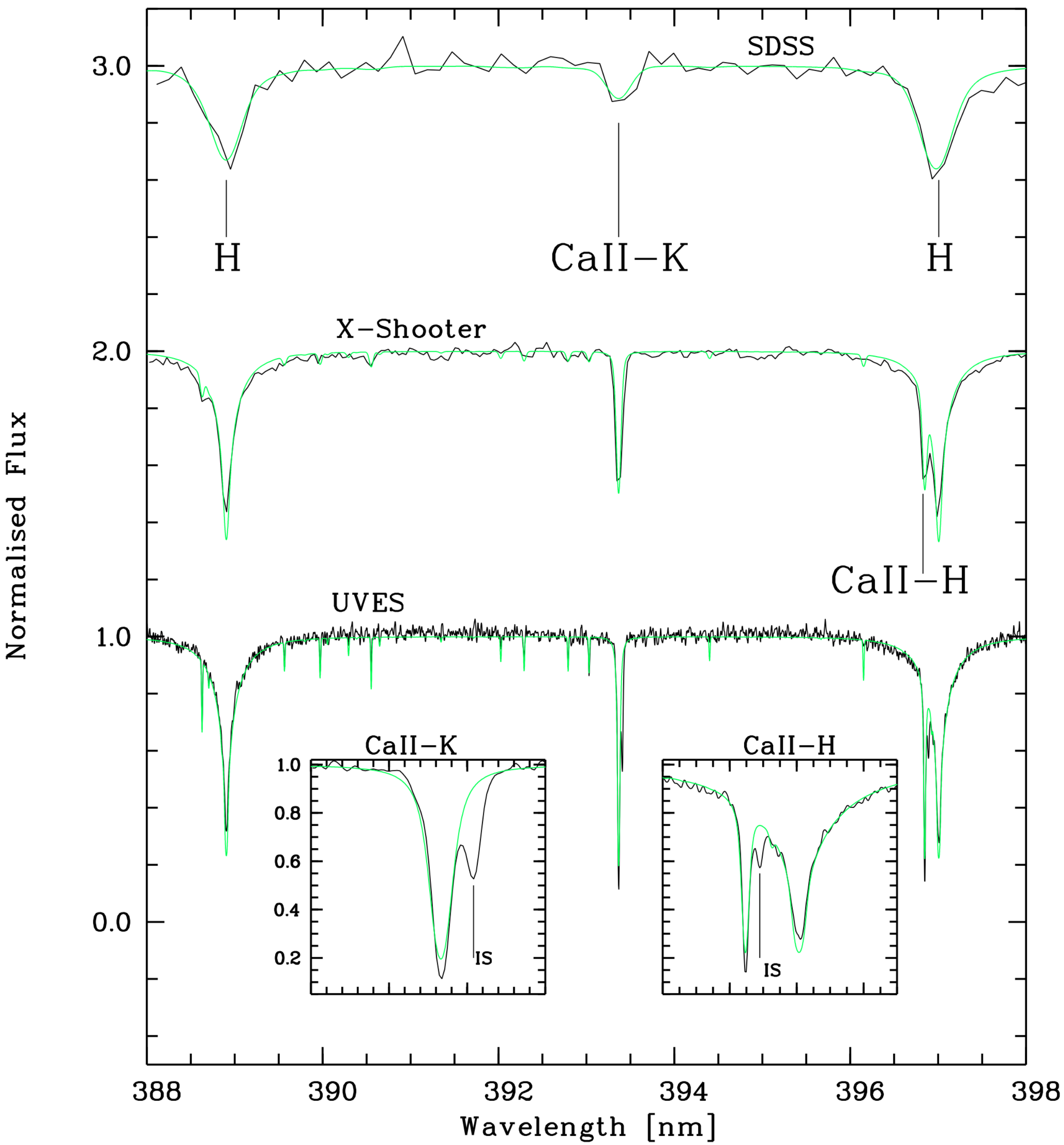


MOSAIC

Mixed Architecture Design

Focal plate close up





EMP stars … when the Spectral resolution IS a crucial issue ….

Caffau et al. (2012)

Metal-poor stars

EMP extremely rare objects, in their spectra few lines: necessary low-resolution large surveys to select good candidates and useful follow-up observations

Present and future facilities for EMP stars in the MW and local group galaxies

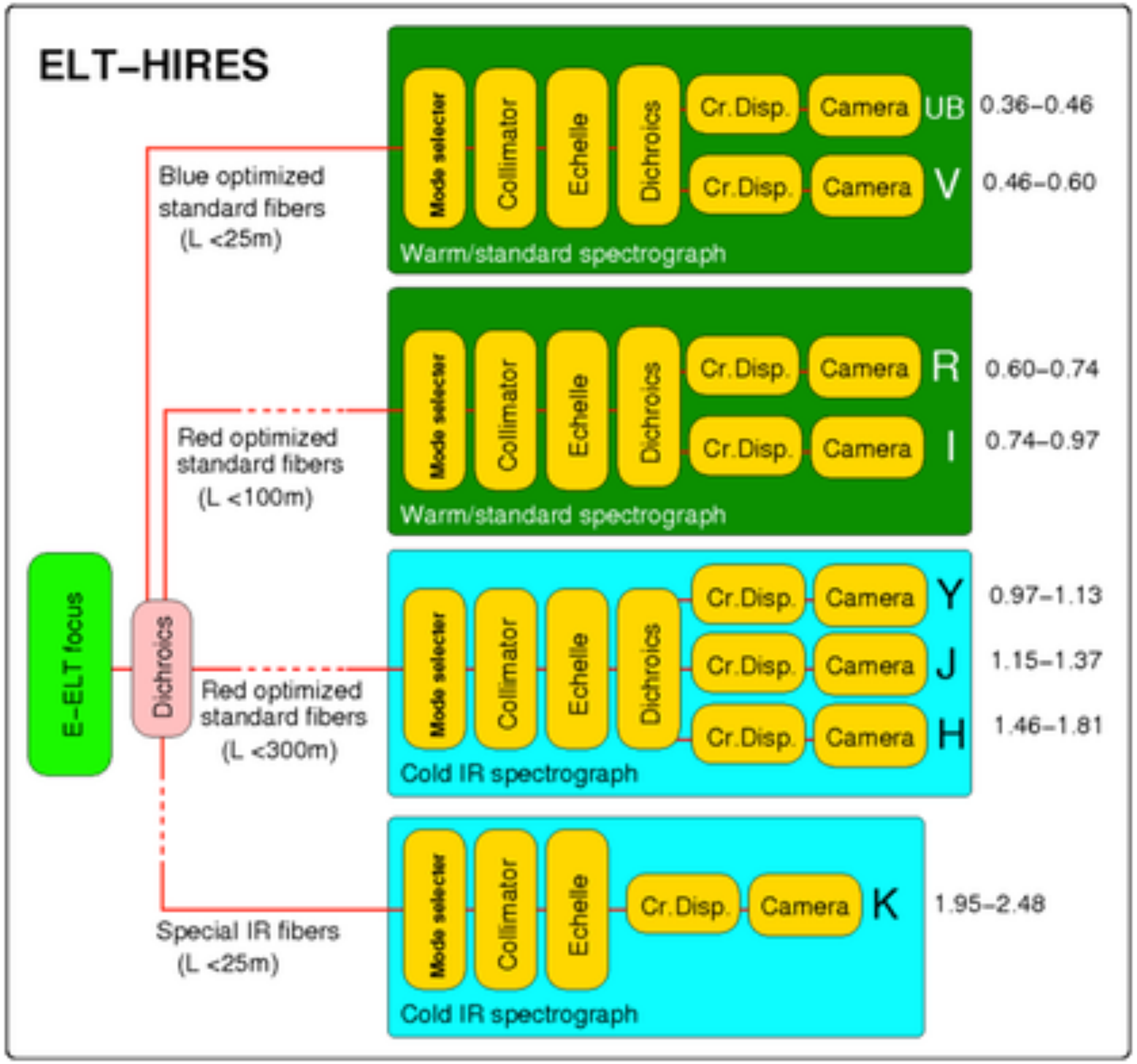
Search for EMP stars, LR:

- Several survey on-going to find out EMP stars
  - SDSS
  - LAMOST
  - RAVE
- Future:
  - 4MOST
  - WEAVE
  - MOONS (? Bulge)
  - Hermes

HR follow-up:

- Present
  - UVES@VLT
  - X-Shooter@VLT
  - HDS@Subaru
  - HIRES@Keck
- Future
  - Pepsi@LBT
  - ESPRESSO

E-ELT: HIRES



ELT–HIRES
E–ELT focus
Dichroics
Blue optimized standard fibers (L <25m)
Red optimized standard fibers (L <100m)
Red optimized standard fibers (L <300m)
Special IR fibers (L <25m)
Mode selecter
Collimator
Echelle
Dichroics
Cr.Disp.
Camera
UB 0.36–0.46
V 0.46–0.60
Warm/standard spectrograph
R 0.60–0.74
I 0.74–0.97
Warm/standard spectrograph
Y 0.97–1.13
J 1.15–1.37
H 1.46–1.81
Cold IR spectrograph
K 1.95–2.48
Cold IR spectrograph

HIRES: possible observing modes …

Mode	R	D-fib	N.obj	Size of Res. Element		Comment
				sky	pixels	
HR	100,000	0.76″	$2 + \lambda_{cal}$	0.127″ x 5.0″	2.8 x 63	1x6 slicing
MR MOS	14,500	0.86″	10	0.86″ x 0.86″	20 x 11	MOS on ELT 10′ fov
HR^2 IFU	80,000	7mas	35	7mas x 7mas	3.5 x 2	SCAO fov 35x49 mas
Other options						
HR^2 MOS	80,000	0.030″	35	.030″ x .030″	3.5 x 2	MOS on MCAO 2′ fov
LR MOS	7,000	0.89″	16	1.79″ x 0.45″	40 x 6	2x1 slicing

- **MR-MOS for all modules/wavelengths with <u>full spec coverage</u>**
- **HR^2 MOS/IFU only in IR where AO works**
- **patrol field of MOS depends on where the fibers positioner is located**
- **parallel modes, e.g. MR-MOS in optical while HR in IR on a single object**

HIRES: stellar science

stellar atmospheres (3D structure, asteroseismology, surface parameters & activity, mixing, diffusion, yields etc.)

stellar evolution (critical stages, e.g. pre-Main & WD-cooling sequences, star/disk/planet formation)

stellar pop (chemical evolution, environment effects, LG and beyond)

high spectral resolution critical

- to fully de-blend lines of any chemical specie (including isotopes)
- to kinematically resolve line profiles, i.e. to resolve [sub]structures

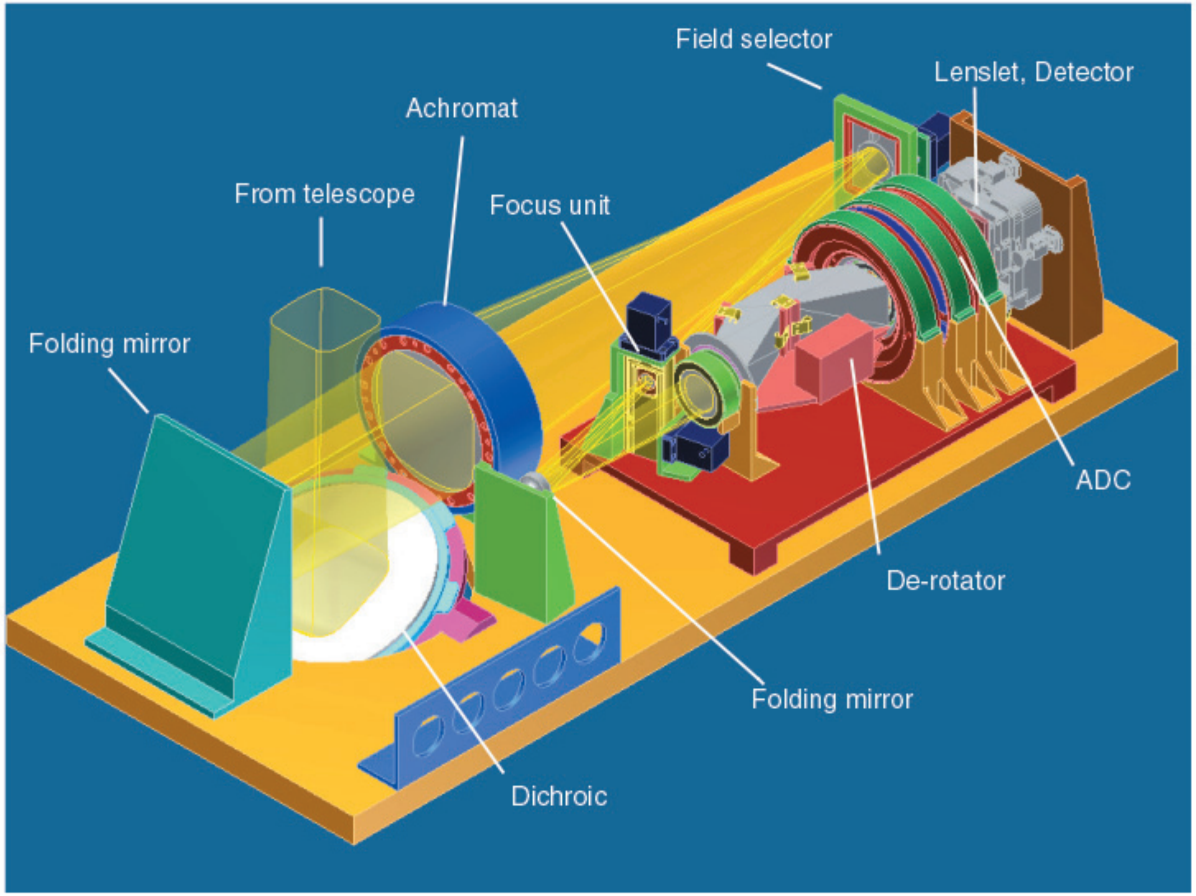
E-ELT critical

- to get high SNR with impact on accuracy (e.g. chemical abundances)
- for quantitative spectroscopy of faint stellar pop (TO stars, W/B dwarfs)

IR critical

- to study cool & metal rich stellar populations
- star forming regions and proto-planetary disks
- for specific line diagnostics (e.g. O isotopes in the K band, O from many OH lines in the H band)

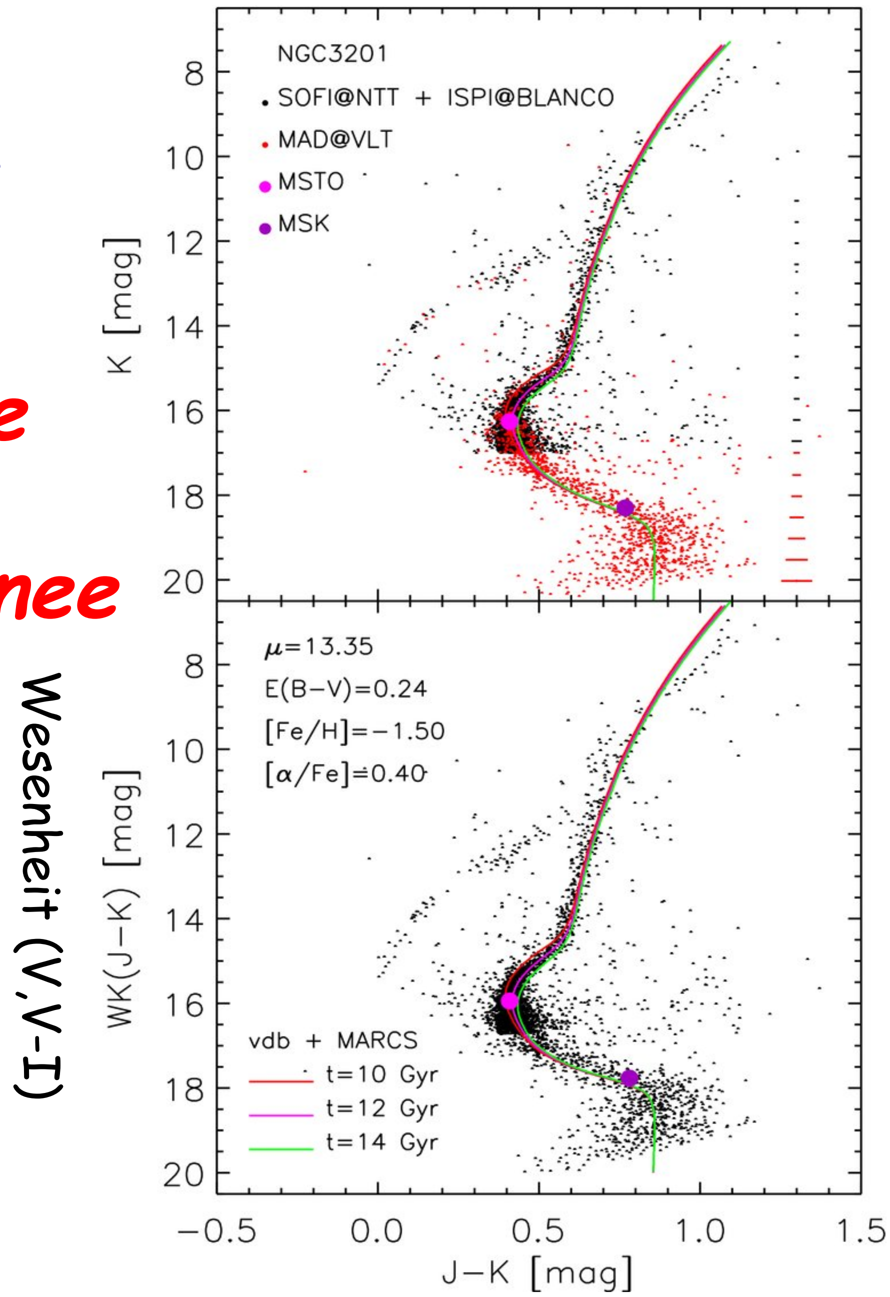
E-ELT METIS


Field selector
Lenslet, Detector
Achromat
From telescope
Focus unit
Folding mirror
ADC
De-rotator
Folding mirror
Dichroic

The absolute age of NGC3201: NIR

A new method to estimate the Absolute age of stellar systems

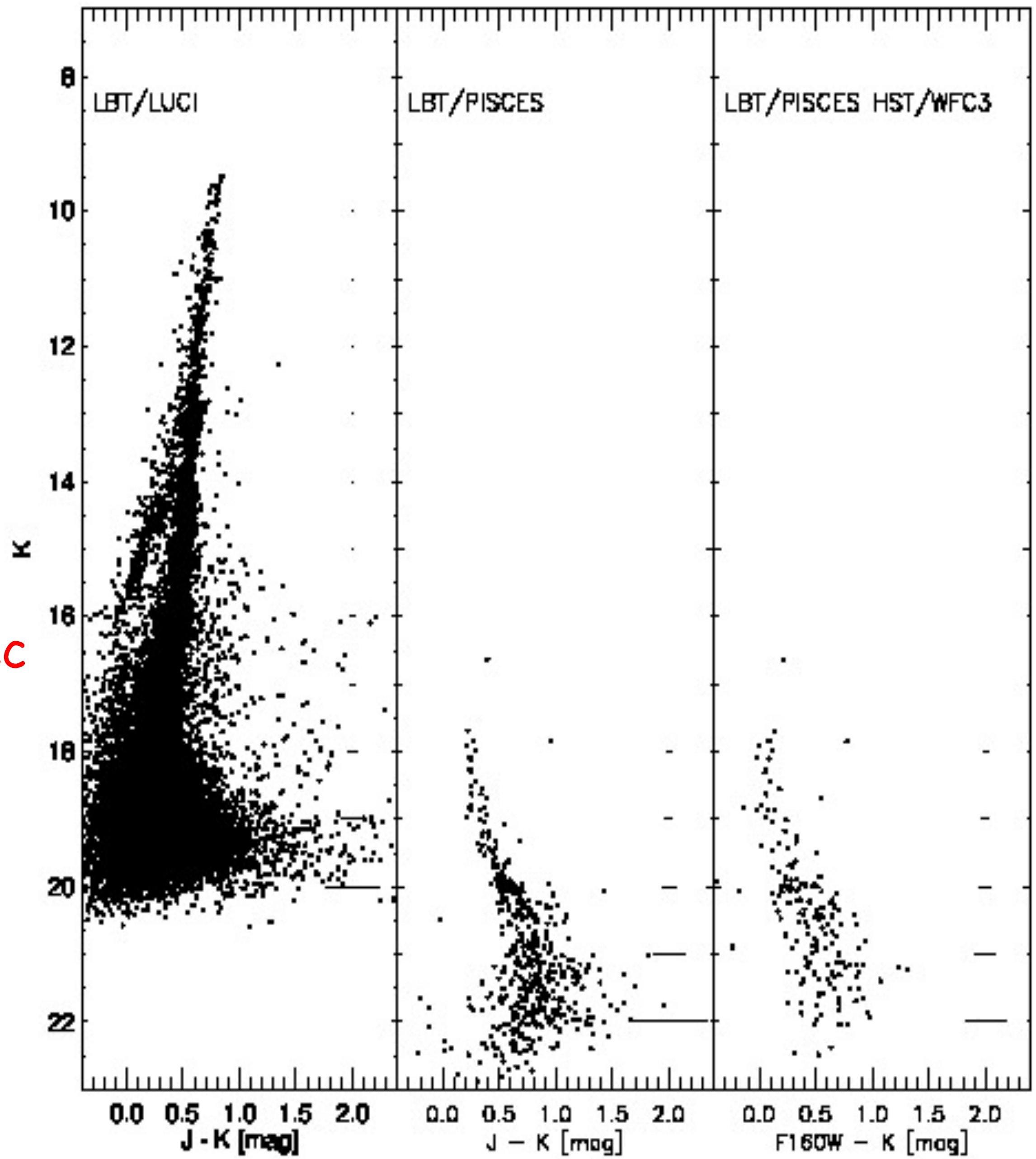
the difference in magnitude and/or in color between the TO and the NIR MS knee



The absolute age of M15: NIR

LUCI (4x4arcmin):
19J 20-40 sec
20K 20 sec
PISCES (26X26arcsec):
30J 30 sec
30K 15 sec
WFC3:
F160W(H) 3X200+6X250sec

Monelli et al. (2014)



NGC6528 & WFC3

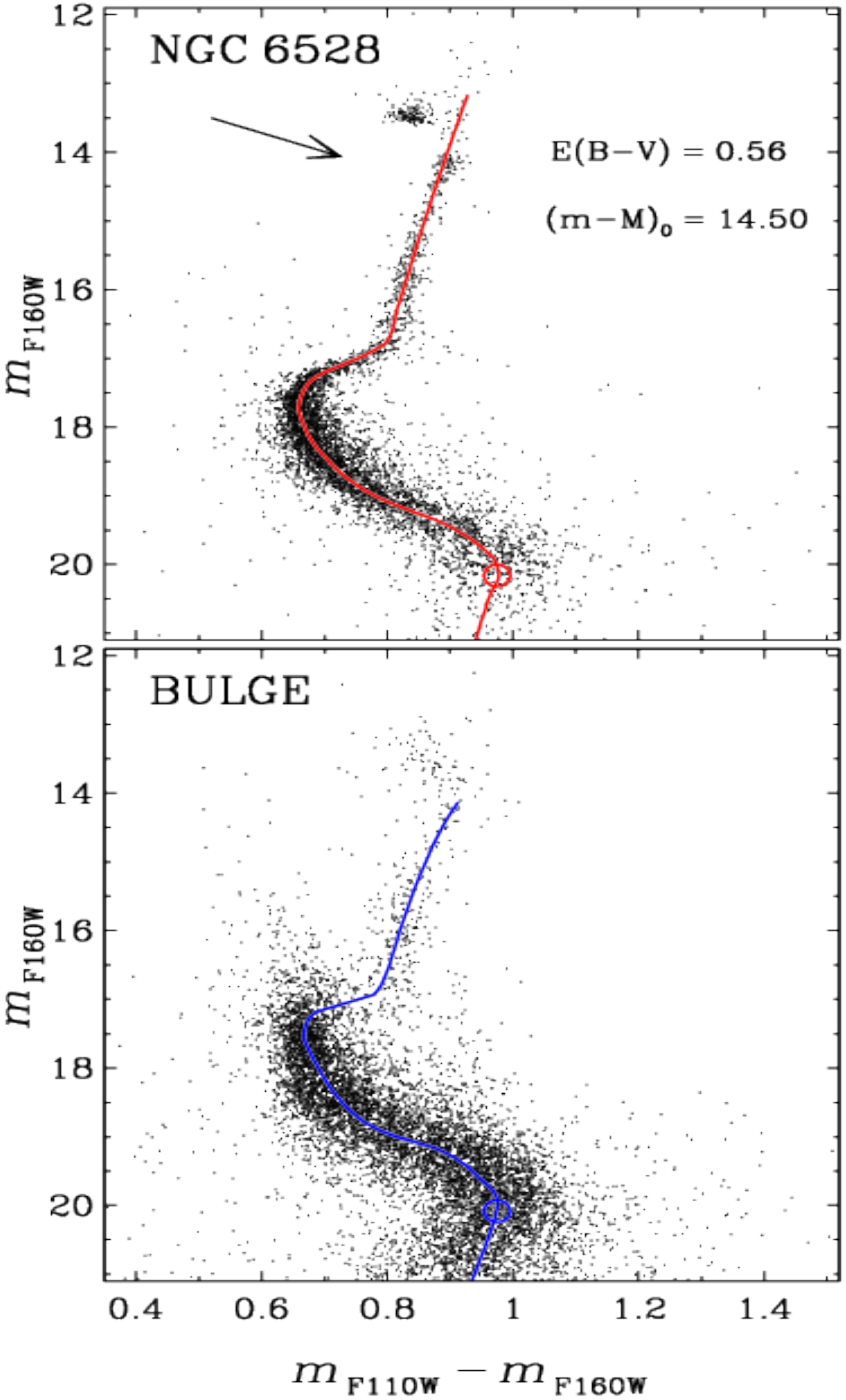
Same selection for proper motion

RGB Bump and RHB are well defined

Bending along the MS due to CIA appears in NIR Bands very robust absolute age indicator

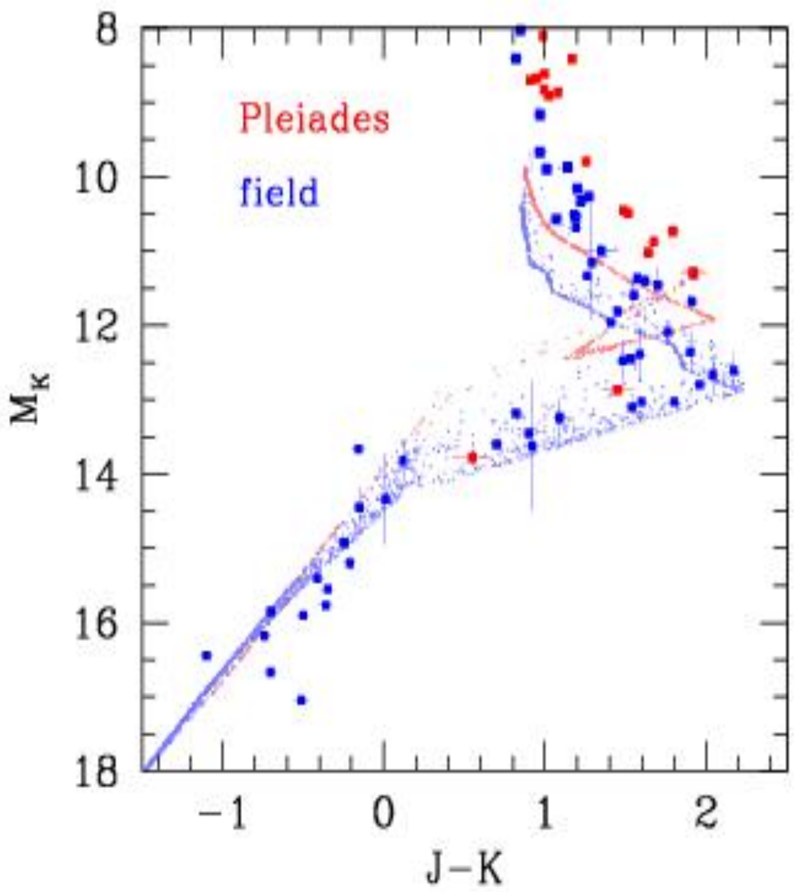
Robust selection for field stars

Lagioia, Milone + to be subm.



Approaching H-burning limit & beyond
Transition between VLMS & BDs

MS-Knee → Mk~5.5



Saumon et al. (2008)

Transition from late-M to L-type

Diatomic metal species (TiO, VO, FeH) incorporated in grains

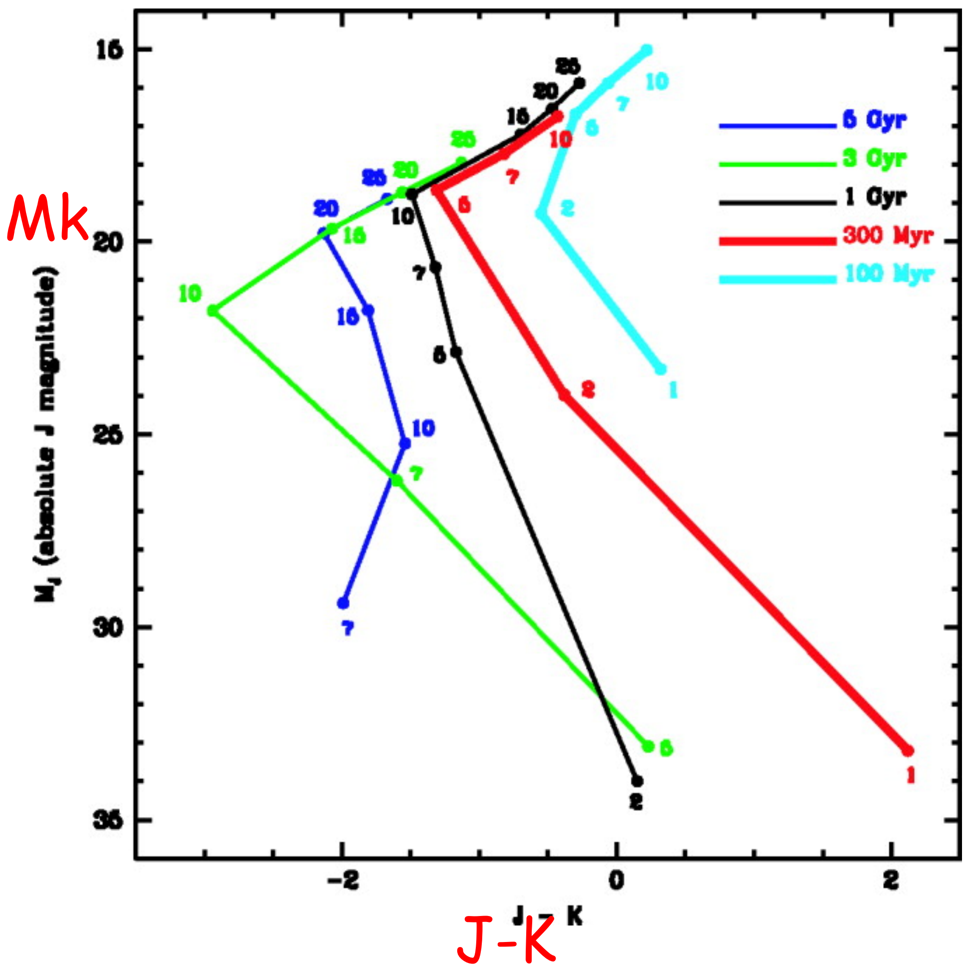
Formation of Fe & Si grains produce optically thick clouds that veil gaseous absorption bands →
L-type Redder NIR colors 1.5k-2.0k K

At lower Teff the clouds start to sink and CH4 supplant CO as the dominat C-bearing molecule →
T-type Bluer NIR colors (Te~1.0k K)

For types later than T5 CIA by H2 enhances bluer NIR colors

Transition between BDs & Free Floating Giant Planets

Late T-type → Mk~16



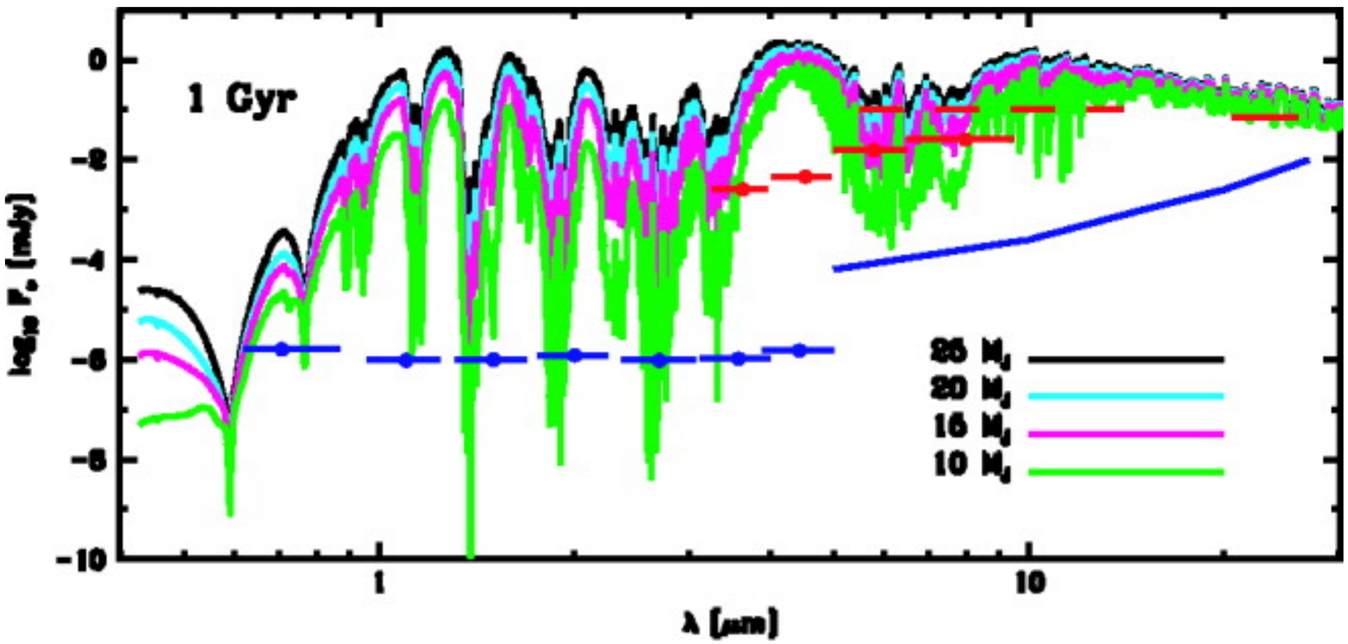
Burrows et al. (2003)

For Teff ~600K the NH3 join Water and CH4 absorption

N2 vertical mixing the NIR Flux COLLAPSE → Y spectral type

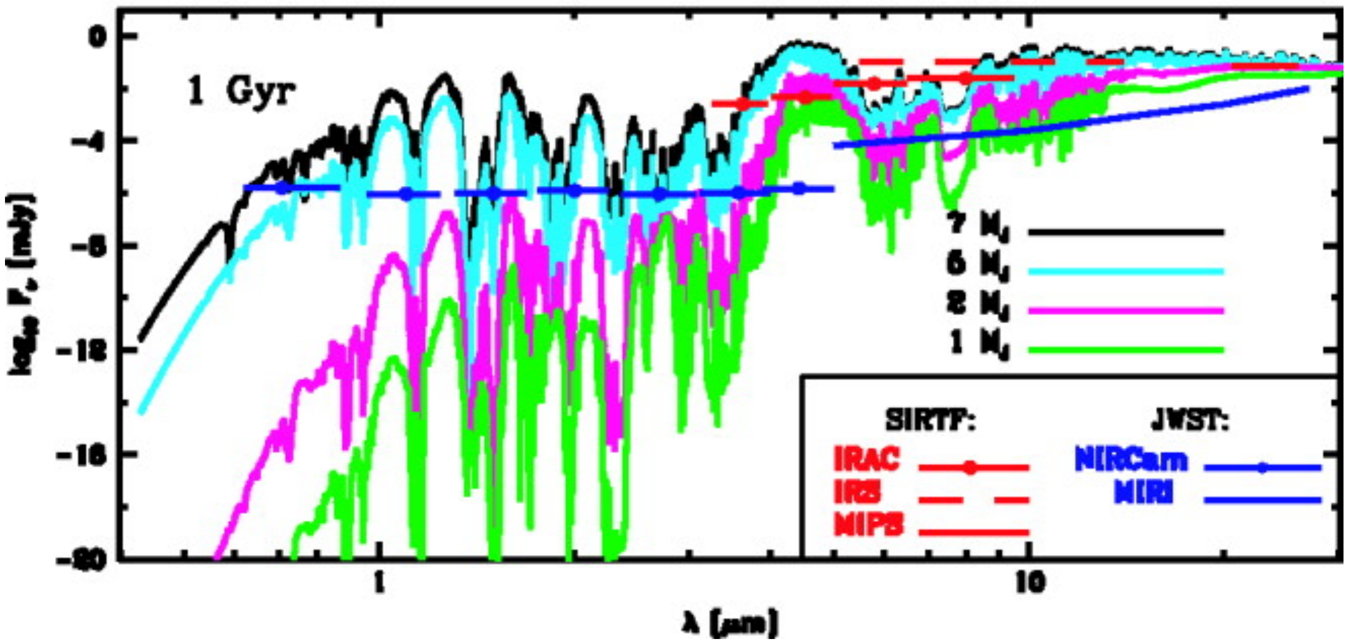
For ages older than 1 Gyr the Decrease is 10-15 mag!!!

NIRCAM@JWST & E-ELT CAM Will constrain the change in the IMF in the transition VLMs-BDs-GPs



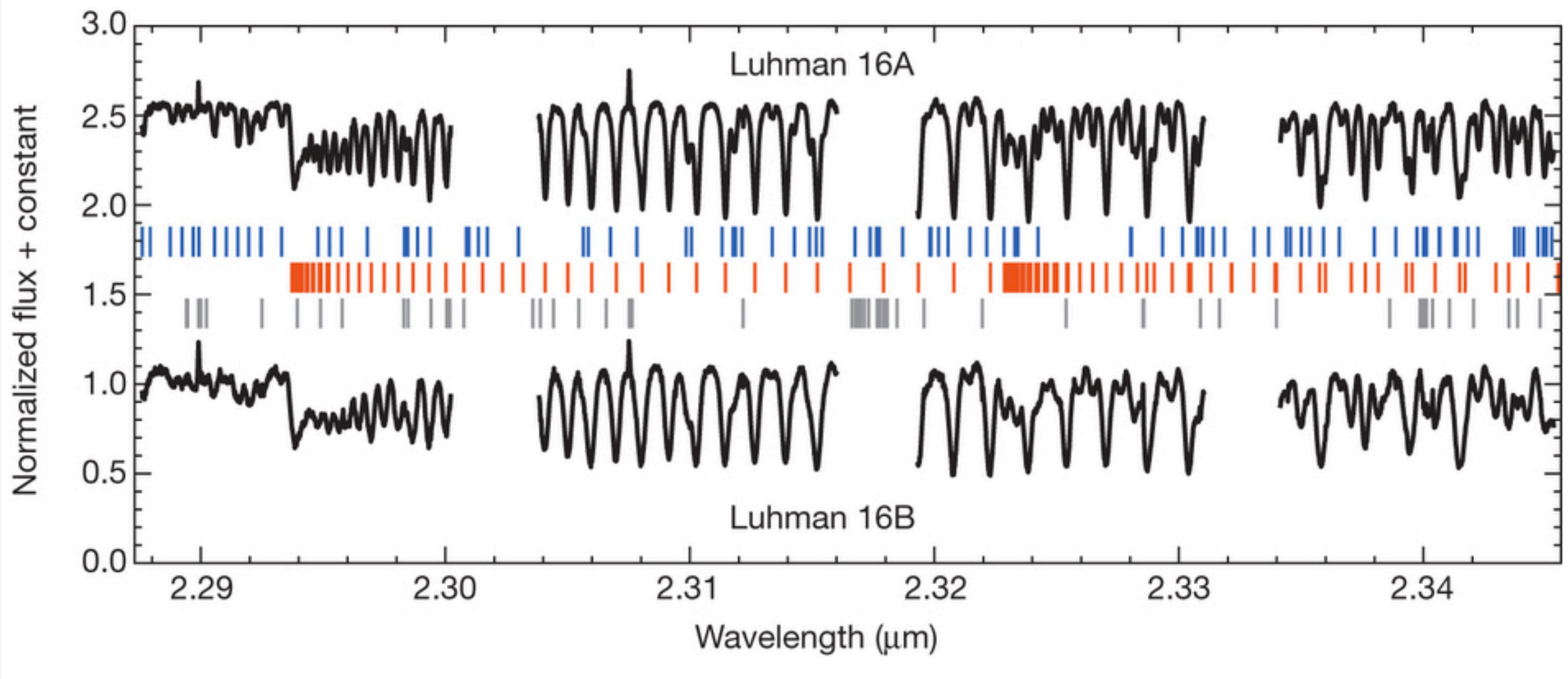
Spectroscopy in the MIR region

HR spectroscopy in L, M bands



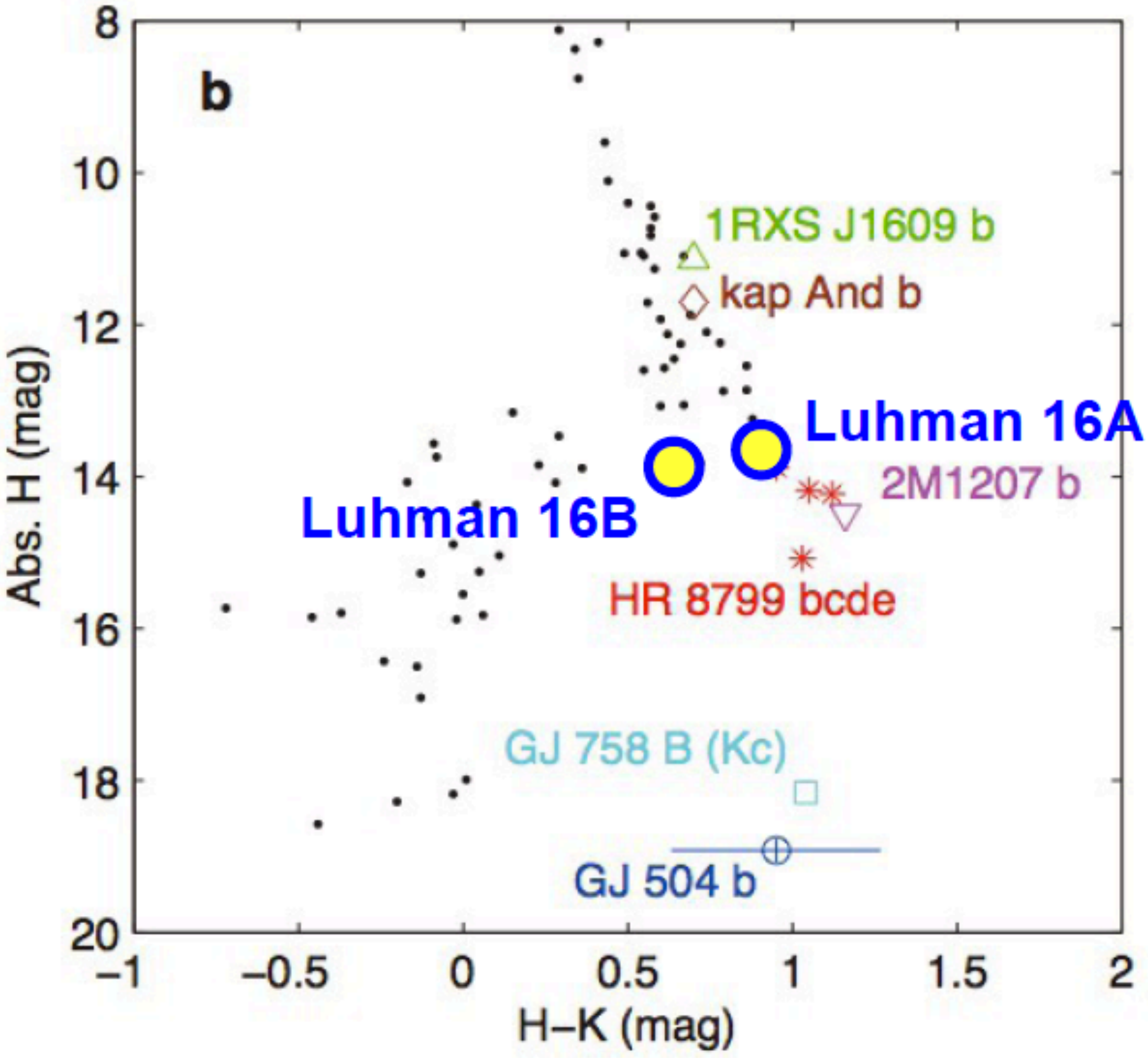
Line list for NH3 and N2 are incomplete in NIR!

A global cloud map of brown dwarfs

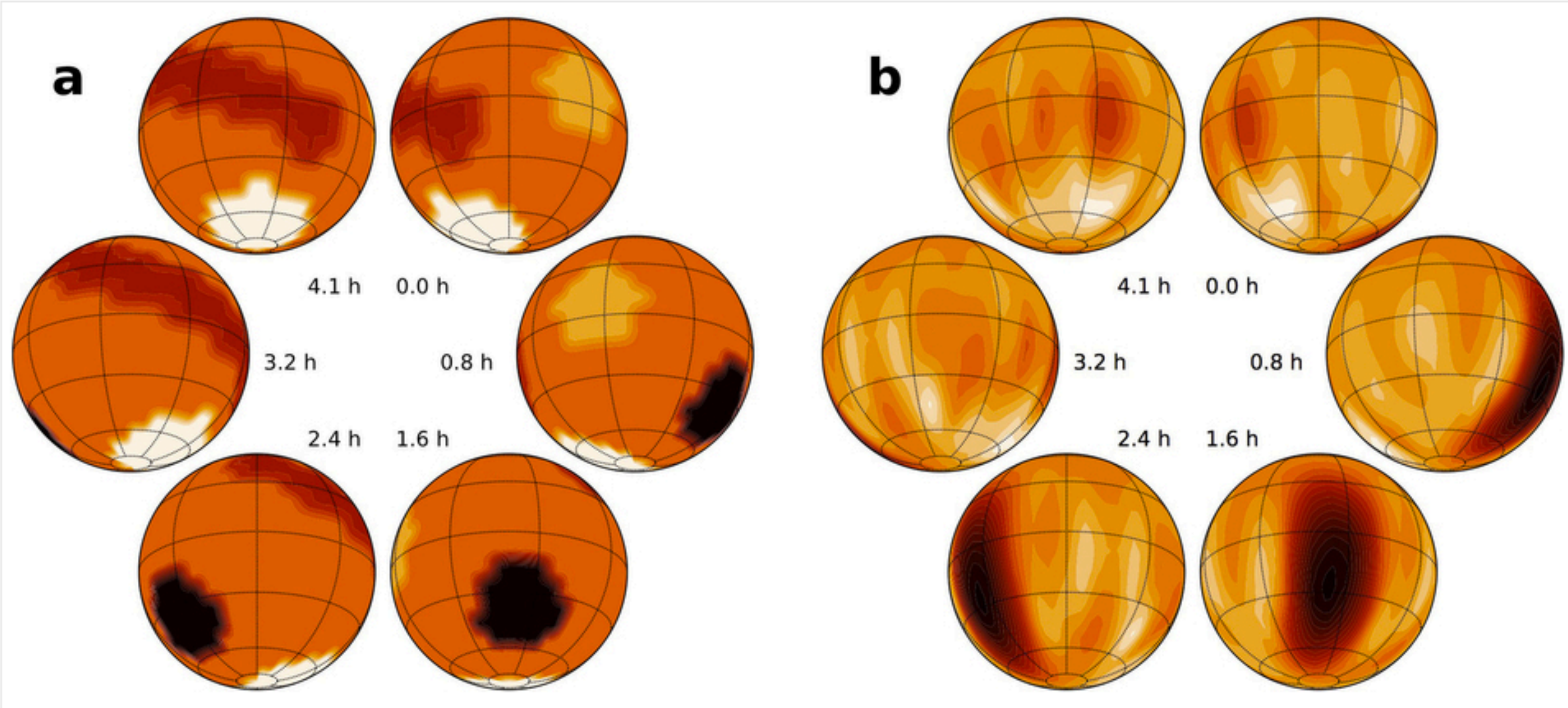


CRIRES spectra by Crossfield et al. (2014, Nature)

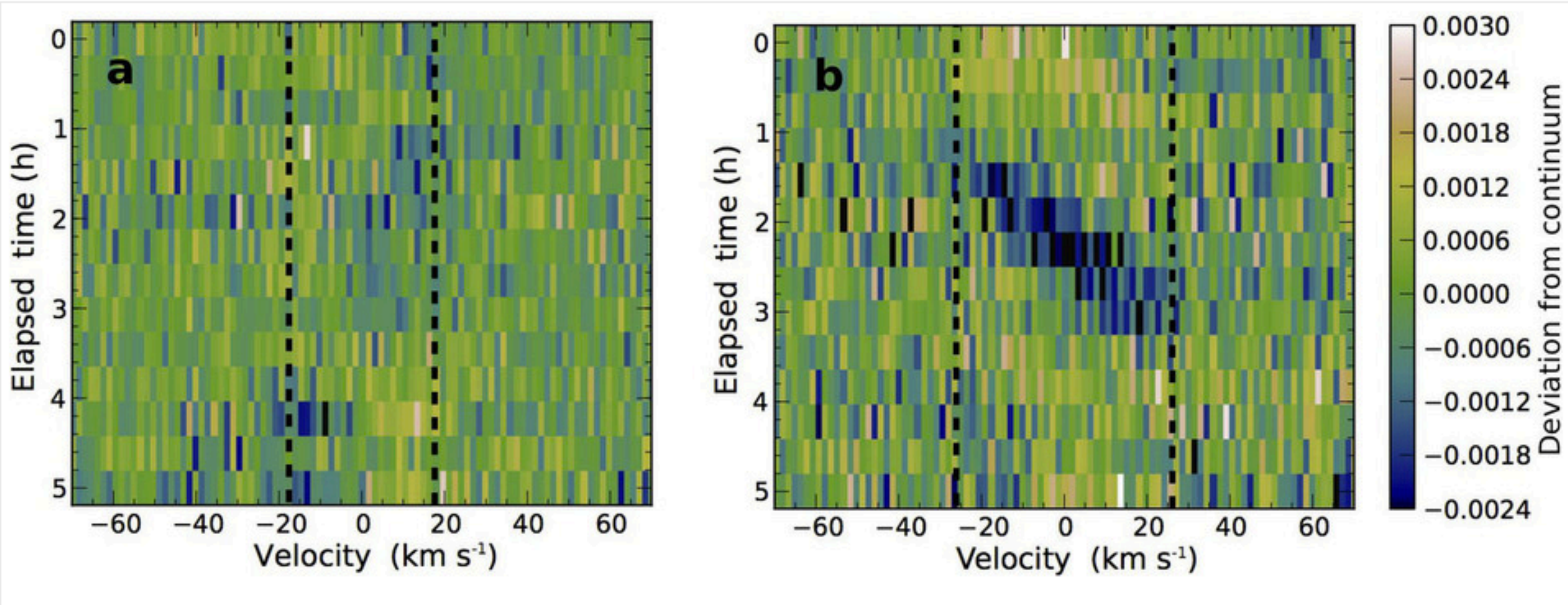
A global cloud map of brown dwarfs



A global cloud map of brown dwarfs



A global cloud map of brown dwarfs



E-ELT Project Science Team

Meeting on Extrasolar Planets & E-ELT in Garching (March 2014)

Resolved & Unresolved Stellar Populations
RASPUTIN 13-17 October 2014 (Garching)

NEXT PST Meeting early Septemeber 2014 in Rome

Meeting on Solar System & E-ELT
September 2015 (Garching, T. Encrenaz)

School on Science & Technology with E-ELT
October 2015 (Erice, I. Hook, S. Ramsay, G. Bono)

Conclusions I

The 8-10m class telescopes are paving the road for ELTs:

The transitions L—T—Y & Giant Planets (20 years!)
One of the two regions of the HRD HIC SUNT LEONES!

Li & EMP stars in nearby dwarfs:
environmental effects, chemical enrichment histories

Opening new approaches to handle data from IFSs

A new spin on theoretical modeling: Atmospheres (nir lines), envelopes, interiors

New spectro-photometric indices for nearby dwarfs
Statistics & precision down to V~25

Conclusions II

We are facing a substantial change in the approach for doing astrophysics:

User Oriented → Experiment Oriented

I suspect that we are lagging in this paradigm change