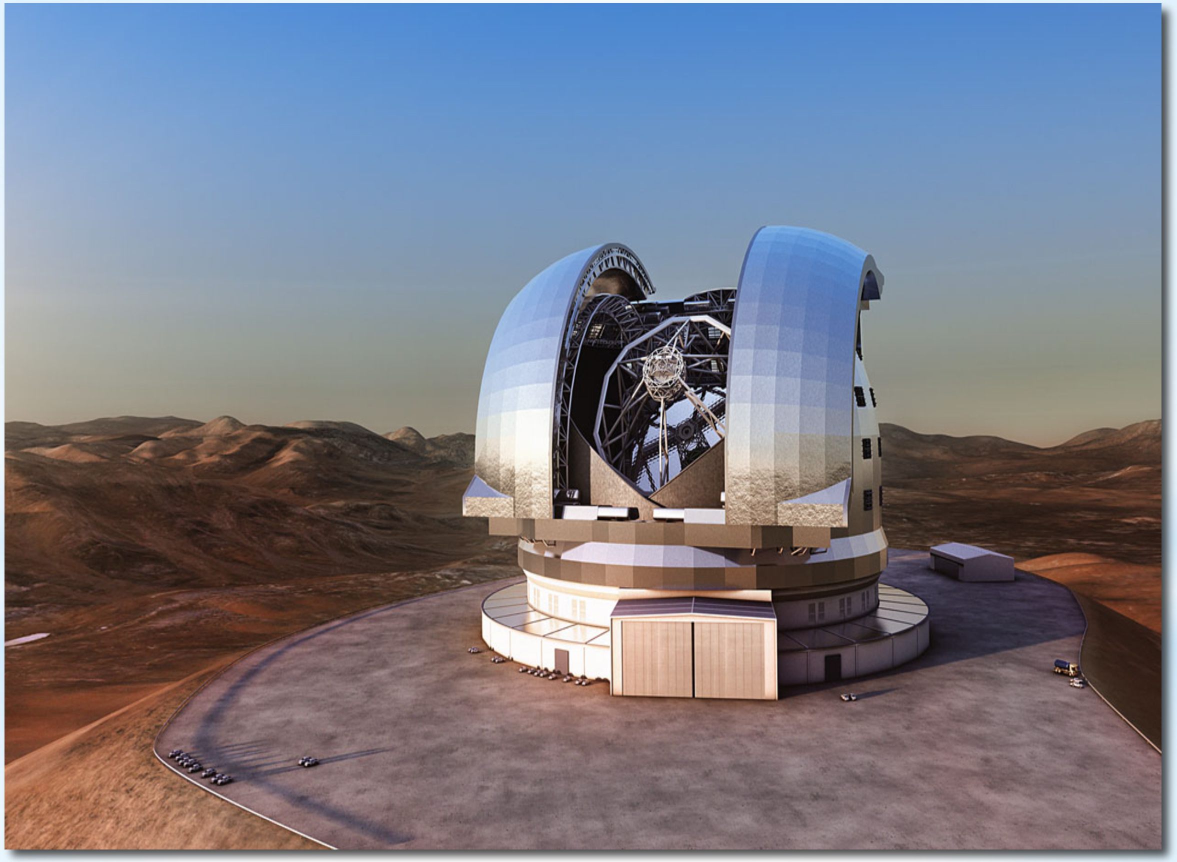
Status of E-ELT & stellar populations

G. Bono

UNIVERSITA' DEGLI STUDI DI ROMA
Tor Vergata



Setting the scene

E-ELT in a nutshell

First light instruments +

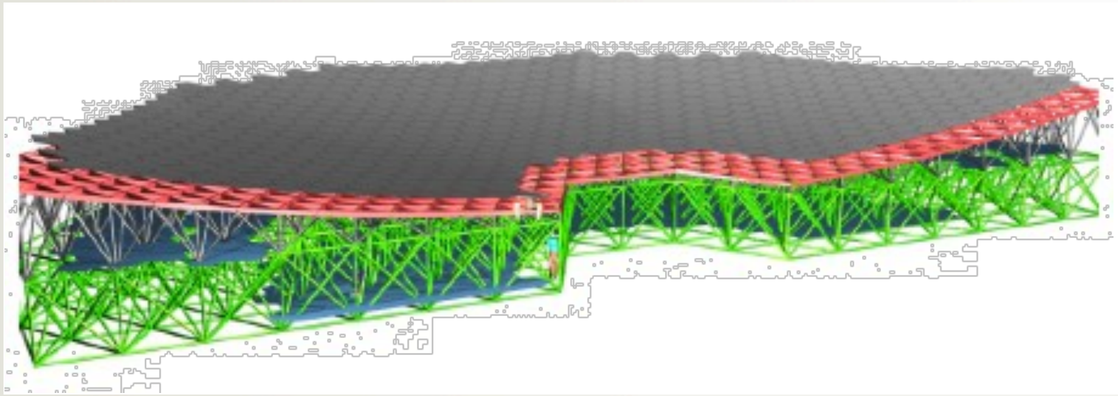
First generation

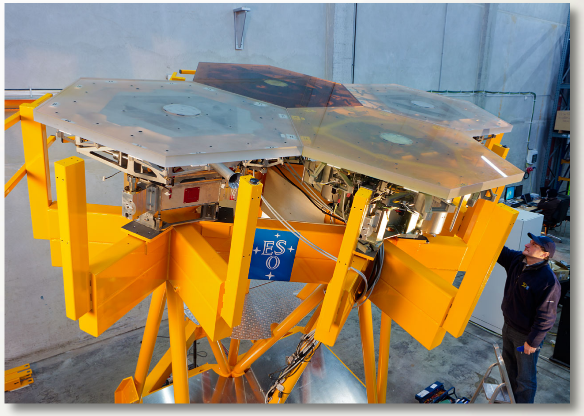
Paving the road for E-ELT

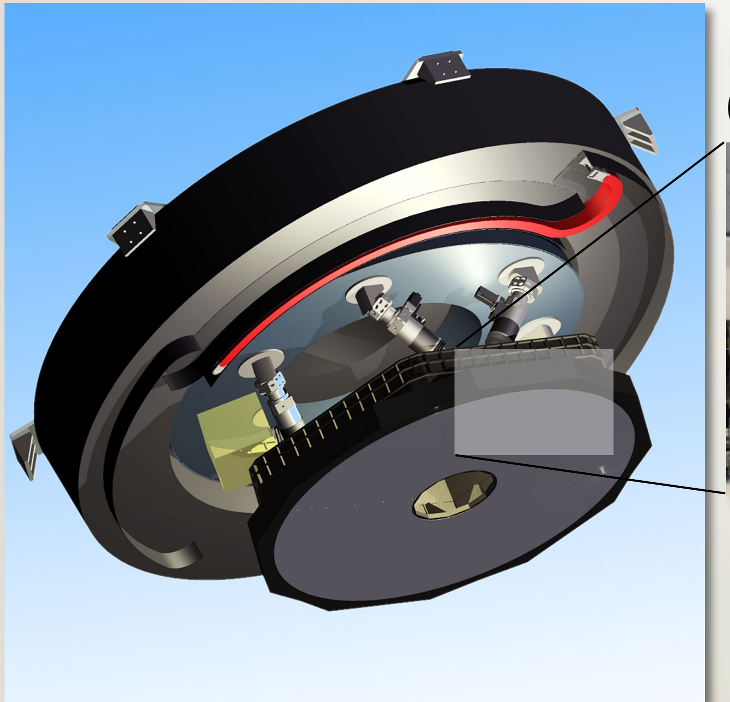
Future Perspectives

The Mirrors

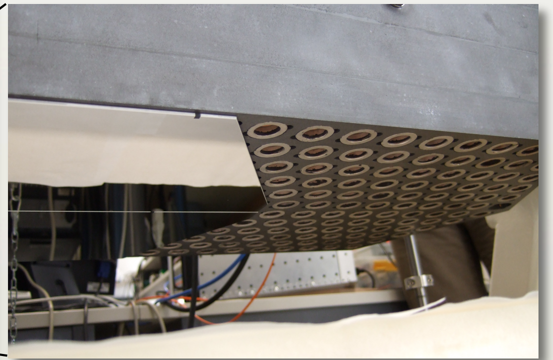
M1: 39.3 m, 798 hexagonal segments of 1.45 m tip-to-tip: 978 m^2 collecting area







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



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

First Generation E-ELT Instruments

First Light

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

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

E-ELT – MIR: L, M, N: B. Brandl

MAORY (AO module) E. Diolaiti

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 [SWG--2012[

PST + ESO representative + Scientific PIs of approved instruments

P. Padovani (HIRES) R. Davies, N. Thatte, B. Brandl

V. Mainieri (MOS)

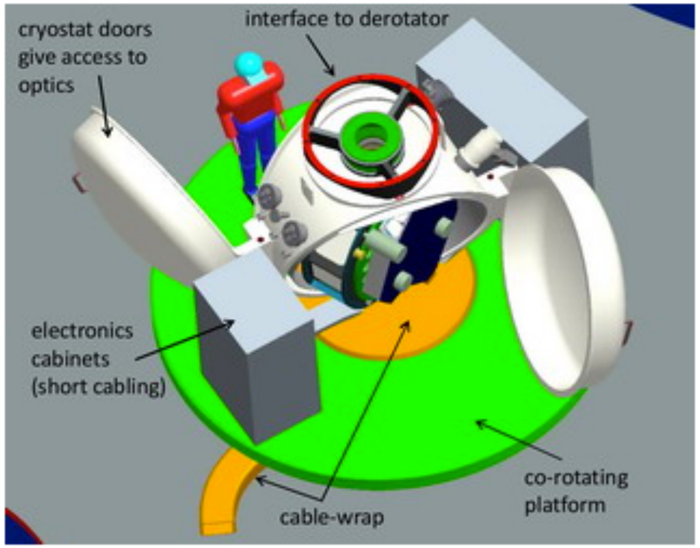
S. Ramsay (Instrument Scientist)

Solar & Extra-solar planets	Stellar Populations	Galaxies & Cosmology	Technology
Y. Alibert *	G. Bono (chair)	I. Hook	T. Herbst
G. Chauvin	O. Kochukhov	N. Forster-Schreiber *	R. Ragazzoni
A. Sanchez Lavega *	E. Lokas *	C. Martins	C. Keller
	N. Przybilla *		

Reports: E-ELT Programme Scientist (M. Cirasuolo)

Advices: E-ELT Programme Manager (R. Tamai)

Top Level Requirements

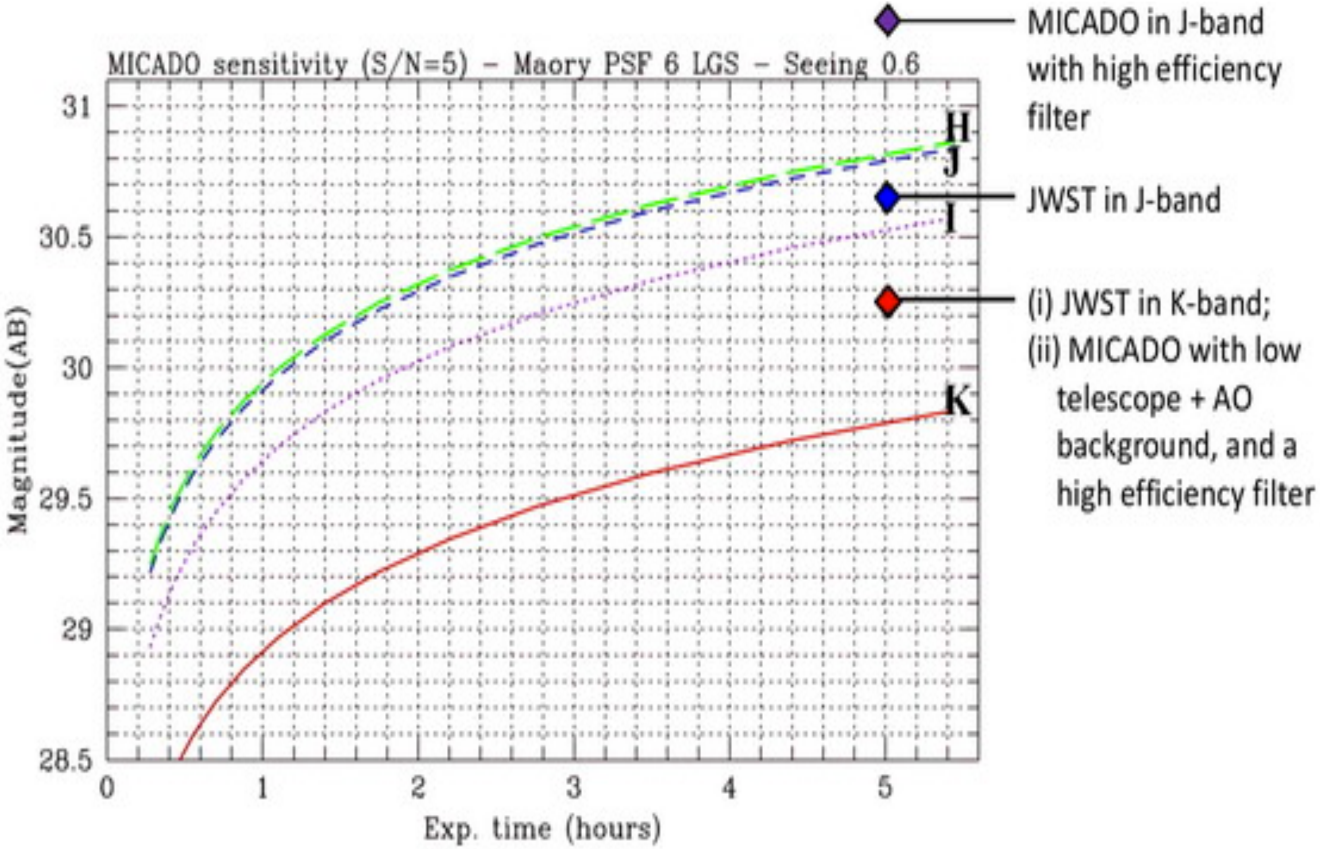


Overview of MICADO

E-ELT CAM: MICADO

Plus SCAO + MCAO (MAORY)

NIR long-slit medium resolution spectrog.



Broadband imaging sensitivity of MICADO as a function of integration time

MICADO@E-ELT vs NIRCAM@JWST

	MICADO@E-ELT	NIRCAM@JWST
FoV	~1′ X 1′	2 X (2.16′ X 2.16′)
Pixel scale	~3 mas + "HR"	~30 mas
K-band	~29.5	~30
J-band	~31	~29.5

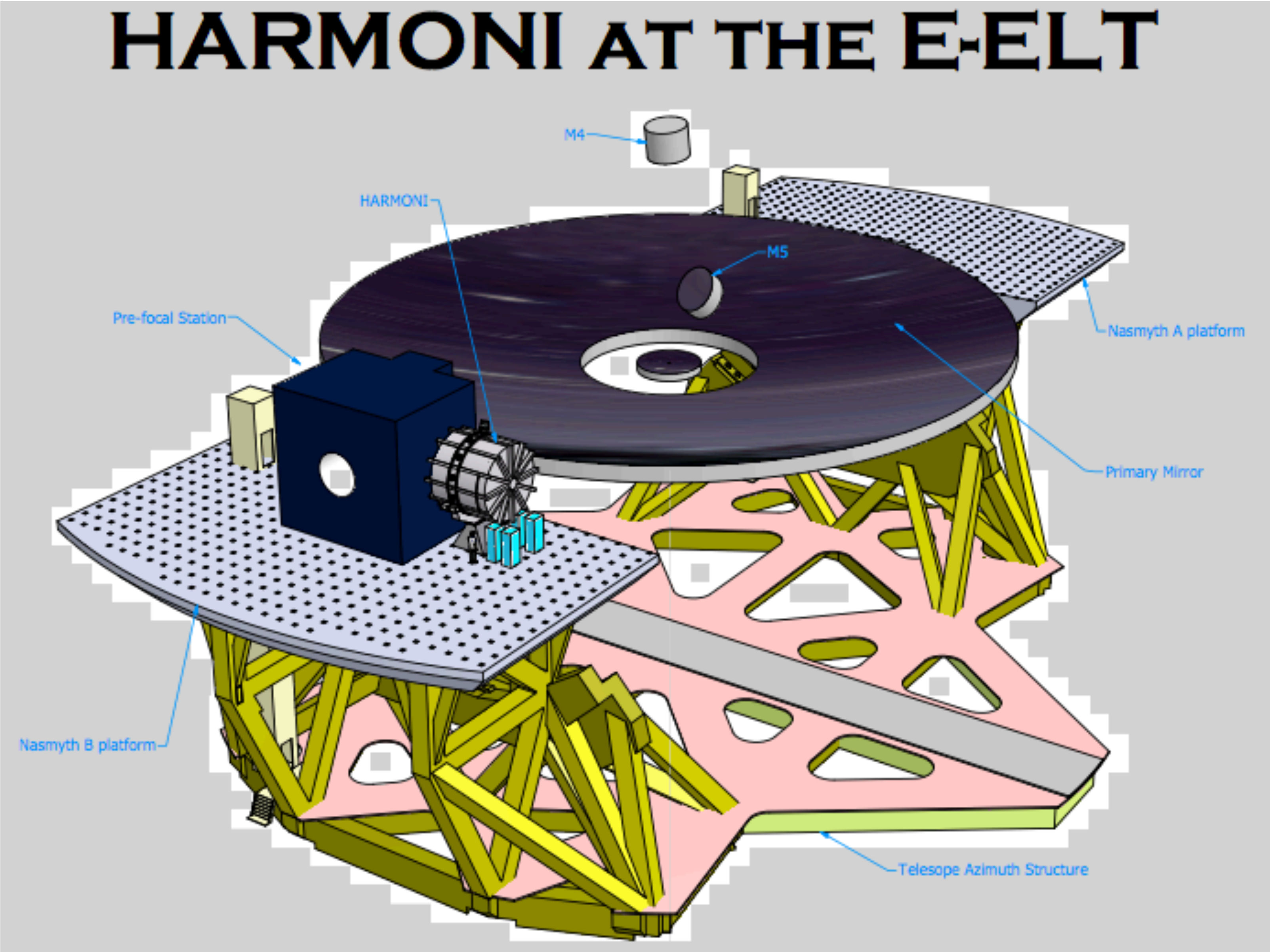
t_exp=5 hrs -- S/N=5 -- MAORY + 6 LGS -- seeing 0.06

high efficiency filters → AB Mag -- HR→ 1.5 mas smaller FoV

F115W & F220W -- t_exp=5 hrs -- S/N~5
Extraction region in a circle of 0.8""

Synergies among JWST, EUCLID & ERIS@VLT

E-ELT Integral Field Spectrograph: HARMONI



NIRSPEC@JWST

FoV	~3′ X 3′ for MOS
Slit width	~200 mas
Slits	Micro Shutter Array Fixed slits IFU (3″″ X 3″)
Spectral Resolution	R~100 → 0.7 -- 5 μm (single prism) R~1000 → 1 -- 5 μm (3 gratings) R~2700 → 1 -- 5 μm (3 gratings)

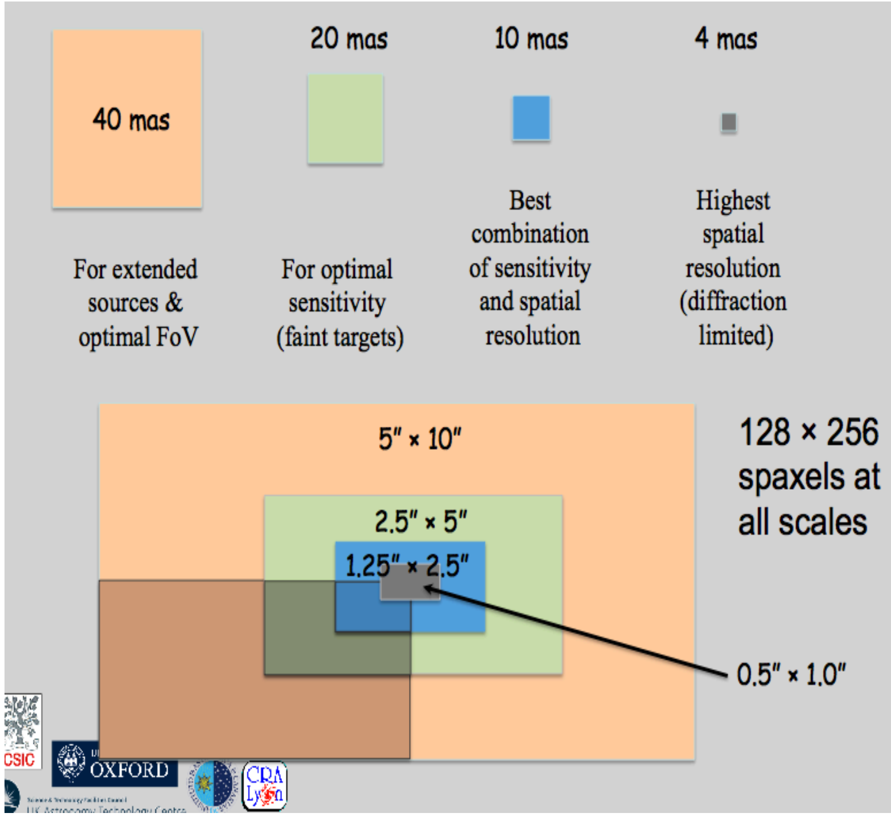
R=100 → t_exp ~ 10,000 sec point source continuum at 3 μm

S/N=10 is AB~26 mag

Synergies between JWST & ELTs

E-ELT Integral Field Spectrograph: HARMONI

Plus SCAO + LTAO



33,000 spaxels per exposure!

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

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

Abundances (Iron, α–, s–, r–elements)

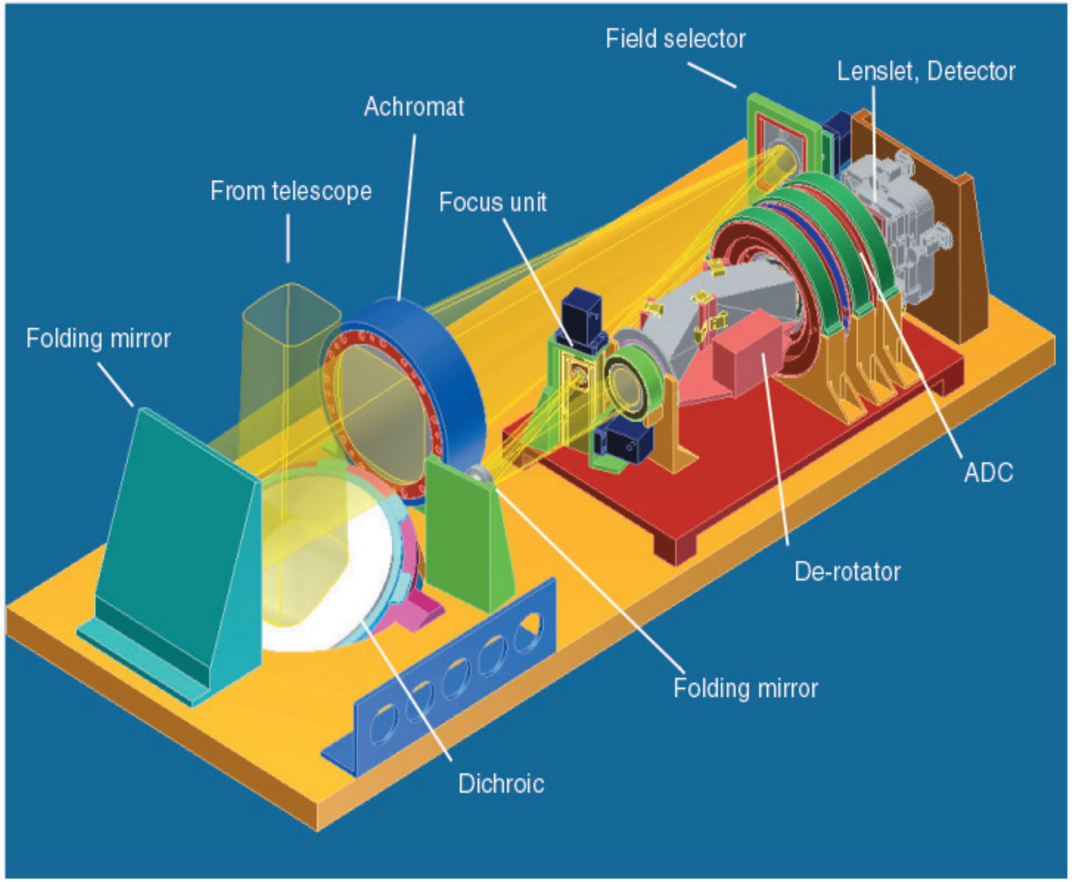
High-res R~20,000

Limiting mag. K~23 mag

CRIRES (+GIANO+WINERED)

crucial preliminary steps

E-ELT METIS



Coronagraphy in L & N bands

N-band polarimetry

Diffraction-limited imaging in L, M & N bands FoV 18 x 18”

Low resolution slit spectrograph (R < 5000)

IFU high-resolution spectrograph in L & M bands, FoV 0.4 x 1.5”

and resolving power of ~100,000

Adaptive Optics

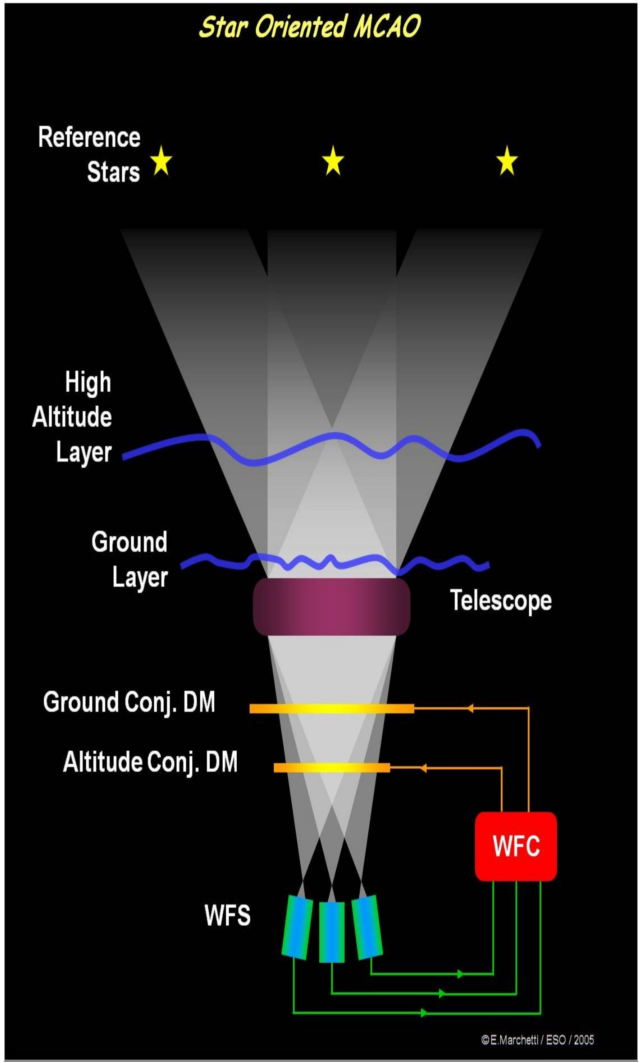
SCAO, MCAO, MOAO, LTAO

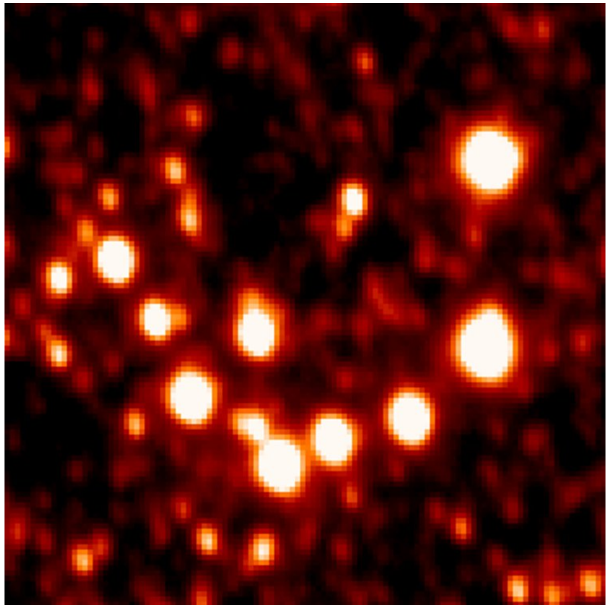
HERE & NOW

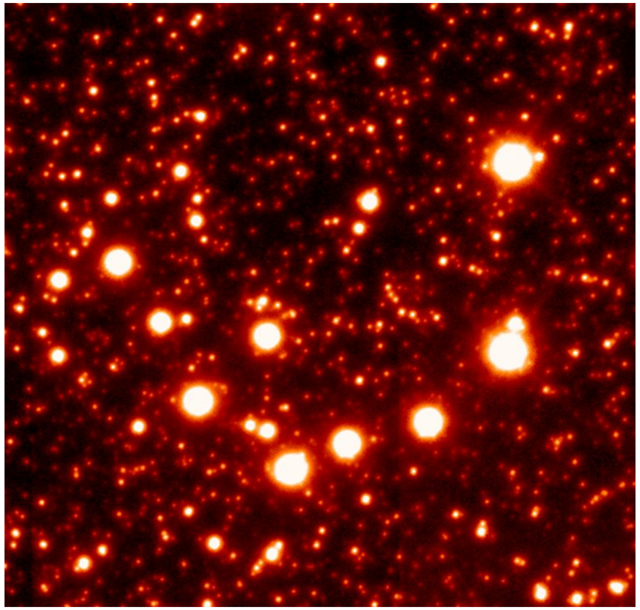
.....But life isn't a bed of roses!!

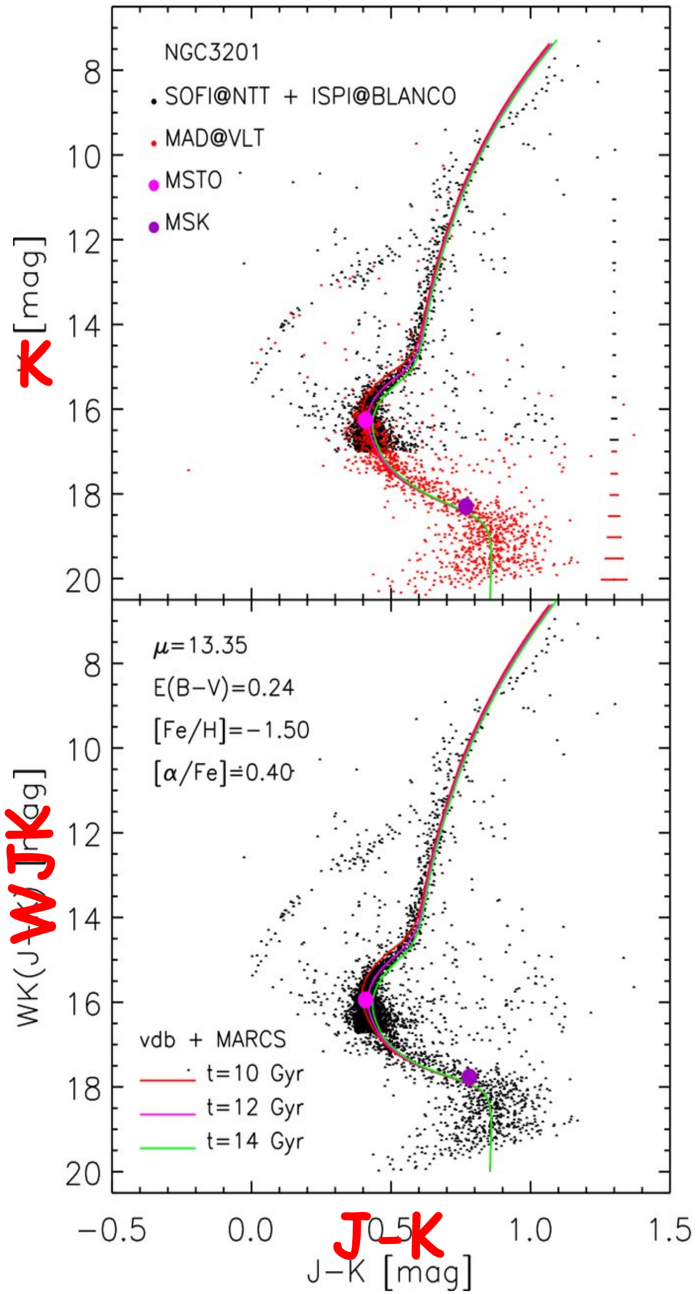
In the beginning was …. MAD@VLT

Marchetti + (2007)
GB + (2010)
t~11±1 Gyr

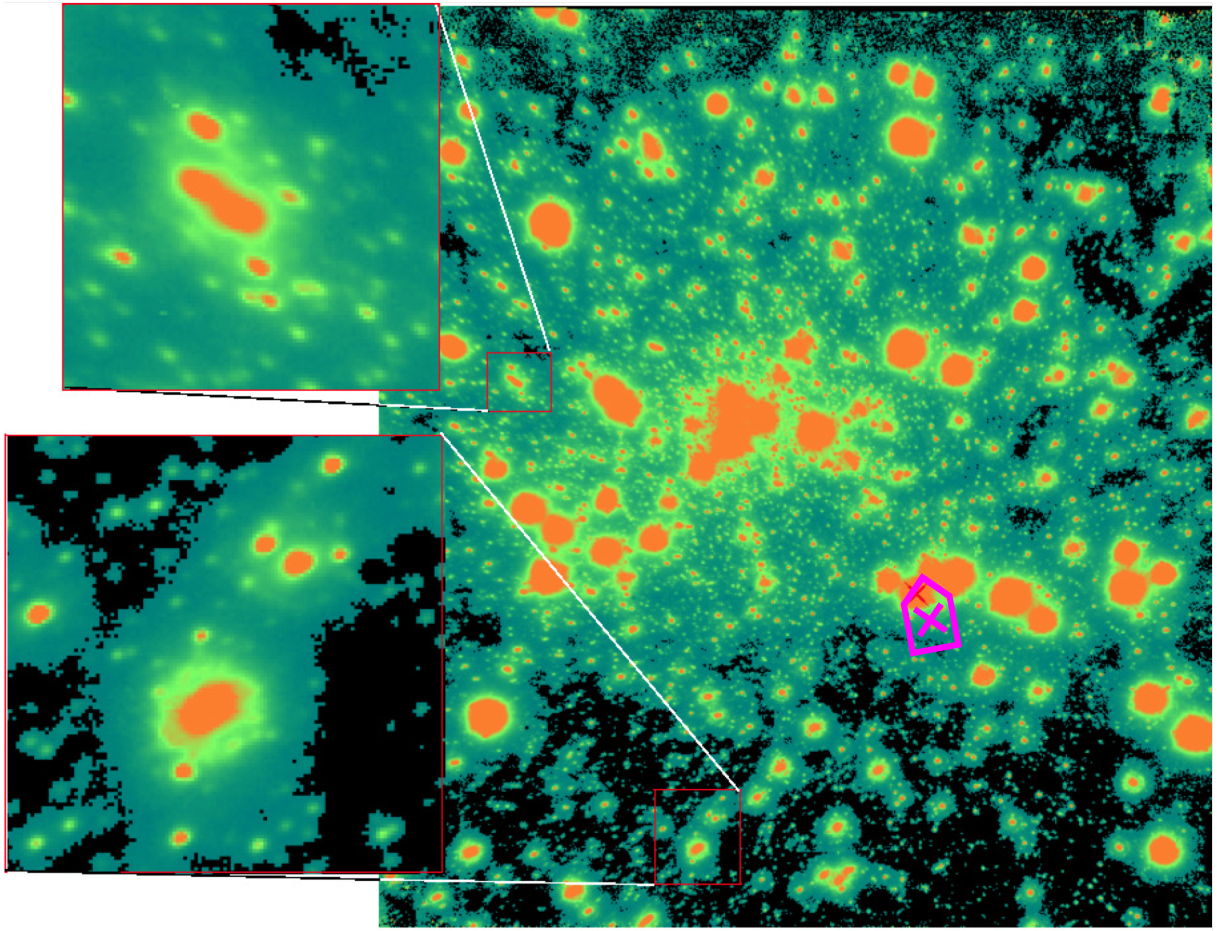








Later on was FLAO@LBT



J-band image

Drift of the PSF shape at larger
Distances from the NGS

SCAO

M15 core (pcc)

FWHM of 0.05 (J) &
0.06 (Ks) arcsec.

Strehl ratio
13-30% (J), 50-65% (Ks)

Limiting magnitudes:
J~22.5 mag
Ks~23 mag

Esposito + (2010)+lecture

The absolute age of M15

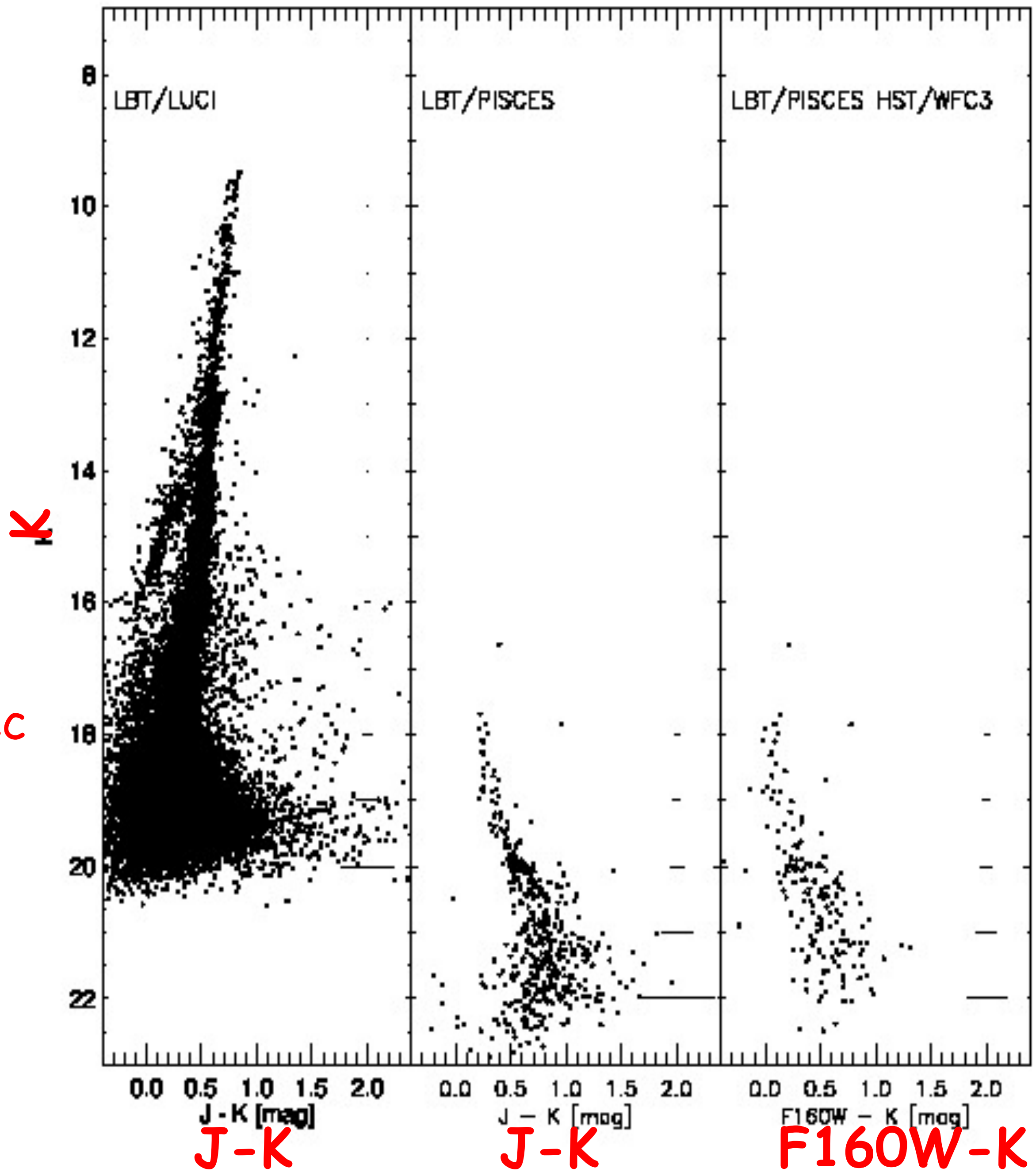
LUCI (4x4arcmin):
19J 20-40 sec
20K 20 sec

PISCES (26X26arcsec):
30J 30 sec
30K 15 sec

WFC3:
F160W(H) 3X200+6X250sec

t= 13±1 Gyr

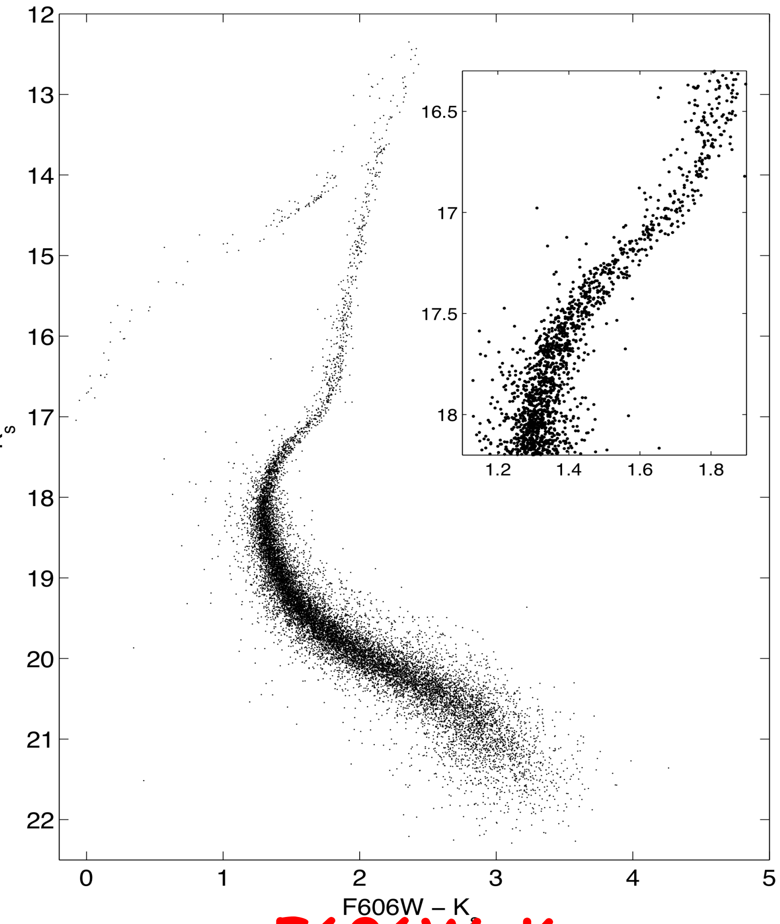
Monelli et al. (2015)



… and more recently GEMs@Gemini

Rigaut + (2014)
Turri + (2015)

NGC1851 core



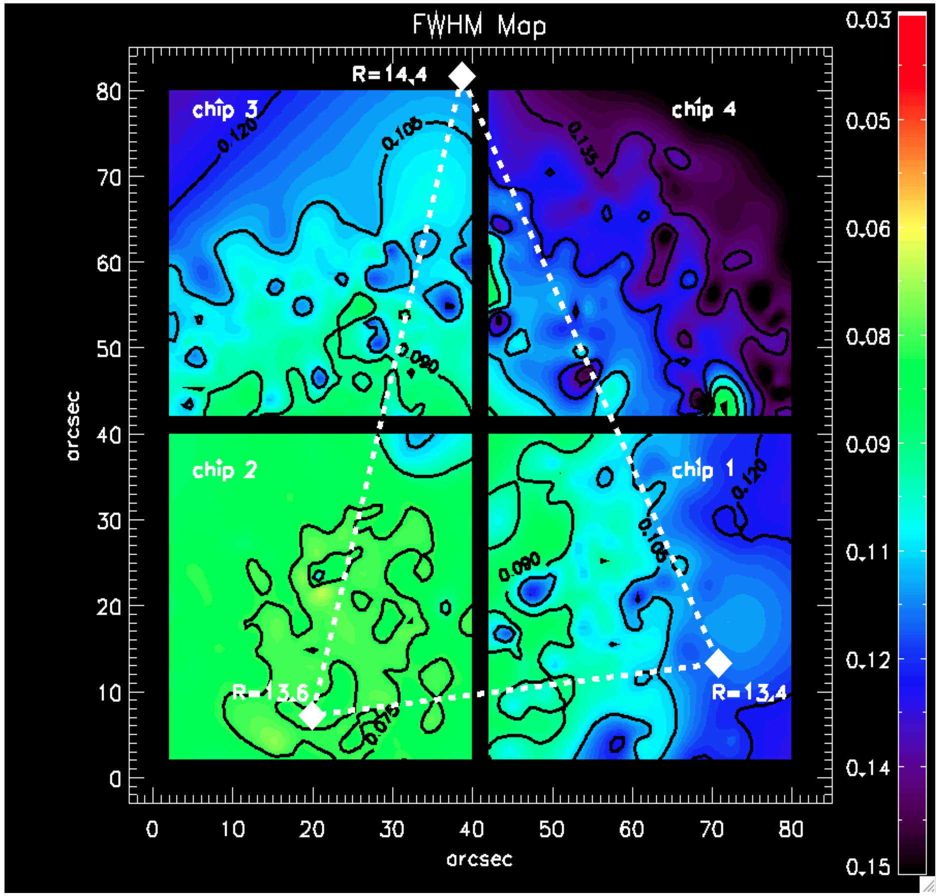
Two DMs + 5 Na LGS to deliver a FoV of 83" X 83"

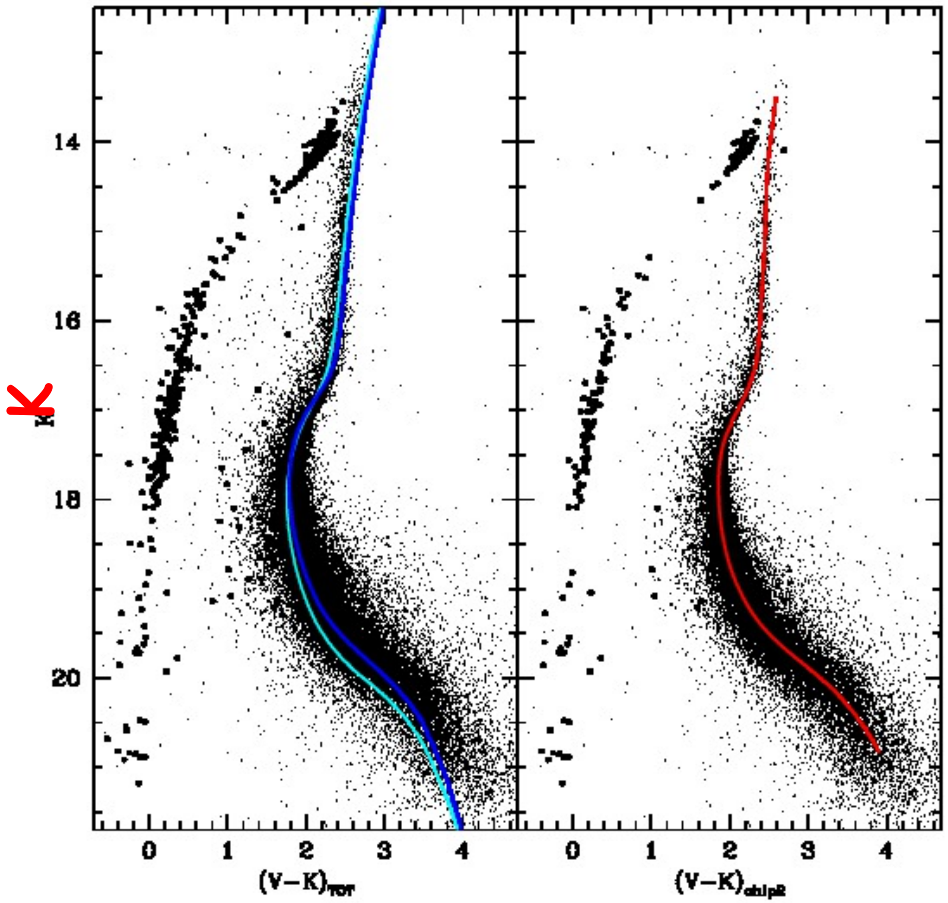
Detection of multiple populations in the SGB confirming opt. findings

… and more recently GEMs@Gemini

NGC2808 core

Massari + (2015)



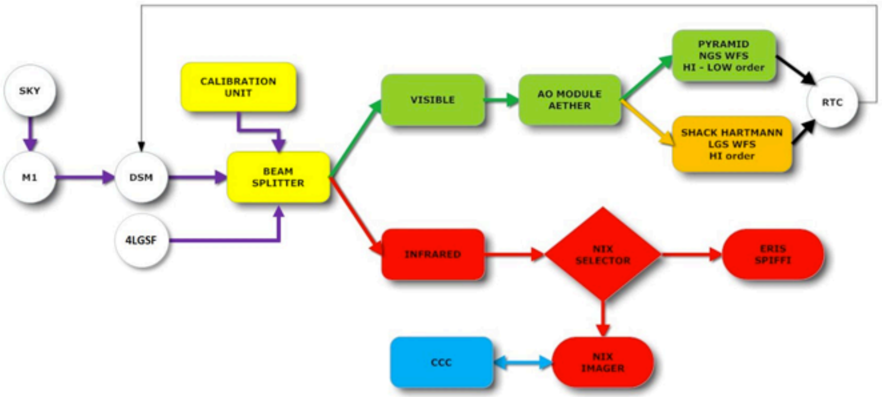


K

F606W-K

t=10.9±0.7 (intrinsic)±0.45 ([Fe/H]) Gyr
error 3X smaller MSTO

ERIS@VLT [2018]



Enhanced Resolution Imager & Spectrograph

1-5 µm for UT4
[AOF, laser] + SCAO

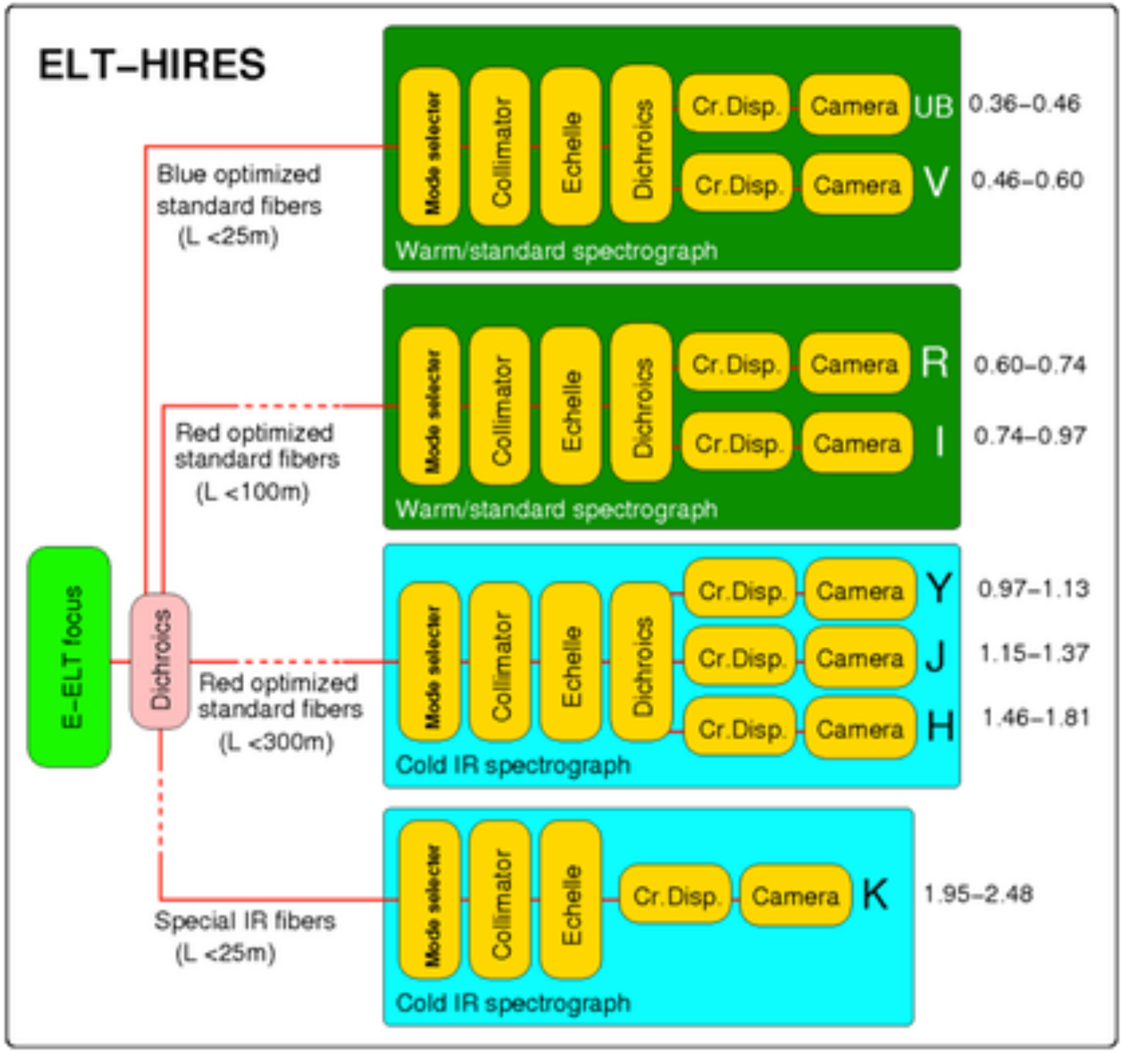
Imager

FoV 27x27, 54x54 arcsec^2
Pixel scale 0.013, 0.027 mas/pix
Spectral coverage J -- M

Integral Field Spectrograph

FoV 8x8, 3.2x3.2, 0.8x0.8 arcsec^2
Pixel scale 250—25 mas/spaxel
Spectral coverage JHK → R up to 8000

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

Extremely MP Halo Stars

Five objects:
[Christlieb+2002; Frebel+2005;
Norris+2007; Caffau+2011
Keller+2013 → **skymapper**

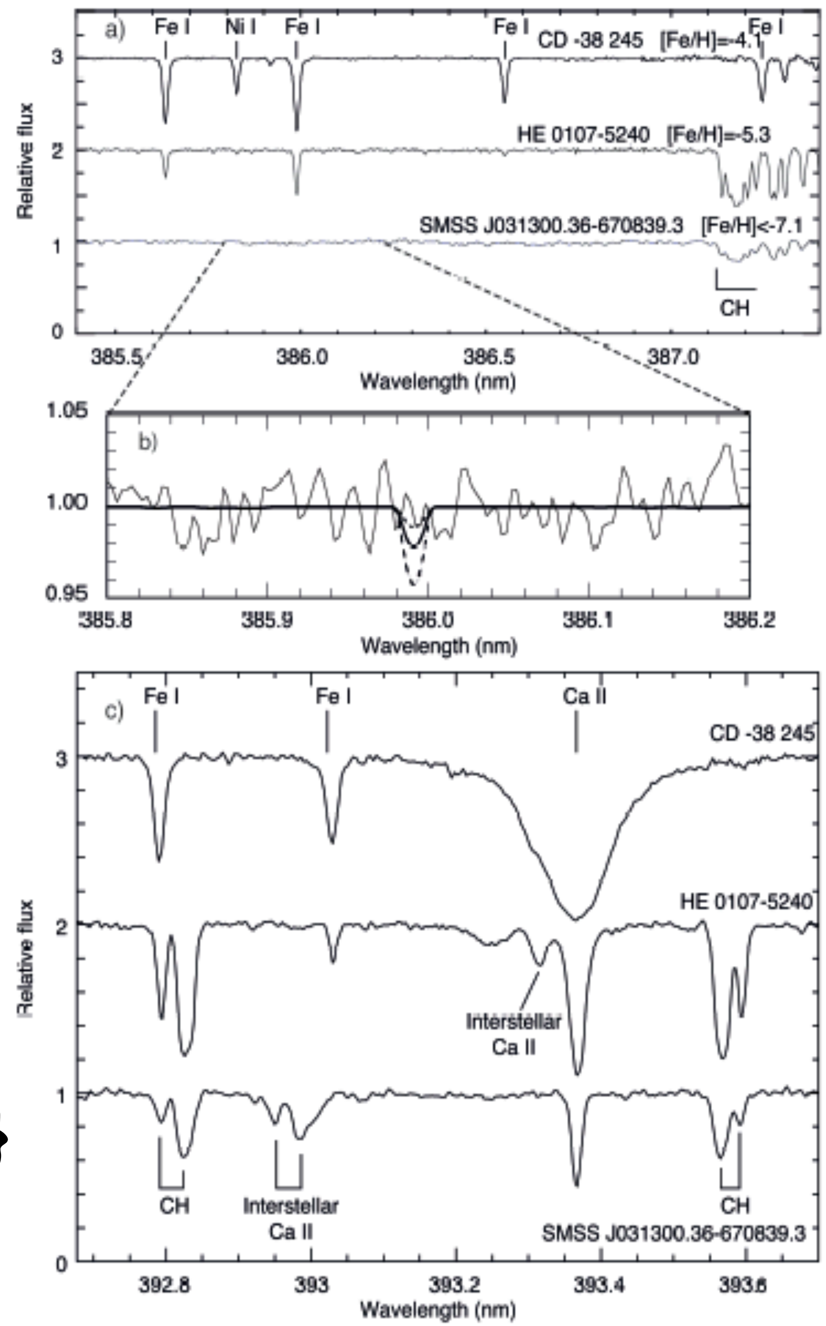
Carbon enhanced
Extremely Iron poor

A few & probably a single
low-energy SN

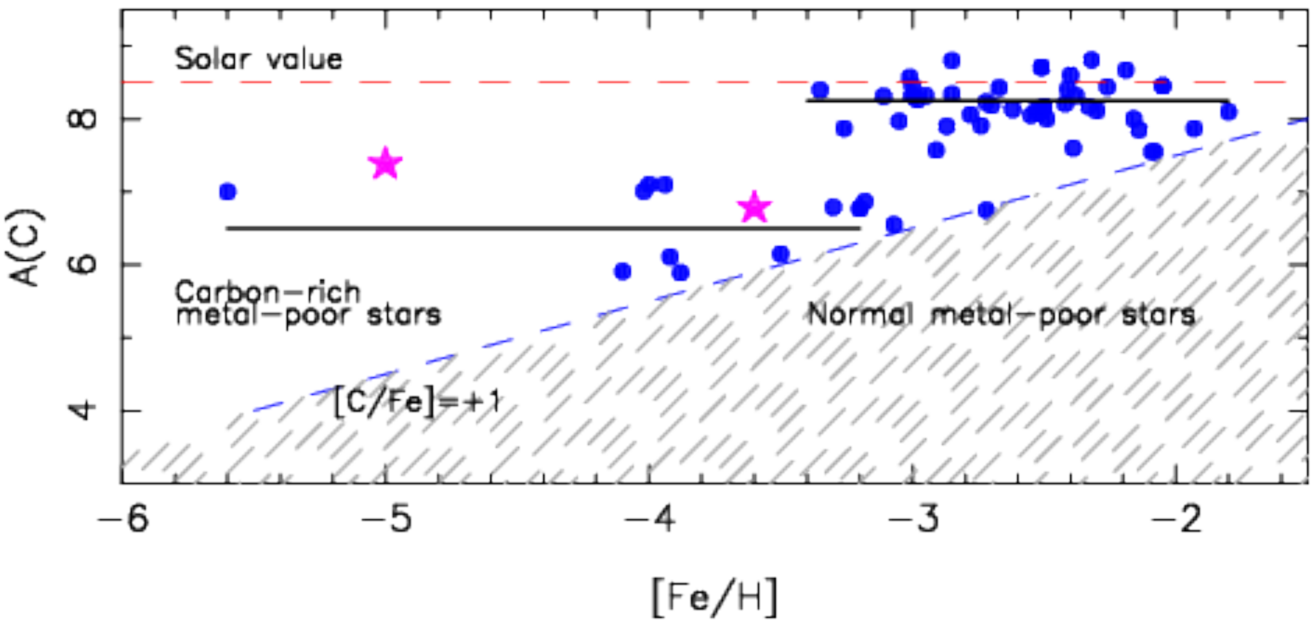
Extremely massive SN
(pair-instability) should
Rapidly increase Fe content

UPPER LIMIT 10^{-7.1}
3σ c.l.

SMSS J031300.36-670839.3



Carbon-enhanced M.P. stars



Only MSTO & dwarves

blue- dashed line → [C/Fe]=+1

Spite+ (2013)

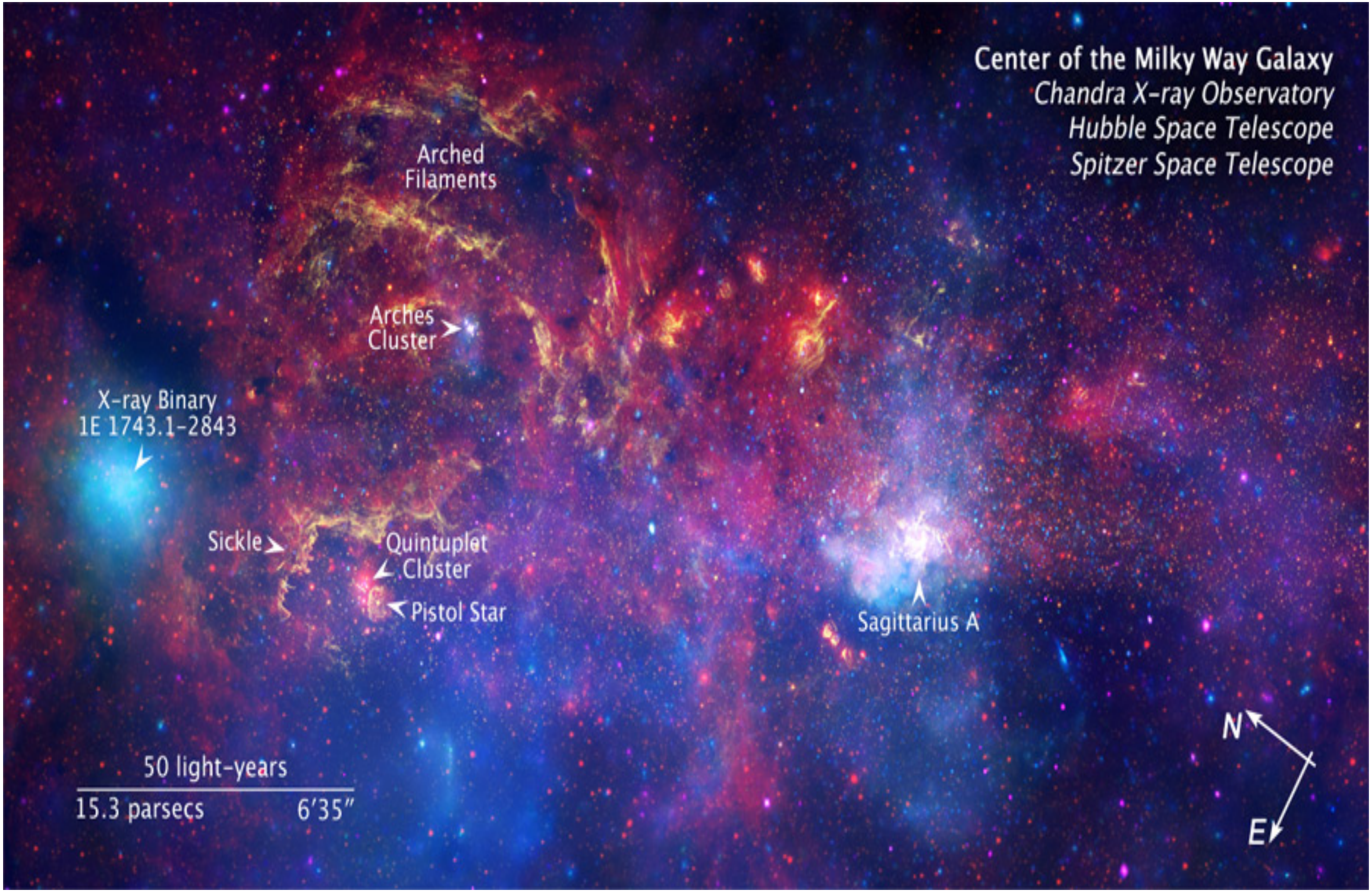
Caffau+ (2013)
+
X-SHOOTER LP pending!

Identification of a few C enhanced & α-poor

SMSSJ031300.36→ A(C)~9~solar!!

Statistics to impact on pop. III stars

Gaia
Global Astrometric Interferometer for Astrophysics

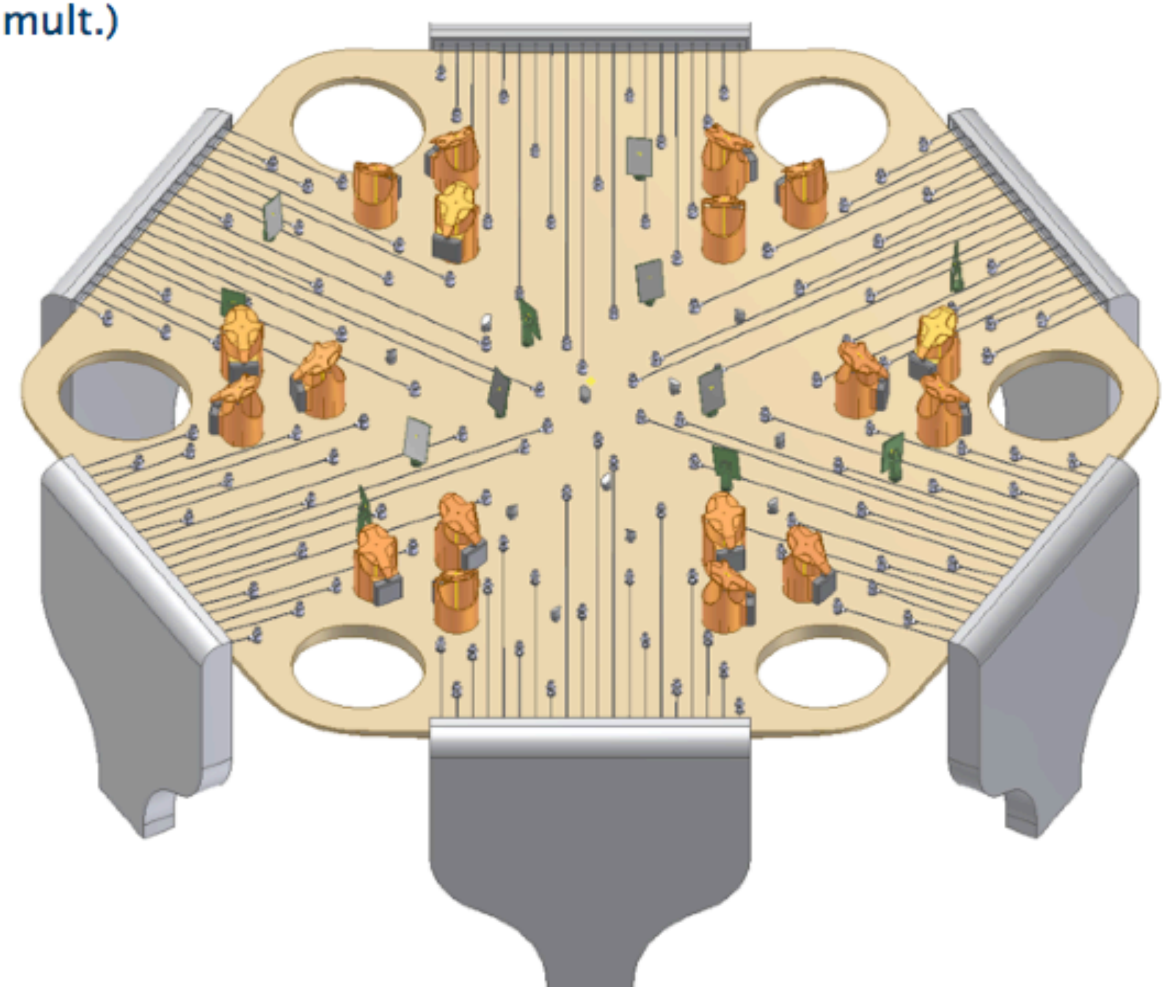


Center of the Milky Way Galaxy
Chandra X-ray Observatory
Hubble Space Telescope
Spitzer Space Telescope
Arched Filaments
Arches Cluster
X-ray Binary 1E 1743.1-2843
Sickle
Quintuplet Cluster
Pistol Star
Sagittarius A
50 light-years
15.3 parsecs
6′35″
N
E

E-ELT: MOS

MOSAIC: Fiber Only Option

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



Requirements for MOS@E-ELT in Optical seeing limited (GLAO)

Large FoV	> 7'x7'
High multiplex	> 100-200 fibers
Spatial res.	< 0.3—0.9 arcsec

Identification

(DA vs DO – He and/or C enhanced)

Low-res R~3,000

Limiting mag. V~23 mag

Abundances

High-res R~10,000—20,000

Limiting mag. V~21 mag

S/N~80--100 (30h)

Roadmap: Galactic archeology with low/medium resolution spectra.

Requirements for MOS@E-ELT in the NIR AO (MOAO) assisted

Large FoV	> 7'x7'
High multiplex	> 12 → IFUs
Spatial res.	< 0.003—0.009 arcsec

Kinematics (+met. Ind.)

Low-res R~3,000—4000

Limiting mag. J,H~23--25 mag

S/N ~10-15 (50h)

Abundances

High-res R~10,000—20,000

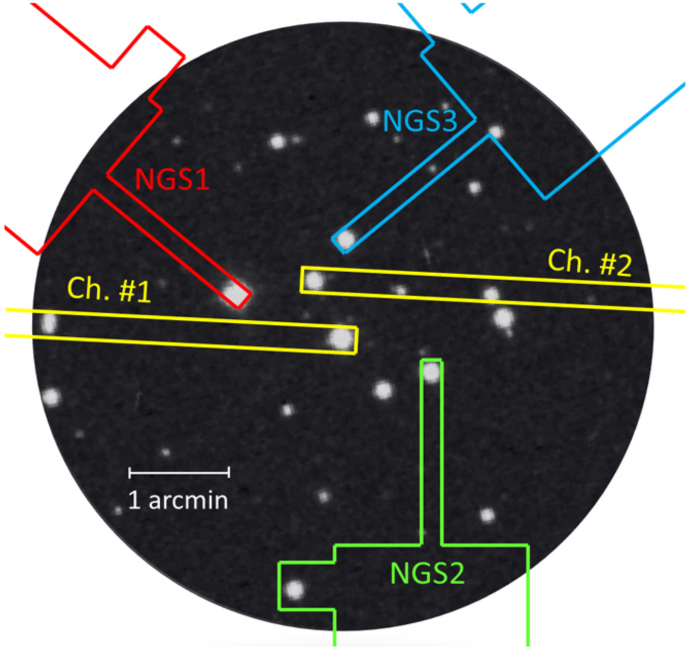
Limiting mag. J,H~21--23 mag

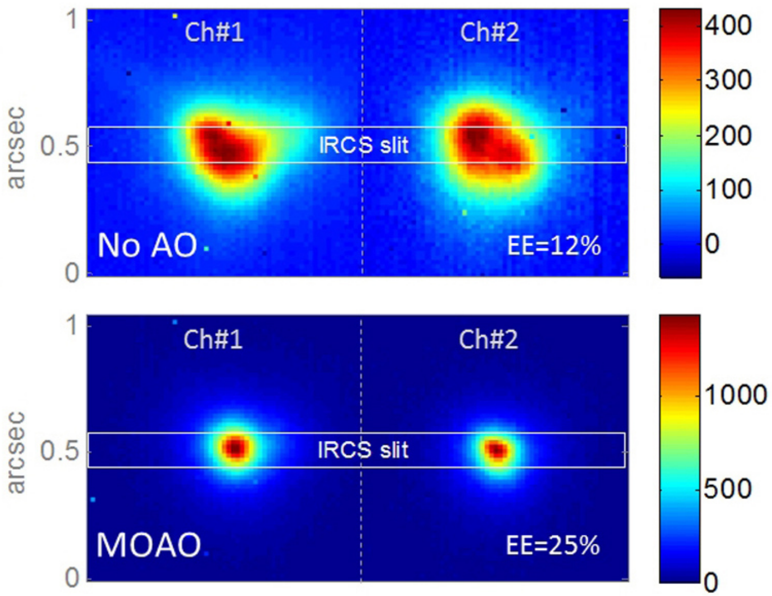
S/N~60-80 (30h)

Simultaneous medium and high-resolution

INTEGRAL FIELD SPECTROSCOPY – PSF fitting spectra extraction at the confusion limit

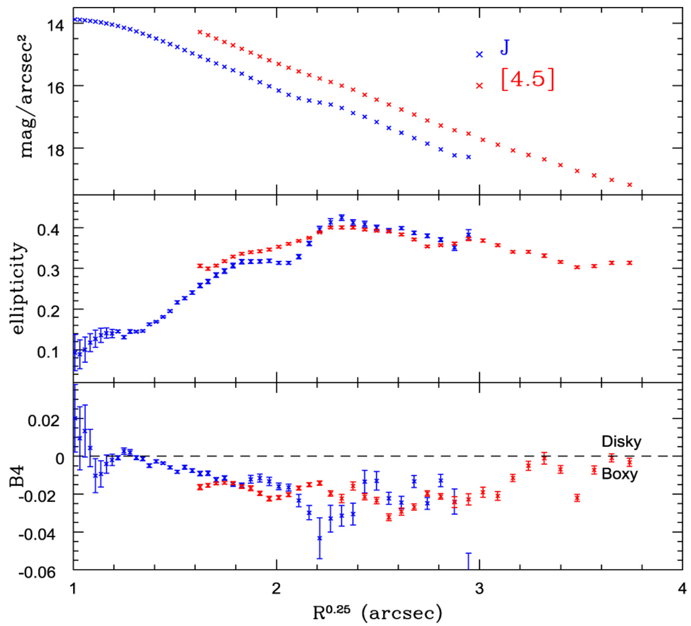
Paving the way for MOAO: RAVEN@SUBARU





AO188 + IRSF + HiCiao

Images taken with Raven 14/05/2014 at the Subaru Telescope. (Credit: Lardière/UVic)



SED of Maffei 1 RAVEN+IRCS spectroscopy

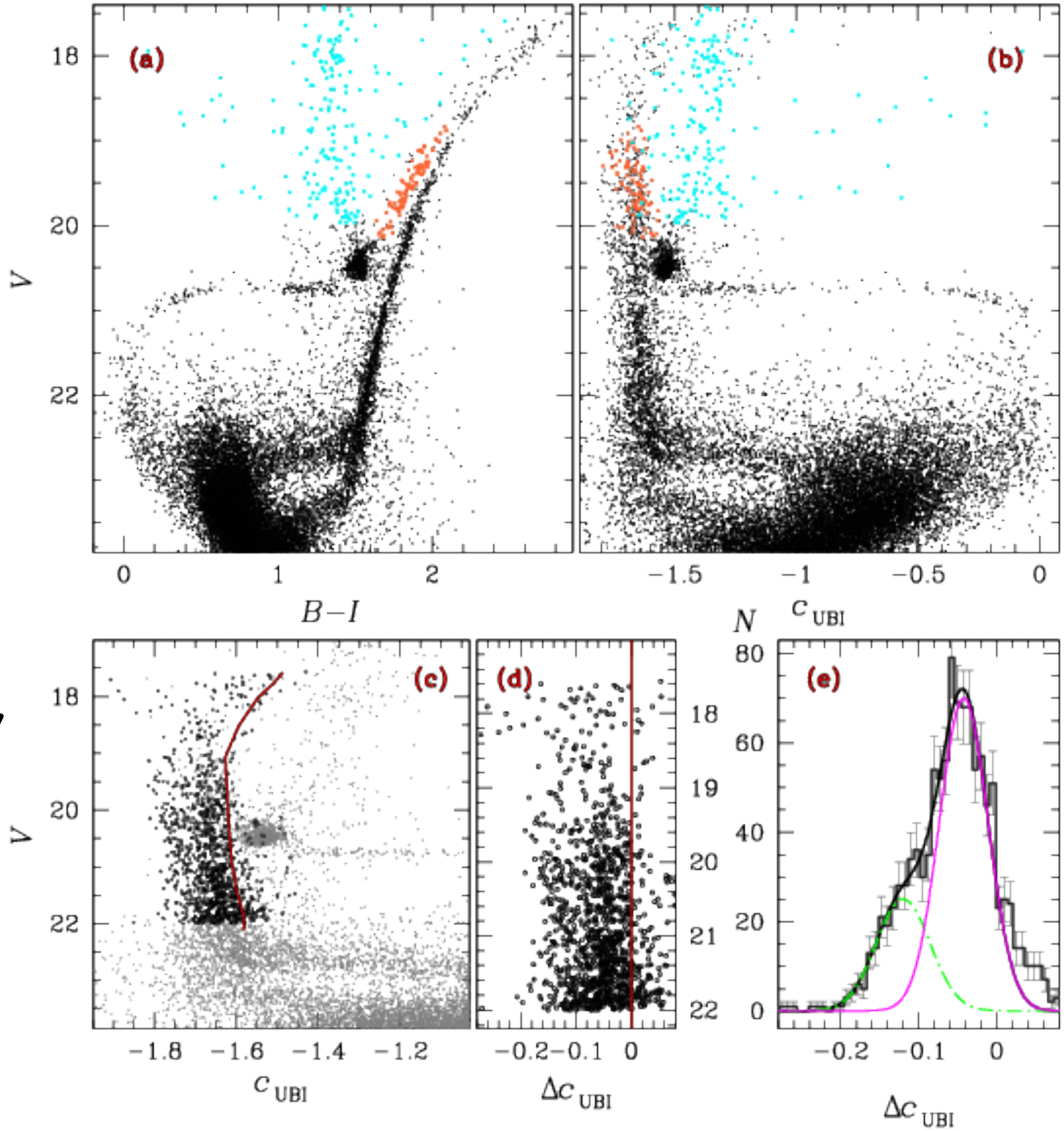
Davidge + (2015)

A new spin on dSphs: Carina

C_UBI=(U-B)-(B-I)

A clear separation between old & intermediate-age along the RGB

The age-metallicity Degeneracy fixed!!



Monelli + (2014)

Carina dSph: metallicity distribution
Old & intermadiate-age stars

[Fe/H]
μ(int) =−1.74±0.38±0.20

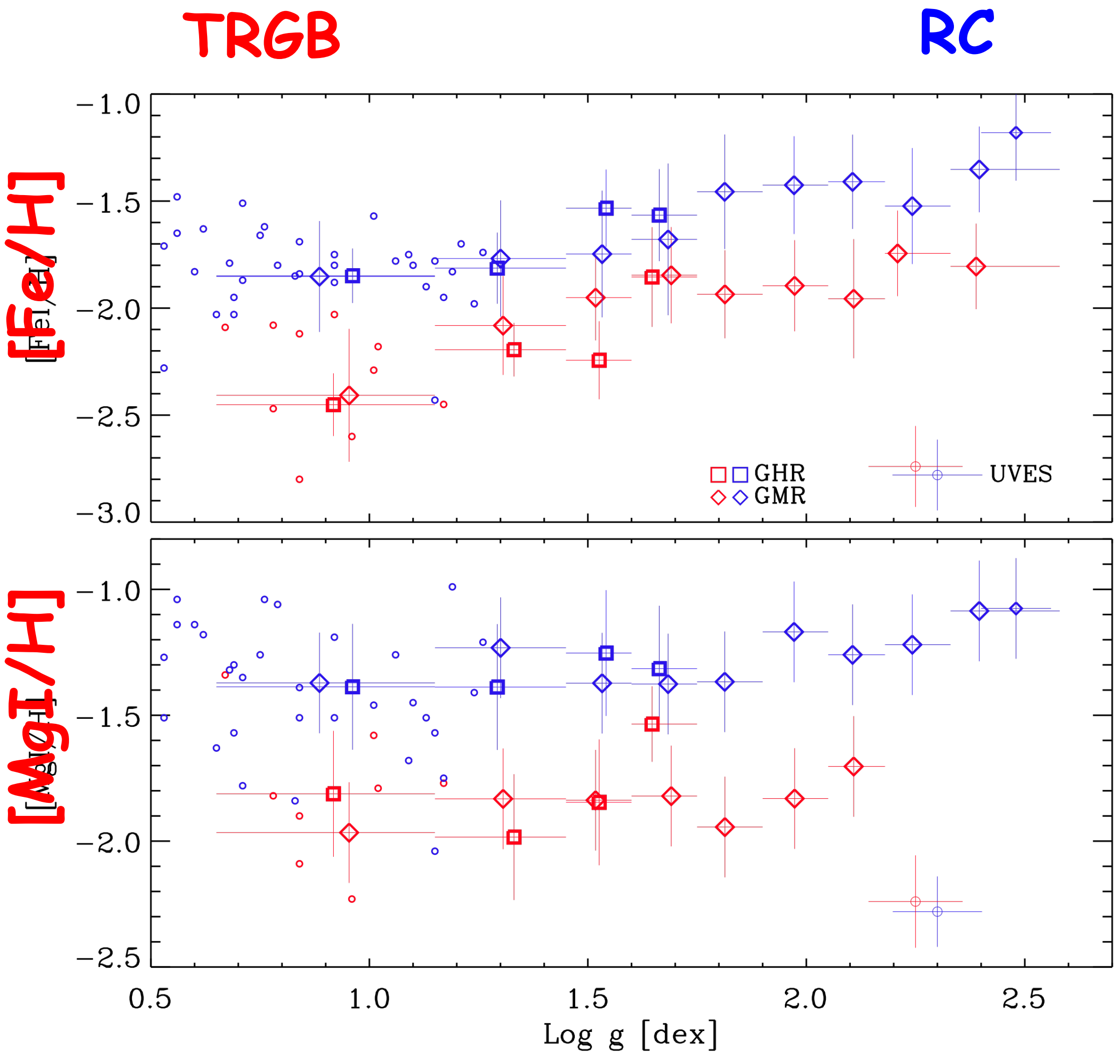
μ(old)=−2.13±0.06±0.28

They differ 75% c.l.

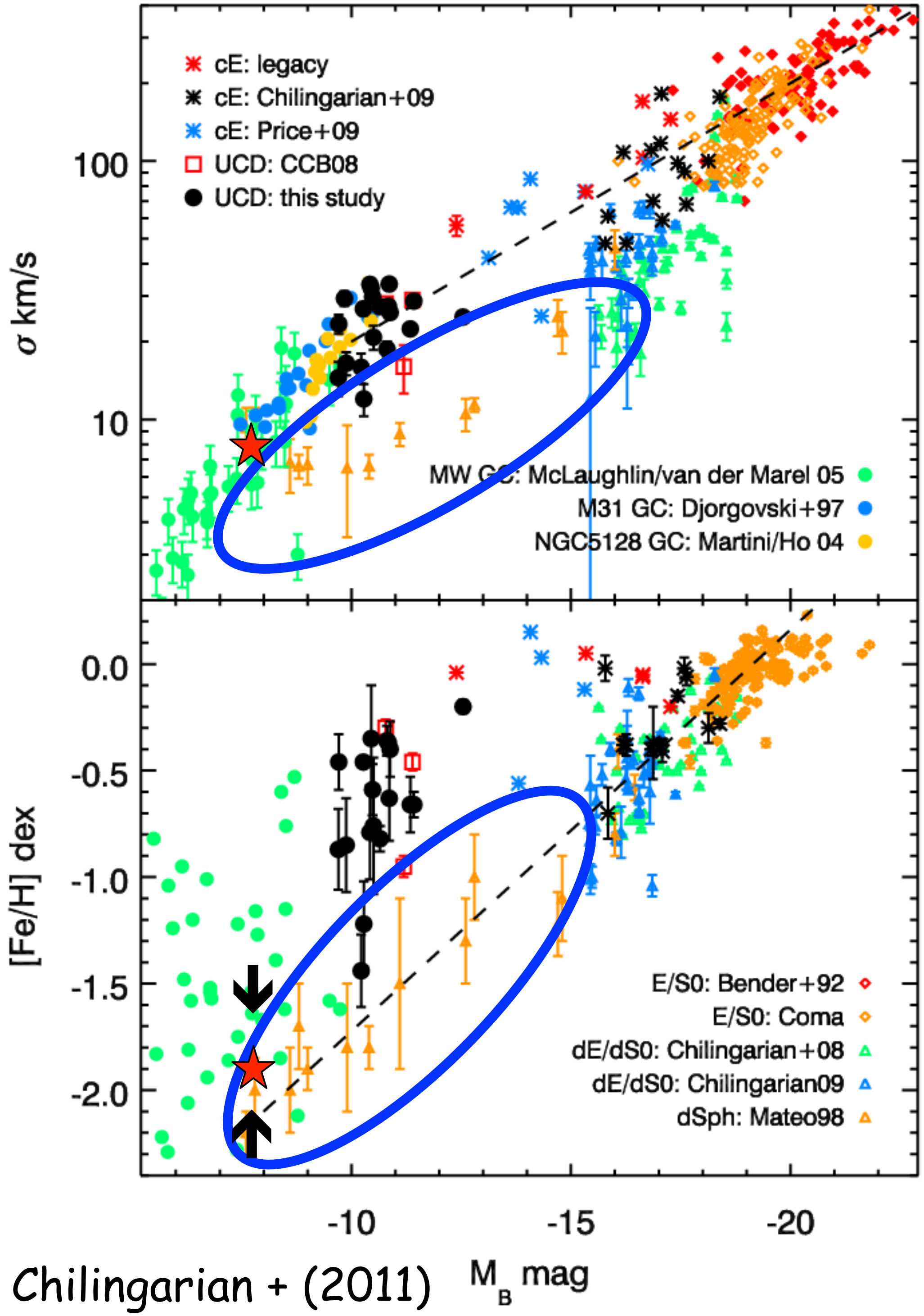
[Mg/H]
μ(int) =−1.37±0.04±0.27

μ(old)=−1.77±0.08±0.36

They differ 83% c.l.



Fabrizio + 2015



Chilingarian + (2011)

Dichotomy in the Faber-Jackson relation
$L \approx \sigma^4$

dSphs follow the metallicity-luminosity relations

Are these relations age invariant?

Age is becoming more popular …

BUT NO RGB!!!! asteroseismology

GLOBAL GROWTH

Evolutionary, Pulsation, Atmosphere models → 1D vs 3D

Opacity, EOS, line identifications, molecules (NIR)

Multiband Asymmetric PSF

Integral field spectroscopy

Subaru User's Meeting
Maunakea International Observatories

We move in different hemispheres

Adaptive Optics

(SCAO, MCAO, MOAO, LTAO)

We have to learn from our mistakes

Conclusions I (SUBARU)

« Ἐν μὲν γαῖαν ἔτευξ', ἐν δ' οὐρανόν, ἐν δὲ θάλασσαν,
ἠέλιόν τ' ἀκάμαντα σελήνην τε πλήθουσαν,
ἐν δὲ τὰ τείρεα πάντα, τά τ' οὐρανὸς ἐστεφάνωται,
Πληϊάδας θ' Ὑάδας τε τό τε σθένος Ὠρίωνος
Ἄρκτόν θ', ἣν καὶ Ἄμαξαν ἐπίκλησιν καλέουσιν,
ἥ τ' αὐτοῦ στρέφεται καί τ' Ὠρίωνα δοκεύει,
οἴη δ' ἄμμορός ἐστι λοετρῶν Ὠκεανοῖο. »
(Omero, *Iliade, XVIII)*

Omero, Odysseus V