The Gaia-ESO Public Spectroscopic Survey

a lesson for our community in use of limited telescope access

Gerry Gilmore

Sofia Randich

Gaia-ESO Co-PIs

We have Gaia! We want more…

- Gaia will provide 60 million spectra to V=15.2
- Many ambitious ground-based projects plan to complement the Gaia astrometry
- Weave, 4most …+ AAT, lamost, US…
- eg MOONS contract signed 25/09
- One precursor is the Gaia-ESO Spectroscopic Survey http://www.gaia-eso.eu

Gaia-ESO Survey

300+ VLT-night survey of Galaxy stellar pops

- Co-PIs Gerry Gilmore, Sofia Randich
- +400 Co-Is, 90+ Institutes across all ESO

- 19 Working Groups
- active wiki internal communications – 100-800 views/day
- ~110 Co-I science projects listed in wiki

- DR1 data release through ESO completed
- 25+ refereed papers published or in late draft (+archive)
- Big ESO DR2 due in a few months

http://gaia-eso.eu (public survey pages)
http://casu.ast.cam.ac.uk/gaiaeso/
http://great.ast.cam.ac.uk/GESwiki/GESHome
http://ges.roe.ac.uk (public archive)

The Gaia-ESO Spectroscopic Survey

This is an ambitious Survey

1st large telescope stellar survey

1st use of multiple reductions

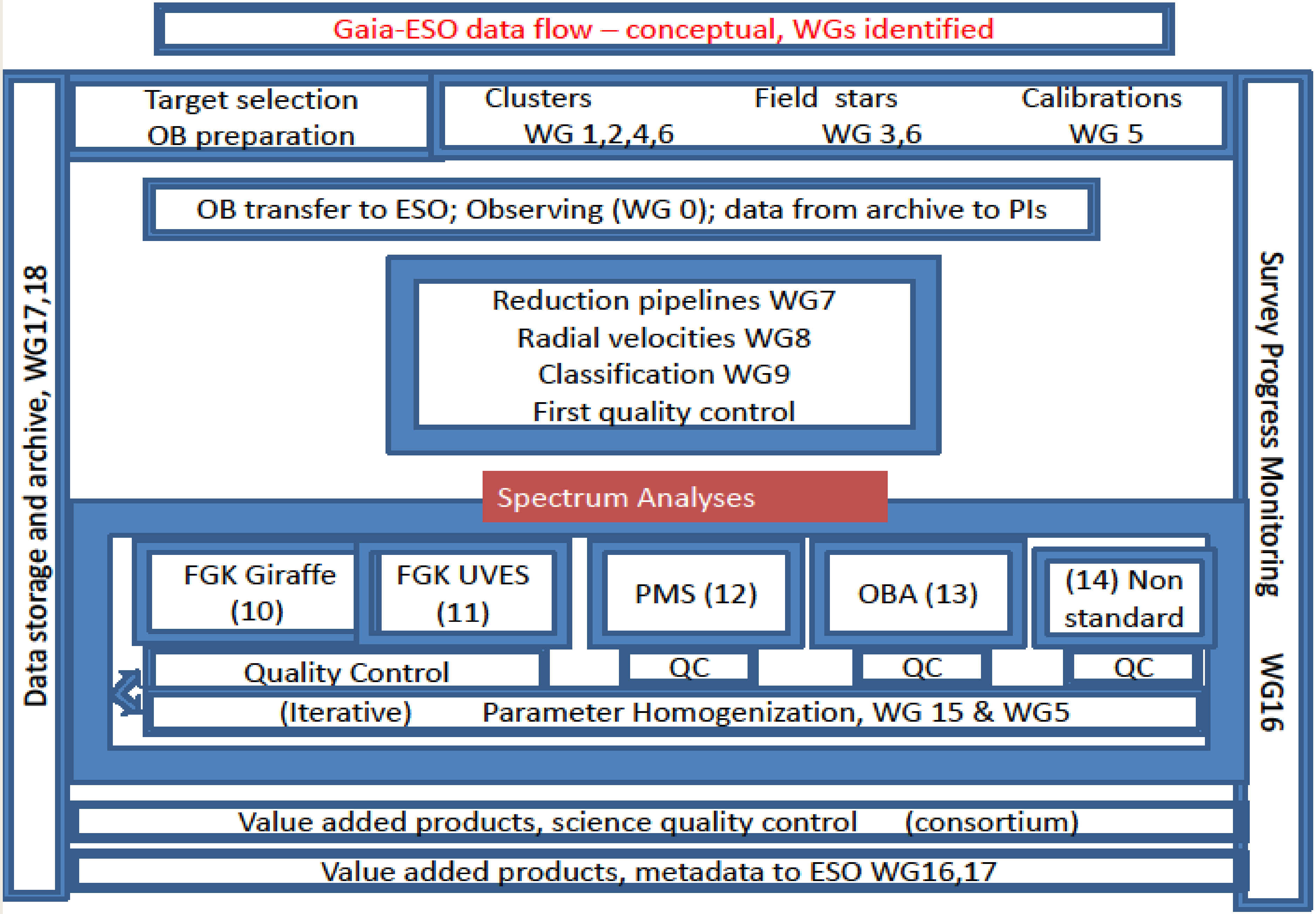
1st to target all populations

400+ Co-I's
95+ Institutes

Co-PIs: Gerry Gilmore[1370], Sofia Randich[1335]

CoIs: M. Asplund[1490], J. Binney[1611], P. Bonifacio[1588], J. Drew[1668], S. Feltzing[1473], A. Ferguson[1649], R. Jeffries[1132], G. Micela[1344], I. Negueruela[7609], T. Prusti[1278], H-W. Rix[1489], A. Vallenari[1343], D. Aden[1473], L. Affer[1344], J-M. Alcala[1340], E. Alfaro[1392], C. Allende Prieto[1393], G. Altavilla[7530], J. Alves[1893], T. Antoja[1422], F. Arenou[1588], C. Argiroffi[1883], A. Asensio Ramos[1393], C. Babusiaux[1588], C. Bailer-Jones[1489], L. Balaguer-Nunez[1821], B. Barbuy[1828], G. Barisevicius[1376], D. Barrado y Navascues[1088], C. Battistini[1473], I. Bellas-Velidis[1555], M. Bellazzini[1329], V. Belokurov[1370], T. Bensby[1473], M. Bergemann[1490], G. Bertelli[1343], K. Biazzo[1335], O. Bienayme[1582], J. Bland-Hawthorn[2044], R. Blomme[1650], C. Boeche[2112], S. Bonito[1344], S. Boudreault[1242], J. Bouvier[1449], A. Bragaglia[1337], I. Brandao[1200], A. Brown[1716], J. de Brujine[1278], M. Burleigh[1244], J. Caballero[8545], E. Caffau[2112], F. Calura[1197], R. Capuzzo-Dolcetta[1857], M. Caramazza[1344]. G. Carraro[1261], L. Casagrande[1490], S. Casewell[1244], S. Chapman[1370], C. Chiappini[1135], Y. Chorniy[1376], N. Christlieb[1982], M. Cignoni[7530], G. Cocozza[7530], M. Colless[1017], R. Collet[1490], M. Collins[1489], M. Correnti[1329], E. Covino[1340], D. Crnojevic[1649], M. Cropper[1242], M. Cunha[1200], F. Damiani[1344], M. David[1233], A. Delgado[1392], S. Duffau[2112], S. Van Eck [1358], B. Edvardsson[6181], H. Enke[1135], K. Eriksson[2079], N.W. Evans[1370], L. Eyer[1377], B. Famaey[1582], M. Fellhauer[1824], I. Ferreras[1242], F. Figueras[1821], G. Fiorentino[1422], E. Flaccomio[1344], C. Flynn[2044], D. Folho[1200], E. Franciosini[1335], P. Francois[1588], A. Frasca[1341], K. Freeman[1139], Y. Fremat[1650], B. Gaensicke[1241], J. Gameiro[1200], F. Garzon[1393], S. Geier[5677], D. Geisler[1824], B. Gibson[1197], A. Gomboc[1995], A. Gomez[1588], C. Gonzalez-Fernandez[7609], J. Gonzalez Hernandez[1393], E. Grebel[2112], R. Greimel[1423], M. Groenewegen[1650], F. Grundahl[1368], M. Guarcello[1312], B. Gustafsson[2079], P. Hadrava[1116], D. Hadzidimitriou[1559], N. Hambly[1649], P. Hammersley[1258], C. Hansen[2112], M. Haywood[1588], U. Heber[5677], U. Heiter[6181], A. Helmi[1422], G. Hensler[1893], A. Herrero[1393], V. Hill[1591], S. Hodgkin[1370], N. Huelamo[8545], A. Huxor[2112], R. Ibata[1582], M. Irwin[1370], R. Jackson[1132], R. de Jong[1135], P. Jonker[1660], S. Jordan[2112], C. Jordi[1821], A. Jorissen[1358], D. Katz[1588], D. Kawata[1242], S. Keller[1139], N. Kharchenko[1135], R. Klement[1489], A. Klutsch[1803], J. Knude[1966], A. Koch[1244], O. Kochukhov[6181], M. Kontizas[1560], S. Koposov[1370], A. Korn[6181], P. Koubsky[1116], A. Lanzafame[1874], R. Lallement[1588], P. de Laverny[1591], F. van Leeuwen[1370], B. Lemasle[1422], G. Lewis[2044], K. Lind[1490], H.P.E. Lindstrom[1966], J. Lopez santiago[1803], P. Lucas[1668], H. Ludwig[2112], T. Lueftinger[1893], L. Magrini[1335], J. Maiz Apellaniz[1392], J. Maldonado[1803], G. Marconi[1261], G. Matijevic[1995], R. McMahon[1370], S. Messina[1341], M. Meyer[1377], A. Miglio[1359], S. Mikolaitis[1376], I. Minchev[1135], D. Minniti[1801], A. Moitinho[8848], N. Molawi[1583], Y. Momany[1261], L. Monaco[1261], M. Montalto[1200], M.J. Monteiro[1200], R. Monier[5695], D. Montes[1803], A. Mora[1350], E. Moraux[1449], T. Morel[1359], A. Morino[1490], N. Mowlavi[1583], A. Mucciarelli[7530], U. Munari[1343], R. Napiwotzki[1668], N. Nardetto[1824], T. Naylor[1130], G. Nelemans[1638], S. Okamoto[1616], S. Ortolani[6311], G. Pace[1200], F. Palla[1335], J. Palous[1116], E. Pancino[1337], R. Parker[1377], E. Paunzen[1893], J. Penarrubia[1828], I. Pillitteri[1312], G. Piotto[1343], H. Posbic[1588], L. Prisinzano[1344], E. Puzeras[1376], A. Quirrenbach[2112], S. Ragaini[7530], D. Ramano[1337], J. Read[1377], M. Read[1649], A. Recio-Blanco[1591], C. Reyles[1592], N. Robichon[1588], A. Robin[1592], S. Roeser[2112], F. Royer[1588], G. Ruchti[1490], A. Ruzicka[1116], S. Ryan[1668], N. Ryde[1473], G. Sacco[1645], N. Santos[1200], J. Sanz Forcada[1456], L.M. Sarro Baro[5688], L. Sbordone[1139], E. Schilbach[2112], S. Schmeja[2112], O. Schnurr[1135], R. Schoenrich[1490], R-D. Scholz[1135], G. Seabroke[1242], S. Sharma[2044], G. De Silva[1017], R. Smiljanic[1258], M. Smith[1616], E. Solano[8545], C. Soubiran[1592], S. Sousa[1200], A. Spagna[1346], M. Steffen[1135], M. Steinmetz[1135], B. Stelzer[1344], E. Stempels[6181], H. Tabernero[1803], G. Tautvaisiene[1376], F. Thevenin[1591], J. Torra[1821], M. Tosi[1337], E. Tolstoy[1422], C. Turon[1588], M. Walker[1312], N. Walton[1370], J. Wambsganss[2112], C. Worley[1591], K. Venn[2061], J. Vink[1111], R. Wyse[1419], S. Zaggia[1343], W. Zeilinger[1893], M. Zoccali[1801], J. Zorec[1361], D. Zucker[1477], T. Zwitter[1995]

A survey requires complementary skills



Gaia-ESO core philosophy

- Involve all spectroscopic analysis methods
- Identify the dominant systematic variables, and fix them – version control
- Analyse spectra through all interested groups
- In principle, this allows us to identify both systematic method errors and random errors
- ➔ parameter +/- random +/- systematic

- Here's my explanation of the [Mg/Fe] difference between the 2010 paper
- and the current (2012) value, beginning with an extract from the table
- ____
- ___ All lines Blue & Red ________Only lines redder than 4800A___
- (see Tab 2 ApJ, 711, 350)
- log(eps) s.e. Nlines log(eps) s.e. Nlines Delta log(eps)
- ____
- Mg I 4.34 0.10 8 4.20 0.02 3 0.14
- Fe I 3.79 0.02 81 3.84 0.03 35 -0.05
- ____
- The relevant data by our publication year are:
- Year 2010 2012
- logeps(Mg) 4.34 4.20
- logeps(Fe) 3.79 3.84
- logeps(Mg)sun 7.53* 7.60#
- logeps(Fe)sun 7.45* 7.50#

- * = Asplund (2005); # = Asplund (2009)
- ____
- Then
- [Mg/Fe] = (logeps(Mg)-logeps(Mg)sun) - (logeps(Fe)-logeps(Fe)sun)
- In 2010 we have
- [Mg/Fe] = (4.34-7.53) - (3.79-7.45) = 0.47
- and in 2012
- [Mg/Fe] = (4.20-7.60) - (3.84-7.50) = 0.26

All data must be calibrated –
that means systematics, and changes,
which need careful consideration
This from Venn etal ApJ

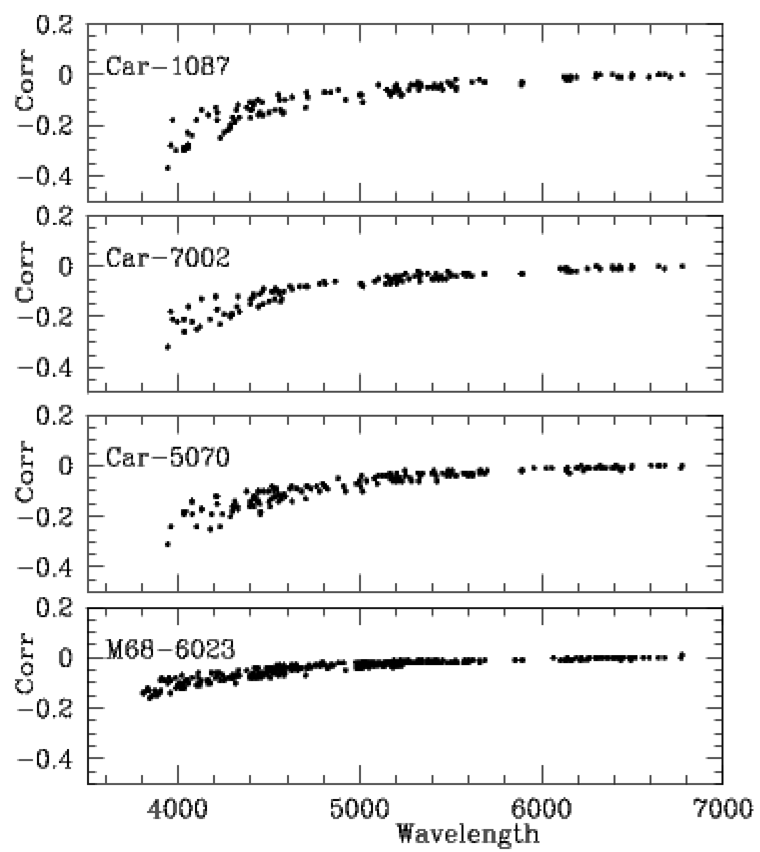


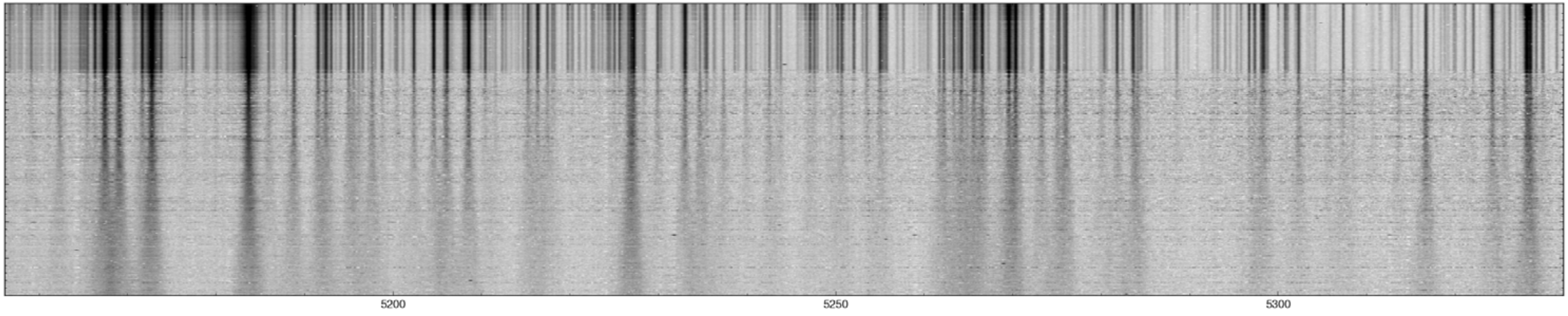
FIG. 5.— A comparson of the line abundance *corrections* from MOOG-SCAT for one of the M68 standard star and the three most metal-poor stars in Carina. The y-label "Corr" = MOOG-SCAT − MOOG.

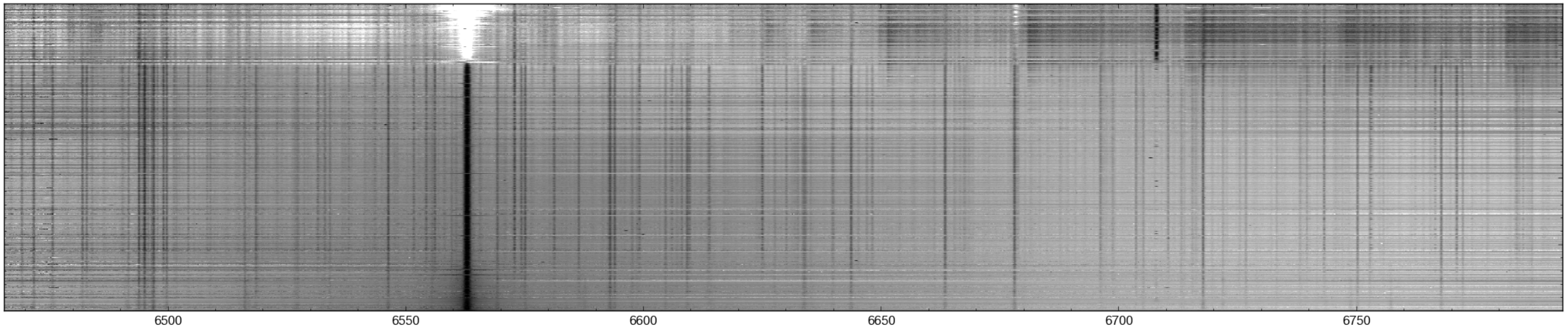
Metallicity calibration involves the Solar value – changing!!! And data selection: hi/lo SNR
Systematic errors rarely known or quoted, but can be relatively large.

Gaia-ESO Giraffe spectra

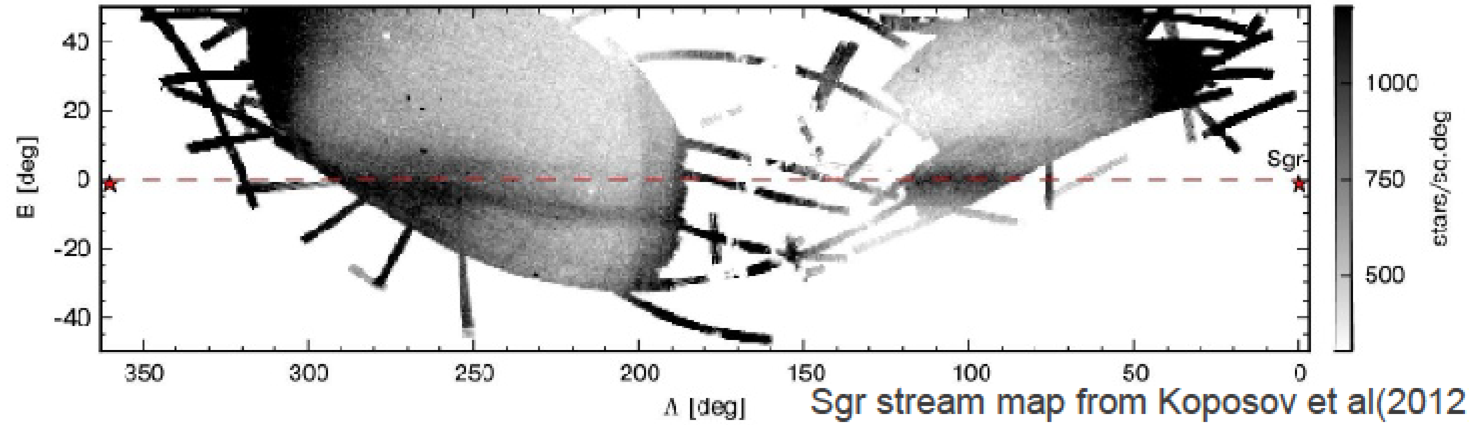
even with narrow target selection, a very wide range of parameters is evident

➔ there is no single analysis aproach

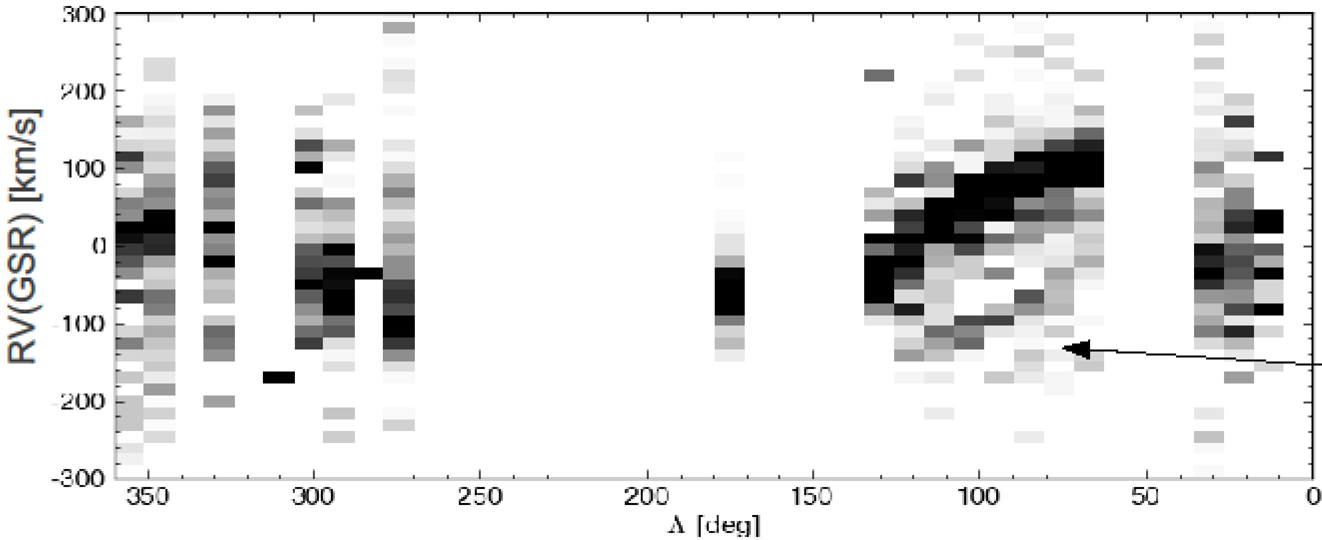




A bit of science from RVs: Sgr stream

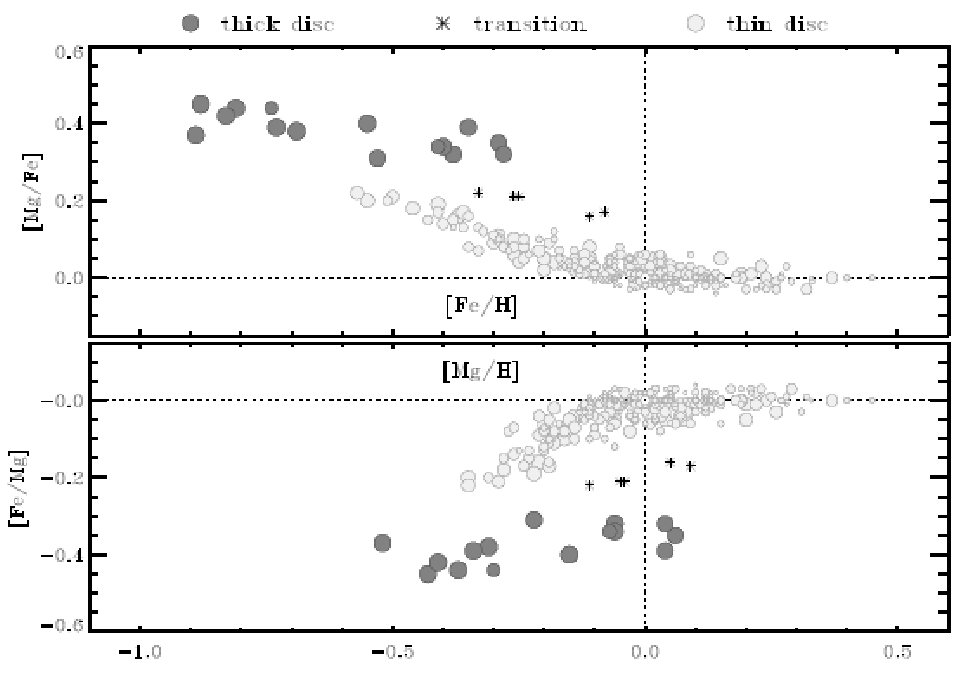


Sgr stream map from Koposov et al(2012)



Sgr strean

Is there a thin-thick difference in alpha/Fe DF?
Furhmann was there first – careful, single method approach



Fuhrmann MNRAS 414 2893 (2011)

The Astrophysical Journal, 738:187 (17pp), 2011 September 10

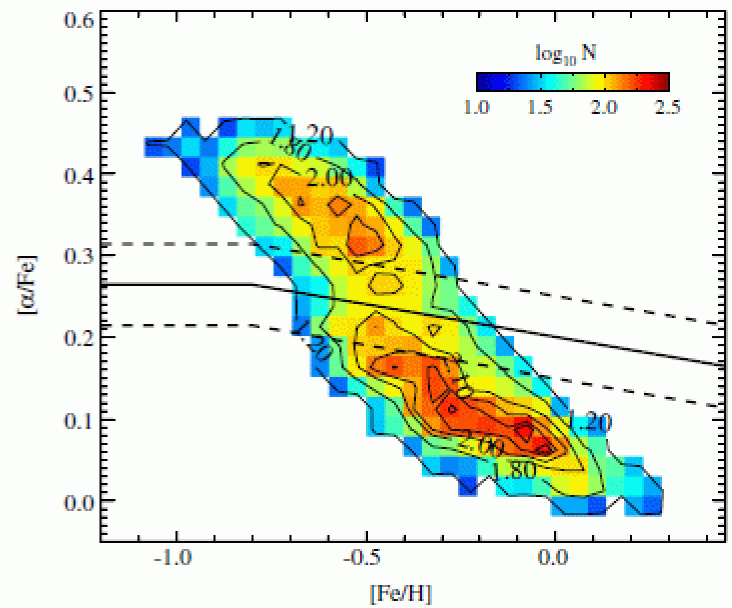
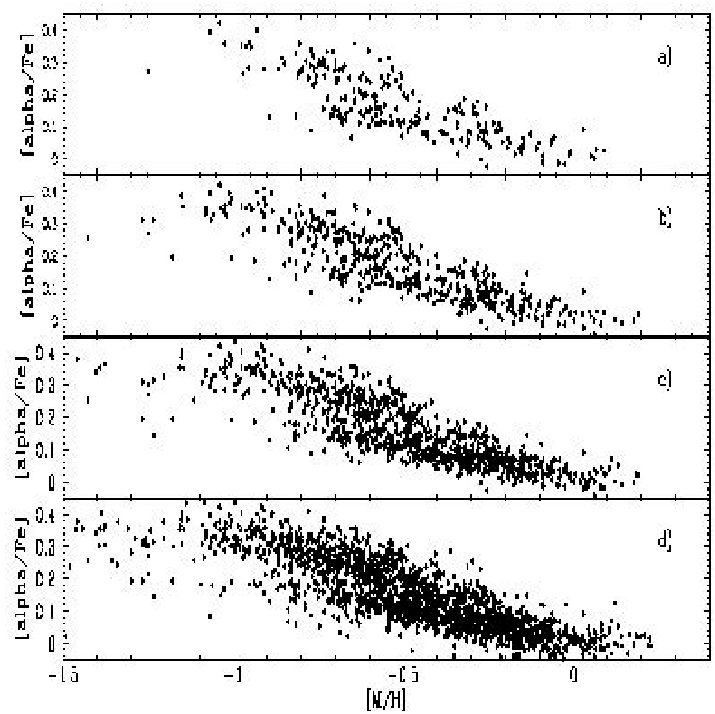


Figure 2. Distribution of logarithmic number densities, in the [α/Fe] vs. [Fe/H] plane, overplotted with equidensity contours. Each bin is 0.025 dex in [α/Fe] by 0.05 dex in [Fe/H] and is occupied by a minimum of 20 stars. The median occupancy is 70 stars. The solid line is the fiducial for division into likely thin- and thick-disk populations; the dashed lines located ±0.05 dex in [α/Fe] on either side of the solid line indicate the adopted dividing points for the high-[α/Fe] (upper-dashed) and low-[α/Fe] (lower-dashed) stars in our sample.

Recent fuss from SDSS about (lack of) complexity in disk chemistry-kinematics
Disagreed with available high-resolution studies: issue was biases, need survey

The Gaia-ESO Survey: the Galactic Thick to Thin Disc transition*

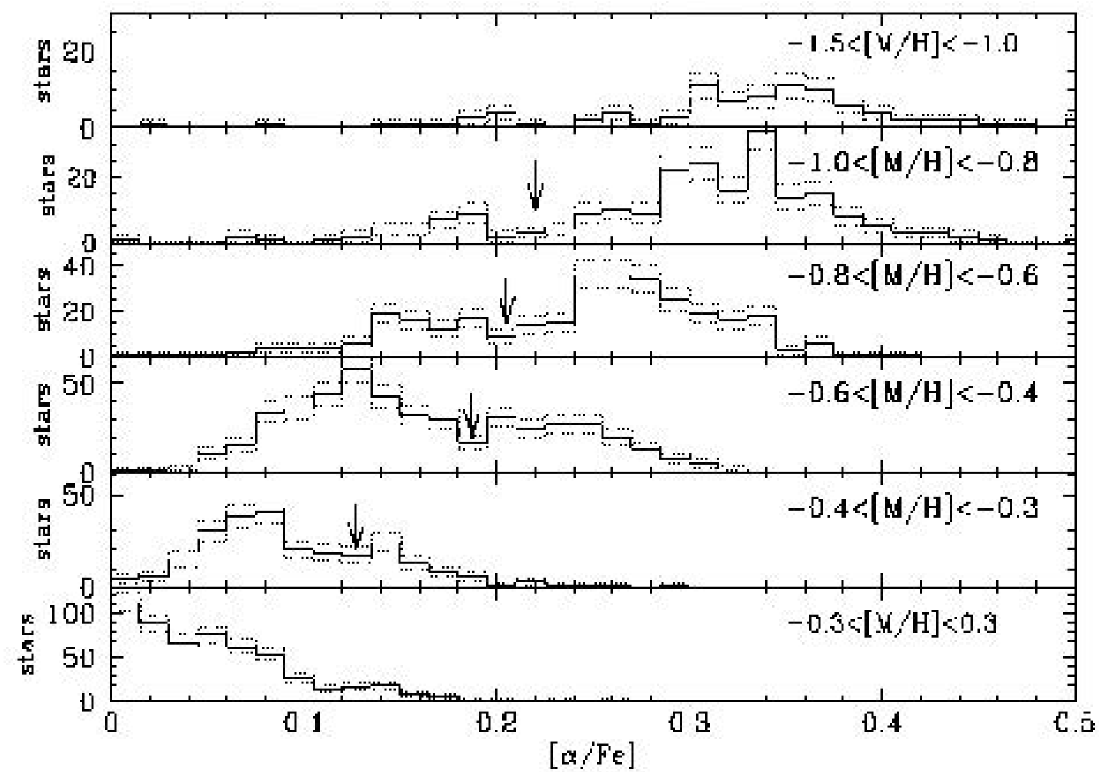
A. Recio-Blanco[1], P. de Laverny[1], G. Kordopatis[2], A. Helmi[3], V. Hill[1], G. Gilmore[2], R. Wyse[4], S. Randich[5],



Clear bimodality between thick and thin disks

The Gaia-ESO Survey: the chemical structure of the Galactic discs from the first internal data release *

Š. Mikolaitis[1,2], V. Hill[1], A. Recio–Blanco[1], P. de Laverny[1] C. Allende Prieto[9], G. Kordopatis[3], G. Tautvaišiene[2] D. Romano[10], G. Gilmore[3], S. Randich[4], S. Feltzing[5], G. Micela[6], A. Vallenari[7], E. J. Alfaro[8], T. Bensby[5], A. Bragaglia[10], E. Flaccomio[6], A. C. Lanzafame[11], E. Pancino[10,12], R. Smiljanic[13,14], M. Bergemann[3], G. Carraro[15], M. T. Costado[8], F. Damiani[6], A. Hourihane[3], P. Jofré[3], C. Lardo[10], L. Magrini[4], E. Maiorca[4], L. Morbidelli[4], L. Sbordone[16], S. G. Sousa[17,18], C. C. Worley[3], and S. Zaggia[7]



Disks kinematics – going beyond low resolution unresolved 1 or 2-component

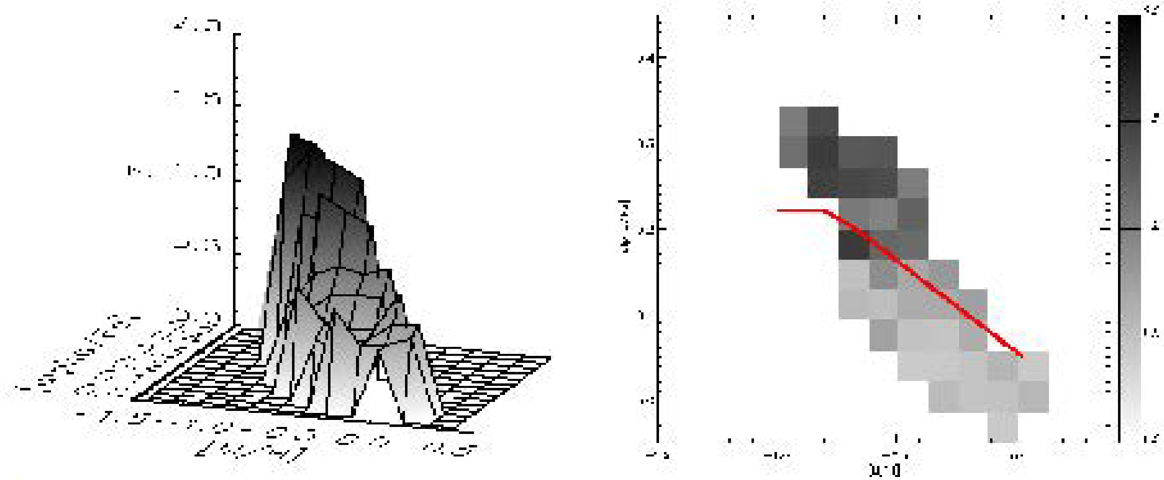


Fig. 15. *Left panel*: 3D plot of the distance to the Galactic plane, in the z axis, shown as a function of [M/H] and [α/Fe] for the analysed stars (sub-sample *e* of Fig. 12). *Right panel*: distribution of the distances to the Galactic plane in [α/Fe] vs. [M/H]. The red line shows the separation between the thick and the thin disc sequences defined in Sect. 4. In this panel, high-Z values are coded in darker grey than lower Z values.

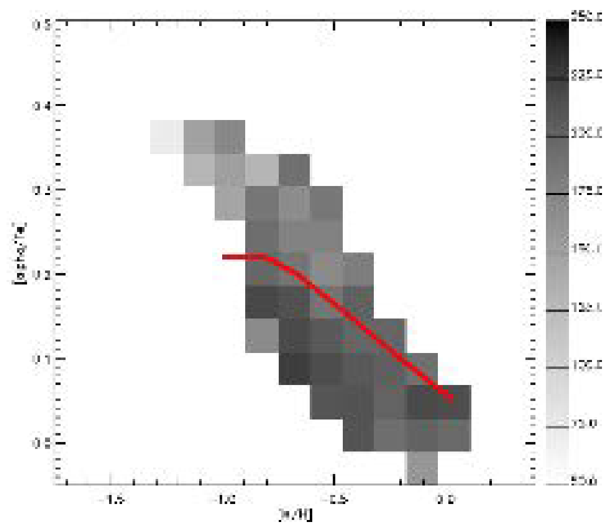


Fig. 16. Distribution of the cylindrical rotational velocity, V_ϕ, in the [α/Fe] vs. [M/H] plane. High velocity values are coded in darker grey than lower ones. As in Fig. 15, the red line shows the separation between the thick and the thin discs.

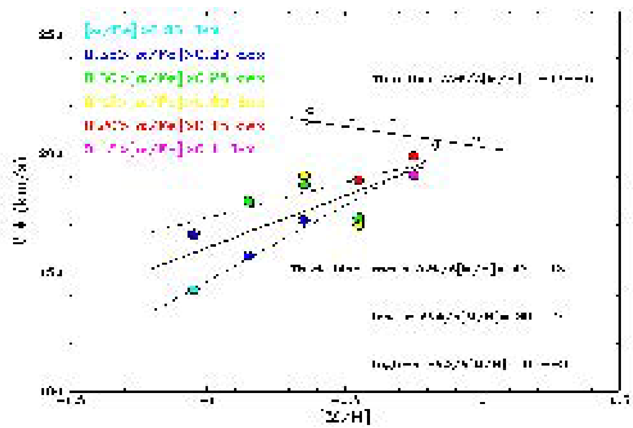
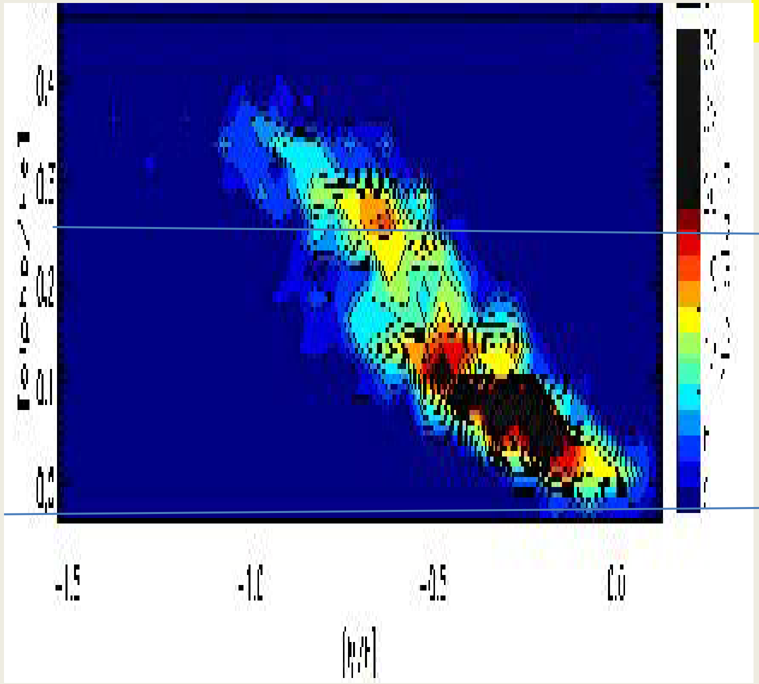
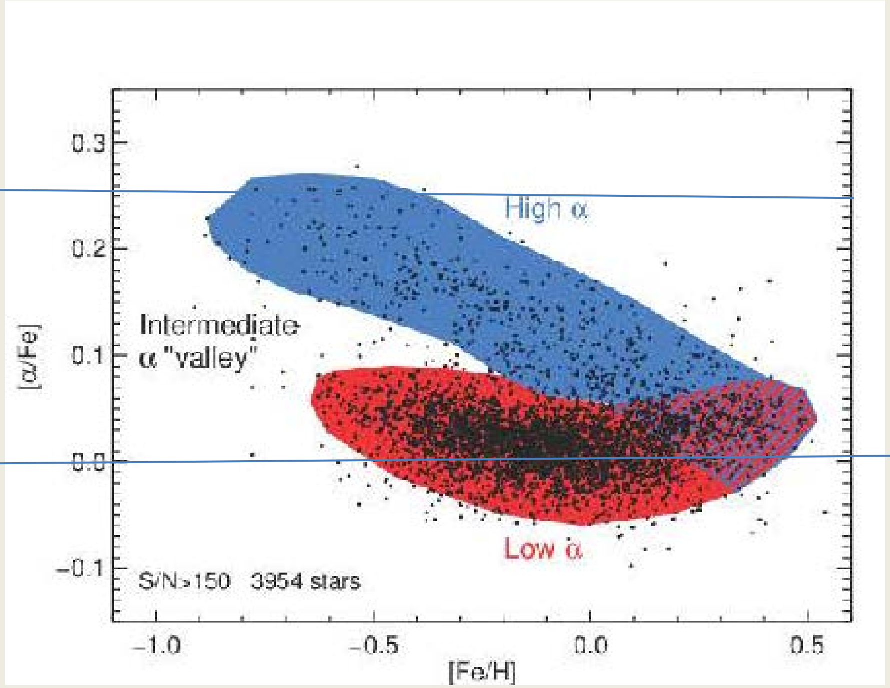


Fig. 17. Rotational velocity gradients with metallicity for the thin (open circles) and thick (filled circles) sequences. The thick disc points are colour-coded by [α/Fe] abundance intervals. The Spearman's rank correlation coefficient between V_ϕ and [M/H] is 0.73.

Note the different alpha calibrations..



Gaia-ESO



Apogee 1409.3566 agree?

Lesson: calibrating abundance scales is hard

The Gaia-ESO Survey: α-abundances of Metal-Poor Stars in the Milky Way halo

R. Jackson-Jones[1], P. Jofré[1], K. Hawkins[1], A. Hourihane[1], G. Gilmore[1], G. Kordopatis[1], C. Worley[1], T. Bensby[4], M. T.

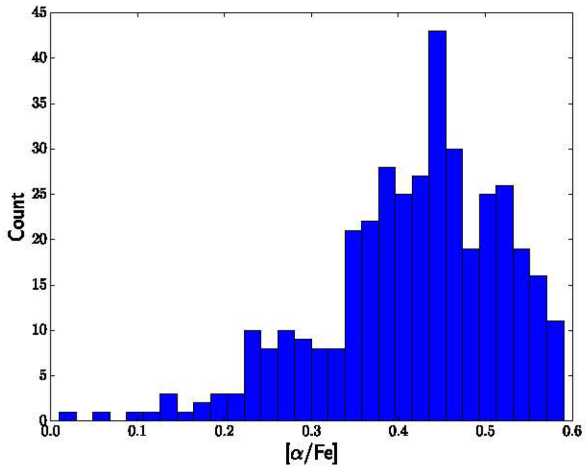
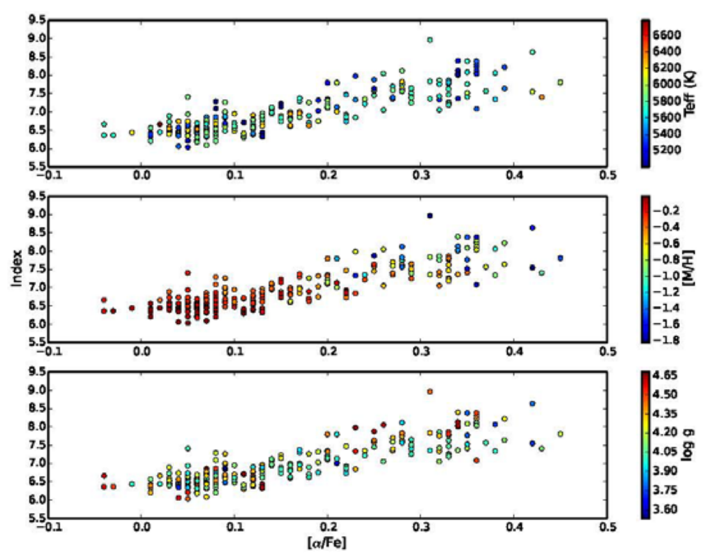


Fig. 2: The distribution of [α/Fe] of the metal-poor sample from the internal second data release of GES. An $\alpha-$poor and and $\alpha-$rich population can be seen.

The low-alpha halo fraction is less-unlike dSph populations – makes ~20% of halo. Most of halo formed very early and fast.

The Age of α-Rich and α-Poor Populations in the Galactic Halo from SDSS

K. Hawkins[1⋆], P. Jofré [1], G. Gilmore[1], and T. Masseron[1]



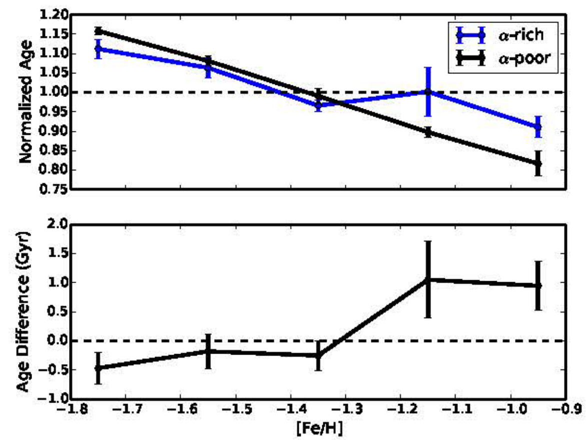


Figure 14. Top panel: normalized Y^2 isochrone ages as a function of metallicity for α-rich (blue) and α-poor (black) populations. Bottom Panel: age difference between the α-rich and α-poor populations as a function of metallicity .

The Rich Are Different: Evidence from the RAVE Survey for Stellar Radial Migration

G. Kordopatis,[1*] J. Binney,[2] G. Gilmore,[1] R.F.G. Wyse,[3] V. Belokurov,[1] P.J. McMillan,[2]

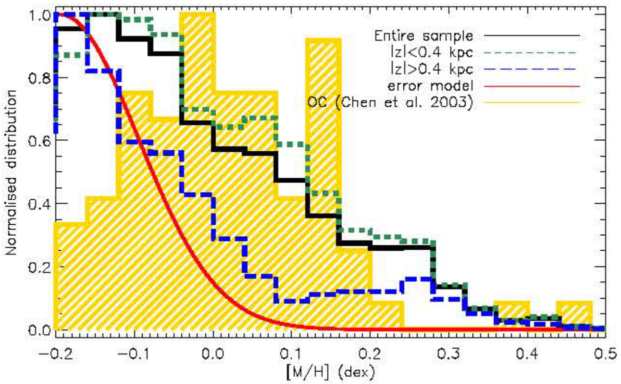


Figure 7. Same as Fig. 5, but for a separation as a function of the distance from the Galactic plane. The error model is a Gaussian of $\sigma = 0.1$ dex, centred at the peak of the blue histogram, at [M/H] $= -0.2$ dex.

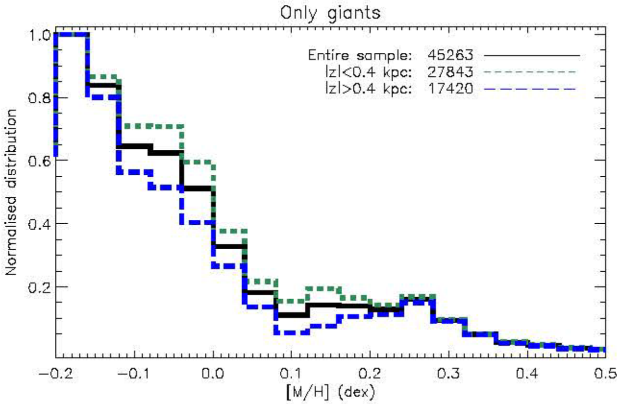
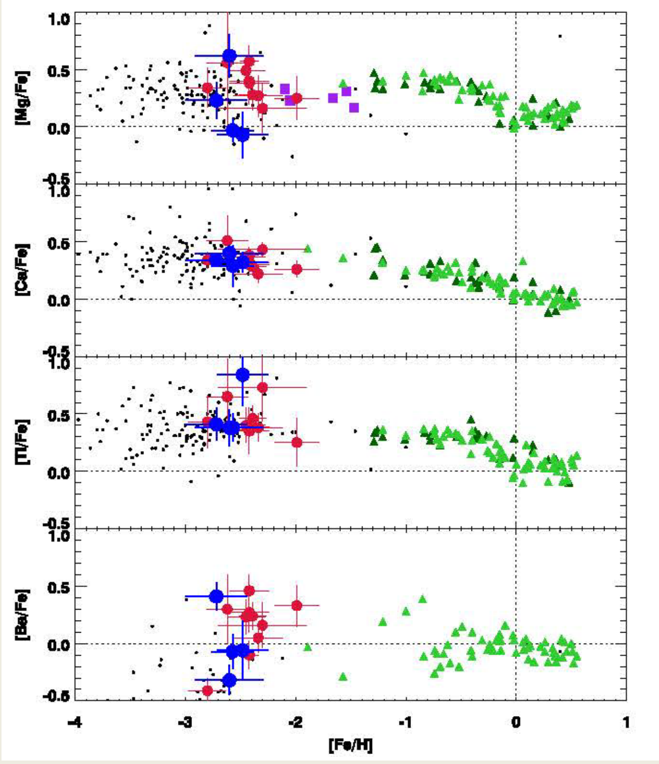


Figure 8. Same as Fig. 7, but only for stars with $\log g < 3.5$ dex. For [M/H] > 0.1 dex the metallicity distribution is flat for both the subsamples: that close to the plane and that far from it.

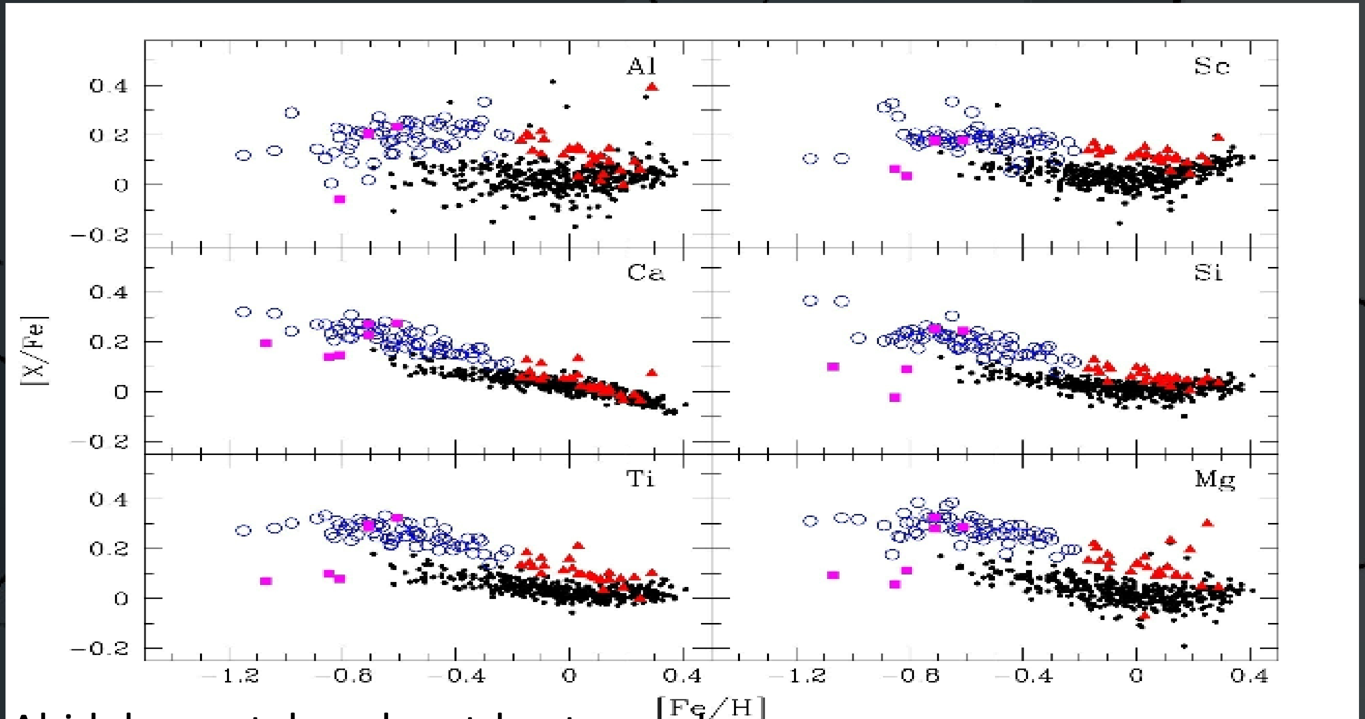
Local SMR stars on disk orbits indicate migration
Metallicity DF not obvious.



The Gaia-ESO survey: the most metal-poor stars in the Galactic bulge

L. M. Howes,[1*] M. Asplund,[1] A. R. Casey,[2] S. C. Keller,[1] D. Yong,[1] G. Gilmore,[2]

SMR stars have been known for some time: their chemistry is very young thin disk – future challenge to find where their siblings are. Not yet found in inner-bulge surveys



Abidekyan etal: planet-host sample

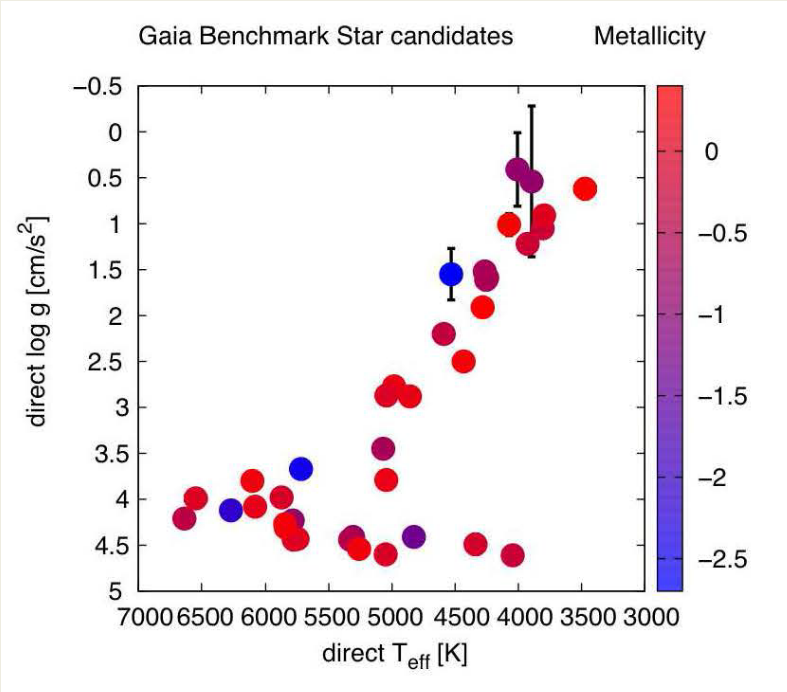
calibration concept

- use (open) clusters to test hot-cool-GB-ms consistency of methods and zero points;
- use (globular) clusters to test metallicity;
- use benchmark stars to

interpolate and test SNR;

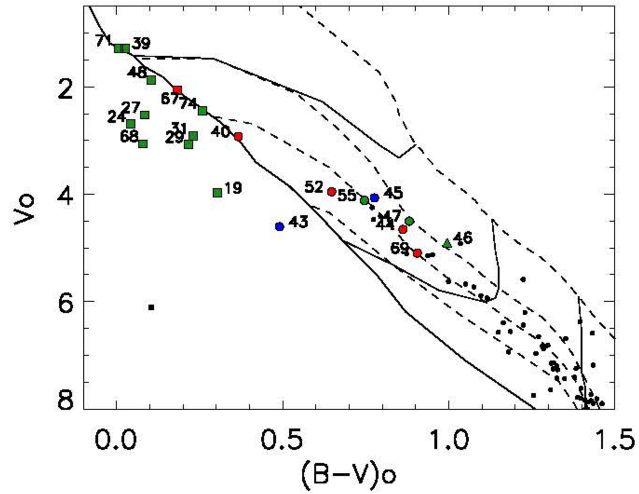
- special case –

CoRoT – major effort underway: 1000 seismic RGs observed already



The *Gaia*-ESO Survey: the first abundance determination of the pre-main-sequence cluster gamma Velorum⋆,⋆⋆

L. Spina[1,2], S. Randich[1], F. Palla[1], G. G. Sacco[1], L. Magrini[1], E. Franciosini[1], L. Morbidelli[1], L. Prisinzano[3], E. J. Alfaro[4], K. Biazzo[5], A. Frasca[5], J. I. González Hernández[6,7], S. G. Sousa[8,9], V. Adibekyan[8], E. Delgado-Mena[8], D. Montes[10], H. Tabernero[10], A. Klutsch[5], G. Gilmore[11], S. Feltzing[12], R. D. Jeffries[13], G. Micela[3], A. Vallenari[14], T. Bensby[11], A. Bragaglia[15], E. Flaccomio[13], S. Koposov[10], A. C. Lanzafame[16], E. Pancino[15,17], A. Recio-Blanco[18], R. Smiljanic[19,20], M. T. Costado[4], F. Damiani[3], V. Hill[18], A. Hourihane[10], P. Jofré[10], P. de Laverny[18], T. Masseron[11], and C. Worley[11]



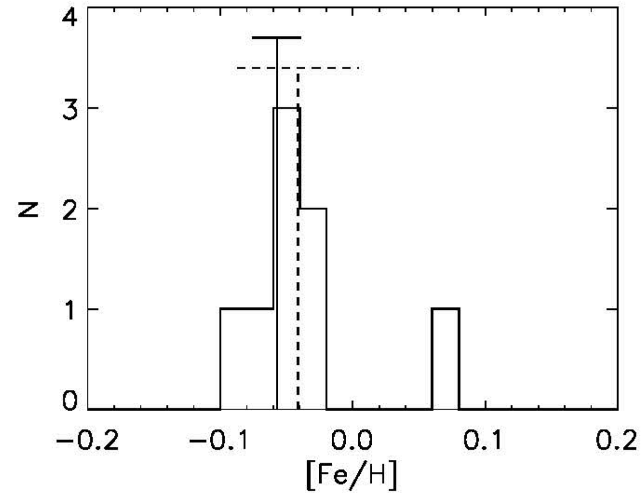


Fig. 7. V_0 vs. $(B-V)_0$ diagram of the UVES high-probability members (circles), HCM (squares) and Li-rich binary system (triangle). Stars are color coded according to the RV membership. Each star is labelled according to the ID number given in Table 1. The Giraffe members from Jeffries et al. (2014) are shown as black dots. The solid and dashed lines

Fig. 8. Distribution of the iron abundance of the eight UVES high-probability cluster members. The mean values are $\langle[Fe/H]\rangle = -0.04 \pm 0.05$ dex (dashed line) and $\langle[Fe/H]\rangle = -0.057 \pm 0.018$ dex (solid line) discarding the star #52 with [Fe/H] = 0.07 dex.

Young star-forming region – this must be the local ISM abundance

Note the high-metallicity outlier – post-planet merger??

The *Gaia*-ESO Survey: Abundance ratios in the inner-disk open clusters Trumpler 20, NGC 4815, NGC 6705★

L. Magrini[1], S. Randich[1], D. Romano[2], E. Friel[3], A. Bragaglia[2], R. Smiljanic[4,5], H. Jacobson[6], A. Vallenari[7], M. Tosi[2],

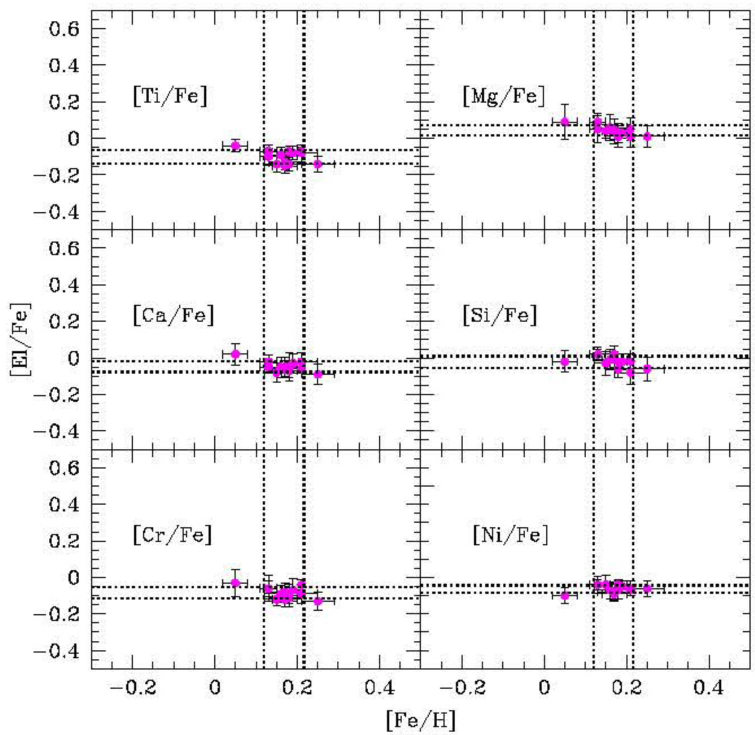


Fig. 3. Abundance ratios versus [Fe/H] for individual member stars in Tr20. Errors on abundance ratios [El/Fe] are computed by summing the

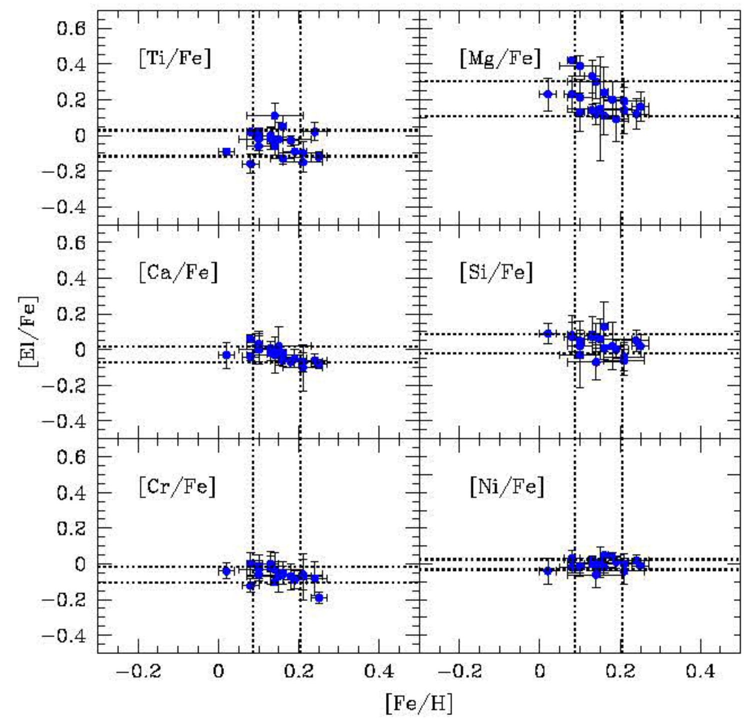


Fig. 5. As in Fig. 3, but for NGC 6705.

Inner galaxy young clusters are super-solar. Getting to [Fe/H]=+0.4 is less obvious

Calibration again…

- Do we have a consistent calibration between ISM, young clusters, and (older?) field stars above Solar??
- Almost certainly no.

Implications for MOS surveys

- The Galactic community is still learning how to collaborate on big projects (and use FITS)
- New science demands high spectral resolution, good signal-noise, wide wavelength coverage
- Analysis of stellar spectra is not a single pipeline: many methods are essential ➔ much effort
- Calibrating internal results onto a sensible scale is a very, very big challenge
- Include all major spectroscopic analysis methods, from O-star to M-star, cluster and field
  - Resolved the major systematics underlying spectrum analyses
  - Atomic and Molecular Linelists
    - Major effort in creating and publishing cleaned, calibrated line lists (VALD3) for general use
  - Model Atmosphere & Synthetic Spectra Grids
    - Gaia-ESO Survey community providing comprehensive parameter coverage
- Gaia Calibration
    - Benchmark stars: Definition of accepted parameters & abundances
    - COROT: Fundamental parameters by astero-seismology iterated on Gaia-ESO parameters
- **The origin of the method residuals is an open question.**

summary

- Gaia is working. First science alerts are appearing now. Data will be good.
- Gaia-ESO is working. First science is good.
- The sociology in astronomy is changing, towards large consortia.
- Realising the Gaia potential will require that we learn to organise our community, as well as our data.
- Its worth the considerable effort.