Galactic Surveys: New Results on Formation Evolution Structure and Chemical Evolution of the Milky Way

25-29 January 2016, Kurhotel at Bad Moos – Sexten

cool supergiants as probes of the chemical evolution in obscured stellar systems

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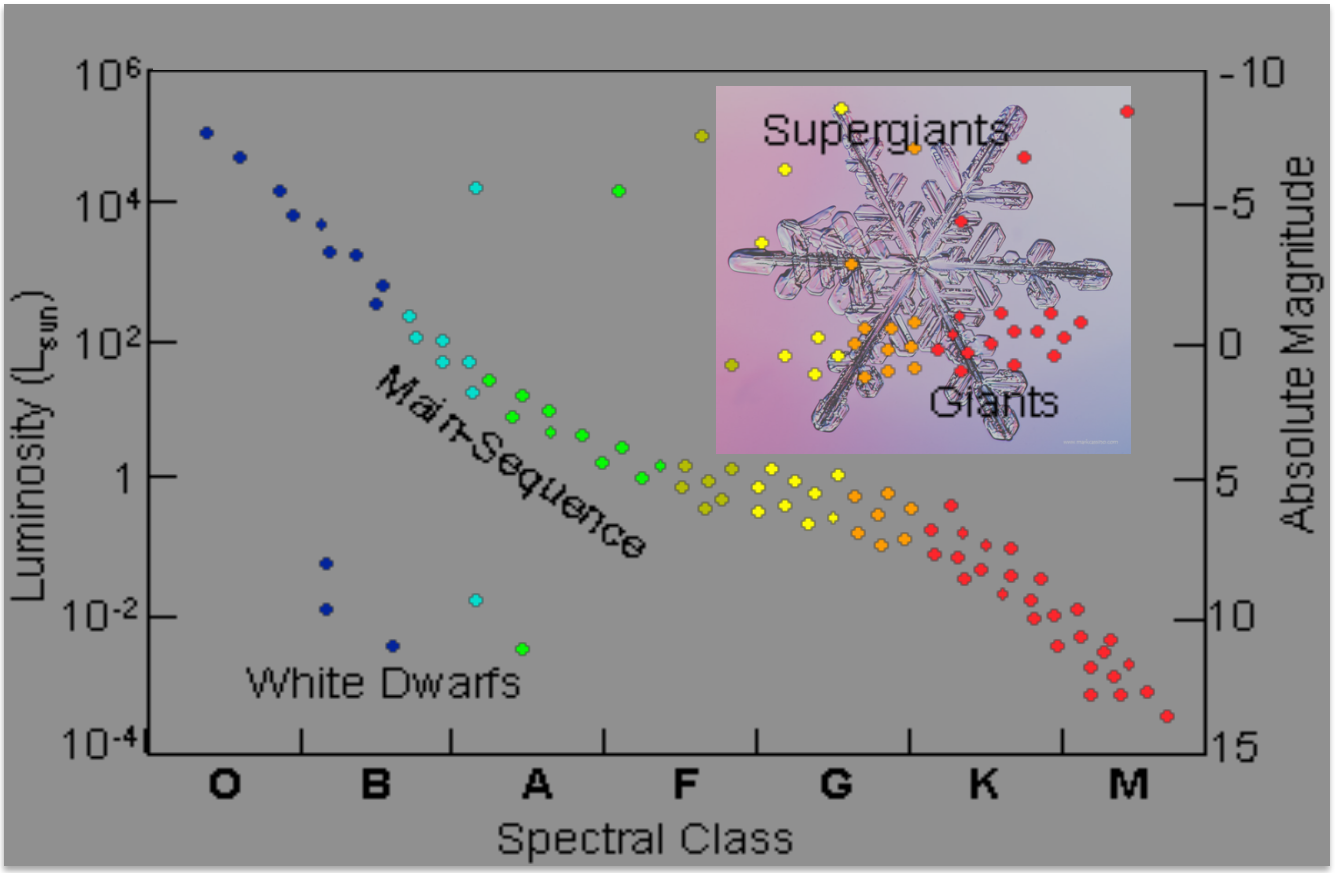
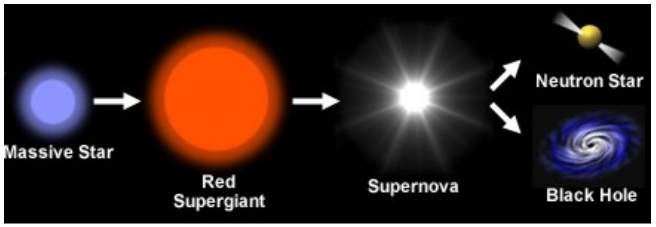
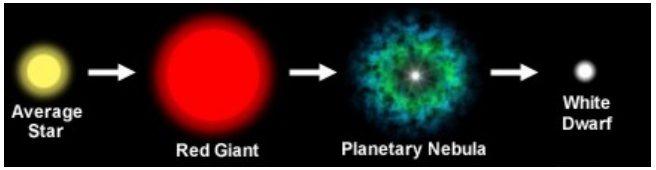
cool giants and supergiant stars







trace the latest stages of stellar evolution for a wide range of mass progenitors (~0.8-40 Mo)

trace stellar populations over a wide range of ages (>5 Myr ➔ oldest) and over the full range of metallicities

fundamental labs to study stellar nucleosynthesis and chemical enrichment, 3D structure, mixing, magnetic fields, winds, mass loss etc.

luminous ➔ trace stellar populations out to large distances

RSGs can probe stellar abundances in star-forming regions

dominate the integrated luminosity of stellar systems

chemistry of cool supergiants

a recent field of investigation, on the learning curve

IR spectroscopy often needed because of the low temperatures and high reddening of the environment

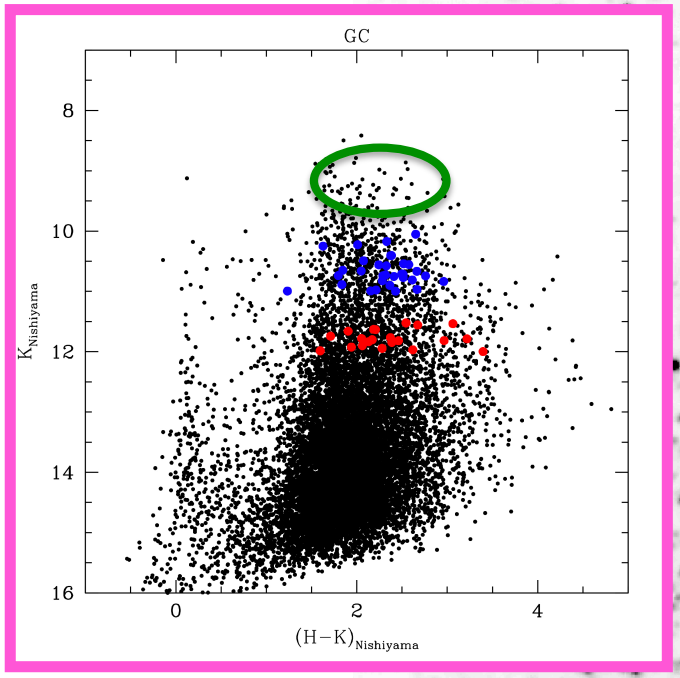
state-of-the-art chemical analysis of metal-rich RSGs by means of medium-high resolution IR spectroscopy

- CNO and F abundances from molecular (CO, CN, OH, HF) lines, all the other metal abundances from atomic (mostly neutral) lines
- mostly based on 1D or spherical model atmospheres
- abundances with random errors of <0.1 dex, systematic errors (stellar parameters and degeneracy, log(gf), model atmospheres etc.) ~0.2 dex on average

fov ~3'x3' →
7pc x 7pc

The Galactic Center
Av>30 mag!

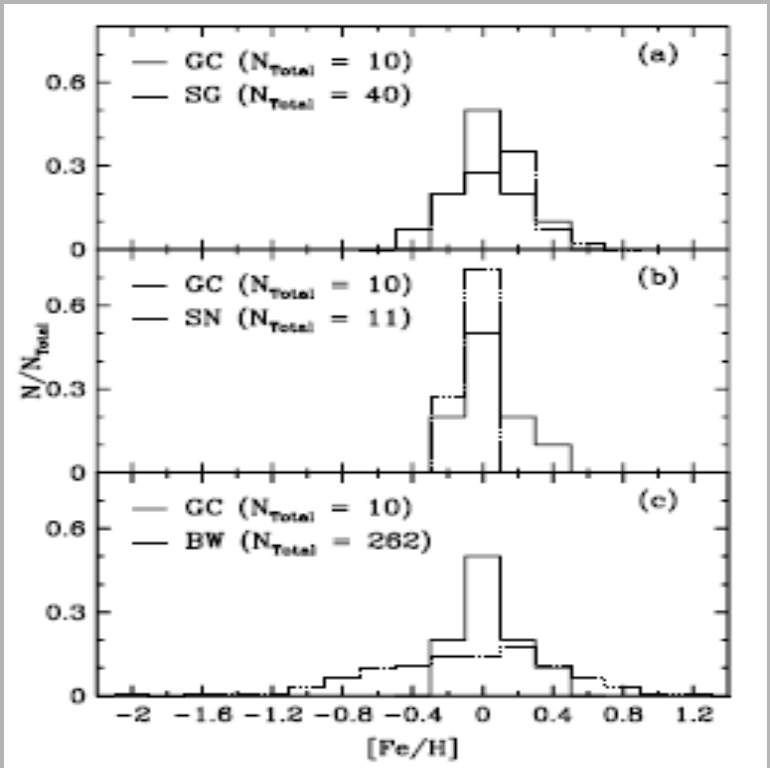
RSG
bright giants
RGB



courtesy of M. Schultheis
& the UKIDSS collaboration

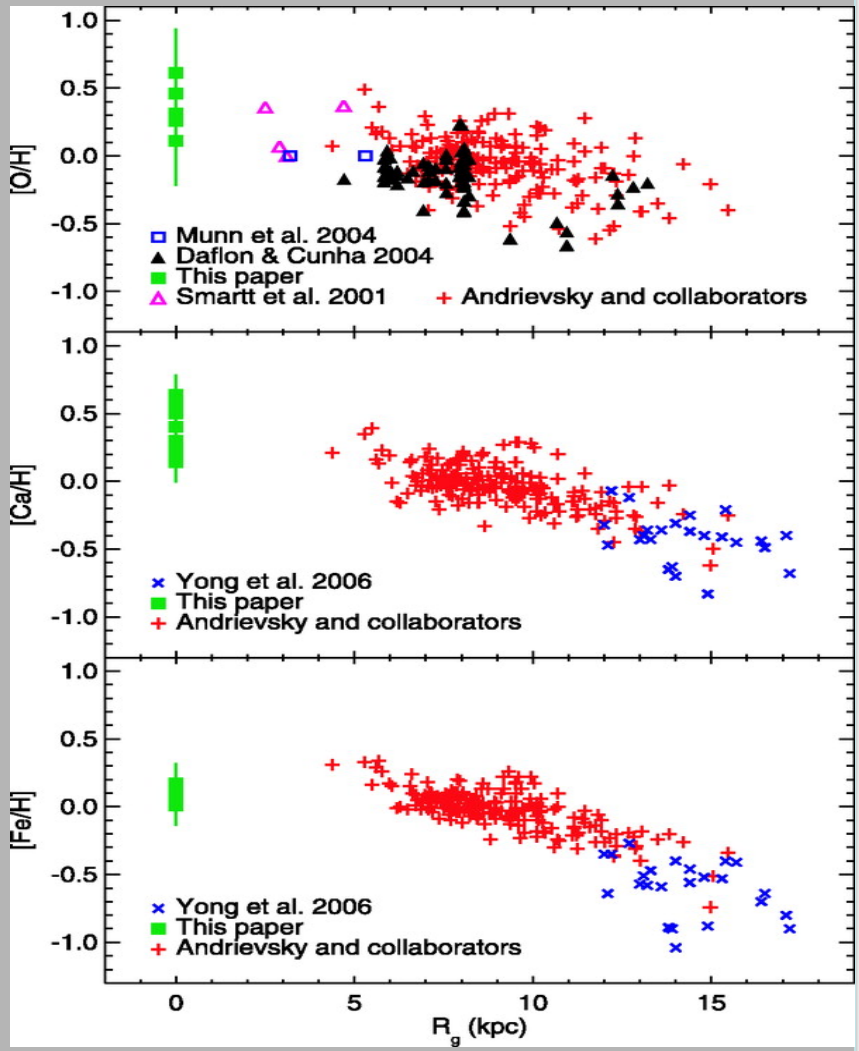
chemical abundances of RSGs in the Galactic center

high resolution IR spectroscopy



Ramirez+ '00 CSHELL@IRTF

~solar [Fe/H]



Ryde & Schultheis '15 CRIRES@VLT

9 M-giants: [Fe/H]~+0.1

about solar [α/Fe]

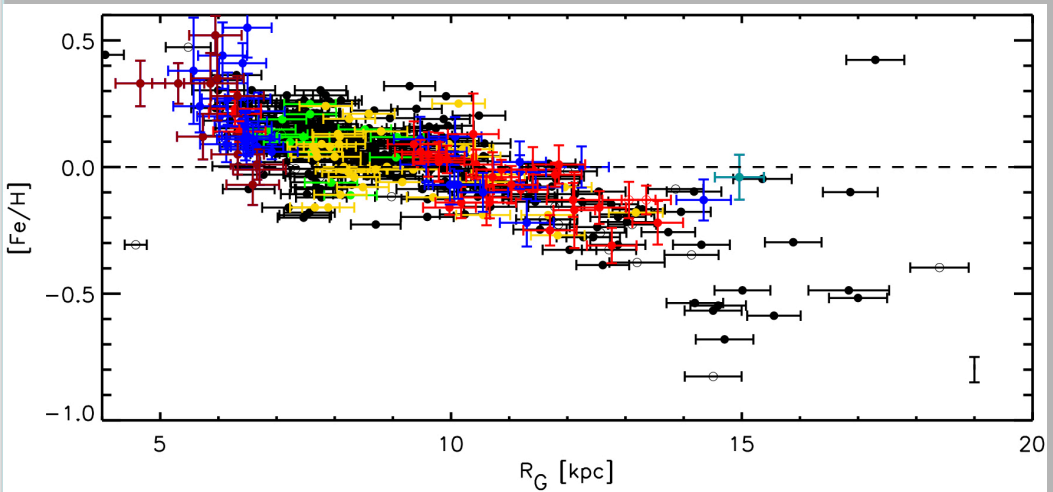
Cunha+07 PHOENIX@Gemini

~solar [Fe/H]

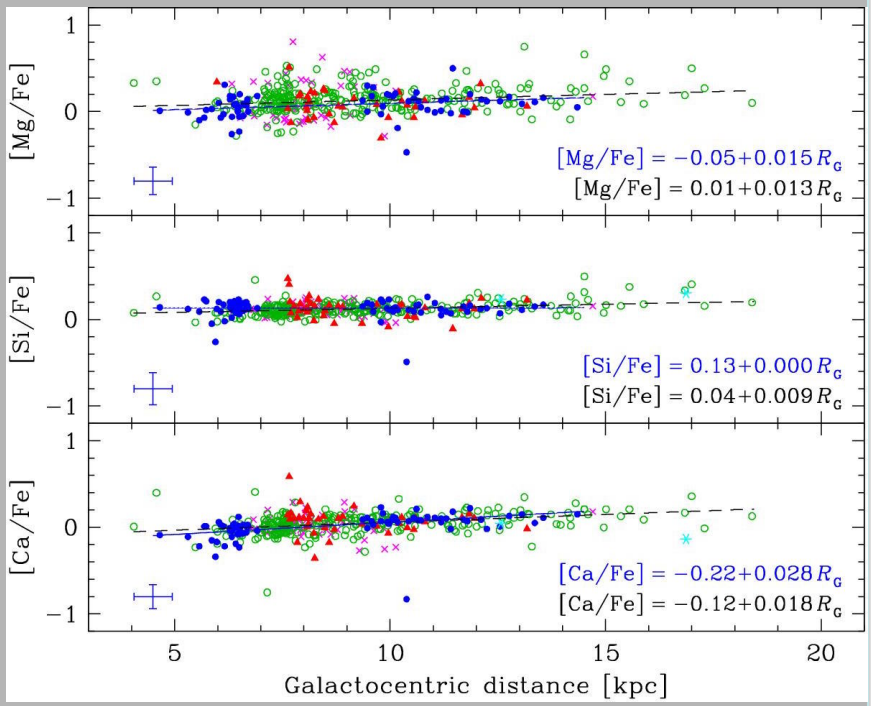
some [α/Fe] enhancement

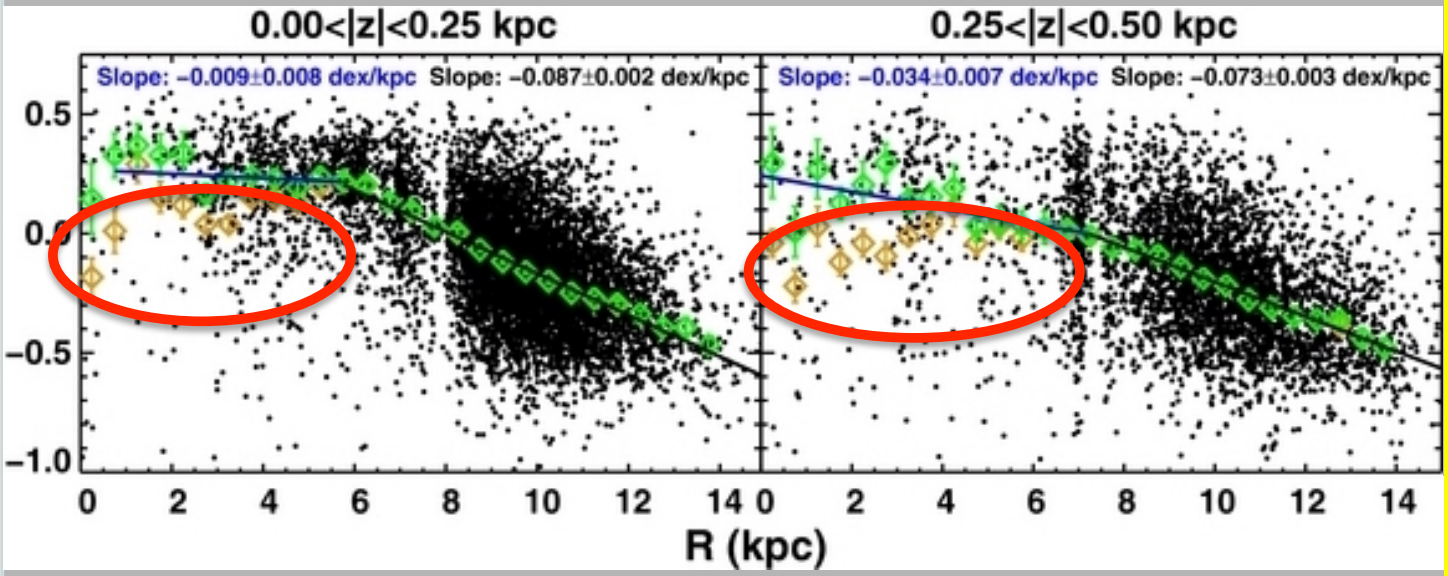
the inner disk chemistry

Cepheids e.g. Genovali+15



metallicity gradient out of 5 kpc
about solar [α/Fe]





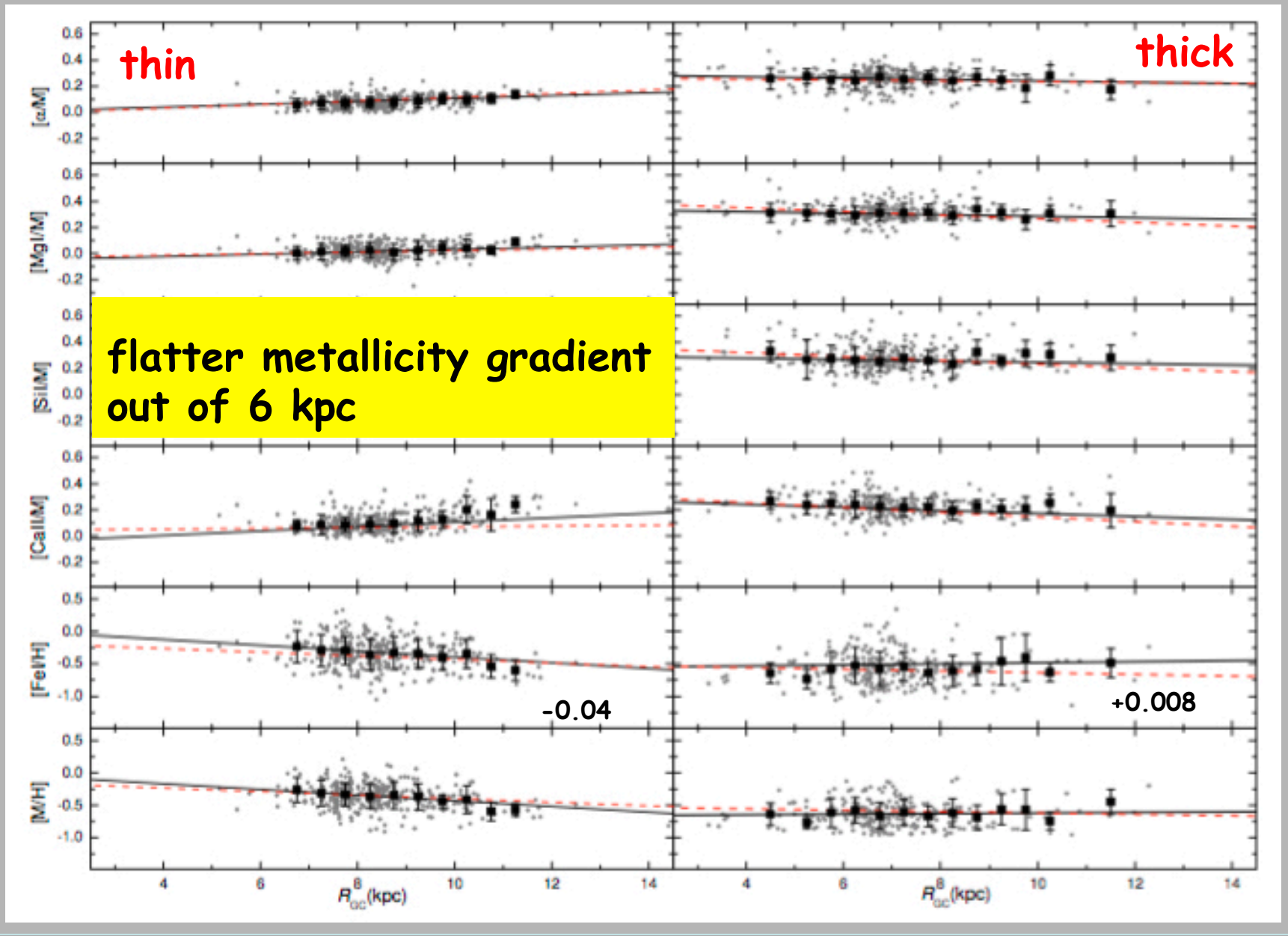
APOGEE
e.g. Hayden+ 2014
flattening in the inner 5 kpc

warmer giants → 2x solar met

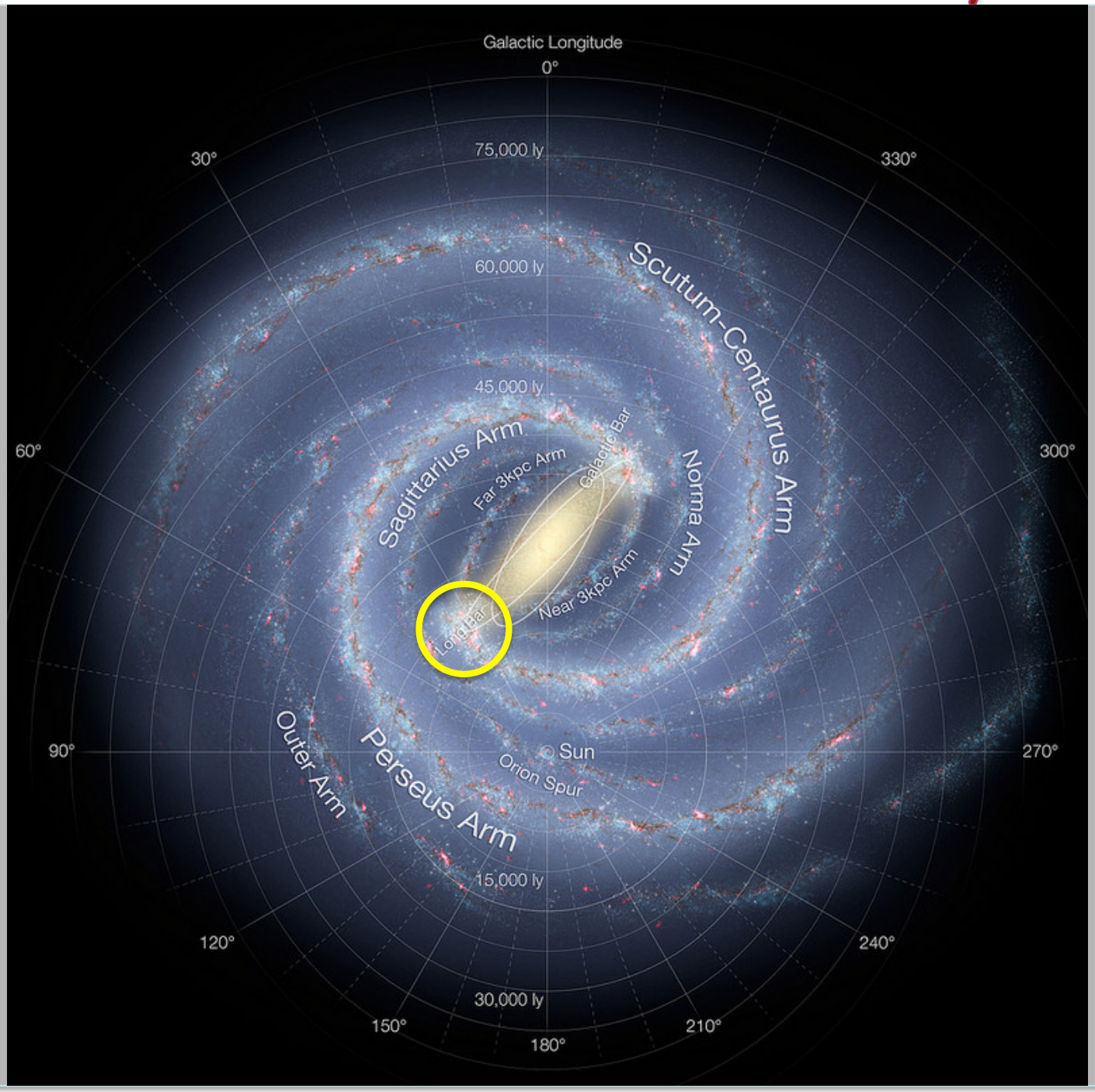
cooler giants → about solar met

the inner disk chemistry

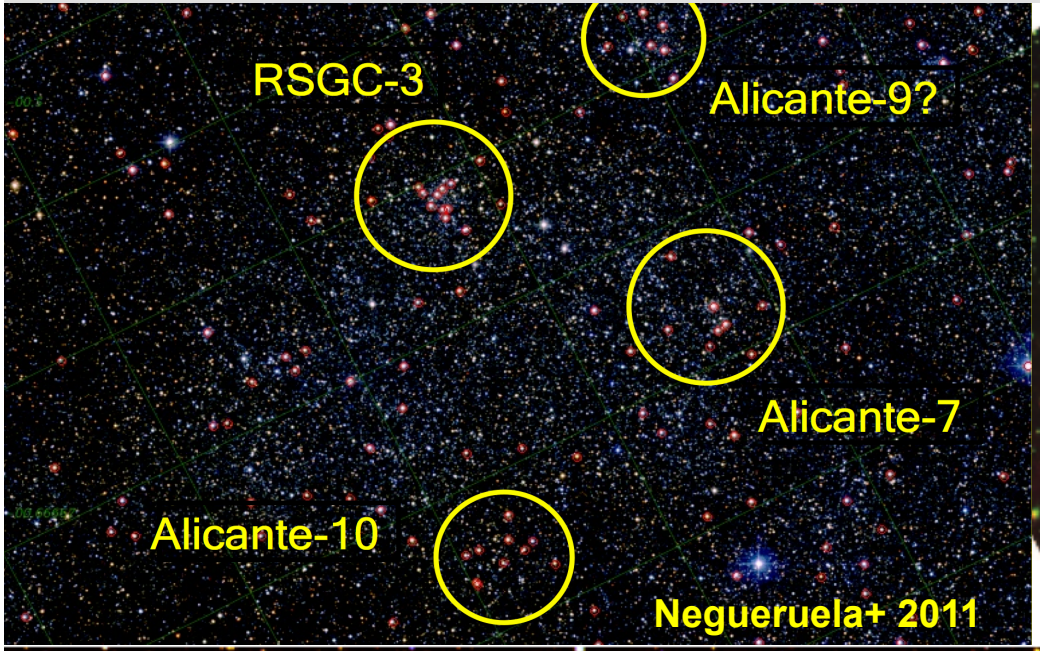
GES e.g. Mikolatis+ 2014

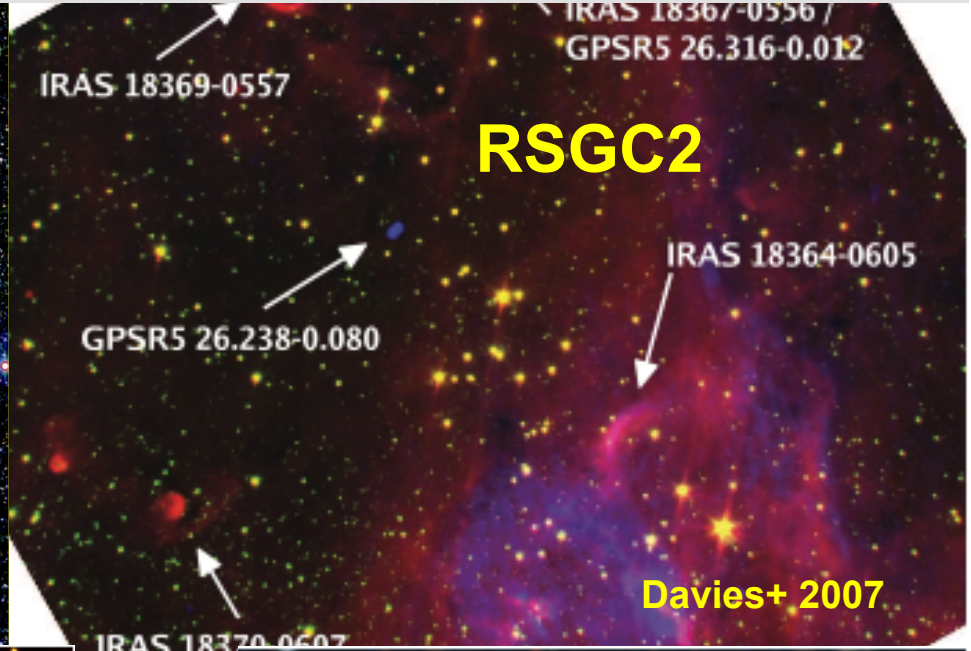


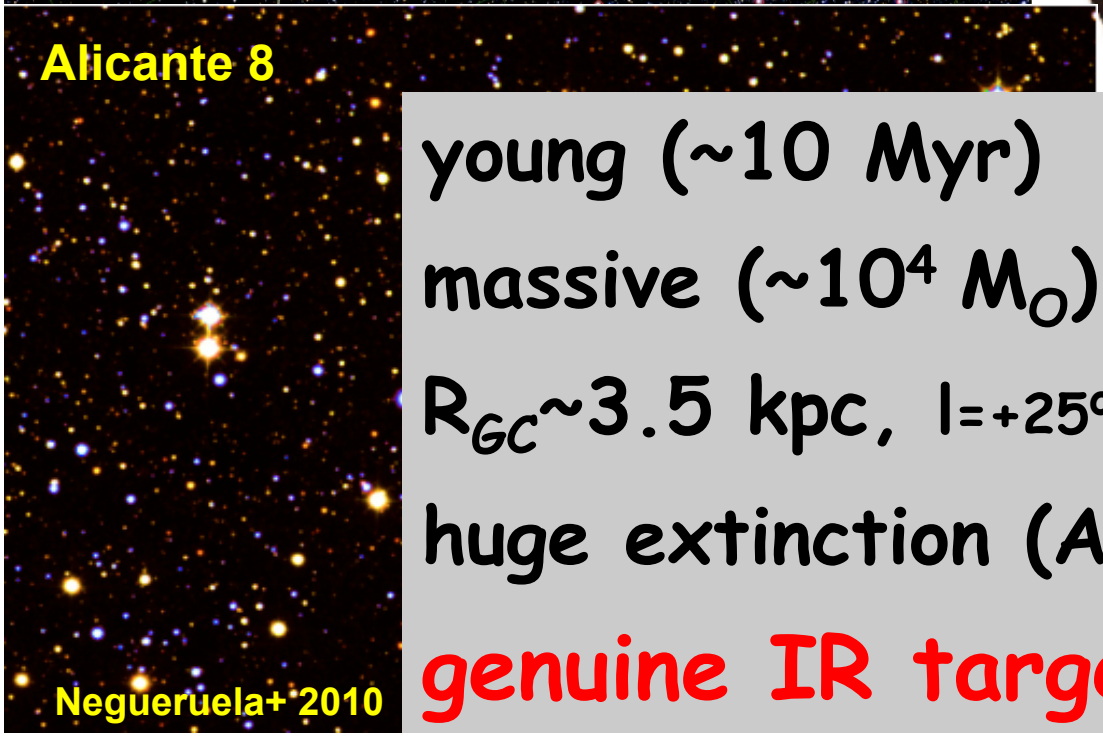
the inner disk chemistry



RSGs in the Scutum arm young clusters







RSGC1

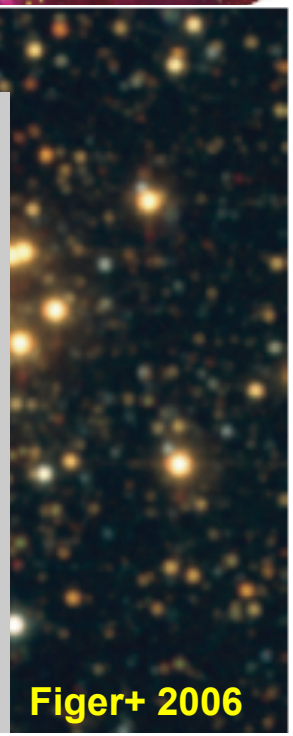
young (~10 Myr)

massive (~10^4 M_O)

R_{GC}~3.5 kpc, l=+25°→29° b=-0.2→0.0°

huge extinction (A_V>10 mag!)

genuine IR targets

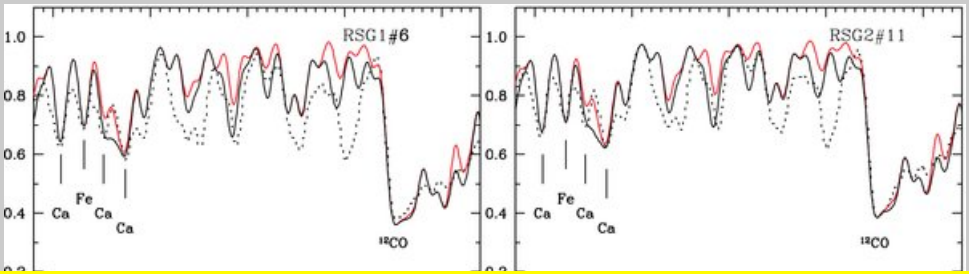


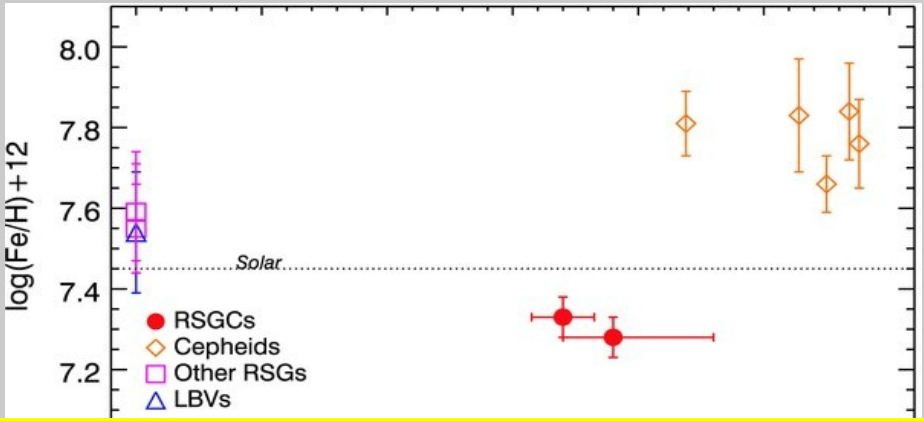
chemical abundances of RSGs in the Scutum young clusters

14 RSGs in RSGC1 and 13 RSGs in RSGC2

NIRSPEC-Keck, H-band, R~17,000

Davies+ 2009

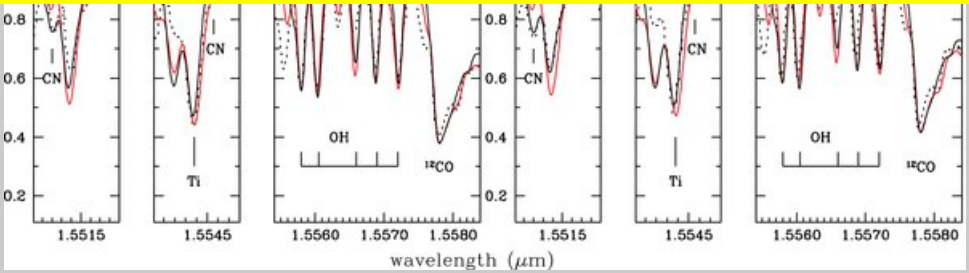


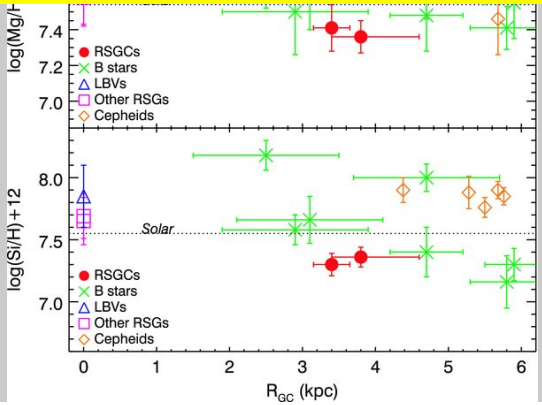


Fe, C, O, Ca, Si, Mg, Ti

half-solar metallicity, solar-scaled alpha
lower envelope of the metallicity distribution in the inner disk

C-depletion consistent with extra-mixing (rotational)





chemical abundances of RSGs in the Scutum young clusters

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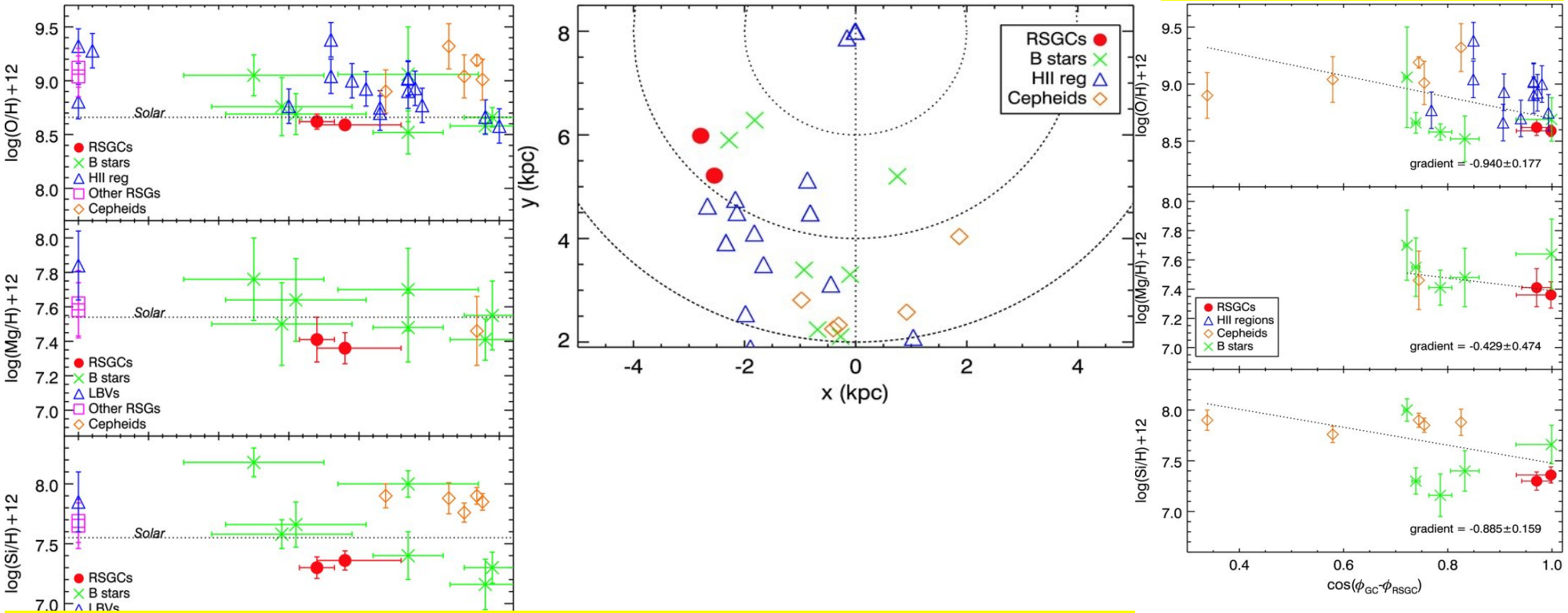
Azimuthal gradient

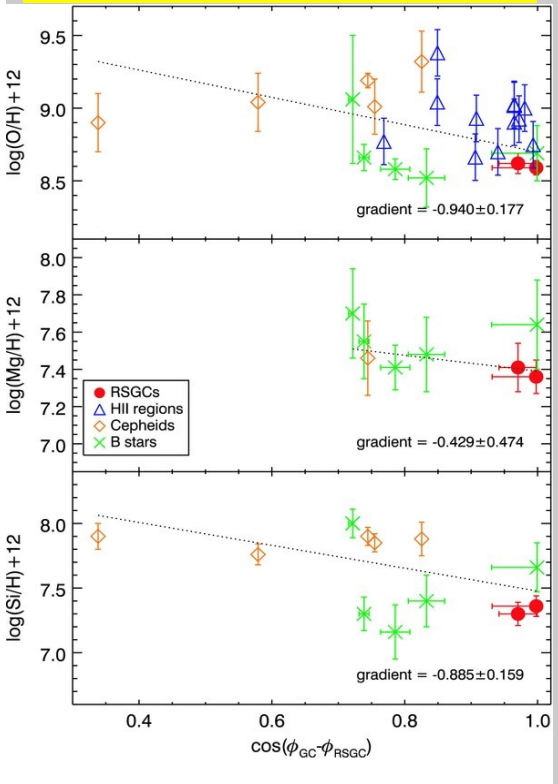


large-scale (~ kpc) azimuthal variations in abundances at Galactocentric distances of 3–5 kpc from the intense but patchy SF driven by the potential of the central bar

chemical abundances of RSGs in the Scutum young clusters

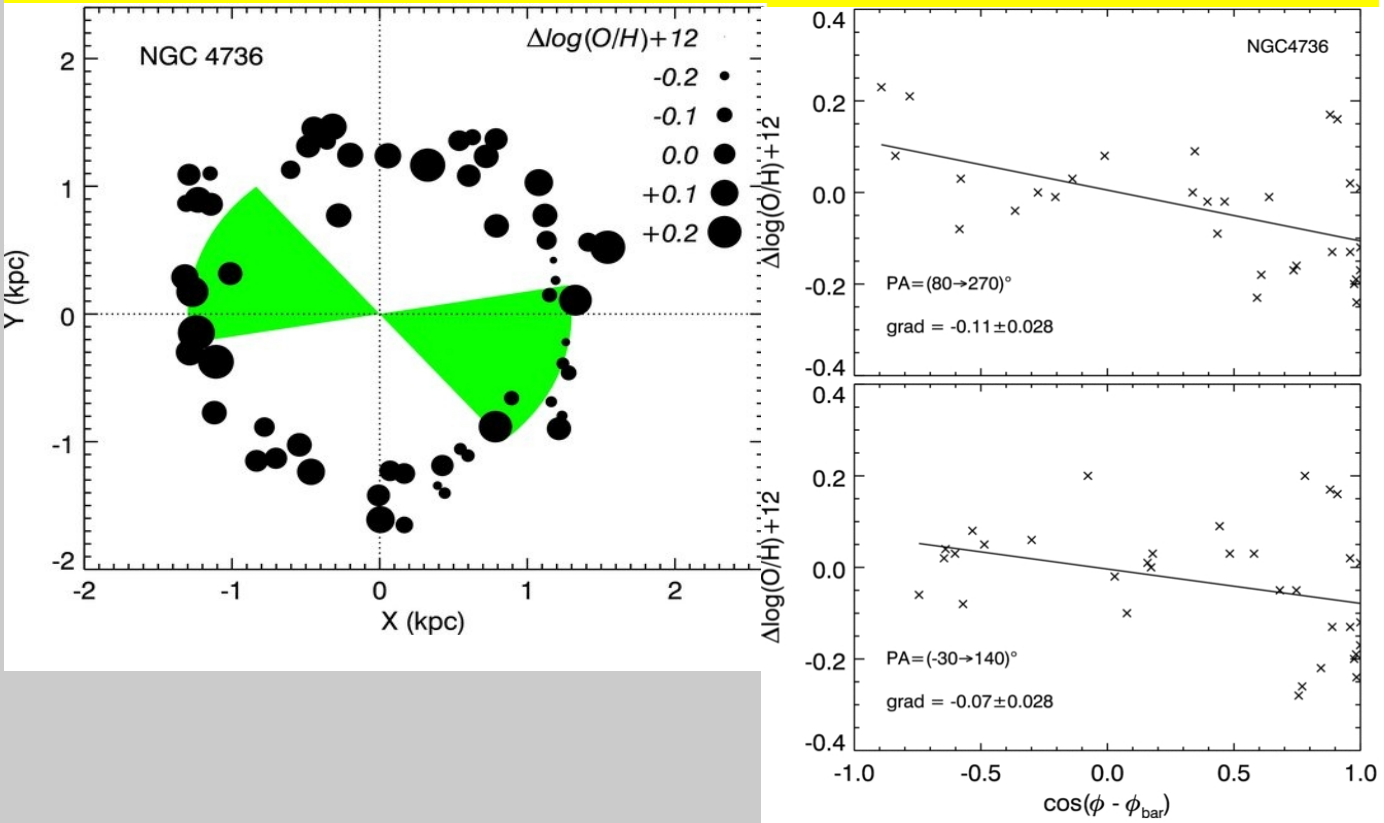
large-scale (~ kpc) azimuthal variations in abundances at Galactocentric distances of 3–5 kpc from the intense but patchy SF driven by the potential of the central bar

Azimuthal gradient

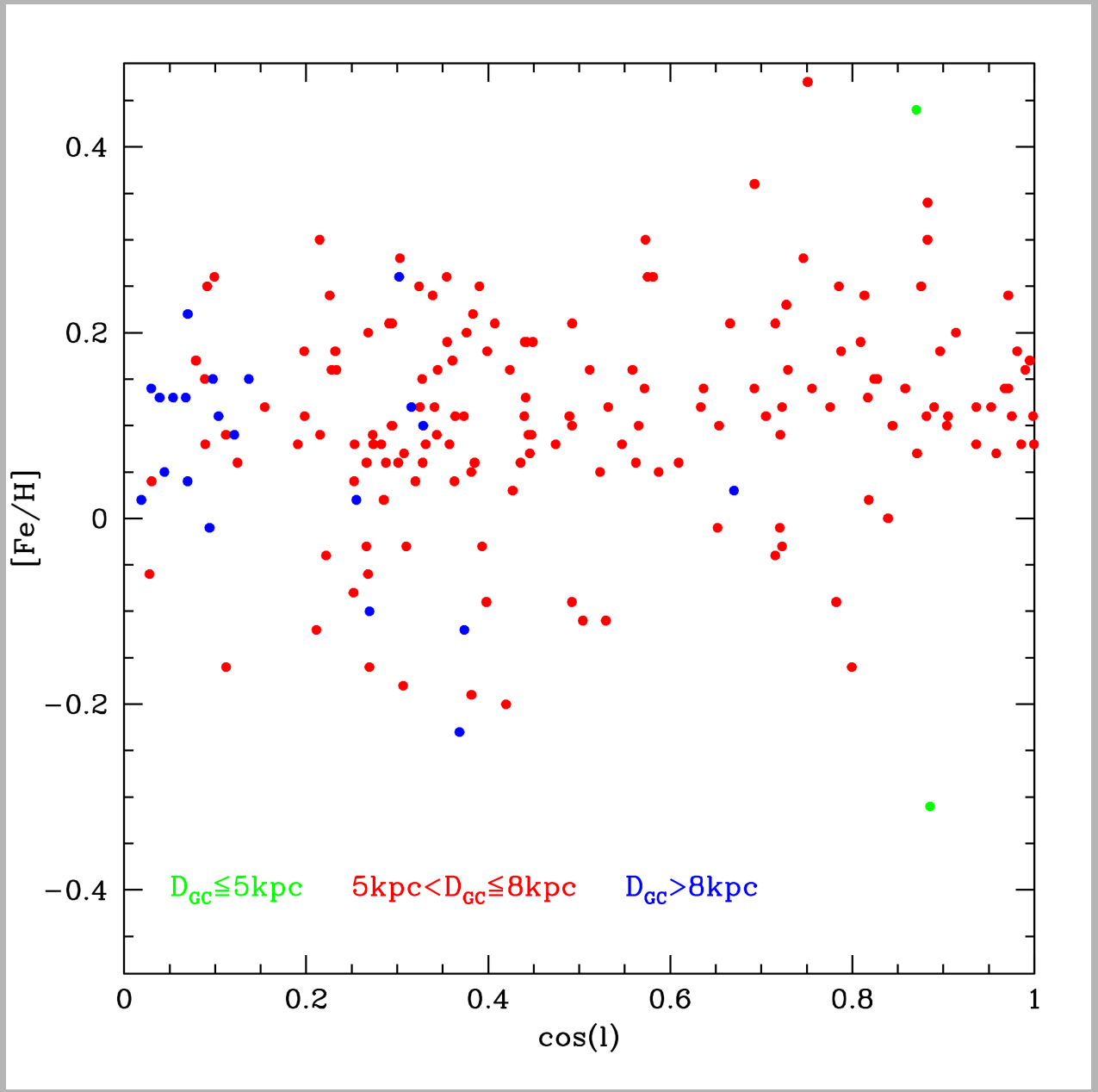


Azimuthl abundance gradient in the barred spiral NGC4736

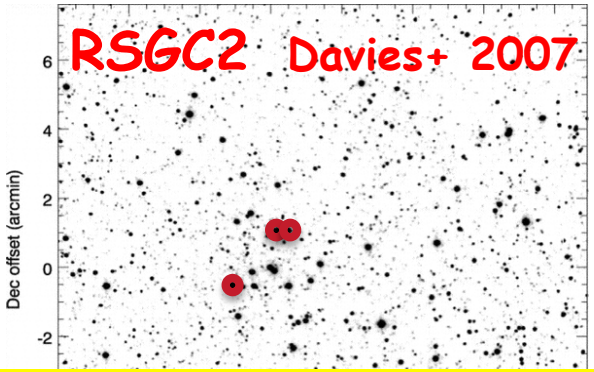
homogeneous abundance determination from nebular lines in the HII regions surroundng the central kpc Davies+ 2009



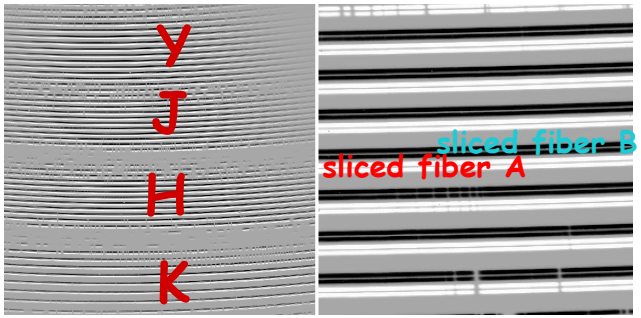
Cepheids


0.4
0.2
0
−0.2
−0.4
[Fe/H]
0
0.2
0.4
0.6
0.8
1
cos(l)
$D_{GC}\leq 5$kpc
$5\text{kpc}<D_{GC}\leq 8$kpc
$D_{GC}>8$kpc

chemical abundances of RSGs in the Scutum young clusters



GIANO-TNG
R~50,000
Origlia+ 2013;2015



from several to a few tens lines per specie

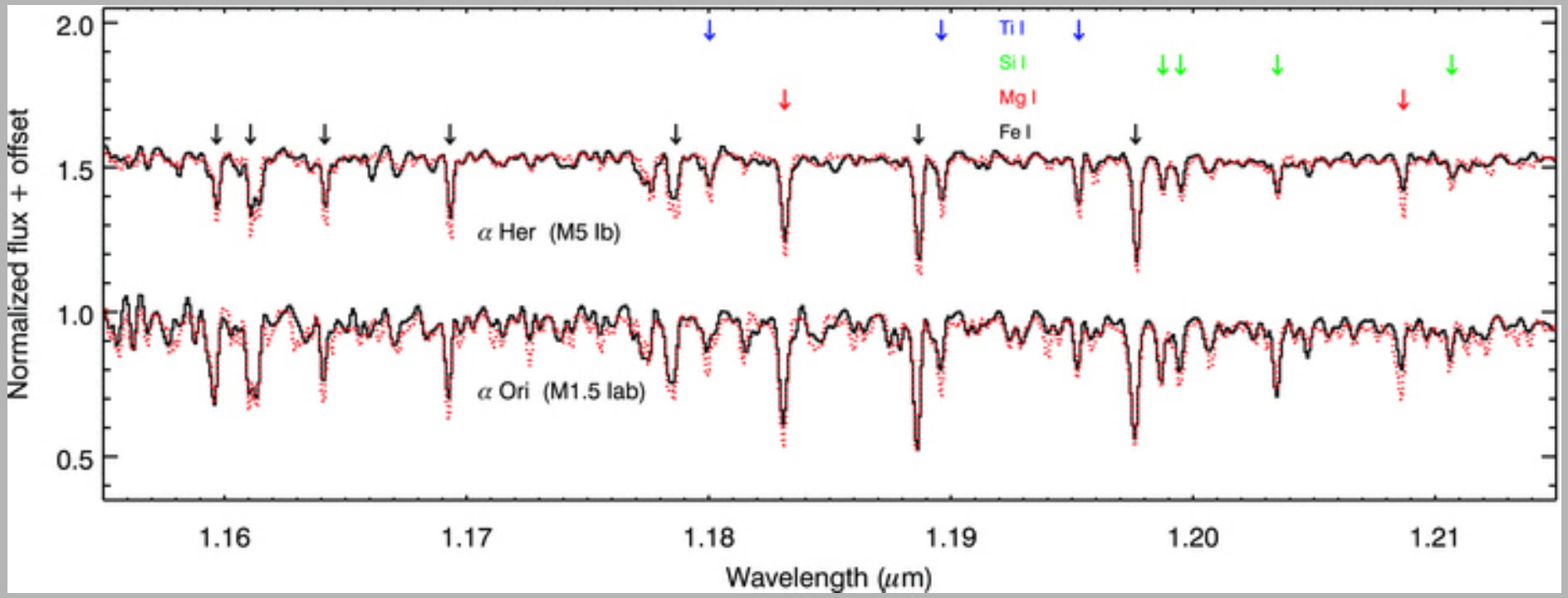
~20 different species: CNO, alpha, some other light, iron-peak, neutron-capture elements

- **[Fe/H] and other iron-peak elements (Cr,Ni,V,Cu) ~ half solar**
- **about solar-scaled α, K, Na, Al, s-process elements (Sr,Y)**
- **some (if any) enhancement of F, Sc**
- **depleted (2-3x) C enhanced (2-3x) N $^{12}C/^{13}C$ ~ 10±1**

homogeneous kinematics and chemistry within the Scutum arm as traced by RSGs in RSGC 1,2,3

RSGs as cosmic abundance probes

low resolution J-band spectroscopy of individual metal-rich RSGs

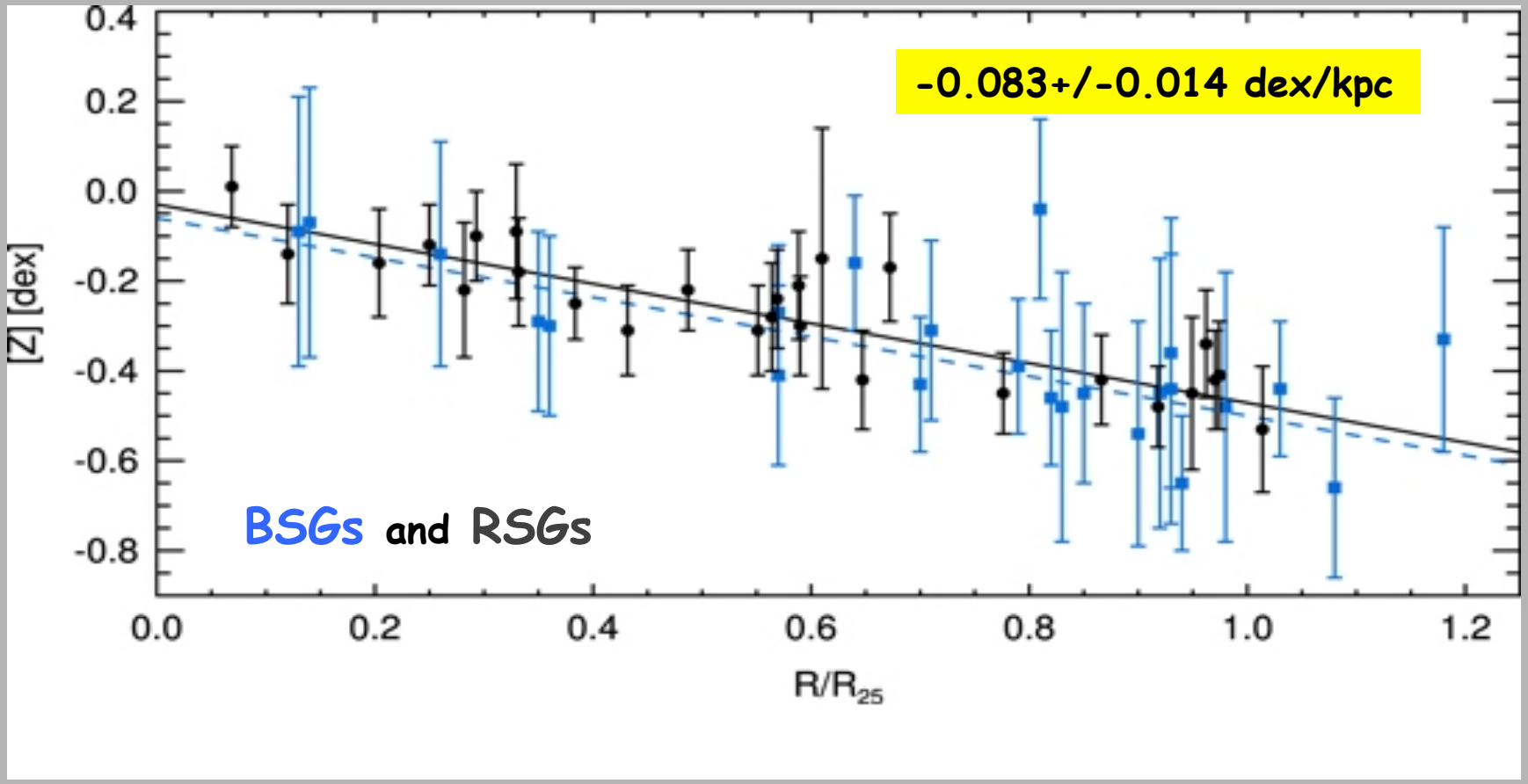


Davies+ 2010, MNRAS 407, 1203; Evans+ 2011, A&A 530, 108

Davies+ 2015: RSGs in the MCs XShooter@VLT

RSGs as cosmic abundance probes

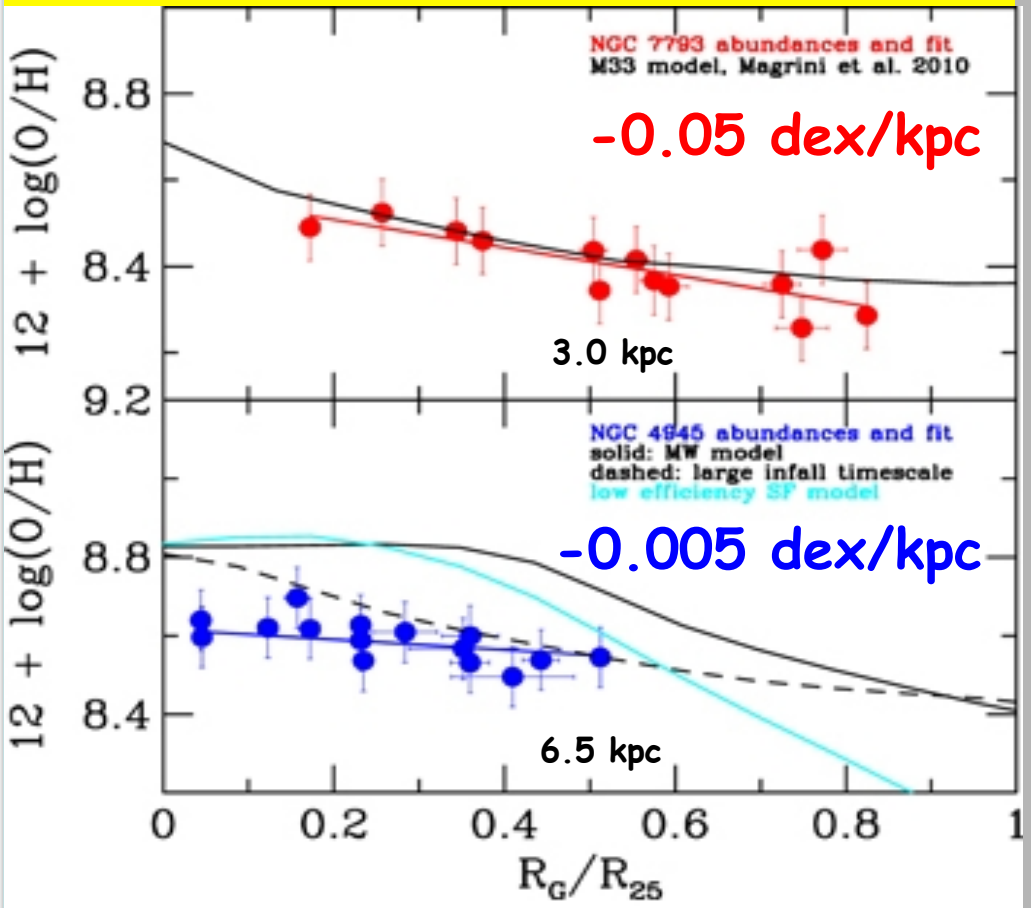
low resolution J-band spectroscopy of individual metal-rich RSGs



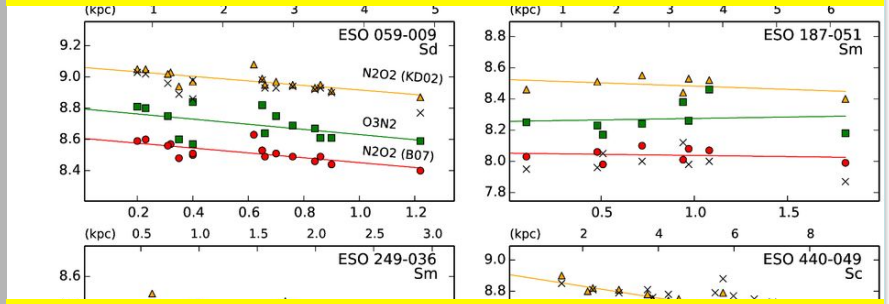
Gazak+ 2015: RSGs in the Sculptor spiral galaxy NGC300 (1.9 Mpc)
KMOS@VLT

metallicity gradient in spirals: nebular abundances

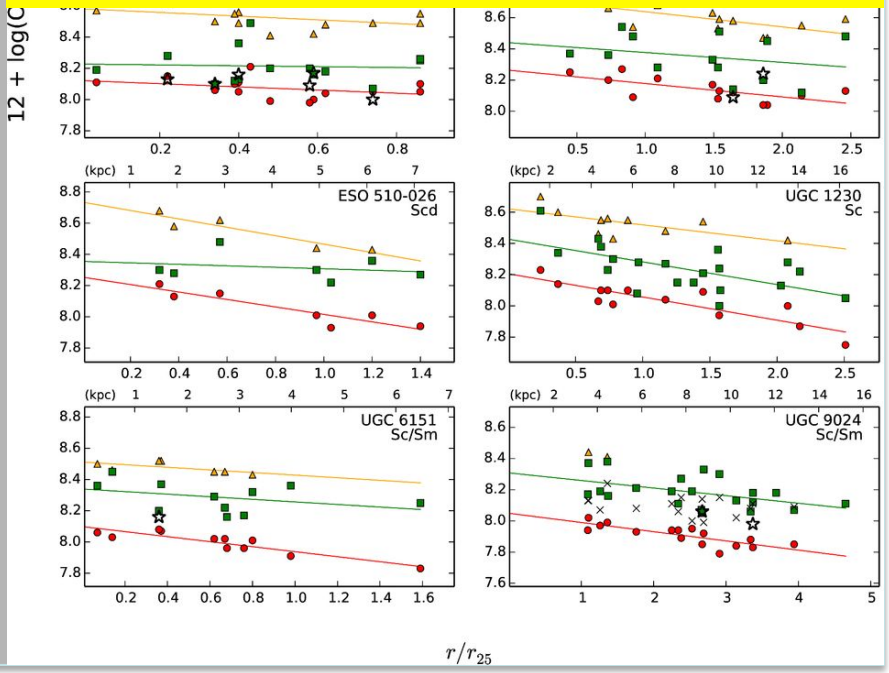
local massive HII galaxies
Stanghellini+ 2015



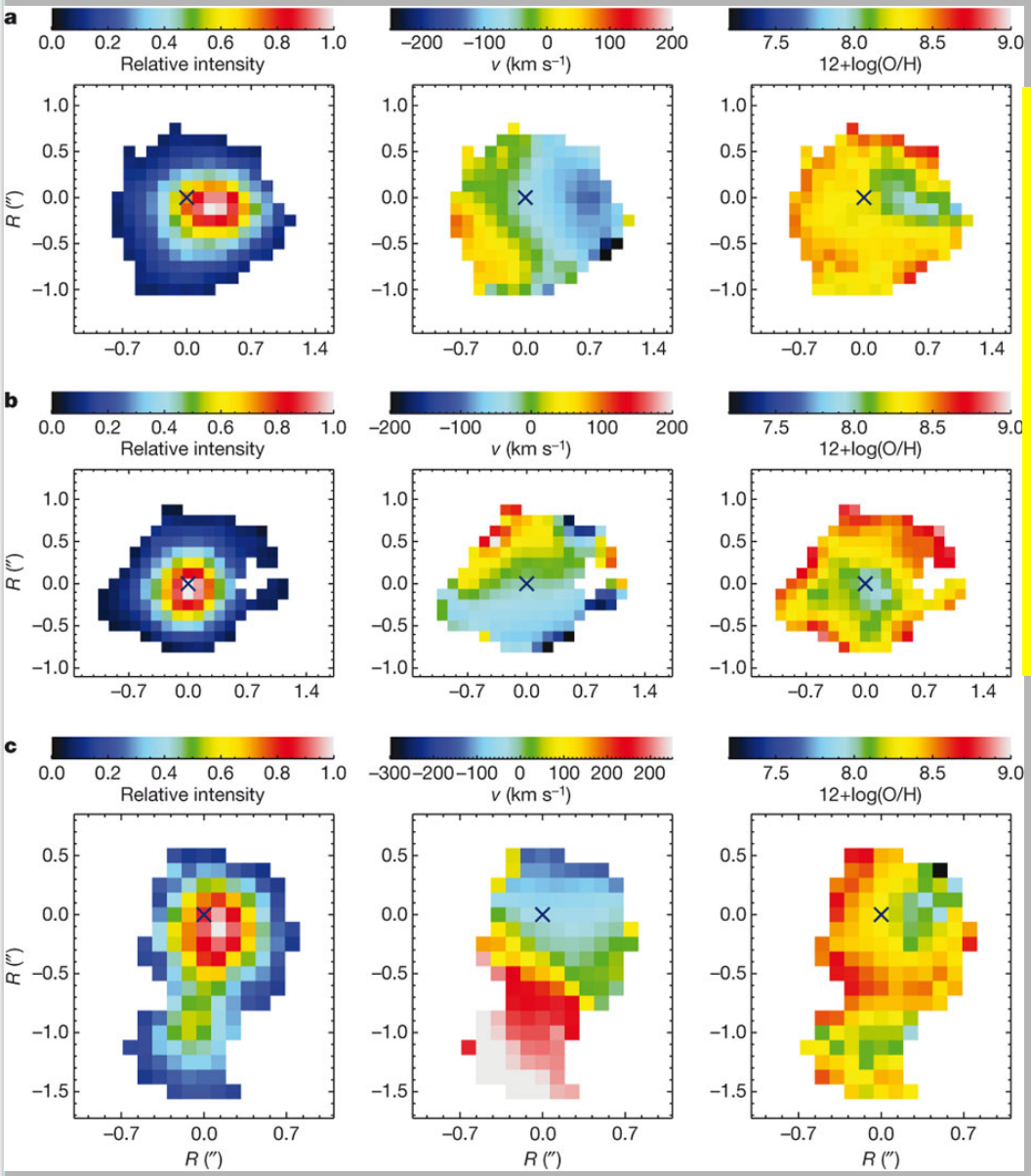
LSB HII galaxies
Bresolin & Kennicutt 2015



average gradient:
-0.033+/-0.016 dex/kpc



metallicity gradient in spirals: nebular abundances



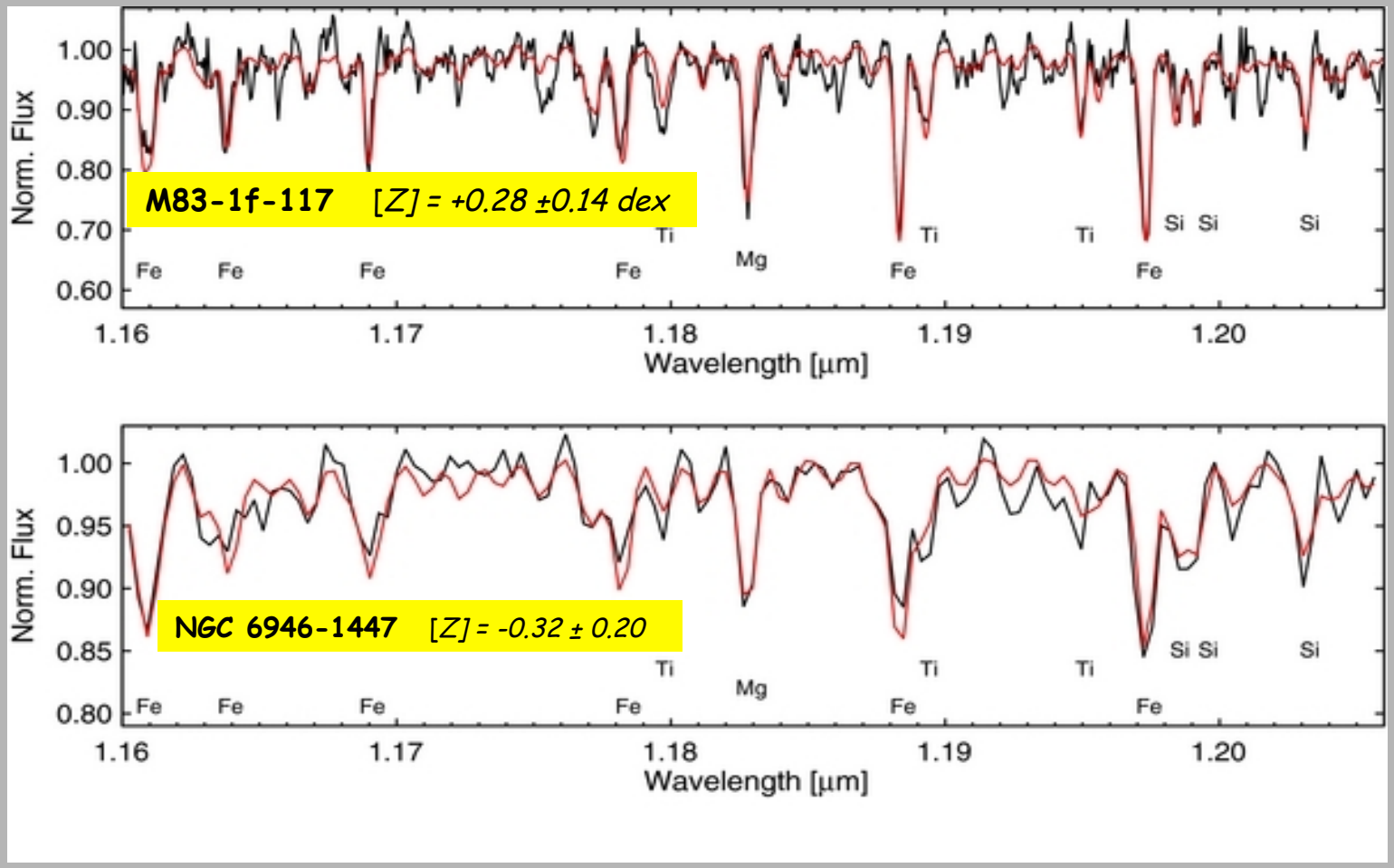
Lyman break galaxies at z~3
Cresci+ 2009

lower (by a few tenths of a dex) met than in the outer regions!

inflow of primordial (low met) halo gas into the center

young SSCs in nearby SB galaxies

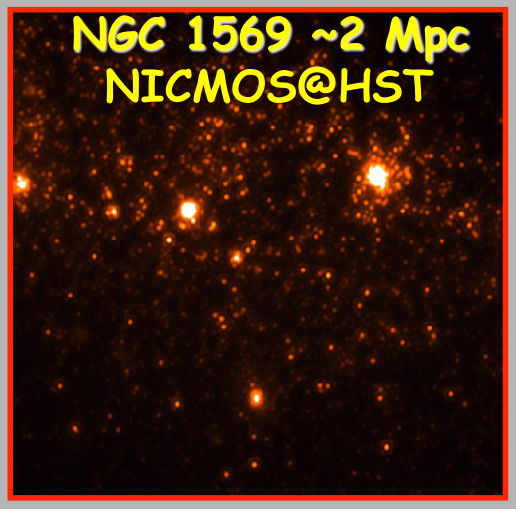
low resolution J-band integrated spectroscopy of RSGs in SCCs

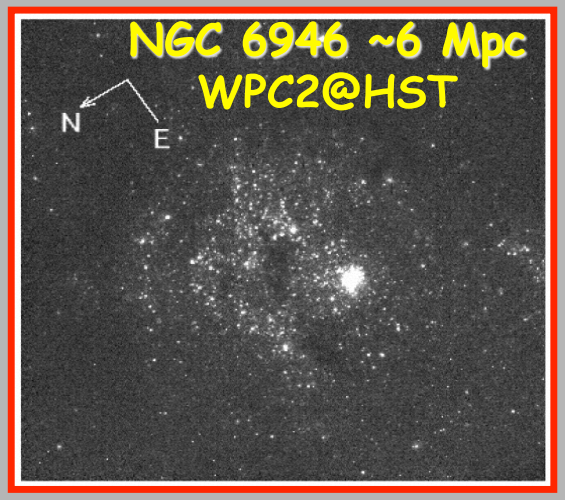


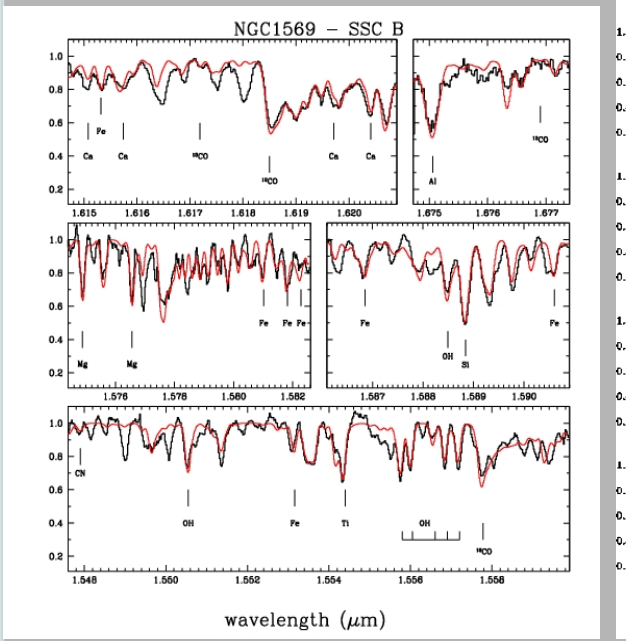
Gazak+ 2015: RSGs in extra-galactic SSCs

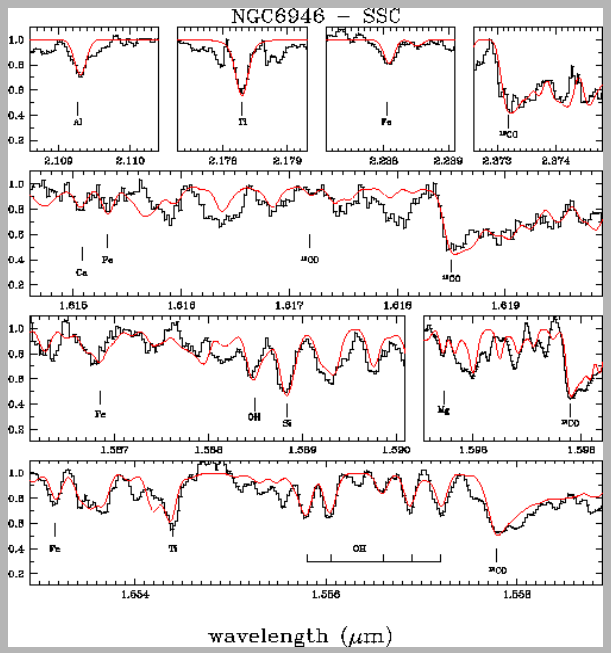
KMOS@VLT; MOSFIRE@Keck

young SSCs in nearby SB galaxies









unique tracers of the stellar metal abundances and IMF in SB galaxies

KeckII-NIRSPEC
R=25,000
integrated light spectra
dominated by RSGs

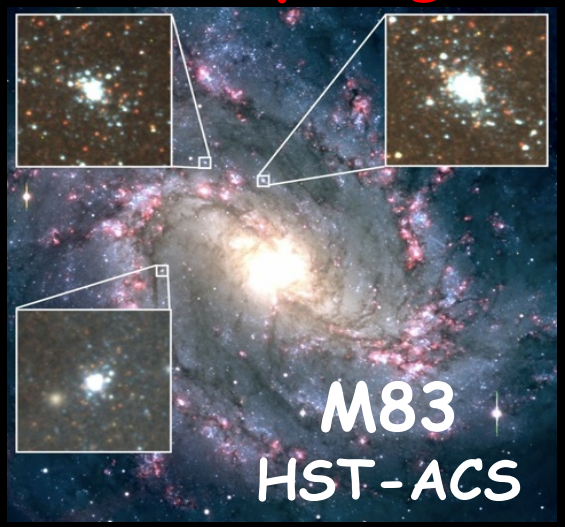
chemical abundances
sub-solar iron
some alpha enhancement
and carbon depletion

dynamical masses
σ~10 km/s, M_{dyn}~5x10^5 M_o

Larsen+ 2006, 2008

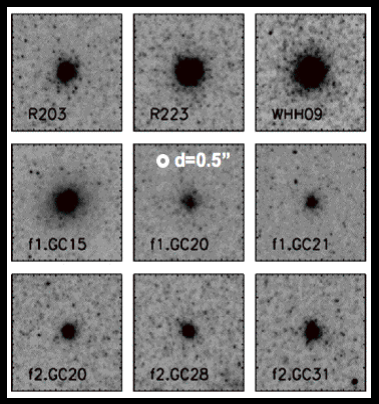
extra-galactic star clusters with ELTs out to ~20 Mpc distances

RSGs in young SSCs

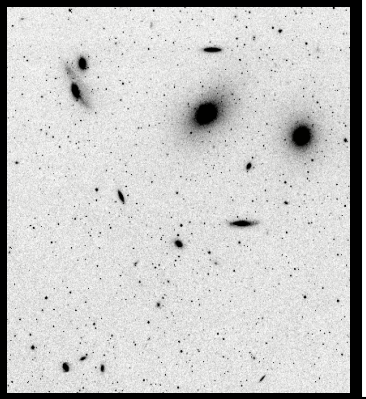


giants in old star clusters & UCDs

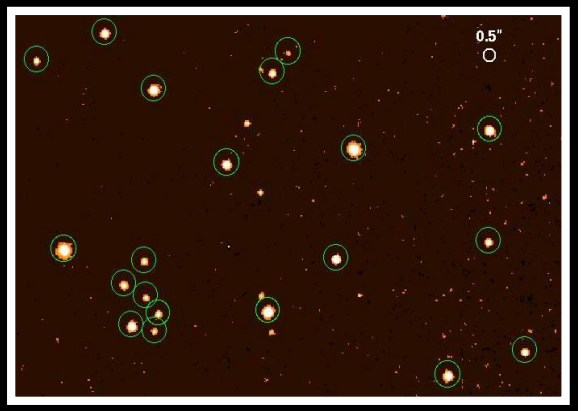
Centaurus



Virgo Cluster



M87



typical extension ➔ from a few hundreds mas to a few arcsec

medium-high (R~20,000+) resolution spectroscopy in integrated light ➔ chemistry and dynamical mass

AO-assisted IFU ➔ velocity dispersion & rotational profiles in the outer regions (in steps of a few core radii) to check for DM halos