Lorenzo Monaco

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lmonaco@eso.org

Education

2001-2004:	PhD @ Bologna University (Italy), supervisors: M. Bellazzini, F.R. Ferraro
2004-2005:	Postdoc @ Trieste Observatory (Italy), supervisor: P. Bonifacio
Since June 2005:	ESO Fellow (Chile)

Research Interests

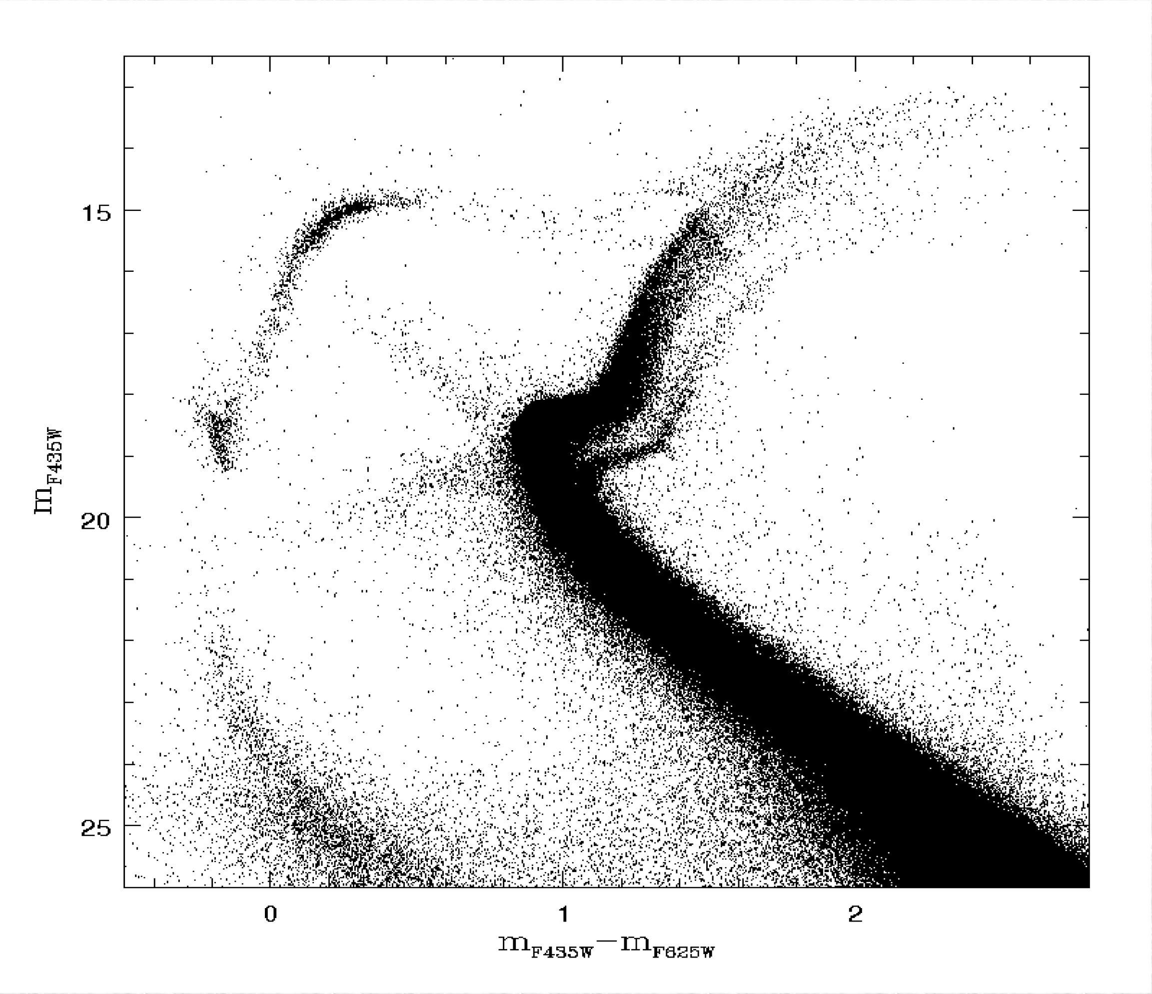
Resolved Stellar Populations:

I. Globular Clusters

II. Local group galaxies

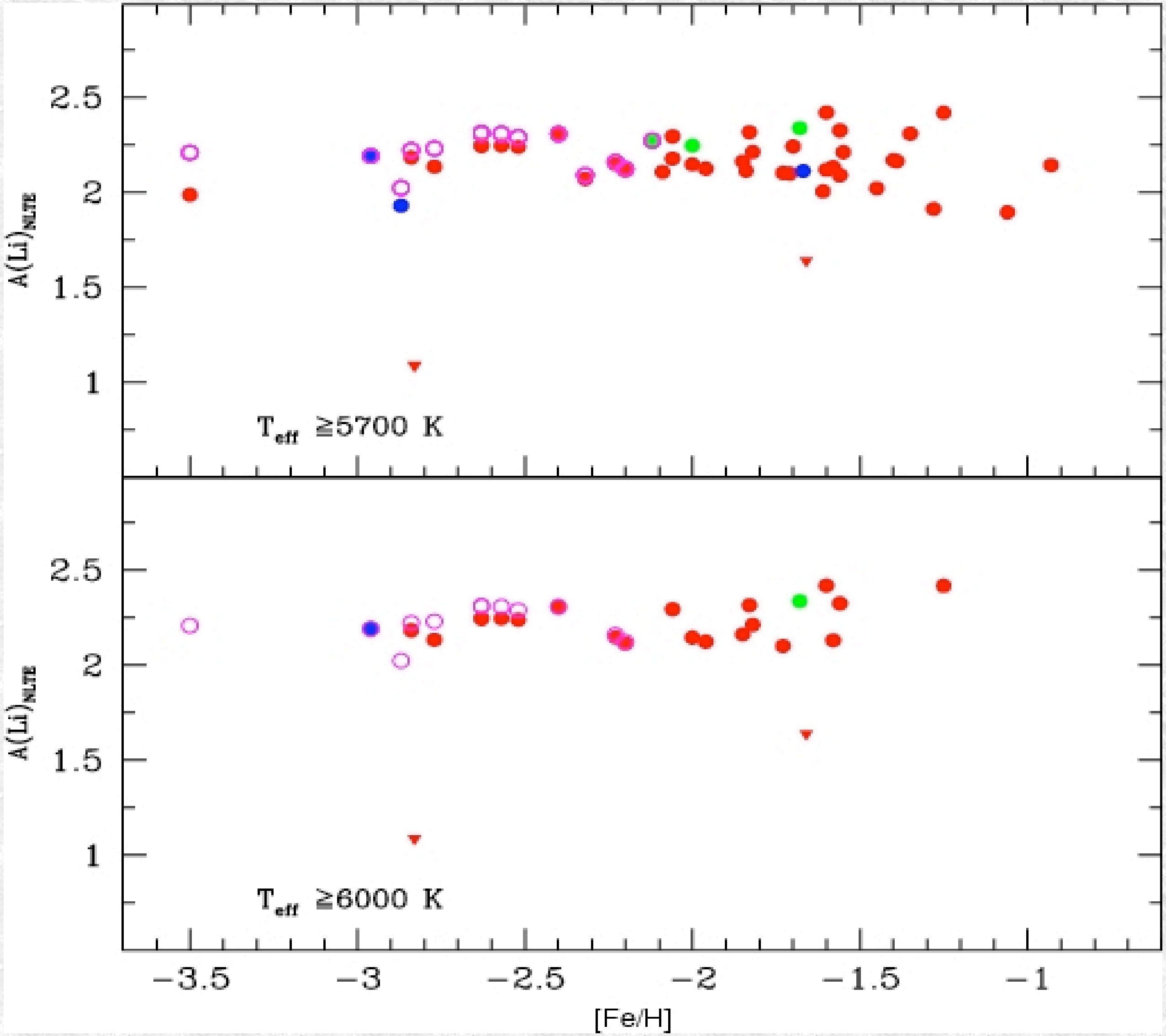
Peculiar Globular Clusters: W Centauri

WCentauri is the most massive GC and is commonly considered as the remnant of an accreted dwarf galaxy



Villanova et al 2007

Peculiar Globular Clusters: W Centauri



Ongoing Project:

The Lithium content of WCentauri

FLAMES@VLT

data obtained for ~100 MS stars.

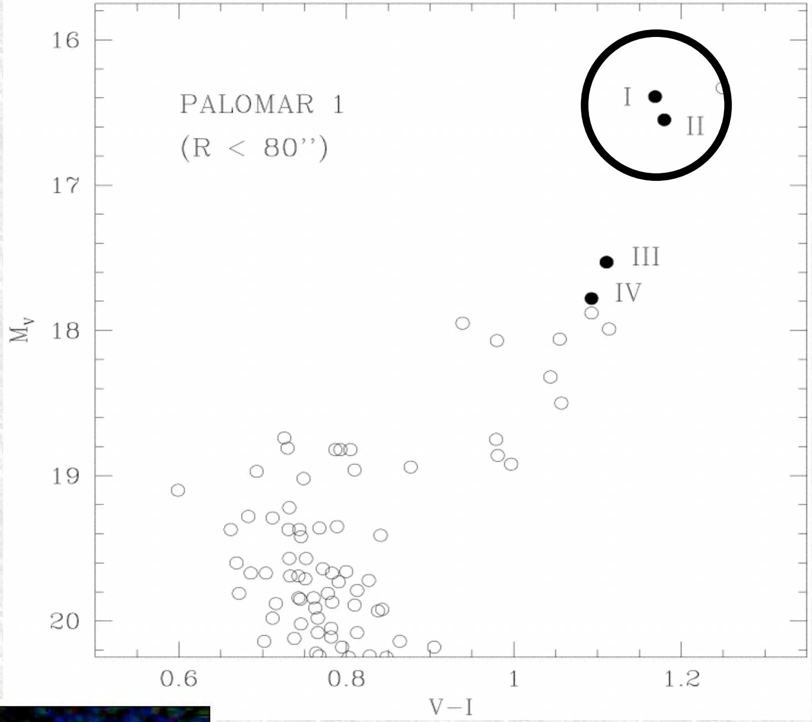
Data under analysis

Charbonnel &Primas2005

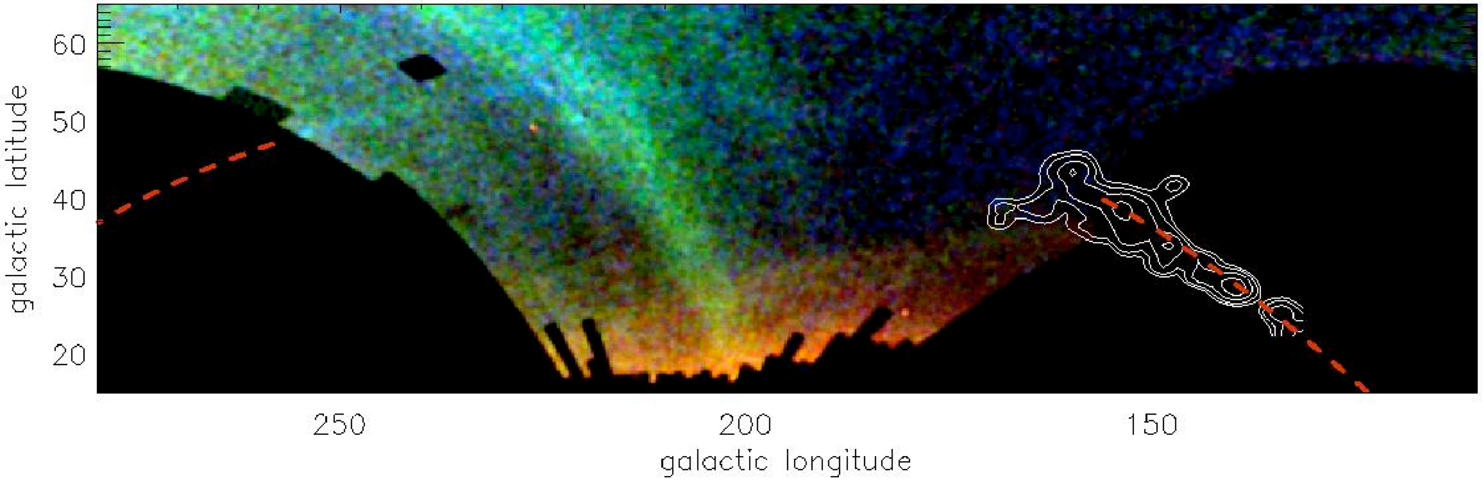
Peculiar Globular Clusters: Pal1

Pal1 is the youngest MW GC

HDS@SUBARU high resolution spectra recently obtained



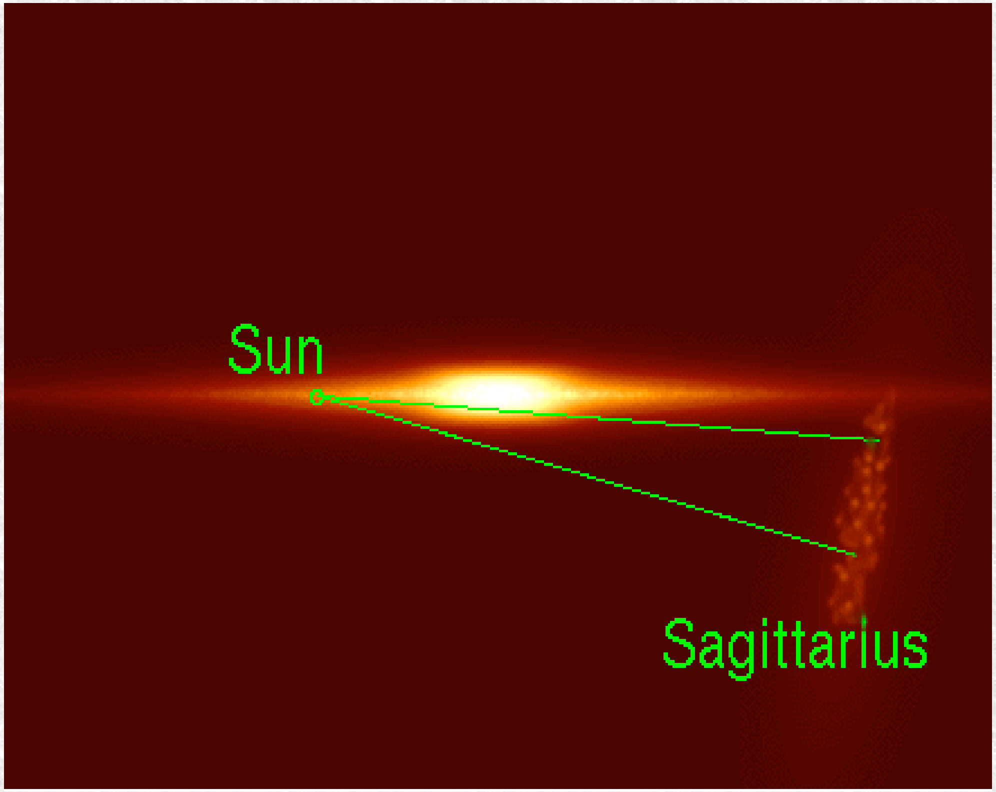
Pal1 lies on the same great circle as the "orphan stream", Rup106 and the Complex A association of high velocity clouds



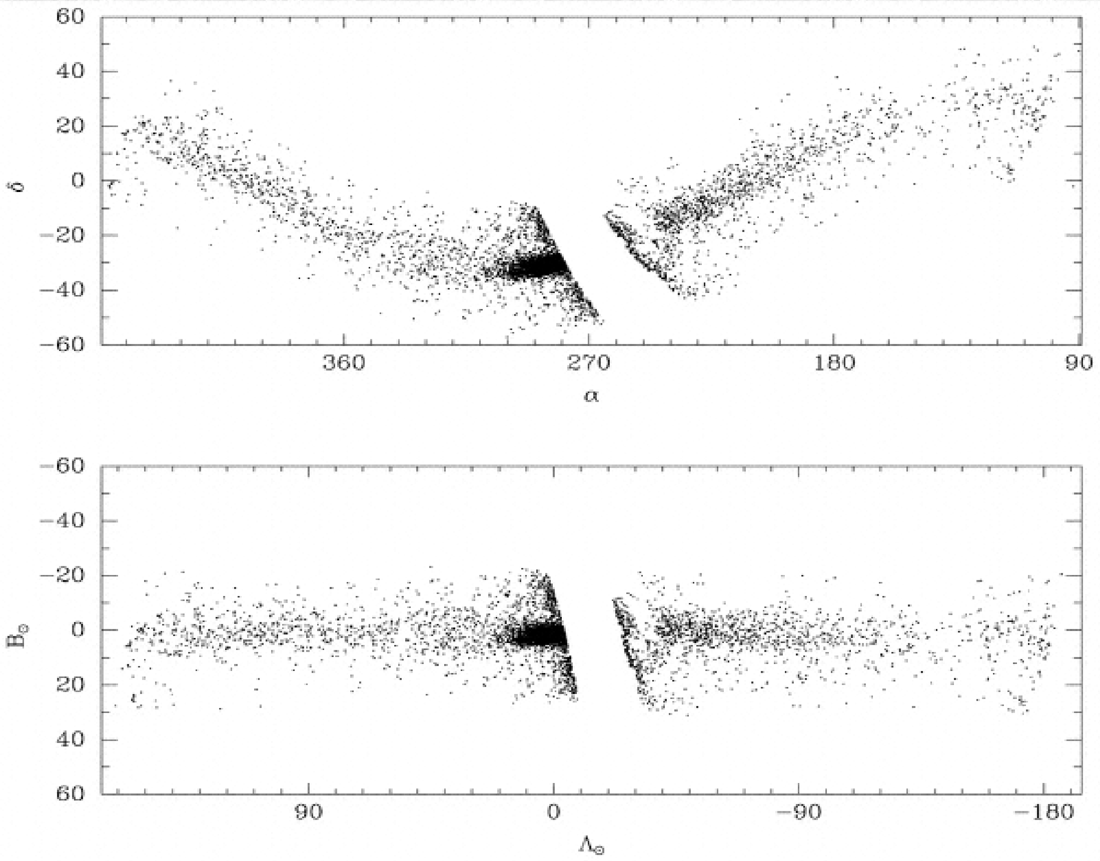
Rosenberg et al. 1998

Belokurov et al. 2007

The Sgr dSph



Sgr is a contributor to the
stellar population of the galactic halo

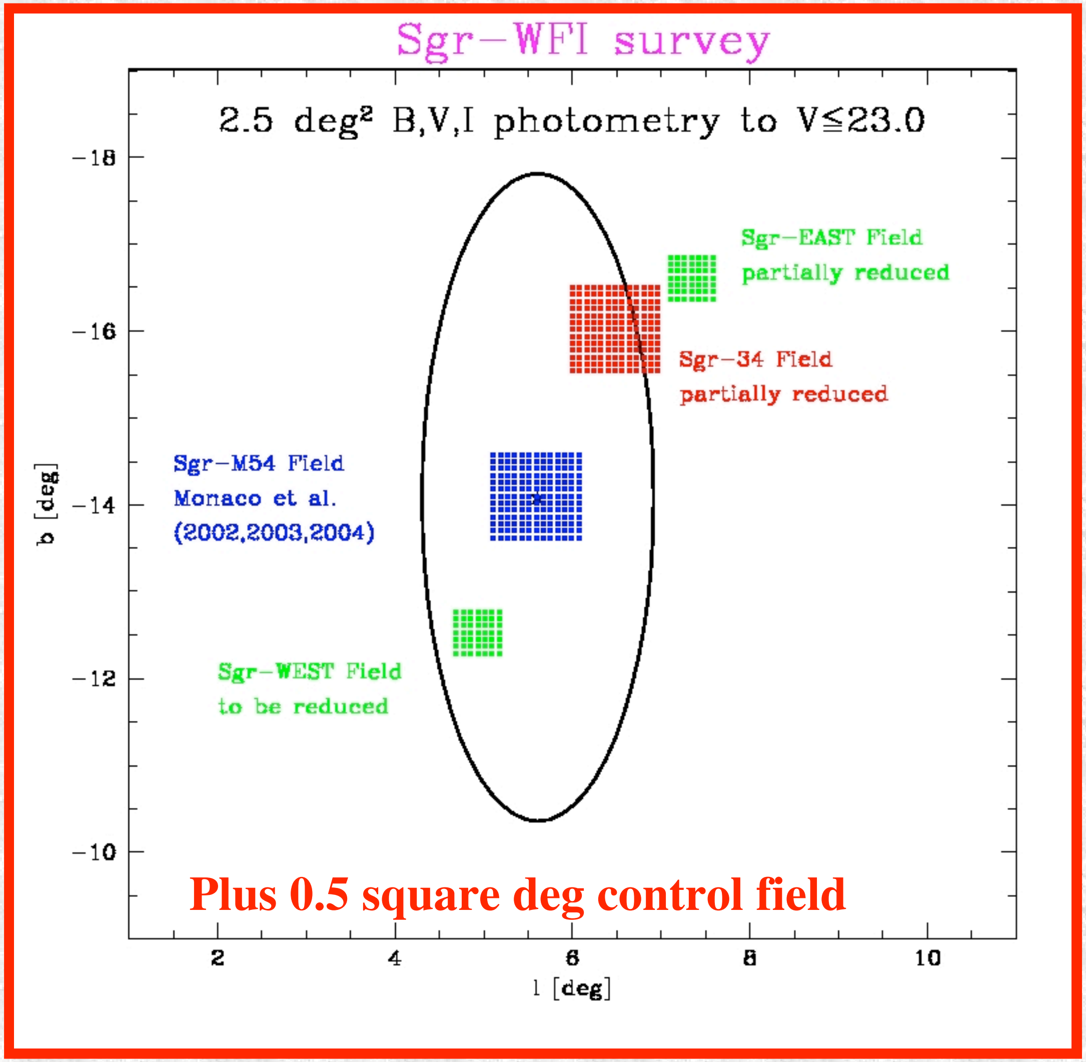


Majewski et al. 2003, using
2MASS data traced
the Sgr streams all over the sky

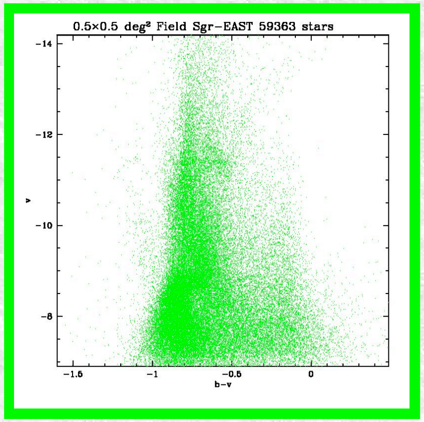
Part I

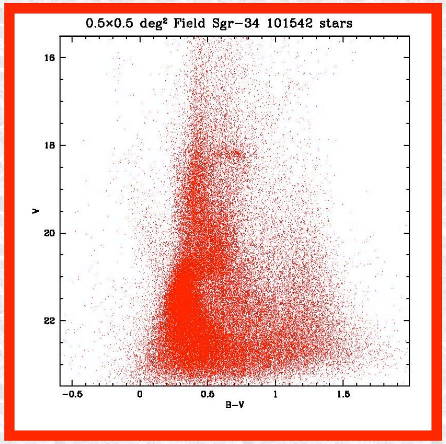
The Sgr Main Body

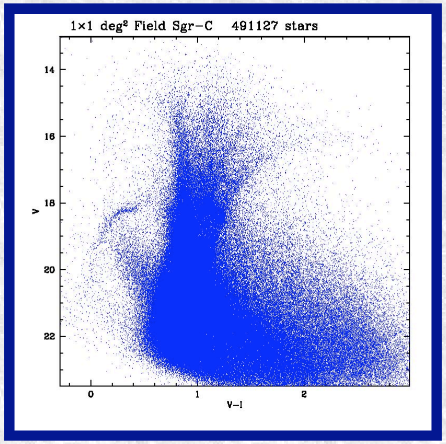
Wide Field Photometry

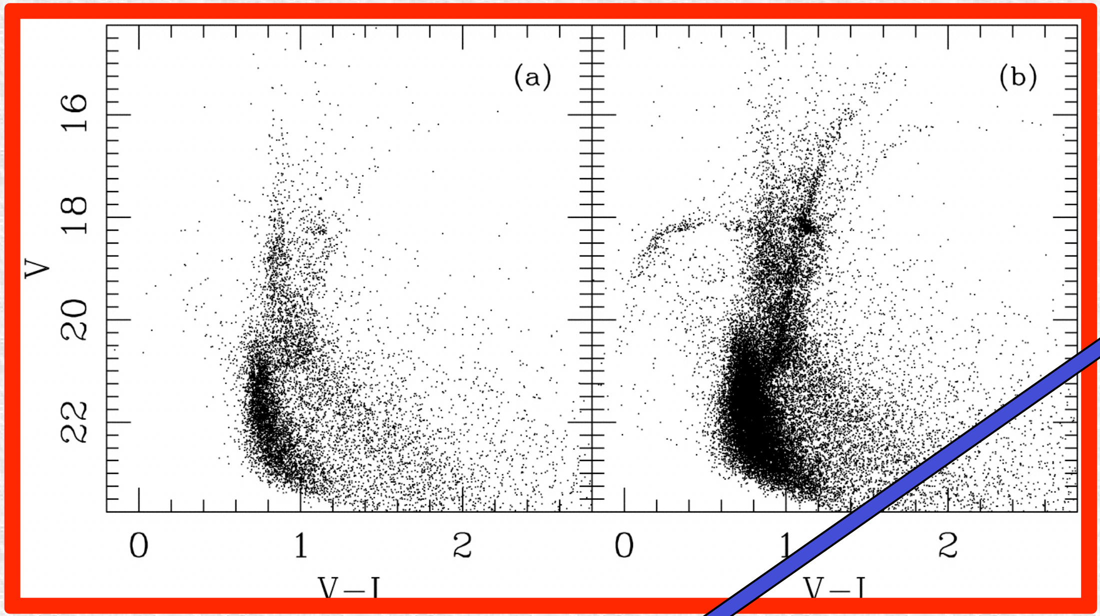


Plus 0.5 square deg control field

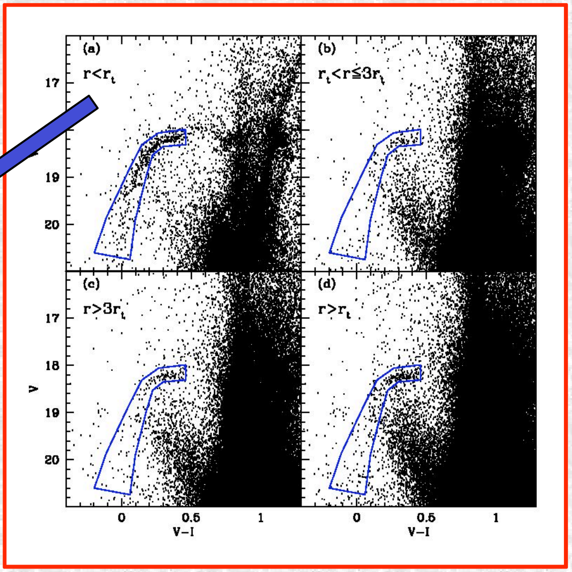


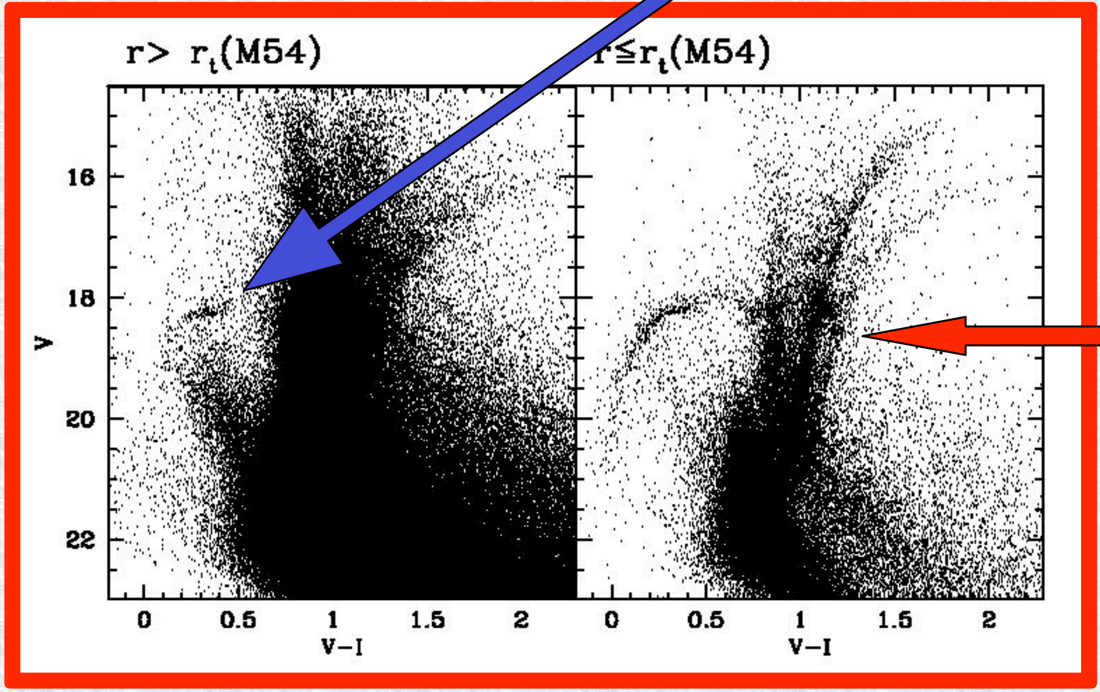




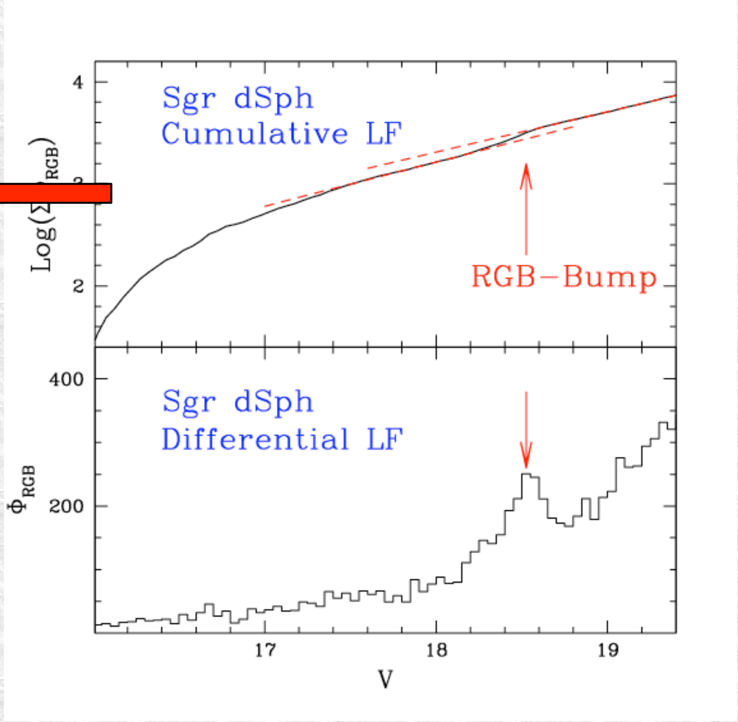


Layden & Sarajedini 2000

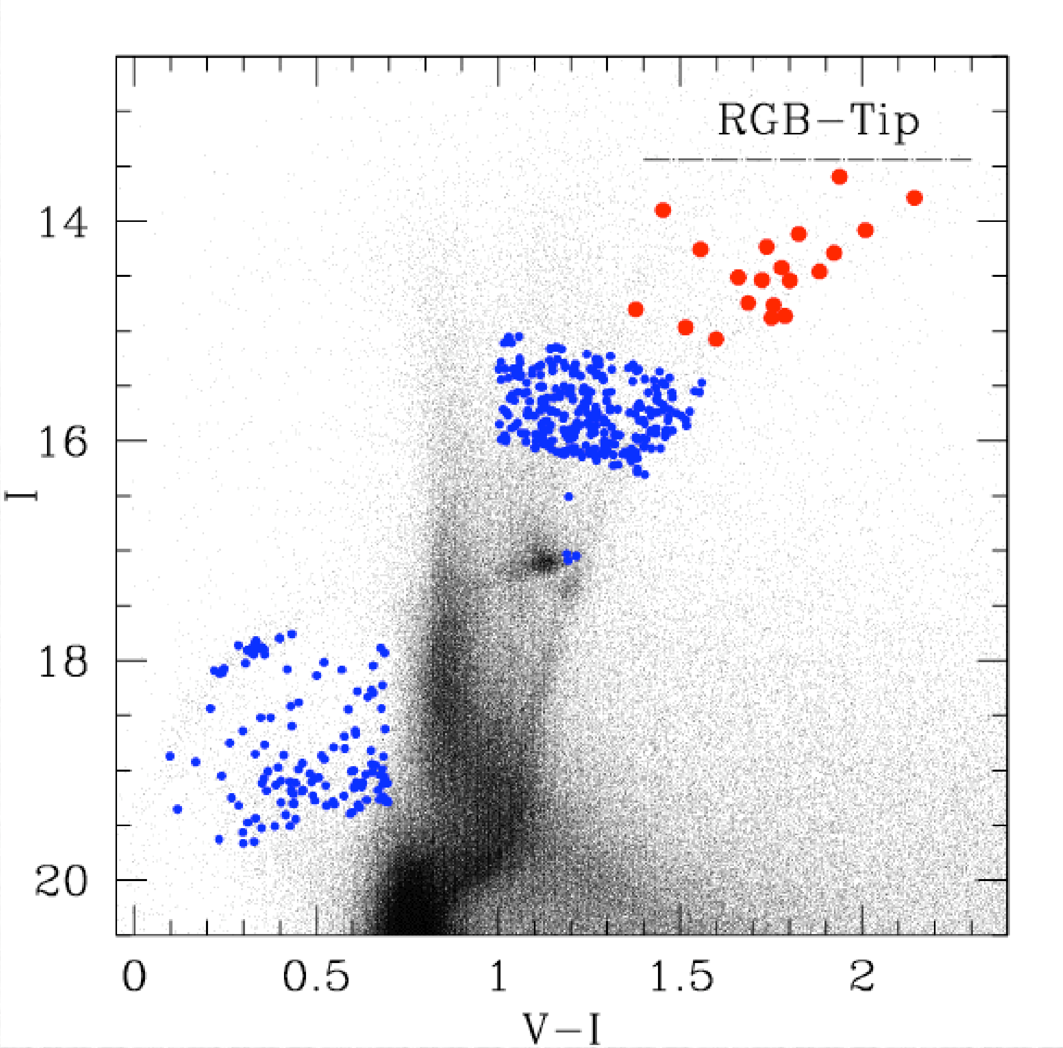




Monaco et al. 2002, 03, 04



The Ital-FLAMES survey of Sgr



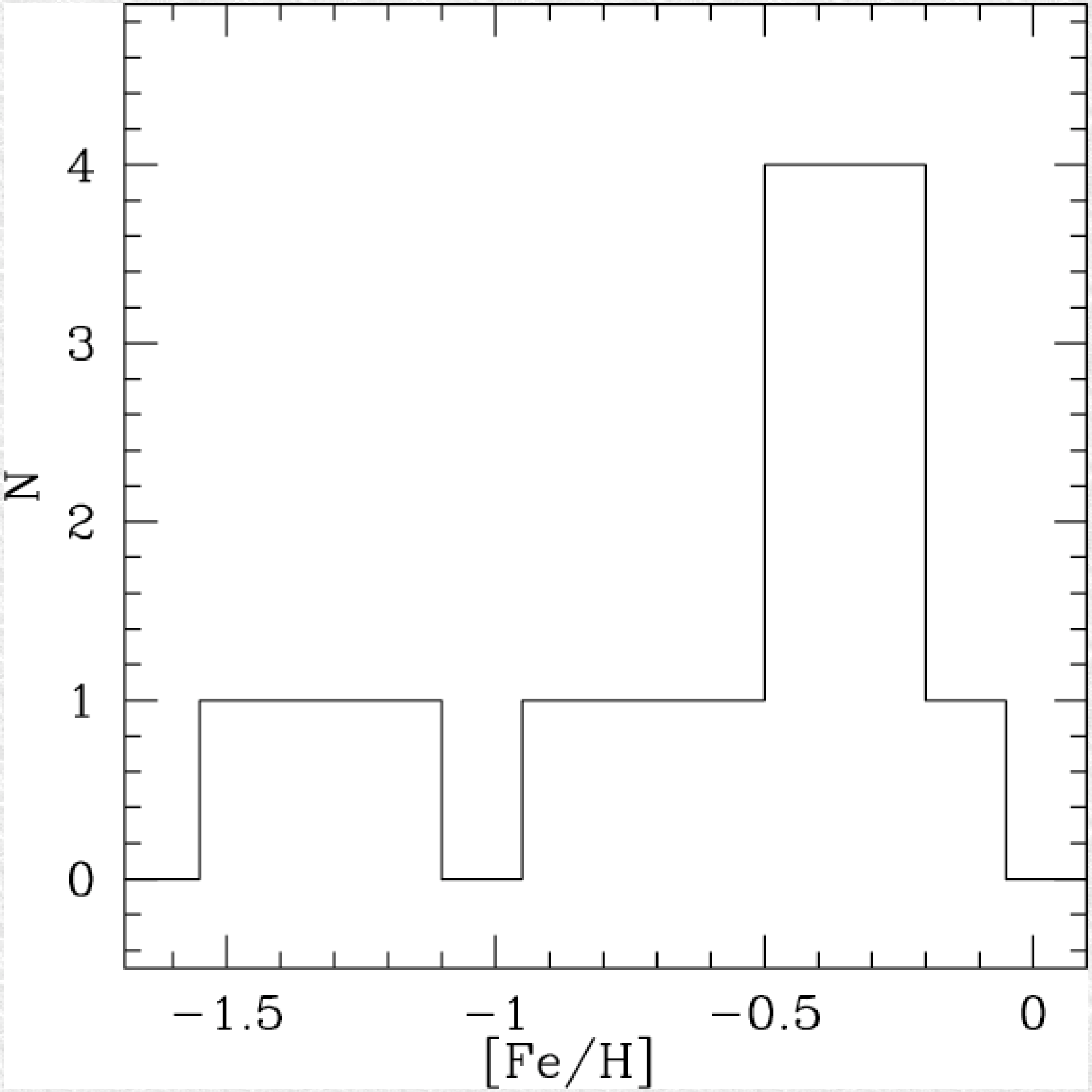
- Part of the Ital-FLAMES consortium (Bologna, Trieste, Palermo and Cagliari Observatories) GTO time was devoted to the study of Sgr
- More than 400 spectra (RGB, BHB, BP) taken

Chemical abundances of Bright RGB stars

Well defined main peak
in the metallicity distribution:

[Fe/H]=-0.41±0.20

Monaco et al. 2005,
A&A, 441, 141

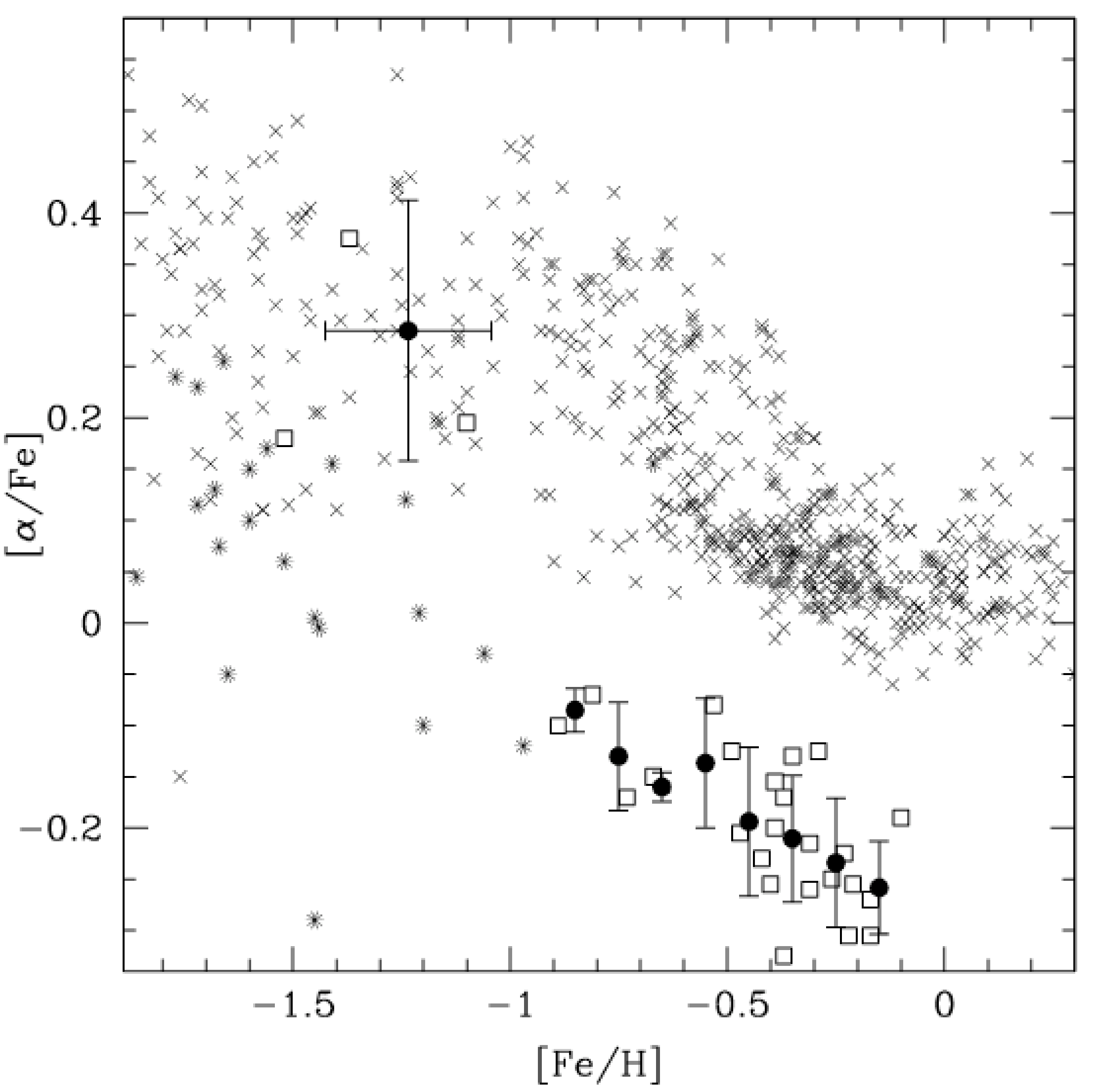


Chemical abundances of Bright RGB stars

Sgr appears to have chemical patterns different from both the MW and other dSphs

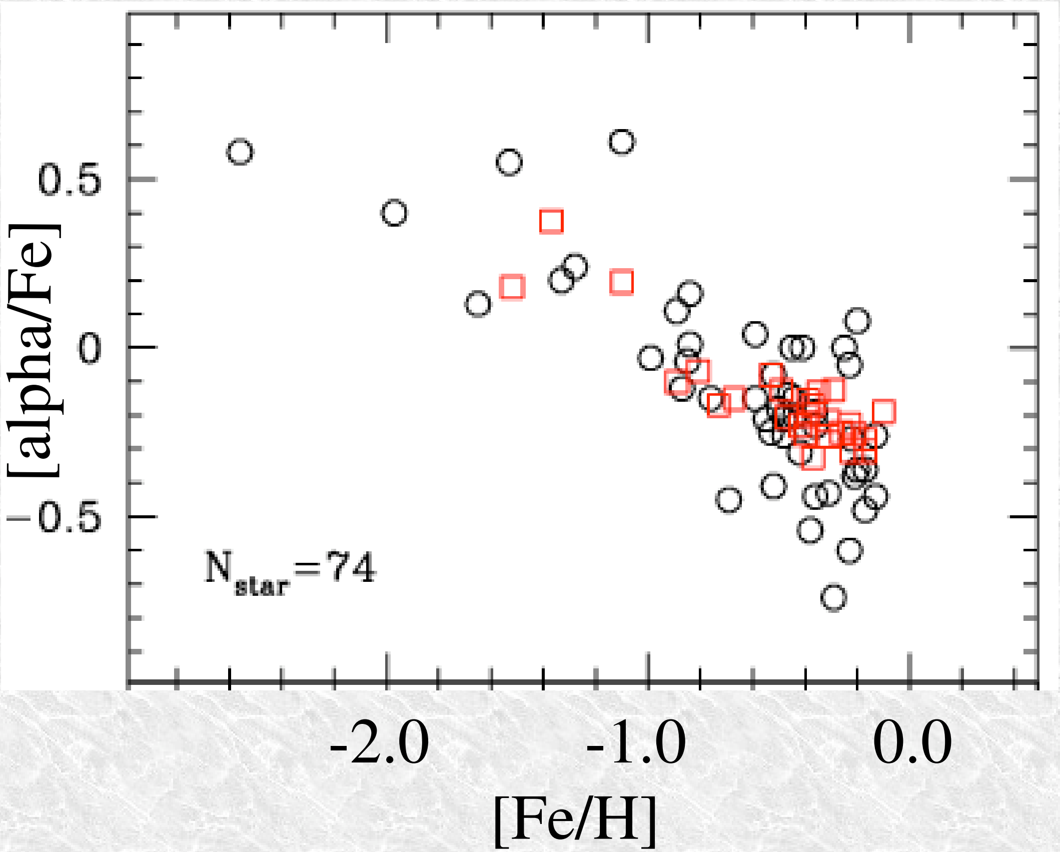
dSph and MW data
from Venn et al. 2004

Monaco et al. 2005, A&A, 441, 141



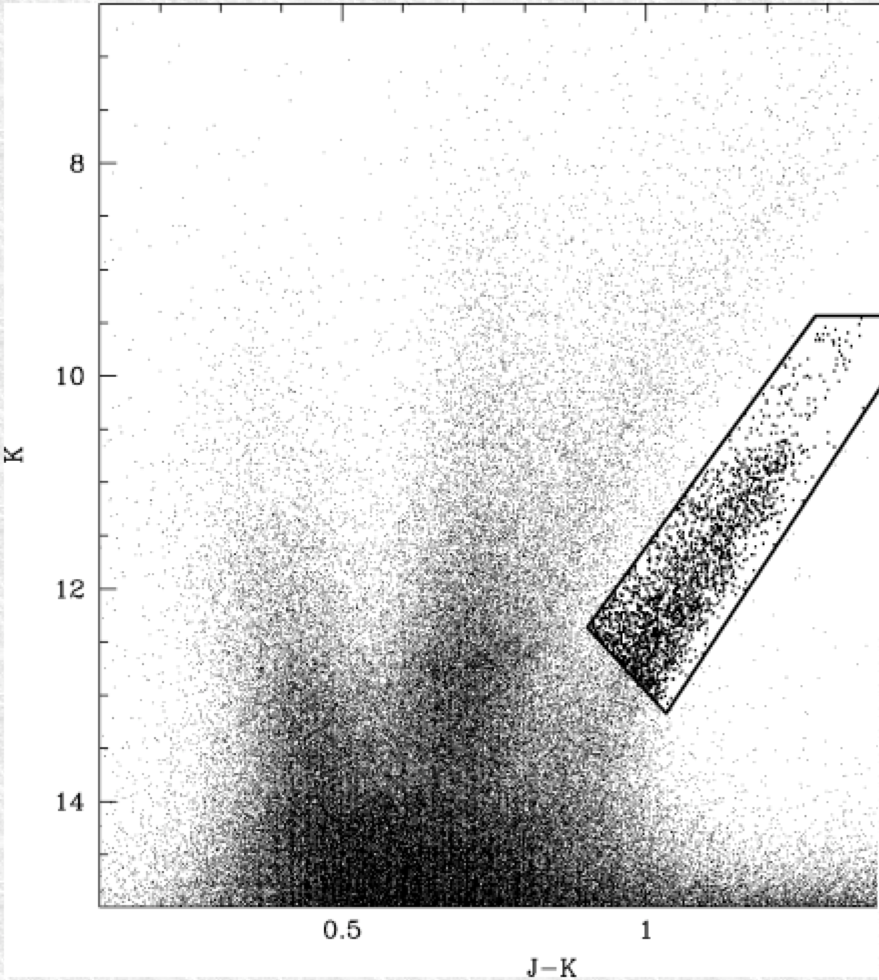
GIRAFFE sample

GIRAFFE data confirms the trend evidenced by the UVES sub-sample

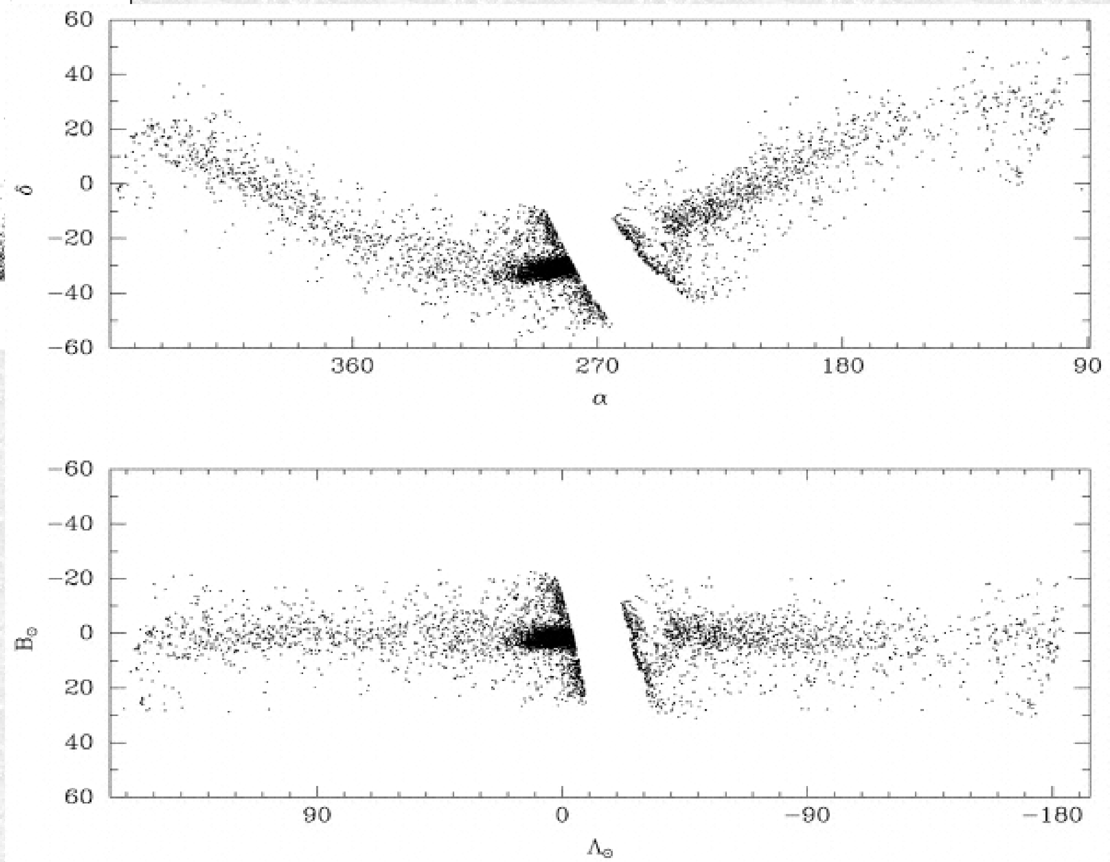


Part II

The Sgr Tidal Streams



The upper Sgr RGB stands out very clearly from the contaminating MW field in the infrared 2MASS CMD



It is possible to define a color-color relation which select 'likely' Sgr member stars

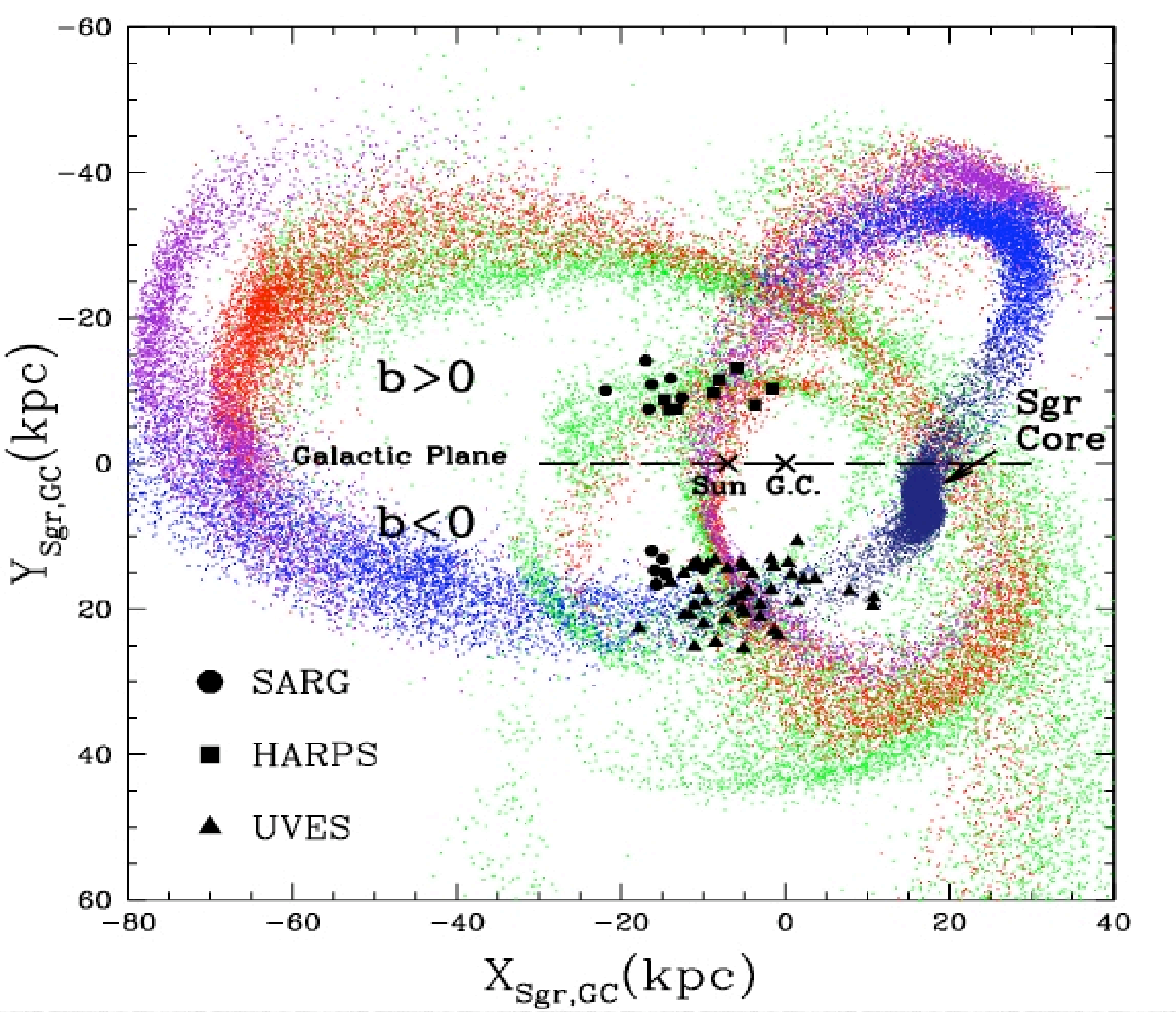
Majewski et al. 2003

Chemical abundances of RGB-stars in the Sgr Stream

67 stars observed with high-resolution spectrographs to date:

SARG sub-sample (12 stars) analysed for chemical abundances

Monaco et al. 2007



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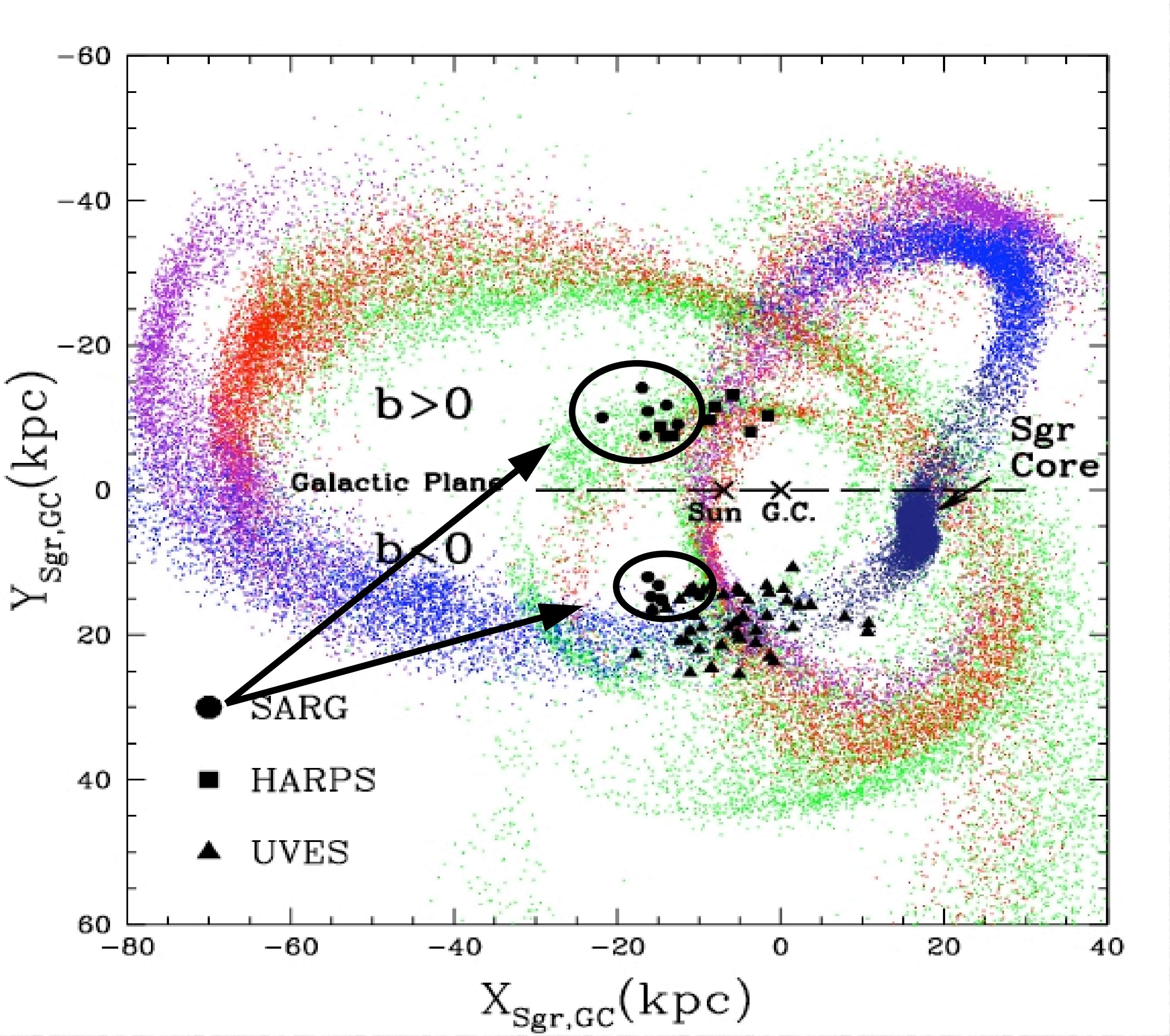
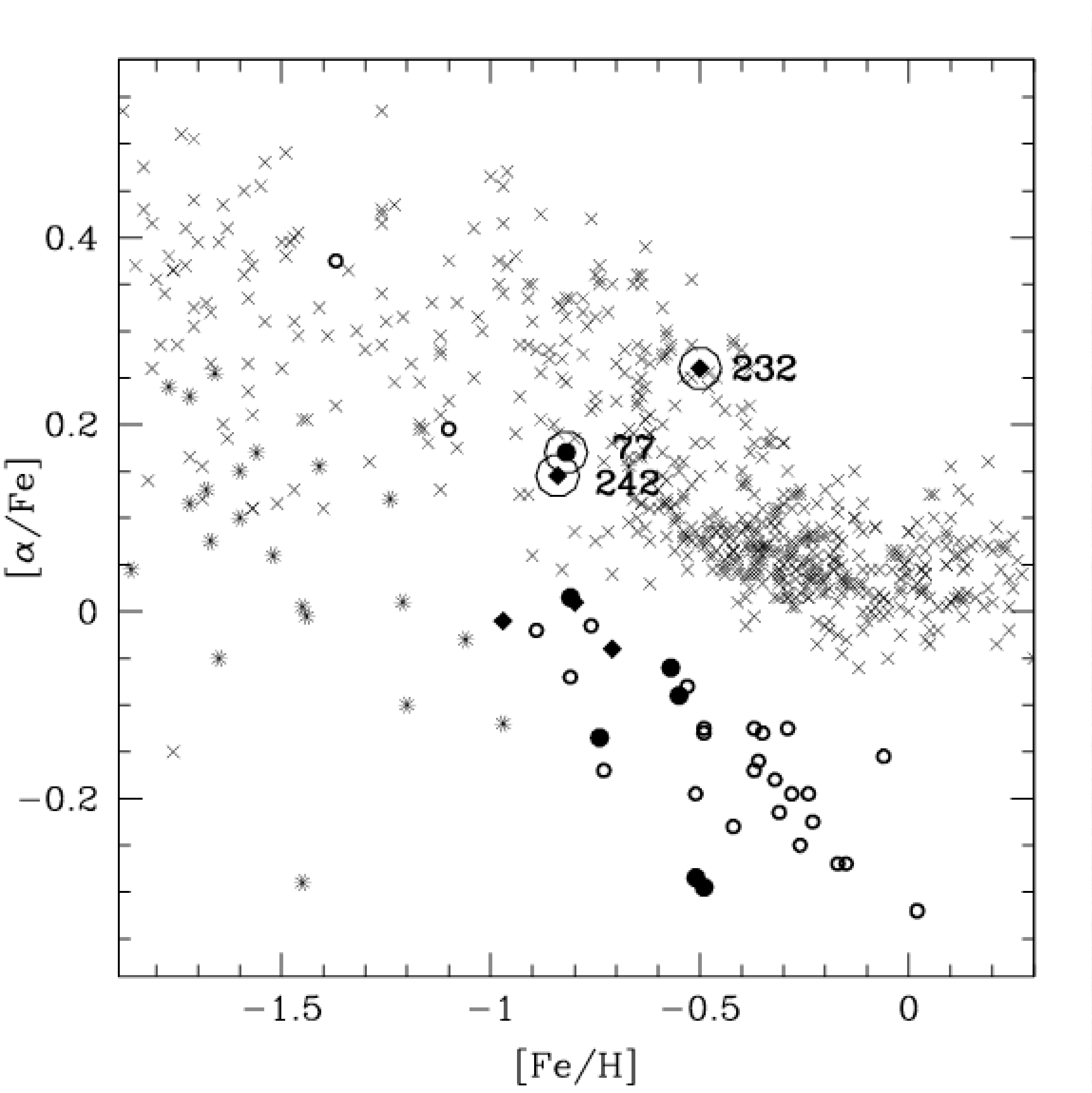


Chemical abundances of RGB-stars in the Sgr Stream

Stream stars follow the same patter as star which are still bound to the Sgr core

Monaco et al. 2007

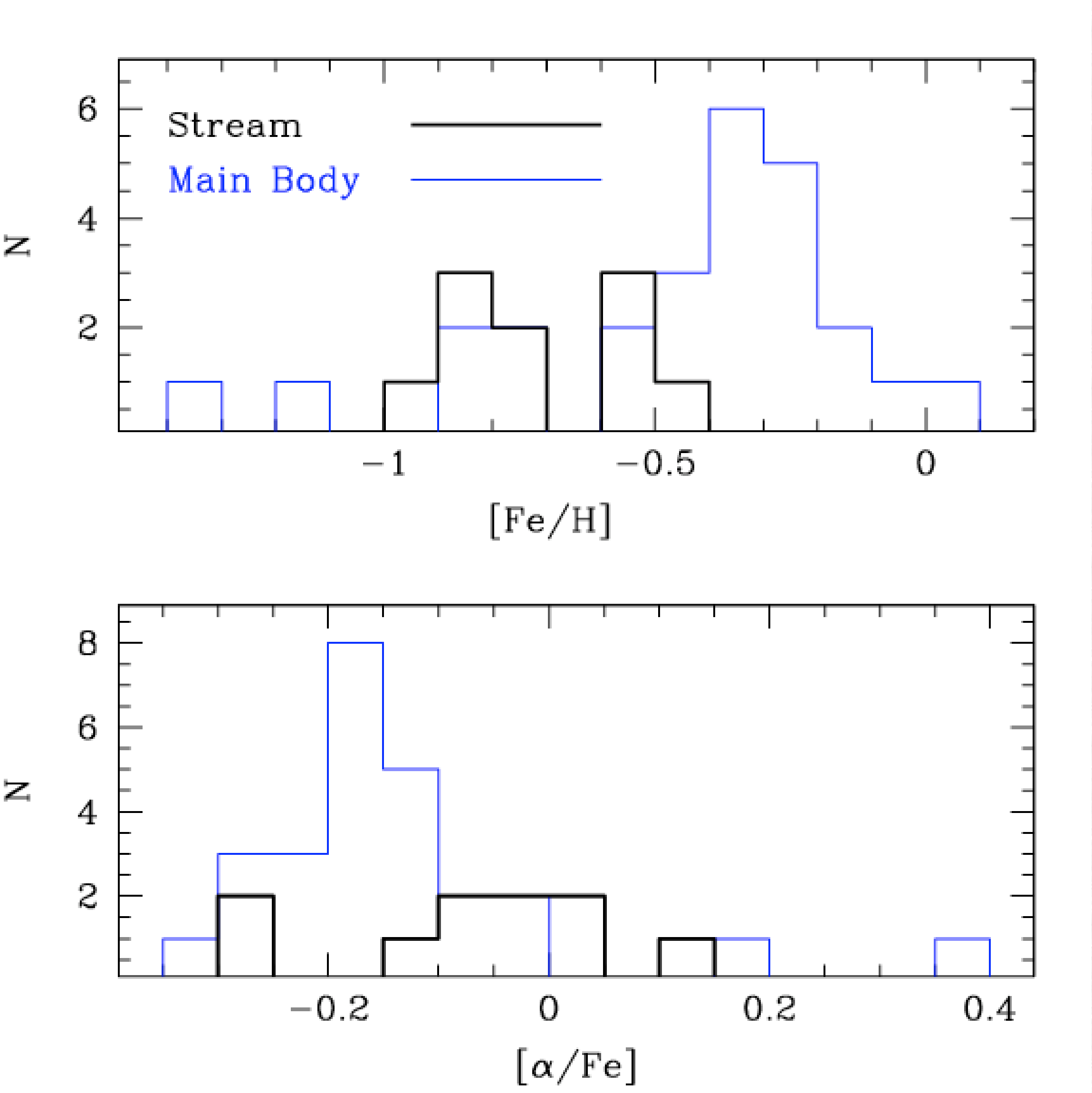


Chemical abundances of RGB-stars in the Sgr Stream

Stream stars are on average slightly more metal poor than main body stars:

[Fe/H]=-0.70±0.16

evidence for a metallicity gradient inside the former Sgr galaxy

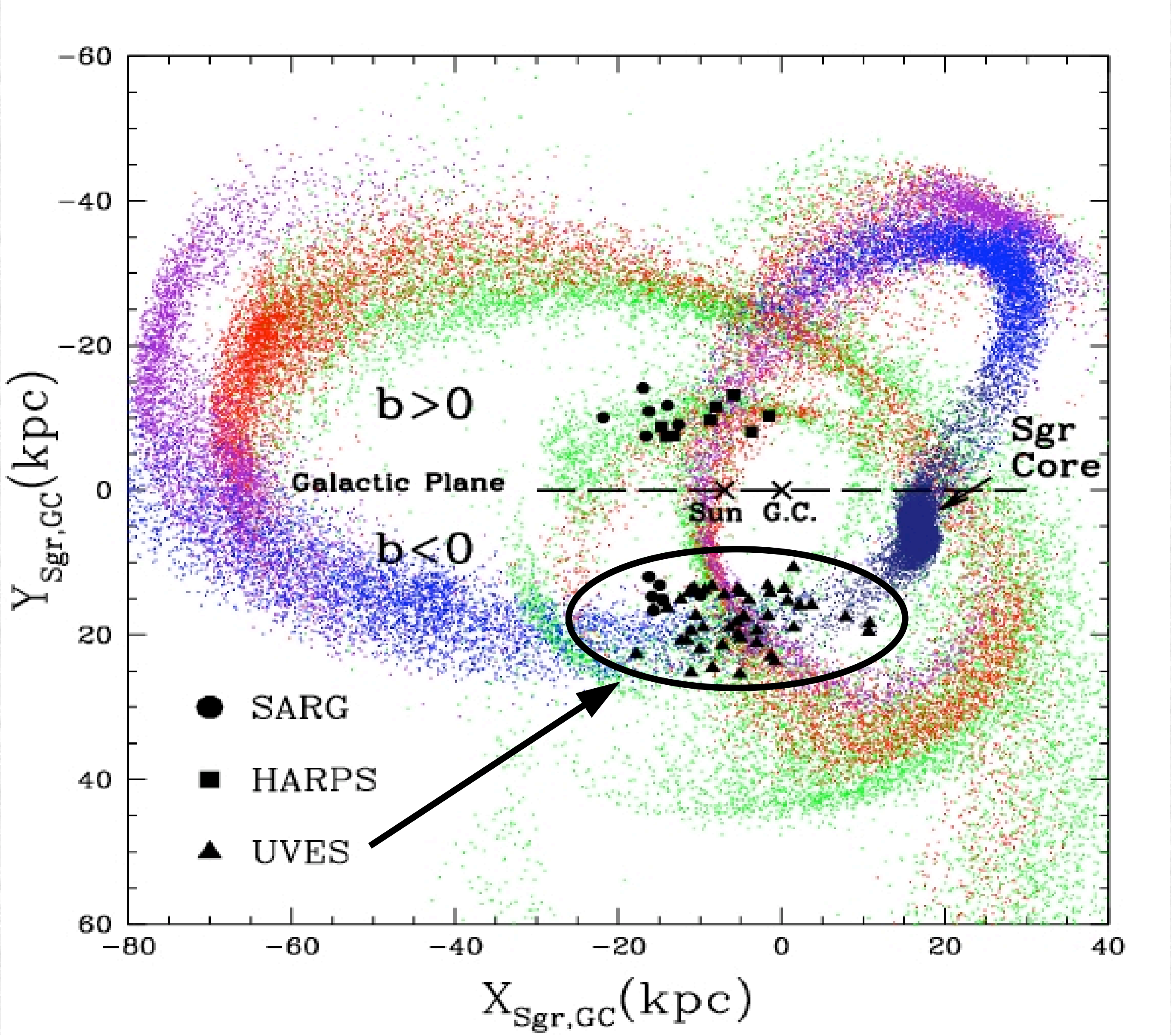


Li-rich Giants in
The Sgr Tidal Streams

Chemical abundances of RGB-stars in the Sgr Stream

46 Stars belonging to the Sgr southern stream observed using UVES@VLT

Monaco et al. 2007

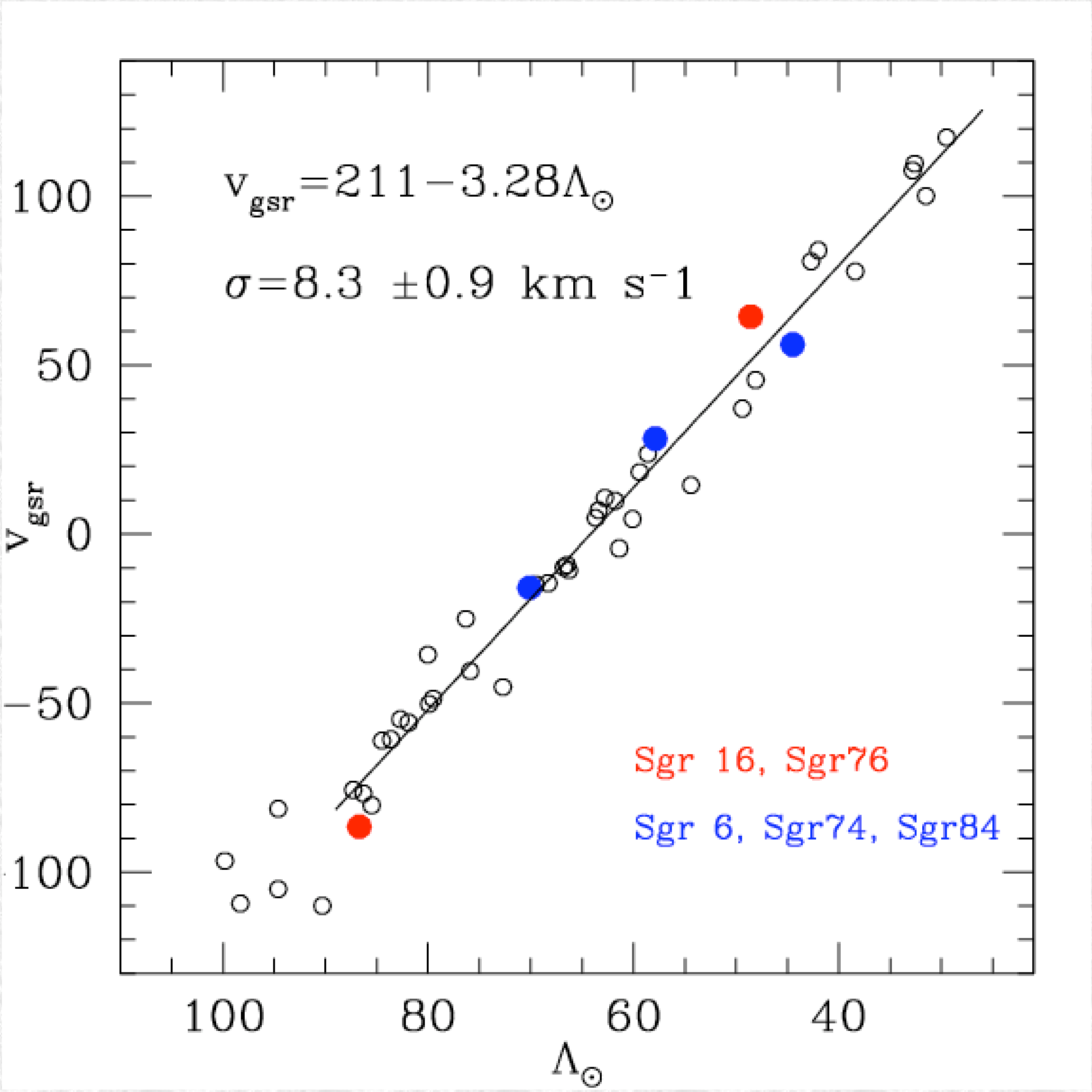


The UVES sub-sample: The Sgr Southern Stream

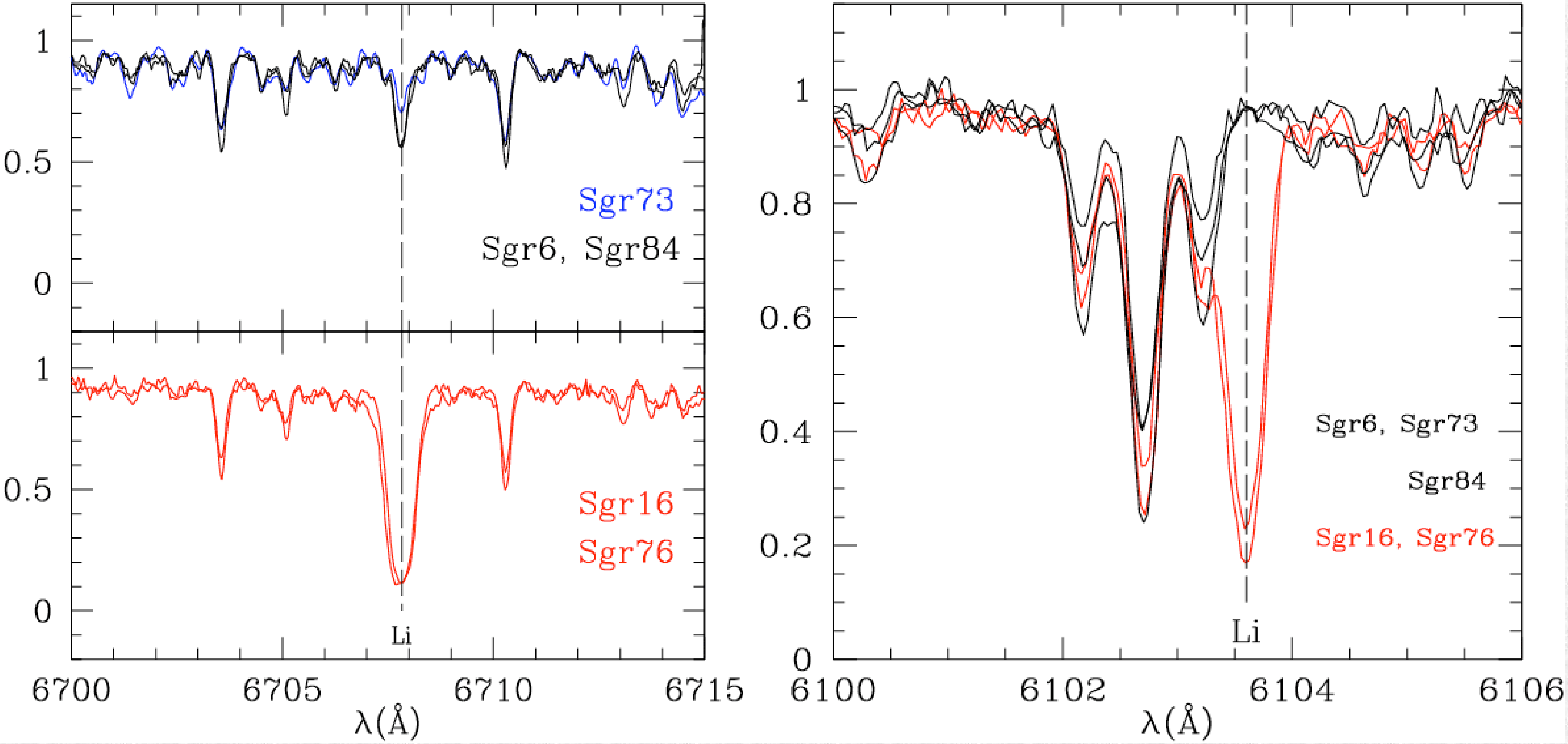
We re-observed a sub-sample (46) of the stars already observed by Majewski et al. 2004

The Stream is a coherent and cold structure (8.3 km/s)

We are confident in the Sgr "origin" of the sample stars



Li absorption lines



Li dilution in Giant Stars

Li is destroyed at T > 2-3 x 10^6 K

RGB dilution: the convective envelope brings to the surface Li-depleted material which is then mixed with unprocessed material. Li is also brought from the surface down to regions where T might exceeds 10^6 K. Li might be also depleted during the pre-MS and MS phases.

Dilution Factor: 1.8-1.5 dex (3-1 M_{SUN})

~1% of giant stars are Li-rich

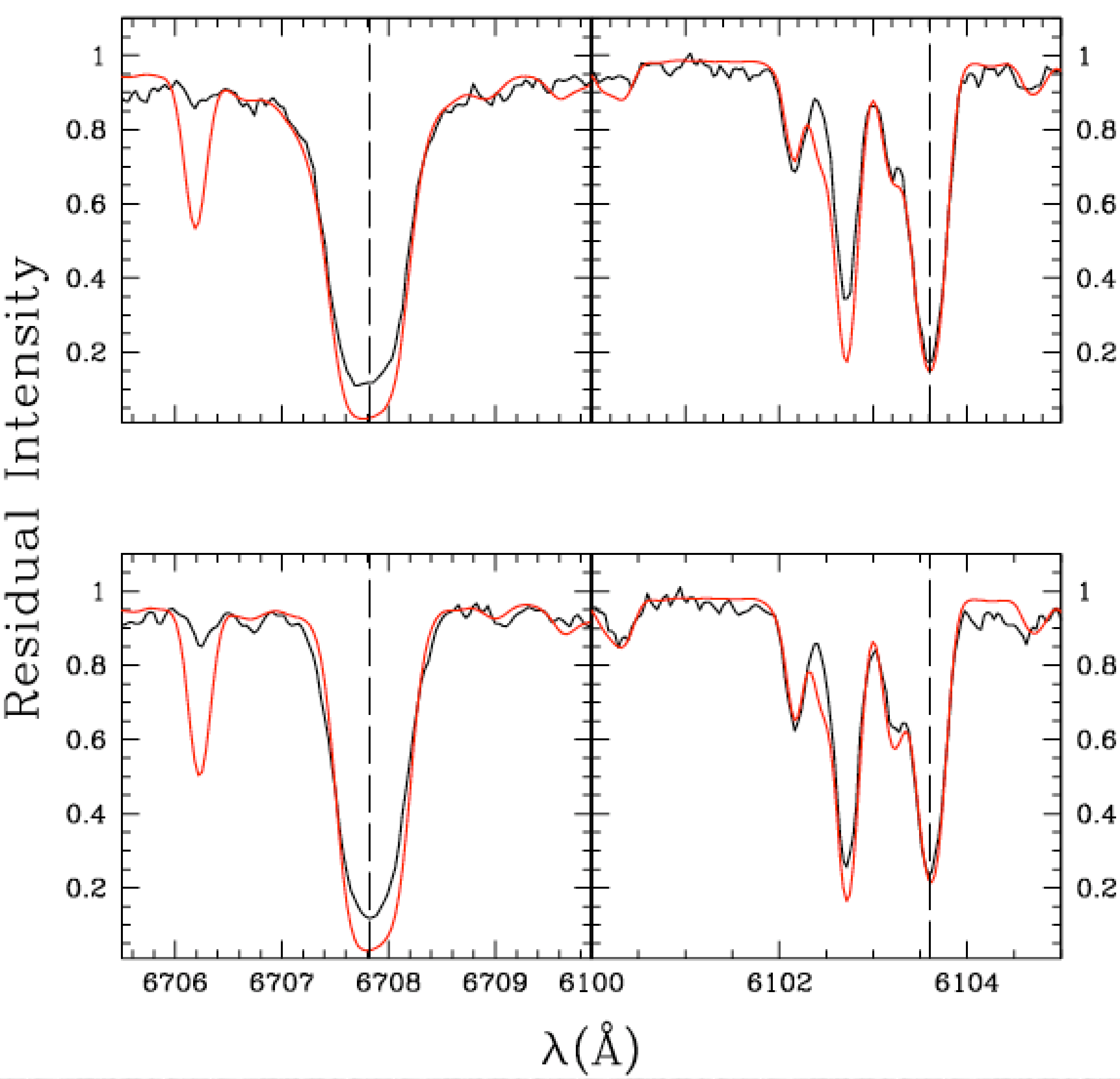
A(Li)=log[n(^{7}Li)/n(H)]+12.00

A(Li)~3.0 meteoritic value

LTE Li Spectro-Synthesis

Sgr16

Sgr76



LTE Abundance Analysis

A(^{7}Li):	4.29 / 4.20	Sgr16
	3.58 / 3.50	Sgr76
	0.14	Sgr6, Sgr84

[Fe/H]= -0.75 ÷ -1.1

Oxygen rich stars: C/O=0.10 ÷ 0.30

The nature of Li-rich Giants

- Preservation of primordial Li

  problems: stars with super-meteoritic abundances
  low $^{12}C/^{13}C$ isotopic ratios, depleted ^{9}Be

- Planet / Brown Dwarf ingestion

  problems: ^{6}Li, ^{9}Be, ^{11}B enrichment not observed
  stars with super-meteoritic abundances

- Lithium Synthesis

Li production

Cameron & Fowler 1971 - ^{7}Be-transport mechanism:

$$^3\mathrm{He}(\alpha, \gamma)\ ^7\mathrm{Be}$$

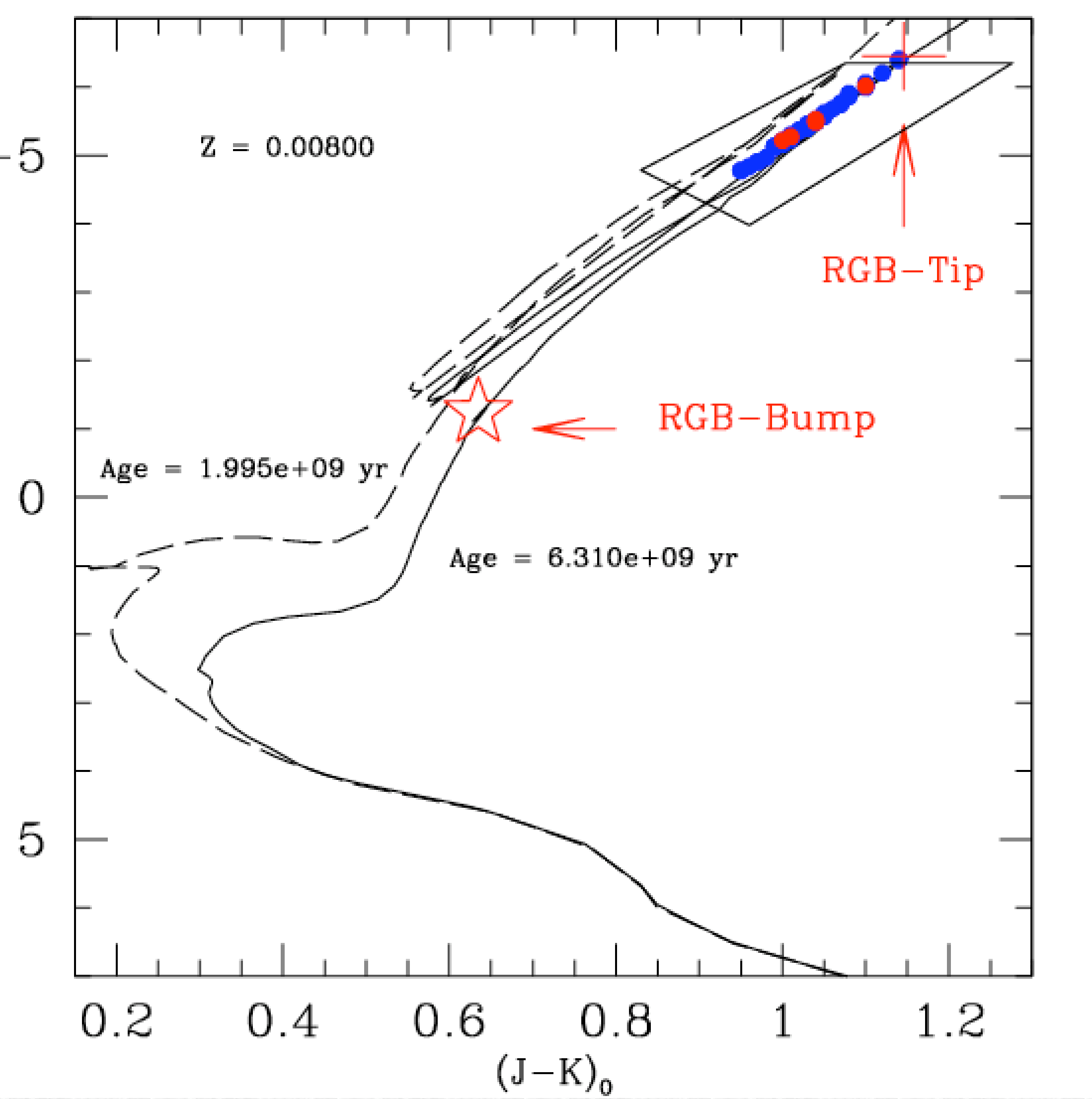
$$^7\mathrm{Be}(e^-, \nu)\ ^7\mathrm{Li}$$

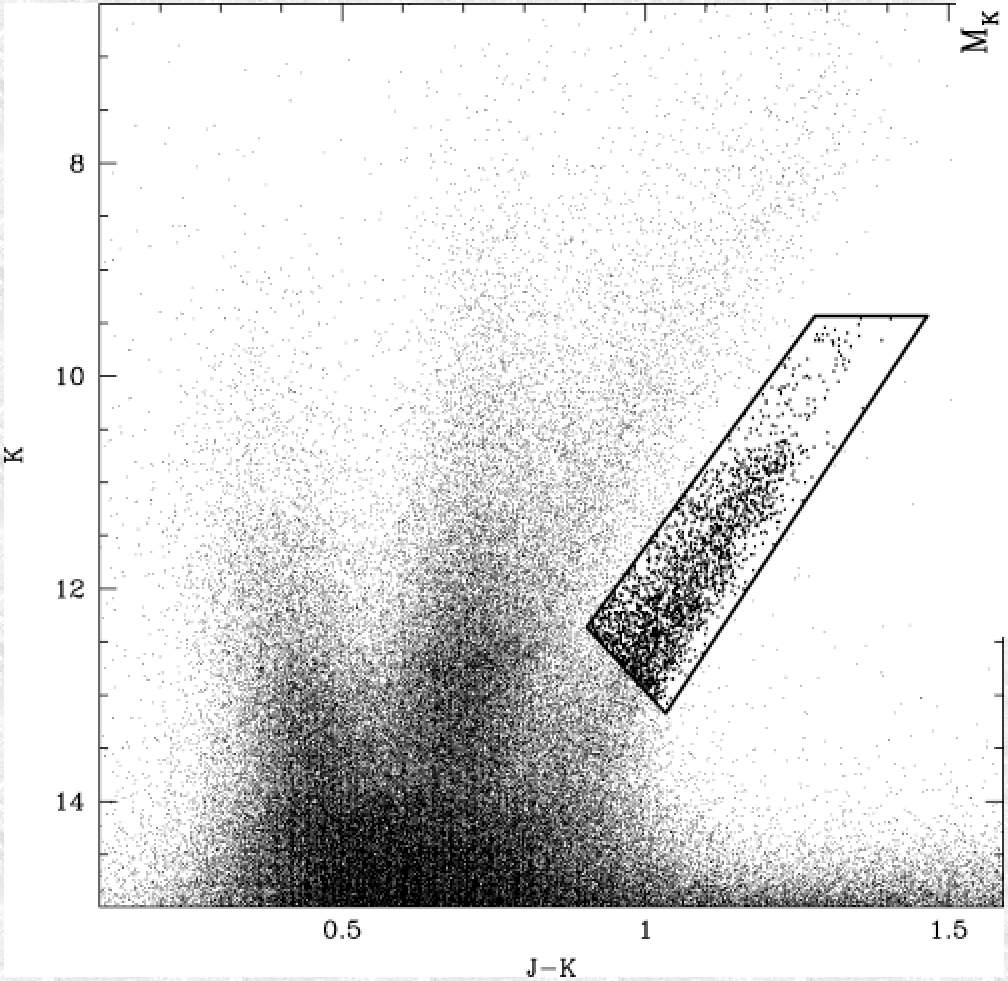
^{3}He burning:

- 3-6 M_{SUN} - Hot Bottom Burning (M_{Bol}<-6) at the base of the AGB convective envelope
- low mass stars (< 2.5 M_{SUN}) – ^{3}He has to be circulated from the convective envelope in and out of the Hydrogen Burning Shell (cool bottom processing - CBP, Sackmann & Boothroyd 1999)

We are dealing with low mass stars on the RGB/AGB:

No Hot Bottom Burning





$\log L/L_{sun} \sim 3 \div 3.3$

$M \sim 1.0 \div 1.5\ M_{sun}$

$M_{bol} \sim -2.5 \div -3.4$

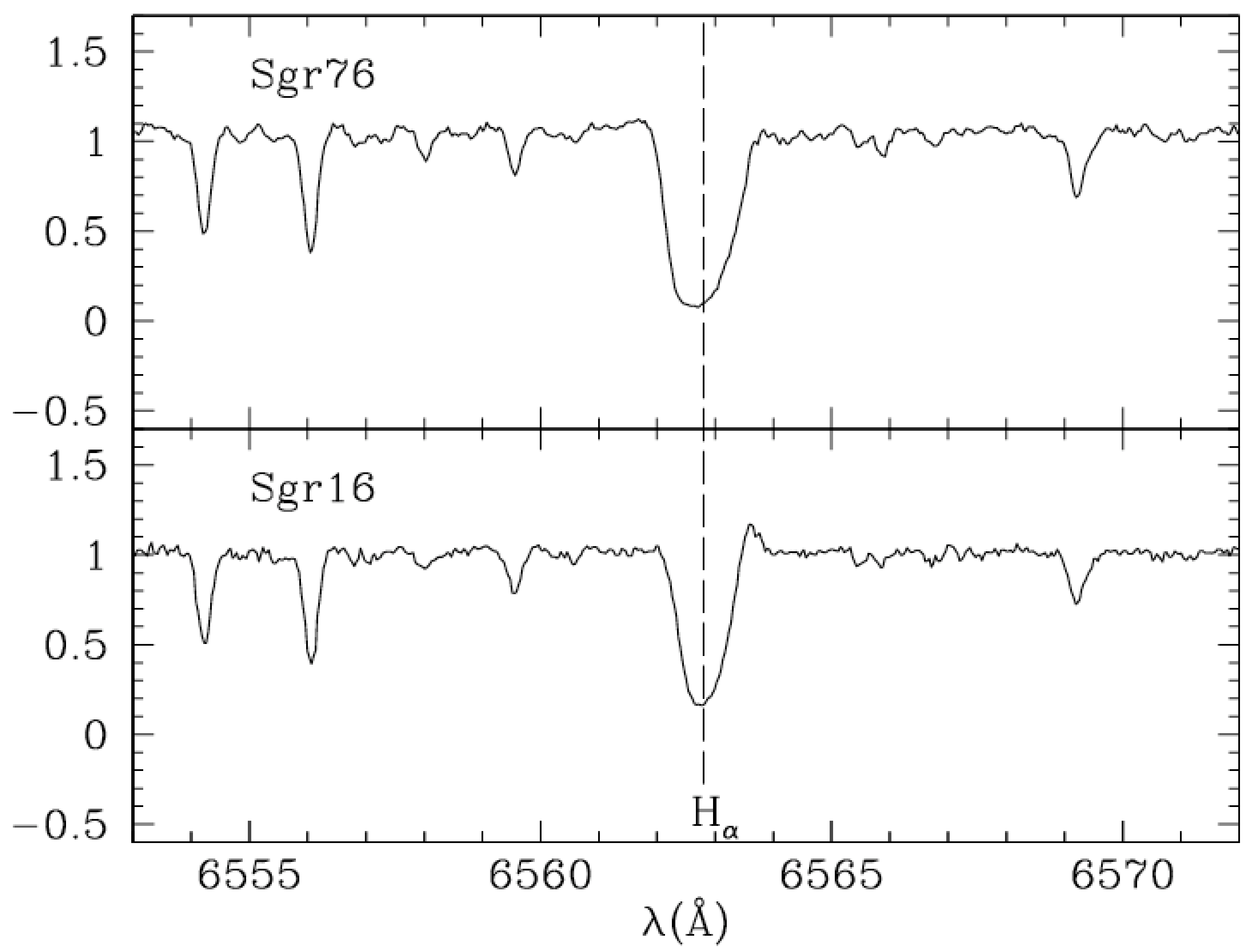
Li-rich stars and Mass Loss

Based on the existence of a far-IR (IRAS) excess in the majority of Li-rich giant stars de la Reza et al 1996,97 suggested the Li-rich phase to be connected to a Mass-Loss episode

Circumstellar Material?

Ha

asymmetric
blue shifted
Ha profiles
and/or
emission
components



Circumstellar Material?

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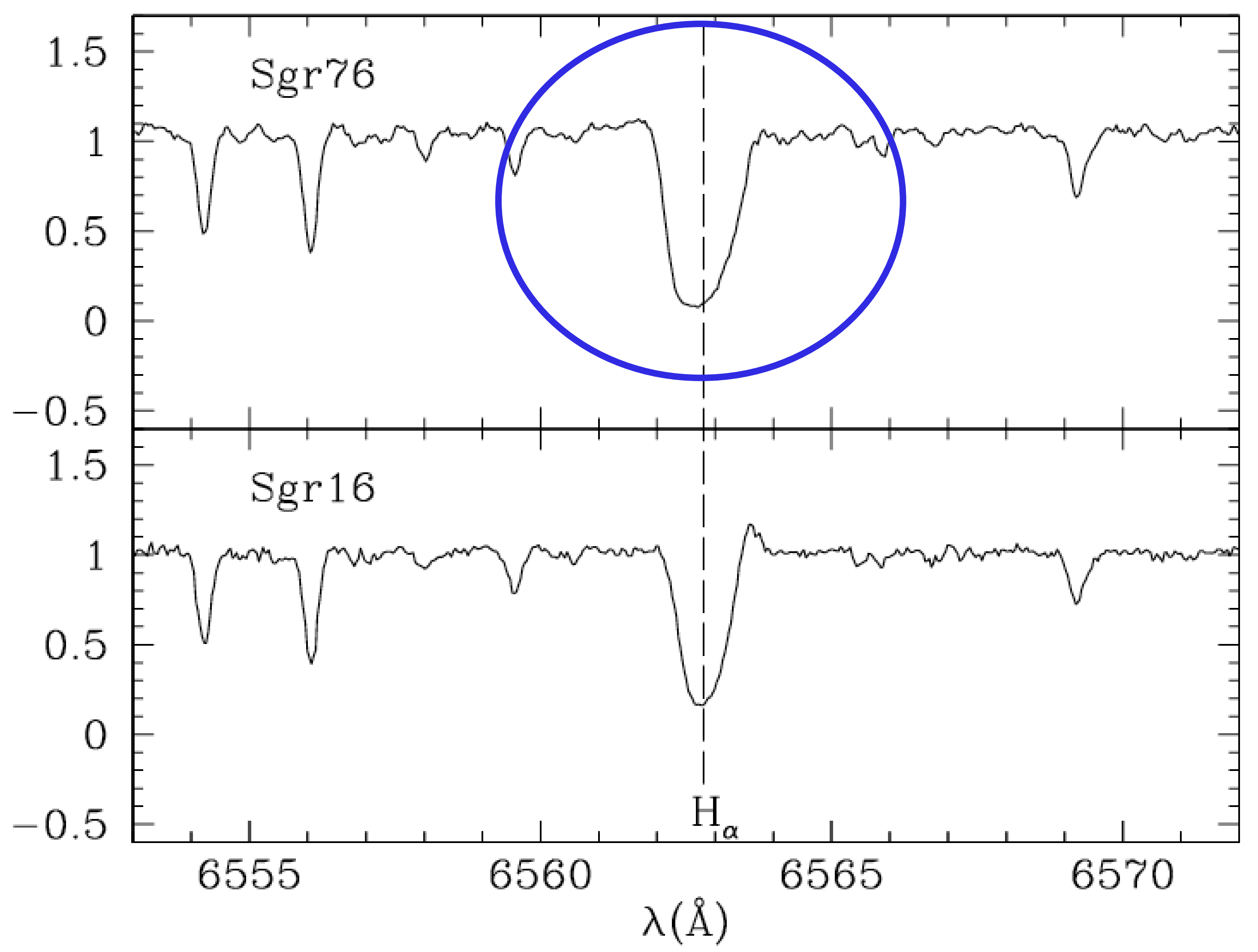


Circumstellar Material?

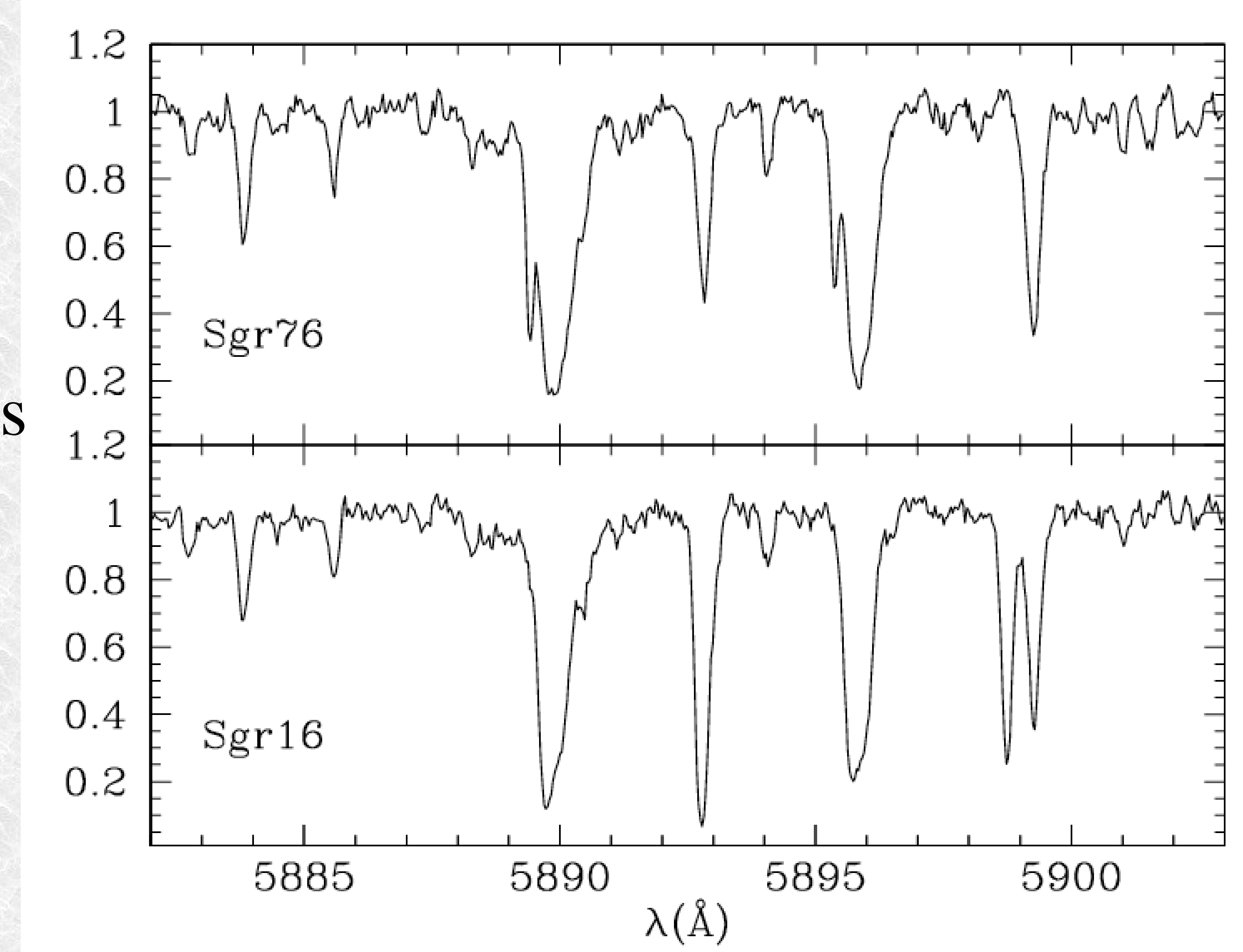
Na D

asymmetric –

blue shifted lines

or additional

components



Circumstellar Material?

Na D

asymmetric –
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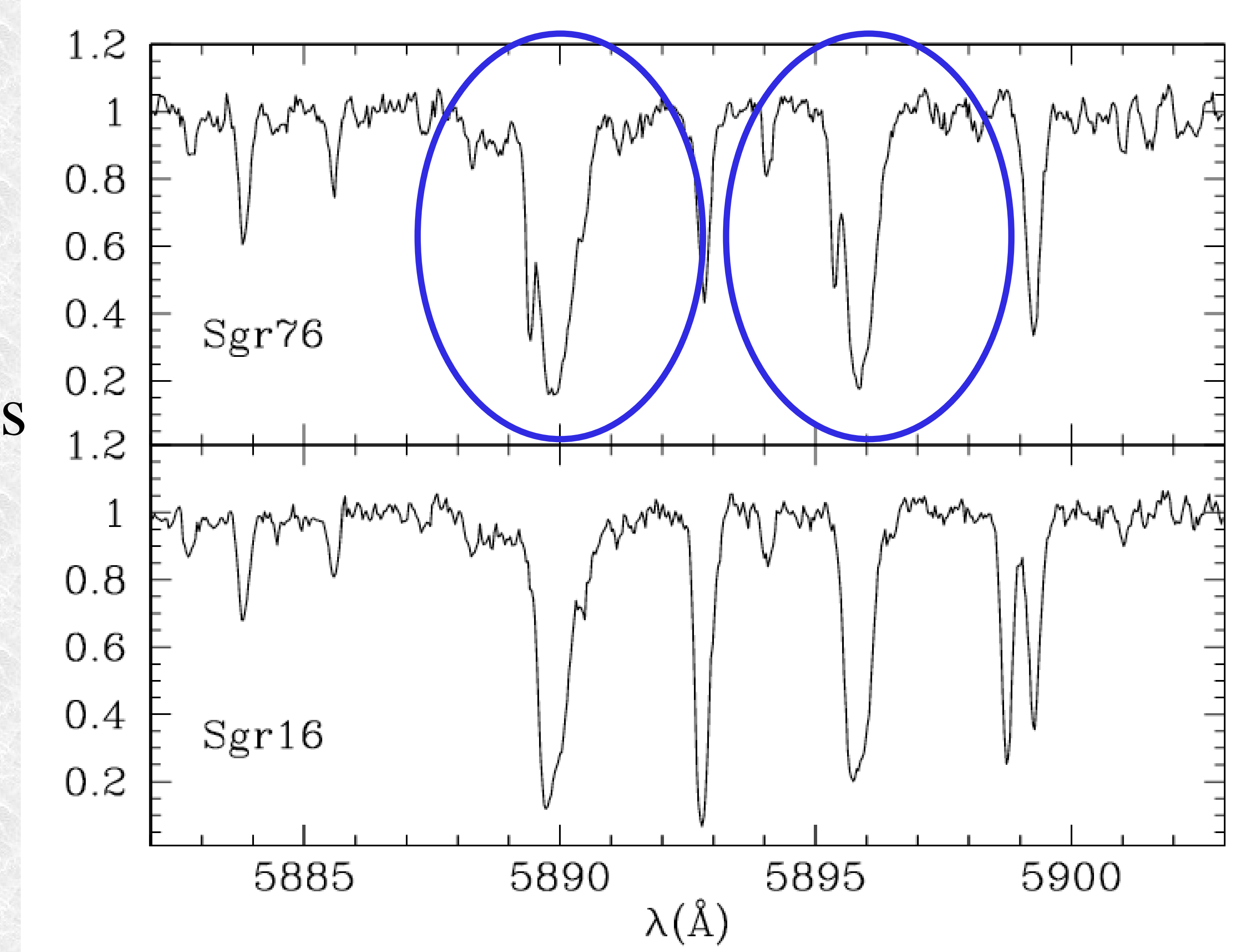


Rotational Mixing *vs* Chromospheric activity

Rotation was suggested as the driver for the extra-mixing process which produces Li-rich giants

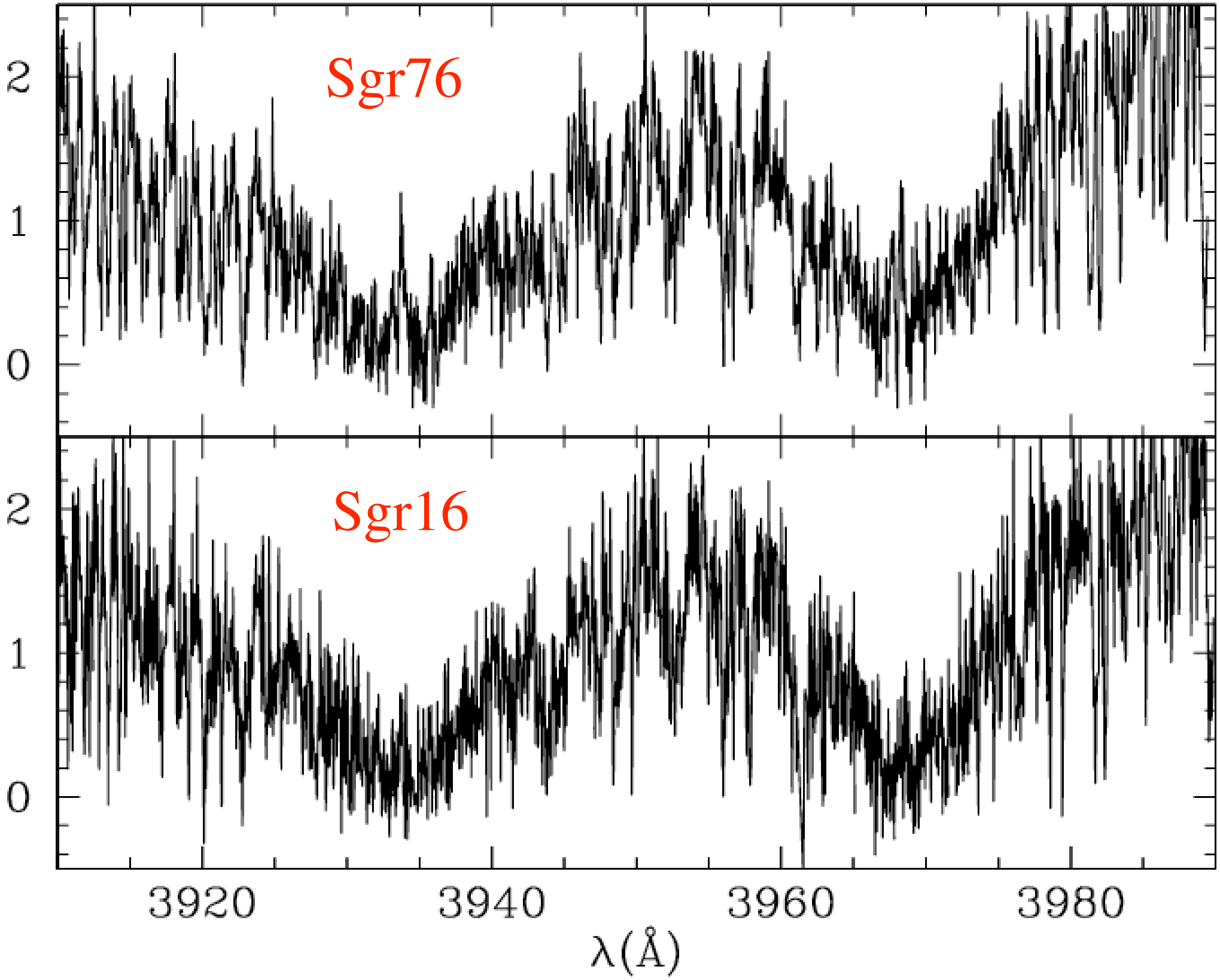
Some red giants may dredge up angular momentum from an internal reservoir. Such a transfer may results in chromospheric activity and being accompanied by ^{7}Be dredge-up
– Simon & Drake 1989

Many chromospherically active single giants have high Li abundances – Fekel & Balachandran (1993)

Chromospheric Activity?

Ca II H K

possible emission components in the core of the Ca II HK lines



Chromospheric Activity?

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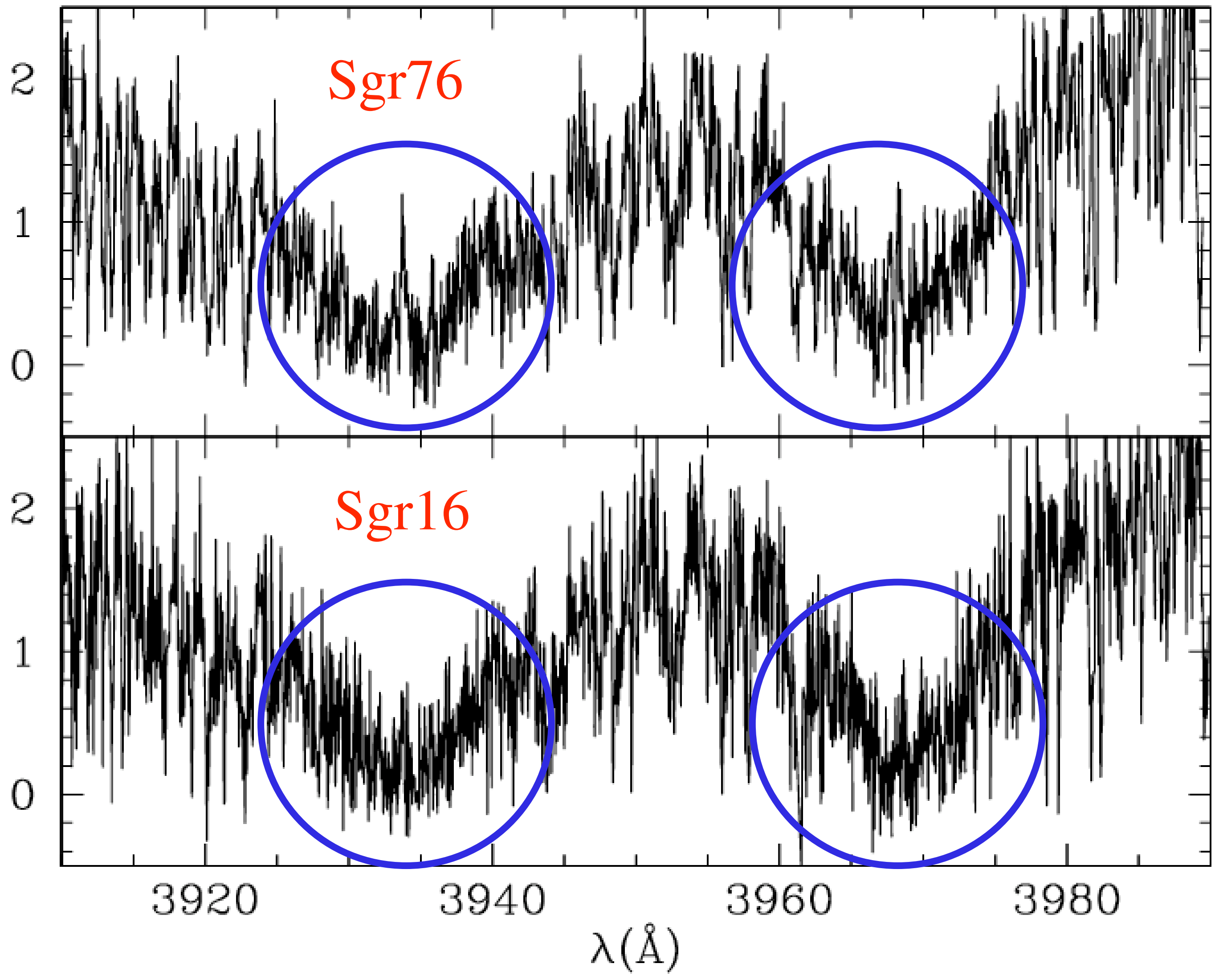


Summary

- We have detected Li absorption lines in 5 stars (11%) belonging to the Tidal Streams of the Sgr dSph

- Two stars (4%) have super-meteoritic Li abundances (A(Li)~4.2 and 3.5) as of our preliminary LTE analysis

Summary

- Li-production associated with some kind of circulation mechanism (cool bottom processing) appears as the most likely cause for the observed Li abundances

- Complex spectral features in the Ha and/or Na D suggest the presence of circumstellar material, in agreement with de la Reza et al 1996.

- Emission in the core of the Ca II HK lines suggests chromospheric activity (rotational mixing?)

The End

Yet to be done...

$^{12}C/^{13}C$ isotopic ratio:

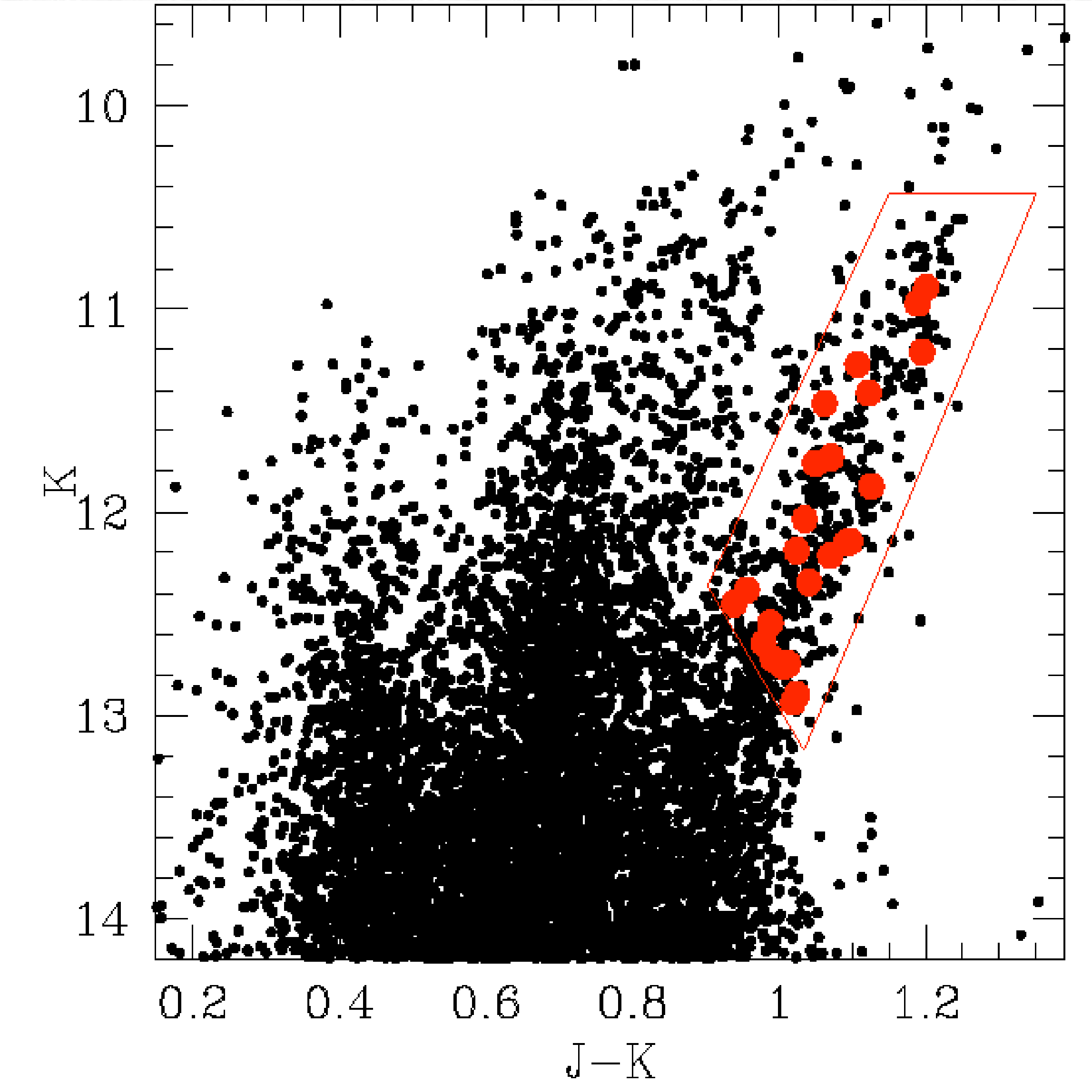
Cool Bottom Processing for low mass stars implies low (< 20-25) isotopic ratios

Rotational velocities:

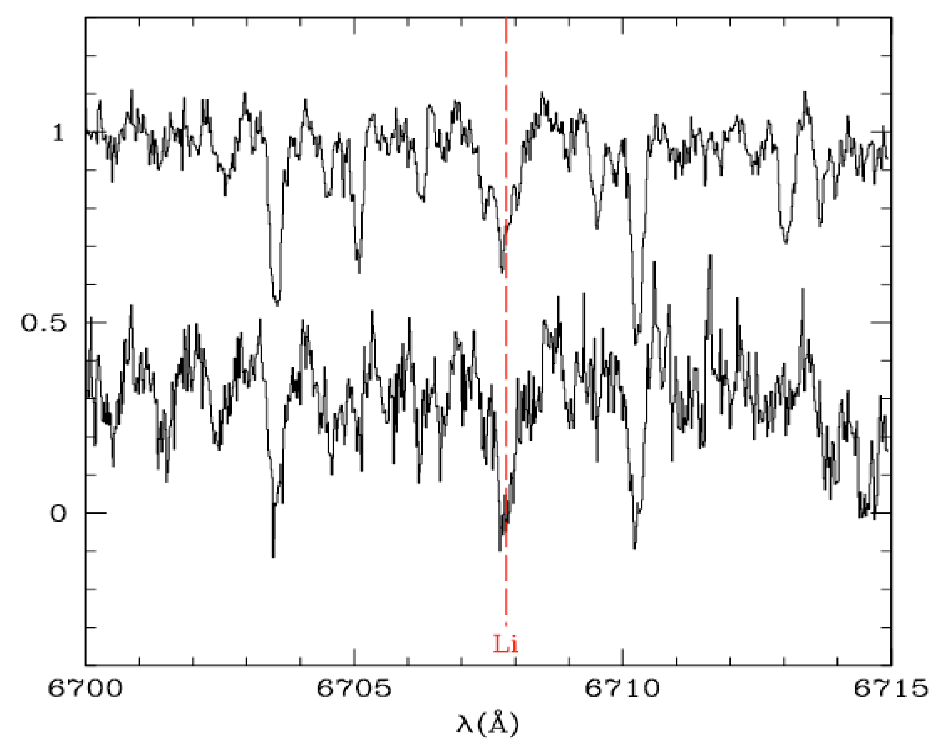
Drake et al. 2002 found ~50% of K giants with high rotational velocity ($v \sin i > 8$ km s^{-1}) to be Li-rich

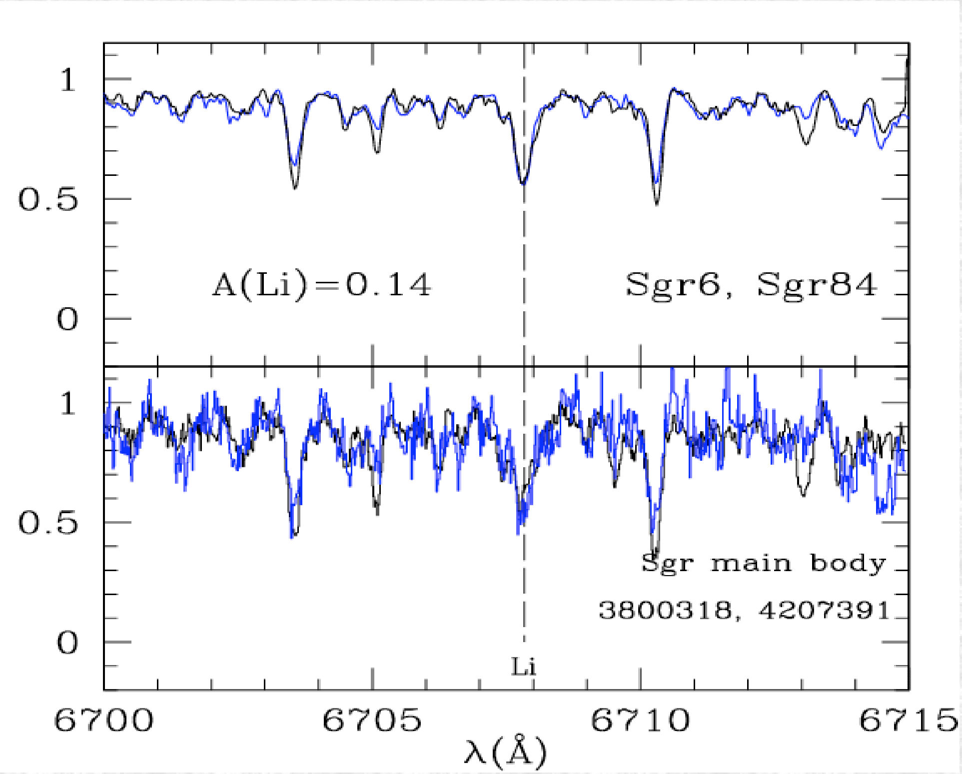
Li-rich stars in the Sgr main body?

23 stars observed in the main body of Sgr



Li-rich stars in the Sgr main body?





2 stars present Li lines comparable to Sgr6, Sgr84 (A(Li)=0.14)

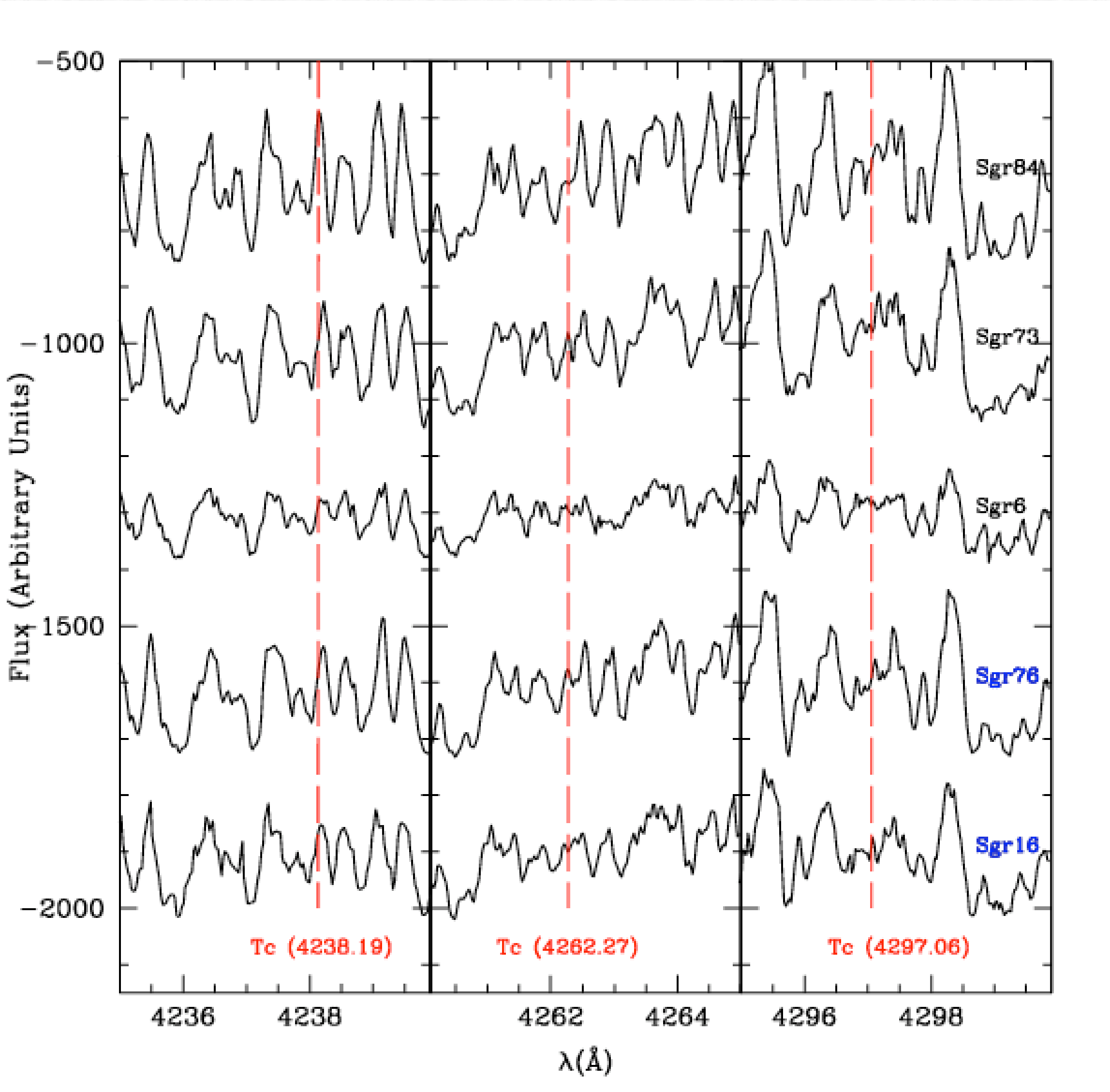
S-process Elements and 3rd dredge up

Tc

Tc is a diagnostic for the occurrence of a 3rd dredge up

No clear detection of Tc lines

Uttenhaler et al. 2007 studying a sample of low mass O-rich Bulge AGB showed that the Li-rich phase is not necessarily connected with a 3rd dredge up episode

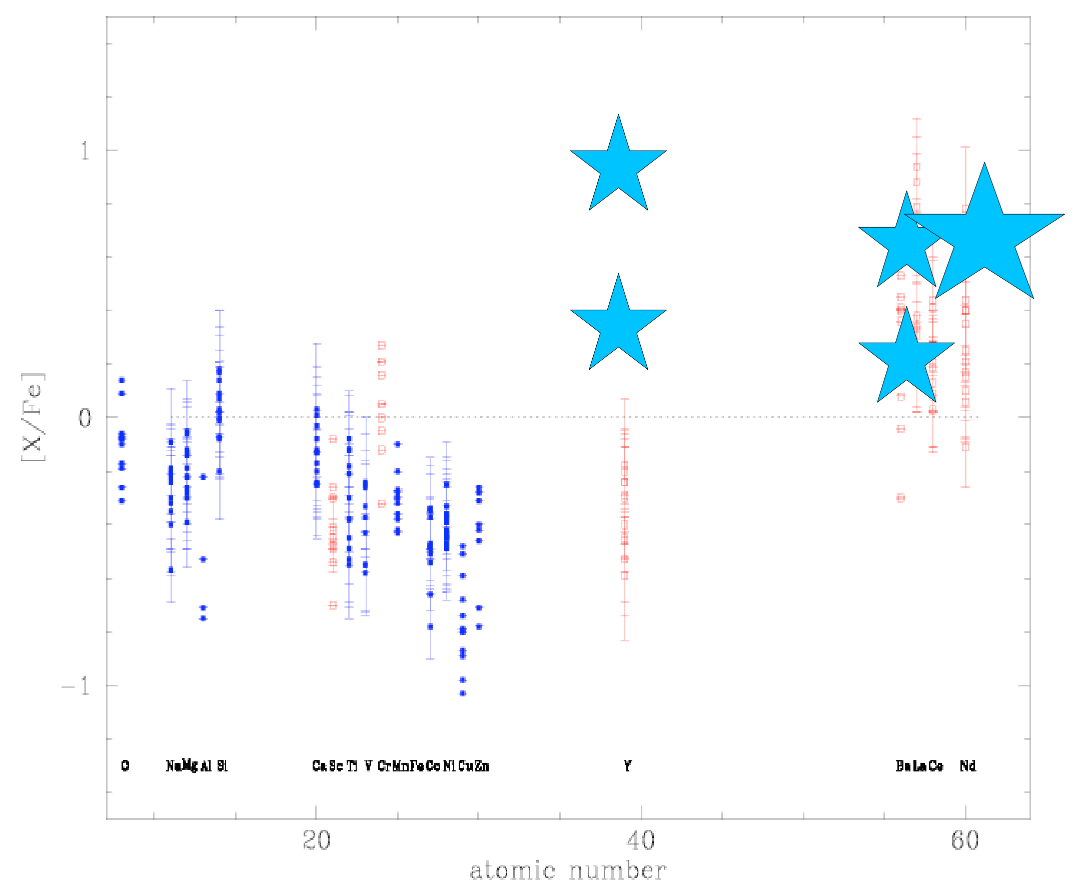


S-process Elements and 3rd dredge up

S-process

[S/Fe] = 0.28 Sgr16
0.70 Sgr76
0.41 Sgr6
0.99 Sgr84

S=(Y+Ba+La+Nd)/4



Sbordone et al 2007

TiO & Teff

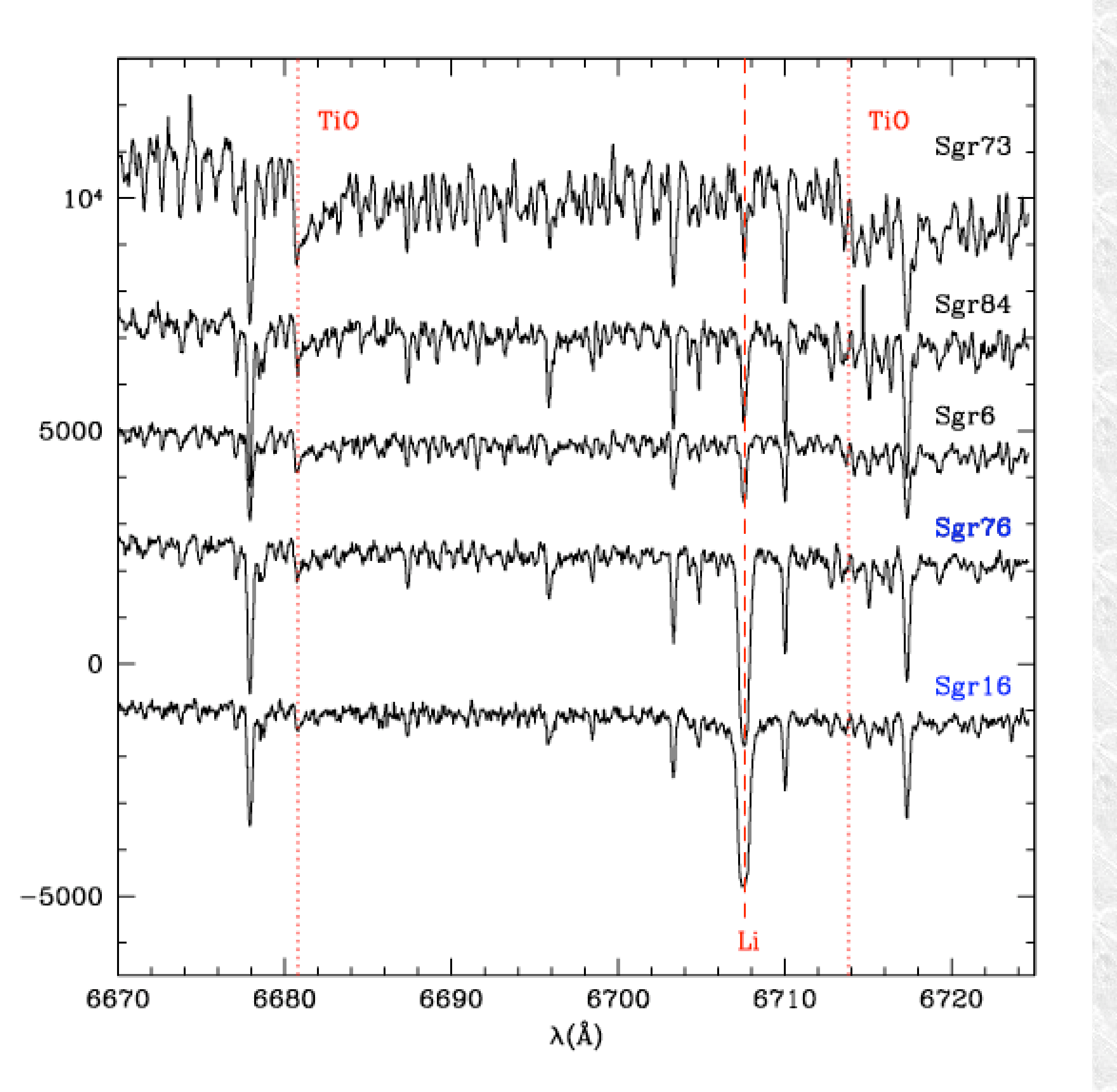
Teff = 3650

Teff = 3750

Teff = 3800

Teff = 3750

Teff = 3800



Statistics

Stars with Li lines:

5/46=11%	Sgr Stream
2/23=9%	Main Body

Li-rich stars:

2/46= 4%	Sgr Stream

Outline

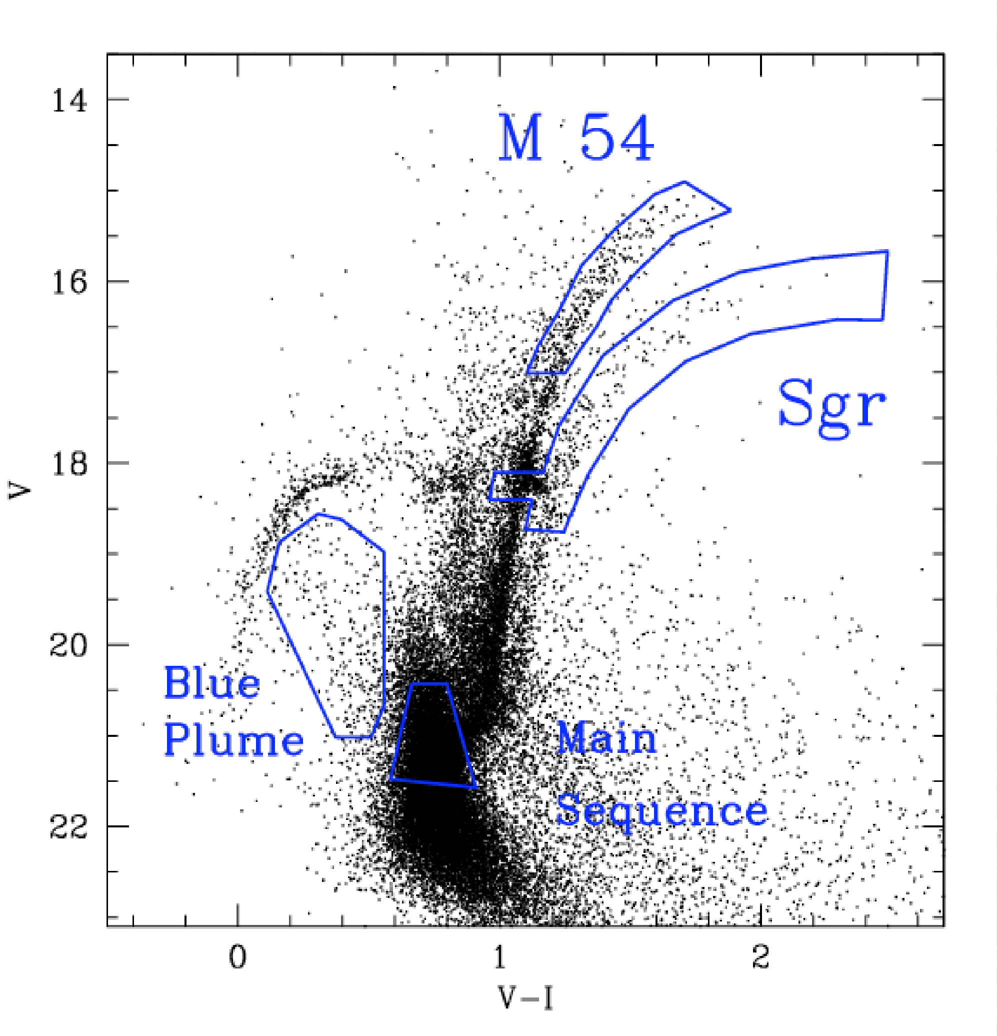
I: The main Body

- Wide Field Photometry of the Sgr main body
- The Sgr Nuclear Structure
- The Ital-FLAMES survey of Sgr

II: The Sgr Tidal Streams

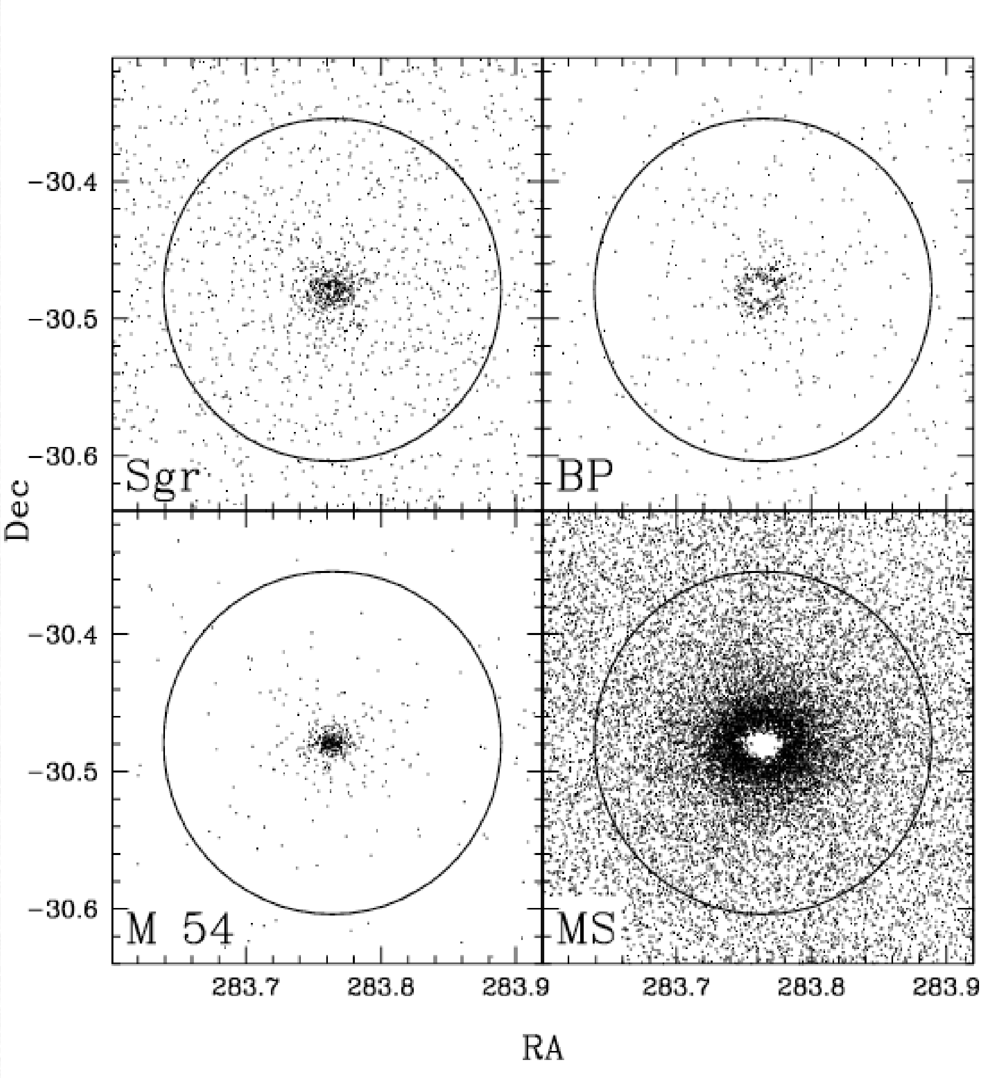
- Chemical abundances of M-Giants
- Comparing the streams and main body stellar populations
- Li-rich giants

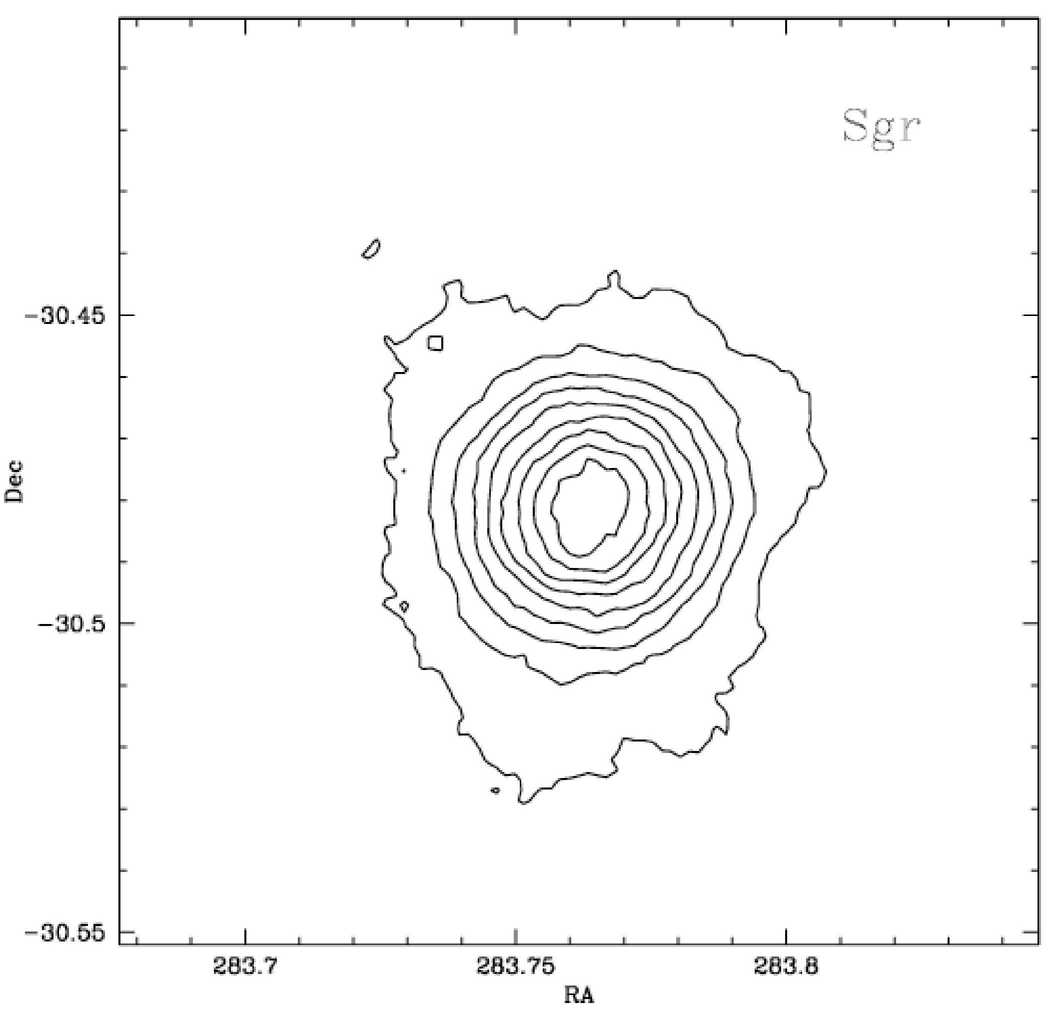
The Sgr Nuclear Structure



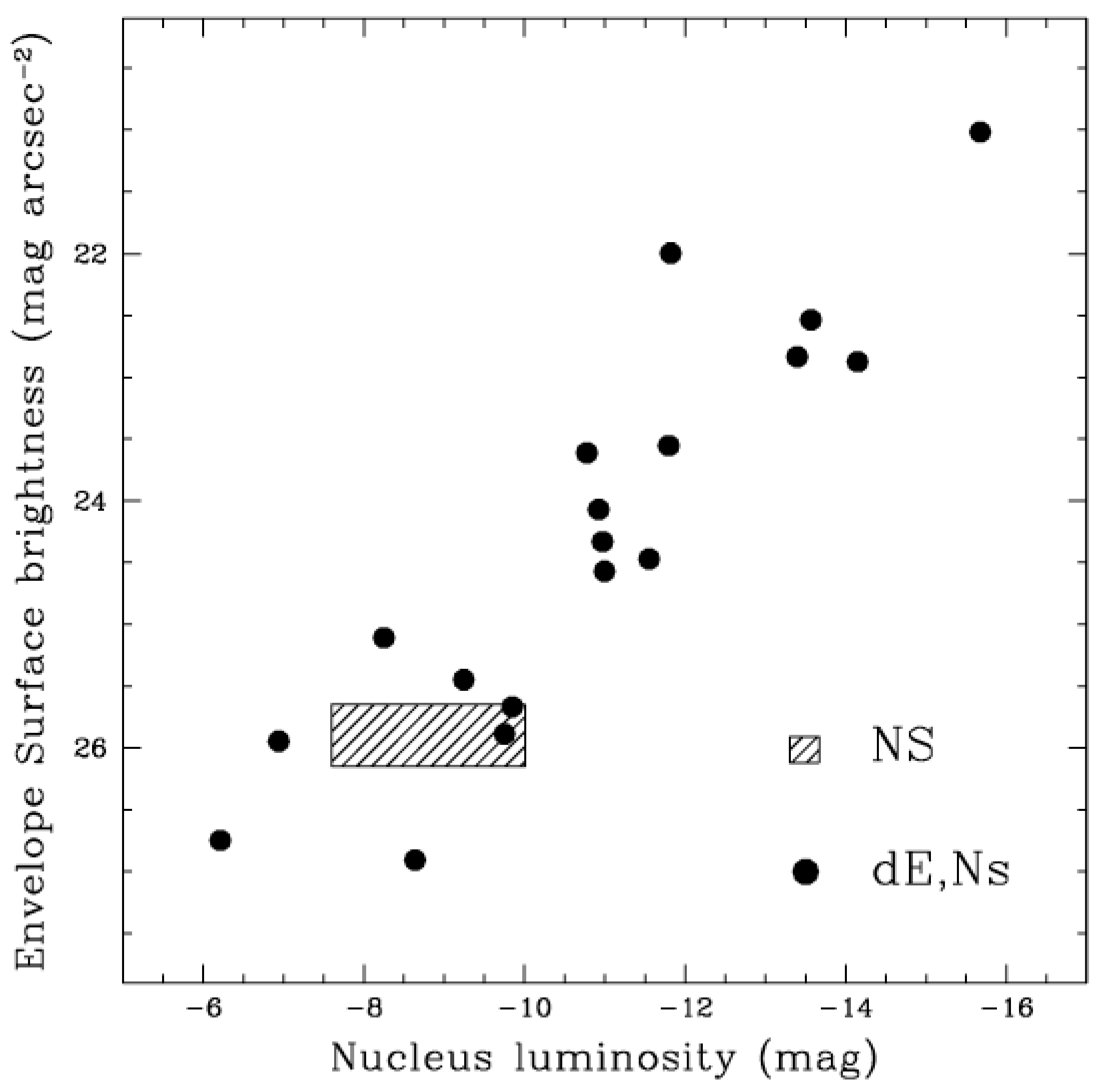
- Stellar population of different age & metallicity are somewhat clustered around M 54
- M 54 and Pop-A stars are easily discriminated on the CMD

The Sgr Nuclear Structure





The Sgr Nuclear Structure

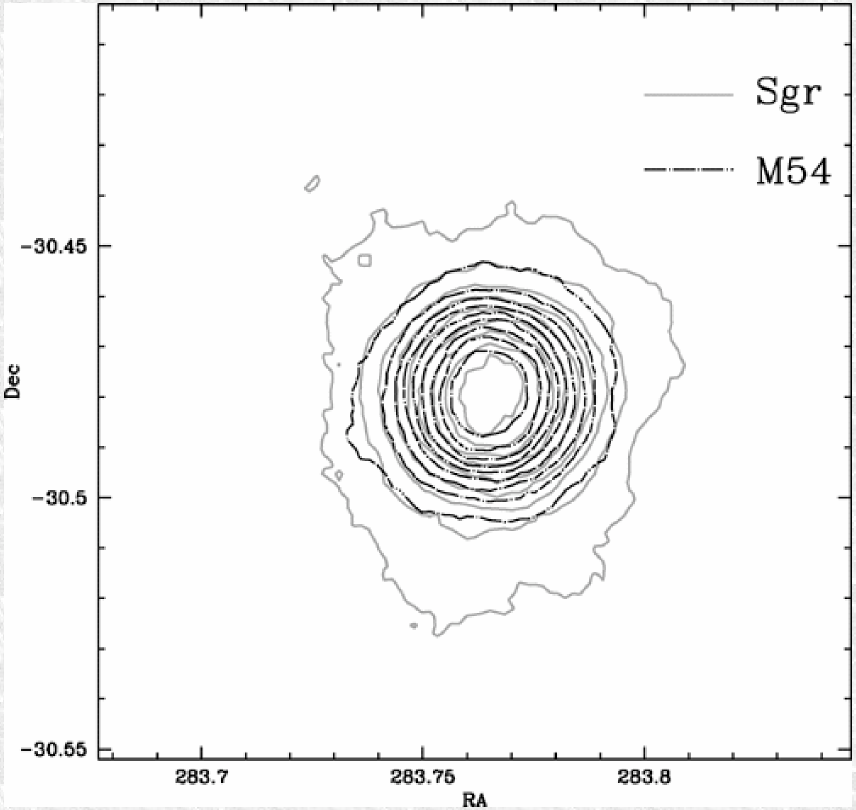


The NS structural characteristics are compatible with a dE Nucleus

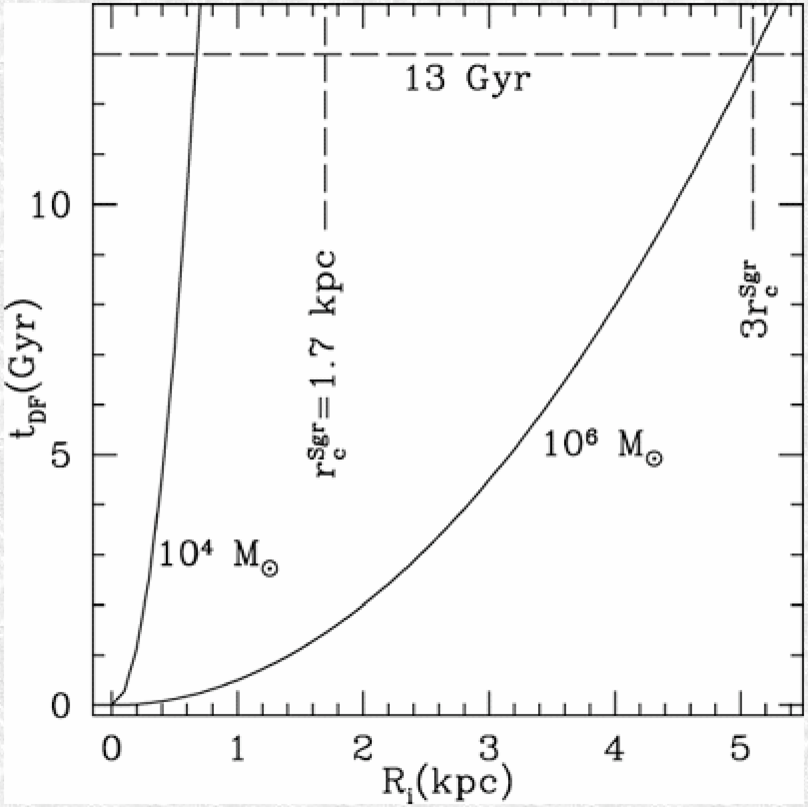
Filled Circles:
dE,N in the Fornax Cluster,
Drinkwater et al 2003

Monaco et al. 2005, MNRAS, 356, 1396

The Sgr Nuclear Structure



The center of M54 and the Sgr-NS coincide at the best of our resolution (6 arcsec).



The dynamical friction time is lower than a Hubble time on a $10^6 M_\odot$ object (M54) born inside 5 kpc from the center with a circular velocity identical to the Sgr velocity dispersion

Monaco et al. 2005, MNRAS, 356, 1396

GIRAFFE sample

FLAMES-GIRAFFE@VLT:

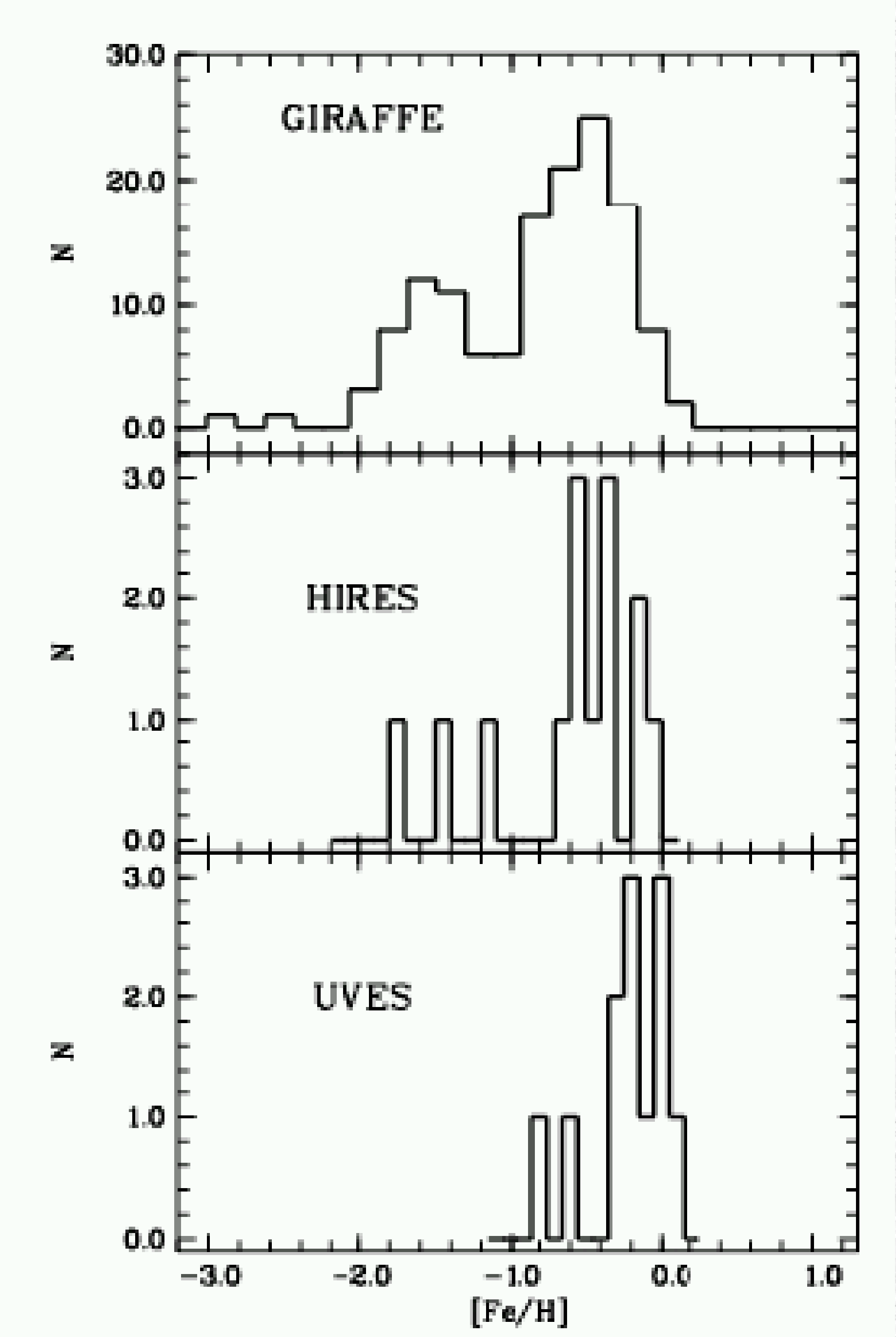
Bonifacio et al., in preparation

HIRES@KECK:

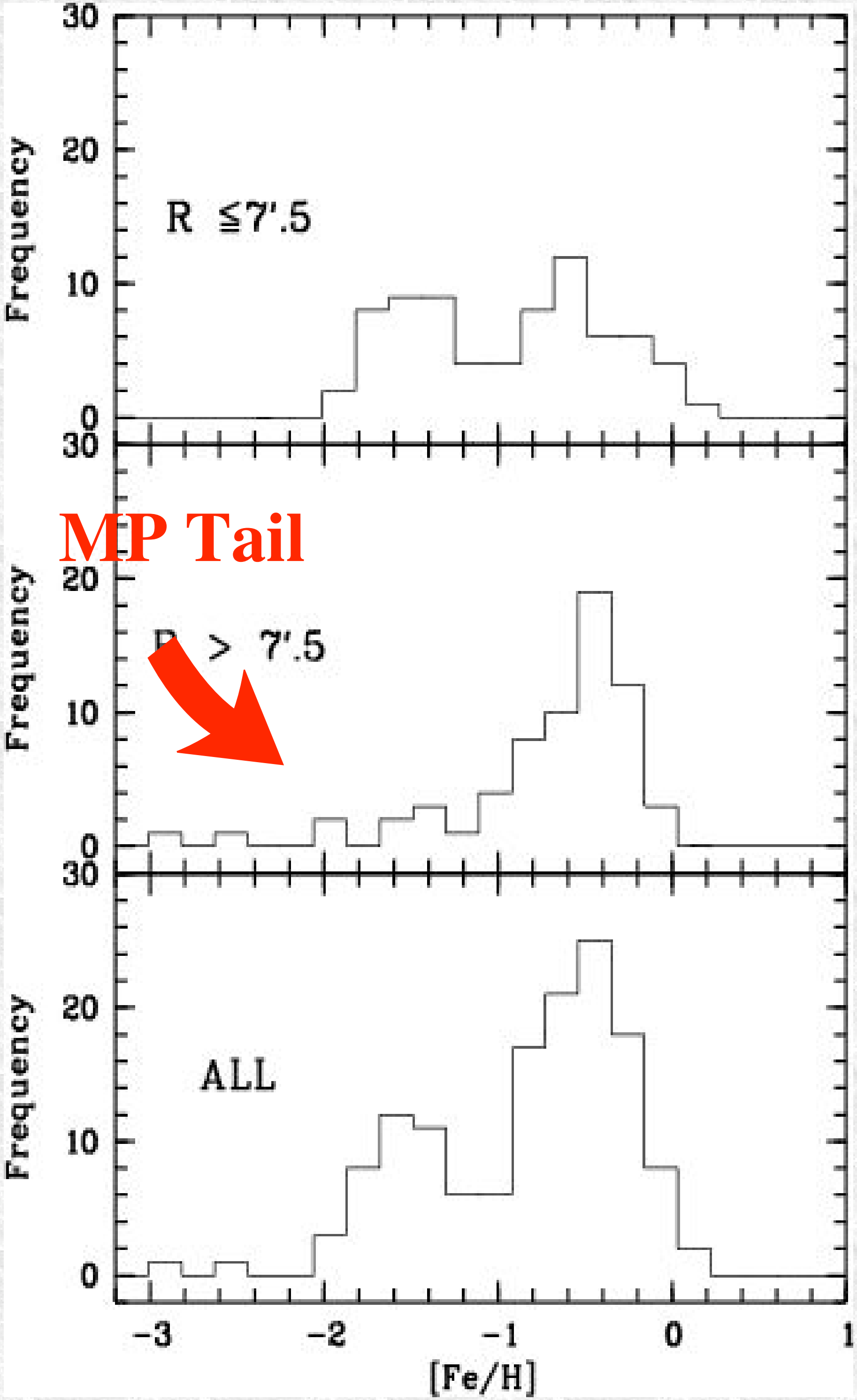
Smecker-Hane & McWilliam, astro-ph/0205411

UVES@VLT:

Bonifacio et al., 2004



Metallicity Distributzion and Metal Poor tail



MP Tail

13 stars with [Fe/H]<-1.7 i.e. considerably more metal-poor than M54

The most metal poor Sgr star is as metal poor as DRACO119: [Fe/H]=-3.0

Part I Conclusions:The Sgr Core

Wide Field Photometry

Sgr stellar content:

RGB-bump: Strong episode of stars formation (~5Gyr ago with [M/H]~-0.5)

BHB stars: Sgr hosts a significant fraction (~10%) of old and metal poor stars

RGB-Tip: Enough stars collected to detect for the first time the RGB-Tip

The Nuclear Structure:

Sgr would appear as a nucleated galaxy independently of the presence of M54 at its centre.

Part I Conclusions:The Sgr Core

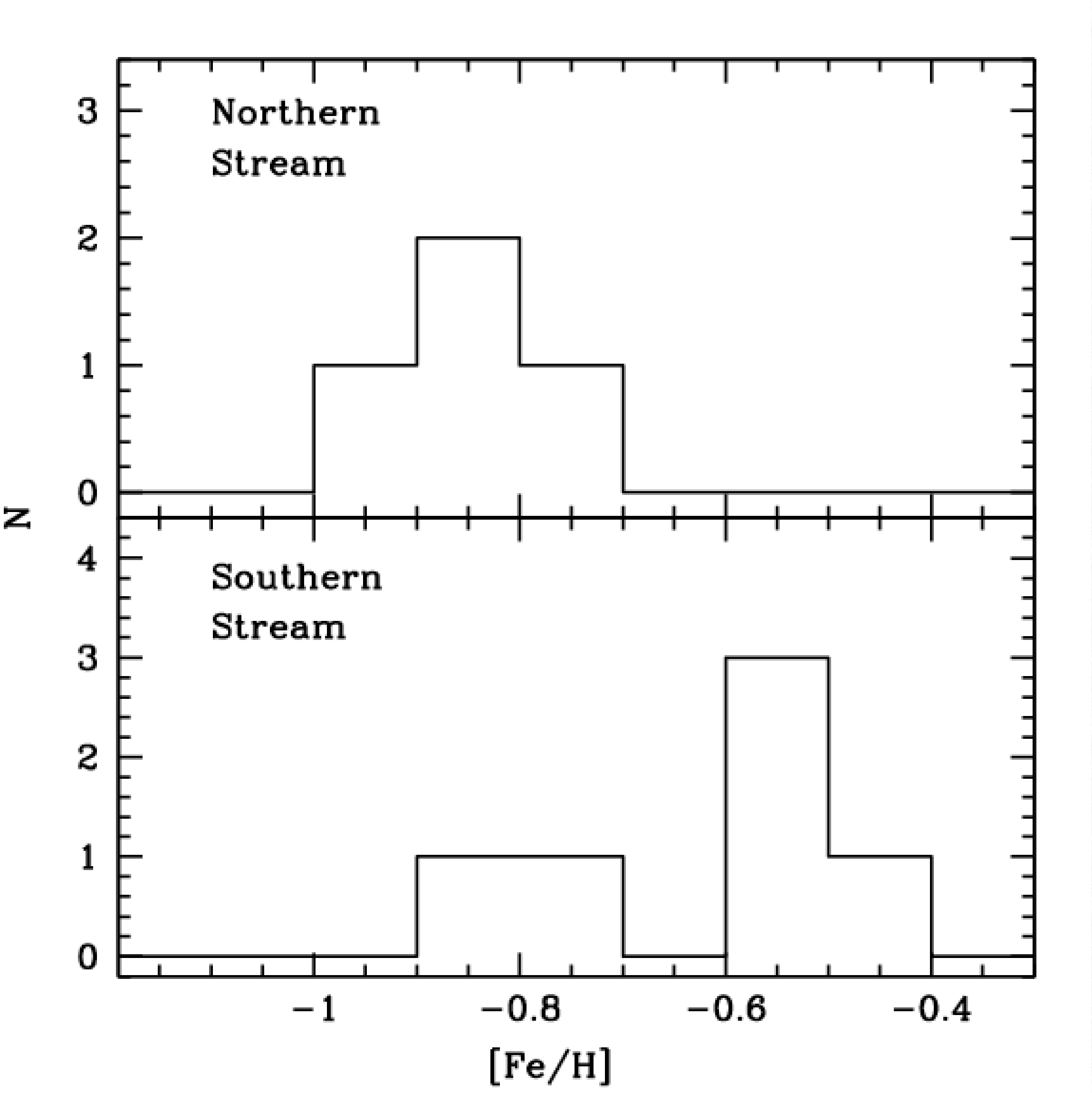
The Ital-FLAMES multi-object spectroscopic survey

- The first realistic Metallicity distribution
- Discovery of a very metal poor tail never observed before
- Sgr presents peculiar chemical abundance ratios different from both MW stars and the other dSph galaxies

Chemical abundances of RGB-stars in the Sgr Stream

Stars more distant from the main body are also more metal poor

See also Chou et al.,
astro-ph/0605101
and Vivas et al. 2005, AJ, 129, 189



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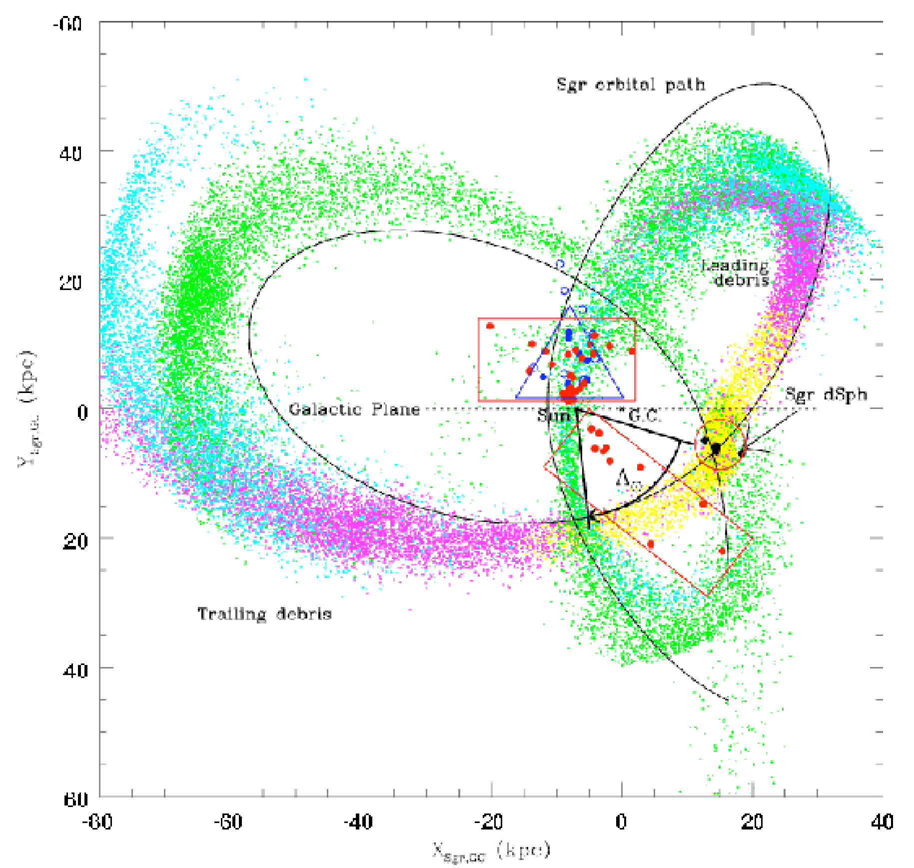
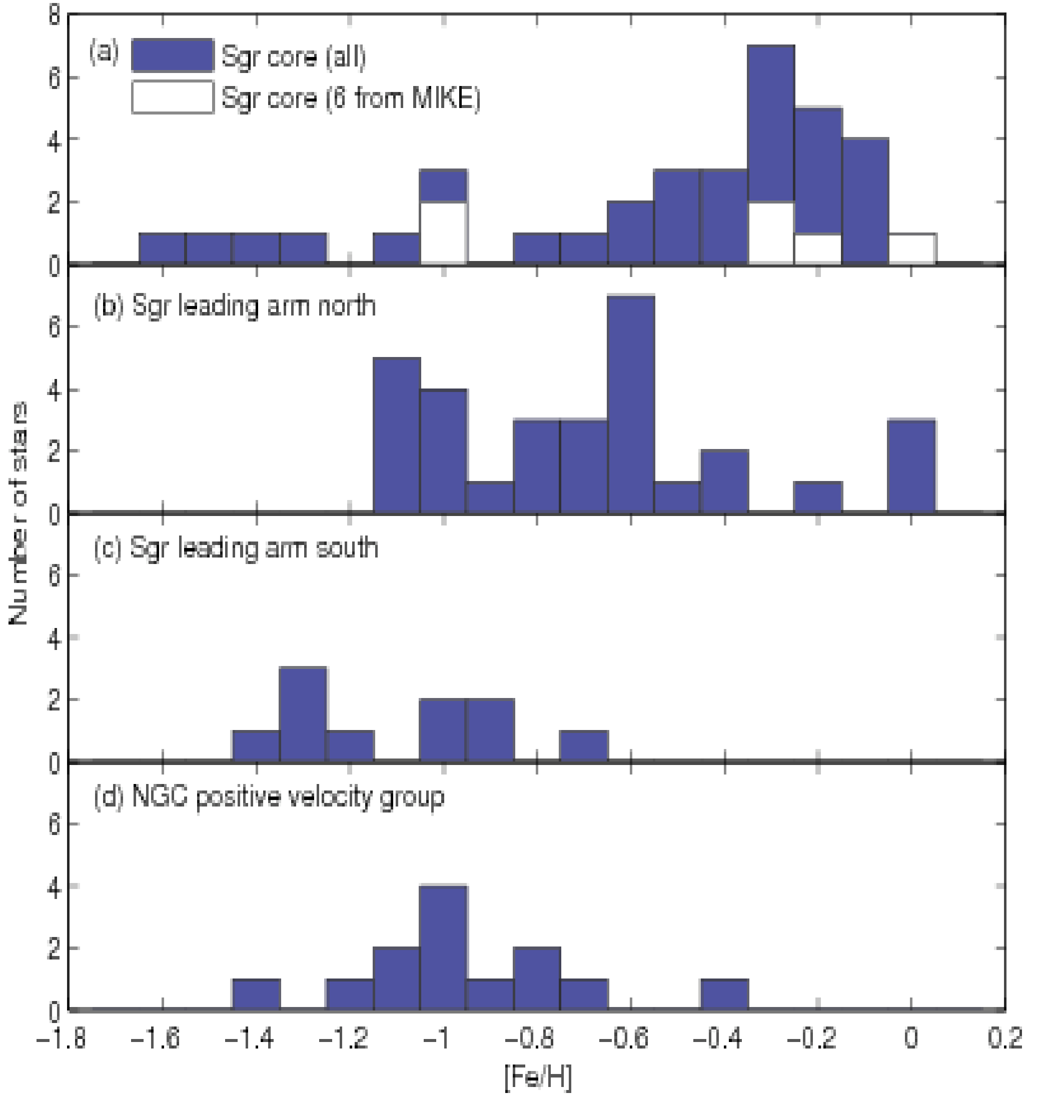
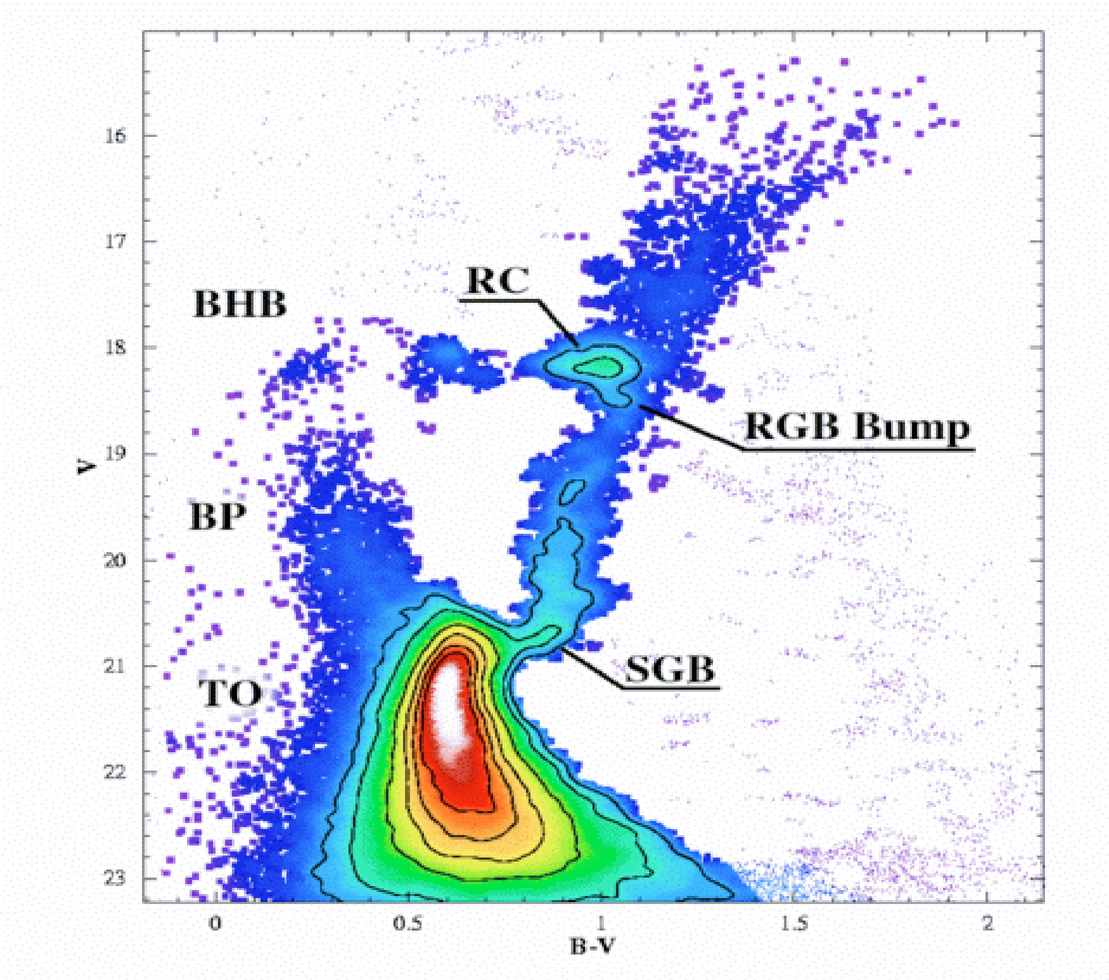


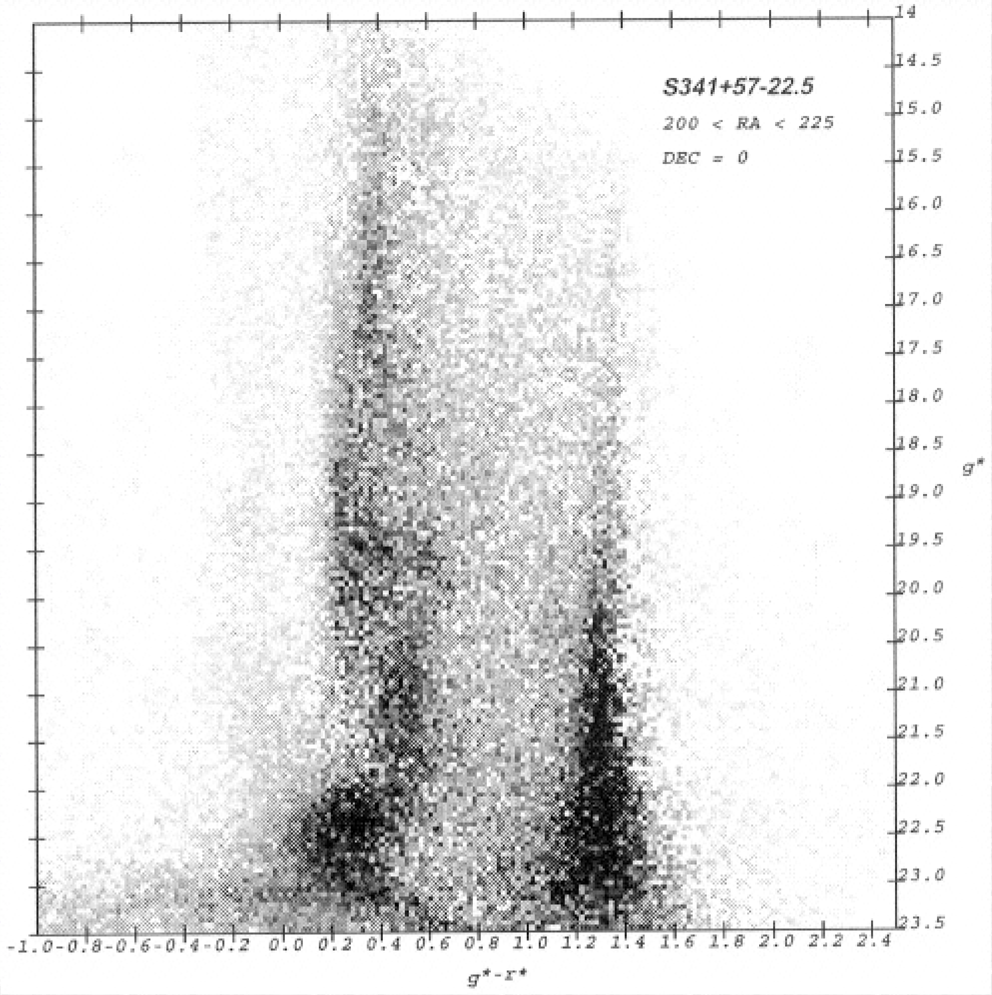


Chou et al. astro-ph/0605101

Population Gradient in the Sgr Stream

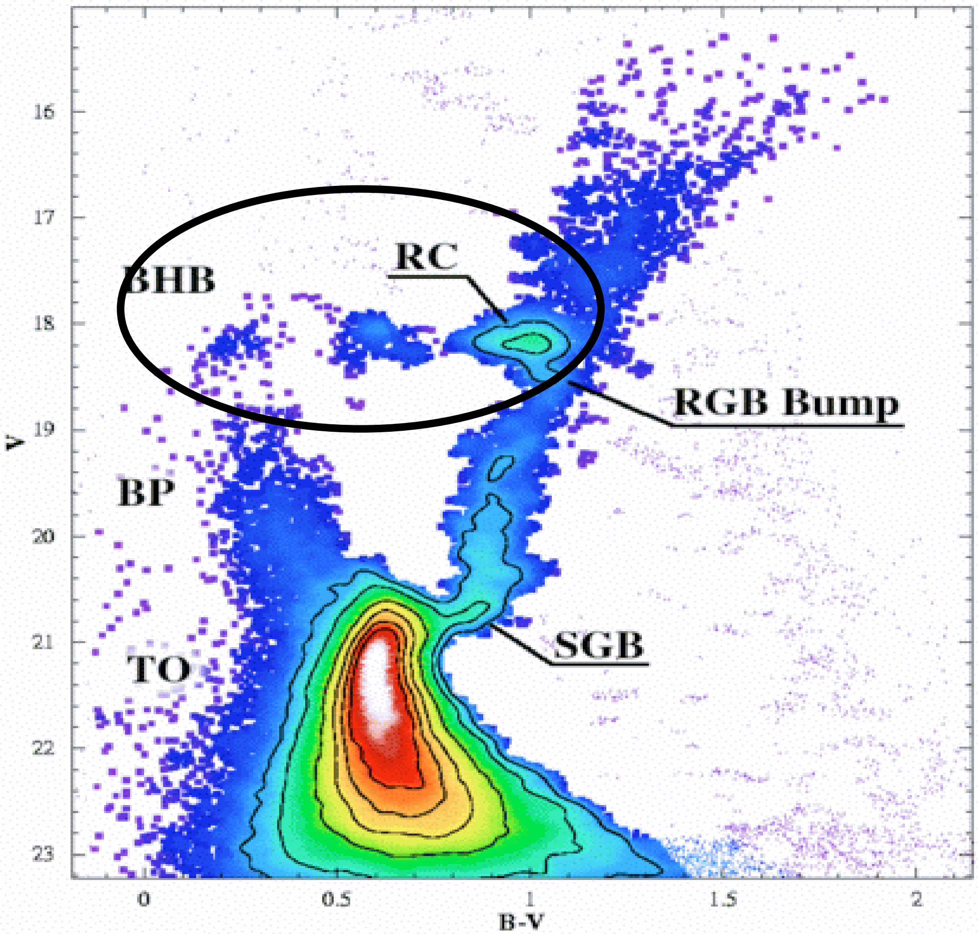


Sgr34

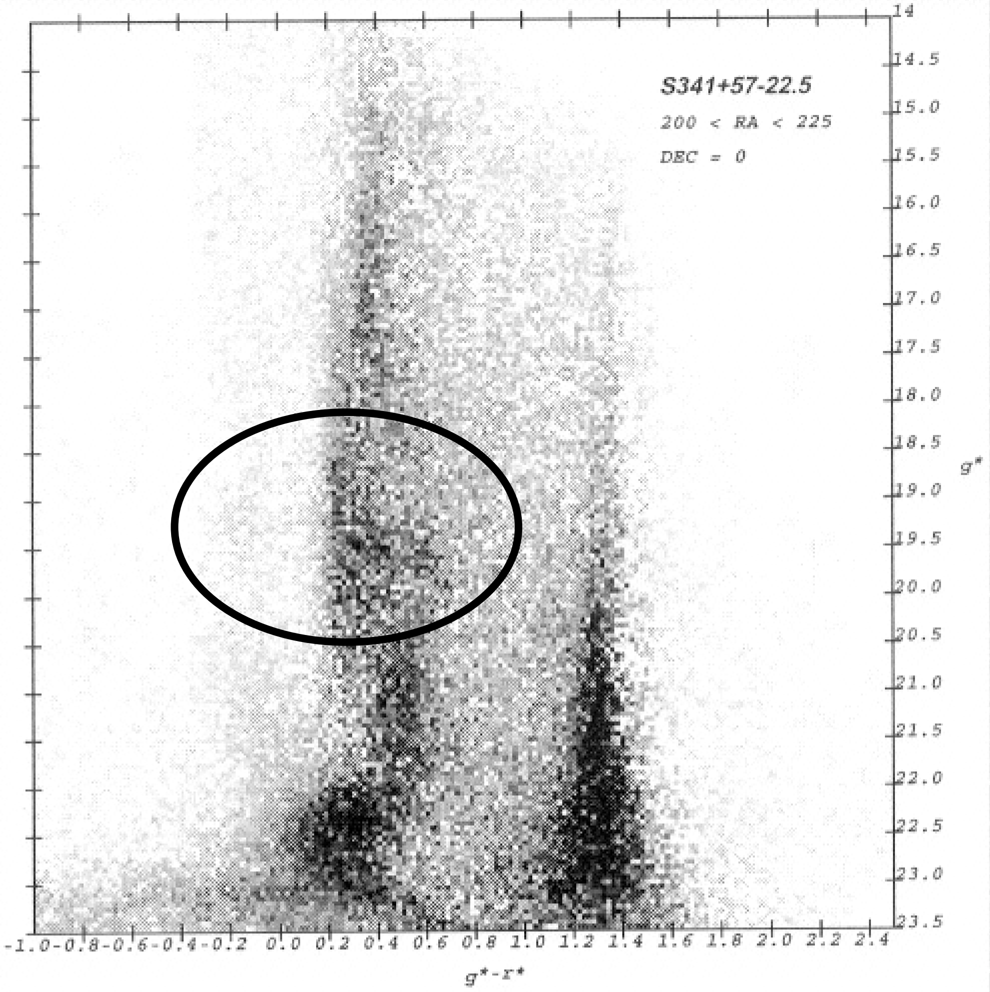


S341+57-22.5

Population Gradient in the Sgr Stream



Sgr34



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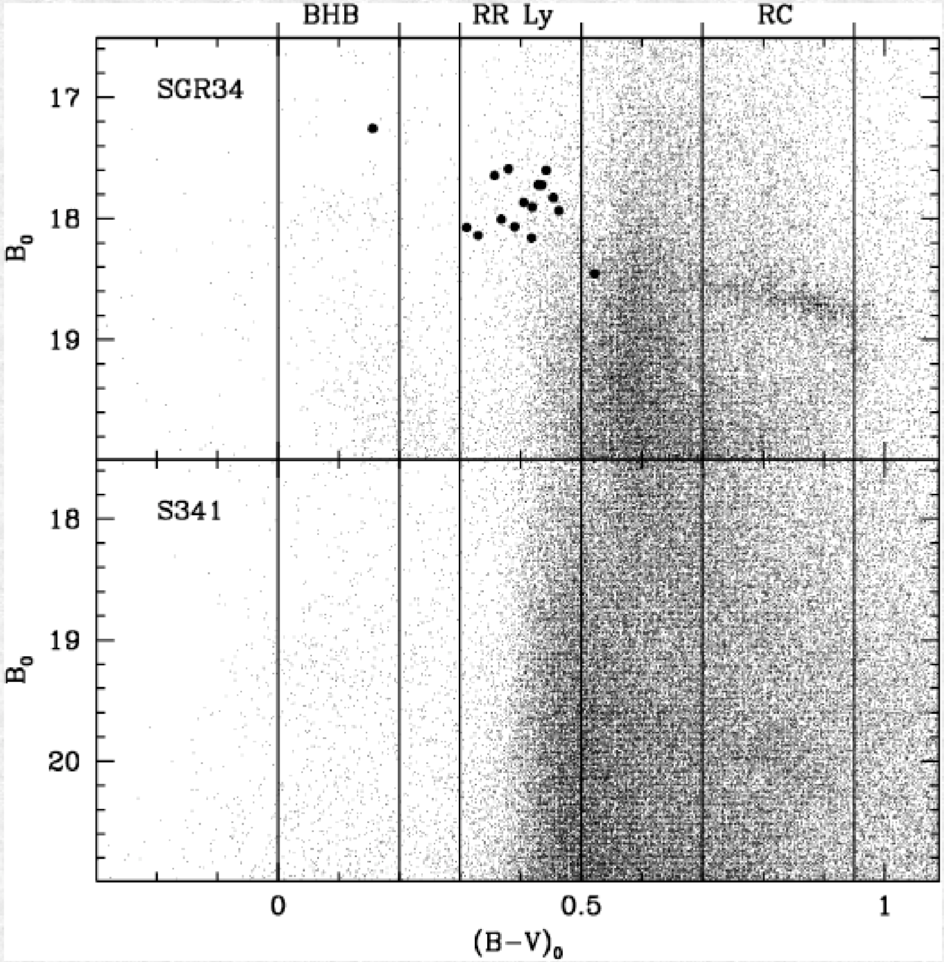
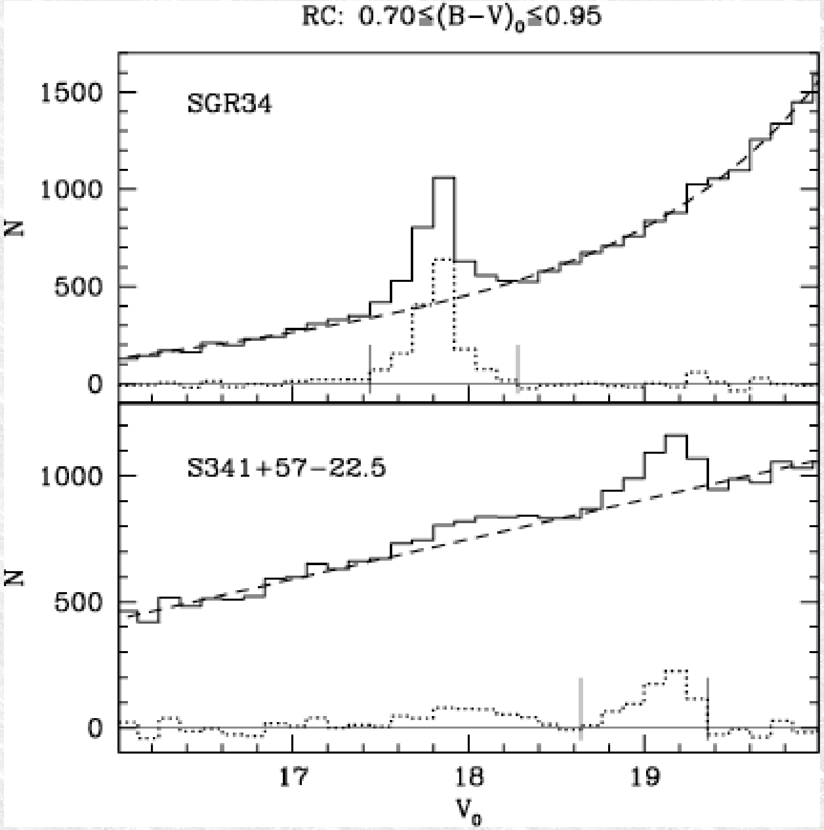
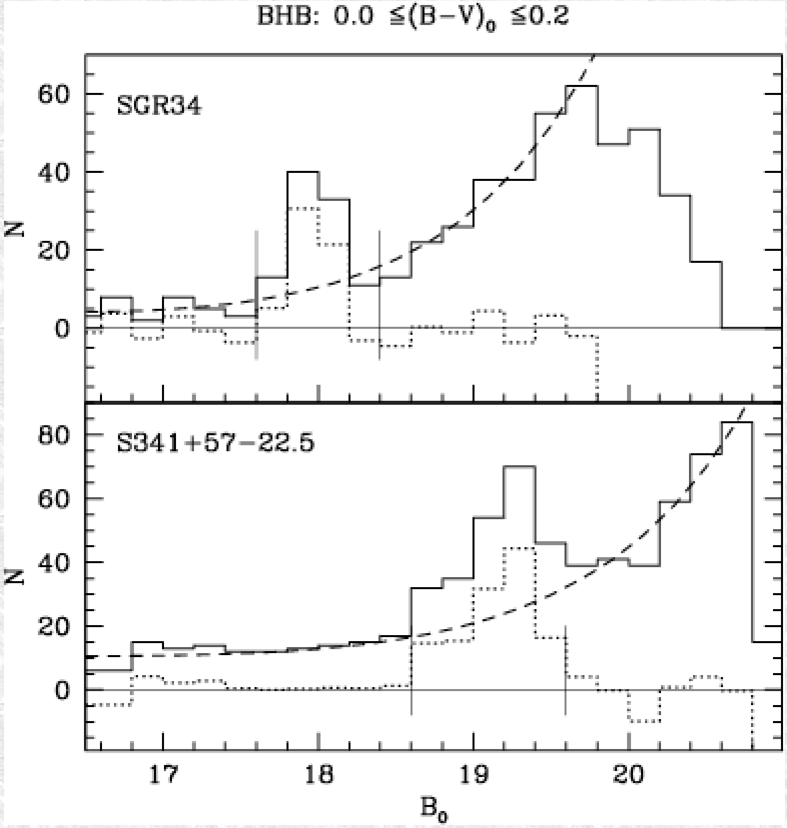


The Horizontal Branch morphology is a very powerful tool to study population gradients within galaxies

Bellazzini et al., 2006, A&A,457,L21

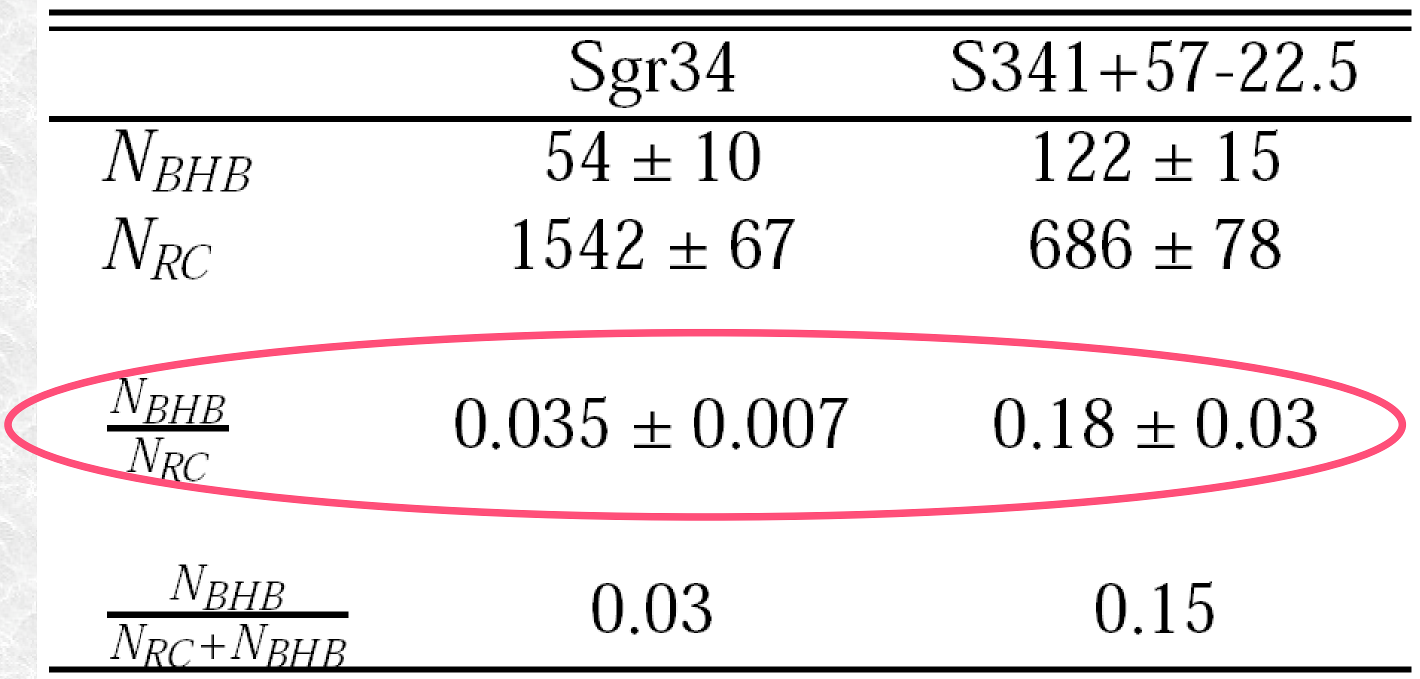
Population Gradient in the Sgr Stream





Bellazzini et al., 2006, A&A,457,L21

Population Gradient in the Sgr Stream



	Sgr34	S341+57-22.5
N_{BHB}	54 ± 10	122 ± 15
N_{RC}	1542 ± 67	686 ± 78
$\frac{N_{BHB}}{N_{RC}}$	0.035 ± 0.007	0.18 ± 0.03
$\frac{N_{BHB}}{N_{RC}+N_{BHB}}$	0.03	0.15

N_{BHB}/N_{RC} is 5 times higher in the stream than in the core

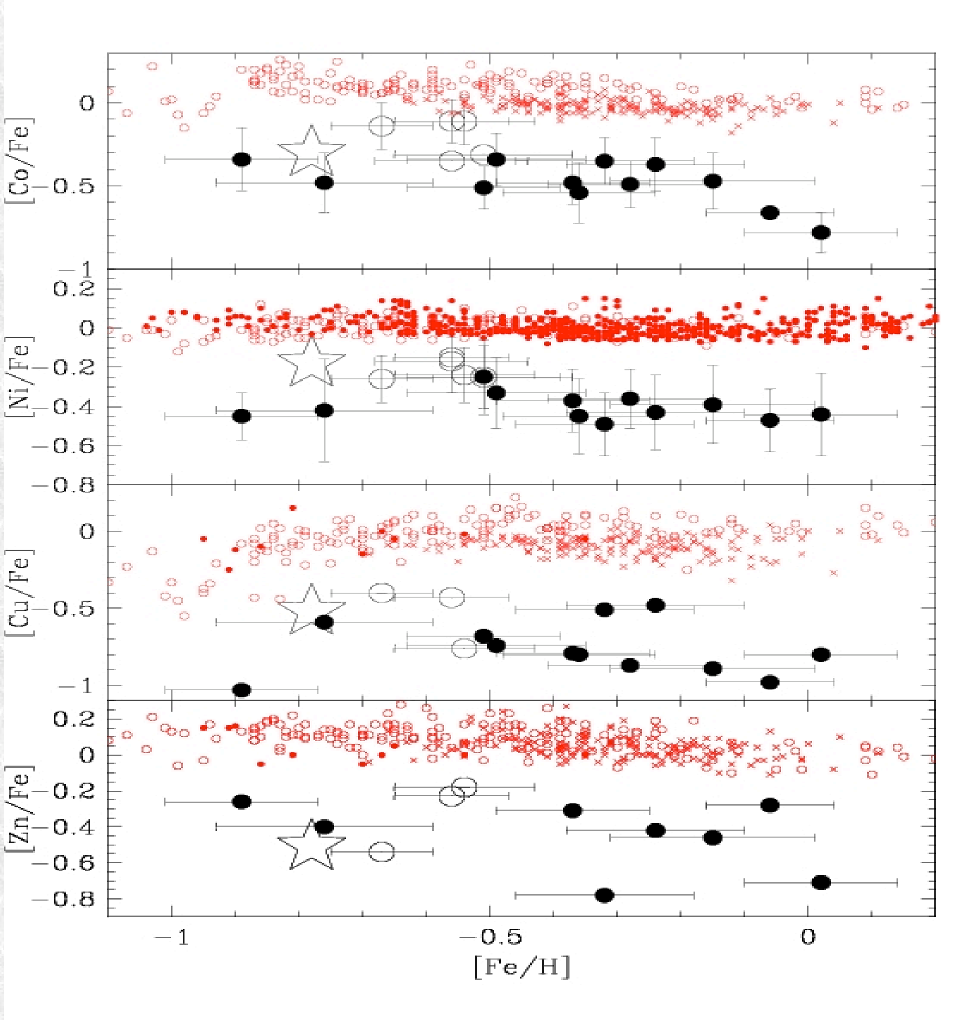
Bellazzini et al., 2006, A&A,457,L21

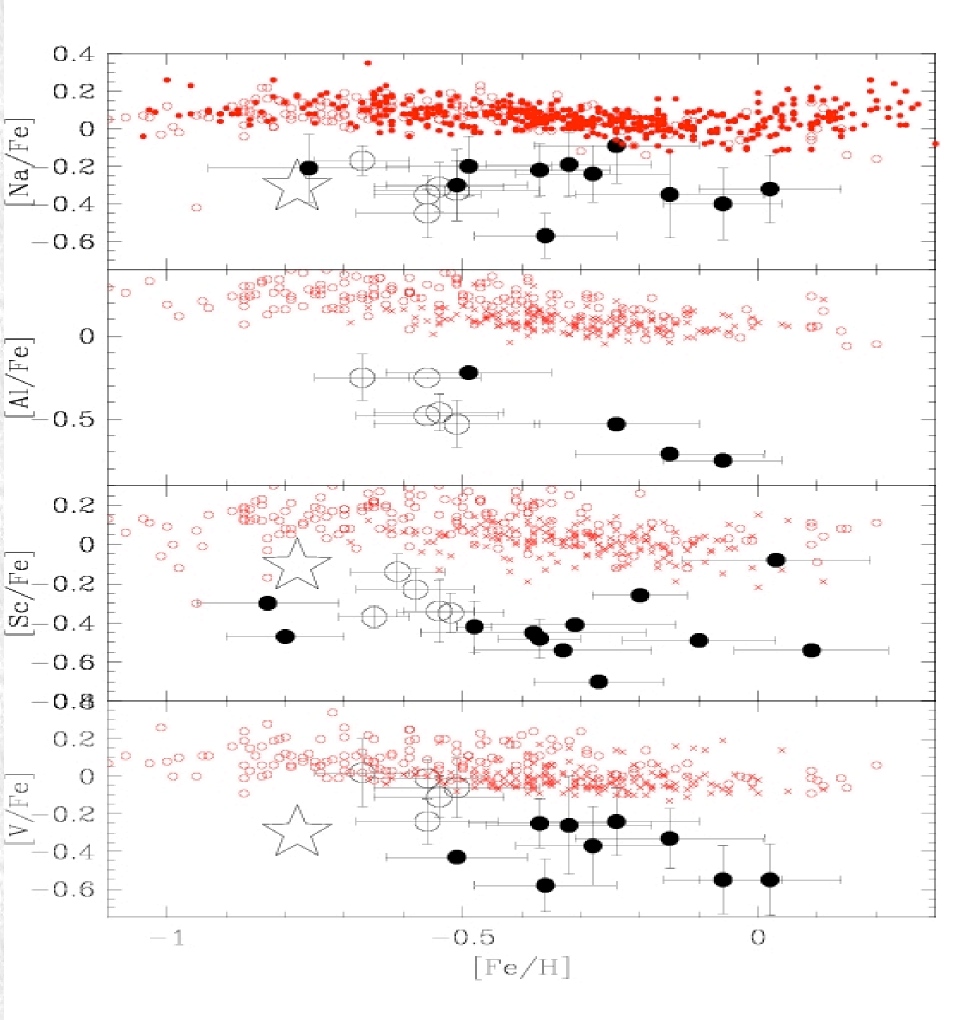
The Sgr Stream metallicity distribution is likely skewed toward even lower metallicities

then

Had Sgr contributed to the 'normal' galactic halo stellar population?

Detailed chemical abundances of RGB stars in the Sgr core





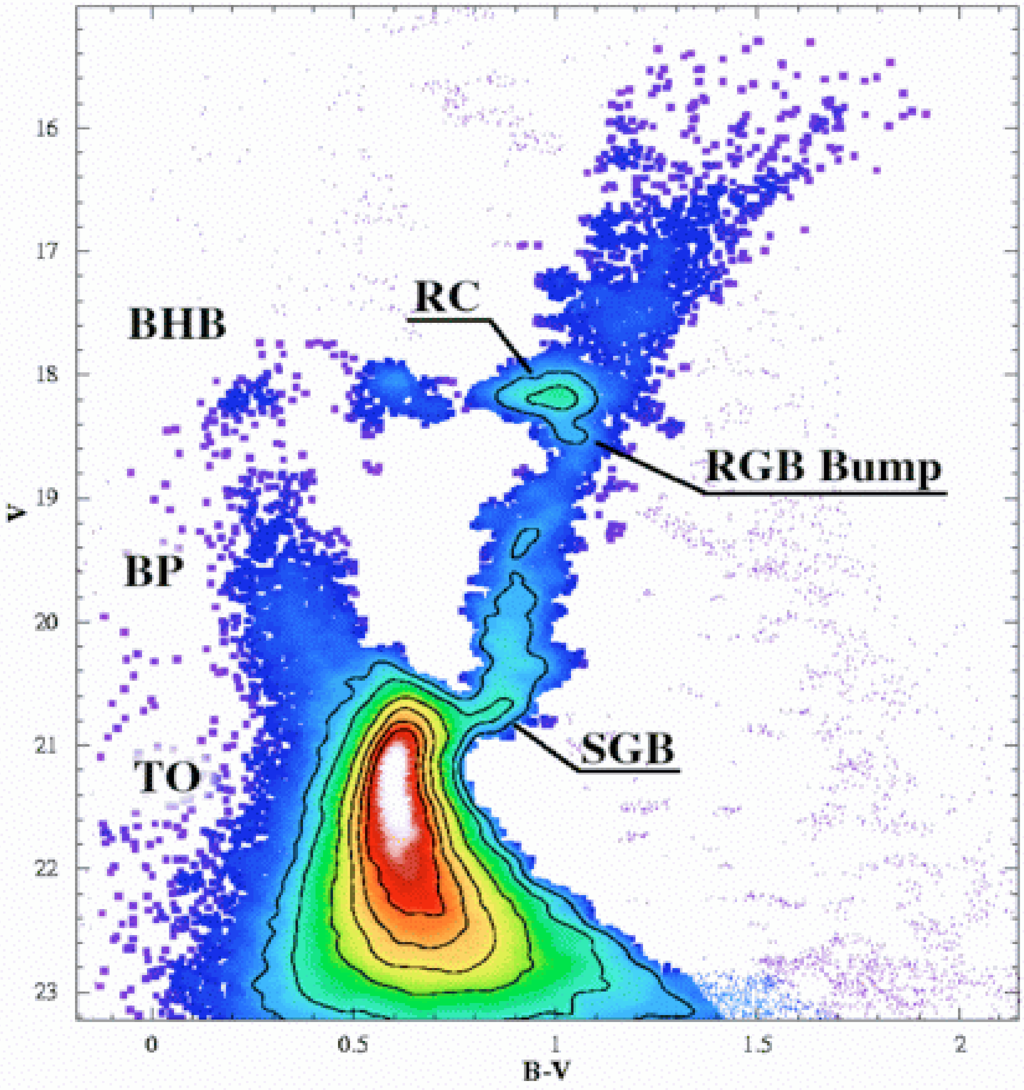
Sbordone et al. 2007

The M-Giants conundrum

- Sgr Stream M giants should be younger than 5 Gyr and a significant fraction of them have an age of 2-3 Gyr

- According to the N-body models which best reproduce the Sgr galaxy + Stream system we are observing in the Stream M giants that were torn apart from their parent galaxy up to 3.2 Gyr ago

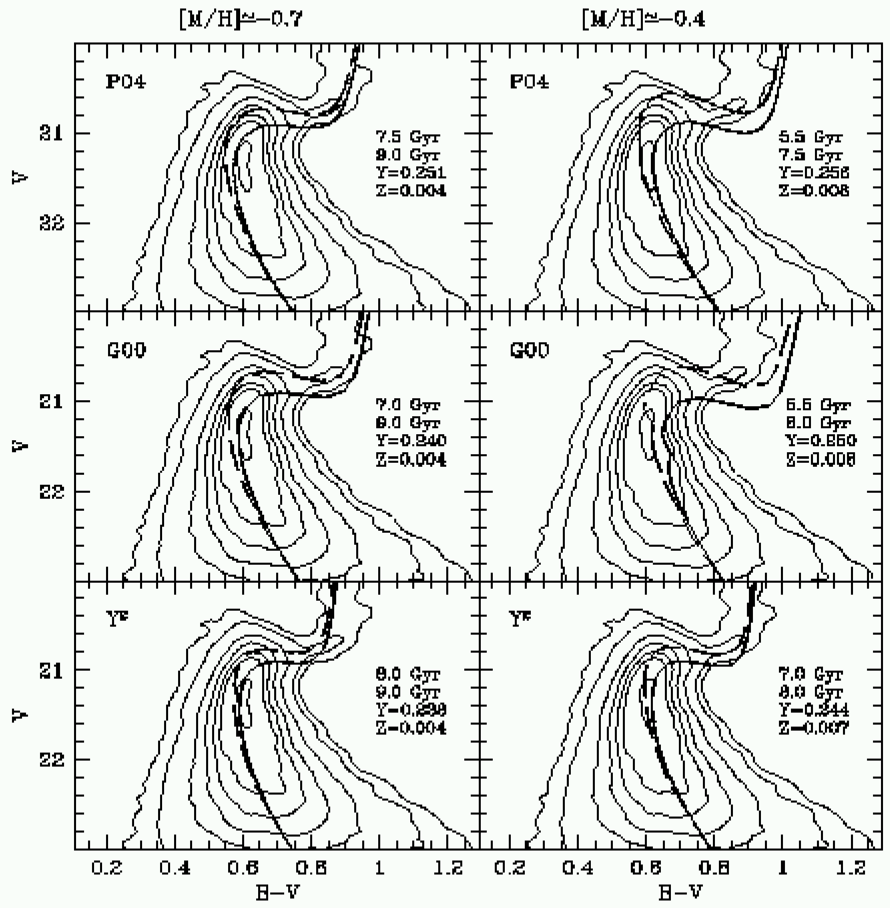
A possible inconsistency or at least a fine tuning problem: stars cannot be torn apart from a galaxy before their birth!



SGR34 region: 1x1 degree wide area

Statistically decontaminated CMD

Spectroscopic chemical abundances provide for the Sgr main population: [M/H]=-0.55 σ =0.22 (26 stars)



Age of the Sgr main population: 5.5-9.5 Gyr

Bellazzini et al., 2006, A&A, 446, L1

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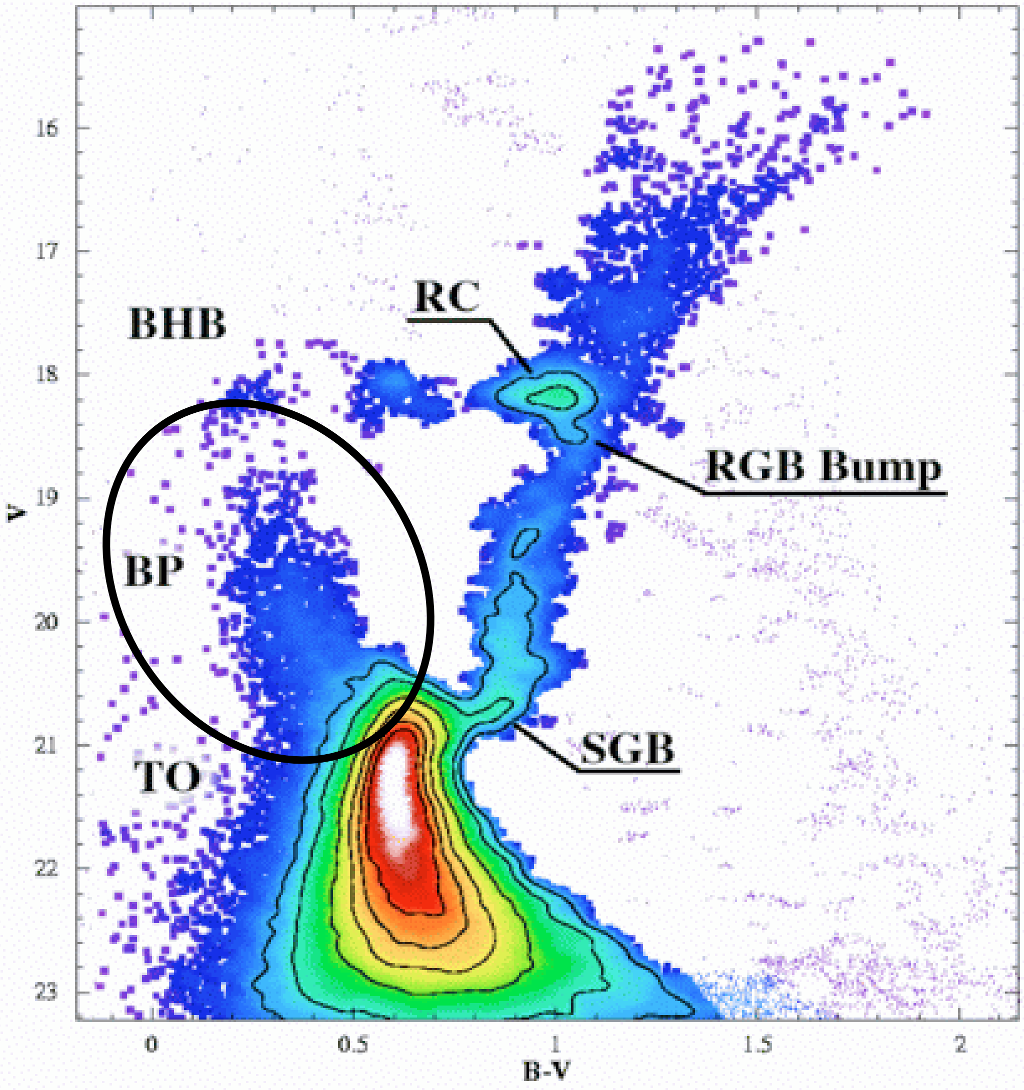

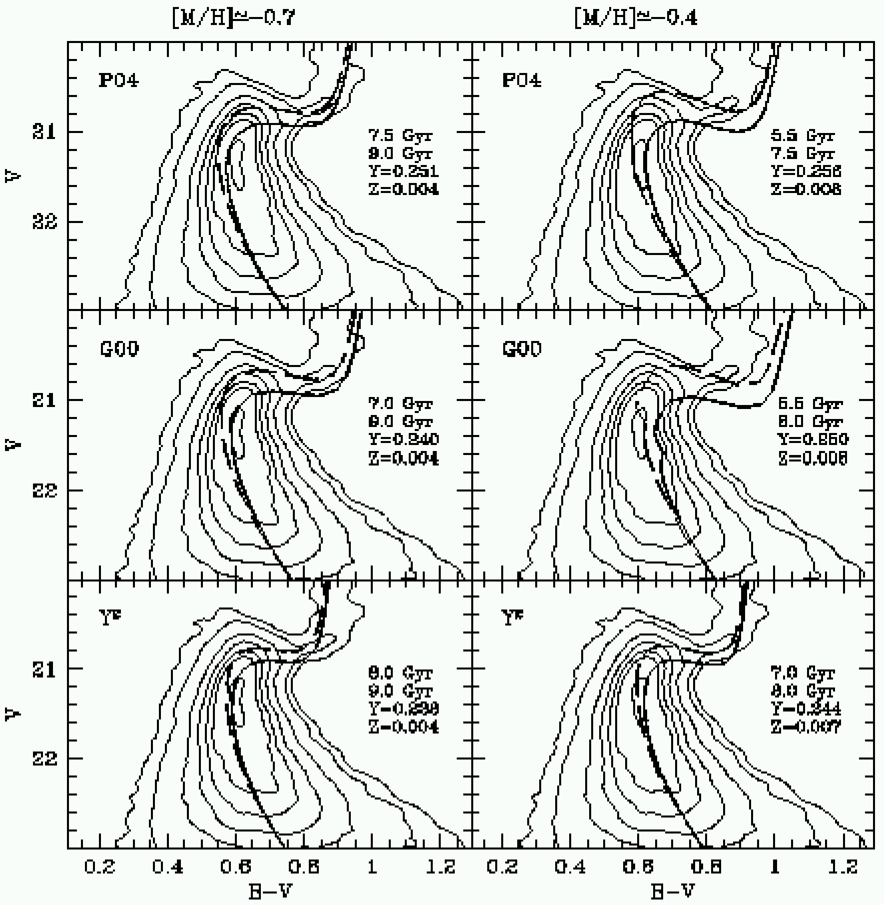

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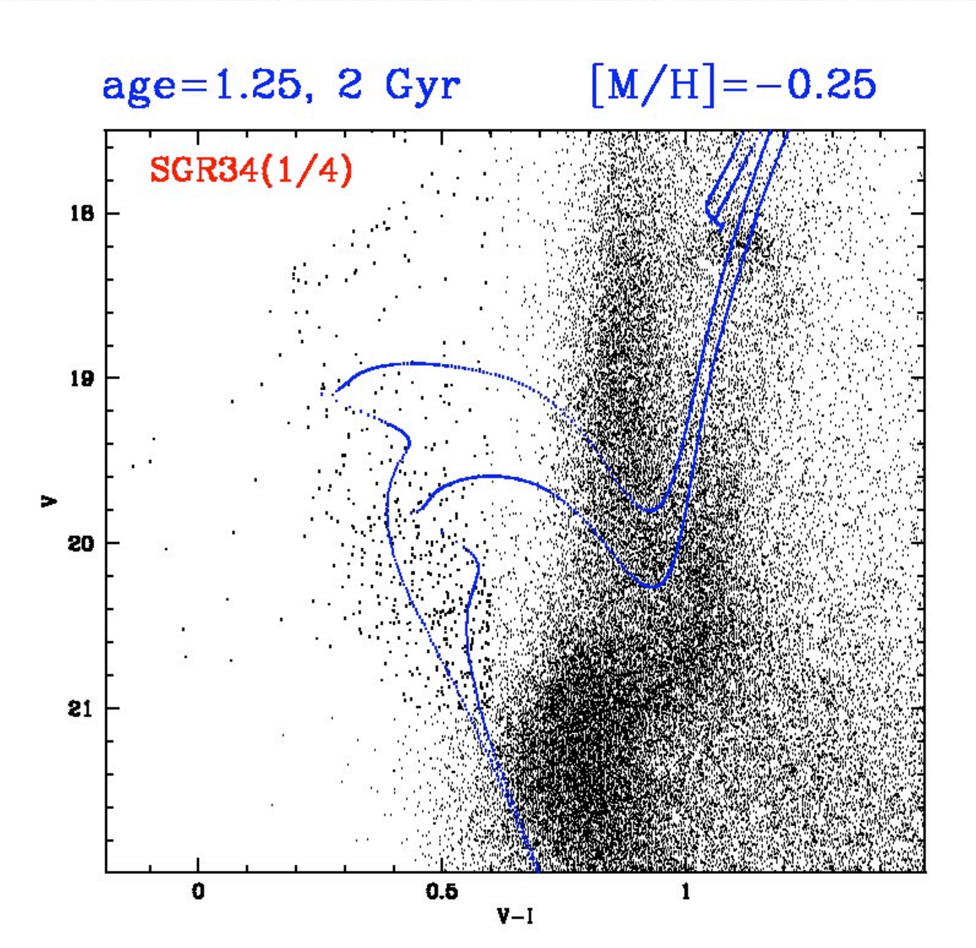

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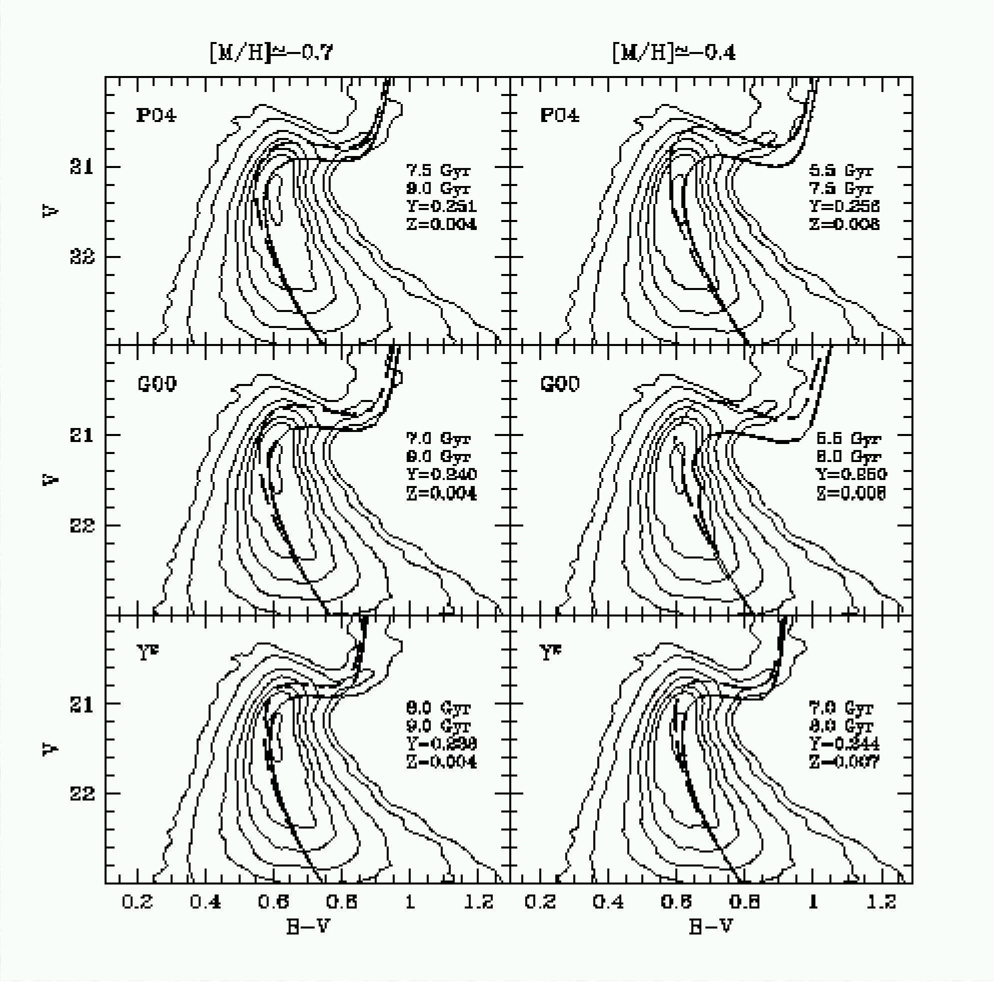

Age of the Sgr main population:
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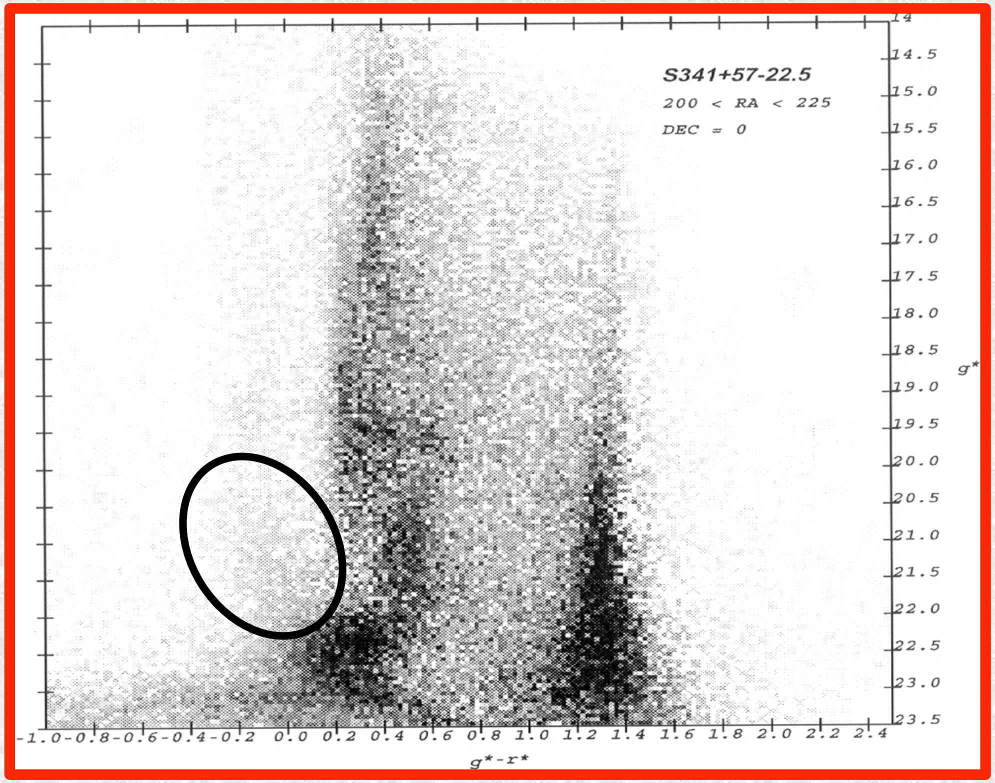
Bellazzini et al., 2006, A&A, 446, L1

...But...
The Blue Plume!

A true age conundrum? The BP is seen in all the regions of the Sgr Stream that have been sampled by the SDSS

BP stars may be BSS formed from primordial binaries (as those observed in the MW field).

$F=N_{BSS}/N_{HB}$ ~ 1 in Sgr, i.e. the same as in the loose cluster NGC 288 where NO BSS is expected to be formed by collisions.



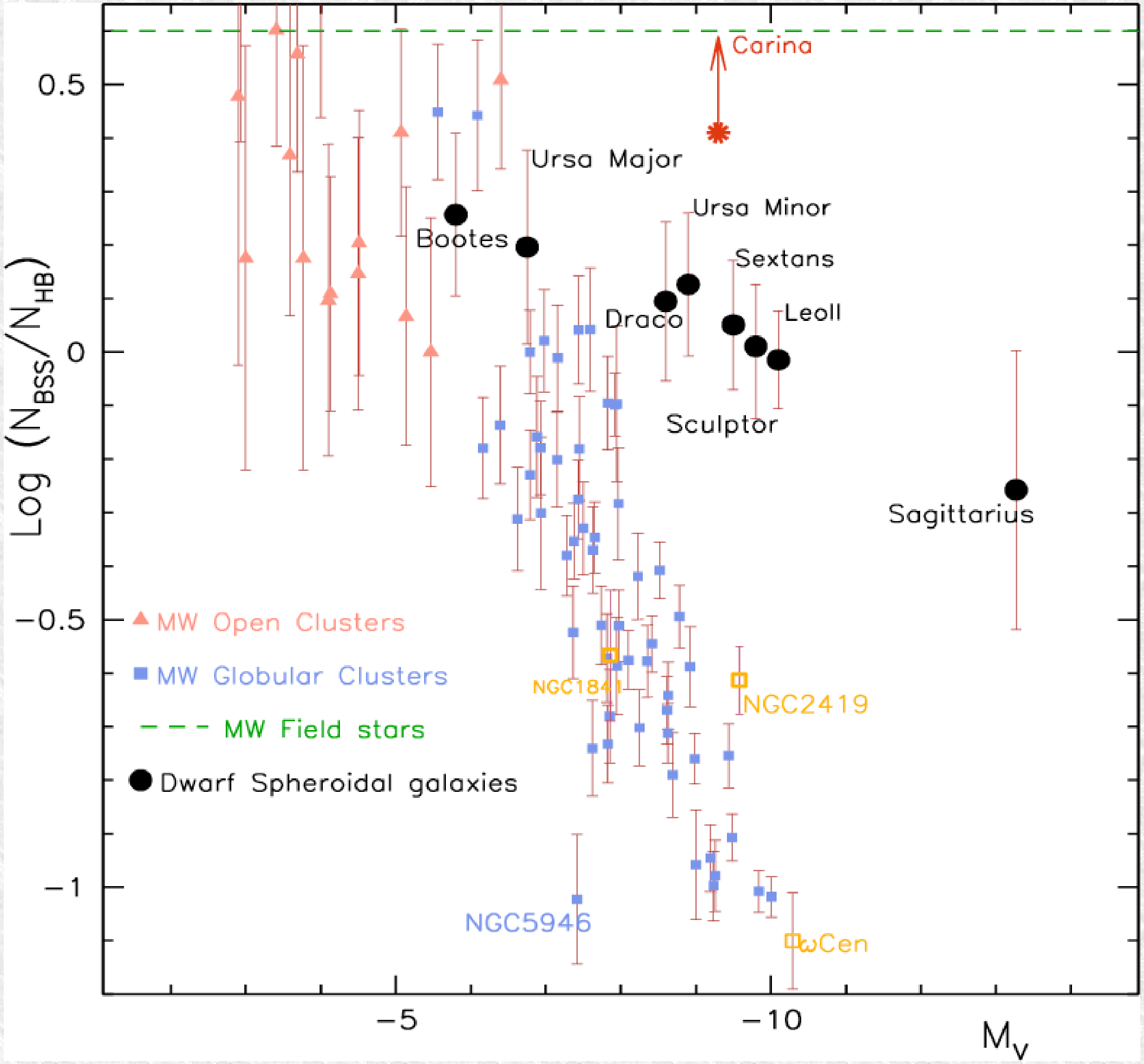
Newberg et al. 2002

A binary origin for stars in the Blue Plume of dSphs ?

The N_{BSS}/N_{HB} vs M_V anticorrelation

observed in dSphs may suggest a binary origin for stars in the BP

Momany et al. 2007



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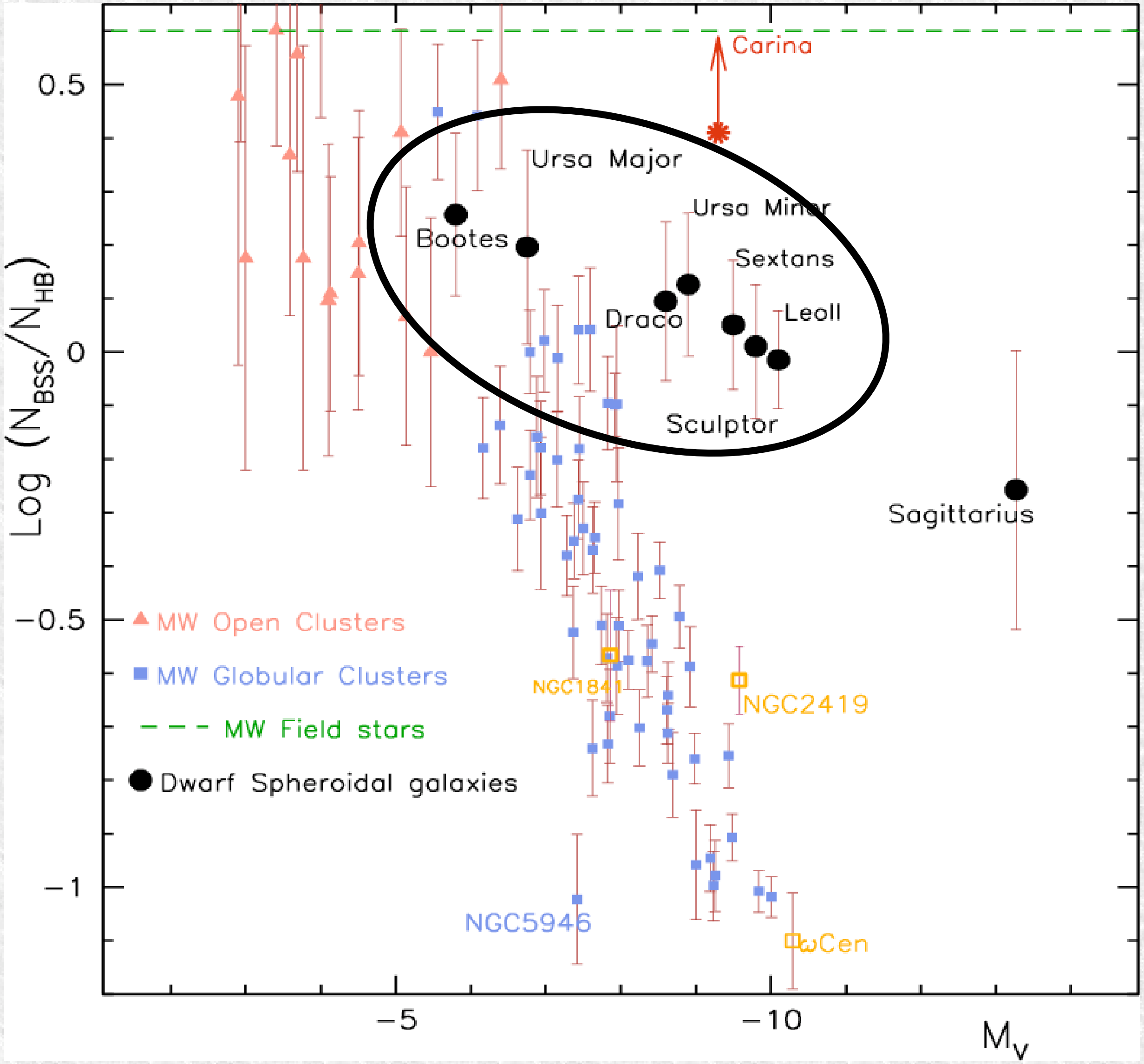


Part II Conclusions: The Sgr Stream

- Sgr Stream stars follow the same trend as core stars in the [α /Fe] *vs* [Fe/H] plane

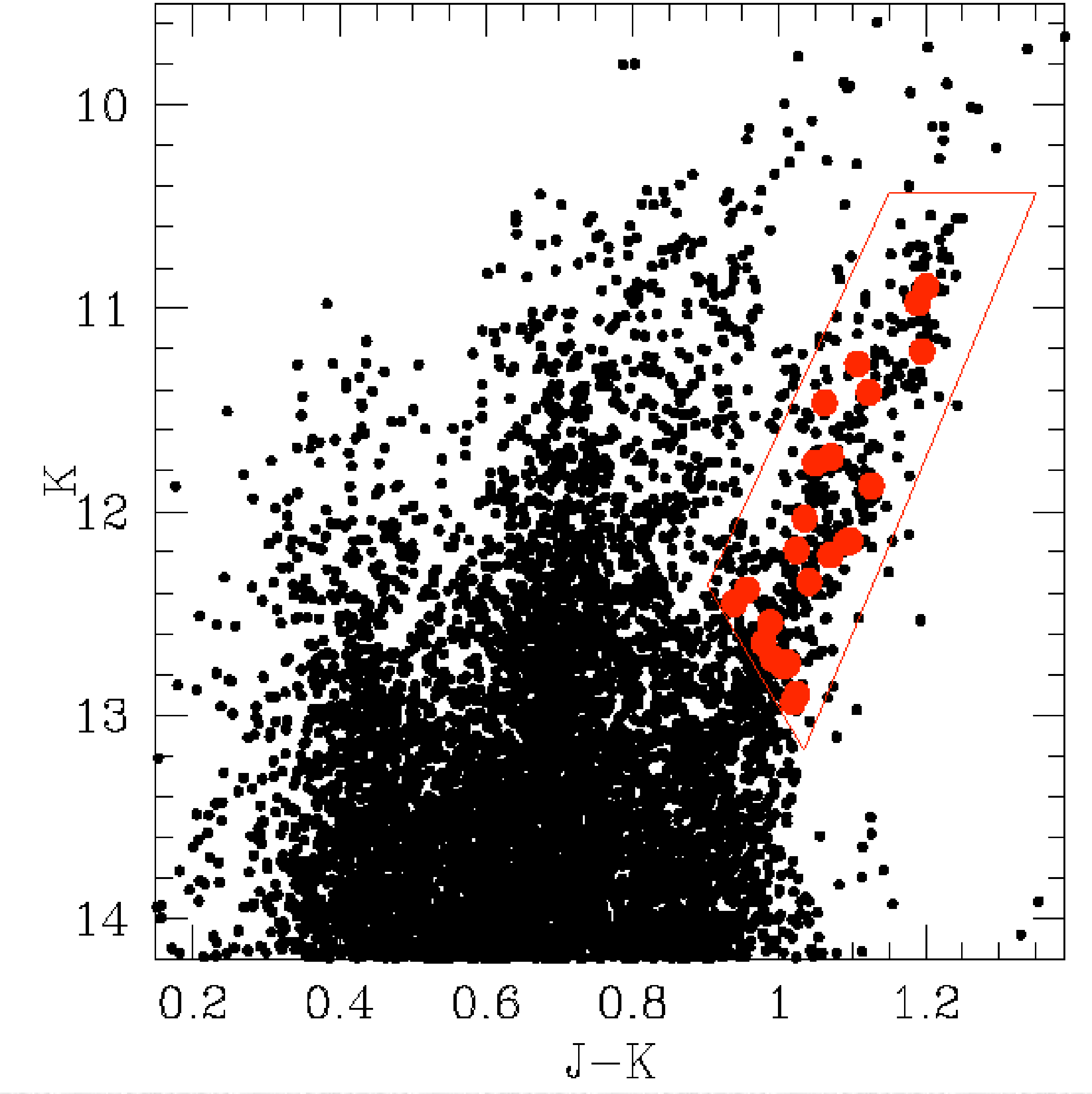
- Sgr stars are – on average – more metal poor in the Stream than in the core

- The fraction of metal poor stars to the dominant metal rich population increases significantly in the streams with respect to the core

The Ital-FLAMES survey of Sgr

FLAMES-UVES sample selected using the 2MASS photometry.
We peaked-up the Sgr dominant population.
23 stars (over 24 observed) are radial velocity members.

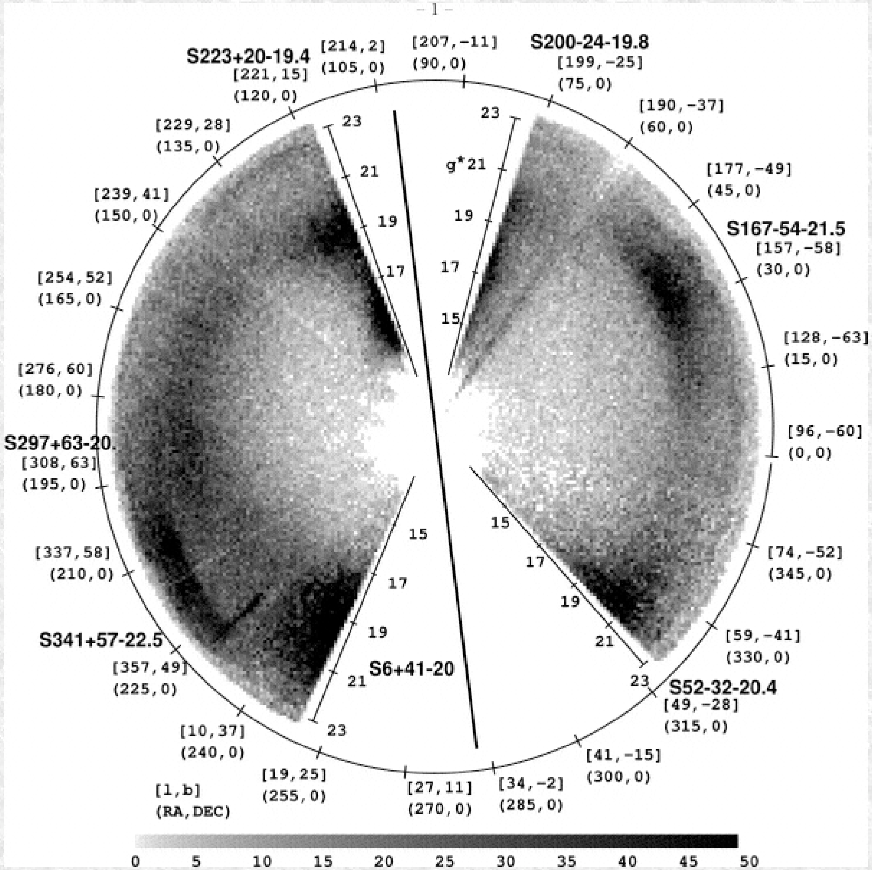
Monaco et al. 2005,
A&A, 441, 141



Equatorial Slices:
RA and g*/K

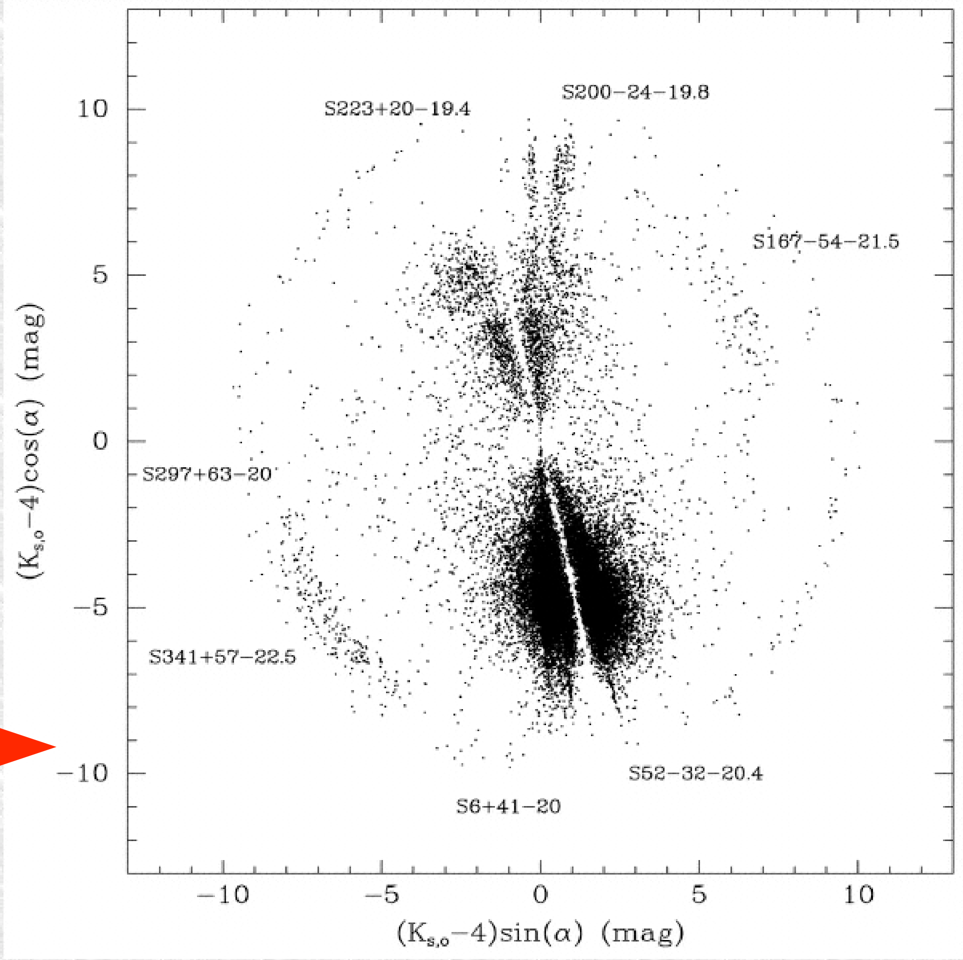
SDSS

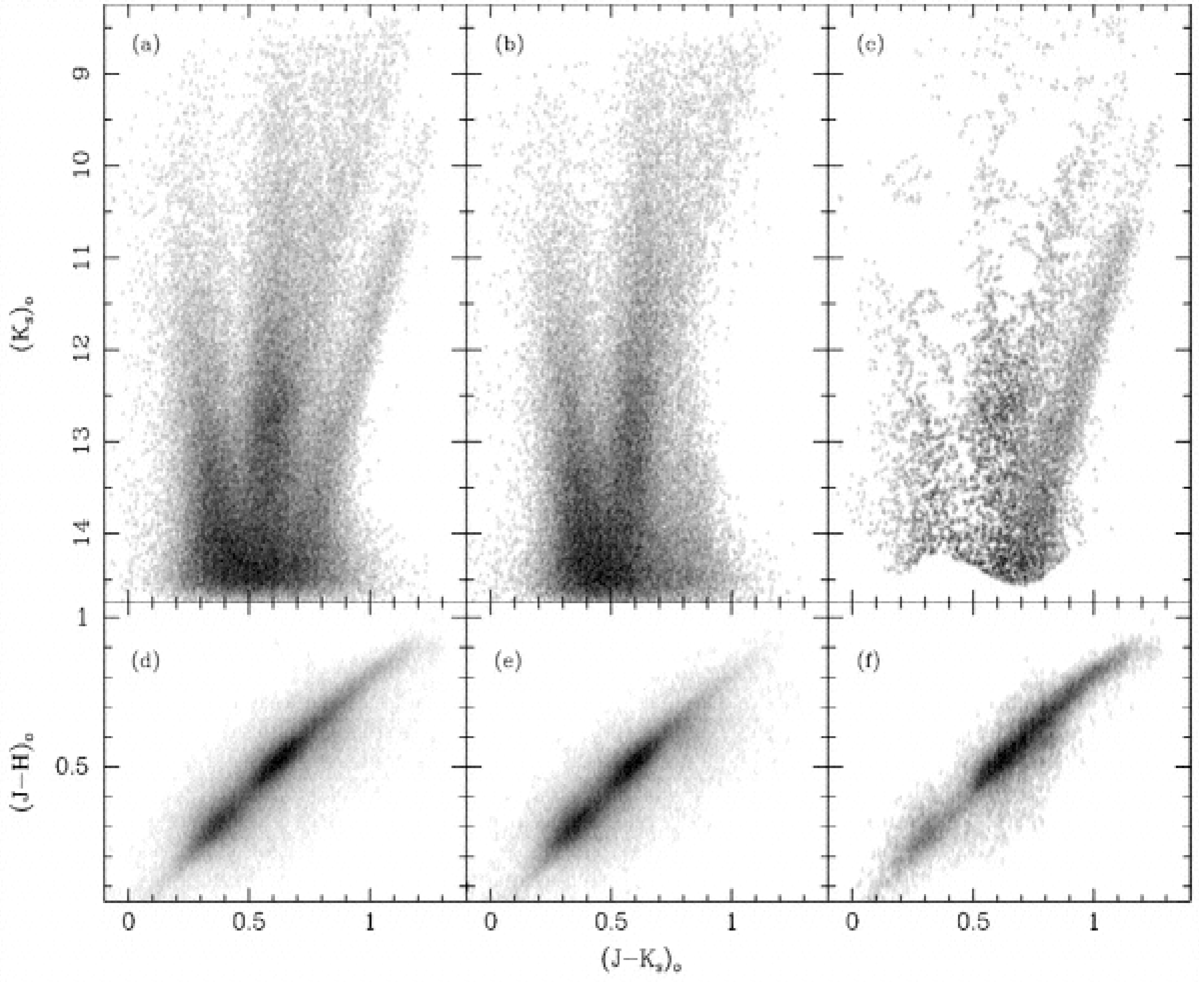
Newberg et al 2002



2MASS

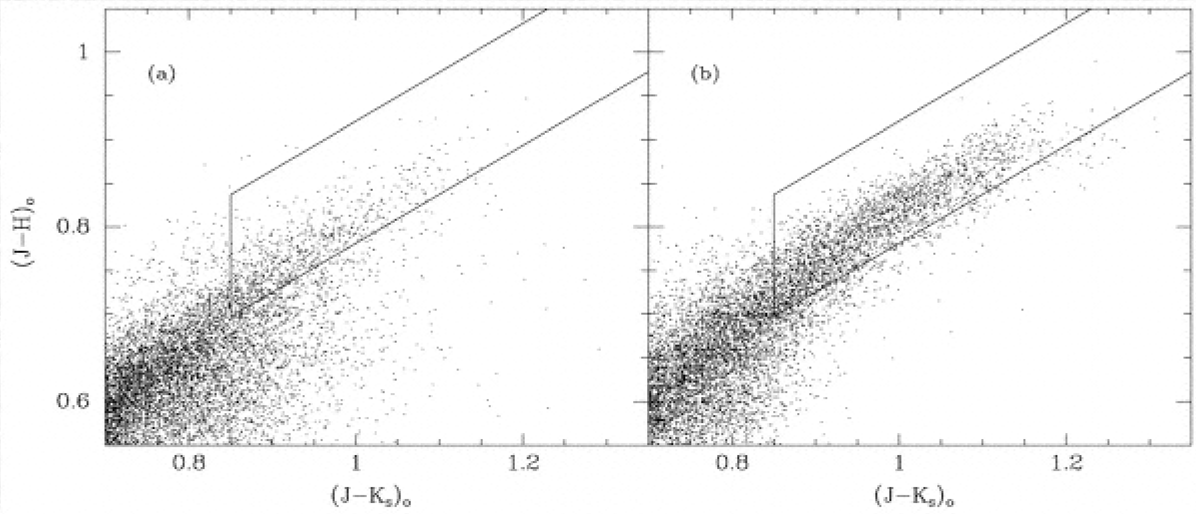
Majewski et al 2003





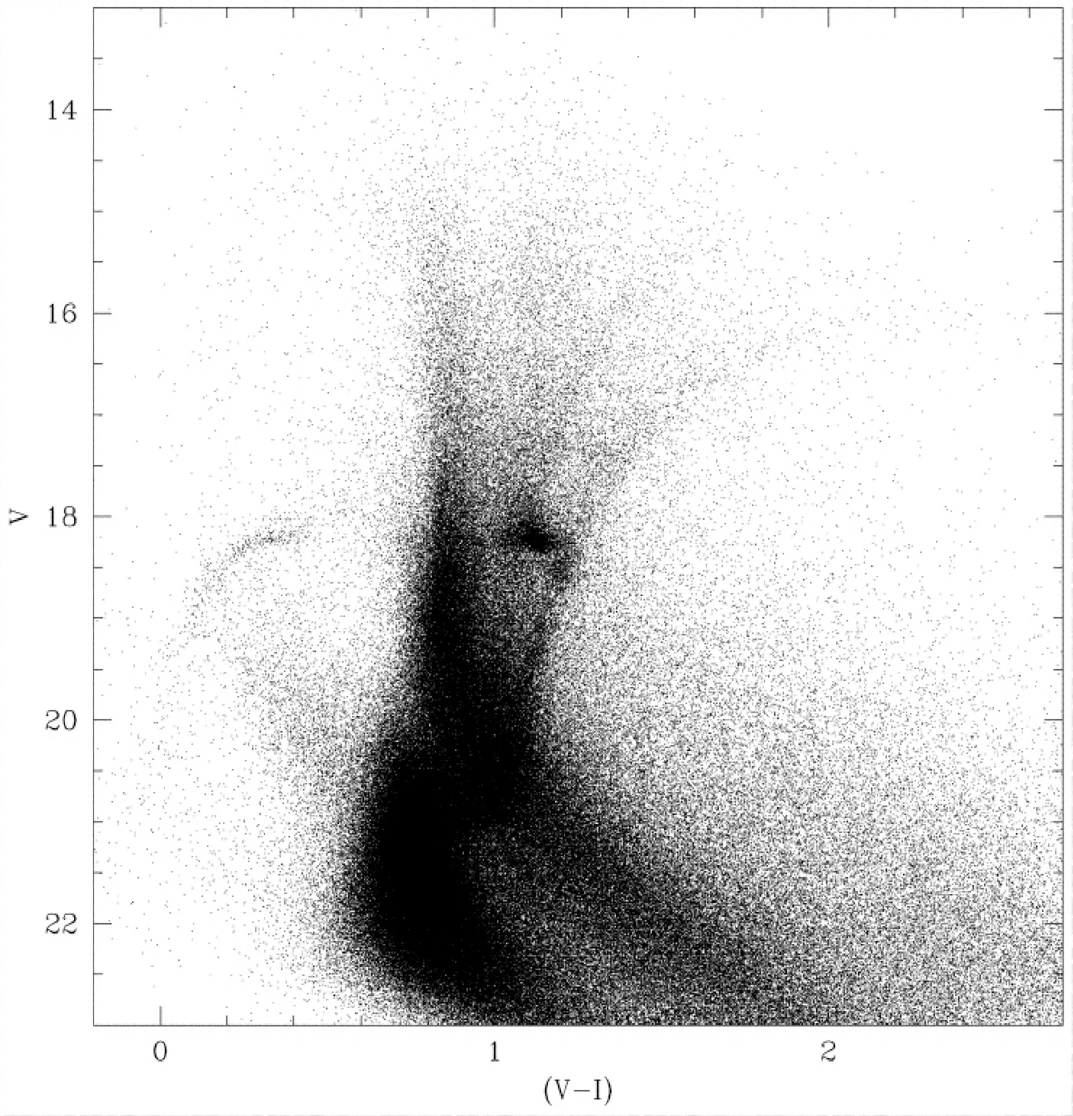
The upper Sgr RGB stands out very clearly from the contaminating MW field in the infrared 2MASS CMD

It is possible to define a color-color relation which select 'likely' Sgr member stars



Majewski et al. 2003

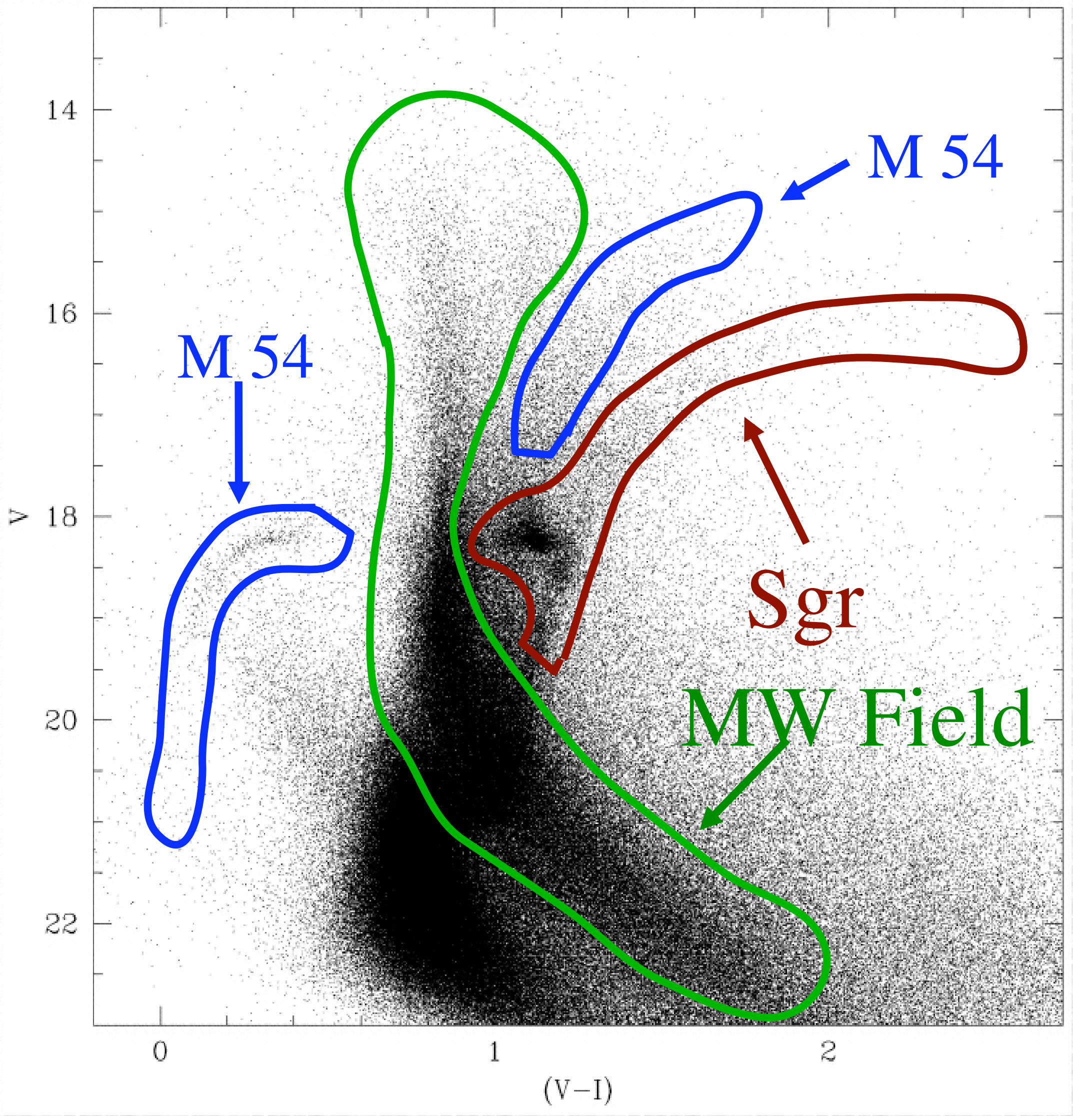
Wide Field Photometry



- The largest database ever obtained: V,I photometry of ~490.000 stars
- Three main contributors to the observed CMD: Field – M54 – Sgr

Monaco et al 2002

Wide Field Photometry



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